Progress of PandaX-III Readout Electronics

Changqing Feng
on behalf of PandaX-III collaboration

State Key Laboratory of Particle Detection & Electronics
University of Science and Technology of China

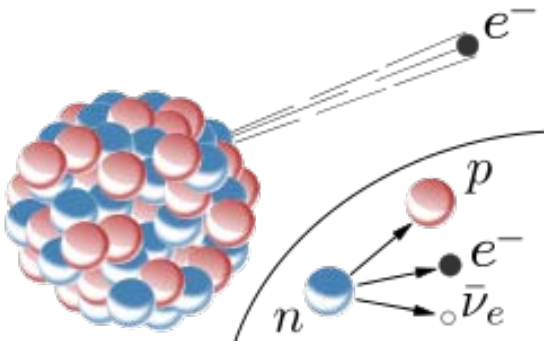
25th May 2017, Beijing

Outline

- Background
- Introduction to PandaX-III TPC Detector
- Design of the readout system
- Recent progress
- Summary

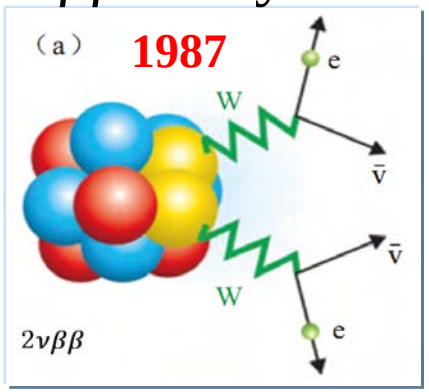
Background

β decay



$$^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + e^- + \nu_e$$

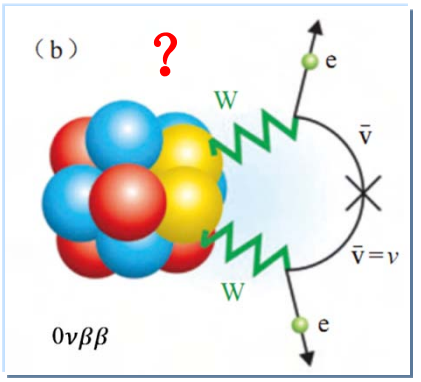
ββ decay



$$^{A}_{Z}X \rightarrow {}^{A}_{Z+2}Y + 2e^- + 2\nu_e$$

Double-β decay: a conventional 2nd order process in Standard Model

0νββ decay



$$^{A}_{Z}X \rightarrow {}^{A}_{Z+2}Y + 2e^-$$

Neutrinoless double-β decay: Beyond the Standard Model

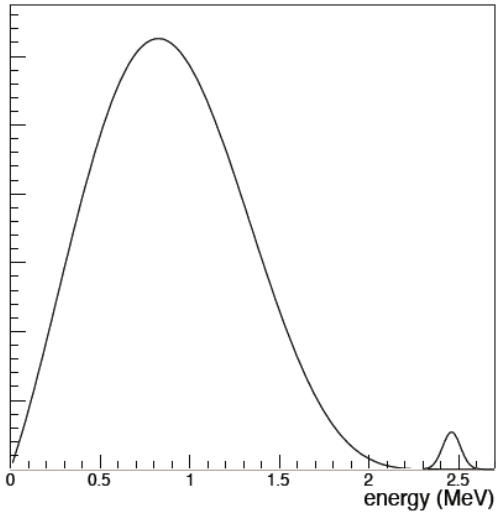
Scientific significances of searching for 0νββ

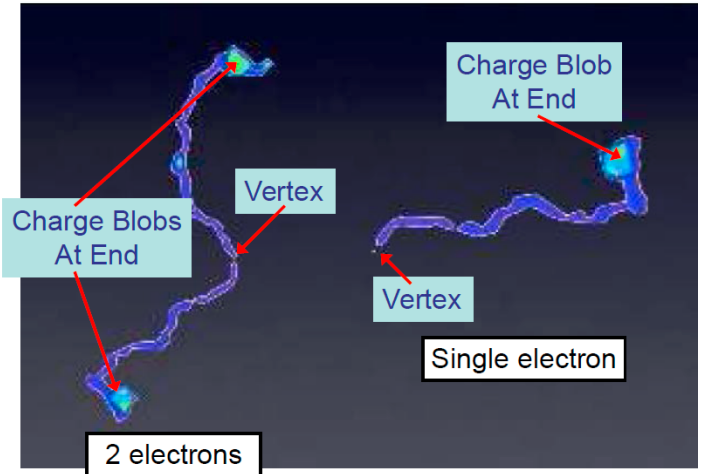
- Whether neutrino is a Majorana particle or a Dirac particle
- Know the mass scale of neutrino
- Lepton number violation
- ...

Essential characteristics of 0νββ experiments

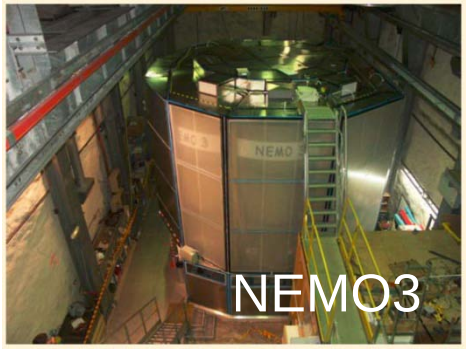
- High energy resolution
  - Several percents to less than 1%
- Large scale and long term operation
  - ~100 kilogram or even scalable to ~1 ton
- Ultralow radioactive background
  - High radiation purity for detector materials and auxiliary facilities
  - Perfect shielding (deeply under ground)
  - Tracking (or other?) information may be utilized for background discrimination

