Early Universe hypercharge breaking & neutrino mass generation

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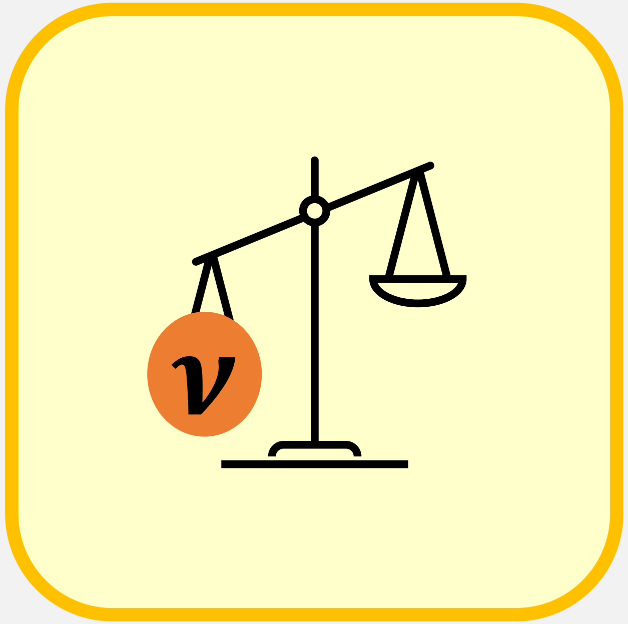
Based on arXiv:2308.09206 [hep-ph]

