

Oscillation research with KM3NeT/ORCA

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On behalf of the KM3NeT collaboration

Lake Louise Winter Institute 2022
23/02



KM3NeT/ORCA: Overview



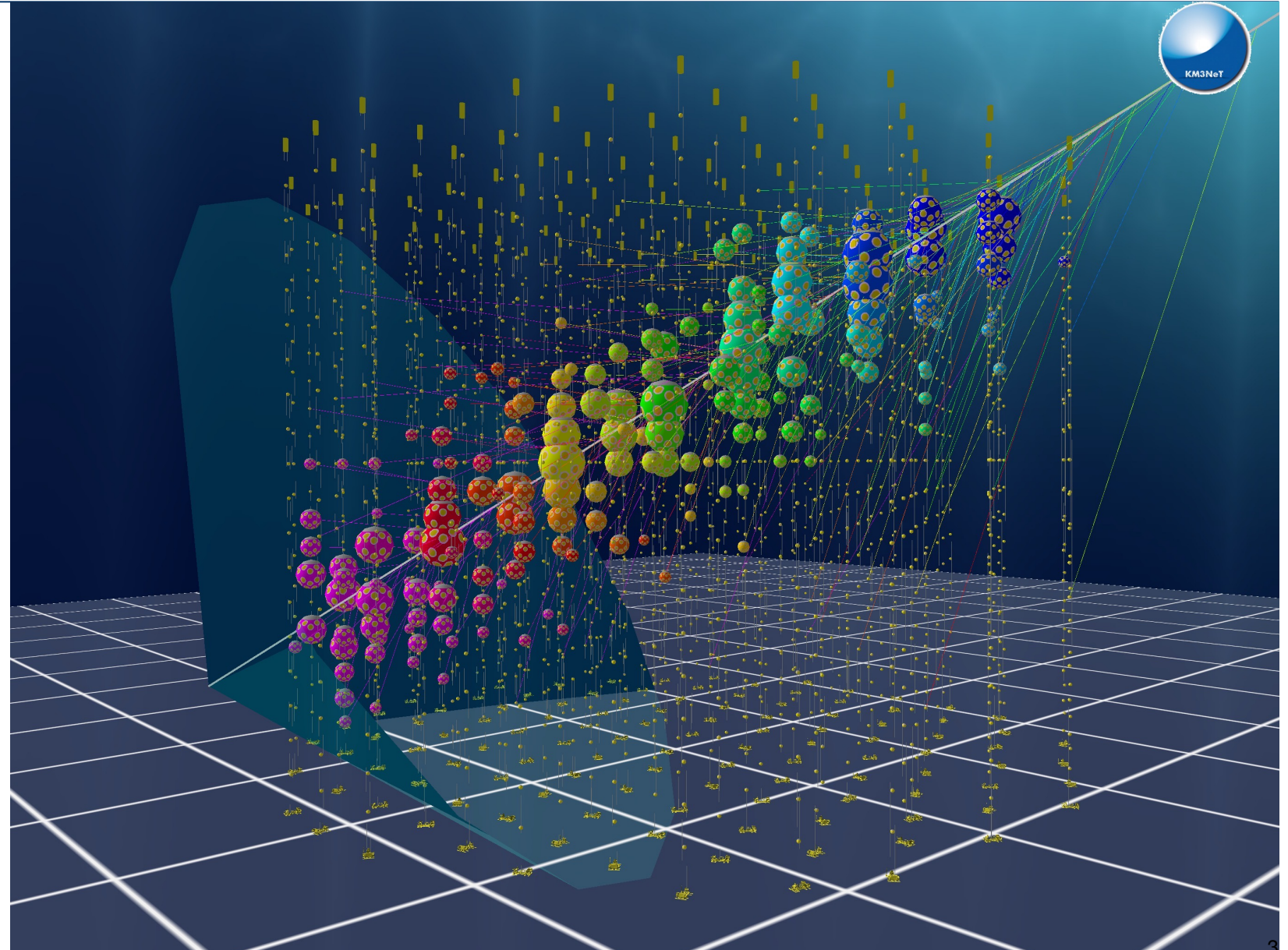
- **O**scillation **R**esearch with **C**osmics in the **A**byss
- 115 detection units (**DU**) with 18 optical modules (**DOM**) to detect Cherenkov light from neutrino interactions
- Instrumented volume \approx 7Mton water
- Currently **10 DUs** deployed and operating

Event display



Use **time** and **space** information of hits to reconstruct neutrino **energy** and **direction**

