

# SHERPA mini documentation

(preliminary version 1.0.4)



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## Abstract

This is a short primer on how to get started and how to use the **SHERPA** framework for the *Simulation for High-Energy Reactions of PArticles*. It is not meant to fully reflect the physics implemented in this program nor does it give an account of the program structure or the coding principles underlying it. For different physics aspects and especially for external code that has been linked, corresponding references are given and users are encouraged to cite them accordingly. Also, users of this framework are kindly asked to refer to its original publication [1].

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## Introduction

This mini guide is meant as a help to get users started with **SHERPA**. It does not replace a careful study of the manual(s) or the many excellent publications on different aspects of event generation or physics at collider experiments. Users of the code are encouraged to read and to cite original work of the authors or others whenever justified.

This mini documentation is written for those mainly interested in getting started as quickly as possible. Reading it should be sufficient to understand, which switches and options have been provided, how to use them, and how the output may be interpreted.

For those, who are interested in playing with this tool and, maybe, in adding some new features to the program, a part II explaining the possibilities of easily extending the code will be made available very soon.

It should be stressed that in the construction of such a code a number of implicit assumptions, unjustified simplifications of complicated situations, potential bugs and other shortcomings of the authors are included. Therefore, the results of event generators, independent of their quality, should always be verified and cross-checked with results obtained by the programs of other authors.

It should also be stressed that there is a number of physics processes **SHERPA** cannot simulate (yet). These include, among others,

- DIS-like situations. **SHERPA** may calculate cross sections for DIS and similar processes, however, the parton shower of **APACIC** is not ready to deal with the situation of performing only one spacelike evolution.
- the underlying event. The treatment of multiple parton interactions and the soft underlying event is lacking so far. Multiple interactions in a basic form can be expected to be included in the next release, presumably in July 2004.
- pile-up events.

In addition, the hadronisation and the hadron decays are still completely handled by **Pythia**; an interface is provided.

The authors welcome suggestions, bug reports, etc. and endeavour to answer any question as quickly as possible. Furthermore they try to provide user support as far as possible. In order to improve **SHERPA**, please do not hesitate to send any form of comment to their common mail account

`sherpa@theory.phy.tu-dresden.de` .

For bug fixings, updates, etc., please refer to the homepage

<http://www.physik.tu-dresden.de/~krauss/hep/index.html> .

## Part I

# Basics: Getting started with SHERPA

## 1 Structure of the SHERPA framework

The SHERPA package is constructed in a modular fashion, where each module encapsulates different aspects of event generation for high-energy particle reactions. Each module resides within its own namespace. In the names of the modules a version number is included. For instance, there are the modules `ATOOLS-2.0` or `AMEGIC++-2.0`. The label “++” thereby signals that the corresponding module has been developed independently and, therefore, is equipped with a separate documentation<sup>1</sup>. After the SHERPA package has been installed in a directory, each module is located in its own subdirectory of the same name. The main steering module defining how the events are actually generated is called – in its current version – `SHERPA-1.0`. Altogether, the following modules are currently distributed with the SHERPA framework:

- `ATOOLS-2.0`

This is the toolbox for all other modules. Since the SHERPA framework does not rely on CLHEP etc., the `ATOOLS` contain classes with mathematical tools like vectors and matrices, organisation tools such as read-in or write-out devices, and physics tools like particle data or classes for the event record.

- `BEAM-1.0`

This module manages the treatment of the initial beam spectra for different colliders. At the moment two options are implemented for the beams: they can either be monochromatic, and therefore require no extra treatment, or, for the case of an electron collider, laser backscattering off the electrons is supported leading to photonic initial states<sup>2</sup>.

- `PDF-1.0`

In this module the handling of initial state radiation (ISR) is located. It provides interfaces to various proton [5, 6] parton density functions (PDFs), and to the LHAPDF (version 1) interface [8], which makes a full wealth of proton PDFs available. In addition, an (analytical) electron structure function is supplied there as well.

- `MODEL-1.0`,

This module comprises the basic physics parameters (like masses, mixing angles, etc.) of the simulation run. Thus it specifies the corresponding physics model. At the moment three different physics models are supported: the Standard Model (SM), its Minimal Supersymmetric extension (MSSM) [9] and the ADD model of large extra dimensions [10]. For the SM and the ADD model most of the required parameters are directly read in, the SM (and also the MSSM) Higgs boson width(s) and branching ratios can be computed through the program `HDecay` [11], which is interfaced to SHERPA. For the MSSM, an interface to the program `Isasusy 7.67` [12] is provided. It is used to generate the MSSM spectra in dependence on the SUSY breaking scenario and its parameters. Both programs directly feed their results into SHERPA.

---

<sup>1</sup>However, the documentation for the versions 1.0 of both, `APACIC` [2] and `AMEGIC` [3], is not up to date anymore. Documentation for the new versions of these modules should be made available in near future.

<sup>2</sup>It should be stressed, however, that the parameterisation [4], which has been implemented, is valid for the proposed TESLA photon collider only. This is because various assumptions concerning the laser parameters and especially the initial energy of the electrons have been made.

- **EXTRA\_XS-1.0**

In this module a (limited) collection of analytic expressions for simple  $2 \rightarrow 2$  processes within the SM and the corresponding classes embedding them into the **SHERPA** framework are provided. This includes methods used for the definition of the parton shower evolution, such as colour connections and the hard scale of the process. However, the classes for phase space integration, which are common with **AMEGIC**, are located in a special module called **PHASIC**.

- **AMEGIC+-2.0**

**AMEGIC** [3] is **SHERPA**'s preferred matrix element generator, which employs the method of helicity amplitudes [13, 14]. It works as a generator, which generates generators:

During the initialisation run the matrix elements for a set of given processes within the SM, the MSSM or the ADD model, as well as their specific phase space mappings are created by **AMEGIC** and stored in library files. In the initialisation of the production run, these libraries are linked to the program. They are used to calculate cross sections and to generate single events based on them. Also, a directory may be specified to store the cross sections, the status of the phase space integrators, and the maximal weights of the processes. These information may be used to shorten the potentially lengthy calculation phase for further event generation runs.

- **PHASIC+-1.0**

Here all classes dealing with the Monte Carlo phase space integration are located. As default the adaptive multi-channel method of [15, 16] is used for the evaluation of the initial state (laser backscattering, initial state radiation) and final state integrals. In addition, final state integration accomplished by **Rambo** [17] and **Sarge** [18] is supported.

- **APACIC+-2.0**

**APACIC** [2] contains classes for the simulation of both, the initial and the final state shower. The shower evolution is organised by employing the parton virtual mass as the ordering variable. Coherence effects are accounted for by an explicit ordering of the opening angles in subsequent branchings<sup>3</sup>. All features for a consistent merging with matrix elements [23, 24] are included, however the main part of the merging procedure is situated in the **SHERPA-1.0** module itself.

- **SHERPA-1.0**

Finally, **SHERPA** is the steering module that initialises, controls and evaluates the different phases in the entire process of event generation. Furthermore, all necessary routines for the combining of parton showers and matrix elements, which are independent of the specific parton shower, are found in this module. In addition, this subpackage provides an interface to the Lund String Fragmentation of **Pythia 6.214** including its hadron decay routines.

- In addition to the modules of **SHERPA**, two scripts for alleviated installation of the package and easier handling are distributed: **makeinstall** and **makedist**.

The actual executable of the **SHERPA** generator is located in the subdirectory **SHERPA-1.0/Run** and is called **Sherpa**. By default, all input and output files are located in this directory.

---

<sup>3</sup>This is similar to the way **Pythia** [19, 20] handles the parton shower. **Herwig** [21, 22], in contrast, ensures coherence by using an ordering parameter respecting the angle of the parton branching.

## 2 Installing SHERPA

Usually, SHERPA is distributed as a tarred and gzipped file named `Sherpa-<version>.tar.gz`. The file for the latest version can be unpacked in the current working directory with

```
tar -zxvf Sherpa-1.0.4.tar.gz .
```

All modules stated above are located as directories in the current working directory. To install the framework, the `makeinstall` script is used. To guarantee a successful installation, the following tools should be available on the system: `make`, `autoconf`, `automake` and `libtool`. The authors recommend to use the following command line

```
./makeinstall -t
```

in order to start the installation. While processing the installation a log file called `sherpa_install.log` is created, which records the entire installation procedure. This is useful in cases where the automatic compilation process fails. Then, users are invited to send the log file as a bug report to the authors. The `makeinstall` script provides a number of combinable options listed and described in Table 1, including a help option available through the flag `-h`. In case that the `make`, `autoconf`, `automake` and

<code>-c</code>	configure before compiling (subset of ‘-t’)
<code>-t</code>	rebuild ‘Makefile.in’s and ‘configure’s; configure before compiling
<code>-f</code>	display the full information on the setup
<code>-r</code>	display minimal information but write a log file instead
<code>-s</code>	create simple install scripts to be customised by the user
<code>-n</code>	never extract tar files
<code>--clean</code>	execute ‘make clean’ in every module before compiling
<code>--clean-run</code>	execute ‘./SHERPA-1.0/Run/makeclean’ before compiling
<code>--no-abort</code>	ignore exit status of ‘make’
<code>--copt</code>	define option for ‘configure’
<code>--mopt</code>	define option for ‘make’ (default is ‘-j2’)
<code>--cxx</code>	define CXX flag for ‘make’
<code>--f</code>	define Fortran flag for ‘make’
<code>--force-tar</code>	force extraction of tar files (enables ‘-e’)
<code>--clean-up</code>	execute ‘make clean’ in every module
<code>--rm-libs</code>	remove shared libraries; does not remove ‘.lo’ files
<code>-h</code>	display this help and exit

Table 1: Options of the `makeinstall` script.

`libtool` tools are not available or if the user prefers to employ and customise his/her own simple install scripts, the `makeinstall` script is equipped with the option `-s`, constructing such scripts.

The SHERPA package has successfully been installed, compiled and tested on SuSE, RedHat and Debian Linux systems using the GNU C++ compiler `gcc` versions 2.95/3.2/3.3. Note, that `gcc` version 2.96 is **not** supported.

For those daring users, who modified parts of SHERPA according to their own needs or who added own modules and who would like to distribute the code, the `makedist` script is available. Its options are listed in Table 2. Note that a successful generation requires the following preparation. Before creating a distribution, all automatically generated process libraries in `./SHERPA-1.0/Run` must be removed.

This can be accomplished through applying `makedist` with the `-c` option or by directly running the `makeclean` script in `./SHERPA-1.0/Run`.

<code>-c</code>	execute <code>./SHERPA-1.0/Run/makeclean</code> first
<code>-f</code>	include full time information in distribution name
<code>--clean</code>	execute <code>'make clean'</code> before <code>'make dist'</code>
<code>--configure</code>	configure before <code>'make dist'</code> (enabled with <code>'-t'</code> )
<code>--hide-cvs</code>	do not include cvs directories in distribution
<code>--total</code>	rebuild <code>'Makefile.in's'</code> and <code>'configure's'</code> before <code>'make dist'</code>
<code>--copt</code>	define option for <code>'configure'</code>
<code>--no-abort</code>	ignore exit status of <code>'make'</code>
<code>-h</code>	display this help and exit

Table 2: Options of the `makedist` script.

## 3 First runs with SHERPA

### 3.1 Running SHERPA

Whenever a new process is initialised in SHERPA – including the case of a freshly installed program using the default setup – `Sherpa` needs to run twice in order to calculate cross sections or to generate events. This is because in most cases the matrix elements are generated by AMEGIC during the first run. In this initialisation run started by changing into the `./SHERPA-1.0/Run` directory and executing

```
./Sherpa ,
```

the Feynman diagrams for the contemplable process(es) are constructed and translated into helicity amplitudes. Furthermore suitable phase space mappings are produced. The amplitudes and the integration channels are stored in library files that need to be compiled and linked to the framework. In order to do so, the `makelibs` script located in the same directory has to be run according to

```
./makelibs .
```

In the second run then the cross sections are evaluated and events are generated. In most cases it is advantageous to store the cross sections obtained during the production run for later use.

However, one remark is in order here:

Whenever the physics setup is considerably changed, i.e. whenever particles are switched on or off or whenever the physics model is changed, it is absolutely mandatory to erase the library files. Since the library files are linked to SHERPA, it is not sufficient to remove them, they have to be erased from different `Makefiles` etc.. For this purpose the script

```
./makeclean
```

located in the `./SHERPA-1.0/Run` directory as well has been provided. The urge to erase old library files is because in principle they are blind to the specific physics environment they are created in and meant for. So (ab)using them in another frame will in nearly all cases lead to drastically wrong results or to the crashing of SHERPA.

## 3.2 Default setup: Hadron production in $e\gamma$ collisions

### 3.2.1 The setup

The distributed version of SHERPA comes with a default setup for the following type of process to be simulated within the SM:

$$e^-e^- \rightarrow e^-\gamma \rightarrow e^-\gamma \rightarrow e^-d\bar{d} \rightarrow e^- + \text{hadrons},$$

where in the first step the photon is produced through laser backscattering off one of the incoming electrons. In the second step the other electron experiences some initial state radiation according to a structure function (S.F.), before the electron and photon produce a  $d\bar{d}$  pair through some kind of peripheral scattering. In calculating the cross section for this process and for the generation of events, some cuts are applied on the initial and final state, namely

$$E_{\perp}(e^-) > 1\text{GeV}, \quad E_{\perp}(d) > 1\text{GeV}, \quad E_{\perp}(\bar{d}) > 1\text{GeV},$$

$$\cos\theta_{e^-} \in [-0.9, 0.9], \quad \cos\theta_d \in [-0.9, 0.9], \quad \cos\theta_{\bar{d}} \in [-0.9, 0.9],$$

where the angles are w.r.t. the positive beam axis. Then, the parton shower starts before the resulting final state partons are afterwards translated into hadrons. To modify this default process or to set up SHERPA for a completely different collider with a different process in a different model, various data files (of the form `*.dat`) may be changed. Details and instructions for doing this can be found in Sec. 4. The default setup comes in the output mode “info+events+tracking”. However, for the brevity of this manual, the authors consider the output mode “info+events” in the following. Apart from error messages, in the “info” mode, SHERPA lets the user know what it is currently working on. In particular, this includes

- messages concerning the modules that have been initialized for the run with some basic information about the setup;
- a frequent update of the result of eventual integration of processes that have been initialized.

In the “events” mode, the events are printed on screen. For more options to output events in different formats and for information on how to interpret the generic SHERPA output, cf. Sec. 6.

### 3.2.2 First run

For the first – the initialization run – the output would look like

```
Welcome to Sherpa,username. Initialization of framework underway.

-----
-----  Event generation run with SHERPA started .....  -----
-----
..... | +
..... || | + +
..... | | / +
..... _- | ... || +| + +
..... _-' ;\| ... || / +| +
..... ( \ \ ... || | ++ \ +
..... ( \ -/ ... || + | +
..... <S /()))~##### + /\ +
..... (!H (~))~######/ + + | +
..... (!E (~))~#####/|/ + +
..... (!R (~))~##### ||| + + +
..... (!P (~))~##### /| + + +
```



```

..... (!A> (~~~~~##      + +      +
..... ~(!      ~~~~~ \      + +      +
..... ~~~~~ QQQQDb // |      + +      +
..... IDDDDP|| \      + + + +      +
..... IDDDI|| \      +
..... IHD HD|| \ + + + + + + + +
..... IHD ##|      :- ) + + \
..... IHI ## /      / + + + + \
..... IHI/ /      / + + + +
..... ## | | /      / + +      + /
..... /TT\ ..... ##/ /// / + + + + + /
..... /TTT/T\ ... /TT\ \ \ \ / + + + + + + / \
version 1.0.4 ..... /TTT/TTTT\...|TT/T\ \ \ / + ++ + /
-----

```

SHERPA version 1.0.4.

AUTHORS: Tanju Gleisberg, Stefan Hoeche, Frank Krauss,  
 Andreas Schaelicke, Steffen Schumann, Jan Winter

This program uses a lot of genuine and original research  
 work by other people. Users are encouraged to refer to  
 the various original publications.

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Please visit also our homepage  
<http://www.physik.tu-dresden.de/~krauss/hep/index.html>  
 for news, bugreports, updates and new releases.

```

-----
Initialize the Standard Model from ./ / Model.dat
Initialized the beams Laser_Backscattering*Monochromatic
Initialized the ISR : (None)*(SF)
Amegic::InitializeProcesses :
  Process initialization started; new libraries may be created.
Single_Process::Tests for 2_3_P_e-__e-d_db
  Prepare gauge test and init helicity amplitudes. This may take some time.
In String_Handler::Complete : this may take some time...
Single_Process::CheckLibraries : Looking for a suitable library. This may take some time.
Single_Process::WriteLibrary :
  Library for 2_3_P_e-__e-d_db has been written, name is P2_3_8_7_100_32_13_0
Amegic::InitializeProcesses :
  Some new libraries were created and have to be compiled and linked.
  Type "./makelibs" and rerun.

Time: 0.24 s (clocks=24)
(User: 0.1 s ,System: 0.05 s ,Children User: 0.03 s ,Children System: 0.04)

```

### 3.2.3 Second run

By performing `./makelibs` the freshly generated process libraries will be compiled and stored as shared libraries. Restarting the run produces the following output:

Welcome to Sherpa, *username*. Initialization of framework underway.

```

-----
----- Event generation run with SHERPA started -----
-----

```

```

..... | +
..... || | + +
..... | | / +
..... _- | ... || +| + +
..... _- ' ,\| ... || / +| + +
..... ( \ \ \ ... || | ++ \ +
..... ( \ -/ ... || + + | + +
..... <S /()))~##### + / \ +
..... (!H (~))~######/ + + | +
..... (!E (~))~#####/|/ + +
..... (!R (~))~##### ||| + +
..... (!P (~))~##### /| + +
..... (!A> (~))~##### + + +
..... ~(! ,##### \ + + + +
..... '##### // | + + + + +
..... IDDDDP|| \ + + + + +
..... IDDDI|| \ +
..... IHD HD|| \ + + + + +
..... IHD ##| :-~) + \ +
..... IHI ## / / + + + + \ +
..... IHI / / / + + + + +
..... ## | | / / + + + + / +
..... /TT\ ..... ##/ /// / + + + + + / +
..... /TTT/T\ ... /TT\/\ \ / + + + + + / \ +
version 1.0.4 ...../TTT/TTTT\...|TT/T\ \ / + ++ + /
-----

```

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 for news, bugreports, updates and new releases.

```

-----
Initialize the Standard Model from ./ / Model.dat
Initialized the beams Laser_Backscattering*Monochromatic
Initialized the ISR : (None)*(SF)
Amegic::InitializeProcesses :
  Process initialization started; new libraries may be created.
VP2_3_8_7_100_32_13_0 loaded.
  No new libraries have been created.
Initialized the Matrix_Element_Handler for the hard processes :Amegic
Initialized the Shower_Handler.
Initialized the Fragmentation_Handler.
Initialized the Beam_Remnant_Handler.
=====
Start calculating the hard cross sections. This may take some time.
All_Processes::CalculateTotalXSec for 2_3_P_e-__e-d_db
In Single_Process::CalculateTotalXSec(./Results) for 2_3_P_e-__e-d_db
Starting the calculation. Lean back and enjoy ... .

```

```

0.0600266 pb +- ( 0.00212335 pb = 3.53735 % ), n=20000 .
0.05772 pb +- ( 0.00111474 pb = 1.93129 % ), n=40000 .
0.0566867 pb +- ( 0.000763704 pb = 1.34724 % ), n=60000 .
0.0564573 pb +- ( 0.0005868 pb = 1.03937 % ), n=80000 .
0.0562563 pb +- ( 0.000480023 pb = 0.853279 % ), n=100000 .
2_3_P_e-___e-d_db : 0.0562563 pb +/- 0.853279 %, exp. eff: 0.626838 %.
Store result : xs for 2_3_P_e-___e-d_db : 0.0562563 pb +/- 0.853279%,
max : 2.30485e-08
Calculating the hard cross sections has been successful.
=====

```

```

Sherpa will start event generation now : 2 events
=====

```

This is followed by the output of the two events. Note that the results of the integration have been stored in the file `./Results/MC_2_3_P_e-___e-d_db4`.

