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The Mu3e Detector

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The Mu3e experiment searches for the lepton flavour violating decay μ⟶ eee with an ultimate aimed sensitivity of 1 event in 10ˆ16 decays. This goal can only be achieved by reducing the material budget per tracking layer to X/X0 ≈ 0.1%. For this purpose, the vertex detector is based on HV-MAPS thinned to 50 μm. Also, the powering and data transmission is performed by means of kapton-aluminum HDIs, which serve as mechanical support as well. This talk will show the detector concept, focusing on the technical aspects of the pixel tracker and its several challenges.

Summary (500 words)

With a maximum electron energy of 53 MeV and a magnetic field of 1 T, the task of tracking recurling electrons produced in muon decays with silicon sensors is very challenging. In these conditions, multiple Coulomb scattering becomes a key factor in the track momentum resolution. Nevertheless, with a material budget per tracking layer of 0.1%, the Mu3e experiment is expected to achieve a momentum resolution of less than 1 MeV. This is achieved by several means, which will be explained in the presentation. The chosen sensors are 50 micron thin High-Voltage Monolithic Active Pixel Sensors, the Mupix sensors, where the readout is implemented inside the detection substrate itself. This solution allows fast and efficient tracking without using the thick hybrid sensors. Furthermore, in the tracker's acceptance region the electric circuitry is implemented in the support structure into High Density Interconnects (HDIs). There, Aluminum traces are etched in thin polyimide substrates. Also, all sensors are connected through Single-point Tape Automated Bonding (SpTAB), which allows to connect the Aluminum traces without additional bonding material. Following the path towards material budget minimization, a Helium based cooling system has been designed. It is conceived to keep the temperature in the tracker below 35 C against a power dissipation of 200 mW/cm2.
Furthermore, the triggerless readout system presents major complexities: 2844 HV-MAPS pixel sensors deliver data from about 3000 LVDS channels at 1.25 Gbit/s. The data is then filtered through a system of boards and then fed to a GPU-based online track reconstruction farm. This readout configuration allows to perform event selection without a hardware-based trigger system.
With the construction phase quickly approaching, all these aspects have been investigated and the responses to the several challenges are implemented in detail. To prove the mechanical concept of the pixel ladders, a thermo-mechanical mockup has been produced with Silicon heater chips. This emulates the power consumption and heat dissipation of the tracker, and is ultimately used to verify the solidity of the whole structure and the efficiency of the cooling system. The electrical properties of the ladder themselves, instead, are investigated with test HDIs. Thanks to them, a single chip can be configured and read through Aluminum traces up to 24 cm long, whereas the maximum distance in the tracking system is 18 cm. As for the DAQ system, several testbeam runs have been organized, where the DAQ components are operated with different slices of the experiment. The characterization of the Mupix devices shows an efficiency of 99.5 % with less than 25 ns time resolution.
Since the Mu3e experiment implements novel and challenging solutions for several cutting-edge applications, reporting the results of the pre-production phase in such a large audience conference will be very fruitful. It could benefit both the possibly interested viewers and the Mu3e members themselves, as they may receive important inputs to further improve the design of their experiment for the Phase 2 of the experiment, where rates will be 20 times higher.

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