The Online Multi-Messenger Program of KM3NeT

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The KM3NeT detector

KM3NeT

Water Cherenkov neutrino detector currently in construction at the bottom of the Mediterranean Sea

Two detectors

3D arrays of optical modules, each with 31 PMTs, attached to vertical lines
ARCA: 2 arrays of 115 lines each. Scarsily instrumented volume, optimized for detection of TeV-PeV neutrinos
ORCA: 1 array of 115 lines. Volume densely instrumented for detection of GeV-TeV neutrinos
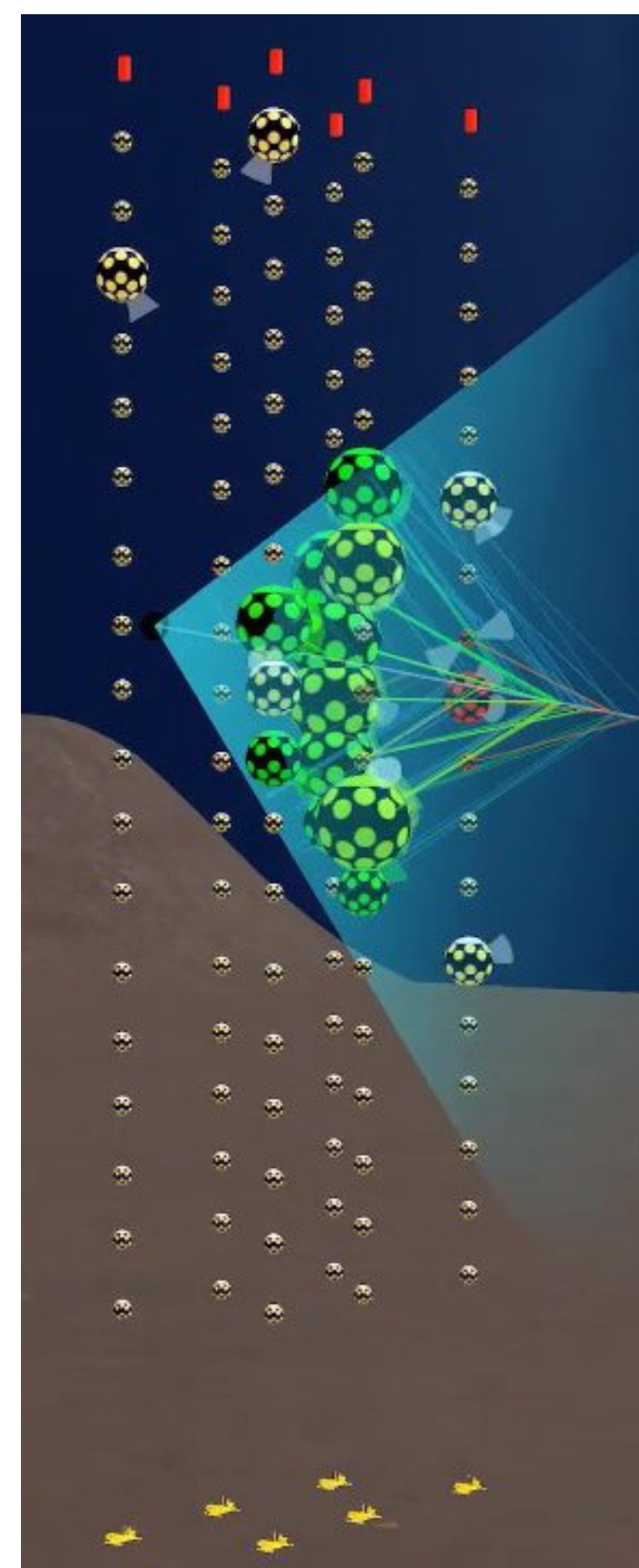
Online Framework Overview

Response time: below 30 seconds
Event Reconstruction and Classification:
Same reconstruction as offline, except for dynamic positioning (yet)
ORCA: both track and cascade reconstruction running online, classification for tracks using BDTs and shower classifier under development, angular resolution of 8° at 20 GeV, ~1° at TeV
ARCA: online track reconstruction operational with cascade soon to be added, GNN classifiers under development, angular resolution of ~0.8° at TeV, less than 0.3° above 1 PeV (for now)

Objectives

Goals of KM3NeT Real-time Neutrino Astro analyses:
– Core-Collapse Supernova monitoring for prompt alerts
– Receive external EM/GW/neutrino alerts and search for correlated neutrino
– Send all flavor, all-sky neutrino alerts (multiplets, HE) to external observatories for follow-up

