

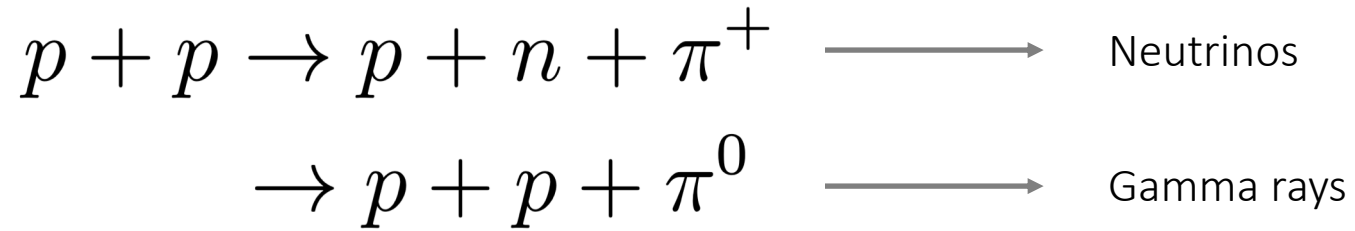
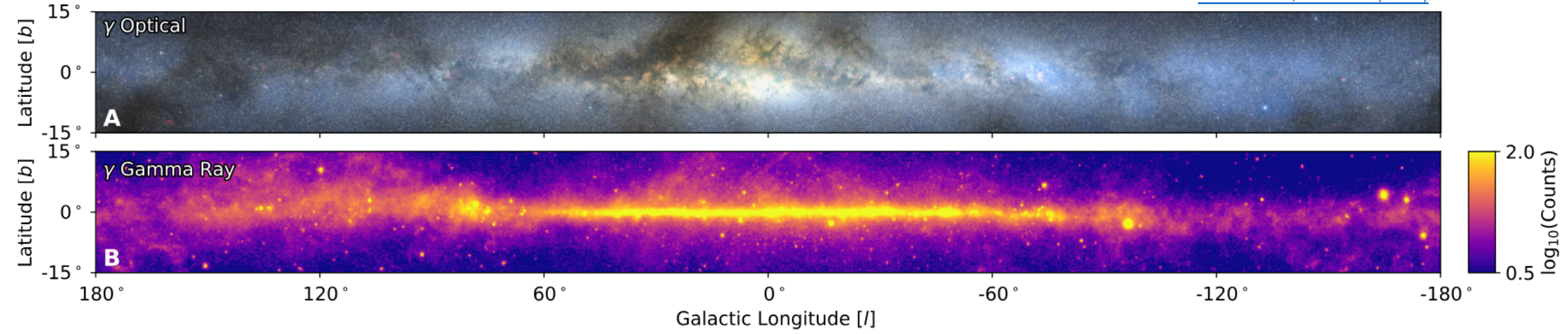
The neutrino sky with KM3NeT/ARCA



Clara Gatus Oliver & Thijs Juan van Eeden
Nikhef Jamboree - May 2024

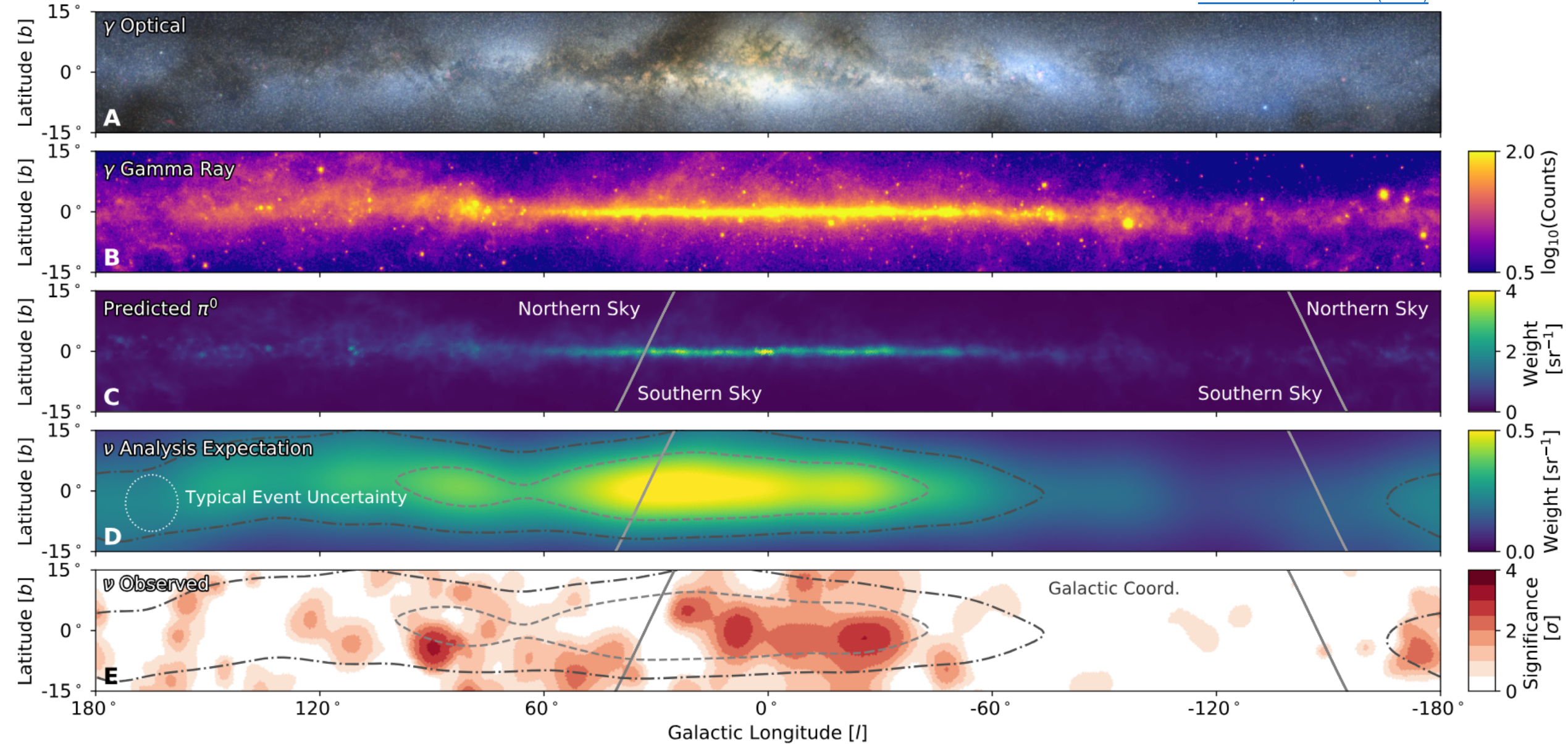
Neutrinos as cosmic messengers

[Science 380, no. 6652 \(2023\)](#)



Neutrinos as cosmic messengers

[Science 380, no. 6652 \(2023\)](#)



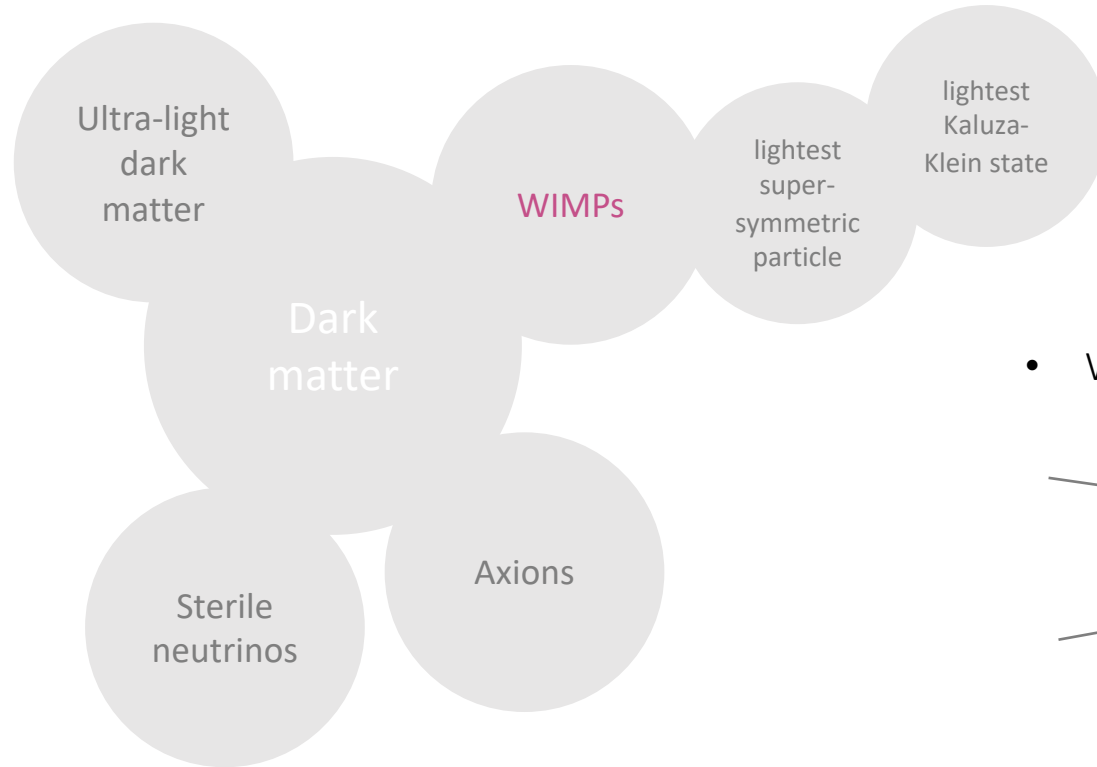
What else can neutrinos teach us?

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

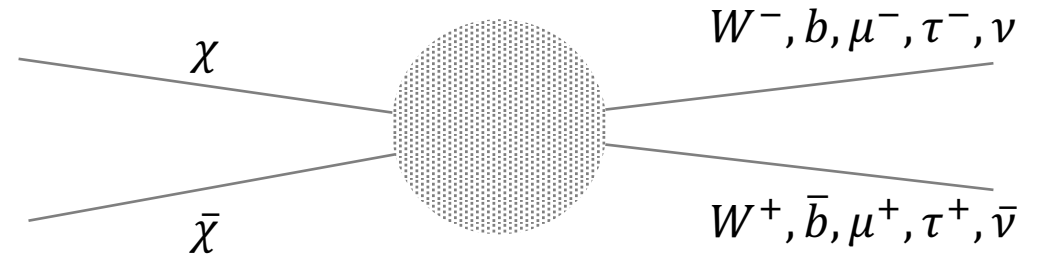


What else can neutrinos teach us?

