

Rivet user manual

version 1.8.3

Andy Buckley

PPE Group, School of Physics, University of Edinburgh, UK.
E-mail: andy.buckley@ed.ac.uk

Jonathan Butterworth

HEP Group, Dept. of Physics and Astronomy, UCL, London, UK.
E-mail: J.Butterworth@ucl.ac.uk

Hendrik Hoeth

IPPP, Durham University, UK.
E-mail: hendrik.hoeth@cern.ch

Leif Lönnblad

Theoretical Physics, Lund University, Sweden.
E-mail: lonnblad@thep.lu.se

James Monk

HEP Group, Dept. of Physics and Astronomy, UCL, London, UK.
E-mail: jmonk@hep.ucl.ac.uk

Holger Schulz

Institut für Physik, Berlin Humboldt University, Germany.
E-mail: holger.schulz@physik.hu-berlin.de

Jan Eike von Seggern

Institut für Physik, Berlin Humboldt University, Germany.
E-mail: vseggern@physik.hu-berlin.de

Frank Siegert

Physikalisches Institut, Freiburg University, Germany.
E-mail: frank.siegert@cern.ch

Lars Sonnenschein

RWTH Aachen University, III. Phys. Inst. A, 52056 Aachen, Germany.
E-mail: Lars.Sonnenschein@cern.ch

ABSTRACT: This is the manual and user guide for the Rivet system for the validation and tuning of Monte Carlo event generators. As well as the core Rivet library, this manual describes the usage of the `rivet` program and the AGILE generator interface library. The depth and level of description is chosen for users of the system, starting with the basics of using validation code written by others, and then covering sufficient details to write new Rivet analyses and calculational components.

KEYWORDS: [Event generator](#), [simulation](#), [validation](#), [tuning](#), [QCD](#).

Contents

1. Introduction	7
1.1 Typographic conventions	8
 I Getting started with Rivet	 9
2. Quickstart	9
2.1 Getting generators for AGILe	11
2.2 Command completion	11
 3. Running Rivet analyses	 11
3.1 The FIFO idiom	12
3.2 Analysis status	12
3.3 Example <code>rivet</code> commands	13
 4. Using analysis data	 14
4.1 Histogram formats	14
4.2 Chopping histograms	15
4.3 Normalising histograms	15
4.4 Plotting and comparing data	16
 II Standard Rivet analyses	 17
5. LEP and SLC analyses	17
5.1 ALEPH_1991_S2435284	17
5.2 ALEPH_1996_S3196992	18
5.3 ALEPH_1996_S3486095	19
5.4 ALEPH_1999_S4193598	20
5.5 ALEPH_2001_S4656318	21
5.6 ALEPH_2002_S4823664	22
5.7 ALEPH_2004_S5765862	23
5.8 DELPHI_1995_S3137023	24
5.9 DELPHI_1996_S3430090	25
5.10 DELPHI_1999_S3960137	26
5.11 DELPHI_2000_S4328825	27
5.12 DELPHI_2002_069_CONF_603	28
5.13 JADE_OPAL_2000_S4300807	29
5.14 OPAL_1993_S2692198	30
5.15 OPAL_1994_S2927284	31

5.16	OPAL_1995_S3198391	32
5.17	OPAL_1996_S3257789	33
5.18	OPAL_1997_S3396100	34
5.19	OPAL_1997_S3608263	35
5.20	OPAL_1998_S3702294	36
5.21	OPAL_1998_S3749908	37
5.22	OPAL_1998_S3780481	38
5.23	OPAL_2000_S4418603	39
5.24	OPAL_2001_S4553896	40
5.25	OPAL_2002_S5361494	41
5.26	OPAL_2004_S6132243	42
5.27	SLD_1996_S3398250	43
5.28	SLD_1999_S3743934	44
5.29	SLD_2002_S4869273	45
5.30	SLD_2004_S5693039	46
6.	Tevatron analyses	47
6.1	CDF_1988_S1865951	47
6.2	CDF_1990_S2089246	48
6.3	CDF_1994_S2952106	49
6.4	CDF_1996_S3418421	50
6.5	CDF_1998_S3618439	51
6.6	CDF_2000_S4155203	52
6.7	CDF_2000_S4266730	53
6.8	CDF_2001_S4517016	54
6.9	CDF_2001_S4563131	55
6.10	CDF_2001_S4751469	56
6.11	CDF_2002_S4796047	57
6.12	CDF_2004_S5839831	58
6.13	CDF_2005_S6080774	59
6.14	CDF_2005_S6217184	60
6.15	CDF_2006_S6450792	61
6.16	CDF_2006_S6653332	62
6.17	CDF_2007_S7057202	63
6.18	CDF_2008_LEADINGJETS	64
6.19	CDF_2008_NOTE_9351	65
6.20	CDF_2008_S7540469	66
6.21	CDF_2008_S7828950	67
6.22	CDF_2008_S8093652	68
6.23	CDF_2008_S8095620	69
6.24	CDF_2009_NOTE_9936	70
6.25	CDF_2009_S8233977	71
6.26	CDF_2009_S8383952	72

6.27	CDF_2009_S8436959	73
6.28	CDF_2010_S8591881_DY	74
6.29	CDF_2010_S8591881_QCD	75
6.30	CDF_2012_NOTE10874	76
6.31	D0_2000_S4480767	77
6.32	D0_2001_S4674421	78
6.33	D0_2004_S5992206	79
6.34	D0_2006_S6438750	80
6.35	D0_2007_S7075677	81
6.36	D0_2008_S6879055	82
6.37	D0_2008_S7554427	83
6.38	D0_2008_S7662670	84
6.39	D0_2008_S7719523	85
6.40	D0_2008_S7837160	86
6.41	D0_2008_S7863608	87
6.42	D0_2009_S8202443	88
6.43	D0_2009_S8320160	89
6.44	D0_2009_S8349509	90
6.45	D0_2010_S8566488	91
6.46	D0_2010_S8570965	92
6.47	D0_2010_S8671338	93
6.48	D0_2010_S8821313	94
6.49	D0_2011_I895662	95
7.	LHC analyses	96
7.1	ALICE_2010_S8624100	96
7.2	ALICE_2010_S8625980	97
7.3	ALICE_2010_S8706239	98
7.4	ALICE_2011_S8909580	99
7.5	ALICE_2011_S8945144	100
7.6	ALICE_2012_I1181770	101
7.7	ATLAS_2010_S8591806	102
7.8	ATLAS_2010_S8817804	103
7.9	ATLAS_2010_S8894728	104
7.10	ATLAS_2010_S8914702	105
7.11	ATLAS_2010_S8918562	106
7.12	ATLAS_2010_S8919674	107
7.13	ATLAS_2011_I894867	108
7.14	ATLAS_2011_I919017	109
7.15	ATLAS_2011_I925932	110
7.16	ATLAS_2011_I926145	111
7.17	ATLAS_2011_I944826	112
7.18	ATLAS_2011_I945498	113

7.19	ATLAS_2011_I954993	114
7.20	ATLAS_2011_S8924791	115
7.21	ATLAS_2011_S8971293	116
7.22	ATLAS_2011_S8983313	117
7.23	ATLAS_2011_S8994773	118
7.24	ATLAS_2011_S9002537	119
7.25	ATLAS_2011_S9019561	120
7.26	ATLAS_2011_S9120807	121
7.27	ATLAS_2011_S9126244	122
7.28	ATLAS_2011_S9128077	123
7.29	ATLAS_2011_S9131140	124
7.30	ATLAS_2011_S9212183	125
7.31	ATLAS_2011_S9225137	126
7.32	ATLAS_2012_CONF_2012_001	127
7.33	ATLAS_2012_I1082936	128
7.34	ATLAS_2012_I1084540	129
7.35	ATLAS_2012_I1091481	130
7.36	ATLAS_2012_I1093738	131
7.37	ATLAS_2012_I1094061	132
7.38	ATLAS_2012_I1094568	133
7.39	ATLAS_2012_I1112263	134
7.40	ATLAS_2012_I1117704	135
7.41	ATLAS_2012_I1118269	136
7.42	ATLAS_2012_I1119557	137
7.43	ATLAS_2012_I1125575	138
7.44	ATLAS_2012_I1125961	139
7.45	ATLAS_2012_I1183818	140
7.46	ATLAS_2012_I1188891	141
7.47	ATLAS_2012_I943401	142
7.48	ATLAS_2013_I1217867	143
7.49	CMS_2010_S8547297	144
7.50	CMS_2010_S8656010	145
7.51	CMS_2011_I954992	146
7.52	CMS_2011_S8884919	147
7.53	CMS_2011_S8941262	148
7.54	CMS_2011_S8950903	149
7.55	CMS_2011_S8957746	150
7.56	CMS_2011_S8968497	151
7.57	CMS_2011_S8973270	152
7.58	CMS_2011_S8978280	153
7.59	CMS_2011_S9086218	154
7.60	CMS_2011_S9088458	155
7.61	CMS_2011_S9120041	156

7.62	CMS_2011_S9215166	157
7.63	CMS_2012_I1087342	158
7.64	CMS_2012_I1102908	159
7.65	CMS_2012_I1107658	160
7.66	CMS_2012_I1184941	161
7.67	CMS_2012_I1193338	162
7.68	CMS_2012_PAS_FWD_11.003	163
7.69	CMS_2012_PAS_QCD_11.010	164
7.70	CMS_QCD_10.024	165
7.71	LHCB_2010_I867355	166
7.72	LHCF_2012_I1115479	167
7.73	TOTEM_2012.002	168
7.74	TOTEM_2012_I1115294	169
8.	SPS analyses	170
8.1	UA1_1990_S2044935	170
8.2	UA5_1982_S875503	171
8.3	UA5_1986_S1583476	172
8.4	UA5_1987_S1640666	173
8.5	UA5_1988_S1867512	174
8.6	UA5_1989_S1926373	175
9.	HERA analyses	176
9.1	H1_1994_S2919893	176
9.2	H1_2000_S4129130	177
10.	RHIC analyses	178
10.1	STAR_2006_S6500200	178
10.2	STAR_2006_S6860818	179
10.3	STAR_2006_S6870392	180
10.4	STAR_2009_UE_HELEN	181
11.	Monte Carlo analyses	182
11.1	MC_DIPHOTON	182
11.2	MC_GENERIC	183
11.3	MC_HINC	184
11.4	MC_HJETS	185
11.5	MC_HKTSPLITTINGS	186
11.6	MC_IDENTIFIED	187
11.7	MC_JETS	188
11.8	MC_LEADJETUE	189
11.9	MC_PDFS	190
11.10	MC_PHOTONINC	191
11.11	MC_PHOTONJETS	192

11.12	MC_PHOTONKTSPLITTINGS	193
11.13	MC_PHOTONS	194
11.14	MC_PRINTEVENT	195
11.15	MC_QCD_PARTONS	196
11.16	MC_SUSY	197
11.17	MC_TTBAR	198
11.18	MC_VH2BB	199
11.19	MC_WINC	200
11.20	MC_WJETS	201
11.21	MC_WKTSPLITTINGS	202
11.22	MC_WPOL	203
11.23	MC_WWINC	204
11.24	MC_WWJETS	205
11.25	MC_WWKTSPLITTINGS	206
11.26	MC_XS	207
11.27	MC_ZINC	208
11.28	MC_ZJETS	209
11.29	MC_ZKTSPLITTINGS	210
11.30	MC_ZZINC	211
11.31	MC_ZZJETS	212
11.32	MC_ZZKTSPLITTINGS	213
12.	Example analyses	214
12.1	EXAMPLE	214
13.	Misc. analyses	215
13.1	ARGUS_1993_S2653028	215
13.2	ARGUS_1993_S2669951	216
13.3	ARGUS_1993_S2789213	217
13.4	BABAR_2003_I593379	218
13.5	BABAR_2005_S6181155	219
13.6	BABAR_2007_S6895344	220
13.7	BABAR_2007_S7266081	221
13.8	BELLE_2001_S4598261	222
13.9	BELLE_2006_S6265367	223
13.10	CLEO_2004_S5809304	224
13.11	JADE_1998_S3612880	225
13.12	PDG_HADRON_MULTIPLICITIES	226
13.13	PDG_HADRON_MULTIPLICITIES_RATIOS	227
13.14	TASSO_1990_S2148048	228
III	How Rivet works	229

14. The science and art of physically valid MC analysis	229
15. Projections	231
15.1 Projection caching	231
15.2 Using projection caching	232
16. Analyses	233
16.1 Writing a new analysis	233
16.2 Utility classes	234
16.2.1 FourMomentum	235
16.2.2 Particle	235
16.2.3 Jet	235
16.2.4 Mathematical utilities	236
16.3 Histogramming	236
16.4 Analysis metadata	237
16.4.1 Analysis info files	237
16.4.2 Plot styling files	237
16.5 Pluggable analyses	238
16.5.1 Plugin paths	238
17. Using Rivet as a library	239
 IV Appendices	 243
A. Typical <code>agile-runmc</code> commands	243
B. Acknowledgements	243
 V Bibliography	 245

1. Introduction

This manual is a users' guide to using the Rivet generator validation system. Rivet is a C++ class library, which provides the infrastructure and calculational tools for simulation-level analyses for high energy collider experiments, enabling physicists to validate event generator models and tunings with minimal effort and maximum portability. Rivet is designed to scale effectively to large numbers of analyses for truly global validation, by transparent use of an automated result caching system.

The Rivet ethos, if it may be expressed succinctly, is that user analysis code should be extremely clean and easy to write — ideally it should be sufficiently self-explanatory to in itself be a reference to the experimental analysis algorithm — without sacrificing power or extensibility. The machinery to make this possible is intentionally hidden from the view of all but the most prying users. Generator independence is explicitly required by virtue of all analyses operating on the generic “HepMC” event record.

The simplest way to use Rivet is via the `rivet` command line tool, which analyses textual HepMC event records as they are generated and produces output distributions in a structured textual format. The input events are generated using the generator’s own steering program, if one is provided; for generators which provide no default way to produce HepMC output, the AGILE generator interface library, and in particular the `agile-runmc` command which it provides, may be useful. For those who wish to embed their analyses in some larger framework, Rivet can also be run programmatically on HepMC event objects with no special executable being required.

Before we get started, a declaration of intent: this manual is intended to be a guide to using Rivet, rather than a comprehensive and painstakingly maintained reference to the application programming interface (API) of the Rivet library. For that purpose the online documentation at <http://rivet.hepforge.org> should be sufficient – in case of confusion please contact the authors at rivet@projects.hepforge.org. Similar API documentation is maintained for AGILE at <http://agile.hepforge.org>.

1.1 Typographic conventions

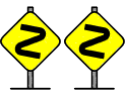
As is normal in computer user manuals, the typography in this manual is used to indicate whether we are describing source code elements, commands to be run in a terminal, the output of a command etc.

The main such clue will be the use of **typewriter-style** text: this indicates the name of a command or code element — class names, function names etc. Typewriter font is also used for commands to be run in a terminal, but in this case it will be prefixed by a dollar sign, as in `$ echo 'Hello' | cat`. The output of such a command on the terminal will be typeset in **sans-serif** font. When we are documenting a code feature in detail (which is not the main point of this manual), we will use square brackets to indicate optional arguments, and italic font between angle brackets to represent an argument name which should be replaced by a value, e.g. `Event::applyProjection(<proj>)`.

Following the example of Donald Knuth in his books on T_EX, in this document we will indicate paragraphs of particular technicality or esoteric nature with a “dangerous bend” sign. These will typically describe internals of Rivet of which most people will be fortunate enough to remain happily ignorant without adverse effects. However they may be of interest to detail obsessives, the inordinately curious and Rivet hackers. You can certainly skip them on a first reading. Similarly, you may see double bend signs — the same rules apply for these, but even more strongly.



Dangerous bend



Double bend

Part I

Getting started with Rivet

As with many things, Rivet may be meaningfully approached at several distinct levels of detail:

- The simplest, and we hope the most common, is to use the analyses which are already in the library to study events from a variety of generators and tunes: this is enormously valuable in itself and we encourage all manner of experimentalists and phenomenologists alike to use Rivet in this mode.
- A more involved level of usage is to write your own Rivet analyses — this may be done without affecting the installed standard analyses by use of a “plugin” system (although we encourage users who develop analyses to submit them to the Rivet developers for inclusion into a future release of the main package). This approach requires some understanding of programming within Rivet but you don’t *need* to know about exactly what the system is doing with the objects that you have defined.
- Finally, Rivet developers and people who want to do non-standard things with their analyses will need to know something about the messy details of what Rivet’s infrastructure is doing behind the scenes. But you’d probably rather be doing some physics!

The current part of this manual is for the first sort of user, who wants to get on with studying some observables with a generator or tune, or comparing several such models. Since everyone will fall into this category at some point, our present interest is to get you to that all-important “physics plots” stage as quickly as possible. Analysis authors and Rivet service-mechanics will find the more detailed information that they crave in Part [III](#).

2. Quickstart

The point of this section is to get you up and running with Rivet as soon as possible. Doing this by hand may be rather frustrating, as Rivet depends on several external libraries — you’ll get bored downloading and building them by hand in the right order. Here we recommend two much simpler ways — for the full details of how to build Rivet by hand, please consult the Rivet Web page.

Ubuntu/Debian package archive A selection of HEP packages, including Rivet, are maintained as Debian/Ubuntu Linux packages on the Launchpad PPA system: <https://launchpad.net/~hep/+archive>. This is the nicest option for Debian/Ubuntu, since not only will it work more easily than anything else, but you will also automatically benefit from bug fixes and version upgrades as they appear.

The PPA packages have been built as binaries for a variety of architectures, and the package interdependencies are automatically known and used: all you need to do on a

Debian-type Linux system (Ubuntu included) is to add the Launchpad archive address to your APT sources list and then request installation of the `rivet` package in the usual way. See the Launchpad and system documentation for all the details.

Bootstrap script For those not using Debian/Ubuntu systems, we have written a bootstrapping script which will download tarballs of Rivet, AGILE and the other required libraries, expand them and build them in the right order with the correct build flags. This is generally nicer than doing it all by hand, and virtually essential if you want to use the existing versions of FastJet, HepMC, generator libraries, and so on from CERN AFS: there are issues with these versions which the script works around, which you won't find easy to do yourself.

To run the script, we recommend that you choose a personal installation directory. Personally, I make a `~/local` directory for this purpose, to avoid polluting my home directory with a lot of files. If you already use a directory of the same name, you might want to use a separate one, say `~/rivetlocal`, such that if you need to delete everything in the installation area you can do so without difficulties.

Now, change directory to your build area (you may also want to make this, e.g. `~/build`), and download the script:

```
$ wget http://svn.hepforge.org/rivet/bootstrap/rivet-bootstrap
```

```
$ chmod +x rivet-bootstrap
```

Now run it to get some help: `$./rivet-bootstrap --help`

Now to actually do the install: for example, to bootstrap Rivet and AGILE to the install area specified as the prefix argument, run this:

```
$ ./rivet-bootstrap --install-agile --prefix=<localdir>
```

If you are running on a system where the CERN AFS area is mounted as `/afs/cern.ch`, then the bootstrap script will attempt to use the pre-built HepMC[1], LHAPDF[2], FastJet[3, 4] and GSL libraries from the LCG software area. Either way, finally the bootstrap script will write out a file containing the environment settings which will make the system useable. You can source this file, e.g. `source rivetenv.sh` to make your current shell ready-to-go for a Rivet run (use `rivetenv.csh` if you are a C shell user).

You now have a working, installed copy of the Rivet and AGILE libraries, and the `rivet` and `agile-runmc` executables: respectively these are the command-line frontend to the Rivet analysis library, and a convenient steering command for generators which do not provide their own main program with HepMC output. To test that they work as expected, source the setup scripts as above, if you've not already done so, and run this:

```
$ rivet --help
```

This should print a quick-reference user guide for the `rivet` command to the terminal. Similarly, for `agile-runmc`,

```
$ agile-runmc --help
```

```
$ agile-runmc --list-gens
```

```
$ agile-runmc --beams=pp:14000 Pythia6:425
```

which should respectively print the help, list the available generators and make 10 LHC-type events using the Fortran Pythia[5] 6.423 generator. You're on your way! If no generators are

listed, you probably need to install a local Genser-type generator repository: see section 2.1.

In this manual, because of its convenience, we will use `agile-runmc` as our canonical way of producing a stream of HepMC event data; if your interest is in running a generator like Sherpa[6], Pythia 8[7, 8], or Herwig++[9] which provides their own native way to make HepMC output, or a generator like PHOJET which is not currently supported by AGILe, then substitute the appropriate command in what follows. We'll discuss using these commands in detail in section 3.

2.1 Getting generators for AGILe

One last thing before continuing, though: the generators themselves. Again, if you're running on a system with the CERN LCG AFS area mounted, then `agile-runmc` will attempt to automatically use the generators packaged by the LCG Genser team.

Otherwise, you'll have to build your own mirror of the LCG generators. This process is evolving with time, and so, rather than provide information in this manual which will be outdated by the time you read it, we simply refer you to the relevant page on the Rivet wiki: <http://rivet.hepforge.org/trac/wiki/GenserMirror>.

If you are interested in using a generator not currently supported by AGILe, which does not output HepMC events in its native state, then please contact the authors (via the Rivet developer contact email address) and hopefully we can help.

2.2 Command completion

A final installation point worth considering is using the supplied bash-shell programmable completion setup for the `rivet` and `agile-runmc` commands. Despite being cosmetic and semi-trivial, programmable completion makes using `rivet` positively pleasant, especially since you no longer need to remember the somewhat cryptic analysis names¹!

To use programmable completion, source the appropriate files from the install location:

```
$ . <localdir>/share/Rivet/rivet-completion
$ . <localdir>/share/AGILe/agile-completion
```

(if you are using the setup script `rivetenv.sh` this is automatically done for you). If there is already a `<localdir>/etc/bash_completion.d` directory in your install path, Rivet and AGILe's installation scripts will install extra copies into that location, since automatically sourcing all completion files in such a path is quite standard.

Apologies to {C,k,z,...}-shell users, but this feature is currently only available for the `bash` shell. Anyone who feels like supplying fixes or additions for their favourite shell is very welcome to get in touch with the developers.

3. Running Rivet analyses

The `rivet` executable is the easiest way to use Rivet, and will be our example throughout this manual. This command reads HepMC events in the standard ASCII format, either from file or from a text stream.

¹Standard Rivet analyses have names which, as well as the publication date and experiment name, incorporate the 8-digit Spires ID code.

3.1 The FIFO idiom

Since you rarely want to store simulated HepMC events and they are computationally cheap to produce (at least when compared to the remainder of experiment simulation chains), we recommend using a Unix *named pipe* (or “FIFO” — first-in, first-out) to stream the events. While this may seem unusual at first, it is just a nice way of “pretending” that we are writing to and reading from a file, without actually involving any slow disk access or building of huge files: a 1M event LHC run would occupy $\sim 60GB$ on disk, and typically it takes twice as long to make and analyse the events when the filesystem is involved! Here is an example:

```
$ mkfifo fifo.hepmc
```

```
$ agile-runmc Pythia6:425 -o fifo.hepmc &
```

```
$ rivet -a EXAMPLE fifo.hepmc
```

Note that the generator process (`agile-runmc` in this case) is *backgrounded* before `rivet` is run.

Notably, `mkfifo` will not work if applied to a directory mounted via the AFS distributed filesystem, as widely used in HEP. This is not a big problem: just make your FIFO object somewhere not mounted via AFS, e.g. `/tmp`. There is no performance penalty, as the filesystem object is not written to during the streaming process.

In the following command examples, we will assume that a generator has been set up to write to the `fifo.hepmc` FIFO, and just list the `rivet` command that reads from that location. Some typical `agile-runmc` commands are listed in [appendix A](#).

3.2 Analysis status

The standard Rivet analyses are divided into four status classes: validated, preliminary, obsolete, and unvalidated (in roughly decreasing order of academic acceptability).

The Rivet “validation procedure” is not (as of February 2011) formally defined, but generally implies that an analysis has been checked to ensure reproduction of MC points shown in the paper where possible, and is believed to have no outstanding issues with analysis procedure or cuts. Additionally, analyses marked as “validated” and distributed with Rivet should normally have been code-checked by an experienced developer to ensure that the code is a good example of Rivet usage and is not more complex than required or otherwise difficult to read or maintain. Such analyses are regarded as fully ready for use in any MC validation or tuning studies.

Validated analyses which implement an unfinished piece of experimental work are considered to be trustworthy in their implementation of a conference note or similar “informal” publication, but do not have the magic stamp of approval that comes from a journal publication. This remains the standard mark of experimental respectability and accordingly we do not include such analyses in the Rivet standard analysis libraries, but in a special “preliminary” library. While preliminary analyses may be used for physics studies, please be aware of the incomplete status of the corresponding experimental study, and also be aware that the histograms in such analyses may be renamed or removed entirely, as may the analysis itself.

Preliminary analyses will not have a SPIRES preprint number, and hence on their move into the standard Rivet analysis library they will normally undergo a name change: please ensure when you upgrade between Rivet versions that any scripts or programs which were using preliminary analyses are not broken by the disappearance or change of that analysis in the newer version. The minor perils of using preliminary analyses can be avoided by the cautious by building Rivet with the `--disable-preliminary` configuration flag, in which case their temptation will not even be offered.

To make transitions between Rivet versions more smooth and predictable for users of preliminary analyses, preliminary analyses which are superseded by a validated version will be reclassified as obsolete and will be retained for one major version of Rivet with a status of "obsolete" before being removed, to give users time to migrate their run scripts, i.e. if an analysis is marked as obsolete in version 1.4.2, it will remain in Rivet's distribution until version 1.5.0. Obsolete analyses may have different reference histograms from the final version and will not be maintained. Obsolete analyses will not be built if either the `--disable-obsolete` configuration flag is specified at build time: for convenience, the default value of this flag is the value of the `--disable-preliminary` flag.

Finally, unvalidated analyses are those whose implementation is incomplete, flawed or just troubled by doubts. Running such analyses is not a good idea if you aren't trying to fix them, and Rivet's command line tools will print copious warning messages if you do. Unvalidated analyses in the Rivet distribution are not built by default, as they are only of interest to developers and would be distracting clutter for the majority of users: if you *really* need them, building Rivet with the `--enable-unvalidated` configuration flag will slake your thirst for danger.

3.3 Example rivet commands

- **Getting help:** `rivet --help` will print a (hopefully) helpful list of options which may be used with the `rivet` command, as well as other information such as environment variables which may affect the run.
- **Choosing analyses:** `rivet --list-analyses` will list the available analyses, including both those in the Rivet distribution and any plugins which are found at runtime. `rivet --show-analysis <patt>` will show a lot of details about any analyses whose name match the `<patt>` regular expression pattern — simple bits of analysis name are a perfectly valid subset of this. For example, `rivet --show-analysis CDF_200` exploits the standard Rivet analysis naming scheme to show details of all available CDF experiment analyses published in the "noughties."
- **Running analyses:** `rivet -a DELPHI_1996_S3430090 fifo.hepmc` will run the Rivet `DELPHI_1996_S3430090` [10] analysis on the events in the `fifo.hepmc` file (which, from the name, is probably a filesystem named pipe rather than a normal file). This analysis is the one originally used for the DELPHI "PROFESSOR" generator tuning. If the first event in the data file does not have appropriate beam particles, the

analysis will be disabled; since there is only one analysis in this case, the command will exit immediately with a warning if the first event is not an e^+e^- event.

- **Histogramming:** `rivet fifo.hepmc -H foo.aida` will read all the events in the `fifo.hepmc` file. The `-H` switch is used to specify that the output histogram file will be named `foo.aida`. By default the output file is called `Rivet.aida`.
- **Fine-grained logging:** `rivet fifo.hepmc -A -l Rivet.Analysis=DEBUG \`
`-l Rivet.Projection=DEBUG -l Rivet.Projection.FinalState=TRACE \`
`-l NEvt=WARN` will analyse events as before, but will print different status information as the run progresses. Hierarchical logging control is possible down to the level of individual analyses and projections as shown above; this is useful for debugging without getting overloaded with debug information from *all* the components at once. The default level is “INFO”, which lies between “DEBUG” and “WARNING”; the “TRACE” level is for very low level information, and probably isn’t needed by normal users.

4. Using analysis data

In this section, we summarise how to use the data files which Rivet produces for plotting, validation and tuning.

4.1 Histogram formats

Rivet currently produces output histogram data in the AIDA XML format. Most people aren’t familiar with AIDA (and we recommend that you remain that way!), and it will disappear entirely from Rivet in version 2.0. You will probably wish to cast the AIDA files to a different format for plotting, and for this we supply several scripts.

Conversion to ROOT Your knee-jerk reaction is probably to want to know how to plot your Rivet histograms in ROOT[11]. Don’t worry: a few months of therapy can work wonders. For unrepentant ROOT junkies, Rivet installs an `aida2root` script, which converts the AIDA records to a `.root` file full of ROOT `TGraphs`. One word of warning: a bug in ROOT means that `TGraphs` do not render properly from file because the axis is not drawn by default. To display the plots correctly in ROOT you will need to pass the “AP” drawing option string to either the `TGraph::Draw()` method, or in the options box in the `TBrowser` GUI interface.

Conversion to “flat format” Most of our histogramming is based around a “flat” plain text format, which can easily be read (and written) by hand. We provide a script called `aida2flat` to do this conversion. Run `aida2flat -h` to get usage instructions; in particular the Gnuplot and “split output” options are useful for further visualisation. Aside from anything else, this is useful for simply checking the contents of an AIDA file, with `aida2flat Rivet.aida | less`.



We get asked a lot about why we don't use ROOT internally: aside from a general unhappiness about the design and quality of the data objects in ROOT, the monolithic nature of the system makes it a big dependency for a system as small as Rivet. While not an issue for experimentalists, most theorists and generator developers do not use ROOT and we preferred to embed the AIDA system, which in its LWH implementation requires no external package. The replacement for AIDA will be another lightweight system rather than ROOT, with an emphasis on friendly, intuitive data object design, and correct handling of sample merging statistics for all data objects.

4.2 Chopping histograms

In some cases you don't want to keep the complete histograms produced by Rivet. For generator tuning purposes, for example, you want to get rid of the bins you already know your generator is incapable of describing. You can use the script `rivet-chopbins` to specify those bin-ranges you want to keep individually for each histogram in a Rivet output-file. The bin-ranges have to be specified using the corresponding x-values of that histogram. The usage is very simple. You can specify bin ranges of histograms to keep on the command-line via the `-b` switch, which can be given multiple times, e.g.

```
rivet-chopbins -b /CDF_2001_S4751469/d03-x01-y01:5:13 Rivet.aida
```

will chop all bins with $x < 5$ and $x > 13$ from the histogram `/CDF_2001_S4751469/d03-x01y01` in the file `Rivet.aida`. (In this particular case, x would be a leading jet p_{\perp} .)

4.3 Normalising histograms

Sometimes you want to use histograms normalised to, e.g., the generator cross-section or the area of a reference-data histogram. The script `rivet-rescale` was designed for these purposes. The usage is the following:

```
rivet-rescale -O observables -r RIVETDATA -o normalised Rivet.aida
```

By default, the normalised histograms are written to file in the AIDA-XML format. You can also give the `-f` switch on the command line to produce flat histograms.

Normalising to reference data You will need an output-file of Rivet, `Rivet.aida`, a folder that contains the reference-data histograms (e.g. `rivet-config --datadir`) and optionally, a text-file, `observables` that contains the names of the histograms you would like to normalise - those not given in the file will remain un-normalised. These are examples of how your `observables` file might look like:

```
/CDF_2000_S4155203/d01-x01-y01
```

If a histogram `/CDF_2000_S4155203/d01-x01-y01` is found in one of the reference-data files in the folder specified via the `-r` switch, then this will result in a histogram `/CDF_2000_S4155203/d01-x01-y01` being normalised to the area of the corresponding reference-data histogram. You can further specify a certain range of bins to normalise:

```
/CDF_2000_S4155203/d01-x01-y01:2:35
```

will chop off the bins with $x < 2$ and $x > 35$ of both, the histogram in your `Rivet.aida` and the reference-data histogram. The remaining MC histogram is then normalised to the remaining area of the reference-data histogram.

Normalising to arbitrary areas In the file `observables` you can further specify an arbitrary number, e.g. a generator cross-section, as follows:

```
/CDF_2000_S4155203/d01-x01-y01 1.0
```

will result in the histogram `/CDF_2000_S4155203/d01-x01-y01` being normalised to 1.0, and

```
/CDF_2000_S4155203/d01-x01-y01:2:35 1.0
```

will chop off the bins with $x < 2$ and $x > 35$ of the histogram

`/CDF_2000_S4155203/d01-x01-y01` first and normalise the remaining histogram to one.

4.4 Plotting and comparing data

Rivet comes with three commands — `rivet-mkhtml`, `compare-histos` and `make-plots` — for comparing and plotting data files. These commands produce nice comparison plots of publication quality from the AIDA format text files.

The high level program `rivet-mkhtml` will automatically create a plot webpage from the given AIDA files. It searches for reference data automatically and uses the other two commands internally. Example:

```
$ rivet-mkhtml withUE.aida:'Title=With UE' withoutUE.aida:'LineColor=blue'
```

Run `rivet-mkhtml --help` to find out about all features and options.

You can also run the other two commands separately:

- `compare-histos` will accept a number of AIDA files as input (ending in `.aida`), identify which plots are available in them, and combine the MC and reference plots appropriately into a set of plot data files ending with `.dat`. More options are described by running `compare-histos --help`.

