Search for neutrino non-standard interactions with 10 years of ANTARES data and perspectives for KM3NeT/ORCA

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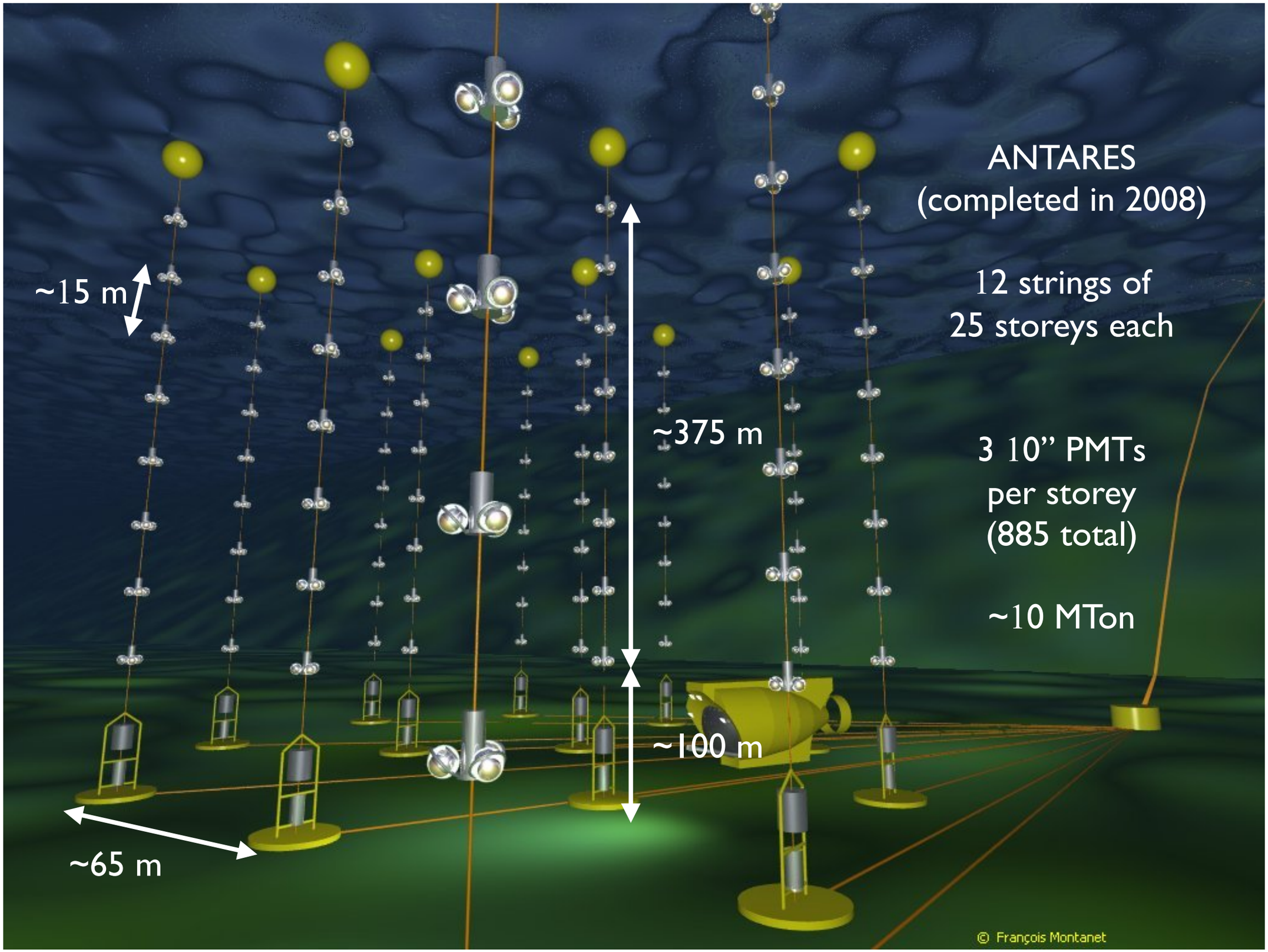
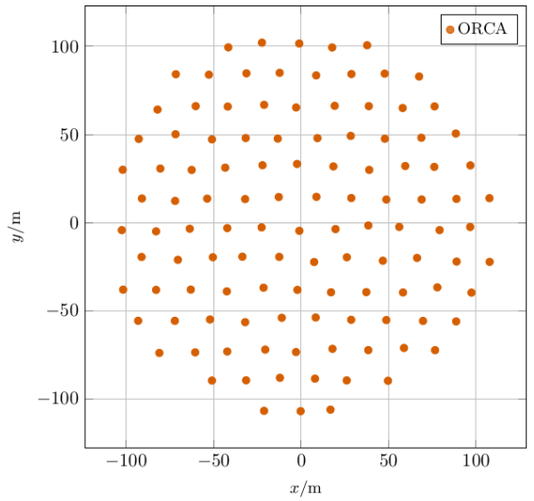
ANTARES


~15 m
~375 m
~100 m
~65 m
ANTARES
(completed in 2008)
12 strings of
25 storeys each
3 10” PMTs
per storey
(885 total)
~10 MTon
© François Montanet

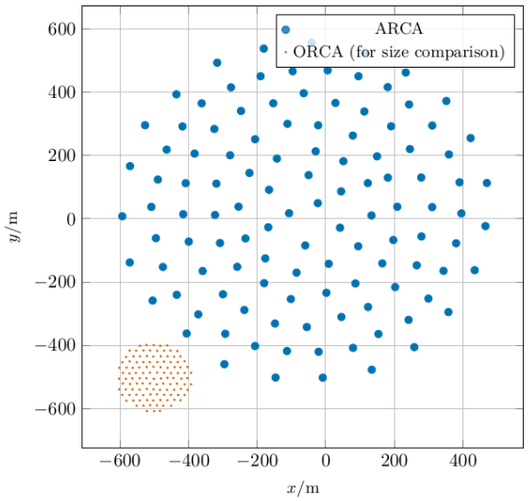
KM3NeT/ORCA & ARCA

ORCA: Low energy physics ~ few GeV
Neutrino Oscillations, Supernovae ….