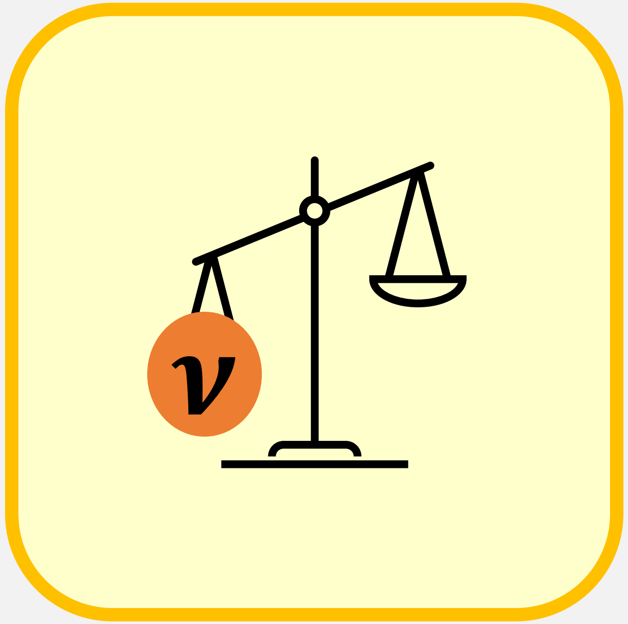
in collaboration with

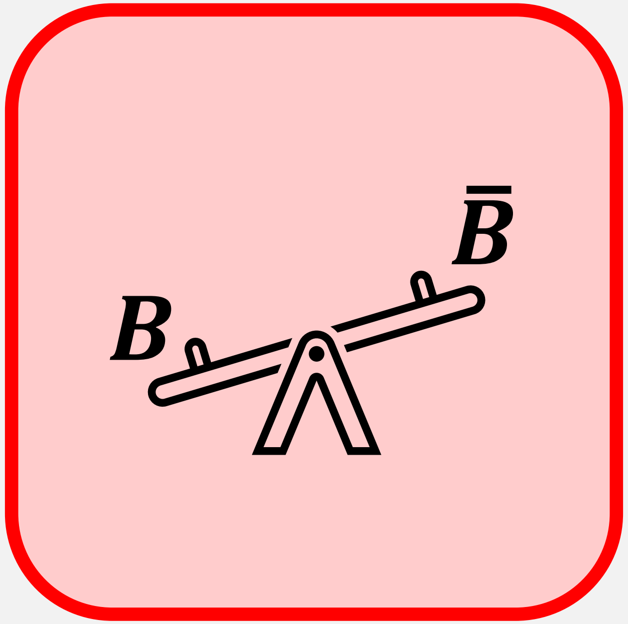
S. López Zurdo, L. Merlo, J. M. No

Invisibles23 Workshop, 29/08/2023

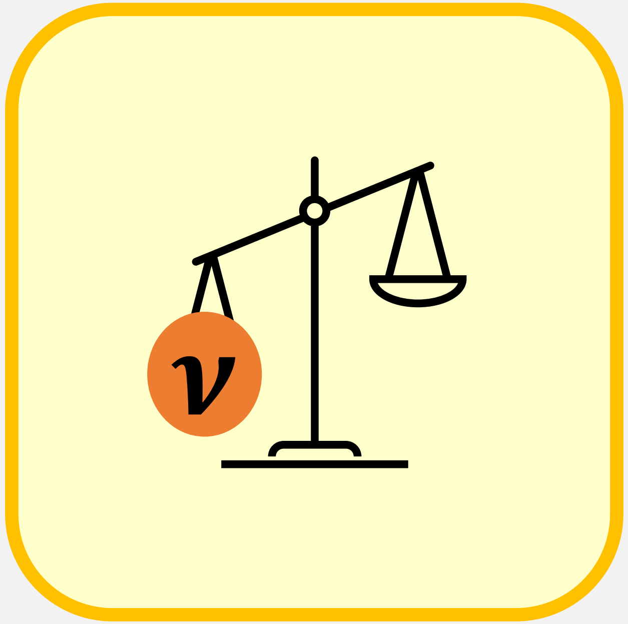


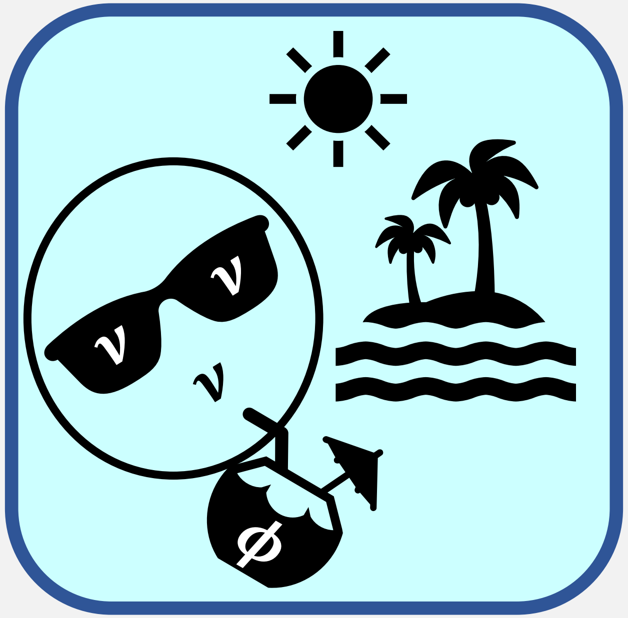
Neutrino masses

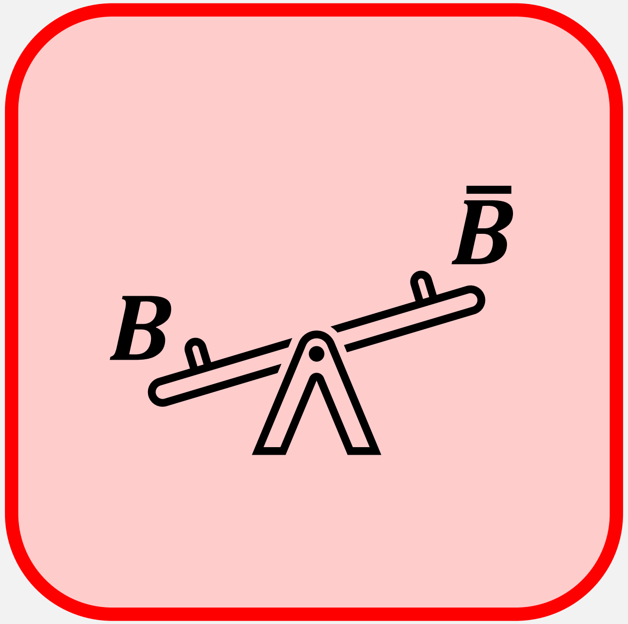




Baryon asymmetry







Exotic pheno

Zee-Babu (ZB) model

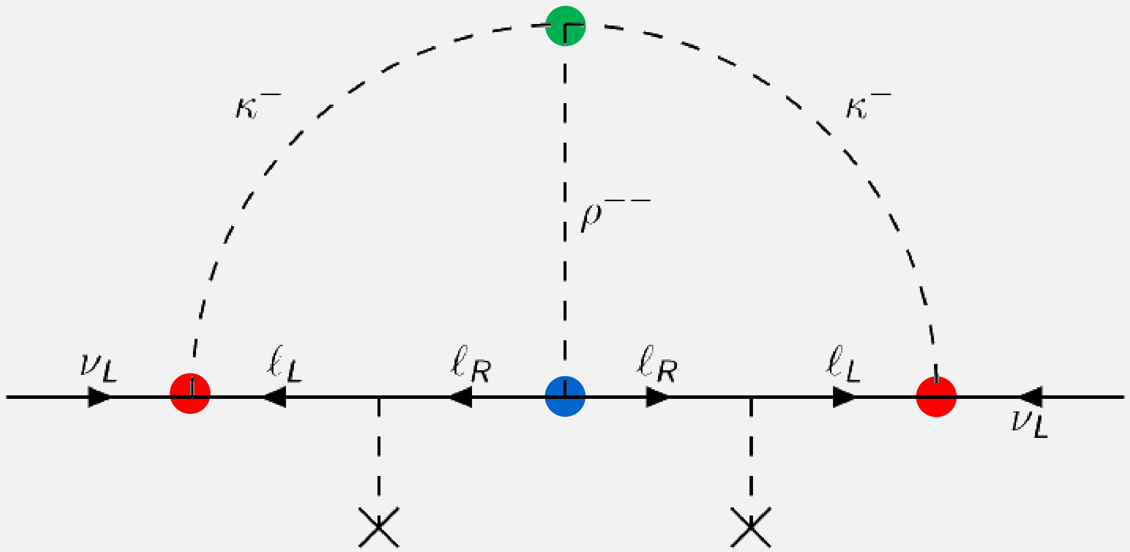


Fig. 1: Feynman diagram generating the neutrino masses in the ZB model [1, 2].

