

DM

Neutrinos from the Sun as a discovery tool for dark matter–electron scattering

DM

Tarak Nath Maity

Based on:

TNM, A K Saha, S Mondal, R Laha; in preparation



Dark Interactions
New Perspectives from Theory and Experiment



Dark Matter exists!

Dark Matter exists!

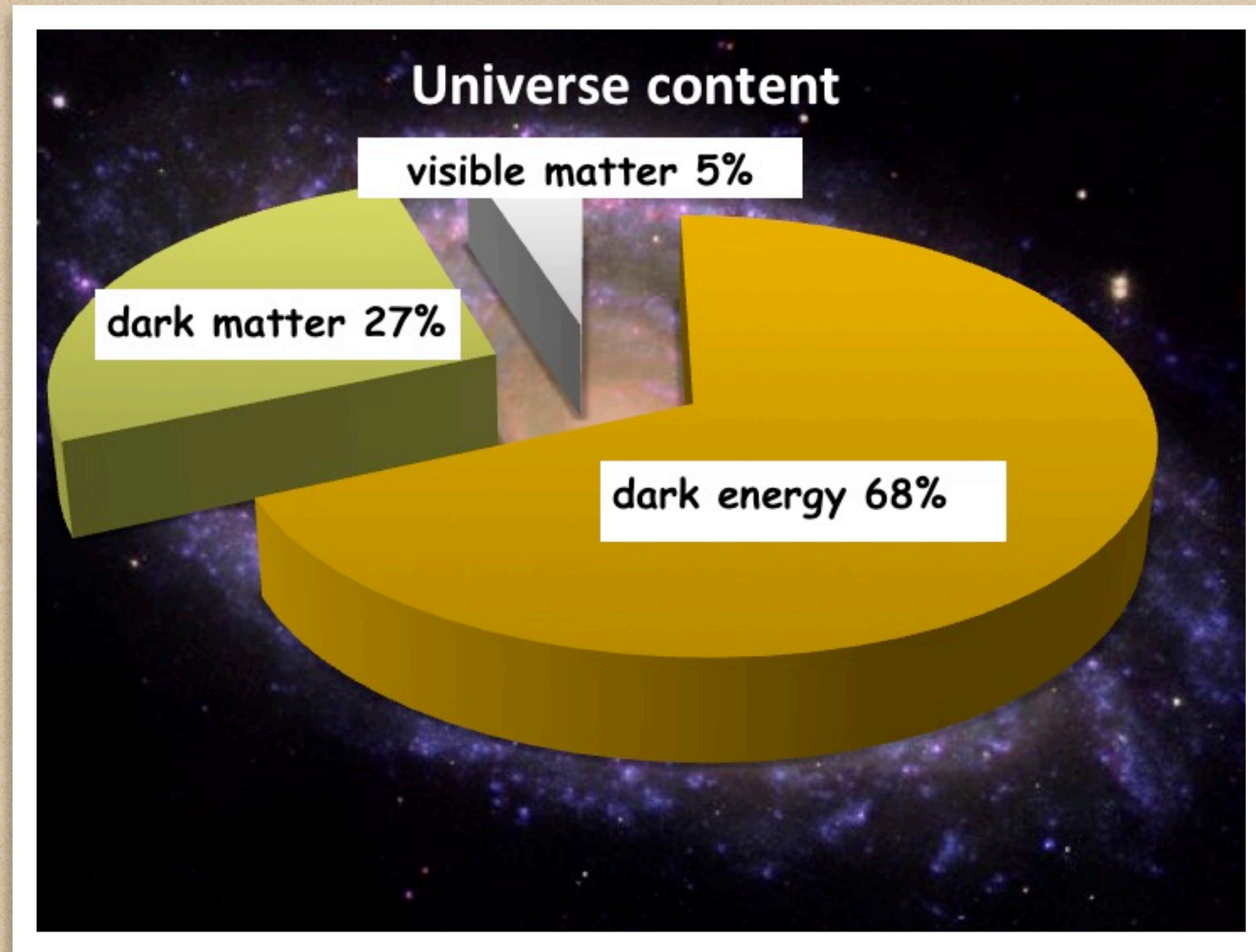


Image credit: QUANTUM DIARIES

Dark Matter exists!

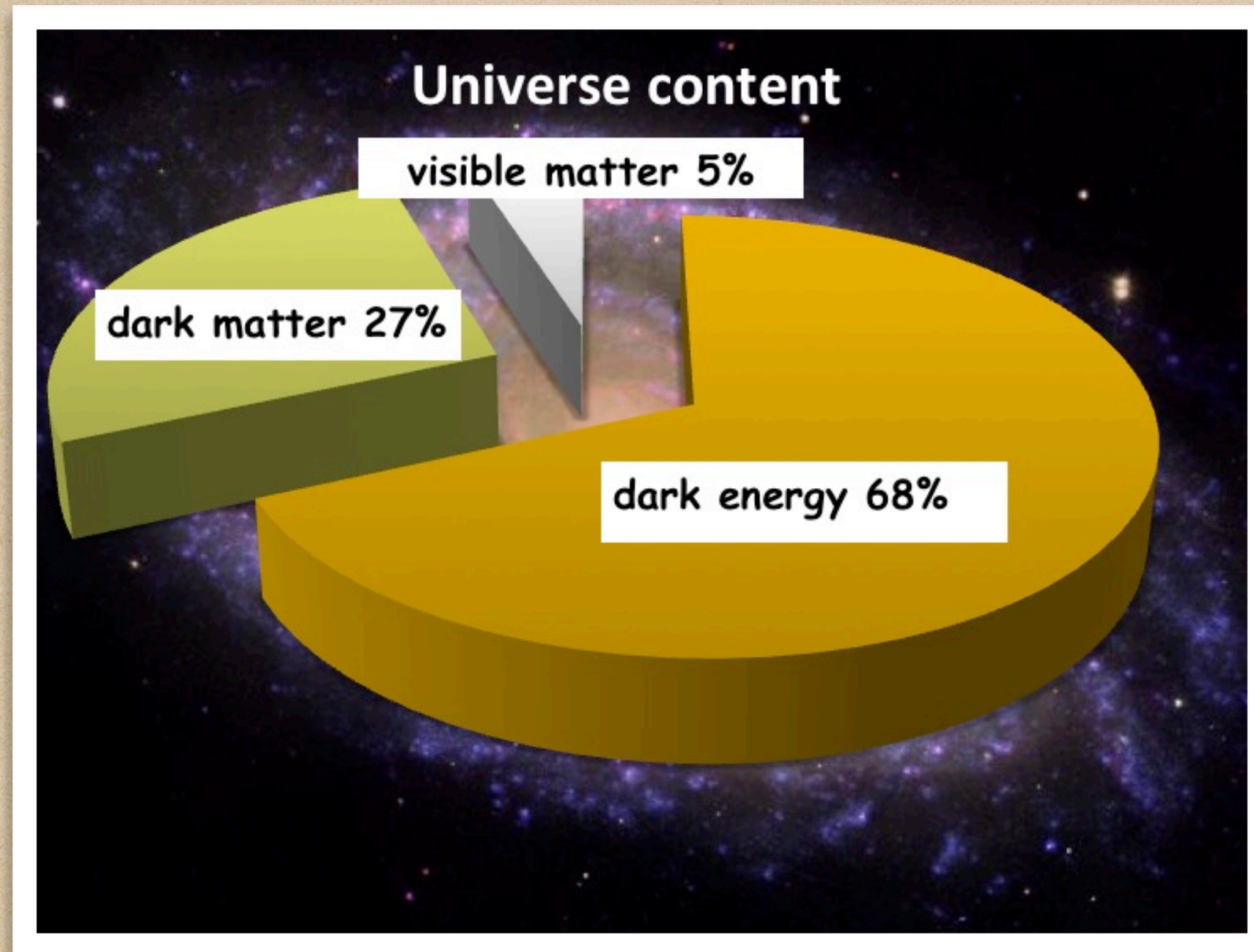


Image credit: QUANTUM DIARIES

- Stable: No decay, very long-lived
- Cold: Non-relativistic
- Massive: Wide range
- ...

Dark Matter exists!

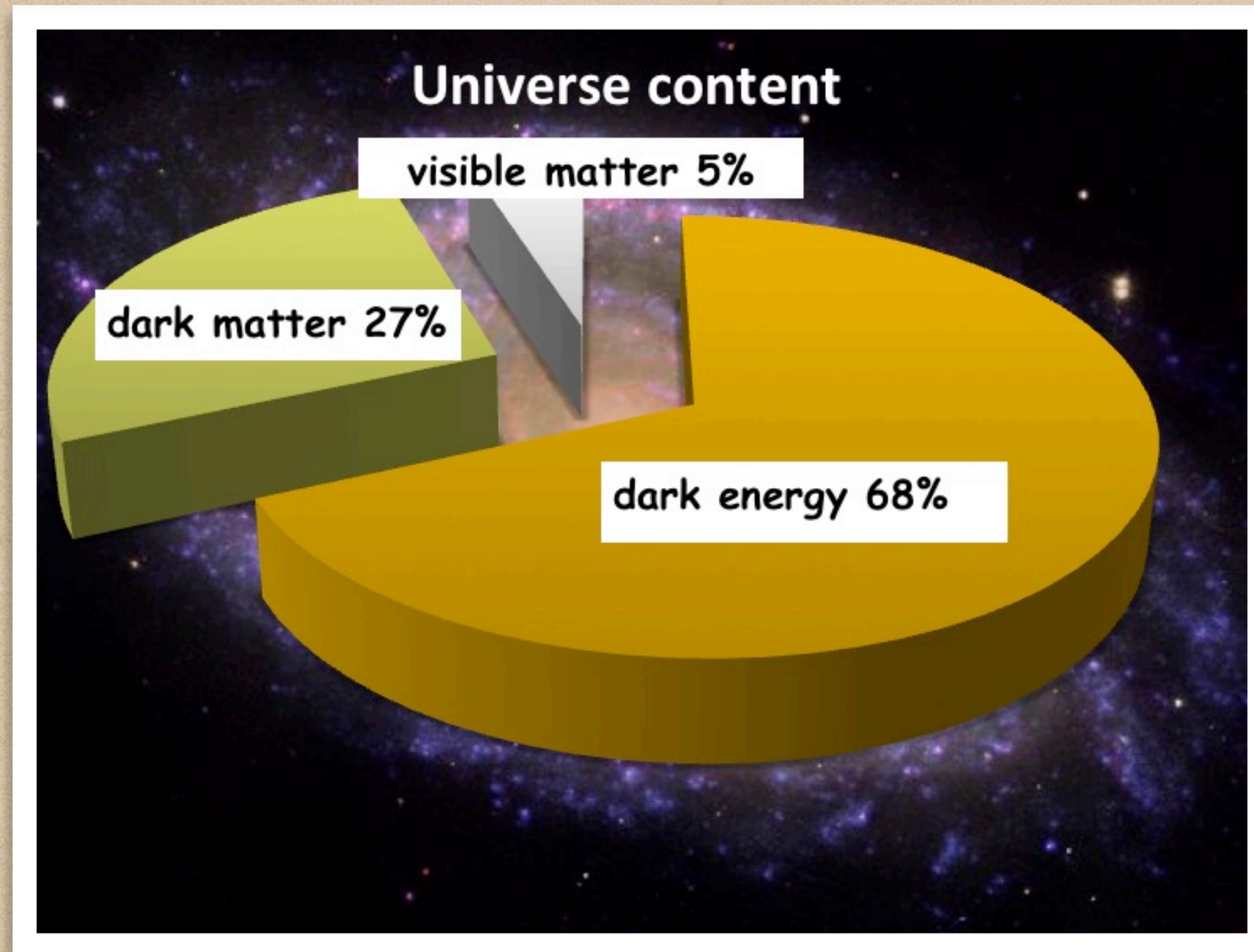


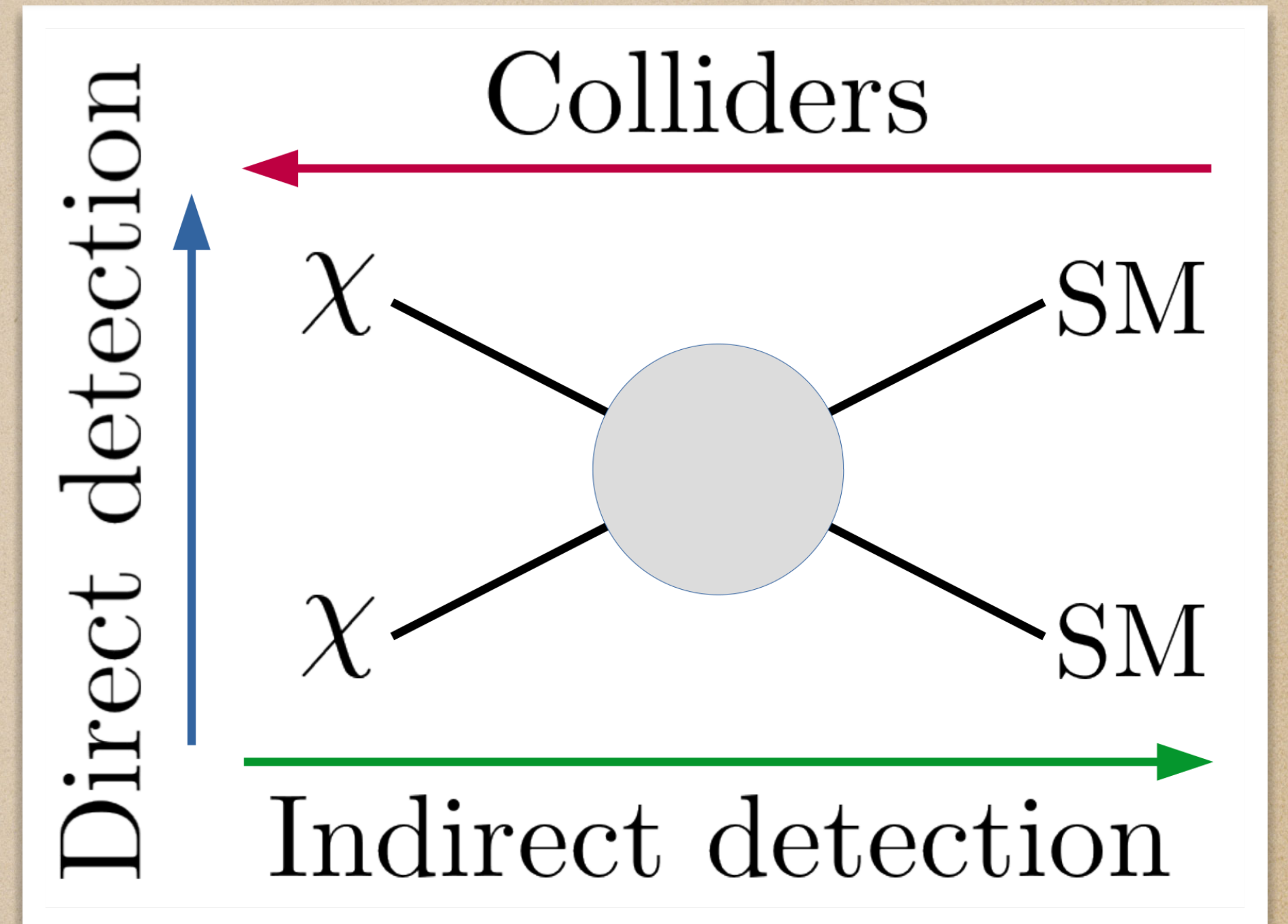
Image credit: QUANTUM DIARIES

- Stable: No decay, very long-lived
- Cold: Non-relativistic
- Massive: Wide range
- ...

