PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC

上海交通大學
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Status and Plan of PandaX Experiment

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On behalf of the PandaX Collaboration

TeVPA2019, Sydney
2019-12-05

PandaX Collaboration

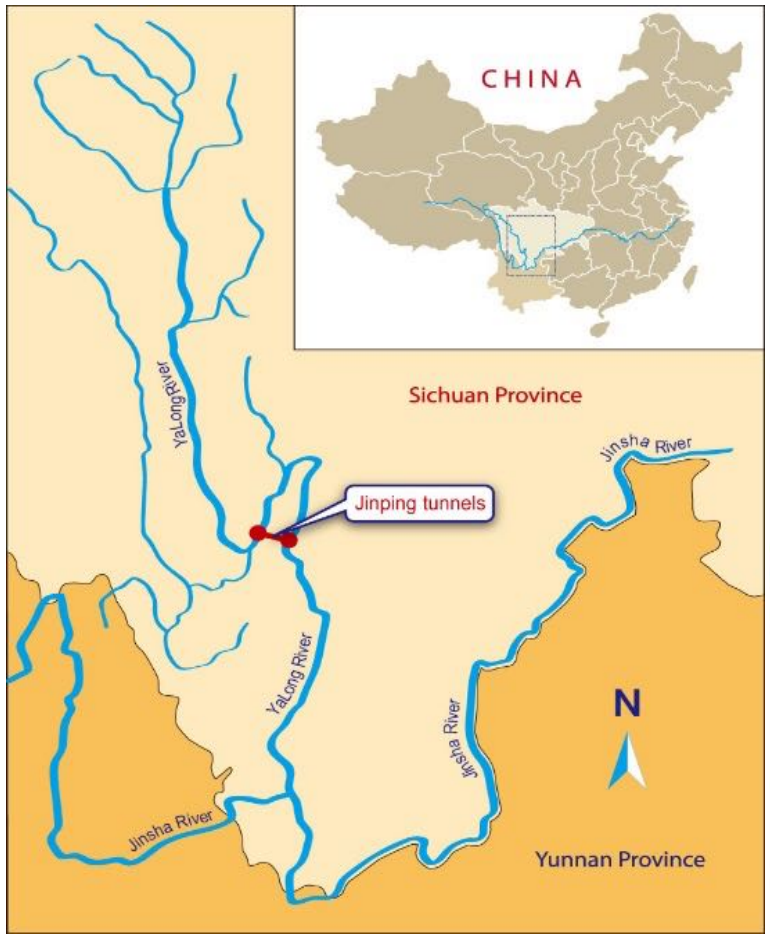
- **Particle and Astrophysical Xenon Experiment**
  - Formed in 2009

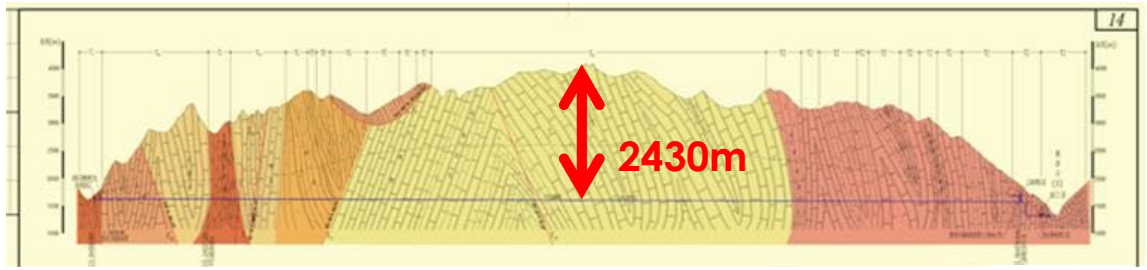
PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC

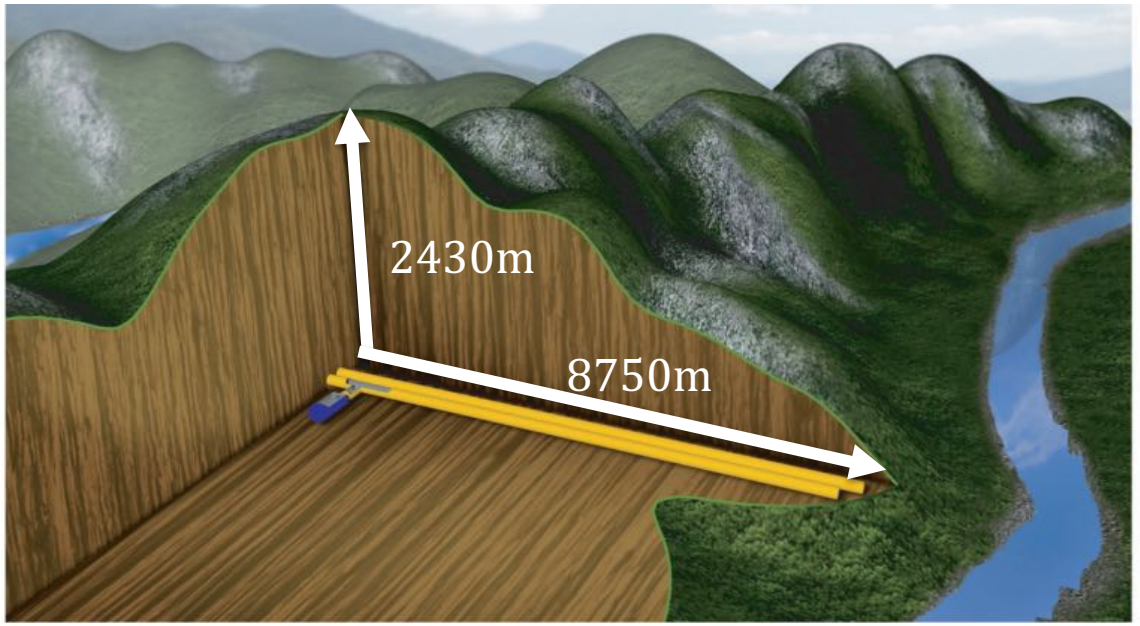
Universidad Zaragoza

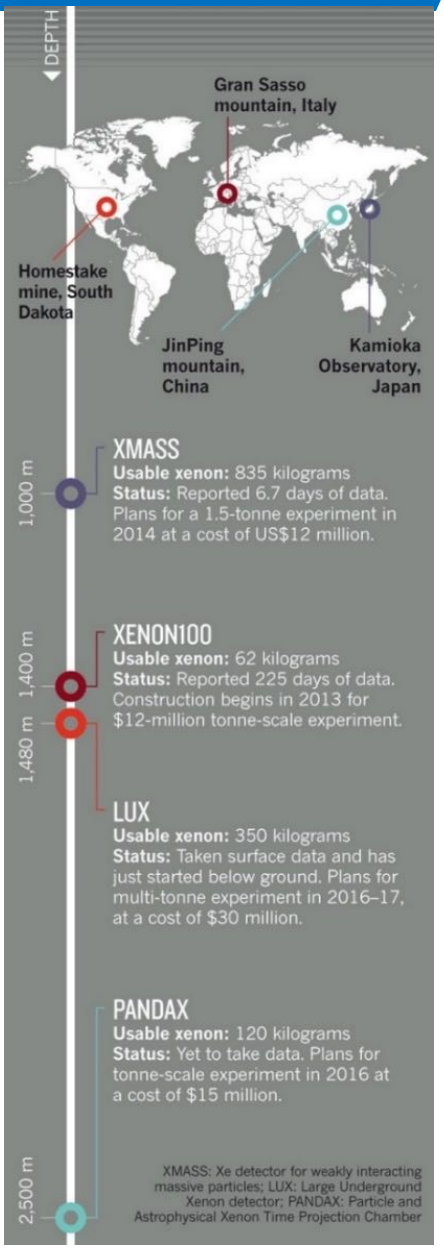
China Jinping Underground Laboratory

- Deepest (6800 m.w.e): < 0.2 muons/m^2/day
- Horizontal access: 9 km long tunnel





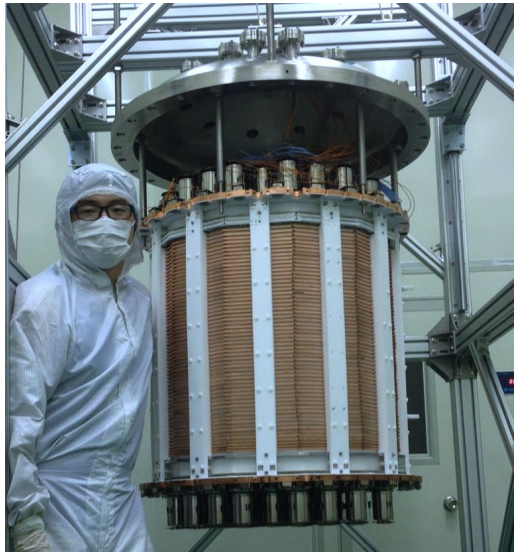




PandaX Dark Matter Experiments

- PandaX-II:
  - completed in 2019
- **PandaX-4T**
  - 4 ton liquid xenon in sensitive volume

PandaX-I: 120 kg DM experiment
2009-2014

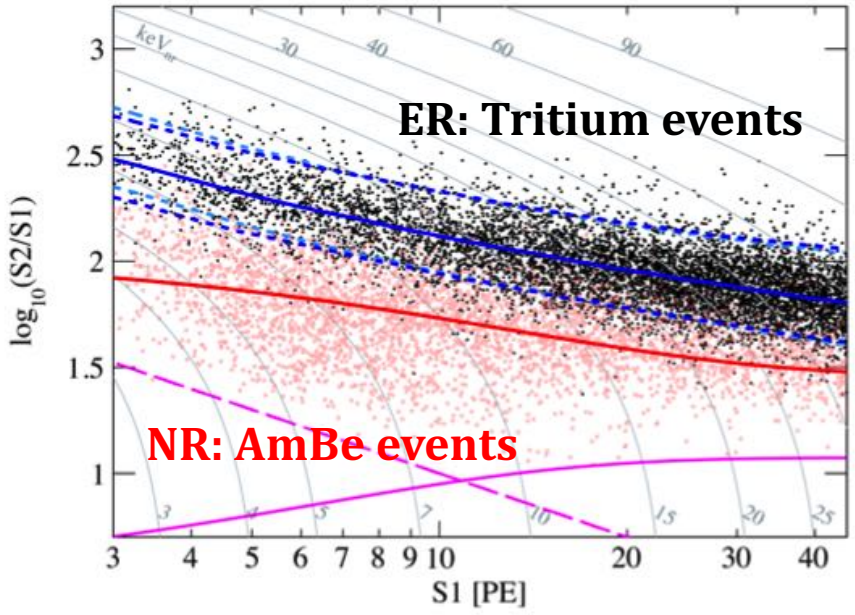


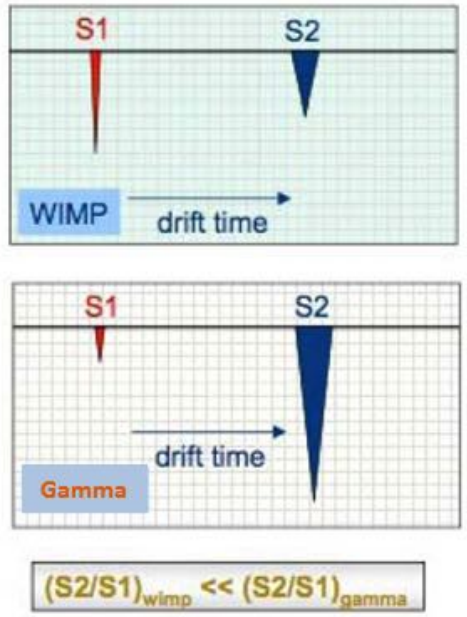
PandaX-II: 580 kg DM experiment
2014-2019

