PROCEEDINGS OF SCIENCE

The LHCb Mighty-Tracker

Tai-Hua Lin[a,*] for the LHCb collaboration

[a] *The Rutherford Appleton Laboratory, STFC, UK*

E-mail: tai-hua.lin@stfc.ac.uk

The Large Hadron Collider Beauty experiment (LHCb) is designed to detect decays of b- and c-hadrons for the study of flavour physics, CP violation, and rare decays. The LHCb experiment will undergo its high luminosity detector upgrade in 2033-2034 to operate at a instantaneous luminosity between 1 to 1.5 $\times 10^{34}\text{cm}^{-2}\text{s}^{-1}$. This significant increase in luminosity presents a major challenge for the tracking system, which must achieve track reconstruction under ten times higher occupancy. Here, we focus on proposed solutions for the new tracking stations after the magnet, called the Mighty-Tracker. It is a hybrid system, comprising silicon pixels in the inner region and scintillating fibres in the outer region. The silicon pixels provide the necessary granularity and radiation tolerance to handle the high track density expected in the central region, while the scintillating fibres are well-suited for the peripheral acceptance region. New R&D activities are required for both technologies to cope with the highest instantaneous luminosity and the substantial rise in radiation. An overview of the current status of the Mighty-Tracker project will be presented, with the focus on the silicon pixel component.

International Conference on High Energy Physics, ICHEP
17-24 July 2024
Prague, The Czech Republic

*Speaker

PoS(ICHEP2024)959

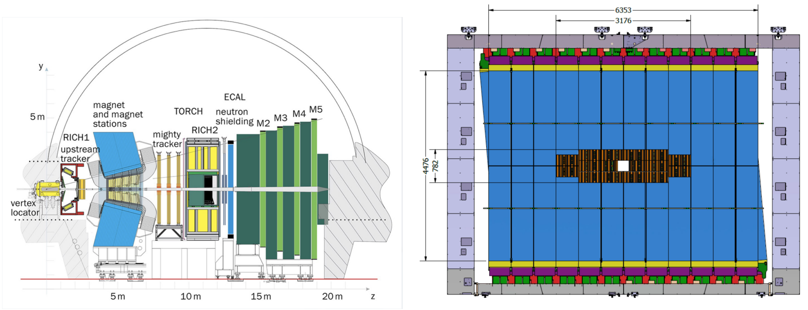

Figure 1: Left: The cross-section of the LHCb detector featuring the Mighty-Tracker upgrade. [1]. Right: The front view of the concept for the Mighty-Tracker. [2].

1. The Mighty-Tracker Concept

The proposed Mighty-Tracker is a hybrid tracking system designed to optimize the reconstruction of charged particle tracks by integrating two complementary technologies: silicon pixels and scintillating fibers. Its location and design concept within LHCb are shown in Fig. 1. Current R&D on the silicon pixels in the inner region (Mighty-Pixel) focuses on enhancing radiation hardness, improving readout speed, and reducing the material budget through the use of HV CMOS monolithic active pixel sensor (HV-MAPS). The scintillating fibers (SciFi) at the outer region (Mighty-SciFi) provide excellent light yield and timing ,but face challenges in maintaining performance under increased radiation levels. Ongoing SciFi R&D includes the development of cryogenic cooling to lower Silicon Photo-Multiplier (SiPM) noise levels and improve light collection using micro-lens (μLens) enhanced detectors.

2. Performance Simulation

Preliminary performance simulations of the Mighty-Tracker indicate highly promising results. With the inclusion of Mighty-Pixel coverage in the inner region, the occupancy is effectively limited to 2%, significantly reducing the chances of overlapping signals. Efficiency studies demonstrate that the silicon pixel sensors can achieve a tracking efficiency of over 95%, ensuring high precision in particle trajectory reconstruction [2]. Furthermore, integrating the pixel sensors with the SciFi system results in a notable reduction in the ghost rate, minimizing false tracks, and enhancing the overall accuracy of the tracking system.

