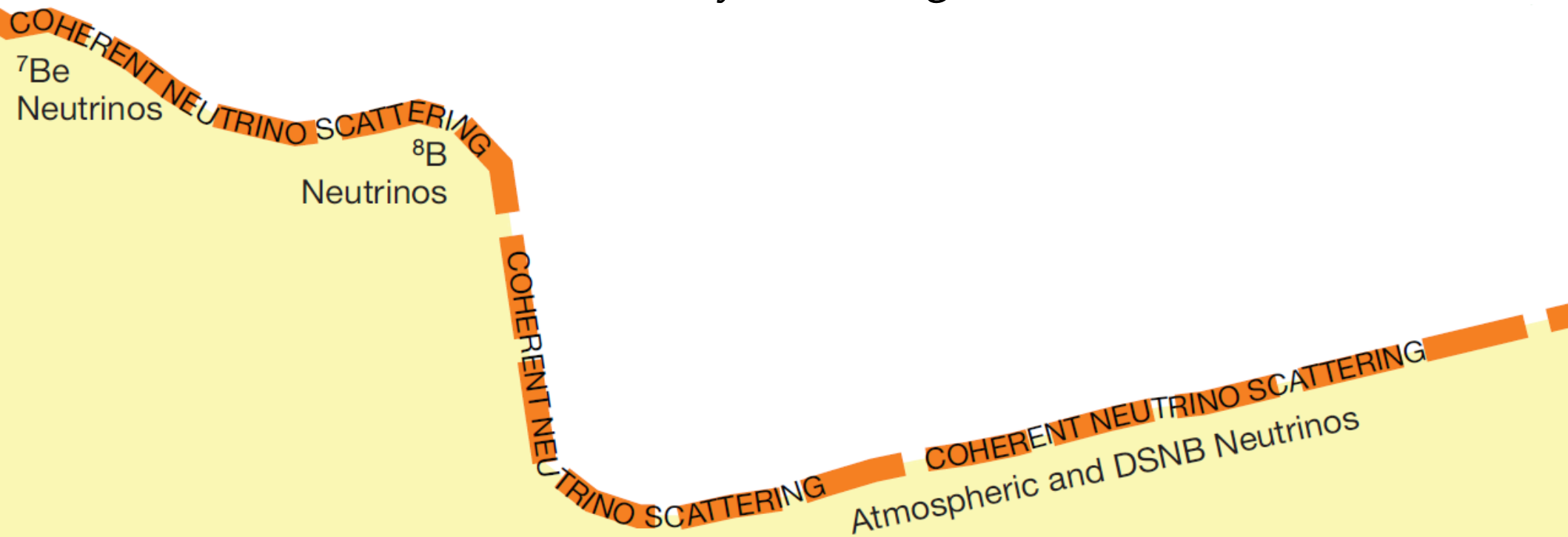




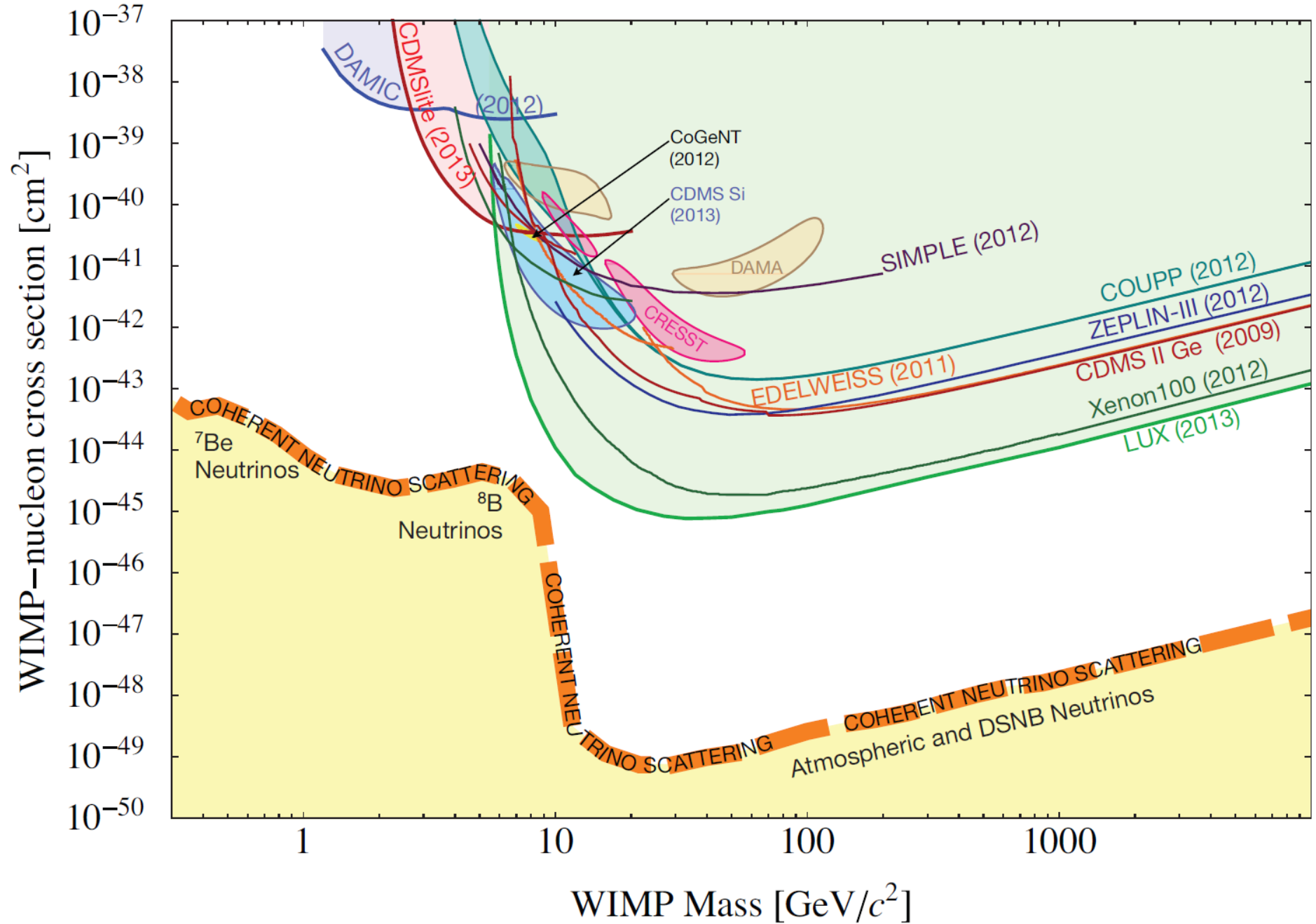
Direct detection and the neutrino floor

Ciaran A. J. O'Hare

University of Nottingham



J Billard, L Strigari, E Figueroa-Feliciano arXiv:1307.5458



Outline

- **Neutrino backgrounds**
- **Mapping the neutrino floor**
- **Strategies**

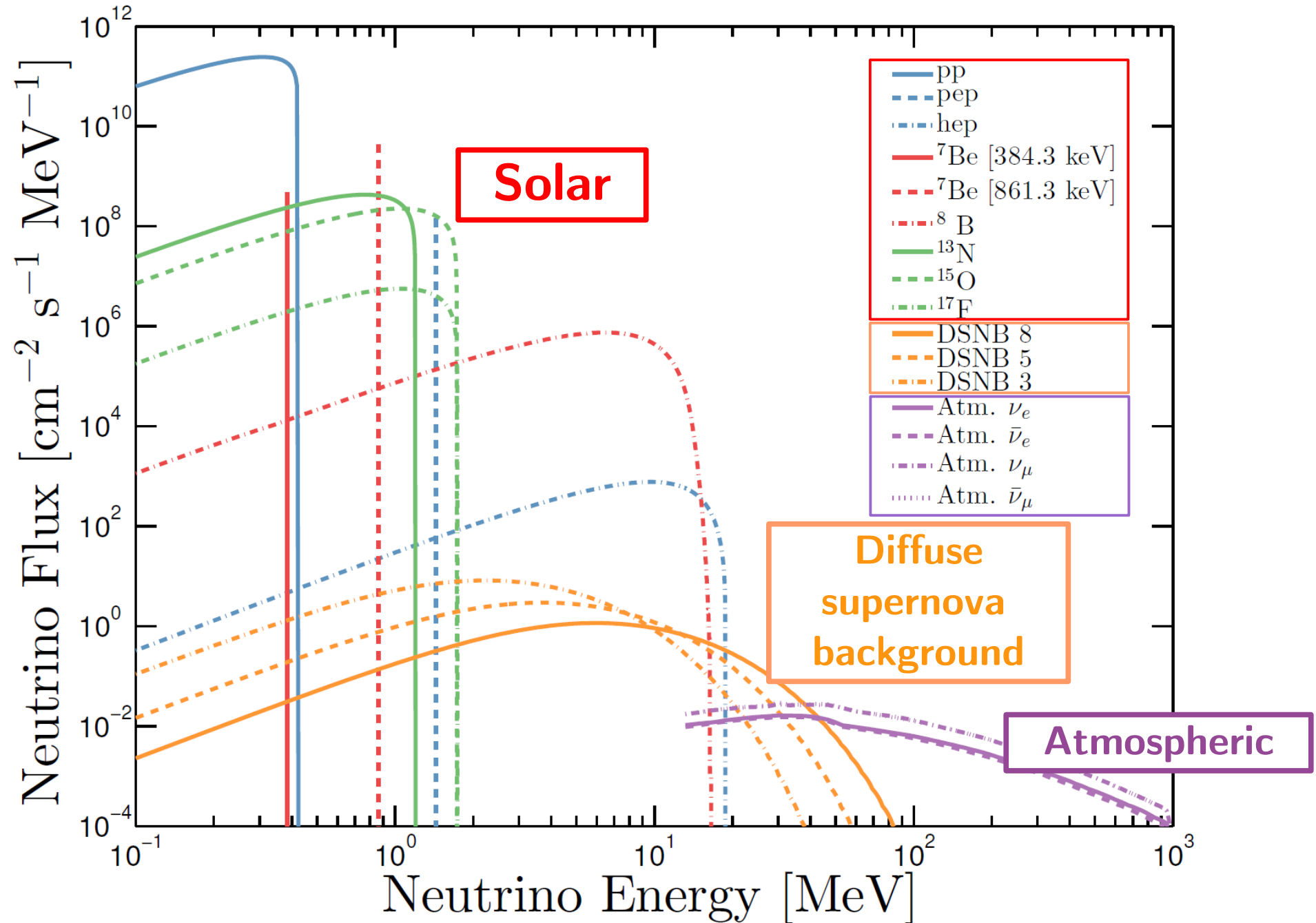
Based on

C.A.J. O'Hare, J. Billard, E. Figueroa-Feliciano, A. Green & L. Strigari [[1505.08061](#)]

