SCHOOL OF PHYSICS AND ASTRONOMY
UNDERGRADAUTE PROJECTS ABSTRACTS
SPA6776 EXTENDED INDEPENDENT PROJECT

This booklet contains a series of abstracts designed to help students pick their supervisor for the Extended Independent Project component of the BSc programme.

Once you have read through these abstracts and decided on which 8 supervisors you wish to list in the online form please go to the online selection area make your choices about which supervisor you prefer. If you do not pick 8 different supervisors you will be randomly allocated supervisors to fill the remaining slots (i.e. if you only pick one person we will add in the remaining 7 choices for you!).

Project selections must be submitted by 13^{h} June 2014. You will be notified by email of your supervisor in early July.

When choosing a supervisor you must make sure that their abstracts correlate with your degree programme. Therefore students on the Astrophysics programme must do a project related to Astrophysics. Students on the Theoretical Physics programme must undertake a theory project (although this could be theoretical astrophysics and theoretical condensed matter as well as projects supervised by CRST staff). Students on Physics with Particle Physics must likewise select a project related to their degree programme.

The abstracts in this booklet are listed by research group and then alphabetically by staff member within that group.

CONTENTS

ASTRONOMY UNIT

Craig Agnor

Origin and Evolution of Planetary Systems

Origin and Evolution of Planetary Systems
With the expanding inventory of extrasolar planets, multiple robotic missions roaming the solar system, and the continued discovery of additional primitive bodies (e.g., near Earth asteroids, planetary satellites, Kuiper Belt objects and comets) planetary astrophysics is the fastest growing area in astronomy. The formation and evolution of planetary systems involves a wide range of physical process (e.g., stellar evolution, collisions, tidal interactions, gravitational dynamics, atmospheric evolution, geodynamics, giant collisions, orbital migration, ...etc.). In this project, the student will study a particular system of interest (e.g. the giant planets of the solar system, systems of satellites, Earth's Moon, planetary rings, planetary rings, the asteroid or Kuiper belts, or an extrasolar planetary system) conduct a critical review of the fundamental processes that best account for the origin of its properties. The student will then use analytical and numerical approaches to explore the dynamics and history of the system.

Prerequites: programming background and an interest in numerical modeling.

Guilem Anglada-Escude

Confident detection of super-Earths around nearby stars using Doppler spectroscopy

In the last 20 years, most extra-solar planet candidates have been found using Doppler spectroscopy. After years of technical improvements, Doppler precision is now sufficient to detect planets down to a few Earth-masses in the habitable zone of nearby stars. Confident detection of such small signals requires a good understanding of all sources of noise (random, instrumental, activity induced) and how to include them in the model of the data. The performance of Bayesian, spectral and other data analysis methods will be compared using real and simulated data-sets. This project involves writing and running codes to i) analyze new and archival spectra from the HARPS spectrograph, ii) perform Bayesian Monte Carlo Markov Chain analyses of time-series.

Prerequisites : interest in data-analysis and programming (basic programming training will be provided).

David Burgess

The outer boundary of the heliosphere

The solar wind is an example of an astrophysical plasma. As the solar wind expands away from the sun it eventually interacts with the local interstellar medium. A number of important boundaries form as the solar wind decelerates including the termination shock and heliopause. This project will investigate what is known from observations by the Voyager and IBEX missions about the outer limits of the heliosphere. The project will require study of some basic plasma physics including particle motion in electromagnetic fields and plasma waves. Some analysis of spacecraft data may be possible. Prerequisites: A high level of understanding of basic electromagnetism, and a good level of mathematical ability especially in vector calculus**.**

Bernard Carr

Primordial black holes

This project will examine the various ways in which black holes may have formed in the early universe and their possible cosmological consequences. Sufficiently small ones will have evaporated through Hawking emission but could still leave observable signatures through their contribution to the background radiation, their influence on cosmological nucleosynthesis, their generation of cosmic rays, and a variety of other effects. Larger ones would still exist and could have a variety of interesting dynamical, lensing and astrophysical effects. Students much choose to focus on one of more of these consequences.

Quantum black holes

This project will examine the way in which black holes provide an interface between quantum theory and general relativity. The most famous example of this is black hole radiation. Although this was discovered nearly 40 years ago, several outstanding issues are still unresolved, such as the black hole information paradox and the nature of the processes which occur in the final explosive phase of an evaporating black hole. There is also the issue of what happens as the black hole mass falls towards the Planck scale, which impinges on theories of quantum gravity. If there are large extra dimensions, Planck black holes may be detectable in accelerators like the LHC. Students much choose to focus on one of more of these aspects.

Baryonic and non-baryonic dark matter

This project will examine the evidence for the dark matter in the universe (known to comprise about 25% of its total mass density) and its possible explanations. Candidates are generally classified as non-baryonic (WIMPs) or baryonic (MACHOs), with a wide variety of candidates in each category. There is still no definite evidence for any of the candidates, but a huge range of data from both astronomy and particle physics constrains the possible proposals. Students may choose to focus on one or more of the candidates in greater detail.

James Cho

Climate

What was the temperature structures of Earth's Pliocene (about 5.3 to 2.6 M years ago) like? What is its link to the general circulation pattern? what are its implication, if any, for present-day global climate change? In this project, the student will review climate dynamics theory and current ideas about Earth's climate in the recent past. The project will involve performing a critical analysis of several recent papers and developing tests for simple general circulation model simulations.

Richard Donnison

The derivation and use of the restricted three-body problem in Astronomy

The restricted three-body problem involves the motion of a body of an infinitesimal mass moving under the gravitational forces of two finite masses. In this project the equations of motion and constants of motion can be derived. These can be applied to a large variety of physical systems in Astronomy both analytically and numerically. In this project the applications would be confined to the Solar System, particularly asteroids, comets and moons or to Extrasolar planetary systems.

James Lidsey

Inflationary Cosmology

Early Universe cosmology. This project will discuss the flatness and horizon problems of the standard, Big Bang theory and explain how a period of accelerated expansion (inflation) can resolve these problems. The cosmic dynamics of massive scalar fields that drove inflation will be developed. Observational parameters (that are ultimately determined by particle physics considerations) will be derived. The methods for linking such parameters with anisotropies in the Cosmic Microwave Background will be explained and some specific models analysed. The consequences for inflation of the first-year data from the Planck satellite will be discussed.

