SHANGHAI JIAO TONG UNIVERSITY

PANDA X

PARTICLE AND ASTROPHYSICAL XENON TPC

PandaX-III High Pressure Gas TPC and its Prototype

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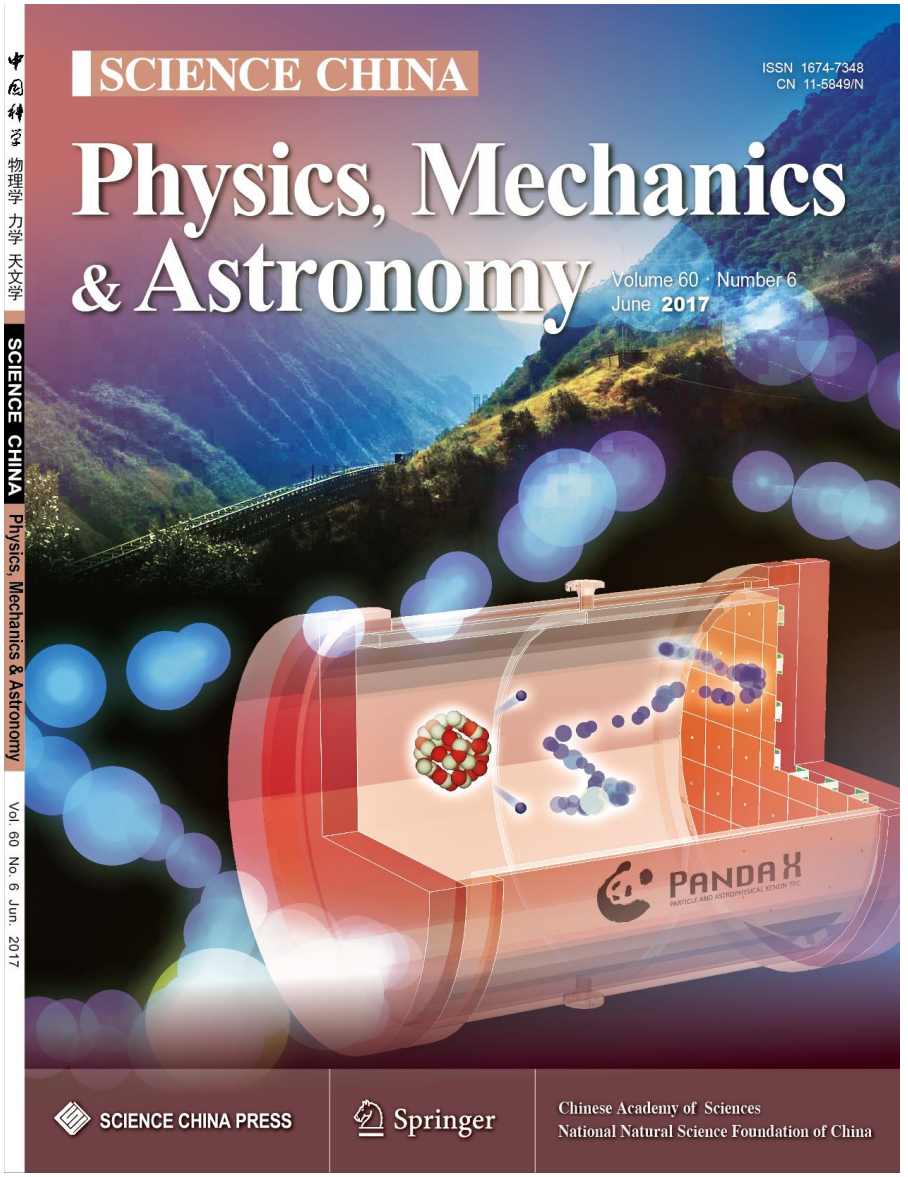
On Behalf of the PandaX-III Collaboration

May 25, 2017

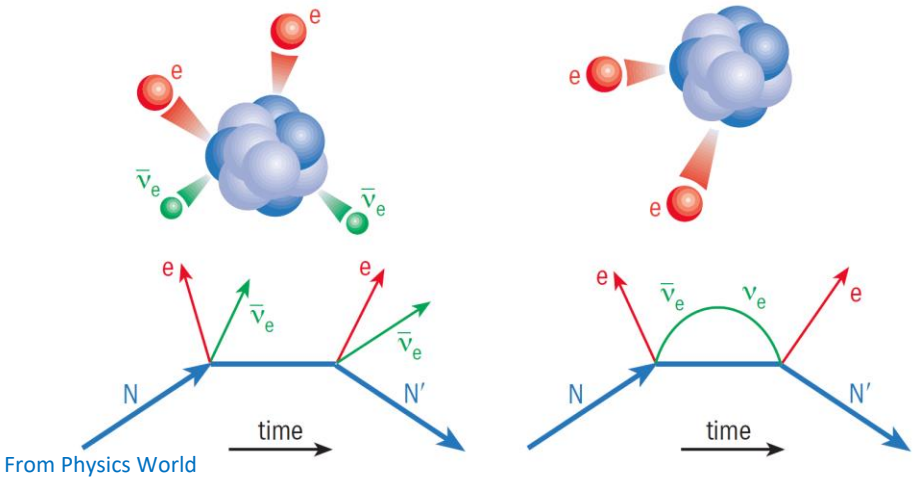
Outline

- PandaX-III project overview
- Design features and physics sensitivity
- Micromegas for PandaX-III
- Prototype TPC under commissioning

More details from our CDR:
SCIENCE CHINA Physics, Mechanics & Astronomy 60(6), 061011(2017)
ArXiv:1610.08883



Detection of double beta decay



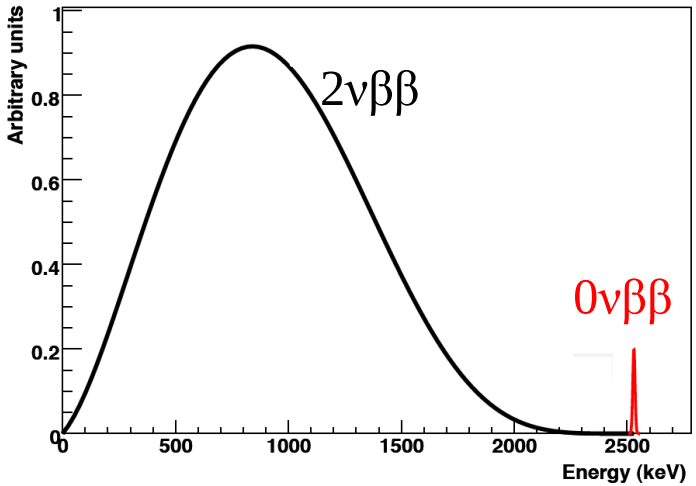
From Physics World

Majorana Neutrino $\bar{\nu} = \nu$

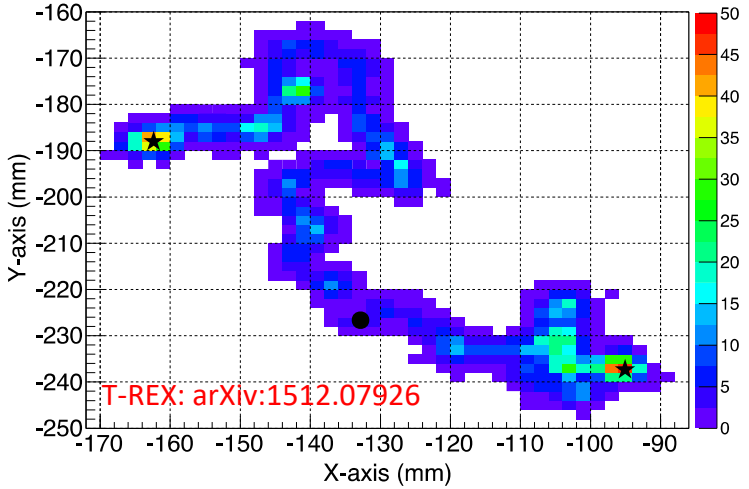
- Example:

$$^{136}Xe \rightarrow {}^{136}Ba + 2e^- + (2\bar{\nu}_e)$$

- Measure energies of emitted e$^-$
- Electron tracks are a huge plus
- Daughter nuclei identification



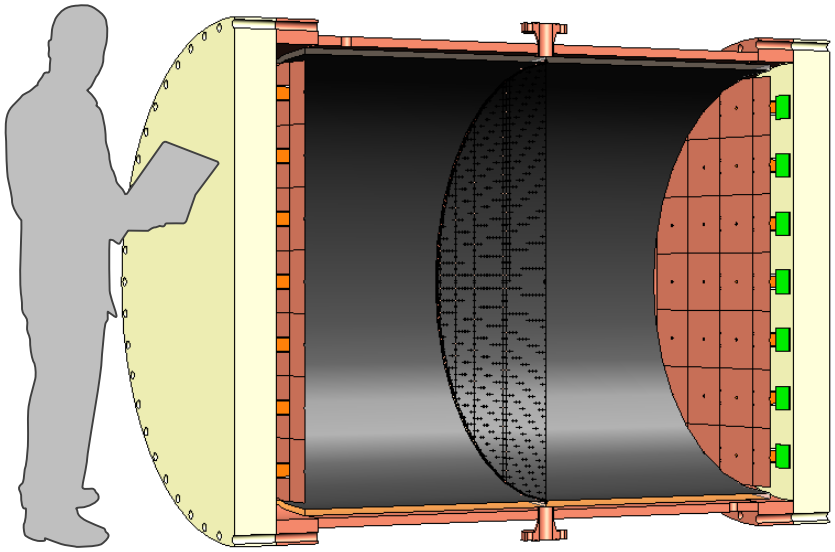
Sum of two electrons energy

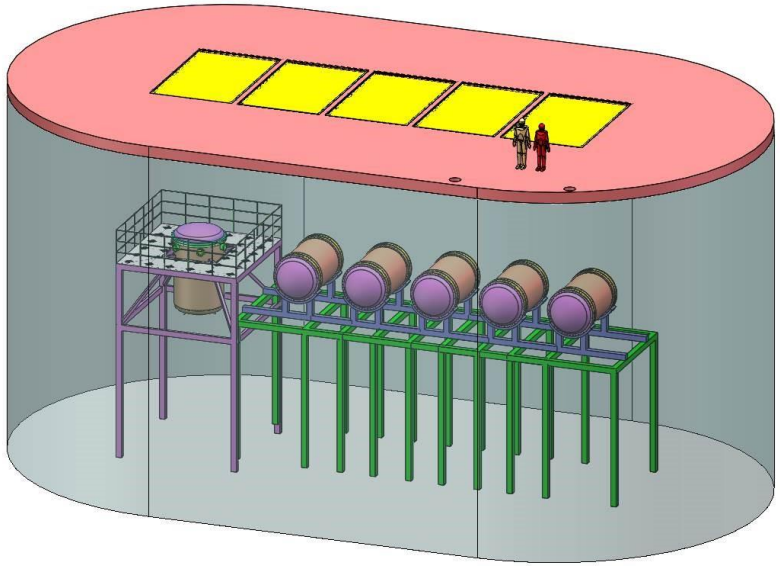


Simulated track of 0νββ in high pressure Xe

PandaX-III: high pressure xenon gas TPC for 0νββ of ^{136}Xe

- TPC: 200 kg scale, symmetric, double-ended charge readout with cathode in the middle
  - Charge readout plane: tiles of microbulk Micromegas (MM) modules with X, Y strips
- Four more upgraded modules for a ton scale experiment
- @ Hall #B4 at China Jin Ping underground Lab (CJPL-II).
- Main design features: good energy resolution, good tracking capability, and low background.