- Canonical 2-loop **radiative $\boldsymbol{\nu}$ mass** model [1, 2]

- Some features:

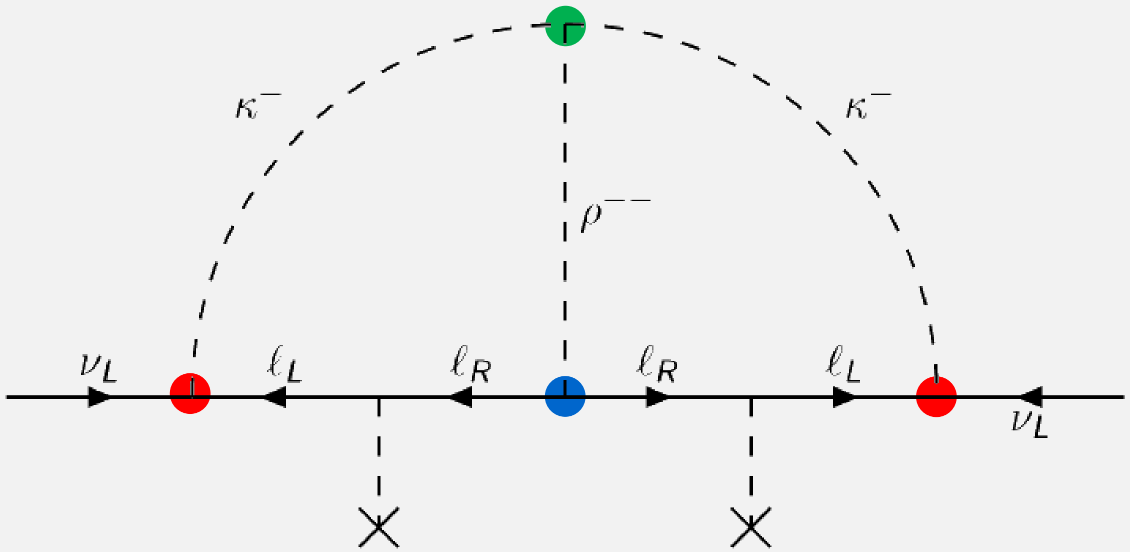
  - scalars $\kappa^+ \sim (1_C, 1_L, \mathbf{2_Y})$ and $\rho^{++} \sim (1_C, 1_L, \mathbf{4_Y})$

  - $\mathcal{L}_{ZB} \supset \overline{\widetilde{L_L}}\, \boldsymbol{f}\, L_L \kappa^+ + \overline{l_R^c}\, \boldsymbol{g}\, l_R\, \rho^{++} + \boldsymbol{\mu}\, \rho^{++}\kappa^-\kappa^- + \text{h.c.}$

    with $\boldsymbol{f}$ antisymmetric and $\boldsymbol{g}$ symmetric.

