

Design of Prototype Readout Electronics of the High Counting Rate Main Drift Chamber in Particle Physics Experiments



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Introduction

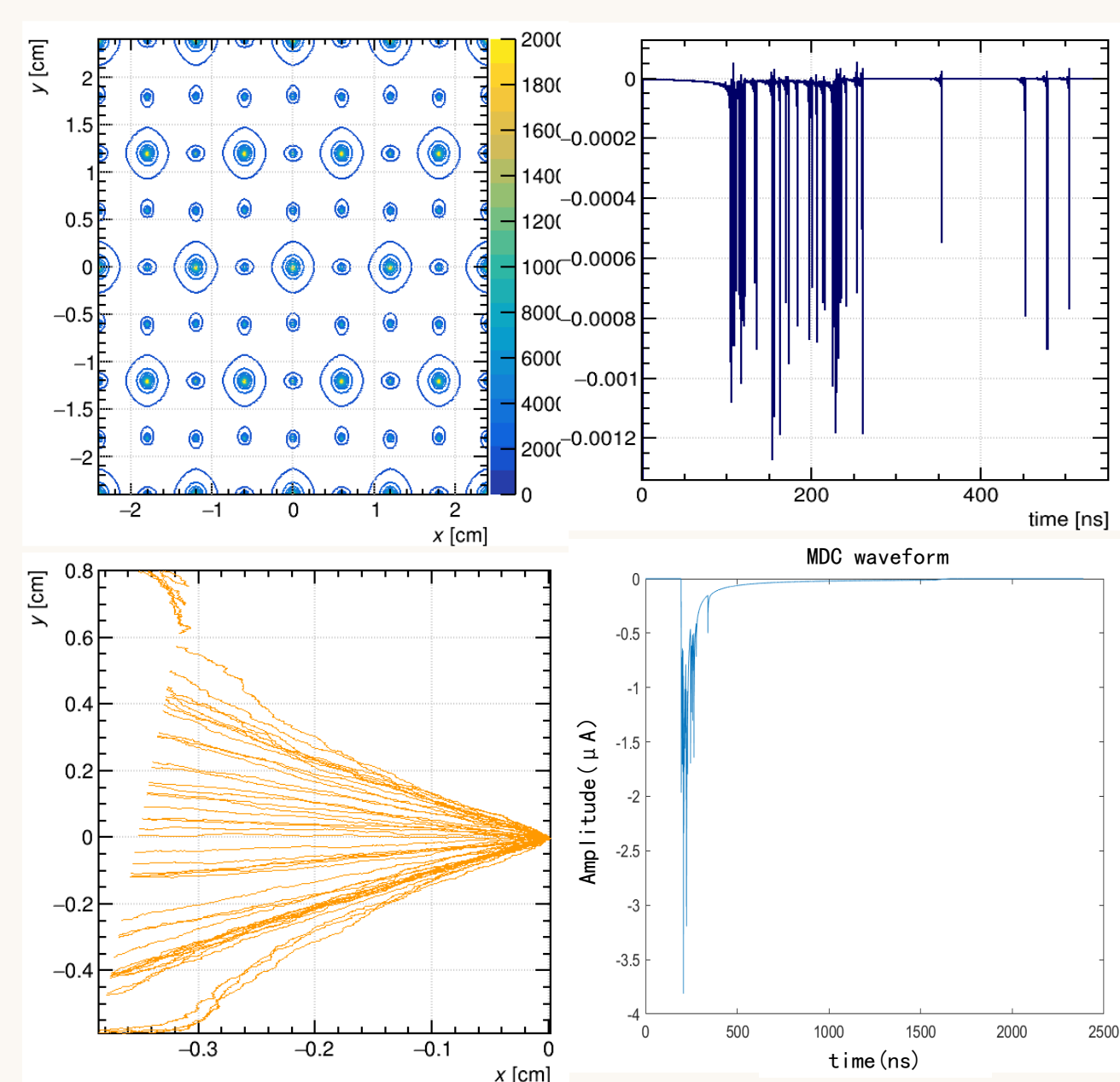
- The Main Drift Chamber (MDC) is a crucial track detector requiring high-precision charge and time measurements.
- As collider luminosity increases, MDC counting rates rise, leading to complex multi-peak structures and waveform pile-up.
- Existing systems cannot handle these high-rate issues. This work introduces a prototype system designed to maintain resolution under high counting rates.
- The prototype addresses signal distortion, waveform inconsistencies, and data processing challenges for future experiments like Super Tau-Charm Facility.

