Search for light dark matter with KM3NeT/ORCA-115

June-October 2023

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LIGHT WIMP DM SEARCHES AT THE GALACTIC CENTER WITH KM3NeT/ORCA-115

DARK MATTER DETECTION WITH KM3NeT

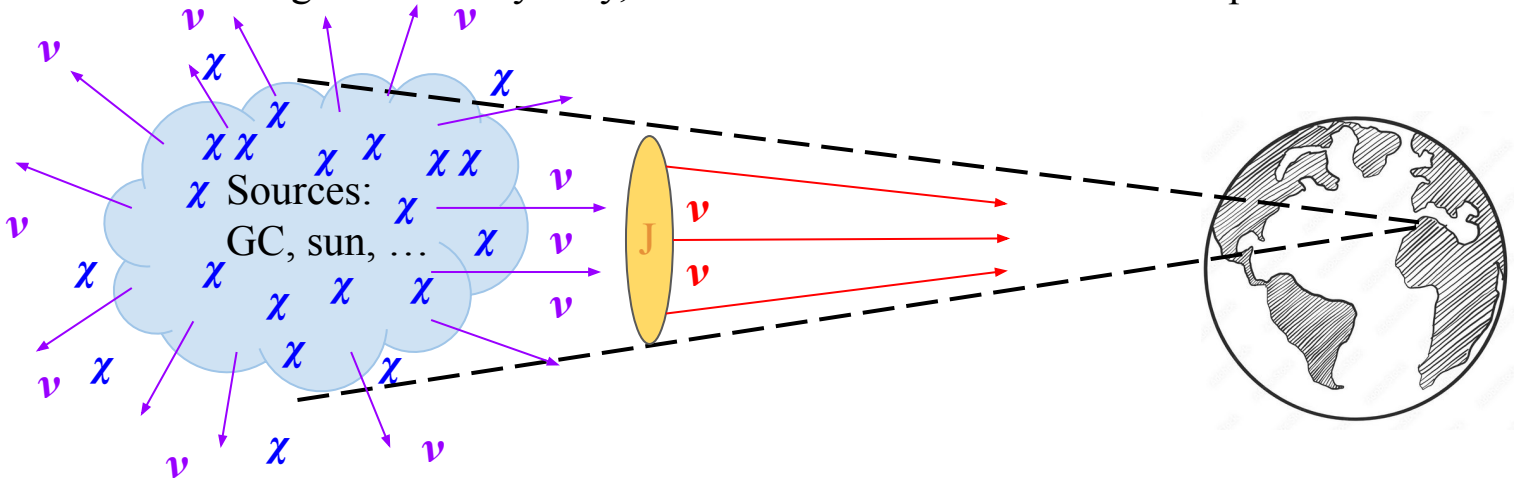
DETECTION PRINCIPLE IN KM3NeT

DATA SET

ANALYSIS METHOD

DARK MATTER DETECTION WITH KM3NeT

- We consider a WIMP-like dark matter particle.
- We expect dark matter to accumulate in regions with a high density of matter. Sources that are usually considered:
  - Milky Way Galactic Center
  - The Sun
- Neutrino telescopes aim to observe the flux of neutrinos produced by pair- annihilation of WIMPs occurring in the Milky Way, in the sun and other sources at the position of the Earth.



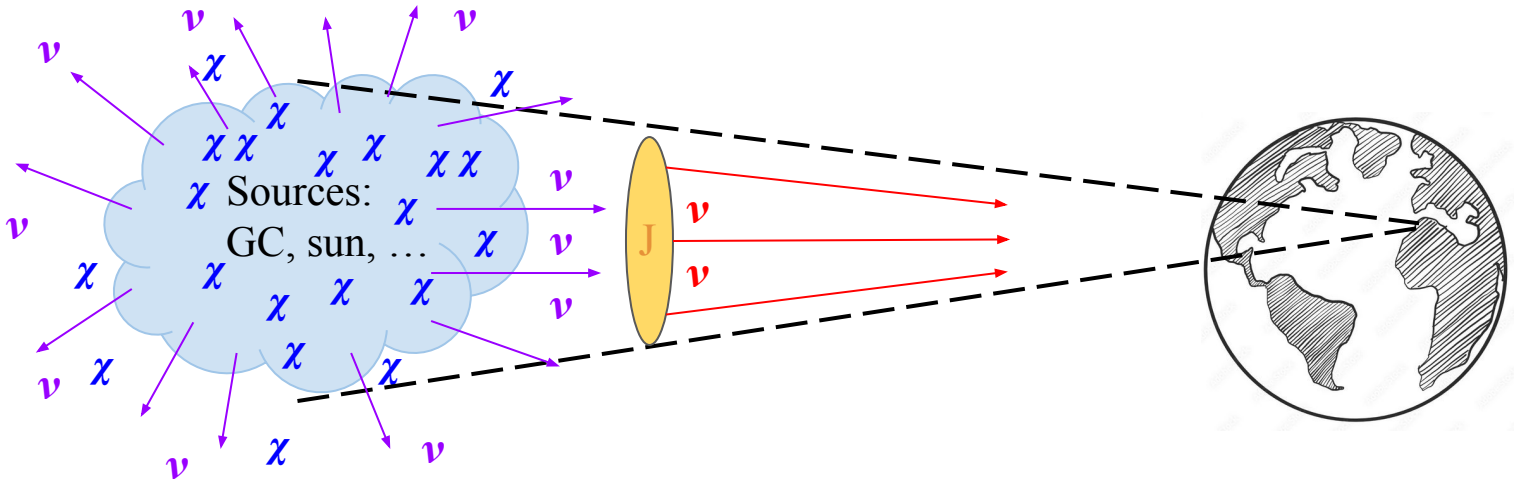
DARK MATTER DETECTION WITH KM3NeT

$$\frac{d\Phi_\nu}{dE_\nu} = \frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2m_\chi{}^2}\frac{dN_\nu}{dE_\nu}\int_{\Delta\Omega}\int_{l.o.s.}\rho^2 dl d\Omega$$

Flux at Earth

Energy Spectrum (Particle Physics)

J-factor (Astrophysics)



