Mapping the viable parameter space for testable leptogenesis

Yannis Georis
based on work in collaboration with M. Drewes and J. Klaric
[arXiv:2106.16226]

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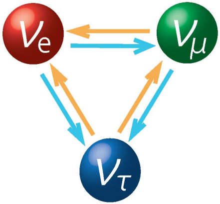
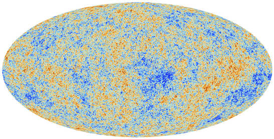
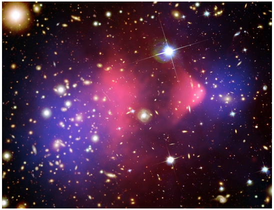
UCLouvain





[Planck]

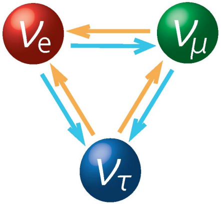


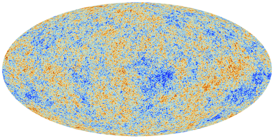
[Chandra]

Neutrino masses

Baryogenesis

Dark matter





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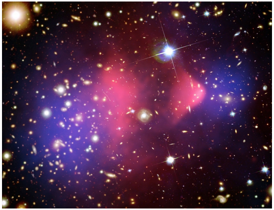

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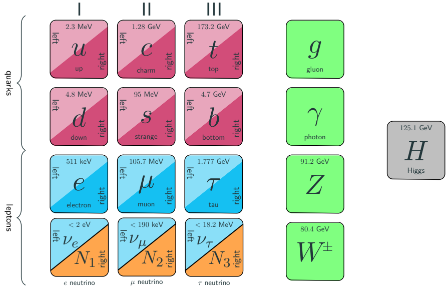
Neutrino masses **Baryogenesis** **Dark matter**

$\longrightarrow$ **Introducing new particles can solve these problems.**

Heavy neutral lepton (HNLs)

Heavy neutrinos can solve three problems at once:



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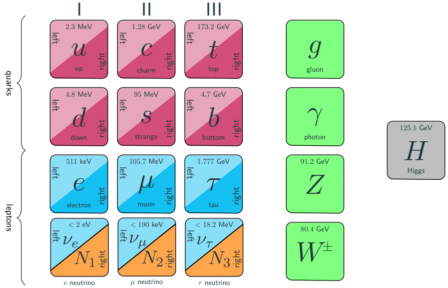

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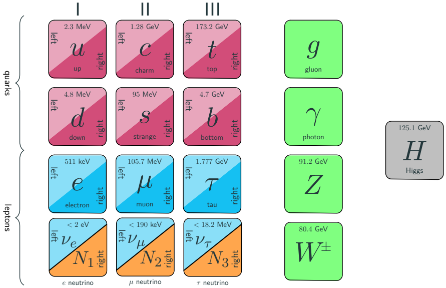

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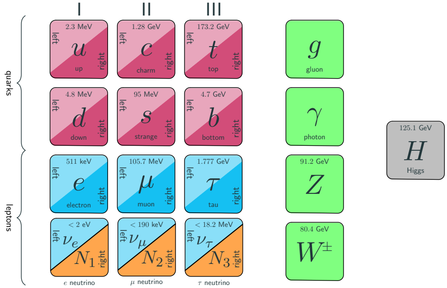
- Can be a **Dark Matter** candidate (Dodelson/Widrow, hep-ph/9303287, Asaka/Shaposhnikov, hep-ph/0505013)



Seesaw type-I

- Seesaw Lagrangian

$$\mathcal{L} \supset F_{ai}(\bar{\ell}_a \tilde{\phi})\nu_{Ri} + \frac{1}{2}\bar{\nu}^c_{Ri}(M_M)_{ij}\nu_{Rj} + \text{h.c.}$$

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Dirac **Majorana**

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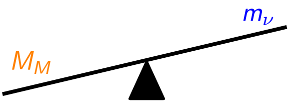
$$m_\nu = -v^2 F \cdot M_M{}^{-1} \cdot F^t.$$



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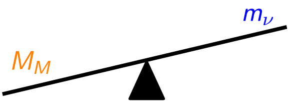

- Interaction strength of the heavy neutrinos

$$U^2 = v^2 \sum_{a,i} |(F \cdot M_M^{-1})_{ai}|^2 \equiv \sum_{a,i} |\theta_{ai}|^2.$$

Thermal leptogenesis

Sakharov conditions:

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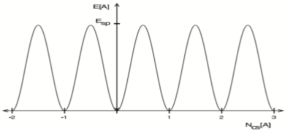

[M-C. Chen, hep-ph/0703087]

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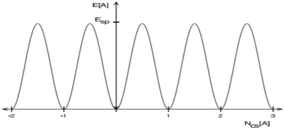

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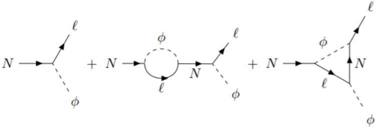

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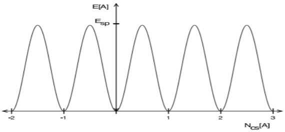

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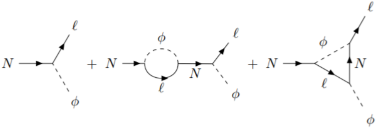
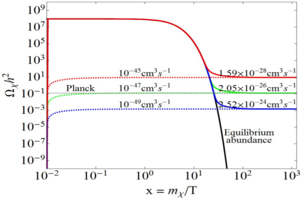


- Deviation from thermal equilibrium
  - ⋆ **HNLs freeze-out** ✓



[Dev/Mazumdar/Qutub, 1311.5297]

Low-scale leptogenesis

- Davidson-Ibarra bound: $M_N \gtrsim 10^9$ GeV if mass hierarchy ($M_1 \ll M_2 \ll M_3$).

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$\hookrightarrow$ Two regimes of the same mechanism ! Represented by the same set of equations. (cfr. B.Garbrecht 1812.02651)

Quantum kinetic equations

$$i\frac{\mathrm{d}\rho}{\mathrm{d}t} = [H, \delta\rho] - \frac{i}{2}\{\Gamma, \delta\rho\} - i \sum_{a\in\{e,\mu,\tau\}} \tilde{\Gamma}_a \frac{\mu_a}{T} f_F(1 - f_F),$$

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Density matrix/**Matter-antimatter asymmetry**/
Effective Hamiltonian/**Interaction rates**

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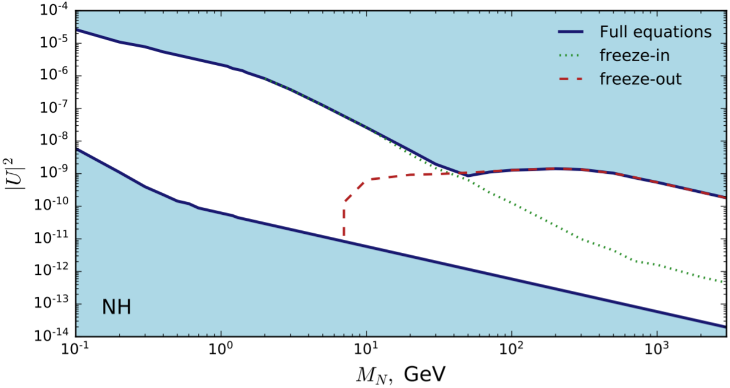
- Mass range from 50 MeV to 70 TeV.

n=2 leptogenesis



(Klaric/Shaposhnikov/Timirsyasov 2008.13771)

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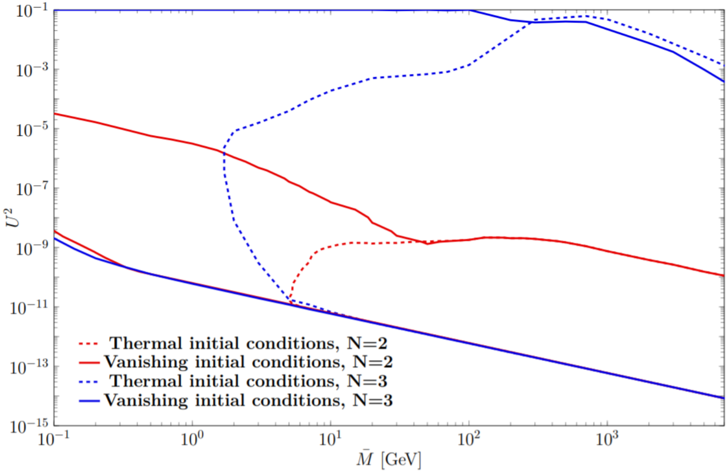
2. Seesaw expansion $U^2 < 0.1$
3. No large radiative corrections $(1 - ||\frac{m_{tree}}{m_{loop}}||)^2 < \frac{1}{4}$.

