ν_τ STUDIES USING KM3NET/ORCA

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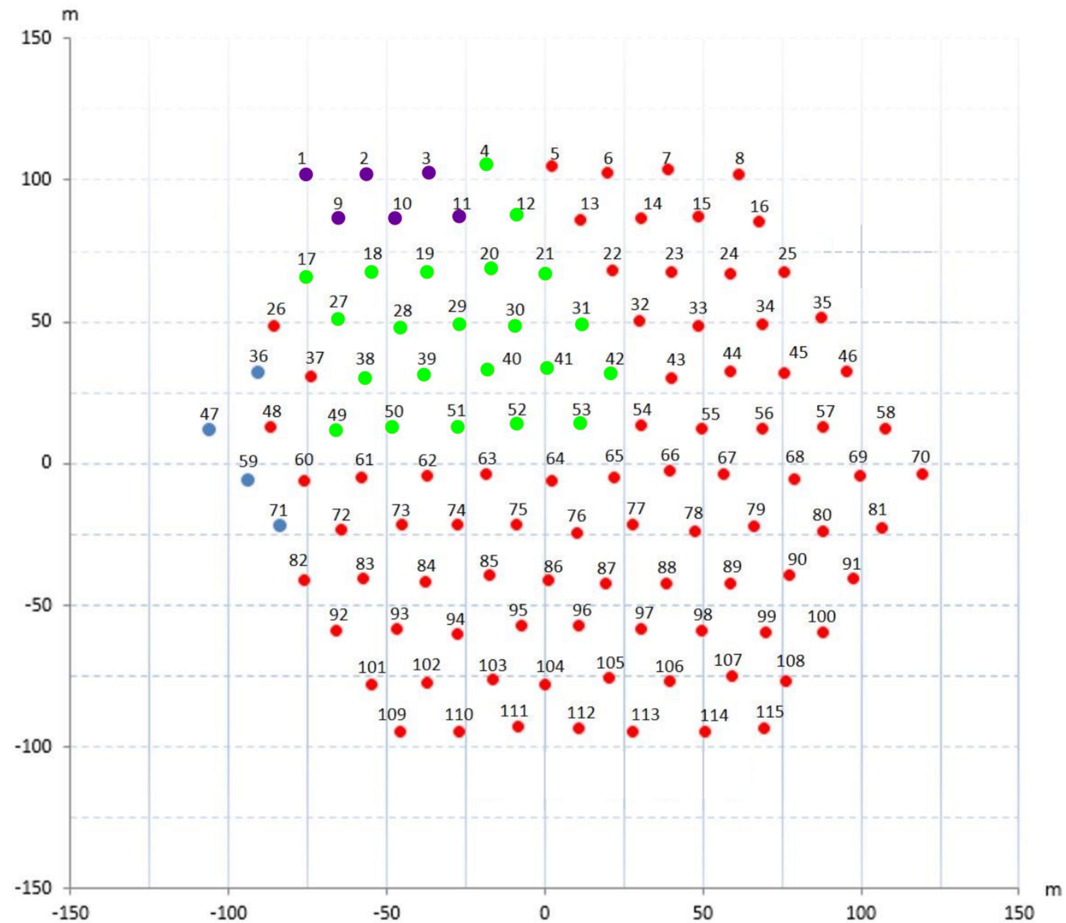
KM3NET/ORCA