Inflationary Cosmology and Large-Scale Structure Inflationary Cosmology

Inflationary Cosmology, whereby the universe underwent a phase of accelerated expansion in its most distant past, is the cornerstone of modern, Early Universe cosmology. The flatness/horizon problems of the standard Big Bang will be discussed. The resolution of these problems through inflation will be explained. This project will focus on how the cosmic dynamics of inflation laid down the initial conditions for the formation of galaxies and clusters of galaxies, by the present era. The linear theory of density perturbation growth will be developed to provide a link with recent observations. Some specific models will be tested.

Karim Malik

Inflationary Cosmology

In this project the student will review the "standard model" of modern cosmology, including the period of accelerated expansion in the early universe called inflation.

Late universe project

In this project the student will review some basic general relativity and the "standard model" of modern cosmology. The late time acceleration of the universe and observational evidence for this acceleration will be discussed, with a brief introduction to dark energy and modified gravity.

Carl Murray

The structure of planetary ring systems

The planets Jupiter, Saturn, Uranus and Neptune all possess ring systems of differing sizes and complexity. The aim of the project is to make use of the latest space- and ground-based observations to review current knowledge of the dynamical structure of each planetary ring system as well as the theories that have been proposed to account for them. The student would be expected to summarise the key features of each system, identifying the basic properties and the physical processes involved in determining ring structure at each planet. Any examples of the same processes operating in different ring systems should be identified.

Saturn's F ring

Cassini images of Saturn's F ring show a complicated structure that is determined by a combination of the gravitational and collisional effects of nearby satellites. There are regular features due to the perturbing effect of the moon Prometheus but there are also several smalland large-scale "jets" which are the product of collisions with small moonlets orbiting nearby. The aim of the project is to analyse existing image mosaics of the ring using software tools developed in Mathematica. The student would be expected to write their own routines to characterise the nature of the ring and its changing appearance over time; this would include looking for periodicities in the ring as well as tracking the motion of clumps seen in the images. They would also be expected to draw conclusions about the nature and distribution of the objects affecting the ring.

Ring-satellite interactions

There are several examples in the solar systems of planetary rings being gravitationally perturbed by nearby satellites. This is a computational project involving a numerical study of how the orbits of rings particles are affected by their encounters with a satellite with applications to real examples of ring-satellite interactions in the solar system. The student would be expected to develop their own code to study the time evolution of the orbital elements of the ring particles by solving the relevant equations of motion and then relate these to spacecraft observations of features such as edge waves, clumps, streamers and channels observed in ring systems.

Richard Nelson

Extrasolar planets and planet formation

Since 1995 more than 1000 confirmed planets have been discovered orbiting stars other than the Sun, with many additional discoveries being announced on a weekly basis. In this project you will review the detection methods used to discover these systems, the range of planetary system architectures that have been discovered, and our current understanding of how planetary systems form. The project will involve writing and/or running a computer code to examine one of the following issues: (i) The dynamical stability of multi-planet systems and the origins of the orbital eccentricity of extrasolar planets; (ii) Orbital migration of planets due to interaction with the protoplanetary disc in which they form and the formation of short-period extrasolar planets.

Alexander Polnarev

Gravitational Wave Astronomy

According to General Relativity non-stationary gravitating objects generate the curvature of space-time which far away from these objects can propagate as gravitational waves (GWs). GWs can bring unique astrophysical information about compact objects (such as spinning neutron stars and binary black holes). The first direct detection of gravitational waves based on laser interferometry will be a milestone for fundamental physics and it will open the new observational science of gravitational wave astronomy. But gravitational waves already play an important role in the interpretation of observational data on binary pulsars and cosmic microwave background radiation (CMB).

This project will introduce the student to the basic concepts of GWs starting with the analogy of electromagnetic waves, moving on to the description of the main sources of GWs and observational evidence of GWs. The student will also study basic concepts of laser interferometry including the development of detector sensitivity both on the ground (such as Laser Inerferometric Gravitational wave Observatory) and in space (Laser Interferometric Space Antenna).

(Prerequisites and Co-requisites: any courses on Relativity and Optics including lasers)

Primordial Black Holes (PBHs)

PBHs as a unique probe of the Very Early Universe. The range of masses, different mechanisms of PBH’s formation, amplification of their fractional density in radiation dominated expansion, Hawking radiation, observational constraints (nucleosynthesis, gamma-ray background and gamma-ray bursts). The hydrodynamics of PBH’s formation and the problem of initial conditions.

Co-requisites: Any courses on Cosmology and General Relativity

Will Sutherland

Baryon Acoustic Oscillations
Baryon acoustic oscillations are created by sound waves in the baryon-photon plasma in the early universe; these both create the famous series of "acoustic peaks" in the microwave background, and also leave a faint imprint in the distribution of galaxies today; there is a slight excess of galaxy pairs separated by a distance near 450 million light years. This project will explore the ways in which observations of the BAO signature can be used to constrain cosmological parameters.

Some basic computations with Mathematica, Python or IDL will be required.

Dark matter in dwarf galaxies
The theory of cold dark matter is very successful on scales larger than the Milky Way, but has some problems on sub-galactic scales; in particular, it appears to predict too many dwarf galaxies and too much dark matter in the inner regions of large galaxies. This project will review this problem from both an observational and theoretical perspective, and study some possible solutions, including non-standard properties of dark matter.

David Tsiklauri

Magnetic fields in the solar corona
The project involves (i) writing a numerical code to produce potential extrapolation of magnetic fields from solar photosphere to corona; (ii) comparison with observations (iii) critical analysis of the literature on importance of magnetic field reconnection in solar coronal heating.

Dissipation of Alfven waves via phase mixing
The project involves (i) analytical calculations; (ii) writing a numerical code to study the dissipation of Alfven waves via phase mixing; (iii) critical analysis of the literature on importance of MHD wave dissipation in solar coronal heating.

Sergei Vorontsov

Asteroseismology with Kepler mission
NASA space mission Kepler, targeted primarily at habitable-planet finding, has delivered unprecedented amount of high-quality photometric measurements of stellar oscillations. The project is expected to give a comprehensive review of the results obtained for different stars, a review which would be a current review at the date of submitting the project. Basic understanding of the physical nature of different types of stellar pulsations (p-, f- g- and mixed modes), and of their diagnostic capability (frequency- and period spacings, frequency splittings) is required, which is expected to be

gained as part of the work on the project principally by reading the relevant literature, suggested by the supervisor.

CENTRE FOR CONDENSED MATTER AND MATERIALS PHYSICS

Mark Baxendale

Measurement of the thermoelectric properties of materials

Themoelectric materials convert waste heat energy to usable electrical energy. The primary figure of merit for these materials is the Seebeck coefficient, i.e. the ratio of the voltage measured across the sample in response to a small temperature gradient. This project aims to measure the Seebeck coefficient of some new candidates for thermoelectric energy generation and to make a comparison with that of the best known thermoelectric material, bismuth telluride (~100 uV/K at room temperature. The temperature variation of the Seebeck coefficient will then be measured and the behaviour interpreted in terms of the possible underlying mechanisms.

