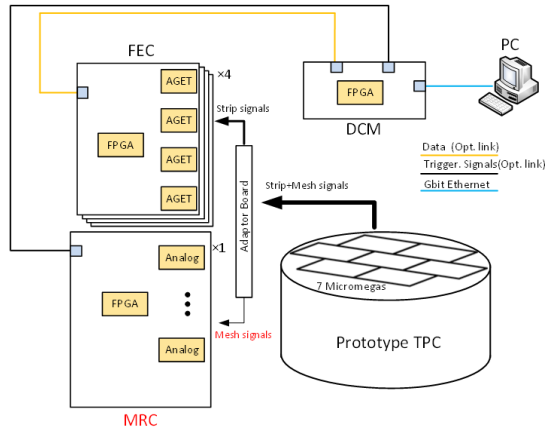


Design of Mesh-signal Readout Electronics for PandaX-III Prototype TPC



Zhen Chen



MRC acquire all mesh signals and generates individual ‘Mesh-trigger’ signals

MRC sends trigger signals to DCM

The trigger signals will be distributed to 4 FECs

Requirement:

$INL \leq 3.2\%$, $RMS\ noise \leq 6\ fC$ with 10 pC range

Design:

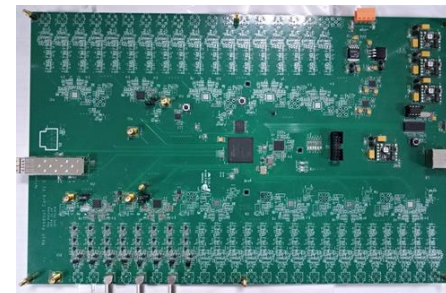
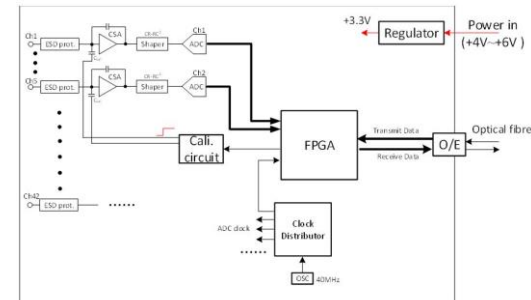
41 analog channels

11 quad, 12-bit, 50MSPS, serial, LVDS A/D

1 FPGA

Test:

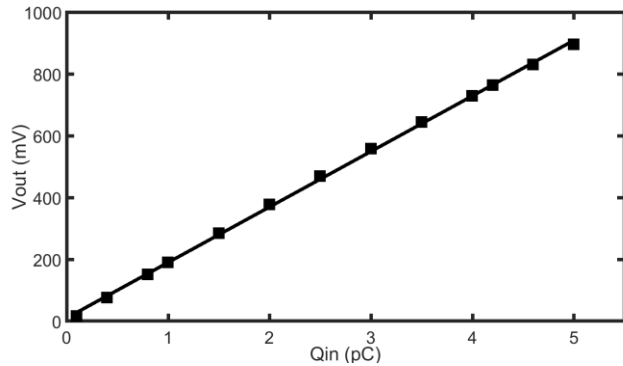
8 input channels with 2 ADCs has been welded now



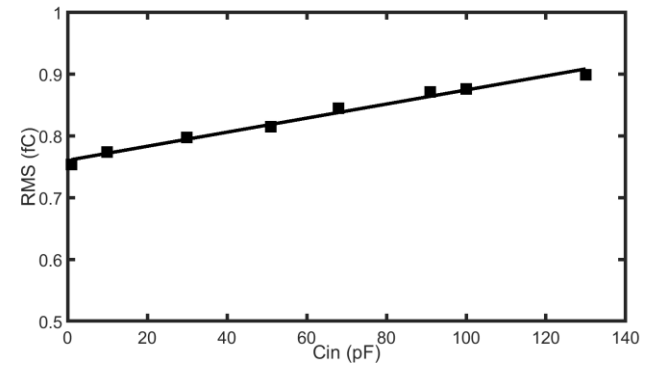
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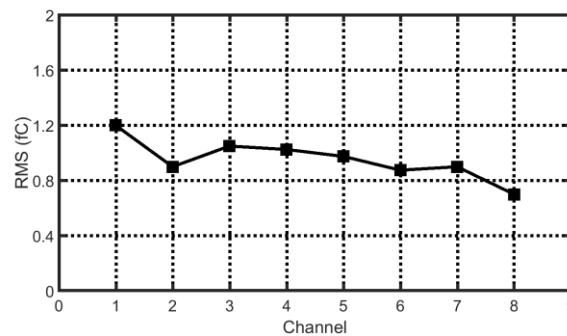
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INL < 3% with 5.5 pC



Noise (RMS) vs capacitor value < 0.9 fC with 100 pF




Noise distribution of 8 channel < 1.25 fC with 1 μ s peaking time with 5.5 pC

Introduction

Description
of Readout
electronics


Description
of MRC



Design of Mesh-signal Readout Electronics for PandaX-III Prototype TPC

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1. Introduction

Particle and Astrophysical System Experiment III (PandaX-III) is an experiment which uses a high-pressure gas TPC to search for Neutrinoless Double Beta Decay (NLODBD) of ^{76}Ge . PandaX-III TPC measures event energy, track and other various features of NLODBD.