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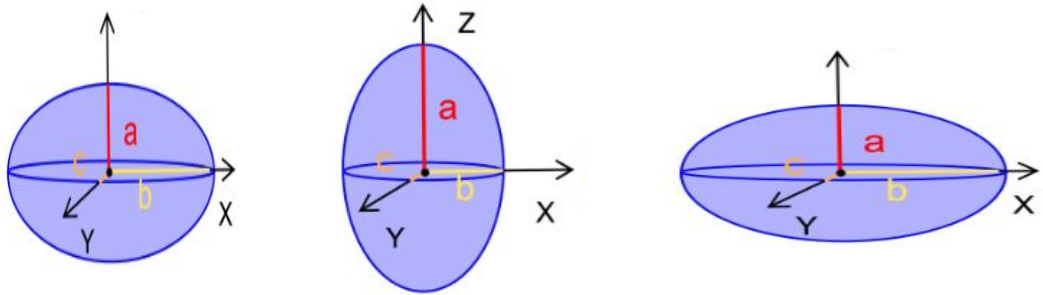
J-factor
(Astrophysics)

- Spherical DM halo with Navarro-Frenk-White density profile.
- Future approach: extend triaxiality of the halo (spherical, prolate, oblate)



CLUMPY software [https://clumpy.gitlab.io/CLUMPY/v3.1.1/]

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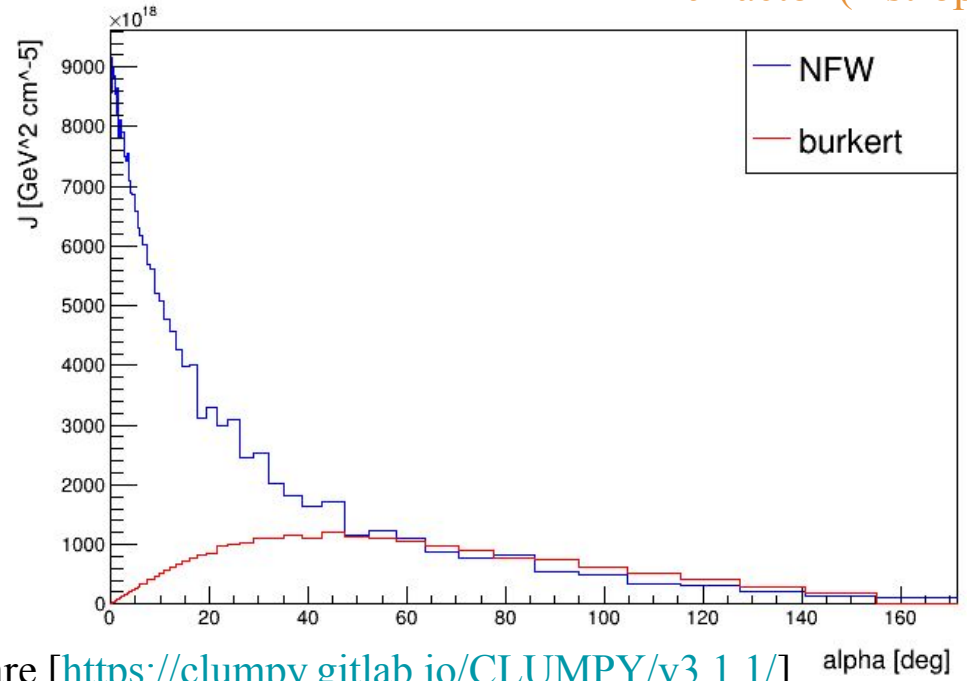

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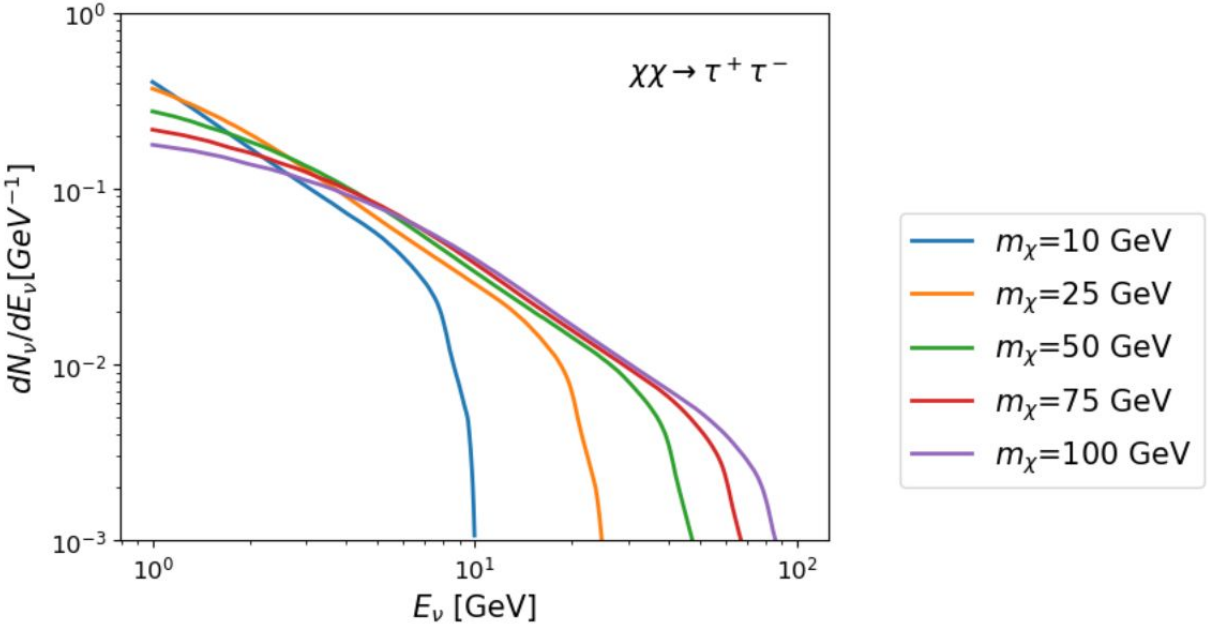

χarov package [https://arxiv.org/pdf/2007.15010.pdf]

