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Development and performance of a pixel chip for the readout of GEM detectors for high-rate particle tracking

Tuesday 3 October 2023 15:00 (20 minutes)

In this talk we report the R&D program underway at CCNU to develop a pixel chip for the readout of GEM detectors appropriate for use in the CSR external-target experiment (CEE) at HIRFL for beam monitoring. The chip offers simultaneous Time over Threshold (ToT) and Time of Arrival (ToA) measurements, with an event-driven readout mode. The chips were tested with injected pulses and a Fe-ion beam of 350 MeV/u, coupled with single GEM. The position resolution, rate capability and reconstruction efficiency for the beam particles were characterized.

Summary (500 words)

Topmetal-CEEv1 is a front-end chip fabricated in GSMC 130 nm CMOS process for the readout of GEM detectors. This prototype features a column of 180 pixels and the peripheral circuitry in a 19 mm $\times$ 4.2 mm die. Each pixel occupies an area of 100 μm $\times$ 1.013 mm, consisting of purely the top metal layer as the charge collecting anode. The charge-sensitive preamplifier (CSA), discriminator, Time over Threshold (ToT) and Time of Arrival (ToA) functionalities of each pixel, as well as the digital readout circuits are all implemented on the periphery.

Injected pulses were used to evaluate the key characteristics of the chip, including the noise, threshold and gain of the CSA and the ToT output. For medium gain setting and a charge threshold of 10k e^-, the temporal noise and the fixed-pattern noise are around 350 e^- and 3000 e^-, respectively. The threshold equalization via the in-pixel DAC could reduce the fixed-pattern noise by more than 80\%. The measured gains of the CSA are consistent with the simulation values for medium and low gain settings, which have the feedback capacitance of 20 and 100 fF, respectively.

The Fe-ion beam of 350 MeV/u at HIRFL-CSR was used to characterize the response of the Topmetal-CEEv1 chips. Four chips were arranged in three columns in the bonding board, placed under single GEM and acting as the anode of a 6 cm $\times$ 5 cm $\times$ 5 cm field cage. The beam density varied between about 10^4 pps and 10^6 pps. Scans of the GEM voltages and pixel thresholds were performed. At the time of the beam test, the readout system was not fully developed. As a result, only binary readout and coarse ToA measurement with the accuracy of 25 ns were used. With binary readout, the position resolution of the beam particle for one column of pixels varied between about 70 to 150 μm, depending on the GEM voltage and pixel threshold. The cluster reconstruction efficiency as a function of the requirement on the number of pixels were evaluated. The rate capability up to 10^6 pps was demonstrated.

More results are foreseen by the time of the conference, including the position resolution with ToT measurements, and the test results using minimum ionization particles with triple GEM.

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