### 3.2.4 Third run

In a further run with the same setup, the integration results are read in; the output then looks like:

```

Welcome to Sherpa,username. Initialization of framework underway.

```

```

----- Event generation run with SHERPA started -----
-----
..... | +
..... || | + +
..... | | / +
..... _ , | ... || +| + +
..... _ , \ | ... || / +| + +
..... ( \ \ ... || | + + \ +
..... ( \ -/ ... || + | +
..... <S /())~##### + /\ +
..... (!H (~))~##### #/ + + | +
..... (!E (~))~##### /|/ + +
..... (!R (~))~##### ||| + + +
..... (!P (~))~##### /| + + +
..... (!A> (~)##### # + + +
..... ~(! ,##### \ + + + +
..... '~~~~QQQQDb // | + + + + +
..... IDDDDP|| \ + + + + +
..... IDDDI|| \ +
..... IHD HD|| \ + + + + + + +
..... IHD ##| :-~) + \ +
..... IHI ## / / + + + + \ +
..... IHI / / / + + + + +
..... ## | | / / + + + + / +
..... /TT\ ... ##/ /// / + + + + + + / +
..... /TTT/T\ ... /TT\/// / + + + + + + / \ +
version 1.0.4 ...../TTT/TTTT\...|TT/T\\ / + + + + /
-----

```

```

SHERPA version 1.0.4.

```

```

AUTHORS: Tanju Gleisberg, Stefan Hoeche, Frank Krauss,
         Andreas Schaelicke, Steffen Schumann, Jan Winter

```

<sup>4</sup>Note that the directory `Results` has to be created by the user himself before running `Sherpa`. Furthermore, the directory has to be emptied whenever a parameter, such as the c.m. energy, has been changed so that the cross section needs to be recalculated.

This program uses a lot of genuine and original research work by other people. Users are encouraged to refer to the various original publications.

Users are kindly asked to refer to the documentation published under JHEP 0402 (2004) 056.

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for news, bugreports, updates and new releases.

```
-----
Initialize the Standard Model from ./ / Model.dat
Initialized the beams Laser_Backscattering*Monochromatic
Initialized the ISR : (None)*(SF)
Amegic::InitializeProcesses :
  Process initialization started; new libraries may be created.
VP2_3_8_7_100_32_13_0 loaded.
  No new libraries have been created.
Initialized the Matrix_Element_Handler for the hard processes :Amegic
Initialized the Shower_Handler.
Initialized the Fragmentation_Handler.
Initialized the Beam_Remnant_Handler.
=====
Start calculating the hard cross sections. This may take some time.
All_Processes::CalculateTotalXSec for 2_3_P_e-__e-d_db
In Single_Process::CalculateTotalXSec(./Results) for 2_3_P_e-__e-d_db
Read in channels from directory : ./Results/MC_2_3_P_e-__e-d_db
Random::ReadInStatus from ./Results/MC_2_3_P_e-__e-d_db/Random index 0
2_3_P_e-__e-d_db : 0.0562564 pb +/- 0.853277 %, exp. eff: 0.626839 %.
Calculating the hard cross sections has been successful.
=====
Sherpa will start event generation now : 2 events
=====
```

This is again followed by the event output.

### 3.2.5 Event output

The event output is listed as:

```
Blob [0]( 9, Bunch           , from Beam 1, 1 -> 1 @ (0,0,0)
Incoming particles :
[X] 2 e-              13 (  -> 9) [( 2.5000e+02, 0.0000e+00, 0.0000e+00,-2.5000e+02), 2.6113e-07] (0,0)
Outgoing particles :
[X] 2 e-              9 ( 9 -> 7) [( 2.5000e+02, 0.0000e+00, 0.0000e+00,-2.5000e+02), 2.6113e-07] (0,0)

Blob [0]( 8, Bunch           , from Beam 0, 1 -> 2 @ (0,0,0)
Incoming particles :
[X] 2 e-              11 (  -> 8) [( 2.5000e+02, 0.0000e+00, 0.0000e+00, 2.5000e+02), 2.6113e-07] (0,0)
Outgoing particles :
[G] 2 photon          1 ( 8 -> 5) [( 1.8987e+02, 0.0000e+00, 0.0000e+00, 1.8987e+02), 7.2760e-12] (0,0)
[X] 1 e-              12 ( 8 -> ) [( 6.0133e+01, 0.0000e+00, 0.0000e+00, 6.0133e+01), 6.2805e-08] (0,0)

Blob [2]( 7, Beam           , from Beam 1, 1 -> 2 @ (0,0,0)
Incoming particles :
[X] 2 e-              9 ( 9 -> 7) [( 2.5000e+02, 0.0000e+00, 0.0000e+00,-2.5000e+02), 2.6113e-07] (0,0)
Outgoing particles :
[G] 2 e-              2 ( 7 -> 6) [( 2.2709e+01, 0.0000e+00, 0.0000e+00,-2.2709e+01), 7.9581e-13] (0,0)
[F] 1 photon          10 ( 7 -> ) [( 2.2729e+02, 0.0000e+00, 0.0000e+00,-2.2729e+02), 2.3739e-07] (0,0)

Blob [2]( 6, IS Shower      , from Beam 1, 1 -> 1 @ (0,0,0)
Incoming particles :
```

```

[G] 2 e-                2 ( 7 -> 6) [( 2.2709e+01, 0.0000e+00, 0.0000e+00,-2.2709e+01), 7.9581e-13] (0,0)
Outgoing particles :
[G] 2 e-                2 ( 6 -> 0) [( 2.2709e+01, 0.0000e+00, 0.0000e+00,-2.2709e+01), 7.9581e-13] (0,0)

Blob [2]( 5, IS Shower      , from Beam 0, 1 -> 1 @ (0,0,0,0)
Incoming particles :
[G] 2 photon           1 ( 8 -> 5) [( 1.8987e+02, 0.0000e+00, 0.0000e+00, 1.8987e+02), 7.2760e-12] (0,0)
Outgoing particles :
[G] 2 photon           1 ( 5 -> 0) [( 1.8987e+02, 0.0000e+00, 0.0000e+00, 1.8987e+02), 7.2760e-12] (0,0)

Blob [0]( 0, Signal Process , 2 -> 3 @ (0,0,0,0)
Incoming particles :
[G] 2 photon           1 ( 5 -> 0) [( 1.8987e+02, 0.0000e+00, 0.0000e+00, 1.8987e+02), 7.2760e-12] (0,0)
[G] 2 e-               2 ( 6 -> 0) [( 2.2709e+01, 0.0000e+00, 0.0000e+00,-2.2709e+01), 7.9581e-13] (0,0)
Outgoing particles :
[H] 2 e-               2 ( 0 -> 1) [( 3.1462e+01,-1.2903e+01,-2.4982e+01, 1.4115e+01), 1.1369e-13] (0,0)
[H] 2 d                3 ( 0 -> 1) [( 6.7159e+01,-1.1165e+01,-3.2554e+01, 5.7671e+01), 1.8190e-12] (601,0)
[H] 2 anti-d           4 ( 0 -> 1) [( 1.1396e+02, 2.4069e+01, 5.7537e+01, 9.5373e+01),-3.6380e-12] (0,601)

Blob [0]( 1, ME PS Interface , 3 -> 3 @ (0,0,0,0)
Incoming particles :
[H] 2 e-               2 ( 0 -> 1) [( 3.1462e+01,-1.2903e+01,-2.4982e+01, 1.4115e+01), 1.1369e-13] (0,0)
[H] 2 d                3 ( 0 -> 1) [( 6.7159e+01,-1.1165e+01,-3.2554e+01, 5.7671e+01), 1.8190e-12] (601,0)
[H] 2 anti-d           4 ( 0 -> 1) [( 1.1396e+02, 2.4069e+01, 5.7537e+01, 9.5373e+01),-3.6380e-12] (0,601)
Outgoing particles :
[H] 1 e-               2 ( 1 -> 2) [( 3.1462e+01,-1.2903e+01,-2.4982e+01, 1.4115e+01), 2.6112e-07] (0,0)
[H] 1 d                3 ( 1 -> 3) [( 6.7159e+01,-1.1165e+01,-3.2554e+01, 5.7671e+01), 1.0000e-04] (601,0)
[H] 1 anti-d           4 ( 1 -> 4) [( 1.1396e+02, 2.4069e+01, 5.7537e+01, 9.5373e+01), 1.0000e-04] (0,601)

Blob [1]( 2, FS Shower      , 1 -> 1 @ (4.728e-17,-7.884e-07,-1.526e-06,8.624e-07)
Incoming particles :
[H] 1 e-               2 ( 1 -> 2) [( 3.1462e+01,-1.2903e+01,-2.4982e+01, 1.4115e+01), 2.6112e-07] (0,0)
Outgoing particles :
[H] 1 e-               3 ( 2 -> ) [( 3.1462e+01,-1.2903e+01,-2.4982e+01, 1.4115e+01), 2.6112e-07] (0,0)

Blob [1]( 3, FS Shower      , 1 -> 1 @ (1.475e-19,-4.276e-08,-1.247e-07,2.209e-07)
Incoming particles :
[H] 1 d                3 ( 1 -> 3) [( 6.7159e+01,-1.1165e+01,-3.2554e+01, 5.7671e+01), 1.0000e-04] (601,0)
Outgoing particles :
[H] 2 d                5 ( 3 -> 10) [( 6.7159e+01,-1.1165e+01,-3.2554e+01, 5.7671e+01), 1.0000e-04] (601,0)

Blob [1]( 4, FS Shower      , 1 -> 1 @ (4.69e-19,8.341e-09,1.994e-08,3.305e-08)
Incoming particles :
[H] 1 anti-d           4 ( 1 -> 4) [( 1.1396e+02, 2.4069e+01, 5.7537e+01, 9.5373e+01), 1.0000e-04] (0,601)
Outgoing particles :
[H] 2 anti-d           7 ( 4 -> 10) [( 1.1396e+02, 2.4069e+01, 5.7537e+01, 9.5373e+01), 1.0000e-04] (0,601)

Blob [0]( 10, Fragmentation , 2 -> 22 @ (2.209e-07,-4.276e-08,-1.247e-07,2.209e-07)
Incoming particles :
[H] 2 d                5 ( 3 -> 10) [( 6.7159e+01,-1.1165e+01,-3.2554e+01, 5.7671e+01), 1.0000e-04] (601,0)
[H] 2 anti-d           7 ( 4 -> 10) [( 1.1396e+02, 2.4069e+01, 5.7537e+01, 9.5373e+01), 1.0000e-04] (0,601)
Outgoing particles :
[p] 1 rho(770)-        14 ( 10 -> 11) [( 1.8611e+01,-3.0886e+00,-9.0070e+00, 1.5981e+01), 2.9920e-01] (0,0)
[p] 1 rho(770)+        19 ( 10 -> 13) [( 3.7389e+01,-6.2098e+00,-1.8108e+01, 3.2107e+01), 6.8146e-01] (0,0)
[P] 1 pi-               24 ( 10 -> ) [( 2.7633e-01, 2.1927e-02, 4.3989e-02, 2.3337e-01), 1.9480e-02] (0,0)
[p] 1 omega(782)       25 ( 10 -> 15) [( 4.4363e+00,-6.8953e-01,-2.0246e+00, 3.8067e+00), 6.1490e-01] (0,0)
[p] 1 pi               31 ( 10 -> 17) [( 6.4867e-01,-9.7998e-02,-2.8863e-01, 5.5646e-01), 1.8220e-02] (0,0)
[p] 1 rho(770)+        34 ( 10 -> 18) [( 1.9455e+00,-1.6821e-01,-5.3606e-01, 1.6617e+00), 7.0817e-01] (0,0)
[p] 1 rho(770)-        39 ( 10 -> 20) [( 1.5994e+00,-7.3002e-02,-2.6954e-01, 1.3623e+00), 6.2422e-01] (0,0)
[p] 1 rho(770)+        44 ( 10 -> 22) [( 2.8546e+00, 4.9522e-01, 1.1589e+00, 2.3953e+00), 8.2268e-01] (0,0)
[p] 1 omega(782)       49 ( 10 -> 24) [( 1.4865e+00,-1.8575e-02,-1.2133e-01, 1.2633e+00), 5.9871e-01] (0,0)
[P] 1 pi-               55 ( 10 -> ) [( 1.3608e+00, 2.8256e-01, 6.7434e-01, 1.1392e+00), 1.9480e-02] (0,0)
[p] 1 omega(782)       56 ( 10 -> 26) [( 1.4989e+00,-1.6950e-02,-1.1767e-01, 1.2737e+00), 6.1016e-01] (0,0)
[P] 1 pi+               62 ( 10 -> ) [( 2.9651e-01,-1.8999e-02,-6.4298e-02, 2.5287e-01), 1.9480e-02] (0,0)
[p] 1 rho(770)         63 ( 10 -> 28) [( 2.3606e+00, 3.9091e-01, 9.0959e-01, 1.9818e+00), 6.6435e-01] (0,0)
[p] 1 rho(770)-        66 ( 10 -> 29) [( 1.2635e+00, 1.4924e-01, 3.2956e-01, 1.0643e+00), 3.3295e-01] (0,0)
[p] 1 rho(770)+        71 ( 10 -> 31) [( 1.0328e+00, 3.4132e-01, 7.9557e-01, 1.7064e+00), 4.7100e-01] (0,0)
[p] 1 rho(770)-        76 ( 10 -> 33) [( 2.1826e+00, 3.6903e-01, 8.6092e-01, 1.8320e+00), 5.3013e-01] (0,0)
[p] 1 rho(770)+        81 ( 10 -> 35) [( 1.7933e+01, 3.7766e+00, 9.0255e+00, 1.5010e+01), 5.9085e-01] (0,0)
[P] 1 pi-               86 ( 10 -> ) [( 1.6085e+00, 3.3564e-01, 8.0142e-01, 1.3465e+00), 1.9480e-02] (0,0)
[p] 1 rho(770)+        87 ( 10 -> 37) [( 9.8078e+00, 2.0470e+00, 4.8877e+00, 8.2099e+00), 7.1071e-01] (0,0)
[p] 1 K                 92 ( 10 -> 39) [( 2.1790e+01, 4.5984e+00, 1.0992e+01, 1.8237e+01), 2.4768e-01] (0,0)
[P] 1 K-                94 ( 10 -> ) [( 3.7229e+00, 7.6396e-01, 1.8211e+00, 3.1172e+00), 2.4364e-01] (0,0)
[p] 1 rho(770)+        95 ( 10 -> 40) [( 4.6009e+01, 9.7132e+00, 2.3219e+01, 3.8506e+01), 5.8492e-01] (0,0)

```

```

Blob [1]( 11, Hadron Decay      , 1 -> 2 @ (2.209e-07,-4.276e-08,-1.247e-07,2.209e-07)
Incoming particles :
[p] 1 rho(770)-                14 ( 10 -> 11) [( 1.8611e+01,-3.0886e+00,-9.0070e+00, 1.5981e+01), 2.9920e-01] (0,0)
Outgoing particles :
[D] 1 pi-                      15 ( 11 ->  ) [( 8.1576e+00,-1.3907e+00,-4.1456e+00, 6.8852e+00), 1.9480e-02] (0,0)
[d] 1 pi                       16 ( 11 -> 12) [( 1.0453e+01,-1.6978e+00,-4.8614e+00, 9.0958e+00), 1.8220e-02] (0,0)

Blob [1]( 12, Hadron Decay      , 1 -> 2 @ (0.006005,-0.0009753,-0.002793,0.005225)
Incoming particles :
[d] 1 pi                       16 ( 11 -> 12) [( 1.0453e+01,-1.6978e+00,-4.8614e+00, 9.0958e+00), 1.8220e-02] (0,0)
Outgoing particles :
[D] 1 photon                   17 ( 12 ->  ) [( 9.2427e+00,-1.4891e+00,-4.3362e+00, 8.0254e+00),-2.8422e-14] (0,0)
[D] 1 photon                   18 ( 12 ->  ) [( 1.2104e+00,-2.0873e-01,-5.2517e-01, 1.0704e+00),-6.6613e-16] (0,0)

Blob [1]( 13, Hadron Decay      , 1 -> 2 @ (2.209e-07,-4.276e-08,-1.247e-07,2.209e-07)
Incoming particles :
[p] 1 rho(770)+                19 ( 10 -> 13) [( 3.7389e+01,-6.2098e+00,-1.8108e+01, 3.2107e+01), 6.8146e-01] (0,0)
Outgoing particles :
[D] 1 pi+                      20 ( 13 ->  ) [( 1.1546e+01,-2.1924e+00,-5.3756e+00, 9.9792e+00), 1.9480e-02] (0,0)
[d] 1 pi                       21 ( 13 -> 14) [( 2.5843e+01,-4.0174e+00,-1.2732e+01, 2.2127e+01), 1.8220e-02] (0,0)

Blob [1]( 14, Hadron Decay      , 1 -> 2 @ (0.003277,-0.0005094,-0.001615,0.002806)
Incoming particles :
[d] 1 pi                       21 ( 13 -> 14) [( 2.5843e+01,-4.0174e+00,-1.2732e+01, 2.2127e+01), 1.8220e-02] (0,0)
Outgoing particles :
[D] 1 photon                   22 ( 14 ->  ) [( 4.7734e+00,-7.0871e-01,-2.3889e+00, 4.0713e+00),-1.0658e-14] (0,0)
[D] 1 photon                   23 ( 14 ->  ) [( 2.1070e+01,-3.3087e+00,-1.0343e+01, 1.8056e+01),-1.1369e-13] (0,0)

```

Some more hadron decays are following. The event is finished with the statement:

```

-----
Sherpa : Passed 1 events.
-----

```

At the same time this also indicates the start of a new event. Finally, the run ends up with a little statistics output:

```

In Event_Handler::Finish : Summarizing the run may take some time.
=====
Sherpa finished its simulation run with 0 errors.
=====
Statistics Sudakov Rejection
3 : weight=1 +- -0 (-0)
Time: 0.21 s (clocks=21)
(User: 0.13 s ,System: 0.01 s ,Children User: 0.01 s ,Children System: 0.01)

```

### 3.3 Default setup: $W$ production at the Tevatron Run I

Since SHERPA is mainly designed for the simulation of hadron collisions, a default setup for the  $W$  boson production at the Tevatron Run I is also part of the distribution. This example should illustrate the usage of SHERPA in the framework of combining matrix elements and the parton shower [23, 24]. The matrix element processes included in this setup are the following:

$$\begin{aligned}
p\bar{p} &\rightarrow jet\ jet \rightarrow e^-\bar{\nu}_e, \\
p\bar{p} &\rightarrow jet\ jet \rightarrow e^-\bar{\nu}_e + jet, \\
p\bar{p} &\rightarrow jet\ jet \rightarrow e^-\bar{\nu}_e + jet\ jet.
\end{aligned}$$

Employing this setup SHERPA should be able to describe, for instance, the  $p_\perp$  distribution of the  $W$  boson as measured by the D0 and CDF collaborations at Tevatron Run I.

For more information about the merging of matrix elements and parton showers in the SHERPA framework, cf. Sec. 5.1. In any case please make sure that

- a jet finder with an appropriate  $y_{cut}$  has been specified (here 20 GeV),

- the Sudakov weights have been enabled (SUDAKOV\_WEIGHT=1) and
- both showers, initial **and** final state shower, have been turned on.

