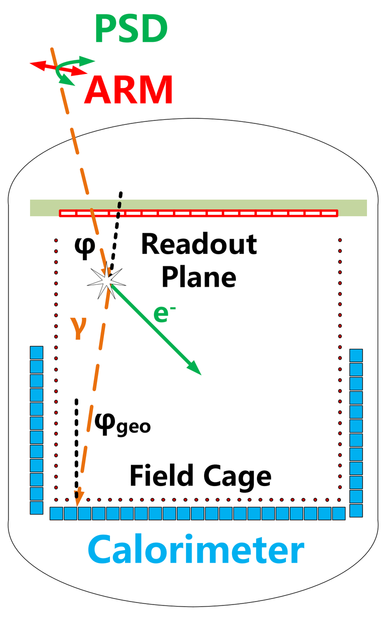
Readout Electronics for TPC-based MeV Gamma-ray Telescope in Space

Maoyuan Zhao[1,2], Yu Wang[1,2*], Zhengguang Yang[1,2], Ting Wang[1,2], Hao Zhuang[1,2], Changqing Feng[1,2], Zhiyong Zhang[1,2], Leipeng Hu[1,2], Shubin Liu[1,2]

Introduction

- MeV gamma detection in space is a new window to astronomy.
- The most important enhancement of the MeV gamma-ray telescope we are developing is to improve ARM resolution by improving the energy and spatial resolution of detectors.
- The resistive and novel thermal-bonding Micromegas detectors developed by the project team have significant advantages in terms of energy resolution, high gain, and stability.
- Pixelated CZT has the advantages of high energy resolution and high spatial resolution.
- We are developing the prototype telescope, which contains a 30 cm cubic TPC with a Micromegas detector as the readout plane, surrounded by high-energy resolution CZT arrays.

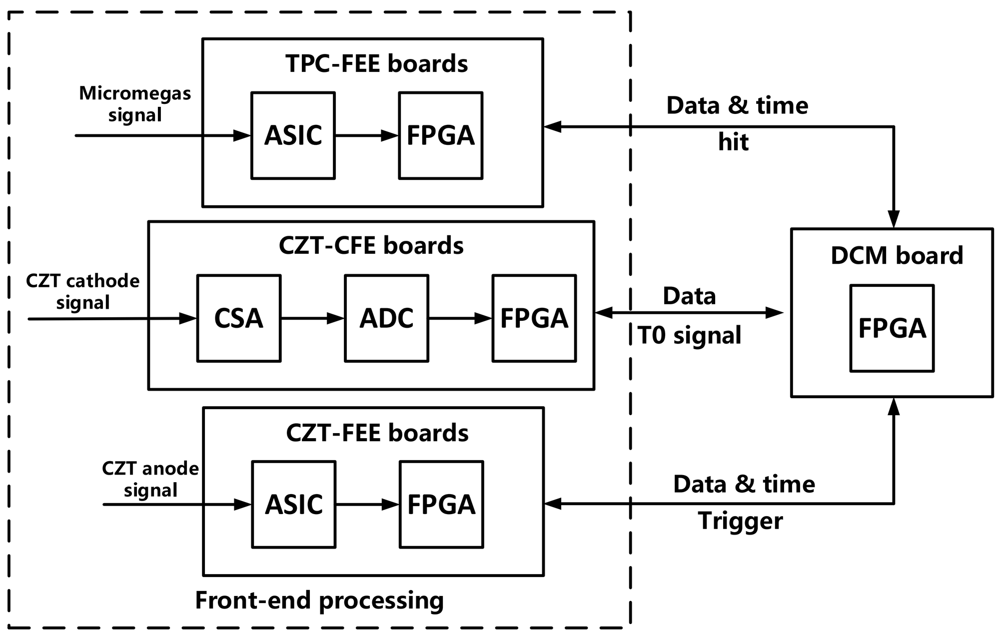


Readout Scheme

Electronics Design

The readout electronics have been designed for the telescope, including for Micromegas detectors and pixelated CZT arrays.

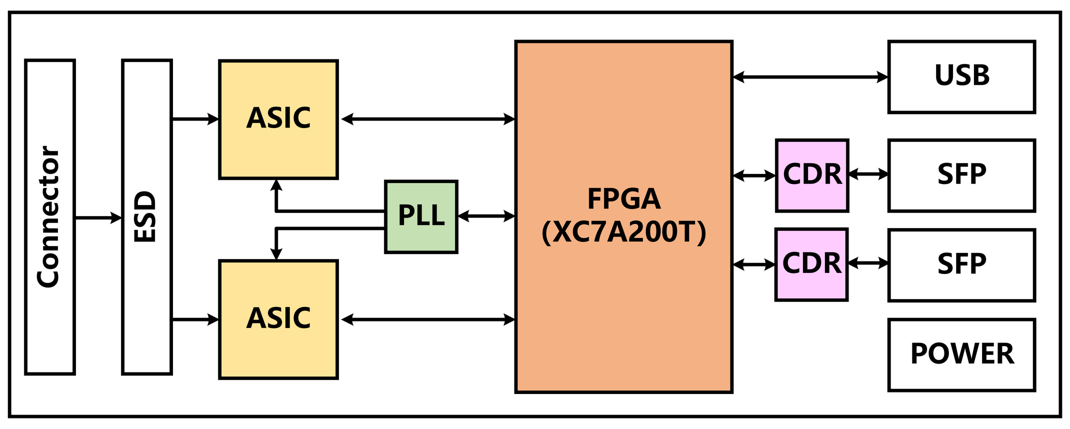
- 16 TPC-FEEs (TPC Front-End Electronics) are applied for two-dimensional TPC anode strip readout;
- 4 CZT-FEEs (CZT Front-End Electronics) are applied for four independent CZT readouts;
- 1 CFE (Cathode Front-End Electronics) performs CZT cathode signal processing;
- 1 DCM (Data Concentration Module) is responsible for the back-end data processing.