Assume dark matter standard model coupling

Test it

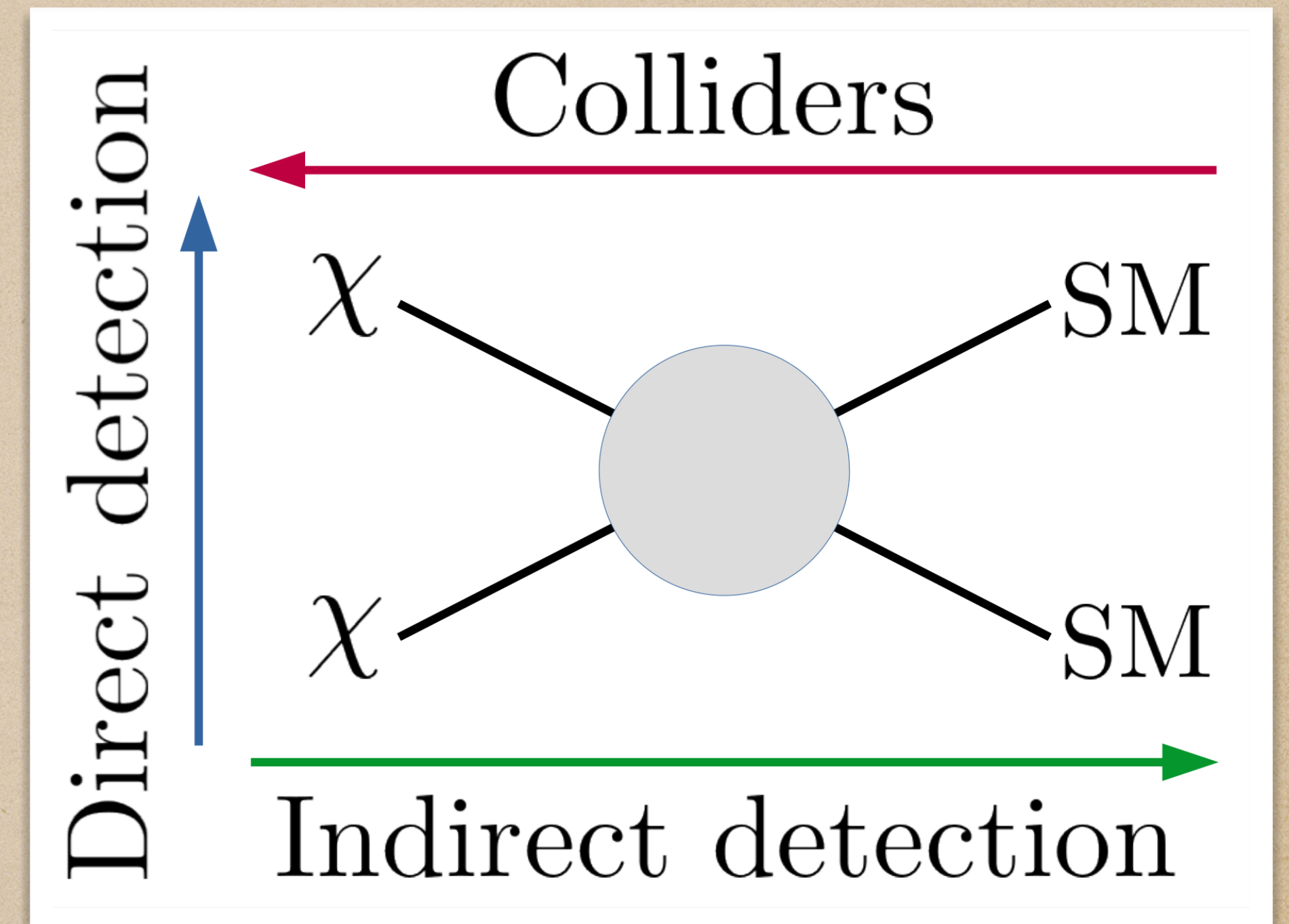
Test it



2104.11488

Test it

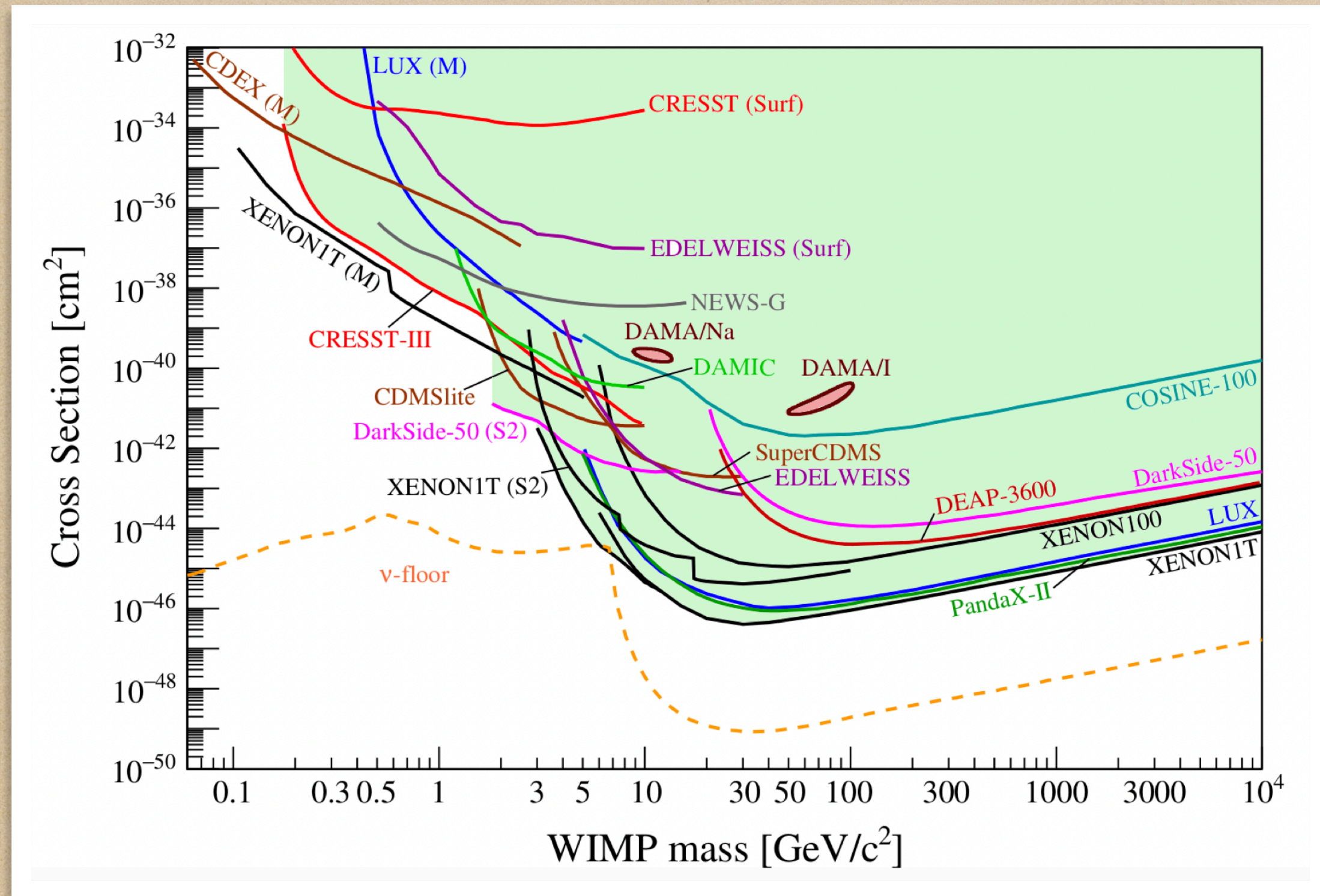
- ▶ Direct detection Mostly focuses on DM-nuclear scattering
- ▶ Made extraordinary progress



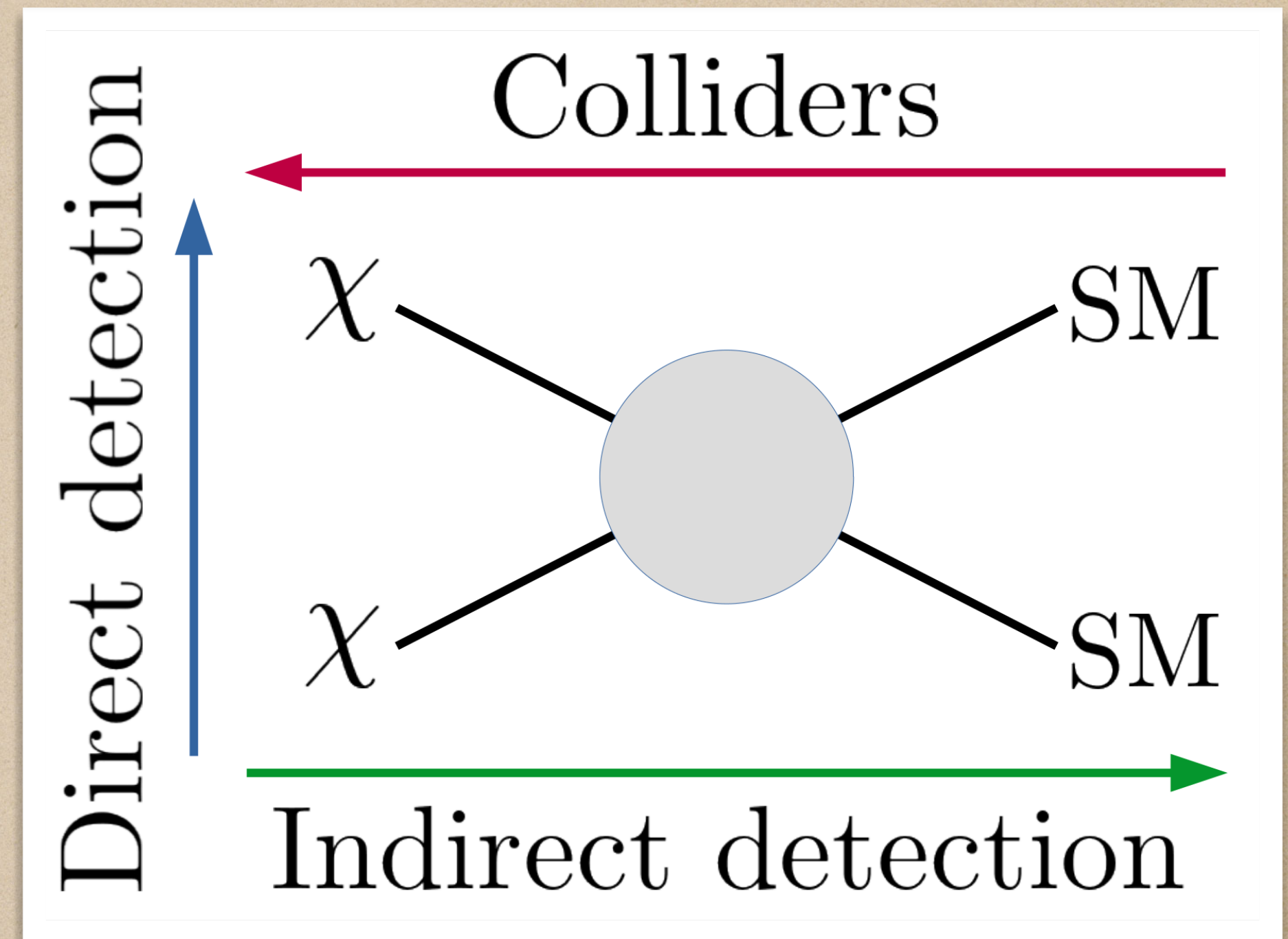
2104.11488

Test it

- ▶ Direct detection Mostly focuses on DM-nuclear scattering
- ▶ Made extraordinary progress



