Sterile Neutrino search with KM3NeT/ORCA6-18 dataset

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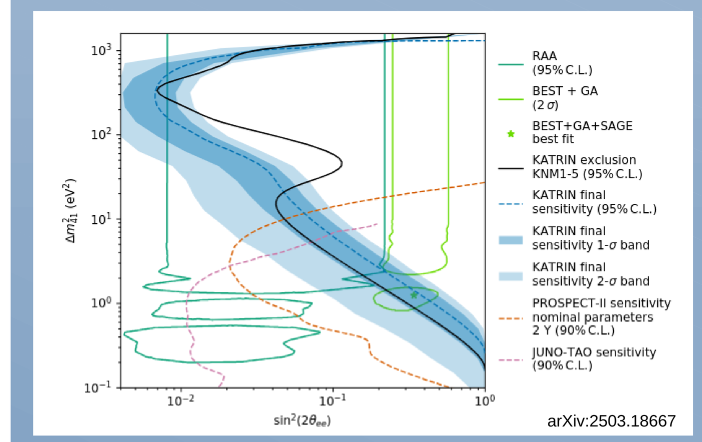
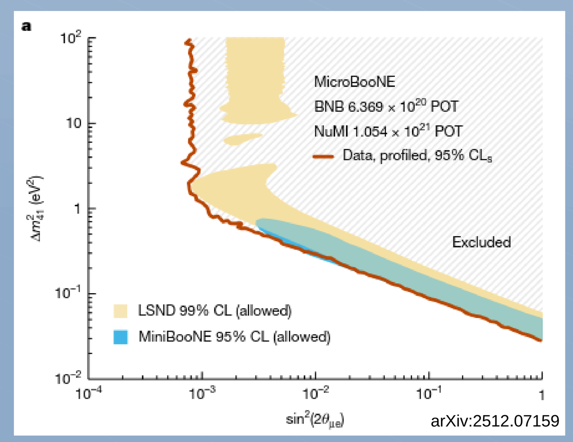
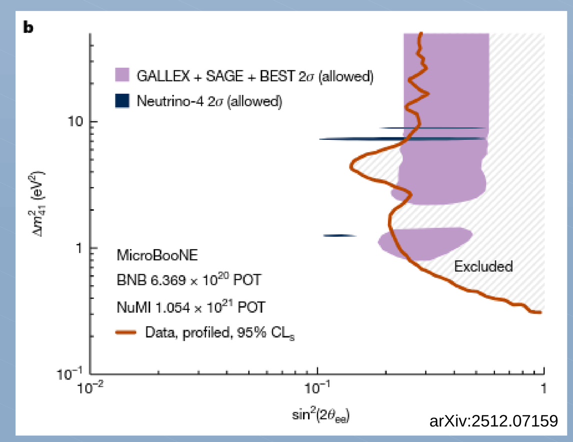
The History

- Historic results from LSND, MiniBooNE, reactor anomalies indicate sterile neutrino signal with **Δm^2_{41} ~ 1 eV²**
- Recent results from MicroBooNE, KATRIN show no indication of sterile
- **Atmospheric neutrinos allow check on different mixing matrix elements U_{x4} for the same sterile mass splitting**



