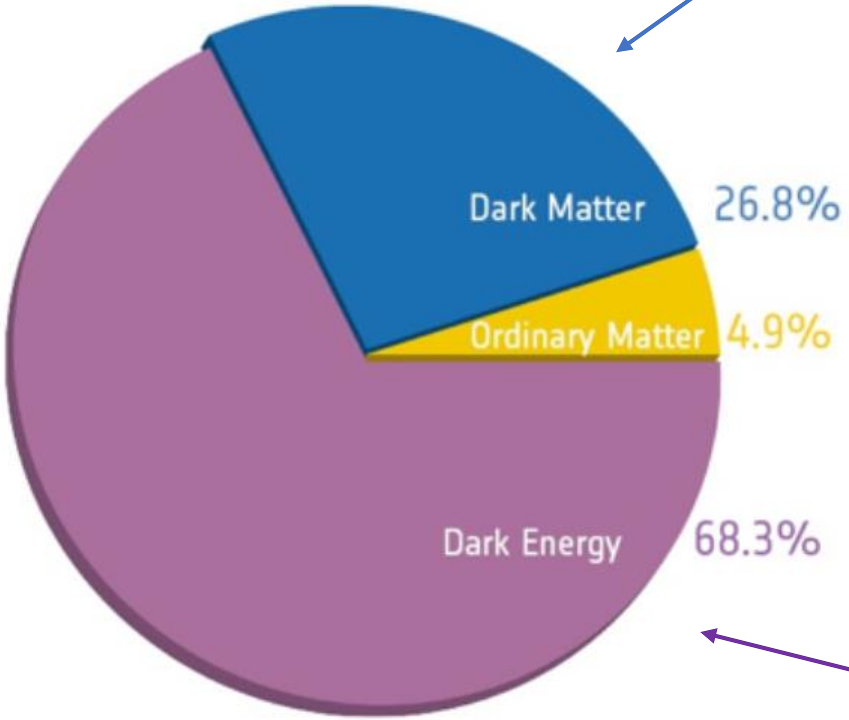
Astroparticle Tests for BSM Theories

Giorgio Arcadi



Origin and nature of the DM component of the Universe

Generation mechanism for neutrino masses

Origin of the Matter-Antimatter asymmetry

Origin and nature of the Dark Energy/Cosmological Constant (not covered in this presentation)

Experimental evidences suggest the need for extension of the Standard Model.

Research activity in Rome 3

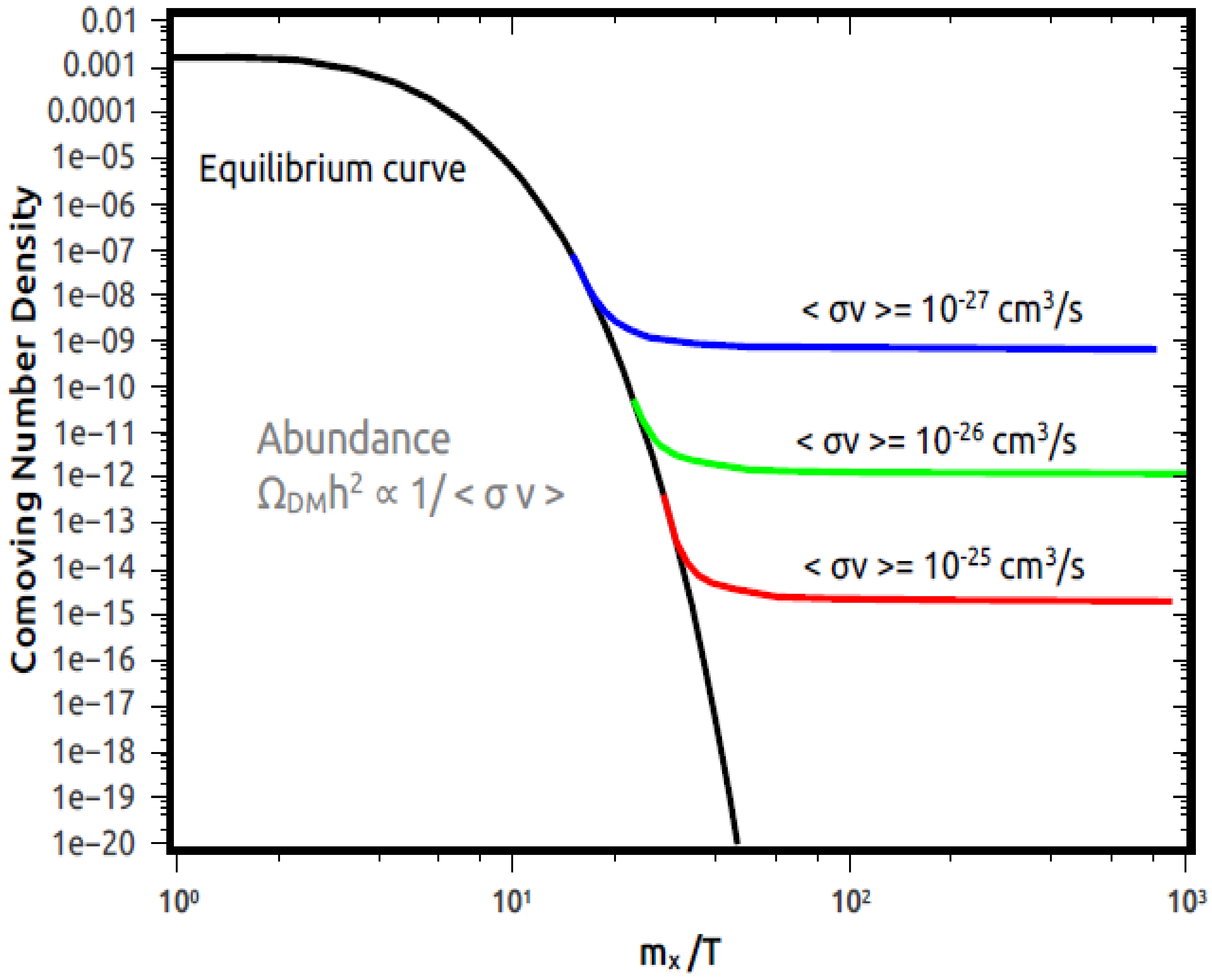
Model building and phenomenology of DM (mostly WIMPs). (Arcadi)

Neutrino mass models. (Meloni)

Leptogenesis. (Arcadi)

Study of light weakly coupled sectors. (Arcadi/Meloni)

