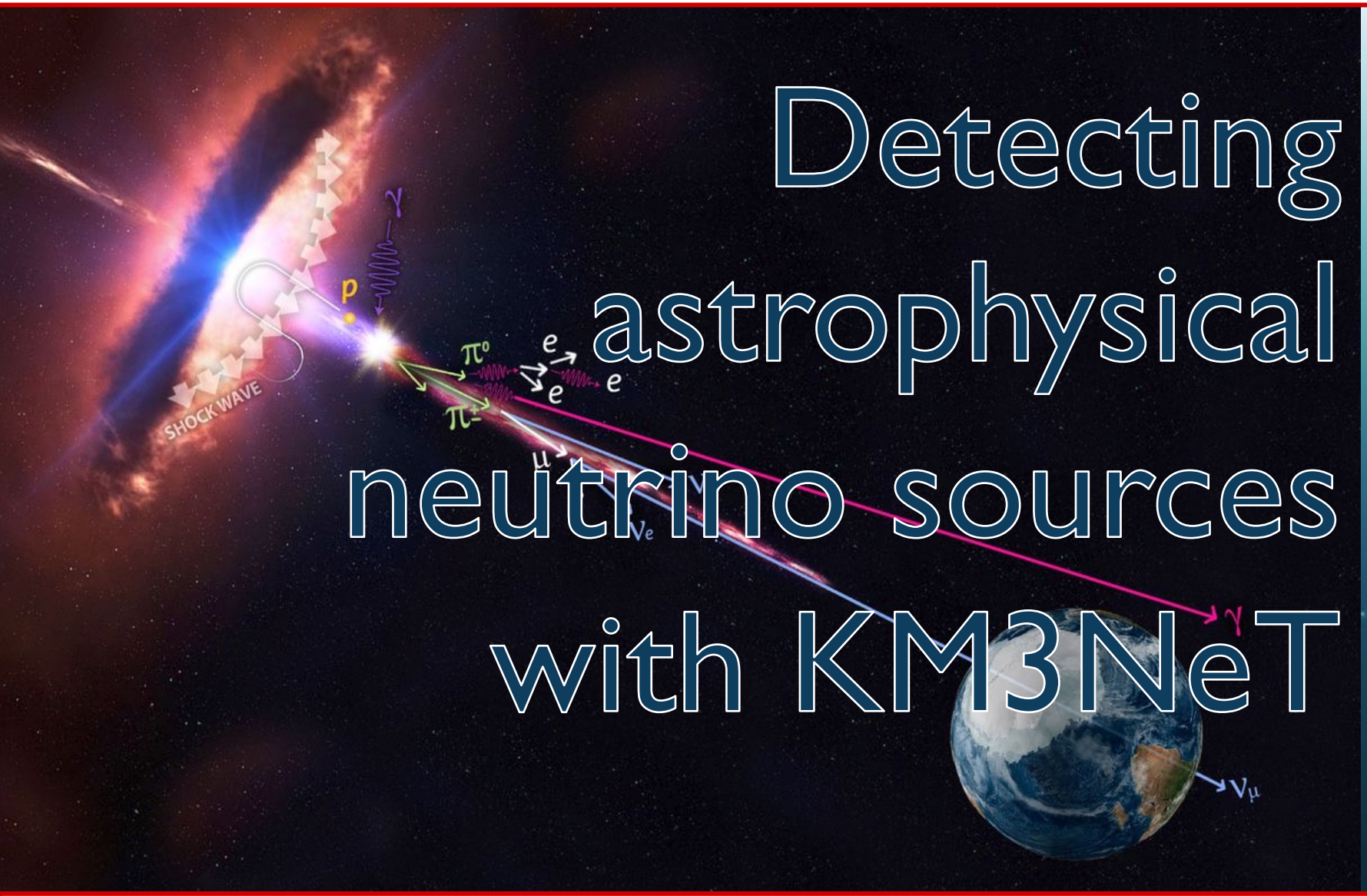
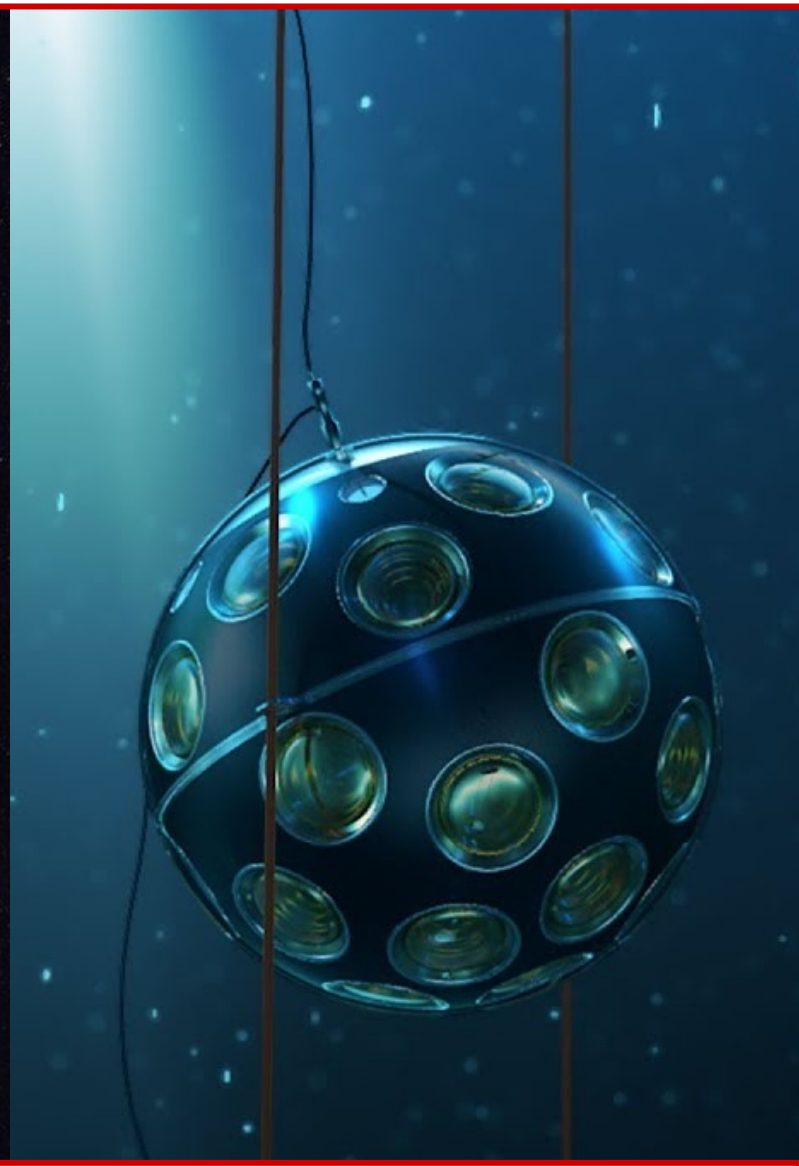
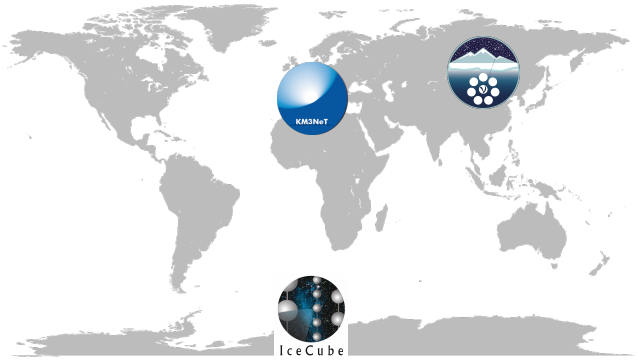
Detecting astrophysical neutrino sources with KM3NeT

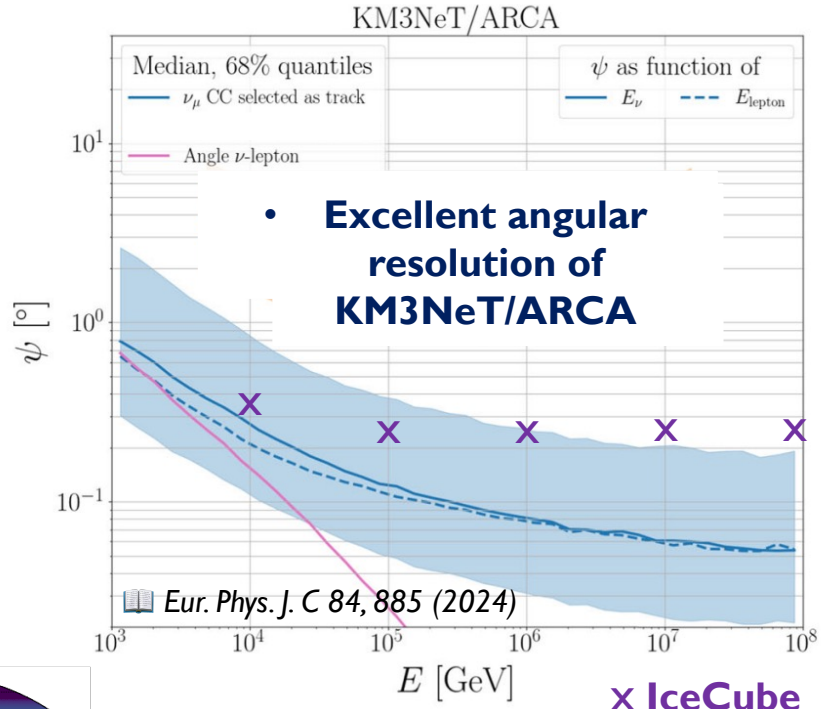




Key features of KM3NeT



- 1 km³ instrumented volume
- All-sky FoV with clear view of the southern sky (complementary to IceCube)
- Almost 100% duty cicle



