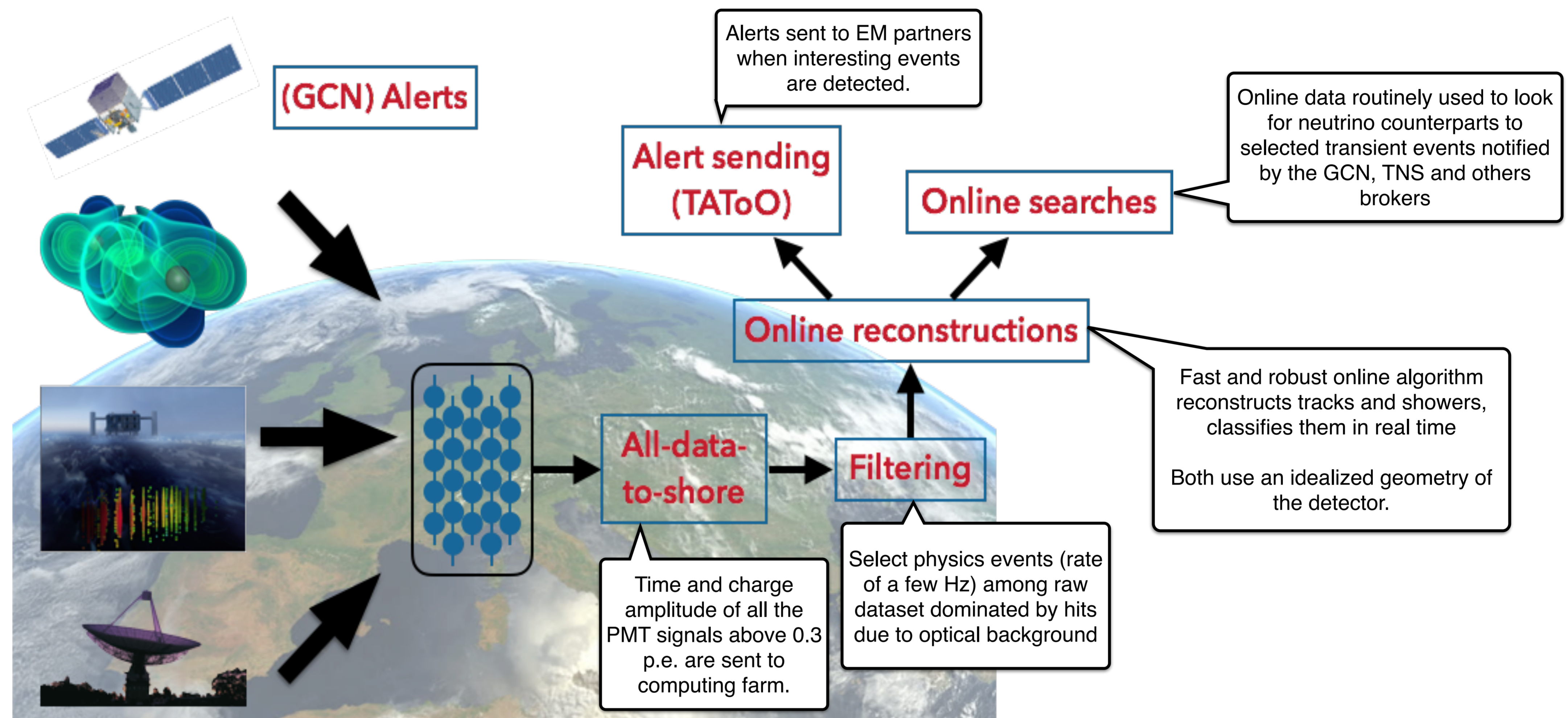# 10-yrs follow-up of the ANTARES neutrino alerts by Swift and KM3NeT neutrino alert program

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By constantly monitoring at least one complete hemisphere of the sky, neutrino telescopes are well designed to detect neutrinos emitted by transient astrophysical events. Real-time searches for high-energy neutrino candidates coincident with GRBs, FRB, high-energy transients, IceCube HE neutrino events and gravitational wave candidates observed by LIGO/Virgo are performed with the ANTARES and KM3NeT telescopes. ANTARES during its life, 2009-2022, has also sent 322 neutrino alerts, for which ~20 have been followed by the Swift/XRT instruments. KM3NeT is almost ready to send its own neutrino alerts (Spring 2025). By requiring temporal and spatial coincident detection or multi-wavelength follow-up, this approach increases the sensitivity and the significance of a potential discovery.

