Neutrino Fog&Floor at CJLP

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Yingjie Fan et al 2025 Chinese Phys. C 49 103001；2503.22155

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Content

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Motivation

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First Glimpses of the Neutrino Fog

PHYSICAL REVIEW LETTERS **133,** 191001 (2024)

Editors' Suggestion | Featured in Physics

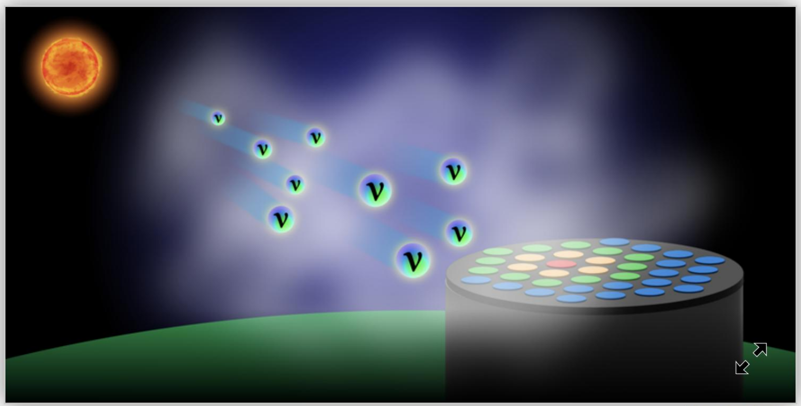
First Indication of Solar ^{8}B Neutrinos through Coherent Elastic Neutrino-Nucleus Scattering in PandaX-4T

PHYSICAL REVIEW LETTERS **133,** 191002 (2024)

Editors' Suggestion | Featured in Physics

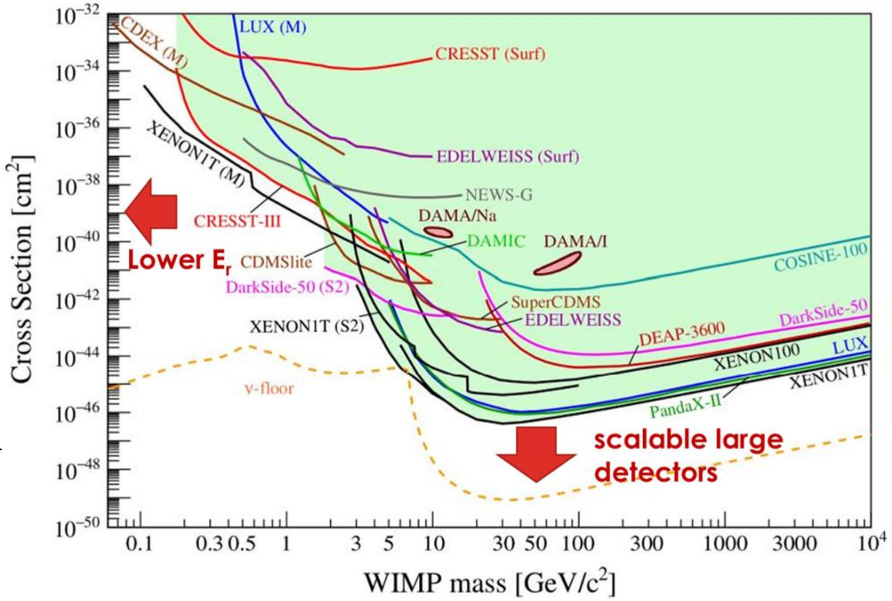
First Indication of Solar ^{8}B Neutrinos via Coherent Elastic Neutrino-Nucleus Scattering with XENONnT

DM direct detection reaching the Neutrino "Fog" at ^{8}B Solar neutrino regi



APS/Alan Stonebraker

Dark matter detectors have now seen indications of a neutrino background—or "fog"—coming from the Sun.



Neutrino Fog and Floor

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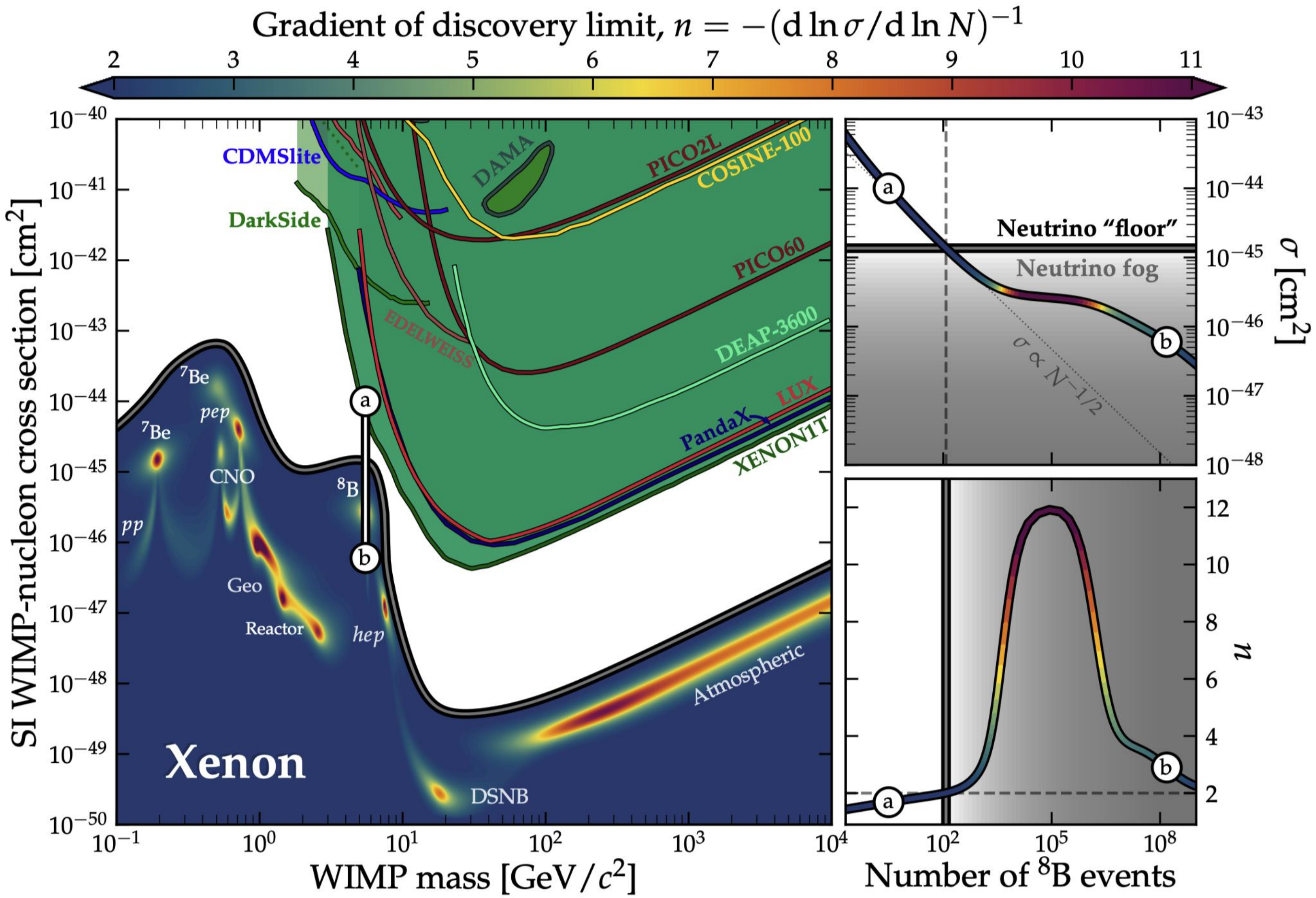
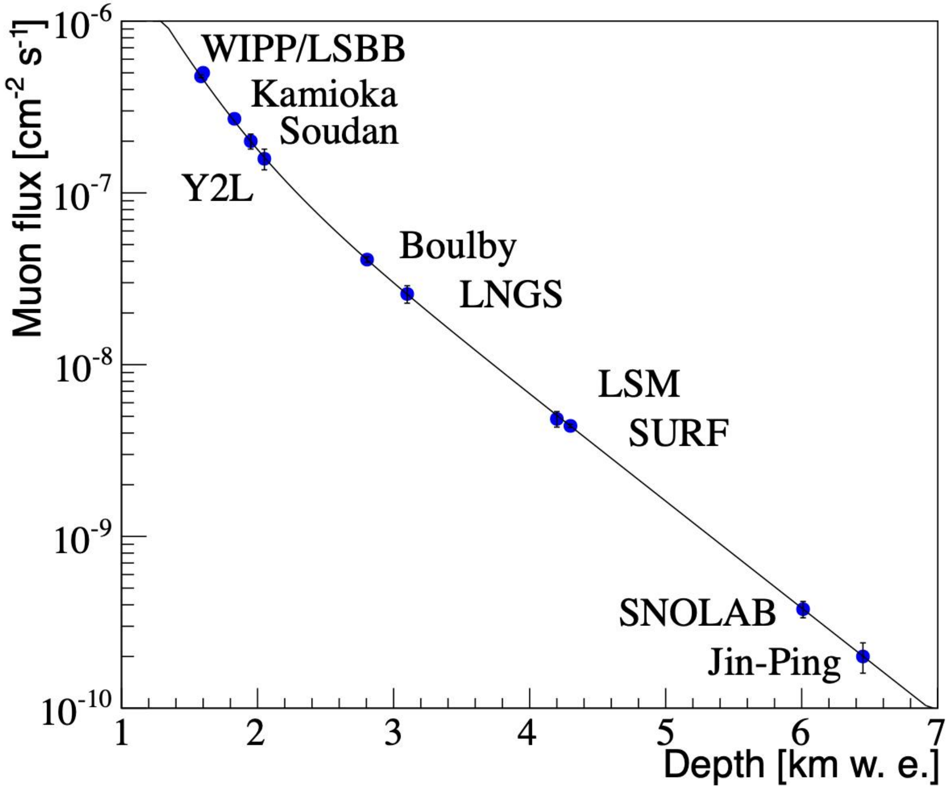
- **Neutrino fog**: DM signal becomes difficult to distinguish due to its spectral similarity with the neutrino background and the presence of **flux systematic uncertainties**

