Status and Perspectives of KM3NeT/ORCA

EPS HEP

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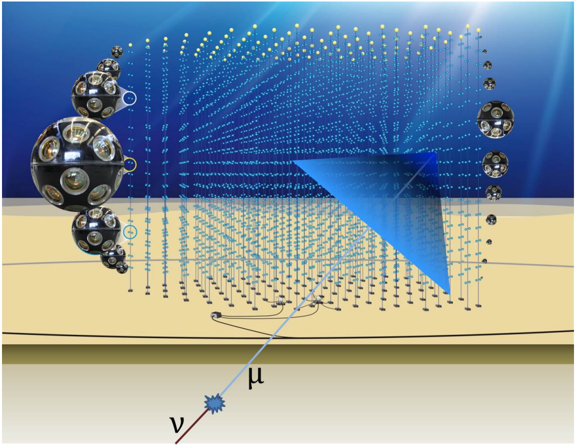

Figure 1: An artist's impression of KM3NeT.

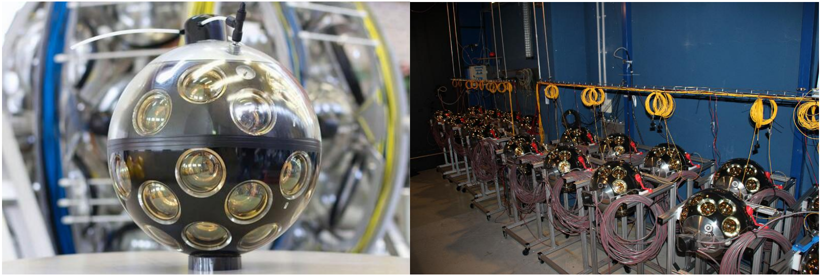

Figure 2: The digital optical module (left). A prototype detection unit in the dark room at CPPM (right).

Introduction
Oscillation Plots

Each zenith angle effectively corresponds to a different baseline.

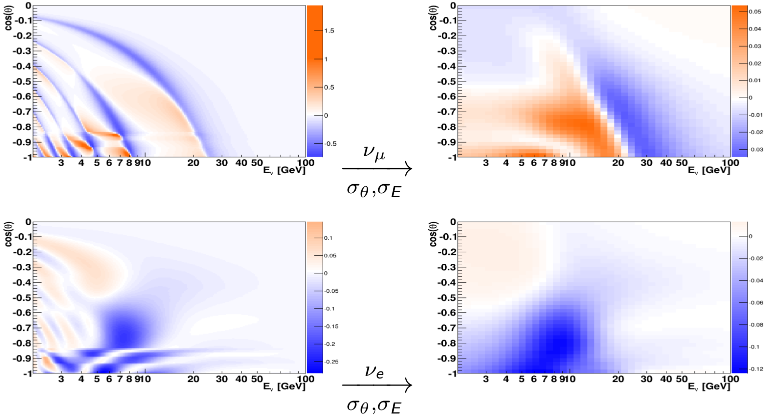

Figure 3: The asymmetry $\frac{N_{IH} - N_{NH}}{N_{NH}}$ for the muon and electron channels.

Tracks | Showers

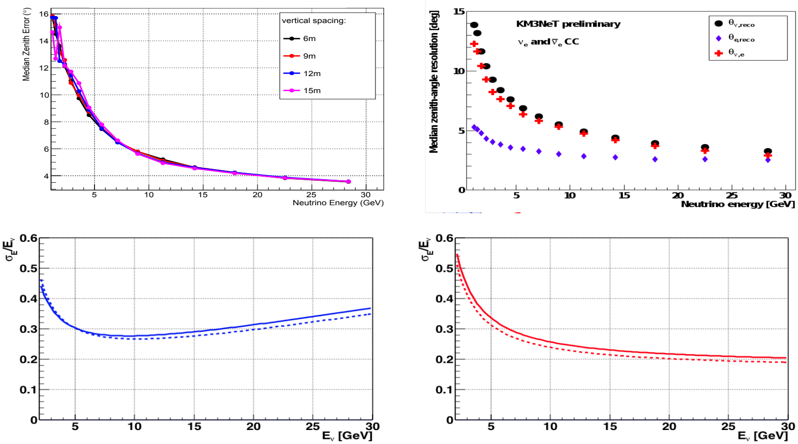

Figure 4: The median energy and zenith resolutions from the LoI (dashed lines are for antineutrinos).

