

Prototype Readout Electronics System for a LET Spectrometer in Space Radiation

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Introduction

Space radiation poses a major threat to astronauts and equipment during space missions. Linear energy transfer (LET) is widely used for quantitatively assessing the effects of space radiation.

Characters of space radiation:

- Heterogeneous composition of particle types.
- Broad energy spectrum.
- Temporal variability.

Resulting in a broad LET distribution that varies over time. Therefore the detection system should have:

- Wide dynamic range.
- High precision.
- Real-time monitoring.

Double-sided silicon strip detectors (DSSD) can be used as detectors with above characters. A novel method was raised to farther extend the dynamic range.

Incident events are divided into 3 cases:

- Invalid case: less than 2 layers are triggered.
- Valid case (a): 2 layers are triggered. The incident depth should be calculated by the deposit energy.
- Valid case (b): 3 layers are triggered.

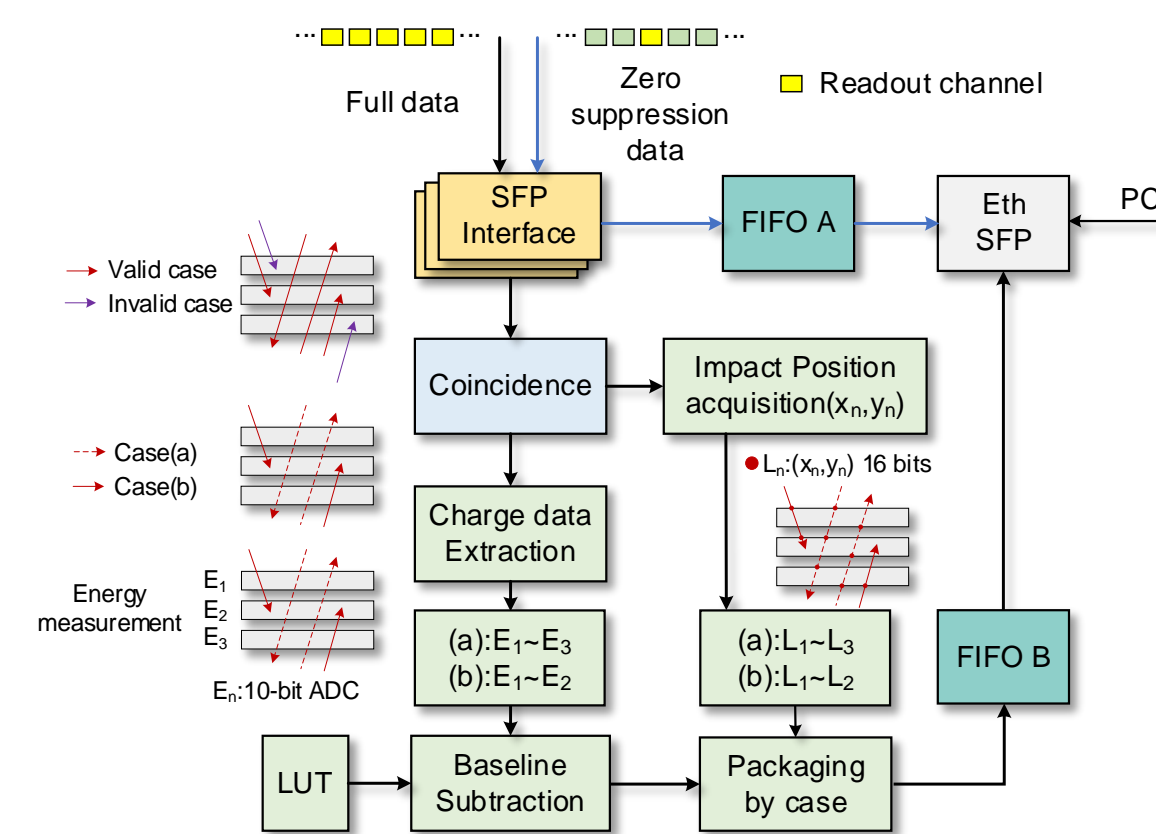


Fig.3 Diagram of the DAM FPGA.

Dynamic range extension method

Simultaneously reading out the signals from different sides of the DSSDs with different gains.

- High-gain channels enable higher measurement precision for small signals
- Low-gain channels ensure the electronics possess a wide dynamic range.

