Pointing to neutrino sources

Our cosmic messengers



Rasa Muller rasam@nikhef.nl
Aart Heijboer aart.heijboer@nikhef.nl
Alfonso Garcia Soto alfonsog@nikhef.nl

The idea in a nutshell

The **identification of cosmic objects emitting high energy (HE) neutrinos (ν)** could provide new insights about the Universe and its active sources. The **KM3NeT/ARCA detector** ① will excel in the identification of these neutrino sources because of its **precise angular resolution** (< 0.2 degree for E > 10 TeV ν_μ events). Statistical **methods** ② are being developed and tested with Monte-Carlo pseudo-experiments to compute the **discovery potential** to and **sensitivity** ③ for **diffuse** and **point-like** cosmic neutrino fluxes for KM3NeT/ARCA. Other flavours (electron and tau neutrinos) will be added to the analysis in the near future . In addition, analysis steps will be refined and prepared for **real data** analysis.

1 Neutrino detection with KM3NeT/ARCA

Detector design

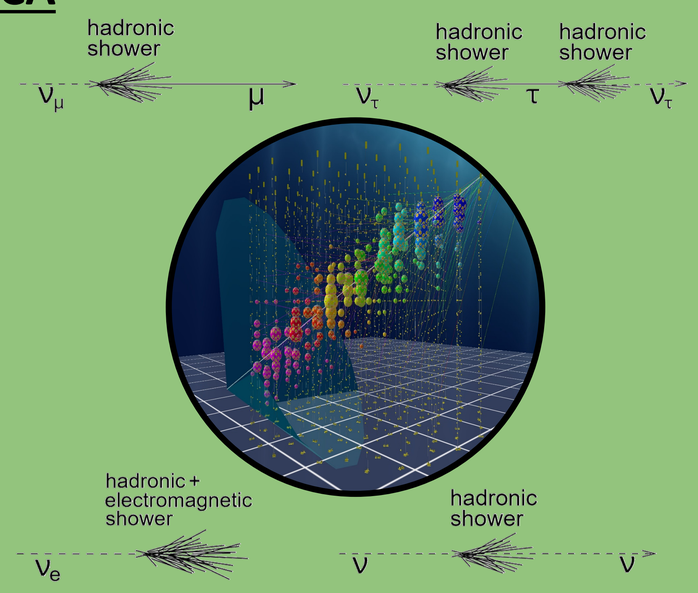
- KM^3 detector at the bottom of the Mediterranean See
- Light sensitive elements to detect *"Cherenkov radiation"* caused by charged particles from neutrino hitting water molecule
- Sensitive to GeV – PeV neutrinos

Event topologies

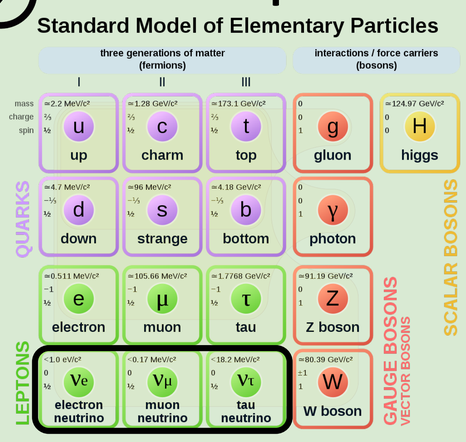
- Track: High E lepton traveling trough water before it decays
  Provides good pointing resolution
- Shower: Electromagnetic shower and/or hadronic
  Provides good energy resolution

Background events

- Atmospheric neutrinos and muons



Neutrino particle



The neutrino (ν) is an elementary particle with spin ½, no electric charge, and a small, but nonzero mass, interacting only via the weak force resulting in extremely small interaction cross sections making them hard to detect but a great source to study cosmological objects and particle acceleration processes.

Sources of high energy cosmic ν's

I) Diffuse

- Isotropic ν flux on top of background
- Observed in 2013 by IceCube detector

II) Point source

- Excess of neutrinos from one (or more) specific direction(s) in the sky may indicate the existence of point source(s)
- Multi-messenger

Physics to extract

- Identify source population(s)
- Origins and acceleration mechanisms & relation to HE cosmic and γ rays

2 Methods

Analyse charged current muon neutrinos (ν_μ^{CC})

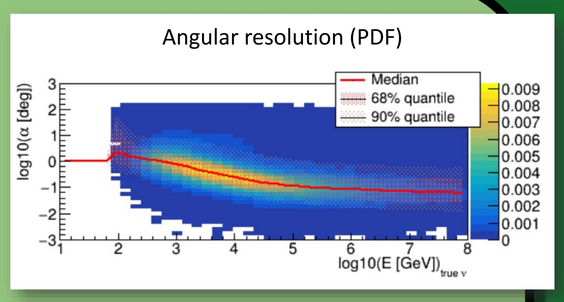
In charged current interactions the ν becomes a lepton through the exchange of a W$^-$ with a nucleon: $\nu_\mu + N \rightarrow \mu + X$

