DUNE @ PRL

Current Members:

Srubabati Goswami

Animesh Chatterjee
(also @CERN)

Supriya Pan
(PDF)

Tamanna Pathan
Project Student

Earlier members : P . Nagraj , K. Chakraborty

Broad areas of activities

- **Hardware** — DUNE High Voltage System in collaboration with CERN (Animesh Chatterjee)
- **Software and Analysis** - Development of Software trigger and analysis for ProtoDUNE-BSM searches (Animesh Chatterjee)
- **Phenomenology** — Atmospheric neutrinos and beam neutrinos and their synergy, both far and near detector

Hardware activities

* Hardware activities are focused on

  - Commissioning and data taking for ProtoDUNE-HD (NP04) (Dec23-November 24)

  - Leading High Voltage System production, testing and installation of the DUNE-VD and DUNE-HD detectors in collaboration with CERN

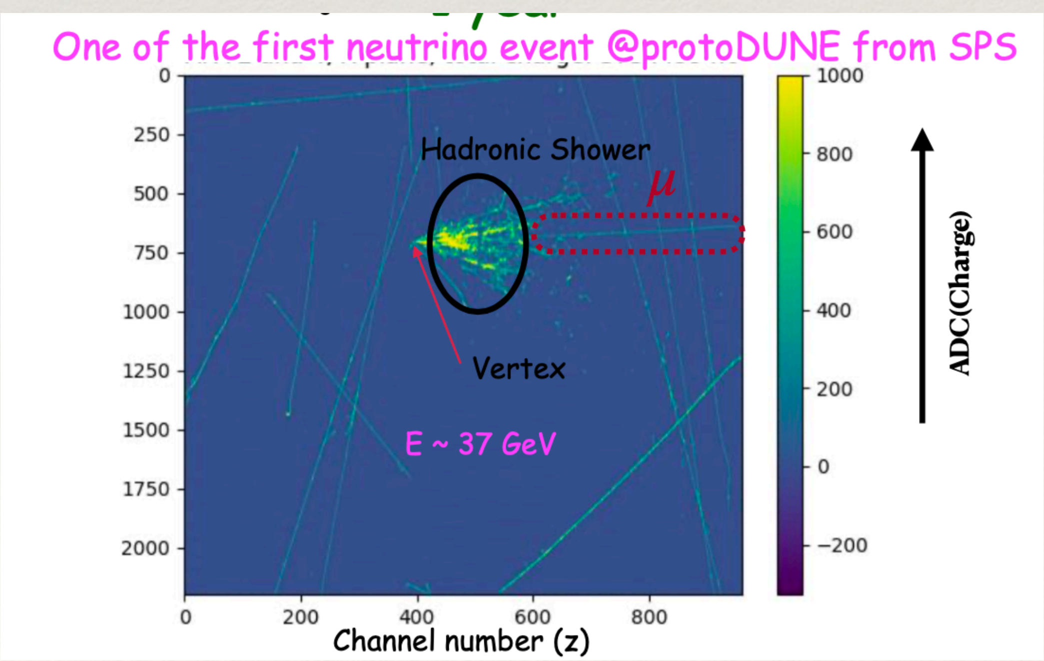
* Future activities : Leading role in ProtoDUNE-VD High voltage system commissioning and operation.

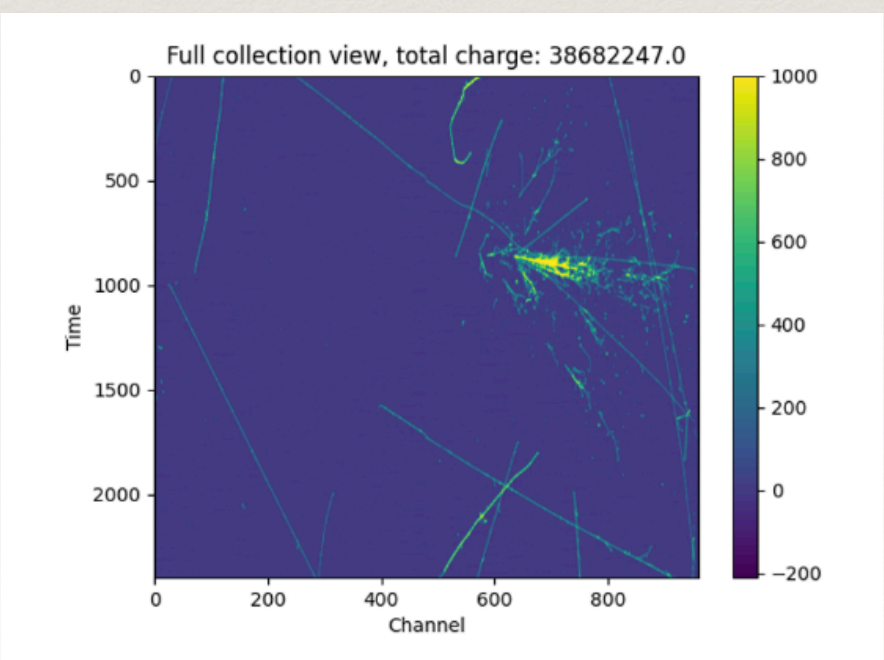
Software and analysis activities

* Recently study (Coloma et al., JHEP 01 (2024) 134) has been performed showing that ProtoDUNE detector with T2 target and Tax in conjunction with SPS (400 GeV) beam will work as beam-dump facility can be ideal setup for BSM searches.

* The demonstration of the feasibility of the T2/ProtoDUNE (PDs) concept will undoubtedly begin with the observation of the neutrino.

