# Solar Antineutrinos Searches and Decaying Sterile Neutrinos

**XIX International Workshop on Neutrino Telescopes**


**Matheus Hostert**
mhostert@umn.edu
*University of Minnesota & Perimeter Institute*

in collaboration w/ Maxim Pospelov
*arXiv:2008.11851*

UNIVERSITY OF MINNESOTA

PERIMETER INSTITUTE

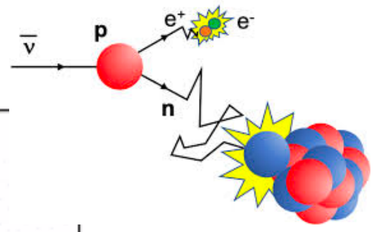
# Short Baseline Anomalies

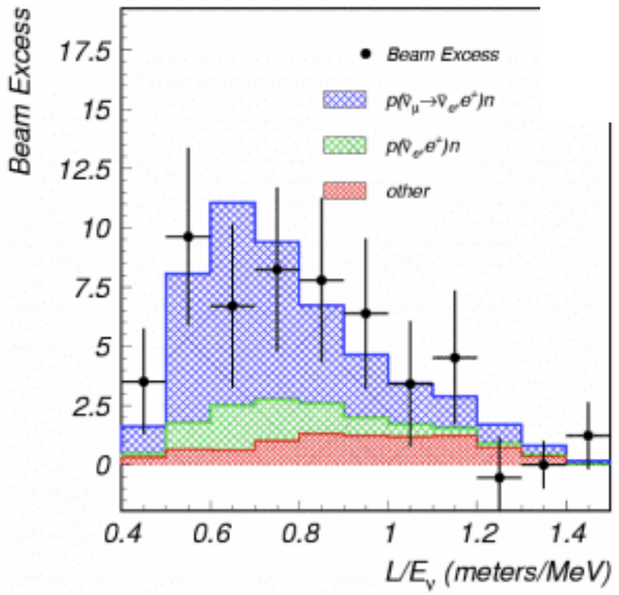
**@ LSND:** $\pi^+ \to \mu^+ \nu_\mu$

arXiv:0104049

$\mu^+ \to e^+ \nu_e \overline{\nu_\mu}$

$\overline{\nu}_\mu \to \overline{\nu}_e$



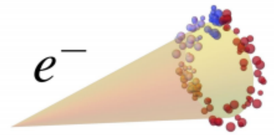



