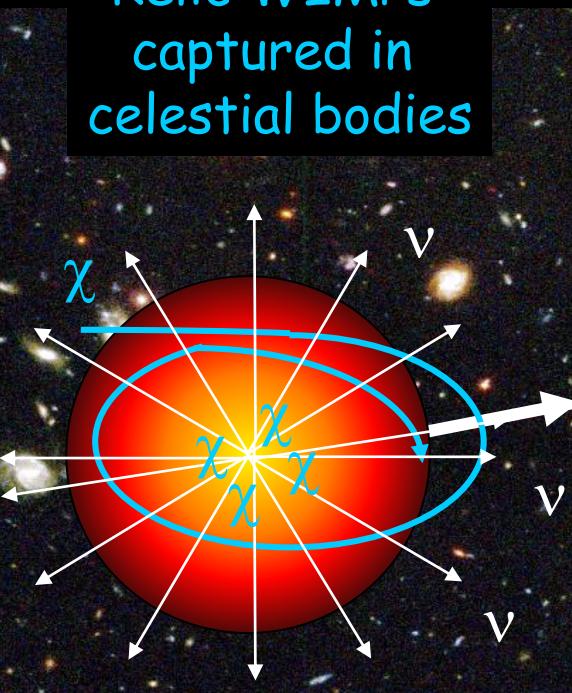
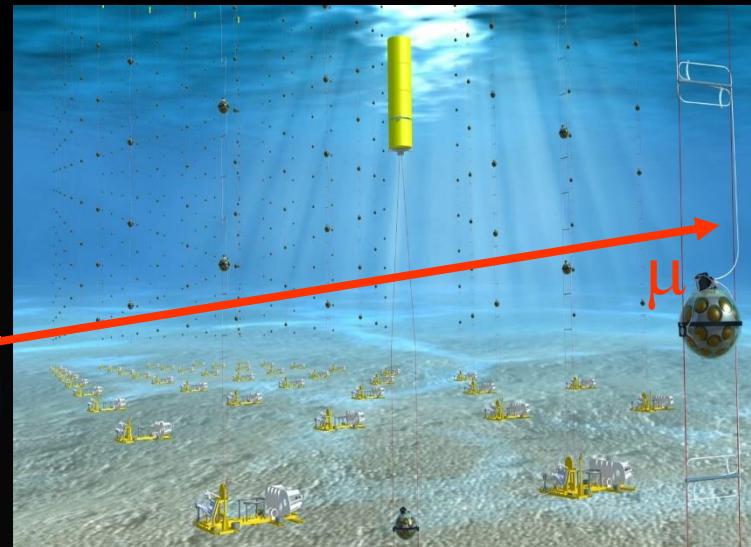
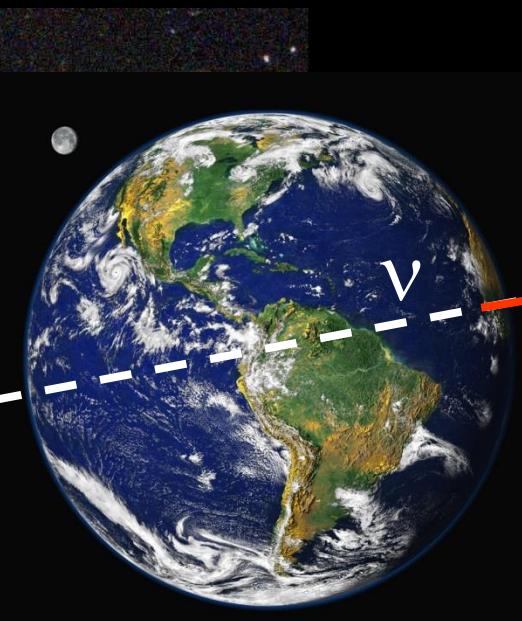


Indirect detection of WIMPs in a neutrino telescope

Relic WIMPs
captured in
celestial bodies



$\chi\chi$ self-annihilations into
c,b,t quarks, τ leptons or W,Z,H bosons
can produce significant
high-energy neutrinos flux

