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Searches for DM with the ANTARES and KM3NeT neutrino telescopes

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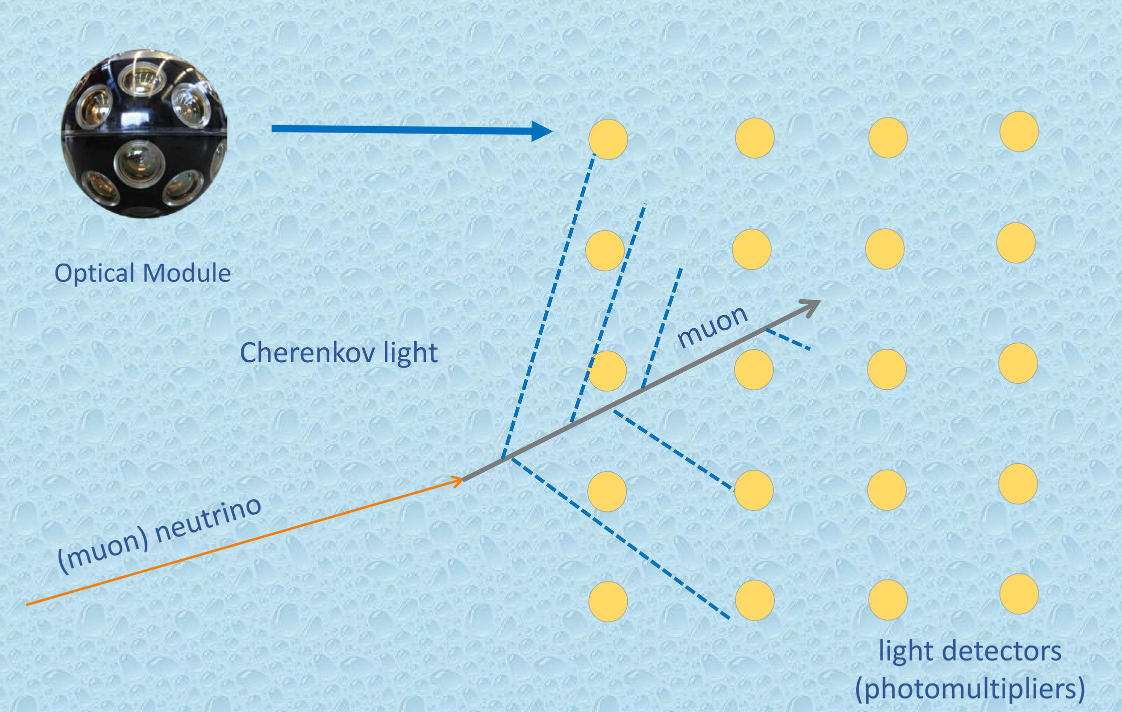
Abstract

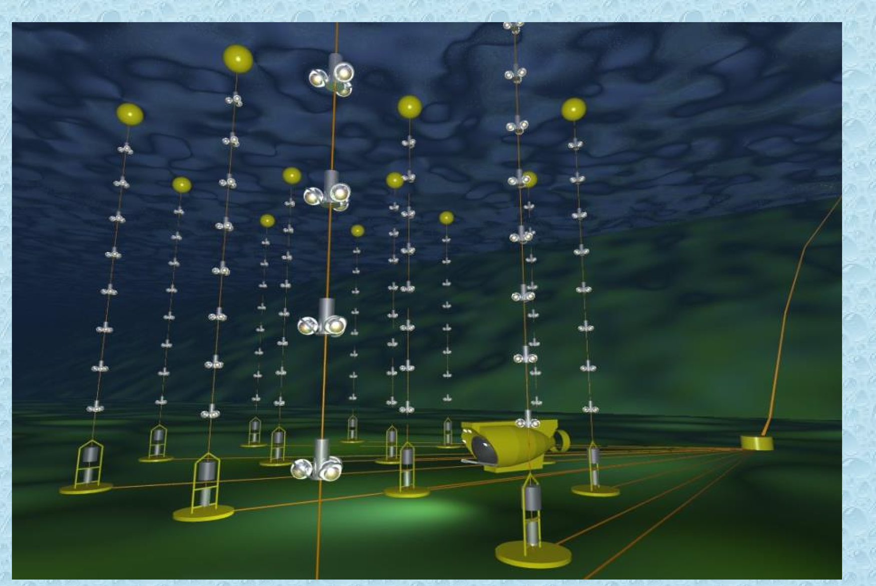
The nature of dark matter is one of the hottest topics in physics nowadays. Neutrino telescopes have an important role in this quest, given their specific characteristics. For instance, the detection of high energy neutrinos from the Sun would be a smoking gun for the presence of dark matter, since the astrophysical uncertainties are small, contrary to what happens with most of other indirect searches, where interpretation of excesses over background is complex. Another very interesting case is the Galactic Centre, where the ANTARES neutrino telescope has already set the best limits in WIMP annihilation cross section for large masses. In this presentation we will review the recent results of ANTARES on dark matter and show the foreseen performance of KM3NeT, which will be the largest neutrino telescope in the world, already in construction. This new detector has two configurations, ORCA (dense) and ARCA (sparse), which complement each other for a wide coverage of WIMP masses.

