# 17th International Conference on Topics in Astroparticle and Underground Physics

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# Indirect search for Dark Matter in the Sun with ANTARES

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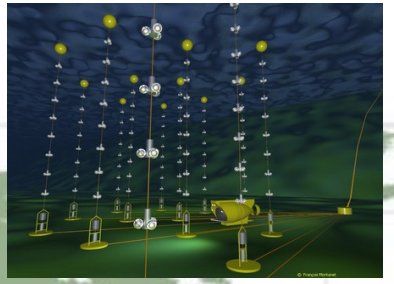
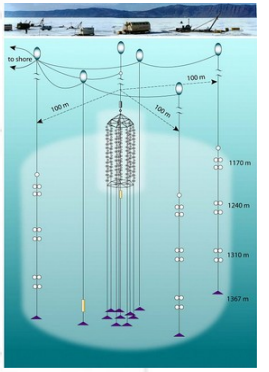
# Cherenkov Neutrino telescopes around the world

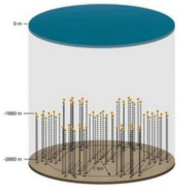


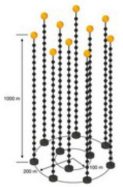
ANTARES, 0.01 km$^3$

Baikal/GVN, 1 km$^3$
(Under construction)

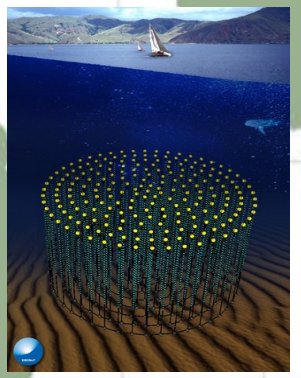


P-ONE
(R&D phase)





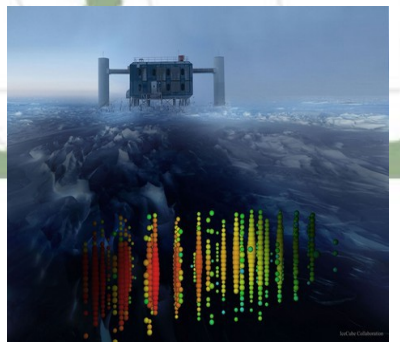
KM3NeT/ORCA,
(Under construction)



KM3NeT/ARCA,
(Under construction)