WIMP Paradigm

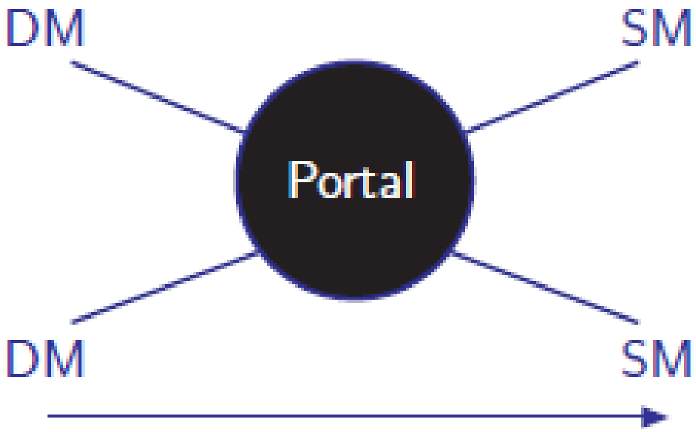


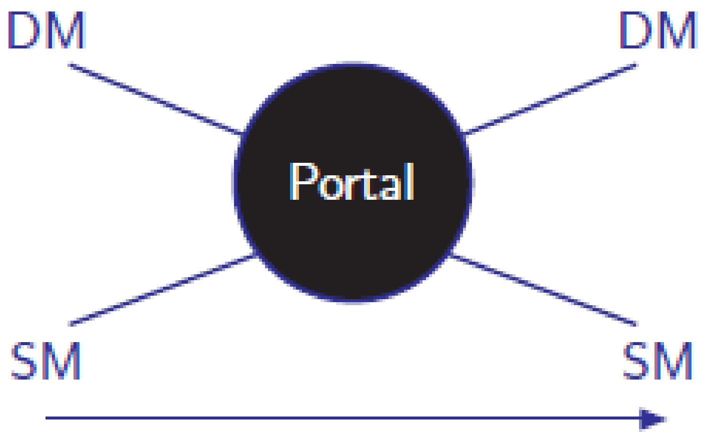
$$\frac{dn}{dt} = -3Hn - \langle \sigma_{\rm ann} v \rangle \left(n^2 - n_{\rm eq}^2\right)$$

$$\frac{dY}{dx} = \frac{1}{3H}\frac{ds}{dx}\langle \sigma v \rangle \left(Y^2 - Y_{eq}^2\right)$$

$$\Omega h^2 \theta^{-3} \approx 8.7661 \times 10^{-11}\,{\rm GeV}^{-2}\left[\overline{g_{\rm eff}}^{1/2}\int_{T_0}^{T_f}\langle \sigma v_{\rm M\o l}\rangle \frac{dT}{m}\right]^{-1}$$

$$\langle \sigma v \rangle = a + bv^2$$





Relic Density

$$\langle \sigma v \rangle \approx \frac{\lambda_f^2 \lambda_\chi^2 m_\chi^2}{(4m_\chi^2 - m_{\text{med}}^2)^2}(a + b v_{\text{f.o}}^2)$$

$$\sigma_{\chi N} = \frac{\mu_{\chi N}^2 \lambda_\chi^2}{\pi m_{\text{med}}^4} f(\lambda_q)$$

$$v_{\text{f.o}} \sim 0.3$$

s-wave

p-wave

Indirect Detection

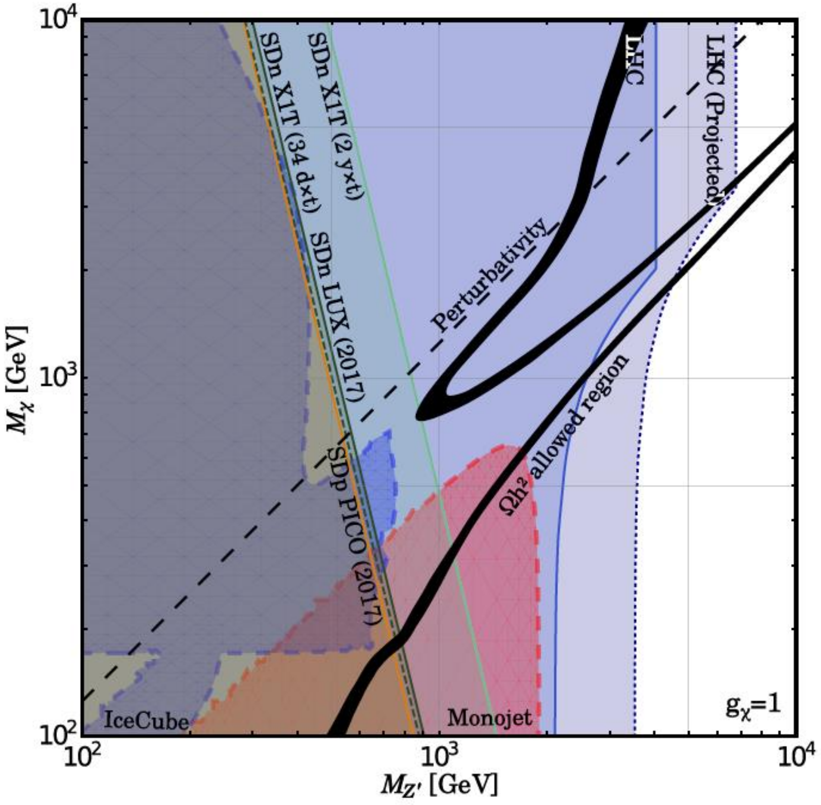
$$\langle \sigma v \rangle \approx \frac{\lambda_f^2 \lambda_\chi^2 m_\chi^2}{(4m_\chi^2 - m_{\text{med}}^2)^2}(a + b v_{\text{now}}^2)$$

$$v_{\text{now}} \sim 10^{-3}$$

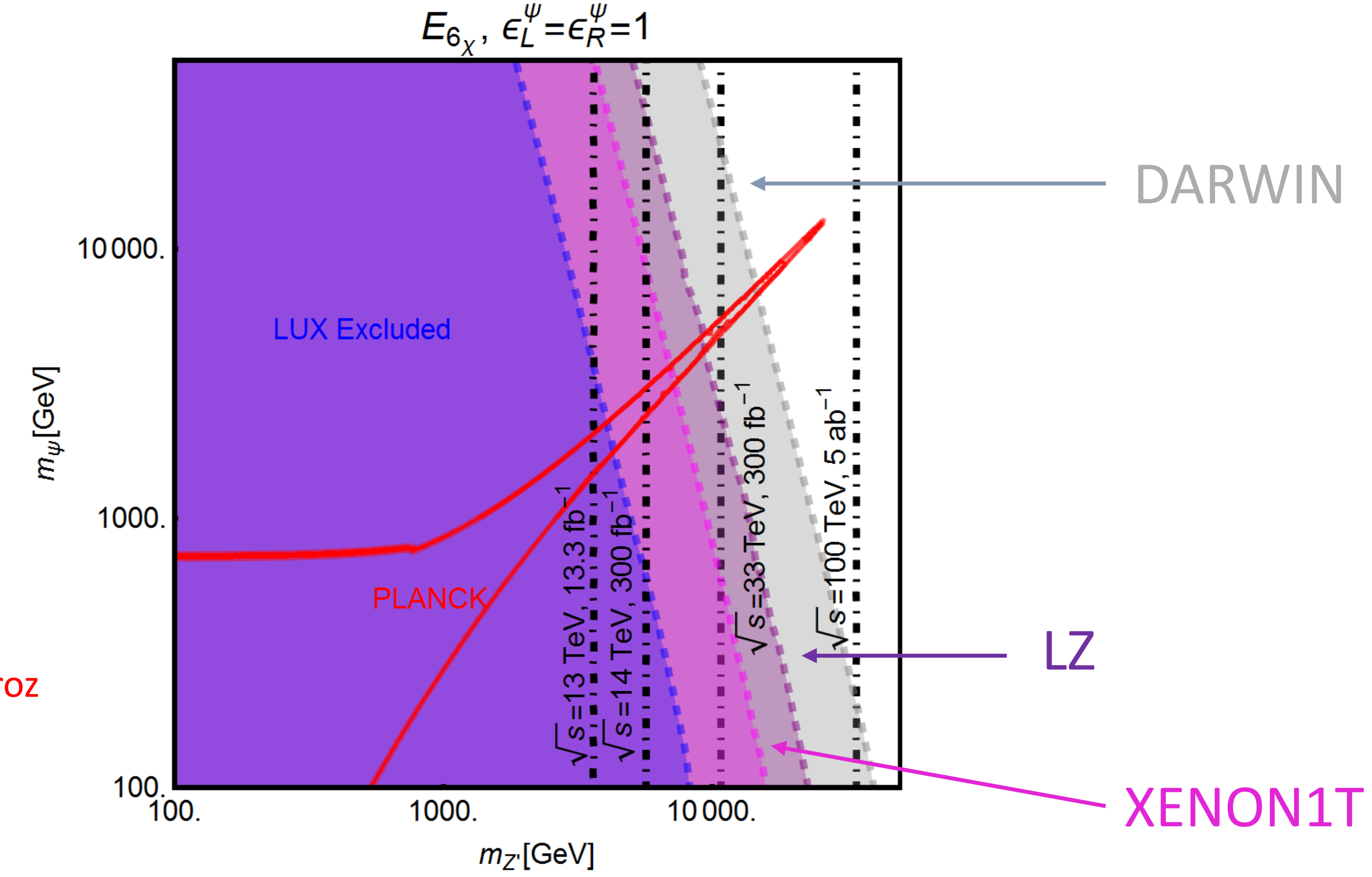
Extensive reviews in:

