Rivet user manual

version 1.4.0

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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

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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, you will hopefully find the online generated documentation at `http://projects.hepforge.org/rivet` to be sufficient. Similar API documentation is maintained for AGILe at `http://projects.hepforge.org/agile`.

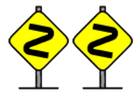
1.1 Typographic conventions

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 TeX, 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:14TeV Pythia6:423
```

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 probaby 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 not standardised by Genser at the moment (this will hopefully change), so we've provided a script, `agile-genser-bootstrap`:

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

Now make yourself a Genser installation directory, e.g. `$HOME/genser`, and `cd` into it. Then run the `agile-genser-bootstrap` script, and wait for it all to build. Finally, set the `$AGILE_GEN_PATH` path variable to contain the ⟨*genserDir*⟩ directory: you should now have a few generators to play with.

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 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 names[1]!

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.

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

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.

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 Pythia6:423 -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 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 particular analyses:** `rivet -a DELPHI_1996_S3430090 fifo.hepmc` will run the Rivet `DELPHI_1996_S3430090` [10] analysis on the events in the `fifo.hepmc` data file. This analysis is the one originally used for the Delphi automated "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.

- **Using all analyses:** `rivet -n 50000 -A -` will read up to 50k events from standard input (specified by the special "-" input filename) and analyse them with *all* the Rivet library analyses. As above, incompatible analyses (based on beam particle IDs), will be removed before the main analysis run begins.

- **Histogramming:** `rivet fifo.hepmc -H foo` 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 `TGraph`s. One word of warning: a bug in ROOT means that `TGraph`s 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-x01-y01` 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.

Note that the plotting tools internally use LaTeX for drawing, and for very complex plots it might sometimes fail with an error message like "TeX memory exceeded" (or "DVI file can't be opened"). In such a case it is recommended to increase the allowed TeX memory size as described in e.g. Section 6.2 of the `pgfplots` manual.

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 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⟩;

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@durham.ac.uk⟩;

References:

- Z.Phys.C69:365-378,1996
- DOI: 10.1007/s002880050037

Run details:

- $e^+e^- \to$ 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 ⟨holger.schulz@physik.hu-berlin.de⟩;

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_2004_S5765862 [15]

Jet rates and event shapes at LEP I and II
Beams: $e^-\,e^+$
Energies: (45.5, 45.5), (66.5, 66.5), (80.5, 80.5), (86.0, 86.0), (91.5, 91.5), (94.5, 94.5), (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@durham.ac.uk⟩;

References:

- Eur.Phys.J.C35:457-486,2004
- DOI: 10.1140/epjc/s2004-01891-4
- http://cdsweb.cern.ch/record/690637/files/ep-2003-084.pdf

Run details:

- $e^+e^- \to$ 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.

5.5 DELPHI_1995_S3137023 [16]

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.

5.6 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 ⟨andy.buckley@cern.ch⟩;
- Hendrik Hoeth ⟨hendrik.hoeth@cern.ch⟩;

References:

- Z.Phys.C73:11-60,1996
- DOI: 10.1007/s002880050295

Run details:

- $\sqrt{s} = 91.2$ GeV, $e^+e^- \to Z^0$ 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.

5.7 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: VALIDATED
Authors:

- Hendrik Hoeth ⟨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 $f(x_B^{\text{prim}})$.

5.8 DELPHI_2003_WUD_03_11

4-jet angular distributions at LEP (note)
Beams: $e^+ e^-$
Energies: (45.6, 45.6) GeV
Experiment: DELPHI (LEP 1)
Status: UNVALIDATED
Authors:

- Hendrik Hoeth ⟨hendrik.hoeth@cern.ch⟩;

References:

- Diploma thesis WUD-03-11, University of Wuppertal

Run details:

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

The 4-jet angular distributions (Bengtsson-Zerwas, Körner-Schierholz- Willrodt, Nachtmann-Reiter, and α_{34}) have been measured with DELPHI at LEP 1 using Jade and Durham cluster algorithms.

5.9 JADE_OPAL_2000_S4300807 [17]

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), (45.5, 45.5), (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@durham.ac.uk⟩;

References:

- Eur.Phys.J.C17:19-51,2000
- arXiv: hep-ex/0001055

Run details:

- $e^+e^- \to$ jet jet (+ jets)

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

5.10 OPAL_1993_S2692198 [18]

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: UNVALIDATED
Authors:

- Peter Richardson ⟨Peter.Richardson@durham.ac.uk⟩;

References:

- Z.Phys.C58:405-418,1993
- DOI: 10.1007/BF01557697

Run details:

- $e^+e^- \to$ jet jet (+ photons)

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

5.11 OPAL_1998_S3780481 [19]

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

5.12 OPAL_2001_S4553896 [20]

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⟩;

References:

- Eur.Phys.J.C20:601-615,2001
- DOI: 10.1007/s100520100699
- arXiv: 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 $y_{\mathrm{cut}} = 0.008$. 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.

5.13 OPAL_2004_S6132243 [21]

Event shape distributions and moments in $e^+e^- \to$ hadrons at 91–209 GeV
Beams: $e^+ e^-$
Energies: (45.5, 45.5), (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 ⟨andy.buckley@cern.ch⟩;

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 with $\sqrt{s}$ above the Z mass need to have ISR suppressed, since the data has been corrected to remove radiative return to the Z.

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.

6. Tevatron analyses

6.1 CDF_1988_S1865951 [22]

CDF transverse momentum distributions at 630 GeV and 1800 GeV.
Beams: $p\bar{p}$
Energies: (315.0, 315.0), (900.0, 900.0) GeV
Experiment: CDF (Tevatron Run I)
Spires ID: 1865951
Status: VALIDATED
Authors:

- Christophe Vaillant ⟨c.l.j.j.vaillant@durham.ac.uk⟩;
- Andy Buckley ⟨andy.buckley@cern.ch⟩;

References:

- Phys.Rev.Lett.61:1819,1988
- DOI: 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 [23]

CDF pseudorapidity distributions at 630 and 1800 GeV
Beams: $p\,\bar{p}$
Energies: (315.0, 315.0), (900.0, 900.0) GeV
Experiment: CDF (Tevatron Run 0)
Spires ID: 2089246
Status: VALIDATED
Authors:

- Andy Buckley ⟨andy.buckley@cern.ch⟩;

References:

- Phys.Rev.D41:2330,1990
- DOI: 10.1103/PhysRevD.41.2330

Run details:

- QCD min bias events at $\sqrt{s} = 630$ and 1800 GeV. Particles with $c\tau > 10$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_1991_S2313472 [24]

W-boson $p_\perp$ measurement in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: CDF (Tevatron)
Spires ID: 2313472
Status: UNVALIDATED
Authors:

- Holger Schulz ⟨hschulz@physik.hu-berlin.de⟩;

References:

- Phys.Rev.Lett.66:2951-2955,1991

Run details:

- QCD events with W+- production and electronic decays

