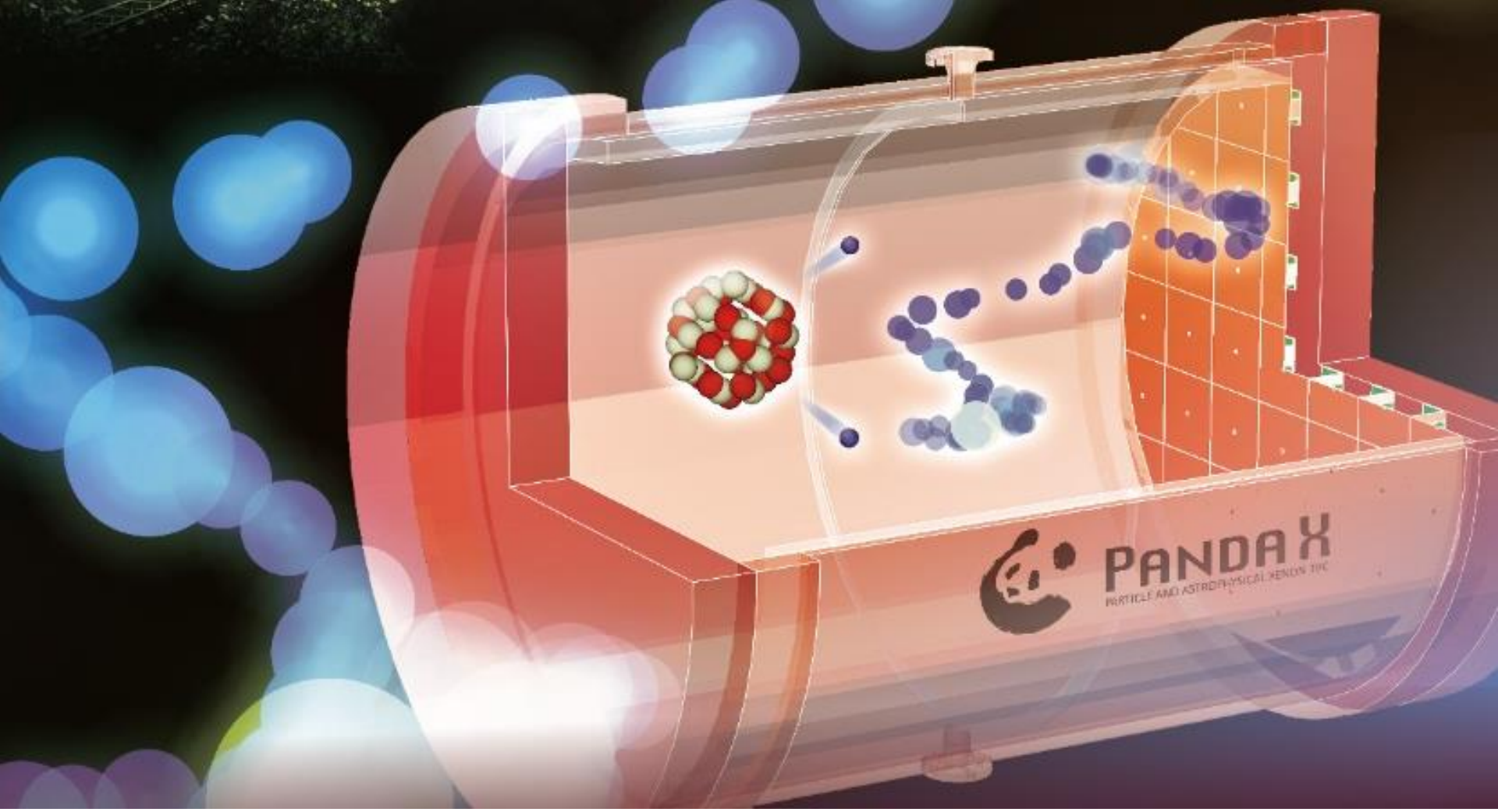


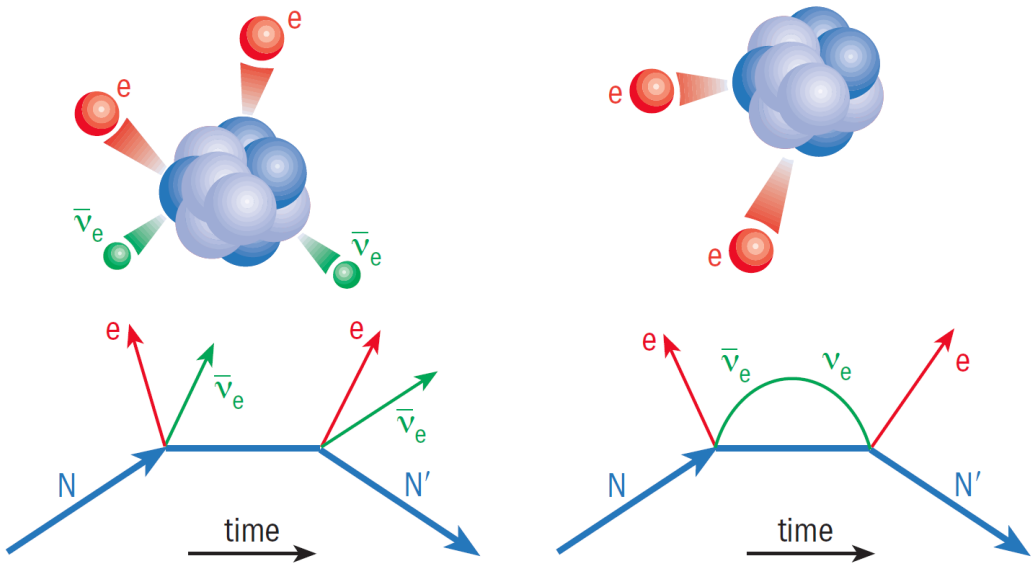
PandaX-III Neutrinoless Double Beta Decay Experiment

韩柯
上海交通大学
2017/11/30

Outline

- Neutrinoless double beta decay
  - Physics and detection
- PandaX-III project
  - High pressure Xe gas TPC with tracking capability
  - Physics reach
- Prototype TPC
  - Preliminary data with one/two readout modules
  - Commissioning of 7 Micromegas modules

Neutrinoless double beta decay



Examples:

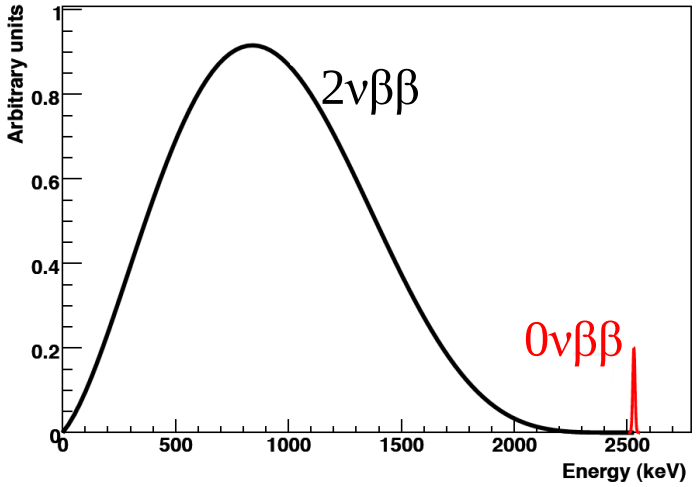
$^{136}Xe \rightarrow {}^{136}Ba + 2e^- + (2\bar{\nu}_e)$

$^{130}Te \rightarrow {}^{130}Xe + 2e^- + (2\bar{\nu}_e)$

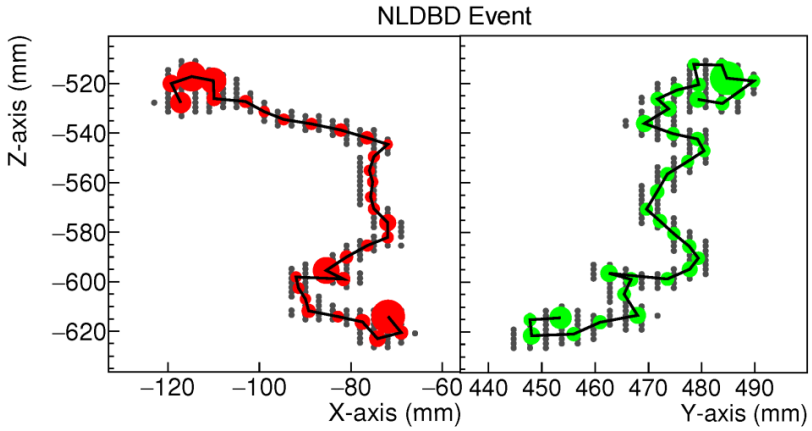
- Explore the Majorana nature of neutrinos $\bar{\nu} = \nu$
- Test lepton number conservation
- Explain naturally the origin of tiny neutrino mass
- Connect to broad neutrino oscillation physics picture