C.A.J. O'Hare [[1604.03858](#)]

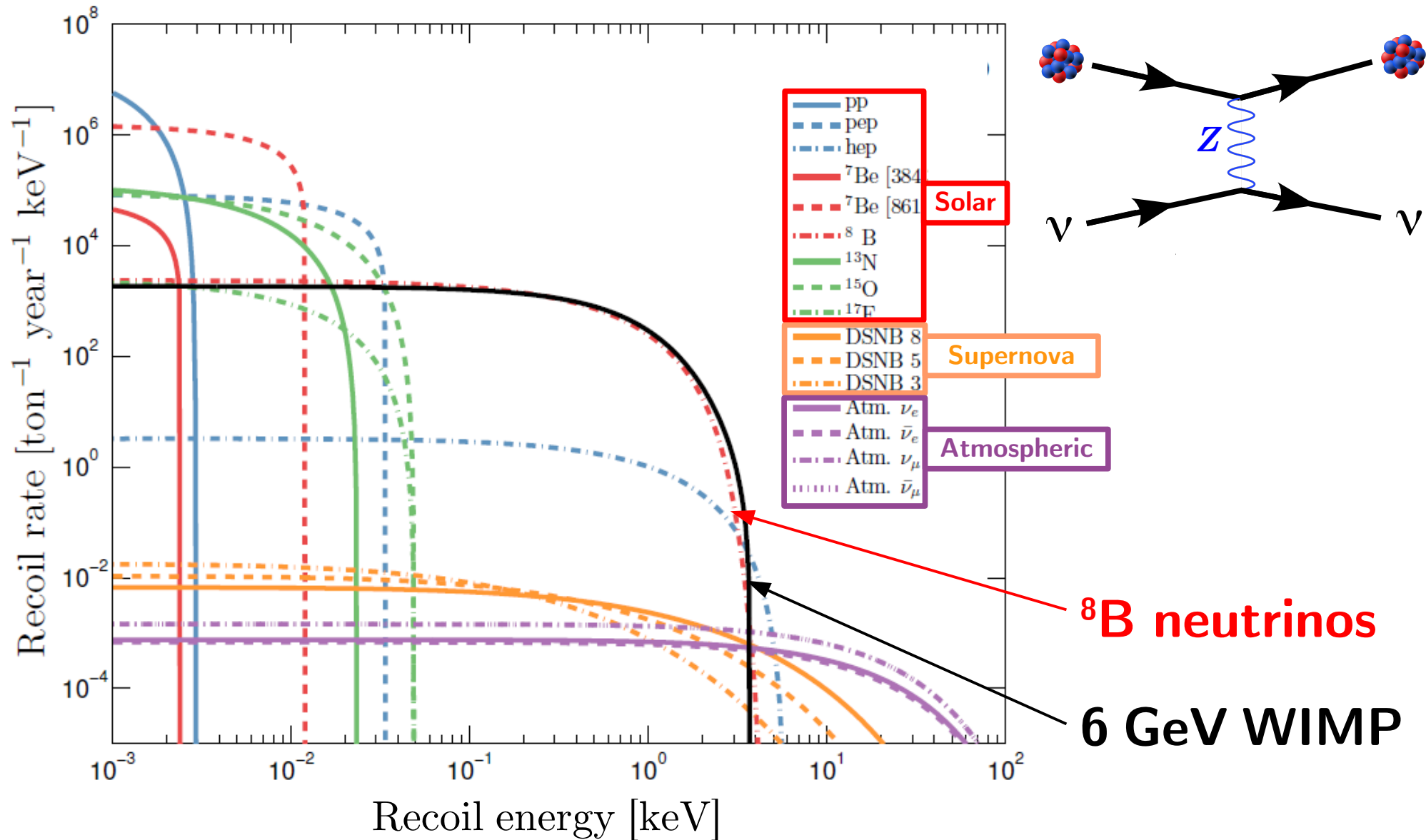
C.A.J. O'Hare & A. Green [[in prep.](#)]

Neutrino backgrounds



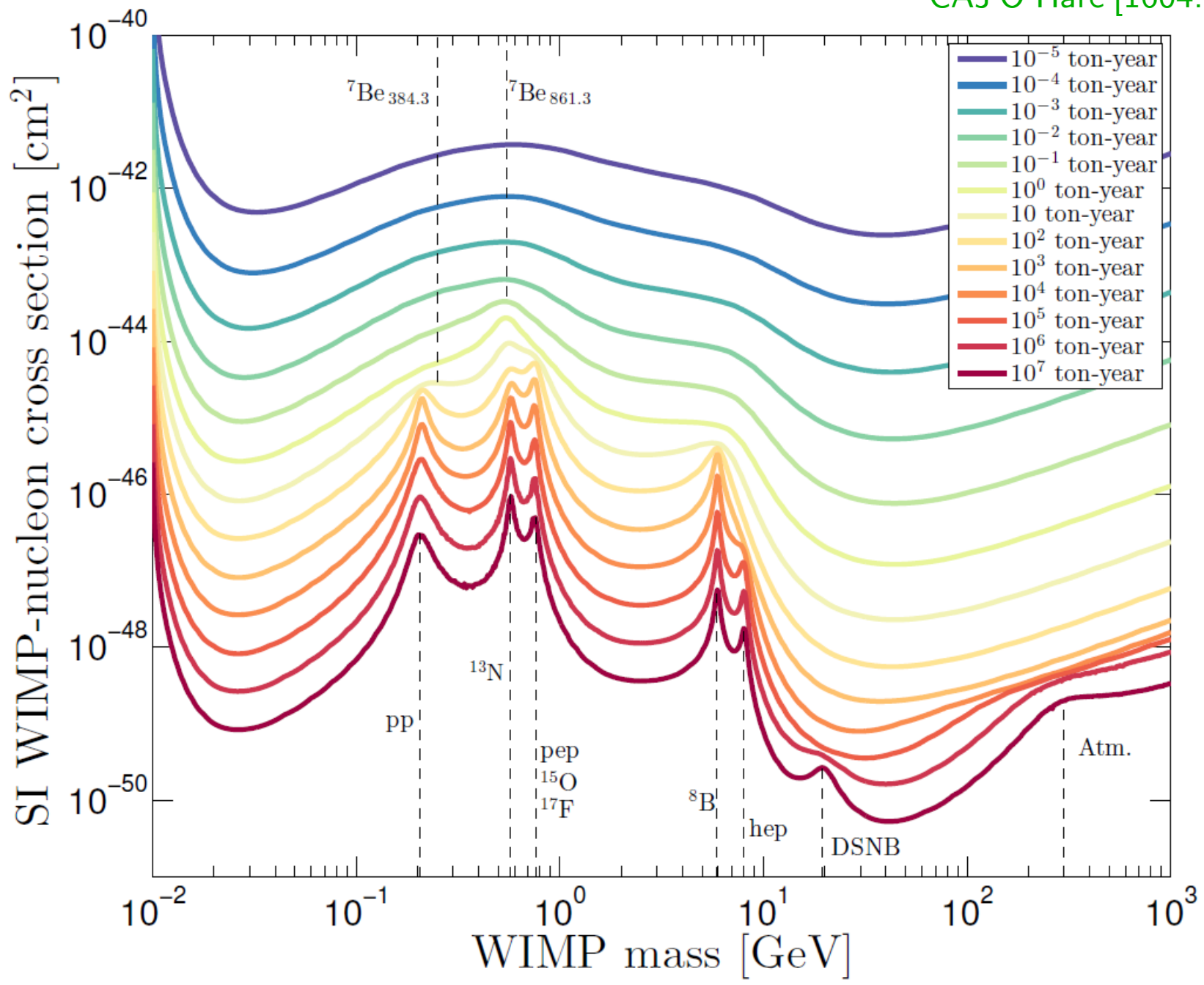
Neutrino backgrounds

Coherent neutrino-nucleus scattering rates on a Xenon target:



Complete Xenon neutrino floor

CAJ O'Hare [1604.03858]

