*Introducing a Simultaneous **Track+Shower Reconstruction Algorithm**, dedicated for **KM3NeT/ORCA***

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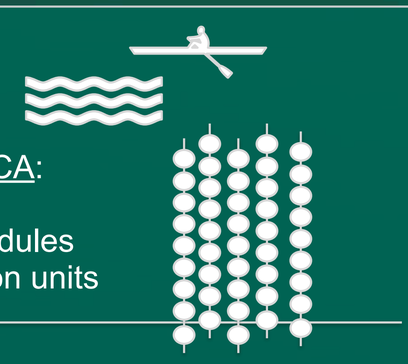
The KM3NeT Infrastructure

- KM3NeT : research infrastructure in the Mediterranean Sea.
- 31 PMTs + electronics -> 1 optical module
  18 optical modules -> detection unit
- KM3NeT/ORCA: neutrino oscillation studies & Neutrino Mass Ordering, 1-100 GeV neutrinos



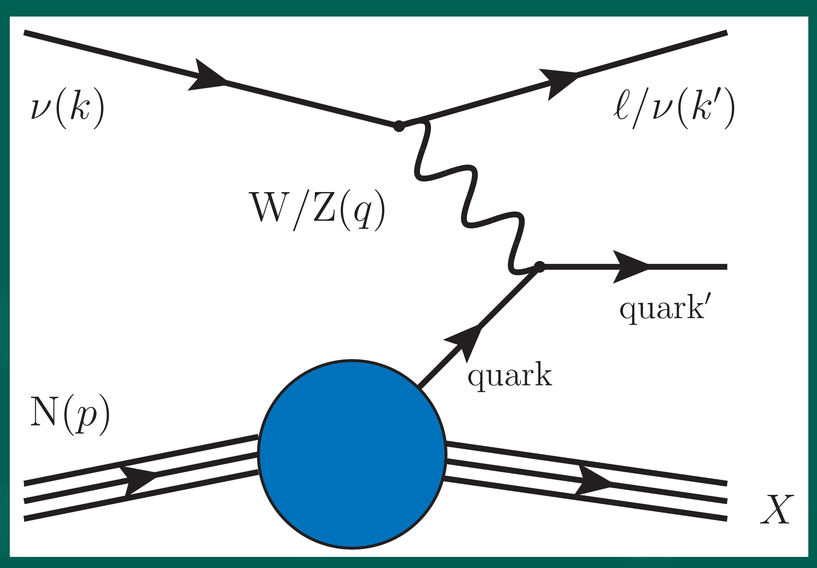
KM3NeT/ORCA:

18 optical modules
x 115 detection units

Motivation

- Cherenkov neutrino detectors: usually reconstruct the track-like and shower-like component of neutrino events separately.
- More complete approach: reconstruct the interactions as simultaneous track+shower events.

Deep inelastic scattering $\Longrightarrow$ there will always be a hadronic shower created alongside a track-like event, e.g. an out-going muon. Relevant for KM3NeT/ORCA.



Garcia A, Gauld R, Heijboer A, Rojo J, JCAP 09 (2020), 025

Track+Shower Reconstruction

- Fit parameters: vertex position, time, two directions and two energies.

- Likelihood function: to be minimised

$$-\log \mathscr{L} = -\sum_{i}^{N_{PMTs}} \log P^{firsthit} - \sum_{i}^{N_{PMTs}} \log P^{hitPMT} - \sum_{i}^{N_{PMTs}} \log P^{non-hitPMT}$$

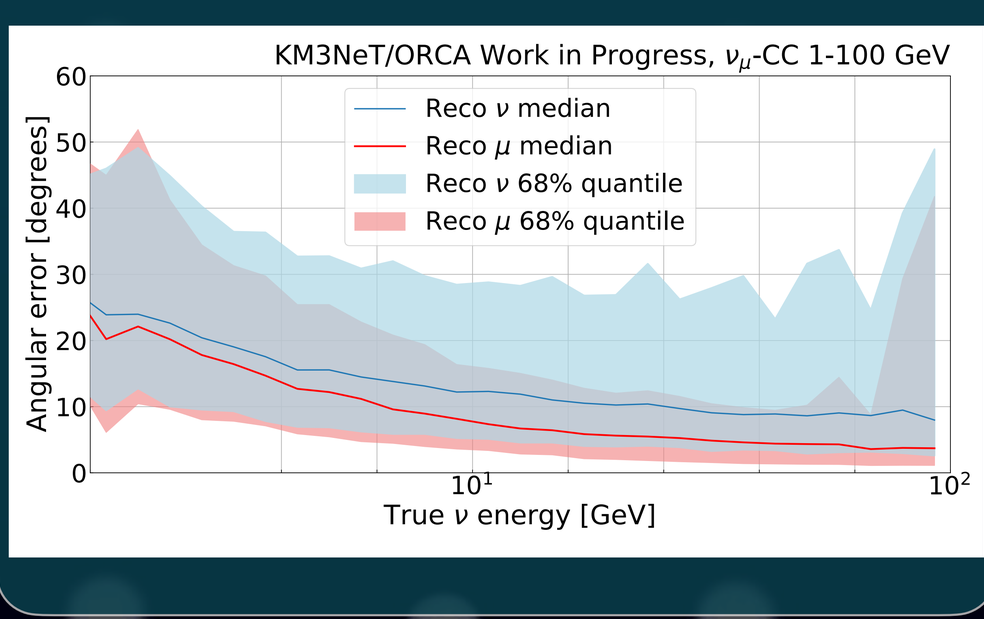
- Expression for reconstructed direction & energy:

$$E_{\nu}^{reco} = E_{\mu}^{reco} + E_{shower}^{reco}$$

$$\vec{\theta}_{\nu}^{reco} = w_{\mu} \frac{E_{\mu}^{reco}}{E_{\nu}^{reco}} \vec{\theta}_{\mu}^{reco} + w_{h} \frac{E_{h}^{reco}}{E_{\nu}^{reco}} \vec{\theta}_{h}^{reco}$$