The theory of the detailed balance limit for the efficiency of solar cells

This project follows the landmark derivation of the detailed balance limit for silicon solar cell efficiency by Schockley and Queisser. A basis is a good understanding of semiconductor physics, the pn-junction, and some statistical physics. The aim is to extract the underling assumptions made in the calculation and to explain qualitatively the calculated maximum efficiency of ~40%. The project will then look at examples of solar cell design with known <40% efficiency and comment on the strategies employed to bring the efficiency closer to this theoretical maximum.

John Dennis

Synthesis, purification and spectroscopic characterisation of isomer-pure fullerenes

Fullerene have been synthesised in the range C60-96. As the number of carbon atoms increases, the number of possible structural isomers (same number of atoms, but different arrangements of them) also increases. For example, C60 has only one isomer, but C84 has 24 possible isomers. Despite the huge number of possible isomers, relatively few have actually been purified (about 20). The student will be tasked with using chromatographic separation techniques to purify a fullerene for which no isomers have previously been purified (e.g., C88) from an as-produced mixture of fullerenes (which range from C60 – C96). After which, the student will further purify their sample into its individual isomers. The isomer pure samples will then be characterised by a number of spectroscopic techniques.

Synthesis, purification and spectroscopic characterisation of thermodynamically stable C70 adducts as precursors for targeted drug delivery systems

Unlike C60, where all carbon atom environments are identical, C70 is a fullerene, which is still available in high yields, has several (5) different carbon-atom environments. Hence, unlike C60, the synthetic chemistry of C70 exhibits both chemo- and region-selectivity. The synthetic chemistry of C70 has until recently been kinetically rather than thermodynamically driven (i.e. the products are those that form the fastest rather than those that are the most stable). Indeed the most thermodynamically stable products were never formed. Recently, we have developed high temperature techniques whereby the most stable product is formed. These have the advantage that a thermodynamically stable anchor can be added to C70, which cannot be removed under normal chemical processes. Hence, C70 can be made water soluble (by adding –OH groups) without affecting the anchor. The anchor on the water-soluble fullerene can then be exploited whereby a drug is attached to it. By also adding a specific tissue-targeting group, a local drug-delivery system may be produced. Research in this area is at an early stage, but the student will have the task synthesising and purifying a thermodynamically stable carbonyl (-C=O) adduct of C70 using out new high temperature techniques. The student will then prove that they have produced the adduct by a number of spectroscopic techniques (including Mass, Infra-red (vibrational), and/or 1H and 13C NMR spectroscopy).

Kevin Donovan

Carbon Nanotubes as Langmuir Blodgett Films

Many organic molecules that possess hydrophilic and hydrophobic parts may be floated on a clean water surface as Langmuir films and compressed in a controlled fashion to form a rigid film of single molecule thickness. This floating film may be transferred to a substrate (eg glass slide) as a single or multilayer Langmuir-Blodgett film by passing the substrate through the water/film interface. It is possible to modify carbon nanotubes, CNTs, such that they are amenable to this process. Using this technique a mixed film of CNTs and a well understood LB molecule, ω tricosenoic acid, ωTA, will be created and its optical and electrical properties studied as the ratio of CNT to ωTA is varied in the film.

Induced Optical Anisotropy in Nanotube Suspensions

Single walled carbon nanotubes in suspension will, under the influence of a pulsed electric field align in that field. This alignment may be observed in real time by observing the temporal growth of induced optical birefringence and or dichroism. This project will use the induced optical birefringence to measure the polarisability of the nanotubes along with their average length and their effect on the viscosity of the suspending medium as their concentration is increased.

The Length Distribution of Single Walled Carbon Nanotubes

Single walled carbon nanotubes, SWCNTs, in suspension will, under the influence of a pulsed electric field align in that field. Once the field is switched off the nanotubes will slowly return to their state of random orientation. The rate of randomisation may be followed by observing the optical anisotropy of the suspension. The rate at which this randomisation occurs will depend on the length of the SWCNT. and therefore the length distribution of the nanotubes may be inferred from the decay. This project will involve using the fitting of such decays to a model where there are many different length SWCNTs present and thus finding the length distribution of the SWCNTs. A good knowledge of Mathematica and/or C++ will be necessary to carry out the fitting.

Drift Velocity of Electrons on One Dimensional Molecular Wires

Charge carriers (electrons or holes) in one dimensional, 1D, semiconductors is that a single electron (hole) in the 1D conduction (valence) band will strongly interact with the 1D lattice forming an electron plus lattice deformation, the composite object being called a solitary wave acoustic polaron, SWAP. A remarkable property of the SWAP is that the charge will travel at the velocity of sound (a relatively low velocity) but will achieve this velocity at very low electric fields entailing and ultra-high mobility. Such a 1D semiconductor is provided by single crystal polydiacetylenes, PDAs, and the properties of the SWAP may be studied through the photoconductive properties of the PDA following excitation by a rapid laser pulse. The object of this project is to measure the transient photocurrent and the total charge created by such a laser pulse and thus deduce the drift velocity of carriers on PDA chains and how it varies with applied electric field.

Growth of Single Crystals of Polydiacetylene Toluene Sulphonate

All polymers with the exception of polydiacetylenes when in the solid state will exist as a high entropy collection of random chains (eg. polyethylene in plastic bags). It is possible, however in the case of polydiacetylenes, to grow large (several mm) single crystals of the monomer diacetylene, DA, provided the DA has appropriate sidegroups allowing particular parameters for the monomer crystal to be achieved. One such sidegroup is the toluene sulphonate sidegroup which allows topochemical solid state polymerisation of the monomer crystal to take place with a resulting highly perfect polymer single crystal where all of the polymer chains are aligned. Such polymer chains behave as one dimensional wires and as such are of great interest to semiconductor physics. This project involves perfecting the oxygen free growth of such monomer crystals and their polymerisation.

Martin Dove

Disordered crystalline materials; what can we learn from novel diffraction methods

We have a strong interest in understanding the fluctuations in the positions of atoms within crystal structures that appear to have a lot of structural disorder. Examples include materials in which some atoms diffuse at a fast rate through the background crystal structure (so called fast-ion conductors that are used as electrolytes in solid-state batteries), and molecular materials where the orientations are disordered and tumbling when the positions are ordered on a lattice, or liquid crystals where the molecules have well-defined orientations but disordered positions.

