UNIVERSITY OF WARWICK

Physics Opportunites at the PandaX Detector

Hong-Kai Tan (陈竑恺)
University of Warwick

XVI NexT PhD Workshop

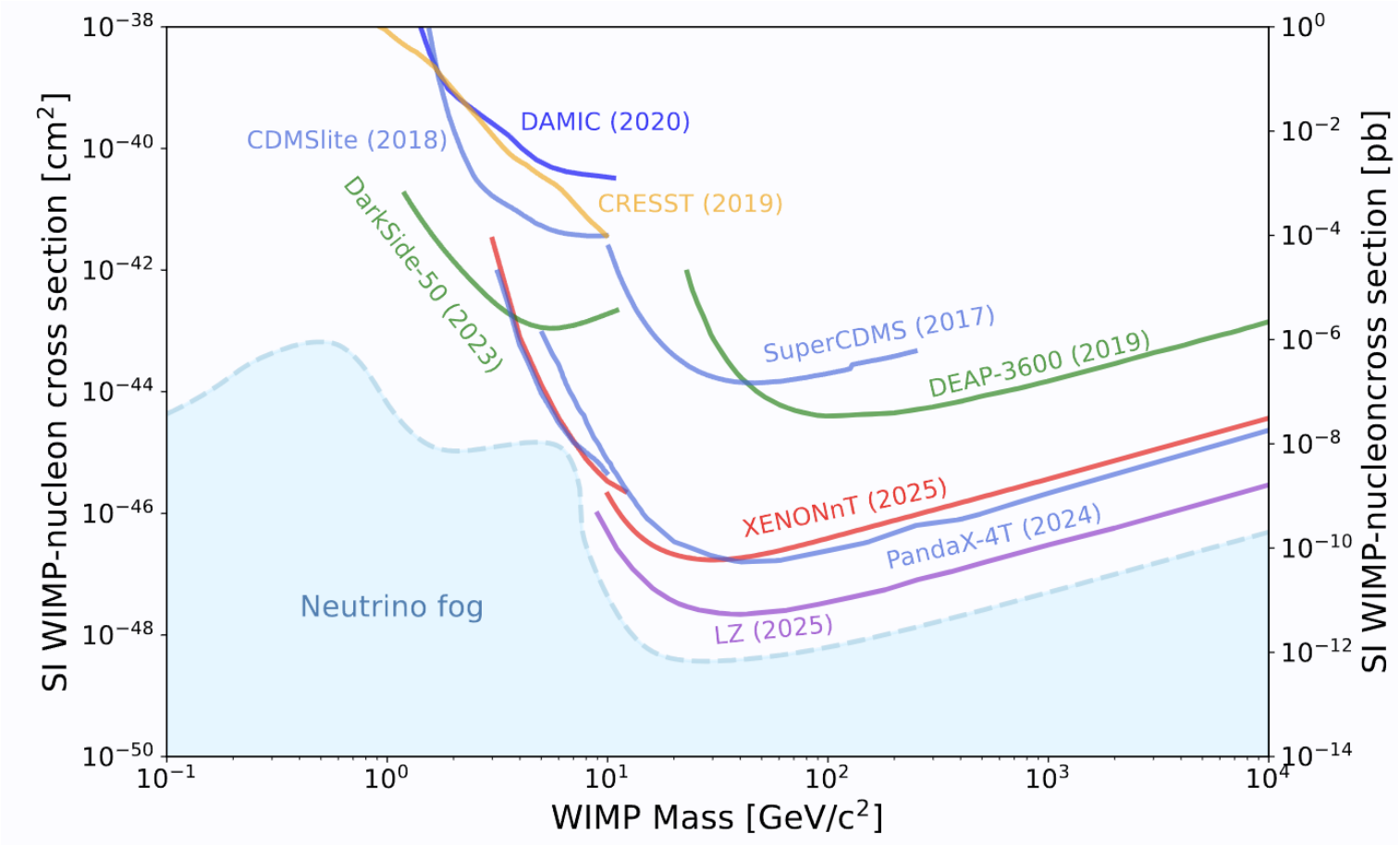
2026 August 24, Abingdon

PANDA X

About Me

- From Singapore
- First-year PhD student (HPgTPCs) under the supervision of Prof. Xianguo Lu (卢显国) at the University of Warwick
- MPhys Physics with Theoretical Physics at the University of Manchester
- LTA at Shanghai Jiao Tong University starting October 2026
  - Will be working on PandaX-20T upgrade with Prof. Junting Huang (黄俊挺)

Status of DM Experiments



Review of Particle Physics 2026, PDG

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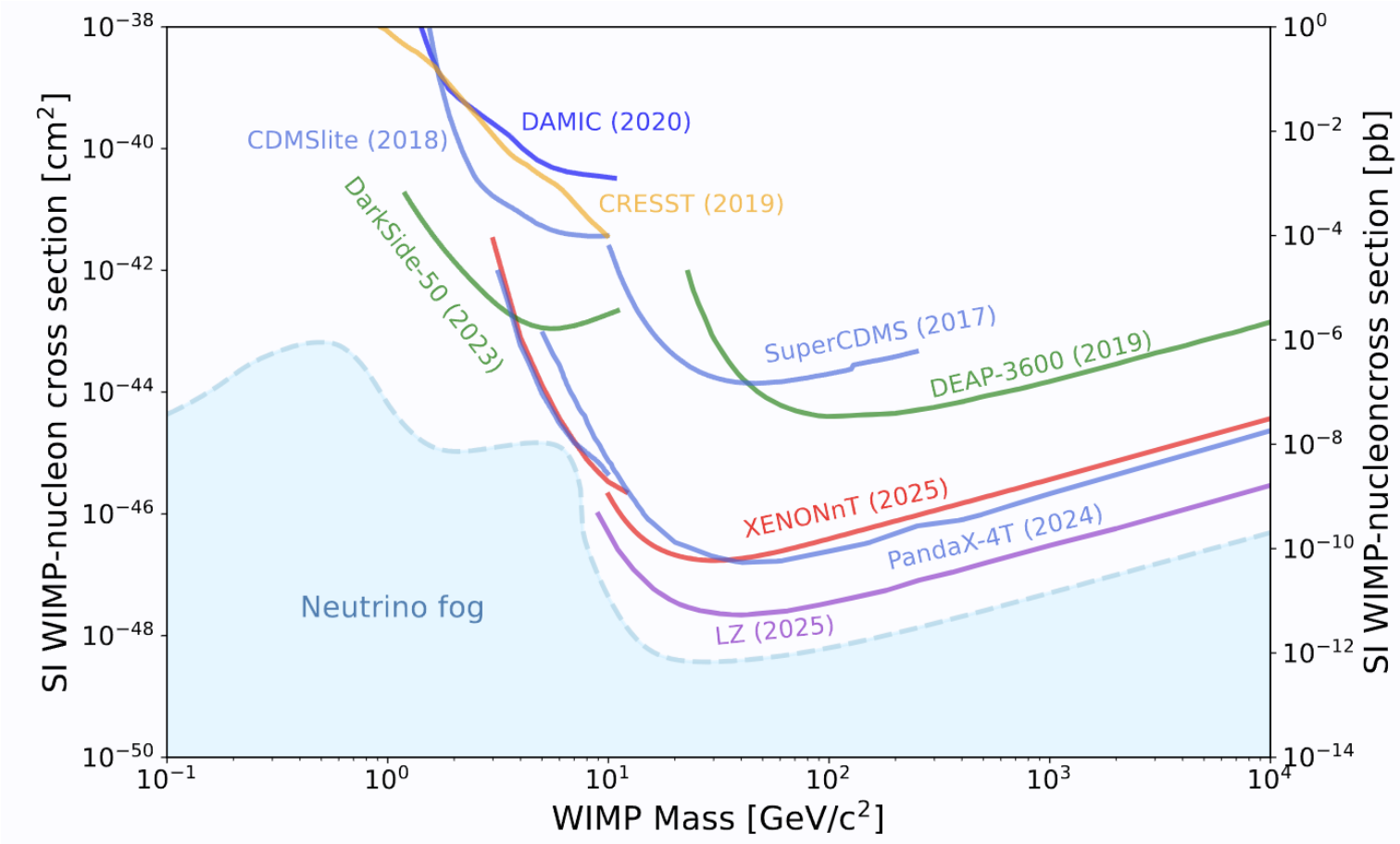

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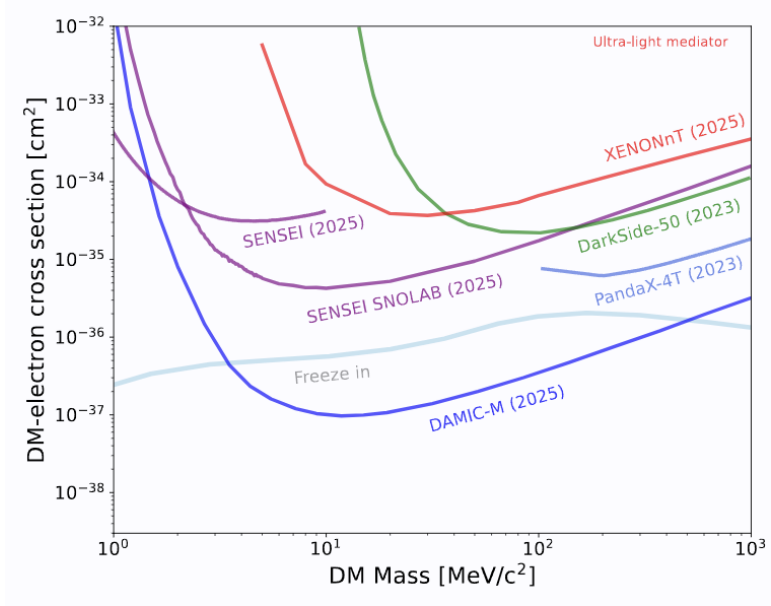

