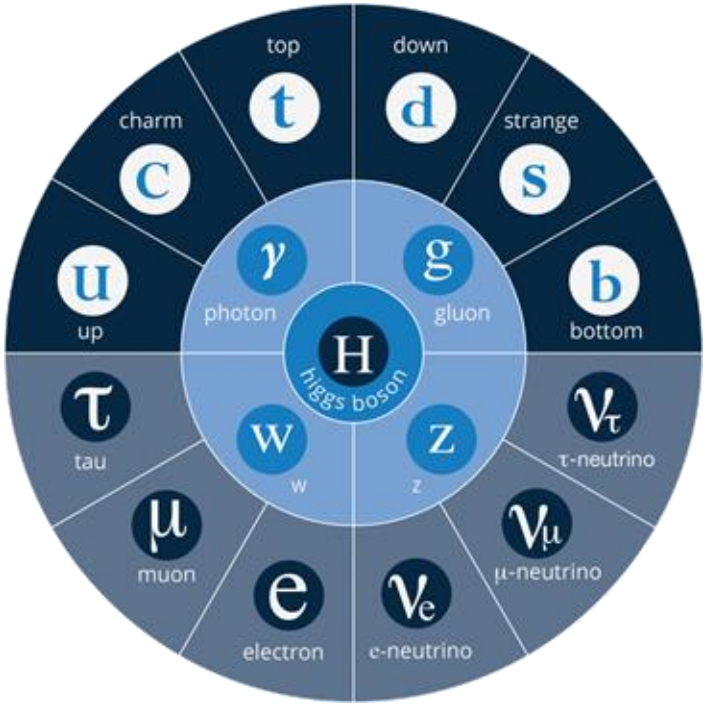
Our Research Areas

High Energy Physics

ATLAS
T. Potter, O. Brandt, C. Lester, S. Williams

LHCb
M. Kenzie, H. Cliff, C. Jones

Neutrinos
M. Thomson, L. Whitehead



Detectors
O. Brandt, S. Wotton

FCC
S. Williams, M. Kenzie

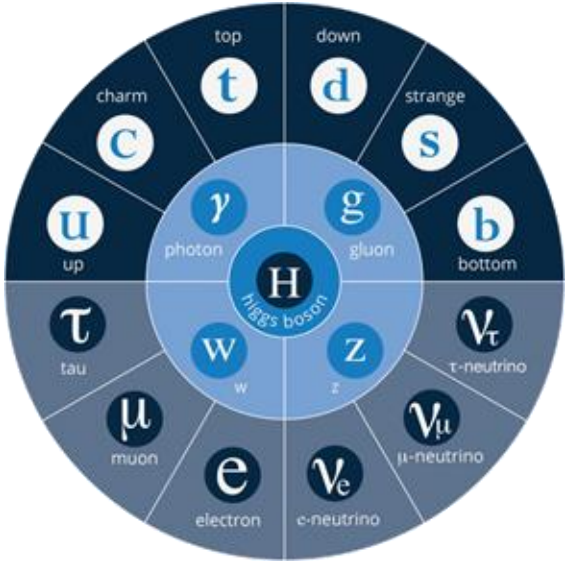
Theory
A. Mitov, B. Gripaios

*Ensure you name **at least one** supervisor on your application (you don't need to have contacted them first)*

Overview

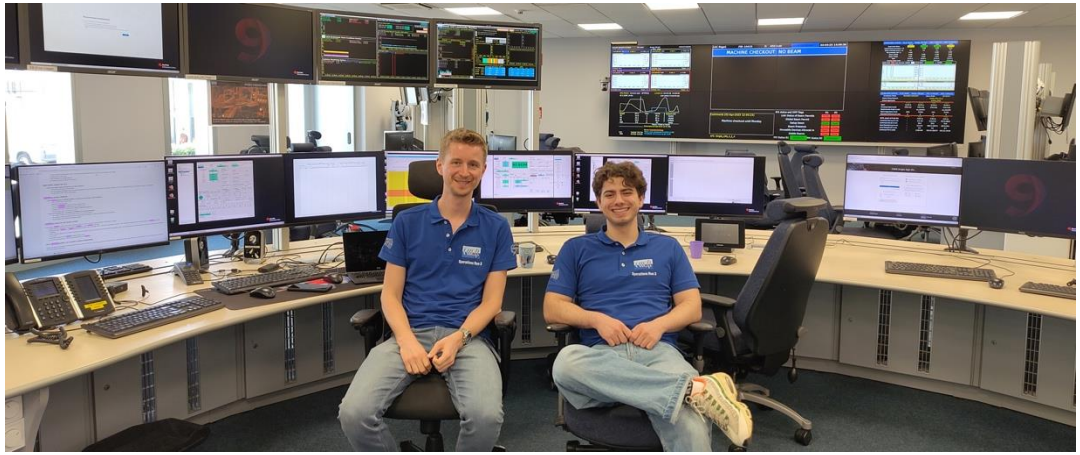
Open questions in HEP

- **What is dark matter?**
- What is responsible for the **matter-antimatter asymmetry?**
- Is there **structure** in the **flavour sector**?
- Why is the **Higgs mass** so low?
- Can we **unify** the **strong** & **EWK** sector?
- What mechanism gives **neutrinos mass**?



