The Topmetal-CEE Prototype, a Direct Charge Sensor for the Beam Monitor of the CSR External-target Experiment

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ABSTRACT

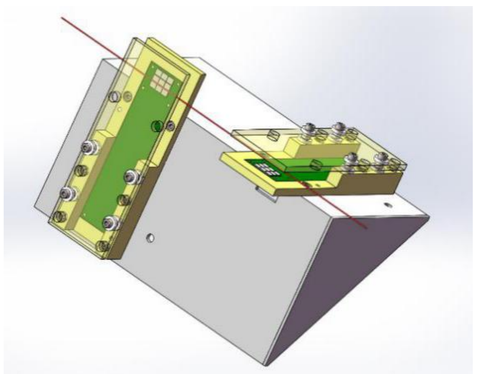
The Cooler-Storage-Ring External-target Experiment (CEE) which is being constructed since 2020 is a spectrometer to study the properties of nuclear matter at high baryon density region. An online beam monitor that is based on the time projection chamber detection principle is being developed for the CEE to accurately determinate the beam incidence position. The Topmetal-CEE sensors are used as the anode array collecting electrons in the beam monitor.

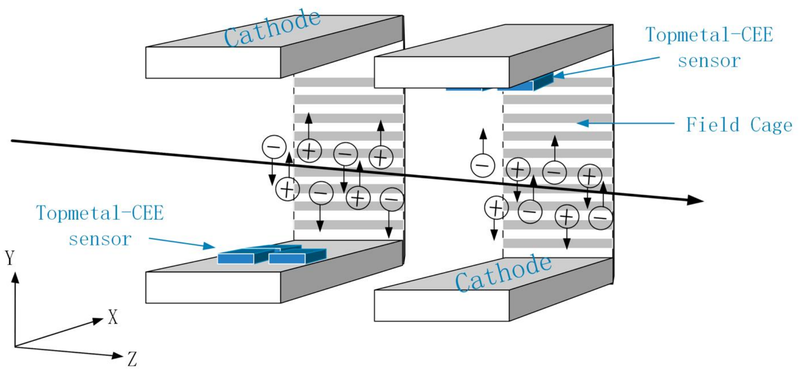
Introduction of the CEE project

The Cooler-Storage-Ring (CSR) External-target Experiment (CEE) is the first large-scale experiment in high-energy nuclear physics built in China covering the GeV energy region. In the future, it can also be used at the High Intensity heavy ion Accelerator Facility (HIAF), which is now under construction. Experimental studies utilizing CEE aim at many physical goals including the phase structure of QCD matter in high baryon density region, as well as the equation of states of nuclear matter at super-saturation densities. CEE includes a micro-pixel beam monitor, a large volume Time Projection Chamber (TPC), a Multi-Wire Drift Chamber (MWDC) array, Time-of-Flight detectors (TOF) and a large acceptance super-conducting dipole magnet.

Requirements:

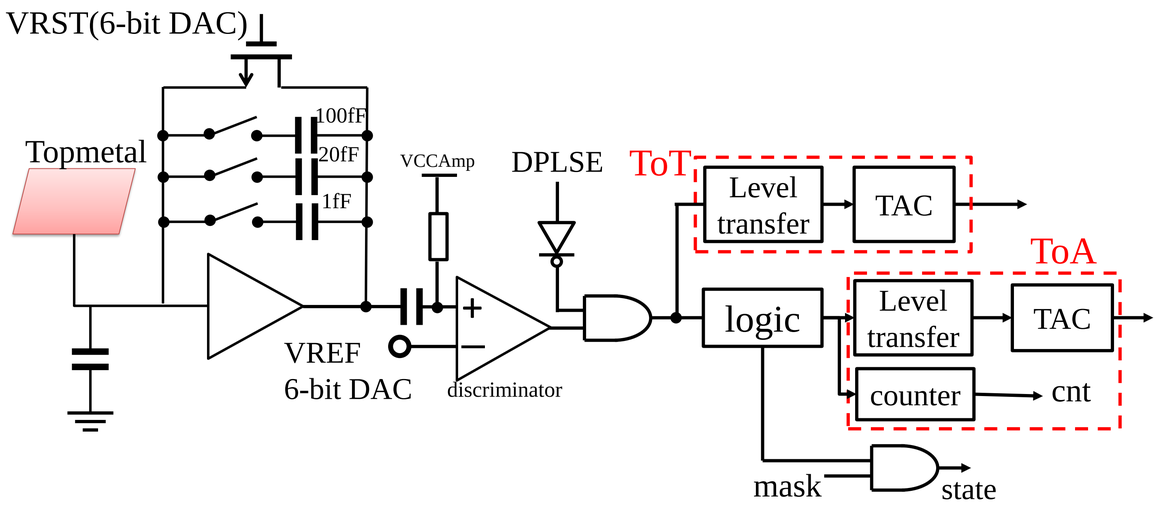
- the hit rate: >1M/Sec
- Spatial resolution: <50μm