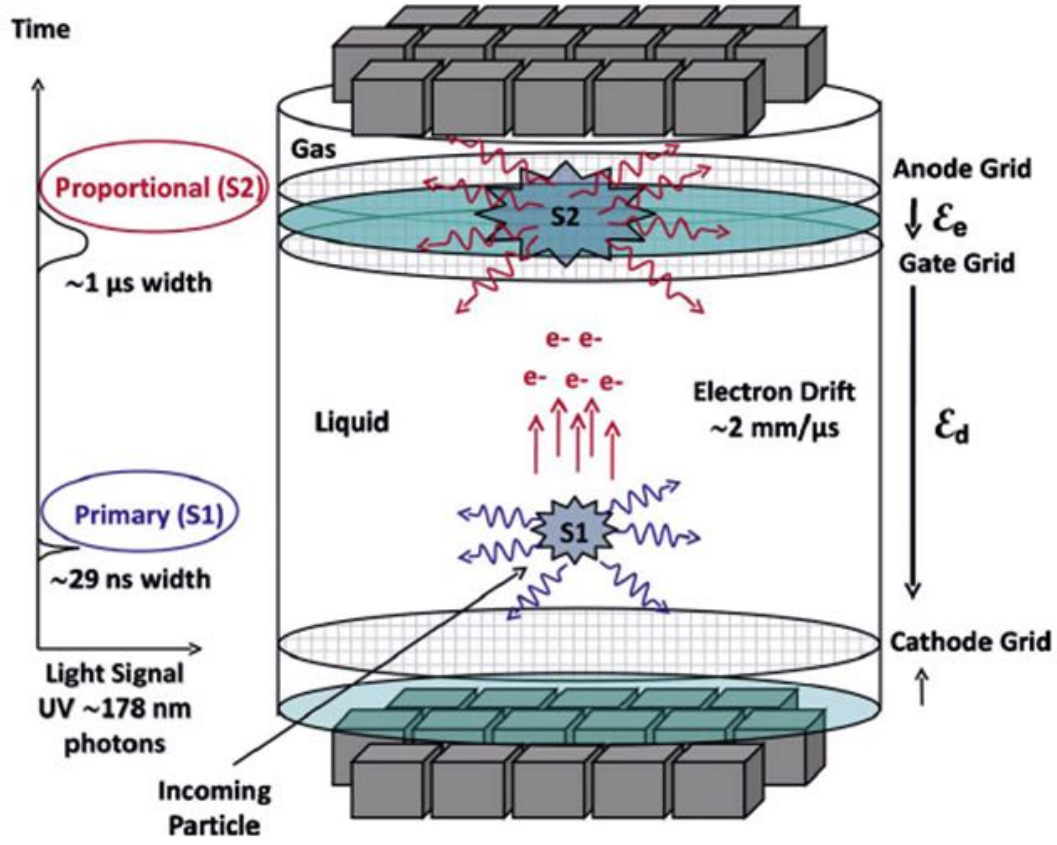
PandaX-4T: multi-ton DM experiment
2019-

Dual-phase Xenon TPC

- Dual-phase xenon TPC
  - prompted S1 (scintillation) and delayed S2 (ionization)signals
- 3D position reconstruction
- Recoil energy measurement
- ER/NR discrimination

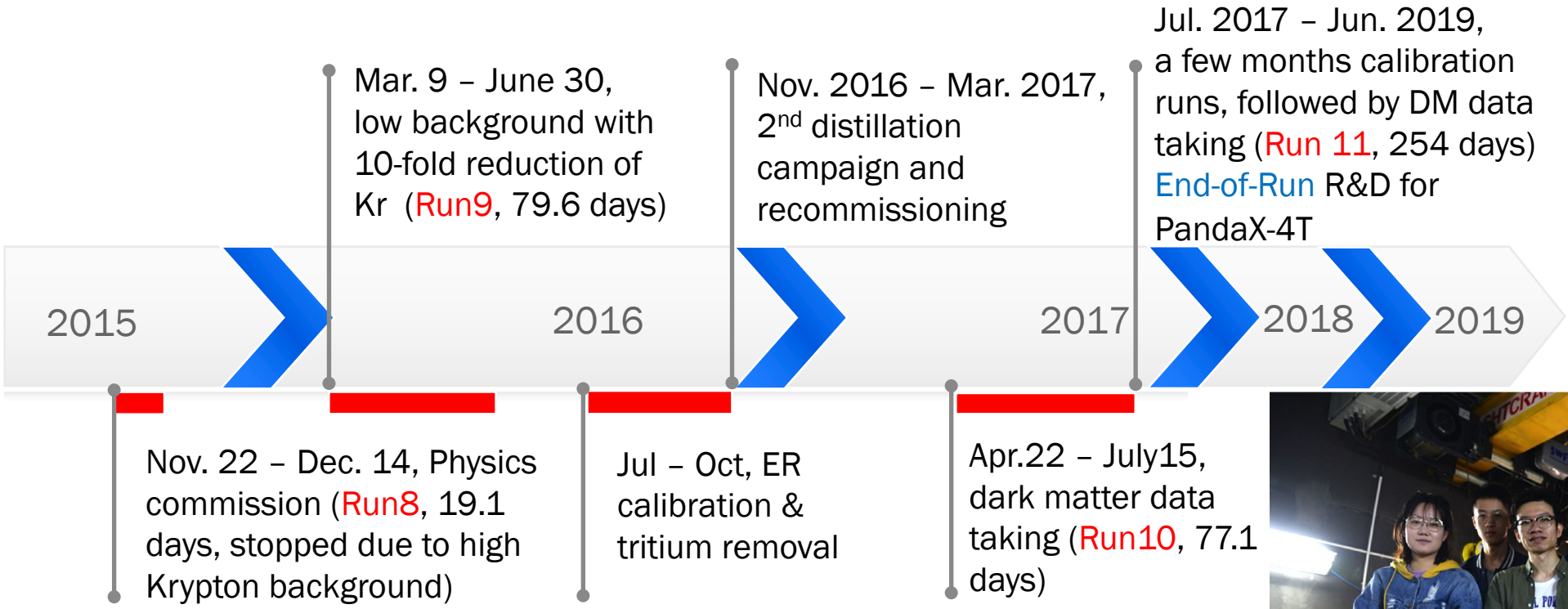




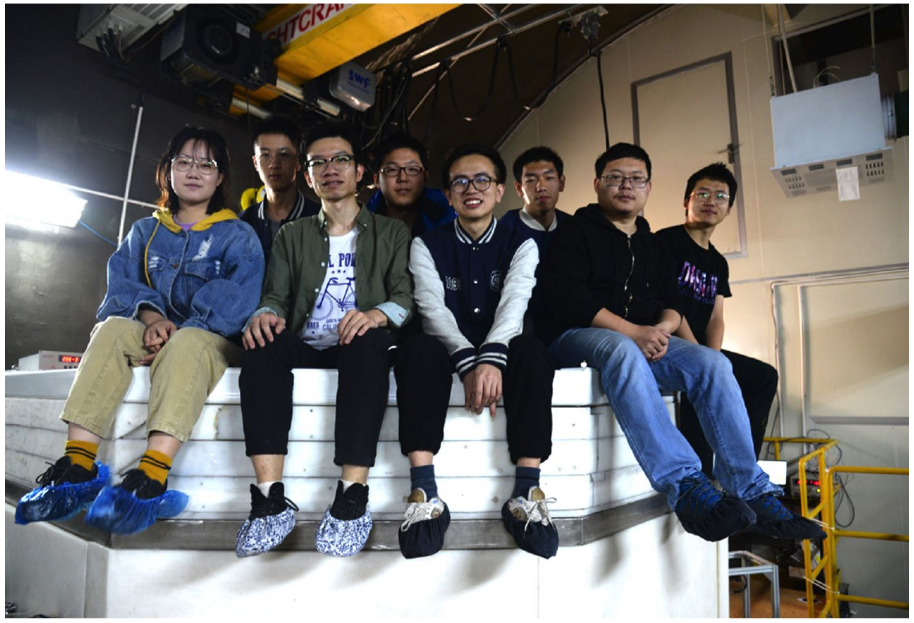


PandaX-II Detector

- Total exposure: ~140 ton-day
  - Full analysis work-in-progress, expected to release early in 2020

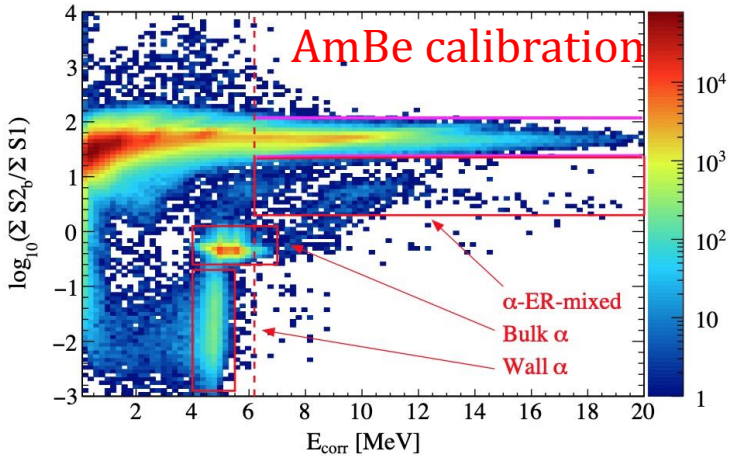


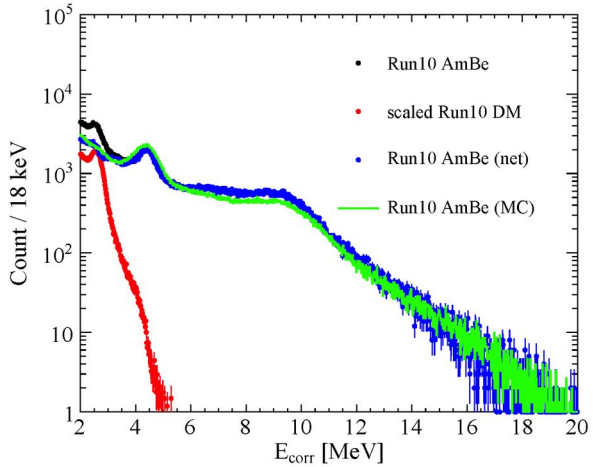
- 2019.06 "End-of-Run" completed
  - 1.16 ton of liquid xenon recuperated

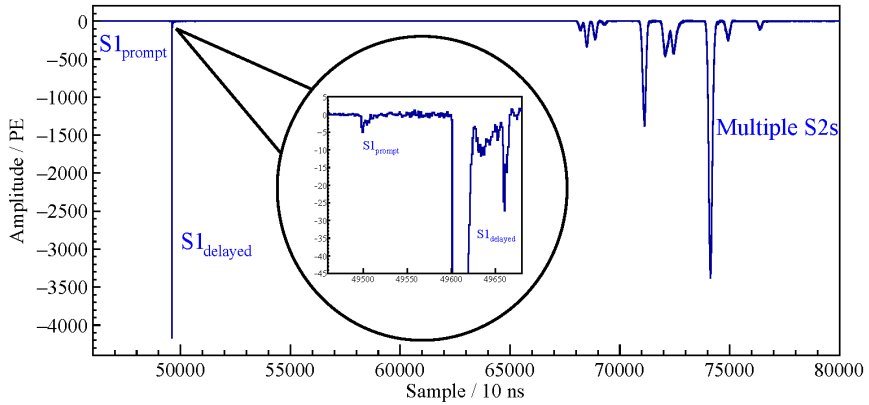


Data-Driven Neutron Background Estimation

- Neutron background can be associated with high energy gammas (HEG signal)
  - Nuclear de-excitation (prompt), neutron capture (delayed)

