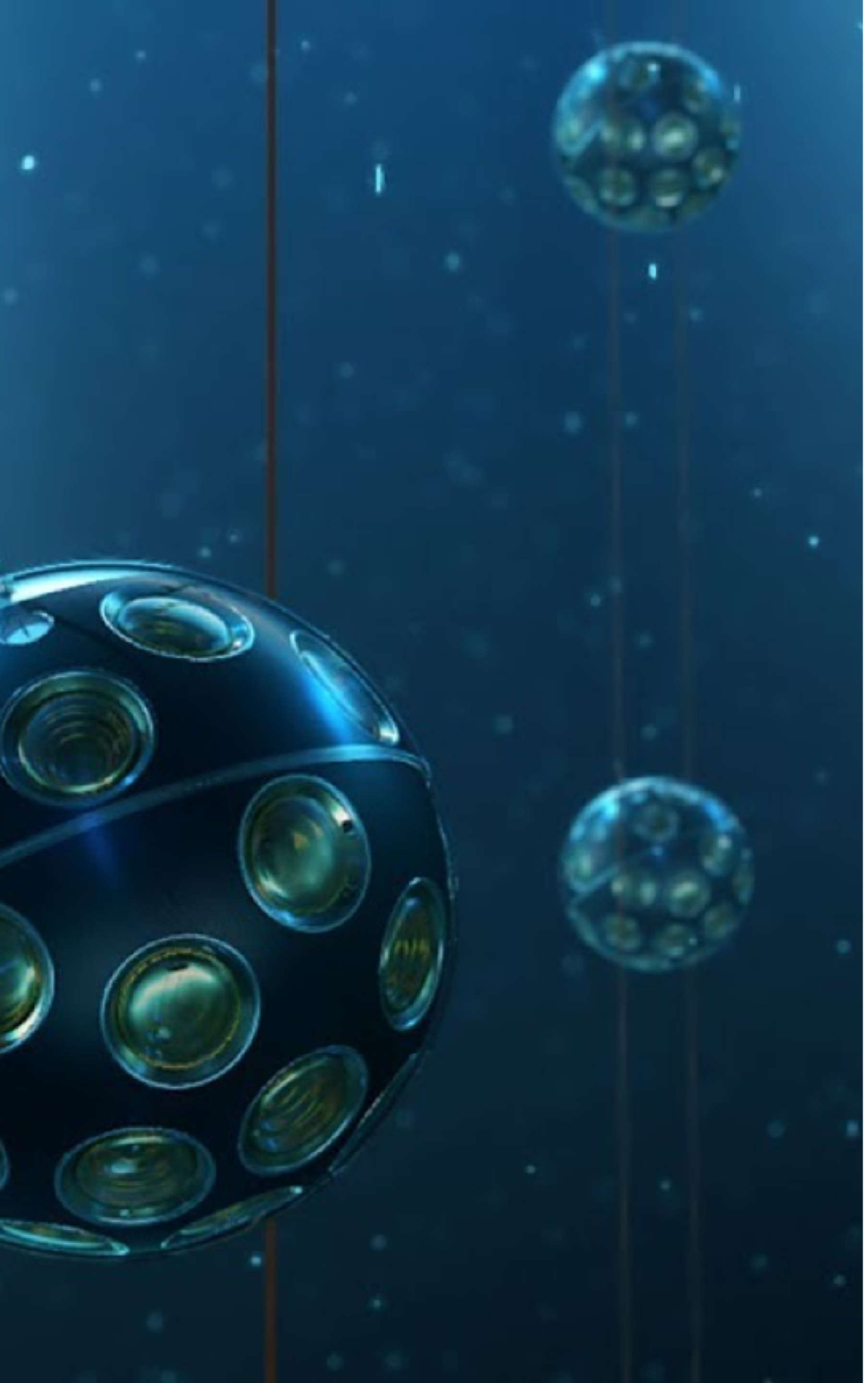


Dark matter searches with the KM3NeT telescope

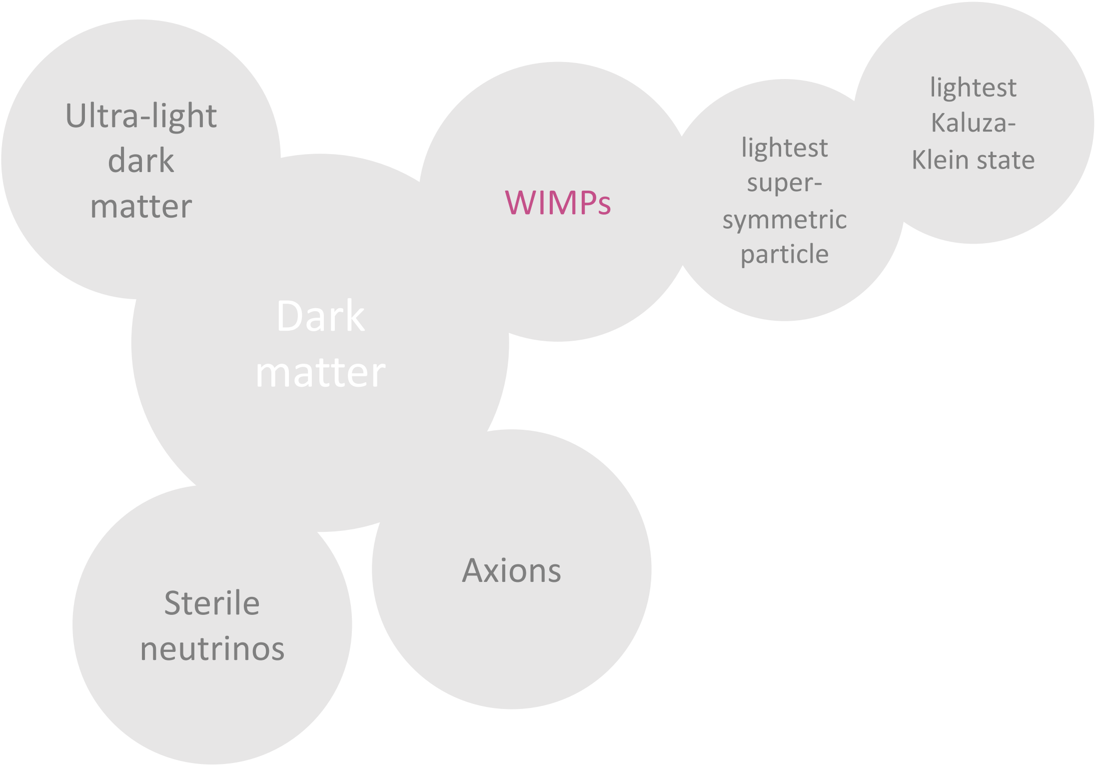
Clara Gatius Oliver, on behalf of the KM3NeT Collaboration
Nikhef - Amsterdam

KM3NeT

RICAP Conference, September 2024

What can neutrinos teach us about dark matter?