log scale



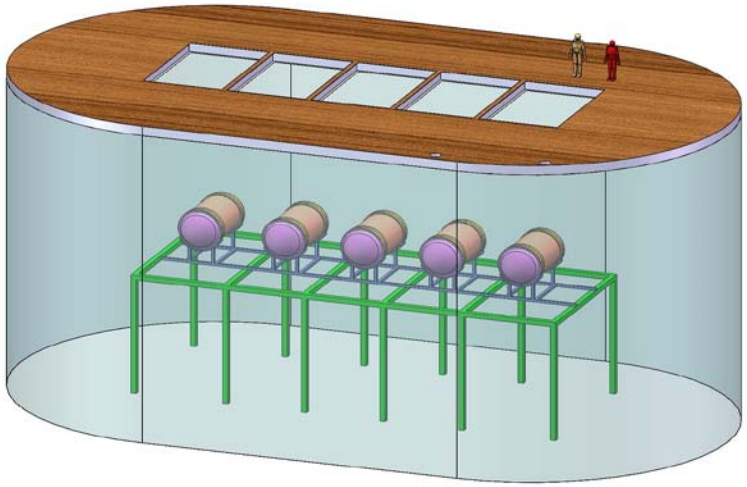


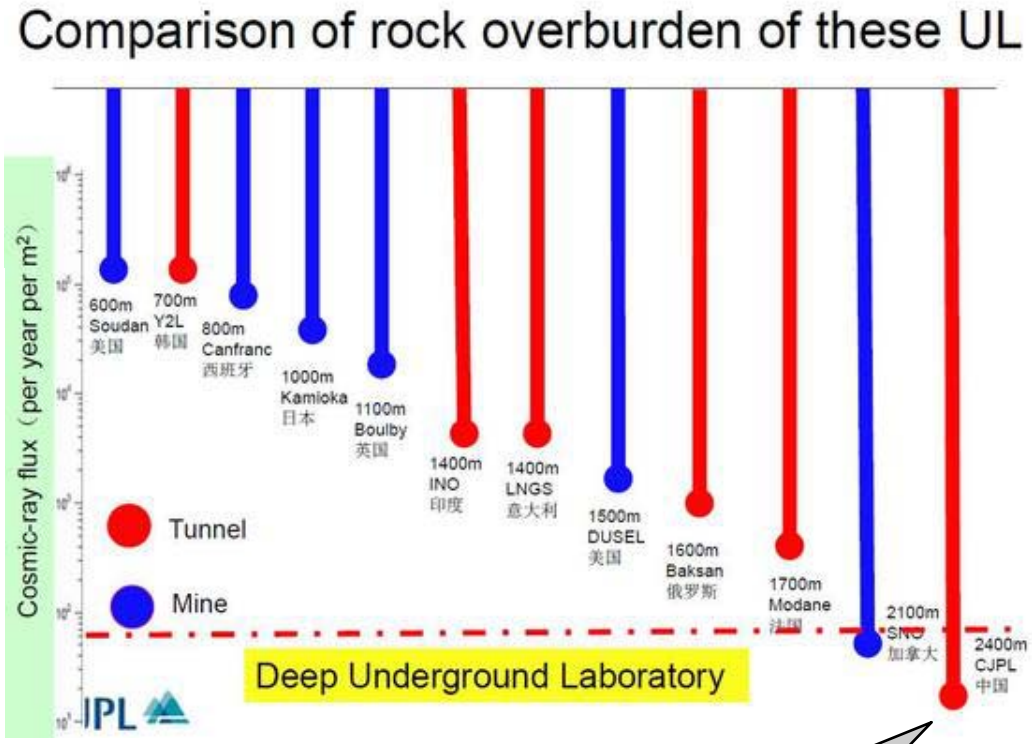
Experiments for 0νββ decay searching



PandaX-III experiment

- Hopefully the first 0νββ experiment in China
- To be carried out at Jinpin underground Laboratory
  - Sichuan province, China
- Proposed in 2015
  - SJTU, USTC, PKU…

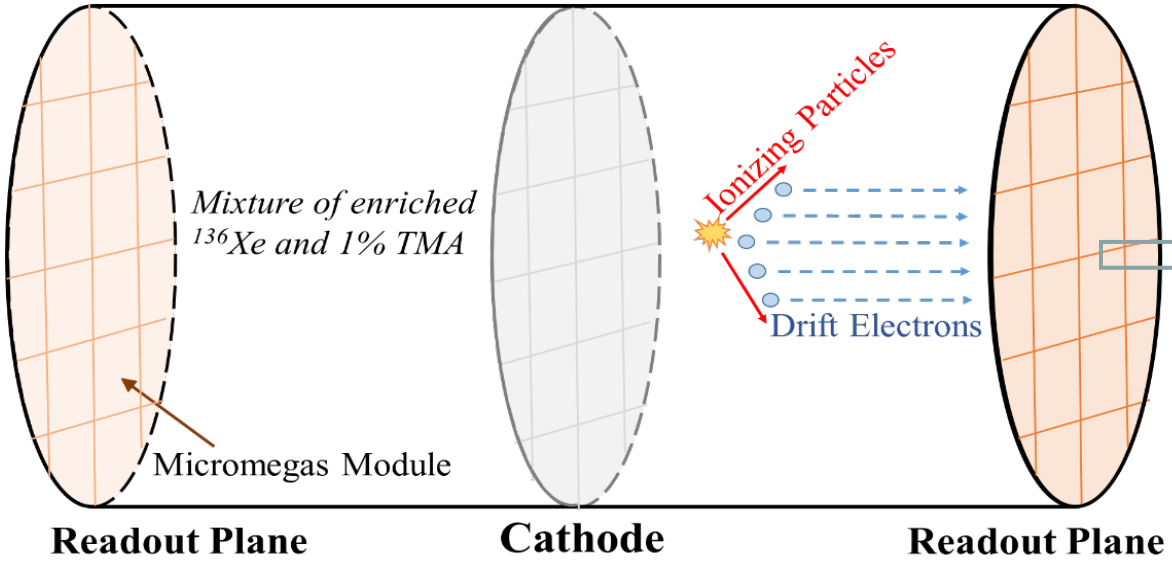


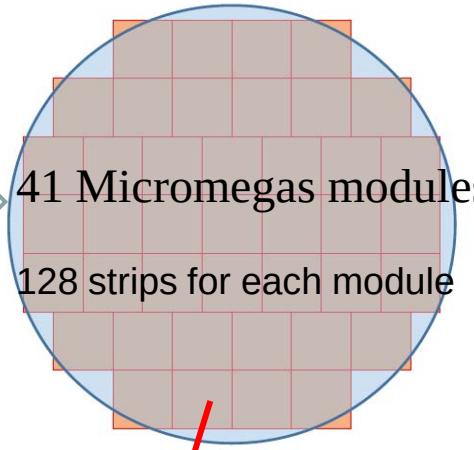


see 25/5/2017 10:12 - 10:30 AM, Ke HAN, TIPP2017 Oral talk

CJPL: 2400m

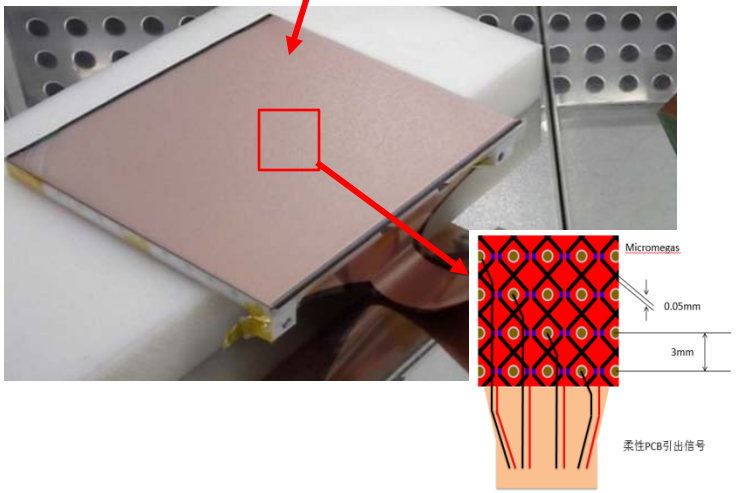
PandaX-III TPC detector (Phase I)



