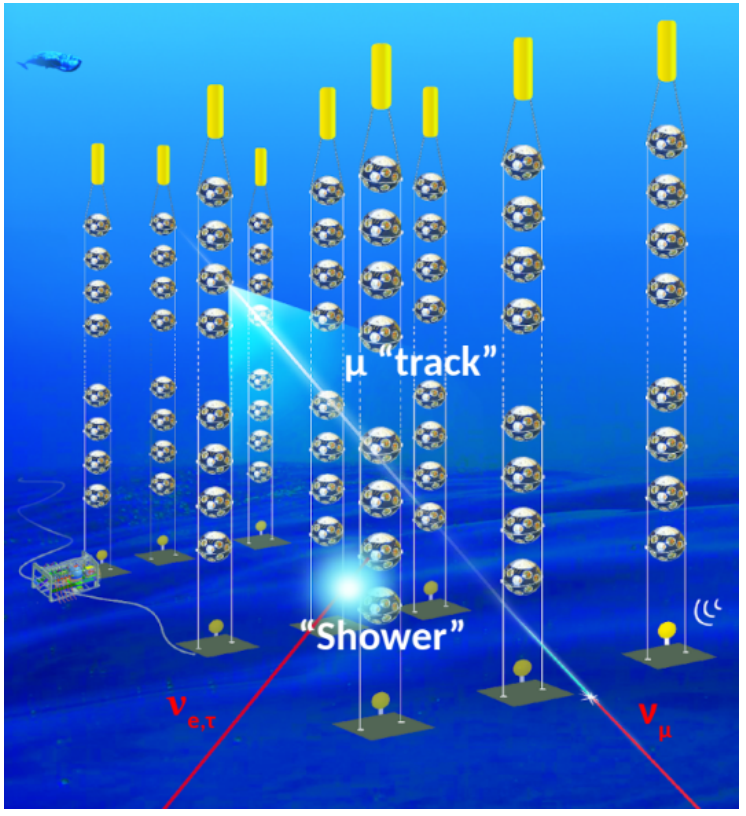
Enhancing low energy reconstruction and classification in KM3NeT/ORCA with transformers

17/06/2025, EuCAIF Conference

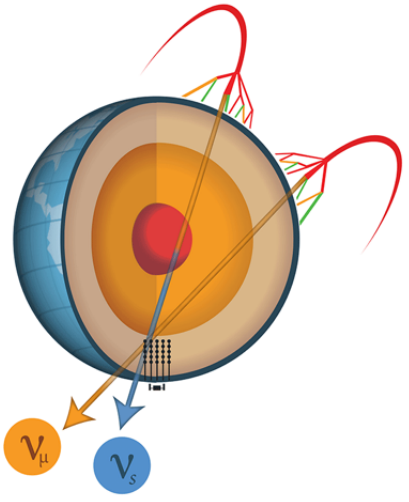
Iván Mozún Mateo

KM3NeT/ORCA telescope

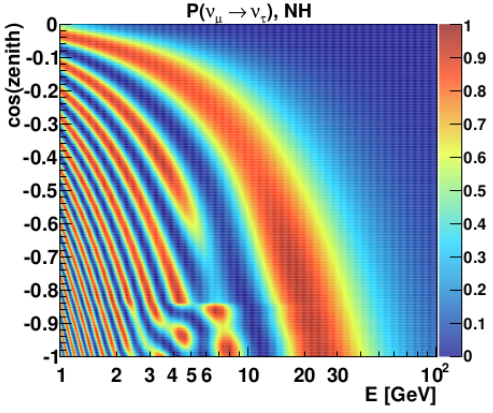


Schematic representation of neutrino events in KM3NeT telescopes.

Neutrinos are indirectly detected in KM3NeT telescopes from the Cherenkov radiation emitted by charged particles produced in neutrino interactions.



Travel of atmospheric neutrinos thourgh the Earth and detected at IceCube neutrino telescope.