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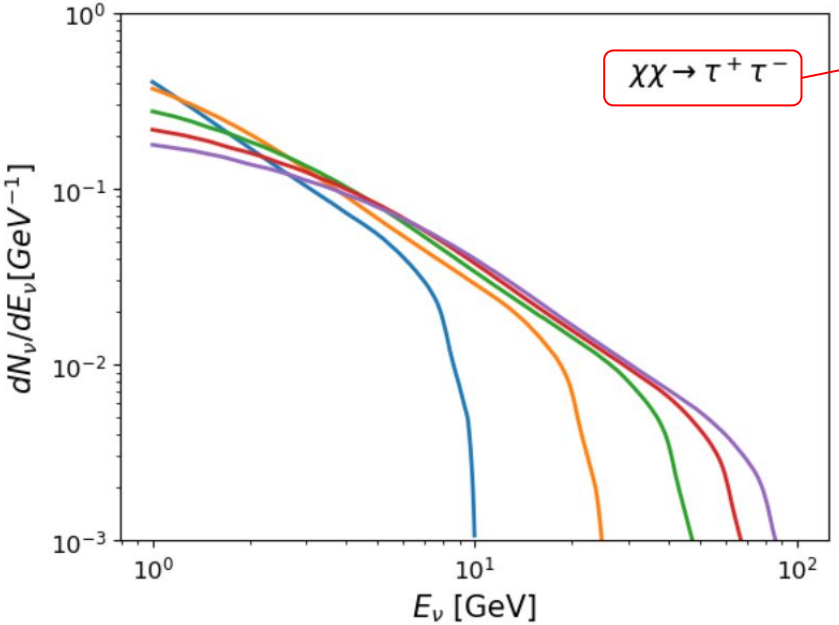
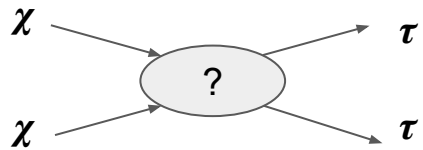


Model independent approach



m_χ=10 GeV
m_χ=25 GeV
m_χ=50 GeV
m_χ=75 GeV
m_χ=100 GeV

χarov package [https://arxiv.org/pdf/2007.15010.pdf]

DARK MATTER DETECTION WITH KM3NeT

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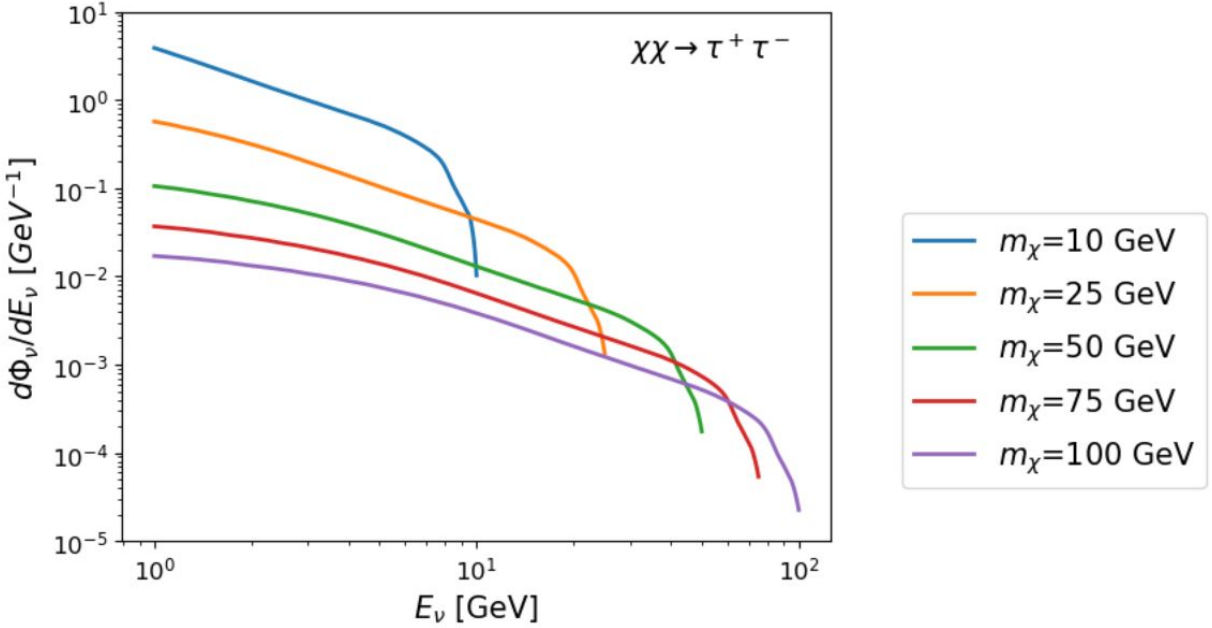
Flux at Earth



DARK MATTER DETECTION WITH KM3NeT

DETECTION PRINCIPLE IN KM3NeT

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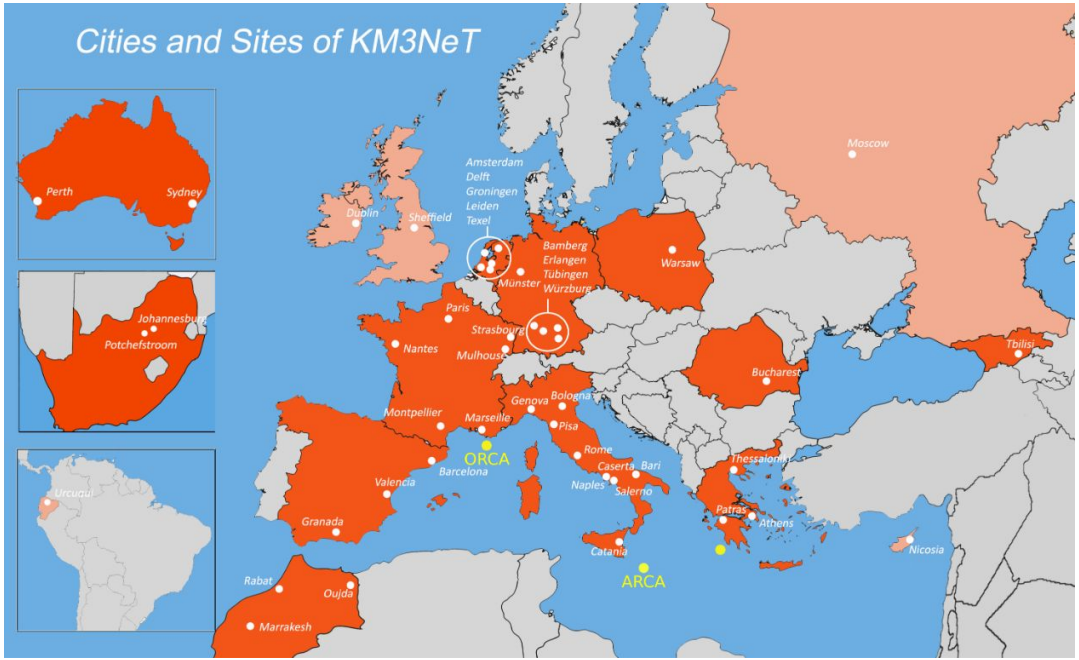
ANALYSIS METHOD

