ν Electroweak Baryogenesis

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Based on: E. Fernández-Martínez, J. López-Pavón, T. Ota and S. Rosauro-Alcaraz, JHEP 10 (2020) 063

Matter-antimatter asymmetry

$$Y_B \equiv \frac{n_b - \bar{n}_b}{s} \simeq (8.59 \pm 0.08) \times 10^{-11}$$

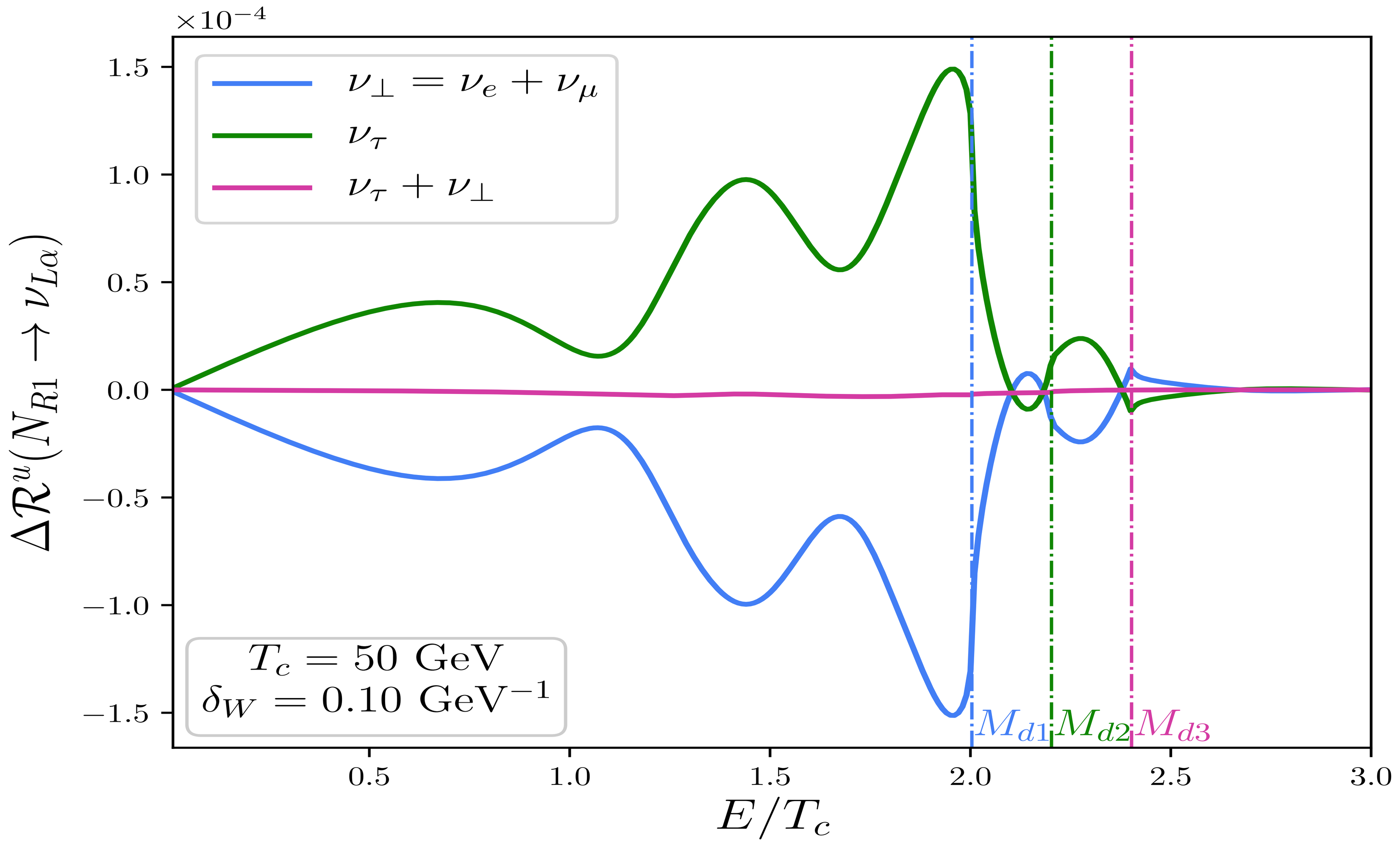
Sakharov conditions to generate the BAU [1] → C and CP violation, B violation, out-of-equilibrium conditions.

