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# Physics Reach Summary of WP5

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4th ESSnuSB+ Annual Meeting, Uppsala

5 – 9 October, 2025



# WP5 presentations

Red: Monojit  
Black: George

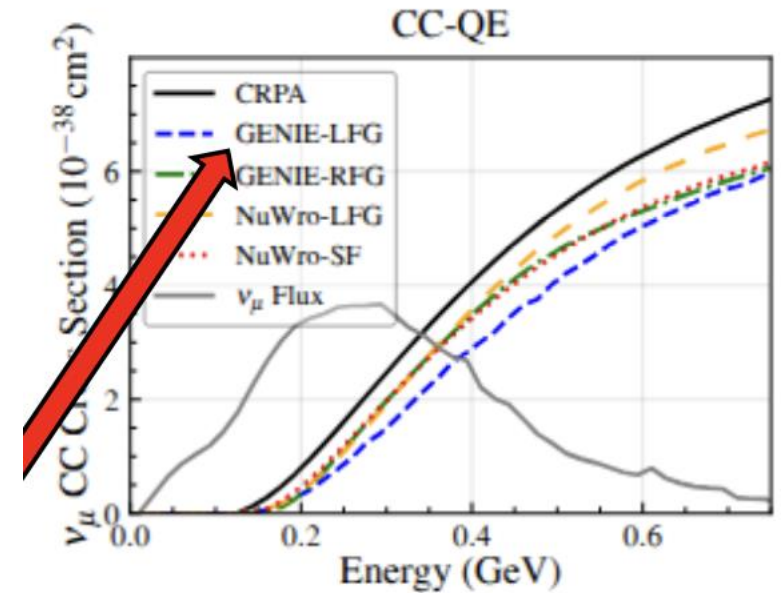
1. Implications of CRPA cross-section at FD: Marco
2. Implications of 2p2h cross-section at FD: Natalie
3. Solar neutrino: Alessio
4. FD simulation and Gd doping: Mahesh
5. Atmospheric neutrino: Sandhya
6. Implication of superscaling cross-section model at FD: Elena
7. Implications of GNN at END: Peter
8. T114 at J-PARC: Towards ESSnuSB Neutrino Cross-Section Measurement: Bruno
9. Recent update on cross-section results and emulsion technology: Fukuda
10. Sterile neutrino and NSI at the NDs: Doris
11. Software framework: Georgi
12. Cross-section at LEMMOND: Spyros

# CRPA cross-section at FD (Marco)

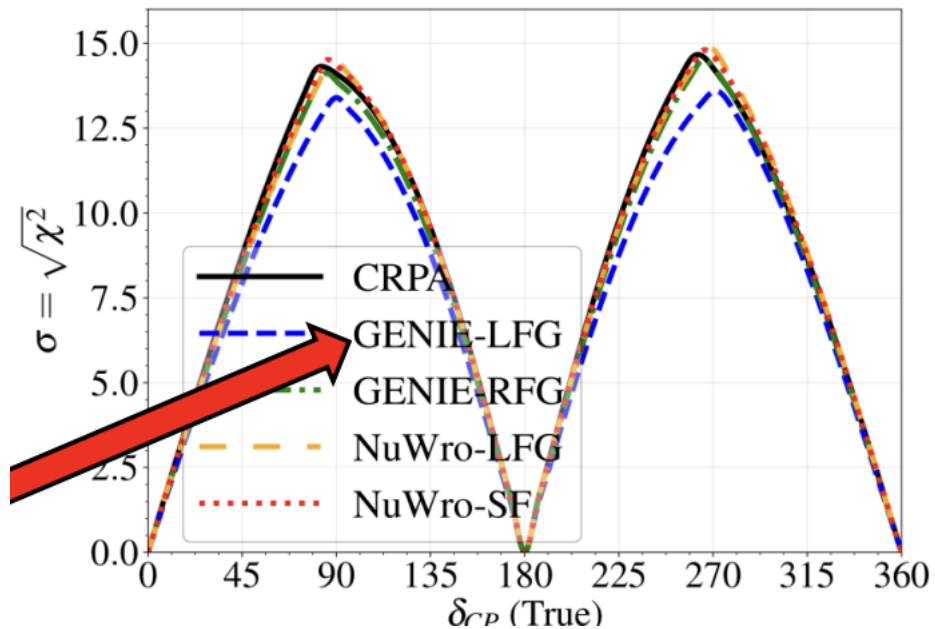
Cross-section has been calculated using CRPA approach for ESSnuSB

