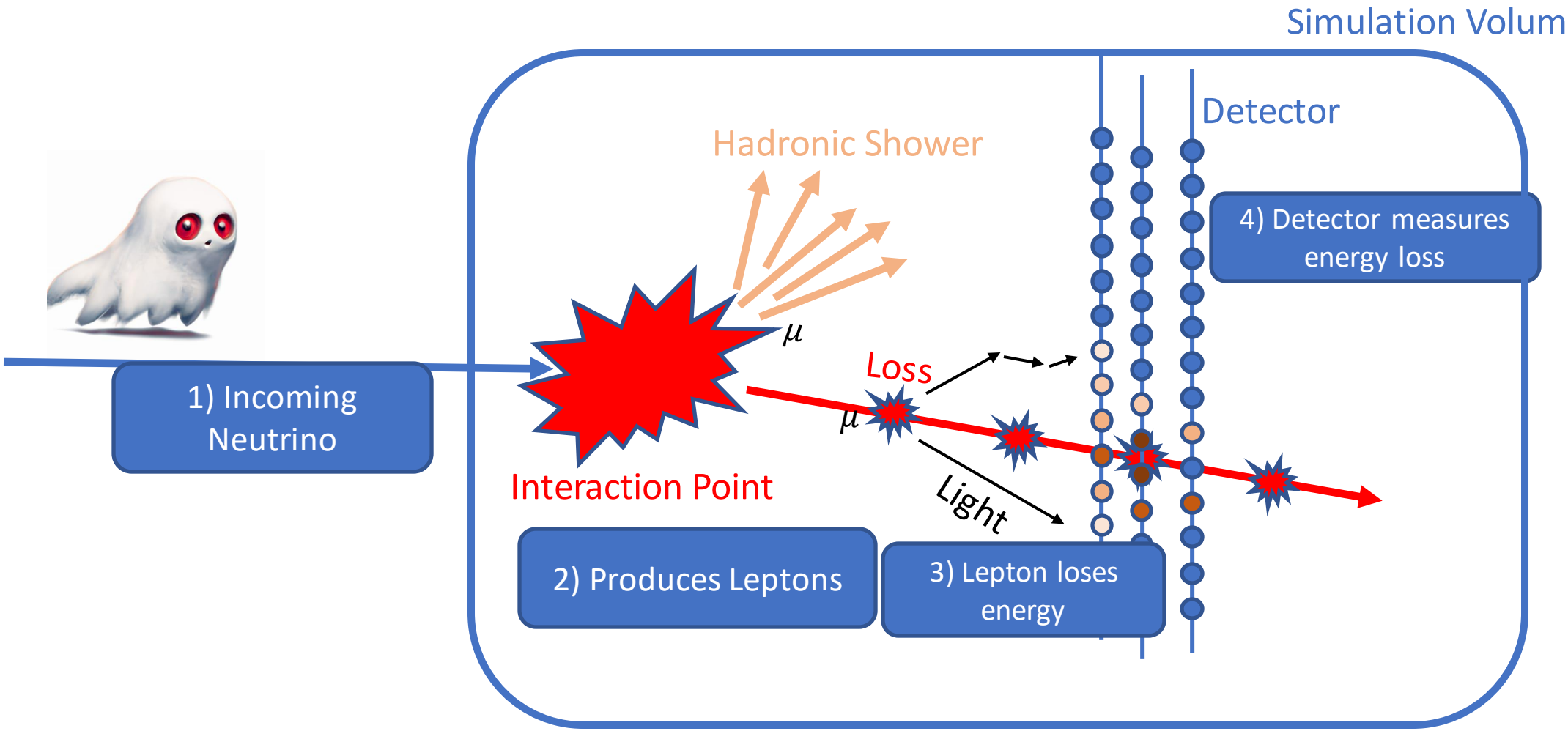
Searching for Dark Matter Annihilation with IceCube and P-ONE

