Basics of QCD
Tutorial: jet finding

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1. Log in, open a terminal, create a directory and go into that directory (e.g. `mkdir fjtutorial; cd fjtutorial`)
2. Open the webpage for the fastjet tutorial: `http://fastjet.fr/quickstart.html`.
   The tutorial has instructions for the compilation of fastjet, but you don't need to following these because it's already installed on the computers.
   That same page gives you access to the fastjet manual (and doxygen reference).
3. Copy the example program and paste into a file `short-example.cc`
4. Compile it with

```
g++ short-example.cc -o short-example \
          `fastjet-config --libs --cxxflags`
```

   (watch out, those are "backquotes")
5. Run it with
   `./short-example`

Check infrared and collinear safety

- Identify the part of the program that specifies the input particles.
- Split one of the particles collinearly. Do the jets change?
- Add a soft particle to the event. Do the hard jets (those above some p_t threshold) change?

An example analysis: looking for a WW resonance

There are three files on the USB stick:

- `dijets-ptmingen400-nev1e4.PU14.gz`: a background sample (dijets)
- `Zp2WW-2TeV-nev1e3.PU14.gz`: an example signal sample (WW resonance decaying hadronically)
- `mixed.PU14.gz`: a sample with background and (maybe) signal.

Execute the following commands to build a very simple analysis program, run it on the background and sample signal and plot histograms with the result

```
make
./VV-search dijets-ptmingen400-nev1e4.PU14.gz dijets.hist 5000
./VV-search Zp2WW-2TeV-nev1e3.PU14.gz         signal.hist 1000
gnuplot plot.gp
gv plot.ps
```

The plot file shows a smooth background and a large signal; for now the second page is identical to the first.

You can inspect output histogram files (`dijets.hist`). When running `VV-search` you can also change the number of events (5000, 1000) up to the maximum contained in the file.

Now run the mixed sample, look at the histogram. Do you see a signal? (You may want to edit the .gp file to examine the results from the mixed sample).

Starting to pull out a signal

Inspect `VV-search.cc` to see what it does (only the most basic jet cuts).

Now try improving things (put the extra cuts after the line "`HERE YOU CAN PLACE...`"

- Place a cut on the rapidity difference between the two leading jets $|y_1 - y_2| < 1.2$.

  Can you figure out why this cut is so effective at high dijet masses? (Think about the propagators in signal and background processes).
- Place cuts on the jet masses: require each jet to be have a mass between 70 GeV and 100 GeV (you can access the mass of jet `i` through `jets[i].m()`)
- You might want to add a histogram with the jet-mass distributions (or print out some values, before the jet-mass cut), to see how signal and background differ. [optional!]
- Try running the mixed sample again: do you start to see anything? At what mass? With what significance? (You'll probably need to run the full 10^5 events in the sample)

Can you get to 5σ?

Try using the mass-drop tagger illustrated in the lecture to improve things further. Define a mass-drop tagger

```
double mucut = 1.0, ycut = 0.20;
MassDropTagger mdt(mucut, ycut);
```

And then for each of the jets, apply it

```
jets[i] = mdt(jets[i]);
```

Then apply the jet-mass cuts (and deduce the dijet mass) with these transformed jets.