Results of the Indirect search for Dark Matter in the Galactic Center with ANTARES

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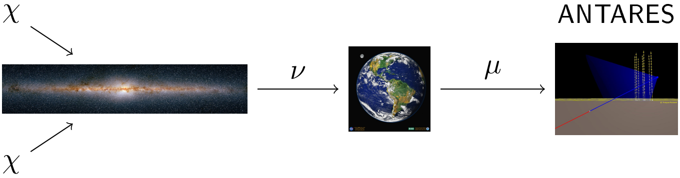
The ANTARES neutrino telescope

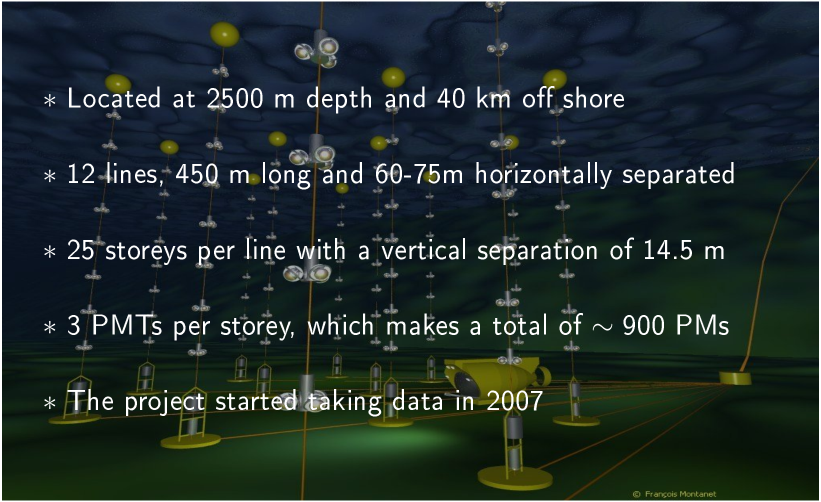
The ANTARES neutrino telescope

Indirect detection of dark matter with neutrino telescopes

- Relic WIMPs accumulate in massive celestial bodies like the Sun, the Earth, the Galactic Center or dwarf galaxies
- The annihilation in $W^{\pm}, Z, H$ bosons, c, b, t quarks and τ leptons can lead to significant neutrino fluxes
- The neutrino signal is less subjected to astrophysical uncertainties than γ-rays or cosmic rays

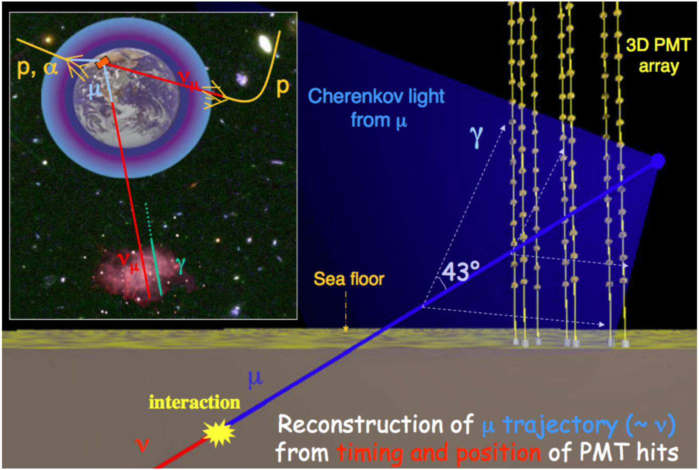


The ANTARES detector



* Located at 2500 m depth and 40 km off shore
* 12 lines, 450 m long and 60-75m horizontally separated
* 25 storeys per line with a vertical separation of 14.5 m
* 3 PMTs per storey, which makes a total of $\sim$ 900 PMs
* The project started taking data in 2007

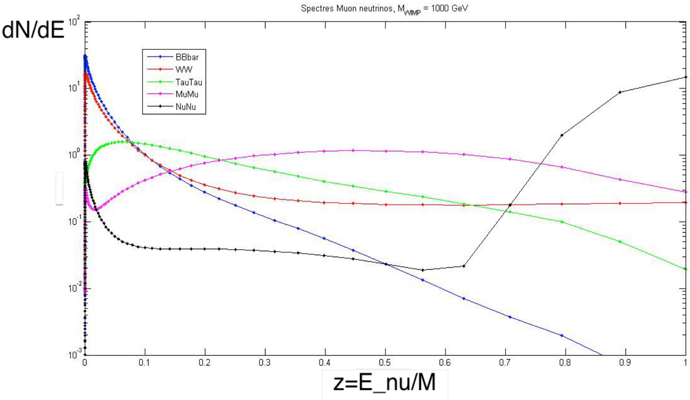
Detection principle



Dark matter neutrino signal

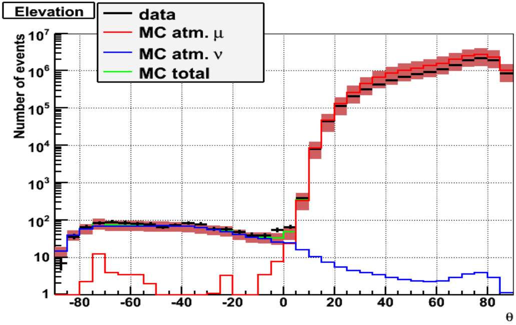
- For the Galactic Centre and the galaxy cluster analysis the spectra of the Cirelli group (M.Cirelli et al., arXiv:1012.4515) are used
- Annihilations into $b\bar{b}$, $\tau^+\tau^-$, W^+W^-, $\mu^+\mu^-$and $\nu_\mu\bar{\nu}_\mu$ are used as benchmark