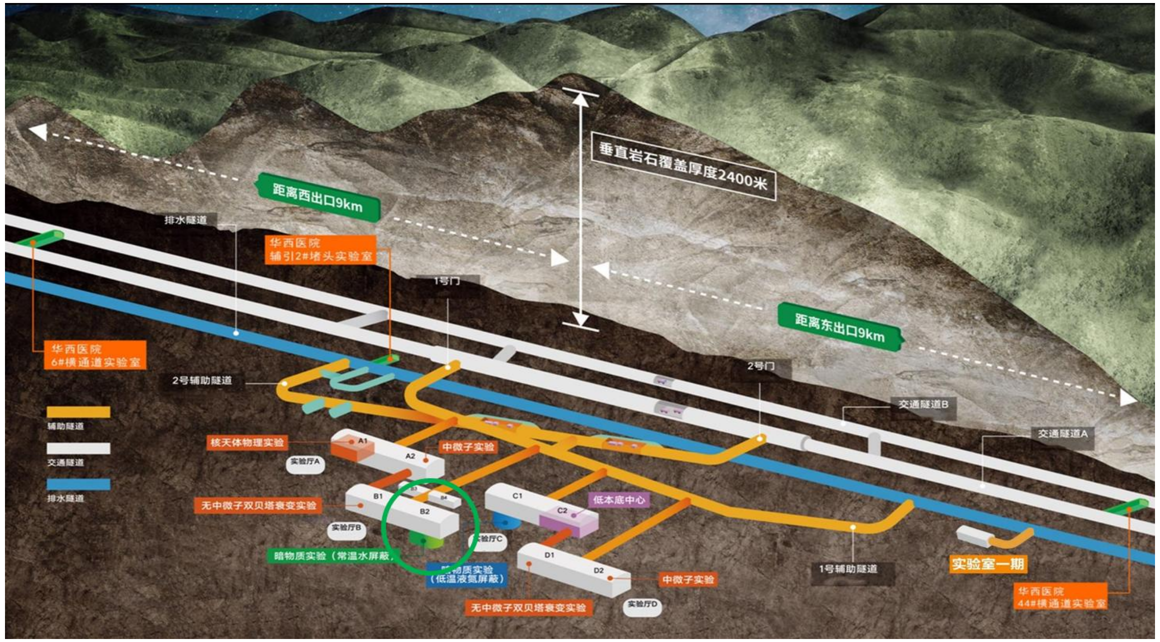
- **Neutrino floor**: interpreted as the boundary of the neutrino fog in a statistically way



O'Hare, Phys.Rev.Lett. 127 (2021) 25, 251802

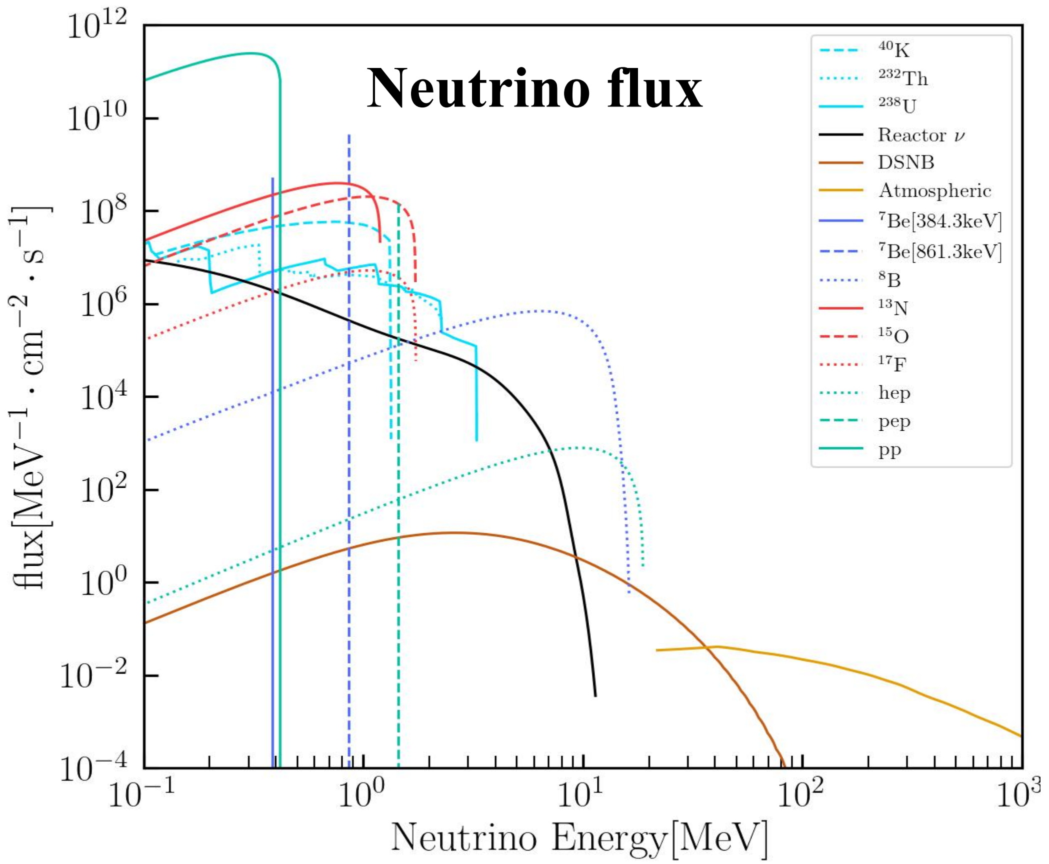
- Located in the tunnel under the Jinping Montain
- Water-equivalent depth: 6400 m.
- The world's deepest

