The KM3NeT online analysis system

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INTRODUCTION

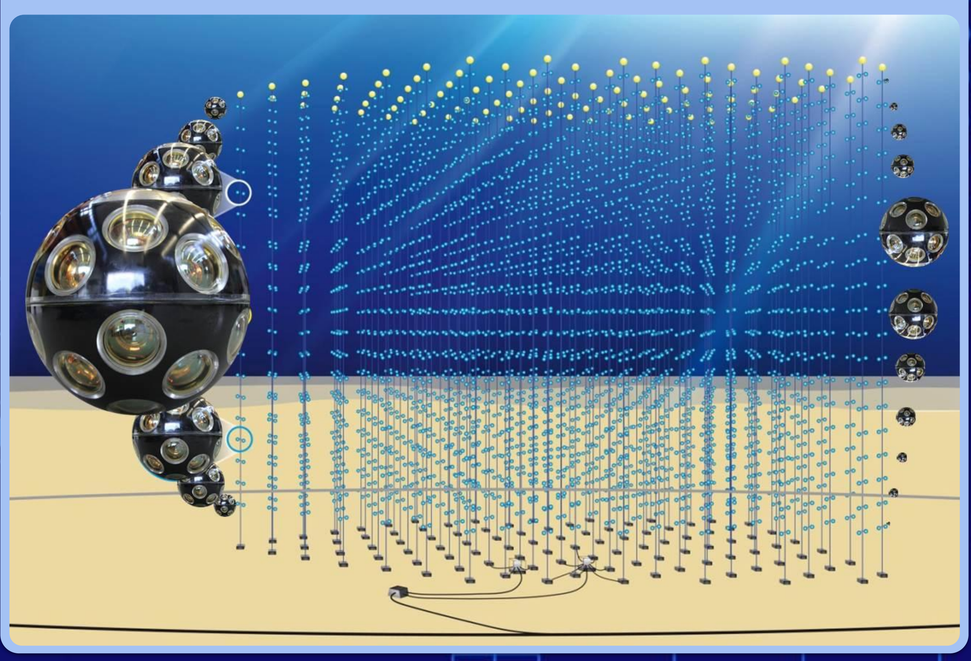
KM3NeT is actively involved in real-time multi-messenger searches, which aim at studying transient astrophysical phenomena by the simultaneous observation of different cosmic messengers. Given its large field of view and almost 100% duty cycle, KM3NeT is ideally suited to early notify other multi-messenger facilities when interesting neutrino candidates are detected and to perform follow-ups of external triggers. To achieve these goals, the KM3NeT Collaboration has set up an online analysis platform that continuously performs real-time reconstruction and classification of all triggered events and automatic multi-messenger searches.