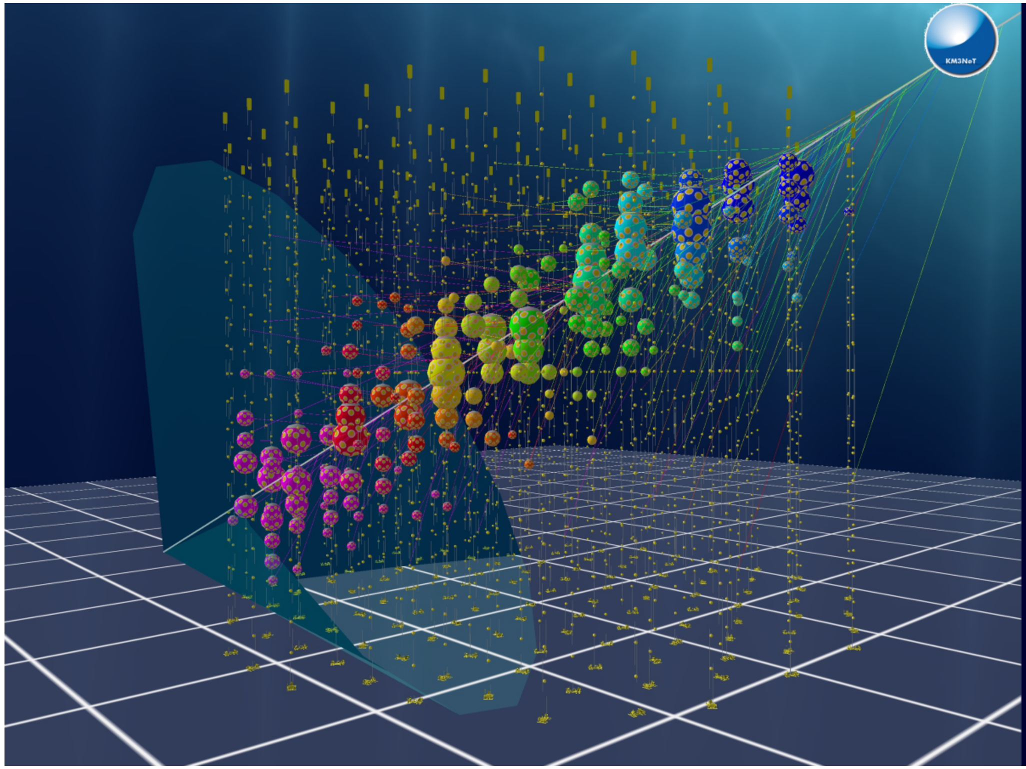
- KM3NeT is a second generation neutrino telescope in the mediterranean sea
- It is planned to consist of 115 cable strings or “Detection Units” (DUs), with a set of 18 photosensors or “Digital Optical Modules” (DOMs)
- Since the start of construction in 2017, 28 DUs have been deployed in multiple stages
- Thus, the underwater infrastructure is designed to allow for data-taking even before the detector reaches its full instrumented mass of 7 Mtons
- Here, we will mostly talk about 510 days of data taken with the first detector layout using 6 DUs (ORCA6: 433 kton-years)