Scheme

Waveform Simulation

Models were constructed using Garfield++ and Geant4 to simulate physical interactions and primary ionization.

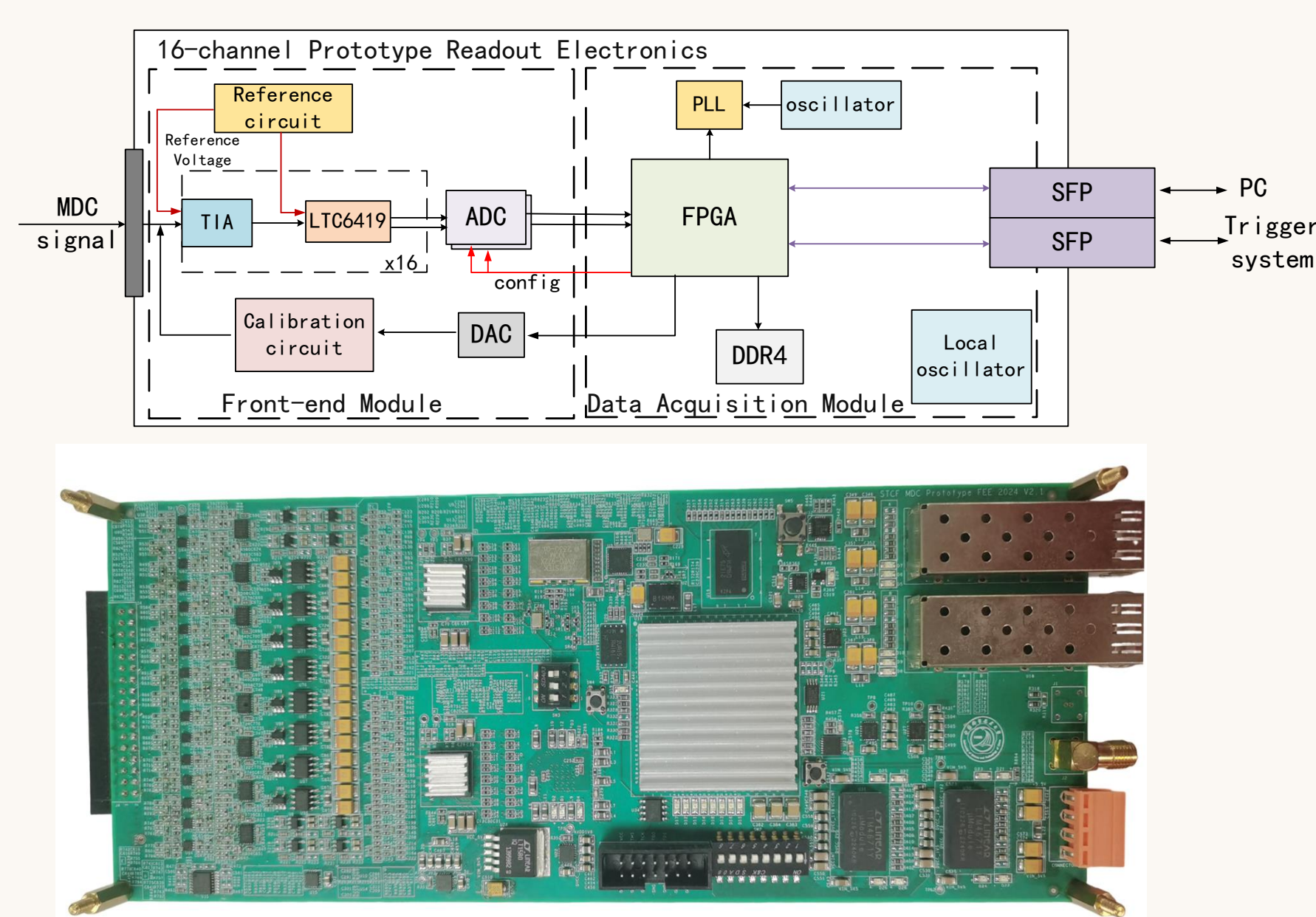
- Simulated trajectories based on momentum and incident angles.
- Identified multi-peak structures and pile-up at rates reaching hundred kHz.



