Particle Physics - Opportunities for Graduate Study

Work on neutrino oscillations

MicroBooNE and ProtoDUNE

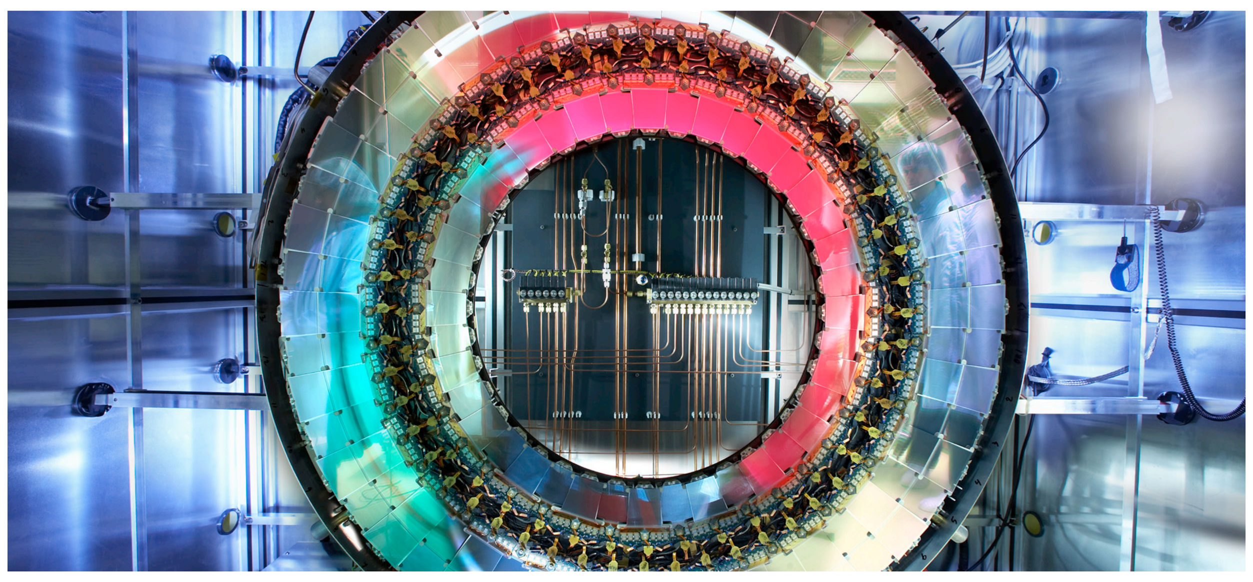
Contact: Mark Thomson (thomson@hep.phy.cam.ac.uk) http://www.hep.phy.cam.ac.uk/microboone/

The MicroBooNE neutrino experiment at Fermilab in the US, started taking data in August 2015. MicroBooNE utilises a large liquid Argon (LAr) time projection chamber (TPC), which allows "photograph quality" images of the particle produced in neutrino interactions. The recorded events contain a wealth of information and Cambridge is playing a leading role in the automated computer reconstruction of these images using advanced pattern recognition software. MicroBooNE will run for a further 2-3 years and will search for sterile neutrinos, testing a number of previous claims for this potentially groundbreaking physics signal.

The PhD project is to work on the development of pattern recognition software for LAr-TPC detectors and then apply this to MicroBooNE data. The full reconstruction chain will developed to go from the raw detector images to the detailed properties of the individual neutrino interactions. This reconstruction will then be used to make precise measurements of neutrino cross sections and to test the claims of the possible existence of sterile neutrinos.

This project represents an exciting opportunity to work on the first large LAr detector in an intense neutrino beam. There will also be the opportunity to apply this experience to the first data from the protoDUNE detector at CERN. ProtoDUNE is a large-scale prototype for the vast far detector modules, currently being planned for the DUNE long-baseline neutrino oscillation experiment, which will observe neutrino oscillations over a distance of 1300km. ProtoDUNE will take first data during the summer of 2018.