Prototype design

The prototype system mainly comprises 3 parts:

- 3 layers of DSSDs as the detector.
- 3 layers of front-end electronics (FEE).
- 1 data acquisition module (DAM)

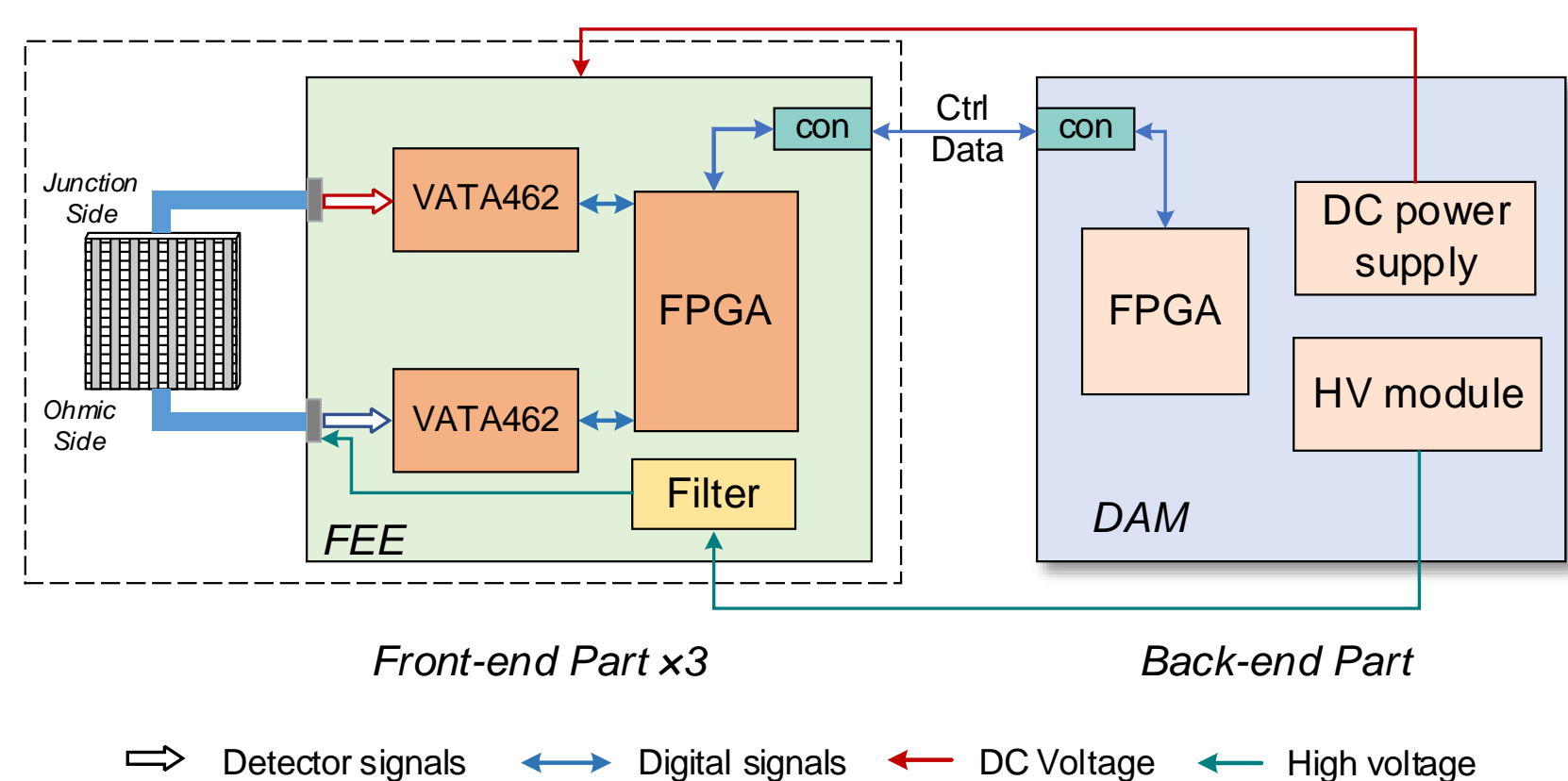


Fig.1 Diagram of the prototype

Each FEE readout signals from both sides of 1-layer DSSD in 2 gains. Charge sensitive amplifiers, shapers, and analog-to-digital converters are integrated in chip VATA462. The field programmable gate arrays (FPGAs) on FEEs collect data and send to DAM. The DAM complies data calculation, matches events, and provides power to FEEs and high voltage to DSSDs.