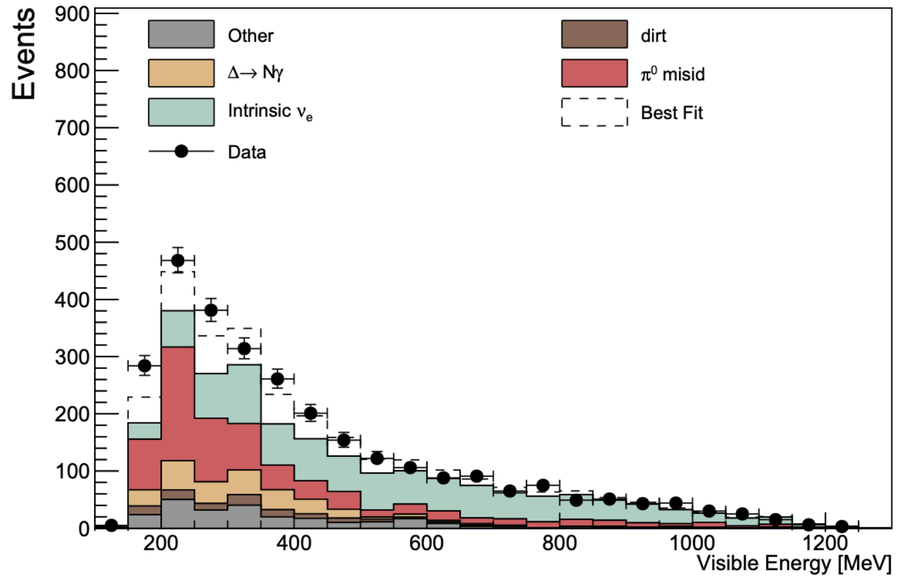

**EXCESS: 87.9 ± 22.4 ± 6 EVENTS**
**3.8 sigma**

**@ MiniBooNE:** $\pi^+ \to \mu^+ \nu_\mu$

arXiv:2006.16883

$\nu_\mu \to \nu_e$



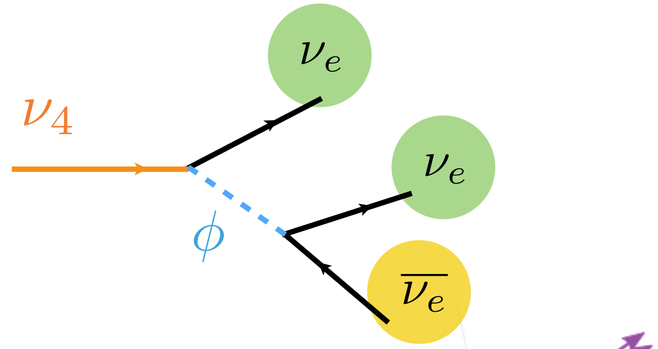

**EXCESS: 560± 119.6 EVENTS only in nu mode**
**4.8 sigma significance**

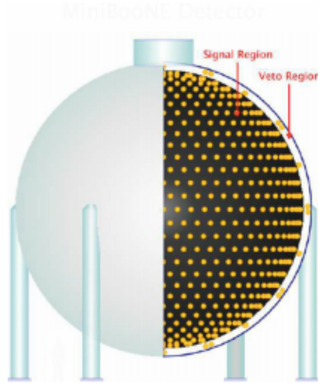
# Decaying sterile neutrinos to explain them

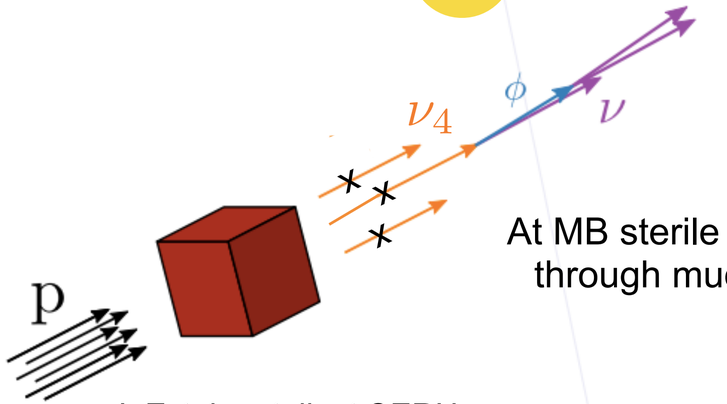
## Sterile neutrino visible decays:

M. Dentler *et al*, PRD101(2020) 115013.

$$-\mathcal{L} \supset g_s \overline{\nu}_s \nu_s \phi + m_{ab} \overline{\nu_a} \nu_b.$$