Not enough CP in the SM or a strong 1^{st} order phase transition

Need for BSM Physics

CP asymmetries and diffusion

Interactions with the bubble wall produce an imbalance of particles over antiparticles if there is CP violation. There is a strong **GIM cancellation** when summing over flavours the reflection and transmission rates



If the rate for **Yukawa interactions** [3] which naturally depend on flavour is **faster** than the **sphaleron** rate, then we need to follow the diffusion of the individual flavoured asymmetries

$$\Gamma_{N_i \nu_{L\alpha}}/T \sim 0.0048\,|\theta_{\alpha i}|^2 M_i^2/v_H^2 > \Gamma_S/T \propto \alpha_W^5 \quad \text{for} \quad M_i \gtrsim 200 \text{ GeV}$$

References

[1] A. D. Sakharov, Violation of CP Invariance, C asymmetry, and baryon asymmetry of the universe, Pisma Zh. Eksp. Teor. Fiz. 5 (1967) 32–35. [2] V. Andreev, D. Ang, D. DeMille, J. Doyle, G. Gabrielse, J. Haefner et al., Improved limit on the electric dipole moment of the electron, Nature 562 (10, 2018) 355–360. [3] M. Joyce, T. Prokopec and N. Turok, Nonlocal electroweak baryogenesis. Part 1: Thin wall regime, Phys. Rev. D53 (1996) 2930–2957 [arXiv:hep-ph/9410281]. [4] E. Fernandez-Martinez, J. Hernandez-Garcia and J. Lopez-Pavon, Global constraints on heavy neutrino mixing, JHEP 08 (2016) 033 [arXiv:1605.08774].