In the output mode “errors” (OUTPUT=0) the output is very sparse. Then, the following output should be obtained for the initialization run:

Welcome to Sherpa,*username*. Initialization of framework underway.

```
----- Event generation run with SHERPA started ..... -----
Amegic::InitializeProcesses :
  Process initialization started; new libraries may be created.
Amegic::InitializeProcesses :
  Some new libraries were created and have to be compiled and linked.
  Type "./makelibs" and rerun.
```

For the cross section integration and the event generation the resulting output should look as follows: Welcome to Sherpa,*username*. Initialization of framework underway.

```
----- Event generation run with SHERPA started ..... -----
Amegic::InitializeProcesses :
  Process initialization started; new libraries may be created.
  No new libraries have been created.
Obs : PT for e- : Range : 0 ... 200 in 100 bins, extra : Lin
Obs : PT for anti-nu_e : Range : 0 ... 200 in 100 bins, extra : Lin
Obs : PT2 for e- anti-nu_e : Range : 0 ... 210 in 84 bins, extra : Lin
Obs : Eta2 for e- anti-nu_e : Range : -5 ... 5 in 50 bins, extra : Lin
=====
Start calculating the hard cross sections. This may take some time.
Calculating the hard cross sections has been successful.
=====
Sherpa will start event generation now : 10000 events
=====
Sherpa finished its simulation run with 0 errors.
=====
```

## 4 Specification of the parameters

All over SHERPA, particles are defined by a particle code, which is in most cases identical to the one proposed by the PDG. These codes are displayed for the elementary particles in `Particle.dat` and for the hadrons in `Hadron.dat`, respectively. In both cases, anti-particles are characterised by an extra minus sign in front of their code. (So a final state  $\mu^-$  has code 13, while a  $\mu^+$  has -13).

There are two general ways of modifying the parameters of SHERPA:

1. Through data files:  
By default they are located in the `./SHERPA-1.0/Run` directory and have the form `Filename.dat`.
2. Through command line input:  
The syntax is `./Sherpa KEYWORD1=value1 KEYWORD2=value2 ...`. To change, e.g., the path to the data files the command line would be `./Sherpa PATH=pathname`, where `pathname` is the path relative to the `./SHERPA-1.0/Run` directory.

### 4.1 Particle data

#### 4.1.1 Particle.dat

In `Particle.dat` all elementary particles available throughout SHERPA are defined. The head of this file and a typical entry, here the *d* quark, looks like:

kf	Mass	Width	3*e	Y	SU(3)	2*Spin	maj	on	stbl	m_on	Name
1	.01	.0	-1	-1	1	1	0	1	1	0	d

Here `kf` – the particle code – labels the internal number characterising the flavour within `SHERPA`, `Mass` is the (current) mass of the particle in GeV. The width of the particle is given by the parameter `Width`. The `3*e` column determines three times the electric charge of the particle, the sign convention is such that the electron has charge  $3 * e = -3$ . The weak hypercharge is given by `Y`. The switch `SU(3)` determines if the particle is strongly interacting (1) or not (0); similarly, the flag `maj` accounts for the majorana character of a particle. Through the switch `on` the particle can be excluded in the processes to be considered. Note that this switch should be used with extreme caution. The `stbl` flag is not used at the moment. In the near future it will steer the way of how `SHERPA` defines the width of particles and their decays. By `m_on` the kinematical mass of the particles can be set to zero within the matrix element generation and evaluation. This kinematical mass is completely decoupled from possible Yukawa couplings. Note that the particle masses and widths of SUSY particles will, by default, be overwritten by those calculated by the spectrum generator program, `Isasusy 7.67`. The last entry of the row actually defines the name of the particle.

#### 4.1.2 Hadron.dat

This file specifying the hadrons of `SHERPA` is in analogy to the file `Particle.dat`. All baryons and mesons that may appear as intermediate or final state particles within events produced by `SHERPA` are listed here. Using the Lund fragmentation and the associated hadron decay package, the only entries of importance are the `kf` codes (according to the PDG numbering scheme) and the names of the hadrons. All other parameters have no influence at present.

## 4.2 Data files

Switches and parameters for the general steering of the program are – by default – found in the file `Run.dat`. In particular, this includes the names (and paths) of the other input data files. In most cases the syntax to specify a parameter in these data files is

KEYWORD = value ,

where spaces are of no consequences. Exclamation marks indicate the begin of a comment line. However, it should be stressed that the read-in devices of the different `SHERPA` modules are case sensitive. If a parameter or switch has not been specified, a default parameter is given.

In the following, the data files and the most important parameters and switches are explained.

#### 4.2.1 Run.dat

As mentioned before, general switches and parameters as well as the names for the additional input files are defined in `Run.dat`. The corresponding file of the default setup is displayed in Fig. 3, see the appendix A. The following parameters can be specified:

1. The number of events is set through `EVENTS`. By default 0 events are generated.
2. The numerical accuracy can be given, e.g. for comparing two numbers.
3. The output level can be specified through `OUTPUT`. By default the output level is 0. Different levels can be overlaid, simply by adding the level number. For their meaning please cf. Table 3. Also, coloured output can be enabled by the switch `PRETTY_PRINT`; by default it is switched off.



0	all error messages, most general run information
1	event output
2	more detailed information about what is going on during the run
4	useful information in order to track problems a user might encounter, i.e. to approximately identify the place/cause of problems

Table 3: The output levels in SHERPA.

4. If the user wishes to have full access to the generated SHERPA events, the following possibilities are provided.
  - If the user wishes to write out full events of the SHERPA format into a file, the variable `SHERPA_OUTPUT=filename` has to be specified. The `filename` will serve as the naming root of event files that have the form `filename#.evts`, where the hash mark stands for an increasing number. The event files contain 1000 events per file and information about the next file of the same run, i.e. in the last line of `sherpa_run0.evts` the next file, `sherpa_run1.evts` will be named.
  - However, if the user wishes to write out full events of the HEPEVT format into a file, the variable `HEPEVT_OUTPUT=filename` has to be specified. The file `filename` will be created and contain all events that have been generated throughout the run.
  - It is also possible to link a user program to `Sherpa`, so that the events can be read and/or analysed “on the flight”. Two configurations are supported. First, the user can access `Sherpa`’s internal `Blob_List`, which contains all necessary information about an event. Second, an interface to HepMC is provided as well <sup>5</sup>.
5. The running time of the code is given in user CPU seconds through `TIMEOUT`. This option is of some relevance when running SHERPA on a batch system. Since in many cases jobs are just terminated, this allows to interrupt a run, to store all relevant information and to restart it without any loss. This is particularly interesting when carrying out long integrations. Contrary, setting the `TIMEOUT` variable to `-1`, which is the default setting, translates into having no run time limitation at all.
6. The internal analysis can be switched on or off by setting the `ANALYSIS` switch to `1` or `0`, respectively. For detailed information, cf. Sec. 4.2.11.
7. A log file can be specified through `LOG_FILE` and is only created if using the output mode “tracking”. It then contains all information about the setup. In case that a `Sherpa` run crashes unexpectedly, it should be used as a part of a bug report.
8. A `BATCH_MODE` variable is given.
9. Different data files can be read in, their names and purposes should be self-explanatory. In the example file shown in Fig. 3 all data files necessary for the proper initialisation of the different modules are listed together with their default value.

#### 4.2.2 Beam.dat

In `Beam.dat`, cf. Fig. 4 for the corresponding file of the default setup, the following beam parameters are specified:

---

<sup>5</sup>In order to activate the interface, HepMC has to be linked to the main program, and the variable `HEPMC_OUTPUT` has to be defined.

option	comment
0	default, the full spectrum
1	the pure Compton component of the spectrum
2	the pure two photon component of the spectrum
3	the pure re-scattering component of the spectrum

Table 4: Different options available for the variable `LASER_MODE` in the file `Beam.dat` and their associated choices for the used components of the entire photon spectrum produced via laser backscattering.

1. The two incoming particles are specified according to their particle code by `BEAM_{1,2}`. For protons or (anti-)electrons the relevant codes are 2212 or 11, respectively. For photons the code is 22. The energies of the incoming beams are defined through `BEAM_ENERGY_{1,2}`. The specification of the beam particles and energies is mandatory. Also, polarised beams can be accounted for by specifying their polarisation degree by `BEAM_POL_{1,2}` in terms of the helicity leading to values in the range of  $-1$  to  $1$ .
2. Having specified the “collider particles” they can be translated into incoming particles (before ISR) through the application of a beam spectrum. The corresponding keyword is `BEAM_SPECTRUM_{1,2}`. Currently the following options are provided:
  - `Monochromatic` : The beam energy is not changed.
  - `Simple_Compton` : This is a simple Laser backscattering spectrum, which is often used in theoretical analyses.
  - `Laser_Backscattering` : This is a realistic spectrum according to the CompAZ parametrisation.
  - `Spectrum_Reader` : Then a user defined spectrum can be specified by `SPECTRUM_FILE_{1,2}`.
3. The minimal and maximal fraction of the total energy  $s$  – the sum of the two beam energies squared – carried by the particles after the beam treatment are determined by the parameters `BEAM_SMIN` and `BEAM_SMAX`. The latter is subject to eventual further reduction due to the form of the chosen spectrum. The laser backscattering mode, for instance, has a limited maximal energy fraction that can be carried by the photon.
4. The remaining parameters deal with the setup of the laser used for the backscattering. The energy and circular polarisation of the lasers is given by `E_LASER_{1,2}` and `P_LASER_{1,2}`, respectively. For the latter, the range of allowed values is again  $-1$  to  $+1$ . The keyword `LASER_MODE` denotes the different components of the laser backscattering photon spectrum. The default value is 0 (all components). The full set of options is summarized in Tab. 4. The spectra and polarisation degrees for photons generated in laser backscattering via `Laser_Backscattering` and `Simple_Compton` are shown in Fig. 1. By changing the switch `LASER_NONLINEARITY` non-linear Laser effects can be taken into account or not. Note that this option is valid only for the full laser backscattering spectrum.

In addition, the `Beam.dat` file of the default setup allows for the specification of the following parameters for the beam remnant handling: the mean value of the intrinsic  $k_{\perp}$  and its variation through the keywords `K_PERP_MEAN_{1,2}` and `K_PERP_SIGMA_{1,2}`. Both values are given in GeV.

### 4.2.3 ISR.dat

In `ISR.dat`, cf. Fig. 5 for the corresponding file of the default setup, the following parameters for the initial state radiation and PDFs are specified:

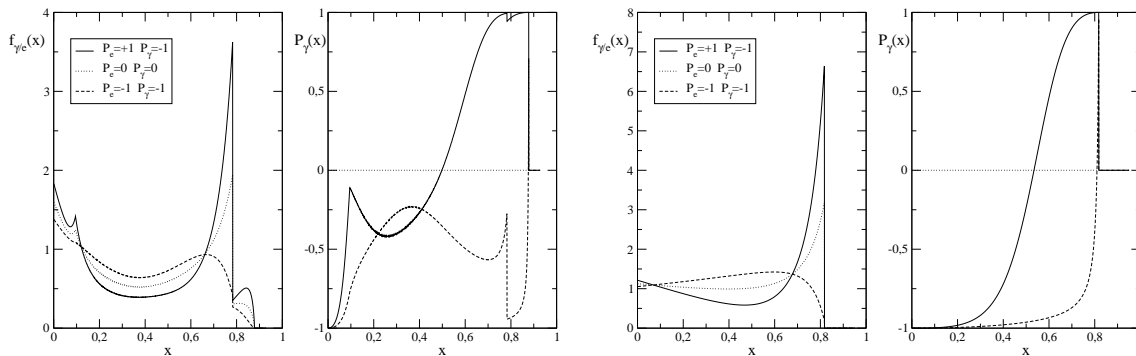


Figure 1: Laser backscattering spectra and degree of circular polarisation for backscattered photons according to the CompAZ parameterisation (left) and to the simple Compton spectrum (right). Different combinations of electron and laser photon polarisation are shown. The energy of the electron beam and the laser are  $E_e = 250$  GeV and  $\omega_\gamma = 1.17 \cdot 10^{-9}$  GeV, respectively ( $x_e = 3.61$ ).

1. After the beam spectra have been applied, the two incoming particles are specified by `BUNCH_{1,2}` according to their particle code. For (anti-)electrons or (anti-)protons the relevant codes are `(-)11` or `(-)2212`, respectively. For photons the code is given through `22`. It is important to note that the beam spectra and the bunch particles have to fit, otherwise `SHERPA` will terminate its run with a corresponding error message during the initialisation phase. If the incoming particle 1,2 is a proton, the `ISR_{1,2}` switch has to be set to `On`, allowing for an internal parton structure. For photons, `ISR` and hence an internal parton structure can be switched on or off. For leptons this switch steers the inclusion of a structure function, which is further specified through the switches `ISR_E_ORDER` and `ISR_E_SCHEME`. The former fixes the perturbative order in the fine structure constant  $\alpha$ , whereas the latter sets the way of including non-leading terms in the structure function. The default values for both switches are given by 1 and 2, respectively. Possible options for the last switch are 0 (“mixed” choice), 1 (“eta” choice), or 2 (“beta” choice).
2. For the case of protons a number of PDFs and different options are supported:
  - an interface to the Fortran `CTEQ6` set of PDFs with their original grid,
  - an interface to the C++ version of `MRST99`,
  - and the `LHAPDF` version 1 interface, which provides access to a multitude of PDFs.

The variable `PDF_SET` determines which PDF is actually used, while `PDF_GRID_PATH` decides where to look for the required grid files. `PDF_VERSION` finally selects the specific tuning out of the different possibilities provided by the authors of the respective set. The three available options for `PDF_GRID_PATH` and the corresponding PDFs are listed in Tab. 5.

3. The minimal and maximal fraction of the total energy  $s$  carried by the particles after the `ISR` treatment are determined by the parameters `ISR_SMIN` and `ISR_SMAX`. The default values are 0 and 1, respectively.

#### 4.2.4 Model.dat

The general model settings are displayed in Fig. 6. They have the following meaning:

1. The physics model used in the `SHERPA` run is defined through the variable `MODEL`, which can have one of the three self-explanatory values `SM`, `MSSM` or `ADD`, its default value is `SM`. In case the `MSSM`

PDF_GRID_PATH	PDF_SET
CTEQ6Grid	cteq6m, cteq6d, cteq6l, cteq6ll
MRST99Grid	MRST99
PDFsets	Alekhin_100, Alekhin_1000, Botje_100, Botje_1000, Fermi2002_100, Fermi2002_1000, MRST2001, MRST98, cteq6, cteq6l, cteq6ll

Table 5: The proton PDFs available within SHERPA and their associated settings of the corresponding parameters PDF\_GRID\_PATH and PDF\_SET. By choosing one of the PDFs out of the available PDF\_SET options the value of PDF\_GRID\_PATH has to be set accordingly.

is selected, the variable `GENERATOR_ON` must have the value 1. This guarantees that `Isasusy 7.67` is called through its interface and that it generates a valid MSSM spectrum out of some high scale parameters defined below, see Fig. 9.

2. SHERPA also provides different schemes to define the parameters of the electroweak sector. The scheme can be set by `EW_SCHEME`. The default value of this parameter is 0. The different schemes correspond to different choices of what is a fixed and what is a flexible physics parameters:

- Case 0 : All EW parameters are explicitly given.  
Here  $M_W$ ,  $M_Z$  and  $M_H$  are taken from `Particle.dat`, and the parameters `1/ALPHAQED(0)`, `SIN2THETA_W`, `VEV` and `LAMBDA` have to be specified as well.
- Case 1 : All EW parameters are calculated out of  $M_W$ ,  $M_Z$ ,  $M_H$  and `1/ALPHAQED(0)`. The first three values are fixed in `Particle.dat`.
- Case 2 : All EW parameters are calculated out of `1/ALPHAQED(0)`, `SIN2THETA_W`, `VEV` and  $M_H$ , whereas  $M_H$  again is given in `Particle.dat`.

The SM parameters are defined through the settings, which are exhibited in Fig. 7. The parameters for physics beyond the SM are defined by the settings exhibited in the next figure, Fig. 9. Most of the keywords are self-explanatory, however, some comments are in order.

1. As already stated above, SHERPA provides an interface to `Isasusy 7.67` for the calculation of MSSM particle spectra and decay widths. It is automatically selected with the choice MSSM for the `MODEL` variable and `GENERATOR_ON = 1`. The only inputs for the MSSM are a SUSY breaking mechanism via `SUSY_SCENARIO` and the corresponding high scale input parameters.

The available options for `SUSY_SCENARIO` and the parameters that have to be accordingly set read:

- `SUSY_SCENARIO = mSUGRA` or `SUGRA_with_enforced_unification`
  - `M0, M12, TAN(BETA), A0, SIGN(MU)`
- `SUSY_SCENARIO = AMSB`
  - `M0, M32, TAN(BETA), A0, SIGN(MU)`
- `SUSY_SCENARIO = mGMSB`
  - `MESSANGER_SCALE, LAMBDA_M, TAN(BETA), GRAVITINO_RATIO, SIGN(MU), NUMBER_MESSENGERS`
- `SUSY_SCENARIO = non-minimal_GMSB`

- MESSENGER\_SCALE, LAMBDA\_M, TAN(BETA), GRAVITINO\_RATIO, GAUGINO\_RATIO, DELTA\_M(Hu), DELTA\_M(Hd), DELTA\_M(Y), N5(U1), N5(SU2), N5(SU3), SIGN(MU), NUMBER\_MESSENGERS
- SUSY\_SCENARIO = non-minimal\_SUGRA
  - M0, M12, TAN(BETA), A0, M(U1)\_GUT, M(SU2)\_GUT, M(SU3)\_GUT, M(e1R)\_GUT, M(l1)\_GUT, M(u1R)\_GUT, M(d1R)\_GUT, M(q1)\_GUT, M(e2R)\_GUT, M(l2)\_GUT, M(u2R)\_GUT, M(d2R)\_GUT, M(q2)\_GUT, M(e3R)\_GUT, M(l3)\_GUT, M(u3R)\_GUT, M(d3R)\_GUT, M(q3)\_GUT, A(tau)\_GUT, A(b)\_GUT, A(t)\_GUT, H(d)\_GUT, H(u)\_GUT, SCALE(SUSY), SIGN(MU)

For the specific meaning of these parameters the reader is referred to the corresponding publication of *Isajet*. It should be noted that for all scenarios the value of the  $t$  quark mass is rather fixed to the value of the parameter `Yukawa.t` than to the value provided in `Particle.dat`.

2. The number of parameters necessary to specify an ADD model is rather small: the variable `N_ED` fixes the number of extra dimension, which should be present. Although its nature is rather to be constant than variable, the used Newtonian constant can be changed. Per default its value is set to the PDG value. The most important parameter of any ADD model is the size of the string scale  $M_S$  denoted by the parameter `M_S`. The value of `KK_CONVENTION` allows to change between three widely used conventions for the definition of  $M_S$  and the way of summing internal Kaluza-Klein propagators. For details of the implementation, the reader is referred to [25].

#### 4.2.5 ME.dat

The `ME.dat` file steers the general settings for matrix element generation. First of all, by setting `ME_SIGNAL_GENERATOR`, the user can choose between `AMEGIC++` or the simple  $2 \rightarrow 2$  cross sections made available through the `EXTRA_XS` package. For both, `SHERPA` provides the option to generate either weighted or unweighted events after the integration has taken place. For unweighted events it seems a priori not so important to have the total cross sections. Nevertheless, the events of different processes are mixed according to the total cross sections after the cuts have been applied. Running the integration for some time guarantees that the multi-channel integrator has been trained such that events with large weight are produced more often. Through the variable `SIGNAL_MODEL` a subset of interactions out of a physical model can be chosen. However, in order to not exclude diagrams unintentionally due to missing interactions, this variable should be equal to the variable `MODEL` in `Model.dat`.