G.A., M. Dutra, P. Ghosh, M. Lindner, Y. Mambrini, M. Pierre, S. Profumo, F. Queiroz Eur. Phys. J. C78 (2018) 203

G.A., A. Djouadi, M. Raidal arXiv:1903.03616



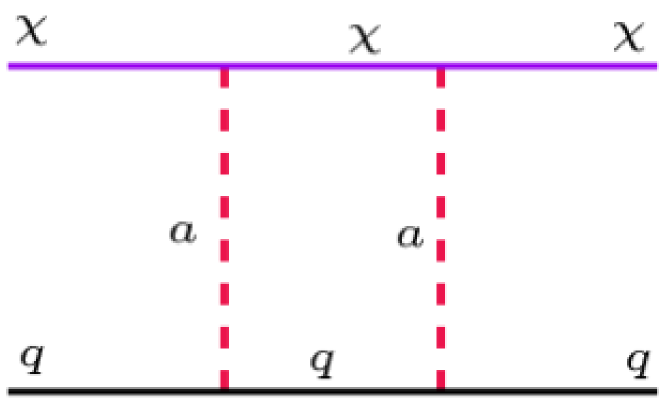
G.A., M. Campos, M. Lindner, A. Masiero, F. S. Queiroz
Phys. Rev. D97 (2018) 043009



G.A., M. Lindner, Y. Mambrini, M. Pierre, F. S. Queiroz
Phys. Lett. B771 (2017) 508

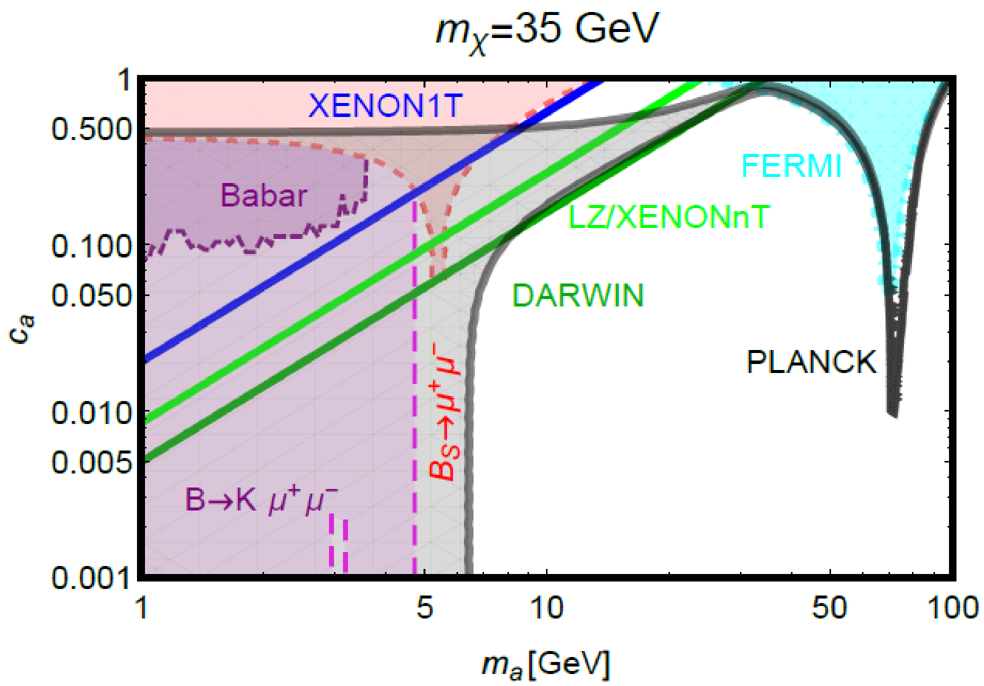
WIMP at the Neutrino Floor

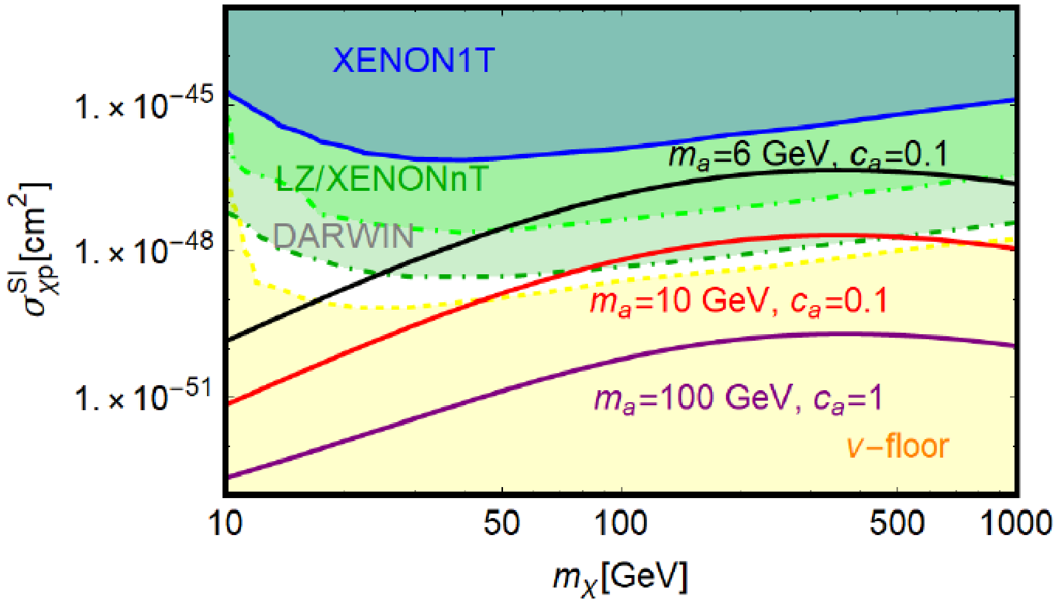
$$\mathcal{L} = g_\chi \bar{\chi}\gamma_5 \chi a + c_a \frac{m_q}{v_h}\bar{q}\gamma_5 q a$$



