Invisible neutrino decay in long-baseline Experiments

Dipyaman Pramanik

In Collaboration with Sandhya Choubey, Srubabati Goswami & Debajyoti Dutta

Invisibles18 workshop, Karlsruhe

September 4, 2018

Karlsruher Institut für Technologie

invisiblesPlus
neutrinos, dark matter & dark energy physics

Neutrino decay :

Invisible decay :

$\nu \longrightarrow S$ (sterile state)

If neutrinos are Dirac:

χ is iso-singlet scalar

$\bar{\nu}_{iR}$ is right-handed singlet

$$\nu_j \rightarrow \bar{\nu}_{iR} + \chi$$

If neutrinos are Majorana:

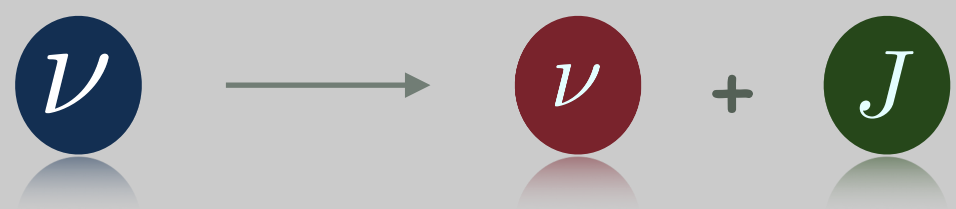
$\bar{\nu}_s$ is a sterile neutrino

J is a Majoron

$$\nu_j \rightarrow \nu_s + J$$

Neutrino decay cont…

Visible decay:



two decay modes :

$$\nu_j \rightarrow \bar{\nu}_i + J$$

$$\nu_j \rightarrow \nu_i + J$$

In this case J is also coupled to the charged lepton

Heavily constrained from the K-decay bounds

Propagation in presence of decay:

We assume ν_3 to decay into $\bar{\nu}_4$ and a singlet scalar

$$\nu_3 = \bar{\nu}_4 + J$$

$$\begin{pmatrix} \nu_\alpha \\ \nu_s \end{pmatrix}$$

Now, the flavour and mass basis get related as

$$\begin{pmatrix} \nu_\alpha \\ \nu_s \end{pmatrix} = \begin{pmatrix} U & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_i \\ \nu_4 \end{pmatrix}$$

