PHYS 488

Modelling Physical Phenomena

Projects

PHYS488 Projects: Schedule

Work on projects: weeks **6, 7, Easter break…., 8, 9, 10**

Week 11: Group **presentations** (consisting of 12 minute individual presentations for each group member) (20% of mark). (Schedule to be announced).

Project reports to be handed in before the end of week 11.

The project report mark of up to 50% will be split up as follows:

- Group report on the aims, science and the overall program structure behind the project: 20% (all students in the group will receive the same mark)
- Individual report by each student describing in particular the code they developed and tested as well as a study of some physics aspects of the project studies using the code: 30%

Note: Presentations and group reports will be (co-)marked by other staff in the department. You should **not** assume the reader/listener already knows about your project.

PHYS488 Projects: 6 projects

All project are done in groups of 3 or 4 students

- Simulation of search for a heavy Higgs decaying to 4 muons in ATLAS
- Simulation of B meson events in LHC-b.
- Simulation study for a possible high momentum trigger for the LHC upgrade
- Simulation positrons from μ^+ decay to optimise g-2 tracker
- Simulation J/Ψ decay into muons, only for groups of 3 students)
- Simulation of charged-lepton flavour violating decays in Mu3e

PHYS488 Projects: how to organise the work

Today first discuss with me your choice of groups and project.

Before starting to write any code, discuss with your group in detail:

- What work is required?
  - **preparation work: look up theory or find other information needed.**
  - **what code needs to be written**
- What would be the most suitable structure of the code?
  - **what classes do you need to write and do they fit together.**
  - **how can data be transferred from one task to the next.**
- Subdivide the work in to different tasks and assign them to group members. There is too much work to do everything together.

  (note: everyone should contribute a part of the java code in the project!)
- Make a schedule for when the individual contributions should come together in a shared group code. Aim for the end of the second week, before the Easter break, to leave yourself time to check the group code works correctly and exploit it for some studies.

Discuss your plans with me or dr. King THIS WEEK.

Talk to us in the teaching lab or come to our offices (or email vossebeld@hep.ph.liv.ac.uk or btk@hep.ph.liv.ac.uk)

PHYS488 Projects: how to organise the work (cont.)

General

- You should all attend the practical sessions so you can discuss progress within your group and each group member can report the progress they have made. We will keep an attendance register.
- Throughout the project, come and see dr. Vossebeld or dr. King, REGULARLY, to discuss your progress and plans.
- In general we expect you to seek help, pro-actively, when you can‘t solve a problem within your group.
- More detailed instructions for the presentations and reports will by posted on Vital in due time.

PHYS488: Projects for 2016.

J/Psi experiment

Higgs at the LHC

LHCb Vertex Locator experiment simulation

Super LHC track-trigger

g-2 tracker

The Mu3e experiment

"J/Psi experiment" project:

The decay of the J/Ψ particle into muons.

In the early 1970's an experiment was done shooting a beam of high energy protons into a Uranium target, and looking at the mass spectrum of $\mu^+\mu^-$ pairs that emerged from the block. This produces a mass distribution that goes like . A "shoulder" or "low bump" was seen around a mass of ~3 GeV/c^2. At the time it was not realized what this was, but in late 1974 when the **J/Ψ** was found in electron colliders, it was realized that the bump had been due to the production and decay of this particle in the target, but the details were "smeared out" due to energy loss and MCS of the muons. The aim of this project **is to try to model this situation and try to reproduce the main features of the original experiment.** Note that in the real experiment some muon pairs are "real" in the sense they both come from the decay of the **J/Ψ**, while others are "fake" in the sense they each come from the decay of two independent particles, e.g. two pi mesons. These are the ones that produce the background that partially obscures the **J/Ψ** true mass peak**.**

The model should be based around J/Ψ's being produced (with some sort of energy distribution) inside a small block of material. These particles then decay into muon pairs that are tracked in a series of counters that enables their path to be reconstructed. You can assume you know the muon energy in the tracking chambers, but use the hit coordinates to work out the muon momentum vector.

Reference: Christenson *et al.,* Phys. Rev. Lett. **25**, 1523 (1970).

“Higgs at the LHC” project :

Search for Higgs decay   followed by   at the LHC.

You are provided with a file containing the 4-vectors (E, p_x ,p_y, p_z) and charges of muons produced in simulated collisions (events) at the LHC accelerator. Each event contains four muons that are generated by a Monte Carlo program used to model collisions at the LHC. You will take these muons and track them through a simple model of an LHC experiment, which includes a magnetic field in the central part of the detector **constant and pointing along the z-axis.** You will generate hits (smeared according to the resolution) in muon chambers that are positioned on the outside of the detector. You will include the effects of MCS by adding a layer of iron before the muon detectors. (representing the material of the magnet coil and the calorimeter.)

