New approaches to the study of BSM models at DUNE Near and Far Detectors

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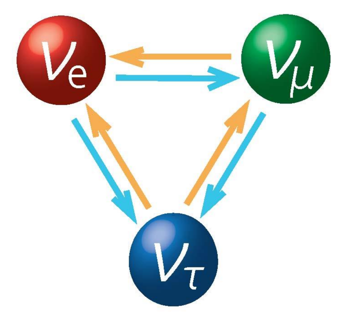
Neutrino oscillations



- Neutrinos change flavor while they travel
- Oscillation probabilties depend on 6 parameters

$\theta_{12}/° = 33.82^{+0.78}_{-0.76}$ $\theta_{13}/° = 8.61^{+0.13}_{-0.13}$ $\theta_{23}/° = 48.3^{+1.1}_{-1.9}$ $\delta_{CP}/° = 250^{+40}_{-33}$

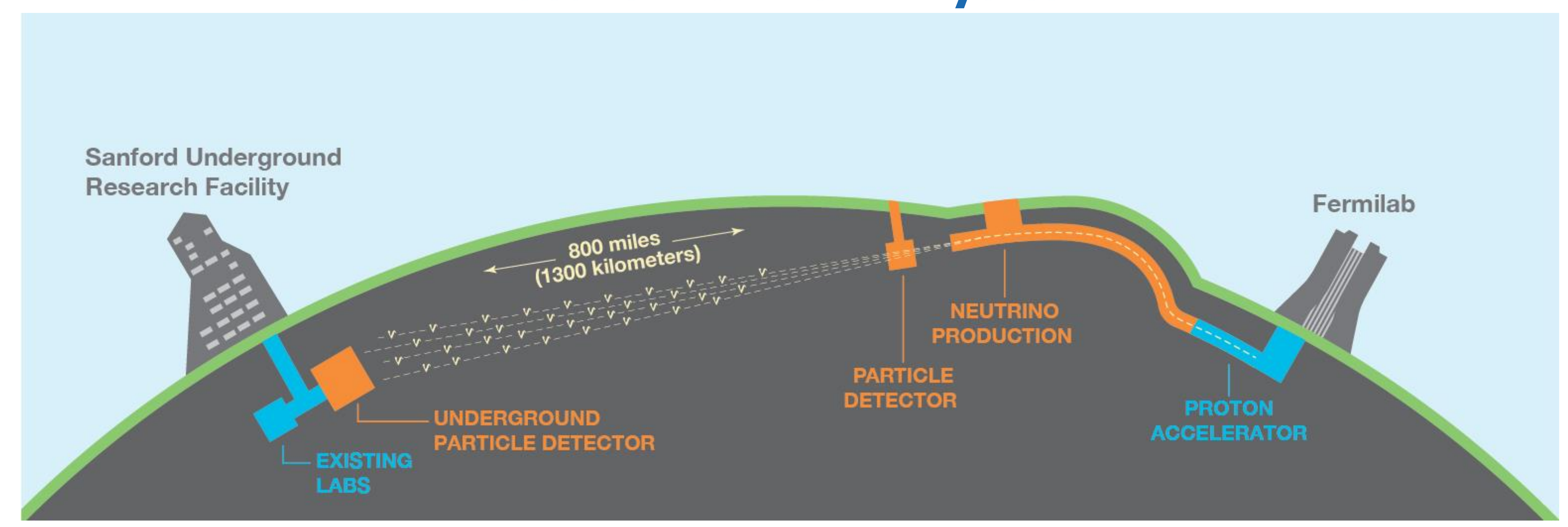
$\Delta m^2_{21} = 7.39^{+0.21}_{-0.20} \cdot 10^{-5}\ eV^2$ $|\Delta m^2_{3l}| = 2.52^{+0.03}_{-0.03} \cdot 10^{-3}\ eV^2$

Three big questions!

- How big is δ_{CP}? *NEW T2K RESULT!*
- Which is the sign of Δm^2_{3l}?
- Which is the θ_{23} octant?

+ BSM!

How can we answer the three questions and search for New Physics?



DUNE (Deep Underground Neutrino Experiment)

- 1300 km baseline
- World's most intense muon neutrino beam with a peak of the energy spectrum around 2.5 GeV
- 40 kt LAr-TPC Far Detector
- Multi purpose Near Detector complex with a 50 tons LAr-TPC as main detector

Huge number of neutrino events!