- **Excellent angular resolution of KM3NeT/ARCA**

x IceCube

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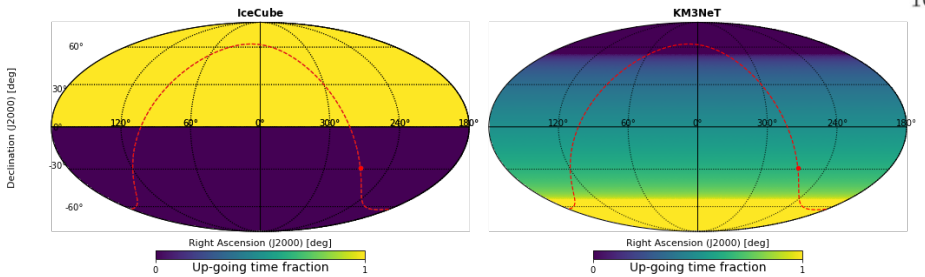
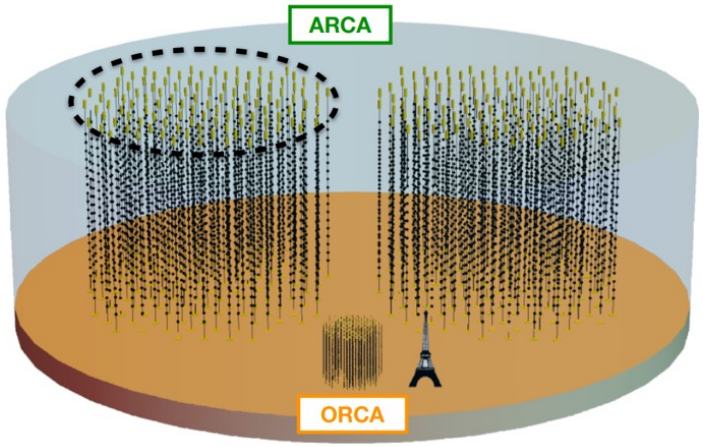
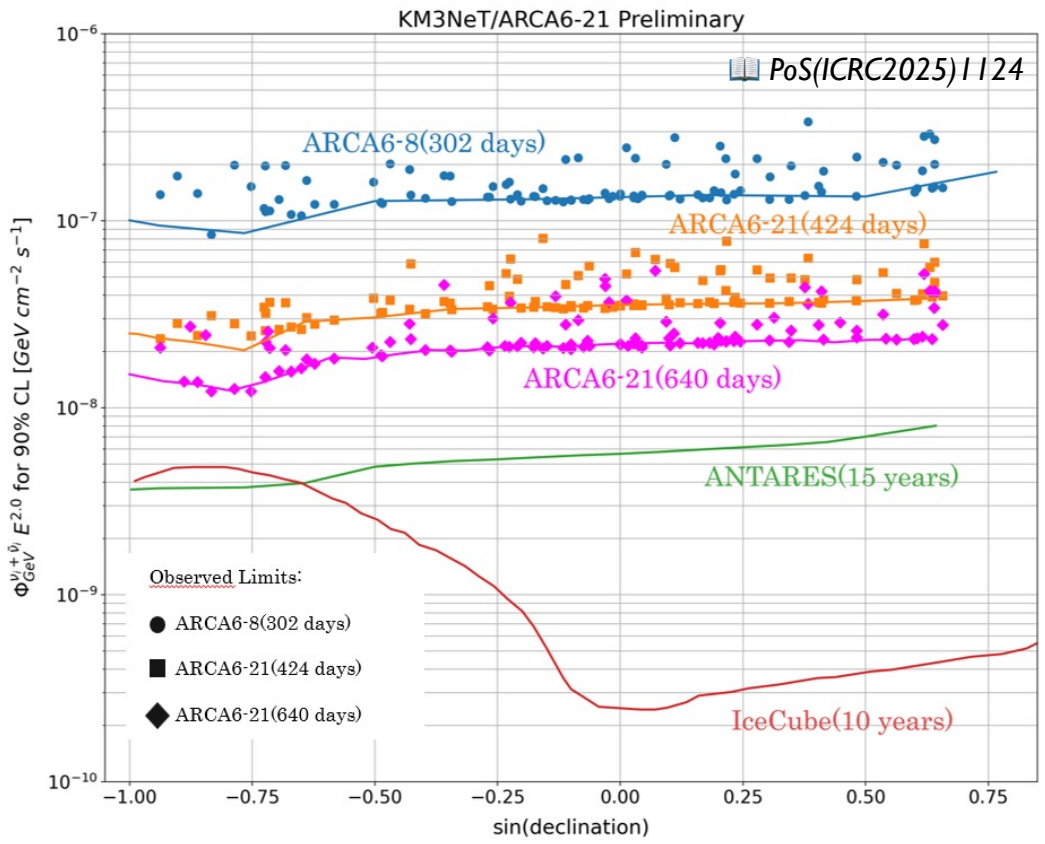




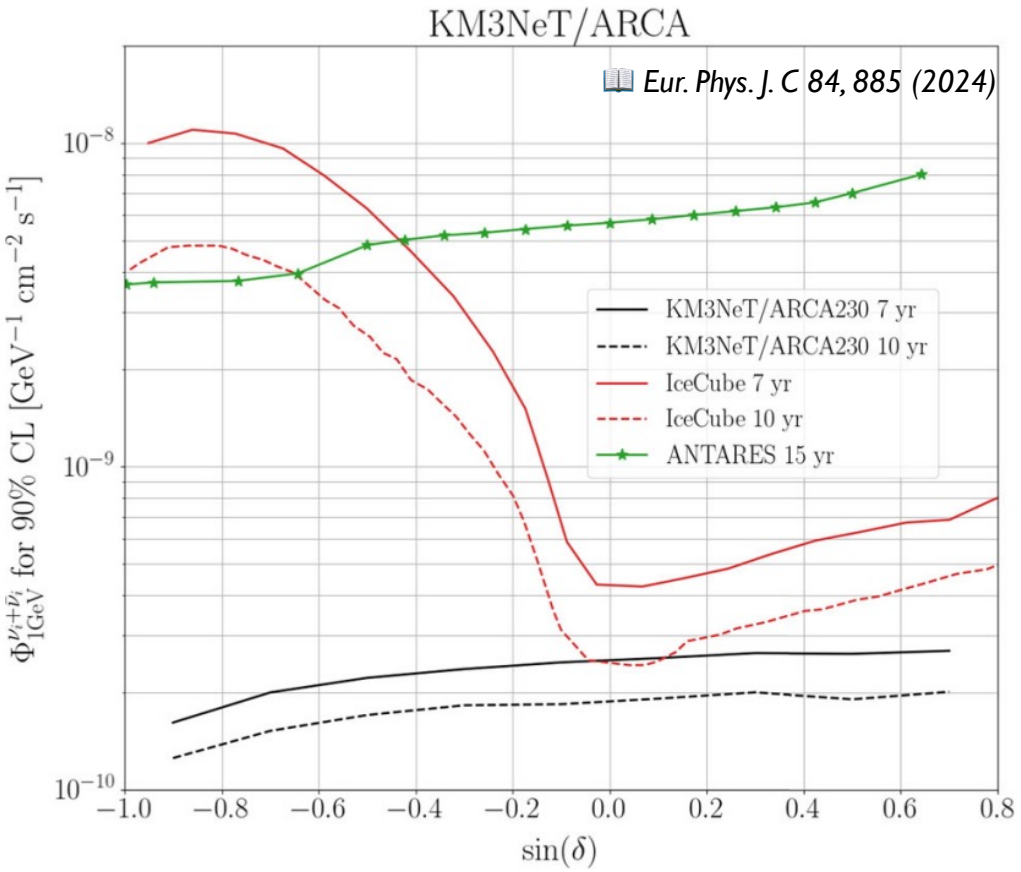
- **Extended energy reach by combining KM3NeT/ORCA and KM3NeT/ARCA: 1-10² GeV + 10²-10⁸ GeV**