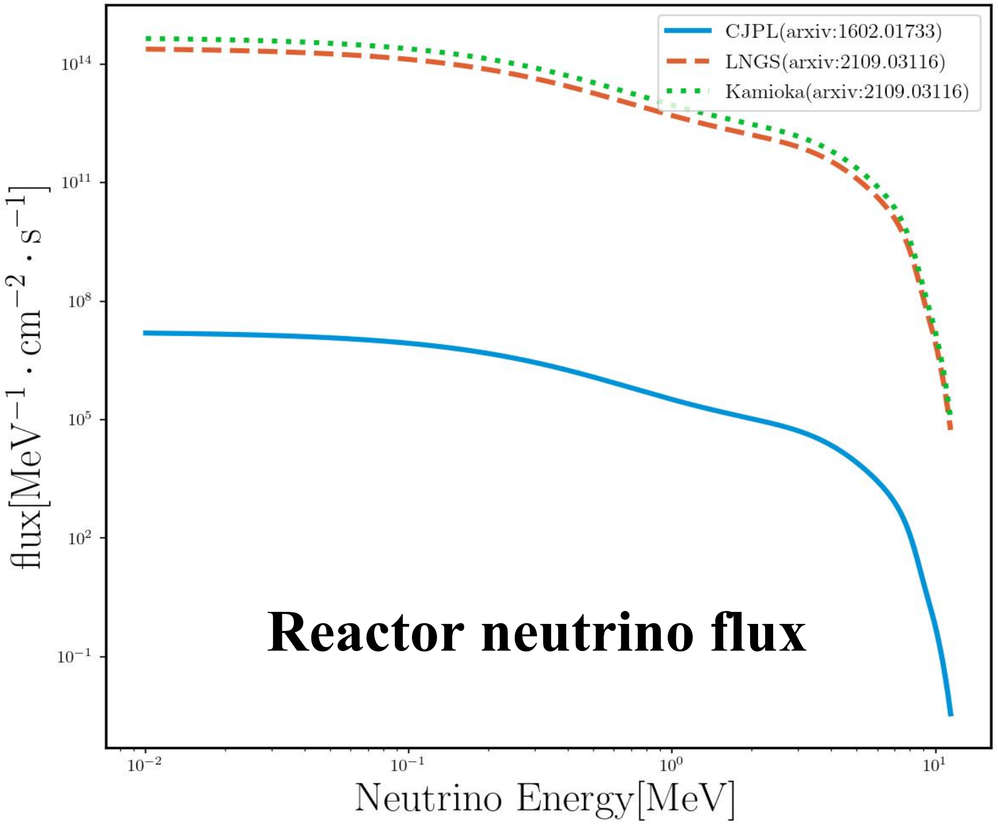




Undagoitia, Rauch, J.Phys.G 43 (2016) 1, 013001, arXiv:1509.08767

Neutrino Fluxes @ CJPL

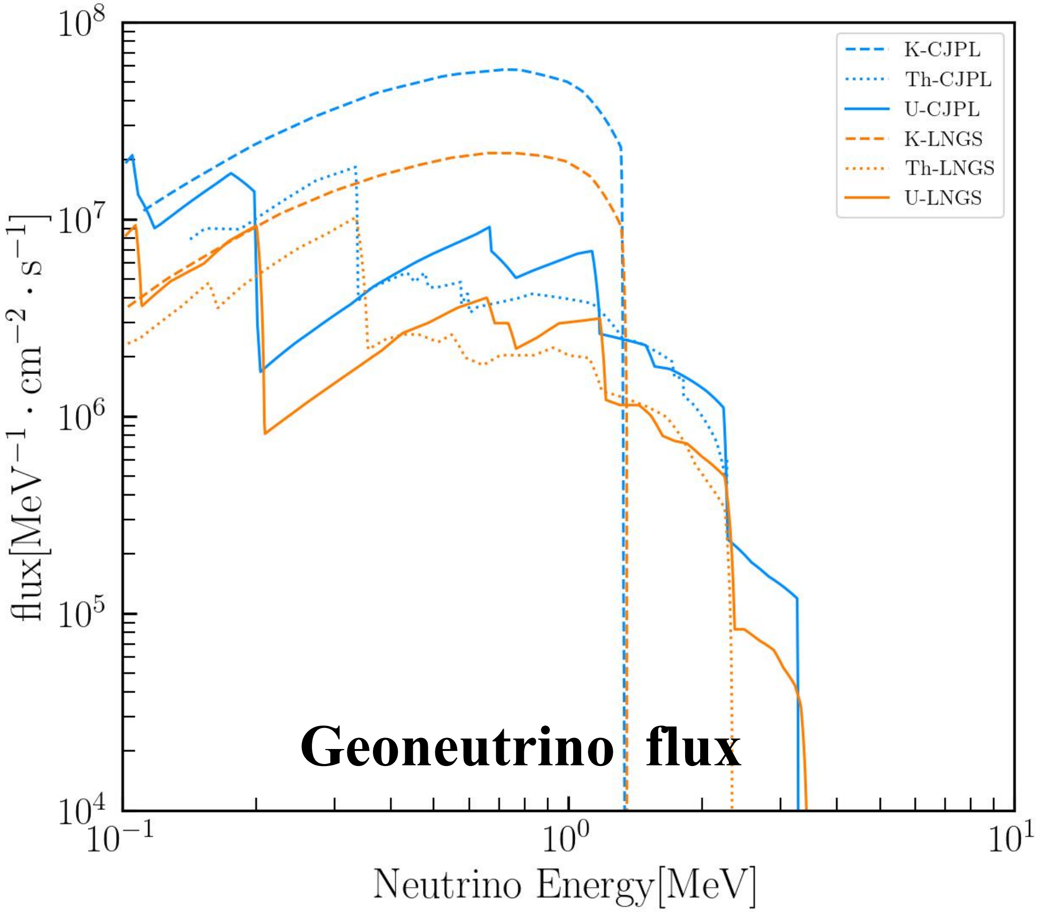


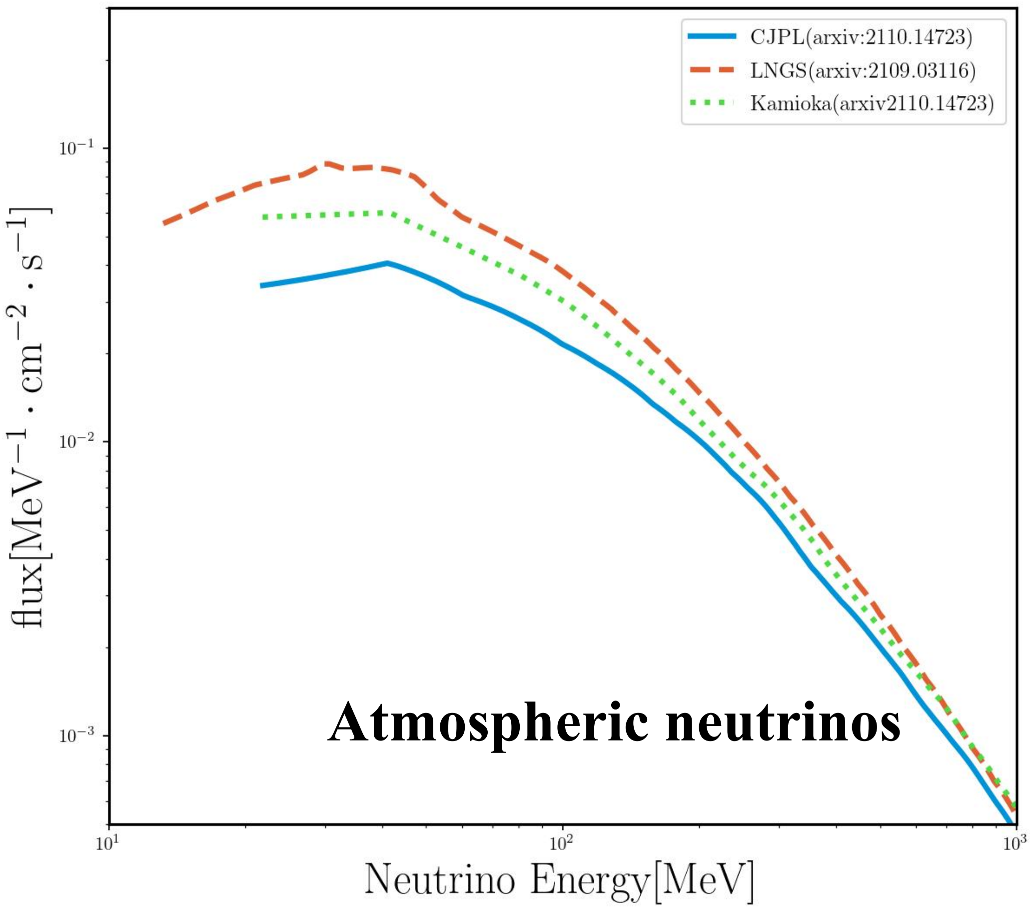


- **Barcelona 2016 calculation**
- **^{8}B neutrino with 2% uncertainty**
- **^{7}Be neutrinos with 6% uncertainties.**

- **International Atomic Energy Agency**
- **Jinping Collaboration, Chin.Phys.C 41 (2017) 2, 023002**

Neutrino Fluxes @ CJPL





- **uranium (^{238}U), thorium (^{232}Th), and potassium (^{40}K)**
- **CJPL is situated near the Himalayan Mountains**
- **the crust is the thickest**

- **CJPL is situated in a geomagnetic low-latitude region**
- **Geomagnetic latitude: 18.06°N)**
- **CORSIKA simulations, arXiv:2110.14723**
- **Placing 25% theoretical uncertainty**

Neutrino Fog and Floor: calculation