6 m water shielding

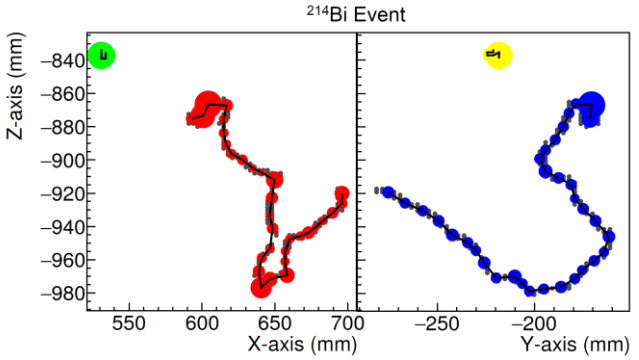
Background budget and projected sensitivity

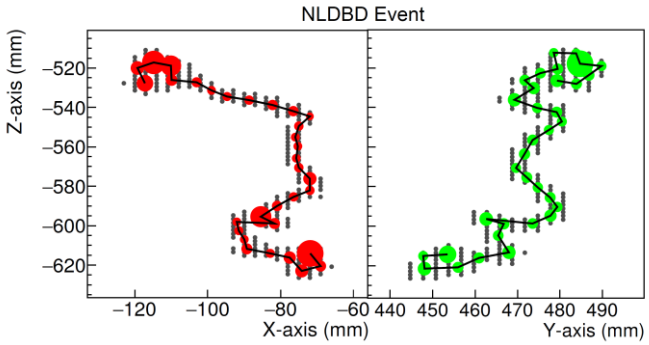
Background rate: 1 x 10^{-4} c/keV/kg/y in the ROI

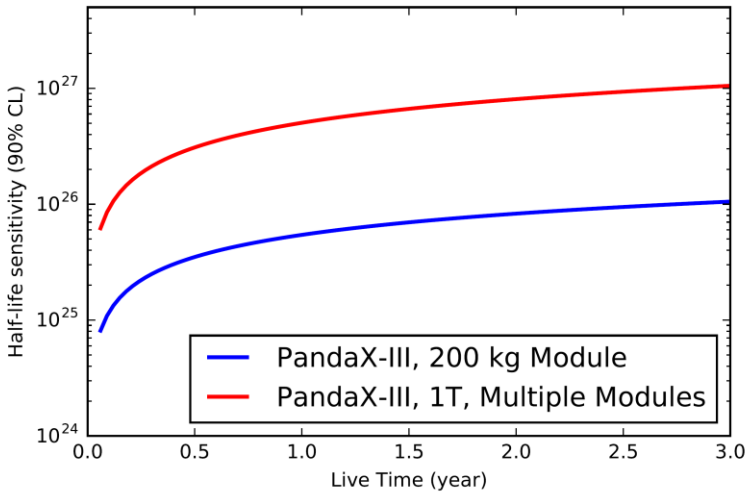
- Two independent Geant-4 based MC packages: RESTG4 and BambooMC
- With topological analysis

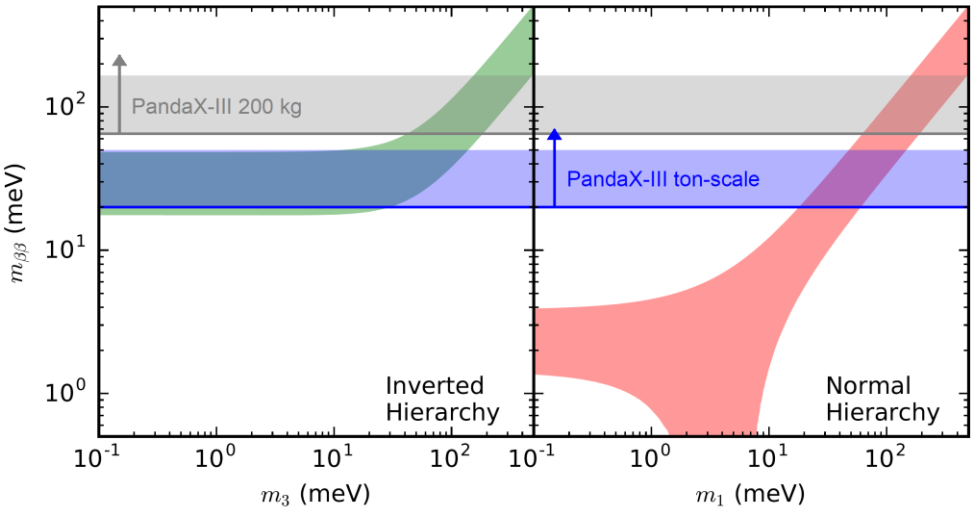
Sensitivity of the first 200 kg module:

- 10^{26} year half-life limit
- 65 – 165 meV $m_{\beta\beta}$

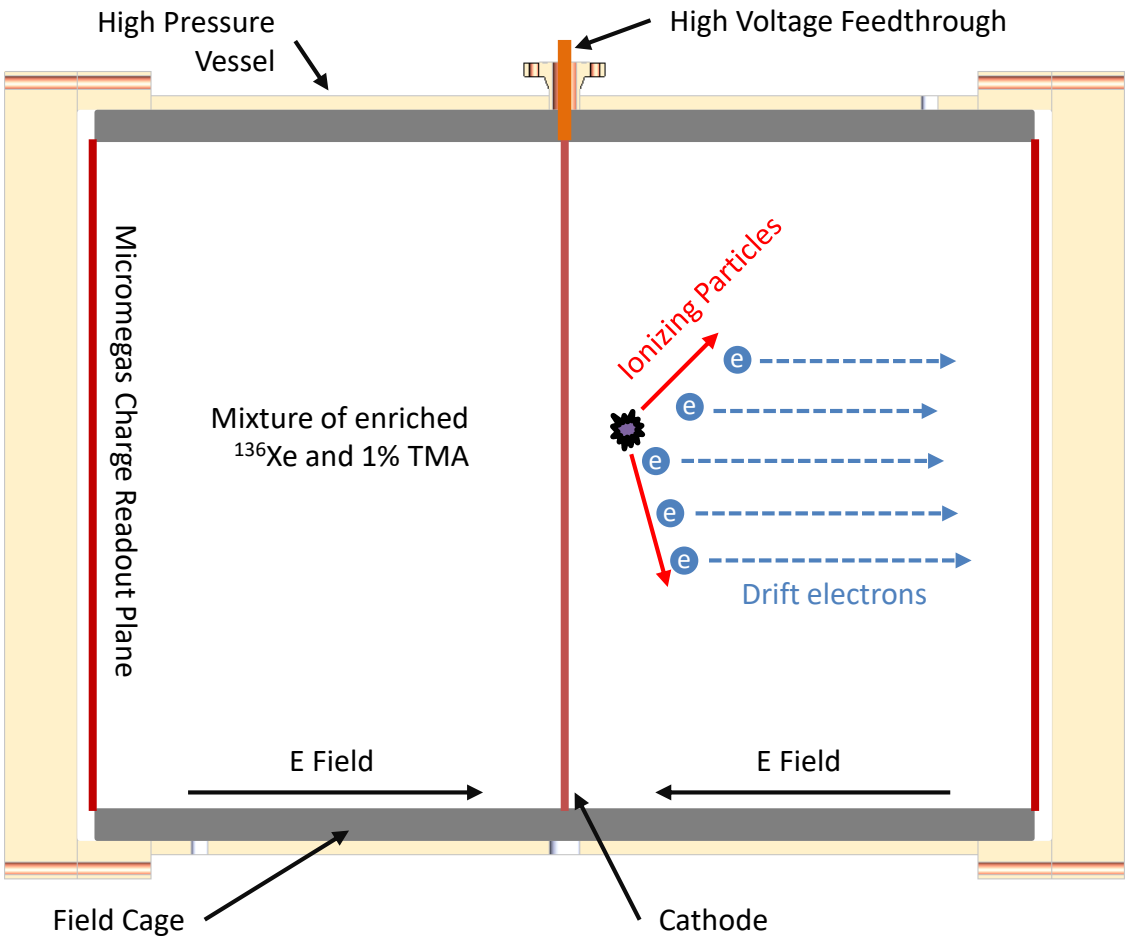








PandaX-III TPC illustrated



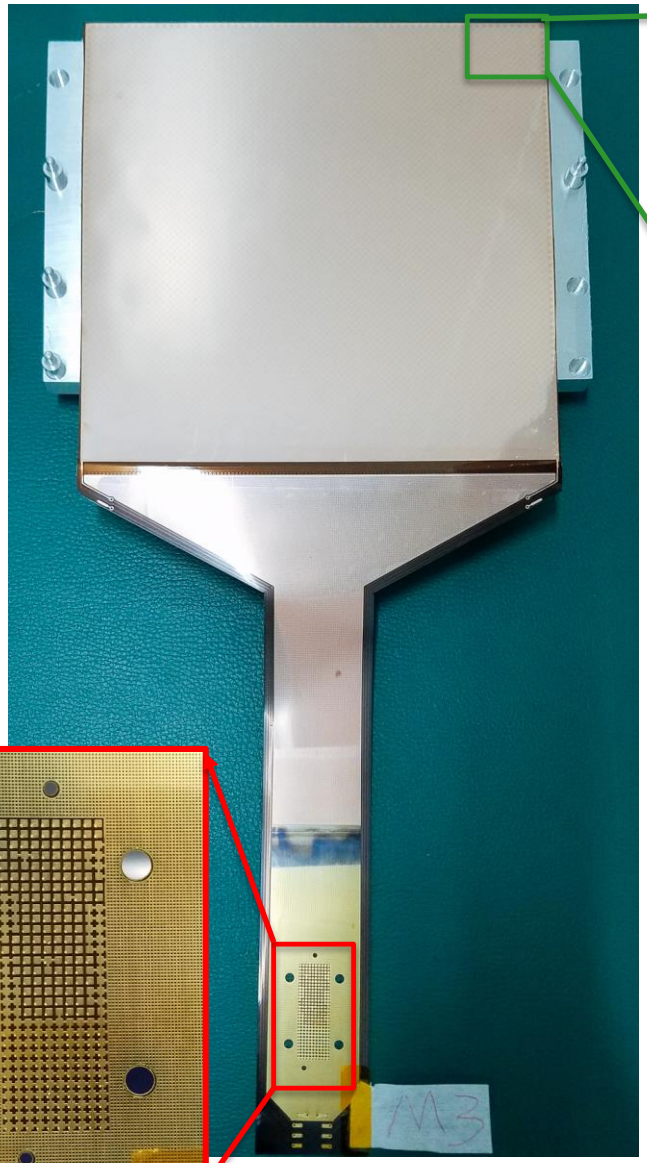
PandaX-III TPC is unique:

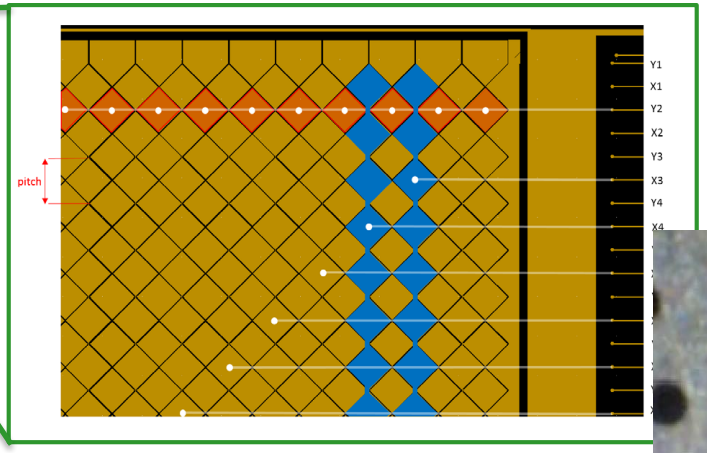
- Radio-purity
- Energy resolution
- High pressure

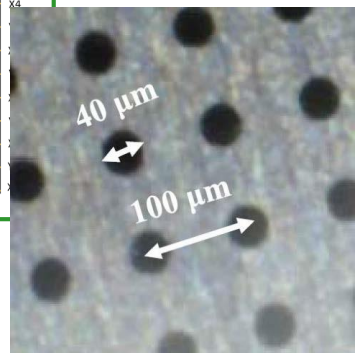
Shared TPC technology:

- Micromegas
- Electronics
- Energy and track reconstruction

Microbulk MicroMegas (MM)



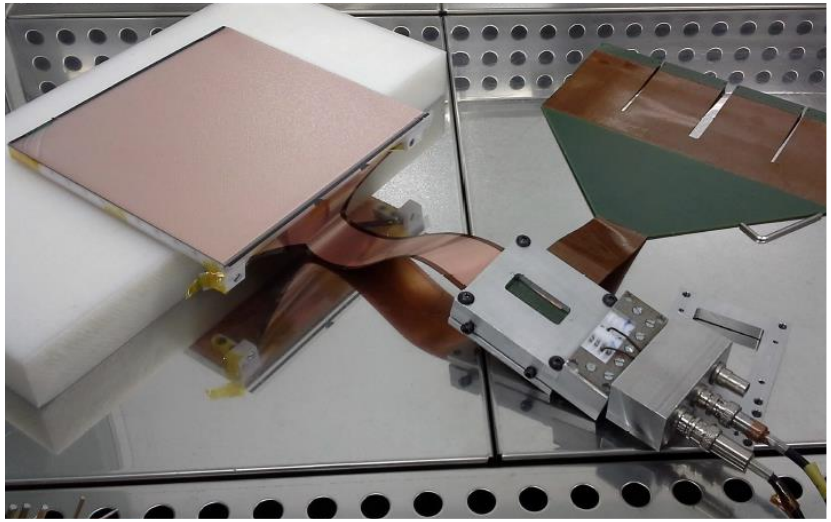


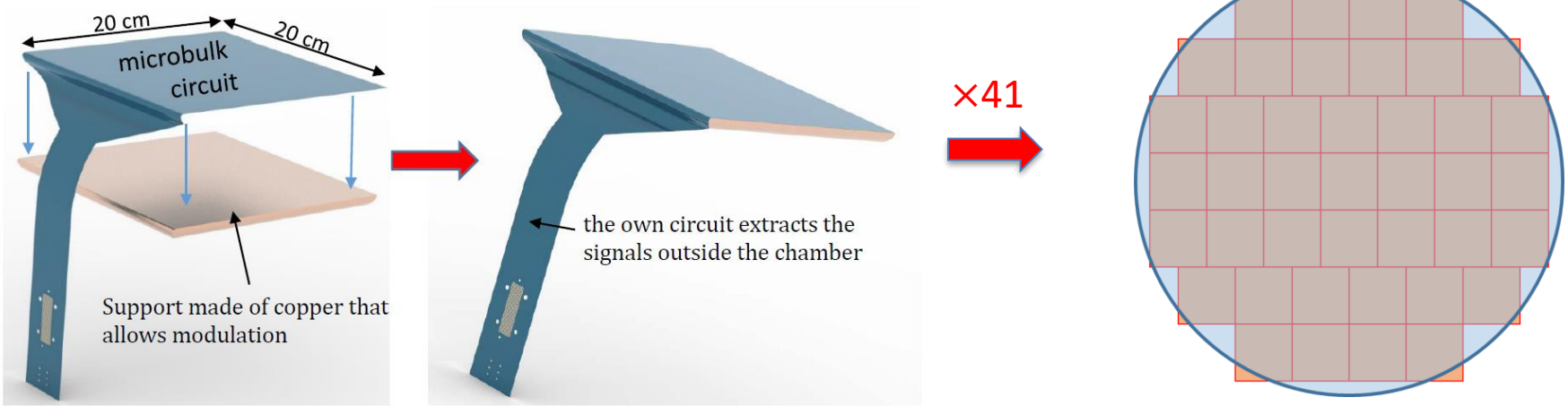


- Microbulk MicroMegas films made of Copper and Kapton only
  - Perfect for radio-purity purpose
- XY strip readout
- ~ 1000X gain
- 3% energy resolution expected at 2.5 MeV.

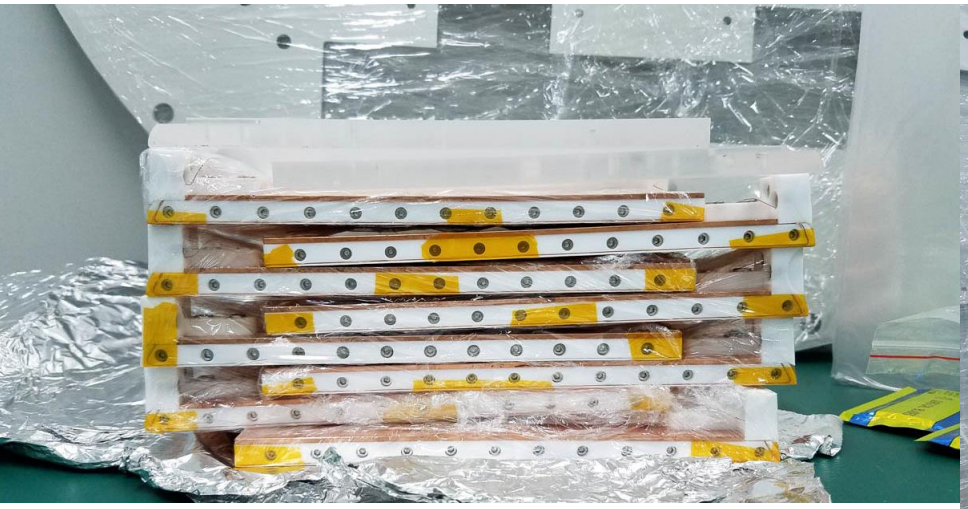
Scalable Radio-pure Readout Module (SR2M)

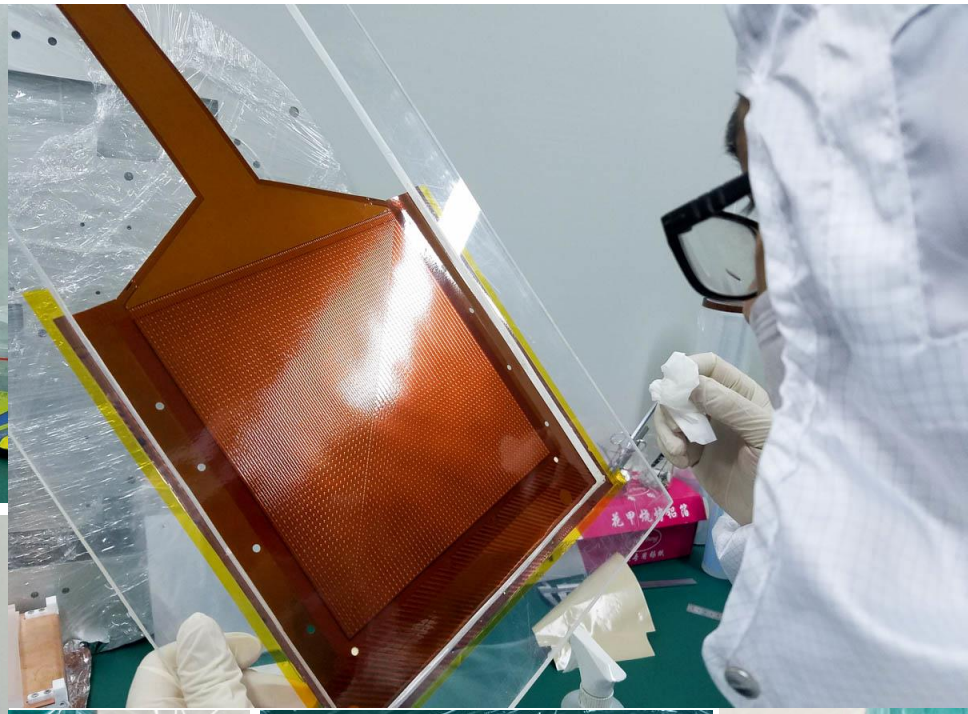
- SR2M: Mosaic layout to cover readout planes
  - Solderless system
  - Strip and mesh signal readout
  - Dead-zone-free arrangement
  - Designed by Zaragoza and SJTU
- Eleven MM films produced at CERN
  - 20 by 20 cm
  - 3 mm pitch size, 128 strip readouts