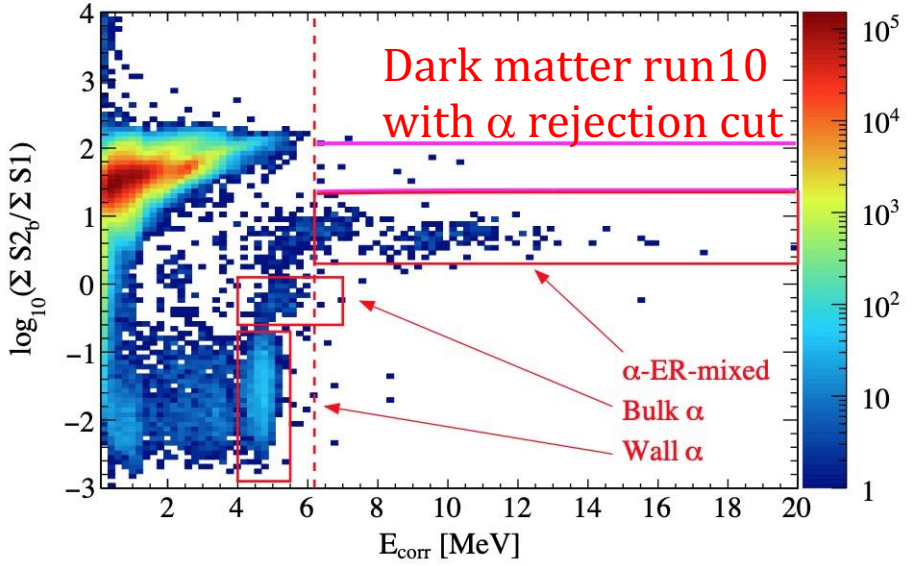






AmBe Run	Data			MC
	# SSNR	# HEG	Ratio	Ratio
Run 9	3415	49159	1/14.4	1/14.7
Run 10	10390	151783	1/14.6	1/15.2

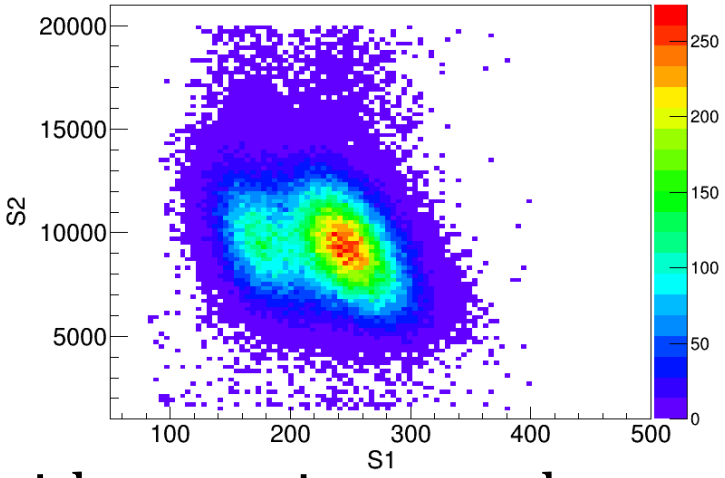
- New neutron MC simulation
  - Take into account the gamma associated process
- Dark matter data
  - Estimated 11.5 ± 5.7 HEGs in Run10 DM data
  - SSNR/HEG ratio ≈ 1/24.6, predicted by MC
  - Estimated neutron background: **0.47 ± 0.25** (vs old MC-based 0.83 ± 0.42)

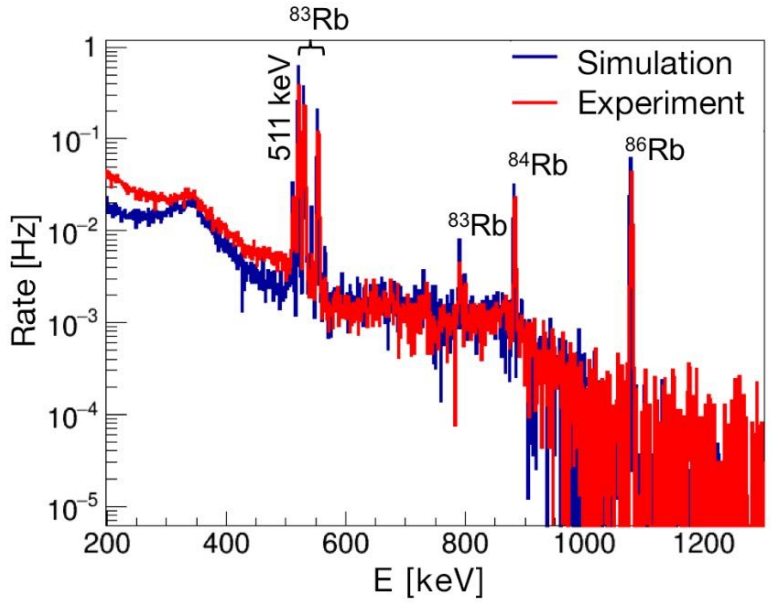


arXiv: 1907.00545

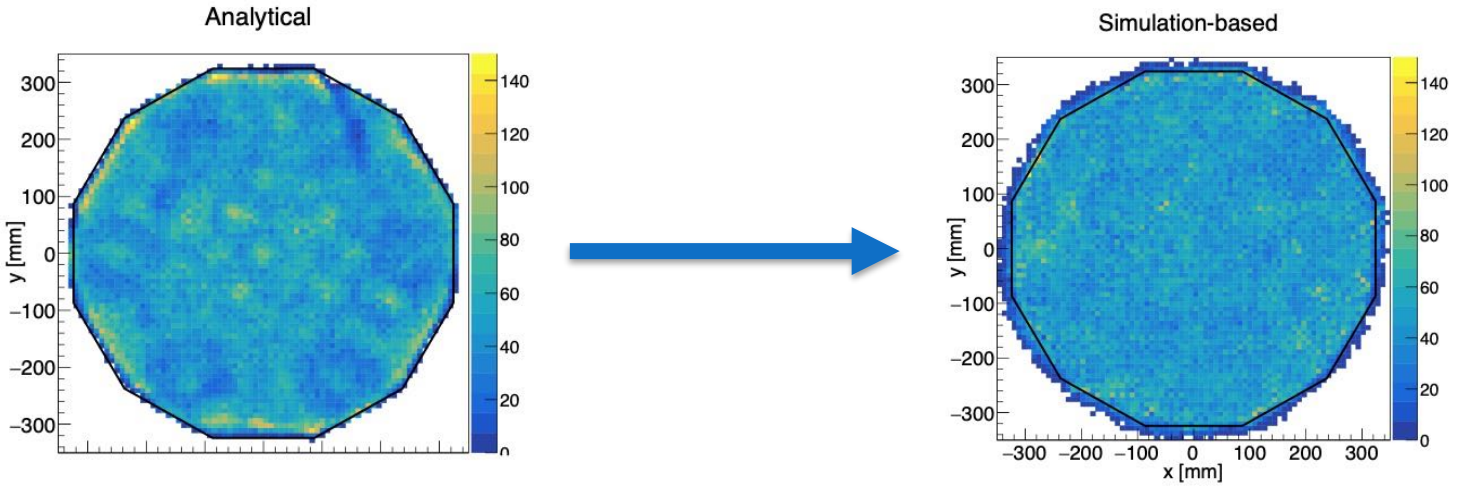
^{83m}Kr Injection Calibration

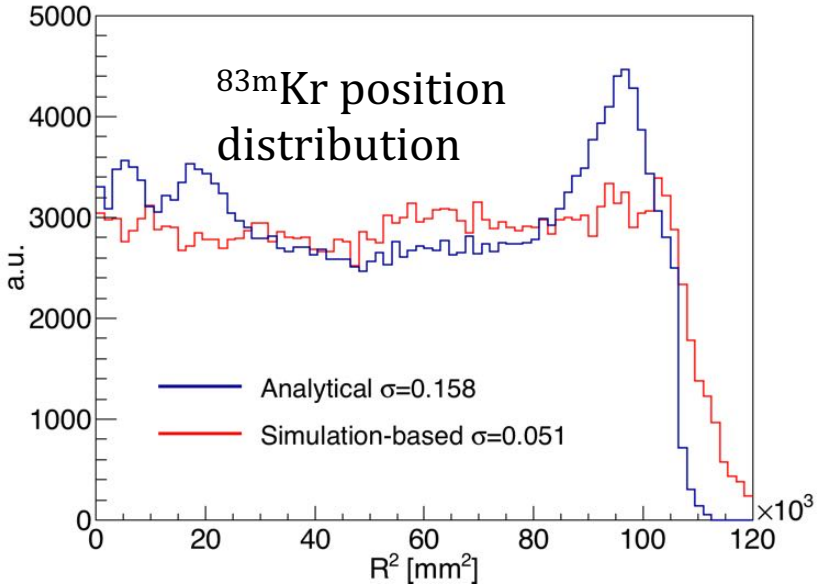
- ^{83m}Kr calibration source for PandaX experiment
  - With the newly built 20 MeV proton beam at IMP, China
- Injection test at PandaX-II
  - 32.1 keV and 9.4 keV energy





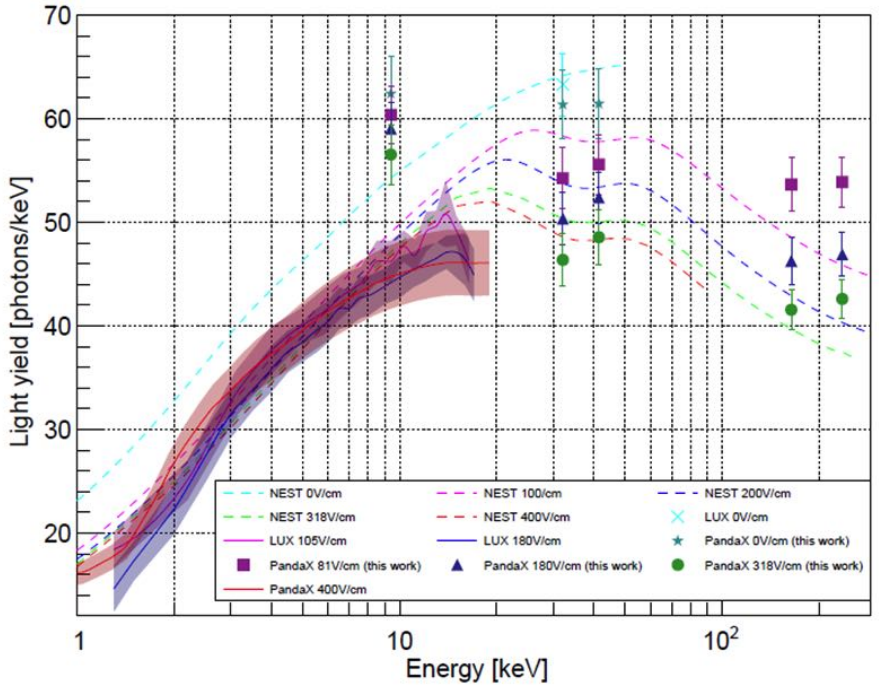
- Position reconstruction algorithm was improved with ^{83m}Kr calibration data



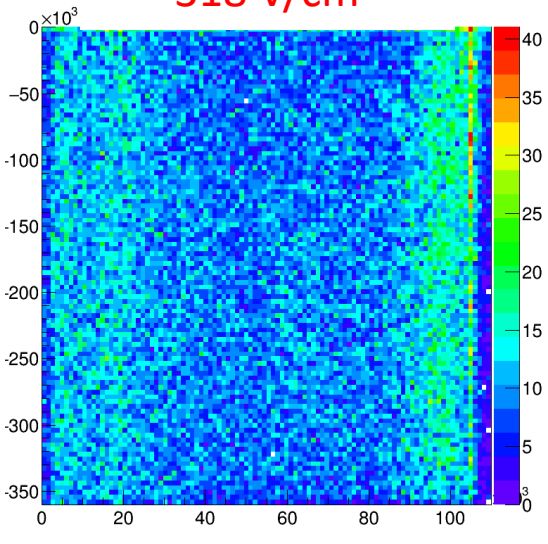


Xenon Light Yield: Field Dependence

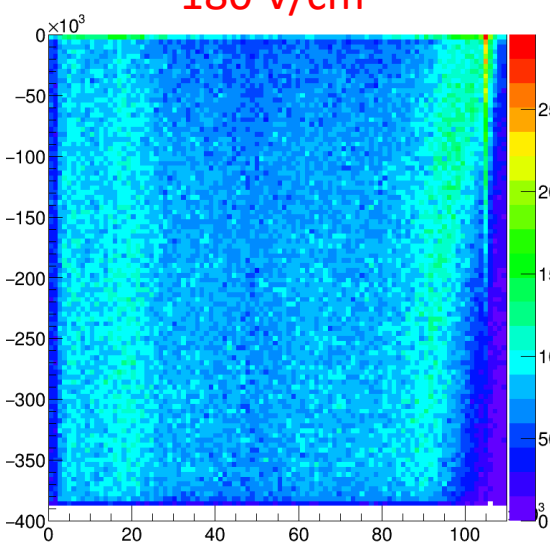
- Calibration data
  - 83mKr (9.4keV, 32.1 keV, 41.5 keV)
  - ^{131m}Xe (164 keV)
  - ^{129m}Xe (236 keV)
- Field variation:
  - 318 V/cm, 180 V/cm, 81 V/cm, 0V/cm
- Light yield variation as expected from Nest
- Reconstruction deformation with weak electric field



