李政道研究所
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TeV Particle Astrophysics
2026
Tendo
Japan
August 30 - September 4, 2026

Probing Dark Matter Annihilation in the Galactic Centre with TRIDENT

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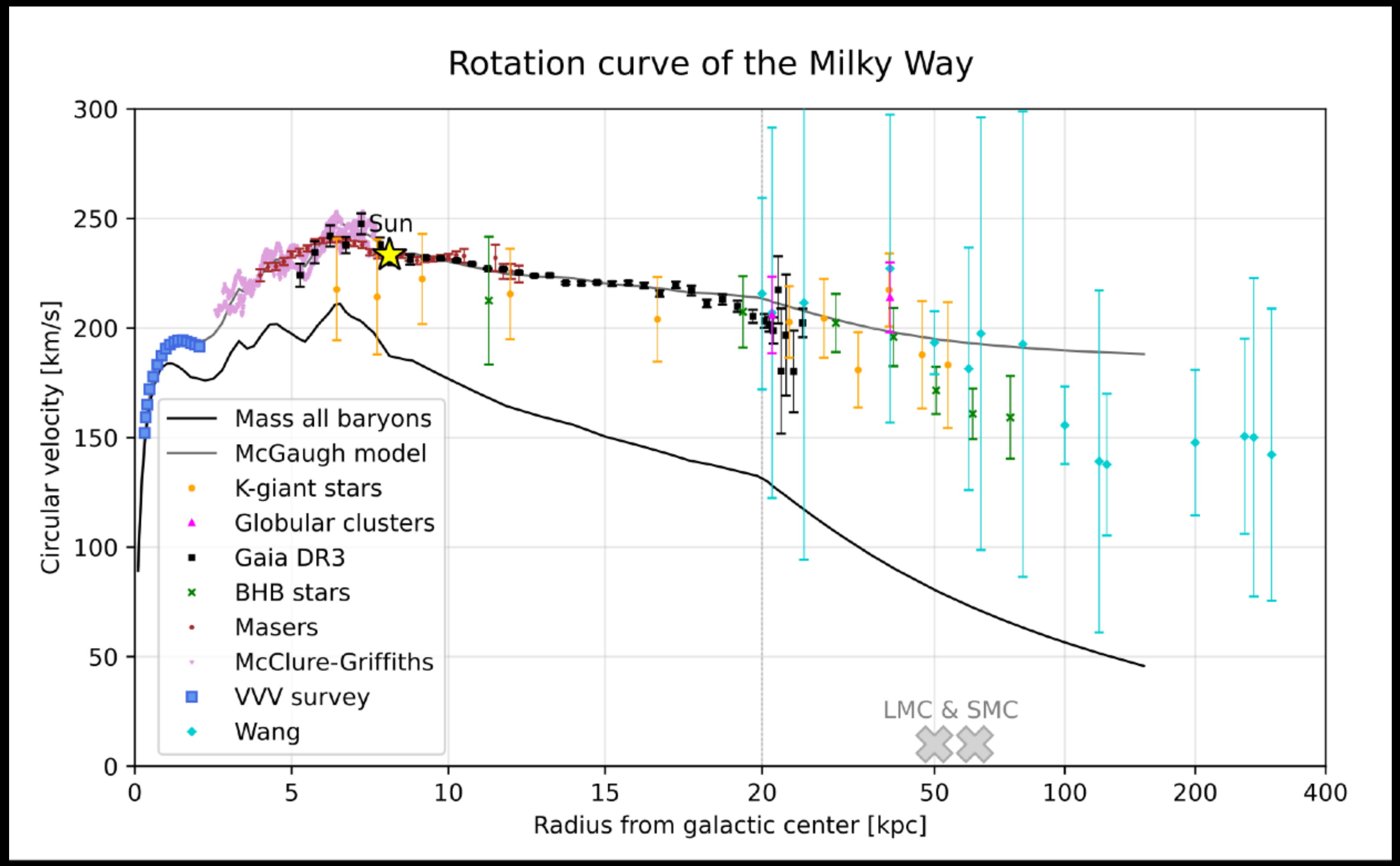
Based on arXiv:2601.06817, PRD accepted

Sep 1, 2026

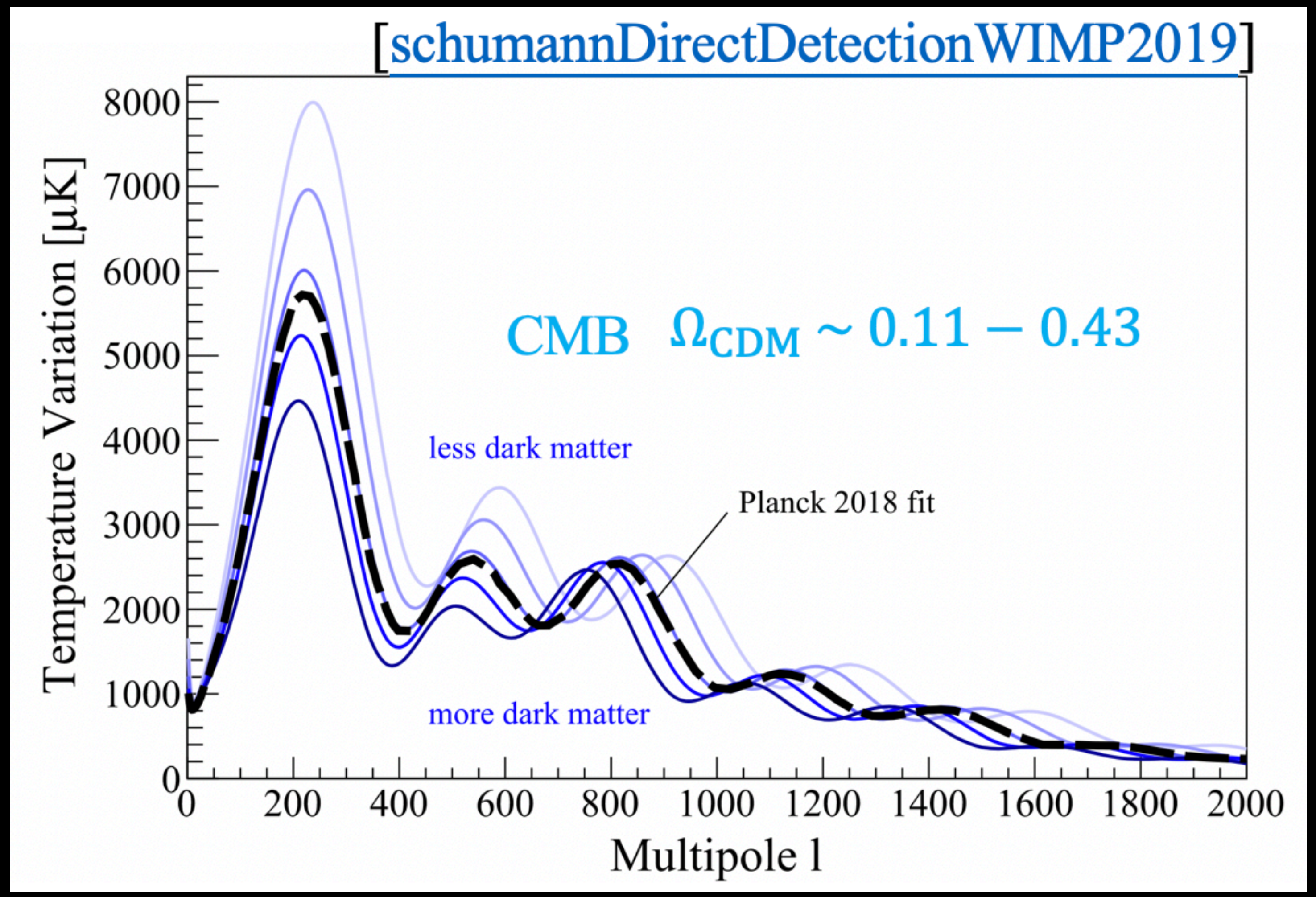
Evidence for Dark Matter

- Astrophysical evidence



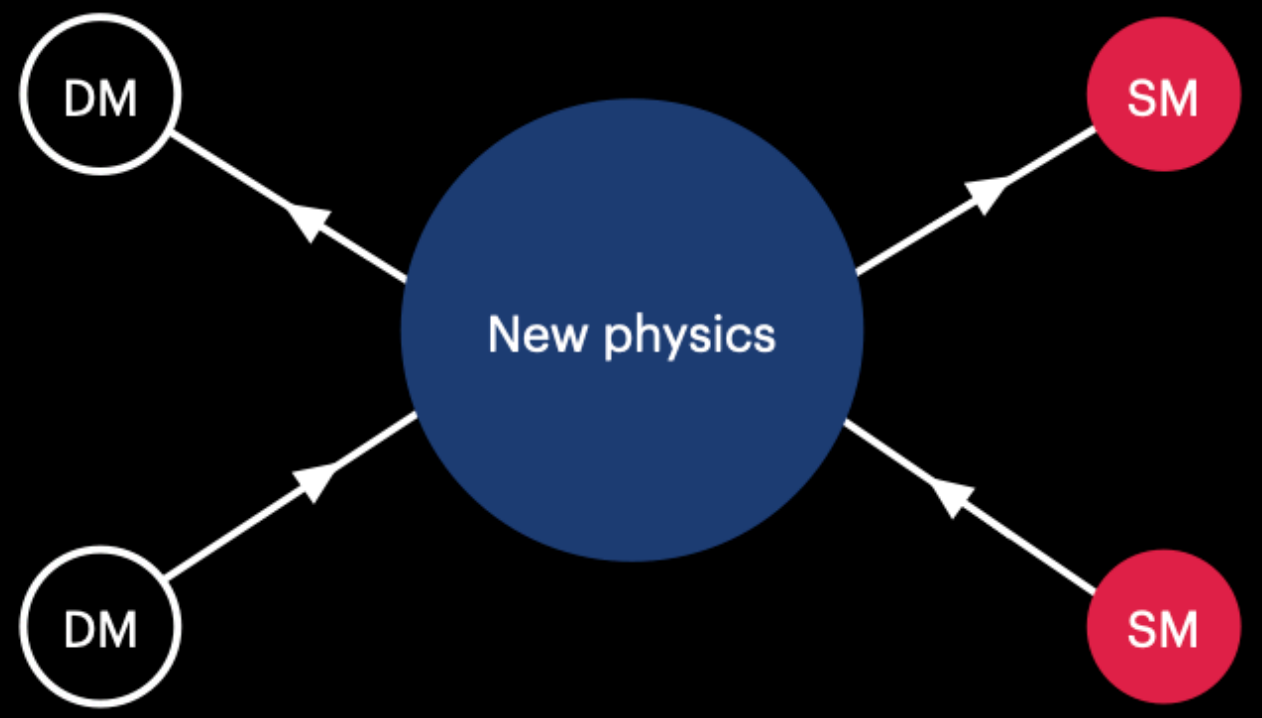
Rotation curve

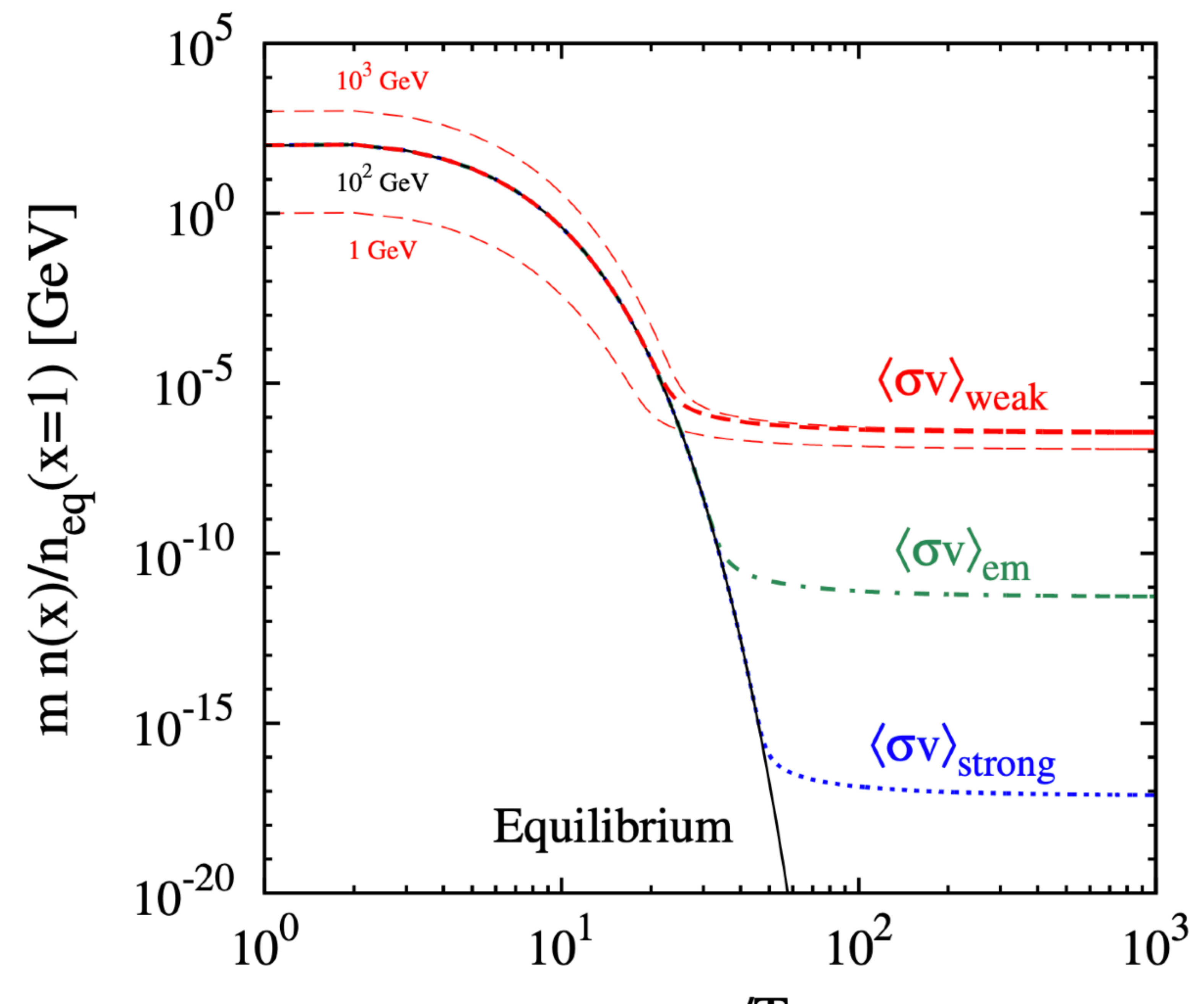
The Bullet cluster



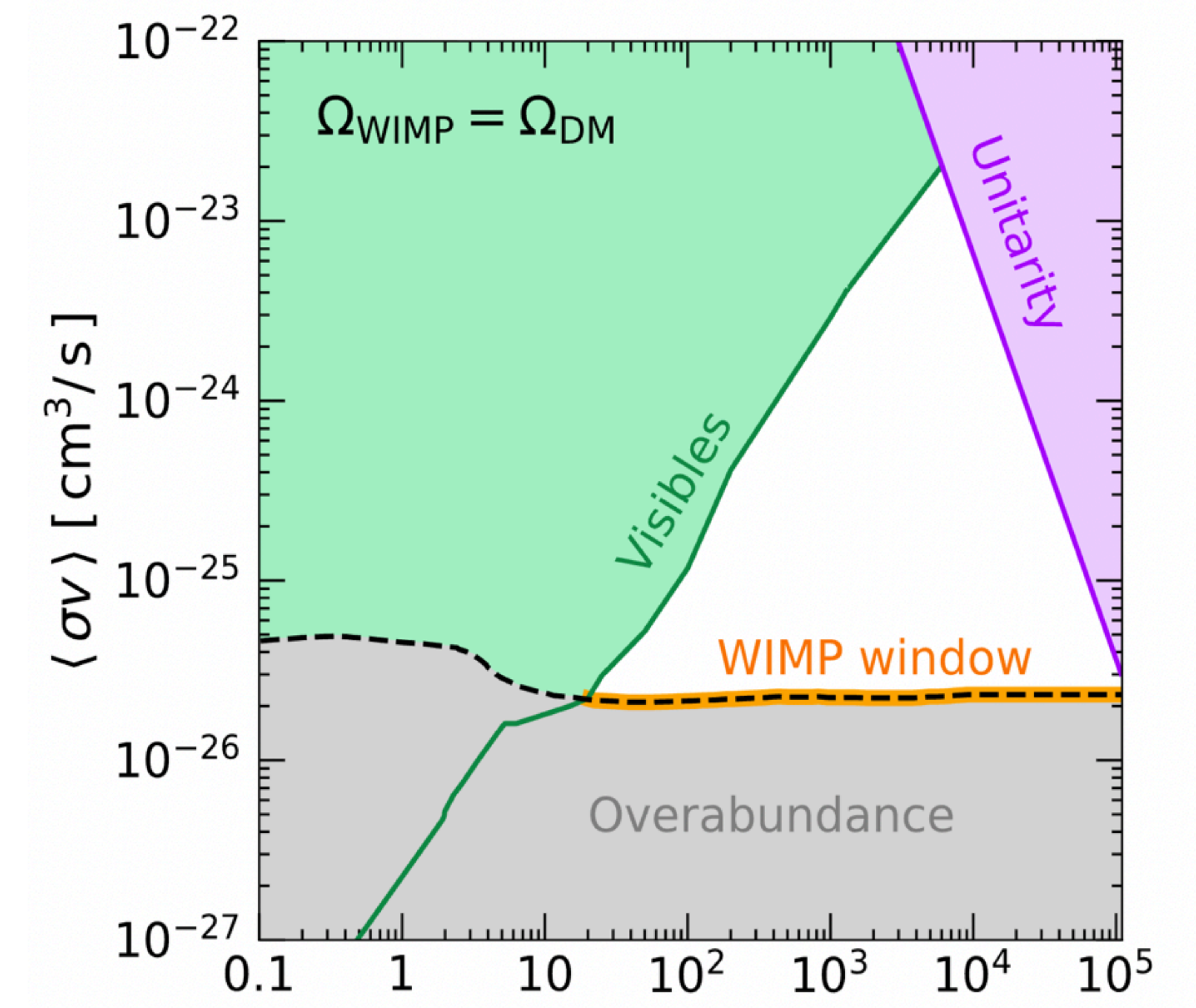
Acoustic peak signature

The "WIMP Miracle"





