

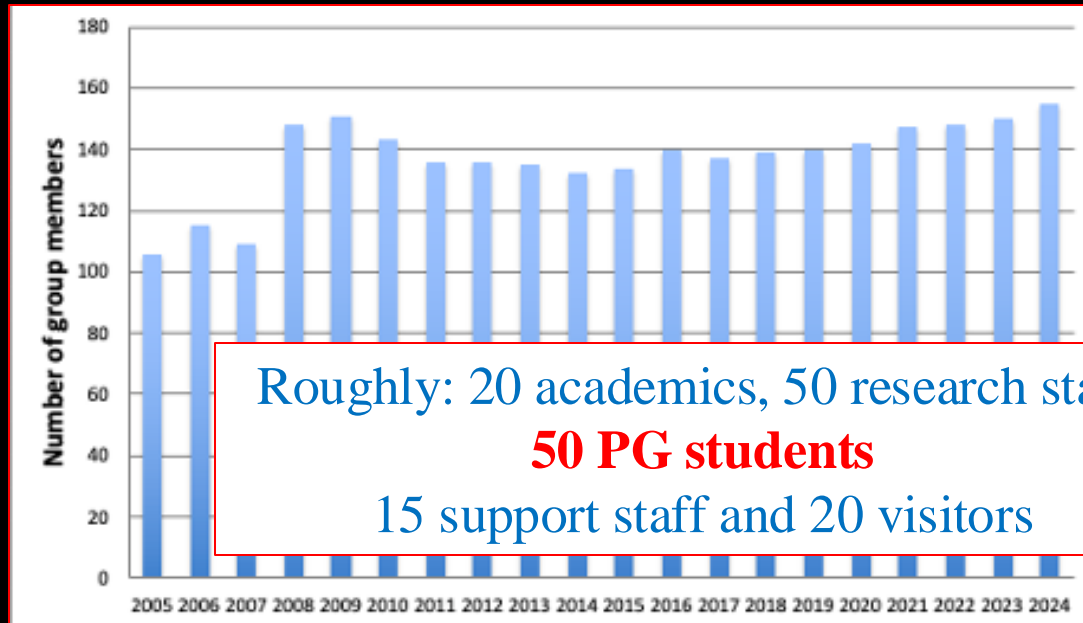
Postgraduate study in the
Imperial Particles Community

Introduction

- Welcome to Imperial's Particles Community!
- This presentation is to:
 - Introduce you to the Community and postgraduate study with us
- After the talk ...
 - ... there will be a tour of some of our research activities
- We'll then reassemble here in 539 at 14:45:
 - For informal discussion with staff and students:
 - Opportunity to get answers to your questions
 - For online participants, this ZOOM channel will stay live throughout the afternoon
 - And, importantly:
 - Opportunity to talk “off the record” to current graduate students

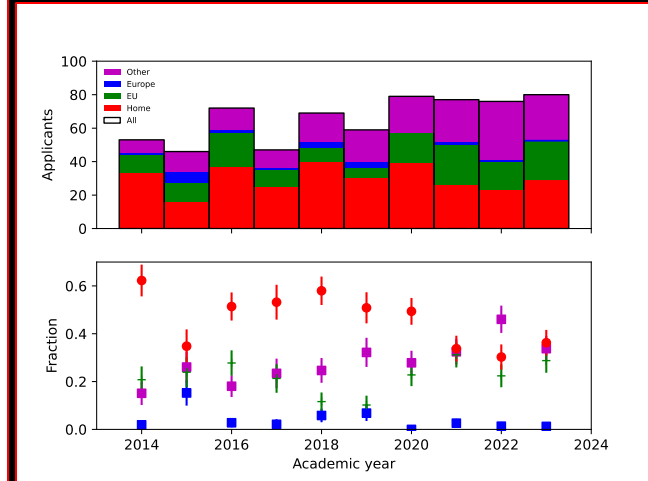
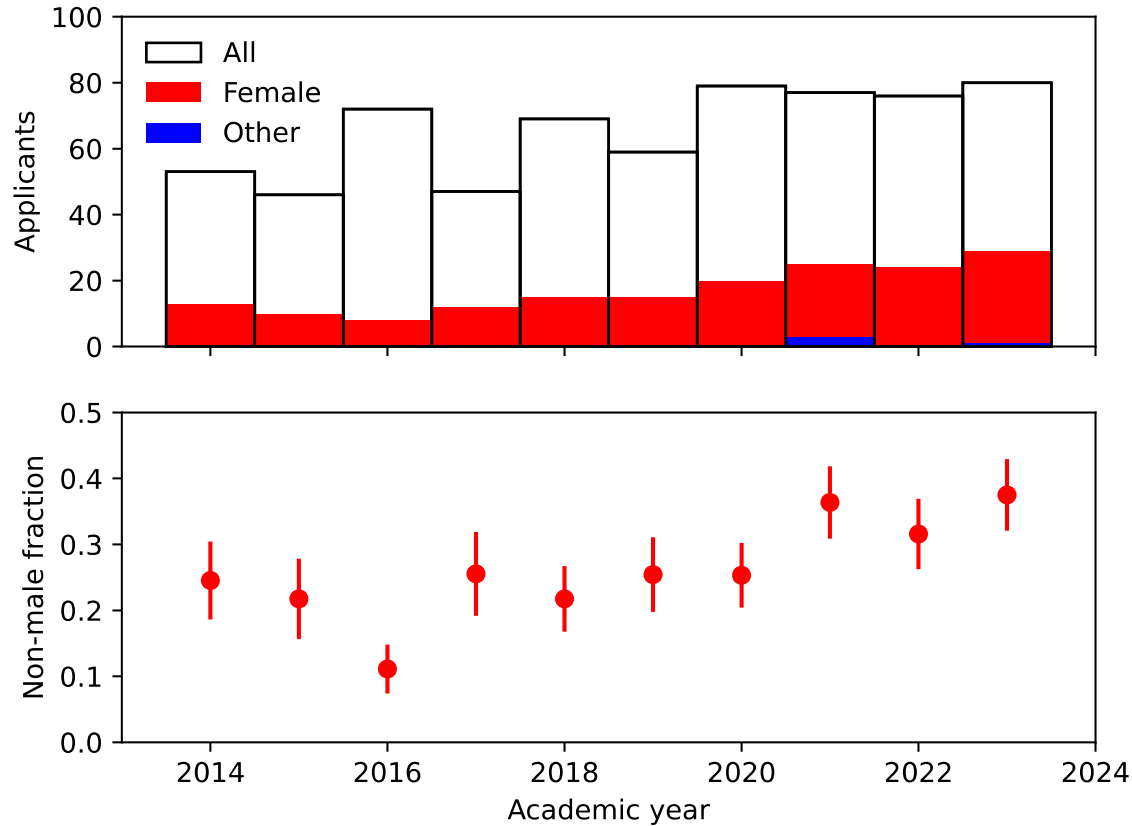
Particle Physics at Imperial

- One of the largest particle physics groups in the UK
 - **~155 members at the moment**



- Involved in the full spectrum of activities across the field
- Among the largest postgraduate cohorts in UK

Some more statistics



Our mission

Is to:

- Search for new fundamental particles, forces and phenomena
- Exploit this knowledge to understand the Universe
- Develop new technologies/techniques to drive our field forward
- Exploit technologies/techniques to benefit of science and society

Understanding Nature's building blocks

Search for new fundamental particles, forces and phenomena

- At the highest possible energies:
CMS at the *LHC* in Switzerland studies the Higgs Boson, searches for new particles, seeks to understand the nature of dark matter
- Through precise measurement of decays at the highest possible rate:
LHCb at the *LHC* studies rare B-meson decays to see whether particles and anti-particles behave the same way and to seek evidence for new particles and forces

Understanding Nature's building blocks

Search for new fundamental particles, forces and phenomena

- By measuring particles evolution as they travel through space and time:
T2K in Japan measures how muon neutrinos change into other types of neutrino to understand why the Universe contains matter, not antimatter
- Using particles provided by Nature:
LZ in the US searches for dark matter particles in a liquid xenon detector operating deep underground
- By probing processes that “should not happen at all”:
COMET in Japan is looking for muons turning into electrons without neutrinos being produced, a process extremely sensitive to new phenomena

SBN experiments (MicroBooNE and SBND) examine the properties of neutrinos; how a neutrino evolves as it moves through space and matter ...
They also search for sterile neutrinos, dark matter, and other new phenomena

Understanding Nature's building blocks

Search for new fundamental particles, forces and phenomena

- Developing revolutionary new detector facilities:
DUNE in the US and *Hyper-K* in Japan are next-generation neutrino experiments with exquisite sensitivity which will allow the neutrino mass hierarchy to be determined, the study of supernovae neutrinos, and much more
Other detector-development activities too, e.g. CMS & LHCb upgrades ...
- Studying gravity using atom interferometry:
AION harnesses new quantum sensors to search for dark matter and new sources of gravitational waves
- Creating accelerator technologies to drive the field forward:
as part of the *John Adam's Institute* the group is developing the techniques for tomorrow's neutrino beams and energy frontier (muon) collider