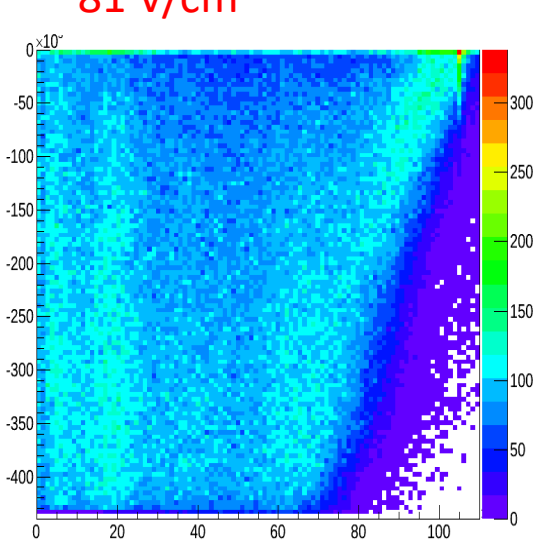
318 V/cm



180 V/cm

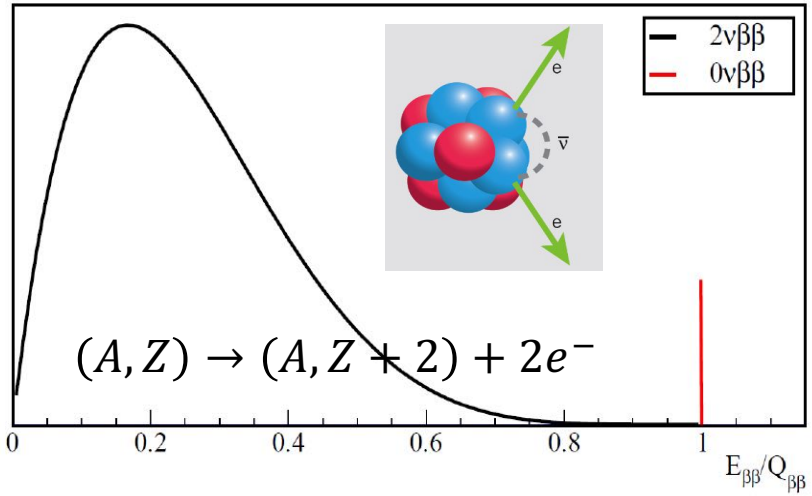


81 V/cm

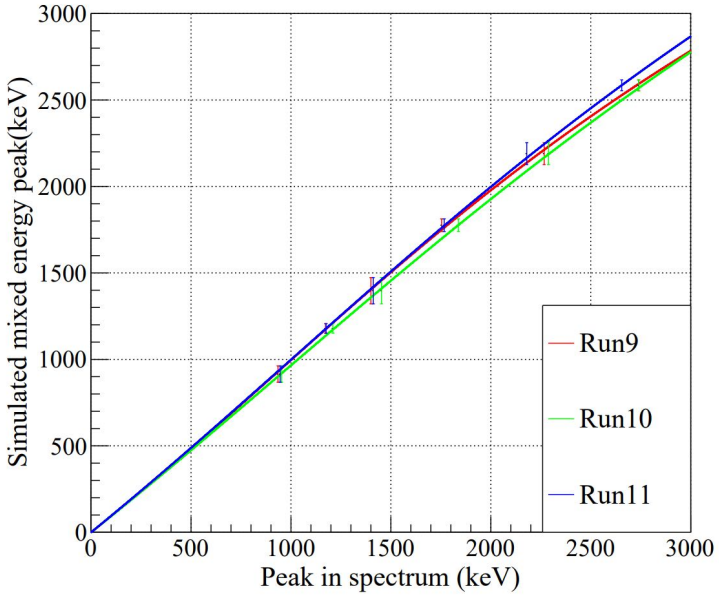


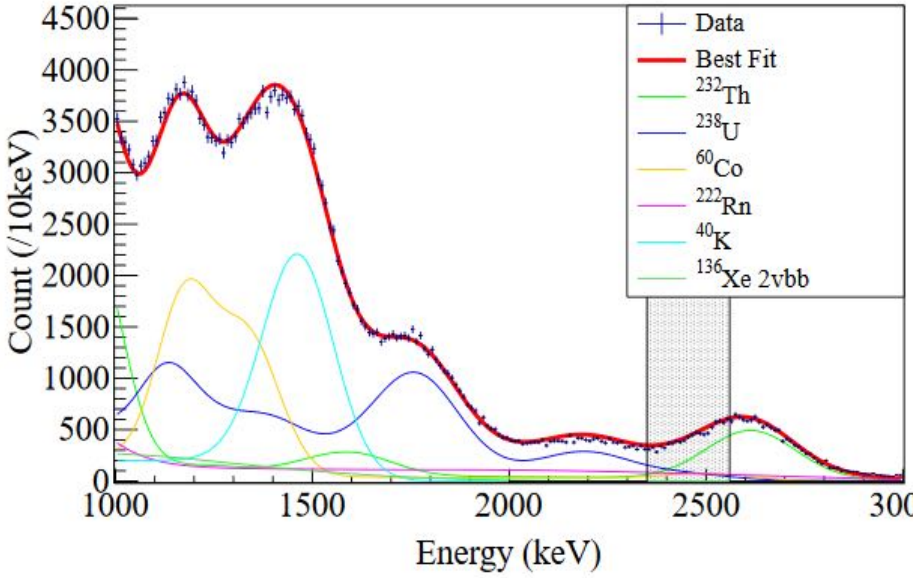
^{136}Xe 0ν2β Search with PandaX-II

- 580kg ^{nat}Xe in PandaX-II detector
  - 51.6kg ^{136}Xe
- ^{136}Xe -> ^{136}Ba Q-value 2458 keV
- High energy reconstruction
  - PMT saturation
  - ^{232}Th calibration



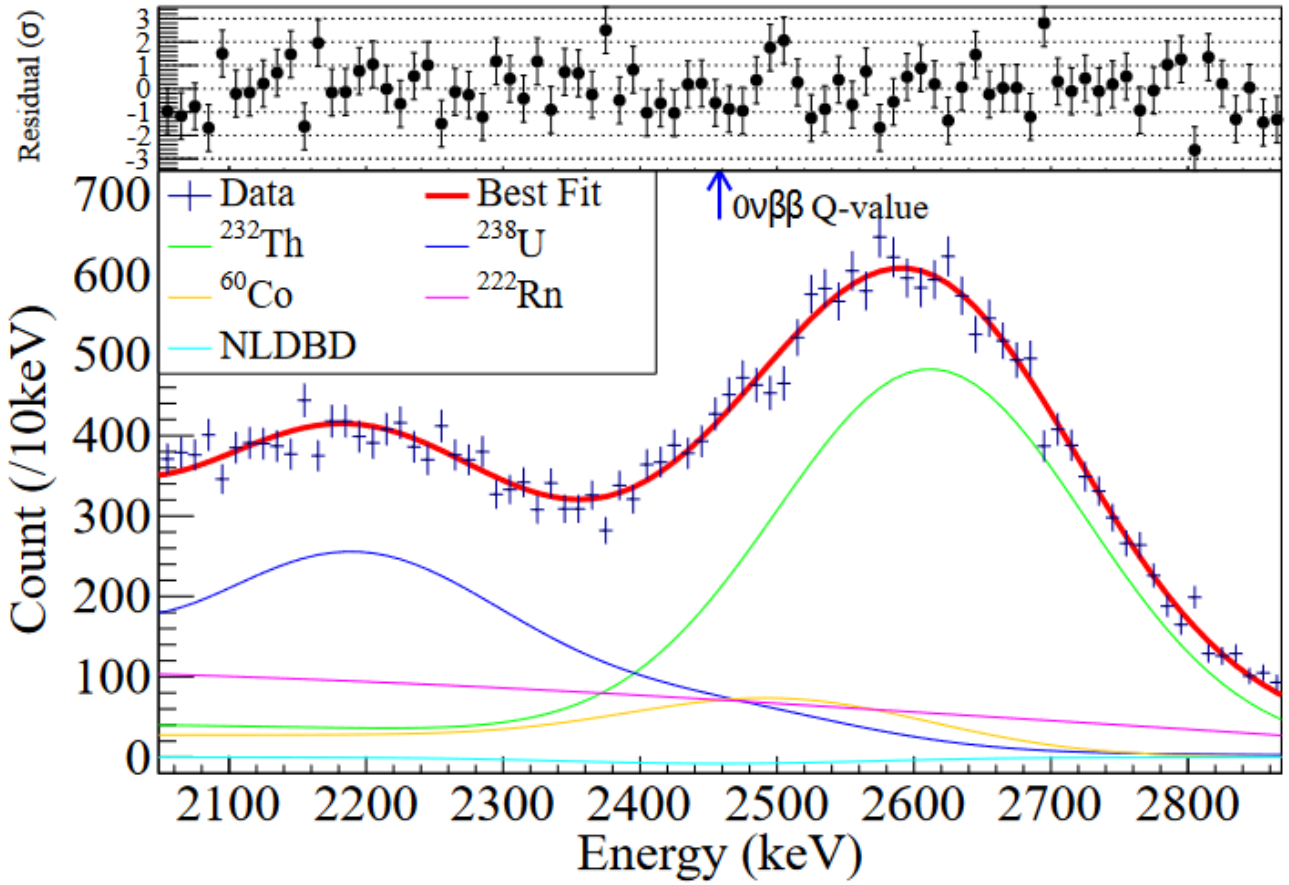
- Examined the high-energy region in the 88 ton-day of DM exposure data (8.1 ton-day of ^{136}Xe)





Constraints on ^{136}Xe 0ν2β

- Obtained 90% CL lower Limits on half-life: 2.4x10^{23} year
- Effective Majorana mass less than 1.3-3.5 eV
- First 0ν2β result from dual-phase xenon experiment