Phys. Rev. D 86, 023506



Phys. Rev. D 86, 023016

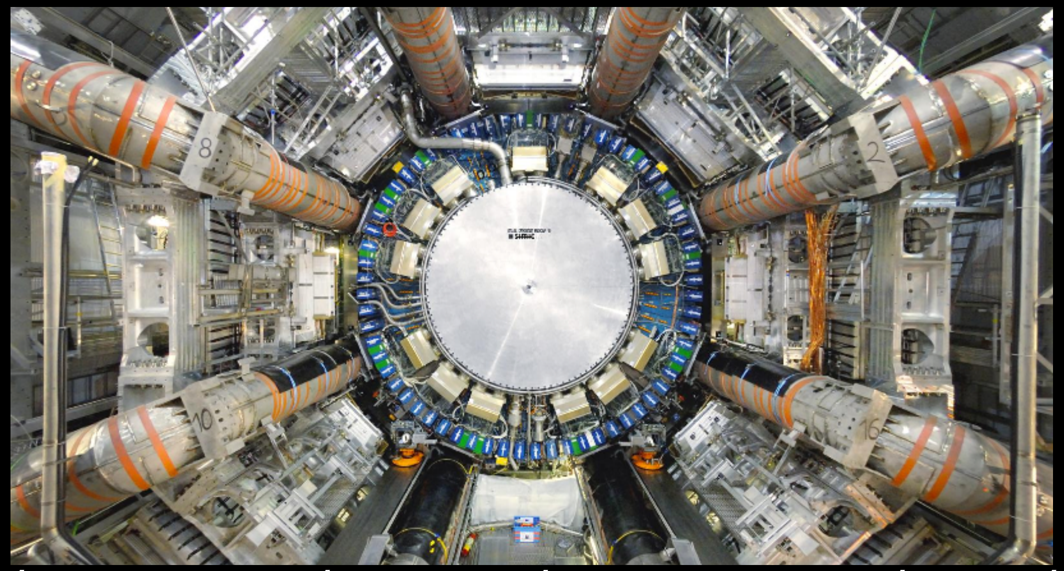
- Weak-scale interaction cross section naturally yields the observed DM relic abundance

$$\langle \sigma v \rangle \sim 10^{-26} \mathrm{cm}^3 \mathrm{s}^{-1}$$

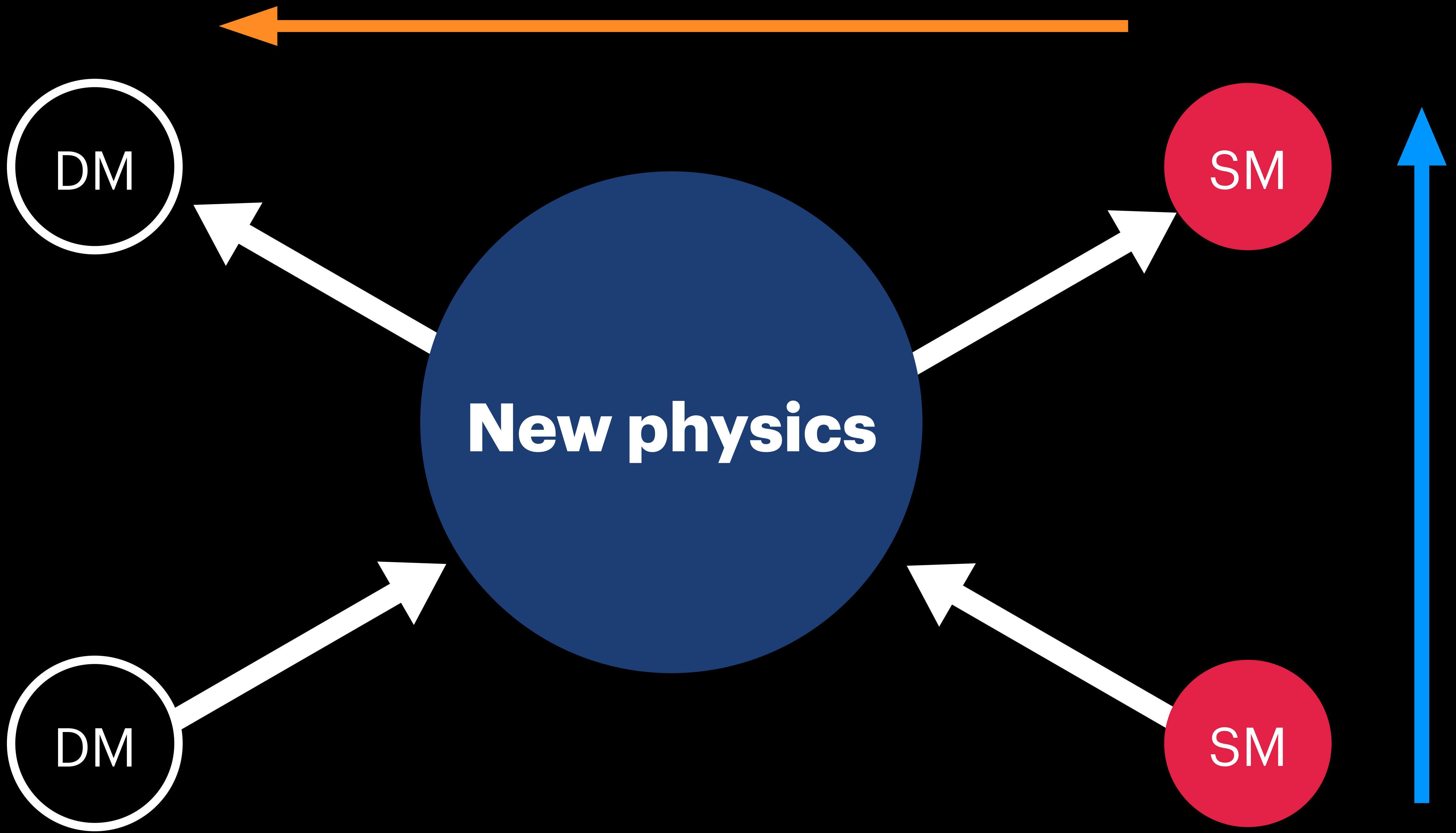
Search for WIMPs

Production

missing transverse momentum



/home.cern/science/experiments/atlas/



https://pandax.sjtu.edu.cn/

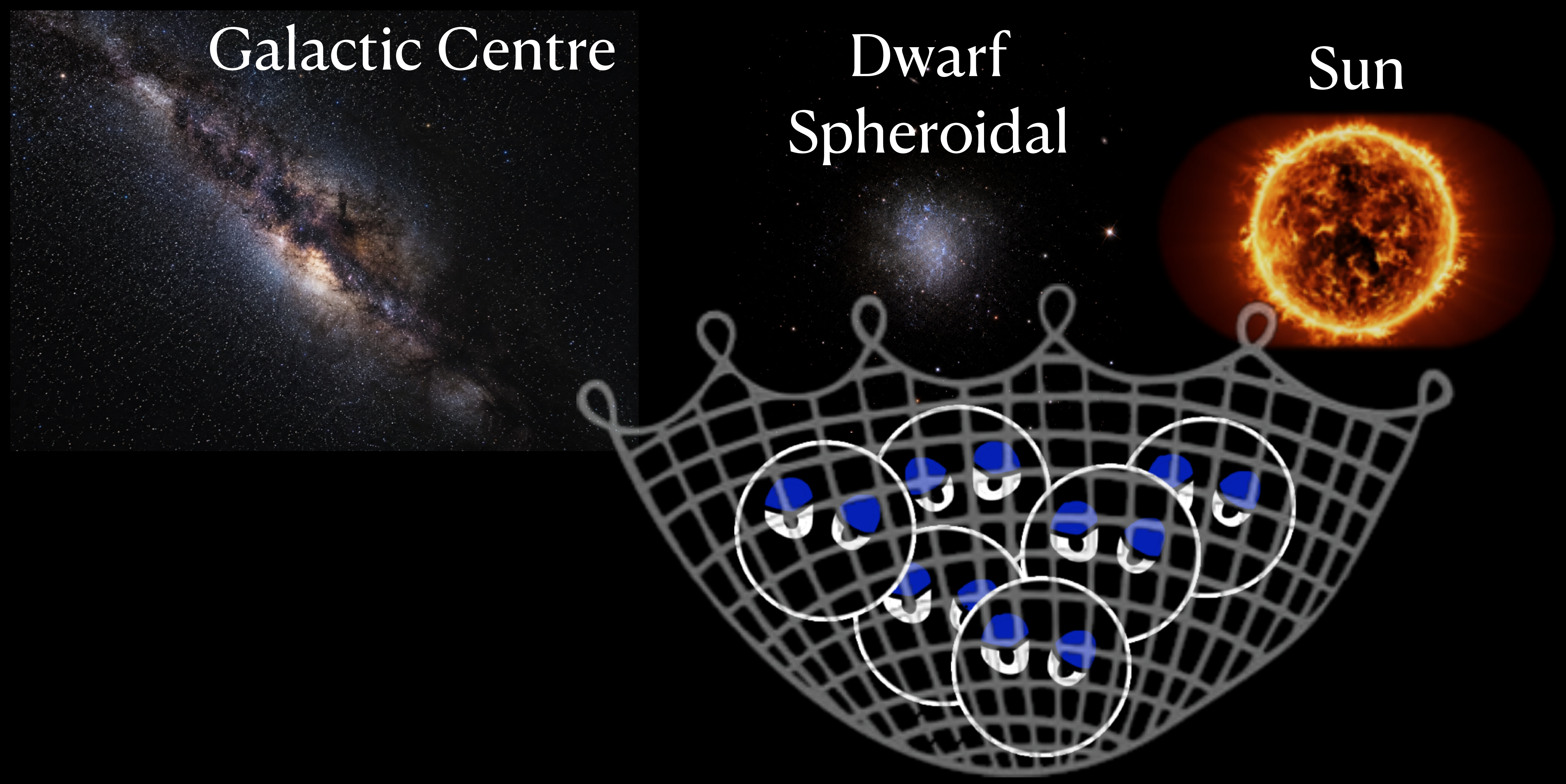
Direct search

Nuclear recoils caused by Galactic WIMPs

Indirect search

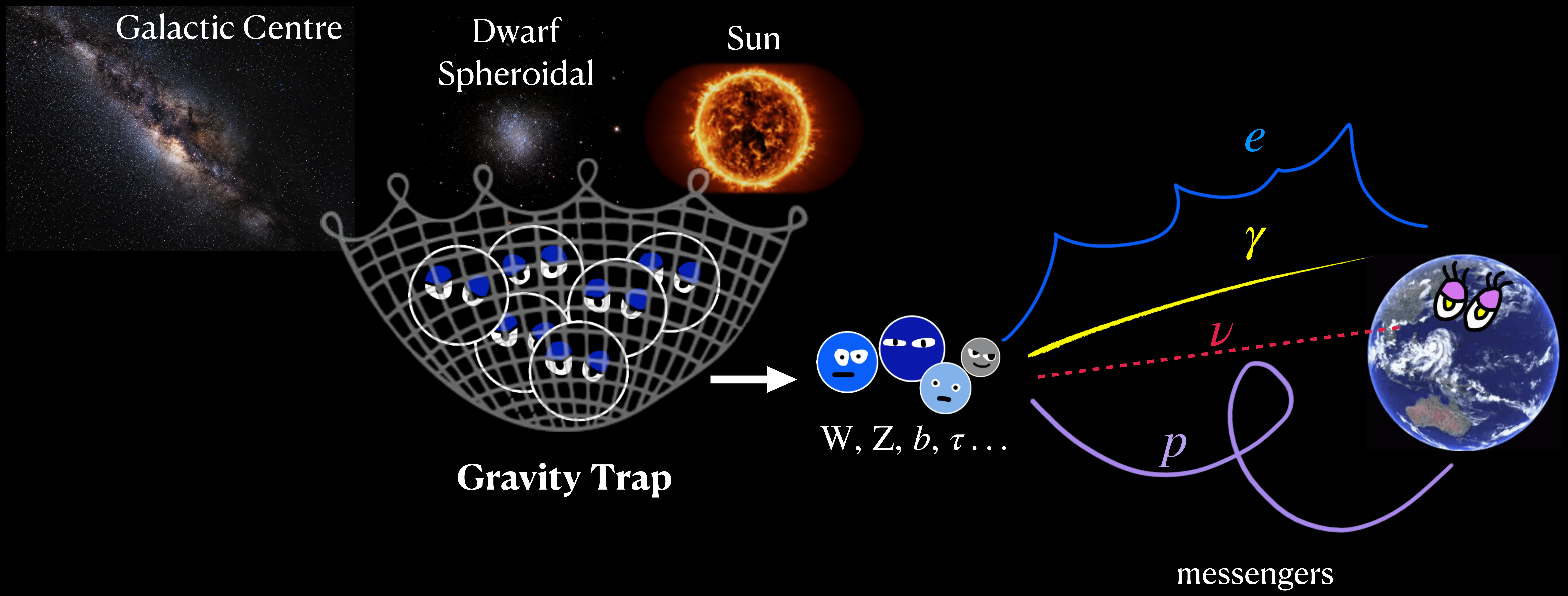
astronomical annihilation products

Indirect Search for Dark Matter



Gravity Trap

Indirect Search for Dark Matter



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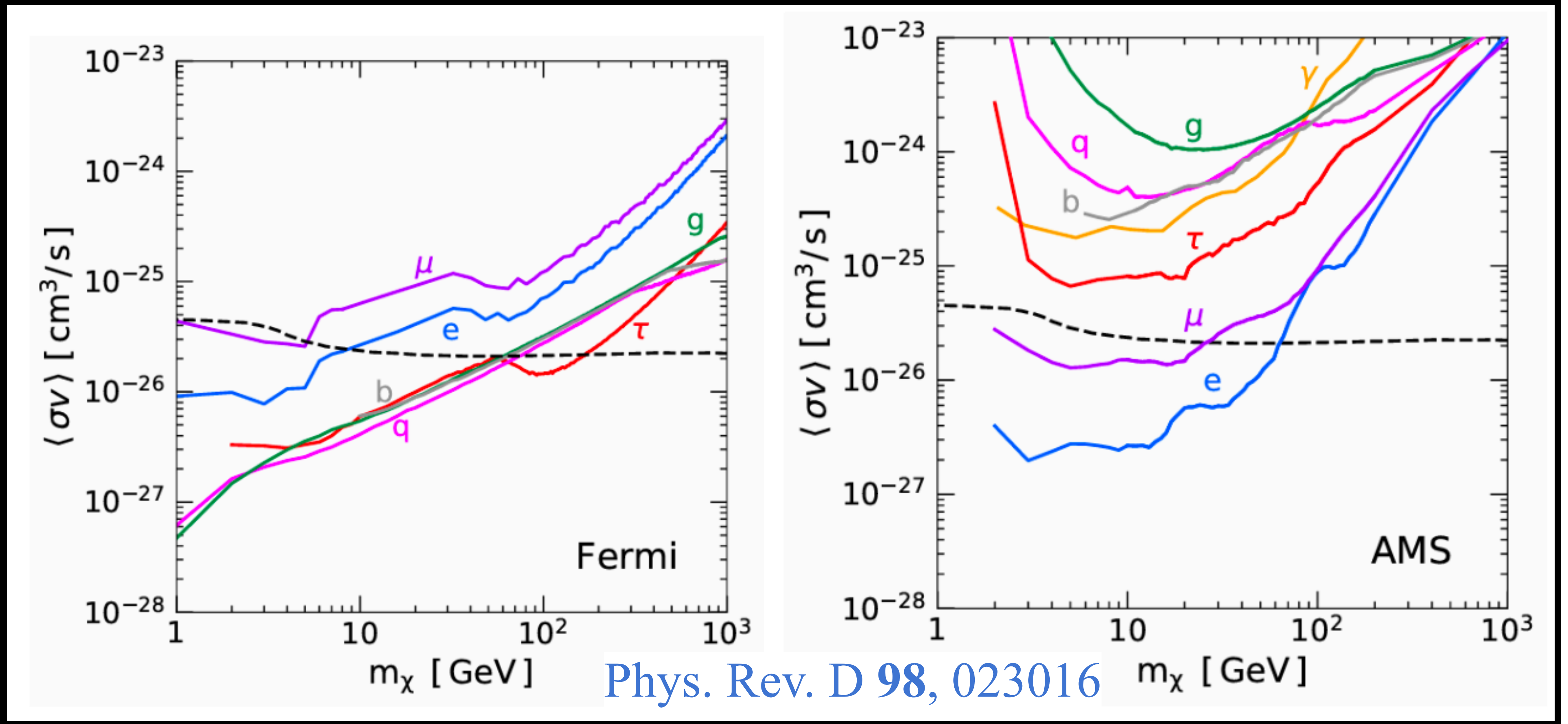
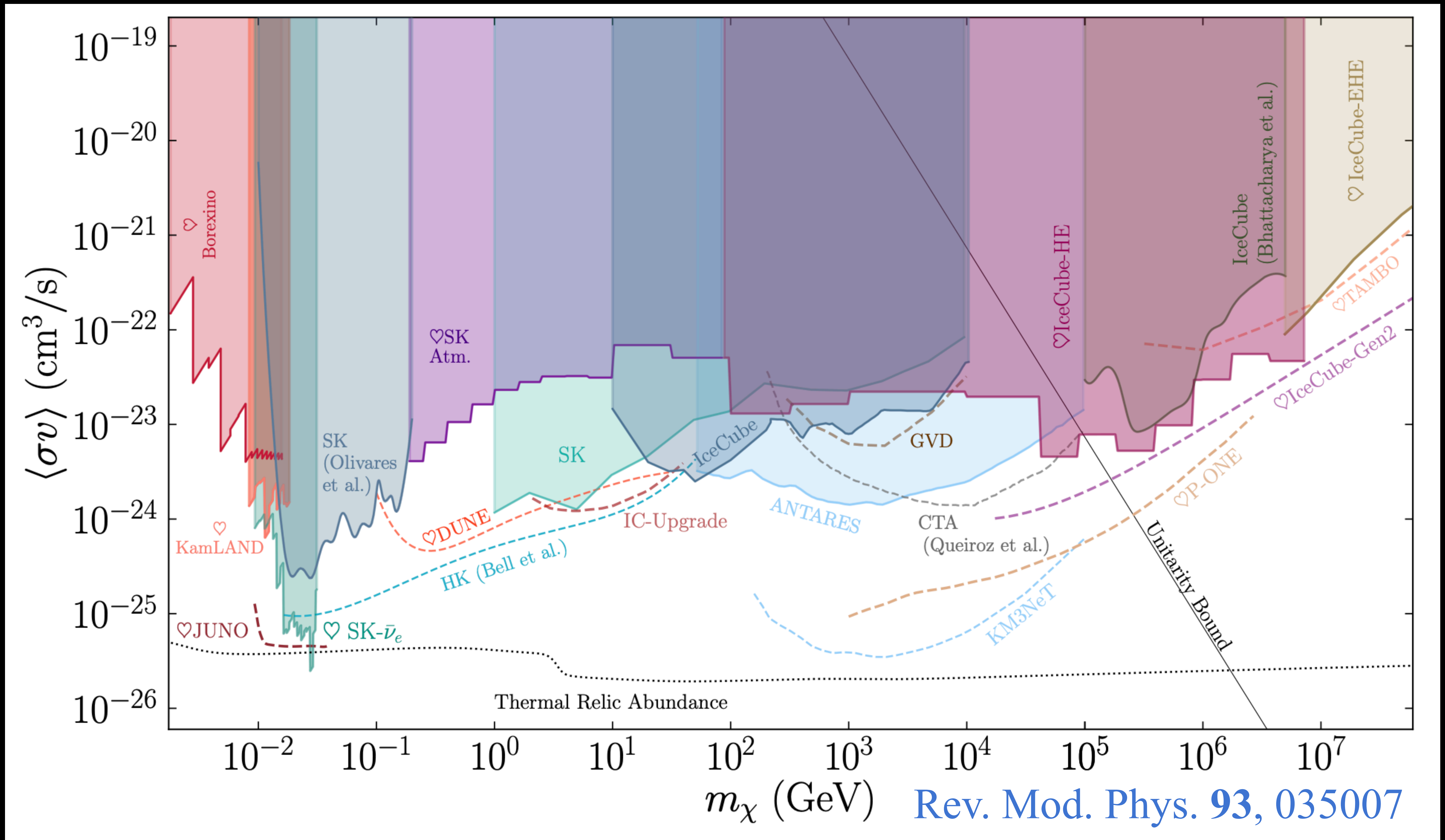
Current Status of Indirect Searches

