Exploring new physics at ESSnuSB+

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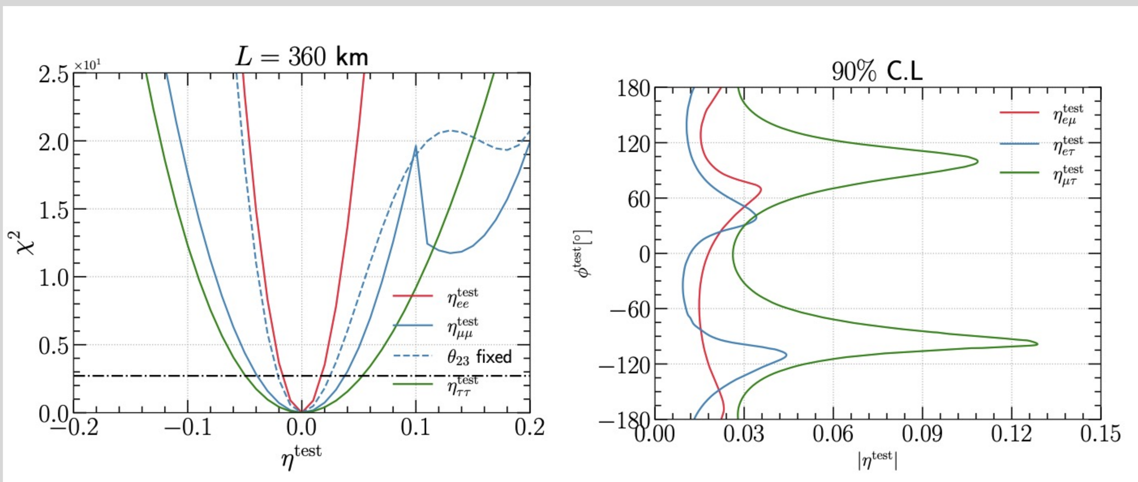
See also poster #40 for decoherence model and #18, #28, #29, #40, #370 for other ESSnuSB topics

Scalar Non Standard Interactions

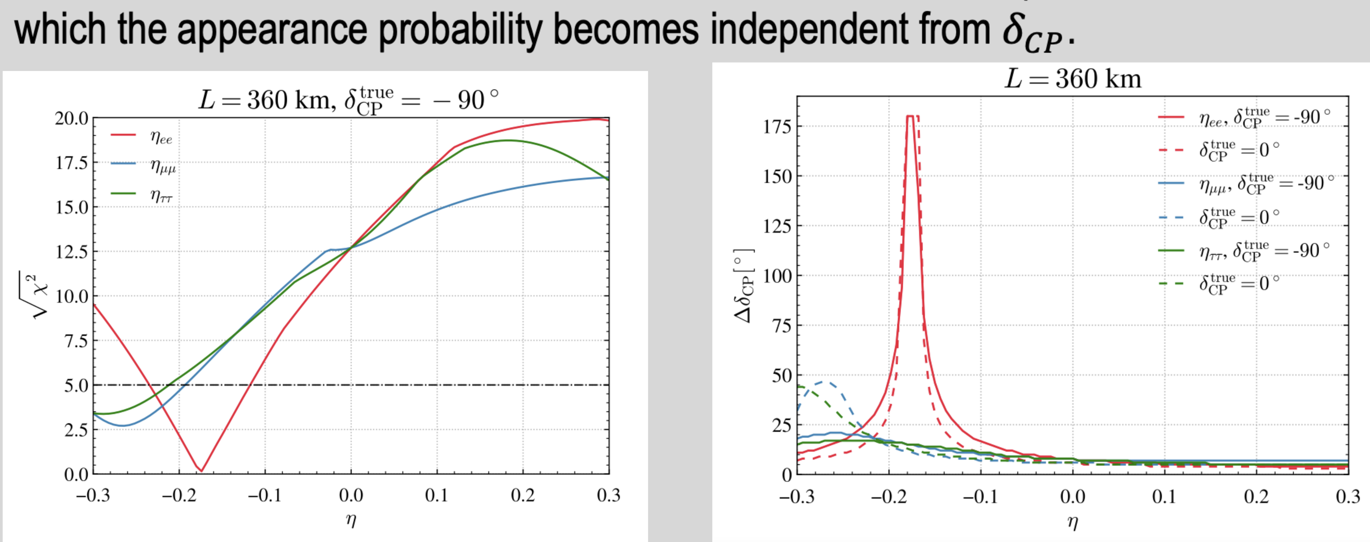
Scalar Non Standard Interactions (sNSI) are four-fermions interactions mediated by a heavy scalar particle. The interaction lagrangian modifies the mass neutrino mass matrix with a shift that can be parameterized as

