Projects update, errata and corrections to the *MPhys Projects Trinity Term 2019*

******WITHDRAWN**PP14 & PP15*** **Higgs Self-Coupling and Search for New Physics with di-Higgs to final states with the ATLAS detector**

Searches for new physics in di-Higgs final states are an active and important field of research at the Large Hadron Collider (LHC).This project will allow the student to search for new heavy states of matter in the ATLAS data in final states with two Higgs bosons, where at least one of them decays into two b-quarks. Important areas of research are the improvements to the b-quark identification, jet* energy and mass calibration and the utilization of novel jet algorithms, which adjust their features to the momentum of the Higgs bosons and neural network analysis techniques.

Depending on the interest of the student it could also involve phenomenological studies on the Higgs self-coupling measurement which the di-Higgs process is sensitive to.

Required skills are Programming in C++, basic understanding of ROOT (https://root.cern.ch/root/htmldoc/guides/primer/ROOTPrimer.pdf) and Linux/Unix.

*jets are collimated sprays of particles, which are initiated by quarks.

Supervisor: ***Prof C Issever***

Email: ***Cigdem.Issever@physics.ox.ac.uk***

******WITHDRAWN**A&L12*** **High Finesse Cavity QED**

Assembly and characterization of optical micro-cavities for light-matter interaction in the strong coupling regime. This includes setting up the resonator, a piezo control of the cavity length and spectroscopic or cavity-ringdown measurements to determine the finesse, mirror reflectivity and mirror losses.

Supervisor: ***Prof A Kuhn***
Email: ***axel.kuhn@physics.ox.ac.uk***

PP26 **Constraining atmospheric neutrino flux predictions for the SuperKamiokande Experiment using cosmic-ray muon data.**

Neutrino oscillation was first seen in neutrinos that had been produced in the atmosphere from cosmic rays by comparing the rates of neutrinos from different directions in the SuperKamiokande experiment. The different directions translate into different oscillation distances. Super-Kamiokande has continued to collect data and now has a formidable amount of statistics, and has recently undergone an upgrade that will allow Gadolinium to be introduced into the water in the near future. The Gadolinium will allow neutrons from the neutrino interactions to be detected by delayed emission of gamma rays after the neutrons are captured by the Gadolinium nuclei.

The flux predictions are made by Monte-Carlo simulation of the atmospheric interactions, and we are involved in a programme to substantially improve them. The simulation involves a whole chain of processes: Generating primary protons and other nuclei according to measured primary fluxes from balloons and satellites, including effects of solar wind and geomagnetic field, generating hadronic interactions when the primaries collide with nuclei in the atmosphere, propagating the resulting particles through the rest of the atmosphere. The simple neutrino-counting argument of the decay of a pion to a muon and neutrino and then the muon to two more neutrinos is insightful for understanding the oscillation phenomena, but because of the variations of the fluxes with energy, this much more detailed simulation approach is necessary for the data analysis.

The main difficulty is that because the strong interaction is unsuitable for calculation with perturbation theory, the hadronic interactions are not possible to predict, and so data from accelerator experiments is used to govern the Monte-Carlo generation instead. While SuperKamiokande has been running, the quality of experimental data on hadron production has increased significantly, and we are in the process of inserting them into the Monte-Carlo calculations. This will produce significantly improved calculations that can be used with the new data from SuperK. By using weighting techniques, it will also be possible to vary the assumptions from the hadron production modelling and provide uncertainties (as has been done before), and to use tuning techniques to apply different forms of input data as constraints. We are intending to use accelerator hadron production data, data from the T2K long-baseline accelerator experiment and from cosmic ray muon data.

The aim of the project is to tackle the application of constraints from the cosmic ray muon data, which has not been attempted by our simulation group before. Independent predictions of the fluxes were carried out in the early days, and the other major flux calculation does include these constraints. We will try to parameterise how both the muon flux and neutrino fluxes vary when the assumptions about hadron production are changed, and then apply the muon data as a constraint using a fitting procedure which we will devise. One of the investigations will be to understand whether all of the phase space for neutrinos is constrained by the muons, it is likely that it isn't, but there may be ways we can investigate to overcome this.