Incidentally, the reference files for each Rivet analysis are to be found in the installed Rivet shared data directory, `<installdir>/share/Rivet`. You can find the location of this by using the `rivet-config` command:

```
$ rivet-config --datadir
```

- You can plot the created data files using the `make-plots` command:

```
$ make-plots --pdf *.dat
```

The `--pdf` flag makes the output plots in PDF format: by default the output is in PostScript (`.ps`), and flags for conversion to EPS and PNG are also available.

Part II

Standard Rivet analyses

In this section we describe the standard experimental analyses included with the Rivet library. To maintain synchronisation with the code, these descriptions are generated automatically from the metadata in the analysis objects themselves.

5. LEP and SLC analyses

5.1 ALEPH_1991_S2435284 [12]

Hadronic Z decay charged multiplicity measurement

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: ALEPH (LEP 1)

Spires ID: [2435284](#)

Status: VALIDATED

Authors:

- Andy Buckley [⟨andy.buckley@cern.ch⟩](mailto:andy.buckley@cern.ch)

References:

- Phys. Lett. B, 273, 181 (1991)

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

The charged particle multiplicity distribution of hadronic Z decays, as measured on the peak of the Z resonance using the ALEPH detector at LEP. The unfolding procedure was model independent, and the distribution was found to have a mean of 20.85 ± 0.24 . Comparison with lower energy data supports the KNO scaling hypothesis. The shape of the multiplicity distribution is well described by a log-normal distribution, as predicted from a cascading model for multi-particle production.

5.2 ALEPH_1996_S3196992 [13]

Measurement of the quark to photon fragmentation function

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: ALEPH (LEP Run 1)

Spires ID: [3196992](#)

Status: VALIDATED

Authors:

- Frank Siegert (frank.siegert@cern.ch)

References:

- Z.Phys.C69:365-378,1996
- DOI: [10.1007/s002880050037](https://doi.org/10.1007/s002880050037)

Run details:

- $e^+e^- \rightarrow$ jets with π and η decays turned off.

Earlier measurements at LEP of isolated hard photons in hadronic Z decays, attributed to radiation from primary quark pairs, have been extended in the ALEPH experiment to include hard photon production inside hadron jets. Events are selected where all particles combine democratically to form hadron jets, one of which contains a photon with a fractional energy $z > 0.7$. After statistical subtraction of non-prompt photons, the quark-to-photon fragmentation function, $D(z)$, is extracted directly from the measured 2-jet rate.

5.3 ALEPH_1996_S3486095 [14]

Studies of QCD with the ALEPH detector.

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: ALEPH (LEP 1)

Spires ID: 3486095

Status: VALIDATED

Authors:

- Holger Schulz \langle holger.schulz@physik.hu-berlin.de \rangle

References:

- Phys. Rept., 294, 1–165 (1998)

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

Summary paper of QCD results as measured by ALEPH at LEP 1. The publication includes various event shape variables, multiplicities (identified particles and inclusive), and particle spectra.

5.4 ALEPH_1999_S4193598 [15]

Scaled energy distribution of D^* at LEP

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: ALEPH (LEP)

Spires ID: [4193598](#)

Status: VALIDATED

Authors:

- Holger Schulz \langle hschulz@physik.hu-berlin.de \rangle

References:

- Eur.Phys.J.C16:597-611,2000
- hep-ex/9909032
- CERN-EP-99-094

Run details:

- Hadronic Z decays at 91.2 GeV.

Study of Charm Production in Z Decays. Here, only the scaled energy distribution of $D^{*\pm}$ is implemented. Should be very important for fragmentation tuning.

5.5 ALEPH.2001.S4656318 [16]

Study of the fragmentation of b quarks into B mesons at the Z peak

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: ALEPH (LEP 1)

Spires ID: [4656318](#)

Status: VALIDATED

Authors:

- Peter Richardson (Peter.Richardson@durham.ac.uk)

References:

- Phys.Lett.B512:30-48,2001.
- hep-ex/0106051

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

Measurement of the b -quark fragmentation function by ALEPH using LEP 1 data. The fragmentation function for both weakly decaying and leading b -quarks has been determined. The data used for the plots has been renormalised to give a differential distribution rather than the bin-by-bin average in HEPDATA.

5.6 ALEPH_2002_S4823664 [17]

η and ω Production in Hadronic Z^0 Decays

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: OPAL (LEP 1)

Spires ID: [4823664](#)

Status: VALIDATED

Authors:

- Peter Richardson \langle Peter.Richardson@durham.ac.uk \rangle

References:

- Phys.Lett. B528 (2002) 19-33
- hep-ex/0201012

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

The production of η and ω mesons measured using 4 million Z^0 events by the ALEPH experiment at LEP. Only the fragmentation functions are implemented.

5.7 ALEPH_2004_S5765862 [18]

Jet rates and event shapes at LEP I and II

Beams: $e^+ e^-$

Energies: (45.6, 45.6), (66.5, 66.5), (80.5, 80.5), (86.0, 86.0), (91.5, 91.5), (94.5, 94.5), (98.5, 98.5), (100.0, 100.0), (103.0, 103.0) GeV

Experiment: ALEPH (LEP Run 1 and 2)

Spires ID: [5765862](#)

Status: VALIDATED

Authors:

- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

References:

- Eur.Phys.J.C35:457-486,2004
- DOI: [10.1140/epjc/s2004-01891-4](https://doi.org/10.1140/epjc/s2004-01891-4)
- <http://cdsweb.cern.ch/record/690637/files/ep-2003-084.pdf>

Run details:

- $e^+ e^- \rightarrow \text{jet jet (+ jets)}$

Jet rates, event-shape variables and inclusive charged particle spectra are measured in $e^+ e^-$ collisions at CMS energies between 91 and 209 GeV. The previously published data at 91.2 GeV and 133 GeV have been re-processed and the higher energy data are presented here for the first time. Note that the data have been corrected to include neutrinos.

5.8 DELPHI.1995.S3137023 [19]

Strange baryon production in Z hadronic decays at Delphi

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: DELPHI (LEP 1)

Spires ID: [3137023](#)

Status: VALIDATED

Authors:

- Hendrik Hoeth (hendrik.hoeth@cern.ch)

References:

- Z. Phys. C, 67, 543–554 (1995)

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

Measurement of the Ξ^- and $\Sigma^+(1385)/\Sigma^-(1385)$ scaled momentum distributions by DELPHI at LEP 1. The paper also has the production cross-sections of these particles, but that's not implemented in Rivet.

5.9 DELPHI.1996.S3430090 [10]

Delphi MC tuning on event shapes and identified particles.

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: DELPHI (LEP 1)

Spires ID: 3430090

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@cern.ch \rangle
- Hendrik Hoeth \langle hendrik.hoeth@cern.ch \rangle

References:

- Z.Phys.C73:11-60,1996
- DOI: [10.1007/s002880050295](https://doi.org/10.1007/s002880050295)

Run details:

- $\sqrt{s} = 91.2$ GeV, $e^+ e^- \rightarrow Z^0$ production with hadronic decays only

Event shape and charged particle inclusive distributions measured using 750000 decays of Z bosons to hadrons from the DELPHI detector at LEP. This data, combined with identified particle distributions from all LEP experiments, was used for tuning of shower-hadronisation event generators by the original PROFESSOR method. This is a critical analysis for MC event generator tuning of final state radiation and both flavour and kinematic aspects of hadronisation models.

5.10 DELPHI_1999_S3960137 [20]

Measurement of inclusive ρ^0 , $f_0(980)$, $f_2(1270)$, $K_2^{*0}(1430)$ and $f_2'(1525)$ production in Z^0 decays

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: DELPHI (LEP 1)

Spires ID: [3960137](#)

Status: VALIDATED

Authors:

- Peter Richardson [⟨Peter.Richardson@durham.ac.uk⟩](mailto:Peter.Richardson@durham.ac.uk)

References:

- Phys.Lett.B449:364-382,1999

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

DELPHI results for the production of ρ^0 , $f_0(980)$, $f_2(1270)$, $K_2^{*0}(1430)$ and $f_2'(1525)$ in Z^0 decays. Only the identified particle spectra for ρ^0 , $f_0(980)$ and $f_2(1270)$ are implemented.

5.11 DELPHI.2000.S4328825 [21]

Hadronization properties of b quarks compared to light quarks in $e^+e^- \rightarrow q\bar{q}$ from 183 GeV to 200 GeV

Beams: $e^+ e^-$

Energies: (91.5, 91.5), (94.5, 94.5), (96.0, 96.0), (98.0, 98.0), (100.0, 100.0), (103.0, 103.0) GeV

Experiment: OPAL (LEP 2)

Spires ID: 4328825

Status: VALIDATED

Authors:

- Peter Richardson (Peter.Richardson@durham.ac.uk)

References:

- Phys.Lett.B479:118-128,2000
- hep-ex/0103022
- DELPHI 2002-052 CONF 586

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

Measurements of the mean charged multiplicities separately for $b\bar{b}$, $c\bar{c}$ and light quark (uds) initiated events in e^+e^- interactions at energies above the Z^0 mass. In addition to the energy points in the original paper one additional point at 206 GeV is included from a later preliminary result.

5.12 DELPHI.2002.069.CONF.603

Study of the b -quark fragmentation function at LEP 1

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: DELPHI (LEP 1)

Status: PRELIMINARY

Authors:

- Hendrik Hoeth [〈hendrik.hoeth@cern.ch〉](mailto:hendrik.hoeth@cern.ch)

References:

- DELPHI note 2002-069-CONF-603 (ICHEP 2002)

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

Measurement of the b -quark fragmentation function by DELPHI using 1994 LEP 1 data. The fragmentation function for both weakly decaying and primary b -quarks has been determined in a model independent way. Nevertheless the authors trust $f(x_B^{\text{weak}})$ more than $f(x_B^{\text{prim}})$.

5.13 JADE_OPAL_2000_S4300807 [22]

Jet rates in e^+e^- at JADE [35–44 GeV] and OPAL [91–189 GeV].

Beams: e^+e^-

Energies: (17.5, 17.5), (22.0, 22.0), (45.6, 45.6), (66.5, 66.5), (80.5, 80.5), (86.0, 86.0), (91.5, 91.5), (94.5, 94.5) GeV

Experiment: JADE_OPAL (PETRA and LEP)

Spires ID: 4300807

Status: VALIDATED

Authors:

- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

References:

- Eur.Phys.J.C17:19-51,2000
- arXiv: [hep-ex/0001055](https://arxiv.org/abs/hep-ex/0001055)

Run details:

- $e^+e^- \rightarrow \text{jet jet (+ jets)}$

Differential and integrated jet rates for Durham and JADE jet algorithms.

5.14 OPAL_1993_S2692198 [23]

Measurement of photon production at LEP 1

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: OPAL (LEP Run 1)

Spires ID: 2692198

Status: VALIDATED

Authors:

- Peter Richardson (Peter.Richardson@durham.ac.uk)

References:

- Z.Phys.C58:405-418,1993
- DOI: [10.1007/BF01557697](https://doi.org/10.1007/BF01557697)

Run details:

- $e^+e^- \rightarrow \text{jet jet (+ photons)}$

Measurement of the production of photons in $e^+e^- \rightarrow q\bar{q}$ events at LEP 1.

5.15 OPAL_1994_S2927284 [24]

Measurement of the production rates of charged hadrons in e^+e^- annihilation at the Z^0

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: OPAL (LEP 1)

Spires ID: [2927284](#)

Status: VALIDATED

Authors:

- Peter Richardson \langle Peter.Richardson@durham.ac.uk \rangle

References:

- Z.Phys.C63:181-196,1994

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

The inclusive production rates of π^\pm , K^\pm and $p\bar{p}$ in Z^0 decays measured using the OPAL detector at LEP. Only the differential cross sections are currently implemented.

5.16 OPAL_1995_S3198391 [25]

Δ^{++} Production in Hadronic Z^0 Decays

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: OPAL (LEP 1)

Spires ID: 3198391

Status: VALIDATED

Authors:

- Peter Richardson \langle Peter.Richardson@durham.ac.uk \rangle

References:

- Phys.Lett.B358:162-172,1995

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

The production of Δ^{++} baryons measured using 3.5 million Z^0 events by the OPAL experiment at LEP. Only the fragmentation function is implemented.

5.17 OPAL_1996_S3257789 [26]

J/ψ and ψ' Production in Hadronic Z^0 Decays

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: OPAL (LEP 1)

Spires ID: [3257789](#)

Status: VALIDATED

Authors:

- Peter Richardson [⟨ Peter.Richardson@durham.ac.uk ⟩](mailto:Peter.Richardson@durham.ac.uk)

References:

- Z.Phys. C70 (1996) 197-210

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

The production of J/ψ and ψ' mesons measured by the OPAL experiment at LEP. The fragmentation function for J/ψ and the multiplicities of J/ψ and ψ' are included.

5.18 OPAL_1997_S3396100 [27]

Strange baryon production in Z hadronic decays at OPAL

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: OPAL (LEP 1)

Spires ID: 3396100

Status: VALIDATED

Authors:

- Peter Richardson \langle Peter.Richardson@durham.ac.uk \rangle

References:

- Z. Phys. C, 73, 569–586 (1997)

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

Measurement of the Ξ^- , Λ^0 , $\Sigma^+(1385)$, $\Sigma^-(1385)$, $\Xi^0(1530)$ and $\Lambda^0(1520)$ scaled momentum distributions by OPAL at LEP 1. The paper also has the production cross-sections of these particles, but that is not implemented in Rivet.

5.19 OPAL_1997_S3608263 [28]

K^{*0} meson production measured by OPAL at LEP 1.

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: OPAL (LEP 1)

Spires ID: 3608263

Status: VALIDATED

Authors:

- Peter Richardson (Peter.Richardson@durham.ac.uk)

References:

- Phys.Lett.B412:210-224,1997
- hep-ex/9708022

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

The K^{*0} fragmentation function has been measured in hadronic Z^0 decays. In addition the helicity density matrix elements for inclusive $K^*(892)^0$ mesons from hadronic Z^0 decays have been measured over the full range of K^{*0} momentum using data taken with the OPAL experiment at LEP. Only the fragmentation function measurement is currently implemented.

5.20 OPAL_1998_S3702294 [29]

Production of $f_0(980)$, $f_2(1270)$ and $\phi(1020)$ in hadronic Z^0 decay

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: OPAL (LEP 1)

Spires ID: [3702294](#)

Status: VALIDATED

Authors:

- Peter Richardson (Peter.Richardson@durham.ac.uk)

References:

- Eur.Phys.J.C4:19-28,1998
- hep-ex/9802013

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

Inclusive production of the $f_0(980)$, $f_2(1270)$ and $\phi(1020)$ resonances studied in a sample of 4.3 million hadronic Z^0 decays from the OPAL experiment at LEP. Fragmentation functions are reported for the three states.

5.21 OPAL_1998_S3749908 [30]

Photon and Light Meson Production in Hadronic Z^0 Decays

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: OPAL (LEP 1)

Spires ID: [3749908](#)

Status: VALIDATED

Authors:

- Peter Richardson (Peter.Richardson@durham.ac.uk)

References:

- Eur.Phys.J.C5:411-437,1998
- hep-ex/9805011

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

The inclusive production rates and differential cross sections of photons and mesons with a final state containing photons have been measured with the OPAL detector at LEP. The light mesons covered by the measurements are the π^0 , η , $\rho(770)^\pm$, $\omega(782)$, $\eta'(958)$ and $a_0(980)^\pm$.

5.22 OPAL_1998_S3780481 [31]

Measurements of flavor dependent fragmentation functions in $Z^0 \rightarrow q\bar{q}$ events

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: OPAL (LEP 1)

Spires ID: 3780481

Status: VALIDATED

Authors:

- Hendrik Hoeth (hendrik.hoeth@cern.ch)

References:

- Eur. Phys. J, C7, 369–381 (1999)
- hep-ex/9807004

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

Measurement of scaled momentum distributions and total charged multiplicities in flavour tagged events at LEP 1. OPAL measured these observables in uds-, c-, and b-events separately. An inclusive measurement is also included.

5.23 OPAL_2000_S4418603 [32]

Multiplicities of π^0 , η , K^0 and of charged particles in quark and gluon jets

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: OPAL (LEP 1)

Spires ID: [4418603](#)

Status: VALIDATED

Authors:

- Peter Richardson (Peter.Richardson@durham.ac.uk)

References:

- Eur.Phys.J.C17:373-387,2000
- hep-ex/0007017

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

Multiplicities of π^0 , η , K^0 and of charged particles in quark and gluon jets in 3-jet events, as measured by the OPAL experiment at LEP. The main implemented measurement is the K^0 fragmentation function.

5.24 OPAL_2001_S4553896 [33]

Four-jet angles using Durham algorithm

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: OPAL (LEP Run 1)

Spires ID: [4553896](#)

Status: VALIDATED

Authors:

- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

References:

- Eur.Phys.J.C20:601-615,2001
- DOI: [10.1007/s100520100699](https://doi.org/10.1007/s100520100699)
- arXiv: [hep-ex/0101044](https://arxiv.org/abs/hep-ex/0101044)

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV) Hadronisation should be turned off because the data is corrected back to the parton level.

Angles between the leading (in energy) four jets defined using the Durham algorithm with $y_{\text{cut}} = 0.008$. The data is presented at the parton level and includes the Bengtsson-Zerwas, Korner-Schierholz-Willrodt and Nachtmann-Reiter angles as well as the angle between the two softest jets.

5.25 OPAL_2002_S5361494 [34]

Charged particle multiplicities in heavy and light quark initiated events above the Z^0 peak

Beams: $e^+ e^-$

Energies: (65.0, 65.0), (68.0, 68.0), (80.5, 80.5), (86.0, 86.0), (91.5, 91.5), (94.5, 94.5), (96.0, 96.0), (98.0, 98.0), (100.0, 100.0), (101.0, 101.0), (103.0, 103.0) GeV

Experiment: OPAL (LEP 2)

Spires ID: 5361494

Status: VALIDATED

Authors:

- Peter Richardson \langle Peter.Richardson@durham.ac.uk \rangle

References:

- Phys.Lett. B550 (2002) 33-46
- hep-ex/0211007

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

Measurements of the mean charged multiplicities separately for $b\bar{b}$, $c\bar{c}$ and light quark (uds) initiated events in e^+e^- interactions at energies above the Z^0 mass. The data is from the LEP running periods between 1995 and 2000.

5.26 OPAL_2004_S6132243 [35]

Event shape distributions and moments in $e^+e^- \rightarrow \text{hadrons}$ at 91–209 GeV

Beams: e^+e^-

Energies: (45.6, 45.6), (66.5, 66.5), (88.5, 88.5), (98.5, 98.5) GeV

Experiment: OPAL (LEP 1 & 2)

Spires ID: 6132243

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@cern.ch \rangle

References:

- Eur.Phys.J.C40:287-316,2005
- hep-ex/0503051

Run details:

- Hadronic e^+e^- events at 4 representative energies (91, 133, 177, 197). Runs need to have ISR suppressed, since the analysis was done using a cut of $\sqrt{s} - \sqrt{s_{\text{reco}}} < 1 \text{ GeV}$. Particles with a lifetime $> 3 \cdot 10^{-10} \text{ s}$ are considered to be stable.

Measurement of e^+e^- event shape variable distributions and their 1st to 5th moments in LEP running from the Z pole to the highest LEP 2 energy of 209 GeV.

5.27 SLD_1996_S3398250 [36]

Charged particle multiplicities in heavy and light quark initiated events on the Z^0 peak

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: SLD (SLC)

Spires ID: 3398250

Status: VALIDATED

Authors:

- Peter Richardson \langle Peter.Richardson@durham.ac.uk \rangle

References:

- Phys.Lett.B386:475-485,1996
- hep-ex/9608008

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

Measurements of the mean charged multiplicities separately for $b\bar{b}$, $c\bar{c}$ and light quark (uds) initiated events in e^+e^- interactions at the Z^0 mass.

5.28 SLD_1999_S3743934 [37]

Production of π^+ , K^+ , K^0 , K^{*0} , Φ , p and Λ^0 in hadronic Z^0 decay

Beams: e^+e^-

Energies: (45.6, 45.6) GeV

Experiment: SLD (SLC)

Spires ID: [3743934](#)

Status: VALIDATED

Authors:

- Peter Richardson [⟨ Peter.Richardson@durham.ac.uk ⟩](mailto:Peter.Richardson@durham.ac.uk)

References:

- Phys.Rev.D59:052001,1999
- hep-ex/9805029

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

Measurement of scaled momentum distributions and fragmentation functions in flavour tagged events at SLC. SLD measured these observables in uds-, c-, and b-events separately. An inclusive measurement is also included.

5.29 SLD_2002_S4869273 [38]

Measurement of the b -quark fragmentation function in Z^0 decays

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: SLD (SLC)

Spires ID: [4869273](#)

Status: VALIDATED

Authors:

- Peter Richardson \langle Peter.Richardson@durham.ac.uk \rangle

References:

- Phys. Rev.D65:092006,2002
- hep-ex/0202031

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

Measurement of the b -quark fragmentation function by SLC. The fragmentation function for weakly decaying b -quarks has been measured.

5.30 SLD_2004_S5693039 [39]

Production of π^+ , π^- , K^+ , K^- , p and \bar{p} in Light (uds), c and b Jets from Z Decays

Beams: $e^+ e^-$

Energies: (45.6, 45.6) GeV

Experiment: SLD (SLC)

Spires ID: 5693039

Status: VALIDATED

Authors:

- Peter Richardson \langle Peter.Richardson@durham.ac.uk \rangle

References:

- Phys.Rev.D69:072003,2004
- hep-ex/0310017

Run details:

- Hadronic Z decay events generated on the Z pole ($\sqrt{s} = 91.2$ GeV)

Measurements of the differential production rates of stable charged particles in hadronic Z^0 decays, and of charged pions, kaons and protons identified over a wide momentum range. In addition to flavour-inclusive Z^0 decays, measurements are made for Z^0 decays into light (u , d , s), c and b primary flavors.

6. Tevatron analyses

6.1 CDF_1988_S1865951 [40]

CDF transverse momentum distributions at 630 GeV and 1800 GeV.

Beams: $\bar{p}p$

Energies: (315.0, 315.0), (900.0, 900.0) GeV

Experiment: CDF (Tevatron Run I)

Spires ID: [1865951](#)

Status: VALIDATED

Authors:

- Christophe Vaillant \langle c.l.j.vaillant@durham.ac.uk \rangle
- Andy Buckley \langle andy.buckley@cern.ch \rangle

References:

- Phys.Rev.Lett.61:1819,1988
- DOI: [10.1103/PhysRevLett.61.1819](https://doi.org/10.1103/PhysRevLett.61.1819)

Run details:

- QCD min bias events at $\sqrt{s} = 630$ GeV and 1800 GeV, $|\eta| < 1.0$.

Transverse momentum distributions at 630 GeV and 1800 GeV based on data from the CDF experiment at the Tevatron collider.

6.2 CDF_1990_S2089246 [41]

CDF pseudorapidity distributions at 630 and 1800 GeV

Beams: $\bar{p}p$

Energies: (315.0, 315.0), (900.0, 900.0) GeV

Experiment: CDF (Tevatron Run 0)

Spires ID: [2089246](#)

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@cern.ch \rangle

References:

- Phys.Rev.D41:2330,1990
- DOI: [10.1103/PhysRevD.41.2330](https://doi.org/10.1103/PhysRevD.41.2330)

Run details:

- QCD min bias events at $\sqrt{s} = 630$ and 1800 GeV. Particles with $c\tau > 10\text{mm}$ should be set stable.

Pseudorapidity distributions based on the CDF 630 and 1800 GeV runs from 1987. All data is detector corrected. The data confirms the UA5 measurement of a N/η rise with energy faster than $\ln \sqrt{s}$, and as such this analysis is important for constraining the energy evolution of minimum bias and underlying event characteristics in MC simulations.

6.3 CDF_1994_S2952106 [42]

CDF Run I color coherence analysis.

Beams: $\bar{p}p$

Energies: (900.0, 900.0) GeV

Experiment: CDF (Tevatron Run 1)

Spires ID: 2952106

Status: VALIDATED

Authors:

- Lars Sonnenschein [⟨Lars.Sonnenschein@cern.ch⟩](mailto:Lars.Sonnenschein@cern.ch)
- Andy Buckley [⟨andy.buckley@cern.ch⟩](mailto:andy.buckley@cern.ch)

References:

- Phys.Rev.D50,5562,1994
- DOI: [10.1103/PhysRevD.50.5562](https://doi.org/10.1103/PhysRevD.50.5562)

Run details:

- QCD events at $\sqrt{s} = 1800$ GeV. Leading jet $p_{\perp}^{\min} = 100$ GeV.

CDF Run I color coherence analysis. Events with ≥ 3 jets are selected and Et distributions of the three highest- p_{\perp} jets are obtained. The plotted quantities are the ΔR between the 2nd and 3rd leading jets in the p_{\perp} and pseudorapidity of the 3rd jet, and $\alpha = d\eta/d\phi$, where $d\eta$ is the pseudorapidity difference between the 2nd and 3rd jets and $d\phi$ is their azimuthal angle difference. Since the data has not been detector-corrected, a bin by bin correction is applied, based on the distributions with ideal and CDF simulation as given in the publication.

6.4 CDF_1996_S3418421 [43]

Dijet angular distributions

Beams: $\bar{p}p$

Energies: (900.0, 900.0) GeV

Experiment: CDF (Tevatron Run 1)

Spires ID: [3418421](#)

Status: VALIDATED

Authors:

- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- Phys.Rev.Lett.77:5336-5341,1996
- DOI: [10.1103/PhysRevLett.77.5336](https://doi.org/10.1103/PhysRevLett.77.5336)
- arXiv: [hep-ex/9609011](https://arxiv.org/abs/hep-ex/9609011)

Run details:

- QCD dijet events at Tevatron $\sqrt{s} = 1.8$ TeV without MPI.

Measurement of jet angular distributions in events with two jets in the final state in 5 bins of dijet invariant mass. Based on 106pb^{-1}

6.5 CDF_1998_S3618439 [44]

Differential cross-section for events with large total transverse energy

Beams: $\bar{p}p$

Energies: (900.0, 900.0) GeV

Experiment: CDF (Tevatron Run 1)

Spires ID: [3618439](#)

Status: UNVALIDATED

Authors:

- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- Phys.Rev.Lett.80:3461-3466,1998
- 10.1103/PhysRevLett.80.3461

Run details:

- QCD events at Tevatron with $\sqrt{s} = 1.8$ TeV without MPI.

Measurement of the differential cross section $d\sigma/dE_{\perp}^j$ for the production of multijet events in $p\bar{p}$ collisions where the sum is over all jets with transverse energy $E_{\perp}^j > E_{\perp}^{\min}$.

6.6 CDF_2000_S4155203 [45]

Z p_{\perp} measurement in CDF $Z \rightarrow e^+e^-$ events

Beams: $\bar{p}p$

Energies: (900.0, 900.0) GeV

Experiment: CDF (Tevatron Run 1)

Spires ID: [4155203](#)

Status: VALIDATED

Authors:

- Hendrik Hoeth (hendrik.hoeth@cern.ch)

References:

- Phys.Rev.Lett.84:845-850,2000
- arXiv: [hep-ex/0001021](#)
- DOI: [10.1103/PhysRevLett.84.845](#)

Run details:

- $p\bar{p}$ collisions at 1800 GeV. Z/γ^* Drell-Yan events with e^+e^- decay mode only. Restrict Z/γ^* mass range to roughly $50 \text{ GeV}/c^2 < m_{ee} < 120 \text{ GeV}/c^2$ for efficiency.

Measurement of transverse momentum and total cross section of e^+e^- pairs in the Z-boson region of $66 \text{ GeV}/c^2 < m_{ee} < 116 \text{ GeV}/c^2$ from $p\bar{p}$ collisions at $\sqrt{s} = 1.8 \text{ TeV}$, with the Tevatron CDF detector. The Z p_{\perp} , in a fully-factorised picture, is generated by the momentum balance against initial state radiation (ISR) and the primordial/intrinsic p_{\perp} of the Z's parent partons in the incoming hadrons. The Z p_{\perp} is important in generator tuning to fix the interplay of ISR and multi-parton interactions (MPI) ingenerating ‘underlying event’ activity. This analysis is subject to ambiguities in the experimental Z p_{\perp} definition, since the Rivet implementation reconstructs the Z momentum from the dilepton pair with finite cones for QED bremsstrahlung summation, rather than non-portable direct use of the (sometimes absent) Z in the event record.

6.7 CDF_2000_S4266730 [46]

Differential Dijet Mass Cross Section

Beams: $\bar{p}p$

Energies: (900.0, 900.0) GeV

Experiment: CDF (Tevatron Run 1)

Spires ID: [4266730](#)

Status: VALIDATED

Authors:

- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- Phys.Rev.D61:091101,2000
- DOI: [10.1103/PhysRevD.61.091101](https://doi.org/10.1103/PhysRevD.61.091101)
- arXiv: [hep-ex/9912022](https://arxiv.org/abs/hep-ex/9912022)

Run details:

- Dijet events at Tevatron with $\sqrt{s} = 1.8$ TeV

Measurement of the cross section for production of two or more jets as a function of dijet mass in the range 180 to 1000 GeV. It is based on an integrated luminosity of 86pb^{-1} .

6.8 CDF_2001_S4517016 [47]

Two jet triply-differential cross-section

Beams: $\bar{p}p$

Energies: (900.0, 900.0) GeV

Experiment: CDF (Tevatron Run 1)

Spires ID: 4517016

Status: UNVALIDATED

Authors:

- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- Phys.Rev.D64:012001,2001
- DOI: [10.1103/PhysRevD.64.012001](https://doi.org/10.1103/PhysRevD.64.012001)
- arXiv: [hep-ex/0012013](https://arxiv.org/abs/hep-ex/0012013)

Run details:

- Dijet events at Tevatron with $\sqrt{s} = 1.8$ TeV

A measurement of the two-jet differential cross section, $d^3\sigma/dE_T d\eta_1 d\eta_2$, based on an integrated luminosity of 86pb^{-1} . The differential cross section is measured as a function of the transverse energy, E_\perp , of a jet in the pseudorapidity region $0.1 < |\eta_1| < 0.7$ for four different pseudorapidity bins of a second jet restricted to $0.1 < |\eta_2| < 3.0$.

6.9 CDF_2001_S4563131 [48]

Inclusive jet cross section

Beams: $\bar{p}p$

Energies: (900.0, 900.0) GeV

Experiment: CDF (Tevatron Run 1)

Spires ID: [4563131](#)

Status: UNVALIDATED

Authors:

- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- Phys.Rev.D64:032001,2001
- DOI: [10.1103/PhysRevD.64.032001](https://doi.org/10.1103/PhysRevD.64.032001)
- arXiv: [hep-ph/0102074](https://arxiv.org/abs/hep-ph/0102074)

Run details:

- Dijet events at Tevatron with $\sqrt{s} = 1.8$ TeV

Measurement of the inclusive jet cross section for jet transverse energies from 40 to 465 GeV in the pseudo-rapidity range $0.1 < |\eta| < 0.7$. The results are based on 87 pb^{-1} of data.

6.10 CDF_2001_S4751469 [49]

Field & Stuart Run I underlying event analysis.

Beams: $\bar{p}p$

Energies: (900.0, 900.0) GeV

Experiment: CDF (Tevatron Run 1)

Spires ID: 4751469

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@cern.ch \rangle

References:

- Phys.Rev.D65:092002,2002
- FNAL-PUB 01/211-E

Run details:

- $p\bar{p}$ QCD interactions at 1800 GeV. The leading jet is binned from 0–49 GeV, and histos can usually be filled with a single generator run without kinematic sub-samples.

The original CDF underlying event analysis, based on decomposing each event into a transverse structure with “toward”, “away” and “transverse” regions defined relative to the azimuthal direction of the leading jet in the event. Since the toward region is by definition dominated by the hard process, as is the away region by momentum balance in the matrix element, the transverse region is most sensitive to multi-parton interactions. The transverse regions occupy $|\phi| \in [60^\circ, 120^\circ]$ for $|\eta| < 1$. The p_\perp ranges for the leading jet are divided experimentally into the ‘min-bias’ sample from 0–20 GeV, and the ‘JET20’ sample from 18–49 GeV.

6.11 CDF_2002_S4796047 [50]

CDF Run 1 charged multiplicity measurement

Beams: $\bar{p}p$

Energies: (315.0, 315.0), (900.0, 900.0) GeV

Experiment: CDF (Tevatron Run 1)

Spires ID: [4796047](#)

Status: VALIDATED

Authors:

- Hendrik Hoeth (hendrik.hoeth@cern.ch)

References:

- Phys.Rev.D65:072005,2002
- DOI: [10.1103/PhysRevD.65.072005](https://doi.org/10.1103/PhysRevD.65.072005)

Run details:

- QCD events at $\sqrt{s} = 630$ and 1800 GeV.

A study of $p\bar{p}$ collisions at $\sqrt{s} = 1800$ and 630 GeV collected using a minimum bias trigger in which the data set is divided into two classes corresponding to ‘soft’ and ‘hard’ interactions. For each subsample, the analysis includes measurements of the multiplicity, transverse momentum (p_{\perp}) spectra, and the average p_{\perp} and event-by-event p_{\perp} dispersion as a function of multiplicity. A comparison of results shows distinct differences in the behavior of the two samples as a function of the center of mass energy. The properties of the soft sample are invariant as a function of c.m. energy. It should be noticed that minimum bias tunings of PYTHIA made by ATLAS in early 2010, which used this among all other available data from CDF and from ATLAS at 900 GeV and 7 TeV, found an unavoidable tension between this data and the rest. Accordingly, this data was excluded from the fits. Whether this reflects a problem with this dataset or with the PYTHIA MPI model is a judgement for users to make!