ARCA: High energy physics ~ GeV - PeV
High energy astronomy, DM searches …



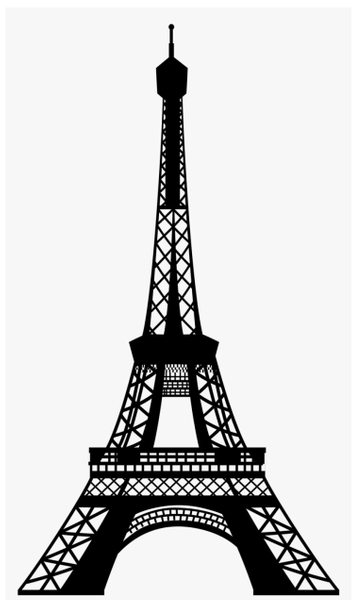
ORCA

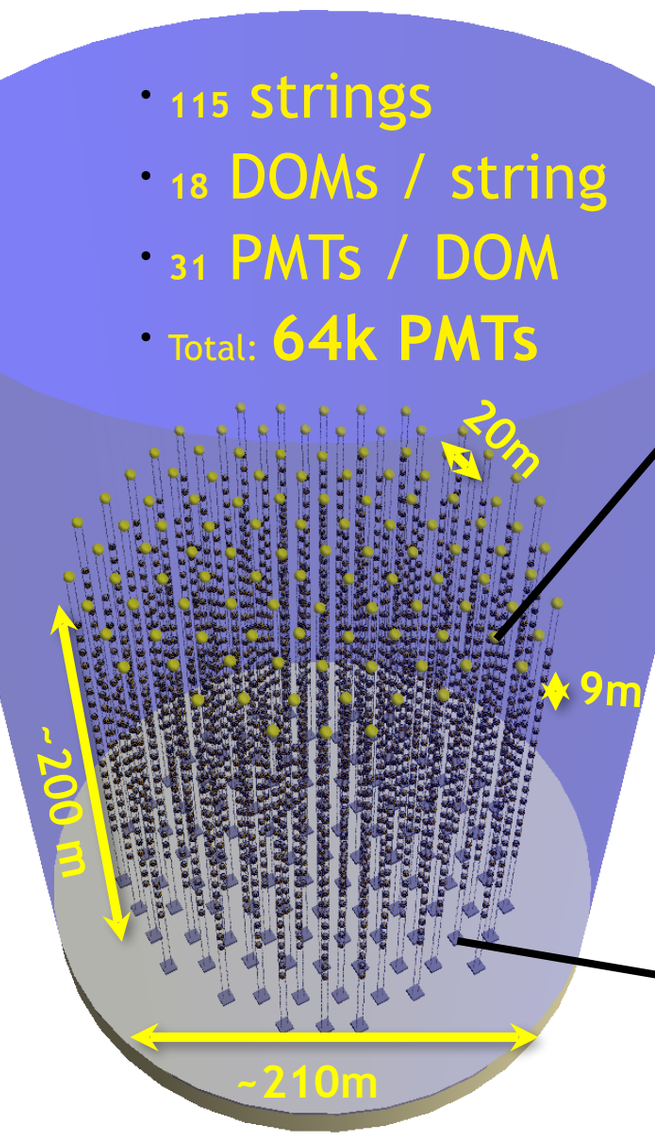


ARCA

ORCA instrumented Volume ~ 5 Mton

- 115 strings
- 18 DOMs / string
- 31 PMTs / DOM
- Total: 64k PMTs



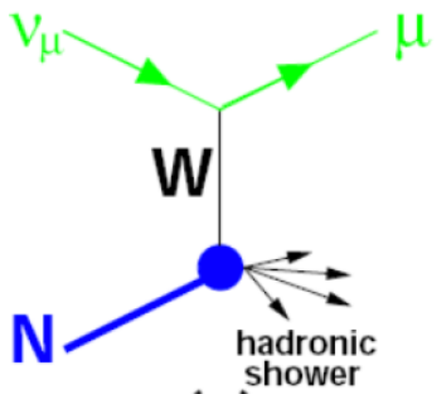


Detection Unit (DU)
aka "string/line"

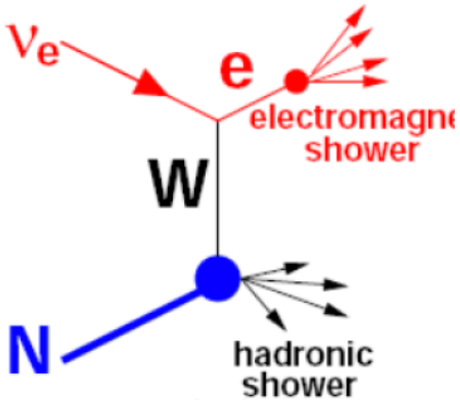
KM3NeT DOM
housing 31 3" PMTS

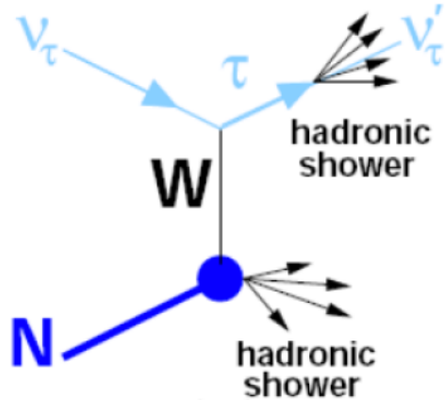
Event Topologies

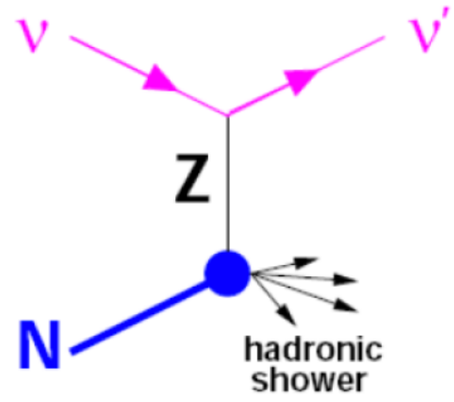
Tracks: ν_μ^{CC}, ν_τ^{CC}(muonic decay)

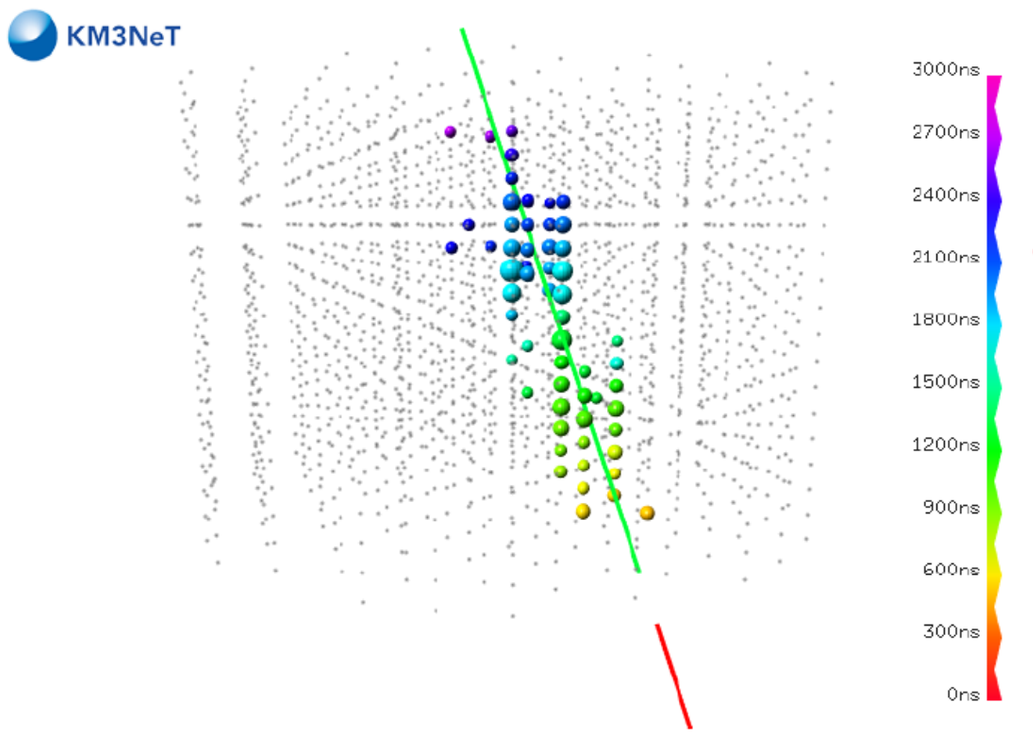


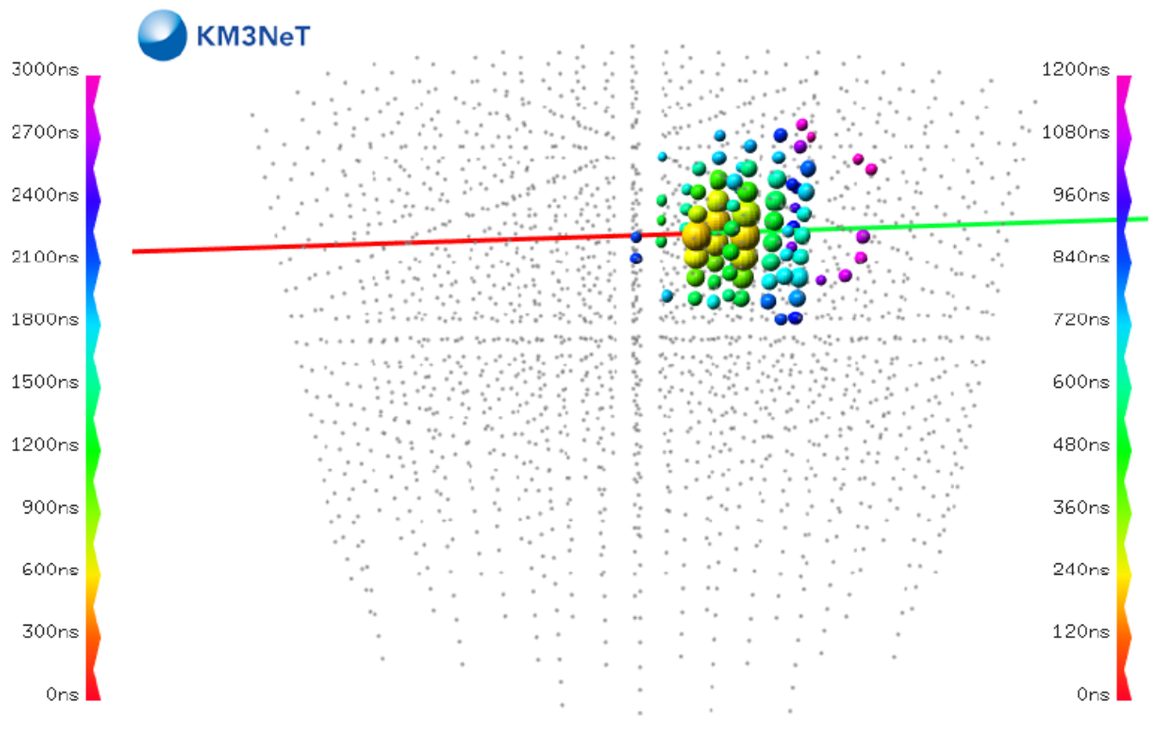
Showers: ν_e^{CC}, ν_τ^{CC}, ν^{NC}











Position, time and charge pattern within the detector used to reconstruct particle direction and energy.