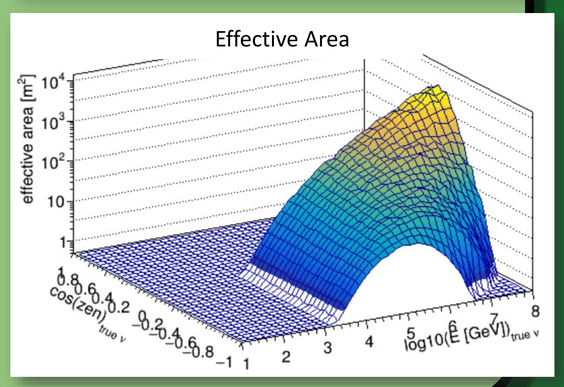
Selection cuts

Reduce background while maintaining as much signal as possible by selecting only up-going track-like events, for which the reconstruction algorithm passed successfully, with: $E_{reco} > 10$ GeV, estimated error on the reconstructed angle of 1 degree or less, estimated track length of at least 300 meters and a cut on the reduced likelihood (likelihood/N_{hits} > 0.7)

Detector response functions for ν_μ^{CC} with cuts:

1) Expected background rates as a function of reconstructed energy & direction
2) Reconstructed direction as a function of true energy & direction
3) Reconstructed energy as a function of true energy & direction





3 Sensitivity and discovery potential for neutrino sources

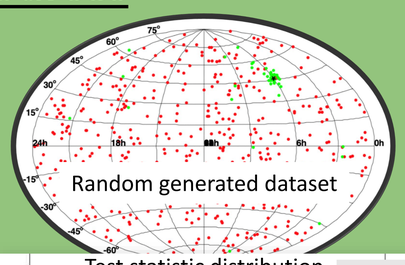
Analysis framework for KM3NeT

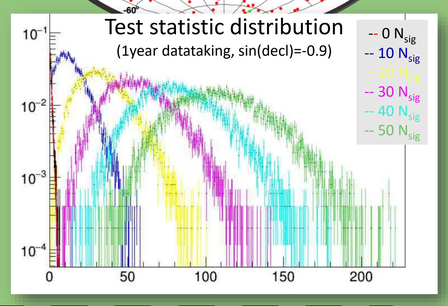
In the new framework based on work for the ANTARES collaboration, we build our H0 (background) model, and our H1 (signal + background) model consisting of several components (a point source / a diffuse isotropic flux / background) depending on the analysis to test.

With the detector response PDF's we can generate Monte Carlo pseudo experiments to analyse the sensitivity and discovery potential of KM3NeT/ARCA to diffuse and point source fluxes.

Statistical analysis [work ongoing]

Varying the amount of years of detection, the position of the source, the number of events we expect, and leaving the fit parameters free (N_{sig}, N_{bkg}, spectral index ($E^{-\gamma}$), position of the source) we will compute sensitivities and discovery potentials.





Take Home Message

With the new build analysis framework for KM3NeT we can compute sensitivities and discovery potentials to point sources and diffuse fluxes. With the found cuts, and the promising angular resolution for ν_μ KM3NeT/ARCA with 1 building block is expected to perform better than IceCube. Work is ongoing to verify the exact values that substantiate this statement.

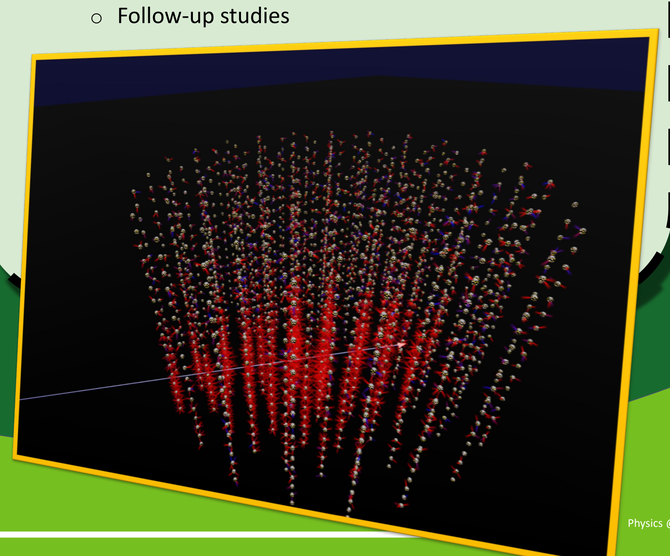
Next steps

1: Expand current MC-based work

- Include more information: other flavors (ν_e, ν_τ) / showers / extended sources / time dependence
- Fine tune analysis methods / statistical errors

2: Do an analysis with real data from the sea!

- In 2021, the detector is planned to increase in size from 2 lines to >20 lines! This means real data for:
  - Multi-messenger analysis
  - Follow-up studies



* References

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