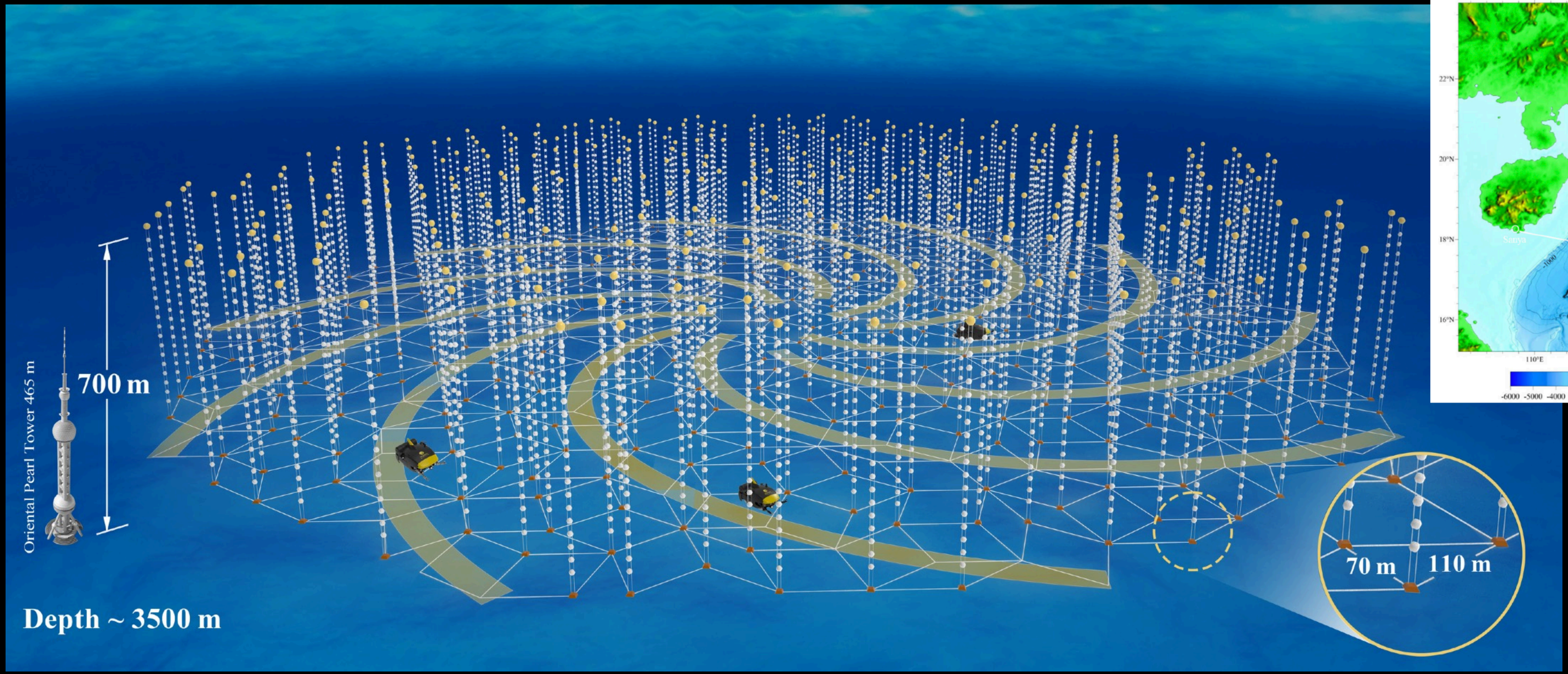


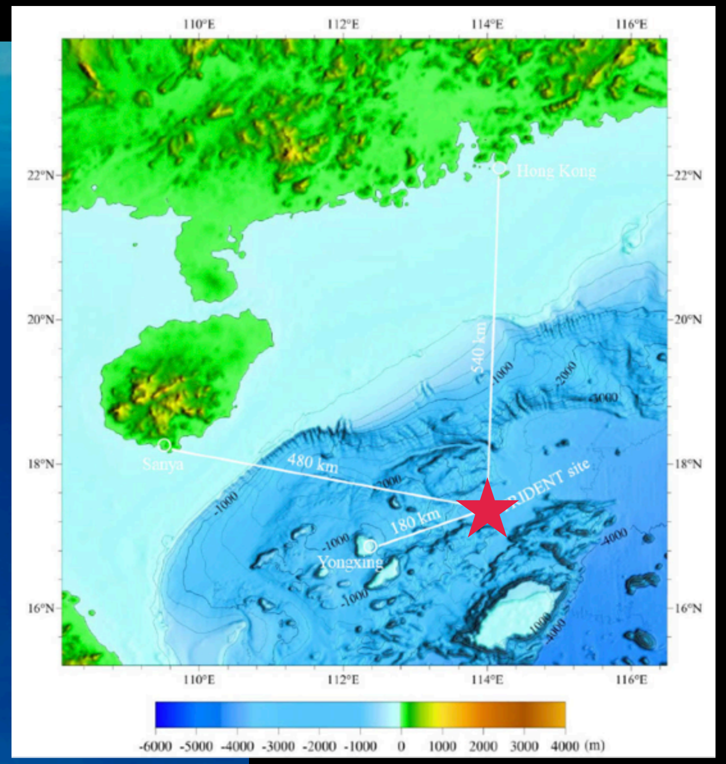


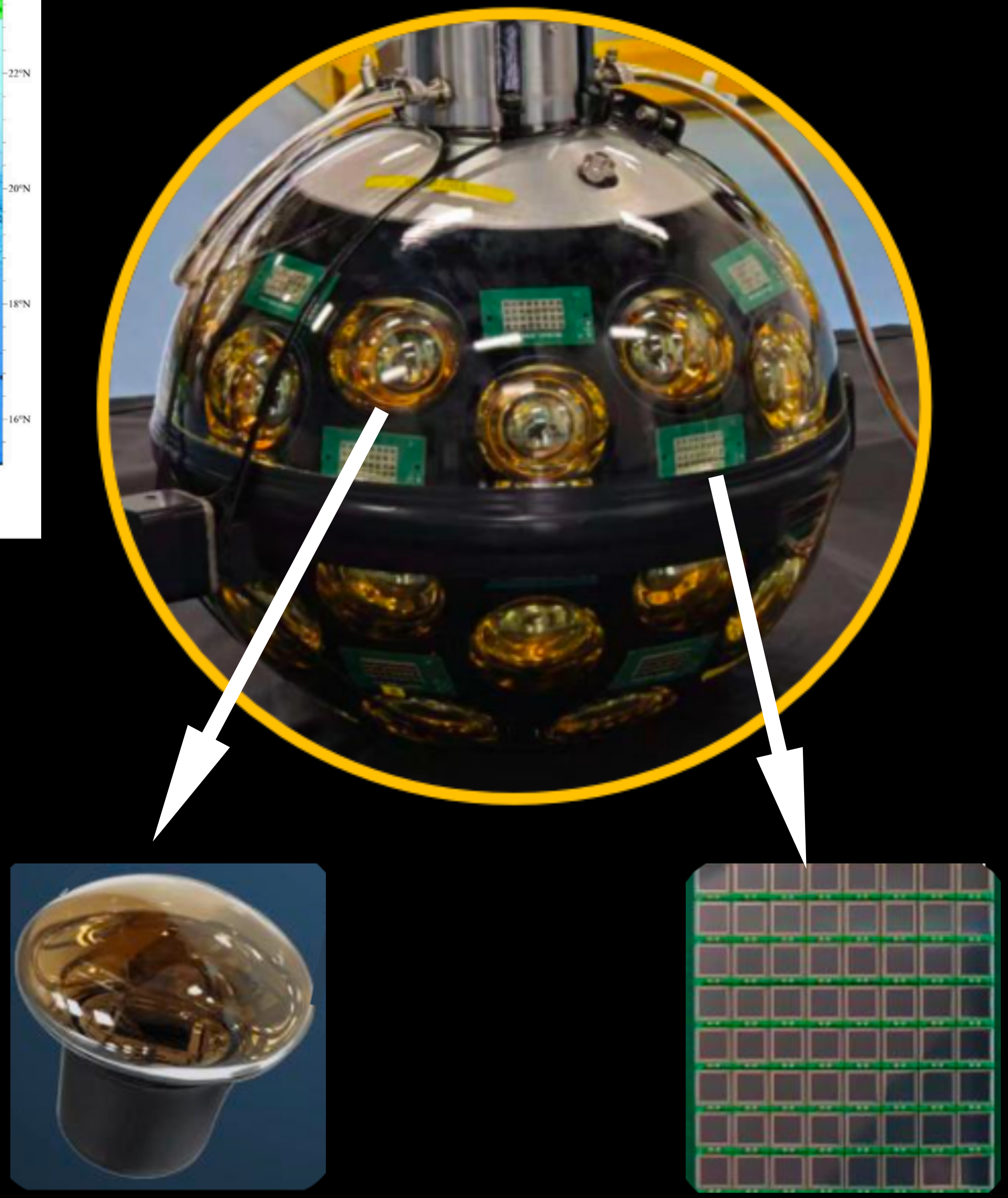
- Velocity independent annihilations are strongly constrained for lower dark matter masses
- region above ~200 GeV less constrained

- Neutrino can be a probe for DM searches

The TRIDENT Neutrino Telescope







- at depth of 3500 m
- Detection volume~8km^3, ~1000 strings
- 20 hybrid DOMs per string

PMTs
<2ns TTS
~30% QE

SiPMs
<0.3ns jitter

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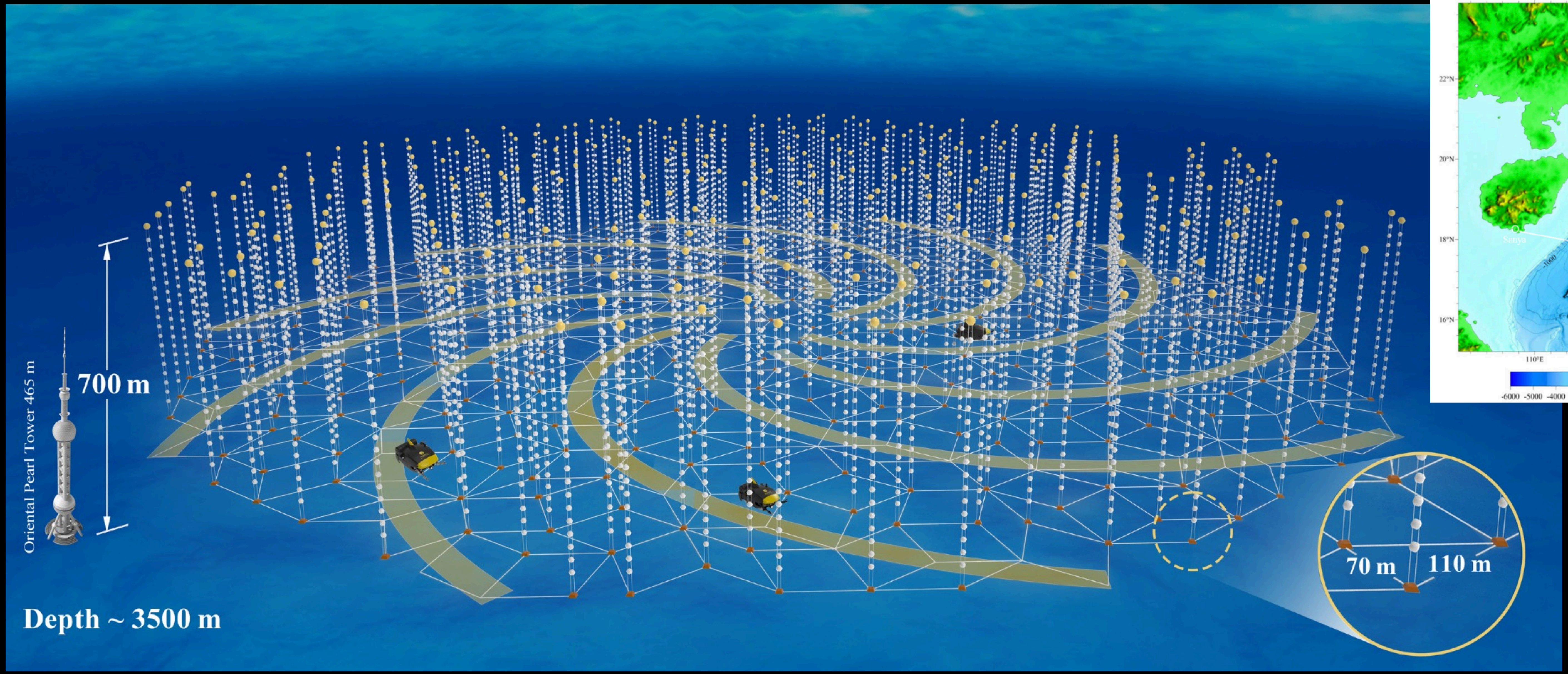
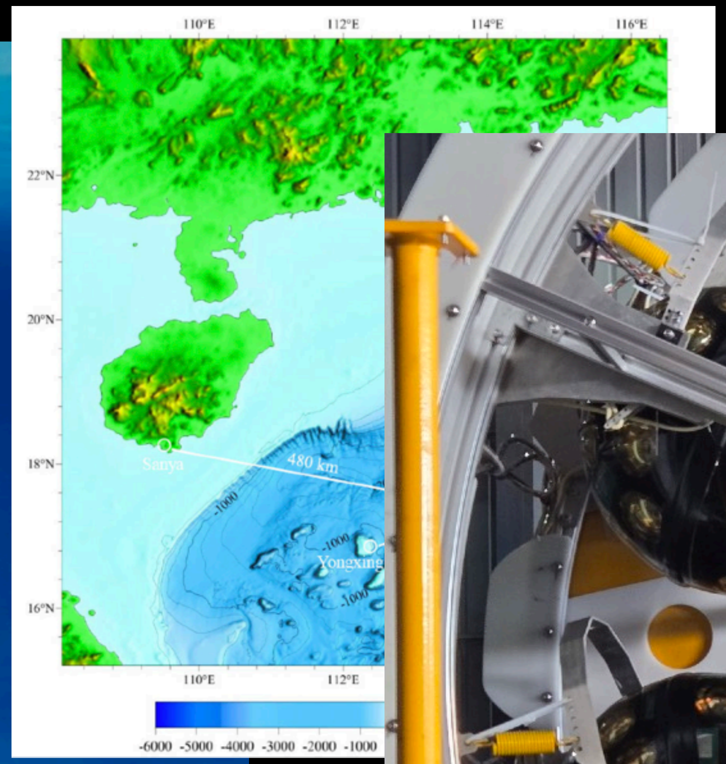
The TRIDENT Neutrino Telescope





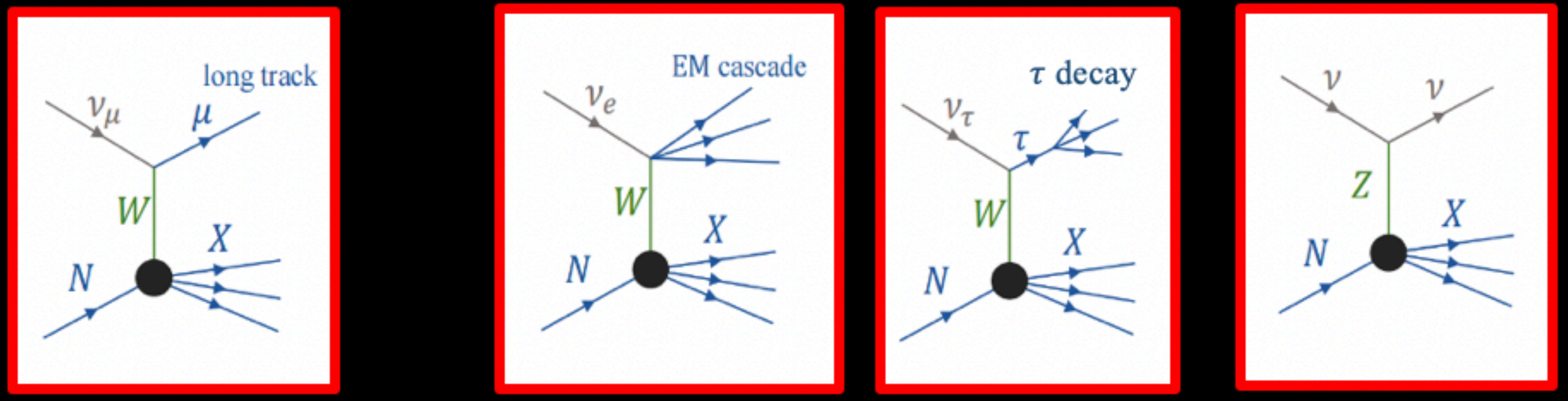
- at depth of 3500 m
- Detection volume~8km^3, ~1000 strings
- 20 hybrid DOMs per string

Prototype String deployment in Sep 2026
See talk by Fuyudi Zhang on Sep 1 16:25

Event Interaction Types

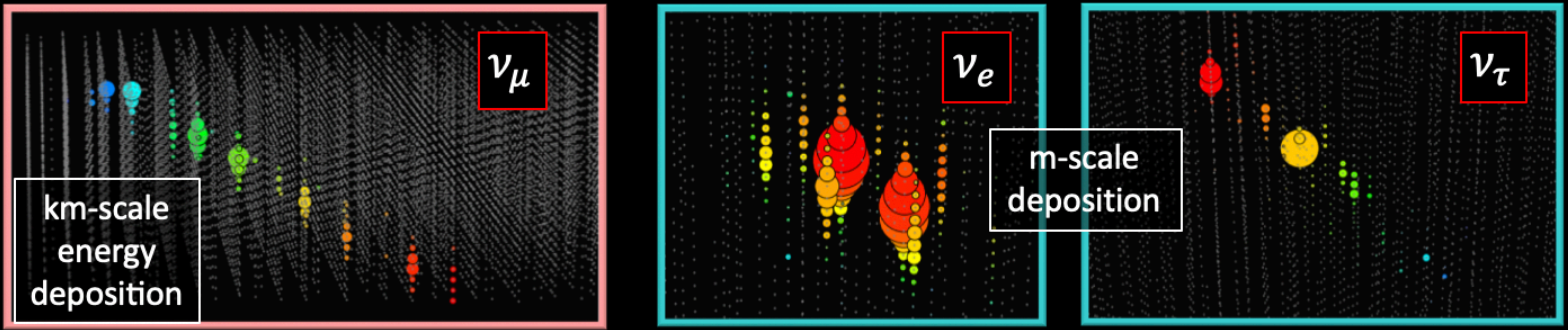
- Precise direction information

Charged-Current Neutral-Current



Muon tracks Cascades

- Better energy resolution
- Lower backgrounds



TRIDENT simulation

Neutrinos from DM Annihilation in Galactic Centre

$$\frac{d\Phi_\nu}{dE_\nu} = \frac{1}{4\pi}\frac{\langle\sigma v\rangle}{\kappa m_\chi^2}\left(\sum_\alpha \frac{dN_{\nu\alpha}^{\mathrm{prod}}}{dE_{\nu\alpha}} P_{\nu\alpha\to\nu\beta}\right) J(\Omega)$$