You will then reconstruct the direction of the muons, after they passed through the magnetic field and the iron, by fitting a straight line to the muon chamber hits, to estimate the original charge, momentum and direction of the muons. With these muon momenta you will look for evidence of a Higgs boson in the simulated data set you were given and if found you will try to estimate the Higgs mass.

"LHCb Vertex Locator experiment simulation" project :

Simulation of B0 production in the LHCb detector.

In this project you are given a file of several thousand simulated B0 particle 4-vectors produced at the collision point at the centre of the LHCb detector: x,y,z = (0,0,0).

The B0s have a finite lifetime and each produced B0 is forced to decay following the characteristic exponential distribution.

You are given this decay point for each B0. Each B0 decays into 2 muons and 2 pions whose production point is therefore the decay vertex of the B0. You are given the 4-vectors of these decay products.

The main task of the project is to step these four particles out through a simulation of the geometry of the LHCb VELO (Vertex Locator) detector. This detector consists of 15 layers of silicon detectors, the precise positions and geometry of which you are given. Whenever you cross material you determine the multiple scattering angles of the tracks and whenever you intersect detectors you generate hits in those detectors.

Having generated all the hits for a particular event, you can fit straight lines to the hits emanating from each of the tracks. By extrapolating the tracks backwards you determine the B0 decay vertex for each event, which you can then compare with the actual decay position. By varying the amount of material and the hit resolution you can study how the accuracy of the determination of the decay vertex is affected.

Having obtained the distribution of decay points for the event sample you should be able to determine the B0 lifetime that was used in generating the simulated samples.

“Super LHC track-trigger” project :

Feasibility/design study for a track trigger to be implemented Study in the ATLAS experiment at the LHC.

The LHC and its proposed successor the super-LHC produce billions of collisions per second. Experiments, such as the ATLAS experiment, can record at best a few hundred such collisions per second. It is therefore required to accept or reject collisions on-the-fly based on a very fast determination of the properties of these collisions.

An important selection criterion can be the presence of a trajectory in the tracking detectors of the experiment, originating from a high momentum lepton. You will study whether a very simple 2 layer coincidence detector could be used for this purpose. As part of the project you will generate muons, which you will track through a series of thin detectors located in a magnetic field, and generate hits in two of these detectors. Using these hits you then assess how well these data allow you to separate between very abundant low momentum particle and rare high momentum particles. At a later stage you can study how well you would expect this performance to hold up in the presence of thousands of other particles from the same collision.

“g-2 Tracker“ project:

Optimisation study for a tracking detector for the g-2 experiment

g-2 will make a precise measurement of the Lande g-factor of muons. Previous measurements have indicated a discrepancy between the Standard Model prediction and data of 3.8 sigma. The current experiment will repeat this measurement with much higher statistics and a better detector in order to reduce the statistical and systematic errors on the result. If the discrepancy were to persist it would be measured in the new experiment at the level of 8 sigma, indicating new physics not included in the Standard Model.

The Liverpool group are building the tracking chambers which will be installed in front of some of the calorimeters at crucial points around the accelerator.They will measure the momentum of the e^+ from μ^+ decay as precisely as possible in order to determine the decay point of the muon.

The project will simulate the decay of μ^+ in the accelerator and track the decay e^+ through the tracking detector taking into account the magnetic field in this region. Hits will be generated when the positron crosses the tracker planes. Having generated the hits, a circle will be fitted to the hits to determine the best estimate of the positron's path. The fitted track is then extrapolated back to the decay point of the muon.

The Mu3e experiment

The mu3e experiment at PSI in Switzerland proposes to look for the charged-lepton flavour violating decay of an anti-muon to 2 positrons and an electron. The experiment will do this with a sensitivity that should allow to set an upper limit of 10^{-16} on the branching ratio for this process. In the standard model this decay has an extremely low branching ration of approximately 10^{-54}, well beyond the reach of any experiment. An observation of this decay would thus be direct evidence for physics beyond the SM.

One of the main backgrounds to the mu->3e process are muon decays to $\mu^+ \rightarrow e^+e^+e^-\nu\nu$. For the signal process the total invariant mass of the positrons and the electron should add up to the muon mass and the total momentum should be zero. This is not the case for the background events as the neutrinos will carry away some momentum.

As the experiment looks at muons decaying at rest, the electrons and positron have typically very low momenta (<53 MeV) and are thus very sensitive to MCS. An extremely low mass tracker is needed to measure these momenta accurately.

You will generate signal events and track these through a simple simulation of the proposed Mu3e experiment. To establish the resolution in the total summed momentum and the invariant mass.