The PandaX-4T Dark Matter Experiment

Low Background Control

Zhicheng Qian

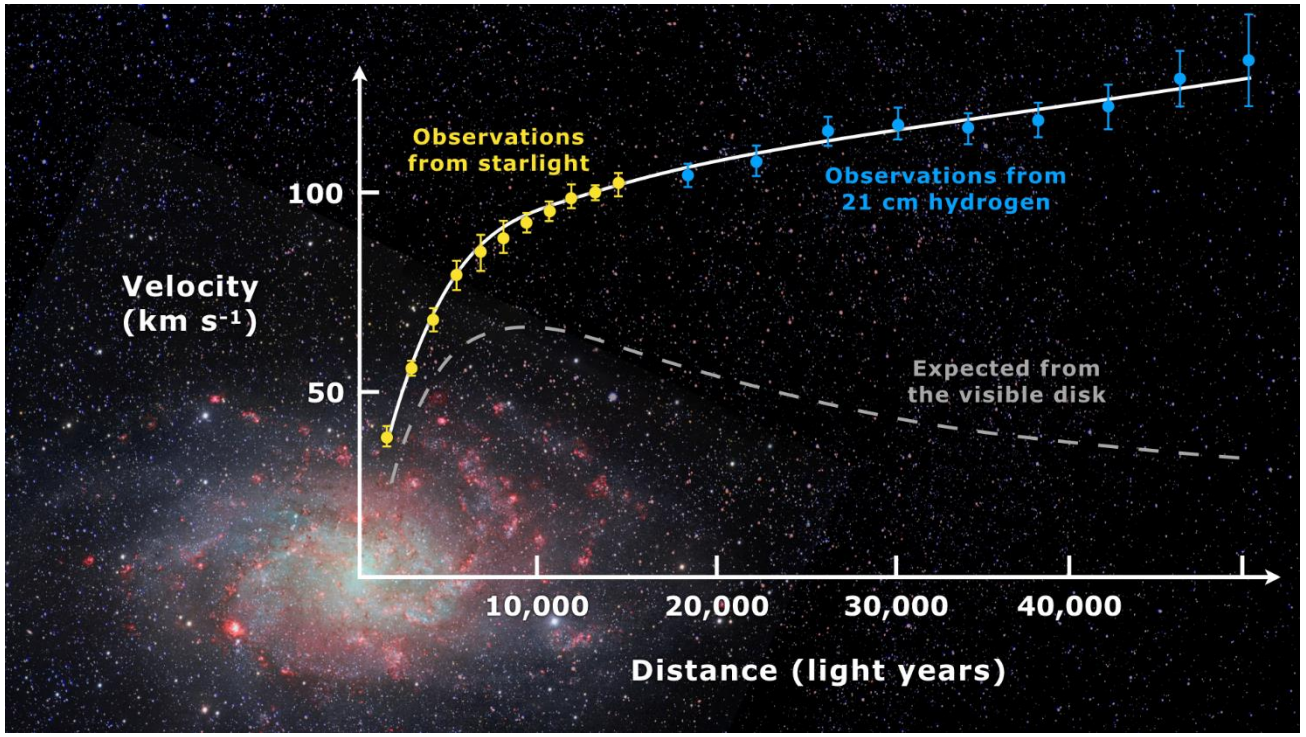
Institute of Nuclear and Particle Physics

