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The MuPix Telescope –A Thin, High Rate Particle Tracking Telescope

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The MuPix Telescope is a particle tracking telescope, optimized for low momentum particles and high rates. It was build to test and integrate the novel High-Voltage MonolithicActivePixelSensors (“HV-MAPS”), designed for the Mu3e tracking detector. It is also used to test the Mu3e readout concept.
The telescope consists of four layers of the newest prototypes, the MuPix7 sensors, which send the fast serial data self triggered to an FPGA, where the data is time ordered and written to the PC, where online tracking is performed.
The presentation covers the chip architecture, readout concept, online reconstruction and test beam performance.

Summary

The Mu3e Experiment will search for the lepton flavor violating decay of a positive muon into two positrons and one electron with a target sensitivity of 1 in 10^{16} decays. A high rate beam, of 10^{9} muons/s will be stopped on a passive target and the low momentum decay particles momentum (p < 53MeV/c) as well as the vertex will be measured with a thin four layer pixelated detector. The high rate (10^{19})of low momentum particles asks for a new detector technology: High-Voltage-Monolithic-Active-Pixel-Sensors (“HV-MAPS”), combing the advantages of thin MAPS sensors with the fast charge collection of classical hybrid pixel sensors, are chosen for Mu3e.

The MuPix7 prototype is produced in a commercial HV-CMOS process. It is a fully monolithic pixel chip with a 32x40 pixel matrix and operates in a continuous, self triggered, non-shuttered zero suppressed readout. Each pixel contains its own amplifier and source-follower and has a point to point connection to its own digital cell in the pixel periphery. Each digital cell has second amplification stage, a comparator and an 8bit time stamp latch. In addition, a finite state machine is realized in the digital part, performing a priority readout. The hit information is 8bit/10bit encoded and serialized on chip. A 1.25 Gbit/s LVDS link is used to stream out the data.

To integrate the HV-MAPS into a larger tracking device, to test the feasibility of the aspects of the Mu3e readout concept and for test beam characterization, a tracking telescope is build:
To keep the readout concept close to the Mu3e concept, 4 stacked layers of HV-MAPS are read out in a self triggered mode and stream the 8bit/10bit encoded data at 1.25 Gbit/s over low-voltage-differential-signaling links to a FPGA, mounted in an PCIe slot of the readout PC. On the FPGA, decoding and time sorting of the incoming data is performed on the fly. The data is directly copied over PCIe to the local RAM. The data transfer is realized either by polling or direct memory access (DMA). A versatile graphical user interface provides direct access to the online monitoring, run control and sensor configurations.
The data is then directly dumped to memory and forwarded to the online monitoring. Here, online tracking on the CPU is performed, which offers online monitoring of alignment, beam properties and sensor efficiencies. GPU tracking has been implemented and used to test the Mu3e online reconstruction setup.
The presentation will focus on the readout concept and the performance at test beams. The online reconstruction will also be addressed, as well as the chip architecture. At the end a short outlook, including our future plans for the telescope and Mu3e are given.

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