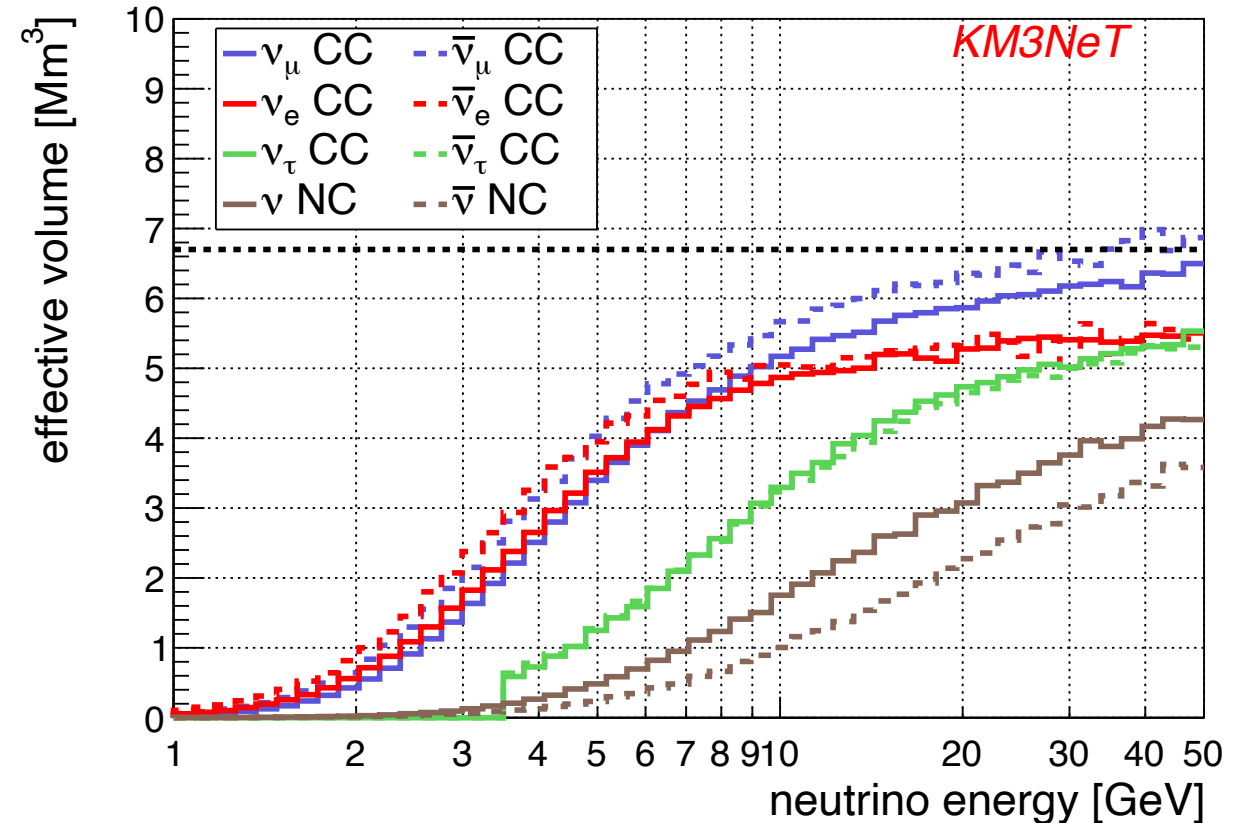
$\mathcal{O}(10^5)$ ν -events/year



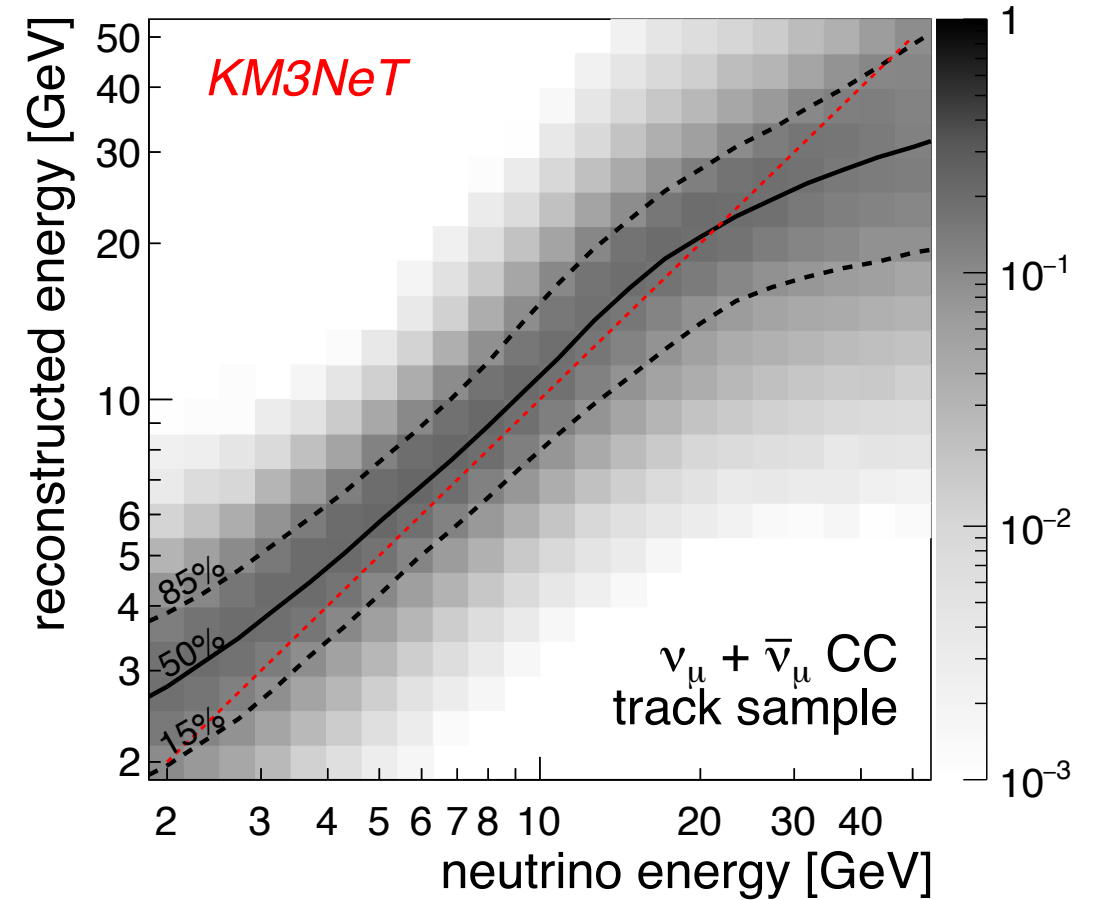
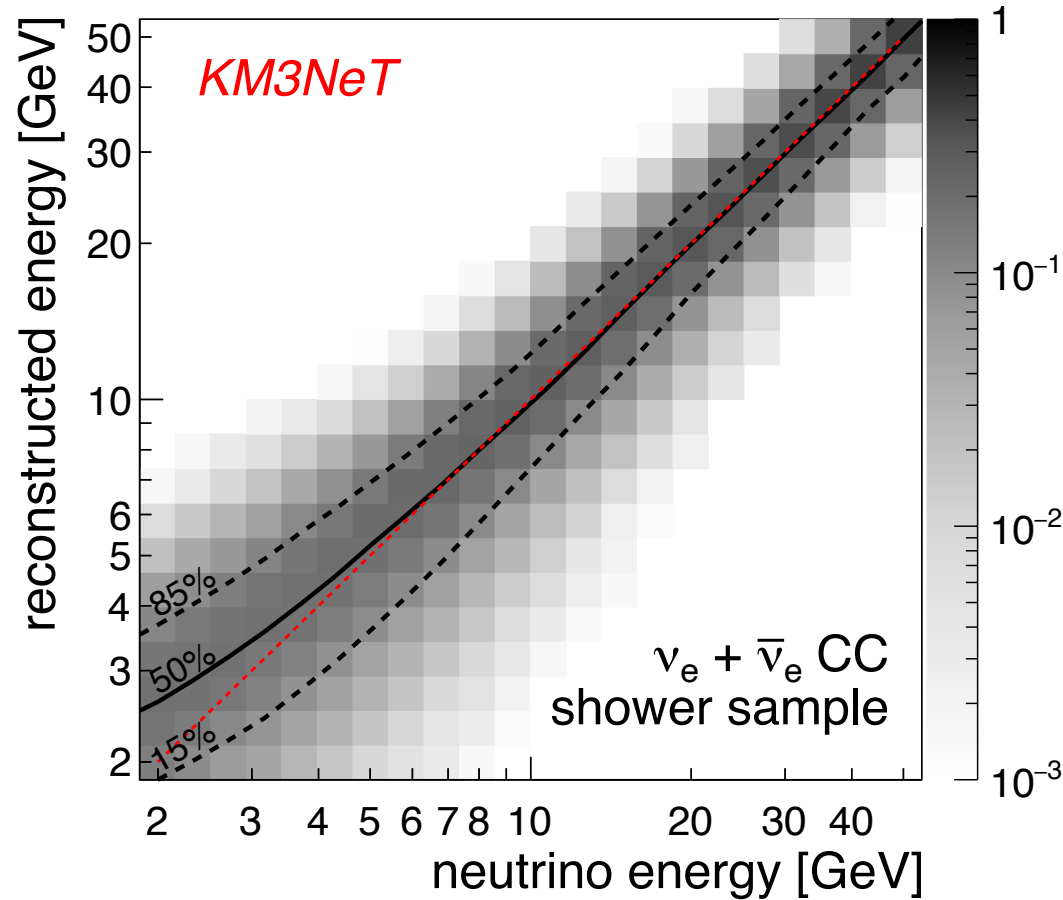
Effective volume



- Effective volume after **trigger condition** and **selection cuts**
- Less light at low energies => lower detection rates
- ν_μ can be seen due to long muon tracks => increase of effective volume

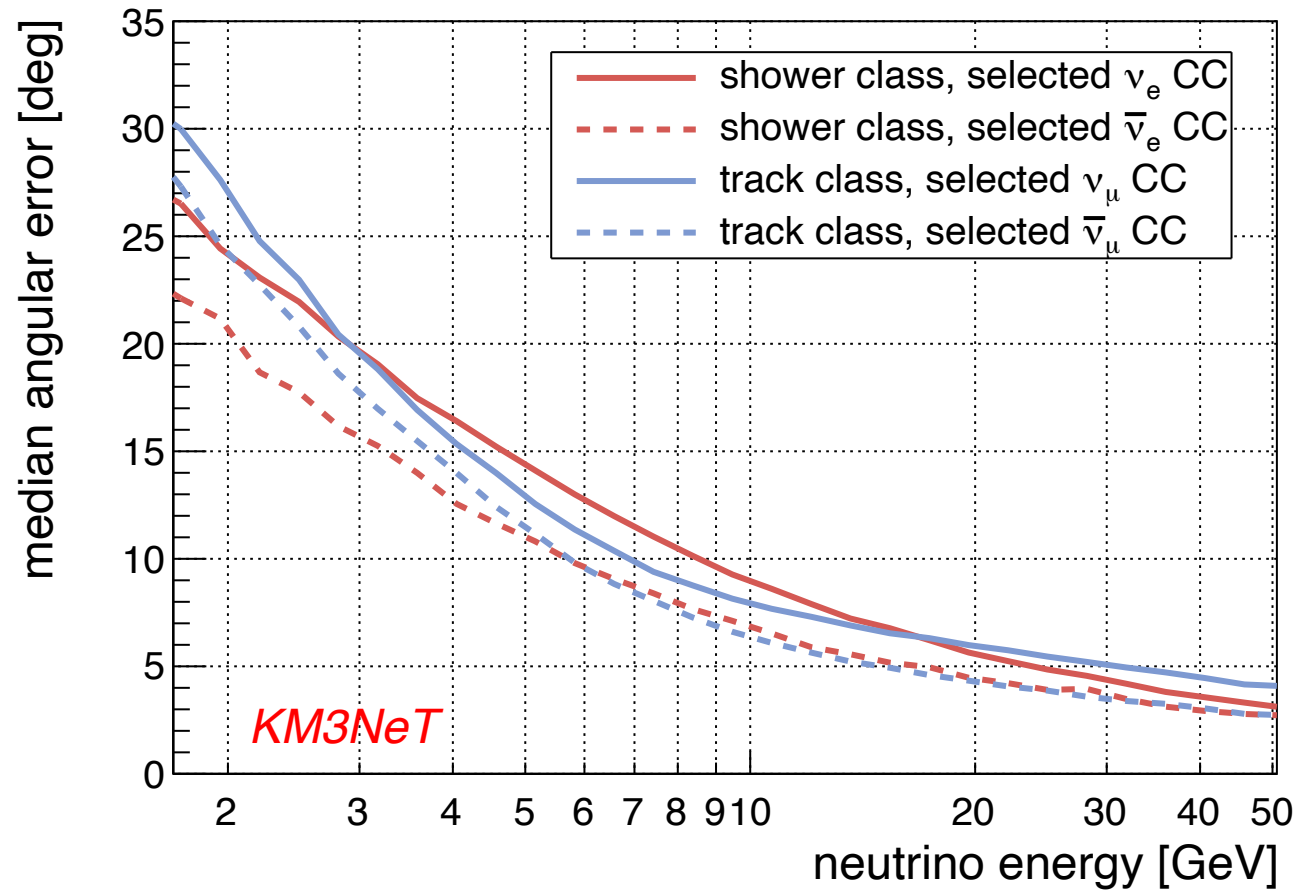


Energy reconstruction



2 reconstruction algorithms (tracks & shower)