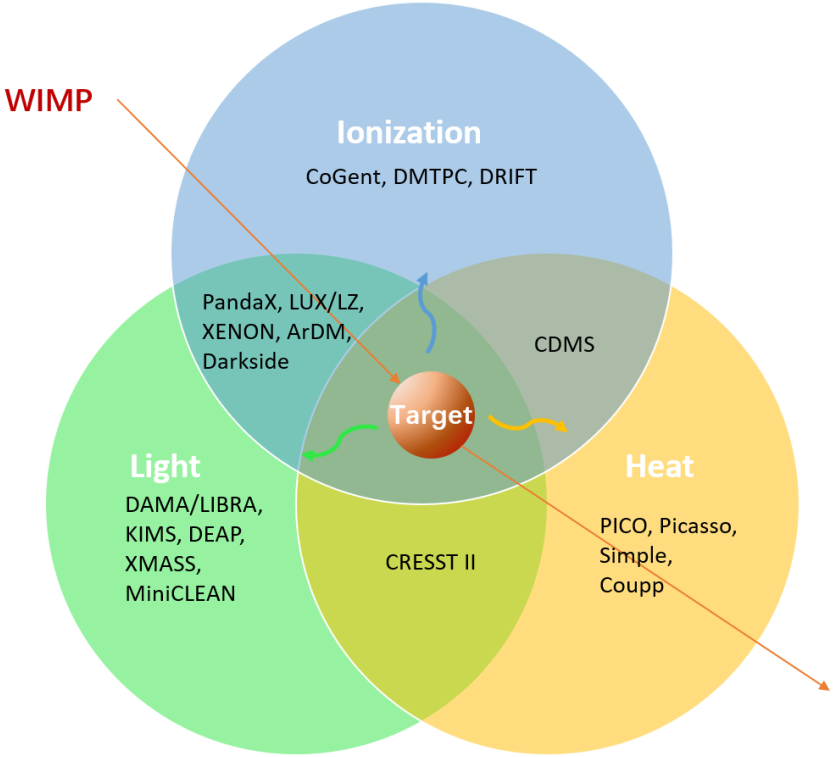
Shanghai Jiao Tong University

2021/5/25, TIPP 2021

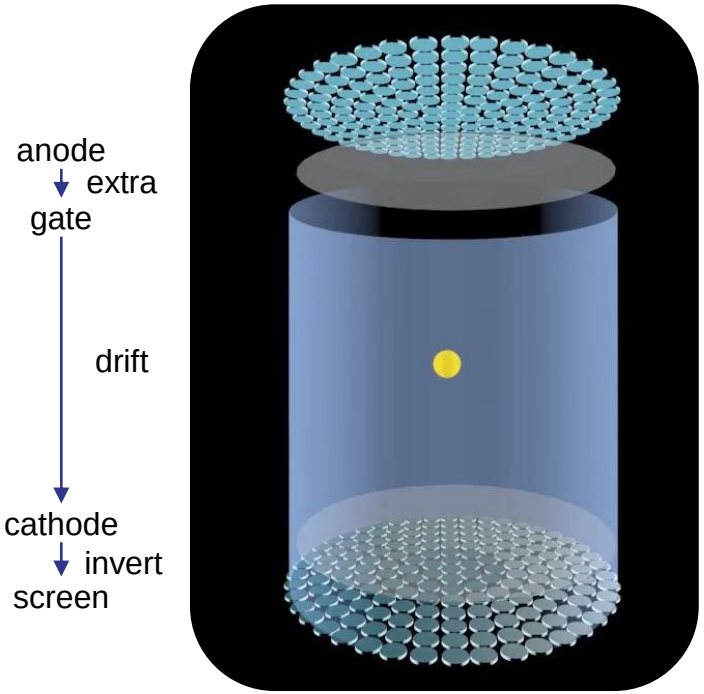
CONTENT

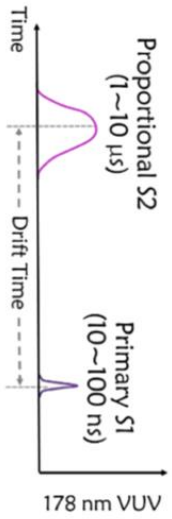
Dark matter

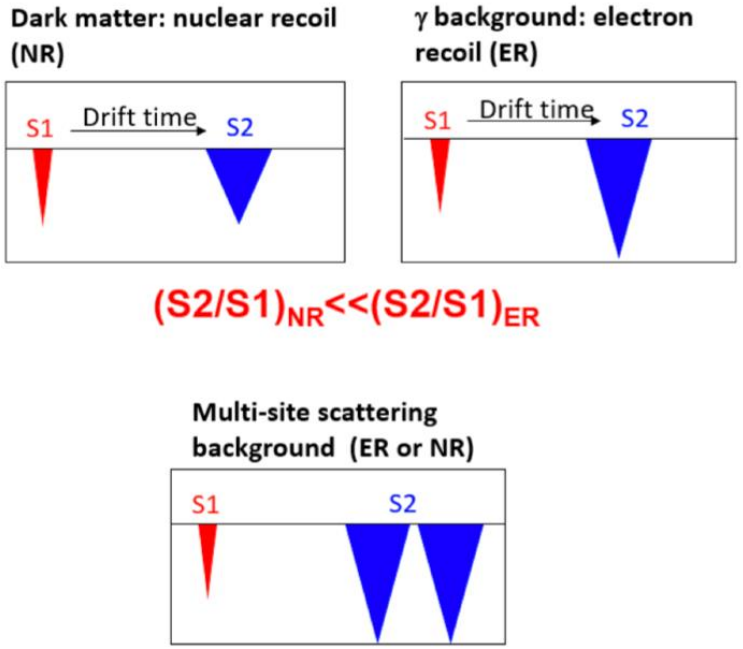

Observations from starlight
Observations from 21 cm hydrogen
Velocity (km s-1)
100
50
Expected from the visible disk
10,000
20,000
30,000
40,000
Distance (light years)


WIMP
Ionization
CoGent, DMTPC, DRIFT
PandaX, LUX/LZ, XENON, ArDM, Darkside
CDMS
Target
Light
DAMA/LIBRA, KIMS, DEAP, XMASS, MiniCLEAN
Heat
PICO, Picasso, Simple, Coupp
CRESST II

Dual-phase xenon TPC technique







Signal feature

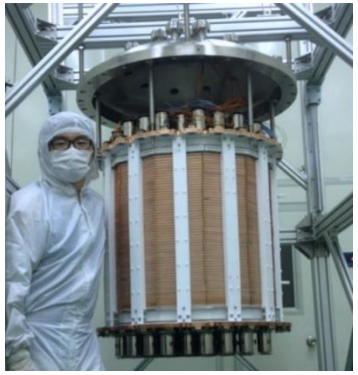
- S1: prompt scintillation signal
- S2: delayed ionization signal

Advantages of Time Projection Chamber (TPC)

- Liquid xenon
  shielding ability
  no long-life isotopes
  easy to be purified
- 3-D position reconstruction
  Z position from S1-S2 drift time
  X-Y positions from S2 photomultiplier (PMT) pattern
- Identification of electron recoil (ER) and nuclear recoil (NR) signals

PandaX project

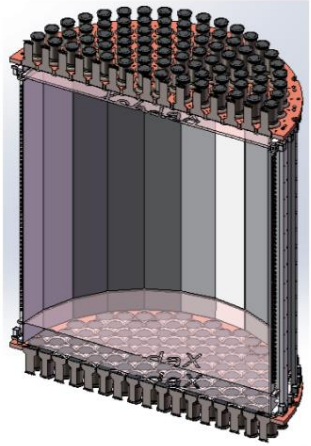
PANDAX=
Particle
and
Astrophysical
Xenon Experiments