(GCN) Alerts

Alerts sent to EM partners when interesting events are detected.

Online data routinely used to look for neutrino counterparts to selected transient events notified by the GCN, TNS and others brokers

Alert sending (TAToO)

Online searches

Online reconstructions

Fast and robust online algorithm reconstructs tracks and showers, classifies them in real time

Both use an idealized geometry of the detector.

All-data-to-shore

Filtering

Time and charge amplitude of all the PMT signals above 0.3 p.e. are sent to computing farm.

Select physics events (rate of a few Hz) among raw dataset dominated by hits due to optical background

ANTARES - Swift

**Triggers:**
* Doublet of neutrinos: ~0.04 event / yr.
* Single neutrino with direction close to local galaxies: ~1 TeV, ~10 events / yr.
* Single HE neutrinos: ~7 TeV, ~15 event / yr
   => Sub-sample HE neutrinos: ~5 TeV, 20 events / yr
   => Sub-sample VHE neutrinos: ~30 TeV, ~3-4 events / yr.
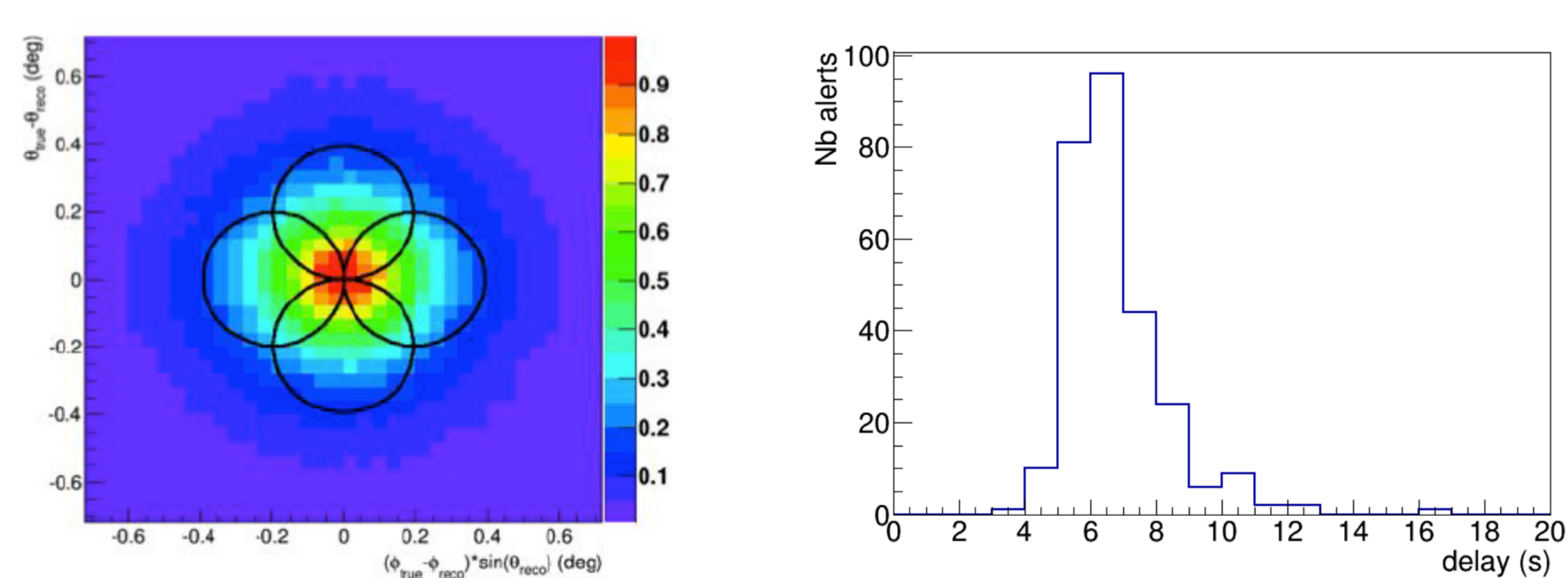
• Statistics:
   * 2009-2020: 322 neutrino alerts sent to robotic telescopes (TAROT, ROTSE, MASTER), ~68% have a follow-up with a delay lower than 24h, 18% within 1 min.
   * 26 ToO Swift, 19 accepted with delay around 8h (min 1.1h)
   * Observation strategy: 4 tiles of ~2ks exposure
   * No significant counterpart detected. Only for ANT150901A, there was a X-ray source finally associated with a young accreting G-K flaring star or a RS CVn.
* Probability to reject an on-axis GRB~70% if follow-up within a few hours after the neutrino trigger.
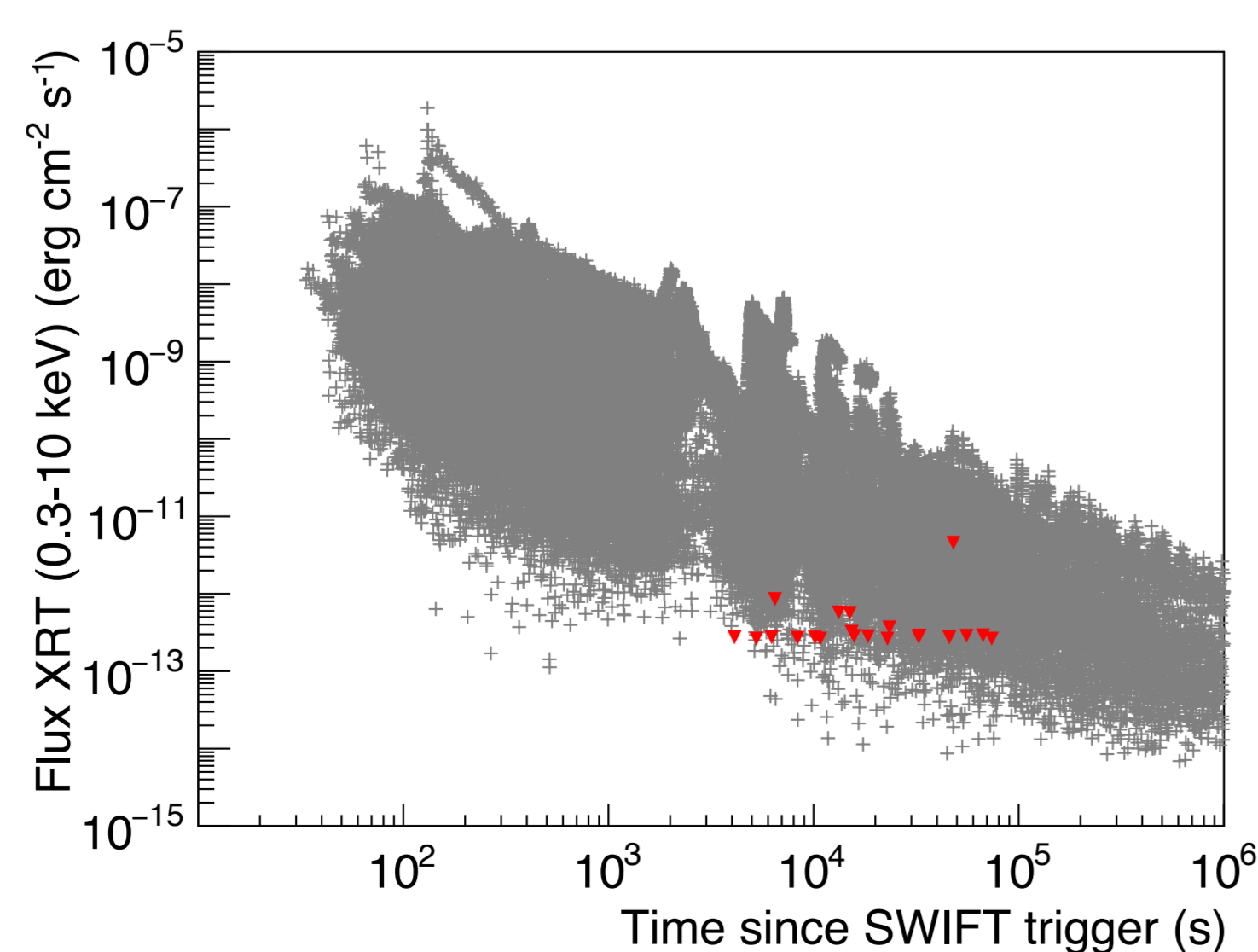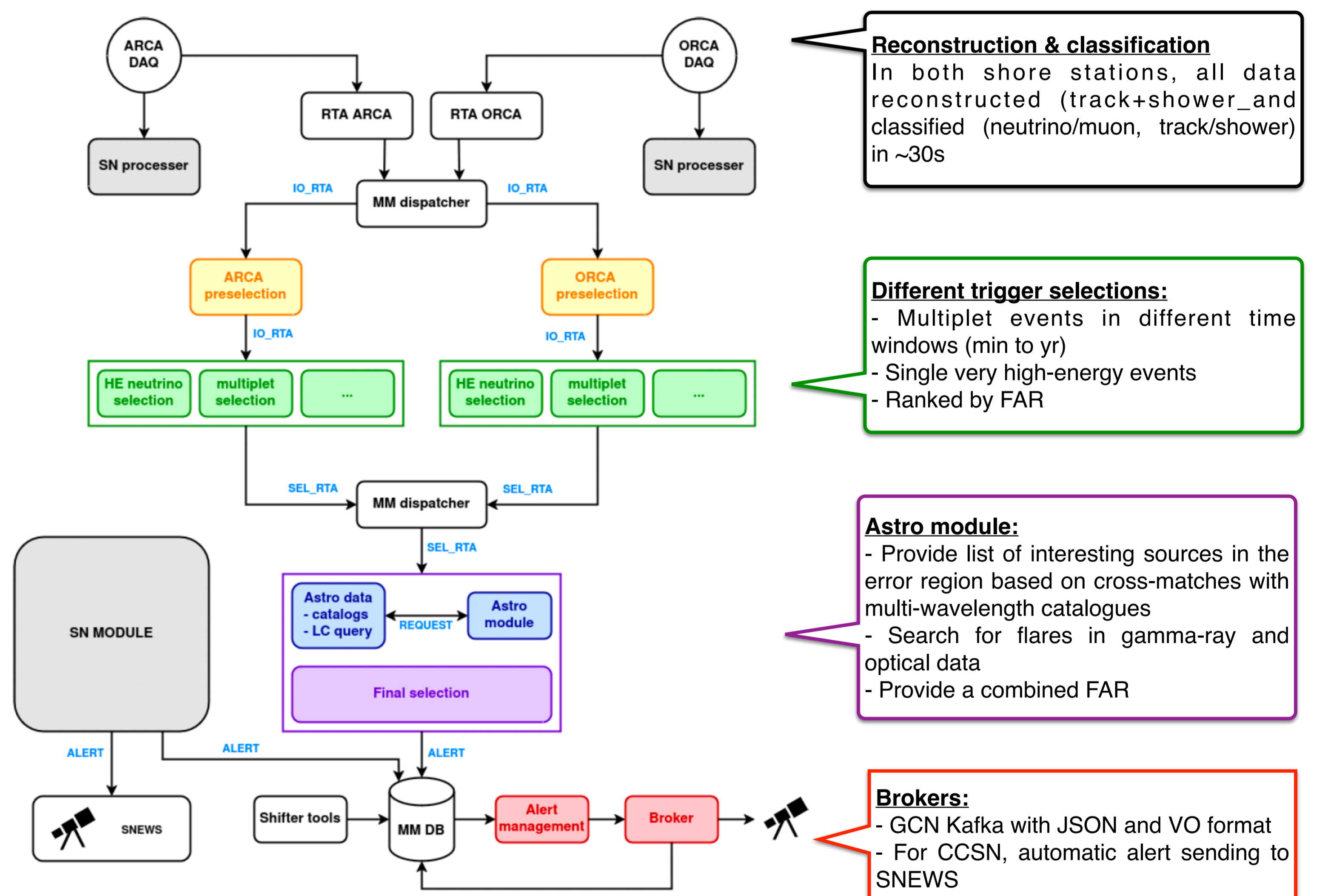