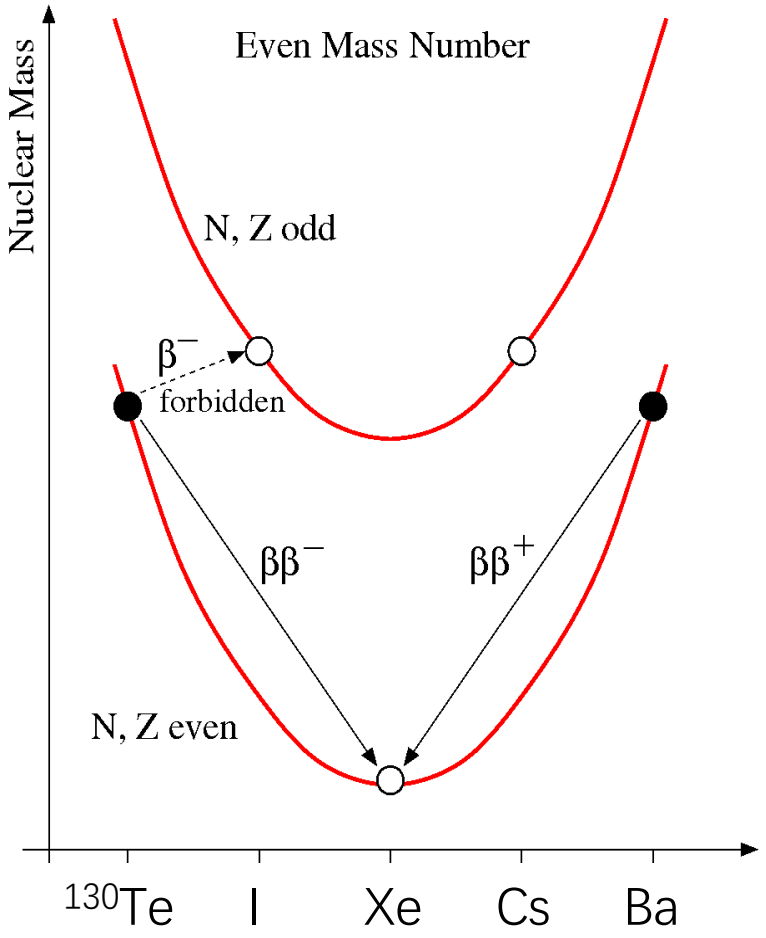
Detection of double beta decay

- Measure energies of emitted e^-



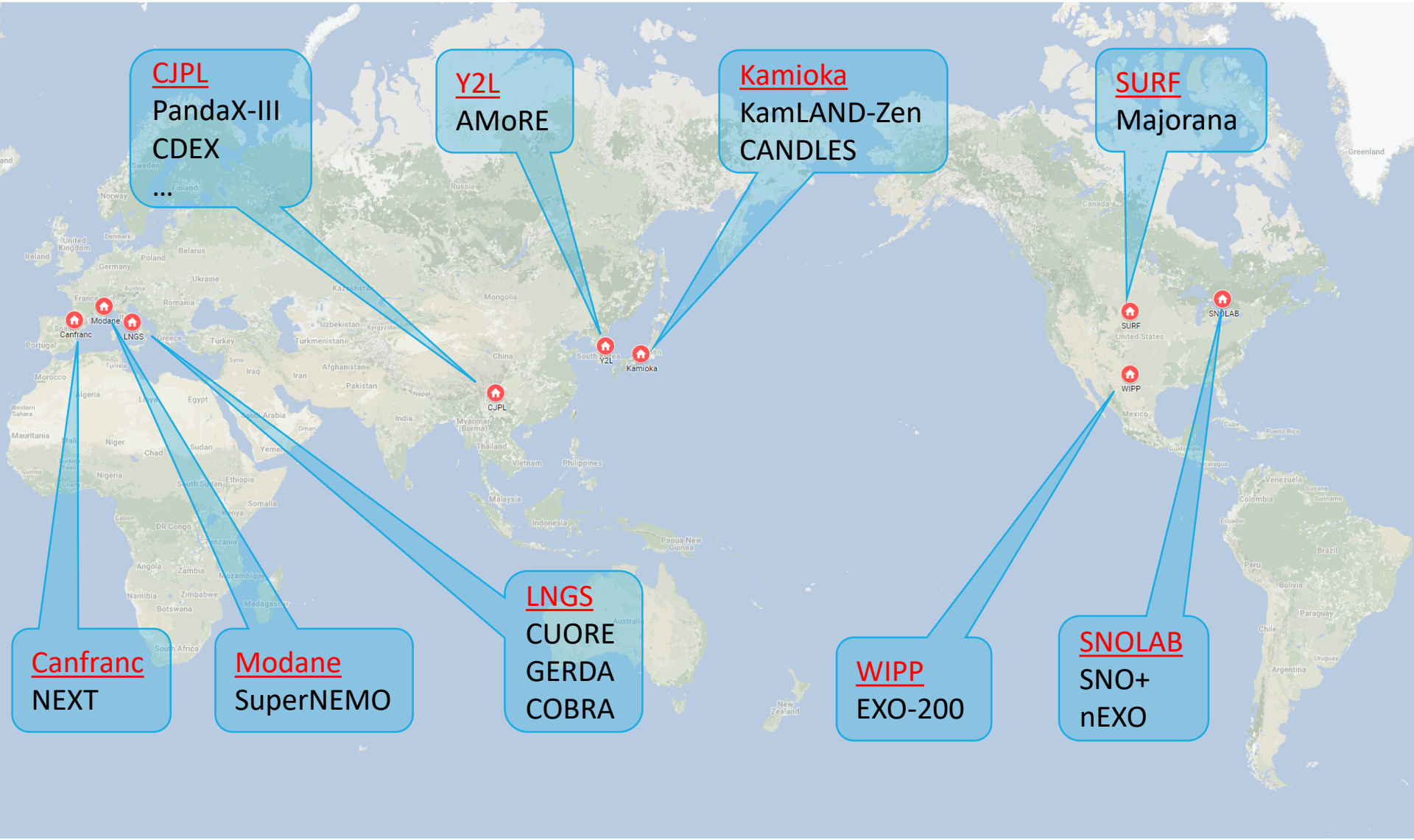
- Electron tracks are a huge plus



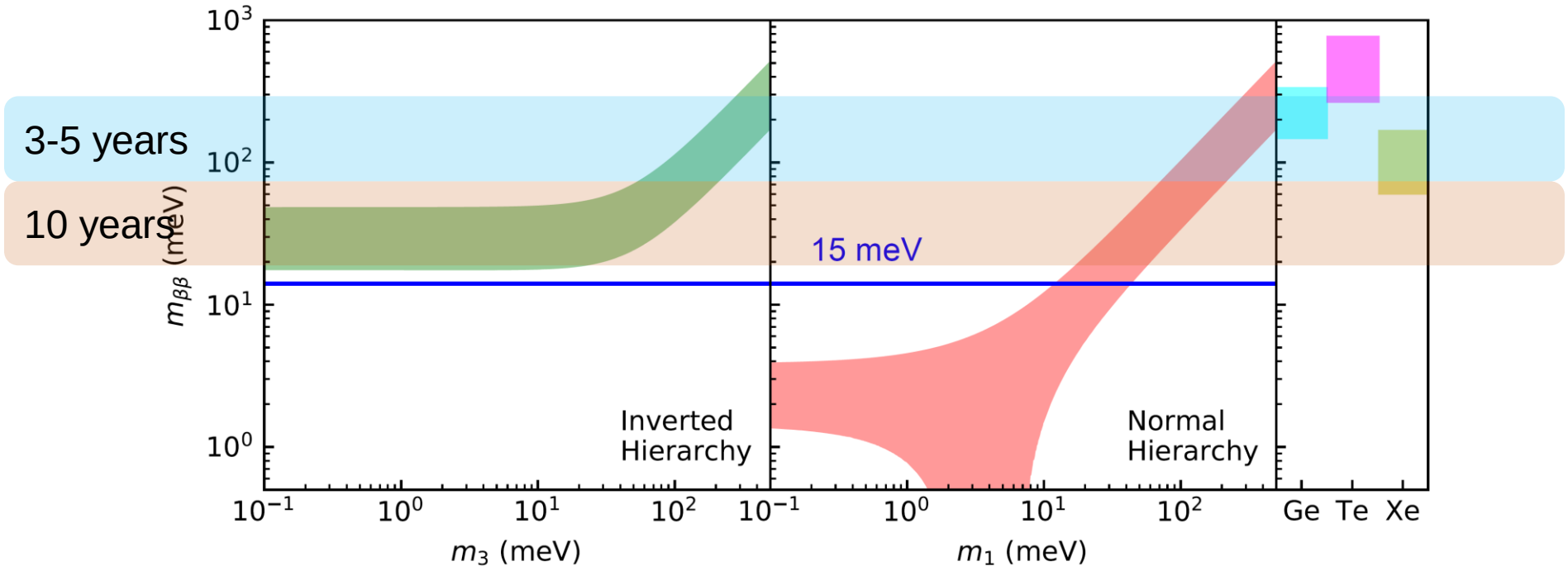


Major 0νββ experiments around the world

PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC



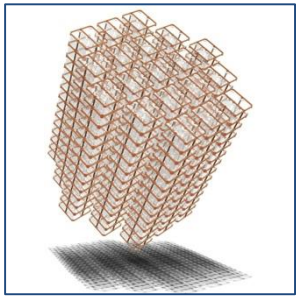
Current landscape



Detection channels

PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC

Phonons



CUORE

AMoRE
CUPID

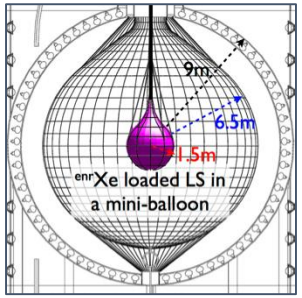
Electrons holes

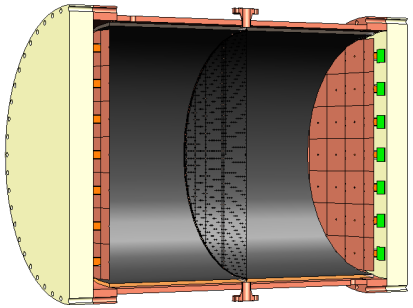
GERDA
Majorana
COBRA
PandaX-III

EXO/nEXO
NEXT
