A Flexible Electronics System for the Readout of Multi-Purpose TPC at CSNS Back-n

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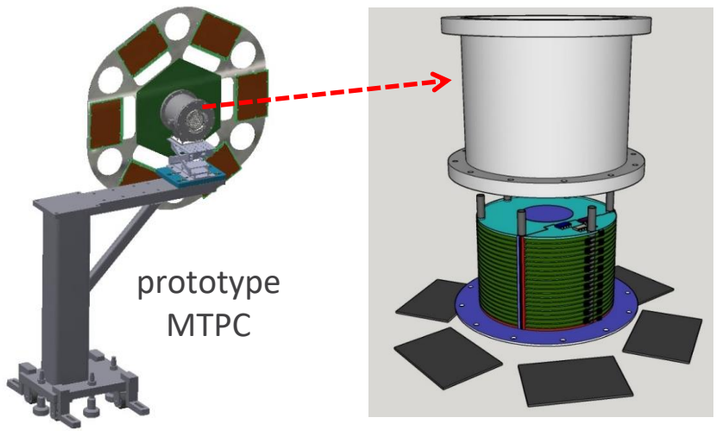
Background

- The China Spallation Neutron Source (CSNS), operational since 2018, is China's first and the world's fourth spallation neutron source.
- The back-n beam line of CSNS (**Back-n**), with a neutron energy range from 0.5 eV to 200 MeV, has great advantages in nuclear data measure- ments, driving the development of advanced particle spectrometers.
- In response to various scientific objectives, the CSNS back-n group has developed several spectrometers, one of which is the Multi-purpose Time Projection Chamber (MTPC), introduced in this poster.

Readout Electronics

- **Scientific Objective of MTPC:** The MTPC is designed for neutron nuclear data measurement, crucial for applications in nuclear power, medicine (BNCT), and astrophysics.
- **Project Proposal:** The MTPC project, led by CSNS back-n and USTC groups, primarily aims to measure light charged particles, with additional uses in fission product detection, neutron imaging, and beam profiling.
- **TPC System Design:** The goal is to build a TPC system with 20,000 readout channels, starting with a prototype featuring 1,519 channels.
- **Micromegas Detector:** The core of the TPC system is the Micromegas detector, developed by USTC. It's a cost-effective, low-maintenance, and environmentally friendly gaseous detector using thermal-bonding technology.

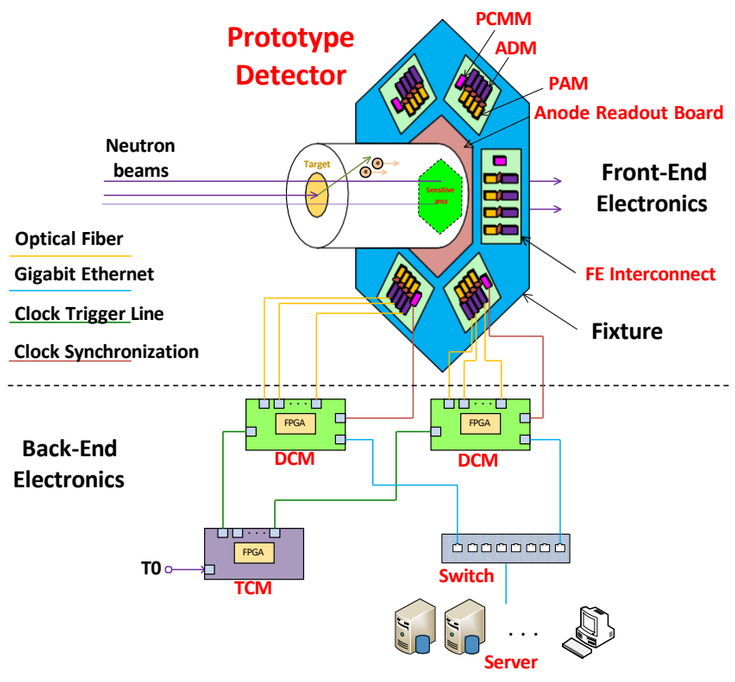


Readout Electronics System

Design Requirements

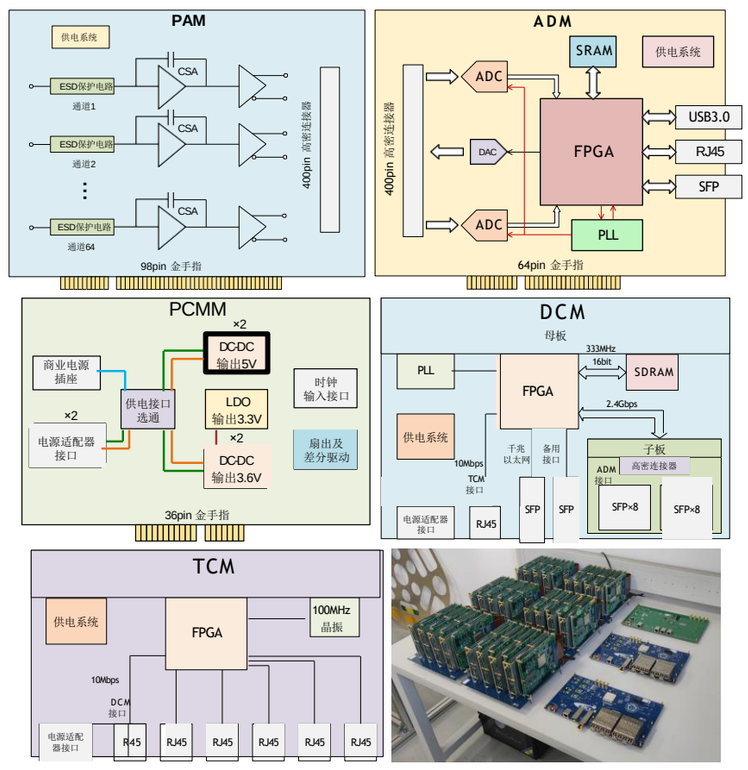
- **Channels:** 1519 anode, 1 cathode, 1 mesh
- **Dynamic Range:** 4.2 fC to 1.7 pC
- **Sampling Rate:** ≥20 MSPS
- **Timing Accuracy:** <10 ns
- **Dead Time:** <50 μs

