# Status, performance and recent results of PandaX

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On behalf of the PandaX Collaboration

CHEP, 2022/08/08 – 2022/08/11

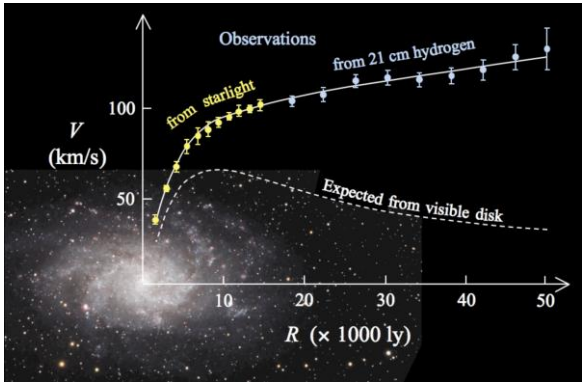
PANDA X

PARTICLE AND ASTROPHYSICAL XENON TPC

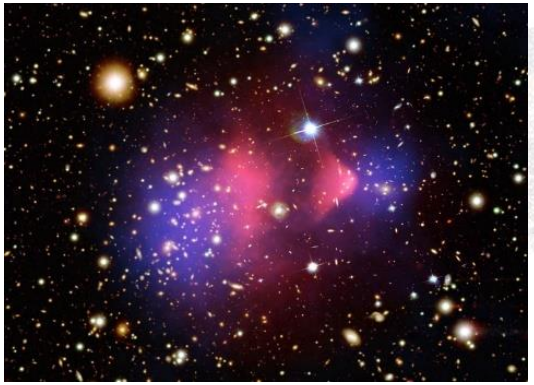
# PandaX Collaboration

# Dark matter and its evidence

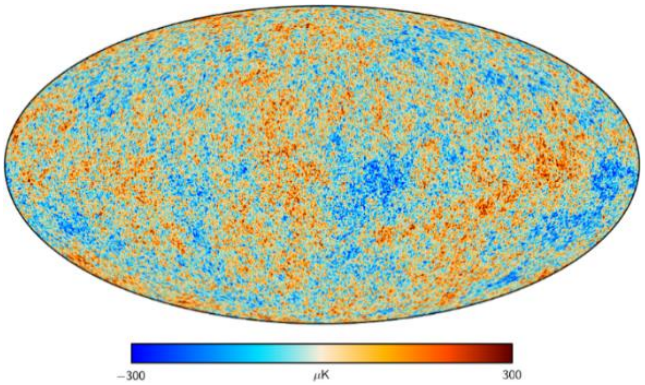
### Galactic rotation curve

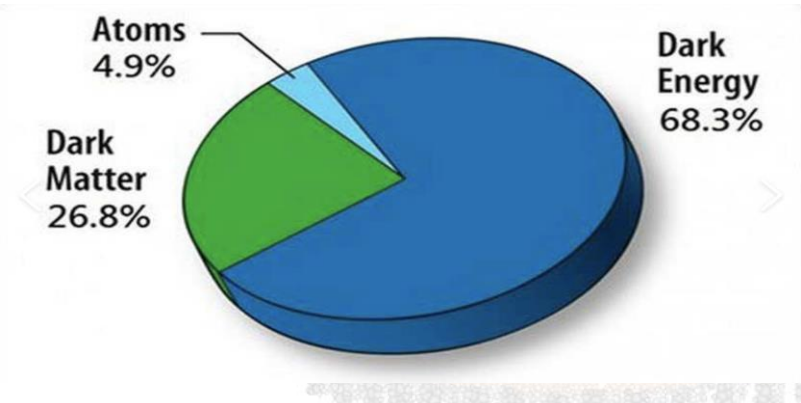



### Bullet Cluster



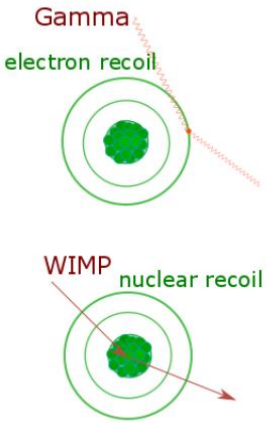
### Cosmic Microwave Background

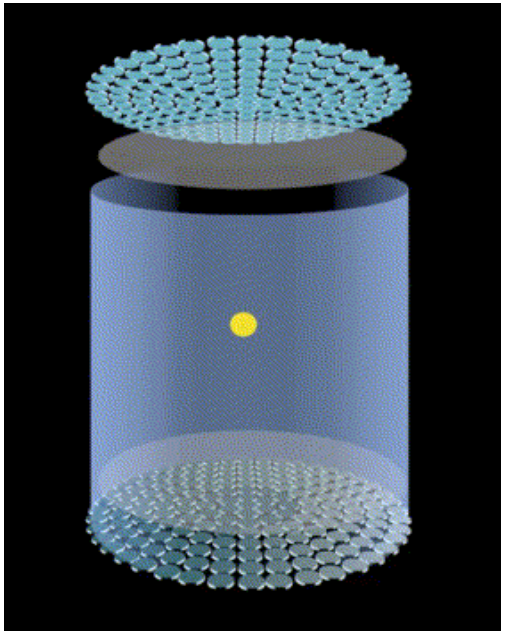


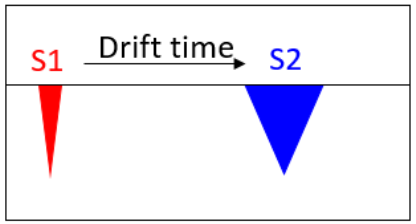

- Gravitational evidences suggest dark matter is the dominant form of matter in Universe!
- The nature of dark matter is still a mystery: WIMPs?

