PandaX-III: HP Gaeous TPC based detector for NLDBD search

Shaobo Wang (王少博), **Tao Li (李涛)**

On behalf of

PandaX-III collaboration

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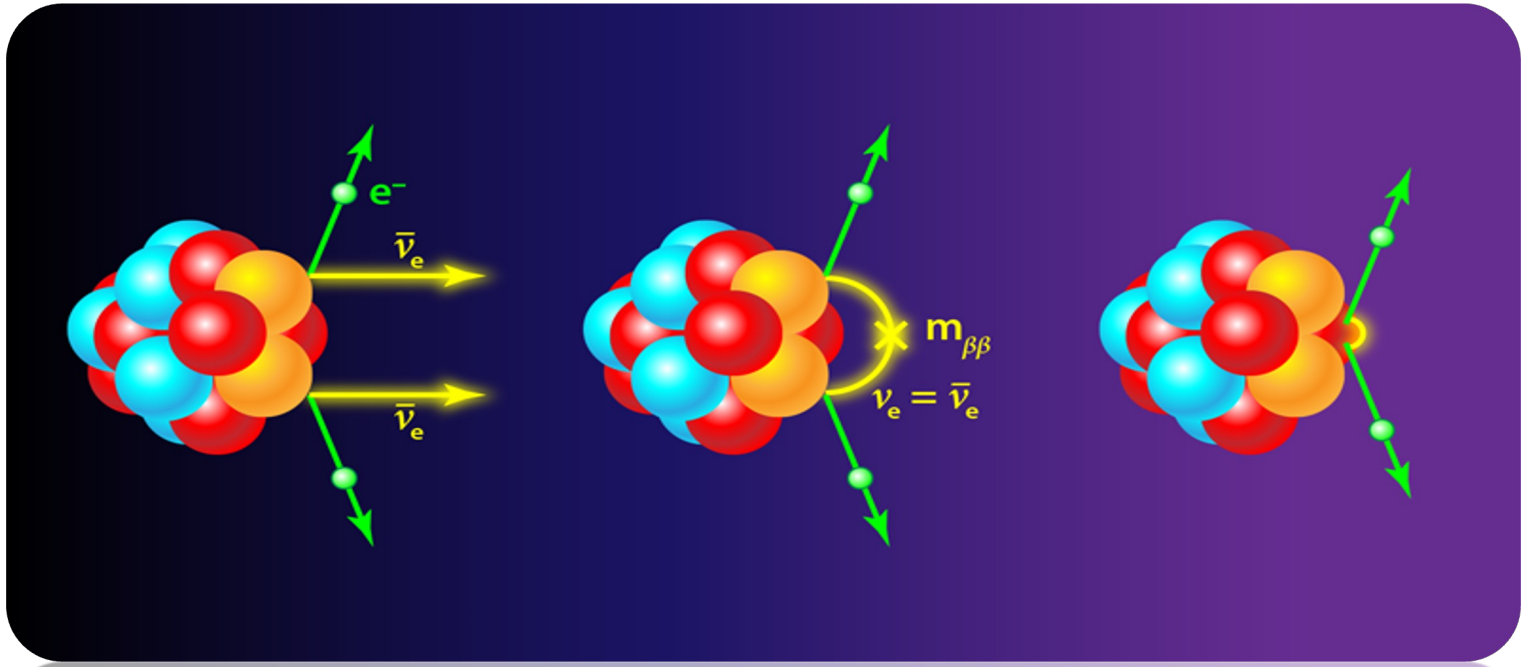
Neutrinoless double beta decay ($0\nu\beta\beta$)



$${}^{N}_{Z}A \rightarrow {}^{N-2}_{Z+2}A + 2\beta^- + 2\bar{\nu}_e \qquad {}^{N}_{Z}A \rightarrow {}^{N-2}_{Z+2}A + 2\beta^-$$

$$\bar{\nu} = \nu$$

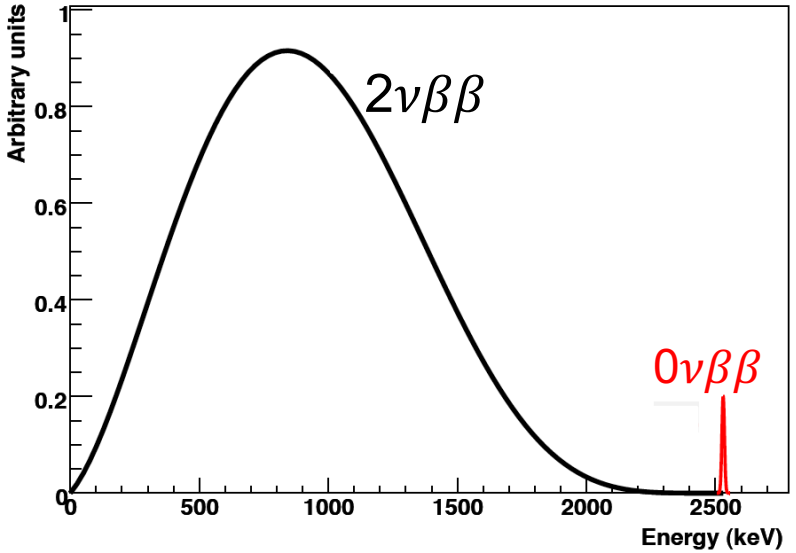
- Neutrino is Majorana particle?
- Lepton number violation and asymmetry of matter-antimatter;
- Origin of neutrino mass;

$$T^{0\nu}_{1/2} = (G_{0\nu}|\mathbb{M}^{0\nu}|^2 < m_{\beta\beta} >^2)^{-1}$$
$$\approx 10^{27-28}(\frac{0.01\ eV}{< m_{\beta\beta} >})^2$$

Detection of $0\nu\beta\beta$

- Measure energies of emitted electrons
- Electron tracks are a huge plus
- Daughter nuclei identification

$$^{136}_{54}\mathrm{Xe} \rightarrow {}^{136}_{56}\mathrm{Ba} + 2e^{-} + (2\bar{\nu}_e)$$



Sum of two electrons energy

$$T_{1/2}^{0\nu}(\mathrm{exp}) = (\ln 2) N_a \frac{a}{A} \varepsilon \sqrt{\frac{MT}{b\Delta E}}$$

Isotopic Abundance

Detection Efficiency

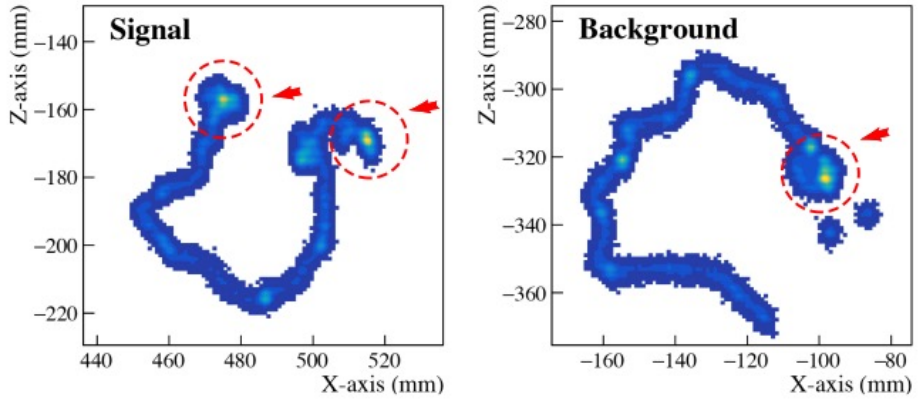
Detector Mass

Time

Atomic mass

Background level (count/keV kg year)

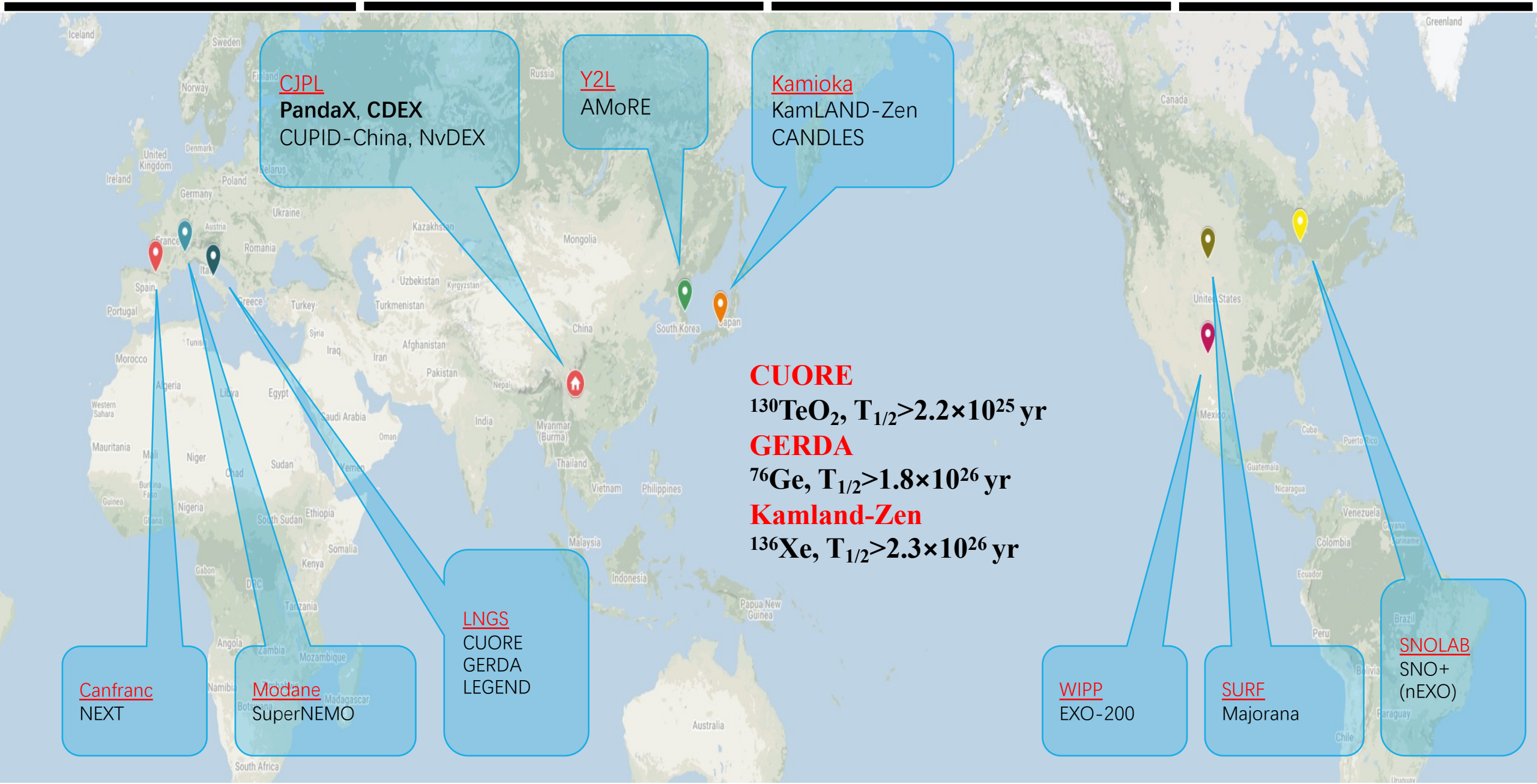
Energy Resolution



Simulated tracks in high pressure Xe

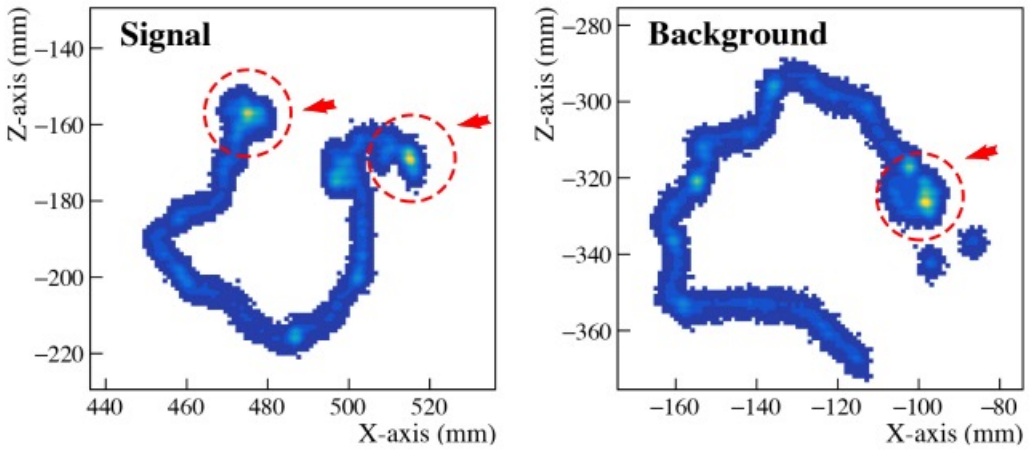
Experiment: large exposure, high energy resolution, low background level and signal-background discrimination