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



- WIMP annihilations

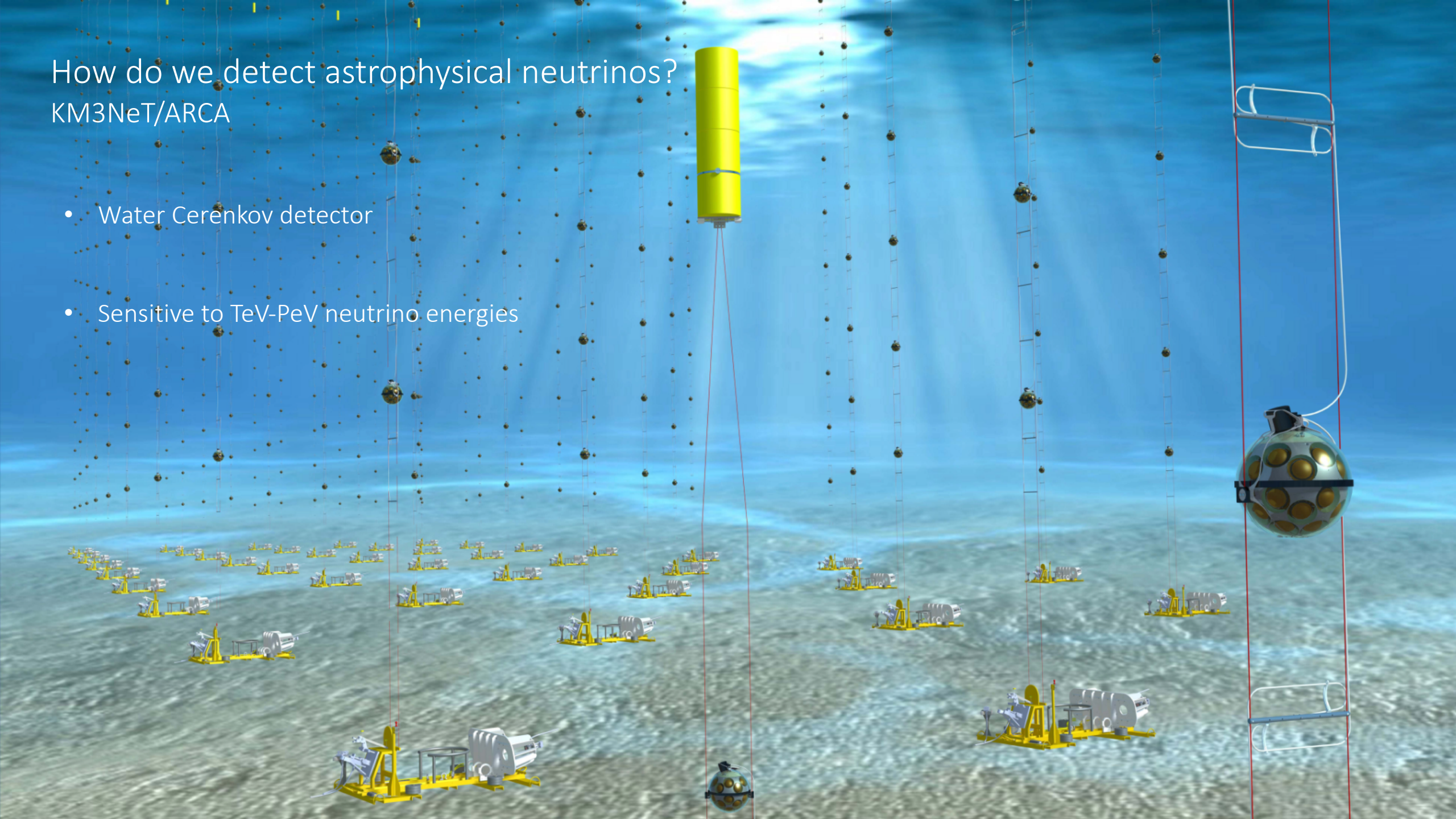


- Neutrino excess from regions with high dark matter density, as the Galactic centre

How do we detect astrophysical neutrinos?

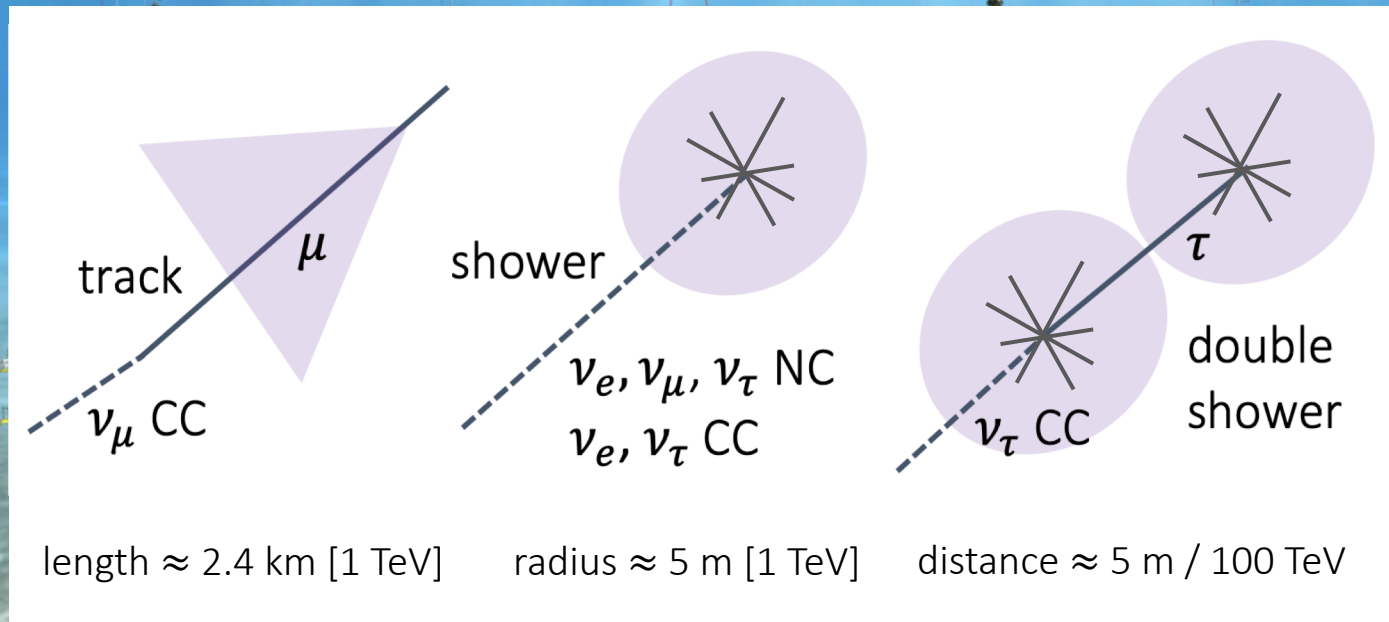
KM3NeT/ARCA

- Water Cerenkov detector
- Sensitive to TeV-PeV neutrino energies

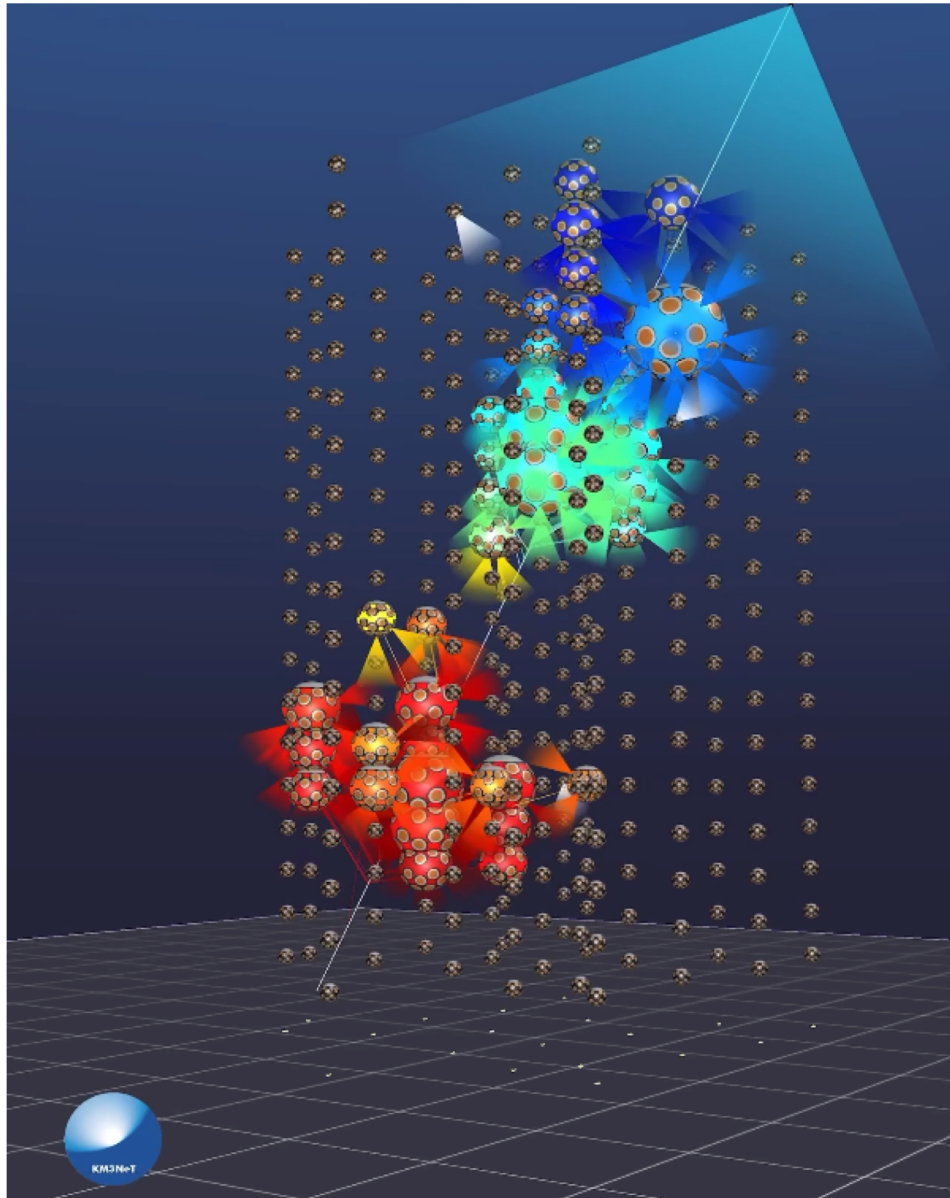


How do we detect astrophysical neutrinos? KM3NeT/ARCA

- Different type of neutrino interactions \rightarrow different event topologies



How does the KM3NeT/ARCA data look like?