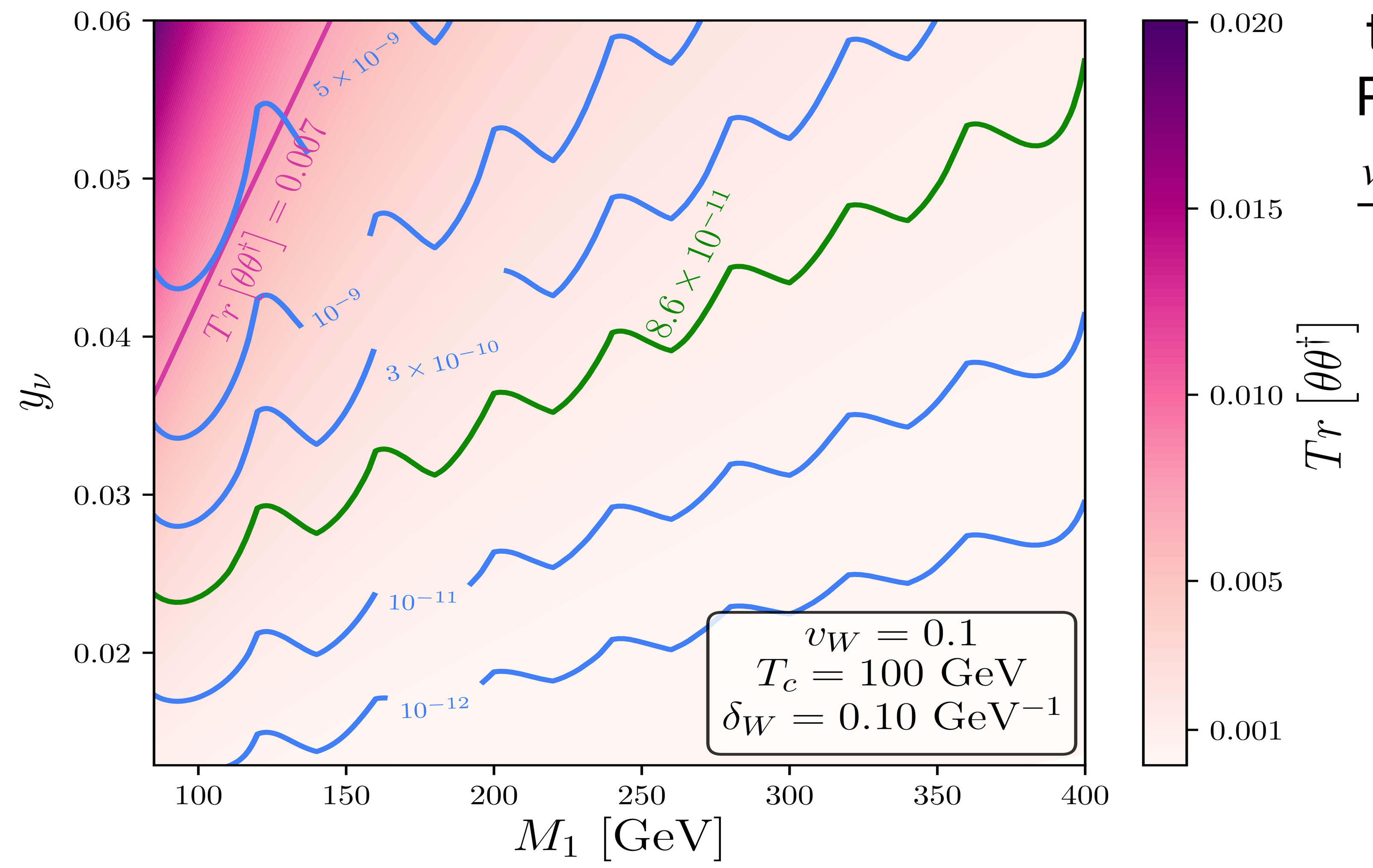
Ingredients for Electroweak Baryogenesis