PandaX-II:
580 kg

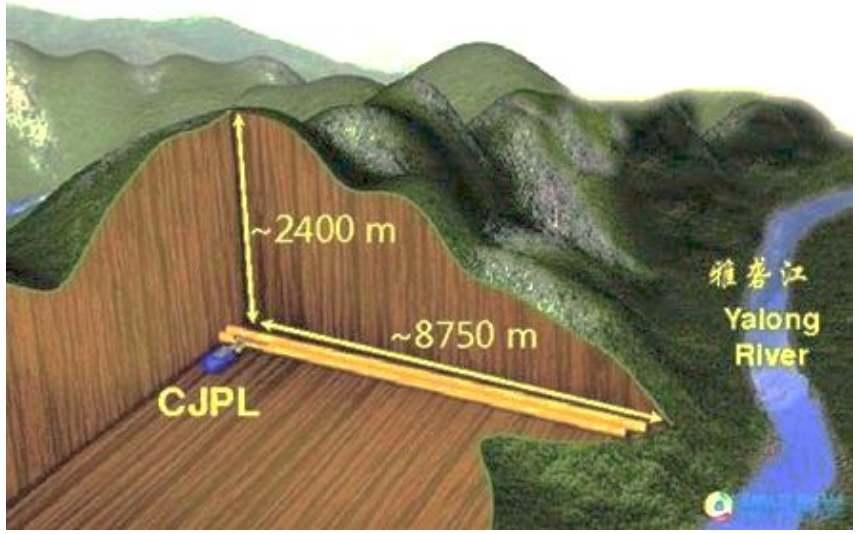
2009 | **2014** | **2019** | .....