Neutrino telescopes: ANTARES and KM3NeT

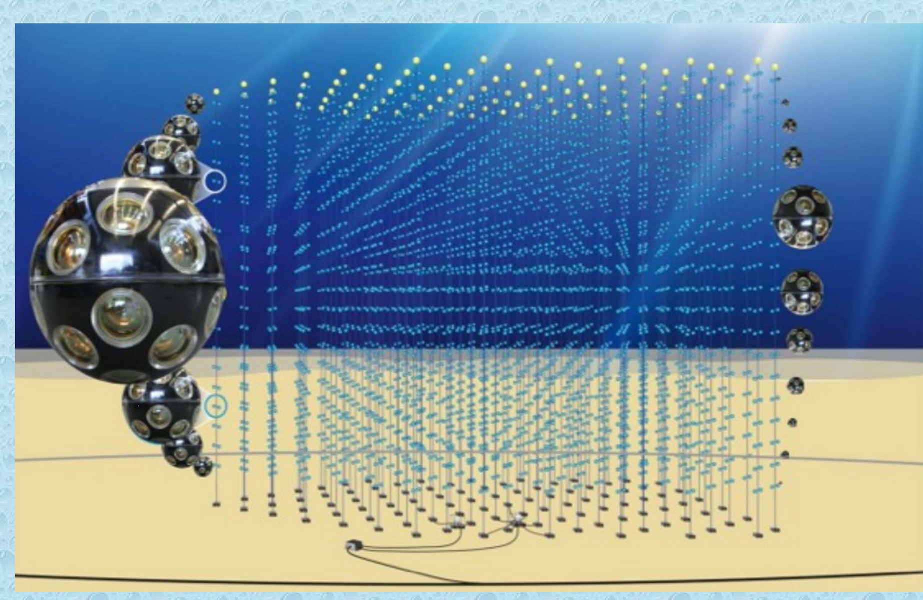
- Neutrino telescopes have **unique advantages** in the search for dark matter, since neutrinos are neutral, stable and only interact weakly
- The operation principle is based on detection of the Cherenkov light induced by the relativistic leptons produced in the interaction of high energy neutrinos in the water.
- In the analyses presented here, only events corresponding to CC interaction of **muon neutrinos** are used, since they offer the best angular resolution.

- The **ANTARES** detector [1], located in the French coast close to Toulon and completed in 2008, has shown the feasibility of under water Cherenkov detectors
- The **KM3NeT** detector [2], next step after ANTARES, is already under construction. It will have two configurations
  - ORCA: dense array 115 lines, located close to Toulon (France)
  - ARCA: sparse array of 230 lines (1 km^3), close to Sicily (Italy)
- The plan for KM3NeT foresees the construction of ORCA and the first building block of ARCA (115 lines) by 2020