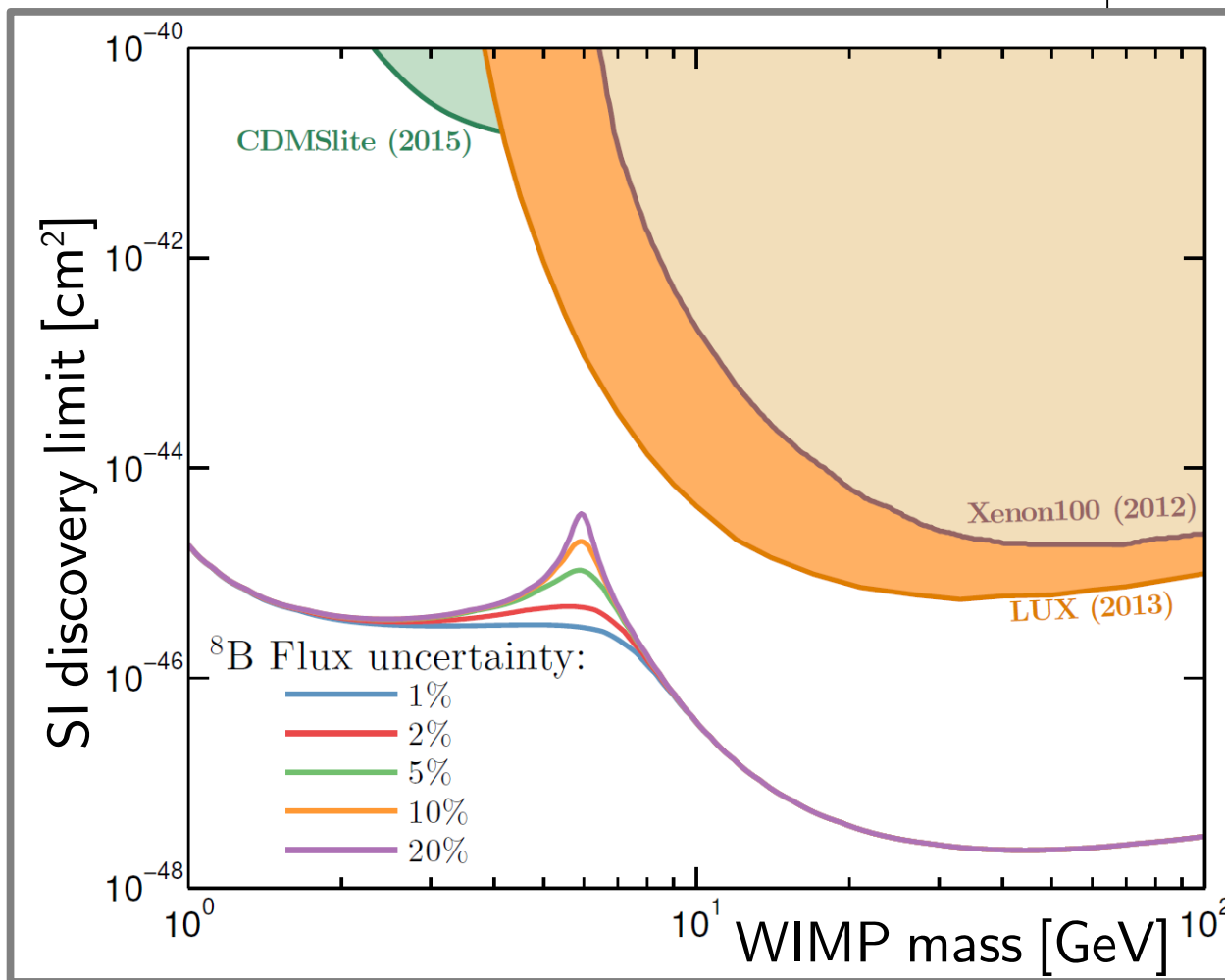
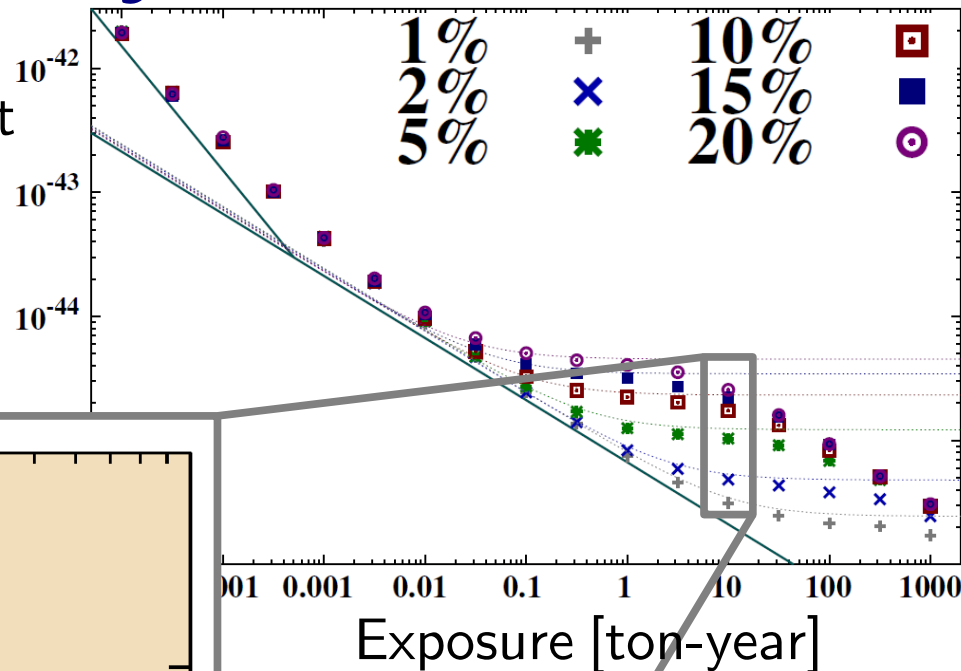


Neutrino flux uncertainty

F. Ruppin *et al* [1408.3581]

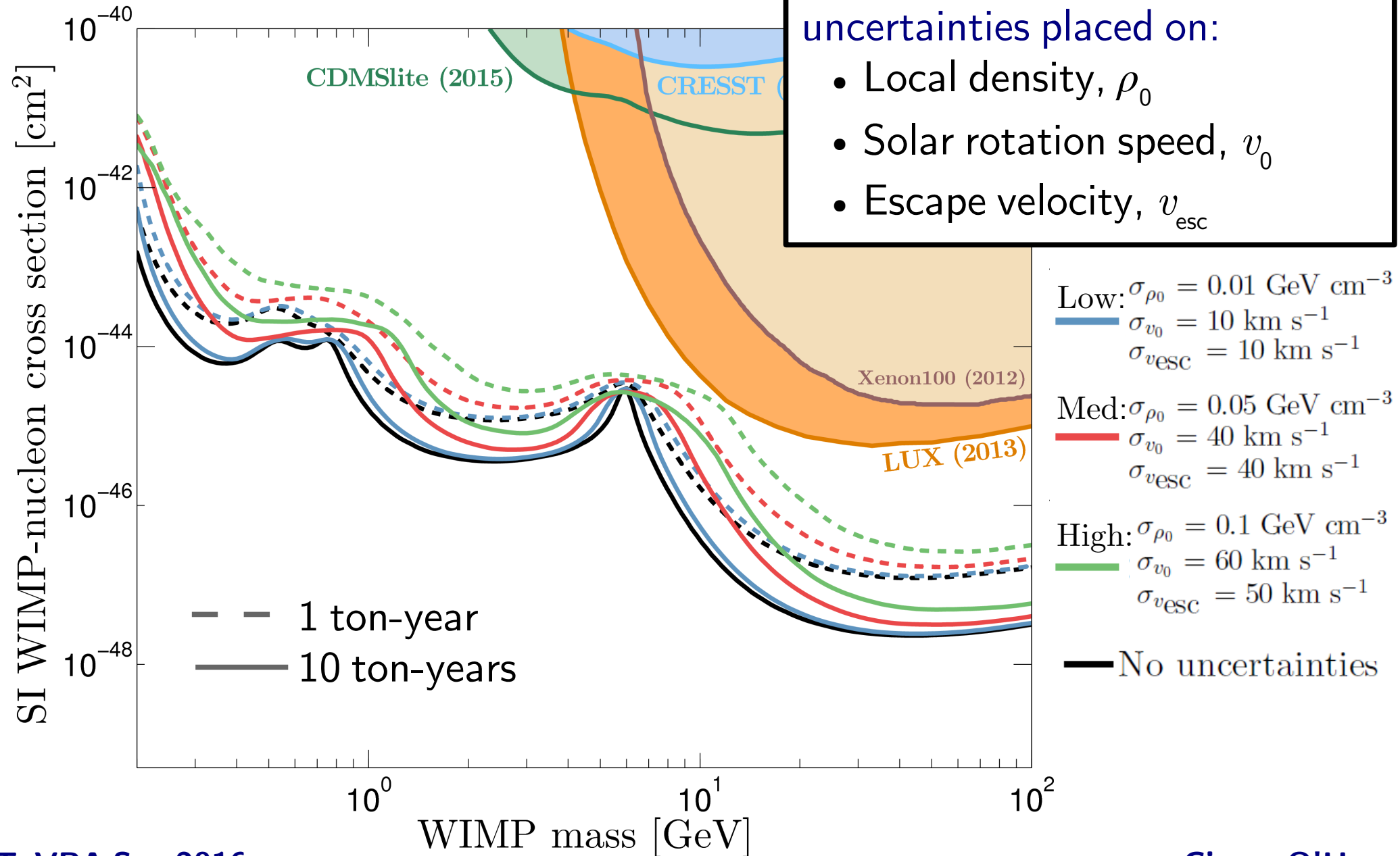
“ floor ” depends on flux uncertainty used in calculation

SI discovery limit @ 6 GeV [cm²]



Astrophysical uncertainties

CAJ O'Hare [1604.03858]

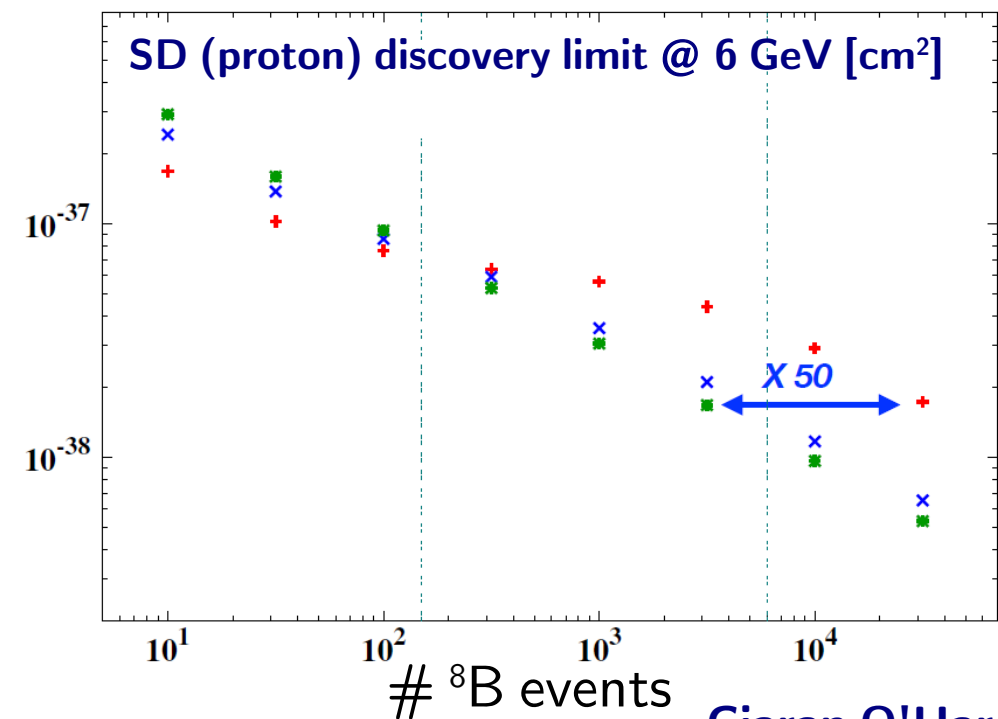
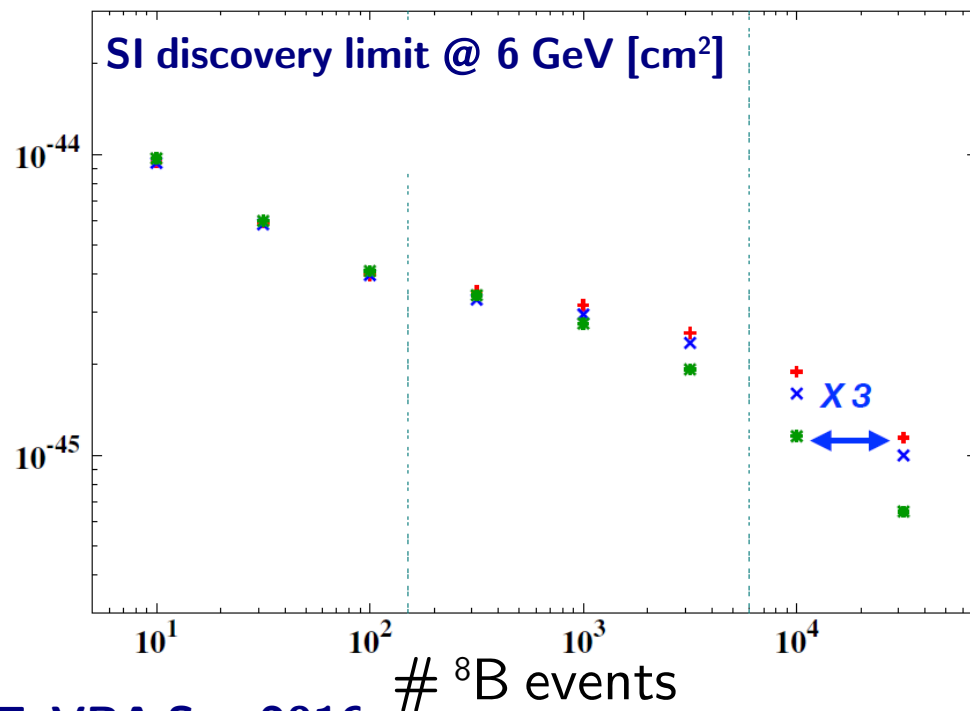