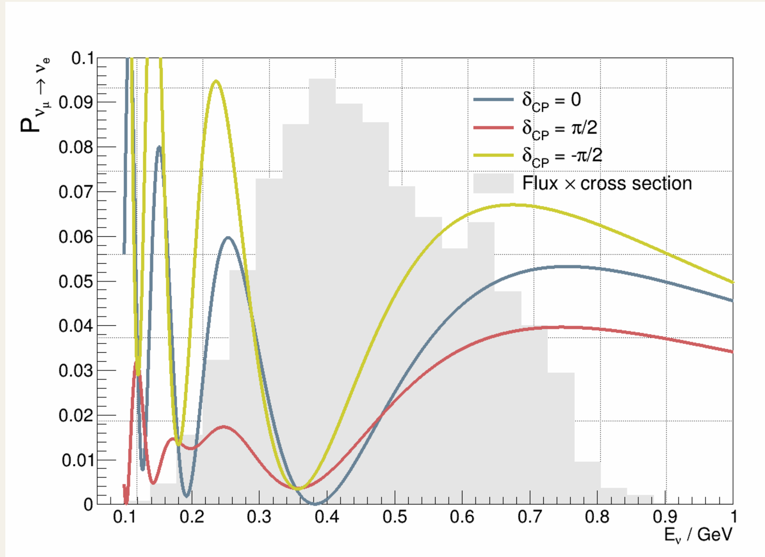
$$\delta M = \sqrt{\Delta m^2_{31}} \begin{pmatrix} \eta_{ee} & \eta_{e\mu} & \eta_{e\tau} \\ \eta_{\mu e} & \eta_{\mu\mu} & \eta_{\mu\tau} \\ \eta_{\tau e} & \eta_{\tau\mu} & \eta_{\tau\tau} \end{pmatrix}$$

Where the new parameters η-s depends on the fermion density of the medium that neutrino crosses, on the mediator mass and on the new interactions' couplings.

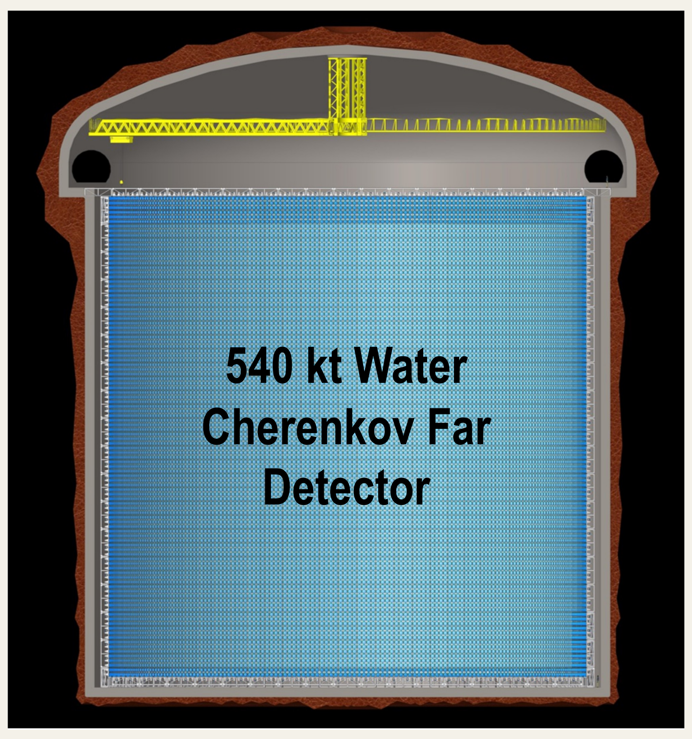


CPV sensitivity and precision unaltered except for a specific $\eta_{e\mu}$ negative value for which the appearance probability becomes independent from δ_{CP}.