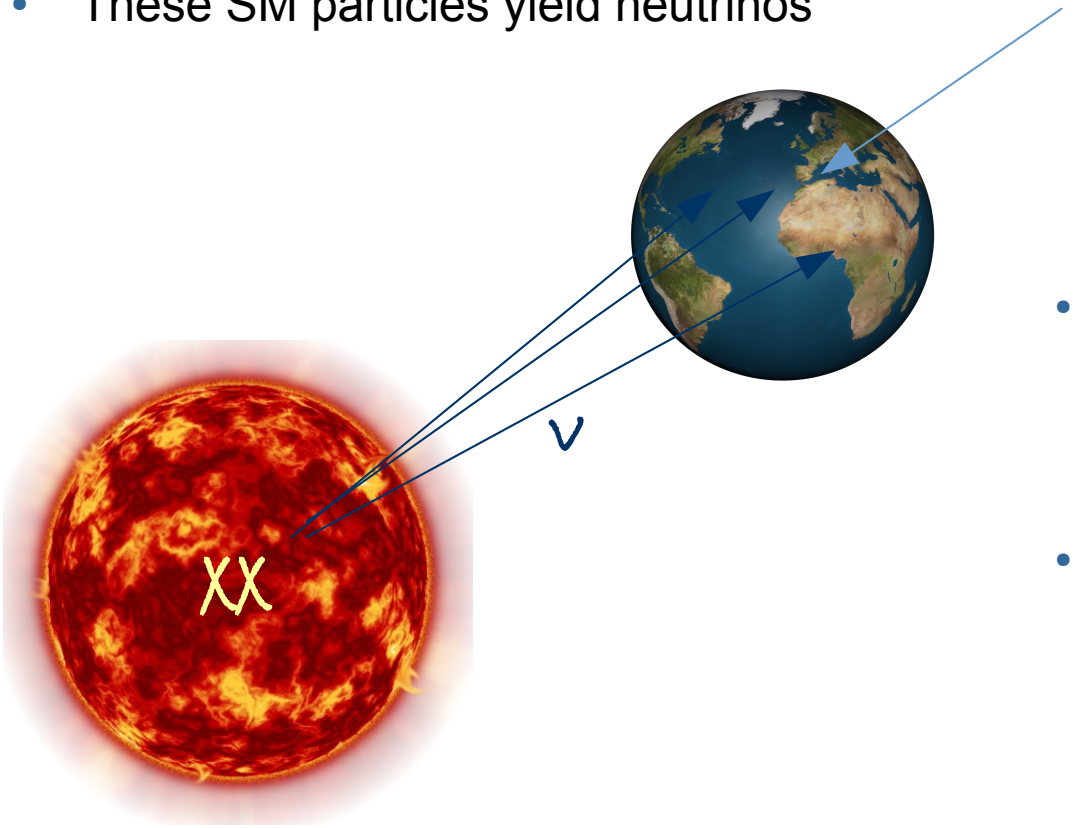
IceCube, 1 km$^3$

IceCube Gen 2, 10 km$^3$
(projected)

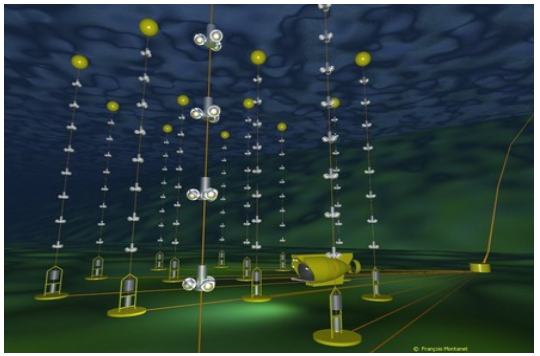


# WIMP Dark Matter Indirect Detection

- DM can be captured by massive bodies, as the Sun
- Inside these bodies, DM can annihilate into Standard Model particles
- These SM particles yield neutrinos

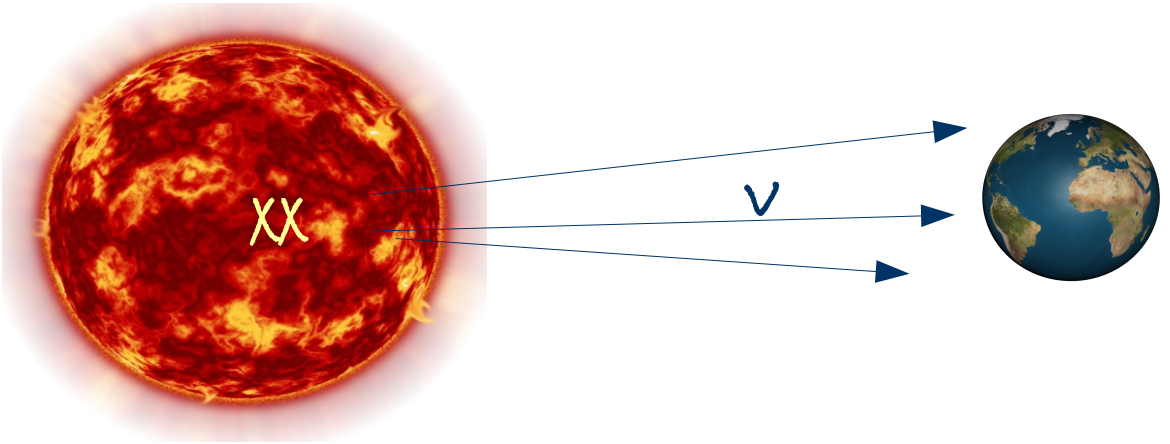



ANTARES Neutrino Telescope



- Neutrinos are detected through Cherenkov light emitted by the products (relativistic charged particles) of the neutrino interaction
- Neutrinos are less affected by astrophysical uncertainties than γ-ray indirect detection