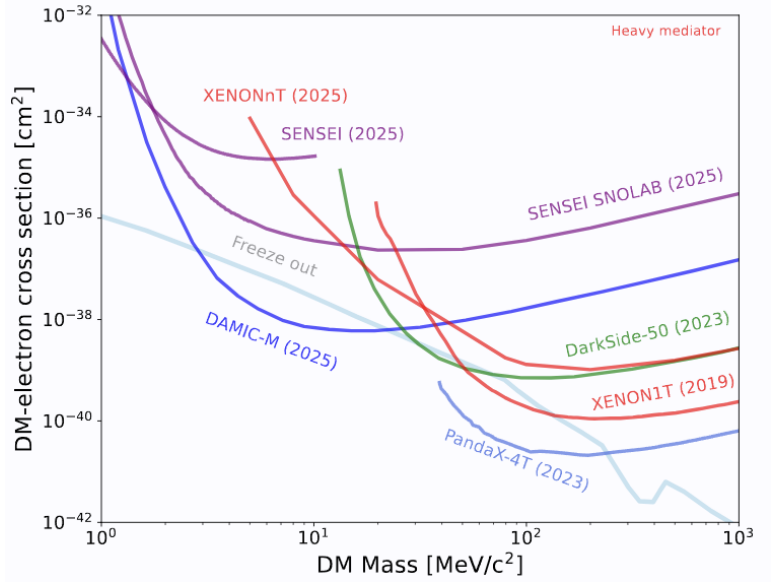

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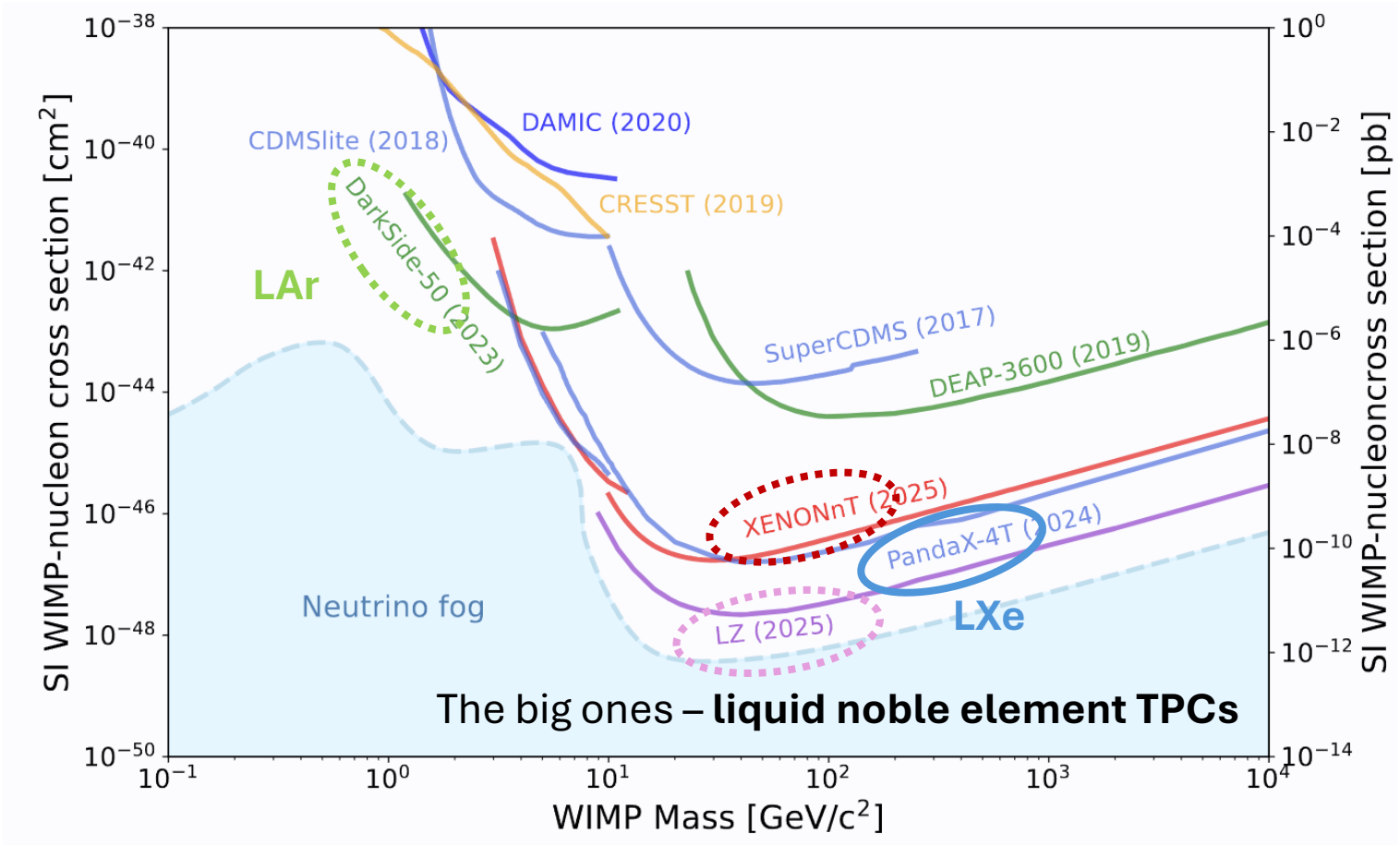

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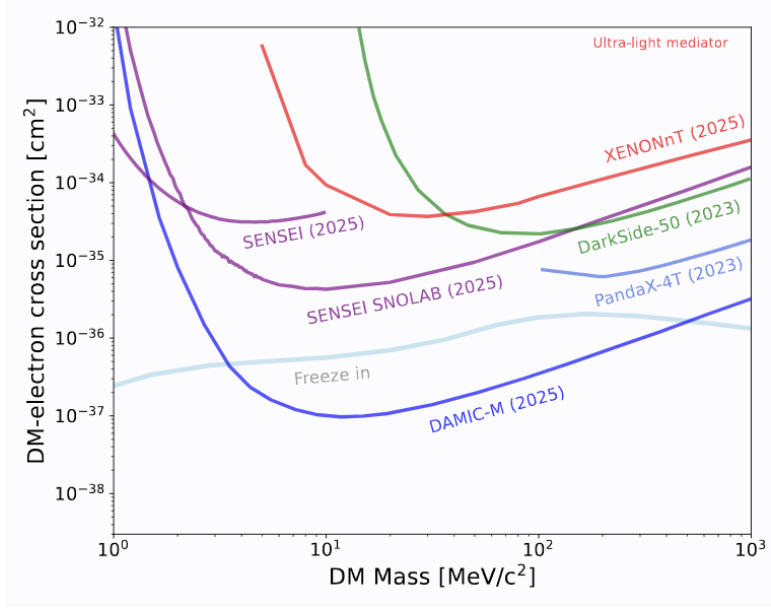
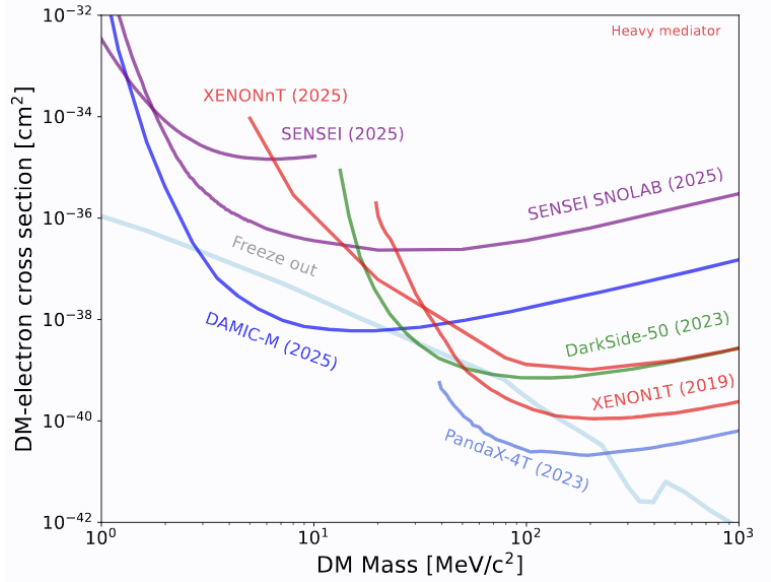
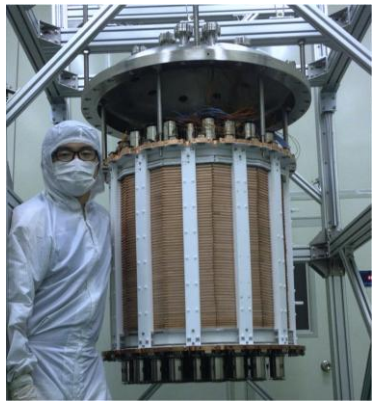




PandaX – **P**article **and** **A**strophysical **X**enon Experiment

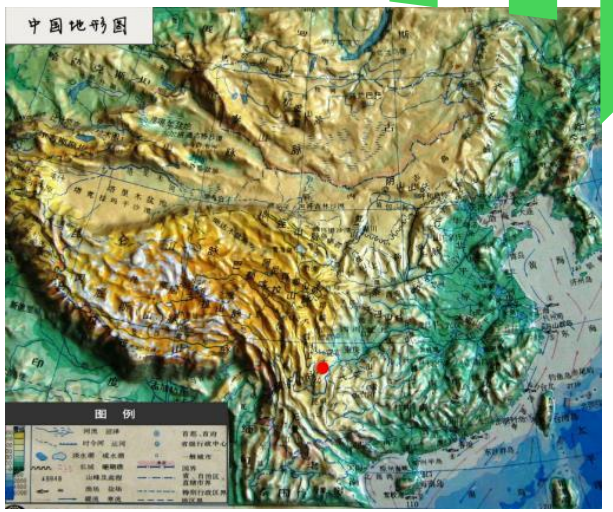
2009
Collaboration formed



2014
PandaX-I
(120 kg)

2016
PandaX-II
(580 kg)

2020
PandaX-4T



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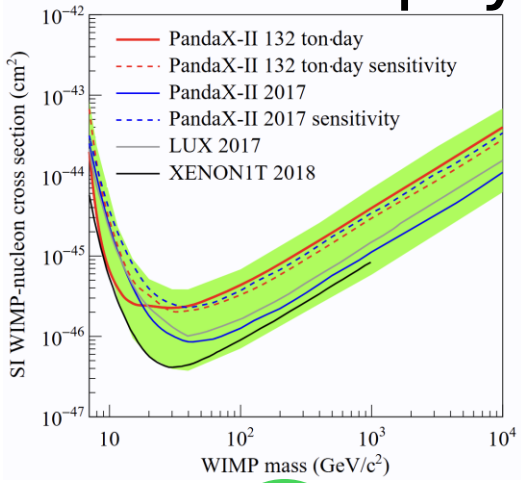

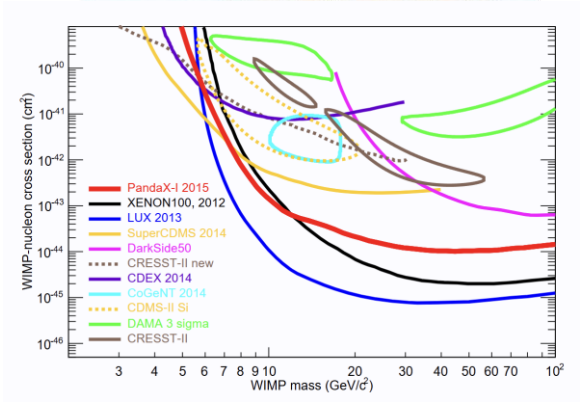

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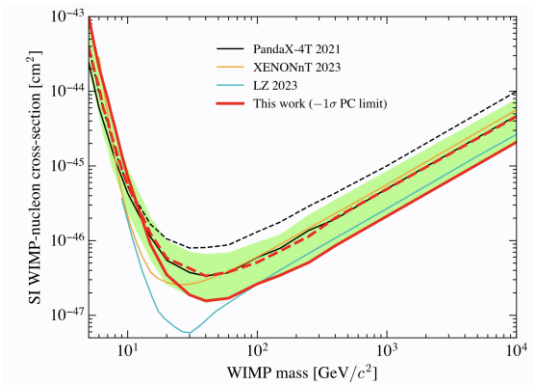
PandaX-4T

WE ARE HERE



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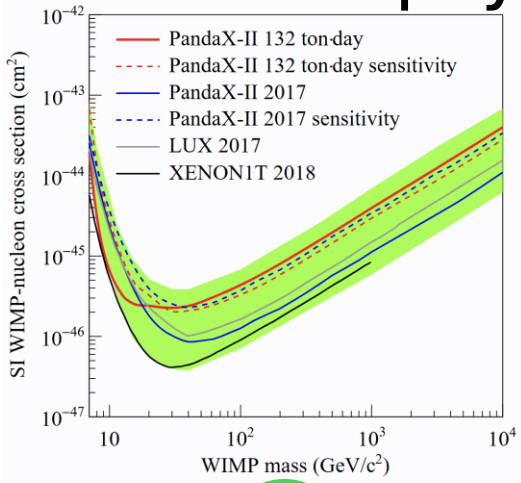

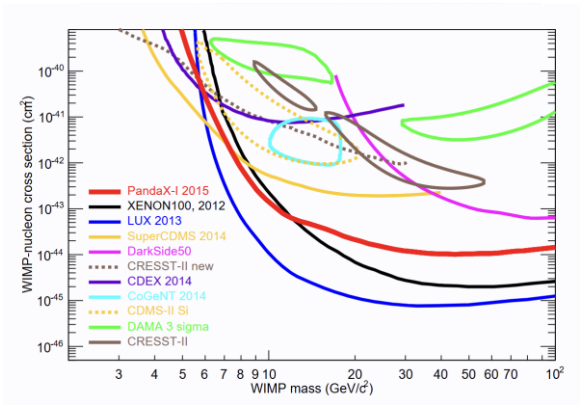

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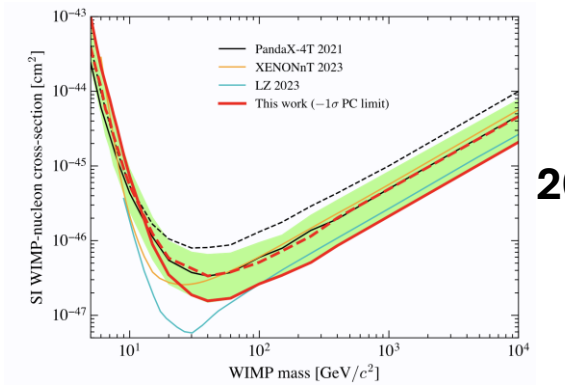

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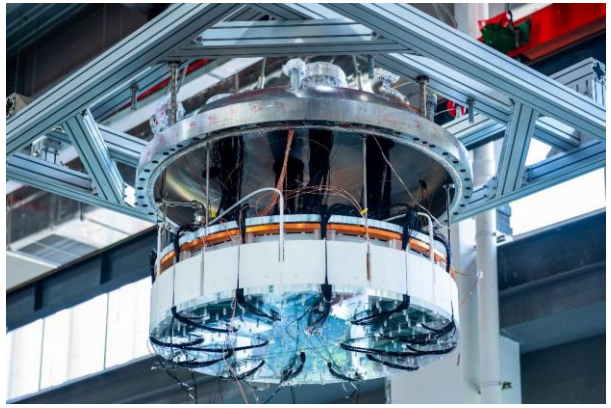

2027
PandaX-xT
20T First Stage

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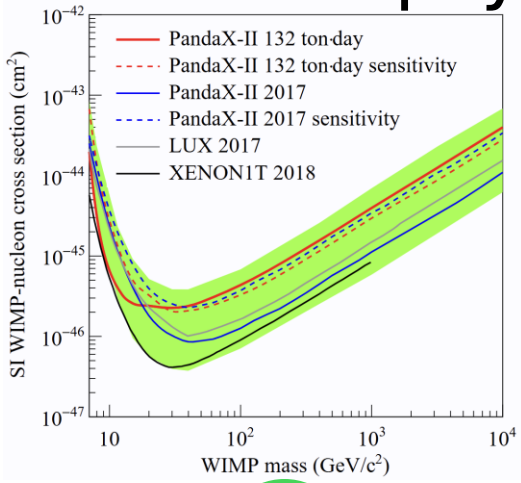