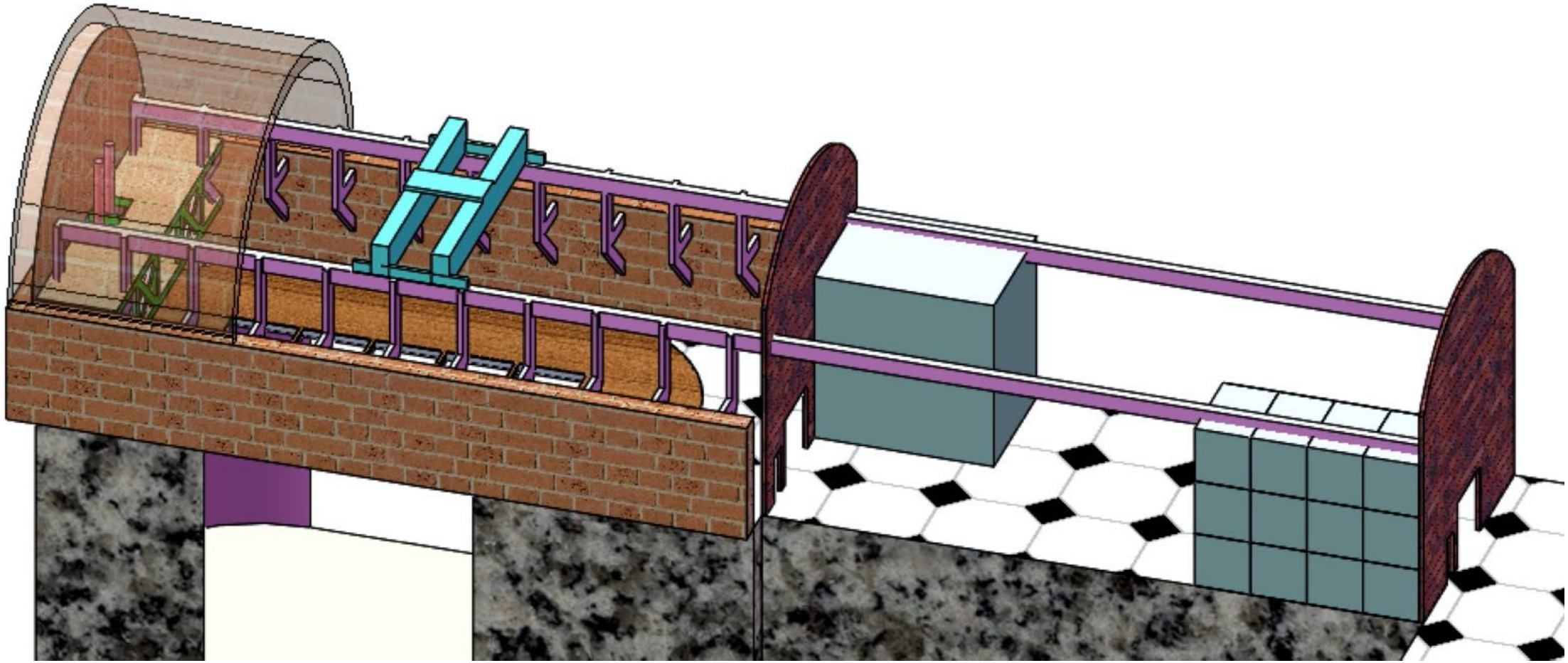
Chin. Phys. C43 (2019) no.11, 113001 arXiv: 1906.11457

New Experiment Hall at CJPL-II

Kick-off ceremony of CJPL-II facility construction project, July20, 2019

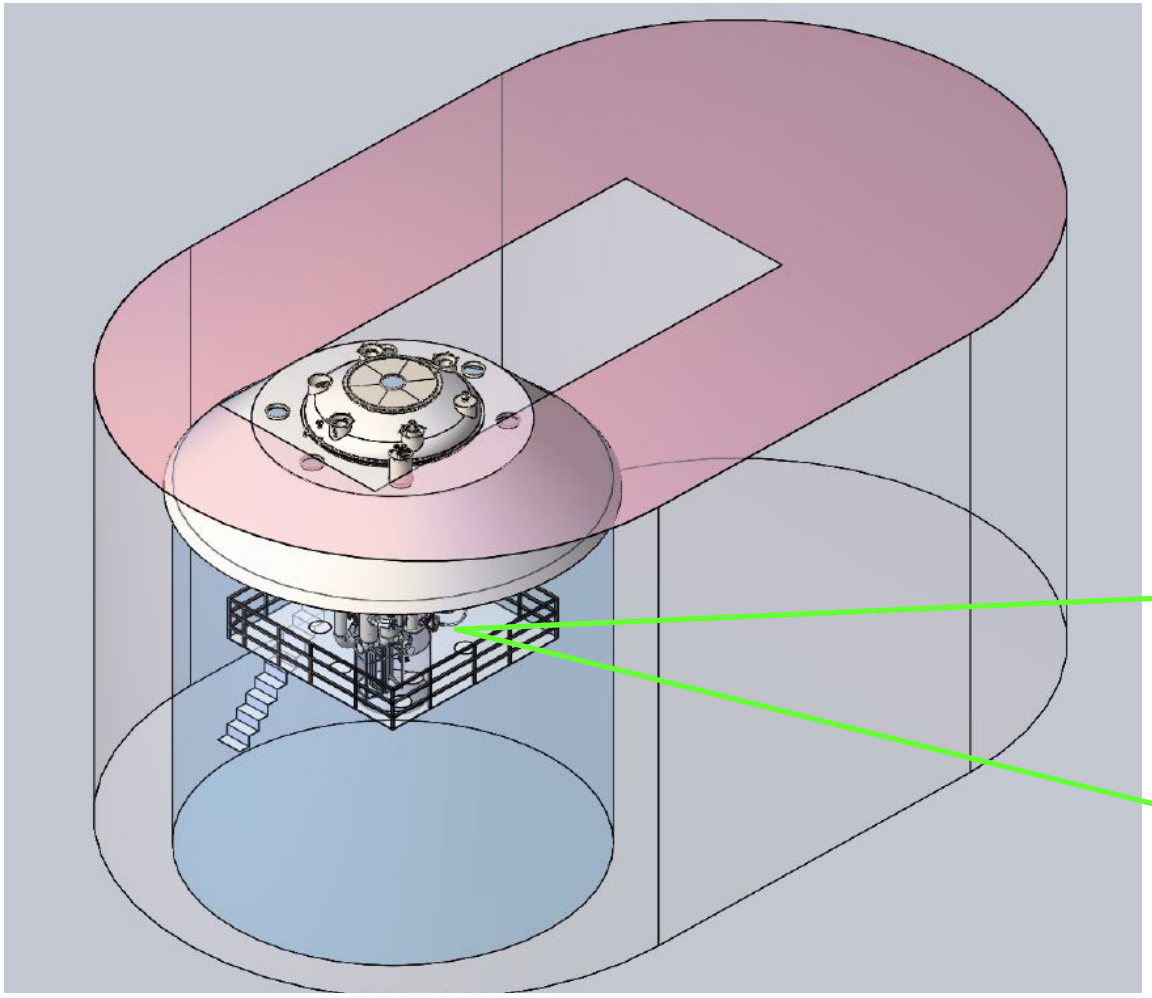
B2 hall in CJPL-II construction plan

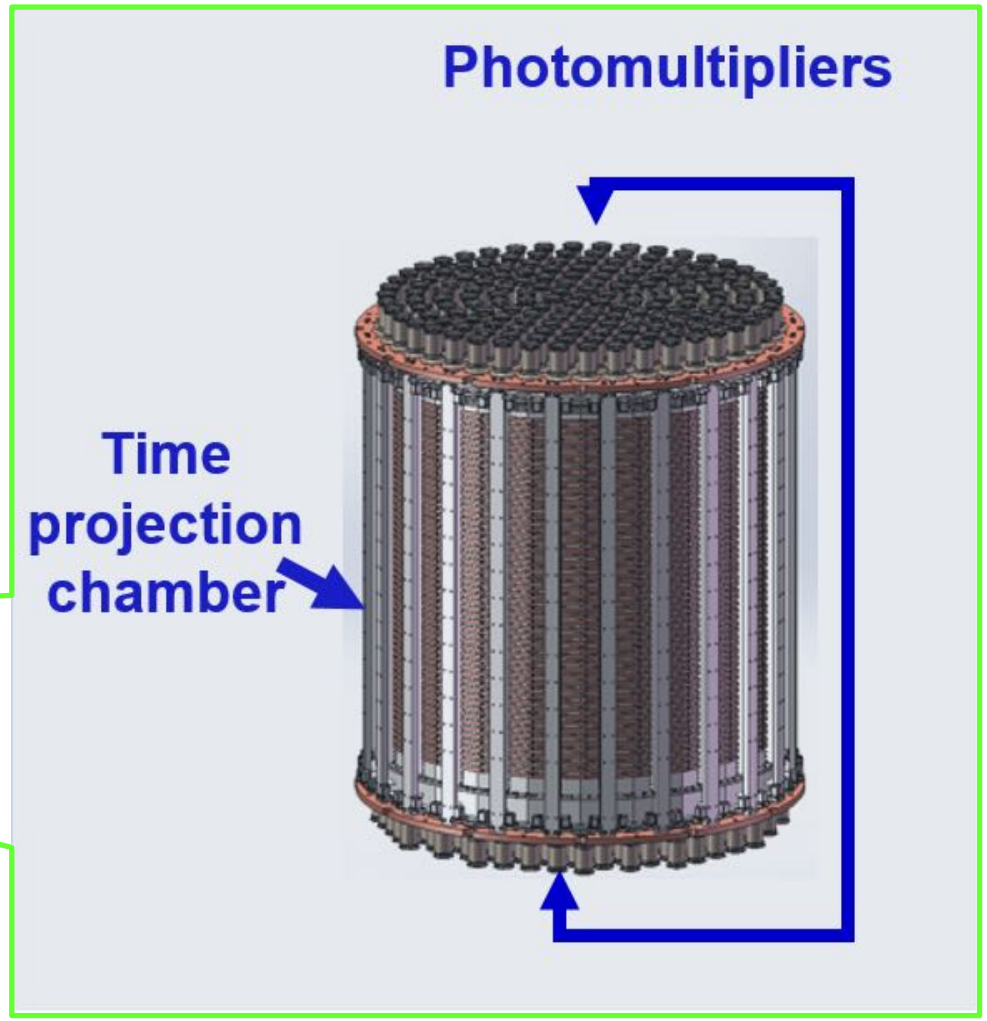
- A general facility containing an ultrapure water shield of 4500 m^3 to host large scale DM and $0\nu2\beta$ experiments



Short-Term Plan in B2 Hall

- **Temporary infrastructure** (fresh air, dual electricity supply, ultrapure water supply, Rn-free clean room), primarily funded by SJTU, to ensure a timely deployment of PandaX-4T



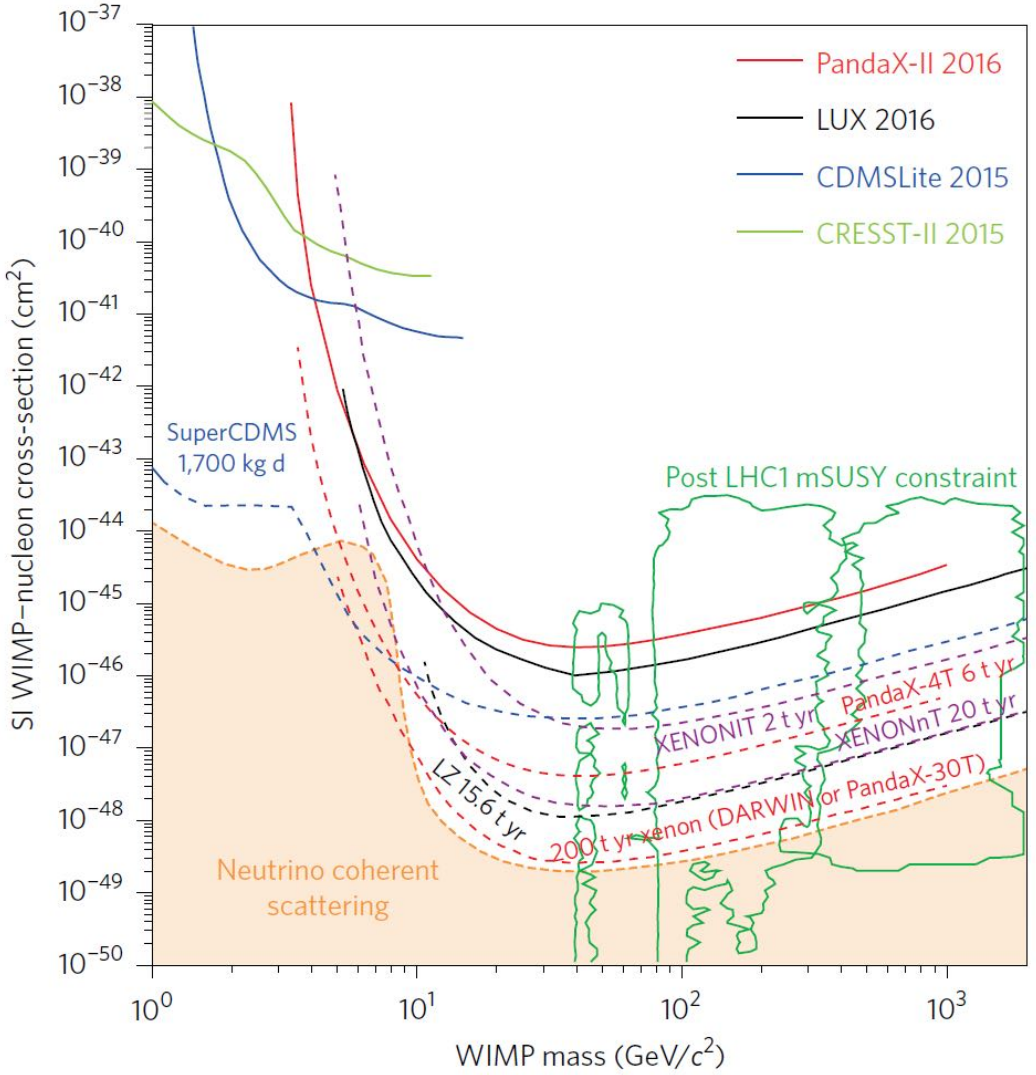


PandaX-4T Experiment

- 4-ton liquid xenon in sensitive volume (2.8 ton in fiducial volume)
- Onsite detector assembly started: Aug. 2019
- Expected sensitivity
  - **10x** more sensitive than PandaX-II