Kruteesh Desai, Ruohan Li, and Stephan Meighen-Berger

Following **arXiv:2302.10542**

Detection Principle

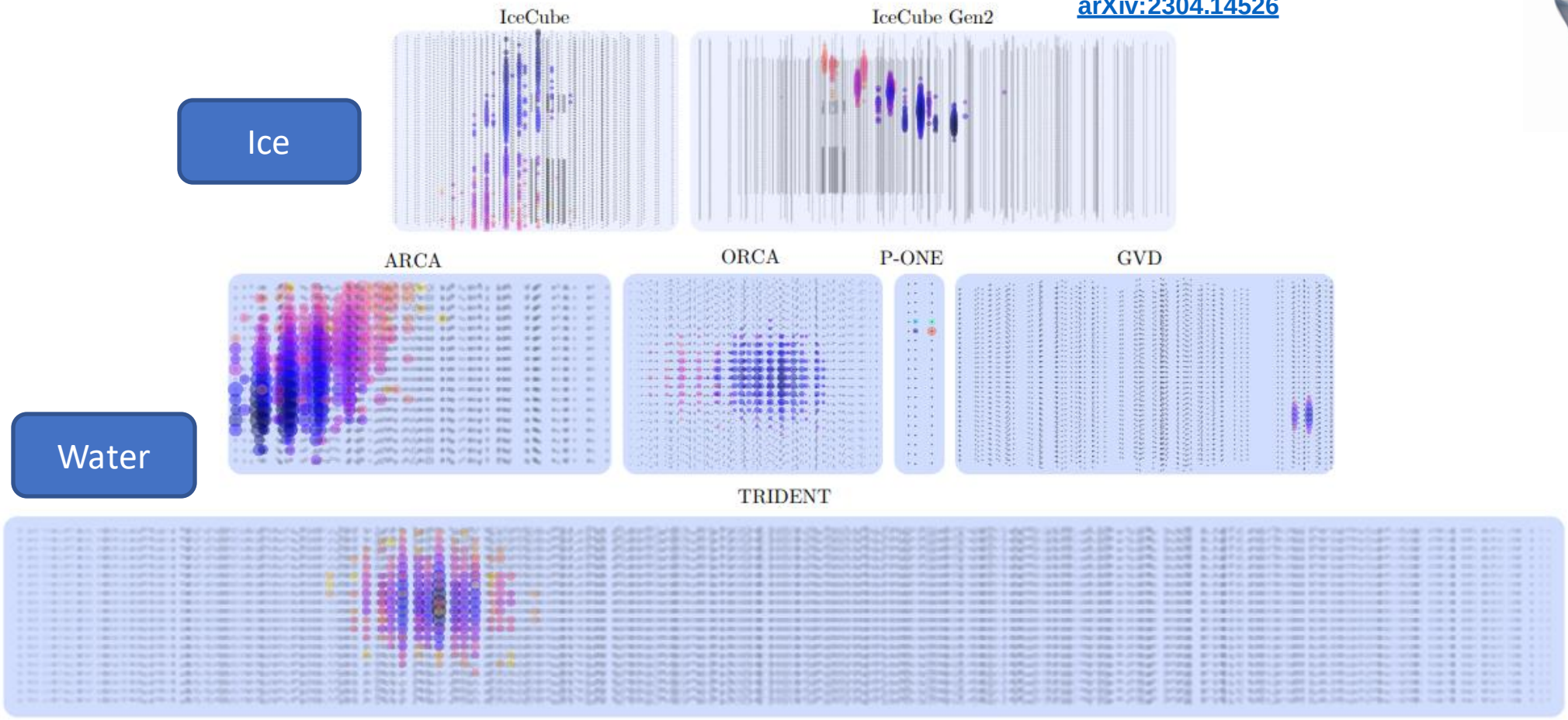


Multiple Detectors Exist/Planned

arXiv:2304.14526

Ice

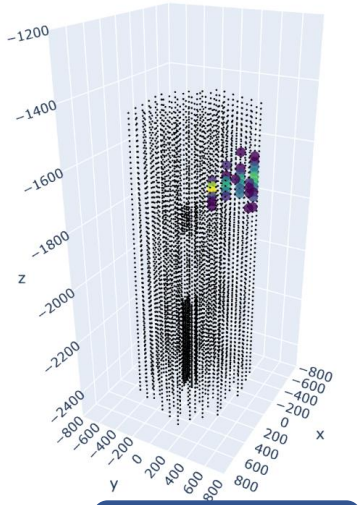
Water



Here we will focus on IceCube and P-ONE

What are the Differences?

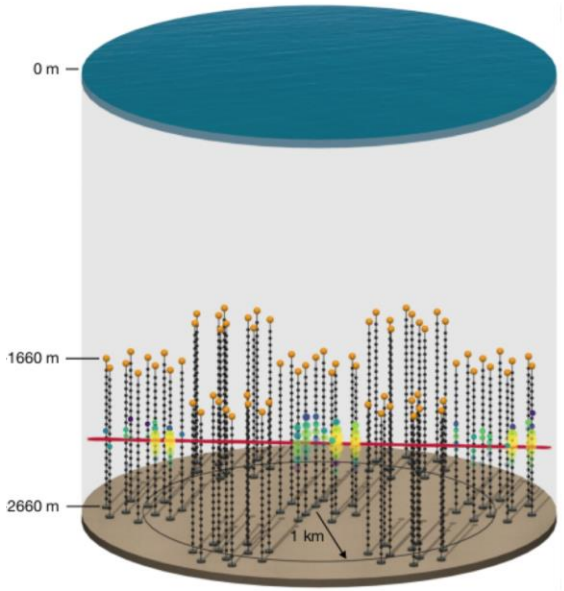
IceCube

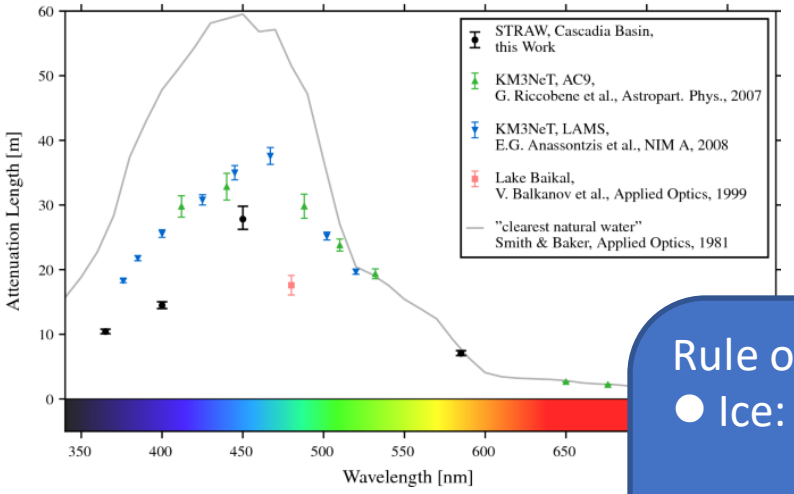


Geometry

P-ONE

arXiv:2005.09493



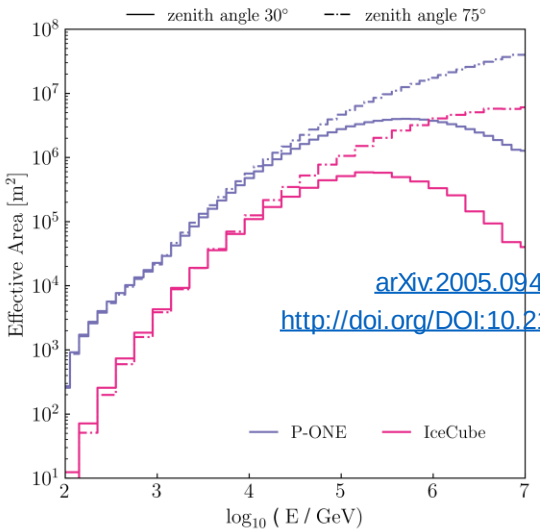


Eur. Phys. J. C **81,** 1071 (2021)

Optical Properties

Rule of Thumb:

- Ice:
  - Attenuation: 150 m
  - Scattering: 30 m
- Water:
  - Attenuation: 30 m
  - Scattering: 150 m



arXiv:2005.09493

http://doi.org/DOI:10.21234/sxvs-mt83

All of this is usually combined into an effective area

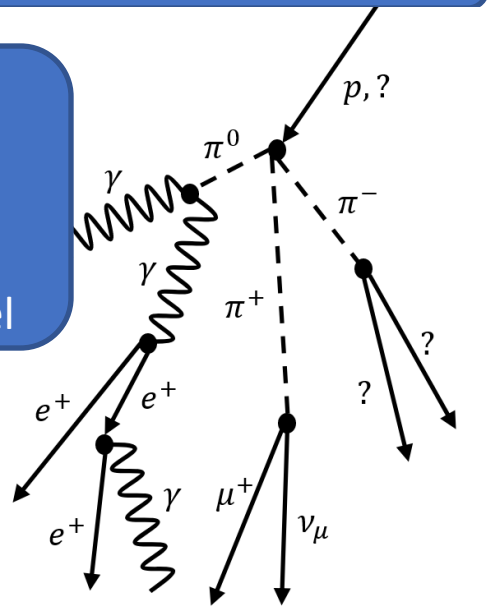
$$N = \int A \frac{\mathrm{d}\phi}{\mathrm{d}E} \mathrm{d}E$$

One Last Thing...

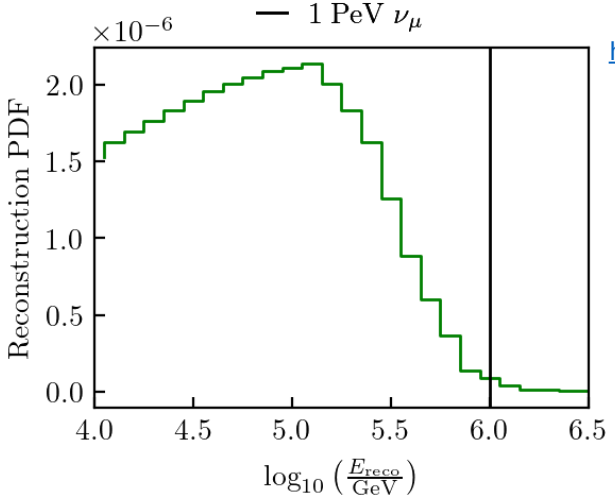
Everyone's favorite topic: Backgrounds

Let's ignore some uncertainties:

- Interaction Model
- Primary Model
- Atmospheric Model

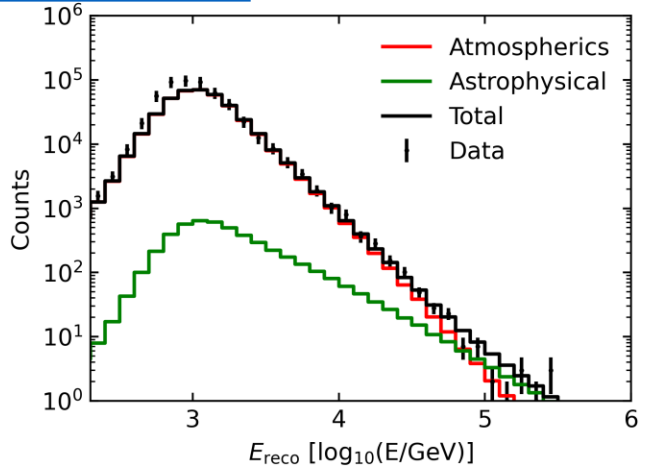


The reconstruction isn't perfect either (especially for muon neutrinos)