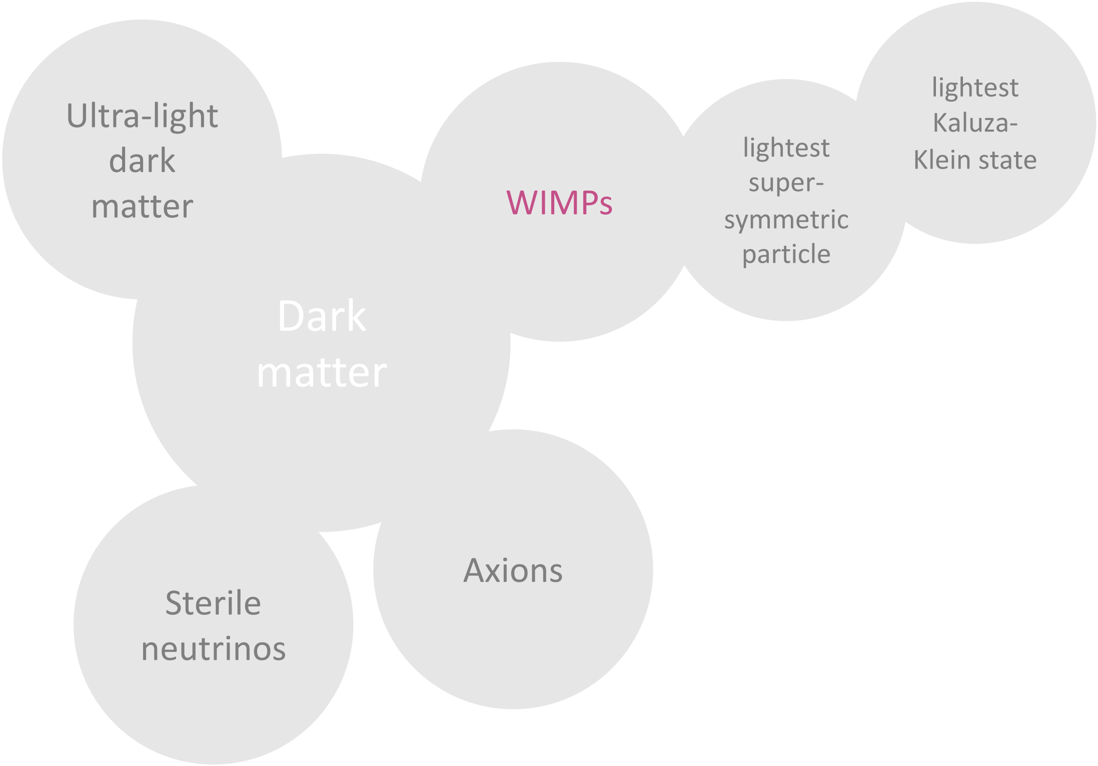
- Cosmological observations set few constraints on the nature of dark matter



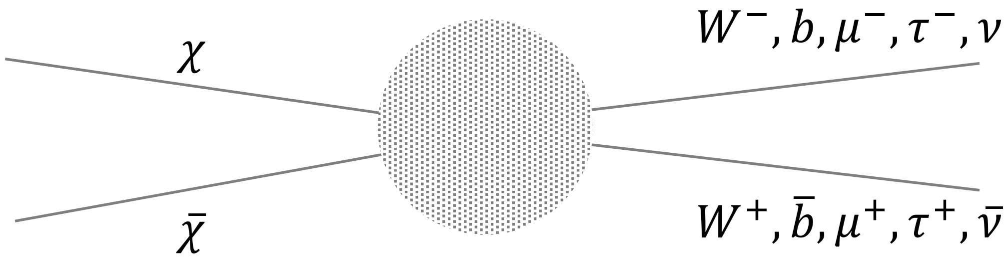
✓ Correct cosmological properties
✓ Arise naturally in many particle physics theories
✓ Many and diverse set of implications for observable phenomena

What can neutrinos teach us about dark matter?

- Cosmological observations set few constraints on the nature of dark matter



- WIMP annihilations

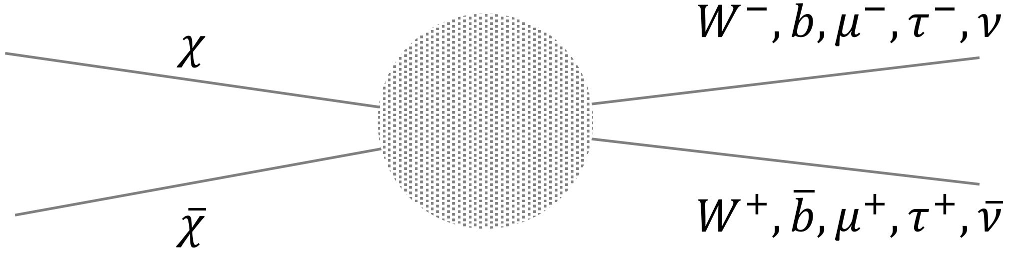


- Neutrino excess from regions with high dark matter density

✓ Correct cosmological properties
✓ Arise naturally in many particle physics theories
✓ Many and diverse set of implications for observable phenomena

What can we measure with the KM3NeT?

- Different annihilation channels (100% branching ratio)



- WIMP dark matter candidates with masses:

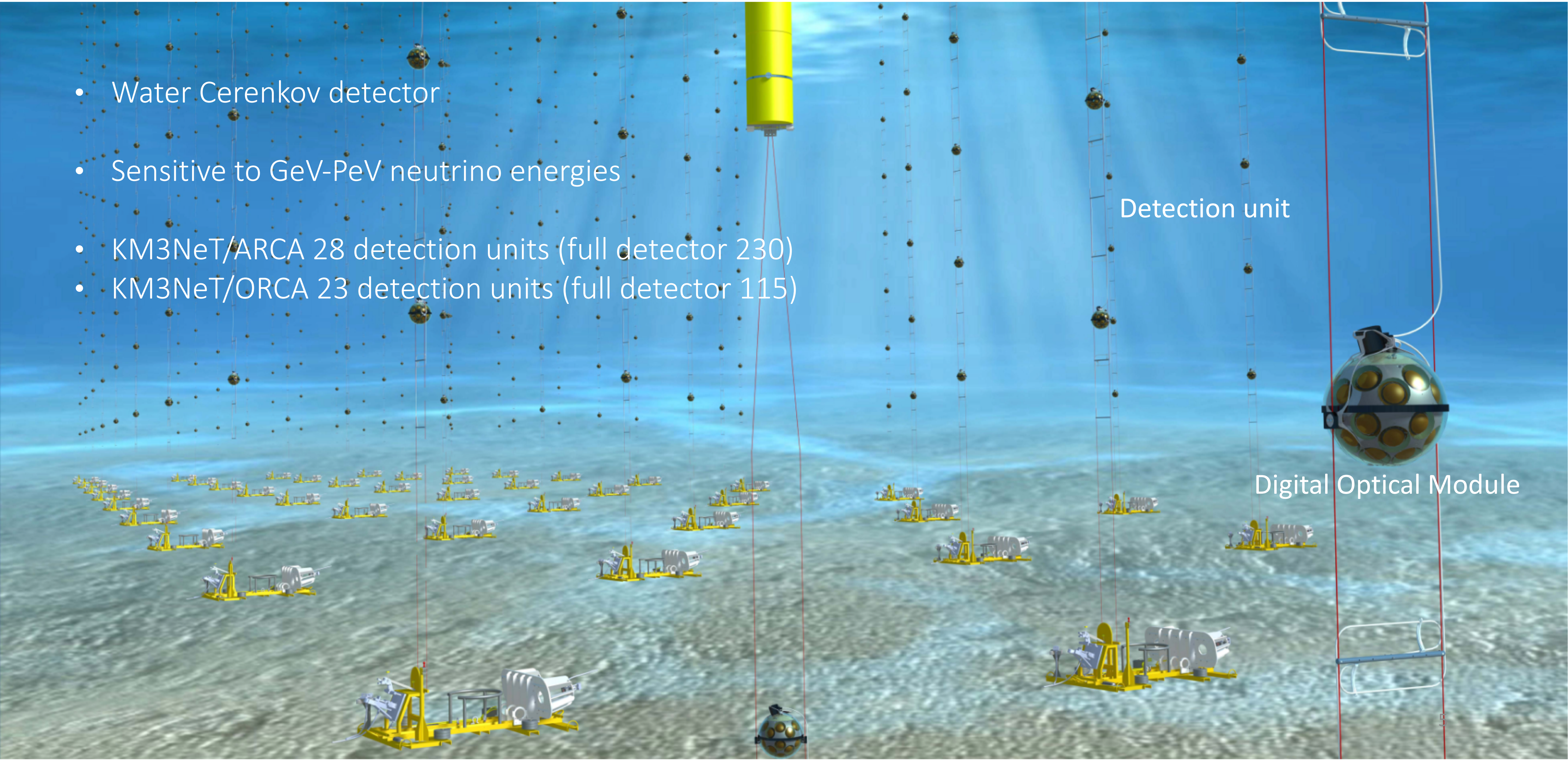
$$M_{DM} \in \ [1\ GeV, 100\ TeV]$$

- Lower limit given by detector capabilities
- Upper limit by cosmological constraints

- Regions with high dark matter density:
  - Galactic Centre (dark matter halo)
  - Sun (capture of local halo dark matter)

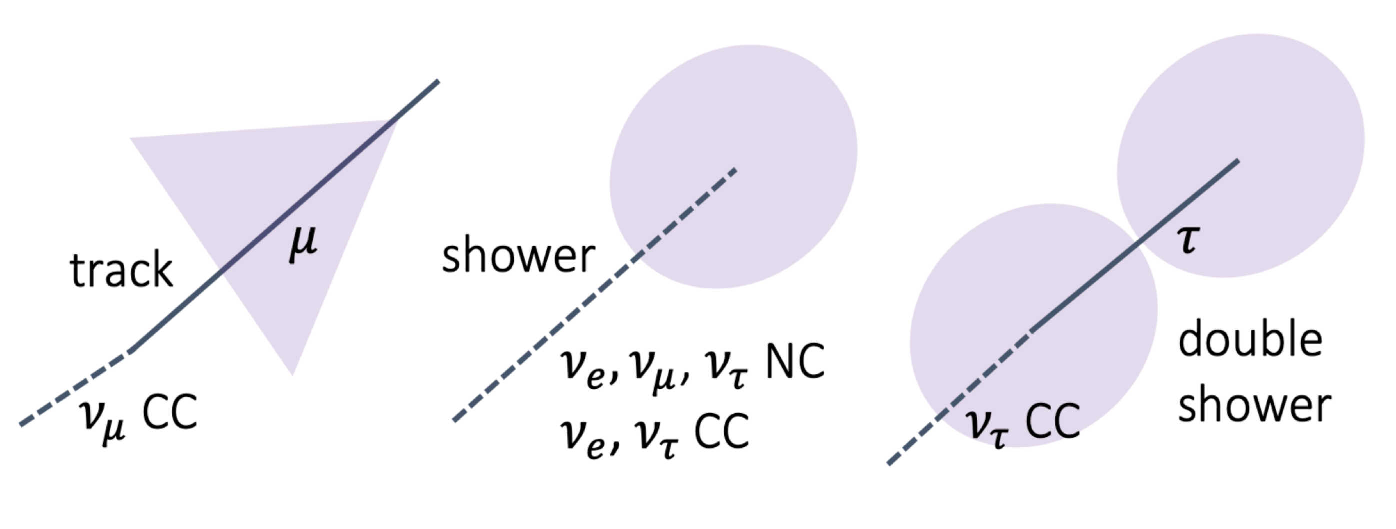
KM3NeT telescope

- Water Cerenkov detector
- Sensitive to GeV-PeV neutrino energies
- KM3NeT/ARCA 28 detection units (full detector 230)
- KM3NeT/ORCA 23 detection units (full detector 115)