Additionally, different scale choices relevant at different stages of process integration and event generation are made available. First of all, gauge and Yukawa couplings in the matrix element can be set through `COUPLING_SCHEME` and `YUKAWA_MASSES`. It should be stressed that this setting occurs on the level of vertices. It is permanent and independent of what is suggested by the keyword “Running”. In particular, the `COUPLING_SCHEME = Fixed` refers to using the `ALPHAS(default)` and `1/ALPHAQED(default)` values given in `Model.dat` for the respective coupling. In contrast, when using the `COUPLING_SCHEME = Running` the couplings are evaluated at the c.m. scale of the incoming beams starting the evolution at `ALPHAS(MZ)` and `1/ALPHAQED(0)`. On top of that the c.m. scale can be modified by setting the `COUPLING_SCALE_FACTOR` different from 1. Similarly, for the Yukawa couplings, the options “Running” and “Fixed” correspond to the c.m. energy and the pole mass of the considered particle. The keywords are `YUKAWA_MASSES` and `YUKAWA_MASSES_FACTOR`. During the calculation of the matrix elements, the renormalisation scale for the strong coupling constant and the factorisation scale can be modified. `SCALE_SCHEME` selects the scale definition for both – again a pre-factor is available through `SCALE_FACTOR`. A fixed, user-defined scale squared can be defined through the keyword `FIXED_SCALE`. The `KFACTOR_SCHEME` switches on and off the influence of the (eventually modified) renormalisation scale on  $\alpha_s$ , provided that `COUPLING_SCHEME` is set to “Running”.

The available scale schemes are listed in Table 6.

setting	$Q^2$
default	$\hat{s}$
1	$s_0 = \text{fixed scale}$
2	$4\hat{s}\hat{t}\hat{u}/(\hat{s}^2 + \hat{t}^2 + \hat{u}^2)$ for $2 \rightarrow 2$ processes
	$\sum_i \{p_{\perp,i}^2\}$ else
3	$\text{Min}\{p_{\perp,i}^2\}$

Table 6: Available scale schemes within SHERPA. Note that for the transverse momenta  $i$  runs over all outgoing particles.

The variable SUDAKOV\_WEIGHT is responsible for preparing the matrix elements for combining with the parton shower, cf. Sec. 5.1.

#### 4.2.6 Processes.dat

In `Processes.dat` the process(es) to be evaluated by the matrix element generator are defined. They also serve as seeds for the event generation. The admixture of different hard signal processes in the events is determined according to the respective total cross section after the cuts have been applied, times, possibly, Sudakov weights from the merging procedure with the parton showers. The particles are distributed according to the respective matrix elements, again, this can be reweighted with some Sudakov form factors. In setting up the processes it is necessary that the requested initial states are consistent with the settings in the file `ISR.dat`, otherwise SHERPA will terminate the run immediately. Therefore, elementary bunches like electrons have to be the initial state of the hard processes as well. For the case of proton bunches the initial states can be either quarks or gluons.

To characterise the initial and final states of the processes, the particle codes displayed in `Particle.dat` are needed. Besides elementary particles SHERPA allows for containers that contain different particles with similar properties, namely

- lepton (carrying number 90),
- neutrino (carrying number 91),
- fermion (carrying number 92),
- jet (carrying number 93),
- quark (carrying number 94).

These containers contain all massless particles of the denoted type and allow for a more efficient definition of initial and final states to be considered. The jet container consists of massless quarks (as defined by the mass value and/or the `mass_on` switch) and the gluon.

The syntax of calling a specific process is:

```
Process : 93 93 -> -11 12 93
Order electroweak : 2
Order strong : 1
End process
```

Here all processes of the kind  $jet\ jet \rightarrow e^+\bar{\nu}_e\ jet$  are initialised, leaving out contributions originating from the production of heavy quarks. The parameters `Order electroweak` and `Order strong` restrict the number of electroweak or strong couplings occurring in single Feynman diagrams. The default values are 99, meaning that all electroweak and strong contributions are taken into account. Additionally, scale choices and pre-factors can be defined on a process-by process base different from the global settings. The keywords look similar and have the same meaning:

- “Scale scheme : ”,
- “Scale factor : ”,
- “KFactor scheme : ”, and
- “Fixed scale : ”.

Examples for process files are given in Figs. 11 and 12.

#### 4.2.7 Selector.dat

SHERPA provides a number of pre-defined selectors to define kinematical cuts on external particles. Any selector is included through its keyword, followed by the particles it acts on, and by the minimal and maximal value of the variable to cut on. In `Selector.dat` particles are called by their code defined in `Particle.dat`. All available pre-defined selectors in SHERPA are listed in Table 7 together with possible applications. Of course there are selectors related to only one particle – therefore no second particle has

Keyword/Variable	Particle1	Particle2	Minimal value	Maximal value
Energy	22		10.	10000.
ET	22		10.	10000.
PT	22		10.	10000.
Rapidity	22		-2.5	2.5
PseudoRapidity	22		-2.5	2.5
Mass	1	-2	75.	85.
Angle	11	22	-0.995	0.995
BeamAngle	1	0	-0.98	0.98
JetFinder			0.01	1.
ConeFinder			0.4	

Table 7: All possible types of cuts exemplified.

to be specified. For the case of the `BeamAngle` selector particle 0 describes the first incoming particle. All angle selectors are defined in terms of the cosine of the angle between two particles. The thresholds for all energy and mass selectors have to be given in GeV. An example for a selector file is given in Fig. 13.

#### 4.2.8 Integration.dat

In `Integration.dat` the setup of the phase space integration is done. An example file is given in Fig. 14. The possible settings are:

1. The variable `ERROR` determines the maximal relative integration error (statistical error of the MC integration) to which a total cross section is evaluated. The parameter is also important for the generation of unweighted events, since before the actual event generation can start the phase space

has to be integrated as accurately as requested by the variable `ERROR`. However, the appropriate choice of the integration accuracy is clearly process and purpose dependent. For the case of extensive processes with many final state particles a very small value of this variable can be very time consuming. In most cases an adequate choice seems to be of the order of 0.01.

2. The variable `INTEGRATOR` determines which integration algorithm is used for the final state phase space integration, see Table 8. The default is the pure Rambo integrator, however, the standard

option	comment
0	pure Rambo
1	pure Sarge
2	Rambo + Sarge
3	Rambo + Multi-channel
4	pure Multi-channel
5	RamboKK

Table 8: The available integrators within `SHERPA` and their corresponding values of the variable `INTEGRATOR` to be set in `Integration.dat`.

choice should be option 4 namely the Multi-channel. Considering processes in the framework of the `ADD` model the integrator must be set to `RamboKK`. At the moment this is the only integrator in `SHERPA` that correctly accounts for the required sum over the tower of external real gravitons.

#### 4.2.9 Shower.dat

The parton shower settings are exhibited in Fig. 15. Most of the variables determine the details of the shower evolution. They should be changed with caution, since a wrong combination can lead to unphysical results. There is some hope to provide tuned values soon. In detail the various keywords relate to the following features:

1. The variable `SHOWER_GENERATOR` specifies the shower module, at the moment the only valid value is `Apacic`.
2. The main switches are `FSR_SHOWER` and `ISR_SHOWER`, which turn on and off the initial and final state shower, respectively. Note that it is not necessary to turn on the showers to calculate cross sections with `ISR`, for this purpose it is sufficient to turn on `ISR_1` and/or `ISR_2` in the `ISR.dat` file. Contrary, in case of event generation for `QCD` processes at hadron colliders it should be stressed that it is essential to have turned on both showers in order to obtain physical meaningful results.
3. The parton showers in the initial and final state terminate when no more parton can be emitted with a transverse momentum squared larger than the values given by `IS_PT2MIN` and `FS_PT2MIN`, respectively. The default choices are

$$p_{\perp}^2(\text{IS}) = 4\text{GeV}^2 \quad \text{and} \quad p_{\perp}^2(\text{FS}) = 1\text{GeV}^2.$$

#### 4.2.10 Fragmentation.dat

In `Fragmentation.dat` the parameters of the Lund string fragmentation are set. An example is given in Fig. 16, the meaning of the keywords is as follows:

1. The keyword `FRAGMENTATION`, default value `Lund`, steers whether fragmentation is switched on - it is off. At the moment, only `Lund` is available leading to hadronisation according to the Lund string model. In the long run, a modified version of the cluster fragmentation model [26] will be made available as well.



#### 4.2.11 Analysis.dat

**Sherpa** has a built-in framework, which is capable of carrying out simple analyses of the generated events. It is possible to restrict the analysis on single event phases, such as the level of the hard matrix element, the parton shower evolution or the hadronization or to join certain of these analyses into a single one. The main switch to enable the framework is the variable **ANALYSIS** which can be set in **Run.dat** or from the command line. There are two possible options, either **ANALYSIS = 1** or **ANALYSIS = 0** which correspond to the analysis framework being switched on and off respectively.

The results of the analysis are histograms, which are written to disk as text files. These files appear like

```
10 102 -0.221849 1.77815 0.004 0 100000
-0.221849 0
-0.201849 0.001
. .
. .
. .
-0.181849 0.0015
-0.161849 0.001
-0.141849 0.001
```

where the first line gives (in order of appearance) the type of the histogram, the number of bins, the lower and the upper edge of the histogram, the underflow and the overflow weight and the number of entries. The type of the histogram is **10** if the histogram is binned logarithmically and **0** if it is binned linearly. The remaining lines each give the lower edges of the bins and the corresponding entries.

By default, the analysis setup will be read from the file **Analysis.dat**. It is however possible to specify another filename by setting the variable **ANALYSIS\_DATA\_FILE** in **Run.dat** to the corresponding value. The syntax of the setup file is as follows

- First an event phase for the analysis must be specified through the keyword **ANALYSIS\_PHASE**. The possible phases are **ME**, **Showers** and **Hadrons**. To join the analyses for multiple phases, the corresponding values may be concatenated by a **+**. In this case no spaces are allowed between the single values, e.g. **ME+Showers+Hadrons**.
- An output directory for the analysis results must be given via **OUTPUT = <directory>**. If a directory with the corresponding name does not exist yet, **Sherpa** will create it if there are sufficient permissions on the selected medium.
- The next step is to specify cuts to be applied on the final state particle list. If any of these cuts is not passed the event enters the analysis as a null event. There are several possibilities to restrict the final state. In particular

```
11 1 -1
```

means that it must contain at least one and at most an arbitrary number of electrons (specified by the kf code **11** for electrons and the numbers **1** for the minimum and **-1** for the open maximum respectively). Similarly the line

```
11 10.0 -2.0 2.0
```

indicates that each electron must pass a cut on  $p_{\perp} \geq 10$  and a cut on  $-2 \leq \eta \leq 2$ . It is important for the correct setup of the analysis framework that in each number which corresponds to a **double** value there appears a point, e.g. **2.0**.

Another possibility is to use the Tevatron Run II  $K_T$  jet algorithm [28]. The setup reads

```
93 10.0 -4.5 4.5 0.7 1.
```

which means that on the relevant particles (i.e. all quarks and gluons in the case of an analysis on the matrix element or the shower level and all hadrons in the case of an analysis on the hadron level) the jet algorithm with  $D = 0.7$  is applied. From list of jets there are selected all those with  $p_{\perp} \geq 10$  and  $-4.5 \leq \eta \leq 4.5$ .

- Finally the observables have to be specified. There are basically two types, the one-particle and the two-particle observables. A setup of a one-particle observable may read like

```
PT 11 1. 150. 20 Log
```

which means that the  $\log p_{\perp}$  distribution of electrons is analysed within 20 bins and within a range of  $\log 1 \leq p_{\perp e} \leq \log 150$ . A setup for a two-particle observable looks like

```
Eta2 11 -12 -2. 2. 10 Lin
```

which means analysing the  $\eta$  distribution of  $e \bar{\nu}_e$  pairs within the range of  $-2 \dots 2$ . The possible one-particle observables are **E**, **ET**, **PT** and **Eta**. Two-particle observables are **PT2**, **Eta2** and **Mass**. As was the case for the cut setup it is important also for the observable specification that each value which does not correspond to an integer contains a point. At the end of the event generation run, there will be created a histogram output file for each observable. It resides in a directory with the name of the corresponding analysis phase which itself resides in the directory given by **ANALYSIS\_OUTPUT**. The filename is a concatenation of the observable name and the name of the particle for which the analysis has been carried out (or the names of both particles in the case of a two-particle observable) preceded by the default filename extension **.dat**.

- The end of an analysis setup is indicated by the statement **END\_ANALYSIS\_PHASE**.

Throughout the file comments are indicated by the character **%**. It is possible to specify multiple analyses in the setup file. These analyses may, e.g. contain different restrictions on the final state. To avoid confusions it is however necessary to specify different output directories for different analyses, since histograms that occurred twice will be overwritten otherwise.

### 4.3 Command lines

For the command lines option of specifying parameters, all keywords of all data files are available, which refer to parameters that can be specified through a structure like

```
KEYWORD=value .
```

In fact, for the command lines option it is crucial that no spaces separate the “=” mark and the keyword or value. In contrast, an arbitrary number of spaces is needed to separate the settings of different keywords/parameters/switches. If events written out by **SHERPA** in a previous run should be read in, e.g. for another analysis, the keyword is **EVTDATA** and the command looks like

```
./Sherpa EVTDATA=filename .
```

## 5 Selecting processes - merging matrix elements with parton showers

### 5.1 How the merging works

SHERPA's most prominent feature is the consistent merging of matrix elements at the tree-level and the parton shower, exact to (next-to) leading logarithmic order according to the algorithms proposed in [23, 24]. The key idea of this procedure is to separate the phase space for parton emission into a hard region of jet production accounted for by suitable matrix elements and the softer region of jet evolution covered by the parton shower. Then, extra weights are applied on the former and vetoes are applied on the latter region such that the overall dependence on the intersection cut is minimal. This merging proceeds in a fully automated way: for the user it is, in principle, sufficient to select some processes in `Processes.dat` and to switch on the parton shower(s) in the initial and final states.

The merging proceeds along the following steps:

1. The total cross sections for all processes are calculated or read-in by calling the method `CalculateTheHardProcesses()` of the `InitializationHandler`. This is done during the initialisation and preparation phase of SHERPA. It is important that the admixture of different processes is chosen with care; for inclusive processes, for instance, the number of extra jets in the processes must be continuous with “no gap”. Also, no extra one-particle cuts (such as cuts on  $E_{\perp}$ ,  $p_{\perp}$ ,  $E$ , etc.) should be applied on particles through the file `Selector.dat` apart from the ones provided by the jet algorithm. The reason for this is that the parton shower automatically induces boosts not only along the beam axis – they tend to be comparably mild – but also in the transverse plane<sup>6</sup>. In contrast, invariant masses of pairs of particles tend to be almost stable under the parton shower treatment, their application therefore is uncritical.

It is of crucial importance that, if results are to be written out and recycled in later runs, already during the corresponding integration the parton showers have to be switched on in `Shower.dat`. Although the parton showers are of no direct consequence for the cross sections, they influence the information written out in the resulting data files.

2. Before the actual event generation starts, look-up tables for the Sudakov form factors are prepared. The Sudakov form factors depend on two scales, one of which is the jet resolution scale, which characterises the softest scale for emission of QCD particles accessible by the matrix elements. This scale is ultimately defined by the jet algorithm and it is of utmost importance that the phase space for jet production is not further constrained. This guarantees that the two regions – jet production and jet emission – match. Note that the Sudakov form factors for the highest jet multiplicity treatment are calculated “on the flight”.
3. The hard matrix element of each event is selected according to the total cross section of the corresponding process. The particles are distributed according to the differential cross section. These events are generated through the method `GenerateOneEvent()` of the `MatrixElementHandler`, the information concerning momenta etc. is made available through corresponding simple access methods. The `SignalProcesses` handler will fill a tentative `Blob`<sup>7</sup>.
4. Before the parton shower(s) may start, the parton configuration of the hard matrix element has to be analysed. SHERPA provides an interface structure, the most involved one being the `Amegic-`

---

<sup>6</sup>Remember that the parton shower is an expansion around the collinear limit; the initial state parton shower therefore will respect to good approximation the beam direction; in contrast, since critical transverse momenta are usually much smaller than the beam energy, any mild change in this direction really matters. This is why cuts on the pseudo-rapidity of individual particles do not have such a tremendous impact.

<sup>7</sup>For details concerning the event record, cf. Sec. 6.

`ApacicInterface`, employed by the `EventPhaseHandler` for the parton shower, dubbed `Jet_Evolution`. In this interface, the partons are clustered backwards according to the same jet algorithm used for the cuts on the final state phase space of the matrix elements. The clustering automatically yields the nodal values of each parton emission; in fact, by this “clustering-backwards” procedure, a pseudo-classical limit of the radiation pattern has been constructed, which reproduces the parton shower history in its logarithmic approximation. Equipped with the nodal values the Sudakov rejection weight (including the reweighting of the  $\alpha_s$ ) can be calculated. The parton configuration and thus the (tentative) hard event is accepted or rejected according to this weight. In case it is rejected, the event generation continues with the step before, eventually leading possibly to a completely new process with different flavours and different multiplicity.

5. In case the hard event is accepted, the parton shower is invoked, starting from the pseudo history constructed before. Each parton starts its evolution at the scale where it was produced, subject to the condition that no extra jet is produced. For the virtuality ordered parton shower of `APACIC`, the scale is the corresponding invariant mass. The exception to this veto is for configurations with the maximal number of jets produced through the matrix elements. There, the parton shower has to cover the phase space for more jets than produced by the matrix elements, the veto therefore is on partons at scales harder than the softest scale of the hard event.

## 5.2 How the merging does not work

There are a number of ways screwing up the merging procedure. Some of them are briefly discussed below.

### 5.2.1 Missing jets

When mixing processes with different numbers of jets, it is not a good idea to “miss” some of them. For instance, for inclusive  $W$  production the user may want to initialise processes with a  $W$  final state plus a number of additional jets:  $jj \rightarrow e\bar{\nu}_e, e\bar{\nu}_e + j, e\bar{\nu}_e + 2j, e\bar{\nu}_e + 3j, \dots$ . The treatment for the highest jet multiplicity is such that the interplay of Sudakov suppression on the matrix elements and jet veto on extra jets in the parton shower allows for more than this highest number of jets in a fashion that reproduces the soft/collinear limit of the according matrix element(s). Therefore omitting the highest jet multiplicity has a significant unpleasant effect only, if the user is interested in correlation on this number of jets that are sensitive to a full quantum-mechanically correct treatment.

However, missing the subprocesses with some of the lowest numbers of jets (like, for instance the subprocess  $jj \rightarrow e\bar{\nu}_e$ ) may lead to significant holes in the soft region of many distributions. Similarly, missing some intermediate numbers of jets will lead to bumps, holes and other funny structures.

### 5.2.2 Extra cuts on the phase space of jets

As explained above, cuts on jets, especially on their  $p_\perp$ , energy, etc., have two effects: First of all they define the measure of the Sudakov suppression, second they define, which region is populated by the parton shower or the matrix element. Both, the Sudakov suppression and the parton shower phase space are defined solely by the jet definition. Applying cuts, e.g. on the  $p_\perp$  of jets, which are harder than the jet cuts, will immediately result in a gap. This gap is the deeper the worse the mismatch of scales is. Therefore, applying extra cuts, especially on the jets, will almost always lead to wrong predictions of physics.

### 5.2.3 Wrong result directories

To store results of the matrix element calculations in a directory and to recycle them in future runs seems to be a good idea. Especially when going to high final state multiplicities, it saves quite a lot of CPU time. However, there are a number of potential mismatches, for example:

- different c.m. energy of the beams or different cuts on the final state;
- different values of  $\alpha_s$ ;
- the merging has been switched off during the calculation;
- different numbers of maximal jet multiplicities.

The latter two matter, since the results of the matrix element calculation are evaluated with the  $\alpha_s$  at the merging scale, if the merging is switched on. This scale is either given by the jet resolution scale or by the scale of the softest jet in those matrix elements with the maximal jet multiplicity.