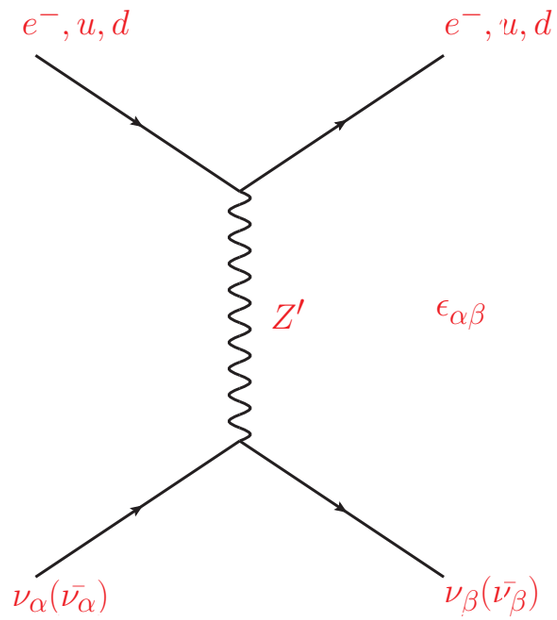
The Cherenkov signature of the outgoing lepton is used for Particle IDentification (PID).

Non-Standard Interactions (NSIs)

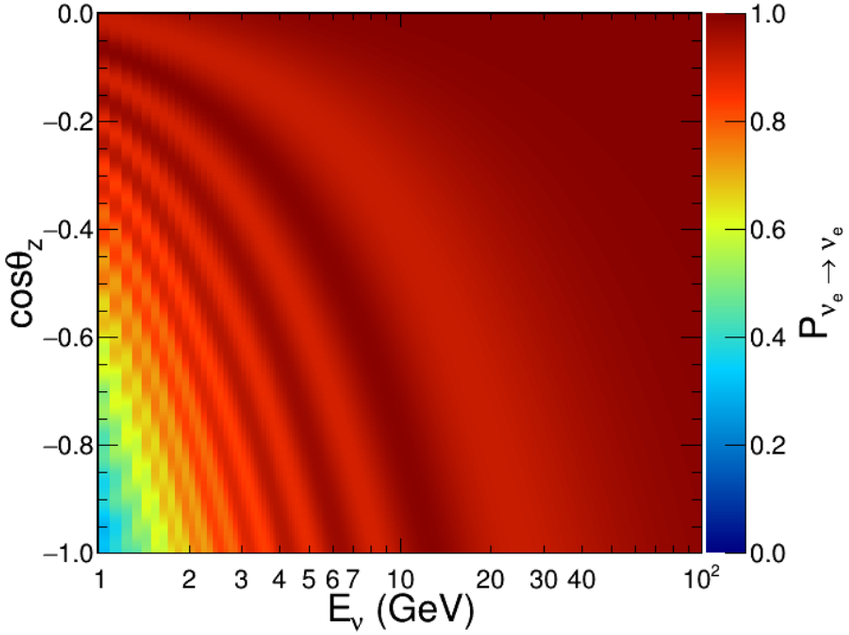
- The neutrino propagation Hamiltonian in presence NSIs:

$$H = \frac{1}{2E} U_{PMNS} \begin{bmatrix} 0 & 0 & 0 \\ 0 & \Delta m^2_{21} & 0 \\ 0 & 0 & \Delta m^2_{31} \end{bmatrix} U^{\dagger}_{PMNS} + \begin{bmatrix} A_{CC} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} + \sqrt{2} G_F N_d(x) \begin{bmatrix} \epsilon_{ee} & \epsilon_{e\mu} & \epsilon_{e\tau} \\ \epsilon^*_{e\mu} & \epsilon_{\mu\mu} & \epsilon_{\mu\tau} \\ \epsilon^*_{e\tau} & \epsilon^*_{\mu\tau} & \epsilon_{\tau\tau} \end{bmatrix}$$

