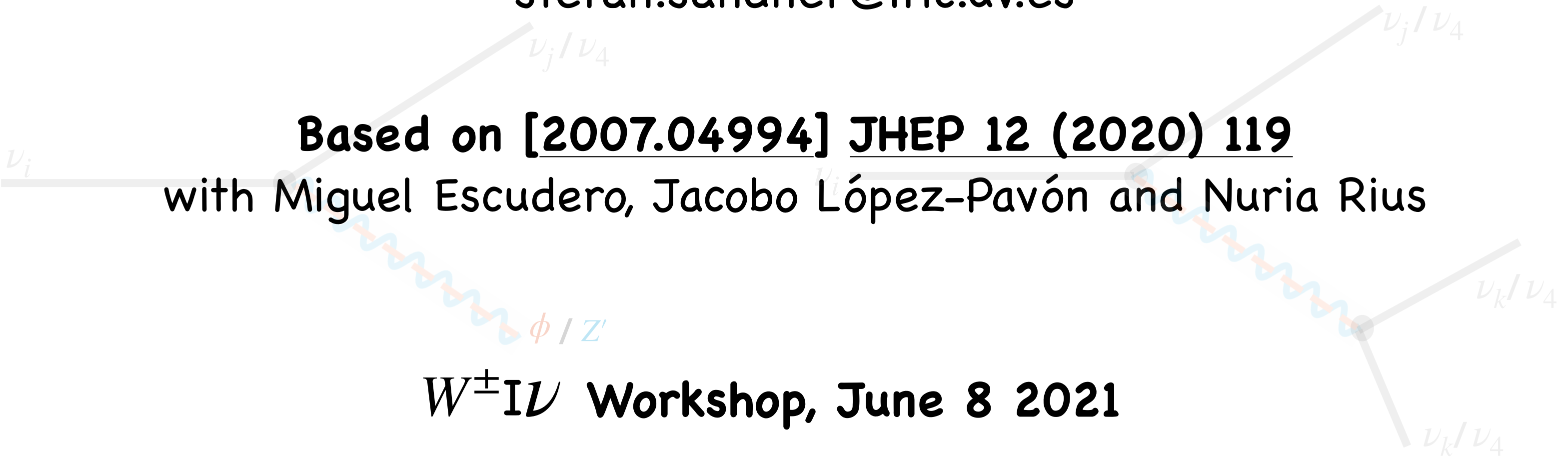
Relaxing Cosmological Neutrino Mass Bounds with Unstable Neutrinos

Stefan Sandner
stefan.sandner@ific.uv.es



Based on [2007.04994] JHEP 12 (2020) 119
with Miguel Escudero, Jacobo López-Pavón and Nuria Rius