  - neutrino masses: $M_\nu \sim \mu\, f\, Y_l\, g^\dagger\, Y_l\, f^T$

Zee-Babu (ZB) model



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  - neutrino masses: $M_\nu \sim \mu\, f\, Y_l\, g^\dagger\, Y_l\, f^T$
- **Majorana mass terms** for L_L and l_R are interesting.

Inverse high T symmetry breaking

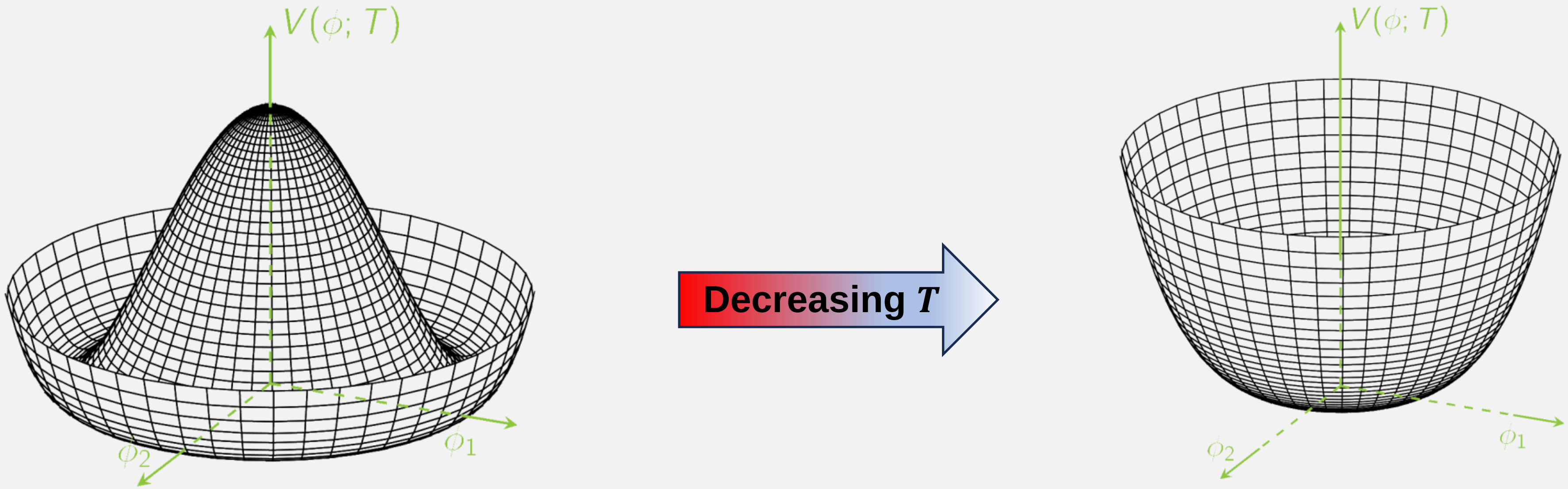

Fig. 2: Multi-scalar potential under high-T symmetry breaking and low-T symmetry restoration.

- To leading order in temperature T and 1-loop: $V^T{}_{1l} \sim \sum_{i,j\neq i}[(m_i^2 + C_{\phi_i} T^2)\phi_i^2 + \lambda_i \phi_i^4 + \lambda_{ij}\phi_i^2\phi_j^2]$
- For $C_{\phi_k} < 0 \rightarrow \langle \phi_k \rangle \neq 0$ at high enough T
- If ϕ_k carries hypercharge: **SSB of $U(1)_Y$**
- Caveat: $C_{\phi_k} < 0$ **difficult**