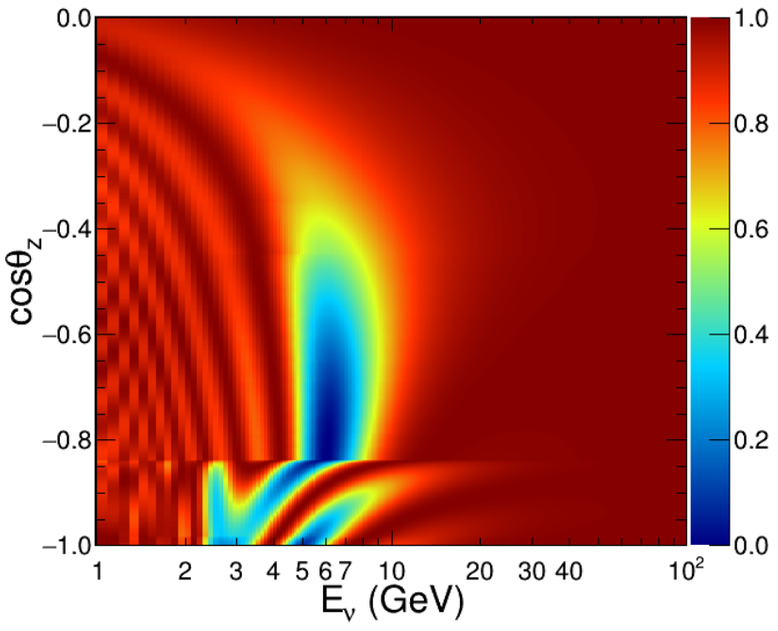
Vacuum | SM MSW | NSI



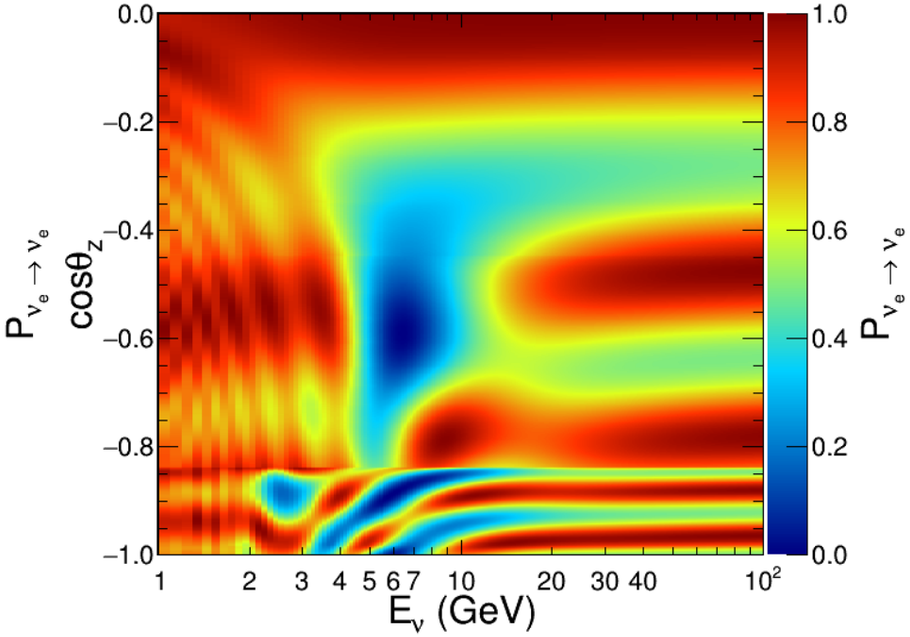
Normal Ordering, Oscillations in vacuum



Normal Ordering, Oscillations in matter



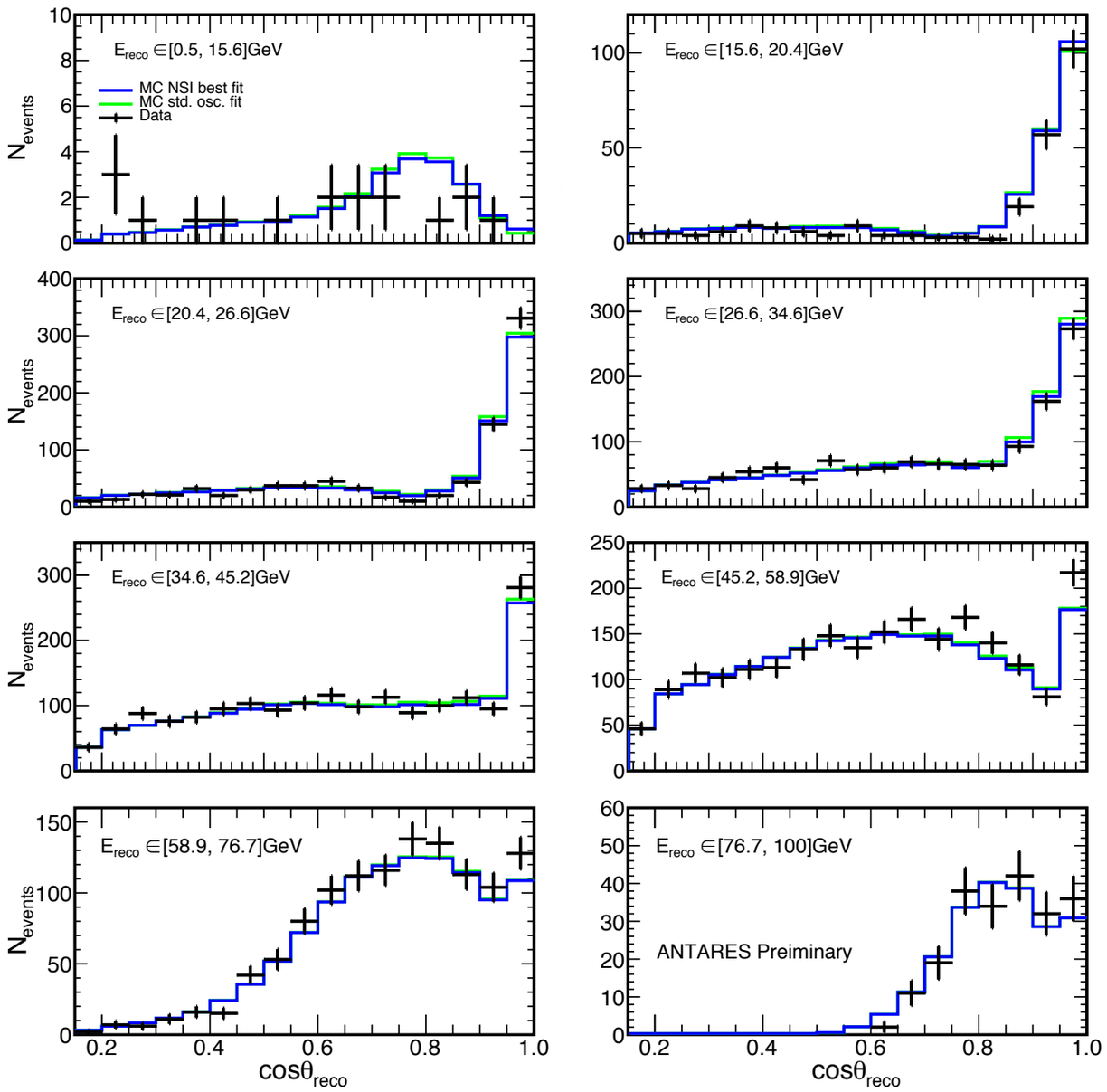
Normal Ordering, Oscillations with NSI



- Signature at detector: a statistical excess/deficit of $(\nu + \bar{\nu})$ events from anomalous flavour transitions expected with standard oscillations predictions.

ANTARES Limits

- ANTARES dataset corresponding to 2007-2016 (both years included) has been used.

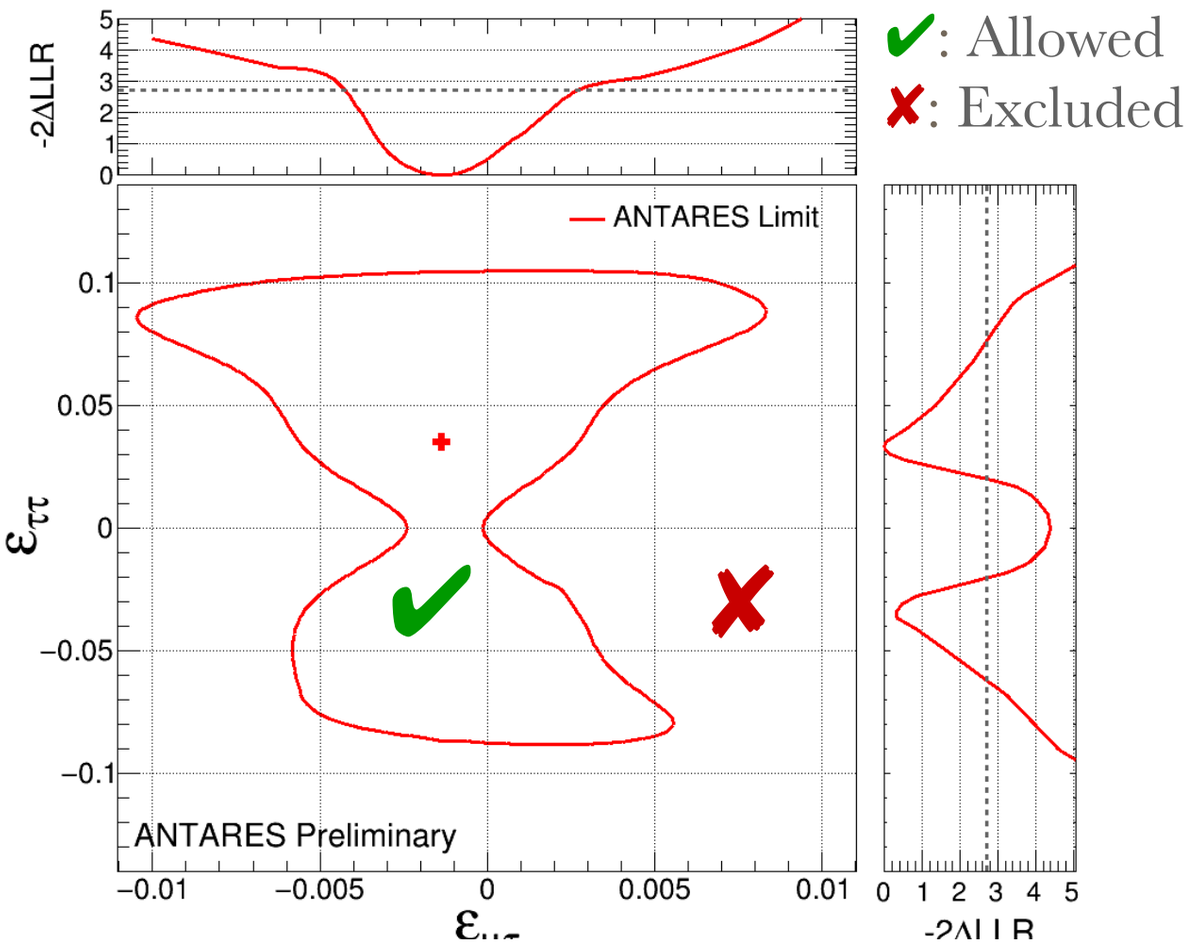


best-fit points

$\epsilon_{\mu\tau}$: -1.3e-3

$\epsilon_{\tau\tau}$: 3.2e-2

χ^2/ d.of. : 152.36/ 136.