This is a CDF analysis from run 1, where the distribution of the transverse momentum of W candidates that decay electronically, is measured. The electron is required to be within $|\eta| < 1.1$, to have a transverse energy of $E_\perp > 20$ GeV and a $p_\perp > 12$ GeV. The neutrino is required to produce a missing energy of $E_{\perp,\,\mathrm{miss}} > 20$ GeV.

6.4 CDF_1993_S2742446 [25]

Angular distribution of prompt photon
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: CDF (Tevatron Run 1)
Spires ID: 2742446
Status: UNVALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Rev.Lett.71:679-683,1993
- DOI: 10.1103/PhysRevLett.71.679

Run details:

- All prompt photon production processes in $p\bar{p}$ at 1800 GeV. Hadronisation should be switched off, because non-prompt photon production has been corrected for.

Data taken with the Collider Detector at Fermilab (CDF) during the 1988-1989 run of the Tevatron are used to measure the distribution of the center-of-mass (rest frame of the initial state partons) angle between isolated prompt photons and the beam direction.

6.5 CDF_1994_S2952106 [26]

CDF Run I color coherence analysis.
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: CDF (Tevatron Run 1)
Spires ID: 2952106
Status: VALIDATED
Authors:

- Lars Sonnenschein ⟨Lars.Sonnenschein@cern.ch⟩;
- Andy Buckley ⟨andy.buckley@cern.ch⟩;

References:

- Phys.Rev.D50,5562,1994
- DOI: 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 $\alpha = \mathrm{d}\eta/\mathrm{d}\phi$, where $\mathrm{d}\eta$ is the pseudorapidity difference between the 2nd and 3rd jets and $\mathrm{d}\phi$ 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.

6.6 CDF_1996_S3108457 [27]

Properties of High-Mass Multijet Events
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: CDF (Tevatron Run 1)
Spires ID: 3108457
Status: UNVALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Rev.Lett.75:608-612,1995
- DOI: 10.1103/PhysRevLett.75.608

Run details:

- Pure QCD events without underlying event.

Properties of two-, three-, four-, five-, and six-jet events... Multijet-mass, leading jet angle, jet $p_\perp$.

6.7 CDF_1996_S3349578 [28]

Further properties of high-mass multijet events
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: CDF (Tevatron Run 1)
Spires ID: 3349578
Status: UNVALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Rev.D54:4221-4233,1996
- DOI: 10.1103/PhysRevD.54.4221
- arXiv: hep-ex/9605004

Run details:

- Pure QCD events without underlying event.

Multijet distributions corresponding to $(4N-4)$ variables that span the N-body parameter space in inclusive $N = 3$-, 4-, and 5-jet events.

6.8 CDF_1996_S3418421 [29]

Dijet angular distributions
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: CDF (Tevatron Run 1)
Spires ID: 3418421
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Rev.Lett.77:5336-5341,1996
- DOI: 10.1103/PhysRevLett.77.5336
- arXiv: 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}

6.9 CDF_1997_S3541940 [30]

Properties of six jet events with large six jet mass
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: CDF (Tevatron Run 1)
Spires ID: 3541940
Status: UNVALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Rev.D56:2532-2543,1997
- DOI: 10.1103/PhysRevD.56.2532
- http://lss.fnal.gov/archive/1997/pub/Pub-97-093-E.pdf

Run details:

- Pure QCD events without underlying event.

Multijet distributions corresponding to 20 variables that span the 6-body parameter space in inclusive 6-jet events.

6.10 CDF_1998_S3618439 [31]

Differential cross-section for events with large total transverse energy
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: CDF (Tevatron Run 1)
Spires ID: 3618439
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

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

6.11 CDF_2000_S4155203 [32]

Z $p_\perp$ measurement in CDF Z $\rightarrow e^+e^-$ events
Beams: $p\,\bar{p}$
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 GeV/$c^2 < m_{ee} <$ 120 GeV/c^2 for efficiency.

Measurement of transverse momentum and total cross section of e^+e^- pairs in the Z-boson region of 66 GeV/$c^2 < m_{ee} <$ 116 GeV/c^2 from pbar-p collisions at $\sqrt{s} = 1.8$ 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 bremstrahlung summation, rather than non-portable direct use of the (sometimes absent) Z in the event record.

6.12 CDF_2000_S4266730 [33]

Differential Dijet Mass Cross Section
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: CDF (Tevatron Run 1)
Spires ID: 4266730
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Rev.D61:091101,2000
- DOI: 10.1103/PhysRevD.61.091101
- arXiv: 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}.

6.13 CDF_2001_S4517016 [34]

Two jet triply-differential cross-section
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: CDF (Tevatron Run 1)
Spires ID: 4517016
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Rev.D64:012001,2001
- DOI: 10.1103/PhysRevD.64.012001
- arXiv: hep-ex/0012013

Run details:

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

A measurement of the two-jet differential cross section, $\mathrm{d}^3\sigma/\mathrm{d}E_T\,\mathrm{d}\eta_1\,\mathrm{d}\eta_2$, based on an integrated luminosity of $86\mathrm{pb}^{-1}$. 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 $0.1 < |\eta_2| < 3.0$.

6.14 CDF_2001_S4563131 [35]

Inclusive jet cross section
Beams: $p\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: CDF (Tevatron Run 1)
Spires ID: 4563131
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Rev.D64:032001,2001
- DOI: 10.1103/PhysRevD.64.032001
- arXiv: 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.

6.15 CDF_2001_S4751469 [36]

Field & Stuart Run I underlying event analysis.
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: CDF (Tevatron Run 1)
Spires ID: 4751469
Status: VALIDATED
Authors:

- Andy Buckley ⟨andy.buckley@cern.ch⟩;

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 can 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 $|\phi| \in [60°, 120°]$ 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.

6.16 CDF_2002_S4796047 [37]

CDF Run 1 charged multiplicity measurement
Beams: $p\,\bar{p}$
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

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!

6.17 CDF_2004_S5839831 [38]

Transverse cone and 'Swiss cheese' underlying event studies
Beams: $p\,\bar{p}$
Energies: (315.0, 315.0), (900.0, 900.0) GeV
Experiment: CDF (Tevatron Run 1)
Spires ID: 5839831
Status: VALIDATED
Authors:

- Andy Buckley ⟨andy.buckley@cern.ch⟩;

References:

- Phys. Rev. D70, 072002 (2004)
- arXiv: 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.

6.18 CDF_2005_S6080774 [39]

Differential cross sections for prompt diphoton production
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: 6080774
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys. Rev. Lett. 95, 022003
- DOI: 10.1103/PhysRevLett.95.022003
- arXiv: hep-ex/0412050

Run details:

- $p\bar{p} \to \gamma\gamma$ [+ jets] at 1960 GeV. The analysis uses photons with $p_\perp$ larger then 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.

6.19 CDF_2005_S6217184 [40]

CDF Run II jet shape analysis
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: 6217184
Status: VALIDATED
Authors:

- Lars Sonnenschein ⟨Lars.Sonnenschein@cern.ch⟩;
- Andy Buckley ⟨andy.buckley@cern.ch⟩;

References:

- Phys.Rev.D71:112002,2005
- DOI: 10.1103/PhysRevD.71.112002
- arXiv: 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 pbar 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.

6.20 CDF_2006_S6450792 [41]

Inclusive jet cross section differential in $p_\perp$
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: 6450792
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Rev.D74:071103,2006
- DOI: 10.1103/PhysRevD.74.071103
- arXiv: hep-ex/0512020

Run details:

- $p\bar{p} \to$ 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.