U is the standard PMNS matrix

Cont…

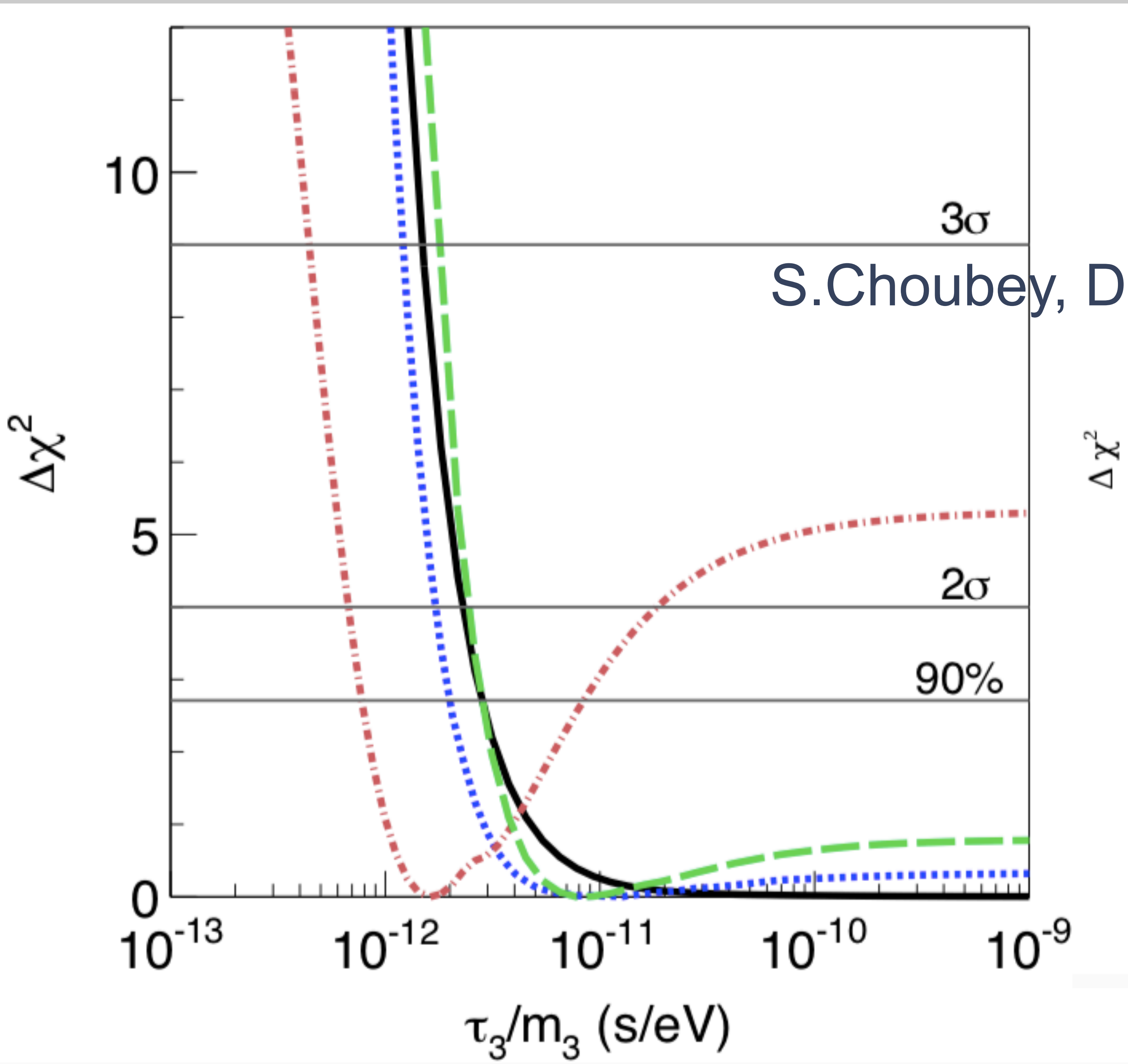
The effect of decay can be incorporated in the evolution equation by :

$$i\frac{d}{dx}\begin{pmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\end{pmatrix} = \left[U\left[\frac{1}{2E}\begin{pmatrix}0 & 0 & 0\\ 0 & \Delta m_{21}^2 & 0\\ 0 & 0 & \Delta m_{31}^2\end{pmatrix} - i\frac{m_3}{2E\tau_3}\begin{pmatrix}0&0&0\\0&0&0\\0&0&1\end{pmatrix}\right]U^\dagger + \begin{pmatrix}A&0&0\\0&0&0\\0&0&0\end{pmatrix}\right]\begin{pmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\end{pmatrix}$$