Front-end Electronics for TPC

The TPC anode electronics require multi-channel CSAs to integrate charge from the TPC anode. It is necessary to obtain the original waveforms of TPC anode signals with the ASIC. Thus we can identify the signals by waveform analysis when two groups of electrons drift to the same strip successively. The front-end electronics includes following parts:

- 926 channels total for two-dimensional crossed strips readout.
- Two 32-channel 128-cell SCA ASICs with maximum range of 240 fC and maximum sample rate of 160MSPS, designed by FEL USTC.
- A T0 module for receiving T0 signals from CZT for three-dimensional hit position reconstructed by calculating the drift time of each channel.



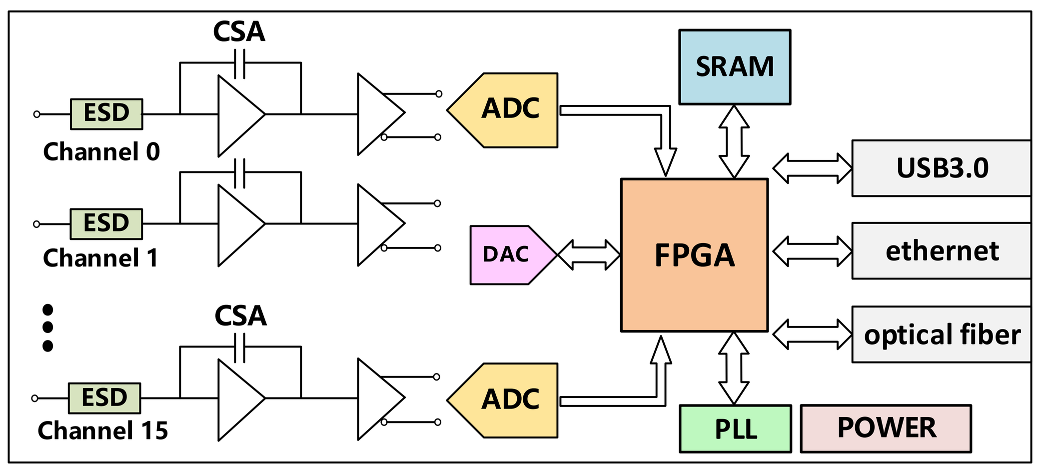
Front-end Electronics for CZT

CZT anode electronics require multi-channel, low-noise CSAs. A 64-channel low-noise ASIC named VATA453 is chosen, which was developed by IDEAS. Each channel of the VATA453 chip has:

- A preamplifier with 250 e^{-} noise within the linear range of -120 fC
- Parallel trigger output followed by 12-bit ADC data output.

CZT cathode electronics require CSAs to obtain the waveforms to calculate the starting time and the depth of interaction to improve the z-direction spatial resolution. It includes following parts:

- A 16-channel preamplifier module.
- A 12-bit 40MSPS ADC module.

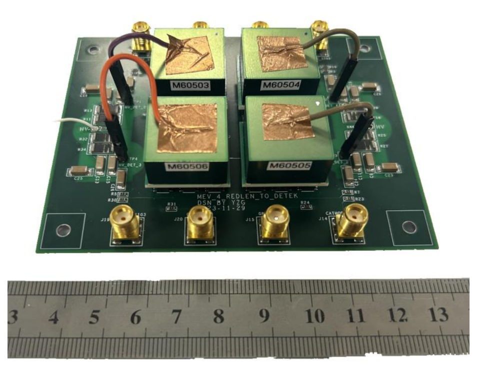


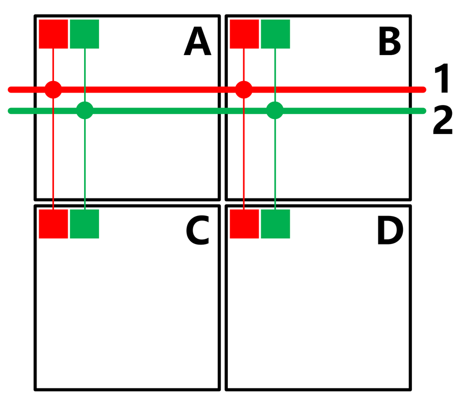
Design and Test

CZT Multiplexing Readout

If multiple detectors are used, the amount of channels will increase. In order to reduce power consumption and complexity, the readout of the CZT detector should be multiplexing. The method is as follows:

- All detectors are divided into several groups and ensure that multiple pads on the surface of different detectors in the same group can be connected to one readout channel.
- The cathode signal of CdZnTe can be used to judge which detector in the same group has been hit.