Artistic view of ANTARES

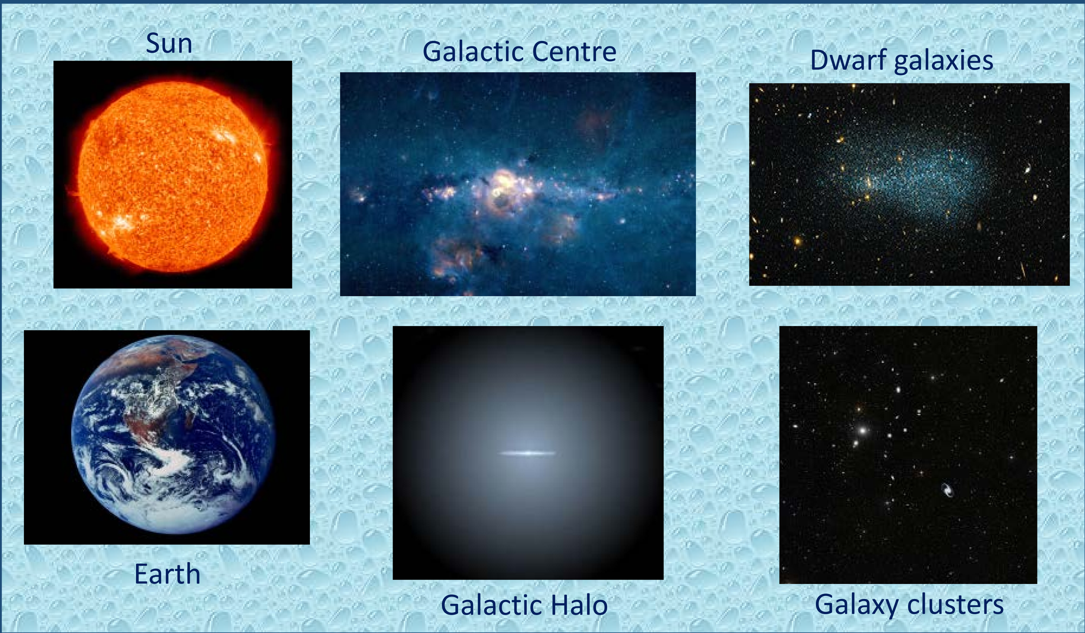


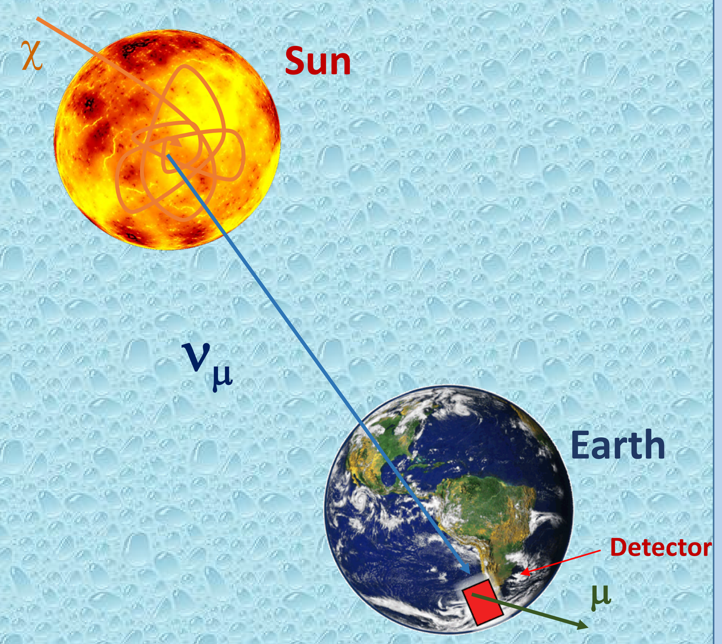
Artistic view of KM3NeT

Dark matter detection

- The nature of dark matter is **one of the most important topics** in Physics nowadays.
- It constitutes about 80% of the matter of the Universe but their properties are quite unknown
- Neutrino telescopes **complement** the search for dark matter, with unique advantages
- WIMPs detected after their self-annihilation when they accumulate in celestial bodies
- The most promising sources for neutrino telescopes are the Sun and the Galactic Center
- Neutrino fluxes are produced in the annihilation of W$^\pm$, Z, H bosons, c, b, t quarks, τ lepton. We consider the b and W$^\pm$/τ channels as **benchmarks.** In the results presented here, 100% branching ratio is assumed for any considered cannel.