Point-like sources: results and prospects

Results with *current* KM3NeT/ARCA

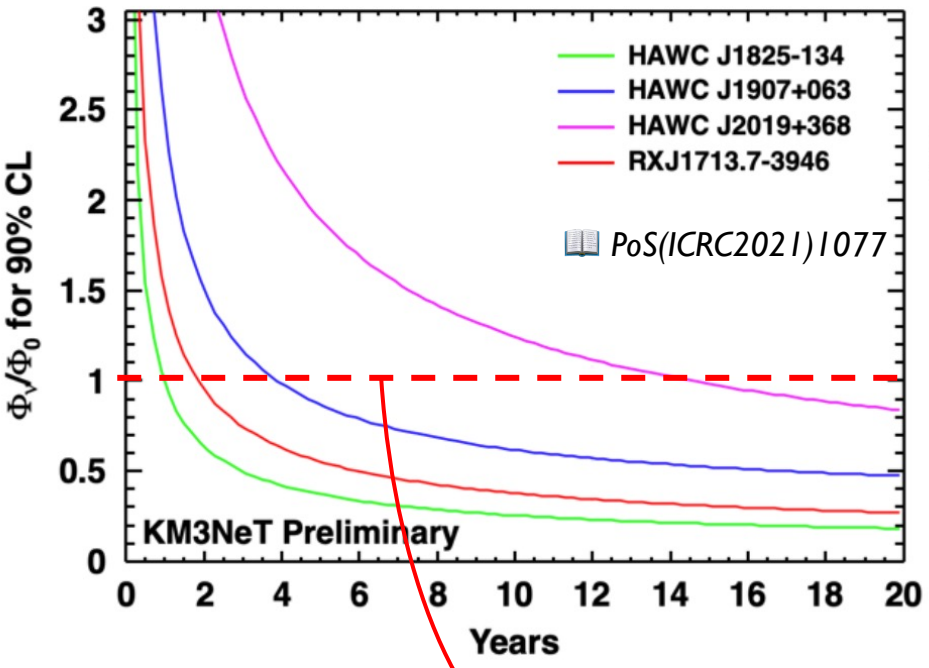


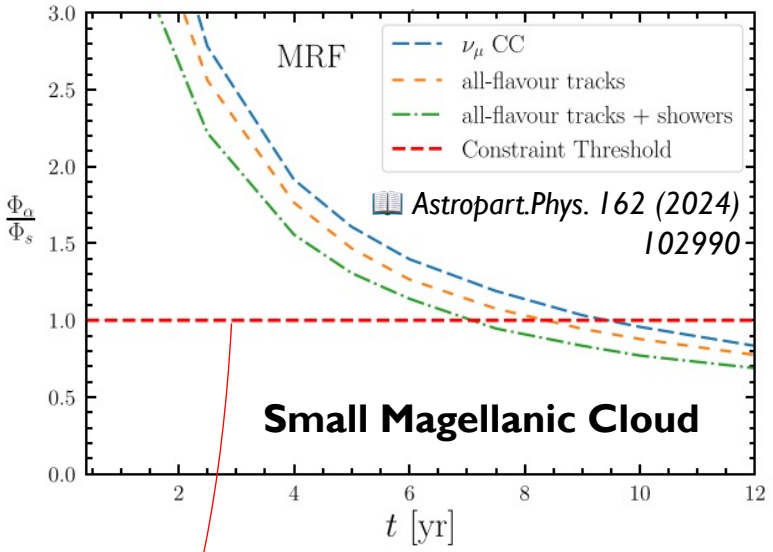
Prospects with complete KM3NeT/ARCA



Point-like sources: results and prospects

Galactic sources

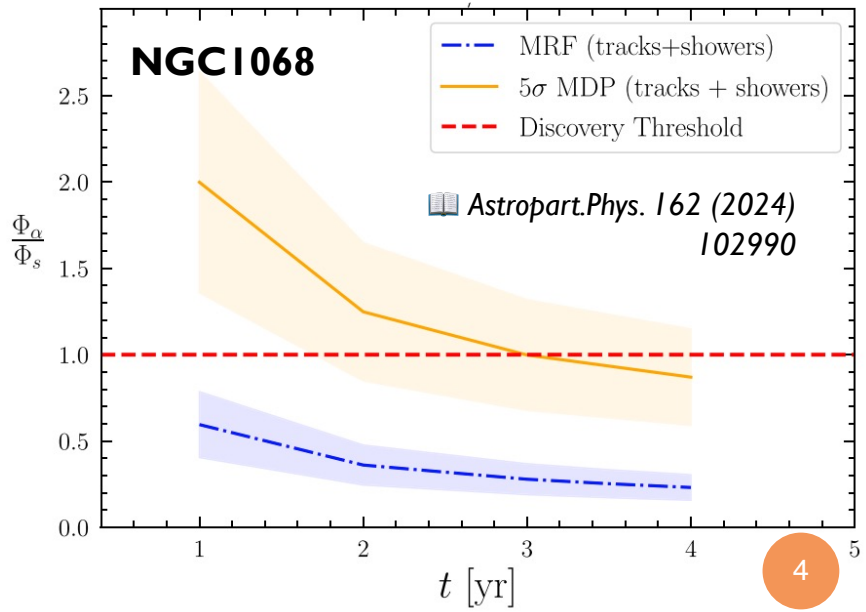




Sensivity at expected neutrino flux level (assuming 100% hadronic emission) reached in a few years of operation with the complete KM3NeT/ARCA detector*

Extra-galactic sources

NGC1068 will be observed at 5σ CL in 3 years of operation with full KM3NeT/ ARCA*



*data accumulated with the detector in partial configurations not taken into account