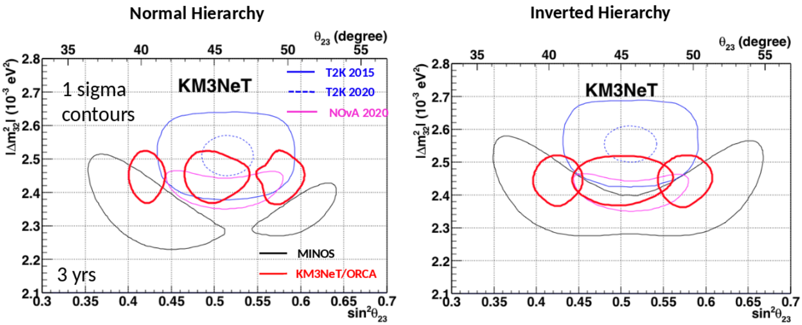

Figure 5: Measurement precision in Δm^2_{32} and $\sin^3\theta_{23}$ after three years of data taking with ORCA, shown for three test points.

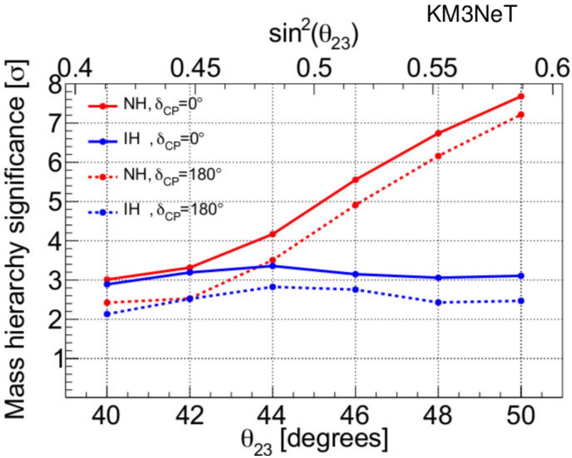

Figure 6: The ORCA sensitivity to the neutrino mass hierarchy after 3 years of data taking with a full detector, as reported in the KM3NeT LoI.

- Tau neutrinos are not identified on an event by event basis
- Measuring tau appearance allows unitarity measurements

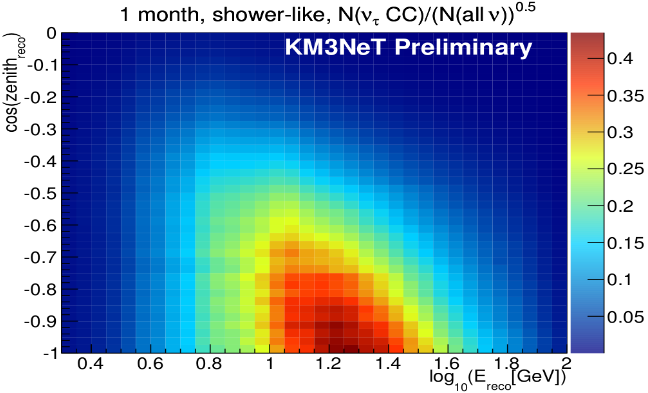

Figure 7: The per-bin significance of the detected ν_τ signal for a month of events classified as showers.

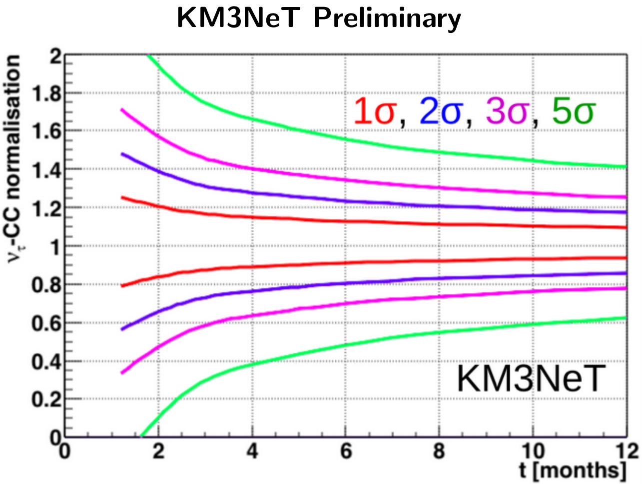

Figure 8: Sensitivity of the ORCA detector to appearance of ν_τ as a function of time. For unitary mixing, the $\nu_\tau - CC$ mixing is equal to one.