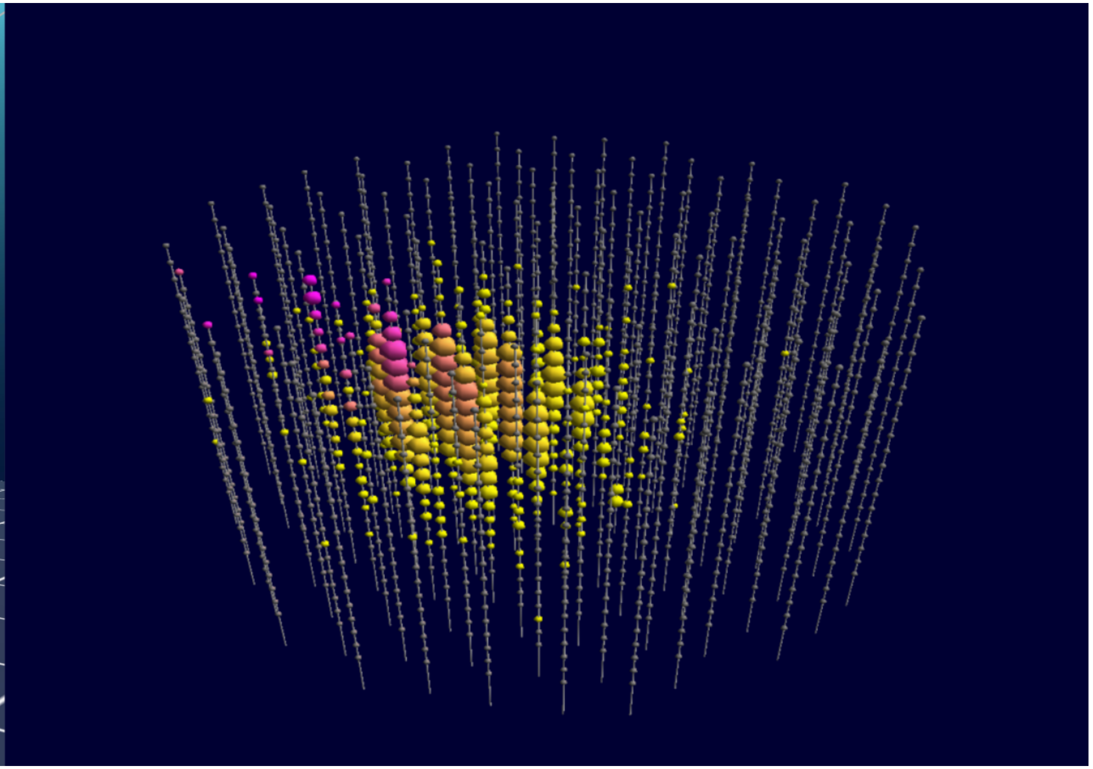


ORCA DATA

- ORCA measures different kinds of event topologies:

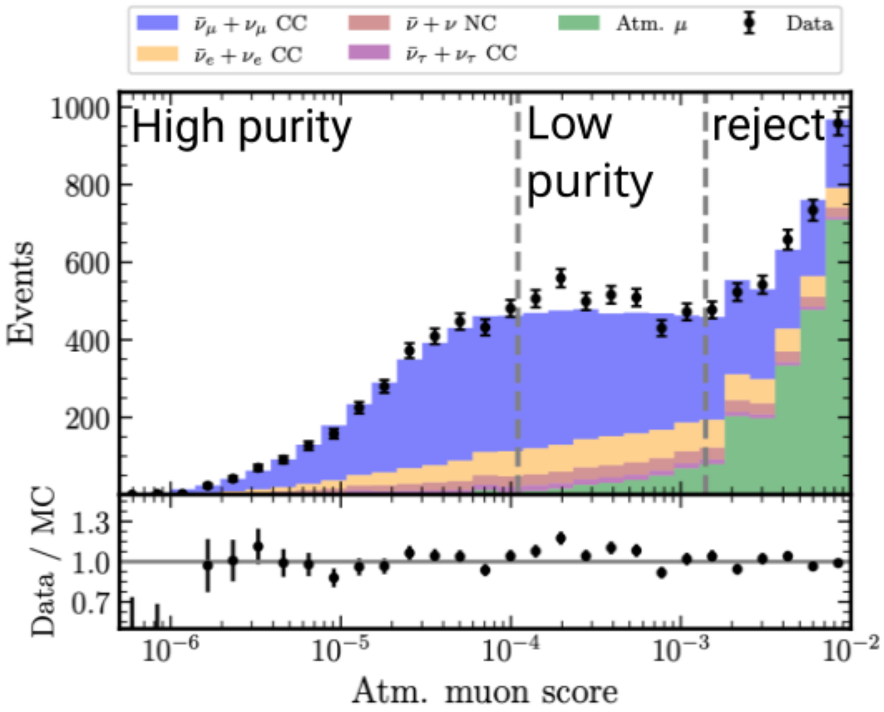
- Particle Tracks: particle moves through the detector without interacting (mostly muons)
- Particle Showers: particle interacts within the detector creating a cascade of secondary particles