The project is computer based and will involve extensive use of either C++ or python programming (to make histograms)

Supervisor: ***Prof G Barr***
Email: **giles.barr@physics.ox.ac.uk**
Webpage with a bit more info: http://www-pnp.physics.ox.ac.uk/~barr/mphys/proj2019.html
Safety: Display screen equipment (computers) safety

****WITHDRAWN***AO21*** **Nonlinear aerosol effects on clouds**

Clouds act as air conditioners of the climate system by reflecting a vast amount of the sun's energy to space. An increase in anthropogenic aerosols, tiny particles commonly produced by combustion, are hypothesized to enhance cloud reflectivity through nucleation of more cloud droplets. As a result, anthropogenic aerosols may offset part of the global warming response due to the buildup of greenhouse gases. Although, the amount of cooling by aerosols is highly uncertain due in part to an assumed linear relationship between the cloud reflectivity and cloud droplet number concentration. The goal of this project is to quantify the linearity of the aerosol-cloud relationship over a wide range of spatial scales and meteorological conditions. The project will make use of multiple state-of-the-art satellite data sets and output from global climate models. The retrieved quantities will be obtained from active (e.g. radar and lidar) and passive imaging satellite products in a comprehensive analysis, also including corroborating measurements from surface-based instruments. These products will utilize the collocation tools within the Community Intercomparison Suite (CIS). Statistical methodologies will need to be developed based on theoretical models describing aerosol-cloud interactions in order to the quantify climate impacts.

The student will have the opportunity to deepen their computer programming skills, learn about and develop the theory behind aerosol cloud interactions, and apply numerous integrated datasets together to test a wide range of theoretical relationships on aerosol-cloud interactions. The project demands basic analytical and programming skills (preferably in IDL, Matlab, or Python).

Supervisors: ***Dr M Christensen*** and ***Prof P Stier***
Email: ***matthew.christensen@physics.ox.ac.uk***; ***philip.stier@physics.ox.ac.uk***

IND003 **Optimisation of an in-plane vector magnet for RASOR**

The RASOR end station (Reflectivity and Advanced Scattering from Ordered Regimes) at the Diamond Light Source (www.diamond.ac.uk) is a soft x-ray diffractometer with a full polarisation analyser and low temperature capabilities. It is equipped with a liquid helium cryostat enabling the sample to reach temperatures of 12 K. RASOR has two main rotation circles, theta for the sample and two theta for the detector, that both provide a full range of motion. For the investigation of magnetic samples, such as magnetic multilayers that are at the heart of modern computing, a defined magnetic field has to be applied. Providing a variable and homogeneous magnetic field in various geometrical configurations poses a technical challenge. Halbach arrays with rotatable permanent magnets are one way to achieve this goal.

This project will involve modelling of Halbach arrays using finite element methods. Further, using a 3D magnetic field sensor, real Halbach systems (with non-ideal magnets) have to be mapped out and machine learning has to be applied to achieve any desired magnetic field (and field history).

Recent group publications: https://www2.physics.ox.ac.uk/research/thin-film-quantum-materials/publications

Essential skills: programming, machine learning, simple electronics projects (e.g. using Arduino)

Desired skills: interest in magnetism, practical skills, strong work ethics

Industrial Supervisors: ***Dr P Steadman*** and ***Dr R Fan***
(Diamond Light Source)
Oxford Supervisor: ***Prof T Hesjedal***
Email***: thorsten.hesjedal@physics.ox.ac.uk***