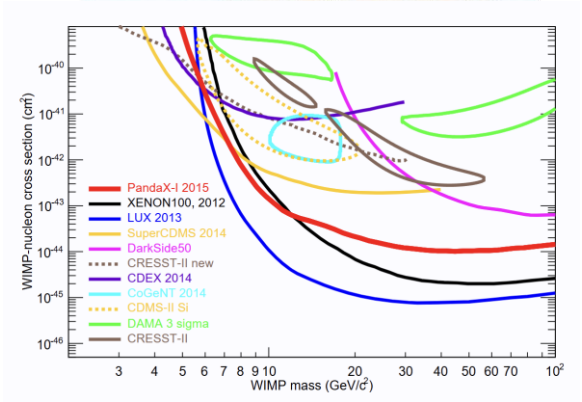

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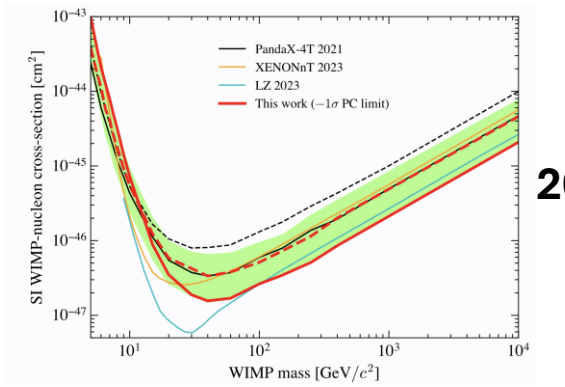

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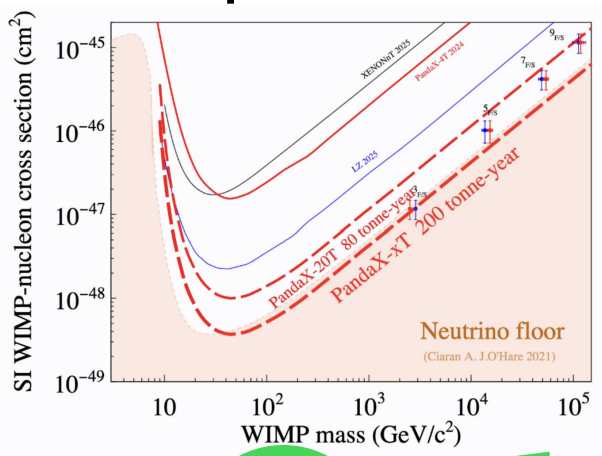


2027
PandaX-xT
20T First Stage

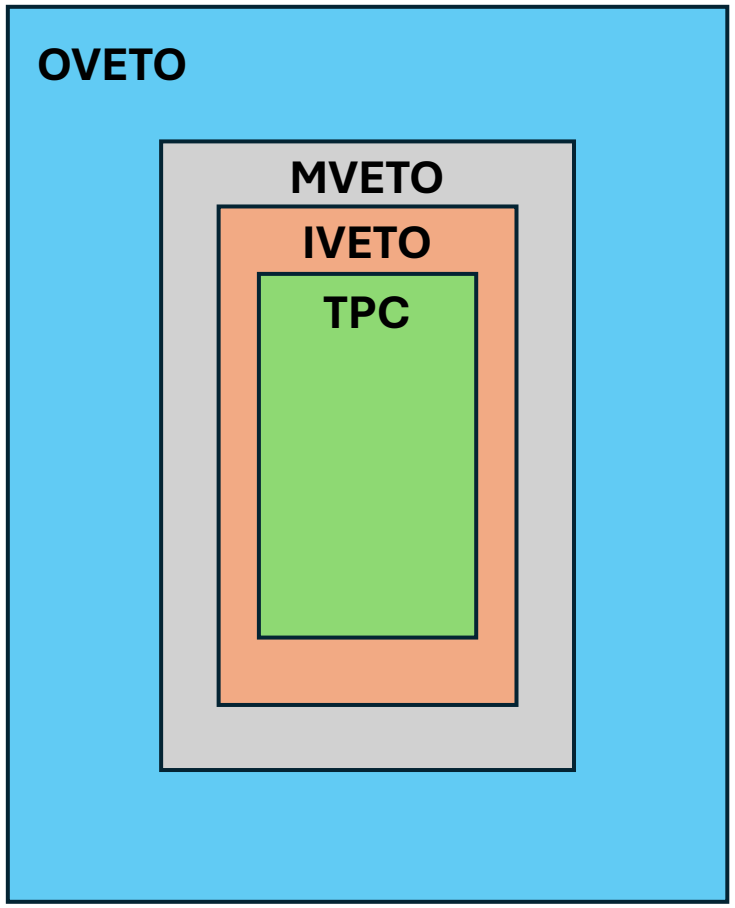
The PandaX-20T Detector

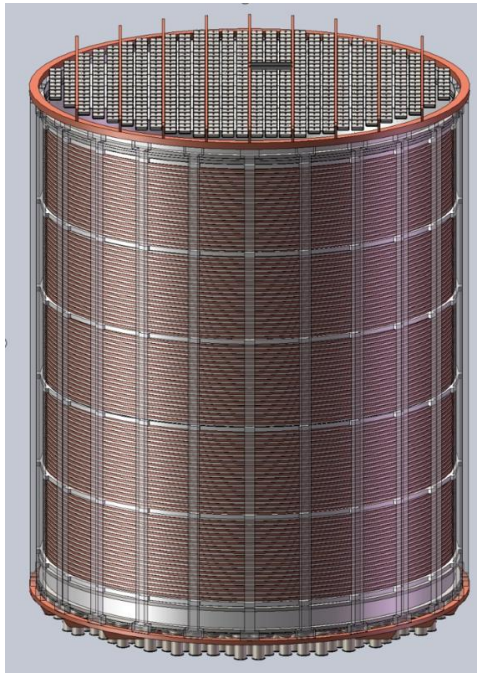
OVETO (under construction):
4 kton water Cherenkov detector
~4000 3-inch PMTs

MVETO (operational):
0.9 kton water Cherenkov detector
~265 8-inch PMTs

IVETO (R&D):
0.5 m thick liquid scintillator jacket
Wavelength shifting fibres

TPC (under construction)**:**
Dual-phase LXe TPC
17t LXe sensitive volume
~600 2-inch + ~400 3-inch PMTs





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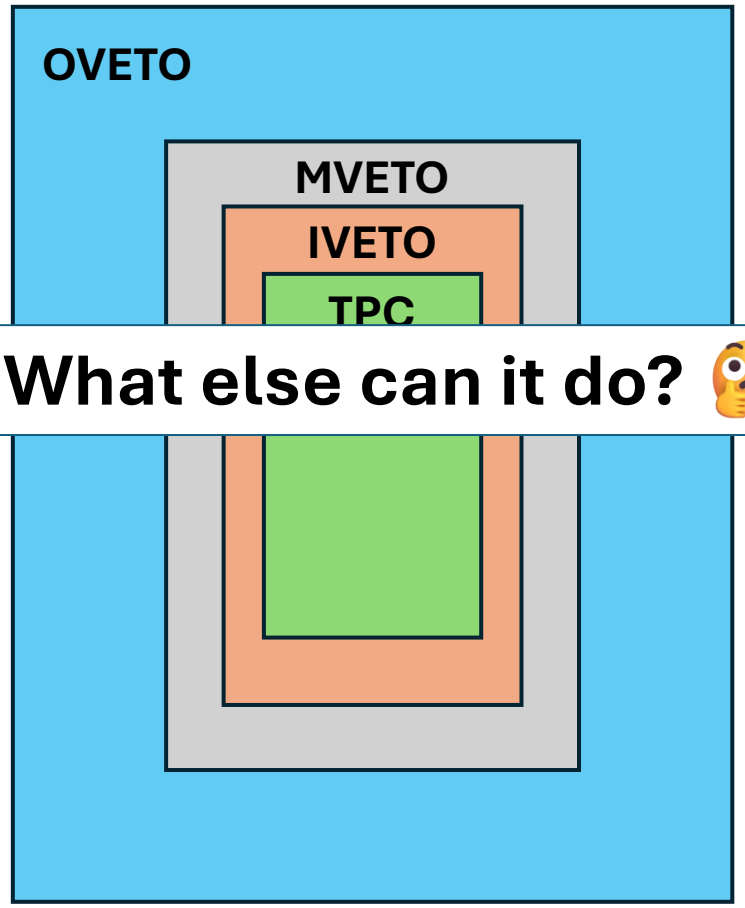
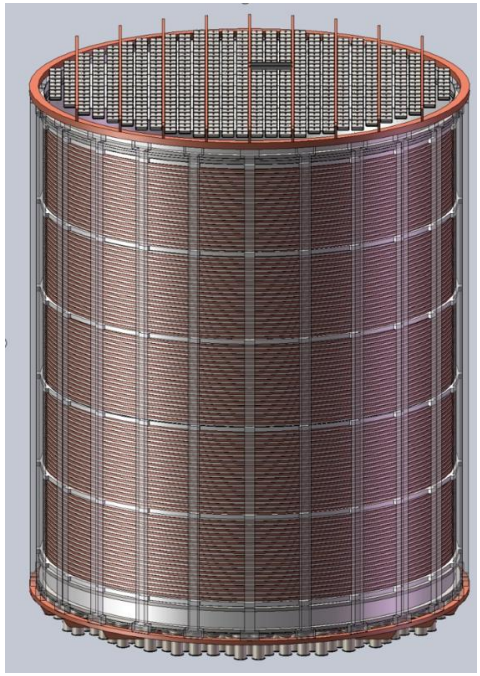
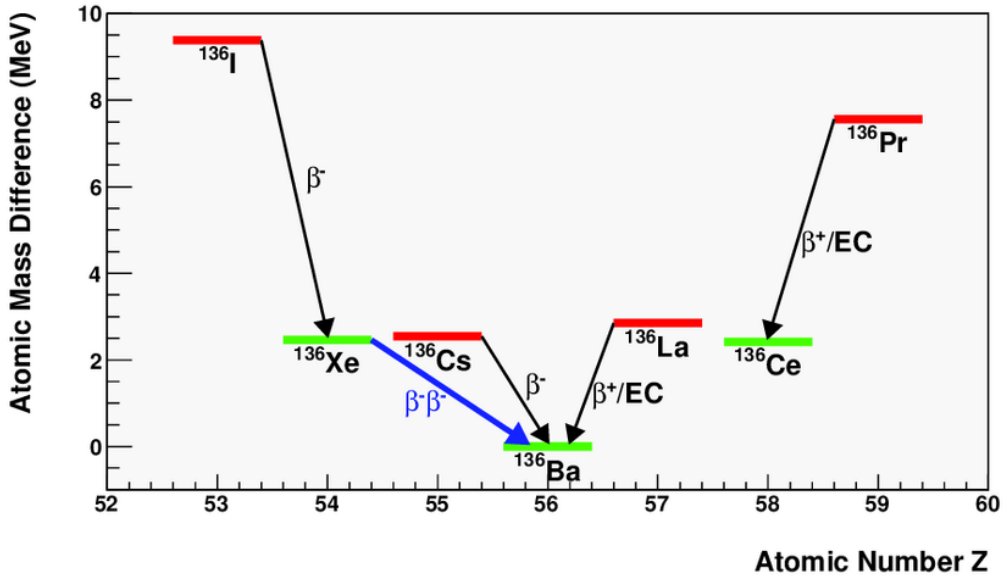


What else can it do? 🤔



Search for Xe $0\nu\beta\beta$



54 Xe	124	123.905 8920(19)	0.000 952(3)	18 Ar 36	35.967 545 105(28)	0.003 336(21)
	126	125.904 2983(38)	0.000 890(2)	38	37.962 732 11(21)	0.000 629(7)
	128	127.903 5310(11)	0.019 102(8)	40	39.962 383 1237(24)	0.996 035(25)
	129	128.904 780 8611(60)	0.264 006(82)			
	130	129.903 509 349(10)	0.040 710(13)			
	131	130.905 084 06(24)	0.212 324(30)			
	132	131.904 155 0856(56)	0.269 086(33)			
	134	133.905 394 66(90)	0.104 357(21)			
	136	135.907 214 484(11)	0.088 573(44)			