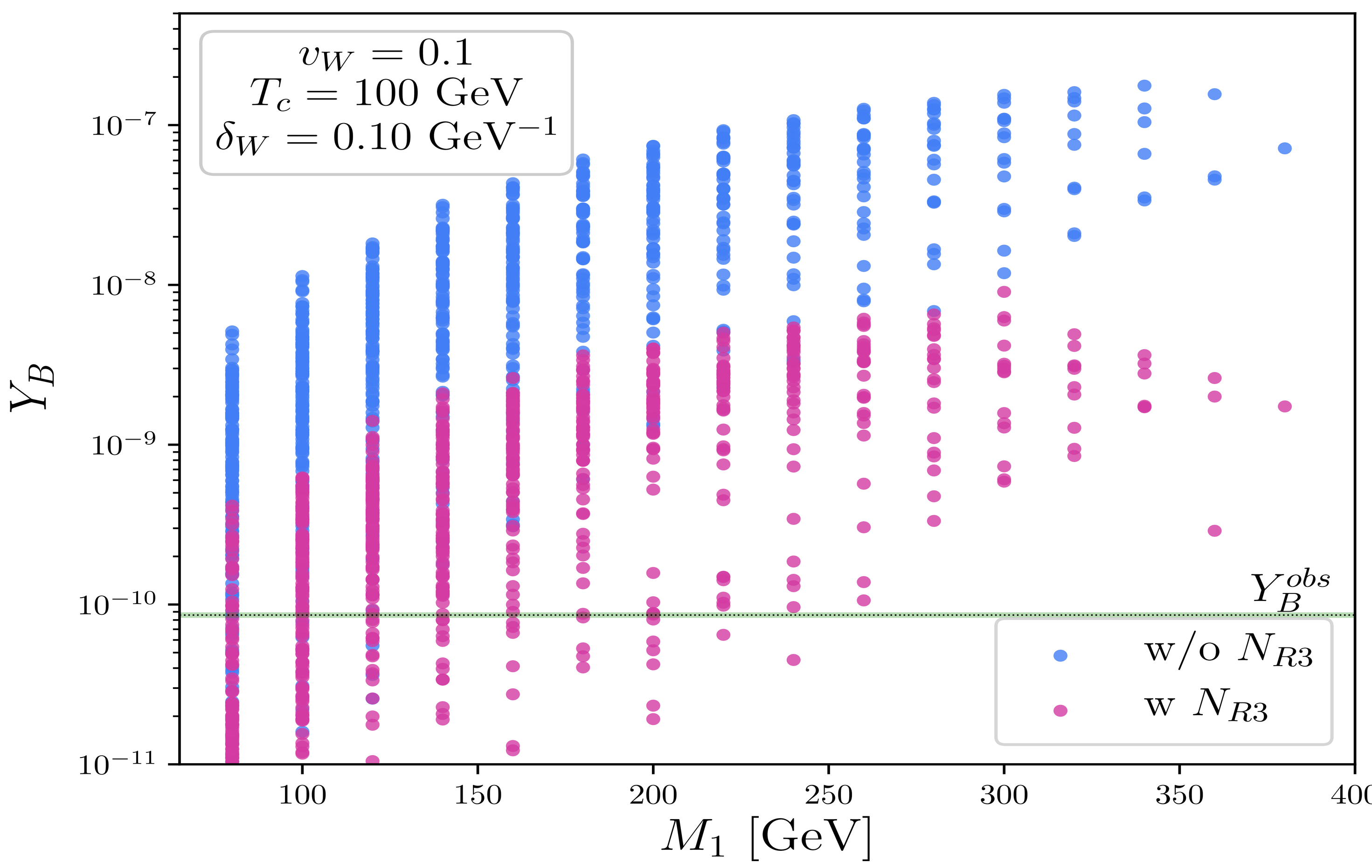
1. Include new scalars to trigger 1^{st} order phase transition
2. Add **new sources of CP violation** in a **dark sector** to avoid strong constraints from EDM [2]

Final baryon asymmetry

Explain the BAU while satisfying the bounds on θ [4].

In the upper panel we show contours of constant BAU as a function of the mass and Yukawa coupling.





CP violation from neutrinos?

$$\mathcal{L} \supset -\bar{L}_L Y_\nu \tilde{H} N_R - \bar{N}_L \phi Y_N N_R + h.c. - V(\phi^*\phi, H^\dagger H)$$