KM3NeT telescope

- Different type of neutrino interactions → different event topologies



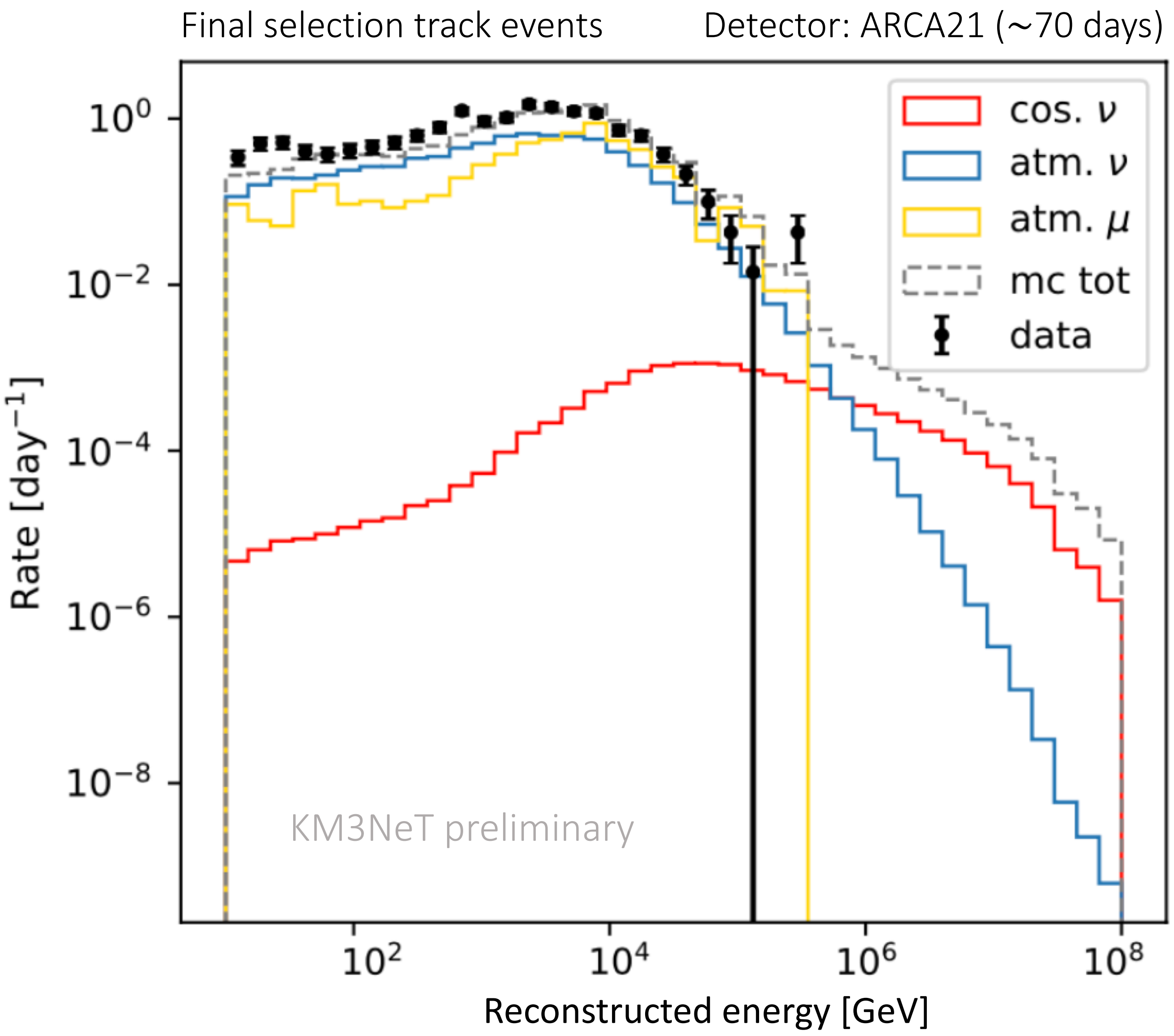
Analysis method: **event selection**

- Optical background (^{40}K decays and bioluminescence) → removed by looking at coincidences between optical modules.

Selection:

- Atmospheric muons → cut events coming from above the horizon
- Atmospheric neutrinos → irreducible background.
- Quality cuts on reconstruction variables + Boosted Decision Tree

Good data – Monte Carlo agreement thanks to improvement in calibration, reconstruction and simulations.



Analysis method: **source modelling**

- Neutrino flux from WIMP annihilations

Galactic Centre

$$\frac{d\Phi_\alpha^c}{dE\,dt} = \frac{1}{4\pi}\frac{<\sigma v>}{2m_\chi^2}\frac{dN_\alpha^c}{dE}\int_{\Delta\Omega}\int_{l.o.s.}\rho^2(\theta,l)dl\,d\Omega$$

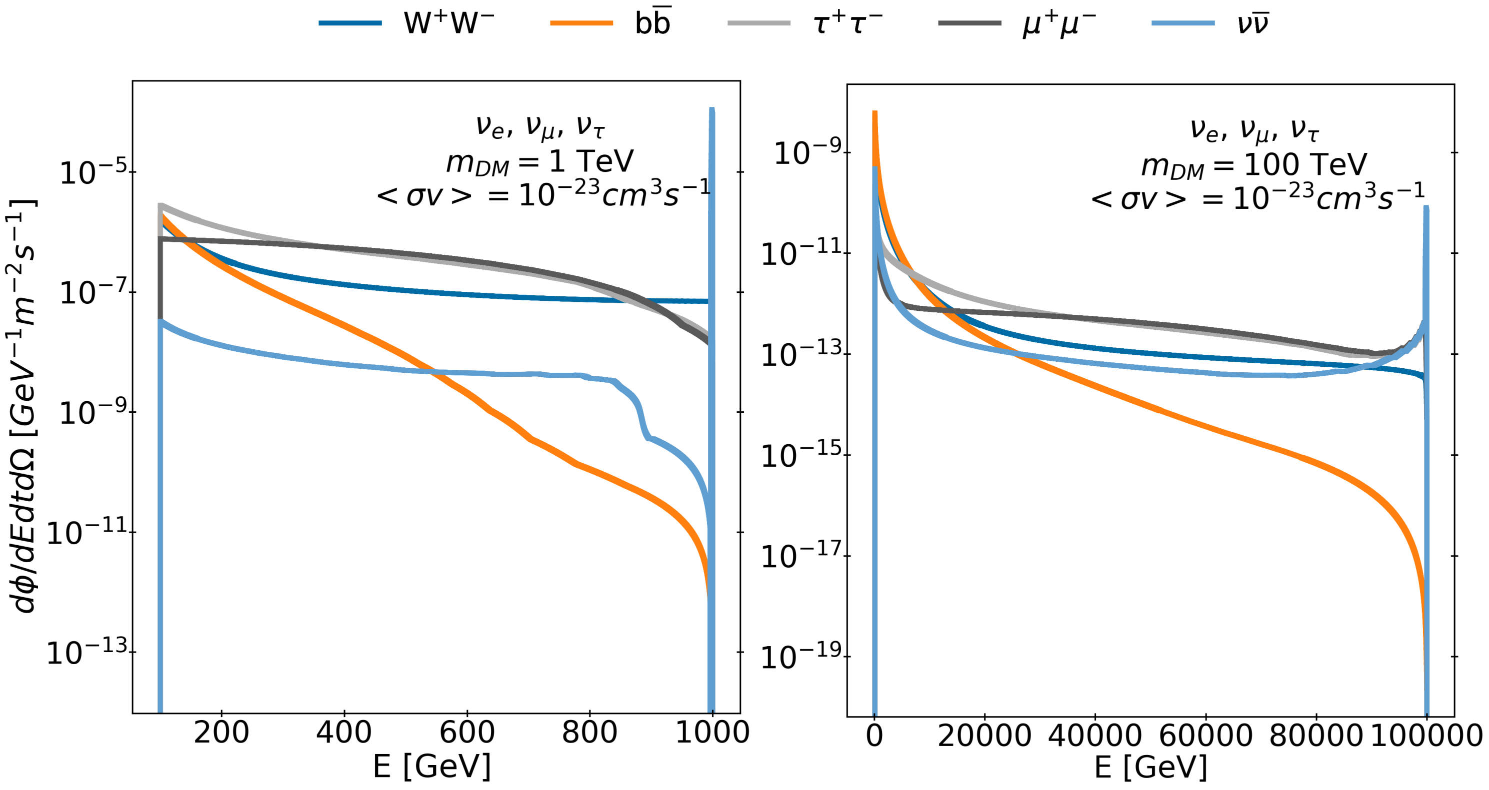
- Dark matter density: NFW profile
- Spectra oscillated through vacuum.
- Line-like feature $\nu\bar{\nu}$ annihilation channel.
- Simulated with *Charon* [1].

Sun

$$\frac{d\phi_\alpha^c}{dE\,dt} = \frac{C_r}{8\pi d^2}\frac{dN_\alpha^c}{dE}$$

C_r = capture rate

- Equilibrium between capture and annihilation processes. Flux depends on WIMP-nucleon scattering cross section (spin dependent or independent).
- Simulated with WimpSim [2].