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- **Discovery limits:** the cross section σ_d at which a given experiment has a 90% probability to detect a WIMP with a scattering cross section $\sigma > \sigma_d$ at ≥3 sigma.

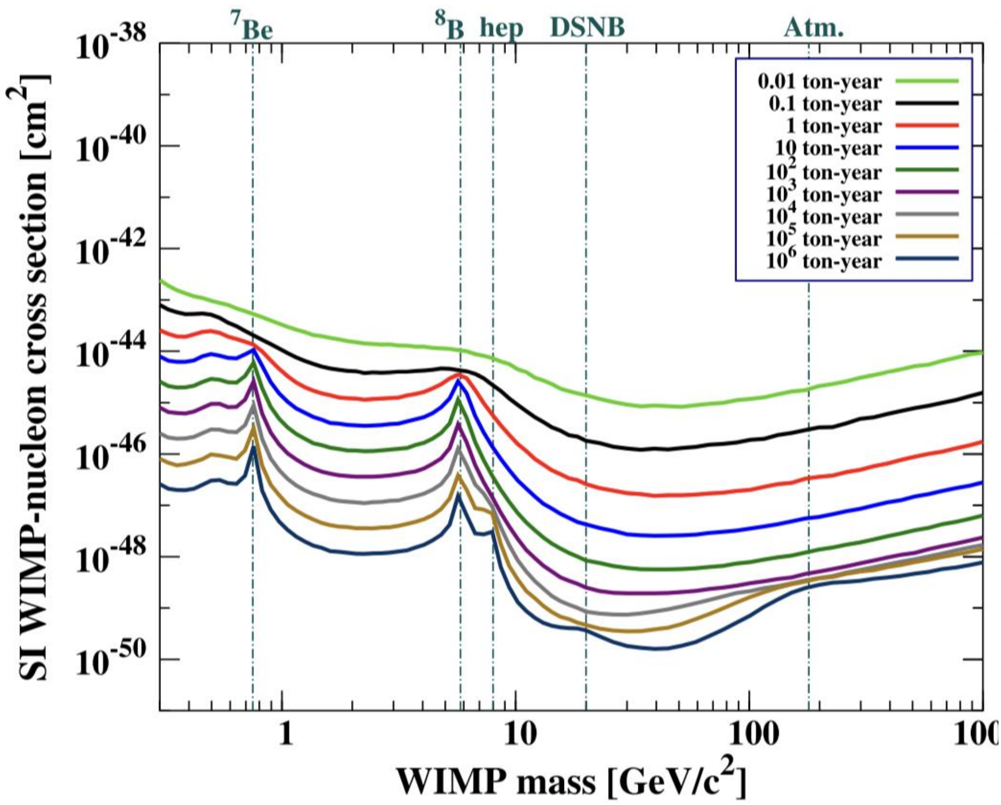
- **Likelihood function**:

$$\mathscr{L}(\sigma,\Phi)=\prod_{i=1}^{N_{\text{bins}}}\mathscr{P}\left[N_i^{\text{obs}}|N_i^{\chi}+\sum_{j=1}^{n_\nu}N_i^{\nu}(\Phi_j)\right]\prod_{j=1}^{n_\nu}\mathscr{G}(\Phi_j)$$

- **Test Statistic:** background-only & signal+background model

$$q_0=\begin{cases}-2\ln\left[\dfrac{\mathscr{L}\left(0,\hat{\hat{\Phi}}|\mathcal{M}_{\sigma=0}\right)}{\mathscr{L}\left(\hat{\sigma},\hat{\Phi}|\mathcal{M}\right)}\right] & \hat{\sigma}>0,\\ 0 & \hat{\sigma}\le 0.\end{cases}$$

- $q_0 \geq 9$, σ is the **Discovery Limit** with $\sqrt{q_0}$ =3 sigmas significance



