CRMC exercise

CRMC

Cosmic **R**ay **M**onte **C**arlo:

common interface to the hadronic interaction models used in Cosmic Ray physics

Reference : C. Baus, T. Pierog and R. Ulrich. To be published (2016)
(please ask colin.baus@alumni.kit.edu when needed)

Available models:

post-LHC: EPOS-LHC (-m0), QGSJETII-04 (-m7), SIBYLL 2.3c(-m6)

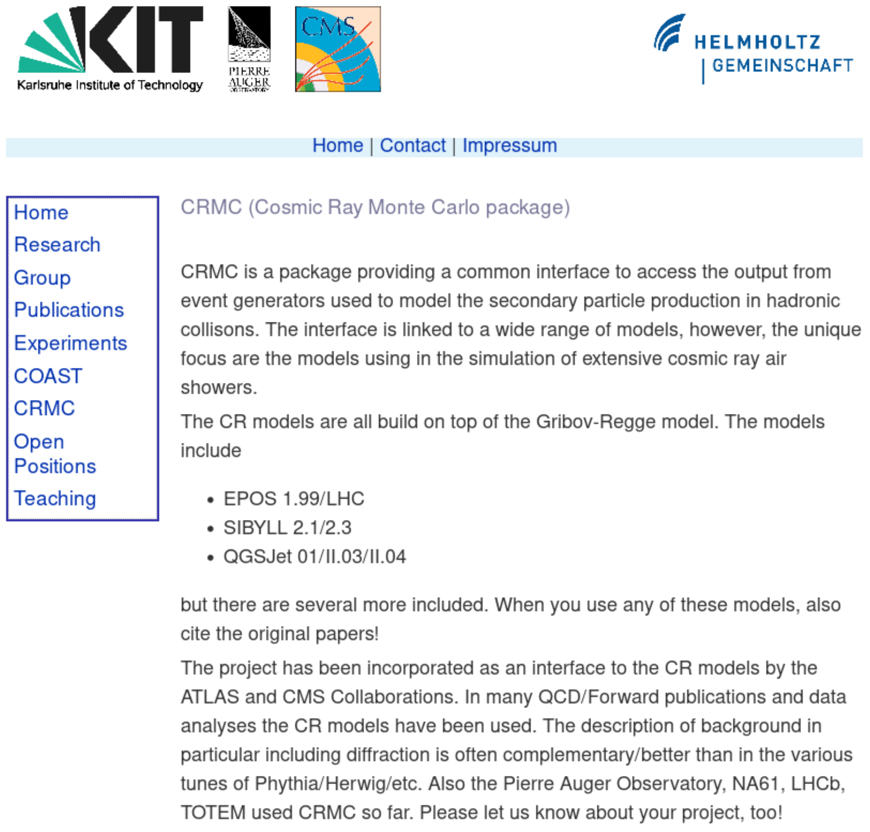
pre-LHC: EPOS 1.99 (-m1), QGSJET01 (-m2), QGSJETII-03 (-m11), DPMJET 3.06

Where to get CRMC ?

CRMC
webpage:

https://web.ikp.kit.edu/rulrich/crmc.html

CORSIKA school: distributed on USB/VM



CRMC (Cosmic Ray Monte Carlo package)

CRMC is a package providing a common interface to access the output from event generators used to model the secondary particle production in hadronic collisons. The interface is linked to a wide range of models, however, the unique focus are the models using in the simulation of extensive cosmic ray air showers.

The CR models are all build on top of the Gribov-Regge model. The models include

- EPOS 1.99/LHC
- SIBYLL 2.1/2.3
- QGSJet 01/II.03/II.04

but there are several more included. When you use any of these models, also cite the original papers!

The project has been incorporated as an interface to the CR models by the ATLAS and CMS Collaborations. In many QCD/Forward publications and data analyses the CR models have been used. The description of background in particular including diffraction is often complementary/better than in the various tunes of Phythia/Herwig/etc. Also the Pierre Auger Observatory, NA61, LHCb, TOTEM used CRMC so far. Please let us know about your project, too!