Total event rate of ARCA with 21 detection strings (ARCA21):

$\sim 10^6$ events per day

(~ 40 neutrinos per day)

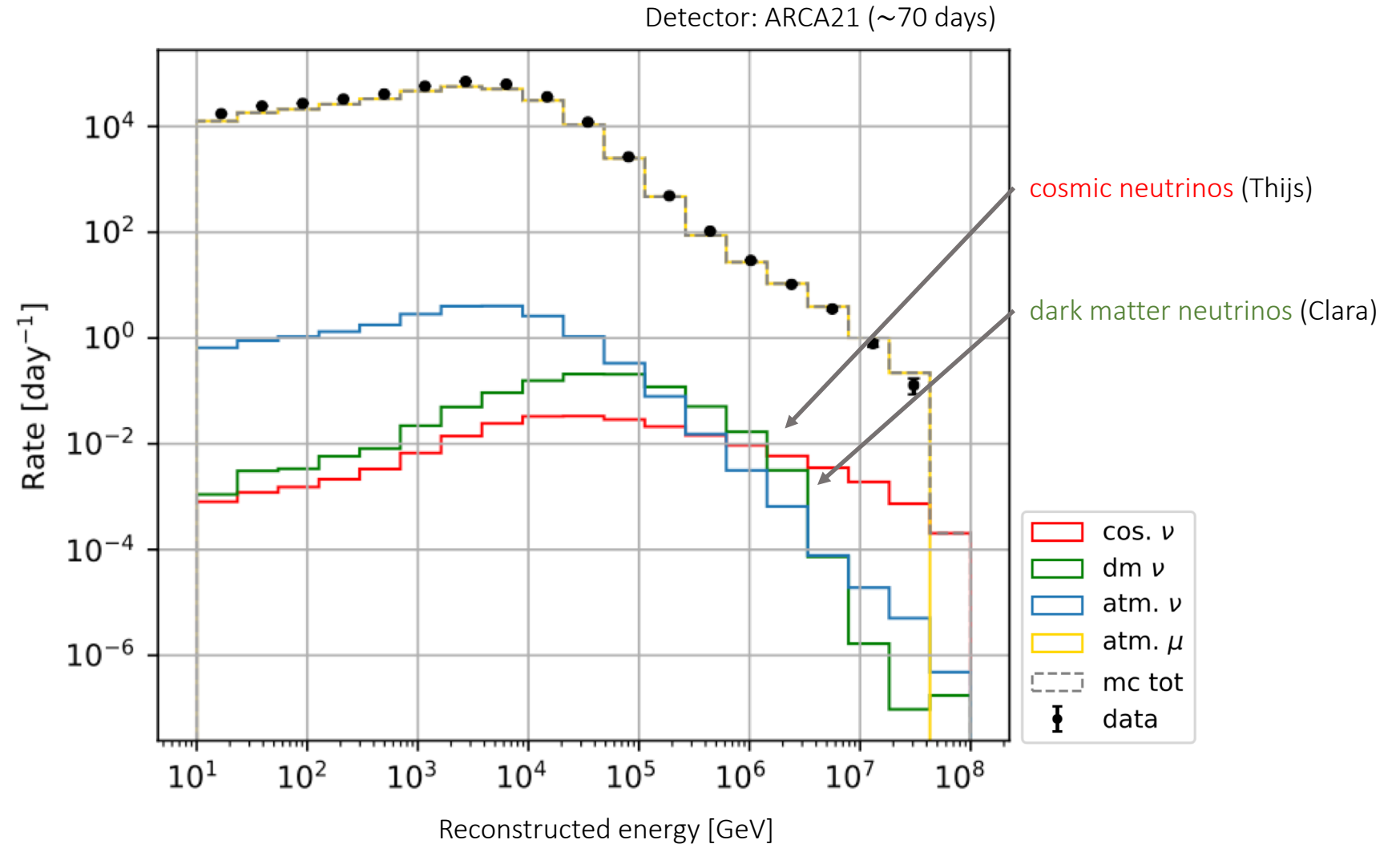
Data selection

How can we differentiate neutrinos created by cosmic sources or dark matter from other type of events?

DATA-MC agreement thanks to:

- Improvements in calibration, reconstruction and simulations

(all with strong Nikhef contributions)

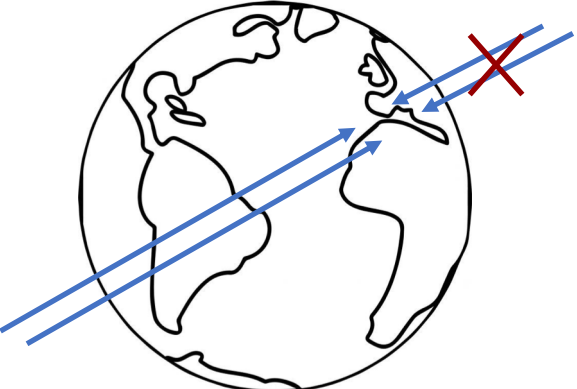


Data selection

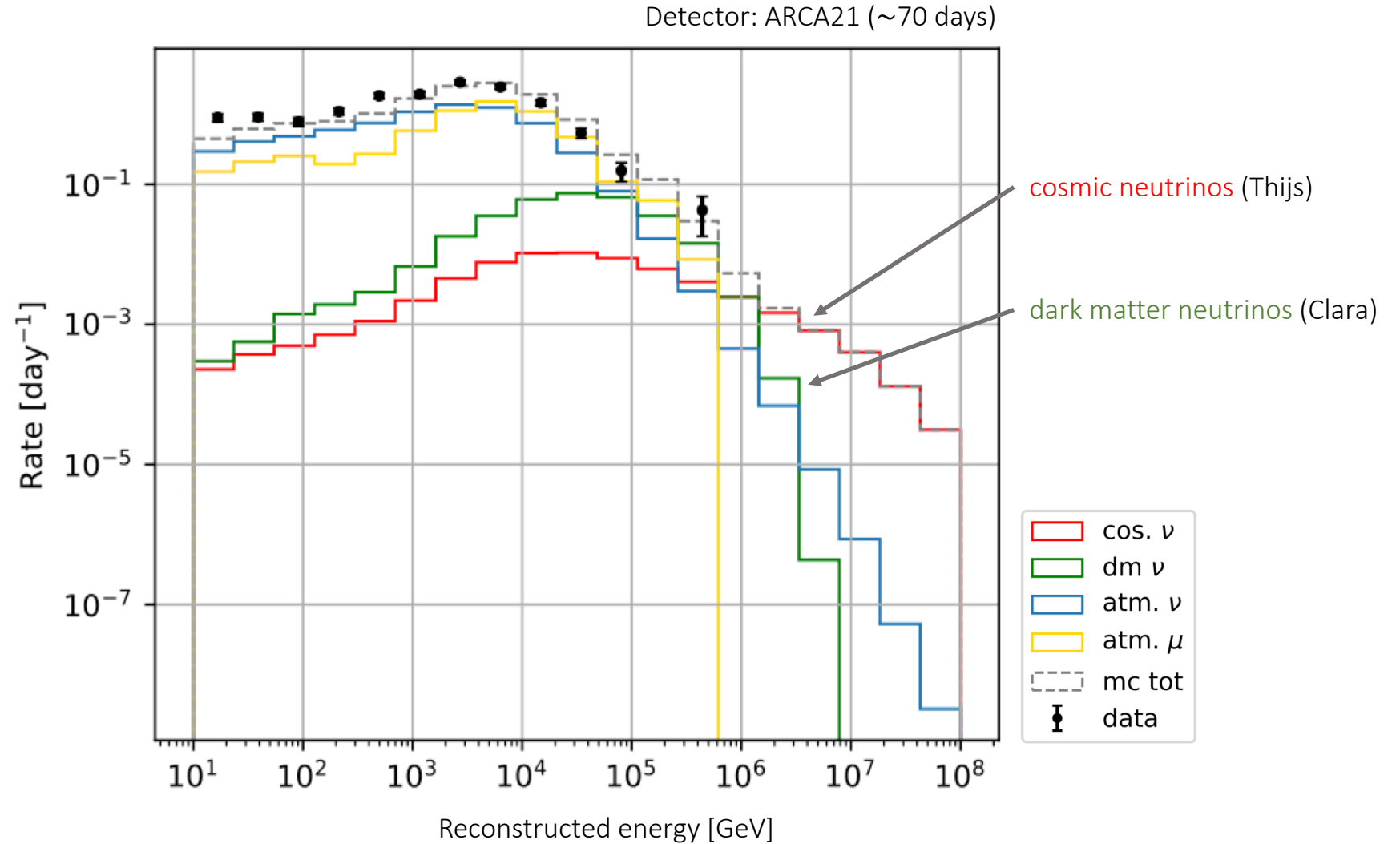
How can we differentiate neutrinos created by cosmic sources or dark matter from other type of events?

Selection:

- We cut all events coming from above the horizon



- We apply quality cuts + Boosted Decision Tree



Modelling the source

How do neutrinos created by cosmic sources or dark matter look like?