✔: Allowed

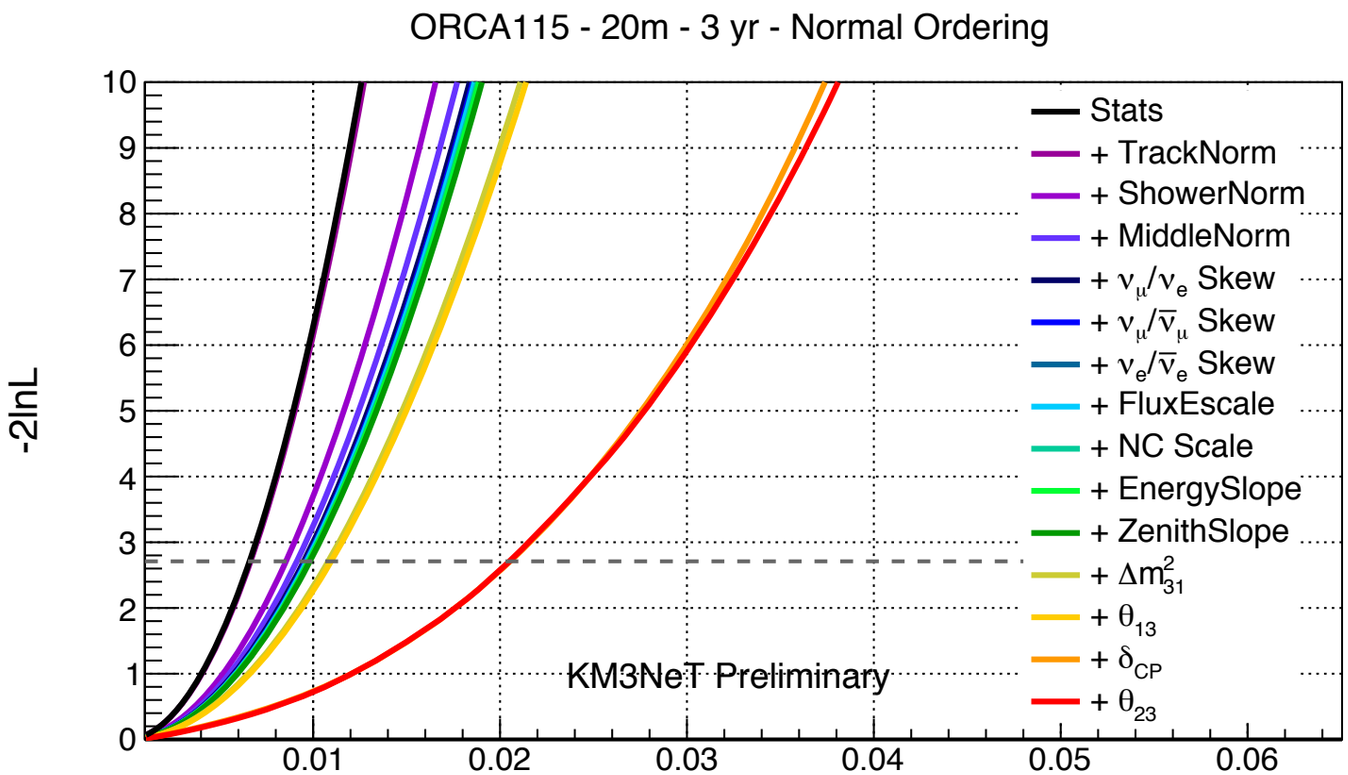
✘: Excluded

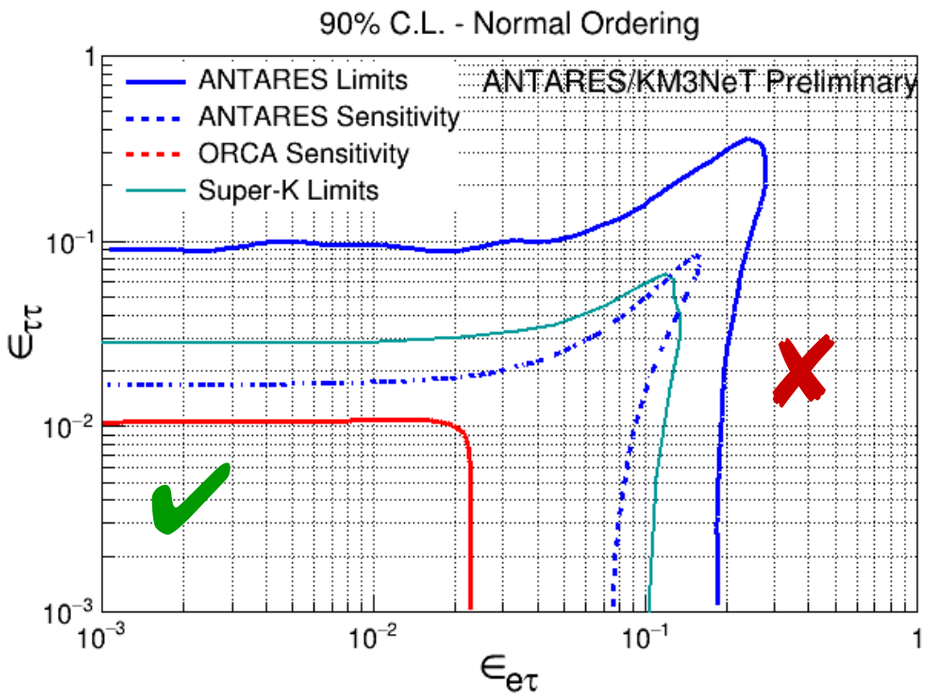
$$-4.2 \times 10^{-3} < \epsilon_{\mu\tau} < 2.7 \times 10^{-3} \quad \text{(at 90\% C.L)},$$
$$-6.1 \times 10^{-2} < \epsilon_{\tau\tau} < -2.1 \times 10^{-2} \quad \text{and} \quad 2.1 \times 10^{-2} < \epsilon_{\tau\tau} < 7.3 \times 10^{-2} \quad \text{(at 90\% C.L)}.$$

https://nusoft.fnal.gov/nova/nu2020postersession/pdf/posterPDF-178.pdf

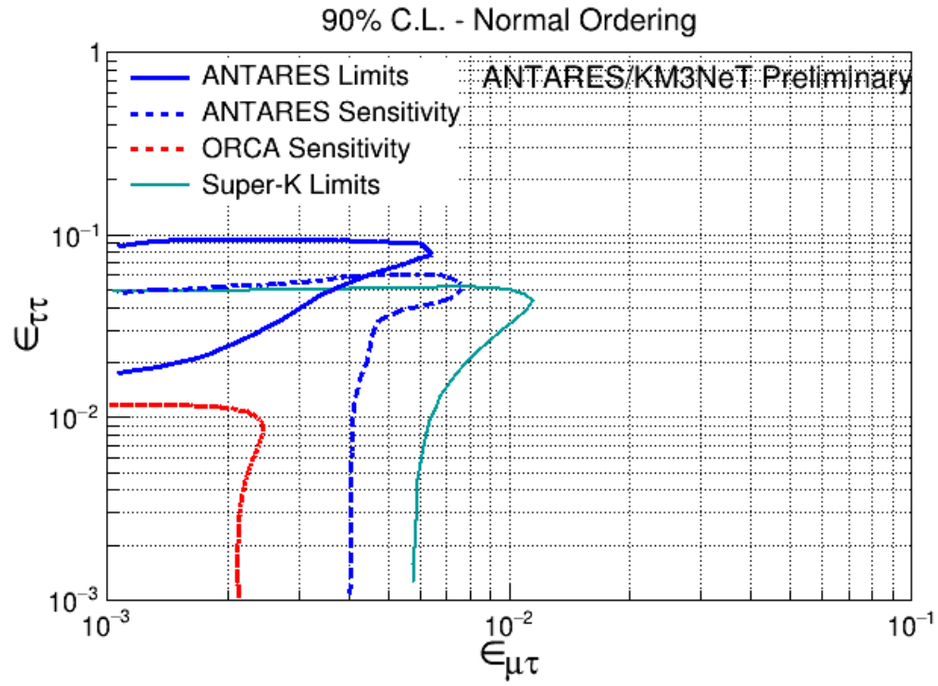
World's best limits!

ORCA Sensitivities





NSI Couplings	Assumed True NMO	Bounds (90% C.L.)
$\epsilon_{e\mu}$	NO	$(-1.7 \times 10^{-2}, 1.7 \times 10^{-2})$
	IO	$(-2.0 \times 10^{-2}, 2.0 \times 10^{-2})$
$\epsilon_{e\tau}$	NO	$(-1.8 \times 10^{-2}, 2.1 \times 10^{-2})$
	IO	$(-3.1 \times 10^{-2}, 2.7 \times 10^{-2})$
$\epsilon_{\mu\tau}$	NO	$(-1.7 \times 10^{-3}, 1.7 \times 10^{-3})$
	IO	$(-1.7 \times 10^{-3}, 1.7 \times 10^{-3})$
$\epsilon_{\tau\tau}$	NO	$(-0.8 \times 10^{-2}, 1.1 \times 10^{-2})$
	IO	$(-1.1 \times 10^{-2}, 0.8 \times 10^{-2})$