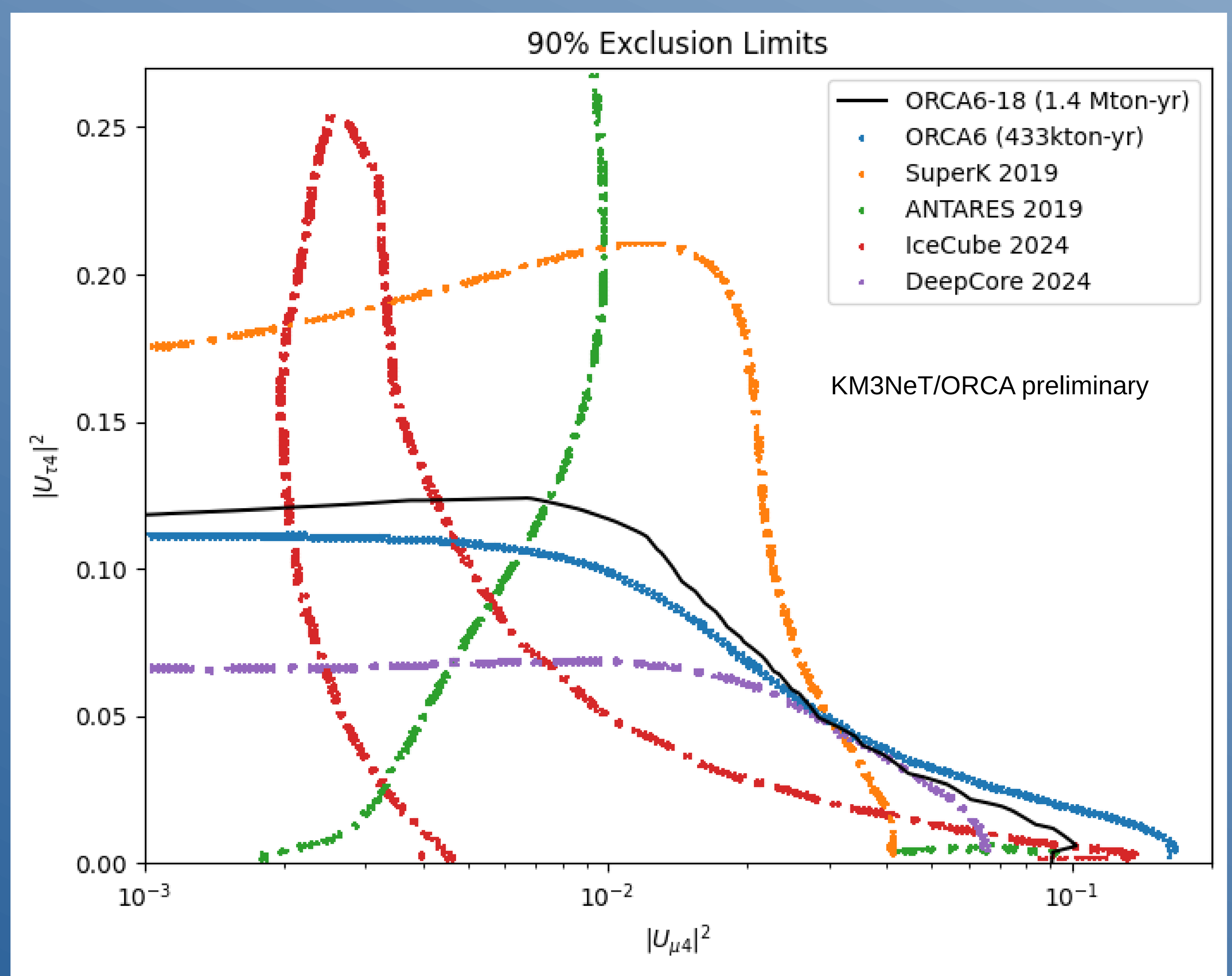




The Analysis Method

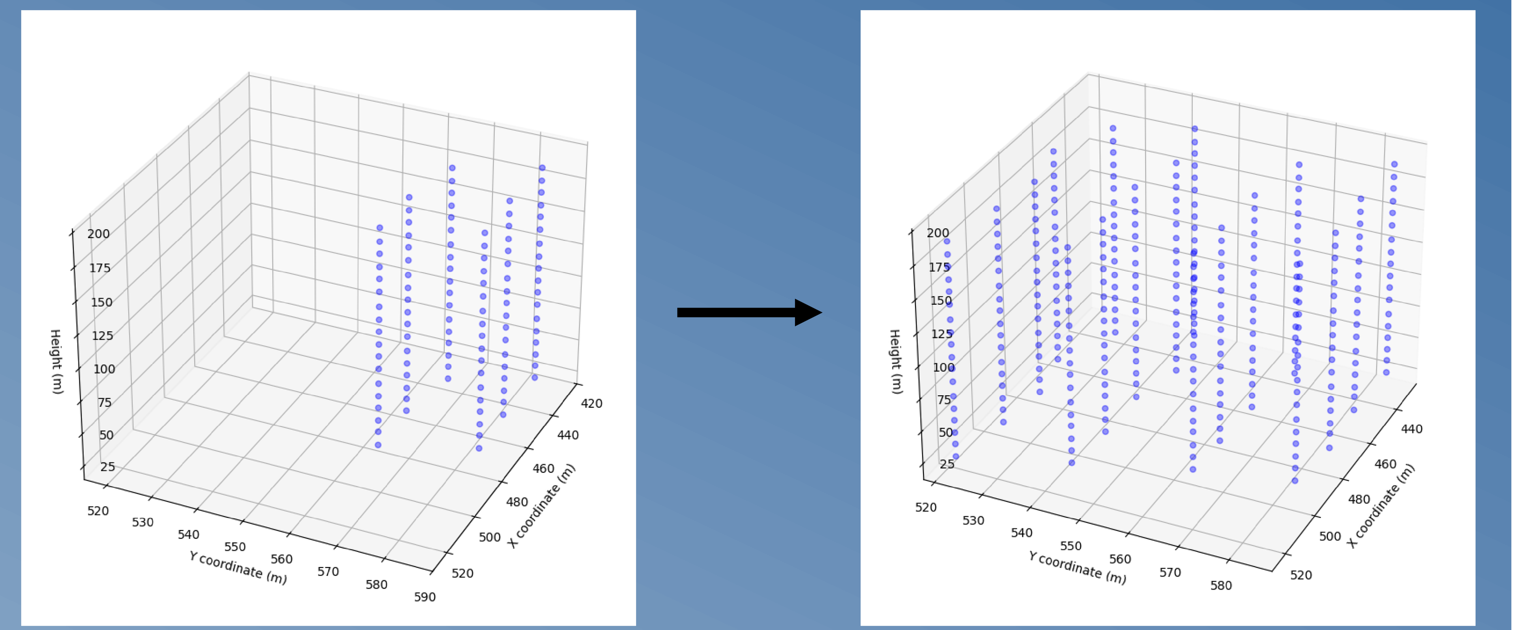
Perform multi-dimensional binned log-likelihood fit in

