Exercises for Tutorial 1

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

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1 Hadron-collider variables

Consider a particle with energy E and three-momentum p. At hadron colliders the most commonly used kinematic variables are transverse momentum (p_t), rapidity (y), defined as

$$y = \frac{1}{2} \ln \frac{E + p_z}{E - p_z}, \tag{1}$$

pseudorapidity (η), defined as

$$\eta = -\ln \tan \frac{\theta}{2}, \tag{2}$$

where θ is the angle of the momentum with respect to the $+z$ direction, and azimuthal angle ϕ,

$$\phi = \arctan \frac{p_y}{p_x}, \tag{3}$$

1. Show that rapidity and pseudorapidity are equal for massless particles.

2. Establish how the rapidity of a particle changes under the effect of a boost with velocity β along the z ("longitudinal") direction.

   What does this imply for the transformation of differences of rapidities of two particles, $\Delta y_{12} = y_1 - y_2$?

3. Why is the simplicity of transformations under longitudinal boosts a useful feature of the rapidity variable at hadron colliders?

4. Show that for two massless particles with rapidity $|y_1|, |y_2| \ll 1$ and $\Delta\phi_{12} = \phi_1 - \phi_2 \ll 1$, (a) $E_i \simeq p_{t,i}$ and (b) $\Delta y_{12}^2 + \Delta\phi_{12}^2 \simeq \theta_{12}^2$, where θ_{12} is the angle between the particles.

5. For a massive particle, is $|y| < |\eta|$ or the other way around?

6. Get a feel for the numbers. The two main LHC experiments have extensive complementary instrumentation for $|\eta| \lesssim 2.5$ and more coarse-grained instrumentation for $2.5 \lesssim |\eta| \lesssim 5$. What angles (with respect to the z axis) do these correspond to?

2 Try out Pythia

Clone the tutorials github repository (if you haven't already done so):

```
git clone https://github.com/gavinsalam/2017-Edinburgh-jet-lectures.git
cd 2017-Edinburgh-jet-lecture/tutorial-1
```

and then run a script to download and install Pythia8 (look at the script before you run it...)

```
./get-pythia.sh
```

You can find lots of information about Pythia at `http://home.thep.lu.se/~torbjorn/Pythia.html`. But for now, try to build and run a simple example. First go into the example directory

```
cd pythia-example-1
```

and look at the file `main01.cc`. Then build and run it

```
make main01
./main01
```

Try to understand the output that it sends to the screen (you may need to scroll back in your terminal). . Can you understand why most of the final-state particles are photons?

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Then plot the output file `main01.out` with your favourite plotting program. I like `gnuplot` and if you use that you can simply type:

```
gnuplot main01.gp
```

What's plotted, why does the histogram end around ± 10?

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Modify the program to plot the rapidity of muons (you may want to run a larger number of events to get a smooth distribution). Can you understand why the rapidity spectrum is narrower?

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