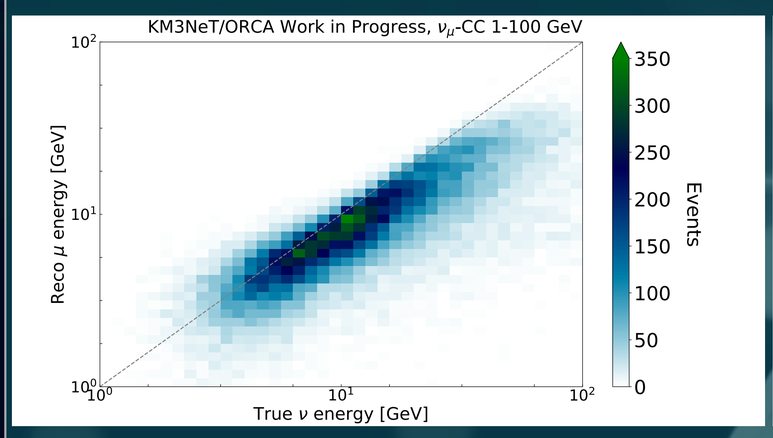
Neutrino Direction Resolution

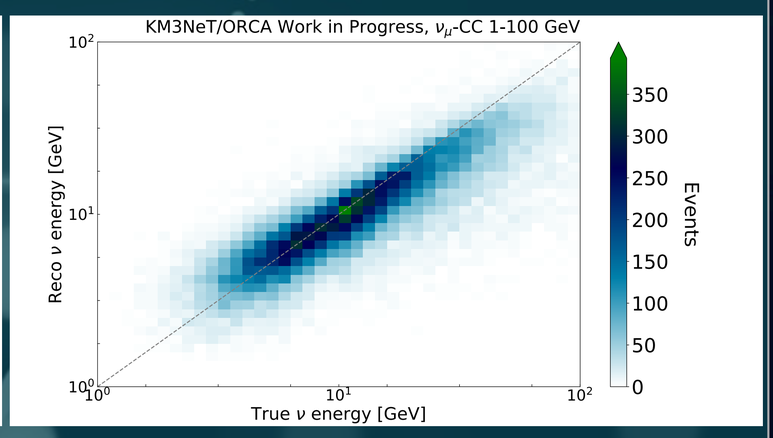
- Reco muon direction gives a better estimate of the true neutrino direction, compared to using reco neutrino direction



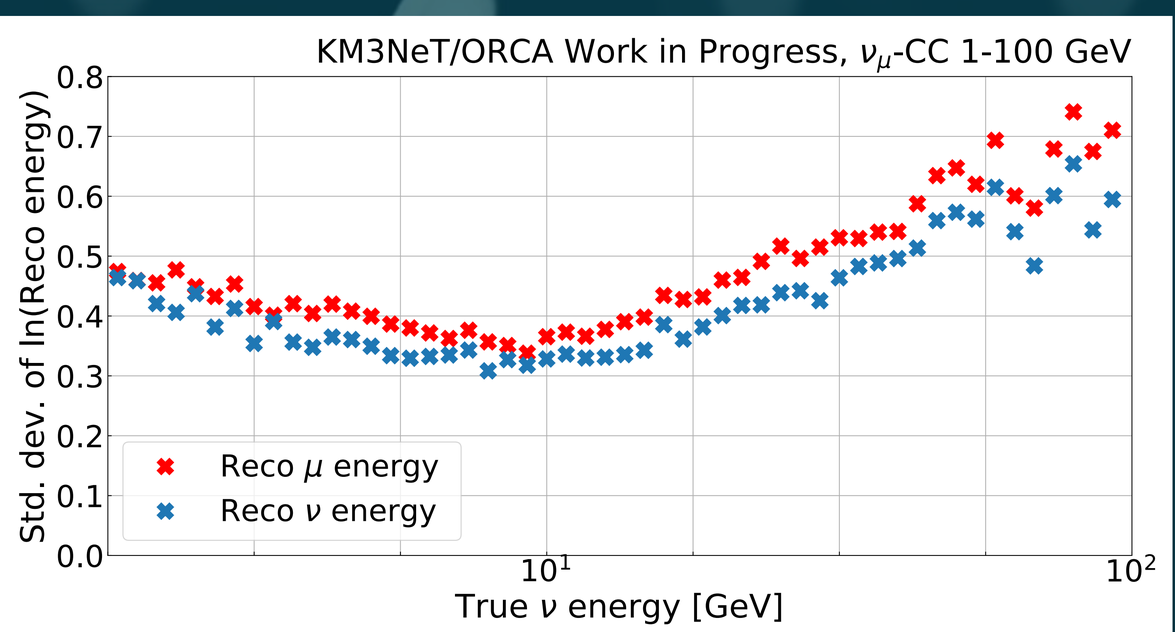
Neutrino Energy Resolution

- track+shower reconstruction results in a better estimate of true neutrino energy compared to track reconstruction





- track+shower reco neutrino energy gives a better estimate of true neutrino energy across the full range, compared to using track energy only



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Following the Light, Brían Ó Fearraigh, University of Amsterdam 2024.
KM3Net Collaboration, S. Adrian-Martinez et al., J.Phys.G 43 (2016) 8, 084001
KM3Net Collaboration, S. Adrian-Martinez et al., JHEP 05 (2017), 008