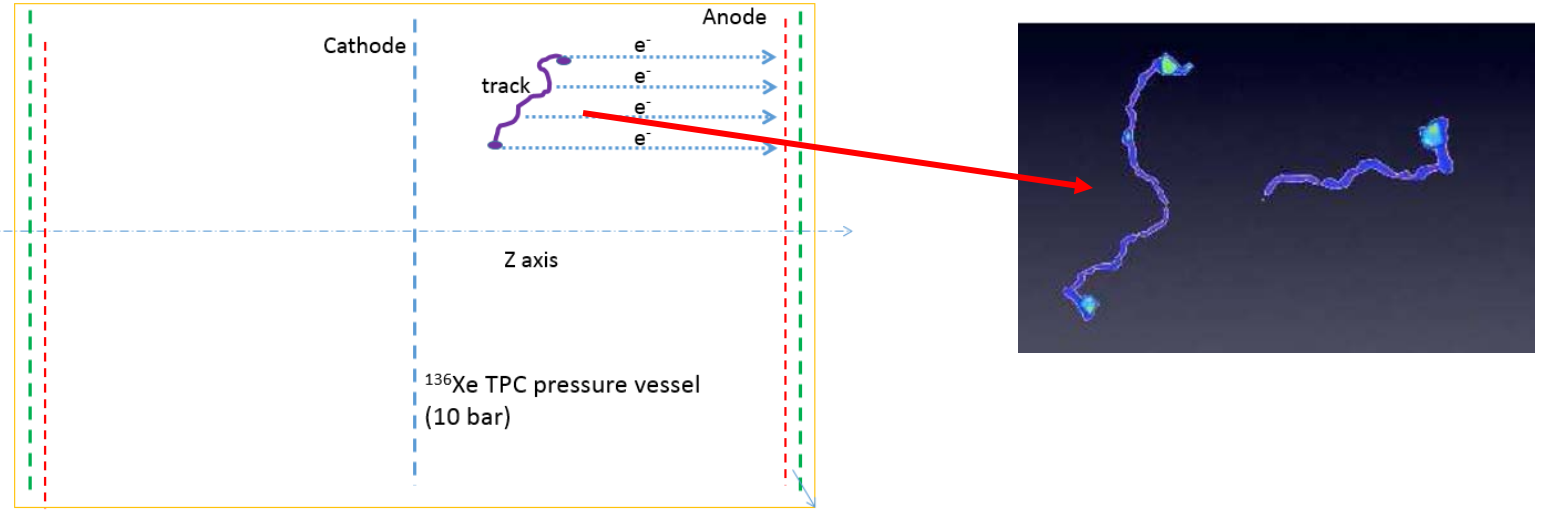


TPC with 200kg Xeon gas

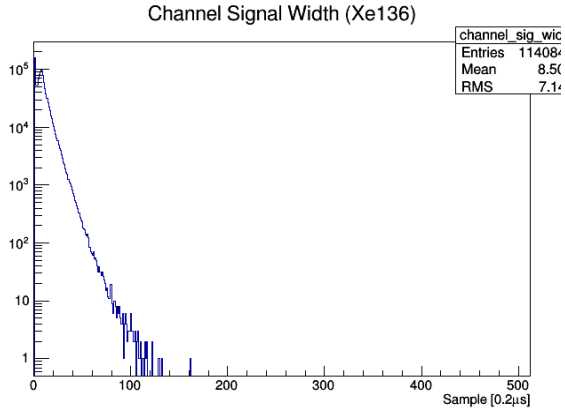
- High pressure Xe gas (~10bar)
  - ^{136}Xe enriched (Q_{ee}=2457.8 keV)
- Length: 2m, Diameter: 1.5m
- Endcap detector: Microbulk Micromegas

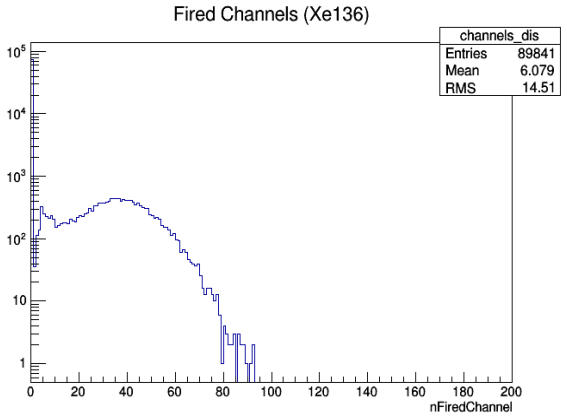


Signal features of PandaX-III TPC



- Signal amplitude: 10pC in total
  - Gain of Micromegas: 10^3
  - Q_{ee}=2.5MeV, ε= 30eV/e
- Drift velocity : 1mm/us
- Drift length: ~1m
- Max. tracking length: ~30cm





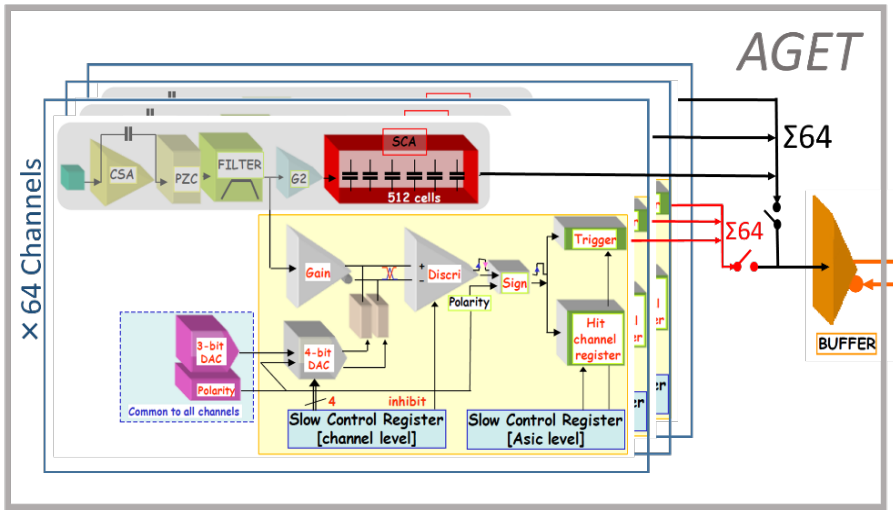
Design specifications for the readout electronics

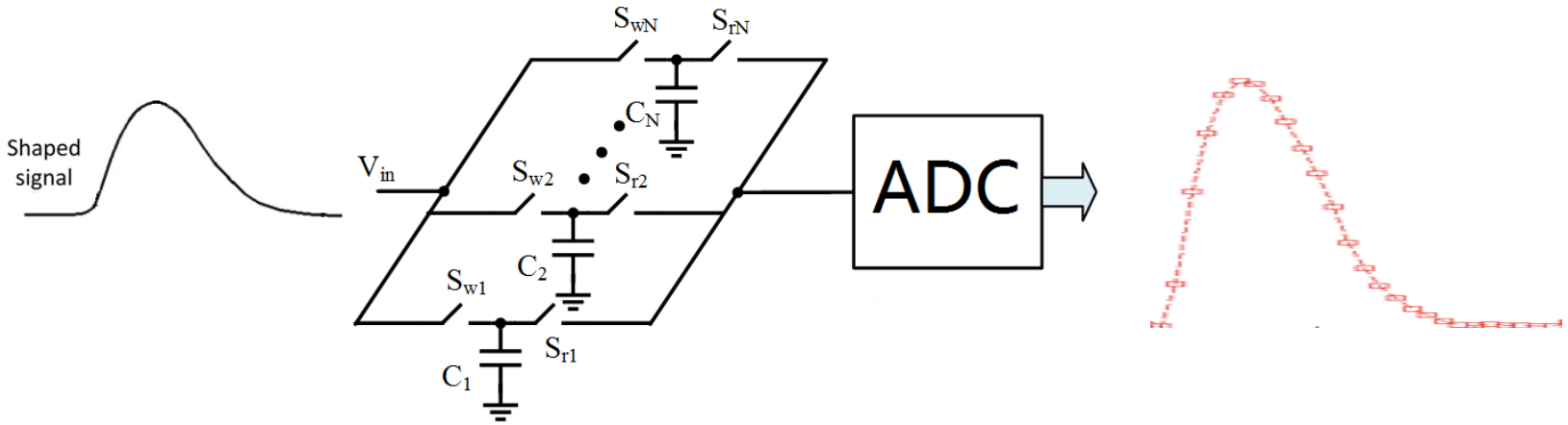
- Readout Channels:
  - 10496 channels of Micromegas strip signal
  - 82 channels of mesh signal (for trigger)
- Dynamic range of each channel: ≥ 10pC
- Time window: ≥ 40μs
- INL: < 2%
- Noise: < 12fC (in RMS)

Choice of front-end ASIC: AGET chip

Main Features:

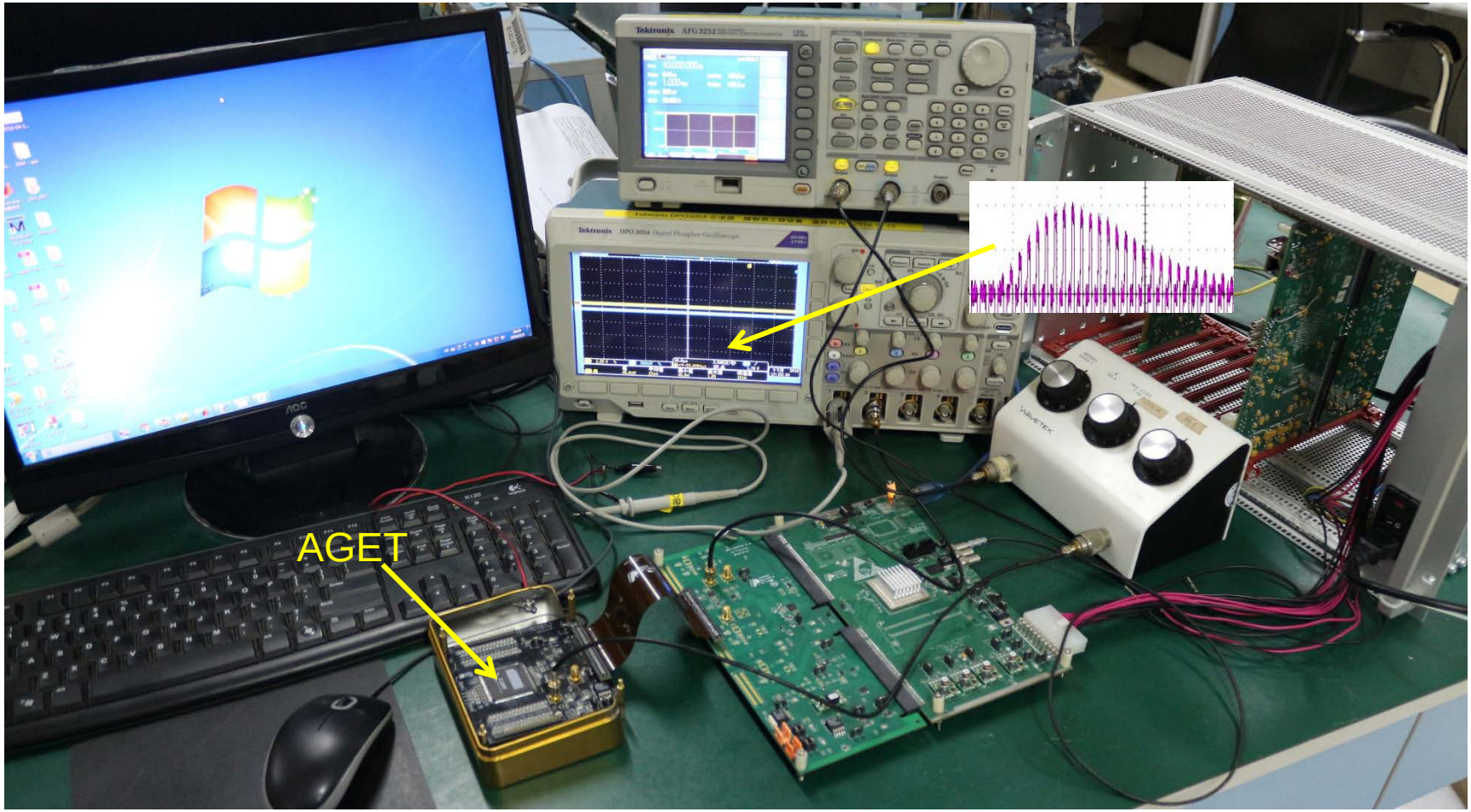
- Designed by Saclay, IRFU CEA, France
- 0.35um AMS CMOS technology
- 64 input channels
- Input range: 120fC/240fC/1pC/10pC
- Shaping time: 50ns - 1us, configurable
- 512-cell SCA for each channel
- Sampling rate: 1MHz - 100MHz, configurable





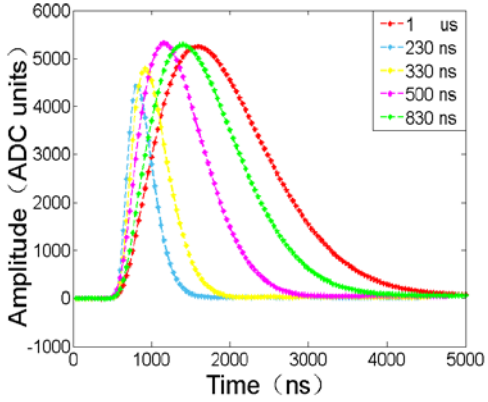
Prototype electronics with AGET chip

- To verify the design concept of front-end electronics with AGET chip

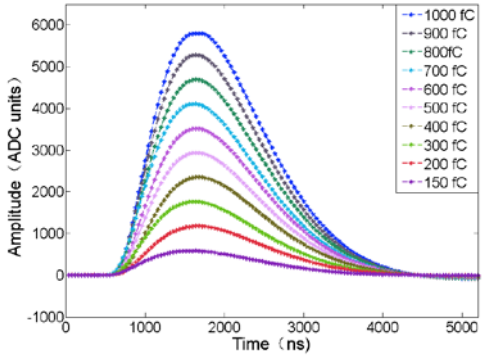


Test results of prototype electronics

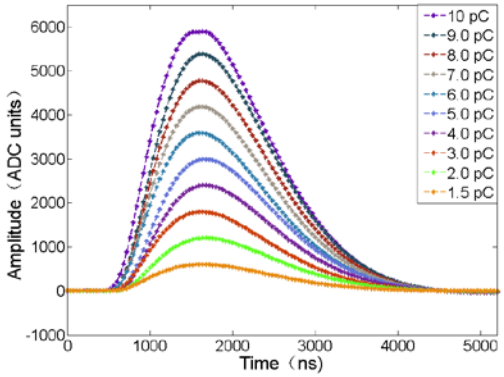
- *Sample rate : 25MHz*
- *Peak time : 120fC*



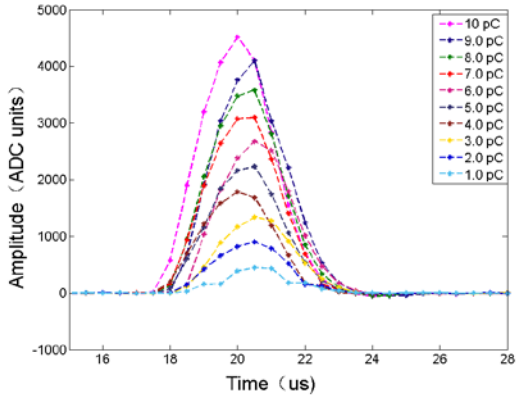
- *Sample rate : 25MHz*
- *达Peak time : 1μs*
- *Dy. range : 1pC*

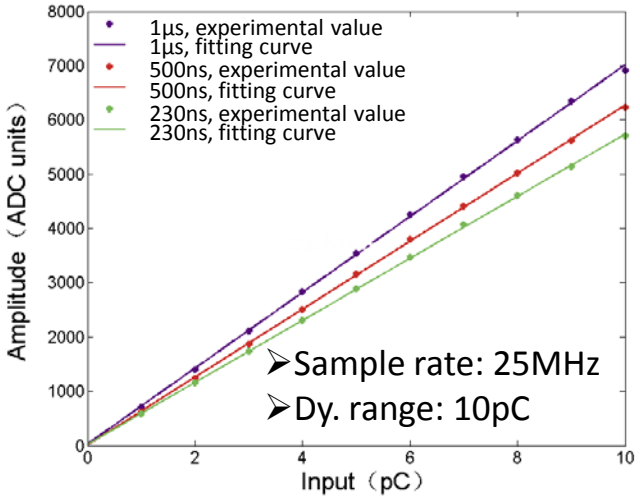


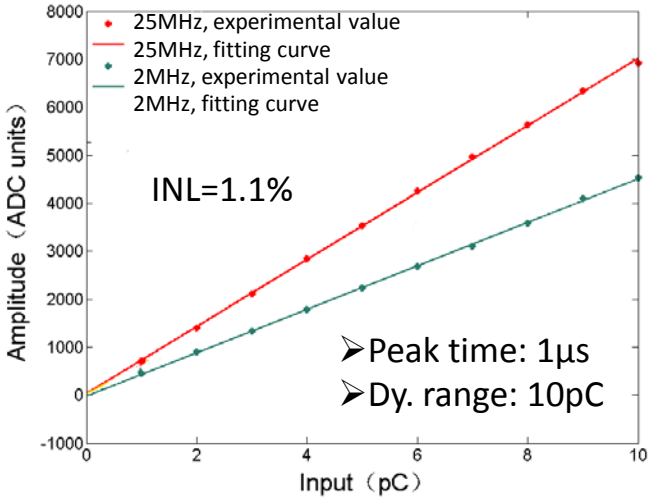
- *Sample rate : 25MHz*
- *达Peak time : 1μs*
- *Dy. range : 10pC*