Collaborating multi-messenger experiments

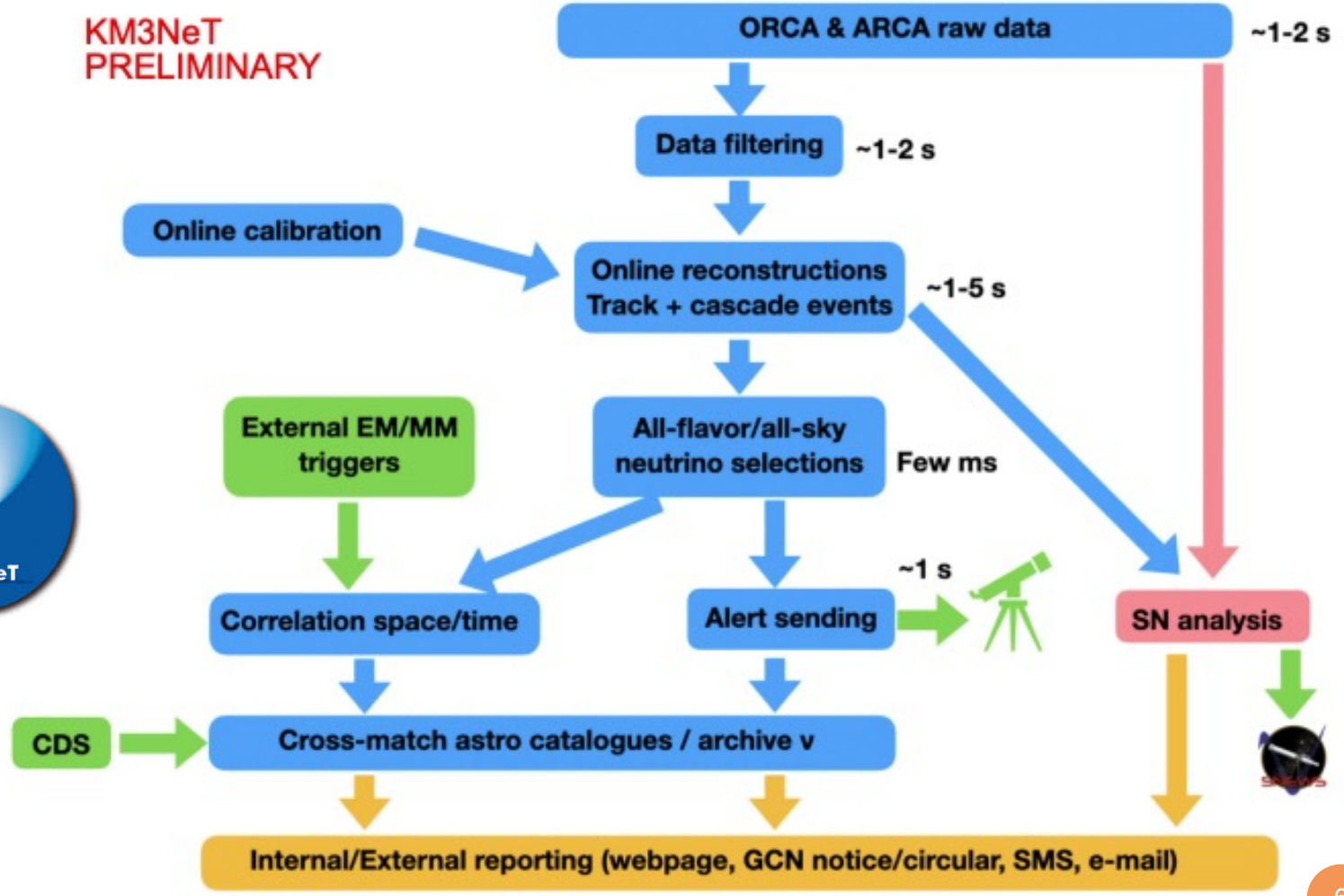
Astronomy in real time

Follow-up of external alerts
→ **operational since early 2023**

Broadcast of KM3NeT alerts
→ **work in progress**

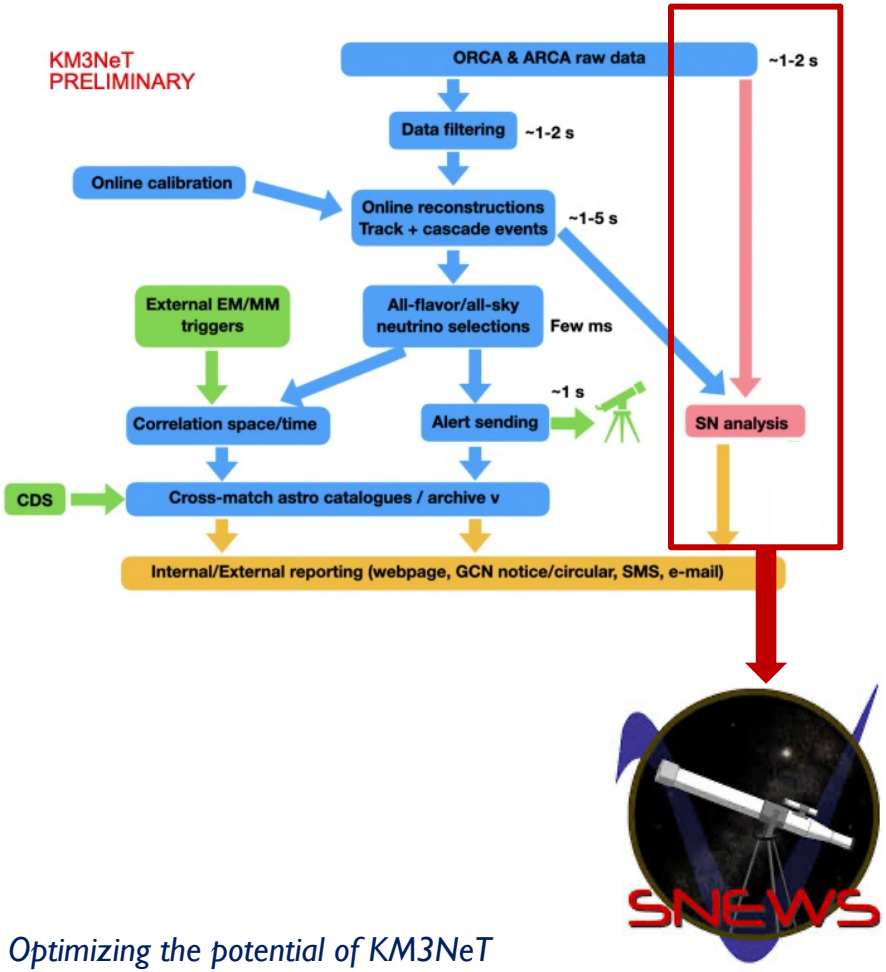
KM3NeT

KM3NeT PRELIMINARY



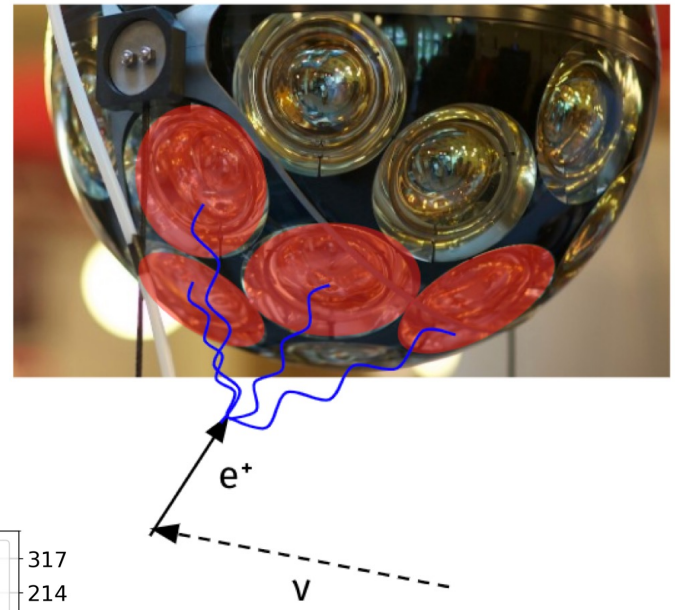
📖 ***Real-time architecture:*** *PoS(ICRC2025)1115*
📖 ***Follow-up of external triggers:*** *PoS(ICRC2025)1038*
📖 ***Neutrino alerts:*** *PoS(ICRC2025)920*

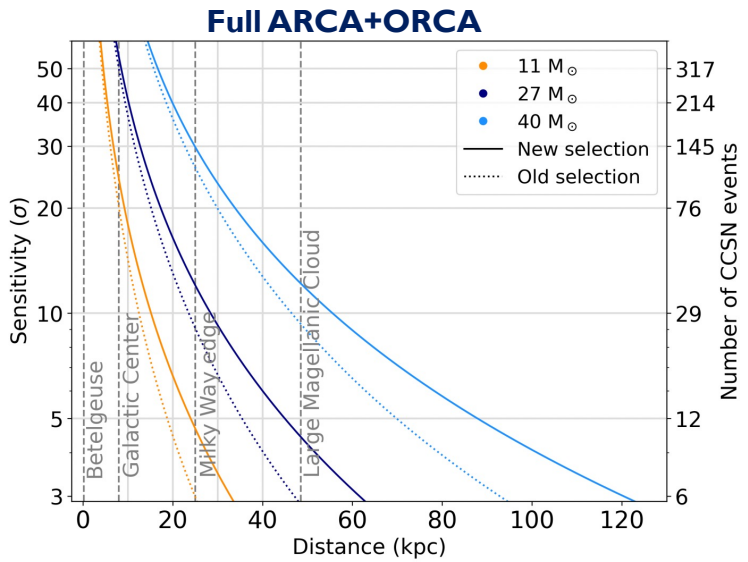
Neutrinos from Core Collapse Supernovae



At MeV energy, reconstruction of individual trajectories using multiple DOMs impossible

Analysis principle: search for an excess of coincidences between PMTs in single DOMs above the expected background





📖 *Optimizing the potential of KM3NeT in detecting core-collapse supernovae,* arXiv:2511.18565 [astro-ph.HE]