Unsuppressed (s-wave) annihilation cross-section into SM fermions

SI cross-section induced at the loop level





G.A., M. Lindner, F. Queiroz, W. Rodejohann, S. Vogl, JCAP 1803 (2018) 042

DM and Leptogenesis in Low Energy See-Saw

Inverse See-Saw

$$-\mathcal{L} = \frac{1}{2} n_L^T C M n_L + \text{h.c.} \longrightarrow n_L \equiv \left(\nu_{L,\alpha}, \nu^c_{R,i}, s_j\right)^T.$$

$$M \equiv \begin{pmatrix} 0 & d & 0 \\ d^T & m & n \\ 0 & n^T & \mu \end{pmatrix} \longrightarrow$$

3 light active states with masses of the form $m_\nu \approx \mathcal{O}(\mu) \frac{k^2}{1+k^2}$, $k \simeq \frac{\mathcal{O}(d)}{\mathcal{O}(n)}$

$\#s - \#\nu_R$ light sterile states (present only if $\#s > \#\nu_R$) with masses $\mathcal{O}(\mu)$

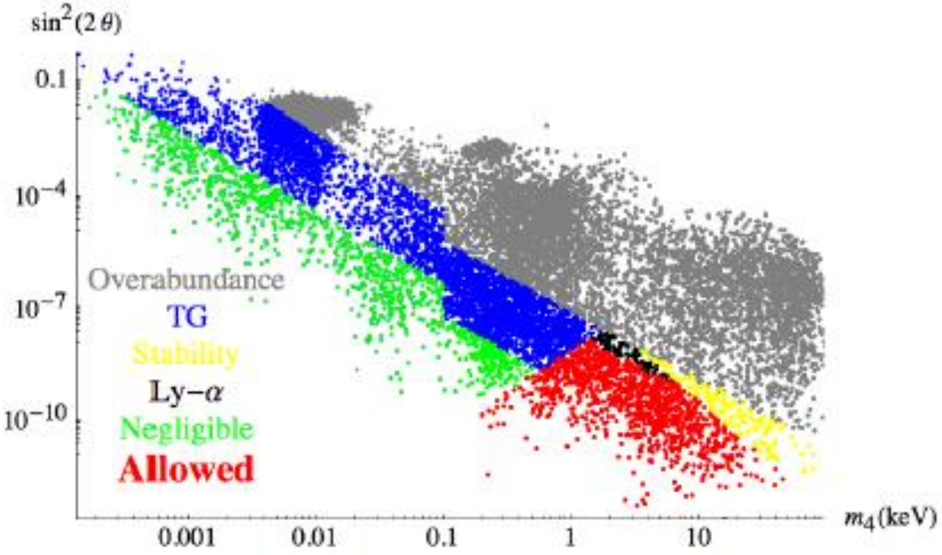
$\#\nu_R$ pairs of pseudo-Dirac heavy neutrinos with masses $\mathcal{O}(n) + \mathcal{O}(d)$

$$Y_{\alpha i} \overline{\ell^\alpha_L} \widetilde{H} \nu^i_R + \text{h.c.}$$

$$\mu \simeq 1 \text{ keV} \left(\frac{\langle \Sigma \rangle}{100 \text{ GeV}}\right) \left(\frac{h_{\alpha\alpha}}{10^{-8}}\right)$$

$$\mathcal{L} = \frac{1}{2}\partial_\mu \Sigma \partial^\mu \Sigma - \frac{h_{\alpha\alpha}}{2} \Sigma \overline{s^c}_\alpha s_\alpha + V(H, \Sigma)$$

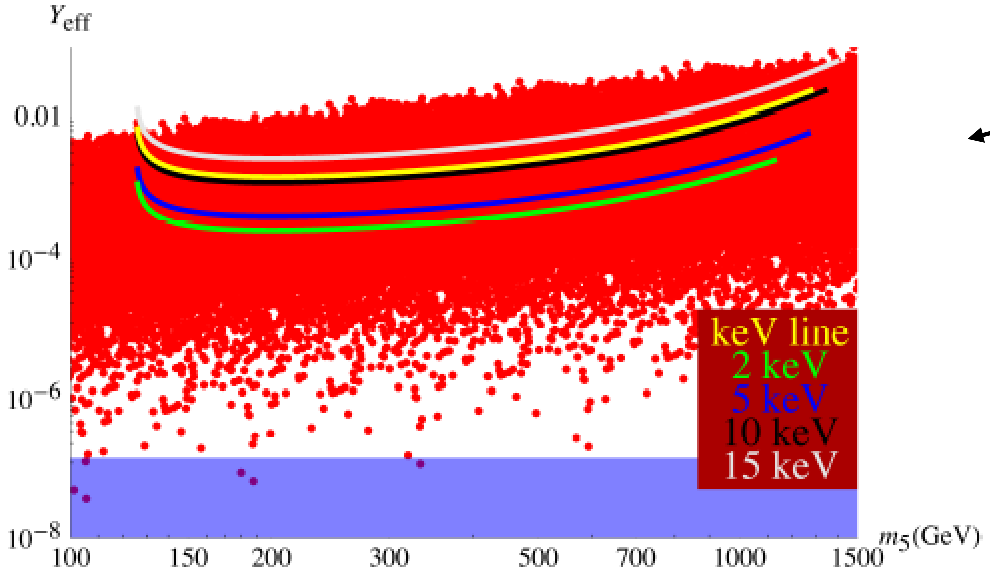
$$V(H,\Sigma) = -\mu_H^2 |H|^2 - \frac{1}{2}\mu_\Sigma^2 \Sigma^2 + 2\lambda_{H\Sigma} |H|^2 \Sigma^2$$



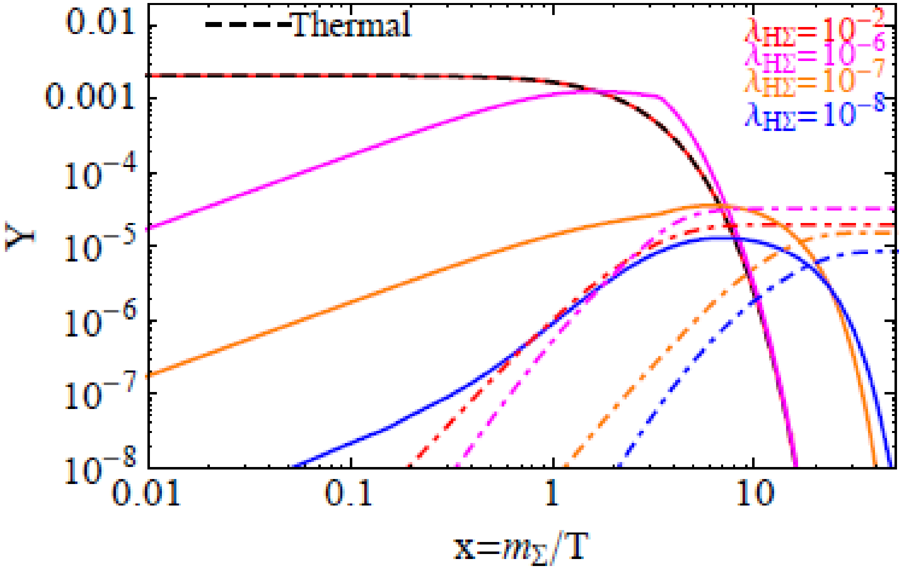
A. Abada, G.A., M. Lucente; JCAP 1410 (2014) 001