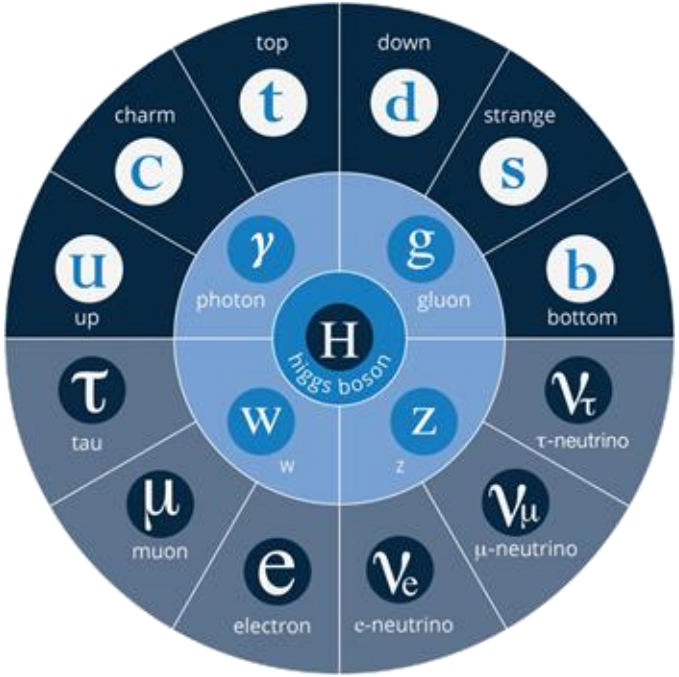
Our groups

- We use **high energy particle accelerators** to probe the **fundamental nature** of the universe
- The experimental group is involved in major experiments at **CERN** (**ATLAS**, **LHCb**) and **Fermilab** (**Dune**) and in **R&D** projects for **future colliders**.
- The **Cavendish Theory Group** collaborates strongly with the group's experimental activities.
- The **Detectors Group** exploits our state-of-the-art laboratories for R&D
- The **Phenomenology Working Group** is a collaboration between our experimental groups, the Cavendish Theory group and the DAMTP HEP group.



One of our postdocs (left) and one of our PhD students (right) in the LHCb control room as shift leader and data manager, respectively

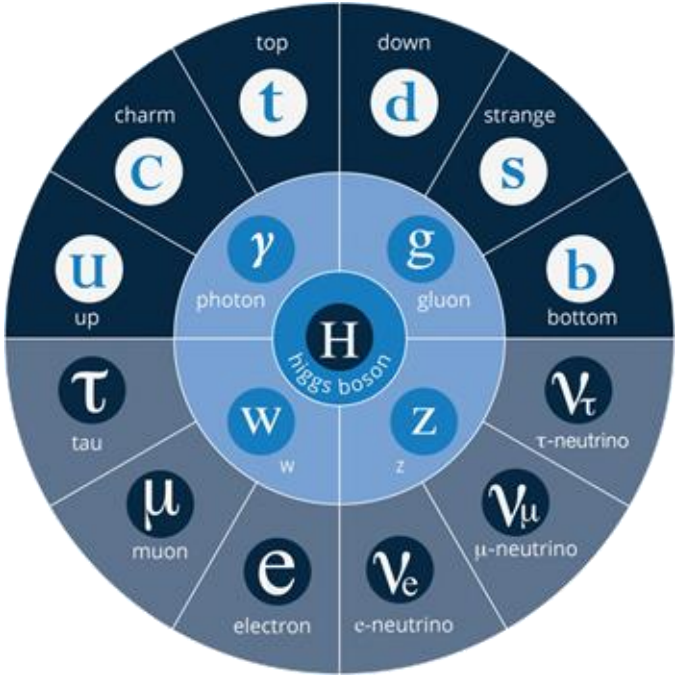
Typical PhD in HEP



What do I do in my PhD?

- You normally have **one main project** (a specific physics analysis, a detector development goal, implementation of a new method)
- The majority of students will at some point take on a **second project** or projects (detector development, reconstruction software, calibration and alignment tasks, future projections) sometimes this gains you authorship (known as a Qualification Task)
- Then some also contribute towards **the day-to-day operation** of the experiment and collaboration (taking shifts, produce central simulation, manage datasets)
- Most students spend up to a year on **long term attachment** (at CERN or Fermilab)
- We encourage you to get involved in teaching but don't overcommit
- We also give our own in-house lecture series in Lent
- Expectation is a PhD lasting 3.5 – 4 years
- You do not need to have a strong preference for project or supervisor for the application or interview

What can you bring?



What are we looking for?