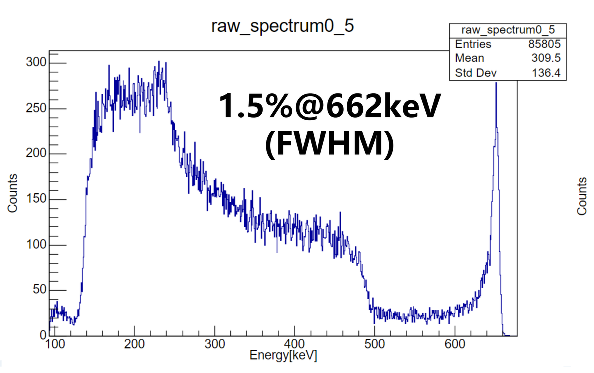


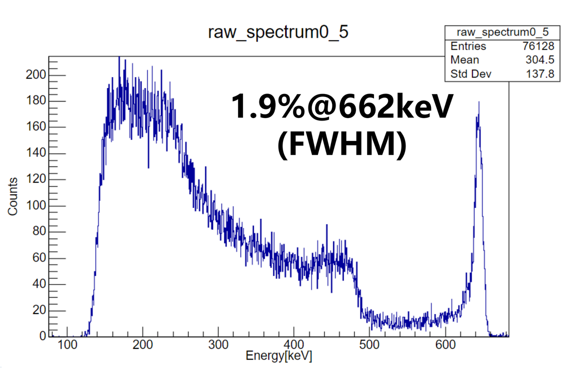


Test Result

A 256-channel preamplifier and a 12-bit, 40 MSPS waveform digitization module with a trapezoid filter were employed to test the performance of multiplexing readout.

- The CZT detectors we used has a sensitive volume of 20 mm × 20 mm × 10 mm with 11 × 11 anode pixels.
- The energy resolution of a single pixel get a bit worse than the original one, from 1.5% to 1.9% at 662 keV (FWHM), but the channel amount is decreased.

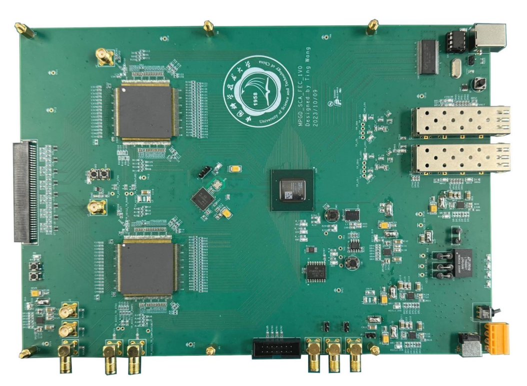


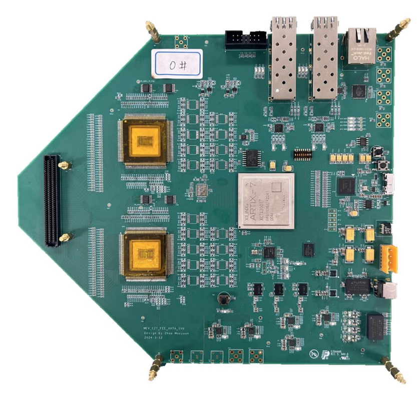


Next Stage

In the future work, we will:

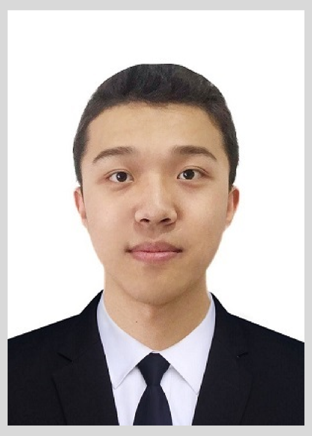
- Complete the assembly of all modules.
- Complete the measurement of incident gamma ray direction and conduct the performance test of the prototype.
- Continue the imaging research of the CZT detector to improve the energy resolution and spatial resolution of the detector through data processing algorithms.





Conclusion

- We have preliminarily completed the readout electronics design, including front-end electronics for TPC and CZT and back-end electronics.
- The multiplexing method can be used to read out CZT detectors.
- In future work, the prototype will be assembled and tested. A gamma imaging system will be developed.



[1]*Deep Space Exploration Laboratory/School of Physical Sciences, University of Science and Technology of China, Hefei 230026, China*
[2]*State Key Laboratory of Particle Detection and Electronics, University of Science and Technology of China, Hefei 230026, China*
E-mail: zmy9730@mail.ustc.edu.cn