The School of Physics

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Computational Physics 4(M)
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Title: Analysis of Data from the BABAR Experiment

Area: Particle Physics Experiment

Supervisors: Dr F Muheim and Dr SM Playfer

The Edinburgh PPE group is involved in the BABAR colliding-beam experiment at the Stanford Linear Accelerator Centre (SLAC) in California. The experiment is taking data since 1999. The primary objective is the study of CP violation in the decays of B mesons. In 2001, the BABAR experiment made the first observation of time-dependent CP violating asymmetries between the decays of B^0 mesons ($\bar{b}d$), and $\bar{B}^0$ mesons ($b\bar{d}$).

This project will provide the opportunity to analyse data recorded by the BABAR experiment. This will be a good introduction to present day particle physics detectors, and to the computing software that is used in data analysis.

There are over a hundred decay modes of the B meson, many of which are very poorly known from previous experiments. The aim of the project will be to attempt to find a signal for one of these decay modes and compare it with previous measurements (if any). The decay mode chosen will depend upon the quantity of data that is available at the time of the project. Some modes are now sensitive to direct CP violation.

References:

1. B decays, 2nd edition, ed. Sheldon Stone (World Scientific, 1994)
2. BABAR Physics Book, available on the web at
   `http://hepunx.rl.ac.uk/BFROOT/doc/Physics/PhysBook/physBook.html`
   This text provides a general low-key introduction to the context of this project.
3. Our BABAR Webpage : `http://www.ph.ed.ac.uk/particle/Exp/BaBar`

Title: Mock Data Challenge for the LHCb Experiment

Area: Particle Physics Experiment

Supervisor: Dr Franz Muheim

The Edinburgh PPE group is involved in the LHCb experiment at the Large Hadron Collider, LHC, at CERN. The goal of the LHCb experiment is to measure precisely CP violating asymmetries in the decay of B mesons. The results can be compared to the predictions of the Standard Model of particle physics. Deviations from the predictions would signal the existence of new fundamental interactions and particles.

The LHC accelerator and the LHCb detector are currently under construction. The detector design has just been optimised by simulating its peformance for varying scenarios. These Monte Carlo techniques also allow to emulate the actual experiment by first generating events which are expected to occur according to theory and then simulating their passage through materials and the signals they produce in detectors. Subsequently, these events are reconstructed as if they were real data. We are currently producing about 50 million events for a Mock Data Challenge for the LHCb experiment. Computing centres from collaborating institutes in many countries participate in this production, including our own ScotGrid. For these Mock data challenges, e-science/Grid tools are being implemented and tested.

The project would use the software packages "DaVinci" and "Brunel" to analyse a benchmark B meson decay channel and its backgrounds on these Monte Carlo data. It will provide a very good opportunity to get involved in the current analysis techniques and in the computing software and e-science/Grid tools that are being used in particle physics.

References:

1. The LHCb webpages: `http://lhcb.web.cern.ch/lhcb`
   and `http://lhcb-comp.web.cern.ch/lhcb-comp`
2. Status of the LHCb Detector Reoptimisation, CERN/LHCC 2003-003,
   `http://www.ph.ed.ac.uk/particle/Exp/LHCb/notes/report.pdf`
3. The PPE group's LHCb webpage: `http://www.ph.ed.ac.uk/particle/Exp/LHCb`
4. The ScotGrid webpage: `http://www.ph.ed.ac.uk/particle/Exp/GRID`

Title: Measuring Single Cherenkov Photons with High Resolution

Area: Particle Physics Experiment

Supervisors: Dr Franz Muheim and Dr Stephan Eisenhardt

The Edinburgh PPE group is involved in the LHCb experiment at the Large Hadron Collider, LHC, currently under construction at CERN. The goal of the LHCb experiment is to measure precisely CP violating asymmetries in the decay of B mesons.

The LHCb detector must be able to perform particle identification of charged pions, kaons and protons over the momentum range 1 to 100 GeV/c. Two Ring Imaging CHerenkov (RICH) detector will be built to determine the velocity of a charged particle traversing the detector by measuring the the angle between its trajectory and the direction of the emitted Cherenkov light. The RICH detectors must be equipped with photon counters that are capable of detecting single photons with good spatial resolution. In addition, the counters must have a very fast response time compatible with the 40 MHz LHC bunch crossing frequency.

At Edinburgh, we have a test facility for measuring properties of photo detectors such as the Hybrid Photodiode (Pixel-HPD) or Multianode Photo Multiplier Tubes (MaPMTs), one of which will be chosen by the LHCb experiment. These devices have a good quantum efficiency and produce large signals which can be measured with fast front-end electronics.

This project would involve the testing of the properties of a photo detector. It will include the setting up of equipment and programming for tasks like steering the apparatus, collecting data and analysis of data. This project will provide an opportunity to get involved in the tools that are used in the design, development and construction of a new particle physics detector.

References:

1. F. Muheim, Status of the LHCb experiment,
   `http://www.ph.ed.ac.uk/particle/Exp/LHCb/notes/lhcb-beauty.pdf`

2. E. Albrecht *et al.* Performance of a cluster of multi-anode photomultipliers equipped with lenses for use in a prototype RICH detector, Nucl.Instrum.Meth.A488:110-130,2002
   `http://www.ph.ed.ac.uk/particle/Exp/LHCb/notes/nimpaper.pdf`

3. The PPE group's LHCb webpage: `http://www.ph.ed.ac.uk/particle/Exp/LHCb`

Title: Neutrino Factory Design

Area: Particle Physics Experiment

Supervisors: Dr Akram Khan, Mr Alan Walker and Dr Franz Muheim

Particle accelerators have been the centre piece of particle physics research for the past half-century, and are still the only way to study particles in a well controlled manner. Studies are underway to see if the acceleration of muons is feasable.

One of the main difficulties with a muon accelerator is to produce a beam of muons in which the particles are contained in sufficiently small bunches to allow them to be manipulated, accelerated and collide before they decay. Developing a neutrino factory, is a first step towards a muon collider. A neutrino factory is made by producing a beam of muons circulating in a 'storage ring'. The ring is built with several straight sections and the muons which decay along these directions will produce a beam of neutrinos. These can be fired across the earth to do neutrino oscillation experiments.

In the project, you will simulate a muon beamline at the ISIS accelerator at the Rutherford Appleton Laboratory (18 miles south of Oxford) which is planned to be extended for developing and testing a 'cooling channel' for a neutrino factory (cooling means reducing the phase space of small bunches of in the beam). The simulation will use transformation matrices to represent the changes which are made to the bunches as they traverse a range of accelerator components (dipole bending magnets, quadrupole focussing magnets, etc.).

This project will be a close collaboration with people at RAL, with the student being sent to RAL for short periods. Existing computer code is available as a basis for this work, and the project will require knowing (or learning) computer programming in C++.

The aims of the project are:

- To understand how the different beam elements (dipoles, quadrupoles etc.) affect the characteristics of the beam (i.e. the change in beam size and particle direction distribution)
- To improve the calculation of the characteristics of the ISIS muon beam as a function of the incoming beam from the accelerator and the magnet current settings.

References:

1. A directory with some files about the muon test facility at RAL
   `http://hepunx.rl.ac.uk/~edgecock/muons/test-beam`
2. A page of detailled links about muon storage rings
   `http://muonstoragerings.cern.ch`
3. D. A. Edwards and M. J. Syphers, 'An introduction to the physics of high energy accelerators', John Wiley & Sons, 1993 (very good)
4. H. Wiedemann, 'Particle accelerator physics', Springer-Verlag 1993 (very good, contains something about beam bunchers)