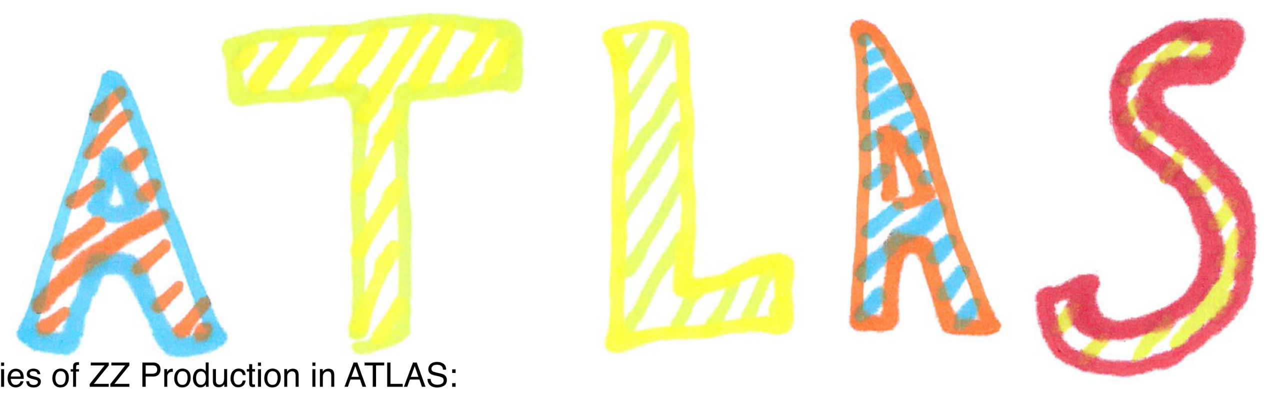
Projects at the high-energy and high-intensity frontier (LHC)



ATLAS : Beyond Standard Model:

Contact: Christopher Lester (lester@hep.phy.cam.ac.uk)

The Higgs Boson discovery, while interesting, was really part of "old", very much expected physics. The ATLAS detector has, so far, found no traces of "new" physics: supersymmetric particles, extra dimensions, and so on, despite many searches. Given this situation, phenomenologists need to be sure that all possible search strategies are covered. In the last three years Cambridge ATLAS has used established search methods to look for supersymmetry and black holes. However, a recent discovery of what appears to be an entirely new way of looking for R-parity violating supersymmetry encourages the Cambridge BSM team to focus the coming year's efforts on developing that new technique. Cambridge ATLAS is also working on two separate upgrade projects (one in the next ATLAS tracker, one in the calorimeter trigger) that will need increasing support over the next four years. A student pursuing a PhD based on BSM searches could potentially use it as an opportunity to gain some experience of detector design and/or operation, thereby increasing his or her future employability. We therefore welcome applications from students who believe they might be able to inject similar creativity into the field of BSM searches, a field which otherwise is perhaps ripe for being shaken up after a period in which it has seen little innovation, and those who might like to combine that with detector work.



Studies of ZZ Production in ATLAS:

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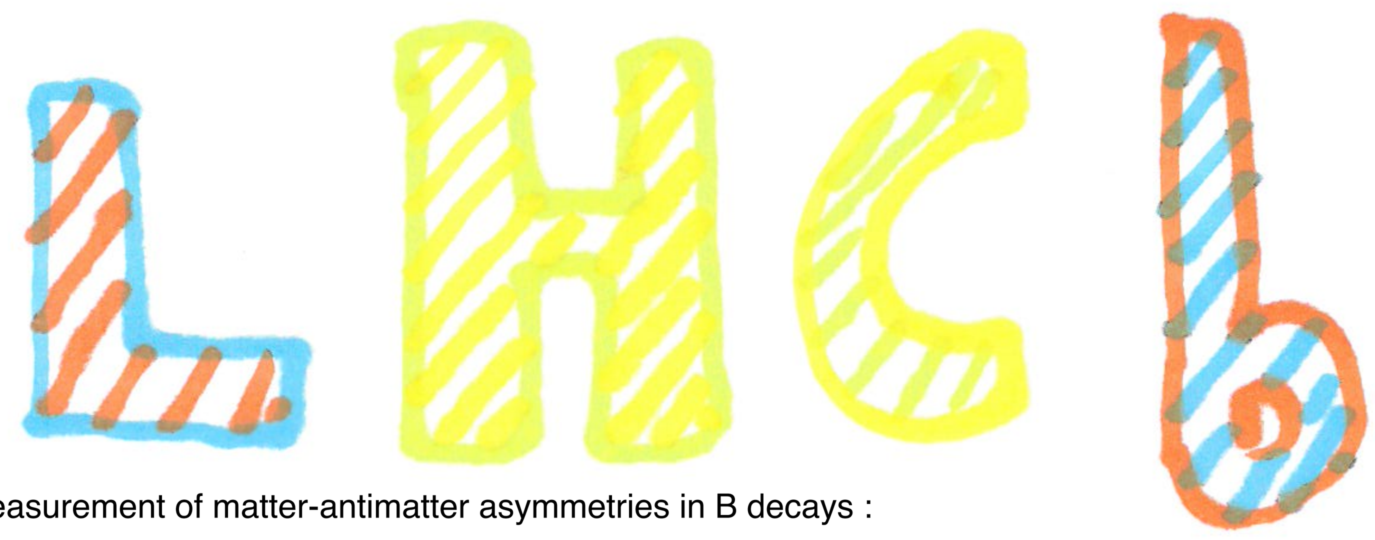
A key process currently being intensively studied at the LHC is the production of gauge boson pairs (diboson production). By testingthe gauge structure of the Standard Model, measurements of diboson production allow indirect searches for new physics beyond the SM and are also important in understanding backgrounds to other processes such as Higgs boson production. The Cambridge group has focused on the production of ZZ pairs decaying to final states containing two leptons (electrons or muons) plus missing energy (neutrinos), or containing four leptons. The 4-lepton channel is one of the recent Higgs boson discovery channels, and the SM process Z->4l serves as a test-bed for the reconstruction of H->4l decays.The PhD project(s) would be based on analyses of the full 13 TeV data set recorded by ATLAS throughout 2015-2018. As well as improved measurements due to the higher energy and larger data sample, existing analyses could be extended by, for example, looking for new modes of ZZ production such as vector boson scattering.



Measurement of matter-antimatter asymmetries in B decays :

Contact: Val Gibson (gibson@hep.phy.cam.ac.uk) http://www.hep.phy.cam.ac.uk/lhcb/