6.12 CDF_2004_S5839831 [51]

Transverse cone and ‘Swiss cheese’ underlying event studies

Beams: $\bar{p}p$

Energies: (315.0, 315.0), (900.0, 900.0) GeV

Experiment: CDF (Tevatron Run 1)

Spires ID: 5839831

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@cern.ch \rangle

References:

- Phys. Rev. D70, 072002 (2004)
- arXiv: [hep-ex/0404004](https://arxiv.org/abs/hep-ex/0404004)

Run details:

- QCD events at $\sqrt{s} = 630$ & 1800 GeV. Several p_{\perp}^{\min} cutoffs are probably required to fill the profile histograms, e.g. 0 (min bias), 30, 90, 150 GeV at 1800 GeV, and 0 (min bias), 20, 90, 150 GeV at 630 GeV.

This analysis studies the underlying event via transverse cones of $R = 0.7$ at 90 degrees in ϕ relative to the leading (highest E) jet, at $\sqrt{s} = 630$ and 1800 GeV. This is similar to the 2001 CDF UE analysis, except that cones, rather than the whole central η range are used. The transverse cones are categorised as TransMIN and TransMAX on an event-by-event basis, to give greater sensitivity to the UE component. ‘Swiss Cheese’ distributions, where cones around the leading n jets are excluded from the distributions, are also included for $n = 2, 3$. This analysis is useful for constraining the energy evolution of the underlying event, since it performs the same analyses at two distinct CoM energies. **WARNING!** The p_{\perp} plots are normalised to raw number of events. The min bias data have not been reproduced by MC, and are not recommended for tuning.

6.13 CDF_2005_S6080774 [52]

Differential cross sections for prompt diphoton production

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: 6080774

Status: VALIDATED

Authors:

- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- Phys. Rev. Lett. 95, 022003
- DOI: [10.1103/PhysRevLett.95.022003](https://doi.org/10.1103/PhysRevLett.95.022003)
- arXiv: [hep-ex/0412050](https://arxiv.org/abs/hep-ex/0412050)

Run details:

- $p\bar{p} \rightarrow \gamma\gamma$ [+ jets] at 1960 GeV. The analysis uses photons with p_{\perp} larger than 13 GeV. To allow for shifts in the shower, the ME cut on the transverse photon momentum shouldn't be too hard, e.g. 5 GeV.

Measurement of the cross section of prompt diphoton production in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV using a data sample of 207 pb⁻¹ as a function of the diphoton mass, the transverse momentum of the diphoton system, and the azimuthal angle between the two photons.

6.14 CDF_2005_S6217184 [53]

CDF Run II jet shape analysis

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: [6217184](#)

Status: VALIDATED

Authors:

- Lars Sonnenschein \langle Lars.Sonnenschein@cern.ch \rangle
- Andy Buckley \langle andy.buckley@cern.ch \rangle

References:

- Phys.Rev.D71:112002,2005
- DOI: [10.1103/PhysRevD.71.112002](https://doi.org/10.1103/PhysRevD.71.112002)
- arXiv: [hep-ex/0505013](https://arxiv.org/abs/hep-ex/0505013)

Run details:

- QCD events at $\sqrt{s} = 1960$ GeV. Jet p_{\perp}^{\min} in plots is 37 GeV/c — choose generator min p_{\perp} somewhere well below this.

Measurement of jet shapes in inclusive jet production in $p\bar{p}$ collisions at center-of-mass energy $\sqrt{s} = 1.96$ TeV. The data cover jet transverse momenta from 37–380 GeV and absolute jet rapidities in the range 0.1–0.7.

6.15 CDF_2006_S6450792 [54]

Inclusive jet cross section differential in p_{\perp}

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: [6450792](#)

Status: VALIDATED

Authors:

- Frank Siegert (frank.siegert@cern.ch)

References:

- Phys.Rev.D74:071103,2006
- DOI: [10.1103/PhysRevD.74.071103](https://doi.org/10.1103/PhysRevD.74.071103)
- arXiv: [hep-ex/0512020](https://arxiv.org/abs/hep-ex/0512020)

Run details:

- $p\bar{p} \rightarrow$ jets at 1960 GeV

Measurement of the inclusive jet cross section in ppbar interactions at $\sqrt{s} = 1.96$ TeV using 385 pb^{-1} of data. The data cover the jet transverse momentum range from 61 to 620 GeV/c in $0.1 < |y| < 0.7$. This analysis has been updated with more data in more rapidity bins in CDF_2008_S7828950.

6.16 CDF_2006_S6653332 [55]

b-jet cross section in $Z + \text{jets}$ events

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: [6653332](#)

Status: VALIDATED

Authors:

- Lars Sonnenschein [⟨Lars.Sonnenschein@cern.ch⟩](mailto:Lars.Sonnenschein@cern.ch)
- Steffen Schumann [js.schumann\(at\)thphys.uni-heidelberg.de](mailto:js.schumann(at)thphys.uni-heidelberg.de)

References:

- Phys.Rev.D.74:032008,2006
- DOI: [10.1103/PhysRevD.74.032008](https://doi.org/10.1103/PhysRevD.74.032008)
- arXiv: [hep-ex/0605099v2](https://arxiv.org/abs/hep-ex/0605099v2)

Run details:

- $Z + \text{jets}$ events at $\sqrt{s} = 1960$ GeV. Jets min p_{\perp} cut = 20 GeV, leptons min p_{\perp} cut = 10 GeV

Measurement of the b -jet cross section in events with Z boson in $p\bar{p}$ collisions at center-of-mass energy $\sqrt{s} = 1.96$ TeV. The data cover jet transverse momenta above 20 GeV and jet pseudorapidities in the range -1.5 to 1.5. Z bosons are identified in their electron and muon decay modes in an invariant dilepton mass range between 66 and 116 GeV.

6.17 CDF_2007_S7057202 [56]

CDF Run II inclusive jet cross-section using the kT algorithm

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: 7057202

Status: VALIDATED

Authors:

- David Voong
- Frank Siegert (frank.siegert@cern.ch)

References:

- Phys.Rev.D75:092006,2007
- Erratum-ibid.D75:119901,2007
- FNAL-PUB 07/026-E
- hep-ex/0701051

Run details:

- p-pbar collisions at 1960 GeV. Jet p_{\perp} bins from 54 GeV to 700 GeV. Jet rapidity $< |2.1|$.

CDF Run II measurement of inclusive jet cross sections at a p-pbar collision energy of 1.96 TeV. Jets are reconstructed in the central part of the detector ($|y| < 2.1$) using the kT algorithm with an R parameter of 0.7. The minimum jet p_{\perp} considered is 54 GeV, with a maximum around 700 GeV. The inclusive jet p_{\perp} is plotted in bins of rapidity $|y| < 0.1$, $0.1 < |y| < 0.7$, $0.7 < |y| < 1.1$, $1.1 < |y| < 1.6$ and $1.6 < |y| < 2.1$.

6.18 CDF_2008_LEADINGJETS

CDF Run 2 underlying event in leading jet events

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: [NONE](#)

Status: OBSOLETE

Authors:

- Hendrik Hoeth (hendrik.hoeth@cern.ch)

No references listed

Run details:

- $p\bar{p}$ QCD interactions at 1960 GeV. Particles with $c\tau > 10$ mm should be set stable. Several p_{\perp}^{\min} cutoffs are probably required to fill the profile histograms. $p_{\perp}^{\min} = 0$ (min bias), 10, 20, 50, 100, 150 GeV. The corresponding merging points are at $p_T = 0, 30, 50, 80, 130, 180$ GeV

Rick Field’s measurement of the underlying event in leading jet events. If the leading jet of the event is within $|\eta| < 2$, the event is accepted and “toward”, “away” and “transverse” regions are defined in the same way as in the original (2001) CDF underlying event analysis. The leading jet defines the ϕ direction of the toward region. The transverse regions are most sensitive to the underlying event.

6.19 CDF_2008_NOTE_9351

CDF Run 2 underlying event in Drell-Yan

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: [NONE](#)

Status: OBSOLETE

Authors:

- Hendrik Hoeth (hendrik.hoeth@cern.ch)

References:

- CDF public note 9351

Run details:

- ppbar collisions at 1960 GeV.
- Drell-Yan events with $Z/\gamma^* \rightarrow ee$ and $Z/\gamma^* \rightarrow \mu\mu$.
- A mass cut $m_{ll} > 70$ GeV can be applied on generator level.
- Particles with $c\tau > 10$ mm should be set stable.

Deepak Kar and Rick Field’s measurement of the underlying event in Drell-Yan events. $Z \rightarrow ee$ and $Z \rightarrow \mu\mu$ events are selected using a Z mass window cut between 70 and 110 GeV. “Toward”, “away” and “transverse” regions are defined in the same way as in the original (2001) CDF underlying event analysis. The reconstructed Z defines the ϕ direction of the toward region. The leptons are ignored after the Z has been reconstructed. Thus the region most sensitive to the underlying event is the toward region (the recoil jet is boosted into the away region).

6.20 CDF_2008_S7540469 [57]

Measurement of differential $Z/\gamma^* + \text{jet} + X$ cross sections

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: 7540469

Status: VALIDATED

Authors:

- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- Phys.Rev.Lett.100:102001,2008
- arXiv: [0711.3717](https://arxiv.org/abs/0711.3717)

Run details:

- $p\bar{p} \rightarrow e^+e^- + \text{jets}$ at 1960 GeV. Needs mass cut on lepton pair to avoid photon singularity, looser than $66 < m_{ee} < 116$

Cross sections as a function of jet transverse momentum in 1 and 2 jet events, and jet multiplicity in ppbar collisions at $\sqrt{s} = 1.96$ TeV, based on an integrated luminosity of 1.7 fb^{-1} . The measurements cover the rapidity region $|y_{\text{jet}}| < 2.1$ and the transverse momentum range $p_{\perp}^{\text{jet}} > 30 \text{ GeV}/c$.

6.21 CDF_2008_S7828950 [58]

CDF Run II inclusive jet cross-section using the Midpoint algorithm

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: 7828950

Status: VALIDATED

Authors:

- Craig Group \langle group@fnal.gov \rangle
- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- arXiv: [0807.2204](#)
- Phys.Rev.D78:052006,2008

Run details:

- Requires $2 \rightarrow 2$ QCD scattering processes. The minimum jet E_{\perp} is 62 GeV, so a cut on kinematic p_{\perp}^{\min} may be required for good statistics.

Measurement of the inclusive jet cross section in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV as a function of jet E_{\perp} , for $E_{\perp} > 62$ GeV. The data is collected by the CDF II detector and has an integrated luminosity of 1.13 fb^{-1} . The measurement was made using the cone-based Midpoint jet clustering algorithm in rapidity bins within $|y| < 2.1$. This measurement can be used to provide increased precision in PDFs at high parton momentum fraction x .

6.22 CDF_2008_S8093652 [59]

Dijet mass spectrum

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: [8093652](#)

Status: VALIDATED

Authors:

- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- arXiv: [0812.4036](#)

Run details:

- $p\bar{p} \rightarrow$ jets at 1960 GeV

Dijet mass spectrum from 0.2 TeV to 1.4 TeV in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, based on an integrated luminosity of 1.13 fb^{-1} .

6.23 CDF_2008_S8095620 [60]

CDF Run II Z+b-jet cross section paper, 2 fb-1

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: 8095620

Status: VALIDATED

Authors:

- Emily Nurse [⟨nurse@hep.ucl.ac.uk⟩](mailto:nurse@hep.ucl.ac.uk)
- Steffen Schumann [js.schumann\(at\)thphys.uni-heidelberg.de](mailto:js.schumann(at)thphys.uni-heidelberg.de)

References:

- arXiv: [0812.4458](https://arxiv.org/abs/0812.4458)

Run details:

- Requires the process $p\bar{p} \rightarrow Z \rightarrow \ell\ell$, where ℓ is e or μ . Additional hard jets will also have to be included to get a good description.

Measurement of the b-jet production cross section for events containing a Z boson produced in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, using data corresponding to an integrated luminosity of 2 fb^{-1} collected by the CDF II detector at the Tevatron. Z bosons are selected in the electron and muon decay modes. Jets are considered with transverse energy $E_T > 20$ GeV and pseudorapidity $|\eta| < 1.5$. The ratio of the integrated $Z + \text{b-jet}$ cross section to the inclusive Z production cross section is measured differentially in jet E_T , jet η , Z -boson transverse momentum, number of jets, and number of b-jets. The first two measurements have an entry for each b-jet in the event, the last three measurements have one entry per event.

6.24 CDF_2009_NOTE_9936

CDF Run 2 min bias charged multiplicity analysis

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: [None](#)

Status: PRELIMINARY

Authors:

- Holger Schulz [⟨ holger.schulz@physik.hu-berlin.de ⟩](mailto:holger.schulz@physik.hu-berlin.de)

References:

- CDF public note 9936
- http://www-cdf.fnal.gov/physics/new/qcd/minbias_mult09/multpage.html

Run details:

- $p\bar{p}$ QCD interactions at 1960 GeV. Particles with c
 $\tau > 10$ mm should be set stable.

Niccolo Moggi's min bias analysis. Minimum bias events are used to measure the charged multiplicity distribution. The multiplicity distribution was not published in S8233977 but the numbers and a public note are available from the CDF website given above. Note: the systematic and statistical errors in Rivet were added in quadrature.

6.25 CDF_2009_S8233977 [61]

CDF Run 2 min bias cross-section analysis

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: [8233977](#)

Status: VALIDATED

Authors:

- Hendrik Hoeth \langle hendrik.hoeth@cern.ch \rangle
- Niccolo' Moggi \langle niccolo.moggi@bo.infn.it \rangle

References:

- Phys.Rev.D79:112005,2009
- DOI: [10.1103/PhysRevD.79.112005](https://doi.org/10.1103/PhysRevD.79.112005)
- arXiv: [0904.1098](https://arxiv.org/abs/0904.1098)

Run details:

- $p\bar{p}$ QCD interactions at 1960 GeV. Particles with c
 $\tau > 10$ mm should be set stable.

Niccolo Moggi's min bias analysis. Minimum bias events are used to measure the average track p_{\perp} vs. charged multiplicity, a track p_{\perp} distribution and an inclusive $\sum E_T$ distribution.

6.26 CDF_2009_S8383952 [62]

Z rapidity measurement

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: [8383952](#)

Status: VALIDATED

Authors:

- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

References:

- arXiv: [0908.3914](#)

Run details:

- $p\bar{p} \rightarrow e^+e^- + \text{jets}$ at 1960 GeV. Needs mass cut on lepton pair to avoid photon singularity, looser than $66 < m_{ee} < 116$ GeV

CDF measurement of the total cross section and rapidity distribution, $d\sigma/dy$, for $q\bar{q} \rightarrow \gamma^*/Z \rightarrow e^+e^-$ events in the Z boson mass region ($66 < M_{ee} < 116$ GeV/c²) produced in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV with 2.1 fb⁻¹ of integrated luminosity.

6.27 CDF_2009_S8436959 [63]

Measurement of the inclusive isolated prompt photon cross-section

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: [8436959](#)

Status: VALIDATED

Authors:

- Frank Siegert (frank.siegert@cern.ch)

References:

- arXiv: [0910.3623](#)

Run details:

- γ + jet processes in ppbar collisions at $\sqrt{s} = 1960$ GeV. Minimum p_{\perp} cut on the photon in the analysis is 30 GeV.

A measurement of the cross section for the inclusive production of isolated photons. The measurement covers the pseudorapidity region $|\eta^{\gamma}| < 1.0$ and the transverse energy range $E_T^{\gamma} > 30$ GeV and is based on 2.5 fb^{-1} of integrated luminosity. The cross section is measured differential in $E_{\perp}(\gamma)$.

6.28 CDF_2010_S8591881_DY

CDF Run 2 underlying event in Drell-Yan

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: [8591881](#)

Status: VALIDATED

Authors:

- Hendrik Hoeth (hendrik.hoeth@cern.ch)

References:

- Phys.Rev.D82:034001,2010

Run details:

- ppbar collisions at 1960 GeV.
- Drell-Yan events with $Z/\gamma^* \rightarrow ee$ and $Z/\gamma^* \rightarrow \mu\mu$.
- A mass cut $m_{ll} > 70$ GeV can be applied on generator level.
- Particles with $c\tau > 10$ mm should be set stable.

Deepak Kar and Rick Field’s measurement of the underlying event in Drell-Yan events. $Z \rightarrow ee$ and $Z \rightarrow \mu\mu$ events are selected using a Z mass window cut between 70 and 110 GeV. “Toward”, “away” and “transverse” regions are defined in the same way as in the original (2001) CDF underlying event analysis. The reconstructed Z defines the ϕ direction of the toward region. The leptons are ignored after the Z has been reconstructed. Thus the region most sensitive to the underlying event is the toward region (the recoil jet is boosted into the away region).

6.29 CDF_2010_S8591881_QCD

CDF Run 2 underlying event in leading jet events

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: [8591881](#)

Status: VALIDATED

Authors:

- Hendrik Hoeth (hendrik.hoeth@cern.ch)

References:

- Phys.Rev.D82:034001,2010

Run details:

- $p\bar{p}$ QCD interactions at 1960 GeV. Particles with $c\tau > 10$ mm should be set stable. Several p_{\perp}^{\min} cutoffs are probably required to fill the profile histograms. $p_{\perp}^{\min} = 0$ (min bias), 10, 20, 50, 100, 150 GeV. The corresponding merging points are at $p_T = 0, 30, 50, 80, 130, 180$ GeV

Rick Field’s measurement of the underlying event in leading jet events. If the leading jet of the event is within $|\eta| < 2$, the event is accepted and “toward”, “away” and “transverse” regions are defined in the same way as in the original (2001) CDF underlying event analysis. The leading jet defines the ϕ direction of the toward region. The transverse regions are most sensitive to the underlying event.

6.30 CDF_2012_NOTE10874

CDF energy scan underlying event analysis

Beams: $\bar{p}p$

Energies: (150.0, 150.0), (450.0, 450.0), (980.0, 980.0) GeV

Experiment: CDF (Tevatron energy scan)

Status: VALIDATED

Authors:

- Rick Field rfield@phys.ufl.edu

References:

- CDF Note 10874

Run details:

- $p\bar{p}$ QCD interactions at 300, 900, and 1960 GeV. Particles with $c\tau > 10$ mm should be set stable.

In this analysis the behavior of the underlying event in hard scattering proton-antiproton collisions at 300 GeV, 900 GeV, and 1.96 TeV is studied. The 300 GeV and 900 GeV data are a result of the Tevatron Energy Scan which was performed just before the Tevatron was shut down. The energy ratio histograms can be created from different runs with a merging script available in the Rivet bin directory.

6.31 D0_2000_S4480767 [64]

Transverse momentum of the W boson

Beams: $\bar{p}p$

Energies: (900.0, 900.0) GeV

Experiment: D0 (Tevatron Run 1)

Spires ID: [4480767](#)

Status: VALIDATED

Authors:

- Frank Siegert (frank.siegert@cern.ch)

References:

- Phys.Lett. B513 (2001) 292-300
- DOI: [10.1016/S0370-2693\(01\)00628-1](https://doi.org/10.1016/S0370-2693(01)00628-1)
- arXiv: [hep-ex/0010026](https://arxiv.org/abs/hep-ex/0010026)

Run details:

- Production of W⁺ and W⁻ decaying into the electron channel.

Measurement of the differential cross section for W boson production as a function of its transverse momentum. The data were collected by the D0 experiment at the Fermilab Tevatron Collider during 1994-1995 and correspond to an integrated luminosity of 85 pb⁻¹.

6.32 D0_2001_S4674421 [65]

Tevatron Run I differential W/Z boson cross-section analysis

Beams: $\bar{p}p$

Energies: (900.0, 900.0) GeV

Experiment: D0 (Tevatron Run 1)

Spires ID: [4674421](#)

Status: VALIDATED

Authors:

- Lars Sonnenschein [⟨Lars.Sonnenschein@cern.ch⟩](mailto:Lars.Sonnenschein@cern.ch)

References:

- Phys.Lett.B517:299-308,2001
- DOI: [10.1016/S0370-2693\(01\)01020-6](#)
- arXiv: [hep-ex/0107012v2](#)

Run details:

- W/Z events with decays to first generation leptons, in ppbar collisions at $\sqrt{s} = 1800$ GeV

Measurement of differential W/Z boson cross section and ratio in $p\bar{p}$ collisions at center-of-mass energy $\sqrt{s} = 1.8$ TeV. The data cover electrons and neutrinos in a pseudo-rapidity range of -2.5 to 2.5.

6.33 D0_2004_S5992206 [66]

Run II jet azimuthal decorrelation analysis

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Spires ID: [5992206](#)

Status: VALIDATED

Authors:

- Lars Sonnenschein (lars.sonnenschein@cern.ch)

References:

- Phys. Rev. Lett., 94, 221801 (2005)
- arXiv: [hep-ex/0409040](#)

Run details:

- QCD events in ppbar interactions at $\sqrt{s} = 1960$ GeV.

Correlations in the azimuthal angle between the two largest p_{\perp} jets have been measured using the D0 detector in ppbar collisions at 1960 GeV. The analysis is based on an inclusive dijet event sample in the central rapidity region. The correlations are determined for four different p_{\perp} intervals.

6.34 D0_2006_S6438750 [67]

Inclusive isolated photon cross-section, differential in p_{\perp} (gamma)

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Spires ID: 6438750

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@cern.ch \rangle
- Gavin Hesketh \langle gavin.hesketh@cern.ch \rangle
- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- Phys.Lett.B639:151-158,2006, Erratum-ibid.B658:285-289,2008
- DOI: [10.1016/j.physletb.2006.04.048](https://doi.org/10.1016/j.physletb.2006.04.048)
- arXiv: [hep-ex/0511054](https://arxiv.org/abs/hep-ex/0511054)

Run details:

- ppbar collisions at $\sqrt{s} = 1960$ GeV. Requires gamma + jet (q,qbar,g) hard processes, which for Pythia 6 means MSEL=10 for with MSUB indices 14, 18, 29, 114, 115 enabled.

Measurement of differential cross section for inclusive production of isolated photons in p pbar collisions at $\sqrt{s} = 1.96$ TeV with the DØdetector at the Fermilab Tevatron collider. The photons span transverse momenta 23–300 GeV and have pseudorapidity $|\eta| < 0.9$. Isolated direct photons are probes of pQCD via the annihilation ($q\bar{q} \rightarrow \gamma g$) and quark-gluon Compton scattering ($qg \rightarrow \gamma q$) processes, the latter of which is also sensitive to the gluon PDF. The initial state radiation / resummation formalisms are sensitive to the resulting photon p_{\perp} spectrum

6.35 D0_2007_S7075677 [68]

$Z/\gamma^* + X$ cross-section shape, differential in $y(Z)$

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Spires ID: 7075677

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@cern.ch \rangle
- Gavin Hesketh \langle ghesketh@fnal.gov \rangle
- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- Phys.Rev.D76:012003,2007
- arXiv: [hep-ex/0702025](https://arxiv.org/abs/hep-ex/0702025)

Run details:

- Drell-Yan $p\bar{p} \rightarrow Z/\gamma^* + \text{jets}$ events at $\sqrt{s} = 1960$ GeV. Needs mass cut on lepton pair to avoid photon singularity, looser than $71 < m_{ee} < 111$ GeV

Cross sections as a function of di-electron rapidity $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, based on an integrated luminosity of 0.4 fb^{-1} .

6.36 D0_2008_S6879055 [69]

Measurement of the ratio $\sigma(Z/\gamma^* + n \text{ jets})/\sigma(Z/\gamma^*)$

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Spires ID: [6879055](#)

Status: VALIDATED

Authors:

- Giulio Lenzi
- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- [hep-ex/0608052](#)

Run details:

- $p\bar{p} \rightarrow e^+e^- + \text{jets}$ at 1960 GeV. Needs mass cut on lepton pair to avoid photon singularity, looser than $75 < m_{ee} < 105$ GeV.

Cross sections as a function of p_\perp of the three leading jets and n -jet cross section ratios in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, based on an integrated luminosity of 0.4 fb^{-1} .

6.37 D0_2008_S7554427 [70]

$Z/\gamma^* + X$ cross-section shape, differential in $p_\perp(Z)$

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Spires ID: [7554427](#)

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@cern.ch \rangle
- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- arXiv: [0712.0803](#)

Run details:

- * $p\bar{p} \rightarrow e^+e^- + \text{jets}$ at 1960 GeV.
- Needs mass cut on lepton pair to avoid photon singularity, looser than $40 < m_{ee} < 200$ GeV.

Cross sections as a function of p_\perp of the vector boson inclusive and in forward region ($|y| > 2$, $p_\perp < 30$ GeV) in the di-electron channel in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, based on an integrated luminosity of 0.98 fb^{-1} .

6.38 D0_2008_S7662670 [71]

Measurement of D0 Run II differential jet cross sections

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Spires ID: 7662670

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@cern.ch \rangle
- Gavin Hesketh \langle gavin.hesketh@cern.ch \rangle

References:

- Phys.Rev.Lett.101:062001,2008
- DOI: [10.1103/PhysRevLett.101.062001](https://doi.org/10.1103/PhysRevLett.101.062001)
- arXiv: [0802.2400v3](https://arxiv.org/abs/0802.2400v3)

Run details:

- QCD events at $\sqrt{s} = 1960$ GeV. A p_{\perp}^{\min} cut is probably necessary since the lowest jet p_{\perp} bin is at 50 GeV

Measurement of the inclusive jet cross section in $p\bar{p}$ collisions at center-of-mass energy $\sqrt{s} = 1.96$ TeV. The data cover jet transverse momenta from 50–600 GeV and jet rapidities in the range -2.4 to 2.4.

6.39 D0_2008_S7719523 [72]

Isolated γ + jet cross-sections, differential in $p_{\perp}(\gamma)$ for various y bins

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Spires ID: 7719523

Status: VALIDATED

Authors:

- Andy Buckley [〈andy.buckley@cern.ch〉](mailto:andy.buckley@cern.ch)
- Gavin Hesketh [〈gavin.hesketh@cern.ch〉](mailto:gavin.hesketh@cern.ch)
- Frank Siegert [〈frank.siegert@cern.ch〉](mailto:frank.siegert@cern.ch)

References:

- Phys.Lett.B666:435-445,2008
- DOI: [10.1016/j.physletb.2008.06.076](https://doi.org/10.1016/j.physletb.2008.06.076)
- arXiv: [0804.1107v2](https://arxiv.org/abs/0804.1107v2)

Run details:

- Produce only gamma + jet (q, \bar{q}, g) hard processes (for Pythia 6, this means MSEL=10 and MSUB indices 14, 29 & 115 enabled). The lowest bin edge is at 30 GeV, so a kinematic p_{\perp}^{\min} cut is probably required to fill the histograms.

The process $p\bar{p} \rightarrow \text{photon} + \text{jet} + X$ as studied by the D0 detector at the Fermilab Tevatron collider at center-of-mass energy $\sqrt{s} = 1.96$ TeV. Photons are reconstructed in the central rapidity region $|y_{\gamma}| < 1.0$ with transverse momenta in the range 30–400 GeV, while jets are reconstructed in either the central $|y_{\text{jet}}| < 0.8$ or forward $1.5 < |y_{\text{jet}}| < 2.5$ rapidity intervals with $p_{\perp}^{\text{jet}} > 15$ GeV. The differential cross section $d^3\sigma/dp_{\perp}^{\gamma} dy_{\gamma} dy_{\text{jet}}$ is measured as a function of p_{\perp}^{γ} in four regions, differing by the relative orientations of the photon and the jet. MC predictions have trouble with simultaneously describing the measured normalization and p_{\perp}^{γ} dependence of the cross section in any of the four measured regions.

6.40 D0_2008_S7837160 [73]

Measurement of W charge asymmetry from D0 Run II

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Spires ID: 7837160

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@cern.ch \rangle
- Gavin Hesketh \langle gavin.hesketh@cern.ch \rangle

References:

- Phys.Rev.Lett.101:211801,2008
- DOI: [10.1103/PhysRevLett.101.211801](https://doi.org/10.1103/PhysRevLett.101.211801)
- arXiv: [0807.3367v1](https://arxiv.org/abs/0807.3367v1)

Run details:

- * Event type: W production with decay to $e\nu_e$ only
- for Pythia 6: MSEL = 12, MDME(206,1) = 1
- Energy: 1.96 TeV

Measurement of the electron charge asymmetry in $p\bar{p} \rightarrow W + X \rightarrow e\nu_e + X$ events at a center of mass energy of 1.96 TeV. The asymmetry is measured as a function of the electron transverse momentum and pseudorapidity in the interval $(-3.2, 3.2)$. This data is sensitive to proton parton distribution functions due to the valence asymmetry in the incoming quarks which produce the W. Initial state radiation should also affect the p_\perp distribution.

6.41 D0_2008_S7863608 [74]

Measurement of differential $Z/\gamma^* + \text{jet} + X$ cross sections

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Spires ID: 7863608

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@cern.ch \rangle
- Gavin Hesketh \langle gavin.hesketh@fnal.gov \rangle
- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- Phys.Lett. B669 (2008) 278-286
- DOI: [10.1016/j.physletb.2008.09.060](https://doi.org/10.1016/j.physletb.2008.09.060)
- arXiv: [0808.1296](https://arxiv.org/abs/0808.1296)

Run details:

- $p\bar{p} \rightarrow \mu^+\mu^- + \text{jets}$ at 1960 GeV. Needs mass cut on lepton pair to avoid photon singularity, looser than $65 < m_{\mu\mu} < 115$ GeV.

Cross sections as a function of p_\perp and rapidity of the boson and p_\perp and rapidity of the leading jet in the di-muon channel in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, based on an integrated luminosity of 1.0 fb^{-1} .

6.42 D0_2009_S8202443 [75]

$Z/\gamma^* + \text{jet} + X$ cross sections differential in p_\perp (jet 1,2,3)

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Spires ID: [8202443](#)

Status: VALIDATED

Authors:

- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

References:

- arXiv: [0903.1748](#)

Run details:

- $p\bar{p} \rightarrow e^+e^- + \text{jets}$ at 1960 GeV. Needs mass cut on lepton pair to avoid photon singularity, looser than $65 < m_{ee} < 115$ GeV.

Cross sections as a function of p_\perp of the three leading jets in $Z/\gamma^*(\rightarrow e^+e^-) + \text{jet} + X$ production in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, based on an integrated luminosity of 1.0 fb^{-1} .

6.43 D0_2009_S8320160 [76]

Dijet angular distributions

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Spires ID: 8320160

Status: VALIDATED

Authors:

- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- arXiv: [0906.4819](https://arxiv.org/abs/0906.4819)

Run details:

- $p\bar{p} \rightarrow$ jets at 1960 GeV

Dijet angular distributions in different bins of dijet mass from 0.25 TeV to above 1.1 TeV in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, based on an integrated luminosity of 0.7 fb^{-1} .

6.44 D0_2009_S8349509 [77]

Z+jets angular distributions

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Spires ID: [8349509](#)

Status: VALIDATED

Authors:

- Frank Siegert (frank.siegert@cern.ch)

References:

- arXiv: [0907.4286](#)

Run details:

- $p\bar{p} \rightarrow \mu^+\mu^- + \text{jets}$ at 1960 GeV. Needs mass cut on lepton pair to avoid photon singularity, looser than $65 < m_{ee} < 115$ GeV.

First measurements at a hadron collider of differential cross sections for $Z(\rightarrow \mu\mu)+\text{jet}+X$ production in $\Delta\phi(Z, j)$, $|\Delta y(Z, j)|$ and $|y_{\text{boost}}(Z, j)|$. Vector boson production in association with jets is an excellent probe of QCD and constitutes the main background to many small cross section processes, such as associated Higgs production. These measurements are crucial tests of the predictions of perturbative QCD and current event generators, which have varied success in describing the data. Using these measurements as inputs in tuning event generators will increase the experimental sensitivity to rare signals.

6.45 D0_2010_S8566488 [78]

Dijet invariant mass

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Spires ID: [8566488](#)

Status: VALIDATED

Authors:

- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

References:

- arXiv: [1002.4594](#)

Run details:

- $p\bar{p} \rightarrow \text{jets}$ at 1960 GeV. Analysis needs two hard jets above 40 GeV.

The inclusive dijet production double differential cross section as a function of the dijet invariant mass and of the largest absolute rapidity ($|y|_{\text{max}}$) of the two jets with the largest transverse momentum in an event is measured using 0.7 fb^{-1} of data. The measurement is performed in six rapidity regions up to $|y|_{\text{max}} = 2.4$.

6.46 D0_2010_S8570965 [79]

Direct photon pair production

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: CDF (Tevatron Run 2)

Spires ID: [8570965](#)

Status: VALIDATED

Authors:

- Frank Siegert (frank.siegert@cern.ch)

References:

- arXiv: [1002.4917](#)

Run details:

- All processes that can produce prompt photon pairs, e.g. $jj \rightarrow jj$, $jj \rightarrow j\gamma$ and $jj \rightarrow \gamma\gamma$. Non-prompt photons from hadron decays like π and η have been corrected for.

Direct photon pair production cross sections are measured using 4.2 fb^{-1} of data. They are binned in diphoton mass, the transverse momentum of the diphoton system, the azimuthal angle between the photons, and the polar scattering angle of the photons. Also available are double differential cross sections considering the last three kinematic variables in three diphoton mass bins. Note, the numbers in version 1 of the arXiv preprint were missing the dM normalisation in the double differential cross sections. This has been reported to and fixed by the authors in v2 and the journal submission. HepData as well as the Rivet analysis have also been updated.