Angular resolution

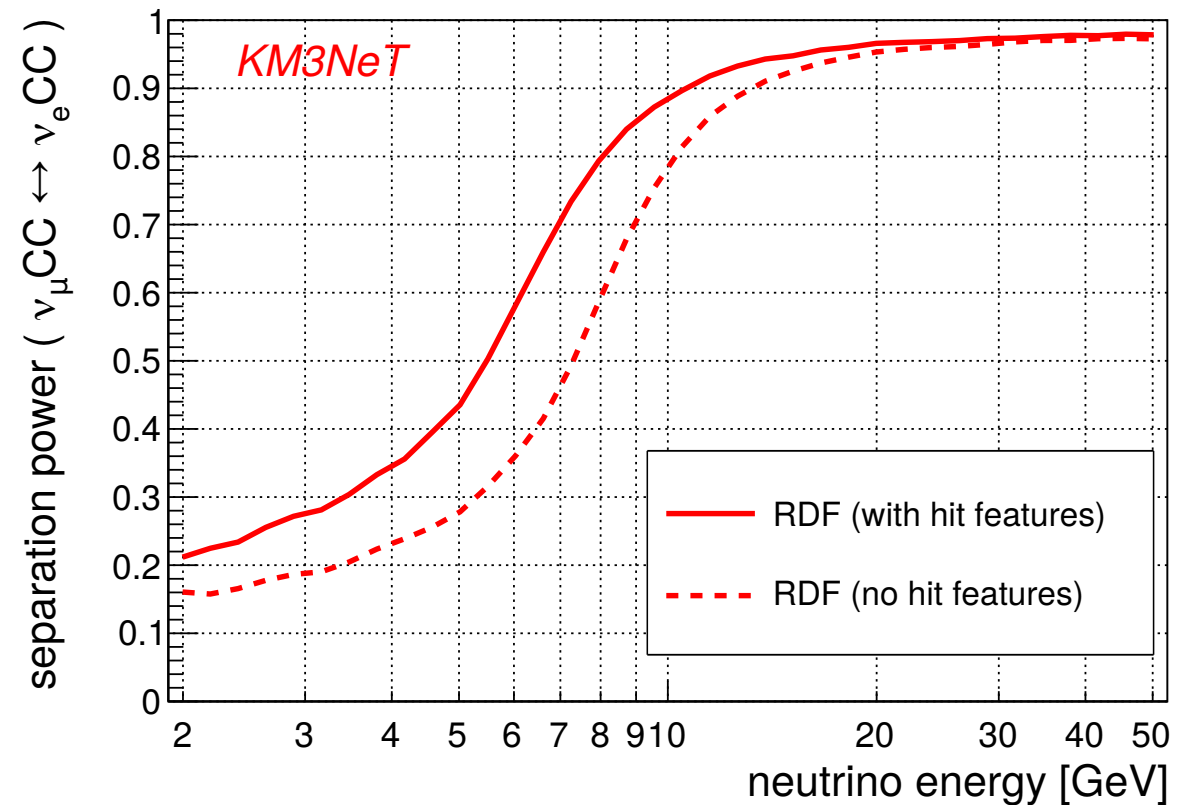


Particle identification

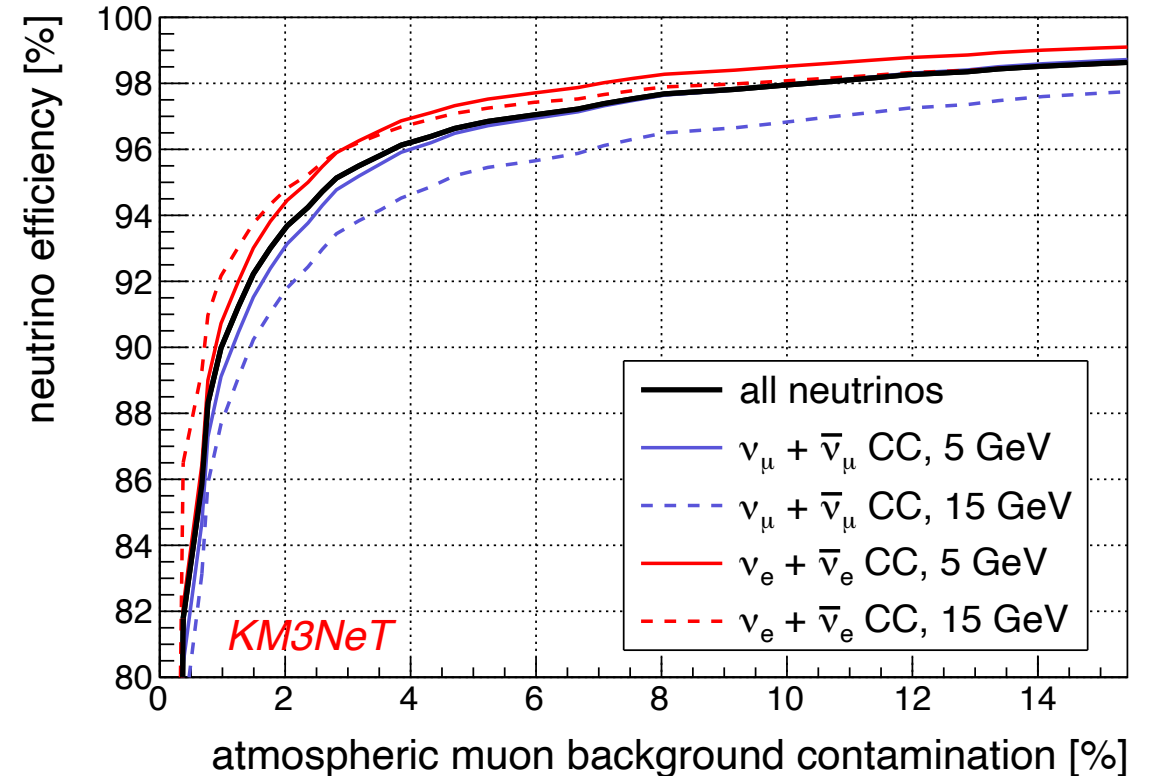
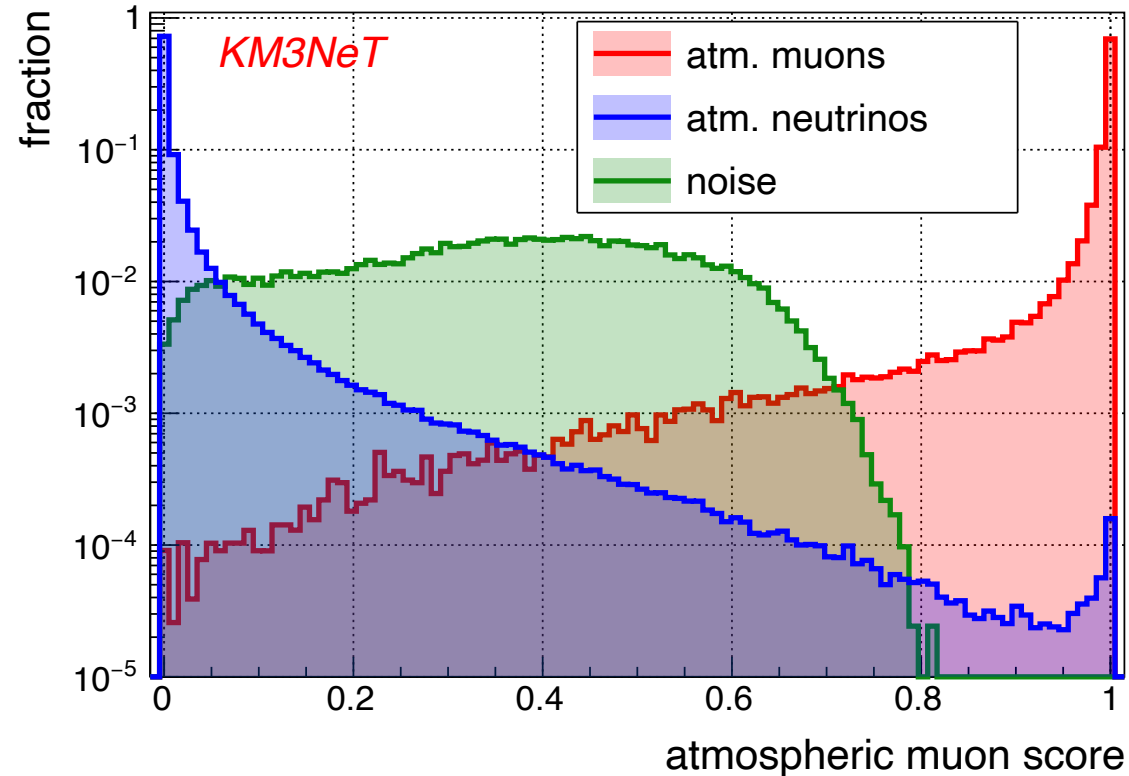


Track/shower separation via
Random decision forest (RDF)
based on:

- Reconstruction output
- Fit likelihoods
- Geometry conditions
- Hit distribution PDFs
- Etc. ...