How to install / compile ?

pre-requisites: BOOST, HEPMC, CMAKE

(all present on VM)

Principal steps:

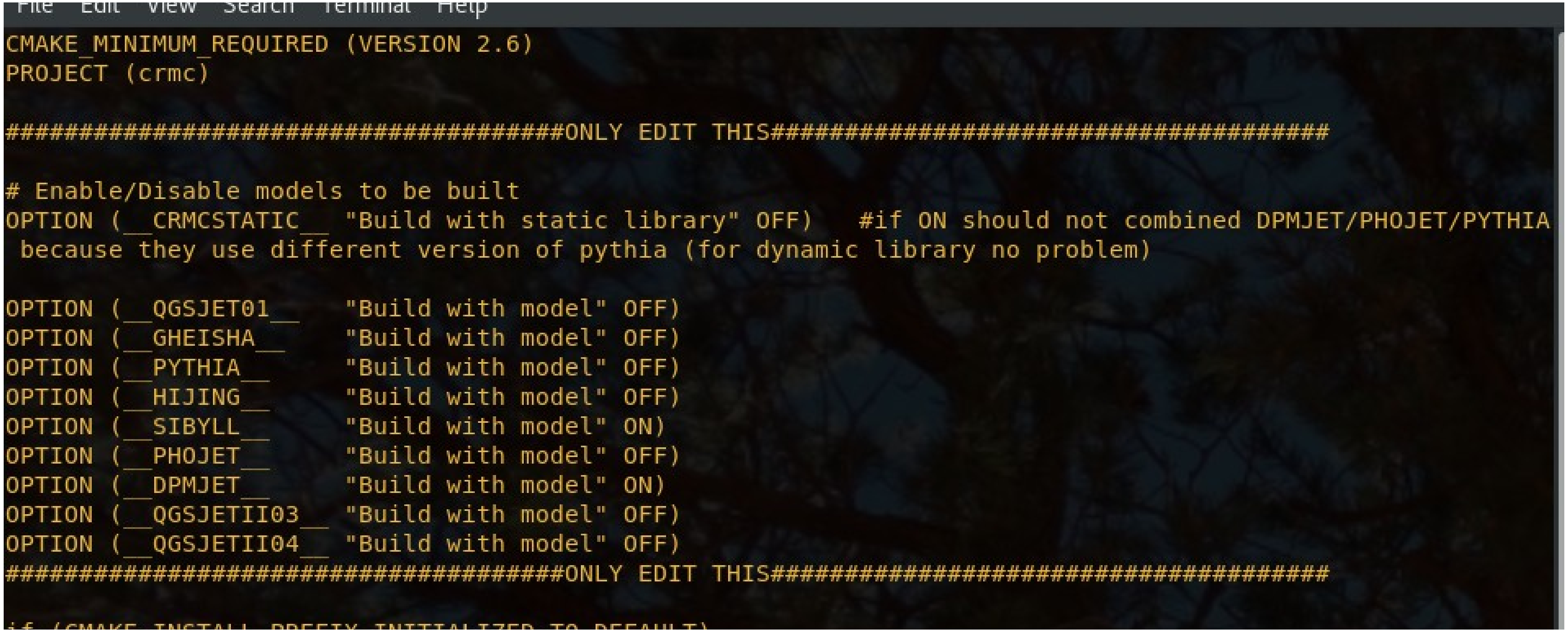
1. unpack
2. configure
3. prepare install directory
4. cmake
5. make
6. make install

⚠ 2. Configure step

Not all models active by default.
E.g. to use QGSjetII04 need to edit 'CmakeLists.txt' to activate

Configure

In main directory of crmc-archive: CMakeLists.txt



```
CMAKE_MINIMUM_REQUIRED (VERSION 2.6)
PROJECT (crmc)

######################################ONLY EDIT THIS######################################

# Enable/Disable models to be built
OPTION (__CRMCSTATIC__ "Build with static library" OFF)   #if ON should not combined DPMJET/PHOJET/PYTHIA
 because they use different version of pythia (for dynamic library no problem)

OPTION (__QGSJET01__   "Build with model" OFF)
OPTION (__GHEISHA__    "Build with model" OFF)
OPTION (__PYTHIA__     "Build with model" OFF)
OPTION (__HIJING__     "Build with model" OFF)
OPTION (__SIBYLL__     "Build with model" ON)
OPTION (__PHOJET__     "Build with model" OFF)
OPTION (__DPMJET__     "Build with model" ON)
OPTION (__QGSJETII03__ "Build with model" OFF)
OPTION (__QGSJETII04__ "Build with model" OFF)
######################################ONLY EDIT THIS######################################

if (CMAKE_INSTALL_PREFIX_INITIALIZED_TO_DEFAULT)
```