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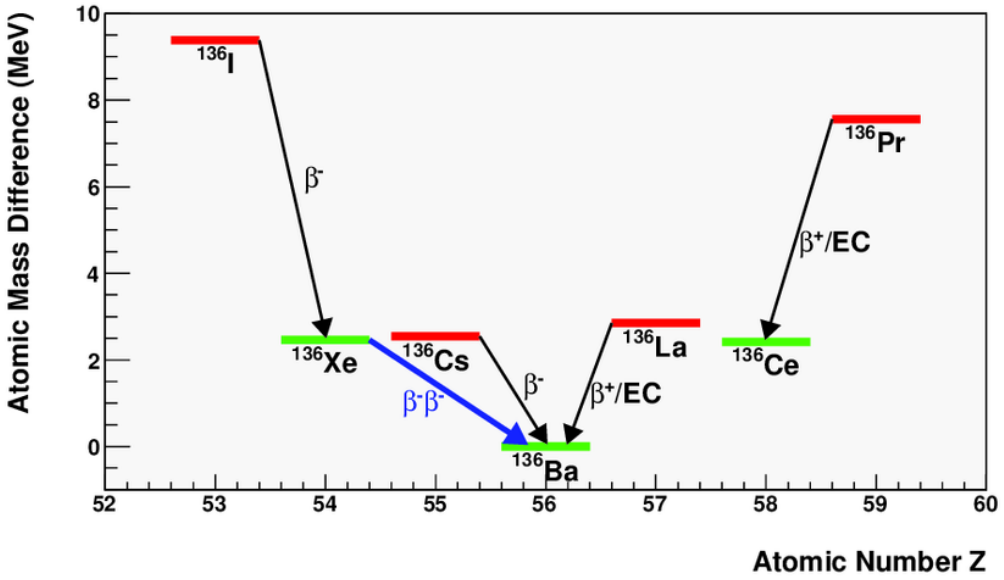

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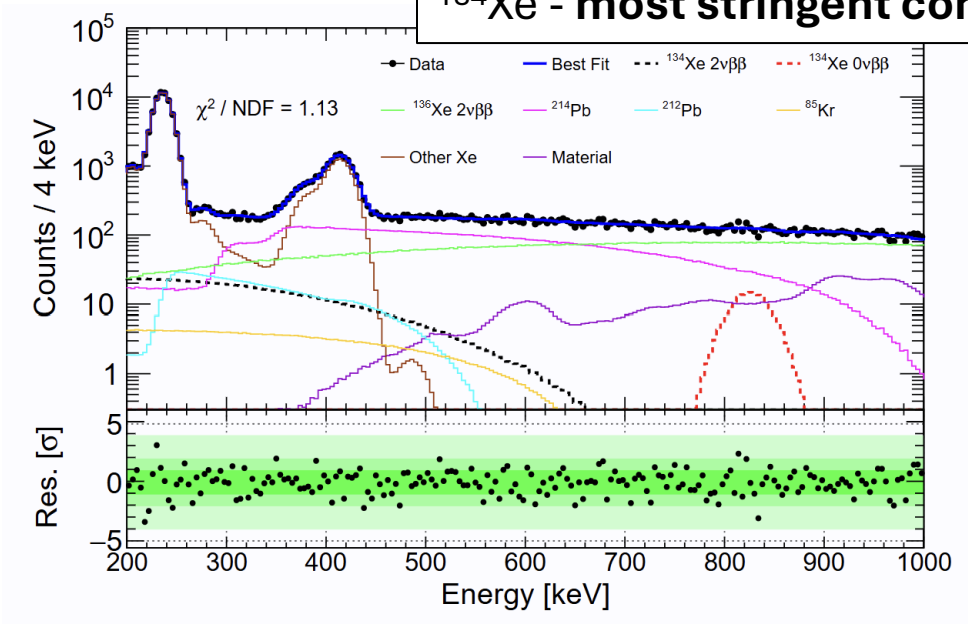
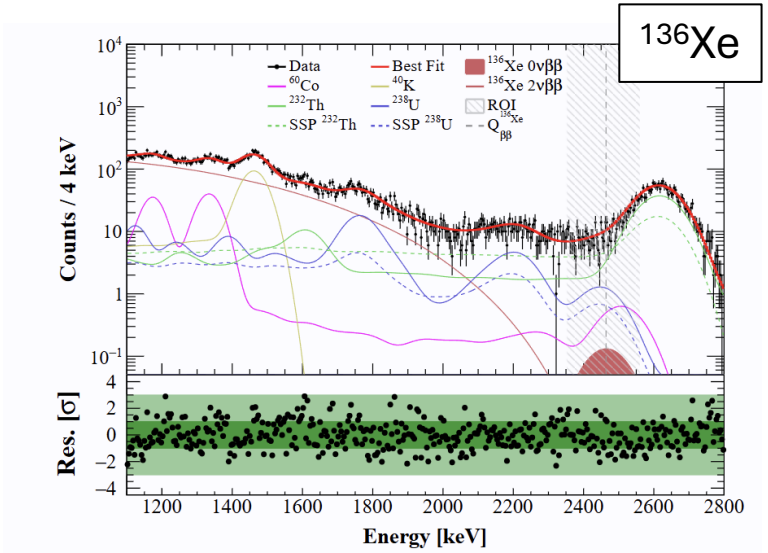
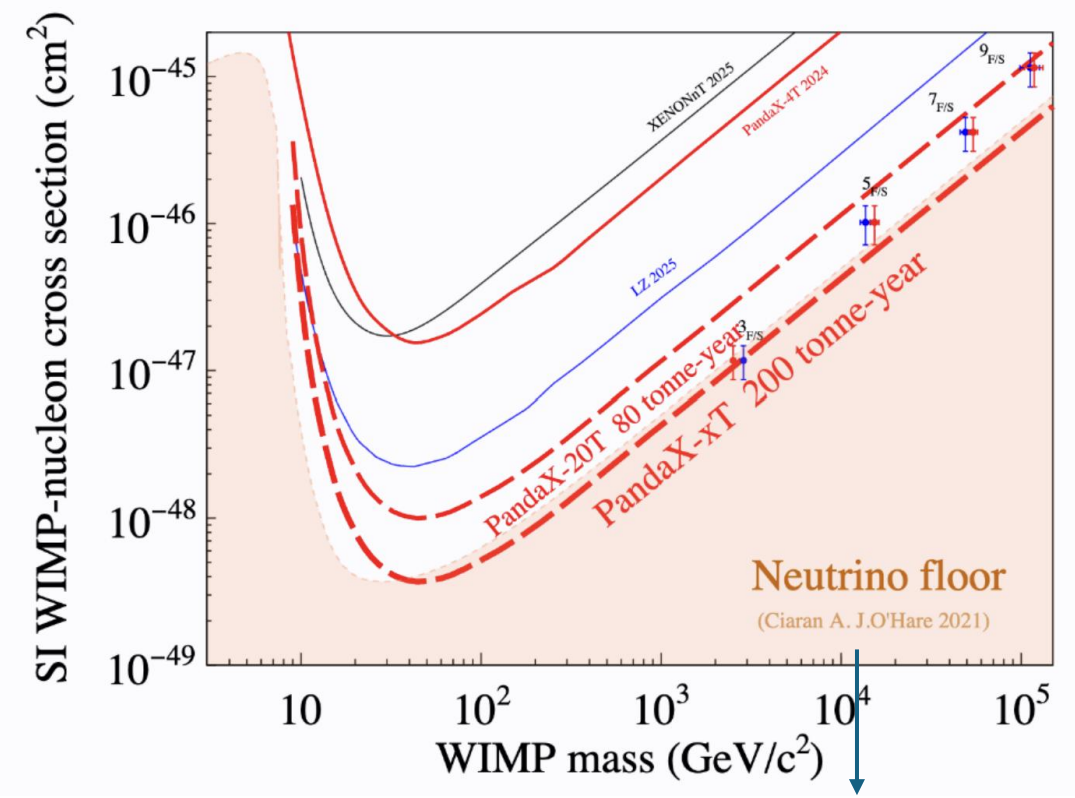
^{134}Xe - **most stringent constraints!**



^{136}Xe

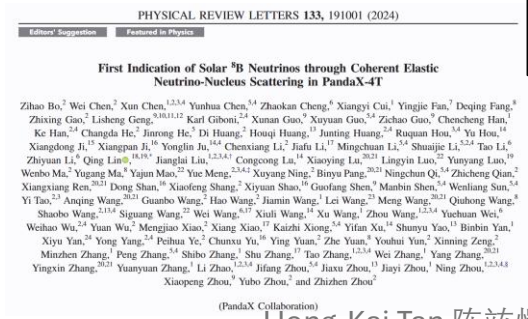


Solar Neutrinos



First glimpse of neutrino fog!
PRL 133.191001

with 2.2 tonne-years!



PHYSICAL REVIEW LETTERS 133, 191001 (2024)

Editors' Suggestion | Featured in Physics

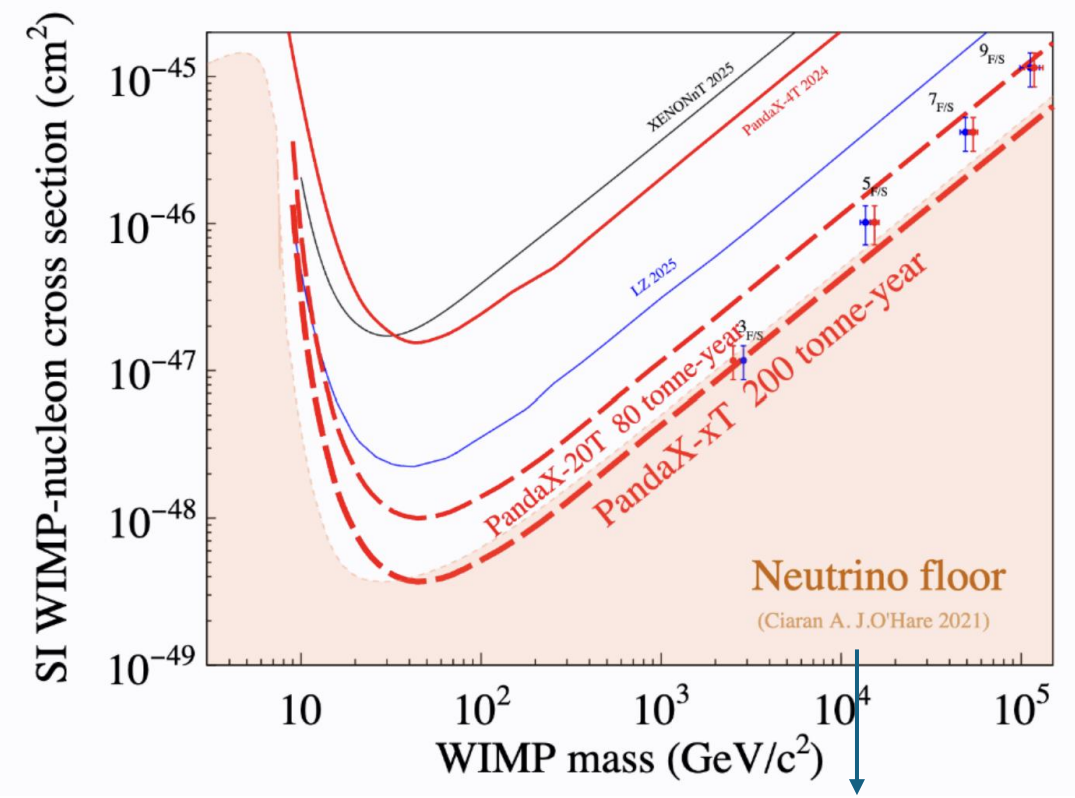
First Indication of Solar ^{8}B Neutrinos through Coherent Elastic Neutrino-Nucleus Scattering in PandaX-4T

Zihao Bo,[2] Wei Chen,[2] Xun Chen,[1,2,3,4] Yunhua Chen,[5,4] Zhaokan Cheng,[6] Xiangyi Cui,[1] Yingjie Fan,[7] Deqing Fang,[8] Zhixing Gao,[2] Lisheng Geng,[9,10,11,12] Karl Giboni,[2,4] Xunan Guo,[9] Xuyuan Guo,[5,4] Zichao Guo,[9] Chencheng Han,[1] Ke Han,[2,4] Changda He,[2] Jinrong He,[5] Di Huang,[2] Houqi Huang,[13] Junting Huang,[2,4] Ruquan Hou,[5,4] Yu Hou,[14] Xiangdong Ji,[15] Xiangpan Ji,[16] Yonglin Ju,[14,4] Chenxiang Li,[2] Jiafu Li,[17] Mingchuan Li,[5,4] Shuaijie Li,[5,2,4] Tao Li,[6] Zhiyuan Li,[6] Qing Lin,[18,19,*] Jianglai Liu,[1,2,3,4,†] Congcong Lu,[14] Xiaoying Lu,[20,21] Lingyin Luo,[22] Yunyang Luo,[19] Wenbo Ma,[2] Yugang Ma,[8] Yajun Mao,[22] Yue Meng,[2,3,4,‡] Xuyang Ning,[2] Binyu Pang,[20,21] Ningchun Qi,[5,4] Zhicheng Qian,[2] Xiangxiang Ren,[20,21] Dong Shan,[16] Xiaofeng Shang,[2] Xiyuan Shao,[16] Guofang Shen,[9] Manbin Shen,[5,4] Wenliang Sun,[5,4] Yi Tao,[2,3] Anqing Wang,[20,21] Guanbo Wang,[2] Hao Wang,[2] Jiamin Wang,[1] Lei Wang,[23] Meng Wang,[20,21] Qiuhong Wang,[8] Shaobo Wang,[2,13,4] Siguang Wang,[22] Wei Wang,[6,17] Xiuli Wang,[14] Xu Wang,[1] Zhou Wang,[1,2,3,4] Yuehuan Wei,[6] Weihao Wu,[2,4] Yuan Wu,[2] Mengjiao Xiao,[2] Xiang Xiao,[17] Kaizhi Xiong,[5,4] Yifan Xu,[14] Shunyu Yao,[13] Binbin Yan,[1] Xiyu Yan,[24] Yong Yang,[2,4] Peihua Ye,[2] Chunxu Yu,[16] Ying Yuan,[2] Zhe Yuan,[8] Youhui Yun,[2] Xinning Zeng,[2] Minzhen Zhang,[1] Peng Zhang,[5,4] Shibo Zhang,[1] Shu Zhang,[17] Tao Zhang,[1,2,3,4] Wei Zhang,[1] Yang Zhang,[20,21] Yingxin Zhang,[20,21] Yuanyuan Zhang,[1] Li Zhao,[1,2,3,4] Jifang Zhou,[5,4] Jiaxu Zhou,[13] Jiayi Zhou,[1] Ning Zhou,[1,2,3,4,§] Xiaopeng Zhou,[9] Yubo Zhou,[2] and Zhizhen Zhou[2]