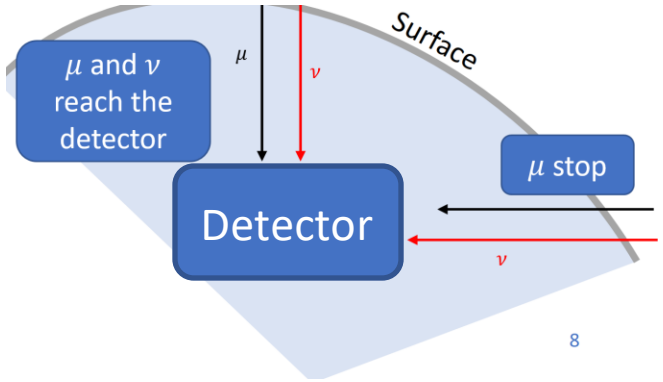


arXiv:2109.07885

http://doi.org/DOI:10.21234/sxvs-mt83



https://github.com/MeighenBergerS/fledgeling

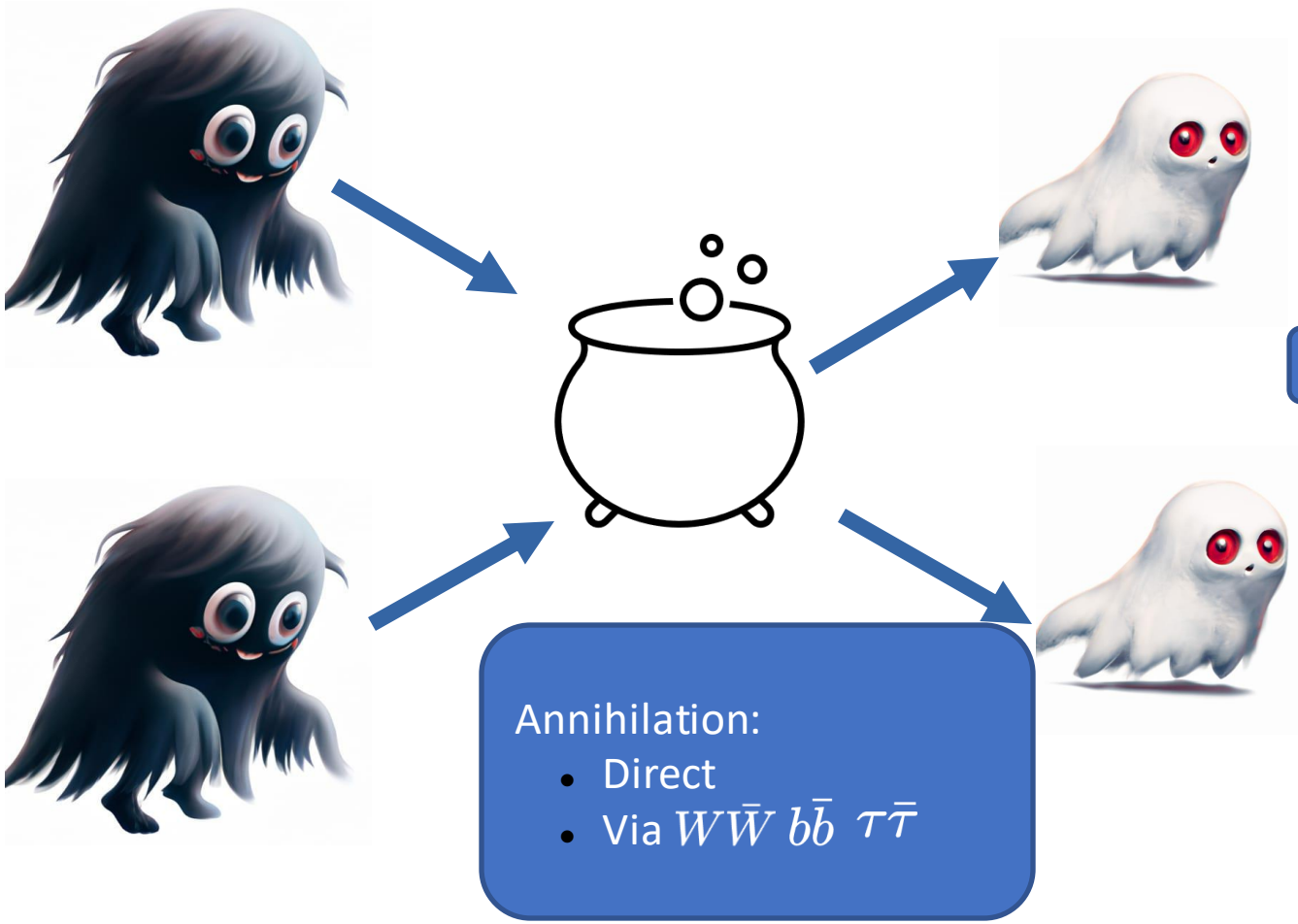


Even the astrophysical diffuse flux is a background!

You found me!

… Took you long enough

Let's go with the simplest case I



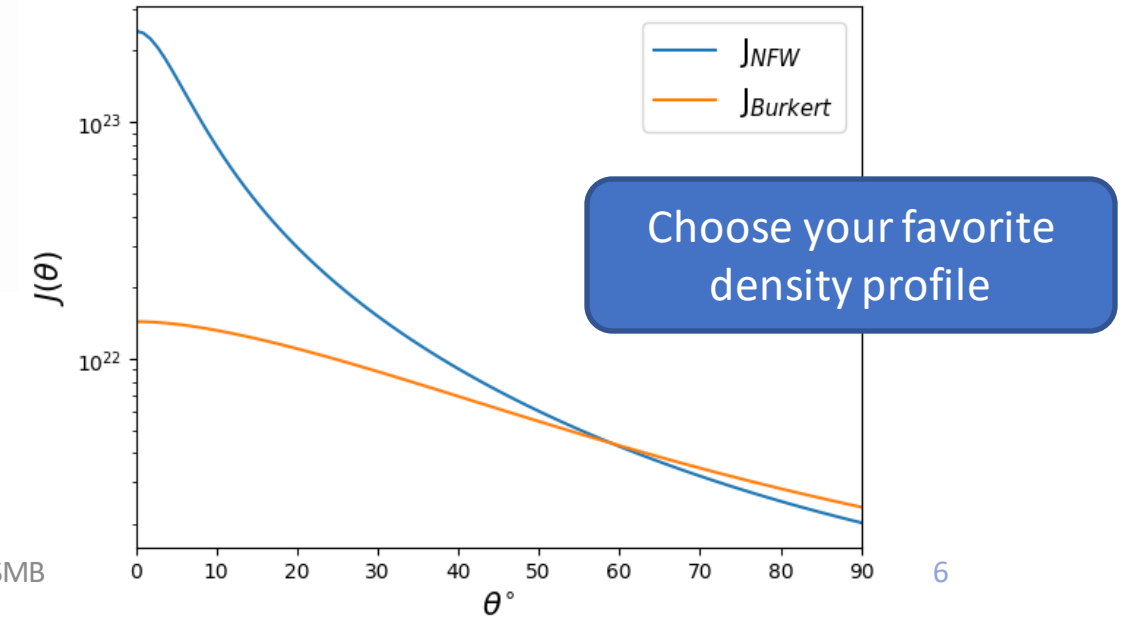
Annihilation:
- Direct
- Via $W\bar{W}$ $b\bar{b}$ $\tau\bar{\tau}$

Galactic

$$\frac{d\Phi_{galactic}}{dE} = \frac{1}{4\pi}\frac{\langle\sigma\nu\rangle}{\kappa m_\chi^2}\frac{1}{3}\frac{dN_\nu}{dE_\nu}J(\Omega)$$

Direct

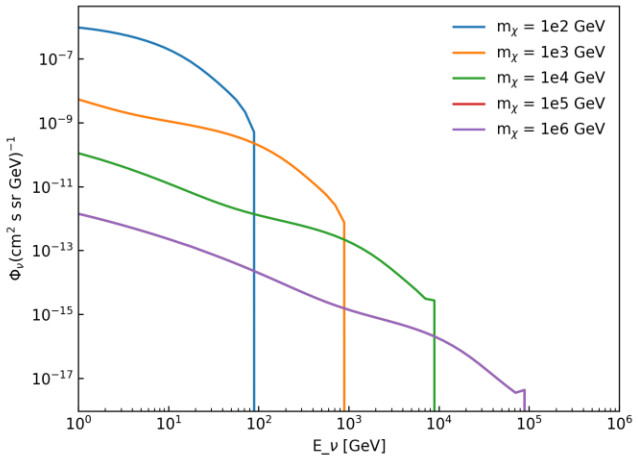
$$\frac{dN_\nu}{dE_\nu} = 2\delta\left(1-\frac{E}{m_\chi}\right)\frac{m_\chi}{E^2}$$