$W^{\pm}I\nu$ **Workshop, June 8 2021**

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Motivation & Main Result

- Cosmology set most stringent neutrino mass bound: $\Sigma m_\nu < 0.12$ eV

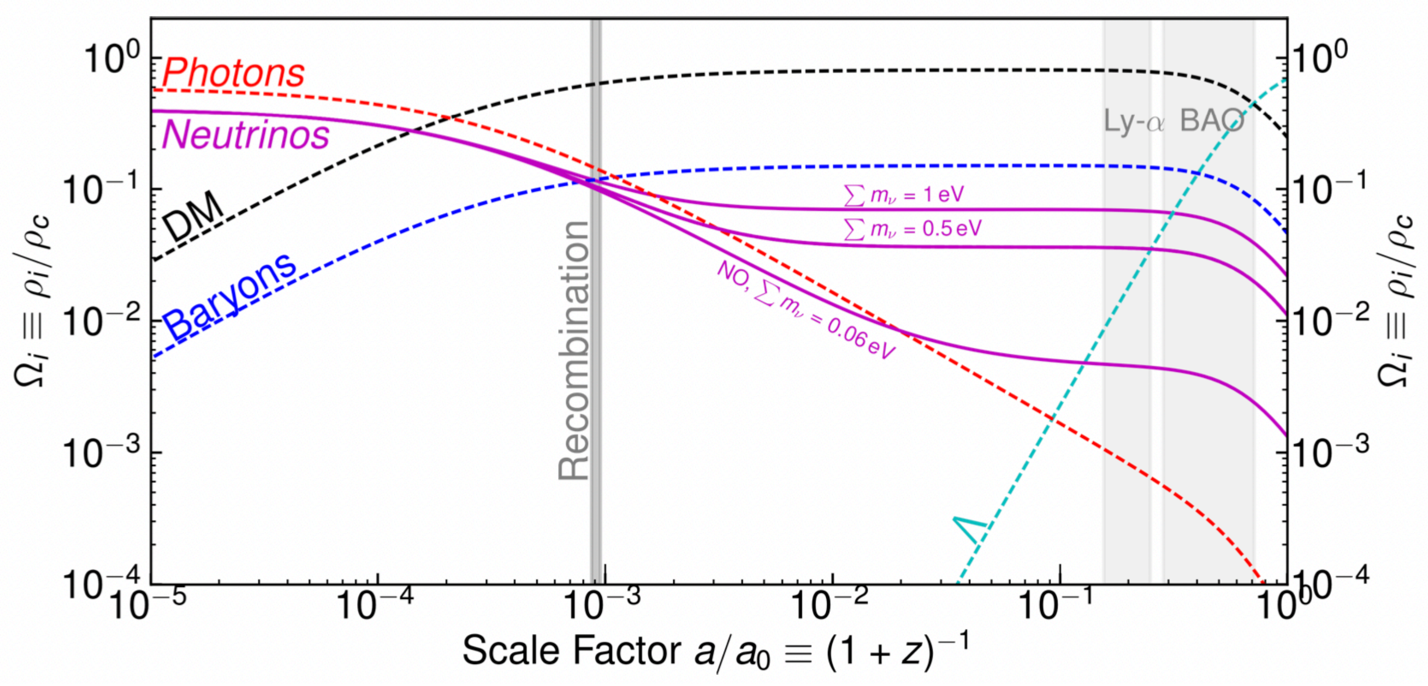
  —> Excludes many neutrino mass models; most 2-zero textures ruled out [1806.06785]

- The bound, however, assumes ΛCDM with stable neutrinos!

Generic Neutrino Decay with $\tau_\nu < t_U$ via light bosons can relax the bound to up to $\Sigma m_\nu \sim 1$ eV and can be incorporated into e.g. $U(1)_{\mu-\tau}$ models.

Preliminaries

PLANCK constraint on Σm_ν mainly arises from its contribution to non-cold Dark Matter today



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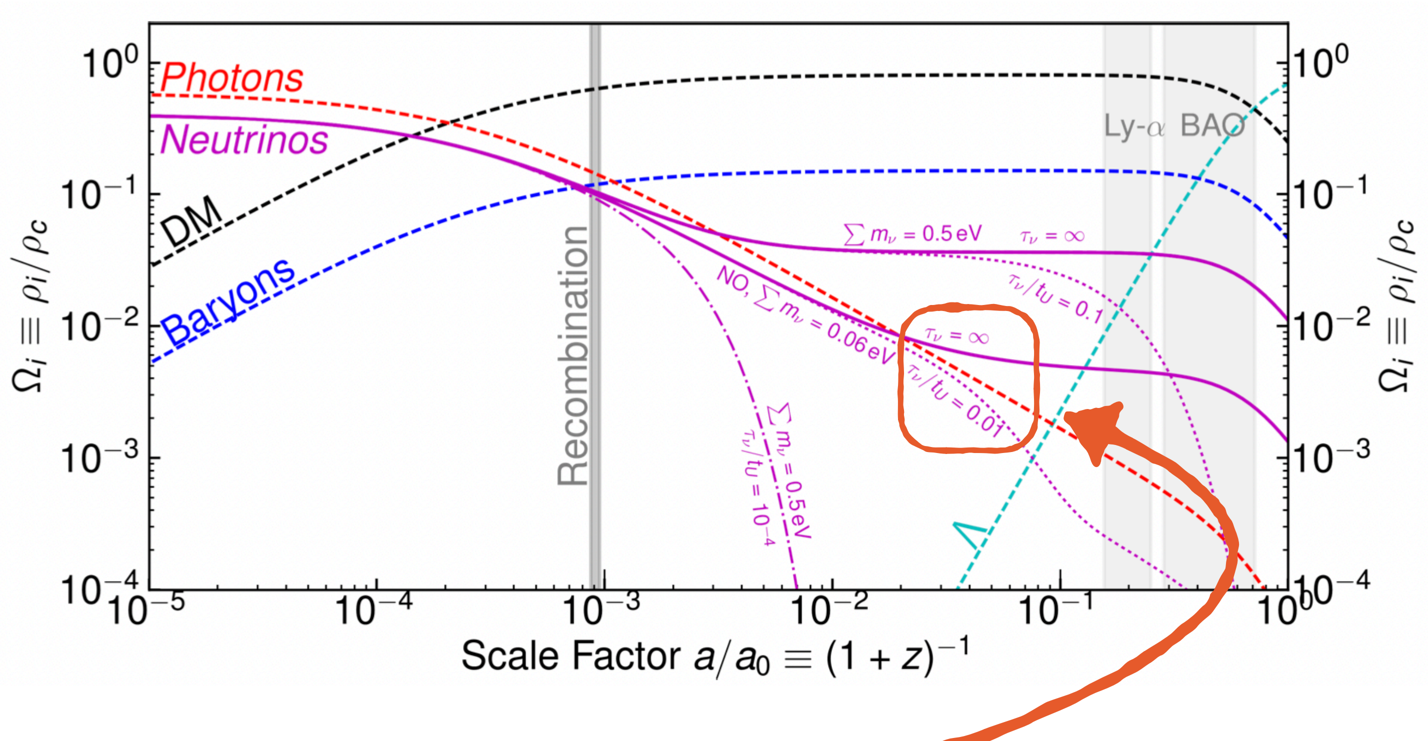