Cosmic neutrino point sources

- Neutrino flux

- Power law flux:

$\text{---} E^{-2} \text{astro. flux}$

- Directional information

- From each point source

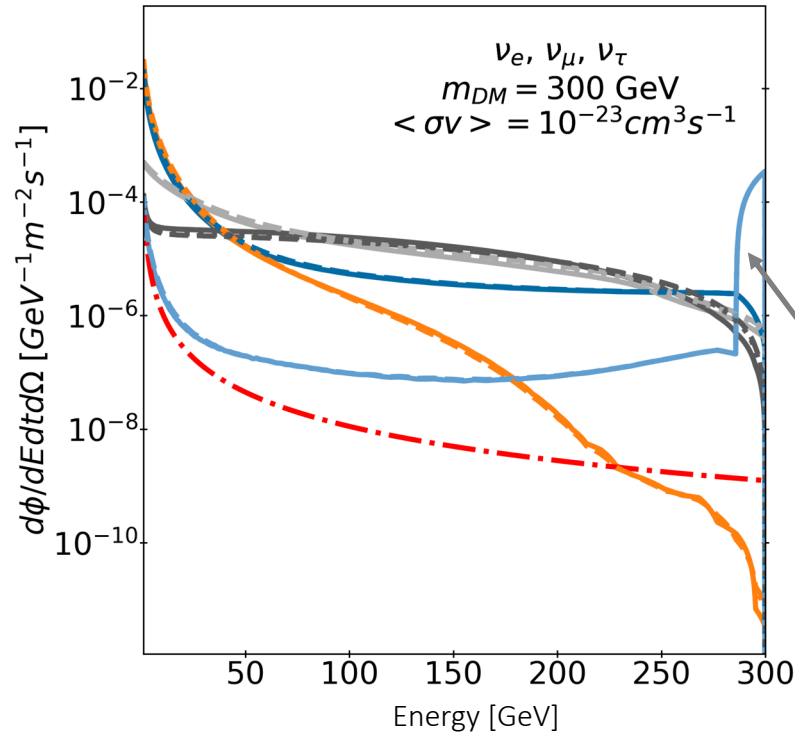
Dark matter in our galaxy

- Different flux for each annihilation channel:

$\text{---} W^+W^- \quad \text{---} b\bar{b} \quad \text{---} \tau^+\tau^- \quad \text{---} \mu^+\mu^- \quad \text{---} \nu\bar{\nu}$

Most interesting signature!

- Dark matter distribution around Galactic Centre



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

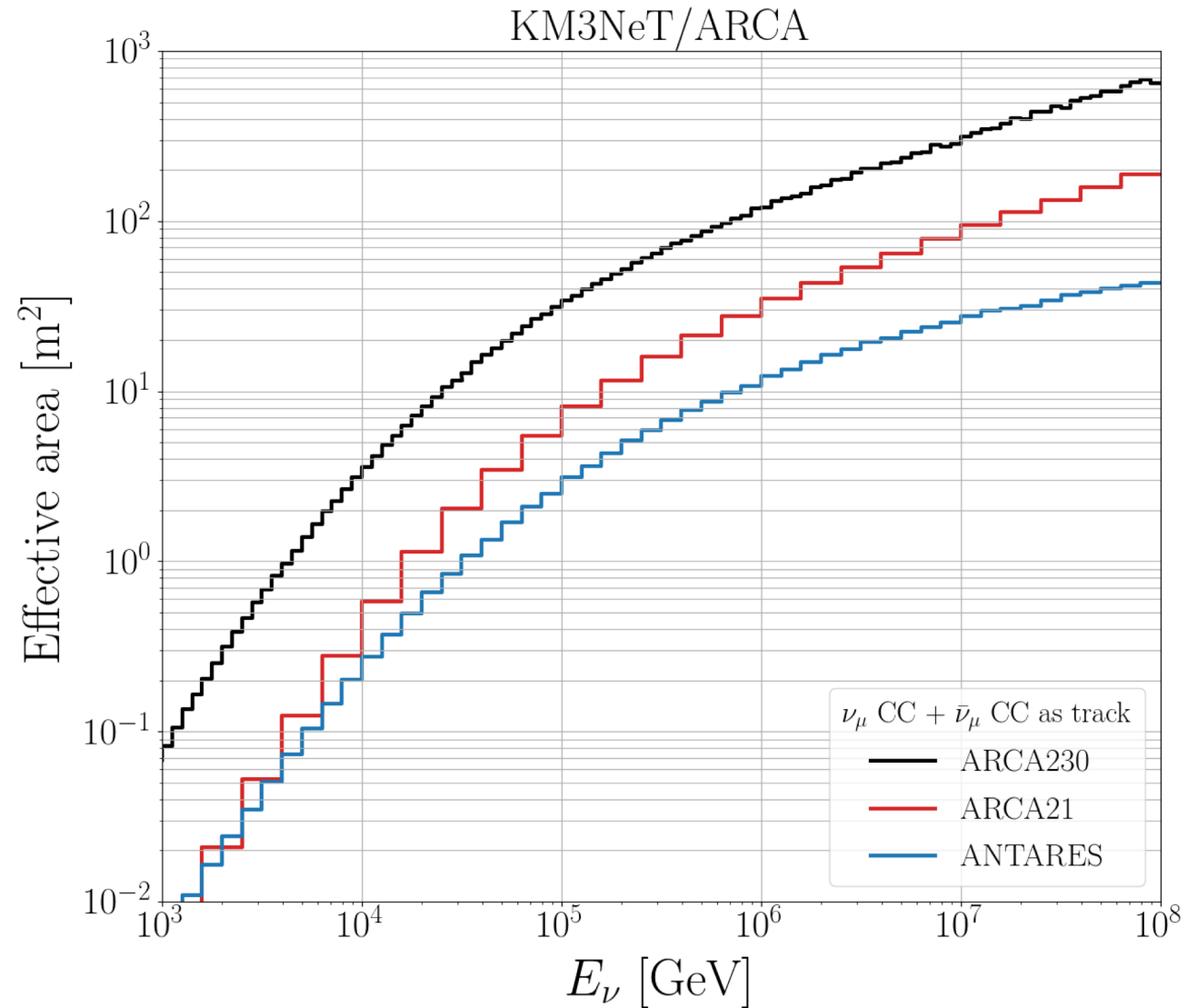
Detector response

KM3NeT/ARCA: a growing detector

Growing detector leads to:

- Higher effective area
→ More neutrinos / day

$$N_{events} = \phi \cdot A \cdot t$$

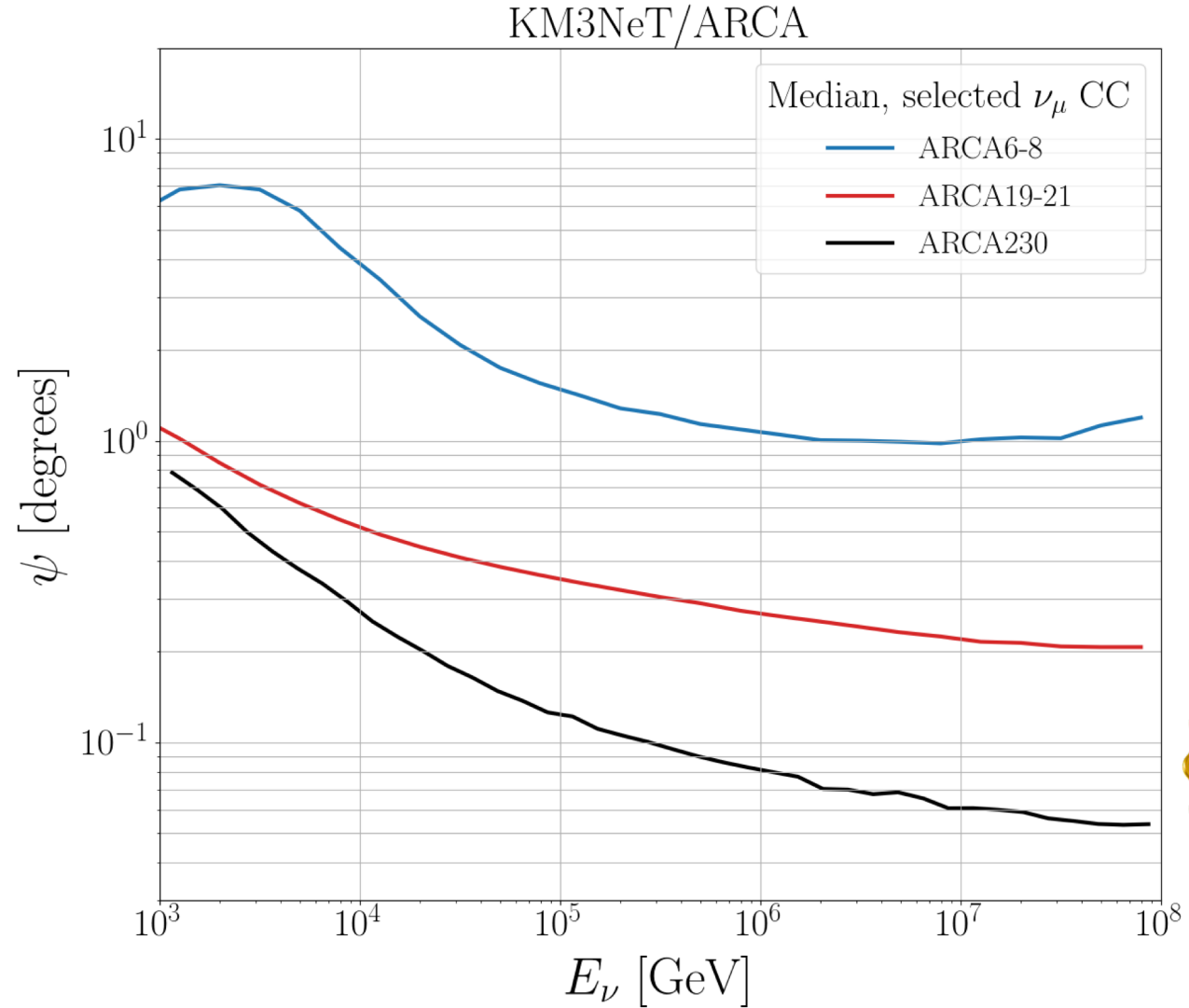
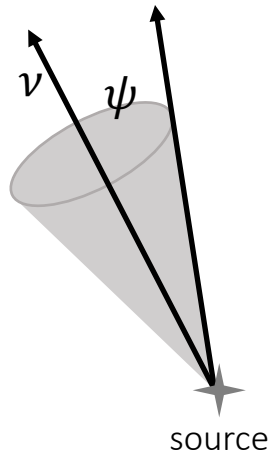


Detector response

KM3NeT/ARCA: a growing detector

Growing detector leads to:

