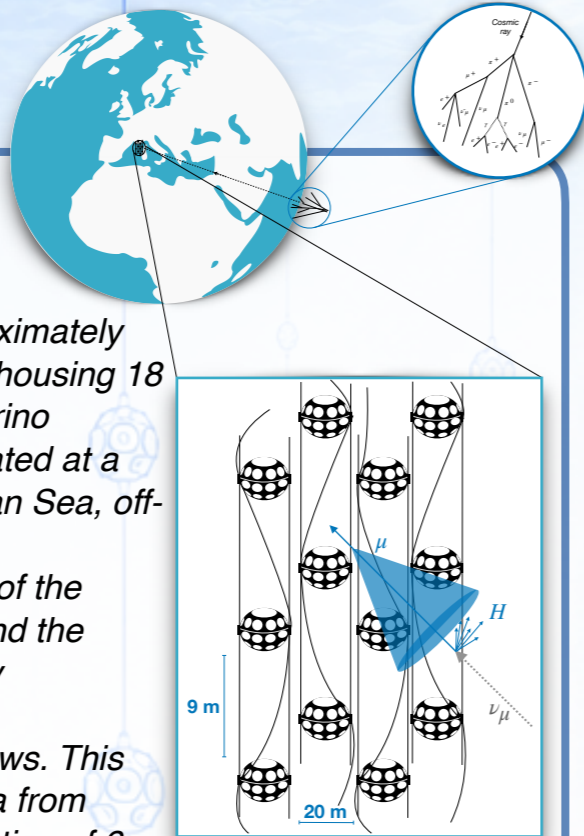


Measurement of the Neutrino Mass Ordering and Oscillation Parameters with KM3NeT/ORCA

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KM3NeT/ORCA

- KM3NeT/ORCA will be a 7Mton water-Cherenkov neutrino detector
- The final detector consists of approximately 200 meter-long vertical lines, each housing 18 optical modules, forming a 3D neutrino detection array. The detector is located at a depth of 2.5 km in the Mediterranean Sea, off-shore from Toulon, France
- **Main physics goal:** determination of the neutrino **oscillation parameters** and the **neutrino mass ordering (NMO)** by measuring atmospheric neutrinos
- The detector is taking data as it grows. This analysis presents accumulated data from early detector configurations consisting of 6, 7, 11, 13, 15 and 18 detection lines
- **Dataset for this analysis:** ~1.4 Mton-years of total exposure
- The NMO sensitivity is mainly driven by the **matter effect in ν_e and $\bar{\nu}_e$ appearance channels**



Analysis Method

- The model is a 2D PDF having reconstructed neutrino energy and $\cos(\text{zenith angle})$ as observables. A simultaneous fit was performed for the 2 data subsets and the 3 classes
- The oscillation parameters are estimated through negative likelihood minimisation
- The NMO is determined through hypothesis testing
- The test statistic (λ) is defined as:

$$\lambda = -2(\ln(\mathcal{L}(D|IO)) - \ln(\mathcal{L}(D|NO))),$$

where D is data, NO is normal ordering, IO is inverted ordering and \mathcal{L} is the likelihood

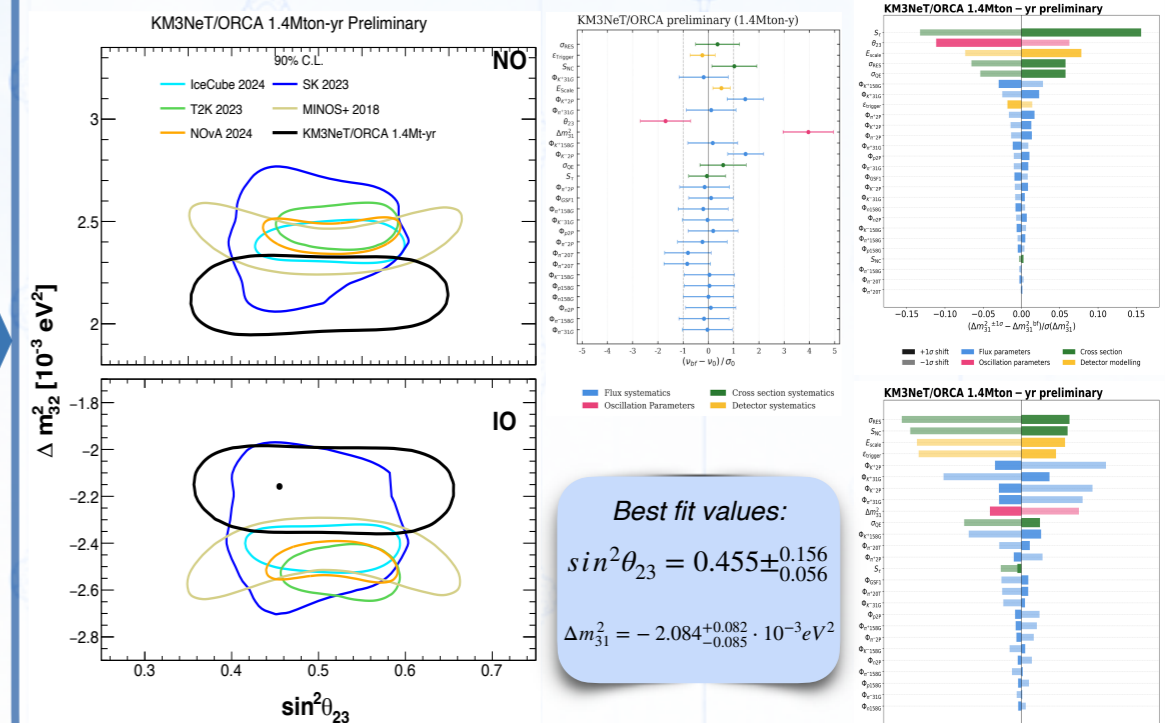
- The TS distribution for each hypothesis is approximated by generating pseudo-experiments
- The significance on the inferred NMO is presented as the p -value of the TS of the data, given the test statistic distribution
- Systematic errors are considered for neutrino cross sections, neutrino fluxes and detector effects