* A. Chatterjee led the ProtoDUNE group at CERN from idea stage to the execution stage





* This effort was presented during January 2025 DUNE Collaboration meeting at CERN

* The effort also published with CERN COURIER and within CERN EP News Letter

* Proof of principle now established and analysis ongoing both the neutrino and for BSM event selection

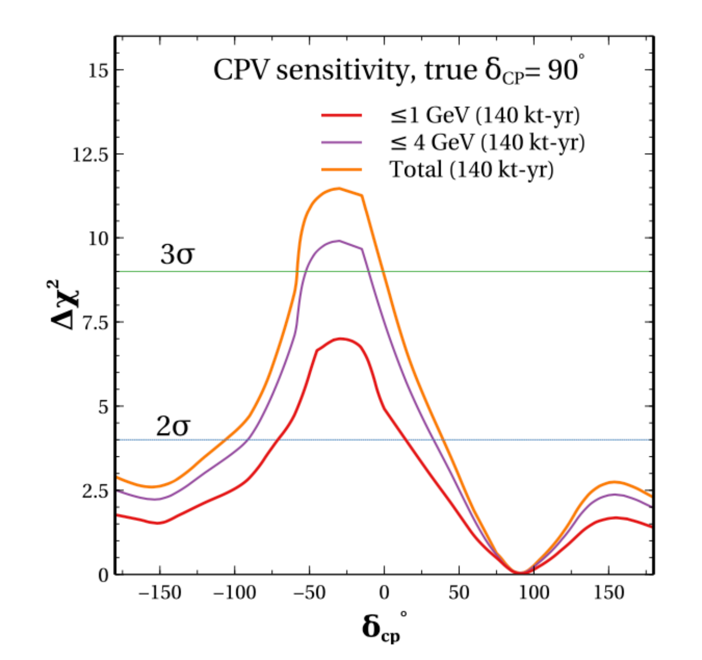
Neutrino oscillations with atmospheric neutrinos@DUNE: Initial few years

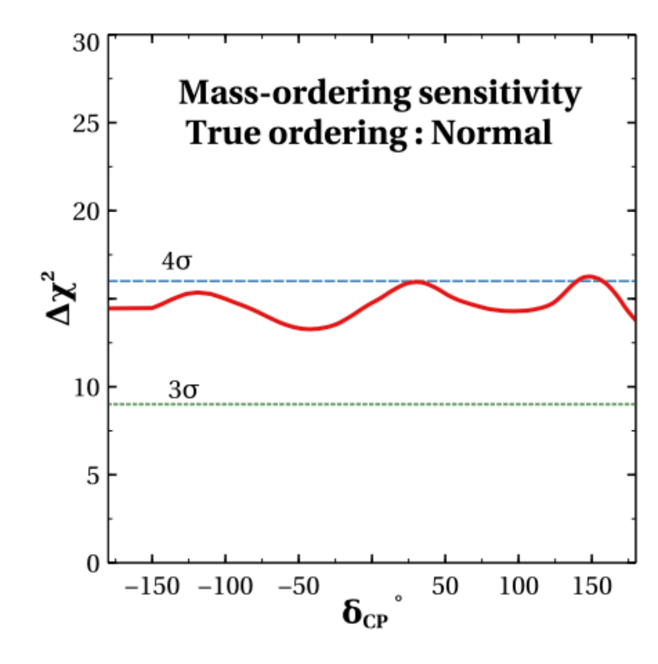
* A.Chatterjee, A.De.Roeck, *Phys.Lett.B* 855 (2024) 138838

* The study shows the atmospheric neutrino interactions with a unique event topology to distinguish neutrinos and anti-neutrinos using a liquid argon time projection chamber in DUNE.

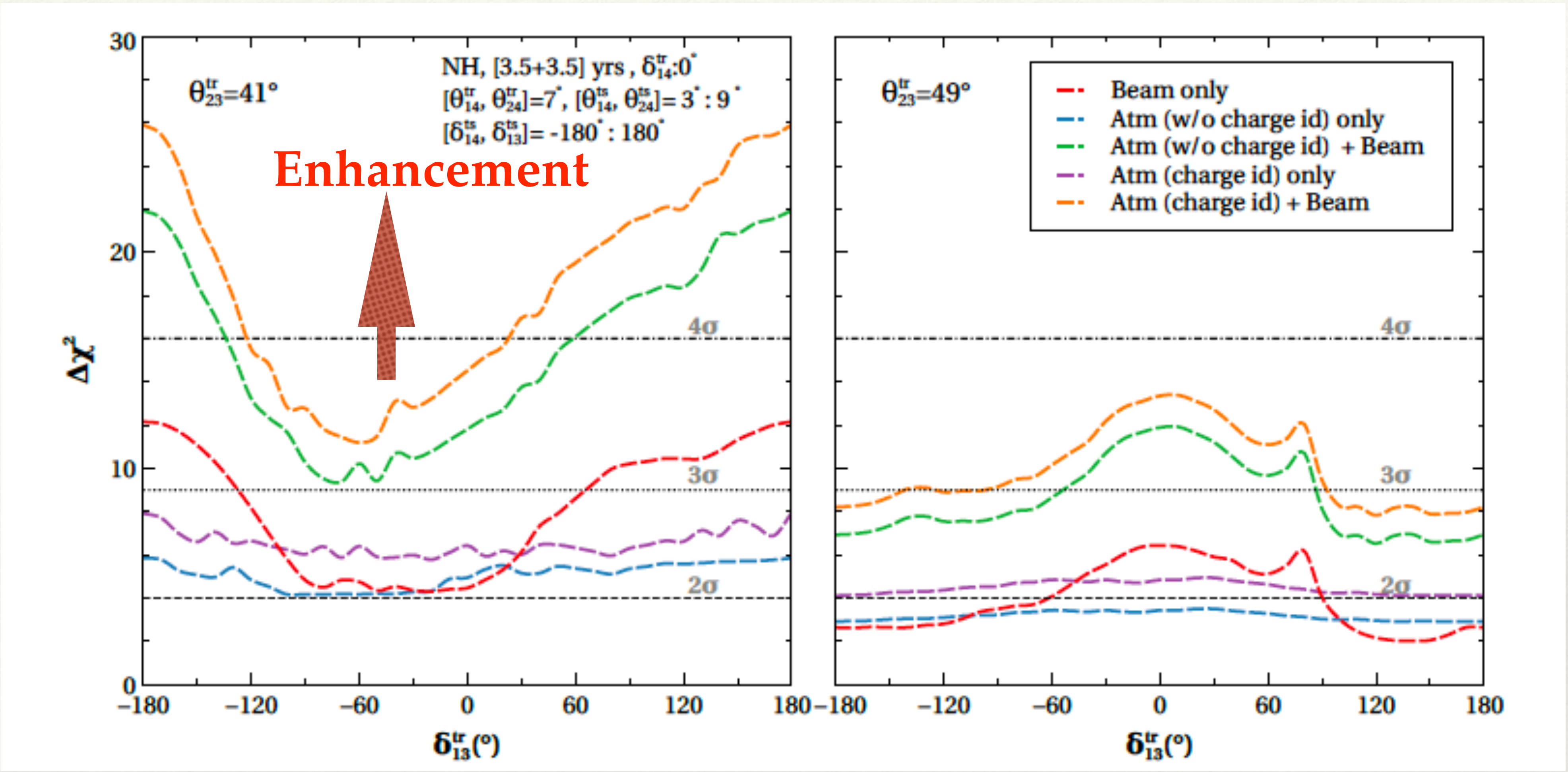
* The detection of charged-current 1 proton (CC1P) and charged-current no proton (CC0P) events will allow us to access neutrino oscillation physics complementary to accelerator-based beam neutrinos

* Considering the presently planned sequencing schedule for DUNE, where several Far Detector modules will be installed before the intense neutrino beam from FNAL becomes available, such measurements can be likely per- formed to a significant part already before the beam data reaches its full power.