Strategies for the neutrino floor

- Need detectors >100 tons to probe below neutrino saturation
- Improving neutrino flux calculations/measurements can **delay** onset of floor
- What about target complementarity? [F. Ruppin et al \[1408.3581\]](#)

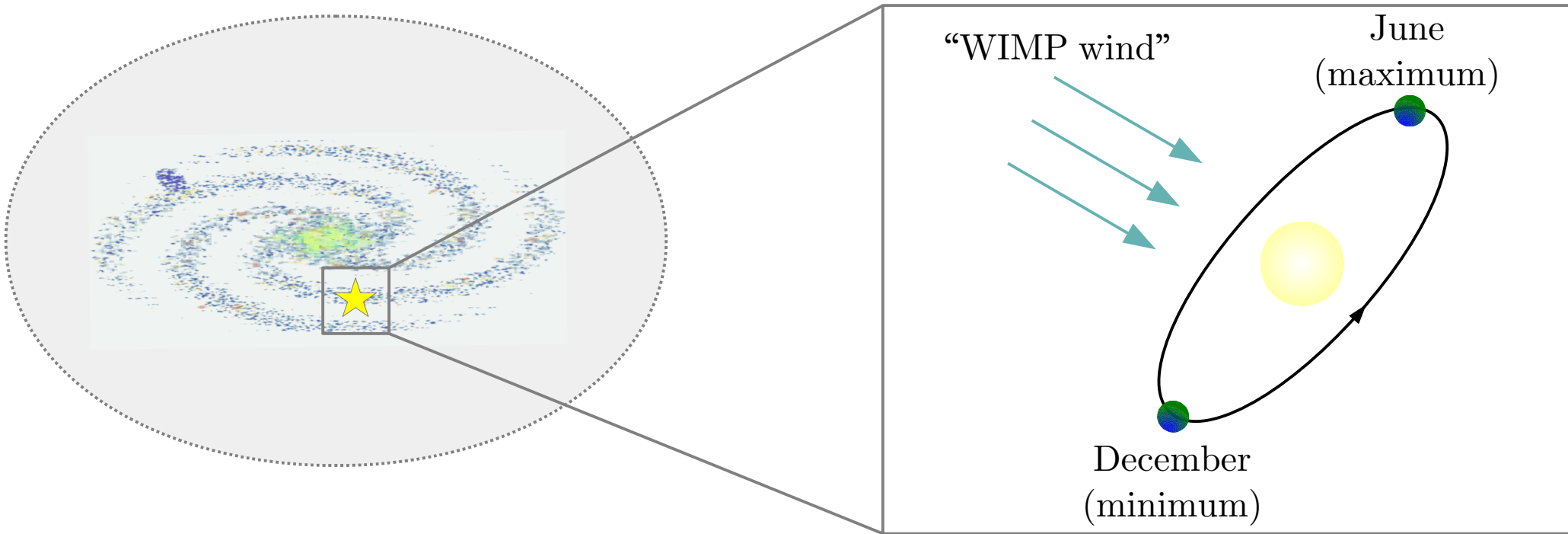
[Plots stolen from J. Billard]

Xe	+
Xe+Ge	×
Xe+Ge+Si	✱



Strategies for the neutrino floor

- Use distinguishing features of dark matter signal:
 - Annual modulation [J. Davis \[1407.1052\]](#)
 - Direction dependence [P. Grothaus et al \[1406.5047\]](#) [CAJ O'Hare et al \[1505.08061\]](#)



Directional signatures

- Sun does not coincide with peak WIMP direction at any time
- It should be possible to distinguish the two signals with direction:

^8B neutrino recoils

WIMP recoils

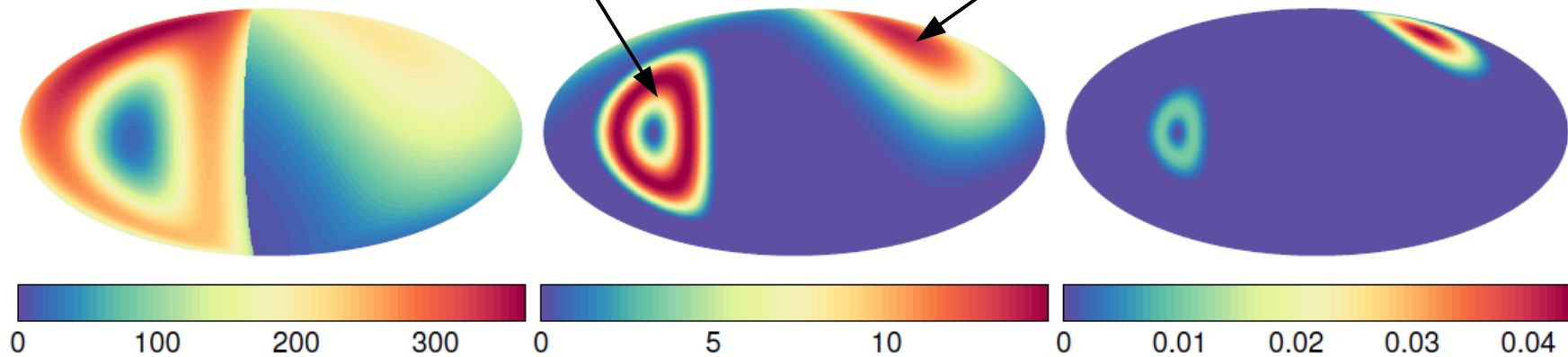
0 - 1.6 keV

1.6 - 3.3 keV

3.3 - 5 keV

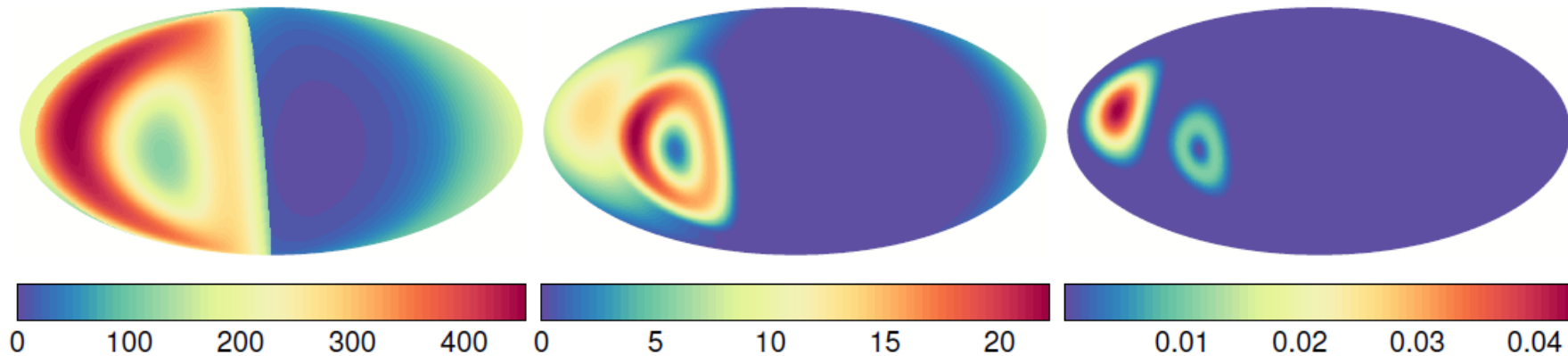
Sep. 6th

Max. separation
between WIMP
and neutrinos



Feb. 26th

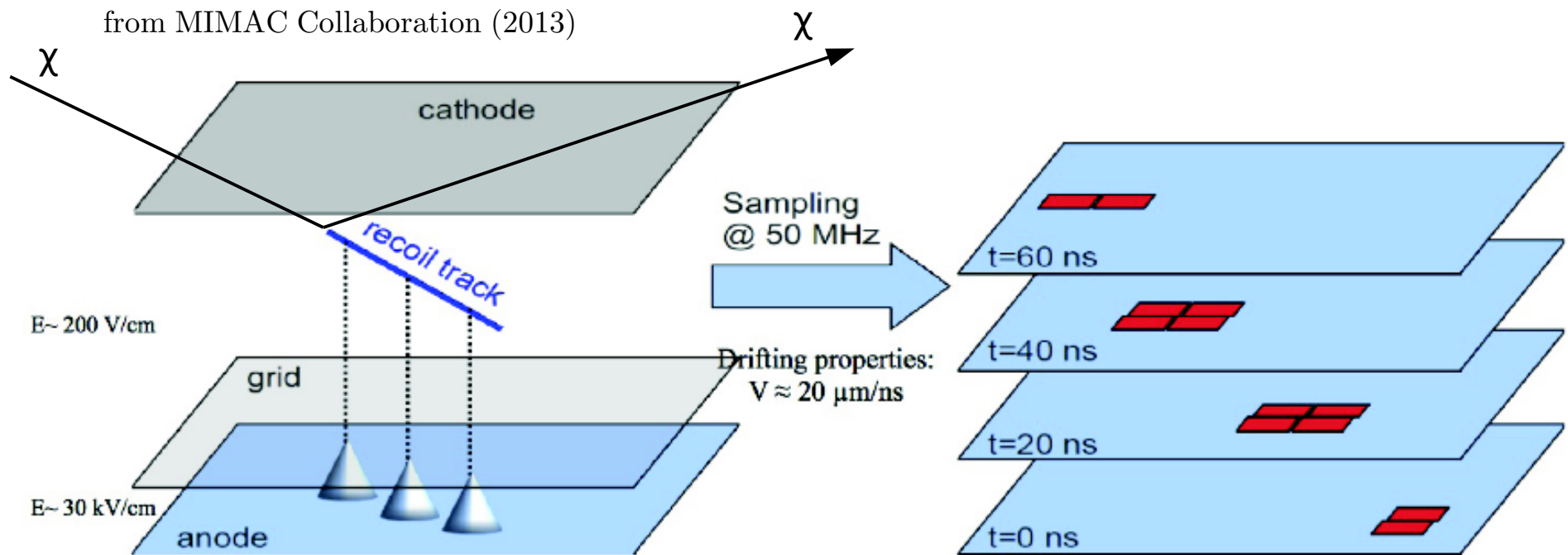
Min. separation
between WIMP
and neutrinos