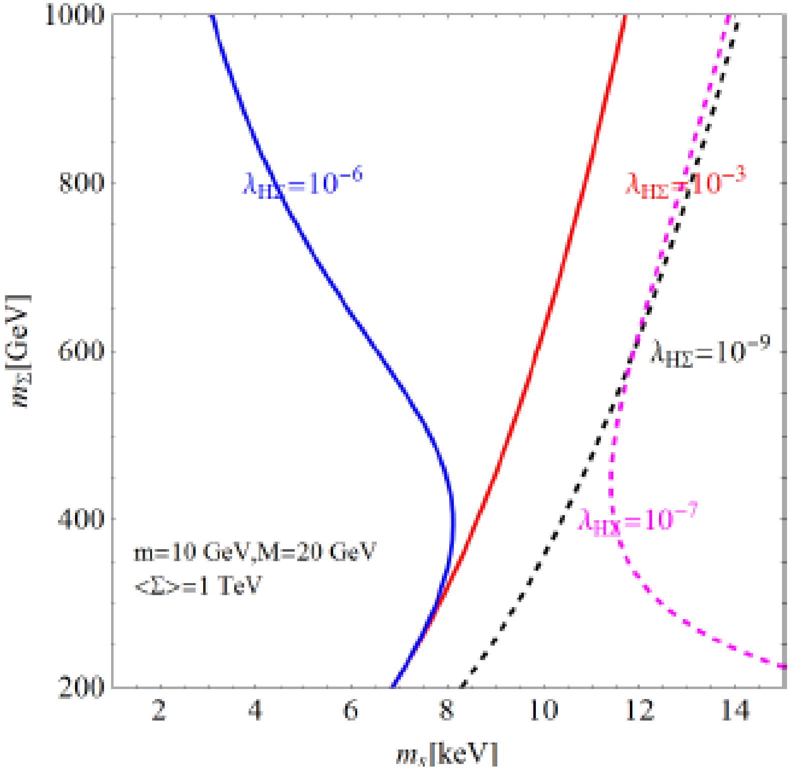
Freeze-in from

$$\Gamma\left(N_I \to h \ + \ \mathrm{DM}\right)$$



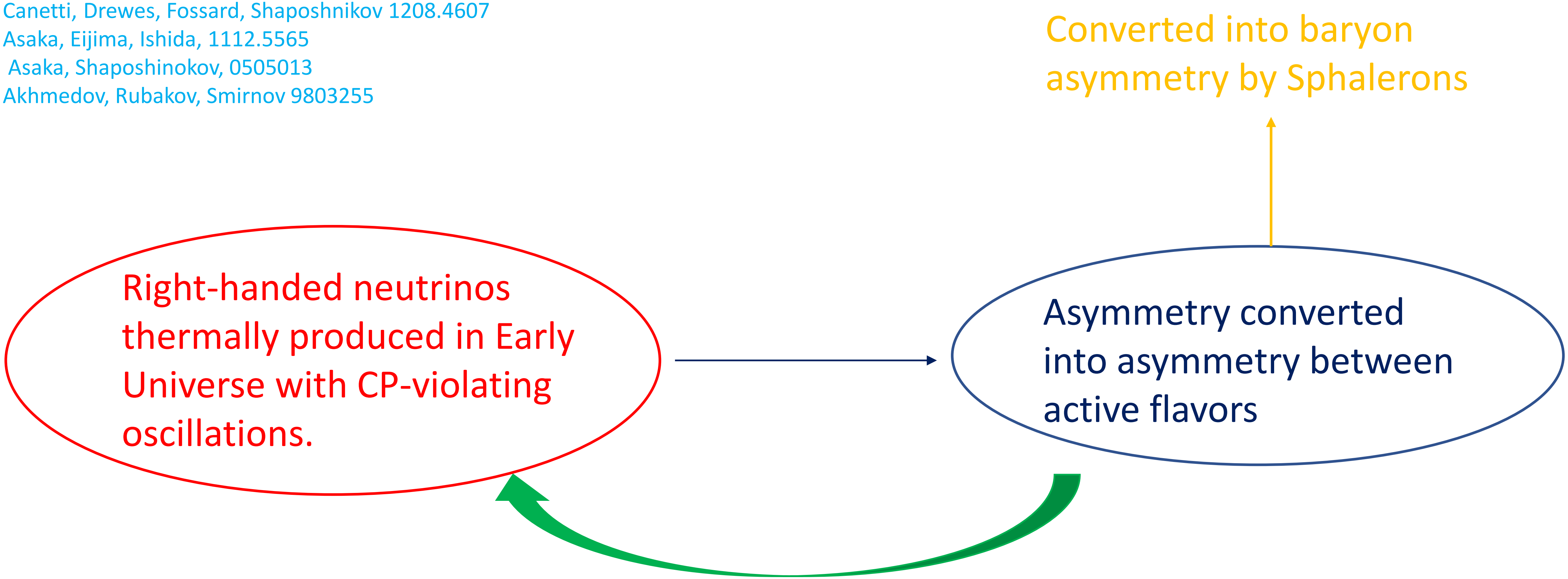
Adding production from the scalar field





ARS Leptogenesis

Hernandez, Kekic, Lopez-Pavon, Racker, Salvado 1606.06719
Canetti, Drewes, Fossard, Shaposhnikov 1208.4607
Asaka, Eijima, Ishida, 1112.5565
Asaka, Shaposhinokov, 0505013
Akhmedov, Rubakov, Smirnov 9803255