Neutrinos from DM Annihilation in Galactic Centre

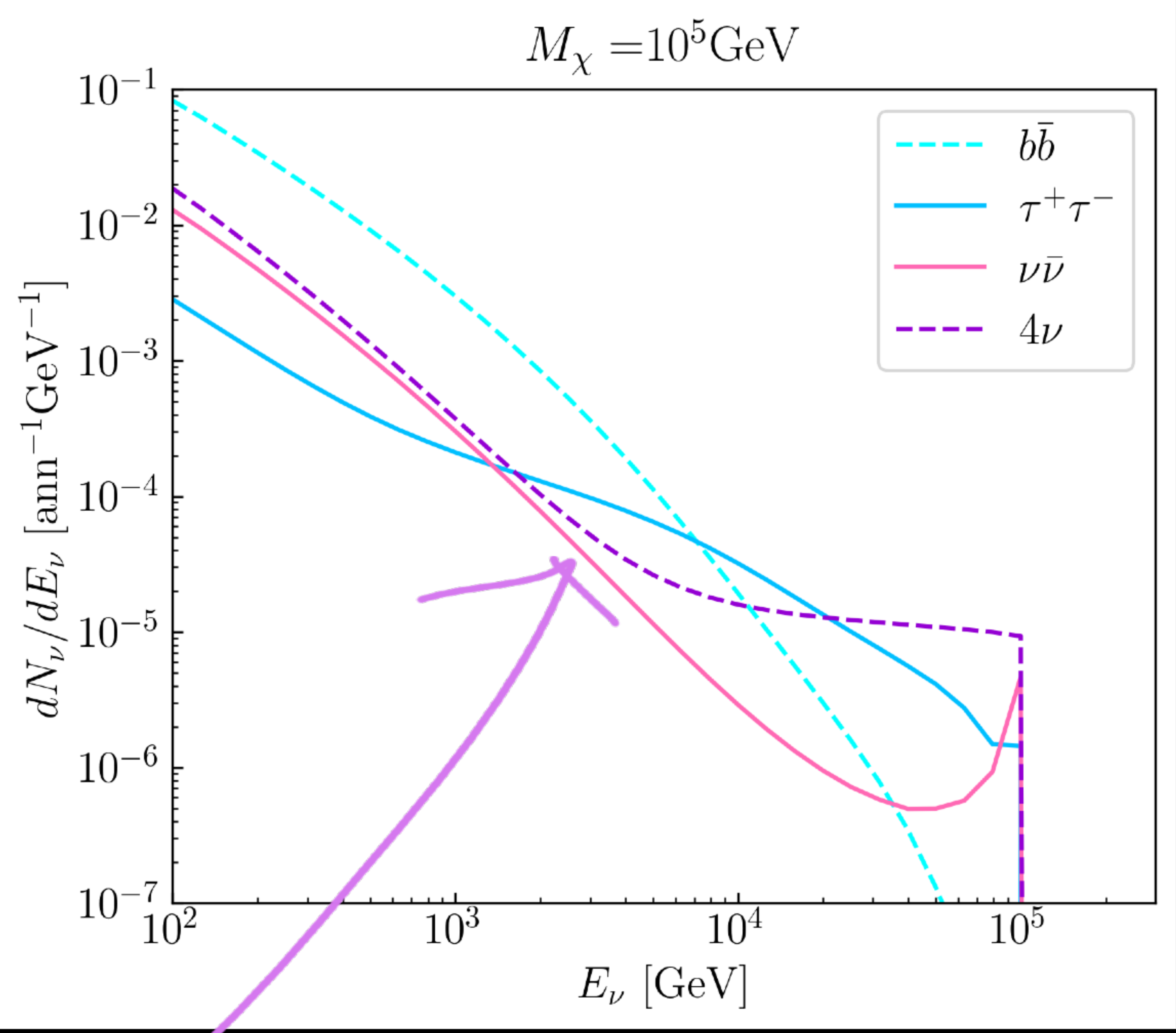
annihilation cross section

spectra per annihilation

oscillation probability

$$\frac{d\Phi_\nu}{dE_\nu} = \frac{1}{4\pi} \frac{\langle \sigma v \rangle}{\kappa m_\chi^2} \left(\sum_\alpha \frac{dN^{\mathrm{prod}}_{\nu\alpha}}{dE_{\nu\alpha}} P_{\nu\alpha \to \nu\beta} \right) J(\Omega)$$

$\kappa = 2$ for Majorana DM



- assuming 100% branching ratio for each channels
- $b\bar{b}$, $\tau^+\tau^-$ spectra from *χarov*, ν-direct spectra from *HDMspectra*
  - Include EW correction for $E_\nu > 500$GeV
- Averaged oscillation over large scale

Neutrinos from DM Annihilation in Galactic Centre

annihilation cross section

flux per annihilation

oscillation probability

J-factor

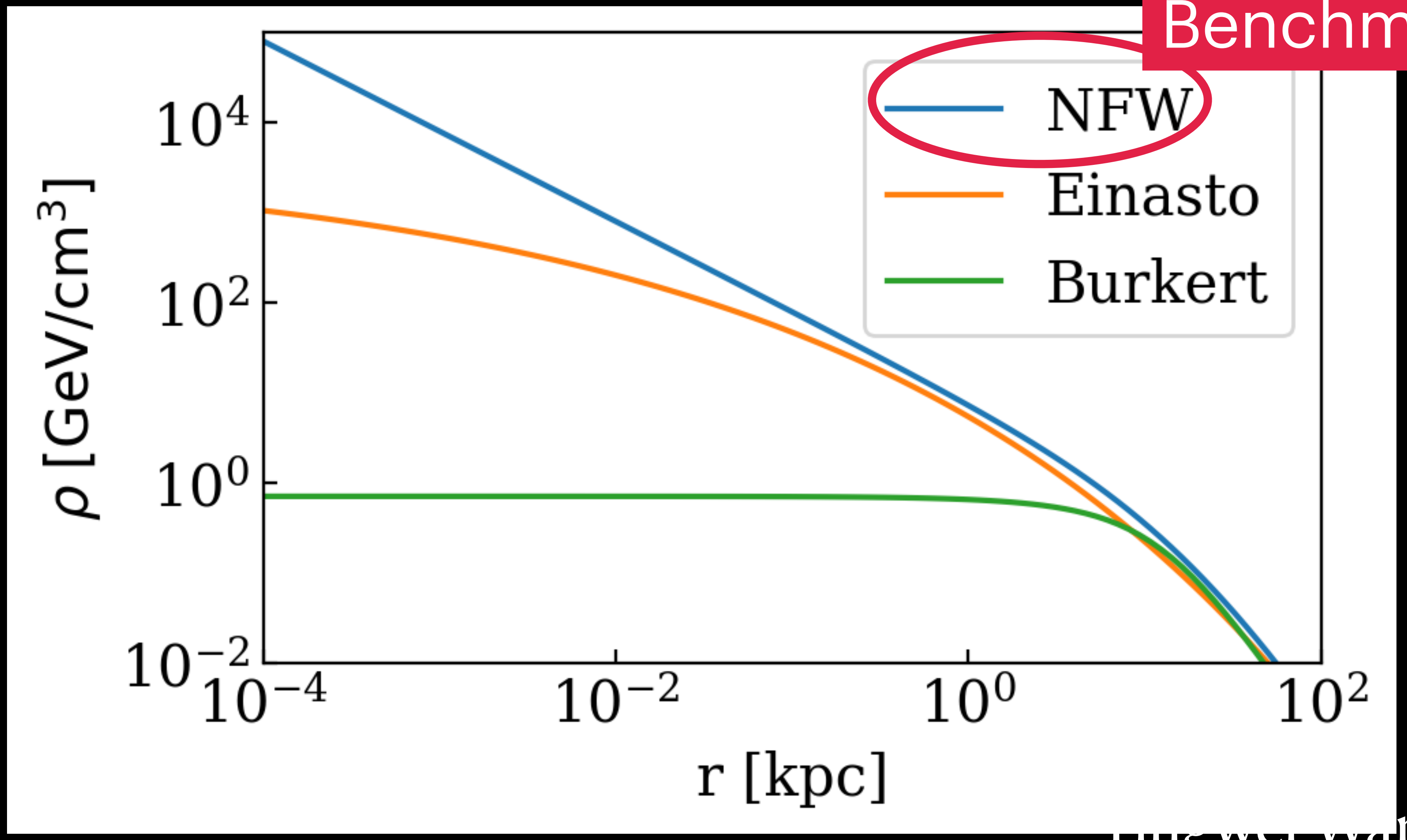
$$J \equiv \int d\Omega \int_{\text{l.o.s.}} \rho_\chi^2(x)dx$$

$$\frac{d\Phi_\nu}{dE_\nu} = \frac{1}{4\pi}\frac{\langle\sigma v\rangle}{\kappa m_\chi^2}\left(\sum_\alpha \frac{dN_{\nu\alpha}^{\text{prod}}}{dE_{\nu\alpha}} P_{\nu\alpha\to\nu\beta}\right) J(\Omega)$$

$\kappa = 2$ for Majorana DM

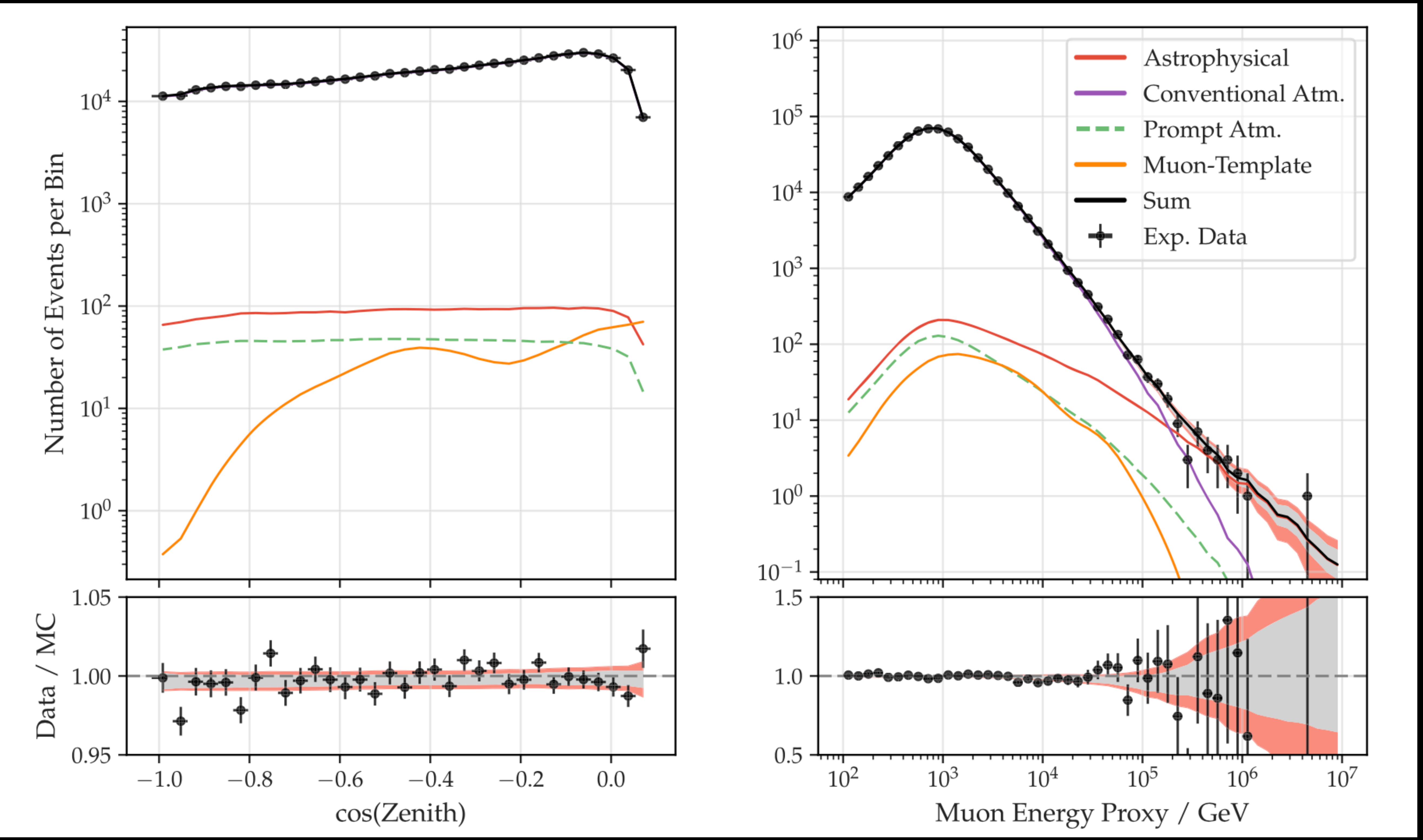
integral of the DM density along the line of sight

Benchmark



Main Background

- Atmospheric μ
- Atmospheric $\nu_\mu + \nu_e$
- Diffuse astrophysical $\nu_\mu + \nu_e + \nu_\tau$
- Galactic plane ν

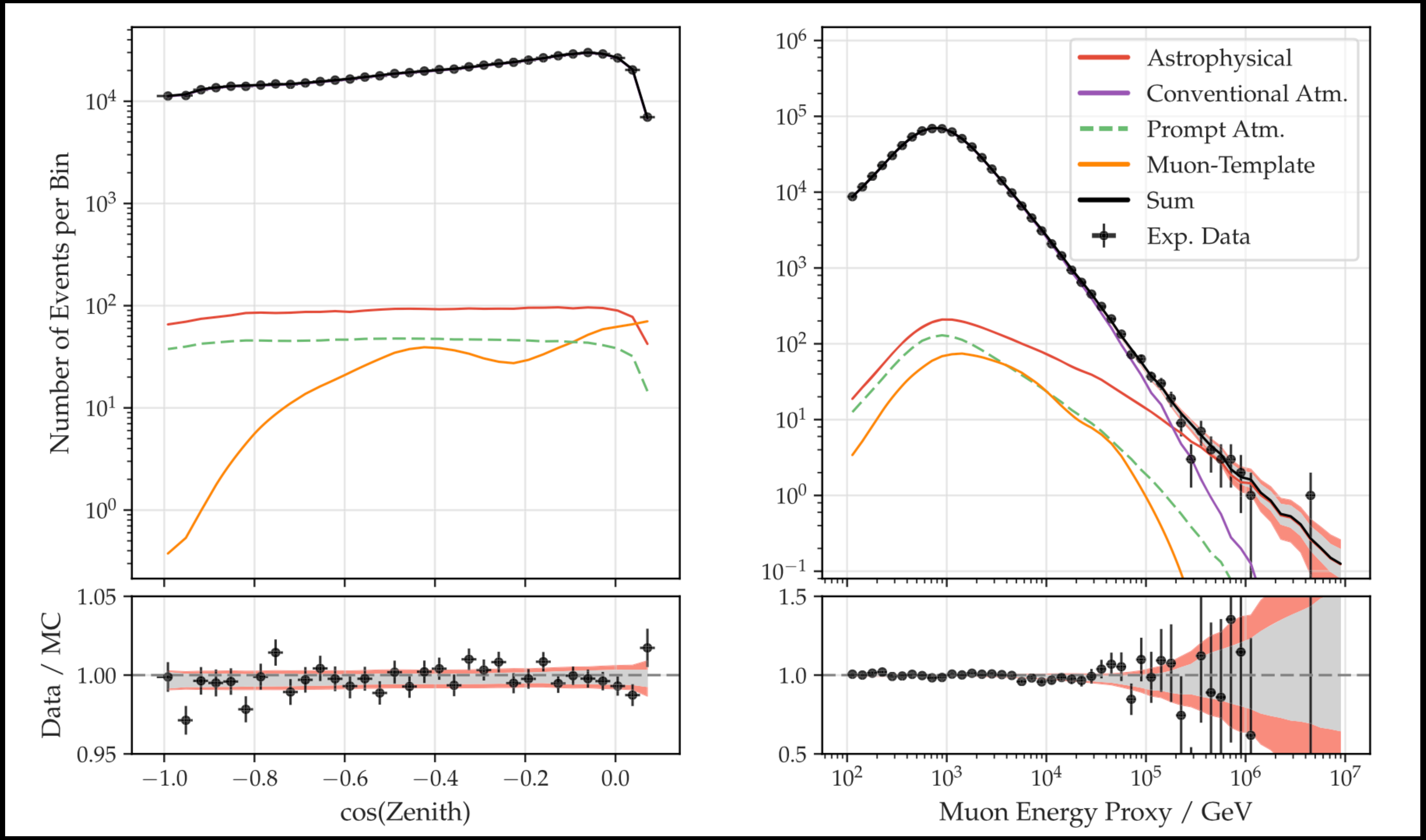


IceCube *Astrophys. J.*, 928(1):50, 2022

Main Background

- Atmospheric μ
- Atmospheric $\nu_\mu + \nu_e$
- Diffuse astrophysical $\nu_\mu + \nu_e + \nu_\tau$
- Galactic plane ν

Newly implemented



IceCube *Astrophys. J.*, 928(1):50, 2022

Search for DM with TRIDENT

- **Expected events**

effective area

$$\mu = \boxed{T} \int d\Omega_\nu \int dE_\nu \boxed{\frac{d^2\Phi_\nu}{dE_\nu d\Omega_\nu}} \boxed{A_{\rm eff}} \int_{\Delta E_{\rm rec}} dE_{\rm rec} \int_{\Delta\Omega_{\rm rec}} d\Omega_{\rm rec} \boxed{\mathcal{G}_E(E_{\rm rec}|E_\nu)} \boxed{\mathcal{G}_\Omega(\Omega_{\rm rec}|E_\nu)}$$

exposure time 10 yrs

ν flux per angular & energy bin

energy smearing

angular smearing

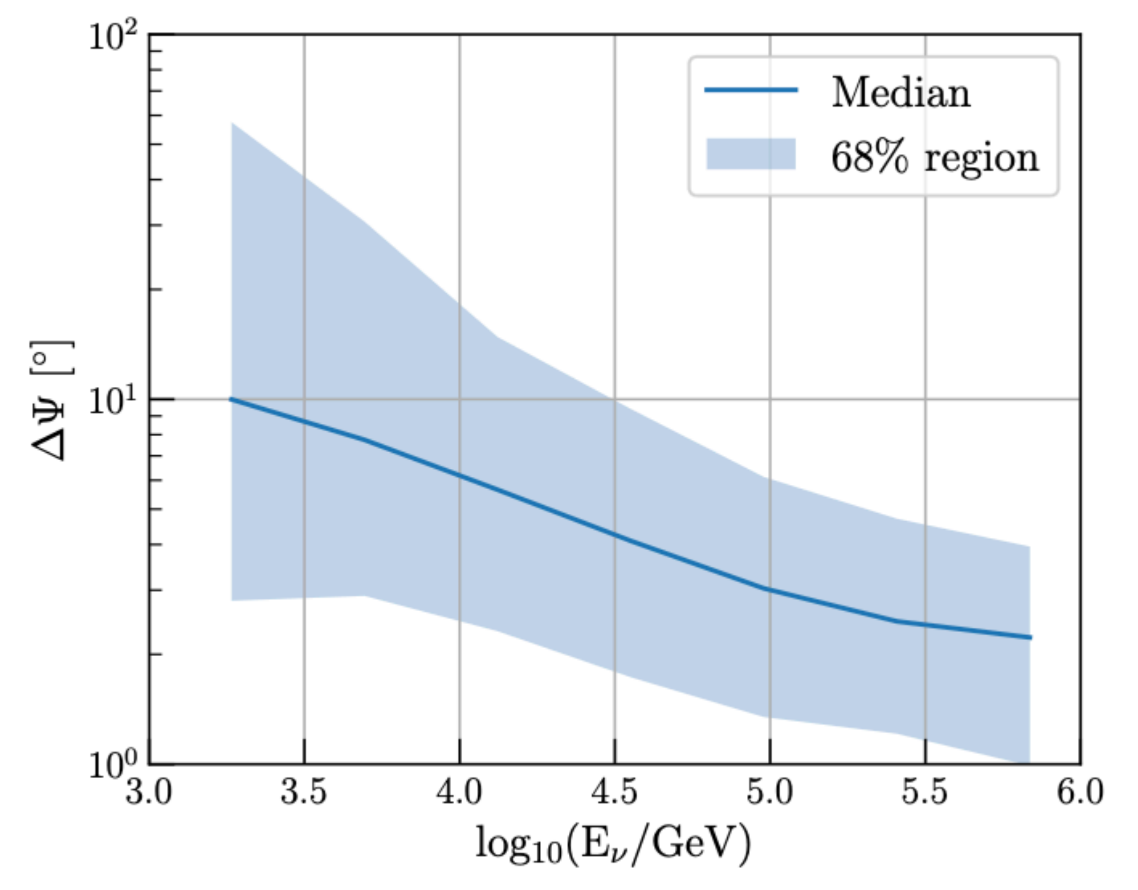
- **Poisson Likelihood**

$$\mathcal{L}(\langle\sigma v\rangle) = \prod_{ij} \frac{(s_{ij}+b_{ij})^{n_{ij}}}{n_{ij}!} e^{-(s_{ij}+b_{ij})}$$