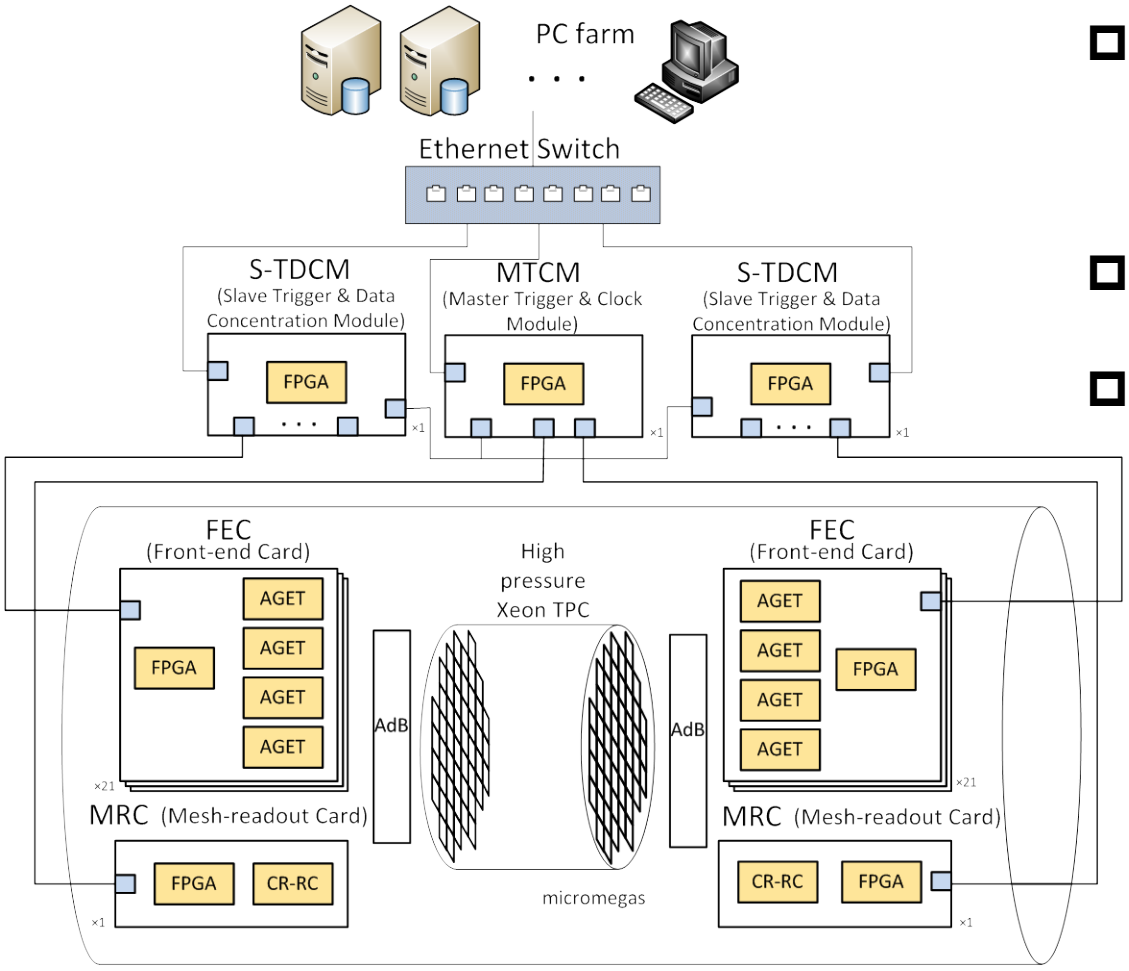
- *Sample rate: 2MHz*
- *Peak time: 1μs*
- *Dy. range : 10pC*





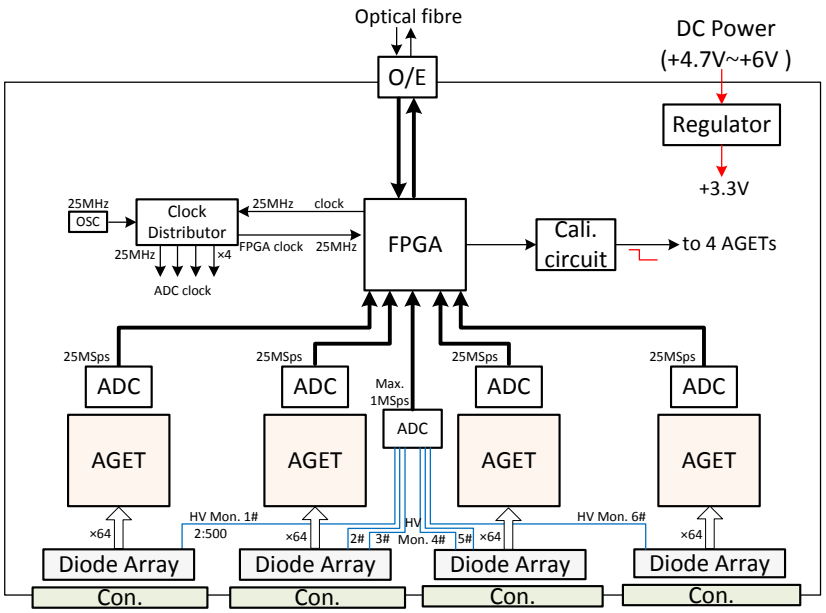


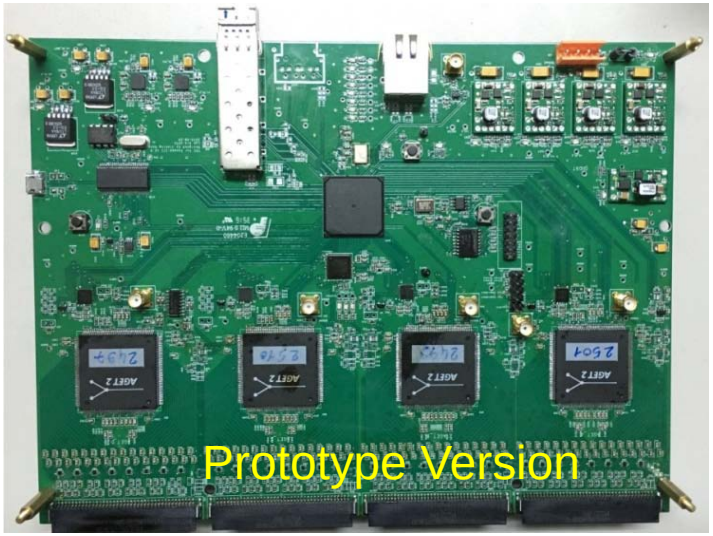
Architecture of PandaX-III readout system



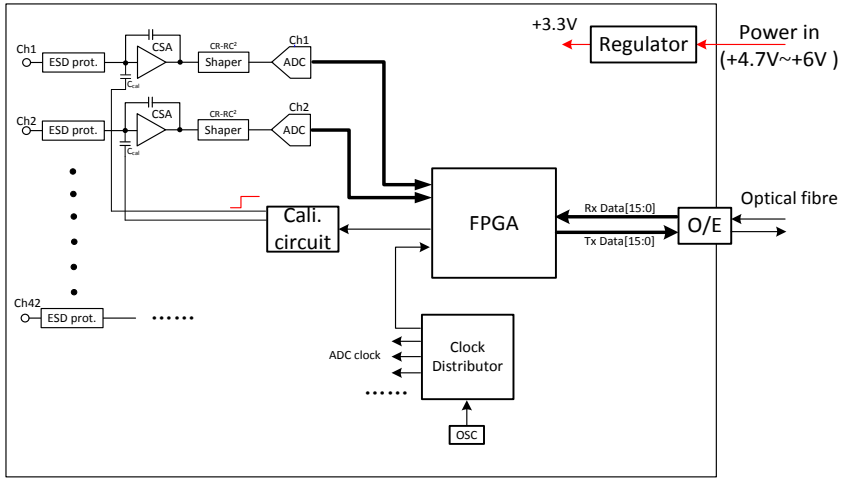
- 42 Front End Card (FEC)
  - ✓ 256 channels/FEC
- 2 Mesh Readout Card (MRC)
- Backend electronics cards
  - ✓ S-TDCM, M-TCM
  - ✓ DAQ&Trigger&Clock functions