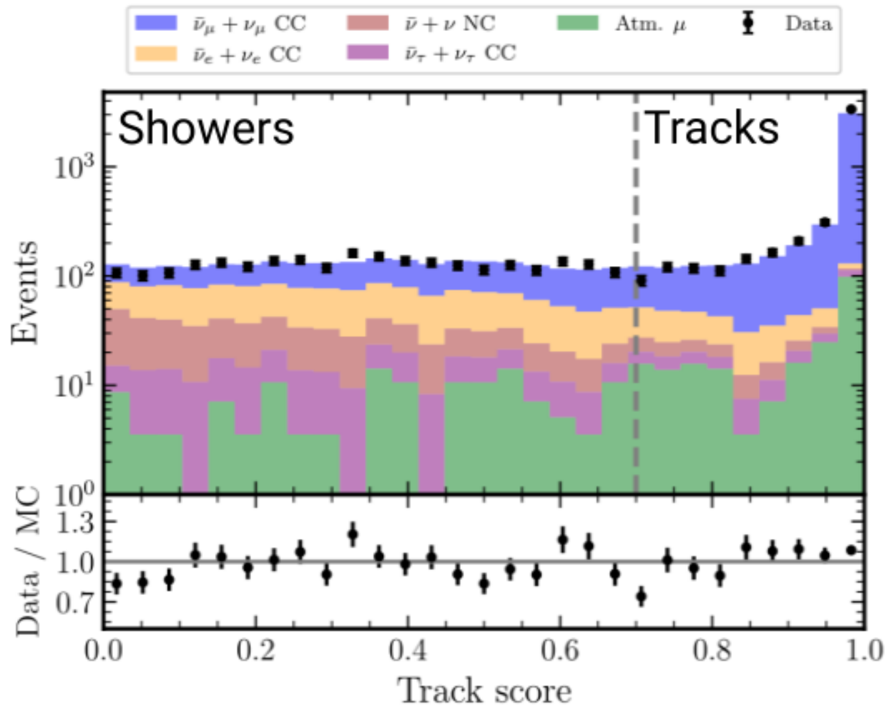




DATA FILTERING

- Background:
  - Radioactive K^{40} Isotopes
  - Bioluminescence
  - Atmospheric muons
- Tracks vs. Showers