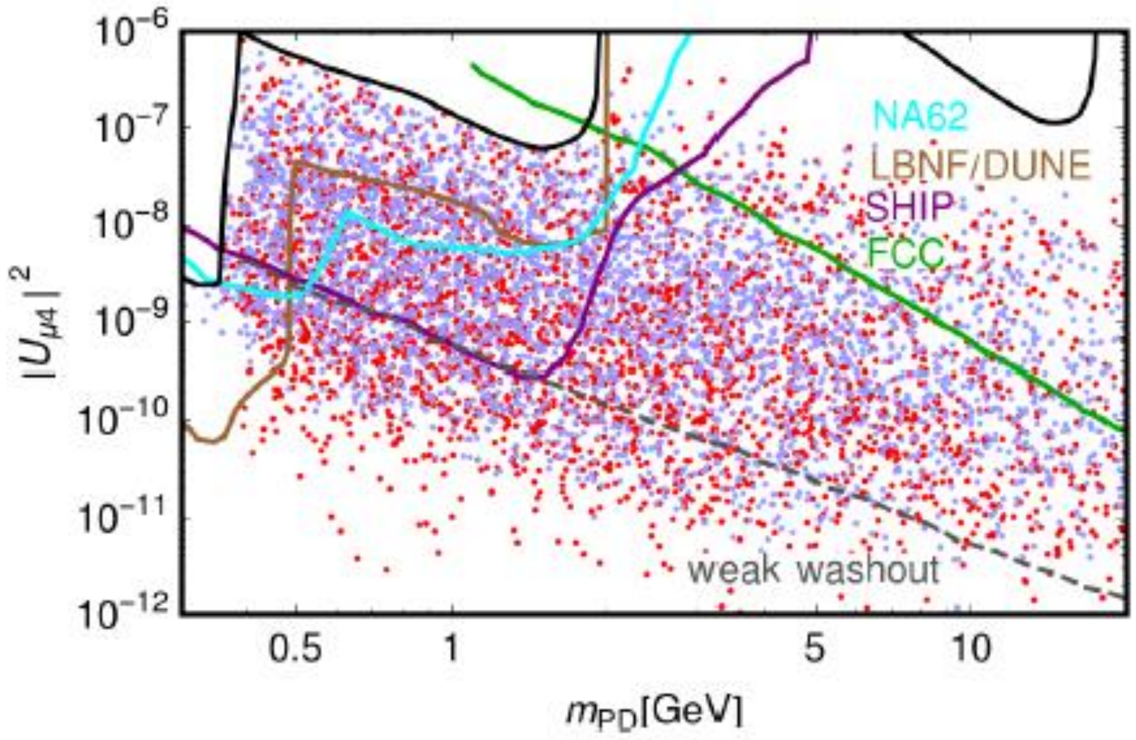


Asymmetry in the active sector acts as background potential and enhances the asymmetry in the RH sector

The total lepton asymmetry in the active and new neutrino sector is null.

Minimal version of ARS leptogenesis requires a pair of nearly mass degenerate neutrinos.

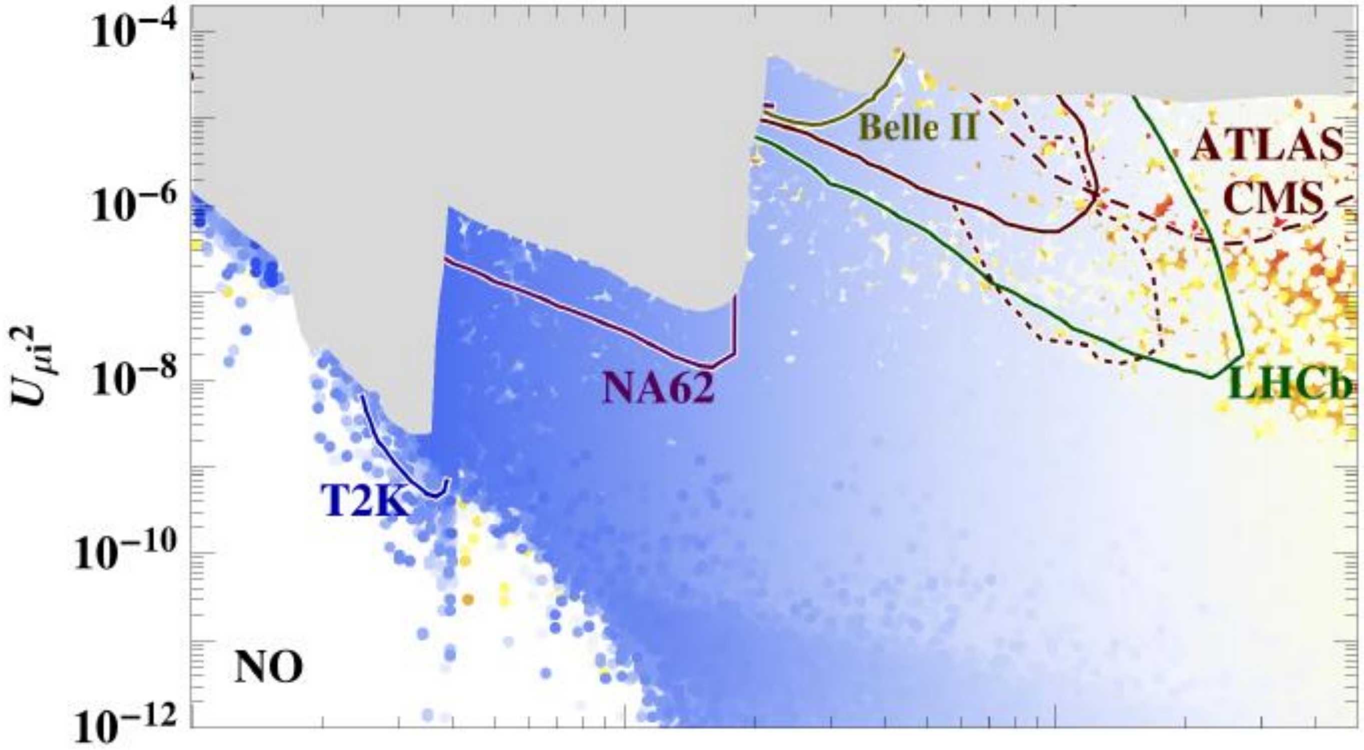
ARS requires GeV (O(10) at most) scale neutrinos. Low energy neutrino mass mechanism required.



A. Abada, G.A., V. Domcke, M. Lucente JCAP 1712 (2017) 024

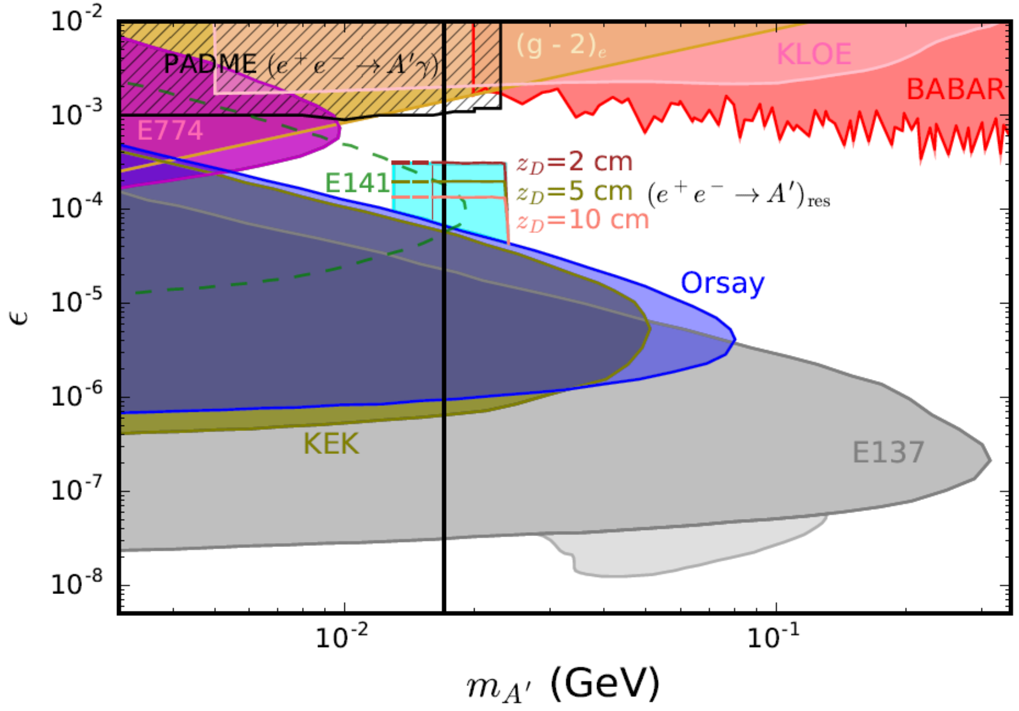
Degeneracy removed for leptogenesis from 3 (or more) neutrinos.