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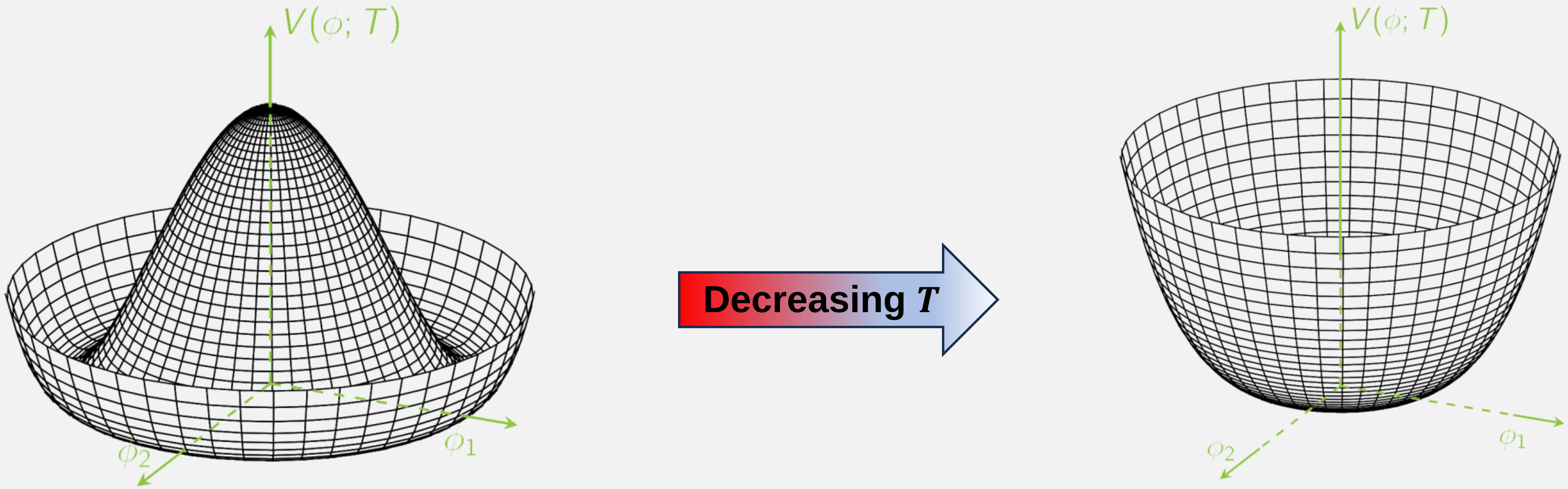

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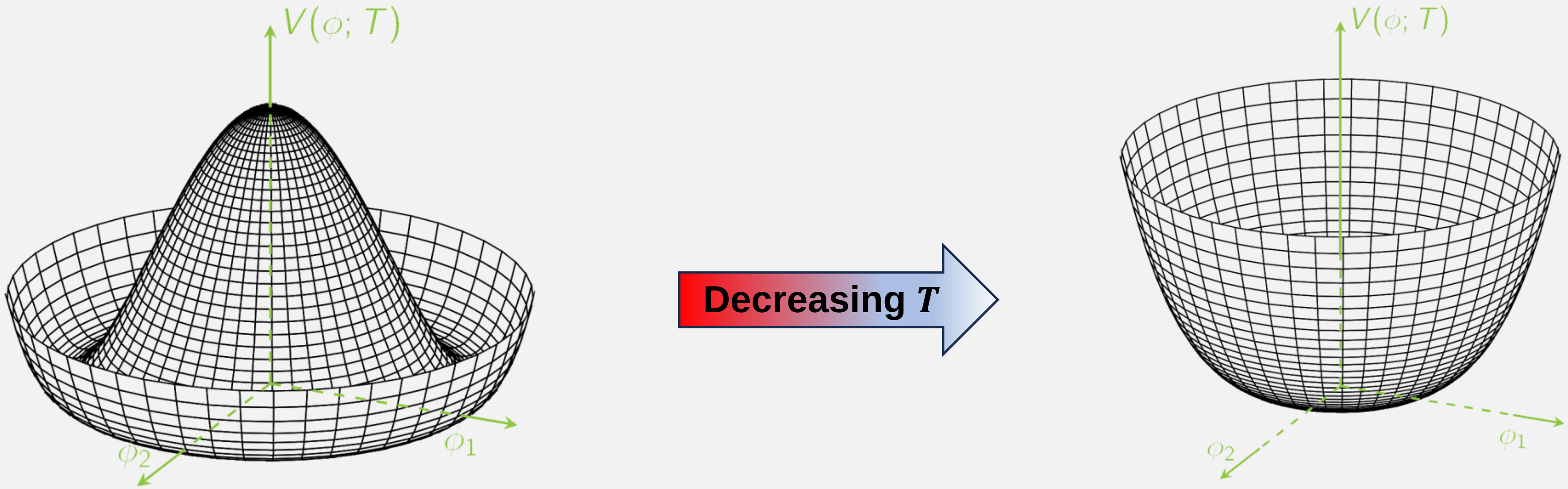