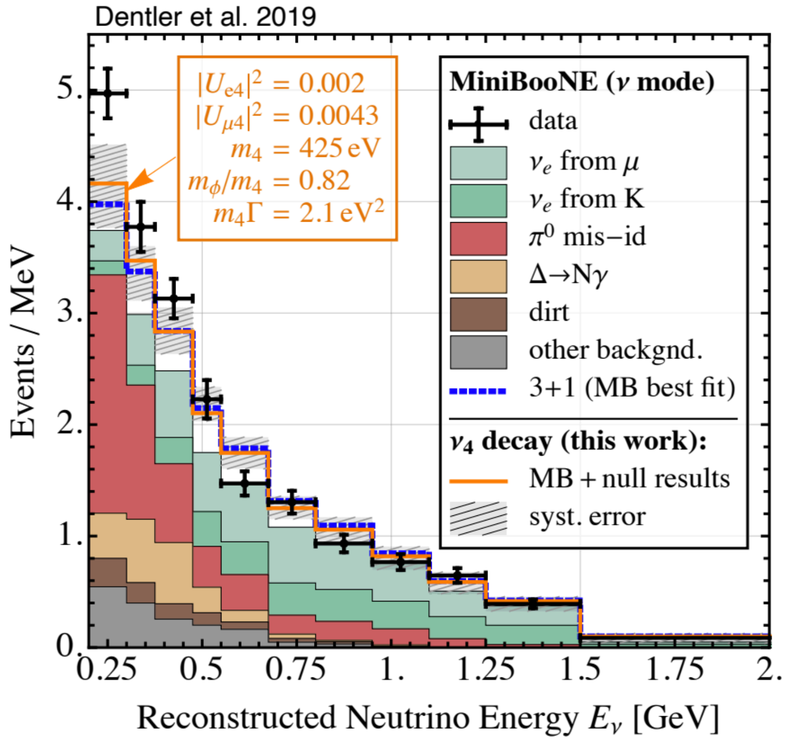




*I. Esteban talk at CERN*
*10.5281/zenodo.3509890.*

At MB sterile is produced through muon-mixing.

MiniBooNE energy distribution




Avoids tension with disappearance exps, and may be extended to satisfy cosmology.

An effective $\nu \longrightarrow \overline{\nu}$ transition



See also, Palomares-Ruiz *et al*, JHEP09(2005)048 A. deGouvea *et al*, JHEP07(2020)141

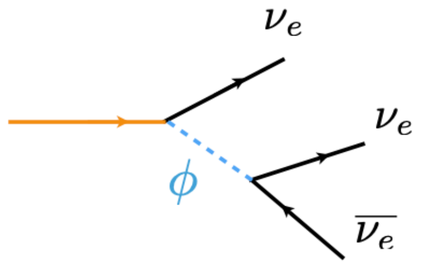
# Effective neutrino-antineutrino transition

Suppression in $\nu_4$ flux

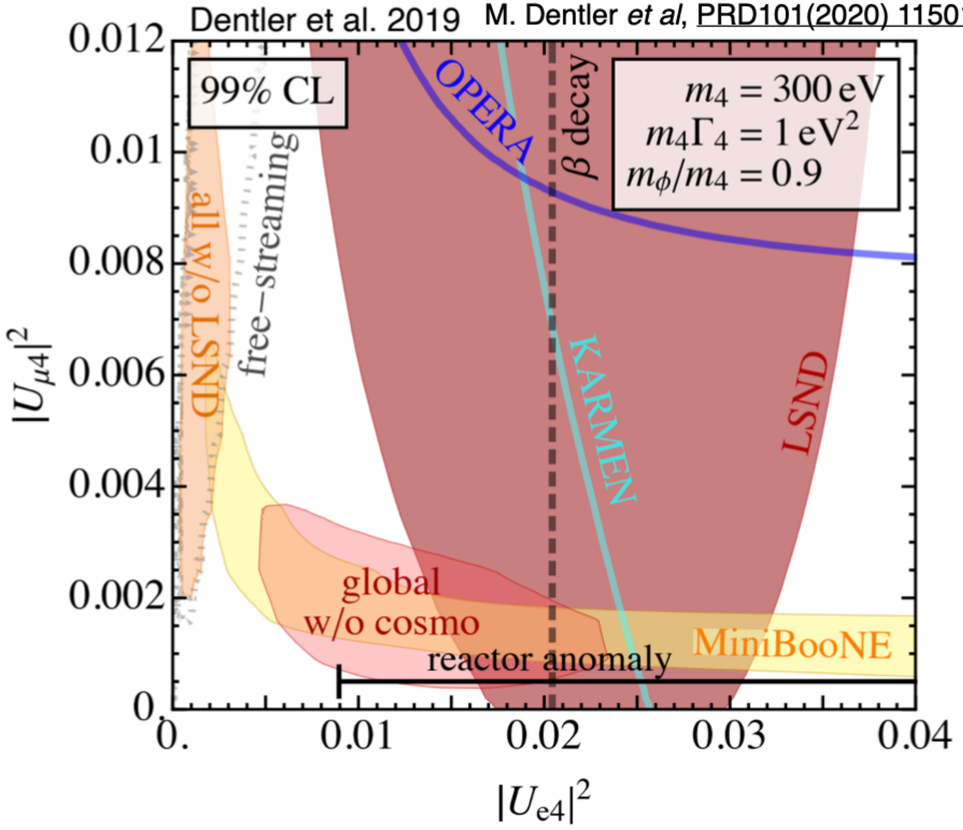
@ LSND: $\pi^+ \to \mu^+ \nu_\mu \longrightarrow |U_{\mu 4}|$

