The LHCb Mighty Tracker

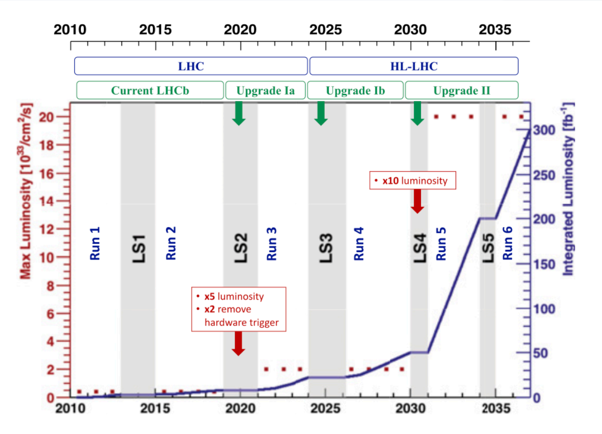
Tai-Hua Lin on behalf of the LHCb collaboration

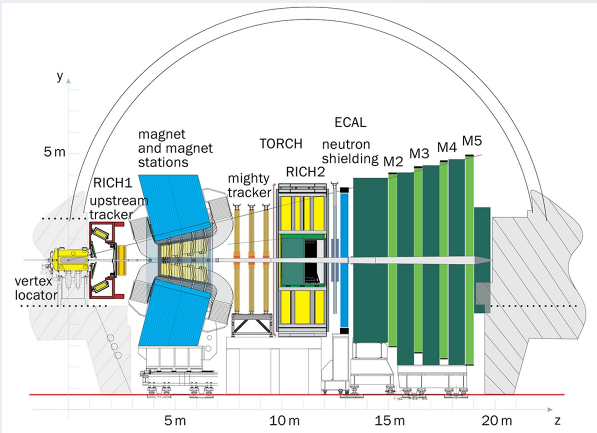
LHCb | Particle Physics STFC Rutherford Appleton Laboratory | UKRI Science and Technology Facilities Council

Introduction & Background

- **LHCb Upgrade:** Set for 2033-2034 to increase instantaneous luminosity to 1.5×10^{34} $cm^{-2}s^{-1}$
- **Challenge:** Effective track reconstruction with a tenfold increase in occupancy

2022 JINST 17 C10005

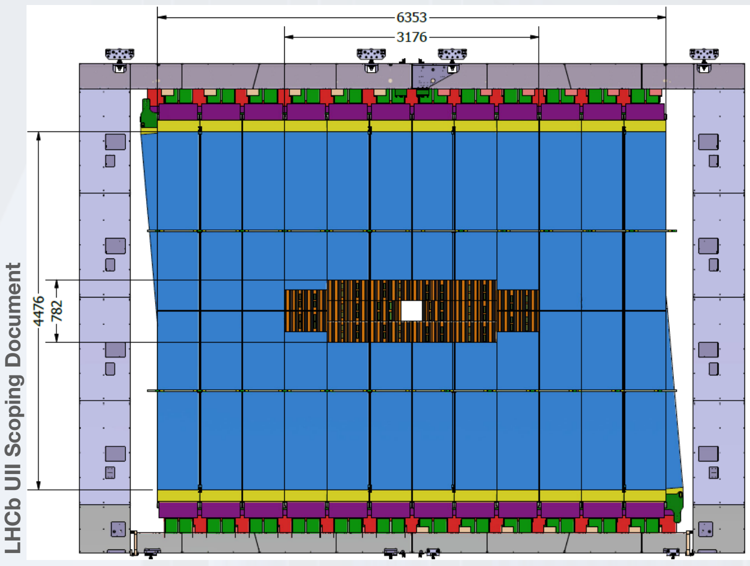


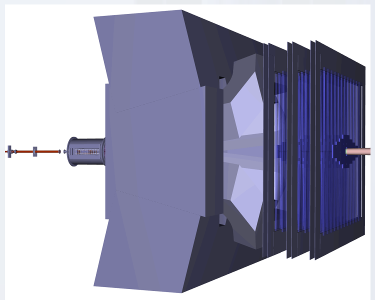


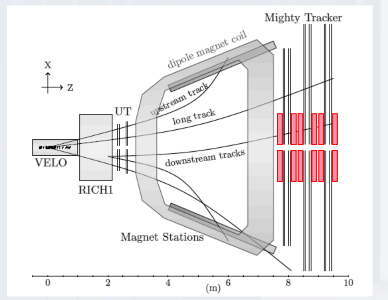
The Mighty Tracker Concept

- Solution:
  Mighty Tracker, a hybrid tracking system.
- Components:
  - **Silicon Pixels:** Inner region for high granularity and radiation tolerance.
  - **Scintillating Fibres:** Outer region for peripheral acceptance.
- Benefit:
  Combines strengths of both technologies for efficient track reconstruction.