DETECTION PRINCIPLE IN KM3NeT

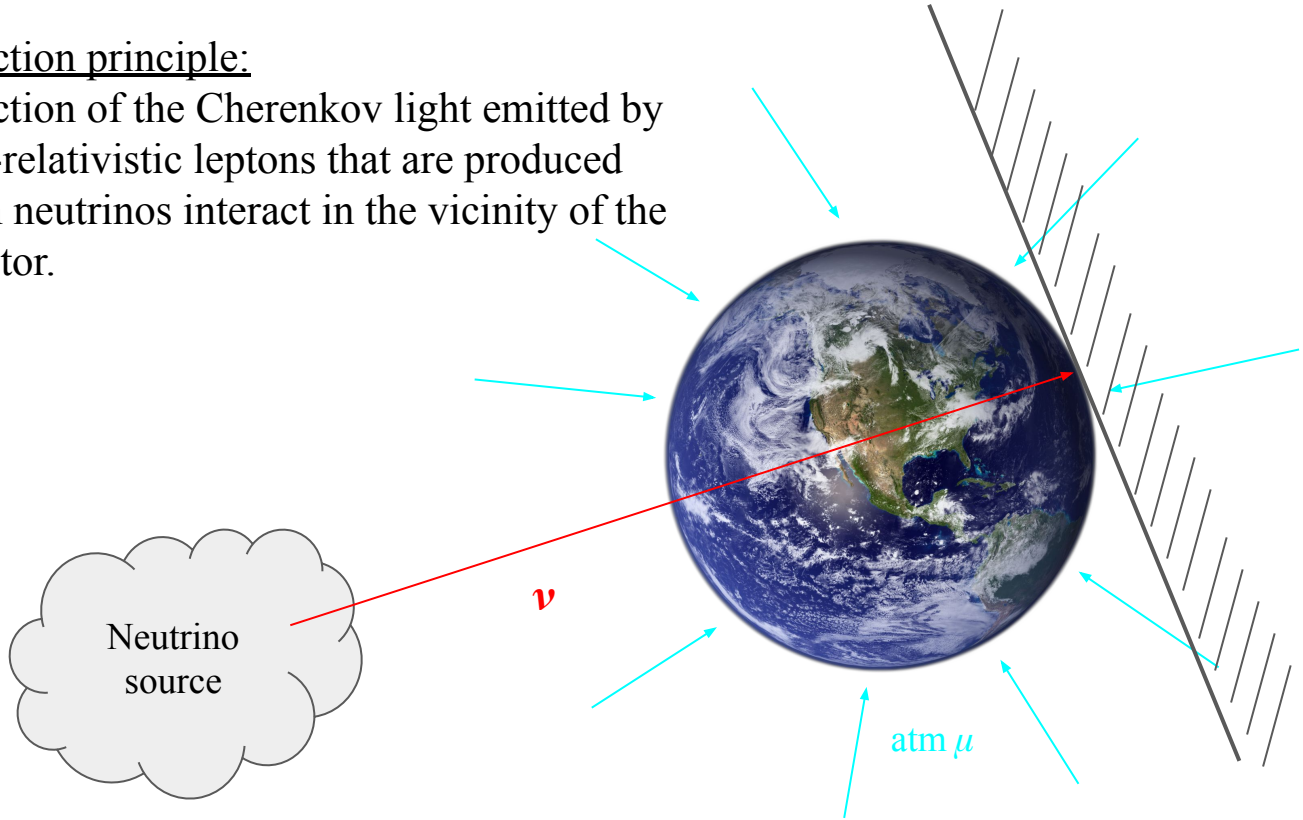
Undersea Cherenkov neutrino telescopes positioned at two sites in the Mediterranean Sea [KM3NeT Collaboration, Journal of Physics G: Nuclear and Particle Physics 43.8 (2016):084001].

- KM3NeT-ARCA [TeV-PeV] astrophysical neutrinos currently 28 DUs
- KM3NeT-ORCA [GeV-TeV] neutrino mass ordering currently 18 DUs



DETECTION PRINCIPLE IN KM3NeT

<u>Detection principle:</u>
Detection of the Cherenkov light emitted by ultra-relativistic leptons that are produced when neutrinos interact in the vicinity of the detector.



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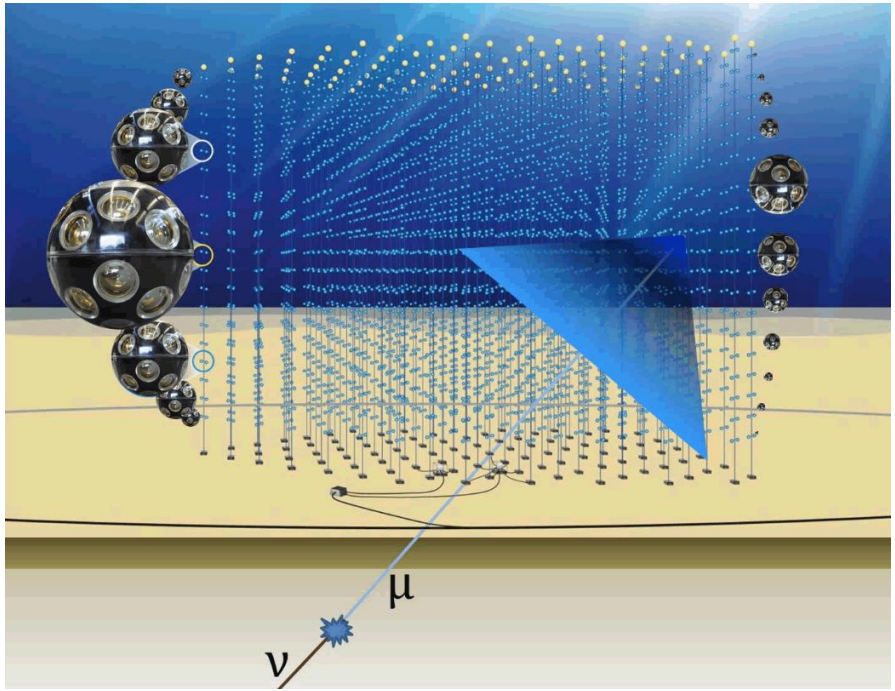