References

- [1] NuFIT 6.1 (2025), www.nu-fit.org
 [2] JHEP 12 (2024) 216 [arXiv:2410.05380]

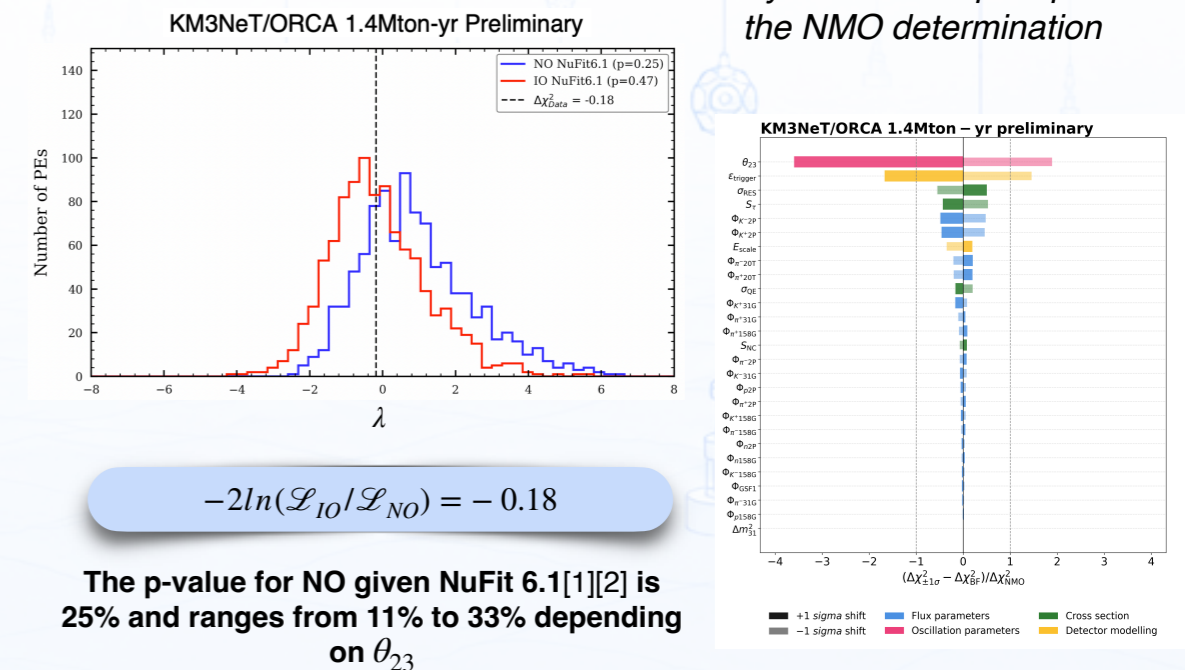
Oscillation Parameter Measurement

- 90% CL contour plot:
- Systematics impact and pull plots:



NMO Significance

- NMO is determined by evaluating p -values for both hypotheses using the data and TS distributions
- Systematics impact plot for the NMO determination



Event Selection

The data is divided into 2 subsets: ORCA6-7 and ORCA11-18

- **Background:**
 - ➔ Atmospheric muons, mostly filtered by the Earth by keeping only up-going events
 - ➔ Random noise (bioluminescence, potassium-40 decay)
- **Event filtering and classification:**
 - ➔ Classes and sample purity are defined using 'muon' scores, 'track' scores and 'noise' scores that are assigned to each event using a BDT model
 - ➔ Optimal physics sensitivities were found for 3 classes: Tracks, Intermediate, Showers

| Event Type | ORCA6/7 | | | ORCA11-18 | | |
|-----------------------------------|----------------|-----------------|-----------------|------------------|-------------------|-------------------|
| | ORCA6/7 tracks | ORCA6/7 interm. | ORCA6/7 showers | ORCA11-18 tracks | ORCA11-18 interm. | ORCA11-18 showers |
| $\nu_e CC + \bar{\nu}_e CC$ | 50 | 336 | 682 | 87 | 646 | 911 |
| $\nu_\mu CC + \bar{\nu}_\mu CC$ | 3869 | 748 | 493 | 5641 | 1151 | 557 |
| $\nu_\tau CC + \bar{\nu}_\tau CC$ | 36 | 80 | 176 | 53 | 141 | 212 |
| $\nu NC + \bar{\nu} NC$ | 19 | 112 | 276 | 31 | 219 | 430 |
| atmospheric $\mu + \bar{\mu}$ | 29 | 22 | 30 | 31 | 20 | 21 |
| Total MC | 4003 | 1298 | 1657 | 5843 | 2176 | 2131 |
| Total Data | 4098 | 1361 | 1586 | 6329 | 2236 | 2016 |