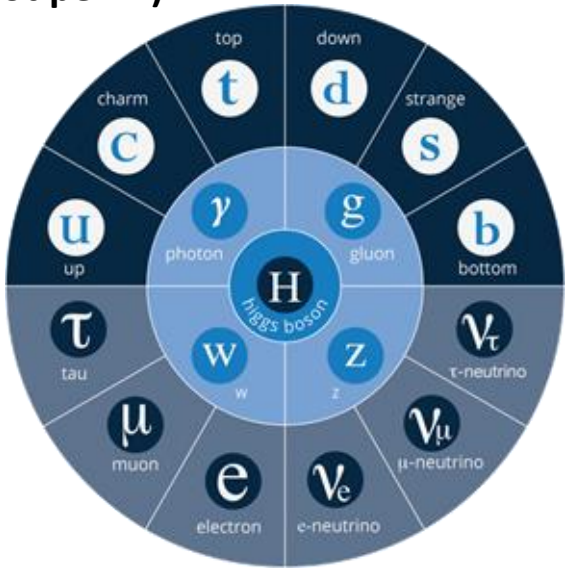
- Energy, enthusiasm and a passion for the field and the research that we are doing in the Cavendish HEP group
- Strong performance in undergraduate physics, especially particle physics topics (this normally means a 1st Class or Distinction or equivalent). For PhD candidates you need to have or be studying for a Masters level degree. For MPhil candidates you need to have or be studying for a Bachelors level degree.
- Relevant research experience. Ideally this is in particle physics but it doesn't have to be. Do you have data analysis, coding or machine learning experience that could be relevant? Examples include undergraduate projects and / or summer projects. We will expect you to be able to discuss and defend your research at interview.
- Reference letters (two are required) where at least one has worked with you on some research topic. We want a reference to not just speak to your academic abilities but your suitability as a research student.
- Demonstrate in the interview that you understand some particle physics and can discuss / think about topics in the field and defend your statements.

Application Process

Applications in HEP are decided by the entire group of academics * (not per PI)

Application

- Be sure to select **Apply For Funding**
- Name **at least one** HEP supervisor on your application *
- Provide **CV** and **two reference letters**
- An academic transcript which demonstrates exceptional performance



Funding

- You will automatically be considered if you select **Apply For Funding**
- It is extremely competitive (especially for non-Home fees)
- If you can bring your own funding the threshold for admission is typically lower

Deadlines

- Be sure to apply by **5th Dec** to be considered
- For more info see: https://www.hep.phy.cam.ac.uk/graduate-admissions

Interviews

- Invites to interview will go out just before Christmas
- Interviews will take place the week of **11th Jan 2027**
- Reasonable travel costs can be reclaimed
- Can also be remote if from abroad

* Potential supervisors are:

Oleg Brandt, Chris Lester, Tina Potter, Sarah Williams, Harry Cliff, Chris Jones, Matt Kenzie, Leigh Whitehead, Steve Wotton

Detectors

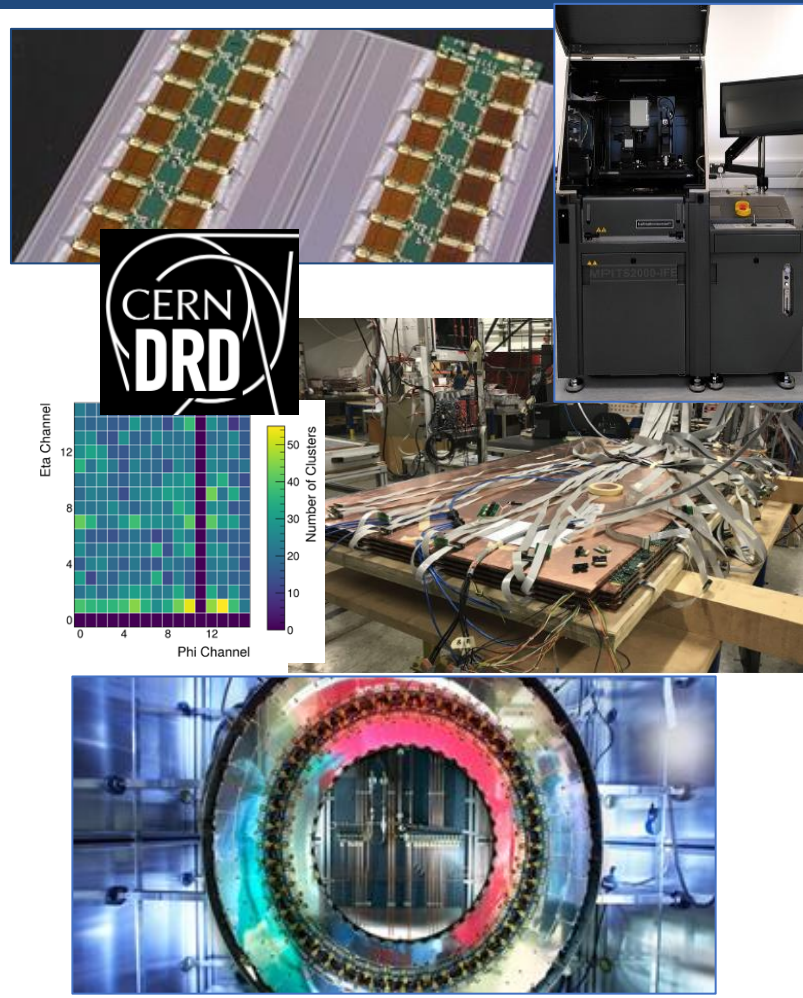
Development of sensors and novel technologies for particle detection in HEP and beyond -- with Stephen Wotton or Oleg Brandt