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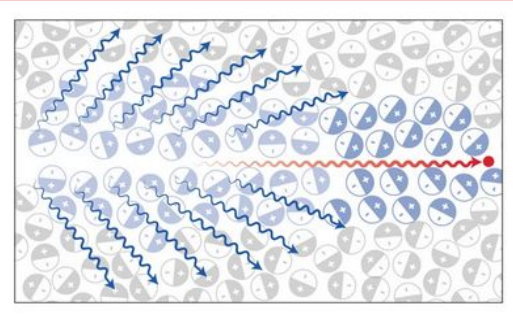
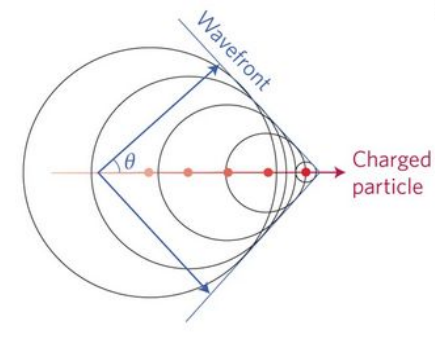
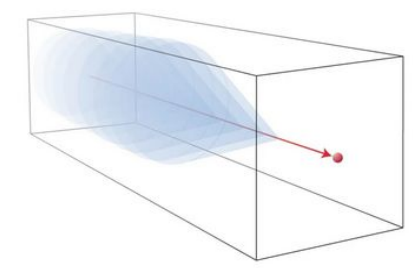
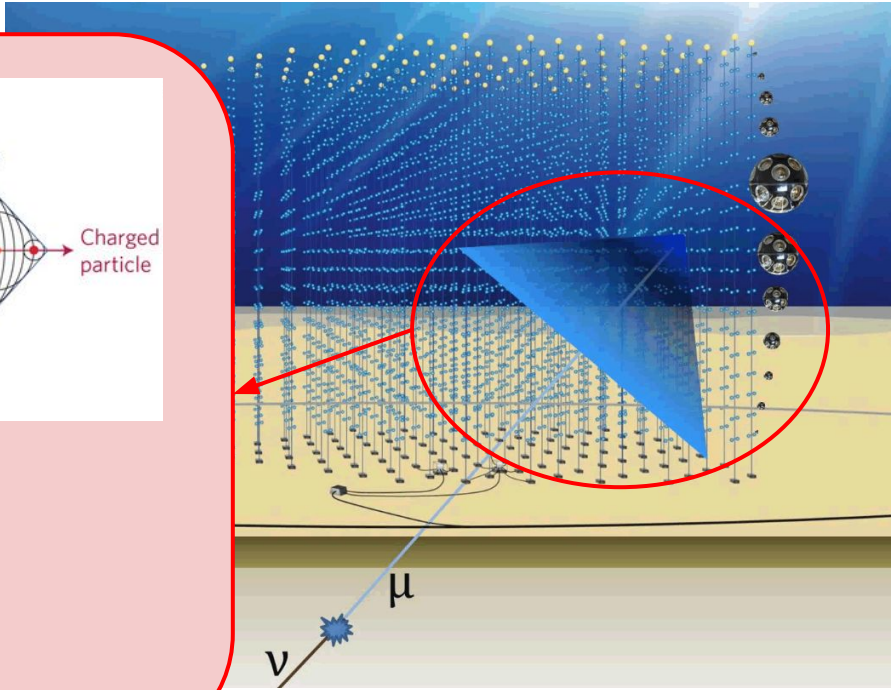