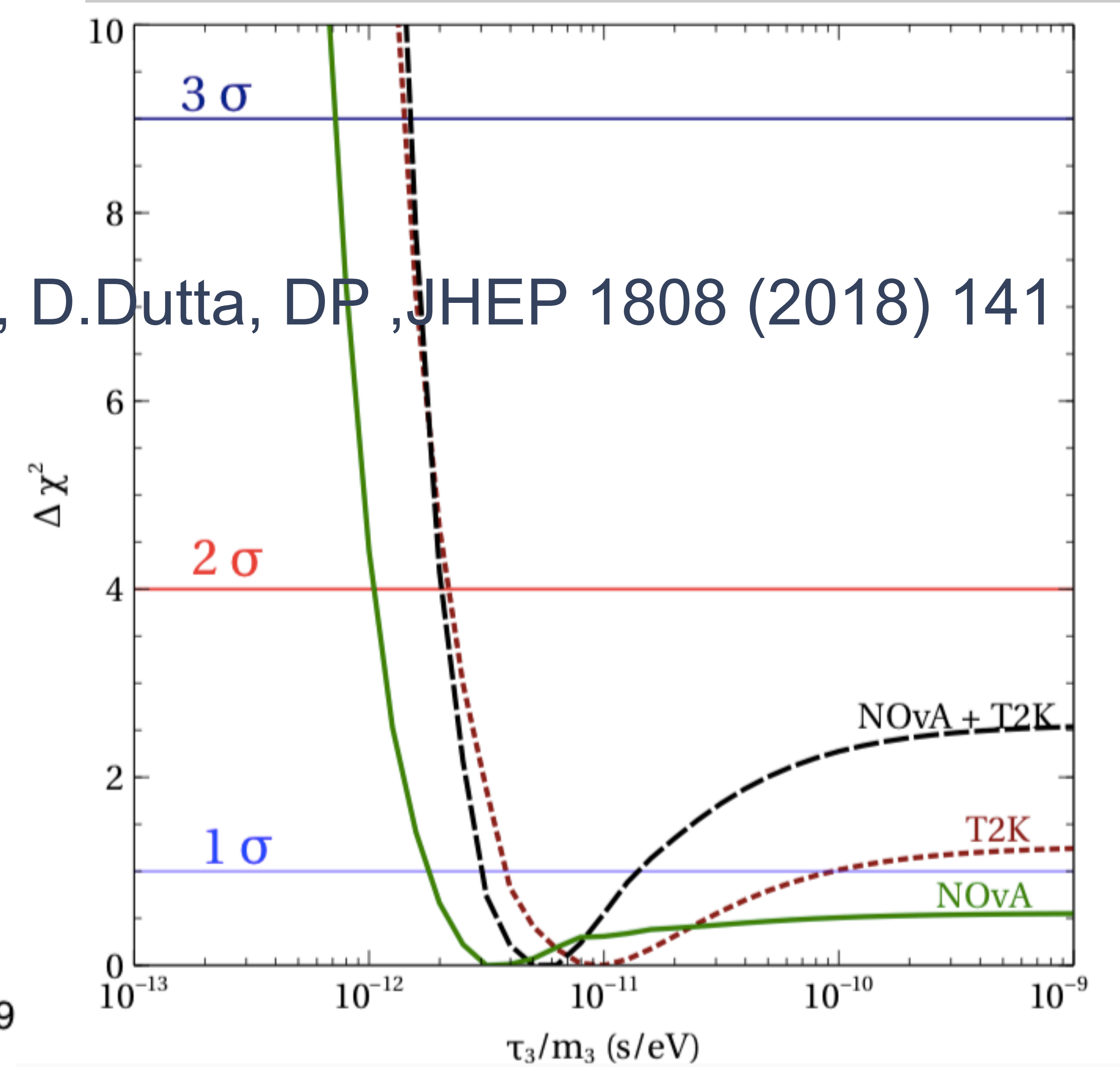
decay lifetime is τ_3

Note: Here we assume that the mass matrix and the decay matrix can be simultaneously diagonalised