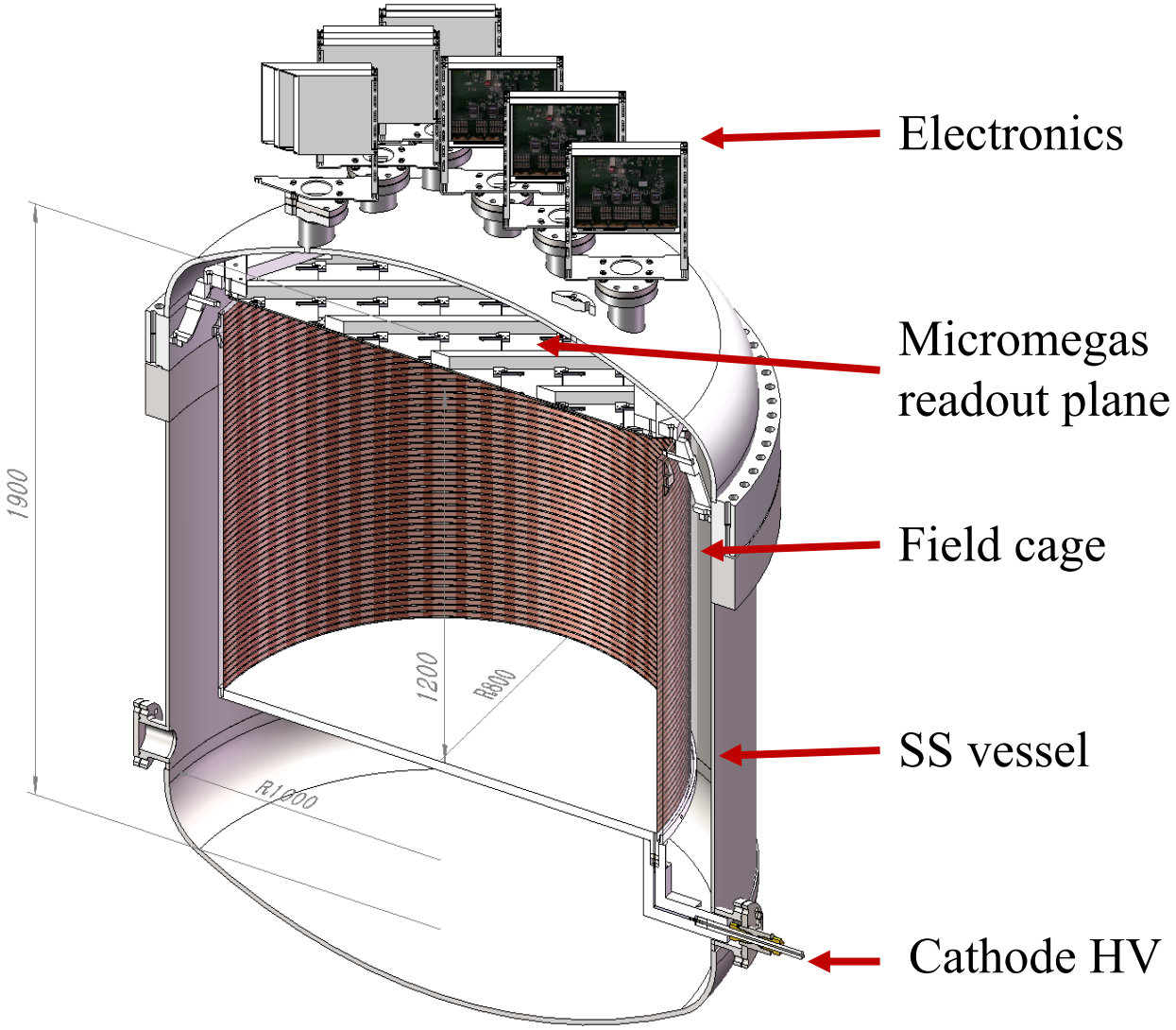
$0\nu\beta\beta$ experiments



PandaX-III detector: search for $0\nu\beta\beta$ of ^{136}Xe

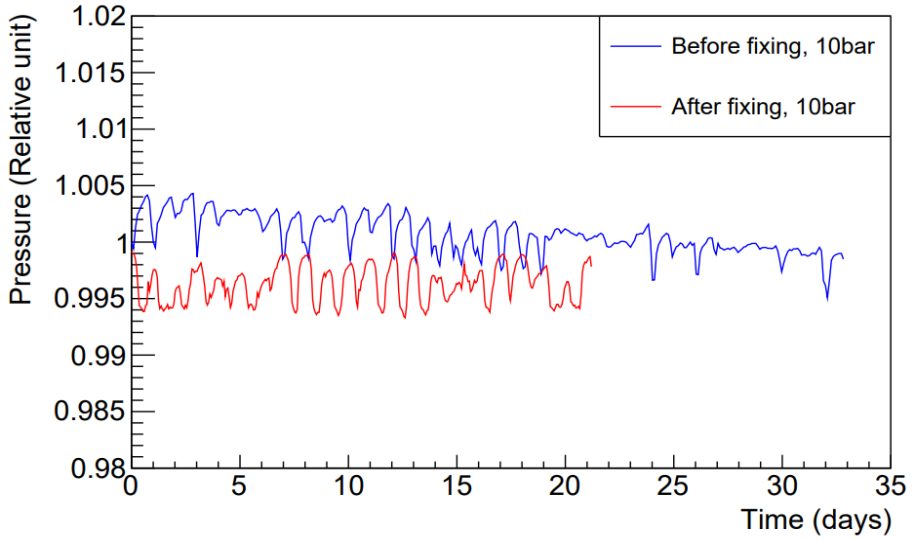
- **TPC:** Single-end charge readout on the upper side, the cathode on the bottom;
- **charge readout:** 52 20x20 cm^2 Micromegas;
- **Readout:** 2 series of strips (x, y) of 3 mm;
- **140 kg 90% ^{136}Xe**: 10 bar Xe-(1%)TMA (trimethylamine);
- **Energy resolution**: 3% FWHM expected at 2.458 MeV

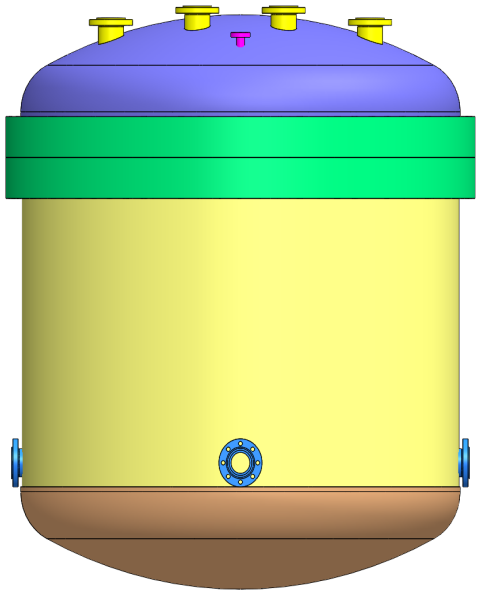


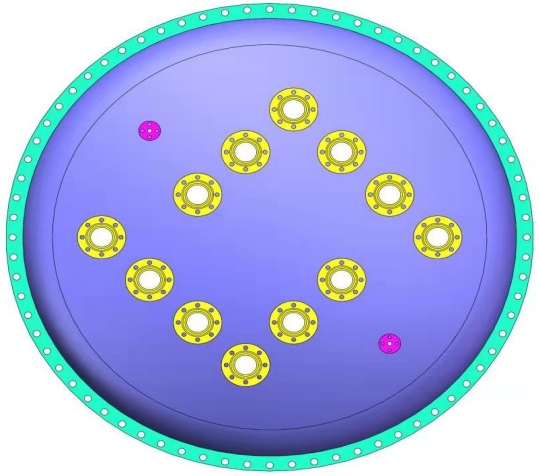


PandaX-III detector: SS vessel

- The vessel is made of low background stainless steel with a pressurization of 15 bar;
- 20 flanges on the top flange and barrel for signal cables, HV feedthrough, and gas circulation;
- Leak check and long-term high-pressure test;

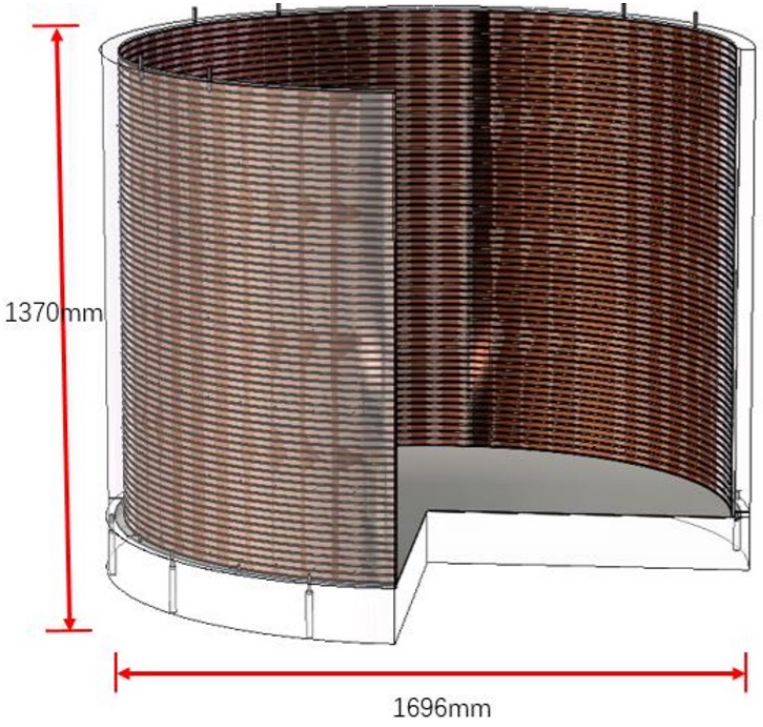


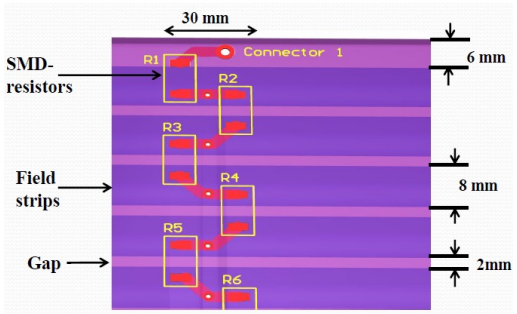


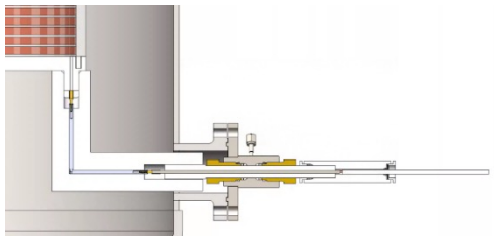


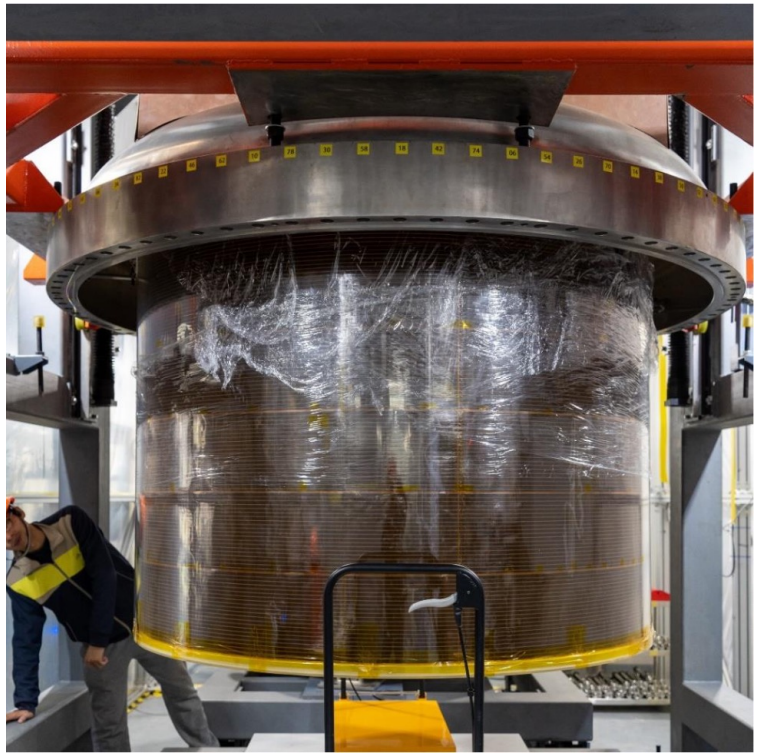
PandaX-III detector: TPC

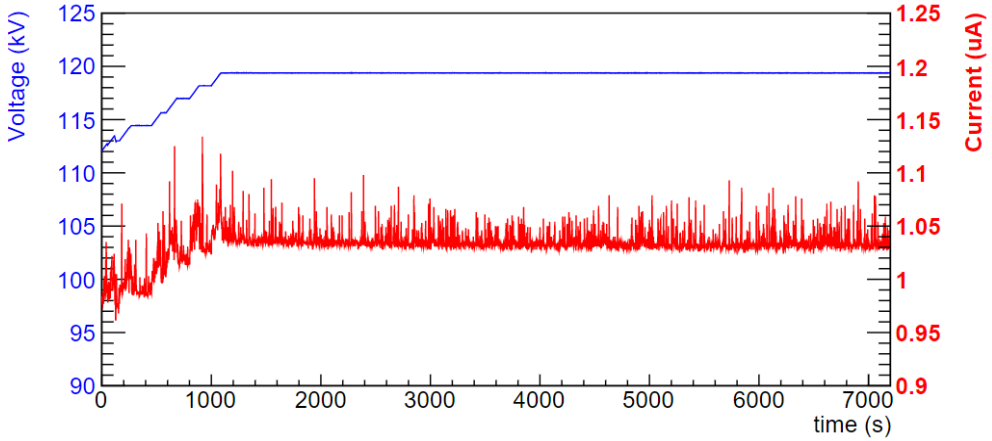
- Field cage: Flexible PCB + SMD resistors supported by a low background acrylic barrel;
- L shape feedthrough to apply HV on the cathode;
- Apply 120 kV in the atmosphere steadily;





