Combined search for dark matter in the Galactic center with ANTARES and IceCube

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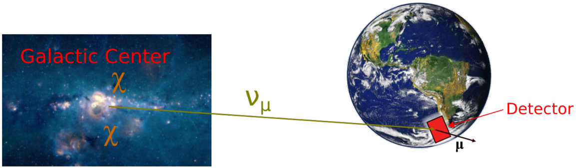
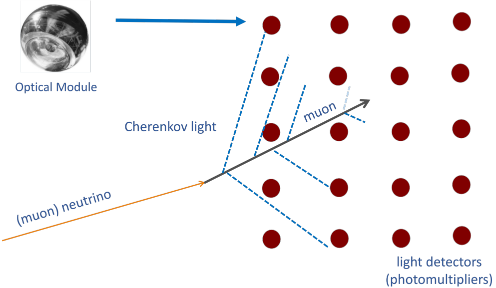
Dark Matter indirect detection



- The galactic centre is enveloped in a massive halo of dark matter particles
- In annihilations dark matter can then yield a neutrino flux by directly producing neutrinos or producing neutrinos in secondary processes
- Neutrino telescopes can then look for these neutrino fluxes
- The galactic centre is expected to yield the highest neutrino signal of all such searches

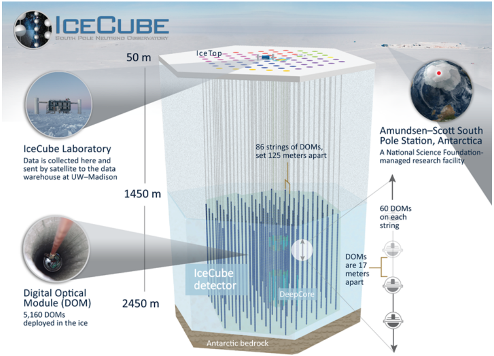
Neutrino telescopes



- Neutrino Telescopes detect neutrinos via charged leptons produced in the vicinity of the detector by weak interactions.

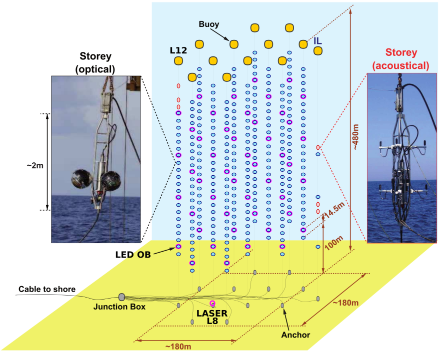
- Depending on the neutrino flavour and the interaction type different event type can be generated
- In this analysis the focus is on muon tracks of Cherenkov light
- These tracks can be detected by 3-arrays of photodetectors (e.g. neutrino telescopes)

IceCube



- IceCube is located near the geographic south pole and consists of 86 strings of cable equipped with 60 DOMs each that are installed in 2.5 km deep holes in the ice
- The Photomultipliers are installed between 1.5 and 2.5 km depth
- In the centre of IceCube there is a total of 8 additional lines creating a more densely instrumented area called Deepcore

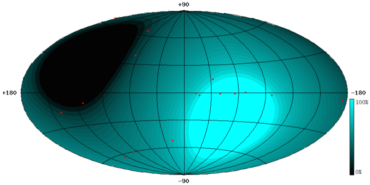
ANTARES



- ANTARES is located 40 km off the southern French coast 2475 m under the surface of the sea an extends up to a depth of 2025 m

- ANTARES has 12 lines with 25 storeys each. Per storey there are 3 photomultiplier tubes that are pointed downwards at an 45 degree angle
- The detection lines are 450 m long with a difference of 12.5 m between storeys and 60-75 m apart horizontally.

Visibility



The visibility ov farious positions to ANTARES

- The Galactic centre is located at a declination of -29.1 degrees whis makes it visible 75% of the time to ANTARES,

- IceCube can only directly see the northern hemisphere
- To see the Galactic centre IceCube has to use a muon veto that rejects all tracks starting outside the detector
- This greatly reduces the sensitivity of IceCube at higher neutrino energies

Analysis method

- The method used here is a binned likelihood with a two-component mixture model to combine the sensitivities of IceCube and ANTARES
- The likelihood function used here is:

$$\mathcal{L}(n_s) = \prod_{bin_i = bin_{min}}^{bin_{max}} Poisson\left(n_{obs}(bin_i) | n_{obs}^{tot} f(bin_i, n_s)\right)$$

with

$$f(bin_i, n_s) = n_s f_s(bin_i) + (1 - n_s) f_{bg}(bin_i)$$

- n_s is the supposed fraction of signal events, n_tot is the total number of events in the sample and f_s and f_{bg} are the signal and background probability density functions
- The likelihoods for ANTARES and IceCube are then multiplied and optimised with respect to n_s