How to install, step-by-step

1. unpack

```
tar -xvzf <crmc-archive>
cd <crmc-dir>
```

2. configure

   edit CmakeLists.txt

3. prepare install & build directory

```
mkdir build
mkdir ../<crmc-dir>-install
cd build
```

4. cmake -DCMAKE_INSTALL_PREFIX=<path to crmc-dir-install> ../

   e.g. on VM for ISAPP school:

```
cmake -DCMAKE_INSTALL_PREFIX=/home/isapp2018/work/crmc.v1.7.0-install ../
```

How to install, step-by-step II

5. make

   cross fingers

6. make install

To test crmc:

```
cd <crmc-dir-install>
./bin/crmc -m6 -T
```

Configuration file

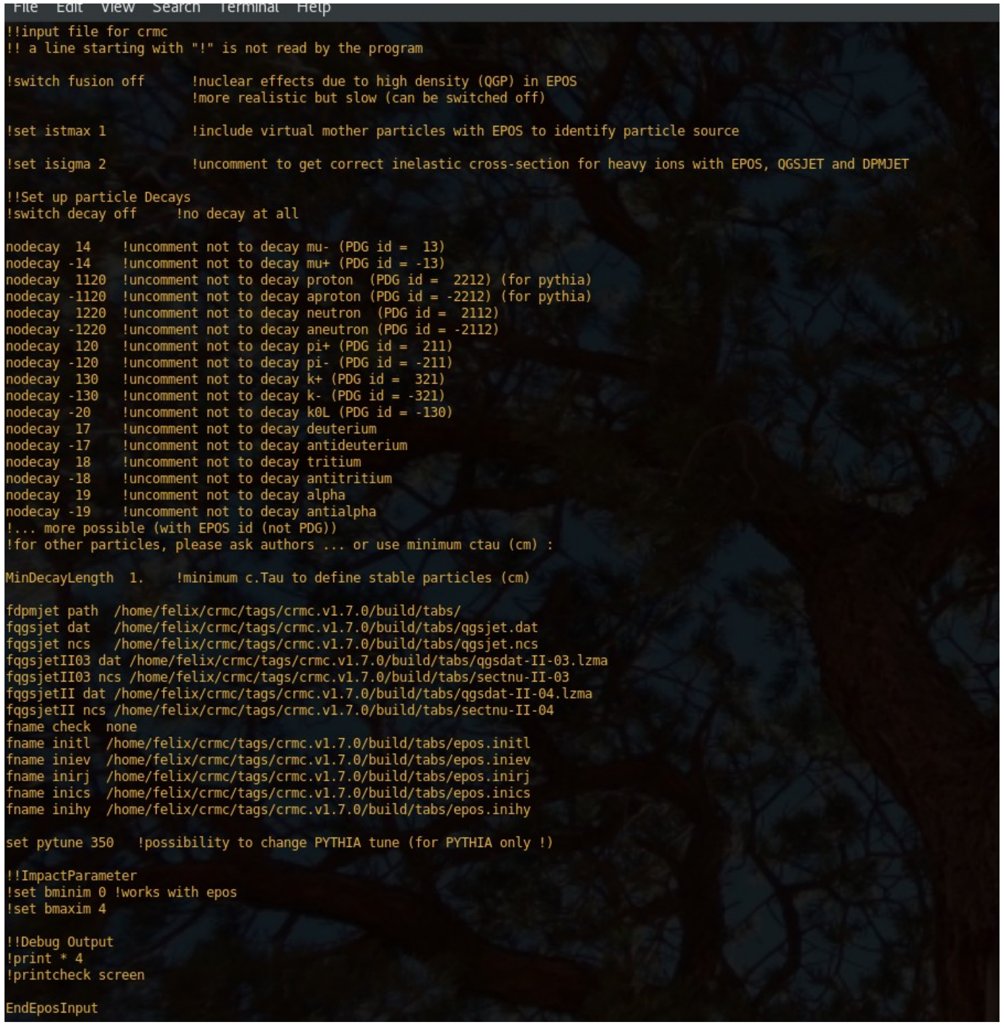
Default location:

<crmc-dir-install>/crmc.param

Copy into your working directory!