Comparison was made with the event generators

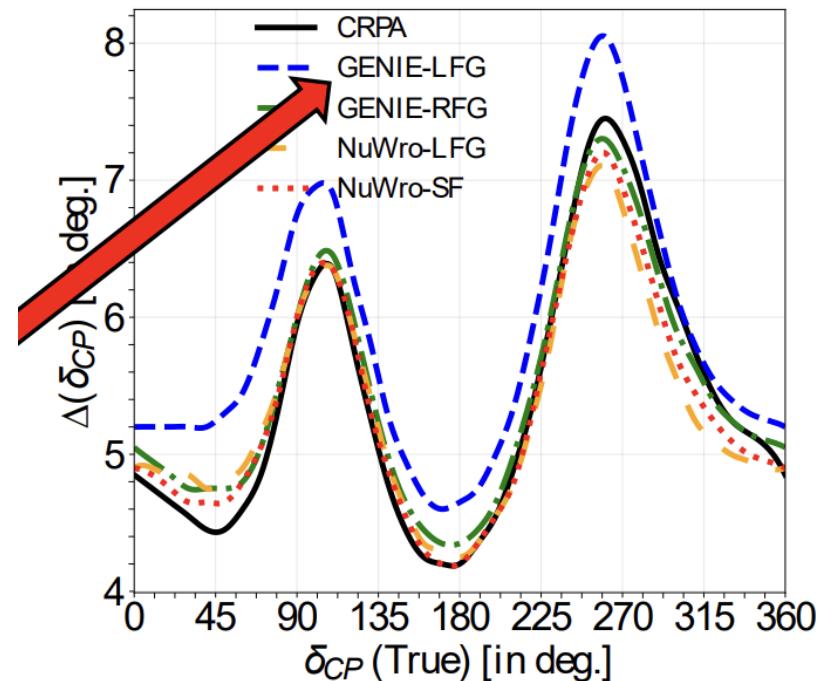
CP sensitivity estimated with the new cross-section



CPV Sensitivity with : QE



CP Precision with : QE



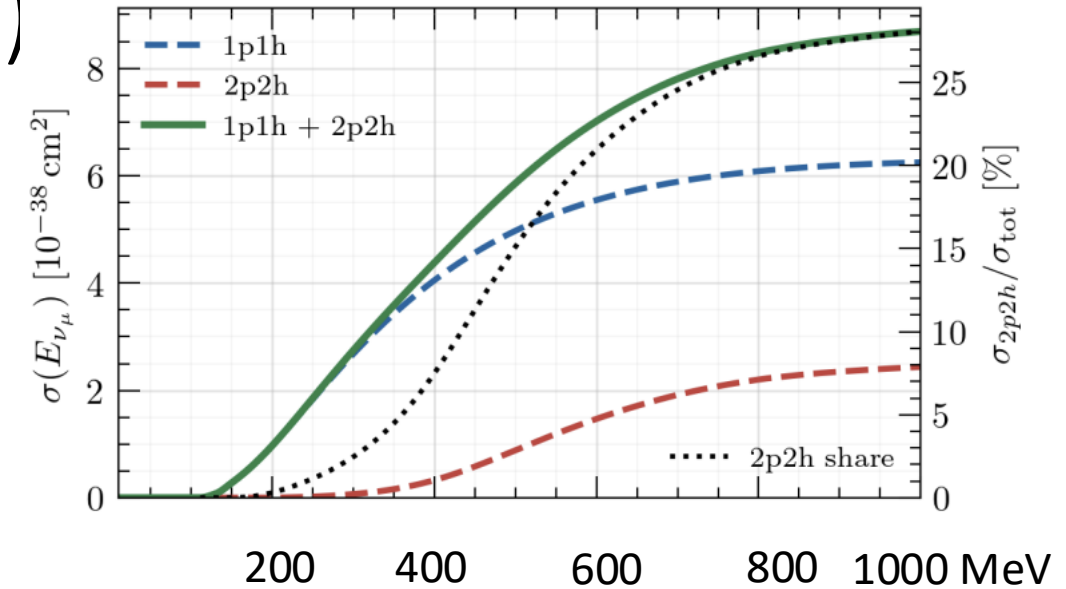
Manuscript under preparation

# 2p2h cross-section at FD (Natalie)

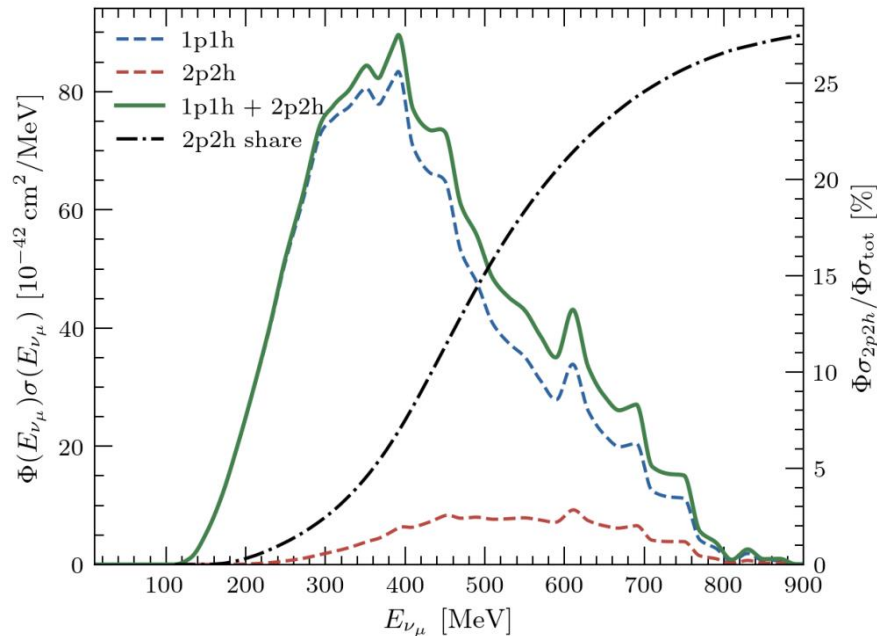
2p2h cross-section is calculated in the ESSnuSB energies

