Part 1 – Set up the environment

1. Login to one of the CMS workgroup servers:
   
   ssh -X naf-cms.desy.de

1. Create a directory e.g. “rivet”. Go to that directory.

2. The software you need is already installed at DESY. In order to use it, you need to set the correct environment variables. For convenience you can copy
   
   /afs/desy.de/user/j/jung/public/summerstudents/2021/setup.sh

   to your home directory. Run it with:
   
   source setup.sh

   Note: You need to initiate the correct environment each time you login to a workgroup server.

3. Check available Rivet analyses with rivet --list-analyses.
   
   If you have analyses proceed to the next step.

4. To run the generator, copy all the PYTHIA directory to your own directory:
   
   mkdir pythia
   
   cp -rp /afs/desy.de/user/j/jung/public/summerstudents/2021/pythia .

Part 2 – Event Generation and Coding

A documentation on Rivet you will find on http://projects.hepforge.org/rivet/.

There are two option to start: running directly the MC generator and analyzing events in one go, or using pre-generated hepmc events and run only rivet.

1. Either running MC generator and Rivet

   The most important commands are given below.

   Generate 1000 events in $e^+ e^-$ with the Pythia MC generator and analyze the output by using an existing analysis routine. For example DELPHI_1991_I324035.cc, which is an analysis of charged particles.

   Use a FIFO (First-In-First-Out) Linux pipe on the /tmp area:

   cd bin
   mkdir /tmp/$(whoami)
   mkfifo /tmp/$(whoami)/myhepmc.fifo
   rm output.out
   export HEMPCOUT=/tmp/$(whoami)/myhepmc.fifo
   export PYSEED=12345
   nice ./main31 > output.out&
   rivet --analysis=DELPHI_1991_I324035 $HEMPCOUT

   (Note the &-sign after the main31 line, which makes PYTHIA run in the background. You want to fill the output file with events at the same time as you run your analysis.)

   To avoid typing in too many commands every time you want to run the program, copy the script runscript.sh from /afs/desy.de/user/j/jung/public/summerstudents/2021/pythia/bin to your directory
pythia/bin/.
edit runscript.sh and change HEPMCOUT to /tmp/$(whoami)/myhepmc.fifo
run the script with
./runscript.sh

5. **Or** running with pre-generated hepmc events:
   cd bin
   mkdir /tmp/$(whoami)
   mkfifo /tmp/$(whoami)/myhepmc.fifo
   rm output.out
   export HEPMCOUT=ee-Z0.hepmc.gz
   rivet --analysis=DELPHI_1991_I324035 $HEPMCOUT

6. Look at your MC predictions by creating a html page:
   rivet-mkhtml --mc-errs -o myrivet Rivet.yoda:"Title=mytest"
   this will create a html page in directory myrivet from the file rivet.yoda with title="mytest"

7. Create a new analysis routine with only the most essential parts “Init()”, “Analyze()”
   , “Finalize()”. Looking at the code DELPHI_1991_I324035.cc will be of help. You find these
   analyses under
   https://rivet.hepforge.org/analyses/DELPHI_1991_I324035.html
   You can create a new analysis template with:
   rivet-mkanalysis myanalysis
   Command for compiling your code: rivet-buildplugin RivetMyCode.so myanalysis.cc
   Compile your code and use your routine to “analyse” 25 events from the Pythia MC generator.
   Make a “Hello World”.print statement in the “Analyze()”-part to be sure the routine is running.
   You should see the print-out for each event. Add print statements also in Init() and Finalize() to
   be sure these functions are used.

8. Add the charged particle projection to your code. Print out the number of charge particles for
   each event instead of “Hello World”. Hint: Look inside DELPHI_1991_I324035.cc.
   export RIVET_ANALYSIS_PATH=full_path_name_to_where_RivetMyCode.so

9. Calculate and print the transverse momentum and pseudo rapidity of the charged particles.
   Compare your calculated values with the values provided by the particles momentum()
   member functions.

10. study the MC event record: use READ_HEPMC, which needs to be compiled

**Part 3 – Histogramming**

11. Create histograms for \( \eta \), \( \phi \) and \( p_t \) in Init(). (Here CMS_2010_S8656010.cc can help as a guide)

12. Fill histograms with \( \eta \), \( \phi \) and \( p_t \) of the charged particles. Generate 10 000 \( e^+e^- \) collisions with
    a center of mass energy of 92 GeV. This corresponds to the energy LEP1 was running.

13. In “Finalize()”, normalize the histograms to the number of events.

**Part 4 – Plotting**

14. Plot the distributions of \( \eta \), \( \phi \) and \( p_t \) respectively. Make plots with rivet-mkhtml

**Part 5 – Physics**

Change some of the MC generator steering parameters. For example:

15. switch off parton showers