Fundamental technologies for fundamental physics

Ambitious R&D that underpins the discovery programme

- Enormous computing power:

The volume of data from our experiments demands a step change in computing: we are leaders in the development of GridPP, a paradigm shift in the way we analyse our data with the potential for wide application

- Creating impact; applying our technologies to the problems of today:

LhARA and the *CCAP* seek to harness laser acceleration using novel accelerator techniques to transform cancer treatment using much improved particle beam therapy

deltaDOT Ltd has the world's best diagnostic and prognostic tools for renal failure and many other biomedical applications - all based on particle physics

Our laboratories



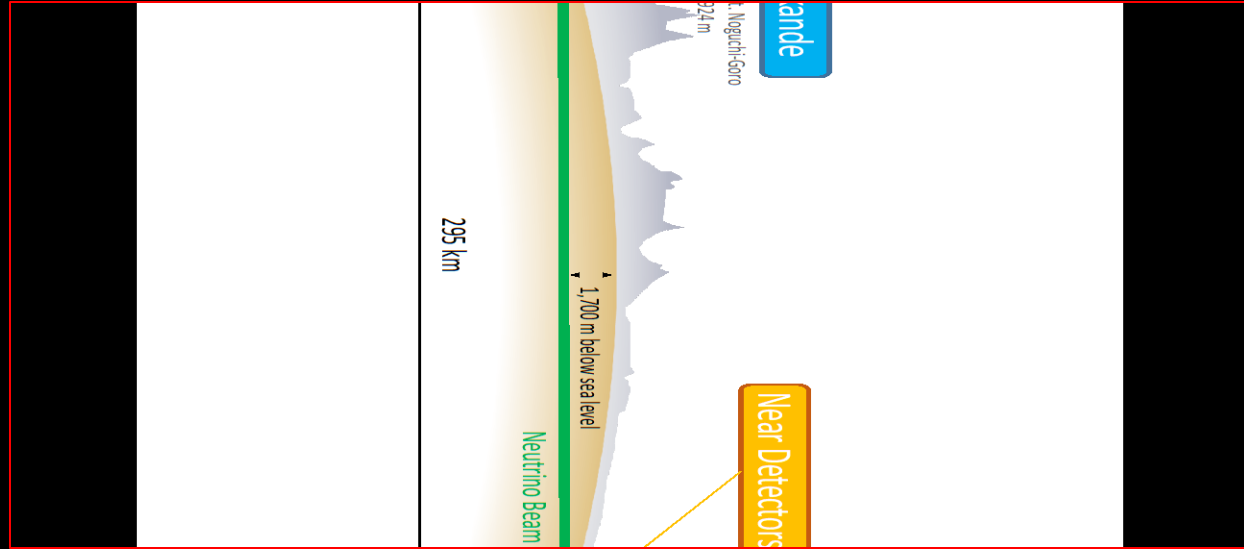
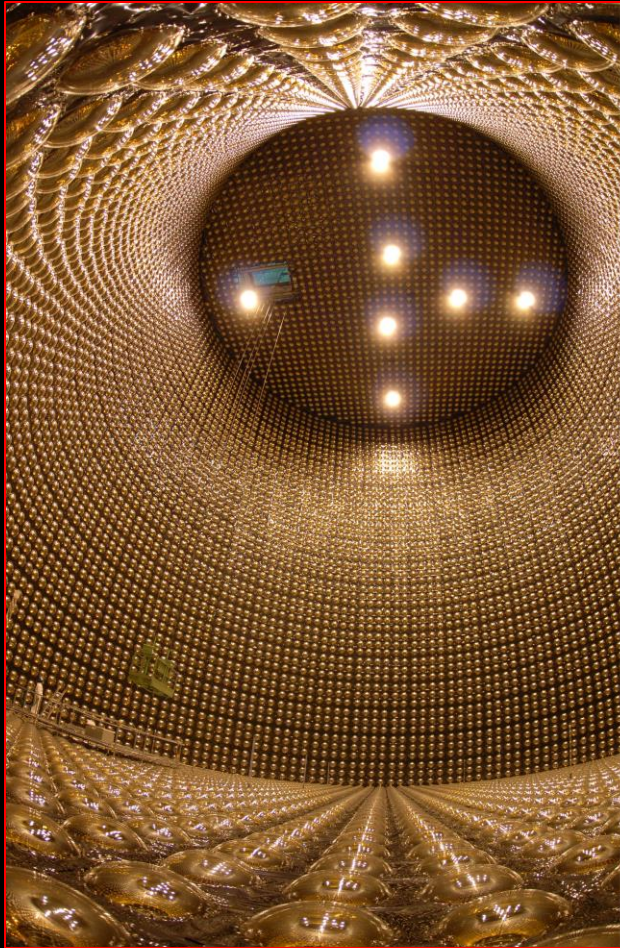
CERN, Geneva: CMS, LHCb



J-PARC, Japan (T2K, Hyper-K, COMET)



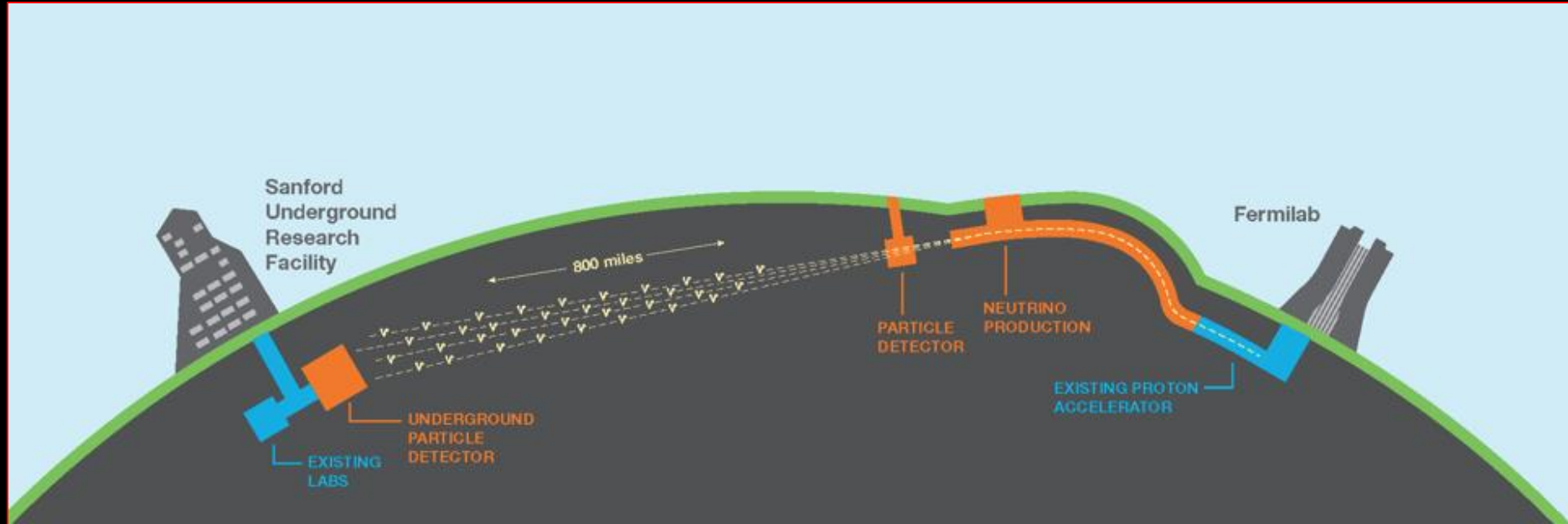
Kamioka, Japan (T2K, Hyper-K, Super-K)