Comparison was made with GENIE

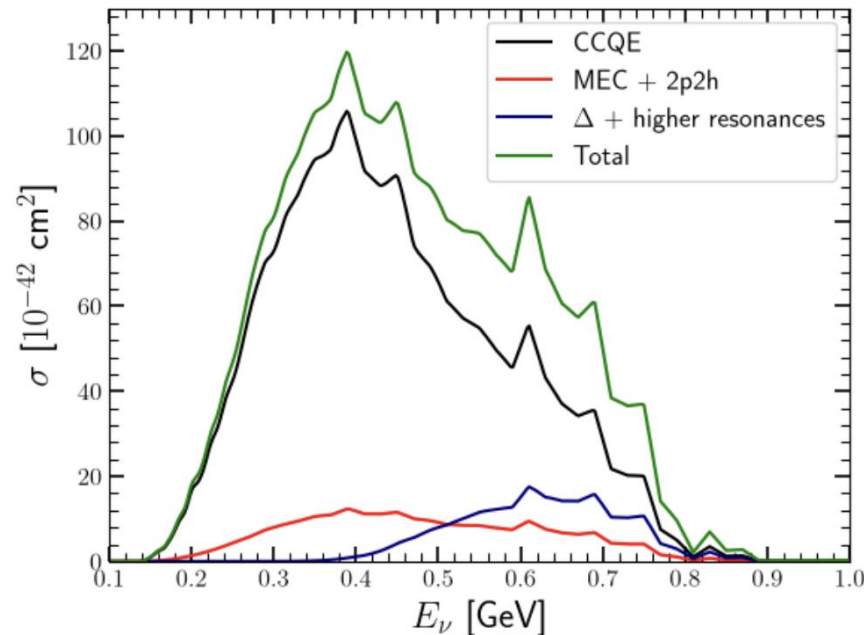
ESSnuSB can distinguish difference in low energy



Ghent group calculation



GENIE



Will do further analysis in terms of event rates and  $\chi^2$

# Superscaling cross-section at FD (Elena)

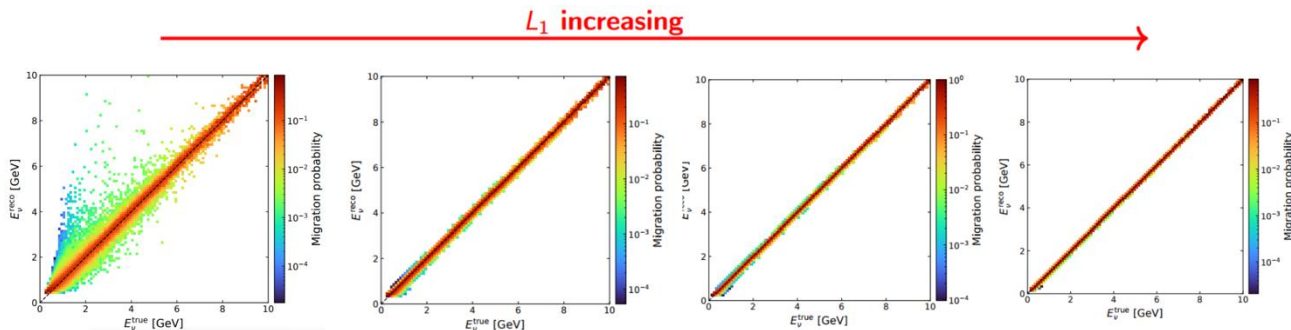
## Superscaling variable $\psi'$

Dimensionless measure of  $\Delta E_\nu \equiv E_\nu^{\text{true}} - E_\nu^{\text{reco}}$