(PandaX Collaboration)

Solar ^{8}B flux

Solar Neutrinos



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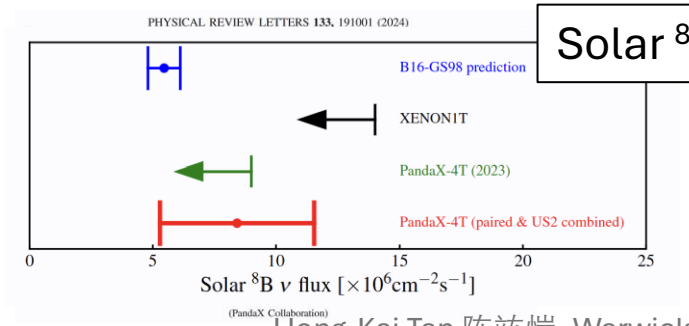

Solar ^{8}B flux

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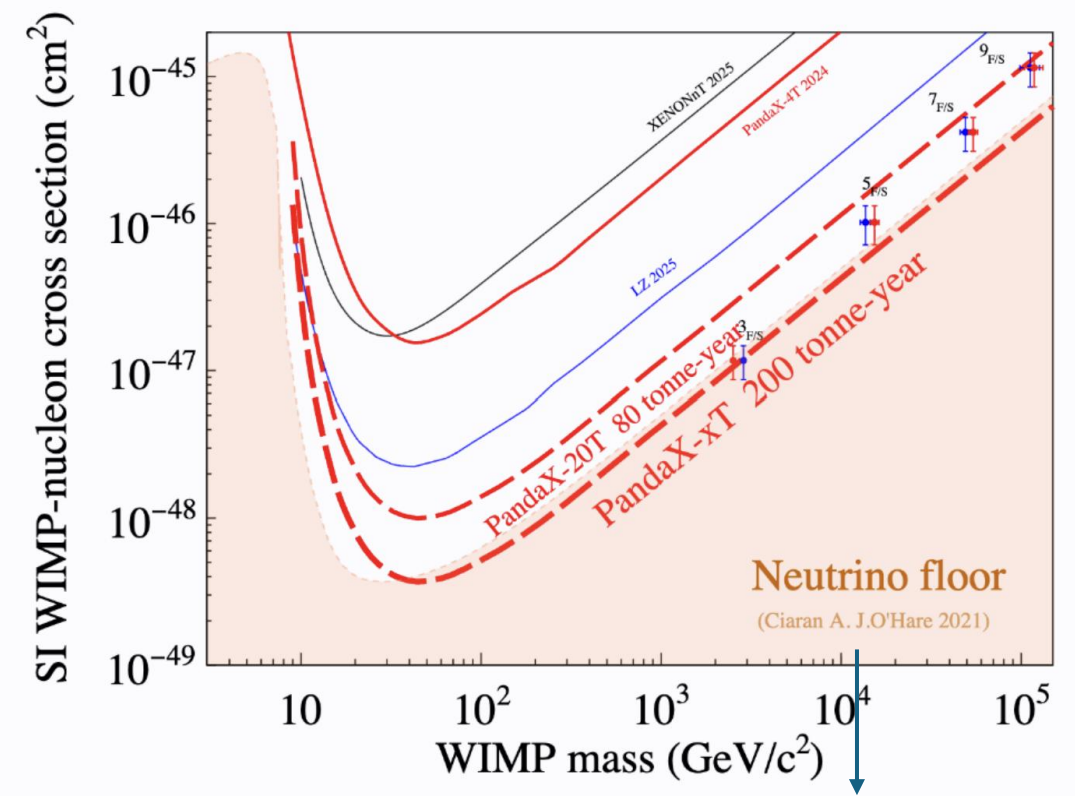

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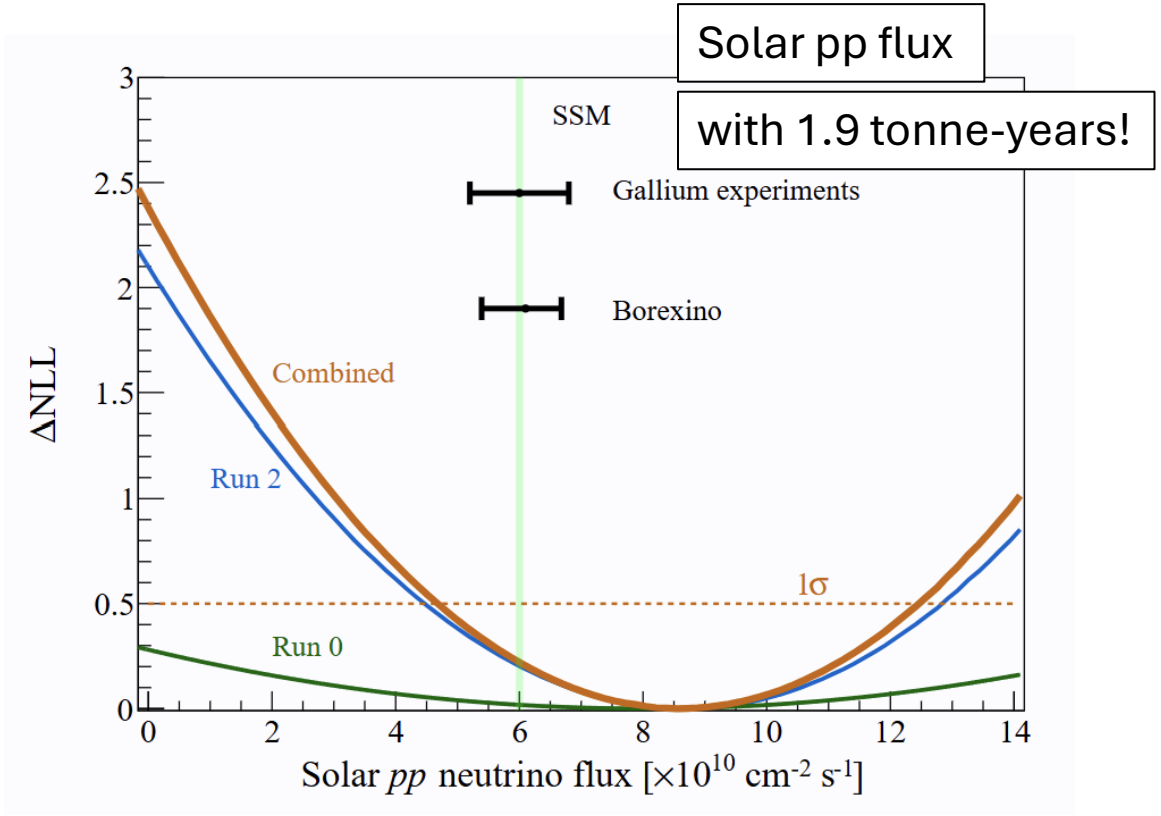
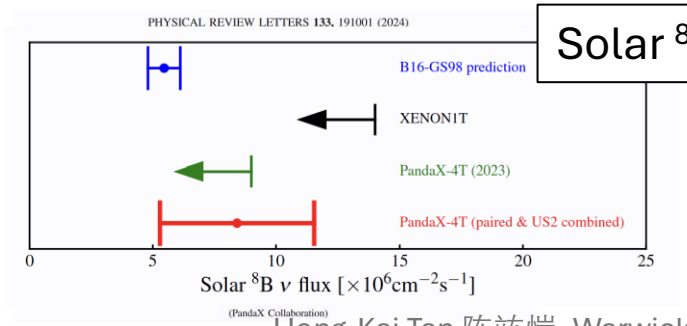
Solar pp flux

with 1.9 tonne-years!

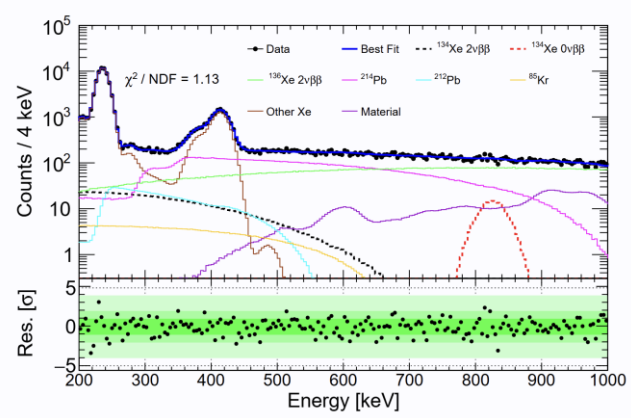




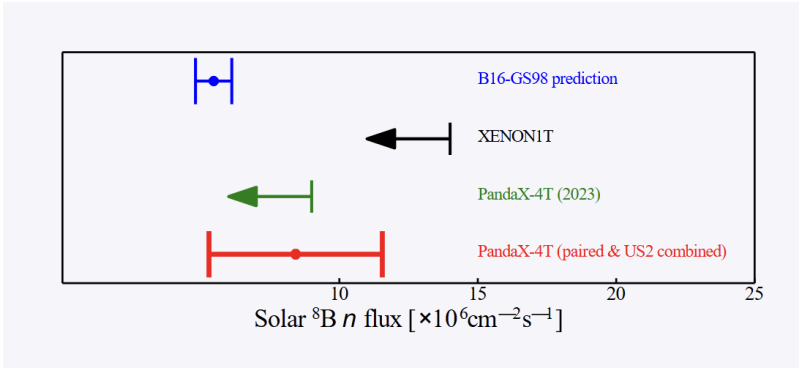
Solar ^{8}B flux

Need to know well to see through the **neutrino fog**...

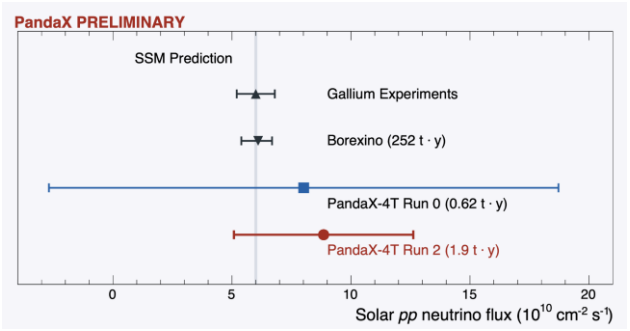
Plus more!



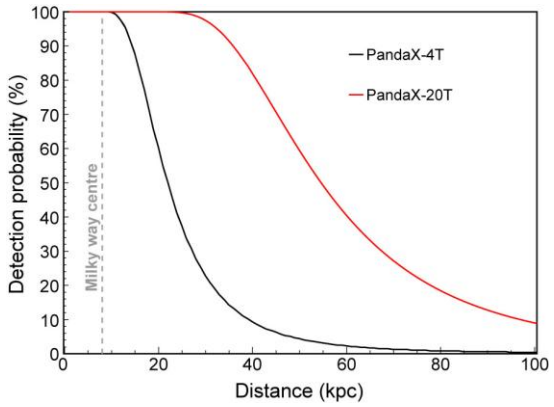
^{134}Xe $0\nu\beta\beta$ and $2\nu\beta\beta$ decay



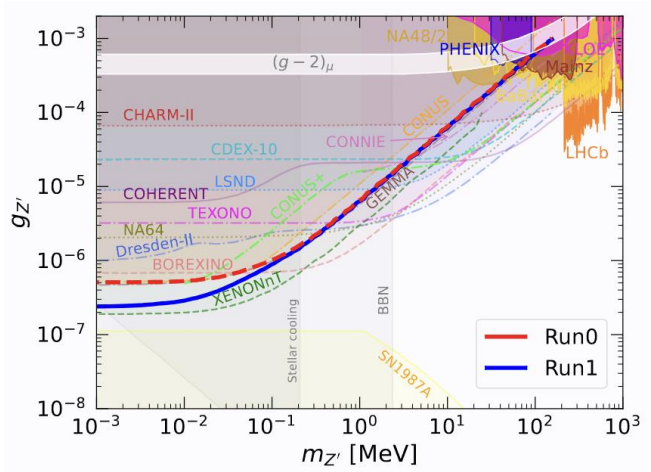
Solar ^{8}B CEνENs



Solar pp ER



SNEWS – Supernova Early Warning System



Extensions to the SM

Conclusion

- PandaX-xT 20T first stage scheduled for first physics run in **Jan 2028**
- Once completed, it will be the **largest DM direct detection experiment** in the world
- Breathtaking wealth of physics to be explored at PandaX
- Stay tuned!