- Higher effective area
- Better angular resolution

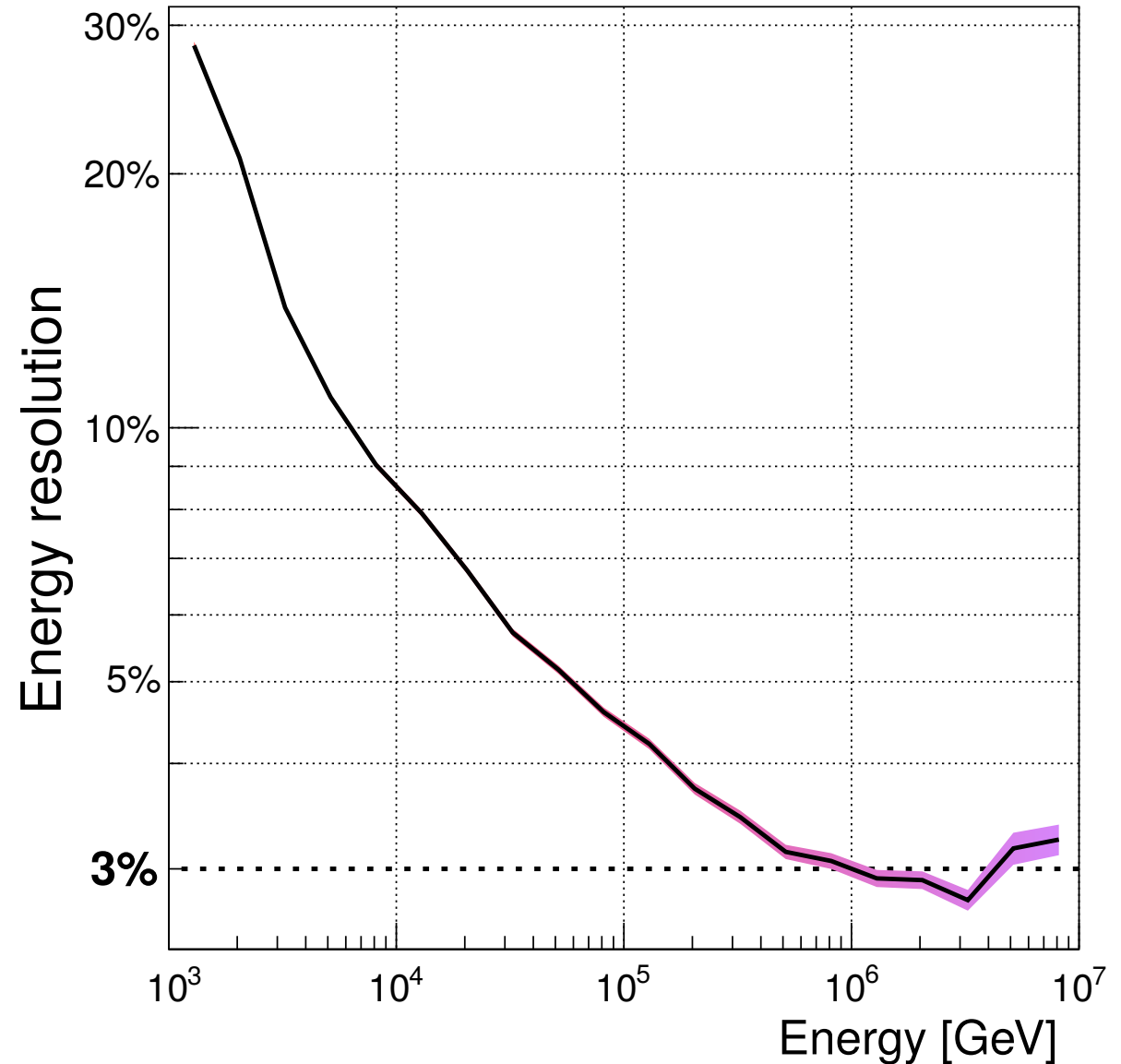


Detector response

KM3NeT/ARCA: a growing detector

Growing detector leads to:

- Higher effective area
- Better angular resolution
- Including showers
→ Better energy resolution



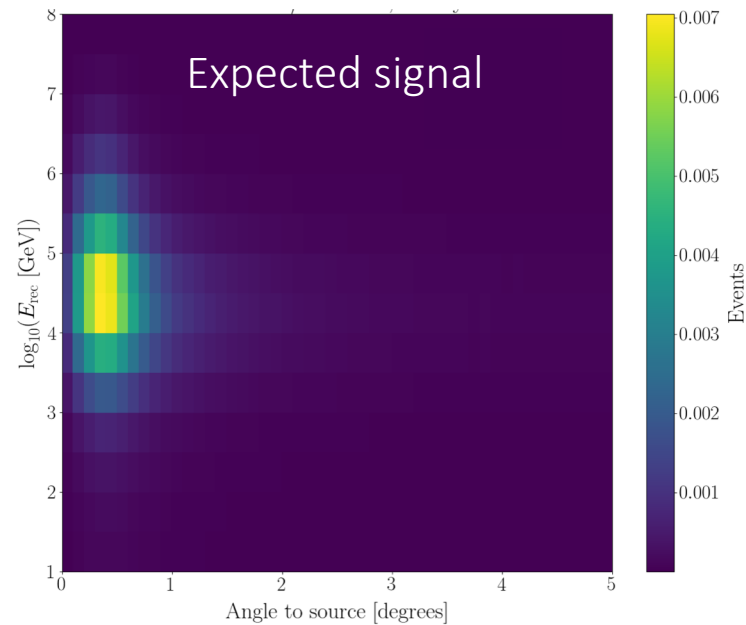
Method

How do we find them?

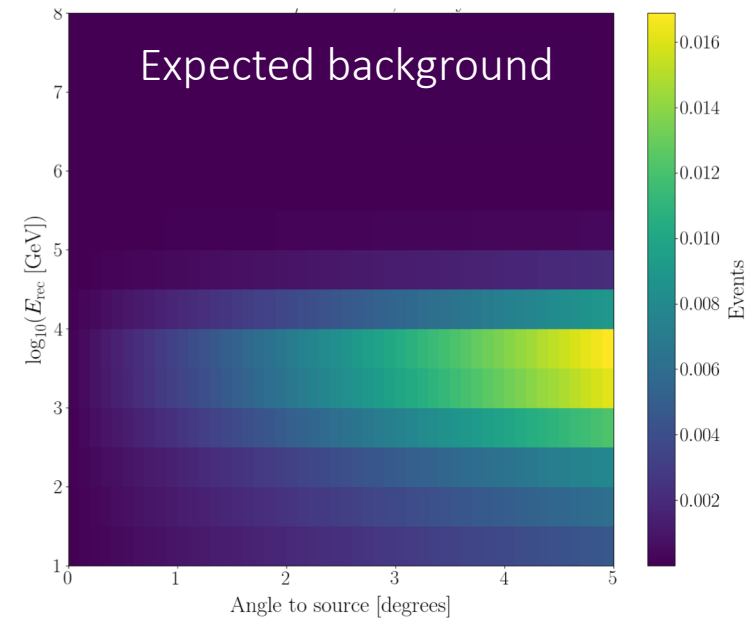
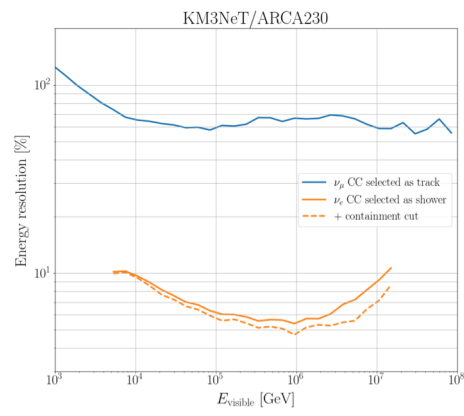
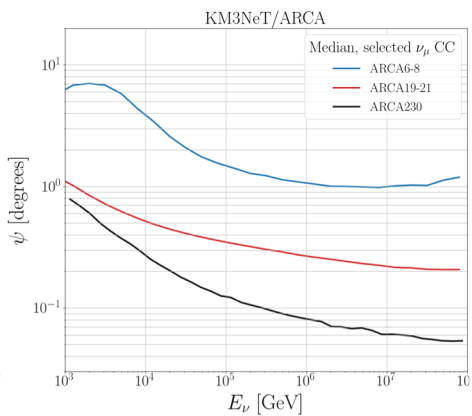
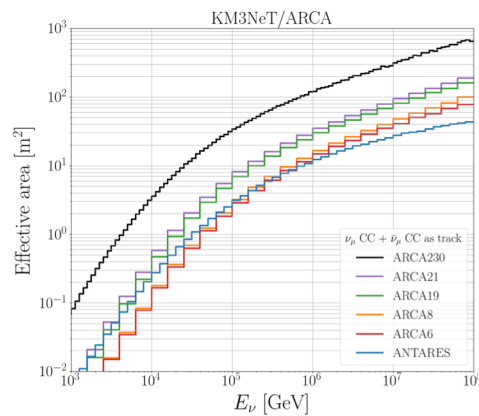