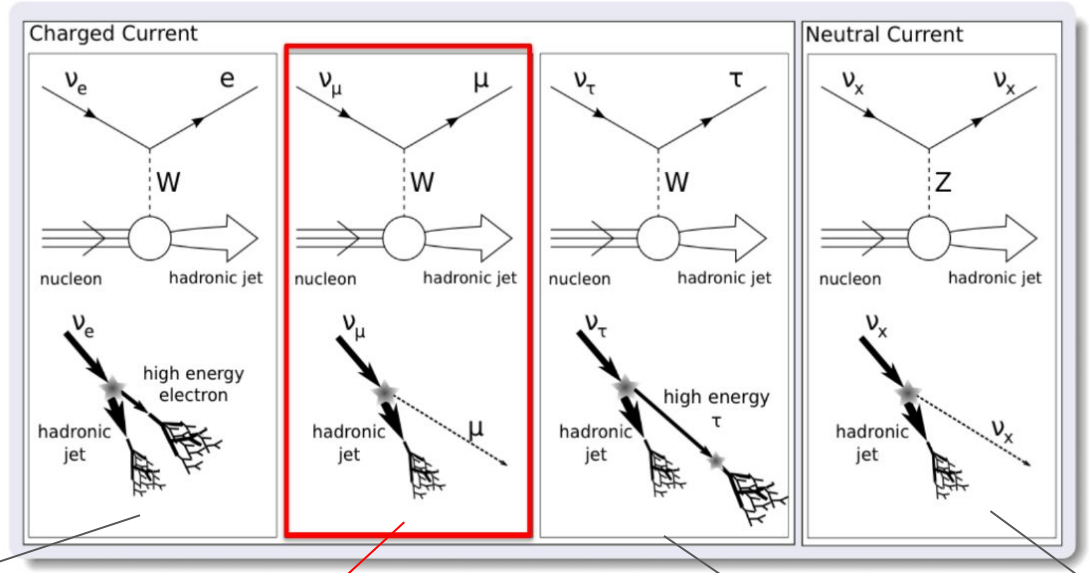


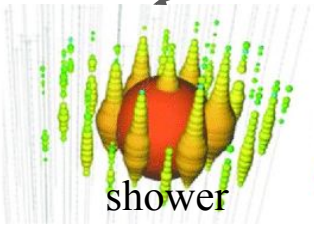




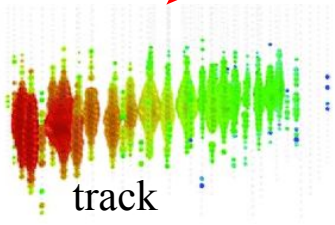
DETECTION PRINCIPLE IN KM3NeT

Signature of the neutrino interaction

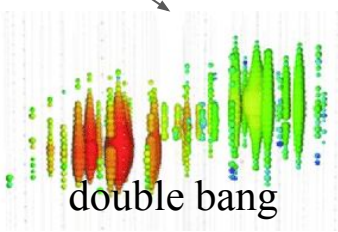




shower



track



double bang

No signature

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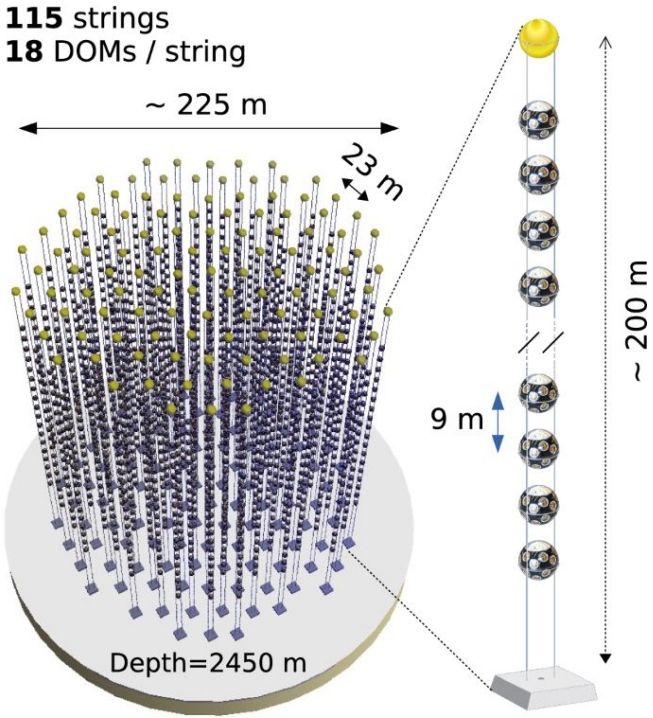
ANALYSIS METHOD

DATA SET

→ Use of **ORCA-115** to search for WIMP like Dark Matter in the mass range of 1-100 GeV coming from annihilations at the Galactic Center.

Analysis details:

DM source	Spherical DM halo with NFW profile centered at GC
WIMP annihilation channels	$\mu^+\mu^-, \tau^+\tau^-, b\bar{b}$, $W^+W^-, HH, \nu\bar{\nu}$
Observation time	1 yr
Detector configuration	ORCA-115
Methodology	unbinned analysis



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Unbinned likelihood method:

$$n_{bg} = N_{events} - n_{sg}$$

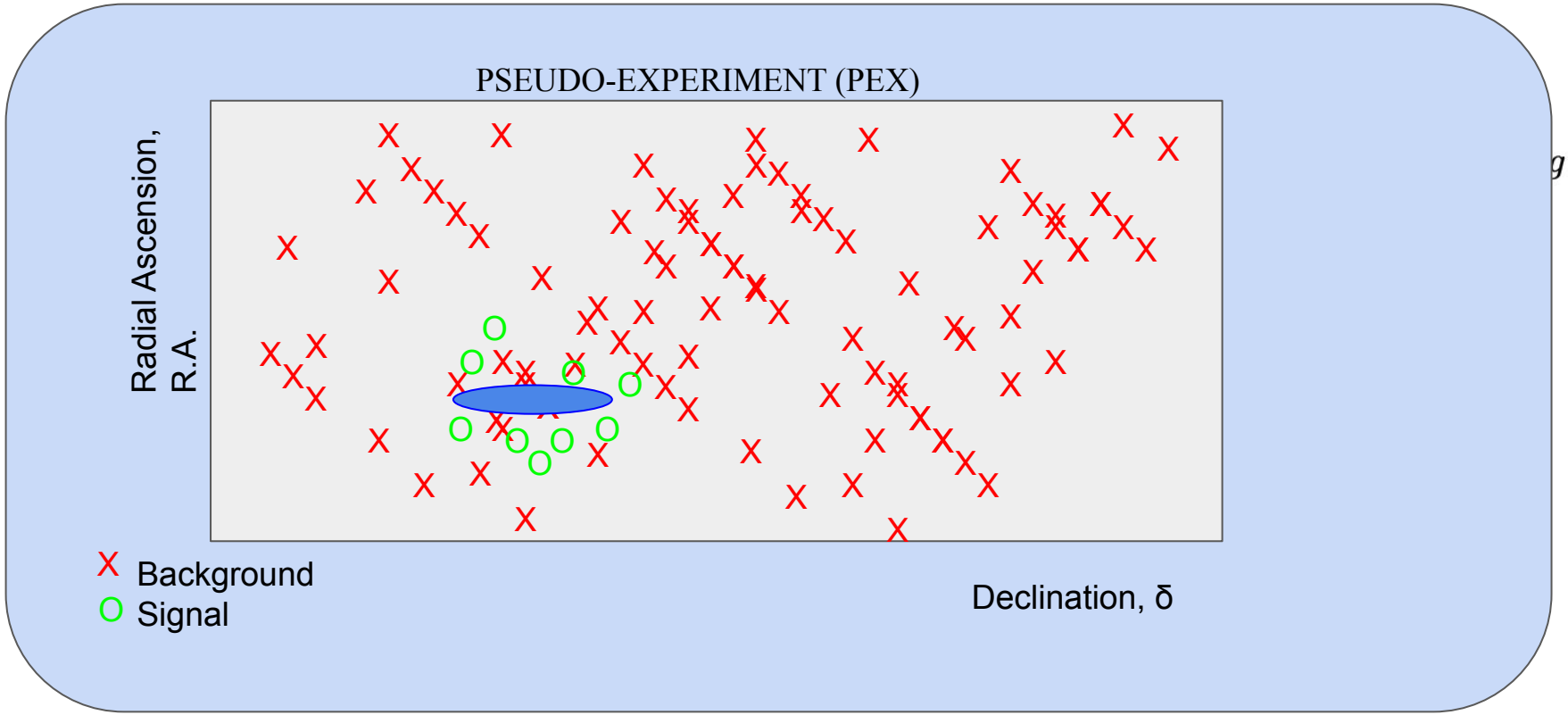
$$-log\,\mathcal{L} = -\prod_{i=1}^{Nevents} log[n_{sg}P_{sg}(\psi_i, E_i) + n_{bg}P_{bg}(\delta_i, E_i)]$$

SIGNAL

BACKGROUND

We minimise the likelihood and fit the number of signal events.