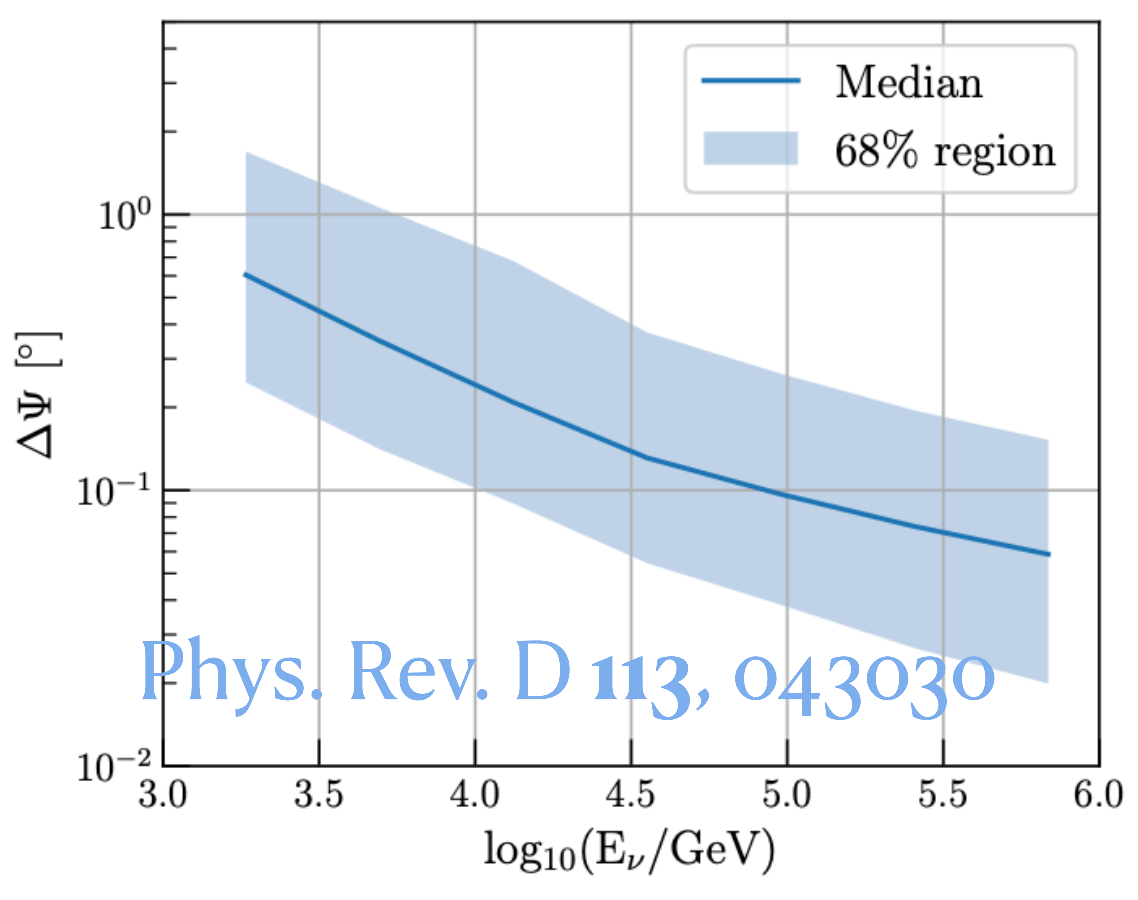
$$\mathrm{TS} = -2\ln\left(\frac{\mathcal{L}(\hat{s})}{\mathcal{L}(s=0)}\right)$$

Search for DM with TRIDENT

Cascade



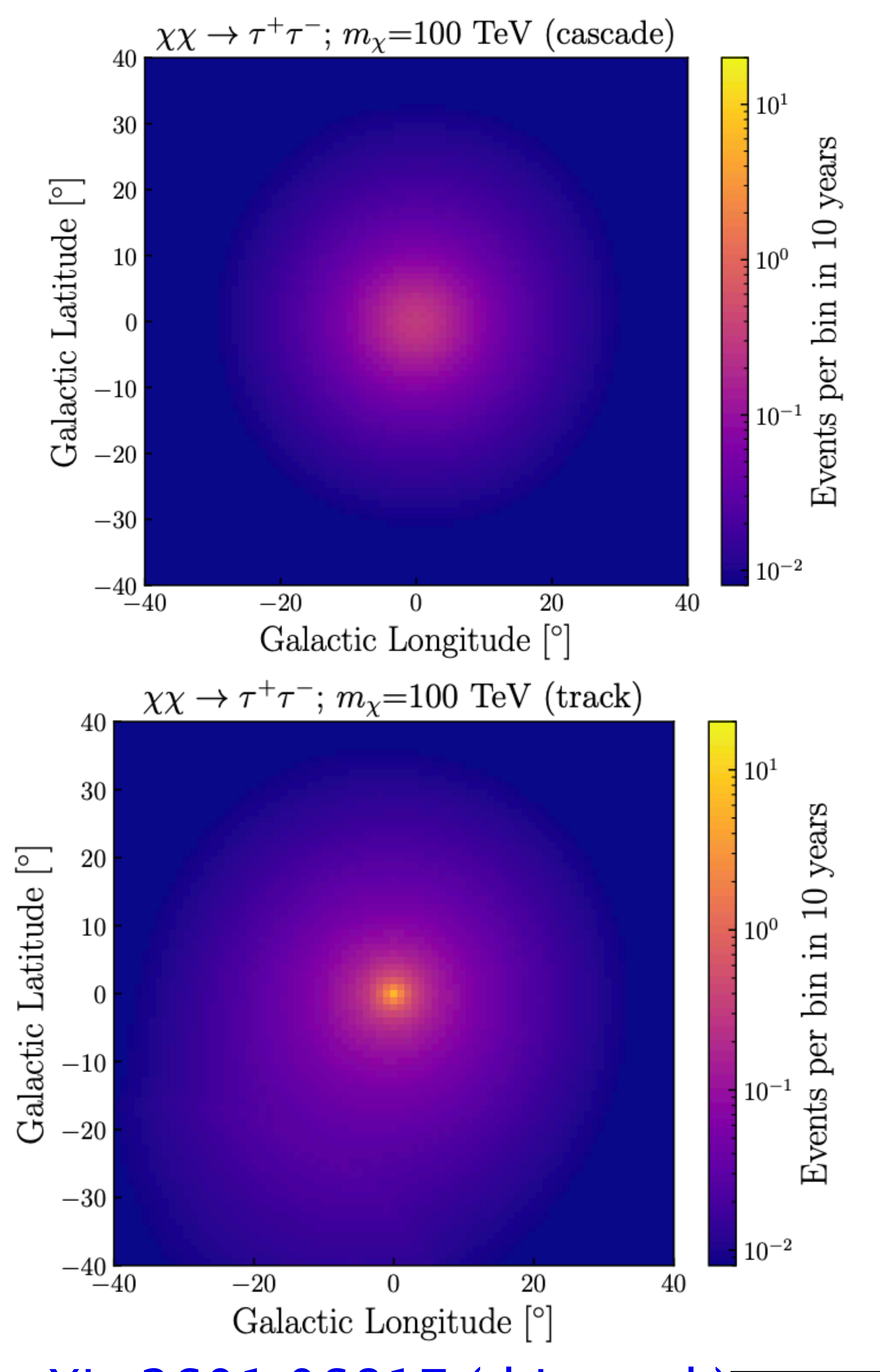
Track



Phys. Rev. D 113, 043030

angular resolution

angular smearing



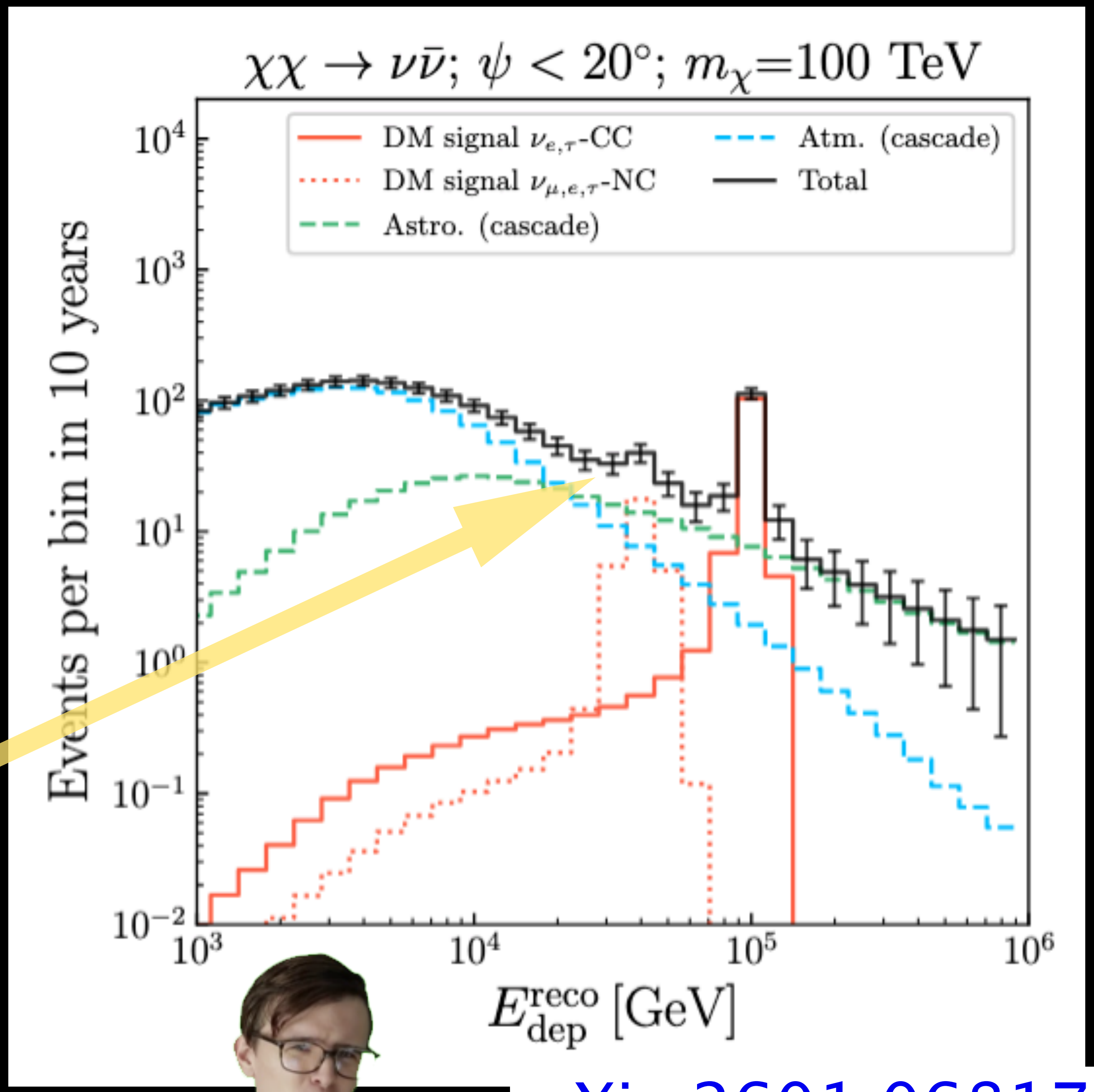
arXiv:2601.06817 (this work)

wei Wang

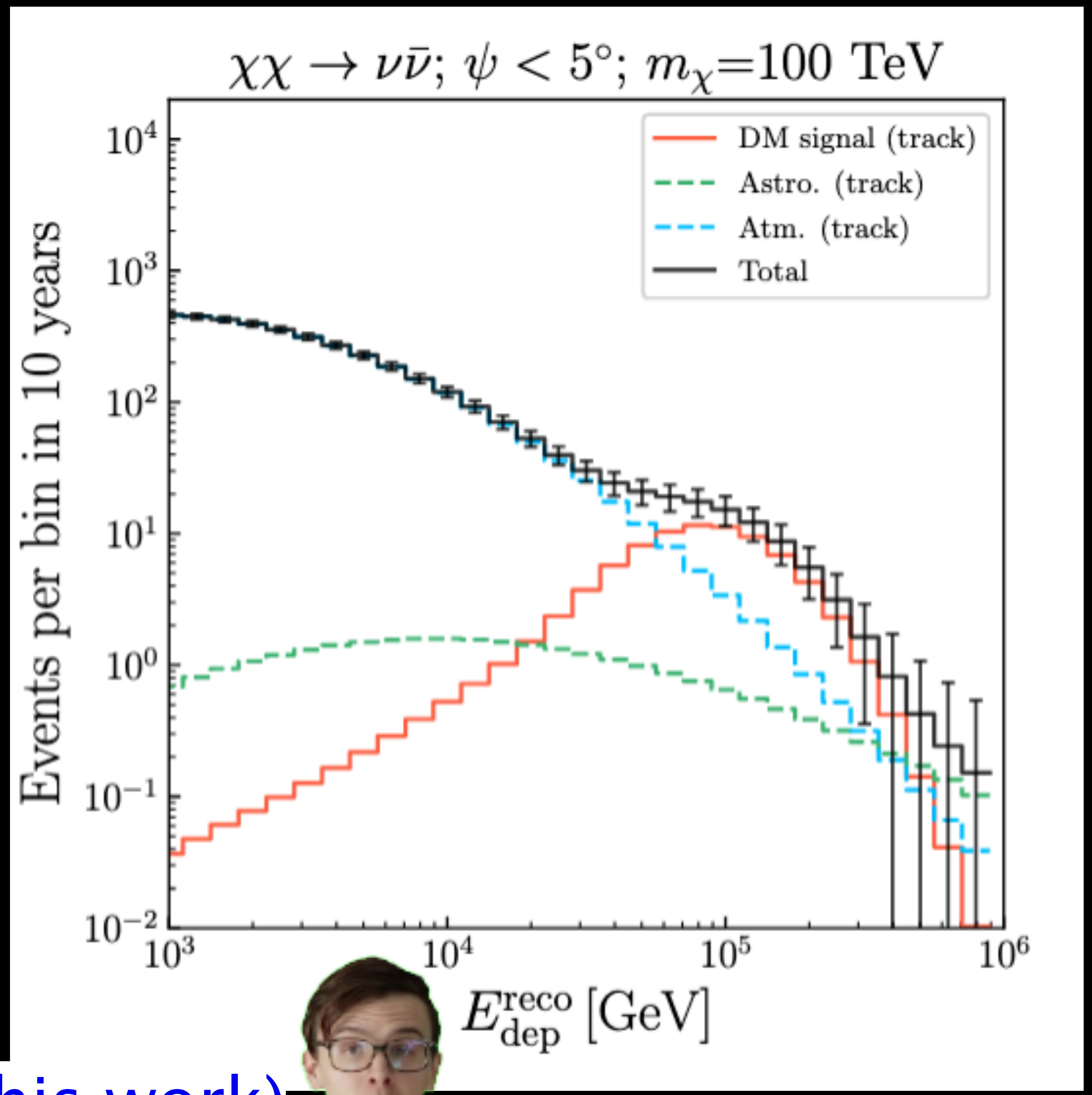
Search for DM with TRIDENT

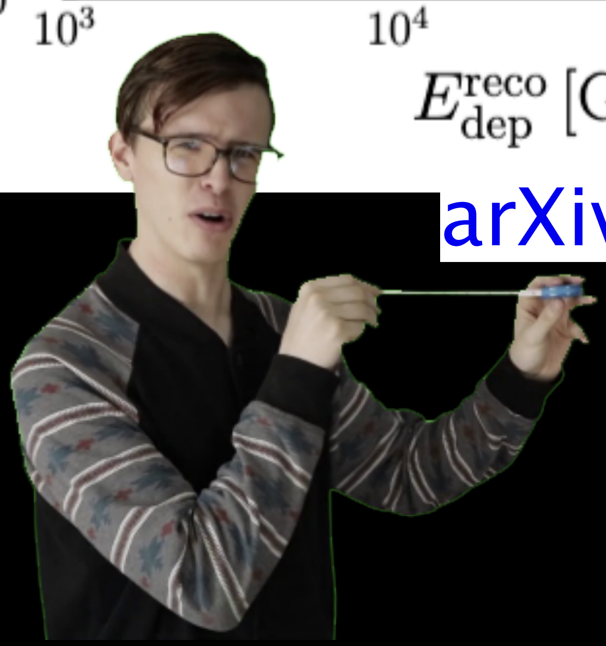
- Energy resolution assumed based on TRIDENT GNN reconstruction
  Phys. Rev. D **112**, 072012
  - ν_μ CC: $\sigma(log_{10}(E_{reco}/E_\nu)) = 0.27$
  - ν_e CC: $\sigma(log_{10}(E_{reco}/E_\nu)) = 0.04$
- scaled reconstructed energy for NC events

