Double cascades with IceCube and DUNE

IceDUNE workshop - June 16-18, 2021

Massachusetts Institute of Technology

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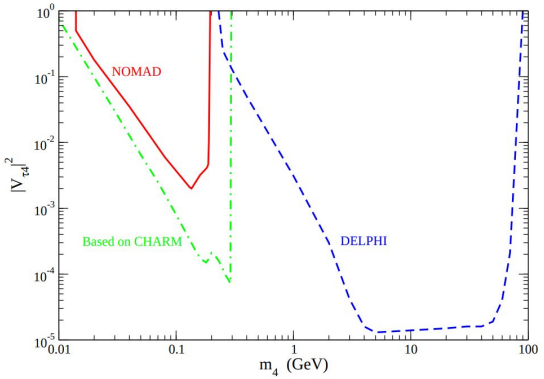
What are we talking about?

Sterile neutrinos, or Heavy Neutral Leptons (HNL's)

SM singlets but can be observed through their extended-PMNS mixing with SM neutrinos:

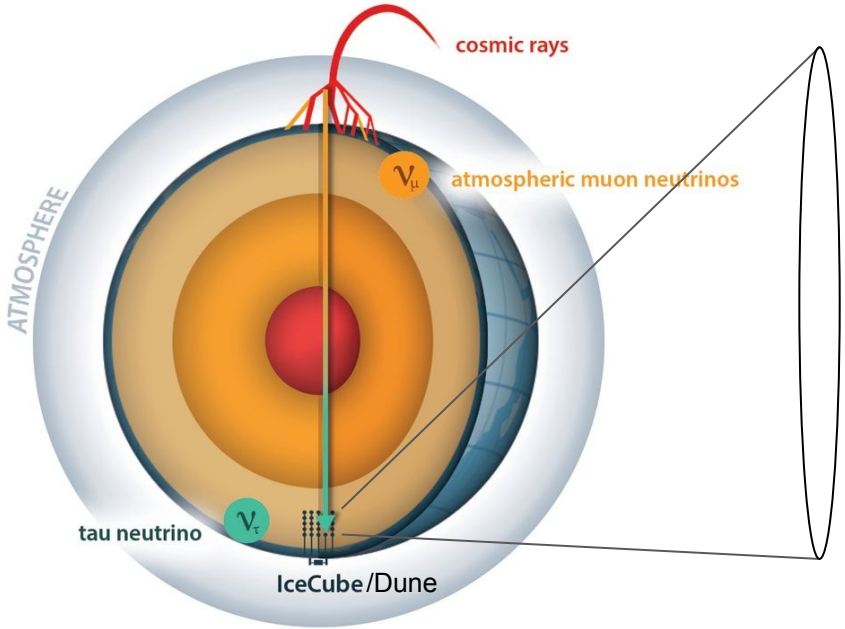
$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \\ \nu_s \end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} & U_{e4} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} & U_{\mu 4} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} & U_{\tau 4} \\ U_{s1} & U_{s2} & U_{s3} & U_{s4} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \\ \nu_4 \end{pmatrix}$$