Electronics Design

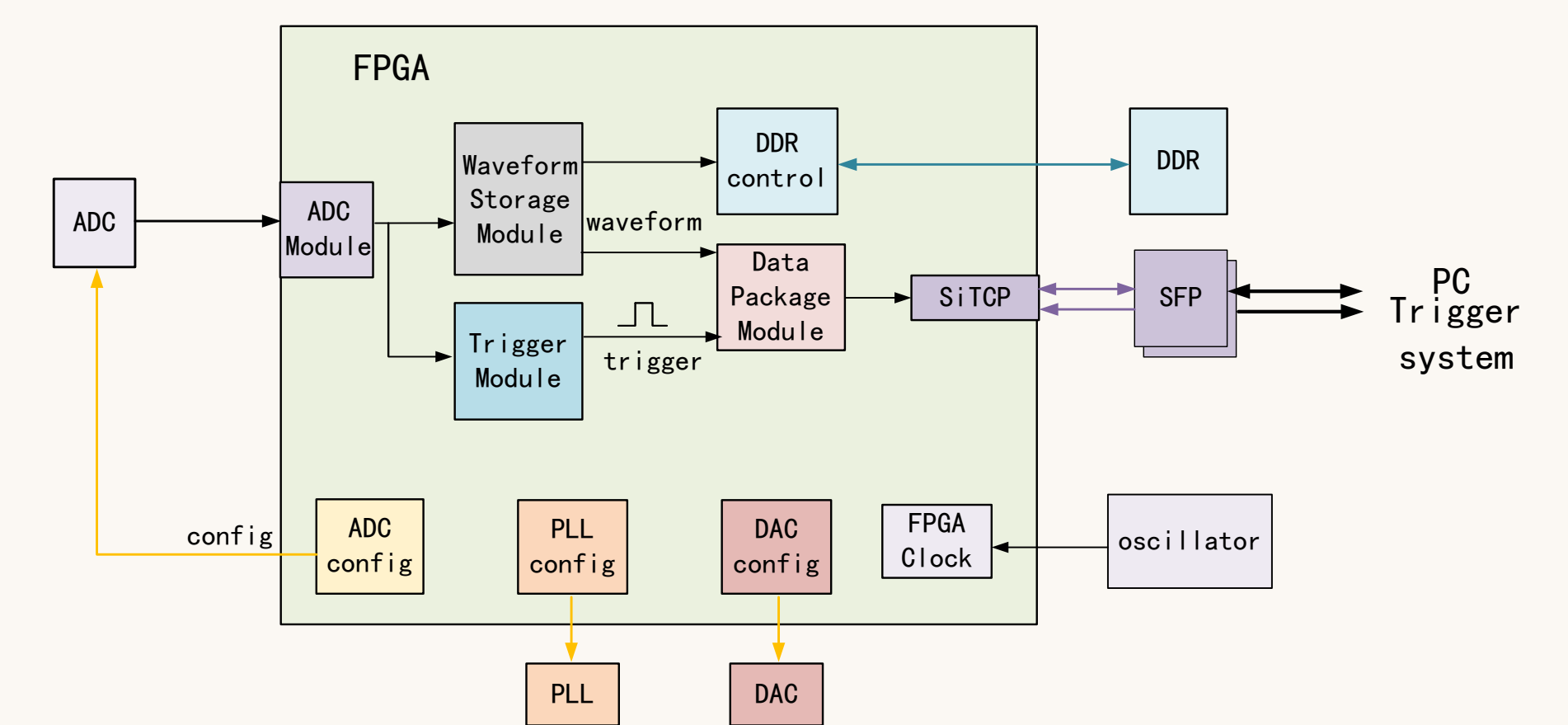
The system consists of a **Front-End Module (FEM)** and a **Data Acquisition Module (DAM)**.