Follow-up of external alerts

Follow-up of external alerts → operational since early 2023

KM3NeT

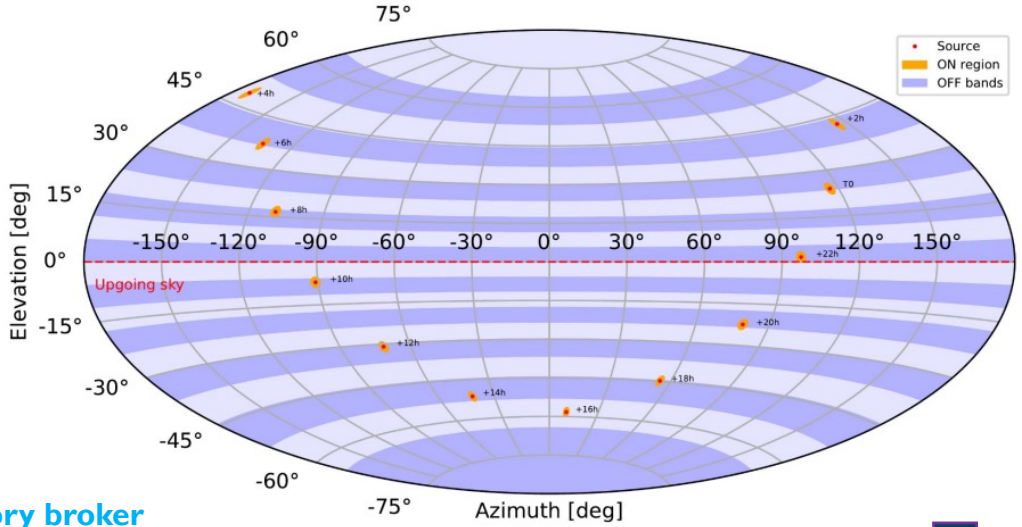
GCN notices

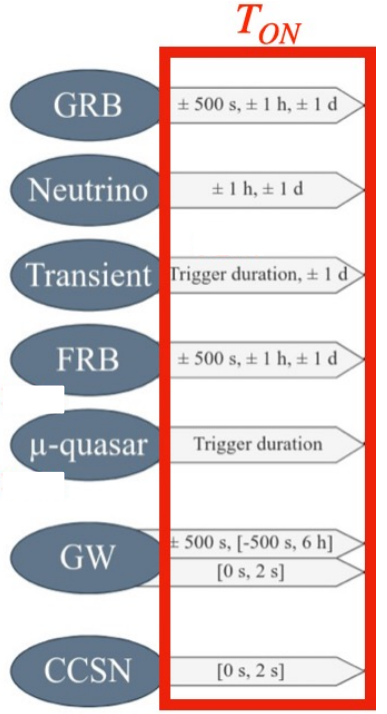
- INTEGRAL (GRB)
- FERM_GBM (GRB/Transient/Undef)
- FERMI_LAT (Transient)
- SWIFT_BAT_GRB (GRB/Transient/Undef)
- SWIFT_XRT (GRB/Transient/Undef)
- SWIFT_BAT_TRAN (Transient)
- MAXI (Transient)
- HAWC (Transient)
- IceCube (Neutrino)
- LVK (GW)
- SNEWS (CCSN)
- SK_SN (CCSN)
- Chime online notices (FRB) ➡ 🔔 Chime radio-observatory broker
- TNS catalog updates (FRB) ➡ 🔔 **KM3NeT script to monitor new FRBs appended to the Transient Name Server**
- µQuasar (Micro-quasar)

🔔 **KM3NeT script to monitor x-ray light-curves publicly provided by MAXI and Swift-BAT for a list of microquasars and identify luminosity increase**

ON/OFF search

- **ON region:** where the signal is expected. Includes source location error + angular uncertainty
- **OFF region:** local zenith bands to compute the expected background, following the ON region movement due to Earth's rotation

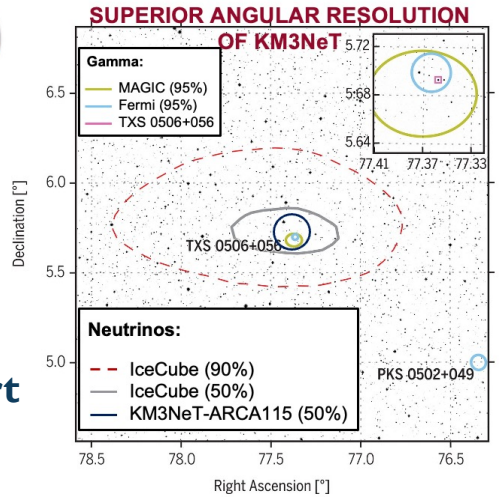




If a follow-up shows interesting results or an astrophysical event is notable enough ➔ **Send a GCN circular**

Broadcast of KM3NeT alerts

- Work in progress
- Plan to send alerts for:
  - **high-energy events**
  - **multiplets**
  - **events with probable astrophysical counterpart**
- Trigger selection based on FAR



Working to strengthen our connection with the multi-messenger community: essential to ensure that our **real-time alerts receive timely, coordinated follow-up**

Several successful observing proposals for alert follow-up

Example of such synergy:
📖 KM3NeT-Collab, *Characterising Candidate Blazar Counterparts of the Ultra-High-Energy Event KM3-230213A*, arXiv:2502.08484 [astro-ph.HE]

Conclusions

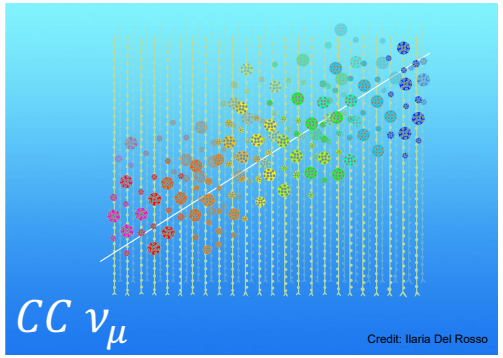
- **Neutrino astronomy:** a young field and a new messenger for astrophysics
- **Feasibility proven:** a diffuse neutrino flux (Galactic + extragalactic) is established
- **Open problem:** the sources remain largely unidentified (only a few observed)
- To identify them we need:
  1) Large instrumented volume
  2) Wide energy range
  3) Excellent angular resolution
  4) Multi-messenger/wavelength synergies

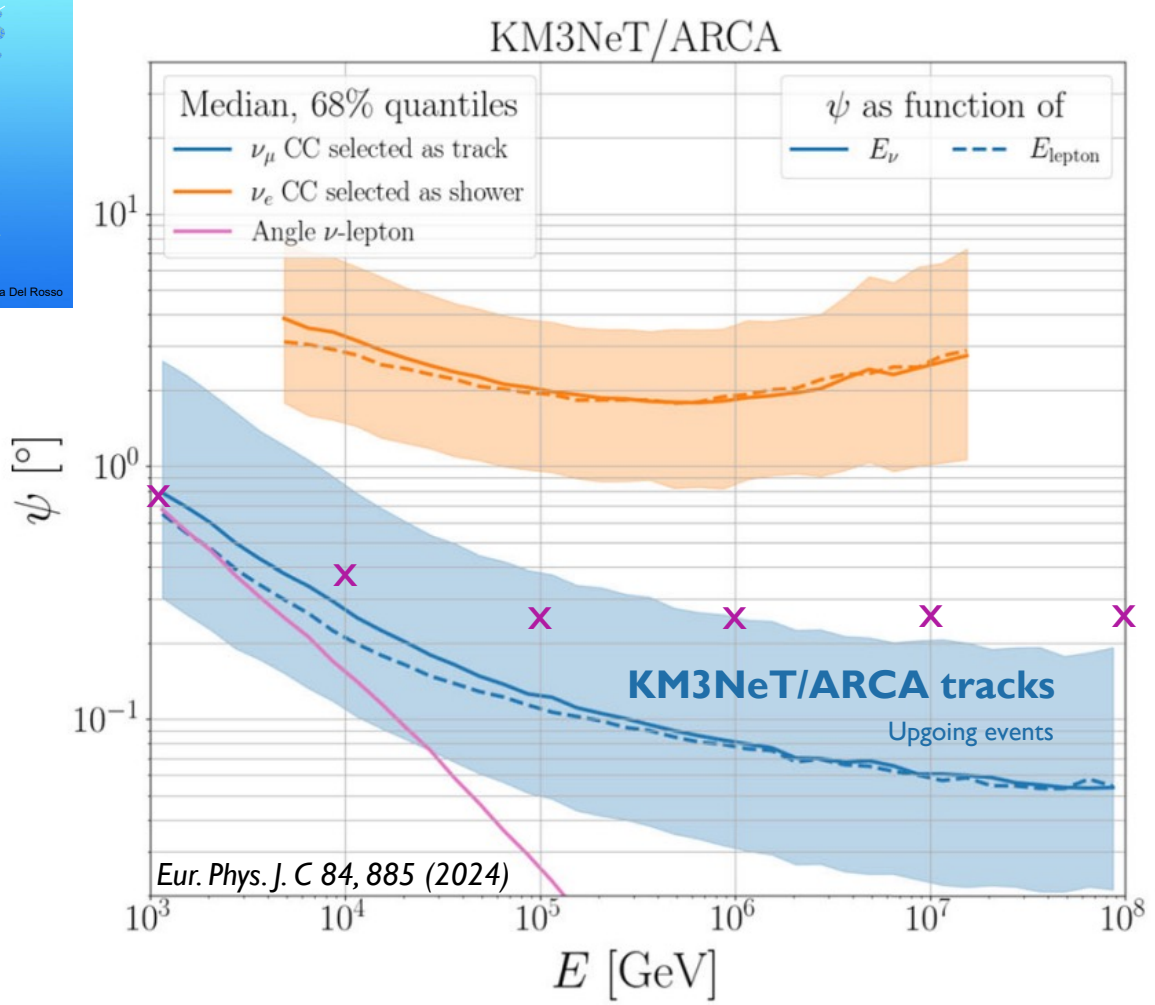
KM3NeT delivers 1–3 and is actively developing 4 ⟹ key instrument for source discovery and leading actor in multi-messenger astronomy