Comparing $n = 2$ and $n = 3$.



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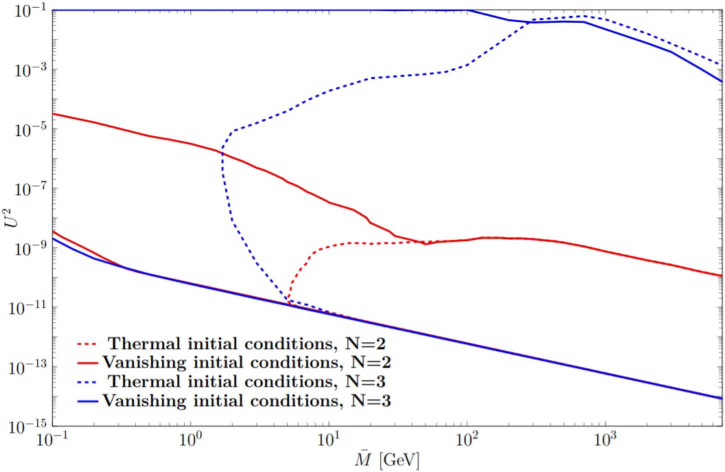

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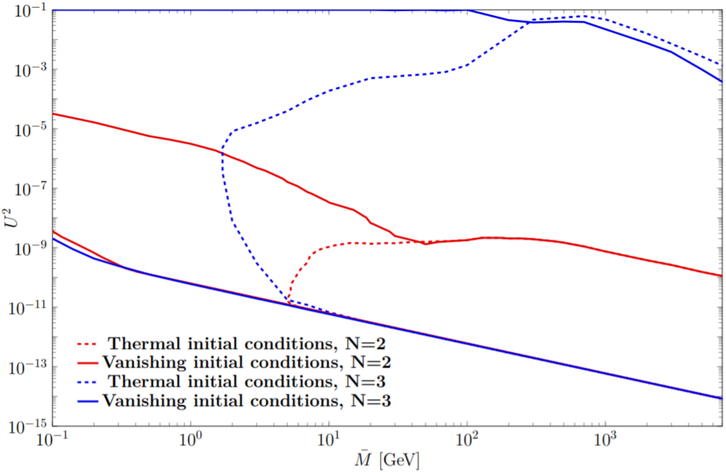

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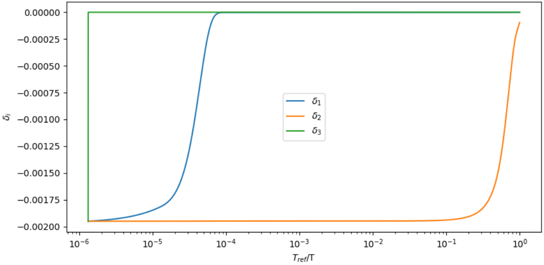
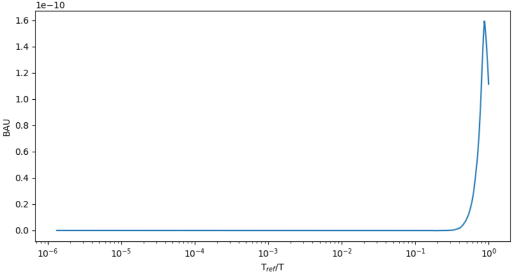
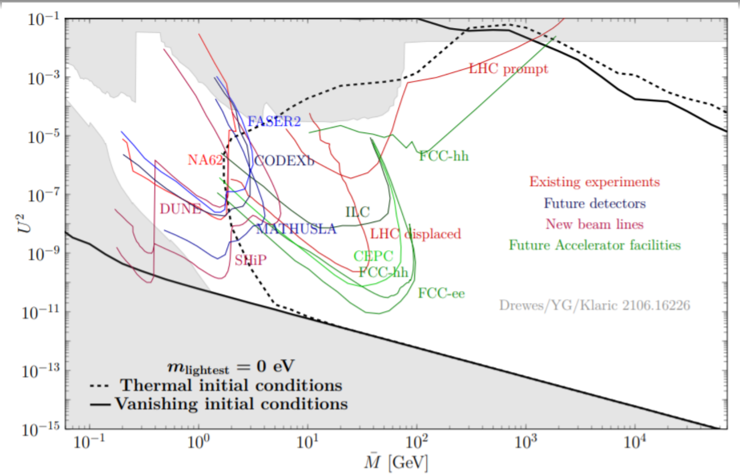
- Reaches theoretical constraint at low masses.