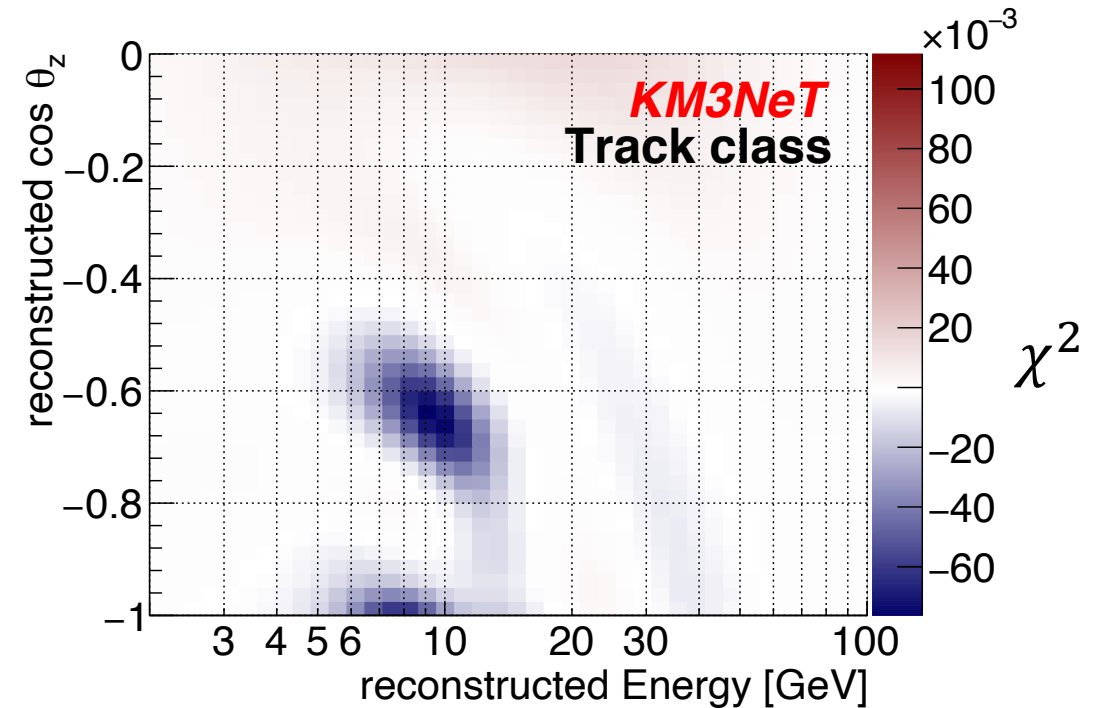
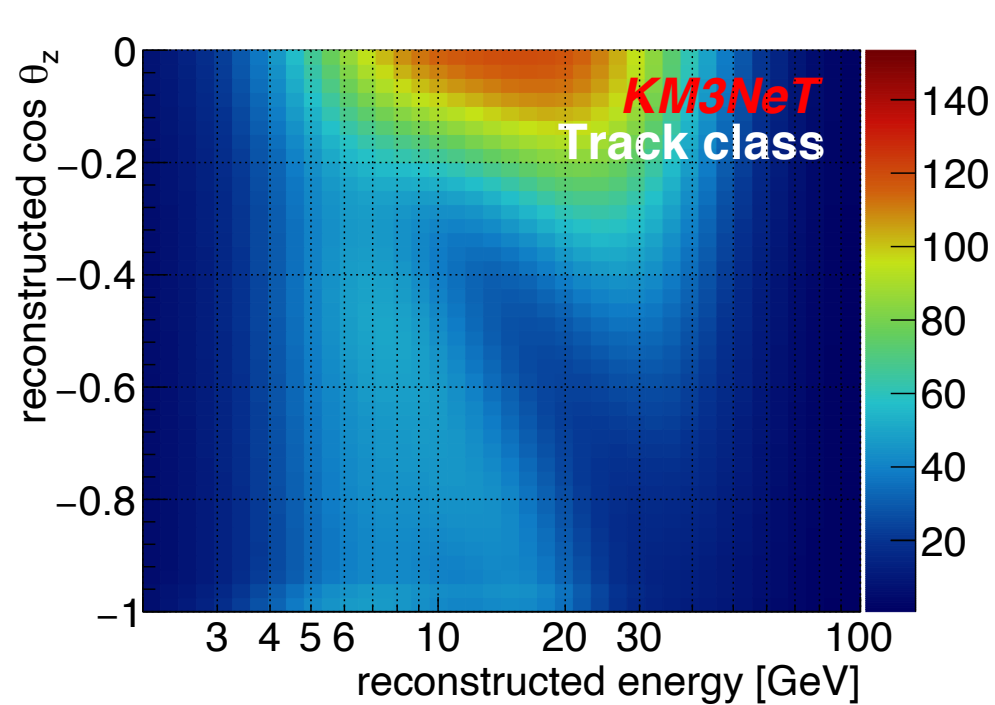
Atmospheric muon suppression



- RDF classifies ν /atm. Muon
- Analogue for noise (K40 decay, bioluminescence)

NMO sensitivity

NMO hypothesis test



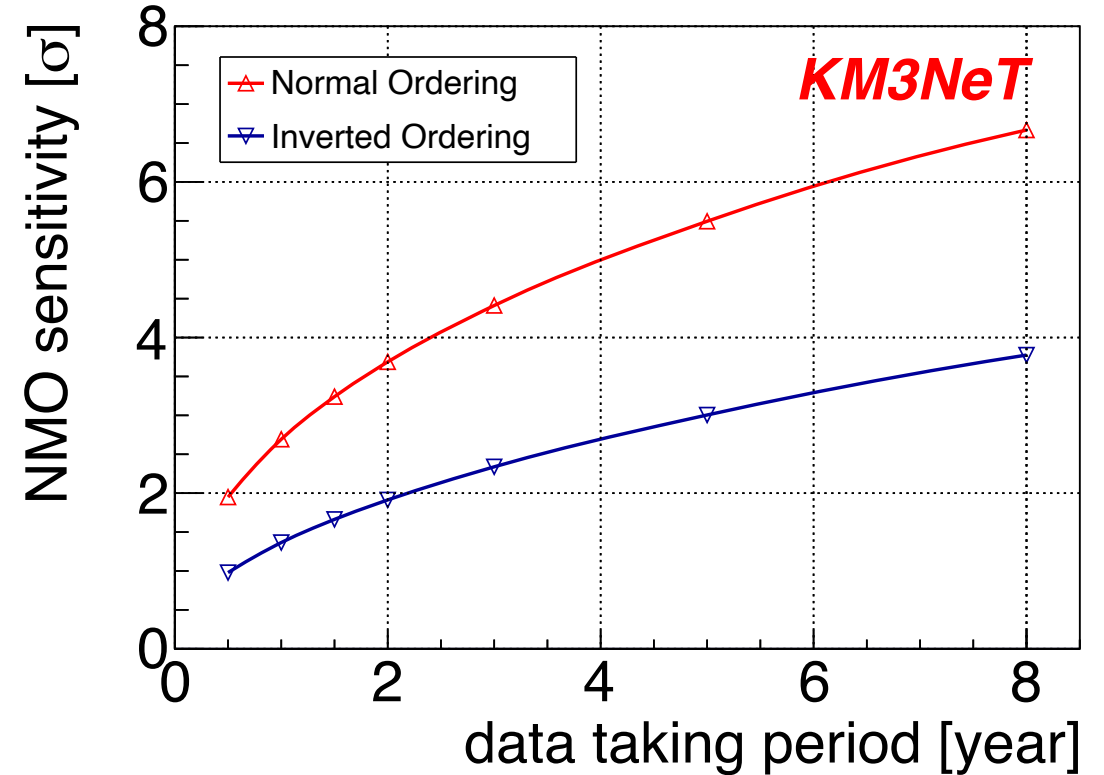
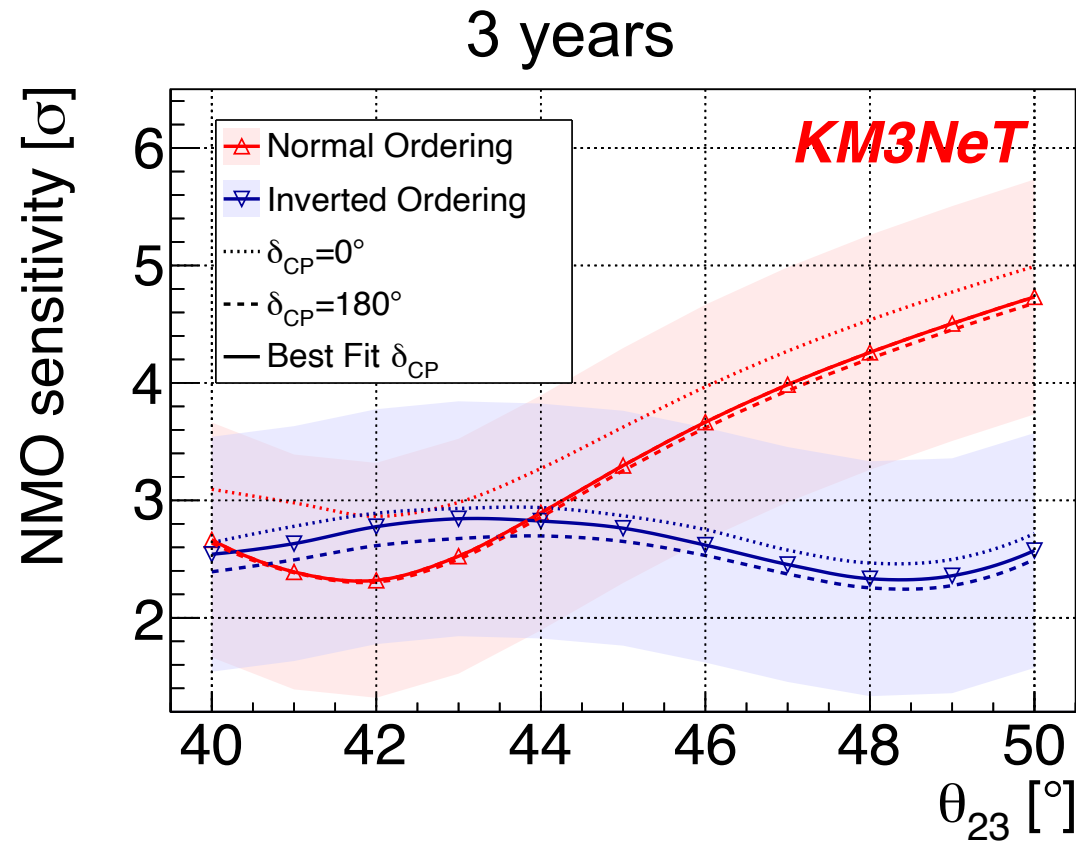
Matter enhanced oscillations occur for (anti-)neutrinos in case of NO(IO):

1. Simulate expected event rate (3yrs) for normal ordering (NO)
2. Calculate Poisson likelihood χ^2 vs. inverted ordering (IO)

NMO sensitivity



Osc. Parameters from NuFit 4.1
DOI: 10.1007/JHEP01(2019)106.