Two pipelines:
– Core-Collapse Supernova Detection and Follow-up of external alerts with MeV neutrinos
– Event Based with GeV to PeV neutrinos: Filtering, Reconstruction, Classification, Correlation and Alert Generation
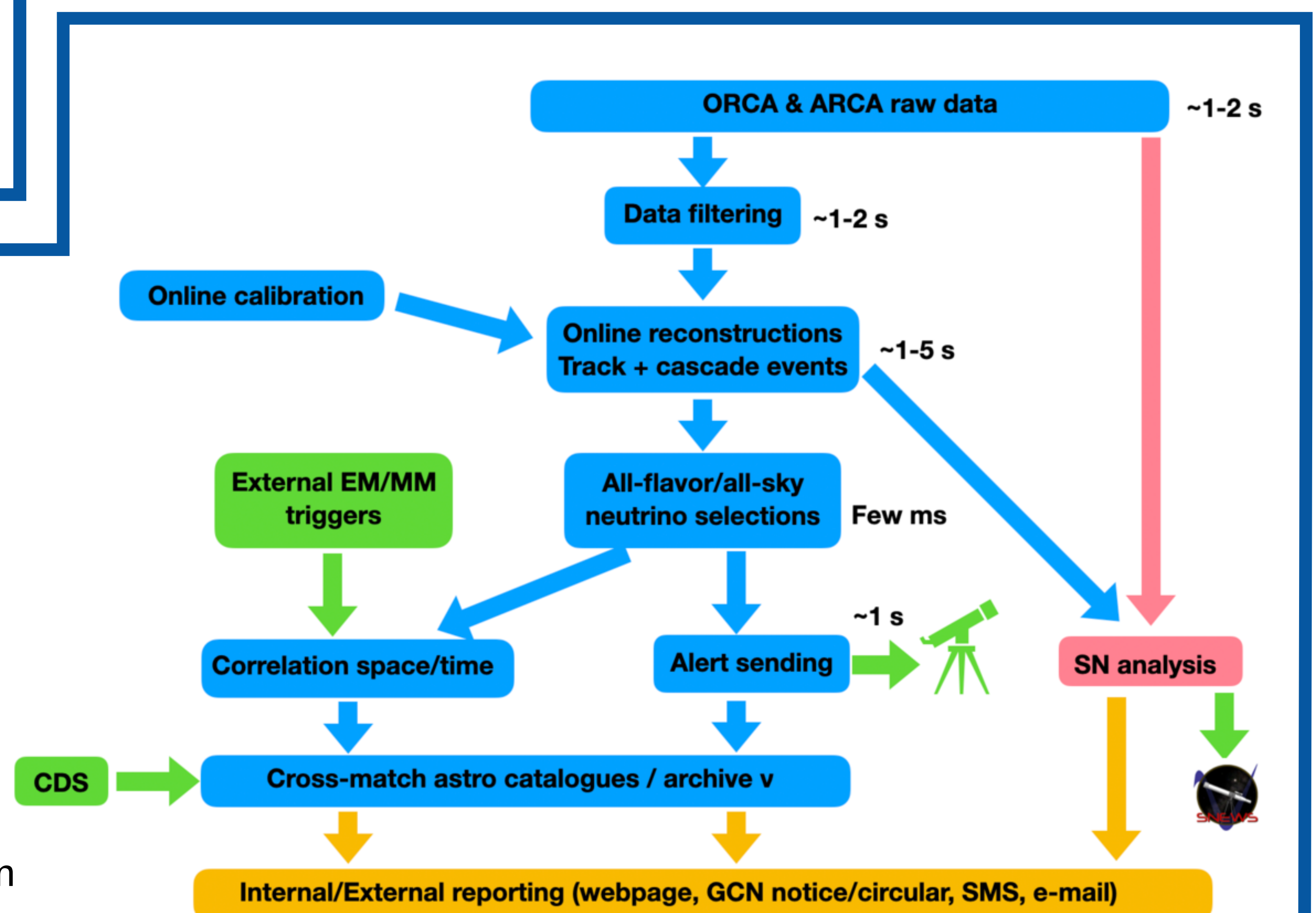

Correlation Analysis

Principle of the analyis
– Parse external triggers of interest from the GCN
– From data, compute an expected number of background events from different temporal and spatial regions (OFF region) and compare to the number of events in the region of interest (ON region)
– Multiple iterations as time goes on to take into account potential delayed neutrinos