6.47 D0_2010_S8671338 [80]

Measurement of differential $Z/\gamma^* p_\perp$

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Spires ID: [8671338](#)

Status: VALIDATED

Authors:

- Flavia Dias [⟨fladiaz@gmail.com⟩](mailto:fladiaz@gmail.com)
- Gavin Hesketh [⟨gavin.hesketh@cern.ch⟩](mailto:gavin.hesketh@cern.ch)
- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

References:

- arXiv: [1006.0618](#)

Run details:

- $p\bar{p} \rightarrow \mu^+\mu^- + \text{jets}$ at 1960 GeV. Needs mass cut on lepton pair to avoid photon singularity, looser than $65 < m_{\mu\mu} < 115$ GeV. Restrict Z/γ^* mass range to roughly $50 \text{ GeV}/c^2 < m_{\mu\mu} < 120 \text{ GeV}/c^2$ for efficiency. Weighted events and kinematic sampling enhancement can help to fill the p_\perp tail.

Cross section as a function of p_\perp of the Z boson decaying into muons in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, based on an integrated luminosity of 0.97 fb^{-1} .

6.48 D0_2010_S8821313 [81]

Precise study of $Z p_{\perp}$ using novel technique

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Spires ID: [8821313](#)

Status: VALIDATED

Authors:

- Frank Siegert (frank.siegert@cern.ch)

References:

- arXiv: [1010.0262](#)

Run details:

- Inclusive Z/γ^* production in both electron and muon channels. Cut on invariant lepton mass should be wider than $70 < m_{\ell\ell} < 110$ GeV.

Using 7.3 pb⁻¹ the distribution of the variable ϕ^* is measured, which probes the same physical effects as the Z/γ^* boson transverse momentum, but is less susceptible to the effects of experimental resolution and efficiency. Results are presented for both the di-electron and di-muon channel.

6.49 D0_2011_I895662 [82]

3-jet invariant mass

Beams: $\bar{p}p$

Energies: (980.0, 980.0) GeV

Experiment: D0 (Tevatron Run 2)

Status: VALIDATED

Authors:

- Hendrik Hoeth \langle hendrik.hoeth@cern.ch \rangle

References:

- arxiv:1104.1986

Run details:

- QCD events, three jets above 40 GeV.

Inclusive three-jet differential cross-section as a function of invariant mass of the three jets with the largest transverse momenta. The measurement is made in three rapidity regions ($|y| < 0.8, 1.6, 2.4$) and with jets above 40, 70, and 100 GeV.

7. LHC analyses

7.1 ALICE_2010_S8624100 [83]

Charged particle multiplicities at 0.9 & 2.36 TeV in three different pseudorapidity intervals.

Beams: pp

Energies: (450.0, 450.0), (1180.0, 1180.0) GeV

Experiment: ALICE (LHC)

Spires ID: 8624100

Status: VALIDATED

Authors:

- Holger Schulz [⟨ holger.schulz@physik.hu-berlin.de ⟩](mailto:holger.schulz@physik.hu-berlin.de)
- Jan Fiete Grosse-Oetringhaus@cern.ch [⟨ Jan.Fiete.Grosse-Oetringhaus@cern.ch ⟩](mailto:Jan.Fiete.Grosse-Oetringhaus@cern.ch)

References:

- Eur.Phys.J.C68:89-108,2010
- arXiv: [1004.3034](https://arxiv.org/abs/1004.3034)

Run details:

- QCD and diffractive events at $\sqrt{s} = 0.9$ TeV and $\sqrt{s} = 2.36$ TeV

This is an ALICE analysis where charged particle multiplicities (including the zero bin) have been measured in three different pseudorapidity intervals ($|\eta| < 0.5$; $|\eta| < 1.0$; $|\eta| < 1.3$). Only the INEL distributions have been considered here, i.e. this analysis can only be meaningfully compared to PYTHIA 6 with diffractive processes disabled. The data were taken at 900 and 2360 GeV.

7.2 ALICE_2010_S8625980 [84]

Pseudorapidities at three energies, charged multiplicity at 7 TeV.

Beams: pp

Energies: (450.0, 450.0), (1180.0, 1180.0), (3500.0, 3500.0) GeV

Experiment: ALICE (LHC)

Spires ID: [8625980](#)

Status: VALIDATED

Authors:

- Holger Schulz \langle holger.schulz@physik.hu-berlin.de \rangle
- Jan Fiete Grosse-Oetringhaus@cern.ch \langle Jan.Fiete.Grosse-Oetringhaus@cern.ch \rangle

References:

- Eur.Phys.J. C68 (2010) 345-354
- arXiv: [1004.3514](#)

Run details:

- Diffractive events need to be enabled.

This is an ALICE publication with pseudorapities for 0.9, 2.36 and 7 TeV and the charged multiplicity at 7 TeV. The analysis requires at least on charged particle in the event. Only the INEL distributions are considered here

7.3 ALICE_2010_S8706239 [85]

Charged particle $\langle p_{\perp} \rangle$ vs. N_{ch} in pp collisions at 900 GeV

Beams: pp

Energies: (450.0, 450.0) GeV

Experiment: ALICE (LHC)

Spires ID: [8706239](#)

Status: VALIDATED

Authors:

- Holger Schulz \langle holger.schulz@physik.hu-berlin.de \rangle
- Jan Fiete Grosse-Oetringhaus@cern.ch \langle Jan.Fiete.Grosse-Oetringhaus@cern.ch \rangle

References:

- Phys.Lett.B693:53-68,2010
- arXiv: [1007.0719](#)

Run details:

- Diffractive events need to be switched on

ALICE measurement of $\langle p_{\perp} \rangle$ vs. N_{ch} and invariant particle yield (as function of p_{\perp}) in proton-proton collisions at $\sqrt{s} = 900$ GeV.

7.4 ALICE_2011_S8909580 [86]

Strange particle production in proton-proton collisions at $\sqrt{s} = 0.9$ TeV with ALICE at the LHC.

Beams: pp

Energies: (450.0, 450.0) GeV

Experiment: ALICE (LHC)

Spires ID: 8909580

Status: VALIDATED

Authors:

- Pablo Bueno Gomez [⟨UO189399@uniovi.es⟩](mailto:UO189399@uniovi.es)
- Eva Sicking [⟨esicking@cern.ch⟩](mailto:esicking@cern.ch)

References:

- Eur.Phys.J.C71:1594,2011.

Run details:

- Diffractive events need to be switched on.

Transverse momentum spectra of strange particles (K_S^0 , Λ , ϕ and Ξ) in pp collisions at $\sqrt{s} = 0.9$ TeV with ALICE at the LHC. The ratio of cross-sections as a function of p_\perp for Λ/K_S^0 is also included.

7.5 ALICE_2011_S8945144 [87]

Transverse momentum spectra of pions, kaons and protons in pp collisions at 0.9 TeV

Beams: pp

Energies: (450.0, 450.0) GeV

Experiment: ALICE (LHC)

Spires ID: [8945144](#)

Status: VALIDATED

Authors:

- Pablo Bueno Gomez [⟨UO189399@uniovi.es⟩](mailto:UO189399@uniovi.es)
- Eva Sicking [⟨esicking@cern.ch⟩](mailto:esicking@cern.ch)

References:

- Eur.Phys.J.C71:1655,2011.

Run details:

- Diffractive events need to be enabled.

Obtaining the transverse momentum spectra of pions, kaons and protons in pp collisions at $\sqrt{s} = 0.9$ TeV with ALICE at the LHC. Mean transverse momentum as a function of the mass of the emitted particle is also included.

7.6 ALICE_2012_I1181770 [88]

Measurement of inelastic, single- and double-diffraction cross sections in proton–proton collisions at the LHC with ALICE

Beams: pp

Energies: (450.0, 450.0), (1380.0, 1380.0), (3500.0, 3500.0) GeV

Experiment: ALICE (LHC)

Status: VALIDATED

Authors:

- Martin Poghosyan [⟨ Martin.Poghosyan@cern.ch ⟩](mailto:Martin.Poghosyan@cern.ch)
- Sercan Sen [⟨ Sercan.Sen@cern.ch ⟩](mailto:Sercan.Sen@cern.ch)
- Burak Bilki [⟨ bbilki@gmail.com ⟩](mailto:bbilki@gmail.com)
- Andy Buckley [⟨ andy.buckley@cern.ch ⟩](mailto:andy.buckley@cern.ch)

References:

- arXiv: [1208.4968](https://arxiv.org/abs/1208.4968)

Run details:

- Inelastic events (non-diffractive and inelastic diffractive).

Measurements of cross-sections of inelastic and diffractive processes in proton-proton collisions at $\sqrt{s} = 900, 2760$ and 7000 GeV. The fractions of diffractive processes in inelastic collisions were determined from a study of gaps in charged particle pseudorapidity distributions. Single-diffractive events are selected with $M_X < 200$ GeV/ c^2 and double-diffractive events defined as NSD events with $\Delta\eta > 3$. To measure the inelastic cross-section, beam properties were determined with van der Meer scans using a simulation of diffraction adjusted to data. Note that these are experimental approximations to theoretical concepts – it is not totally clear whether the data point values are model-independent.

7.7 ATLAS_2010_S8591806 [89]

Charged particles at 900 GeV in ATLAS

Beams: pp

Energies: (450.0, 450.0) GeV

Experiment: ATLAS (LHC 900GeV)

Spires ID: 8591806

Status: VALIDATED

Authors:

- Frank Siegert (frank.siegert@cern.ch)

References:

- arXiv: [1003.3124](#)

Run details:

- pp QCD interactions at 900 GeV including diffractive events.

The first measurements with the ATLAS detector at the LHC. Data were collected using a minimum-bias trigger in December 2009 during proton-proton collisions at a centre of mass energy of 900 GeV. The charged- particle density, its dependence on transverse momentum and pseudorapid- ity, and the relationship between transverse momentum and charged-particle multiplicity are measured for events with at least one charged particle in the kinematic range $|\eta| < 2.5$ and $p_{\perp} > 500$ MeV. All data is corrected to the particle level.

7.8 ATLAS_2010_S8817804 [90]

Inclusive jet cross section and di-jet mass and chi spectra at 7 TeV in ATLAS

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC 7TeV)

Spires ID: 8817804

Status: VALIDATED

Authors:

- James Monk \langle jmonk@cern.ch \rangle

References:

- arXiv: [1009.5908](https://arxiv.org/abs/1009.5908)

Run details:

- pp QCD jet production with a minimum jet p_{\perp} of 60 GeV (inclusive) or 30 GeV (di-jets) at 7 TeV.

The first jet cross section measurement made with the ATLAS detector at the LHC. Anti-kt jets with $R = 0.4$ and $R = 0.6$ are reconstructed within $|y| < 2.8$ and above 60 GeV for the inclusive jet cross section plots. For the di-jet plots the second jet must have $p_{\perp} \geq 30$ GeV. Jet p_{\perp} and di-jet mass spectra are plotted in bins of rapidity $|y| < 0.3$, $0.3 < |y| < 0.8$, $0.8 < |y| < 1.2$, $1.2 < |y| < 2.1$, $2.1 < |y| < 2.8$. Di-jet χ spectra are plotted in bins of di-jet mass $340 \text{ GeV} < m_{12} < 520 \text{ GeV}$, $520 \text{ GeV} < m_{12} < 800 \text{ GeV}$ and $800 \text{ GeV} < m_{12} < 1200 \text{ GeV}$.

7.9 ATLAS_2010_S8894728

Track-based underlying event at 900 GeV and 7 TeV in ATLAS

Beams: pp

Energies: (450.0, 450.0), (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: [8894728](#)

Status: VALIDATED

Authors:

- Andy Buckley [⟨ andy.buckley@cern.ch ⟩](mailto:andy.buckley@cern.ch)
- Holger Schulz [⟨ holger.schulz@physik.hu-berlin.de ⟩](mailto:holger.schulz@physik.hu-berlin.de)

References:

- arXiv: [1012.0791](#)

Run details:

- pp QCD interactions at 900 GeV and 7 TeV. Diffractive events should be included, but only influence the lowest bins. Multiple kinematic cuts should not be required.

The underlying event measurements with the ATLAS detector at the LHC at the center of mass energies of 900 GeV and 7 TeV. The observables sensitive to the underlying event, i.e the charged particle density and charged p_{\perp} sum, as well as their standard deviations and the average p_{\perp} , are measured as functions of the leading track. A track p_{\perp} cut of 500 MeV is applied for most observables, but the main profile plots are also shown for a lower track cut of 100 MeV, which includes much more of the soft cross-section. The angular distribution of the charged tracks with respect to the leading track is also studied, as are the correlation between mean transverse momentum and charged particle multiplicity, and the ‘plateau’ height as a function of the leading track $|\eta|$.

7.10 ATLAS_2010_S8914702 [91]

Inclusive isolated prompt photon analysis

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC 7TeV)

Spires ID: [8914702](#)

Status: VALIDATED

Authors:

- Mike Hance \langle michael.hance@cern.ch \rangle

References:

- arXiv: [1012.4389](#)

Run details:

- Inclusive photon+X events (primary gamma+jet events) at $\sqrt{s} = 7$ TeV.

A measurement of the cross section for inclusive isolated photon production at $\sqrt{s} = 7$ TeV. The measurement covers three ranges in $|\eta|$: $[0.00, 0.60)$, $[0.60, 1.37)$, and $[1.52, 1.81)$, for $E_T^\gamma > 15$ GeV. The measurement uses 880nb^{-1} of integrated luminosity collected with the ATLAS detector.

7.11 ATLAS_2010_S8918562

Track-based minimum bias at 900 GeV and 2.36 and 7 TeV in ATLAS

Beams: pp

Energies: (450.0, 450.0), (1180.0, 1180.0), (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: [8918562](#)

Status: VALIDATED

Authors:

- Thomas Burgess [⟨ thomas.burgess@cern.ch ⟩](mailto:thomas.burgess@cern.ch)
- Andy Buckley [⟨ andy.buckley@cern.ch ⟩](mailto:andy.buckley@cern.ch)

References:

- arXiv: [1012.5104](#)

Run details:

- pp QCD interactions at 0.9, 2.36, and 7 TeV. Diffractive events should be included. Multiple kinematic cuts should not be required.

Measurements from proton-proton collisions at centre-of-mass energies of $\sqrt{s} = 0.9, 2.36$, and 7 TeV recorded with the ATLAS detector at the LHC. Events were collected using a single-arm minimum-bias trigger. The charged-particle multiplicity, its dependence on transverse momentum and pseudorapidity and the relationship between the mean transverse momentum and charged-particle multiplicity are measured. Measurements in different regions of phase-space are shown, providing diffraction-reduced measurements as well as more inclusive ones. The observed distributions are corrected to well-defined phase-space regions, using model-independent corrections.

7.12 ATLAS_2010_S8919674 [92]

W+jets jet multiplicities and p_{\perp}

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: [8919674](#)

Status: VALIDATED

Authors:

- Frank Siegert (frank.siegert@cern.ch)

References:

- arXiv: [1012.5382](#)

Run details:

- W+jets events ideally with matrix element corrections to describe the higher jet multiplicities correctly. Both channels, electron and muon, are part of this analysis and should be run simultaneously.

Cross sections, in both the electron and muon decay modes of the W boson, are presented as a function of jet multiplicity and of the transverse momentum of the leading and next-to-leading jets in the event. Measurements are also presented of the ratio of cross sections for inclusive jet multiplicities. The results, based on an integrated luminosity of 1.3 pb⁻¹, have been corrected for all known detector effects and are quoted in a limited and well-defined range of jet and lepton kinematics.

7.13 ATLAS_2011_I894867 [93]

Measurement of the inelastic proton-proton cross-section at $\sqrt{s}=7$ TeV.

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Status: VALIDATED

Authors:

- Anton Karneyeu [〈Anton.Karneyeu@cern.ch〉](mailto:Anton.Karneyeu@cern.ch)
- Sercan Sen [〈Sercan.Sen@cern.ch〉](mailto:Sercan.Sen@cern.ch)

References:

- arXiv: [1104.0326](#)

Run details:

- Inelastic events (non-diffractive and inelastic diffractive).

Inelastic cross-section is measured for $\xi > 5 \times 10^{-6}$, where $\xi = M_X^2/s$ is calculated from the invariant mass, M_X , of hadrons selected using the largest rapidity gap in the event.

7.14 ATLAS_2011_I919017 [94]

Measurement of ATLAS track jet properties at 7 TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Status: VALIDATED

Authors:

- Seth Zenz \langle seth.zenz@cern.ch \rangle
- Andy Buckley \langle andy.buckley@cern.ch \rangle

References:

- Phys.Rev.D 84 (2011) 054001
- DOI: [10.1103/PhysRevD.84.054001](https://doi.org/10.1103/PhysRevD.84.054001)
- arXiv: [1107.3311](https://arxiv.org/abs/1107.3311)
- ATLAS-STDm-2010-14
- CERN-PH-EP-2011-110

Run details:

- Min bias QCD at 7 TeV.

ATLAS measurement of track jet p_{\perp} , multiplicity per jet, longitudinal fragmentation, transverse momentum, radius w.r.t jet axis distributions, with jets constructed from charged tracks with $p_{\perp} > 300$ MeV, using the anti- k_T jet algorithm with $R = 0.4, 0.6$.

7.15 ATLAS_2011_I925932 [95]

Measurement of the W p_{\perp} with electrons and muons at 7 TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Status: VALIDATED

Authors:

- Elena Yatsenko [⟨ elena.yatsenko@desy.de ⟩](mailto:elena.yatsenko@desy.de)
- Judith Katzy [⟨ jkatzy@mail.cern.ch ⟩](mailto:jkatzy@mail.cern.ch)

References:

- arXiv: [1108.6308v1](#)

Run details:

- Run with W decays to $e\nu_e$ and/or $\mu\nu_{\mu}$.

The W p_{\perp} at $\sqrt{s} = 7$ TeV is measured using $W \rightarrow e\nu_e$ and $W \rightarrow \mu\nu_{\mu}$ decay channels. The dressed leptons kinematics calculated from the sum of the post-FSR lepton momentum and the momenta of all photons radiated in a cone around the lepton, while the bare uses the lepton kinematics after all QED radiation.

7.16 ATLAS_2011_I926145 [96]

Measurement of electron and muon differential cross-section from heavy-flavour decays

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: 9185208

Status: VALIDATED

Authors:

- Paul Bell \langle paul.bell@cern.ch \rangle
- Holger Schulz \langle holger.schulz@physik.hu-berlin.de \rangle

References:

- CERN-PH-EP-2011-108
- arXiv: [1109.0525](https://arxiv.org/abs/1109.0525)

Run details:

- pp to $e + X$ or $\mu + X$ at 7 TeV, heavy-flavour (bb and cc) production with $B/D \rightarrow e$ or μ

Measurement of inclusive electron and muon cross sections for $7 <$

$pT < 26$ GeV in $|\eta| < 2.0$, excluding $1.37 < |\eta| < 1.52$, and muon cross section for $4 <$

$pT < 100$ GeV in $|\eta| < 2.50$. $W/Z/\gamma^*$ component must be subtracted to leave the heavy flavour contribution.

7.17 ATLAS_2011_I944826 [97]

KS0 and Lambda production at 0.9 and 7 TeV with ATLAS

Beams: pp

Energies: (450.0, 450.0), (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Status: VALIDATED

Authors:

- Holger Schulz [⟨ holger.schulz@physik.hu-berlin.de ⟩](mailto:holger.schulz@physik.hu-berlin.de)

References:

- arXiv: [1111.1297v2](#)
- Phys.Rev. D85 (2012) 012001

Run details:

- QCD events, 900GeV and 7TeV, Lambdas and Kshorts must be able to decay. Allow only charged decay modes to improve efficiency.

The production of Kshort and Lambda hadrons is studied in inelastic pp collisions at $\sqrt{s} = 0.9$ and 7 TeV collected with the ATLAS detector at the LHC using a minimum-bias trigger. The observed distributions of transverse momentum, rapidity, and multiplicity are corrected to hadron level in a model-independent way within well defined phase-space regions. The distribution of the production ratio of Lambdabar to Lambda baryons is also measured. The results are compared with various Monte Carlo simulation models. Although most of these models agree with data to within 15

7.18 ATLAS_2011_I945498 [98]

Z+jets in pp at 7TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Status: UNVALIDATED

Authors:

- Evelin Meoni evelin.meoni@cern.ch
- Holger Schulz

References:

- arXiv: [1111.2690v1](#)
- CERN-PH-EP-2011-162

Run details:

- Z+jets, electronic and muonic Z-decays. Jets with transverse momentum $p_T > 30$ GeV and jet rapidity $|y| < 4.4$.

Production of jets in association with a Z/γ^* boson in proton-proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector. The analysis includes the full 2010 data set, collected with a low rate of multiple proton-proton collisions in the accelerator, corresponding to an integrated luminosity of 36 pb^{-1} . Inclusive jet cross sections in Z/γ^* events, with Z/γ^* decaying into electron or muon pairs, are measured for jets with transverse momentum $p_T > 30$ GeV and jet rapidity $|y| < 4.4$.

7.19 ATLAS_2011_I954993 [99]

WZ fiducial cross-section at 7 TeV in ATLAS

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC 7TeV)

Status: VALIDATED

Authors:

- Lynn Marx \langle Lynn.Marx@hep.manchester.ac.uk \rangle
- Roman Lysak \langle lysak@fzu.cz \rangle

References:

- Phys.Lett. B709 (2012) 341-357
- arXiv: [1111.5570](https://arxiv.org/abs/1111.5570)

Run details:

- pp WZ events at 7 TeV with direct e, mu W/Z boson decays (no taus from W/Z)

This is a measurement of WZ production in 1.02 fb^{-1} of pp collision data at $\sqrt{s}=7 \text{ TeV}$ collected by the ATLAS experiment in 2011. Doubly leptonic decay events are selected with electrons, muons and missing transverse momentum in the final state. The measurement of the combined fiducial cross section for the WZ bosons decaying directly into electrons and muons is performed.

7.20 ATLAS_2011_S8924791

Jet shapes at 7 TeV in ATLAS

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: [8924791](#)

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@cern.ch \rangle
- Francesc Vives \langle fvives@ifae.es \rangle
- Judith Katzy \langle judith.katzy@cern.ch \rangle

References:

- arXiv: [1101.0070](#)

Run details:

- pp QCD interactions at 7TeV GeV, corresponding to JX samples. Matching plots to kinematic p_{\perp} cut samples, or merging from slices or p_{\perp} -enhanced sampling is advised.

Measurement of jet shapes in inclusive jet production in pp collisions at 7 TeV based on 3pb^{-1} of data. Jets are reconstructed in $|\eta| < 5$ using the anti- k_{\perp} algorithm with $30 < p_{\perp} < 600$ GeV and $|y| < 2.8$.

7.21 ATLAS_2011_S8971293 [100]

Dijet azimuthal decorrelations

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: [8971293](#)

Status: VALIDATED

Authors:

- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

References:

- arXiv: [1102.2696](#)

Run details:

- pp QCD interactions at 7000 GeV. The distributions are binned in leading p_{\perp} starting at 110 GeV with the last bin starting at 800 GeV.

Dijet azimuthal decorrelation measured by ATLAS at 7 TeV. Jets are anti-kt with $R = 0.6$, $p_{\perp} > 100$ GeV, $|\eta| < 0.8$. The analysis is binned in leading jet p_{\perp} bins. All data is fully corrected.

7.22 ATLAS_2011_S8983313 [101]

0-lepton squark and gluino search

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: [8983313](#)

Status: VALIDATED

Authors:

- David Grellscheid [⟨david.grellscheid@durham.ac.uk⟩](mailto:david.grellscheid@durham.ac.uk)

References:

- arXiv: [1102.5290](#)

Run details:

- BSM signal events at 7000 GeV.

0-lepton search for squarks and gluinos by ATLAS at 7 TeV with an integrated luminosity of 35 pb^{-1} . Event counts in four signal regions A-D are implemented as one-bin histograms.

7.23 ATLAS_2011_S8994773

Calo-based underlying event at 900 GeV and 7 TeV in ATLAS

Beams: pp

Energies: (450.0, 450.0), (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: [8994773](#)

Status: VALIDATED

Authors:

- Jinlong Zhang [⟨jinlong@mail.cern.ch⟩](mailto:jinlong@mail.cern.ch)
- Andy Buckley [⟨andy.buckley@cern.ch⟩](mailto:andy.buckley@cern.ch)

References:

- arXiv: [1103.1816](#)

Run details:

- pp QCD interactions at 900 GeV and 7 TeV. Diffractive events should be included, but only influence the lowest bins. Multiple kinematic cuts should not be required.

Underlying event measurements with the ATLAS detector at the LHC at center-of-mass energies of 900 GeV and 7 TeV, using calorimeter clusters rather than charged tracks.

7.24 ATLAS_2011_S9002537

Muon charge asymmetry in W events at 7 TeV in ATLAS

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: [9002537](#)

Status: VALIDATED

Authors:

- Frank Krauss \langle frank.krauss@durham.ac.uk \rangle
- Hendrik Hoeth \langle hendrik.hoeth@cern.ch \rangle

References:

- arXiv: [1103.2929](#)

Run details:

- $W \rightarrow \mu\nu$ events at 7 TeV

Measurement of the muon charge asymmetry from W bosons produced in proton-proton collisions at a centre-of-mass energy of 7 TeV with ATLAS. The asymmetry is measured in the $W \rightarrow \mu$ decay mode as a function of the muon pseudorapidity using a data sample corresponding to a total integrated luminosity of 31pb^{-1} .

7.25 ATLAS_2011_S9019561 [102]

Two lepton supersymmetry search

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: 9019561

Status: VALIDATED

Authors:

- Angela Chen \langle aqchen@fas.harvard.edu \rangle

References:

- arXiv: [1103.6214](#)

Run details:

- BSM signal events at 7000 GeV.

2-lepton search for supersymmetric particles by ATLAS at 7 TeV. Event counts in signal regions (3 same sign and 3 opposite sign) are implemented as one bin histograms. Histograms for missing transverse energy are implemented.

7.26 ATLAS_2011_S9120807

Inclusive isolated diphoton analysis

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC 7TeV)

Spires ID: [9120807](#)

Status: VALIDATED

Authors:

- Giovanni Marchiori (giovanni.marchiori@cern.ch)

References:

- arXiv: [1107.0581](#)

Run details:

- Inclusive diphoton+X events at $\sqrt{s} = 7$ TeV.

A measurement of the cross section for inclusive isolated photon production at $\sqrt{s} = 7$ TeV. The measurement is done in bins of $M_{\gamma\gamma}$, $p_{T\gamma\gamma}$, and $\Delta\phi_{\gamma\gamma}$, for isolated photons with $|\eta| < 2.37$ and $E_T^\gamma > 16$ GeV. The measurement uses 37 pb^{-1} of integrated luminosity collected with the ATLAS detector.

7.27 ATLAS_2011_S9126244

Measurement of dijet production with a veto on additional central jet activity

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: [9126244](#)

Status: VALIDATED

Authors:

- Graham Jones (grahamj@cern.ch)

References:

- arXiv: [1107.1641](#)

Run details:

- Require QCD interactions at 7TeV. A substantial number of events are required to populate the large rapidity separation region.

A measurement of the jet activity in rapidity intervals bounded by a dijet system. The fraction of events passing a veto requirement are shown as a function of both the rapidity interval size and the average transverse momentum of the dijet system. The average number of jets above the veto threshold are also shown as a function of the same variables. There are two possible selection criteria applied to data. Either the two highest transverse momentum jets or the jets most forward and backward in rapidity are taken to define the dijet system, where the veto threshold is 20GeV. Additionally for the latter selection an alternative veto transverse momentum threshold which is equal to the average transverse momentum is applied. Jet selections are based on anti-kt with $R = 0.6$, $p_{\perp} > 20$ GeV and $|y| < 4.4$.

7.28 ATLAS_2011_S9128077 [103]

Measurement of multi-jet cross sections

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: 9128077

Status: VALIDATED

Authors:

- Frank Siegert (frank.siegert@cern.ch)

References:

- arXiv: [1107.2092](https://arxiv.org/abs/1107.2092)

Run details:

- Pure QCD, inclusive enough for jet p_{\perp} down to 60 GeV.

Inclusive multi-jet production is studied using an integrated luminosity of 2.4 pb⁻¹. Results on multi-jet cross sections are presented differential in p_{\perp} of the four leading jets, HT. Additionally three-to-two jet fractions are presented differential in different observables. Jets are anti-kt with $R = 0.4$ and $R = 0.6$, $p_{\perp} > 80(60)$ GeV and $|\eta| < 2.8$.

7.29 ATLAS_2011_S9131140 [104]

Measurement of the $Z p_{\perp}$ with electrons and muons at 7 TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: 9131140

Status: VALIDATED

Authors:

- Elena Yatsenko \langle elena.yatsenko@desy.de \rangle
- Judith Katzy \langle jkatzy@mail.cern.ch \rangle

References:

- arXiv: [1107.2381](https://arxiv.org/abs/1107.2381)

Run details:

- Run with inclusive Z events, with Z/γ^* decays to electrons and/or muons.

The $Z p_{\perp}$ at $\sqrt{s} = 7$ TeV is measured using electron and muon Z decay channels. The dressed leptons definition uses photons clustered in a cone around the charged leptons, while the bare lepton definition uses the post-FSR charged leptons only in the Z reconstruction. The data used in the bare leptons calculation are based on a forward application of a PHOTOS-based energy loss correction and are hence not quite model-independent.

7.30 ATLAS_2011_S9212183 [105]

0-lepton squark and gluino search

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: [9212183](#)

Status: VALIDATED

Authors:

- Chris Wymant \langle c.m.wymant@durham.ac.uk \rangle
- David Grellscheid \langle david.grellscheid@durham.ac.uk \rangle

References:

- arXiv: [1109.6572](#)

Run details:

- BSM signal events at 7000 GeV.

0-lepton search for squarks and gluinos by ATLAS at 7 TeV with an integrated luminosity of 1.04 fb^{-1} . Event counts in five signal regions are implemented as one-bin histograms.

7.31 ATLAS_2011_S9225137 [106]

High jet multiplicity squark and gluino search

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: [9225137](#)

Status: VALIDATED

Authors:

- Peter Richardson (peter.richardson@durham.ac.uk)

References:

- arXiv: [1110.2299](#)

Run details:

- BSM signal events at 7000 GeV.

Search for SUSY using events with 6 or more jets in association with missing transverse momentum produced in proton-proton collisions at a centre-of-mass energy of 7 TeV. The data sample has a total integrated luminosity of 1.34 fb^{-1} . Distributions in the W and top control regions are not produced, while in addition to the plots from the paper the count of events in the different signal regions is included.

7.32 ATLAS_2012_CONF_2012_001

4 or more lepton plus missing transverse energy SUSY search

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Status: PRELIMINARY

Authors:

- Peter Richardson (peter.richardson@durham.ac.uk)

References:

- ATLAS-CONF-2012-001
- ATLAS-CONF-2012-035

Run details:

- BSM signal events at 7000 GeV.

Search for SUSY using events with 4 or more leptons in association with missing transverse energy in proton-proton collisions at a centre-of-mass energy of 7 TeV. The data sample has a total integrated luminosity of 2.06 fb^{-1} . There is no reference data and in addition to the control plots from the paper the number of events in the two signal regions, correctly normalized to an integrated luminosity 2.06 fb^{-1} , are calculated.

7.33 ATLAS_2012_I1082936 [107]

Inclusive jet and dijet cross sections at 7 TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Status: VALIDATED

Authors:

- Holger Schulz hschulz@physik.hu-berlin.de

References:

- arXiv: [1112.6297v2](#)
- CERN-PH-EP-2011-192

Run details:

- QCD jet production with a minimum leading jet p_{\perp} of 30 GeV and minimum second jet p_{\perp} of 20 GeV at 7 TeV.

Inclusive jet and dijet cross sections have been measured in proton-proton collisions at a centre-of-mass energy of 7 TeV using the ATLAS detector at the Large Hadron Collider. The cross sections were measured using jets clustered with the anti-kT algorithm with parameters $R=0.4$ and $R=0.6$. These measurements are based on the 2010 data sample, consisting of a total integrated luminosity of 37 inverse picobarns. Inclusive jet double-differential cross sections are presented as a function of jet transverse momentum, in bins of jet rapidity. Dijet double-differential cross sections are studied as a function of the dijet invariant mass, in bins of half the rapidity separation of the two leading jets. The measurements are performed in the jet rapidity range $|y| < 4.4$, covering jet transverse momenta from 20 GeV to 1.5 TeV and dijet invariant masses from 70 GeV to 5 TeV. This is the successor analysis of ATLAS_2010_S8817804

7.34 ATLAS_2012_I1084540

Rapidity gap cross sections measured with the ATLAS detector in pp collisions at $\sqrt{s} = 7$ TeV.

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC 7TeV)

Spires ID: [1084540](#)

Status: VALIDATED

Authors:

- Oldrich Kepka [⟨ kepka@fzu.cz ⟩](mailto:kepka@fzu.cz)
- Tim Martin [⟨ tim.martin@cern.ch ⟩](mailto:tim.martin@cern.ch)
- Paul Newman [⟨ Paul.Newman@cern.ch ⟩](mailto:Paul.Newman@cern.ch)
- Pavel Ruzicka [⟨ ruzicka@fzu.cz ⟩](mailto:ruzicka@fzu.cz)

References:

- arXiv: [1201.2808](#)

Run details:

- Minimum bias inelastic pp collision at 7 TeV including diffractive component and overall cross section.