- **FEM:** Uses Transimpedance Amplifiers (TIA) for distortion-free 16-channel signal processing.
- **DAM:** Based on FPGA and high-speed ADCs for real-time digitization.



FPGA Logic

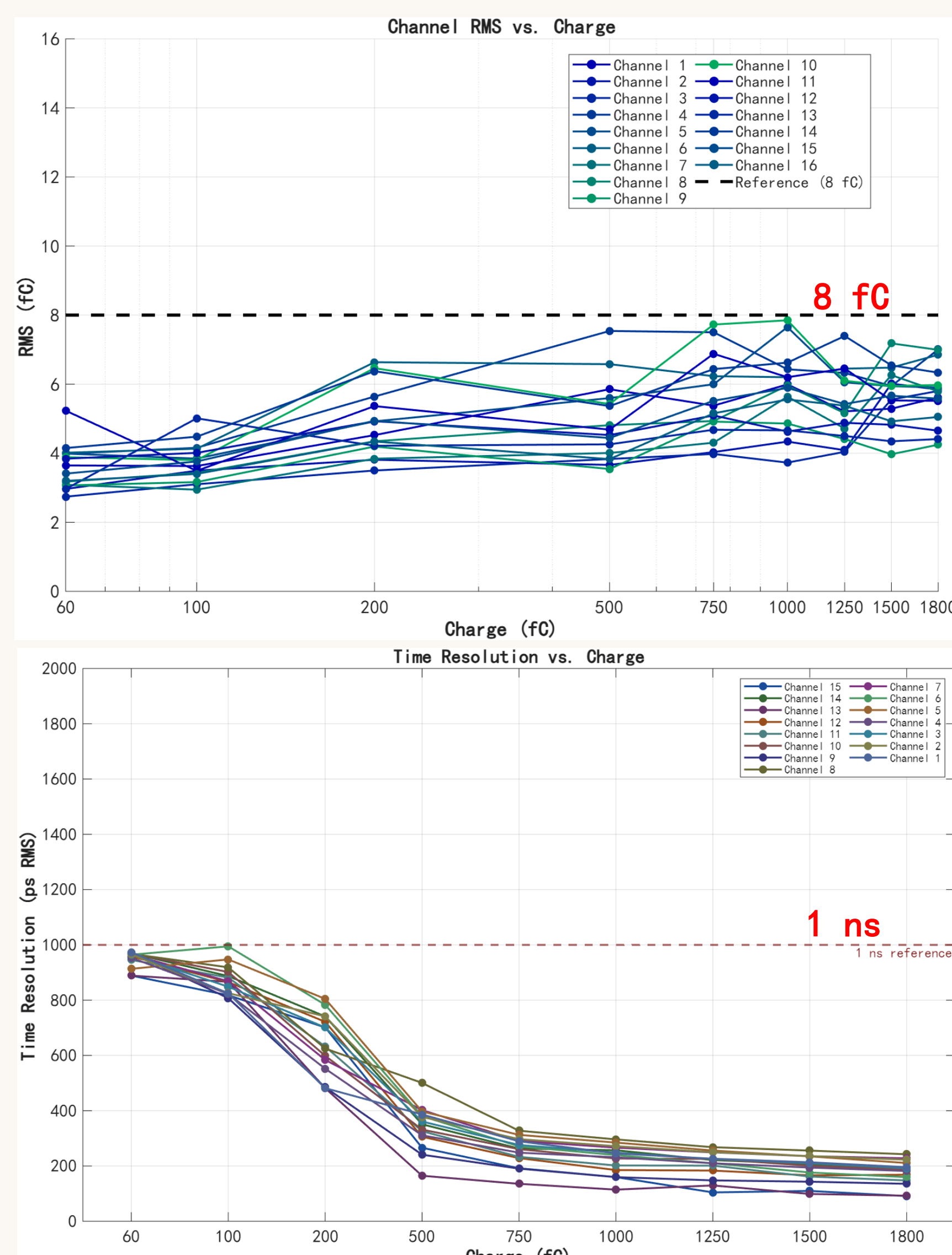
- ADC Module receives and decodes the digitized waveforms which are digitized by ADC.
- Waveform Storage Module stores the waveform dynamically.
- Trigger Module operates in two modes: self-triggering and external triggering. It will send a trigger signal to Data Package Module when the ADC code value of any channel exceeds the threshold or Trigger Module involves a trigger signal from sources such as external trigger systems.