ESSnuSB flux and appearance probabilities



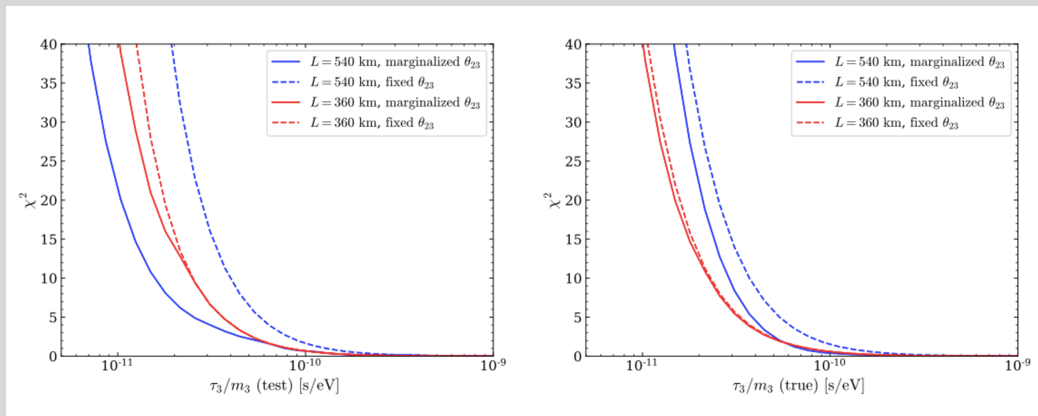
360 km baseline oscillation

Invisible neutrino decay

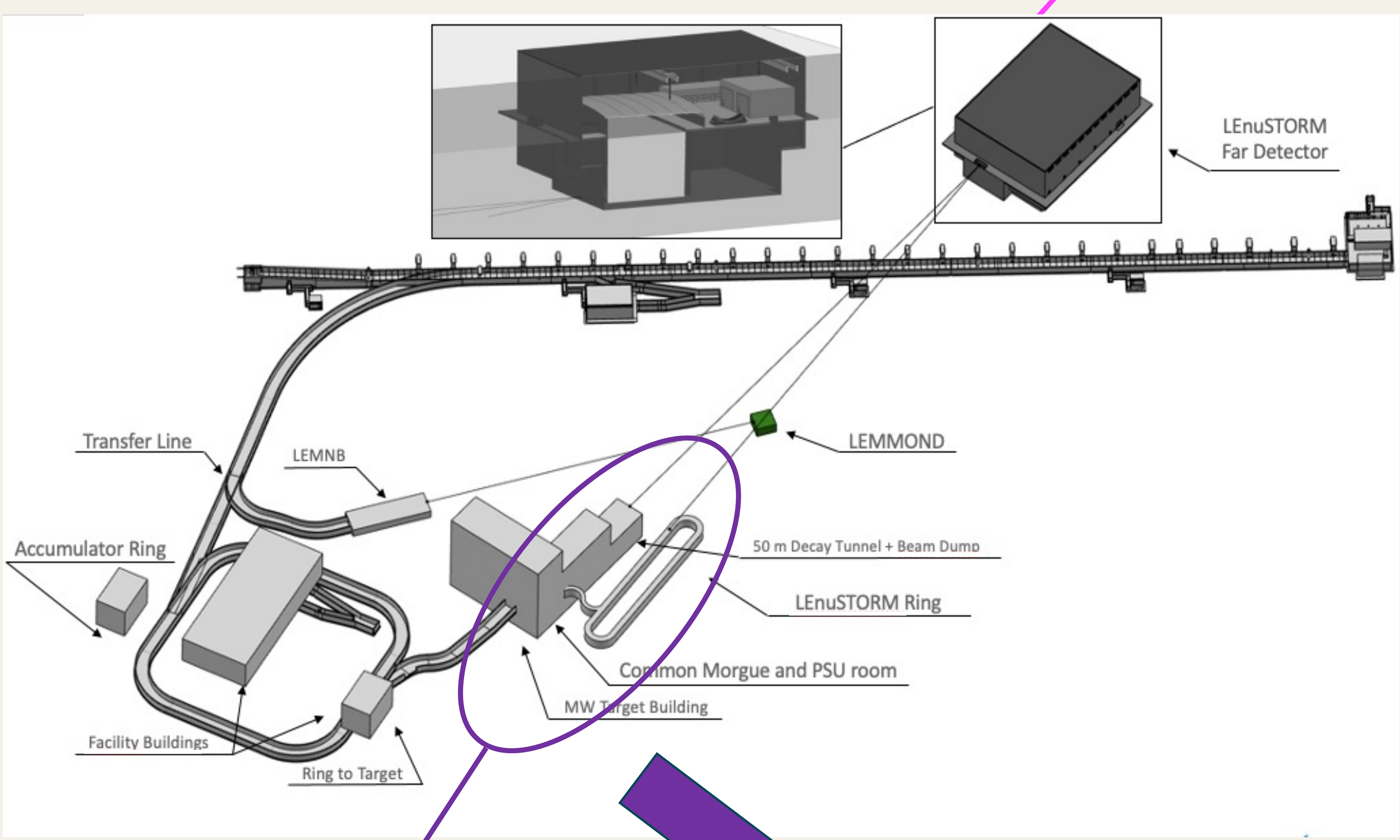
If an extremely light or massless particle could mediate the neutrino decay into invisible, sterile states, the oscillation probabilities result to be exponentially depleted by a factor