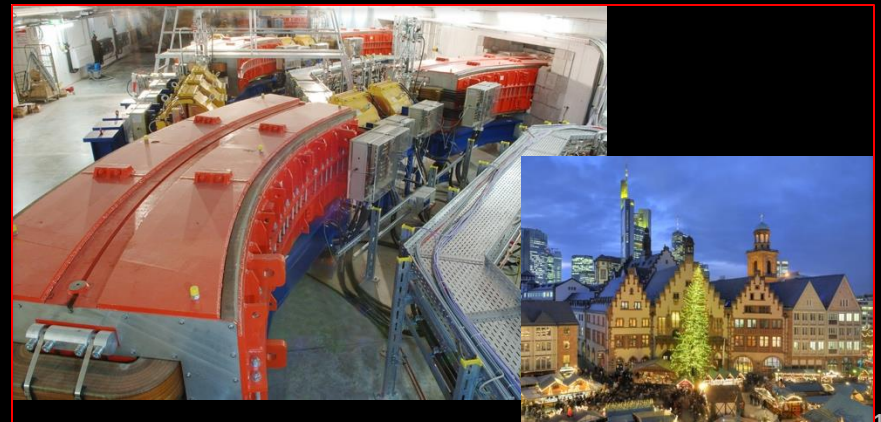
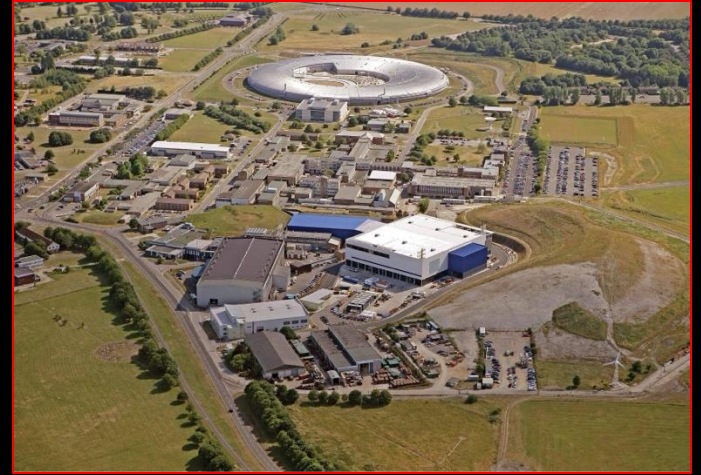
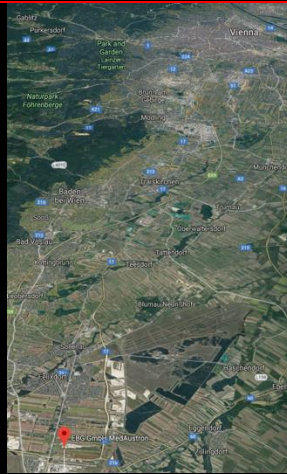
Sanford Lab, South Dakota (LZ, DUNE)



Fermilab/Sanford (DUNE, MicroBooNE, SBND)



CERN, DL, MedAustron, RAL (CCAP, LhARA)



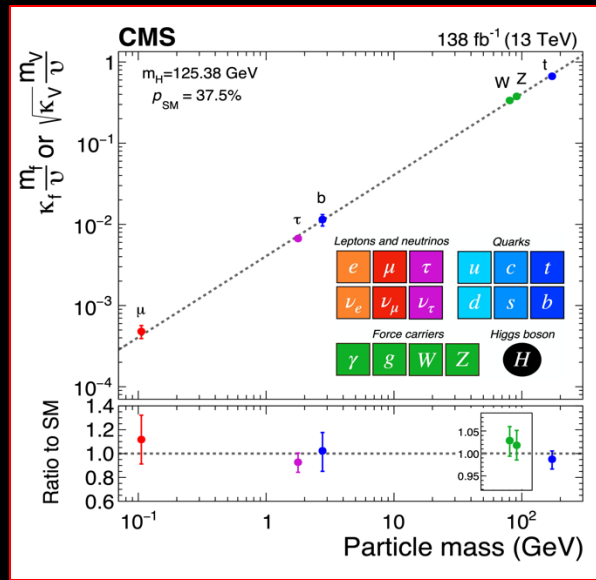
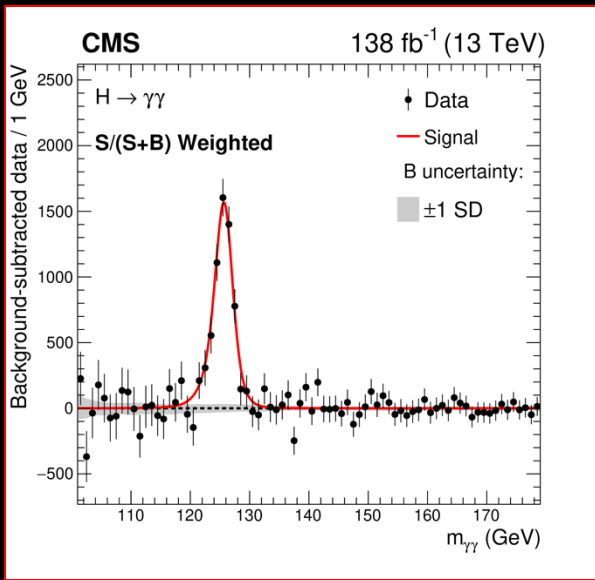
South Kensington



CMS: Higgs



Imperial played central role in Higgs discovery in 2012



Now we:

Study Higgs decays searching for new particles and phenomena

Measure Higgs boson properties precisely seeking evidence for the breakdown of the Standard Model

CMS: search for new particles and forces

- We search the data for:

- Dark matter particles:

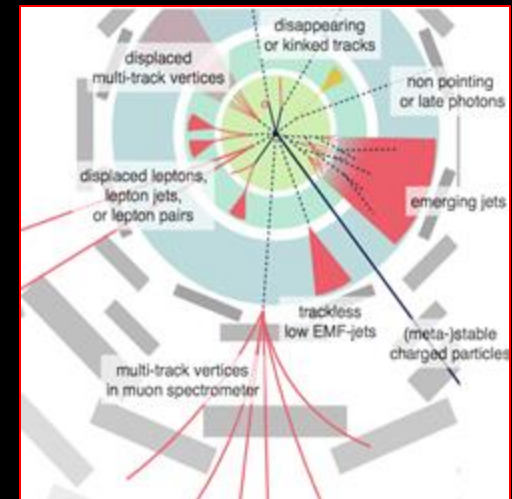
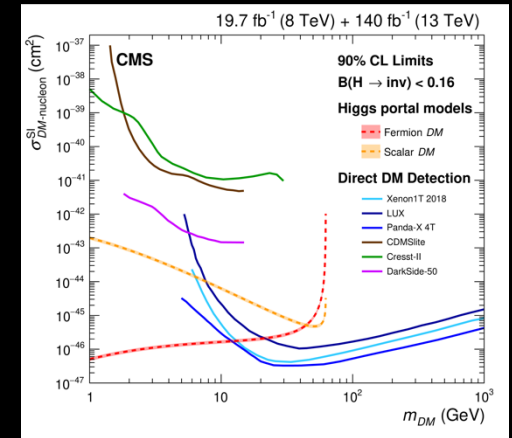
- DM known to exist but no DM particle yet

- We seek evidence for DM:

- Directly produced in pp collision

- Produced in Higgs decay

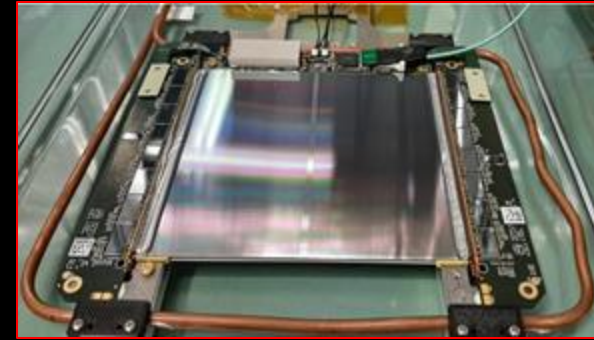
- Exotic long-lived particles with spectacular signatures



CMS: upgrade

R&D for significant improvements to CMS detector

- Readout chip designed at Imperial
 - Gives momentum selection critical to reduce rates from backgrounds