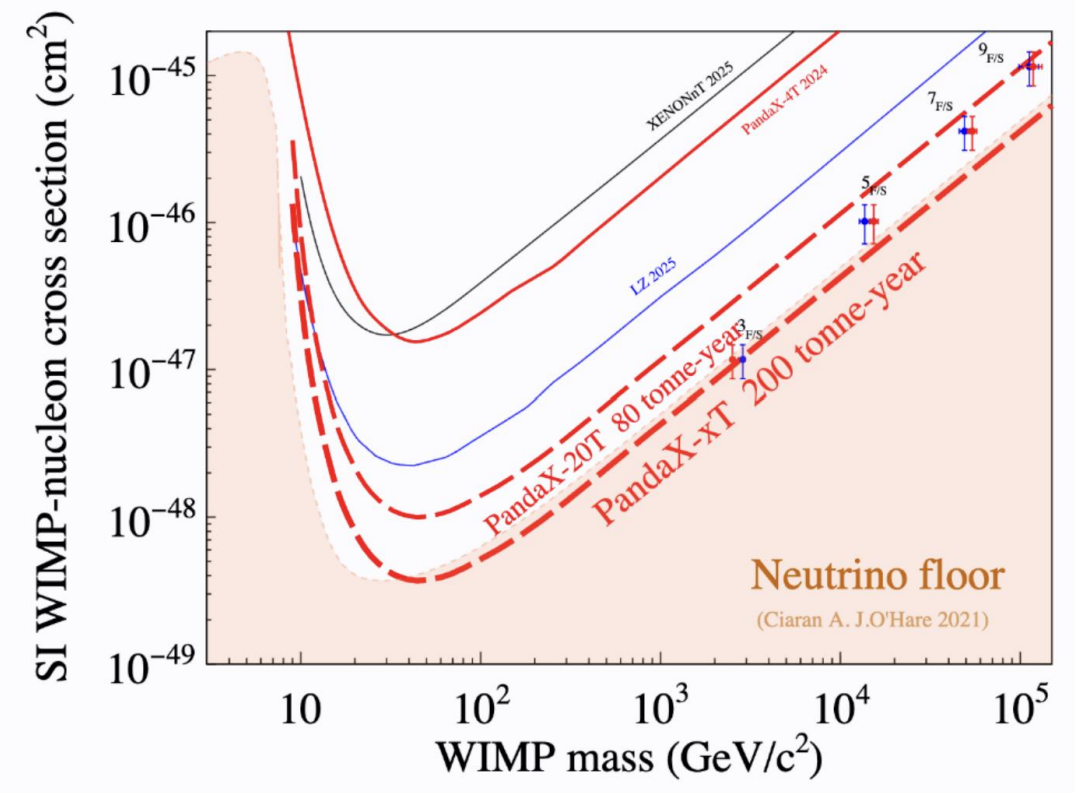
Open Meeting @ Huangshan, Feb 2026

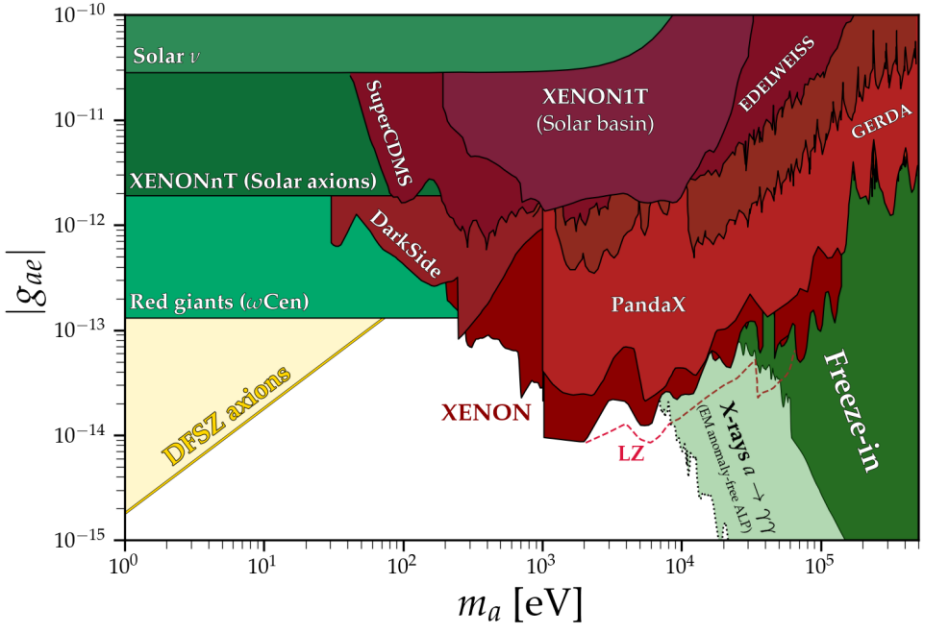
Lab tour @ CJPL, Feb 2026

Backup Slides

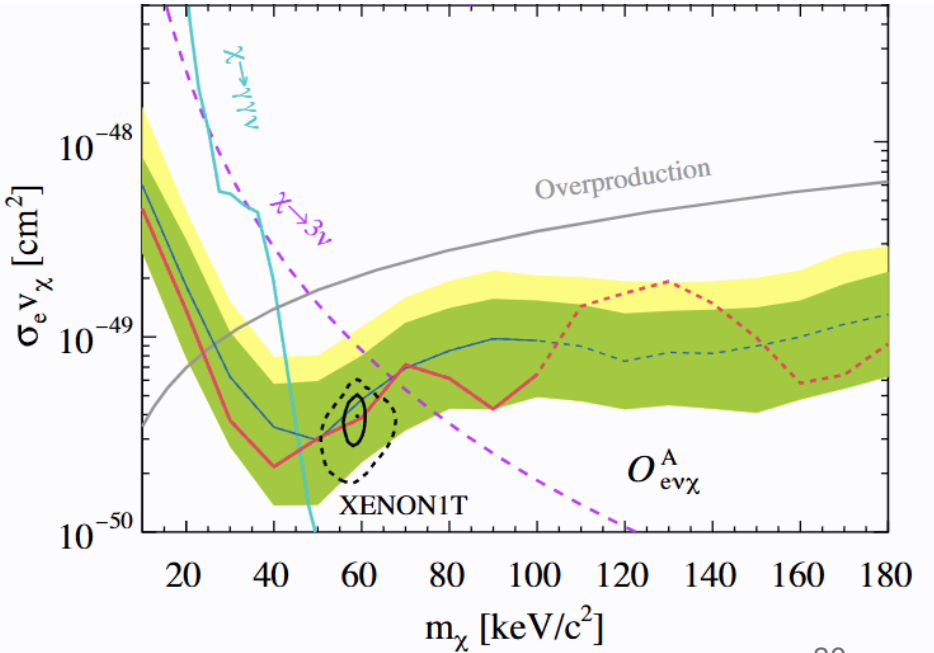
DM Sensitivity of PandaX-xT

WIMP models!





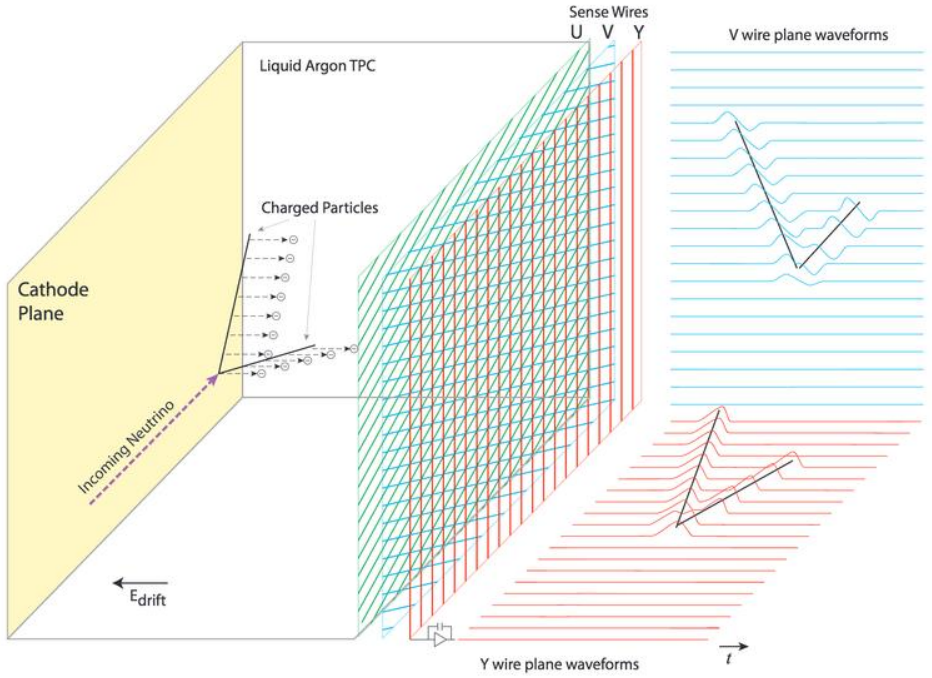
Axions and **ALP** models!



Light fermionic DM models!

Time Projection Chambers

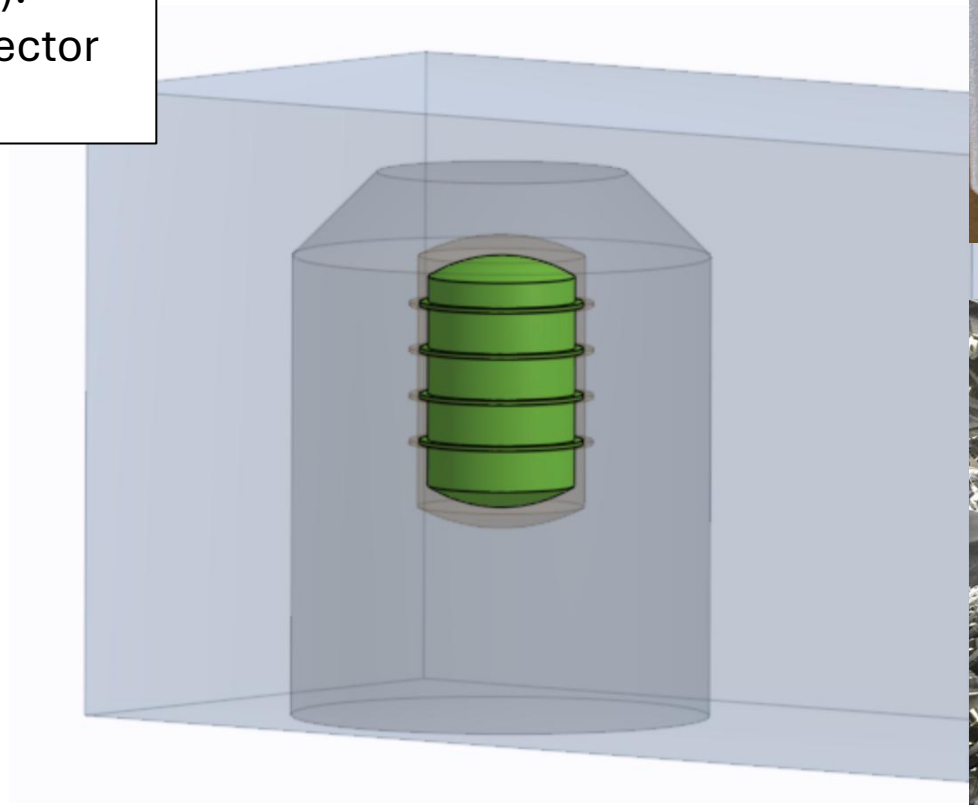
- TPCs operate on principle of reading out a 2D slice of the detector continuously
- Electrons from the primary ionisation are **drifted** onto the readout plane
- **Time** coordinate is then **projected** into the z-coordinate
  - **Full 3D track reconstruction!**
  - Drift velocity, diffusion, etc. – tracking properties of **TPC medium**



MicroBooNE Collaboration. The MicroBooNE Technical Design Report. Tech. rep. 2012.