# Dual phase xenon TPC

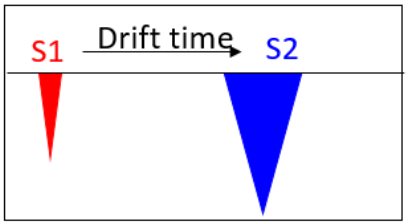


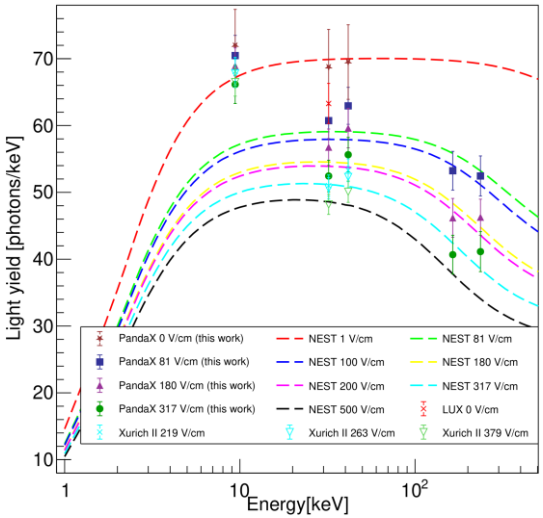
**Dark matter: nuclear recoil (NR)**




**γ background: electron recoil (ER)**




$(S2/S1)_{NR} << (S2/S1)_{ER}$




JINST 17 P01008 (2022)

Detector capability:

- ❑ Large monolithic target
- ❑ Good ER/NR rejection
- ❑ 3D reconstruction and fiducialization
- ❑ High light and charge yields