Choose your favorite density profile

Let's go with the simplest case II

Galactic via $\tau\bar{\tau}$



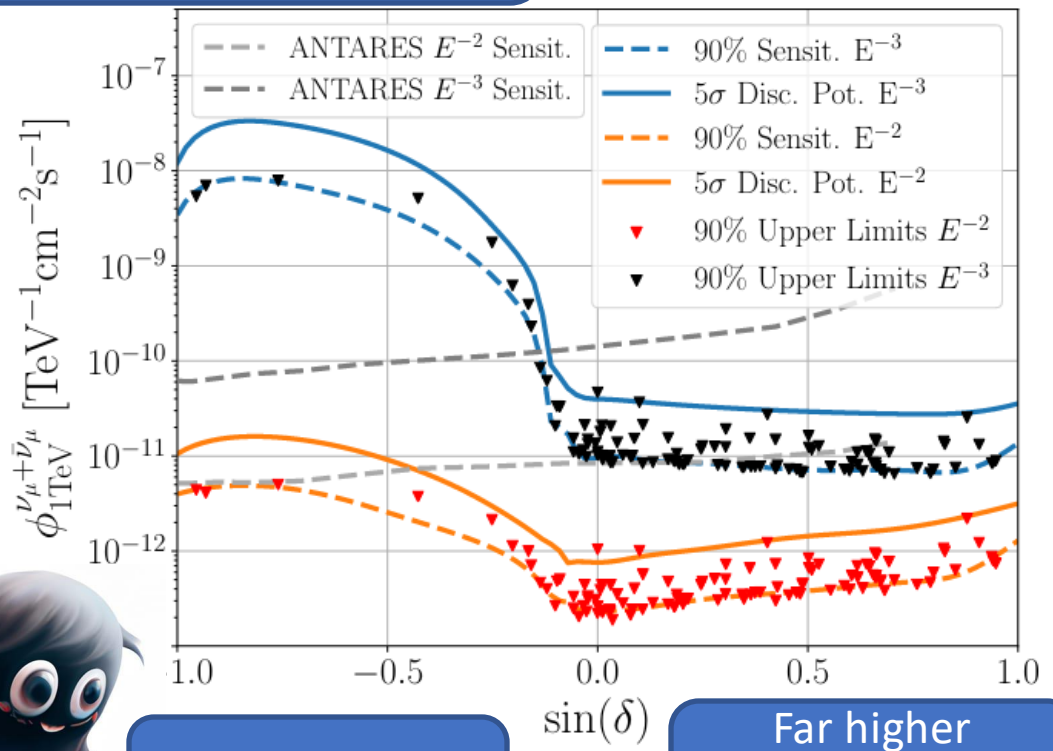
Current Limits and Predictions

Let's see what this means for IceCube and P-ONE with 10 years of data

Until we have Northern Data

Since IceCube is in the South, it is "blind" to the GC → x20 penalty to sensitivity

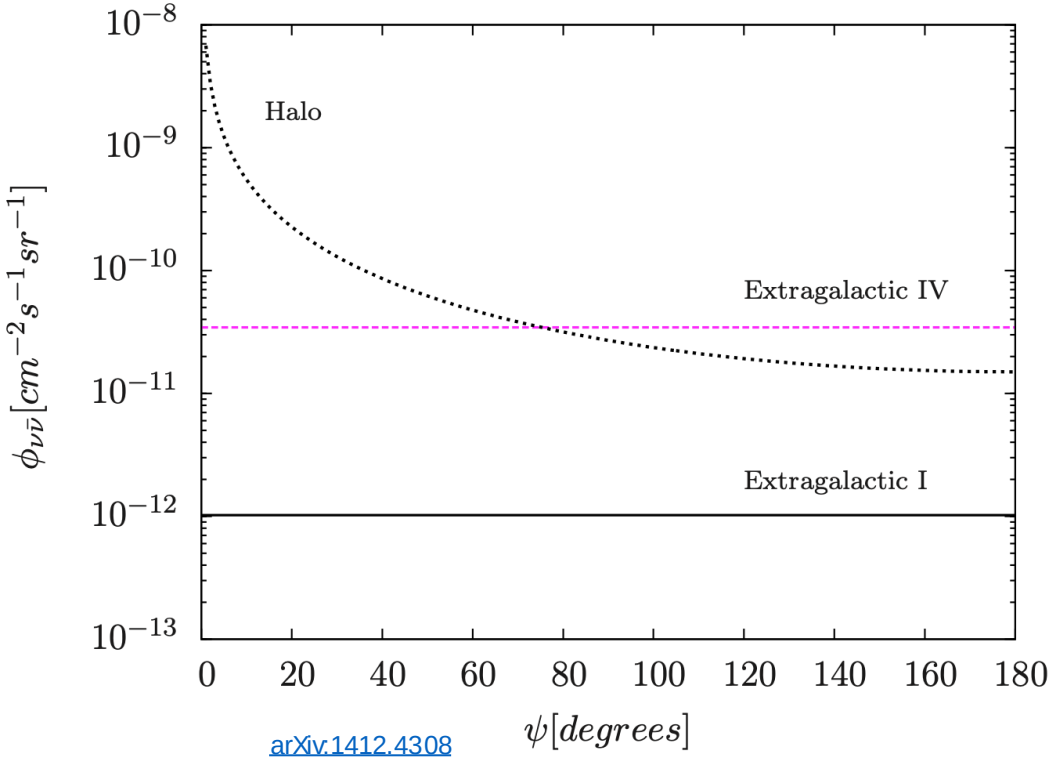
arXiv:1910.08488



GC is over here

Far higher sensitiviy to "up-going"

