Exercises for Tutorial 2

Gavin Salam, Edinburgh Jet Lectures
Tutors: Enrico Bothmann, Leonardo Vernazza

May/June 2017

1 Infrared and Collinear safety

Recall the definitions of infrared and collinear safety:

> Infrared safety: invariance of a observable under emission of an extra soft particle.
>
> Collinear safety: invariance of an observable under splitting of a particle into two collinear ones.

For each of the following observables, establish if they are infrared safe and if they're collinear safe. It's helpful to imagine concrete examples of events and add IR emissions or collinear splittings.

- The total number of particles in an event.
- The energy of the most energetic ("hardest") particle in an event
- The number of particles with $E > 0.2\sqrt{s}$ where s is the squared centre of mass energy
- The weighted energy-energy correlation sum $\sum_{i=2}^{n} \sum_{j=1}^{i-1} E_i E_j \theta_{ij}^{\beta}$ ($\beta > 0$) (particles in the event are numbered 1 to n)
- The same quantity for $\beta = 0$.
- Considering an $e^+e^- \to$ hadrons event, imagine drawing a cone of opening angle R around every particle. For each cone, determine of the particles contained within that cone. Is the energy of the highest-energy cone IRC safe?

2 Looking at events and clustering them

Get the directory for tutorial 2. If you cloned it with git yesterday, do

```
git stash
git pull
```

and then go to the directory `tutorial-2/pythia-example-2`. Otherwise download a fresh zip file, unpack it and edit the `Makefile` in the above directory so that the path to Pythia points to where you built it yesterday.

The example here (once again called `main01`) generates events $e^+e^- \to Z \to$ hadrons and also contains code to cluster the particles into jets.

Build and run the code

```
make
./main01
```

and then open an interactive session of gnuplot by typing `gnuplot`. From within gnuplot, visualise the particle momenta

```
load 'particles.gp'
```

and then superimpose the jet momenta

```
load 'jets.gp'
```

In some versions of gnuplot you can drag the field of view to get a better 3d-visualisation of the event. (On linux this should work out of the box; on a mac you may have to type something such as `set terminal wxt` prior to the "load" commants).

Now change the value of the `ycut` variable in the code (`main01.cc`) (e.g. to 0.0002 and to 0.2) and repeat the above steps and see how the number of jets changes. .

Put `ycut` back to 0.02 and now change the line in the code that sets the random number seed, so as to generate and visualise a few events. Roughly what fraction of events have 3 or more jets?