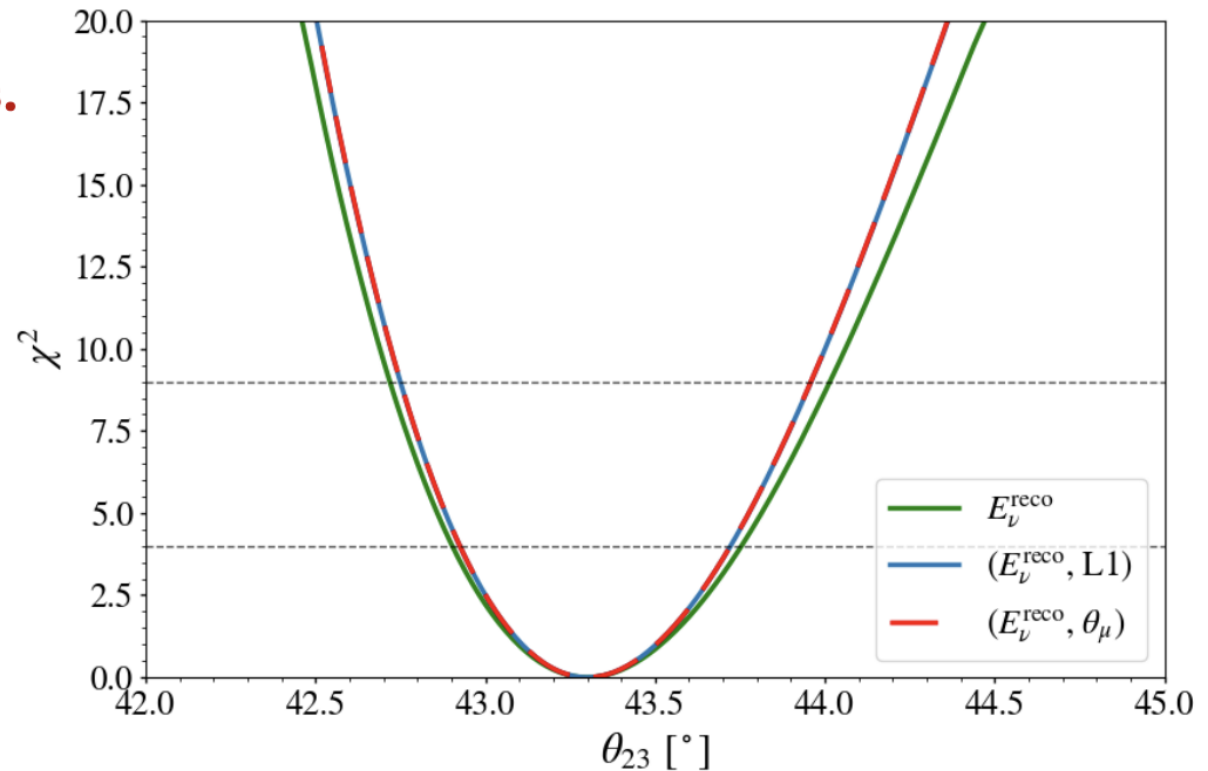
Taylor expansion around  $\Delta E_\nu = 0$

$$\psi' = \chi_F L_1(\vec{p}_\ell, \theta_\ell) \Delta E_\nu + \mathcal{O}(\Delta E_\nu^2)$$

$L_1$  depends only on the measured lepton kinematics.