* Defines stable/unstable particles

* can be used to configure
  interaction models



```
!!input file for crmc
!! a line starting with "!" is not read by the program

!switch fusion off      !nuclear effects due to high density (QGP) in EPOS
                        !more realistic but slow (can be switched off)

!set istmax 1           !include virtual mother particles with EPOS to identify particle source

!set isigma 2           !uncomment to get correct inelastic cross-section for heavy ions with EPOS, QGSJET and DPMJET

!!Set up particle Decays
!switch decay off     !no decay at all

nodecay  14    !uncomment not to decay mu- (PDG id =  13)
nodecay -14    !uncomment not to decay mu+ (PDG id = -13)
nodecay  1120  !uncomment not to decay proton  (PDG id =  2212) (for pythia)
nodecay -1120  !uncomment not to decay aproton (PDG id = -2212) (for pythia)
nodecay  1220  !uncomment not to decay neutron  (PDG id =  2112)
nodecay -1220  !uncomment not to decay aneutron (PDG id = -2112)
nodecay  120   !uncomment not to decay pi+ (PDG id =  211)
nodecay -120   !uncomment not to decay pi- (PDG id = -211)
nodecay  130   !uncomment not to decay k+ (PDG id =  321)
nodecay -130   !uncomment not to decay k- (PDG id = -321)
nodecay -20    !uncomment not to decay k0L (PDG id = -130)
nodecay  17    !uncomment not to decay deuterium
nodecay -17    !uncomment not to decay antideuterium
nodecay  18    !uncomment not to decay tritium
nodecay -18    !uncomment not to decay antitritium
nodecay  19    !uncomment not to decay alpha
nodecay -19    !uncomment not to decay antialpha
!... more possible (with EPOS id (not PDG))
!for other particles, please ask authors ... or use minimum ctau (cm) :

MinDecayLength  1.    !minimum c.Tau to define stable particles (cm)

fdpmjet path  /home/felix/crmc/tags/crmc.v1.7.0/build/tabs/
fqgsjet dat   /home/felix/crmc/tags/crmc.v1.7.0/build/tabs/qgsjet.dat
fqgsjet ncs   /home/felix/crmc/tags/crmc.v1.7.0/build/tabs/qgsjet.ncs
fqgsjetII03 dat /home/felix/crmc/tags/crmc.v1.7.0/build/tabs/qgsdat-II-03.lzma
fqgsjetII03 ncs /home/felix/crmc/tags/crmc.v1.7.0/build/tabs/sectnu-II-03
fqgsjetII dat /home/felix/crmc/tags/crmc.v1.7.0/build/tabs/qgsdat-II-04.lzma
fqgsjetII ncs /home/felix/crmc/tags/crmc.v1.7.0/build/tabs/sectnu-II-04
fname check  none
fname initl  /home/felix/crmc/tags/crmc.v1.7.0/build/tabs/epos.initl
fname iniev  /home/felix/crmc/tags/crmc.v1.7.0/build/tabs/epos.iniev
fname inirj  /home/felix/crmc/tags/crmc.v1.7.0/build/tabs/epos.inirj
fname inics  /home/felix/crmc/tags/crmc.v1.7.0/build/tabs/epos.inics
fname inihy  /home/felix/crmc/tags/crmc.v1.7.0/build/tabs/epos.inihy

set pytune 350   !possibility to change PYTHIA tune (for PYTHIA only !)

!!ImpactParameter
!set bminim 0 !works with epos
!set bmaxim 4

!!Debug Output
!print * 4
!printcheck screen

EndEposInput
```

How to use ?