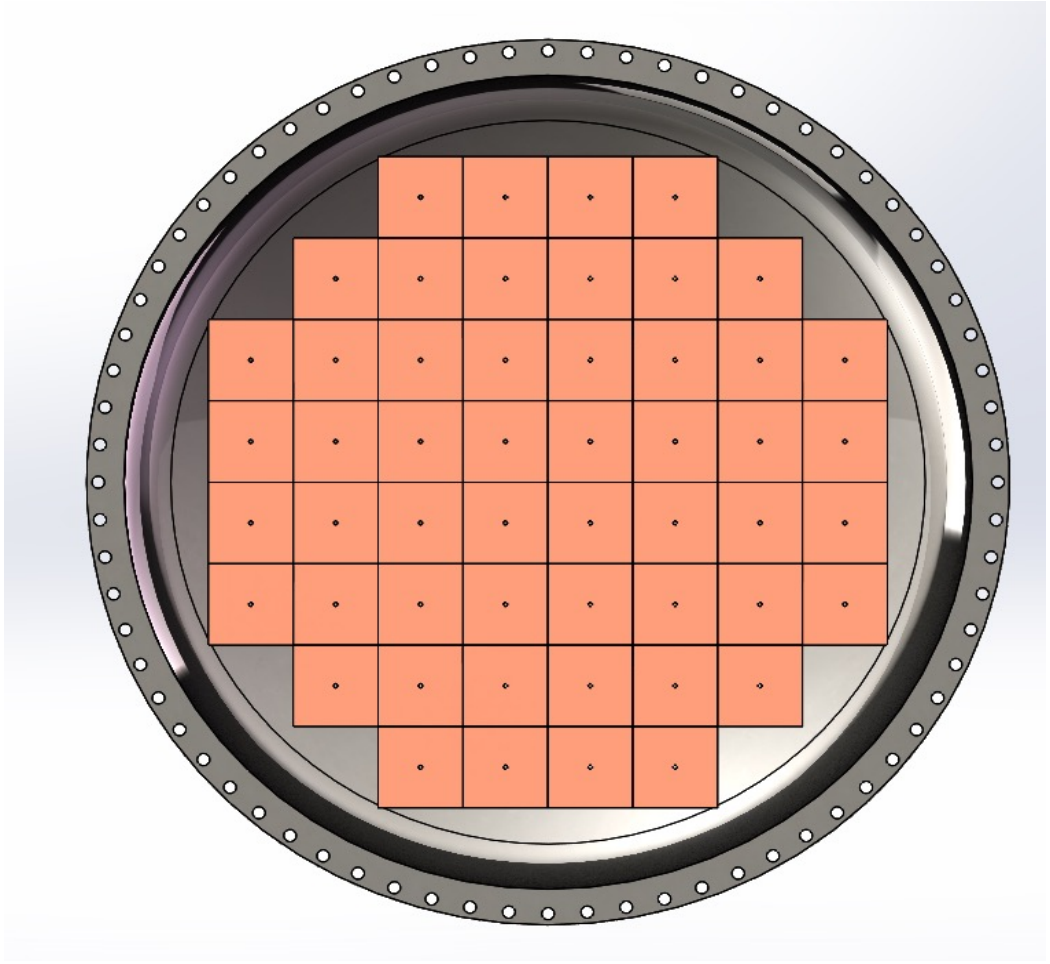


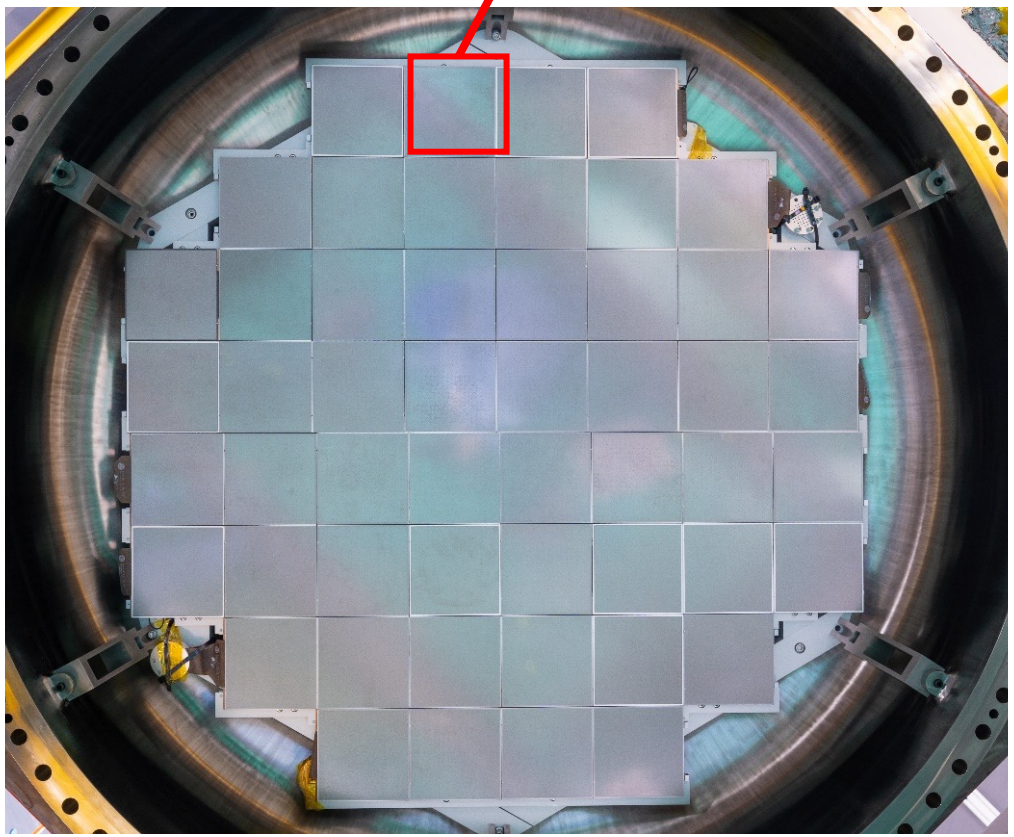




PandaX-III detector: TPC

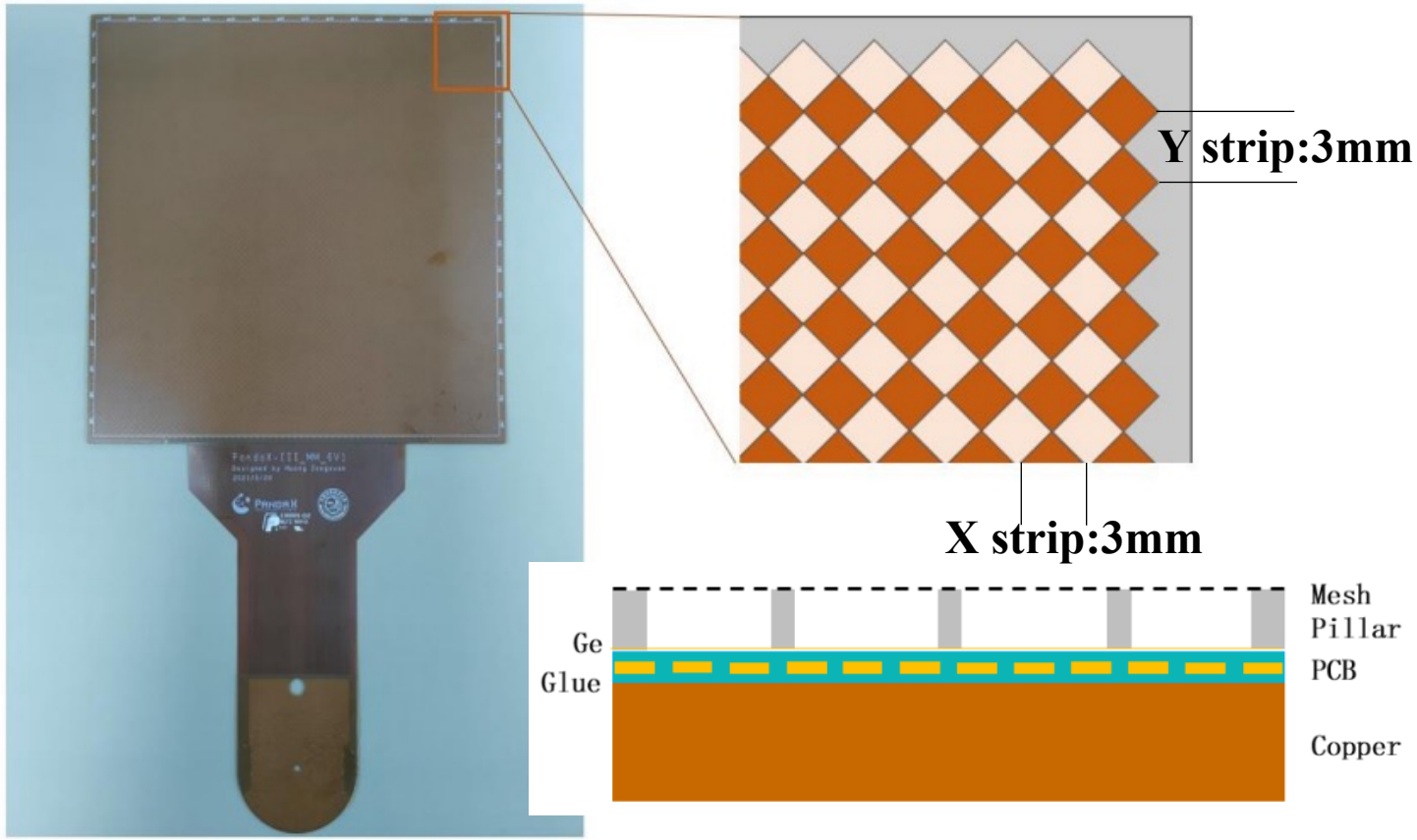
- Readout plane consists of 52 modular Micromegas;
- Each module is 20×20 cm^2;

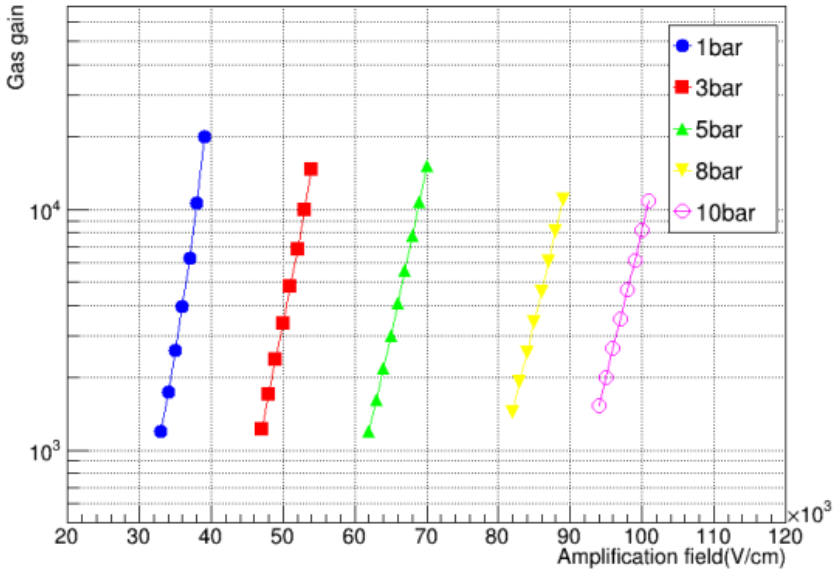


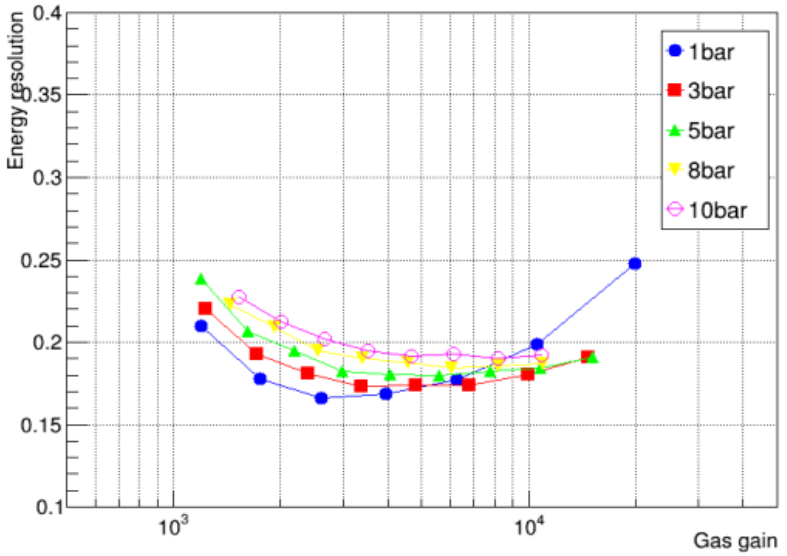


Micromegas

- Low background thermal banding Micromegas designed by USTC and SJTU;
- Micromegas made of flexible PCB and glued on a copper supporter;
- ~10% uniformity and several thousand gain in high pressure;