Will do analysis in  
ESSnuSB

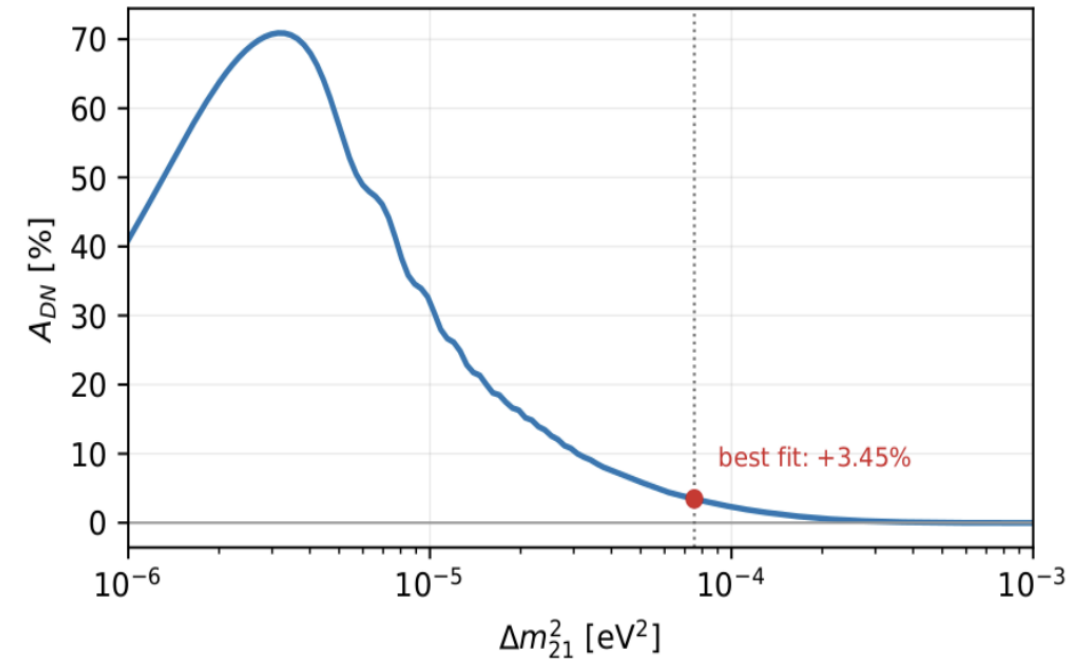


# Solar neutrino at FD (Alessio)

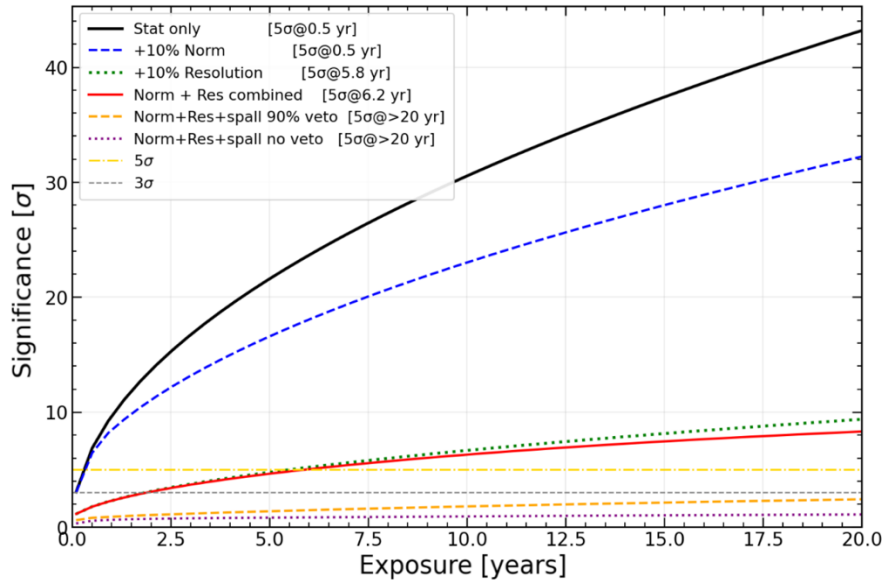
Sensitivities for (i) upturn, (ii) hep discovery and (iii) day-night asymmetry has been studied

Manuscript under preparation

$E_\nu = 10 \text{ MeV}$



upturn



**0.5 year**

5 $\sigma$  with statistics only

**5.8 years**

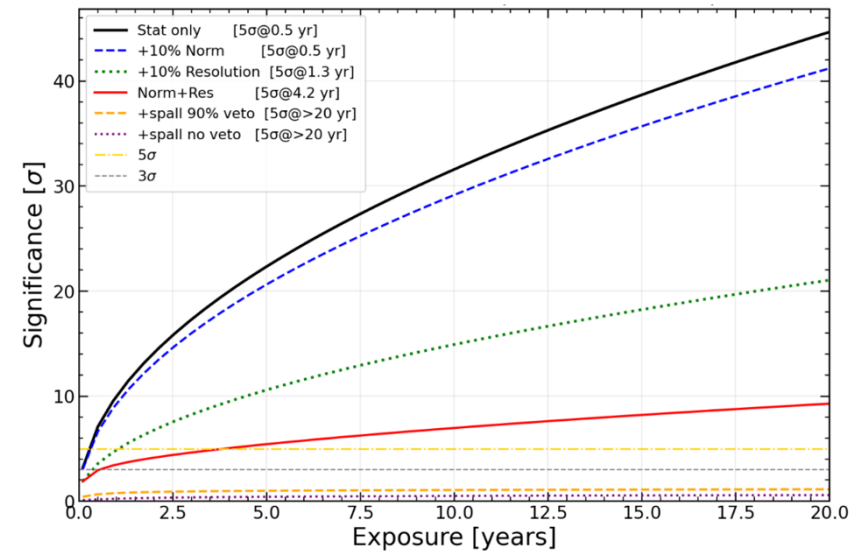
5 $\sigma$  with the resolution nuisance only

**6.2 years**

5 $\sigma$  with normalization and resolution systematics

A 90% veto remains below 3 $\sigma$  after 20 years.

Hep discovery



**4.2 years**

5 $\sigma$  with normalization and resolution systematics only

**$\approx 1.2\sigma$**

after 20 years with a 90% veto

Environmental background dominates the result

# Atmospheric neutrino at FD (Sandhya)

NSI

Mass ordering

**$3\sigma$  after 4 years,  $5\sigma$  after 10 years**

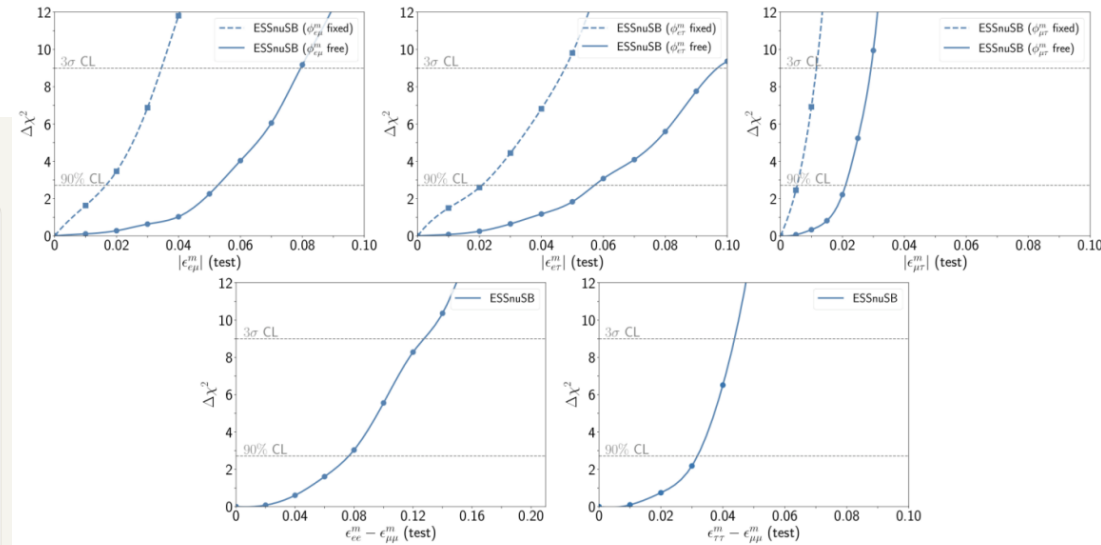
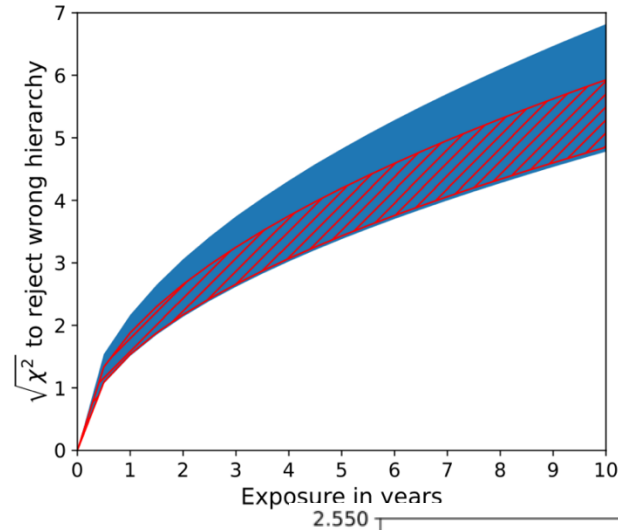
**$3\sigma$**