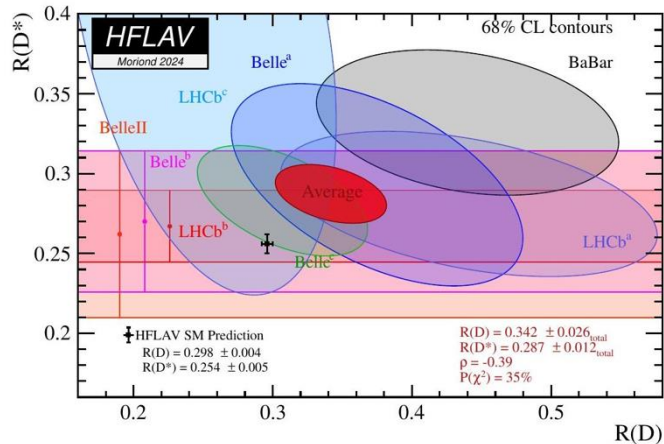
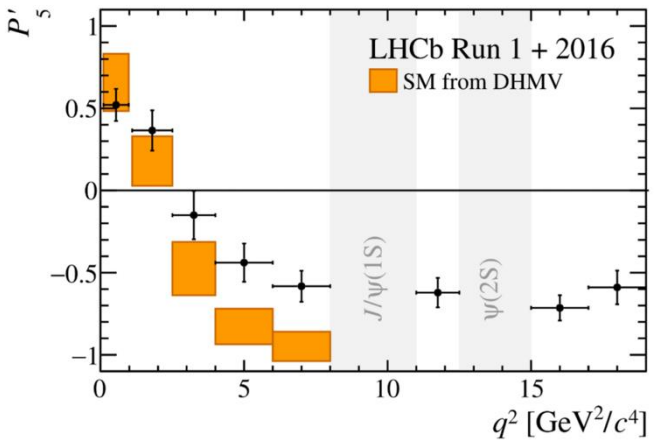
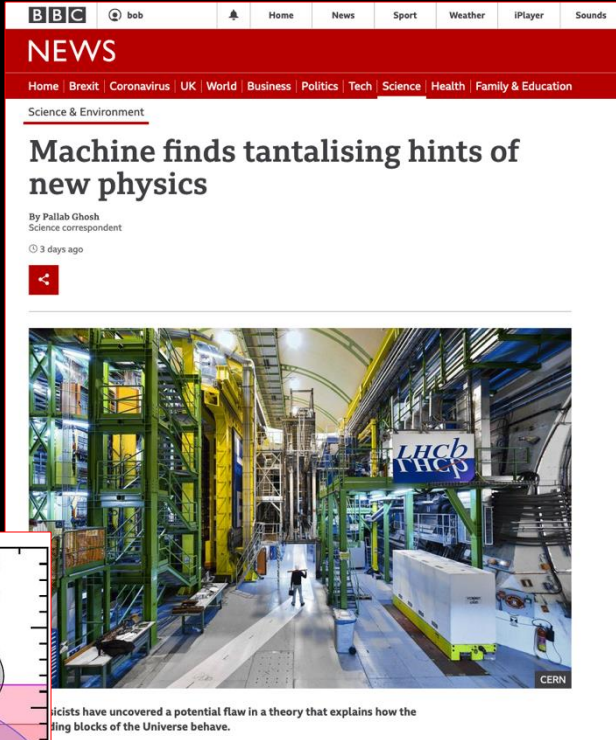
Serenity board designed at Imperial

- Handle huge data volumes from upgrades detector
- Host sophisticated data-processing algorithms



We have leading roles across CMS upgrade programme

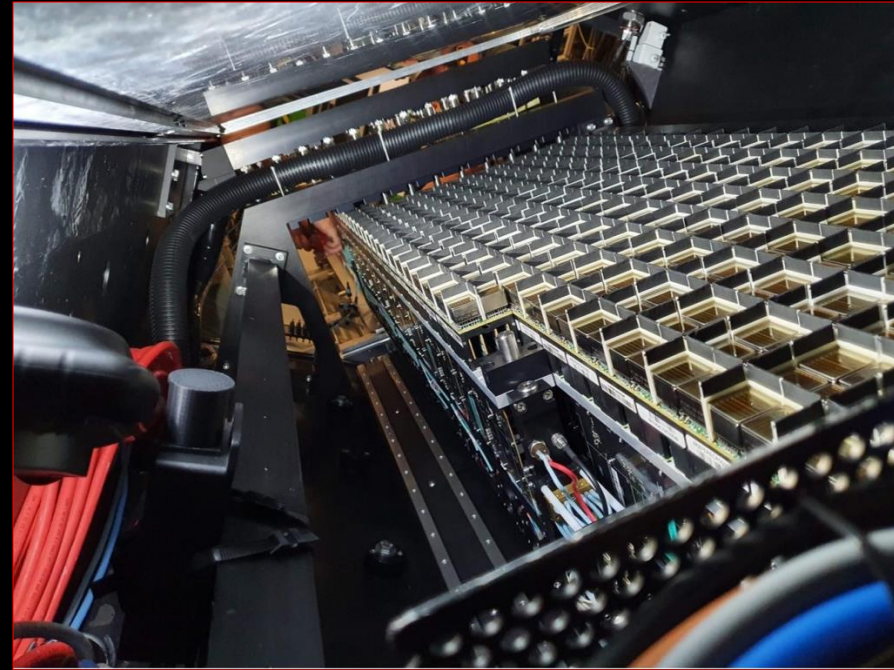
We have made several measurements that show evidence for “*new physics*” which have been widely reported



Continuing to explore these effects with new decays and much more data

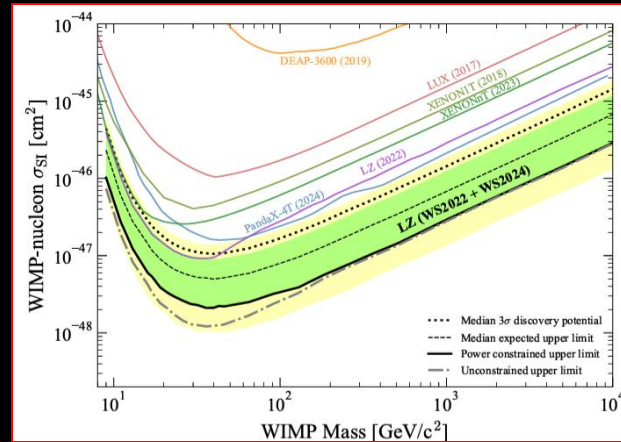
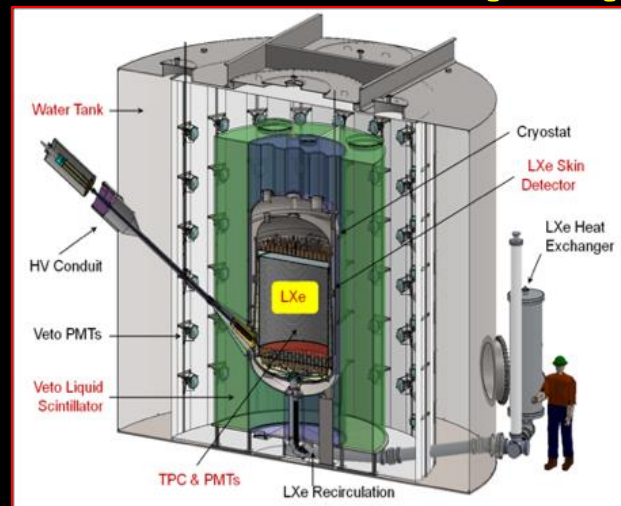
LHCb upgrade

- LHCb has undergone a major upgrade:
 - Much higher data rates to accumulate large samples more quickly
- We led design of key parts of the Ring Imaging Cherenkov (RICH) detectors:
 - Essential for many of the most exciting final states
- Further upgrades to LHCb now being planned (RICH and Tracker):
 - Excellent opportunity to get involved!



LUX-ZEPLIN (LZ)

- Gravitational effects imply:
 - 85% of matter in Universe is dark but no candidate dark-matter particle in Standard Model
- LZ collaboration aims to:
 - Directly detect scattering of dark matter off xenon nuclei



- World's most sensitive searches for Weakly Interacting Massive Particles:

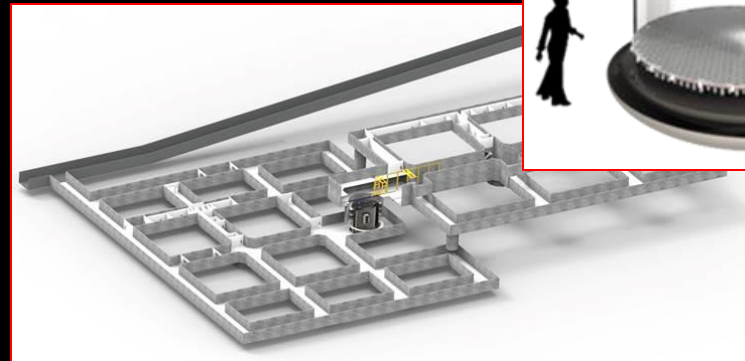
- Taking data until 2028 ...

- by far the world's most sensitive experiment!