Source model

Example for a cosmic neutrino point source



Detector response

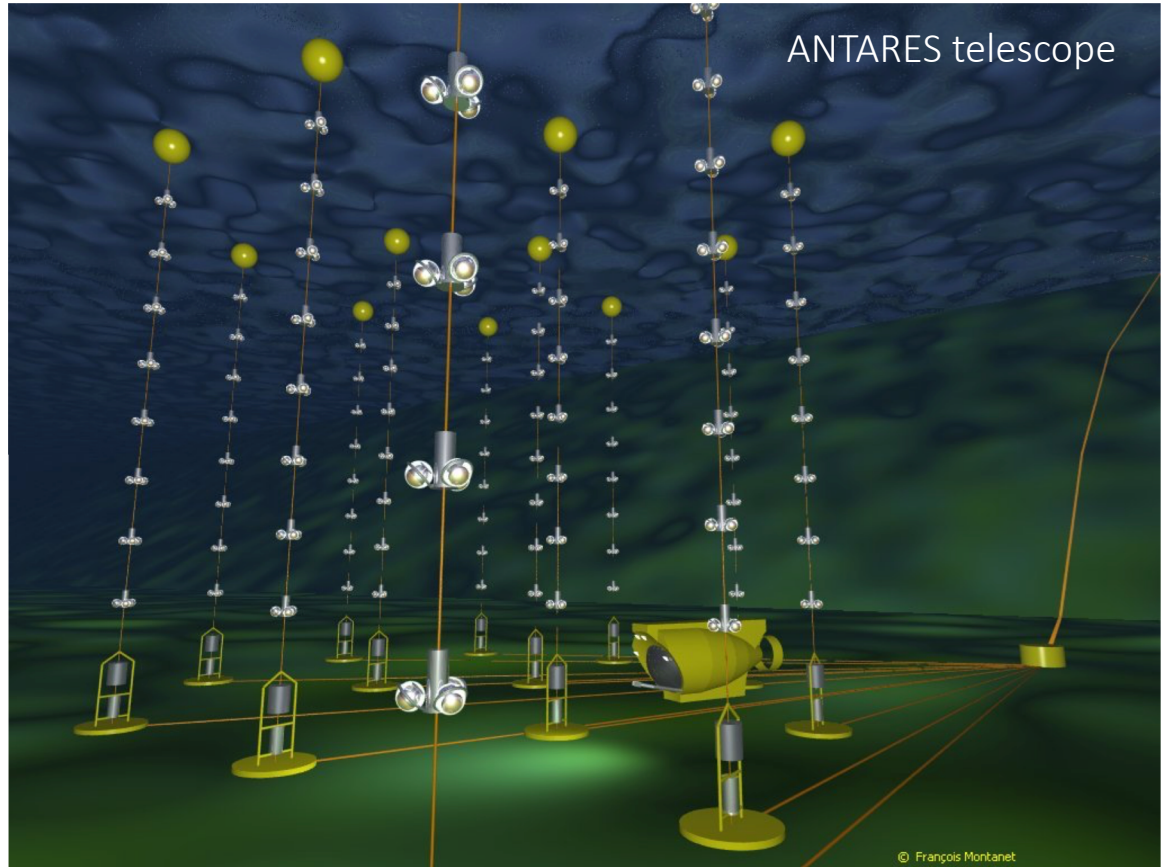
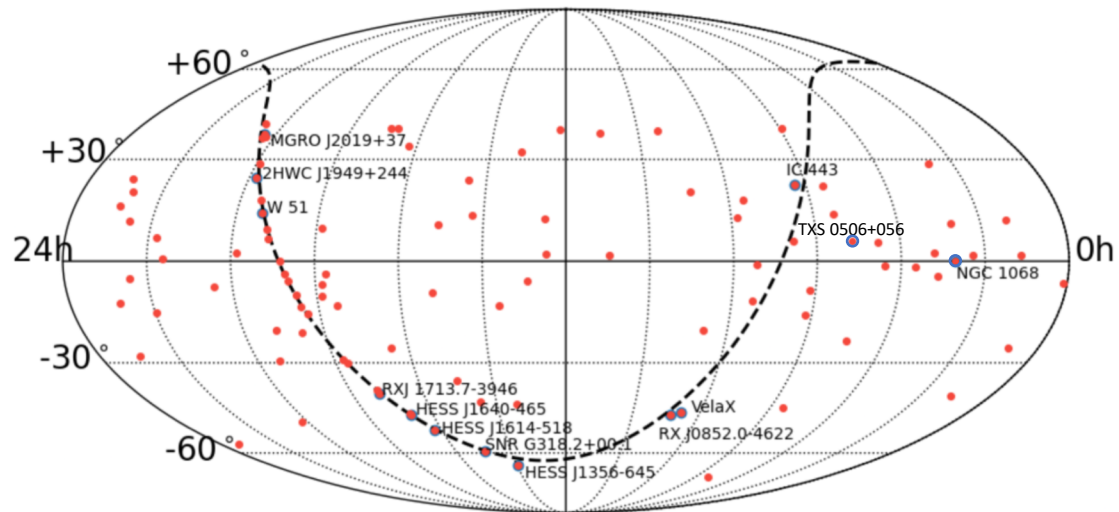


Results

For cosmic neutrino point source candidates

101 candidate sources

- Interesting objects from other ν telescopes

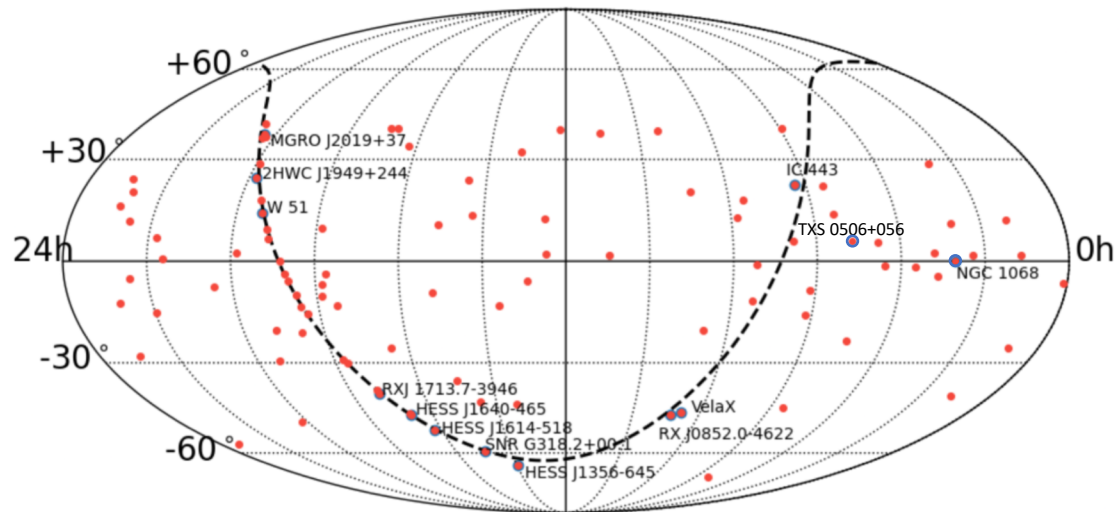


Results

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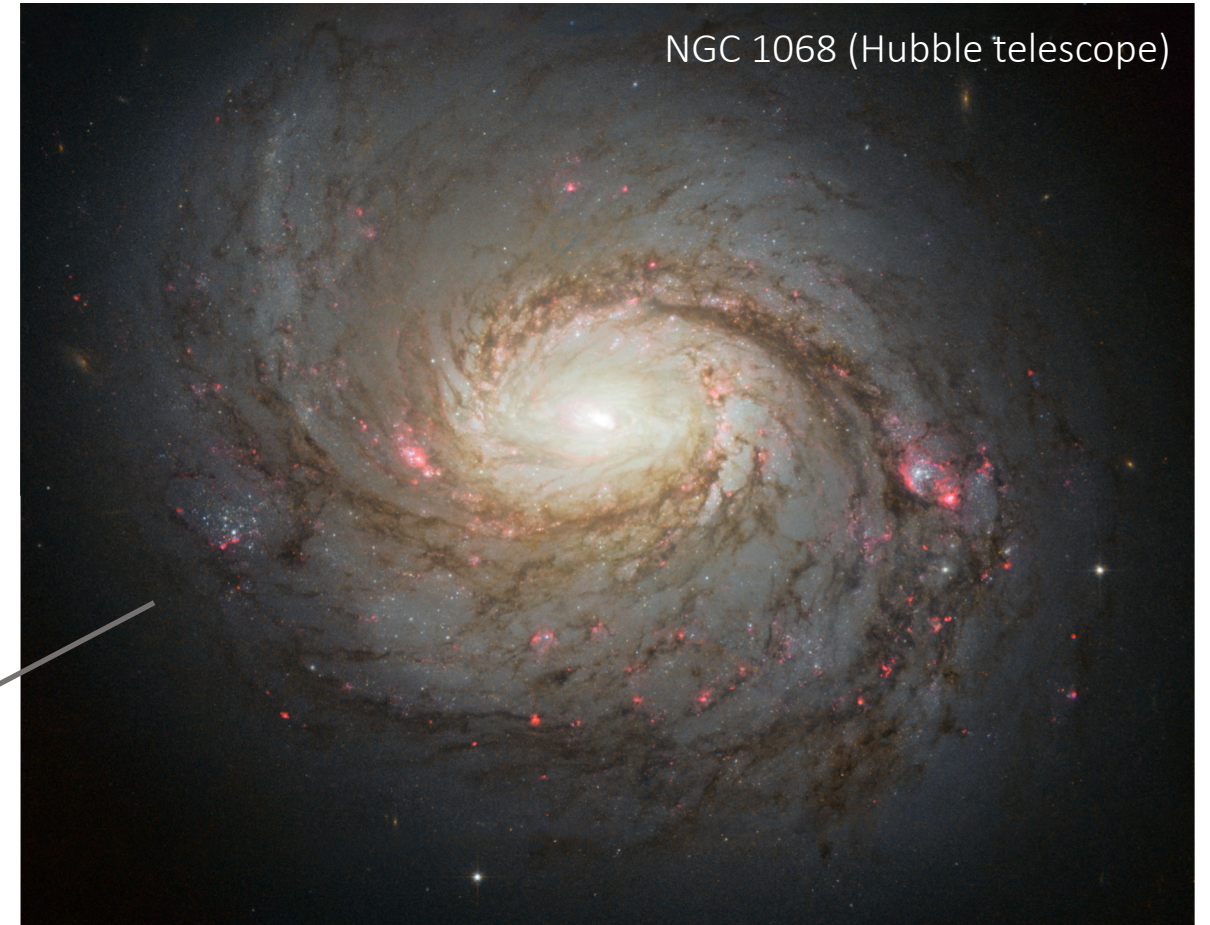
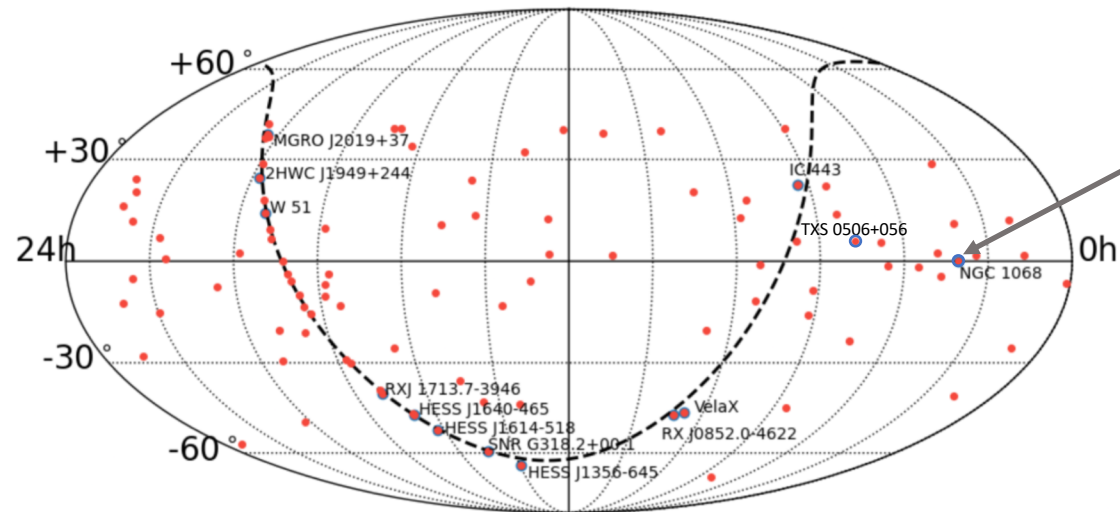