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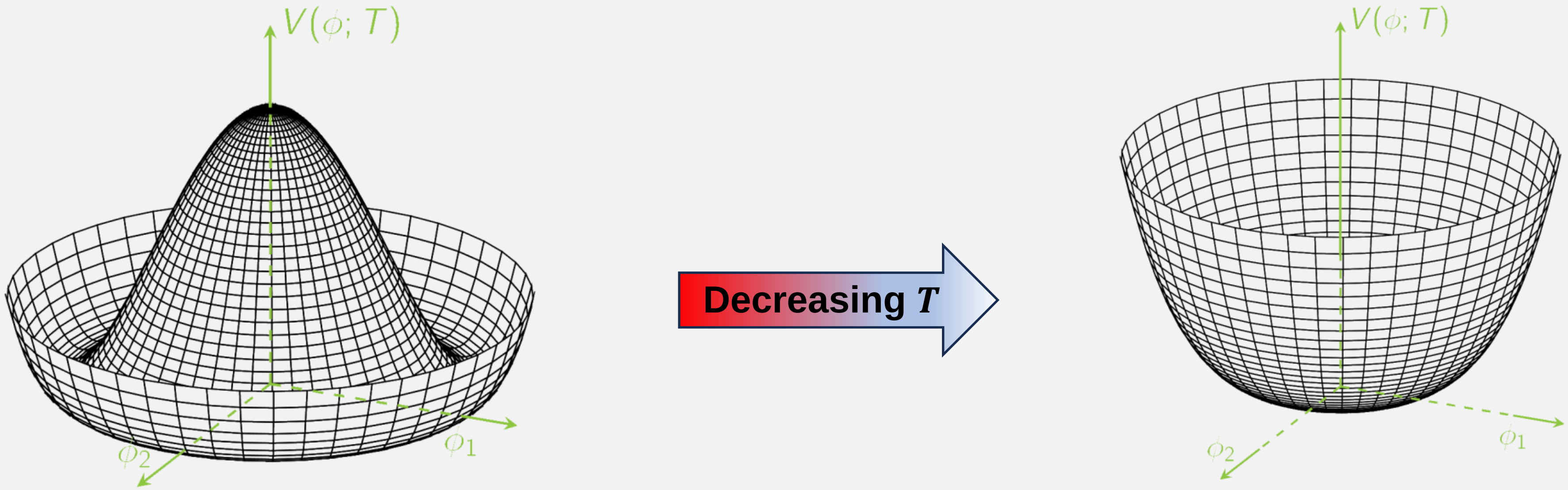

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High T SSB of $U(1)_Y$ in ZB?

$$C_h = \frac{g'^2 + 3g^2}{32} + \frac{y_t^2}{8} + \frac{\lambda_h}{4} + \frac{\lambda_{h\kappa} + \lambda_{h\rho}}{24} \qquad + \Delta C_h$$

$$C_\kappa = \frac{g'^2}{4} + \frac{4\lambda_\kappa + 2\lambda_{h\kappa} + \lambda_{\kappa\rho}}{12} + \frac{1}{24}\sum_{j\neq k} |f_{jk}|^2 + \Delta C_\kappa$$

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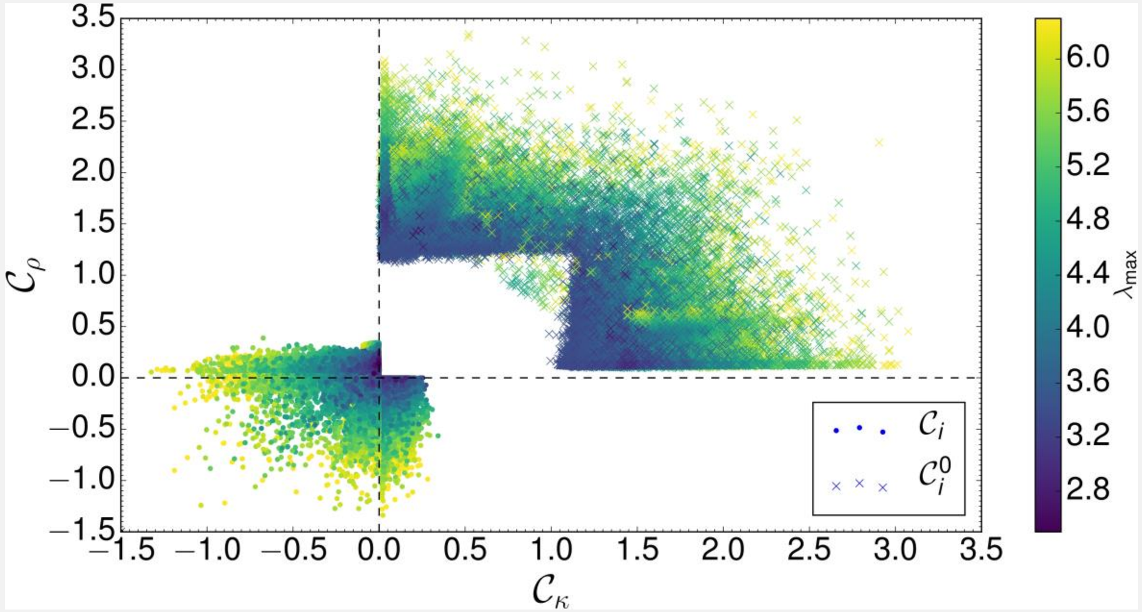