# Dark Matter in the Sun



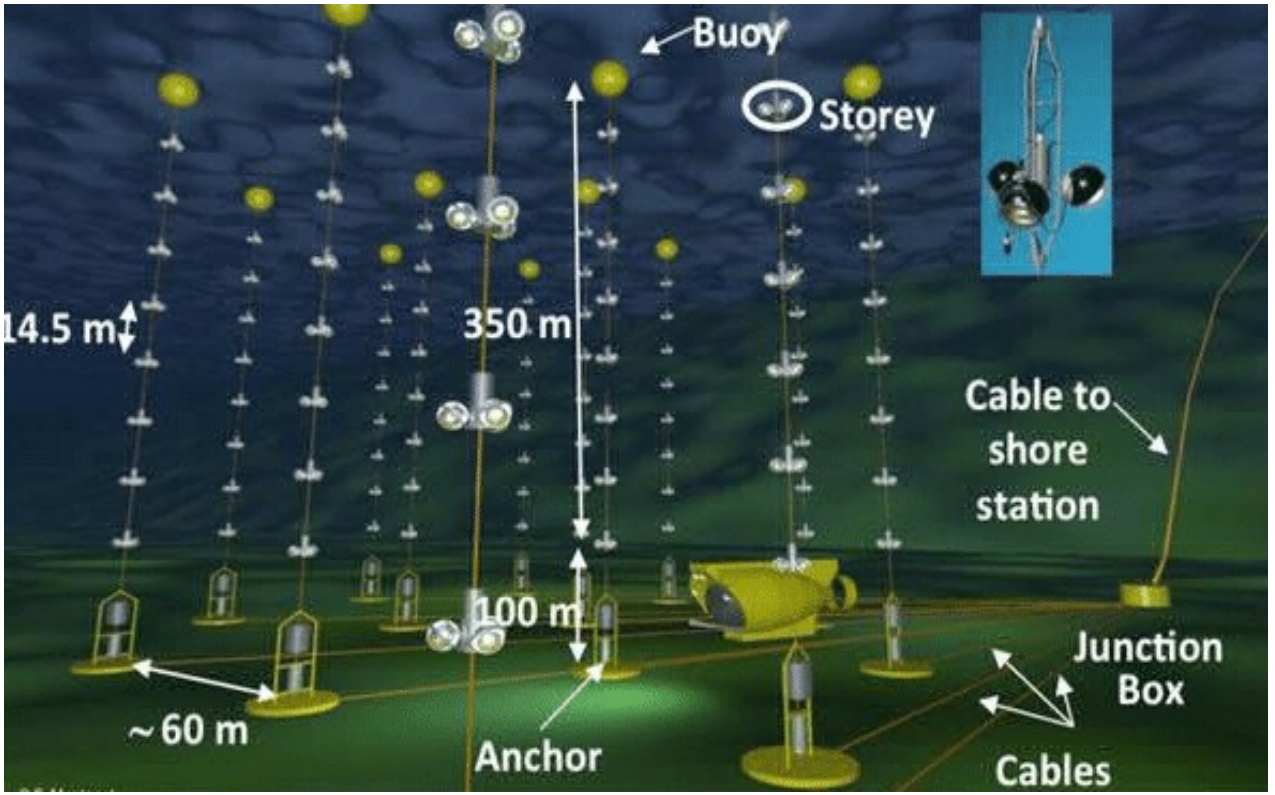

- Sensitive to DM-nucleon scattering cross-section, spin-dependent and spin-independent
- Differential neutrino flux is related with the annihilation rate

$$\frac{d\Phi}{dE_\nu} = \frac{\Gamma}{4\pi d^2}\frac{dN_\nu}{dE_\nu}$$

- In equilibrium between capture and annihilation $\Gamma = C/2$ with C capture rate
- Very clean: if signal $\rightarrow$ direct interpretation (astrophysical background well known)