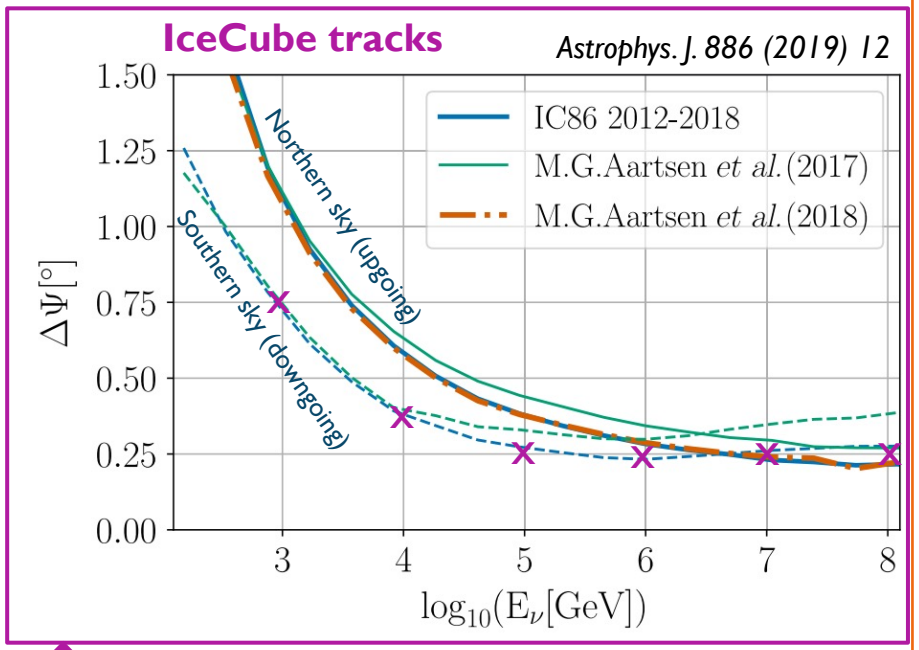
Backup

Superior angular resolution of KM3NeT

Track channel

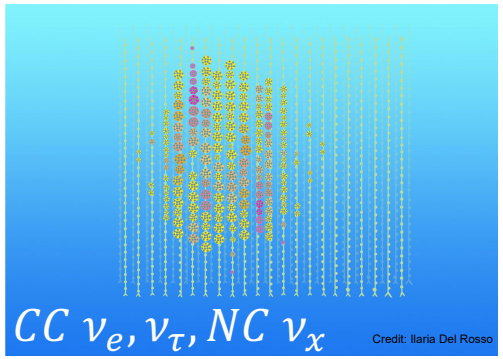


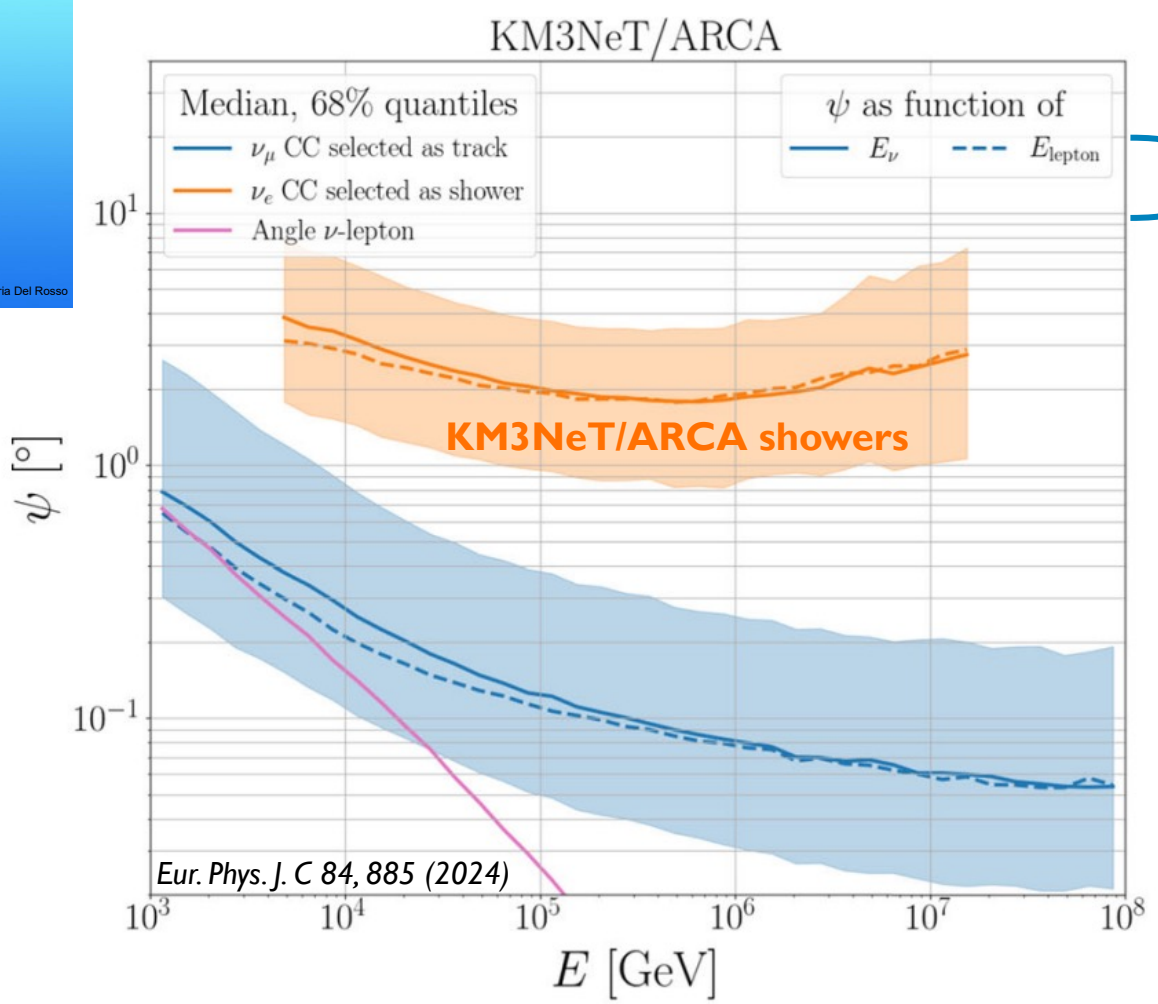


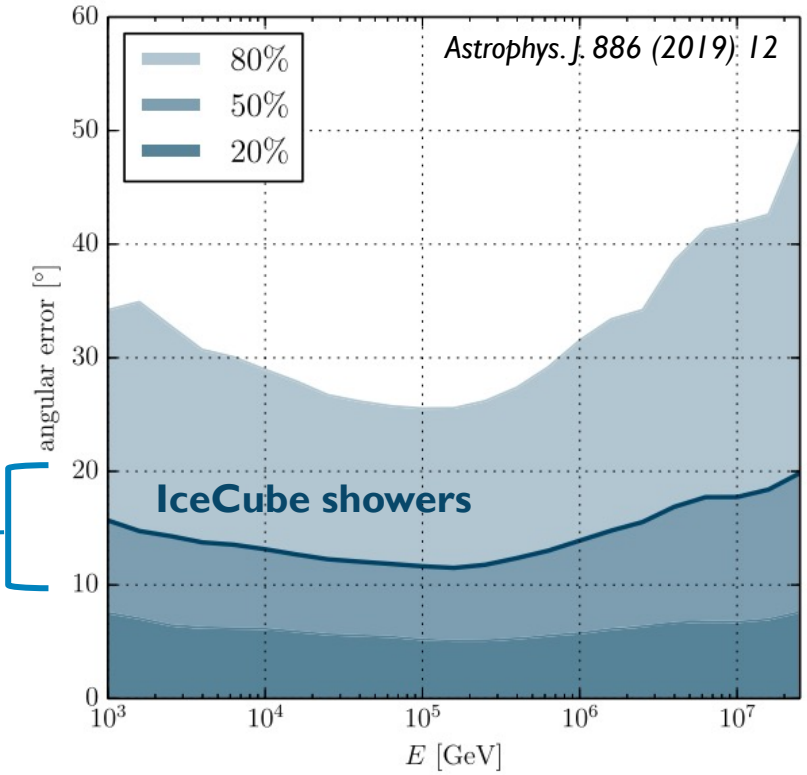


Superior angular resolution of KM3NeT

Shower channel

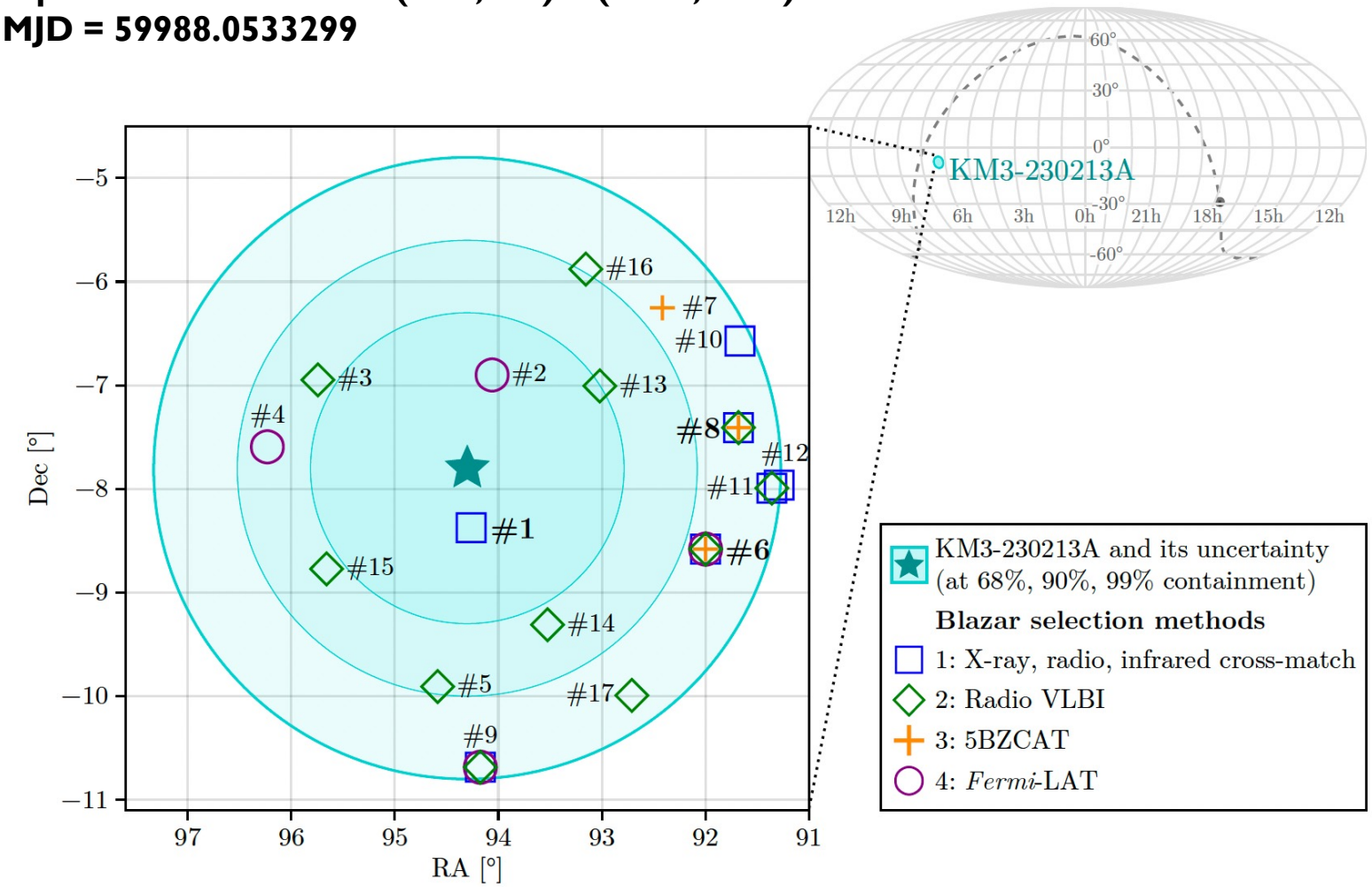






Follow-up of KM3-230213A

Equatorial coordinates: (Dec, RA) = (94.3°, -7.8°)
MJD = 59988.0533299



📖 KM3NeT-Collab, *Characterising Candidate Blazar Counterparts of the Ultra-High-Energy Event KM3-230213A*, arXiv:2502.08484 [astro-ph.HE]

- *Nature* paper → **12 blazars** identified in RoI
- Increased to **17 blazars** thanks to dedicated VLBI observations with VLBA
- Blazars studied using **archival data** and **dedicated observations**