Constraints from Long-baseline experiments

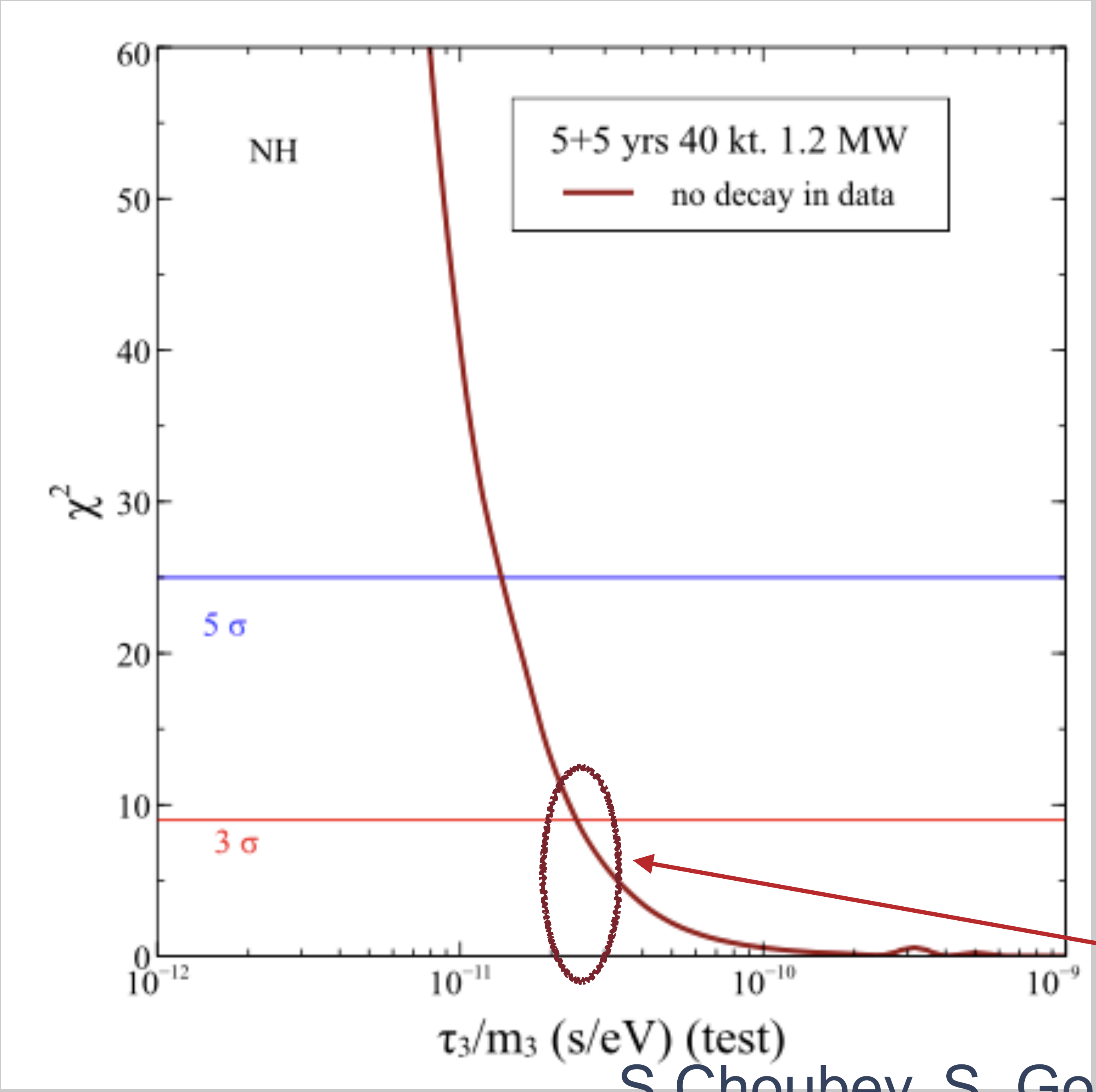


S.Choubey, D.Dutta, DP ,JHEP 1808 (2018) 141



Gomez et. Al., Phys. Lett. B740 (2015) 345-352