Sterile Neutrino Phenomenology



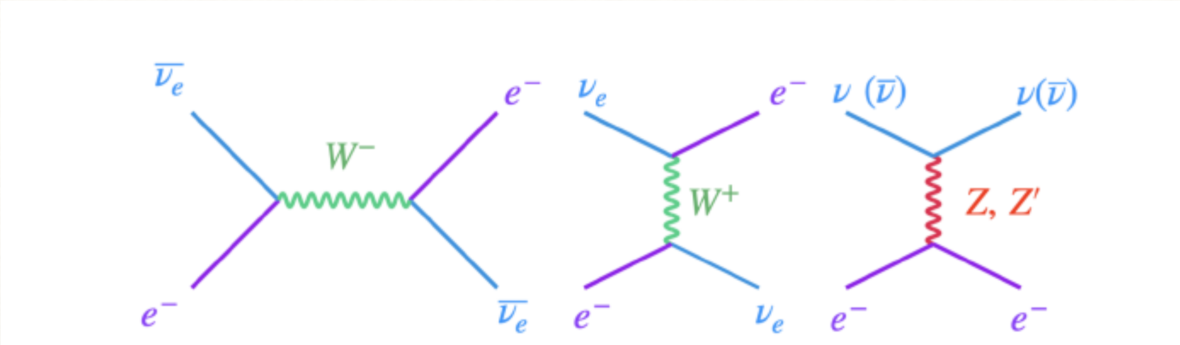
Animesh Chatterjee, Supriya Pan, SG, Phys. Rev. D 2023

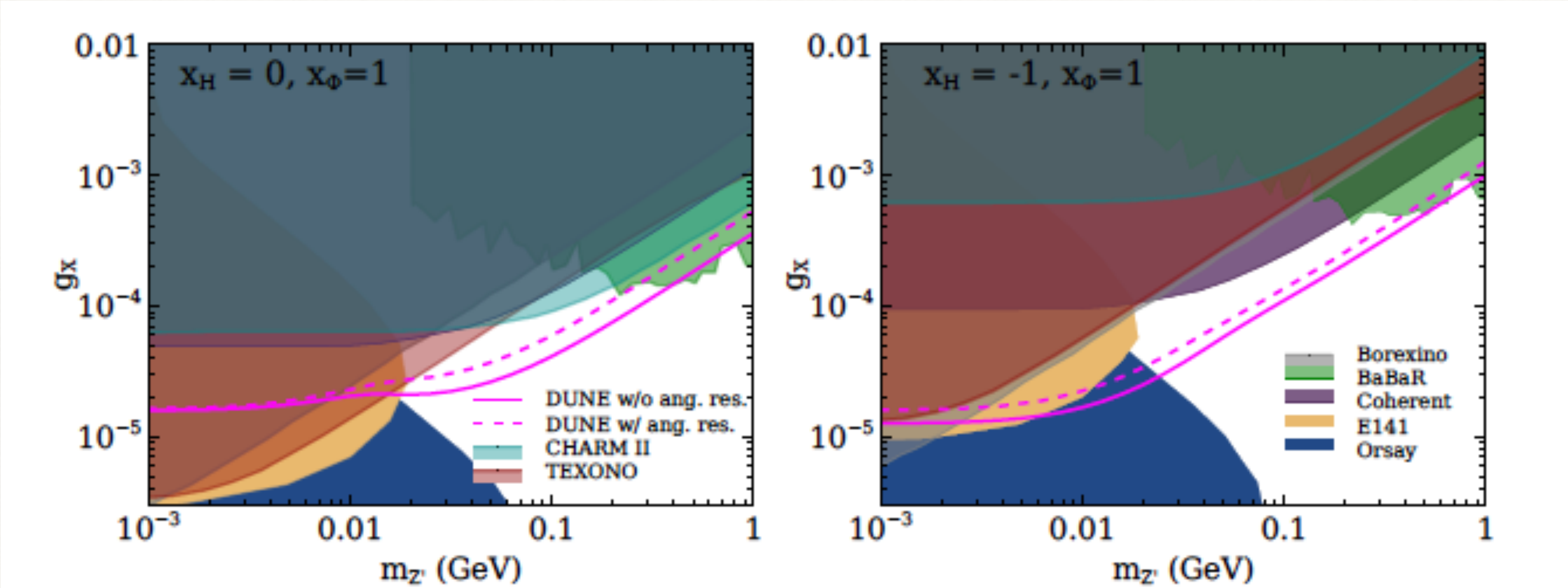
Beam and atmospheric neutrinos combined for a Liquid Argon detector

Beam 3.5 + 3.5 years   Atmospheric : 40 kt X 7 years = 280 kty

General U(1) interaction at DUNE

Consider general U(1) model with extra Z'





- We consider neutrino-electron scattering at DUNE ND

Constraints (90% C.L.) on mass and coupling plane of

1.2 MW beam, 75 ton mass, 3.5 +3.5 years exposure in neutrino +antineutrino

Chakraborty, Das, Goswami, Roy, JHEP 2022

Future plans for contributing DUNE

- Continued work on the Hardware actives in collaboration with CERN

- We would be interested to contribute with our expertise on the R&D activities within the DUNE-India group

- Testing neutrino mass models in DUNE

- Phenomenological studies to understand the synergy between beam and atmospheric neutrinos at DUNE both for standard neutrino oscillation as well different BSM signatures. (Collaboration : Northwestern University, US; S.N. Bose Centre, Krea University, India)

- Development of a Genie/GEANT based code for atmospheric neutrinos (Collaboration : IIT Mumbai, India)

- BSM activities using the ProtoDUNE detector, software and analysis framework development for the DUNE FD modules.

