YETI 2009 Tutorials: Day 2
Z+Jets

For today's session, you will be working in small groups to create data for Z+jets events. At the end of the tutorial you will combine your results and discuss them.

1 ME Level

1.1 Physics

The signal process in event generation is calculated perturbatively using matrix elements. In this section of the tutorial, we will look at the effects on observables of adding additional hard radiation in the matrix element to production of Z-bosons.

1.2 Running Sherpa

The setups for this section can be copied from the folders **'max0jet'**, **'max1jet'** and **'max2jet'** in the directory `/mt/data-grid/yeti/setups/z+jets/ME`. For example:

```
mkdir ME
cd ME
mkdir max0jet
cp  /mt/data-grid/yeti/setups/z+jets/ME/max0jet/Run.dat  max0jet/
cd max0jet
```

Take a look at the **'Run.dat'** files. In particular, look at the (processes) section to see the number of additional jets produced by the matrix element. Also inspect the shower settings, which basically disable the shower.
Once you are satisfied, create a fifo pipe, and then run Sherpa and Rivet using the commands below. Remember that the long Rivet and Sherpa command must be on one line.

```
mkfifo fifo.hepmc2g
rivetgun -a MC_TVT1960_ZJETS -a CDF_2008_S7540469 -a D0_2008_S7863608
  -a D0_2007_S7075677 -a D0_2008_S7554427 -H maxXjet -i fifo.hepmc2g
  -n 100000 & Sherpa EVENTS=100000
```

where the 'X' in `maxXjet` is the relevant number between 0 and 2.

1.3 Plotting your Results

Collect results from other members of your group by copying all relevant '.aida' files to a common directory (use scp to transfer files to another user's home directory).
To plot your results, open a terminal in your Vega window (not on the cluster node!), and enter the following two commands:

```
compare-histos $DATADIR/CDF_2008_S7540469.aida $DATADIR/D0_2007_S7075677.aida
  $DATADIR/D0_2008_S7554427.aida $DATADIR/D0_2008_S7863608.aida
  max0jet.aida:'max0jet' max1jet.aida:'max1jet' max2jet.aida:'max2jet'
make-plots D0*.dat CDF*.dat MC*.dat
```

This produces plots in .ps files, which you can view using, for example, the command **'gv CDF_2008_S7540469-d01-x01-y01.ps'** etc.
Why is the agreement with data in the low $p_\perp$ region so poor? Can you see where the effect of multi-jet events shows up?
For the "max0jet" sample, one would naively expect the $p_\perp$ of the Z boson to be 0 (why?). But as you should see, it does get a very soft $p_\perp$ kick. Do you have any idea, where that comes from?

2 ME/PS Merging

2.1 Physics

Monte Carlo event generators generally rely on separating events into different stages. As mentioned above, the hard interaction is calculated perturbatively using the matrix element approach. However, the computational work required for this increases approximately factorially with the order, so it is not realistically possible to calculate high-multiplicity events using purely this method.
The parton shower describes the soft and collinear emissions from final state partons by resumming the leading logarithmic terms. However, as the non-leading terms are neglected, the parton shower does not describe hard or wide-angled parton emission well.
Therefore, the multi-jet phase space is separated into two regions, with the hard, wide-angled emissions described by the matrix element, and the soft, collinear emissions described by the parton shower. Sherpa employs a procedure called CKKW merging to combine the matrix elements with the parton shower, while avoiding double-counting of phase space, and minimizing the dependence on the choice of phase space cut.
This tutorial will give you the opportunity to compare the radiation patterns produced from tree-level matrix element calculations with the corresponding parton shower results, by comparing results of event generation with a maximum of 0, 1, 2, or 3 jets in the matrix element.
Please note: *The comparison of results for different numbers of jets in the matrix element is just an exercise for this tutorial. When using ME/PS merging it is always advisable to have as many jets as computationally possible in the matrix element.*