We are leading LZ in the UK

Next-generation, dark matter and neutrino physics *Rare Event Observatory*

- Up to 100 tonnes of liquid Xe:
 - The definitive WIMP experiment!
 - Excellent sensitivity to neutrinoless double-beta decay
 - Astrophysical neutrino detection
- Leading XLZD in the UK
 - Working towards hosting in the Boulby Underground Laboratory



Long baseline neutrinos

Strong contribution to T2K experiment:

- Studies of neutrino oscillations using J-PARC neutrino beam
- Far detector is Super-K
- We have leading role measuring neutrino oscillations ...
 - ... and unoscillated beam in near detector
- *New near detector in 2024!*
- 2016 Breakthrough Prize recipients

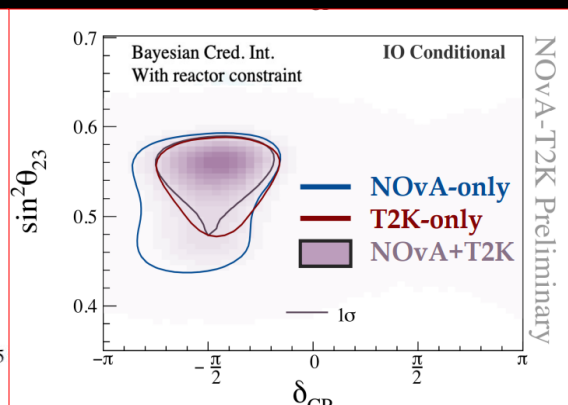
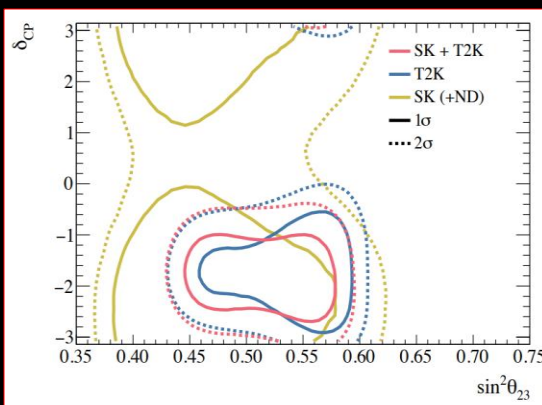
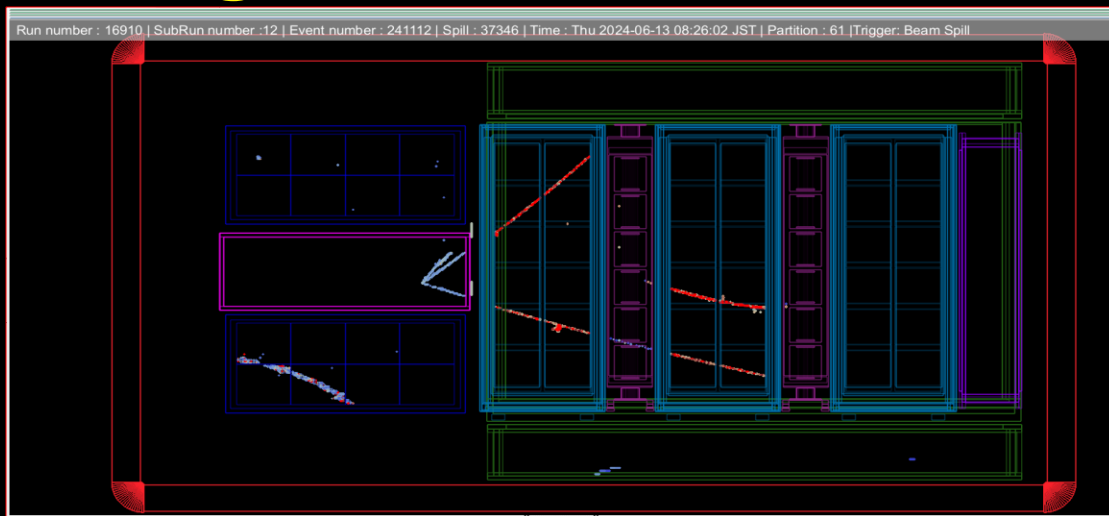
And:

- Leading data combination between NOvA (longer baseline) and SK experiments

Main objective now:

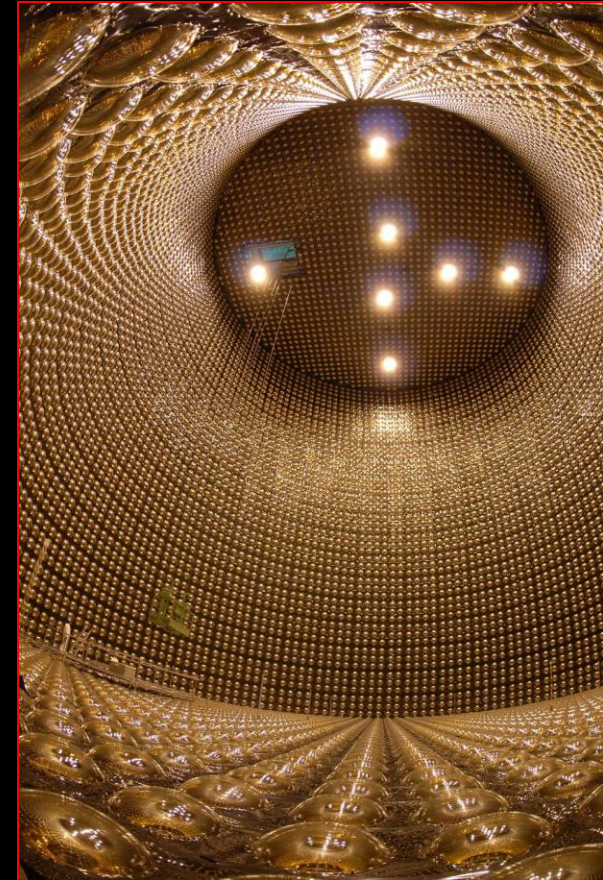
- Determine whether neutrinos violate matter/antimatter (CP) symmetry

Starting to exclude regions of CP space!



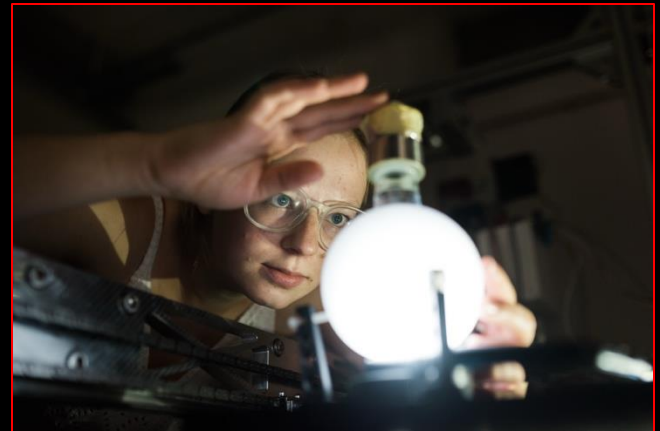
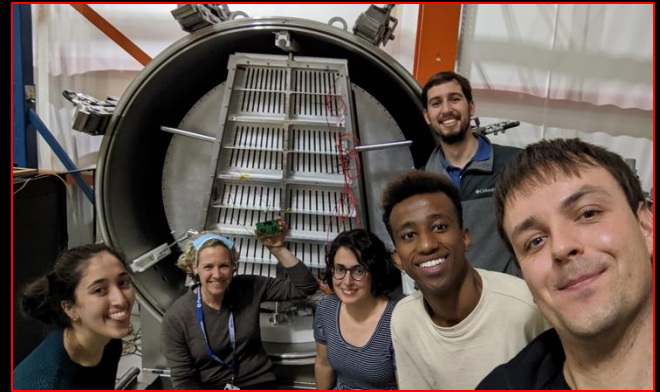
Super-K

- Astrophysical and atmospheric neutrinos with Super-K expt
 - 2002 Nobel prize to predecessor (Kamiokande)
 - 2015 Nobel prize for neutrino oscillations
 - Will Hyper-K join family?
- Gadolinium added to pure water in 2020:
 - Tag neutrons that capture on Gd
 - Separate neutrinos from anti-neutrinos → Better mass ordering and CP sensitivity
- Developing novel calibration methods, also applicable to Hyper-K expt

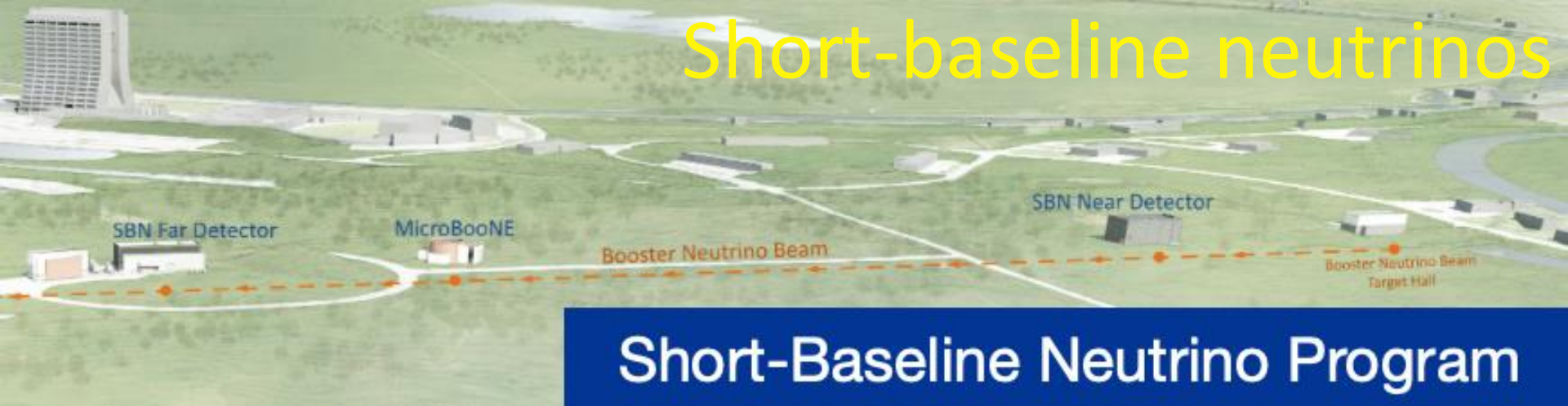


Future long-baseline neutrinos

- Strong contributions to both DUNE and HK
 - Future experiments will measure CP violation *precisely*
 - We have leading roles in oscillation physics in both DUNE and Hyper-K
- DUNE:
 - Very high power neutrino beam and high resolution argon detectors
 - We are building data acquisition system, the anode planes, and develop the high-pressure argon gas near detector
- Hyper-K:
 - Will have the largest far detector and upgrade of T2K beam for high power
 - We are building novel PRISM-technique near detector
 - Test-beam experiment at CERN: WCTE