1. KM3NeT

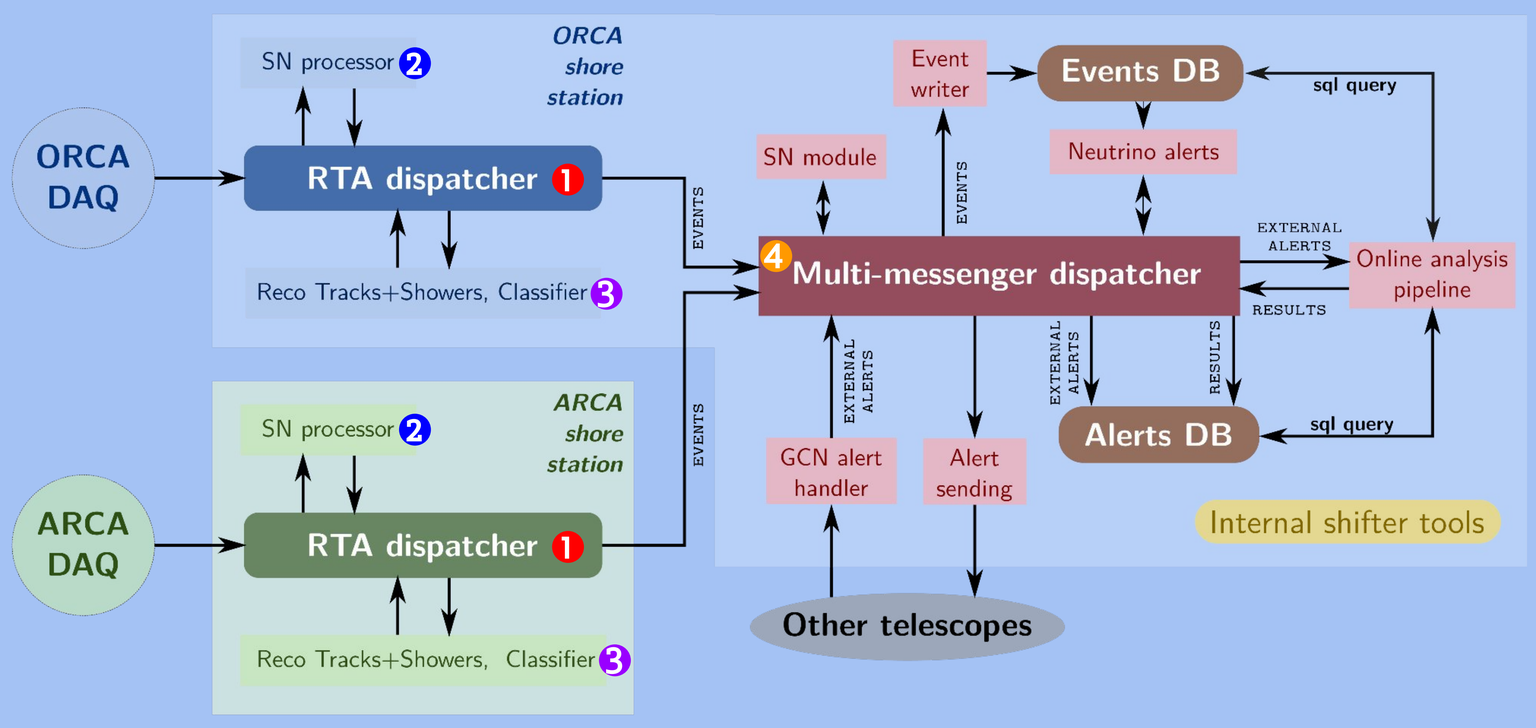
KM3NeT [1] is a deep-sea neutrino telescope under construction at two sites in the Mediterranean Sea and currently taking data with a partial detector configuration. It consists of a three dimensional grid of Digital Optical Modules (DOMs) [2] detecting the Cherenkov light produced by relativistic charged particles arising from neutrino interactions, arranged in vertically aligned Detection Units (DUs) each hosting 18 DOMs.

- ARCA is placed 100 km offshore from Portopalo di Capo Passero, Italy at a depth of 3500 m with a DU horizontal spacing of 90 m and a DOM vertical spacing of 36 m. It is optimised for the detection of high-energy cosmic neutrinos;
- ORCA is situated 40 km offshore from Toulon, France at 2450 m depth with a DU horizontal spacing of 20 m and a DOM vertical spacing of 9 m. It is optimised for the detection of low-energy atmospheric neutrinos.

Both detectors are sensitive also to MeV neutrinos emitted by Core-Collapse supernovae (CCSNe). The final goal of KM3NeT is to operate 3 building blocks, 2 for ARCA and 1 for ORCA, each containing 115 DUs. KM3NeT is now taking data with ARCA30 (30 DUs) and ORCA24 (24 DUs).



2. The KM3NeT online analysis system



1 At each shore station, a Real-Time Analysis (RTA) dispatcher continuously sends collected data to a MeV module (2) and a GeV-PeV module (3).

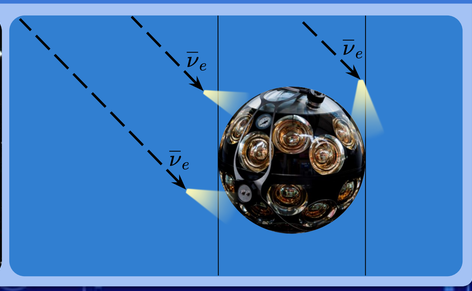
2 The MeV module (i.e., SN processor) aims at identifying CCSN events, taking the raw PMT data as input.