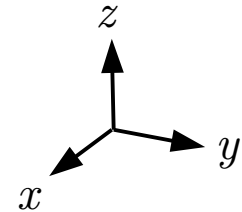
CAJ O'Hare *et al* [1505.08061]

Directional detection

e.g. Low pressure gas time projection chamber

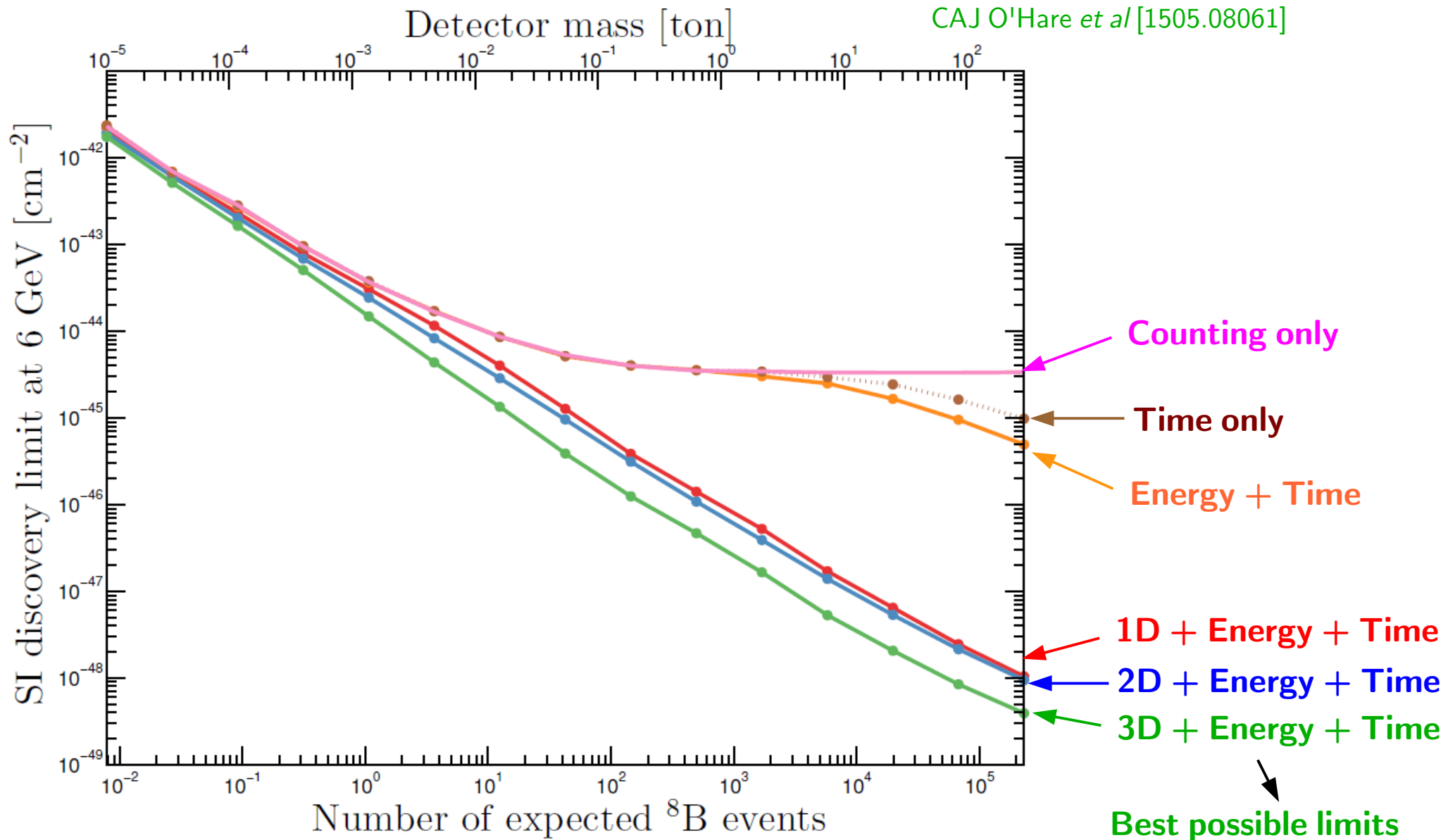


- **3D readout:** full recoil track (x, y, z)
- **2D readout:** projection on anode (x, y)
- **1D readout:** projection along drift direction (z)

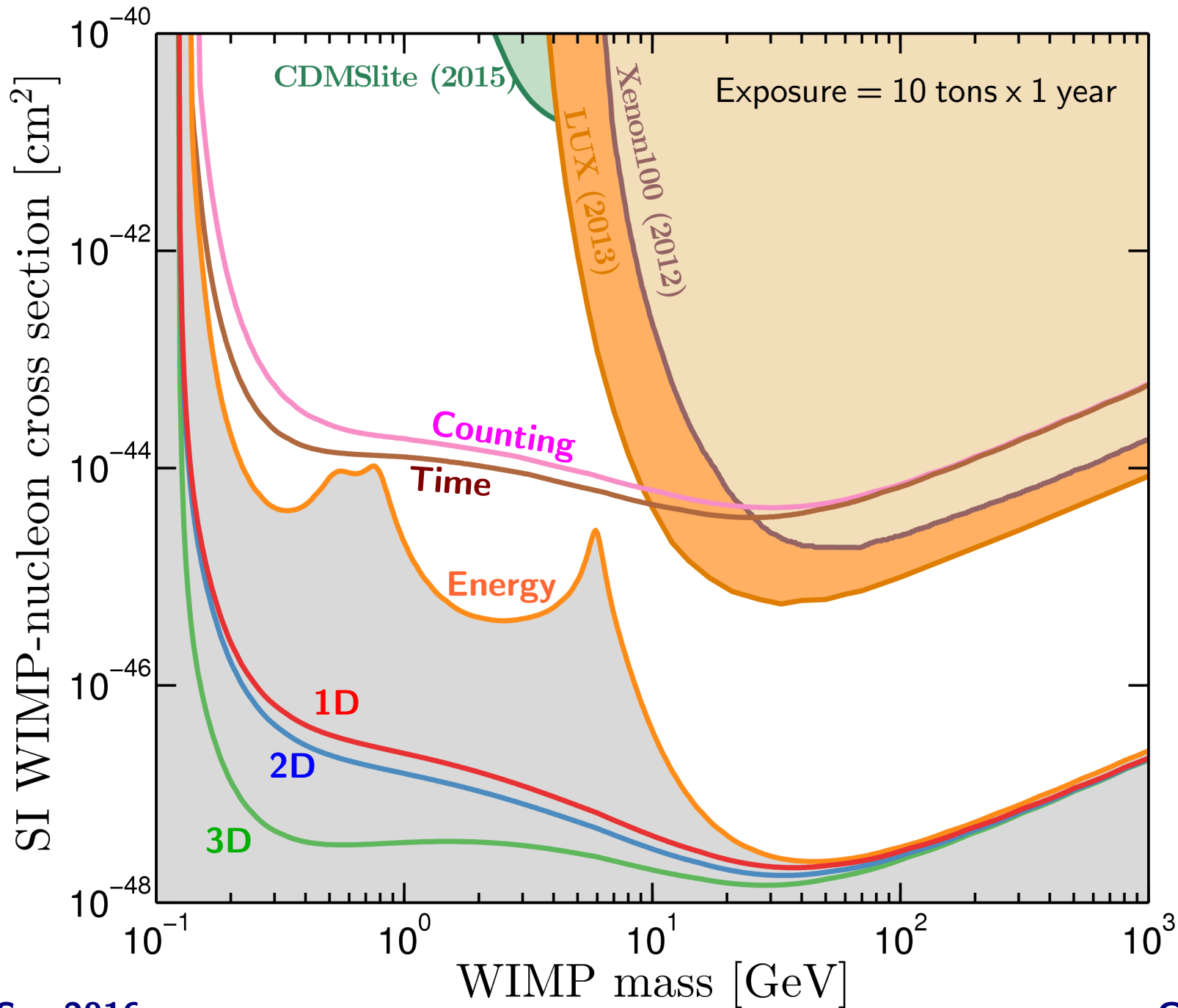


Comparing readout strategies

Evolution of discovery limit @ 6 GeV as a function of detector mass:



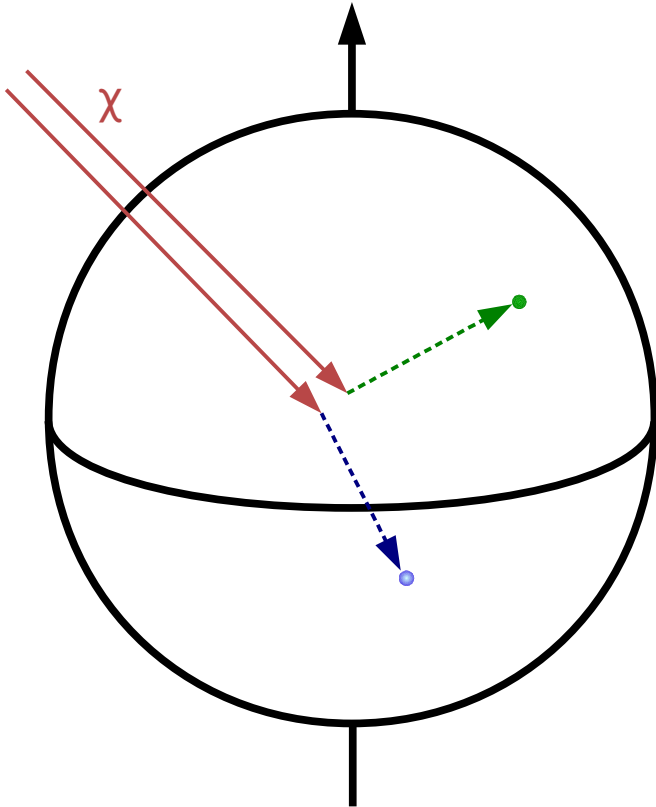
Comparing readout strategies



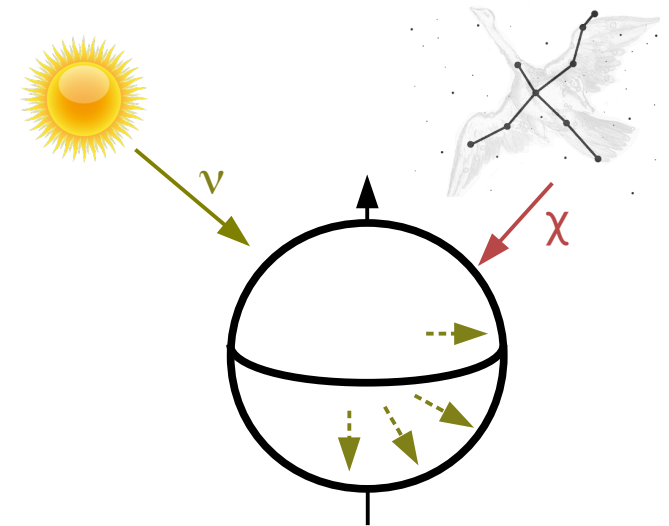
Hemispherical detector

(preliminary)