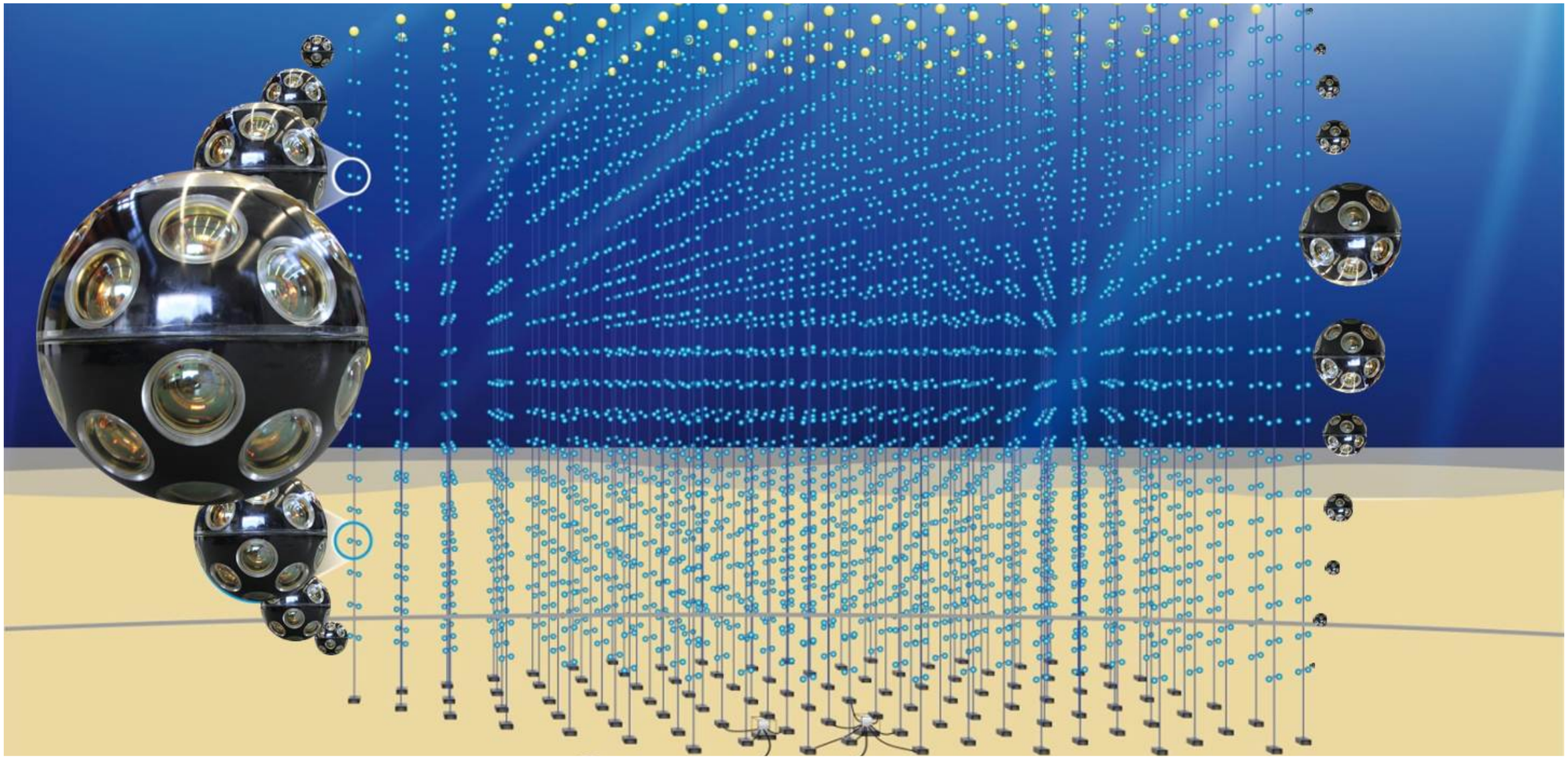
3 year projected sensitivities towards NSI parameters at ORCA.

Outlook

ANTARES has produced significant results in constraining many new physics scenarios by studying neutrinos at the abyss of the Mediterranean Sea.

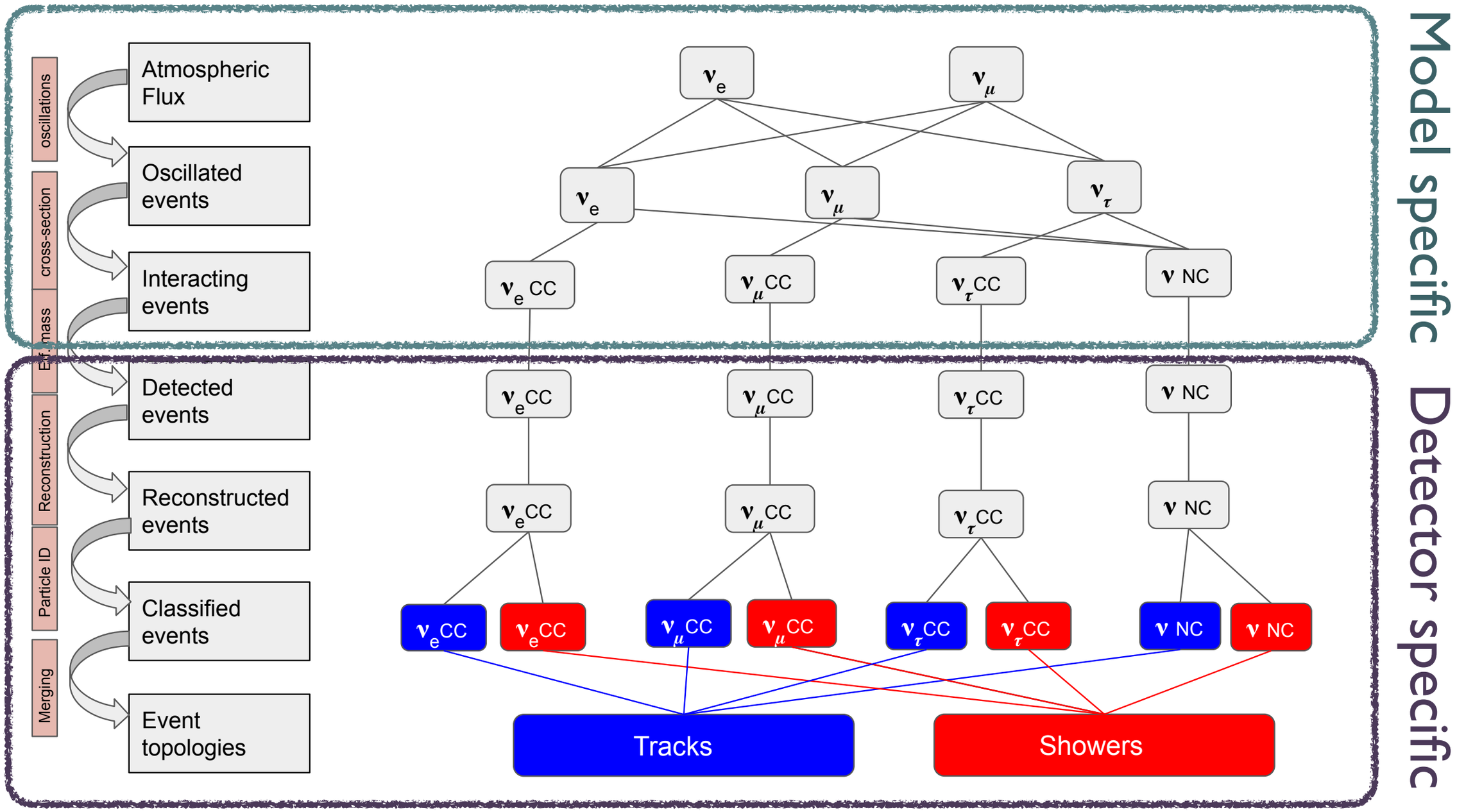
KM3NeT will make further improvements.
6 ORCA (and 1 ARCA) strings are operational. (Stay tuned for first results!)