# PandaX Experiments

## Particle and Astrophysical Xenon Experiments

**Collaboration formed**


2009.3

2012.7

**PandaX-I apparatus moved to Jinping**

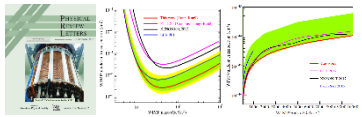
**PandaX-I started**


2014.3

2014.5-10

**PandaX-I, 120 kg operation**

**PandaX-II, 580 kg operation**

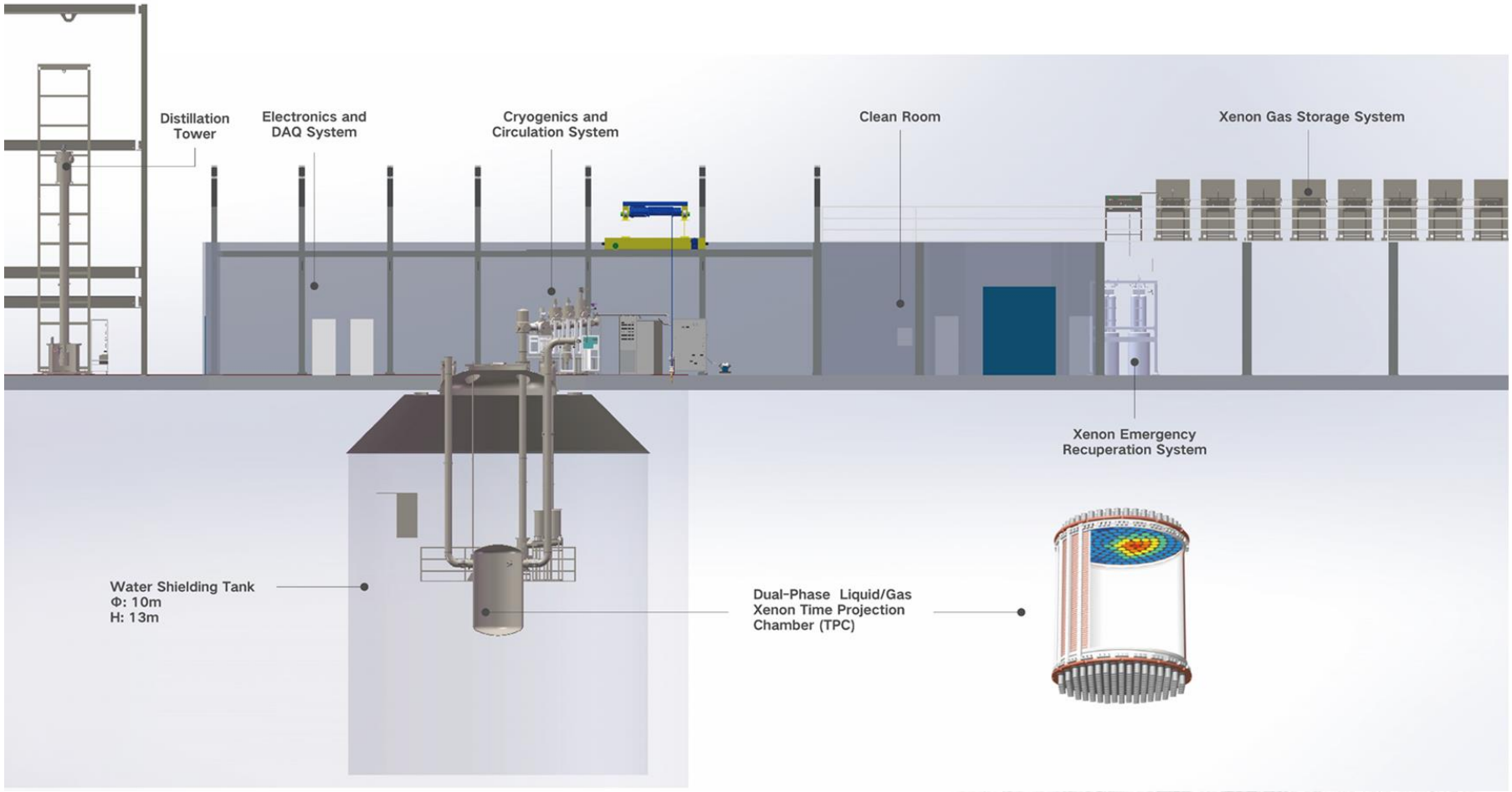


2016.7 -2019.7

2019.8-

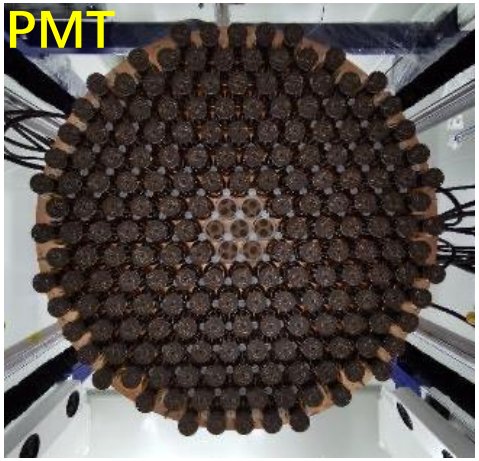
**PandaX-4T, 3.7 t moved to CJPL-II**

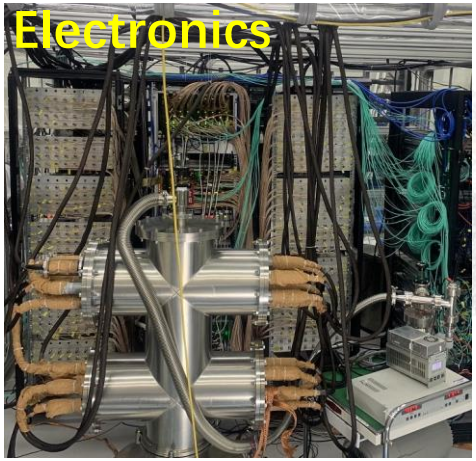
# PandaX-4T overview



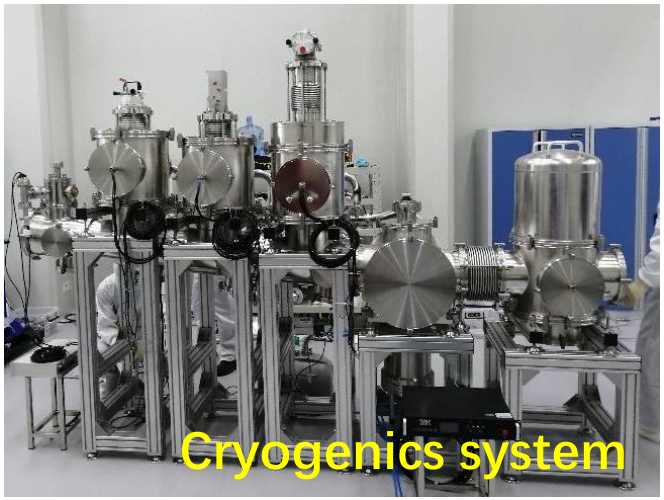

- Ultrapure water shield: 13 m (H) x 10 m (D) ~ 900 $m^3$
- TPC: 1.2 m (H) x 1.2 m (D)
- 3-in PMTs: 169 top/199 bottom

# PandaX-4T Subsystems

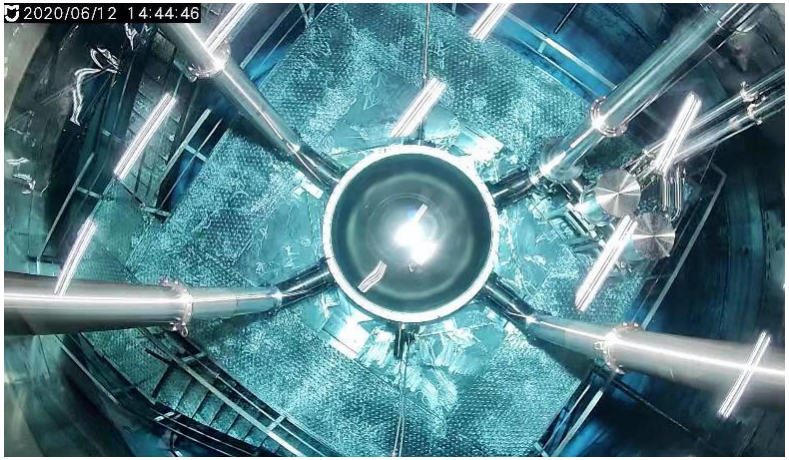



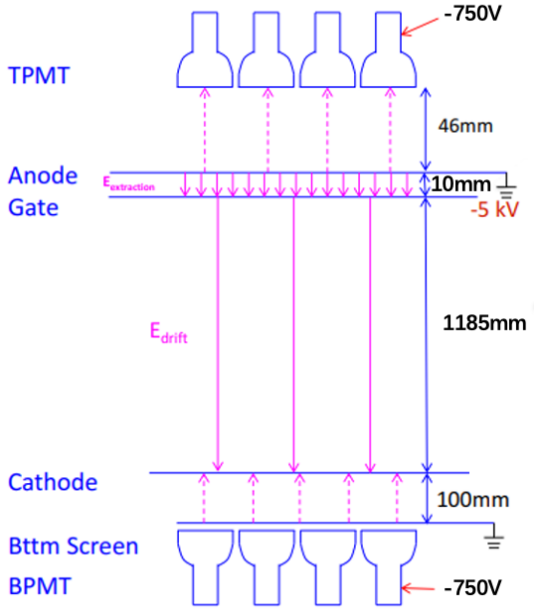



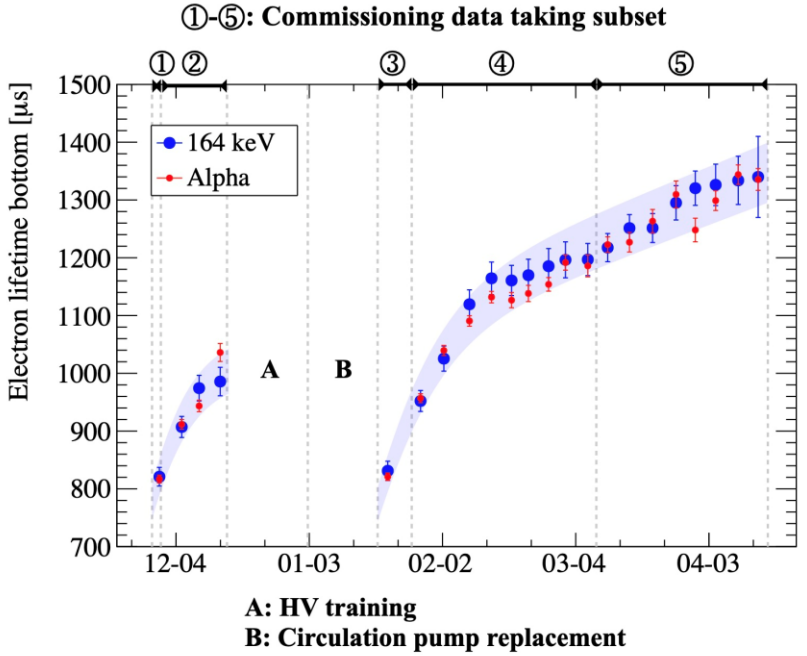





# PandaX-4T commissioning



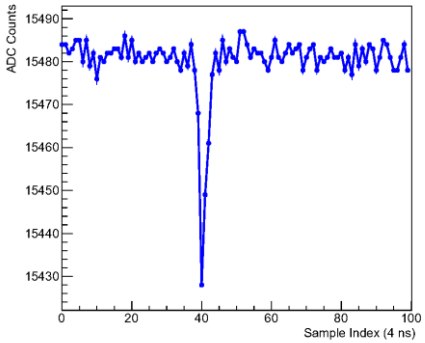




- Electron lifetime: *in situ* S2 vertical uniformity calibration
- Ref: the maximum drift time ~ 840 μs
- Stable data running period: 95.0 calendar days (86 days after selection)
- Exposure: 0.63 tonne-year