6.21 CDF_2006_S6653332 [42]

$p_\perp$ and eta distributions of jets in Z + jet production
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: 6653332
Status: VALIDATED
Authors:

- Lars Sonnenschein ⟨Lars.Sonnenschein@cern.ch⟩;
- Steffen Schumann ¡s.schumann(at)thphys.uni-heidelberg.de¿

References:

- Phys.Rev.D.74:032008,2006
- DOI: 10.1103/PhysRevD.74.032008
- arXiv: hep-ex/0605099v2

Run details:

- Z + 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 pbar 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.

6.22 CDF_2007_S7057202 [43]

CDF Run II inclusive jet cross-section using the kT algorithm
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: 7057202
Status: VALIDATED
Authors:

- David Voong
- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

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 $1.6 < |y| < 2.1$.

6.23 CDF_2008_LEADINGJETS

CDF Run 2 underlying event in leading jet events
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: NONE
Status: VALIDATED
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.

6.24 CDF_2008_NOTE_9351

CDF Run 2 underlying event in Drell-Yan
Beams: $p\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: NONE
Status: VALIDATED
Authors:

- Hendrik Hoeth ⟨hendrik.hoeth@cern.ch⟩;

References:

- CDF public note 9351

Run details:

- ppbar collisions at 1960 GeV.
- Drell-Yan events with $Z/\gamma* \to ee$ and $Z/\gamma* \to \mu\mu$.
- 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. $Z \to ee$ and $Z \to \mu\mu$ 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).

6.25 CDF_2008_S7540469 [44]

Measurement of differential Z/γ^* + jet + X cross sections
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: 7540469
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Rev.Lett.100:102001,2008
- arXiv: 0711.3717

Run details:

- $p\bar{p} \to e^+e^-$ + 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 $p_\perp^\text{jet} > 30$ GeV/c.

6.26 CDF_2008_S7541902 [45]

Jet $p_\perp$ and multiplicity distributions in W + jets events
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: 7541902
Status: UNVALIDATED
Authors:

- Ben Cooper ⟨b.d.cooper@qmul.ac.uk⟩;
- Emily Nurse ⟨nurse@hep.ucl.ac.uk⟩;

References:

- arXiv: 0711.4044
- Phys.Rev.D77:011108,2008

Run details:

- Requires the process $p\bar{p} \to W \to e\nu$. Additional hard jets will also have to be included to get a good description. The LO process in Herwig is set with IPROC=1451.

Measurement of the cross section for W boson production in association with jets in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV. The analysis uses 320 pb^{-1} of data collected with the CDF II detector. W bosons are identified in their $e\nu$ decay channel and jets are reconstructed using an $R < 0.4$ cone algorithm. For each $W+ \geq$ n-jet sample (where n = 1–4) a measurement of d$\sigma(p\bar{p} \to W+ \geq$ n jet)/d$E_T(n^{th}$-jet) $\times$ BR($W \to e\nu$) is made, where d$E_T(n^{th}$-jet) is the Et of the nth-highest Et jet above 20 GeV. A measurement of the total cross section, $\sigma(p\bar{p} \to W+ \geq$ n-jet) $\times$ BR($W \to e\nu$) with $E_T(n^{th} - jet) > 25$ GeV is also made. Both measurements are made for jets with $|\eta| < 2$ and for a limited region of the $W \to e\nu$ decay phase space; $|\eta^e| < 1.1$, $p_T^e > 20$ GeV, $p_T^\nu > 30$ GeV and $M_T > 20$ GeV. The cross sections are corrected for all detector effects and can be directly compared to particle level W + jet(s) predictions. These measurements can be used to test and tune QCD predictions for the number of jets in and kinematics of W + jets events.

6.27 CDF_2008_S7782535 [46]

CDF Run II b-jet shape paper
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: 7782535
Status: UNVALIDATED
Authors:

- Alison Lister ⟨alister@fnal.gov⟩;
- Emily Nurse ⟨nurse@hep.ucl.ac.uk⟩;
- Andy Buckley ⟨andy.buckley@cern.ch⟩;

References:

- arXiv: 0806.1699
- Phys.Rev.D78:072005,2008

Run details:

- Requires $2 \to 2$ QCD scattering processes. The minimum jet $E_\perp$ is 52 GeV, so kinematic cuts on $p_\perp^{\mathrm{min}}$ may be required for statistical validity.

A measurement of the shapes of b-jets using 300 pb^{-1} of data obtained with CDF II in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV. The measured quantity is the average integrated jet shape, which is computed over an ensemble of jets. This quantity is expressed as $\Psi(r/R) = \langle \frac{p_\perp(0 \to r)}{p_\perp(0 \to R)} \rangle$, where $p_\perp(0 \to r)$ is the scalar sum of the transverse momenta of all objects inside a sub-cone of radius r around the jet axis. The integrated shapes are by definition normalized such that $\Psi(r/R = 1) = 1$. The measurement is done in bins of jet $p_\perp$ in the range 52 to 300 GeV/c. The jets have $|\eta| < 0.7$. The b-jets are expected to be broader than inclusive jets. Moreover, b-jets containing a single b-quark are expected to be narrower than those containing a $b\bar{b}$ pair from gluon splitting.

6.28 CDF_2008_S7828950 [47]

CDF Run II inclusive jet cross-section using the Midpoint algorithm
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: 7828950
Status: VALIDATED
Authors:

- Craig Group ⟨group@fnal.gov⟩;
- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- arXiv: 0807.2204
- Phys.Rev.D78:052006,2008

Run details:

- Requires $2 \to 2$ 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.

6.29 CDF_2008_S8093652 [48]

Dijet mass spectrum
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: 8093652
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- arXiv: 0812.4036

Run details:

- $p\bar{p} \to$ 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}.

6.30 CDF_2008_S8095620 [49]

CDF Run II Z+b-jet cross section paper, 2 fb-1
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: 8095620
Status: VALIDATED
Authors:

- Emily Nurse ⟨nurse@hep.ucl.ac.uk⟩;
- Steffen Schumann ¡s.schumann(at)thphys.uni-heidelberg.de¿

References:

- arXiv: 0812.4458

Run details:

- Requires the process $p\bar{p} \to Z \to \ell\ell$, 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 + 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.

6.31 CDF_2009_NOTE_9936

CDF Run 2 min bias charged multiplicity analysis
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: None
Status: VALIDATED
Authors:

- Holger Schulz ⟨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.

6.32 CDF_2009_S8233977 [50]

CDF Run 2 min bias cross-section analysis
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: 8233977
Status: VALIDATED
Authors:

- Hendrik Hoeth ⟨hendrik.hoeth@cern.ch⟩;
- Niccolo' Moggi ⟨niccolo.moggi@bo.infn.it⟩;

References:

- Phys.Rev.D79:112005,2009
- DOI: 10.1103/PhysRevD.79.112005
- arXiv: 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.

6.33 CDF_2009_S8383952 [51]

Z rapidity measurement
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: 8383952
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- arXiv: 0908.3914

Run details:

- $p\bar{p} \to e^+e^-$ + 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, $\mathrm{d}\sigma/\mathrm{d}y$, for $q\bar{q} \to \gamma^*/Z \to e^+e^-$ events in the Z boson mass region ($66 < M_{ee} < 116$ GeV/c^2) produced in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV with 2.1 fb^{-1} of integrated luminosity.

6.34 CDF_2009_S8436959 [52]

Measurement of the inclusive isolated prompt photon cross-section
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: 8436959
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

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 $E_\perp(\gamma)$.

6.35 D0_1996_S3214044 [53]

Topological distributions of inclusive three- and four-jet events
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: D0 (Tevatron Run 1)
Spires ID: 3214044