SuperNEMO

KamLAND-Zen
SNO+
CANDLES

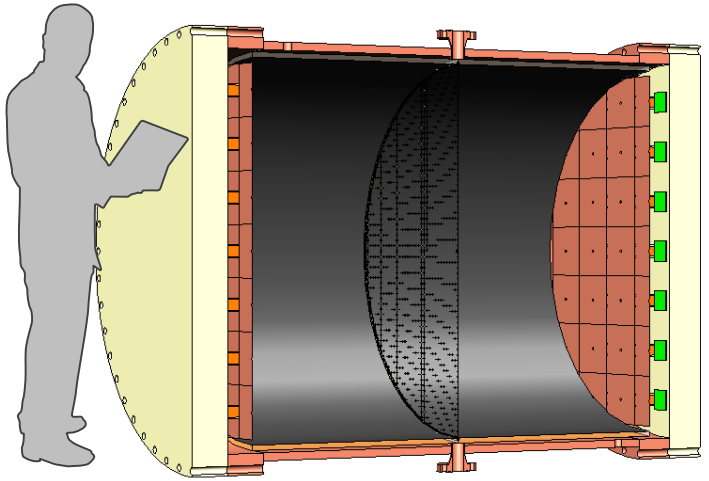
Photons

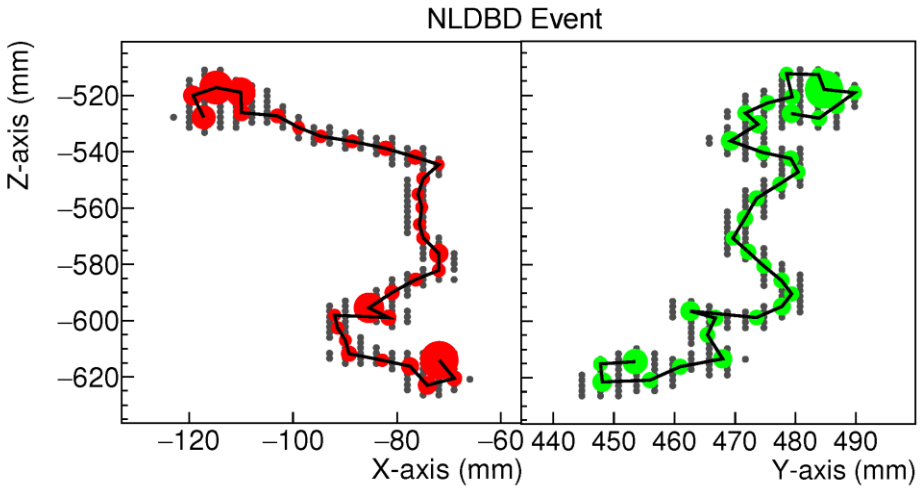


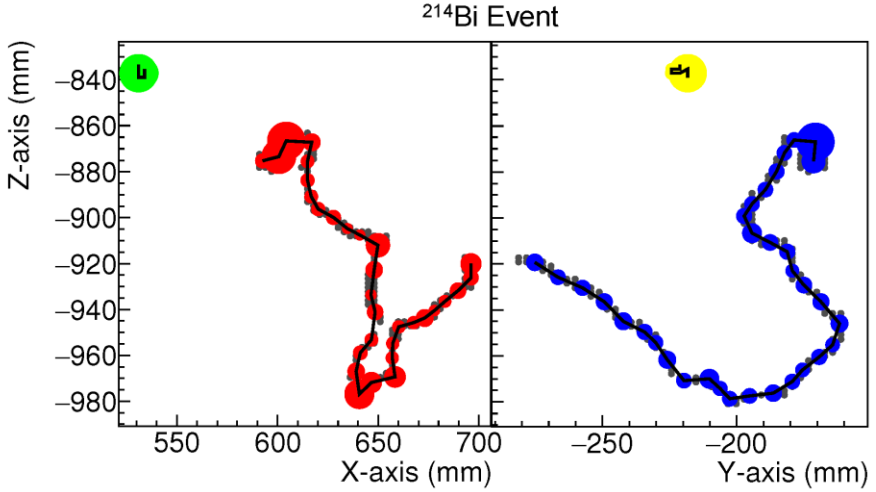


PandaX-III high pressure gas TPC

- TPC: 200 kg scale, symmetric, double-ended charge readout, with 10 bar of ^{136}Xe
- Main features: good energy resolution and background suppression with tracking

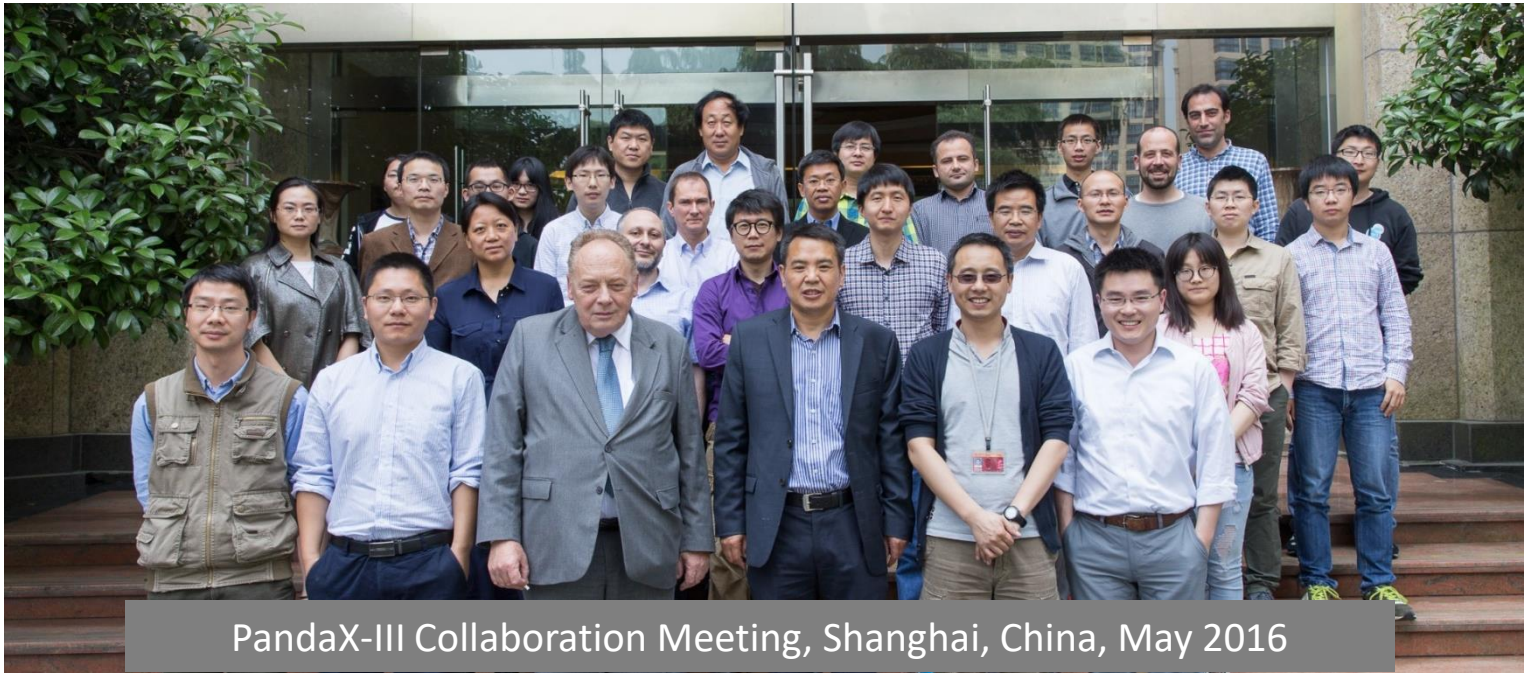






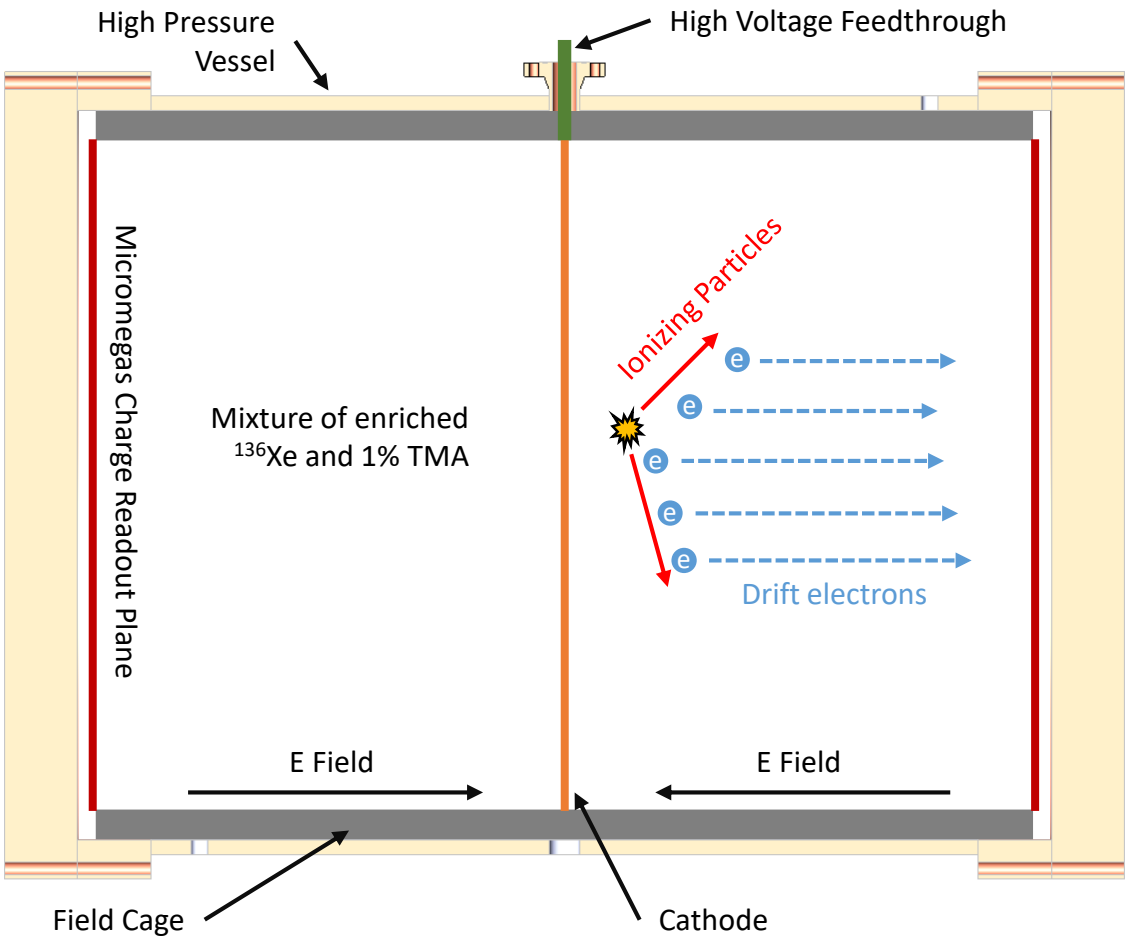
PandaX-III collaboration

- 上海交通大学
- 中国科学技术大学
- 北京大学
- 中山大学
- 山东大学
- 华中师范大学
- 中国原子能科学研究院
- 美国University of Maryland
- 美国Berkeley Lab
- 法国CEA Saclay
- 西班牙University of Zaragoza
- 泰国苏拉那里技术大学 SUT