Ruppin, Billard, etal., 1408.3581

Key point: Discovery limits evolution with Exposure

J. Billard et al., Phys.Rev.D 89 (2014) 2, 023524

(1) Background free, $N < 1$, $\sigma \propto N^{-1}$

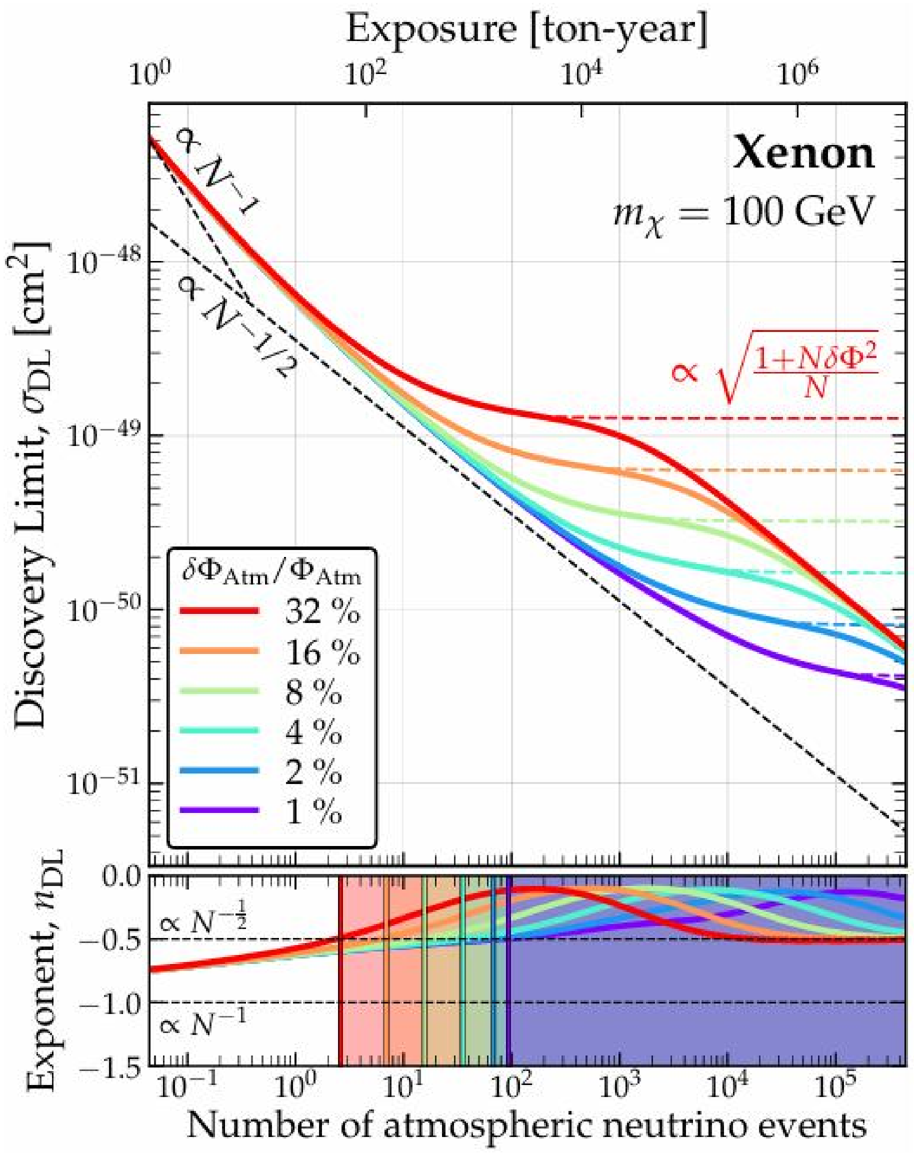
(2) Poisson statistic regime, statistical fluctuation dominant, $N>1$, $\sigma \propto N^{-1/2}$

(3) Saturation regime: systematic uncertainties dominant, discovery limit plateaus $\sigma \propto \sqrt{(1+N\delta\Phi^2)/N}$

- **Neutrino fog's opacity:**

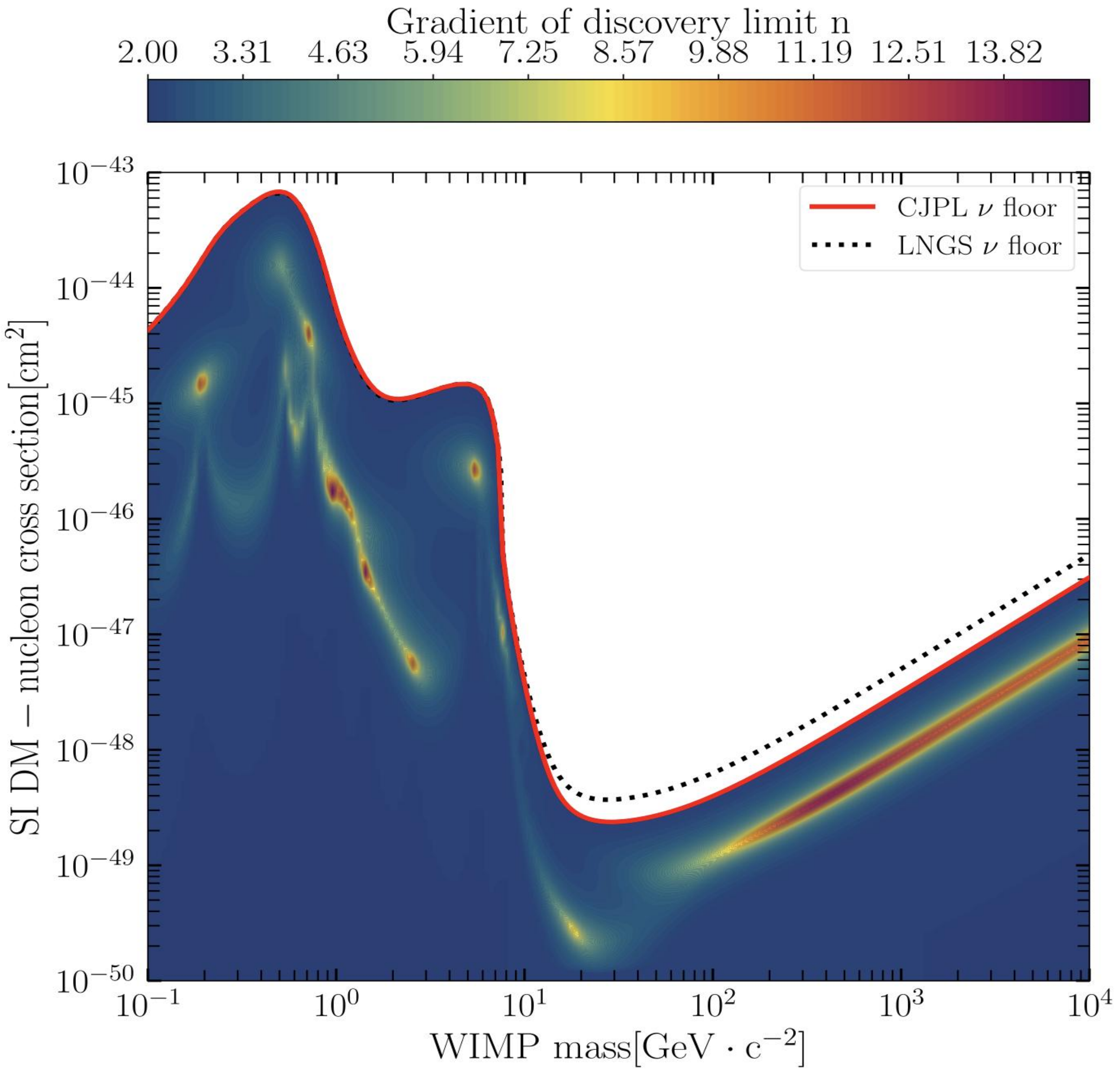
$$n = -\left(\frac{d \log \sigma}{d \log N}\right)^{-1}$$