$$e^{-\frac{m_3}{\tau_3}\frac{L}{2E}}$$

Which depends on the heaviest neutrino mass and lifetime (in NO they correspond to the third eigenstate properties)

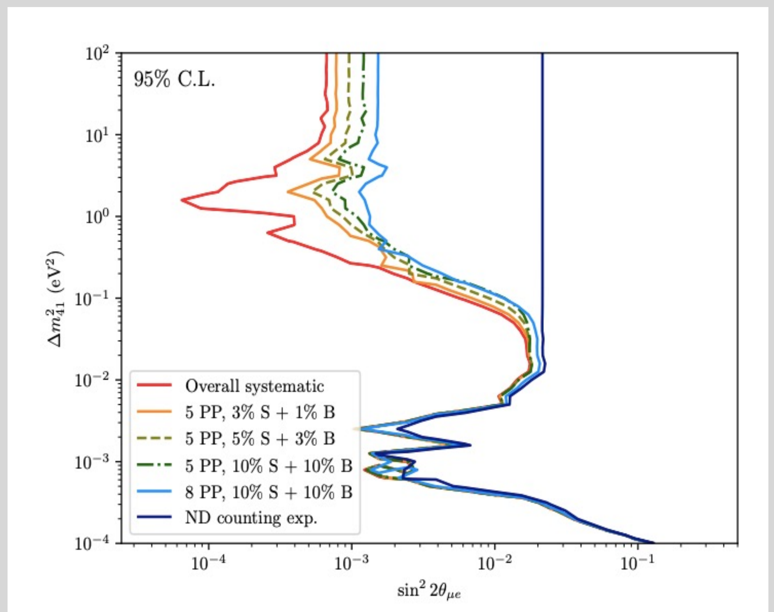


Better results than next-generation experiments ones. <u>CPV sensitivity remains strong!</u>

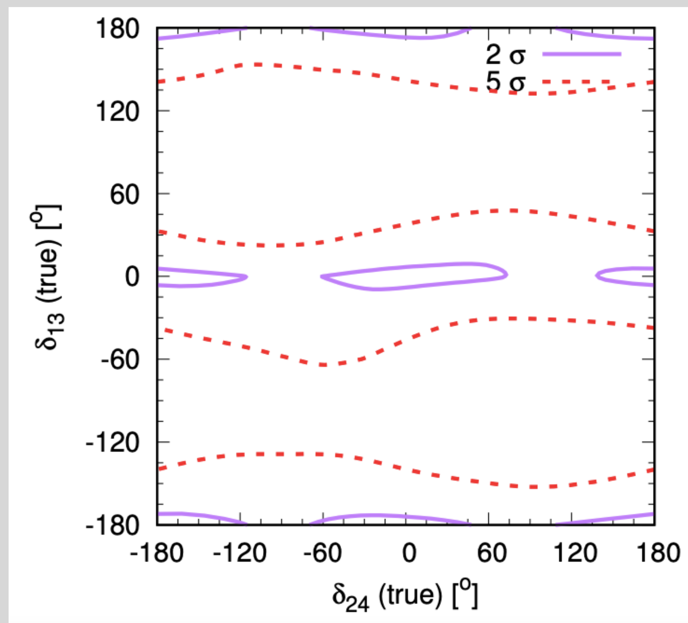


Sterile neutrinos at ESSnuSB

The presence of a light sterile neutrino modifies the oscillation physics at long baseline. The new 4x4 mixing matrix can be probed comparing far and near detector data.



