Refining the Simulation of LHCb SciFi Detectors in Geant4

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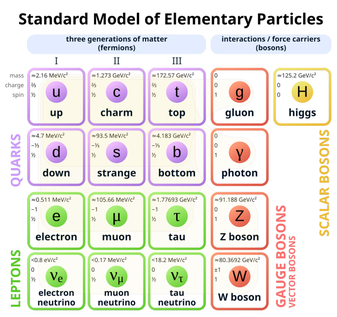
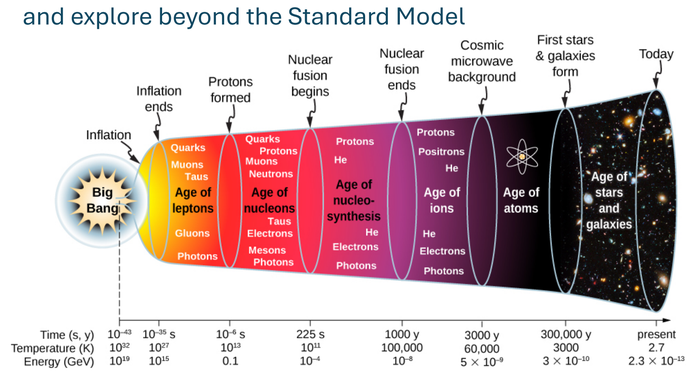
CERN & High Energy Physics

- European Organisation for Nuclear Research / Conseil Européen pour la Recherche Nucléaire, founded in 1954, near Geneva, Switzerland
- World's largest High Energy Physics laboratory; hosts thousands of scientists from over 100 countries
- Major achievements include the discovery of the Higgs boson

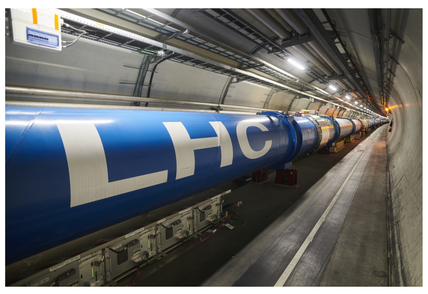


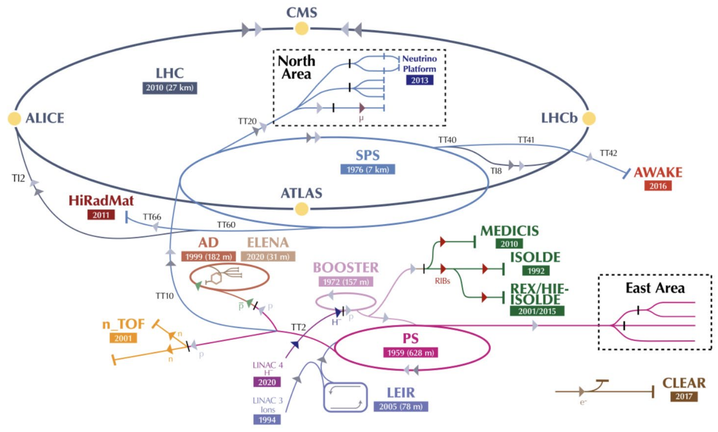
- High Energy Physics (HEP): studies the smallest building blocks of matter and the forces between them
- Uses particle accelerators to recreate early-universe conditions and explore beyond the Standard Model



The Large Hadron Collider (LHC)

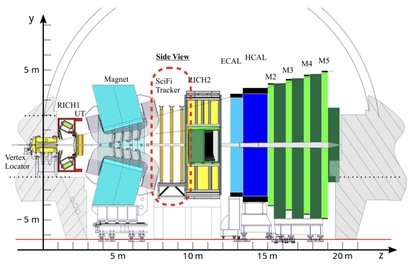
- World's largest and most powerful particle accelerator
- 27 km circular tunnel, located 100 m underground on the French–Swiss border
- Accelerates protons close to the speed of light before colliding them at four main experiments: ATLAS, CMS, ALICE, and LHCb
- Produces conditions similar to fractions of a second after the Big Bang
- High energy interactions enables precision tests of the Standard Model and searches for new physics