- **Neutrino floor**: boundary of the fog with n=2



arXiv：2002.07499

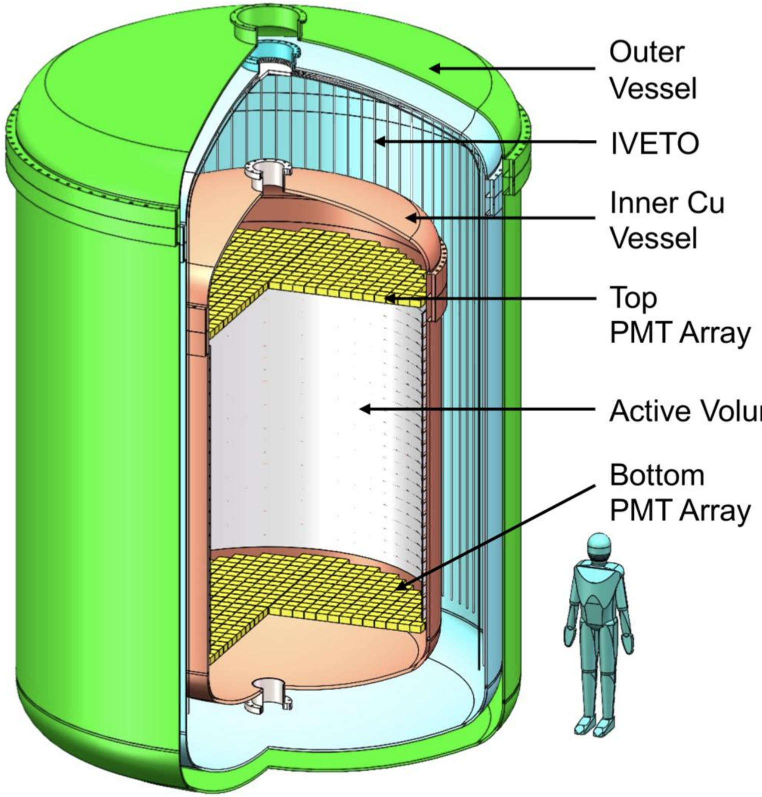
Neutrino Fog and Floor @ CJPL

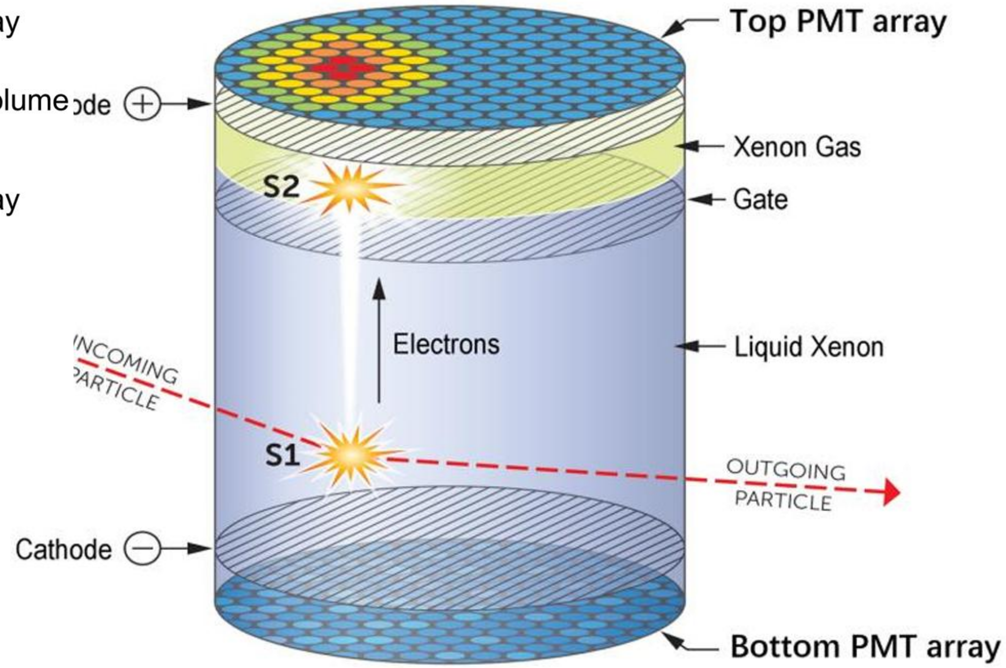


- Similar in the Solar neutrino region
- 30% decrease compares to LNGS when m_{DM}>40GeV
- Due to the small atmospheric neutrino flux

Sensitivity of the future PandaX-xT

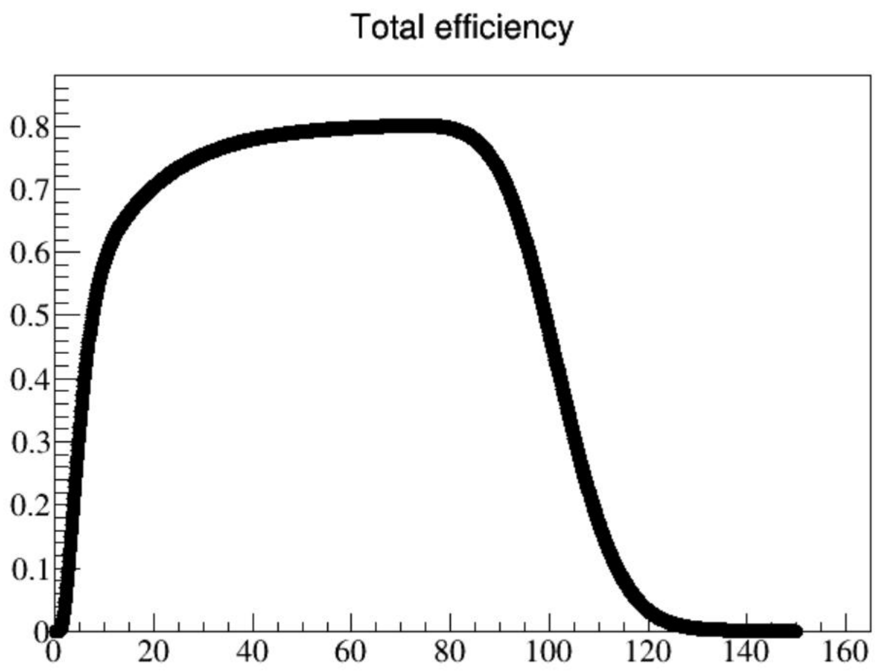
- Detector： PandaX-xT
- height 2.95m
- Diameter 2.55m
- Target： 20t Liquid xenon





arXiv:2402.03596

Efficiency of PandaX and the background



recoil energy (keV)