Can we use the extra-galactic flux to improve the IceCube limits?



arXiv:1412.4308

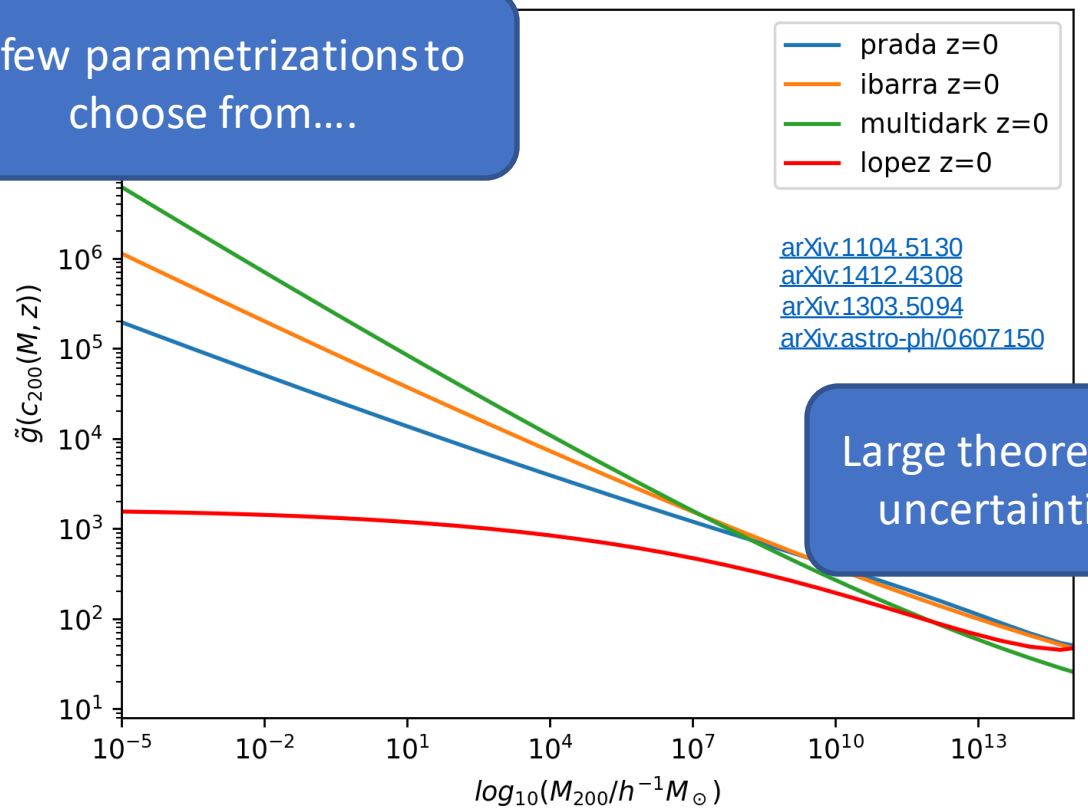
Let's talk about the Models I

$$\frac{d\Phi_{extra}}{dE_\nu} = \frac{1}{4\pi}\frac{\Omega_{DM}^2\rho_c^2\langle\sigma\nu\rangle}{\kappa m_\chi^2}\frac{1}{3}$$

$$\times\int_0^{z_{up}} dz \frac{[1+G(z)](1+z)^3}{H(z)}\frac{dN_\nu}{dE_\nu}$$

$$G(z) = \frac{1}{\Omega_{DM,0}^2\rho_c^2(1+z)^6}\times\int dM\frac{dn(M,z)}{dM}\int dr 4\pi r^2\rho_\chi^2(r)$$

A few parametrizations to choose from….



