WIMP dark matter searches in the Galactic Centre with KM3NeT

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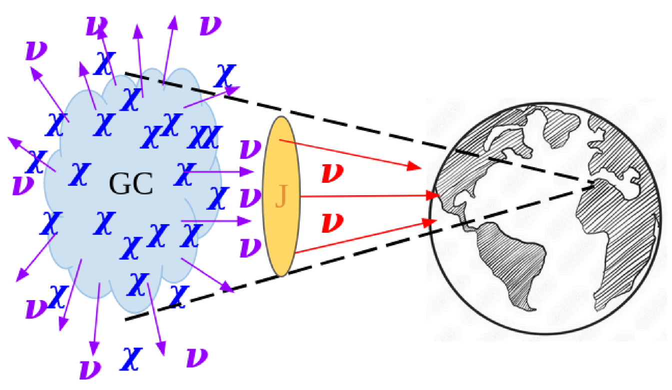
1 KM3NeT: ORCA AND ARCA DETECTORS

- The KM3NeT infrastructure [1], located in abyssal sites of the Mediterranean Sea, is composed of two undersea Cherenkov neutrino telescopes: ORCA, a dense detector optimised for the measurement of low energy neutrinos, and ARCA, a cubic kilometer detector, intended for low fluxes of astrophysical neutrinos.
- It is composed of Digital Optical Modules with a segmented photo-sensitive area provided by 31 photomultiplier tubes (PMTs), arranged in vertical strings called Detection Units.
- The Cherenkov light is induced by ultra-relativistic charged particles that are produced in neutrino interactions near the detector, this light is measured in the PMTs.
- 19 DUs have been already deployed at the ORCA site and 28 at ARCA .

2 THEORETICAL FRAMEWORK

The existence of Dark Matter (DM) has been postulated from its gravitational effects on astrophysical objects at various scales. So far, a particle nature of this non-baryonic form of matter remains unknown. Weakly Interacting Massive Particles (WIMPs) are a good candidate choice that is in agreement with the observations of DM.

Searches for the products of DM annihilation are performed in dense regions, such as the Galactic Centre (GC), because galaxy formation theory predicts the existence of galactic DM halos with very high densities at the centre of the object, and also in heavy celestial bodies [2], such as the Sun.

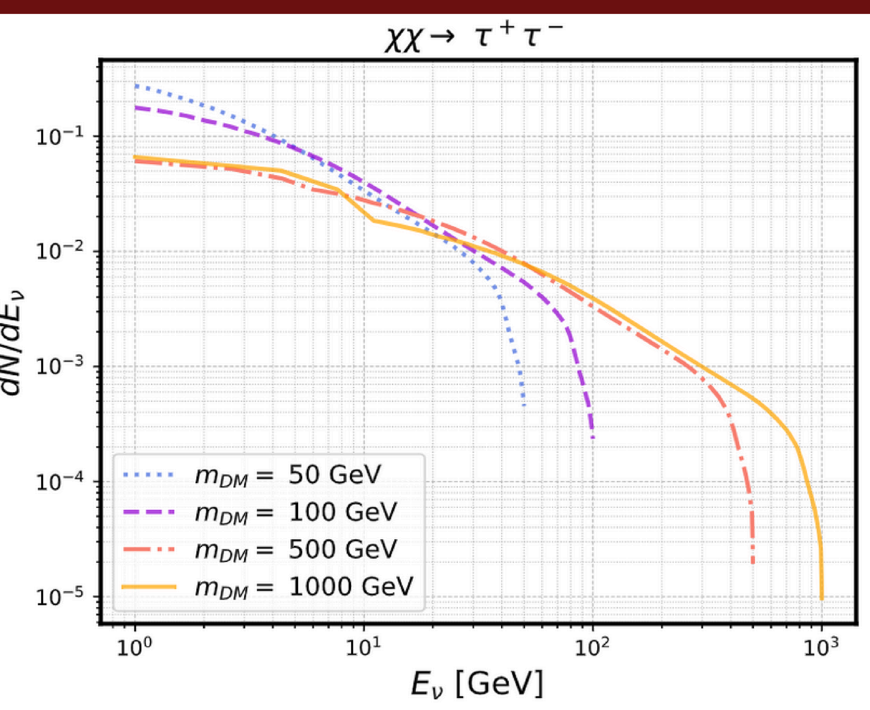


$$\frac{d\Phi_\nu}{dE_\nu} = \frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2m_\chi^2}\frac{dN_\nu}{dE_\nu}\int_{\Delta\Omega}\int_{l.o.s.}\rho^2 dl d\Omega$$