## 6 Interpreting the event record

### 6.1 SHERPA's output format

SHERPA's event record is based on a list of linked `Blobs`. They reflect some very general structure that transforms particles into other particles. Consequently they have a number  $n_{\text{in}}$  and a number  $n_{\text{out}}$  of incoming and outgoing particles, respectively<sup>8</sup>. Some care is taken that each of the `Blobs` respects local four-momentum conservation. Apart from the particles attached to them, `Blobs` are located in space-time, giving rise to production and decay positions of their particles.

`Blobs` are further specified by giving them an identity number, a status flag, and a type (coded as an `enum` structure), such as `Signal_Process`, `ME_PS_Interface_IS` or `FS_Shower`.

Physical particles in SHERPA are implemented in their own class. As mentioned before, apart from those entering the event as beams and those leaving it as final state particles, all other have a production and a decay blob, providing them with information of where they have been produced and where they have been decayed. This structure also incorporates in a natural way mother-daughter relations. When the parton shower is switched on, partons, i.e. quarks and gluons, also carry colour indices in a kind of  $\mathbf{3} \otimes \mathbf{\bar{3}}$  representation, but with  $N_c$  going to infinity<sup>9</sup>. Of course, particles carry a four momentum, given in units of GeV and an id-number. Finally, particles also have a status flag, basically 1 or 2 for particles, which are still active, or particles, which are decayed or fragmented, respectively. Finally, more information can be obtained from an info flag with the meanings listed in Table 9.

The full output of the second event of the  $e\gamma$  default setup is listed in appendix B, its structure is represented pictorially in Fig. 2. To exemplify how this works, consider the last `blob`, which reads:

```
Blob [1] ( 58, Hadron Decay      , 1 -> 3 @ (8.56e-05,-3.032e-05,-5.306e-05,-5.98e-05)
Incoming particles :
[d] 1 pi                147 ( 56 -> 58) [( 2.9158e+00,-1.0320e+00,-1.8082e+00,-2.0370e+00), 1.8220e-02] (0,0)
Outgoing particles :
[D] 1 photon            148 ( 58 -> ) [( 1.7688e+00,-6.0006e-01,-1.1475e+00,-1.2048e+00), 1.3323e-15] (0,0)
[D] 1 e+                149 ( 58 -> ) [( 6.9901e-01,-2.6415e-01,-3.9638e-01,-5.1159e-01), 2.6010e-07] (0,0)
[D] 1 e-                150 ( 58 -> ) [( 4.4805e-01,-1.6783e-01,-2.6423e-01,-3.2058e-01), 2.6010e-07] (0,0)
```

<sup>8</sup>In terms of programming the `Blobs` own pointers to the respective `Particles` and they are responsible of erasing them after each event.

<sup>9</sup>This, by the way, is one of the assumptions implicit in one way or the other in all event generators.

Info	Meaning
G	IS parton for hard interaction
H	FS parton from hard interaction
I	initial parton (shower initiator)
i	parton from ISR
F	final parton (active)
f	parton from FSR (decayed)
D	particle from hadron decays (active)
d	particle from hadron decays (decayed)
P	primary active hadrons, directly from fragmentation (active)
p	primary active hadrons, directly from fragmentation (decayed)

Table 9: Particle info codes and their meaning in the event record.

The first line is for the blob, its status ([1]), its number (58) and type (**Hadron Decay**), the number of incoming and outgoing particles ( $1 \rightarrow 3$ ), and its four-position in the notation  $(t, \vec{x})$ . Then the particles are listed with its particle info code, status, type (in most cases, when the particle is electrically neutral, the charge subscript is missing), its number, information about the production and decay blobs (for instance, the incoming  $\pi^0$  is produced in **blob** 56 and decays in number 58), its four-momentum in the notation  $(E, \vec{p})$ , and finally its colour charges (obviously, hadron, photons, etc. have no colour charges). The colour flow is represented in the  $N_c \rightarrow \infty$  limit by two numbers, standing for the  $\mathbf{3} \otimes \bar{\mathbf{3}}$  components.

## 6.2 Other formats and outputting events

SHERPA provides the possibility to output events – either to file or to screen – in two other output formats: the user may output events in the **HepEVT**-common block structure or in the **HepMC**-format [27]. The authors of SHERPA assume that the user is sufficiently acquainted with these formats when selecting them.

In order to write events into files, one of the keywords **SHERPA\_OUTPUT**, **HEPEVT\_OUTPUT**, or **HEPMC\_OUTPUT** have to be provided with a name.

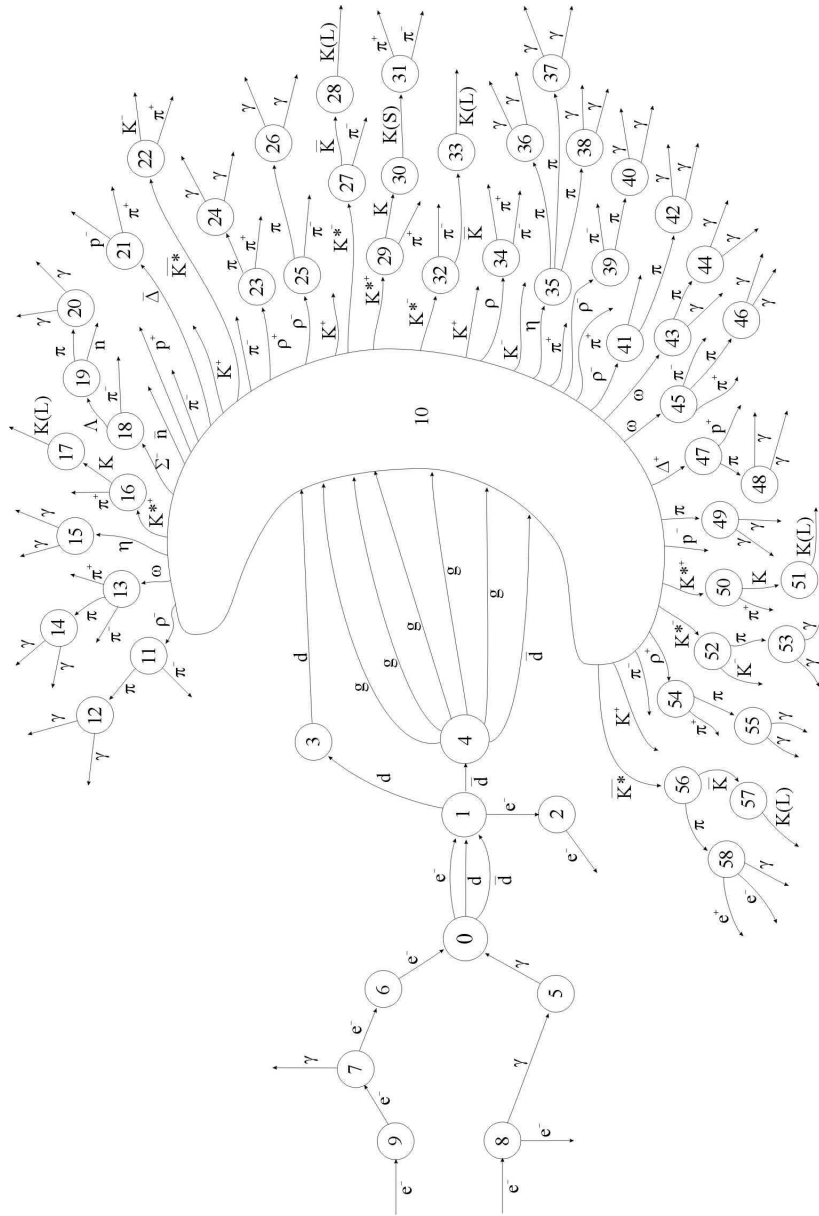


Figure 2: An example event (the second one) of the  $e\gamma$  default setup.

## A Data files

```
!-----  
!--- Run parameters -----  
!-----  
EVENTS          = 2          ! Number of Events  
Num. Accuracy   = 1.e-10     !  
OUTPUT          = 7          ! Output level :  
!               ! 0=errors,1=events,2=info,  
!               ! 4=tracking,6=info+tracking, etc.  
!  
PRETTY_PRINT    = 0n         ! Coloured output  
!  
BEAM_DATA_FILE  = Beam.dat  
ISR_DATA_FILE   = ISR.dat  
ME_DATA_FILE    = ME.dat  
MODEL_DATA_FILE = Model.dat  
SHOWER_DATA_FILE = Shower.dat  
!  
ANALYSIS        = 0          ! 0=Off, 1=On  
!  
BATCH_MODE      = 1          ! interactive=0, batch=1  
LOG_FILE        = sherpa_run_ep.log
```

Figure 3: The `Run.dat` file of the default setup. Most of the keywords should be self-explanatory, output levels are added (for their individual definition, cf. Table 3).



```

!-----
!-- Beam parameters -----
!-----
BEAM_1          = 11          ! possible beam particles: P+, P-, e+, e-
BEAM_ENERGY_1   = 250.       ! in GeV
BEAM_POL_1      = 0.         ! Polarization degree -1 ... 1
BEAM_SPECTRUM_1 = Laser_Backscattering ! Monochromatic,Laser_Backscattering,
!                               Simple_Compton
!
BEAM_2          = 11          ! possible beam particles: P+, P-, e+, e-
BEAM_ENERGY_2   = 250.       ! in GeV
BEAM_POL_2      = 0.         ! Polarization degree -1 ... 1
BEAM_SPECTRUM_2 = Monochromatic ! Monochromatic,Laser_Backscattering,
!                               Simple_Compton
!
BEAM_SMIN       = 0.3        ! Minimal fraction of nominal s
!                               after beam spectra
BEAM_SMAX       = 1.0        ! Maximal fraction of nominal s
!                               after beam spectra
!
E_LASER_1       = 1.17e-9    ! Laser energy in GeV
P_LASER_1       = 0.         ! Laser polarization +-1
E_LASER_2       = 1.17e-9    ! Laser energy in GeV
P_LASER_2       = 0.         ! Laser polarization +-1
LASER_MODE       = 0         ! 0 = all, 1,2,3 = individual components
LASER_NONLINEARITY = On      ! On/Off
!-----
!-- Beam remnant parameters-----
!-----
K_PERP_MEAN_1   = 0.
K_PERP_SIGMA_1  = 0.
K_PERP_MEAN_2   = 0.
K_PERP_SIGMA_2  = 0.

```

Figure 4: The `Beam.dat` file of the default setup. Again, most keywords should be self-explanatory, however, a few comments are in order: all energies are in GeV, for particle codes cf. Figs. 18 and 19. Beam polarisations are given as (circular) polarisation/helicity degree ranging from -1 to 1. `BEAM_SMIN` and `BEAM_SMAX` rule the  $s$ -range ( $E_{c.m.}^2$ ) after the beam spectra have been applied, `Monochromatic` obviously results in  $s = (E_1 + E_2)^2$ . The laser specifications apply only, if `Laser_Backscattering` or `Simple_Compton` are selected. The `K_PERP`-specifications steer the breakup of the beam remnants by specifying the  $k_{\perp}$  distribution.

```

!-----
!-- ISR parameters -----
!-----
BUNCH_1      = 22      ! possible beam particles: P+, P-, e+, e-
ISR_1        = Off     ! On/Off
!
BUNCH_2      = 11      ! possible beam particles: P+, P-, e+, e-
ISR_2        = On      ! On/Off
!
ISR_SMIN     = 0.01    ! Minimal fraction of nominal s for parton
!                    after ISR
ISR_SMAX     = 1.0     ! Maximal fraction of nominal s for parton
!                    after ISR
!
ISR_E_ORDER  = 1       ! Perturbative order of electron S.F.
ISR_E_SCHEME = 2       ! Beta-scheme : 0,1,2 , default = 2
!
PDF_SET      = cteq611 ! For LHAPDF use the following PDFs in
!                    in combination with PDFsets
!                    Alekhin_100,Alekhin_1000,
!                    Botje_100,Botje_1000,
!                    Fermi2002_100,Fermi2002_1000,
!                    MRST2001,MRST98,cteq6,cteq6l,cetq6l1
!
!                    ! alternatively use cteq6 via CTEQ6Grid
!                    ! cteq6m,cteq6d,cteq6l,cteq6l1
!
!                    ! Or use interface to MRST99 via MRST99Grid
!                    ! MRST99

PDF_SET_VERSION = 1
PDF_GRID_PATH   = CTEQ6Grid ! PDFsets,MRST99Grid,CTEQ6Grid

```

Figure 5: The `ISR.dat` file of the default setup. Again, most keywords are self-explanatory, the `ISR_SMIN` and `ISR_SMAX` steer the  $s$ -range after the bunch particle-parton transition has taken place. Note that some of the PDFs (cteq6-sets) are available either in its “original form” through the Fortran interface or through the LHAPDF interface. Which one is selected depends on the variable `PDF_GRID_PATH`. If the user chooses to simulate proton-proton collisions (or similar) the corresponding ISR has to be switched on.

```

!-----
!-- Model parameters -----
!-----
MODEL                = SM          ! Model
!
GENERATOR_ON         = 0           ! use external spectrum generator
EW_SCHEME            = 0           ! choice of defining the ew sector.

```

Figure 6: The general part of the file `Model.dat` of the default setup. The external spectra generators can be switched on or off (For SUSY they must be switched on at the moment!). The different schemes to set the electroweak parameters are listed in the text.

```

!
! SM parameters
!
ALPHAS(MZ)           = 0.1188     ! strong coupling at scale M_Z
ALPHAS(default)     = 0.0800     ! strong coupling
1/ALPHAQED(0)       = 137.036    ! inverse of alpha QED (Thomson limit)
1/ALPHAQED(default) = 127.0      ! inverse of alpha QED
SIN2THETAW          = 0.23       ! Weinberg angle at scale M_Z
VEV                  = 246.       ! Higgs vev
LAMBDA               = 0.47591    ! SM Higgs self coupling
YUKAWA_E             = 0.         ! Yukawa coupling of electron
YUKAWA_MU            = 0.105     ! Yukawa coupling of mu
YUKAWA_TAU           = 1.77      ! Yukawa coupling of tau
YUKAWA_U              = 0.        ! Yukawa coupling of u quark
YUKAWA_D              = 0.        ! Yukawa coupling of d quark
YUKAWA_S              = 0.        ! Yukawa coupling of s quark
YUKAWA_C              = 1.3       ! Yukawa coupling of c quark
YUKAWA_B              = 4.5       ! Yukawa coupling of b quark
YUKAWA_T              = 175.      ! Yukawa coupling of t quark
MSTRANGE_EFF         = 0.48      ! effective strange mass (higgs-loops)
CKMORDER             = 0         ! expansion of CKM (in Cabibbo angle)
CABIBBO              = 0.22      ! Cabibbo angle (Wolfenstein)
A                    = 0.85      ! A (Wolfenstein parametrization)
RHO                   = 0.50      ! rho (Wolfenstein parametrization)
ETA                   = 0.50      ! eta (Wolfenstein parametrization)

```

Figure 7: The SM part of the file `Model.dat` of the default setup. For details cf. Sec. 4.2.4.

```

HIGGS_GENERATOR      = Hdecay   ! Generator for Higgs masses & widths
HIGGS_NNLO(M)       = 1         ! Use nnlo running of masses in higgs decays :
                                ! allowed values 1,2
HIGGS_ON_SHELL_WZ   = 1         ! Only on-shell gauge bosons in higgs decays :
                                ! 0 = double,1 = single
HIGGS_MASS_SCHEME    = 0         ! Scheme for higgs masses in higgs decays      :
                                ! running/pole
HIGGS_NF_LIGHT_Q_IN_G = 5       ! Number of light flavours in higgs
                                ! decays h->gg*->g qqbar

```

Figure 8: The part of the default setup file Model.dat steering the HDecay program. For details cf. Sec. 4.2.4.

```

!
! SUSY parameters
!
SUSY_SCENARIO        = mSUGRA   ! also available : AMSB, mGMSB,
                                ! non-minimal_GMSB,
                                ! non-universal_SUGRA,
                                ! SUGRA_with_enforced_unification
M0                   = 200.      !
M12                  = 200.      !
A0                   = 100.      !
TAN(BETA)            = 3.        !
SIGN(MU)             = -1       !
!
! ADD parameters
!
N_ED                 = 2         ! Number of extra dimensions
G_NEWTON             = 6.707e-39 ! Newton gravity constant
M_S                  = 2.5e3     ! string scale for ADD model,
                                ! meaning depends on KK_CONVENTION
M_CUT                = 2.5e3     ! cut-off scale for the
                                ! c.m.energy
KK_CONVENTION        = 1         ! 0=const mass
                                ! 1=simplified sum(HLZ)
                                ! 2=exact sum(HLZ)
                                ! 3=Hewett +1    4=Hewett -1
                                ! 5=GRW (Lambda_T(GRW)=M_S
                                ! for virtual Graviton exchange
                                ! or M_D=M_S for real Graviton
                                ! production)
! only KK_CONVENTION's 1,2 or 5 are applicable
! for real Graviton production!

```

Figure 9: The new physics part of Model.dat of the default setup. For details cf. Sec. 4.2.4.

```

!-----
!-- ME generators -----
!-----
ME_SIGNAL_GENERATOR = Amegic      ! Internal or Amegic
EVENT_GENERATION_MODE = Unweighted
!
SIGNAL_MODEL        = SM          ! subset of a physical model
                                ! or the whole SM, MSSM, ADD
!
COUPLING_SCHEME     = Fixed       ! Fixed (default value) or
                                ! Running (s for ME generators, pt for 2->2)
COUPLING_SCALE_FACTOR = 1.        ! Additional prefactor for ME's scale.
YUKAWA_MASSES       = Fixed       ! Fixed (polemass) or
                                ! Running (higgs mass)
YUKAWA_MASSES_FACTOR = 1.        ! Additional prefactor for yukawas
!
SCALE_SCHEME        = 0           ! default is 0=shat,
KFACTOR_SCHEME      = 0           ! 1=as(pt2)/as(ecms)^nstrong,default=1
SUDAKOV_WEIGHT      = 0           ! apply sudakov weight on single events
!FIXED_SCALE        = 8315.25    ! fixed scale for the processes in GeV^2
SCALE_FACTOR        = 1.          ! factor the scale is multiplied with

```

Figure 10: The ME.dat file of the default setup

```

%-----
%-- Processes to calculate -----
%-----
%
% photon electron -> electron d anti-d
%
Process : 22 11 -> 11 1 -1
End process

```

Figure 11: The Processes.dat file of the default setup.

```

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
% jet jet -> electron anti-neutrino + n-jets
%
Process : 93 93 -> 11 -12
Order electroweak : 2
Order strong : 0
End process
%
Process : 93 93 -> 11 -12 93
Order electroweak : 2
Order strong : 1
End process
%
Process : 93 93 -> 11 -12 93 93
Order electroweak : 2
Order strong : 2
End process
%
%Process : 93 93 -> 11 -12 93 93 93
%Order electroweak : 2
%Order strong : 3
%End process
%
%Process : 93 93 -> 11 -12 93 93 93 93
%Order electroweak : 2
%Order strong : 4
%End process

```

Figure 12: The Processes.dat file of the alternative default setup .

```

!-----
!-- Parton level selectors -----
!-----
JetFinder  4.e-3  1.
ET         11     1.  10000.
ET         1      1.  10000.
ET        -1      1.  10000.
BeamAngle  1  0   -0.9   0.9
BeamAngle -1  0   -0.9   0.9
BeamAngle 11  0   -0.9   0.9

```

Figure 13: The Selector.dat file of the default setup.

```

!-----
!-- Phase space setup -----
!-----
ERROR = 1.e-2 ! Error by calculating matrix-elements
!
INTEGRATOR = 4 ! Phasespace : Rambo=0, Sarge=1,
!                   Rambo + Sarge=2,
!                   Rambo + Multi-channel=3,
!                   pure Multi-channel=4
!                   RamboKK=5

```

Figure 14: The `Integration.dat` data file of the default setup. Note that `RamboKK` is the only choice when considering outgoing Kaluza-Klein resonances.

```

!-----
!-- Parton showers -----
!-----
SHOWER_GENERATOR = Apacic !
FSR_SHOWER       = 1      ! 1=On,0=Off
ISR_SHOWER       = 0      ! 1=On,0=Off
!
IS_PT2MIN        = 4.     !
FS_PT2MIN        = 1.     !