Flux from Galactic Centre

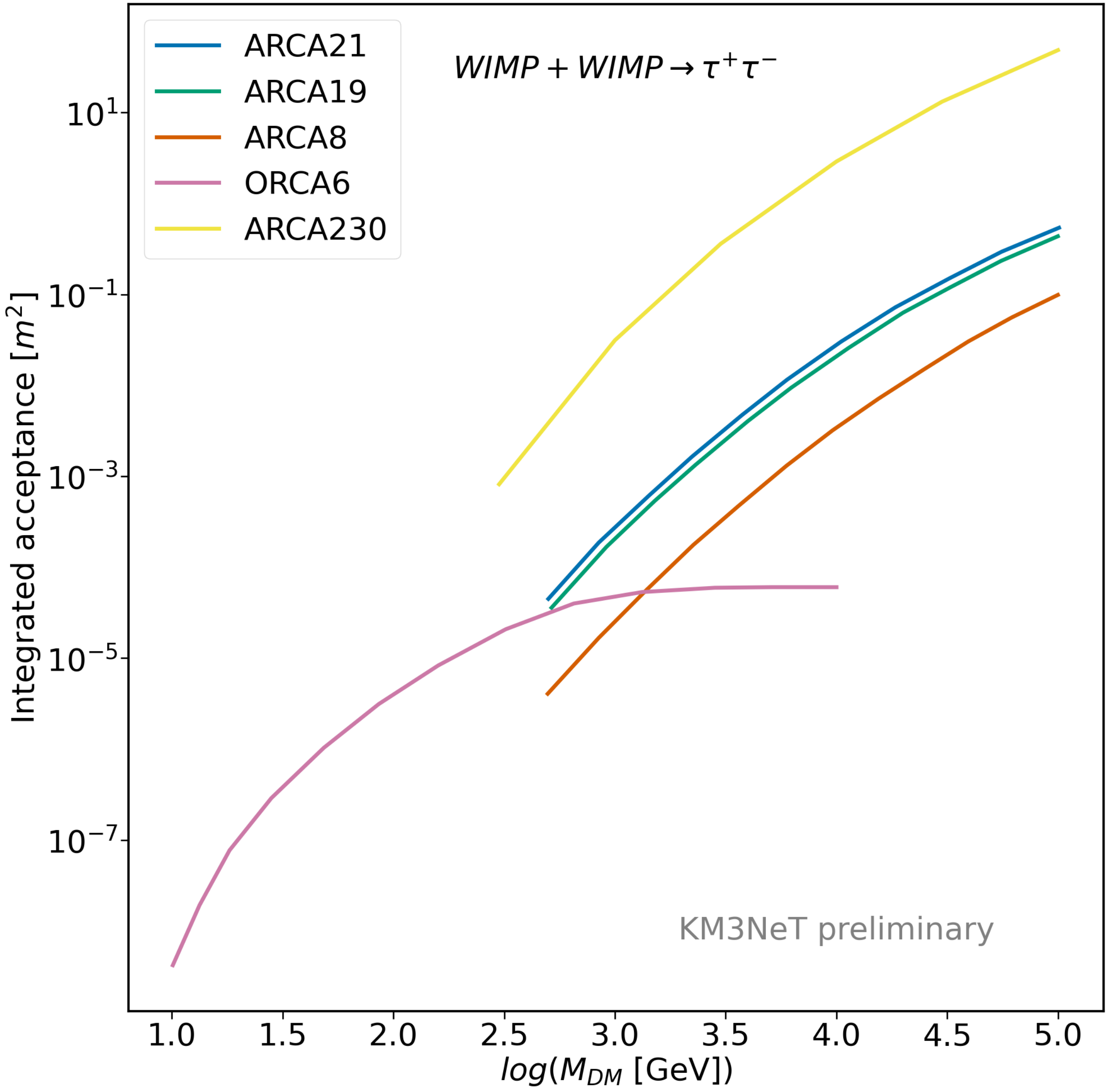
Analysis method: **detector response**

Acceptance of the dark matter neutrino signal given the detector response.

Detector response characterised by:

- Effective area
- Angular error
- Energy error

Which improve with a growing detector.



Analysis method: **Log likelihood approach**

- Binned and un-binned log likelihood method

- **Dark matter signal events** → as a function of the reconstructed energy and direction

- **Background expectation** → as a function of the reconstructed energy and direction
    - Uniform in right ascension
    - Declination dependent
    - Derived from MC data or scrambled data if possible

- **Log likelihood minimised**

- Creation pseudo-experiments varying the signal strength → signal strength **limit at 90% C.L.** obtained from the test-statistic distribution.

    - 90% C.L. translated into:
        - **Thermally averaged annihilation cross-section limit/sensitivity** (Galactic Centre searches)
        - **Spin dependent cross-section or neutrino flux limit/sensitivity** (Sun searches)

Results: **Galactic Centre**

Annihilation cross section sensitivity for the **full KM3NeT/ARCA detector (1yr)**

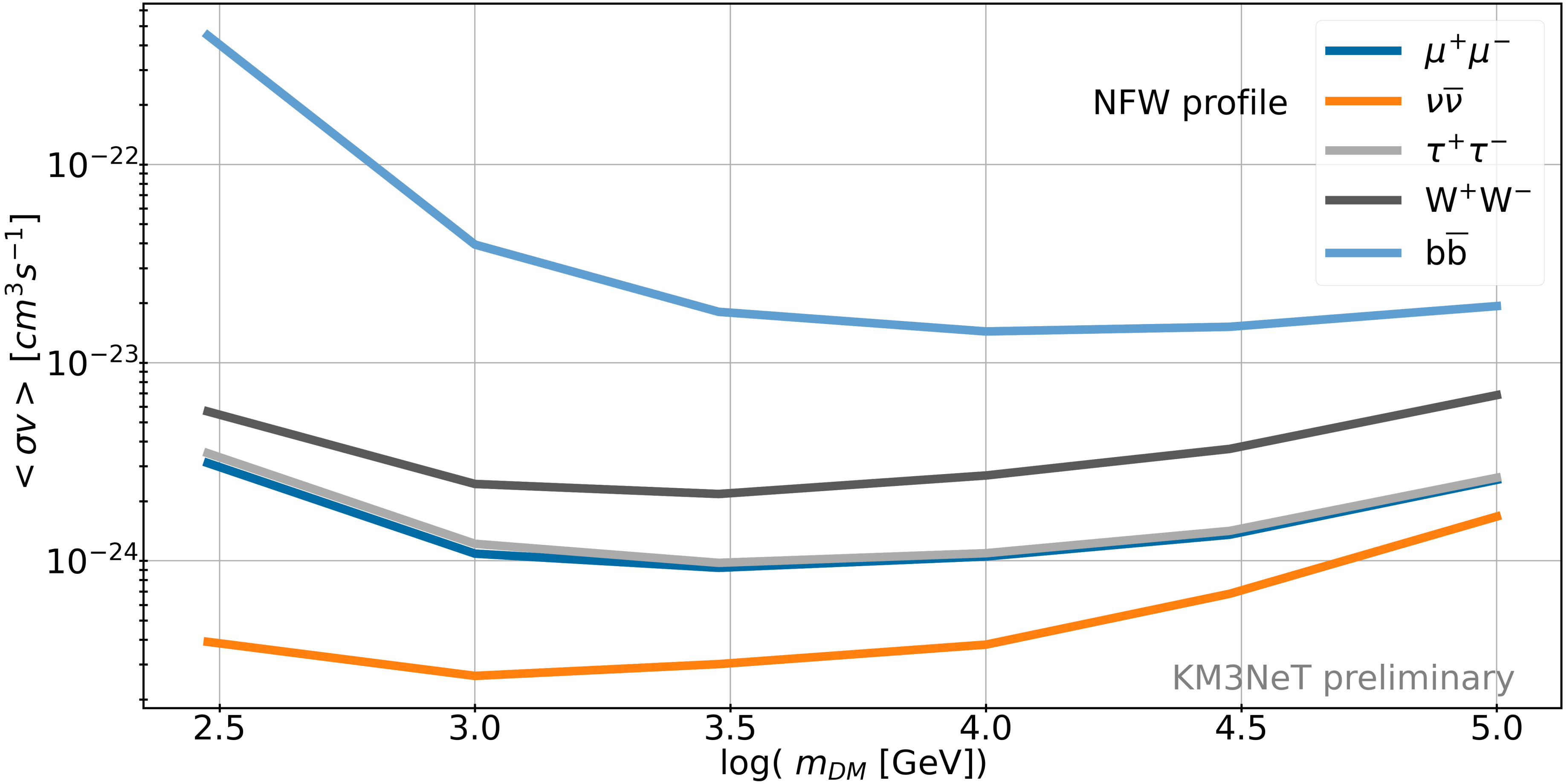
- Best sensitivities for the $\nu\bar{\nu}$ annihilation channel.