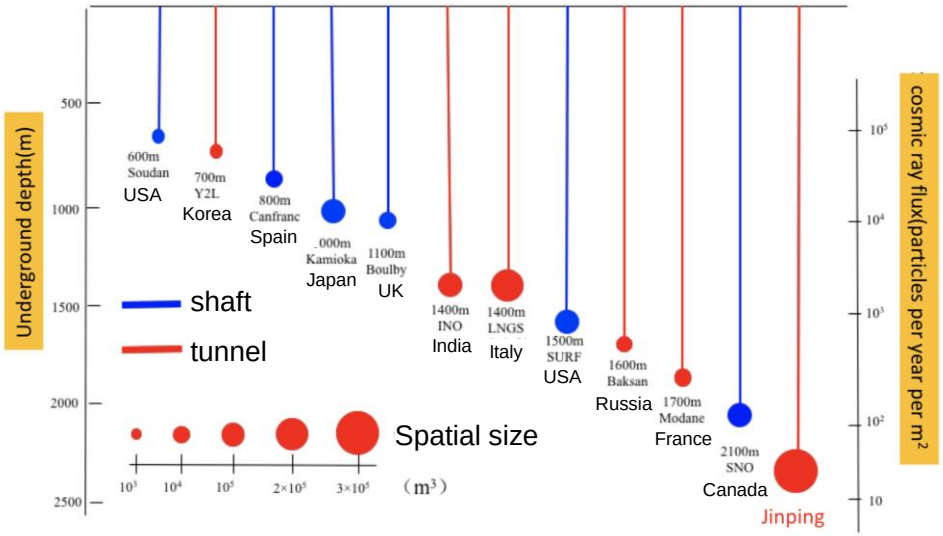
PandaX-I:
120 kg



PandaX-4T:
4 tons

China Jinping Underground Laboratory





Jinping Underground Laboratory, Sichuan, China

2400-m marble overburden

Cosmic ray flux

about 1.2 events/m^2/week

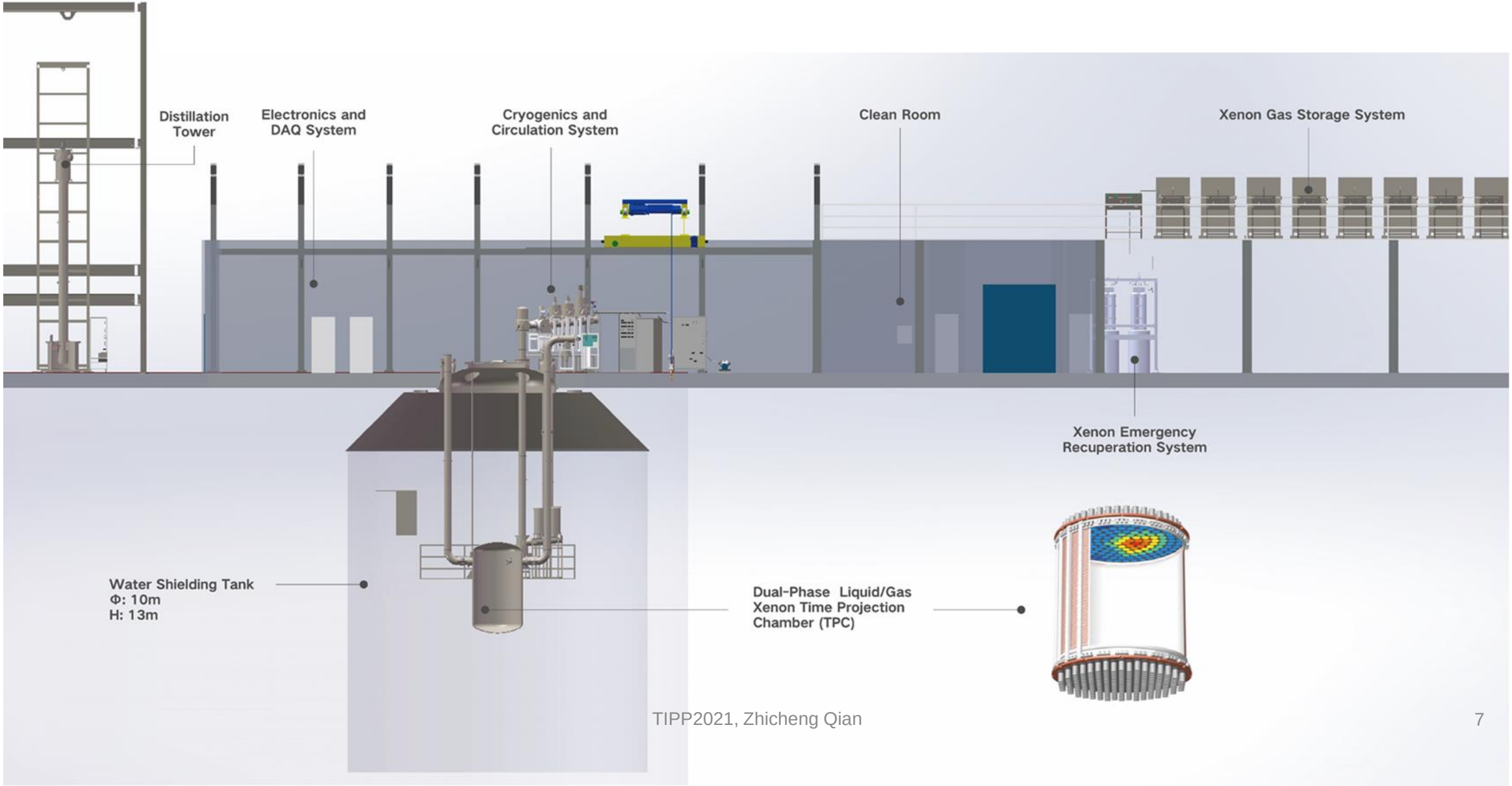
Radioactivity of natural marble

^{238}U ~4 Bq/kg, ^{232}Th ~0.6 Bq/kg, ^{40}K ~4 Bq/kg

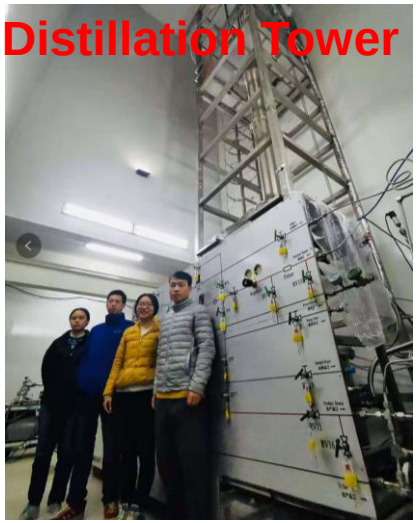
Horizontal access

convenient

PandaX-4T layout



Subsystem assembly



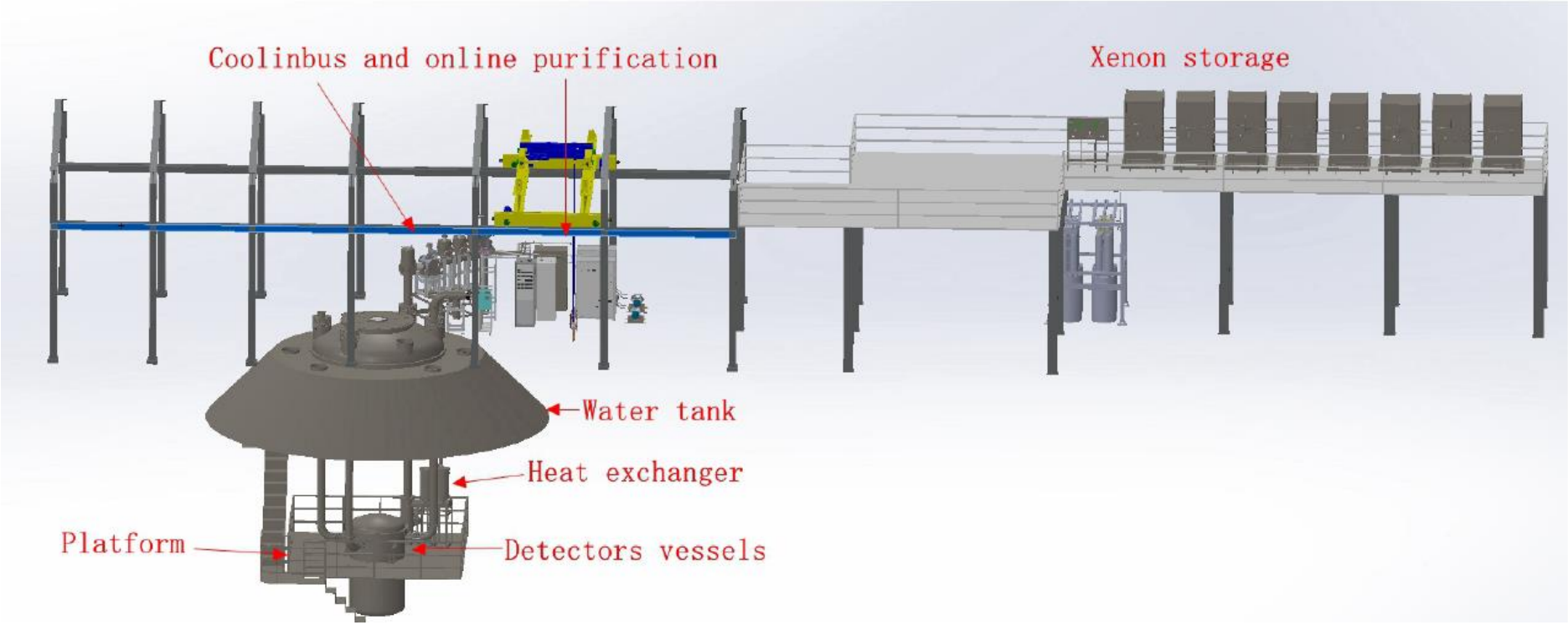
Distillation system for removing ^{85}Kr and ^{222}Rn

Distillation Tower	PandaX-II (achieved)	PandaX-4T (designed)
^{nat}Kr level	6 ppt	0.1 ppt
^{222}Rn level	^{222}Rn ~ 25 μBq/kg	^{222}Rn<1 μBq/kg
Operation mode	Offline	Offline and online

- Successfully commissioned the tower
- 0.5 ppm ^{nat}Kr/Xe in commercial xenon reduced to <10 ppt (RGA + cold trap system limit) after distillation
- ^{222}Rn can be removed during online distillation