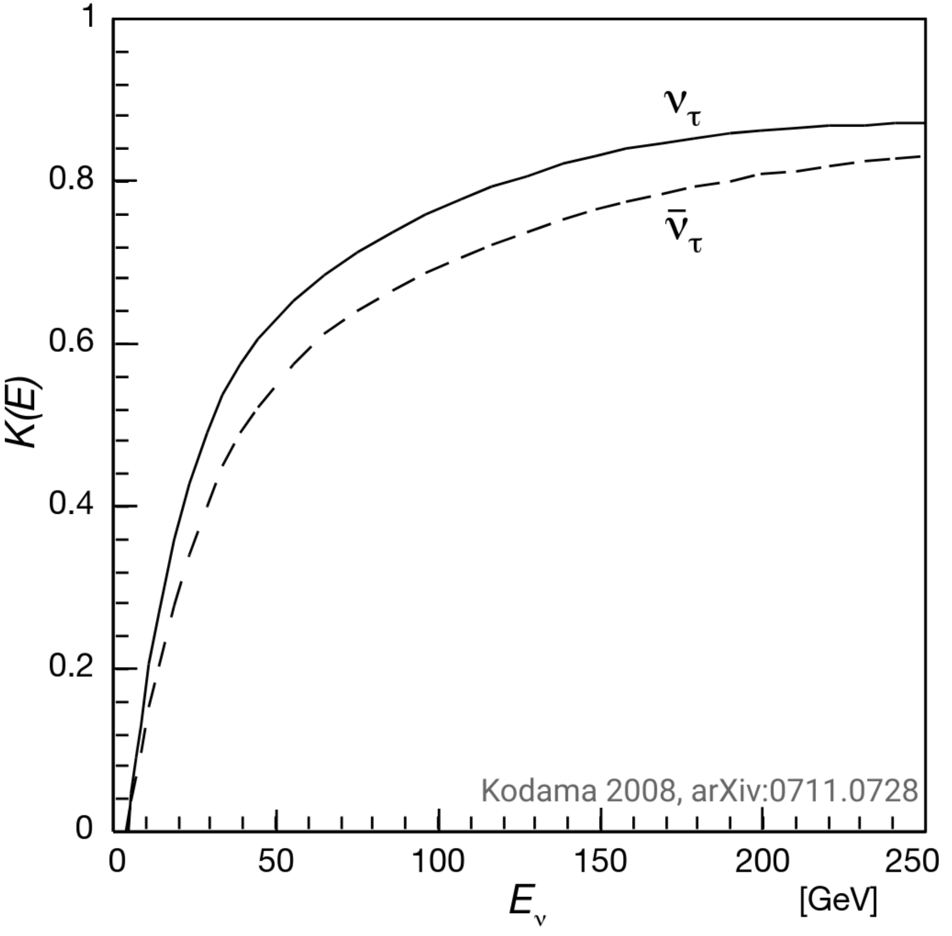
ORCA6 DATA

- The atmospheric muons can be very well rejected
- The $\nu_{\tau,CC}$ set is dominated by showers
- Still the sample of $\nu_{\tau,CC}$ is subdominant within the sample, so the number of $\nu_{\tau,CC}$ has to be computed with statistical arguments, not event by event
- The size of the $\nu_{\tau,CC}$ sample is as big as the 14 year sample by Super-Kamiokande

Event Type	**Showers**	**High Purity Tracks**	**Low Purity Tracks**	**Total**
$\nu_{e,CC} + \bar{\nu}_{e,CC}$	603	51	85	739
$\nu_{\mu,CC} + \bar{\nu}_{\mu,CC}$	902	1777	1786	4465
$\nu_{\tau,CC} + \bar{\nu}_{\tau,CC}$	143	22	20	185
$\nu_{NC} + \bar{\nu}_{NC}$	289	13	22	324
atm. $\mu + \bar{\mu}$	22	7	89	118
Total MC	1959	1870	2002	5831
Total Data	1958	1868	2002	5828

ν_τ CHARGED CURRENT CROSS SECTION

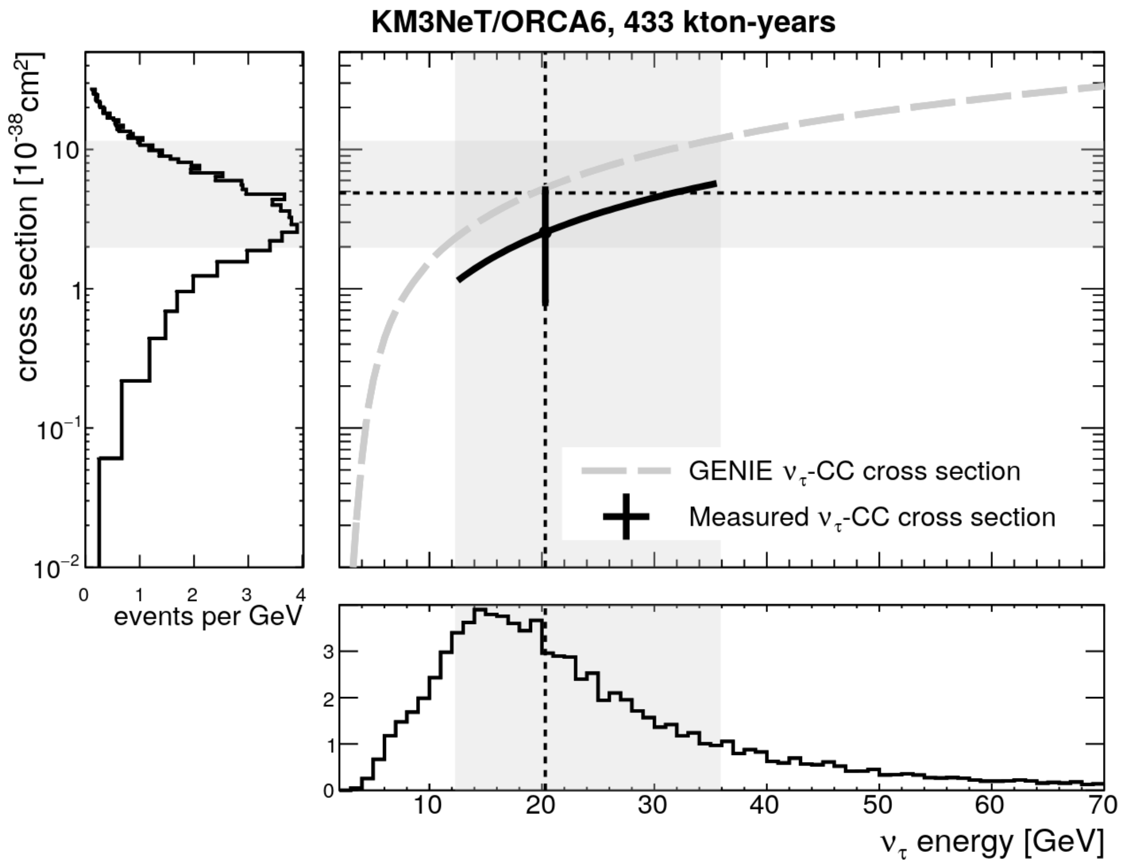
- In order to be detectable in KM3NeT, a ν_τ needs enough energy to produce a τ
- This leads to a kinematic cut off energy of $E = m_\tau \left(1 + \frac{m_\tau}{2m_N}\right) = 3.5\,\text{GeV}$
- This makes cross section measurement particularly interesting as those cut offs are particularly sensitive to Beyond the Standard Model effects
- Also, current cross-section measurements for $\nu_{\tau,CC}$ have big errors