Table 4 Final background budget within the WIMP search window

Sources	ER in mDRU	NR in mDRU
Materials	0.0210±0.0042	$(2.0 \pm 0.3) \times 10^{-4}$
^{222}Rn	0.0114±0.0012	–
^{85}Kr	0.0053±0.0011	–
^{136}Xe	0.0023±0.0003	–
Neutrino	0.0090±0.0002	$(0.8 \pm 0.4) \times 10^{-4}$
Sum	0.049±0.005	$(2.8 \pm 0.5) \times 10^{-4}$
2-year yield (evts)	1001.6±102.2	5.7±1.0
after selection (evts)	2.5±0.3	2.3±0.4



Ultrapure Water Shield

- Low background SS detector platform: 13m(H)x10m(D)～900 m^3
- Ultrapure water: 18 Mohm-cm, production rate 10 m^3/h
  - ^{238}U: 0.03ppt (ICPMS)
  - ^{232}Th: 0.06ppt (ICPMS)
  - Rn requirements:
    - 0.2 Bq/m^3 for DM
    - 2 mBq/m^3 for 0vDBD (R&D)

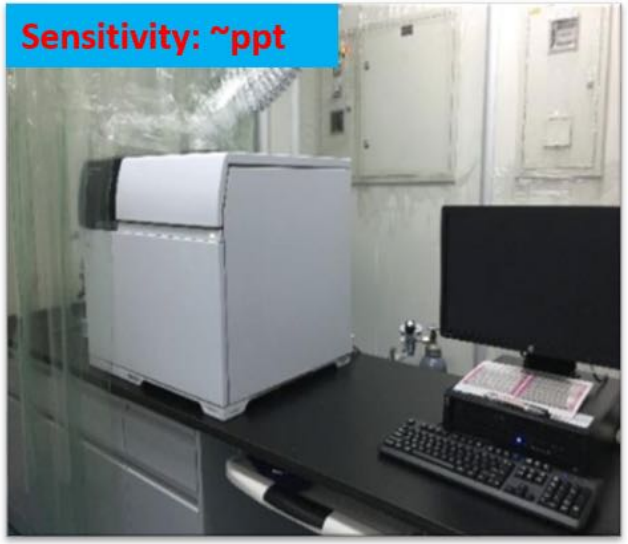
Radon-Free, Clean, Assembly

- Class-10000 and class-1000 rooms constructed
- Radon-free air provided for class-1000 clean room
  - Radon level < 1 Bq/m^3

Low background control (assay)

- Materials screening with variety of ultra-low radioactive detection techniques

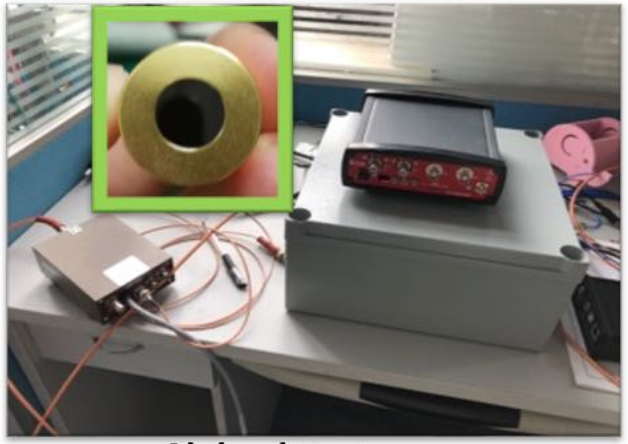
HPGe



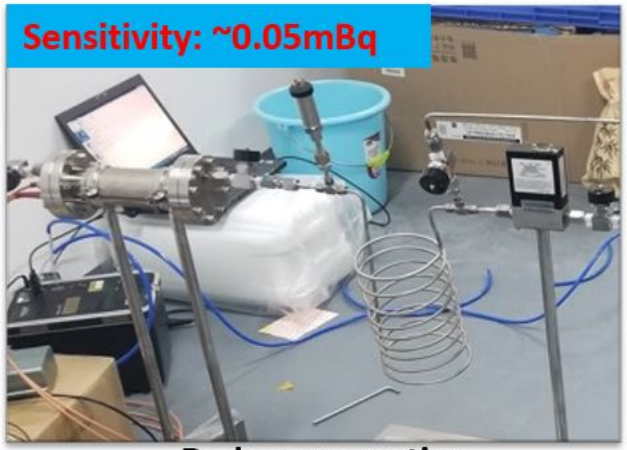
ICPMS

Radon emanation measurement system

Kr assay system



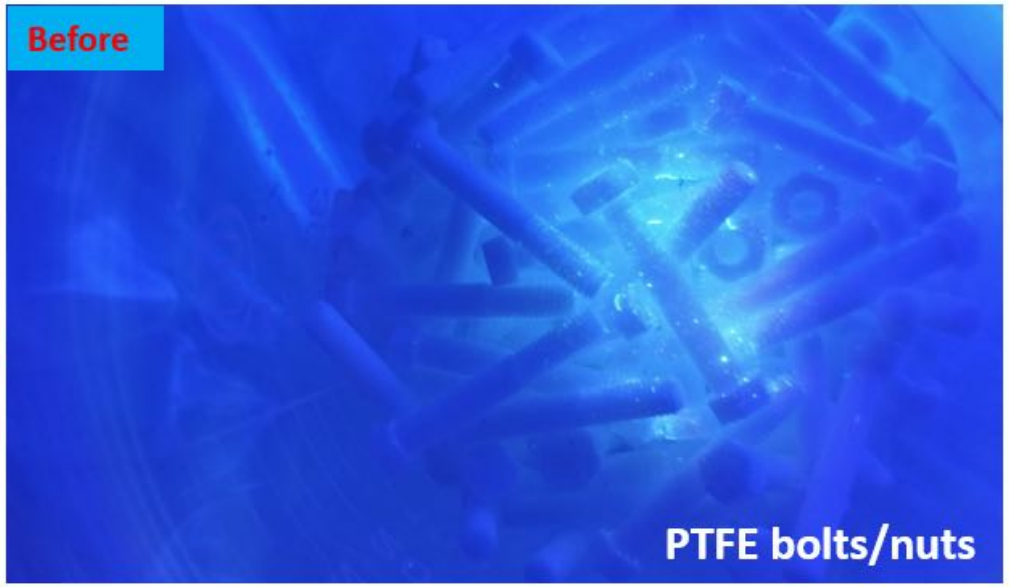
Alpha detector (commissioning)

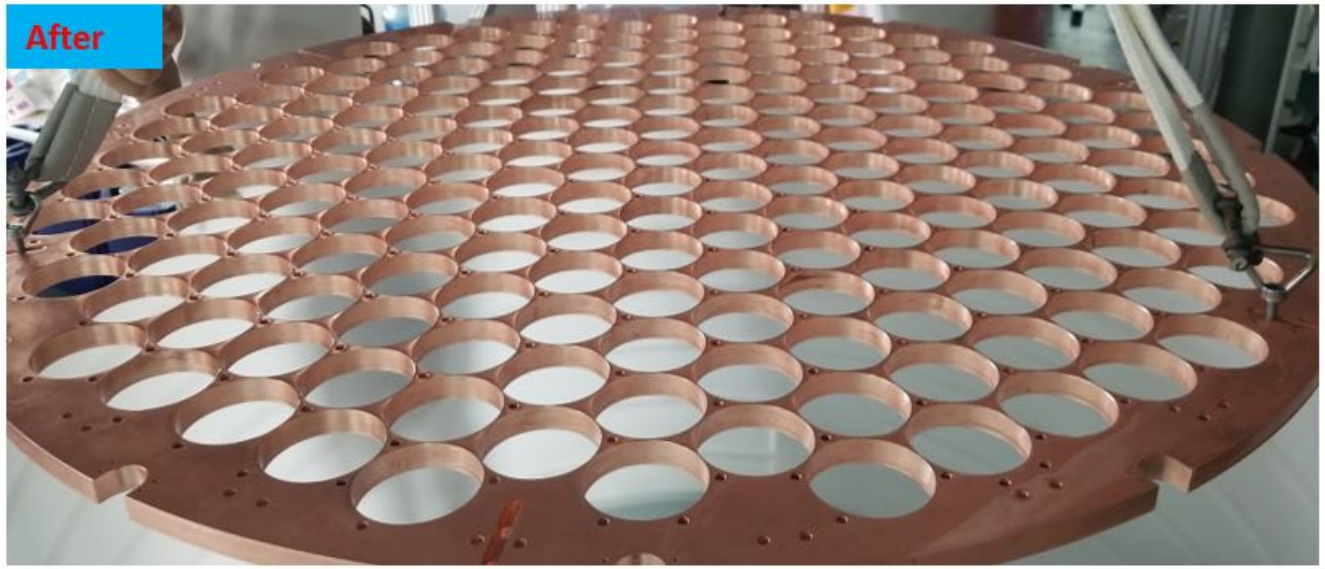


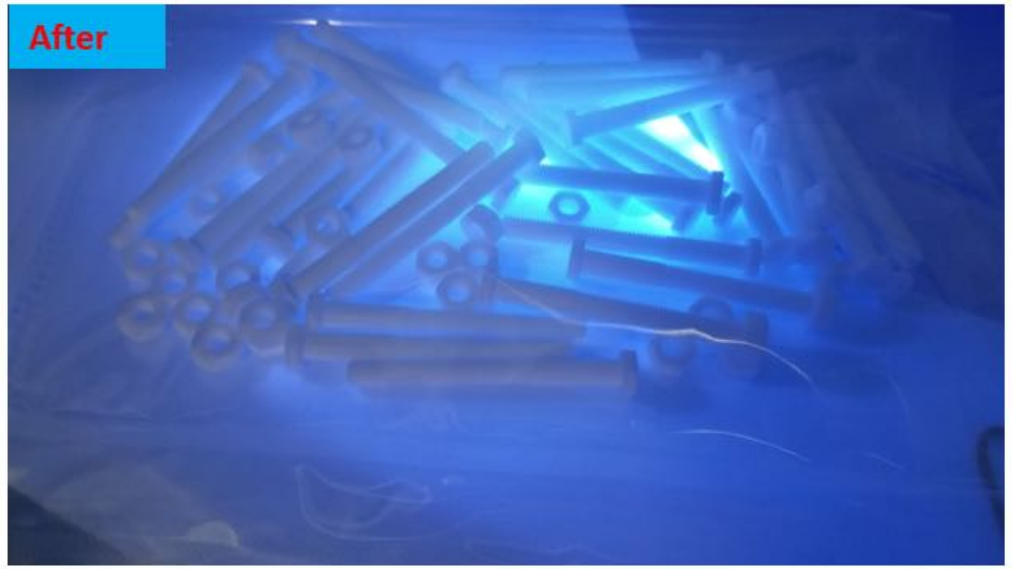
Radon emanation cold trap system

Low background control (surface)