Pseudorapidity gap distributions in proton-proton collisions at $\sqrt{s} = 7$ TeV are studied using a minimum bias data sample with an integrated luminosity of 7.1 inverse microbarns. Cross sections are measured differentially in terms of $\Delta\eta_F$, the larger of the pseudorapidity regions extending to the limits of the ATLAS sensitivity, at $\eta = \pm 4.9$, in which no final state particles are produced above a transverse momentum threshold p_T Cut. The measurements span the region $0 \leq \Delta\eta_F \leq 8$ for $200 \leq p_T \text{ Cut} \leq 800$ MeV. At small $\Delta\eta_F$, the data test the reliability of hadronisation models in describing rapidity and transverse momentum fluctuations in final state particle production. The measurements at larger gap sizes are dominated by contributions from the single diffractive dissociation process ($pp \rightarrow Xp$), enhanced by double dissociation ($pp \rightarrow XY$) where the invariant mass of the lighter of the two dissociation systems satisfies $M_Y \leq 7$ GeV. The resulting cross section is $d\sigma / d\Delta\eta_F \approx 1$ mb for $\Delta\eta_F \leq 3$. The large rapidity gap data are used to constrain the value of the pomeron intercept appropriate to triple Regge models of soft diffraction. The cross section integrated over all gap sizes is compared with other LHC inelastic cross section measurements.

7.35 ATLAS_2012_I1091481 [108]

Azimuthal ordering of charged hadrons

Beams: pp

Energies: (450.0, 450.0), (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Status: UNVALIDATED

Authors:

- Sharka Todorova [⟨sarka.todorova@cern.ch⟩](mailto:sarka.todorova@cern.ch)
- Holger Schulz [⟨hschulz@physik.hu-berlin.de⟩](mailto:hschulz@physik.hu-berlin.de)

References:

- CERN-PH-EP-2011-197
- arXiv: [1203.0419](https://arxiv.org/abs/1203.0419)

Run details:

- QCD events with diffractives switched on.

Measurement of the ordering of charged hadrons in the azimuthal angle relative to the beam axis at the Large Hadron Collider (LHC). A spectral analysis of correlations between longitudinal and transverse components of the momentum of the charged hadrons is performed. Data were recorded with the ATLAS detector at centre-of-mass energies of $\sqrt{s} = 900$ GeV and $\sqrt{s} = 7$ TeV. The correlations measured in a phase space region dominated by low- p_{\perp} particles are not well described by conventional models of hadron production. The measured spectra show features consistent with the fragmentation of a QCD string represented by a helix-like ordered gluon chain.

7.36 ATLAS_2012_I1093738 [109]

Isolated prompt photon + jet xsection

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: 1093738

Status: VALIDATED

Authors:

- Giovanni Marchiori (giovanni.marchiori@cern.ch)

References:

- arXiv: [1203.3161](#)

Run details:

- Inclusive photon+jet+X events at $\sqrt{s} = 7$ TeV.

A measurement of the production cross section for isolated photons in association with jets in pp collisions at $\sqrt{s} = 7$ TeV. Photons with $|\eta| < 1.37$ and $E_T > 25$ GeV and jets with $|y| < 4.4$ and $p_T > 20$ GeV are selected. The differential cross section as a function of the photon transverse energy is measured, for three leading jet rapidity configurations, separately for the cases where the photon and jet rapidities have the same or the opposite sign. The measurement uses 37 pb^{-1} of integrated luminosity collected with the ATLAS detector.

7.37 ATLAS_2012_I1094061 [110]

Measurement of two-particle correlation function at 900 GeV and 7 TeV

Beams: pp

Energies: (450.0, 450.0), (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Status: VALIDATED

Authors:

- James Monk [⟨jmonk@cern.ch⟩](mailto:jmonk@cern.ch)

References:

- JHEP 1205 (2012) 157
- CERN-PH-EP-2012-011
- DOI: [10.1007/JHEP05\(2012\)157](https://doi.org/10.1007/JHEP05(2012)157)
- arxiv:1203.3549

Run details:

- Soft-QCD proton-proton interactions (including diffraction) at 900 GeV or 7 TeV.
Generated events should include an average lifetime cut of $\tau \lesssim 10\text{mm}$

Two-particle angular correlations are measured in proton-proton collisions at $\sqrt{s} = 900\text{ GeV}$ and 7 TeV . Correlations are determined for charged particles with

$p_T > 100\text{ MeV}$ and $|\eta| < 2.5$. A complicated function of both pseudorapidity and azimuth is observed. Results are obtained from an inclusive sample of events (900 GeV and 7 TeV), as well as a sample satisfying $n_{ch} \geq 20$ (7 TeV only).

7.38 ATLAS_2012_I1094568

Measurement of $t\bar{t}$ production with a veto on additional central jet activity

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: [1094568](#)

Status: VALIDATED

Authors:

- Kiran Joshi [⟨kiran.joshi@cern.ch⟩](mailto:kiran.joshi@cern.ch)

References:

- arXiv: [1203.5015](#)

Run details:

- Require dileptonic $t\bar{t}$ events at 7TeV.

A measurement of the additional jet activity in dileptonic $t\bar{t}$ events. The fraction of events passing a veto requirement are shown as a function the veto scale for four central rapidity intervals. Two veto definitions are used: events are vetoed if they contain an additional jet in the rapidity interval with transverse momentum above a threshold, or alternatively, if the scalar transverse momentum sum of all additional jets in the rapidity interval is above a threshold.

7.39 ATLAS_2012_I1112263 [111]

3 lepton plus missing transverse energy SUSY search

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Status: VALIDATED

Authors:

- Peter Richardson (peter.richardson@durham.ac.uk)

References:

- ATLAS-CONF-2012-023
- arXiv: [1204.5638](https://arxiv.org/abs/1204.5638)

Run details:

- BSM signal events at 7000 GeV.

Search for SUSY using events with 3 leptons in association with missing transverse energy in proton-proton collisions at a centre-of-mass energy of 7 TeV. The data sample has a total integrated luminosity of 2.06 fb^{-1} . There is no reference data and in addition to the control plots from the paper the number of events in the two signal regions, correctly normalized to an integrated luminosity 2.06 fb^{-1} , are calculated.

7.40 ATLAS_2012_I1117704

High jet multiplicity squark and gluino search

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Status: VALIDATED

Authors:

- Peter Richardson (peter.richardson@durham.ac.uk)

References:

- arXiv: [1206.1760](#)

Run details:

- BSM signal events at 7000 GeV.

Search for SUSY using events with 6 or more jets in association with missing transverse momentum produced in proton-proton collisions at a centre-of-mass energy of 7 TeV. The data sample has a total integrated luminosity of 4.7 fb^{-1} . Distributions in the W and top control regions are not produced, while in addition to the plots from the paper the count of events in the different signal regions is included.

7.41 ATLAS_2012_I1118269 [112]

Measurement of the b-hadron production cross section using decays to $D^*\mu^-X$ final states in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Spires ID: 9626190

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@ed.ac.uk \rangle
- Sercan Sen \langle sercan.sen@cern.ch \rangle
- Peter Skands \langle Peter.Skands@cern.ch \rangle

References:

- arXiv: [1206.3122](https://arxiv.org/abs/1206.3122)

Run details:

- pp to b-hadron + X at 7 TeV, i.e. switch on "HardQCD:gg2bbbar" and "HardQCD:qqbar2bbbar" flags in Pythia8.

Measurement of b -hadron production cross section using 3.3 pb^{-1} of integrated luminosity, collected during the 2010 LHC run. The b -hadrons are selected by partially reconstructing $D^*\mu^-X$ final states using only direct semileptonic decays of b to $D^*\mu^-X$. Differential cross sections as functions of p_\perp and $|\eta|$.

7.42 ATLAS_2012_I1119557 [113]

Jet shapes and jet masses

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC 7TeV)

Status: VALIDATED

Authors:

- Lily Asquith [⟨lasquith@hep.anl.gov⟩](mailto:lasquith@hep.anl.gov)
- Roman Lysak [⟨lysak@fzu.cz⟩](mailto:lysak@fzu.cz)

References:

- Phys.Rev. D86 (2012) 072006
- DOI: [10.1103/PhysRevD.86.072006](https://doi.org/10.1103/PhysRevD.86.072006)
- arXiv: [1206.5369](https://arxiv.org/abs/1206.5369)

Run details:

- QCD events at 7 TeV, leading- p_{\perp} jets with $pT > 300 \text{ GeV}$.

Measurements are presented of the properties of high transverse momentum jets, produced in proton-proton collisions at a center-of-mass energy of $\sqrt{s} = 7 \text{ TeV}$. Jet mass, width, eccentricity, planar flow and angularity are measured for jets reconstructed using the anti- k_t algorithm with distance parameters $R = 0.6$ and 1.0 , with transverse momentum $p_{\perp} > 300 \text{ GeV}$ and pseudorapidity $|\eta| < 2$.

7.43 ATLAS_2012_I1125575 [114]

Distributions sensitive to the underlying event are studied in events containing one or more charged-particle.

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Status: VALIDATED

Authors:

- Kiran Joshi [⟨kiran.joshi@cern.ch⟩](mailto:kiran.joshi@cern.ch)

References:

- arXiv: [1208.0563](#)

Run details:

- Minimum bias events at 7 TeV.

Distributions sensitive to the underlying event are studied in events containing one or more charged-particle. Jets are reconstructed using the antikt algorithm with radius parameter R varying between 0.2 and 1.0. Distributions of the charged-particle multiplicity, the scalar sum of the transverse momentum of charged particles, and the average charged-particle p_{\perp} are measured as functions of $p_{\perp}^J ET$ in regions transverseto and oppositethe leading jet for $4\text{GeV} < p_{\perp}^J ET < 100\text{GeV}$. In addition, the R -dependence of the mean values of these observables is studied.

7.44 ATLAS_2012_I1125961

0-lepton squark and gluino search

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Status: VALIDATED

Authors:

- Peter Richardson \langle Peter.Richardson@durham.ac.uk \rangle
- David Grellscheid \langle david.grellscheid@durham.ac.uk \rangle
- Chris Wymant \langle c.m.wymant@durham.ac.uk \rangle

References:

- arXiv: [1208.0949](https://arxiv.org/abs/1208.0949)

Run details:

- BSM signal events at 7000 GeV.

0-lepton search for squarks and gluinos by ATLAS at 7 TeV. Event counts in five signal regions are implemented as one-bin histograms.

7.45 ATLAS_2012_I1183818 [115]

pseudorapidity dependence of the total transverse energy at 7 TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC 7TeV)

Status: VALIDATED

Authors:

- Robindra Prabhu [⟨prabhu@cern.ch⟩](mailto:prabhu@cern.ch)
- Peter Wijeratne [⟨paw@hep.ucl.ac.uk⟩](mailto:paw@hep.ucl.ac.uk)
- Roman Lysak [⟨lysak@fzu.cz⟩](mailto:lysak@fzu.cz)

References:

- arXiv: [1208.6256](#)

Run details:

- pp QCD interactions at 7 TeV, min bias and di-jet events

The measurement of the sum of the transverse energy of particles as a function of particle pseudorapidity, η , in proton-proton collisions at a centre-of-mass energy, $\sqrt{s} = 7\text{TeV}$ using the ATLAS detector at the Large Hadron Collider. The measurements are performed in the region $|\eta| < 4.8$ for two event classes: those requiring the presence of particles with a low transverse momentum and those requiring particles with a significant transverse momentum (dijet events where both jets have $E_T > 20$ GeV). In the second dataset measurements are made in the region transverse to the hard scatter.

7.46 ATLAS_2012_I1188891 [116]

flavour composition of dijet events at 7 TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC 7TeV)

Status: VALIDATED

Authors:

- Cecile Lapoire \langle clapoire@cern.ch \rangle
- Roman Lysak \langle lysak@fzu.cz \rangle

References:

- arXiv: [1210.0441](https://arxiv.org/abs/1210.0441)

Run details:

- pp di-jet events at 7 TeV

The measurement of the flavour composition of dijet events produced in pp collisions at $\sqrt{s} = 7\text{TeV}$ using the ATLAS detector. Six possible combinations of light, charm and bottom jets are identified in the dijet events, where the jet flavour is defined by the presence of bottom, charm or solely light flavour hadrons in the jet. The fractions of these dijet flavour states as functions of the leading jet transverse momentum in the range 40 GeV to 500 GeV and jet rapidity $|y| < 2.1$ are measured.

7.47 ATLAS_2012_I943401 [117]

Search for supersymmetry with 2 leptons and missing transverse energy

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Status: VALIDATED

Authors:

- Peter Richardson \langle Peter.Richardson@durham.ac.uk \rangle

References:

- arXiv: [1110.6189](https://arxiv.org/abs/1110.6189)

Run details:

- BSM signal events at 7000 GeV.

Results of three searches for the production of supersymmetric particles decaying into final states with missing transverse momentum and exactly two isolated leptons, electrons or muons. The analysis uses a data sample collected during the first half of 2011 that corresponds to a total integrated luminosity of 1 fb^{-1} of $\sqrt{s} = 7 \text{ TeV}$ proton-proton collisions recorded with the ATLAS detector at the Large Hadron Collider. Opposite-sign and same-sign dilepton events are studied separately. Additionally, in opposite-sign events, a search is made for an excess of same-flavour over different-flavour lepton pairs.

7.48 ATLAS_2013_I1217867 [118]

kT splitting scales in $W \rightarrow \ell \nu$ events

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: ATLAS (LHC)

Status: VALIDATED

Authors:

- Frank Siegert \langle frank.siegert@cern.ch \rangle

References:

- arXiv: [1302.1415](#)

Run details:

- W+jet events in the electron and/or the muon decay channel.

Cluster splitting scales are measured in events containing W bosons decaying to electrons or muons. The measurement comprises the four hardest splitting scales in a kT cluster sequence of the hadronic activity accompanying the W boson, and ratios of these splitting scales.

7.49 CMS_2010_S8547297 [119]

Charged particle transverse momentum and pseudorapidity spectra from proton-proton collisions at 900 and 2360 GeV.

Beams: pp

Energies: (450.0, 450.0), (1180.0, 1180.0) GeV

Experiment: CMS (LHC)

Spires ID: [8547297](#)

Status: VALIDATED

Authors:

- A. Knutsson

References:

- JHEP 02 (2010) 041
- DOI: [10.1007/JHEP02\(2010\)041](#)
- arXiv: [1002.0621](#)

Run details:

- Non-single-diffractive (NSD) events only. Should include double-diffractive (DD) events and non-diffractive (ND) events but NOT single-diffractive (SD) events. Examples, in Pythia6 the SD processes to be turned off are 92 and 93, and in Pythia8 the SD processes are 103 and 104 (also called SoftQCD:singleDiffractive).

Charged particle spectra are measured in proton-proton collisions at center-of-mass energies 900 and 2360 GeV. The spectra are normalized to all non-single-diffractive (NSD) events using corrections for trigger and selection efficiency, acceptance, and branching ratios. There are transverse-momentum (p_{\perp}) spectra from 0.1 to 2 GeV in bins of pseudorapidity (η) and p_{\perp} spectra from 0.1 to 4 GeV for $|\eta| \leq 2.4$. The η spectra come from the average of three methods and cover $|\eta| \leq 2.5$ and are corrected to include all p_{\perp} . The data were corrected according to the SD/DD/ND content of the CMS trigger, as predicted by pythia6. The uncertainties connected with correct or uncorrect modelling of diffraction were included in the systematic errors.

7.50 CMS_2010_S8656010 [120]

Charged particle transverse momentum and pseudorapidity spectra from proton-proton collisions at 7000 GeV.

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Spires ID: [8656010](#)

Status: VALIDATED

Authors:

- A. Knutsson

References:

- Phys.Rev.Lett.105:022002,2010
- DOI: [10.1103/PhysRevLett.105.022002](#)
- arXiv: [1005.3299](#)

Run details:

- Non-single-diffractive (NSD) events only. Should include double-diffractive (DD) events and non-diffractive (ND) events but NOT single-diffractive (SD) events. For example, in Pythia6 the SD processes to be turned off are 92 and 93, and in Pythia8 the SD processes are 103 and 104 (also called SoftQCD:singleDiffractive).

Charged particle spectra are measured in proton-proton collisions at center-of-mass energies 7000 GeV. The spectra are normalized to all non-single-diffractive (NSD) events using corrections for trigger and selection efficiency, acceptance, and branching ratios. There are transverse-momentum (p_{\perp}) spectra from 0.1 to 2 GeV in bins of pseudorapidity (η) and the p_{\perp} spectrum from 0.1 to 6 GeV for $|\eta| \leq 2.4$. The η spectra come from the average of three methods and cover $|\eta| \leq 2.5$ and are corrected to include all p_{\perp} . The data were corrected according to the SD/DD/ND content of the CMS trigger, as predicted by pythia6. The uncertainties connected with correct or incorrect modelling of diffraction were included in the systematic errors.

7.51 CMS_2011_I954992 [121]

Exclusive photon-photon production of muon pairs in proton-proton collisions
at $\sqrt{s} = 7$ TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Spires ID: 9279938

Status: VALIDATED

Authors:

- David d’Enterria [⟨dde@cern.ch⟩](mailto:dde@cern.ch)
- Jonathan Hollar [⟨jjhollar@mail.cern.ch⟩](mailto:jjhollar@mail.cern.ch)
- Sercan Sen [⟨Sercan.Sen@cern.ch⟩](mailto:Sercan.Sen@cern.ch)

References:

- arXiv: [1111.5536](#)

Run details:

- gamma gamma TO mu+ mu- process.

A measurement of the exclusive two-photon production of muon pairs in proton-proton collisions at a centre-of-mass energy 7 TeV with the final state $p\mu^+\mu^-p$, is reported using data corresponding to an integrated luminosity of 40 pb⁻¹ collected in 2010. The measured cross section is obtained with a fit to the dimuon p_T distribution for muon pairs with invariant mass greater than 11.5 GeV with each muon $p_T > 4$ GeV and $|\eta| < 2.1$.

7.52 CMS_2011_S8884919 [122]

Measurement of the NSD charged particle multiplicity at $\sqrt{s} = 0.9, 2.36$, and 7 TeV with the CMS detector.

Beams: pp

Energies: (450.0, 450.0), (1180.0, 1180.0), (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Spires ID: 8884919

Status: VALIDATED

Authors:

- Romain Rougny [⟨romain.rougny@cern.ch⟩](mailto:romain.rougny@cern.ch)

References:

- J. High Energy Phys. 01 (2011) 079
- DOI: [10.1007/JHEP01\(2011\)079](https://doi.org/10.1007/JHEP01(2011)079)
- arXiv: [1011.5531](https://arxiv.org/abs/1011.5531)

Run details:

- Non-single-diffractive (NSD) events only. Should include double-diffractive (DD) events and non-diffractive (ND) events but NOT single-diffractive (SD) events. For example, in Pythia6 the SD processes to be turned off are 92 and 93 and in Pythia8 the SD processes are 103 and 104 (also called SoftQCD:singleDiffractive).

Measurements of primary charged hadron multiplicity distributions are presented for non-single-diffractive events in proton-proton collisions at centre-of-mass energies of $\sqrt{s} = 0.9, 2.36$, and 7 TeV, in five pseudorapidity ranges from $-\eta_{\text{f}}0.5$ to $-\eta_{\text{f}}2.4$. The data were collected with the minimum-bias trigger of the CMS experiment during the LHC commissioning runs in 2009 and the 7 TeV run in 2010. The average transverse momentum as a function of the multiplicity is also presented. The measurement of higher-order moments of the multiplicity distribution confirms the violation of Koba-Nielsen-Olesen scaling that has been observed at lower energies.

7.53 CMS_2011_S8941262 [123]

Production cross-sections of muons from b hadron decays in pp collisions

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Spires ID: [8941262](#)

Status: VALIDATED

Authors:

- Wolfram Erdmann (wolfram.erdmann@psi.ch)

References:

- JHEP 1103,090
- DOI: [10.1007/JHEP03\(2011\)090](https://doi.org/10.1007/JHEP03(2011)090)
- arXiv: [hep-ex/1101.3512](https://arxiv.org/abs/hep-ex/1101.3512)

Run details:

- Inclusive QCD at 7 TeV, with no p_{\perp} cuts.

A measurement of the b -hadron production cross-section in proton-proton collisions at $\sqrt{s} = 7$ TeV. The dataset, corresponding to 85 inverse nanobarns, was recorded with the CMS experiment at the LHC using a low-threshold single-muon trigger. Events are selected by the presence of a muon with transverse momentum greater than 6 GeV with respect to the beam direction and pseudorapidity less than 2.1. The transverse momentum of the muon with respect to the closest jet discriminates events containing b hadrons from background. The inclusive b -hadron production cross section is presented as a function of muon transverse momentum and pseudorapidity.

7.54 CMS_2011_S8950903 [124]

Dijet azimuthal decorrelations in pp collisions at $\sqrt{s} = 7$ TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Spires ID: 8950903

Status: VALIDATED

Authors:

- Tomo Umer \langle tomo.umer@cern.ch \rangle

References:

- Phys. Rev. Lett. 106 (2011) 122003
- arXiv: [1101.5029](https://arxiv.org/abs/1101.5029)

Run details:

- Inclusive QCD at 7TeV comEnergy, ptHat (or equivalent) greater than 20 GeV

Measurements of dijet azimuthal decorrelations in pp collisions at $\sqrt{s} = 7$ TeV using the CMS detector at the CERN LHC are presented. The analysis is based on an inclusive dijet event sample corresponding to an integrated luminosity of 2.9/pb. Jets are anti-kt with $R = 0.5$, $p_{\perp} > 80(30)$ GeV and $|\eta| < 1.1$.

7.55 CMS_2011_S8957746 [125]

Event shapes

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Spires ID: 8957746

Status: VALIDATED

Authors:

- Hendrik Hoeth (hendrik.hoeth@cern.ch)

References:

- Phys.Lett.B699:48-67,2011
- arXiv: [1102.0068](https://arxiv.org/abs/1102.0068)

Run details:

- pp QCD interactions at 7000 GeV. Particles with $c\tau \lesssim 10\text{mm}$ are stable.

Central transverse Thrust and Minor have been measured in proton-proton collisions at $\sqrt{s}=7$ TeV, with a data sample collected with the CMS detector at the LHC. The sample corresponds to an integrated luminosity of 3.2 inverse picobarns. Input for the variables are anti-kt jets with $R = 0.5$.

7.56 CMS_2011_S8968497 [126]

Measurement of dijet angular distributions and search for quark compositeness in pp collisions at $\sqrt{s} = 7$ TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: CMS (CERN LHC)

Spires ID: [8968497](#)

Status: VALIDATED

Authors:

- A. Hinzmann

References:

- Phys.Rev.Lett.106:201804,2011
- DOI: [10.1103/PhysRevLett.106.201804](#)
- arXiv: [hep-ex/1102.2020](#)

Run details:

-

Measurement of dijet angular distributions in proton-proton collisions at a center-of-mass energy of 7 TeV. The data sample, collected with single jet triggers, has a total integrated luminosity of 36 pb⁻¹, with jets being reconstructed using the anti-KT clustering algorithm using R=0.5. The data are presented for the variable CHI defined as EXP(—Y1-Y2—) where Y1 and Y2 are the rapidities of the two leading (highest PT) jets.’

7.57 CMS_2011_S8973270 [127]

B/anti-B angular correlations based on secondary vertex reconstruction in pp collisions

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Spires ID: 8973270

Status: VALIDATED

Authors:

- Lukas Wehrli (wehrliku@cern.ch)

References:

- JHEP 1103 136
- DOI: [10.1007/JHEP03\(2011\)136](https://doi.org/10.1007/JHEP03(2011)136)
- arXiv: [hep-ex/1102.3194](https://arxiv.org/abs/hep-ex/1102.3194)

Run details:

- Inclusive QCD at 7TeV comEnergy, p_{that} cut (or similar) recommended (leading jet p_t > 56 GeV required)

The differential $B\bar{B}$ cross-section is measured as a function of the opening angle ΔR and $\Delta\phi$ using data collected with the CMS detector during 2010 and corresponding to an integrated luminosity of 3.1 pb^{-1} . The measurement is performed for three different event energy scales, characterized by the transverse momentum of the leading jet in the event (above 56 GeV, above 84 GeV and above 120 GeV). Simulated events are normalised in the region $\Delta R > 2.4$ and $\Delta\phi > 3/4\pi$ respectively.

7.58 CMS_2011_S8978280 [128]

Kshort, Lambda, and Cascade- transverse momentum and rapidity spectra from proton-proton collisions at 900 and 7000 GeV.

Beams: pp

Energies: (450.0, 450.0), (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Spires ID: 8978280

Status: VALIDATED

Authors:

- Kevin Stenson (kevin.stenson@colorado.edu)

References:

- JHEP 05 (2011) 064
- DOI: [10.1007/JHEP05\(2011\)064](https://doi.org/10.1007/JHEP05(2011)064)
- arXiv: [1102.4282](https://arxiv.org/abs/1102.4282)

Run details:

- Non-single-diffractive (NSD) events only. Should include double-diffractive (DD) events and non-diffractive (ND) events but NOT single-diffractive (SD) events. For example, in Pythia6 the SD processes to be turned off are 92 and 93, and in Pythia8 the SD processes are 103 and 104 (also called SoftQCD:singleDiffractive).

The spectra of Kshort, Lambda, and Cascade- particles were measured versus transverse-momentum (p_{\perp}) and rapidity(y) in proton-proton collisions at center-of-mass energies 900 and 7000 GeV. The production is normalized to all non-single-diffractive (NSD) events using corrections for trigger and selection efficiency, acceptance, and branching ratios. The results cover a rapidity range of $-y-|2$ and a p_{\perp} range from 0 to 10 GeV (Kshort and Lambda) and 0 to 6 GeV (Cascade-). Antiparticles are included in all measurements so only the sum of Lambda and Lambdabar and Cascade- and anti-Cascade- are given. The rapidity distributions are shown versus $-y-$ but normalized to a unit of y . Ratios of Lambda/Kshort and Cascade-/Lambda production versus p_{\perp} and $-y-$ are also given, with somewhat smaller systematic uncertainties than obtained from taking the ratio of the individual distributions.’ The data were corrected according to the SD/DD/ND content of the CMS trigger, as predicted by pythia6. The uncertainties connected with correct or uncorrect modelling of diffraction were included in the systematic errors.

7.59 CMS_2011_S9086218 [129]

Measurement of the inclusive jet cross-section in pp collisions at $\sqrt{s} = 7$ TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Spires ID: 9086218

Status: VALIDATED

Authors:

- Rasmus Sloth Hansen rsh07@phys.au.dk

References:

- <http://cdsweb.cern.ch/record/1355680>

Run details:

- Inclusive QCD at 7TeV comEnergy, ptHat (or equivalent) greater than 10 GeV

The inclusive jet cross section is measured in pp collisions with a center-of-mass energy of 7 TeV at the LHC using the CMS experiment. The data sample corresponds to an integrated luminosity of 34 inverse picobarns. The measurement is made for jet transverse momenta in the range 18-1100 GeV and for absolute values of rapidity less than 3. Jets are anti-kt with $R = 0.5$, $p_{\perp} > 18$ GeV and $|y| < 3.0$.

7.60 CMS_2011_S9088458 [130]

Measurement of ratio of the 3-jet over 2-jet cross section in pp collisions at $\sqrt{s} = 7$ TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Spires ID: 9088458

Status: VALIDATED

Authors:

- Tomo Umer \langle tomo.umer@cern.ch \rangle

References:

- Phys. Lett. B 702 (2011) 336

Run details:

- Inclusive QCD at 7TeV comEnergy, ptHat (or equivalent) greater than 30 GeV

A measurement of the ratio of the inclusive 3-jet to 2-jet cross sections as a function of the total jet transverse momentum, HT, in the range $0.2 \leq HT \leq 2.5$ TeV is presented. The data have been collected at a proton-proton centre-of-mass energy of 7 TeV with the CMS detector at the LHC, and correspond to an integrated luminosity of 36/pb. Jets are anti-kt with $R = 0.5$, $p_{\perp} > 50$ GeV and $|\eta| < 2.5$.

7.61 CMS_2011_S9120041 [131]

Traditional leading jet UE measurement at $\sqrt{s} = 0.9$ and 7 TeV

Beams: pp

Energies: (450.0, 450.0), (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Spires ID: 9120041

Status: VALIDATED

Authors:

- Mohammed Zakaria (mzakaria@ufl.edu)

References:

- J. High Energy Phys 09 (2011) 109

Run details:

- Requires inclusive inelastic events (non-diffractive and inelastic diffractive). The profile plots require large statistics.

A measurement of the underlying activity in scattering processes with a hard scale in the several-GeV region is performed in proton-proton collisions at Energies of 0.9 and 7 TeV, using data collected by the CMS experiment at the LHC. The production of charged particles with pseudorapidity $|\eta| < 2$ and transverse momentum $p_{\perp} > 0.5$ GeV/c is studied in the azimuthal region transverse to that of the leading set of charged particles forming a track-jet. Various comparisons are made between the two different energies and also between two sets of cuts on p_{\perp} for leading track jet p_{\perp} -leading > 3 GeV and p_{\perp} -leading > 20 GeV. The activity is studied using 5 types of plots. 2 profile plots for the multiplicity of charged particles and the scalar sum of p_{\perp} . and 3 distributions for the two previous quantities as well as p_{\perp} for all the particles in the transverse region.

7.62 CMS_2011_S9215166 [132]

Forward energy flow in MB and dijet events at 0.9 and 7 TeV

Beams: pp

Energies: (450.0, 450.0), (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Spires ID: 9215166

Status: VALIDATED

Authors:

- S. Dooling \langle samantha.dooling@cern.ch \rangle
- A. Knutsson \langle albert.knutsson@cern.ch \rangle

References:

- JHEP 1111 148
- DOI: [10.1007/JHEP11\(2011\)148](https://doi.org/10.1007/JHEP11(2011)148)
- arXiv: [hep-ex/1110.0211](https://arxiv.org/abs/hep-ex/1110.0211)

Run details:

- pp MB and QCD interactions at 0.9 and 7 TeV. No p_{\perp} -cuts.

Forward energy flow measured by CMS at $\sqrt{s} = 0.9$ and 7 TeV in MB and dijet events.

7.63 CMS_2012_I1087342 [[133](#)]

Measurement of forward and forward+central jets at $\sqrt{s} = 7$ TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Spires ID: [1087342](#)

Status: VALIDATED

Authors:

- Albert Knutsson \langle albert.knutsson@cern.ch \rangle
- Rasmus Sloth Hansen \langle rsh07@phys.au.dk \rangle
- Bo Zhu

References:

- JHEP 1206 (2012) 036
- CMS-FWD-11-002
- CERN-PH-EP-2011-179
- doi 10.1007/JHEP06(2012)036
- arXiv: [1202.0704](#)

Run details:

- pp QCD interactions at 7 TeV.

Inclusive forward jets and forward+central jets measured by CMS at $\sqrt{s}=7$ TeV.

7.64 CMS_2012_I1102908 [134]

Measurement of inclusive and exclusive dijet production ratio at large rapidity intervals at center-of-mass energy 7 TeV.

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Status: VALIDATED

Authors:

- Grzegorz Brona
- Vladimir Gavrilov
- Hannes Jung
- Victor Kim
- Victor Murzin
- Vadim Oreshkin
- Grigory Pivovarov
- Ivan Pozdnyakov
- Grigory Safronov

References:

- CMS-FWD-10-014
- CERN-PH-EP-2012-088
- arXiv: [1204.0696](#)
- Submitted to the EPJ C

Run details:

- Inclusive QCD at 7TeV comEnergy, $p_{T\text{Hat}}$ (or equivalent) greater than 15 GeV

This is a measurement of the ratio of inclusive to exclusive dijet production as a function of the absolute distance in rapidity, Δy , between jets. The ratio of the Mueller-Navelet to exclusive dijet production is also measured. These measurements were performed with the CMS detector in proton-proton collisions at $\sqrt{s} = 7$ TeV for jets with $p_T > 35$ GeV and $|y| < 4.7$ taken from a mixture of two data samples, one of which containing dijets with moderate rapidity separation and the other containing dijets with large rapidity separation, with integrated luminosity of 33/nb and 5/pb respectively. The measured observables are corrected for detector effects.

7.65 CMS_2012_I1107658 [135]

Measurement of the underlying event activity in the Drell-Yan process at a centre-of-mass energy of 7 TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Status: VALIDATED

Authors:

- Sunil Bansal (sunil.bansal@cern.ch)

References:

- CMS-QCD-11-012
- CERN-PH-EP-2012-085
- arXiv: [1204.1411](#)

Run details:

- Drell-Yan events with $Z/\gamma^* \rightarrow \mu\mu$. $m(\mu, \mu) > 20$ GeV

A measurement of the underlying event activity using Drell-Yan events using muonic final state. The production of charged particles with pseudorapidity $|\eta| < 2$ and transverse momentum $p_\perp > 0.5$ GeV/ c is studied in towards, transverse and away region w.r.t. to the direction of di-muon system. The UE activity is measured in terms of a particle density and an energy density. The particle density is computed as the average number of primary charged particles per unit pseudorapidity and per unit azimuth. The energy density is expressed in terms of the average of the scalar sum of the transverse momenta of primary charged particles per unit pseudorapidity and azimuth. The ratio of the energy and particle density is also reported in 3 regions. UE activity is studied as a function of invariant mass of muon pair ($M_{\mu\mu}$) by limiting the ISR contribution by requiring transverse momentum of muon pair $p_\perp(\mu\mu) < 5$ GeV/ c . The $p_\perp(\mu\mu)$ dependence is studied for the events having $M_{\mu\mu}$ in window of 81–101 GeV/ c . The normalized charged particle multiplicity and p_\perp spectrum of the charged particles in three regions also been reported for events having $M_{\mu\mu}$ in window of 81–101 GeV/ c . Multiplicity and p_\perp spectra in the transverse region are also reported, for events having $p_\perp(\mu\mu) < 5$ GeV/ c .

7.66 CMS_2012_I1184941 [136]

Measurement of the differential cross section for inclusive dijet production as a function of ξ in 7 TeV proton-proton collisions.