Publications (DUNE related)

- Srubabati Goswami, Kaustav Chakraborty, Arindam Das, and Samiran Roy; Constraining general U(1) interactions from neutrino-electron scattering measurements at DUNE near detector; JHEP 04 (2022) 008

- Srubabati Goswami, Animesh Chatterjee, and Supriya Pan; Matter effect in presence of a sterile neutrino and resolution of the octant degeneracy using a liquid argon detector; Phys.Rev.D 108 (2023) 9, 095050

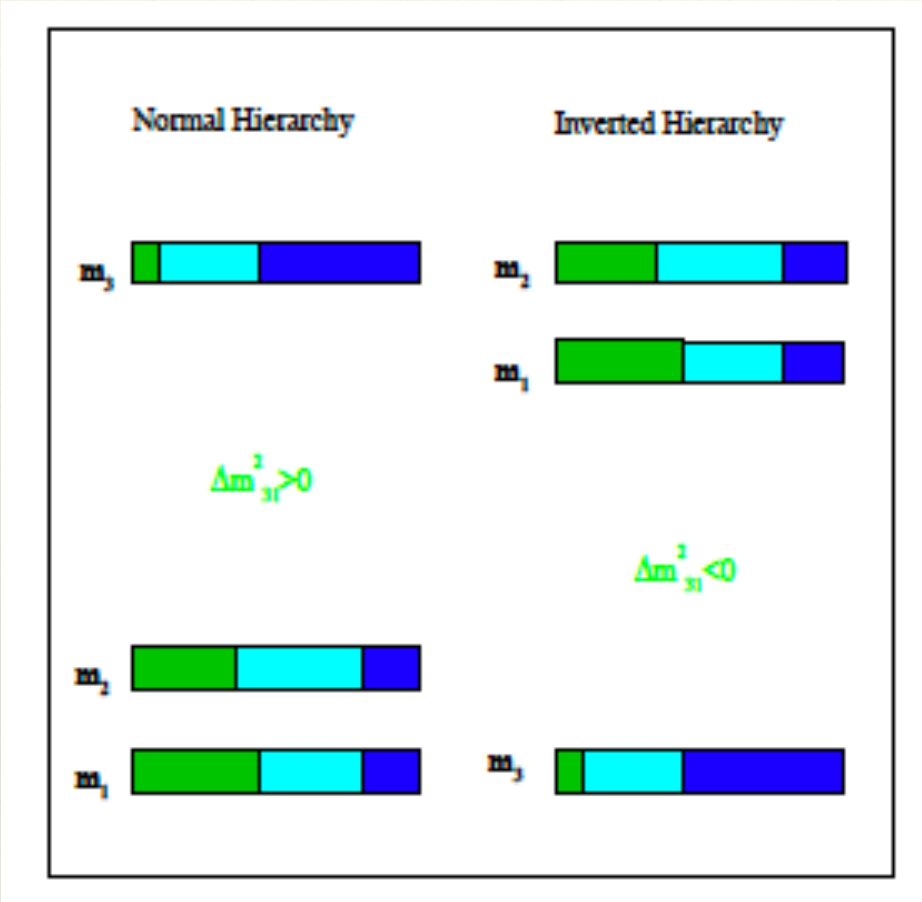
- Srubabati Goswami, Animesh Chatterjee, and Supriya Pan; Probing mass orderings in presence of a very light sterile neutrino in a liquid argon detector; Nucl.Phys.B 996 (2023) 116370

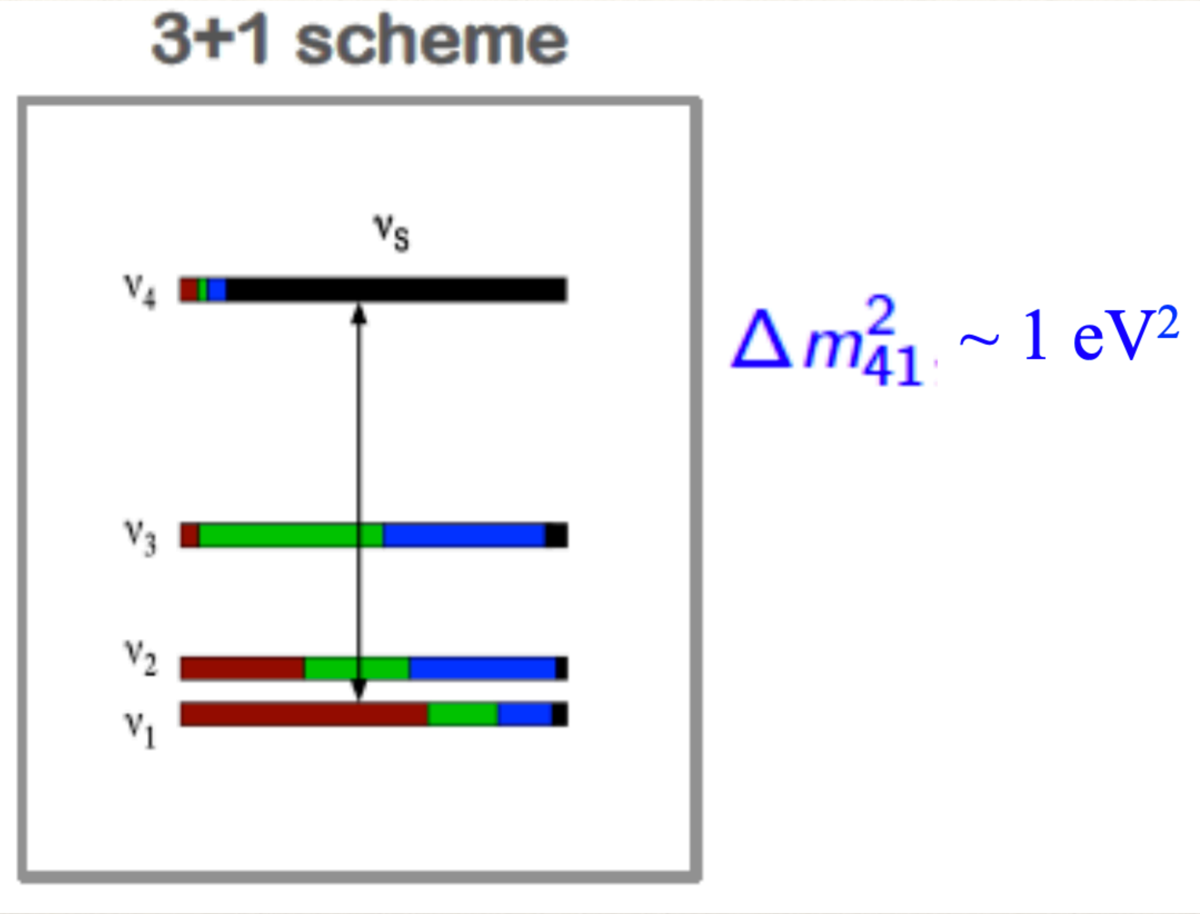
- Animesh Chatterjee, and Albert De Roeck; Neutrino oscillations with atmospheric neutrinos at large liquid argon TPCs; Phys.Lett.B 855 (2024) 138838