$\mu^+ \to e^+ \nu_e \overline{\nu_\mu} \longrightarrow |U_{\mu 4}|$ & $|U_{e4}|$

@ MiniBooNE: $\pi^+ \to \mu^+ \nu_\mu \longrightarrow |U_{\mu 4}|$

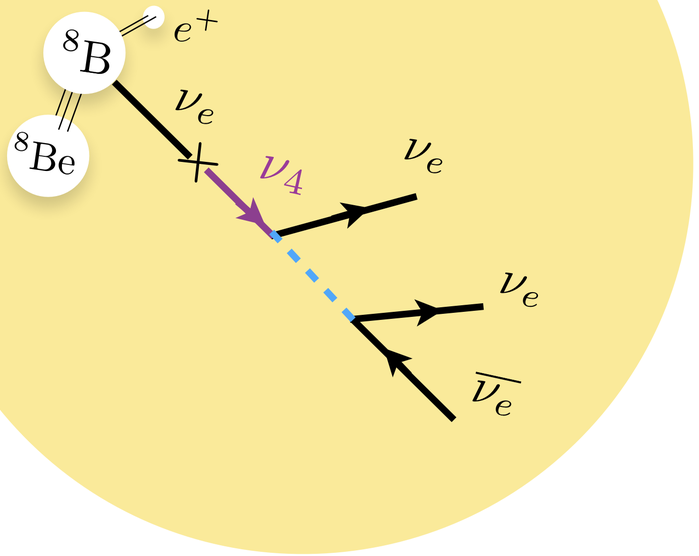



**An effective $\nu \to \overline{\nu}$ transition**




The global fit **prefers** that the **massive scalar** decays to reconcile LSND & MiniBooNE.

# Antineutrinos from the Sun?




e.g. $\Phi_\nu^{^8B} \sim 6 \times 10^6 \ \mathrm{cm^{-2} s^{-1}}$ $\qquad E_\nu \lesssim 16\,\mathrm{MeV}$

Nuclear fusion *cauldron* of the Sun **massively overwhelms** antineutrino emission at MeV energies. R. A. Malaney, et al, Astrophys. J. 352, 767 (1990)

$\overline{\nu_e}$ from long-lived radioactive isotopes (232Th, 238U, ...): $\Phi_{\overline{\nu}_e} \sim 200 \ \mathrm{cm^{-2}\ s^{-1}}$ with $E_\nu \lesssim 3\ \mathrm{MeV}$

$\overline{\nu_e}$ from photo-fission reactions: $\Phi_{\overline{\nu}_e} \sim 10^{-3} \ \mathrm{cm^{-2}\ s^{-1}}$ with $E_\nu \sim 3 - 9\ \mathrm{MeV}$

$\overline{\nu_e}$ detection through
*Inverse Beta Decay*

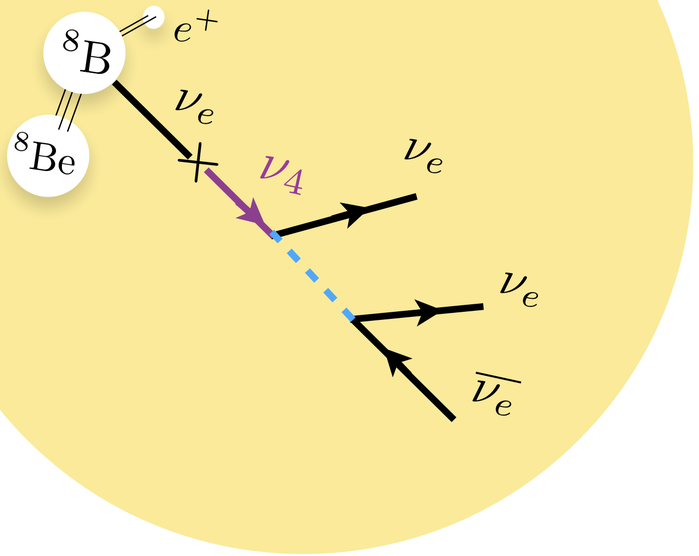
$$\overline{\nu_e} + p^+ \rightarrow e^+ + n$$

IBD has **small backgrounds** and much **larger cross section** than nu-e elastic!