$$K(E) \sim \frac{\sigma_{\nu_\mu}}{\sigma_{\nu_\tau}}$$

ν_τ CHARGED CURRENT CROSS SECTION

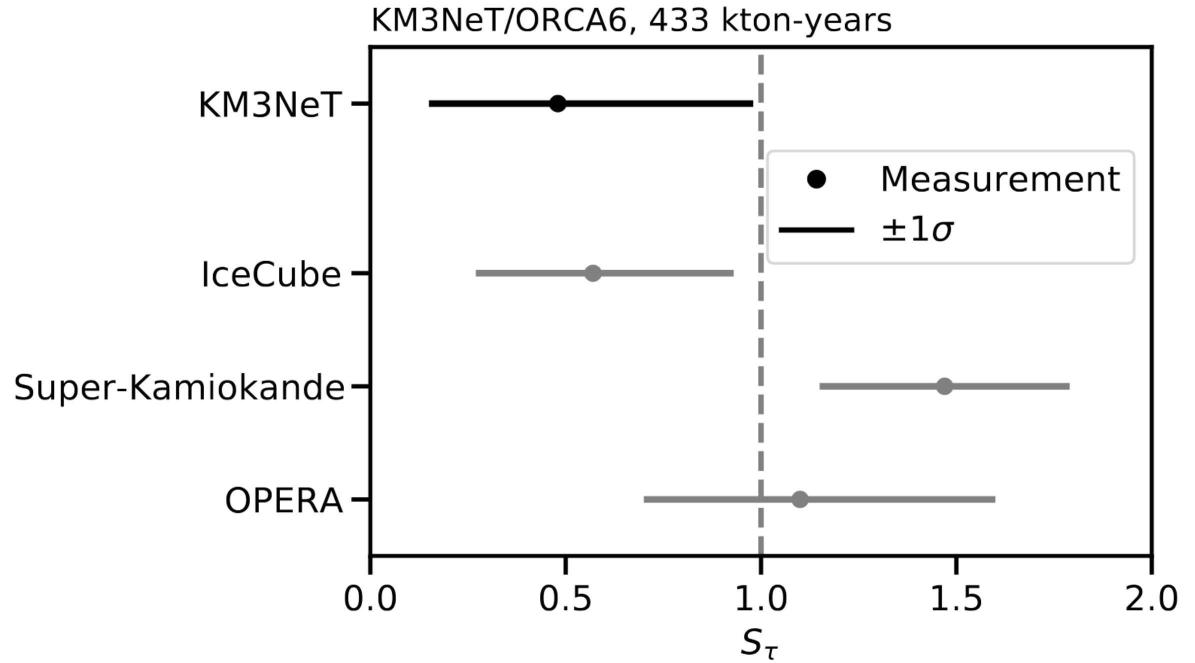
- The ν_τ Charged Current (CC) cross-section $\sigma_\tau^{meas}(E_\nu)$ can be computed using $\sigma_\tau^{meas}(E_\nu) = S_\tau \times \sigma_\tau^{theo}(E_\nu)$
  - $S_\tau \hat{=}$ normalisation
  - $\sigma_\tau^{theo} \hat{=}$ theoretical cross section
- S_τ can be fitted via a maximum-likelihood fit
- Here, we fit Δm_{31}, θ_{23}, S_τ and systematics