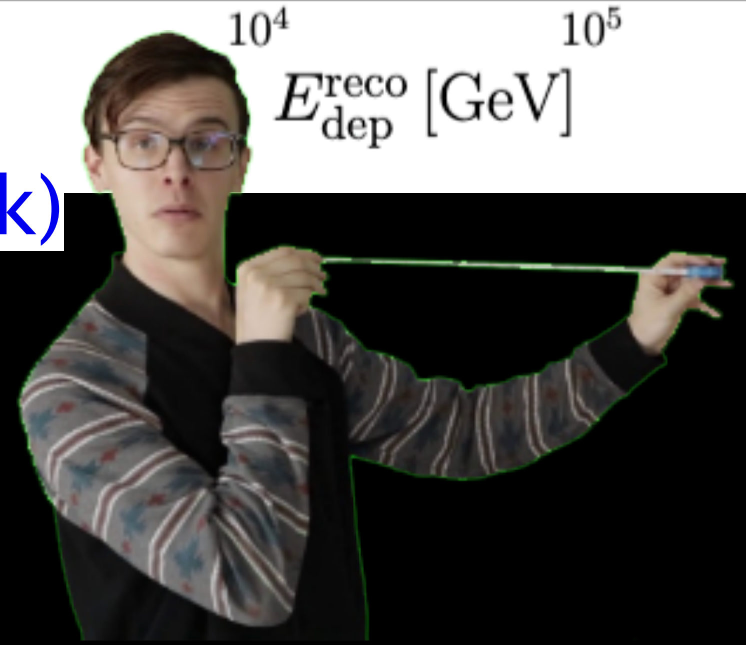
Cascade



Track

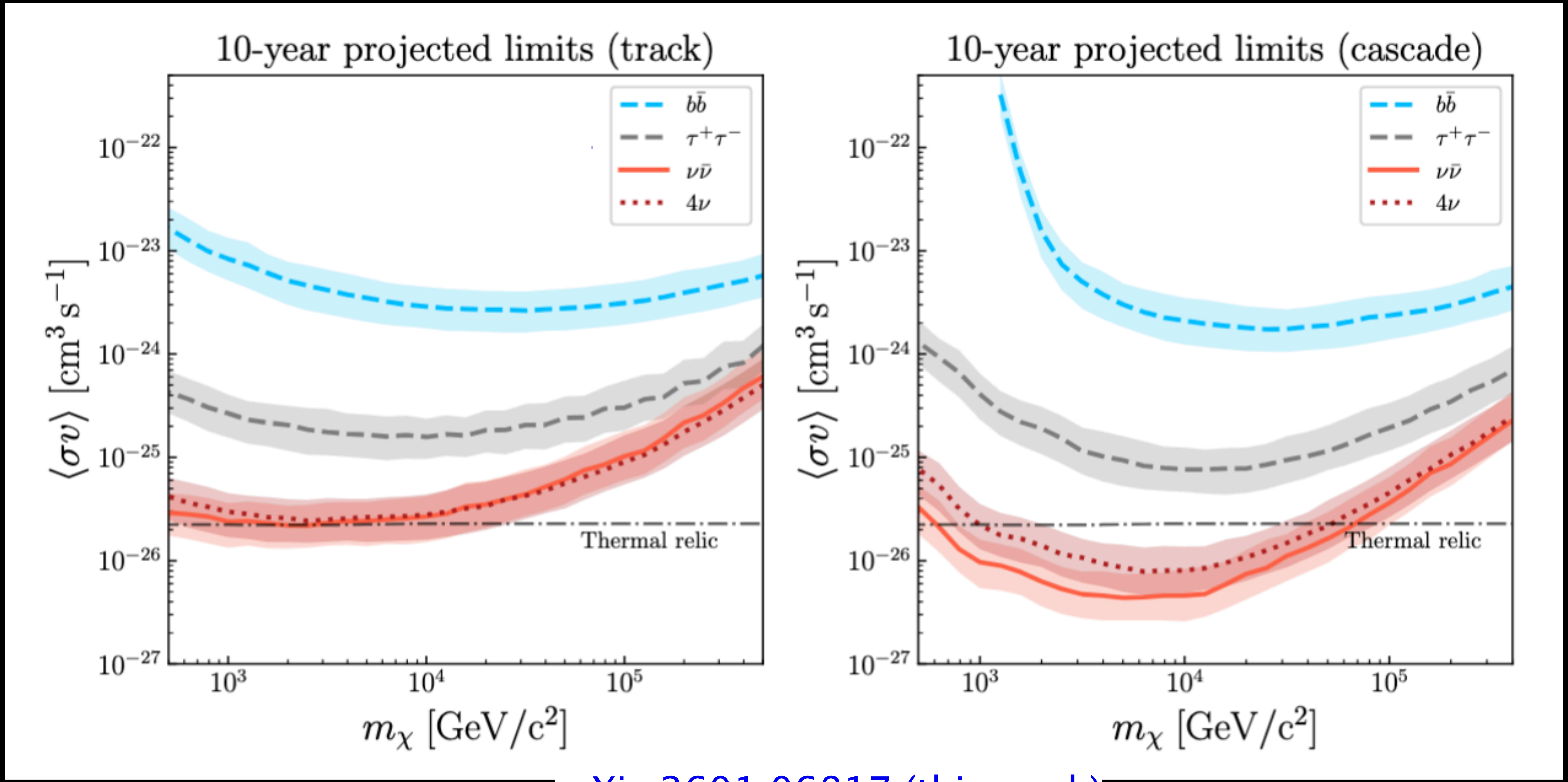






arXiv:2601.06817 (this work)

10-year Projected Sensitivity

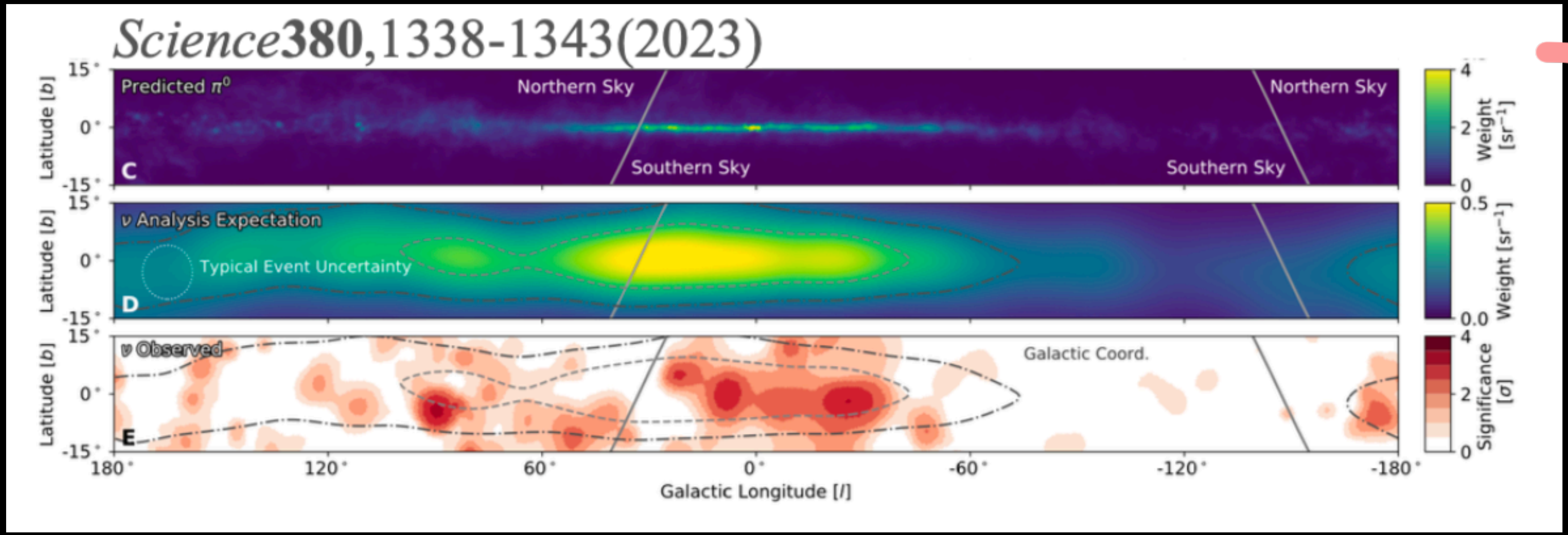


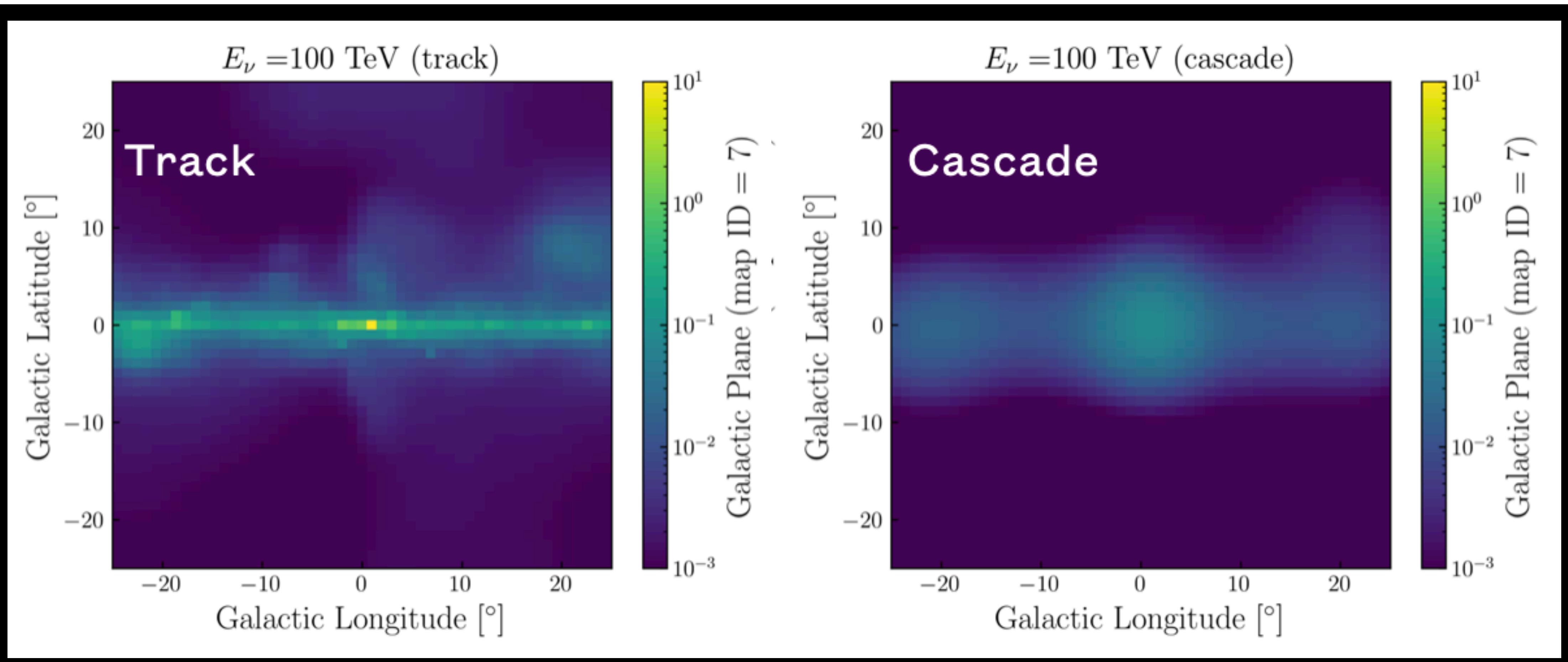
arXiv:2601.06817 (this work)

- BKG: Atm. + Astro.
- ν-direct channels provide strongest sensitivity
- Non-neutrino channels are weaker due to softer spectra
- Cascade channel performs better due to precise energy resolution and lower background level