Status: UNVALIDATED - currently wrong jet algorithm!
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Rev.D53:6000-6016,1996
- DOI: 10.1103/PhysRevD.53.6000
- arXiv: hep-ex/9509005

Run details:

- $p\bar{p} \to$ jets at 1800 GeV with minimum jet $p_\perp$ in analysis = 20 GeV

The global topologies of inclusive three- and four-jet events produced in pbar p interactions are described. The three- and four-jet events are selected from data recorded by the D0 detector at the Fermilab Tevatron Collider operating at a center-of-mass energy of $\sqrt{s}$=1800 GeV. The studies also show that the topological distributions of the different subprocesses involving different numbers of quarks are very similar and reproduce the measured distributions well. The parton-shower Monte Carlo generators provide a less satisfactory description of the topologies of the three- and four-jet events.

6.36 D0_1996_S3324664 [54]

Azimuthal decorrelation of jets widely separated in rapidity
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: D0 (Tevatron Run 1)
Spires ID: 3324664
Status: UNVALIDATED - currently wrong jet algorithm!
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Rev.Lett.77:595-600,1996
- DOI: 10.1103/PhysRevLett.77.595
- arXiv: hep-ex/9603010

Run details:

- $p\bar{p} \to jets$ at 1800 GeV

First measurement of the azimuthal decorrelation between jets with pseudorapidity separation up to five units. The data were accumulated using the D0 detector during Tevatron Run 1 at $\sqrt{s} = 1.8$ TeV.

6.37 D0_1998_S3711838 [55]

W-boson $p_\perp$ measurement in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: D0 (Tevatron)
Spires ID: 3711838
Status: UNVALIDATED
Authors:

- Holger Schulz ⟨hschulz@physik.hu-berlin.de⟩;

References:

- Phys. Rev. Lett. 80, 54985503

Run details:

- QCD events with W+- production and electronic decays

This is a D0 analysis from Run 1, where the distribution of the transverse momentum of W candidates that decay electronically, is measured. The electron is required to be within $|\eta| < 1.1$ and to have a transverse energy of $E_\perp > 25$ GeV. The neutrino is required to produce a missing energy of $E_{\perp,\text{ miss}} > 25$ GeV. The analysed data sample is three times as large as the similar measurement performed at CDF in 1991.

6.38 D0_2000_S4480767 [56]

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
- arXiv: 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}.

6.39 D0_2001_S4674421 [57]

Tevatron Run I differential W/Z boson cross-section analysis
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: D0 (Tevatron Run 1)
Spires ID: 4674421
Status: VALIDATED
Authors:

- Lars Sonnenschein ⟨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.

6.40 D0_2004_S5992206 [58]

Run II jet azimuthal decorrelation analysis
Beams: $p\,\bar{p}$
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.

6.41 D0_2006_S6438750 [59]

Inclusive isolated photon cross-section, differential in $p_\perp$ (gamma)
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: D0 (Tevatron Run 2)
Spires ID: 6438750
Status: VALIDATED
Authors:

- Andy Buckley ⟨andy.buckley@cern.ch⟩;
- Gavin Hesketh ⟨gavin.hesketh@cern.ch⟩;
- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Lett.B639:151-158,2006, Erratum-ibid.B658:285-289,2008
- DOI: 10.1016/j.physletb.2006.04.048
- arXiv: 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 ($q\bar{q} \to \gamma g$) and quark-gluon Compton scattering ($qg \to \gamma q$) 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

6.42 D0_2007_S7075677 [60]

$Z/\gamma^* + X$ cross-section shape, differential in $y(Z)$
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: D0 (Tevatron Run 2)
Spires ID: 7075677
Status: VALIDATED
Authors:

- Andy Buckley ⟨andy.buckley@cern.ch⟩;
- Gavin Hesketh ⟨ghesketh@fnal.gov⟩;
- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Rev.D76:012003,2007
- arXiv: hep-ex/0702025

Run details:

- Drell-Yan $p\bar{p} \to Z/\gamma^*$ + 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 boson rapidity in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, based on an integrated luminosity of 0.4 fb^{-1}.

6.43 D0_2008_S6879055 [61]

Measurement of the ratio sigma(Z/γ^* + n jets)/sigma(Z/γ^*)
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: D0 (Tevatron Run 2)
Spires ID: 6879055
Status: VALIDATED
Authors:

- Giulio Lenzi
- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- hep-ex/0608052

Run details:

- $p\bar{p} \to e^+e^-$ + 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}.

6.44 D0_2008_S7554427 [62]

$Z/\gamma^* + X$ cross-section shape, differential in $p_\perp(Z)$
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: D0 (Tevatron Run 2)
Spires ID: 7554427
Status: VALIDATED
Authors:

- Andy Buckley ⟨andy.buckley@cern.ch⟩;
- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- arXiv: 0712.0803

Run details:

- * $p\bar{p} \to e^+e^-$ + 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 $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, based on an integrated luminosity of 0.98 fb^{-1}.

6.45 D0_2008_S7662670 [63]

Measurement of D0 Run II differential jet cross sections
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: D0 (Tevatron Run 2)
Spires ID: 7662670
Status: VALIDATED
Authors:

- Andy Buckley ⟨andy.buckley@cern.ch⟩;
- Gavin Hesketh ⟨gavin.hesketh@cern.ch⟩;

References:

- Phys.Rev.Lett.101:062001,2008
- DOI: 10.1103/PhysRevLett.101.062001
- arXiv: 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.

6.46 D0_2008_S7719523 [64]

Isolated γ + jet cross-sections, differential in $p_\perp$ (γ) for various y bins
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: D0 (Tevatron Run 2)
Spires ID: 7719523
Status: VALIDATED
Authors:

- Andy Buckley ⟨andy.buckley@cern.ch⟩;
- Gavin Hesketh ⟨gavin.hesketh@cern.ch⟩;
- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Lett.B666:435-445,2008
- DOI: 10.1016/j.physletb.2008.06.076
- arXiv: 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 $p\bar{p} \to$ photon + 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 $|y_\mathrm{jet}| < 0.8$ or forward $1.5 < |y_\mathrm{jet}| < 2.5$ rapidity intervals with $p_\perp^\mathrm{jet} > 15$ GeV. The differential cross section $\mathrm{d}^3\sigma/\mathrm{d}p_\perp^\gamma \mathrm{d}y_\gamma \mathrm{d}y_\mathrm{jet}$ is measured as a function of $p_\perp^\gamma$ 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 $p_\perp^\gamma$ dependence of the cross section in any of the four measured regions.

6.47 D0_2008_S7837160 [65]

Measurement of W charge asymmetry from D0 Run II
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: D0 (Tevatron Run 2)
Spires ID: 7837160
Status: VALIDATED
Authors:

- Andy Buckley ⟨andy.buckley@cern.ch⟩;
- Gavin Hesketh ⟨gavin.hesketh@cern.ch⟩;

References:

- Phys.Rev.Lett.101:211801,2008
- DOI: 10.1103/PhysRevLett.101.211801
- arXiv: 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 $p\bar{p} \to W + X \to e\nu_e + X$ 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.

6.48 D0_2008_S7863608 [66]

Measurement of differential Z/γ^* + jet + X cross sections
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: D0 (Tevatron Run 2)
Spires ID: 7863608
Status: VALIDATED
Authors:

- Andy Buckley ⟨andy.buckley@cern.ch⟩;
- Gavin Hesketh ⟨gavin.hesketh@fnal.gov⟩;
- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- Phys.Lett. B669 (2008) 278-286
- DOI: 10.1016/j.physletb.2008.09.060
- arXiv: 0808.1296

Run details:

- $p\bar{p} \to \mu^+\mu^-$ + 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 $p_\perp$ and rapidity of the boson and $p_\perp$ and rapidity of the leading jet in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, based on an integrated luminosity of 1.0 fb^{-1}.

6.49 D0_2009_S8202443 [67]

Z/γ^* + jet + X cross sections differential in $p_\perp$ (jet 1,2,3)