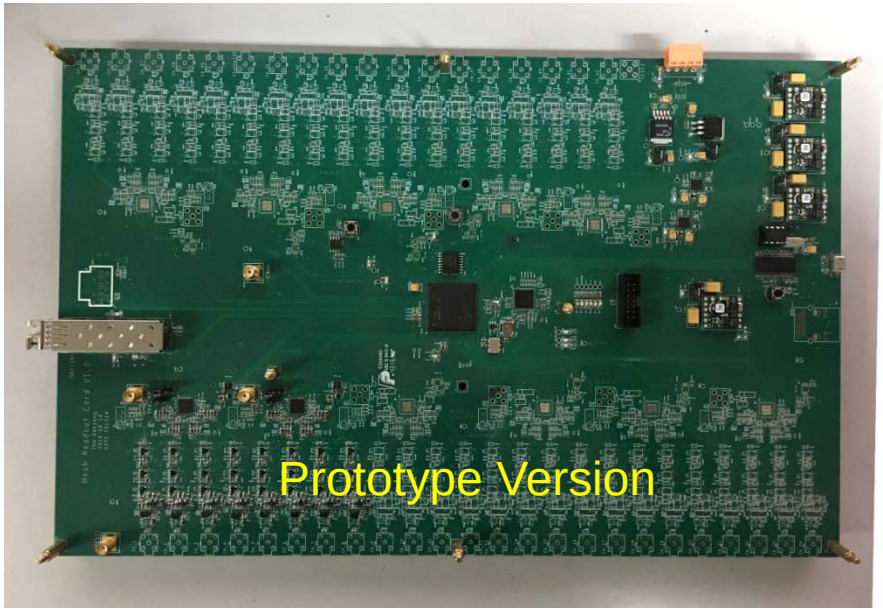
Design of FEC module





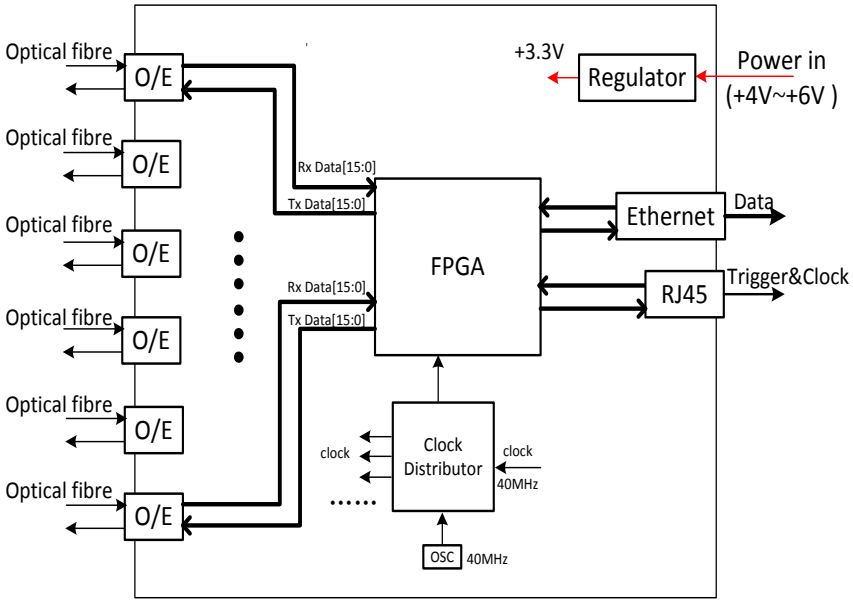
Design of MRC module

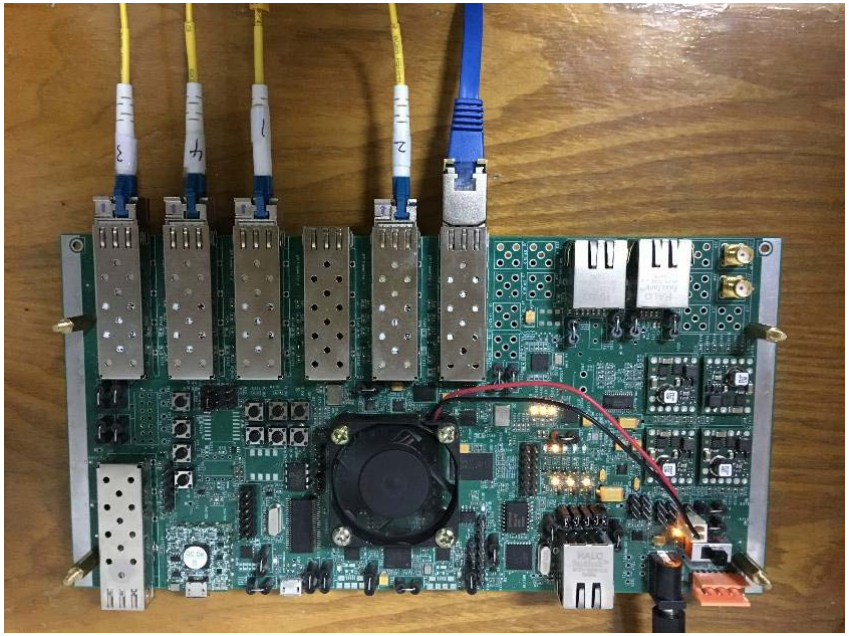




Design of a prototype DAQ module

- A simplified version to verify the design concept of back-end electronics
- To operate together with FEC and MRC for the test of TPC R&D