Flux at Earth — Energy Spectrum [3] — J-factor [4]

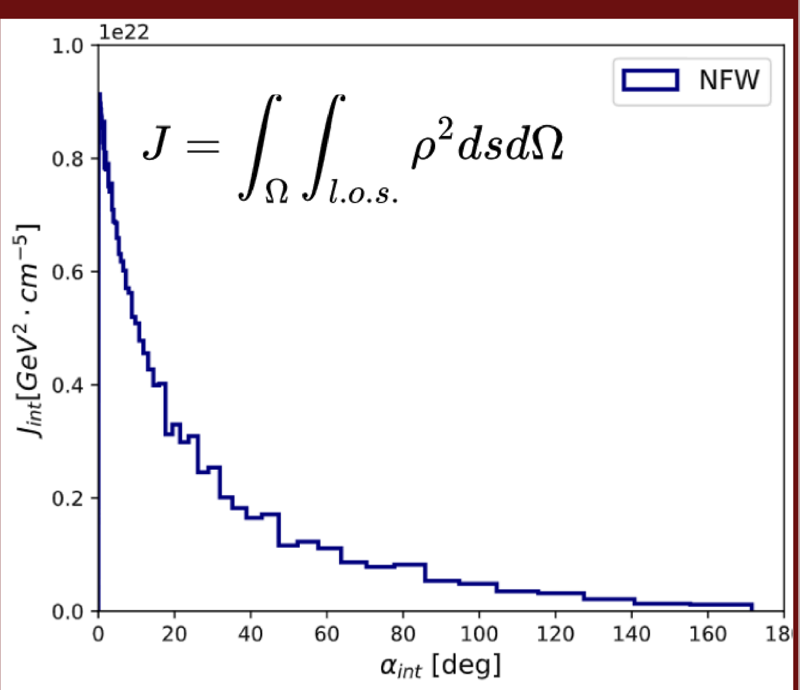
Neutrino telescopes aim to observe the flux of neutrinos produced by pair-annihilation of WIMPs originating in the Milky Way, the Sun and other sources. A model-independent approach is followed in which we search for a signal excess of neutrinos considering annihilation channels $\tau^+\tau^-, \mu^+\mu^-, b\bar{b}, \nu\bar{\nu}, HH, W^+W^-$ all with 100% BR.

SPECTRUM ($\chi aro\nu$)



Spectrum for different DM masses annihilating at the GC into $\tau^+\tau^-$ channel.

J-FACTOR (CLUMPY)



Distribution of DM around the GC observed through a cone with an opening angle α.

3 ANALYSIS DETAILS

Event selection for ORCA-6

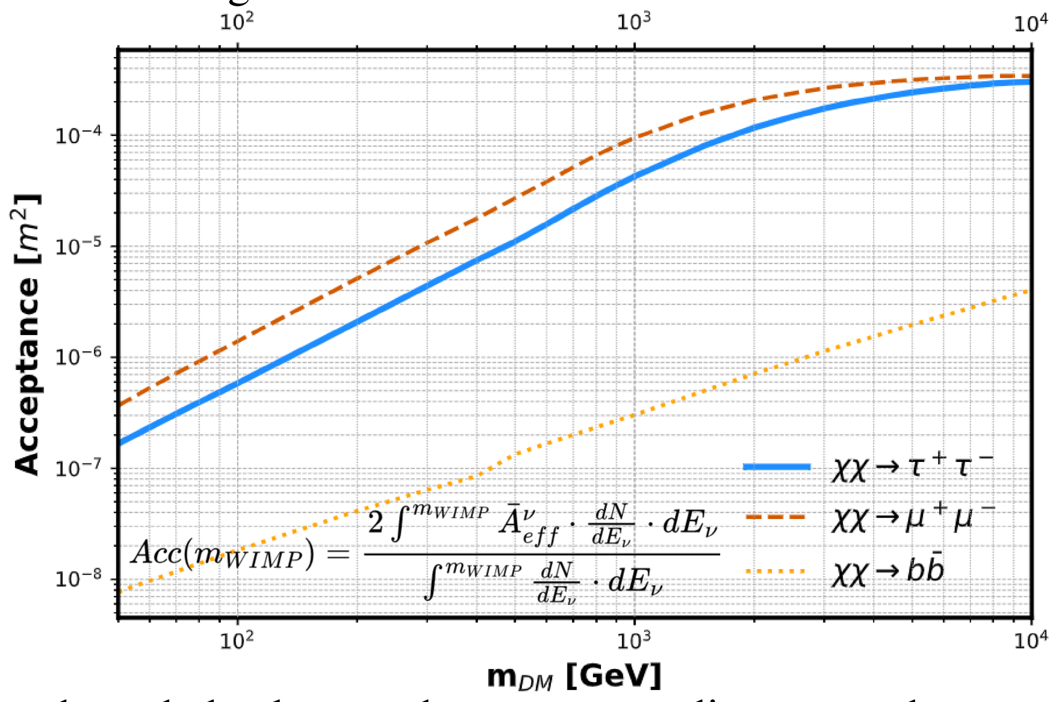
- A data sample corresponding to 510 days taken with the 6 DUs configuration of ORCA.
- Neutrinos are detected through their associated muons, we consider track events: $\nu_\mu + X \xrightarrow[CC]{} \mu + Y$
- Our background is composed of atmospheric muons, we apply cuts to reject them.
- A number of 4445 events in the data sample survive the cuts.
- Selection cuts:
  - Background rejection cuts: upgoing events, number of hits per event > 15, likelihood of the track reconstruction > 40
  - PID cuts for tracks: probability of an event to be an atmospheric muon < 0.0018