Letter of Intent

- Simplified detector geometry, 9m vertical separation and 20m horizontal separation
- Trigger based on L1 hits (i.e. at least two coincident photons on the same DOM in a 10ns time window)

New Analysis

- Realistic detector geometry, average 9m vertical separation and 23m horizontal separation with variation on the order of a metre
- New mixed trigger, based on a single L1 and a cluster of causally connected individual photons

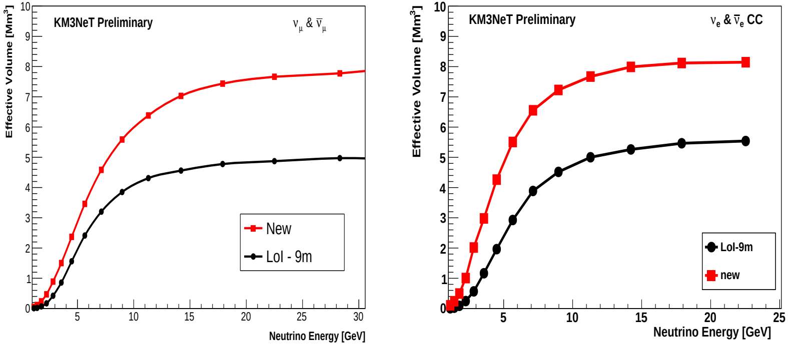

Figure 9: The change in ORCA effective volume after reconstruction, but before particle ID, for the muon (left) and electron (right) channels.

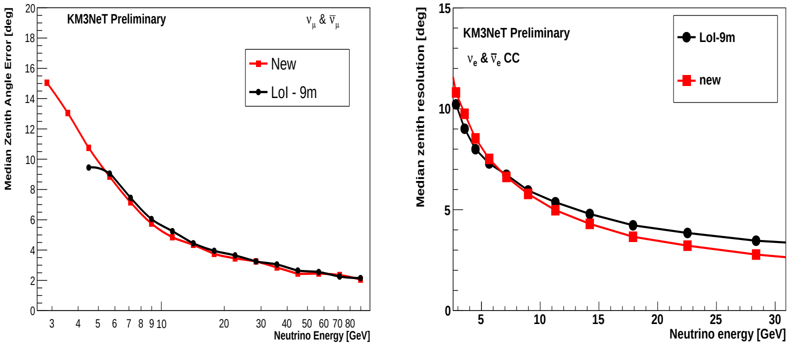

Figure 10: The corresponding change in zenith resolution after reconstruction, but before particle ID, for the muon (left) and electron (right) channels.

Conclusions

After three years of data taking with a full detector

- Determine the NMH with a significance of at least 3σ, in the worst case scenario
- Demonstrate tau appearance and constrain the unitarity of the PMNS matrix
- Measure the atmospheric oscillation parameters with a competitive precision

Furthermore, we expect our NMH sensitivity to improve substantially, with a larger instrumented volume and a new trigger.

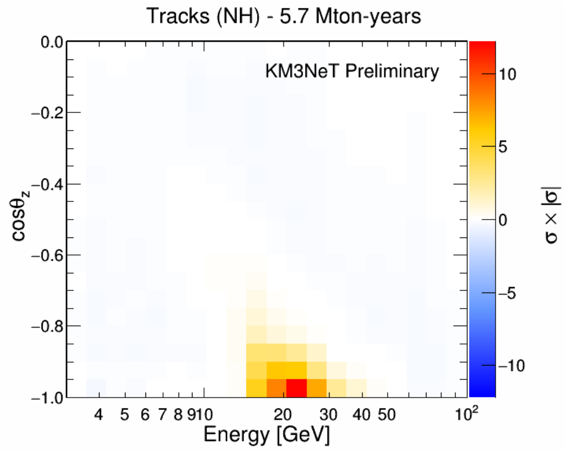

Figure 11: The signed chi square $\sigma = \frac{N_{\text{sterile}} - N_{\text{nominal}}}{\sqrt{N_{\text{nominal}}}}$ for a single sterile neutrino with $\Delta m^2_{41} = 0.3eV^2$.

