Exploring New Physics at nuSTORM

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Introduction

- Neutrinos from STORed Muons (nuSTORM) is a proposed facility to measure the neutrino nucleon cross-section.
- The neutrino flux from nuSTORM has excellent capability to search for sterile neutrinos at short baseline.
- We investigate the usefulness of nuSTORM to probe two new physics scenarios which are sterile neutrinos and a-pair or triplet of the neutrino mixing matrix with a magnetic iron calorimeter detector.
- For sterile neutrinos we show the importance of the neutral current events when considered with the charged current events to constrain the effective mixing angle $\theta_{\nu\mu}$, also the sterile mixing angles $\theta_{13}$ and $\theta_{24}$.
- We elucidate the role of nuSTORM considering both charged current and neutral current events to resolve the various non-unitarity parameters like $\alpha_{11}$, $|\alpha_{21}|$ and $\alpha_{22}$.

Simulation Details

- The numerical simulations have been performed with GLOBES.
- $\chi^2_{\nu\mu} = 2 \sum_{i} \left( \frac{N_{\text{test}} - N_{\text{true}}}{N_{\text{true}}} \right)^2$.
- True values: $\sin^2 \theta_{12} = 0.287$, $\sin^2 \theta_{13} = 0.085$, $\theta_{23} = 42^{\circ}$(LO), $48^{\circ}$(HO), $\Delta m^2_{31} = 7.4 \times 10^{-5}$ eV$^2$ and $\Delta m^2_{21} = 2.5 \times 10^{-3}$ eV$^2$.

Non-Unitarity Mixing Probabilities

In presence of non unitarity, the time evolution of the mass eigenstate in vacuum is:

$$\frac{d}{dt} |\nu_i> = H |\nu_i>,$$

where $H$ is the Hamiltonian in the mass basis. After time $t = E_L$, the flavour state can be written as

$$|\nu_\alpha(t) = N_\alpha \nu_i(t) = N_\alpha (e^{-\Delta m^2_{12} E_L}) |\nu_i(t = 0) >.$$

In this framework the mixing matrix $N$ can be parametrized as:

$$N = \begin{pmatrix}
\alpha_{11} & 0 & 0 \\
\alpha_{21} & \alpha_{22} & 0 \\
\alpha_{31} & \alpha_{32} & \alpha_{33}
\end{pmatrix}.$$

nuSTORM with a baseline of 2 km the transition probabilities become independent of the baseline length because $\Delta m^2_{12} E_L \ll 1$. Therefore, the relevant transition probabilities are:

- $P_{\nu e} = |\alpha_{12}|^2$
- $P_{\nu \mu} = (|\alpha_{21}|^2 + |\alpha_{22}|^2)^2$

Conclusion

- nuSTORM will prove to be crucial in investigating the LSND/MiniBOONE anomalies.
- nuSTORM will have the capability to study $P_{\nu e}$, $P_{\nu \mu}$ channels with the proposed MIND detector.
- CC interactions can constrain the mixing angles $\theta_{14}$ and $\theta_{24}$.
- Introduction of neutral current enhances the capability of nuSTORM to probe the parameters.
- nuSTORM can probe the non-unitarity parameters $\alpha_{11}$, $|\alpha_{21}|$ and $\alpha_{22}$. 3σ sensitivities for $\alpha_{11}$, $|\alpha_{21}|$ and $\alpha_{22}$ are obtained at 0.995, 0.06 and 0.97 respectively for 2 km baselines combining both CC and NC events.