

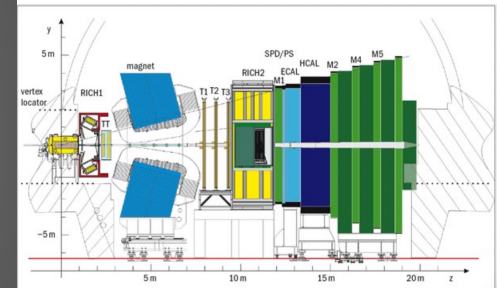
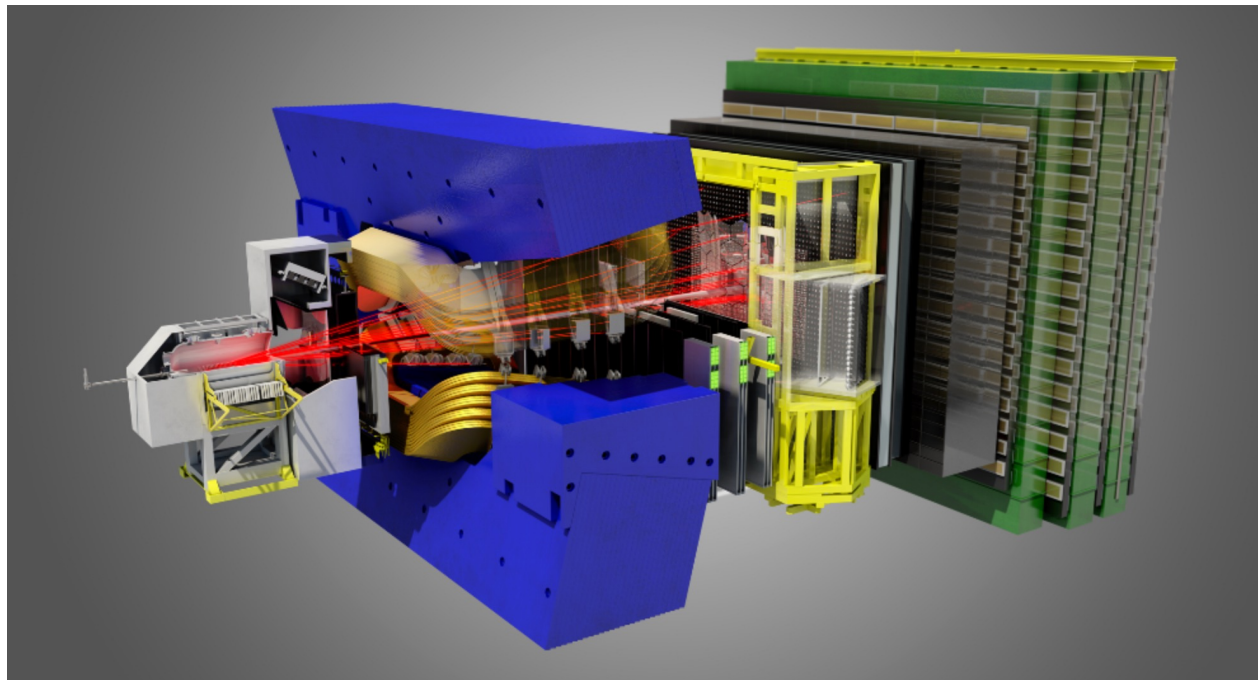
Project 5 (LHCb Experiment):

Measurement of the unitarity angle α and development of the
Mighty Tracker readout

Atanu Modak (STFC-RAL) and Paul Soler (University of Glasgow)

The LHCb Experiment at CERN

- LHCb collaboration: Over 1500 members from ~50 institutes across 20 countries
- Unique apparatus to probe new physics: CP violation (matter anti-matter asymmetry), precision test to heavy-flavor SM, rare decays, hadron spectroscopy



Research Project

- In this research project, you will perform a Physics analysis using LHCb data and perform a hardware project to read out modules for the Mighty Tracker, the upgraded tracker for LHCb Upgrade-2
- This is a joint project between PPD and the University of Glasgow, jointly supervised by Dr Atanu Modak and Prof Paul Soler
- Two parts:
 - Measurement of unitarity angle alpha (ϕ_2) from CP violation in $B^0 \rightarrow \pi^+ \pi^- \pi^+ \pi^-$ decays
 - Develop read out systems for pixel Mighty Tracker, the downstream tracker for the LHCb Upgrade-2 (to be ready for LHC Run 5)