- Srubabati Goswami, Animesh Chatterjee, Supriya Pan, and Paras Tacker; Effect of invisible neutrino decay on neutrino oscillation at long baselines; arXiv: 2411.09677

Back up slides

Phenomenology : 3 and 3+1 Scheme



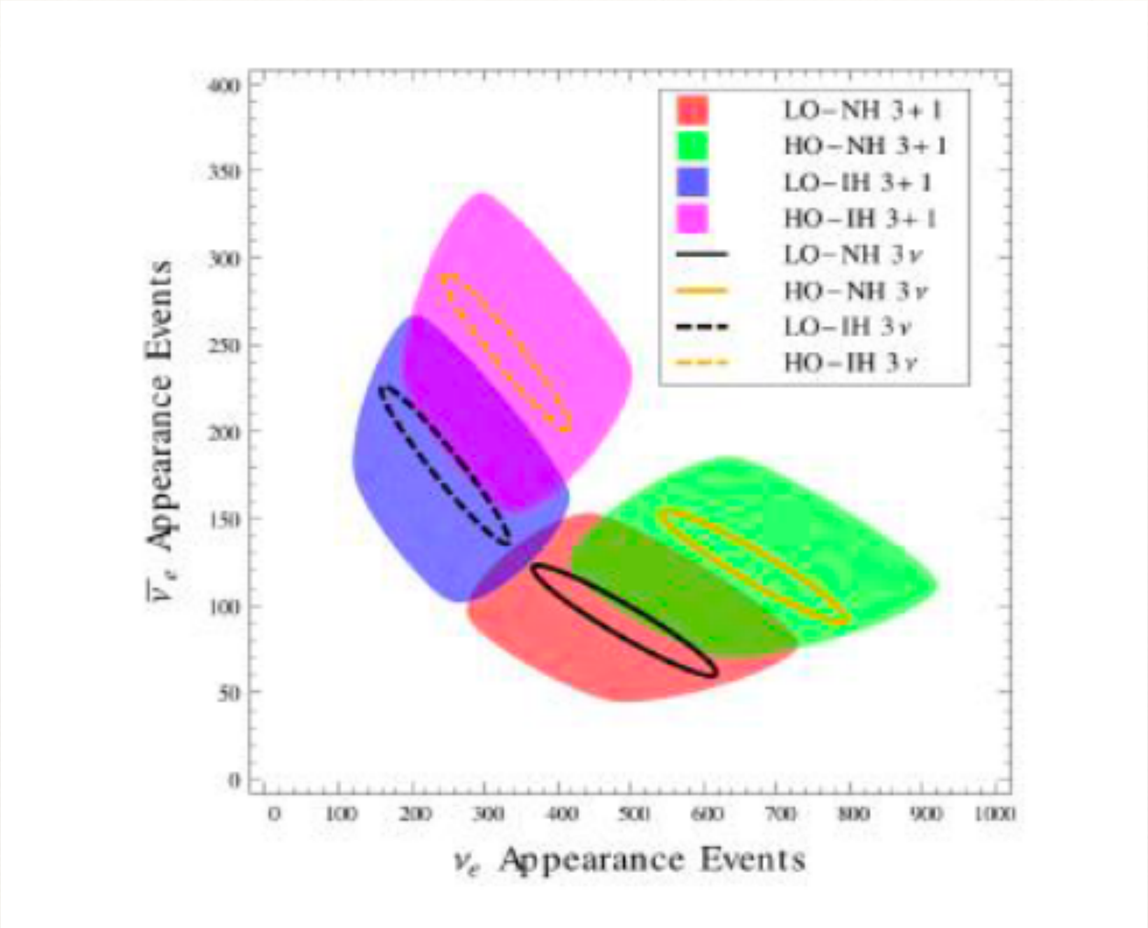


$$U_{st} = \tilde{R}_{34}(\theta_{34}, \delta_{34}) R_{24}(\theta_{24}) \tilde{R}_{14}(\theta_{14}, \delta_{14}) R_{23}(\theta_{23}) \tilde{R}_{13}(\theta_{13}, \delta_{13}) R_{12}(\theta_{12})$$

3 additional angles, two additional phases

Octant sensitivity in danger ?

eV scale sterile neutrino



Agarwalla, Chatterjee, Palazzo, PRL (2016)