About the DM model

- Source: Galactic Center
- DM spherical halo with Navarro-Frenk-White (NFW) density profile [5]
- DM mass from 50 to 1000 GeV/c²

4 ANALYSIS METHOD

The effective area and the acceptances of the detector are obtained to study the ability of the detector to detect signal events.

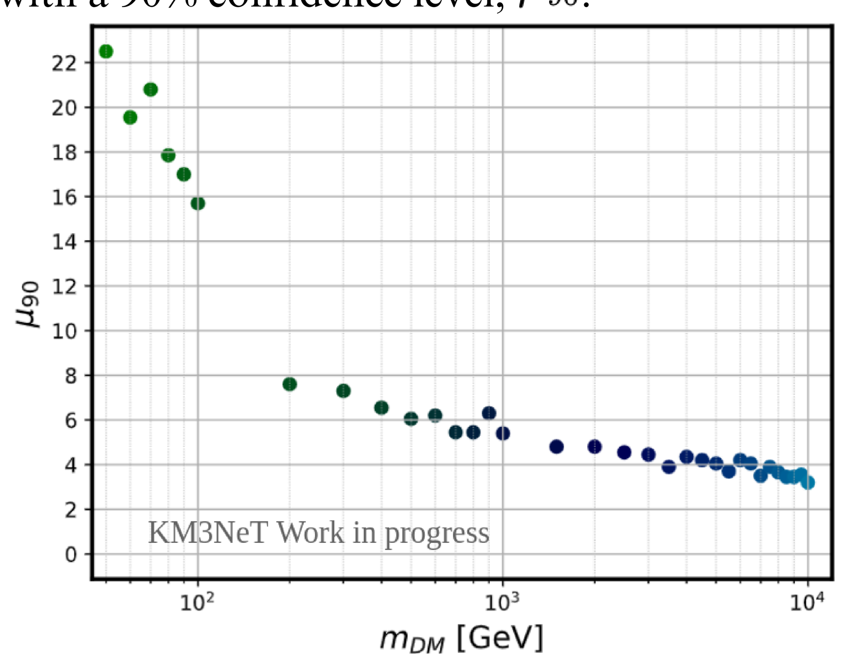


We create signal and background event coordinates and energies in pseudo-experiments. Signal and background probability functions are used to determine the amount of signal in each pseudo-experiment. We maximise the likelihood to fit the number of signal events n_{sg} that we are sensitive to

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

Probability of an event to be signal: events characterised by angular distance and energy. Probability of an event to be background: events characterised by declination and energy.

The test statistic distributions $TS = \frac{\mathcal{L}(n_{sg,max})}{\mathcal{L}(n_{sg}=0)}$ are used to determine the number of signal events we can exclude with a 90% confidence level, μ_{90}.