Additional LNV processes might be relevant.



A. Abada, G.A, V. Domcke, M. Drewes, J. Klaric, M. Lucente JHEP 1901 (2019) 164

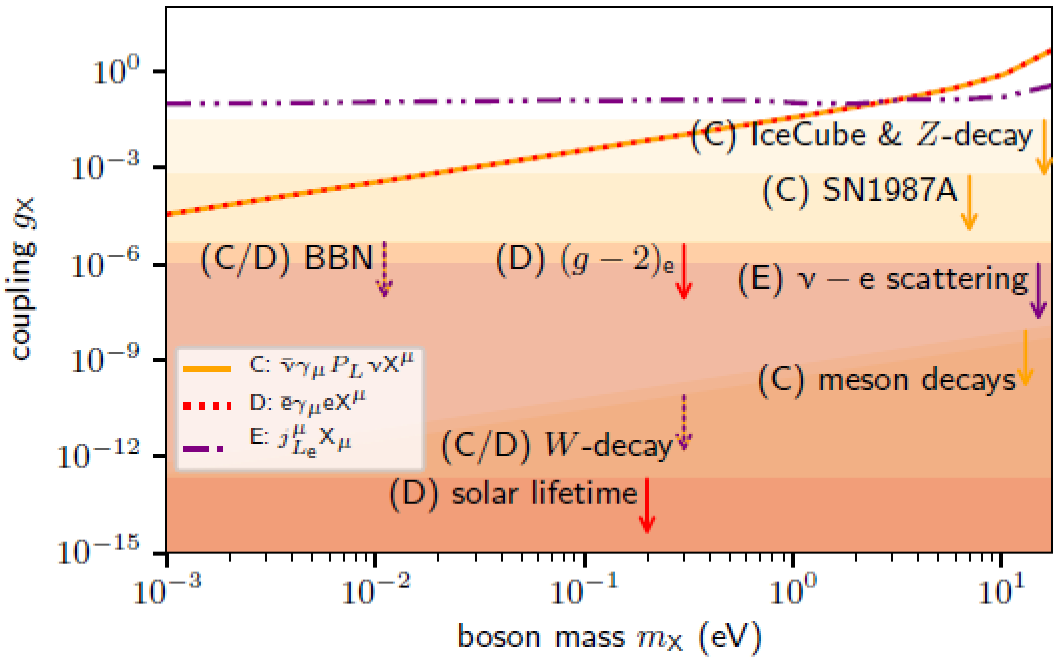
Searches of Dark Photons electron-positron annihilations (PADME)



E. Nardi, J. Carvajal, A. Ghoshal, D. Meloni, M. Raggi
Phys. Rev. D97 (2018) 095004

New Physics in Tritium decay (KATRIN Experiment)

$$^3\mathrm{H} \to {}^3\mathrm{He}^+ + e^- + \bar{\nu}_e + X$$

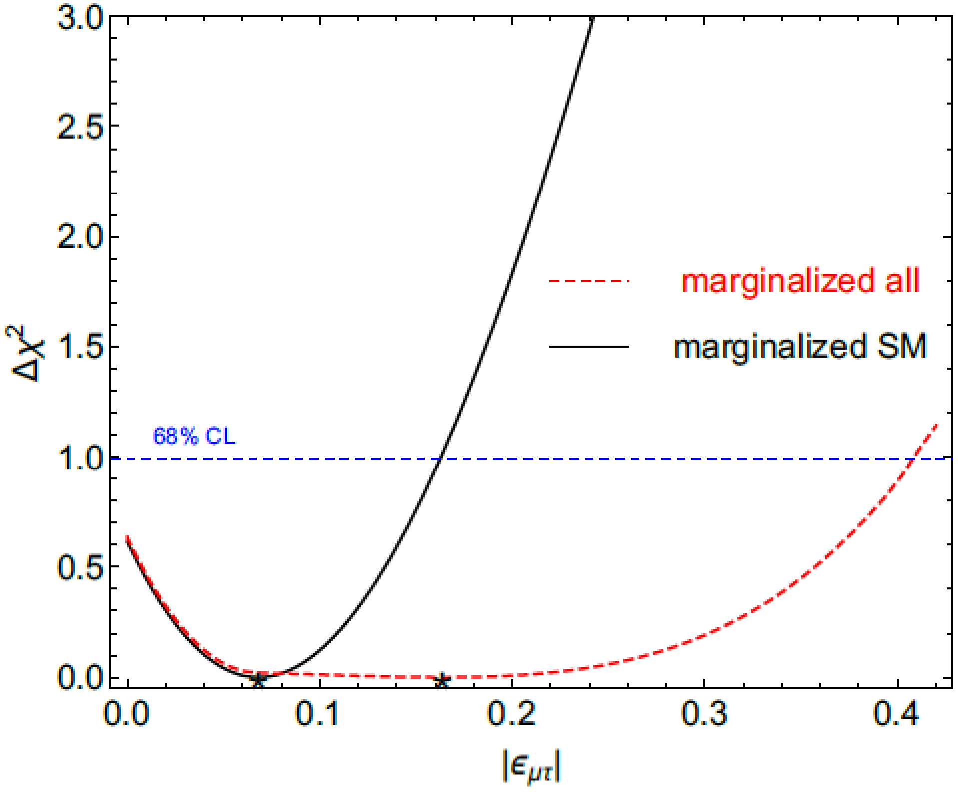


G.A., J. Heeck, F. Heizmann, S. Mertens, F. Queiroz, W. Rodejohann, M. Slezak, JHEP 1901 (2019) 206