- Dependence on dark matter mass given by:

Larger neutrino flux for smaller m_{DM}.

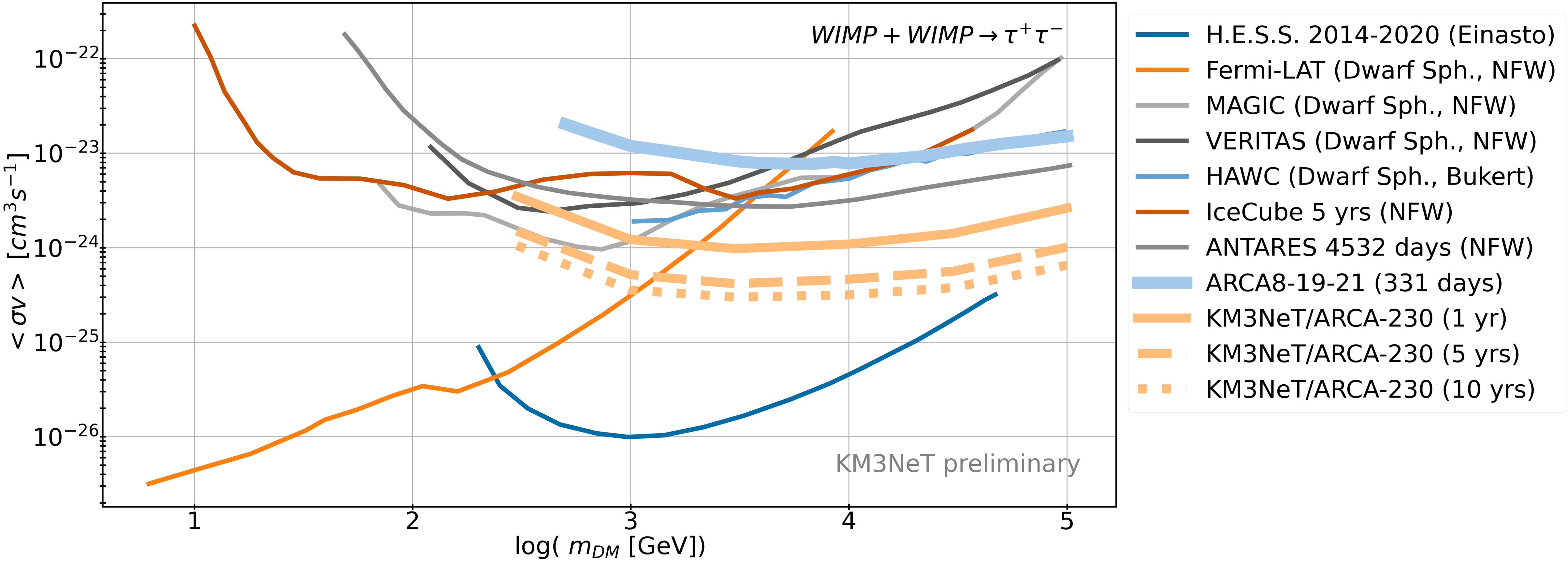
Better reconstruction of higher energy events.

Better signal-background discrimination at higher energies.



Results: **Galactic Centre**

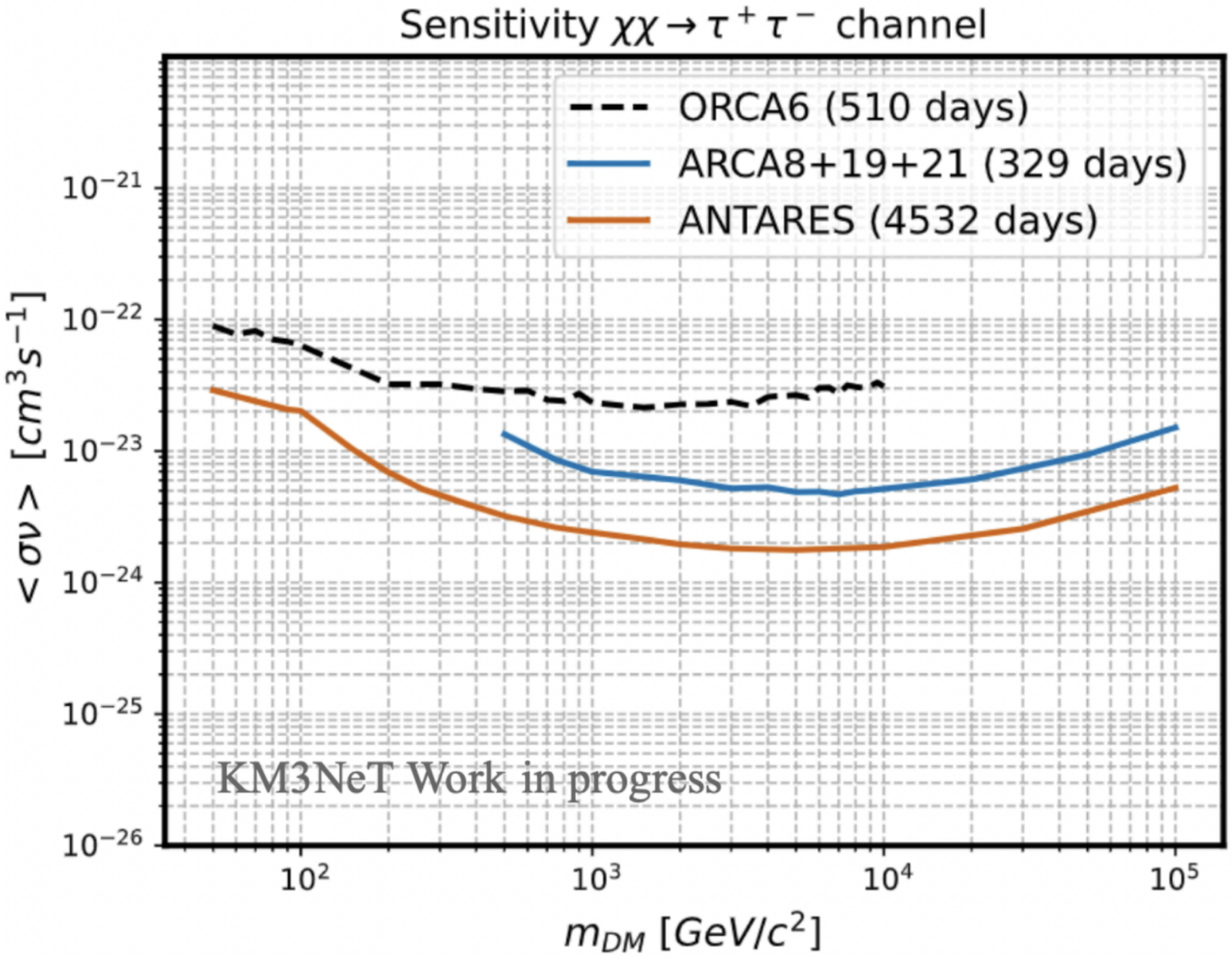
Annihilation cross section sensitivity/limits for the **full and partial KM3NeT/ARCA detector, $\tau^+\tau^-$ channel.**
Comparison to other experiments [3,4,5,6,7,8,9].



