Results of the follow-up of external triggers with KM3NeT

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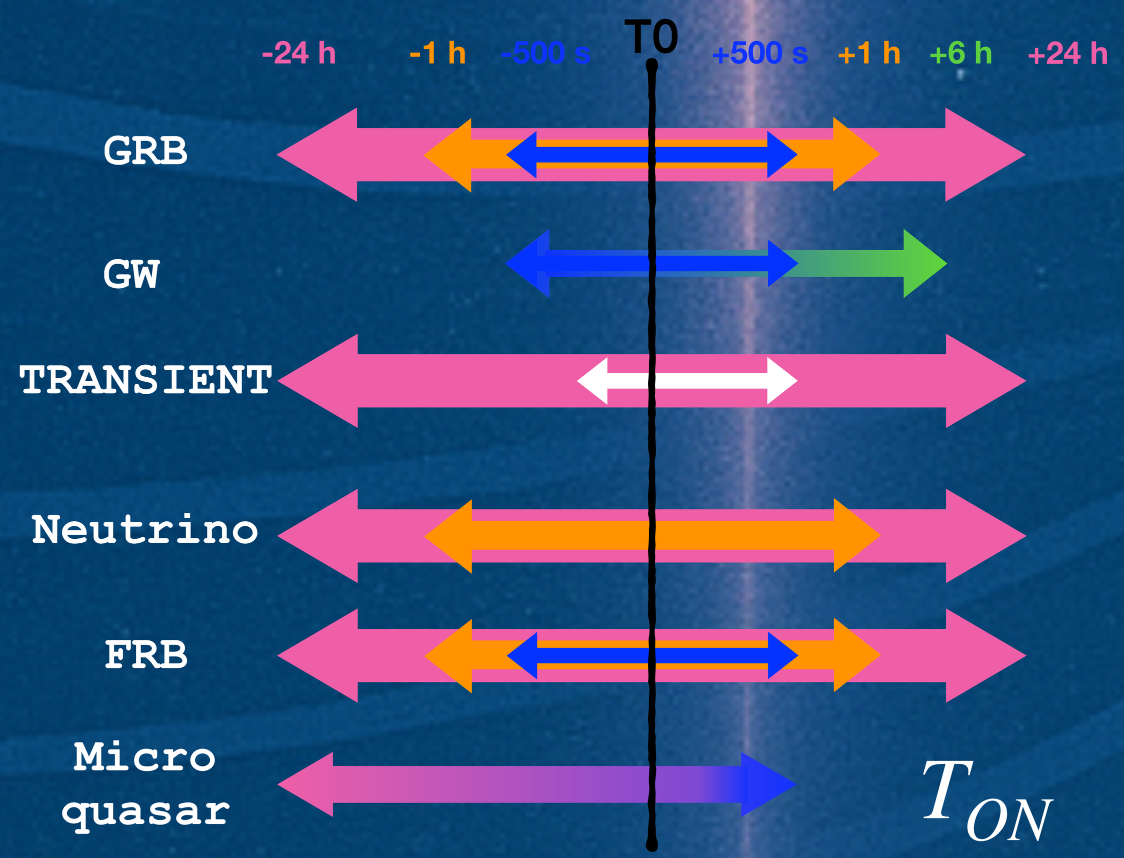
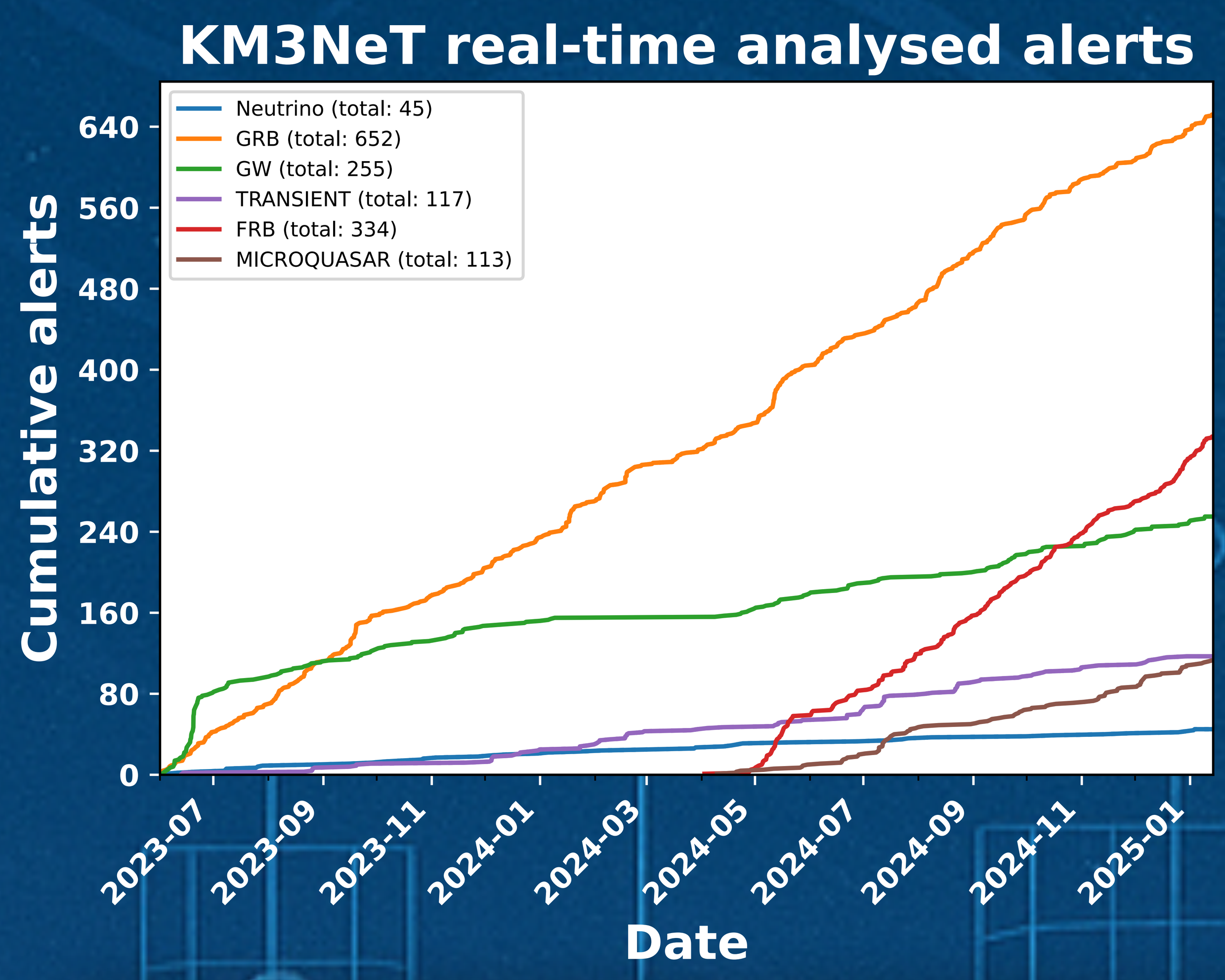
KM3NeT