LHCb UII Scoping Document



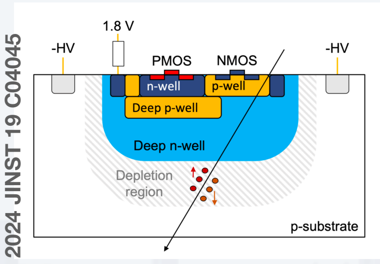


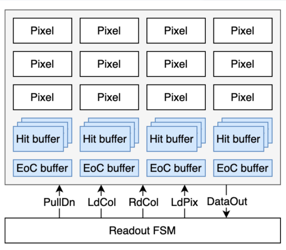


Silicon Pixels (Mighty Pixel)

- Role:
  High resolution and radiation tolerance for dense track environments.
- Current R&D:
  Enhancing radiation hardness.
  Improving readout speed.
  Reducing material budget.
- Techniques:
  - HV CMOS monolithic active pixel sensor (HV-MAPS)

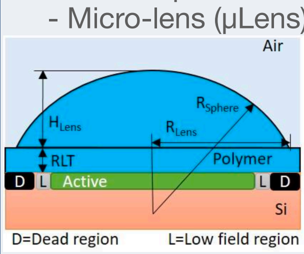
2024 JINST 19 C04045



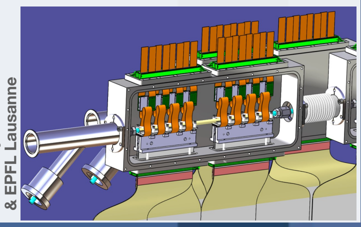


Scintillating Fibres (Mighty Fibre)

- Role:
  Optimised for lower track densities in outer regions.
- Properties:
  Excellent light yield and timing.
- Challenges:
  Ensuring performance under increased radiation.
- Current R&D:
  - Cryogenic cooling to lower the noise level
  - Fibre improvement
  - Micro-lens (µLens) enhanced SiPMs



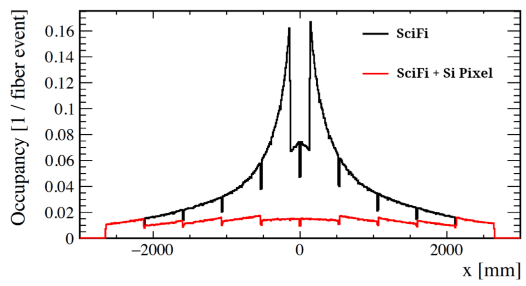
University of Aachen & EPFL Lausanne



Performance Simulation

- With MightyPix coverage the occupancy is limited to 2%.
- Preliminary studies show >95% efficiency with pixels.
- Ghost rate is significantly reduced with pixels.

Occupancy of SciFi (+/- Mighty Pixel)



Efficiency of SciFi (+/- Mighty Pixel)

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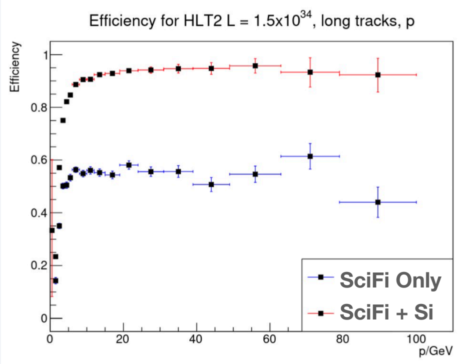
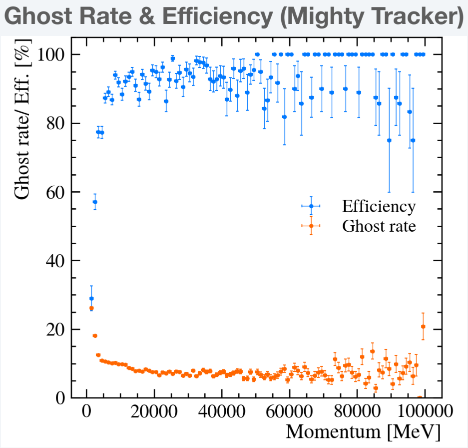


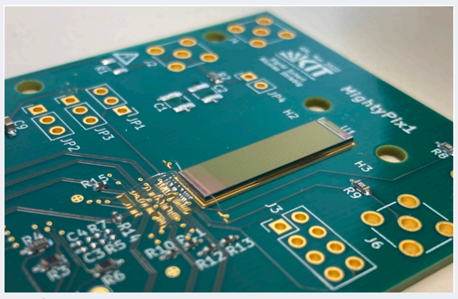
Ghost Rate & Efficiency (Mighty Tracker)

LHCb UII Scoping Document



Sensor Development

MightyPix1, Design by KIT



Requirements:

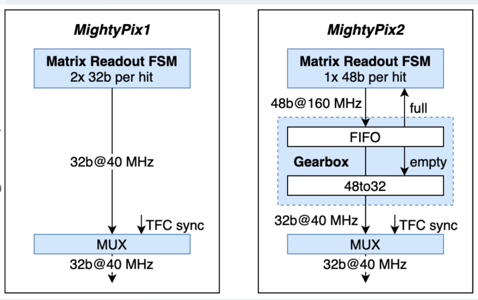
- **Pixel size:** < 100 µm x 300 µm
- **Hit-rate capability:** > 17 MHz/cm²
- **In-time efficiency:** > 99% within 25ns window
- **Radiation hardness:** > 6 x 10^{14} n_{eq}/cm^2
- **Noise rate:** < 5Hz / pixel
- **Power consumption:** < 150 mW/cm²