(add <crmc-dir>/bin to PATH variable!)
On ISAPP VM:
‘export PATH=$PATH:/home/isapp2018/crmc.v1.7.0-install/bin’

Input: beam particles, beam momenta

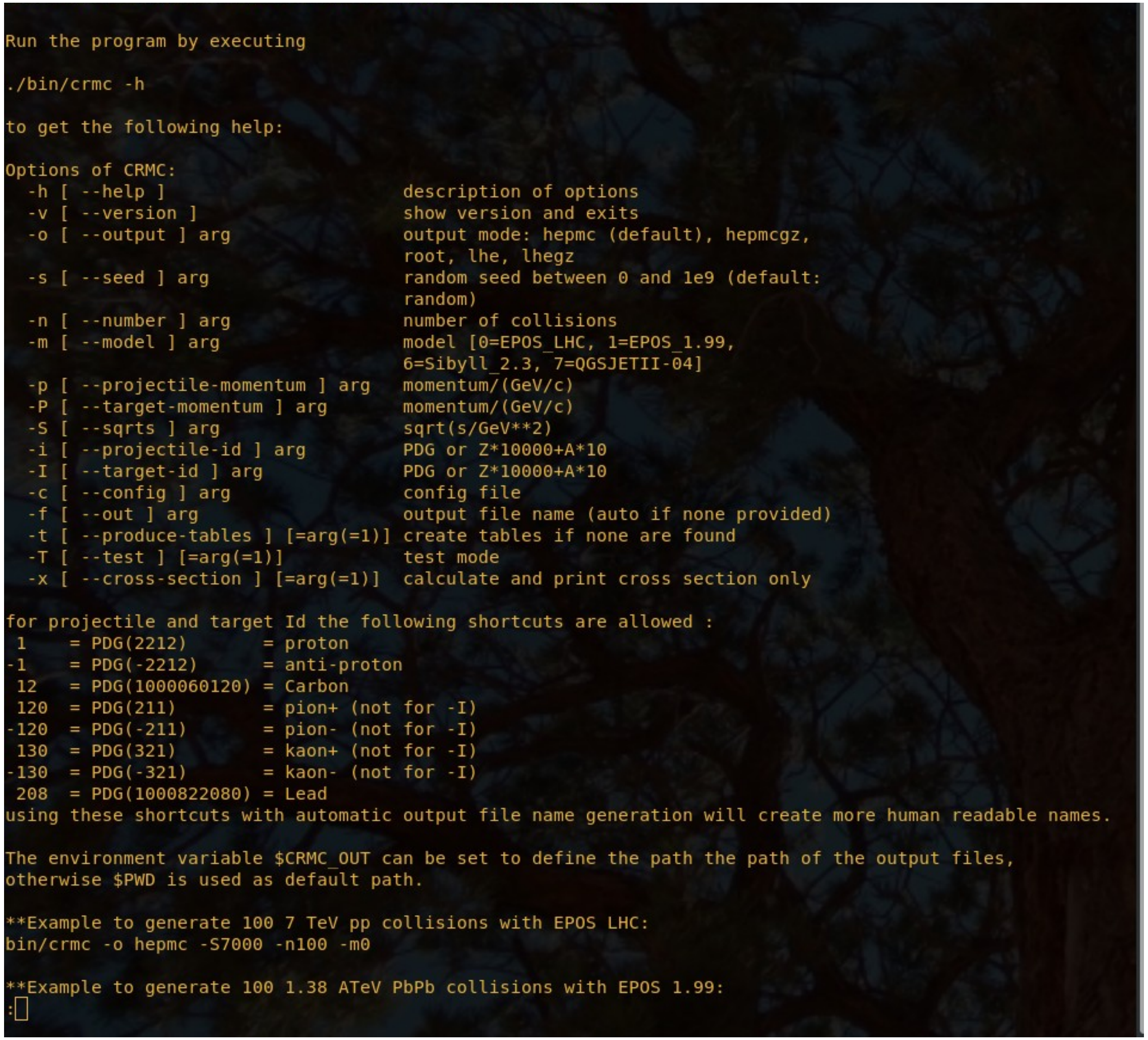
e.g. create LHC p-p events at 7TeV with SIBYLL

```
crmc -m6 -i 2212 -p 3500. -I 2212 -P 3500.
```