# ANTARES Neutrino Telescope

- Toulon, France
- Data taking: 2007 → 2021
- 2500 m depth



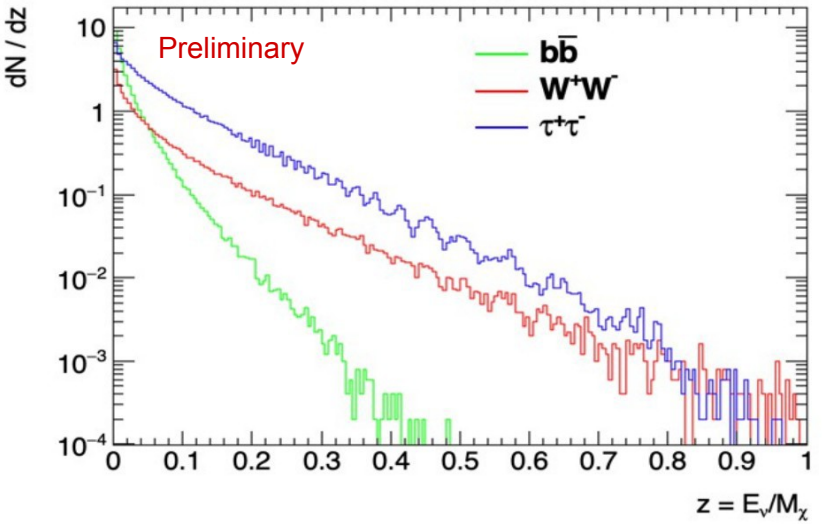

- 12 lines
- 25 storeys/line
- 3 PMT/storey (~ 900 PMTs)

# This analysis

- This analysis is based on a *binned method*
- The results presented are obtained with *Blinded data* for 2007-2019
- Three channels are considered: $b\bar{b}, W^+W^-, \tau^+\tau^-$
- To evaluate the best sensitivity different quality cuts are considered