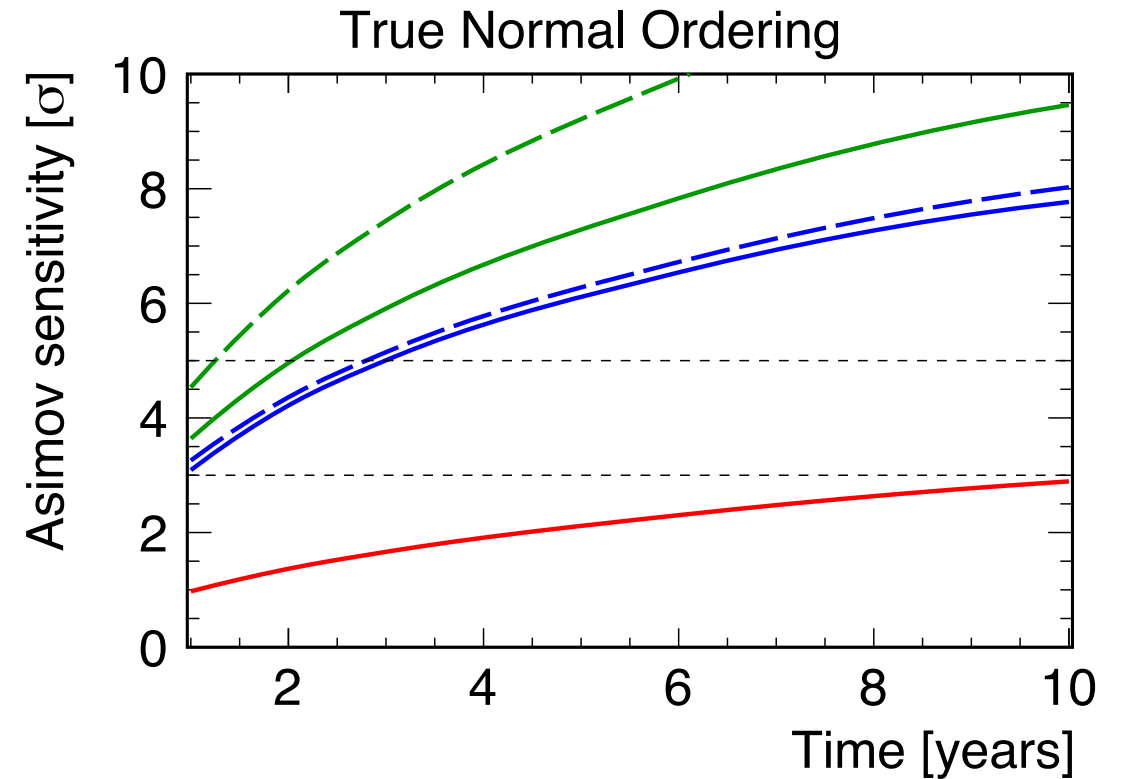
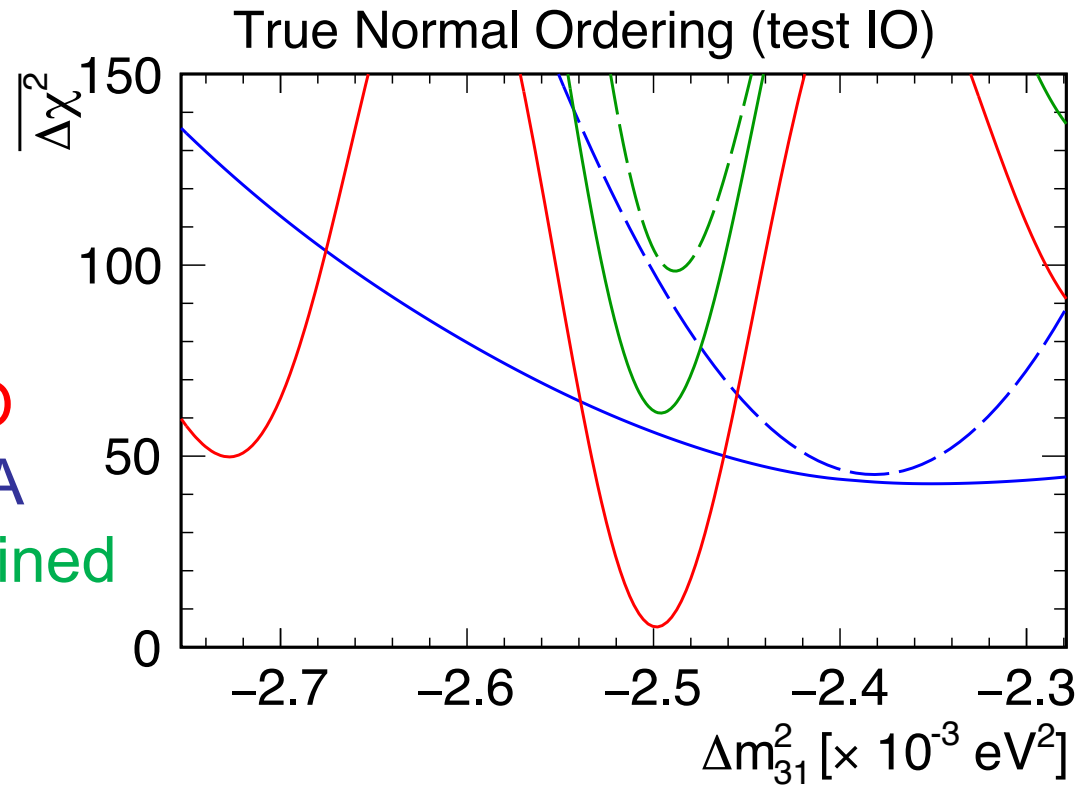


- NMO sensitivity dependent on θ_{23} octant and true NMO
- Favourable normal ordering scenario: 5σ in ~ 4 years

NMO sensitivity ORCA + JUNO



JUNO
ORCA
combined



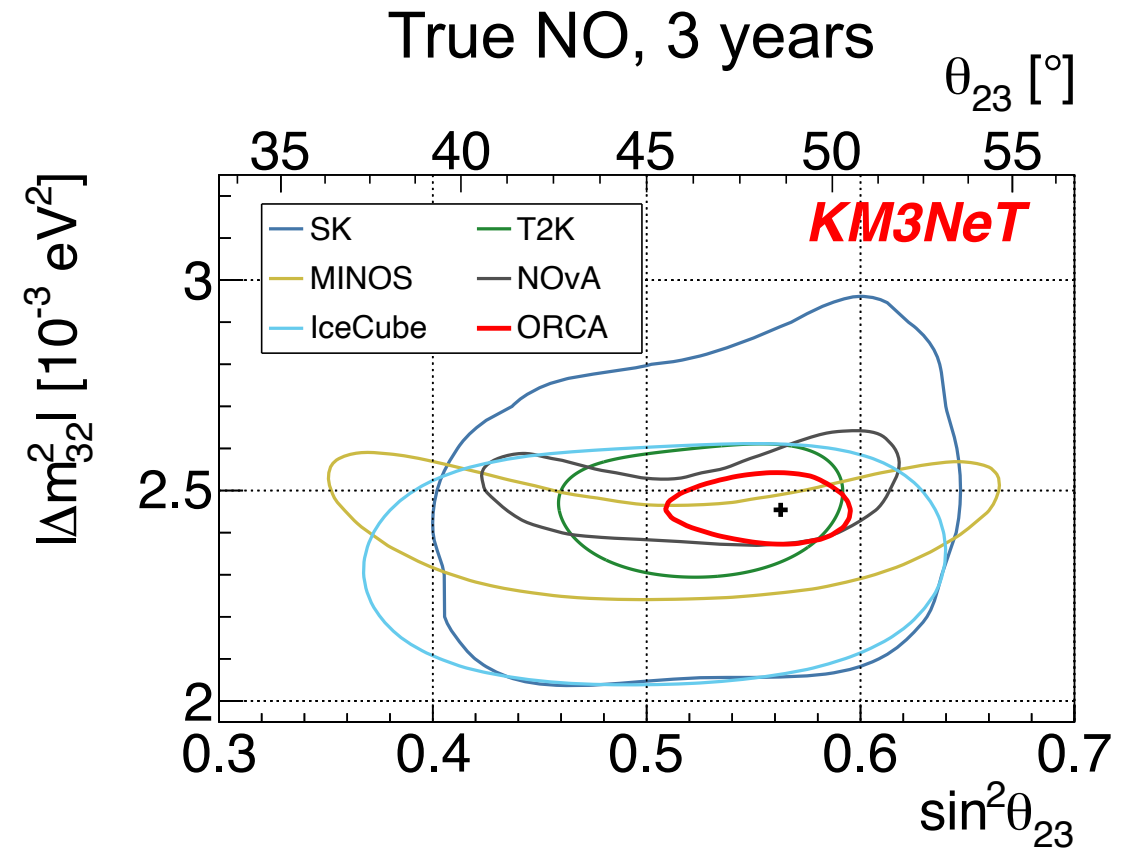
Independent approach of NMO determination