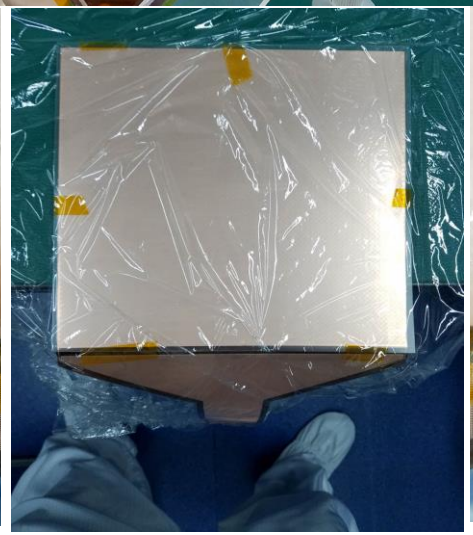




From MM films to SR2M



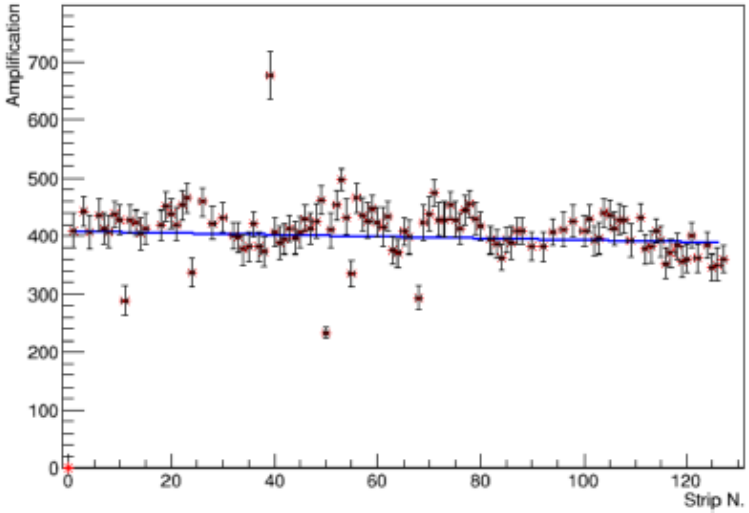


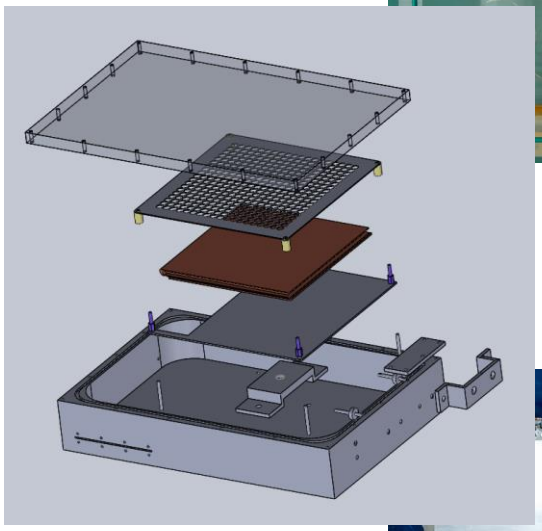


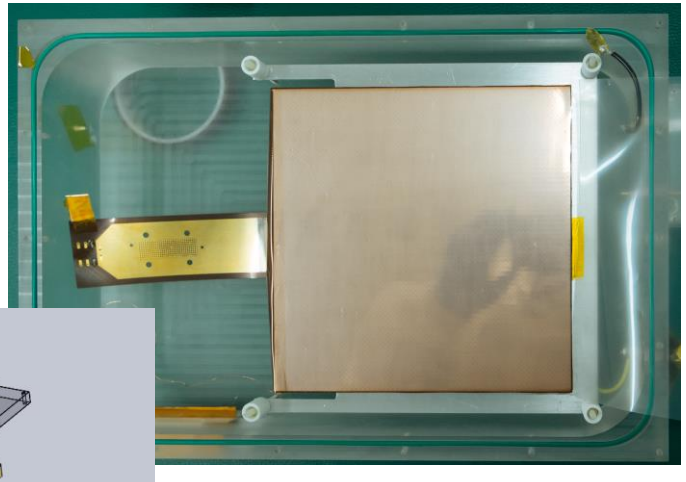
MM Characterization

Gain and gain uniformity measured

- Argon + CO_2 (30%)
- 1 bar flowing gas
- 7.5% RMS uniformity
- Dead channels

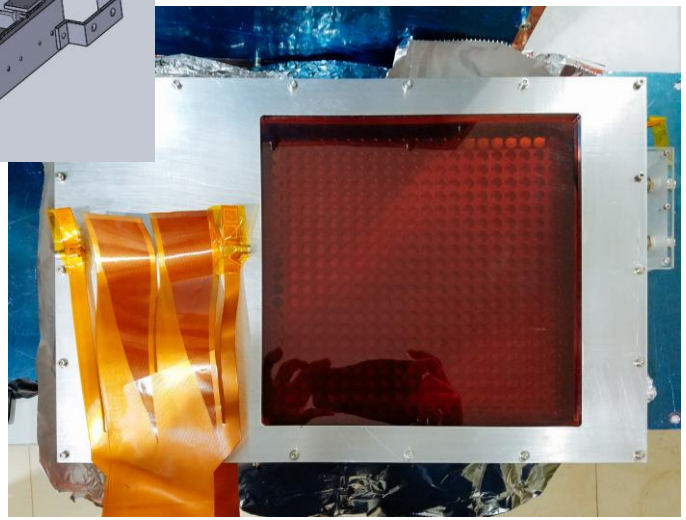






Without

with cathode, top lid

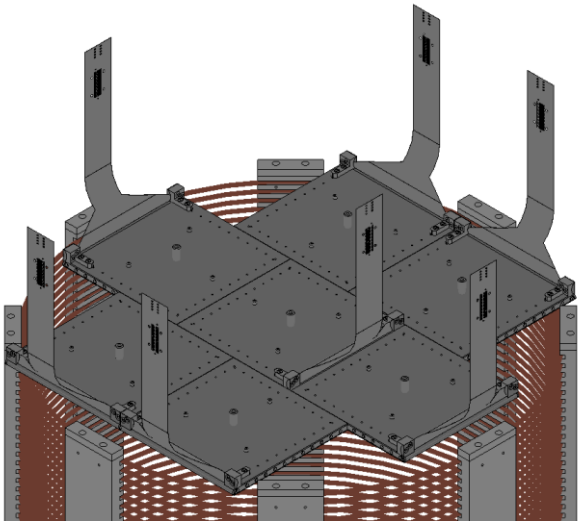


Future updates:

- Motorized source scanning
- More uniform drift field
- Pressurized xenon gas
- Multiple MM cross comparison

Prototype TPC at SJTU

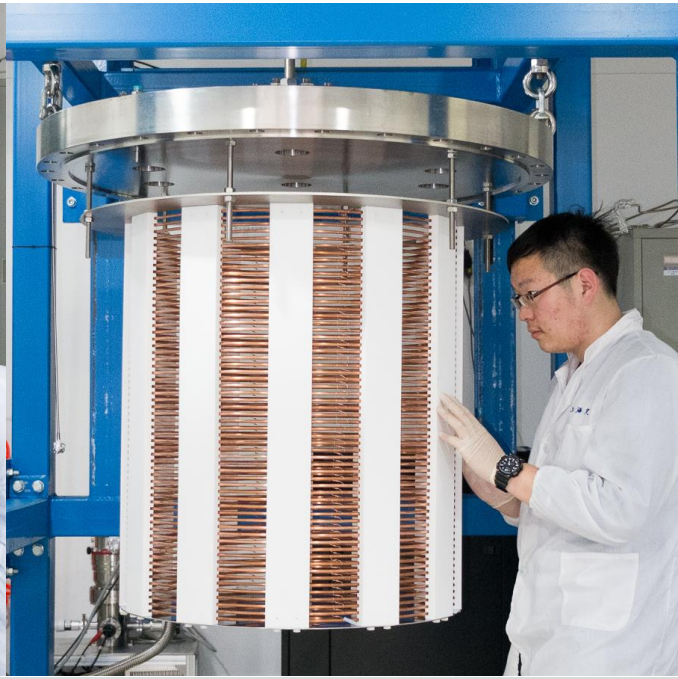
- To optimize the design of Micromegas readout plane
- To optimize the energy calibration of TPC
- To develop algorithm of 3D track reconstruction
- To explore the impact of t_0 with light readout
- To test custom electronics*



More details, see:

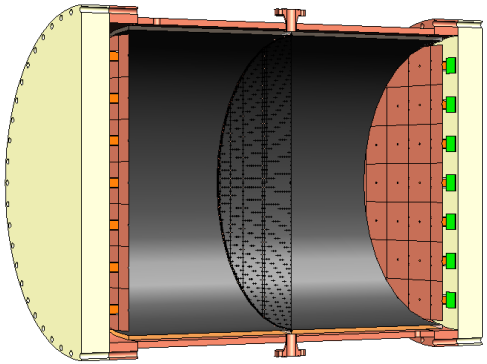
Talk: Changqing FENG, Progress of PandaX-III readout electronics (Thursday R3 11:18)

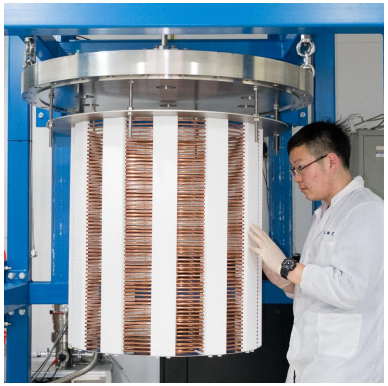
Poster: Cheng LI, Design of the FPGA-based Gigabit Serial Link for PandaX-III Experiment



