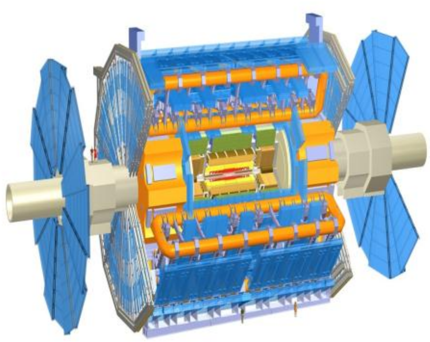
Particle Physics

The Particle Physics Group at Manchester offers projects in both experiment and theory. It is, also, possible to combine these two areas, and students can choose joint projects supervised by both an experimentalist and a theorist from the group. Projects are also available in accelerator physics and detector development.

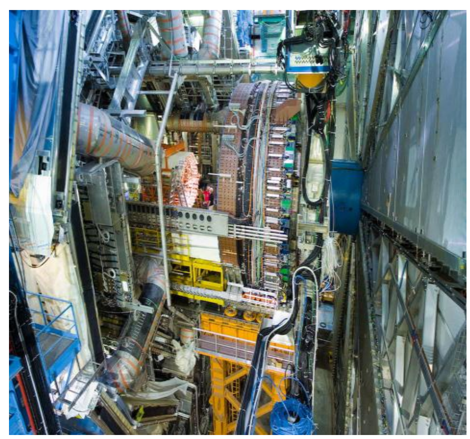
Experimental Particle Physics

Title: The ATLAS Experiment

Contact: Prof Fred Loebinger



(a)



(b)

(a) Computer simulation of the ATLAS detector

(b) The Inner Tracker, partly built at Manchester University, being Installed into the heart of ATLAS in The LHC tunnel

Description:

The ATLAS experiment started taking preliminary data at the Large Hadron Collider (LHC) at CERN in December 2009. The LHC will bring 7 TeV beams of protons into head-on collision to increase significantly the centre of mass energy available for the production of new particles. The Manchester group has constructed over 600 silicon-strip detectors which measure the positions of the particles produced at the heart of the detector to precisions of a few microns. The group is also heavily involved in the ATLAS triggering system which selects those interactions of particular interest at this new high energy frontier. The experiment is looking for signs of the Higgs boson together with evidence of a whole range of new particles predicted by Supersymmetric models. The Manchester Group is involved with many of the main physics analyses. In particular, it plays a leading role in study of Top physics, which is expected to be one of the most fruitful areas of research at the LHC. Not only will top quarks be prolifically produced, but they should give a clear indication of the discovery of any new physics processes which should be seen for the first time at these highest energies. The Group is also involved in searches for Physics Beyond the Standard Model

Title: The LHCb Experiment

Contact: Prof George Lafferty

The LHCb experiment installed at the LHC

Description:

Manchester is also part of the LHCb experiment, which is designed to study the properties of the B hadrons which will be produced in large numbers at the high energies of the LHC. We are involved in the interface between the experiment and the accelerator, understanding how to run the LHC to produce the best conditions for data taking, and in the design and construction of the replacement and upgrade of the vertex detector. There are research projects to look at the detailed decays of B mesons, and to measure and understand the CP violation which appears in this sector. Many different measurements can be made in this rich field, and it is important to establish whether they can all be explained by the Standard Model or whether the hints of small differences turn out to be the first sign of something beyond it.

Title: The SuperNEMO Project

Contact: Prof Stefan Soldner-Rembold

The NEMO-3 detector installed under the Alps

Description:

SuperNEMO is a new international experiment proposed as a successor to the current NEMO-3. It will search for neutrinoless double-beta decay, a process which is only possible if neutrinos have mass, and they are their own anti-particles. This possibility would require modifications to the Standard Model of Particle Physics. The experiment would be based deep underground to screen out the effect of cosmic rays. A first module will be installed in Modane in 2012. The project would involve both the analysis of current data from the NEMO-3 experiment, as well as detector development and simulations for SuperNEMO.