☐ **eROSITA** catalog + **NRAO VLA** Sky Survey catalog + Wide-field Infrared Survey Explorer (**WISE**)

Follow-up of KM3-230213A

Equatorial coordinates: (Dec, RA) = (94.3°, -7.8°)
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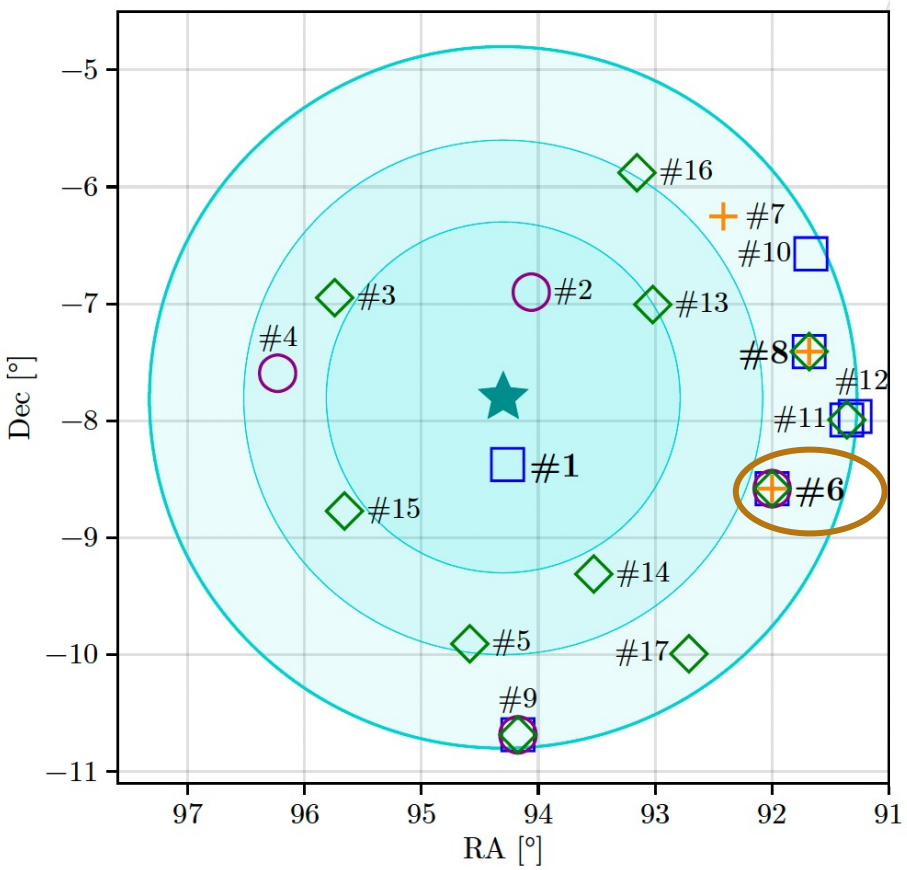
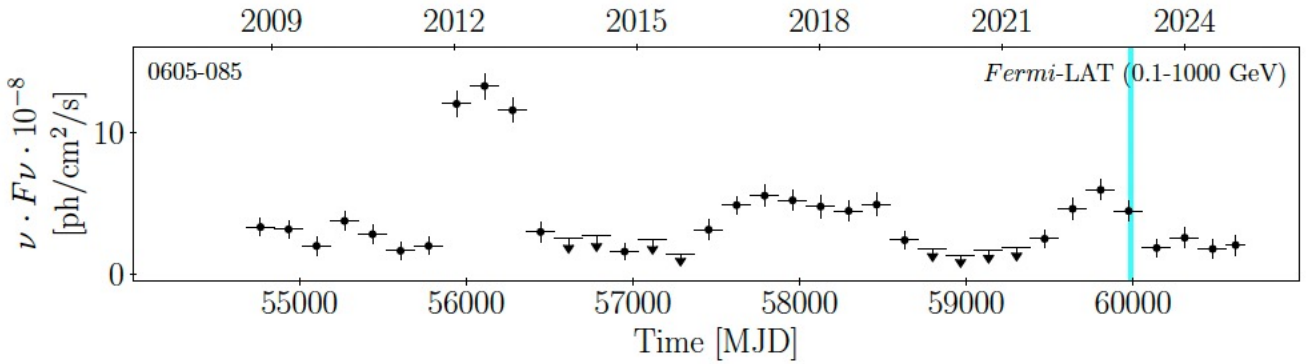
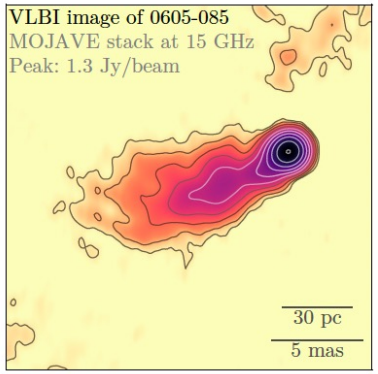


Source **0605-085 (#6)**: experiences **gamma-ray flaring** activity



(a) The *Fermi*-LAT light curve and a VLBI image of 0605-085: the brightest radio source in the neutrino localization region that experiences a gamma-ray flaring activity around the neutrino arrival

Among the **50 brightest radio objects** in the whole sky based **on VLBI flux density** → high degree of relativistic beaming