200 kg module vs prototype

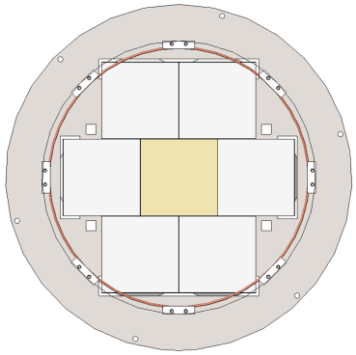
	First 200 kg module	Prototype TPC
Design	Symmetric	Single-ended
Active volume	~3.5m^3	0.25m^3
Number of MM	82	7
Readout channels	10496	896
Electronics	AGET + Custom FEC	ASAD/CoBo; then Custom FEC
HP vessel	OFHC copper	Stainless Steel
Field cage	2π acrylic wall with resistive film	Copper rings with Teflon bars

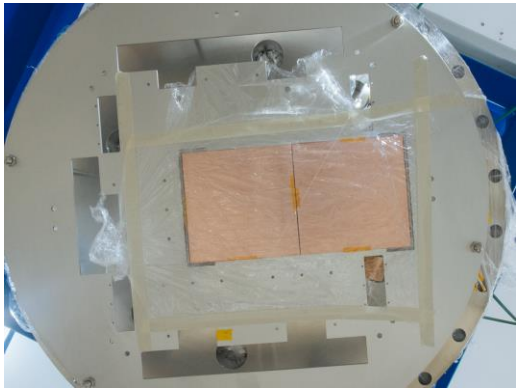


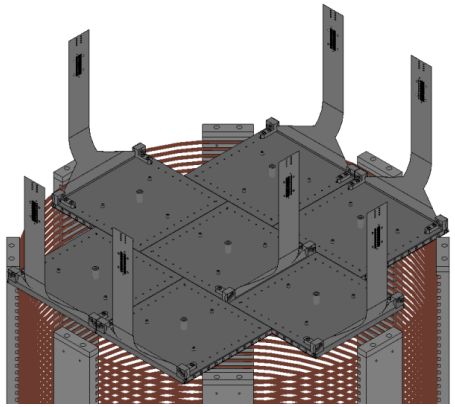


Progress towards prototype

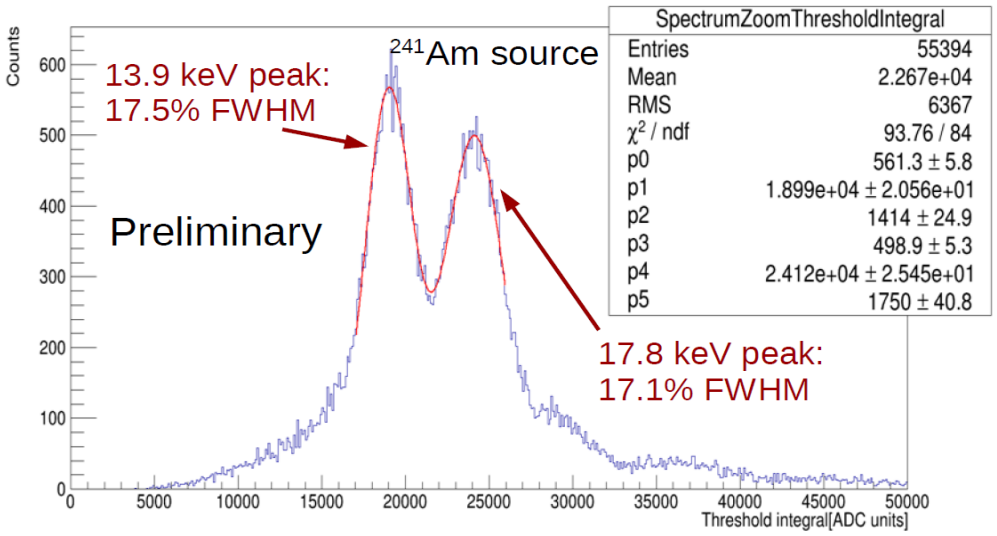
	1 MM run	2 MM run	Full Prototype
Number of MM	1	2	7
channels	128	256	896
Gas medium	Ar/CO_2, Ar/Iso,	+ Xenon/TMA	+ Xenon/TMA
Pressure	Up to 5 bar	Up to 10 bar	Up to 10 bar
Calibration	Internal ^{241}Am	+ Motorized ^{55}Fe	+ External ^{232}Th
Electronics	ASAD/CoBo	ASAD/CoBo	+ Custom FEC
Status	Done; data analysis	Data taking	Next month

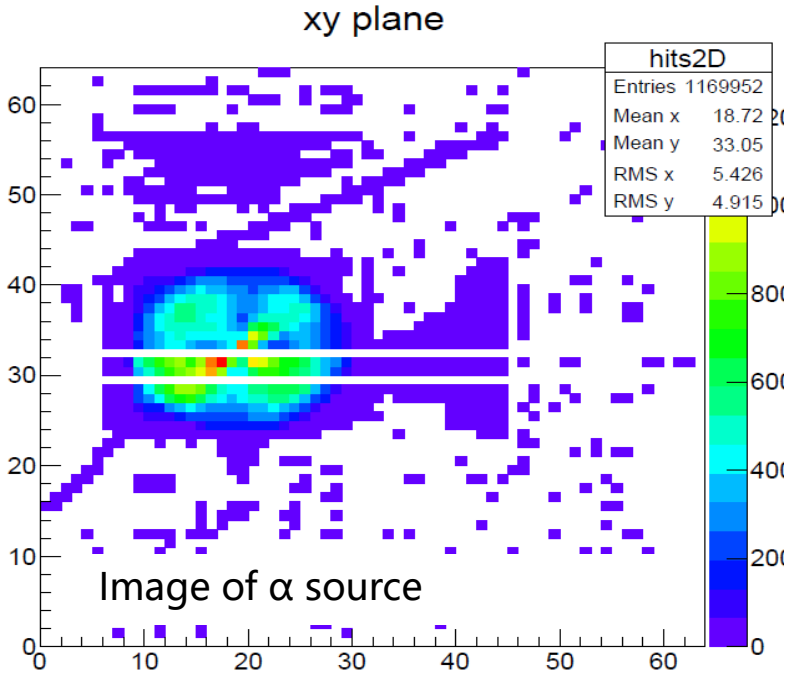




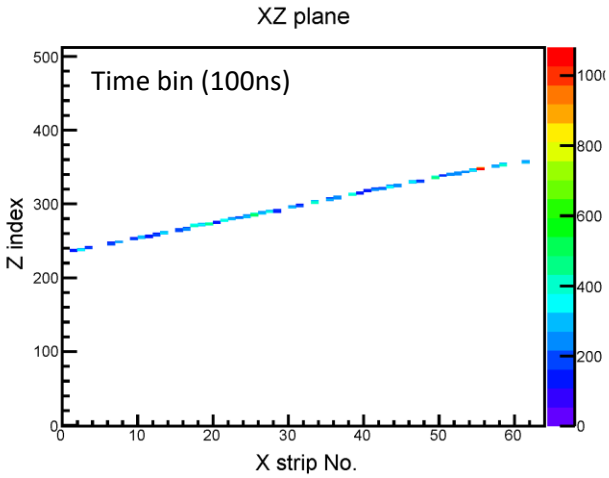


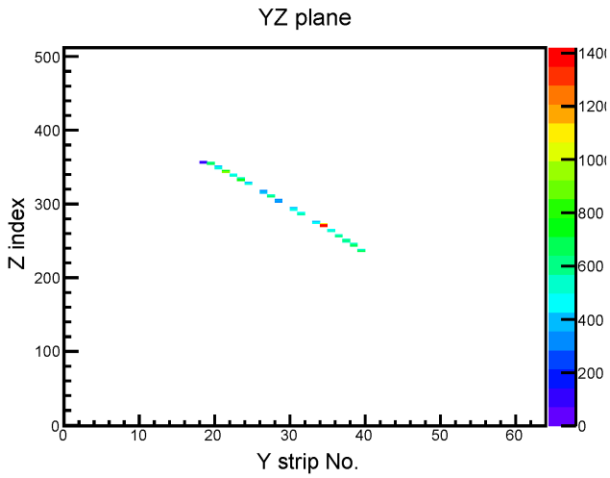
Data from prototype TPC – 1MM (PRELIMINARY)