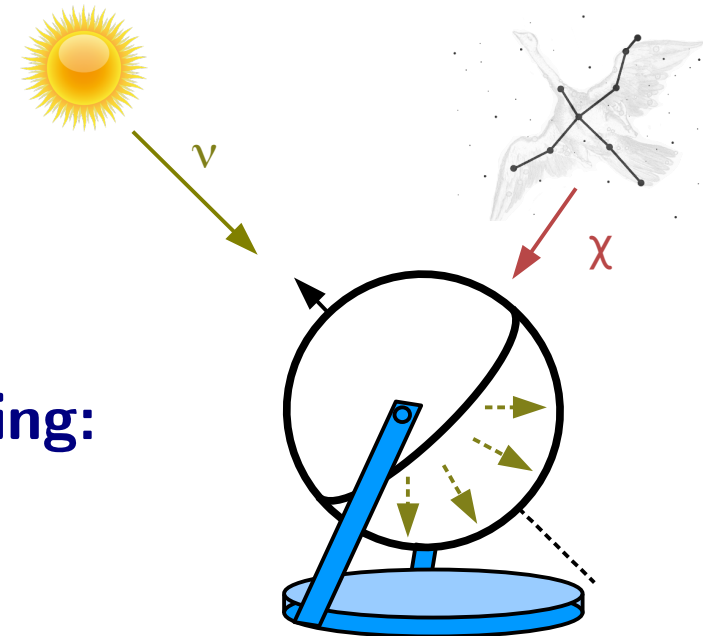
Can only measure directionality
down to hemispheres



Stationary:



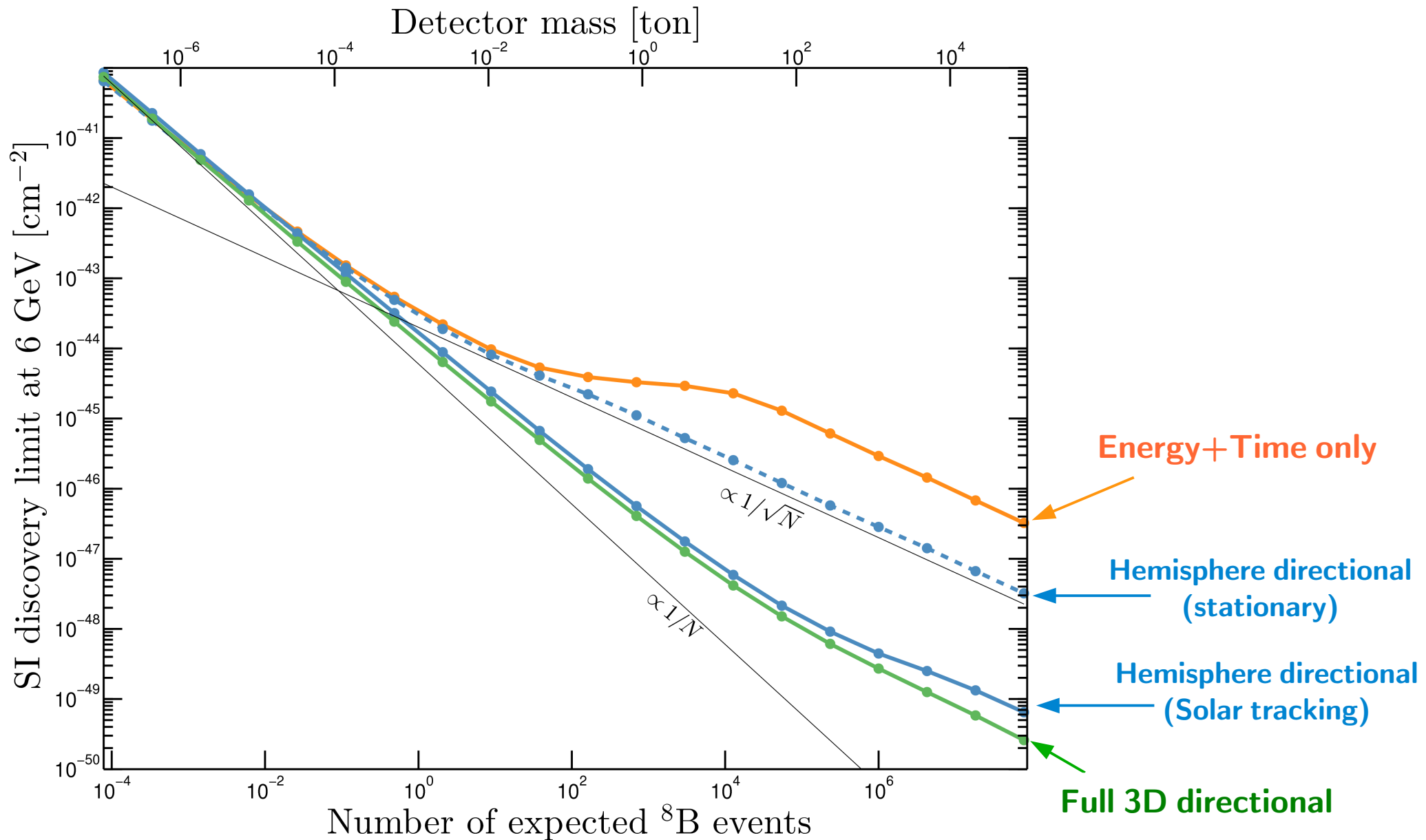
Solar tracking:



Solar ν recoils scatter 0 - 90 deg. from Solar direction
→ always have hemisphere with *no* Solar ν background

Hemispherical detector

(preliminary)