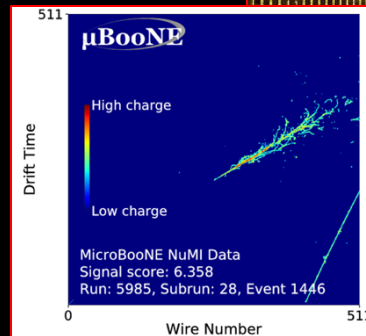


Short-baseline neutrinos



Short-Baseline Neutrino Program

- **Strong contributions to MicroBooNE & SBND**
 - **Liquid-argon detectors in high intensity neutrino beams**
 - **Principal objectives:**
 - **Study neutrino-argon interactions**
 - **Measure neutrino oscillations at short baselines**
 - **Search for sterile neutrinos, dark matter, other new phenomena**



COMET: Muon-to-Electron Conversion Search at J-PARC

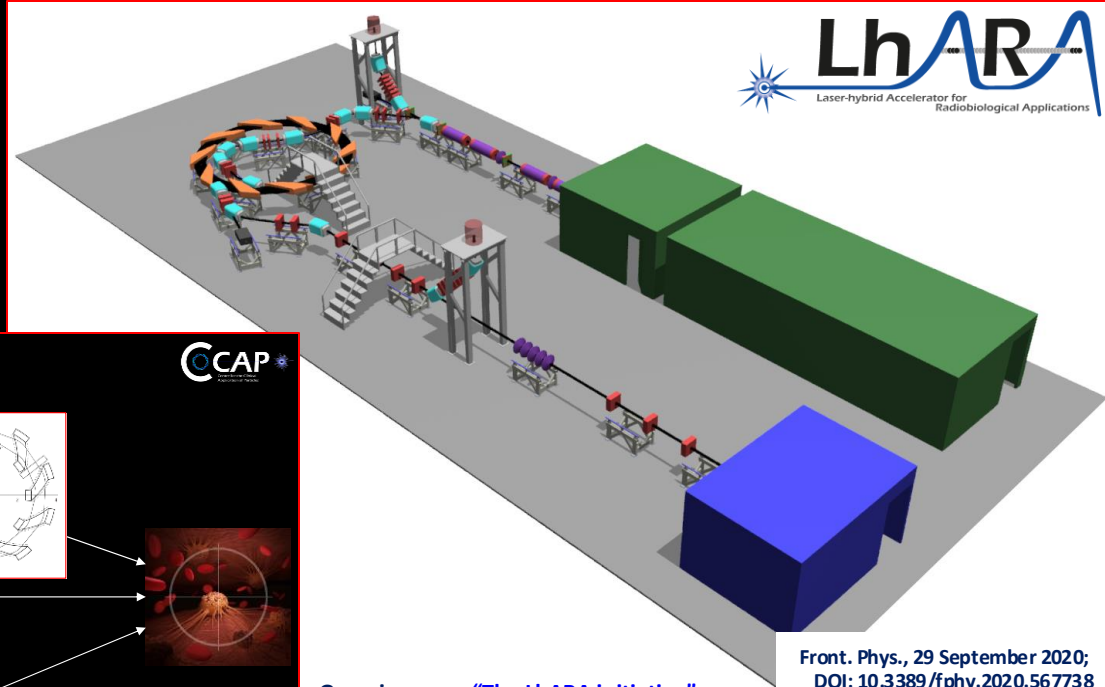
- Broad search for new phenomena in:
 - The spontaneous conversion of a muon into an electron inside a nucleus

Physics beyond the Standard Model
smoking gun!

- Multi-year programme:
 - Preliminary data (Phase- α) *NOW*
 - Phase-I data-taking starts in 2026
 - Phase-II to follow
 - PRISM experiment in the long term



LhARA: the Laser-hybrid accelerator for Radiobiological Applications



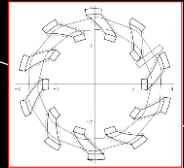
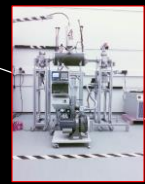
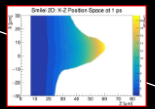
Front. Phys., 29 September 2020;
DOI: 10.3389/fphy.2020.567738

Overview, see: ["The LhARA initiative"](#)

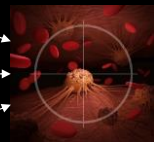
Ambitious programme: create transformative capability!

Opportunities from development of novel techniques, to biomedical research and PP spin-in

