# Indirect search for dark matter in the Galactic Centre with IceCube

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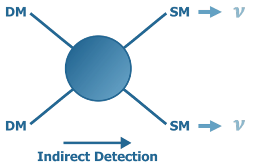
## Abstract

Even though there are strong astrophysical and cosmological indications to support the existence of dark matter, its exact nature remains unknown. We expect dark matter to produce standard model particles when annihilating or decaying, assuming that it is composed of Weakly Interacting Massive Particles (WIMPs). These standard model particles could in turn yield neutrinos that can be detected by the IceCube neutrino telescope. The Milky Way is expected to be permeated by a dark matter halo with an increased density towards its centre. This halo is expected to yield the strongest dark matter annihilation signal at Earth coming from any celestial object, making it an ideal target for indirect searches. In this contribution, we present the sensitivities of an indirect search for dark matter in the Galactic Centre using IceCube data. This low energy dark matter search allows us to cover dark matter masses ranging from 5 GeV to 1 TeV. The sensitivities obtained for this analysis show considerable improvements over previous IceCube results in the considered energy range.

## Dark Matter Phenomenology

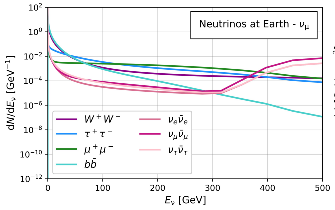
- Observations imply that galaxies are surrounded by dark matter (DM) halo with increased density towards the centre of the halo [1].
- Common assumption is that DM consists of Weakly Interactive Massive Particles (WIMPs) [2].

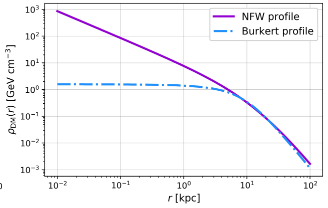



- DM particles expected to produce standard model (SM) particles when decaying or annihilating
- Indirect DM experiments can detect these SM particles
- Indirect search: look for neutrinos produced by dark matter annihilation in the centre of the Milky Way with IceCube [3]
- Neutrino flux from dark matter annihilation in the GC [4]:

$$\frac{d\phi_\nu}{dE_\nu} = \frac{1}{2}\frac{\langle\sigma_A v\rangle}{4\pi\, m_{\rm DM}^2}\frac{dN_\nu}{dE_\nu}\int_0^{\Delta\Omega} d\Omega \int_{l.o.s} \rho_{\rm DM}^2(r(\Psi,l))dl\,, \qquad [1]$$

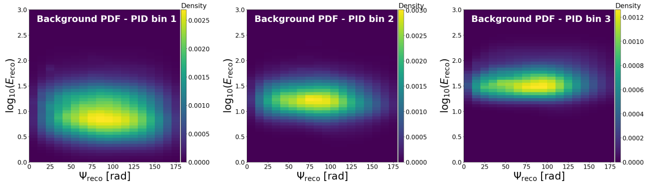
where $m_{\rm DM}$ is the DM mass, $\langle\sigma_A v\rangle$ is the thermally-averaged DM self-annihilation cross-section, $dN_\nu/dE_\nu$ is the differential number of neutrinos per annihilating pair of DM particles [5] and $\rho_{\rm DM}$ is the DM density [6]



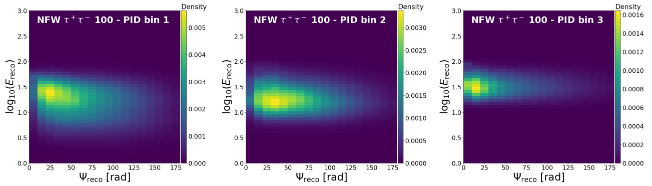




## Background and Signal Expectations

- Background dominated by atmospheric muons and neutrinos created by interactions of cosmic rays in upper atmosphere
- Considered event selection consists of 8.03 years of DeepCore data recorded from 2012 to 2020
- Use 3-dimensional PDFs with the opening angle to the GC ($\Psi_{\rm reco}$), the energy ($E_{\rm reco}$) and the neutrino flavour (PID)
- Background PDF built from Monte Carlo (MC) simulations weighted according to the expected atmospheric flux




- Signal PDFs built from generic MC weighted with the source morphology and the neutrino spectra according to Equation 1 for:
  - DM halo profile: NFW and Burkert
  - DM annihilation channel: $W^+W^-$, $bb$ , $\nu_i\nu_i$, $\tau^+\tau^-$, $\mu^+\mu^-$
  - DM mass: 5 GeV to 1 TeV




## Sensitivities

- Search for an excess of signal neutrinos in the direction of the GC by comparing observed data distribution signal and background expectations
- Binned likelihood method assuming the following likelihood function:

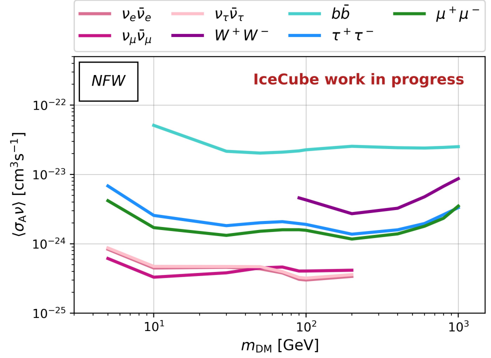
$$\mathcal{L}(\mu) = \prod_{i=min}^{max} \frac{(n_{obs}^{tot} f^i(\mu))^{n_{obs}^i}}{n_{obs}^i!} e^{-n_{obs}^{tot}} f^i(\mu), \qquad [2]$$

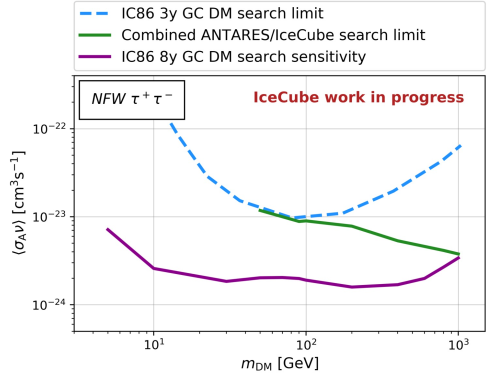
where $n_{obs}^{tot}$ is the total number of events in the sample and $\mu \in [0,1]$ is the signal fraction. The fraction of events within a bin $i$ is given by:

$$f(i\,;\mu) = \mu f_s(i) + (1-\mu)\, f_{BG}(i), \qquad [3]$$

where $f_{BG}$ and $f_{sig}$ are the background and signal PDFs.

- Upper limit on the signal fraction at 90% CL computed according to the likelihood interval method [7]
- Define 90% CL sensitivity as the median value of the upper limits obtained for 100,000 pseudo-experiments sampled from the background-only PDF
- Sensitivities show considerable improvement with respect to previous IceCube results [8,9]




## Conclusion and Outlooks

- Computed sensitivities on $\langle\sigma_A v\rangle$ for a dark matter search in the Galactic Centre with 8 years of IceCube data
- Sensitivities show considerable improvements with respect to previous IceCube results
- Improvements due to the enhanced event selection considered, as well as the inclusion of energy and flavour information in the event distributions.
- The final official results should soon be available. If no signal neutrinos are to be found, limits on $\langle\sigma_A v\rangle$ will be computed

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