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

PandaX-III TPC illustrated



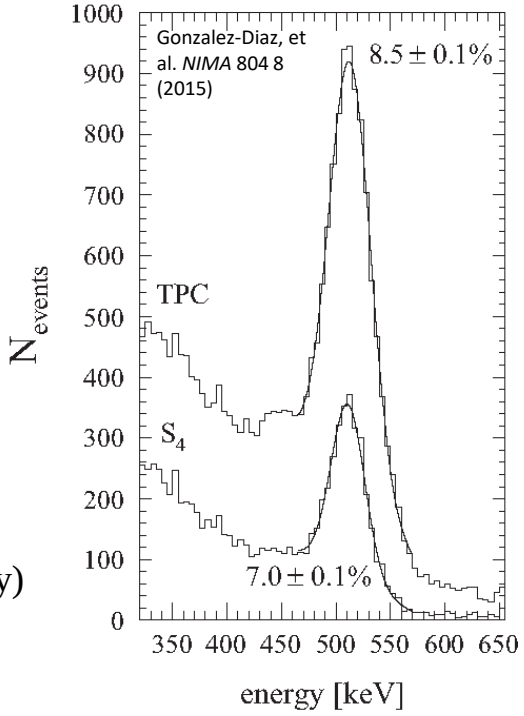
- ~4m^3 active volume
- 10 bar working pressure
- ~10000 readout channels
- Xe+TMA gas mixture
- Charge-only readout with Microbulk Micromegas

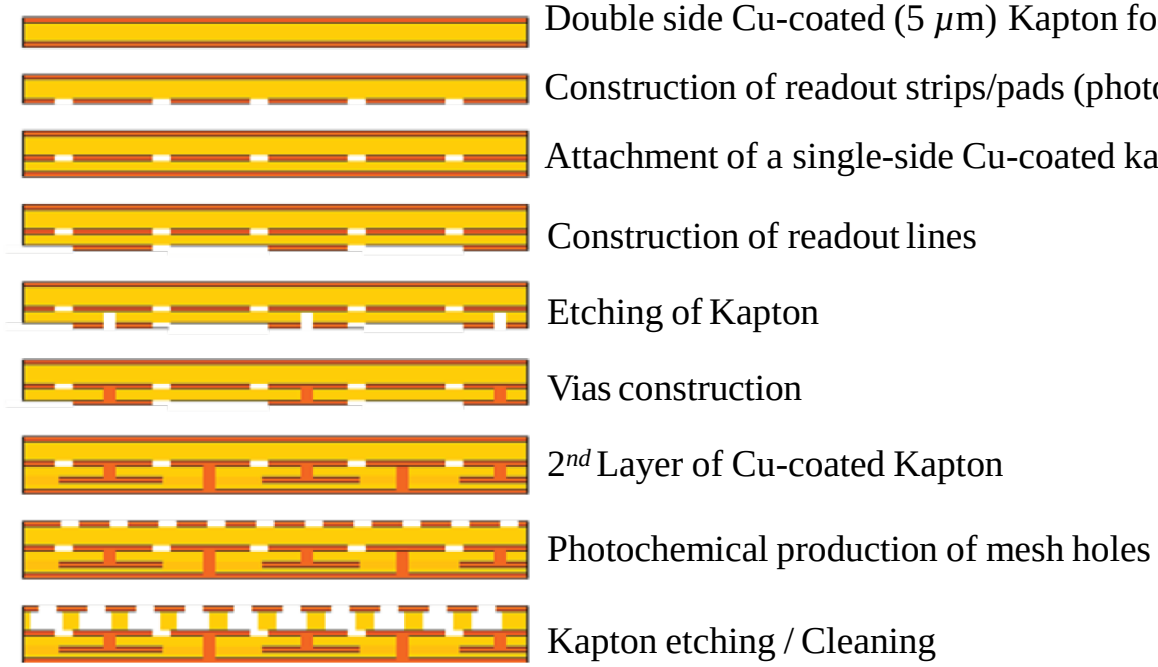
PandaX-III TPC is unique:

- Radio-purity
- Energy resolution
- High pressure

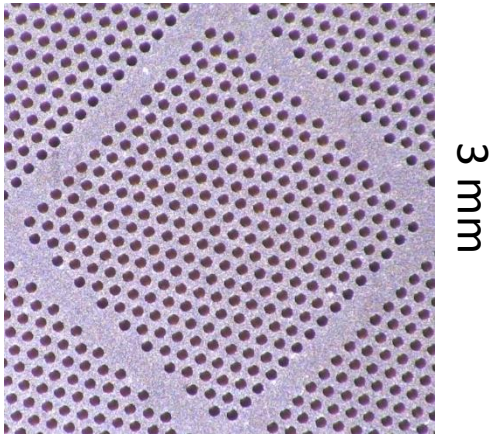
Microbulk MicroMegas (MM)

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



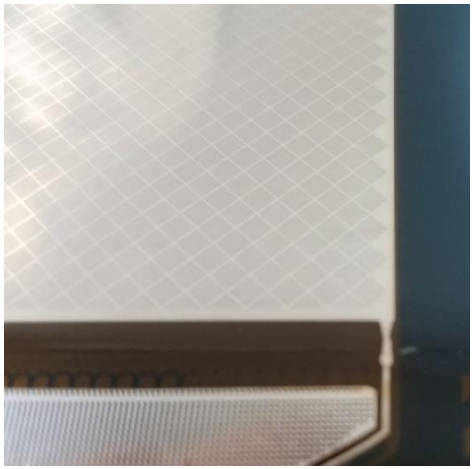


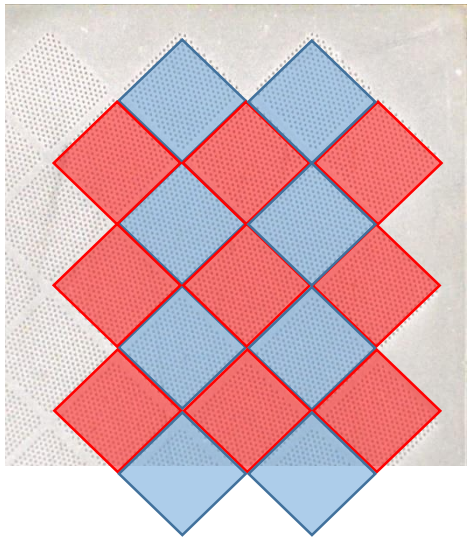
Andriamonje, S. et al. JINST 02 (2010): P02001



PandaX-III Microbulk MicroMegas (MM)

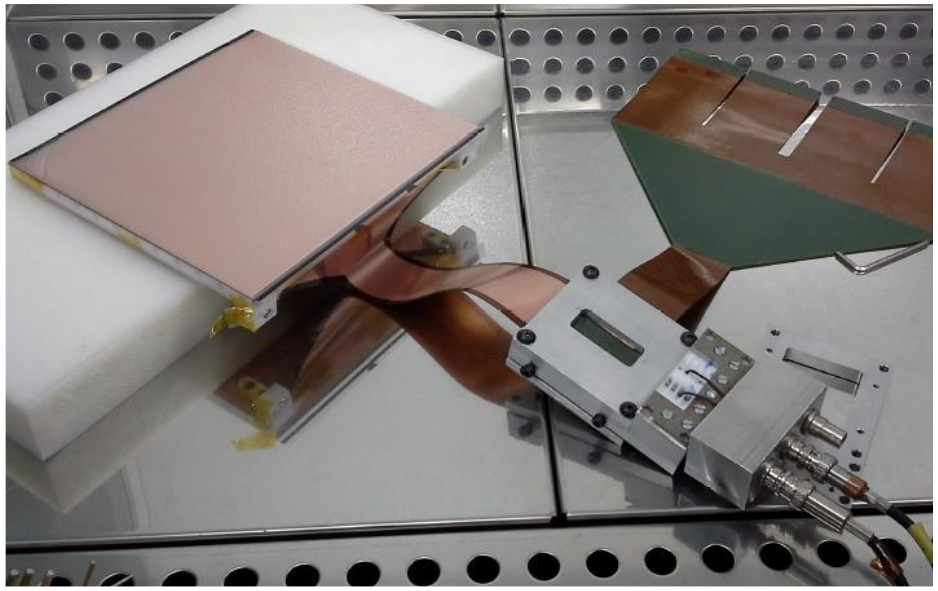
- 20 cm by 20 cm module
- 50 um amplification gap
- 3 mm pitch size
  - XY strip readout
  - X and Y strip share the total deposited energy
  - 128 channels per module
- Manufactured by CERN
- >10000 channels for PandaX-III