The PandaX-20T Detector

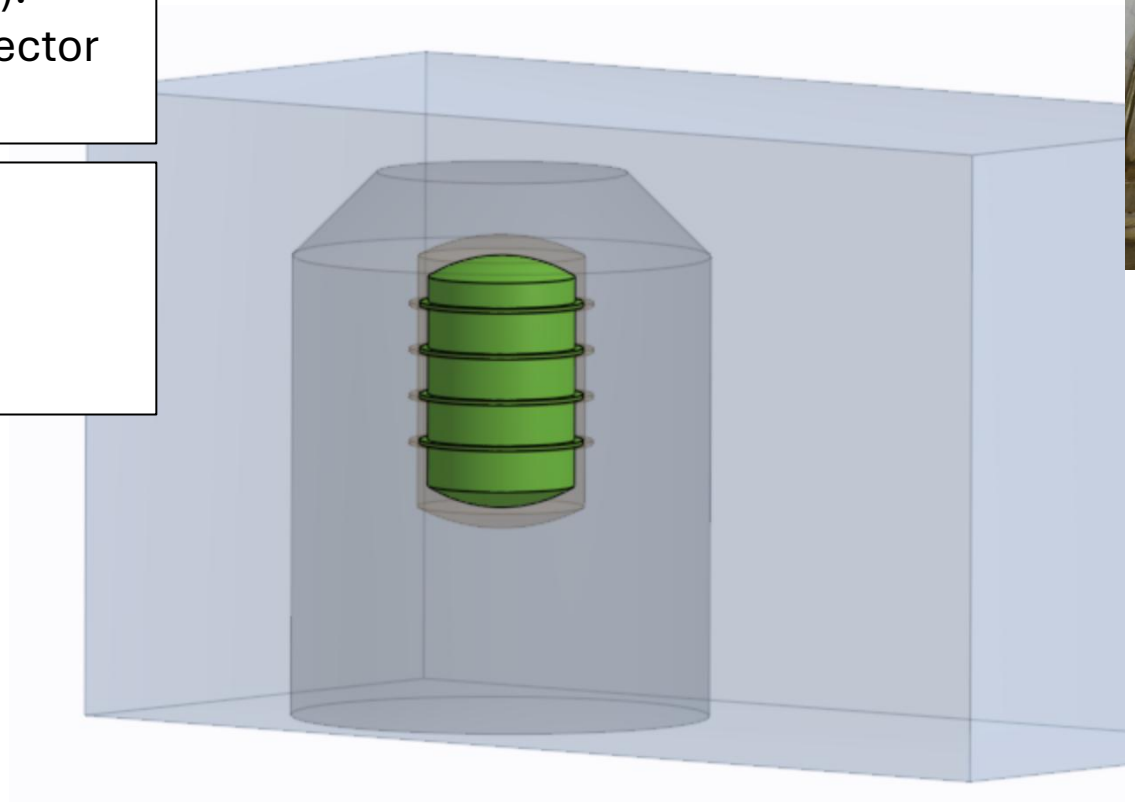
OVETO (under construction):
4 kton water Cherenkov detector
~4000 3-inch PMTs

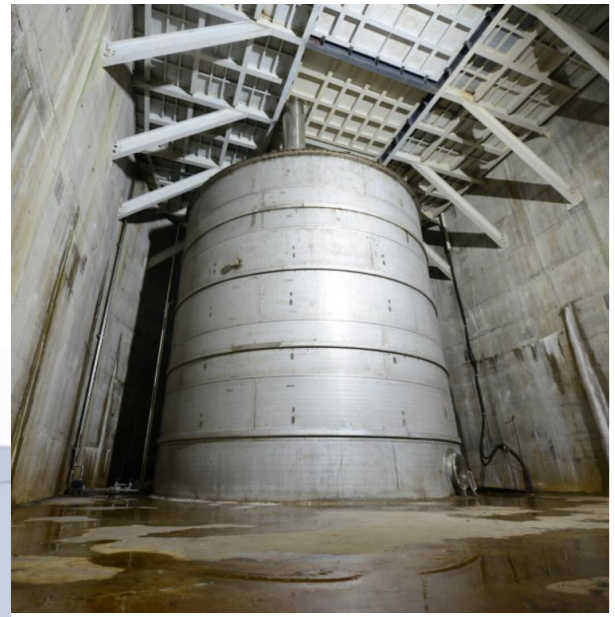


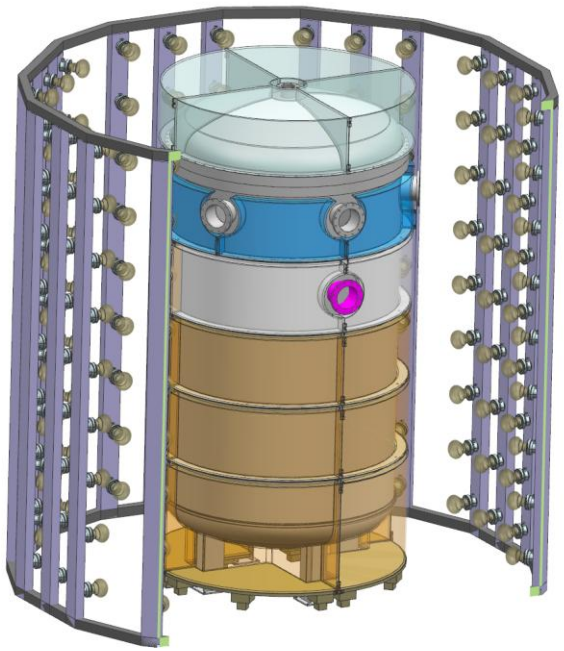
The PandaX-20T Detector

OVETO (under construction):
4 kton water Cherenkov detector
~4000 3-inch PMTs

MVETO (operational):
0.9 kton water Cherenkov detector
~265 8-inch PMTs





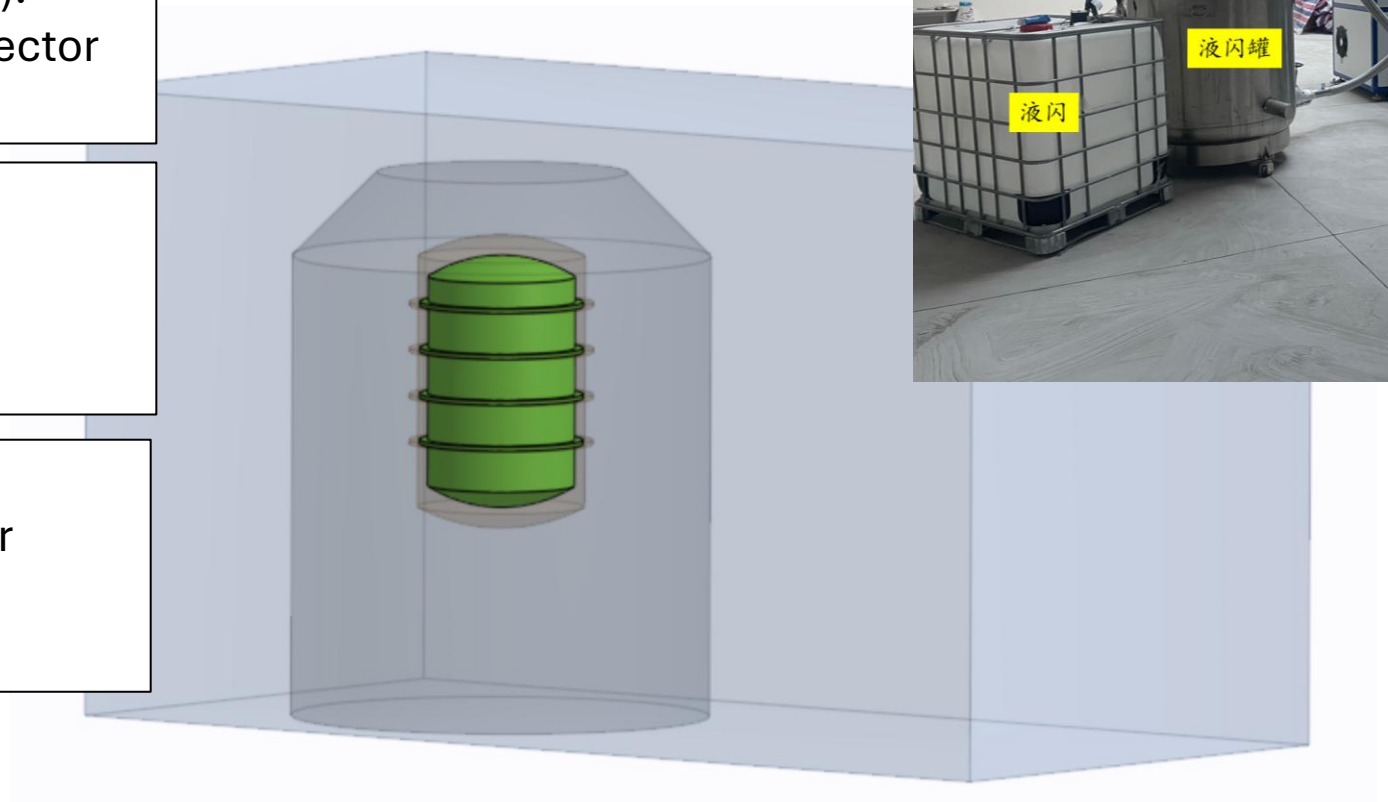


The PandaX-20T Detector

OVETO (under construction):
4 kton water Cherenkov detector
~4000 3-inch PMTs

MVETO (operational):
0.9 kton water Cherenkov detector
~265 8-inch PMTs

IVETO (R&D):
0.5 m thick liquid scintillator jacket
Wavelength shifting fibres



Prototype Testing

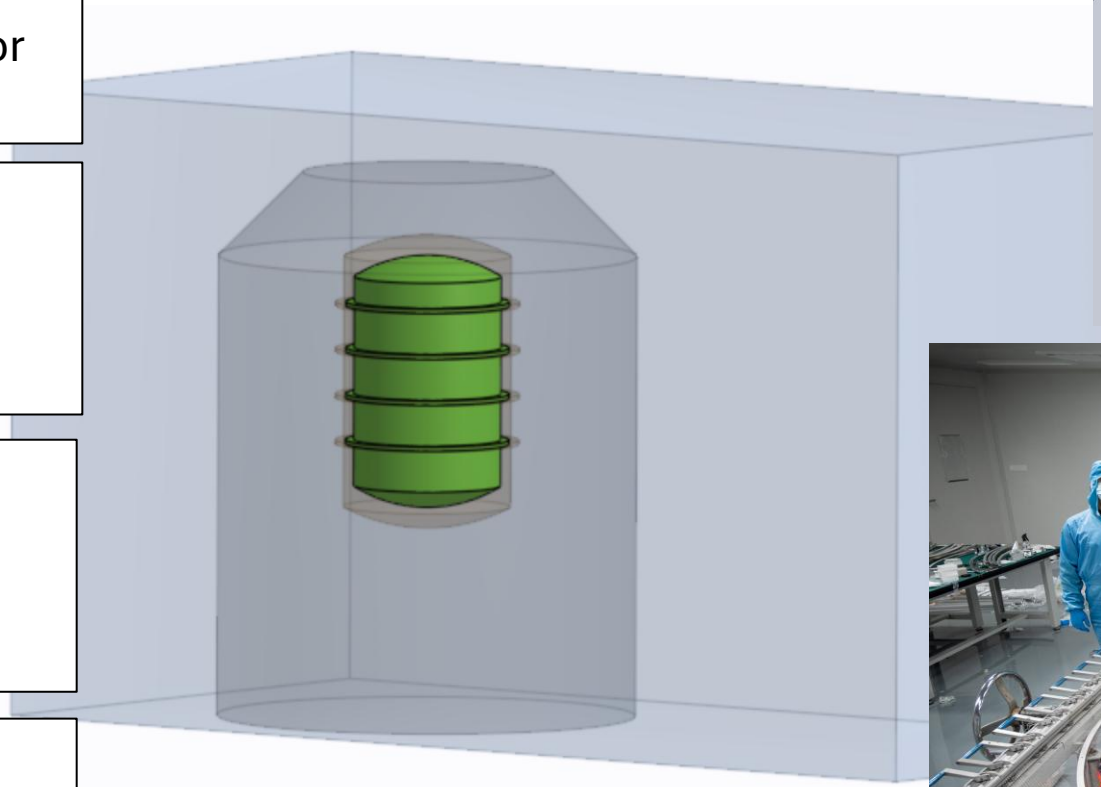
The PandaX-20T Detector

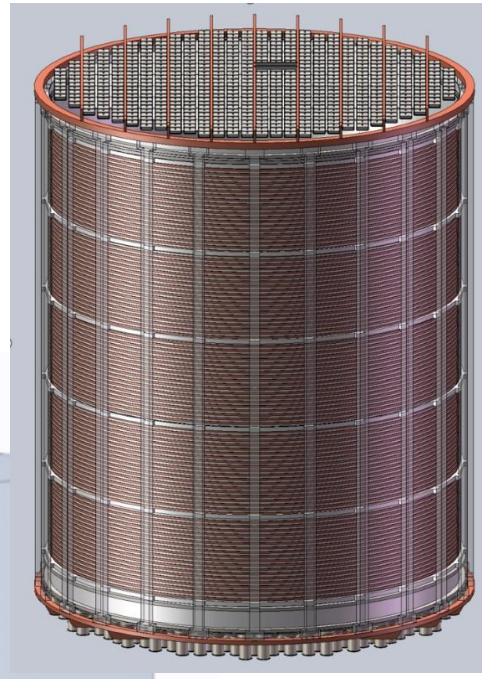
OVETO (under construction):
4 kton water Cherenkov detector
~4000 3-inch PMTs