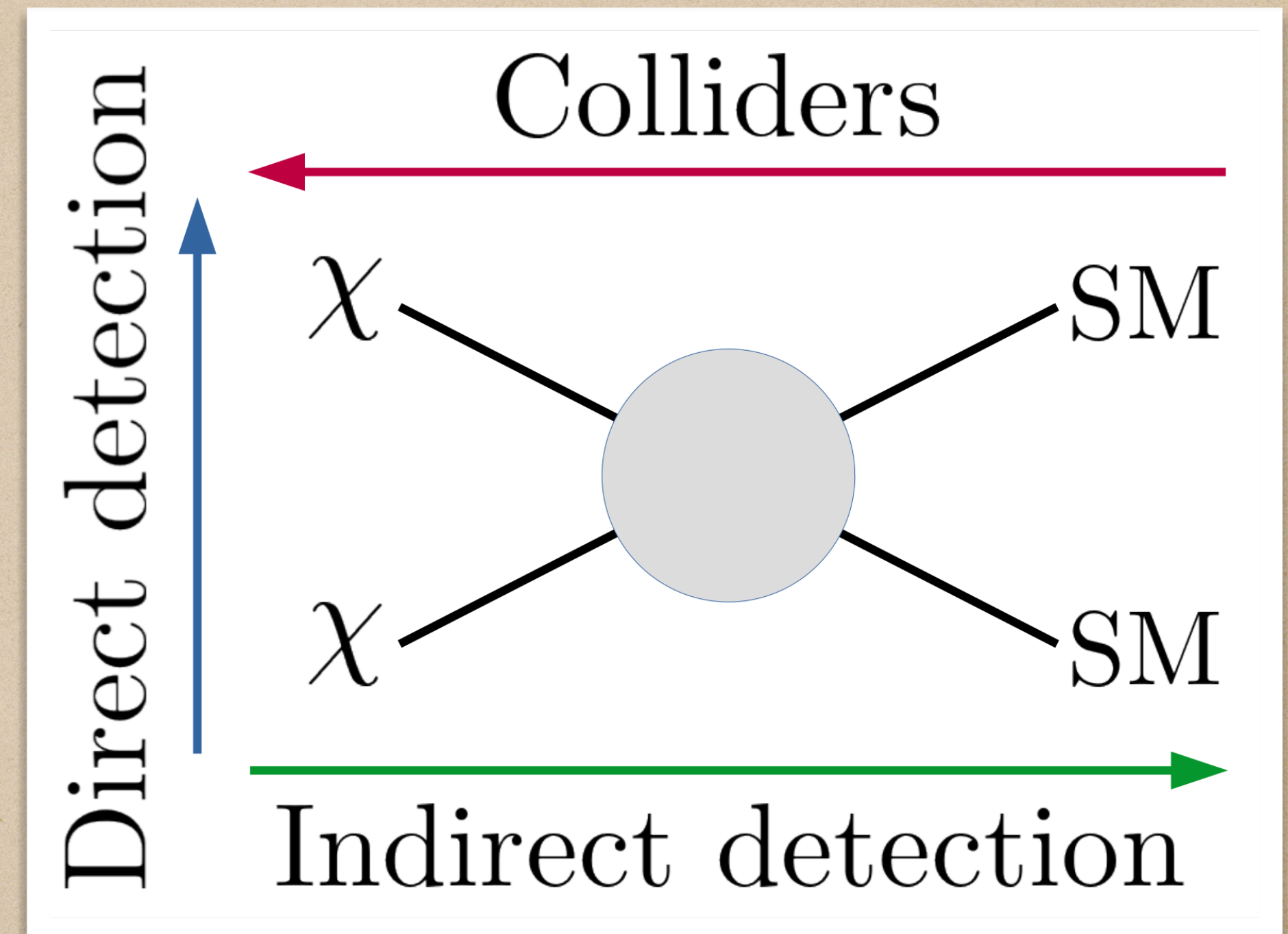
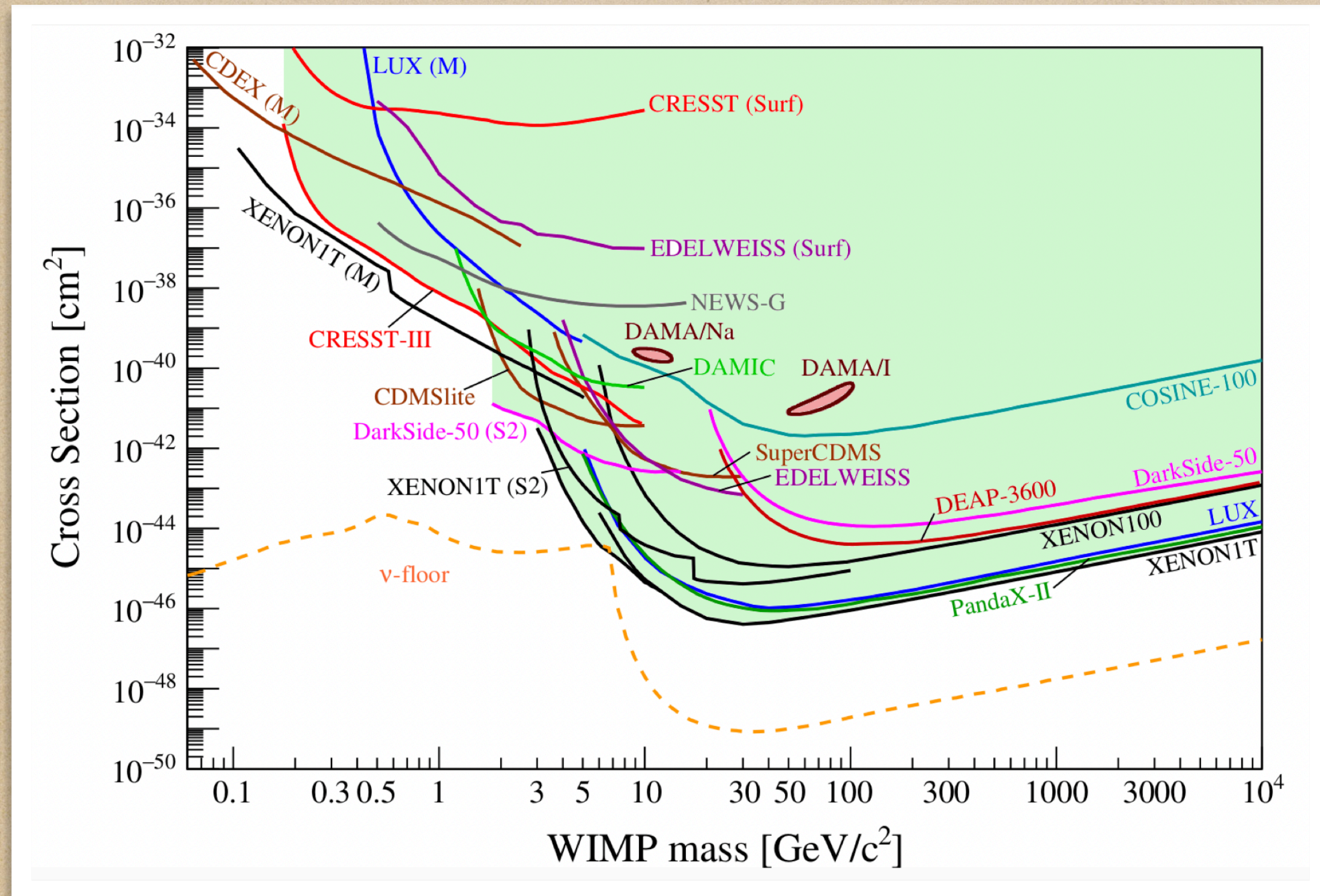
2104.07634



2104.11488

Test it

- ▶ Direct detection Mostly focuses on DM-nuclear scattering
- ▶ Made extraordinary progress



2104.11488

- Is it the only possibility?

Shake differently

DM-electron scattering

Fox et al, 0811.0399

Cirelli et al 0809.2409

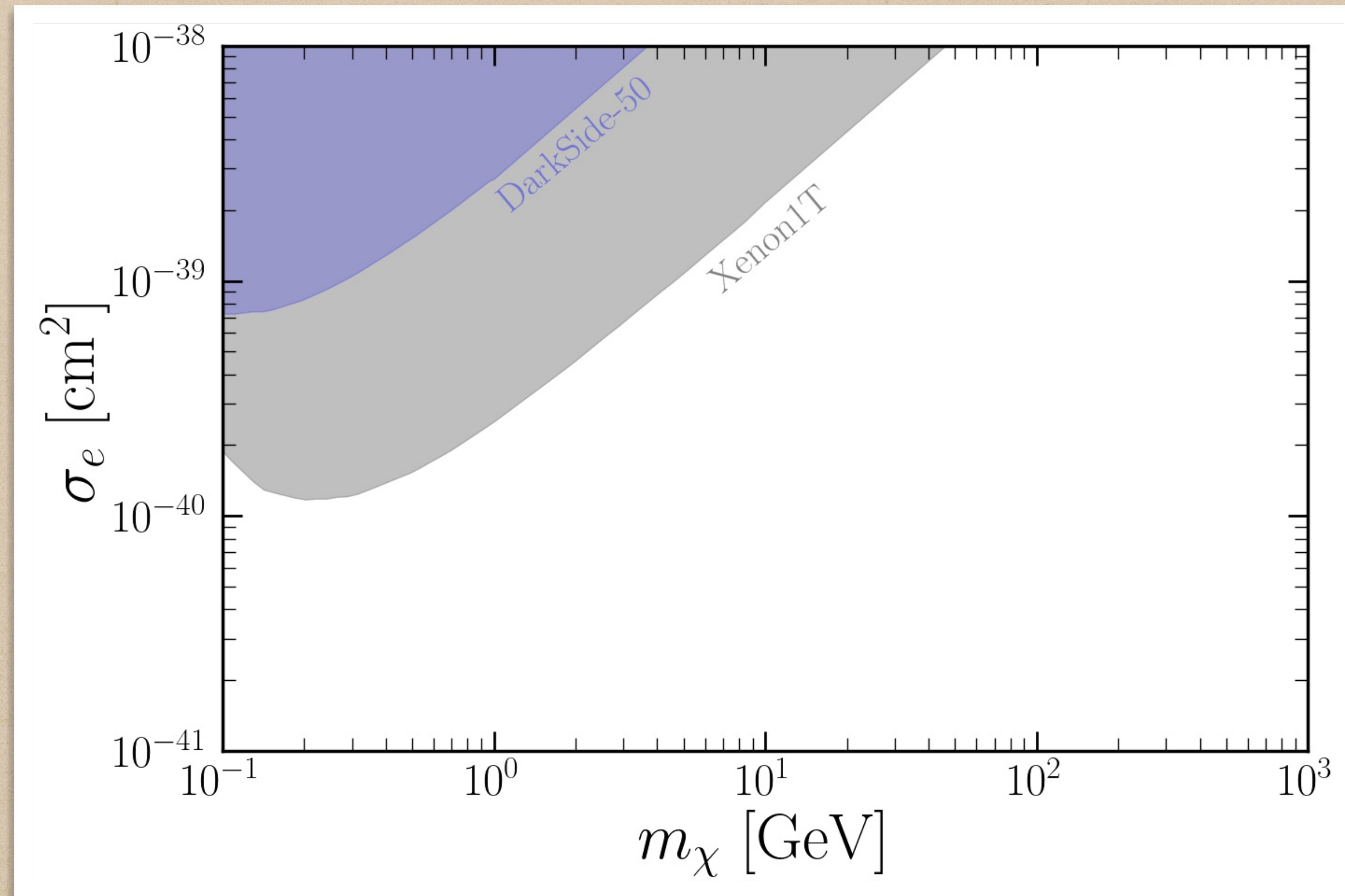
Bell et al 1407.3001

Horigome et al 2102.08645

+ many more

Shake differently

DM-electron scattering

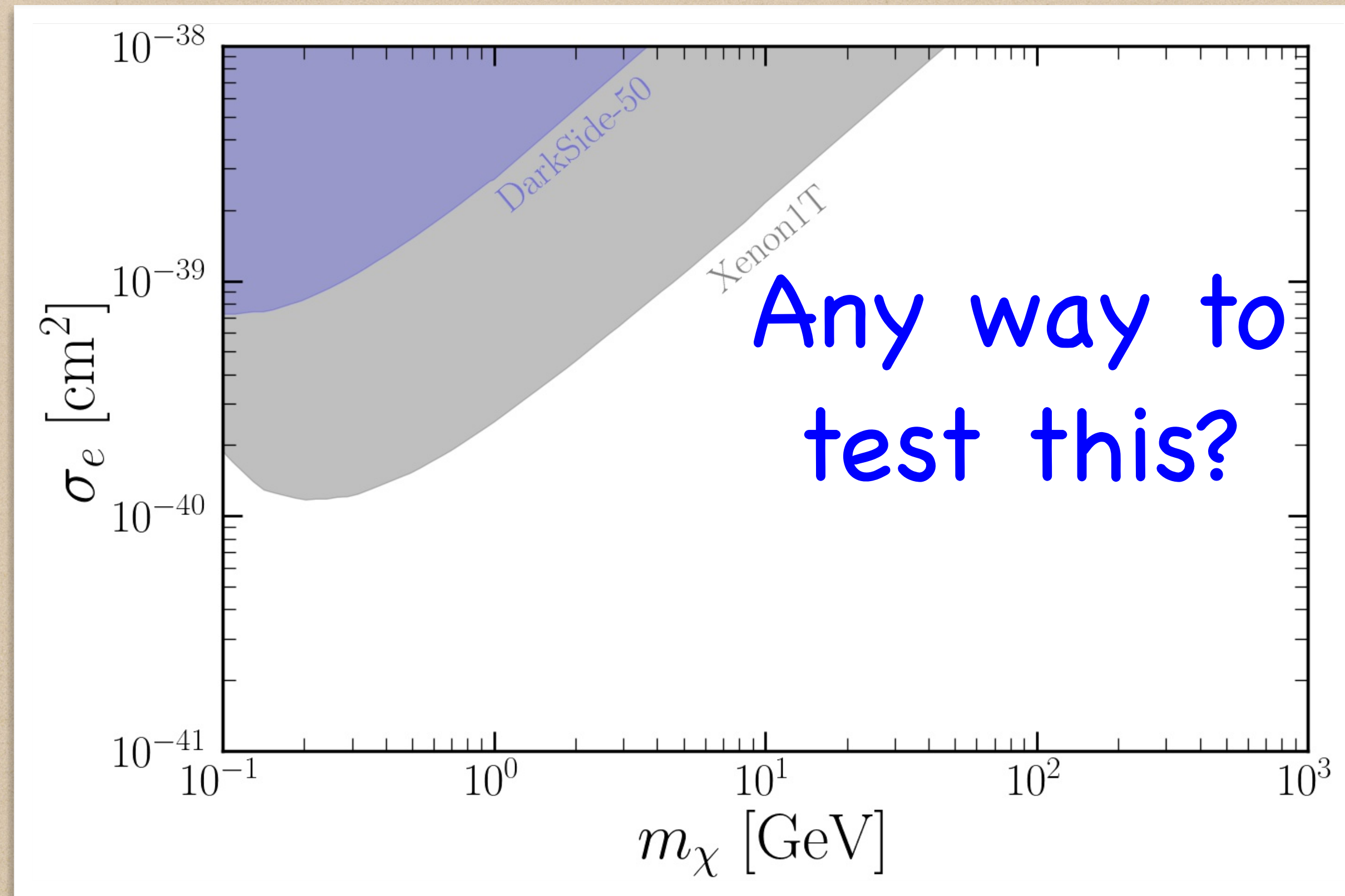


Fox et al, 0811.0399
Cirelli et al 0809.2409
Bell et al 1407.3001
Horigome et al 2102.08645
+ many more