after about 4 years, whatever the true ordering and  $\delta_{CP}$

**$5\sigma$**

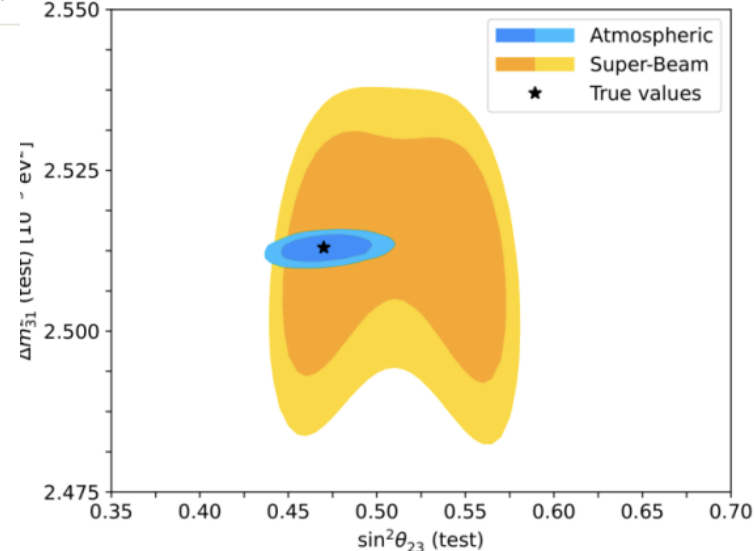
after 10 years (5.4 Mt-yr), independent of the true ordering

This result is independent of the beam programme and complements it.

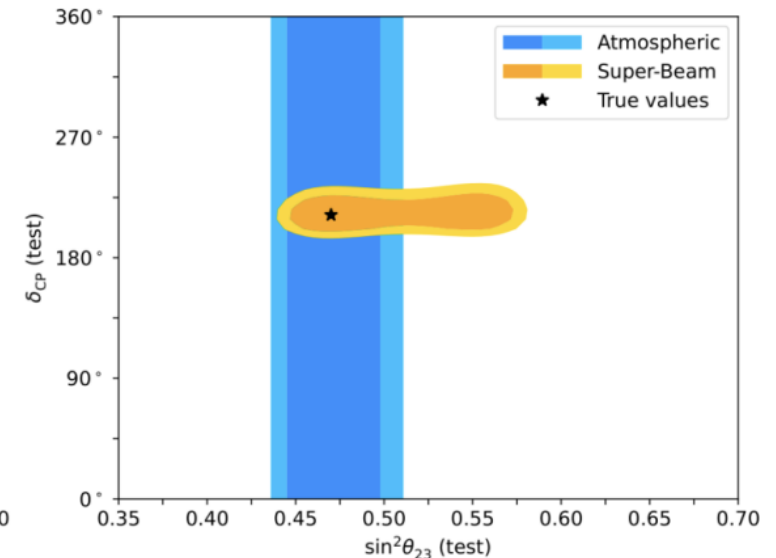


Sensitivities for (i) standard, (ii) NSI and (iii) synergy with beam has been studied