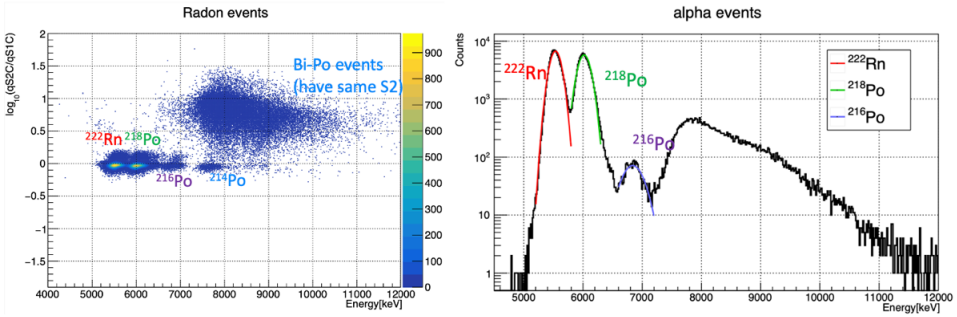
# PandaX-4T major improvement

- **Triggerless DAQ**: low threshold
  - read out pulses above 20 ADC (~1/3 PE)
- **$^{222}$Rn**: ~ 5 uBq/kg
  - 1/6 of PandaX-II
- **$^{85}$Kr**: ~0.3 ppt mol/mol
  - 1/20 of PandaX-II

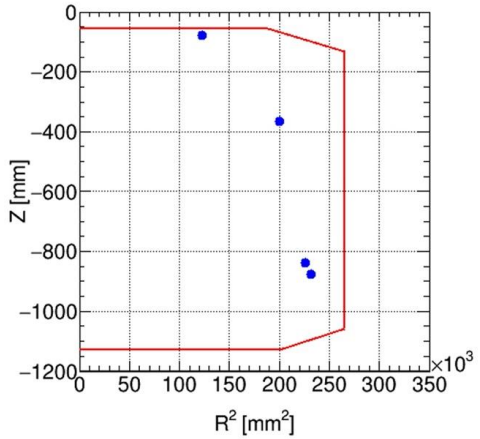


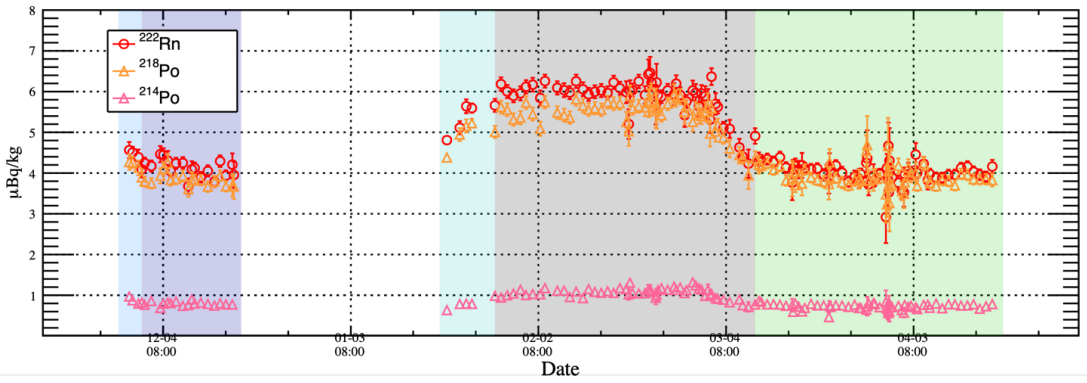

Typical single photon pulse

average single photon detection efficiency: 96%.




Vertex distribution of $^{85}$Kr's β-γ candidates

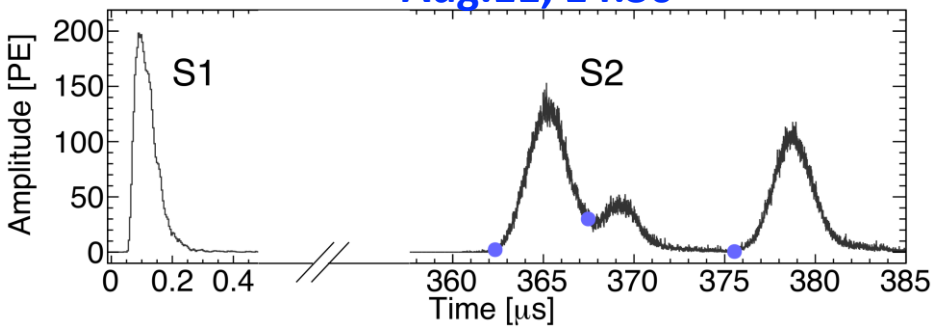


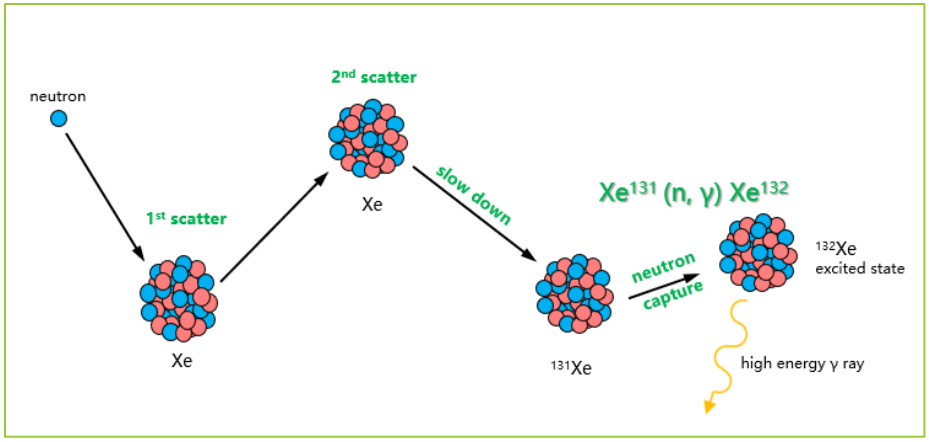
# Improvement in analytical techniques

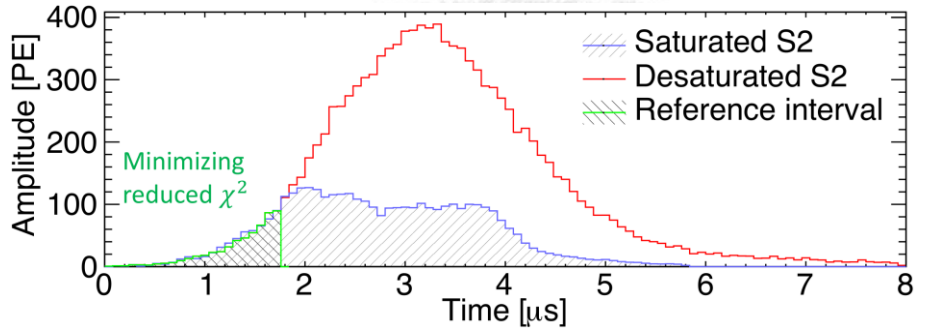
- **Background estimation**
  - 3 methods for neutron background: multi-scatters, captures, simulation
  - Benchmarked by D-D and Am-Be neutron source calibration
- **Extend DM detector response to MeV range**
  - Identifying multi-site and single-site events
  - Correct PMT pulse saturation effect