=> Tension in Δm_{31}^2 best-fit value for wrong assumption of NMO

Oscillation parameters



- High resolution of oscillation parameters
- Determination of Θ_{23} octant



Tau appearance

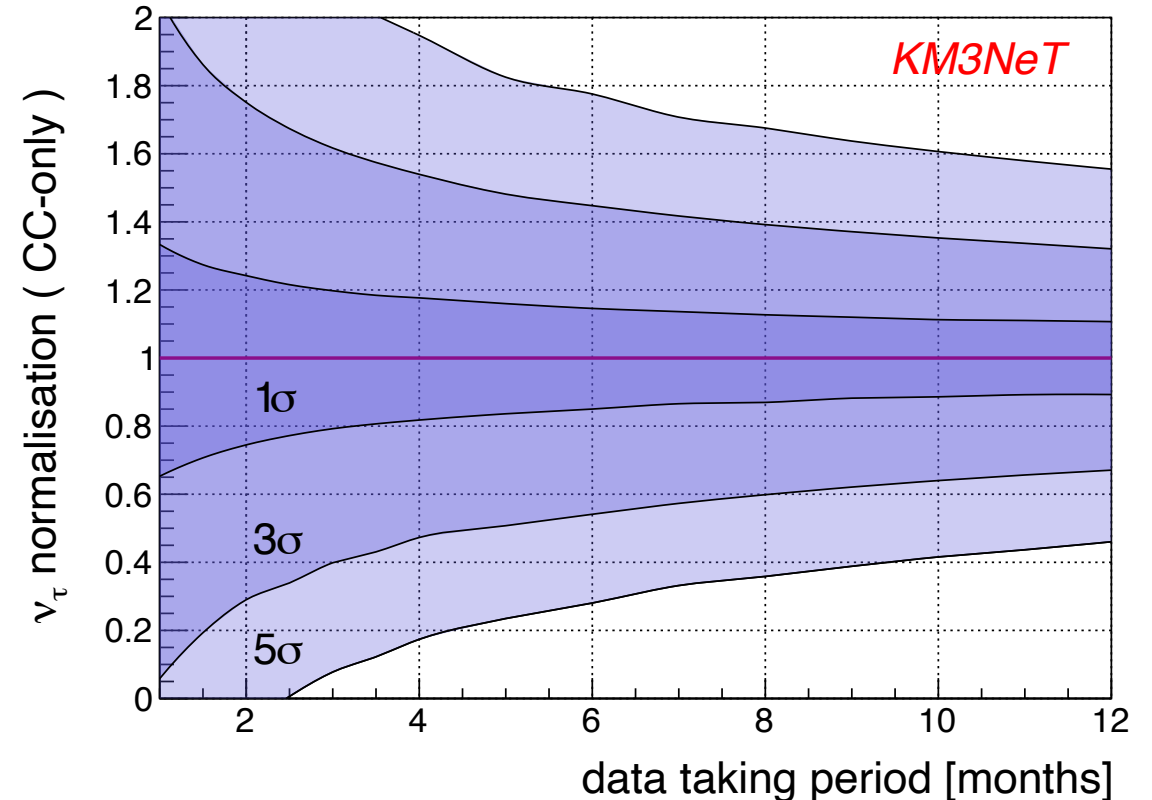
Tau appearance



Atm. Neutrino flux is (almost) pure of $\nu_\tau \Rightarrow$

1. Tau appearance as evidence for oscillation
2. Measurement of PMNS τ -sector - test unitarity!

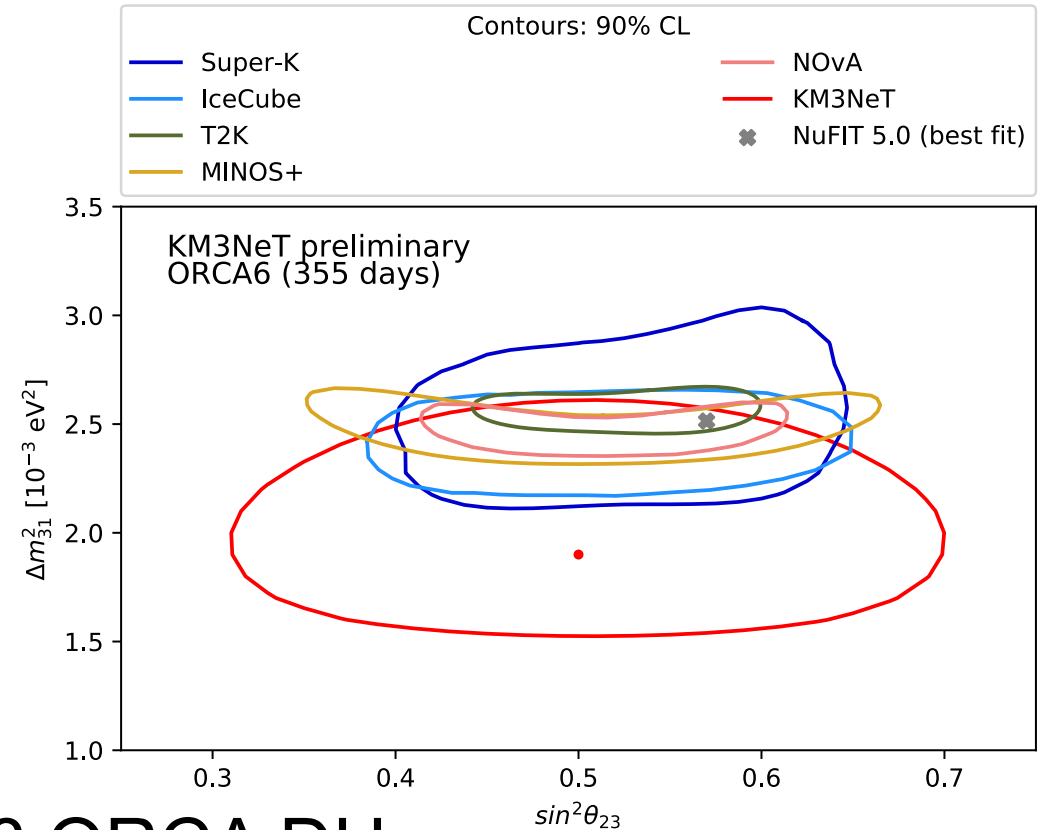
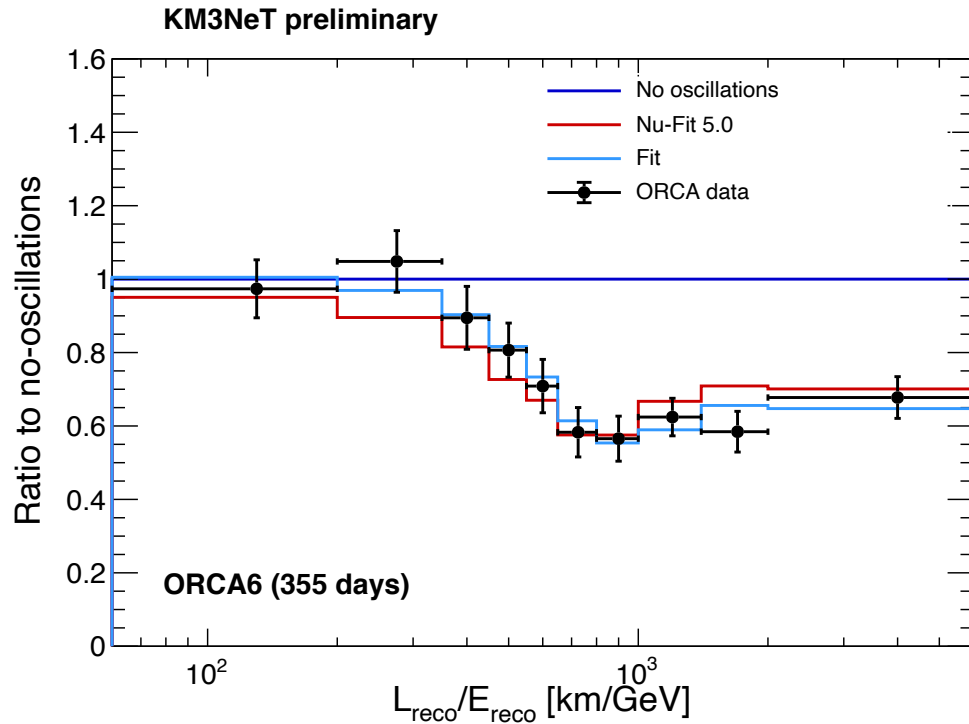
Hypothesis test with scaling of ν_τ^{CC} event rate



May be already visible in current data!