The HEP group has a strong track record in the development of extremely radiation-hard silicon sensors with O(10 µm) resolution for tracking and single-photon position-sensitive devices for Ring Imaging Cherenkov (RICH) Detectors. In addition, we recently established a new detector R&D activity to develop Resistive Plate Chamber (RPC) detectors for large-scale precise-timing applications, like the proposed ANUBIS experiment or future facilities like the FCC.

Projects may include the development, refinement or upgrade of existing detectors such as these or may focus on the development of novel experimental detection techniques for use in future experiments. Examples of current projects are the development of a RICH detector prototype using solid state sensors, the application of the ATLAS silicon tracking technology to areas beyond HEP, and the search for novel eco-friendly gases for future RPC detectors. All detector R&D projects will involve data analysis; there will also be an opportunity to analyse data from running experiments or data taken at beam test facilities.

Characterisation of novel radiation-hard semiconductor sensors -- with Matt Kenzie

An upgrade of the tracking system to novel sensors with unprecedented radiation-hardness would allow to harvest significantly more data with the LHCb experiment at the High-Luminosity LHC. This is key to cast the ultimate judgement on the indications of a potential lepton flavour universality violation seen by LHCb physicists. The unprecedented radiation hardness can be achieved with novel CMOS sensor technology. With the first release of CMOS sensor prototypes the Cambridge HEP group offers an exciting opportunity to get involved in the characterisation of these early prototypes. To establish the performance of the sensors, the key areas that need probing are the intrinsic, sub-ns timing resolution of the sensors, their charge collection efficiency and the corresponding pulse height characteristics. Comparative studies will be made to study the performance degradation of sensors due to radiation damage accumulations during their operation in the LHC. Sensor samples irradiated with protons, neutrons and gamma photons are to be subjected to studies using advanced techniques such as Transient Current analysis of laser or fast electron induced signals. Advanced device simulation techniques (TCAD) will be used to cross correlate experimental results with predicted outcomes to assess end-of-life performance figures for operation in the HL-LHC in other possible applications.



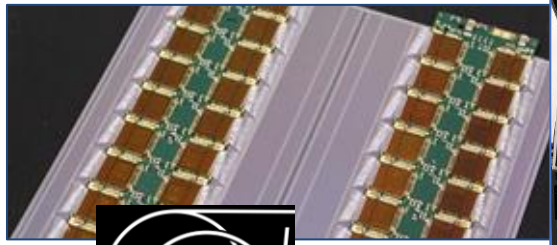
Detectors

Eco-friendly gas mixtures for future gaseous detectors at the HL-LHC and beyond -- with Oleg Brandt

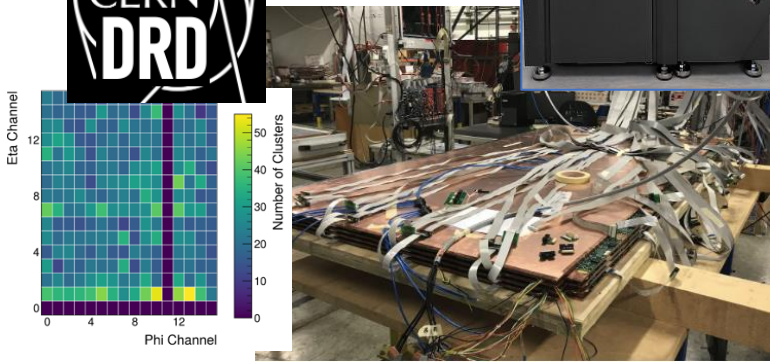
Gaseous detectors are an integral part of modern HEP detectors: they are used in large-area tracking applications requiring precise timing and/or position resolution at the LHC and beyond. Example applications are our in-house R&D activities on the ANUBIS detector, future FCC detectors, and muon tomography.

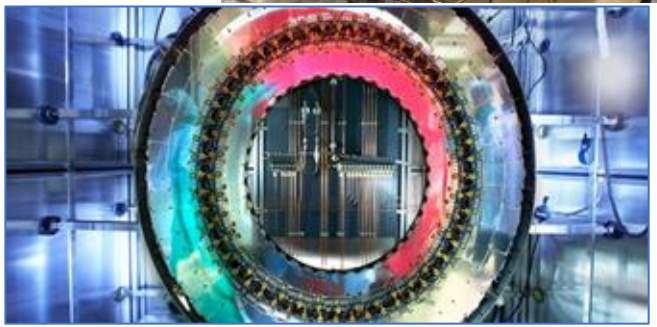
The active gas is a key driver for the performance of gaseous detectors. However, the established gas mixtures have a prohibitively high global warming potential (GWP) of ~1,500 x CO_2, calling for urgent action to identify alternative eco-friendly low-GWP gas mixtures without compromising detector performance.