KM3NeT detectors

- Network of Cherenkov detectors [1]:
  - ➡ **KM3NeT/ARCA** optimized for high-energy (TeV-PeV) astrophysical neutrinos.
  - ➡ **KM3NeT/ORCA** optimized for few-GeV atmospheric neutrinos.
- 31 x 3" PMTs hosted in pressure resistant glass sphere: Digital Optical Module (DOM);
- 18 DOMs anchored at the seafloor with buoyancy at the top form a detection unit (DU).
- 115 DUs evenly spaced form a building block.





External follow-ups

- **Gamma-ray Bursts (GRBs)** detected by INTEGRAL, Fermi and Swift: ~ 1 selected trigger/day.
- **Gravitational Wave (GW)** events detected by LIGO and Virgo: ~ 0.5 selected trigger/day.
- **Transient** events detected by observatories like Fermi, Swift, MAXI or HAWC: ~ 1 selected trigger/week.
- **Neutrino** events shared by IceCube: ~ 1 selected trigger/2 weeks.
- **Fast Radio Bursts (FRB)** reported by Chime and the TNS catalogue: ~ 1 selected trigger/day.
- **Micro-quasar** flares studied through an internal broker: ~ 1 selected trigger/week.

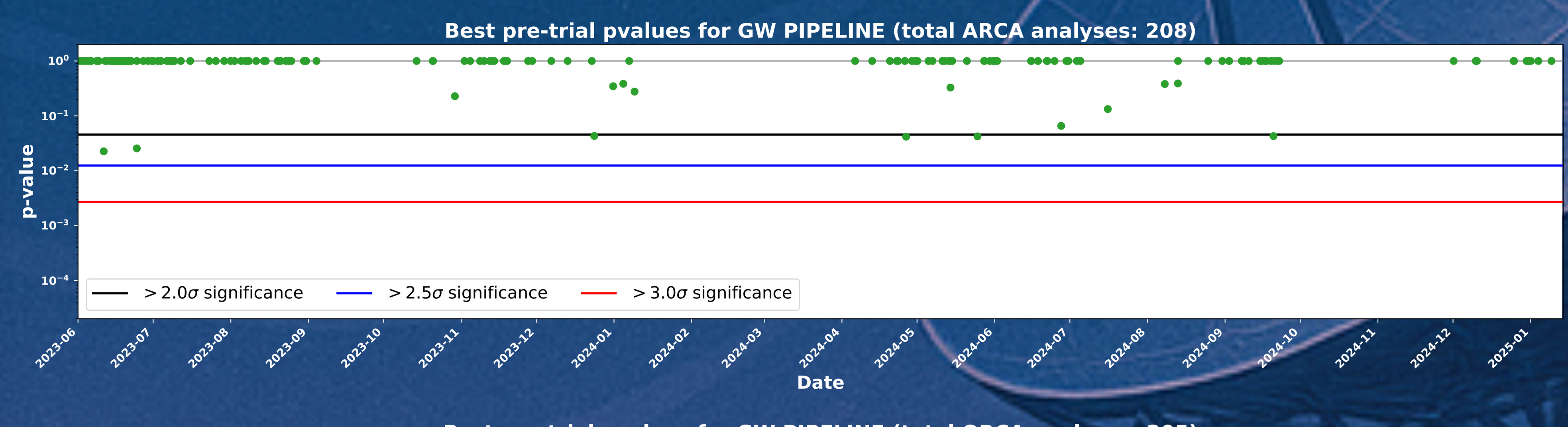
Methodology

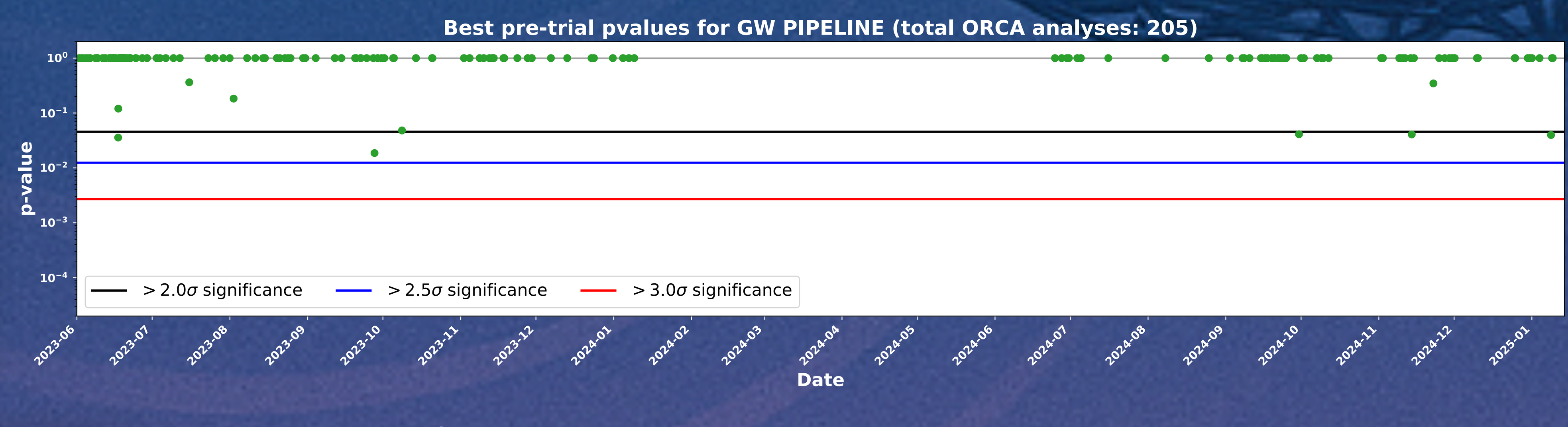
Correlation analysis based on a ON-OFF technique [2]:

- ON region: where the signal is expected. Convolution of the angular error of the external alert and of the median angular uncertainty of the KM3NeT events (2° for KM3NeT/ARCA and 4° for KM3NeT/ORCA).
- OFF region: data-driven background estimate considering zenith bands, enclosing the ON region movement due to the Earth's rotation.
- T_{ON}: predefined time intervals, representing the window in which to search for a possible time correlation.
- T_{OFF} : two weeks of data collected prior to T_{ON} which are used for the background estimation.
- Livetime and solid angle rescaling. If events are detected in the ON region, the Poisson significance is calculated. Additionally, if pre-computed acceptances are available, upper limits are also determined.
- Generation of plots and skymaps to validate the results and support external reporting.