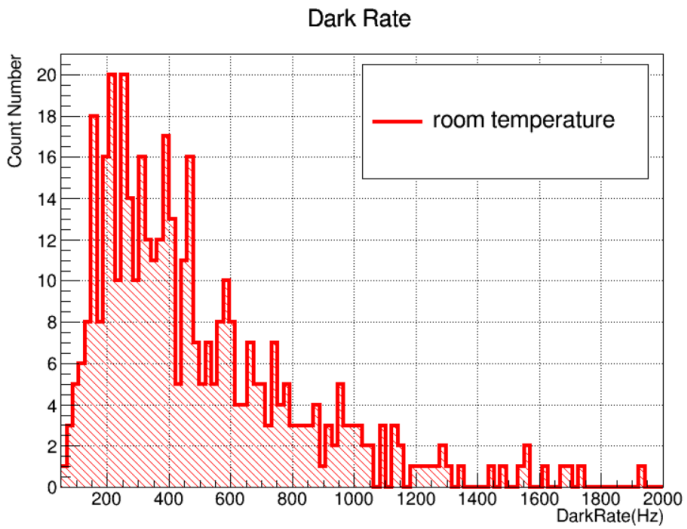
Cryogenics and xenon handling system

- Designed total cooling power: > 360 W @ 178 K
- Operating two cooling heads (plus one spare) for ~6 tons liquid xenon, capable to liquify ~0.7 tons liquid xenon per day
- Expected flow rate of online circulation with zirconium getter ~100 slpm

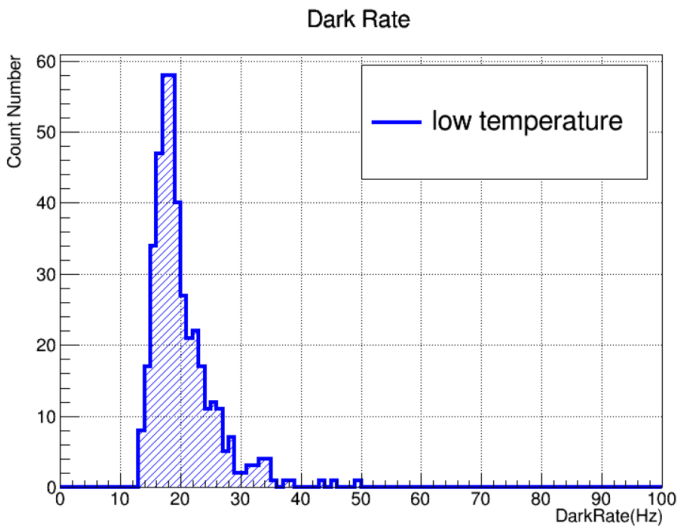


PMT, Electronics & DAQ

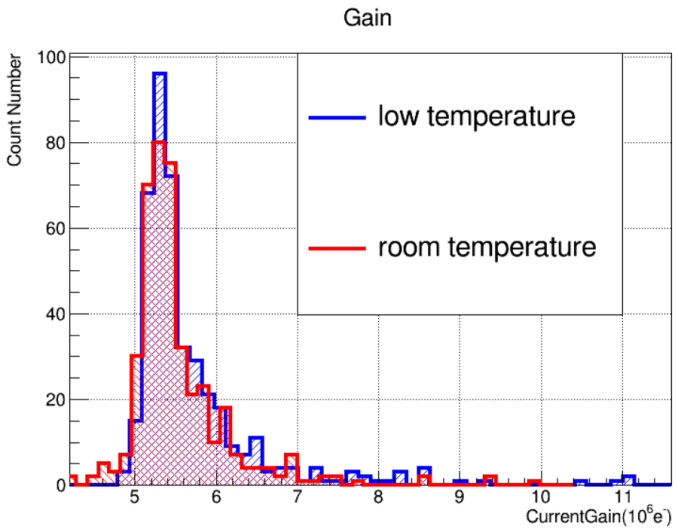
Experiment	Total channels	FADC Sampling Rate	Trigger mode for DM runs	Data transmission
PandaX-II	158	100 MS/s	Global Trigger (for S2 signals)	Daisy chains, limit ~80 MB/s
PandaX-4T	~500	250 MS/s	Triggerless (channel self-trigger)	Parallel Readout, limit ×10