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Status: VALIDATED

Authors:

- Sercan Sen [〈ssen@cern.ch〉](mailto:ssen@cern.ch)
- Alexander Proskuryakov [〈aproskur@mail.cern.ch〉](mailto:aproskur@mail.cern.ch)

References:

- arXiv: [1209.1805](#)
- Submitted to Phys. Rev. D

Run details:

- High statistics is needed to observe events in the lowest (ξ) bin. Distributions are presented for HardQCD events (i.e., in PYTHIA with $pt_{\text{HatMin}}=15\text{GeV}$) and Diffractive events.

Measurement of the differential cross section for inclusive dijet production as a function of ξ which approximates the fractional momentum loss of the scattered proton in single-diffraction events. The data used has a total integrated luminosity of 2.7 nb⁻¹ collected during 2010 with low instantaneous luminosity. Events are selected with at least two jets in $|\eta| < 4.4$ with $p_{\perp} > 20$ GeV and all final state particles are used for the reconstruction of ξ .

7.67 CMS_2012_I1193338 [137]

Measurement of the inelastic proton-proton cross section at $\sqrt{s}=7$ TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Status: VALIDATED

Authors:

- Sercan Sen [〈ssen@cern.ch〉](mailto:ssen@cern.ch)

References:

- arXiv: [1210.6718](#)

Run details:

- Inelastic events (non-diffractive and inelastic diffractive).

The inelastic cross-section is measured through two independent methods based on information from (i) forward calorimetry (for pseudorapidity $3 < |\eta| < 5$), in collisions where at least one proton loses more than $\xi > 5 \cdot 10^{-6}$ of its longitudinal momentum, and (ii) the central tracker ($|\eta| < 2.4$), in collisions containing an interaction vertex with more than 1, 2, or 3 tracks with $p_{\perp} > 200$ MeV/c.

7.68 CMS_2012_PAS_FWD_11_003

Study of the Underlying Event at Forward Rapidity in Proton-Proton Collisions at the LHC

Beams: pp

Energies: (450.0, 450.0), (1380.0, 1380.0), (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Spires ID: ~

Status: VALIDATED

Authors:

- Samantha Dooling [⟨samantha.dooling@desy.de⟩](mailto:samantha.dooling@desy.de)

References:

- CMS-PAS-FWD-11-003
- <http://cdsweb.cern.ch/record/1434458>

Run details:

- Inelastic events (non-diffractive and diffractive) at $\sqrt{s} = 0.9, 2.76$ and 7 TeV.

Ratio of the energy deposited in the pseudorapidity range $-6.6 < \eta < -5.2$ for events with a charged particle jet with $|\eta| < 2$ with respect to the energy in inclusive events, as a function of charged particle jet transverse momentum for $\sqrt{s}=0.9, 2.76$ and 7 TeV.

7.69 CMS_2012_PAS_QCD_11_010 [138]

Strange particle production in underlying events in proton–proton collisions at $\sqrt{s} = 7$ TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Status: PRELIMINARY

Authors:

- Sercan Sen [⟨Sercan.Sen@cern.ch⟩](mailto:Sercan.Sen@cern.ch)

References:

- CMS-PAS-QCD-11-010
- <http://cdsweb.cern.ch/record/1463352>

Run details:

- Inelastic events (non-diffractive and inelastic diffractive) at $\sqrt{s} = 7$ TeV.

Measurements of the production of K_S^0 , Λ and Λ particles in the underlying activity of events with a p_{\perp} scale ranging from 1 to 50 GeV/ c in pp collisions at $\sqrt{s} = 7$ TeV.

7.70 CMS_QCD_10.024 [139]

Pseudorapidity distributions of charged particles at $\sqrt{s}=0.9$ and 7 TeV

Beams: pp

Energies: (450.0, 450.0), (3500.0, 3500.0) GeV

Experiment: CMS (LHC)

Spires ID: ~

Status: VALIDATED

Authors:

- P. Katsas \langle panagiotis.katsas@cern.ch \rangle
- A. Knutsson \langle albert.knutsson@cern.ch \rangle

References:

- CMS-PAS-QCD-10-024
- <https://cdsweb.cern.ch/record/1341853?ln=en>

Run details:

- pp collisions at 0.9 and 7 TeV. Minimum bias events.

Pseudorapidity distributions of charged particles in pp collisions at $\sqrt{s} = 0.9$ and 7 TeV with at least one central charged particle.

7.71 LHCb_2010_I867355 [140]

Measurement of $\sigma(pp \rightarrow b\bar{b} X)$ at $\sqrt{s}=7$ TeV in the forward region

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: LHCb (LHC)

Spires ID: 8785570

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@ed.ac.uk \rangle
- Sercan Sen \langle sercan.sen@cern.ch \rangle
- Peter Skands \langle Peter.Skands@cern.ch \rangle
- Sheldon Stone \langle stone@physics.syr.edu \rangle

References:

- arXiv: [1009.2731](#)

Run details:

- $pp \rightarrow b\text{-hadron} + X$ at 7 TeV. i.e., Switch on "HardQCD:gg2bbbar" and "HardQCD:qqbar2bbbar" flags in pythia8(v165).

The average cross-section to produce b-flavoured or $b\bar{b}$ -flavoured hadrons is measured in different pseudorapidity intervals over the entire range of p_{\perp} assuming the LEP (and Tevatron) fractions for fragmentation into b-flavoured hadrons.

7.72 LHCF_2012_I1115479 [141]

Measurement of forward neutral pion transverse momentum spectra for $\sqrt{s} = 7$ TeV proton-proton collisions at LHC

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: LHCF (LHC)

Status: VALIDATED

Authors:

- Sercan Sen [〈ssen@cern.ch〉](mailto:ssen@cern.ch)

References:

- arXiv: [1205.4578](https://arxiv.org/abs/1205.4578)

Run details:

- Inelastic events (ND+SD+DD) at $\sqrt{s} = 7$ TeV.

The inclusive production rate of neutral pions has been measured by LHCf experiment during $\sqrt{s} = 7$ TeV pp collision operation in early 2010. In order to ensure good event reconstruction efficiency, the range of the π^0 rapidity and p_{\perp} are limited to $8.9 < y < 11.0$ and $p_{\perp} < 0.6$ GeV, respectively.

7.73 TOTEM_2012_002 [142]

Measurement of proton-proton elastic scattering and total cross section at $\sqrt{s} = 7$ TeV.

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: TOTEM (LHC)

Status: VALIDATED

Authors:

- Sercan Sen [⟨Sercan.Sen@cern.ch⟩](mailto:Sercan.Sen@cern.ch)
- Peter Skands [⟨Peter.Skands@cern.ch⟩](mailto:Peter.Skands@cern.ch)

References:

- CERN-PH-EP-2012-239
- <http://cds.cern.ch/record/1472948>

Run details:

- Elastic events only.

Measurement of the elastic differential cross-section in proton-proton interactions at a centre-of-mass energy $\sqrt{s} = 7$ TeV at the LHC. The data, which cover the $|t|$ range 0.005–0.2 GeV², were collected using Roman Pot detectors very close to the outgoing beam in October 2011, allowing the precise extrapolation down to the optical point, $t = 0$, and hence the derivation of the elastic as well as the total cross-section via the optical theorem.

7.74 TOTEM_2012_I1115294

Forward $dN/d\eta$ at 7 TeV

Beams: pp

Energies: (3500.0, 3500.0) GeV

Experiment: TOTEM (LHC)

Status: VALIDATED

Authors:

- Hendrik Hoeth [〈hendrik.hoeth@cern.ch〉](mailto:hendrik.hoeth@cern.ch)

References:

- Europhys.Lett. 98 (2012) 31002
- arXiv: [1205.4105](#)
- CERN-PH-EP-2012-106
- TOTEM 2012-01

Run details:

- pp QCD interactions at 900 GeV and 7 TeV.

The TOTEM experiment has measured the charged particle pseudorapidity density $dN_{\text{ch}}/d\eta$ in pp collisions at $\sqrt{s} = 7$ TeV for $5.3 < |\eta| < 6.4$ in events with at least one charged particle with transverse momentum above 40 MeV/c in this pseudorapidity range.

8. SPS analyses

8.1 UA1_1990_S2044935 [143]

UA1 multiplicities, transverse momenta and transverse energy distributions.

Beams: $\bar{p}p$

Energies: (31.5, 31.5), (100.0, 100.0), (250.0, 250.0), (450.0, 450.0) GeV

Experiment: UA1 (SPS)

Spires ID: 2044935

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@cern.ch \rangle
- Christophe Vaillant \langle c.l.j.vaillant@durham.ac.uk \rangle

References:

- Nucl.Phys.B353:261,1990

Run details:

- QCD min bias events at $\sqrt{s} = 63, 200, 500$ and 900 GeV.

Particle multiplicities, transverse momenta and transverse energy distributions at the UA1 experiment, at energies of 200, 500 and 900 GeV (with one plot at 63 GeV for comparison).

8.2 UA5_1982_S875503 [144]

UA5 multiplicity and pseudorapidity distributions for pp and $p\bar{p}$.

Beams: $\bar{p}p$, pp

Energies: (26.5, 26.5) GeV

Experiment: UA5 (SPS)

Spires ID: 875503

Status: VALIDATED

Authors:

- Andy Buckley \langle andy.buckley@cern.ch \rangle
- Christophe Vaillant \langle c.l.j.vaillant@durham.ac.uk \rangle

References:

- Phys.Lett.112B:183,1982

Run details:

- Min bias QCD events at $\sqrt{s} = 53$ GeV. Run with both pp and $p\bar{p}$ beams.

Comparisons of multiplicity and pseudorapidity distributions for pp and $p\bar{p}$ collisions at 53 GeV, based on the UA5 53 GeV runs in 1982. Data confirms the lack of significant difference between the two beams.

8.3 UA5_1986_S1583476 [145]

Pseudorapidity distributions in $p\bar{p}$ (NSD, NSD+SD) events at $\sqrt{s} = 200$ and 900 GeV

Beams: $\bar{p}p$

Energies: (100.0, 100.0), (450.0, 450.0) GeV

Experiment: UA5 (CERN SPS)

Spires ID: 1583476

Status: VALIDATED

Authors:

- Andy Buckley [⟨andy.buckley@cern.ch⟩](mailto:andy.buckley@cern.ch)
- Holger Schulz [⟨holger.schulz@physik.hu-berlin.de⟩](mailto:holger.schulz@physik.hu-berlin.de)
- Christophe Vaillant [⟨c.l.j.j.vaillant@durham.ac.uk⟩](mailto:c.l.j.j.vaillant@durham.ac.uk)

References:

- Eur. Phys. J. C33, 1, 1986

Run details:

- * Single- and double-diffractive, plus non-diffractive inelastic, events.
- $p\bar{p}$ collider, $\sqrt{s} = 200$ or 900 GeV.
- The trigger implementation for NSD events is the same as in, e.g., the UA5_1989 analysis. No further cuts are needed.

This study comprises measurements of pseudorapidity distributions measured with the UA5 detector at 200 and 900 GeV center of momentum energy. There are distributions for non-single diffractive (NSD) events and also for the combination of single- and double-diffractive events. The NSD distributions are further studied for certain ranges of the events charged multiplicity.

8.4 UA5_1987_S1640666 [146]

UA5 charged multiplicity measurements at 546 GeV

Beams: $\bar{p}p$

Energies: (273.0, 273.0) GeV

Experiment: UA5 (CERN SPS)

Spires ID: 1640666

Status: VALIDATED

Authors:

- Holger Schulz (holger.schulz@physik.hu-berlin.de)

References:

- Phys.Rept.154:247-383,1987

Run details:

- QCD and diffractive events at 546 GeV

Charged particle multiplicity measurement.

8.5 UA5_1988_S1867512 [147]

Charged particle correlations in UA5 p

***barp* NSD events at $\sqrt{s} = 200, 546$ and 900 GeV.**

Beams: $\bar{p}p$

Energies: (100.0, 100.0), (273.0, 273.0), (450.0, 450.0) GeV

Experiment: UA5 (CERN SPS)

Spires ID: 1867512

Status: VALIDATED

Authors:

- Holger Schulz \langle holger.schulz@physik.hu-berlin.de \rangle

References:

- Z.Phys.C37:191-213,1988

Run details:

- ppbar events. Non-single diffractive events need to be switched on. The trigger implementation is the same as in UA5_1989_S1926373. Important: Only the correlation strengths with symmetric eta bins should be used for tuning.

Data on two-particle pseudorapidity and multiplicity correlations of charged particles for non single-diffractive $\bar{p}p$ collisions at c.m. energies of 200, 546 and 900 GeV. Pseudorapidity correlations interpreted in terms of a cluster model, which has been motivated by this and other experiments, require on average about two charged particles per cluster. The decay width of the clusters in pseudorapidity is approximately independent of multiplicity and of c.m. energy. The investigations of correlations in terms of pseudorapidity gaps confirm the picture of cluster production. The strength of forward-backward multiplicity correlations increases linearly with ins and depends strongly on position and size of the pseudorapidity gap separating the forward and backward interval. All our correlation studies can be understood in terms of a cluster model in which clusters contain on average about two charged particles, i.e. are of similar magnitude to earlier estimates from the ISR.

8.6 UA5_1989_S1926373 [148]

UA5 charged multiplicity measurements

Beams: $\bar{p}p$

Energies: (100.0, 100.0), (450.0, 450.0) GeV

Experiment: UA5 (CERN SPS)

Spires ID: 1926373

Status: VALIDATED

Authors:

- Holger Schulz \langle holger.schulz@physik.hu-berlin.de \rangle
- Christophe L. J. Vaillant \langle c.l.j.vaillant@durham.ac.uk \rangle
- Andy Buckley \langle andy.buckley@cern.ch \rangle

References:

- Z. Phys. C - Particles and Fields 43, 357-374 (1989)
- DOI: [10.1007/BF01506531](https://doi.org/10.1007/BF01506531)

Run details:

- Minimum bias events at $\sqrt{s} = 200$ and 900 GeV. Enable single and double diffractive events in addition to non-diffractive processes.

Multiplicity distributions of charged particles produced in non-single-diffractive collisions between protons and antiprotons at centre-of-mass energies of 200 and 900 GeV. The data were recorded in the UA5 streamer chambers at the CERN collider, which was operated in a pulsed mode between the two energies. This analysis confirms the violation of KNO scaling in full phase space found by the UA5 group at an energy of 546 GeV, with similar measurements at 200 and 900 GeV.

9. HERA analyses

9.1 H1_1994_S2919893 [149]

H1 energy flow and charged particle spectra in DIS

Beams: $p e^-$, $p e^+$

Energies: (820.0, 26.7) GeV

Experiment: H1 (HERA)

Spires ID: 2919893

Status: VALIDATED

Authors:

- Peter Richardson \langle peter.richardson@durham.ac.uk \rangle

References:

- Z.Phys.C63:377-390,1994
- DOI: [10.1007/BF01580319](https://doi.org/10.1007/BF01580319)

Run details:

- $e^- p$ / $e^+ p$ deep inelastic scattering, 820 GeV protons colliding with 26.7 GeV electrons

Global properties of the hadronic final state in deep inelastic scattering events at HERA are investigated. The data are corrected for detector effects. Energy flows in both the laboratory frame and the hadronic centre of mass system, and energy-energy correlations in the laboratory frame are presented. Historically, the Ariadne colour dipole model provided the only satisfactory description of this data, hence making it a useful 'target' analysis for MC shower models.

9.2 H1_2000_S4129130 [150]

H1 energy flow in DIS

Beams: pe^+

Energies: (820.0, 27.5) GeV

Experiment: H1 (HERA)

Spires ID: 4129130

Status: VALIDATED

Authors:

- Peter Richardson [⟨peter.richardson@durham.ac.uk⟩](mailto:peter.richardson@durham.ac.uk)

References:

- Eur.Phys.J.C12:595-607,2000
- DOI: [10.1007/s100520000287](https://doi.org/10.1007/s100520000287)
- arXiv: [hep-ex/9907027v1](https://arxiv.org/abs/hep-ex/9907027v1)

Run details:

- e^+p deep inelastic scattering with p at 820 GeV, e^+ at 27.5 GeV $\rightarrow \sqrt{s} = 300$ GeV

Measurements of transverse energy flow for neutral current deep- inelastic scattering events produced in positron-proton collisions at HERA. The kinematic range covers squared momentum transfers Q^2 from 3.2 to 2200 GeV²; the Bjorken scaling variable x from 8×10^{-5} to 0.11 and the hadronic mass W from 66 to 233 GeV. The transverse energy flow is measured in the hadronic centre of mass frame and is studied as a function of Q^2 , x , W and pseudorapidity. The behaviour of the mean transverse energy in the central pseudorapidity region and an interval corresponding to the photon fragmentation region are analysed as a function of Q^2 and W . This analysis is useful for exploring the effect of photon PDFs and for tuning models of parton evolution and treatment of fragmentation and the proton remnant in DIS.

10. RHIC analyses

10.1 STAR_2006_S6500200 [151]

Identified hadron spectra in pp at 200 GeV

Beams: pp

Energies: (100.0, 100.0) GeV

Experiment: STAR (RHIC pp 200 GeV)

Spires ID: 6500200

Status: VALIDATED

Authors:

- Bedanga Mohanty \langle bedanga@rcf.bnl.gov \rangle
- Hendrik Hoeth \langle hendrik.hoeth@cern.ch \rangle

References:

- Phys. Lett. B637, 161
- nucl-ex/0601033

Run details:

- pp at 200 GeV

p_{\perp} distributions of charged pions and (anti)protons in pp collisions at $\sqrt{s} = 200$ GeV, measured by the STAR experiment at RHIC in non-single-diffractive minbias events.

10.2 STAR_2006_S6860818 [152]

Strange particle production in pp at 200 GeV

Beams: pp

Energies: (100.0, 100.0) GeV

Experiment: STAR (RHIC pp 200 GeV)

Spires ID: 6860818

Status: VALIDATED

Authors:

- Hendrik Hoeth (hendrik.hoeth@cern.ch)

References:

- Phys. Rev. C75, 064901
- nucl-ex/0607033

Run details:

- pp at 200 GeV

p_{\perp} distributions of identified strange particles in pp collisions at $\sqrt{s} = 200$ GeV, measured by the STAR experiment at RHIC in non-single-diffractive minbias events. WARNING The $\langle p_{\perp} \rangle$ vs. particle mass plot is not validated yet and might be wrong.

10.3 STAR_2006_S6870392 [153]

Inclusive jet cross-section in pp at 200 GeV

Beams: pp

Energies: (100.0, 100.0) GeV

Experiment: STAR (RHIC pp 200 GeV)

Spires ID: 6870392

Status: VALIDATED

Authors:

- Hendrik Hoeth (hendrik.hoeth@cern.ch)

References:

- Phys. Rev. Lett. 97, 252001
- hep-ex/0608030

Run details:

- pp at 200 GeV

Inclusive jet cross section as a function of p_{\perp} in pp collisions at $\sqrt{s} = 200$ GeV, measured by the STAR experiment at RHIC.

10.4 STAR_2009_UE_HELEN

UE measurement in pp at 200 GeV

Beams: pp

Energies: (100.0, 100.0) GeV

Experiment: STAR (RHIC pp 200 GeV)

Spires ID: [None](#)

Status: PRELIMINARY

Authors:

- Helen Caines [⟨helen.caines@yale.edu⟩](mailto:helen.caines@yale.edu)
- Hendrik Hoeth [⟨hendrik.hoeth@cern.ch⟩](mailto:hendrik.hoeth@cern.ch)

References:

- arXiv: [0910.5203](#)
- arXiv: [0907.3460](#)
- WARNING! Mark as "STAR preliminary" and contact authors when using it!

Run details:

- pp at 200 GeV

UE analysis similar to Rick Field's leading jet analysis. SIScone with radius/resolution parameter $R=0.7$ is used. Particles with $p_{\perp} > 0.2$ GeV and $|\eta| < 1$ are included in the analysis. All particles are assumed to have zero mass. Only jets with neutral energy < 0.7 are included. For the transMIN and transMAX $\Delta(\phi)$ is between $\pi/3$ and $2\pi/3$, and $\Delta(\eta) < 2.0$. For the jet region the area of the jet is used for the normalization, i.e. the scaling factor is πR^2 and not $d\phi d\eta$ (this is different from what Rick Field does!). The tracking efficiency is ~ 0.8 , but that is an approximation, as below $p_{\perp} \sim 0.6$ GeV it is falling quite steeply.

11. Monte Carlo analyses

11.1 MC_DIPHOTON

Monte Carlo validation observables for diphoton production at LHC

Beams: **

Status: VALIDATED

Authors:

- Frank Siebert <frank.siebert@cern.ch>

No references listed

Run details:

- LHC $pp \rightarrow \text{jet}+\text{jet}, \text{photon}+\text{jet}, \text{photon}+\text{photon}$, all with EW+QCD shower

Different observables related to the two photons

11.2 MC_GENERIC

Generic MC testing analysis

Beams: **

Status: VALIDATED

Authors:

- Ian Bruce [⟨ibruce@cern.ch⟩](mailto:ibruce@cern.ch)
- Andy Buckley [⟨andy.buckley@cern.ch⟩](mailto:andy.buckley@cern.ch)

No references listed

Run details:

- Any!

Generic analysis of typical event distributions such as η , y , p_{\perp} , $\phi \dots$

11.3 MC_HINC

Monte Carlo validation observables for $h[\tau^+ \tau^-]$ production

Beams: **

Status: VALIDATED

Authors:

- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

No references listed

Run details:

- $h[\rightarrow \tau^+ \tau^-]$.

Monte Carlo validation observables for $h[\tau^+ \tau^-]$ production

11.4 MC_HJETS

Monte Carlo validation observables for $h[\tau^+ \tau^-] + \text{jets}$ production

Beams: **

Status: VALIDATED

Authors:

- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

No references listed

Run details:

- $h[\rightarrow \tau^+ \tau^-] + \text{jets}$.

The available observables are the Higgs mass, p_\perp of jets 1–4, jet multiplicity, $\Delta\eta(h, \text{jet1})$, $\Delta R(\text{jet2}, \text{jet3})$, differential jet rates 0→1, 1→2, 2→3, 3→4, and integrated 0–4 jet rates.

11.5 MC_HKTSPLITTINGS

Monte Carlo validation observables for $h[\tau^+ \tau^-] + \text{jets}$ production

Beams: **

Status: VALIDATED

Authors:

- Frank Siebert <frank.siebert@cern.ch>

No references listed

Run details:

- $h[\rightarrow \tau^+ \tau^-] + \text{jets}$.

Monte Carlo validation observables for $h[\tau^+ \tau^-] + \text{jets}$ production

11.6 MC_IDENTIFIED

MC testing analysis for identified particle distributions

Beams: **

Status: VALIDATED

Authors:

- Andy Buckley [〈andy.buckley@cern.ch〉](mailto:andy.buckley@cern.ch)

No references listed

Run details:

- Any!

Plotting of distributions of PID codes (all/stable/unstable) and ID-specific distributions such as the $|\eta|$ of K , π and Λ mesons.

11.7 MC_JETS

Monte Carlo validation observables for jet production

Beams: **

Status: VALIDATED

Authors:

- Frank Siebert <frank.siebert@cern.ch>

No references listed

Run details:

- Pure QCD jet production events at an arbitrary collider.

Jets with $p_{\perp} > 20$ GeV are constructed with a k_{\perp} jet finder with $D = 0.7$ and projected onto many different observables.

11.8 MC_LEADJETUE

Underlying event in leading jet events, extended to LHC

Beams: **

Status: VALIDATED

Authors:

- Andy Buckley [⟨andy.buckley@cern.ch⟩](mailto:andy.buckley@cern.ch)

No references listed

Run details:

- LHC pp QCD interactions at 0.9, 10 or 14 TeV. Particles with $c\tau > 10$ mm should be set stable. Several p_{\perp}^{\min} cutoffs are probably required to fill the profile histograms.

Rick Field's measurement of the underlying event in leading jet events, extended to the LHC. As usual, the leading jet of the defines an azimuthal toward/transverse/away decomposition, in this case the event is accepted within $|\eta| < 2$, as in the CDF 2008 version of the analysis. Since this isn't the Tevatron, I've chosen to use k_{\perp} rather than midpoint jets.

11.9 MC_PDFS

Analysis to study PDF sampling in any MC run

Beams: **

Status: VALIDATED

Authors:

- Andy Buckley [〈andy.buckley@cern.ch〉](mailto:andy.buckley@cern.ch)

No references listed

Run details:

- Any!

Plotting of PDF sampling info, such as the Q^2 and both x values of the sampling (aggregated and distinguished as max/min, and some correlations with event properties.

11.10 MC_PHOTONINC

Monte Carlo validation observables for single isolated photon production

Beams: **

Status: VALIDATED

Authors:

- Frank Siebert <frank.siebert@cern.ch>

No references listed

Run details:

- Tevatron Run II ppbar \rightarrow gamma + jets.

Monte Carlo validation observables for single isolated photon production

11.11 MC_PHOTONJETS

Monte Carlo validation observables for photon + jets production

Beams: **

Status: VALIDATED

Authors:

- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

No references listed

Run details:

- Tevatron Run II ppbar \rightarrow gamma + jets.

Different observables related to the photon and extra jets.

11.12 MC_PHOTONKTSPLITTINGS

Monte Carlo validation observables for photon + jets production

Beams: **

Status: VALIDATED

Authors:

- Frank Siebert <frank.siebert@cern.ch>

No references listed

Run details:

- Tevatron Run II ppbar \rightarrow gamma + jets.

Monte Carlo validation observables for photon + jets production

11.13 MC_PHOTONS

Monte Carlo validation observables for general photons

Beams: **

Status: VALIDATED

Authors:

- Steve Lloyd
- Andy Buckley [〈andy.buckley@cern.ch〉](mailto:andy.buckley@cern.ch)

No references listed

Run details:

- Any event type, but there are many observables for photons associated to (semi-)hard leptons.

Observables for testing general unisolated photon properties, especially those associated with charged leptons (e and mu).

11.14 MC_PRINTEVENT

Print out a dump of each event to standard output

Beams: **

Status: VALIDATED

Authors:

- Andy Buckley [⟨andy.buckley@cern.ch⟩](mailto:andy.buckley@cern.ch)

No references listed

Run details:

- Can be used with any event type.

Print out a dump of the event structure to the terminal standard output, in a conveniently human readable form with e.g. particle names in addition to the usual numerical ID codes.

11.15 MC_QCD_PARTONS

Generic parton-level Monte Carlo validation analysis for $jX_L + \text{jets}$.

Beams: **

Status: VALIDATED

Authors:

- Frank Siebert (frank.siebert@cern.ch)

No references listed

Run details:

- Any $jX_L + \text{jets}$.

Only partons (excluding top quarks) are taken into account to construct a kt cluster sequence. Thus this analysis can be used as a generic validation tool for QCD activity.

11.16 MC_SUSY

Validate generic SUSY events, including various lepton invariant mass

Beams: **

Status: VALIDATED

Authors:

- Andy Buckley [⟨andy.buckley@cern.ch⟩](mailto:andy.buckley@cern.ch)

No references listed

Run details:

- SUSY events at any energy. p_{\perp} cutoff at 10 GeV may be advised.

Analysis of generic SUSY events at the LHC, based on Atlas Herwig++ validation analysis contents. Plotted are eta, phi and p_{\perp} observables for charged tracks, photons, isolated photons, electrons, muons, and jets, as well as various dilepton mass ‘edge’ plots for different event selection criteria.

11.17 MC_TTBAR

MC analysis for ttbar studies

Beams: **

Status: VALIDATED

Authors:

- Hendrik Hoeth [⟨hendrik.hoeth@cern.ch⟩](mailto:hendrik.hoeth@cern.ch)
- Andy Buckley [⟨andy.buckley@cern.ch⟩](mailto:andy.buckley@cern.ch)
- Dave Mallows
- Michal Kawalec

No references listed

Run details:

- * For Pythia6, set MSEL=6 and fix W^+ and W^- decays to semi-leptonic modes via the MDME array.
- For Fortran Herwig/Jimmy select IPROC=1706.

This is a pure Monte Carlo study for semi-leptonic $t\bar{t}$ production.

11.18 MC_VH2BB

MC unboosted VH2bb validation plots

Beams: **

Status: UNVALIDATED

Authors:

- Ben Smart [〈bsmart@cern.ch〉](mailto:bsmart@cern.ch)
- Andy Buckley [〈andy.buckley@cern.ch〉](mailto:andy.buckley@cern.ch)

No references listed

Run details:

- VH with $H \rightarrow b\bar{b}$ and the vector boson decaying to electron or muon channels.

Various plots for characterising the process $VH \rightarrow b\bar{b}$

11.19 MC_WINC

Monte Carlo validation observables for inclusive $W[e\nu]$ production

Beams: **

Status: VALIDATED

Authors:

- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

No references listed

Run details:

- $e\nu$ + jets analysis.

Monte Carlo validation observables for inclusive $W[e\nu]$ production

11.20 MC_WJETS

Monte Carlo validation observables for $W[e\nu]$ + jets production

Beams: **

Status: VALIDATED

Authors:

- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

No references listed

Run details:

- $e\nu$ + jets analysis.

Monte Carlo validation observables for $W[e\nu]$ + jets production

11.21 MC_WKTSPLITTINGS

Monte Carlo validation observables for k_{\perp} splitting scales in $W[e\nu] + \text{jets}$ events

Beams: **

Status: VALIDATED

Authors:

- Frank Siegert (frank.siegert@cern.ch)

No references listed

Run details:

- $e\nu + \text{jets}$ analysis.

Monte Carlo validation observables for k_{\perp} splitting scales in $W[e\nu] + \text{jets}$ events

11.22 MC_WPOL

Monte Carlo validation observables for W polarisation

Beams: **

Status: VALIDATED

Authors:

- Frank Siebert <frank.siebert@cern.ch>

No references listed

Run details:

- $W \rightarrow e \nu + \text{jets}$.

Observables sensitive to the polarisation of the W boson: A0, ... A7, fR, fL, f0, separately for W^+ and W^- .

11.23 MC_WWINC

Monte Carlo validation observables for $W^+[e^+ \nu]W^-[\mu^- \nu]$ production

Beams: **

Status: VALIDATED

Authors:

- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

No references listed

Run details:

- WW analysis.

Monte Carlo validation observables for $W^+[e^+ \nu]W^-[\mu^- \nu]$ production

11.24 MC_WWJETS

Monte Carlo validation observables for $W^+[e^+ \nu]W^-[\mu^- \nu]$ + jets production

Beams: **

Status: VALIDATED

Authors:

- Frank Siebert <frank.siebert@cern.ch>

No references listed

Run details:

- WW + jets analysis.

In addition to the typical jet observables this analysis contains observables related to properties of the WW -pair momentum, correlations between the WW , properties of the W bosons, properties of the leptons, correlations between the opposite charge leptons and correlations with jets.

11.25 MC_WWKTSPPLITTINGS

Monte Carlo validation observables for $W^+[e^+ \nu]W^-[\mu^- \nu] + \text{jets}$ production

Beams: **

Status: VALIDATED

Authors:

- Frank Siebert [⟨frank.siebert@cern.ch⟩](mailto:frank.siebert@cern.ch)

No references listed

Run details:

- $WW + \text{jets}$ analysis.

Monte Carlo validation observables for $W^+[e^+ \nu]W^-[\mu^- \nu] + \text{jets}$ production

11.26 MC_XS

MC analysis for process total cross section

Beams: **

Status: VALIDATED

Authors:

- Marek Schoenherr (marek.schoenherr@tu-dresden.de)

No references listed

Run details:

- Suitable for any process.

Analysis for bookkeeping of the total cross section, number of generated events and the ratio of events with positive and negative weights.

11.27 MC_ZINC

Monte Carlo validation observables for $Z[e^+ e^-]$ production

Beams: **

Status: VALIDATED

Authors:

- Frank Siebert <frank.siebert@cern.ch>

No references listed

Run details:

- e^+e^- analysis. Needs mass cut on lepton pair to avoid photon singularity, e.g. a min range of $66 < m_{ee} < 116$ GeV

Monte Carlo validation observables for $Z[e^+ e^-]$ production

11.28 MC_ZJETS

Monte Carlo validation observables for $Z[e^+ e^-] + \text{jets}$ production

Beams: **

Status: VALIDATED

Authors:

- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

No references listed

Run details:

- $e^+e^- + \text{jets}$ analysis. Needs mass cut on lepton pair to avoid photon singularity, e.g. a min range of $66 < m_{ee} < 116$ GeV

Available observables are Z mass, p_\perp of jets 1-4, jet multiplicity, $\Delta\eta(Z, \text{jet1})$, $\Delta R(\text{jet2}, \text{jet3})$, differential jet rates $0 \rightarrow 1$, $1 \rightarrow 2$, $2 \rightarrow 3$, $3 \rightarrow 4$, integrated 0–4 jet rates.