Large theoretical uncertainties

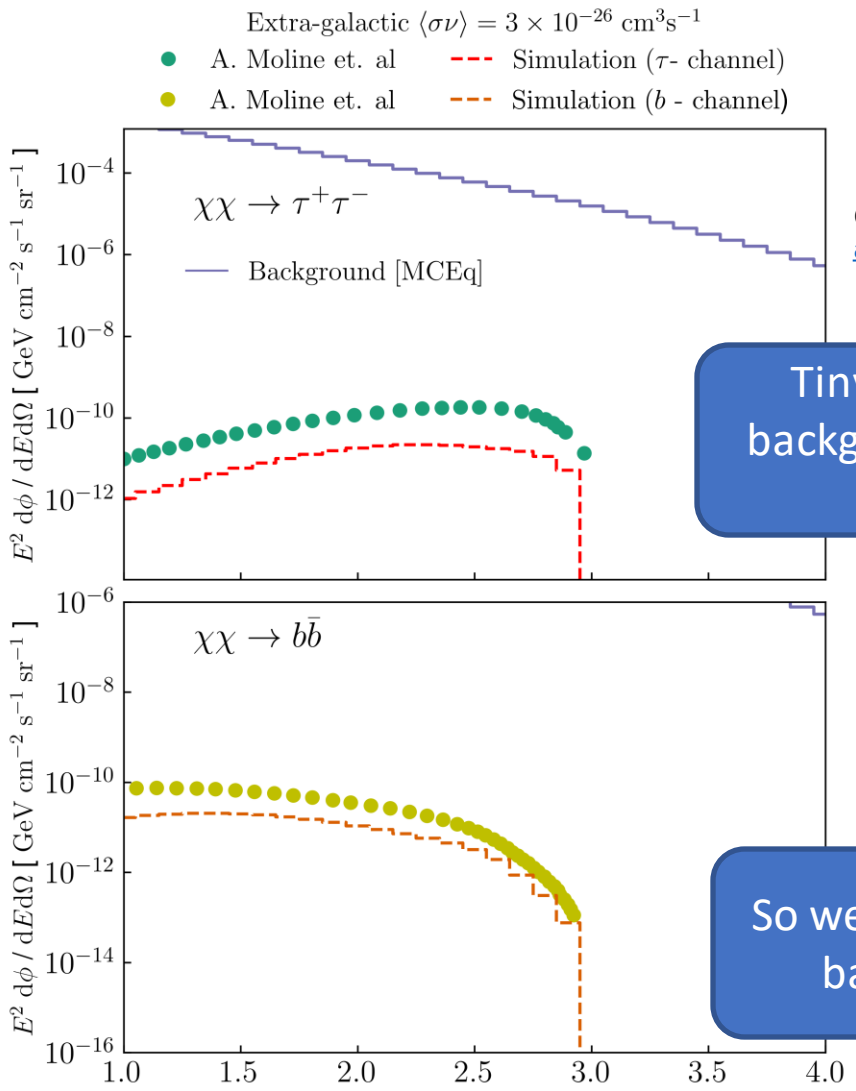
Quite a few sources of uncertainty

$$\int_0^{r_\Delta} \mathrm{d}r 4\pi r^2\rho_{halo}^2(r) = \tilde{g}(c_\Delta)\frac{M\Delta\rho_c(z)}{3}$$

Let's talk about the Models II

$$\frac{d\Phi_{extra}}{dE_\nu} = \frac{1}{4\pi}\frac{\Omega_{DM}^2\rho_c^2\langle\sigma\nu\rangle}{\kappa m_\chi^2}\frac{1}{3}$$

$$\times\int_0^{z_{up}} dz \frac{[1+G(z)](1+z)^3}{H(z)}\frac{dN_\nu}{dE_\nu}$$



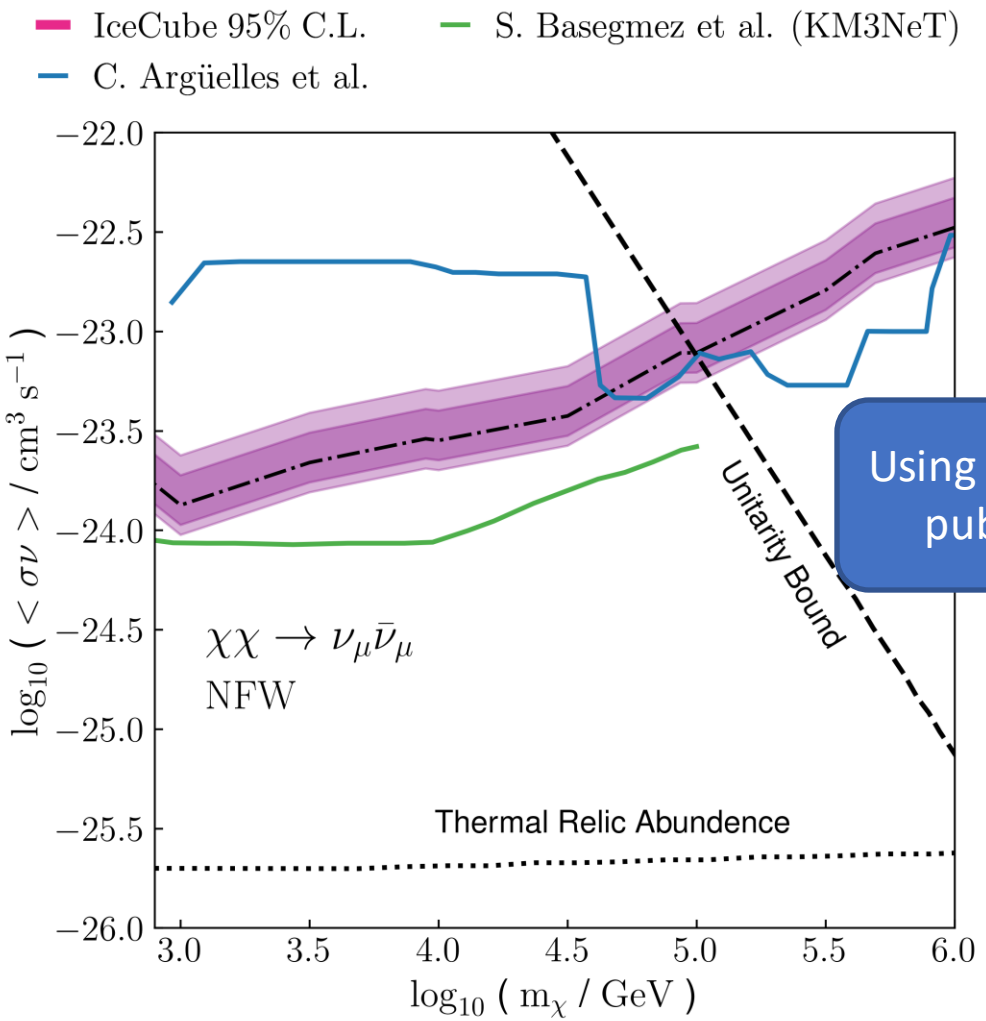
Comparing to:
[arXiv:1602.07282]

Tiny compared to the background and expected galactic signal.

So we'll to keep this on the backburner for now

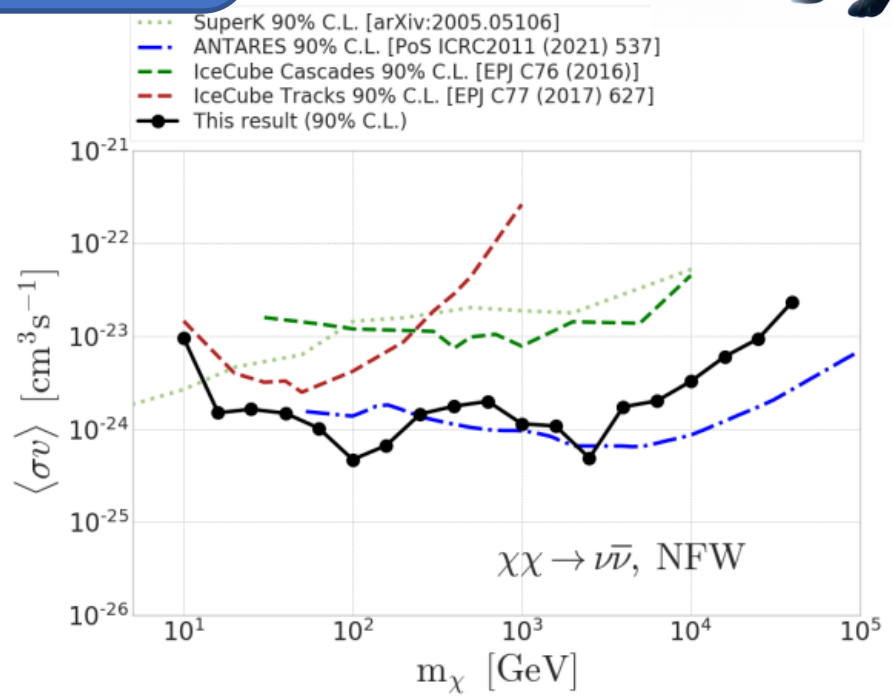
[arXiv:1912.09486]

So what limits can we set right now?