In this project we will combine a diffraction-based method (using either neutrons or x-rays) with subsequent date-oriented computer simulation to study one specific example (this will be chosen by the student). You will be using state-of-the-art experimental methods (which may include a visit to the UK neutron scattering facility, and the use of an x-ray facility at Queen Mary) together with novel analysis methods developed in part by Queen Mary scientists.

The end result will be a new insight into the local structure and fluctuations of a material, which will certainly be publishable in the scientific literature.

Capture of carbon dioxide using porous crystalline materials

One critically important environmental problem for modern societies is that of controlling the mount of CO2 we put into the environment. One solution is to capture CO2 at the industrial sources. Current methods are expensive, and there is a lot of interest in looking for new materials for this task. One approach is to use porous crystalline materials, with a lot of interest in hybrid metal-organic materials that form crystal structures that contain large pores and channels.

The project is to use computer simulations to understand the mechanisms of CO2 absorption in materials. The approach is to use a technique called molecular dynamics, which is a form of virtual reality at atomic length and time scales. The project will involve setting up a simulation of passing gases across a sample and observing the way that the material soaks carbon dioxide out of the gas stream. The project will require simulations over a range of temperatures and for a range of gas compositions, and will focus on both the capture of CO2 and it subsequent release. The end result will be an evaluation of a specific type of material for capture of CO2, which can be published as a scientific paper.

Anomalous properties of framework materials

One very curious property of some materials is that they shrink when heated, contrary to the normal case of expanding. We have ideas about why this might be so, and here I am offering two projects, both of which are based on computer simulations. Both will lead to results we will publish as scientific papers.

1. One family of materials that displays negative thermal expansion is zeolites, which have chemical formula SiO2 and in which the structure forms SiO4 tetrahedra that are linked at corners to form infinite connected networks. The existence of negative thermal expansion is associated with the ability of the network to flex with low energy cost. The project will involve simulations of the dynamics, using lattice dynamics calculations and molecular dynamics (a form of virtual reality). The aim will be to identify negative thermal expansion in a group of zeolites (those with hexagonal crystal structure) and to then assess it against models of network flexibility.

2. A second family, represented by the formula ZrP_2O_7, shows negative or positive thermal expansion depending on the detailed chemical composition. The crystal structure consists of ZrO_6 octahedra and PO_4 tetrahedra linked at corners to form an infinite connected network. This network, however, is not flexible, and the origin of negative thermal expansion must lie in the ability of either the octahedra or tetrahedra to distort. The project will use ab initio lattice dynamics calculations (calculations based on a form of quantum mechanics) to evaluate the phonons, and we will then match the associated atomic motions with flexibility models. The aim will be to identify the mechanism of negative thermal expansion, and to understand why some members of this family of structures show negative thermal expansion whereas other members don't.

David Dunstan

The Size Effect in Small-Scale Plasticity

The student will join an on-going research programme on the strength of soft metals and the increase in strength when a characteristic dimension (wire diameter, foil thickness ...) is small, on a length-scale of microns. According to the student's interests, they may develop new equipment, take data, and undertake theoretical analysis.

A new medical instrument for monitoring diabetes

Together with a small optics and lighting company, we are developing an instrument intended to measure the loss of nerve function that triggers many complications in diabetic patients. There are a range of problems which a student on this project may choose to work on, ranging from writing software, building hardware, to inventing and testing measurement protocols.

Bill Gillin

Design of an automated interferometer

Interferometers rely on splitting a beam of light and sending it it two directions before recombining, a change in path difference between beams causes a change in the interference pattern. This can be used to detect very small changes in the length of objects, or to detect changes in refractive index. The purpose of this project is to design a computer interface for an optical detector and to characterise the stability of an interferometer and to determine the smallest length changes that can be measured. The second stage will be to design apparatus to allow for accurate measurements to be made in a range of systems.

Organic magnetoresistance

It has recently been discovered that the application of a magnetic field to an organic light emitting diode causes a change in both the efficiency of the device and the current passing through it. This project will involve fabricating a variety of organic light emitting diode devices and characterising their properties as a function of magnetic field.

Computer automation of the measurement of big G
Big G (The gravitational constant) is the most poorly defined physical constant we have with accepted value only being defined to about 0.01%. The Cavendish experiment to measure Big G relies on measuring the gravitational attraction of a pair of lead masses which is measured by the force they apply to a torsion balance using the deflection of a laser beam of a mirror attached to the balance. The purpose of this project is to design the electronics to detect the deflection of the laser beam and to interface this information into a PC so that the experimental data collection can be automated.

Theo Kreouzis

Time of Flight measurements on Organic Semiconductors

The Time of Flight (ToF) technique can be used to directly measure the drift velocity and range of charge carriers photogenerated within various organic (Carbon based) semiconducting systems (polymers, small molecules and liquid crystals). A variety of sample preparation techniques is available in house to prepare a system or systems for measurement by ToF within the Condensed Matter laser laboratory. As organics offer a wide parameter space in terms of composition, microstructure and phase the effects of these on carrier mobilty can be directly investigated.

Alston Misquitta

Topics in intermolecular interactions
This is a big field encompassing all of non-chemical molecular interactions. The intermolecular interactions are responsible for much of the interesting phenomena in the physical world: the existence of gases, liquids and some solids, the self-assembly of complex molecular systems. The Casimir effect is a more general case of the van der Waals (or dispersion) interaction. In this review project you will be able to choose from a number of topics in this field.

** General theory of intermolecular interaction

** Charge-transfer : this is a special interaction seen in hydrogen-bonds

** The van der Waals interaction : In particular, exploring the link between perturbation theory expressions for van der Waals and the continuum approach developed by Lifshitz.

Bayesian methods in fitting

When we fit a function to a set of data we usually minimize the error in a least-squares sense. This is all very well and it works, but for multi-dimensional fits this approach has a problem: how can we be sure that we have enough data in all parts of the multi-dimensional space so as to be confident that the fit is reasonable? Here we enter the realm of Bayesian methods that allow us to quantify our confidence in the fitting function itself. Bayesian methods give us a way of quantifying common sense and quantitatively compare models. In this project you will learn the basics of Bayesian methods and review the literature on using these methods to multidimensional fitting problems.

Anthony Phillips

Why are there (still) so few multiferroics?