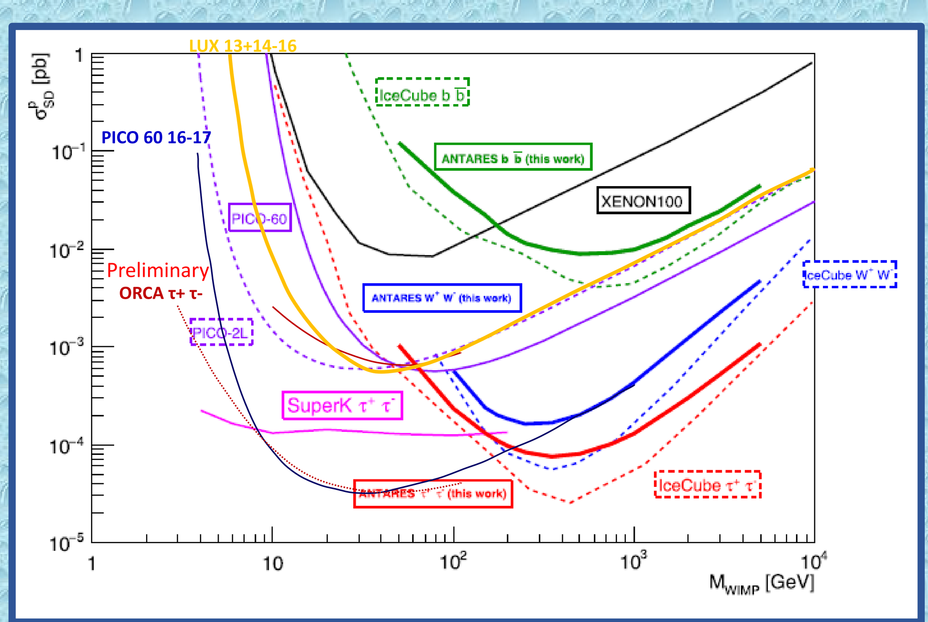
Sources





Sun

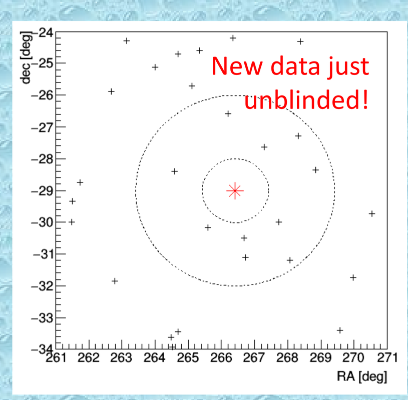
- WIMPs crossing the Sun could **scatter** with nucleons in the Sun and become gravitationally trapped
- After the annihilation of WIMPs and the production of secondaries, **only neutrinos** would escape
- The signal from the Sun in **not subject to significant astrophysical background**, contrary to other indirect searches. A potential detection of high energy neutrinos above the (measured) atmospheric background would be a **smoking gun**
- Searches with neutrino telescopes are **complementary** to direct searches: most sensitive for **low velocities**

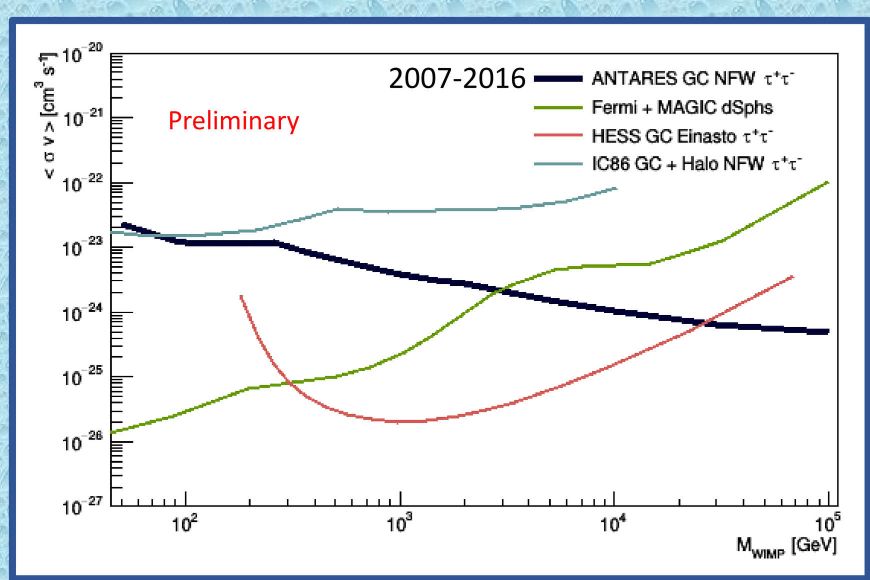


Limits on the spin-dependent cross section of WIMP-p scattering as a function of the WIMP mass [3]