Test and Results

Performance Evaluation

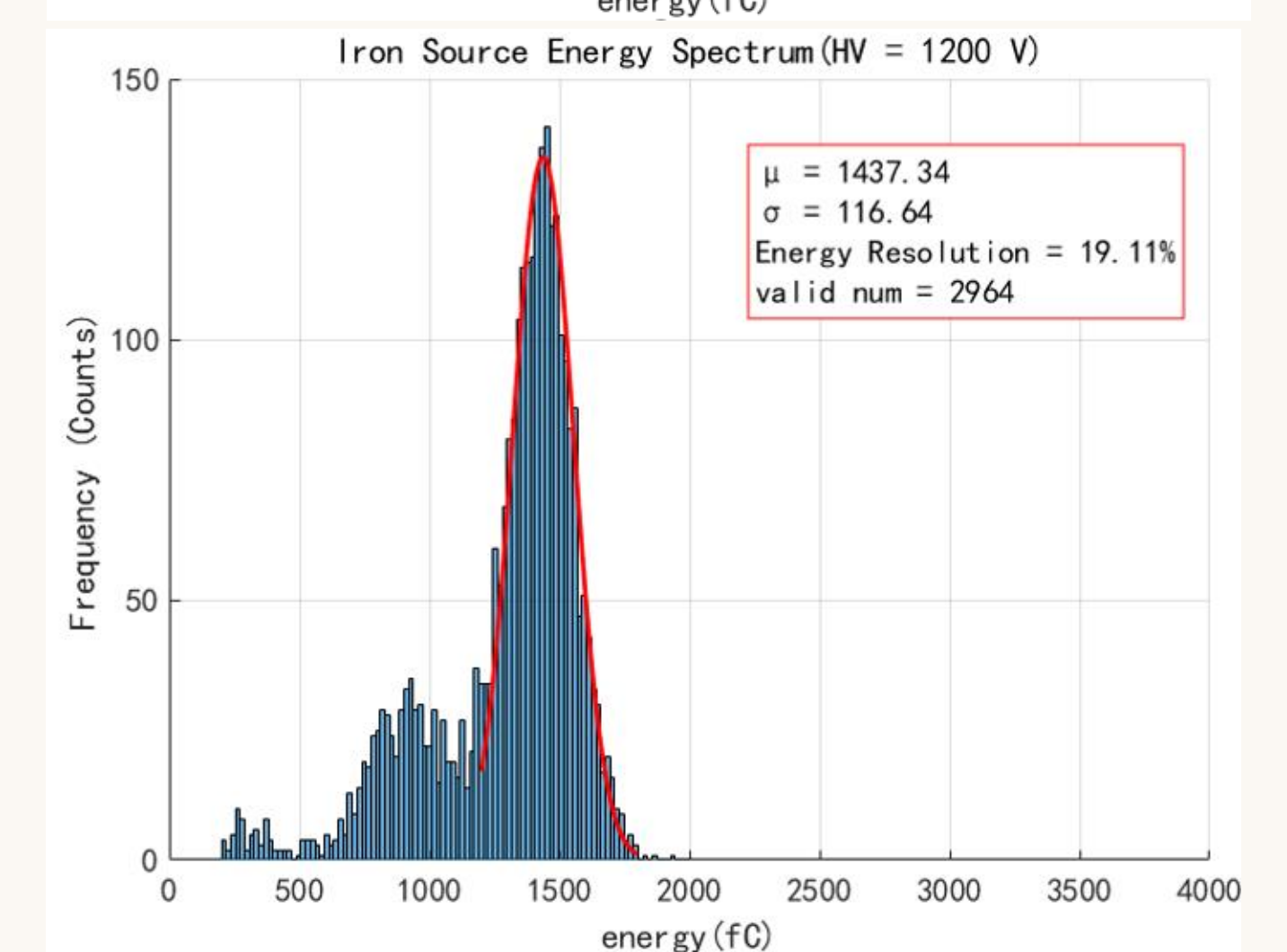
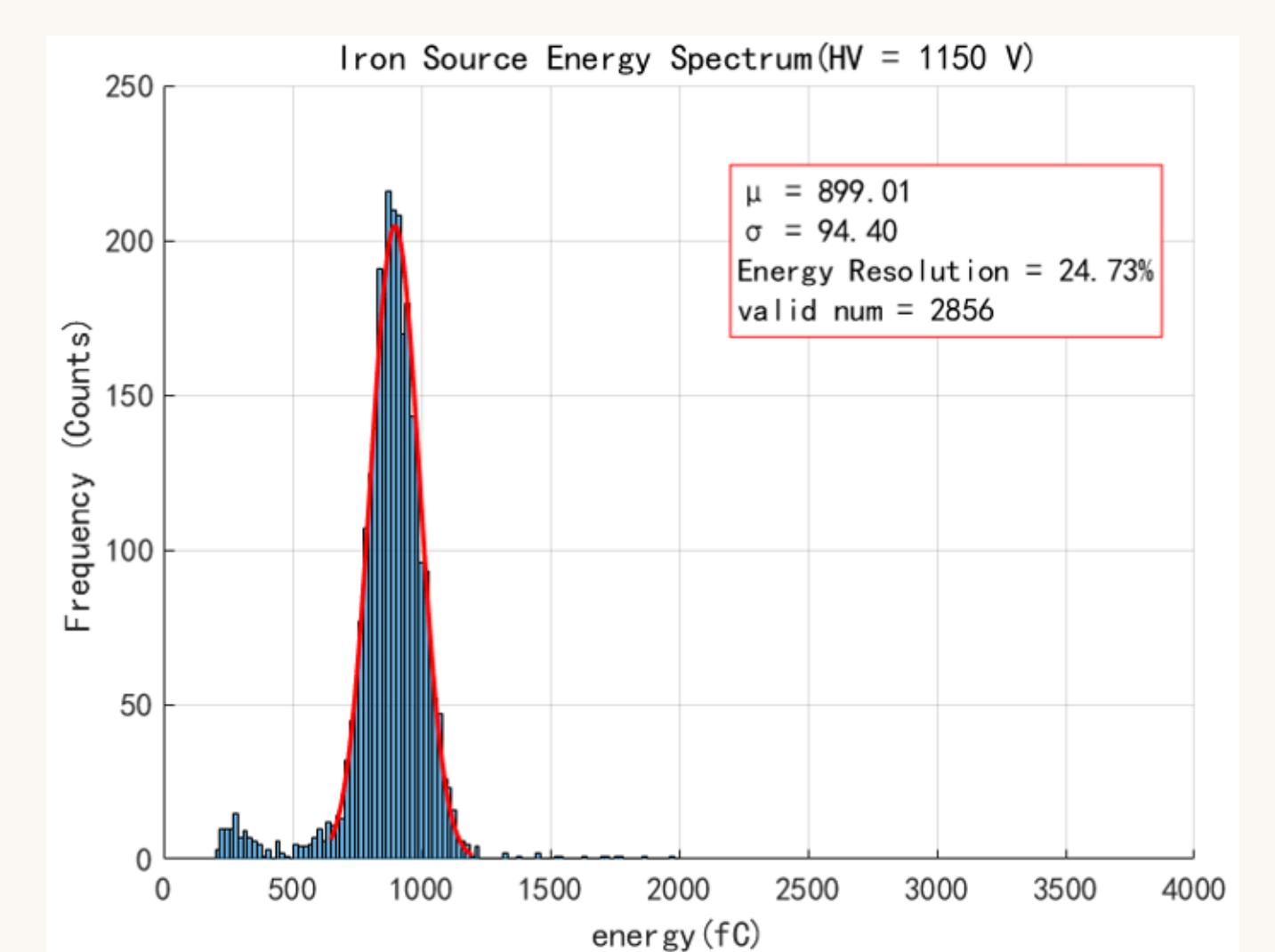
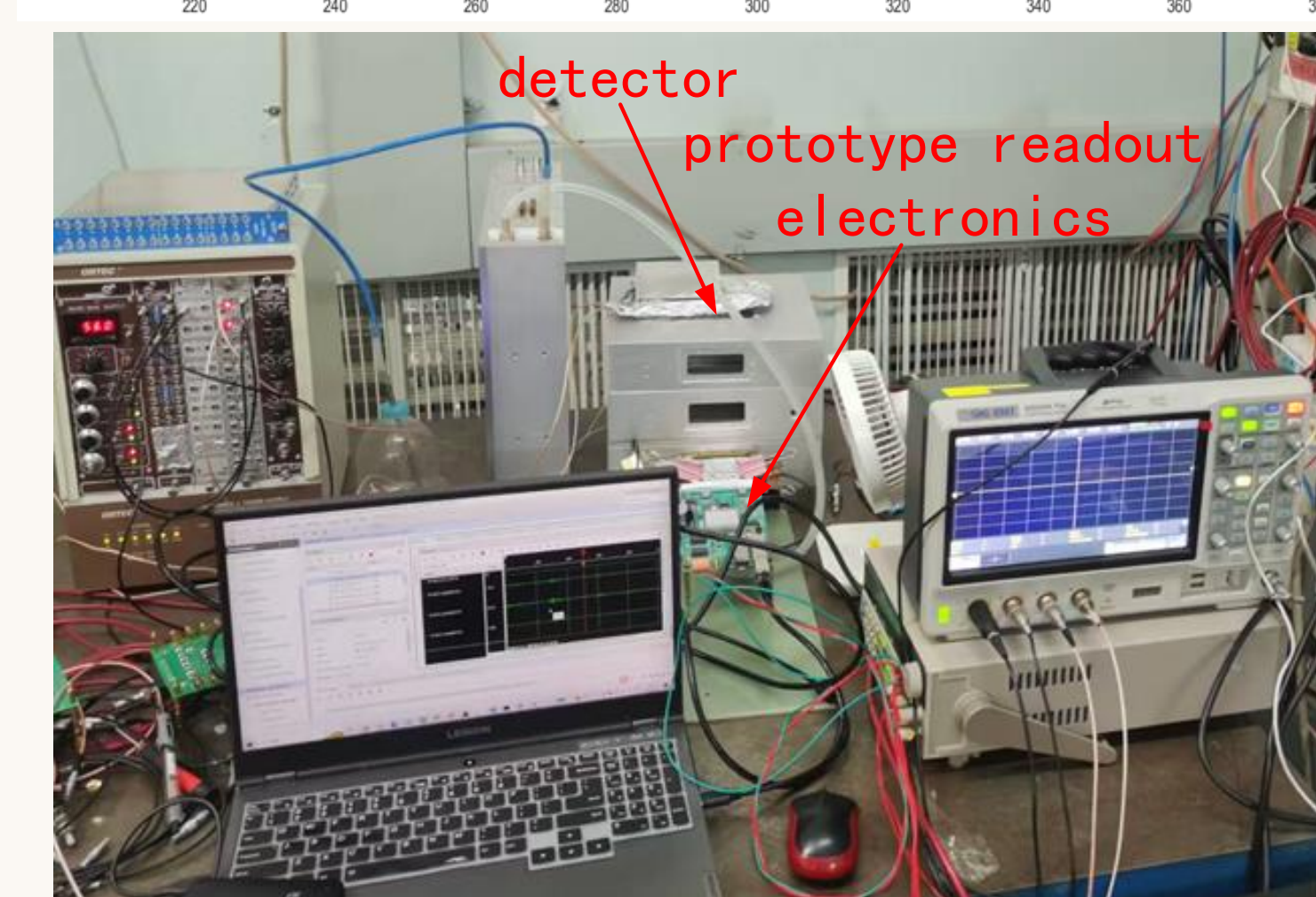
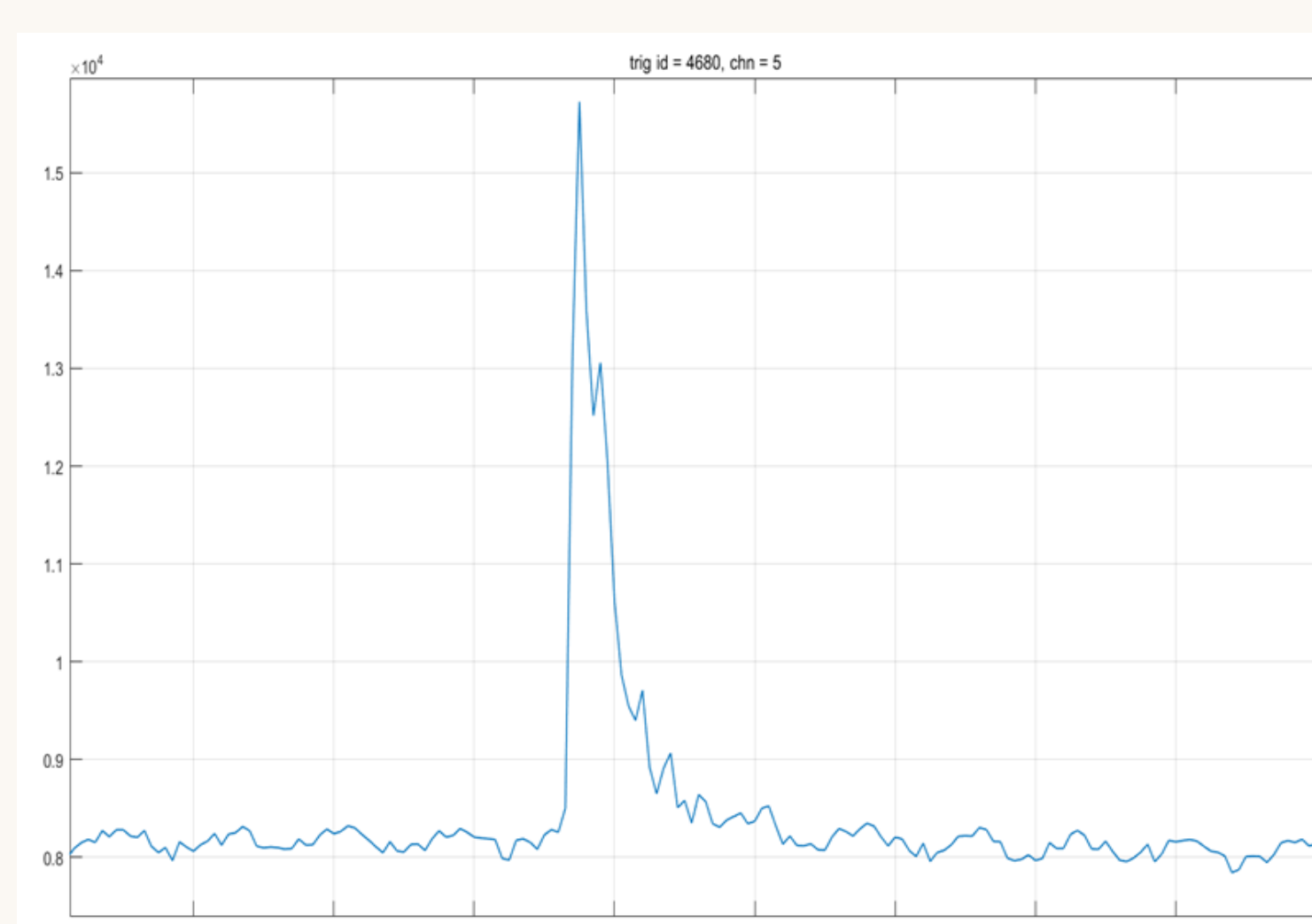
- **Dynamic Range:** 60–1800 fC.
- **Charge Resolution:** Better than 8 fC.
- **Time Resolution:** Better than 1 ns RMS.



Joint Detector Test

Joint tests' results shown that the prototype can acquire cosmic ray signals with multi-peak structures without distortion. And it also can collect ⁵⁵Fe source spectra with high energy resolution.

- Successfully resolved multi-peak structures in cosmic ray waveforms.
- **Energy Resolution:** 24.72% at 1150 V and 19.11% at 1200 V using a ⁵⁵Fe source.



Conclusion

- Designed and verified a prototype readout system for high counting rate MDCs.
- Successfully addressed waveform pile-up and complex structures through simulation-driven FEM and DAM design.
- Performance meets the requirements of future large colliders, such as the Super Tau-Charm Facility (STCF).

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