ANALYSIS METHOD



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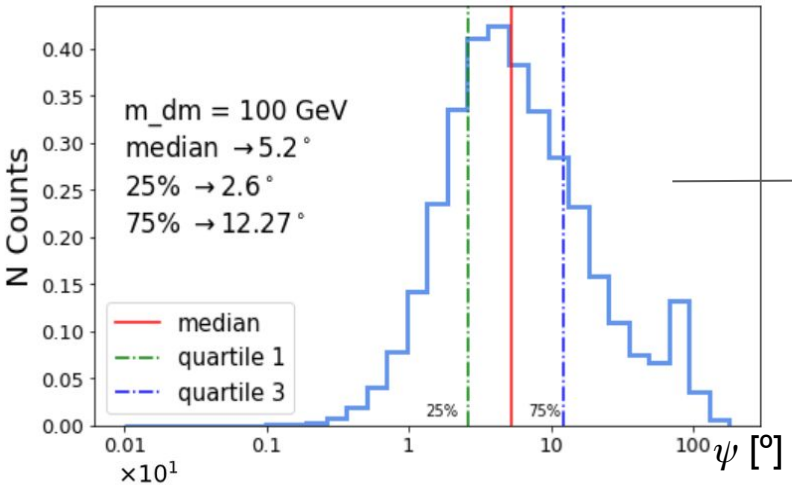
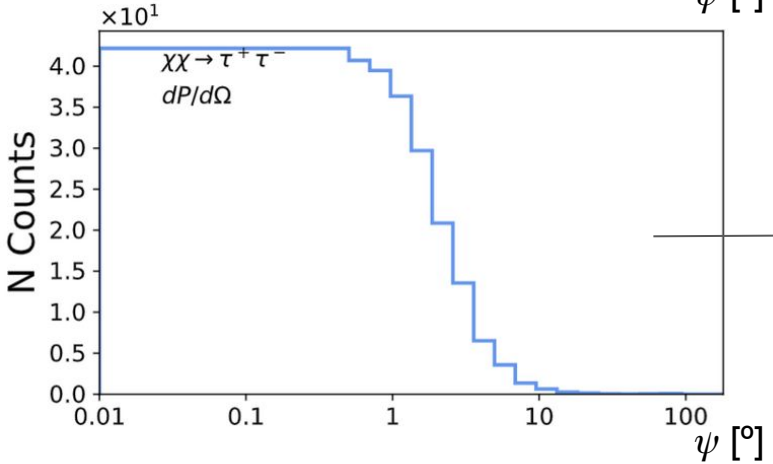


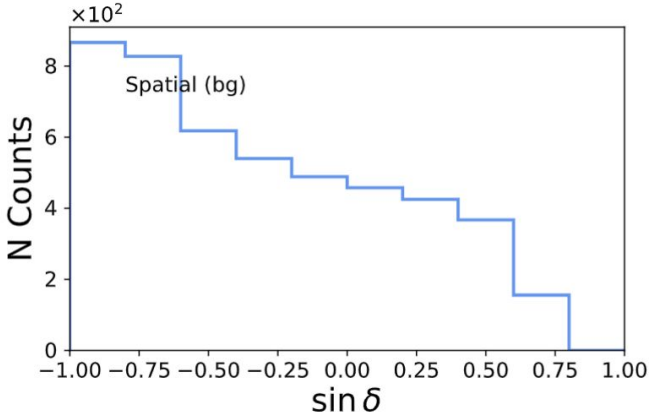


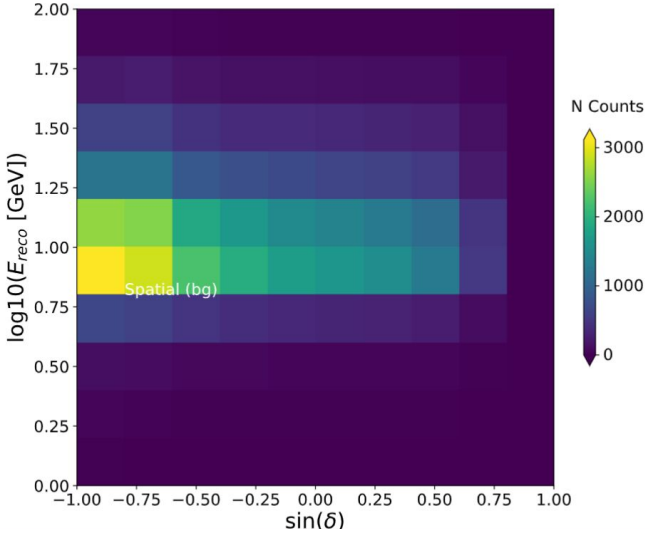
Ingredients for SIGNAL:

dP/dψ →generate event coordinates and energies → E, ψ

dP/d□ →likelihood of events being signal in likelihood function

ANALYSIS METHOD





Ingredients for BACKGROUND:

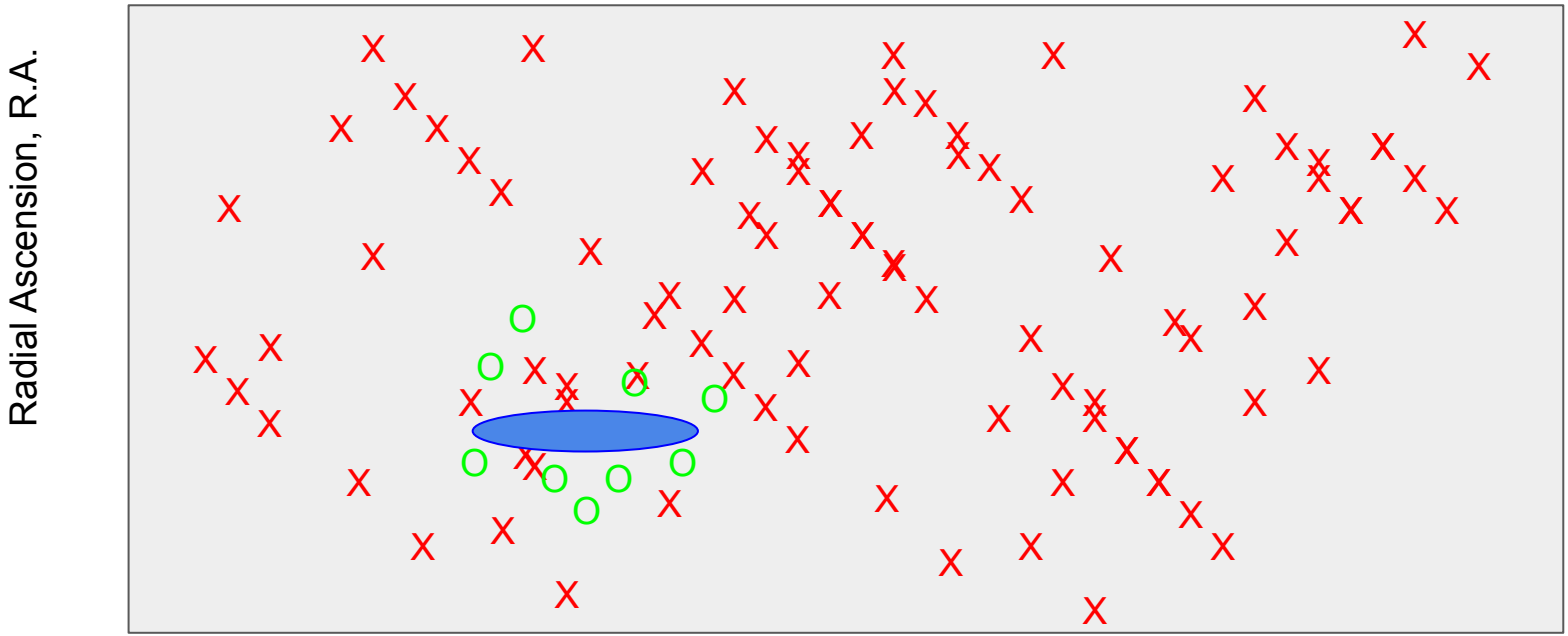
sin(δ) → generate coordinates and evaluate the likelihood of sth being background