Follow-up of KM3-230213A

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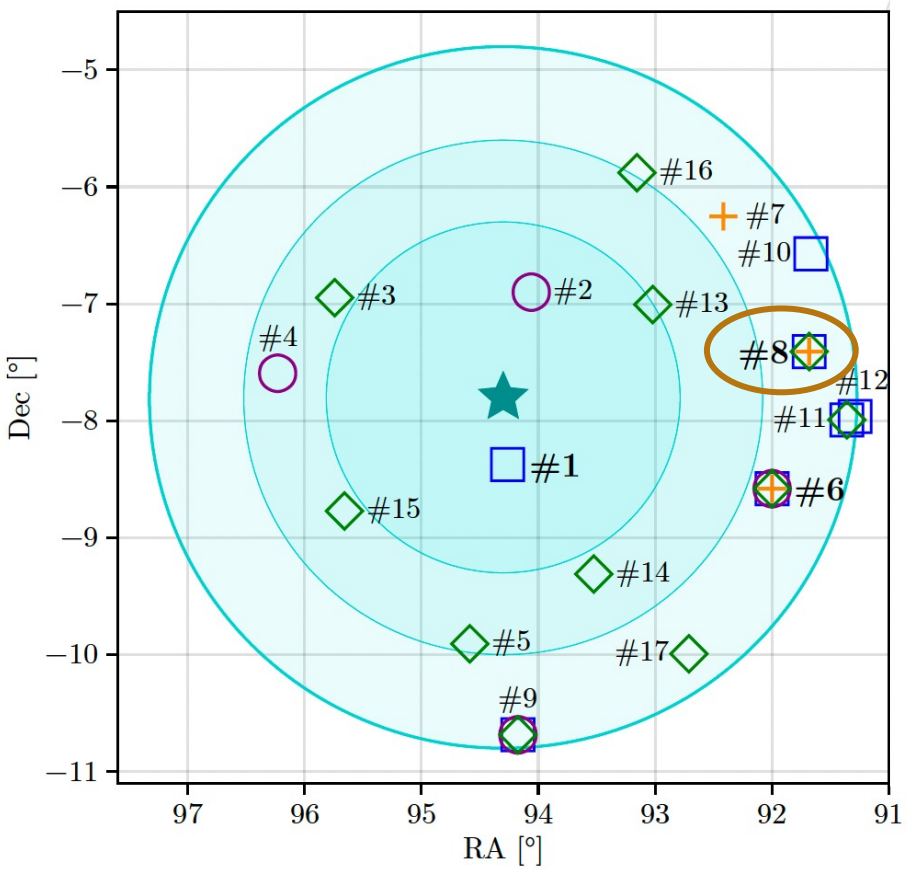
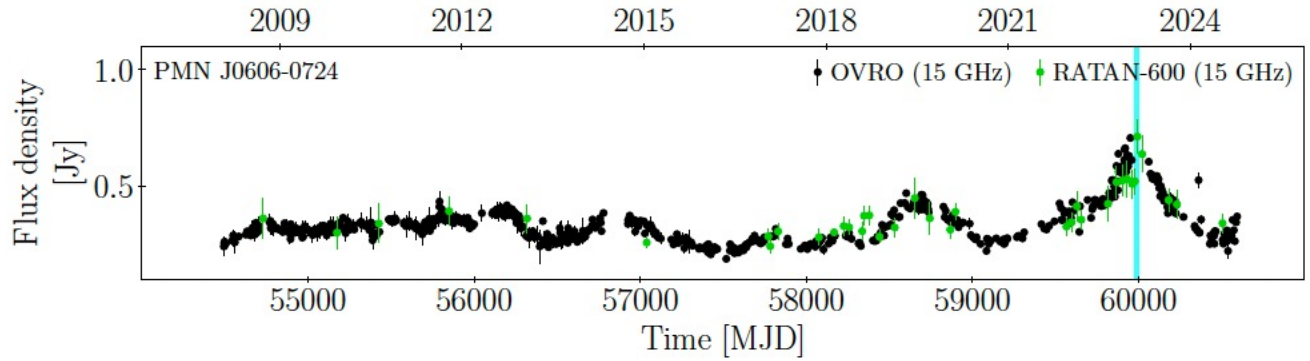
📖 KM3NeT-Collab, *Characterising Candidate Blazar Counterparts of the Ultra-High-Energy Event KM3-230213A*, arXiv:2502.08484 [astro-ph.HE]



Major **radio flare** from **PMNJ0606-0724 (#8)**



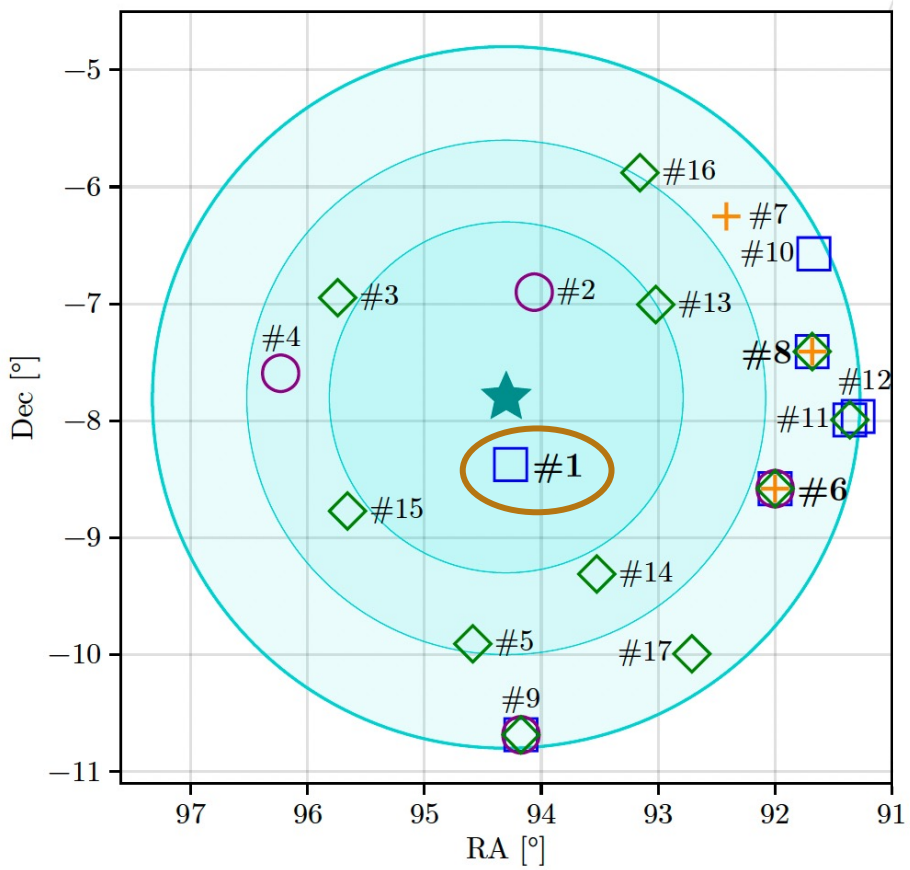
(b) The radio light curve for PMN J0606-0724 that experiences a major flare in close coincidence to the neutrino arrival (Section 5.2).

Time difference of five days between KM3-231213A arrival time and peak of highest radio flare → **0.26% pre-trial chance probability (to be taken with caution!)**

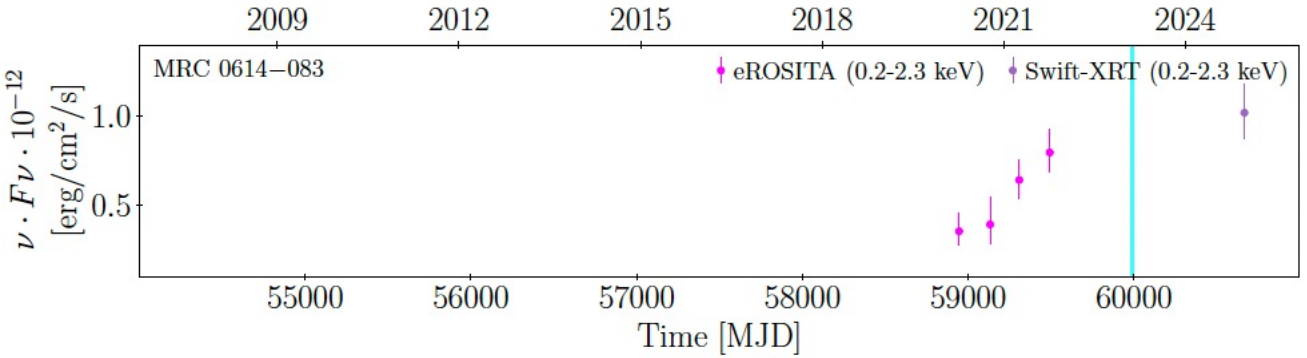
Follow-up of KM3-230213A

Equatorial coordinates: (Dec, RA) = (94.3°, -7.8°)
MJD = 59988.0533299

📖 KM3NeT-Collab, *Characterising Candidate Blazar Counterparts of the Ultra-High-Energy Event KM3-230213A*, arXiv:2502.08484 [astro-ph.HE]



X-ray flaring activity of **MRC0614-083 (#1)**



(c) The X-ray light curve for MRC 0614-083 that indicates a flaring activity around the neutrino arrival

X-ray activity (eROSITA) **increases** steadily in the years leading up to KM3-230213A, and **seems to persist** (Swift follow-up).
However, **mind the > 3 year gap** between eROSITA and Swift data.