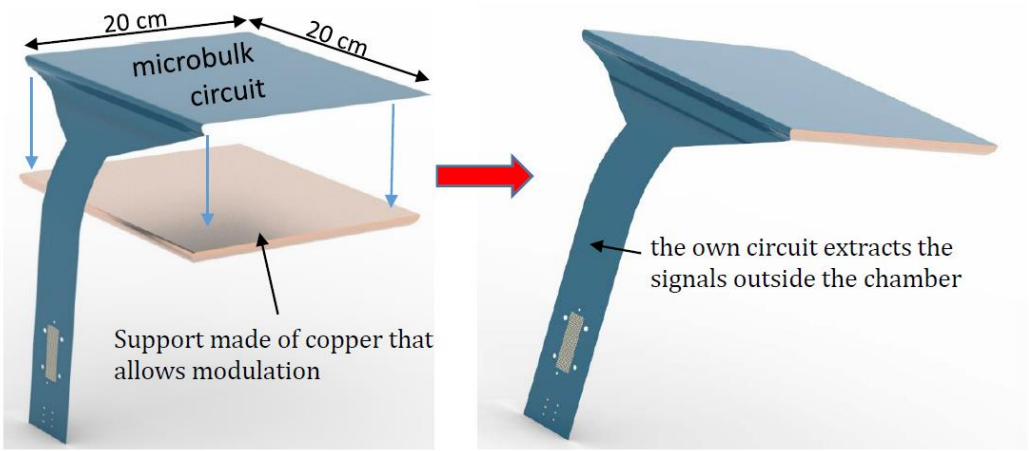




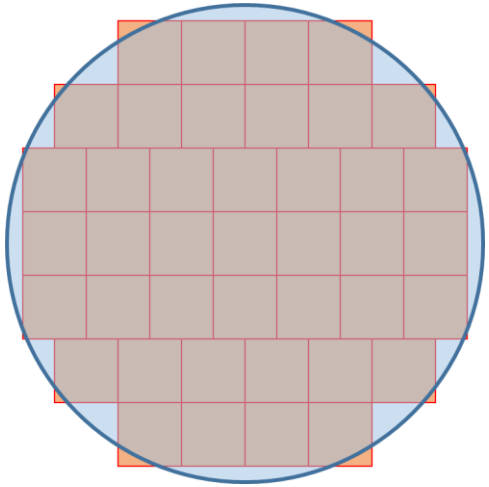
Scalable Radio-pure Readout Module (SR2M)

- SR2M: Mosaic layout to cover readout planes
  - Solderless system
  - Strip and mesh signal readout
  - Dead-zone-free arrangement
  - Designed by Zaragoza and SJTU





×41

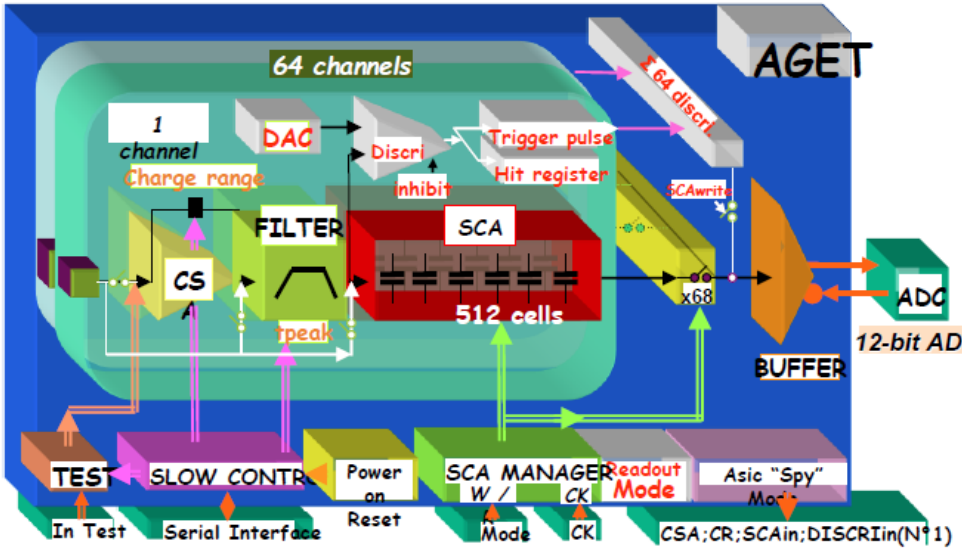


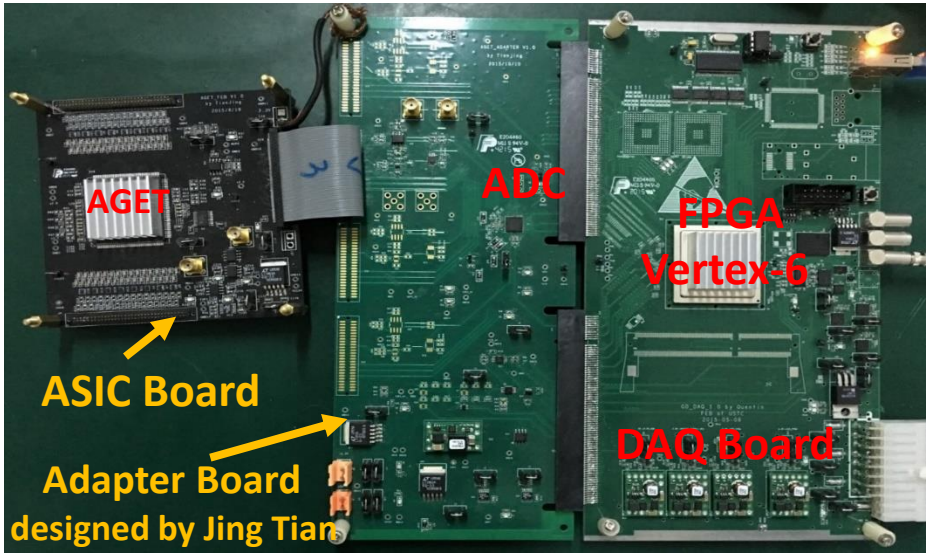
Electronics

ASIC AGET chips: generic electronics for TPC from CEA-Saclay

- 64 channel
- 512 sampling point per channel
- 12 bit ADC
- Dynamic range up to 10 pC
- Sampling rate: 1 MHz to 100 MHz

- Commercial DAQ suite ASAD + CoBo tested and used for our prototype TPC
- Three versions of custom electronics card designed and tested (USTC)
  - 1024 channels!

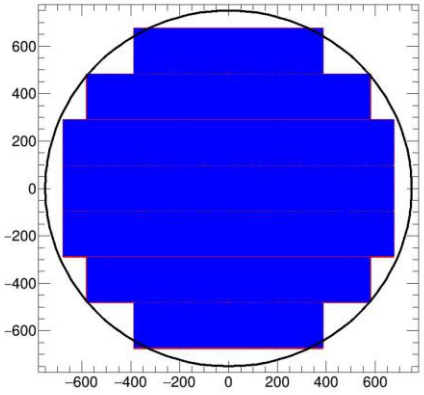


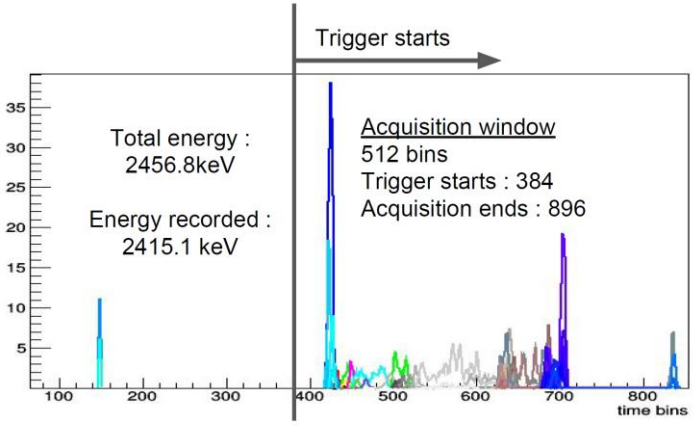


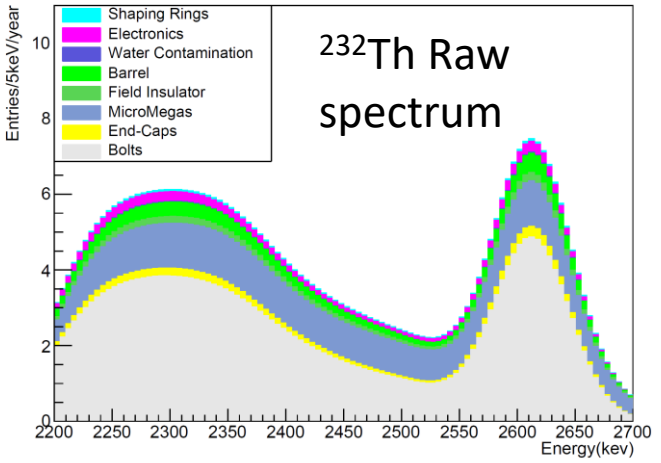
Background budget

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

- Treat PandaX-III as a simple calorimeter
- Then add detector response
- Calculate signal efficiency and background rejection
- ×35 background reduction from topological analysis
  - Track reconstruction and blob identification at both ends
  - Convoluted neural network