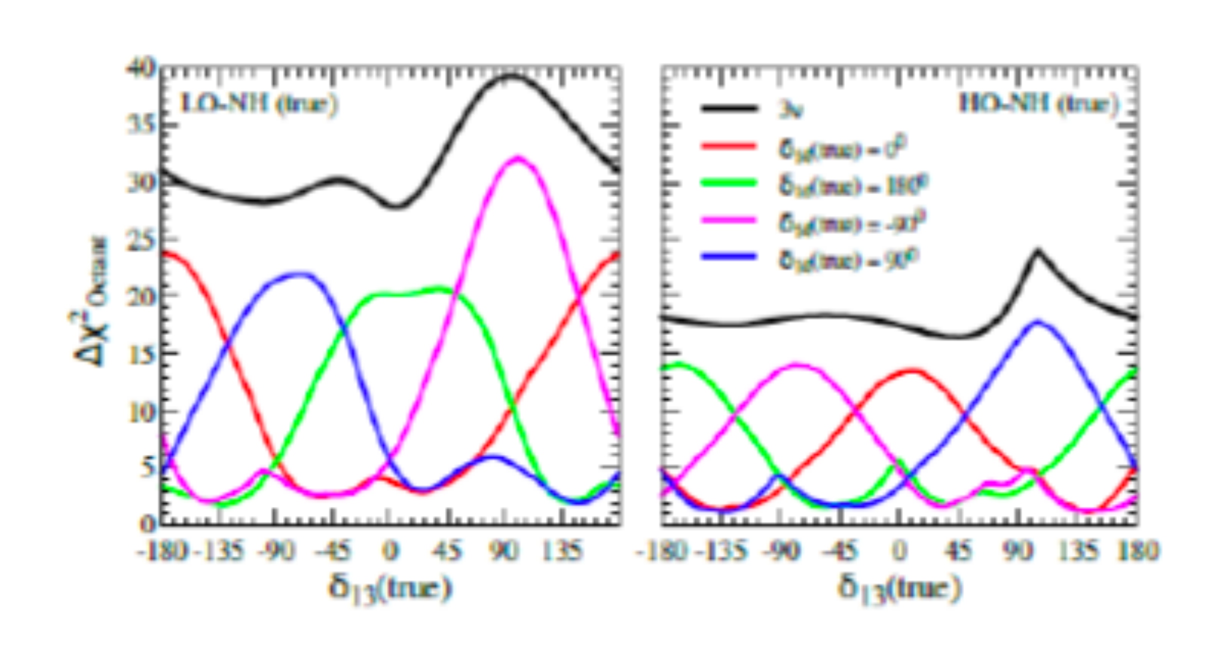
DUNE detector 1300 km baseline

$$P^{4\nu}_{\mu e} \simeq P_0 + P_1 + P_2\,,$$

$$P_0 \simeq 4 s_{23}^2 s_{13}^2 \sin^2\Delta\,,$$

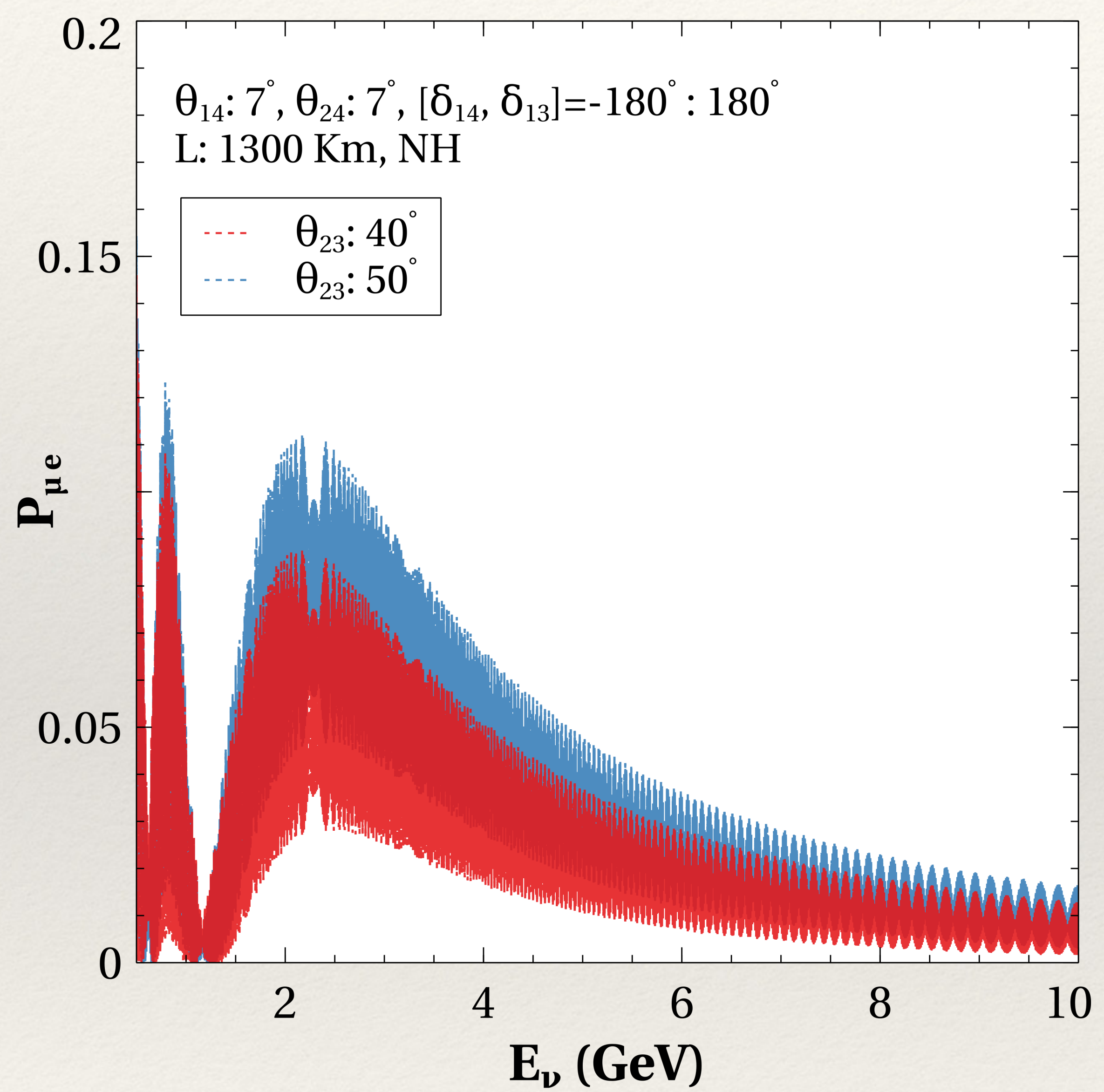
$$P_1 \simeq 8 s_{13} s_{12} c_{12} s_{23} c_{23} (\alpha\Delta) \sin\Delta \cos(\Delta \pm \delta_{13})\,,$$