Dark matter neutrino signal



Background rejection

The largest part of the background consists of atmospheric muons



They can be rejected by making a "horizon cut" thereby using the Earth as a shield against these muons

Reconstruction strategies

- AAFit (likelihood based)
  - Better for high energies (>250 GeV)
  - Event selection parameters are λ (reconstruction quality) and β (angular error estimate)
- BBFit (χ^2 based)
  - Better for low energies (<250 GeV)
  - Can reconstruct single line events (only zenith angle provided)
  - The main event selection parameter is tchi2 ($\sim \chi^2$)

Analysis method

Analysis method

Unbinned method

- The first step of the "unbinned" analysis is to produce several artificial random skies (pseudo experiments) with a varying number of inserted fake signal events.
- The next step of the "unbinned" analysis method is the analysis with the likelihood function, which gives a likelihood value for the random skies to contain a number n_s of signal events.
- The logarithmic likelihood function then gets maximised over the n_s parameter.
- The relation of the optimum likelihood to the likelihood of the background only case is called the test statistics (or TS).

Example for W^+W^- channel

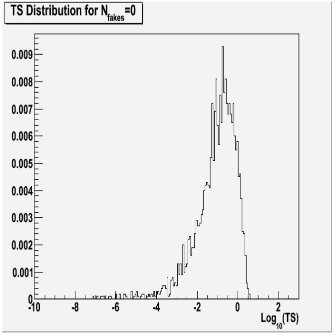


Figure : Background only TS distribution for the W^+W^- Channel and $m_\chi = 0.5\,TeV$.

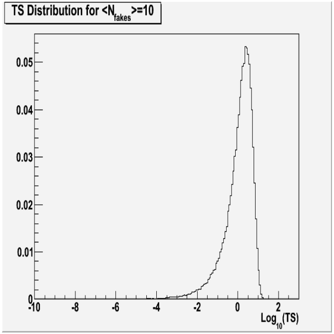


Figure : TS distribution with a average of 10 fake signal events for the W^+W^- Channel and $m_\chi = 0.5\,TeV$.

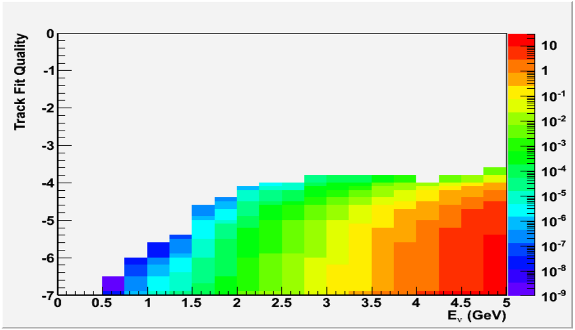
The Effective Area

The Effective Area

Effective Area

- The effective area of the detector relates the neutrino flux through the detector with the number of detected neutrino events.
- The effective area is calculated from Monte Carlo simulation data using statistical weights.
- These weights contain neutrino-nucleus interaction cross sections, the spectrum used for the data production and other relevant parameters connecting the simulated neutrino flux to the number of detected neutrino events

Sensitivities



The effective area of ANTARES in m^2 using the AAFit event reconstruction algorithm

Results

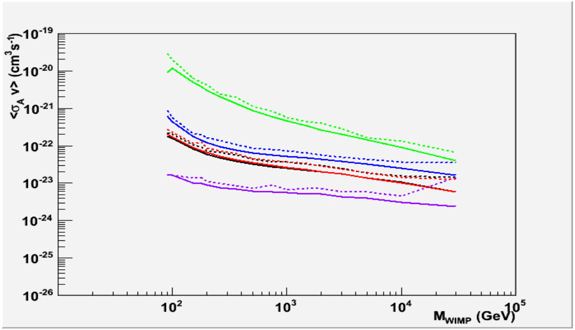
Results

Sensitivities

- From the test statistic distributions senitivities in detected neutrino events are calculated.
- With the effective area these are transformed into neutrino flux and ultimately into annihilation cross section sensitivities.
- A sensitivity is a expected detection limit given the properties of the used detector. Sensitivities are based upon simulations and are not to be confused with actual limits.

Sensitivities

These are sensitivities and not limits



AAFit sensitivities for the NFW profile. Solid:AAFit results, Dashed: BBFit results Green: $b\bar{b}$, Red: $\tau^+\tau^-$,Blue: W^+W^-, Black: $\mu^+\mu^-$, Violet: $\nu\bar{\nu}$

Summary

- The sensitivities of the dark matter search with ANTARES show competetive results.
- The analysis can still be improved by, for example the use of a different reconstruction method or a change in the horizon cut.
- The unblinding might result in limits, that slightly differ from the sensitivities.