Background: Ferromagnetism, the behaviour of familiar magnets, has been known since prehistoric times: in fact, magnetic beads have been discovered in Sumerian tombs built six millenia ago. Since then, other "ferroic" behaviours have been discovered. For instance, just as a ferromagnet can "switch" its magnetisation in response to an external magnetic field, a ferroelectric can switch its polarisation in response to an external electric field. This project will begin as for the review project. In the second semester, depending on students' interests, topics including the symmetry requirements for multiferroic behaviour; the differences between bulk, thin-film, heterostructure and nanostructure systems; or potential applications to technology will be explored. Again depending on students' interests, this could involve computer simulations of potentially multiferroic materials or analysis of experimental neutron scattering data from these materials.

Prerequisites: No specific background other than an interest in condensed matter physics necessary. If you are interested in the computer simulation part of the project, some familiarity with Unix/Linux systems would be helpful.

Diffuse X-ray scattering from framework materials

Framework materials consist of metal ions linked together into a 3D network by organic molecules. To understand these materials' behaviour, we often need to consider not only their average structure, but also local deviations from that average. For instance, if a chain ofatoms is sometimes buckled to the left, and sometimes to the right, the average gives a rather misleading picture of what is going on!

We have recently purchased an X-ray diffractometer optimised for measuring this local structural information. This project will involve measuring the diffuse X-ray scattering from a series of framework materials and running our modelling program RMCProfile to analyse the resulting data. This project will involve loading samples into glass capillaries and mounting them on the diffractometer to collect X-ray scattering data. The resulting data will then be analysed using computer modelling software. The extra time available to students taking 45 credits will be used to compare the X-ray data to previously collected neutron scattering data. Using neutron data will enable us to consider both atomic and magnetic local structure in these materials, and thus to build a more complete model of their behaviour. Prerequisites: None, other than an interest in condensed matter physics.

Andrei Sapelkin

Photoluminescence excitation system for quantum dot research

Within this project we will set up a laser–based photoluminescence excitation (PLE) system and develop Labview software to control data acquisition. The PLE system will be used to access the light emitting properties of variety of off-the-shelf and in-house made quantum dot systems.

(Prerequisites: basic optics, some knowledge of computer programming/analysis (VBasic, C, C++, Origin, etc.)

Synthesis and characterization of germanium quantum dots

Quantum dots – materials reduced in size down to just a few nanometers possess a range of interesting physical properties due to effect of quantum confinement of charge carriers (electrons and holes) and a large surface-to-volume ratio. These properties can be used in variety of applications including tagging of living cells and observation of communication in neuron networks. This experimental project involves preparation of Si and Ge quantum dots by colloidal synthesis; optical (photoluminescence) and structural (Raman, SEM/TEM).

(Prerequisites: basic optics, basic laboratory skills)

Synthesis and characterization of gold quantum dots

Quantum dots – materials reduced in size down to just a few nanometers possess a range of interesting physical properties due to effect of quantum confinement of charge carriers (electrons and holes) and a large surface-to-volume ratio. These properties can be used in variety of electronic, engineering and bio applications and it is essential to understand the relationship between the structure of these materials on the atomic level and their physical properties. Within this project we will synthesise gold quantum tots and will tune the light emission between 530 nm and 630 nm by cooperation ligand exchange using 11-mercaptoundecanoic acid (11-MUA) and D-penicillamine (DPA). Quantum dots will be characterized using photoluminescence and TEM/SEM.

(Prerequisites: basic optics, basic laboratory skills)

Kostya Trachenko

Glasses as encapsulation matrices of nuclear waste

The need for a solution of the problem of dealing with nuclear waste is more urgent now than ever before. For highly-radioactive materials it is necessary to encapsulate the radioactive ions within an inert matrix material (waste form) which prevents the ions from diffusing out and becoming a health and environmental hazard. The last few decades have seen increased research in this area, with new proposals and ideas, experimental and modelling results discussed and debated. This project will review these results, with the emphasis on research efforts and its results on glass waste forms. Both policy documents from the UK and EU communities and research papers will be reviewed, and both advantages and disadvantages of several classes of glass waste forms will be discussed.

Crystalline ceramics as encapsulation matrices of nuclear waste: effects of radiation damage

The need for a solution of the problem of dealing with nuclear waste is more urgent now than ever before. For highly-radioactive materials it is necessary to encapsulate the radioactive ions within an inert matrix material (waste form) which prevents the ions from diffusing out and becoming a health and environmental hazard. The last few decades have seen increased research into using crystalline ceramic materials as waste forms. The important issue is the potential degradation of the waste form due to radiation damage. The project will review recent results and proposals related to using crystalline ceramics as waste forms. Recent reports by the UK and USA laboratories as well as research papers will be reviewed and discussed, with particular emphasis on the effect of radiation damage on the performance of waste forms.

Dr David Berman – experimental project

Optimising quinine extraction from Cinchona bark for the production of natural tonic water

Most commercially available tonic waters use industrially synthesized quinine. This project will produce natural tonic water through extracting quinine from Cinchona bark. The variables in the extraction process include bark concentration, grind size and temperature, all these should be optimised. The final quinine concentration will be determined by constructing a simple spectral analyser to measure the quinine florescence and implementing the Beer-Lambert law. The effects of bark impurities will also be examined.

If you would like to do this project please note that you want to do Dr Berman's experimental project in the 'other information' box on the project choice form.

CENTRE FOR RESEARCH IN STRING THEORY

David Berman

Cellular automata

The construction and exploration of cellular automata of different types.

(Prerequisite: strong computer programming skills)

Experimental project

Optimising quinine extraction from Cinchona bark for the production of natural tonic water

Most commercially available tonic waters use industrially synthesized quinine. This project will produce natural tonic water through extracting quinine from Cinchona bark. The variables in the extraction process include bark concentration, grind size and temperature, all these should be optimised. The final quinine concentration will be determined by constructing a simple spectral analyser to measure the quinine florescence and implementing the Beer-Lambert law. The effects of bark impurities will also be examined.

If you would like to do this project please note that you want to do Dr Berman's experimental project in the 'other information' box on the project choice form.

Andi Brandhuber

Geometric phases

A geometric phase -- also known as Berry phase -- is the phase acquired when a physical system undergoes a cyclic adiabatic process, and is a consequence of geometrical properties of the parameter space of a physical system. This phenomenon can occur in classical systems e.g. Foucault pendulum and in quantum mechanical systems e.g. Aharonov-Bohm effect. This project will examine various examples of geometric phases in the classical and quantum world.

Pre-requisites: Physical Dynamics and Quantum Mechanics A

Co-requisite: Quantum Mechanics B

Black hole physics

One of the most fascinating objects predicted by Einstein's theory of General Relativity (GR) are black holes and a complete understanding of the quantum physics of black holes remains a challenge for theoretical physics. This project will introduce the student to the basic concepts of black holes, starting with their classical description in terms of solutions of Einstein's equation, moving on to the quantum description and the thermodynamics of black holes.