2.2 Running Sherpa

Within your group, decide which jet multiplicities each member will run. Remember that the higher the jet multiplicity, the longer the run will take. The setups can be copied from folders named **'max0jet'**, **'max1jet'**, **'max2jet'** and **'max3jet'** in the directory `/mt/data-grid/yeti/setups/z+jets/merging`. Take a look at the **'Run.dat'** which you copied into your working directory for this run. In particular, look at the (processes) section, and check that you are generating events with the correct number of jets in the final state.
Once you are satisfied, create a fifo pipe, and then run Sherpa and Rivet using the commands below. Remember that the long Rivet and Sherpa command must be on one line.

```
mkfifo fifo.hepmc2g
rivetgun -a MC_TVT1960_ZJETS -a CDF_2008_S7540469 -a D0_2008_S7863608
  -a D0_2007_S7075677 -a D0_2008_S7554427 -H maxXjet -i fifo.hepmc2g
  -n 100000 & Sherpa EVENTS=100000
```

where the 'X' in `maxXjet` is the relevant number between 0 and 3.

2.3 Plotting your Results

Collect results from other members of your group by copying all relevant '.aida' files to a common directory (use scp to transfer files to another users home directory).
To plot your results, open a terminal in your Vega window (not on the cluster node!), and enter the following two commands:

```
compare-histos $DATADIR/CDF_2008_S7540469.aida  $DATADIR/D0_2008_S7863608.aida
  $DATADIR/D0_2007_S7075677.aida $DATADIR/D0_2008_S7554427.aida
  max0jet.aida:'Max 0 jets' max1jet.aida:'Max 1 jets'
  max2jet.aida:'Max 2 jets' max3jet.aida:'Max 3 jets'
make-plots D0*.dat CDF*.dat MC*.dat
```

This produces plots in .ps files, which you can view using, for example, the command **'gv CDF_2008_S7540469-d01-x01-y01.ps'** etc.

3 QED Radiation

3.1 Physics

As well as the QCD effects that produce jets, there are also QED effects from radiated photons. In this part of the tutorial, we are going to look at the effect of this QED radiation by considering three different cases:

- a possible additional photon included in the matrix element, with no final state QED shower
- no additional photon in the matrix element, with final state QED shower turned on
- no QED radiation in either the matix element or shower.

3.2 Running Sherpa

The three setups described above can be copied from folders **'QED_ME'**, **'QED_PS'**, and **'QEDoff'** in `/mt/data-grid/yeti/setups/z+jets/QEDradiation`. Within your group, decide which setup each member will run.
Take a look at **'Run.dat'** which you copied into your working directory for this run. In particular, check in the (processes) section to see if QED radiation is included in the matrix element, and in the (shower) section to see if final state QED radiation is turned on or off in the shower.
Run Sherpa and Rivet using the command:

```
mkfifo fifo.hepmc2g
rivetgun -a MC_TVT1960_ZJETS -a MC_TVT1960_ZJETS_NOQED
  -H QED* -i fifo.hepmc2g -n 100000 & Sherpa EVENTS=100000
```

where the * in 'QED*' is either '_ME', '_PS' or 'off'. Here we are running two pseudo-analyses (i.e. without reference data), on the one hand to compare the runs, and on the other hand to compare two different analyses: In `MC_TVT1960_ZJETS`, the QED radiation in a cone around the lepton has been accounted for in the Z reconstruction, while in `MC_TVT1960_ZJETS_NOQED` this radiation has been ignored.

3.3 Plotting your Results

To plot your results, open a terminal in your Vega window (not on the cluster node!), and enter the following two commands:

```
compare-histos QED_ME.aida:'QED from ME' QED_PS.aida:'QED from PS' QEDoff.aida:'No QED'
make-plots MC*.dat
```

This again produces .ps files, which you can view using, for example, **'gv MC_TVT1960_ZJETS-Z_mass.ps'**.
Which differences can you see between the runs and analyses in the different observables?