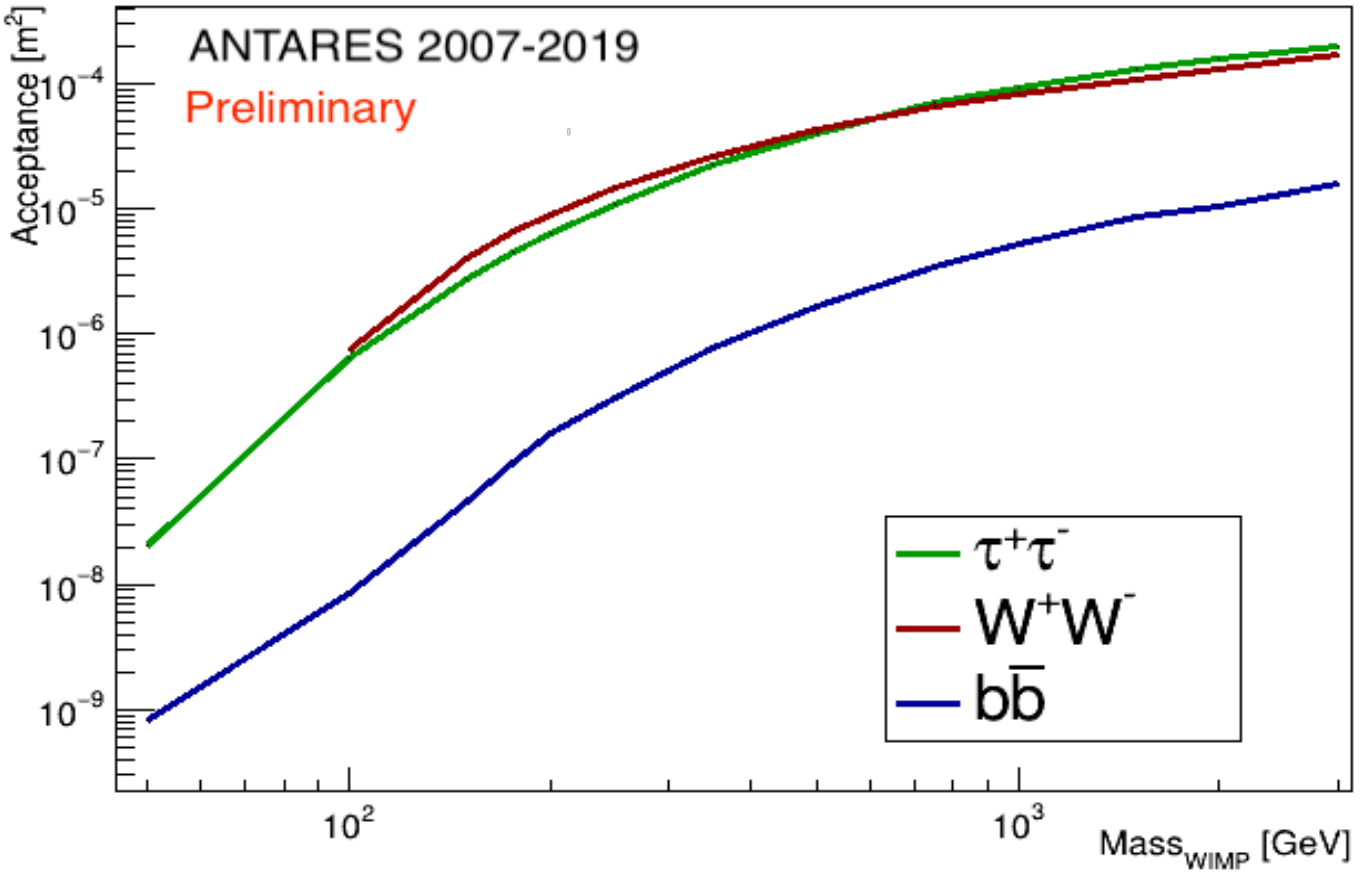
# Acceptance ingredients

$$Acc(M_{WIMP}) = \bar{A}_{eff}(M_{WIMP}) = \frac{\sum_{j=\nu,\bar{\nu}} \left( \int_0^{M_{WIMP}} A^j_{eff}(E_j) \frac{dN_j}{dE_j} dE_j \right)}{\int_0^{M_{WIMP}} \frac{dN_\nu}{dE_\nu} dE_\nu + \frac{dN_{\bar{\nu}}}{dE_{\bar{\nu}}} dE_{\bar{\nu}}}$$




- Annihilation spectrum from WimpSim
- Channels: $b\bar{b}$,$W^+W^-$,$\tau^+\tau^-$
- Acceptances are computed for the different Effective Areas, obtained considering different combinations of quality cut parameters, separately for neutrinos and antineutrinos

# Acceptance


ANTARES 2007-2019
Preliminary
Acceptance [m²]
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10²
10³
Mass_WIMP [GeV]
τ⁺τ⁻
W⁺W⁻
bb̄