**详见罗棱尹的报告**
**Aug.11, 14:30**




**Zhou Huang 2022 CPC**
**doi: 10.1088/1674-1137/ac8539**



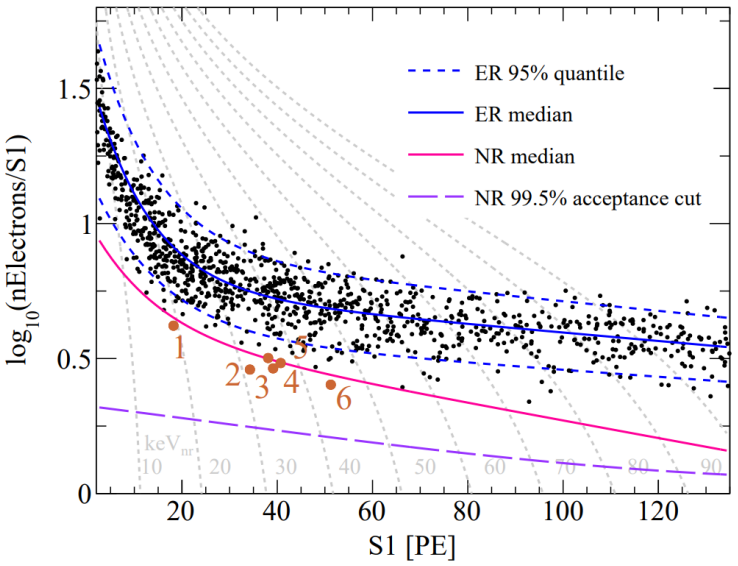
# WIMP-nucleon SI exclusion limits

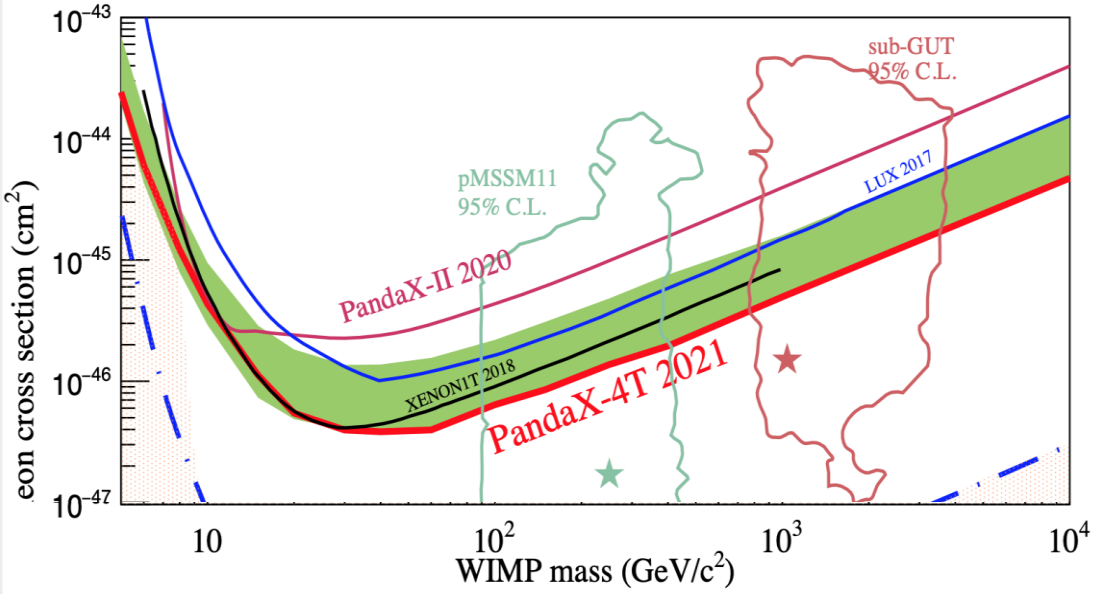
- Sensitivity improved from PandaX-II final analysis by 2.9 times (30 GeV/$c^2$)
- Dived into previously unexplored territory!
- Approaching the “low E” neutrino floor

**PRL 127, 261802 (2021)**

**Editors’ Suggestion**

DM candidates: 6 / 1058



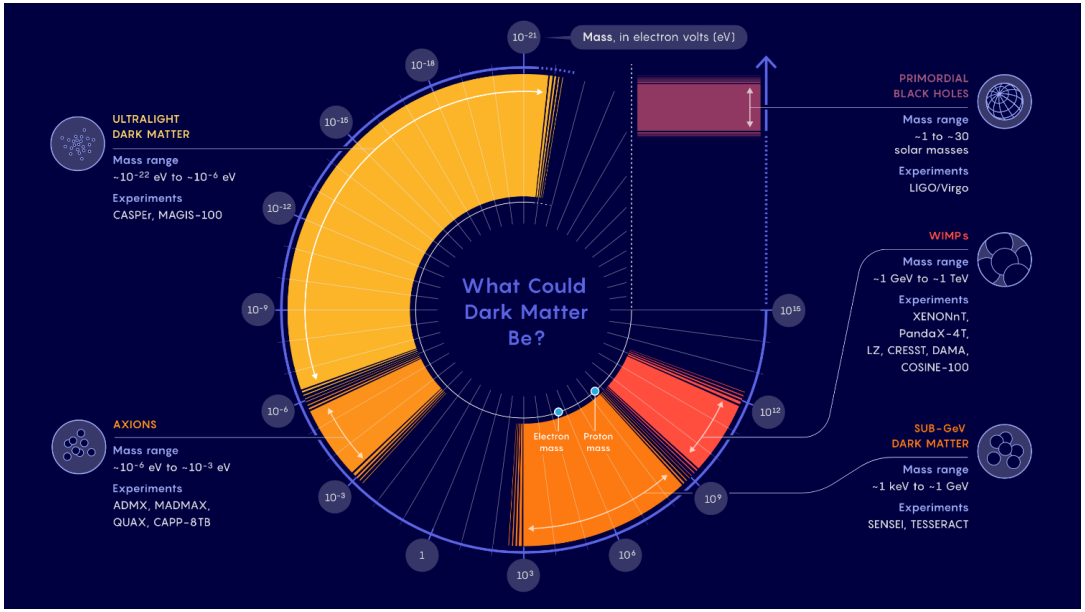




SUSY benchmark contours (MasterCode)