Shake differently

DM-electron scattering

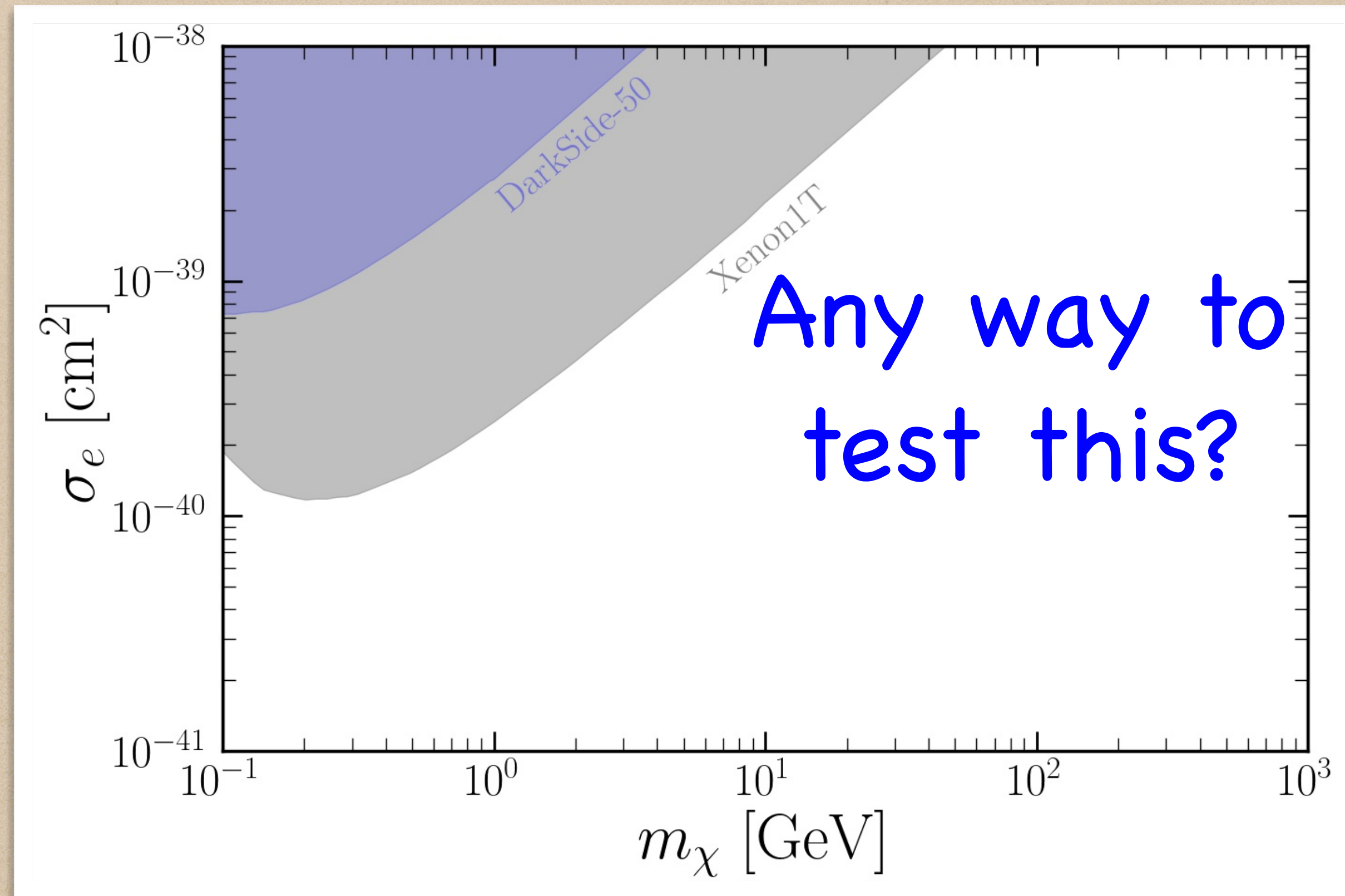
Fox et al, 0811.0399
Cirelli et al 0809.2409
Bell et al 1407.3001
Horigome et al 2102.08645
+ many more



Shake differently

DM-electron scattering

Fox et al, 0811.0399
Cirelli et al 0809.2409
Bell et al 1407.3001
Horigome et al 2102.08645
+ many more



Caveats: Model dependently loop level DM-nucleon interactions

Kopp et al, In progress with D Bose, R Pramanik

Our proposal

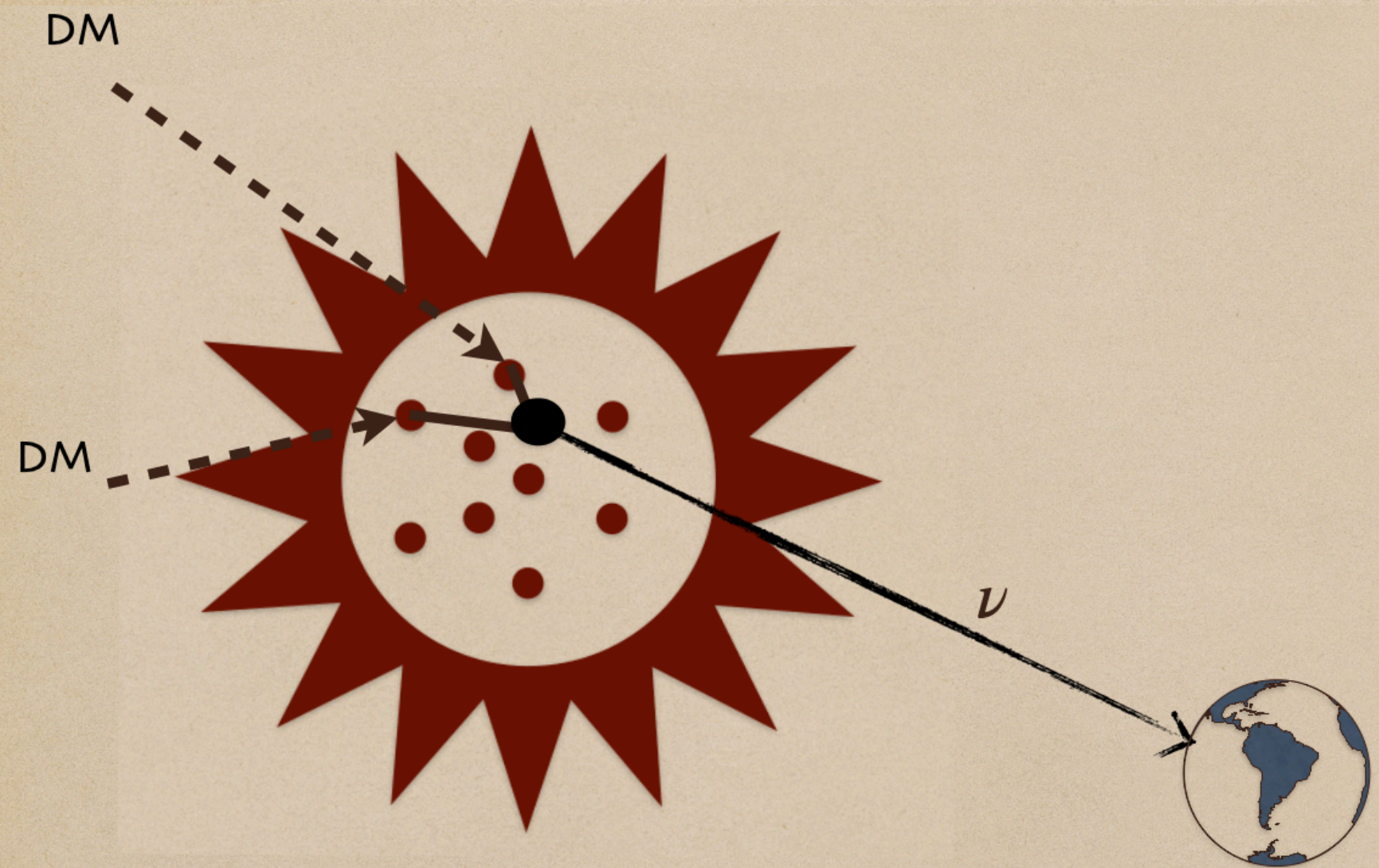
(1) DM capture in Sun through electron scattering

(2) Captured DM annihilation in the Sun

(3) Secondary Neutrinos produce from annihilation will reach earth

(4) Detect these neutrinos in neutrino telescopes

IceCube / DeepCore
Super Kamiokande

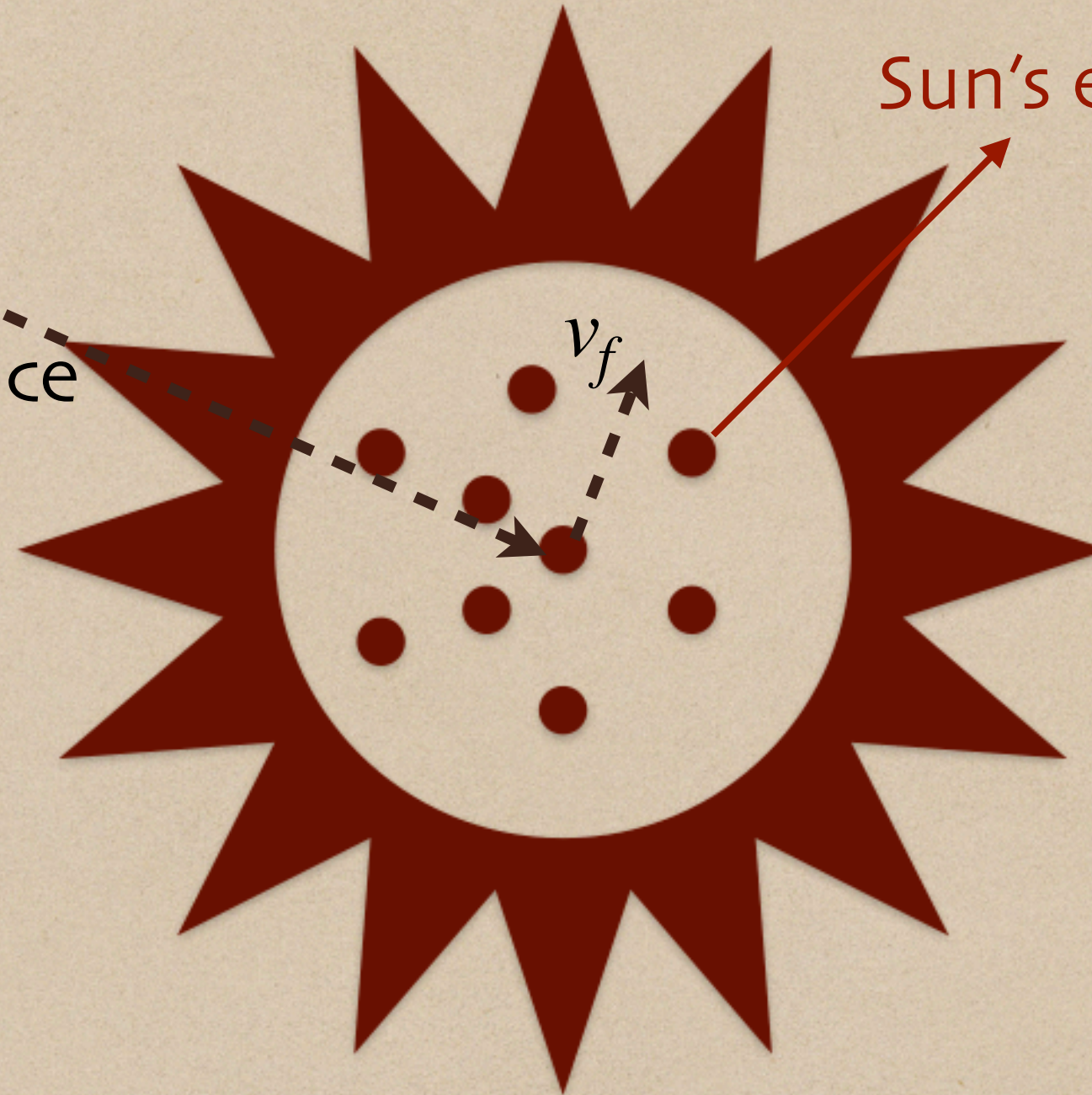


DM capture in Sun

DM particle velocity (u_χ)