A PhD student would join our eco-gas R&D team and perform simulation studies of candidate eco-gases using established simulation frameworks and refining their predictive power using advanced ML techniques, and/or measure the detector performance (timing, spatial resolution, ageing properties, etc) with selected candidate gas mixtures. Their research will be embedded in the DRD1 Collaboration at CERN, with main collaboration partners at CERN and in Germany, Italy, Switzerland.





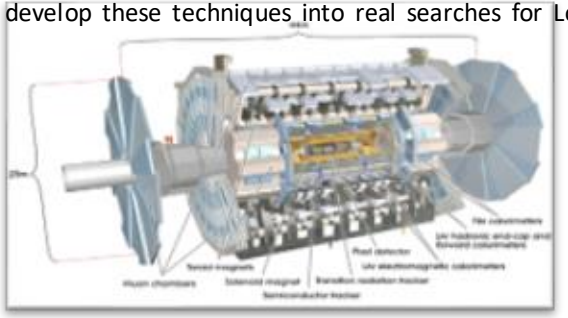


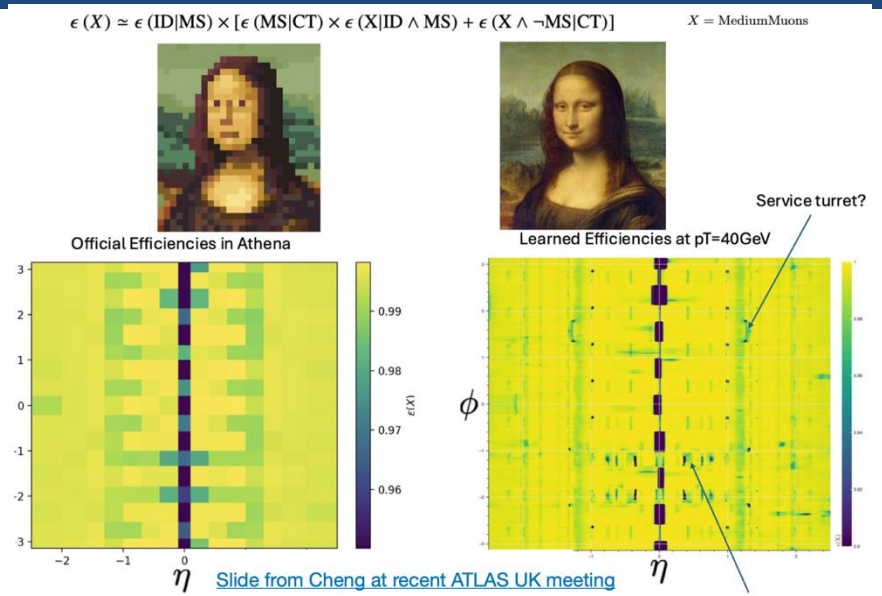


The ATLAS Experiment

ATLAS searches for Beyond-Standard-Model symmetry violations -- with Christopher Lester

Evidence for physics beyond the Standard Model has eluded the LHC so far, despite ample evidence from elsewhere that the Standard Model is incomplete. Christopher Lester and his last four PhD students have collectively developed strategies for looking for general symmetry violations with exclusively data-driven tests (rather than comparing to Monte Carlo predictions). An important component has been finding new ways of calibrating the detector that are orders of magnitude more capable than existing methods. New students are sought to develop these techniques into real searches for Lorentz, parity and flavour violation.