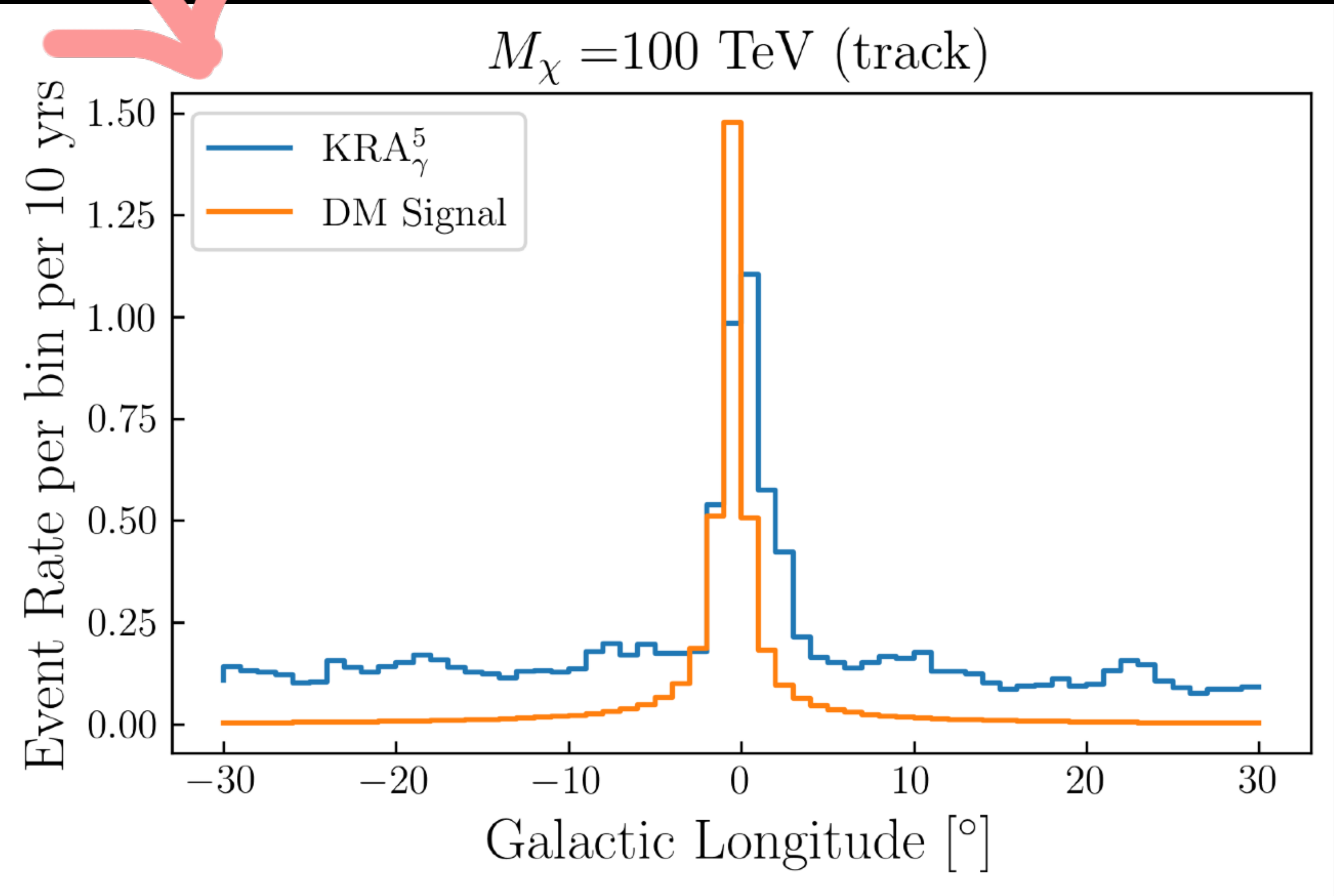
Impact of Galactic Plane Background

- IceCube identified ν emission from Galactic plane at 4.5σ

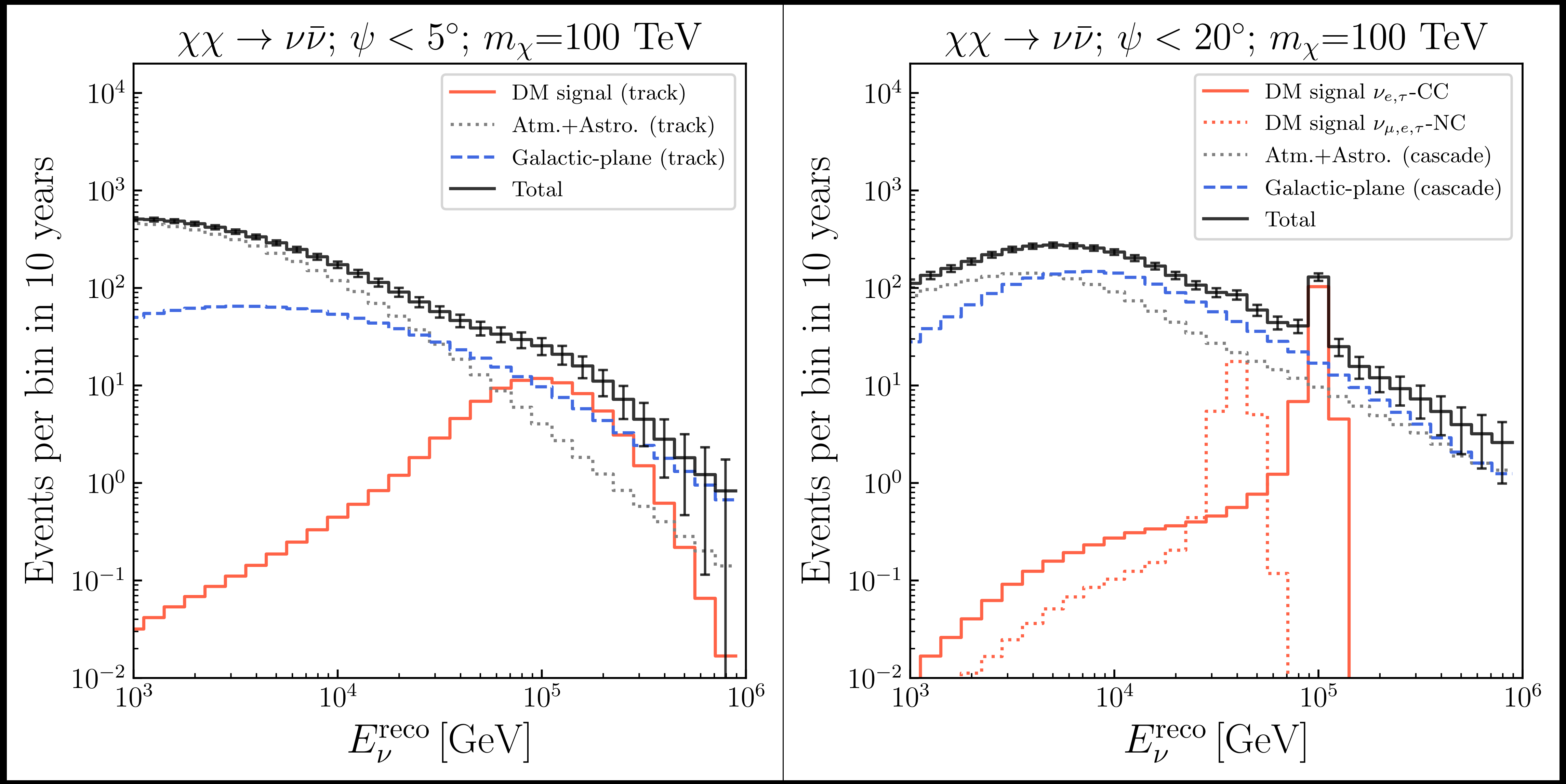


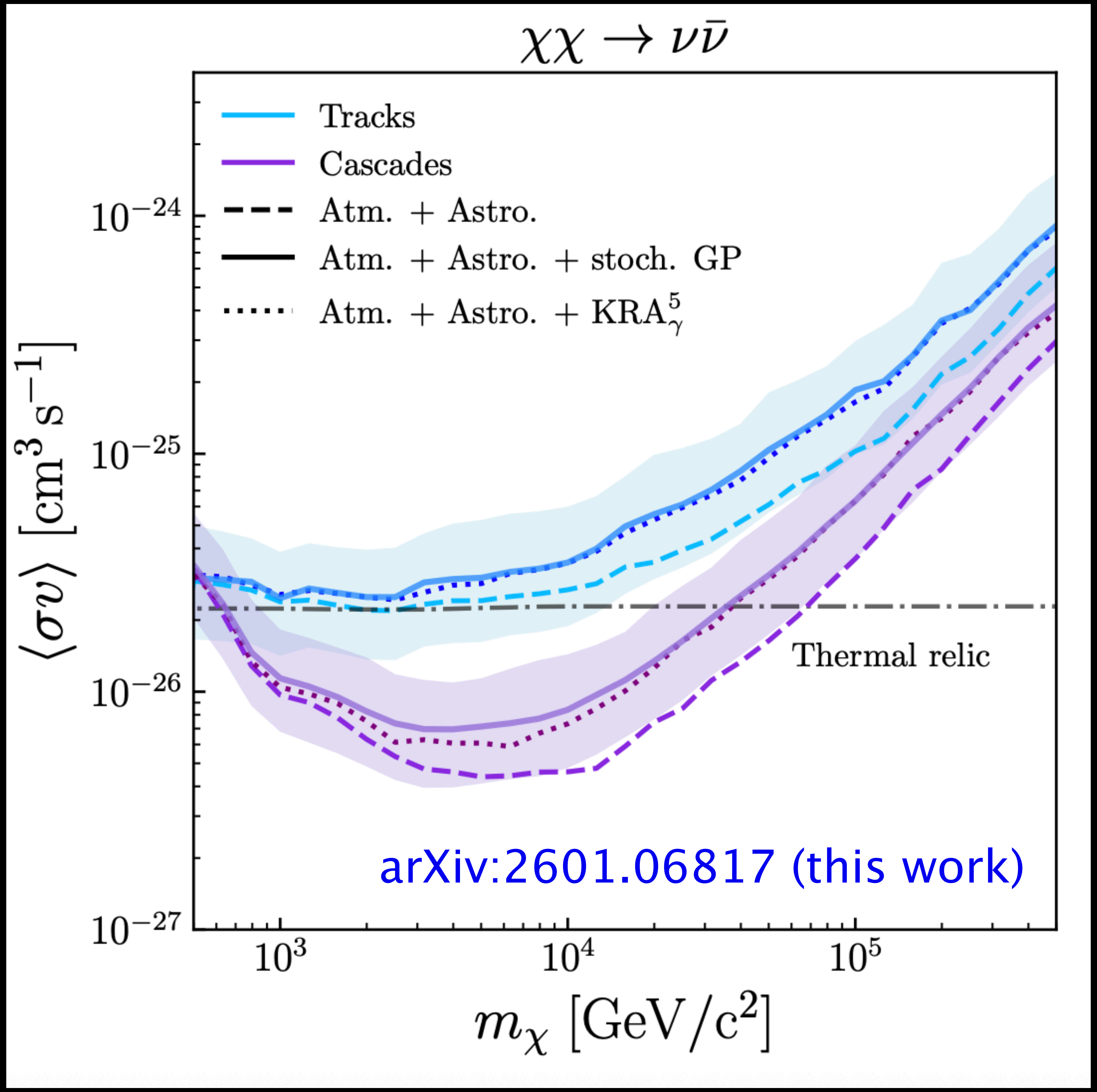


Overlap with DM signal from Galactic Centre



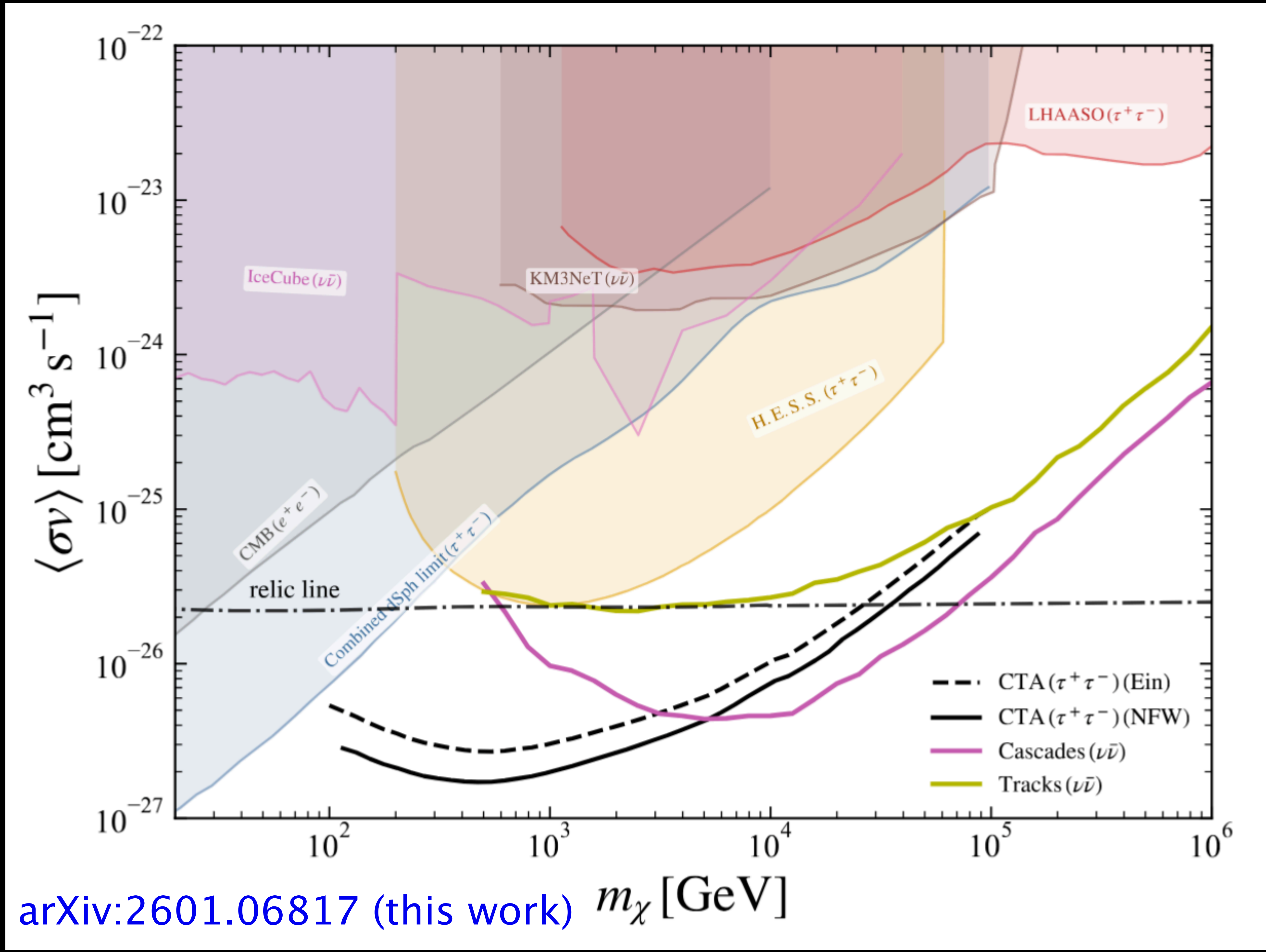
Impact of Galactic Plane Background





- Galactic plane map: JCAP01(2025)049
  - Stoch. GP: discrete PeV cosmic-ray sources simulation
  - KRA_γ^5: IceCube best-fit Science380,1338(2023)
- sensitivities are more degraded above ~ 10TeV
- Maximal weakening of a factor of 2

Summary



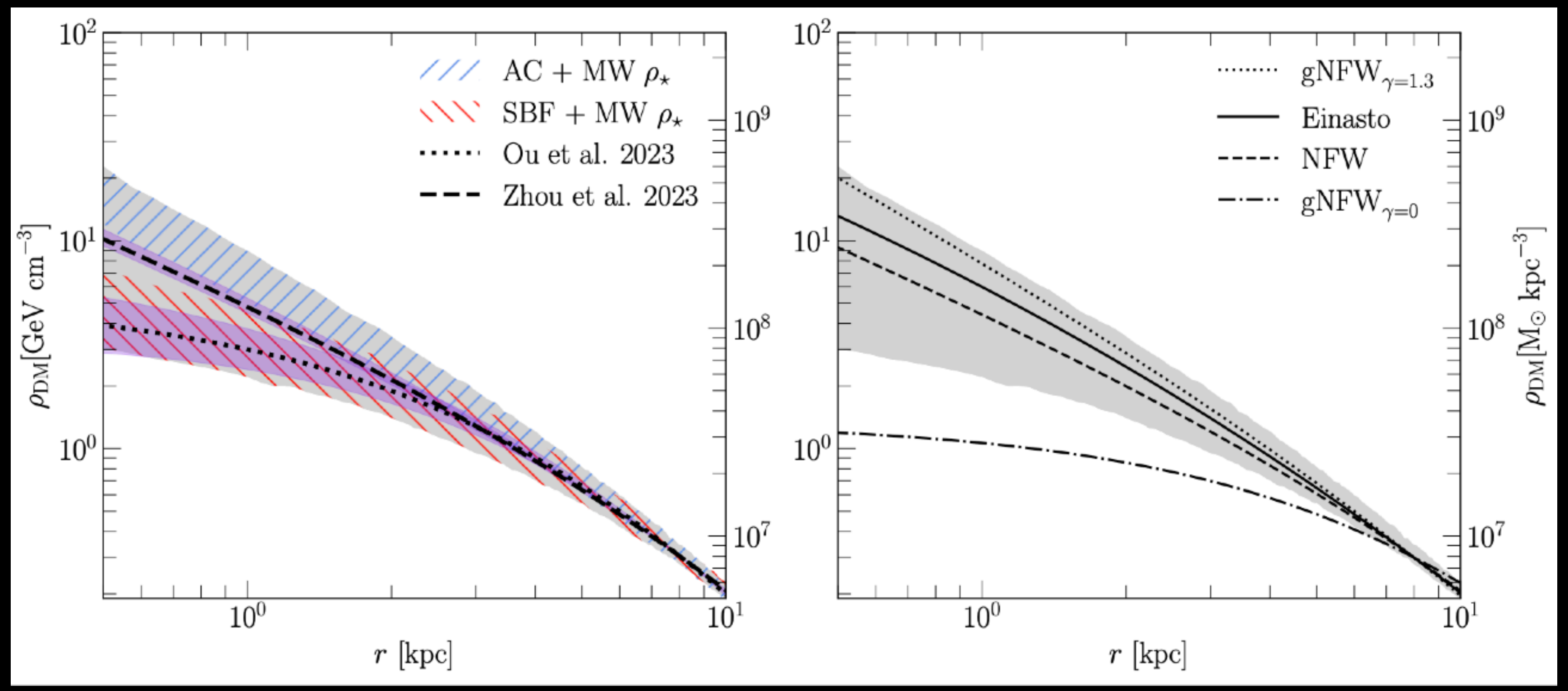
- We forecast the sensitivity of the TRIDENT to the DM annihilation in the Galactic Centre
- The cascade events can boost the sensitivity, with precise energy resolution and lower atmospheric backgrounds
- The Galactic plane background degrades the sensitivity by up to a factor of 2

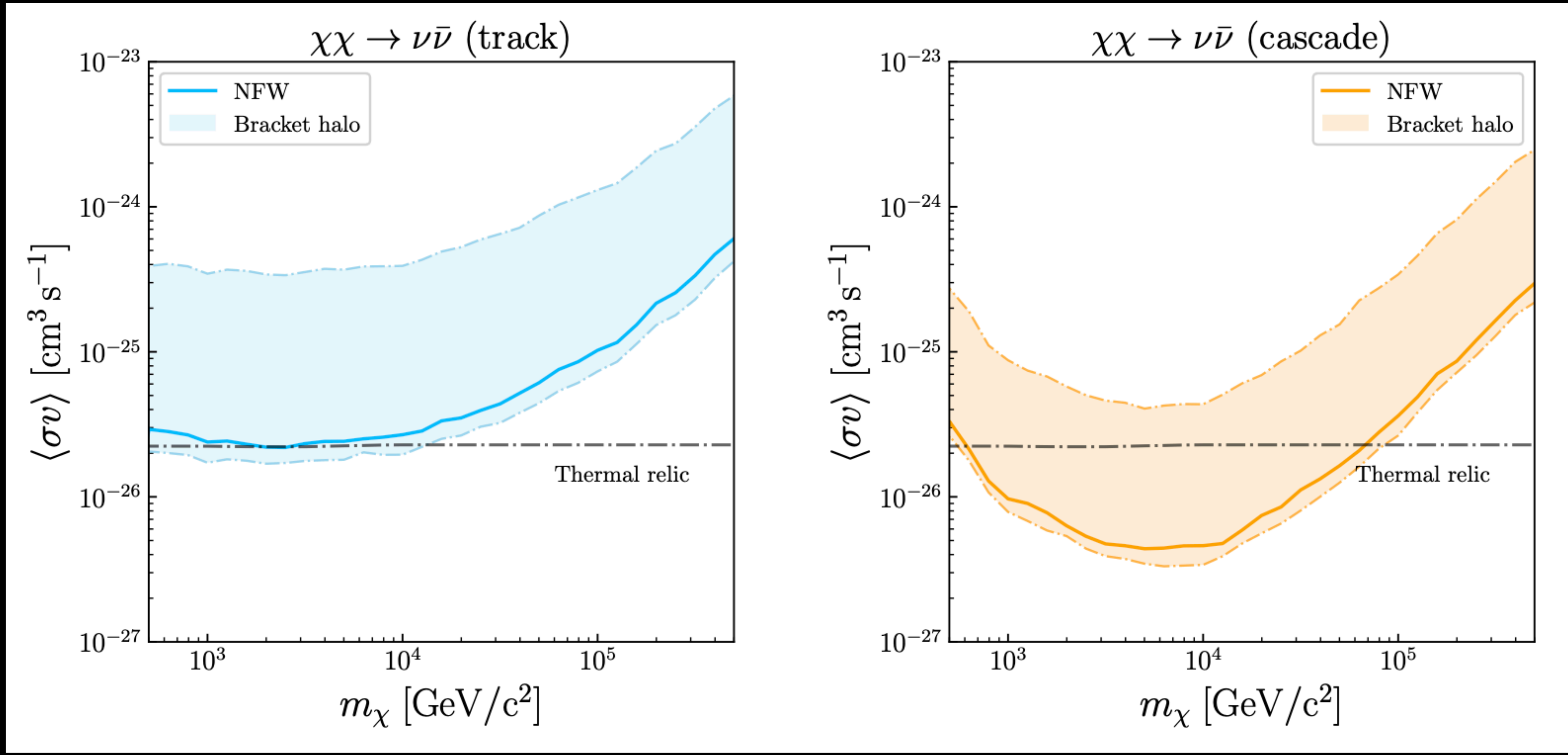

TDLI

backup

Halo Profile Uncertainty

- The bracket profile:
  - Adiabatically contracted→ spherical
  - Baryonic feedback → oblate



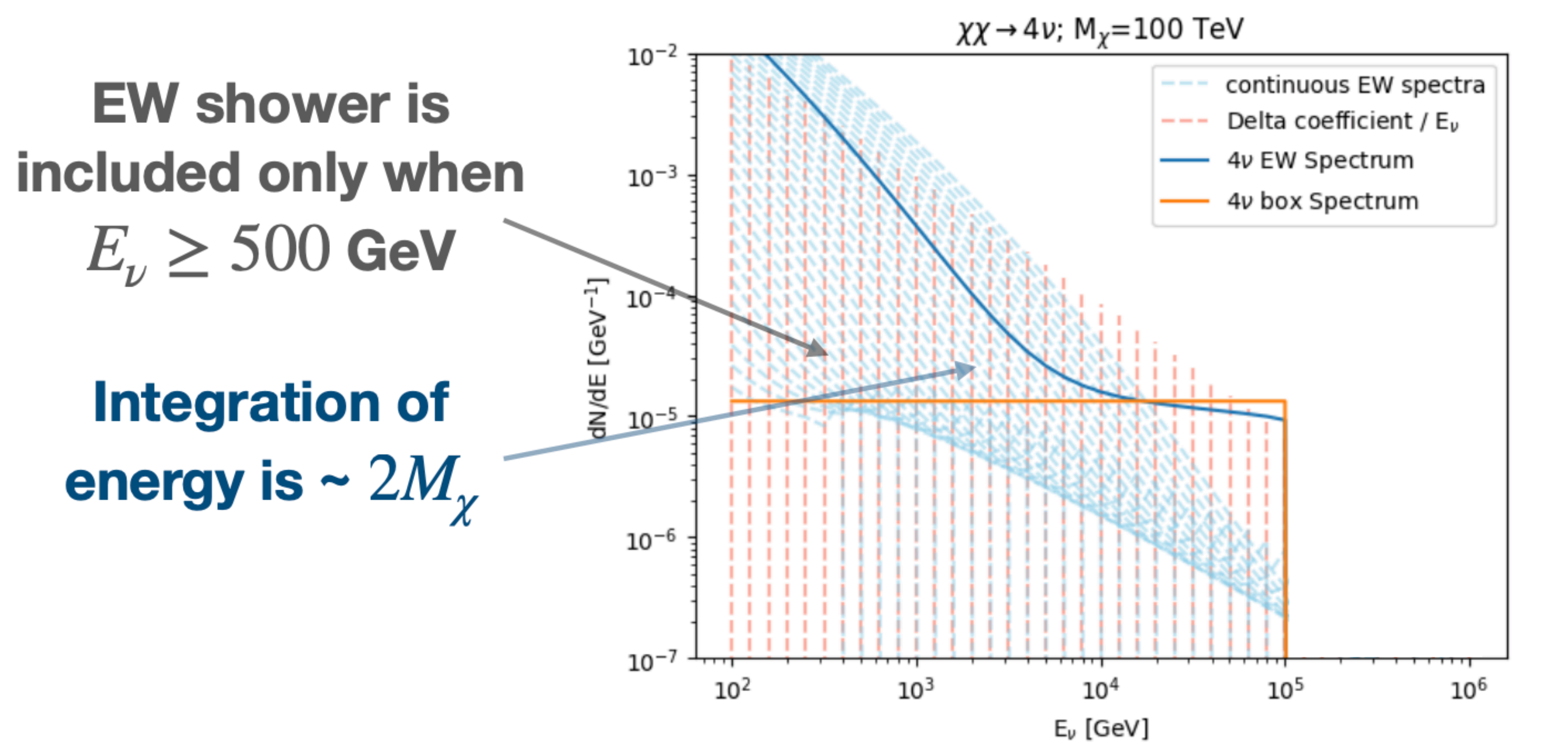


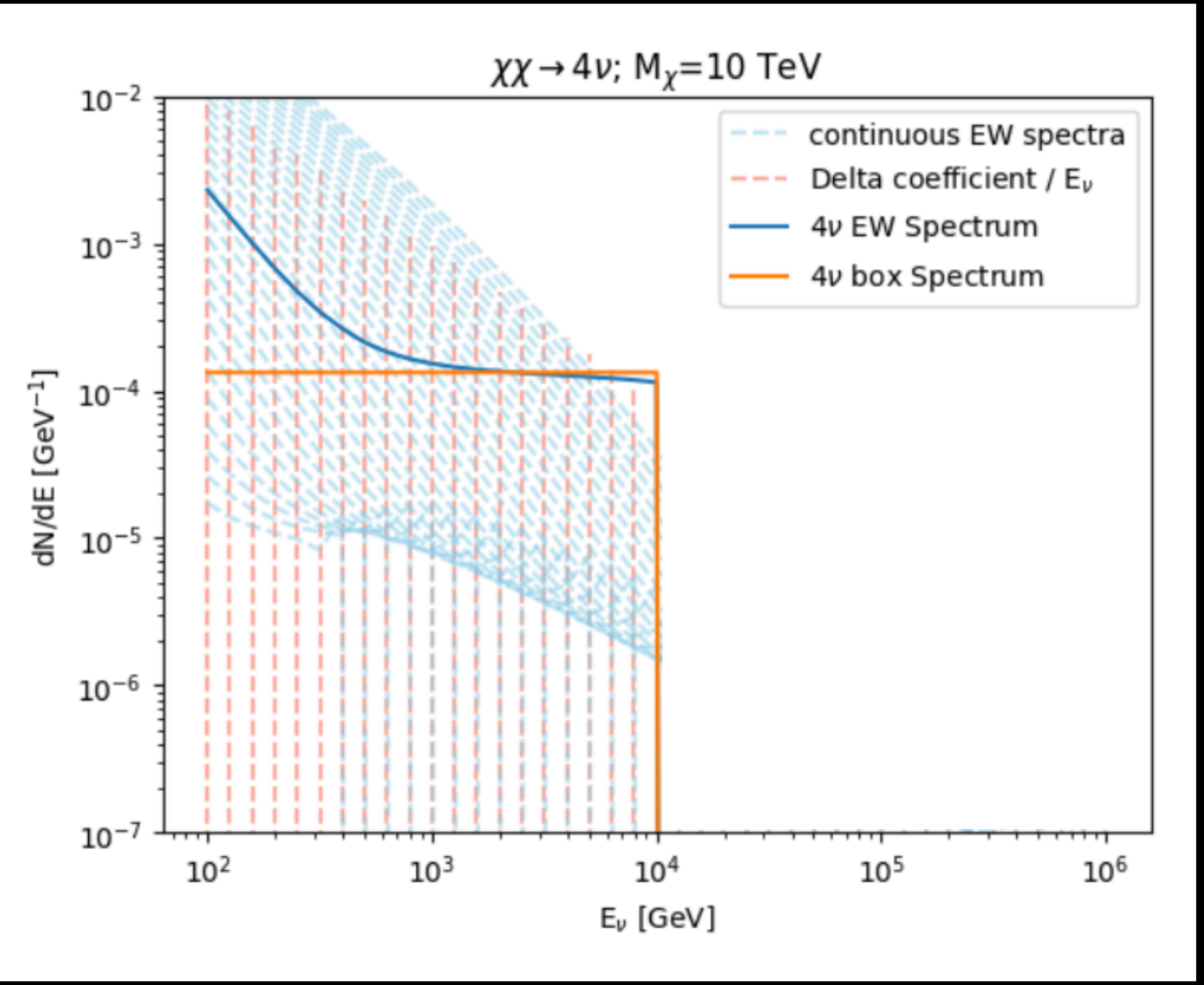
4ν Spectrum + EW correction

- The HDMSpectra doesn't include 4ν channel spectra
- We modelled it as a series of many neutrino lines and performing a weighted sum of corrected 2ν spectra