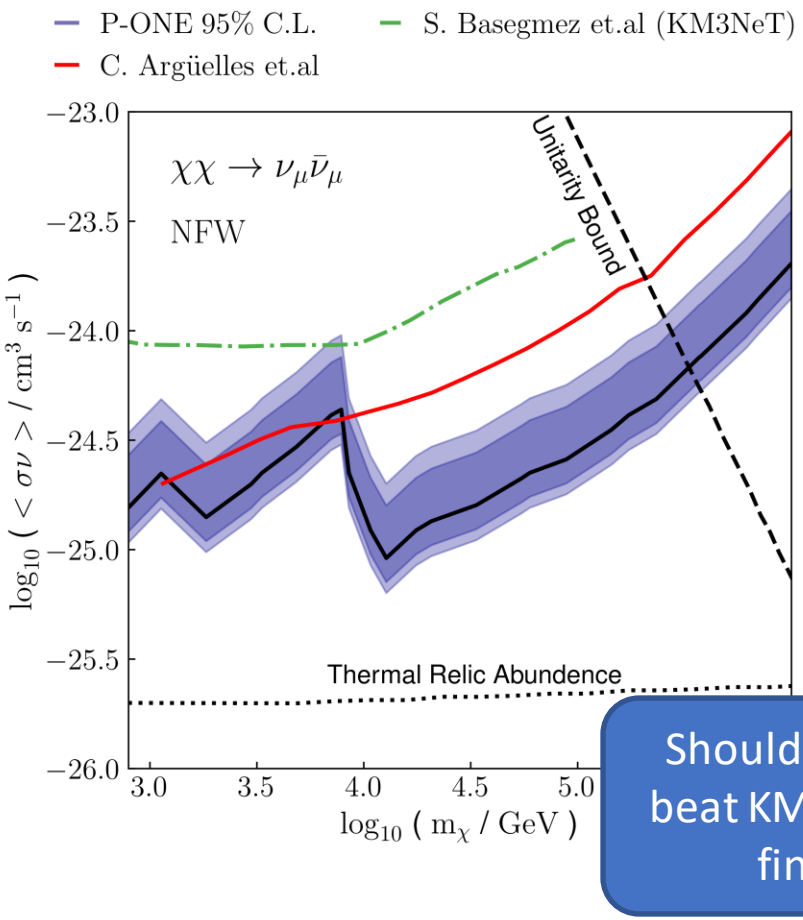
IceCube recently improved these limits for "lower masses" using cascades

Using 10 years of public data

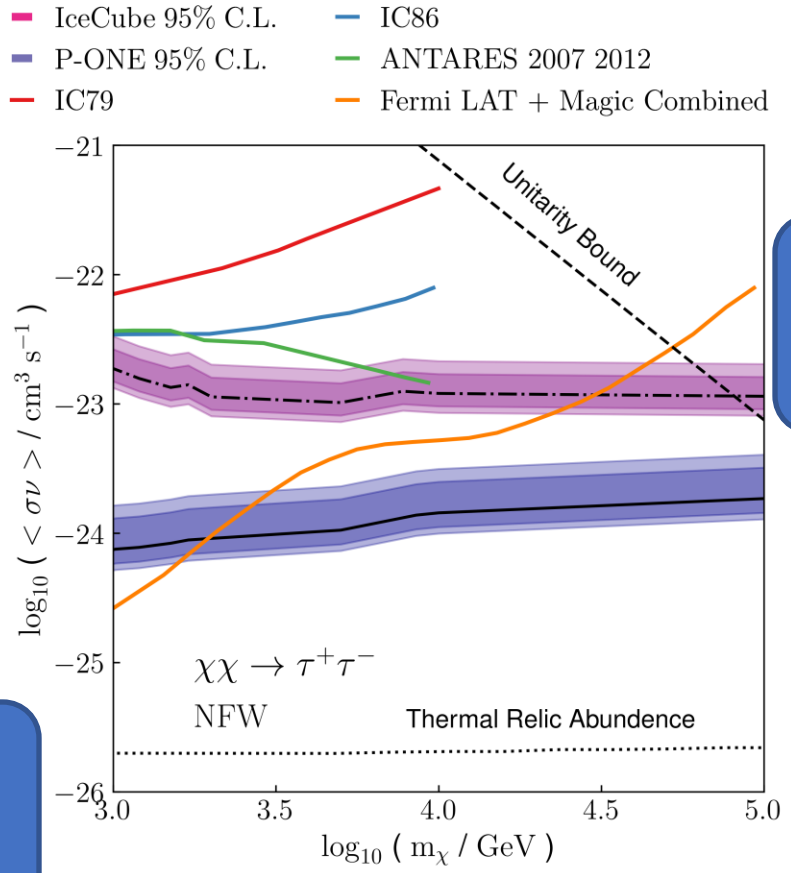


arXiv:2303.13663v1

What about P-ONE?



Should be able to beat KM3NeT once finished



Competitive with Gamma-Rays at high masses

Can be even further improved by using "pointing"!

Take home messages

Future detectors will be a fantastic probe for heavy dark matter

Using extra-galactic (diffuse) DM still proves elusive

Driven by theory and experimental uncertainties

Questions?

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