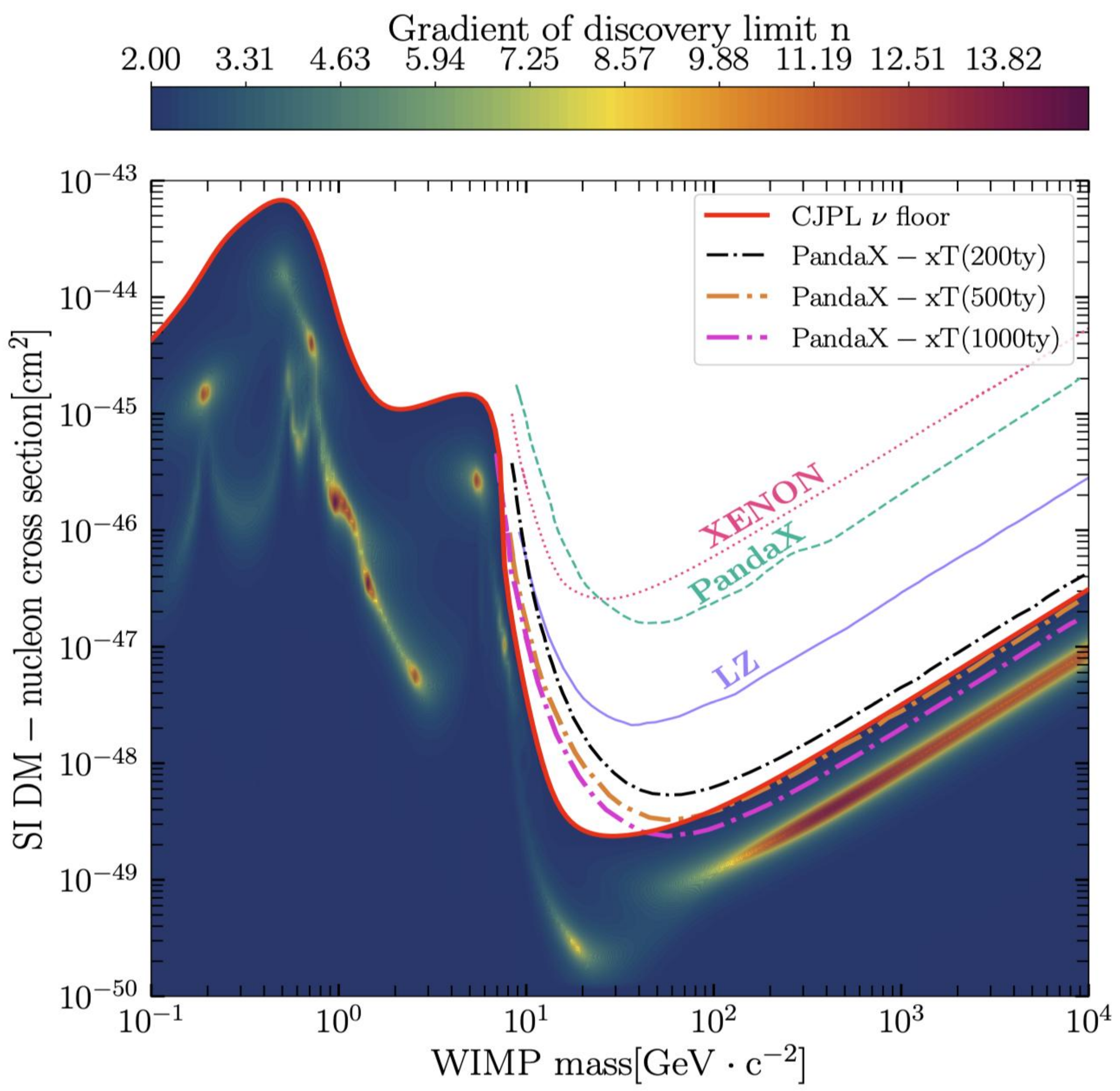
arXiv:2107.13438 fromPandaX-4T

background, arXiv:2402.03596, PandaX-xT

	ER (event/tonne/year)	NR (event/tonne/year)
Photosensors	8.3	0.00007
Copper vessel	0.02	0.000002
^{85}Kr	1.2	-
^{222}Rn	28.2	-
^{136}Xe	9.6	-
Solar ν	27.5	-
Atmospheric ν	0.0	0.02
Diffusive supernova ν	0.0	0.002
Total	**74.8**	**0.02**

- A 99.7% ER rejection power and a 50% NR acceptance
- ER-BG 0.224(event/tonne/year)
- NR-BG 0.01 (event/tonne/year)

Sensitivity of PandaX-xT: Spin-independent case



$$N \approx exposure \times \int_0^{\infty} dE_R \frac{dR}{dE_R} \epsilon(E_R)$$

- Using the similar Likelihood function：

$$\mathscr{L}(\sigma, \Phi) = \prod_{i=1}^{N_{\text{bins}}} \mathscr{P}\left[N_i^{\text{obs}} | N_i^{\chi} + \sum_{j=1}^{n_\nu} n_\nu^i (\Phi^j) + n_i^{\text{bkg}}\right] \times \prod_{j=1}^{n_\nu} \mathscr{G}(\Phi_j) \mathscr{G}\left(n_i^{\text{bkg}}\right)$$

- The **same** test statistic
- Our finding: with **exposure of 500 tonne-years** PandaX-xT can reach the neutrino floor
- Probing down to 3×10^{-49} cm² at m_{DM}= 70 GeV/c²

Summary

- Investigation of the neutrino background in Jinping, where the geographical location significantly reduces the fluxes of atmospheric neutrinos compared to other underground laboratories.
- Redefining the boundary of the neutrino fog in the CJPL region; the neutrino background for high-mass WIMPs (>10 GeV) is reduced by nearly 30 %.
- Simulated the ultimate sensitivity reachable by the next-generation detector PandaX-xT
- With an exposure of 500 tonne-years, PandaX-xT can reach the neutrino floor at Jinping.

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网址：https://indico.pmo.ac.cn/event/975/overview

Thanks！

Backup slides

Sensitivity of PandaX-xT: Spin-dependent case

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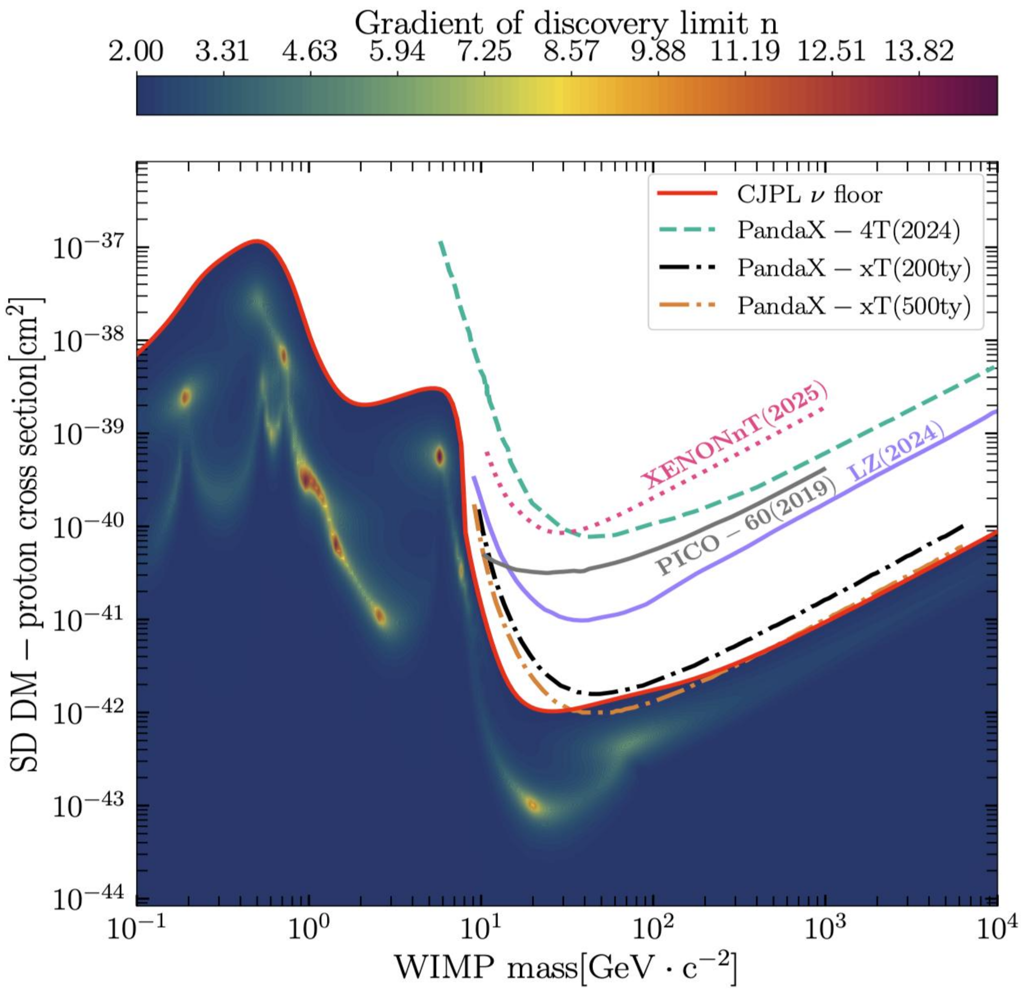