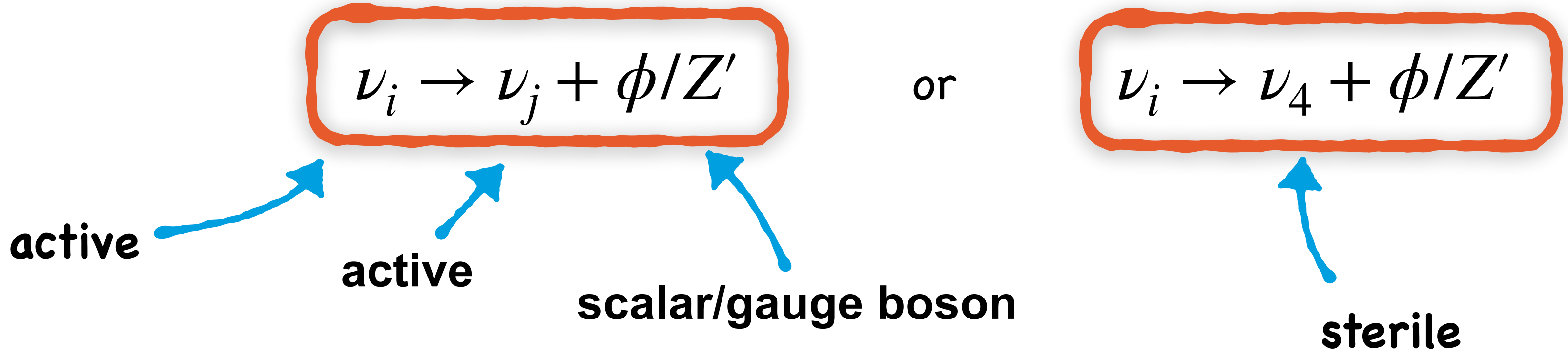
Hence: Fast Neutrino Decay can elude main constraining power of PLANCK!

Achieving Neutrino Decay

- Once they are massive they will decay, but within SM $\tau_\nu \gg t_U$ –> BSM needed
- Generically, neutrino decay can be parametrized by two model independent renormalizable Lagrangians (our work) and classified into two categories:

  i) Are there active neutrinos in the final state?
  ii) What is the number of final state particles?