Compatible with the LHCb readout system

- 4 x 1.28 Gbps data links/chip
- Slow control
- Timing and Fast Control (1command / 25ns)

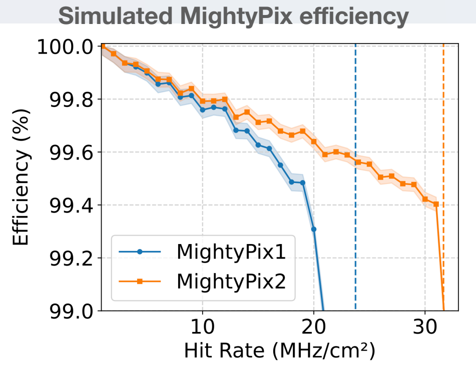
Readout Readout mechanism of MightyPix prototypes: MightyPix1 & improved MightyPix2

N. Striebig et al, KIT



Simulated MightyPix efficiency

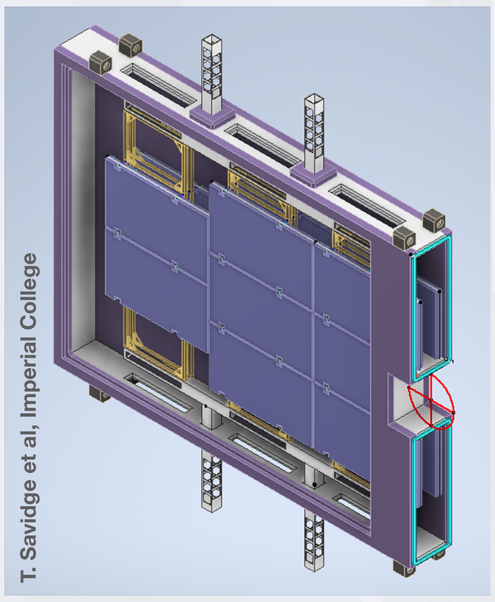
S. Scherl et al, Liverpool & KIT



Mechanics Structure

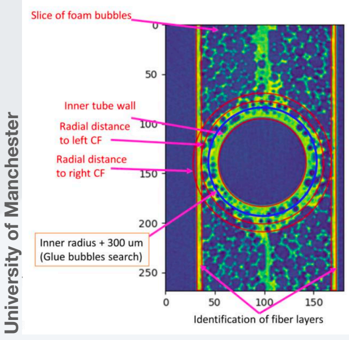
- The mechanical modules and enclosure box are designed to be lightweight while maintaining a minimal material budget and providing strong support.

T. Savidge et al, Imperial College

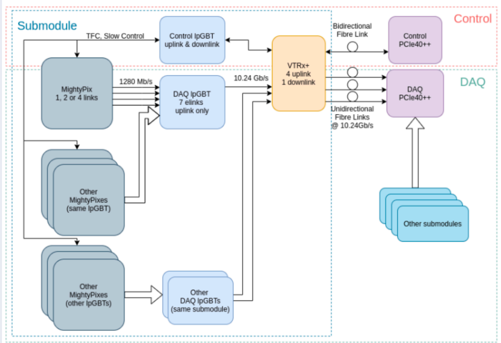


- **The Prototype Development:** U of Manchester is developing module substrates to investigate assembly procedures and measure cooling performance, using carbon fibre and carbon foam samples.
- **Quality Check:** X-ray tomography is used to identify inconsistencies in the produced samples.

A. Bitadze et al, University of Manchester

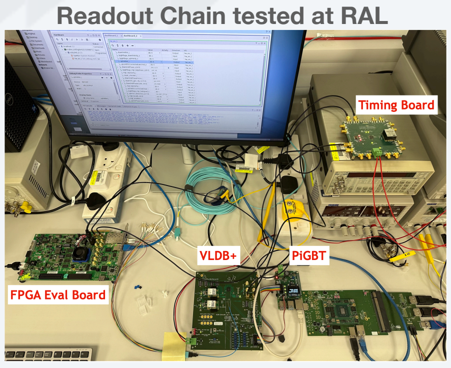


Electronics & Readout



- **The Electronics Design:** Uses CERN radiation hard components; Serial Powering considered to reduce material and meet power constraints.
- **Readout Capacity:** Inner modules need higher capacity; optimised with simulations (innermost MightyPix: 4 links at 1280 Mb/s, outermost: 1 link at 320 Mb/s).
- **Verification Framework:** Ensures conformity to LHCb systems and tests chip bandwidth.
- **Chip Emulator:** FPGA-based emulator mimics MightyPix behaviour for testing.
- **Prototyping and Testing: MARS** (MightyPix Readout System) developed at Uni Bonn for prototyping and functional tests; initial versions tested before chip resubmission.

Readout Chain tested at RAL



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