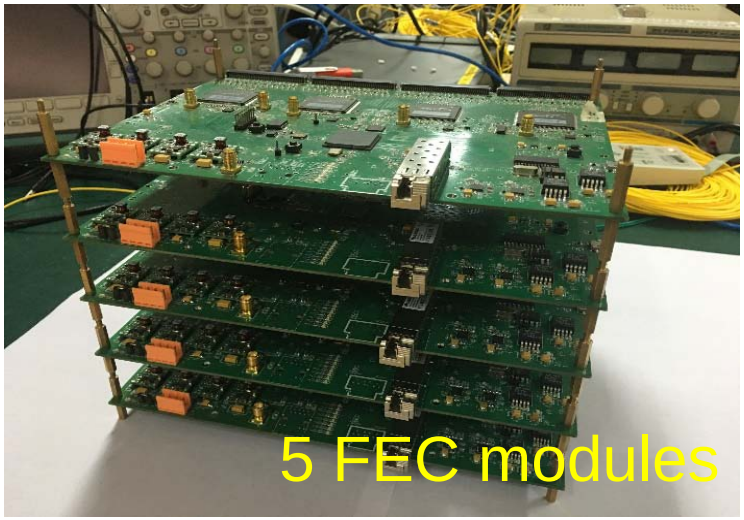


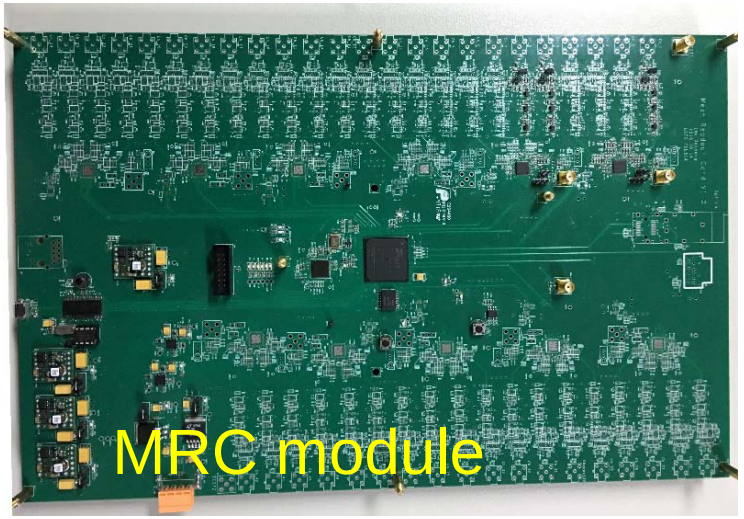


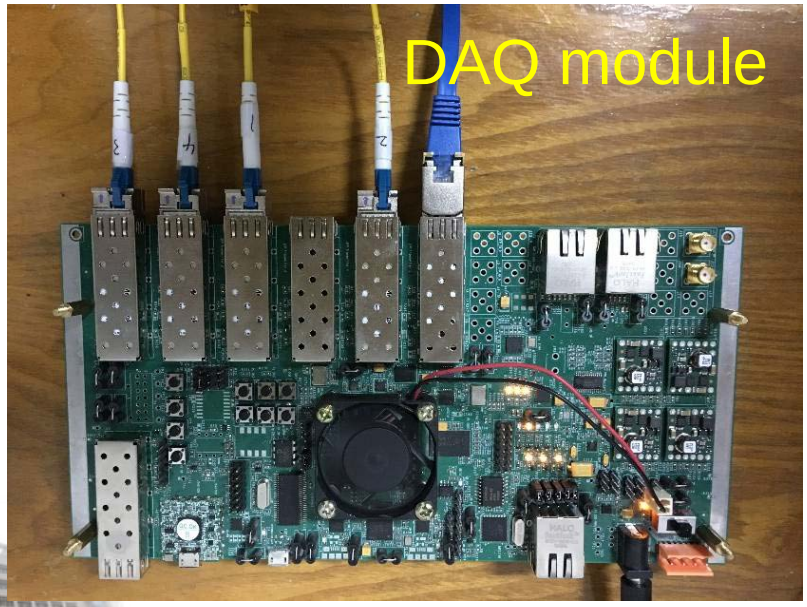
- 6 fiber interface with FEC
- 1 Gb ethernet interface with PC

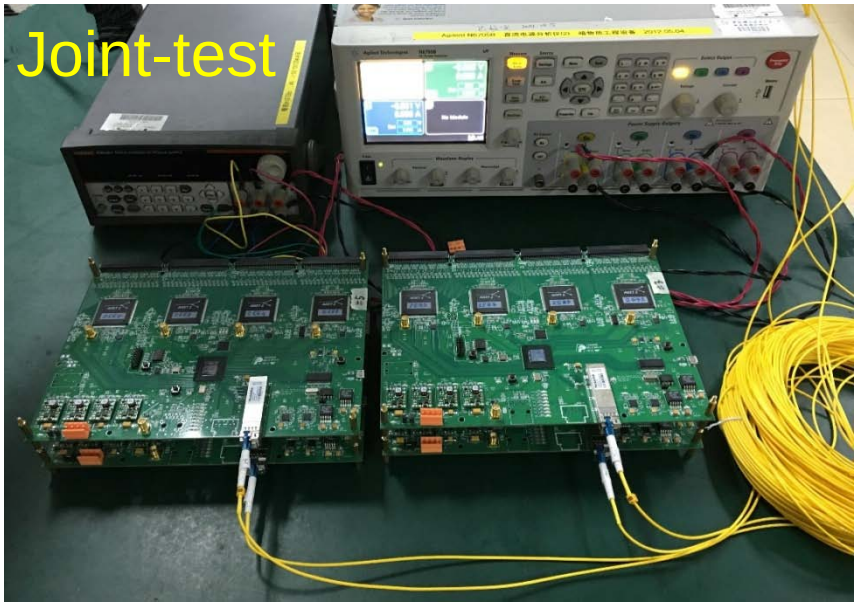
CHENG LI, Design of the FPGA-based Gigabit Serial Link for PandaX-III Experiment, TIPP2017 poster

Mass product





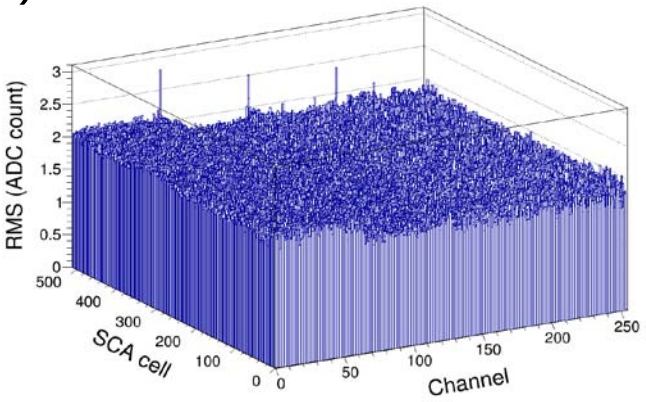




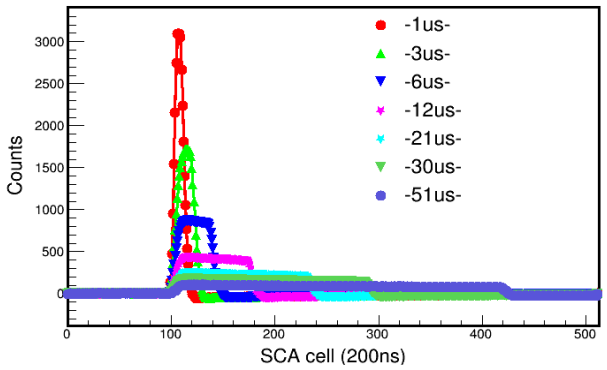
Some results of electronics tests

- FEC
  - Noise: 0.7fC +0.01fC/pF (@1pC input range)
  - INL: ~1%
- MRC：
  - Noise <1.25fC (@10pC input range)
- DAQ
  - BER<10^{-13} (48 hrs)