3 publications



Beam+atm

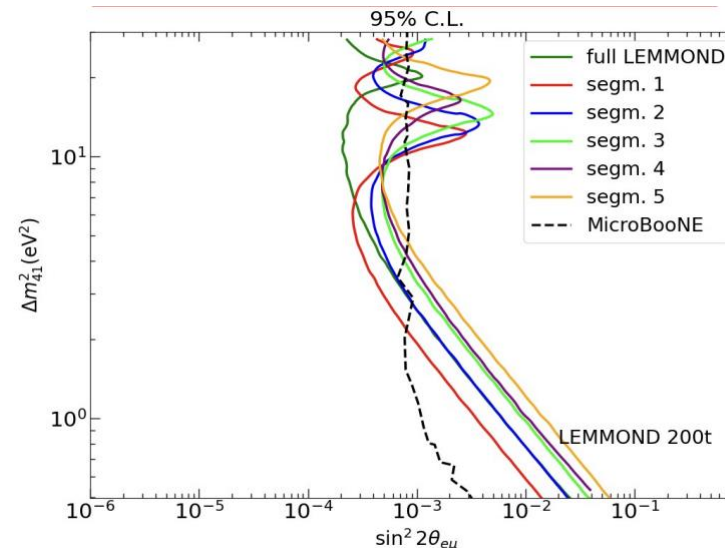
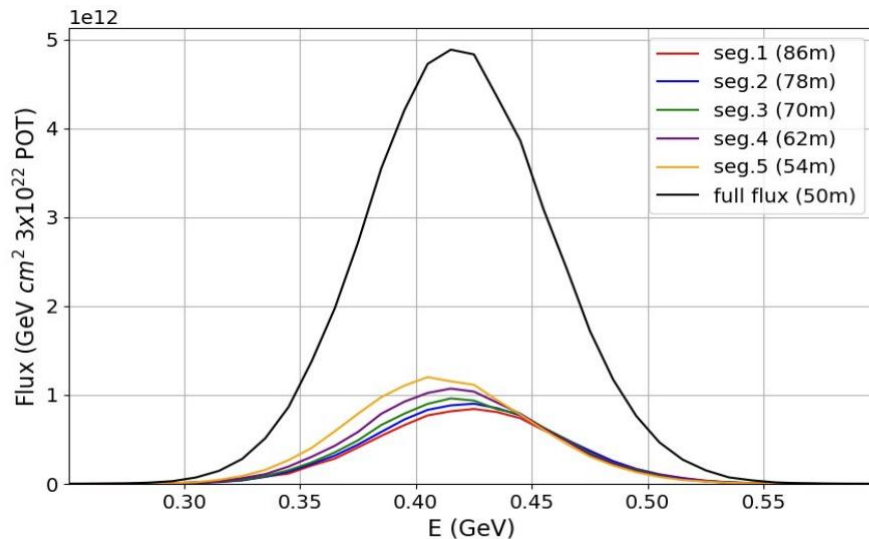
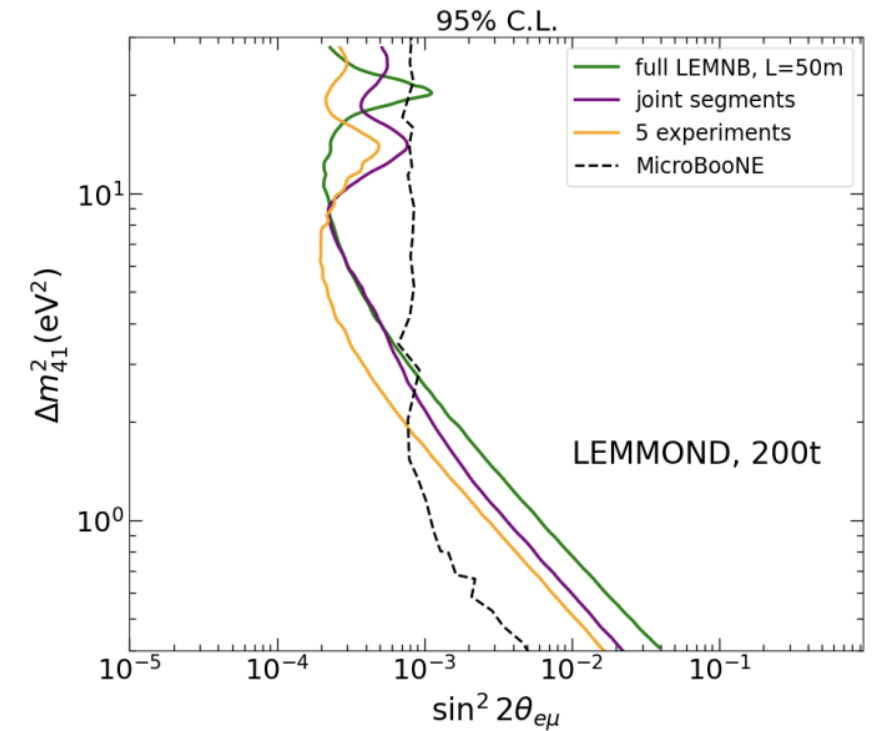


# Sterile neutrino at ND (Doris)

Study with LEMNB - LEMMOND has been performed

Effect of production point in the decay pipe considered

Manuscript under internal review - revision in progress  
- Yesterday had discussion with Fabio and Francesco