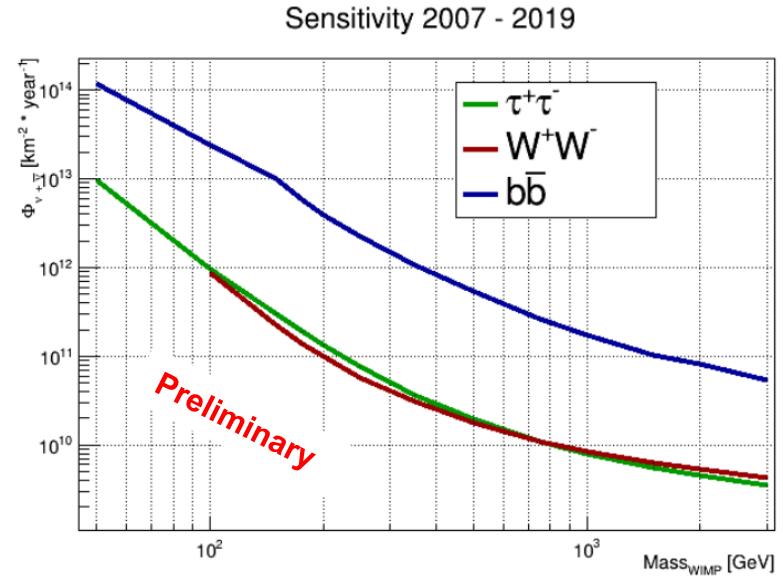
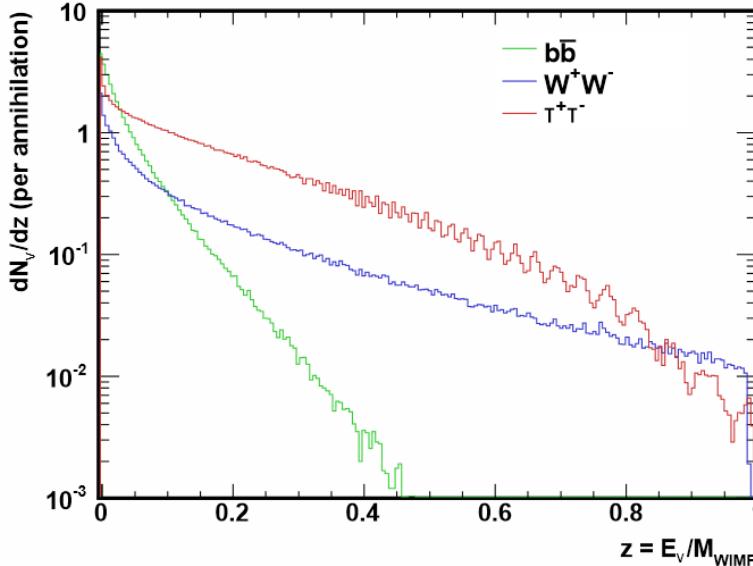


Potential $\chi\chi \rightarrow \nu$ sources are
Sun, Earth & Galactic Centre
Signal less affected by
astrophysical uncertainties
than γ -ray indirect detection

Complementary and competitive limits with ANTARES & KM3NeT
for WIMP masses in [50, 3000] GeV (Sun) and > few TeV (GC)

Indirect search towards the Sun with ANTARES

- WIMPSIM package (Blennow, Edsjö, Ohlsson, 03/2008) used to generate events in the Sun in a **model independent way**
- Annihilations into **b quarks** (soft spectrum) and **τ leptons, WW/ZZ bosons** (hard spectrum) **used as benchmarks**
- Take into account ν **interactions** in the Sun medium, **regeneration of ν_τ** in the Sun and ν **oscillations**





Limits on Spin (In)dependent cross sections

Conversion to limits on WIMP-nucleon Spin (In)dependent cross sections assuming :

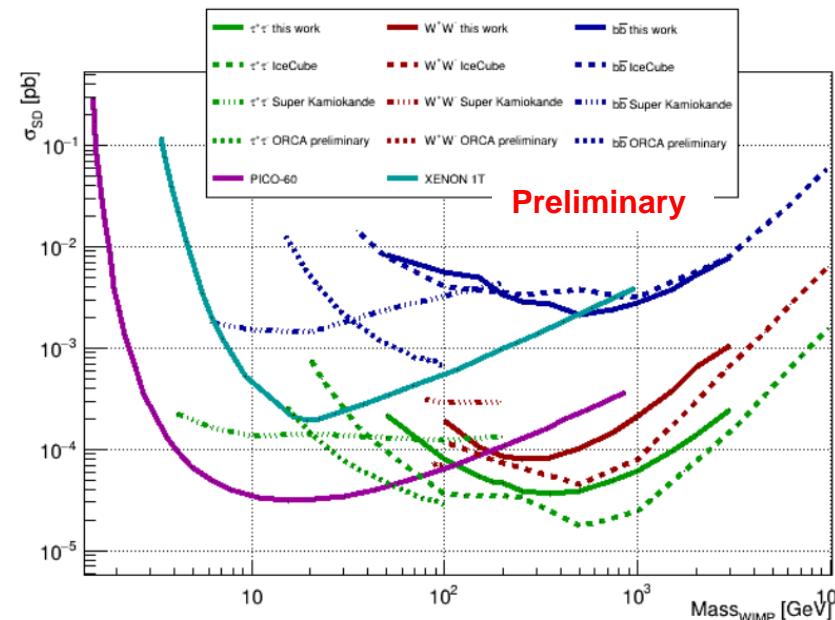
- Equilibrium between capture and annihilation rates inside the Sun
- Local WIMP density = 0.4 GeV/cm³
- Maxwellian velocity distribution of WIMPs with r.m.s. = 270 km/s & escape velocity = 544 km/s