First results
– Two unmodeled GWs follow-ups with MeV neutrinos (GCN Circulars 26249 and 26751)
– Multiple correlation analyses with IceCube neutrino events associated with blazars, with one result published in ATel #15290
– In beginning of October 2022, search for coincident neutrinos at both MeV level and above GeV for GRB221009A, one of the most energetic gamma-ray burst ever observed
No neutrinos were found in the ON region
(GCN Circular 32741)

KM3Net/ARCA sky map, GRB221009A follow-up
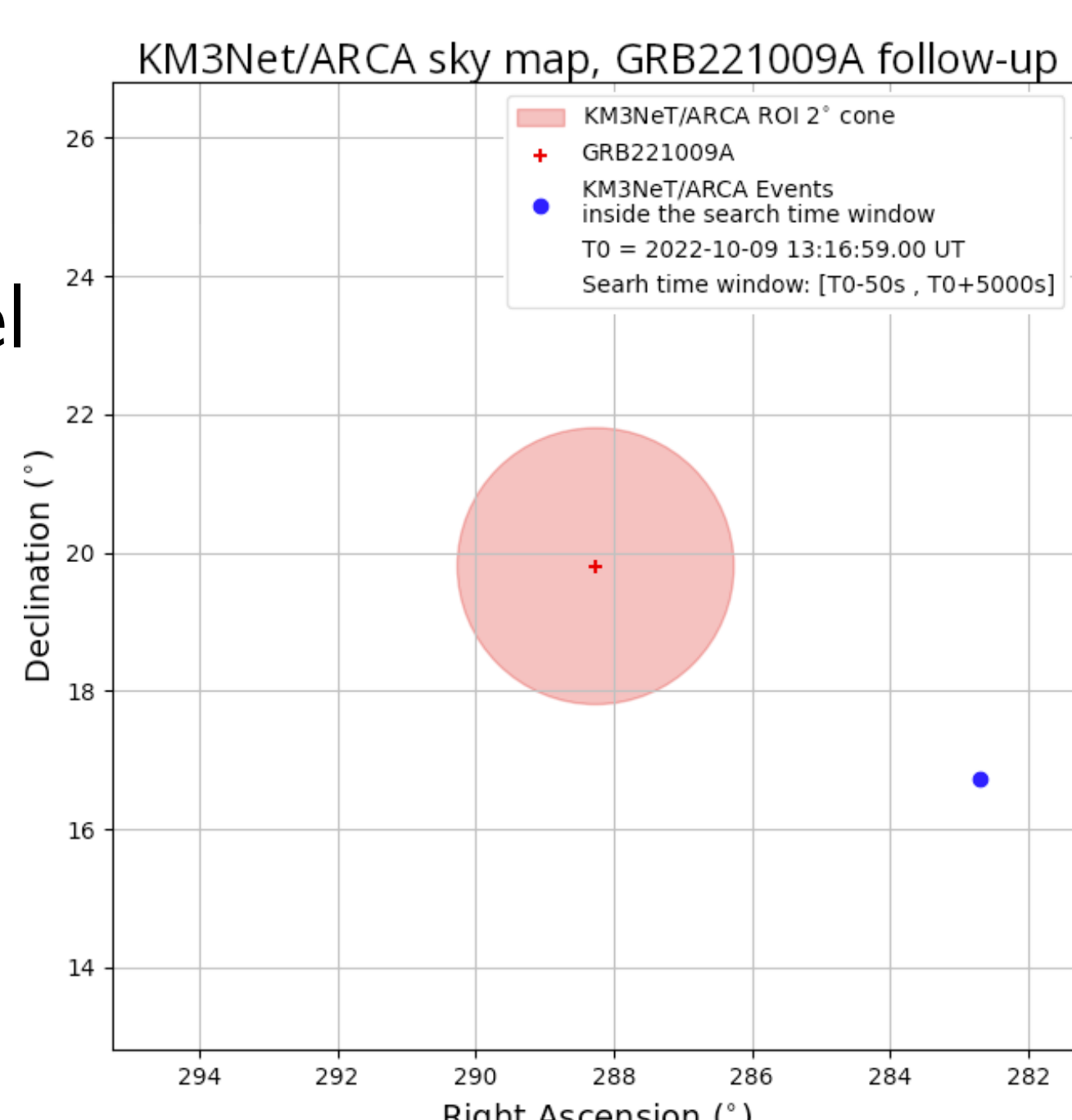
Alerts