3 The GeV-PeV module (i.e., Reco Tracks+Showers, Classifier) provides for multi-core reconstruction and classification of all triggered events.

4 Processed data are used for CCSN final processing, online follow-up searches of external alerts [3], and to identify interesting neutrino candidates [4].

3. The MeV CCSN processing

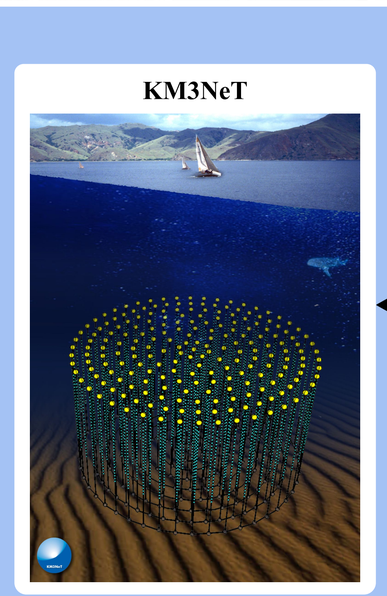
The main detection channel of CCSN MeV neutrinos for KM3NeT is the inverse beta decay of $\bar{\nu}_e$ in water. The MeV module running at each shore station computes, every 100 ms, the number of DOMs with an excess of coincidences between PMTs above the expected background in a 500 ms sliding window [5, 6]. Results from both detectors are then combined. KM3NeT is able to send alerts to SNEWS [7] with a latency <20 s and a false alarm rate <1/week.

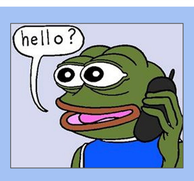


4. Follow-up searches of external alerts

After being processed, data from both the detectors are transmitted to a common multi-messenger dispatcher and then used for follow-up searches of external alerts and to identify interesting neutrino candidates. The following follow-up analyses are currently implemented and are automatically activated every time an interesting multi-messenger alert is received [3], in order to search for KM3NeT events in spatial and temporal coincidence:

- Gravitational Waves (GWs);
- Gamma Ray Bursts (GRBs);
- IceCube neutrinos;
- Fast Radio Bursts (FRBs);
- Microquasars;
- General transients;
- CCSNe.



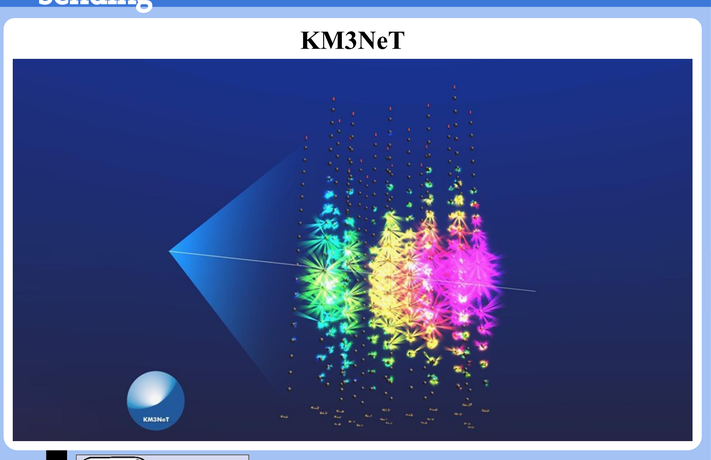


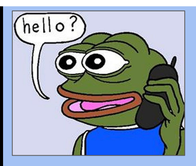
5. Alert sending

The identification of interesting neutrino events relies on a dedicated system [4], which continuously search for significant neutrino candidates using both ARCA and ORCA reconstructed data, according to the following workflow:

- A pre-selection stage is applied to the reconstructed data;
- Dedicated selections for single high-energy neutrino identification and multiplet identification are run in parallel;
- For each event passing the selections, a search for potential sources in the event direction is performed;
- Results are combined and alerts are ready to be sent.

The alert sending system is currently being finalized, and public distribution of alerts is expected to start before the end of this year.





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