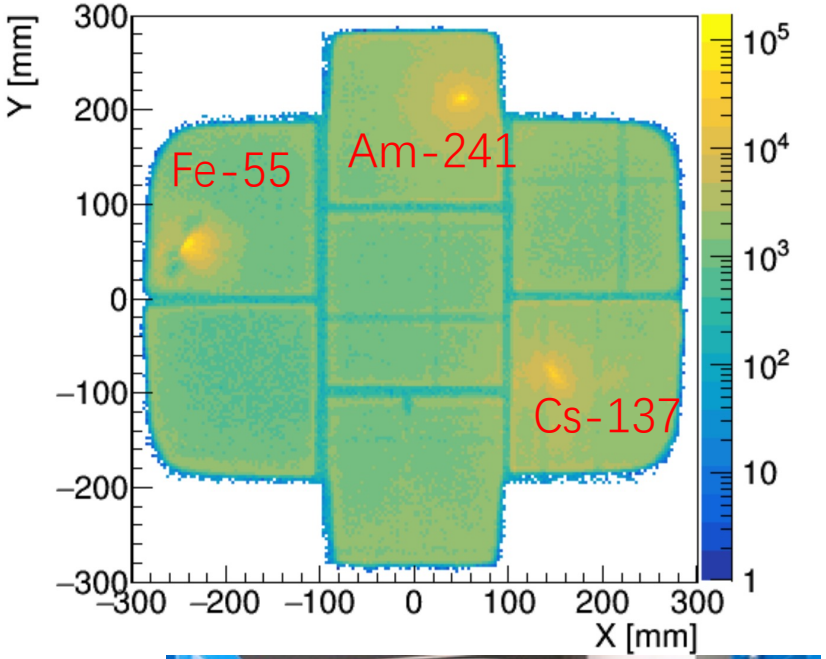


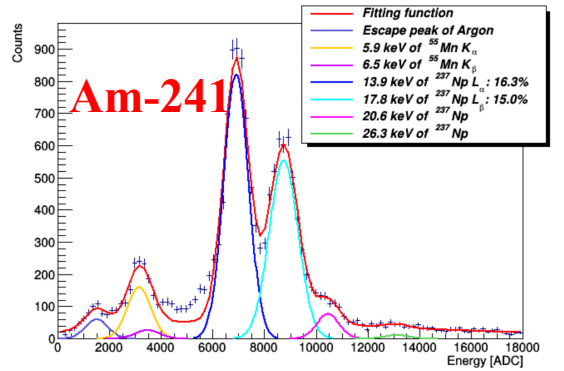


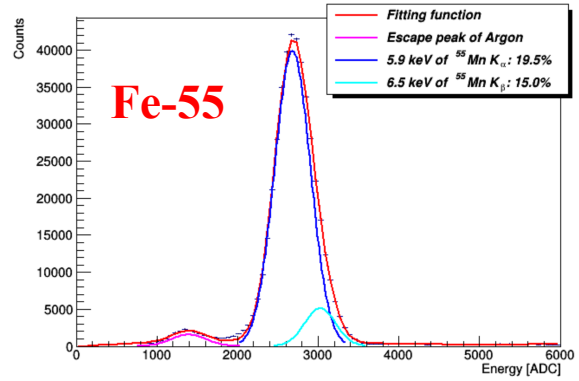


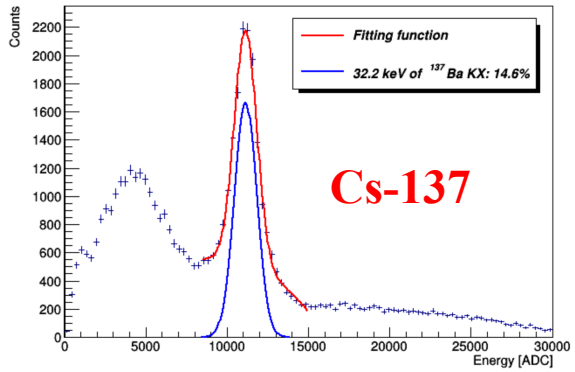
Micromegas test in prototype detector

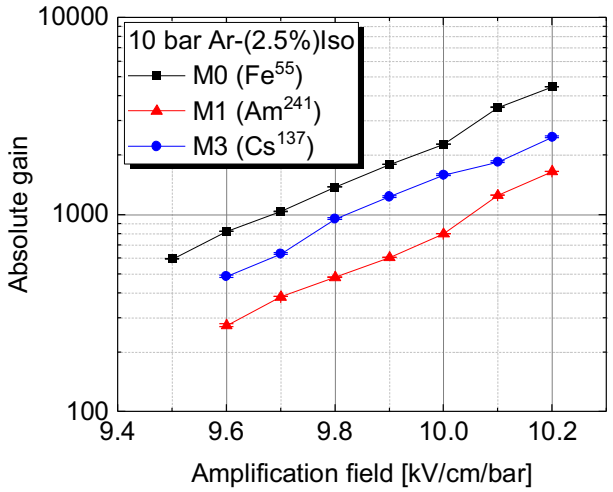
- Prototype TPC test:
  - 700 L volume and 78 cm drift distance;
  - Readout plane: 7 Micromegas;
  - Sources: ^{55}Fe, ^{241}Am and ^{137}Cs;
  - Gas: 1-10 bar Ar-iso;