3. Sensor Development

The development of the Mighty-Pixel sensors focuses on meeting stringent performance requirements. The pixel size is set below $100\mu m \times 300\mu m$, with a hit-rate capability exceeding 17 MHz/cm^2 and an in-time efficiency greater than 99% within a 25 ns window. The sensors are designed to withstand radiation levels above $6 \times 10^{14} \mathrm{n_{eq}}/\mathrm{cm}^2$, while maintaining a low noise rate of under 5 Hz per pixel and power consumption below 150 mW/cm^2. Additionally, the sensors are fully compatible with the LHCb readout system, supporting four 1.28 Gbps data links per chip, as well as slow control and fast control commands every 25 ns [1].

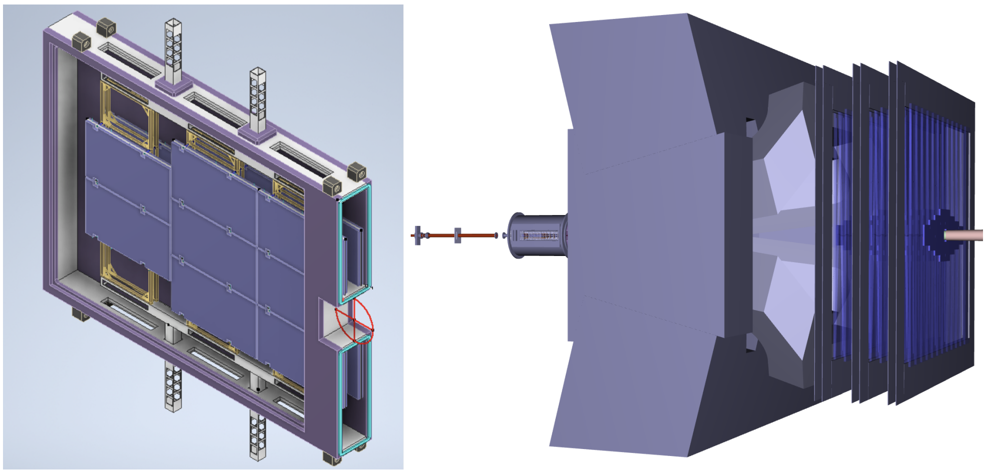

Figure 2: Left: The CAD design of the half station of Mighty-Pixel [3]. Right: The simulated Mighty-Tracker.

4. Mechanics, Electronic and Readout

The mechanical modules and enclosure box are designed to be lightweight while maintaining a minimal material budget and providing a robust support, as shown in Fig. 2. The electronics design of the Mighty-Pixel utilizes radiation-hardened components from CERN, and serial powering is employed to minimize material usage and meet power constraints. Readout capacity is optimized through simulations, with the innermost Mighty-Pixel modules using four links at 1280 Mb/s and outermost modules using one link at 320 Mb/s. A verification framework will ensure system compatibility with LHCb and will test the chip bandwidth, while an FPGA-based emulator mimics Mighty-Pixel behavior for testing purposes. Prototyping and functional tests are conducted using the MARS system (Mighty-Pixel Readout System) [4], with initial versions tested prior to the second submission of the chip.

5. Conclusion

The Mighty-Tracker is a hybrid system using silicon pixels and scintillating fibers for precise particle tracking. R&D focuses on new sensor design, radiation hardness, readout speed, low material budget, and noise reduction, with simulations showing high efficiency and low ghost rates.

References

[1] LHCb collaboration, *Framework TDR for the LHCb Upgrade II*, CERN-LHCC-2021-012

[2] LHCb collaboration, *LHCb Upgrade II Scoping Document*, CERN-LHCC-2024-010

[3] Courtesy of T. Savidge et al. at Imperial College London

[4] H Schmitz et al., *Mighty Tracker - Performance studies of the MightyPix for LHCb*, arXiv:2402.08428