velocity at the surface

$$\sqrt{u_\chi^2 + v_{\text{esc}}^2}$$



Sun's electron

$v_f < v_{\text{esc}}$
For capture

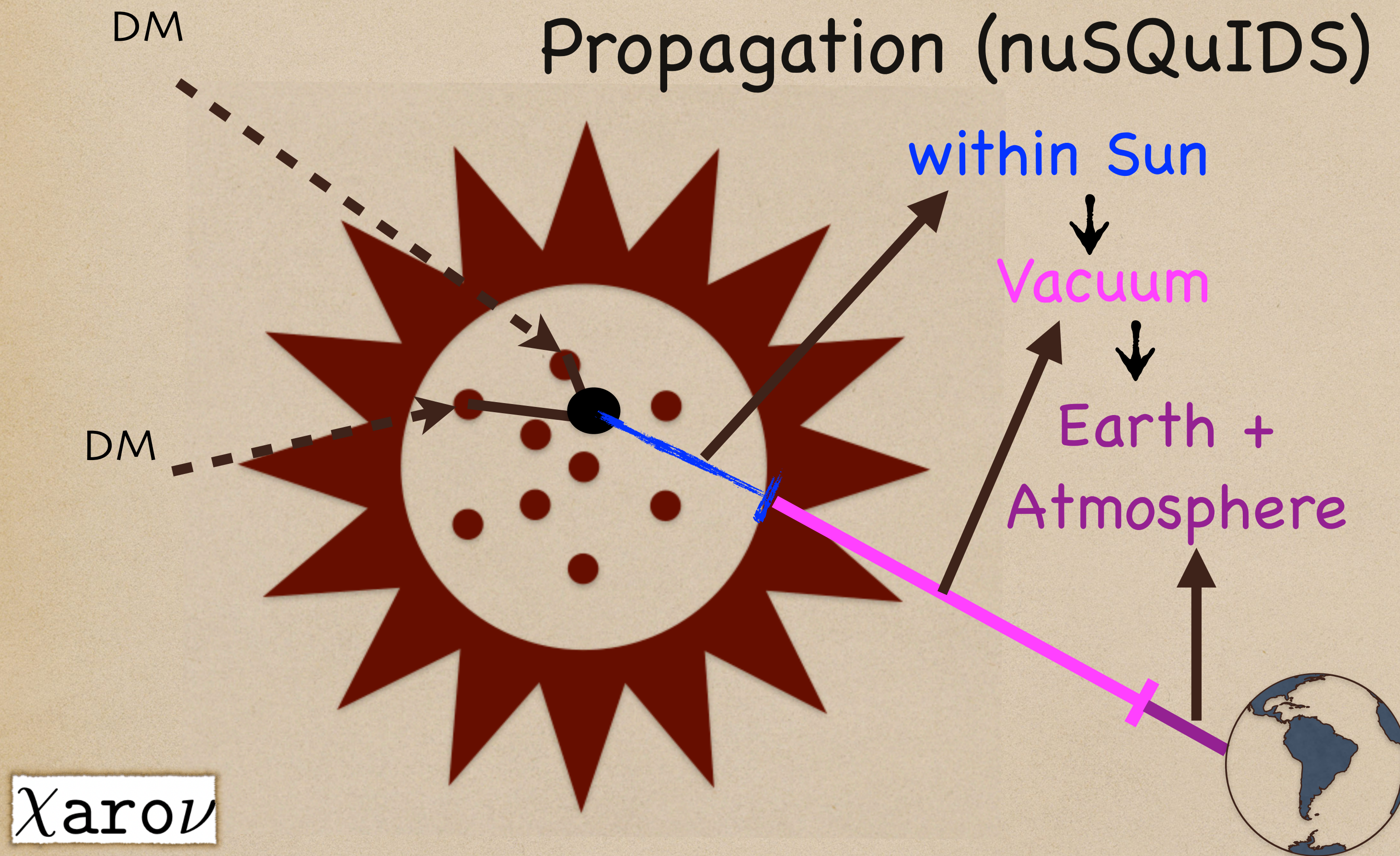
$$C = \int_0^{R_\odot} 4\pi r^2 n(r) dr \int_0^\infty du_\chi \frac{\rho_\chi}{m_\chi} \frac{f_{v_\odot}(u_\chi)}{u_\chi} \sqrt{u_\chi^2 + v_{\text{esc}}(r)^2} g(w) \sigma_e$$

Target number
DM flux
Capture Probability
DM-electron cross section

Gould, ApJ, 1987
Kopp et al 0907.3159
Garani et al 1702.02768

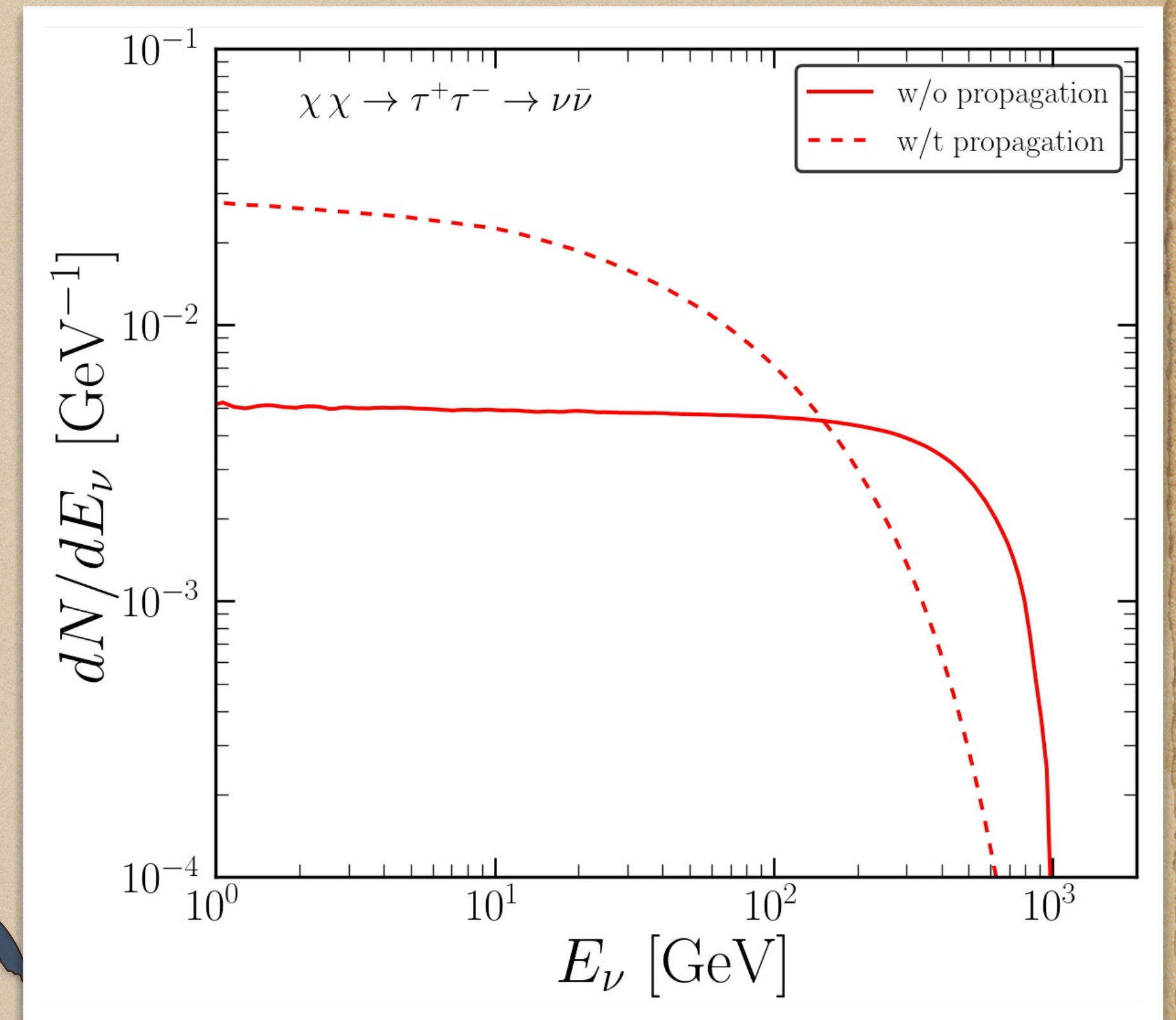
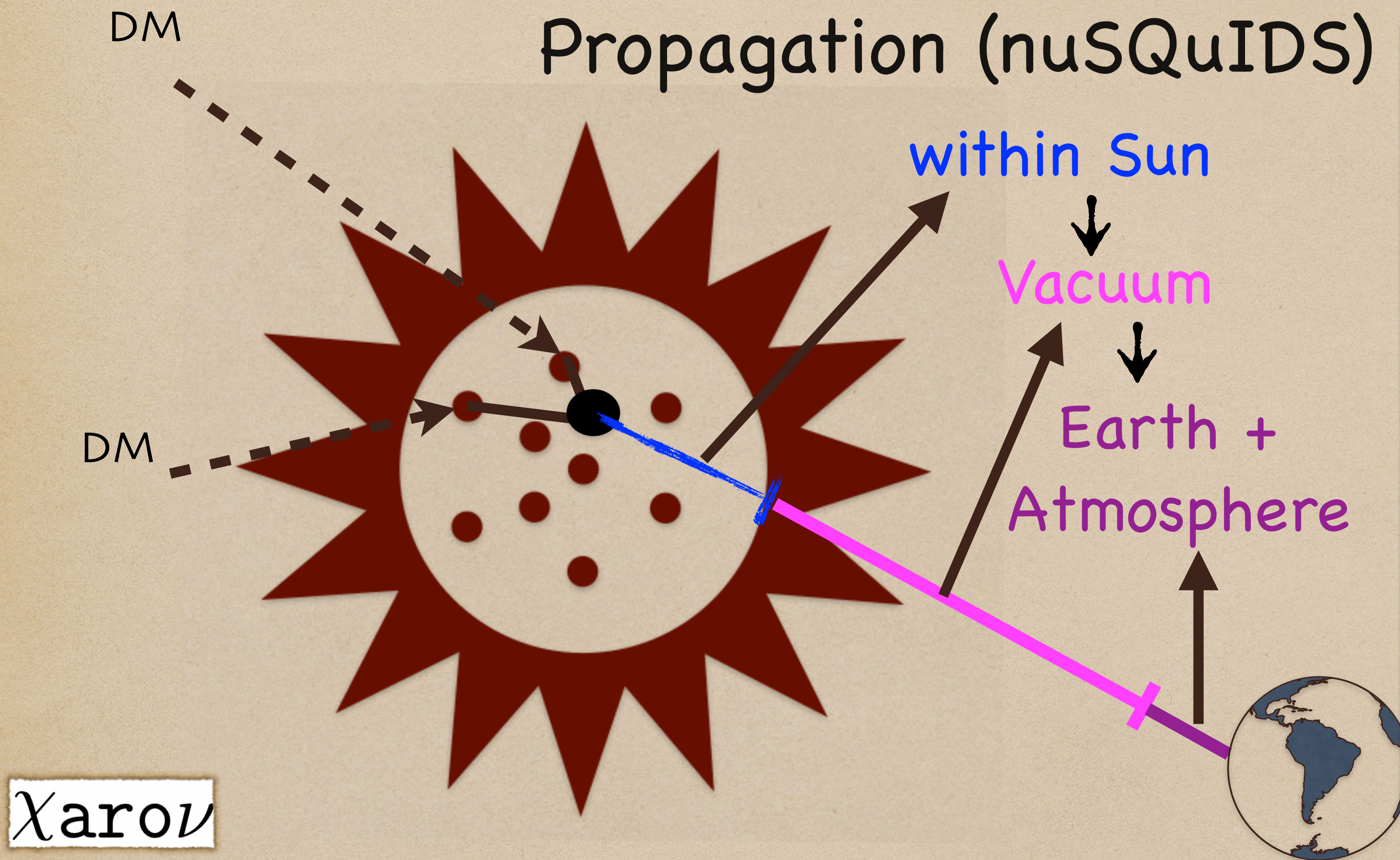
Neutrinos from captured DM

Propagation (nuSQuIDS)