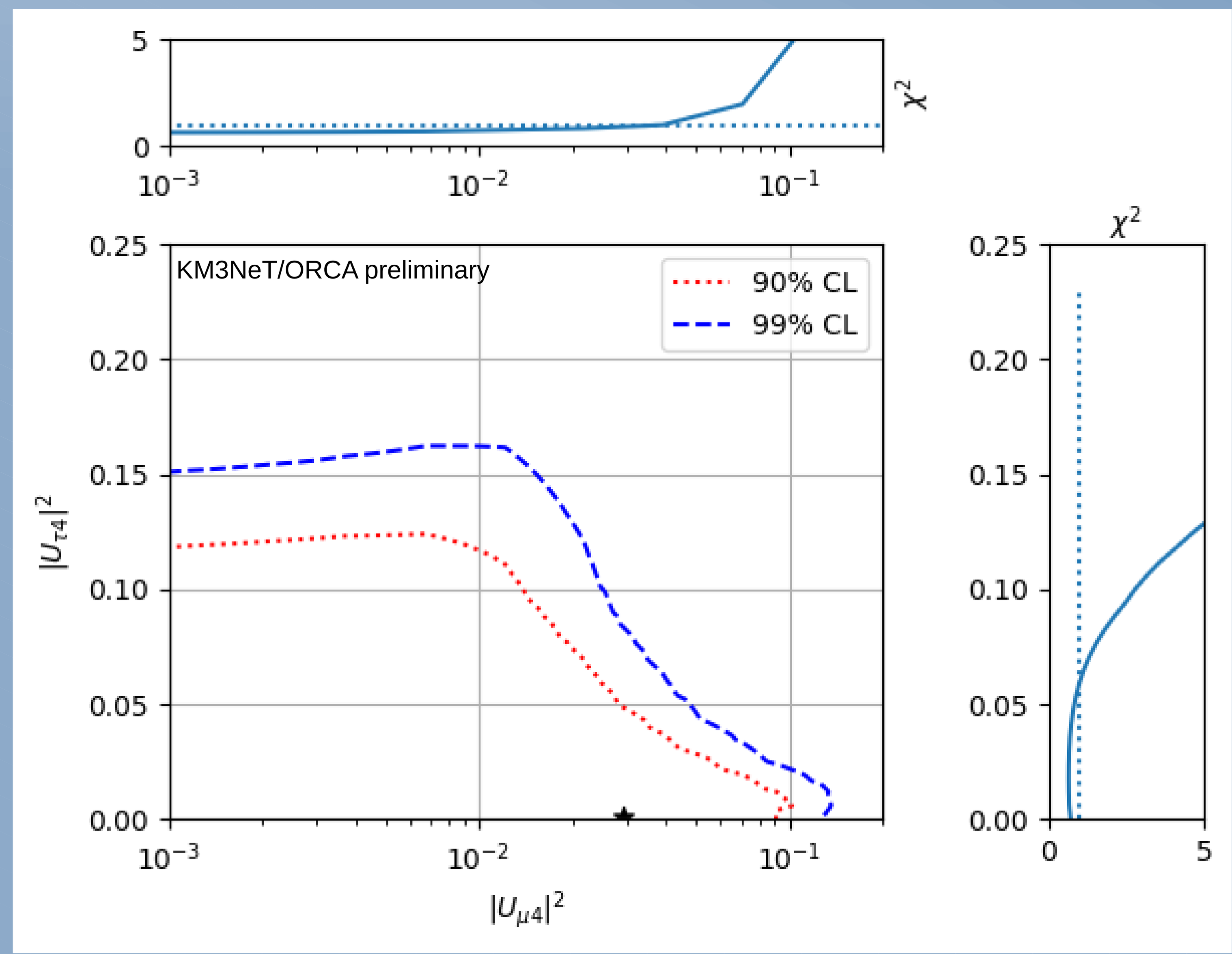
- **Energy** (> 2 GeV)
- **Zenith angle** (Upgoing only)
- **Detector class** (ORCA67 + ORCA11-18)
- **Reconstructed class** (Track + Intermediate + Shower)
- Model systematics for **Standard Oscillations** (Δm^2_{31}, θ_{23}), **Flux Model**, **Cross Section**, **Detector Response**