$$\frac{dN^{EW}_{BOX}}{dE} = \boxed{\int \frac{dN_{BOX}}{dE} \cdot \frac{dN^{EW}}{dE'}} + \boxed{\frac{dN_{BOX}}{dE}(E_\nu = m_\chi) \cdot A_\delta(E_\nu = m_\chi)}$$

Continuous EW shower　　Without EW shower





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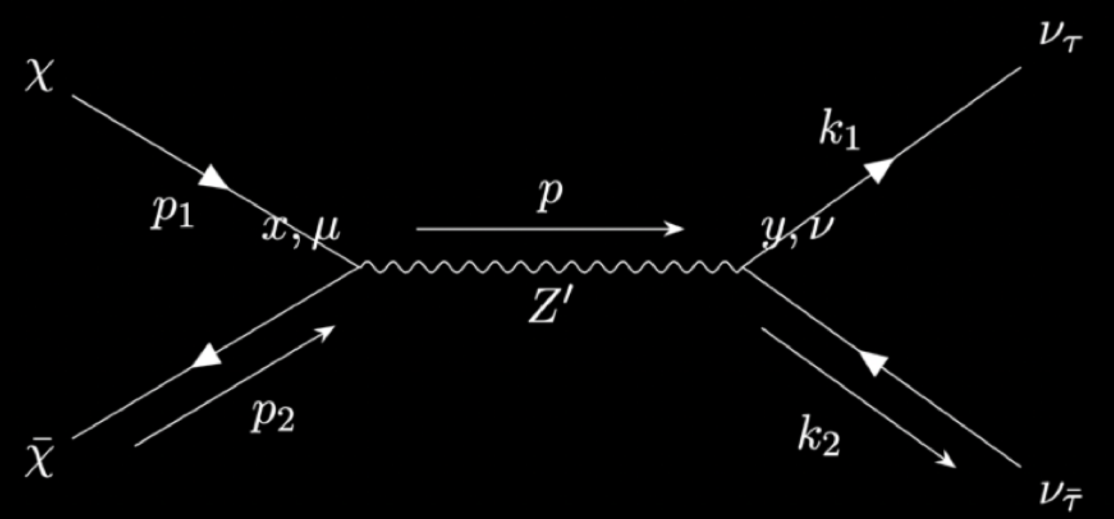
Constraints on $\mathrm{U}(1)_{L_i - L_j}$ Model

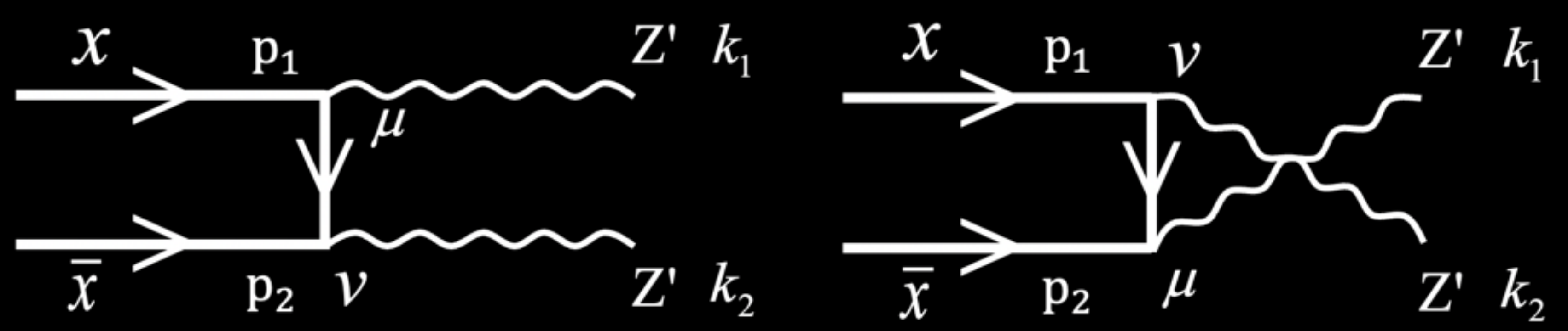
- The constraints on TRIDENT

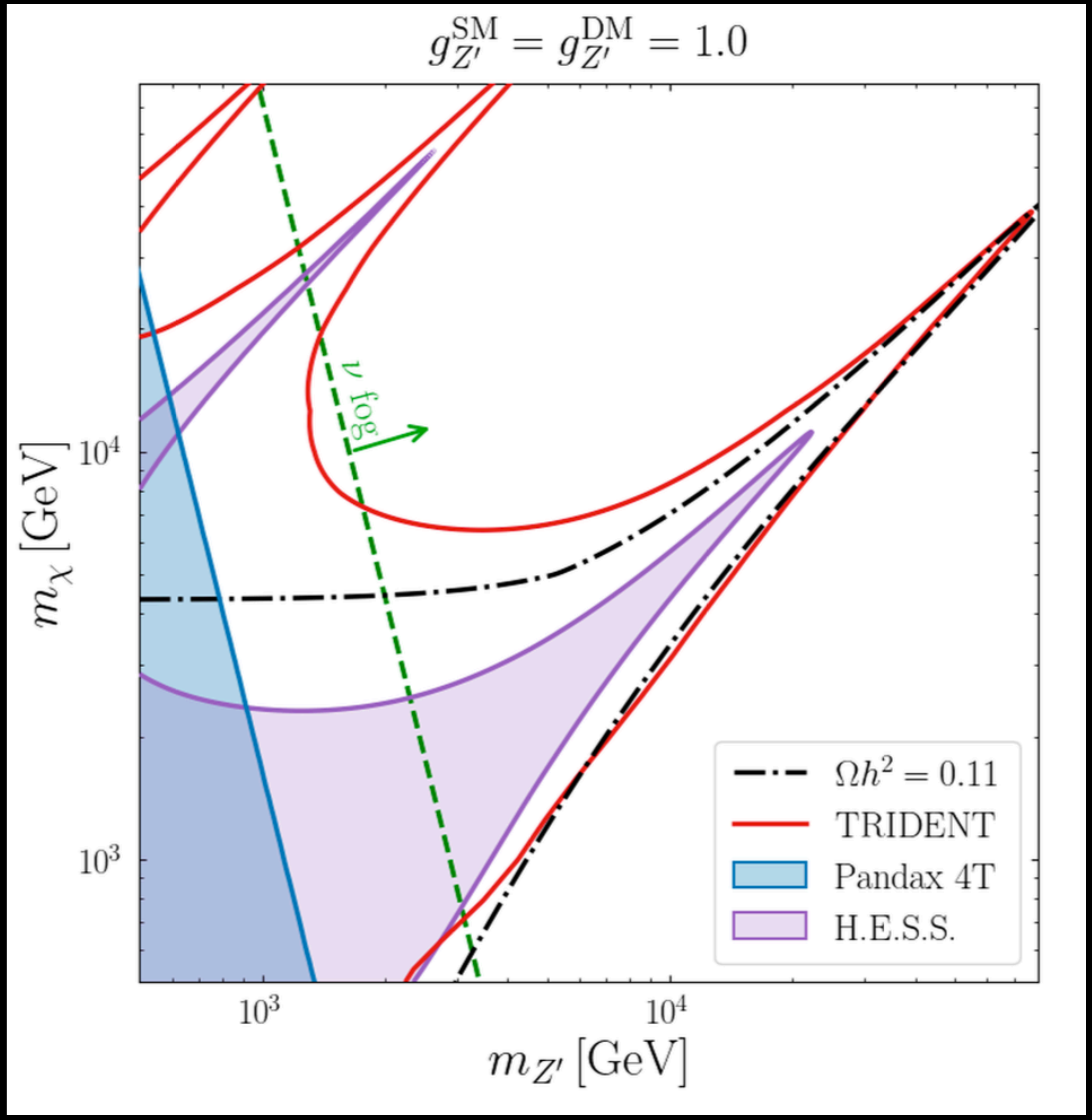
s-channel
$m_{Z'} > m_\chi$



$$\langle \sigma v \rangle \sim \frac{(g_{Z'}^{\mathrm{SM}} g_{Z'}^{\mathrm{DM}})^2}{(4m_\chi^2 - m_{Z'}^2)^2}.$$

t-channel
$m_{Z'} < m_\chi$





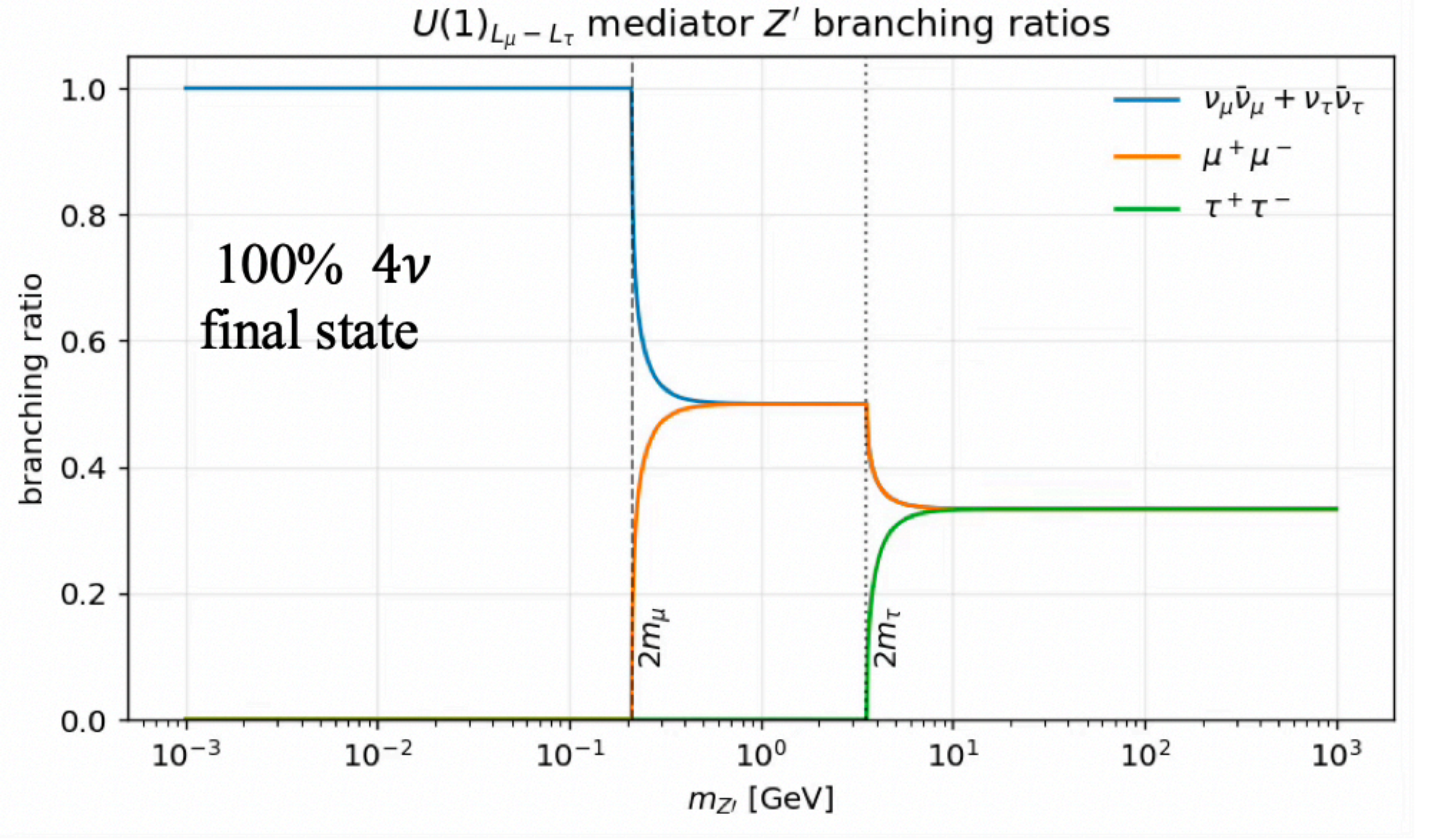
- The constraints from Pandax-4T

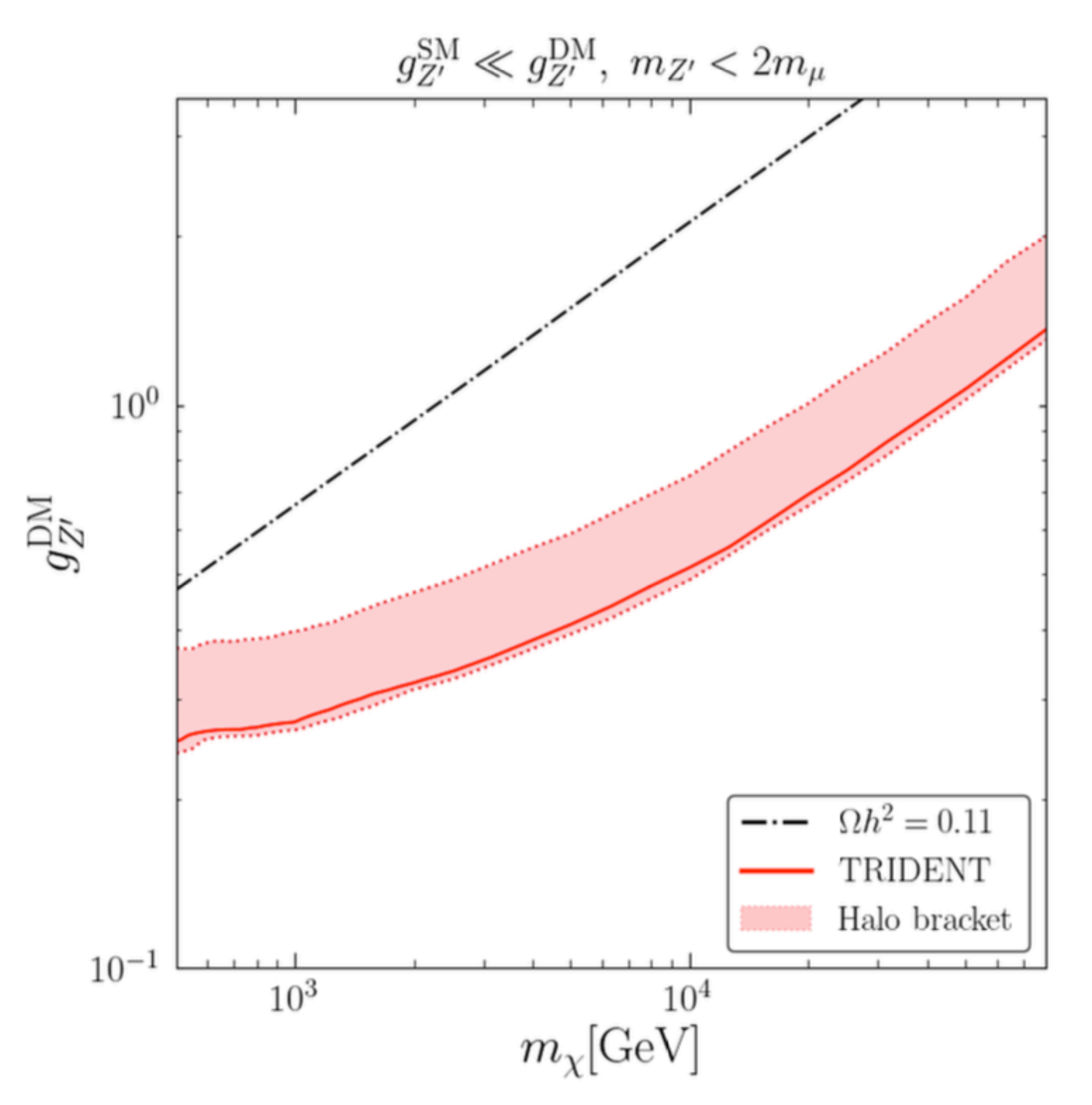
$$\sigma_{\chi p} = \frac{m_\chi^2 m_p^2}{\pi (m_\chi + m_p)^2} \frac{e^2 (g_{Z'}^{\mathrm{DM}})^2 \epsilon^2}{m_{Z'}^4} \propto \frac{1}{m_{Z'}^4}$$

Constraints on $\mathrm{U}(1)_{L_i - L_j}$ Model

When the mediator Z' is lighter than DM, the box-shaped spectra via the decay of Z' after the annihilation $\chi\chi \to Z'Z'$ is considerable. For such channels we determine the branching ratio by (multiply by 2 if $i \neq j$).

$$\mathrm{Br}_{i\bar{i}\,j\bar{j}} = \mathrm{Br}_{Z'Z'} \times \left(\frac{\Gamma\left(Z' \to i\bar{i}\right)}{\Gamma_{\mathrm{tot}}}\right) \times \left(\frac{\Gamma\left(Z' \to j\bar{j}\right)}{\Gamma_{\mathrm{tot}}}\right)$$





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