First glimpse at ORCA6

ORCA6 real data analysis



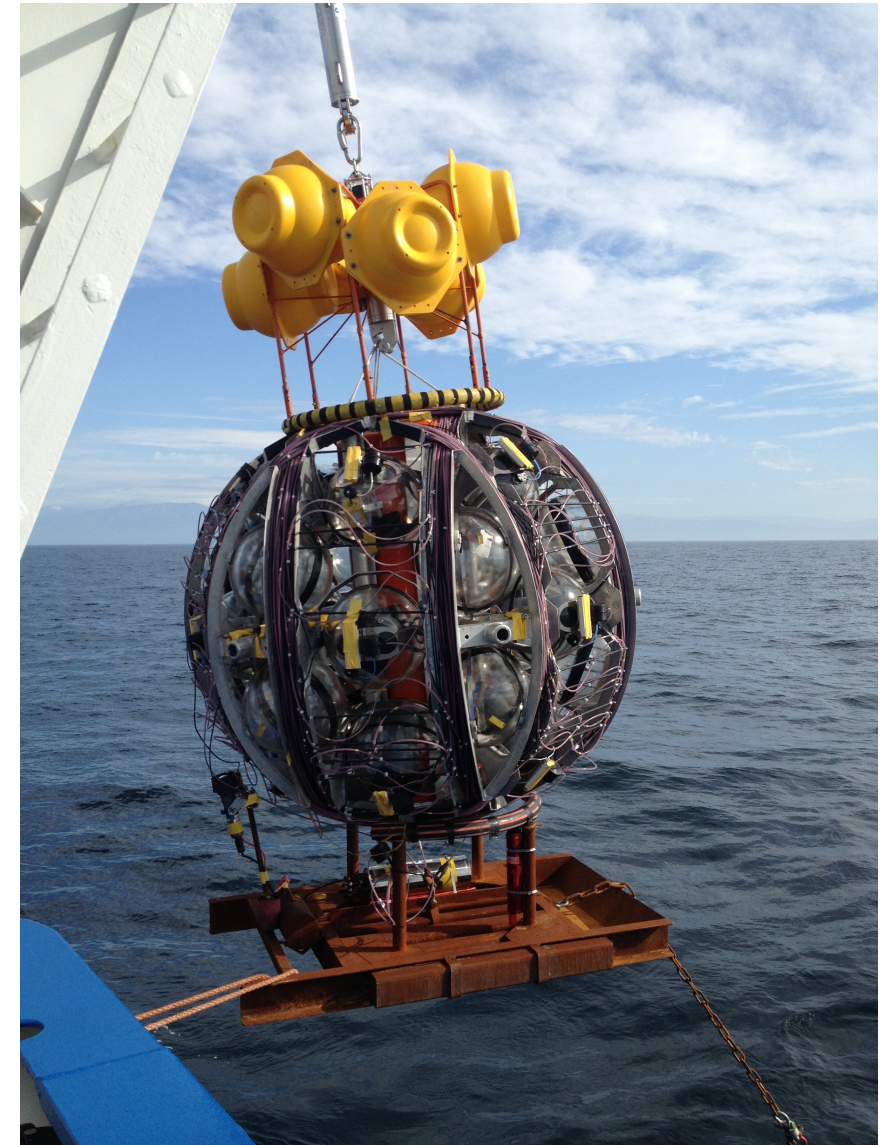
~1 year of data with 6 ORCA DUs

- Oscillations are visible
- Reasonable parameter sensitivity:
 $\sin^2 \theta_{23} = 0.5^{+0.10}_{-0.10}$
 $\Delta m_{31}^2 = 1.95^{+0.24}_{-0.22}$

Summary and outlook



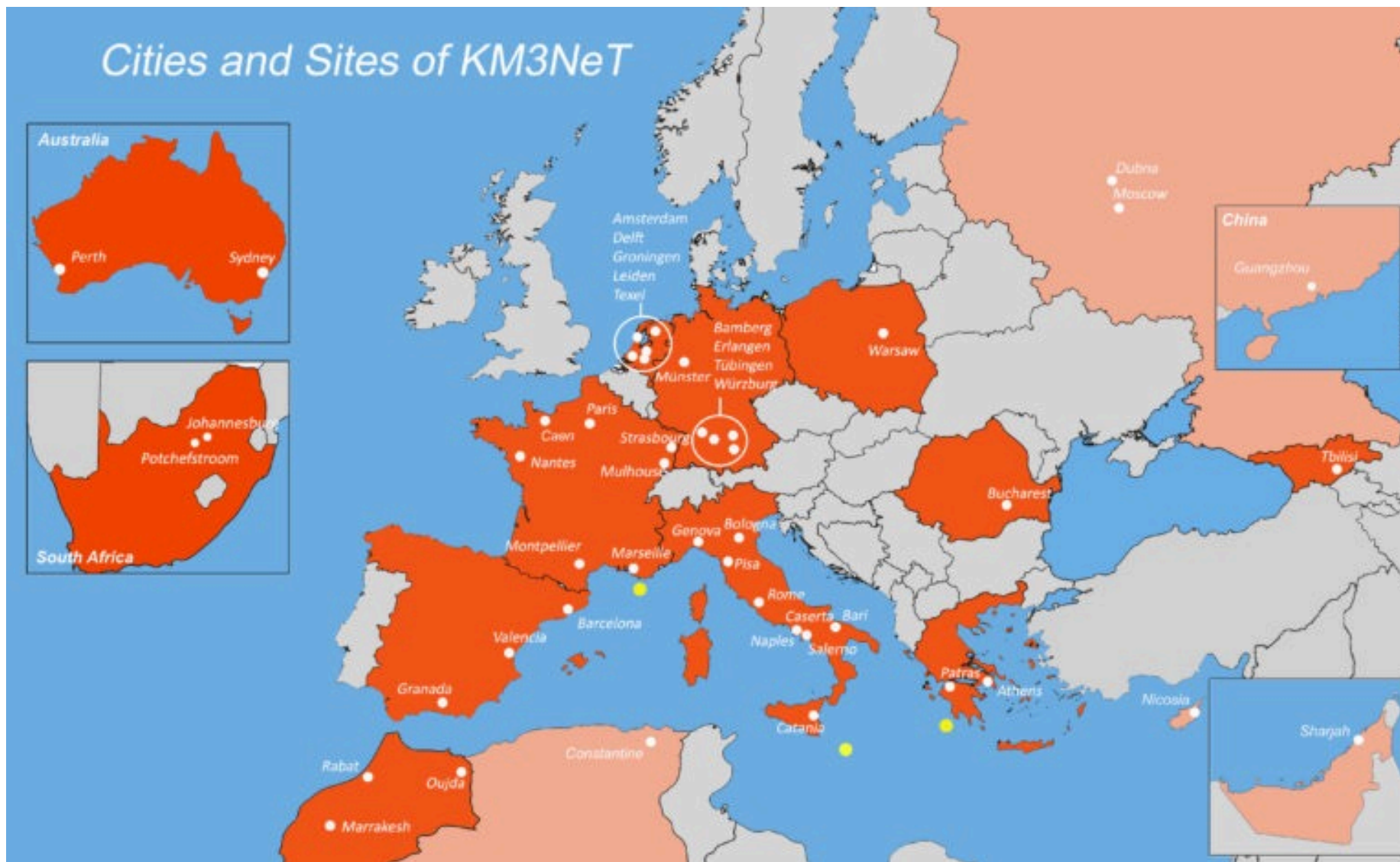
- Published analyses:
 - NMO sensitivity/Tau appearance
 - Sterile neutrinos
- In progress:
 - Quantum decoherence
 - Neutrino decay
 - Non-standard interactions
 - Tau appearance in 6DU data
 - Most important: **more DUs!**