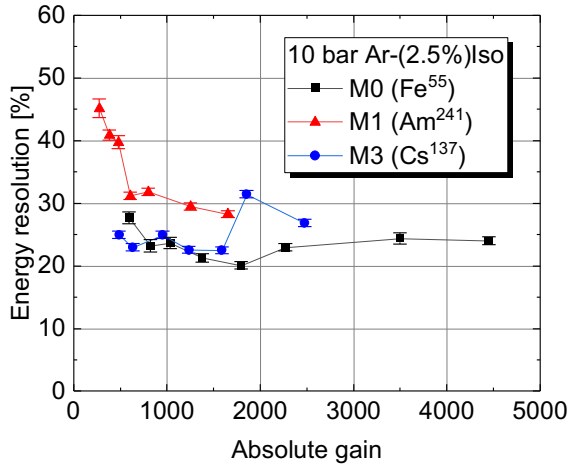




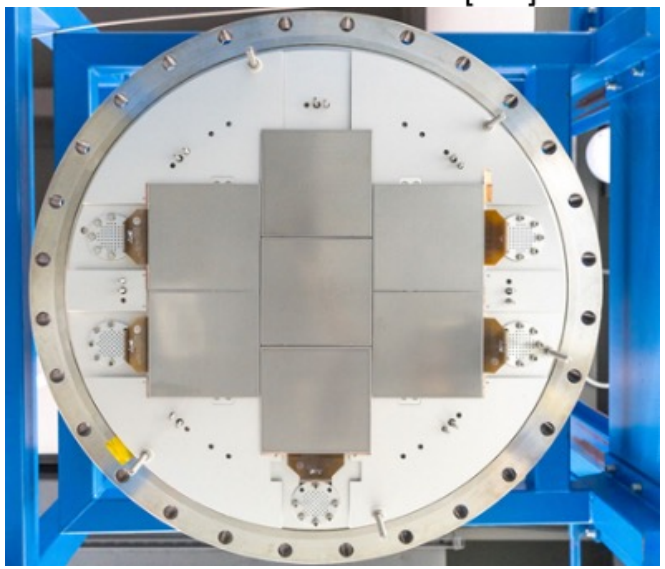




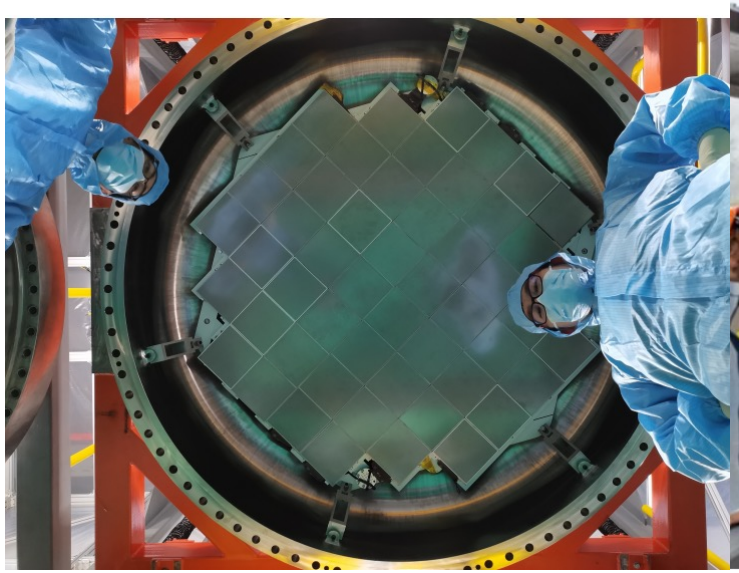


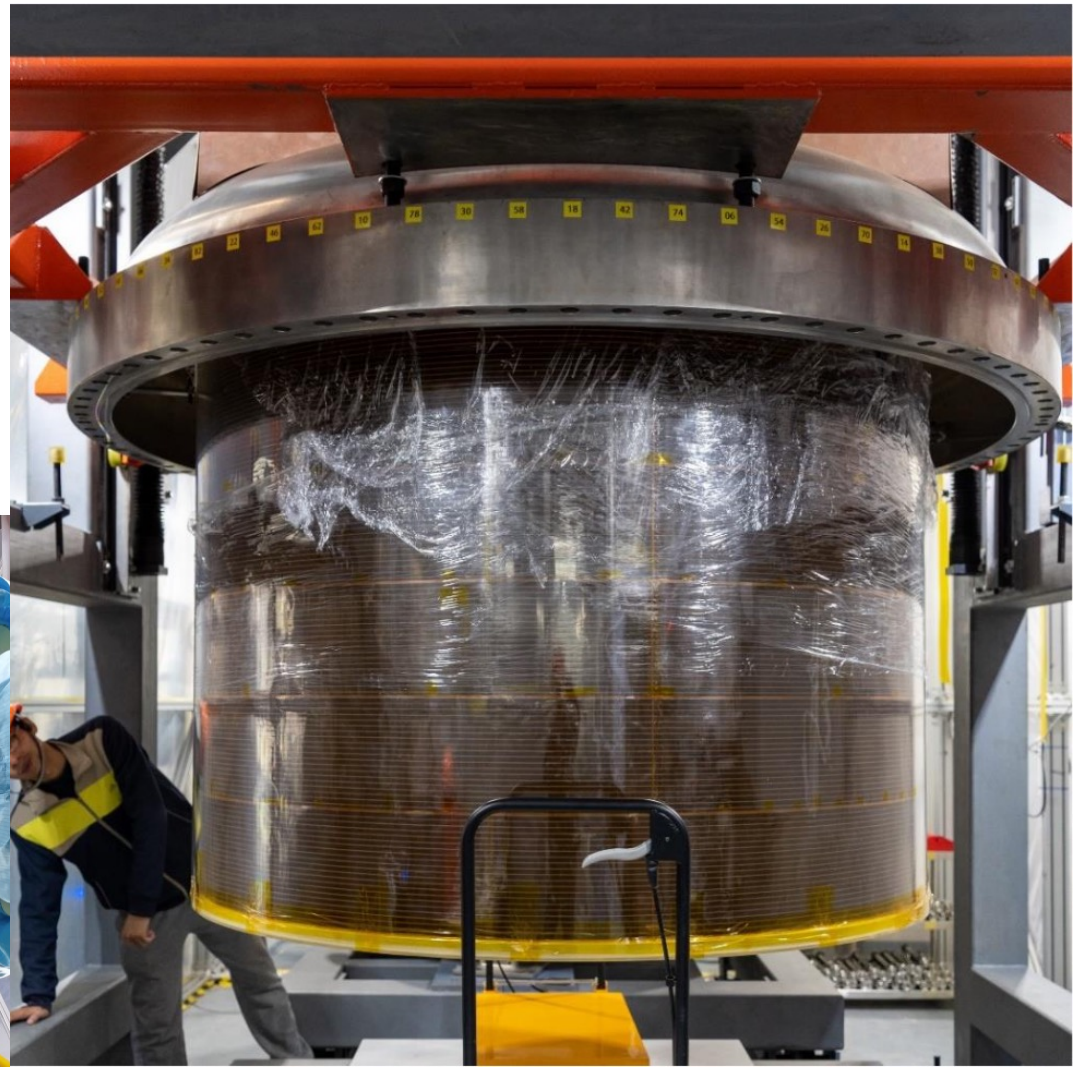


10 bar Ar-2.5%iso



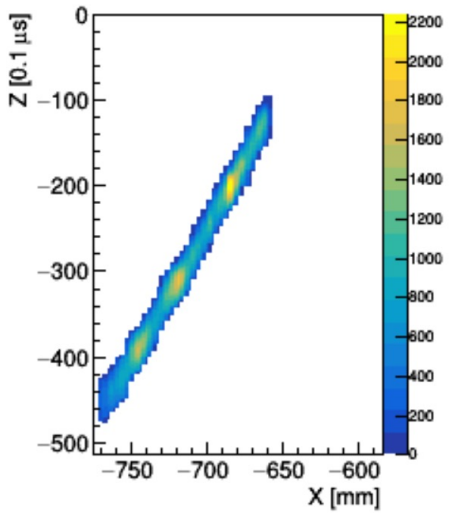
Detector assembling

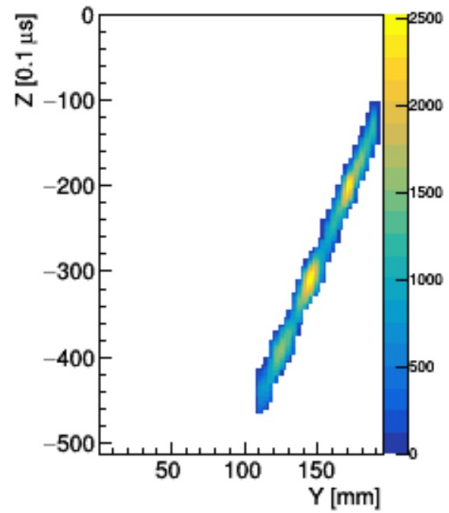


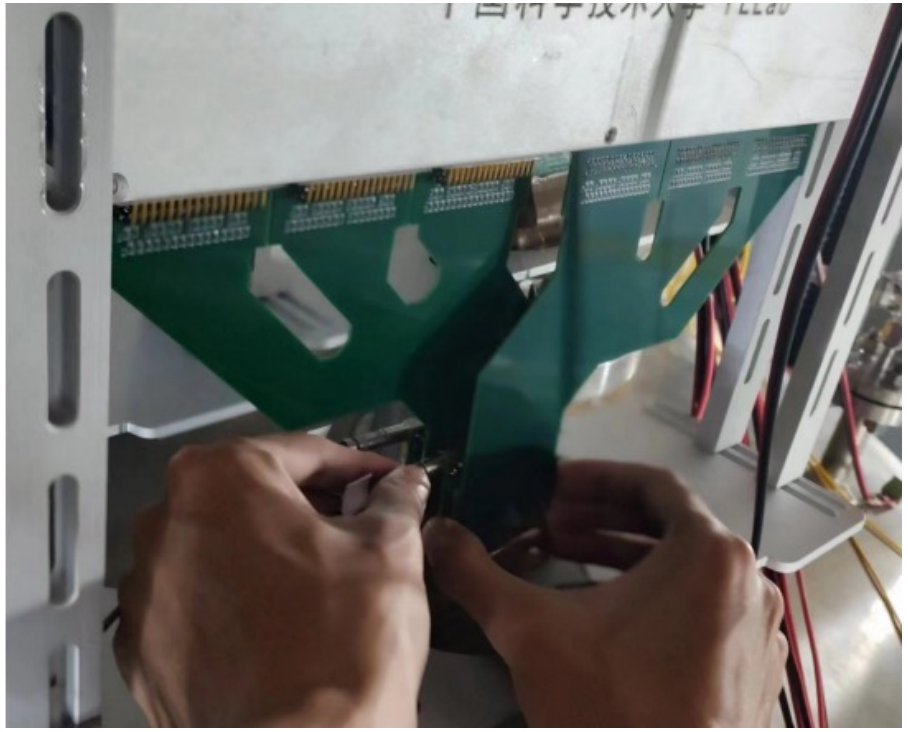


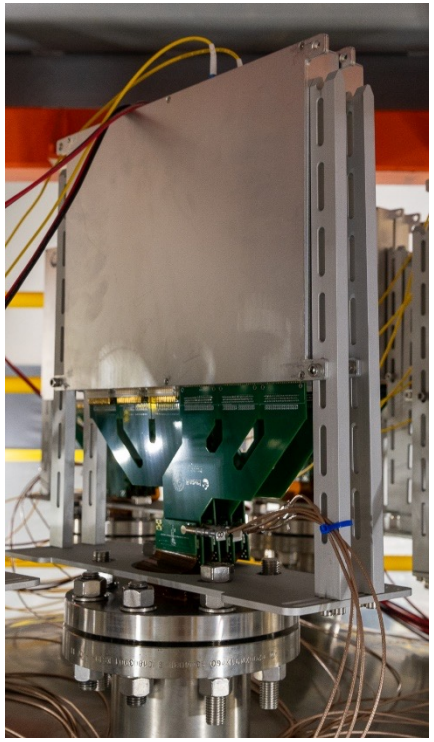
Detector assembling

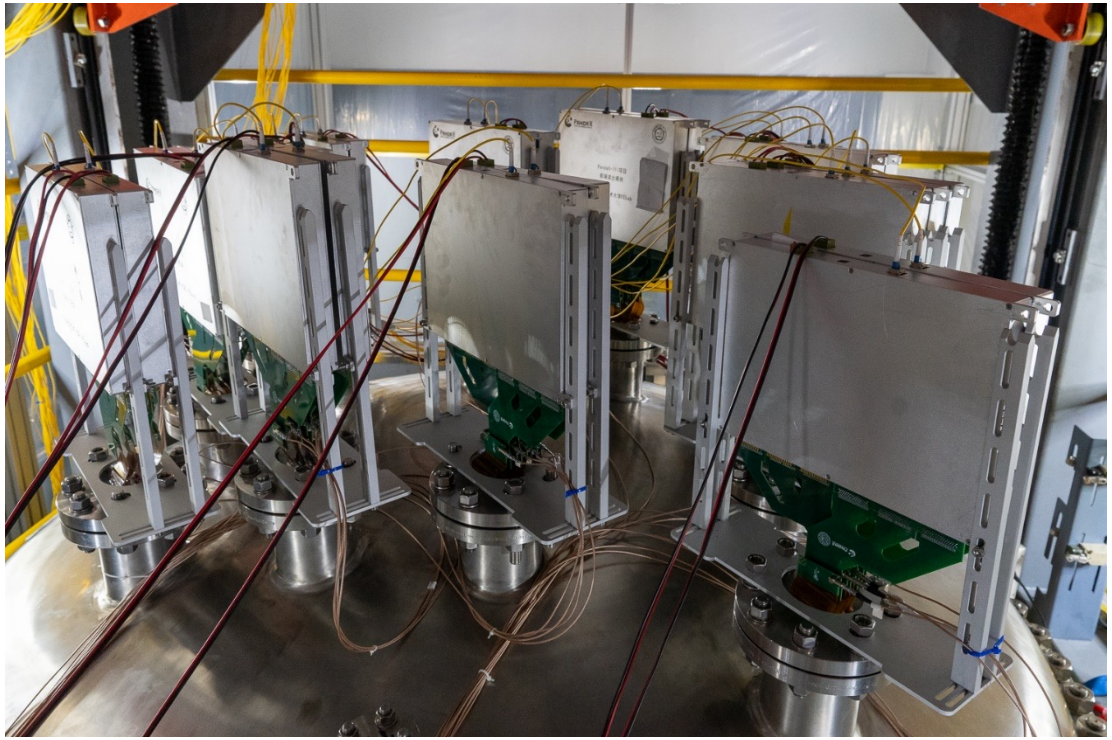
- ❑The detector assembly was completed;
- ❑The subsystems were connected;
- ❑1 bar Ar-2.5% iso was filled for muon calibration;





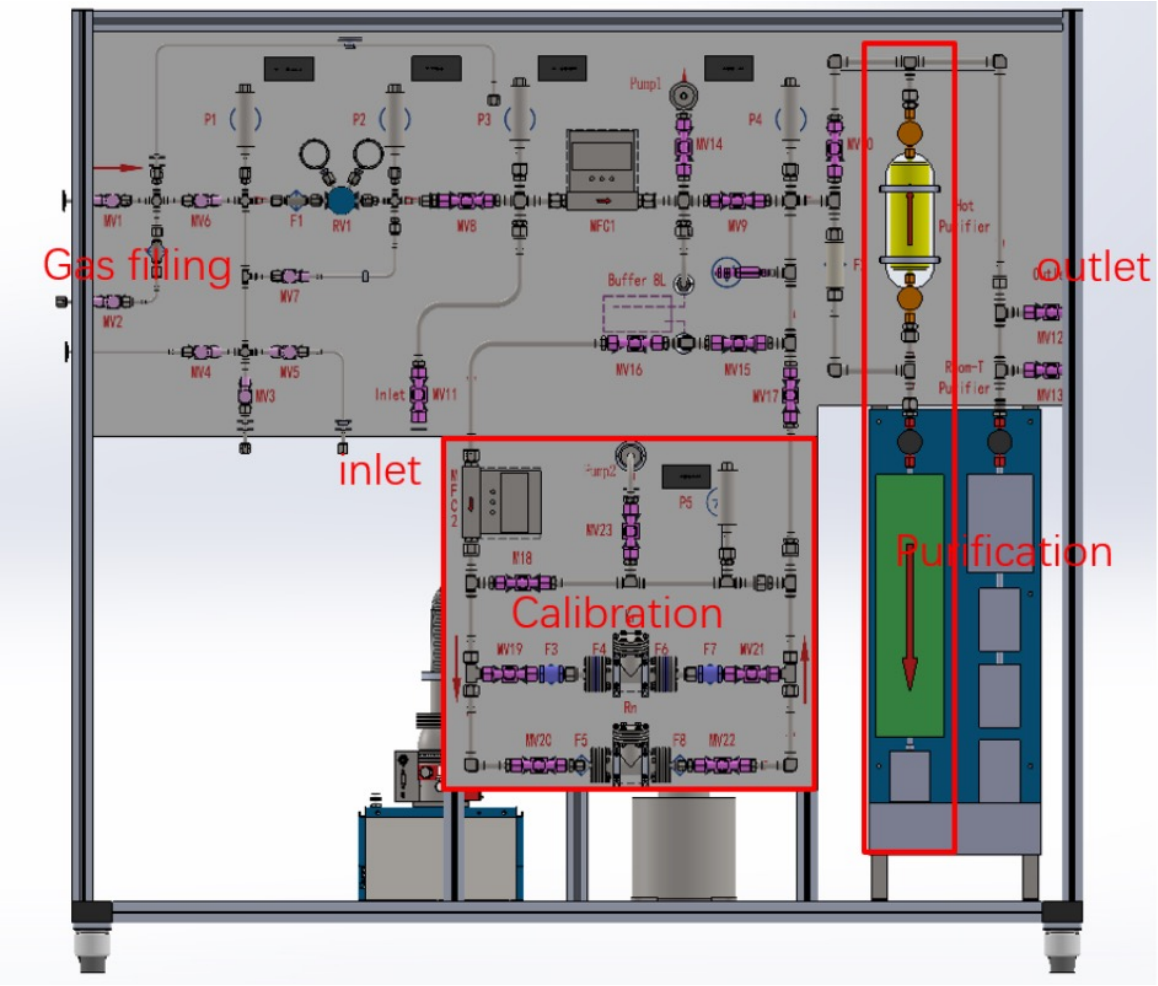




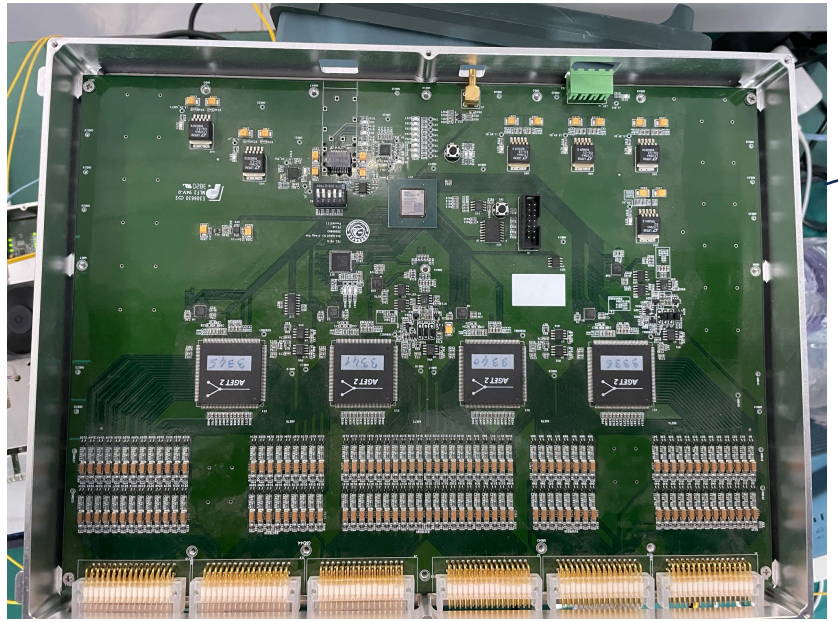


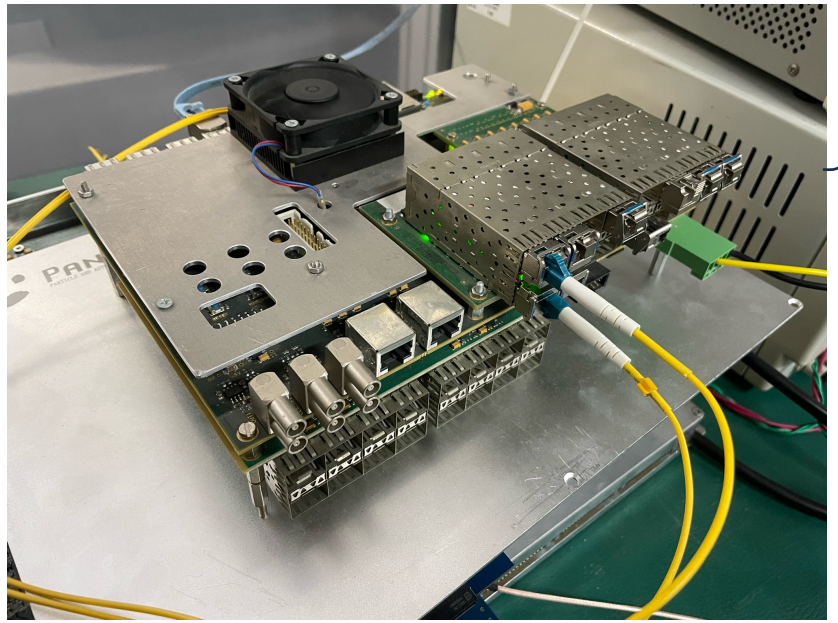
Gas handling and internal calibration system