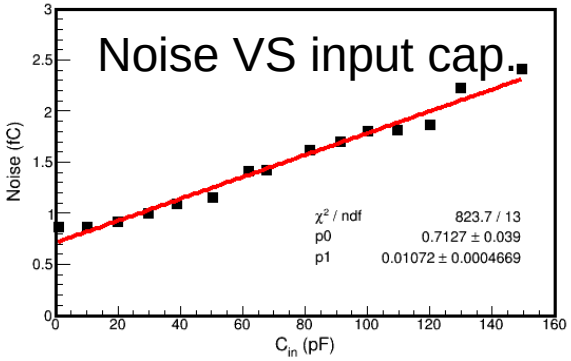
Noise level uniformity



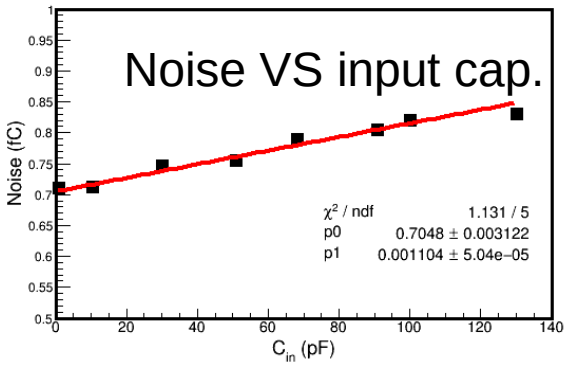
FEC module



FEC module



FEC module

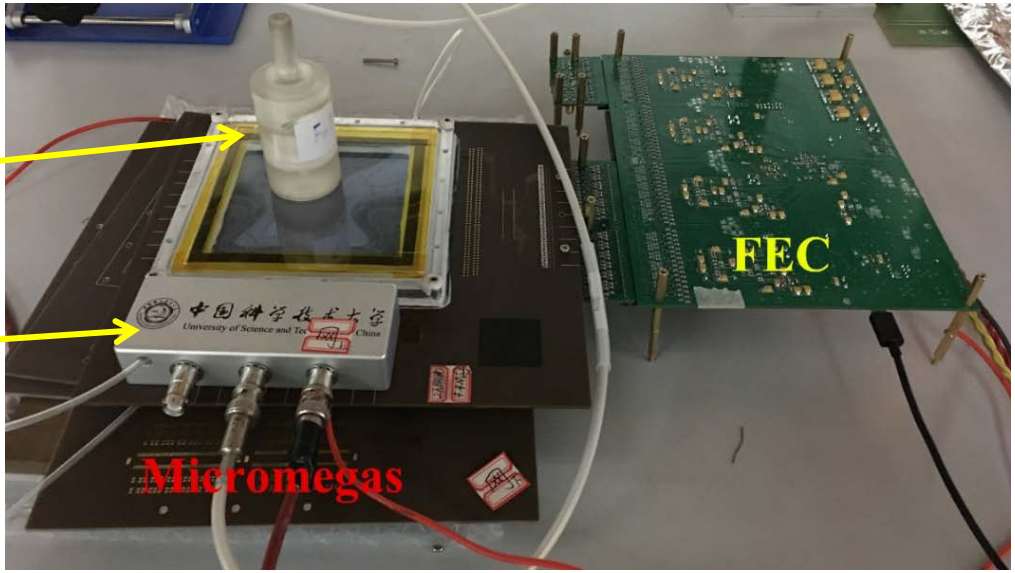


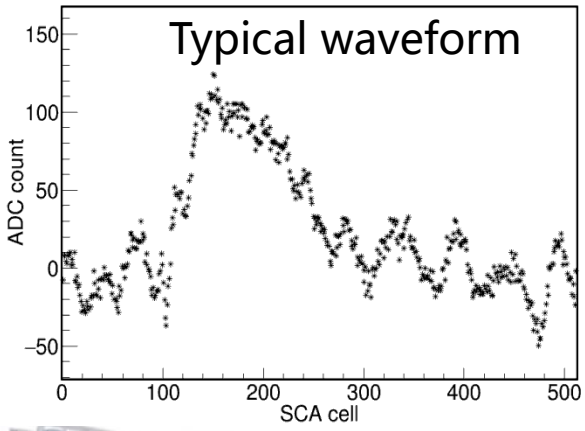
MRC module

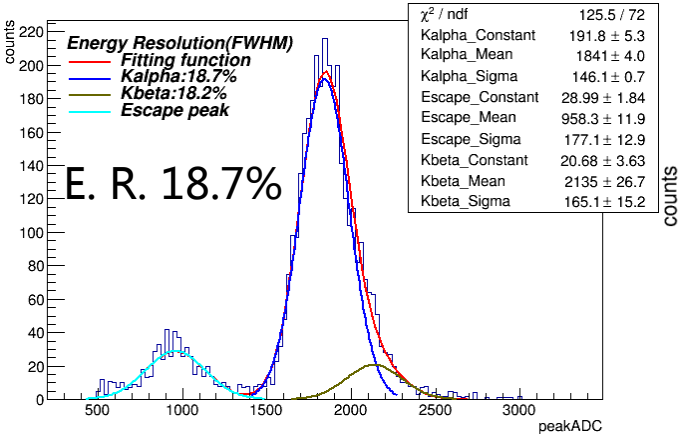
Joint test with Micromegas at USTC

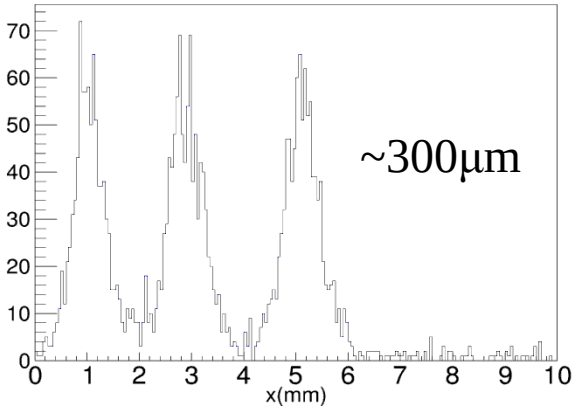
^{55}Fe source

Resistive Micromegas

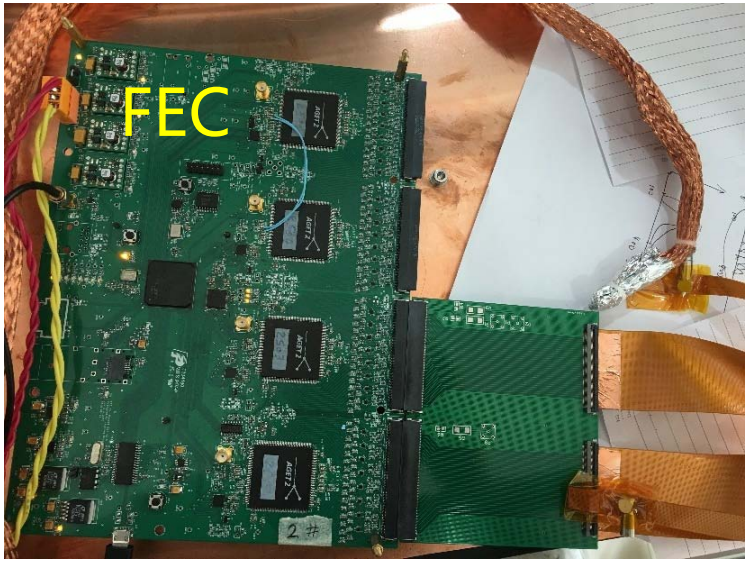




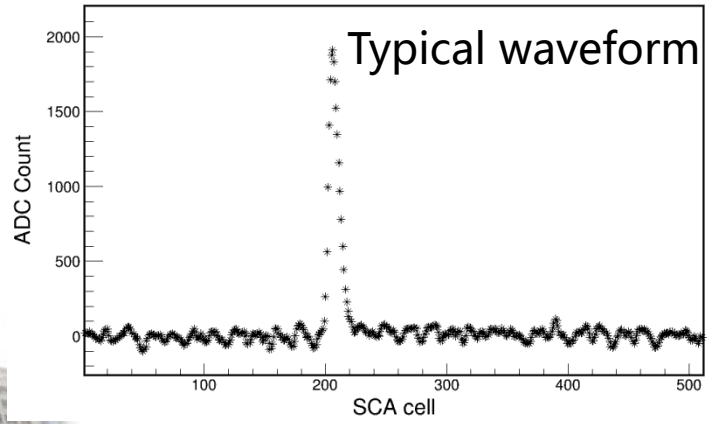


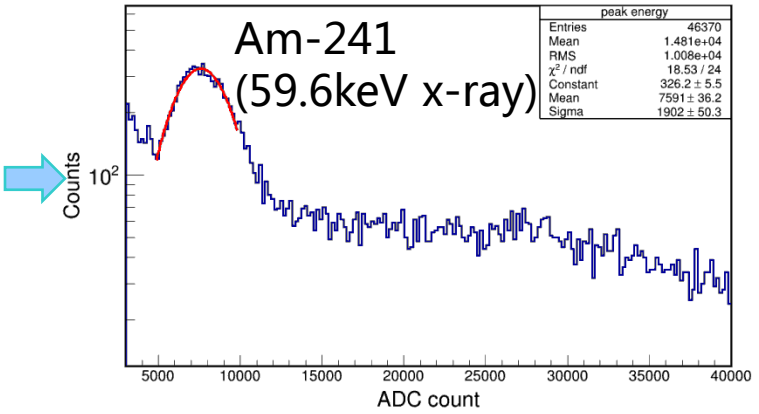


Initial joint test with prototype TPC at SJTU



Gas: Ar + C_4H_{10} (2 bar)





Summary

- Prototype design of PandaX-III readout electronics has been finished.
- A small system of the readout electronics has been setup
  - with 5 FEC +1 MRC +1 DAQ (>1280 channels)
  - Meet the test requirements of PandaX-III TPC R&D and construction process
- Joint test with PandaX-III prototype TPC is ongoing…
  - Preliminary results show that the readout electronics performs well
- Next step: engineering design will be carried out soon

Thank you !