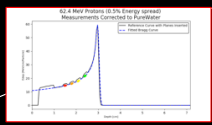
Novel accelerator techniques



System: image processing fast feedback, control



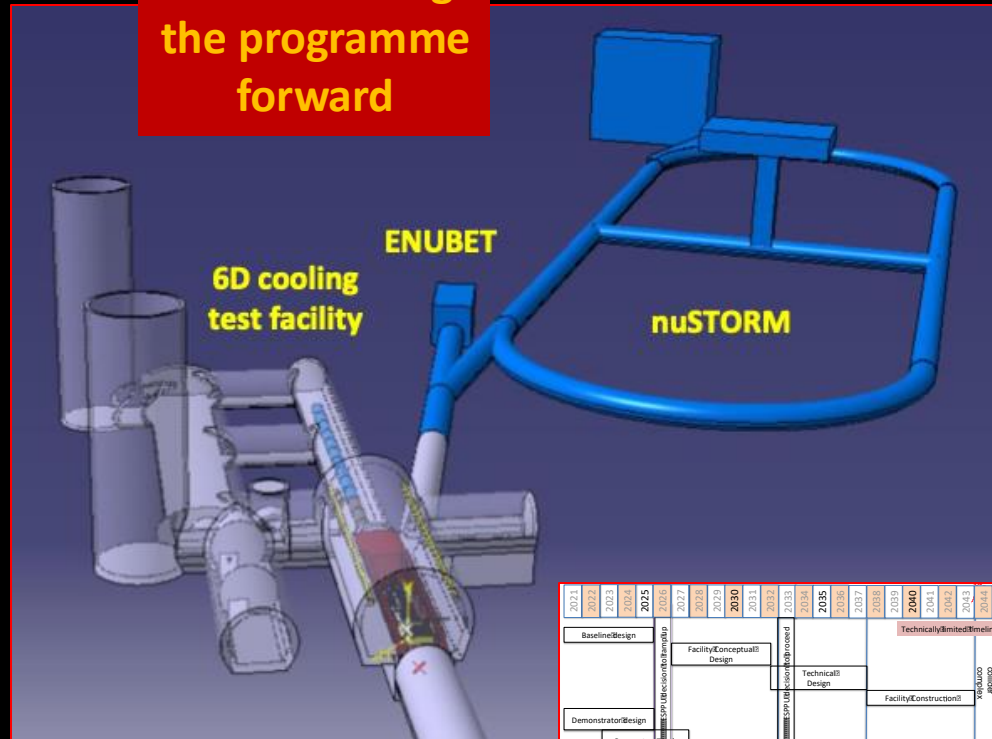
Fundamental Biology & biochemistry



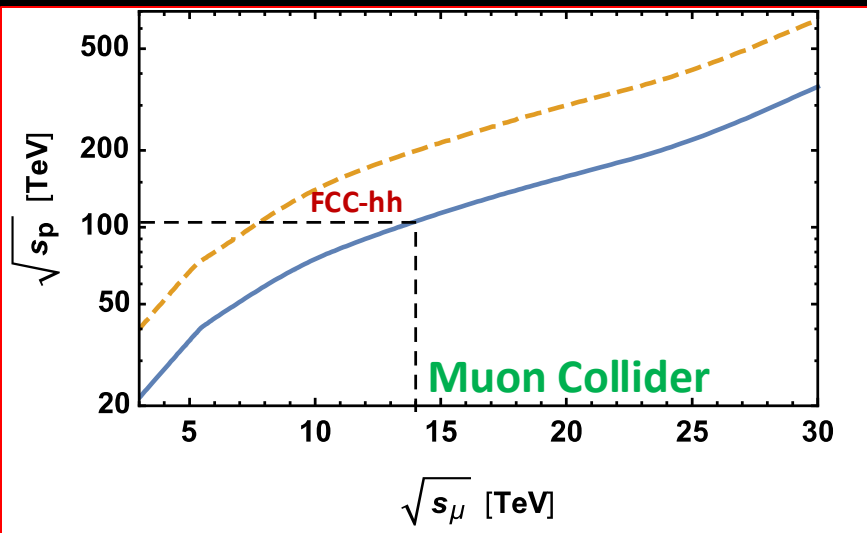
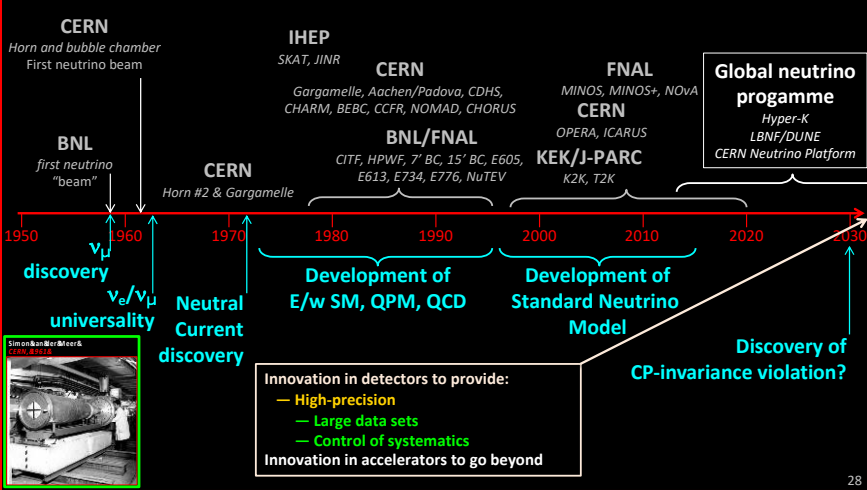
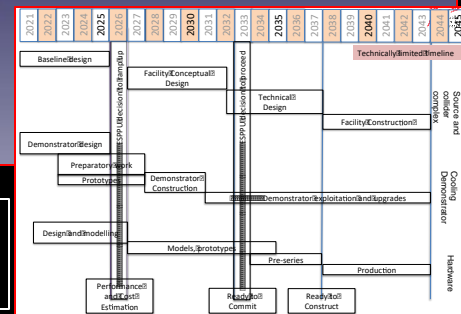
Part of our drive to develop the technologies to drive field forward ...

nuSTORM

We are driving the programme forward

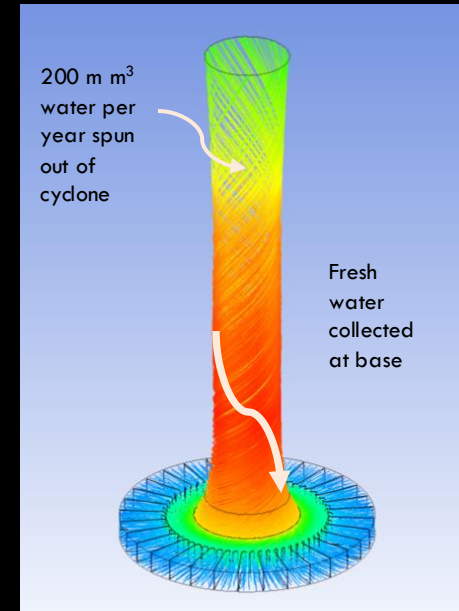
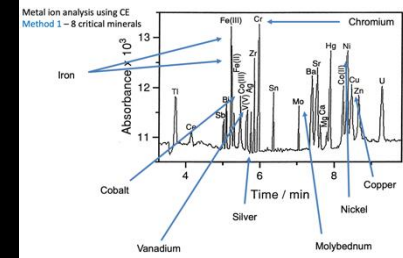


Exploiting techniques developed for e.g. LHARA & ISIS



Advanced Diagnostic Tools, Sensor Arrays

- Label Free Intrinsic Imaging:
 - Over 30 biomedical, and environmental sensing applications
 - Commercialised by Imperial spinout
 - Used in many biotech and biomedical areas
 - Used by NHS in antibody QC/QA
 - Being used in sustainable metals analysis
- Applications in Renewable energy
 - Water and electricity production using
 - Vast HEP-style sensor arrays, montecarlos etc



Development of new analysis techniques

- Extensive big data, machine learning and quantum computing opportunities including:

- Opportunity to attend graduate school ML course
- Involvement with industry via CDT in data science
- Centre of excellence in High-throughput Digital Electronics and Embedded Machine Learning

$$\lim_{n \rightarrow \infty} \sqrt[n]{A} = 1$$

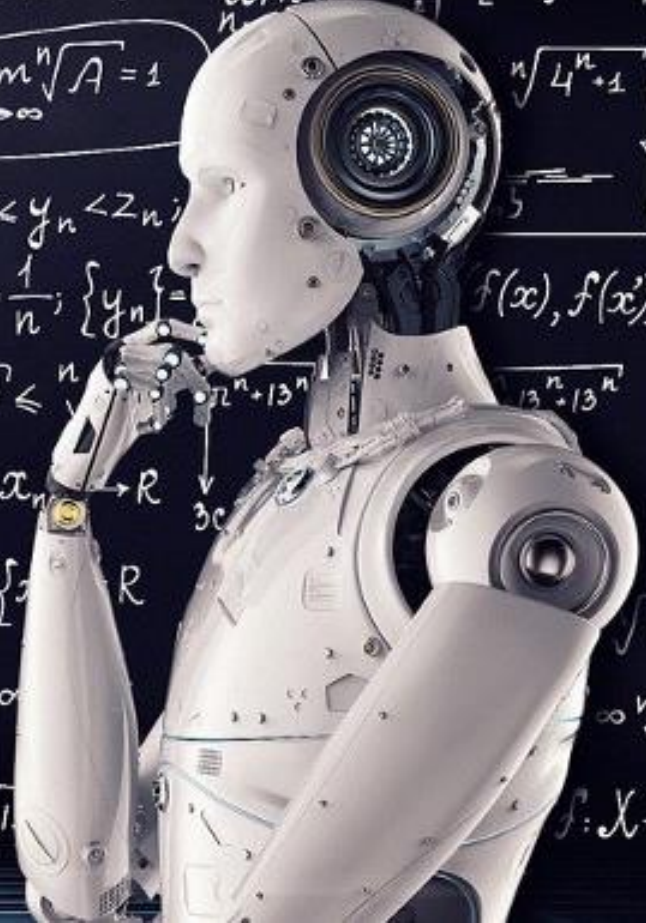
$$\{x_n\}: x_n = \frac{1}{n}; \{y_n\} = \frac{1}{n}$$

$$\sqrt[n]{0+0+0 \leq +13^n}$$

$$\sqrt[n]{13^n}$$

$$\sqrt[n]{13}$$

$$\sqrt[n]{13}$$



The Imperial Particles Community

- One of the largest cohorts of any UK particle physics group
 - Impacts on scale and breadth of graduate education we can offer
 - Scholarships not tied to particular programme decide on their project in December:
 - Once you have been with us for a term
 - Students form a cohort and work and learn from each other
- One of the broadest range of projects in the country
 - Different physics, labs/countries, detector technologies, phase of experiment
 - Leadership in many experiments: academics, RAs and students