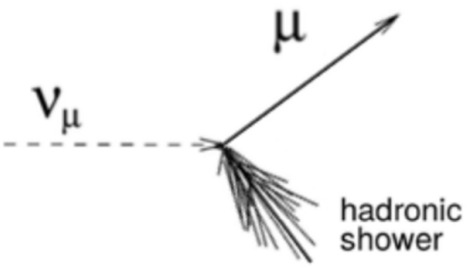
Oscillation pattern for $\nu_{\mu} \rightarrow \nu_{\tau}$ as function of neutrino energy and zenith angle.

Challenges of neutrino reconstruction

Reconstruct neutrinos from light

Maximum Likelihood Fit (MLF) algorithms
- Reconstruct under track or shower hypothesis
- Do not reconstruct the neutrino properties themselves

nuT model beyond MLF
- Directly reconstruct neutrino properties
- Simultaneously reconstruct all event types

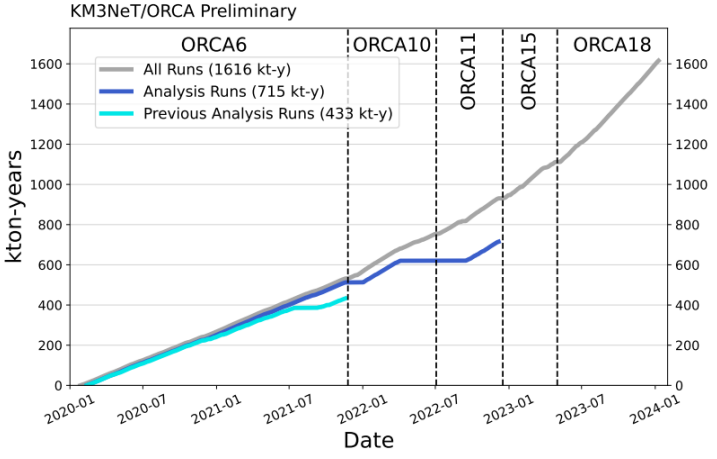


Scaling up the detector

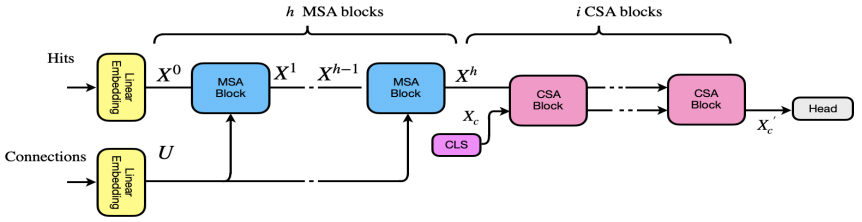
Realistic Monte Carlo samples are generated based on actual data-taking runs, capturing the complexities of deep-sea conditions