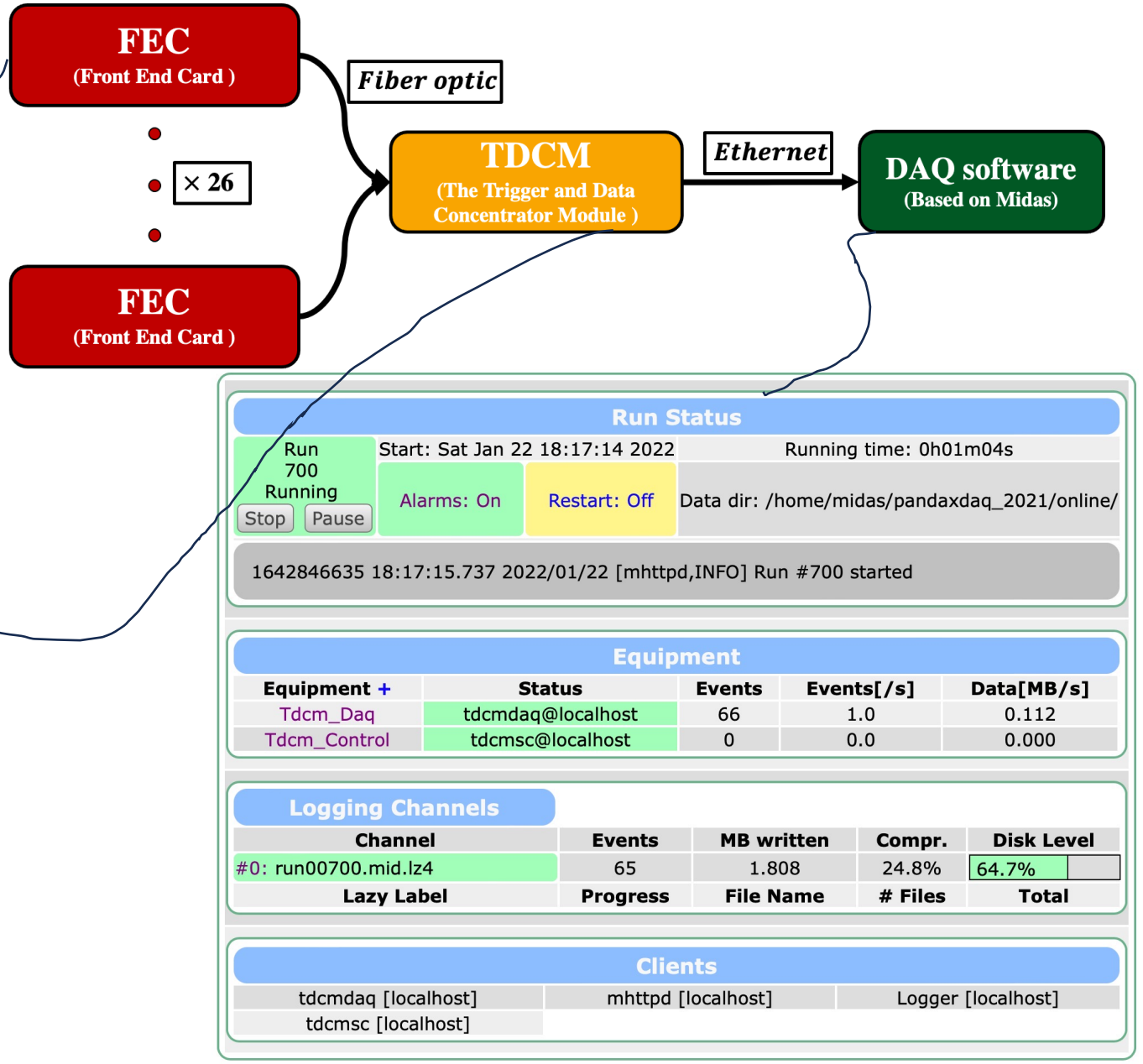
- Gas filling and mixing , circulation and purification, emergency recovery and sampling;
- Internal calibration (gas): ^{220}Rn and ^{83m}Kr;



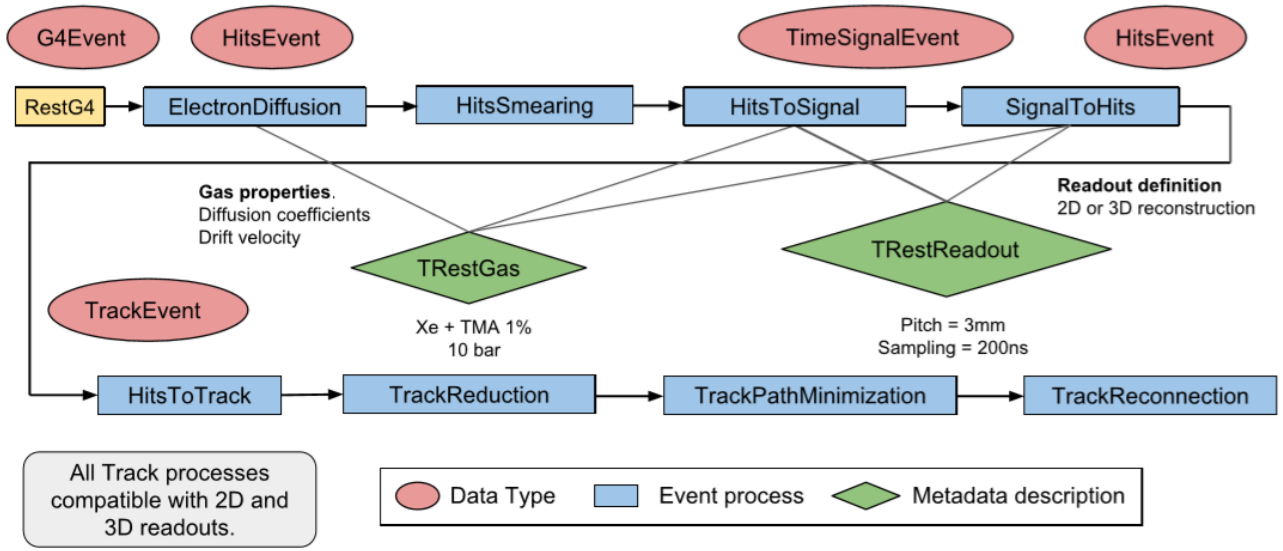
Electronics and DAQ system





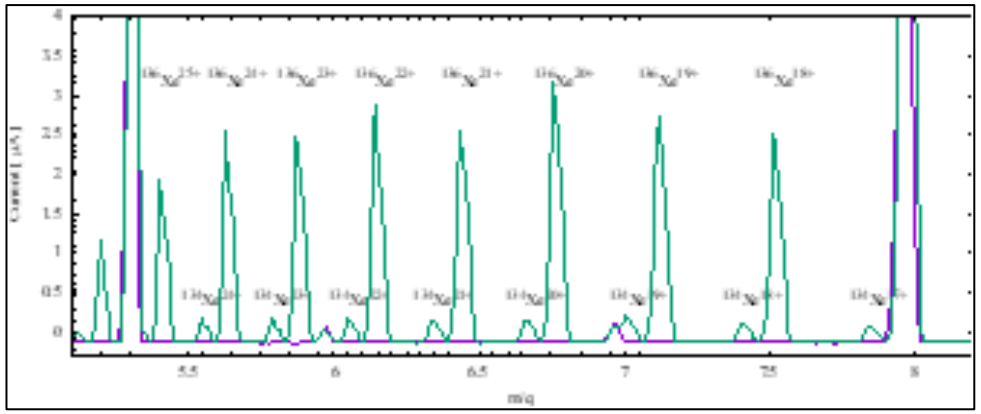


Status of the others



REST: Simulation and data analysis

Slow control system



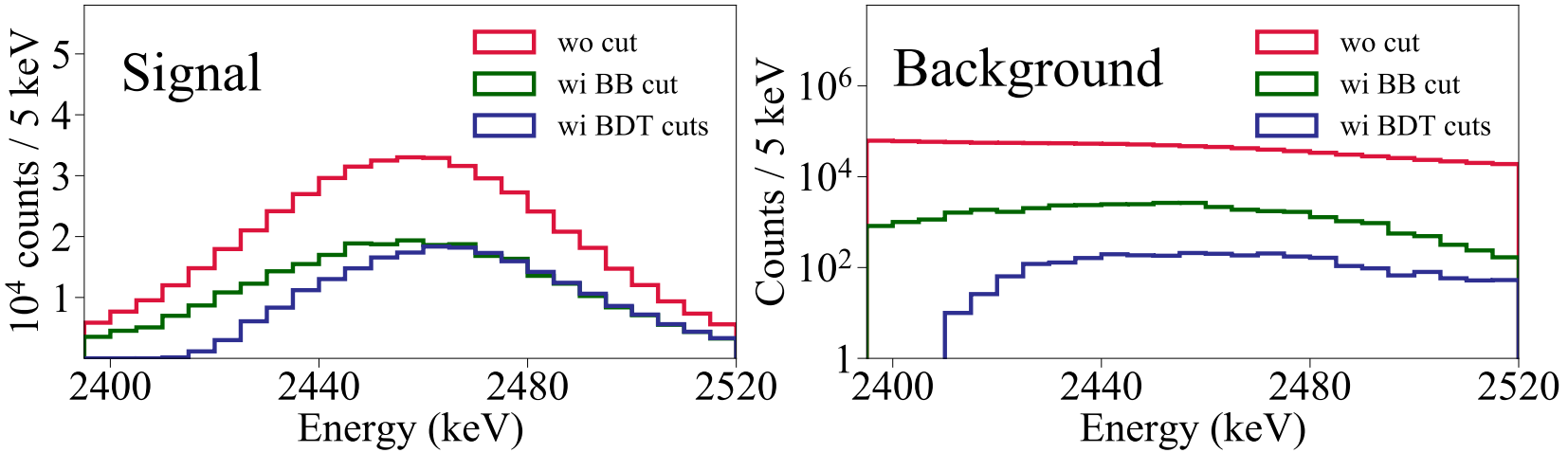
145 kg ^{136}Xe enriched at SJTU

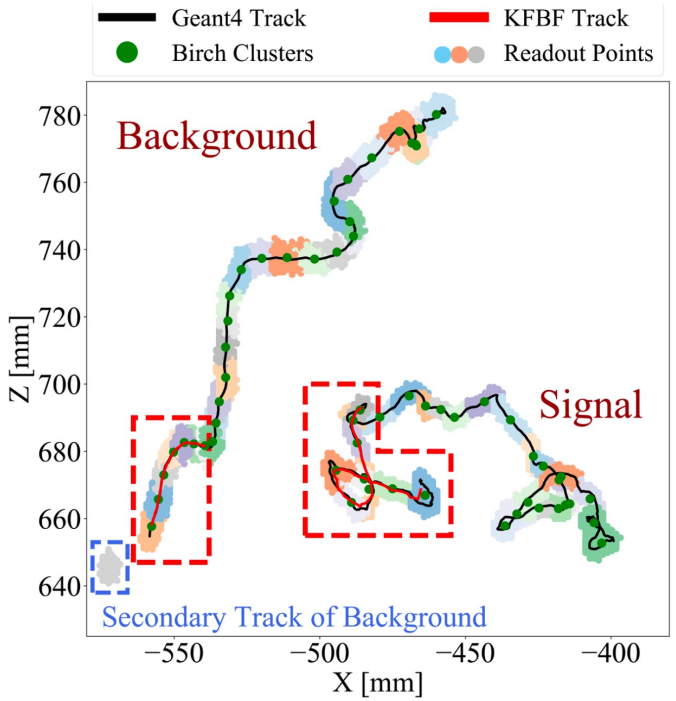
Track features analysis

- Kalman Filter with Bayesian formula for **track reconstruction**

$$\begin{bmatrix} [x]_k \\ [y]_k \\ [z]_k \\ [u_x]_k \\ [u_y]_k \\ [u_z]_k \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & \lambda & 0 & 0 \\ 0 & 1 & 0 & 0 & \lambda & 0 \\ 0 & 0 & 1 & 0 & 0 & \lambda \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} [x]_{k-1} \\ [y]_{k-1} \\ [z]_{k-1} \\ [u_x]_{k-1} \\ [u_y]_{k-1} \\ [u_z]_{k-1} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ G(0, [\theta_x]_k) \\ G(0, [\theta_y]_k) \\ G(0, [\theta_z]_k) \end{bmatrix},$$