```

Figure 15: The `Shower.dat` datafile of the default setup. Showers should be consistently switched on or off.

```

!-----
!-- Fragmentation parameters-----
!-----
FRAGMENTATION = Lund
LUND_FILE     = Lund.dat ! Pythia parameter file

```

Figure 16: The `Fragmentation.dat` data file of the default setup.

```

ANALYSIS_PHASE = Showers
! Available: ME, Showers, Hadrons, added by "+", no spaces.
OUTPUT = OutputS
93 10. -4.5 4.5 0.7 1.
! last parameter: 1.(default): jets include b 0.: b's produce kf::bjet (97)
11 1. -4.5 4.5 0.
OBSERVABLES
PT 11 1. 150. 20 Log
PT 93 1. 150. 20 Log
PT2 11 -12 0. 100. 20 Lin
Eta2 11 -12 -2. 2. 10 Lin
END_ANALYSIS_PHASE
!
!
ANALYSIS_PHASE = Showers
! Available: ME, Showers, Hadrons, added by "+", no spaces.
OUTPUT = OutputS1
93 10. -4.5 4.5 0.7
11 1. -4.5 4.5 0.
OBSERVABLES
PT 11 1. 150. 20 Log
PT 93 1. 150. 20 Log
PT2 11 -12 0. 100. 20 Lin
Eta2 11 -12 -2. 2. 10 Lin
END_ANALYSIS_PHASE

```

Figure 17: The Analysis.dat data file of the default setup.



kf	Mass	Width	3*e	Y	SU(3)	2*Spin	maj	on	stbl	m_on	Name
1	.01	.0	-1	-1	1	1	0	1	1	0	d
2	.005	.0	2	1	1	1	0	1	1	0	u
3	.2	.0	-1	-1	1	1	0	1	1	0	s
4	1.42	.0	2	1	1	1	0	1	1	0	c
5	4.7	.0	-1	-1	1	1	0	1	1	1	b
6	174.3	1.5	2	1	1	1	0	1	1	1	t
11	.000511	.0	-3	-1	0	1	0	1	1	0	e-
12	.0	.0	0	1	0	1	0	1	1	0	nu_e
13	.105	.0	-3	-1	0	1	0	1	1	0	mu-
14	.0	.0	0	1	0	1	0	1	1	0	nu_mu
15	1.777	2.36E-12	-3	-1	0	1	0	1	1	1	tau-
16	.0	.0	0	1	0	1	0	1	1	0	nu_tau
21	.0	.0	0	0	1	2	0	1	1	0	gluon
22	.0	.0	0	0	0	2	0	1	1	0	photon
23	80.419	2.048	-3	0	0	2	0	1	1	1	W-
24	91.188	2.446	0	0	0	2	0	1	1	1	Z
25	120.0	0.0037	0	0	0	0	0	1	1	1	h
27	100.0	.0	0	0	0	4	0	1	1	1	graviton
28	100.0	.0	0	0	0	0	0	1	1	1	gscalar
31	93.9932	.0074	0	0	0	0	0	1	1	1	h0
32	590.726	2.02	0	0	0	0	0	1	1	1	H0
33	585.68	2.25	0	0	0	0	0	1	1	1	A0
34	591.21	.827	-3	0	0	0	0	1	1	1	H-
41	212.293	0.01	3	0	0	1	0	1	1	1	chargino1
42	503.425	0.82	3	0	0	1	0	1	1	1	chargino2
43	115.459	.0	0	0	0	1	1	1	1	1	neutralino1
44	213.234	.0	0	0	0	1	1	1	1	1	neutralino2
45	482.791	.0	0	0	0	1	1	1	1	1	neutralino3
46	506.624	.0	0	0	0	1	1	1	1	1	neutralino4
47	706.822	.0	0	0	1	1	1	1	1	1	gluino
51	633.761	.0	2	1	1	0	0	1	1	1	sup_L
52	633.763	.0	2	1	1	0	0	1	1	1	scharm_L
53	659.643	.0	2	1	1	0	0	1	1	1	stop_2
54	612.413	.0	2	1	1	0	0	1	1	1	sup_R
55	612.415	.0	2	1	1	0	0	1	1	1	scharm_R
56	456.05	.0	2	1	1	0	0	1	1	1	stop_1
61	636.928	.0	-1	-1	1	0	0	1	1	1	sdown_L
62	636.928	.0	-1	-1	1	0	0	1	1	1	sstrange_L
63	611.299	.0	-1	-1	1	0	0	1	1	1	sbottom_2
64	610.76	.0	-1	-1	1	0	0	1	1	1	sdown_R
65	610.76	.0	-1	-1	1	0	0	1	1	1	sstrange_R
66	585.172	.0	-1	-1	1	0	0	1	1	1	sbottom_1
71	228.838	.0	-3	-1	0	0	0	1	1	1	selectron_L
72	228.838	.0	-3	-1	0	0	0	1	1	1	smuon_L
73	228.991	.0	-3	-1	0	0	0	1	1	1	stau_2
74	153.1918	.0	-3	-1	0	0	0	1	1	1	selectron_R
75	153.191	.0	-3	-1	0	0	0	1	1	1	smuon_R
76	152.782	.0	-3	-1	0	0	0	1	1	1	stau_1
81	219.858	.0	0	1	0	0	0	1	1	1	snu_1
82	219.858	.0	0	1	0	0	0	1	1	1	snu_2
83	219.812	.0	0	1	0	0	0	1	1	1	snu_3

Figure 18: Particle listings in Particle.dat. It is highly recommended not to change the following entries: kf, 3\*e, Y, SU(3), maj, and name.

kf	Mass	Width	3*e	Y	2*Spin	on	stbl	Name
111	0.134976	7.8e-09	0	0	0	1	0	pi
113	0.77	0.1507	0	0	0	0	0	rho(770)
130	0.497672	1.273e-17	0	0	0	0	0	K(L)
211	0.13957	2.5284e-17	3	0	0	1	0	pi+
213	0.77	0.1507	3	0	0	0	0	rho(770)+
221	0.5473	1.18e-06	0	0	0	0	0	eta
223	0.78194	0.00841	0	0	0	0	0	omega(782)
310	0.497672	7.373e-15	0	0	0	0	0	K(S)
311	0.497672	0	0	0	0	1	0	K
313	0.8961	0.0505	0	0	0	0	0	K*(892)
321	0.493677	5.314e-17	3	0	0	1	0	K+
323	0.89166	0.0508	3	0	0	0	0	K*(892)+
331	0.95778	0.000203	0	0	0	0	0	eta'(958)
333	1.01941	0.00443	0	0	0	0	0	phi(1020)
411	1.8693	6.23e-13	3	0	0	0	0	D+
413	2.01	0	3	0	0	0	0	D*(2010)+
421	1.8646	1.586e-12	0	0	0	0	0	D
423	2.0067	0	0	0	0	0	0	D*(2007)
431	1.9685	1.41e-12	3	0	0	0	0	D(s)+
433	2.1124	0	3	0	0	0	0	D(s)**
441	2.9798	0.0132	0	0	0	0	0	eta(c)(1S)
443	3.09688	8.7e-05	0	0	0	0	0	J/psi(1S)
445	3.55617	0.002	0	0	0	0	0	chi(c2)(1P)
511	5.2792	4.22e-13	0	0	0	0	0	B
513	5.3249	0	0	0	0	0	0	B*
521	5.2789	3.99e-13	3	0	0	0	0	B+
523	5.3249	0	3	0	0	0	0	B**
531	5.3693	4.27e-13	0	0	0	0	0	B(s)
533	5.41630	0	0	0	0	0	0	B*(s)
541	6.594	0.	3	0	0	0	0	B(c)+
543	6.602	0.	3	0	0	0	0	B*(c)+
551	9.4	0.	0	0	0	0	0	eta_b
553	9.46037	5.25e-05	0	0	0	0	0	Upsilon(1S)
555	9.9132	0	0	0	0	0	0	chi(b2)(1P)
1112	1.62	0.15	-3	0	0	0	0	Delta(1620)-
1114	1.232	0.12	-3	0	0	0	0	Delta(1232)-
1212	1.62	0.15	0	0	0	0	0	Delta(1620)
1214	1.52	0.12	0	0	0	0	0	N(1520)
2112	0.939566	7.424e-28	0	0	0	0	0	n
2114	1.232	0.12	0	0	0	0	0	Delta(1232)
2116	1.675	0.15	0	0	0	0	0	N(1675)
2122	1.62	0.15	3	0	0	0	0	Delta(1620)+
2124	1.52	0.12	3	0	0	0	0	N(1520)+
2212	0.938272	0	3	1	1	1	1	P+
2214	1.232	0.12	3	0	0	0	0	Delta(1232)+
2216	1.675	0.15	3	0	0	0	0	N(1675)+
2222	1.62	0.15	6	0	0	0	0	Delta(1620)**
2224	1.232	0.12	6	0	0	0	0	Delta(1232)**
3112	1.19745	4.45e-15	-3	0	0	0	0	Sigma-
3114	1.3872	0.0394	-3	0	0	0	0	Sigma(1385)-
3116	1.775	0.12	-3	0	0	0	0	Sigma(1775)-

Figure 19: Some hadrons in Hadron.dat of the default settings.

1103	0.77133	0	-2	0	1	1	1	dd_1
2101	0.57933	0	1	0	1	1	1	ud_0
2103	0.77133	0	1	0	1	1	1	ud_1
2203	0.77133	0	4	0	1	1	1	uu_1
3101	0.80473	0	-2	0	1	1	1	sd_0
3103	0.92953	0	-2	0	1	1	1	sd_1
3201	0.80473	0	1	0	1	1	1	su_0
3203	0.92953	0	1	0	1	1	1	su_1
3303	1.09361	0	-2	0	1	1	1	ss_1
4101	1.96908	0	1	0	1	1	1	cd_0
4103	2.00808	0	1	0	1	1	1	cd_1
4201	1.96908	0	4	0	1	1	1	cu_0
4203	2.00808	0	4	0	1	1	1	cu_1
4301	2.15432	0	1	0	1	1	1	cs_0
4303	2.17967	0	1	0	1	1	1	cs_1
4403	3.27531	0	4	0	1	1	1	cc_1
5101	5.38897	0	-2	0	1	1	1	bd_0
5103	5.40145	0	-2	0	1	1	1	bd_1
5201	5.38897	0	1	0	1	1	1	bu_0
5203	5.40145	0	1	0	1	1	1	bu_1
5301	5.56725	0	-2	0	1	1	1	bs_0
5303	5.57536	0	-2	0	1	1	1	bs_1
5401	6.67143	0	1	0	1	1	1	bc_0
5403	6.67397	0	1	0	1	1	1	bc_1
5503	10.07354	0	-2	0	1	1	1	bb_1
5505	1000000.0	1000	0	0	0	0	0	ralf

Figure 20: The di-quarks are part of `Hadron.dat`.

## B An example event output

The full output of the second event of the  $e\gamma$  default setup looks like

```

-----
Blob [0]( 9, Bunch           , from Beam 1, 1 -> 1 @ (0,0,0,0)
Incoming particles :
[X] 2 e-                19 (  -> 9) [( 2.5000e+02, 0.0000e+00, 0.0000e+00,-2.5000e+02), 2.6113e-07] (0,0)
Outgoing particles :
[X] 2 e-                15 ( 9 -> 7) [( 2.5000e+02, 0.0000e+00, 0.0000e+00,-2.5000e+02), 2.6113e-07] (0,0)

Blob [0]( 8, Bunch           , from Beam 0, 1 -> 2 @ (0,0,0,0)
Incoming particles :
[X] 2 e-                17 (  -> 8) [( 2.5000e+02, 0.0000e+00, 0.0000e+00, 2.5000e+02), 2.6113e-07] (0,0)
Outgoing particles :
[G] 2 photon            1 ( 8 -> 5) [( 1.4762e+02, 0.0000e+00, 0.0000e+00, 1.4762e+02), 0.0000e+00] (0,0)
[X] 1 e-                18 ( 8 -> ) [( 1.0238e+02, 0.0000e+00, 0.0000e+00, 1.0238e+02), 1.0693e-07] (0,0)

Blob [2]( 7, Beam           , from Beam 1, 1 -> 2 @ (0,0,0,0)
Incoming particles :
[X] 2 e-                15 ( 9 -> 7) [( 2.5000e+02, 0.0000e+00, 0.0000e+00,-2.5000e+02), 2.6113e-07] (0,0)
Outgoing particles :
[G] 2 e-                2 ( 7 -> 6) [( 2.5000e+02, 0.0000e+00, 0.0000e+00,-2.5000e+02), 1.4552e-11] (0,0)
[F] 1 photon            16 ( 7 -> ) [( 5.4499e-04, 0.0000e+00, 0.0000e+00,-5.4499e-04), 5.6921e-13] (0,0)

Blob [2]( 6, IS Shower      , from Beam 1, 1 -> 1 @ (0,0,0,0)
Incoming particles :
[G] 2 e-                2 ( 7 -> 6) [( 2.5000e+02, 0.0000e+00, 0.0000e+00,-2.5000e+02), 1.4552e-11] (0,0)
Outgoing particles :
[G] 2 e-                2 ( 6 -> 0) [( 2.5000e+02, 0.0000e+00, 0.0000e+00,-2.5000e+02), 1.4552e-11] (0,0)

Blob [2]( 5, IS Shower      , from Beam 0, 1 -> 1 @ (0,0,0,0)
Incoming particles :
[G] 2 photon            1 ( 8 -> 5) [( 1.4762e+02, 0.0000e+00, 0.0000e+00, 1.4762e+02), 0.0000e+00] (0,0)
Outgoing particles :
[G] 2 photon            1 ( 5 -> 0) [( 1.4762e+02, 0.0000e+00, 0.0000e+00, 1.4762e+02), 0.0000e+00] (0,0)

Blob [0]( 0, Signal Process  , 2 -> 3 @ (0,0,0,0)
Incoming particles :
[G] 2 photon            1 ( 5 -> 0) [( 1.4762e+02, 0.0000e+00, 0.0000e+00, 1.4762e+02), 0.0000e+00] (0,0)
[G] 2 e-                2 ( 6 -> 0) [( 2.5000e+02, 0.0000e+00, 0.0000e+00,-2.5000e+02), 1.4552e-11] (0,0)
Outgoing particles :
[H] 2 e-                2 ( 0 -> 1) [( 1.5910e+02, 9.2856e+01, 1.1283e+02, 6.2947e+01), 1.4552e-11] (0,0)
[H] 2 d                 3 ( 0 -> 1) [( 1.5629e+01,-1.1111e+01, 1.0942e+01, 1.0488e+00),-9.9476e-13] (601,0)
[H] 2 anti-d            4 ( 0 -> 1) [( 2.2289e+02,-8.1746e+01,-1.2377e+02,-1.6637e+02), 1.4552e-11] (0,601)

Blob [0]( 1, ME PS Interface , 3 -> 3 @ (0,0,0,0)
Incoming particles :
[H] 2 e-                2 ( 0 -> 1) [( 1.5910e+02, 9.2856e+01, 1.1283e+02, 6.2947e+01), 1.4552e-11] (0,0)
[H] 2 d                 3 ( 0 -> 1) [( 1.5629e+01,-1.1111e+01, 1.0942e+01, 1.0488e+00),-9.9476e-13] (601,0)
[H] 2 anti-d            4 ( 0 -> 1) [( 2.2289e+02,-8.1746e+01,-1.2377e+02,-1.6637e+02), 1.4552e-11] (0,601)
Outgoing particles :
[H] 1 e-                2 ( 1 -> 2) [( 1.5910e+02, 9.2856e+01, 1.1283e+02, 6.2947e+01), 2.6112e-07] (0,0)
[H] 1 d                 3 ( 1 -> 3) [( 5.5278e+00,-3.9296e+00, 3.8700e+00, 3.7093e-01), 1.0000e-04] (601,0)
[H] 2 anti-d            7 ( 1 -> 4) [( 2.3299e+02,-8.8927e+01,-1.1670e+02,-1.6569e+02), 5.3051e+03] (0,601)

Blob [1]( 2, FS Shower      , 1 -> 1 @ (4.256e-17,0.0001079,0.0001311,7.312e-05)
Incoming particles :
[H] 1 e-                2 ( 1 -> 2) [( 1.5910e+02, 9.2856e+01, 1.1283e+02, 6.2947e+01), 2.6112e-07] (0,0)
Outgoing particles :
[H] 1 e-                3 ( 2 -> ) [( 1.5910e+02, 9.2856e+01, 1.1283e+02, 6.2947e+01), 2.6112e-07] (0,0)