Fig. 3: Values of $\mathcal{C}_\kappa$, $\mathcal{C}_\rho$ (circles) and $\mathcal{C}_\kappa^0$, $\mathcal{C}_\rho^0$ (crosses) for a parameter scan of the quartic couplings in the ZB model. The color scheme encodes $\lambda_{max} = \max\{\lambda_i\}$. Both sets correspond to the same λ_i.

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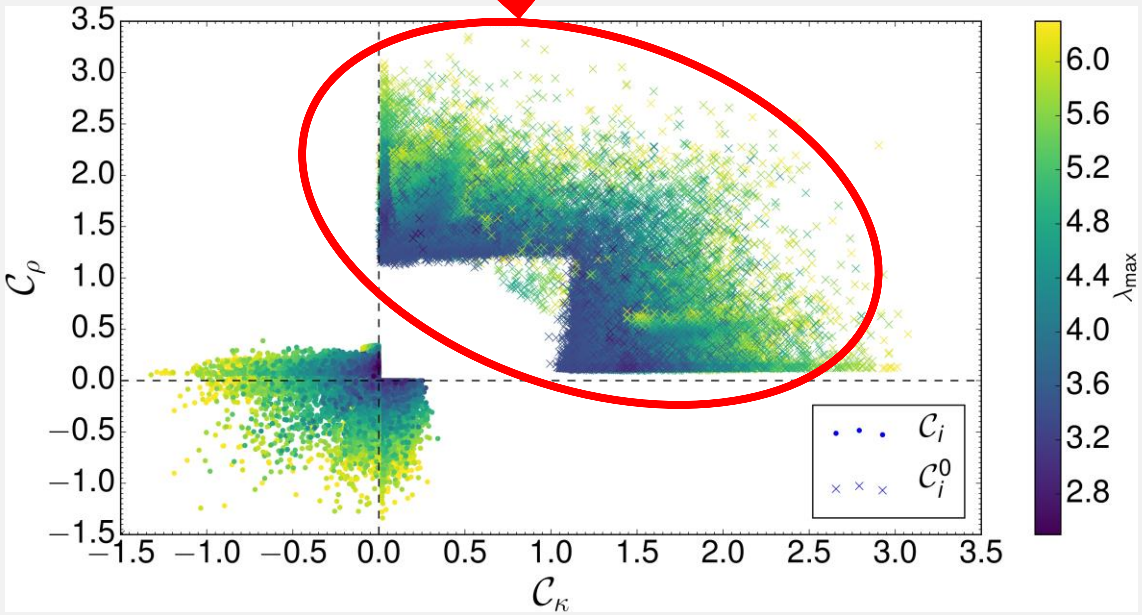
naive calculation



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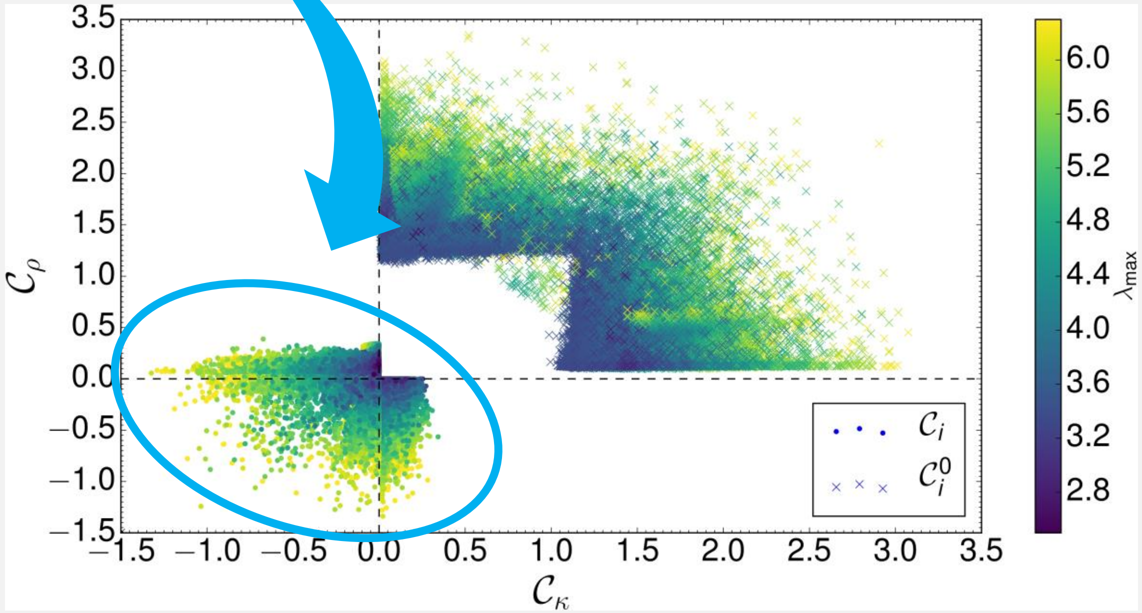
with daisy contributions