$\nu_\mu \to \nu_\mu$ & $\nu_\mu \to \nu_e$ CC events: arXiv:2002.03008 (DUNE TDR)

NC events: arXiv:1707.05348 (Coloma, Forero, Parke)

$\nu_\mu \to \nu_\tau\ (\tau \to h)$ CC events: arXiv:1904.07265 (De Gouvea, Stenico, Kelly, Pasquini)

$\nu_\mu \to \nu_\tau\ (\tau \to e)$ CC events: arXiv:1906.06212 (Ghoshal, Giarnetti, Meloni)

Role of $\nu_\mu \to \nu_\tau\ (\tau \to e)$ events in sterile neutrinos and propagation NSI searches

arXiv:1906.06212 (Ghoshal, Giarnetti, Meloni)

- The ν_τ appearance probability in the 3+1 sterile neutrino model ($\Delta m^2_{14} \sim 1\ eV^2$) reads

$$P_{\mu\tau} = 2|U_{\tau 4}|^2 |U_{\mu 4}|^2 + 4\Re[U_{\mu 3}{}^* U_{\tau 3}(U_{\mu 3}U_{\tau 3}{}^* + U_{\mu 4}U_{\tau 4}{}^*)]\sin^2\left(\frac{\Delta m^2_{31} L}{4E}\right) - 2\Im(U_{\mu 3}{}^* U_{\tau 3} U_{\mu 4} U_{\tau 4}{}^*)\sin\left(\frac{\Delta m^2_{31} L}{2E}\right)$$

$U_{\tau 4} \propto \sin\theta_{34}$

New 90% CL limit θ_{34}<22°

- Considering Non-Standard-Interactions (NSI) in the neutrino propagation through matter, the the ν_τ appearance probability is

$$P_{\mu\tau} = P^{SM}_{\mu\tau} + \left(\frac{1}{2}\varepsilon_{\tau\tau}\cos^2 2\theta_{23} + 2\Re(\varepsilon_{\mu\tau})\cos 2\theta_{23}\right) AL \sin\left(\frac{\Delta m^2_{31} L}{2E}\right)$$

New 90% CL limit $|\varepsilon_{\mu\tau}|$<0.20

Constraints on the Neutrino Invisible decay using NC events

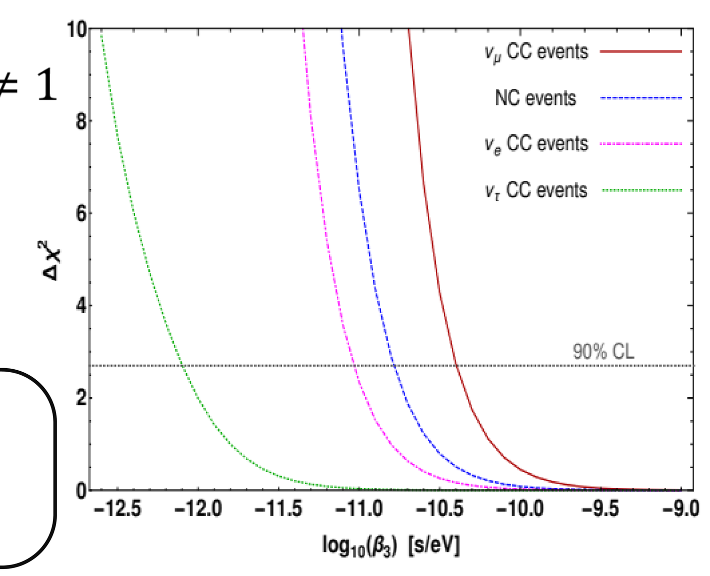
arXiv:2003.09012 (Ghoshal, Giarnetti, Meloni)

If the third neutrino mass eigenstate decays into invisible particles, the number of active neutrinos is not conserved!

$$\sum_{\alpha}^{e,\mu,\tau} P_{\mu\alpha} = 1 + (e^{-\frac{L}{\beta_3 E}} - 1)\cos^2\theta_{13}\sin^2\theta_{23} \neq 1$$

Limits on $\beta_3 = \tau/m_3$ can be improved looking at NC events!

New 90% CL limit $\beta_3 > 5.2 \cdot 10^{-11}\ s/eV$



Probing source and detector NSI at the DUNE Near Detector

arXiv:2005.10272 (Giarnetti, Meloni)

If we take into account the presence of NSI in neutrino production and detection, the probabilities at zero baseline read

$$P_{\alpha\alpha} = 1 + 2|\varepsilon^s_{\alpha\alpha}|\cos\Phi^s_{\alpha\alpha} + 2|\varepsilon^d_{\alpha\alpha}|\cos\Phi^d_{\alpha\alpha}$$

$$P_{\alpha\beta} = |\varepsilon^s_{\alpha\beta}|^2 + |\varepsilon^d_{\alpha\beta}|^2 + 2|\varepsilon^s_{\alpha\beta}||\varepsilon^d_{\alpha\beta}|\cos(\Phi^s_{\alpha\beta} - \Phi^d_{\alpha\beta})$$

Using DUNE Near detector data, we can exclude at a given CL the parameter space regions

$$||\varepsilon^s_{\alpha\beta}| - |\varepsilon^d_{\alpha\beta}|| \gtrsim \Delta_{\alpha\beta}$$
$$|\Re(\varepsilon^s_{\alpha\alpha}) + \Re(\varepsilon^d_{\alpha\alpha})| \gtrsim \Delta_{\alpha\alpha}$$

Δ-s decrease with data taking time!