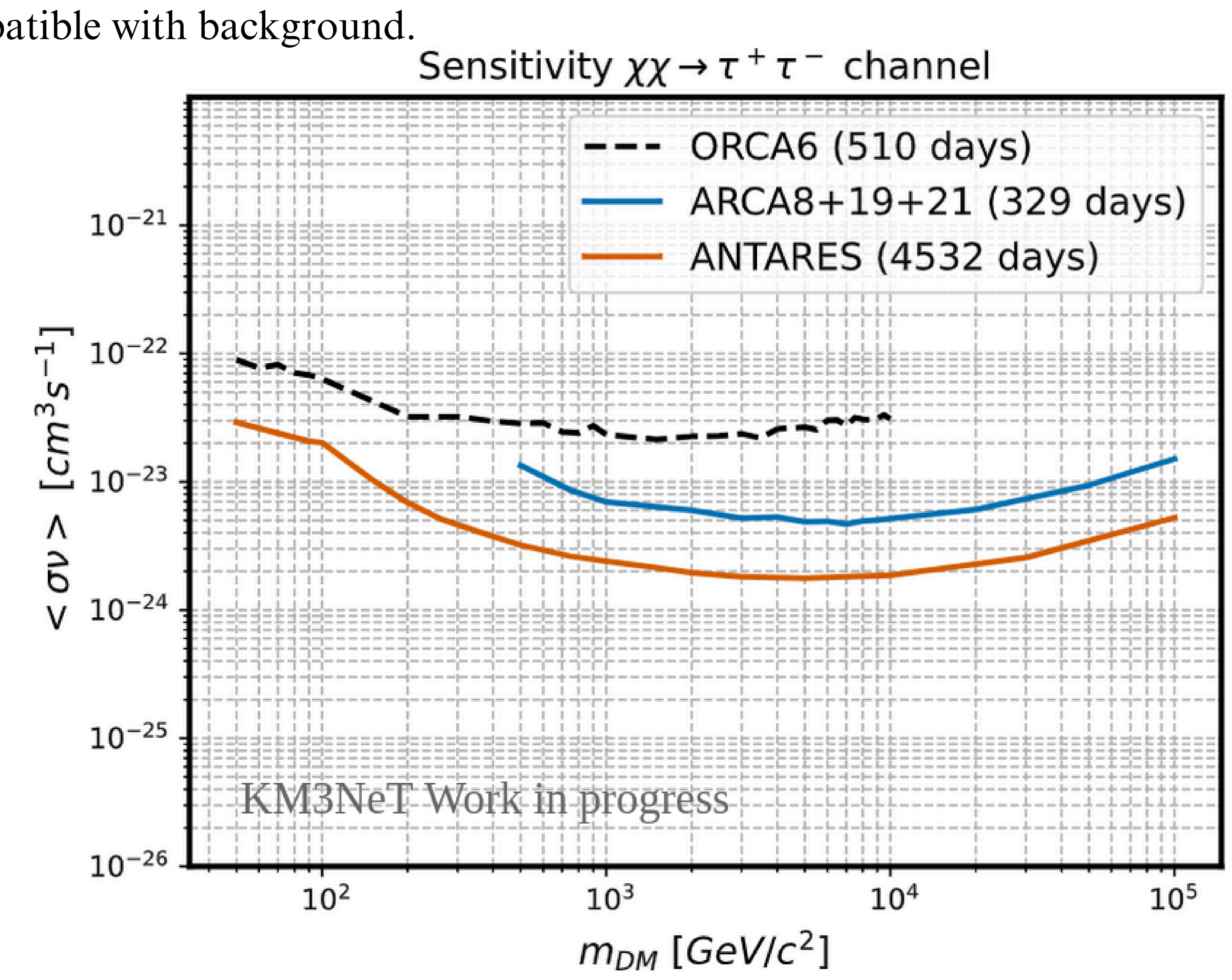
5 RESULTS

The energy range covered by KM3NeT/ORCA allows the study of WIMPs in the 1GeV/c² to 1000 GeV/c² mass range and KM3NeT/ARCA allows to study 500 GeV/c² to 100 TeV/c² DM masses.

For the first time the ORCA-6 data set has been used to search for DM annihilating in the GC. We have obtained the sensitivity of this detector configuration considering WIMP masses in the range 50 GeV/c² to 1000 GeV/c²

$$\langle\sigma v\rangle = \frac{n_{90}}{Acc\cdot T}\cdot\frac{8\pi m_{DM}^2}{J}$$

In addition, the combination of ARCA-8+19+21 has been used to obtain the 90% upper limit of the thermal cross section for the DM annihilating at the GC. This result is compatible with background.



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