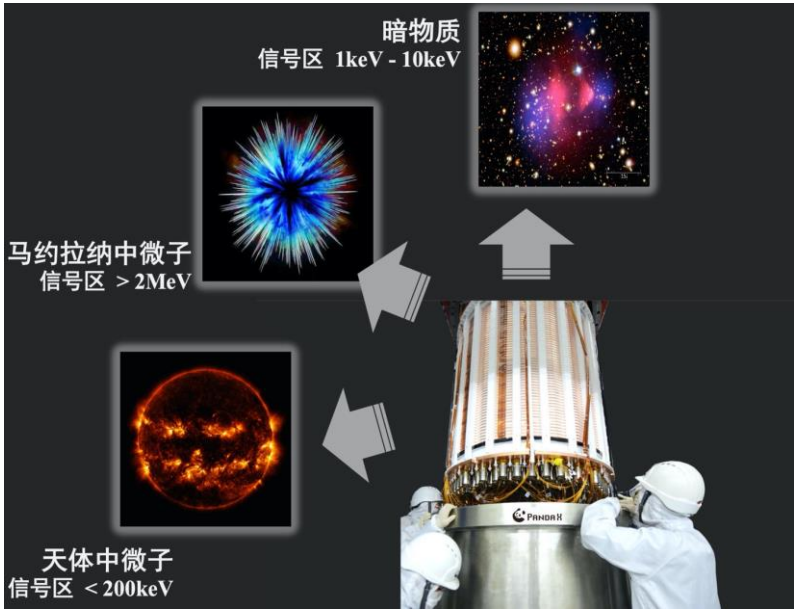
EPJC 78, no.3, 256 (2018), EPJC 78, 158 (2018)

# PandaX-4T as a multi-target detector

- PandaX-4T: ultra-low background, large detection range (keV-10MeV)
- Search for various dark matter candidates besides WIMP
- Search for Majorana neutrinos and astrophysical neutrinos




Samuel Velasco/Quanta Magazine



# Post-WIMP analyses

Deposited energy in PandaX detector

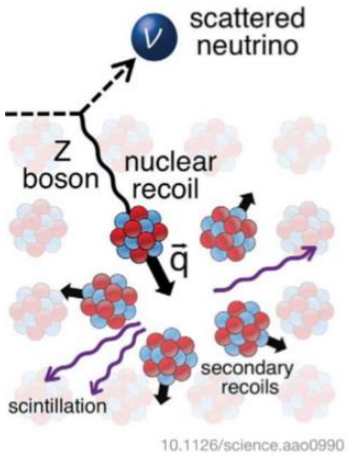
| < keV | ~keV – 30 keV | > 30 keV |
|---|---|---|
| B8 CEvNS (马文博);<br><br>Light DM scatter on electrons and nuclei (武蒙蒙); | Cosmic-ray boosted DM (崔祥仪);<br><br>DM Absorption (陶奕);<br>EFT;<br>Spin-dependent DM;<br>Self-interacting DM;<br>Solar axion & ALPs;<br>Migdal effect; | $^{136}$Xe ($0\nu/2\nu$) $\beta\beta$ decay (司琳);<br><br>$^{124}$Xe double electron capture;<br><br>Solar *pp* neutrino electron scatter; |

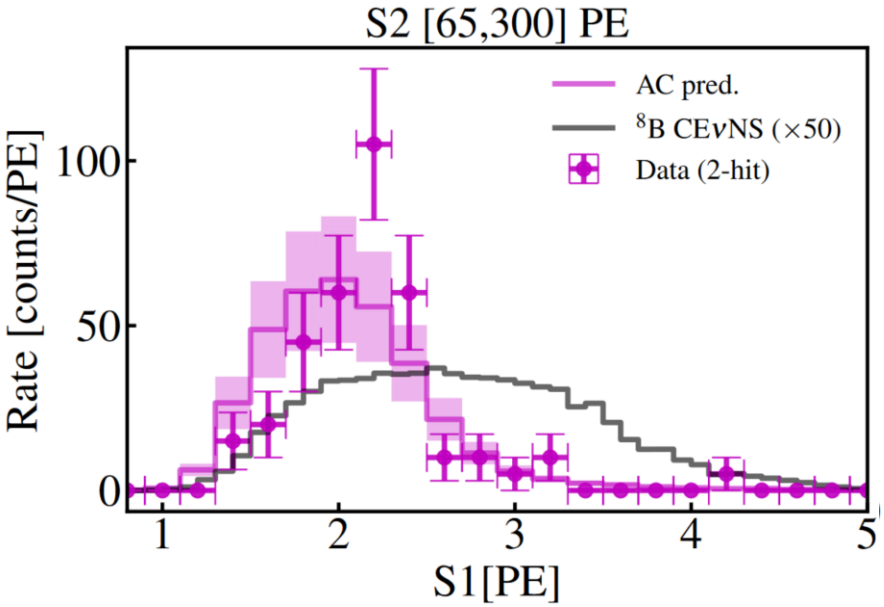
We are taking data with lowered background for more exposure!

# PandaX-4T search on B8 CEvNS

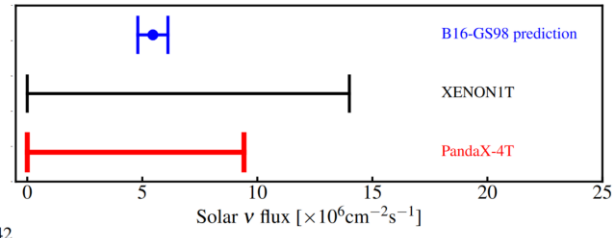
详见马文博的报告
Aug.11, 13:30

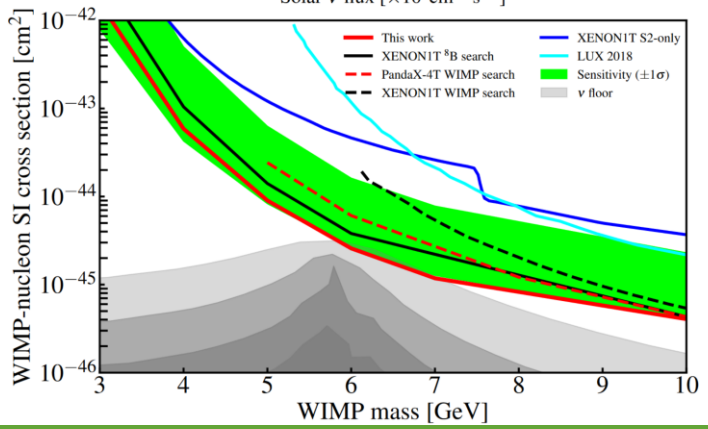
**Solar $^8$B CEvNS (coherent elastic neutrino-nucleus scattering)**