Need to use data and computing resources efficiently

Pre-trained models are leveraged to propagate information across configurations

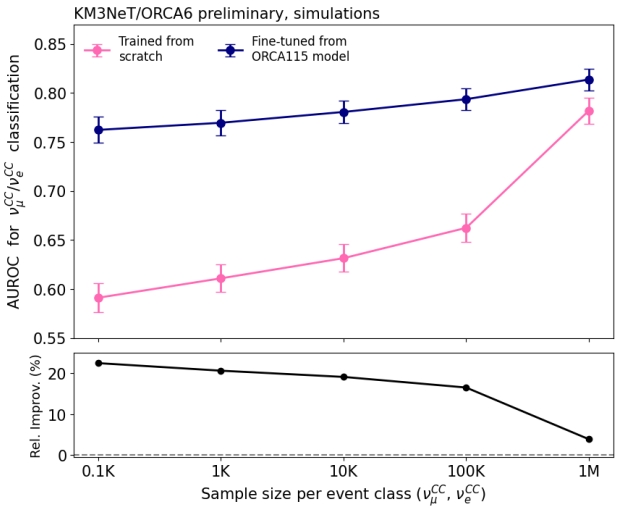


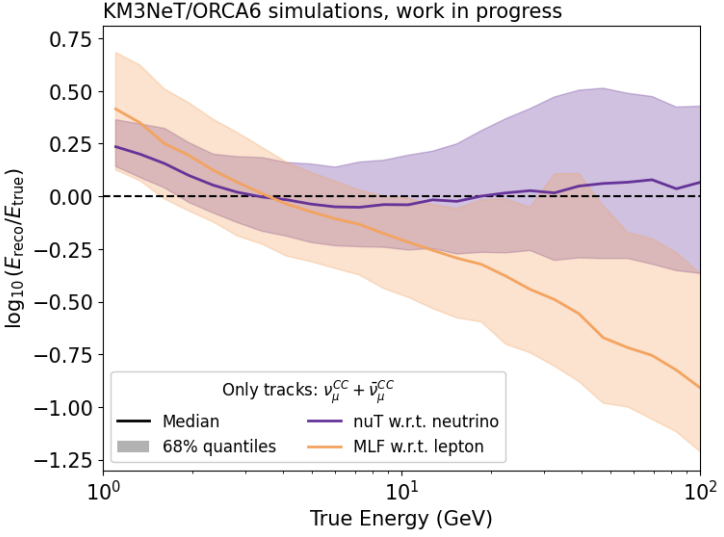
Enhanced reconstruction in KM3NeT/ORCA

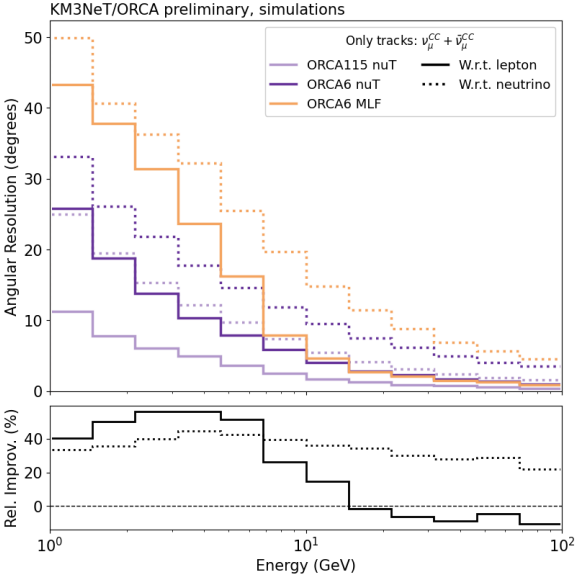


nuT model: neutrino reconstruction with transformers

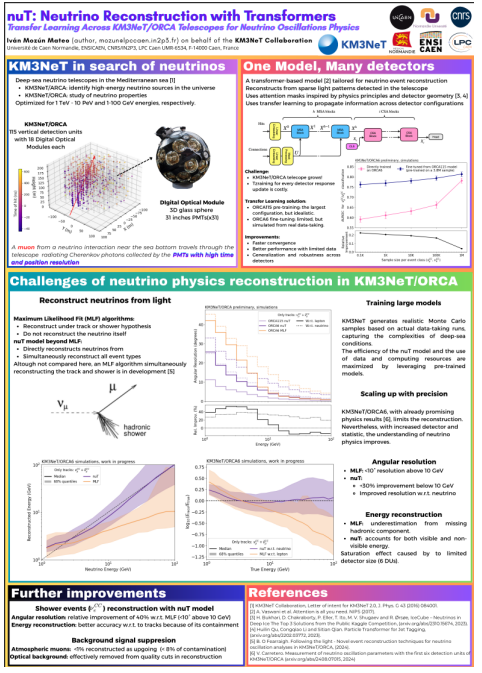
- A transformer-based model [1] tailored for neutrino event reconstruction
- Reconstructs from sparse light patterns detected in the telescope
- Uses attention masks inspired by physics principles and detector geometry [2, 3]
- Uses transfer learning to propagate information across detector configurations







Come and see the poster!



References

[1] A. Vaswani et al. Attention is all you need. NIPS (2017).

[2] H. Bukhari, D. Chakraborty, P. Eller, T. Ito, M. V. Shugaev and R. Ørsøe, IceCube – Neutrinos in Deep Ice The Top 3 Solutions from the Public Kaggle Competition, (arxiv.org/abs/2310.15674, 2023).

[3] Huilin Qu, Congqiao Li and Sitian Qian. Particle Transformer for Jet Tagging, (arxiv.org/abs/2202.03772, 2023).