PP25 Investigating Charge Transfer Inefficiency in sensors for LSST

The LSST is a next generation optical survey telescope which will constrain our knowledge about dark energy through weak lensing surveys. These surveys involve measuring the shapes of galaxies very precisely and are susceptible to many systematic errors, both astronomical and instrumental, which must be well understood and characterised. One major effect is that of charge transfer inefficiency caused by single electron "trap" states below the conduction band in silicon. Characterising these trapping states is important in determining how best to mitigate and/or correct for charge transfer inefficiency. In the OPMD lab we have the capability to perform "trap pumping" experiments at cryogenic temperatures and ultra-high vacuum which can measure the properties of individual silicon trapping sites. In theory, the trap properties are affected by local electric field, though this has yet to be directly demonstrated in experimental data. We have also devised a novel experiment which will use sub-bandgap illumination to fill traps in an energy-dependent fashion, allowing for the first time to measure trap emission time constants separately from their energy level.

The student will work on collecting and analyzing data from these experiments and have input into some aspects of the experimental design (perhaps including optical and electronic aspects). Some experience with programming (python) and image processing would be advantageous. This would ideally suit a student who is interested in working with (sometimes temperamental) experimental data.Supervisor: ***Dr D Weatherill***
Email: ***daniel.weatherill@physics.ox.ac.uk***

PP24 Medipix and Timepix Detectors applicability to multi-spectral x-ray imaging

Oxford physics is a member of the Medipix collaboration; we are currently working with the latest generation hybrid pixel detectors: Medipix3 and Timepix3, both of which have applications in muti-spectral x-ray imaging. This technique uses information of the different emerges of the x-rays detected to determine information about the material in the image, and distinguish it, by looking at elemental absorption characteristic. Calcium atoms in bone, and barium and iodine markers for other tissue types. The Medipix and Timepix detectors operate in fundamentally different ways, and in this project the student will determine the strengths and weaknesses of each system for the task of energy resolved imaging of x-rays. This will be done using a new x-ray generator that will be available in the OPMD facility, as well as working with well characterised radioactive sources.

Supervisor: ***Prof D Bortoletto***
Email: ***Daniela.Bortoletto@physics.ox.ac.uk***

PP23 Extraction of ancient writing from X-ray fluorescence images

This project will look at a novel way of reconstructing archaeological finds from X-ray fluorescence measurements, in particular ancient writing on scrolls that were charred during the eruption of Mt. Vesuvius in 79 AD. Whilst the suggested methodology is reasonably simple, a pin-whole x-ray camera that is energy sensitive, the extraction of the very faint signal over background will require careful analysis of the recorded data. Many measurements have already been made, but few of the data has yet been analysed. The project will allow one to study the sensitivity of the apparatus, based on data recorded from templates, as well as trying to understand actual data recorded on a real object and giving the best shot a making a drem-come-true for the world of ancient classics and archaeology.

Most of the work will involve statistical analysis of recorded 3-dimensional data using either Python or a programming language of your choice. Code exists (in Python/C++) to read in data files and generate simple plots (2D images, 1D energy spectra) of the existing data.

Supervisors: ***Dr J Dopke*** and ***Prof A Weber***
Email: ***alfons.weber@physics.ox.ac.uk***

******WITHDRAWN****** ***AS07* Modified gravity explored through hydrodynamical simulation**

Tests of General Relativity and its alternatives abound on laboratory, Solar System and cosmological scales, but are very rare on the intermediate scale of galaxies. This is despite a number of interesting theories exhibiting their strongest if not their only signals in galaxy structure and dynamics; these include offsets between the kinematics and centres of mass of stars and gas, warping of stellar disks and irregularities in rotation curves, all correlated with gravitational environment.

The factor limiting the use of these signals to probe gravity is the degeneracy between gravitational and baryonic degrees of freedom. The latter describe gas dissipation and stellar feedback, and may mimic the effects of modified gravity by means of processes such as hydrodynamical drag, ram pressure and energy exchange between galactic mass components. The best way to explore these effects is through 'cosmological hydrodynamical simulations', which track the effects of baryonic physics on galaxy evolution under standard gravity.