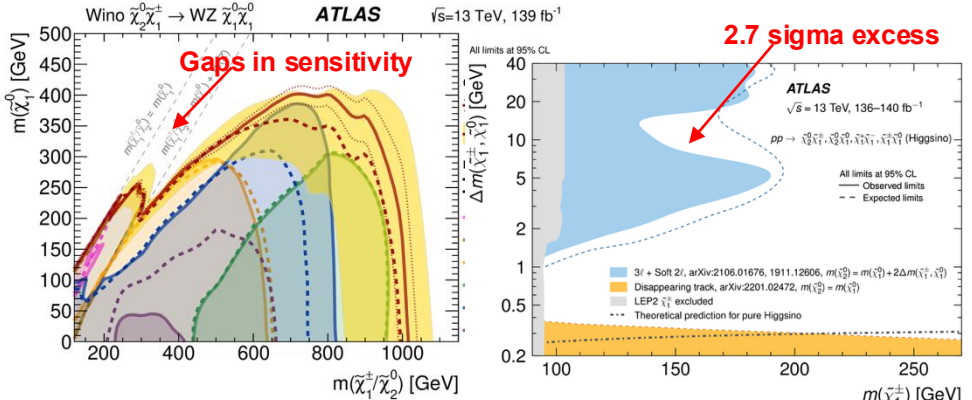




Slide from Cheng at recent ATLAS UK meeting

Hunting for Dark Matter in ATLAS -- with Tina Potter

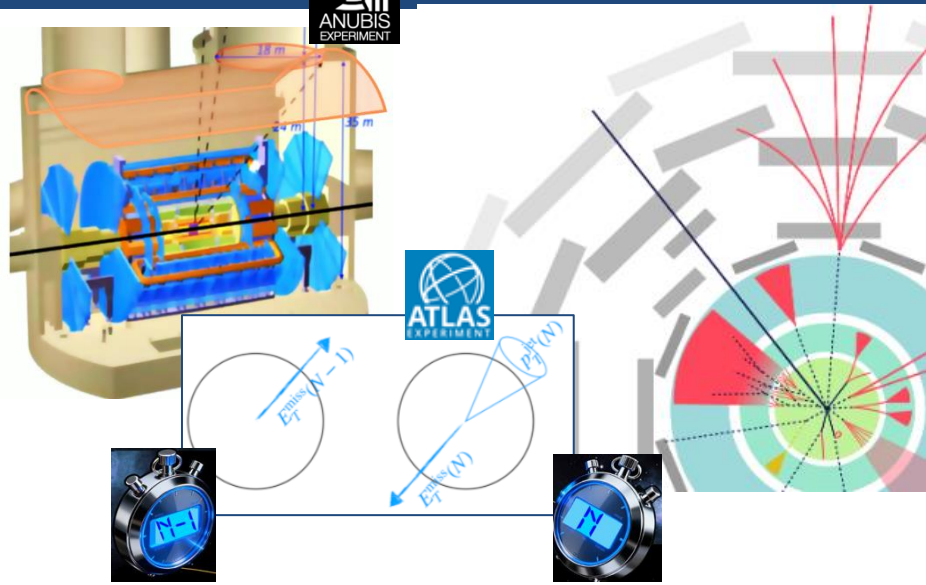
Discovering new physics such as Supersymmetry (SUSY) is a major goal of the ATLAS experiment at the LHC, and a focus of the Cambridge HEP group. However, the lack of a discovery to date tells us that SUSY may not be easy to find. If SUSY particles are close in mass, the experimental signature can be very difficult to separate from the Standard Model processes. A student could identify areas of SUSY parameter space where ATLAS does, and more importantly, doesn't have sensitivity, and design searches to address these uncovered areas. The PhD project(s) would use the latest dataset recorded by ATLAS to search for signs of new physics, using modern multivariate selection techniques, such as artificial neural nets and boosted decision trees.



The ATLAS Experiment

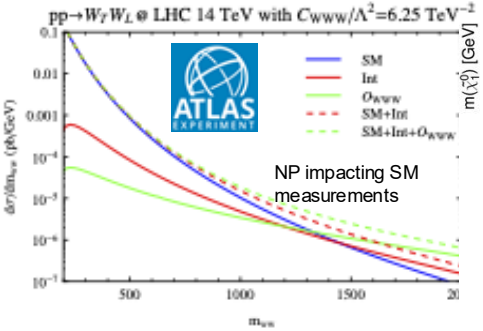
Dark Matter and Dark Sectors with ATLAS and ANUBIS -- with Oleg Brandt

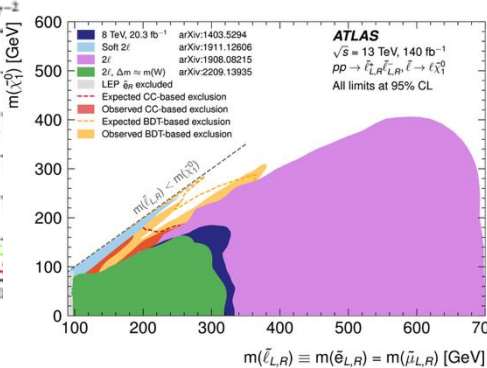
One of the goals of the Cambridge HEP group is to search for dark matter targeting striking detector signatures involving new particles with microscopic lifetimes, i.e., long-lived particles (LLP). This search strategy is strongly motivated by a large class of theories including Higgs portal scenarios and SUSY. Run 3 of the LHC, which started in 2022, opens a 'golden era' for LLP searches, as it is now possible to trigger the recording of events with new exotic LLP signatures for the first time. We also aim to study the sensitivity of future detectors like ANUBIS to such LLP signatures by analysing data of a prototype detector and simulations. A doctoral research project would explore these novel LLP search strategies at the LHC.



Testing the Standard Model with searches and precision measurements -- with Sarah Williams

As well as searching for directly for new particles that could have escaped detection to date, indirect tests of the Standard Model (SM) through precision measurements can be sensitive to new particles at mass scales much higher than those that can be probed directly. The run 3 dataset will enable measurements of rare SM processes not previously observed experimentally as well as increased statistics to perform SM measurements in more extreme decay topologies. A student joining this project would have the opportunity to join a team working on run 3 measurements of electroweak multi-boson processes with a focus on improving the sensitivity to BSM physics. Alternatively, they could focus on the run 3 search programme. In particular they could design and implement new searches for well-motivated dark matter models (either within supersymmetry or other simplified models) and, time-permitting, produce SM measurements in topologies inspired by the search.