Results



We assume no decay in the simulated data

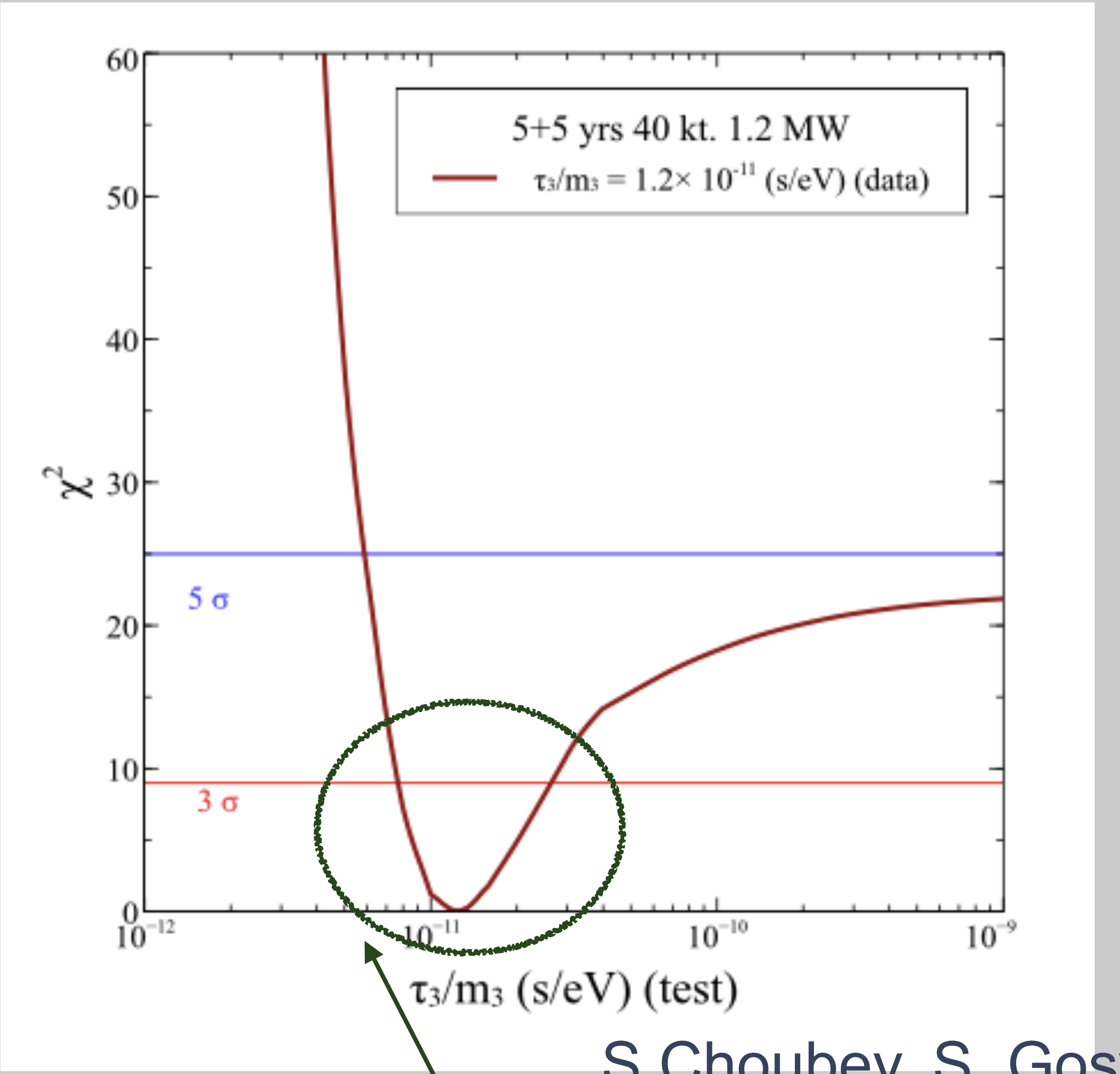
We fit the data with decay marginalising over all the relevant parameters with appropriate priors