Planned Alert types (similar target alert rate for all detector configurations):
– Neutrino triggers (~1/month): High energy and Multiplet neutrino alerts
– Physics triggers (~1-2/month): Correlated neutrinos based on astrophysical properties (AGN/TDE/CCSN/GRB/Sun...)
  Correlation with astro catalogues, archive astro data point searches [FINK for ZTF/LSST and astrogeo for radio, Fermi-LAT 4FGL/FAVA]

Online Shifter Tools
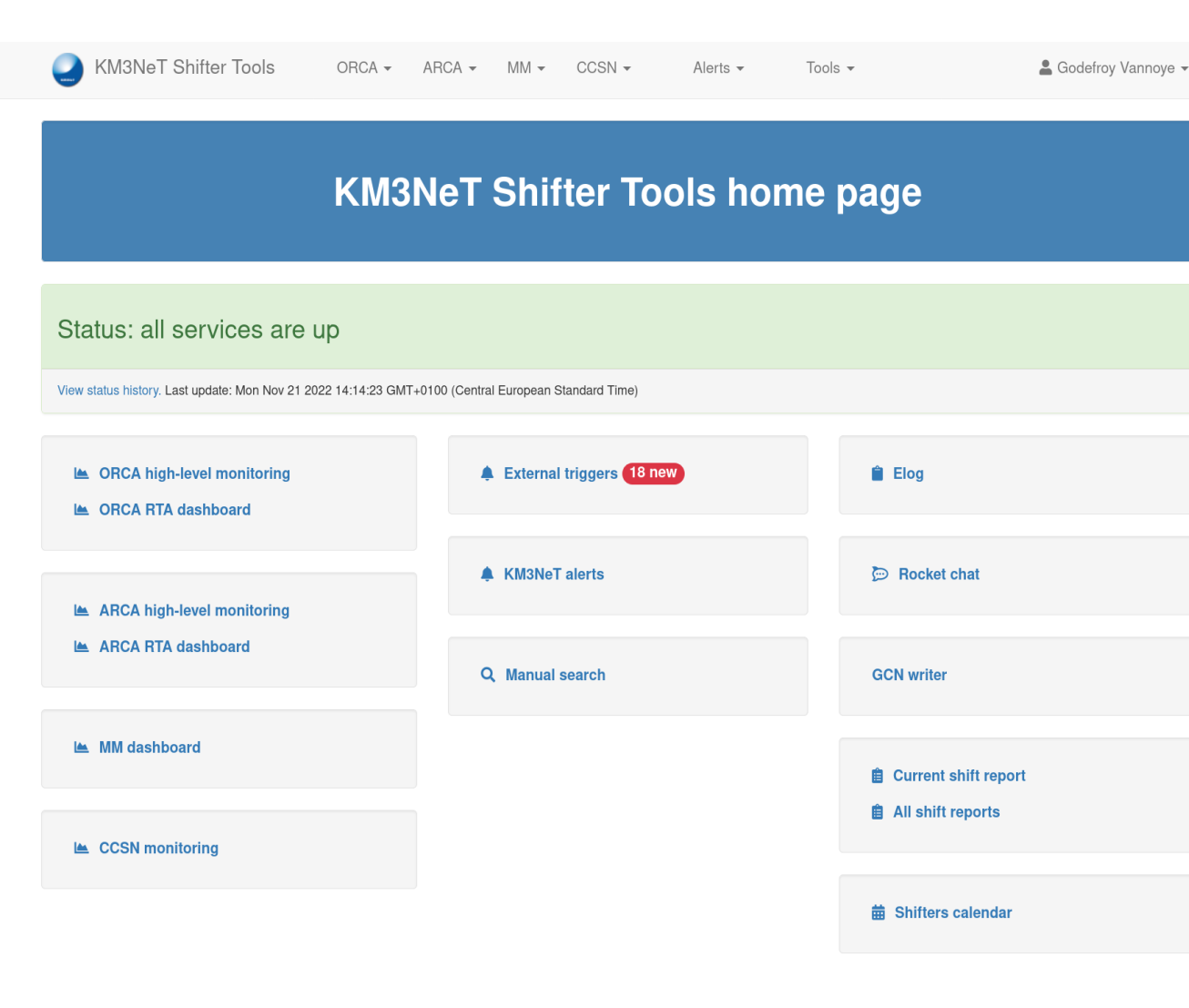
– Monitors the health of data-taking: low level & high level (e.g. data stability)
– Lists external & internal alerts
– Manual search for correlated events in the database given an external trigger
– Internal reporting management

Summary

– KM3NeT online alert system is fast with a latency on the order of 10 s (optimization in progress)
– Automatic follow-up of external alerts by end of 2022 and public alerts foreseen for Summer 2023