Late equilibration





Comparison to experimental sensitivities



- Experiments will cut deep into $n = 3$ parameter space.
- Can expect to produce thousands of displaced vertices at HL-LHC: Testability !
- Resonant leptogenesis working for masses as low as $\mathcal{O}(1.7)$ GeV: testable at *e.g.* NA62.

Take home message

Conclusion

- Leptogenesis under the TeV-scale is a viable solution, even for strongly coupled heavy neutrinos.

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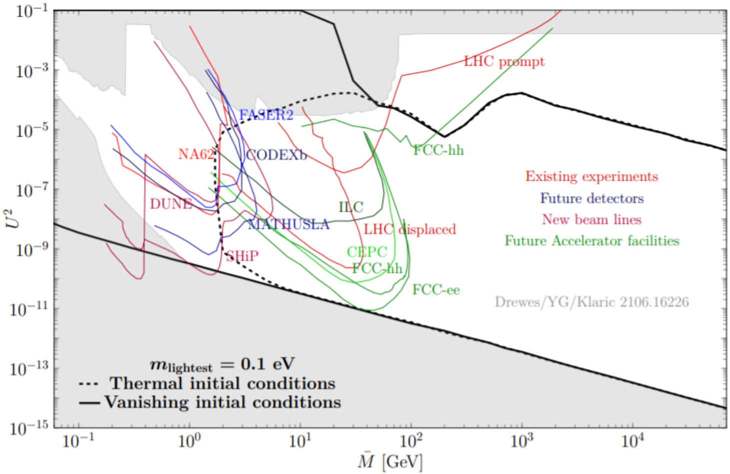
- Parameter space much larger than for the $n = 2$ scenario. No upper bound from leptogenesis in the low mass range.

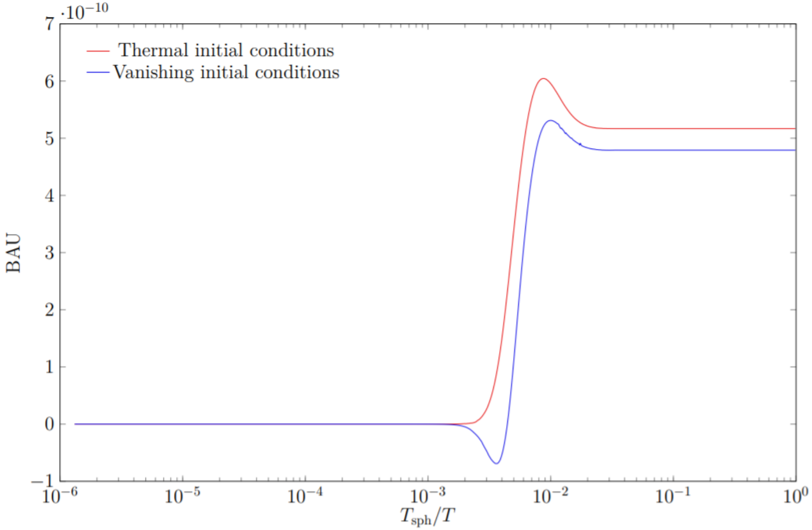
- Leptogenesis with thermal initial conditions is possible for masses as low as 1.7 GeV.

Backup slides



- Parameter space smaller for $m_{\text{lightest}} = 0.1$ eV.

Thermal vs vanishing initial conditions



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$$U_i^2 \sim \frac{\sqrt{\Delta m_{atm}^2 + m_{light}^2}}{M} \lesssim 10^{-10}\frac{\text{GeV}}{M_i}$$

B-L approximate symmetry

Majorana mass

$$\bar{M} \cdot \begin{pmatrix} 1-\mu & 0 & 0 \\ 0 & 1+\mu & 0 \\ 0 & 0 & \mu' \end{pmatrix}$$

Yukawa coupling

$$\begin{pmatrix} f_e(1+\epsilon_e) & if_e(1-\epsilon_e) & f_e\epsilon_e' \\ f_\mu(1+\epsilon_\mu) & if_\mu(1-\epsilon_\mu) & f_\mu\epsilon_\mu' \\ f_\tau(1+\epsilon_\tau) & if_\tau(1-\epsilon_\tau) & f_\tau\epsilon_\tau' \end{pmatrix}$$

for $\mu, \epsilon, \epsilon' \ll 1$.