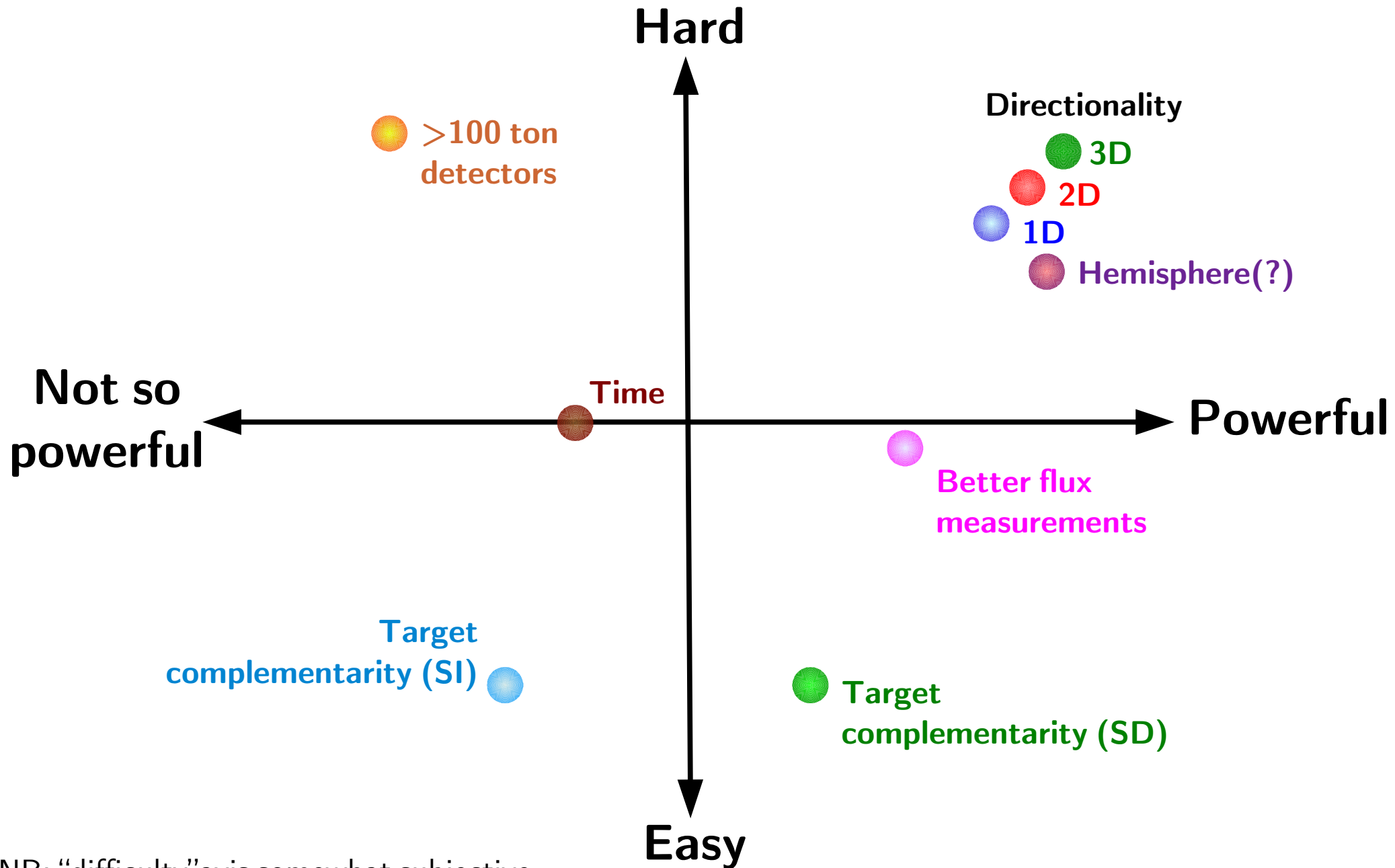


Summary

Neutrino floor not the final limit to direct detection searches

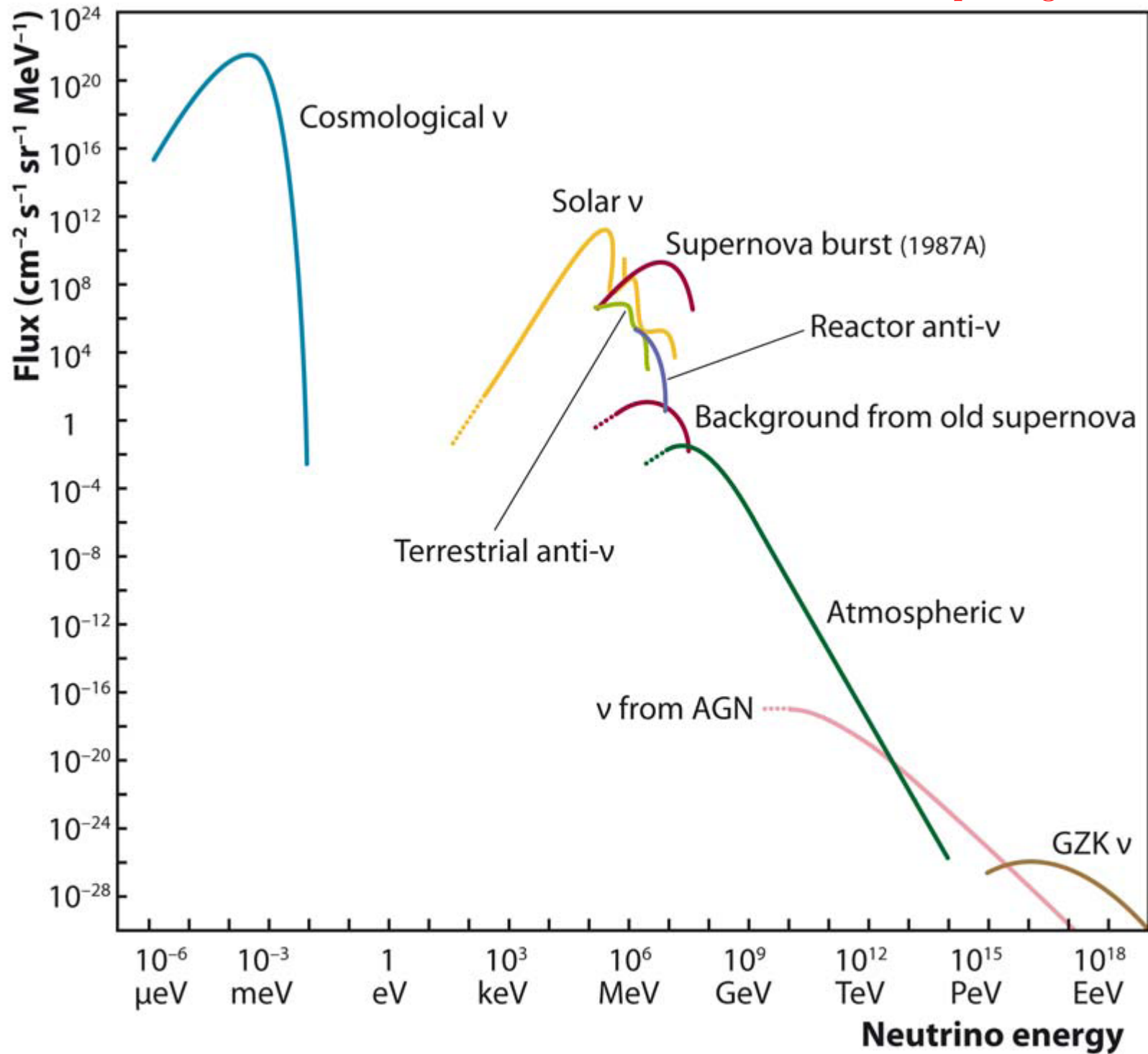
- There are various strategies for probing below the floor
 - Better neutrino flux estimates
 - Larger detectors
 - Target complementarity
 - Annual modulation
 - Directional detection

Strategies for the neutrino floor

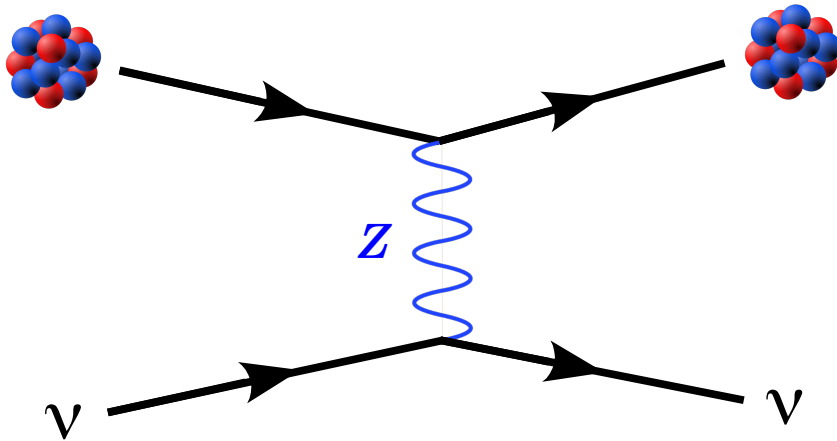


NB: "difficulty" axis somewhat subjective

Bonus slides



Coherent neutrino-nucleus scattering



$$\frac{d\sigma}{dE_r} = \frac{G_f^2}{4\pi} Q_w^2 m_N \left(1 - \frac{m_N E_r}{2E_\nu^2} \right) F^2(E_r)$$

$$\frac{dR}{dE_r} = \int_{E_\nu^{\min}}^{\infty} \frac{d\sigma}{dE_r} \times \frac{d\phi}{dE_\nu} dE_\nu$$

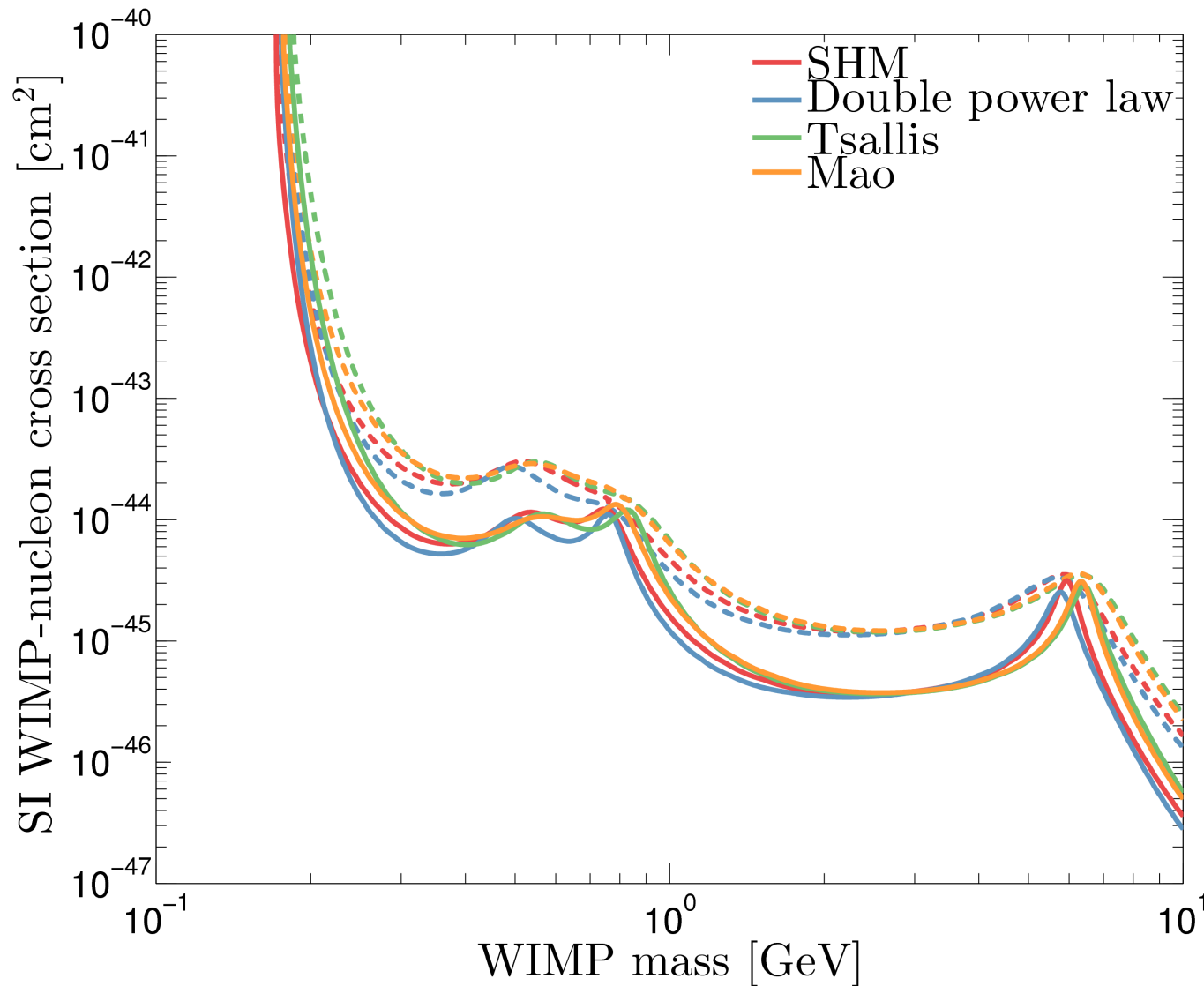
Differential event rate

Cross-section

- Flavour-blind neutral current
- Standard model

Neutrino flux

Neutrino floor with different speed distributions



$$f_{\text{SHM}}(\mathbf{v}) \propto e^{-v^2/v_0^2}$$

$$f_{\text{DPL}}(\mathbf{v}) \propto \left[\exp\left(-\frac{v_{\text{esc}}^2 - v^2}{kv_0^2}\right) - 1 \right]^k$$

$$f_{\text{Tsallis}}(\mathbf{v}) \propto \left[1 - (1-q)\frac{v^2}{v_0^2} \right]^{1/(1-q)}$$