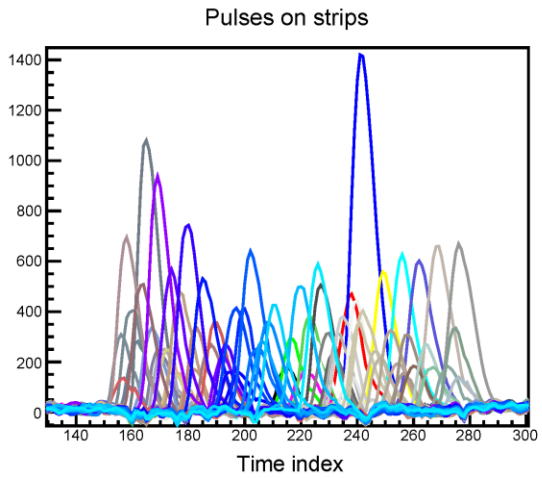




Muon track

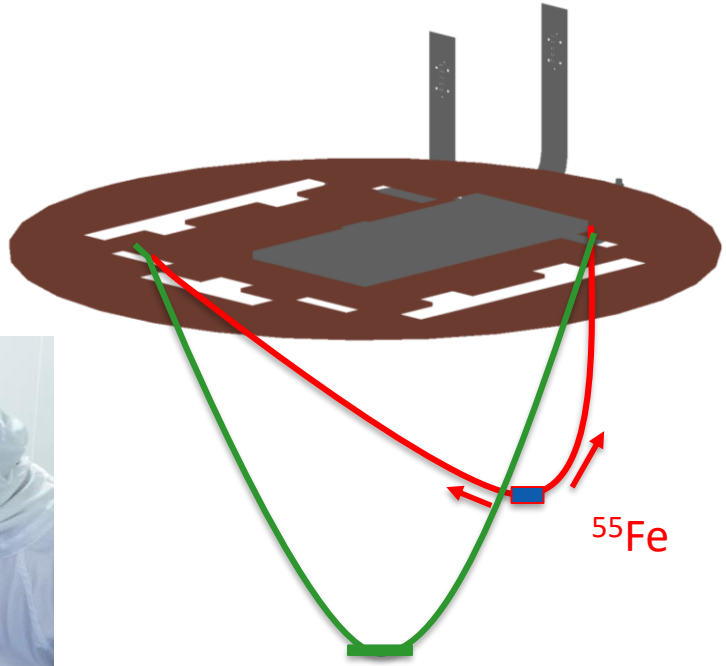


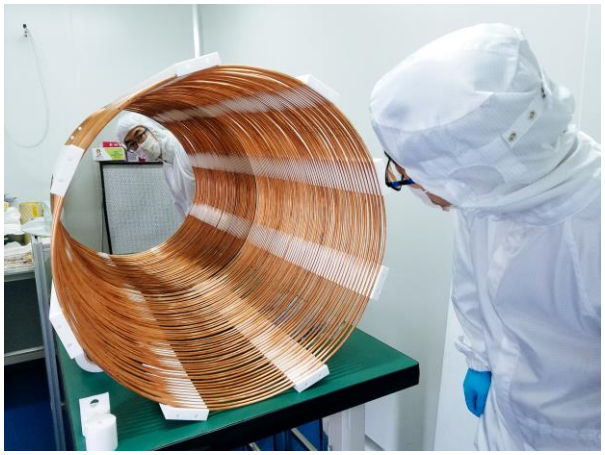


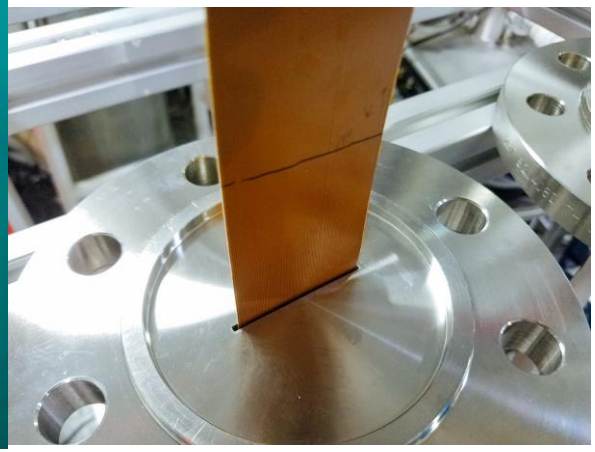


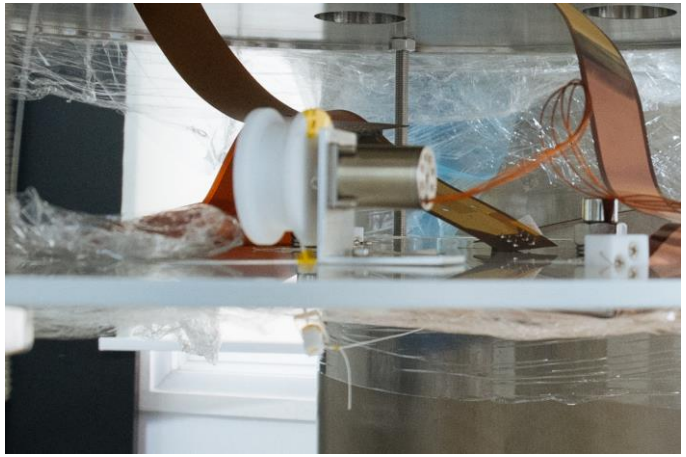
Commissioning the prototype TPC – 2MM

- Better calibration
- Cleaner TPC
- Better signal feedthrough



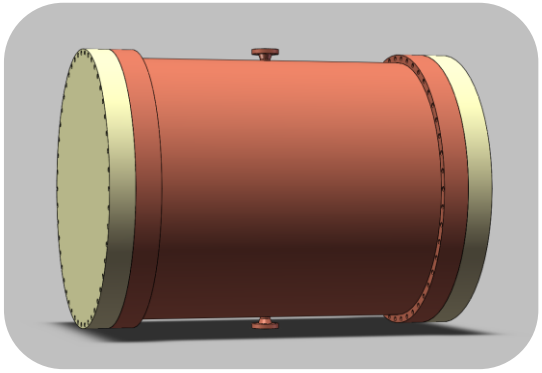




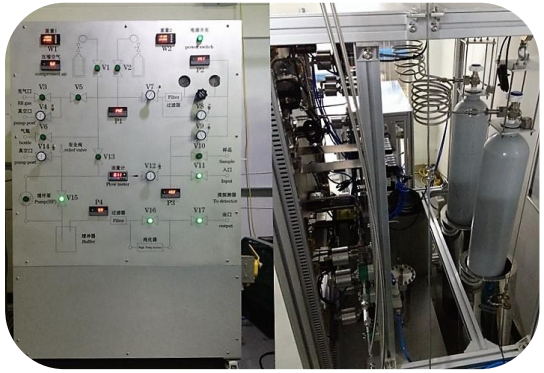


Other critical pieces of PandaX-III

145 kg of 90% enriched ^{136}Xe at Shanghai

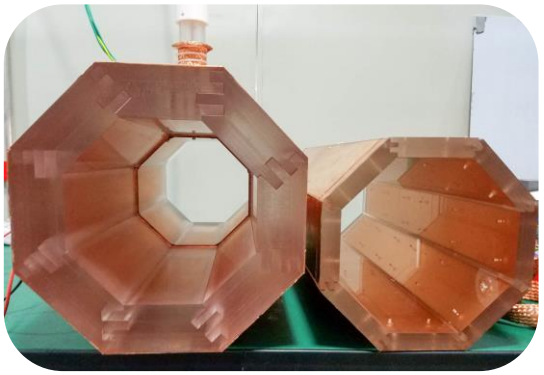


Design and Fabrication of copper vessel in progress



Gas mixing, circulation, and purification system ready

First version of FEC ready for testing with MM

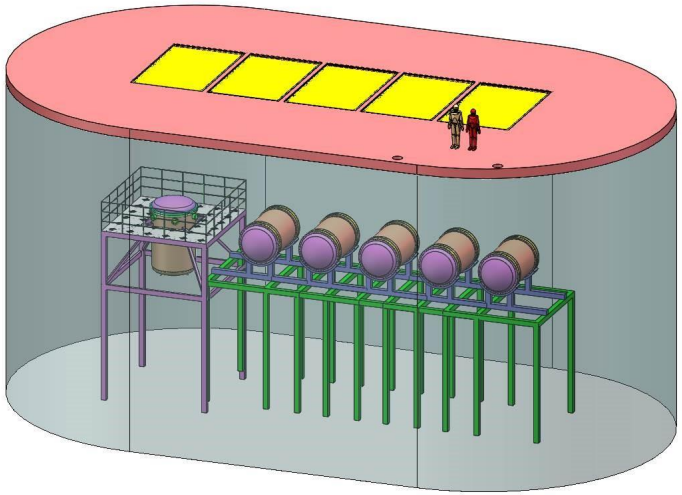


New field cage design under testing

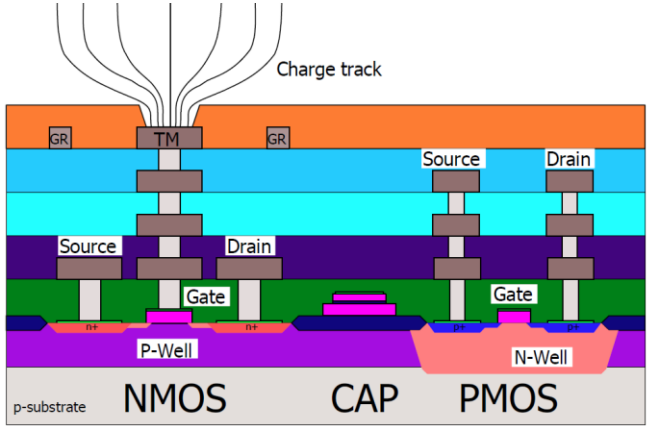
CJPL-II infrastructure under construction

Future beyond the first TPC module

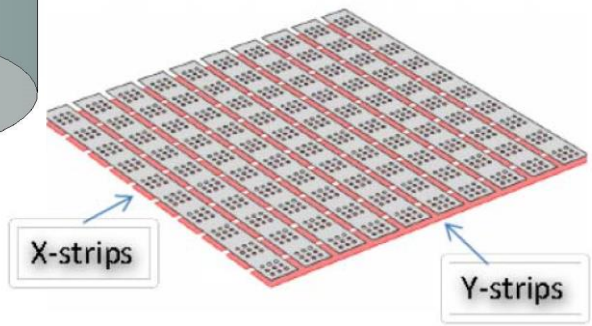
- Additional modules with upgraded options will be installed in the same water shielding pit.
  - 1% energy resolution to approach the intrinsic resolution of high pressure xenon gas with TMA
  - Better material screening
- Reaches ton-scale in 2022.

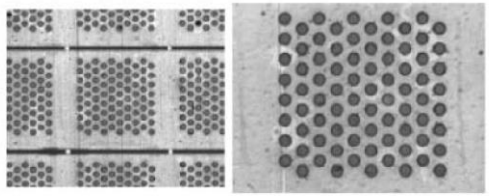


- TopMetal Direct Charge Sensor
  - Direct pixel readout without gas amplification