Energy → generate the energies and evaluate the likelihood of sth being background

ANALYSIS METHOD

We use the ingredients to build with different numbers of injected events:

PSEUDO-EXPERIMENT (PEX)



ANALYSIS METHOD

We do a Test Statistic evaluation: $TS = \frac{\mathcal{L}(n_{sg,max})}{\mathcal{L}(n_{sg}=0)}$ and from there we evaluate the sensitivity to the number of signal events (events we see with 90% confidence). [Saina, A. (2023). ICRC2023, 444, 1377. doi: 10.22323/1.444.1377.]

$$\Phi^{90} = \frac{n_{90}}{Acc \cdot T}$$

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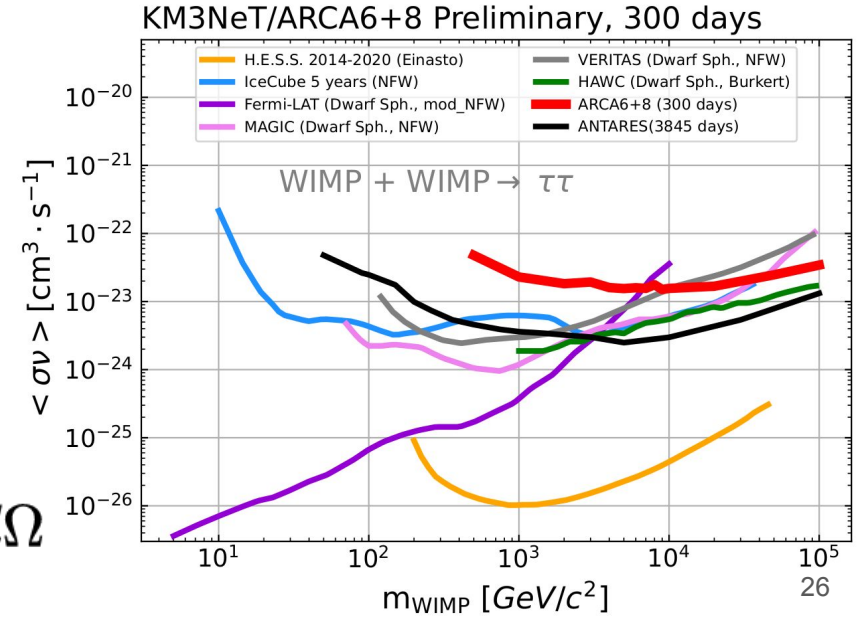
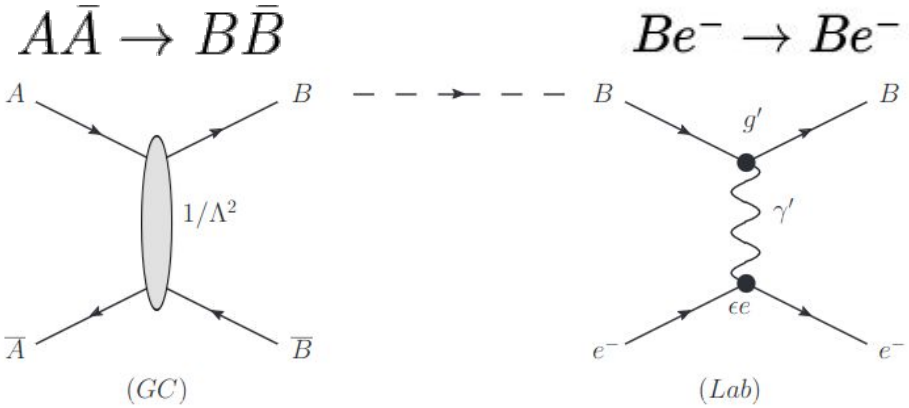


FUTURE APPROACHES: BOOSTED DARK MATTER

DARK MATTER DIRECT DETECTION WITH KM3NeT?

Two species A, B (mA>mB)

- Species A:
  - ➢ Dominant DM component
  - ➢ No direct couplings to SM
- Species B:
  - ➢ Relativistic (Boosted DM)
  - ➢ Couplings with SM



Annihilation

(determines thermal relic of A)

https://arxiv.org/abs/1405.7370

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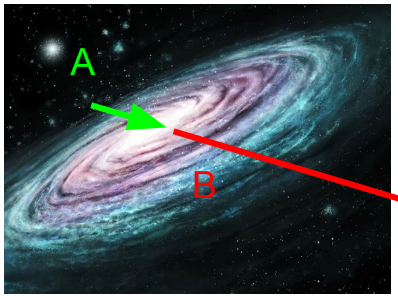
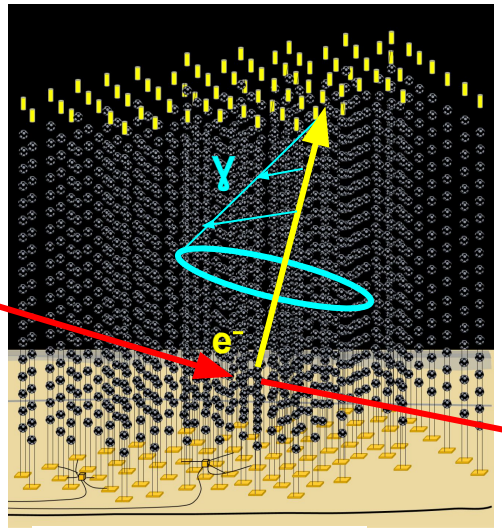


$$A\bar{A} \rightarrow B\bar{B}$$



$$Be^- \rightarrow Be^-$$

https://arxiv.org/abs/1405.7370

THANK YOU!

IFIC group at KM3NeT/ANTARES Collaboration Meeting in Salerno (June 2023)