$$2.38 \times 10^{-11} (s/eV)$$

S.Choubey, S. Goswami, DP, JHEP 1802 (2018) 055

Expected sensitivity at DUNE

Results



Measurement of the decay parameter

Data at

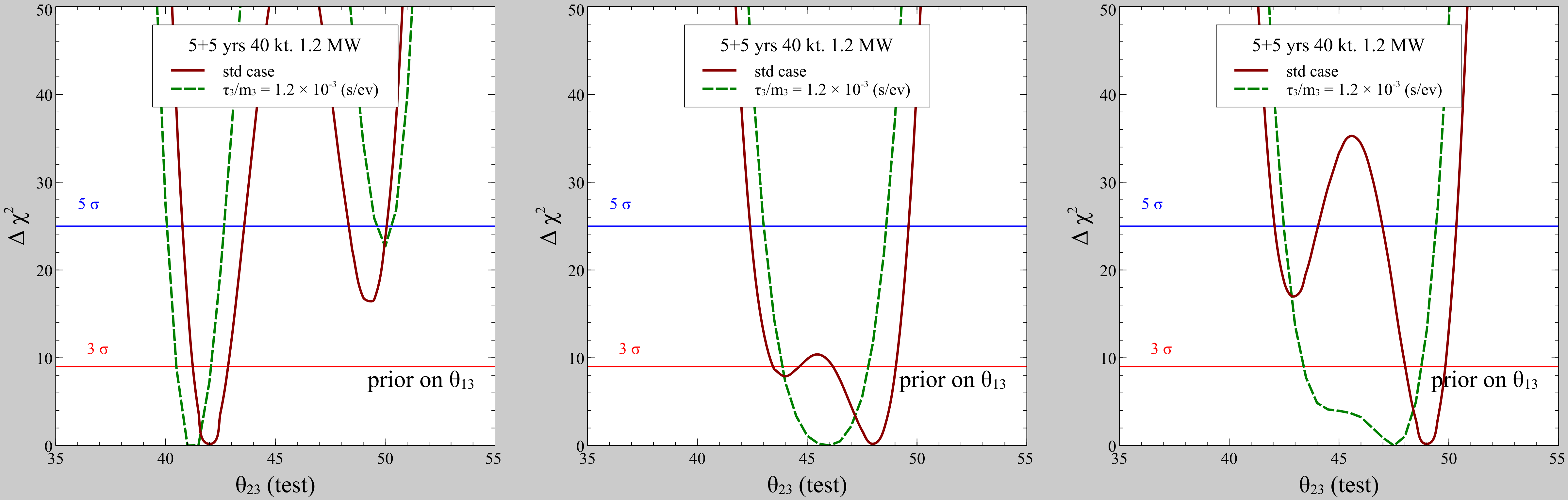
$$\tau_3/m_3 = 1.2 \times 10^{-11}(s/eV)$$