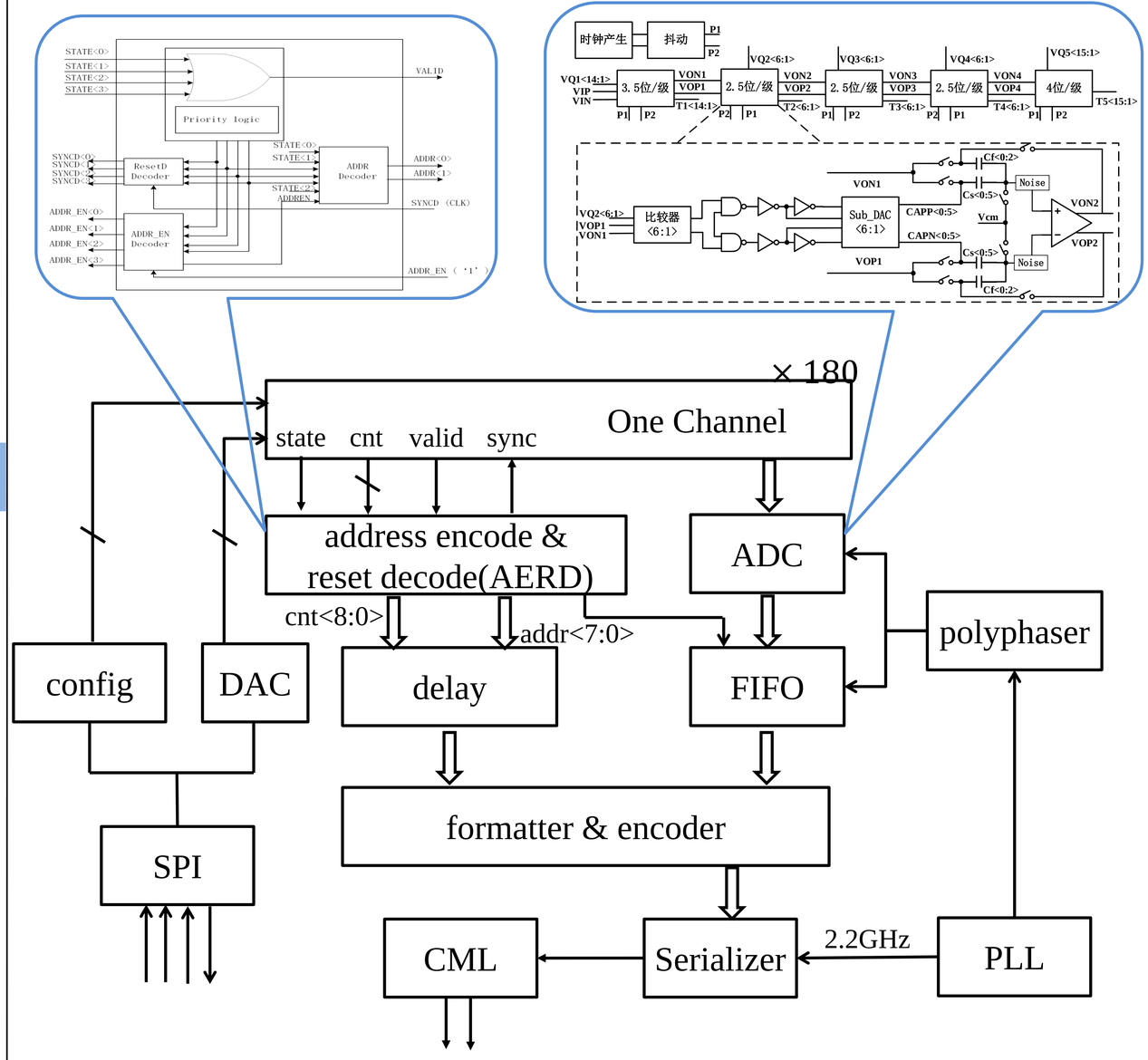


the front-end of each channel

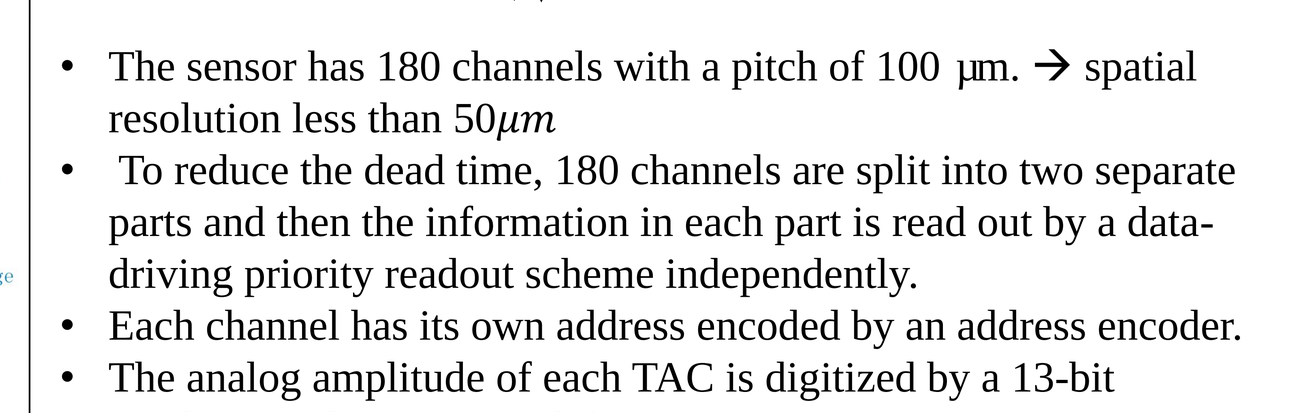
- Electrons are collected by a charge collection electrode which is a top-most metal exposed the surrounding media, amplified by a charge sensitive amplifier, and then feed into a discriminator.
- The output of the discriminator is split into three paths:
  - Records time-of-arrival (ToA) → time information
  - Records time-over-threshold (ToT) → energy information
  - The output of state → hit address information



Topmetal-CEE prototype overview



- The sensor has 180 channels with a pitch of 100 μm. → spatial resolution less than 50μm
- To reduce the dead time, 180 channels are split into two separate parts and then the information in each part is read out by a data-driving priority readout scheme independently.
- Each channel has its own address encoded by an address encoder.
- The analog amplitude of each TAC is digitized by a 13-bit pipeline Analog-to-Digital Convertor (ADC).
- The output codes of the ADC are grouped with the corresponding counter and address, and then they are transferred off chip with a serial speed of 4.4 Gbps.



CONCLUSION AND PERSPECTIVES

We present the design and characterization of a CMOS pixel direct charge sensor, *Topmetal-CEE*, fabricated in a standard 0.13 μm CMOS process. To measure the position and time information of incident beam, the front-end output of each channel is split into three paths. The simulation electrical measurements confirmed the low-noise design and correct readout implementation, further more tests are ongoing.

Acknowledgment

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