11.29 MC_ZKTSPLITTINGS

Monte Carlo validation observables for $Z[e^+ e^-] + \text{jets}$ production

Beams: **

Status: VALIDATED

Authors:

- Frank Siebert (frank.siebert@cern.ch)

No references listed

Run details:

- $e^+e^- + \text{jets}$ analysis. Needs mass cut on lepton pair to avoid photon singularity, e.g. a min range of $66 < m_{ee} < 116$ GeV

Monte Carlo validation observables for $Z[e^+ e^-] + \text{jets}$ production

11.30 MC_ZZINC

Monte Carlo validation observables for $Z[e^+ e^-]Z[\mu^+ \mu^-]$ production

Beams: **

Status: VALIDATED

Authors:

- Frank Siegert [⟨frank.siegert@cern.ch⟩](mailto:frank.siegert@cern.ch)

No references listed

Run details:

- ZZ + jets analysis. Needs mass cut on lepton pairs to avoid photon singularity, e.g. a min range of $66 < m_{ee} < 116$ GeV

Monte Carlo validation observables for $Z[e^+ e^-]Z[\mu^+ \mu^-]$ production

11.31 MC_ZZJETS

Monte Carlo validation observables for $Z[e^+ e^-]Z[\mu^+ \mu^-] + \text{jets}$ production

Beams: **

Status: VALIDATED

Authors:

- Frank Siebert (frank.siebert@cern.ch)

No references listed

Run details:

- $ZZ + \text{jets}$ analysis. Needs mass cut on lepton pairs to avoid photon singularity, e.g. a min range of $66 < m_{ee} < 116$ GeV

In addition to the typical jet observables this analysis contains observables related to properties of the ZZ -pair momentum, correlations between the ZZ , properties of the Z bosons, properties of the leptons, correlations between the opposite charge leptons and correlations with jets.

11.32 MC_ZZKTSPLITTINGS

Monte Carlo validation observables for $Z[e^+ e^-]Z[\mu^+ \mu^-] + \text{jets}$ production

Beams: **

Status: VALIDATED

Authors:

- Frank Siebert [⟨frank.siebert@cern.ch⟩](mailto:frank.siebert@cern.ch)

No references listed

Run details:

- $ZZ + \text{jets}$ analysis. Needs mass cut on lepton pairs to avoid photon singularity, e.g. a min range of $66 < m_{ee} < 116$ GeV

Monte Carlo validation observables for $Z[e^+ e^-]Z[\mu^+ \mu^-] + \text{jets}$ production

12. Example analyses

12.1 EXAMPLE

A demo to show aspects of writing a Rivet analysis

Beams: **

Status: EXAMPLE

Authors:

- Andy Buckley [⟨andy.buckley@cern.ch⟩](mailto:andy.buckley@cern.ch)

No references listed

Run details:

- All event types will be accepted.

This analysis is a demonstration of the Rivet analysis structure and functionality: booking histograms; the initialisation, analysis and finalisation phases; and a simple loop over event particles. It has no physical meaning, but can be used as a simple pedagogical template for writing real analyses.

13. Misc. analyses

13.1 ARGUS_1993_S2653028 [154]

Inclusive production of charged pions, kaons and protons in $\Upsilon(4S)$ decays.

Beams: e^+e^-

Energies: (5.3, 5.3) GeV

Spires ID: 2653028

Status: VALIDATED

Authors:

- Peter Richardson (Peter.Richardson@durham.ac.uk)

References:

- Z.Phys. C58 (1993) 191-198

Run details:

- e^+e^- analysis on the $\Upsilon(4S)$ resonance.

Measurement of inclusive production of charged pions, kaons and protons from $\Upsilon(4S)$ decays. Kaon spectra are determined in two different ways using particle identification and detecting decays in-flight. Results are background continuum subtracted. This analysis is useful for tuning B meson decay modes.

13.2 ARGUS_1993_S2669951 [155]

Production of the $\eta'(958)$ and $f_0(980)$ in e^+e^- annihilation in the Upsilon region.

Beams: e^+e^-

Energies: (4.7, 4.7), (5.0, 5.0), (5.2, 5.2) GeV

Spires ID: 2669951

Status: VALIDATED

Authors:

- Peter Richardson [⟨Peter.Richardson@durham.ac.uk⟩](mailto:Peter.Richardson@durham.ac.uk)

References:

- Z.Phys. C58 (1993) 199-206

Run details:

- e^+e^- analysis near the $\Upsilon(4S)$ resonance.

Measurement of the inclusive production of the $\eta'(958)$ and $f_0(980)$ mesons in e^+e^- annihilation in the Upsilon region. Data are taken on the $\Upsilon(1S)$, $\Upsilon(2S)$ and $\Upsilon(4S)$ resonances and in the nearby continuum (9.36 to 10.45 GeV cm energy)

13.3 ARGUS_1993_S2789213 [156]

Inclusive production of $K^*(892)$, $\rho^0(770)$, and $\omega(783)$ mesons in the upsilon energy region.

Beams: $e^+ e^-$

Energies: (4.7, 4.7), (5.2, 5.2), (5.3, 5.3) GeV

Spires ID: 2789213

Status: VALIDATED

Authors:

- Peter Richardson (Peter.Richardson@durham.ac.uk)

References:

- Z.Phys. C61 (1994) 1-18

Run details:

- e^+e^- analysis in the 10 GeV CMS energy range

Measurement of the inclusive production of the vector mesons $K^*(892)$, $\rho^0(770)$ and $\omega(783)$ in e^+e^- annihilation in the Upsilon region by the Argus Collaboration. Useful for tuning simulations of B meson and bottomium decays.

13.4 BABAR_2003_I593379 [157]

Measurement of inclusive charmonium production

Beams: $e^+ e^-$

Energies: (3.5, 8.0) GeV

Status: VALIDATED

Authors:

- Peter Richardson (Peter.Richardson@durham.ac.uk)

References:

- Phys.Rev. D67 032002, 2003
- hep-ex/0207097

Run details:

- Production of charmonium at the $\Upsilon(4S)$ resonance.

Measurement of J/ψ , ψ' , χ_{c1} and χ_{c2} production using a data sample corresponding to an integrated luminosity of 20.3 fb^{-1} collected with the BABAR detector at the SLAC PEP-II electron-positron storage ring operating at a centre-of-mass energy near 10.58 GeV.

13.5 BABAR_2005_S6181155 [158]

Production and decay of Ξ_c^0 at BABAR.

Beams: $e^+ e^-$

Energies: (3.5, 8.0), (3.5, 7.9) GeV

Spires ID: 6895344

Status: VALIDATED

Authors:

- Peter Richardson \langle Peter.Richardson@durham.ac.uk \rangle

References:

- Phys.Rev.Lett. 95 (2005) 142003
- hep-ex/0504014

Run details:

- $e^+ e^-$ analysis on the $\Upsilon(4S)$ resonance, with CoM boost – 8.0 GeV (e^-) and 3.5 GeV (e^+)

Analysis of Ξ_c^0 production in B decays and from the $c\bar{c}$ continuum, with the Ξ_c^0 decaying into $\Omega^- K^+$ and $\Xi^- \pi^+$ final states measured using 116.1 fb^{-1} of data collected by the BABAR detector. The normalisation of the data as been modified from that presented in the original paper in order to produce a differential cross section rather than the cross section in each bin. In addition to the data presented in the paper plots are alos made with unit normalisation which can be more useful for Monte Carlo tuning.

13.6 BABAR_2007_S6895344 [159]

Inclusive Λ_c^+ Production in e^+e^- Annihilation at $\sqrt{s} = 10.54$ GeV and in $\Upsilon(4S)$ Decays.

Beams: $e^+ e^-$

Energies: (3.5, 8.0), (3.5, 7.9) GeV

Spires ID: [6895344](#)

Status: VALIDATED

Authors:

- Peter Richardson [⟨ Peter.Richardson@durham.ac.uk ⟩](mailto:Peter.Richardson@durham.ac.uk)

References:

- Phys.Rev. D75 (2007) 012003
- hep-ex/0609004

Run details:

- e^+e^- analysis on the $\Upsilon(4S)$ resonance, with CoM boost – 8.0 GeV (e^-) and 3.5 GeV (e^+)

Measurements of the total production rates and momentum distributions of the charmed baryon Λ_c^+ in $e^+e^- \rightarrow$ hadrons at a centre-of-mass energy of 10.54 GeV and in $\Upsilon(4S)$ decays.

13.7 BABAR_2007_S7266081 [160]

Measurements of Semi-Leptonic Tau Decays into Three Charged Hadrons

Beams: $e^+ e^-$

Energies: (3.5, 8.0) GeV

Spires ID: 7266081

Status: VALIDATED

Authors:

- Peter Richardson \langle Peter.Richardson@durham.ac.uk \rangle

References:

- Phys.Rev.Lett.100:011801,2008
- arXiv: [0707.2981](https://arxiv.org/abs/0707.2981)
- SLAC-R-936

Run details:

- Tau production, can be any process but original data was in e^+e^- at the $\Upsilon(4S)$ resonance, with CoM boost – 8.0 GeV (e^-) and 3.5 GeV (e^+)

Measurement of tau decays to three charged hadrons using a data sample corresponding to an integrated luminosity of 342 fb^{-1} collected with the BABAR detector at the SLAC PEP-II electron-positron storage ring operating at a center-of-mass energy near 10.58 GeV.

13.8 BELLE_2001_S4598261 [161]

Measurement of inclusive production of neutral pions from $\Upsilon(4S)$ decays.

Beams: e^+e^-

Energies: (3.5, 8.0) GeV

Spires ID: 4598261

Status: VALIDATED

Authors:

- Peter Richardson \langle Peter.Richardson@durham.ac.uk \rangle

References:

- Phys.Rev. D64 (2001) 072001
- hep-ex/0103041

Run details:

- e^+e^- analysis on the $\Upsilon(4S)$ resonance, with CoM boost – 8.0 GeV (e^-) and 3.5 GeV (e^+)

Measurement of the mean multiplicity and the momentum spectrum of neutral pions from the decays of the Upsilon(4S) resonance using the Belle detector operating at the KEKB e^+e^- storage ring. Useful for tuning B meson decay models.

13.9 BELLE_2006_S6265367 [162]

Charm hadrons from fragmentation and B decays on the $\Upsilon(4S)$

Beams: $e^+ e^-$

Energies: (3.5, 8.0), (3.5, 7.9) GeV

Spires ID: 6265367

Status: VALIDATED

Authors:

- Jan Eike von Seggern [⟨jan.eike.von.seggern@physik.hu-berlin.de⟩](mailto:jan.eike.von.seggern@physik.hu-berlin.de)

References:

- Phys.Rev.D73:032002,2006.
- arXiv: [hep-ex/0506068](https://arxiv.org/abs/hep-ex/0506068)
- DOI: [10.1103/PhysRevD.73.032002](https://doi.org/10.1103/PhysRevD.73.032002)

Run details:

- e^+e^- analysis on the $\Upsilon(4S)$ resonance, with CoM boost – 8.0 GeV (e) and 3.5 GeV (e^+)

Analysis of charm quark fragmentation at 10.6 GeV, based on a data sample of 103 fb collected by the Belle detector at the KEKB accelerator. Fragmentation into charm is studied for the main charmed hadron ground states, namely D^0 , D^+ , D_s^+ and Λ_c^+ , as well as the excited states D^{*0} and D^{*+} . This analysis can be used to constrain charm fragmentation in Monte Carlo generators. As the original data are not corrected for the branching ratios of the decay modes used to observed the charm hadrons we also include distributions with unit normalisation which are more useful for Monte Carlo tuning.

13.10 CLEO_2004_S5809304 [163]

Charm hadrons from fragmentation near the $\Upsilon(4S)$

Beams: $e^+ e^-$

Energies: (5.3, 5.3) GeV

Spires ID: 6265367

Status: VALIDATED

Authors:

- Peter Richardson \langle Peter.Richardson@durham.ac.uk \rangle

References:

- Phys.Rev.D70:112001,2004.
- arXiv: [hep-ex/0402040](https://arxiv.org/abs/hep-ex/0402040)

Run details:

- e^+e^- analysis near the $\Upsilon(4S)$ resonance

Analysis of charm quark fragmentation at 10.5 GeV, based on a data sample of 103 fb collected by the CLEO experiment. Fragmentation into charm is studied for the charmed hadron ground states, namely D^0 , D^+ , as well as the excited states D^{*0} and D^{*+} . This analysis can be used to constrain charm fragmentation in Monte Carlo generators.

13.11 JADE_1998_S3612880 [164]

Event shapes for 22, 35 and 44 GeV

Beams: $e^- e^+$

Energies: (11.0, 11.0), (17.5, 17.5), (22.0, 22.0) GeV

Experiment: JADE (PETRA)

Spires ID: 3612880

Status: VALIDATED

Authors:

- Holger Schulz holger.schulz@physik.hu-berlin.de

References:

- hep-ex/9708034
- Eur.Phys.J.C1:461-478,1998

Run details:

- $Z \rightarrow$ hadronic final states, $b\bar{b}$ contributions have been corrected for as well as ISR

Thrust, Jet Mass and Broadenings, Y23 for 35 and 44 GeV and only Y23 at 22 GeV.

13.12 PDG_HADRON_MULTIPLICITIES [165]

Hadron multiplicities in hadronic e^+e^- events

Beams: e^+e^-

Energies: (5.0, 5.0), (17.5, 17.5), (45.6, 45.6), (88.5, 88.5) GeV

Experiment: PDG (Various)

Spires ID: 7857373

Status: VALIDATED

Authors:

- Hendrik Hoeth (hendrik.hoeth@cern.ch)

References:

- Phys. Lett. B, 667, 1 (2008)

Run details:

- Hadronic events in e^+e^- collisions

Hadron multiplicities in hadronic e^+e^- events, taken from Review of Particle Properties 2008, table 40.1, page 355. Average hadron multiplicities per hadronic e^+e^- annihilation event at $\sqrt{s} \approx 10, 29\text{--}35, 91$, and $130\text{--}200$ GeV. The numbers are averages from various experiments. Correlations of the systematic uncertainties were considered for the calculation of the averages.

13.13 PDG_HADRON_MULTIPLICITIES_RATIOS [165]

Ratios (w.r.t. π^+/π^-) of hadron multiplicities in hadronic e^+e^- events

Beams: e^+e^-

Energies: (5.0, 5.0), (17.5, 17.5), (45.6, 45.6), (88.5, 88.5) GeV

Experiment: PDG (Various)

Spires ID: [7857373](#)

Status: VALIDATED

Authors:

- Holger Schulz (holger.schulz@physik.hu-berlin.de)

References:

- Phys. Lett. B, 667, 1 (2008)

Run details:

- Hadronic events in e^+e^- collisions

Ratios (w.r.t. π^+/π^-) of hadron multiplicities in hadronic e^+e^- events, taken from Review of Particle Properties 2008, table 40.1, page 355. Average hadron multiplicities per hadronic e^+e^- annihilation event at $\sqrt{s} \approx 10, 29\text{--}35, 91$, and $130\text{--}200$ GeV, normalised to the pion multiplicity. The numbers are averages from various experiments. Correlations of the systematic uncertainties were considered for the calculation of the averages.

13.14 TASSO_1990_S2148048 [166]

Event shapes in e+e- annihilation at 14-44 GeV

Beams: $e^- e^+$

Energies: (7.0, 7.0), (11.0, 11.0), (17.5, 17.5), (21.9, 21.9) GeV

Experiment: TASSO (PETRA)

Spires ID: [2148048](#)

Status: VALIDATED

Authors:

- Holger Schulz holger.schulz@physik.hu-berlin.de

References:

- Z.Phys.C47:187-198,1990
- DESY-90-013

Run details:

- $e^+e^- \rightarrow \text{jet jet (+ jets)}$. Kinematic cuts such as CKIN(1) in Pythia need to be set slightly below the CMS energy.

Event shapes Thrust, Sphericity, Aplanarity at four different energies

Part III

How Rivet works

Hopefully by now you’ve run Rivet a few times and got the hang of the command line interface and viewing the resulting analysis data files. Maybe you’ve got some ideas of analyses that you would like to see in Rivet’s library. If so, then you’ll need to know a little about Rivet’s internal workings before you can start coding: with any luck by the end of this section that won’t seem particularly intimidating.

The core objects in Rivet are “projections” and “analyses”. Hopefully “analyses” isn’t a surprise — that’s just the collection of routines that will make histograms to compare with reference data, and the only things that might differ there from experiences with HZTool[167] are the new histogramming system and the fact that we’ve used some object orientation concepts to make life a bit easier. The meaning of “projections”, as applied to event analysis, will probably be less obvious. We’ll discuss them soon, but first a semi-philosophical aside on the “right way” to do physics analyses on and involving simulated data.

14. The science and art of physically valid MC analysis

The world of MC event generators is a wonderfully convenient one for experimentalists: we are provided with fully exclusive events whose most complex correlations can be explored and used to optimise analysis algorithms and some kinds of detector correction effects. It is absolutely true that the majority of data analyses and detector designs in modern collider physics would be very different without MC simulation.

But it is very important to remember that it is just simulation: event generators encode much of known physics and phenomenologically explore the non-perturbative areas of QCD, but only unadulterated experiment can really tell us about how the world behaves. The richness and convenience of MC simulation can be seductive, and it is important that experimental use of MC strives to understand and minimise systematic biases which may result from use of simulated data, and to not “unfold” imperfect models when measuring the real world. The canonical example of the latter effect is the unfolding of hadronisation (a deeply non-perturbative and imperfectly-understood process) at the Tevatron (Run I), based on MC models. Publishing “measured quarks” is not physics — much of the data thus published has proven of little use to either theory or experiment in the following years. In the future we must be alert to such temptation and avoid such gaffes — and much more subtle ones.

These concerns on how MC can be abused in treating measured data also apply to MC validation studies. A key observable in QCD tunings is the p_{\perp} of the Z boson, which has no phase space at exactly $p_{\perp} = 0$ but a very sharp peak at $\mathcal{O}(1\text{-}2\text{ GeV})$. The exact location of this peak is mostly sensitive to the width parameter of a nucleon “intrinsic p_{\perp} ” in MC generators, plus some soft initial state radiation and QED bremsstrahlung. Unfortunately, all the published Tevatron measurements of this observable have either “unfolded” the QED

effects to the “ $Z p_\perp$ ” as attached to the object in the HepMC/HEPEVT event record with a PDG ID code of 23, or have used MC data to fill regions of phase space where the detector could not measure. Accordingly, it is very hard to make an accurate and portable MC analysis to fit this data, without similarly delving into the event record in search of “the boson”. While common practice, this approach intrinsically limits the precision of measured data to the calculational order of the generator — often not analytically well-defined. We can do better.

Away from this philosophical propaganda (which nevertheless we hope strikes some chords in influential places...), there are also excellent pragmatic reasons for MC analyses to avoid treating the MC “truth” record as genuine truth. The key argument is portability: there is no MC generator which is the ideal choice for all scenarios, and an essential tool for understanding sub-leading variability in theoretical approaches to various areas of physics is to use several generators with similar leading accuracies but different sub-leading formalisms. While the HEPEVT record as written by HERWIG and PYTHIA has become familiar to many, there are many ambiguities in how it is filled, from the allowed graph structures to the particle content. Notably, the Sherpa event generator explicitly elides Feynman diagram propagators from the event record, perhaps driven by a desire to protect us from our baser analytical instincts. The Herwig++ event generator takes the almost antipodal approach of expressing different contributing Feynman diagram topologies in different ways (*not* physically meaningful!) and seamlessly integrating shower emissions with the hard process particles. The general trend in MC simulation is to blur the practically-induced line between the sampled matrix element and the Markovian parton cascade, challenging many established assumptions about “how MC works”. In short, if you want to “find” the Z to see what its p_\perp or η spectrum looks like, many new generators may break your honed PYTHIA code...or silently give systematically wrong results. The unfortunate truth is that most of the event record is intended for generator debugging rather than physics interpretation.

Fortunately, the situation is not altogether negative: in practice it is usually as easy to write a highly functional MC analysis using only final state particles and their physically meaningful on-shell decay parents. These are, since the release of HepMC 2.5, standardised to have status codes of 1 and 2 respectively. Z -finding is then a matter of choosing decay lepton candidates, windowing their invariant mass around the known Z mass, and choosing the best Z candidate: effectively a simplified version of an experimental analysis of the same quantity. This is a generally good heuristic for a safe MC analysis! Note that since it’s known that you will be running the analysis on signal events, and there are no detector effects to deal with, almost all the details that make a real analysis hard can be ignored. The one detail that is worth including is summing momentum from photons around the charged leptons, before mass-windowing: this physically corresponds to the indistinguishability of collinear energy deposits in trackers and calorimeters and would be the ideal published experimental measurement of Drell-Yan p_\perp for MC tuning. Note that similar analyses for W bosons have the luxury over a true experiment of being able to exactly identify the decay neutrino rather than having to mess around with missing energy. Similarly, detailed unstable hadron (or tau) reconstruction is unnecessary, due to the presence of these particles in the event record with status code 2. In short, writing an effective analysis which is

automatically portable between generators is no harder than trying to decipher the variable structures and multiple particle copies of the debugging-level event objects. And of course Rivet provides lots of tools to do almost all the standard fiddly bits for you, so there’s no excuse!

Good luck, and be careful!

15. Projections

The name “projection” is meant to evoke thoughts of projection operators, low-dimensional slices/views of high-dimensional spaces, and other things that might appeal to physicists who view the world through quantum-tinted lenses. A more mundane, but equally applicable, name would be “observable calculators”, but since that’s a long name, the things they return aren’t *necessarily* observable, and they all inherit from the **Projection** base class, we’ll stick to that name. It doesn’t take long to get used to using the name as a synonym for “calculator”, without being intimidated by ideas that they might be some sort of high-powered deep magic. 90% of them is simple and self-explanatory, as a peek under the bonnet of e.g. the all-important **FinalState** projection will reveal.

Projections can be relatively simple things like event shapes (i.e. scalar, vector or tensor quantities), or arbitrarily complex things like lossy or selective views of the event final state. Most users will see them attached to analyses by declarations in each analysis’ initialisation, but they can also be recursively “nested” inside other projections² (provided there are no infinite loops in the nesting chain.) Calling a complex projection in an analysis may actually transparently execute many projections on each event.

15.1 Projection caching

Aside from semantic issues of how the class design assigns the process of analysing events, projections are important computationally because they live in a framework which automatically stores (“caches”) their results between events. This is a crucial feature for the long-term scalability of Rivet, as the previous experience with HZTool was that HERA validation code ran very slowly due to repeated calculation of the same k_{\perp} clustering algorithm (at that time notorious for scaling as the 3rd power of the number of particles.)

A concrete example may help in understanding how this works. Let’s say we have two analyses which have the same run conditions, i.e. incoming beam types, beam energies, etc. Each also uses the thrust event shape measure to define a set of basis vectors for their analysis. For each event that gets passed to Rivet, whichever analysis gets called first will immediately (although maybe indirectly) call a **FinalState** projection to get a list of stable, physical particles (filtering out the intermediate and book-keeping entries in the HepMC event record). That FS projection is then “attached” to the event. Next, the first analysis will call a **Thrust** projection which internally uses the same final state projection to define

²Provided there are no dependency loops in the projection chains! Strictly, only acyclic graphs of projection dependencies are valid, but there is currently no code in Rivet that will attempt to verify this restriction.

the momentum vectors used in calculating the thrust. Once finished, the thrust projection will also be attached to the event.

So far, projections have offered no benefits. However, when the second analysis runs it will similarly try to apply its final state and thrust projections to the event. Rather than repeat the calculations, Rivet’s infrastructure will detect that an equivalent calculation has already been run and will just return references to the already-run projections. Since projections can also contain and use other projections, this model allows some substantial computational savings, without the analysis author even needing to be particularly aware of what is going on.

Observant readers may have noticed a problem with all this projection caching cleverness: what if the final states aren’t defined the same way? One might provide charged final state particles only, or the acceptances (defined in pseudorapidity range and a IR p_{\perp} cutoff) might differ. Rivet handles this by making each projection provide a comparison operator which is used to decide whether the cached version is acceptable or if the calculation must be re-run with different settings. Because projections can be nested, applying a top-level projection to an event can spark off a cascade of comparisons, calculations and cache accesses, making use of existing results wherever possible.

15.2 Using projection caching

So far this is all theory — how does one actually use projections in Rivet? First, you should understand that projections, while semantically stored within each other, are actually all registered with a central `ProjectionHandler` object.³ The reason for this central registration is to ensure that all projections’ lifespans are managed in a consistent way, and to protect projection and analysis authors from some technical subtleties in how C++ polymorphism works.

Inside the constructor of a `Projection` or the `init` method of an `Analysis` class, you must call the `addProjection` function. This takes two arguments, the projection to be registered (by `const` reference), and a name. The name is local to the parent object, so you need not worry about name clashes between objects. A very important point is that the passed `Projection` is not the one that is actually centrally registered — that distinction belongs to a newly created heap object which is created within the `addProjection` method by means of the overloaded `Projection::clone()` method. Hence it is completely safe — and recommended — to use only local (stack) objects in `Projection` and `Analysis` constructors.



At this point, if you have rightly bought into C++ ideas like super-strong type-safety, this proliferation of dynamic casting may worry you: the compiler can’t possibly check if a projection of the requested name has been registered, nor whether the downcast to the requested concrete type is legal. These are very legitimate concerns! In truth, we’d like to have this level of extra safety! But in the past, when projections were held

³As of version 1.1 onwards — previously, they were stored as class members inside other `Projection`s and `Analysis` classes.

as members of *ProjectionApplier* classes rather than in the central *ProjectionHandler* repository, the benefits of the strong typing were outweighed by more serious and subtle bugs relating to projection lifetime and object “slicing”. At least when the current approach goes wrong it will throw an unmissable runtime error — until it’s fixed, of course! — rather than silently do the wrong thing.

Our problems here are a microcosm of the perpetual language battle between strict and dynamic typing, runtime versus compile time errors. In practice, this manifests itself as a trade-off between the benefits of static type safety and the inconvenience of the type-system gymnastics that it engenders. We take some comfort from the number of very good programs have been and are still written in dynamically typed, interpreted languages like Python, where virtually all error checking (barring first-scan parsing errors) must be done at runtime. By pushing some checking to the domain of runtime errors, Rivet’s code is (we believe) in practice safer, and certainly more clear and elegant. However, we believe that with runtime checking should come a culture of unit testing, which is not yet in place in Rivet.

As a final thought, one reason for Rivet’s internal complexity is that C++ is just not a very good language for this sort of thing: we are operating on the boundary between event generator codes, number crunching routines (including third party libraries like FastJet) and user routines. The former set unavoidably require native interfaces and benefit from static typing; the latter benefit from interface flexibility, fast prototyping and syntactic clarity. Maybe a future version of Rivet will break through the technical barriers to a hybrid approach and allow users to run compiled projections from interpreted analysis code. For now, however, we hope that our brand of “slightly less safe C++” will be a pleasant compromise.

16. Analyses

16.1 Writing a new analysis

This section provides a recipe that can be followed to write a new analysis using the Rivet projections.

Every analysis must inherit from `Rivet::Analysis` and, in addition to the constructor, must implement a minimum of three methods. Those methods are `init()`, `analyze(const Rivet::Event&)` and `finalize()`, which are called once at the beginning of the analysis, once per event and once at the end of the analysis respectively.

The new analysis should include the header for the base analysis class plus whichever Rivet projections are to be used, and should work under the `Rivet` namespace. Since analyses are hardly ever intended to be inherited from, they are usually implemented within a single `.cc` file with no corresponding header. The skeleton of a new analysis named `UserAnalysis` that uses the `FinalState` projection might therefore start off looking like this, in a file named `UserAnalysis.cc`:

```
#include "Rivet/Analysis.hh"
```

```

namespace Rivet {

    class UserAnalysis : public Analysis {
    public:
        UserAnalysis() : Analysis("USERANA") { }
        void init() { ... }
        void analyze(const Event& event) { ... }
        void finalize() { ... }
    };

}

```

The constructor body is usually left empty, as all event loop setup is done in the `init()` method: the one *required* constructor feature is to make a call to its base `Analysis` constructor, passing a string by which the analysis will *register* itself with the Rivet framework. This name is the one exposed to a command-line or API user of this analysis: usually it is the same as the class name, which for official analyses is always in upper case.



Early versions of Rivet required the user to declare allowed beam types, energies, whether a cross-section is required, etc. in the analysis constructor via methods like `setBeams(...)` and `setNeedsCrossSection(...)`. This information is now *much* preferred to be taken from the `.info` file for the analysis, and *must* be done this way in analyses submitted for inclusion in future Rivet releases.

The `init()` method for the `UserAnalysis` class should add to the analysis all of the projections that will be used. Projections can be added to an analysis with a call to `addProjection(Projection, std::string)`, which takes as argument the projection to be added and a name by which that projection can later be referenced. For this example the `FinalState` projection is to be referenced by the string "FS" to provide access to all of the final state particles inside a detector pseudorapidity coverage of ± 5.0 . The syntax to create and add that projection is as follows:

```

init() {
    const FinalState fs(-5.0, 5.0);
    addProjection(fs, "FS");
}

```

A second task of the `init()` method is the booking of all histograms which are later to be filled in the analysis code. Information about the histogramming system can be found in [Section 16.3](#).

16.2 Utility classes

Rivet provides quite a few object types for physics purposes, such as three- and four-vectors, matrices and Lorentz boosts, and convenience proxy objects for e.g. particles and jets. We

now briefly summarise the most important features of some of these objects; more complete interface descriptions can be found in the generated Doxygen web pages on the Rivet web site, or simply by browsing the relevant header files.

16.2.1 FourMomentum

The `FourMomentum` class is the main physics vector that you will encounter when writing Rivet analyses. Its functionality and interface are similar to the CLHEP `HepLorentzVector` with which many users will be familiar, but without some of the historical baggage.

Vector components The `FourMomentum` `E()`, `px()`, `py()`, `pz()` & `mass()` methods are (unsurprisingly) accessors for the vector’s energy, momentum components and mass. The `vector3()` method returns a spatial `Vector3` object, i.e. the 3 spatial components of the 4-vector.

Useful properties The `pT()` and `Et()` methods are used to calculate the transverse momentum and transverse energy. Angular variables are accessed via the `eta()`, `phi()` and `theta()` for the pseudorapidity, azimuthal angle and polar angle respectively. More explicitly named versions of these also exist, named `pseudorapidity()`, `azimuthalAngle()` and `polarAngle()`. Finally, the true rapidity is accessed via the `rapidity()` method. Many of these functions are also available as external functions, as are algebraic functions such as `cross(vec3a, vec3b)`, which is perhaps more palatable than `vec3a.cross(vec3b)`.

Distances The η - ϕ distance between any two four-vectors (and/or three-vectors) can be computed using a range of overloaded external functions of the type `deltaR(vec1, vec2)`. Angles between such vectors can be calculated via the similar `angle(vec1, vec2)` functions.

16.2.2 Particle

This class is a wrapper around the HepMC `GenParticle` class. `Particle` objects are usually obtained as a vector from the `particles()` method of a `FinalState` projection. Rather than having to directly use the HepMC objects, and e.g. translate HepMC four-vectors into the Rivet equivalent, several key properties are accessed directly via the `Particle` interface (and more may be added). The main methods of interest are `momentum()`, which returns a `FourMomentum`, and `pdgId()`, which returns the PDG particle ID code. The PDG code can be used to access particle properties by using functions such as `PID::isHadron()`, `PID::threeCharge()`, etc. (these are defined in `Rivet/Tools/ParticleIDMethods.hh`.)

16.2.3 Jet

Jets are obtained from one of the jet accessor methods of a projection that implements the `JetAlg` interface, e.g. `FastJets::jetsByPt()` (this returns the jets sorted by p_{\perp} , such that the first element in the vector is the hardest jet — usually what you want.) The most useful methods are `particles()`, `momenta()`, `momentum()` (a representative `FourMomentum`), and some checks on the jet contents such as `containsParticleId(pid)`, `containsCharm()` and `containsBottom()`.

16.2.4 Mathematical utilities

The `Rivet/Math/MathUtils.hh` header defines a variety of mathematical utility functions. These include testing functions such as `isZero(a)`, `fuzzyEquals(a, b)` and `inRange(a, low, high)`, whose purpose is hopefully self-evident, and angular range-mapping functions such as `mapAngle0To2Pi(a)`, `mapAngleMPiToPi(a)`, etc.

16.3 Histogramming

Rivet's histogramming uses the AIDA interfaces, composed of abstract classes `IHistogram1D`, `IProfile1D`, `IDataPointSet` etc. which are built by a factories system. Since it's our feeling that much of the factory infrastructure constitutes an abstraction overload, we provide histogram booking functions as part of the `Analysis` class, so that in the `init` method of your analysis you should book histograms with function calls like:

```
void init() {
    _h_one = bookHistogram1D(2,1,1);
    _h_two = bookProfile1D(3,1,2);
    _h_three = bookHistogram1D("d00-x00-y00", 50, 0.0, 1.0);
}
```

Here the first two bookings have a rather cryptic 3-integer sequence as the first arguments. This is the recommended scheme, as it makes use of the exported data files from HepData, in which 1D histograms are constructed from a combination of x and y axes in a dataset d , corresponding to names of the form $d\langle d \rangle - x\langle x \rangle - y\langle y \rangle$. This auto-booking of histograms saves you from having to copy out reams of bin edges and values into your code, and makes sure that any data fixes in HepData are easily propagated to Rivet. The reference data files which are used for these booking methods are distributed and installed with Rivet, you can find them in the `$\langle installdir \rangle / share / Rivet$` directory of your installation. The third booking is for a histogram for which there is no such HepData entry: it uses the usual scheme of specifying the name, number of bins and the min/max x -axis limits manually.

Filling the histograms is done in the `MyAnalysis::analyse()` function. Remember to specify the event weight as you fill:

```
void analyze(const Event& e) {
    [projections, cuts, etc.]
    ...
    _h_one->fill(pT, event.weight());
    _h_two->fill(pT, Nch, event.weight());
    _h_three->fill(fabs(eta), event.weight());
}
```

Finally, histogram normalisations, scalings, divisions etc. are done in the `MyAnalysis::finalize()` method. For normalisations and scalings you will find appropriate convenience methods `Analysis::normalize(histo, norm)` and `Analysis::scale(histo, scalefactor)`. Many analyses need to be scaled to the generator cross-section, with

the number of event weights to pass cuts being included in the normalisation factor: for this you will have to track the passed-cuts weight sum yourself via a member variable, but the analysis class provides `Analysis::crossSection()` and `Analysis::sumOfWeights()` methods to access the pre-cuts cross-section and weight sum respectively.