Theoretical Particle Physics

The Group has particular expertise in almost all aspects of Collider Physics phenomenology, in the Physics of the Early Universe, in Higgs and Neutrino Physics and in Physics Beyond the Standard Model. Our projects are often focused on aspects of theoretical physics that can be tested in ongoing or future experiments. Consequently we are especially interested in physics that is explored at the world's colliders, both present and future, and work closely with the experimental particle physicists both in the group and at laboratories around the world. Opportunities exist for PhD work in almost all of our research areas and projects are generally tailored to the evolving interests of individual students and their supervisors. The group's theorists regularly collaborate with each other, reflecting the fact that there is considerable overlap between the different areas of particle physics phenomenology. As a result it is usual that PhD students in this area will develop a good breadth of understanding during the course of their studies.

Title: Beyond the Standard Model and Particle Cosmology

Contact: Prof Apostolos Pilaftsis

Description:

The Standard Model of particle physics has been extremely successful in describing all current experiments, but it leaves many questions unanswered, like why particles have the masses and other quantum numbers that they do, why there are three generations of elementary particles, why there is more matter than antimatter in the universe, what the 'dark matter' of the universe is made of, whether the three fundamental forces of particle physics can be unified, and whether this can be further unified with a quantum theory of gravity. To try to answer these questions, we bring together progress in theories Beyond the Standard Model (BSM) with a phenomenological understanding of how those theories could be tested in future experiments and how we can constrain them using the existing data.

A recent exciting development is the application of ideas from particle theory to cosmology, the physics of the early universe, and the realization that cosmological data are becoming precise enough to constrain the structure of BSM physics. The group has strong links with Jodrell Bank's Theoretical Astrophysics and Cosmology Group for research in this direction.

Title: QCD and Collider Physics

Contact: Dr Mrinal Dasgupta

Description:

Quantum ChromoDynamics, the quantum theory of the strong nuclear force, has an extremely rich structure, resulting from the fact that its coupling constant varies with energy. At high energies (or small distances) it is relatively small, and quarks and gluons behave like free particles and physical observables can be calculated as perturbative series in the coupling constant. At low energies (long distances) it becomes so large that perturbation theory becomes inconsistent and the theory becomes non-perturbative. These strong interactions confine quarks and gluons into the hadrons that are observed in experiment in a way that is not understood at a fundamental level. Almost every measurement and search for BSM physics in hadron collider experiments requires corrections from this confinement process in order to connect the measured quantities with the aspects of the fundamental theory that they are trying to probe.

Our research into QCD continues on two fronts. The first is to study QCD itself, through theoretical investigations, making calculations of quantities that can be measured experimentally, and interpreting data to extract a deeper understanding of the theory. The second is to apply this improved understanding to other aspects of collider physics, by providing theoretical tools for simulating and analyzing data, and collaborating with experimenters on the interpretation of their data.

PhD students in this area would have the opportunity to work closely with the LHC experiments in what is an exciting period of early data-taking at the LHC.

Title: Diffraction and QCD at High Energies

Contact: Prof Jeff Forshaw

Description:

In the majority of hadron–hadron collisions, the hadrons are completely torn apart by the interaction and the final states of the collisions contain hadrons emitted at all angles. In some events however, the hadrons scatter off each other intact (diffractive scattering) or relatively unscathed, with only a few hadrons travelling roughly in the original hadrons' directions (diffractive dissociation). In either case, a large angular region of the event contains no hadrons. These diffractive events have long been known in strong interaction physics, but only more recently has theoretical progress been made in connecting this with QCD and in being able to make perturbative predictions for certain types of diffractive processes, through an expansion of QCD valid in the high energy limit (the 'BFKL' equation).

Our research in this area includes: constructing models of diffractive processes that connect the perturbatively-calculable high energy limit with the incalculable but well-measured non-perturbative region; making first-principles calculations of diffractive processes in high energy QCD; making phenomenological studies of these calculations and the extent to which they can be tested experimentally; and working closely with experimenters on the interpretation of diffractive data.

A recent surprise is the realization that diffractive processes give a unique window to search for new particles such as the Higgs boson in some BSM scenarios and the Manchester group of theorists and experimenters are leading the international effort to supplement the LHC detectors with forward proton taggers that would allow this measurement.