Or

```
crmc -m6 -i 2212 -I 2212 -s 7000.
```

Options:



```
Run the program by executing

./bin/crmc -h

to get the following help:

Options of CRMC:
  -h [ --help ]                          description of options
  -v [ --version ]                       show version and exits
  -o [ --output ] arg                    output mode: hepmc (default), hepmcgz,
                                         root, lhe, lhegz
  -s [ --seed ] arg                      random seed between 0 and 1e9 (default:
                                         random)
  -n [ --number ] arg                    number of collisions
  -m [ --model ] arg                     model [0=EPOS_LHC, 1=EPOS_1.99,
                                         6=Sibyll_2.3, 7=QGSJETII-04]
  -p [ --projectile-momentum ] arg       momentum/(GeV/c)
  -P [ --target-momentum ] arg           momentum/(GeV/c)
  -S [ --sqrts ] arg                     sqrt(s/GeV**2)
  -i [ --projectile-id ] arg             PDG or Z*10000+A*10
  -I [ --target-id ] arg                 PDG or Z*10000+A*10
  -c [ --config ] arg                    config file
  -f [ --out ] arg                       output file name (auto if none provided)
  -t [ --produce-tables ] [=arg(=1)]     create tables if none are found
  -T [ --test ] [=arg(=1)]               test mode
  -x [ --cross-section ] [=arg(=1)]      calculate and print cross section only

for projectile and target Id the following shortcuts are allowed :
 1     = PDG(2212)        = proton
-1     = PDG(-2212)       = anti-proton
 12    = PDG(1000060120)  = Carbon
 120   = PDG(211)         = pion+ (not for -I)
-120   = PDG(-211)        = pion- (not for -I)
 130   = PDG(321)         = kaon+ (not for -I)
-130   = PDG(-321)        = kaon- (not for -I)
 208   = PDG(1000822080)  = Lead
using these shortcuts with automatic output file name generation will create more human readable names.

The environment variable $CRMC_OUT can be set to define the path the path of the output files,
otherwise $PWD is used as default path.

**Example to generate 100 7 TeV pp collisions with EPOS LHC:
bin/crmc -o hepmc -S7000 -n100 -m0

**Example to generate 100 1.38 ATeV PbPb collisions with EPOS 1.99:
:
```

Exercises

Get exercise sheet and crmc-exercises.tar.gz
from the school webpage

What we are going to learn:

1. How to run CRMC in different configurations

2. How to run CRMC and create event files, run RIVET

3. How to write your own analysis in HEPMC

PDG ids

Proton 2212
Pi+ 211

Nuclei: Z*10000+A*10

More:

http://pdg.lbl.gov/2007/reviews/montecarlorpp.pdf

Or see .pdf in crmc-exercise directory

Common options are printed by help: “crmc -h”