The prototype is a small-sized, single-ended TPC. The active volume of the prototype TPC is 40 cm in diameter and 71 cm tall, and 10 kg of gas volume is contained within it at 18 bar. 7 MicroMegas detectors are installed in the charge readout plane at the top with cathode at the bottom. The prototype TPC is designed to study the specific solution of PandaX-III experiment in Shanghai JiaoTong University (SJTU).

2. Readout Requirements

As shown in Fig. 1, the front-end electronics is comprised of 4 Front-End Cards (FECs) and 1 Mesh Readout Card (MRC). The back-end electronics is 1 Data Collection Module (DCM).

To reconstruct a complete 3D track by measuring the position of hit strips, trigger synchronization for readout is required. The MRC is designed to acquire all mesh signals and generate individual "Mesh-trigger" signals. While in the prototype TPC, 7 mesh signals are required to analyze by MRC.

Considering that NLODBD Q-value of ^{76}Ge is ~ 2.0 MeV and the optical MicroMegas amplification is ~ 1000 times, the input charge can be calculated as ~ 10 pC. After summation, the integral bias Linearity (IBL) should be less than 3.2%, and the MCR noise should be less than 0.5 fC with 10 pC range.

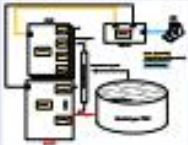


Fig. 1. Block diagram of readout electronics system for PandaX-III prototype TPC.

3. Design of MRC

MRC uses discrete components to implement the charge measurement circuit as shown in Fig. 2. There are 10 analog channels on the MRC receiving all signals from MicroMegas detectors, and 8 input channels with 2 ADCs has been installed for calibration with the prototype TPC. Each input channel contains OSD generation, charge sensitive preamplifier, pole-zero cancellation circuit, CR-RC² shaper, baseline restore and output buffer. MRC uses TI quad, 12-bit, 500kSPS, serial, LVDS ADC conversion to digitize the analog waveform, and outputs data on an FPGA chip. All the data from the MRC are sent to DCM with serial optical links and treated as trigger signals to help the front-end modules readout signals. Fig. 3 shows the photograph of MRC.

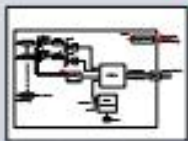


Fig. 2. Block diagram of MRC.

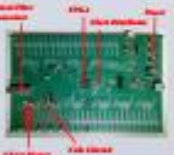


Fig. 3. Photograph of MRC.

During the experiment, oversampling algorithm should be applied to the data from MRC to effectively utilize the bandwidth. If mesh signal is narrow pulse, MRC can only read peak value when it is over the programmable threshold. DCM demands mesh trigger to all FECs. But if mesh signal is wide pulse, MRC uses a low sliding window to calculate pulse area of waveform. By comparing the pulse area with threshold, MRC generates trigger signal and sends it to DCM. Fig. 4 shows the original ADC output waveform. MRC can also send the waveform over threshold, as shown in Fig. 5.

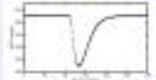


Fig. 4. Original ADC output waveform.

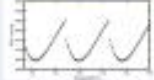


Fig. 5. Waveform over threshold.

4. Performances

The analog input was provided by a signal generator. By adjusting the amplitude of the input pulse in MRC, the integral curve can be plotted, as shown in Fig. 6, and the IBL is less than 3% with 1.0 pC range.

By connecting one MRC input channel to ground with a capacitor of different value to simulate the capacitor of the detector, we measured the relationship of input noise and capacitor value as shown in Fig. 7. When the capacitor capacitance is less than 100 pF, the noise is below 0.5 fC.

Fig. 8 shows the noise (RMS) distribution of 8 channels with 1 ps peaking time and 1.0 pC range in room temperature. The noise of all input channels is less than 0.5 fC.

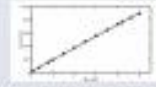


Fig. 6. Integral curve for a typical channel.




Fig. 7. Noise (RMS) vs capacitor value of a typical channel.

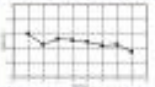


Fig. 8. Noise (RMS) distribution of 8 channels.

5. Test of Trigger Distribution

As shown in Fig. 9, MRC sends trigger signals to DCM and the trigger signals will be distributed to 4 FECs. Fig. 10 shows the trigger delay is 1.0 ps.




Fig. 9. Photograph of the system.




Fig. 10. Trigger delay plot.

6. Conclusion

The design and performances of the MRC for the PandaX-III TPC are presented in this paper. And the performances of MRC meet requirements of PandaX-III prototype TPC experiment. Trigger distribution functions well in the system test. The next plan is to conduct prototype TPC tests by using a MRC and 4 FECs.

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