→ Determination of astrophysical uncertainties on WIMP capture in the Sun :

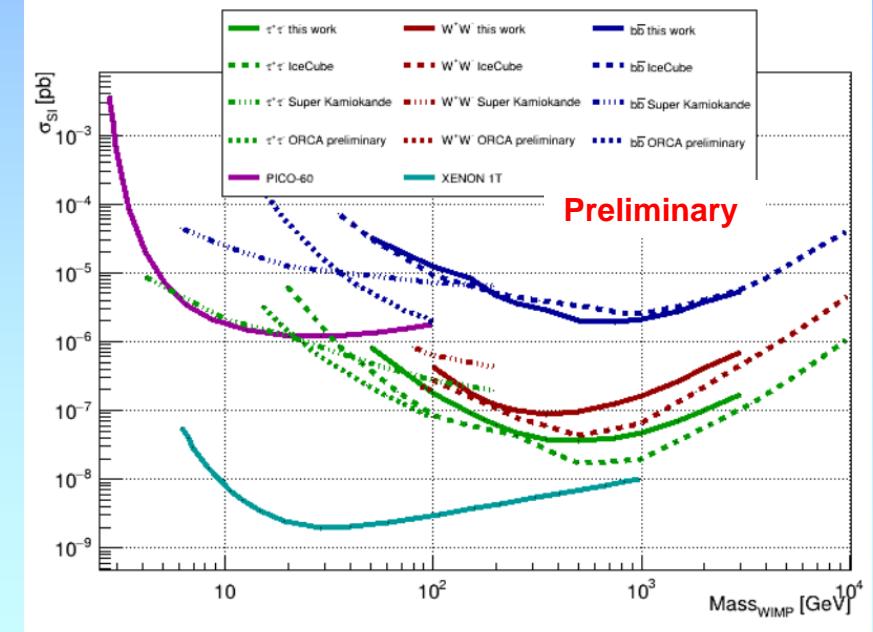
PhD work by A. Nuñez (2016-2019) with E. Nezri, J. Lavalle & VB

Preliminary sensitivity with ANTARES 2007-2019 data, limits with 2007-2012 data Phys.Lett. B 759 (2016) 69

Limit on WIMP-nucleon SD cross-section

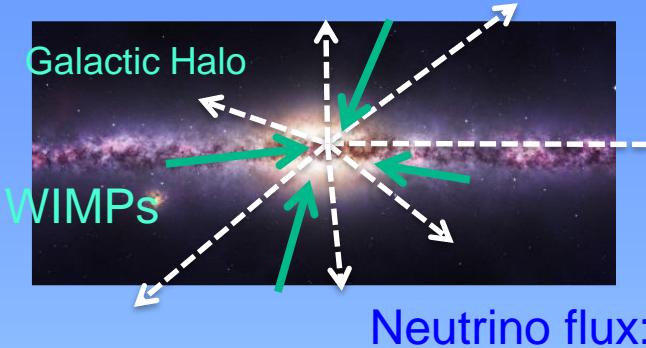


Limit on WIMP-nucleon SI cross-section



→ much better sensitivity of neutrino telescopes on SD cross-section w.r.t. direct detection due to efficient capture on Hydrogen inside the Sun