Title: Monte Carlo Modelling of QCD Interactions
Contact: Prof Mike Seymour

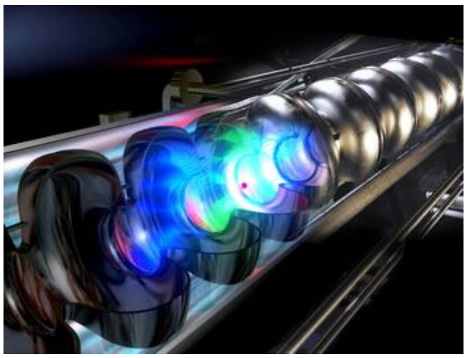
Description:

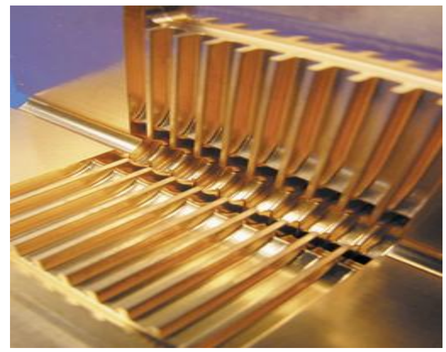
In high energy physics we are usually interested in interactions between partons (quarks and gluons) with high momentum transfer, producing new particles like the Higgs boson or supersymmetric partners, or more familiar ones like the top quark. These decay to produce further partons. However, partons cannot propagate freely but are confined into hadrons, the particles that interact with the detectors around the collision region. This process by which a few hard partons evolve into a system of hundreds of hadrons is far too complicated to calculate analytically and must be modelled numerically, with Monte Carlo techniques. Any attempt to understand the data from the LHC or other high energy collider experiments would be completely impossible without Monte Carlo event generators that simulate them.

Professor Seymour is a senior author of Herwig++, one of the three general purpose event generators used by the LHC experiments. He is currently working on theoretical projects to improve the formal accuracy of the approximations used in event generators, called parton shower algorithms, and on more phenomenological projects, to use current data to validate and tune the modelling in the event generators to provide LHC predictions with quantified accuracy. He also works closely with experimenters using event generators to optimize their analyses and get the maximum value out of their data. He offers PhD opportunities in all of these areas, and also frequently co-supervises students in the ATLAS sub-group to provide a more theoretical strand to their experimental activities.

Accelerator Physics

Manchester plays a major role at the Cockcroft Accelerator Institute, based at Daresbury. Our activities cover a range from the lowest (EMMA 18 MeV) to the highest (the LHC at 7 TeV) energies. We list four projects here, but the field is wide and many others are available.





To the left is shown a computer simulation of wakefields excited in the main linacs of the International Linear Collider (ILC) superconducting cavities. Rightmost is a prototype section of the 20 km high gradient linac for the Compact Linear Collider (CLIC).

Title: Electromagnetic wakefields and beam dynamics in Accelerator structures

Contact: Dr Roger M. Jones
Description:

The accelerator physics group in the school of physics at Manchester places particular emphasis on complex particle motion, optical design and the effects of beam-excited wakefields. We study wakefield effects of beam collimators, and Higher Order Modes (HOMs) in superconducting and normal conducting cavities; this entails understanding their excitation and suppression, and how to use them as an intrinsic beam-based diagnostic. We work on the main high gradient accelerating linac, crab cavities, beam delivery system, interaction region and extraction line dynamics for the ILC and CLIC projects, the study of the dynamics for EMMA and the ATF, the ATLASFP project for the