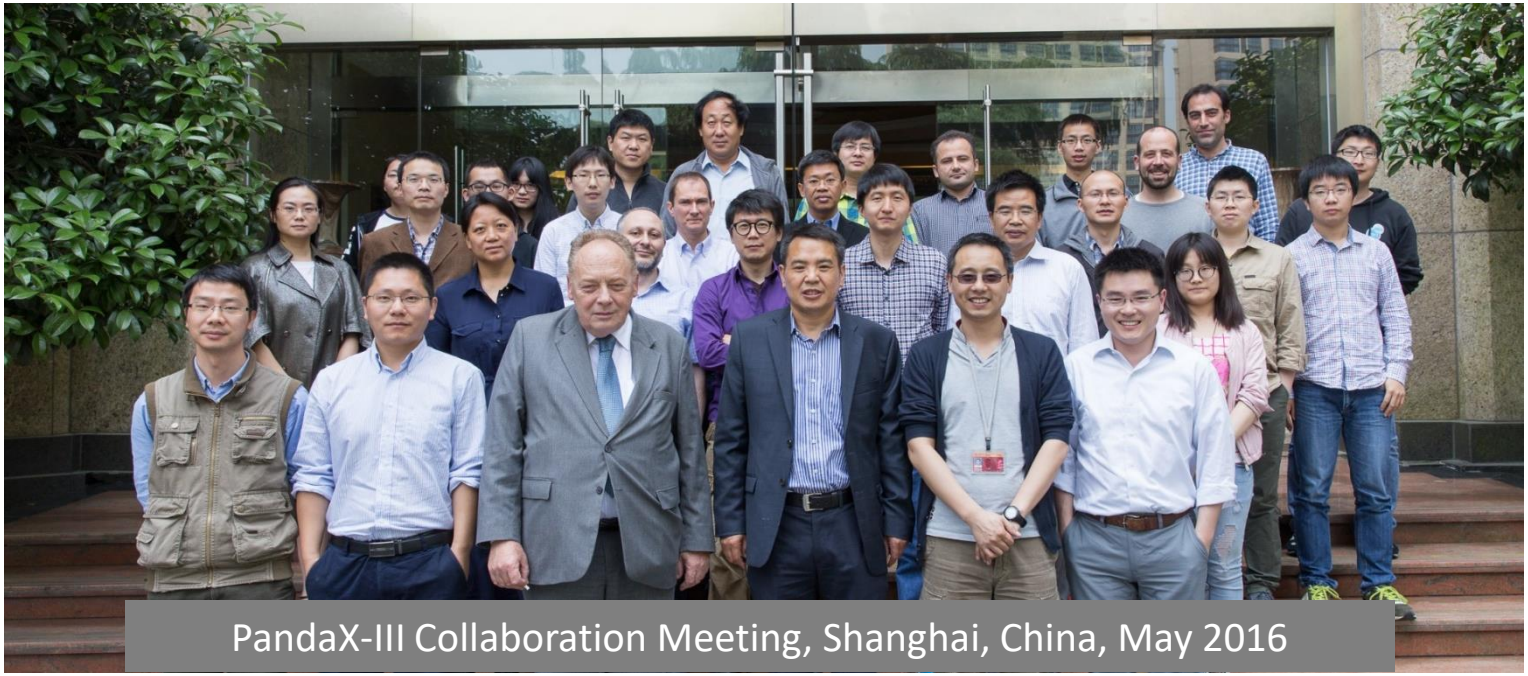
- Alternative readout technologies
  - Improvement on bulk and microbulk technologies





PandaX-III collaboration

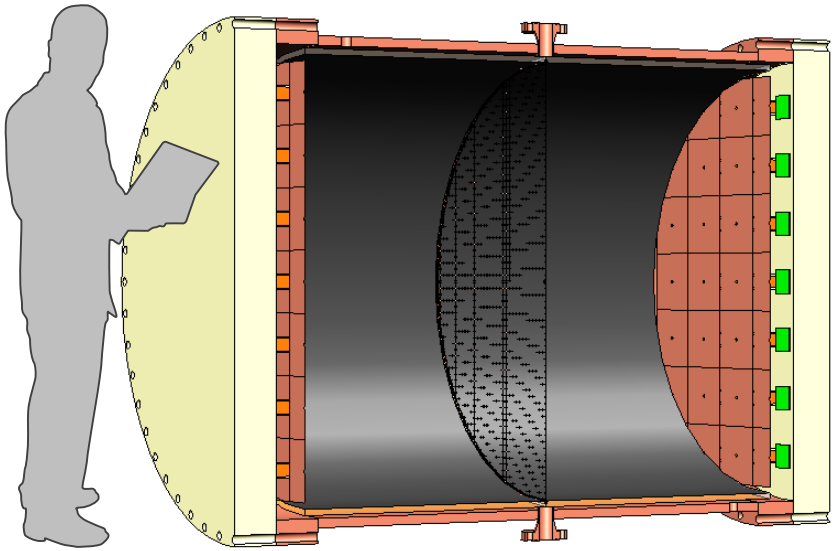
- China: Shanghai Jiao Tong University, University of Science and Technology of China, Peking University, China Institute of Atomic Energy, Shandong University, Sun Yat-Sen University, Central China Normal University
- Spain: Universidad de Zaragoza
- France: CEA Saclay
- US: University of Maryland, Lawrence Berkeley National Laboratory
- Thailand: Suranaree University of Technology

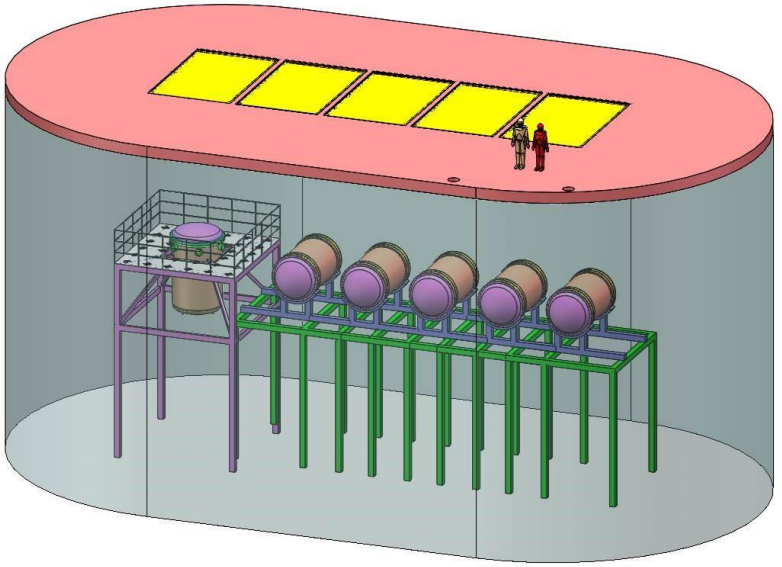


PandaX-III Collaboration Meeting, Shanghai, China, May 2016

Conclusions

- PandaX-III uses high pressure xenon TPCs to search for double beta decay
- Phased approach: 200 kg first, then ton-scale with multiple modules
- 20-kg scale prototype TPC has been built and under commissioning
- PandaX-III is an unique application of gas TPC and Micromegas





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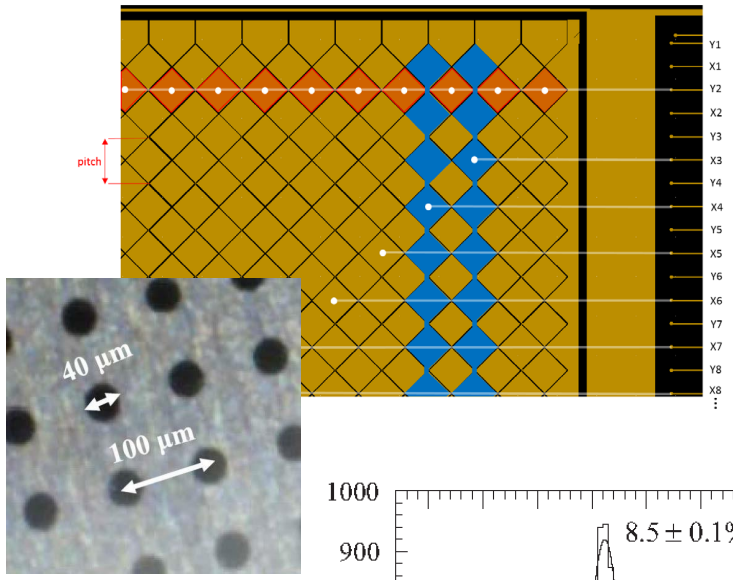
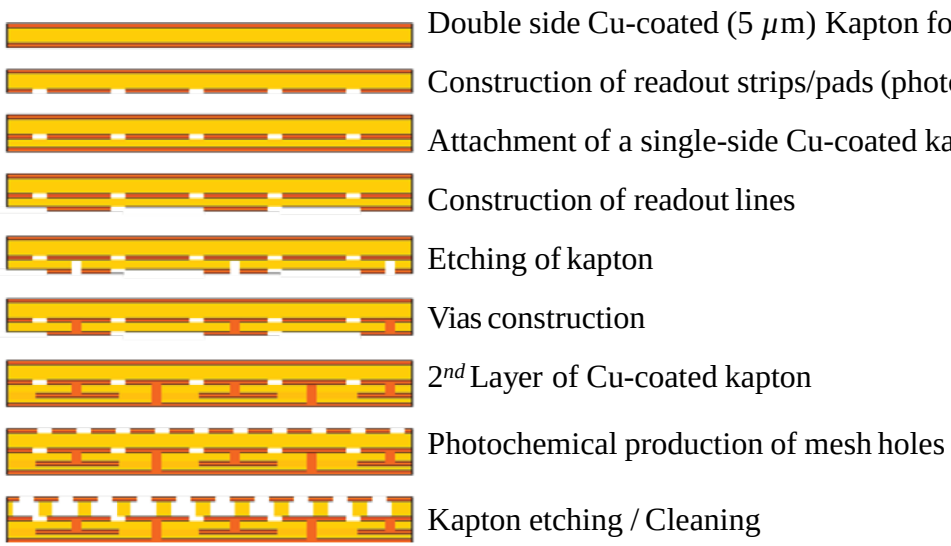
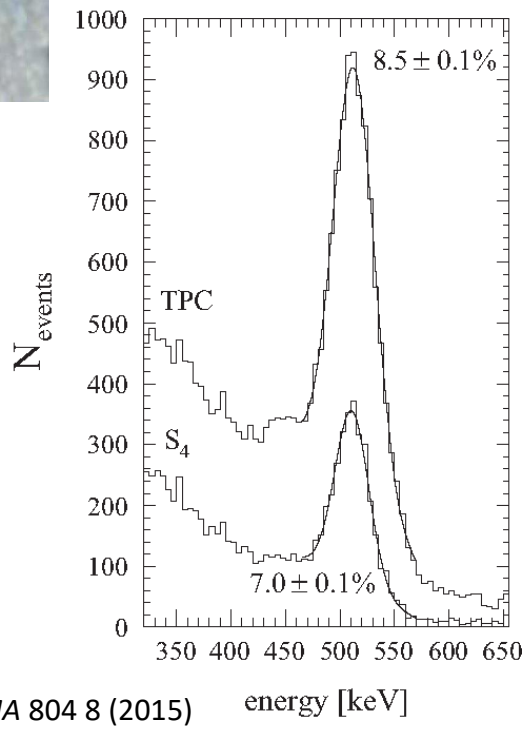
- ~ 1000X gain
- 3% energy resolution expected at 2.5 MeV.