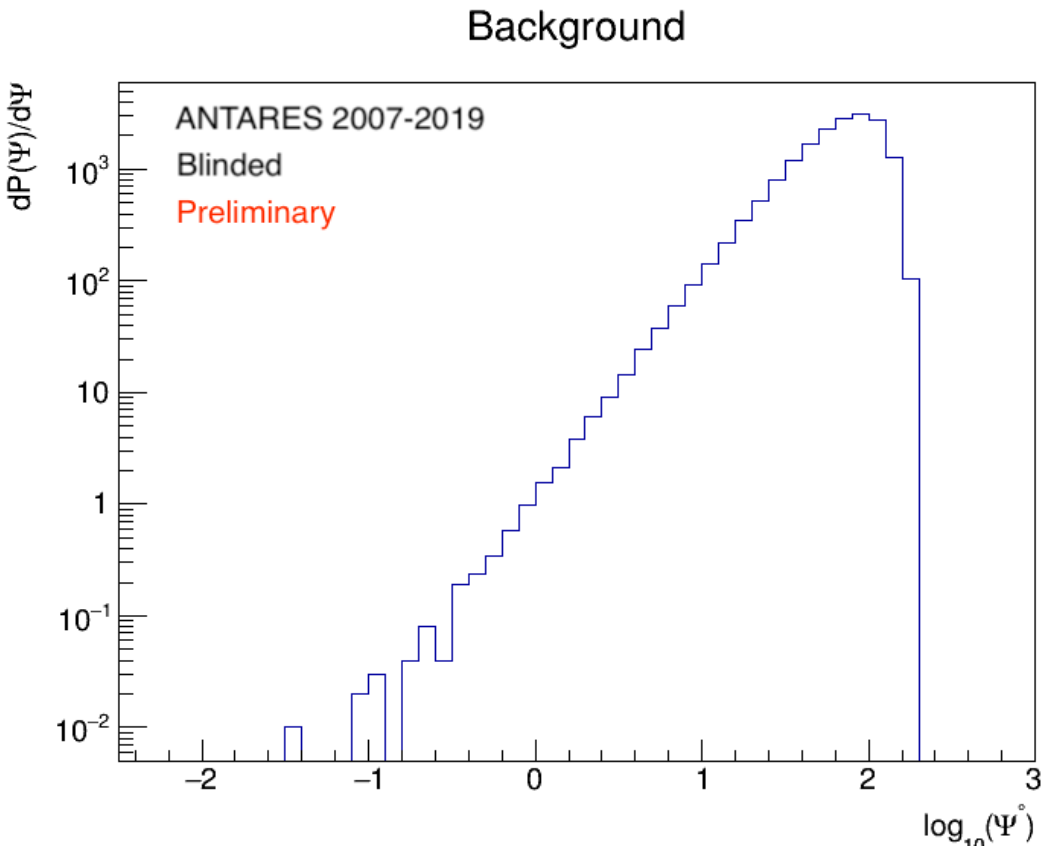
# Sensitivity ingredients

$$\bar{\Phi}_{\nu_\mu+\bar{\nu}_\mu,90\%} = \frac{\bar{\mu}_{90\%}}{\bar{A}_{eff}(M_{WIMP}) \cdot T_{eff}}$$

- $\overline{\mu}^{90\%}$ is computed from the background estimation, according to the Model Rejection Factor definition
- Estimated Background number of events from scrambled data
- $T_{eff}$ is the livetime
  $\longrightarrow$ 9.134 in years for blinded data
- Computed for the different Acceptances (quality cut parameters)