Galactic Centre

- Dark matter has **gravitationally accumulated** in the Galactic Center (GC), where annihilates, producing neutrinos
- Contrary to the case of the Sun, limits are set on the WIMP **annihilation** cross-section
- The location in the Northern Hemisphere offers a very good **visibility** of the GC
- ANTARES has set the **best limits worldwide** for masses above 30 TeV

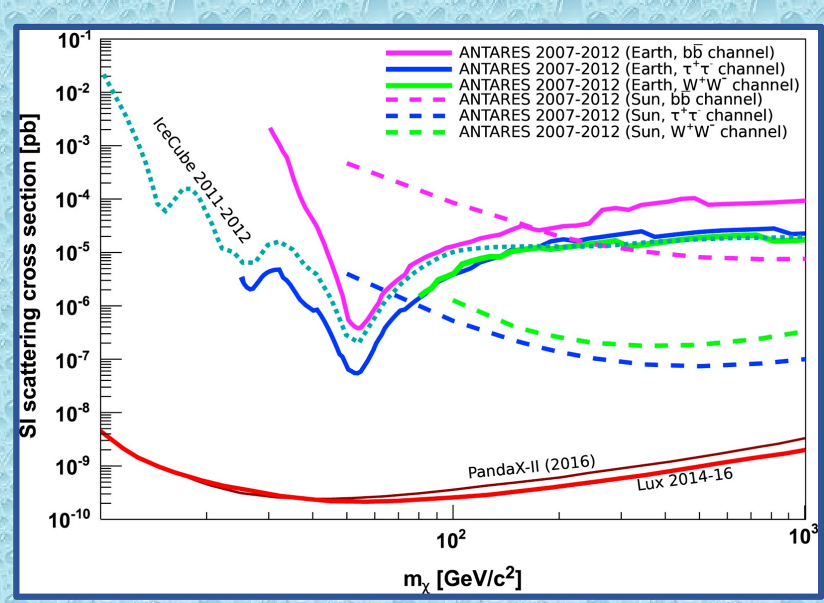




Limits on WIMP annihilation cross section as a function of the WIMP mass, both for Galactic Centre and dwarf galaxies (updated from [4]).

Earth

- Earth can also capture WIMPs, as in the case of the Sun
- Scattering occurs mainly with nuclei of **iron and nickel**, limits are set in the **spin independent** cross-section
- The most constraining limits are set for **masses of WIMPs** close to those of **iron** and **nickel** nuclei
- In order to set limits on the scattering cross section, a **relic abundance** has to be assumed, since there is no equilibrium between capture and annihilation



Limits on the WIMP spin independent cross section as a function of the WIMP mass for the Earth [5]

References

[1] **ANTARES : The first undersea neutrino telescope,** M. Ageron et al., Nucl. Instrum. Meth. A 656 (2011) 11-38, arXiv:1104.1607

[2] **Letter of Intent of the KM3NeT 2.0,** J. Phys. G: Nucl. Phys. 43, 8 (2016), arXiv:1601.07459

[3] **Limits on Dark Matter Annihilation in the Sun using the ANTARES Neutrino Telescope,** Physics Letters B, Volume 759 (2016), arXiv:1603.02228

[4] **Results from the search for dark matter in the Milky Way with 9 years of the ANTARES neutrino telescope,** Phys. Let. B769, 249 (2017), arXiv: 1612.04595

[5] **Search for dark matter annihilation in the Earth using the ANTARES neutrino telescope,** Physics of the Dark Universe, 16, 41 (2017), arXiv:1612.06792

Conclusions

- The search for **dark matter** is **one of the main goals** of neutrino telescopes
- Neutrino telescopes have **specific advantages** as complementary strategy in these searches, giving the best limits for spin-dependent WIMP-nucleon cross section. Moreover, the a signal in the Sun would be a **smoking gun.**
- The **ANTARES** neutrino telescope, has been taking data for a decade, has shown the feasibility of the underwater technique, providing results on the Sun, the Galactic Center and other sources. ANTARES has set the **best limits worldwide** in the DM annihilation cross section for masses **above 30 TeV**, taking advantage of the excellent angular resolution reachable in the water and its location in the Northern Hemisphere (better visibility)
- **KM3NeT**, already in construction, will **improve** these results in the near future, both at low masses (ORCA) and large masses (ARCA)