HiBeam-T: A TPC with pixel readout for heavy-ion beam monitoring

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Abstract

In this work, the HiBeam-T, a time projection chamber (TPC) for monitoring the position and profile of heavy ion beams, has been designed. This gaseous detector features its readout with an array of forty Topmetal-II⁻ CMOS pixel sensors [1], each of which has 72×72 pixels with a size of 83×83 μm^2. The detector part consists of the charge drift and charge collecting regions, separated by a gating grid. The readout electronics consists of three readout control modules and one clock synchronization module. This Hibeam-T has a sensitive area of 20×20 cm^2, and it can acquire the one-dimensional beam position and profile periodically. A test with a continuous 80.55 MeV/u $^{12}C^{6+}$ beam shows that the measurement resolution to the beam center could reach 17 μm.

Detector Design

The detector mainly consists of a detector shell with membranous entrance and exit windows, an electrostatic field cage forming the charge drift area, and the charge collection area defined between a gating grid and a readout chip array. See Fig. 1. The bottom of the field cage is a gating grid, under which the charge collecting area is defined, as shown in Fig. 2. The other components of the charge collecting area are the chip mask and the chip bounding board. The chip array consists of two rows of the Topmetal-II⁻ CMOS pixel sensors [1]. The pixel sensors are inter-distributed in the column direction, forming a 20 cm one-dimensional no-dead-zone length.

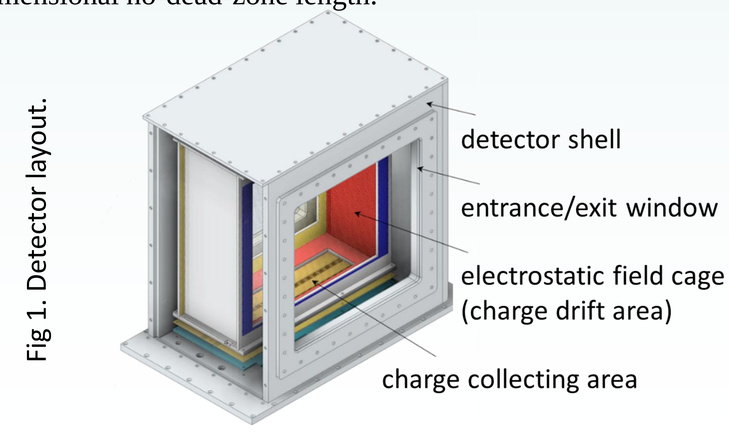

Fig 1. Detector layout.

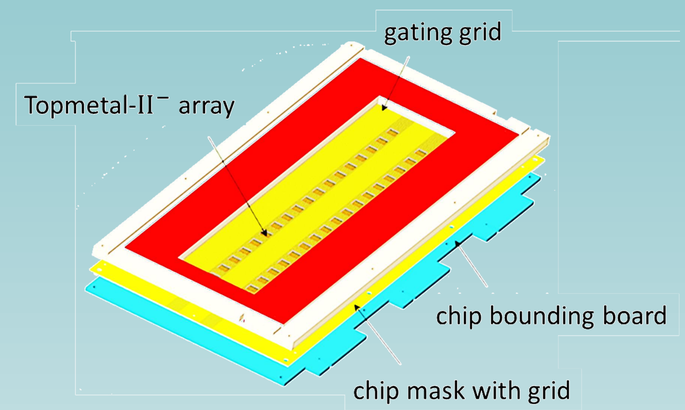

Fig 2. Readout electrodes

Readout Electronics

The forty Topmetal-II⁻ pixel sensors are read by three Readout Control Modules (RCM). Fig. 3 shows the picture of one RCM. It mainly consists of the main field-programmable gate array (Xilinx Kintex-7 FPGA), the analog buffer circuit, two high-resolution ADC (AD9252), two 16bit-DDR3 memories, the power supply circuit, and the Ethernet Interface. The RCM converts the analog signal from the pixel sensors into a digital one, processing it and transmitting it to the DABC software [2] via a 1 Gigabit Ethernet link. At the same time, there is a current-monitoring circuit on the board, which can monitor the current of the Topmetal-II⁻ chip in real-time. In addition, a Clock Synchronization Module (CSM) distributes clocks to the RCMs for synchronization purposes.

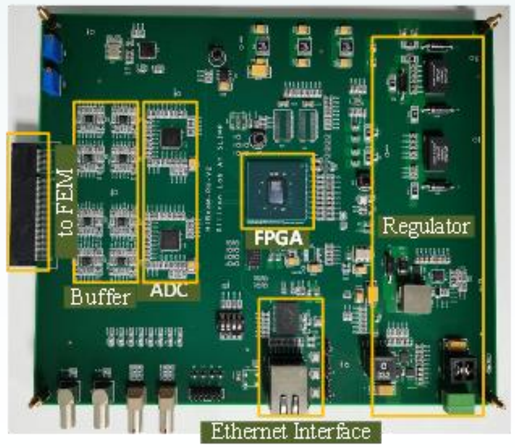

Fig 3. The RCM photo

Beam Test

A beam test is carried out on the HIRFL TR4 radiation terminal. Fig. 4(a) shows the sketch of the experiment condition. P10 gas (%90 Ar and %10 CH4) was used as the working gas. A continuous 80.55 MeV/u $^{12}C^{6+}$ gaussian beam passed through a Ø6 mm stainless steel aperture above the detector and traversed the detector perpendicularly. The gating grid was *not* utilized in this preliminary test. Fig. 4 (b) shows a typical beam profile which corresponds to 4 ms charge collection time. The blue bins are the measured data, and the red bins are fitted to the blue bins using a compressed sensing non-parametric fitting method [3].

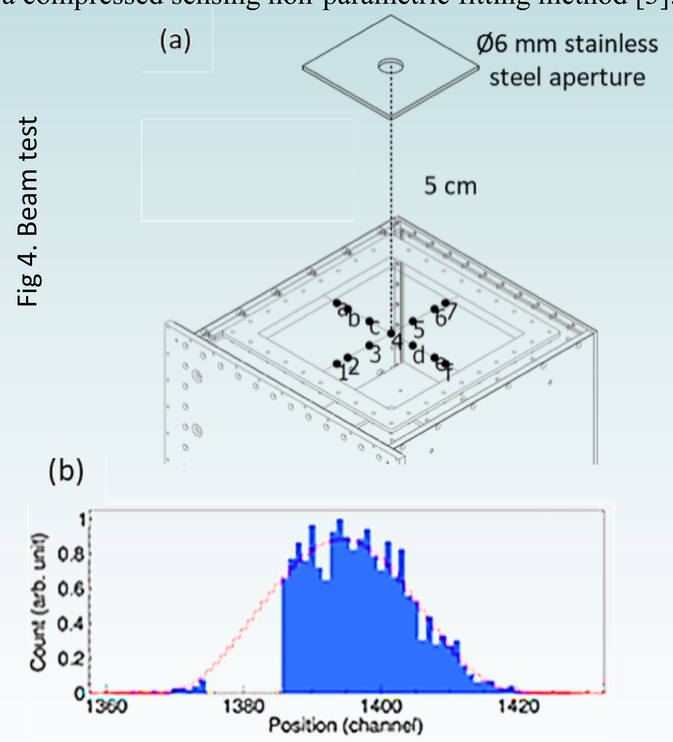

Fig 4. Beam test

References

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