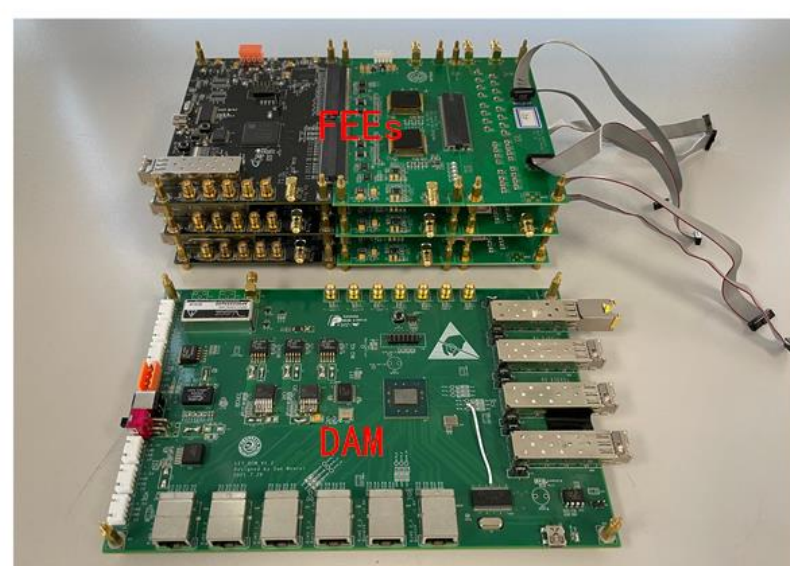


Fig.2 Photograph of the prototype

Test results

The electronics tests shows that the high gain channels have a dynamic range of approximately 80 fC, while the low gain channels cover about 700 fC. The equivalent noise charge (ENC) of all readout channels in high gain mode of the prototype is less than 0.1 fC for most channels, and less than 0.17 fC for all channels, resulting in a dynamic range of about 4000.

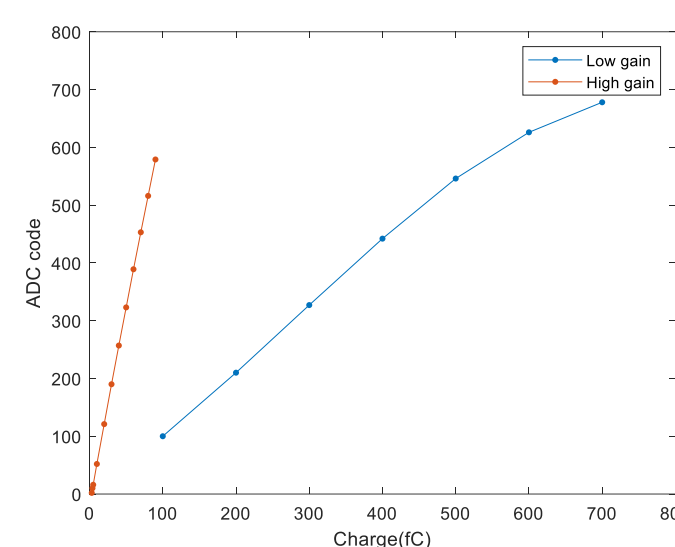


Fig.4 Tested dynamic range of one layer FEE.

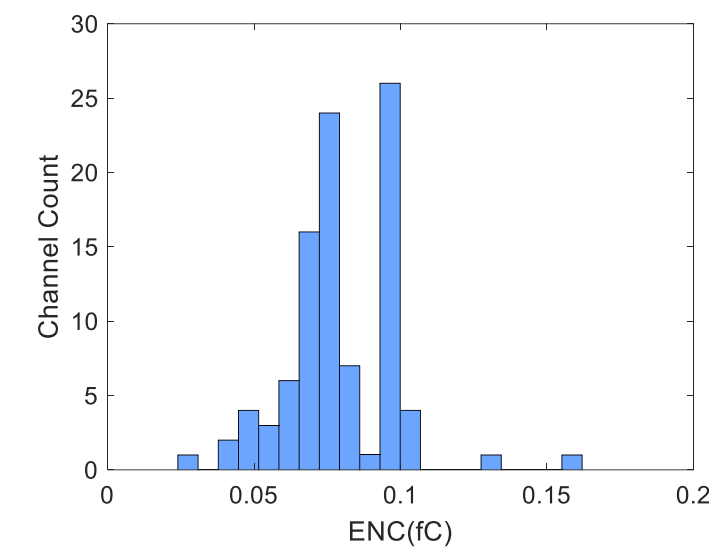


Fig.5 ENC of all 96 channels in high gain mode.

To evaluate the LET measurement capability, a neutron radiation field test was conducted at China Institute of Atomic Energy.

