Real-time Multi-Messenger Analysis Framework of KM3NeT

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Motivation

- Realtime neutrino analysis framework goals:
  - Look for online neutrino transient sources
  - Receive external EM/GW/ν alerts; search ν correlation
  - Send online (all flavor, all-sky) neutrino alerts (e.g. multiplets, HE)
- Requires: Fast online reconstruction & fast selection of high-purity neutrino sample

Online Analysis Framework

- Response time ~ O(10 s)
- Event processing in the ORCA & ARCA shore station common analysis framework for data of both detectors
- Fully operational in ORCA6, in implementation in ARCA6
- Scalable with detector configuration
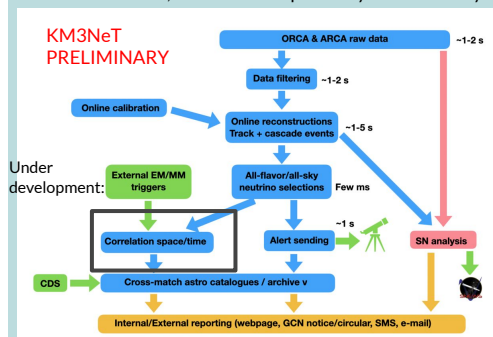- For CCSN search, see dedicated poster by V. Kulikovskiy

Fig. 1. Overview of the online analysis framework.
SNEWS: The SuperNova Early Warning System[1], CDS: Astronomical Data Center with catalogues of the astronomical objects outside the solar system.

Online Reconstruction

- Same fit algorithms as offline reconstruction
- Reconstruction of tracks[2] and cascades[3] separately
- Fast: ~1s (track: 0.1s, cascade: ~1s) /event ORCA6
- Median angular resolution at preliminary selection for numu CC events (limited by size of the detector): 9^0 at 10 GeV, up to 1° at TeV
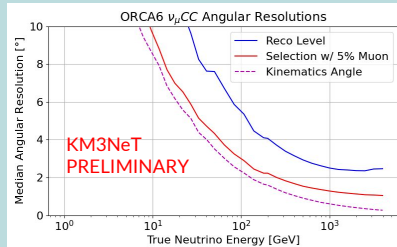

Fig. 2. Median angular resolution vs. true neutrino energy

Online Neutrino Selection

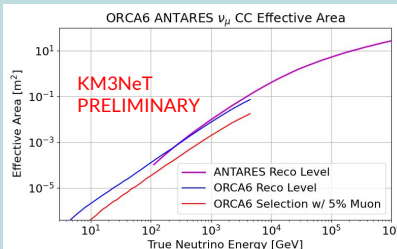### Comparable Effective Area of ORCA 6 & ANTARES:

Fig.3. Effective Area vs. true neutrino energy at the reconstruction level, at neutrino selection with 5% atmospheric muon contamination rate.

Online Neutrino Selection

- Goal: Fast online selection of a high-purity neutrino sample
- Classification model trained with gradient boosting[4] decision tree
- Each event classified with a score indicating probability of neutrino; process time ~ 0.01s
- Preliminary selection at 5% muon contamination (not yet optimized for transient analysis), background muon reduced by 10^6 times & keeping 38% of the upgoing ν_μ CC signal. ~ 10 neutrinos (8.4 numu)/day in ORCA6
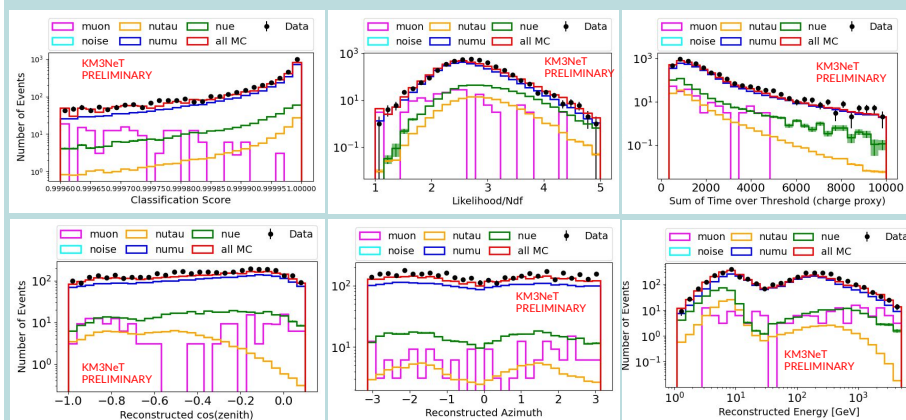- First test on ORCA6 data:

Fig.4. Data/MC comparisons for classification score, the likelihood/ndf, sum ToT (proxy for charge), reco. cos(zenith), reco. azimuth, and reco. energy

Summary & Outlook

- Fast online event reconstruction and classification, framework response time O(10 s), alert receiving, sending ready
- Preliminary online selection in place with high purity neutrino sample
- Starting online analysis now & alert sending beginning in 2022

References

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3. A. Domi, PhD thesis http://hdl.handle.net/11567/985989 (2019)
4. T. Chen, & C. Guestrin, Proceedings Of The 22nd ACM SIGKDD International Conference On Knowledge Discovery And Data Mining pp. 785-794 (2016)