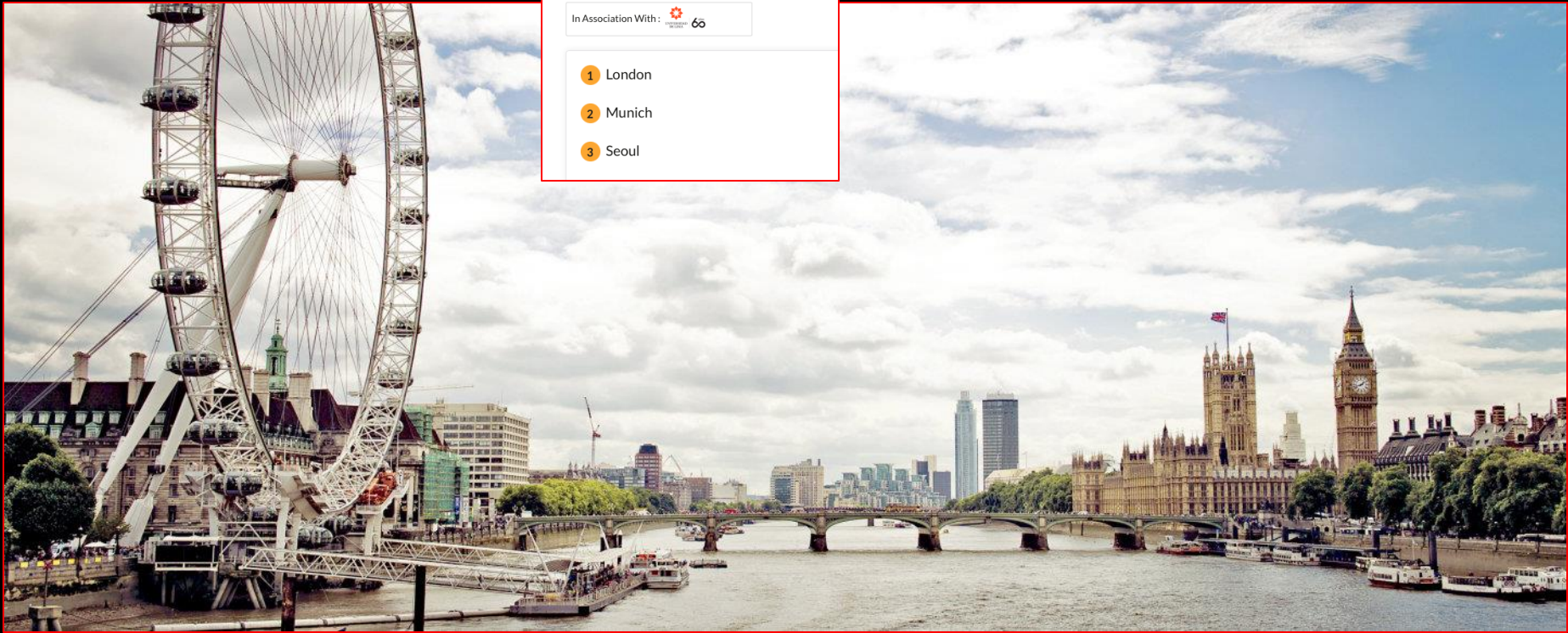
London!

<https://www.topuniversities.com/best-student-cities>

QS Best Student Cities 2023

In Association With:  60

- 1 London
- 2 Munich
- 3 Seoul

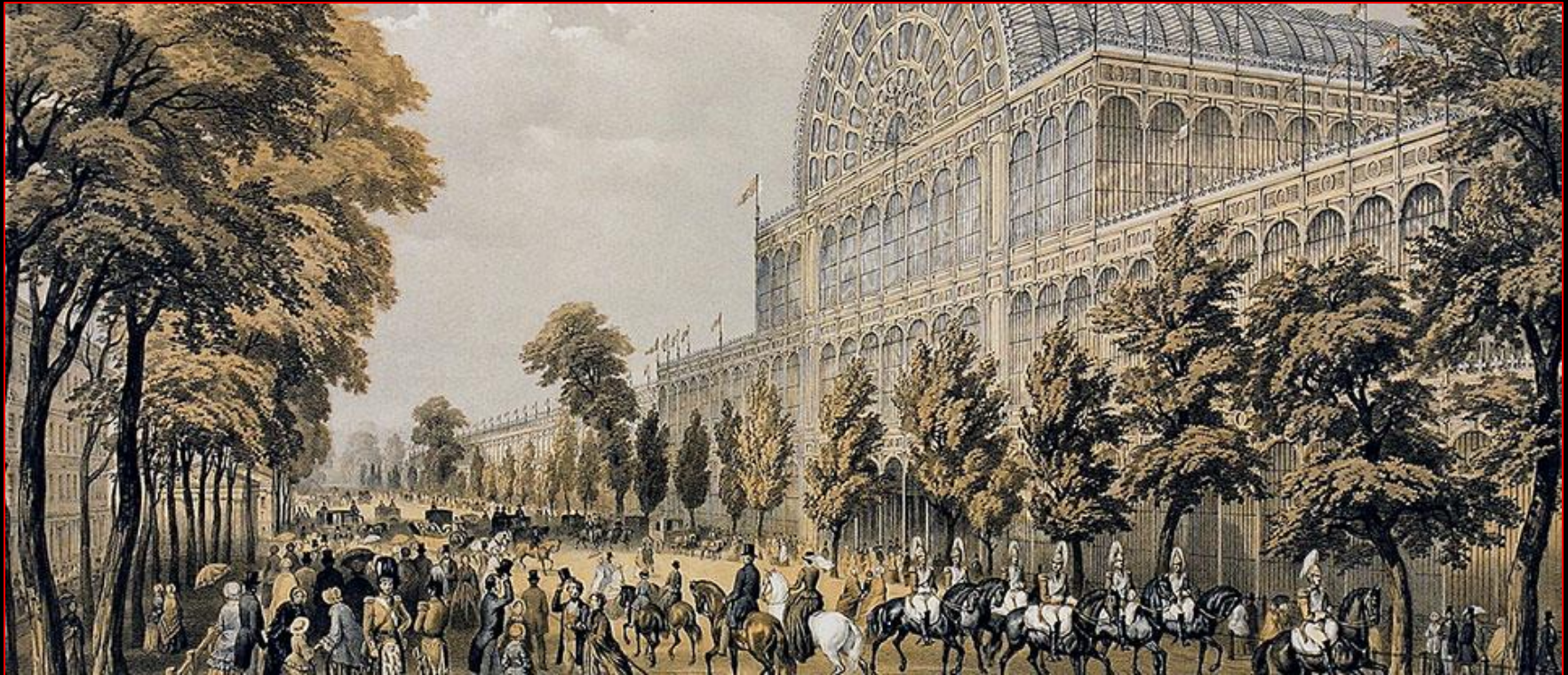


"Why, Sir, you find no man, at all intellectual, who is willing to leave London. No, Sir, when a man is tired of London, he is tired of life; for there is in London all that life can afford."

— Samuel Johnson

South Kensington

A beautiful part of London dedicated to the Arts and Sciences as a legacy of 1851 Great Exhibition



South Kensington

A beautiful part of London dedicated to the Arts and Sciences as a legacy of 1851 Great Exhibition





● Kensington Palace

● Kensington Gardens

● Hyde Park

Nice walk to Paddington Station

● Serpentine Gallery

● Royal Albert Hall

● Blckett Laboratory

● **Ethos** Sports Centre

● Science Museum

● Natural History Museum

V&A ● Museum

● Ciné Lumière

PhD studentships

- We have STFC “quota” studentships
 - Search for “STFC student eligibility requirements”
- Good stipend, excellent travel support – London weighting in addition to UK-wide STFC stipend
- Some flexibility in selecting experiment/project
 - Opportunity for “non-project” scholarships to choose project at end of first term
 - After graduate courses and opportunity to discuss with staff and peers

PhD studentships

- **Project-specific studentships are also available:**
 - **STFC:**
 - Project studentships often secured during recruitment process – will let you know before interview
 - **John Adams' Institute:**
 - Studentship to work on our accelerator science programme (LhARA, nuSTORM, ISIS-II, ...)
- **Non-STFC scholarships**
 - **By nation of origin, particular groupings etc. – search for “Imperial fees and funding” – most require you to specify a potential project and supervisor in the application**
 - **Imperial College President's Scholarships**
 - Hyper-competitive: need to be a top student from a top university, research experience required
 - Particles Community can only support one application per round
 - Very broad eligibility (especially nationality)
 - Get in touch if you you'd like to apply
 - **Also, graduate programmes at our partner Laboratories, e.g.:**
 - CERN Graduate Programme
 - STFC RAL: PPD &/or ISIS Departments

Application and selection process

- See <http://www.imperial.ac.uk/high-energy-physics/opportunities/postgraduate-opportunities/>
- **Fill the Central College application form!**
- **Initial application deadline 20th January 2025**
- **Will hold interviews from end January/start February**

Interviews

- **Two interviewers; about 30 minutes long**
 - **Be ready to discuss your undergraduate or summer projects ...**
 - **And physics in general**
- **Generally at 10am, 11am, 1pm or 2pm**
- **There is a lot of competition for places**
 - **We are interested in how you think (and respond) more than what you already know**
 - **Our discussion is likely to “stretch” you to see how far you can go**
 - **We are looking for the top students to be our future colleagues!**

Remainder of the afternoon

- A tour of the activities in the group:
 - We'll split you into groups
 - Each group will be led by a guide to each stop on the tour
- Please ask anyone anything about how your time with the group might go
- After the tour you will have a chance to meet more group members informally in Blakett 539
 - For online participants this ZOOM link will stay live throughout the afternoon
- Online Q&A sessions: 08Jan25: 10:00—11:00 and 16:00—17:00