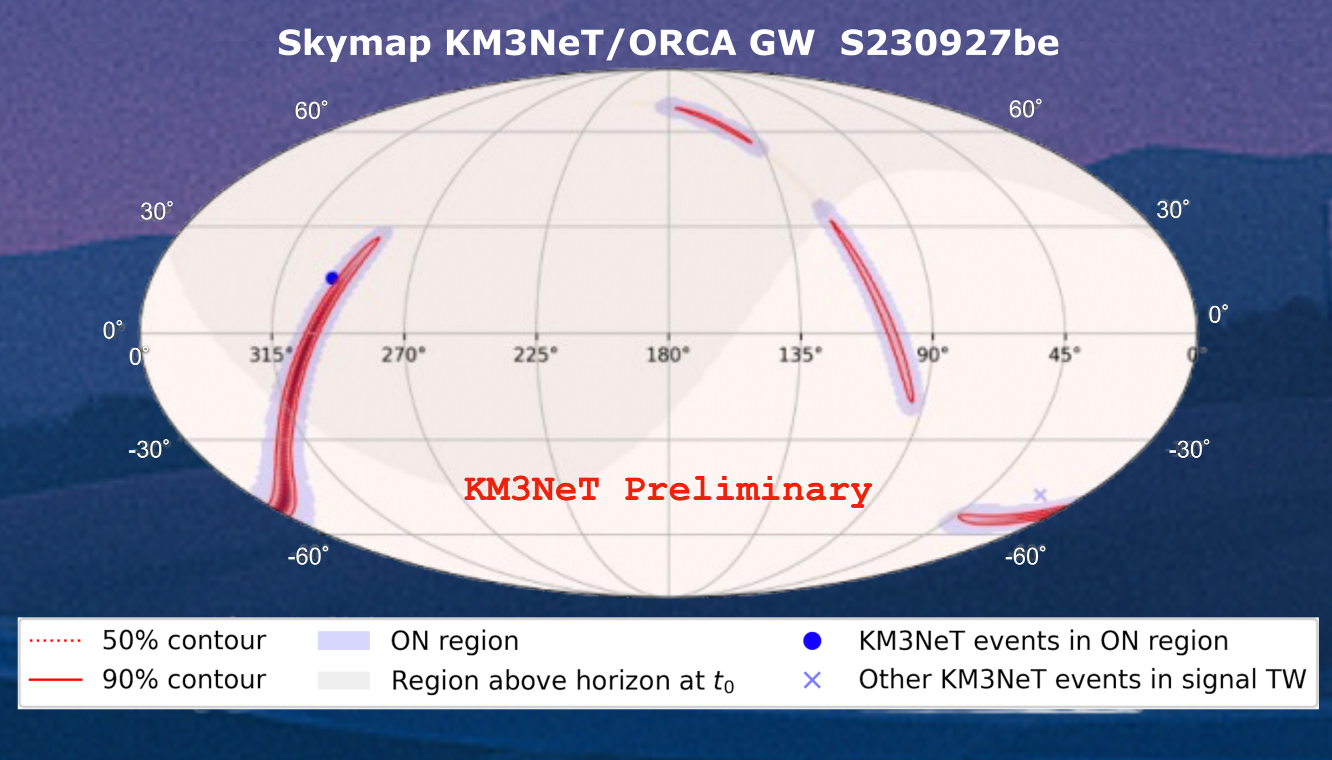
Results

Timeline of the best pre-trial p-values computed for selected GW follow-up performed with data collected with respectively the KM3NeT/ARCA (top) and KM3NeT/ORCA (bottom) detectors during the period 01 June 2023 – 14 January 2025.





Skymap of the GW-neutrino association corresponding to the lowest p-value: alert S230927be [3], for which the pre-trial significance is around 2.3 σ.



Conclusions

The KM3NeT real-time framework has been fully operational for over two years and is efficiently processing data from both detectors. Additionally, continuous weekly shifts are established to monitor the system's performance and report any noteworthy results via dedicated communication channels.

No significant neutrino counterparts have been identified in any of the follow-up analyses.

References

[1] KM3Net collaboration, Letter of intent for KM3NeT 2.0, J. Phys. G 43 (2016) 084001.
[2] T.P. Li and Y.Q. Ma, Analysis methods for results in gamma-ray astronomy., 272 (1983) 317.
[3] https://gracedb.ligo.org/superevents/S230927be/view/, Sept., 2023.