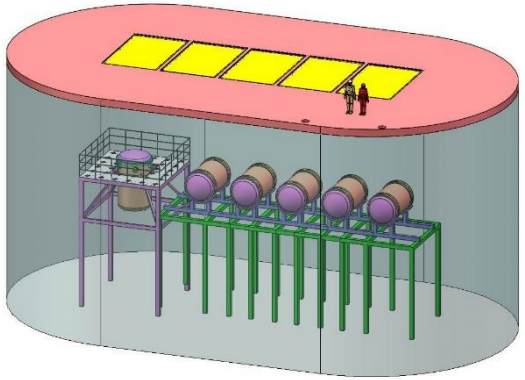


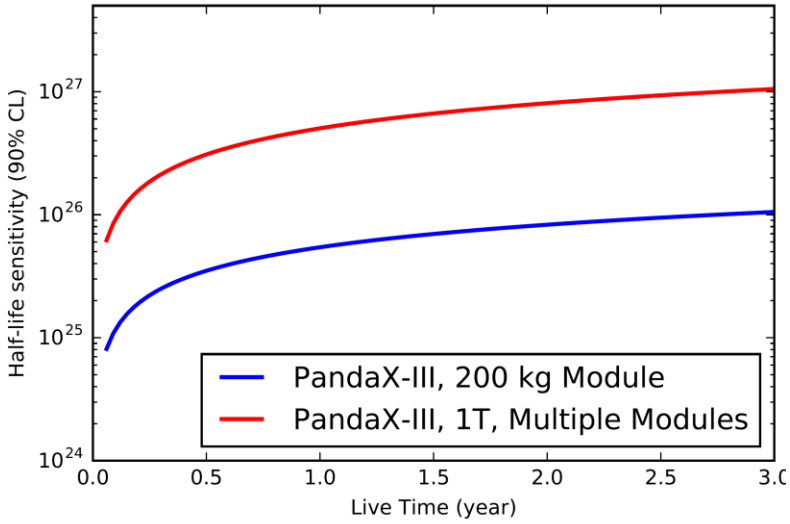


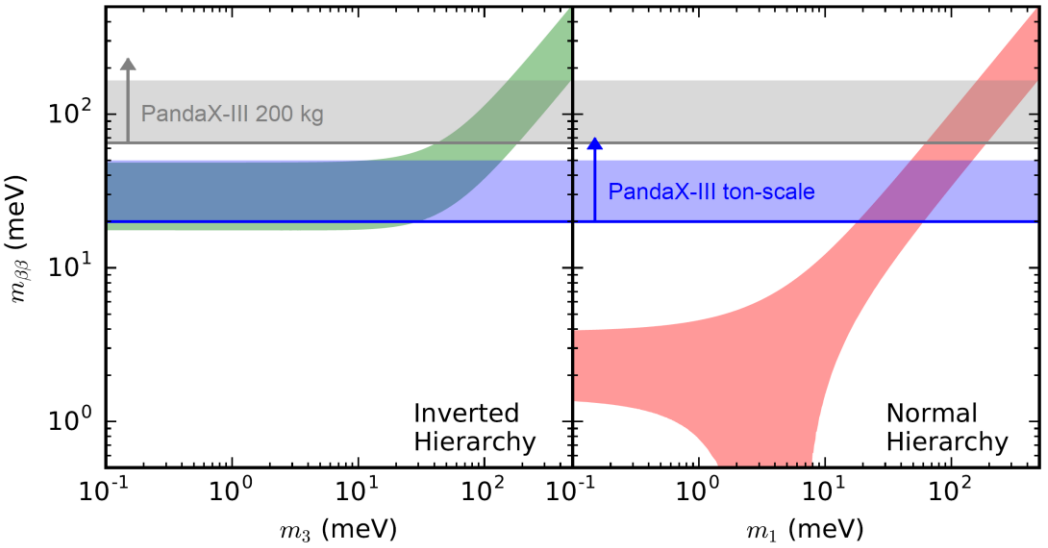


Sensitivity projection

- First 200-kg module:
  - Microbulk Micromegas for charge readout
  - 3% FWHM, 1 x 10^{-4} c/keV/kg/y in the ROI
- Ton-scale:
  - Four more modules with upgraded charge readout and better low-background material screening.
  - 1% FWHM, 1 x 10^{-5} c/keV/kg/y in the ROI

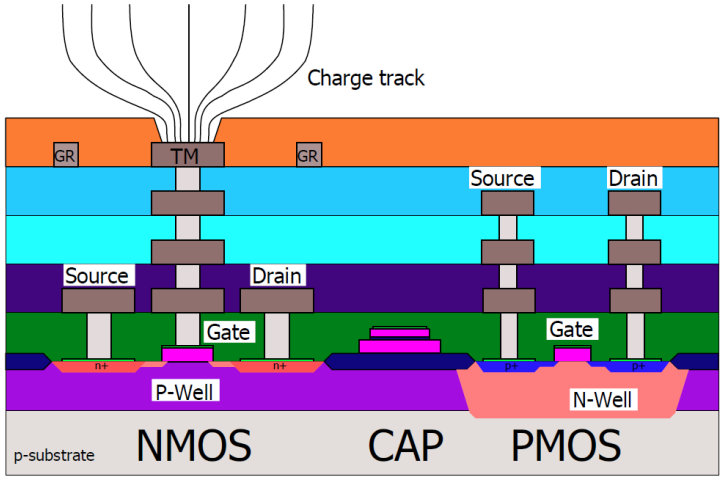




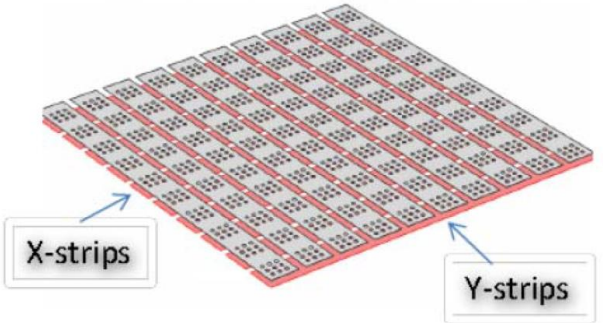


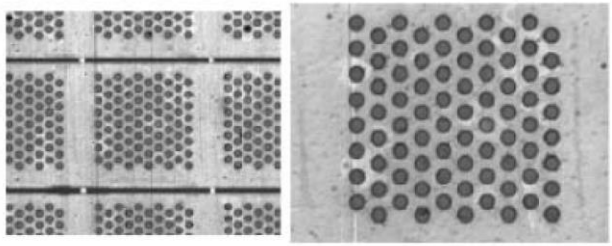
Future energy resolution improvement

- TopMetal Direct Charge Sensor (CCNU&Berkeley)
  - Direct pixel readout without gas amplification
  - 20e noise
  - First 10x10 cm readout plane in production



- Alternative (bulk and Microbulk) Micromegas technologies (Saclay)
  - Strip Mesh readout
  - More uniform amplification gaps.

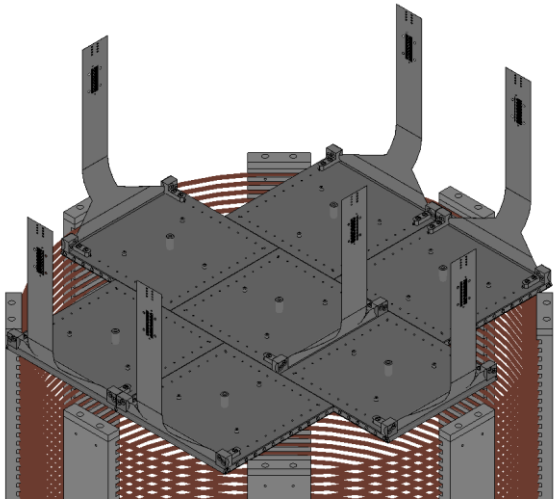


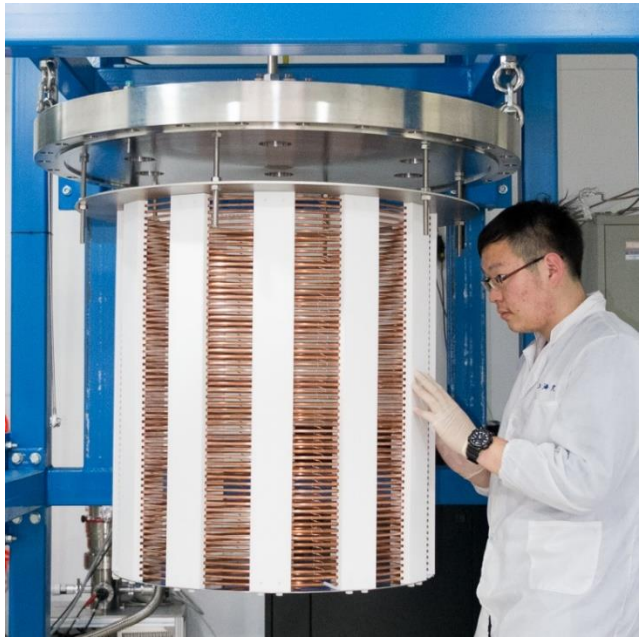


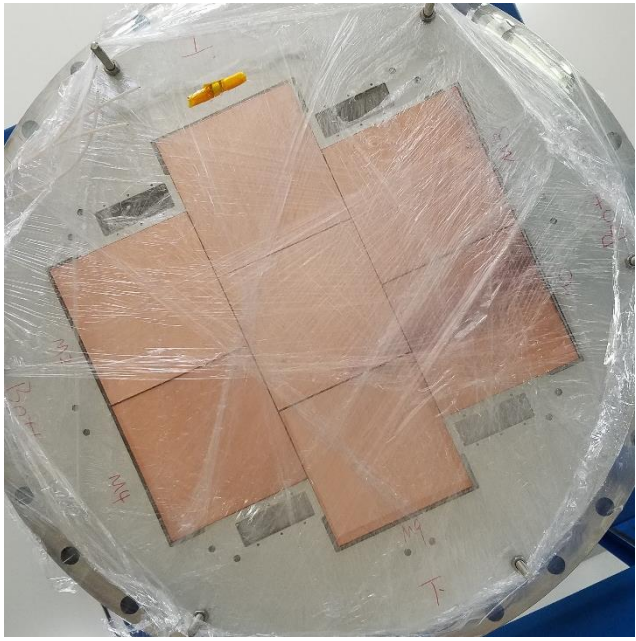
Prototype TPC at SJTU

PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC

- 16 kg of xenon at 10 bar (active mass within TPC)
- To see MeV electron track
- To demonstrate required energy resolution with a large-scale high pressure TPC
- To develop algorithm of 3D track reconstruction
- To explore the impact of t_0 with light readout
- To test custom electronics from USTC

