Neutrino Non-Standard Interactions (NSI)

- naturally emerge from many neutrino mass models
- usually parameterised in terms of effective four-fermion Lagrangian
- $-2\sqrt{2}G_F \sum_{f=r,d} \bar{\nu}_f \gamma^\mu L \nu_f [\bar{\nu}_e \gamma^\mu L L \nu_e + \bar{\nu}_\mu \gamma^\mu L L \nu_\mu] f$
- NC NSI (in propagation)
- effective couplings in low-energy regime ($q^2 \ll m_X^2$):
  \[ \epsilon \sim \mathcal{O}\left( \frac{G_X}{G_F} \right) \propto g_{X \mu} \frac{m_{\nu_X}^2}{m_X^2} X : \text{new mediator} \]
- R-parity violating SUSY
- Zee-Babu model
- through, vertical Earth core
- U(1)$'$ gauge symmetry
- inverse seesaw

Neutrino oscillation in presence of NSI

- NSI give rise to generalised matter potential in a medium
- $\hat{H} = \frac{1}{2}E \left[ \text{diag} (0, \Delta m^2_{21}, \Delta m^2_{31}) U^T + V_\odot (r) \left( \text{diag}(1,0,0) + \sum_\alpha \lambda_\alpha \nu_\alpha \right) \right]$ 
- relevant for atmospheric neutrino propagation through the Earth
- impact of NSI couplings ($\epsilon_{\nu_{\mu}}$) on atmospheric $\nu_{\mu}$ survival probabilities (couplings at upper end of global 90% C.L. allowed range)
- $\Rightarrow$ disappearance of high-energy $\nu_{\mu}$ flux due to $\epsilon_{\nu_{e}}$ & $\epsilon_{\nu_{\mu \mu}}$
- $\Rightarrow$ increased survival at medium energy due to $\epsilon_{\nu_{\mu}}$ & $\epsilon_{\nu_{\tau \mu}}$

IceCube DeepCore

- IceCube: cubic-kilometre in-ice Cherenkov detector at geographic South Pole
- about 5000 optical modules on 86 strings, at depths between 1.5 km–2.5 km
- DeepCore: infill array at deep centre of IceCube, lowers energy threshold to 5 GeV
- no event-by-event discrimination between $\nu$ and $\bar{\nu}$
- energy-dependent efficiency of $\nu_{\mu} + \bar{\nu}_{\mu}$ CC Identification
- measure atmospheric neutrino oscillations
- “tracks” vs. “cascades”

MC signal expectation (FCNC NSI)

- 3-year cascade + track dataset extended to 180 GeV (expect about 50K events in 3 years)
- signals across all energies and full upgoing zenith range (note different colour scales)

NSI sensitivity

- test single real NSI coupling ($\epsilon_{\alpha\beta} = \epsilon_{\alpha\beta}^F \equiv \frac{f_{L\alpha}^F}{f_{R\beta}^F} = \frac{f_{L\alpha}^F}{f_{R\beta}^F} + \epsilon_{\alpha\beta}^R$) at a time
- one-by-one limits compared to a global fit to oscillation + COHERENT data (valid for $m_X \gtrsim 10$ MeV) and previous measurements
- constraints from oscillation experiments independent of scale of new physics
- all-flavour search $\rightarrow$ data sample able to simultaneously constrain multiple NSI couplings, for example:

References


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