average rate: 540 Hz

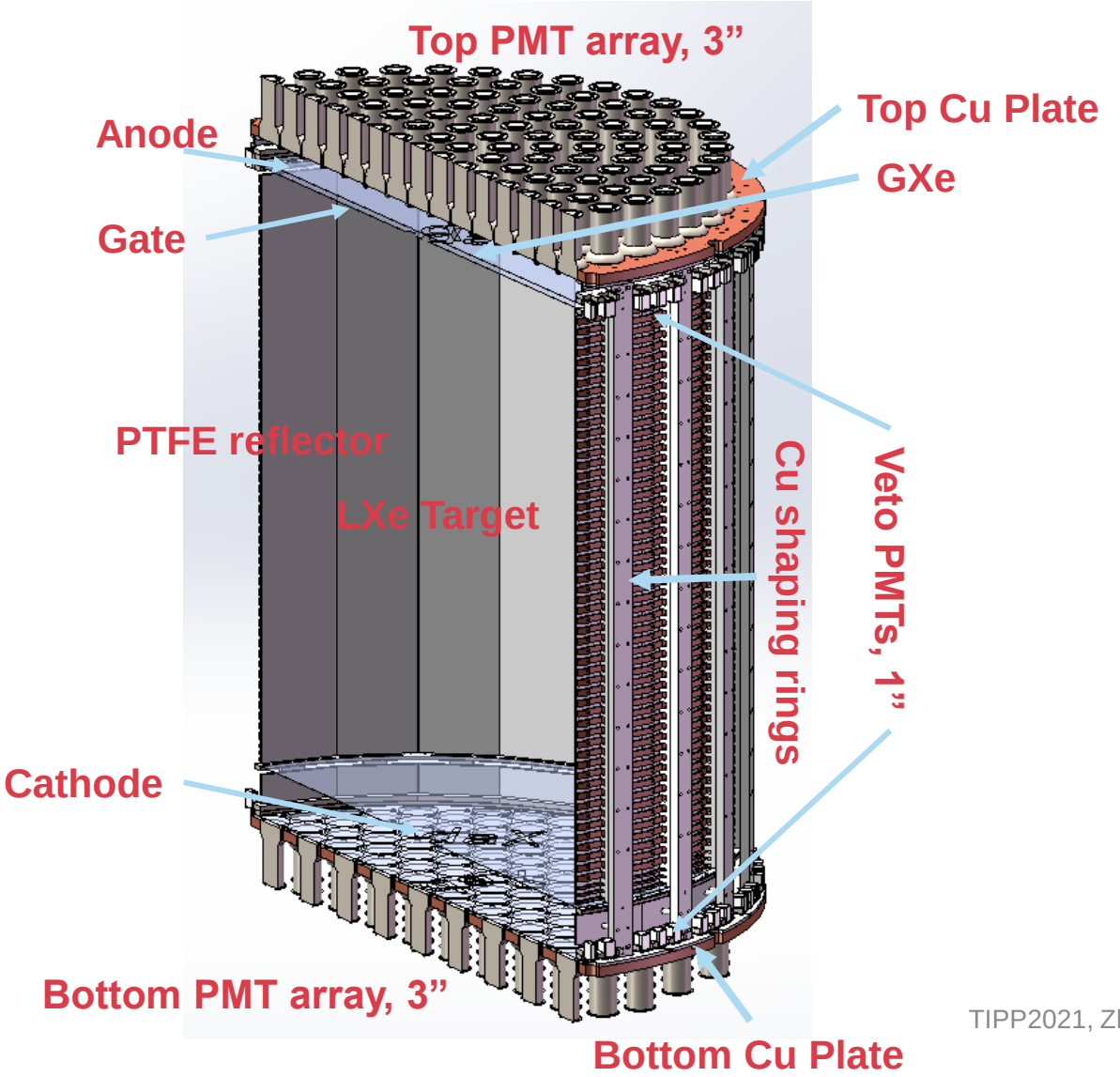


average rate: 20 Hz
-60 ^{0}C in cold chamber



average gain: 5.5E6
high voltage: 1300-1500 V

TPC



- Drift region: 1.2 m(H)x1.2 m(D)
- Designed field:
  Drift: 400 V/cm
  Extraction: 6 kV/cm
- 3-inch PMTs, 169 top/199 bottom
- 1-inch veto PMTs, 144

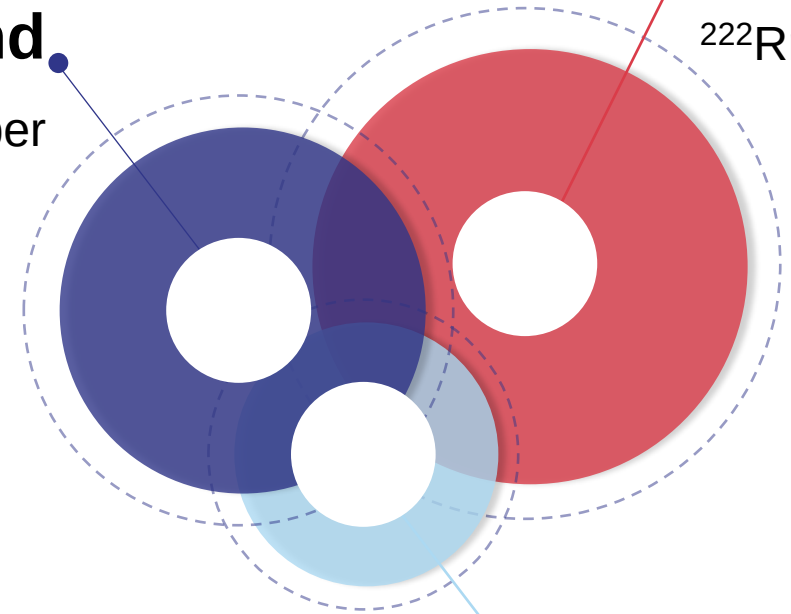
Background Sources

Background in xenon target

^{222}Rn, ^{85}Kr, ^{136}Xe

Material Background

PMT, Stainless Steel, PTFE, Copper

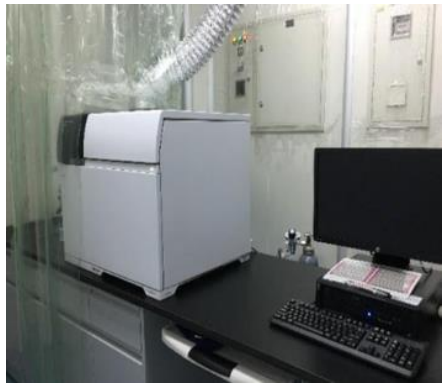


Physics background

^{8}B, hep, ^{7}Be neutrinos

Low Background Control

HPGe
Sensitivity: ~mBq/kg

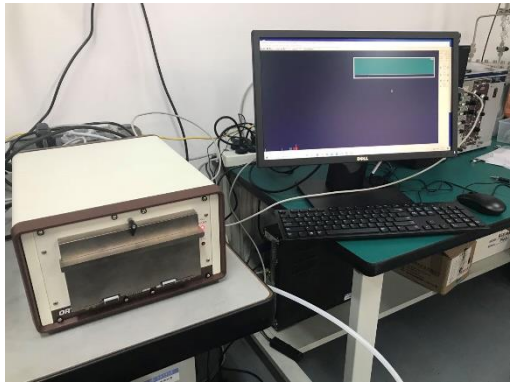


ICPMS @PKU
Sensitivity: ~ppt

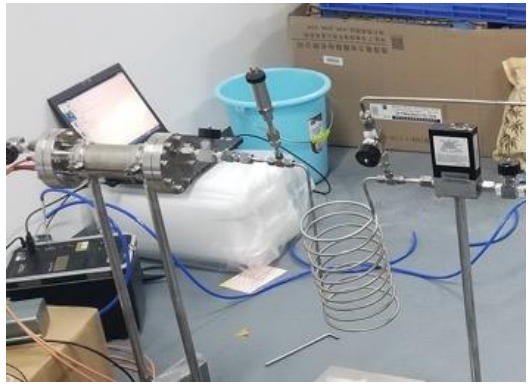
Radon emanation measurement system
Sensitivity: ~2 mBq