The Detector

- KM3NeT is a water cherenkov neutrino detector under construction in the Mediterranean Sea (Toulon, FR and Sicily, IT)
- KM3NeT/ORCA is optimised for energies **2 GeV – 100 GeV** for studies on **atmospheric neutrinos**
- New dataset covering **~1.4Mton-yr of data**, 3.3x increase over ORCA6 analysis
- 18 strings / 108 total – exposure increasing non-linearly!





KM3NeT/ORCA preliminary Event Type	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

The Global Picture

- Consistent and comparable with results from other atmospheric neutrino experiments (Super-K, IceCube, DeepCore, ANTARES)
- Changes from prior ORCA6 analysis come from **increase in exposure** and **improved systematic understanding**

The Results

Scan over θ_{24} / θ_{34} space to profile the 90% / 99% contour in ($|U_{\mu4}|^2$ / $|U_{\tau4}|^2$)

$|U_{\mu4}|^2 = \cos^2\theta_{24}$

$|U_{\tau4}|^2 = \sin^2\theta_{24}\cos^2\theta_{34}$

Fit consistent with no sterile signal and prior 433 kton-yr result

BEST FIT (< 90% 1D confidence limit)

$|U_{\mu4}|^2$ = 0.029 , < 0.094

$|U_{\tau4}|^2$ = 8.8 x 10^{-4} , < 0.11

All systematics compatible with nominal (NuFit6.1 for osc params) at < 2σ

KM3NeT/ORCA preliminary

Parameter	Best fit value (Upper Limit / Lower Limit)
θ_{24}	$0.172^{0.283}_{0.0}$
θ_{34}	$0.03017^{0.271}_{0.0}$
Flux	
Φ_{GSF1}	$0.0984^{0.989}_{-0.795}$
Φ_{K^-2P}	$1.39^{2.14}_{0.660}$
Φ_{K^-31G}	$-0.0420^{0.958}_{-1.04}$
Φ_{K^-158G}	$0.0384^{1.038}_{-0.962}$
Φ_{K^+2P}	$1.38^{2.13}_{-0.638}$
Φ_{K^+31G}	$-0.185^{1.08}_{-1.20}$
Φ_{K^+158G}	$0.187^{1.19}_{-0.817}$
Φ_{π^-2P}	$-0.235^{0.837}_{-1.16}$
Φ_{π^-20T}	$-0.764^{0.174}_{-1.70}$
Φ_{π^-31G}	$-0.0447^{0.952}_{-1.04}$
Φ_{π^-158G}	$-0.173^{0.831}_{-1.18}$
Φ_{π^+2P}	$-0.160e-01^{0.837}_{-1.16}$
Φ_{π^+20T}	$-0.794^{0.144}_{-1.73}$
Φ_{π^+31G}	$0.102^{1.09}_{-0.894}$
Φ_{π^+158G}	$-0.203^{0.814}_{-1.22}$
Φ_{n2P}	$0.0819^{1.08}_{-0.918}$
Φ_{n158G}	$0.00564^{1.00}_{-0.992}$
Φ_{p2P}	$0.171^{1.18}_{-0.839}$
Φ_{p158G}	$0.0400^{1.04}_{-0.962}$
Detector Systematics	
E_{scale}	$-0.0480^{-0.0112}_{-0.0818}$
Trigger Efficiency	$-1.378^{-0.851}_{-1.87}$
Cross Section	
S_{NC}	$1.21^{1.39}_{1.03}$
S_τ	$0.987^{1.14}_{0.839}$
σ_{QE}	$0.545^{1.48}_{-0.383}$
σ_{RES}	$0.387^{1.27}_{-0.485}$
Oscillation Parameters	
δ_{24}	$0.812^{3.14}_{-3.14}$
θ_{23}	$0.708^{0.902}_{0.656}$
Δm^2_{31}	$2.19^{2.29}_{2.09} \times 10^{-03}$

Systematic Effects

- Most important systematics on POIs are
- Standard oscillation parameters **(Δm^2_{31}, θ_{23})**
- Pion 20T uncertainty in flux model
- Kaon + 2P production uncertainty in flux model