Depending on time the student will study (some of) the following topics:

1) experimental evidence for the existence of black holes

2) Hawking radiation as a quantum mechanical tunnelling effect

3) thermodynamics of black holes in Anti-de-Sitter (AdS) space.

Pre-requisites: Physical Dynamics and Quantum Mechanics A
Co-requisite: Spacetime and Gravity

Sanjaye Ramgoolam

Plasma Physics and Nuclear fusion
The project consists of working through equations of fluid dynamics and of charged particle motion in electromagnetic fields, which are relevant to plasma physics. In addition the student will be expected to read reviews of developments in nuclear fusion technology over the last few decades, and to use the theoretical calculations to give a clear exposition of these developments. A good understanding of MT3 is a requirement for this project.

Rodolfo Russo

Kerr Black holes as particle accelerators.
The project is based on the paper 0909.0169 by Banados, Silk and West who proposed that spinning black holes can act as particle accelerators of Planckian energy. As an introduction, Schwarzschild's and Kerr's black holes for standard 4D Einstein gravity are reviewed. Then the proposal by Banados et al. is analysed by studying the geodesics in the black hole metric metrics.
Prerequisites: Physical Dynamics
Co-requisite: Spacetime and Gravity

The QCD string
String theory studies the dynamics of 1-dimensional objects that obey the laws of special relativity and quantum mechanics. Open strings of this type describes well at low energies the meson particles we know. The aim of the project is to take an effective theory point of view and study how symmetries and other physical inputs constrain the action for a string that could describe the mesons.
Prerequisites: Physical Dynamics and Mathematical Techniques 3
Co-requisite: Quantum Mechanics B

Steve Thomas

Kaluza-Klein theory and the origin of symmetries

In recent years the concept that our world may have hidden extra spatial dimensions has played a vital role in fundamental theories that unify the known forces, most notably superstring theory. This idea originates from the work of Kaluza and Klein in the 1920's who showed that a theory in four dimensions that contains gravity and electromagnetism may be explained by a pure gravity theory in one dimension higher. The project will introduce the student to the basic Kaluza-Klein hypothesis, with simple examples based on scalar field theory which will illustrate the physical consequences of compactification. These techniques will then be applied to higher dimensional gravity theories, which gives a clue to the higher dimensional origin of gauge symmetries in four dimensions

Large extra dimensions

This project concerns the recent proposal that we may be living in a world where there could be macroscopically large extra spatial dimensions beyond the three that we are familiar with. This possibility has arisen in so called 'brane-world' models where our 3+1 dimensional Universe is thought of as a kind of membrane moving through a higher dimensional volume. In such models the strong, weak and electromagnetic forces are confined to live in our brane but gravitational forces can penetrate the extra dimensions.

The student will investigate the behavior of Newtonian gravity in different dimensions as a way of understanding the interplay between the perceived strength of gravity and the size of any additional spatial directions. Then, within the framework of General Relativity, brane-world models first described by Randall and Sundrum will be investigated as will the current experimental bounds placed on them arising from LHC data.

From Classical Strings to Photons and Gravitons

The project starts with manipulating equations describing the geometry of string worldsheets and their embedding in space-time. This is followed by working through aspects of formal quantum mechanics and special relativity. It builds up to the worldsheet quantum theory construction of space-time physical states such as photons and gravitons. Zwiebach's string theory book provides the main reference.

Inflationary Cosmology

Inflation has been proposed as a ‘paradigm’ whereby the Universe undergoes a period of exponential expansion during which spatial regions as small as 10^{-25cm} get blown up to something of the order of a few cms in size in only 10^{-32} sec! Such a model explains some long-standing problems in standard Friedman-Roberston-Walker big bang cosmology, namely the so-called horizon and flatness problems as well as (potentially) solving the singularity problem. At the same time it also explains the near scale-invariant spectrum of perturbations that we can observe today through their imprints on the CMB radiation. One particular type of perturbation predicted is a primordial spectrum of gravitational waves whose affect is to polarise, in a very particular way, the microwave light from the CMB. In a spectacular recent experiment, this polarisation has been detected by the BICEP2 collaboration using telescopes based in the South Pole.

This project covers some fundamental aspects of inflationary cosmology. Beginning from the FRW Big Bang model in general relativity, the student will then work through the details of inflation and the conditions required for it to occur. This will primarily involve so called slow roll inflation models and some simple examples will be studied. Classical field evolution and quantum fluctuations will be investigated with the latter giving rise to various perturbation spectra that the student will derive. The resulting cosmological observables will also be derived and predictions tested against current precision CMB data. There is scope within the project to use Mathematica or MatLab as numerical tools.

Brian Wecht

Exact and Numerical Solutions for Solitons

Solitons are interesting solutions to nonlinear wave equations which can be found in a variety of fields of physics, including optics, condensed matter, theoretical high energy physics, and more. In this project, we'll examine solitonic solutions from both exact (analytical) and approximate (numerical) standpoints, with an eye towards modeling interacting solitons on the computer.

Population Models in Mathematical Biology

Nonlinear systems can be used to model populations in a variety of interesting biological systems. By starting with Lotka-Volterra predator-prey models, this project will aim to describe various cycles of population growth and decline throughout the animal kingdom. If time allows, the project can also include oscillatory systems in cells and other biological systems

Electrodynamics in Higher Dimensions

Maxwell's equations describe the electrodynamics of point charges in four dimensional spacetime. In higher dimensions, analogs of electric and magnetic fields can be sourced by extended objects like strings or membranes. This project will examine the generalization of Maxwell's equations to arbitrary dimensions. Mathematical topics to be covered along the way include differential forms and higher dimensional geometry.

Donovan Young

What does Einstein's relativity look like?

When we learn about relativity and length contraction we expect that if we saw a spaceship zooming by near the speed of light we would see its length contracted. Although its length really is contracted it wouldn't look that way to your eyes. In this project you will calculate what relativistic effects actually do to the scene captured by the eye. Depending on time the student will also study the lensing of light produced by black holes.

PARTICLE PHYSICS RESEARCH CENTRE

Adrian Bevan

PeV energy scale particle physics

The Large Hadron Collider represents the high energy frontier in particle physics with 14Te collision energy expected in 2015 once the current upgrade period has finished. This collision energy will be enough for physicists to search for new physics up to 10^12 eV. Accelerator technology is not expected to significantly push beyond this limit without some radical new breakthrough. Cosmic rays can provide particles with energy up to 10^21 eV, with low rates. What can we do with those to further our understanding of physics, and how will we do it?