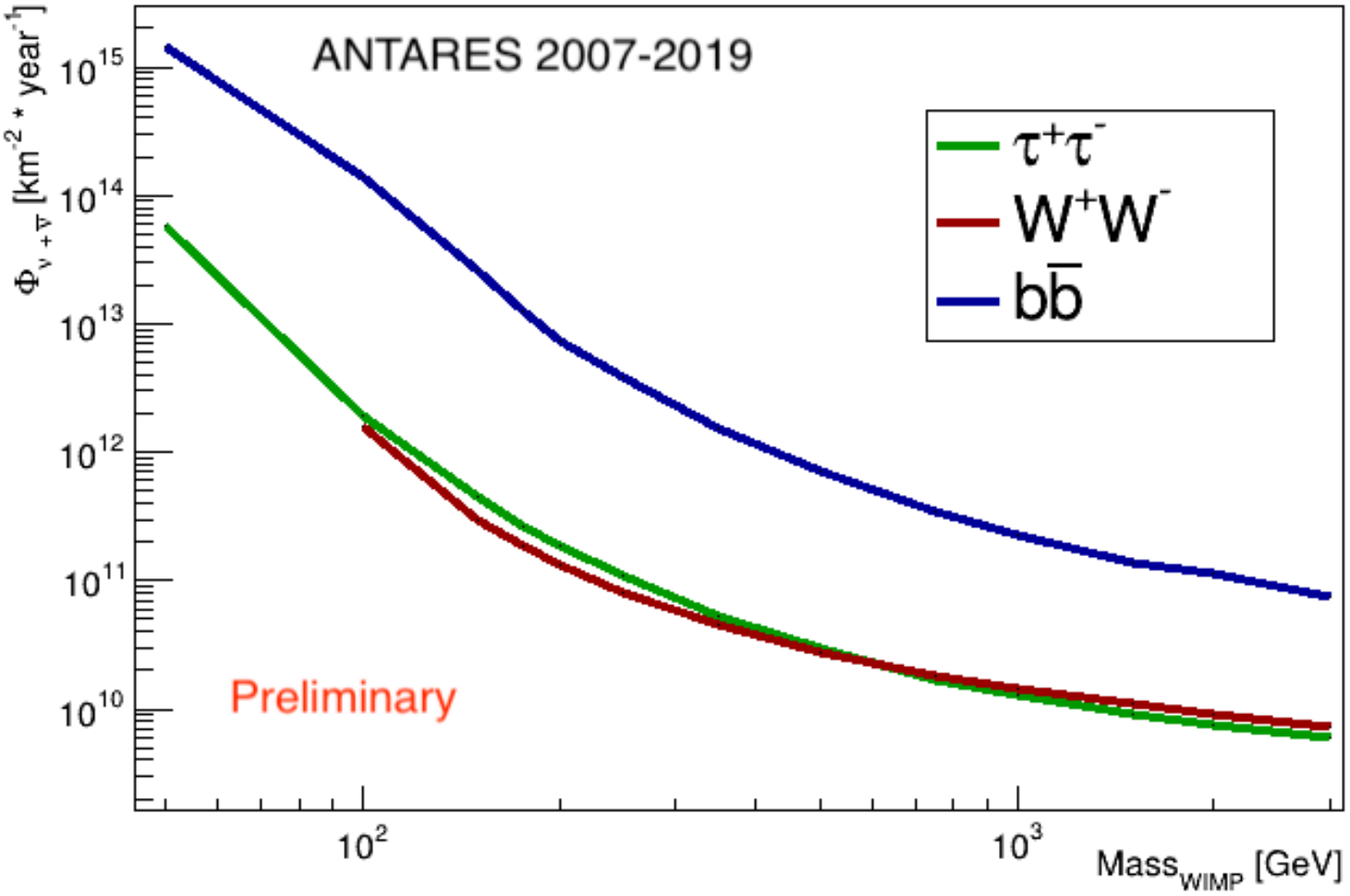
# Background

- Scrambling data, generating 100 maps
- The angle $\Psi$ is the angular separation computed by doing the scalar product of vectors built with $\theta$ and $\varphi$ respectively of reconstructed track and Sun's directions.
- Fit to estimate the number of events for a specific angular separation is done