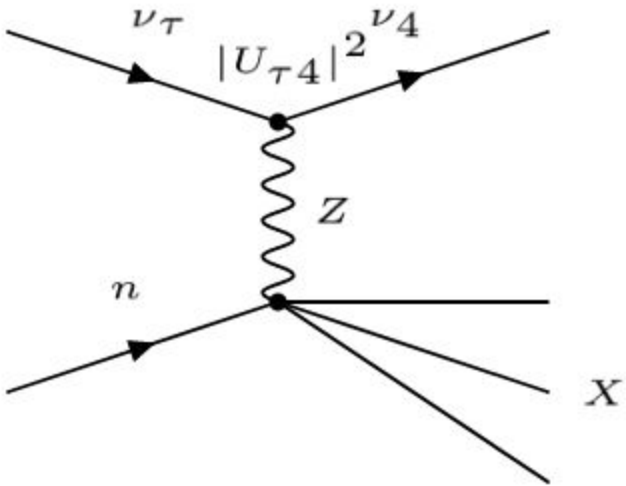
Already well constrained



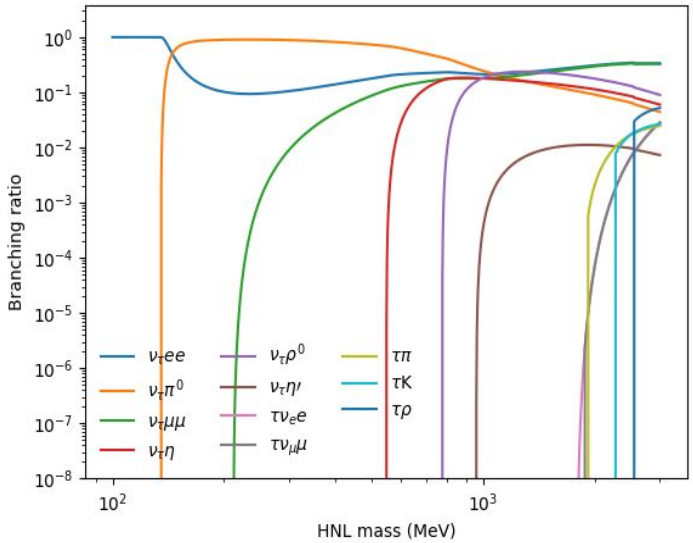
HNL production

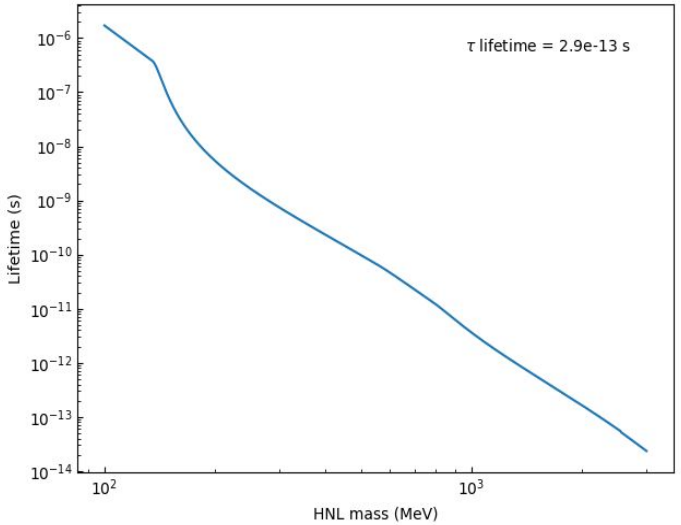
HNL (Heavy Neutral Lepton) **production** in up-scattering of a tau neutrino:

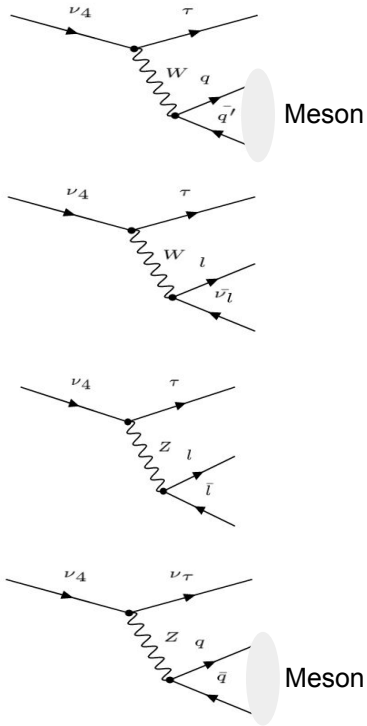




HNL decay


Branching ratio
HNL mass (MeV)
$\nu_\tau ee$
$\nu_\tau \pi^0$
$\nu_\tau \mu\mu$
$\nu_\tau \eta$
$\nu_\tau \rho^0$
$\nu_\tau \eta'$
$\tau \nu_e e$
$\tau \nu_\mu \mu$
$\tau\pi$
τK
$\tau\rho$