Search for Dark Matter towards the Galactic Centre

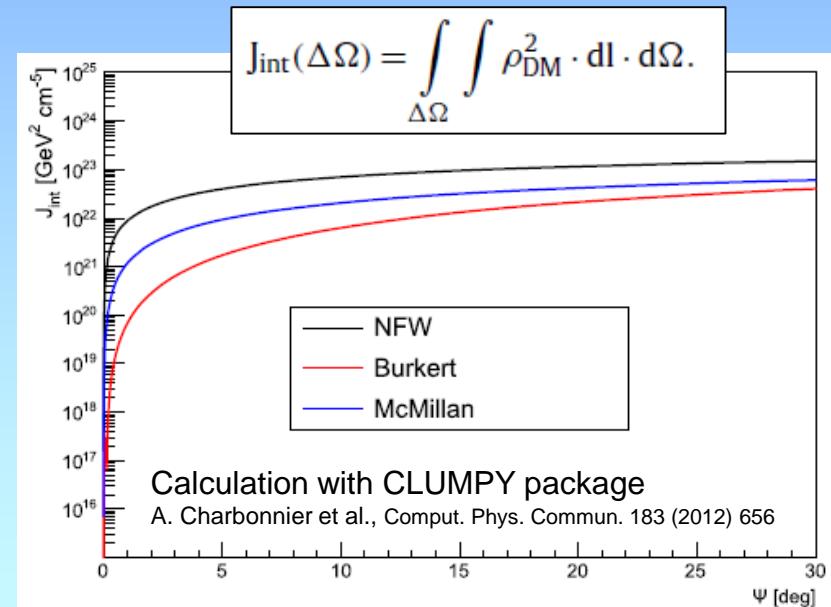
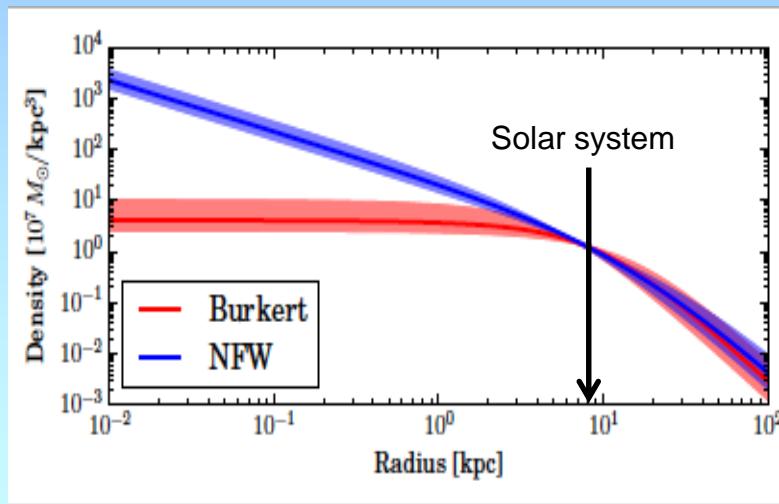


ν_e, ν_μ, ν_τ
 ν oscillations in the vacuum



$$\frac{d\Phi_{\nu_\mu + \bar{\nu}_\mu}}{dE_{\nu_\mu + \bar{\nu}_\mu}} = \frac{\langle \sigma v \rangle}{8\pi M_{\text{WIMP}}^2} \cdot \frac{dN_{\nu_\mu + \bar{\nu}_\mu}}{dE_{\nu_\mu + \bar{\nu}_\mu}} \cdot J_{\text{int}}(\Delta\Omega).$$

Extended source strongly dependent on the galactic halo model



3 benchmark halo model considered :

- Navarro, Frenk, White, ApJ 490 (1997) 493
- A. Burkert, ApJ 447 , L25 (1995)
- P.J. McMillan, Mon. Not. R. Astron. Soc. 414 (2015) 2446

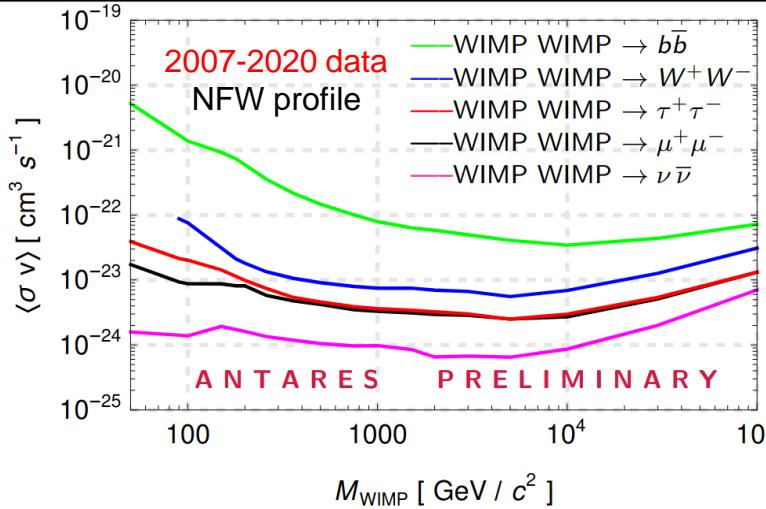
Table of dark matter halo parameters for the Milky Way as taken from [10] and [11]. ρ_{local} is the local density and r_s is the scaling radius.