Sensitivity with LEnuSTORM is limited due to low statistics

# NSI neutrino at ND (Doris)

Source – Detector NSI for all possible scenarios has been studied

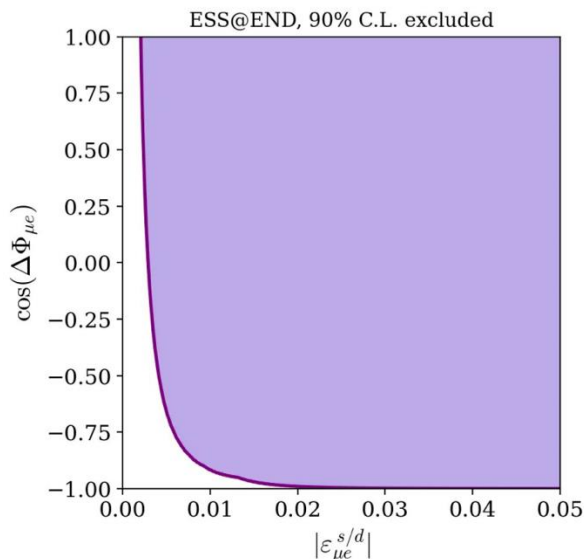
Zero-distance effect is probed

$$P_{\alpha\beta} \simeq \left| \left[ (1 + \varepsilon^d)^T (1 + \varepsilon^s)^T \right]_{\beta\alpha} \right|^2$$

$$|\nu_\alpha^s\rangle = |\nu_\alpha\rangle + \sum_\gamma \varepsilon_{\alpha\gamma}^s |\nu_\gamma\rangle$$

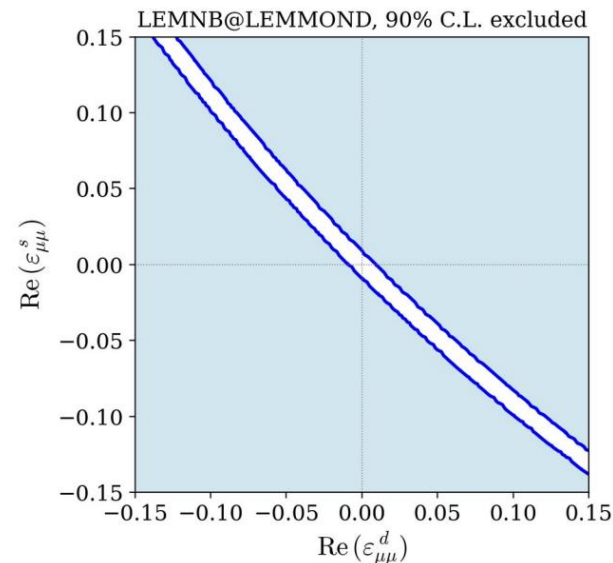
$$\langle \nu_\beta^d | = \langle \nu_\beta | + \sum_\gamma \varepsilon_{\gamma\beta}^d \langle \nu_\gamma |$$

Plan to write a manuscript

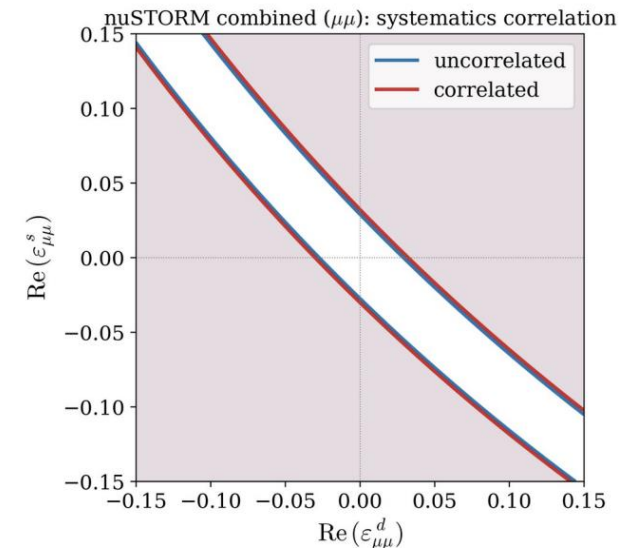


$$|\varepsilon_{\mu e}| \approx 0.005$$

\* for comparison, LEMNB@LEMMOND is around 0.01



$$|\text{Re } \varepsilon_{\mu\mu}| \approx 0.009$$



$$|\text{Re } \varepsilon_{\mu\mu}| < 0.029 \rightarrow 0.032$$

# Final Task- CDR

- Discussed Tuesday with all the groups (almost)
- Agreed on to the skeleton and structure
- All groups agreed (almost)
- Will start writing

## 6. Detector performance and physics reach

### 6.1. Detector performance

summarize the first CDR and write what is new.

Editor: George

#### 6.1.1. Update on far detector simulation

Main Contributor: Budimir, Mahesh, Mehmet, Mariyan and Georgi

#### 6.1.2. Cross-section measurement at LEMMOND

Main Contributor: George and Spyros

#### 6.1.3. Performance of END with GNN

Main Contributor: Peter and Kaare

#### 6.1.4. Software framework for the near detectors

Main Contributor: Mariyan and Georgi

### 6.2. Physics reach

summarize the first CDR and write what is new.

Editor: Monojit

#### 6.2.1. Sensitivity of FD to atmospheric neutrinos

Main Contributor: Tommy, Sandhya and Sampsa

#### 6.2.2. Sensitivity of FD to solar neutrinos

Main Contributor: Doris and Alessio

#### 6.2.3. Sensitivity of FD to supernova neutrinos

Main Contributor: Monojit

#### 6.2.4. Sensitivity of ND to sterile neutrino and NSI

Main Contributor: Doris, Alessio and Monojit

#### 6.2.5. Impact of cross-section models

Main Contributor: Natalie and Marco