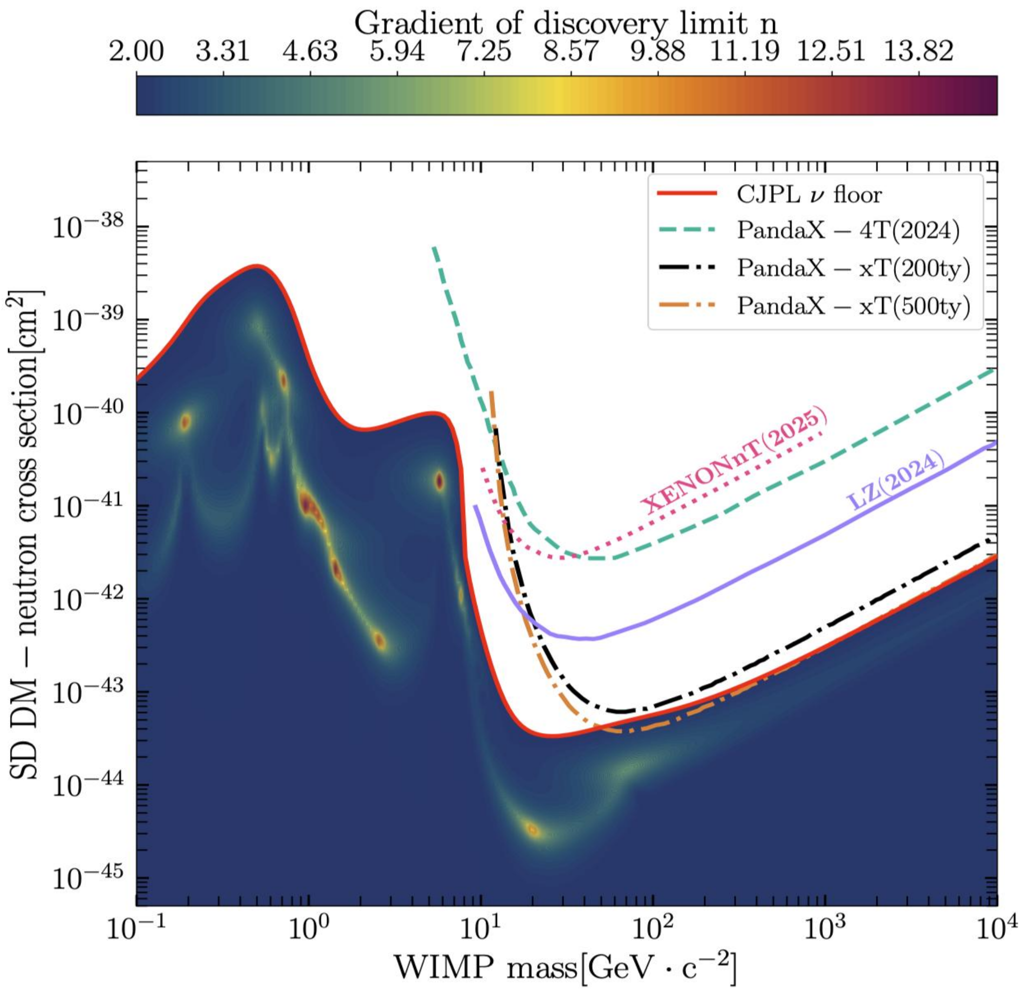

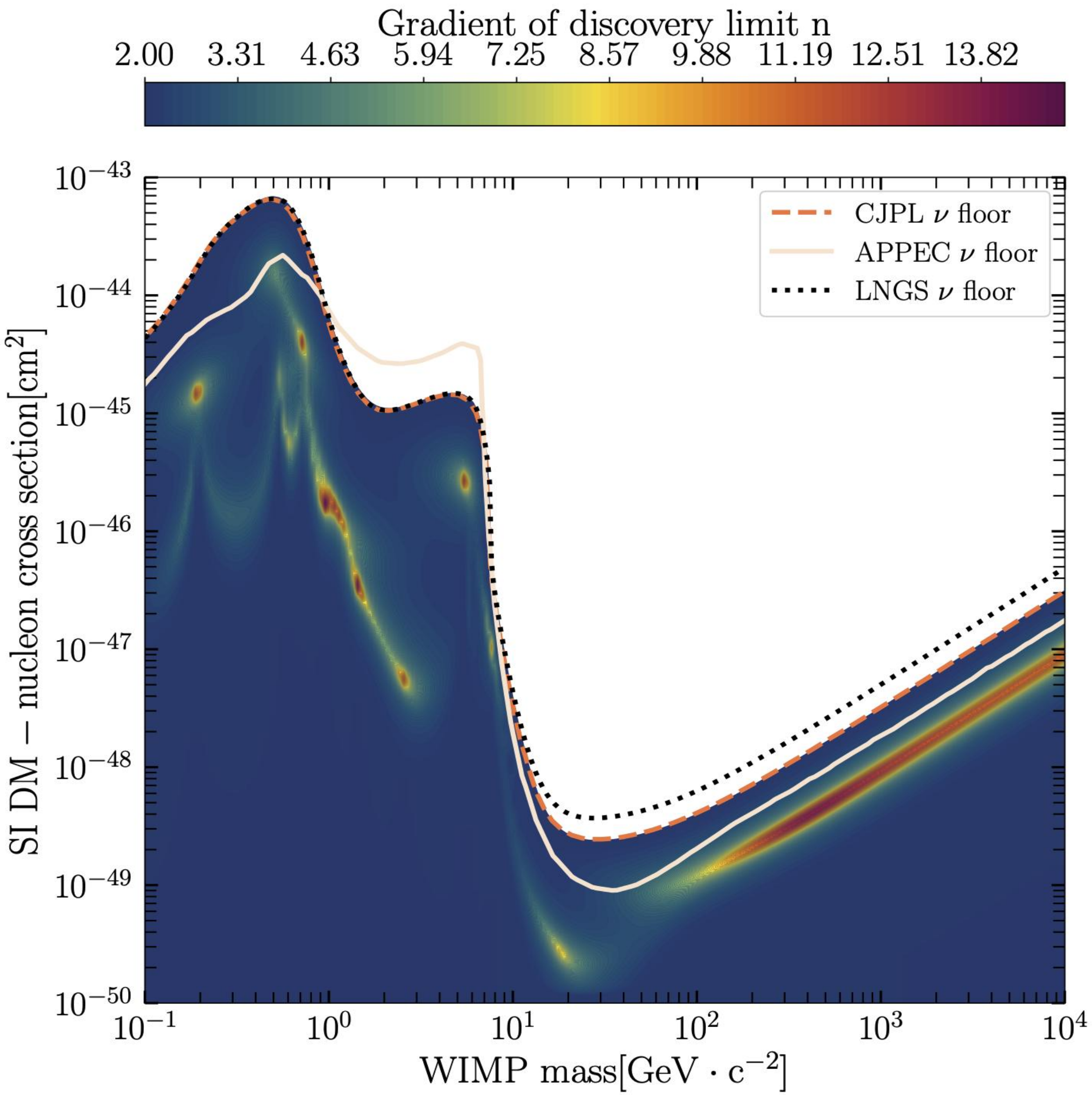

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