- Signal discrimination based on track features such as dE/dx



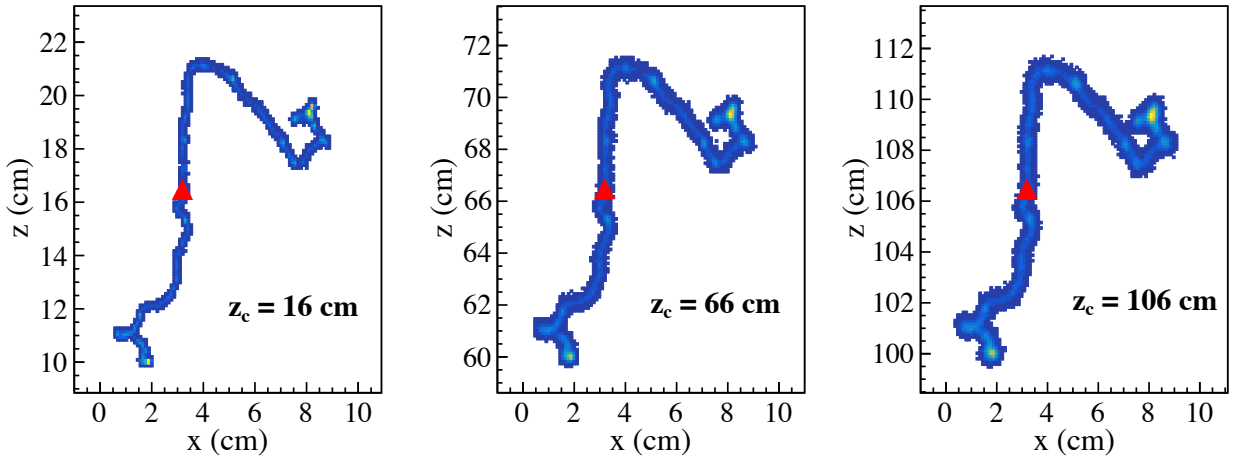


Li, T. et al. JHEP 06, 106 (2021).

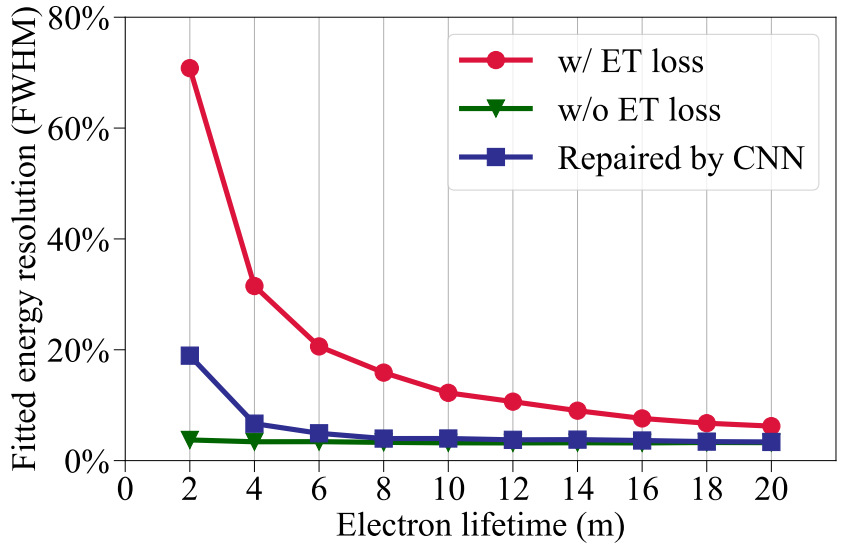
- **Exclusion sensitivity: 2.7 × 10^{26} yr for 5 years, with an improvement in sensitivity by a factor of 2.7.**

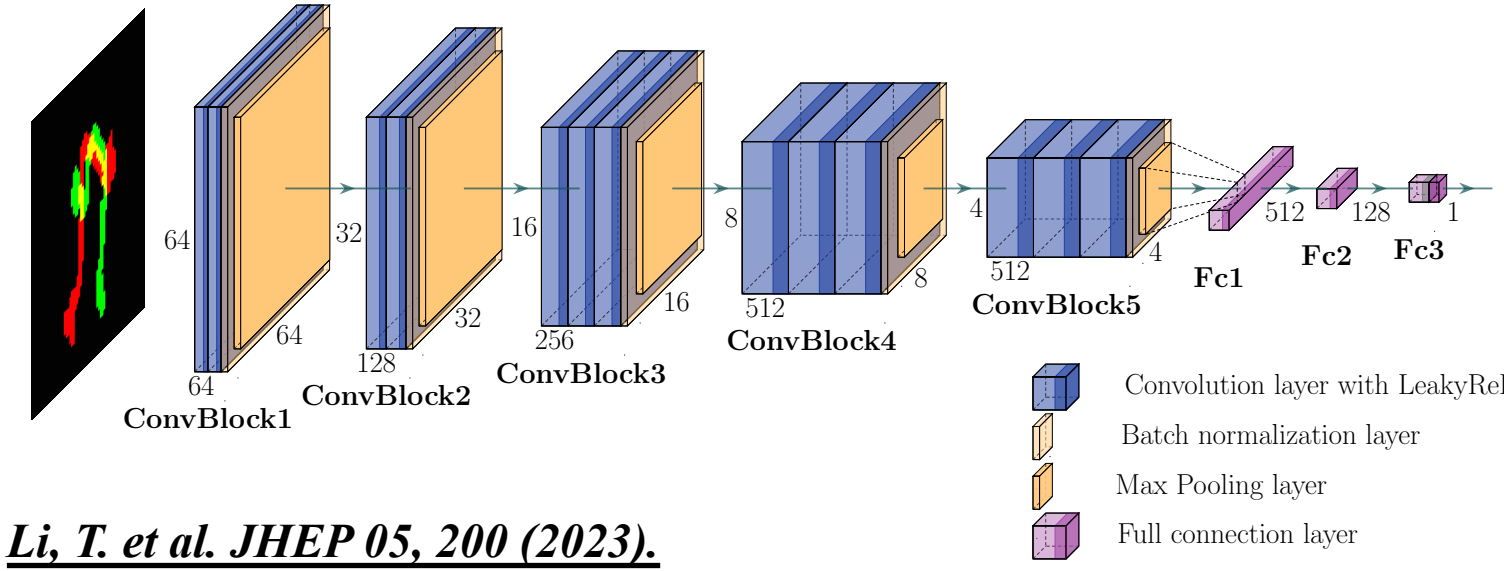
Track features analysis

- Electron diffusion effect
- VGGZ0net for **vertex reconstruction and e-lifetime correction.**

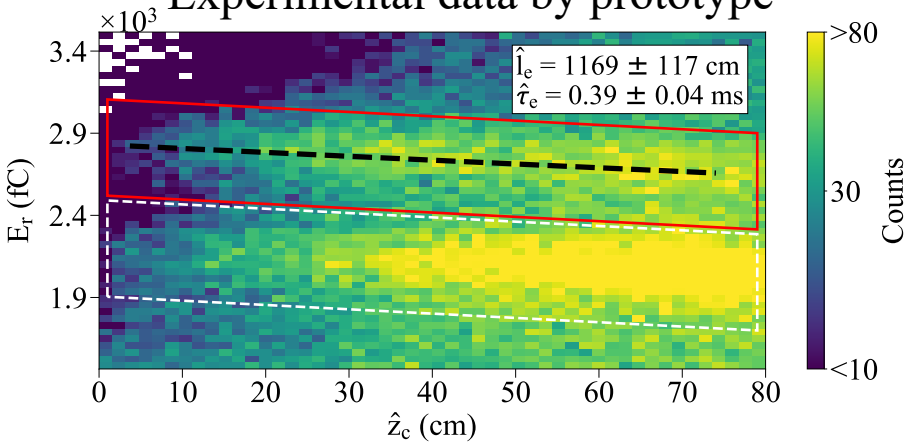


Simulated data





Experimental data by prototype



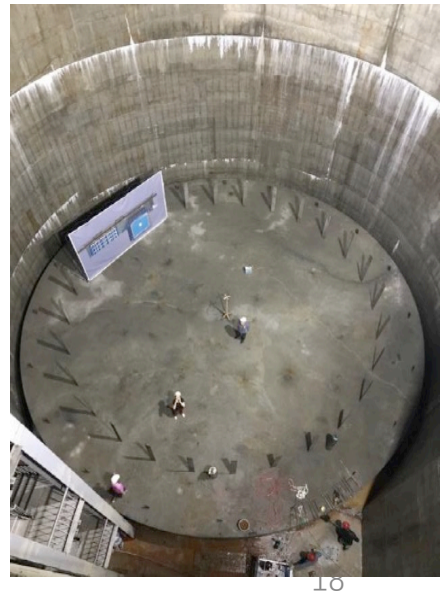
Li, T. et al. JHEP 05, 200 (2023).

PandaX-III collaboration

PandaX-III will be installed in CJPL-II

From: The China Jinping Underground Laboratory and Its Early Science;
Ann.Rev.Nucl.Part.Sci. 67 (2017) 231-251

Thanks and welcome collaborators!



Back up

Shaobo Wang (王少博), **Tao Li (李涛)**

PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC

On behalf of PandaX-III collaboration

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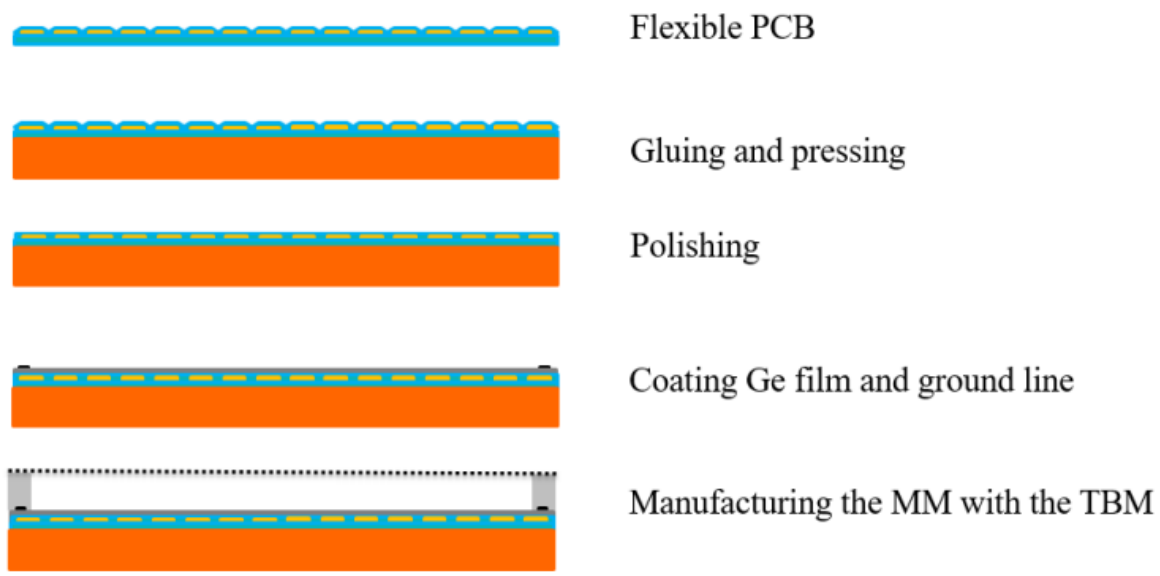
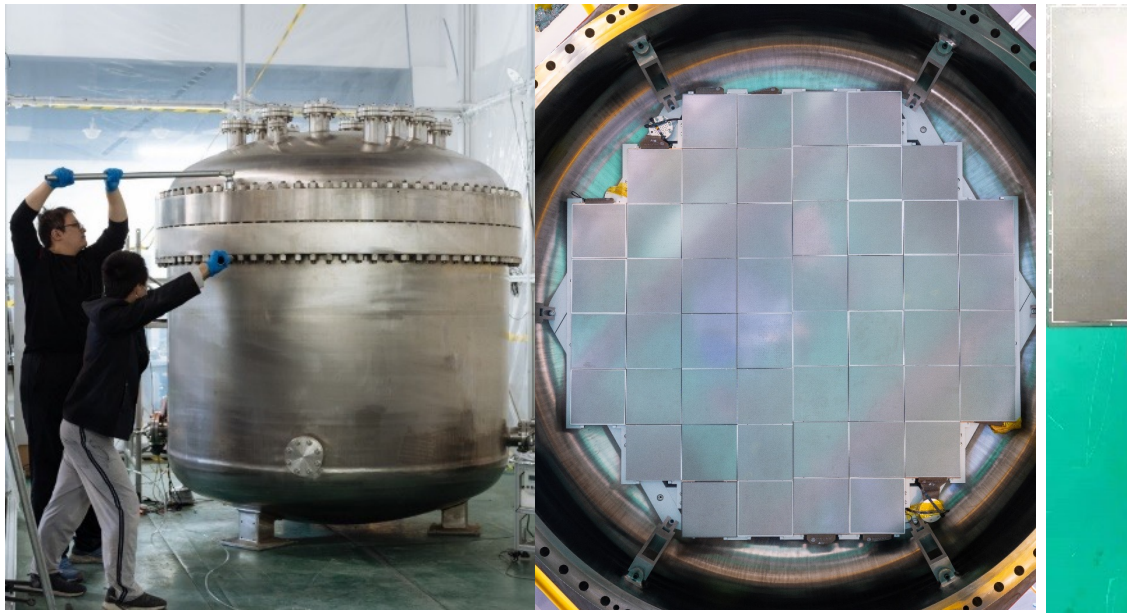
M