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: D0 (Tevatron Run 2)
Spires ID: 8202443
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- arXiv: 0903.1748

Run details:

- $p\bar{p} \to e^+e^-$ + 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 $Z/\gamma^*(\to e^+e^-)$ + jet + X production in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, based on an integrated luminosity of 1.0 fb^{-1}.

6.50 D0_2009_S8320160 [68]

Dijet angular distributions
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: D0 (Tevatron Run 2)
Spires ID: 8320160
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- arXiv: 0906.4819

Run details:

- $p\bar{p} \to$ 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}.

6.51 D0_2009_S8349509 [69]

Z+jets angular distributions
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: D0 (Tevatron Run 2)
Spires ID: 8349509
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- arXiv: 0907.4286

Run details:

- $p\bar{p} \to \mu^+\mu^-$ + 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+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.

6.52 D0_2010_S8566488 [70]

Dijet invariant mass
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: D0 (Tevatron Run 2)
Spires ID: 8566488
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- arXiv: 1002.4594

Run details:

- $p\bar{p} \to$ 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 ($|y|_{\mathrm{max}}$) 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 $|y|_{\mathrm{max}} = 2.4$.

6.53 D0_2010_S8570965 [71]

Direct photon pair production
Beams: $p\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: CDF (Tevatron Run 2)
Spires ID: 8570965
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- arXiv: 1002.4917

Run details:

- All processes that can produce prompt photon pairs, e.g. $jj \to jj$, $jj \to j\gamma$ and $jj \to \gamma\gamma$. 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.

6.54 D0_2010_S8671338 [72]

Measurement of differential Z/γ^* $p_\perp$
Beams: $p\,\bar{p}$
Energies: (980.0, 980.0) GeV
Experiment: D0 (Tevatron Run 2)
Spires ID: 8671338
Status: VALIDATED
Authors:

- Flavia Dias ⟨fladias@gmail.com⟩;
- Gavin Hesketh ⟨gavin.hesketh@cern.ch⟩;
- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

References:

- arXiv: 1006.0618

Run details:

- $p\bar{p} \to \mu^+\mu^-$ + 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 GeV/c^2 $< m_{\mu\mu} <$ 120 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}.

6.55 E735_1998_S3905616 [73]

Charged particle multiplicity in ppbar collisions at $\sqrt{s} = 1.8$ TeV
Beams: $p\,\bar{p}$
Energies: (900.0, 900.0) GeV
Experiment: E735 (Tevatron)
Spires ID: 3905616
Status: UNVALIDATED - need trigger etc.
Authors:

- Holger Schulz ⟨holger.schulz@physik.hu-berlin.de⟩;
- Andy Buckley ⟨andy.buckley@cern.ch⟩;

References:

- Phys.Lett.B435:453-457,1998

Run details:

- QCD events, diffractive processes need to be switched on in order to fill the low multiplicity regions. The measurement was done in $|\eta| < 3.25$ and was extrapolated to full phase space. However, the method of extrapolation remains unclear.

A measurement of the charged multiplicity distribution at $\sqrt{s} = 1.8$ TeV.

7. LHC analyses

7.1 ALICE_2010_S8624100 [74]

Charged particle multiplicities at 0.9 & 2.36 TeV in three different pseudorapidity intervals.
Beams: $p\,p$
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⟩;
- Jan Fiete Grosse-Oetringhaus@cern.ch ⟨Jan.Fiete.Grosse-Oetringhaus@cern.ch⟩;

References:

- Eur.Phys.J.C68:89-108,2010
- arXiv: 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. The data were taken at 900 and 2360 GeV.

7.2 ALICE_2010_S8625980 [75]

Pseudorapidities at three energies, charged multiplicity at 7 TeV.
Beams: $p\,p$
Energies: (0.5, 0.5), (1.2, 1.2), (3.5, 3.5) GeV
Experiment: ALICE (LHC)
Spires ID: 8625980
Status: VALIDATED
Authors:

- Holger Schulz ⟨holger.schulz@physik.hu-berlin.de⟩;
- Jan Fiete Grosse-Oetringhaus@cern.ch ⟨Jan.Fiete.Grosse-Oetringhaus@cern.ch⟩;

References:

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

Run details:

- Diffractive events need to be switched on on addition to QCD.

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 [76]

Charged
Beams: $p\,p$
Energies: (450.0, 450.0) GeV
Experiment: ALICE (LHC)
Spires ID: 8706239
Status: VALIDATED
Authors:

- Holger Schulz ⟨holger.schulz@physik.hu-berlin.de⟩;
- Jan Fiete Grosse-Oetringhaus@cern.ch ⟨Jan.Fiete.Grosse-Oetringhaus@cern.ch⟩;

References:

- Phys.Lett.B693:53-68,2010
- arXiv: 1007.0719

Run details:

- Diffreactive 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 ATLAS_2010_CONF_2010_031

Charged particles at 900 and 7000 GeV in ATLAS
Beams: $p\,p$
Energies: (450.0, 450.0), (3500.0, 3500.0) GeV
Experiment: ATLAS (LHC 900GeV, LHC 7000GeV)
Spires ID: None
Status: VALIDATED – but PRELIMINARY DATA!
Authors:

- Hendrik Hoeth ⟨hendrik.hoeth@cern.ch⟩;

References:

- ATLAS-CONF-2010-031

Run details:

- pp QCD interactions at 900 or 7000 GeV including diffractive events.

Minimum bias data measured by ATLAS at 900 and 7000 GeV. Same as ATLAS_2010_S8591806, but with an additional cut on the charged particle multiplicity of $N_{\mathrm{ch}} \geq 6$. $|\eta| < 2.5$ and $p_\perp > 500$ MeV. All data is corrected to the particle level. ATTENTION - Data read from plots!

7.5 ATLAS_2010_CONF_2010_049

Cross-section of and fragmentation function in anti-kt track jets
Beams: $p\,p$
Energies: (3500.0, 3500.0) GeV
Experiment: ATLAS (LHC 7000GeV)
Spires ID: None
Status: UNVALIDATED – but PRELIMINARY DATA!
Authors:

- Hendrik Hoeth ⟨hendrik.hoeth@cern.ch⟩;

References:

- ATLAS-CONF-2010-049

Run details:

- pp QCD interactions at 7000 GeV including diffractive events.

Jets are identified and their properties studied using tracks measured by the ATLAS Inner Detector. Events are selected using a minimum-bias trigger, allowing the emergence of jets at low transverse momentum to be observed and for jets to be studied independently of the calorimeter. Jets are reconstructed using the anti-kt algorithm applied to tracks with two parameter choices, 0.4 and 0.6. An inclusive jet transverse momentum cross section measurement from 4 GeV to 80 GeV is shown, integrated over $|\eta| < 0.57$ and corrected to charged particle-level truth jets. The probability that a particular particle carries a fixed fraction of the jet momentum (fragmentation function) is also measured. All data is corrected to the particle level. ATTENTION - Data read from plots!

7.6 ATLAS_2010_CONF_2010_081

Track-based underlying event at 900 and 7000 GeV in ATLAS
Beams: $p\,p$
Energies: (450.0, 450.0), (3500.0, 3500.0) GeV
Experiment: ATLAS (LHC 900GeV, LHC 7000GeV)
Spires ID: None
Status: VALIDATED – but PRELIMINARY DATA!
Authors:

- Hendrik Hoeth ⟨hendrik.hoeth@cern.ch⟩;

References:

- ATLAS-CONF-2010-081

Run details:

- pp QCD interactions at 900 or 7000 GeV including diffractive events.

The track based UE analysis in ATLAS, based on data collected at 900 and 7000 GeV in 2009/2010. All data is corrected to the particle level. ATTENTION - Data read from plots!

7.7 ATLAS_2010_CONF_2010_083

Dijet azimuthal decorrelation at 7000 GeV in ATLAS
Beams: $p\,p$
Energies: (3500.0, 3500.0) GeV
Experiment: ATLAS (LHC 7000GeV)
Spires ID: None
Status: UNVALIDATED – but PRELIMINARY DATA!
Authors:

- Hendrik Hoeth ⟨hendrik.hoeth@cern.ch⟩;

References:

- ATLAS-CONF-2010-083

Run details:

- pp QCD interactions at 7000 GeV including diffractive events.

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 four leading jet $p_\perp$ bins. All data is fully corrected. ATTENTION - Data read from plots!

7.8 ATLAS_2010_S8591806 [77]

Charged particles at 900 GeV in ATLAS
Beams: $p\,p$
Energies: (450.0, 450.0) GeV
Experiment: ATLAS (LHC 900GeV)
Spires ID: 8591806
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