```

```

Blob [1]( 3, FS Shower          , 1 -> 1 @ (2.328e-20,-2.652e-08,2.612e-08,2.504e-09)
Incoming particles :
[H] 1 d                3 ( 1 -> 3) [( 5.5278e+00,-3.9296e+00, 3.8700e+00, 3.7093e-01), 1.0000e-04] (601,0)
Outgoing particles :
[H] 2 d                5 ( 3 -> 10) [( 5.5278e+00,-3.9296e+00, 3.8700e+00, 3.7093e-01), 1.0000e-04] (601,0)

Blob [1]( 4, FS Shower          , 1 -> 6 @ (2.284e-26,-2.326e-15,-3.052e-15,-4.334e-15)
Incoming particles :
[H] 2 anti-d          7 ( 1 -> 4) [( 2.3299e+02,-8.8927e+01,-1.1670e+02,-1.6569e+02), 5.3051e+03] (0,601)
Outgoing particles :
[F] 2 anti-d          9 ( 4 -> 10) [( 7.3297e+01,-2.9305e+01,-4.3661e+01,-5.1062e+01), 1.0000e-04] (0,604)
[F] 2 gluon           10 ( 4 -> 10) [( 2.1309e+01,-9.4603e+00,-1.3720e+01,-1.3280e+01),-1.1369e-13] (604,603)
[F] 2 gluon           11 ( 4 -> 10) [( 4.6008e+01,-2.1263e+01,-2.3130e+01,-3.3609e+01),-4.5475e-13] (603,605)
[F] 2 gluon           12 ( 4 -> 10) [( 6.9869e+01,-3.7137e+01,-3.5404e+01,-4.7424e+01),-1.8190e-12] (605,602)
[F] 2 gluon           13 ( 4 -> 10) [( 1.3558e+01, 2.7436e+00,-2.0921e-01,-1.3276e+01),-2.8422e-14] (606,601)
[F] 2 gluon           14 ( 4 -> 10) [( 8.9509e+00, 5.4954e+00,-5.7053e-01,-7.0424e+00), 0.0000e+00] (602,606)

Blob [0]( 10, Fragmentation     , 7 -> 37 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)
Incoming particles :
[H] 2 d                5 ( 3 -> 10) [( 5.5278e+00,-3.9296e+00, 3.8700e+00, 3.7093e-01), 1.0000e-04] (601,0)
[F] 2 gluon           13 ( 4 -> 10) [( 1.3558e+01, 2.7436e+00,-2.0921e-01,-1.3276e+01),-2.8422e-14] (606,601)
[F] 2 gluon           14 ( 4 -> 10) [( 8.9509e+00, 5.4954e+00,-5.7053e-01,-7.0424e+00), 0.0000e+00] (602,606)
[F] 2 gluon           12 ( 4 -> 10) [( 6.9869e+01,-3.7137e+01,-3.5404e+01,-4.7424e+01),-1.8190e-12] (605,602)
[F] 2 gluon           11 ( 4 -> 10) [( 4.6008e+01,-2.1263e+01,-2.3130e+01,-3.3609e+01),-4.5475e-13] (603,605)
[F] 2 gluon           10 ( 4 -> 10) [( 2.1309e+01,-9.4603e+00,-1.3720e+01,-1.3280e+01),-1.1369e-13] (604,603)
[F] 2 anti-d          9 ( 4 -> 10) [( 7.3297e+01,-2.9305e+01,-4.3661e+01,-5.1062e+01), 1.0000e-04] (0,604)
Outgoing particles :
[p] 1 rho(770)-       20 ( 10 -> 11) [( 1.2471e+00,-6.4020e-01, 6.8008e-01,-1.9853e-01), 6.4341e-01] (0,0)
[p] 1 omega(782)      25 ( 10 -> 13) [( 9.9838e-01,-2.8472e-01, 3.6596e-01,-4.1994e-01), 6.0542e-01] (0,0)
[p] 1 eta              31 ( 10 -> 15) [( 9.2245e-01,-5.0842e-01, 5.3036e-01,-1.0690e-01), 2.9970e-01] (0,0)
[p] 1 K*(892)+         34 ( 10 -> 16) [( 1.6360e+00,-9.3520e-01, 9.6687e-01,-1.5124e-01), 8.4426e-01] (0,0)
[p] 1 Sigma(1385)-    38 ( 10 -> 18) [( 1.8401e+00,-3.0233e-01, 5.0023e-01,-1.0289e+00), 1.9859e+00] (0,0)
[p] 1 anti-n           45 ( 10 -> ) [( 1.2169e+00,-2.2515e-01, 3.5057e-01,-6.5148e-01), 8.8279e-01] (0,0)
[p] 1 P+               46 ( 10 -> ) [( 2.6677e+00, 4.0937e-01, 6.1054e-02,-2.4627e+00), 8.8035e-01] (0,0)
[p] 1 pi-              47 ( 10 -> ) [( 2.0586e-01,-5.6533e-03, 3.3892e-02,-1.4738e-01), 1.9480e-02] (0,0)
[p] 1 anti-Delta(1232) 48 ( 10 -> 21) [( 2.6303e+00, 9.3940e-01, 4.0424e-03,-2.1614e+00), 1.3643e+00] (0,0)
[p] 1 K+               51 ( 10 -> ) [( 5.9648e-01, 1.0040e-01, 1.1523e-01,-2.9798e-01), 2.4364e-01] (0,0)
[p] 1 anti-K*(892)    52 ( 10 -> 22) [( 5.8918e+00, 1.1157e+00,-4.0800e-02,-5.7054e+00), 9.1553e-01] (0,0)
[p] 1 pi-              55 ( 10 -> ) [( 6.3338e-01, 2.9289e-01,-2.9108e-02,-5.4319e-01), 1.9480e-02] (0,0)
[p] 1 rho(770)+        56 ( 10 -> 23) [( 1.9843e+00, 1.2018e+00,-2.6858e-01,-1.4084e+00), 4.3747e-01] (0,0)
[p] 1 rho(770)-        61 ( 10 -> 25) [( 2.0000e+00, 3.4653e-01,-1.9033e-01,-1.8003e+00), 6.0281e-01] (0,0)
[p] 1 K+               66 ( 10 -> ) [( 9.2083e-01,-2.2249e-01,-3.6337e-01,-6.5019e-01), 2.4364e-01] (0,0)
[p] 1 K*(892)-        67 ( 10 -> 27) [( 1.5022e+00, 3.5843e-01,-3.1379e-01,-1.1287e+00), 7.5562e-01] (0,0)
[p] 1 K*(892)+        71 ( 10 -> 29) [( 1.6741e+00,-3.6800e-01,-6.4651e-01,-1.1855e+00), 8.4383e-01] (0,0)
[p] 1 K*(892)-        77 ( 10 -> 32) [( 1.3271e+00, 1.7693e-01,-3.3124e-01,-9.8395e-01), 6.5190e-01] (0,0)
[p] 1 rho(770)         81 ( 10 -> 34) [( 1.6882e+00, 6.9078e-01,-2.4130e-01,-1.2957e+00), 6.3602e-01] (0,0)
[p] 1 K+               84 ( 10 -> ) [( 2.4658e+00,-1.2341e+00,-1.2199e+00,-1.6809e+00), 2.4364e-01] (0,0)
[p] 1 K-               85 ( 10 -> ) [( 2.2395e+01,-1.1895e+01,-1.1345e+01,-1.5202e+01), 2.4364e-01] (0,0)
[p] 1 eta              86 ( 10 -> 35) [( 4.7620e+00,-2.4833e+00,-2.3945e+00,-3.2368e+00), 2.9970e-01] (0,0)
[p] 1 pi+              96 ( 10 -> ) [( 6.5012e+00,-3.1226e+00,-3.2768e+00,-4.6645e+00), 1.9480e-02] (0,0)
[p] 1 rho(770)-        97 ( 10 -> 39) [( 2.4726e+00,-1.0616e+00,-1.2099e+00,-1.8105e+00), 2.4485e-01] (0,0)
[p] 1 pi+              102 ( 10 -> ) [( 2.7897e+00,-1.2837e+00,-1.4002e+00,-2.0382e+00), 1.9480e-02] (0,0)
[p] 1 rho(770)-        103 ( 10 -> 41) [( 1.1895e+01,-5.4520e+00,-5.9614e+00,-8.6917e+00), 6.7624e-01] (0,0)
[p] 1 omega(782)       108 ( 10 -> 43) [( 1.0234e+01,-5.2401e+00,-5.3440e+00,-6.9366e+00), 6.0872e-01] (0,0)
[p] 1 omega(782)       113 ( 10 -> 45) [( 1.7194e+01,-9.0216e+00,-8.8963e+00,-1.1596e+01), 6.2817e-01] (0,0)
[p] 1 Delta(1232)+    119 ( 10 -> 47) [( 1.4275e+01,-7.0942e+00,-8.0055e+00,-9.3760e+00), 1.4390e+00] (0,0)
[p] 1 pi               124 ( 10 -> 49) [( 5.3411e+00,-2.6490e+00,-2.6627e+00,-3.7950e+00), 1.8220e-02] (0,0)
[p] 1 P-               127 ( 10 -> ) [( 1.2549e+01,-5.7152e+00,-6.7410e+00,-8.8597e+00), 8.8035e-01] (0,0)
[p] 1 K*(892)+         128 ( 10 -> 50) [( 1.5634e+01,-6.6310e+00,-8.7454e+00,-1.1098e+01), 7.9532e-01] (0,0)
[p] 1 K*(892)-        132 ( 10 -> 52) [( 1.7685e+01,-7.3252e+00,-1.0155e+01,-1.2458e+01), 7.5939e-01] (0,0)
[p] 1 rho(770)+        137 ( 10 -> 54) [( 1.3761e+01,-5.7607e+00,-8.4000e+00,-9.2239e+00), 5.4085e-01] (0,0)
[p] 1 pi-              142 ( 10 -> ) [( 6.5900e+00,-2.6489e+00,-3.9410e+00,-4.5673e+00), 1.9480e-02] (0,0)

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[P] 1 K+ 143 ( 10 -> ) [( 1.6158e+01,-6.5373e+00,-9.7092e+00,-1.1128e+01), 2.4364e-01] (0,0)  
[p] 1 anti-K\*(892) 144 ( 10 -> 56) [( 2.4235e+01,-9.8402e+00,-1.4601e+01,-1.6632e+01), 6.8819e-01] (0,0)

Blob [1]( 11, Hadron Decay , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[p] 1 rho(770)- 20 ( 10 -> 11) [( 1.2471e+00,-6.4020e-01, 6.8008e-01,-1.9853e-01), 6.4341e-01] (0,0)  
Outgoing particles :  
[D] 1 pi- 21 ( 11 -> ) [( 3.1329e-01, 1.3772e-02, 1.7689e-01, 2.1723e-01), 1.9480e-02] (0,0)  
[d] 1 pi 22 ( 11 -> 12) [( 9.3379e-01,-6.5398e-01, 5.0319e-01,-4.1576e-01), 1.8220e-02] (0,0)

Blob [1]( 12, Hadron Decay , 1 -> 2 @ (0.0004512,-0.000316,0.0002431,-0.0002009)  
Incoming particles :  
[d] 1 pi 22 ( 11 -> 12) [( 9.3379e-01,-6.5398e-01, 5.0319e-01,-4.1576e-01), 1.8220e-02] (0,0)  
Outgoing particles :  
[D] 1 photon 23 ( 12 -> ) [( 7.3884e-01,-5.1113e-01, 4.4275e-01,-2.9767e-01), 6.6613e-16] (0,0)  
[D] 1 photon 24 ( 12 -> ) [( 1.9495e-01,-1.4285e-01, 6.0438e-02,-1.1809e-01), 7.6328e-17] (0,0)

Blob [1]( 13, Hadron Decay , 1 -> 3 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[p] 1 omega(782) 25 ( 10 -> 13) [( 9.9838e-01,-2.8472e-01, 3.6596e-01,-4.1994e-01), 6.0542e-01] (0,0)  
Outgoing particles :  
[D] 1 pi- 26 ( 13 -> ) [( 1.5365e-01, 4.9093e-02, 2.3910e-02,-3.3853e-02), 1.9480e-02] (0,0)  
[D] 1 pi+ 27 ( 13 -> ) [( 3.7548e-01, 3.2588e-02, 3.2316e-01,-1.2652e-01), 1.9480e-02] (0,0)  
[d] 1 pi 28 ( 13 -> 14) [( 4.6925e-01,-3.6640e-01, 1.8889e-02,-2.5957e-01), 1.8220e-02] (0,0)

Blob [1]( 14, Hadron Decay , 1 -> 2 @ (8.436e-05,-6.59e-05,3.422e-06,-4.666e-05)  
Incoming particles :  
[d] 1 pi 28 ( 13 -> 14) [( 4.6925e-01,-3.6640e-01, 1.8889e-02,-2.5957e-01), 1.8220e-02] (0,0)  
Outgoing particles :  
[D] 1 photon 29 ( 14 -> ) [( 3.2314e-01,-2.7506e-01, 6.6581e-02,-1.5597e-01), 1.2490e-16] (0,0)  
[D] 1 photon 30 ( 14 -> ) [( 1.4612e-01,-9.1335e-02,-4.7693e-02,-1.0360e-01), 2.0817e-17] (0,0)

Blob [1]( 15, Hadron Decay , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[p] 1 eta 31 ( 10 -> 15) [( 9.2245e-01,-5.0842e-01, 5.3036e-01,-1.0690e-01), 2.9970e-01] (0,0)  
Outgoing particles :  
[D] 1 photon 32 ( 15 -> ) [( 2.2676e-01,-2.0934e-01,-8.6023e-02, 1.3944e-02),-5.5511e-17] (0,0)  
[D] 1 photon 33 ( 15 -> ) [( 6.9569e-01,-2.9908e-01, 6.1639e-01,-1.2084e-01),-2.7756e-16] (0,0)

Blob [1]( 16, Hadron Decay , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[p] 1 K\*(892)+ 34 ( 10 -> 16) [( 1.6360e+00,-9.3520e-01, 9.6687e-01,-1.5124e-01), 8.4426e-01] (0,0)  
Outgoing particles :  
[d] 1 K 35 ( 16 -> 17) [( 1.0707e+00,-7.7307e-01, 4.6344e-01,-2.9388e-01), 2.4768e-01] (0,0)  
[D] 1 pi+ 37 ( 16 -> ) [( 5.6530e-01,-1.6213e-01, 5.0344e-01, 1.4264e-01), 1.9480e-02] (0,0)

Blob [1]( 17, Hadron Decay , 1 -> 1 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[d] 1 K 35 ( 16 -> 17) [( 1.0707e+00,-7.7307e-01, 4.6344e-01,-2.9388e-01), 2.4768e-01] (0,0)  
Outgoing particles :  
[D] 1 K(L) 36 ( 17 -> ) [( 1.0707e+00,-7.7307e-01, 4.6344e-01,-2.9388e-01), 2.4768e-01] (0,0)

Blob [1]( 18, Hadron Decay , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[p] 1 Sigma(1385)- 38 ( 10 -> 18) [( 1.8401e+00,-3.0233e-01, 5.0023e-01,-1.0289e+00), 1.9859e+00] (0,0)  
Outgoing particles :  
[d] 1 Lambda 39 ( 18 -> 19) [( 1.4374e+00,-5.4837e-02, 5.1489e-01,-7.4377e-01), 1.2447e+00] (0,0)  
[D] 1 pi- 44 ( 18 -> ) [( 4.0277e-01,-2.4749e-01,-1.4655e-02,-2.8508e-01), 1.9480e-02] (0,0)

Blob [1]( 19, Hadron Decay , 1 -> 2 @ (97.2,-3.708,34.82,-50.3)  
Incoming particles :  
[d] 1 Lambda 39 ( 18 -> 19) [( 1.4374e+00,-5.4837e-02, 5.1489e-01,-7.4377e-01), 1.2447e+00] (0,0)

Outgoing particles :

[D] 1 n 40 ( 19 -> ) [( 1.2864e+00,-1.1049e-01, 4.8005e-01,-7.2759e-01), 8.8279e-01] (0,0)

[d] 1 pi 41 ( 19 -> 20) [( 1.5097e-01, 5.5655e-02, 3.4837e-02,-1.6179e-02), 1.8220e-02] (0,0)

Blob [1]( 20, Hadron Decay , 1 -> 2 @ (97.2,-3.708,34.82,-50.3)

Incoming particles :

[d] 1 pi 41 ( 19 -> 20) [( 1.5097e-01, 5.5655e-02, 3.4837e-02,-1.6179e-02), 1.8220e-02] (0,0)

Outgoing particles :

[D] 1 photon 42 ( 20 -> ) [( 5.4302e-02,-3.6883e-02, 3.8133e-02, 1.1584e-02), 2.1684e-18] (0,0)

[D] 1 photon 43 ( 20 -> ) [( 9.6670e-02, 9.2539e-02,-3.2962e-03,-2.7764e-02), 3.4694e-18] (0,0)

Blob [1]( 21, Hadron Decay , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)

Incoming particles :

[p] 1 anti-Delta(1232) 48 ( 10 -> 21) [( 2.6303e+00, 9.3940e-01, 4.0424e-03,-2.1614e+00), 1.3643e+00] (0,0)

Outgoing particles :

[D] 1 P- 49 ( 21 -> ) [( 2.2895e+00, 9.3324e-01,-9.2661e-02,-1.8660e+00), 8.8035e-01] (0,0)

[D] 1 pi+ 50 ( 21 -> ) [( 3.4083e-01, 6.1571e-03, 9.6703e-02,-2.9546e-01), 1.9480e-02] (0,0)

Blob [1]( 22, Hadron Decay , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)

Incoming particles :

[p] 1 anti-K\*(892) 52 ( 10 -> 22) [( 5.8918e+00, 1.1157e+00,-4.0800e-02,-5.7054e+00), 9.1553e-01] (0,0)

Outgoing particles :

[D] 1 K- 53 ( 22 -> ) [( 3.7377e+00, 8.3931e-01,-3.3074e-01,-3.5935e+00), 2.4364e-01] (0,0)

[D] 1 pi+ 54 ( 22 -> ) [( 2.1541e+00, 2.7639e-01, 2.8994e-01,-2.1120e+00), 1.9480e-02] (0,0)

Blob [1]( 23, Hadron Decay , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)

Incoming particles :

[p] 1 rho(770)+ 56 ( 10 -> 23) [( 1.9843e+00, 1.2018e+00,-2.6858e-01,-1.4084e+00), 4.3747e-01] (0,0)

Outgoing particles :

[D] 1 pi+ 57 ( 23 -> ) [( 9.3848e-01, 5.9193e-01,-4.1442e-01,-5.8235e-01), 1.9480e-02] (0,0)

[d] 1 pi 58 ( 23 -> 24) [( 1.0458e+00, 6.0989e-01, 1.4585e-01,-8.2601e-01), 1.8220e-02] (0,0)

Blob [1]( 24, Hadron Decay , 1 -> 2 @ (0.0001026,5.981e-05,1.434e-05,-8.104e-05)

Incoming particles :

[d] 1 pi 58 ( 23 -> 24) [( 1.0458e+00, 6.0989e-01, 1.4585e-01,-8.2601e-01), 1.8220e-02] (0,0)

Outgoing particles :

[D] 1 photon 59 ( 24 -> ) [( 7.8478e-01, 4.2349e-01, 7.8808e-02,-6.5598e-01), 4.4409e-16] (0,0)

[D] 1 photon 60 ( 24 -> ) [( 2.6105e-01, 1.8639e-01, 6.7037e-02,-1.7002e-01), 4.1633e-17] (0,0)

Blob [1]( 25, Hadron Decay , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)

Incoming particles :

[p] 1 rho(770)- 61 ( 10 -> 25) [( 2.0000e+00, 3.4653e-01,-1.9033e-01,-1.8003e+00), 6.0281e-01] (0,0)

Outgoing particles :

[D] 1 pi- 62 ( 25 -> ) [( 1.0349e+00, 1.8913e-01, 2.6187e-01,-9.7324e-01), 1.9480e-02] (0,0)

[d] 1 pi 63 ( 25 -> 26) [( 9.6513e-01, 1.5740e-01,-4.5220e-01,-8.2704e-01), 1.8220e-02] (0,0)

Blob [1]( 26, Hadron Decay , 1 -> 2 @ (0.0002391,3.897e-05,-0.000112,-0.0002049)

Incoming particles :

[d] 1 pi 63 ( 25 -> 26) [( 9.6513e-01, 1.5740e-01,-4.5220e-01,-8.2704e-01), 1.8220e-02] (0,0)

Outgoing particles :

[D] 1 photon 64 ( 26 -> ) [( 5.3089e-01, 1.5294e-01,-2.4229e-01,-4.4693e-01), 5.5511e-17] (0,0)

[D] 1 photon 65 ( 26 -> ) [( 4.3424e-01, 4.4598e-03,-2.0991e-01,-3.8011e-01), 1.1102e-16] (0,0)

Blob [1]( 27, Hadron Decay , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)

Incoming particles :

[p] 1 K\*(892)- 67 ( 10 -> 27) [( 1.5022e+00, 3.5843e-01,-3.1379e-01,-1.1287e+00), 7.5562e-01] (0,0)

Outgoing particles :

[d] 1 anti-K 68 ( 27 -> 28) [( 6.2292e-01, 1.8368e-01,-1.3472e-01,-2.9744e-01), 2.4768e-01] (0,0)

[D] 1 pi- 70 ( 27 -> ) [( 8.7925e-01, 1.7475e-01,-1.7907e-01,-8.3127e-01), 1.9480e-02] (0,0)

Blob [1]( 28, Hadron Decay , 1 -> 1 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)

Incoming particles :