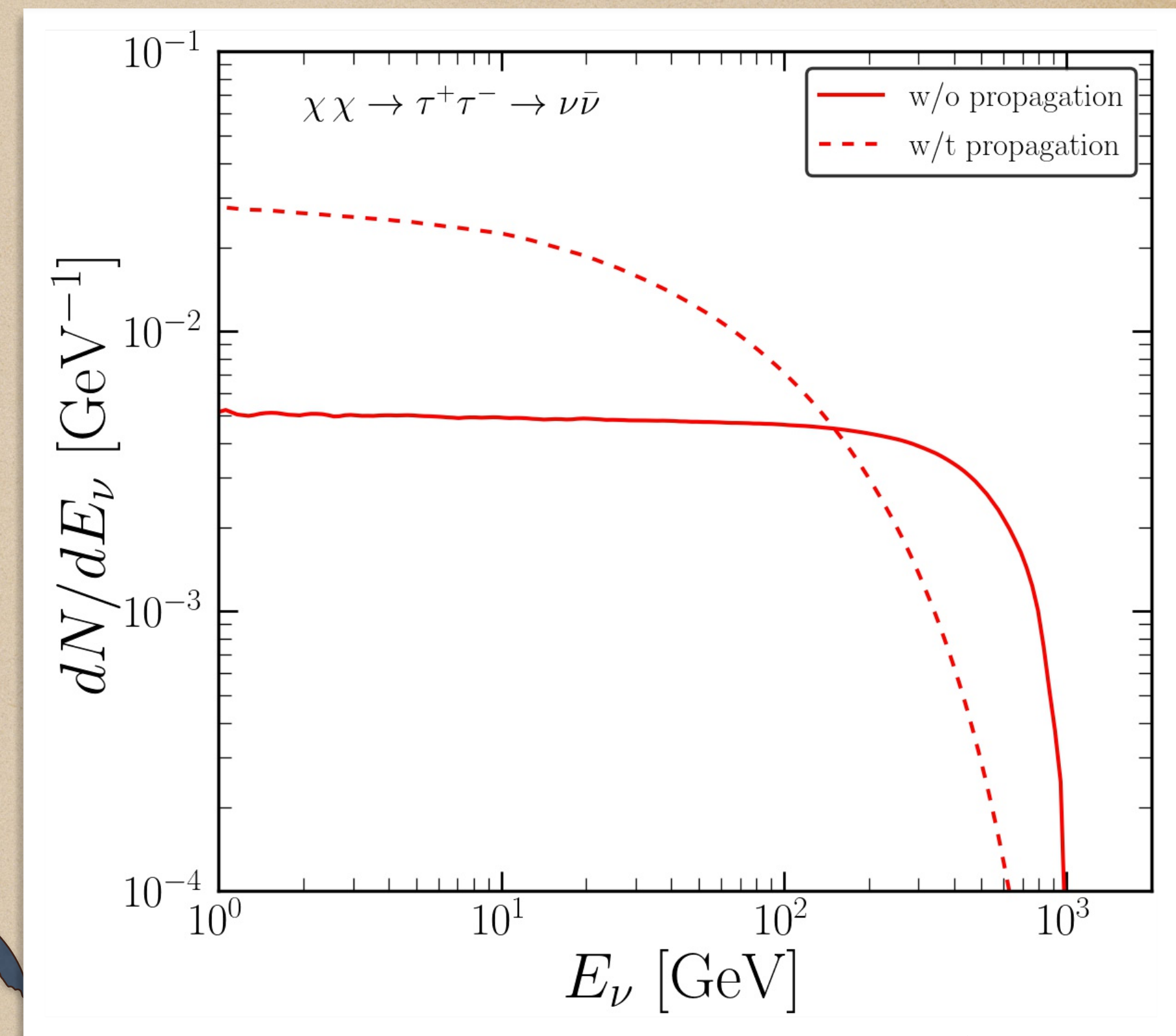
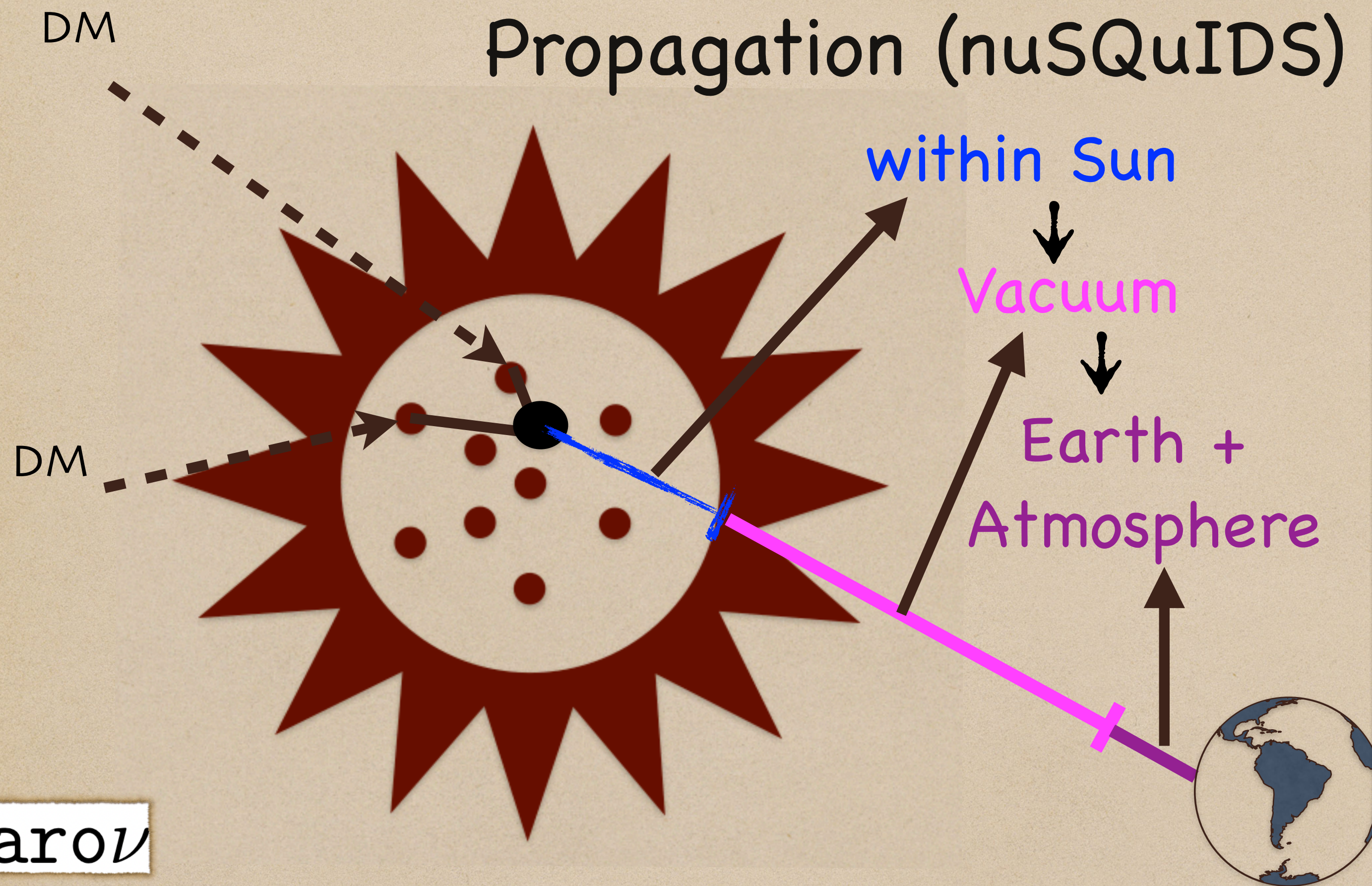
Neutrinos from captured DM

Propagation (nuSQuIDS)



Neutrinos from captured DM

Propagation (nuSQuIDS)



$\chi_{\text{ar}} \nu$

$$\Gamma_{\text{ann}} = \frac{C}{2}$$

At equilibrium, C: Capture rate

Neutrino flux:

$$\frac{d\phi}{dE_\nu} = \frac{\Gamma_{\text{ann}}}{4\pi d_\odot^2} \frac{dN}{dE_\nu}$$

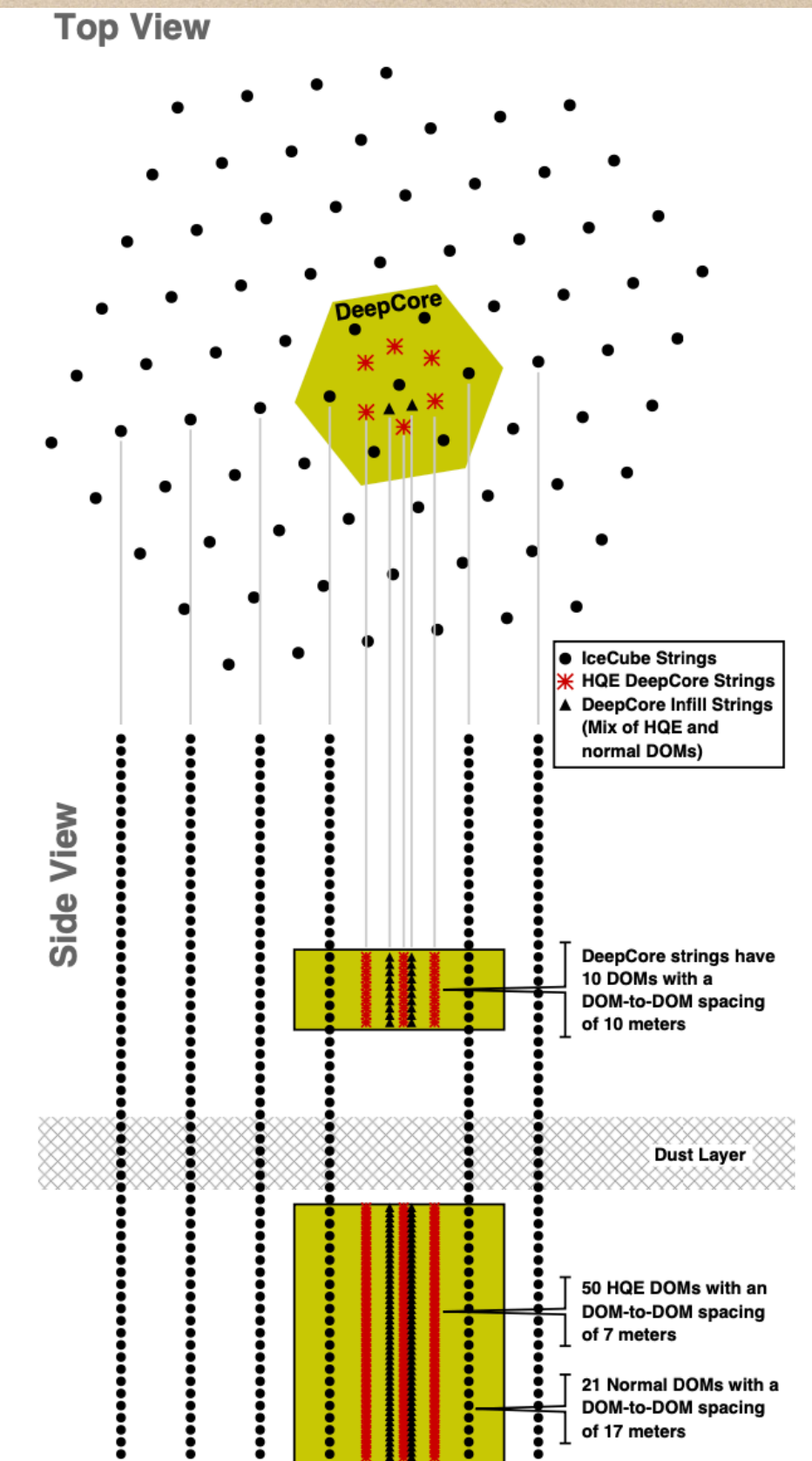
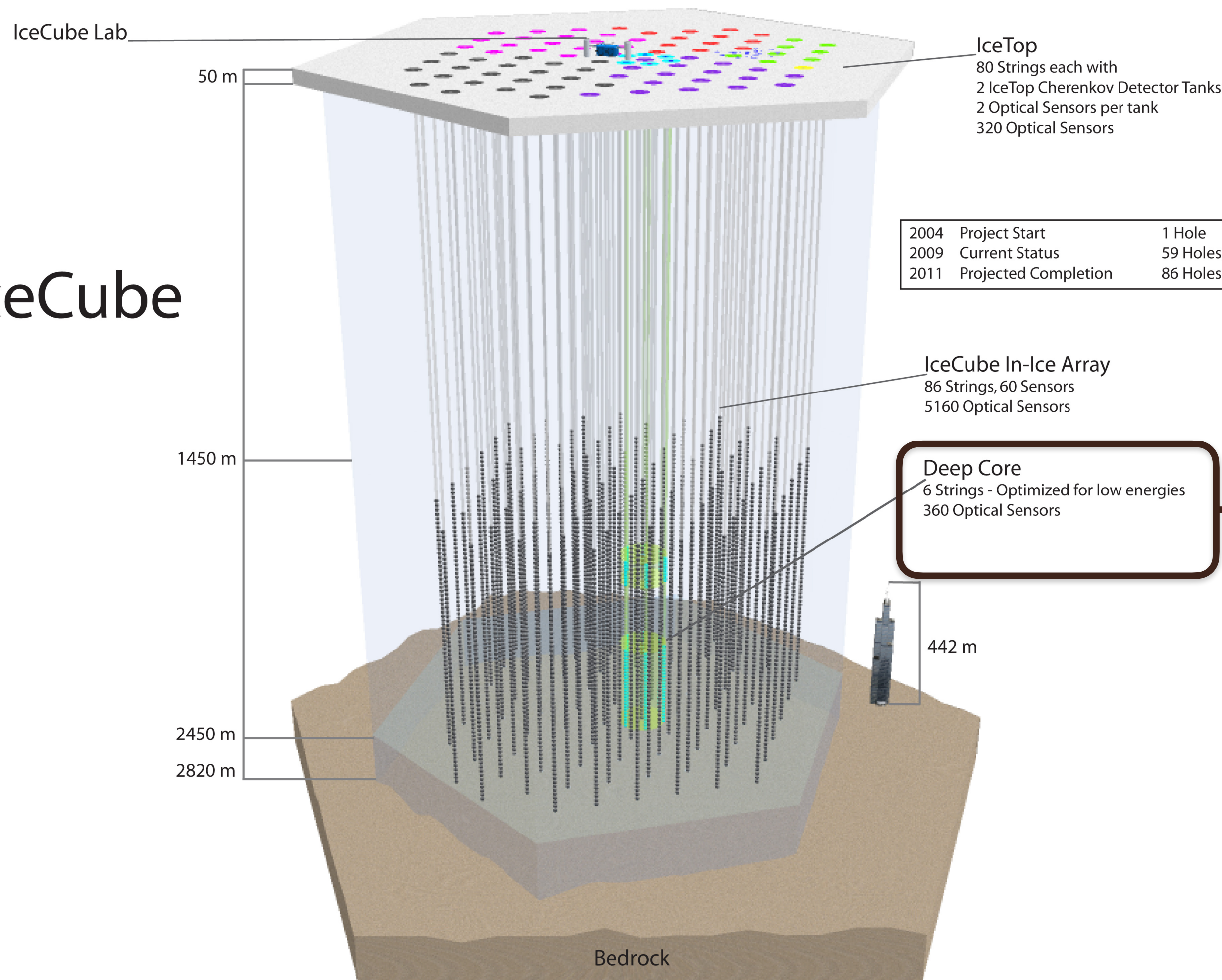
Detect neutrinos