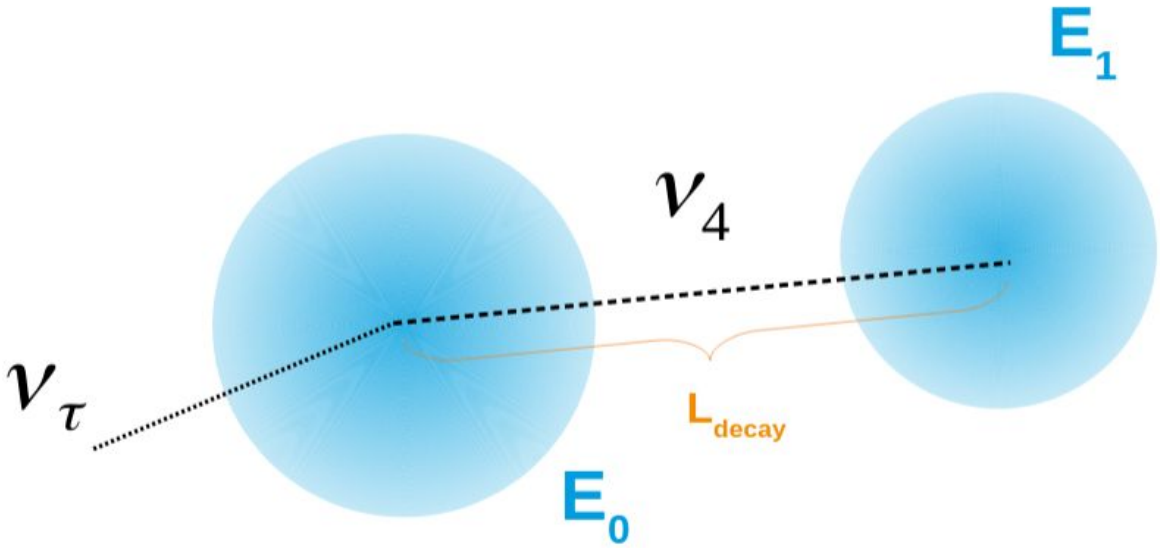

τ lifetime = 2.9e-13 s
Lifetime (s)
HNL mass (MeV)


Meson
Meson

Experimental signature

Low energy double cascade

Tau neutrinos from atmospheric flux



Backgrounds

“Reducible”:

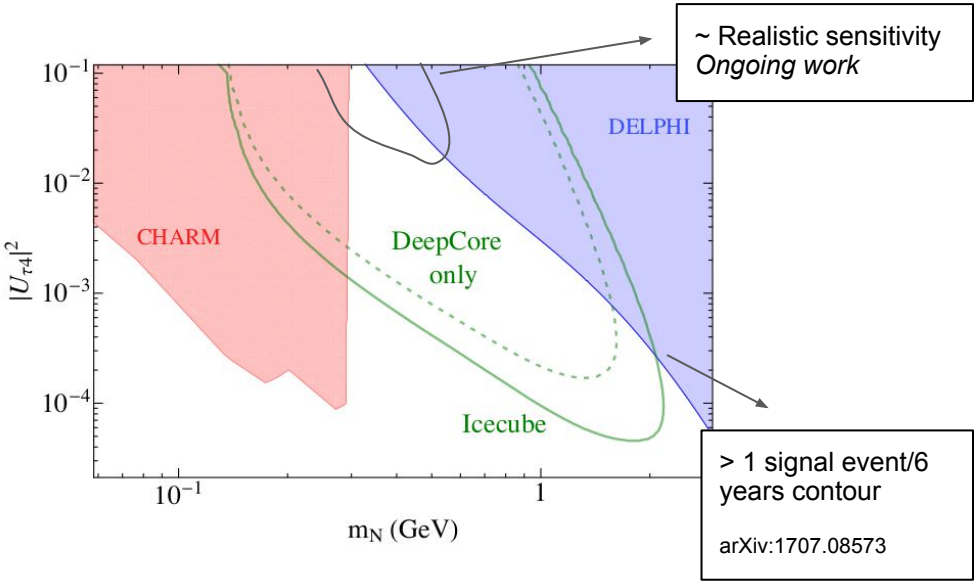
- Single cascades:
  - NC neutrino interactions in the detector
  - NuE CC
  - NuTau CC (low energies)
- Tracks:
  - NuMu CC (+ cascade)
  - Atmospheric muons
- Noise

“Irreducible” (double cascades):

- NuTau CC (high energies)
- Kaon punch-through (KLong decay away from the interaction vertex)
- Coincident events (very low rate, potentially irrelevant for DUNE)

Ideal vs realistic

- **Larger BG rate**: at low energies, the topologies are much harder to distinguish
- **Lower signal rate**: IceCube triggers kill more signal than what is suggested



IceCube-DUNE complementarity