- Rigorous cleaning protocols/procedures established





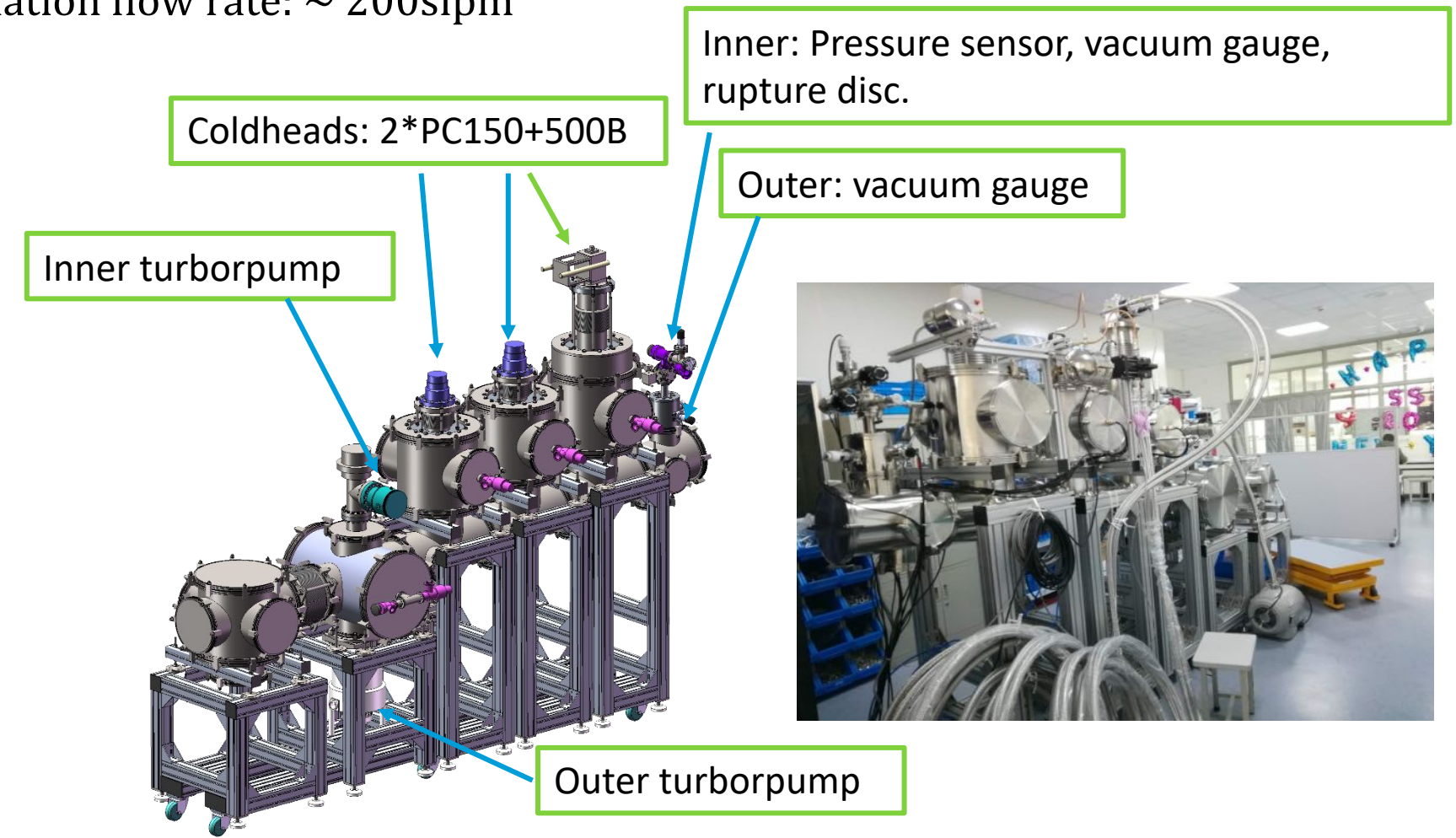


Low background control (noble gas)

- Challenging targets:
  - Kr/Xe <= 0.1 ppt
  - ^{222}Rn = 1 μBq/kg (PandaX-II: ~8 μBq/kg)
- Distillation tower design goals:
  - Operate offline (initial Kr removal) and online
  - Two modes: Kr (10 kg/h, 99% Xe collection) and Rn (56.5 kg/h, need to beat Rn half-life)
- Distillation tower
  - Number of theoretical plates: 17
  - Tower Height: 8m
  - Tower Diameter:125mm

Cryogenics System

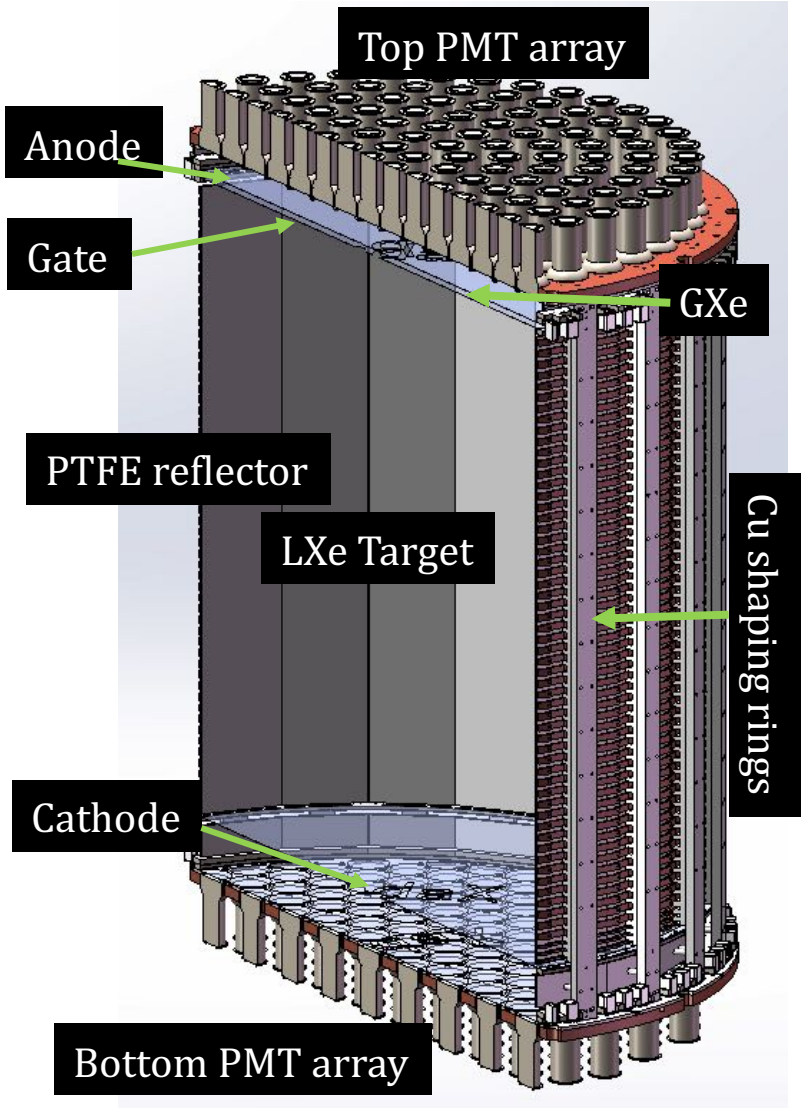
- Design goals
  - Gas storage system for 6-ton xenon
  - Cooling power: >=360 W
  - Total circulation flow rate: ~ 200slpm



TPC

- 4-ton liquid xenon in sensitive volume (2.8 ton in fiducial volume)
- Drift region: 1.2m(H)x1.2m(D)
- Designed field: drift (400 V/cm), extraction (6 kV/cm)
- 3-in PMTs, 169 top/199 bottom
- 1-in veto PMT 126

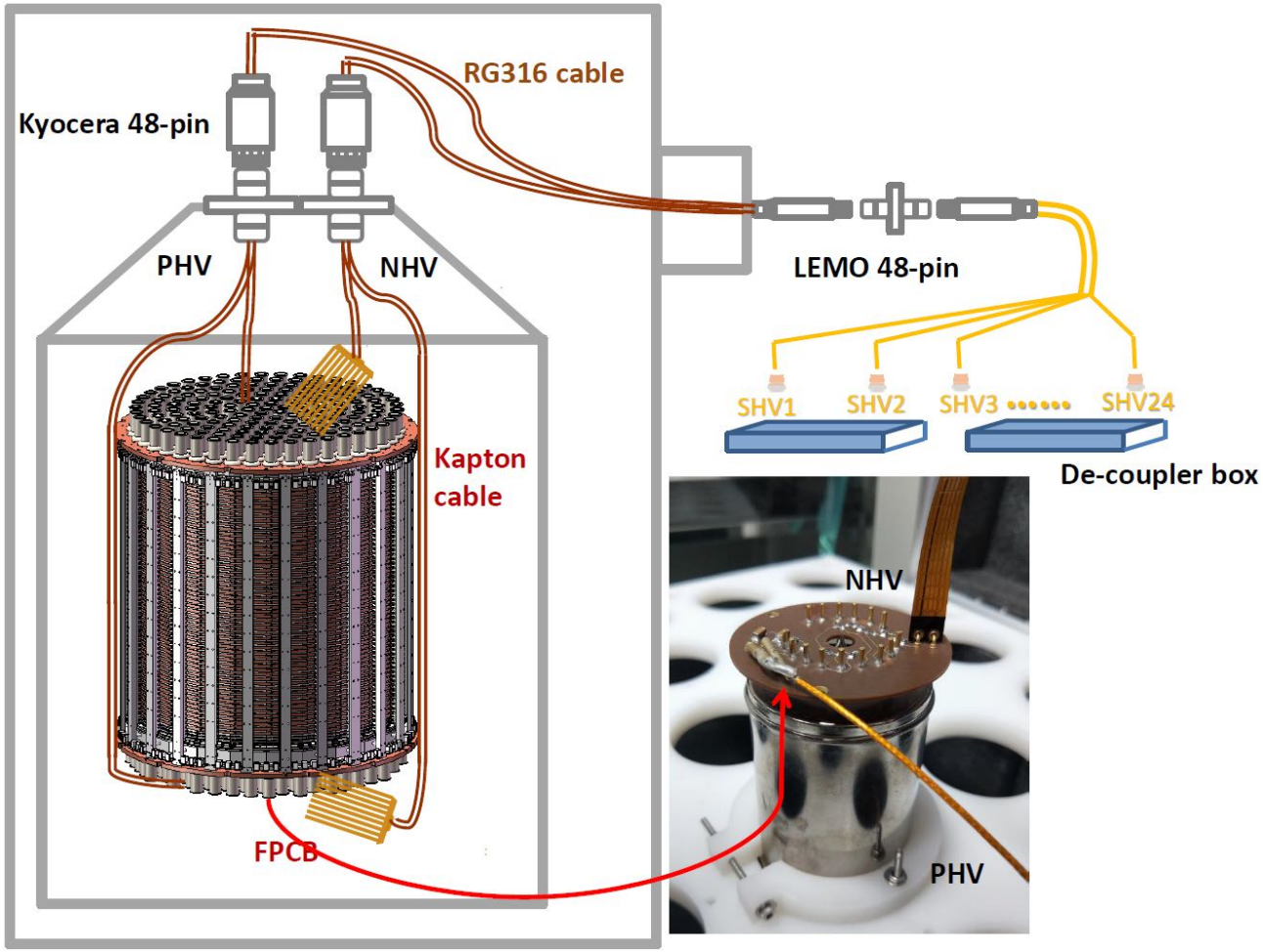
TPC Test Assembly



PMT: R11410-23

- 178 nm QE: 30% typical
- Gain: 5E6 under 1500 V
- Dark Rate: typical<1kHz (20 ℃), typical 50 Hz (-100 ℃), to suppress accidentals
- After-pulsing probability: < 5% between 400 ns to 5 μs
- Split HV divider chain to minimize discharge

- All PMTs measured with 3 cold cycles, acceptance ratio 92.3%!