Requires BIG detector and patience; IceCube (DeepCore) is one such

At South Pole, 1 km³

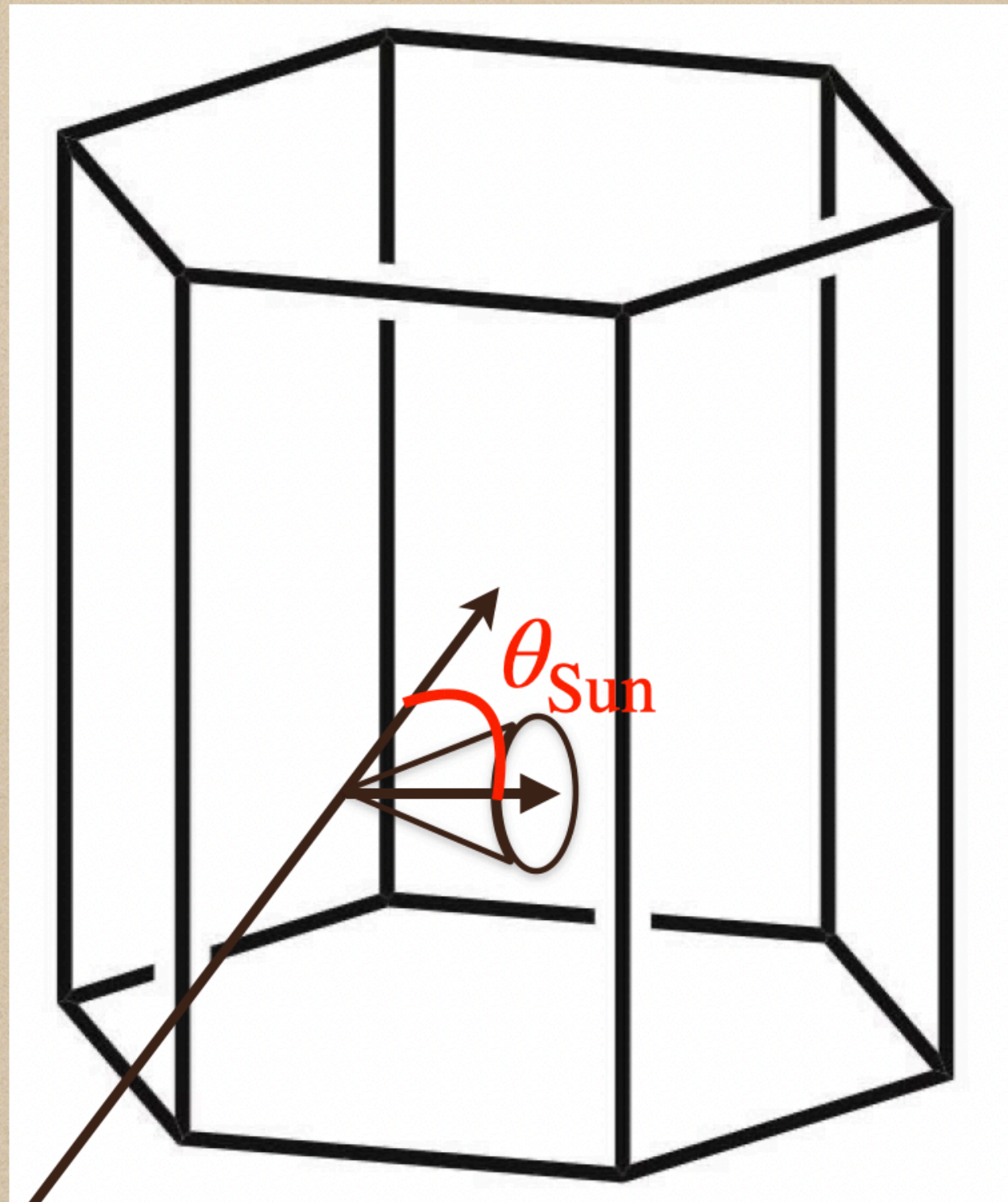
Cherenkov radiation form by product of neutrinos

IceCube

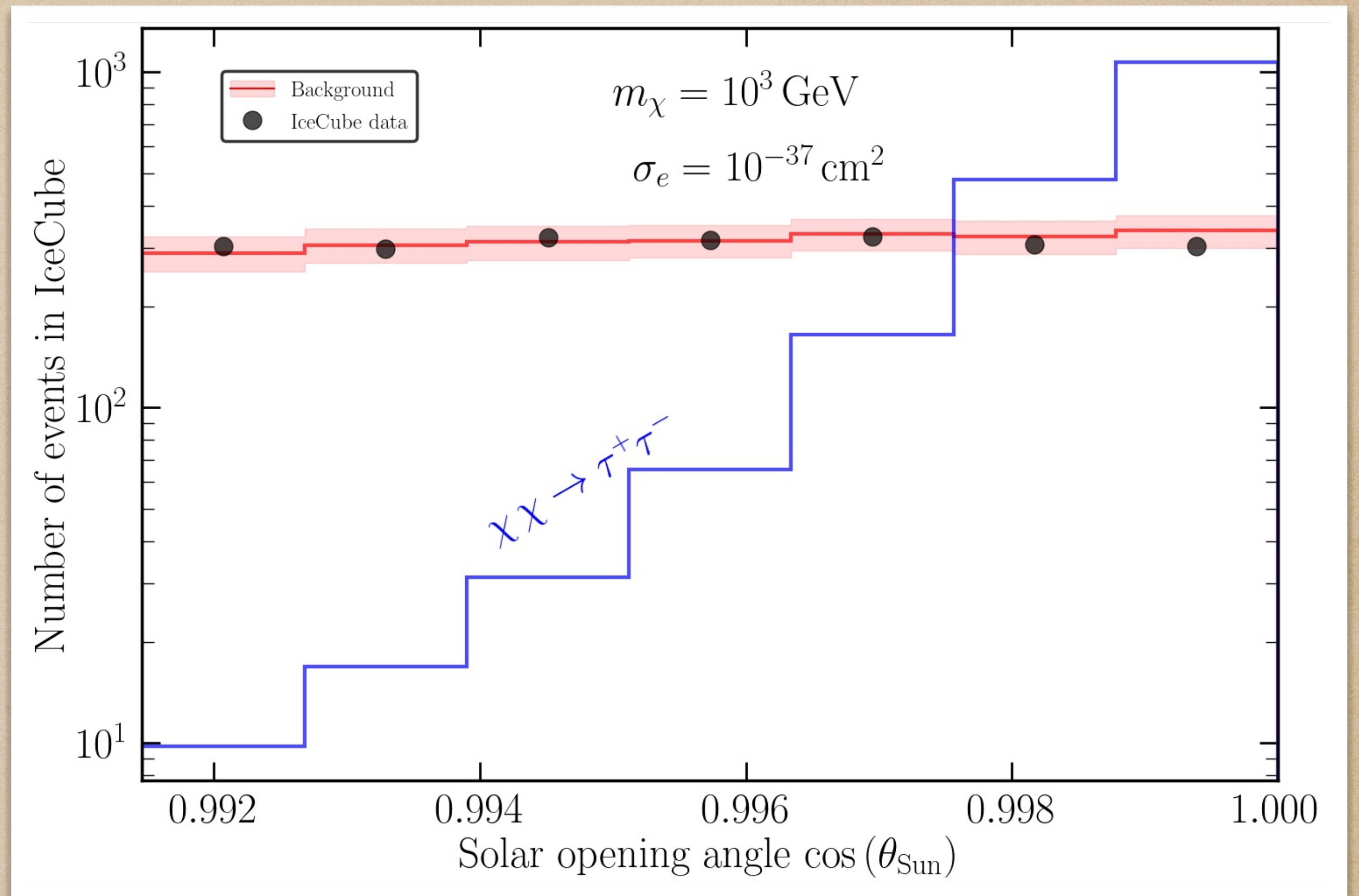
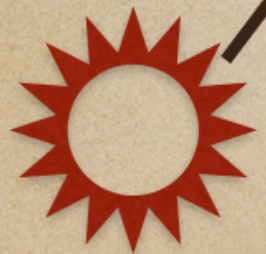


1109.6059

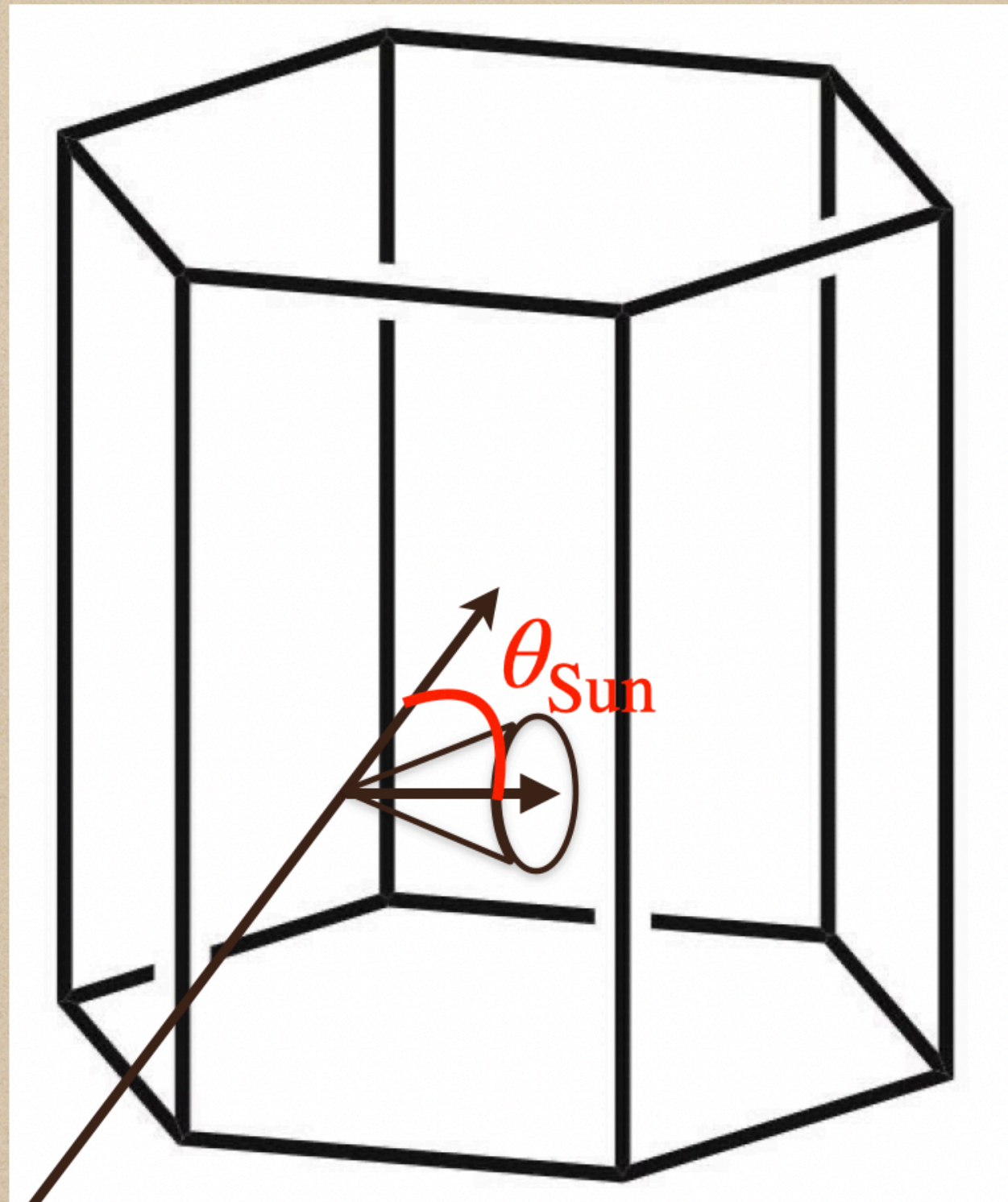
Look towards the Sun



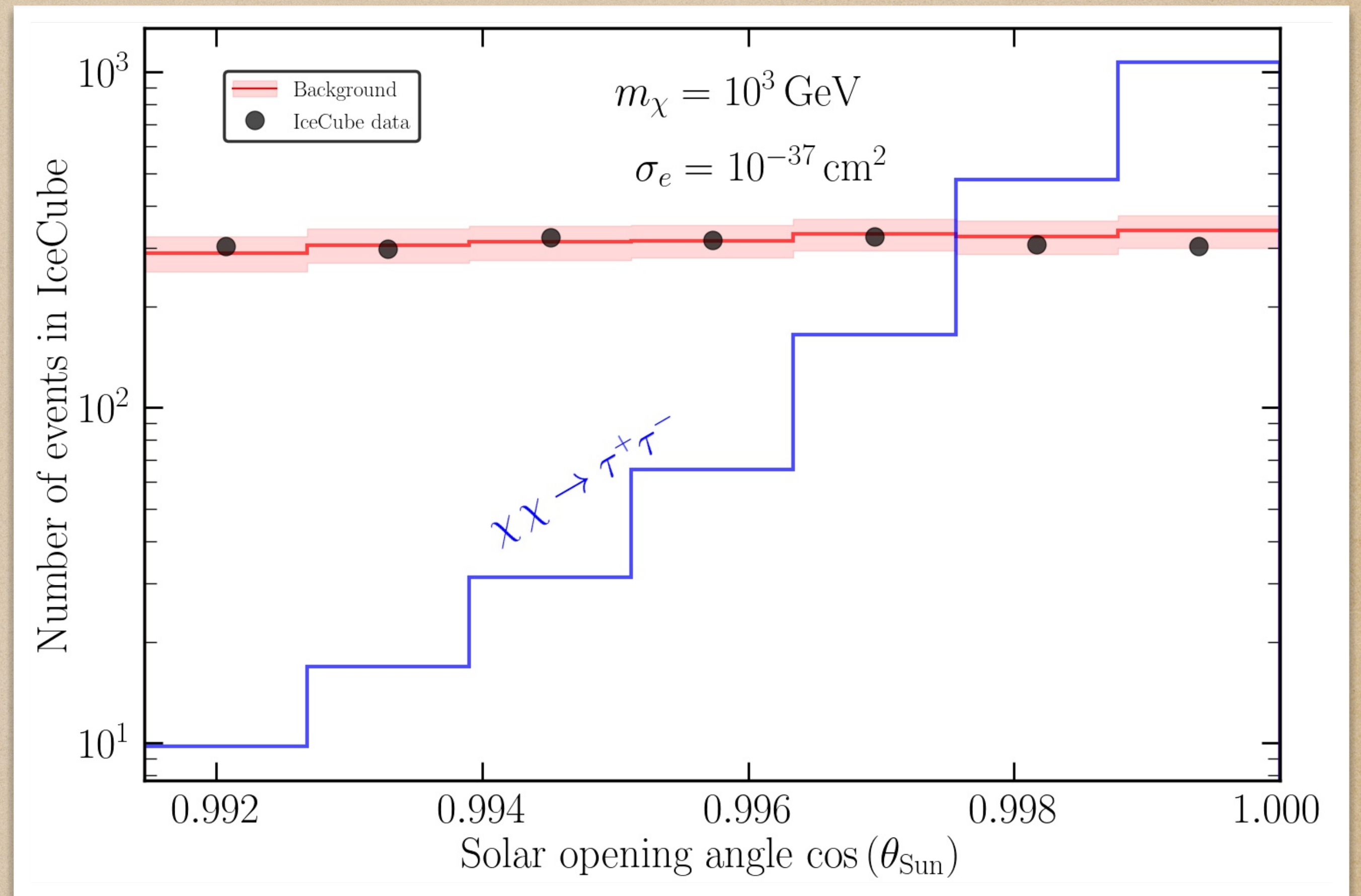
IceCube (DeepCore)