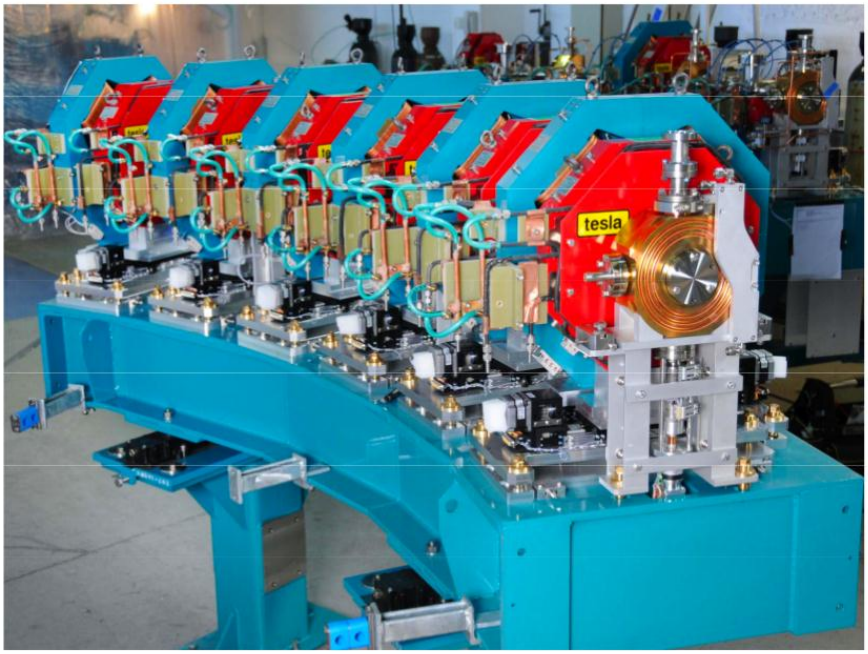
LHC, the HIE-ISOLDE nuclear accelerator upgrade, computational beam dynamics, photocathode beam dynamics, high intensity and high energy nuclear isotope accelerators, and particle beam dumps. Opportunities exist for PhD work in these areas with students developing and using theoretical, computational and experimental skills. Students will have the opportunity to participate in research at major international facilities. Ongoing collaborations exist with the ALICE at Daresbury, CLIC, LHC/ATLASFP and HIE-ISOLDE at CERN, ILCTA at FNAL and the ATF2 at KEK. A developing activity is focused on an analysis of electromagnetic wakefields and beam dynamics in spoke and ellliptical cavities for the European Spallation Source (ESS) in Lund, Sweden. ESS will become 10 times more powerful than facilities in the US and Japan. The main accelerating cavities of ESS will be required to cope with beam-excited higher order modes which have the potential to dilute the beam emittance and in the worst case scenario, to excite a beam break up instability.

Title: Charged Particle Collimation with Wakefields
Contact: Dr Roger M. Jones
Description:

We propose to develop a suitable formalism and simultaneously simulate the effect of particle scattering in collimators and the effect of wakefields on relativistic particle beams. These dynamical effects are conventionally treated separately, and this project will use a unified approach to study the impact on high energy and low emittance beams. The formalism shall be included in the code MERLIN, with many resulting applications. For example, we will study the impact of the wakes and re-scattering in the LHC collimation system upon the dynamics and absorption of the stored particles. To date, only a single code platform has been used to perform collimation simulations on the LHC, using SixTrack with FLUKA to model scattering, loss, and subsequent particle shower generation. Wakefields imparted by the collimators will modify the passing bunches significantly, but this is presently modelled separately to the collimation process. This work necessarily entails a strong collaboration with colleagues at CERN and at the SLAC National Accelerator Laboratory where collimator beam-based experiments are conducted.

Title: Developments of the nsFFAG

Contact: Dr Hywel Owen



A sector of the EMMA accelerator being built at Daresbury

Description:

The world's first non scaling Fixed Field Alternating Gradient accelerator, EMMA, is being built as a Manchester-led project at the Daresbury Laboratory. Its commissioning and early operation will enable machine studies to be done of this new type of accelerator. Students will assist with experiments and later be able to devise their own. Understanding of nsFFAg principles should open the door to FFAg proton accelerators; simpler and more compact than synchrotrons and capable of producing much higher currents. These have been proposed as machines for cancer therapy, and also for 'sustainable' Thorium powered ADSR reactors. Students can look in detail at either of these applications.

Title: Experimental Background Conditions, Collimation and Forward Physics

Contact: Dr Rob Appleby

Description:

The accelerator physics group in the school of physics at Manchester places particular emphasis on complex beam dynamics and the interaction of particles with matter. We are studying the interaction of the proton beam in the Large Hadron Collider (LHC) with the machine elements and with the collimation systems, which is generally designed to protect the machine but will have a large influence on the overall experimental conditions of the six experiments. These studies require calculation of proton beam dynamics, cascade interactions with matter and simulation of background particle evolution into the experiments. The work will study the impact on all the LHC experiments, as well as the background conditions for forward region physics around ATLAS and CMS. The Manchester group is a leading partner in the ATLAS Forward Physics (AFP) collaboration. There will be opportunities to spend time at CERN and work with data from the LHC.

Further details about all Particle Physics areas of research can be found at our website: www.hep.manchester.ac.uk/research.html

Enquiries about postgraduate opportunities in Experimental Particle Physics should be addressed to Fred.Loebinger@manchester.ac.uk, those for Theoretical Particle Physics should be addressed to Mrinal.Dasgupta@manchester.ac.uk, and those for Accelerator Physics should be addressed to Roger.Jones@manchester.ac.uk.