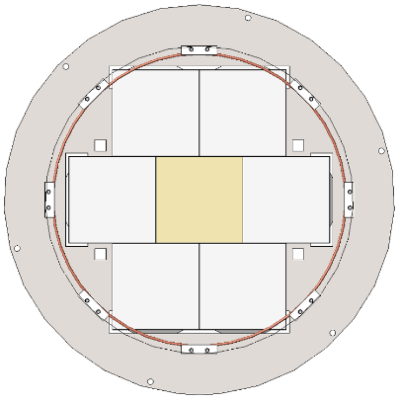


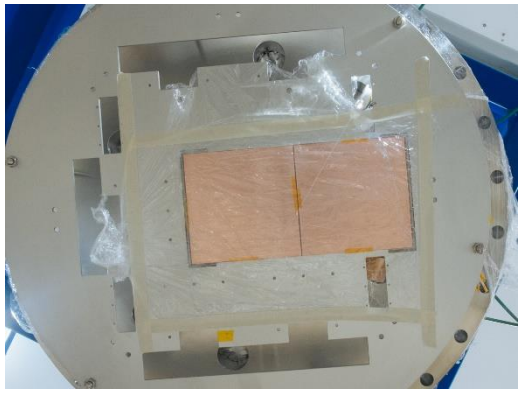


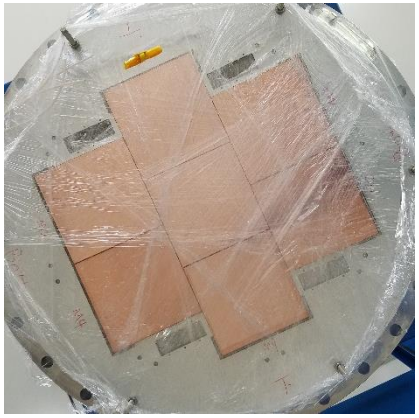


Progress towards prototype

	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 5 bar	Up to 10 bar
Calibration	Internal ^{241}Am	+ Motorized ^{55}Fe	+ ^{137}Cs + ^{232}Th
Electronics	ASAD/CoBo	ASAD/CoBo	+ Custom FEC
Status	Done	Data analysis	Commissioning

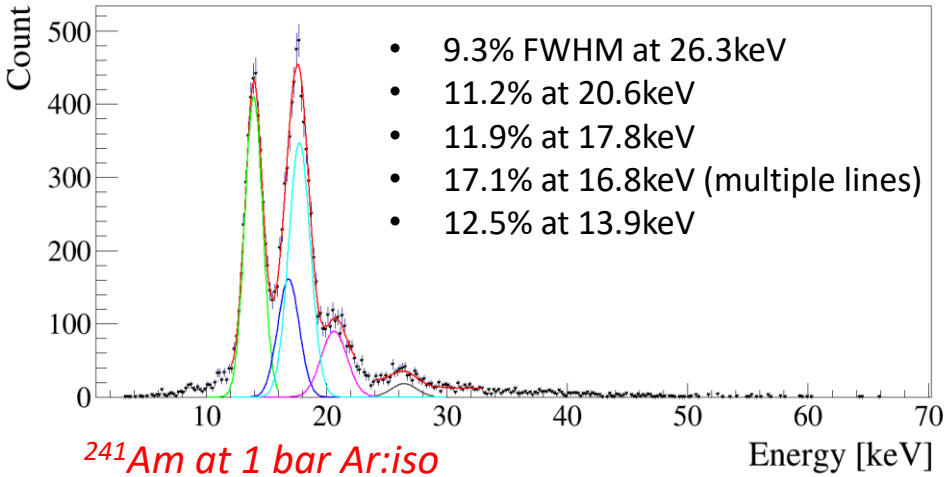






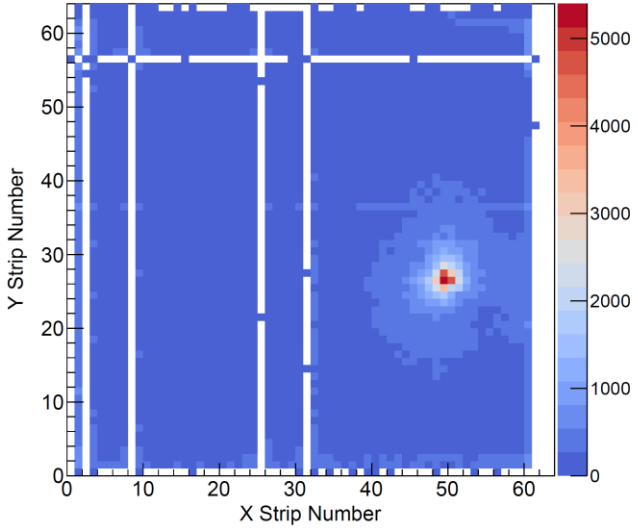
Data taking with 1 Micromegas

- ^{241}Am Gamma source
- Xe:(1%)TMA; Ar:(5%)isobutene
- Continuous gas circulation and purification
- Detector gain up to 8000
- Data analysis is on-going