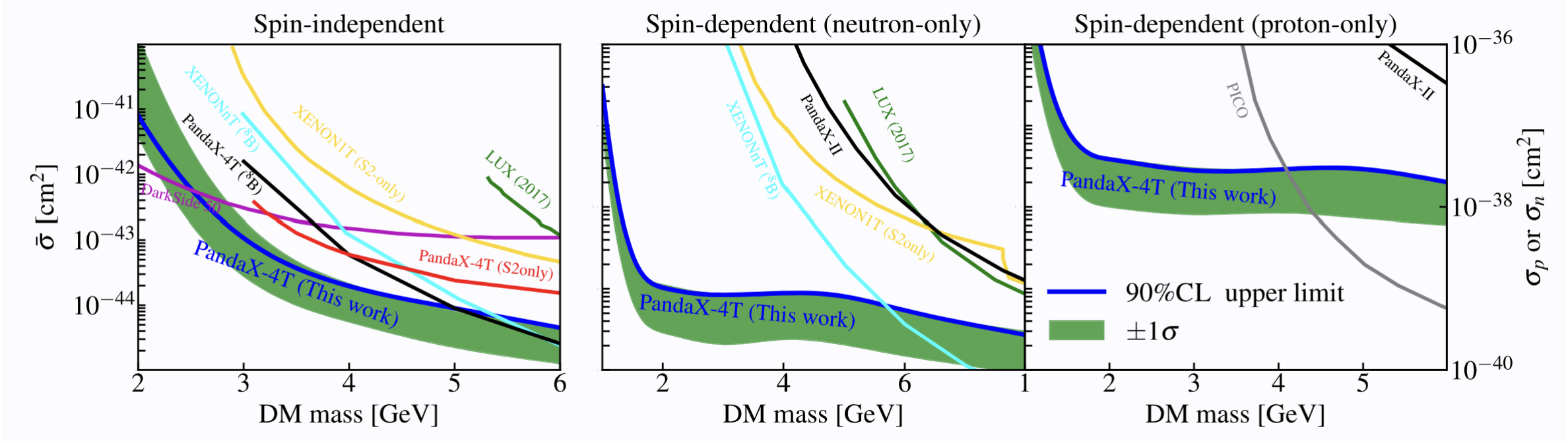
MVETO (operational):
0.9 kton water Cherenkov detector
~265 8-inch PMTs

IVETO (R&D):
0.5 m thick liquid scintillator jacket
Wavelength shifting fibres

TPC (under construction)**:**
Dual-phase LXe TPC
17t LXe sensitive volume
~600 2-inch + ~400 3-inch PMTs

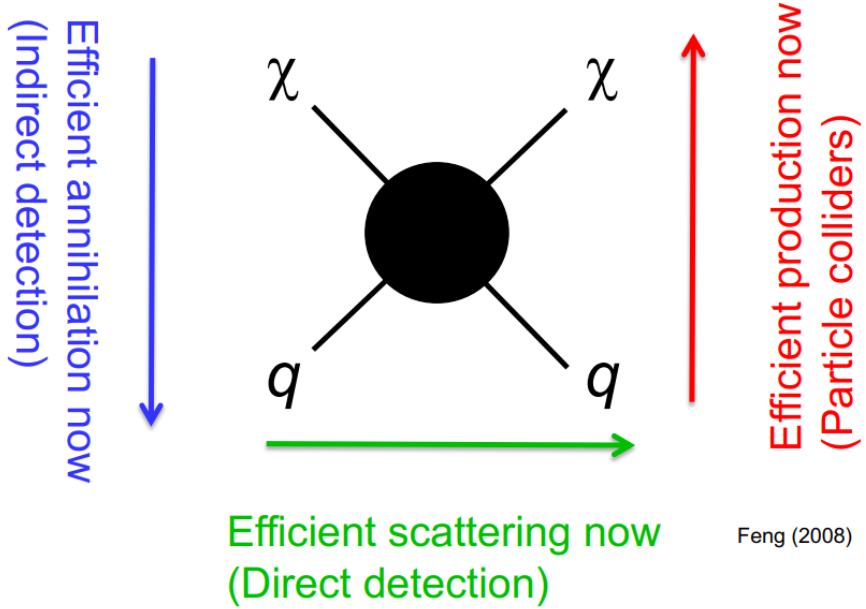





Spin-independent
Spin-dependent (neutron-only)
Spin-dependent (proton-only)
$\bar{\sigma}$ [cm^2]
σ_p or σ_n [cm^2]
DM mass [GeV]
DM mass [GeV]
DM mass [GeV]
XENONnT (^{8}B)
PandaX-4T (^{8}B)
XENON1T (S2-only)
LUX (2017)
DarkSide-50
PandaX-4T (S2only)
PandaX-4T (This work)
XENONnT (^{8}B)
PandaX-II
LUX (2017)
XENON1T (S2only)
PandaX-4T (This work)
PICO
PandaX-II
PandaX-4T (This work)
90%CL upper limit
$\pm 1\sigma$

Dark Matter

- Rotation curves, galactic cluster collisions, **CMB power spectrum**
- Weakly-interacting massive particles (**WIMPs**) - DM candidate
  - Theoretically motivated, relic density, detector/collider accessibility
  - **Direct detection:** main detection channel - WIMP/DM-nucleon interactions produce **nuclear recoil (NR)**
  - Also **novel electronic recoil signatures (NERS)**
- Generic interaction: $\mathcal{L}_{int} = g\,(J_\chi\,\hat{\mathcal{O}}\,J_N)$
  - $\hat{\mathcal{O}}$ - spin-dependent vs spin-independent interactions
    - Important! Xenon is sensitive to both, argon only spin-independent (at leading order)

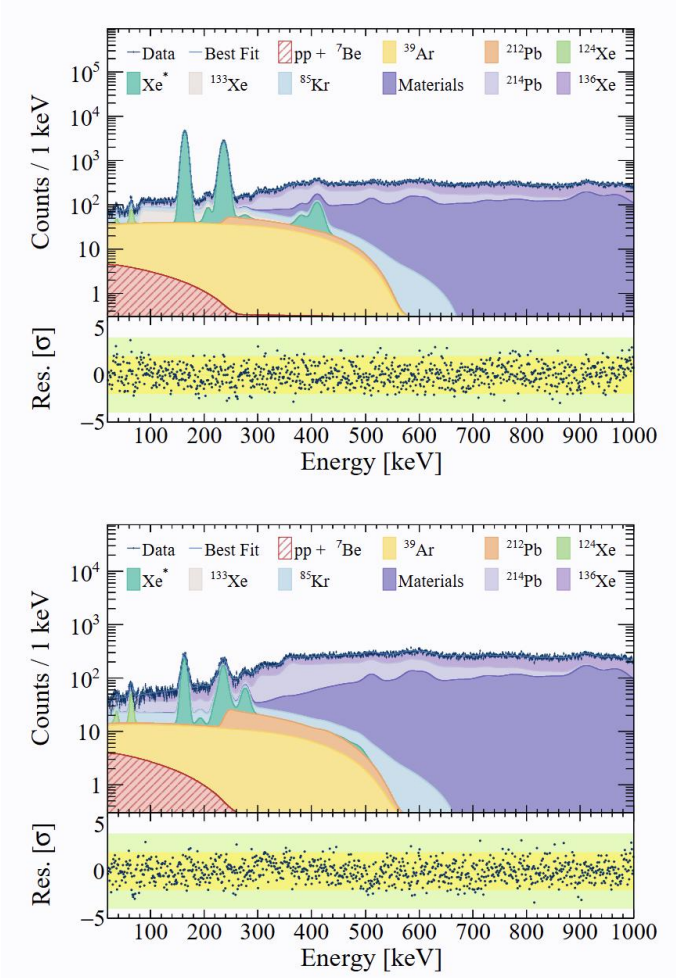


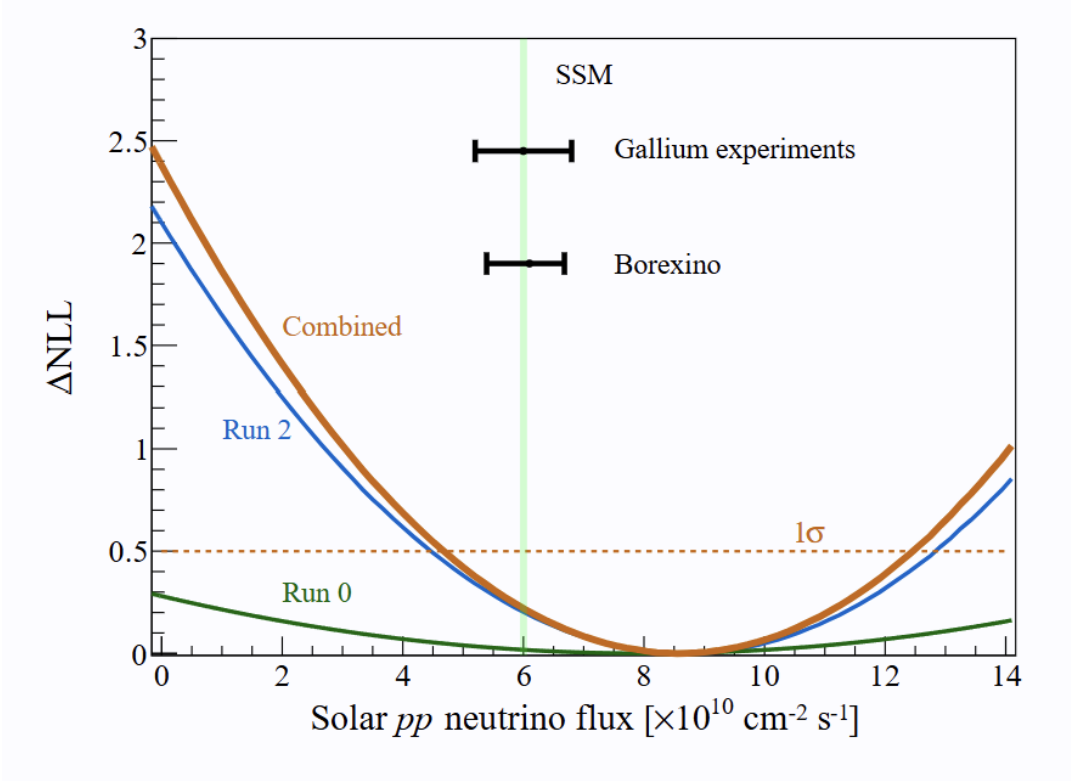
$$\mathcal{O}_1 = 1_\chi 1_N \qquad \mathcal{O}_7 = \vec{S}_N \cdot \vec{v}^{\perp}$$
$$\mathcal{O}_3 = i\,\vec{S}_N \cdot \left(\frac{\vec{q}}{m_N} \times \vec{v}^{\perp}\right) \qquad \mathcal{O}_8 = \vec{S}_\chi \cdot \vec{v}^{\perp}$$
$$\mathcal{O}_4 = \vec{S}_\chi \cdot \vec{S}_N \qquad \mathcal{O}_9 = i\,\vec{S}_\chi \cdot \left(\vec{S}_N \times \frac{\vec{q}}{m_N}\right)$$
$$\mathcal{O}_5 = i\,\vec{S}_\chi \cdot \left(\frac{\vec{q}}{m_N} \times \vec{v}^{\perp}\right) \qquad \mathcal{O}_{10} = i\,\vec{S}_N \cdot \frac{\vec{q}}{m_N}$$
$$\mathcal{O}_6 = \left(\vec{S}_\chi \cdot \frac{\vec{q}}{m_N}\right)\left(\vec{S}_N \cdot \frac{\vec{q}}{m_N}\right) \qquad \mathcal{O}_{11} = i\,\vec{S}_\chi \cdot \frac{\vec{q}}{m_N}$$

$$\frac{dR}{dE_{NR}} = \frac{\rho}{2m_\chi \mu_N^2} \int dv \frac{f(v)}{v} \left(\sigma_N^{SI} F_{SI}^2 + \sigma_N^{SD} F_{SD}^2\right)$$

local DM density; E-independent cross-sections; reduced mass; velocity, from observation + simulation; E-dependent form factors

Solar pp Neutrino Flux





Supernova Physics