IceCube

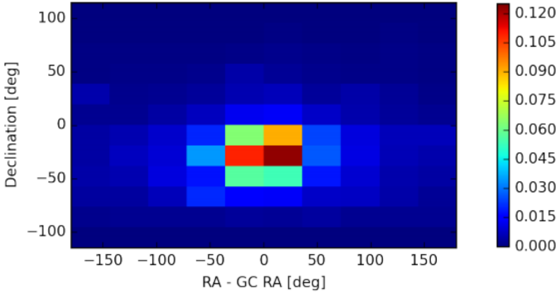


Figure: The normalised signal probability density for IceCube for a 100 GeV WIMP decaying into tauons

IceCube

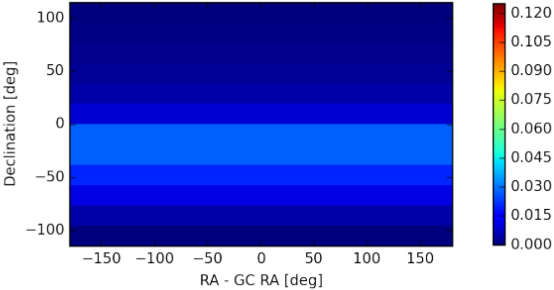


Figure: The normalised background probability density for IceCube

ANTARES

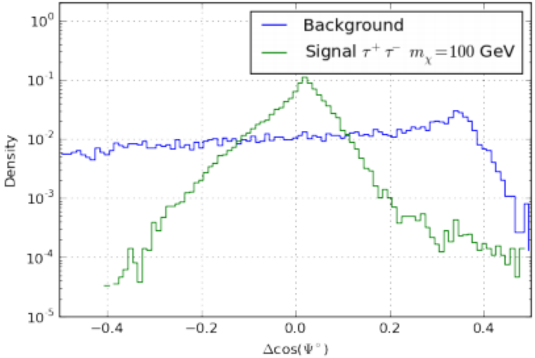


Figure: The signal and background probability density for ANTARES for a 100 GeV WIMP decaying into tauons

Results

Limits in terms of the thermally averaged annihilation cross-section are calculated by:

$$\frac{\mathrm{d}\phi_\nu}{\mathrm{dE}} = \frac{\langle\sigma \mathrm{v}\rangle}{2} J_{\Delta\Omega} \frac{r_s \rho_s^2}{4\pi m_\chi^2} \frac{\mathrm{d}\ N_\nu}{\mathrm{d}E}, \qquad (1)$$

where $J_{\Delta\Omega}$ is the integrated J-Factor and $\frac{\mathrm{d}\ N_\nu}{\mathrm{d}E}$ is the number of neutrinos per annihilation. $J_{\Delta\Omega}$ is calculated by the integral:

$$J_{\Delta\Omega} = \int_0^{2\pi} \int_0^{\theta_{cone}} \int_0^{l_{\max}} \frac{\rho_\chi^2 \left(\sqrt{r_s^2 - 2 l r_s \cos(\theta) + l^2} \right)}{r_s \rho_s^2} dl \sin(\theta) d\theta d\phi, \qquad (2)$$

In this analysis the NFW halo profile was used for the ρ_χ

Results

- The ANTARES data sample includes 595 events from the period 2007-2015 (livetime:2106.6 days, Phys.Lett. B769 (2017))
- The IceCube data sample includes 22,553 events gathered from May 15th 2012 to May 18th 2015 (livetime:1007 days, Eur. Phys. J. C 77 627 (2017))
- In ANTARES, for low energy events only the zenith angle is reconstructed
- The WIMP mass range considered is from 50 GeV to 1 TeV

Results

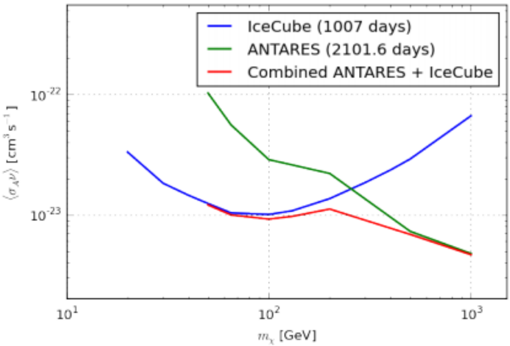


Figure: The combined sensitivities to thermally averaged annihilation cross-sections.

Conclusions and Outlook

- Between 65 GeV and 1 TeV an improvement was achieved with respect to the sensitivities of ANTARES and IceCube
- The analysis procedures of both collaborations were compared
- The analysis will soon be applied to actual unblinded data
- In the future higher masses and more annihilation channels will be included