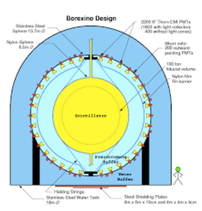
$$\sigma_{\mathrm{IBD}} \gg \sigma_{\nu-e}$$

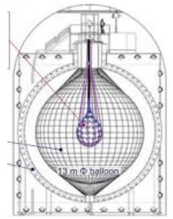
When produced, $\overline{\nu_e}$ undergoes **matter-suppressed** flavour transitions.

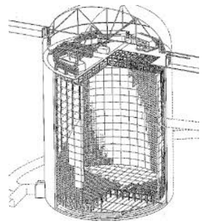
# Existing constraints on Solar antineutrinos




The Sun does not emit antineutrinos:



$$P^{\text{Borexino}}_{\nu_e \to \overline{\nu_e}}(E_\nu \geq 1.8\ \text{MeV}) < 7.2 \times 10^{-5}$$

$$P^{\text{KamLAND}}_{\nu_e \to \overline{\nu_e}}(E_\nu \geq 8.3\ \text{MeV}) < 5.3 \times 10^{-5}$$

$$^*P^{\text{SK-IV}}_{\nu_e \to \overline{\nu_e}}(E_\nu \geq 9.3\ \text{MeV}) \lesssim 1.0 \times 10^{-4}$$

$\overline{\nu_e}$ detection through
*Inverse Beta Decay*

$$\overline{\nu_e} + p^+ \rightarrow e^+ + n$$

IBD has **small backgrounds** and much **larger cross section** than nu-e elastic!