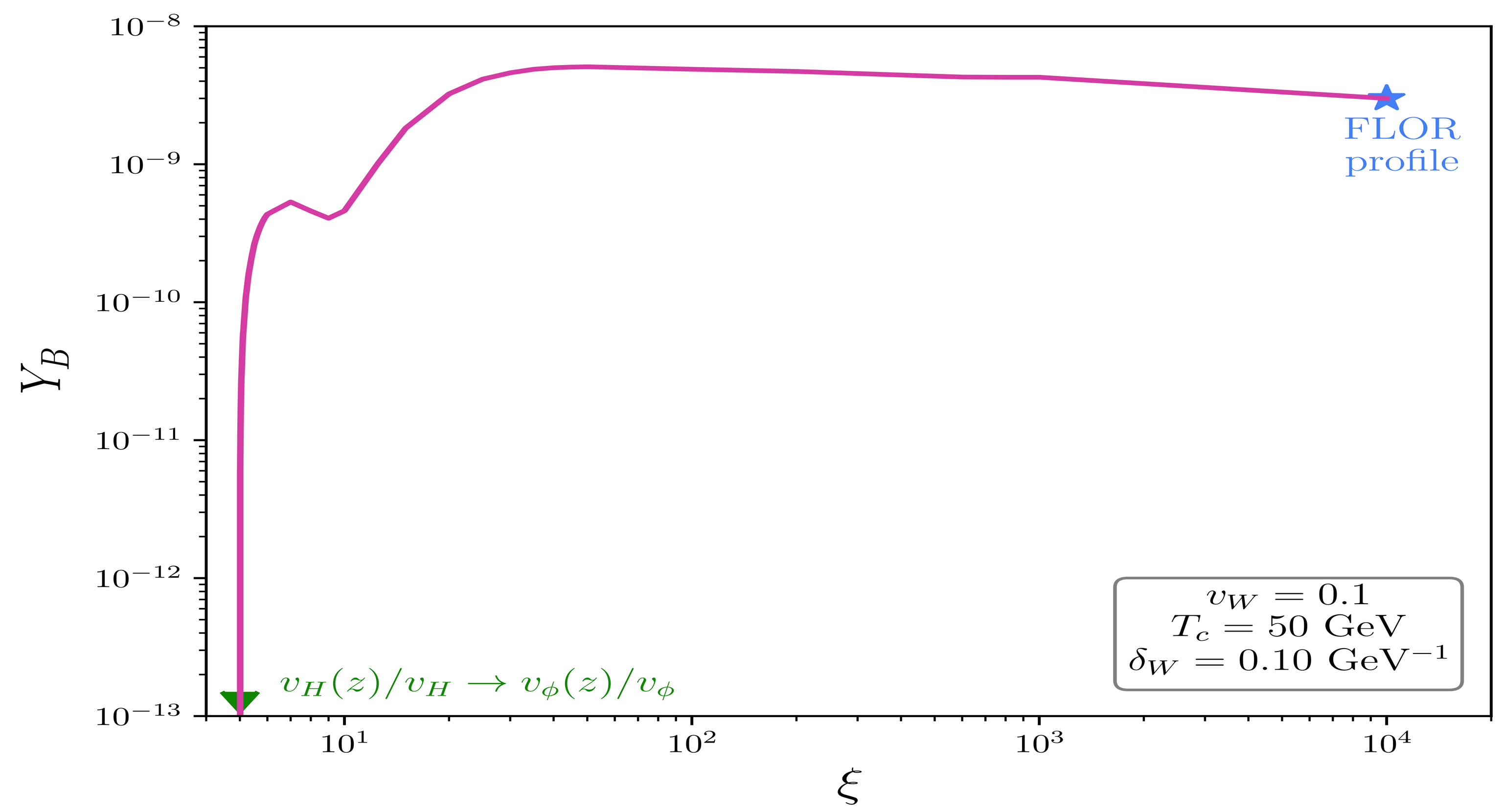
$$\delta_{CP} \propto (M_1^2 - M_2^2)(M_2^2 - M_3^2)(M_3^2 - M_1^2) Im[(\theta^\dagger\theta)_{12}(\theta^\dagger\theta)_{23}(\theta^\dagger\theta)_{31}]$$

In low-scale Seesaw mechanisms, the **mixing** $\theta = m_D M^{-1}$ can be **large**, where $m_D = v_H Y_\nu/\sqrt{2}$ and $M = v_\phi Y_N$, allowing for **potentially large CP violation**

Effect of the vev profiles

The vev of the scalars change along the bubble walls, and the functional dependence can impact the final asymmetry to the extent that if they are equal no BAU is generated. Parametrise the profiles as

$$\frac{v_H(z)}{v_H} = \frac{1}{2}\left[1 + \tanh\left(\xi \frac{z - (5/\xi)\,\delta_W/2}{\delta_W}\right)\right], \quad \frac{v_\phi(z)}{v_\phi} = \frac{1}{2}\left[1 + \tanh\left(5\frac{z - \delta_W/2}{\delta_W}\right)\right].$$



Conclusions

We studied the possibility to **explain the BAU in the context of electroweak baryogenesis** using the neutrino mass mechanism. In particular, **low-scale Seesaw scenarios allow to have all physics at the EW scale** in reach for colliders, and **large neutrino mixing θ is needed to generate the BAU**, such that future experiments could probe the entire parameter space.