The LHCb Experiment

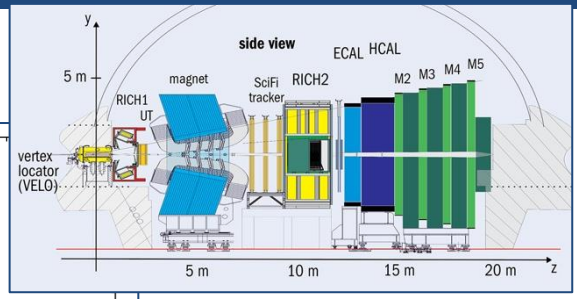
Search for Physics beyond the Standard Model in rare B decays -- with Harry Cliff

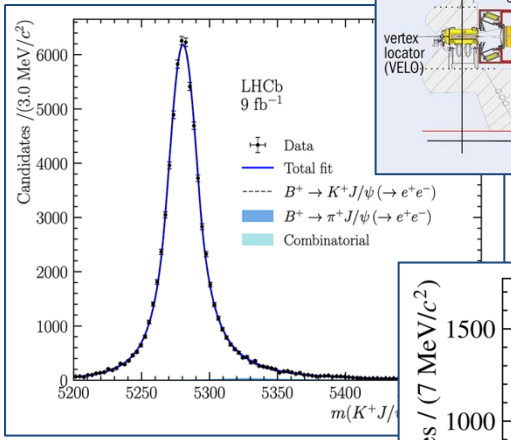
The Standard Model of particle physics is a well established monument. However, New Physics beyond the Standard Model is necessary to describe the mass hierarchy of fundamental particles. The LHCb experiment, running at the Large Hadron Collider at CERN, is particularly well suited to look for indirect 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 the information from several decays e.g. B+ → K+mumu, B+ → K+ee and B+→ K+ττ. 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 direct detection. The project will include the analysis of all data taken by LHCb from the start to the current date.

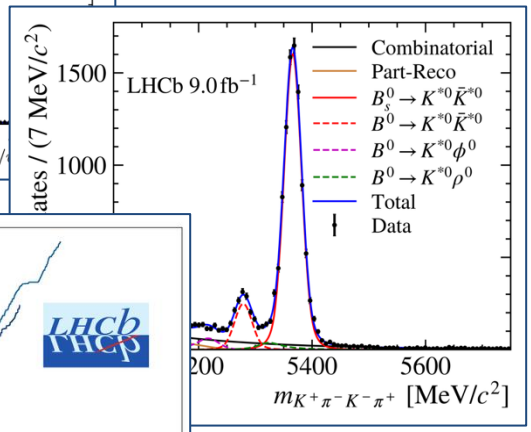
Measurement of matter-antimatter asymmetries in B decays -- with Matt Kenzie

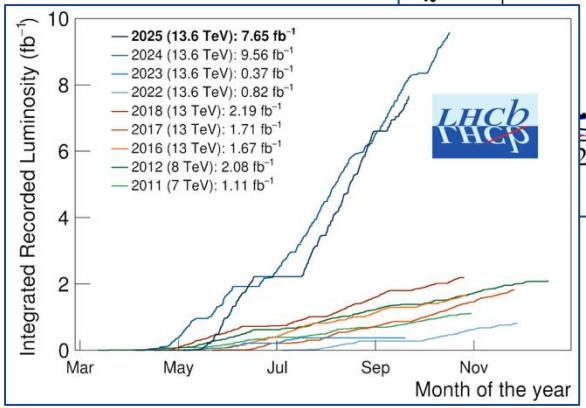
The fact that we live in a Universe made of matter (and no antimatter) is extremely puzzling since, during the Big Bang, matter and antimatter should have been produced in equal amounts. The phenomenon responsible for matter- antimatter asymmetries is called CP violation, which is a well established 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 B → KK, which have exquisite precision to CP violating phases such as γ and φs.