Results: **Galactic Centre**

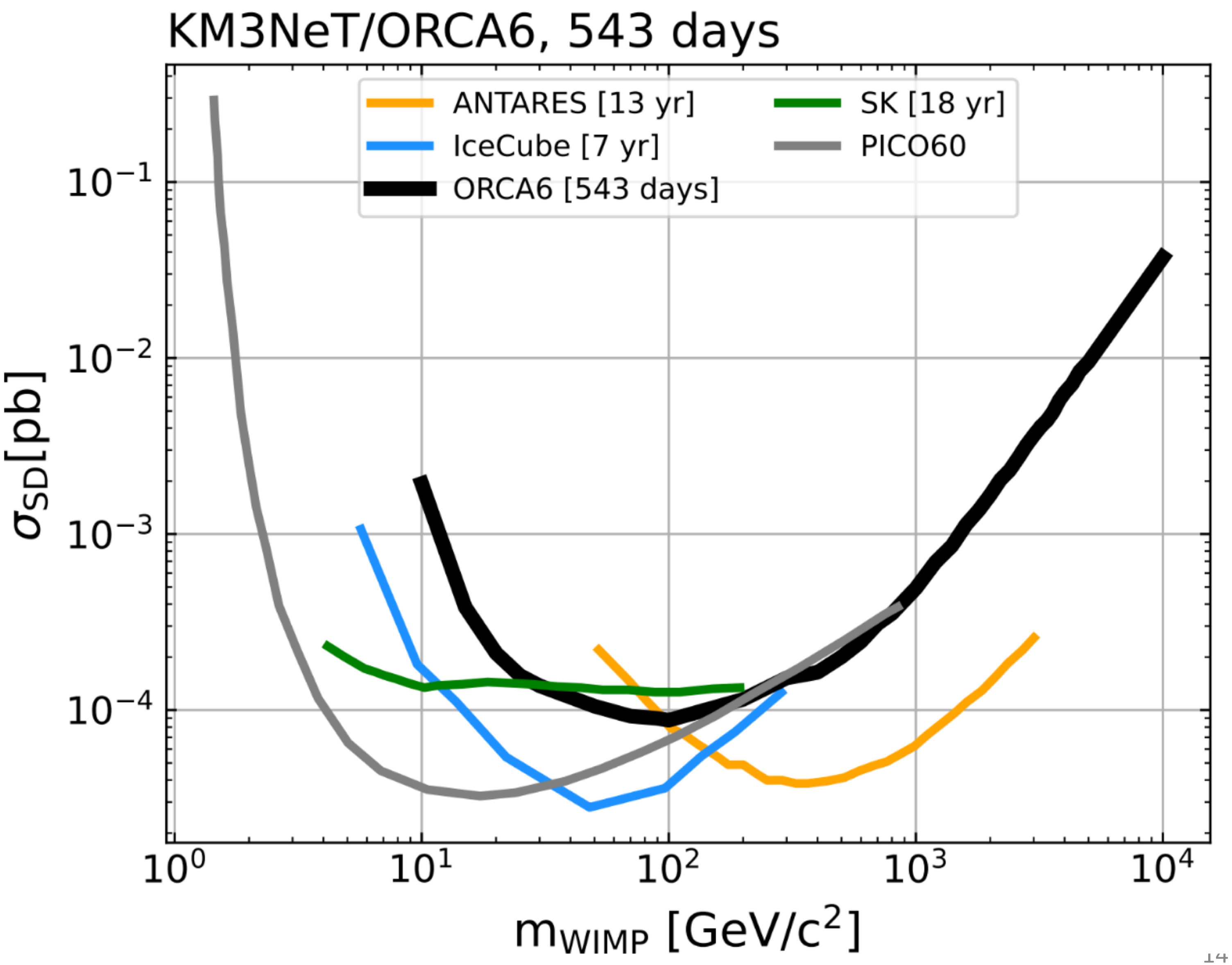
Annihilation cross section sensitivity for a **partial KM3NeT/ORCA detector**, $\tau^+\tau^-$ **channel**.

Comparison to KM3NeT/ARCA partial detector and ANTARES [9].



Spin dependent cross-section upper limit for dark matter in the Sun, with a partial KM3NeT/ORCA detector.

Compared to other experiments [11,12,13,14].



Conclusions

- First limits on WIMP dark matter properties with KM3NeT, in the Sun and Galactic Centre.