Look towards the Sun

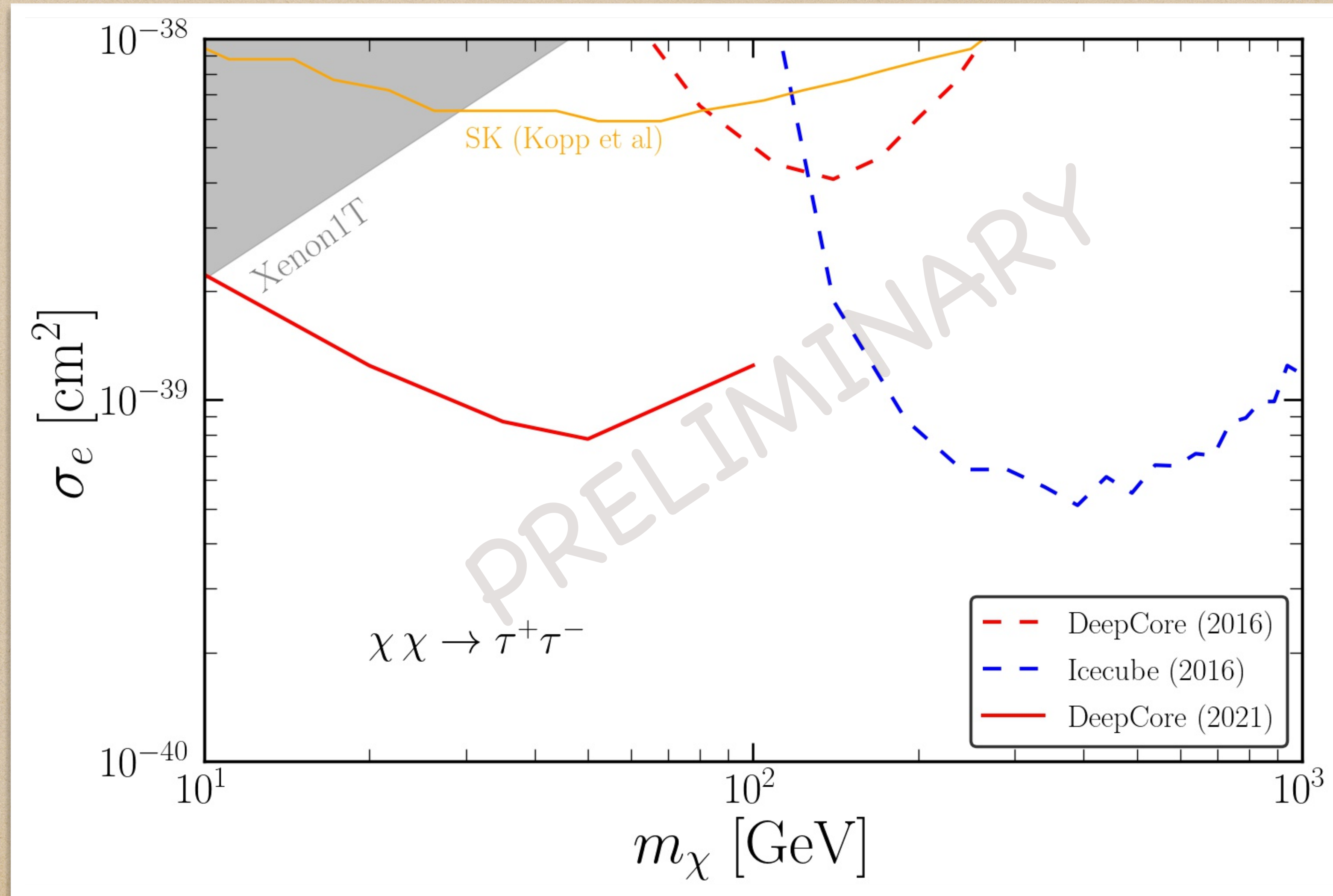


IceCube (DeepCore)



No excess found! \longrightarrow Constraint on DM-e scattering cross section

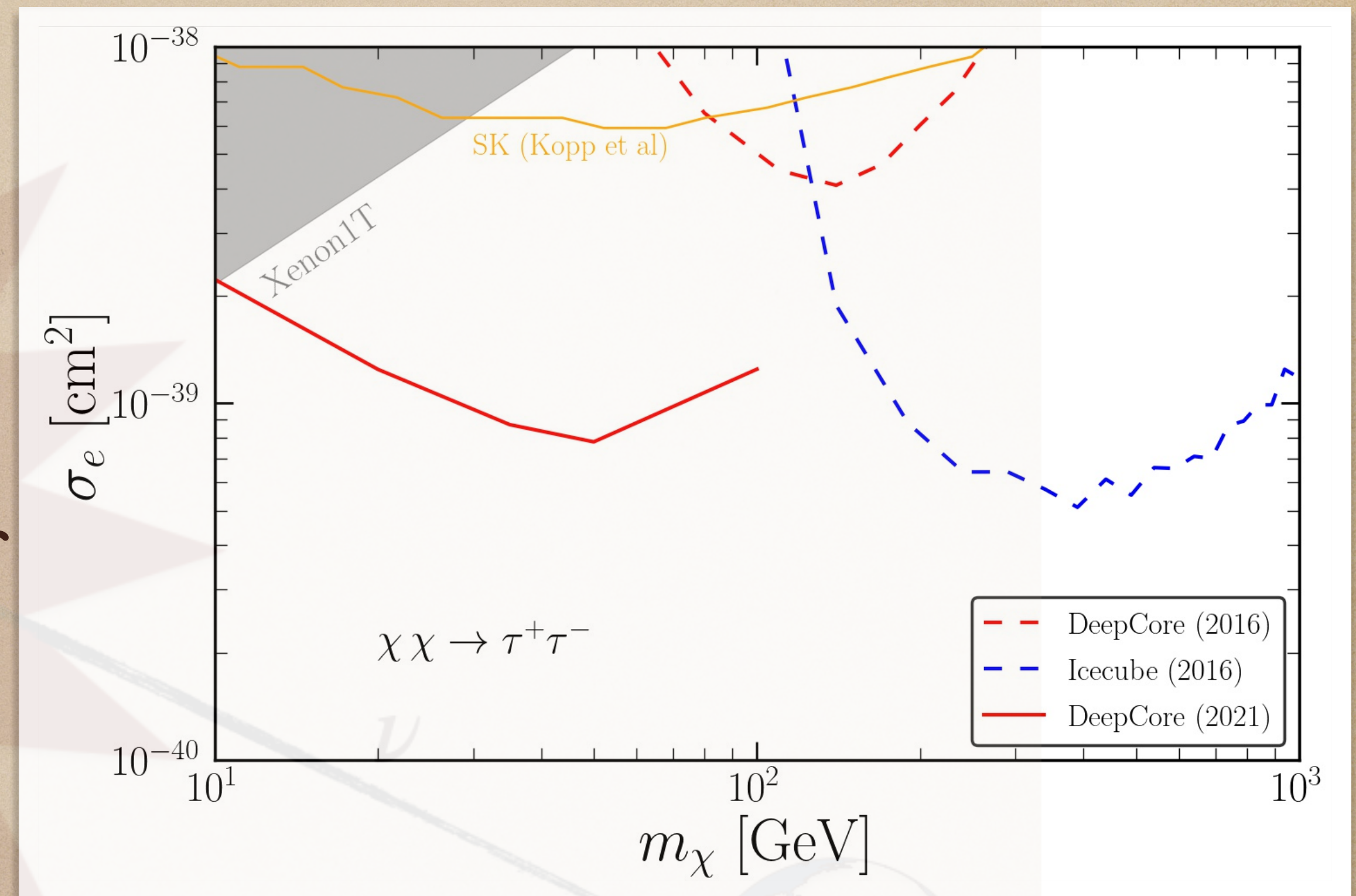
Look towards the Sun: result



TNM, A K Saha, S Mondal, R Laha; in preparation

Take home

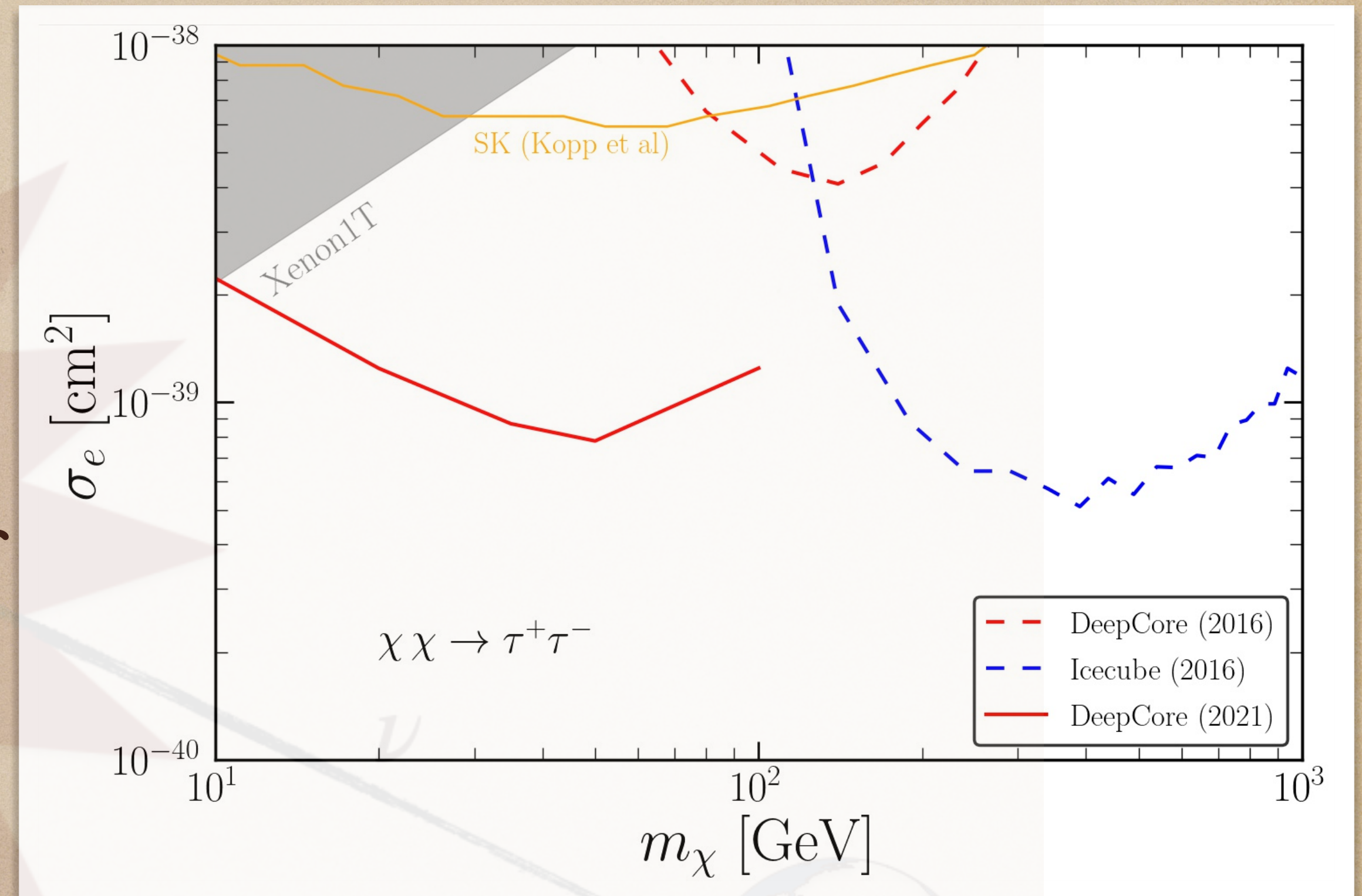
- Neutrinos produce DM capture in Sun through electron scattering
useful probe DM-electron scattering
- IceCube/ DeepCore set leading constraint in large region of parameter Space
- Using this framework future neutrinos telescopes may discover DM-electron scattering



TNM, A K Saha, S Mondal, R Laha; in preparation

Take home

- Neutrinos produce DM capture in Sun through electron scattering
useful probe DM-electron scattering
- IceCube/ DeepCore set leading constraint in large region of parameter Space
- Using this framework future neutrinos telescopes may discover DM-electron scattering



email: tarak.maity.physics@gmail.com

Thank you

TNM, A K Saha, S Mondal, R Laha; in preparation