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.

7.9 ATLAS_2010_S8817804 [78]

Inclusive jet cross section and di-jet mass and chi spectra at 7 TeV in ATLAS
Beams: $p\,p$
Energies: (3500.0, 3500.0) GeV
Experiment: ATLAS (LHC 7TeV)
Spires ID: 8817804
Status: VALIDATED
Authors:

- James Monk ⟨jmonk@cern.ch⟩;

References:

- arXiv: 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. Jets are resconstructed 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 $p_\perp$ ¿30 GeV. Jet $p_\perp$ and di-jet mass spectra are plotted in bins or 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 $340\ GeV < m_{12} < 520\ GeV$, $520\ GeV < m_{12} < 800\ GeV$ and $800\ GeV < m_{12} < 1200\ GeV$.

7.10 LHCB_2010_S8758301 [79]

Differential cross section measurement of K_S^0 production in three rapidity windows at $\sqrt{s} = 0.9$ TeV
Beams: $p\,p$
Energies: (450.0, 450.0) GeV
Experiment: LHCB (LHCB)
Spires ID: 8758301
Status: UNVALIDATED
Authors:

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

References:

- Phys.Lett.B693:69-80,2010
- arXiv: 1008.3105[hep-ex]

Run details:

- QCD events. See paper for MC discussion.

Differential cross-section measurement of prompt K_S^0 production in pp collisions at $\sqrt{s} = 0.9$ TeV in the rapidity windows $2.5 < y < 3.0$, $3.0 < y < 3.5$ and $3.5 < y < 4.0$. Unresolved issues at the moment are the normalisations. Not clear to me how to do this from the paper so I normalise to reference data area.

8. SPS analyses

8.1 UA1_1990_S2044935 [80]

UA1 multiplicities, transverse momenta and transverse energy distributions.
Beams: $p\,\bar{p}$
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 ⟨andy.buckley@cern.ch⟩;
- Christophe Vaillant ⟨c.l.j.j.vaillant@durham.ac.uk⟩;

References:

- Nucl.Phys.B353:261,1990

Run details:

- QCD min bias events at sqrtS = 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 [81]

UA5 multiplicity and pseudorapidity distributions for pp and $p\bar{p}$.
Beams: $\bar{p}\,p$
Energies: (26.5, 26.5) GeV
Experiment: UA5 (SPS)
Spires ID: 875503
Status: VALIDATED
Authors:

- Andy Buckley ⟨andy.buckley@cern.ch⟩;
- Christophe Vaillant ⟨c.l.j.j.vaillant@durham.ac.uk⟩;

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 [82]

Pseudorapidity distributions in $p\bar{p}$ (NSD, NSD+SD) events at $\sqrt{s} = 200$ and 900 GeV
Beams: $p\,\bar{p}$
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⟩;
- Holger Schulz ⟨holger.schulz@physik.hu-berlin.de⟩;
- Christophe Vaillant ⟨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 [83]

UA5 charged multiplicity measurements at 546 GeV
Beams: $p\,\bar{p}$
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 [84]

Charged particle correlations in UA5 p
***barp* NSD events at $\sqrt{s}$ = 200, 546 and 900 GeV.**
Beams: $p\,\bar{p}$
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 ⟨holger.schulz@physik.hu-berlin.de⟩;

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 [85]

UA5 charged multiplicity measurements
Beams: $p\,\bar{p}$
Energies: (100.0, 100.0), (450.0, 450.0) GeV
Experiment: UA5 (CERN SPS)
Spires ID: 1926373
Status: VALIDATED
Authors:

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

References:

- Z. Phys. C - Particles and Fields 43, 357-374 (1989)
- DOI: 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 [86]

H1 energy flow and charged particle spectra in DIS
Beams: $e^- p$
Energies: (820.0, 26.7) GeV
Experiment: H1 (HERA)
Spires ID: 2919893
Status: VALIDATED
Authors:

- Peter Richardson ⟨peter.richardson@durham.ac.uk⟩;

References:

- Z.Phys.C63:377-390,1994
- DOI: 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_1995_S3167097 [87]

Transverse energy and forward jet production in the low-x regime at H1
Beams: $e^- \, p$
Energies: (820.0, 26.7) GeV
Experiment: H1 (HERA Run I)
Spires ID: 3167097
Status: UNVALIDATED
Authors:

- Leif Lonnblad ⟨leif.lonnblad@thep.lu.se⟩;

References:

- Phys.Lett.B356:118,1995
- hep-ex/9506012

Run details:

- 820 GeV protons colliding with 26.7 GeV electrons. DIS events with an outgoing electron energy > 12 GeV. 5 GeV$^2 < Q^2 < 100$ GeV^2, $10^{-4} < x < 10^{-2}$.

DIS events at low x may be sensitive to new QCD dynamics such as BFKL or CCFM radiation. In particular, BFKL is expected to produce more radiation at high transverse energy in the rapidity span between the proton remnant and the struck quark jet. Performing a transverse energy sum in bins of x and η may distinguish between DGLAP and BFKL evolution.

9.3 H1_2000_S4129130 [88]

H1 energy flow in DIS
Beams: $e^+ p$
Energies: (820.0, 27.5) GeV
Experiment: H1 (HERA)
Spires ID: 4129130
Status: VALIDATED
Authors:

- Peter Richardson ⟨ peter.richardson@durham.ac.uk ⟩;

References:

- Eur.Phys.J.C12:595-607,2000
- DOI: 10.1007/s100520000287
- arXiv: 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 GeV^2; 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.

9.4 ZEUS_2001_S4815815 [89]

Dijet photoproduction analysis
Beams: $e^+ p$
Energies: (820.0, 27.5) GeV
Experiment: ZEUS (HERA Run I)
Spires ID: 4815815
Status: UNVALIDATED
Authors:

- Jon Butterworth ⟨jmb@hep.ucl.ac.uk⟩;

References:

- Eur.Phys.J.C23:615,2002
- DESY 01/220
- hep-ex/0112029

Run details:

- 820 GeV protons colliding with 27.5 GeV positrons; Direct and resolved photoproduction of dijets; Leading jet $p_\perp > 14$ GeV, second jet $p_\perp > 11$ GeV; Jet pseudorapidity $-1 < |\eta| < 2.4$

ZEUS photoproduction of jets from proton–positron collisions at beam energies of 820 GeV on 27.5 GeV. Photoproduction can either be direct, in which case the photon interacts directly with the parton, or resolved, in which case the photon acts as a source of quarks and gluons. A photon-proton centre of mass energy of between 134 GeV and 227 GeV is probed, with values of x_P, the fractional momentum of the partons inside the proton, predominantly in the region between 0.01 and 0.1. The fractional momentum of the partons from the photon, $x\gamma$, is in the region 0.1 to 1. Jets are reconstructed in the range $-1 < |\eta| < 2.4$ using the $k_\perp$ algorithm with an R parameter of 1.0. The minimum $p_\perp$ of the leading jet should be greater than 14 GeV, and at least one other jet must have $p_\perp > 11$ GeV.

10. RHIC analyses

10.1 STAR_2006_S6500200 [90]

Identified hadron spectra in pp at 200 GeV
Beams: $p\,p$
Energies: (100.0, 100.0) GeV
Experiment: STAR (RHIC pp 200 GeV)
Spires ID: 6500200
Status: VALIDATED
Authors:

- Bedanga Mohanty ⟨bedanga@rcf.bnl.gov⟩;
- Hendrik Hoeth ⟨hendrik.hoeth@cern.ch⟩;

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 [91]

Strange particle production in pp at 200 GeV
Beams: $p\,p$
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 [92]

Inclusive jet cross-section in pp at 200 GeV
Beams: $p\,p$
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_2008_S7869363 [93]

Multiplicities and $p_\perp$ spectra from STAR for pp at 200 GeV
Beams: $p\,p$
Energies: (100.0, 100.0) GeV
Experiment: STAR (RHIC)
Spires ID: 7869363
Status: UNVALIDATED
Authors:

- Holger Schulz ⟨holger.schulz@physik.hu-berlin.de⟩;

References:

- arXiv: 0808.2041
- http://drupal.star.bnl.gov/STAR/files/starpublications/124/data.html

Run details:

- QCD (pp) events at 200 GeV

Charged Mulitplicity and identified charged particle spectra

10.5 STAR_2008_S7993412 [94]

Di-hadron correlations in d-Au at 200 GeV
Beams: $p\,p$
Energies: (100.0, 100.0) GeV
Experiment: STAR (RHIC d-Au 200 GeV)
Spires ID: 7993412
Status: UNVALIDATED
Authors:

- Christine Nattrass ⟨christine.nattrass@yale.edu⟩;
- Hendrik Hoeth ⟨hendrik.hoeth@cern.ch⟩;

References:

- arXiv: 0809.5261

Run details:

- d-Au at 200 GeV (use pp Monte Carlo! See description)