The readout electronics have two components: front-end for amplification and digitization, and back-end for data collection. Data is transmitted via Gigabit Ethernet. Optical links provide flexibility.



Electronics Modules

- **PAM (Pre-Amplifier Module):** 64 channels, 1 W/board power consumption
- **ADM (Analog-Digital Module):** 64 channels, 40 MSPS sampling rate, 12 bits resolution
- **PCMM (Power and Clock Management Module):** Power supply and clock distribution
- **DCM (Data Concentrating Module):** up to 16 ADMs via optical fiber
- **TCM (Clock Trigger Module):** 100 MHz clock



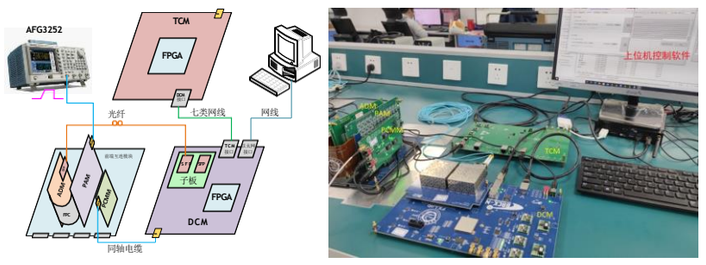
Test Results

Electronics Tests

Key testing items:

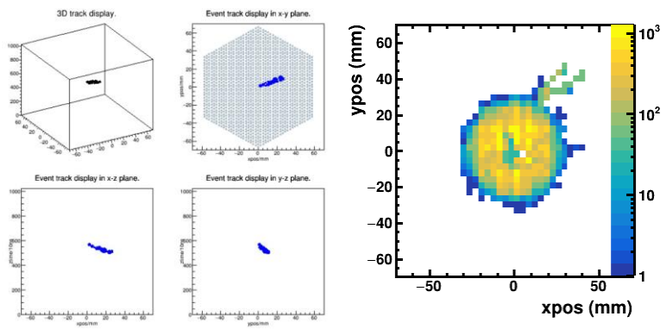
- Charge measurement performance (baseline noise, linearity, inter-channel crosstalk)
- Timing performance: clock synchronization, trigger synchronization, timing accuracy
- Data transmission reliability (long-term bit error rate testing)

Items	Design Requirements	Test Results
Number of Readout Channels	1521 Channels	1536 Channels
Charge Measurement Performance	Dynamic Range: From 4.2 fC to 1.7 pC	RMS: 0.76 fC
		Maximum Dynamic Range: 2.8 pC
Waveform Sampling Rate	Not less than 20 MSPS	40 MSPS
Single Event Sampling Window	More than 20 μs	25.6 μs
Inter-Channel Synchronization Accuracy	Better than 10 ns	Better than 200 ps
Time-of-Flight Measurement Accuracy	Better than 10 ns	Better than 3 ns
Dead Time	Less than 50 μs	Around 25 μs



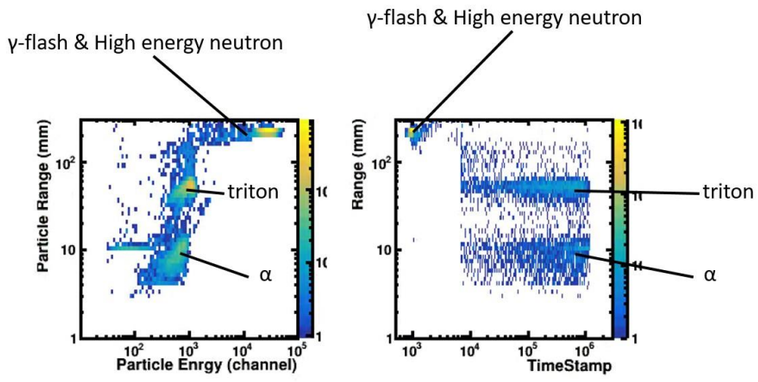
Joint Tests with prototype MTPC

After assembling the TPC system, including the detector and electronics, initial joint tests were conducted using a ^{241}Am radioactive source to verify the measurement capabilities of the readout system for charged particles.



Neutron Beam Experiments at CSNS back-n (^{6}Li)

Several rounds of beam tests have been conducted, with the first experiment carried out in January 2021, during which the TPC system and all electronic channels were confirmed to be operating normally. The results shown here demonstrate that effective discrimination between tritium and alpha particles has been achieved using the prototype TPC.



Conclusion

- An flexible electronic system for the prototype of CSNS Multi-purpose TPC has been developed.
- The prototype MPTC system has been successfully applied in neutron nuclear data measurement experiments and low-energy nuclear physics experiments.
- Future work: Optimize and further improve the performances (Data rate from GbE to 10 GbE, Lower noise, larger dynamic rage, higher density, etc.)