Results

For cosmic neutrino point source candidates

101 candidate sources

- Interesting objects from other ν telescopes
- Active galactic nuclei



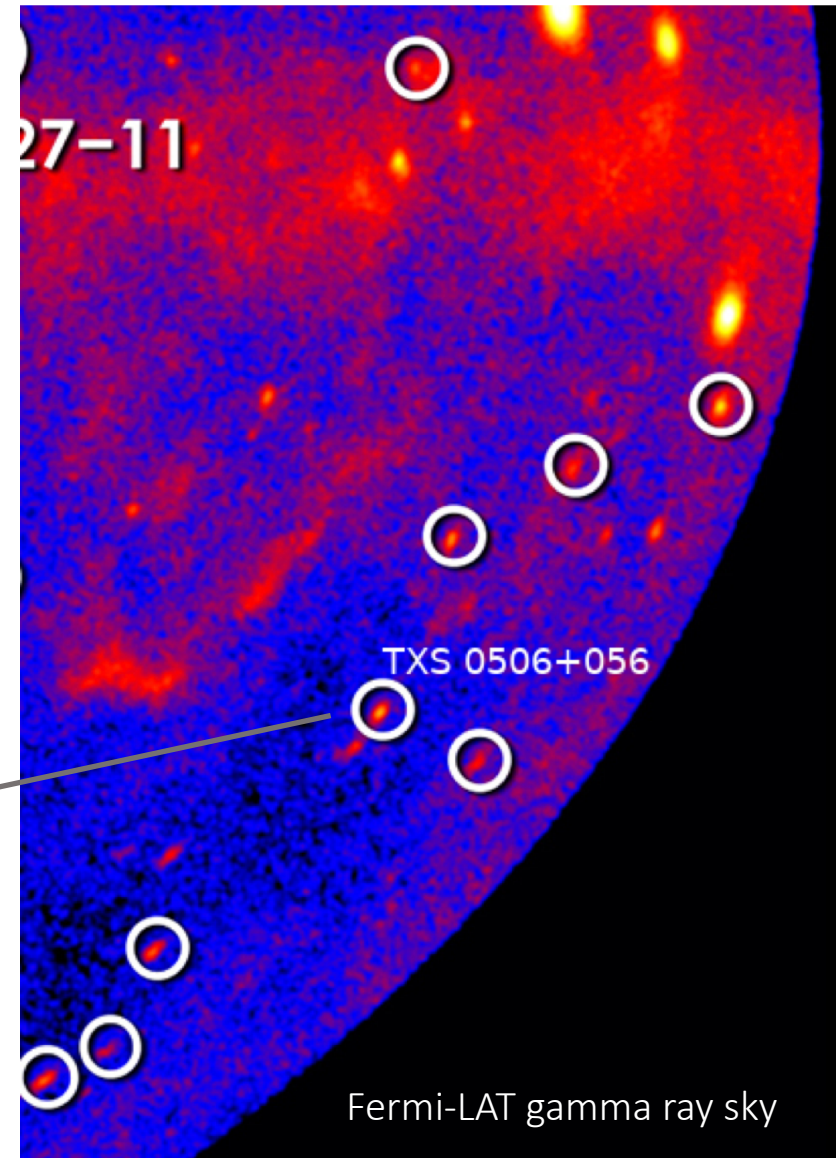
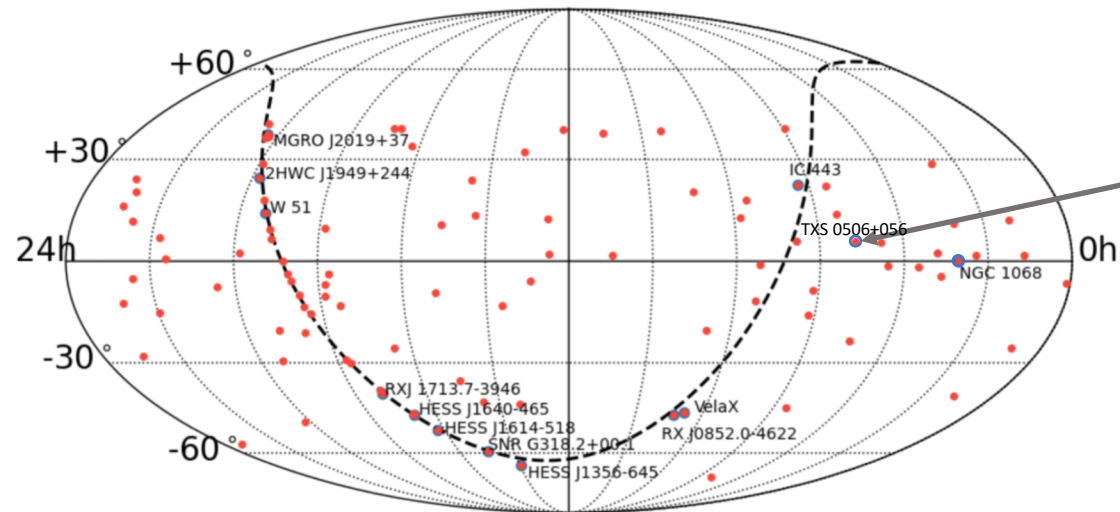
<https://esahubble.org/images/heic1305a/>

Results

For cosmic neutrino point source candidates

101 candidate sources

- Interesting objects from other ν telescopes
- Active galactic nuclei
- High-energy γ -ray sources



<https://svs.gsfc.nasa.gov/11342>

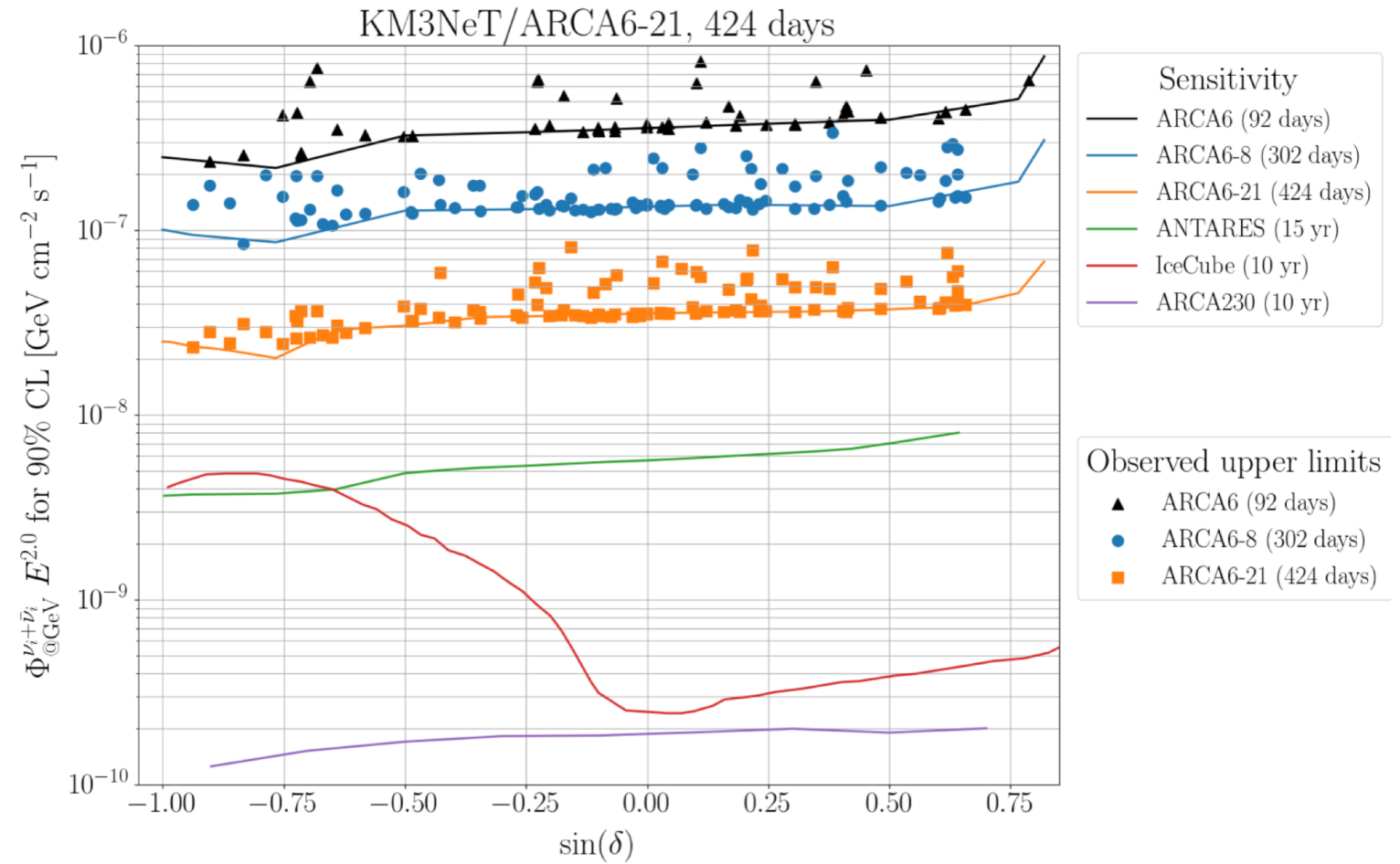
Results

For cosmic neutrino point source candidates

No significant detection made
→ Set limits on the flux

Growing detector and dataset
→ Sensitivity improves

Read more at [PoS\(ICRC2023\)1018](#)
and paper in preparation



Results

For dark matter searches from our galaxy

- Test different M_{dm} and annihilation channels
- Limit or sensitivity on the dark matter annihilation cross-section