RIVET

https://rivet.hepforge.org/

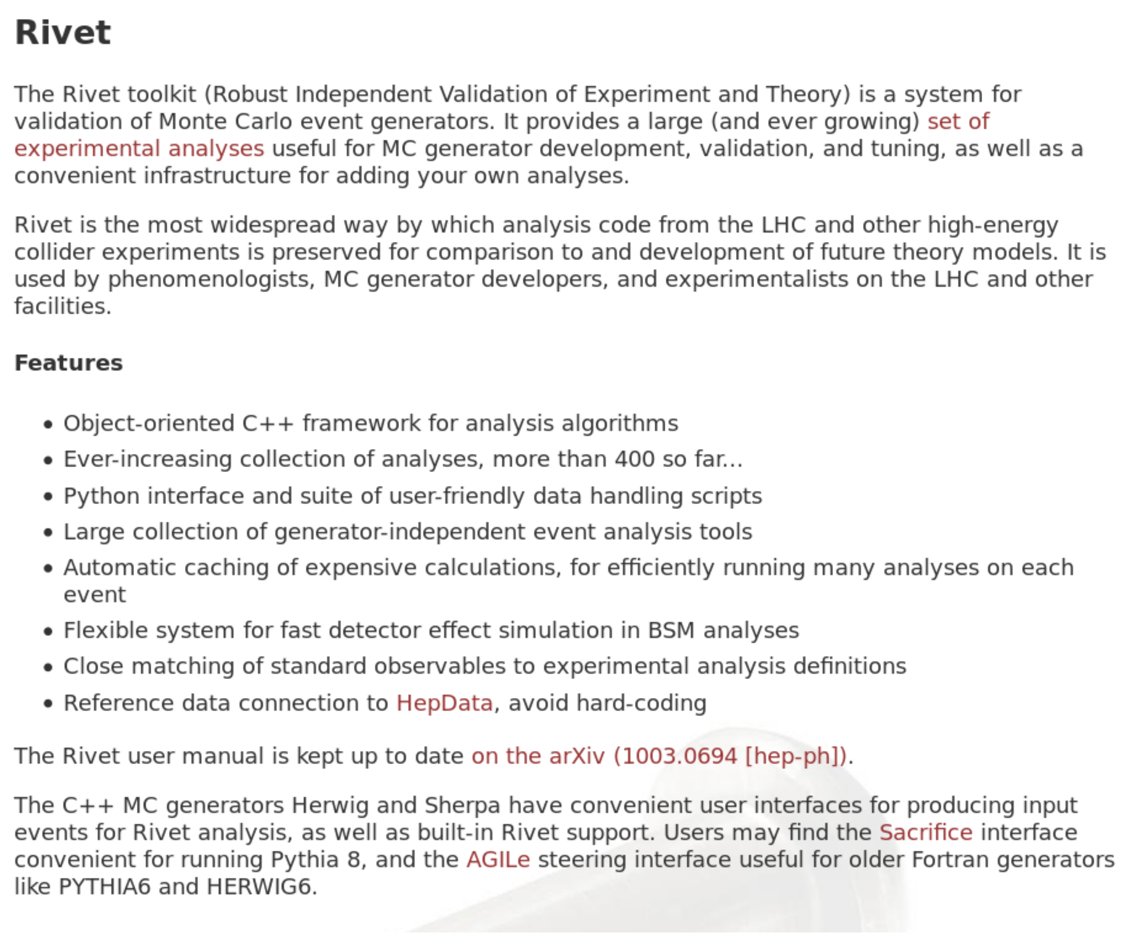
Easily compare theory with experiment.

Experimental analyses pre-implemented

‘rivet -h’
‘rivet - - list’ to see all analyses

‘rivet-mkhtml’

See exercise 2



Rivet

The Rivet toolkit (Robust Independent Validation of Experiment and Theory) is a system for validation of Monte Carlo event generators. It provides a large (and ever growing) set of experimental analyses useful for MC generator development, validation, and tuning, as well as a convenient infrastructure for adding your own analyses.

Rivet is the most widespread way by which analysis code from the LHC and other high-energy collider experiments is preserved for comparison to and development of future theory models. It is used by phenomenologists, MC generator developers, and experimentalists on the LHC and other facilities.

Features

- Object-oriented C++ framework for analysis algorithms
- Ever-increasing collection of analyses, more than 400 so far...
- Python interface and suite of user-friendly data handling scripts
- Large collection of generator-independent event analysis tools
- Automatic caching of expensive calculations, for efficiently running many analyses on each event
- Flexible system for fast detector effect simulation in BSM analyses
- Close matching of standard observables to experimental analysis definitions
- Reference data connection to HepData, avoid hard-coding

The Rivet user manual is kept up to date on the arXiv (1003.0694 [hep-ph]).

The C++ MC generators Herwig and Sherpa have convenient user interfaces for producing input events for Rivet analysis, as well as built-in Rivet support. Users may find the Sacrifice interface convenient for running Pythia 8, and the AGILe steering interface useful for older Fortran generators like PYTHIA6 and HERWIG6.

HEPMC

The output format of CRMC is stored in HEPMC file format.

http://hepmc.web.cern.ch/hepmc/

These events are stored in human-readable ASCII

C++ library with same name that reads these files and provides iterators and things..

→ see exercise 3

For example: each particle in the file is a GenParticle object

GenParticle has a member “momentum” of type FourVector