Materials screening with variety of ultra-low radioactive detection techniques

Krypton counting station
Sensitivity: ~10 ppt

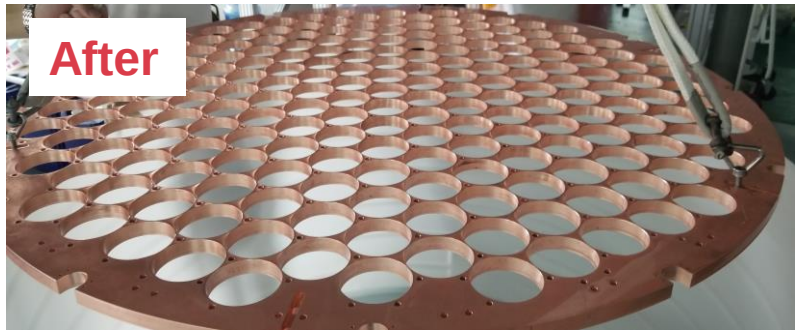


Alpha Mega detector
Blank rate: <24 counts/day

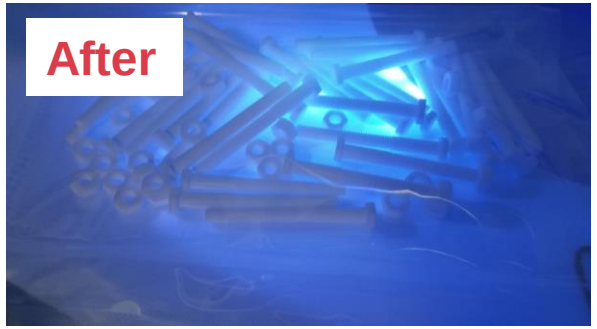


Radon emanation trap system
Sensitivity: ~0.05 mBq

Low Background Control



Copper plate



Teflon bolts/nuts

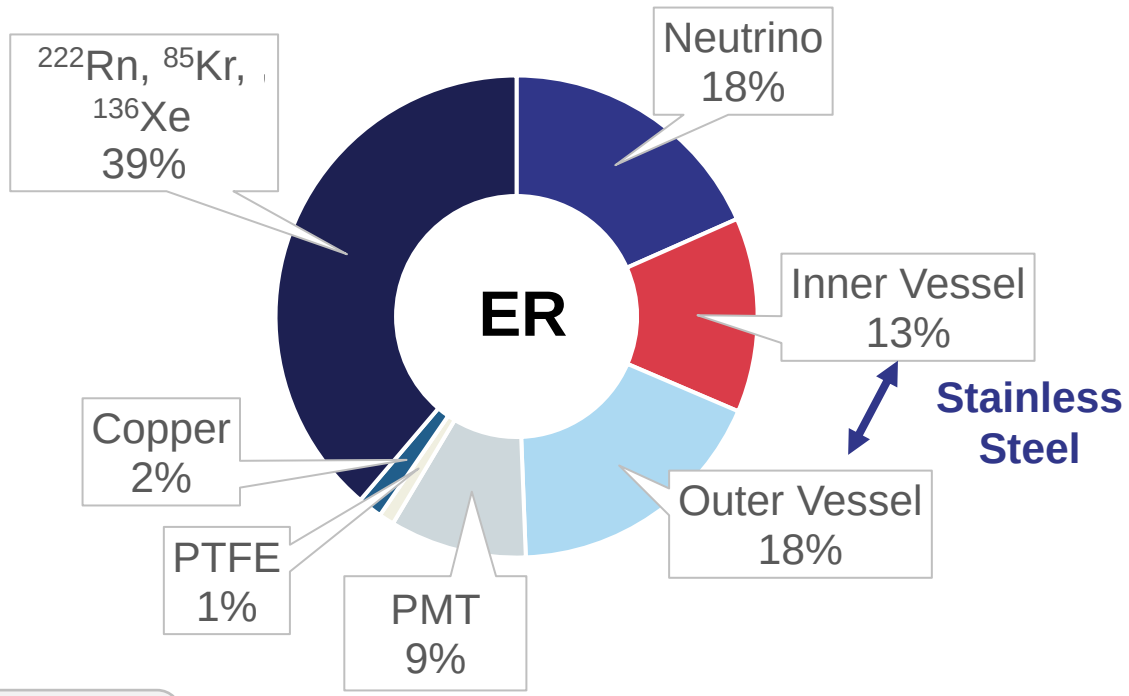
Rigorous cleaning procedures established

Copper	PTFE
• **Degrease**: 1% Alconox® + ultrasonic cleaning (2 times, 15min each) • **Pickling**: 1% H_2SO_4+3%H_2O_2 (5 min) • **Passivation**: 1% $C_6H_8O_7$ (5 min)	• Ultrapure water + ultrasonic cleaning (15 min) • Acetone + ultrasonic cleaning (15 min) • Alcohol + ultrasonic cleaning (15 min) • Ultrapure water + ultrasonic cleaning (15 min) • Immersed in 35% ultrapure HNO3 (1 week) • Ultrapure water + ultrasonic cleaning (15 min)