Correlation in η and ϕ between the charged hadron with the highest $p_\perp$ ("trigger particle") and the other charged hadrons in the event ("associated particles"). The data was collected in d-Au collisions at 200 GeV. Nevertheless, it is very proton-proton like and can therefore be compared to *pp* Monte Carlo (not for tuning, but for qualitative studies.)

10.6 STAR_2009_UE_HELEN

UE measurement in pp at 200 GeV
Beams: $p\,p$
Energies: (100.0, 100.0) GeV
Experiment: STAR (RHIC pp 200 GeV)
Spires ID: None
Status: VALIDATED – but PRELIMINARY DATA!
Authors:

- Helen Caines ⟨helen.caines@yale.edu⟩;
- Hendrik Hoeth ⟨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 $\mathrm{d}\phi\mathrm{d}\eta$ (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_DIJET

Analysis of dijet events at the LHC.
Beams: $**$
Status: UNVALIDATED
No authors listed
No references listed
Run details:

- Generic QCD events at any energy.

Analysis of dijet events for the upcoming runs at the LHC, specifically studying azimuthal angle, transverse momentum distributions (including for leading jet and secondary jet), as well as charged particle multiplicities and transverse momenta.

11.2 MC_DIPHOTON

Monte Carlo validation observables for diphoton production at LHC
Beams: $**$
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

No references listed
Run details:

- LHC pp → jet+jet, photon+jet, photon+photon, all with EW+QCD shower

Different observables related to the two photons

11.3 MC_GENERIC

Generic MC testing analysis
Beams: $**$
Status: UNVALIDATED
Authors:

- Ian Bruce ⟨ibruce@cern.ch⟩;
- Andy Buckley ⟨andy.buckley@cern.ch⟩;

No references listed
No run details listed

Generic analysis of typical event distributions such as η, y, $p_\perp$, ϕ...

11.4 MC_HJETS

Monte Carlo validation observables for $h[\tau^+ \tau^-]$ + jets production
Beams: $* *$
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

No references listed
Run details:

- $h[\to \tau^+\tau^-]$ + jets.

Available observables are 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, integrated 0–4 jet rates.

11.5 MC_JETS

Monte Carlo validation observables for jet production
Beams: $*\,*$
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

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.

11.6 MC_LEADINGJETS

Underlying event in leading jet events, extended to LHC
Beams: $**$
Status: VALIDATED
Authors:

- Andy Buckley ⟨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.

11.7 MC_PHOTONJETS

Monte Carlo validation observables for photon + jets production
Beams: $*\,*$
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

No references listed
Run details:

- Tevatron Run II ppbar → gamma + jets.

Different observables related to the photon and extra jets.

11.8 MC_PHOTONJETUE

Study the usual underlying event observables in photon + jet events
Beams: $p\,p$, $\bar{p}\,p$
Status: UNVALIDATED
Authors:

- Andy Buckley ⟨andy.buckley@cern.ch⟩;

No references listed
Run details:

- Photon + jet events at any energy. $p_\perp$ cutoff at 10 GeV advised.

Modification of the MC leading jets underlying event analysis to study the UE in hard photon+jet events. This may be of interest, because the leading QCD dipole structure is different from that in either dijet or Drell-Yan hard processes. Observables are also extended to include the variation of transverse activity as a function of jet-photon balance, and using the photon rather than the jet to define the event alignment.

11.9 MC_SUSY

Validate generic SUSY events, including various lepton invariant mass
Beams: $**$
Status: VALIDATED
Authors:

- Andy Buckley ⟨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.

11.10 MC_TTBAR

MC analysis for ttbar studies
Beams: $**$
Status: UNVALIDATED
Authors:

- Holger Schulz ⟨hschulz@physik.hu-berlin.de⟩;
- Andy Buckley ⟨andy.buckley@cern.ch⟩;

No references listed
Run details:

- * For Pythia6, set MSEL=6.
- For Fortran Herwig/Jimmy select IPROC=1706.

This is a pure Monte Carlo study for t-tbar production.

11.11 MC_WJETS

Monte Carlo validation observables for $W[e\,\nu]$ + jets production
Beams: $*\,*$
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

No references listed
Run details:

- $e\,\nu$ + jets analysis.

Available observables are W mass, $p_\perp$ of jets 1-4, jet multiplicity, $\Delta\eta(W, \mathrm{jet1})$, $\Delta R(\mathrm{jet2}, \mathrm{jet3})$, differential jet rates 0→1, 1→2, 2→3, 3→4, integrated 0–4 jet rates.

11.12 MC_WWJETS

Monte Carlo validation observables for $W^+[e^+\,\nu]W^-[\mu^-\,\nu]$ + jets production
Beams: $*\,*$
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

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.

11.13 MC_ZJETS

Monte Carlo validation observables for $Z[e^+ e^-]$ + jets production
Beams: $* *$
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

No references listed
Run details:

- e^+e^- + 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→1, 1→2, 2→3, 3→4, integrated 0–4 jet rates.

11.14 MC_ZZJETS

Monte Carlo validation observables for $Z[e^+ e^-]Z[\mu^+ \mu^-]$ + jets production
Beams: $* *$
Status: VALIDATED
Authors:

- Frank Siegert ⟨frank.siegert@durham.ac.uk⟩;

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

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.

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⟩;

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 BELLE_2006_S6265367

Charm hadrons from fragmentation and B decays on the $\Upsilon(4S)$
Beams: $e^- e^+$
Energies: (3.5, 8.0) GeV
Status: VALIDATED
Authors:

- Jan Eike von Seggern ⟨jan.eike.von.seggern@physik.hu-berlin.de⟩;

References:

- Phys.Rev.D73:032002,2006.
- arXiv: hep-ex/0506068
- DOI: 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. Additionally, we determine the average number of these charmed hadrons produced per B decay at the $\Upsilon(4S)$ resonance and measure the distribution of their production angle in e^+e^- annihilation events and in B decays.

13.2 PDG_HADRON_MULTIPLICITIES [95]

Hadron multiplicities in hadronic e^+e^- events
Beams: e^- e^+
Energies: (45.6, 45.6) 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, 29–35, 91, and 130–200 GeV. The numbers are averages from various experiments. Correlations of the systematic uncertainties were considered for the calculation of the averages.

13.3 PDG_HADRON_MULTIPLICITIES_RATIOS [95]

Ratios (w.r.t. π^+/π^-) of hadron multiplicities in hadronic e^+e^- events
Beams: e^- e^+
Energies: (45.6, 45.6) 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 $\sqrt{s} \approx 10$, 29–35, 91, and 130–200 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.

13.4 SFM_1984_S1178091 [96]

Charged multiplicity distribution in pp interactions at CERN ISR energies
Beams: $p\,p$
Energies: (15.2, 15.2), (22.2, 22.2), (26.1, 26.1), (31.1, 31.1) GeV
Experiment: SFM (CERN ISR)
Spires ID: 1178091
Status: UNVALIDATED
Authors:

- Holger Schulz ⟨holger.schulz@physik.hu-berlin.de⟩;
- Andy Buckley ⟨andy.buckley@cern.ch⟩;

References:

- Phys.Rev.D30:528,1984

Run details:

- QCD events, double-diffractive events should be turned on as well.

Charged multiplicities are measured at $\sqrt{s} = 30.4$, 44.5, 52.2 and 62.2 GeV using a minimum-bias trigger. The data is sub-divided into inleastic as well as non-single-diffractive events. However, the implementation of the diffractive events will require some work.

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[97] 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 $\mathcal{O}$(1-2 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 bremstrahlung. 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 projections[2] (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

[2] Provided 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

[3] As 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. The header for a new analysis named `UserAnalysis` that uses the `FinalState` projection might therefore start off looking like this:

```
#include "Rivet/Analysis.hh"

namespace Rivet {
```

```
  class UserAnalysis : public Analysis {
  public:
    UserAnalysis();
    void init();
    void analyze(const Event& event);
    void finalize();
  };

}
```

The constructor for the UserAnalysis may impose certain requirements upon the events that the analysis will work with. A call to the setBeams method declares that the analysis may only be run on events with specific types of beam particles, for example adding the line

```
  setBeams(PROTON, PROTON);
```

ensures that the analysis can only be run on events from proton-proton collisions. Other types of beam particles that may be used include ANTIPROTON, ELECTRON, POSITRON, MUON and ALL. The latter of these declares that the analysis is suitable for use with any type of collision and is the default.

Some analyses need to know the interaction cross section that was generated by the Monte Carlo generator, typically in order to normalise histograms. Depending on the Monte Carlo that is used and its interface to Rivet, the cross section may or may not be known. An analysis can therefore declare at the beginning of a run that it will need the cross section information during the finalisation stages. Such a declaration can be used to prevent what would otherwise be fruitless analyses from running. An analysis sets itself as requiring the cross section by calling inside the constructor

```
  setNeedsCrossSection(true);
```

In the absence of this call the default is to assume that the analysis does not need to know the cross section.

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:

```
Rivet::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 MyAnalysis::init() {
  _h_one = bookHistogram1D(2,1,1, "Title 2", "x label", "y label");
  _h_two = bookProfile1D(3,1,2, "Title 2", "x label", "y label");
  _h_three = bookHistogram1D("d00-x00-y00", "Title",
                             "x label", "y label", 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 MyAnalysis::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 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 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 will disable this standard location to allow you to override standard analyses with same-named variants of your own (provided they are loaded from different directories).

Note that the search path behaviour has changed as of Rivet 1.2.0: previously the standard library install directory was always *used, as were the current directory and* `./.libs`*, if found. While the new system requires a bit more setup if you are to use personal plugin analyses, it also solves many niggling problems and areas for confusion!*

You may also wish or need to use the `$RIVET_REF_PATH` and `$RIVET_INFO_PATH` variables, which respectively provide similar search paths for analysis reference data and analysis metadata (e.g. author, date, run conditions, experiment, etc.) files.

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://projects.hepforge.org/rivet/trac/wiki/`

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 the flawed one 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: these have long been advertised as marked for replacement, and while progress in that area has lagger far behind our ambitions, it *will* happen before the 2.0.0 release, with unavoidable impact on the related parts of the API. You have been warned!

The best way to expain 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("Pythia6:423");
  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 Pythia6:423 --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 "$\langle key \rangle$ $\langle value \rangle$": in this case, the file `lep1.params` is loaded from the $\langle installdir \rangle$`/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 Pythia6:423 --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.

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Part V
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