- This leads to a $\sigma_\tau^{meas}(20.3\,GeV) = 2.5^{+2.6}_{-1.8} \times 10^{-38}\,cm^2$, where $E_\nu = 20.3\,GeV$ is the median true energy in the MC dataset and the errors are obtained using the Feldmann-Cousins method

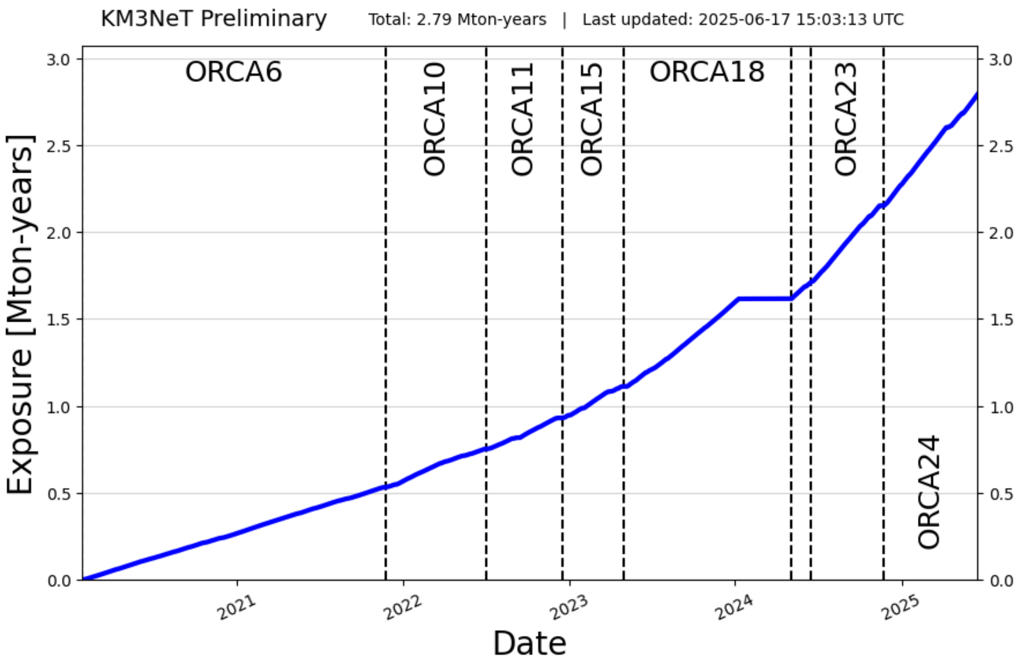
ν_τ CHARGED CURRENT CROSS SECTION

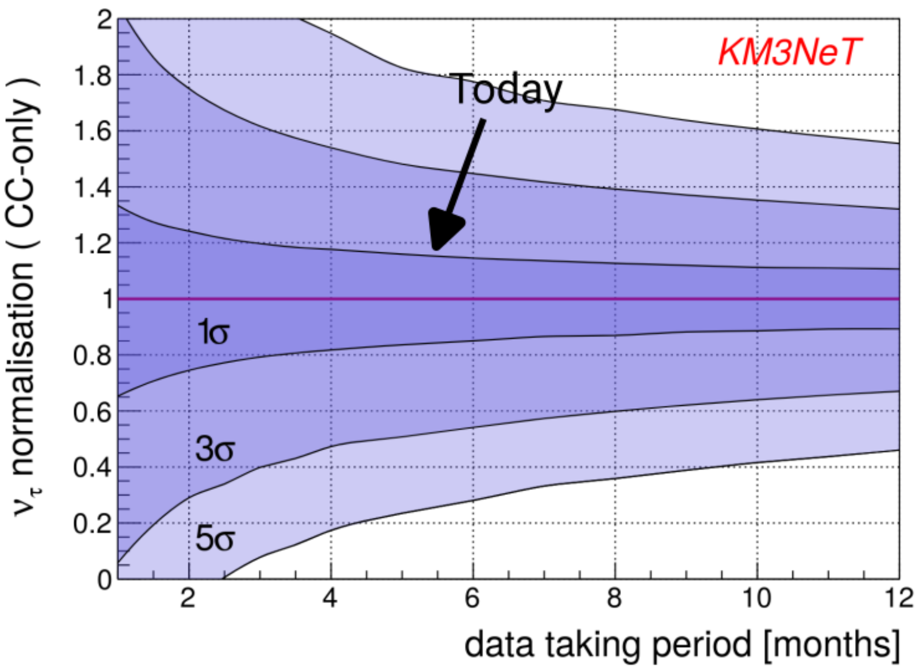
- To get an energy independent comparison, compare $S_\tau = 0.48^{+0.49}_{-0.33}$ with other experiments:
  - OPERA, 2015
  - Super-Kamiokande, 2018
  - IceCube, 2019
- ORCA with only 433 kton-years worth of data is already very competitive



