The IMPix-S, a hybrid pixel readout ASIC for heavy-ion physics

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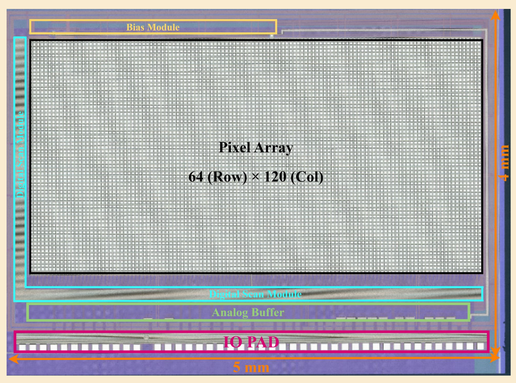
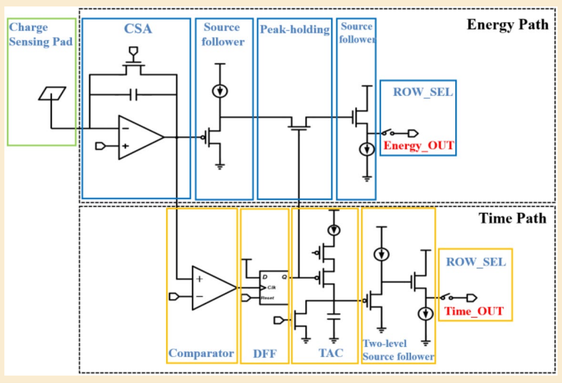
Introduction

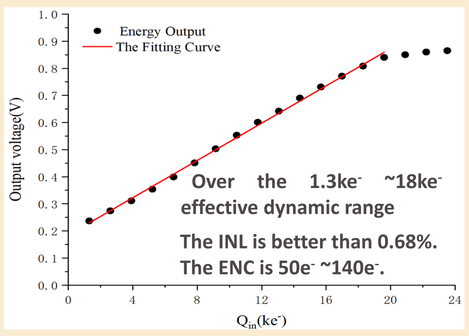
The Heavy Ion Research Facility in Lanzhou (HIRFL) and the High Intensity Heavy-ion Accelerator Facility (HIAF) are advanced heavy-ion accelerators, which will not only make significant contributions to human understanding of the structure of matter and the exploration of the basic laws of nature, but will also provide theoretical, methodological, and technological support for the application of nuclear technology. Beam monitoring systems play a vital role in tuning and monitoring the beam in accelerators. With the development of detector technology, small-scale TPC non-destructive beam detecting with charge collecting pixel ASIC readout is beginning to show great potential. Hence, the silicon pixel sensor IMPix-S has been designed. With its charge sensing pad, the exposed topmost metal layer that collects charge directly. The signal measurable by IMPix-S is the projection of the particle track onto the ASIC. The particle projections are fitted by an online algorithm, which in turn completes the track reconstruction. In addition, the IMPix-S can be bump-bonded with sensor to achieve various applications.

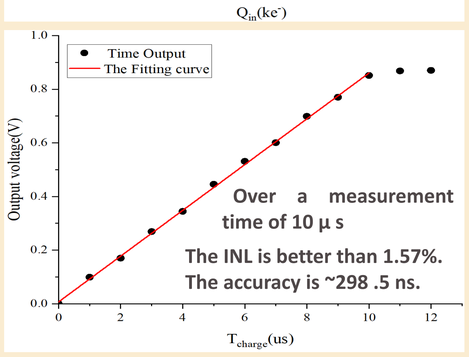
Design and electrical tests of IMPix-S

The IMPix-S measures 4 mm x 5 mm and is designed in GSMC 130nm CMOS technology with 7 metal layers. The main building blocks are the Pixel Array(64 Row x 120 Col of 37 um square pixels), Digital Scan Module (L-shaped and located on the lower left side), Bias Module Analog Buffer and 44 wire-bonding IO pads (placed on the bottom).