Flavour physics at the LHC

The ATLAS detector triggers on di-muon events, and as a result collects data suitable for rare decay_studies. The study of such decays is complementary to the high energy direct detection approach and_relies on understanding subtle interference patterns between different contributions to the final states.
There are two ares of interest for this project: The first pertains to B physics: The family of decays including a b quark transition to a strange quark and di-muon pair is being studied by our at ATLAS. Recent results provide some hint that all may not be well with the Standard Model and we are working on trying to understand if this anomaly is statistical in nature or a hint of something new. I am also expanding my interest in rare top decays, which forms the second possible are for project research. This second area is more challenging as it is less well defined and require students opting for this route to take more initiative in order to understand and define the scope of the project. The former route has the option of allowing students to re-analyse 2011 data from ATLAS in the context of recent theoretical developments.

Marcella Bona

Inputs to the Unitarity Triangle fit.

To completely characterise the Standard Model, we need to extract the values of some parameters from various high energy experiments and theoretical calculation. The UTfit project is a global fit analysis that using the Bayesian statistics extracts SM parameters and SM predictions on various observables using the most updated results from experiments and lattice QCD. Some of the inputs need special statistical treatments and analyses that have to be regularly updated.

C++ programming is necessary.
The analysis is performed within the Root package (root.cern.ch) that should be installed on the used computer.

Invariant Mass Fits For The Search Of Rare B Decays Into Two Muons.

The B mesons can decay into two muons and the probability of this decay is very low but accurately calculated within the Standard Model. ATLAS experiment at LHC is searching for these decays and the crucial part of the analysis is calculating the invariant mass of any pair of two muons in the collision events and then perform a fit to the invariant mass distribution taking into account all the signal and background components.

C++ programming is necessary.
The analysis is performed within the Root package (root.cern.ch) that should be installed on the used computer.

<u>Multivariate analysis methods for rare B decays</u>
As the B mesons decay into two muons with a very low probability, it is fundamental to develop methods to distinguish between the actual signal and the random background component that is dominant in the collision data. There are several methods that can be used to exploit the different topologies and event characteristics and obtaining a single variable that can be used to separate between signal and background. Fisher discriminant, Boosted Decision Tree, Neural Network have to be tested and the optimal method selected for the purpose of the search of rare B decays.

C++ programming is necessary.
The analysis is performed within the Root package (root.cern.ch) that should be installed on the used computer.

Jon Hays

<u>Beyond the Standard Model Higgs at the LHC</u>
Though the Higgs boson discovered by the LHC in 2012 looks, with current measurements, very much like that predicted by the standard model of Particle physics, this does not rule out richer theories with multiple Higgs bosons where only one of them looks like that predicted in the standard model. This project will identify kinematic variables to distinguish between standard model Higgs production, Higgs production in multi Higgs doublet models and standard model background processes. It involves programming in C++ to run event generators based on Monte-Carlo simulation techniques and simple analysis with the ROOT software.

Prerequisites: Strong C++ programming skills

<u>Improving the categorization of events in the search for the Higgs boson in its decays to b quarks</u>

The Higgs boson was discovered at the LHC in the Summer of 2012 with a mass of around 125 GeV. There is strong evidence for its production in a number of its decay modes. However, as yet, there is not a statistically significant signal in the channel where the Higgs decays to a b quark and an anti-b quark. A key parameter in the performance of the search in this important channel is the resolution with which the mass of the Higgs can be reconstructed from measurements of the decay products. Being able to separate events where the mass is well measured from those where it is poorly measured may have an important impact on the sensitivity of the analysis. In this project you will investigate multivariate approaches to estimating the mass resolution on an event-by-event basis.

Prerequisites: Strong C++ programming skills

Teppei Katori

Test of Lorentz violation with neutrinos
work type = phenomenology
Lorentz symmetry is a fundamental symmetry of both Quantum Field Theory (QFT) and General Relativity (GR). However, ultra high energy theories, such as String Theory, imply a violation of Lorentz symmetry, and a tiny violation could be observable in our energy scale. Therefore, test of Lorentz violation offers a rare opportunity to test Planck-scale physics directly. In the effective field theory, Lorentz violation is realized by additional coordinate-dependent couplings with vacuum, and the QFT including Lorentz violation, so-called the "Standard Model Extension (SME)" is a general formalism to test Lorentz violation.

Neutrinos are least known fundamental particles, and their Lorentz violating nature, if it exists, is particularly interesting. In this project, we study the phenomenology of Lorentz violation with neutrinos in SME formalism, and formulate the new phenomenological expression suitable to test Lorentz symmetry by high intensity long-baseline neutrino experiment, such as T2K in Japan.

MiniBooNE experiment data analysis of neutrino interactions
work type = data analysis
MiniBooNE is a neutrino oscillation experiment at Fermilab, USA.
Besides oscillation results, the neutrino interaction data from the MiniBooNE experiment are also valuable for nuclear physics community.
In this project, using the real MiniBooNE data, we further analyze them to provide more useful information to nuclear theorists in the world.
I am especially interested in to provide new kinematic distributions of muon neutrino charged-current quasi-elastic (CCQE) scattering. By the way MiniBooNE is taking data right now to look for possible dark matter production in the beamline. We will participate data taking, which is the quickest way to learn how a real particle physics experiment works.

Electromagnetic calorimeter (ECal) reconstruction for T2K experiment
work type = software development
ECal module is a part of detector being used in T2K neutrino experiment, Japan. The ECal was partially built in Queen Mary, and it was tested at CERN before shipped to Japan. Particle tracks and electromagnetic showers are

reconstructed in ECal, to study the nature of neutrino interactions. Now we need a better algorithm to reconstruct lower energy shower-like events.

In this project, we examine the detail of track and shower finding algorithm of ECal, and further develop it to identify especially low energy shower events. Low energy shower events are key to understanding neutral pion productions which is one of the largest background for neutrino oscillation search. Therefore, developing the ECal reconstruction algorithm is a critical component of T2K neutrino oscillation program.

Atmospheric neutrino study for general new physics search in IceCube experiment
Work type = data analysis
IceCube is the 1 kilometer detector located at the Antarctica, 1 kilometer under the ice. The IceCube detector is so unique and special, and the main goal of IceCube is the detection of ultra high energy neutrinos from the universe. Atmospheric neutrinos are mere backgrounds of such high energy neutrinos. Although we know neutrinos from the atmosphere since 1960's, there is no comprehensive study to find new physics from atmospheric neutrinos.