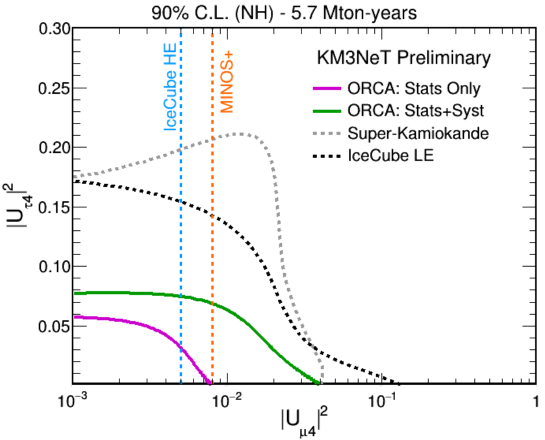

Figure 12: Sensitivity contours for sterile neutrinos, for both tracks and showers. Tracks are expected to dominate.

More details at arXiv:1601.07459

parameter	true value distr.	initial value distr.	treatment	prior
θ_{23} [°]	$\{40, 42, \ldots, 50\}$	uniform over $[35, 55]$ †	fitted	no
θ_{13} [°]	8.42	$\mu = 8.42$, $\sigma = 0.26$	fitted	yes
θ_{12} [°]	34	$\mu = 34$, $\sigma = 1$	nuisance	N/A
ΔM^2 [10^{-3} eV^2]	$\mu = 2.4$, $\sigma = 0.05$	$\mu = 2.4$, $\sigma = 0.05$	fitted	no
Δm^2 [10^{-5} eV^2]	7.6	$\mu = 7.6$, $\sigma = 0.2$	nuisance	N/A
δ_{CP} [°]	0	uniform over $[0, 360]$	fitted	no
overall flux factor	1	$\mu = 1$, $\sigma = 0.1$	fitted	yes
NC scaling	1	$\mu = 1$, $\sigma = 0.05$	fitted	yes
$\nu/\bar{\nu}$ skew	0	$\mu = 0$, $\sigma = 0.03$	fitted	yes
μ/e skew	0	$\mu = 0$, $\sigma = 0.05$	fitted	yes
energy slope	0	$\mu = 0$, $\sigma = 0.05$	fitted	yes

Figure 13: Default parameter settings used for the NMH analysis. Where μ and σ are given, they refer to a Gaussian distribution. The † indicates that seven initial values for θ_{23} are generated. They are $x + i \times 5^\circ$, where x is either 35 or 55 and $i \in [-3, -2, ..., 3]$.

The following base model is used to represent standard 3-flavour oscillations:

$\Delta m^2_{21} = 7.54 \times 10^{-5}\text{eV}^2$
$\Delta m^2_{31} = 2.47 \times 10^{-3}\text{eV}^2$
$\sin^2\theta_{12} = 0.308$
$\sin^2\theta_{13} = 0.0219$
$\sin^2\theta_{23} = 0.437$
$\delta_{cp} = 1.39\pi$

A 3+1 model is assumed with the following sterile parameters:

$\Delta m^2_{41} = 0.3eV^2$
$|U_{e4}|^2 = 0.04$
$|U_{\mu 4}|^2 = 0.02$
$|U_{\tau 4}|^2 = 0.18$

They were chosen to be close to the 90% CL limits in early 2016 and for consistency with previous KM3NeT examples.

Tau Assumptions

oscillation parameters				nuissance parameters			
parameter	true value	prior	start value	parameter	true val.	prior	start val.
θ_{12}	$33.4°$	fixed	fixed	norm ν_e CC	1	–	1
$\Delta m^2[\mathrm{eV}^2]$	7.53×10^{-5}	fixed	fixed	norm ν_μ CC	1	–	1
θ_{13}	$8.42°$	$0.26°$	$8.42°$	norm ν_τ CC	1	–	1
θ_{23}	$42°$	–	$42°$ / $58°$	norm ν NC	1	0.31	1
$\Delta M^2[\mathrm{eV}^2]$	2.44×10^{-3}	–	2.44×10^{-3}	energy slope	0	–	0
δ_{CP}	0	–	0	ν / $\overline{\nu}$ ratio	0	0.1	0