S.Choubey, S. Goswami, DP, JHEP 1802 (2018) 055

$$2.63 \times 10^{-11} > \tau_3/m_3 > 7.62 \times 10^{-12}(s/eV)$$

at 3σ

Effect on measurement of θ_{23}

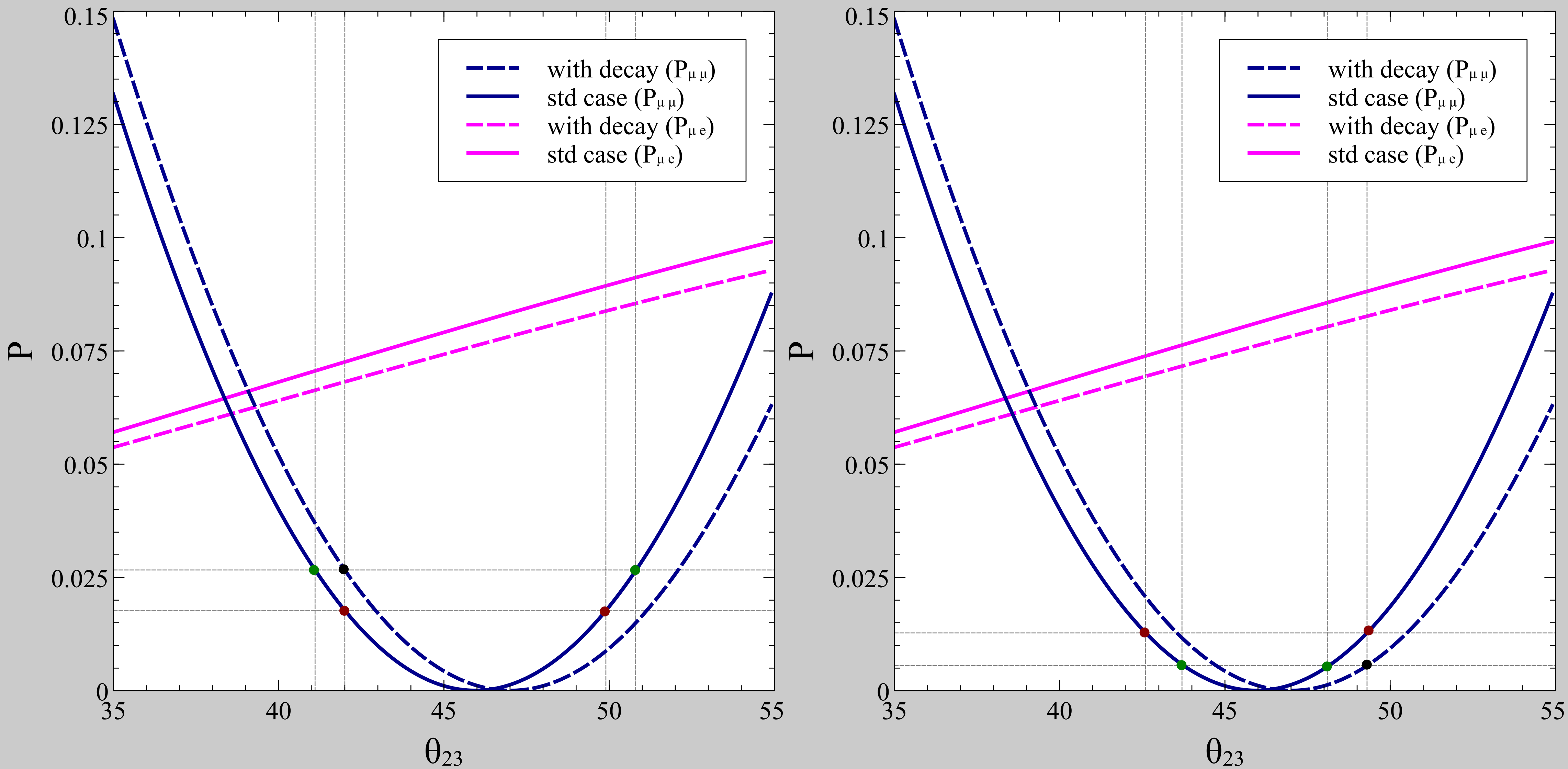


S.Choubey, S. Goswami, DP, JHEP 1802 (2018) 055

$$\sin\theta_{23}^{LO} = \frac{\sin\theta_{\mu\mu}^{LO}}{\cos\theta_{13}} \quad ; \quad \sin\theta_{23}^{HO} = \frac{\sin\theta_{\mu\mu}^{HO}}{\cos\theta_{13}}$$

$$\theta_{\mu\mu}^{LO} = 90^\circ - \theta_{\mu\mu}^{HO} ,$$

[S. K. Raut, Mod. Phys. Lett. A28, 1350093 (2013), 1209.5658]



S.Choubey, S. Goswami, DP, JHEP 1802 (2018) 055

Note:

In appearance the probability Increases monotonically

In disappearance this is complicated

Conclusion

- Invisible Neutrino decay is one of the many possible new physics like sterile neutrino or NSI.
- Current Long-baseline experiments give some hints of neutrino decay.
- Future long-baseline experiment like DUNE has good sensitivity to test the decay hypothesis.
- Neglecting decay in the fit can lead to erroneous measurement of θ_{23}.

Please see the poster for more