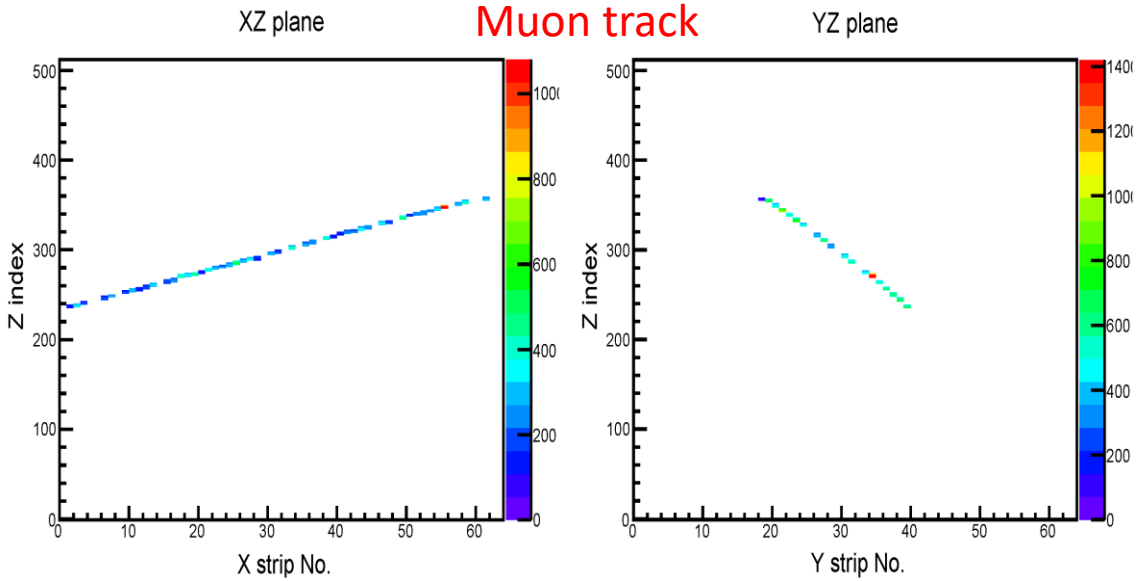


^{241}Am at 1 bar Ar:iso

^{241}Am at 5 bar Xe:TMA



Muon track

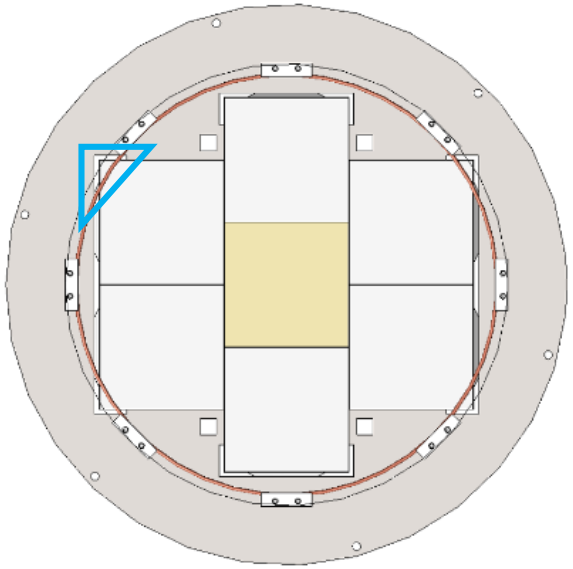


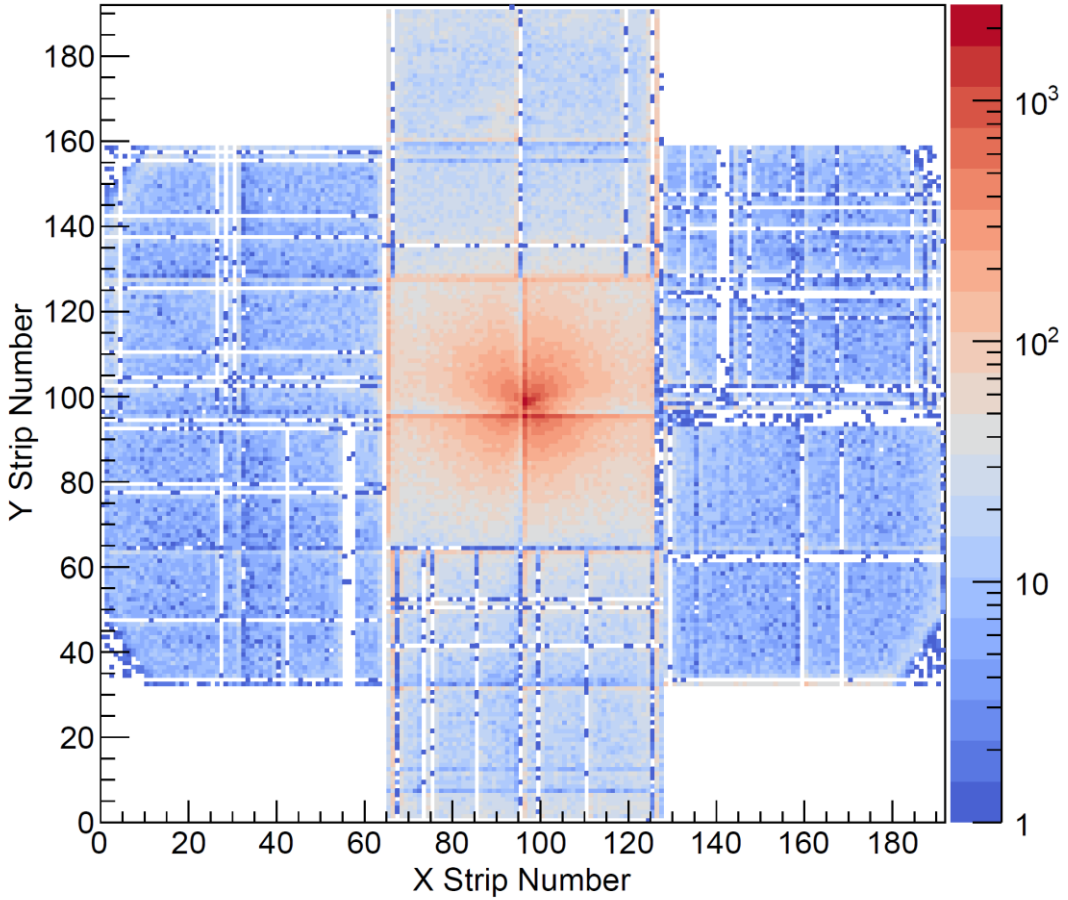
Commissioning of 7 Micromegas

- 7 MM modules have been installed to the TPC
- Now filled with 5 bar Ar:Iso to benchmark its performance
  - No leaks
  - Drift and mesh HV are Okay.
  - Checking bad strips and getting ready for data taking.
- ^{137}Cs and ^{241}Am gamma sources are installed in the TPC
- Will run up to 10 bar of Xe+TMA

Preliminary data taking with 7 MM

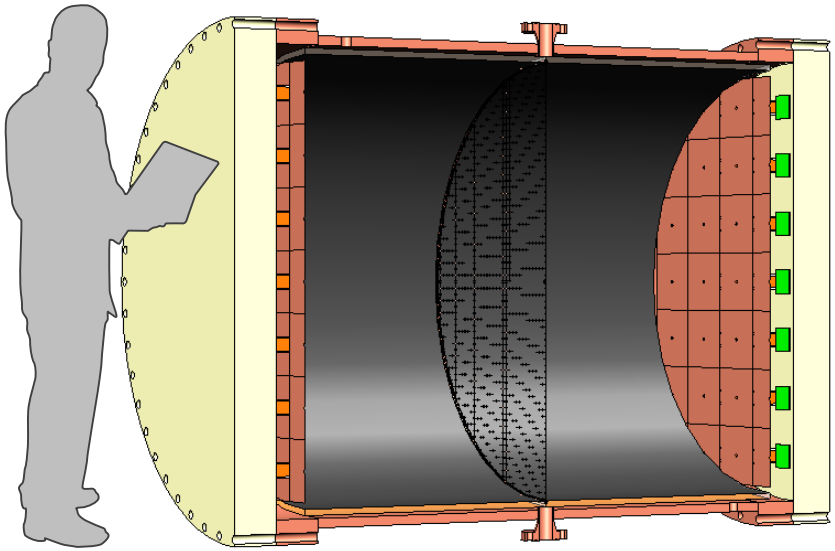
- Established the data flow of 7 Micromegas simultaneously
- 896 channels tested with ASAD+CoBo
  - Largest AGET application domestically.
- ^{137}Cs source at the center
- Commissioning stage

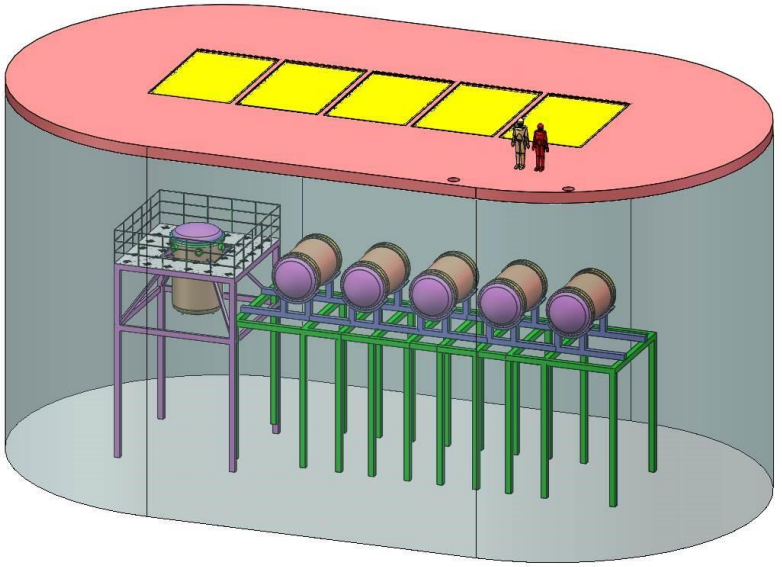




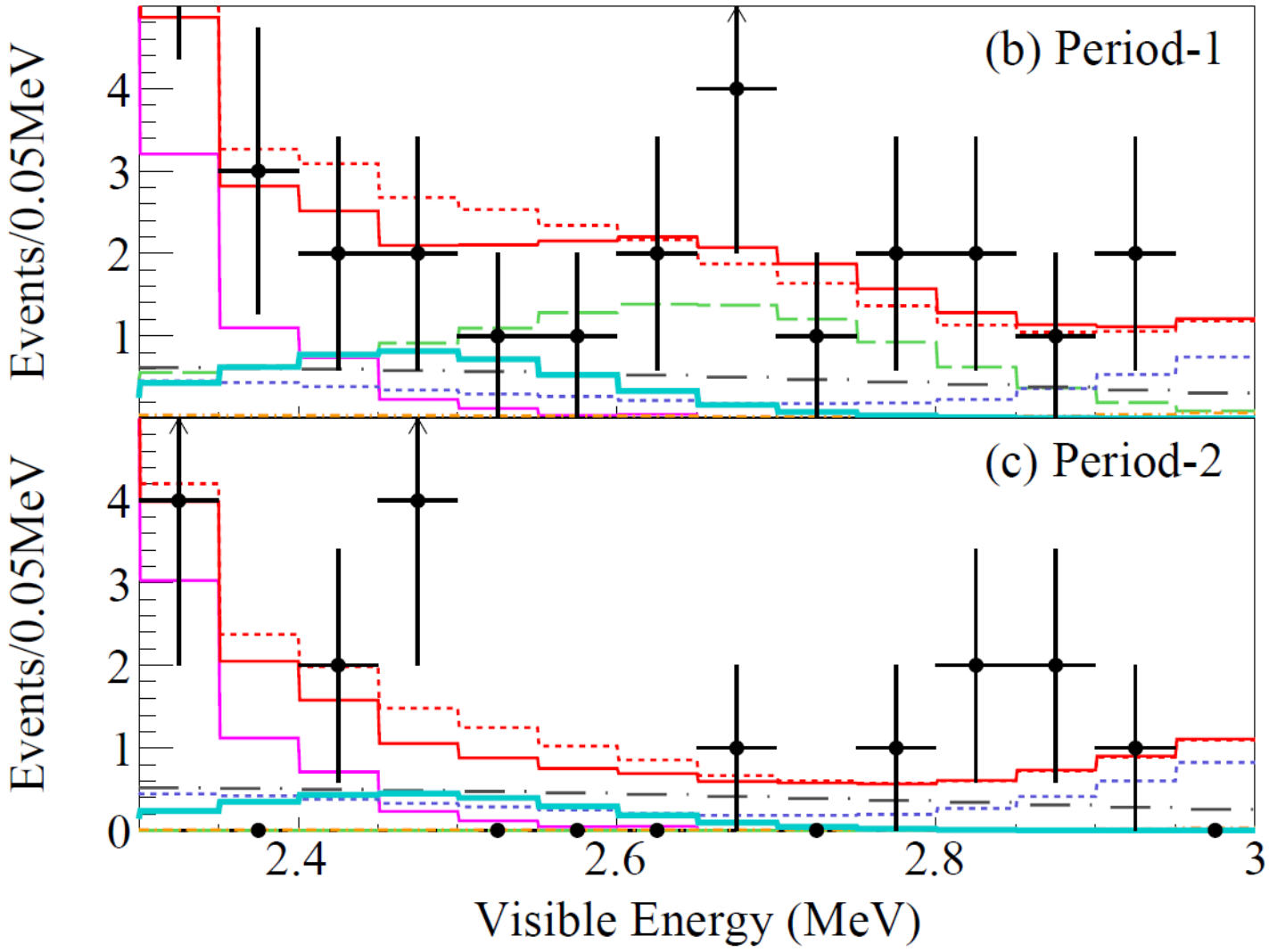
Conclusions

- PandaX-III uses high pressure gas TPCs to search for double beta decay of ^{136}Xe
- Gas TPC provides unique background suppression with tracking capability
- Phased approach: 200 kg first, then ton-scale with multiple modules
- 20-kg scale prototype TPC has been built and under commissioning





Component	Isotope	Background (10^{-5} c/(keV·kg·y))	
		BambooMC	RestG4
Water	^{238}U	-	0.23
	^{232}Th	0.56	0.63
Barrel	^{238}U	1.07	2.41
	^{232}Th	7.54	7.86
	^{60}Co	3.02	2.11
End-caps	^{238}U	0.30	1.26
	^{232}Th	3.89	4.16
	^{60}Co	2.98	0.76
Bolts	^{238}U	3.50	11.9
	^{232}Th	73.8	78.5
Field insulator	^{238}U	19.5	16.5
	^{232}Th	3.80	3.86
and rings	^{238}U	1.52	0.45
	^{232}Th	1.41	1.17
Electronics	^{238}U	-	1.42
	^{232}Th	5.02	8.69
Micromegas	^{238}U	144	158
	^{232}Th	36.9	44.5
Total		308.8	344.4


(b) Period-1
(c) Period-2
Events/0.05MeV
Events/0.05MeV
0
1
2
3
4
2.4
2.6
2.8
3
Visible Energy (MeV)

From MM films to SR2M