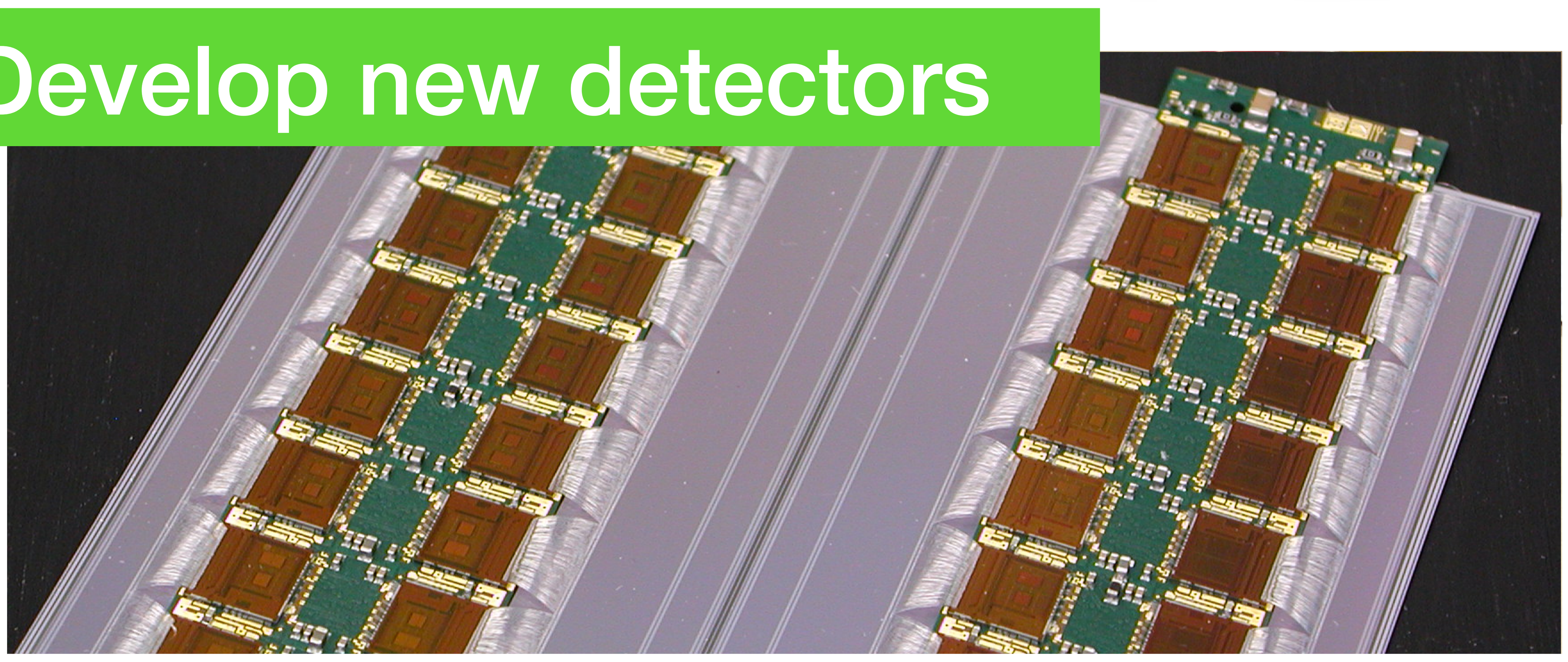
The fact that we live in a Universe made of matter (and no antimatter) is extremely puzzling since, during the Big Bang, matter and antimatter should have been produced in equal amounts. The phenomenon responsible for matter-antimatter asymmetries is called CP violation, which is a well established observation and can be accommodated in a three generation Standard Model. However, the amount of CP violation observed is many orders of magnitude away from that required to produce the amount of matter in the Universe. Therefore physics beyond the Standard Model is required. The project will include the analysis of all the LHCb experiments data taken at the highest LHC centre-of-mass-energy from the start to the current date. The focus of the project will be to use hadronic B meson decays, such as B->DK or Bc->DD, to make a precision measurement of the CP phase - gamma - which is responsible for CP violation in the Standard Model and against which New Physics phenomena can be severely tested.
The project will suit someone who is keen to analyse LHC data.

Search for New Physics beyond the Standard Model in rare B decays

Contact: Val Gibson (gibson@hep.phy.cam.ac.uk) or Marc-Olivier.Bettler@cern.ch http://www.hep.phy.cam.ac.uk/lhcb/

The Standard Model of particle physics is a well established monument. However, New Physics beyond the Standard Model is necessary to describe the mass hierarchy of fundamental particles. The LHCb experiment, running at the Large Hadron Collider at CERN, is particularly well suited to look for indirect evidence of New Physics using quantum loop processes. These include rare decays, such as Bd,s->mumu and Bd → K0*mumu decays, and searches for lepton-flavour violation by combining teh information from several decays e.g. Bd->K0*mumu ad Bd->K*ee. The huge volume of data collected by LHCb allows for a precision measurements of the decay rates, effective lifetimes and angular observables, which measure the intimate properties of these decays. In turn, the measurements are used to constrain New Physics models. This indirect model-independent approach is very powerful, and is crucial since New Physics still evades detection. The project will include the analysis of all data taken by LHCb from the start to the current date. The project will suit someone who is keen to analyse LHC data.