рахмат
danke
謝謝
ngiyabonga
Баярлалаа
spas
teşekkür ederim
mersi
kia ora
barka
welalin
tack
спасибо
faafetai lava
vinaka
blagodaram
dank je
misaotra
matondo
paldies
grazzi
mahalo
kiitos
dankie
спасибі
thank you
gracias
tapadh leat
хвала
nanni
nandri
dhanyavad
maururu
köszönöm
asante
manana
bedankt
bayarlalaa
gràçie
hvala
akun
dankon
aciū
obrigada
tenki
enkosi
djiere dieuf
tau
mochchakkeram
murakoze
dziękuję
дякую
mamnun
chokrane
chnorakaloutioun
gratias ago
gràcies
sulpáy
taiku
go raibh maith agat
sobodi
děkuji
sagolun
sukriya
kop khun krap
obrigado
mèsi
ありがとう
tanemirt
grazie
arigatô
takk
dakujem
trugarez
didi madloba
najis tuke
rahmet
kam sah hamnida
rahmat
terima kasih
ευχαριστώ
diolch
dhanyavadagalu
shukriya
mercé
мерси
তোমাকে ধন্যবাদ
감사합니다
xièxie
merci



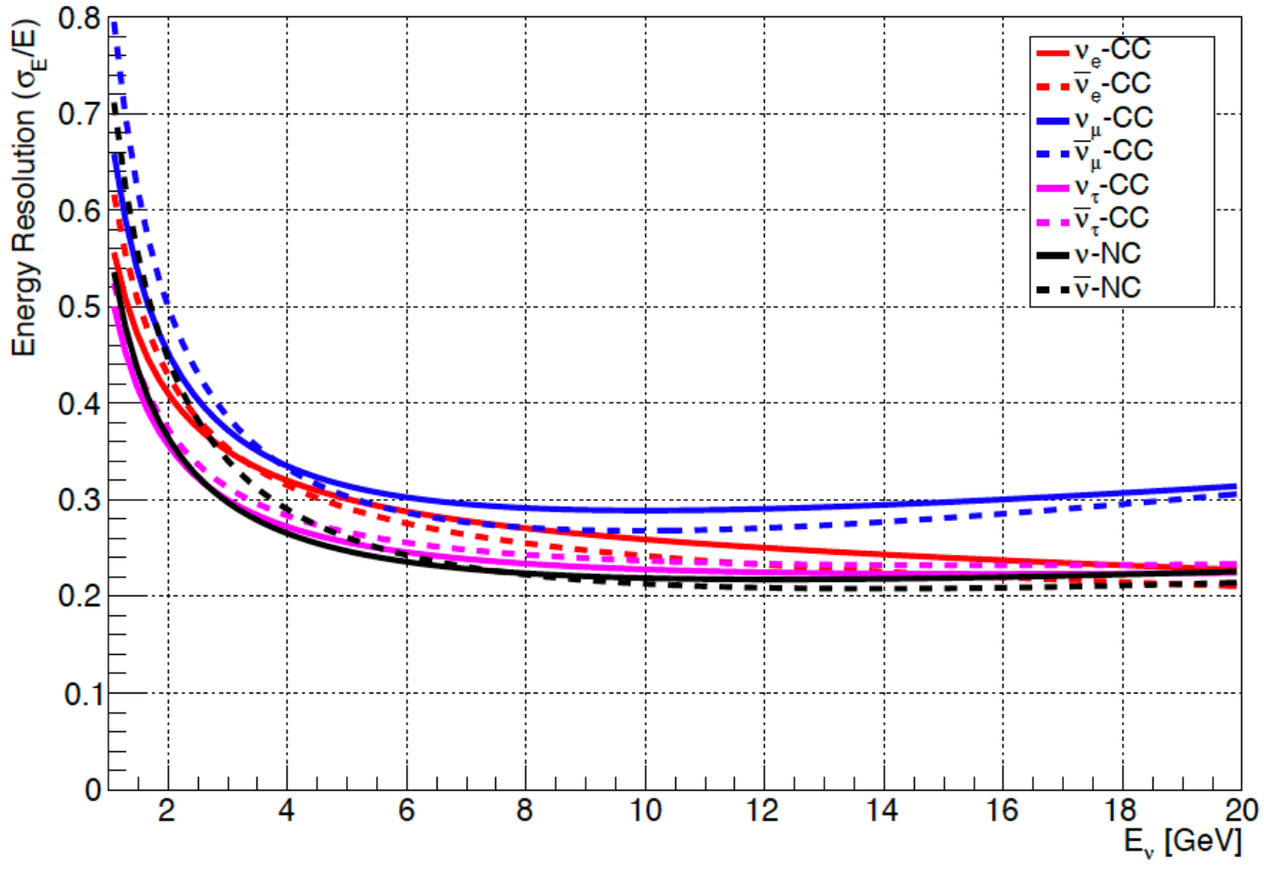
Backup

Computation of event numbers



Energy resolution

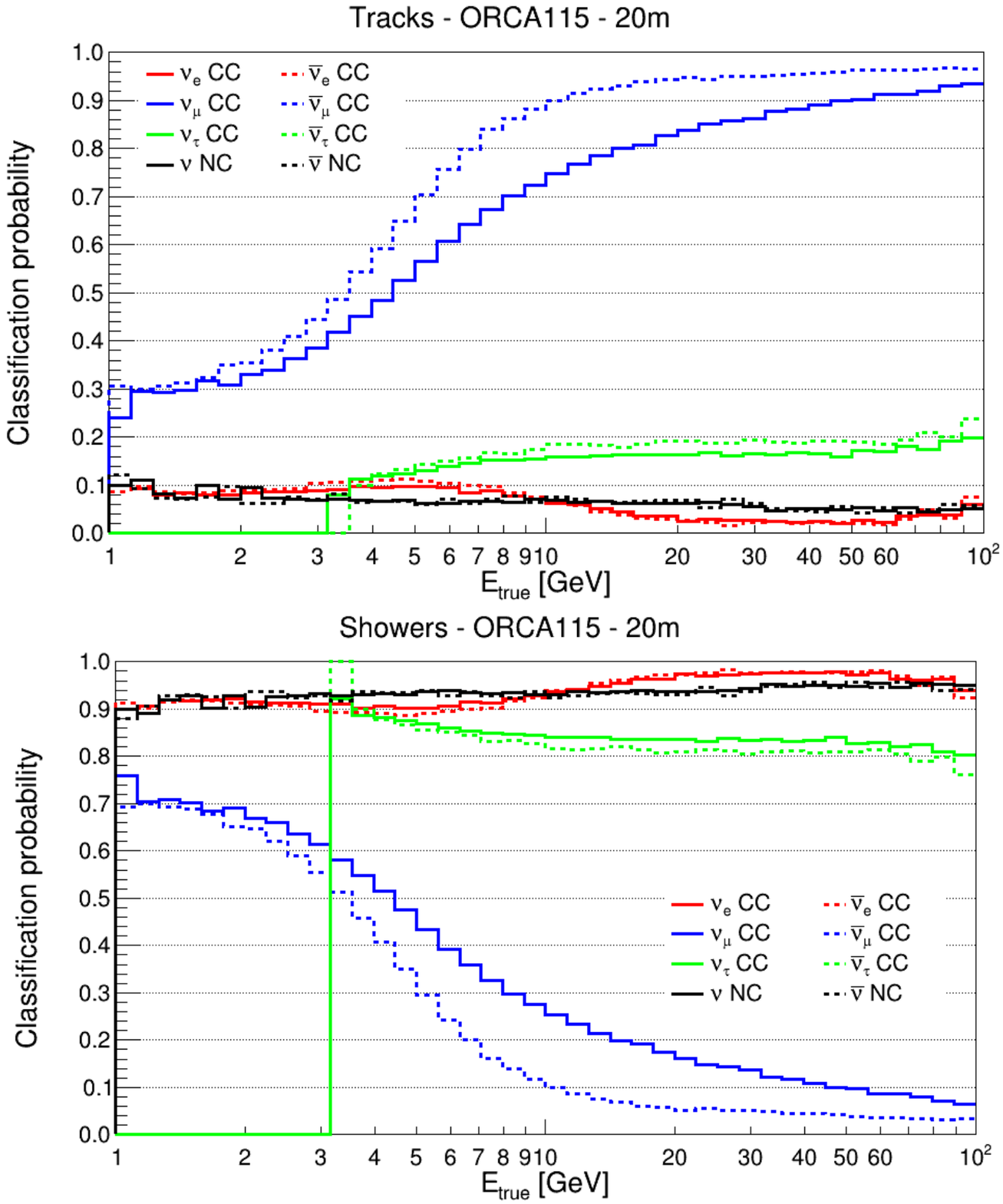
- Energy resolution for different interaction channels.



Particle IDentification (PID)

Event classes based on track probability estimated with Random Decision Forest (RDF) of reconstructed heuristics.