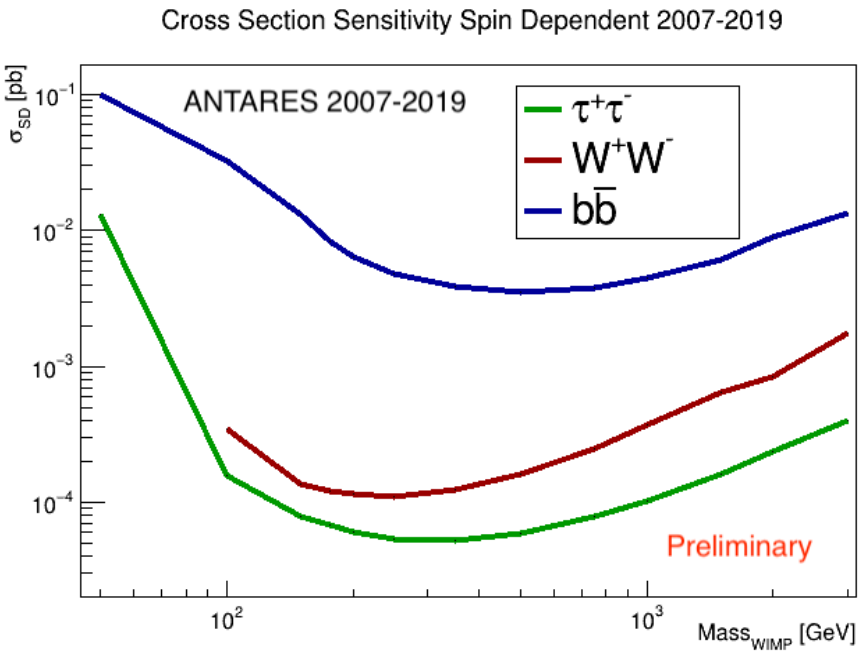


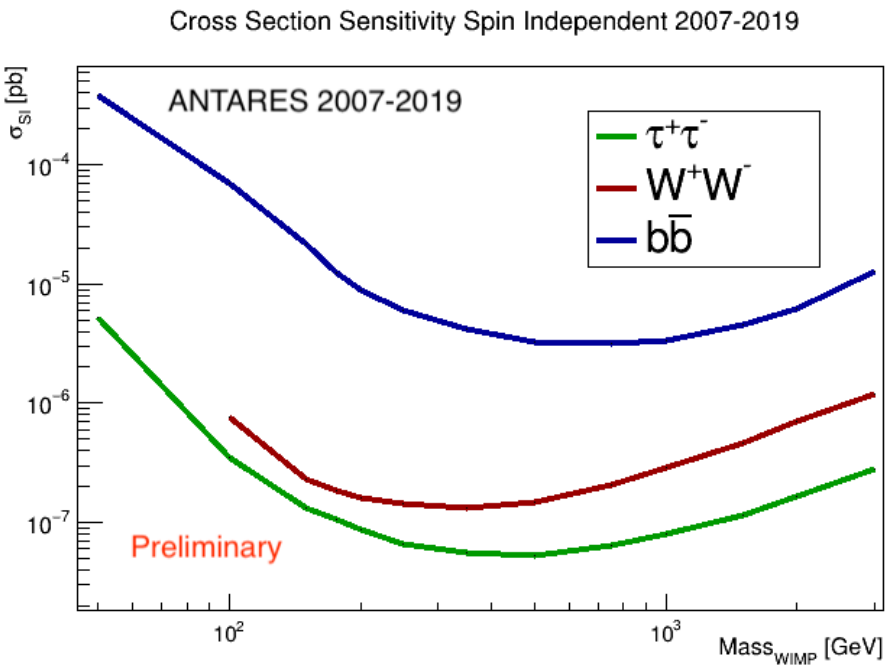
# Sensitivity

Flux sensitivity for neutrinos and antineutrinos from DM in the Sun



# Cross Section Sensitivity




Conversion to limits on WIMP-nucleon SD and SI cross-section, assuming:

→ Equilibrium between capture and annihilation rates inside the Sun.

→ Local WIMP density = 0.4 GeV/cm$^3$.

→ Maxwellian velocity distribution of WIMPs with r.m.s. = 270 km/s.

# Conclusions

- Presented here are the first preliminary results of this analysis
- These results are compared with previous publications with similar analyses (not shown here):
  $\longrightarrow$ the results are comparable
  $\longrightarrow$ livetime larger than a factor 2

Next steps:

- Include other reconstruction strategies more suitable for low DM masses
- Working towards unblinding and comparison with other experiments