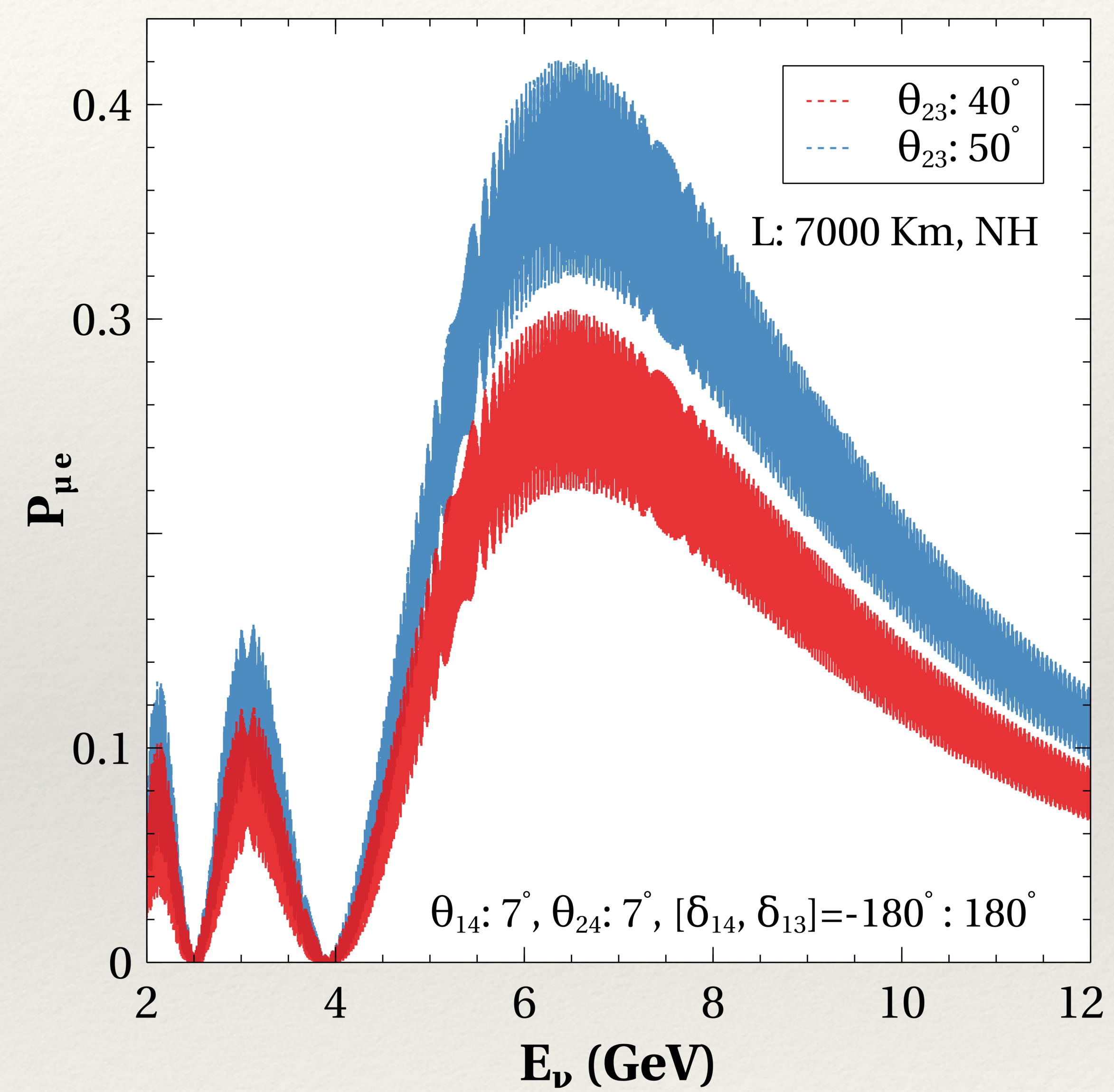
$$P_2 \simeq 4 s_{14} s_{24} s_{13} s_{23} \sin\Delta \sin(\Delta \pm \delta_{13} \mp \delta_{14})\,,$$



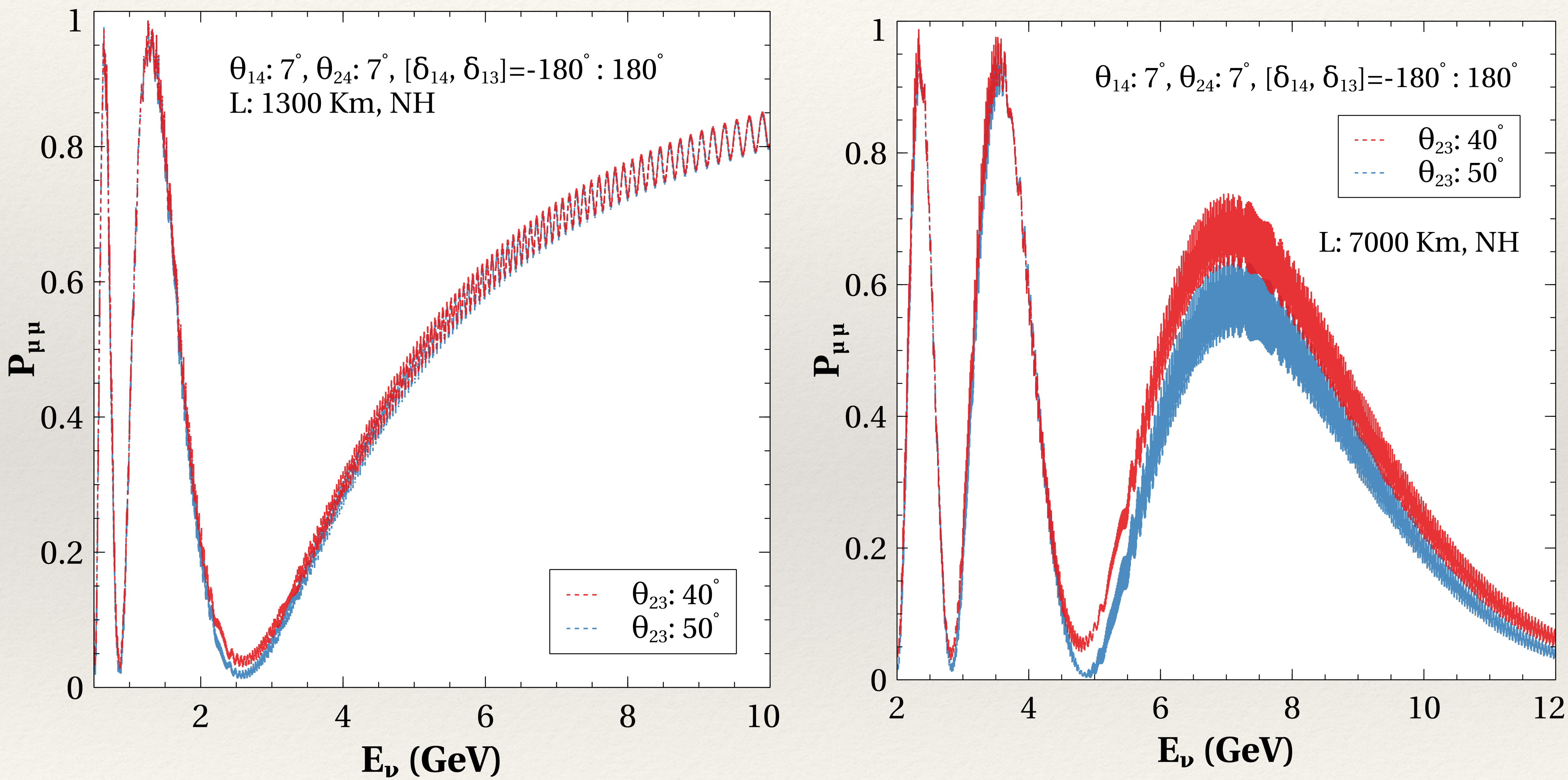
For certain combinations of phases very low octant sensitivity