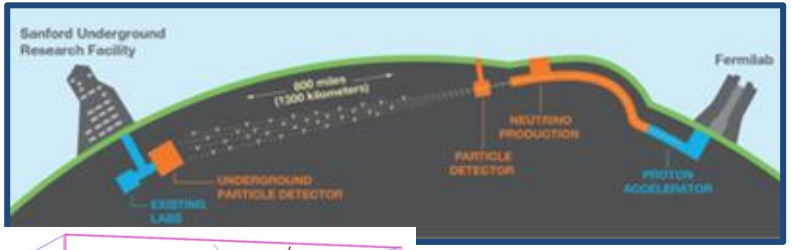
Neutrino Experiments

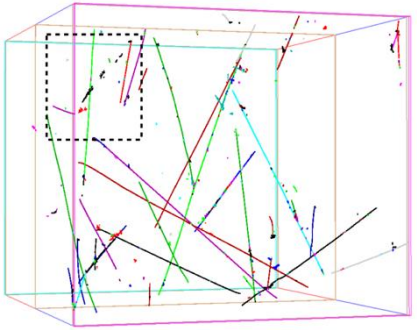
DUNE -- with Leigh Whitehead

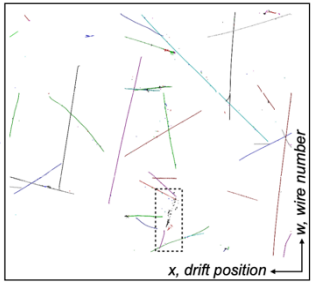
The Deep Underground Neutrino Experiment (DUNE) is a cutting-edge experiment for neutrino science, including: neutrino oscillations, CP violation searches, measuring the neutrino mass hierarchy, proton decay studies as well as astrophysics and beyond the standard model physics searches. DUNE is currently under construction and data taking is set to begin toward the end of the decade.

This project represents an exciting opportunity to work on this cutting-edge neutrino experiment, being part of a team to develop the techniques and designs which DUNE will use to answer the biggest questions in the neutrino physics today, including understanding the role that neutrinos play in the formation of the Universe. The project can involve working across simulation, calibration, event reconstruction in Pandora including deep learning, as well as physics analysis. There may also be opportunities for hardware involvement with some prototype detectors.

First data from the DUNE far detector is expected towards the end of 2029, but data will be available beforehand from the various prototype detectors that are currently running and planned to run in the coming years: hadron beam data from the ProtoDUNE experiments at CERN, and the Near Detector prototype located in a neutrino beam at Fermilab.









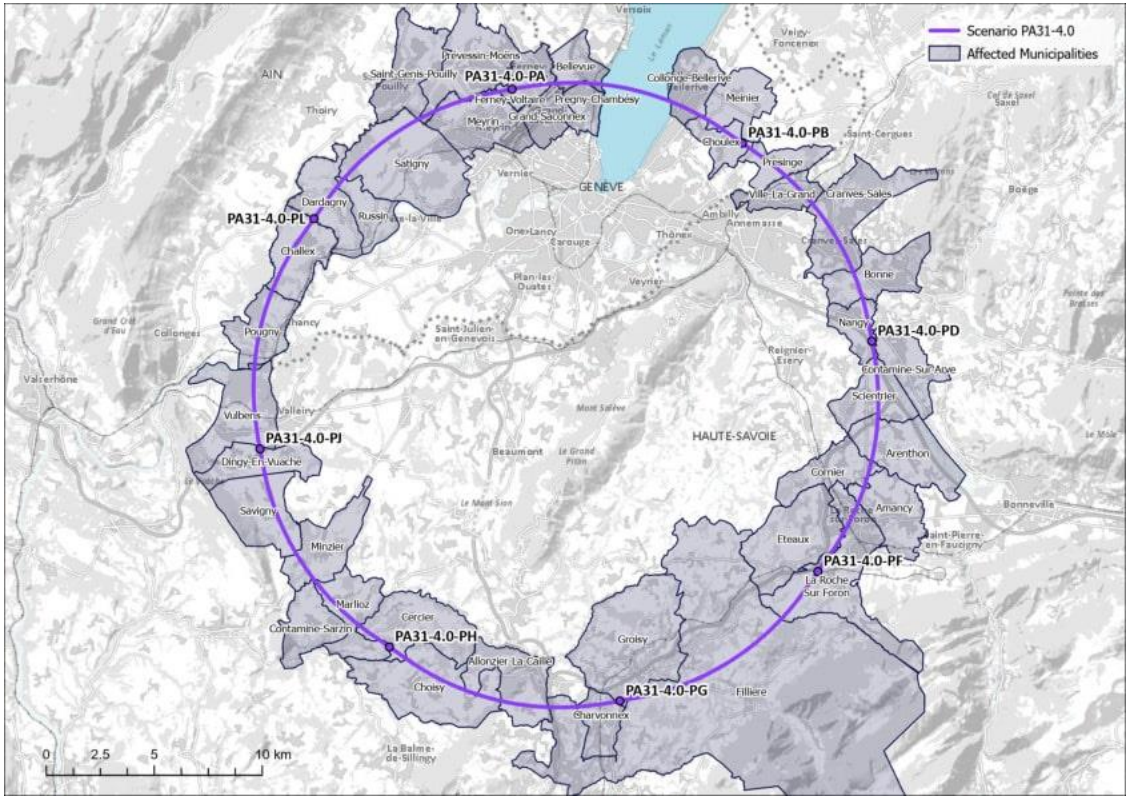


DUNE
DEEP UNDERGROUND
NEUTRINO EXPERIMENT

Future Circular Collider

BSM searches at FCC-ee and FCC-hh -- with Sarah Williams
Interested students should contact PI directly

The Future of Flavour -- with Matt Kenzie
Interested students should contact PI directly



Theory

Precision Studies in Particle Physics -- with Alex Mitov
Interested students should contact PI directly

Beyond Standard Model -- with Ben Gripaios
Interested students should contact PI directly