Parameter	NFW	Burkert	McMillan
r_s [kpc]	$16.1^{+17.0}_{-7.8}$	$9.26^{+5.6}_{-4.2}$	17.6 ± 7.5
ρ_{local} [GeV/cm ³]	$0.471^{+0.048}_{-0.061}$	$0.487^{+0.075}_{-0.088}$	0.390 ± 0.034



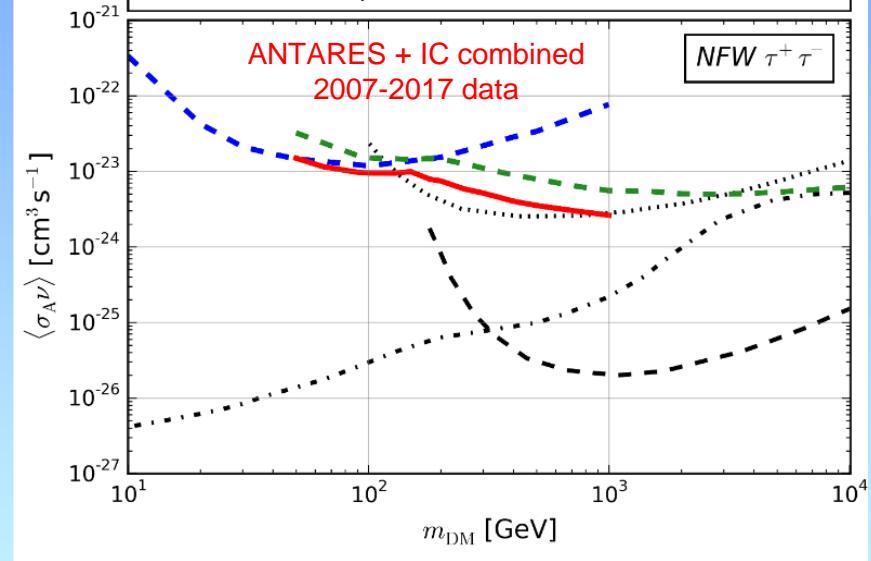
Limits of ANTARES from Galactic Centre

Limit on WIMP annihilation cross-section assuming 100% BR of annihilation into benchmark channel

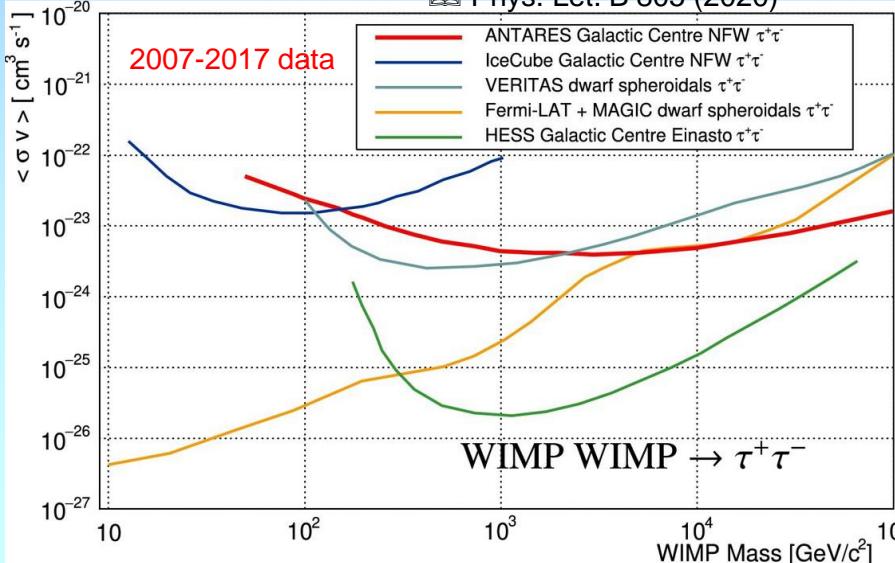


Phys. Rev. D 102 (2020) 082002

- Combined ANTARES/IceCube search
- ANTARES [PLB (2017) 769:249, PLB (2019)]
- IceCube [EPJC (2017) 77:627]
- ... Fermi+MAGIC - dSphs [JCAP (2016) 02:039]
- H.E.S.S. - Einasto [PRL (2016) 117:111301]
- Veritas - dSphs [PR (2017) 95:082001]



Phys. Let. B 805 (2020)



ANTARES gives the **best limit**

in neutrinos above 100 GeV

→Very competitive limit for $M_{WIMP} > 10$ TeV