- Analyzing all possibilities, the most promising one is a 2-body decay:



$$\boxed{\nu_i \to \nu_j + \phi/Z'} \quad \text{or} \quad \boxed{\nu_i \to \nu_4 + \phi/Z'}$$

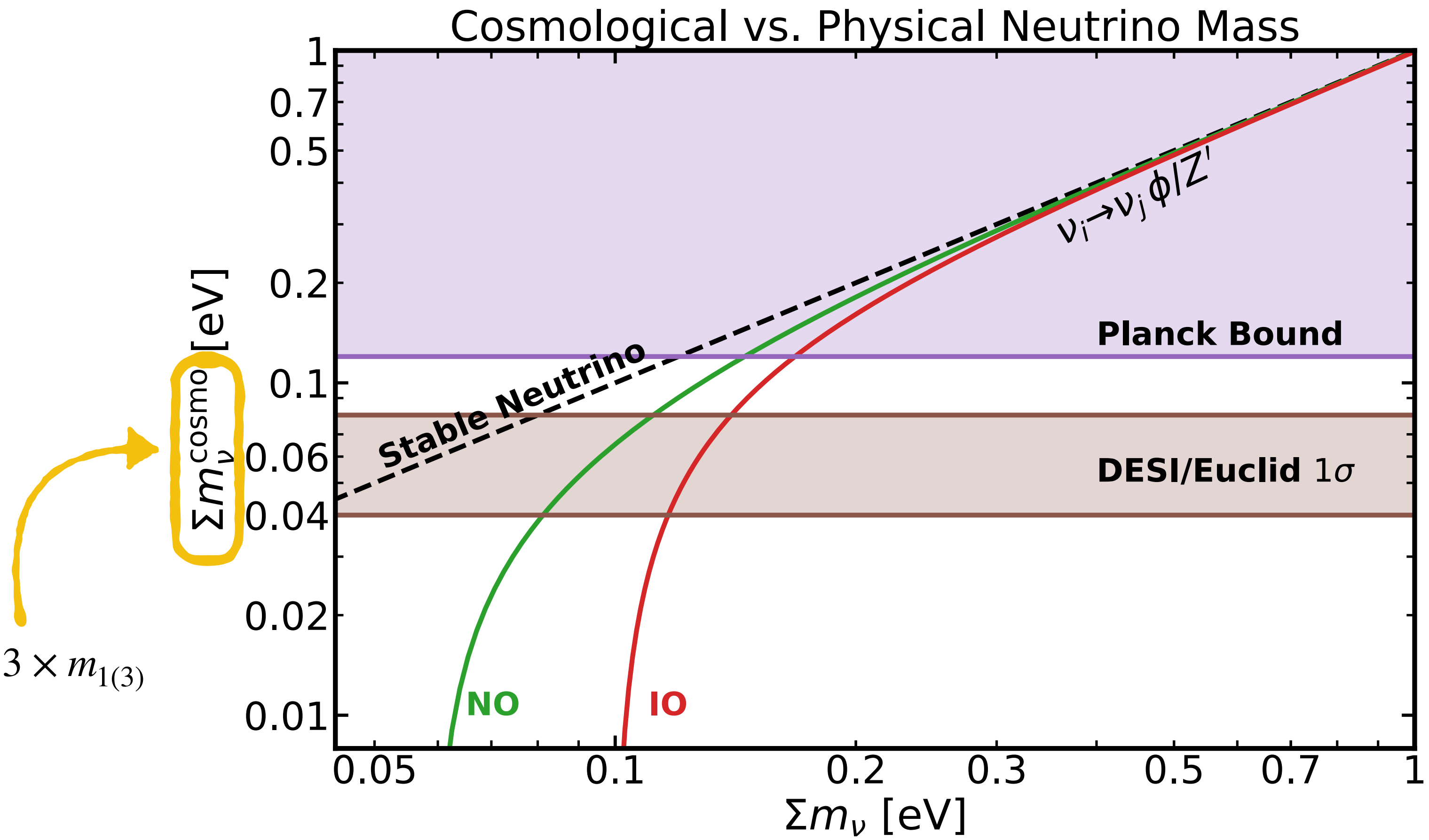
active

active

scalar/gauge boson

sterile

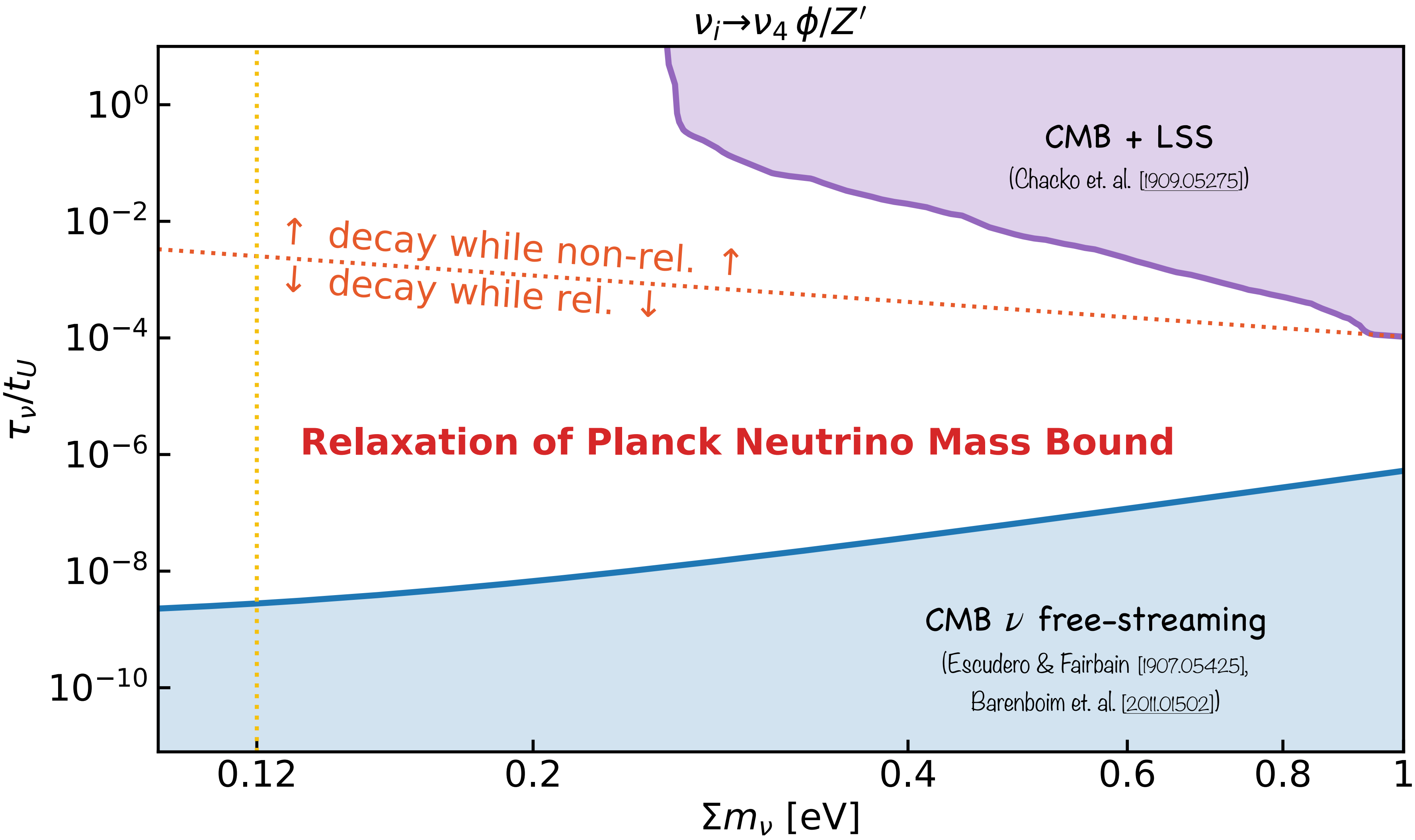
Active Neutrino Decay



$\simeq 3 \times m_{1(3)}$

- Relaxation controlled by active mass splitting

Constraining Sterile Decay



Application to Model

- Impose anomaly free $U(1)_{\mu-\tau}$ symmetry (accidental within SM)

—> SM + 3 right handed neutrinos + 1 charged Scalar + (Z' if gauged)

- Neutrino mass matrix has 2-zero texture:

$$M_{\nu_L}^{-1} = \begin{pmatrix} x & x & x \\ x & 0 & x \\ x & x & 0 \end{pmatrix} = U\text{diag}(m_i)U^\dagger$$

- Fits all observables, **but** $\Sigma m_\nu > 0.126$ eV at 3σ!