Strong bounds on active-sterile mixing for a large range of sterile mass splitting values



Non-negligible sensitivity to CPV due to sterile states

Short baseline physics: Neutrino cross section measurements with:

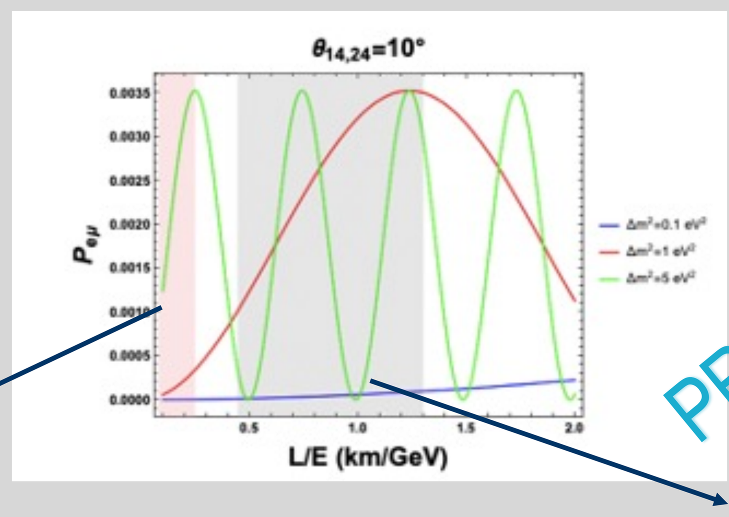
- **ENUBET-like** low energy monitored muon neutrino beam
- **nuSTORM-like** low energy muon and electron neutrino beam from muon decays

Sterile neutrinos at ESSnuSB+ near detectors

Sterile neutrinos oscillations at short baseline might reduce the disappearance events or create unexpected appearance events

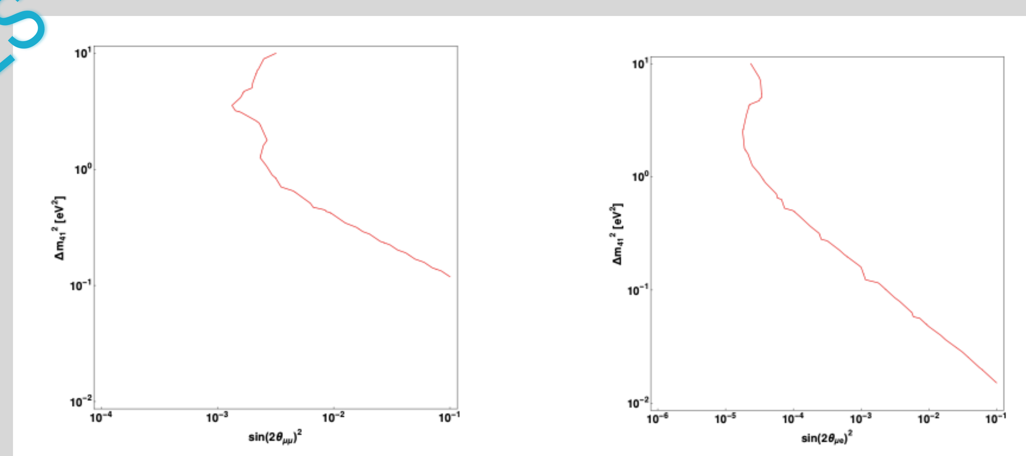
$$P_{\mu e} = sin^2(2\theta_{\mu e})\, sin^2\left(\frac{\Delta m^2_{41} L}{4E}\right) \qquad P_{\mu\mu} = 1 - sin^2(2\theta_{\mu\mu})\, sin^2\left(\frac{\Delta m^2_{41} L}{4E}\right)$$

LEnuSTORM: two detectors fit, might resolve oscillation for $\Delta m^2_{41} \sim 1\ eV^2$



$50\ m\ ND$ $250\ m\ FD$

LE-ENUBET: great limits using ESSnuSB FD, might resolve decay ***pipe length effects*** using the beam monitor



PRELIMINARIES

References

Aguilar, J., et al. "Study of non-standard interaction mediated by a scalar field at ESSnuSB experiment." *Phys. Rev. D* 109, 115010

Alekou, A., et al. "The ESSnuSB design study: overview and future prospects." *Universe* 9.8 (2023): 347.

Choubey, Sandhya, et al. "Exploring invisible neutrino decay at ESSnuSB." *JHEP* 2021.5 (2021): 1-23.

Ghosh, Monojit, et al. "Sensitivity to light sterile neutrinos at ESSnuSB." *JHEP* 2020.3 (2020): 1-17.