1 = Perfect Track
0 = Perfect Shower



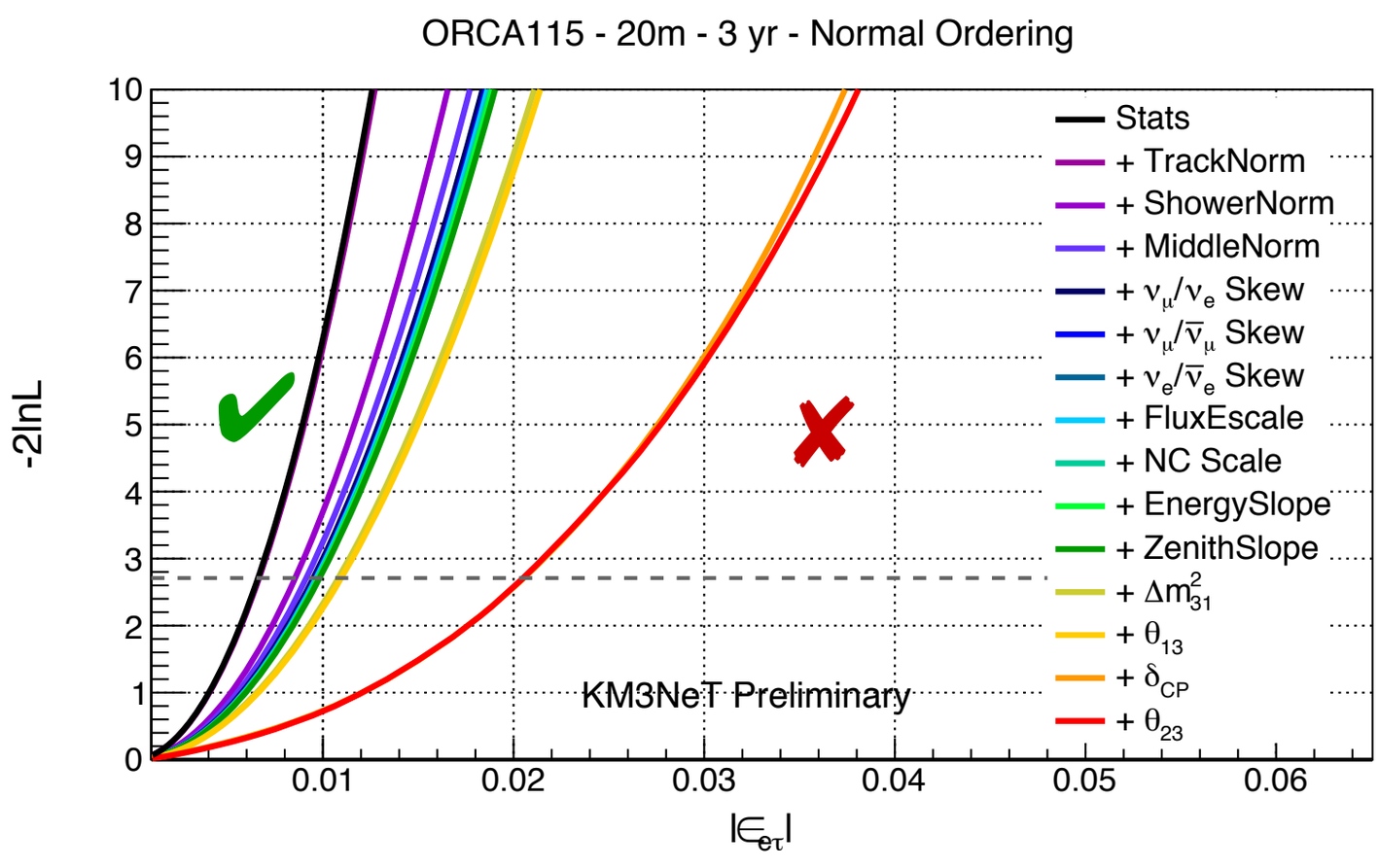
Systematics:

$$-2\log\mathscr{L}_{NSI} = 2\sum_{i\in\{bins\}}\left[N_i^{\mathrm{NSI}}(\bar{o},\bar{s}) - N_i^{\mathrm{SM}}(\bar{o},\bar{s}) + N_i^{\mathrm{SM}}\,.\log\frac{N_i^{\mathrm{SM}}(\bar{o},\bar{s})}{N_i^{\mathrm{NSI}}(\bar{o},\bar{s})}\right] + \sum_{k\in\{syst\}}\frac{(s_k-\hat{s}_k)^2}{\sigma_k^2}$$

parameters	treatment	true values	priors
Track norm.	fitted	1	free
Shower norm.	fitted	1	free
Middle norm.	fitted	1	free
ν_μ/ν_e skew	fitted	0	5%
$\nu_\mu/\bar{\nu}_\mu$ skew	fitted	0	5%
$\nu_e/\bar{\nu}_e$ skew	fitted	0	5%
Flux Escale	fitted	1	10%
NC scale	fitted	1	5%
Energy slope	fitted	0	5%
Zenith slope	fitted	0	2%
$\delta_{CP}(^\circ)$	fitted	221	free
$\Delta m^2_{31}/10^{-3}eV^2$	fitted	2.528	free
$\theta_{13}(^\circ)$	fitted	8.60	0.13
$\theta_{23}(^\circ)$	fitted	48.6	free

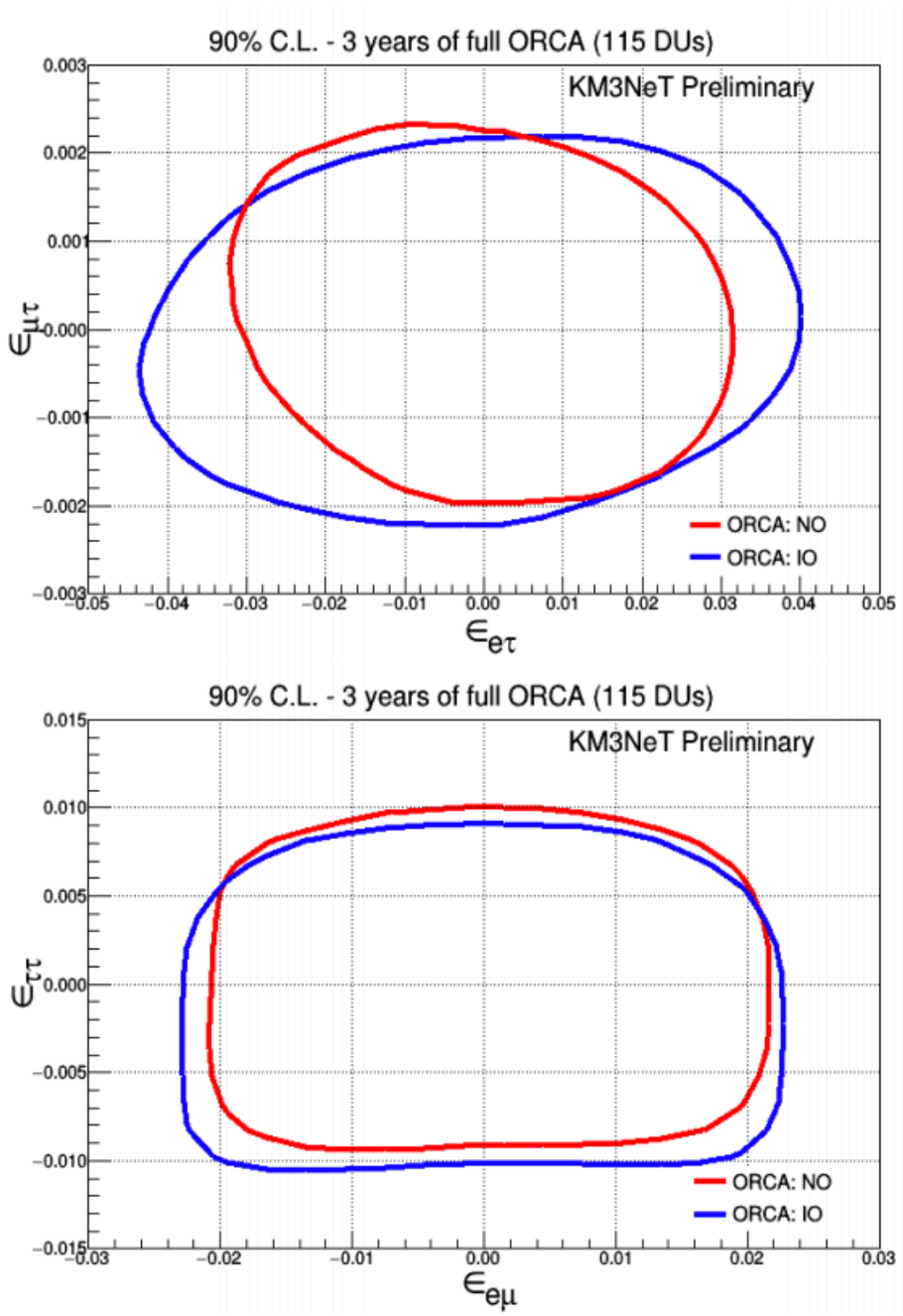
List of systematics

✔: Allowed
✘: Excluded



Effect of systematic uncertainties on $\mathcal{E}_{e\tau}$

Correlated NSI Sensitivities



90% CL contours in different NSI phase spaces.

The region inside the closed curves are the region allowed by ORCA after 3 years of data taking.

https://pos.sissa.it/358/931/