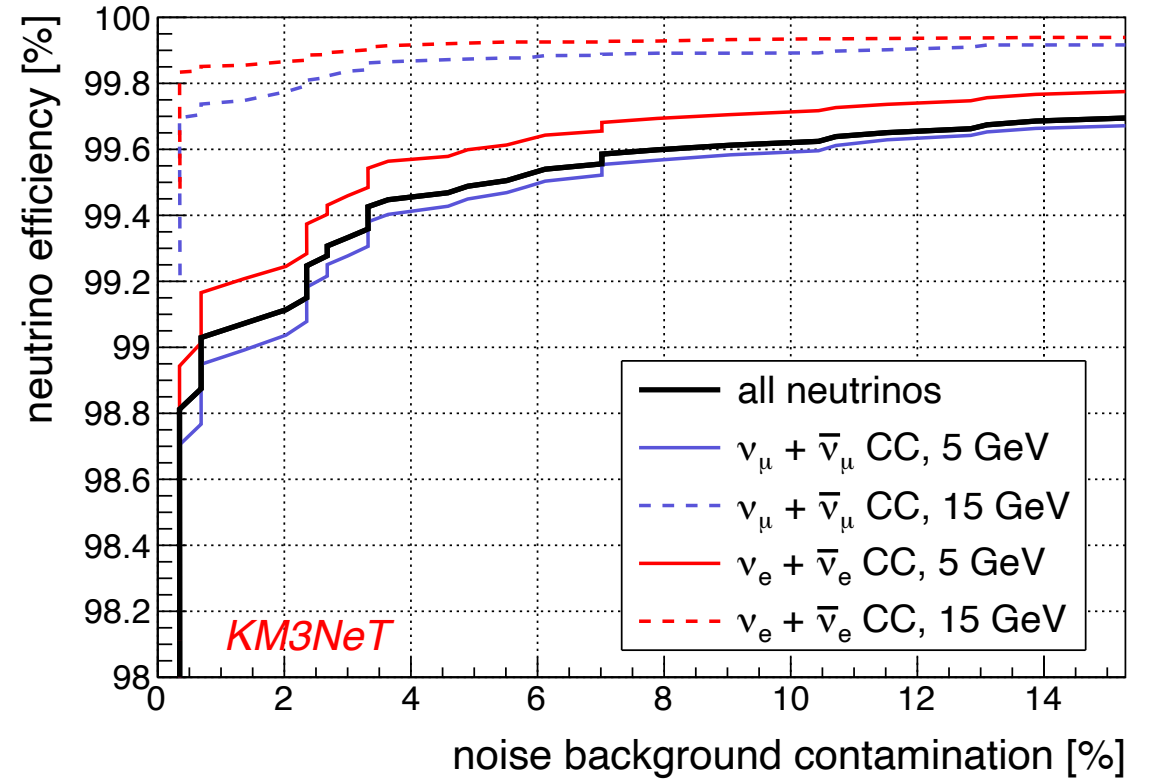
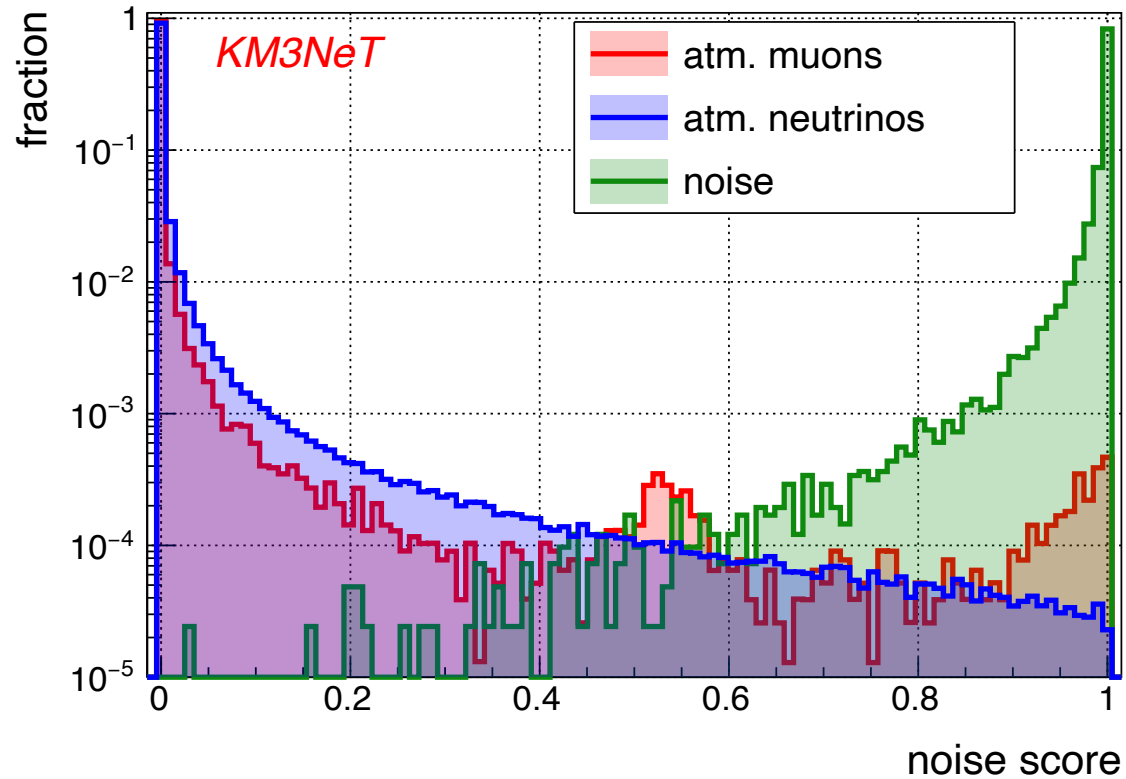


- **KM3NeT** URL: <https://www.km3net.org>
- **NMO/Tau** DOI: 10.1140/epjc/s10052-021-09893-0
- **ORCA/JUNO** DOI: 10.1088/1748-0221/16/11/C11007
- **ORCA6** DOI: 10.22323/1.395.1123
- **Sterile** DOI: 10.1007/JHEP10(2021)180

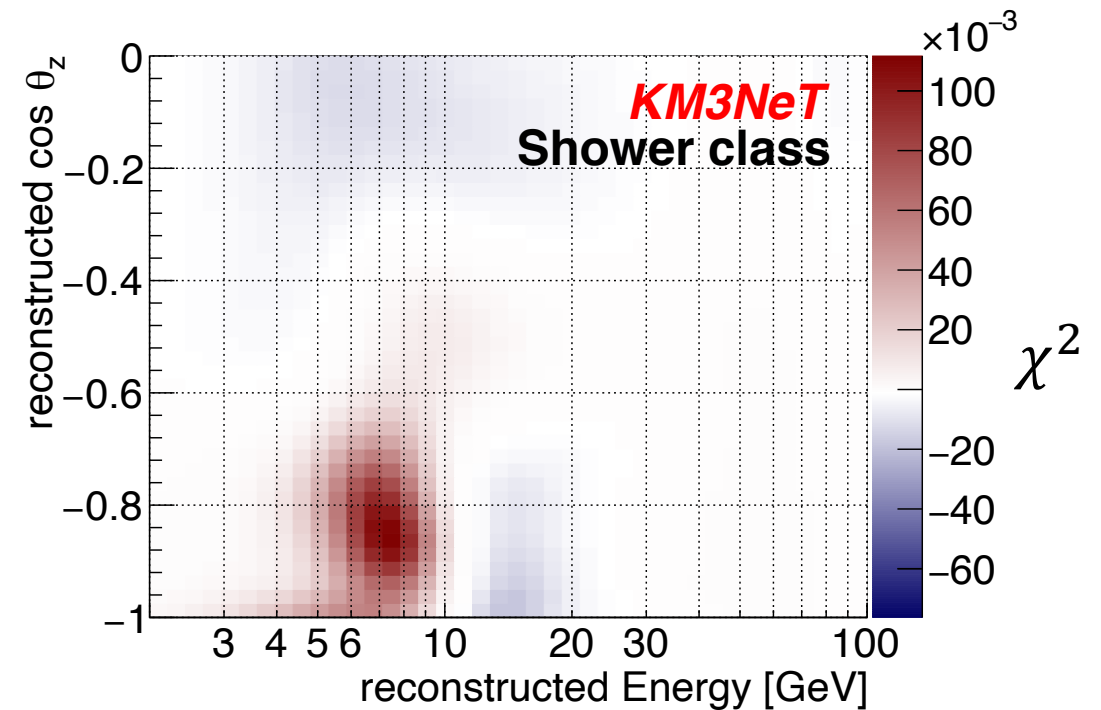
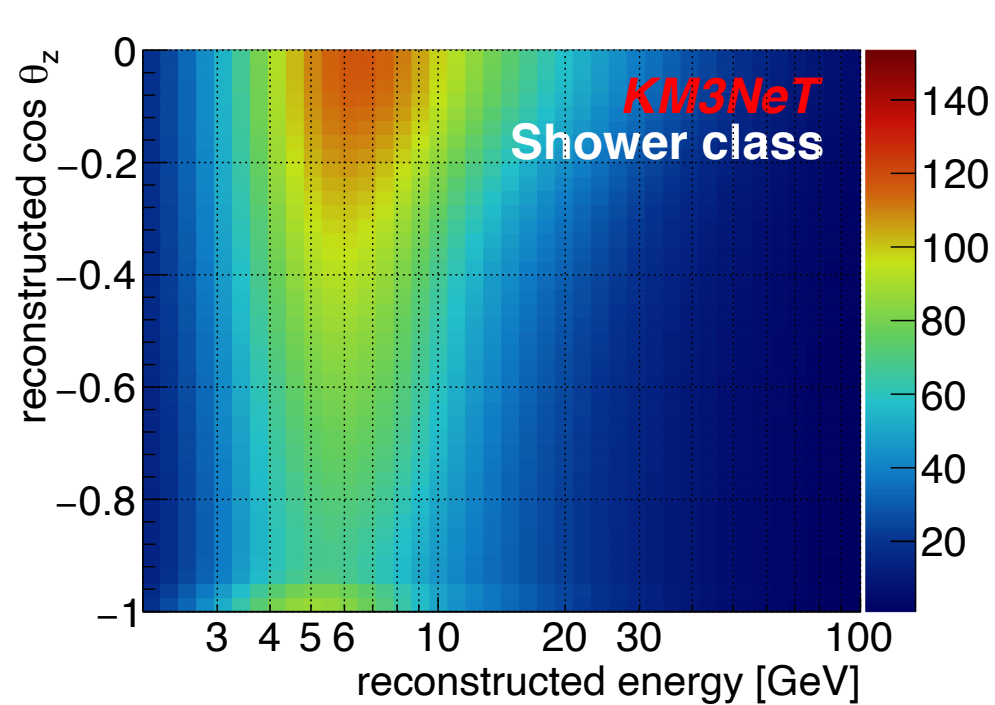
Backup slides



Noise suppression



NMO hypothesis test



1. Simulate expected event rate (3yrs) for normal ordering (NO)
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