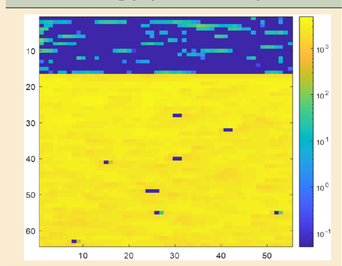
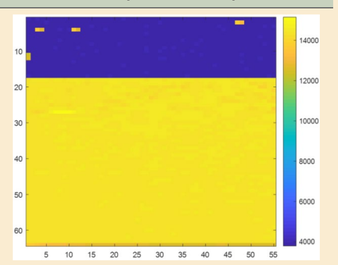








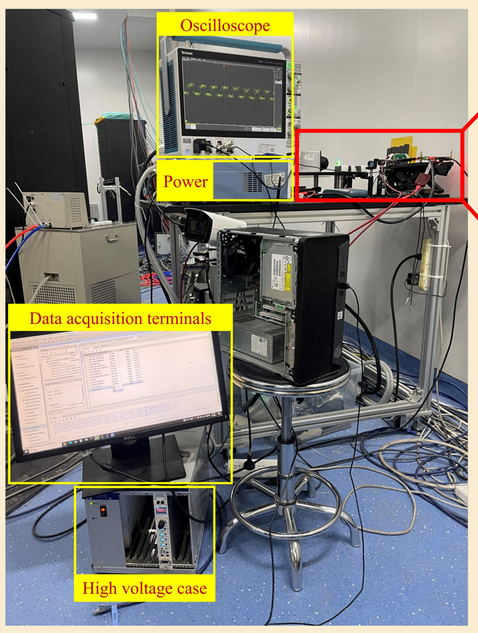
Visualization of the array

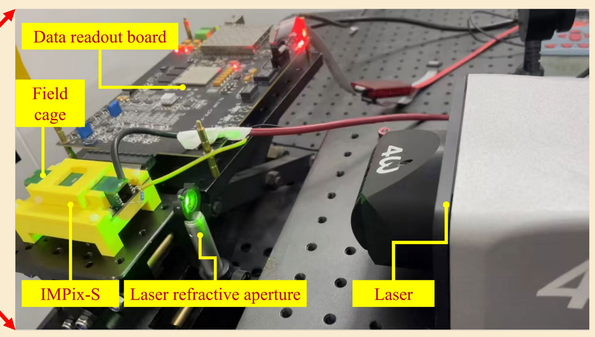
Energy path output	Time path output
	

In the lab, electrical tests were performed on 16 randomly selected pixel units in the array, as well as on the digital scanning capabilities of the entire pixel array, noise levels, etc. The linearity of the energy and time path outputs of a pixel unit is shown on the left.

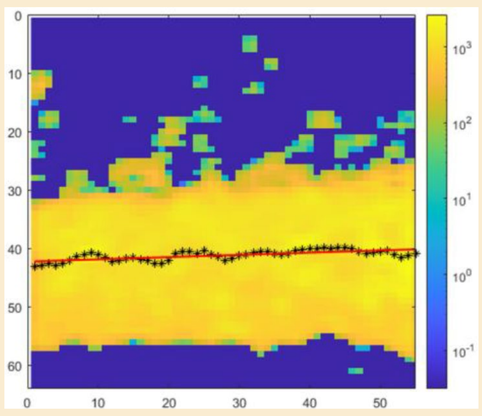
Laser measurement

A laser source with a wavelength of 266 nm is used to provide a single laser signal with a frequency of 20 Hz and an energy greater than 4 mJ before reaching the ASIC.





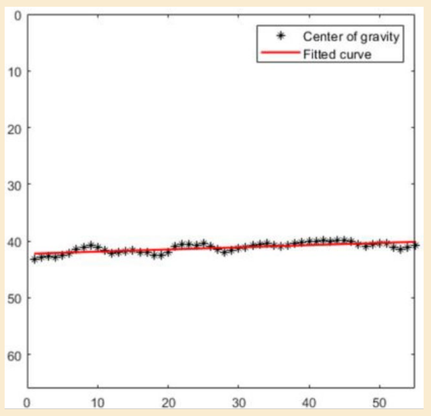
The IMPix-S chip comparator has a threshold of 2 ke⁻ and operates in continuous scan readout mode with a scan frequency of 10 MHz. The high voltage case provides 1500 V high voltage to the field cage.