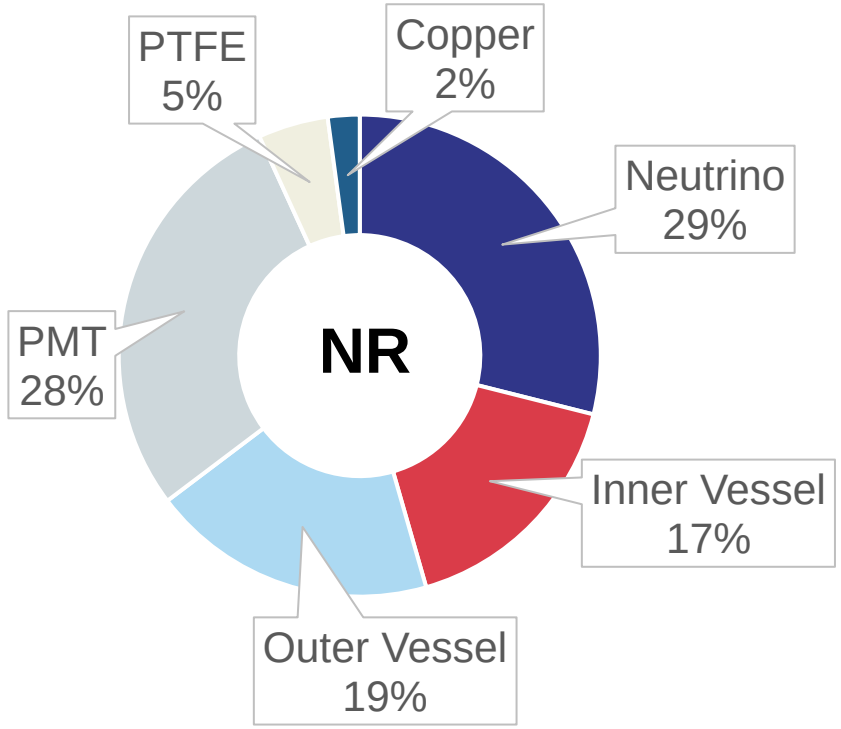
Background Budget

mDRU = 10^{-3} events/day/kg/keV

$(4.9\pm0.5)\times10^{-2}$ mDRU



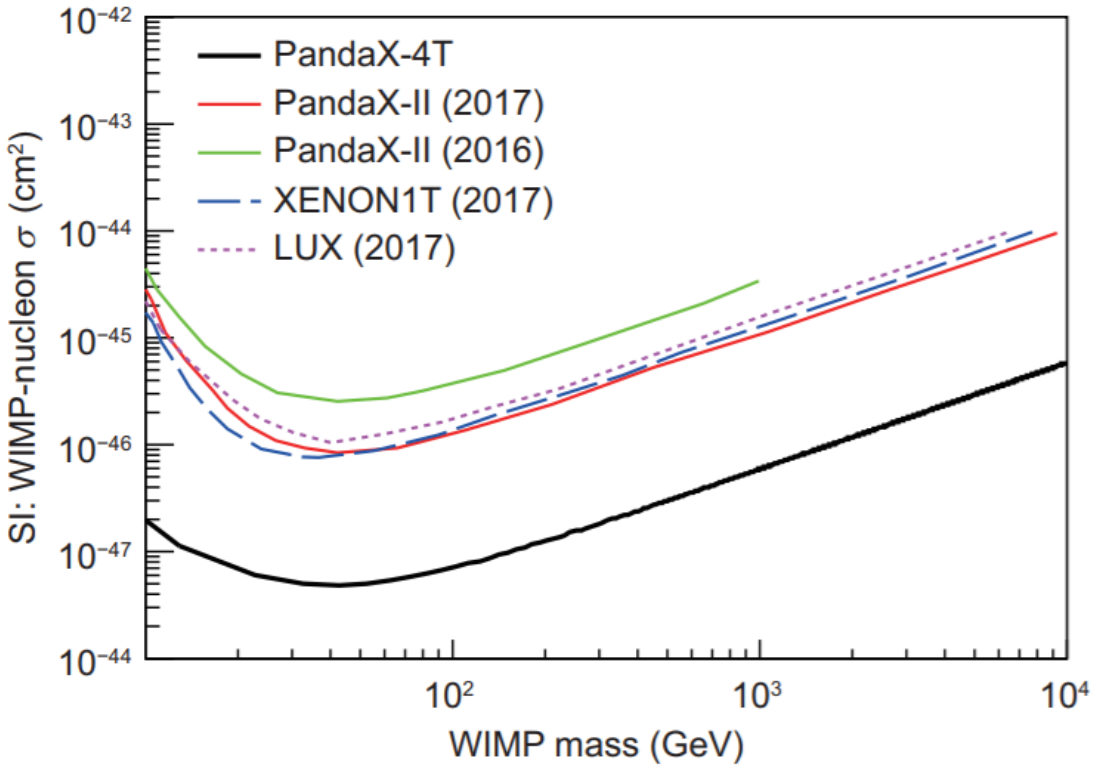
$(2.8\pm0.5)\times10^{-4}$ mDRU



Fiducial mass: 2.8 tons

■ Neutrino ■ Inner Vessel ■ Outer Vessel ■ PMT ■ PTFE ■ Copper ■ ^{222}Rn, ^{85}Kr, ^{136}Xe

Sensitivity



Unit: events	ER	NR
2-year yield	2.5±0.3	2.3±0.4

- Projected WIMP sensitivity is 6×10^{-48} cm^2 with 5.6-ton-year exposure for 40 GeV/c^2 WIMP mass

Summary

- CJPL-II B2 PandaX-4T facilities is ready since 2019/8
- Rigorous material assay and cleaning procedures have been established to control the background contribution
- Subsystem installation and assembly have been completed
- PandaX-4T commissioning is ongoing
- Real data coming soon, stay tuned

PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC

Thanks.

Zhicheng Qian

Institute of Nuclear and Particle Physics, Shanghai Jiao Tong University

2021/5/25, TIPP 2021

SHANGHAI JIAO TONG UNIVERSITY

INPAC
INSTITUTE OF NUCLEAR AND PARTICLE PHYSICS

Backup

Background budget

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