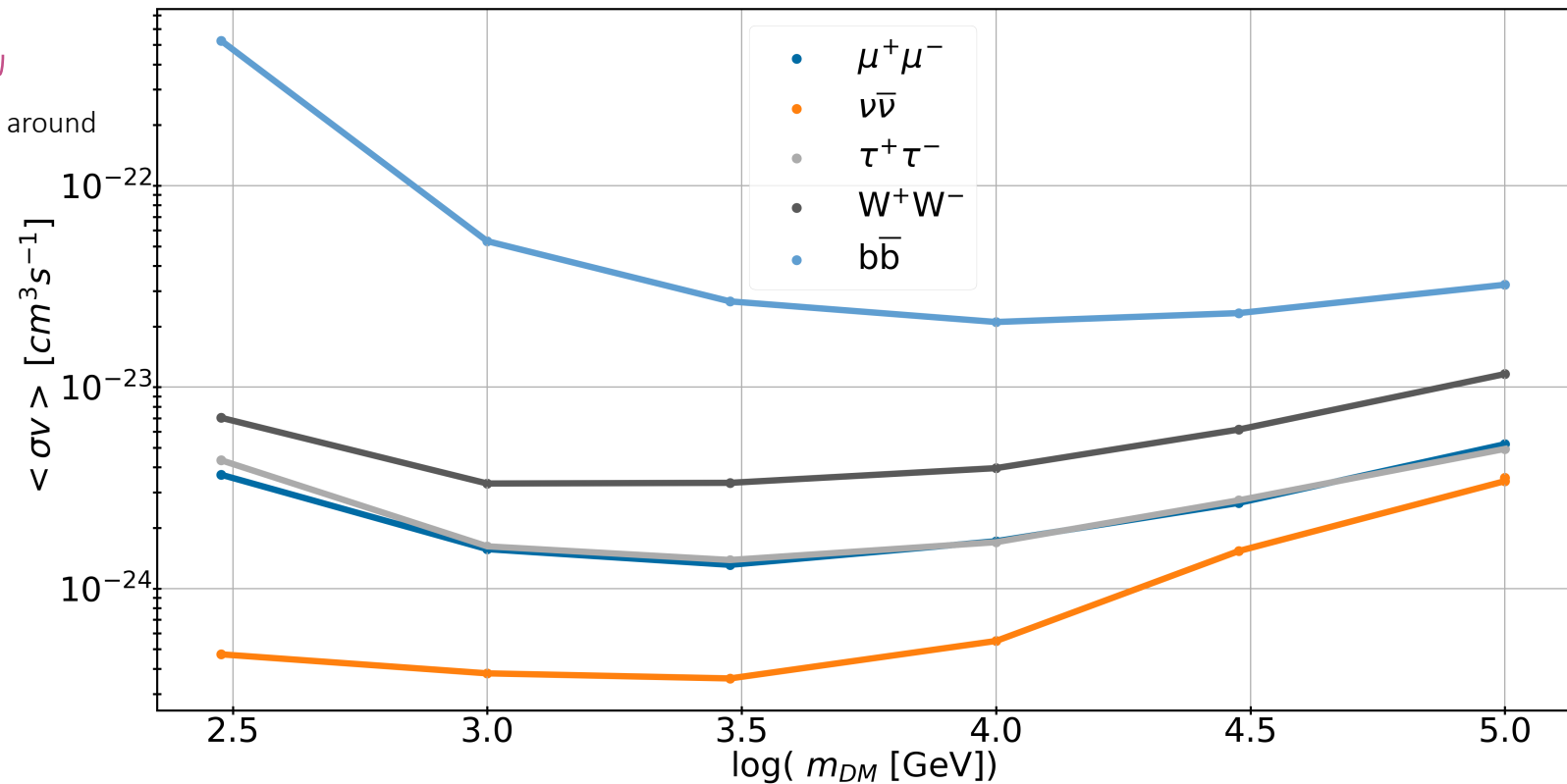
$$\frac{d\Phi_\alpha^c}{dE dt} = \frac{1}{4\pi} \underbrace{\langle \sigma v \rangle}_{\text{Annihilation cross-section and dark matter mass}} \underbrace{\frac{dN_\alpha^c}{dE}}_{\text{Spectra}} \underbrace{\int_{\Delta\Omega} \int_{l.o.s.} \rho^2(\theta, l) dl d\Omega}_{\text{Dark matter distribution around Galactic Centre}}$$

Annihilation cross-section and dark matter mass

Spectra

Dark matter distribution around Galactic Centre

Sensitivities full ARCA detector 1yr (MC data)



Results

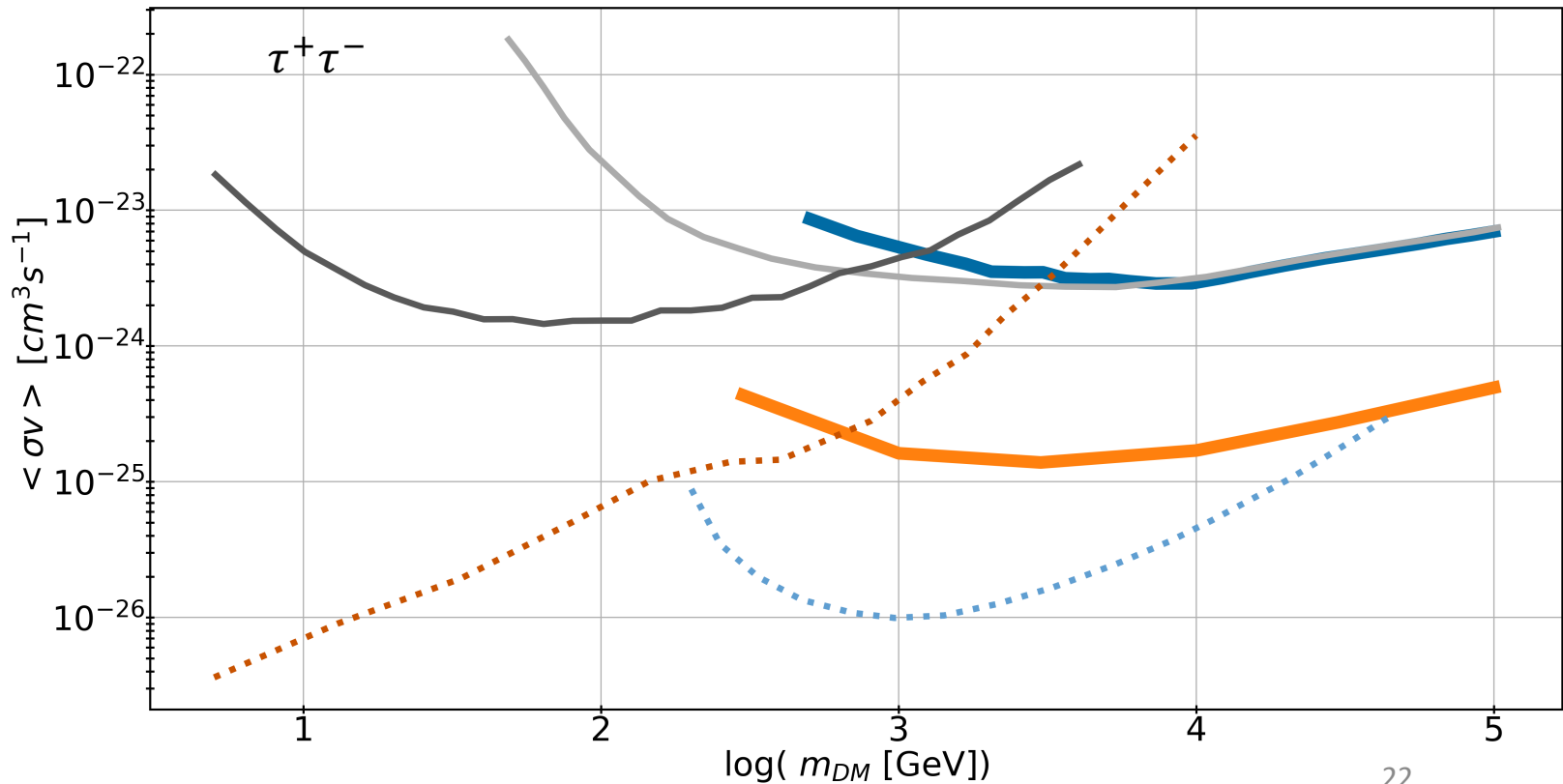
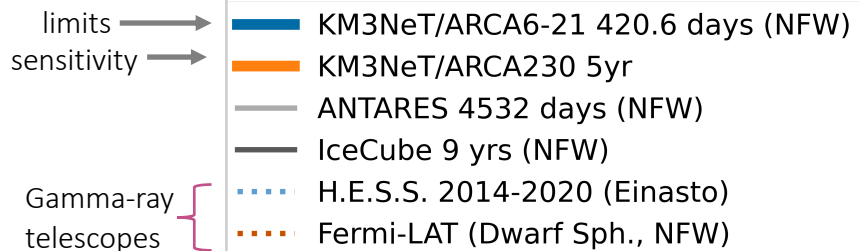
For dark matter searches from our galaxy

- Limit or sensitivity on the dark matter annihilation cross-section

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

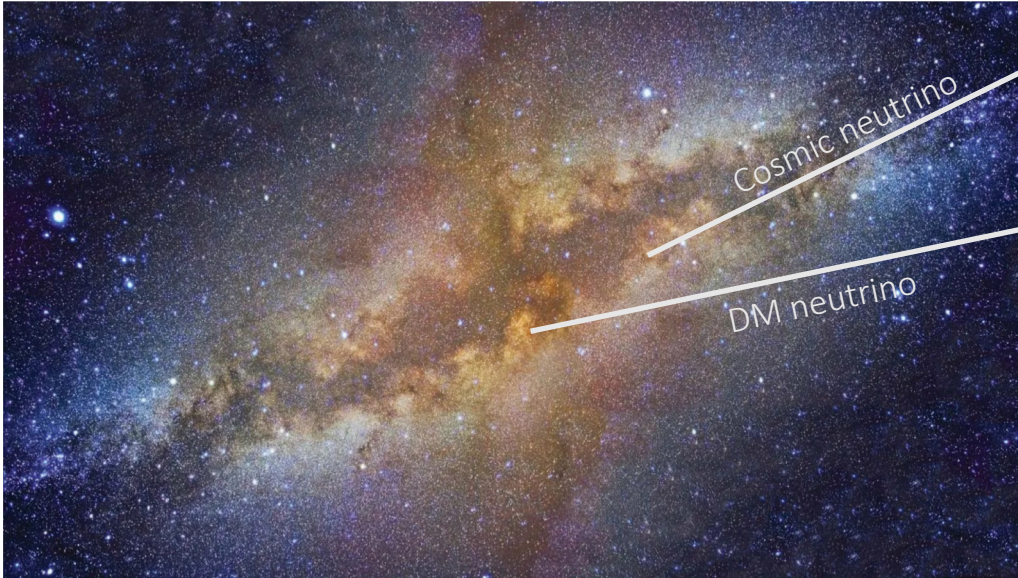
Annihilation cross-section and dark matter mass
Spectra
Dark matter distribution around Galactic Centre

Limits and sensitivities in context



Conclusions

Looking at the neutrino sky with KM3NeT/ARCA



- Good data-MC agreement
- Improving limits with growing detector to
 - Neutrino cosmic sources
 - WIMP dark matter properties
- Monochromatic lines can be a smoking gun signature of dark matter

Discoveries soon to come!