[d] 1 anti-K            68 ( 27 -> 28) [( 6.2292e-01, 1.8368e-01,-1.3472e-01,-2.9744e-01), 2.4768e-01] (0,0)  
Outgoing particles :  
[D] 1 K(L)            69 ( 28 -> ) [( 6.2292e-01, 1.8368e-01,-1.3472e-01,-2.9744e-01), 2.4768e-01] (0,0)

Blob [1]( 29, Hadron Decay        , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[p] 1 K\*(892)+        71 ( 10 -> 29) [( 1.6741e+00,-3.6800e-01,-6.4651e-01,-1.1855e+00), 8.4383e-01] (0,0)  
Outgoing particles :  
[d] 1 K            72 ( 29 -> 30) [( 1.4783e+00,-2.5962e-01,-7.2658e-01,-1.1586e+00), 2.4768e-01] (0,0)  
[D] 1 pi+            76 ( 29 -> ) [( 1.9587e-01,-1.0838e-01, 8.0070e-02,-2.6970e-02), 1.9480e-02] (0,0)

Blob [1]( 30, Hadron Decay        , 1 -> 1 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[d] 1 K            72 ( 29 -> 30) [( 1.4783e+00,-2.5962e-01,-7.2658e-01,-1.1586e+00), 2.4768e-01] (0,0)  
Outgoing particles :  
[d] 1 K(S)            73 ( 30 -> 31) [( 1.4783e+00,-2.5962e-01,-7.2658e-01,-1.1586e+00), 2.4768e-01] (0,0)

Blob [1]( 31, Hadron Decay        , 1 -> 2 @ (228.5,-40.12,-112.3,-179.1)  
Incoming particles :  
[d] 1 K(S)            73 ( 30 -> 31) [( 1.4783e+00,-2.5962e-01,-7.2658e-01,-1.1586e+00), 2.4768e-01] (0,0)  
Outgoing particles :  
[D] 1 pi-            74 ( 31 -> ) [( 1.0101e+00,-2.0999e-02,-5.9385e-01,-8.0486e-01), 1.9480e-02] (0,0)  
[D] 1 pi+            75 ( 31 -> ) [( 4.6814e-01,-2.3862e-01,-1.3274e-01,-3.5371e-01), 1.9480e-02] (0,0)

Blob [1]( 32, Hadron Decay        , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[p] 1 K\*(892)-        77 ( 10 -> 32) [( 1.3271e+00, 1.7693e-01,-3.3124e-01,-9.8395e-01), 6.5190e-01] (0,0)  
Outgoing particles :  
[d] 1 anti-K        78 ( 32 -> 33) [( 8.4955e-01,-1.0656e-01,-2.1956e-01,-6.4382e-01), 2.4768e-01] (0,0)  
[D] 1 pi-            80 ( 32 -> ) [( 4.7750e-01, 2.8349e-01,-1.1168e-01,-3.4013e-01), 1.9480e-02] (0,0)

Blob [1]( 33, Hadron Decay        , 1 -> 1 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[d] 1 anti-K        78 ( 32 -> 33) [( 8.4955e-01,-1.0656e-01,-2.1956e-01,-6.4382e-01), 2.4768e-01] (0,0)  
Outgoing particles :  
[D] 1 K(L)            79 ( 33 -> ) [( 8.4955e-01,-1.0656e-01,-2.1956e-01,-6.4382e-01), 2.4768e-01] (0,0)

Blob [1]( 34, Hadron Decay        , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[p] 1 rho(770)        81 ( 10 -> 34) [( 1.6882e+00, 6.9078e-01,-2.4130e-01,-1.2957e+00), 6.3602e-01] (0,0)  
Outgoing particles :  
[D] 1 pi-            82 ( 34 -> ) [( 8.6108e-01, 3.6195e-02,-2.5474e-01,-8.0980e-01), 1.9480e-02] (0,0)  
[D] 1 pi+            83 ( 34 -> ) [( 8.2716e-01, 6.5458e-01, 1.3435e-02,-4.8586e-01), 1.9480e-02] (0,0)

Blob [1]( 35, Hadron Decay        , 1 -> 3 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[p] 1 eta            86 ( 10 -> 35) [( 4.7620e+00,-2.4833e+00,-2.3945e+00,-3.2368e+00), 2.9970e-01] (0,0)  
Outgoing particles :  
[d] 1 pi            87 ( 35 -> 36) [( 1.5249e+00,-7.7741e-01,-8.5896e-01,-9.8235e-01), 1.8220e-02] (0,0)  
[d] 1 pi            90 ( 35 -> 37) [( 2.1033e+00,-1.1072e+00,-9.1571e-01,-1.5301e+00), 1.8220e-02] (0,0)  
[d] 1 pi            93 ( 35 -> 38) [( 1.1338e+00,-5.9875e-01,-6.1987e-01,-7.2429e-01), 1.8220e-02] (0,0)

Blob [1]( 36, Hadron Decay        , 1 -> 2 @ (9.727e-05,-4.961e-05,-5.476e-05,-6.266e-05)  
Incoming particles :  
[d] 1 pi            87 ( 35 -> 36) [( 1.5249e+00,-7.7741e-01,-8.5896e-01,-9.8235e-01), 1.8220e-02] (0,0)  
Outgoing particles :  
[D] 1 photon        88 ( 36 -> ) [( 7.8089e-01,-4.2035e-01,-3.8431e-01,-5.3422e-01), 0.0000e+00] (0,0)  
[D] 1 photon        89 ( 36 -> ) [( 7.4404e-01,-3.5705e-01,-4.7464e-01,-4.4814e-01),-1.1102e-16] (0,0)

Blob [1]( 37, Hadron Decay        , 1 -> 2 @ (0.0001595,-8.398e-05,-6.941e-05,-0.000116)  
Incoming particles :  
[d] 1 pi            90 ( 35 -> 37) [( 2.1033e+00,-1.1072e+00,-9.1571e-01,-1.5301e+00), 1.8220e-02] (0,0)



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Outgoing particles :
[D] 1 photon      91 ( 37 -> ) [( 1.3367e+00,-7.4046e-01,-5.2888e-01,-9.7922e-01),-2.2204e-16] (0,0)
[D] 1 photon      92 ( 37 -> ) [( 7.6654e-01,-3.6670e-01,-3.8683e-01,-5.5089e-01),-1.1102e-16] (0,0)

Blob [1]( 38, Hadron Decay      , 1 -> 2 @ (0.000386,-0.0002039,-0.000211,-0.0002466)
Incoming particles :
[d] 1 pi          93 ( 35 -> 38) [( 1.1338e+00,-5.9875e-01,-6.1987e-01,-7.2429e-01), 1.8220e-02] (0,0)
Outgoing particles :
[D] 1 photon      94 ( 38 -> ) [( 7.3025e-02,-2.7355e-02,-1.5418e-02,-6.5929e-02), 0.0000e+00] (0,0)
[D] 1 photon      95 ( 38 -> ) [( 1.0608e+00,-5.7139e-01,-6.0445e-01,-6.5836e-01), 0.0000e+00] (0,0)

Blob [1]( 39, Hadron Decay      , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)
Incoming particles :
[p] 1 rho(770)-   97 ( 10 -> 39) [( 2.4726e+00,-1.0616e+00,-1.2099e+00,-1.8105e+00), 2.4485e-01] (0,0)
Outgoing particles :
[D] 1 pi-         98 ( 39 -> ) [( 9.7410e-01,-4.3152e-01,-3.0219e-01,-8.0739e-01), 1.9480e-02] (0,0)
[d] 1 pi          99 ( 39 -> 40) [( 1.4985e+00,-6.3005e-01,-9.0776e-01,-1.0031e+00), 1.8220e-02] (0,0)

Blob [1]( 40, Hadron Decay      , 1 -> 2 @ (7.704e-06,-3.265e-06,-4.639e-06,-5.153e-06)
Incoming particles :
[d] 1 pi          99 ( 39 -> 40) [( 1.4985e+00,-6.3005e-01,-9.0776e-01,-1.0031e+00), 1.8220e-02] (0,0)
Outgoing particles :
[D] 1 photon     100 ( 40 -> ) [( 1.0836e+00,-4.2604e-01,-7.0469e-01,-7.0434e-01),-2.2204e-16] (0,0)
[D] 1 photon     101 ( 40 -> ) [( 4.1490e-01,-2.0401e-01,-2.0307e-01,-2.9881e-01),-5.5511e-17] (0,0)

Blob [1]( 41, Hadron Decay      , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)
Incoming particles :
[p] 1 rho(770)-   103 ( 10 -> 41) [( 1.1895e+01,-5.4520e+00,-5.9614e+00,-8.6917e+00), 6.7624e-01] (0,0)
Outgoing particles :
[D] 1 pi-        104 ( 41 -> ) [( 9.9065e+00,-4.5277e+00,-4.7553e+00,-7.4166e+00), 1.9480e-02] (0,0)
[d] 1 pi         105 ( 41 -> 42) [( 1.9882e+00,-9.2428e-01,-1.2061e+00,-1.2750e+00), 1.8220e-02] (0,0)

Blob [1]( 42, Hadron Decay      , 1 -> 2 @ (0.0002054,-9.549e-05,-0.0001245,-0.0001317)
Incoming particles :
[d] 1 pi         105 ( 41 -> 42) [( 1.9882e+00,-9.2428e-01,-1.2061e+00,-1.2750e+00), 1.8220e-02] (0,0)
Outgoing particles :
[D] 1 photon     106 ( 42 -> ) [( 4.3851e-01,-2.3117e-01,-2.2094e-01,-3.0006e-01),-5.5511e-17] (0,0)
[D] 1 photon     107 ( 42 -> ) [( 1.5497e+00,-6.9311e-01,-9.8513e-01,-9.7498e-01), 4.4409e-16] (0,0)

Blob [1]( 43, Hadron Decay      , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)
Incoming particles :
[p] 1 omega(782)  108 ( 10 -> 43) [( 1.0234e+01,-5.2401e+00,-5.3440e+00,-6.9366e+00), 6.0872e-01] (0,0)
Outgoing particles :
[D] 1 photon     109 ( 43 -> ) [( 4.0345e+00,-2.3630e+00,-1.8944e+00,-2.6654e+00), 7.1054e-15] (0,0)
[d] 1 pi         110 ( 43 -> 44) [( 6.1999e+00,-2.8771e+00,-3.4496e+00,-4.2712e+00), 1.8220e-02] (0,0)

Blob [1]( 44, Hadron Decay      , 1 -> 2 @ (0.001608,-0.0007463,-0.0008947,-0.001108)
Incoming particles :
[d] 1 pi         110 ( 43 -> 44) [( 6.1999e+00,-2.8771e+00,-3.4496e+00,-4.2712e+00), 1.8220e-02] (0,0)
Outgoing particles :
[D] 1 photon     111 ( 44 -> ) [( 2.4598e-01,-9.8639e-02,-1.2526e-01,-1.8732e-01), 7.6328e-17] (0,0)
[D] 1 photon     112 ( 44 -> ) [( 5.9539e+00,-2.7785e+00,-3.3243e+00,-4.0838e+00), 7.1054e-15] (0,0)

Blob [1]( 45, Hadron Decay      , 1 -> 3 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)
Incoming particles :
[p] 1 omega(782)  113 ( 10 -> 45) [( 1.7194e+01,-9.0216e+00,-8.8963e+00,-1.1596e+01), 6.2817e-01] (0,0)
Outgoing particles :
[D] 1 pi-        114 ( 45 -> ) [( 5.9803e+00,-2.9108e+00,-3.1745e+00,-4.1465e+00), 1.9480e-02] (0,0)
[D] 1 pi+        115 ( 45 -> ) [( 7.8790e+00,-4.2119e+00,-3.9890e+00,-5.3299e+00), 1.9480e-02] (0,0)
[d] 1 pi         116 ( 45 -> 46) [( 3.3346e+00,-1.8989e+00,-1.7328e+00,-2.1195e+00), 1.8220e-02] (0,0)

Blob [1]( 46, Hadron Decay      , 1 -> 2 @ (0.0002711,-0.0001544,-0.0001409,-0.0001723)

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Incoming particles :  
[d] 1 pi 116 ( 45 -> 46) [( 3.3346e+00,-1.8989e+00,-1.7328e+00,-2.1195e+00), 1.8220e-02] (0,0)  
Outgoing particles :  
[D] 1 photon 117 ( 46 -> ) [( 3.1339e+00,-1.7839e+00,-1.6060e+00,-2.0148e+00),-3.5527e-15] (0,0)  
[D] 1 photon 118 ( 46 -> ) [( 2.0070e-01,-1.1504e-01,-1.2682e-01,-1.0470e-01), 0.0000e+00] (0,0)

Blob [1]( 47, Hadron Decay , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[p] 1 Delta(1232)+ 119 ( 10 -> 47) [( 1.4275e+01,-7.0942e+00,-8.0055e+00,-9.3760e+00), 1.4390e+00] (0,0)  
Outgoing particles :  
[D] 1 P+ 120 ( 47 -> ) [( 1.2632e+01,-6.1639e+00,-7.2109e+00,-8.2878e+00), 8.8035e-01] (0,0)  
[d] 1 pi 121 ( 47 -> 48) [( 1.6430e+00,-9.3032e-01,-7.9458e-01,-1.0882e+00), 1.8220e-02] (0,0)

Blob [1]( 48, Hadron Decay , 1 -> 2 @ (0.0008025,-0.0004544,-0.0003881,-0.0005316)  
Incoming particles :  
[d] 1 pi 121 ( 47 -> 48) [( 1.6430e+00,-9.3032e-01,-7.9458e-01,-1.0882e+00), 1.8220e-02] (0,0)  
Outgoing particles :  
[D] 1 photon 122 ( 48 -> ) [( 1.2099e+00,-7.3498e-01,-5.7364e-01,-7.7112e-01), 8.8818e-16] (0,0)  
[D] 1 photon 123 ( 48 -> ) [( 4.3306e-01,-1.9534e-01,-2.2093e-01,-3.1713e-01), 2.7756e-17] (0,0)

Blob [1]( 49, Hadron Decay , 1 -> 2 @ (0.0009509,-0.0004716,-0.000474,-0.0006756)  
Incoming particles :  
[p] 1 pi 124 ( 10 -> 49) [( 5.3411e+00,-2.6490e+00,-2.6627e+00,-3.7950e+00), 1.8220e-02] (0,0)  
Outgoing particles :  
[D] 1 photon 125 ( 49 -> ) [( 7.5955e-02,-2.8922e-02,-5.0293e-02,-4.9024e-02),-6.0715e-18] (0,0)  
[D] 1 photon 126 ( 49 -> ) [( 5.2651e+00,-2.6201e+00,-2.6124e+00,-3.7459e+00), 1.4211e-14] (0,0)

Blob [1]( 50, Hadron Decay , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[p] 1 K\*(892)+ 128 ( 10 -> 50) [( 1.5634e+01,-6.6310e+00,-8.7454e+00,-1.1098e+01), 7.9532e-01] (0,0)  
Outgoing particles :  
[d] 1 K 129 ( 50 -> 51) [( 1.2392e+01,-5.3835e+00,-6.7334e+00,-8.8874e+00), 2.4768e-01] (0,0)  
[D] 1 pi+ 131 ( 50 -> ) [( 3.2419e+00,-1.2475e+00,-2.0120e+00,-2.2104e+00), 1.9480e-02] (0,0)

Blob [1]( 51, Hadron Decay , 1 -> 1 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[d] 1 K 129 ( 50 -> 51) [( 1.2392e+01,-5.3835e+00,-6.7334e+00,-8.8874e+00), 2.4768e-01] (0,0)  
Outgoing particles :  
[D] 1 K(L) 130 ( 51 -> ) [( 1.2392e+01,-5.3835e+00,-6.7334e+00,-8.8874e+00), 2.4768e-01] (0,0)

Blob [1]( 52, Hadron Decay , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[p] 1 K\*(892)- 132 ( 10 -> 52) [( 1.7685e+01,-7.3252e+00,-1.0155e+01,-1.2458e+01), 7.5939e-01] (0,0)  
Outgoing particles :  
[D] 1 K- 133 ( 52 -> ) [( 1.4076e+01,-6.0204e+00,-8.1329e+00,-9.7730e+00), 2.4364e-01] (0,0)  
[d] 1 pi 134 ( 52 -> 53) [( 3.6085e+00,-1.3047e+00,-2.0221e+00,-2.6854e+00), 1.8220e-02] (0,0)

Blob [1]( 53, Hadron Decay , 1 -> 2 @ (0.000483,-0.0001747,-0.0002706,-0.0003595)  
Incoming particles :  
[d] 1 pi 134 ( 52 -> 53) [( 3.6085e+00,-1.3047e+00,-2.0221e+00,-2.6854e+00), 1.8220e-02] (0,0)  
Outgoing particles :  
[D] 1 photon 135 ( 53 -> ) [( 2.9502e+00,-1.1145e+00,-1.6331e+00,-2.1897e+00),-3.5527e-15] (0,0)  
[D] 1 photon 136 ( 53 -> ) [( 6.5823e-01,-1.9027e-01,-3.8896e-01,-4.9576e-01),-2.2204e-16] (0,0)

Blob [1]( 54, Hadron Decay , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)  
Incoming particles :  
[p] 1 rho(770)+ 137 ( 10 -> 54) [( 1.3761e+01,-5.7607e+00,-8.4000e+00,-9.2239e+00), 5.4085e-01] (0,0)  
Outgoing particles :  
[D] 1 pi+ 138 ( 54 -> ) [( 3.2455e+00,-1.2680e+00,-1.8071e+00,-2.3749e+00), 1.9480e-02] (0,0)  
[d] 1 pi 139 ( 54 -> 55) [( 1.0516e+01,-4.4927e+00,-6.5929e+00,-6.8490e+00), 1.8220e-02] (0,0)

Blob [1]( 55, Hadron Decay , 1 -> 2 @ (0.001351,-0.0005772,-0.0008469,-0.0008799)

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Incoming particles :
[d] 1 pi      139 ( 54 -> 55) [( 1.0516e+01,-4.4927e+00,-6.5929e+00,-6.8490e+00), 1.8220e-02] (0,0)
Outgoing particles :
[D] 1 photon  140 ( 55 -> ) [( 1.3676e+00,-6.2195e-01,-8.5715e-01,-8.6538e-01),-1.5543e-15] (0,0)
[D] 1 photon  141 ( 55 -> ) [( 9.1479e+00,-3.8707e+00,-5.7357e+00,-5.9836e+00),-1.4211e-14] (0,0)

Blob [1]( 56, Hadron Decay      , 1 -> 2 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)
Incoming particles :
[p] 1 anti-K*(892)  144 ( 10 -> 56) [( 2.4235e+01,-9.8402e+00,-1.4601e+01,-1.6632e+01), 6.8819e-01] (0,0)
Outgoing particles :
[d] 1 anti-K      145 ( 56 -> 57) [( 2.1319e+01,-8.8081e+00,-1.2793e+01,-1.4595e+01), 2.4768e-01] (0,0)
[d] 1 pi          147 ( 56 -> 58) [( 2.9158e+00,-1.0320e+00,-1.8082e+00,-2.0370e+00), 1.8220e-02] (0,0)

Blob [1]( 57, Hadron Decay      , 1 -> 1 @ (2.504e-09,-2.652e-08,2.612e-08,2.504e-09)
Incoming particles :
[d] 1 anti-K      145 ( 56 -> 57) [( 2.1319e+01,-8.8081e+00,-1.2793e+01,-1.4595e+01), 2.4768e-01] (0,0)
Outgoing particles :
[D] 1 K(L)        146 ( 57 -> ) [( 2.1319e+01,-8.8081e+00,-1.2793e+01,-1.4595e+01), 2.4768e-01] (0,0)

Blob [1]( 58, Hadron Decay      , 1 -> 3 @ (8.56e-05,-3.032e-05,-5.306e-05,-5.98e-05)
Incoming particles :
[d] 1 pi          147 ( 56 -> 58) [( 2.9158e+00,-1.0320e+00,-1.8082e+00,-2.0370e+00), 1.8220e-02] (0,0)
Outgoing particles :
[D] 1 photon      148 ( 58 -> ) [( 1.7688e+00,-6.0006e-01,-1.1475e+00,-1.2048e+00), 1.3323e-15] (0,0)
[D] 1 e+          149 ( 58 -> ) [( 6.9901e-01,-2.6415e-01,-3.9638e-01,-5.1159e-01), 2.6010e-07] (0,0)
[D] 1 e-          150 ( 58 -> ) [( 4.4805e-01,-1.6783e-01,-2.6423e-01,-3.2058e-01), 2.6010e-07] (0,0)

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