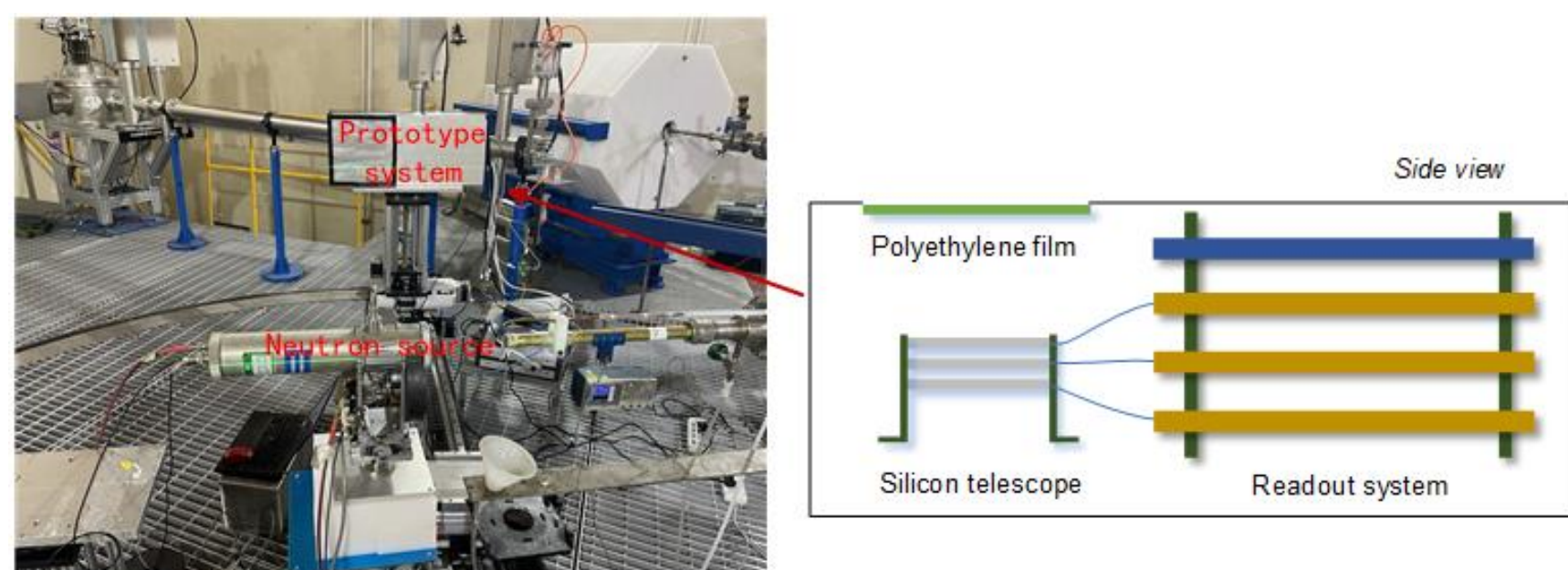


Fig.6 On-site test configuration

A GEANT4 simulation model similar to the testing conditions is built. The tested MPV is 19 keV/μm, is very close to the simulated MPV of 18 keV/μm.

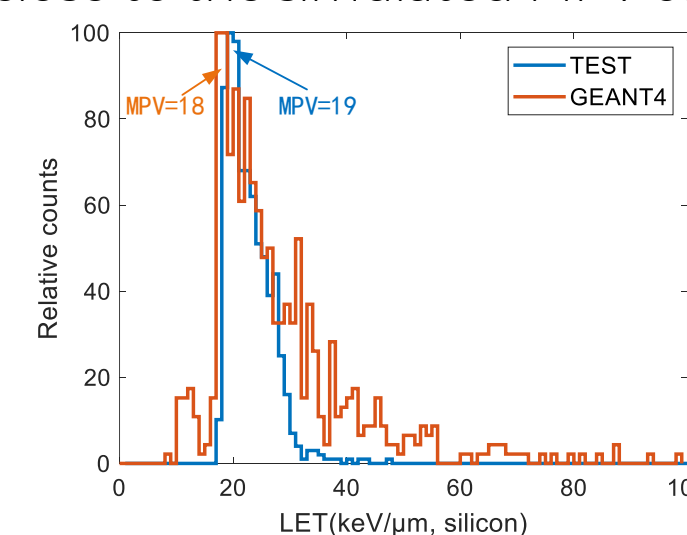


Fig.7 Calculated LET spectrum

Conclusion

A prototype readout electronics system for LET spectrometer was designed for space radiation detection. Precise LET spectrums can be obtained from accurate measurement of hit position and energy loss of incident particle in real-time. The energy dynamic range is extended to about 4000 by readout opposite sides of the DSSDs using different gains. The neutron radiation field test results meet the GEANT4-simulation results.