Sample	^{232}Th	^{235}U	^{238}U	^{40}K	^{60}Co
PCB	0.91±1.42	-	0.28±0.55	22.6±9.07	0.37±0.31
SS wire mesh	0.24±0.12	<0.01	0.08±0.04	0.69±0.58	<0.01
Thermal bonding Film	1.00±0.33	<0.01	11.57±1.57	1.67±1.28	-
Epoxy glue	1.40±0.75	-	0.05±0.25	-	-
Total	3.55±1.64	<0.01	11.98±1.68	24.96±9.18	0.37±0.31



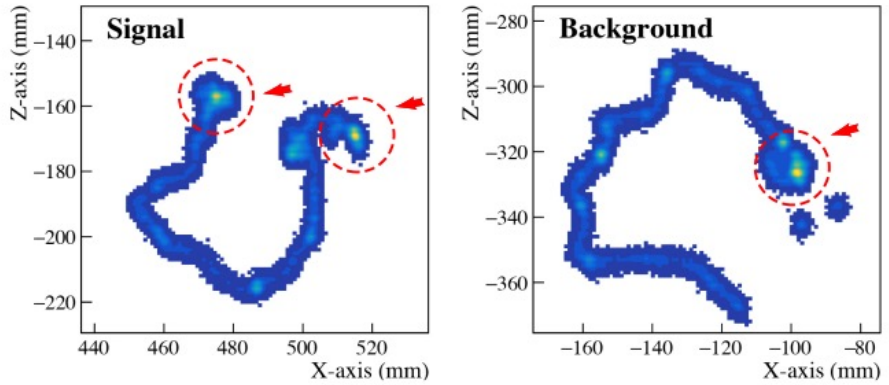
PandaX-III experiment

- PandaX-III: high pressure (10 bar) gaseous TPC (140 kg ^{136}Xe of 90%), 1.2m×1.6m active volume
- Readout plane: 52 20×20 cm^2 Micromegas modules of 3 mm strip (64 strips in each side)
- The topological information is powerful for signal and background discrimination
- Detection sensitivity: 2.7×10^{26} yr with 5-year live tim



PandaX-III detector

Micromegas



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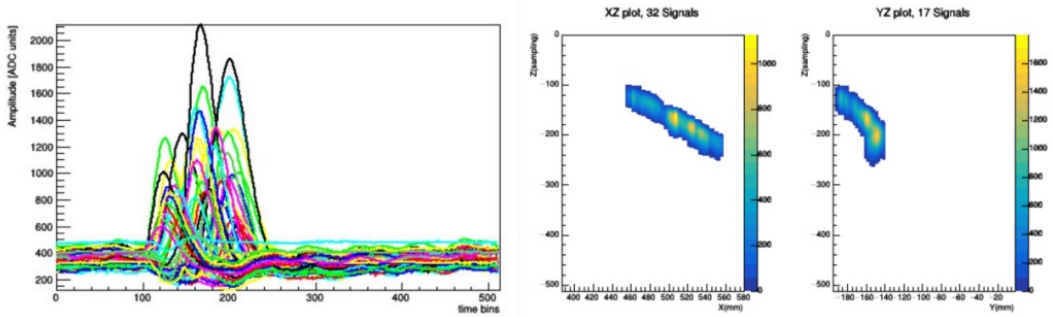
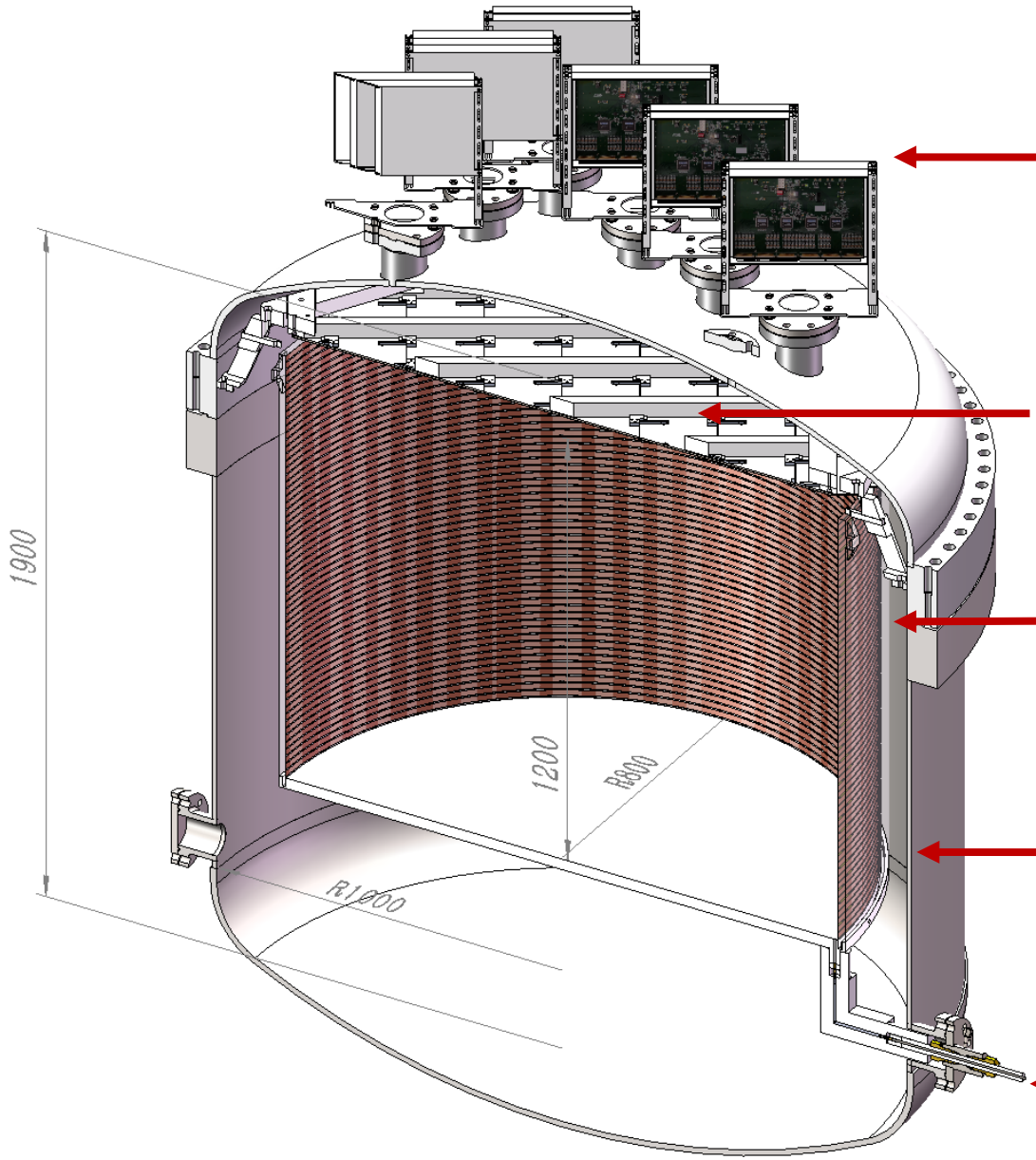




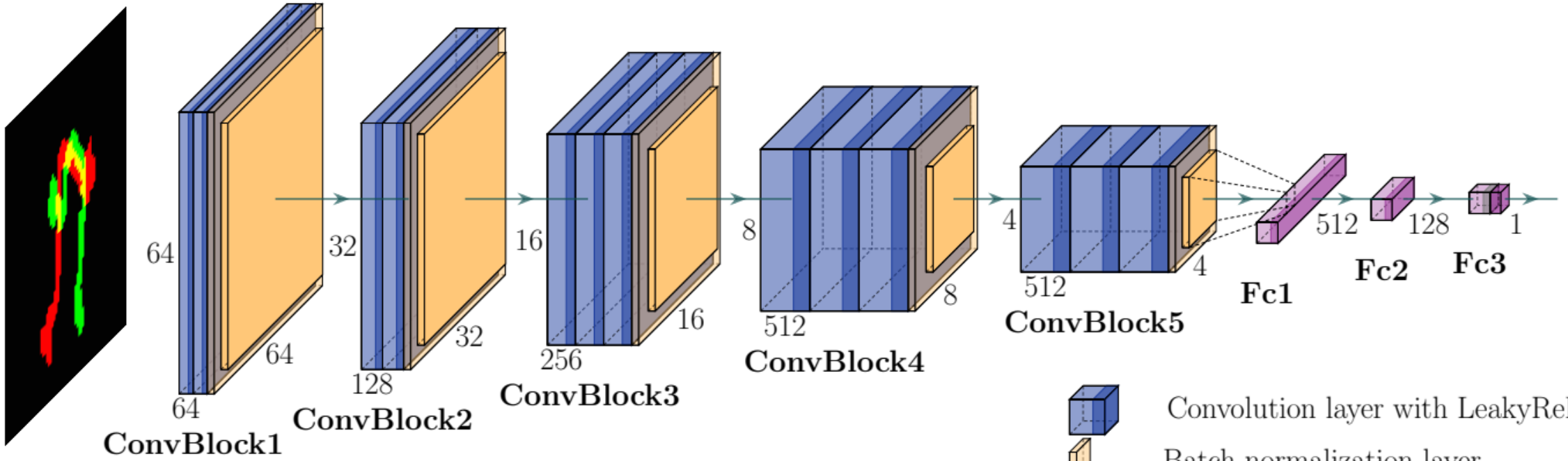
Electronics

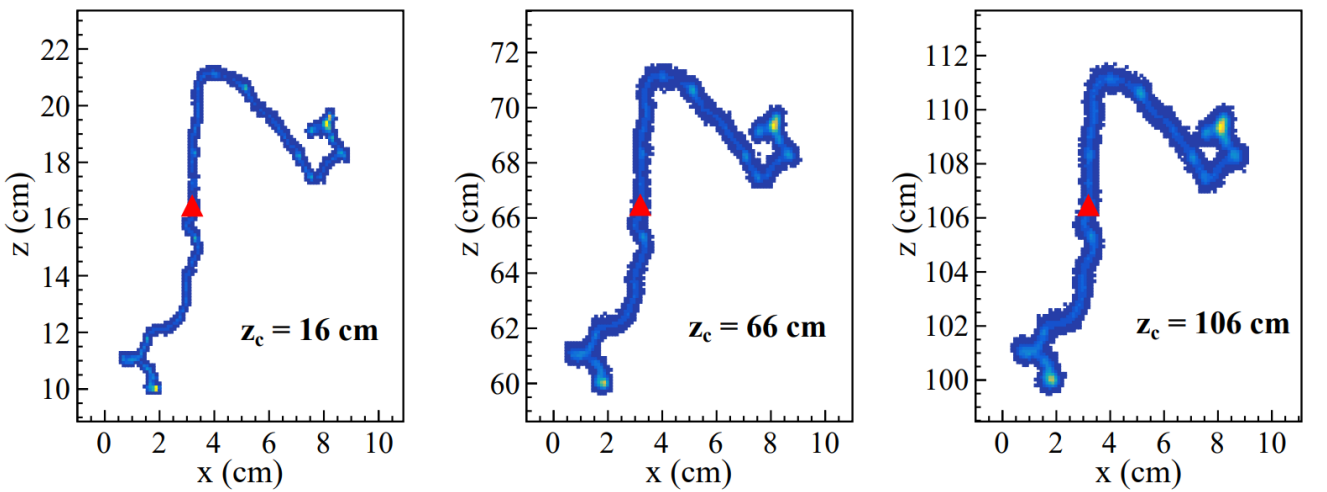
Micromegas readout plane

Field cage

SS vessel

Cathode HV


64
64
64
ConvBlock1
32
128
32
ConvBlock2
16
256
16
ConvBlock3
8
512
8
ConvBlock4
4
512
4
ConvBlock5
512
Fc1
128
Fc2
1
Fc3
Convolution layer with LeakyReLU
Batch normalization layer
Max Pooling layer
Full connection layer


z (cm)
x (cm)
z_c = 16 cm
z_c = 66 cm
z_c = 106 cm