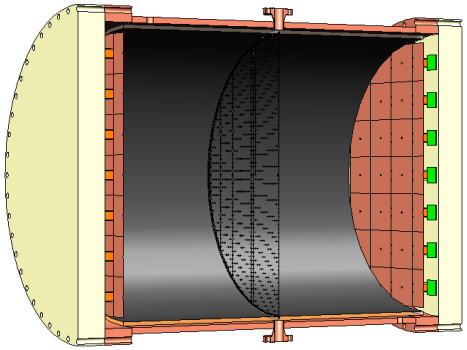


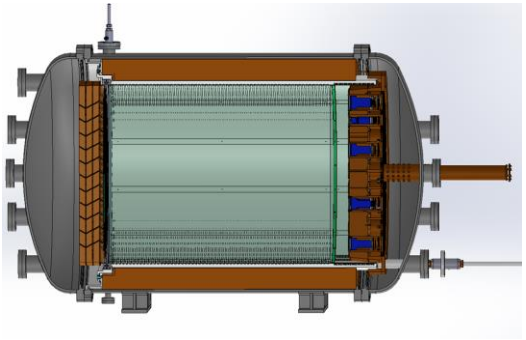
Andriamonje, S. et al. JINST 02 (2010): P02001



Gonzalez-Diaz, et al. *NIMA* 804 8 (2015)

PandaX vs. NEXT





PandaX-III first TPC		NEXT-100
200 kg Xe(enriched) + 1% TMA	Detector medium	100 kg pure Xe (enriched)
----------	Light	Primary + electroluminescence light readout by PMTs
Micromegas	Charge/Tracking	SiPM
3%	Projected energy resolution	0.7%
2-3 mm	Tracking pitch size	1 cm
X,Y	Fiducialization	X,Y,Z
Since 2015		Since ~2008

Xe+TMA

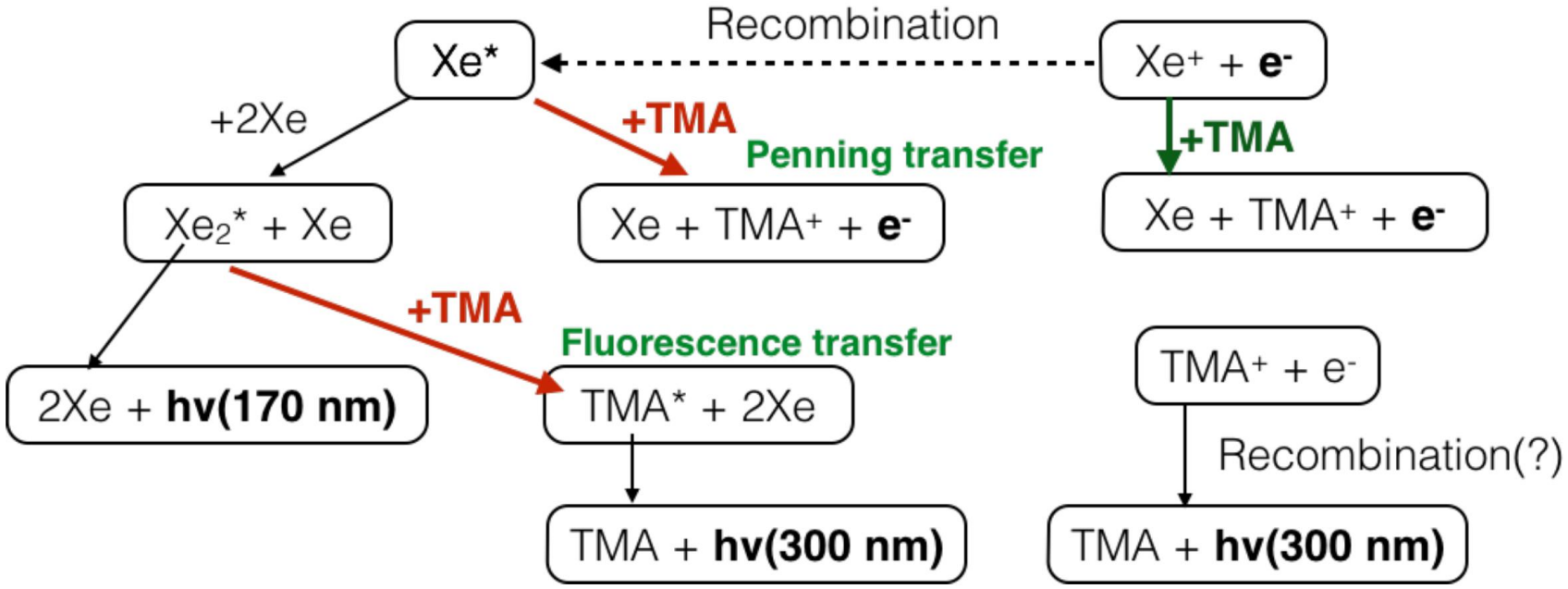
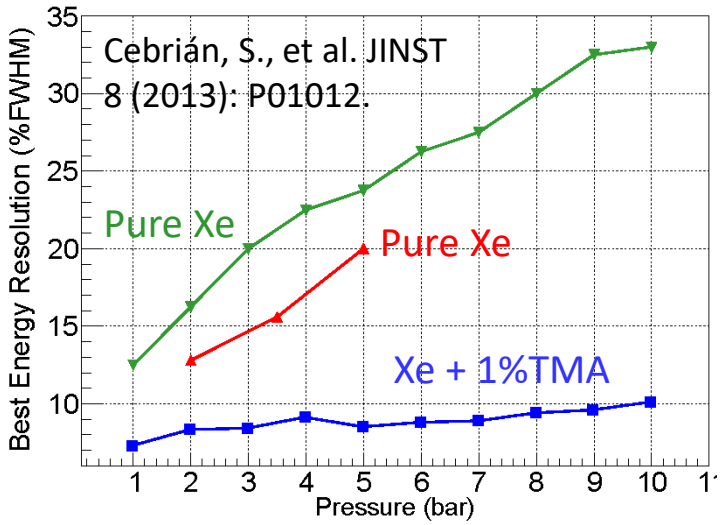
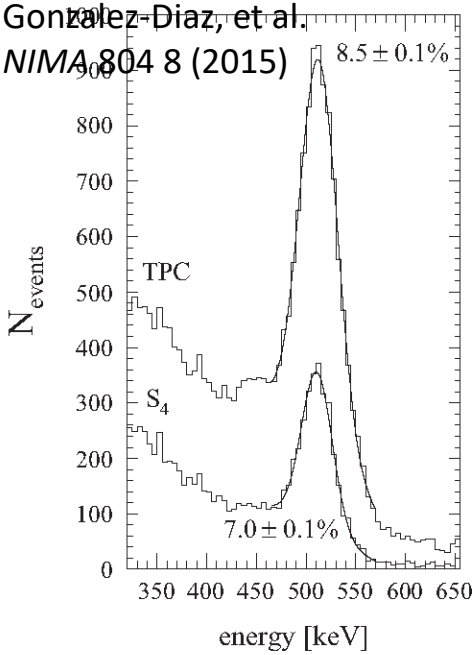


Figure 1. Simplified schematic of Xe and TMA reactions after initial ionization and excitation of Xe. We made the first direct measurement of the processes shown with red arrows.

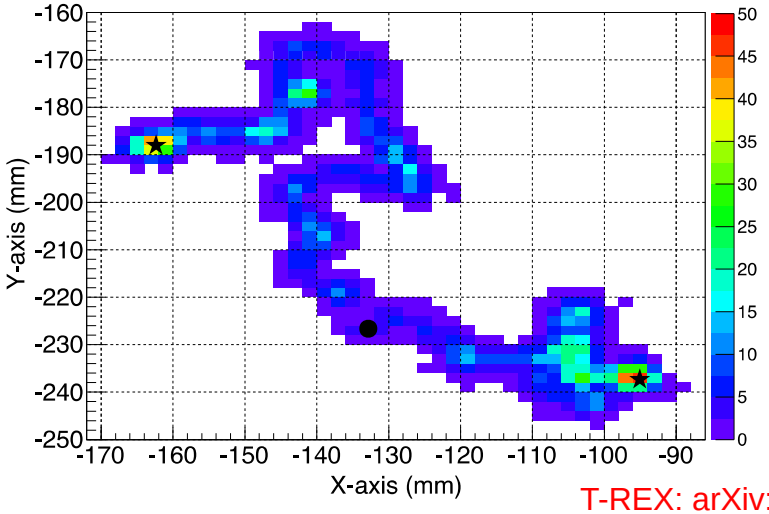
Xe +TMA mixture

- Better energy resolution
  - Extrapolated from 511keV and 1.2MeV peaks: 3% FWHM (@$Q_{0\nu\beta\beta}$)
- Better tracks
  - TMA suppress electron diffusion
- Better operation
  - TMA as a quencher

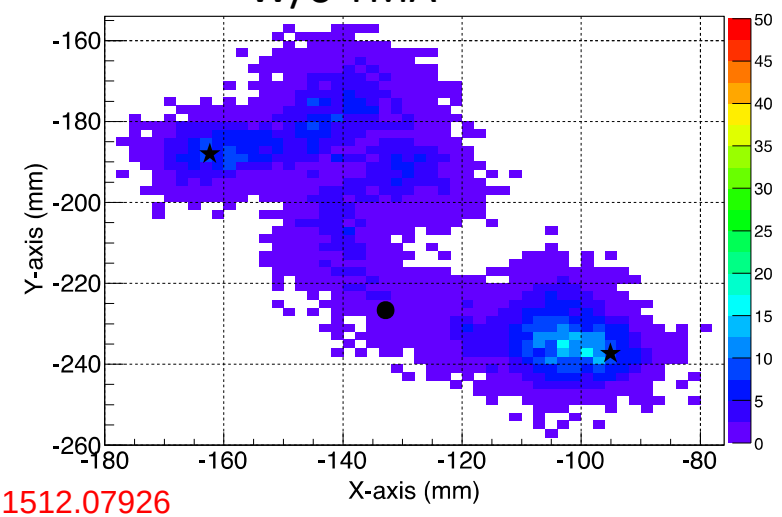




With TMA



W/o TMA



T-REX: arXiv:1512.07926

Electronics

- ASIC AGET chips: generic electronics for TPC from CEA-Saclay
  - 350 nm CMOS, mature technology
  - 64 channel multiplex
  - 512 sampling point per channel
  - 12 bit ADC
  - Dynamic range up to 10 pC
  - Sampling rate: 1 MHz to 100 MHz

Ensure high energy resolution

AGET and the commercial version ASAD are being tested and studied at Zaragoza, USTC, and SJTU