Laser trace

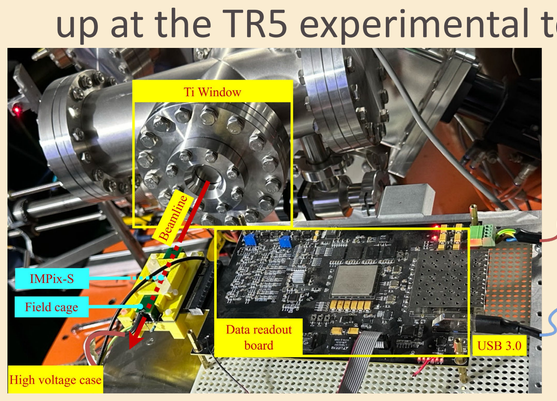
Gaussian fit

Position resolution 2.6 μm.

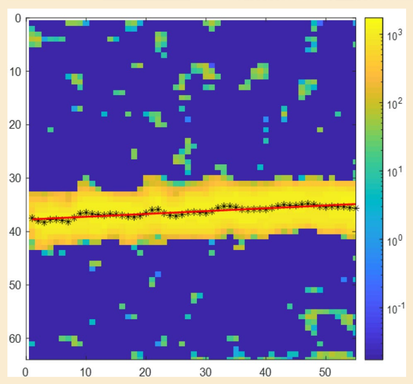


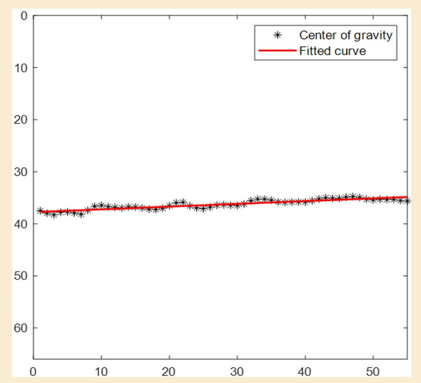
Heavy ion beam measurement

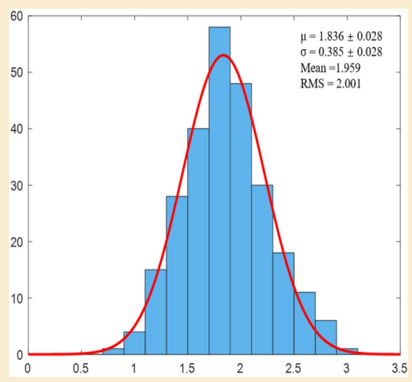
The heavy ion beam measurement platform of IMPix-S was set up at the TR5 experimental terminal at HIRFL.



- The intensity of the beam is 10^3~10^4 ions /(cm^2·s).
- The heavy ion is $^{181}Ta^{35+}$.
- The energy is 15.64 MeV/u.
- LET is 86.4 MeV/(mg/cm^2).







The positional resolution of a single $^{181}Ta^{35+}$ trace is 1.85 μm.

The positional resolution of the 260 traces is 1.836 ± 0.385 μm.

Conclusion and outlook

For the HIAF and HIRFL physics experiments, we have developed a hybrid pixel detector, IMPix-S, with multi-dimensional measurements of energy, time, and position. We have completed electrical tests, laser, and heavy ion beam measurement, which show that the ASIC is working properly and has good performance. It will be setup a non-invasive beam monitoring system to provide accurate positioning for the single-event effect.

In addition, we have also upgraded the ASIC so as to design the IMPix-S2 with a smaller pixel cell size of 29 square microns and a larger array.

The simulation shows:
the ENC of the pixel unit is <100 e^- ,
the operating speed of the array has been increased to 20 MHz.