**arXiv:2207.04883**



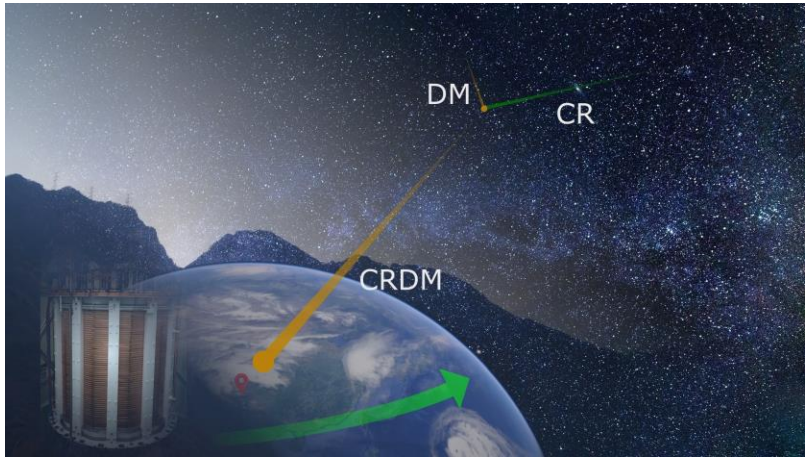




- Leading constraints on B8 neutrino flux through CEvNS
- Into sensitivity of “neutrino floor” due to B8 CEvNS, can cast new insight on neutrino-nucleus interactions.
- Assuming B8 as bkg, give strongest constraints on WIMP in 3-10 GeV region

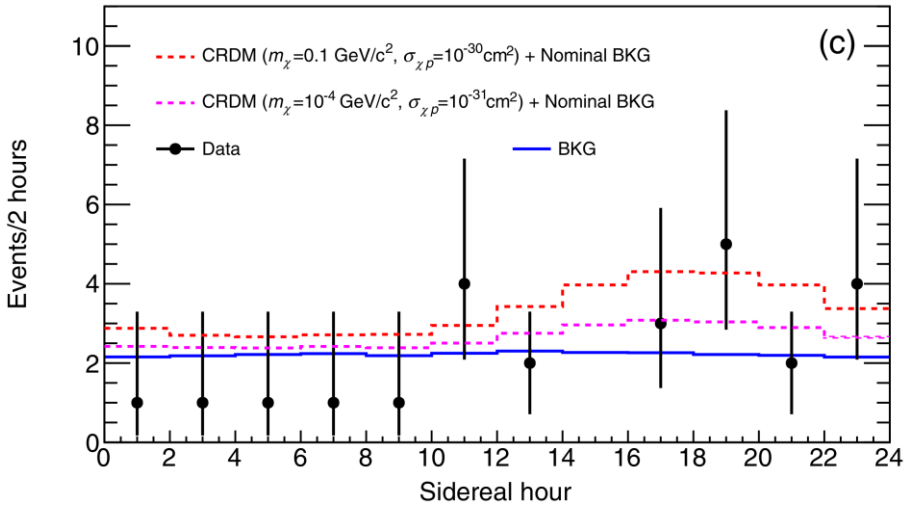
# PandaX-II search on CRDM

详见崔祥仪的报告
Aug.11, 14:00

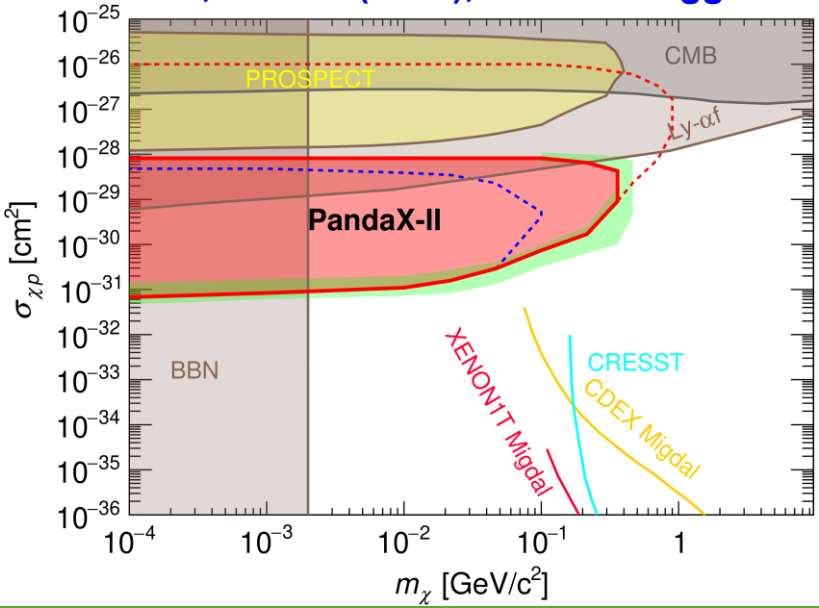
Cosmic-ray boosted dark matter (CRDM)




Sidereal diurnal modulation in CRDM rate




**PRL 128, 171801 (2022), Editors' Suggestion**

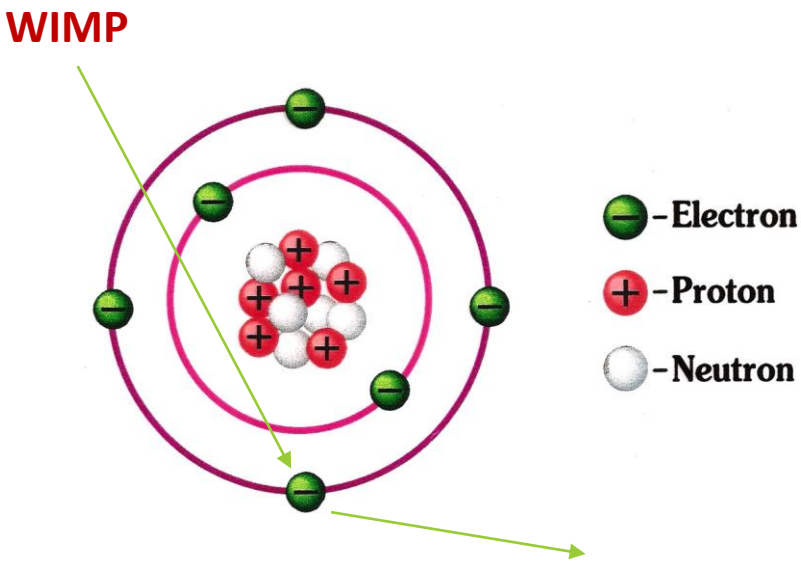



- Cosmic-ray boosts the kinetic energy of Galactic DM with sub-GeV mass
- No significant CRDM signal is found above background
- Constrain the sub-GeV DM beyond the astrophysical and cosmological probes