• Perspectives:
   * ANTARES has been decommissioned February 2022
   * Results available in one legacy paper: *JCAP* 09 (2024) 042

KM3NeT neutrino alerts

• KM3NeT telescopes:
   * ARCA (-3500m Sicily, Italy), 230 detection lines (~1 km3) optimized for TeV-PeV high energy neutrinos. Actually, 33 lines deployed.
   * ORCA (-2500m, Provence, France), 115 detection lines (~7 Mt) optimized for GeV-TeV neutrinos. 24 lines deployed.
⇒ Online analysis platform in operation to analyse in real-time KM3NeT data in coincidence with main MWL/MM alerts and to send KM3NeT neutrino alerts (Spring 2025).

Reconstruction & classification
In both shore stations, all data reconstructed (track+shower_and classified (neutrino/muon, track/shower) in ~30s

Different trigger selections:
- Multiplet events in different time windows (min to yr)
- Single very high-energy events
- Ranked by FAR

Astro module:
- Provide list of interesting sources in the error region based on cross-matches with multi-wavelength catalogues
- Search for flares in gamma-ray and optical data
- Provide a combined FAR

Brokers:
- GCN Kafka with JSON and VO format
- For CCSN, automatic alert sending to SNEWS

• KM3NeT UHE event: KM3-230213A [UHE alert stream in internal test]