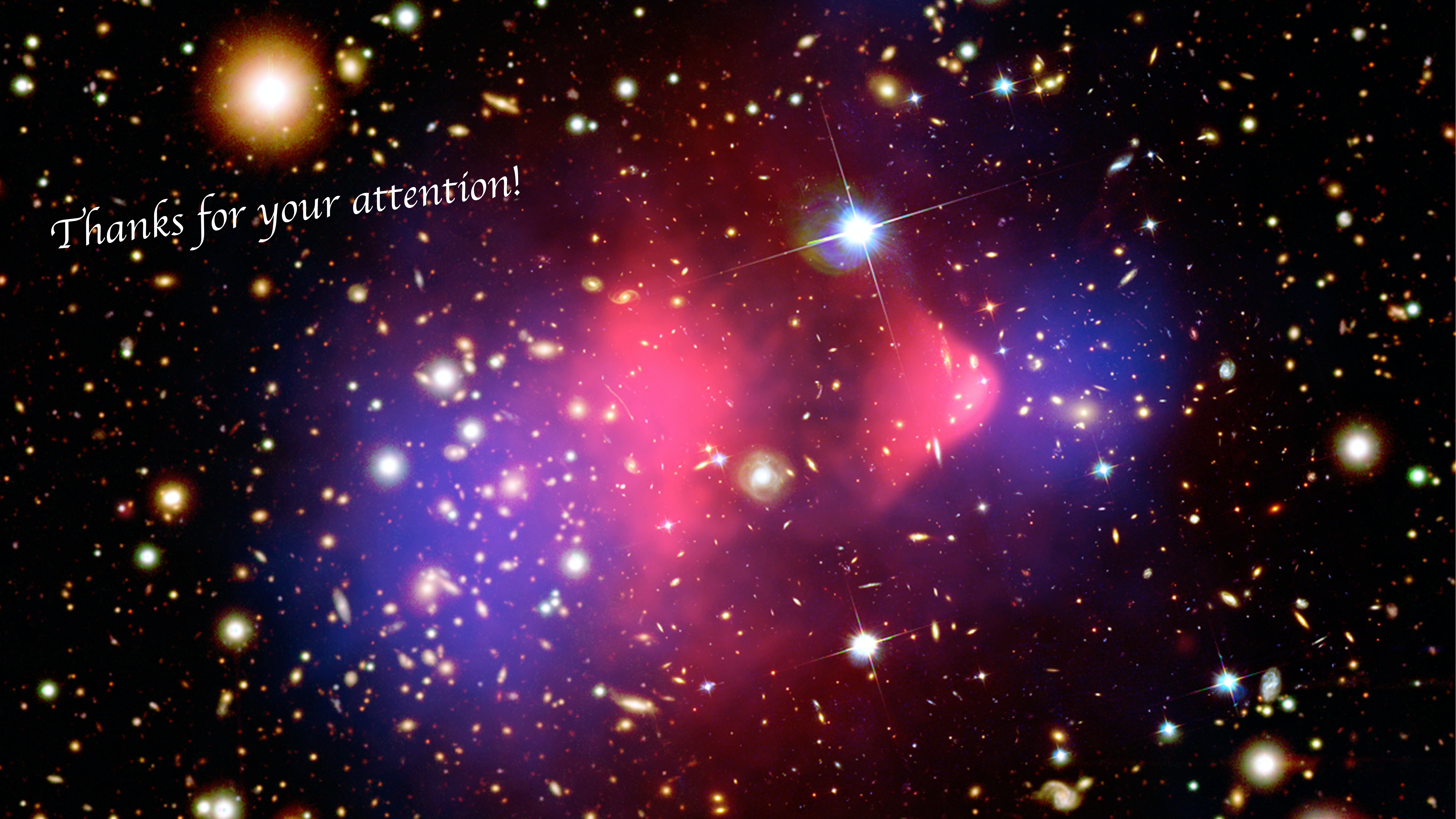
- Very wide range of the mass parameter space explored by KM3NeT/ORCA and KM3NeT/ARCA.

- Sensitivities improve further with growing detectors and livetime.

- KM3NeT quickly reaching ANTARES limits.

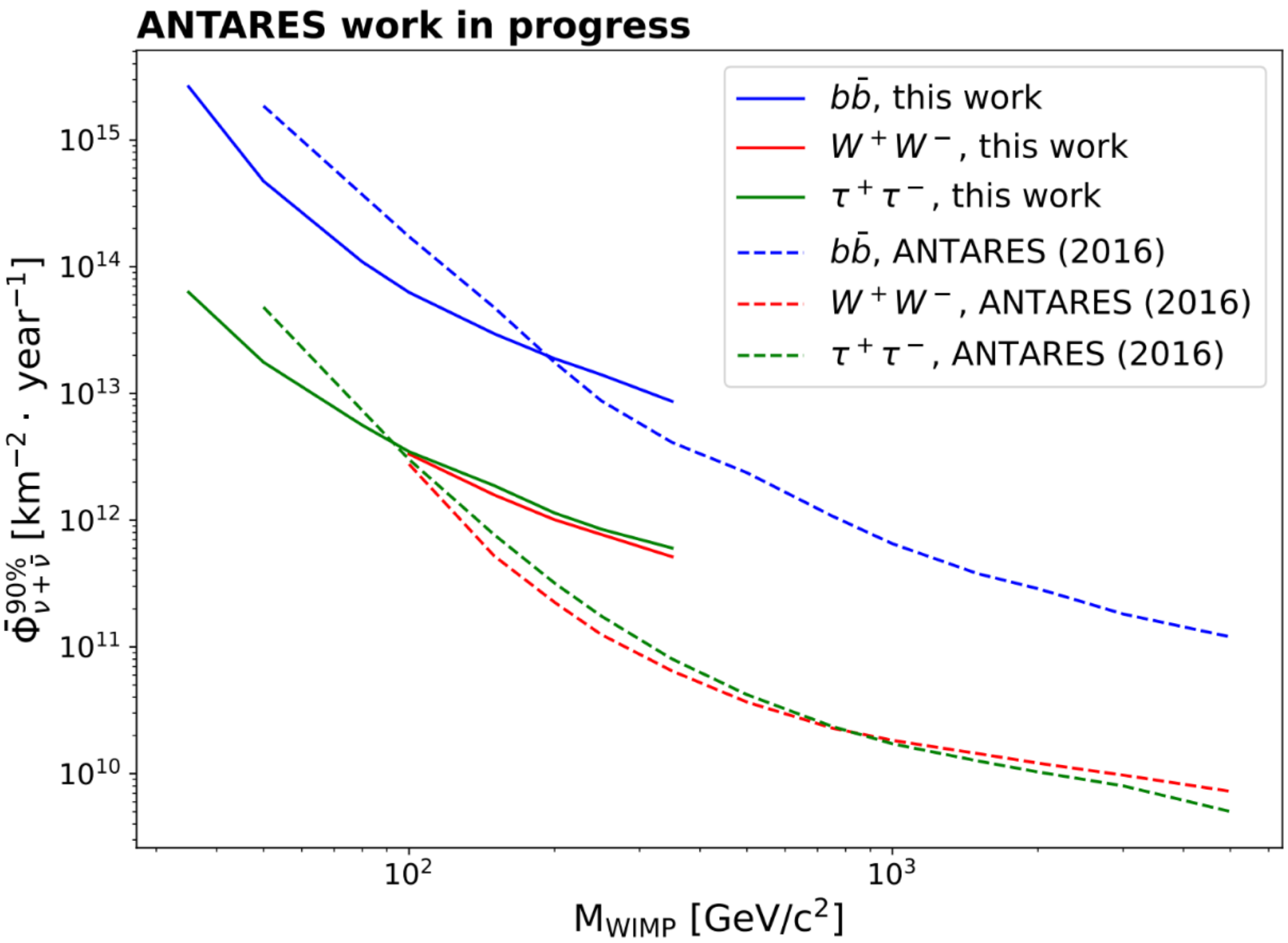
- Promising sensitivities from dark matter in the Galactic Centre with the full KM3NeT/ARCA detector.

- Ongoing efforts to improve the sensitivity at lower masses with novel reconstruction methods for single-line events.


Thanks for your attention!

Additional slides: Results for the **Sun from ANTARES**

Flux sensitivities for dark matter in the Sun with full ANTARES dataset, extending the mass range to lower masses with Neural Network single-line reconstruction. Previous ANTARES result [10].



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