Biographies



- Paul Soler: Professor Experimental Particle Physics, University of Glasgow, with interests in CP violation in hadrons (LHCb) and neutrinos (T2K/HyperK)
 - PhD, University of Sydney (1994)
 - Research Fellow, University of Sydney (1994-1998)
 - Marie Curie Fellow at CERN (1998-2000)
 - Lecturer University of Glasgow, joint appointment with RAL (2000-2005)
 - Senior Lecturer, Reader, Professor, University of Glasgow (2005-...)
- Supervised 38 PGR students (25 as main supervisor)
- Some relevant research highlights:
 - Development LHCb RICH2 detector at RAL, testing 550 Hybrid Photon Detectors for LHCb RICH, Opto and Power Boards LHCb VELO upgrade, Hyper-Kamiokande Outer Detector electronics
 - Discovery Ξ_{cc}^{++} , first observation $B^0 \rightarrow p\bar{p}$, CP violation in $B_s \rightarrow \pi^+\pi^-$, search for CP violation in $D^0 \rightarrow \pi^+\pi^-\pi^0$ and $D^0 \rightarrow \pi^+\pi^-\pi^+\pi^-$

Biographies

- Atanu Modak:
 - Staff Scientist, STFC-PPD (2022 - present), LHCb experiment
 - Research Associate, K-State University, USA (based at CERN 2017-2022), CMS experiment
 - PhD, Saha Institute of Nuclear Physics, India (2017), CMS experiment
- Some relevant research highlights:
 - Lead role in CMS Pixel detector commissioning and operation, Leading STFC-PPD for the Mighty Tracker upgrade – RAL will be one of the production sites for module and stave assembly, LHCb WP-lead for Mighty Tracker sensor and mechanics groups
 - Discovery of the Higgs boson in fermionic mode, vector-like quark search with CMS data, charm production measurement in LHCb

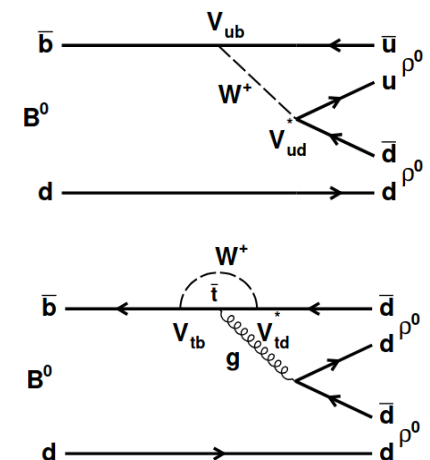
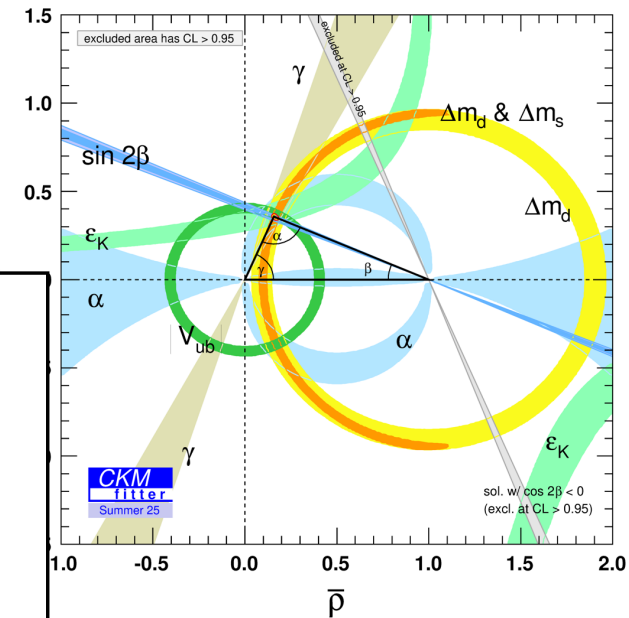
Unitarity angle alpha

- CP violation in Standard Model: CKM matrix
 - CKM unitarity triangle: alpha least well-known angle

- Alpha from interference $b \rightarrow uud$:

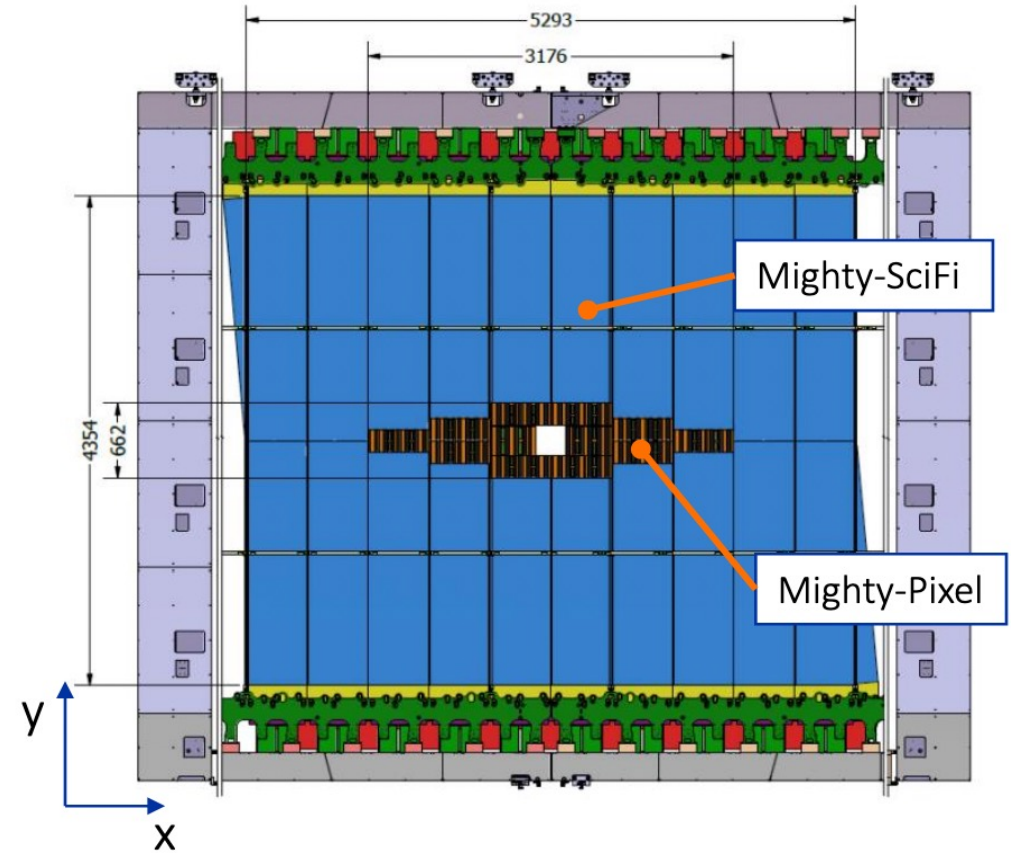
$$\alpha = \arg \left(- \frac{V_{td} V_{tb}^*}{V_{ud} V_{ub}^*} \right)$$

- $B \rightarrow \pi\pi, B \rightarrow \rho\rho, B \rightarrow \rho\pi, B \rightarrow a_1\pi, \dots$
- In LHCb, most promising channel is: $B^0 \rightarrow \pi^+\pi^-\pi^+\pi^-$ since it goes via $B^0 \rightarrow \rho^0\rho^0, B^0 \rightarrow a_1^+\pi^-$, ...
- Amplitude analysis to determine all intermediate channels – first step
- Time dependent asymmetry B^0/\bar{B}^0 is used to extract CP violation and measure $\sin 2\alpha$, removing degeneracies
- We will use Run 1, Run 2 and Run 3 data – largest sample of $B^0 \rightarrow \pi^+\pi^-\pi^+\pi^-$ decays ($\sim 100k$)



Mighty Tracker

- The Mighty Tracker: a scintillating fibre tracker, with silicon pixel tracker in the centre
- Glasgow: developing some of the readout electronics and test boards to read out data from pixel modules
- RAL: R&D on full chain readout and data acquisition for Mighty Pixel; heavily involved in prototyping of modules and staves, one of the production sites in the UK
- Flex tapes with pixel chips read out by opto-electronics HDI boards and FPGA-based data acquisition system



One layer $\sim 1.3 \text{ m}^2$ silicon area, total 6 layers

PhD tentative timeline

- Year 1 (Oct 26-Sept 27): University of Glasgow, with compulsory courses, RAL school in Sept 2027
- Year 2 (Oct 27-Sept 28): Long-term attachment (LTA) at CERN
- Year 3 (Oct 28-Summer 29): RAL, mainly working on MT readout
- Year 4: (Summer 29-Mar 30): Glasgow, finish thesis and write up