Develop new detectors



Development of sensors and novel technologies for particle detection in HEP and beyond :

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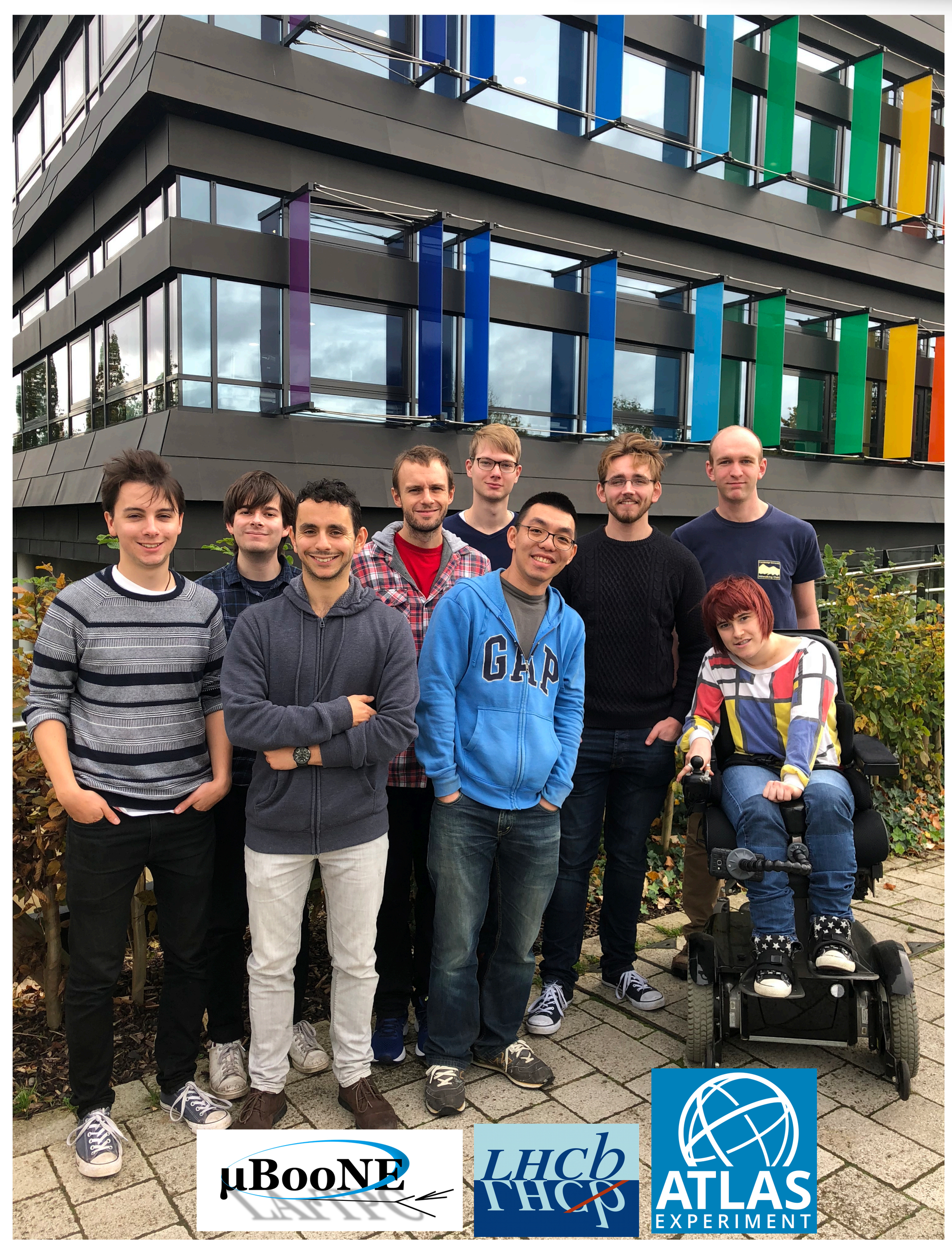
Prospective students with a keen interest in hands-on practical work are invited to contact us to discuss possibilities in this area. The HEP group has a strong track record in the development of silicon sensors for tracking and single-photon position-sensitive devices for Ring Imaging Cherenkov (RICH) Detectors. Projects may include the development, refinement or upgrade of existing detectors such as these or may focus on the development of more speculative techniques for use in future experiments. Examples of current projects are the development of a RICH detector prototype using solid state sensors or the application of the ATLAS silicon tracking technology to areas beyond the field of High Energy Physics. Although focussed on detector research and development, there would also be an opportunity to analyse data from running experiments or data taken at beam test facilities.



PhD Students of 2017