$$f_{\text{Mao}}(\mathbf{v}) \propto e^{-v/v_0} (v_{\text{esc}}^2 - v^2)^p$$

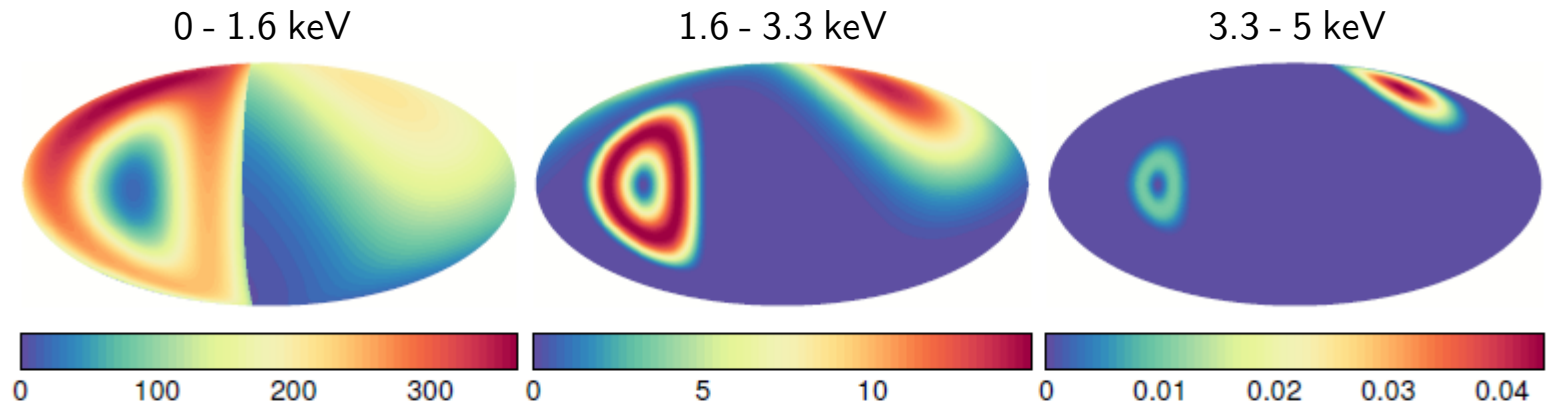
[between 0 and v_{esc}]

- Dashed: 1 ton-yr
- Solid: 10 ton-yr

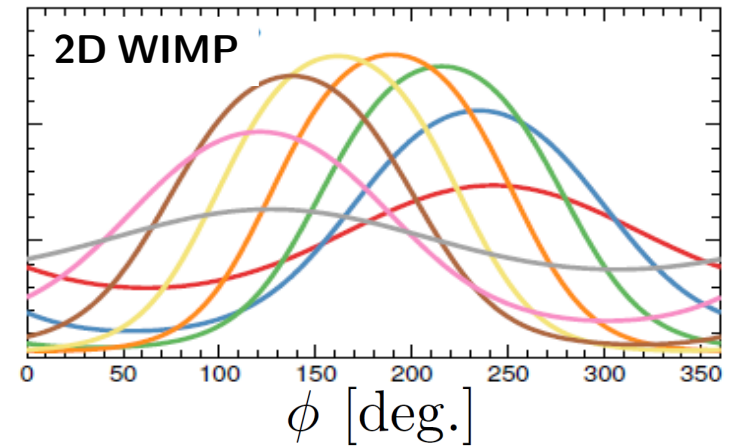
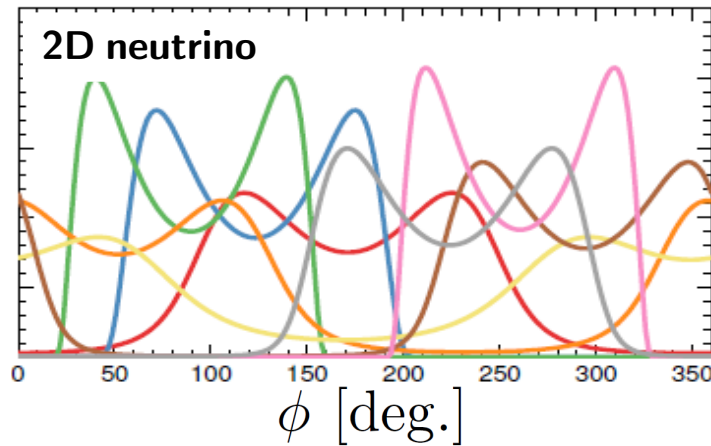
CAJ O'Hare [1604.03858]

Projected angular pdfs

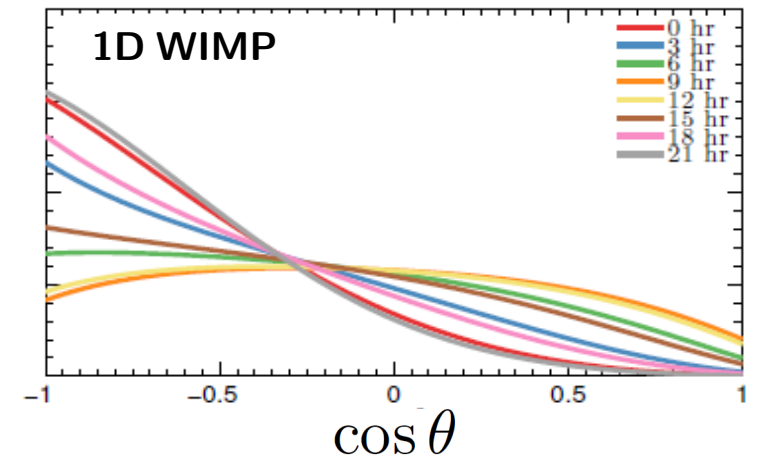
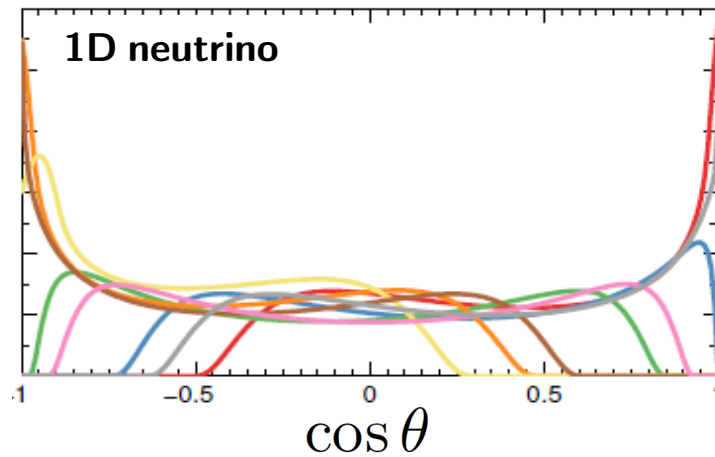
3D readout:



2D readout:

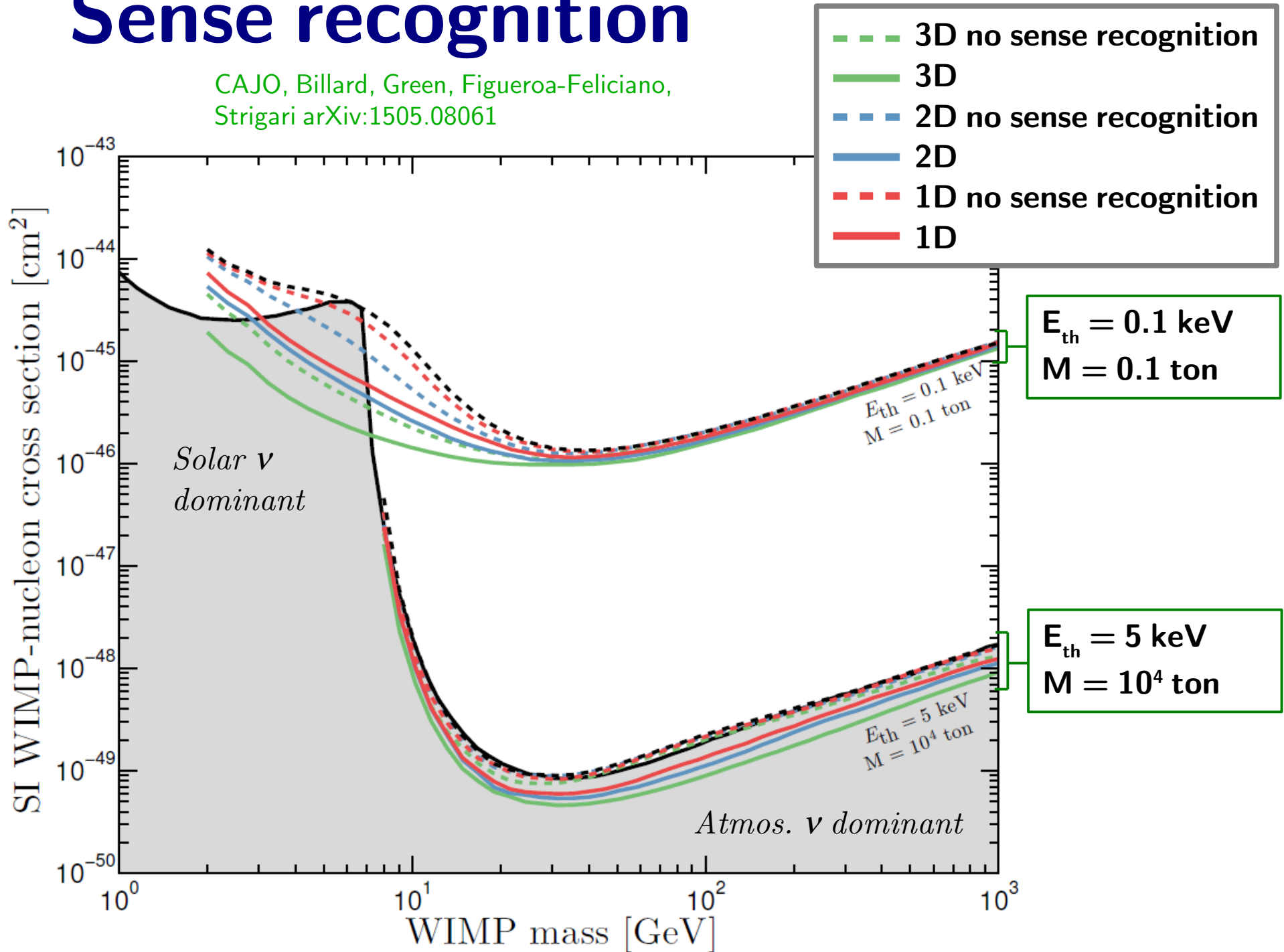


1D readout:



Sense recognition

CAJO, Billard, Green, Figueroa-Feliciano,
Strigari arXiv:1505.08061



Angular resolution

CAJO, Billard, Green, Figueroa-Feliciano,
Strigari arXiv:1505.08061