OUTLOOK

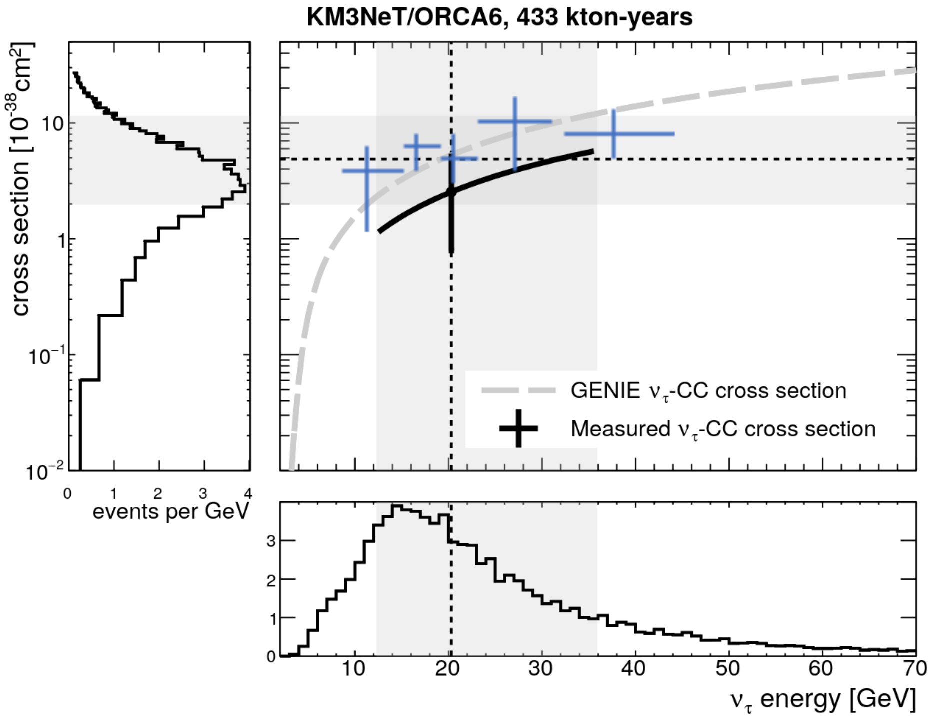
- Currently, there is 2.79 Mton-years of data available (left plot)
- The full sized detector (115 DUs) would take about 5.5 months to obtain this data
- Using this data would already shrink the errors on the ν_τ normalisation to below 20%
- With the growing detector, we will very fast produce one of the biggest ν_τ samples on the planet





SUMMARY

- We used the ORCA6 (433 kton-years) detector to obtain competitive results for the ν_τ normalisation $S_\tau = 0.48^{+0.49}_{-0.33}$
- The results of this analysis and more can be seen in more detail in the most recent KM3NeT publication (arXiv:2502.01443) which was recently accepted by JHEP
- Note, that this analysis only uses 5% of the final detector volume. Using the following detector layouts, the errorbars will shrink by a factor 5 or even more
- With the next analyses we might be able to produce energy dependent measurements of the ν_τ CC cross-section



Thank you all for listening!

BACKUP

SYSTEMATICS ON THE ν_τ NORMALISATION