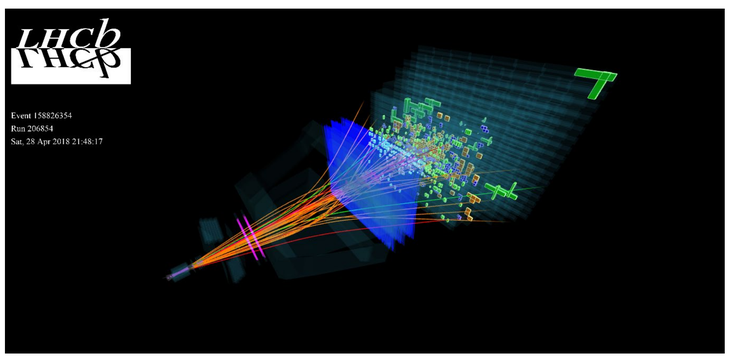




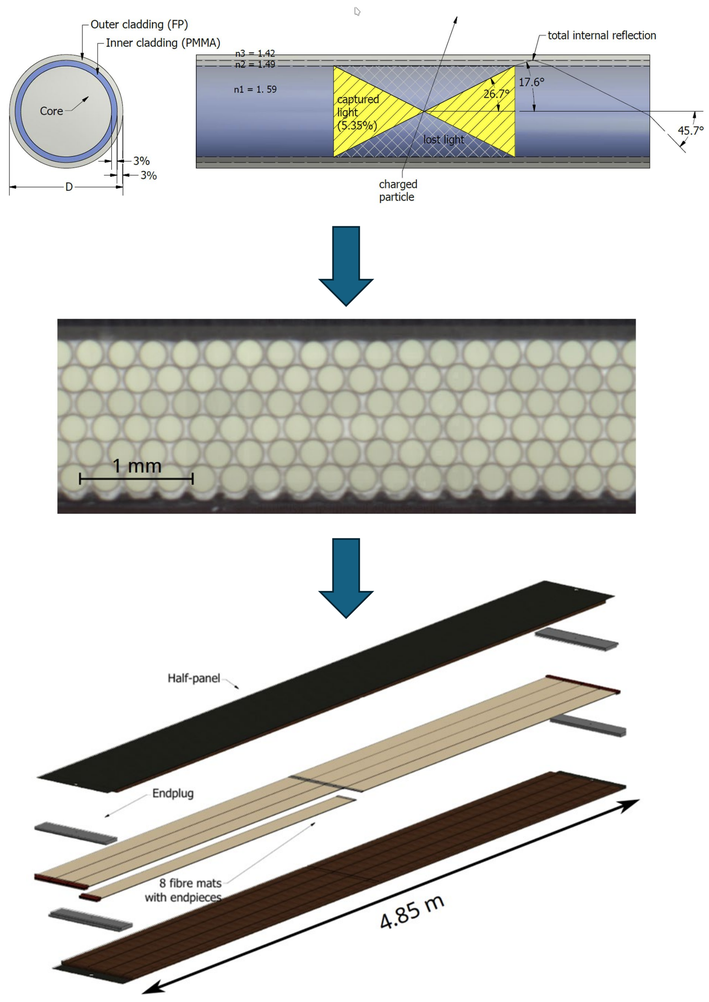
The LHCb Experiment

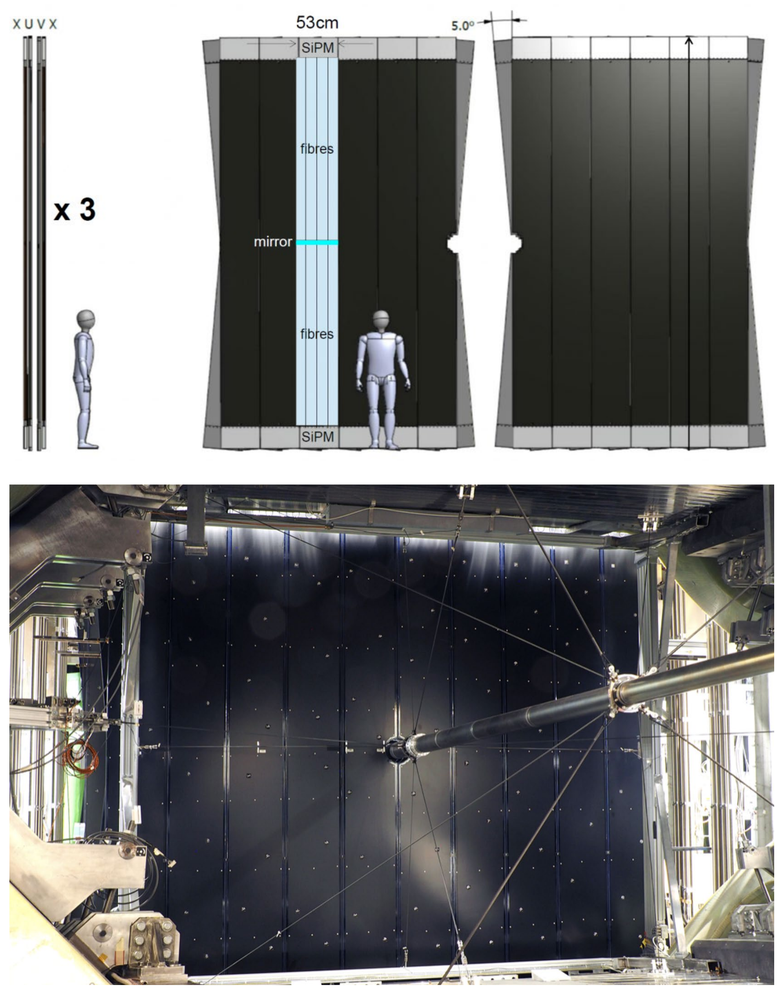
- One of the four main LHC experiments; specialises in flavor physics
- Focuses on studying particles containing b-quarks (beauty quarks)
- Investigates CP violation to understand matter–antimatter asymmetry
- Forward spectrometer design optimised for detecting particles emitted at small angles
- Uses precision measurements to search for effects of new physics beyond the Standard Model





The SciFi Detectors

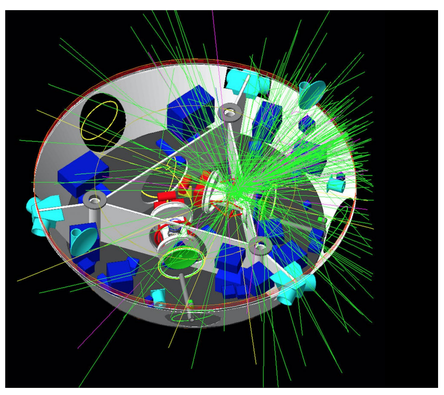




Geant4 Simulation

What is Geant4

- Open-source toolkit for simulating particle interactions with matter
- Models geometry, materials, particle generation, tracking, and interactions in 3D
- Includes detailed physics processes: electromagnetic, hadronic, optical photons, particle decay, etc.
- Widely validated against experimental data → trusted by CERN and global HEP community



Why Simulation Matters

- Accurately replicating the experiment's geometry, materials, and detector response is essential
- Enables direct comparison between simulation and measured data
- Helps separate true physics effects from detector artifacts
- Allows optimisation of detector design and data analysis strategies
- Increases confidence when extrapolating to new physics scenarios

Results & Future Work

Content of this project

- Implemented optical properties of lab-made glue (80% epoxy, 20% TiO_2): refractive index, absorption length, and Mie scattering parameters
- Added polyimide film to detector geometry
- Performed particle injection simulation events with 0.9 MeV e^- at various positions along the SciFi mat with varying designs
- Performed data analysis on simulation results and compared with experimental data

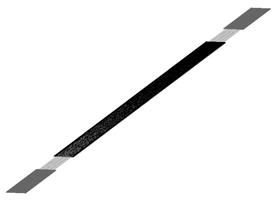
Results

- The close match signifies good estimation and modelling of the detector material properties, however detailed tuning is still needed

Future Objectives

- Refine simulation parameters for improved agreement, including mirror reflectivity and SiPM photon detection efficiency
- Simulate alternative SciFi mat designs for simulation validity check

Double Flex



Flex

Rigid