In this project, we analyze IceCube atmospheric neutrino data to provide kinematic distributions for particle theorists in the world.
Well, I am not smart enough to find any new particles from these data, but hopefully some smartest people in the world could find Nobel prize winning physics from data we provide!

Neutrino interaction development for IceCube and PINGU
work type = data analysis, software development
For particle physics experiments, it is fundamental to understand, and simulate basic interactions. All discoveries (Higgs particle, neutrino oscillation, etc) are based on the knowledge of all known interactions and precise simulation. However, in the reality very few people understand actual interactions in the simulation, and those processes are treated like a "black box" for many physicists. Therefore, people who understand interactions are like "wizards" (meaning people working on something really complicated which nobody understands). This is true for neutrino experiments, too.

In this project, I hope you feel you will become a wizard of neutrino experiments! We develop the global neutrino interaction code called "GENIE". It contributes all neutrino experiments all over the world. I am particularly interested in the development of GENIE hadronization model for the IceCube experiment at Antarctica. This will improve the sensitivity of IceCube experiment and it's follower, called PINGU experiment.

Eram Rizvi

Micro Black Hole Production at the LHC

Some models of low scale quantum gravity predict the formation of micro-black holes in collisions of high energy particles far below the Planck scale and within the energy reach of the Large Hadron Collider. In this project a simulation program BlackMax will be used to investigate the parameter space for some of these models and to estimate the uncertainty on the predictions arising from an imprecise knowledge of the momentum distributions of quarks and gluons within the proton.

The project is split into two parts. The first part will require extensive use of C++ to create compact and efficient data structures within which to store many collision simulations. In the second part of the project the ROOT program developed at CERN will be used to analyse the simulated collisions and to estimate the uncertainties on the predicted cross sections. The parameter space will be explored to reject models which may already be inconsistent with existing collider data.

Physics potential of a proposed new electron-proton collider
A proposal is being made for a new electron-proton collider to run simultaneously with the LHC at CERN. In this project the student will study the possible physics impact of such a new collider in determining electroweak parameters of the Standard Model of particle physics, and the parton densities of the proton. This project will make use of the simple FORTRAN programming language.
(Prerequisite: a working knowledge of linux operating systems would be advantageous.)

Extraction of quark and gluon densities of the proton
The quark and gluon content of the proton can only be determined directly from experimental data of high energy collisions. The extraction of these "parton" density functions (PDFs) uses a least squares approach to minimise a $\chi 2$ function comparing data with theoretical expections based on the PDFs which are parameterised by polynomial functions. The extraction involves finding the best parameters of the polynomial functions consistent with the data. In this project the student will attempt to estimate the uncertainty on the PDFs arising from the choice of functional form - the so-called parameterisation uncertainty. This will require choosing different forms, or even spline functions. This challenging project is suitable for a mathematically able student with a good grasp of programming and knowledge of the linux operating system. The programming will be done in the simple FORTRAN language.

Rutherford scattering
The results of Ernest Rutherford on proving the existence of a nuclear atom will be reproduced in an apparatus on the fifth floor of the Physics Building. This uses a 1.5mC americium 241 alpha source, and a solid state particle detector to study the scattering of alpha particles off heavy elements. The dependence of counting rate on the angle of scattering will be measured and compared with the theoretical predictions for multiple (Thomson) scattering as well as for Rutherford scattering. In addition there is a mechanism to change

the gold targets so enabling a check on the thickness. In the second semester the student may use targets of other material to determine the Z dependence. The variation of pressure in the bell jar enables a range and thus energy measurment, and using a variable system of absorbers the energy dependence of scattering can be checked against Rutherford's predictions. Corrections will be made for background and resolution.

Matthew Machowski (PLEASE CONTACT DR RIZVI WITH ENQUIRIES)

Politics of Physics: The Iranian Bomb

As we sit on the brink of a potential Western/Israeli-led pre-emptive war with Iran over their alleged nuclear weapons programme, this project investigates the impact of nuclear weapons (technology) acquisition on international politics and security. Iran's nuclear programme has now spanned over three decades, much in defiance of both international demands and legal constraints. Despite much political rhetoric and decades-long accusations against Iran, both the IAEA and all the Western intelligence agencies struggle to provide irrefutable evidence for either the presence or the extent of Iran's weaponisation.

This project is predominantly aimed at students considering a career in politics, security, risk management and science policy, but also those willing to investigate the correlation between nuclear physics and current affairs. Although you are encouraged to develop you own niche theme, issues surrounding nuclear weapons technology, nuclear deterrence, legal and political anti- and counter-proliferation efforts, nuclear intelligence gathering and analysis, or support for nuclear terrorism may be of particular interest here.

Bio: Matthew is a Middle Eastern security specialist and a former research analyst for the Middle East and North Africa Programme of the Royal United Services Institute for Defence and Security Studies (RUSI). He has so far consulted the UK Parliament and governments of Japan, Poland and Qatar. He has additional experience in journalism and human rights advocacy. He spent over four years living in the Middle East, where among others he worked for one of the region's royal families. His commentary was featured in international media, including The Times, NHK World News etc.

Jeanne Wilson

SNO+ Modelling and detector response

SNO+ is a multi-purpose neutrino experiment based in an active nickel mine in Sudbury, Canada, due to start data taking in 2013. The SNO+ detector consists of a large volume of liquid scintillator, surrounded by around 9000 PMTs. The experiment will detect neutrinos from the Sun, Earth, nuclear reactors and possibly also SuperNovae allowing precision measurements of neutrino oscillation parameters. In a separate phase of the experiment, Neodymium will be added to the scintillator to allow a search for the rare process of double beta decay which would probe the fundamental properties of the neutrino. These measurements require extremely low levels of radioactive background, and a very precise understanding of the detector response which is achieved through accurate modeling and calibration of the detector. This project would contribute directly to the testing and development of the C++ based Monte Carlo simulation package that is being written by the SNO+ collaboration for this purpose. The student would use the package to simulate various

physics quantities that must be compared against theory or experimental calibration data.

(Prerequisite: an understanding of C++ and linux will be required.)

Study of medipix detector chips

Queen Mary is involved in the so-called CERN@School project which involves equipping several schools with a CERN Medipix chip connected to a laptop in order to gather data about secondary cosmic rays in the atmosphere which is then shared between the schools. The project will involve studying the behaviour of the chip under various conditions (voltage, threshold etc) and with different radiation sources suitable for use in schools. The student will work to interpret the data using and developing existing monte carlo and plotting tools and to develop projects suitable to be carried out in schools.