name: **group:**

Exercise Sheet 10 – Particle Physics – SS 2016

hand in: Tue 28$^{\text{th}}$ June (after the lecture or at INF 226, 3.104 by 4 pm)

10.1 Jet algorithms (8 points)

The JADE collaboration published a jet algorithm in the middle of the 1980's. It is formulated as follows (cf. arXiv:0906.1833, Sect. 2.2.1):

- For each pair of inputs i, j calculate the distance measure

  $$y_{ij} = \frac{2E_i E_j (1 - \cos\theta_{ij})}{Q^2} \; ,$$

  where Q is the total energy in the event, E_i is the energy of particle i and θ_{ij} the angle between particles i and j.
- Find the minimum y_{min} of all the y_{ij}.
- If y_{min} is below a threshold y_{cut}, then recombine i and j into a single new input and repeat from step 1.
- Otherwise, declare all remaining inputs as jets and terminate the iteration.

Table 1 lists the energy deposits reconstructed in an event recorded at an e^+e^--collider operated at $\sqrt{s} = 189\,\text{GeV}$.

a) Calculate the number of jets for a threshold of $y_{\text{cut}} = 0.01$ using the four vectors of Table 1 as input.

b) Make a schematic illustration of the input from Table 1 and jets from part a) in the x-y-plane, showing how particles are combined into jets.

c) $y_{n(n+1)}$ is defined as the value of y_{cut} that defines the transition between an event being labelled as having n and $n+1$ jets. Calculate the value of y_{34} and y_{23} for the inputs listed in Table 1.

p_x[GeV]	p_y[GeV]	p_z[GeV]	E[GeV]
-33.221889	-7.084297	1.483043	41.425606
35.735025	-3.252273	-0.838708	37.560499
-27.804474	-4.540212	-1.607542	36.920528
30.577828	-3.870738	0.852875	30.836727
3.413679	10.964732	0.307153	14.513432
4.449901	10.112192	-0.344404	13.028614
-9.183364	-1.780451	-0.014493	11.059419
-3.670498	-0.663670	0.213196	4.446131

Table 1: Inputs to the jet algorithm.

Use a computer to solve this problem. Hint: for example, ROOT (http://root.cern.ch) is a widely used in HEP package that provides a useful four-momentum object TLorentzVector.

10.2 Wu et al. experiment (6 points)

Read the article "Experimental Test of Parity Conservation in Beta Decay" by C.S. Wu et al. (Phys. Rev. 105 (1957) 1413)) and answer the following questions:

a) What process is used to study parity violation in weak interaction?
b) Why is it important that the ^{60}Co probe is prepared as a thin surface layer?
c) How is the polarization of the nuclei measured?
d) How does the spin of the nucleus change in the decay?
e) How are effects of the remanent magnetization excluded?
f) What is the observed signature which indicates parity violation?
g) Why does the beta asymmetry vanish after several minutes of measurement time?

10.3 Rapidity (6 points)

The rapidity y is defined as

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

where E is the particle's total energy and p_z is its momentum parallel to the beam axis.

a) Show that $\mathrm{d}y = \frac{\mathrm{d}p_z}{E}$.
b) Express the phase space element $\mathrm{d}\tau = \frac{\mathrm{d}^3 p}{E}$ as function of $\mathrm{d}p_T$, $\mathrm{d}\phi$ and $\mathrm{d}y$.
c) Plot $1 + \cos^2\theta$ in the range $y \in [0., 3.]$; assume $m \ll E$.
d) Explain the consequences of b) and c) on $\frac{\mathrm{d}\sigma}{\mathrm{d}y}$. Assume $|M^2| \propto (1 + \cos^2\theta)$.