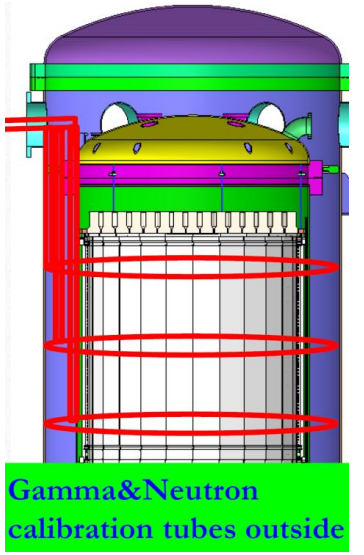


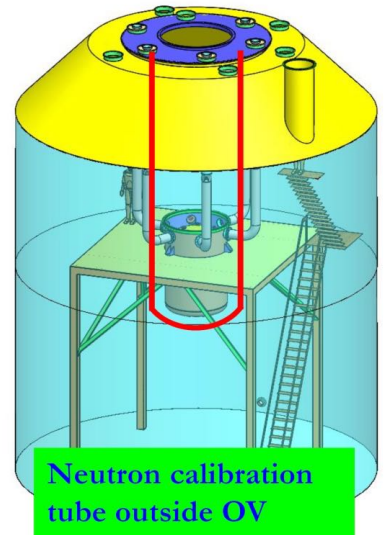
Calibration System

- External source loops for gamma and AmBe neutron sources

- Dedicated SS pipe for DD neutron generator
  - DD generator under commissioning at Shanghai

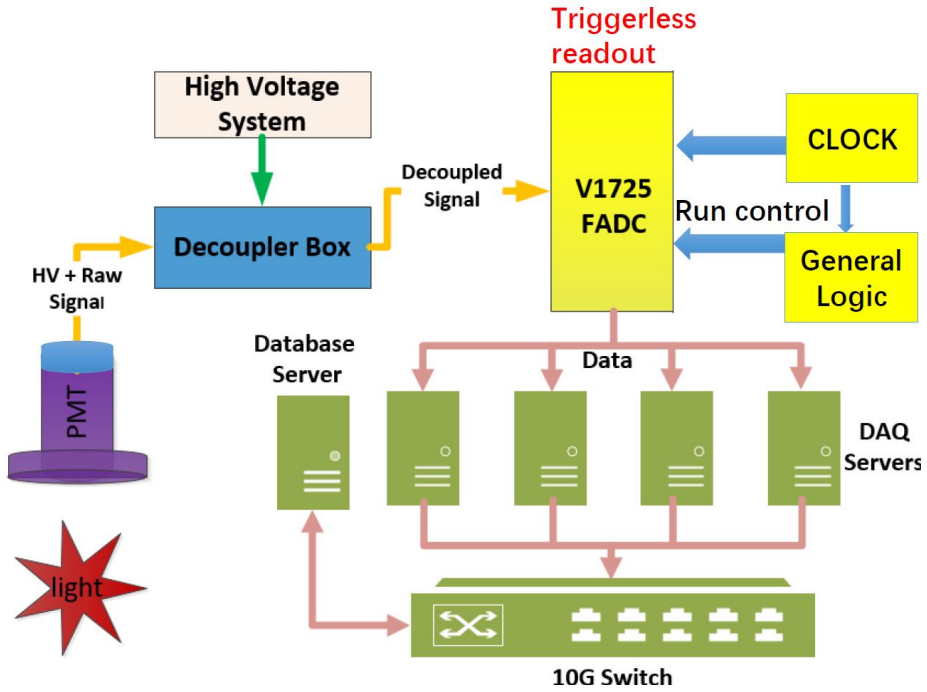
- Internal source
  - Generic injection system for ^{83m}Kr and ^{220}Rn under construction
  - ^{83m}Kr: ^{83}Rb source made at IMP and commissioned in PandaX-II
  - ^{220}Rn:
    - Baseline: lantern mantles (^{232}Th) commissioned in PandaX-II
    - ^{228}Th surface source will be procured and tested

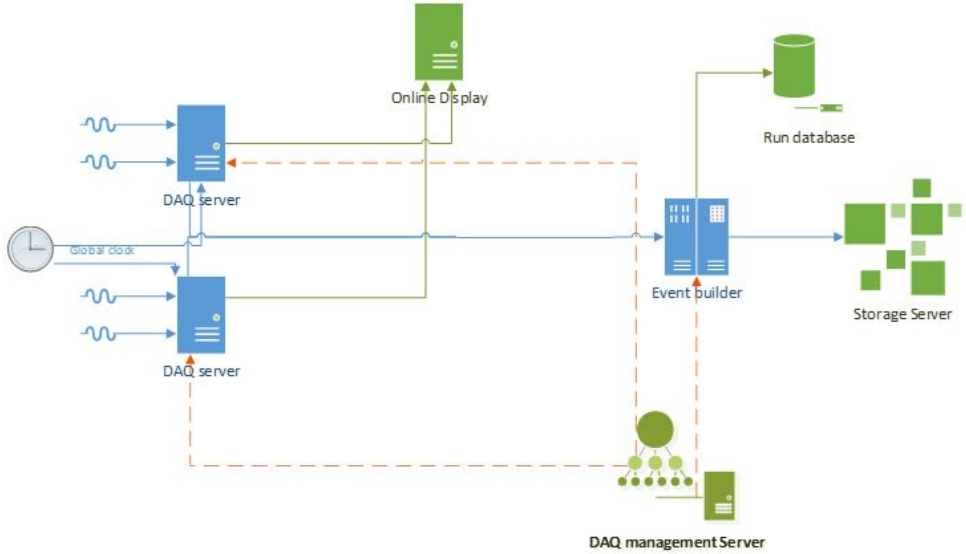




Electronics and DAQ

- Design goal
  - “0 threshold”: triggerless
  - Maximum calibration event rate: 100 Hz, data rate: 300 MB/s
- Architecture
  - One digitizer board (16 channels) per readout link
  - 4 DAQ servers to collect raw data in parallel
  - Raw data sent to one server via 10Gbps switch
- DAQ
  - Event builder to save time-ordered data to SSD
  - Tested bandwidth limit > 1GB/s!
  - Webpage based DAQ software



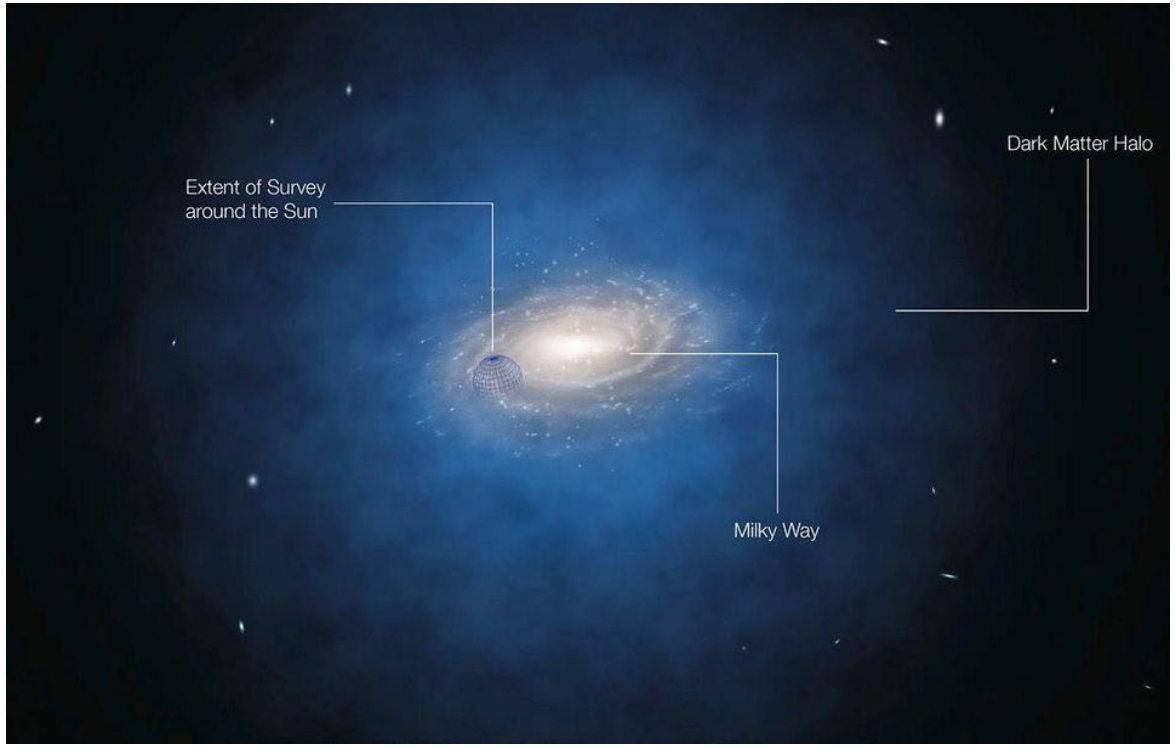


Summary

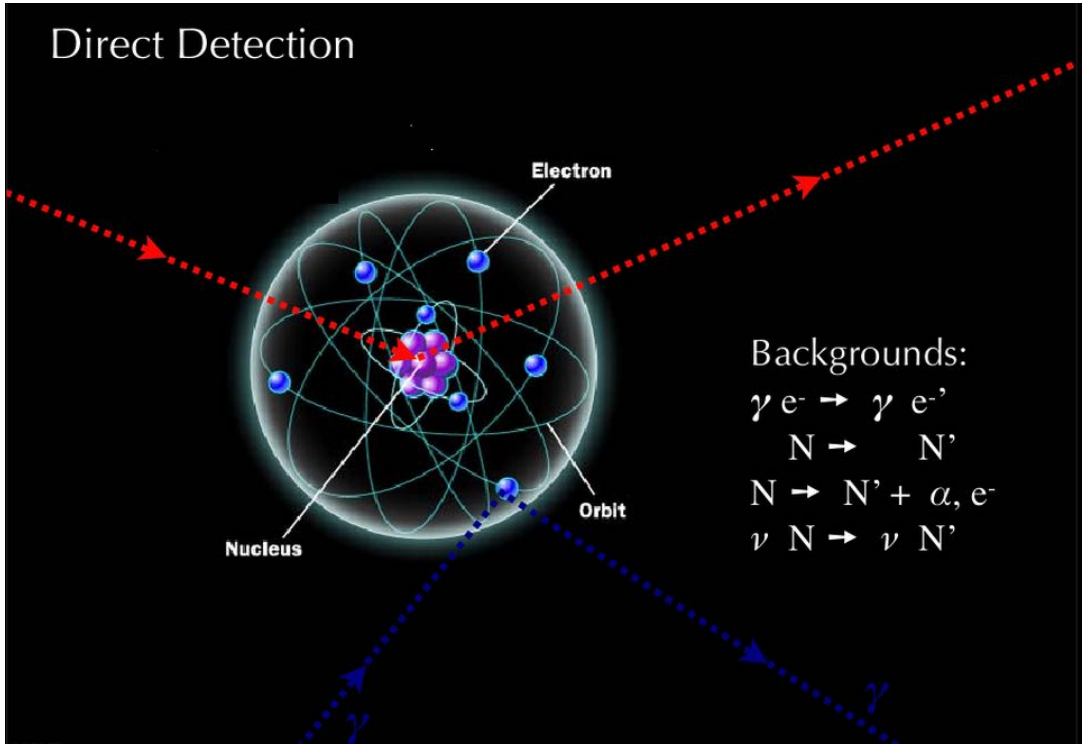
- PandaX-4T experiment, x10 more sensitive than PandaX-II, is going forward rapidly
- Temporary infrastructure construction in B2 hall of CJPL-II recently completed
- Onsite detector assembly started: Aug. 2019
- Expected commissioning of PandaX-4T: end of 2020. The science operation will be in parallel with the CJPL-II facility construction
- Stay tuned!

Dark Matter Direct Detection Experiment

- Solar system in the dark matter halo
- Detection of incoming dark matter scattering off target atom
  - Nuclear recoil (NR) signature
  - Electronic recoil (ER) signature



ESO / L. Calçada.



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