- Model allows already for decays $\nu_i \to \nu_j + \phi/Z'$, but we can do more…

Model Building

- Extend $U(1)_{\mu-\tau}$ model by scalar Φ + fermion singlet S_L charged under new $U(1)_X$

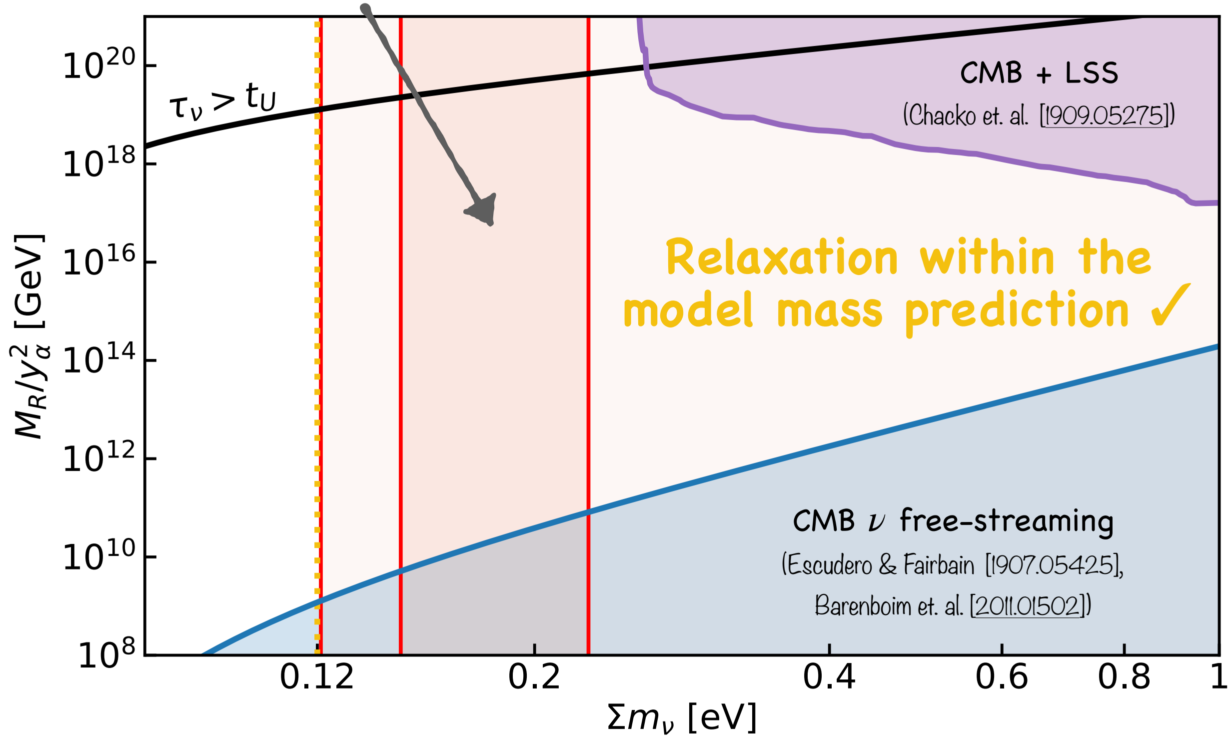
–> unique new term: $\mathscr{L} \supset y\Phi\bar{N}_R S_L$ –> $M_\nu|^{7\times7} = \begin{pmatrix} 0 & m_D & 0 \\ m_D & M_R & y_\alpha v_\Phi \\ 0 & (y_\alpha v_\Phi)^\dagger & 0 \end{pmatrix}$

- Assume $yv_\Phi \ll m_D \ll M_R$
  - **See-Saw at work**
  - **Right ν_4 properties:** $m_{\nu_4} \sim 0$, $U_{\alpha4} \sim yv_\Phi/m_D \ll 1$

Model Building

Neutrino Decay Rate: $\Gamma(\nu_i \to \nu_4\phi) \sim 10^6\ t_U^{-1}\ y^2 \left(\frac{m_\nu}{0.3eV}\right)^2 \left(\frac{10^{14}GeV}{M_R}\right)$

1σ and 3σ mass prediction (NuFIT 5.0)



Summary

- $\nu_i \to \nu_4 + \phi/Z'$ only weakly constraint and can relax cosmological neutrino mass bound to up to $\Sigma m_\nu \sim 1$ eV

- Incorporation into $U(1)_{\mu-\tau}$ neutrino mass model is straightforward and in accordance with all available neutrino data ✓

- **Many more things and details can be found in [2007.04994]**

Outlook

A neutrino mass detection by KATRIN or no signal by DESI/EUCLID would strongly point to cosmological fast Neutrino Decay

— Results expected in 5-10 years