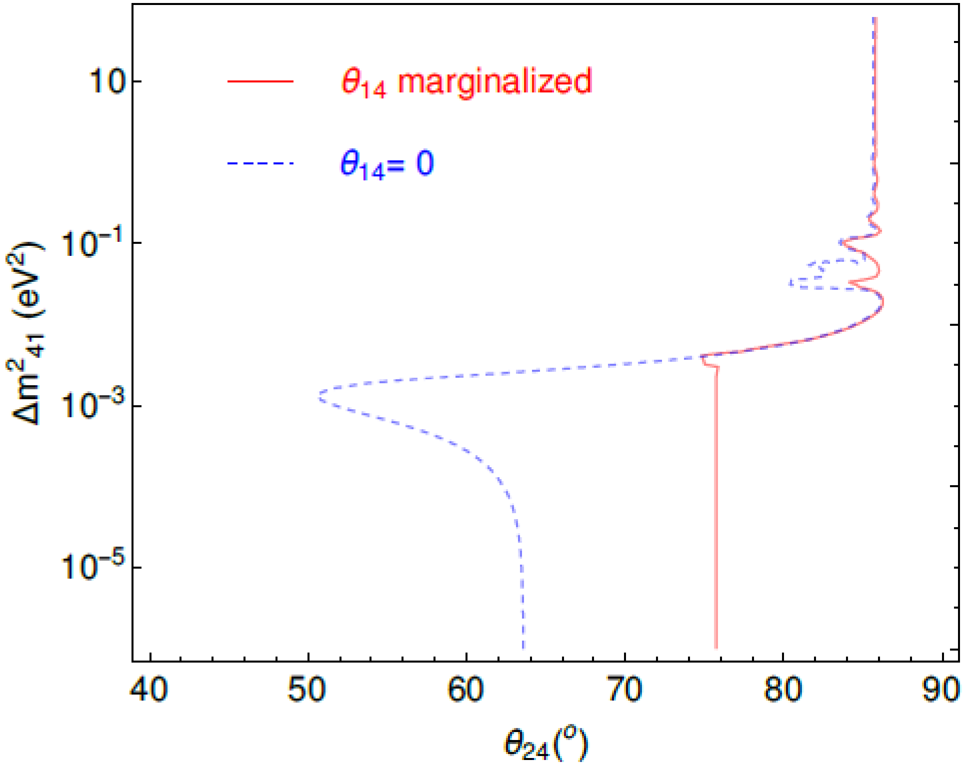
Searches of NP in ν_τ oscillations in OPERA

NSI

$$\mathcal{L}_{\rm NSI} = -\frac{G_F}{\sqrt{2}} \sum_{\substack{f=u,d,e \\ a=\pm 1}} \varepsilon^{fa}_{\alpha\beta} [\overline{f}\gamma^\mu (1 + a\gamma^5) f][\overline{\nu_\alpha}\gamma_\mu (1-\gamma^5)\nu_\beta]$$

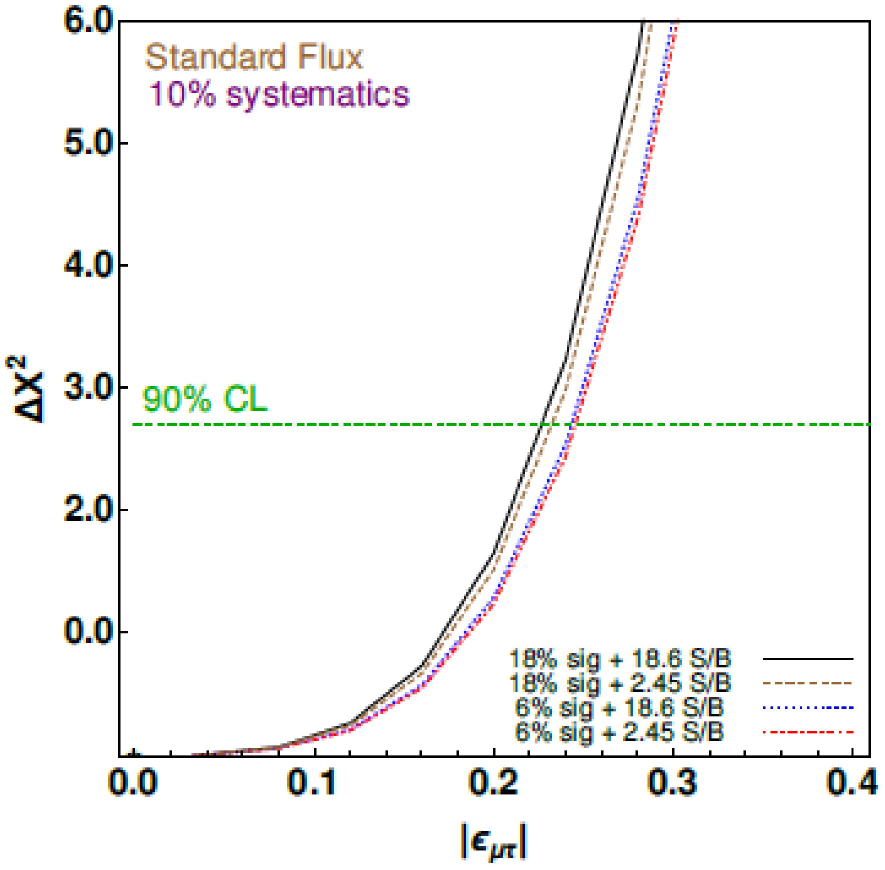


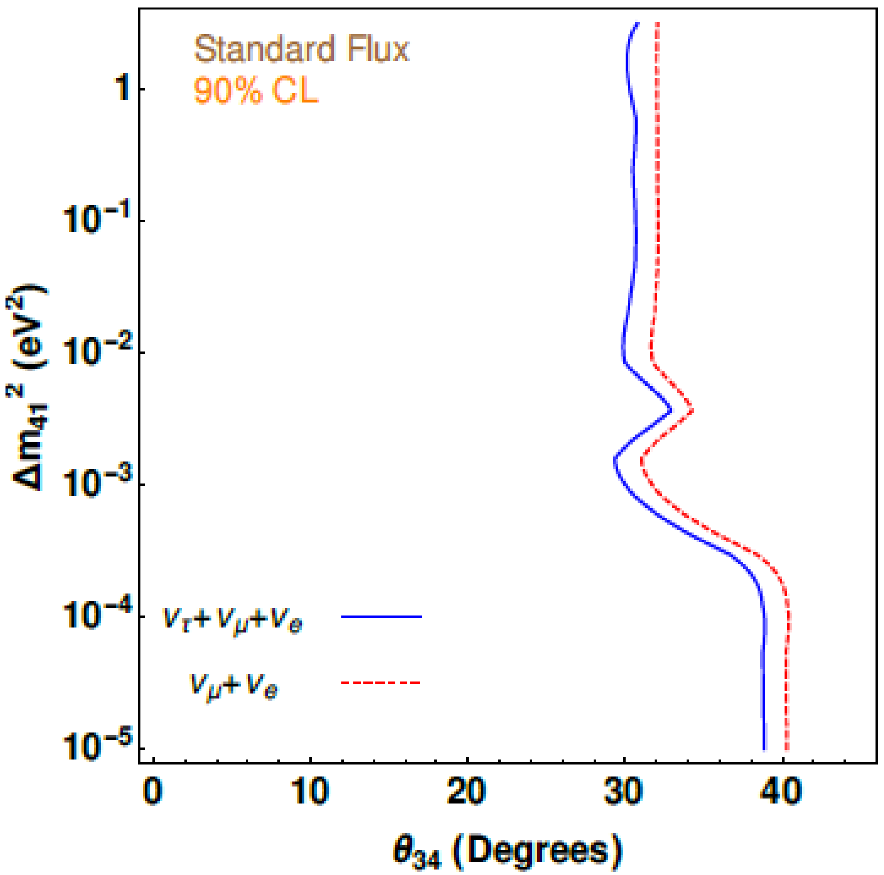
Extra sterile neutrino



D. Meloni Phys. Lett. B792 (2019) 199

Prospects for DUNE





A. Ghoshal, A. Giarnetti, D. Meloni, arXiv:1906.06212