DEPARTMENT OF PHYSICS & ASTRONOMY
3459 EXAM-1
10:00 - 13:00 : November 13th 2013

Please read the exam guidelines, rules, instructions and marking criteria at `http://moodle.ucl.ac.uk/mod/wiki/view.php?id=13963&page=Mid-term+exam` (linked from the *Exams and coursework* page).

This exam is worth 25% of your final mark for the course and is made up of two parts:

- 15 multiple-choice questions, worth 7.5% of your final mark;
- a programming exercise, worth 17.5% of your final mark.

The multiple-choice questions are given as a Moodle quiz.

The Java source code of your solution to the programming exercise should be uploaded using Moodle. Each class should be uploaded as a separate file. You must upload *all* your classes used in your solution, including any you have copied or included from earlier coursework modules.

DEPARTMENT OF PHYSICS & ASTRONOMY
3459 EXAM-1
PROGRAMMING EXERCISE

You will write Java classes and methods to read data from a URL, analyse the data and present the results.

Background

No specialist knowledge of particle physics is needed in this exercise. A reminder of some properties of four-momenta is given below.

An ”event” recorded at a particle collider experiment is a record of the outgoing particles from a particular collision between two incoming beam particles. The rate at which collisions occur is generally too high for all events to be recorded, so potentially interesting events are flagged by a ”trigger”, and only if this trigger fires are the tracks read out and saved to disk.

The data you will analyse in this exercise come from a simulation of an experiment in which the outgoing particles are measured by a tracking detector, which gives a fairly precise measurement of a particle's momentum but not of its energy. There are several triggers in use, each identified by a label such as `B13`.

- The four-momentum of a particle or system comprises its energy and three-dimensional momentum: (E, p_x, p_y, p_z).
- The four-momentum of a pair of particles is calculated by adding the energies and momenta.
- The invariant mass of a particle or system is defined as $m = \sqrt{E^2 - |\mathbf{p}|^2}$.
- You can assume that the outgoing particles are light and can be treated as massless, so $E = |\mathbf{p}|$. (We are using natural units where $c = 1$.)

File format

Each input file can contain a number of events, each covering several lines. An event starts with a line of the form

```
E n_tracks trigger_id
```

e.g.

```
E 12 B13
```

where `n_tracks` is the number of particle tracks in the event and `trigger_id` is the identification label of the trigger that selected this event.

This line is followed by a number `n_tracks` of other lines, each giving details of one of the particle tracks in the form

```
charge momentum theta phi
```

e.g.

```
-1 12.345 0.543 -0.842
```

where `charge` is 1 for a positive particle or -1 for a negative particle, `momentum` is the momentum of the particle in units of GeV/c, and `theta` and `phi` are the polar and azimuthal angles (in radians) of the particle in spherical polar coordinates:

- `theta` (θ) is the angle between the outgoing particle and the z (beam) axis, and takes values from 0 to π
- `phi` (ϕ) is the angle measured anticlockwise from the x axis in the xy plane, and takes values from $-\pi$ to π

Tasks

You should write a program using appropriate classes and methods to read the data from the URL http://www.hep.ucl.ac.uk/undergrad/3459/exam-data/particles.txt and store the data in suitable collection objects.

- For each event, find all pairs of oppositely charged particles (i.e. combine each positive particle with each negative particle in turn) and calculate the invariant mass of each pair.
- Count the total number of pairs in all events that have an invariant mass in the signal region (8 to 10 GeV/c^2) and the number that have an invariant mass in the background region (11 to 15 GeV/c^2), and calculate the signal/background ratio by dividing these numbers.
- Repeat this calculation for each of the triggers, each time using only events selected by that trigger.
- Identify the trigger that gives the highest signal/background ratio.
- Your program should print the following:
  - the total number of particle pairs in the signal region
  - the total number of particle pairs in the background region
  - the signal/background ratio for all events combined
  - the signal/background ratio for each trigger
  - the name of the trigger with the highest signal/background ratio

END OF PAPER