# PandaX-4T search on other DM

- Search light DM interactions with ionization signal only

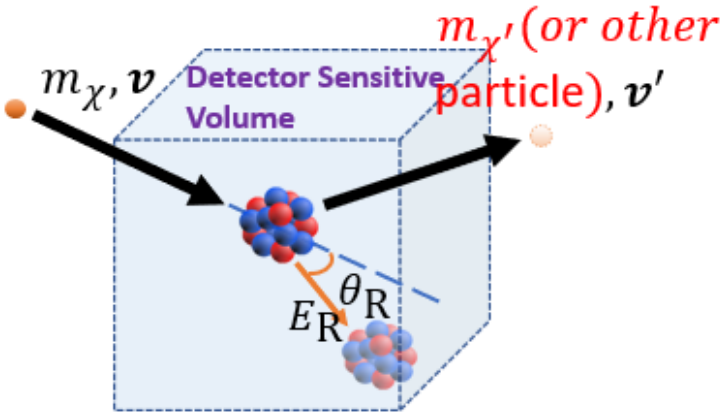
详见武蒙蒙的报告
Aug.11, 10:45




- Search light DM absorption on nuclei/electrons

详见陶奕的报告 Aug.11, 13:45
arXiv:2205.15771
arXiv:2206.02339

$$\overset{(-)}{\chi} + {}^{A}\mathrm{Xe} \rightarrow \overset{(-)}{\nu} + {}^{A}\mathrm{Xe}$$



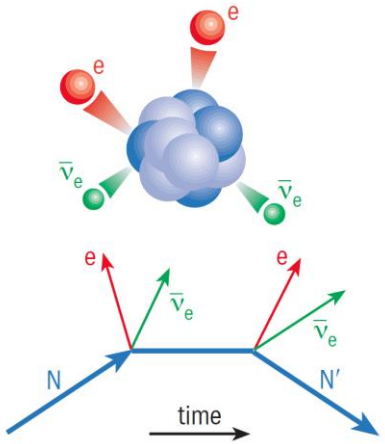
# PandaX-4T search on $^{136}$Xe DBD

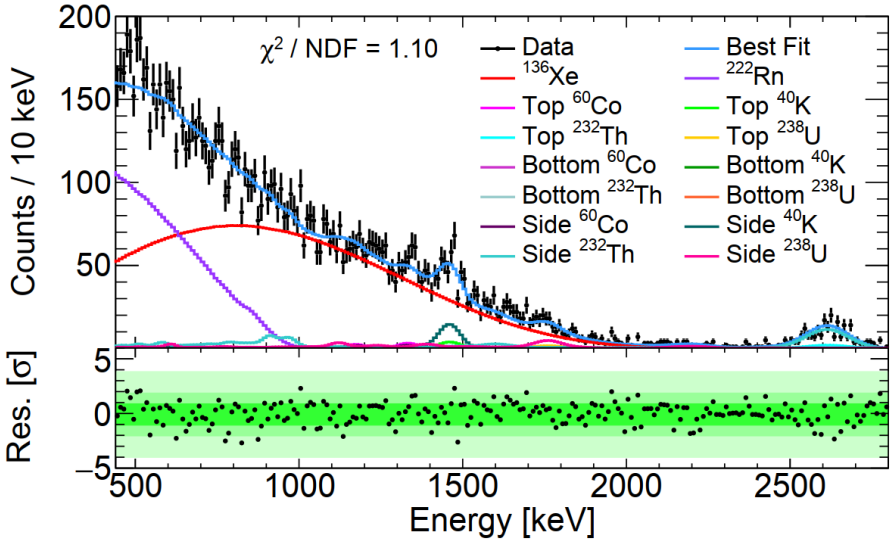
详见司琳的报告
Aug.11, 8:45

PANDA X

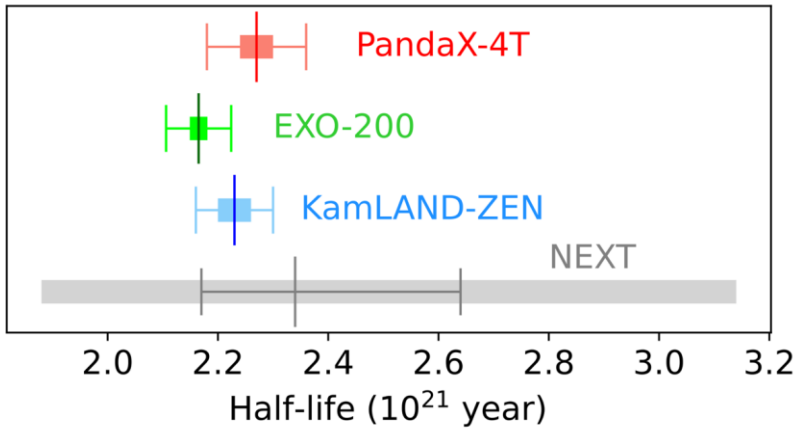
## $^{136}$Xe double beta decay (DBD)

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




**arXiv:2205.12809**




- First measurement from dark matter detector
- The total fitted number of Xe-136 DBD events is 17468±257 in ROI of 440 to 2800 keV
- Xe-136 DBD half-life is measured as: $2.27 \pm 0.03(\text{stat.}) \pm 0.10(\text{syst.}) \times 10^{21}$ yr

# Conclusion and outlook

- PandaX-4T has completed its commissioning run
- With a 0.63 tonne·year exposure, PandaX-4T produced the strongest WIMP-nucleon interaction constraint when the result published in 2021
- An offline tritium removal campaign has been performed, new physics run is on going
- PandaX-II and -4T analysis on other physics topics, including CRDM, B8 CEvNS, double beta decay and etc, are on-going
- In parallel, the collaboration is developing the plan for the next generation experiment at CJPL, we welcome collaborators!

**Thanks very much for your attention!**