In this project the student will analyse the output of Oxford's flagship hydrodynamical simulation -- the Horizon-AGN simulation and its successor New Horizon -- to quantify the magnitude and environment-dependence of potential modified gravity signals produced by galaxy formation physics alone. This is crucial groundwork for assessing the significance of any putative deviation from General Relativity in observational data.

Strong programming skills will be required, preferably Python and/or C.

Supervisor: ***Dr H Desmond***
Email: ***harry.desmond@physics.ox.ac.uk***

******WITHDRAWN****** ***AS13* Modelling the connection between galaxies and dark matter halos**

While correlations among galaxy properties are known empirically from surveys, and those among halo properties are known from dark matter-only simulations, the relations between galaxy and halo properties remain unclear. It is these that we expect to hold the key to galaxy formation in a universe dominated by cold dark matter.

A popular technique for inferring the relation between galaxy and halo mass is 'abundance matching': essentially one assigns the nth most massive galaxy observed in a given region to the nth most massive halo produced in a simulation box of the same volume. Traditionally the measure of galaxy mass has been stellar mass, which is relatively easy to measure. However, a sizeable fraction of galaxies' baryonic mass budgets -- particularly at low mass -- is comprised of cold gas, and the requisite data now exists to upgrade abundance matching to use total baryonic mass (stars + gas). Not only will this provide insight into the physical processes governing the co-evolution of baryons and dark matter, but may also shed light on several apparent failings of LCDM at the dwarf galaxy scale.

To perform this project the student will combine data on galaxies' gas masses from the ALFALFA HI survey with stellar masses from optical surveys, connect this with the halo population from an N-body simulation by abundance matching, and test the result by examining statistics of the galaxy population such as clustering and internal dynamics. Knowledge of Python will be required, and C/C++ may come in handy.

Supervisor: ***Dr H Desmond***
Email: ***harry.desmond@physics.ox.ac.uk***

******WITHDRAWN****** ***AO25* Representing small scale wind variability for improved weather and climate prediction**

Weather and climate prediction is mathematically challenging. The atmosphere, oceans, land-surface, and their interactions, must be represented in a computer simulator. Due to limited computer resources, we can only afford to explicitly calculate the largest scales – those of the order 5-10km in a weather forecast, or 50-100km in a climate prediction. Smaller-scale processes, such as turbulence or clouds, are included using simplified representations called 'parametrisation schemes'. One pathway towards improved weather and climate prediction is to improve these parametrisation schemes. A new approach to parametrisation, called stochastic parametrisation, recognises that, given knowledge of the large-scale atmospheric flow, it is not possible to predict the evolution of the smaller scale processes with certainty. A stochastic parametrisation uses random numbers to represent our lack of knowledge about processes happening on these smaller scales.

This project involves developing a stochastic parametrisation scheme for turbulent transfer of momentum, heat and moisture between the ocean and atmosphere. This process is traditionally parametrised as a function of the large-scale wind speed; however, this does not account for the effects of unresolved sub-grid scale variability. As part of an international collaboration, we have collected statistics for the sub-grid scale variability in wind speed over ocean. The student would use these measurements to construct a stochastic parametrisation and explore the potential impacts of the stochasticity. How are the average turbulent fluxes impacted by the stochastic approach? How does the scheme impact the prediction of other atmospheric processes, such as convective thunderstorms? Can we improve probabilistic weather forecasts using the scheme?

In this project, the student will have the opportunity to cultivate his or her programming skills, work with an operational weather forecasting system, and learn about stochastic processes as a tool for representing uncertainty in dynamical systems.

Skills: Programming experience is very useful, though not essential: a drive to learn programming is more important. The project will make use of ideas about fluid dynamics and turbulent flows from the third year course. Ideally the student should be taking the fourth-year option 'Physics of the Atmosphere and Ocean'.

Supervisor: ***Dr H Christensen***
Email: ***Hannah.christensen@physics.ox.ac.uk***

Projects offered by Dr C Schilling are likely to be withdrawn