Effect of Phases : $P_{\mu e}$





Effect of Phases :



The model

$$\mathcal{L}^{\text{Yukawa}} = -Y_u^{\alpha\beta}\overline{q_L^\alpha} H u_R^\beta - Y_d^{\alpha\beta}\overline{q_L^\alpha}\tilde{H} d_R^\beta - Y_e^{\alpha\beta}\overline{\ell_L^\alpha}\tilde{H} e_R^\beta - Y_\nu^{\alpha\beta}\overline{\ell_L^\alpha} H N_R^\beta - Y_N^\alpha \Phi \overline{N_R^{\alpha c}} N_R^\alpha + \text{h.c.},$$

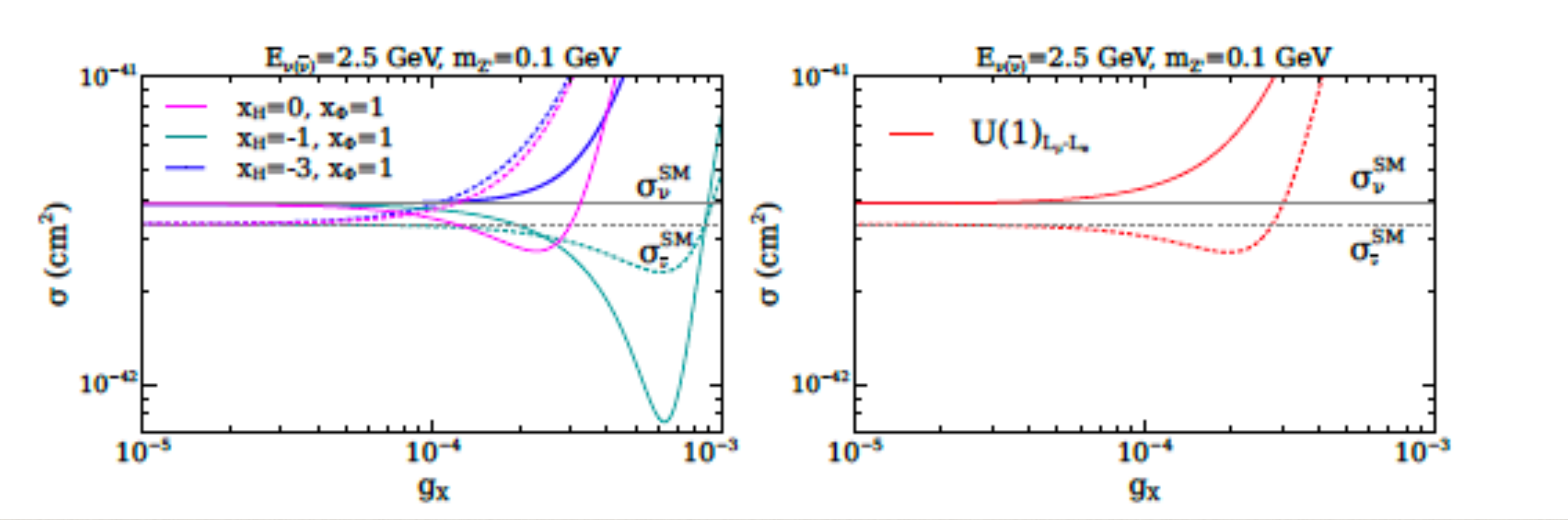
$$-\mathcal{L}^f_{\text{int}} = g_X\left(\overline{\ell_L} Q_X^\ell \gamma^\mu Z'_\mu \ell_L + \overline{\ell_R} Q_X^{e_R} \gamma^\mu Z'_\mu \ell_R\right) + g_X\left(\overline{q_L} q_X^\ell \gamma^\mu Z'_\mu q_L + \overline{q_R} q_{X_R}^{u(/d)} \gamma^\mu Z'_\mu q_R\right)$$

	SU(3)$_c$	SU(2)$_L$	U(1)$_Y$	U(1)$_X$
q_L^i	**3**	**2**	$\frac{1}{6}$	$x'_q = \frac{1}{6}x_H + \frac{1}{3}x_\Phi$
u_R^i	**3**	**1**	$\frac{2}{3}$	$x'_u = \frac{2}{3}x_H + \frac{1}{3}x_\Phi$
d_R^i	**3**	**1**	$-\frac{1}{3}$	$x'_d = -\frac{1}{3}x_H + \frac{1}{3}x_\Phi$
ℓ_L^i	**1**	**2**	$-\frac{1}{2}$	$x'_\ell = -\frac{1}{2}x_H - x_\Phi$
e_R^i	**1**	**1**	-1	$x'_e = -x_H - x_\Phi$
N_R^i	**1**	**1**	0	$x'_\nu = -x_\Phi$
H	**1**	**2**	$-\frac{1}{2}$	$-\frac{x_H}{2} = -\frac{x_H}{2}$
Φ	**1**	**1**	0	$2x_\Phi = 2x_\Phi$

Charge assignment governed by cancellation of anomalies.

$x_H=0,\ x_\Phi=1$ $\longrightarrow$ **B-L**

Changes in the cross section



Neutrino events more than SM while antineutrino less $(L_\mu - L_e$ case).

Antineutrino events more compared to SM, neutrino events less $(B - L$ case).

Enhancement in both neutrino and antineutrino event $(x_H = -3$ and $x_\Phi = 1$ scenario).

Reduction in both neutrino and antineutrino event $(x_H = -1$ and $x_\Phi = 1$ scenario).