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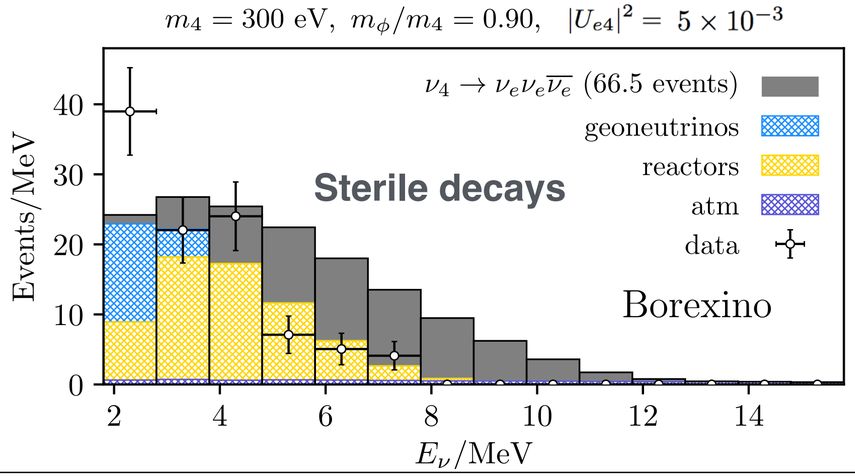
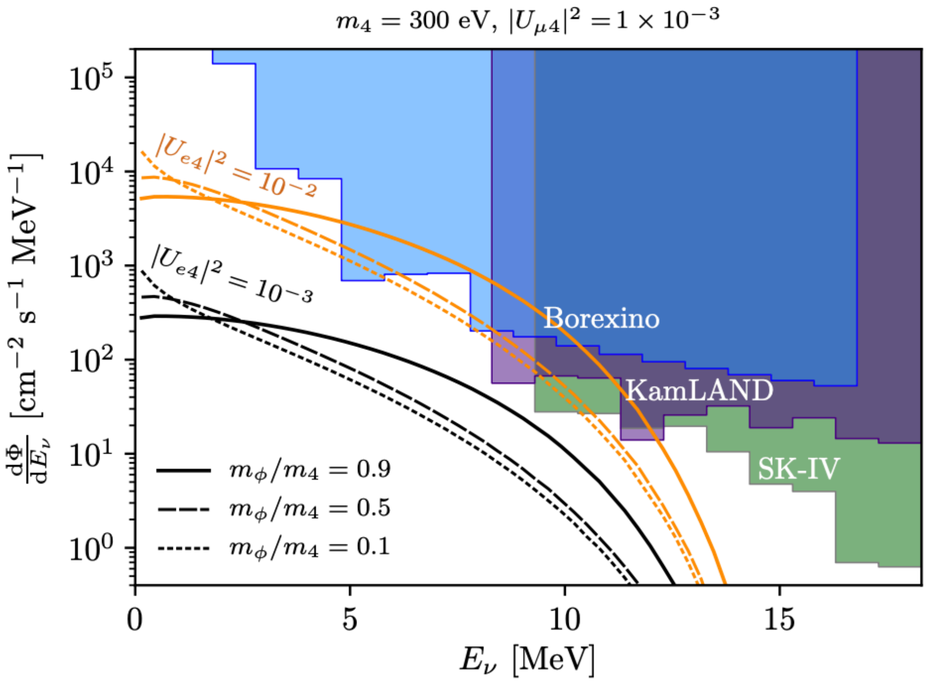
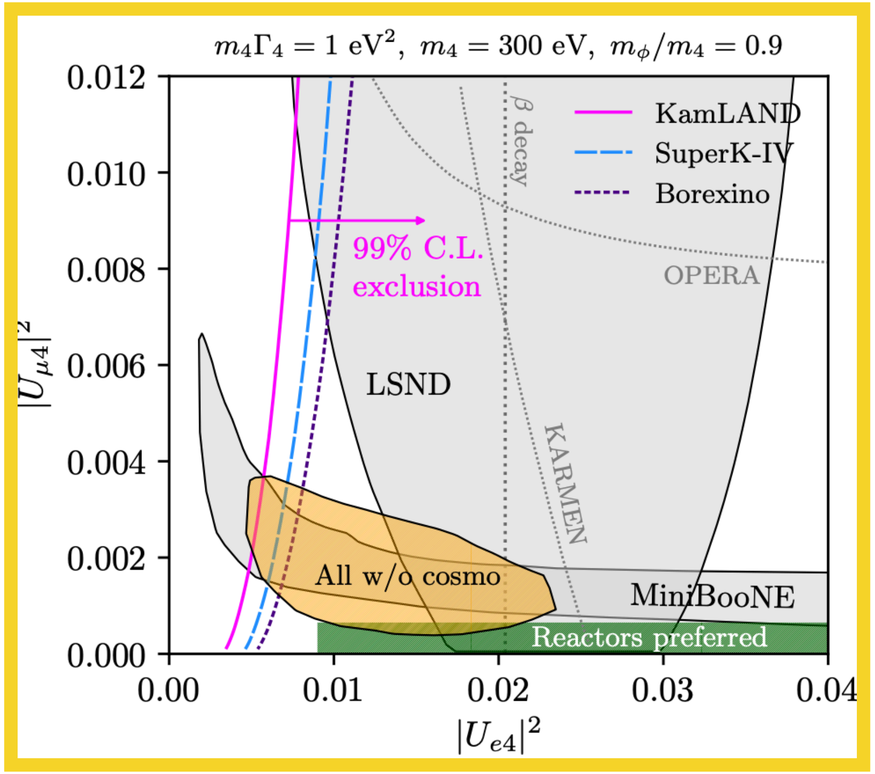
From a dedicated simulation of the NP signature:



# Results & Conclusions




**A simultaneous explanation of LSND and MiniBooNE is in tension with Solar antineutrino searches.**

**Significant improvement expected at JUNO and SK-Gd** S.J. Li *et al,* Nucl.Phys.B 944(2019)114661

Bounds becomes stronger for Majorana neutrinos, but may be weakened if:

- *Caveat: models where phi does not decay are not constrained, but are more baroque.*

S. Palomares-Ruiz *et al,* JHEP09(2005)048

A. deGouvea *et al*, JHEP07(2020)141