16.4 Analysis metadata

To keep the analysis source code uncluttered, and to allow for iteration of data plot presentation without re-compilation and/or re-running, Rivet prefers that analysis metadata is provided via separate files rather than hard-coded into the analysis library. There are two such files: an *analysis info* file, with the suffix `.info`, and a *plot styling* file, with the suffix `.plot`.

16.4.1 Analysis info files

The analysis info files are in YAML format: a simple data format intended to be cleaner and more human-readable/writeable than XML. As well as the analysis name (which must coincide with the filename and the name provided to the `Analysis` constructor, this file stores details of the collider, experiment, date of the analysis, Rivet/data analysis authors and contact email addresses, one-line and more complete descriptions of the analysis, advice on how to run it, suggested generator-level cuts, and BibTeX keys and entries for this user manual. It is also where the validation status of the analysis is declared:

See the standard analyses' info files for guidance on how to populate this file. Info files are searched for in the paths known to the `Rivet::getAnalysisInfoPaths()` function, which many be prepended to using the `$RIVET_INFO_PATH` environment variable: the first matching file to be found will be used.

16.4.2 Plot styling files

The `.plot` files are in the header format for the `make-plots` plotting system and are picked up and merged with the plot data by the Rivet `compare-histos` script which produces the `make-plots` input data files. All the analysis' plots should have a `BEGIN PLOT ...` `END PLOT` section in this file, specifying the title and x/y -axis labels (the `Title`, and `XLabel/YLabel` directives). In addition, you can use this file to choose whether the x and/or y axes should be shown with a log scale (`LogX`, `LogY`), to position the legend box to minimise clashes with the data points and MC lines (`LegendXPos`, `LegendYPos`) and any other valid `make-plots` directives including special text labels or forced plot range boundaries. Regular expressions may be used to apply a directive to all analysis names matching a pattern rather than having to specify the same directive repeatedly for many plots.

See the standard analyses' plot files and the `make-plots` documentation (e.g. on the Rivet website) for guidance on how to write these files. Plot info files are searched for in the paths known to the `Rivet::getAnalysisPlotPaths()` function, which many be prepended to using the `$RIVET_PLOT_PATH` environment variable. As usual, the first matching file to be found will be used.

16.5 Pluggable analyses

Rivet’s standard analyses are not actually built into the main `libRivet` library: they are loaded dynamically at runtime as an analysis *plugin library*. While you don’t need to worry too much about the technicalities of this, it does mean that you can similarly write analyses of your own, compile them into a similar plugin library and run them from `rivet` without ever having to modify any of the main Rivet sources or build system. This means that you can write and run your own analyses with a system-installed copy of Rivet, and not have to re-patch the main library when a newer version comes out (although chances are you will have to recompile, since the binary interface usually change between releases.)

To get started writing your analysis and understand the plugin system better, you should check out the documentation in the wiki on the Rivet website: <http://rivet.hepforge.org/trac/wiki/>. The standard `rivet-mkanalysis` and `rivet-buildplugin` scripts can respectively be used to make an analysis template with many “boilerplate” details filled in (including bibliographic information from Inspire if available), and to build a plugin library with the appropriate compiler options.

16.5.1 Plugin paths

To load pluggable analyses you will need to set the `$RIVET_ANALYSIS_PATH` environment variable: this is a standard colon-separated UNIX path, specifying directories in which analysis plugin libraries may be found. If it is unspecified, the Rivet loader system will assume that the only entry is the `lib` directory in the Rivet installation area. Specifying the variable adds new paths for searching *before* the standard library area, and they will be searched in the left-to-right order in the path variable. If analyses with duplicate names are found, a warning message is issued and the first version to have been found will be used. This allows you to override standard analyses with same-named variants of your own, provided they are loaded from different directories.

Several further environment variables are used to load analysis reference data and metadata files:

`$RIVET_REF_PATH`: A standard colon-separated path list, whose elements are searched in order for reference histogram files. If the required file is not found in this path, Rivet will fall back to looking in the analysis library paths (for convenience, as it is normal for plugin analysis developers to put analysis library and data files in the same directory and it would be annoying to have to set several variables to make this work), and then the standard Rivet installation data directory.

`$RIVET_INFO_PATH`: The path list searched first for analysis `.info` metadata files. The search fallback mechanism works as for `$RIVET_REF_PATH`.

`$RIVET_PLOT_PATH`: The path list searched first for analysis `.plot` presentation style files. The search fallbacks again work as for `$RIVET_REF_PATH`.

These paths can be accessed from the API using the `Rivet::getAnalysisLibPaths()` etc. functions, and can be searched for files using the Rivet lookup rules via the `Rivet::find-`

`AnalysisLibFile(filename)` etc. functions. These functions are also available in the Python `rivet` module. See the Doxygen documentation for more details.

17. Using Rivet as a library

You don't have to use Rivet via the provided command-line programmes: for some applications you may want to have more direct control of how Rivet processes events. Here are some possible reasons:

- You need to not waste CPU cycles and I/O resources on rendering HepMC events to a string representation which is immediately read back in. The FIFO idiom (Section 3.1) is not perfect: we use it in circumstances where the convenience and decoupling outweighs the CPU cost.
- You don't want to write out histograms to file, preferring to use them as code objects. Perhaps for applications which want to manipulate histogram data periodically before the end of the run.
- You enjoy tormenting Rivet developers who know their API is far from perfect, by complaining if it changes!
- ...and many more!

The Rivet API (application programming interface) has been designed in the hope of very simple integration into other applications: all you have to do is create a `Rivet::AnalysisHandler` object, tell it which analyses to apply on the events, and then call its `analyse(evt)` method for each HepMC event – wherever they come from. The API is (we hope) stable, with the exception of the histogramming parts.



The histogramming interfaces in Rivet have long been advertised as marked for replacement, and while progress in that area has lagged far behind our ambitions, it *will* happen with the 2.0.0 release, with unavoidable impact on the related parts of the API. You have been warned!

The API is available for C++ and, in a more restricted form, Python. We will explain the C++ version here; if you wish to operate Rivet (or e.g. use its path-searching capabilities to find Rivet-related files in the standard way) from Python then take a look inside the `rivet` and `rivet-*` Python scripts (e.g. `less 'which rivet'`) or use the module documentation cf.

```
> python
>>> import rivet
>>> help(rivet)
```

And now the C++ API. The best way to explain is, of course, by example. Here is a simple C++ example based on the `test/testApi.cc` source which we use in development to ensure continuing API functionality:

```
#include "Rivet/AnalysisHandler.hh"
#include "HepMC/GenEvent.h"
#include "HepMC/IO_GenEvent.h"

using namespace std;

int main() {

    // Create analysis handler
    Rivet::AnalysisHandler rivet;

    // Specify the analyses to be used
    rivet.addAnalysis("D0_2008_S7554427");
    vector<string> moreanalyses(1, "D0_2007_S7075677");
    rivet.addAnalyses(moreanalyses);

    // The usual mess of reading from a HepMC file!
    std::istream* file = new std::fstream("testApi.hepmc", std::ios::in);
    HepMC::IO_GenEvent hepmcio(*file);
    HepMC::GenEvent* evt = hepmcio.read_next_event();
    double sum_of_weights = 0.0;
    while (evt) {
        // Analyse the current event
        rivet.analyze(*evt);
        sum_of_weights += evt->weights()[0];

        // Clean up and get next event
        delete evt; evt = 0;
        hepmcio >> evt;
    }
    delete file; file = 0;

    rivet.setCrossSection(1.0);
    rivet.setSumOfWeights(sum_of_weights); // not necessary, but allowed
    rivet.finalize();
    rivet.writeData("out");

    return 0;
}
```

Compilation of this, if placed in a file called `myrivet.cc`, into an executable called `myrivet` is simplest and most robust with use of the `rivet-config` script:

```
g++ myrivet.cc -o myrivet `rivet-config --cppflags --ldflags --libs`
```

It *should* just work!

If you are doing something a bit more advanced, for example using the AGILE package's similar API to generate Fortran generator Pythia events and pass them directly to the Rivet analysis handler, you will need to also add the various compiler and linker flags for the extra libraries, e.g.

```
g++ myrivet.cc -o myrivet \  
  `rivet-config --cppflags --ldflags --libs` \  
  `agile-config --cppflags --ldflags --libs`
```

would be needed to compile the following AGILE+Rivet code:

```
#include "AGILE/Loader.hh"  
#include "AGILE/Generator.hh"  
#include "Rivet/AnalysisHandler.hh"  
#include "HepMC/GenEvent.h"  
#include "HepMC/IO_GenEvent.h"  
  
using namespace std;  
  
int main() {  
    // Have a look what generators are available  
    AGILE::Loader::initialize();  
    const vector<string> gens = AGILE::Loader::getAvailableGens();  
    foreach (const string& gen, gens) {  
        cout << gen << endl;  
    }  
  
    // Load libraries for a specific generator and instantiate it  
    AGILE::Loader::loadGenLibs("Pythia6:425");  
    AGILE::Generator* generator = AGILE::Loader::createGen();  
    cout << "Running " << generator->getName()  
         << " version " << generator->getVersion() << endl;  
  
    // Set generator initial state for LEP  
    const int particle1 = AGILE::ELECTRON;  
    const int particle2 = AGILE::POSITRON;  
    const double sqrts = 91;  
    generator->setInitialState(particle1, energy1, sqrts/2.0, sqrts/2.0);  
    generator->setSeed(14283);
```

```

// Set some parameters
generator->setParam("MSTP(5)", "320"); //< PYTHIA tune
// ...

// Set up Rivet with a LEP analysis
Rivet::AnalysisHandler rivet;
rivet.addAnalysis("DELPHI_1996_S3430090");

// Run events
const int EVTMAX = 10000;
HepMC::GenEvent evt;
for (int i = 0; i < EVTMAX; ++i) {
    generator->makeEvent(evt);
    rivet.analyze(evt);
}

// Finalize Rivet and generator
rivet.finalize();
rivet.writeData("out.aida");
generator->finalize();

return 0;
}

```

Part IV

Appendices

A. Typical `agile-runmc` commands

- **Simple run:** `agile-runmc Herwig:6510 -P lep1.params --beams=LEP:91.2 \`
`-n 1000` will use the Fortran Herwig 6.5.10 generator (the `-g` option switch) to generate 1000 events (the `-n` switch) in LEP1 mode, i.e. e^+e^- collisions at $\sqrt{s} = 91.2$ GeV.
- **Parameter changes:** `agile-runmc Pythia6:425 --beams=LEP:91.2 \`
`-n 1000 -P myrun.params -p "PARJ(82)=5.27"` will generate 1000 events using the Fortran Pythia 6.423 generator, again in LEP1 mode. The `-P` switch is actually the way of specifying a parameters file, with one parameter per line in the format “*<key> <value>*”: in this case, the file `lep1.params` is loaded from the *<installdir>/share/AGILE* directory, if it isn’t first found in the current directory. The `-p` (lower-case) switch is used to change a named generator parameter, here Pythia’s `PARJ(82)`, which sets the parton shower cutoff scale. Being able to change parameters on the command line is useful for scanning parameter ranges from a shell loop, or rapid testing of parameter values without needing to write a parameters file for use with `-P`.
- **Writing out HepMC events:** `agile-runmc Pythia6:425 --beams=LHC:14TeV`
`-n 50 -o out.hepmc -R` will generate 50 LHC events with Pythia. The `-o` switch is being used here to tell `agile-runmc` to write the generated events to the `out.hepmc` file. This file will be a plain text dump of the HepMC event records in the standard HepMC format. Use of filename “-” will result in the event stream being written to standard output (i.e. dumping to the terminal).

B. Acknowledgements

Rivet development has been supported by a variety of sources:

- All authors acknowledge support from the EU MCnet research network. MCnet is a Marie Curie Research Training Network funded under Framework Programme 6 contract MRTN-CT-2006-035606.
- Andy Buckley has been supported by grants from the UK Science and Technology Facilities Council (Special Project Grant), the Scottish Universities Physics Alliance (Advanced Research Fellowship), the Institute for Particle Physics Phenomenology (Associateship), and a CERN Scientific Associateship.
- Holger Schulz acknowledges the support of the German Research Foundation (DFG).

We also wish to thank the CERN MCplots (<http://mcplots.cern.ch>) team, and especially Anton Karneyeu, for doing the pre-release testing of the Rivet 1.5 series and later and pointing out all the bits that we got wrong: Rivet is a much better system as a result!

Part V

Bibliography

References

- [1] M. Dobbs and J. B. Hansen, Comput. Phys. Commun. **134**, 41 (2001).
- [2] M. R. Whalley, D. Bourilkov, and R. C. Group, (2005), hep-ph/0508110.
- [3] M. Cacciari and G. P. Salam, Phys. Lett. **B641**, 57 (2006), hep-ph/0512210.
- [4] M. Cacciari and G. Salam and G. Soyez, <http://www.fastjet.fr>.
- [5] T. Sjostrand, S. Mrenna, and P. Skands, JHEP **05**, 026 (2006), hep-ph/0603175.
- [6] T. Gleisberg *et al.*, (2008), 0811.4622.
- [7] T. Sjostrand, S. Mrenna, and P. Skands, Comput. Phys. Commun. **178**, 852 (2008), 0710.3820.
- [8] T. Sjostrand, (2008), 0809.0303.
- [9] M. Bahr *et al.*, Eur. Phys. J. **C58**, 639 (2008), 0803.0883.
- [10] DELPHI Collaboration, P. Abreu *et al.*, Z. Phys. **C73**, 11 (1996).
- [11] I. Antcheva *et al.*, Comput. Phys. Commun. **180**, 2499 (2009).
- [12] ALEPH Collaboration, D. Decamp *et al.*, Phys. Lett. **B273**, 181 (1991).
- [13] ALEPH Collaboration, D. Buskulic *et al.*, Z. Phys. **C69**, 365 (1996).
- [14] ALEPH Collaboration, R. Barate *et al.*, Phys. Rept. **294**, 1 (1998).
- [15] ALEPH COLLABORATION Collaboration, R. Barate *et al.*, Eur.Phys.J. **C16**, 597 (2000), hep-ex/9909032.
- [16] ALEPH Collaboration, A. Heister *et al.*, Phys. Lett. **B512**, 30 (2001), hep-ex/0106051.
- [17] ALEPH COLLABORATION Collaboration, A. Heister *et al.*, Phys.Lett. **B528**, 19 (2002), hep-ex/0201012.
- [18] ALEPH Collaboration, A. Heister *et al.*, Eur. Phys. J. **C35**, 457 (2004).
- [19] DELPHI Collaboration, P. Abreu *et al.*, Z. Phys. **C67**, 543 (1995).
- [20] DELPHI Collaboration, P. Abreu *et al.*, Phys. Lett. **B449**, 364 (1999).
- [21] DELPHI Collaboration, P. Abreu *et al.*, Phys. Lett. **B479**, 118 (2000), hep-ex/0103022.
- [22] JADE Collaboration, P. Pfeifenschneider *et al.*, Eur. Phys. J. **C17**, 19 (2000), hep-ex/0001055.
- [23] OPAL Collaboration, P. D. Acton *et al.*, Z. Phys. **C58**, 405 (1993).
- [24] OPAL Collaboration, R. Akers *et al.*, Z. Phys. **C63**, 181 (1994).
- [25] OPAL Collaboration, G. Alexander *et al.*, Phys. Lett. **B358**, 162 (1995).
- [26] OPAL COLLABORATION Collaboration, G. Alexander *et al.*, Z.Phys. **C70**, 197 (1996).
- [27] OPAL Collaboration, G. Alexander *et al.*, Z. Phys. **C73**, 569 (1997).

- [28] OPAL Collaboration, K. Ackerstaff *et al.*, Phys. Lett. **B412**, 210 (1997), hep-ex/9708022.
- [29] OPAL Collaboration, K. Ackerstaff *et al.*, Eur. Phys. J. **C4**, 19 (1998), hep-ex/9802013.
- [30] OPAL Collaboration, K. Ackerstaff *et al.*, Eur. Phys. J. **C5**, 411 (1998), hep-ex/9805011.
- [31] OPAL Collaboration, K. Ackerstaff *et al.*, Eur. Phys. J. **C7**, 369 (1999), hep-ex/9807004.
- [32] OPAL COLLABORATION Collaboration, G. Abbiendi *et al.*, Eur.Phys.J. **C17**, 373 (2000), hep-ex/0007017.
- [33] OPAL Collaboration, G. Abbiendi *et al.*, Eur. Phys. J. **C20**, 601 (2001), hep-ex/0101044.
- [34] OPAL COLLABORATION Collaboration, G. Abbiendi *et al.*, Phys.Lett. **B550**, 33 (2002), hep-ex/0211007, 18 pages, 5 figures Report-no: CERN-EP-2002-0079.
- [35] OPAL Collaboration, G. Abbiendi *et al.*, Eur. Phys. J. **C40**, 287 (2005), hep-ex/0503051.
- [36] SLD Collaboration, K. Abe *et al.*, Phys. Lett. **B386**, 475 (1996), hep-ex/9608008.
- [37] SLD Collaboration, K. Abe *et al.*, Phys. Rev. **D59**, 052001 (1999), hep-ex/9805029.
- [38] SLD Collaboration, K. Abe *et al.*, Phys. Rev. **D65**, 092006 (2002), hep-ex/0202031, [Erratum-ibid.D66:079905,2002].
- [39] SLD Collaboration, K. Abe *et al.*, Phys. Rev. **D69**, 072003 (2004), hep-ex/0310017.
- [40] CDF Collaboration, F. Abe *et al.*, Phys. Rev. Lett. **61**, 1819 (1988).
- [41] CDF Collaboration, F. Abe *et al.*, Phys. Rev. **D41**, 2330 (1990).
- [42] CDF Collaboration, F. Abe *et al.*, Phys. Rev. **D50**, 5562 (1994).
- [43] CDF Collaboration, F. Abe *et al.*, Phys. Rev. Lett. **77**, 5336 (1996), hep-ex/9609011.
- [44] CDF Collaboration, F. Abe *et al.*, Phys. Rev. Lett. **80**, 3461 (1998).
- [45] CDF Collaboration, T. Affolder *et al.*, Phys. Rev. Lett. **84**, 845 (2000), hep-ex/0001021.
- [46] CDF Collaboration, A. A. Affolder *et al.*, Phys. Rev. **D61**, 091101 (2000), hep-ex/9912022.
- [47] CDF Collaboration, A. A. Affolder *et al.*, Phys. Rev. **D64**, 012001 (2001), hep-ex/0012013.
- [48] CDF Collaboration, A. A. Affolder *et al.*, Phys. Rev. **D64**, 032001 (2001), hep-ph/0102074.
- [49] CDF Collaboration, T. Affolder *et al.*, Phys. Rev. **D65**, 092002 (2002).
- [50] CDF Collaboration, D. Acosta *et al.*, Phys. Rev. **D65**, 072005 (2002).
- [51] CDF Collaboration, D. Acosta *et al.*, Phys. Rev. **D70**, 072002 (2004), hep-ex/0404004.
- [52] CDF Collaboration, D. E. Acosta *et al.*, Phys. Rev. Lett. **95**, 022003 (2005), hep-ex/0412050.
- [53] CDF Collaboration, D. E. Acosta *et al.*, Phys. Rev. **D71**, 112002 (2005), hep-ex/0505013.
- [54] CDF Collaboration, A. Abulencia *et al.*, Phys. Rev. **D74**, 071103 (2006), hep-ex/0512020.
- [55] CDF Collaboration, A. Abulencia *et al.*, Phys. Rev. **D74**, 032008 (2006), hep-ex/0605099.
- [56] CDF Collaboration, A. Abulencia *et al.*, Phys. Rev. **D75**, 092006 (2007), hep-ex/0701051.
- [57] CDF Collaboration, T. Aaltonen *et al.*, Phys. Rev. Lett. **100**, 102001 (2008), 0711.3717.
- [58] CDF Collaboration, T. Aaltonen *et al.*, Phys. Rev. **D78**, 052006 (2008), 0807.2204.
- [59] CDF Collaboration, T. Aaltonen *et al.*, Phys. Rev. **D79**, 112002 (2009), 0812.4036.

- [60] CDF Collaboration, T. Aaltonen *et al.*, Phys. Rev. **D79**, 052008 (2009), 0812.4458.
- [61] CDF Collaboration, T. Aaltonen *et al.*, Phys. Rev. **D79**, 112005 (2009), 0904.1098.
- [62] CDF Collaboration, T. Aaltonen *et al.*, (2009), 0908.3914.
- [63] CDF Collaboration, T. Aaltonen *et al.*, Phys. Rev. **D80**, 111106 (2009), 0910.3623.
- [64] D0 Collaboration, B. Abbott *et al.*, Phys. Lett. **B513**, 292 (2001), hep-ex/0010026.
- [65] D0 Collaboration, V. M. Abazov *et al.*, Phys. Lett. **B517**, 299 (2001), hep-ex/0107012.
- [66] D0 Collaboration, V. M. Abazov *et al.*, Phys. Rev. Lett. **94**, 221801 (2005), hep-ex/0409040.
- [67] D0 Collaboration, V. M. Abazov *et al.*, Phys. Lett. **B639**, 151 (2006), hep-ex/0511054.
- [68] D0 Collaboration, V. M. Abazov *et al.*, Phys. Rev. **D76**, 012003 (2007), hep-ex/0702025.
- [69] D0 Collaboration, V. M. Abazov *et al.*, Phys. Lett. **B658**, 112 (2008), hep-ex/0608052.
- [70] D0 Collaboration, V. M. Abazov *et al.*, Phys. Rev. Lett. **100**, 102002 (2008), 0712.0803.
- [71] D0 Collaboration, V. M. Abazov *et al.*, Phys. Rev. Lett. **101**, 062001 (2008), 0802.2400.
- [72] D0 Collaboration, V. M. Abazov *et al.*, Phys. Lett. **B666**, 435 (2008), 0804.1107.
- [73] D0 Collaboration, V. M. Abazov *et al.*, Phys. Rev. Lett. **101**, 211801 (2008), 0807.3367.
- [74] D0 Collaboration, V. M. Abazov *et al.*, Phys. Lett. **B669**, 278 (2008), 0808.1296.
- [75] D0 Collaboration, V. M. Abazov *et al.*, Phys. Lett. **B678**, 45 (2009), 0903.1748.
- [76] D0 Collaboration, V. M. Abazov *et al.*, Phys. Rev. Lett. **103**, 191803 (2009), 0906.4819.
- [77] D0 Collaboration, V. M. Abazov *et al.*, Phys. Lett. **B682**, 370 (2010), 0907.4286.
- [78] D0 Collaboration, V. M. Abazov *et al.*, (2010), 1002.4594.
- [79] D0 Collaboration, V. M. Abazov *et al.*, (2010), 1002.4917.
- [80] D0 Collaboration, V. M. Abazov *et al.*, (2010), 1006.0618.
- [81] D0 Collaboration, V. M. Abazov *et al.*, (2010), 1010.0262.
- [82] D0 COLLABORATION Collaboration, V. M. Abazov *et al.*, Phys.Lett. **B704**, 434 (2011), 1104.1986.
- [83] ALICE Collaboration, K. Aamodt *et al.*, Eur. Phys. J. **C68**, 89 (2010), 1004.3034.
- [84] ALICE Collaboration, K. Aamodt *et al.*, Eur.Phys.J. **C68**, 345 (2010), 1004.3514.
- [85] ALICE Collaboration, K. Aamodt *et al.*, Phys. Lett. **B693**, 53 (2010), 1007.0719.
- [86] ALICE COLLABORATION Collaboration, K. Aamodt *et al.*, Eur.Phys.J. **C71**, 1594 (2011), 1012.3257.
- [87] ALICE Collaboration, K. Aamodt *et al.*, Eur.Phys.J. **C71**, 1655 (2011), 1101.4110.
- [88] ALICE COLLABORATION Collaboration, B. Abelev *et al.*, Eur. Phys. J. C (2012), 1208.4968.
- [89] ATLAS Collaboration, G. Aad *et al.*, (2010), 1003.3124.
- [90] ATLAS Collaboration, G. Aad *et al.*, (2010), 1009.5908.
- [91] T. A. Collaboration, (2010), 1012.4389.

- [92] T. A. Collaboration, (2010), 1012.5382.
- [93] ATLAS COLLABORATION Collaboration, G. Aad *et al.*, Nature Commun. **2**, 463 (2011), 1104.0326.
- [94] ATLAS Collaboration, G. Aad *et al.*, (2011), 1107.3311.
- [95] THE ATLAS Collaboration, G. Aad *et al.*, (2011), 1108.6308.
- [96] ATLAS COLLABORATION Collaboration, G. Aad *et al.*, (2011), 1109.0525.
- [97] ATLAS COLLABORATION Collaboration, G. Aad *et al.*, Phys.Rev. **D85**, 012001 (2012), 1111.1297.
- [98] ATLAS COLLABORATION Collaboration, (2011), 1111.2690.
- [99] ATLAS COLLABORATION Collaboration, G. Aad *et al.*, Phys.Lett. **B709**, 341 (2012), 1111.5570.
- [100] T. A. Collaboration, (2011), 1102.2696.
- [101] ATLAS Collaboration, J. B. G. da Costa *et al.*, (2011), 1102.5290.
- [102] ATLAS Collaboration, G. Aad *et al.*, (2011), 1103.6214.
- [103] A. Collaboration, (2011), 1107.2092.
- [104] ATLAS Collaboration, G. Aad *et al.*, (2011), 1107.2381.
- [105] ATLAS Collaboration, G. Aad *et al.*, (2011), 1109.6572, * Temporary entry *.
- [106] ATLAS COLLABORATION Collaboration, G. Aad *et al.*, JHEP **1111**, 099 (2011), 1110.2299.
- [107] ATLAS COLLABORATION Collaboration, G. Aad *et al.*, (2011), 1112.6297.
- [108] ATLAS COLLABORATION Collaboration, G. Aad *et al.*, (2012), 1203.0419.
- [109] ATLAS Collaboration, G. Aad *et al.*, (2012), 1203.3161.
- [110] ATLAS COLLABORATION Collaboration, G. Aad *et al.*, JHEP **1205**, 157 (2012), 1203.3549.
- [111] ATLAS COLLABORATION Collaboration, G. Aad *et al.*, (2012), 1204.5638, 5 pages plus author list (18 pages total), 2 figures, 1 table, submitted to Physics Review Letters.
- [112] ATLAS COLLABORATION Collaboration, G. Aad *et al.*, Nucl.Phys. **B864**, 341 (2012), 1206.3122.
- [113] ATLAS COLLABORATION Collaboration, G. Aad *et al.*, Phys.Rev. **D86**, 072006 (2012), 1206.5369.
- [114] ATLAS COLLABORATION Collaboration, G. Aad *et al.*, Phys.Rev. **D86**, 072004 (2012), 1208.0563.
- [115] ATLAS COLLABORATION Collaboration, G. Aad *et al.*, (2012), 1208.6256.
- [116] ATLAS COLLABORATION Collaboration, G. Aad *et al.*, (2012), 1210.0441.
- [117] ATLAS COLLABORATION Collaboration, G. Aad *et al.*, Phys.Lett. **B709**, 137 (2012), 1110.6189.
- [118] THE ATLAS COLLABORATION Collaboration, G. Aad *et al.*, (2013), 1302.1415.

- [119] CMS Collaboration, V. Khachatryan *et al.*, JHEP **02**, 041 (2010), 1002.0621.
- [120] CMS Collaboration, V. Khachatryan *et al.*, Phys. Rev. Lett. **105**, 022002 (2010), 1005.3299.
- [121] CMS COLLABORATION Collaboration, S. Chatrchyan *et al.*, JHEP **1201**, 052 (2012), 1111.5536.
- [122] CMS Collaboration, V. Khachatryan *et al.*, JHEP **01**, 079 (2011), 1011.5531.
- [123] CMS Collaboration, V. Khachatryan *et al.*, JHEP **03**, 090 (2011), 1101.3512.
- [124] CMS COLLABORATION Collaboration, V. Khachatryan *et al.*, Phys.Rev.Lett. **106**, 122003 (2011), 1101.5029.
- [125] CMS Collaboration, V. Khachatryan *et al.*, Phys. Lett. **B699**, 48 (2011), 1102.0068.
- [126] CMS Collaboration, V. Khachatryan *et al.*, Phys. Rev. Lett. **106**, 201804 (2011), 1102.2020.
- [127] CMS Collaboration, V. Khachatryan *et al.*, JHEP **03**, 136 (2011), 1102.3194.
- [128] CMS Collaboration, V. Khachatryan *et al.*, JHEP **05**, 064 (2011), 1102.4282.
- [129] CMS COLLABORATION Collaboration, S. Chatrchyan *et al.*, Phys. Rev. Lett. **107**, 132001 (2011), 1106.0208, Long author list - awaiting processing.
- [130] CMS COLLABORATION Collaboration, S. Chatrchyan *et al.*, Phys.Lett. **B702**, 336 (2011), 1106.0647, * Temporary entry *.
- [131] CMS COLLABORATION Collaboration, S. Chatrchyan *et al.*, (2011), 1107.0330.
- [132] CMS Collaboration, S. Chatrchyan *et al.*, JHEP **11**, 148 (2011), 1110.0211.
- [133] CMS COLLABORATION Collaboration, S. Chatrchyan *et al.*, JHEP **1206**, 036 (2012), 1202.0704.
- [134] CMS COLLABORATION Collaboration, S. Chatrchyan *et al.*, (2012), 1204.0696.
- [135] CMS COLLABORATION Collaboration, S. Chatrchyan *et al.*, (2012), 1204.1411.
- [136] CMS COLLABORATION Collaboration, S. Chatrchyan *et al.*, (2012), 1209.1805.
- [137] CMS COLLABORATION Collaboration, S. Chatrchyan *et al.*, (2012), 1210.6718.
- [138] (2012).
- [139] (2011).
- [140] LHCb COLLABORATION Collaboration, R. Aaij *et al.*, Phys.Lett. **B694**, 209 (2010), 1009.2731.
- [141] LHCf COLLABORATION Collaboration, O. Adriani *et al.*, (2012), 1205.4578.
- [142] TOTEM Collaboration, G. Antchev *et al.*, CERN Report No. CERN-PH-EP-2012-239. TOTEM-2012-002, 2012 (unpublished).
- [143] UA1 Collaboration, C. Albajar *et al.*, Nucl. Phys. **B335**, 261 (1990).
- [144] UA5 Collaboration, K. Alpgard *et al.*, Phys. Lett. **B112**, 183 (1982).
- [145] UA5 Collaboration, G. J. Alner *et al.*, Z. Phys. **C33**, 1 (1986).
- [146] UA5 Collaboration, G. J. Alner *et al.*, Phys. Rept. **154**, 247 (1987).
- [147] UA5 Collaboration, R. E. Ansorge *et al.*, Z. Phys. **C37**, 191 (1988).

- [148] UA5 Collaboration, R. E. Ansorge *et al.*, Z. Phys. **C43**, 357 (1989).
- [149] H1 Collaboration, I. Abt *et al.*, Z. Phys. **C63**, 377 (1994).
- [150] H1 Collaboration, C. Adloff *et al.*, Eur. Phys. J. **C12**, 595 (2000), hep-ex/9907027.
- [151] STAR Collaboration, J. Adams *et al.*, Phys. Lett. **B637**, 161 (2006), nucl-ex/0601033.
- [152] STAR Collaboration, B. I. Abelev *et al.*, Phys. Rev. **C75**, 064901 (2007), nucl-ex/0607033.
- [153] STAR Collaboration, B. I. Abelev *et al.*, Phys. Rev. Lett. **97**, 252001 (2006), hep-ex/0608030.
- [154] ARGUS COLLABORATION Collaboration, H. Albrecht *et al.*, Z.Phys. **C58**, 191 (1993).
- [155] ARGUS COLLABORATION Collaboration, H. Albrecht *et al.*, Z.Phys. **C58**, 199 (1993).
- [156] ARGUS COLLABORATION Collaboration, H. Albrecht *et al.*, Z.Phys. **C61**, 1 (1994).
- [157] BABAR COLLABORATION Collaboration, B. Aubert *et al.*, Phys.Rev. **D67**, 032002 (2003), hep-ex/0207097.
- [158] BABAR COLLABORATION Collaboration, B. Aubert *et al.*, Phys.Rev.Lett. **95**, 142003 (2005), hep-ex/0504014.
- [159] BABAR COLLABORATION Collaboration, B. Aubert *et al.*, Phys.Rev. **D75**, 012003 (2007), hep-ex/0609004.
- [160] BABAR Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **100**, 011801 (2008), 0707.2981.
- [161] BELLE COLLABORATION Collaboration, K. Abe *et al.*, Phys.Rev. **D64**, 072001 (2001), hep-ex/0103041.
- [162] BELLE Collaboration, R. Seuster *et al.*, Phys. Rev. **D73**, 032002 (2006), hep-ex/0506068.
- [163] CLEO Collaboration, M. Artuso *et al.*, Phys. Rev. **D70**, 112001 (2004), hep-ex/0402040.
- [164] JADE Collaboration, P. A. Movilla Fernandez, O. Biebel, S. Bethke, S. Kluth, and P. Pfeifenschneider, Eur. Phys. J. **C1**, 461 (1998), hep-ex/9708034.
- [165] PARTICLE DATA GROUP Collaboration, C. Amsler *et al.*, Phys. Lett. **B667**, 1 (2008).
- [166] TASSO Collaboration, W. Braunschweig *et al.*, Z. Phys. **C47**, 187 (1990).
- [167] J. Bromley *et al.*, (1995), ZEUS and H1 Collaborations.