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Baryogenesis

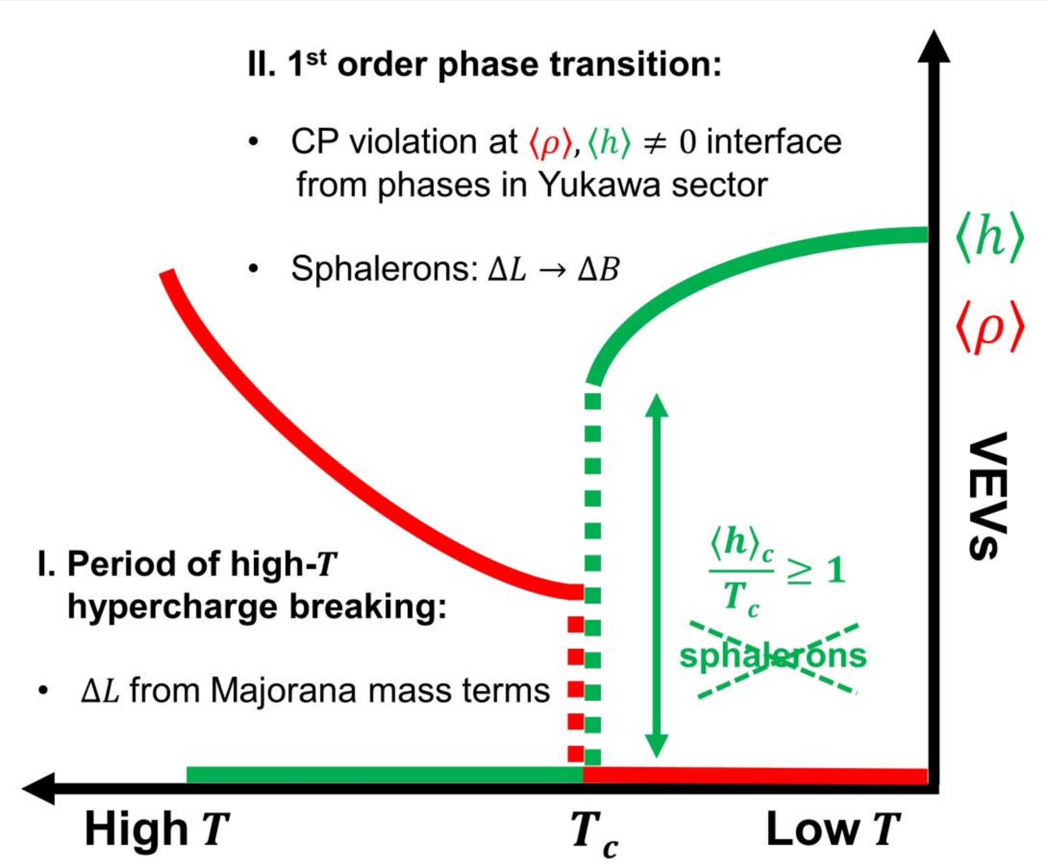


Table 1: Benchmarks

	λ_κ	λ_ρ	$\lambda_{h\kappa}$	$\lambda_{h\rho}$	$\lambda_{\kappa\rho}$	C_h	C_κ	C_ρ
BM1	0.118	5.44	4.70	-0.097	-0.052	0.042	0.048	-0.85
BM2	4.394	0.811	5.134	-0.537	-0.142	0.048	-0.529	0.192

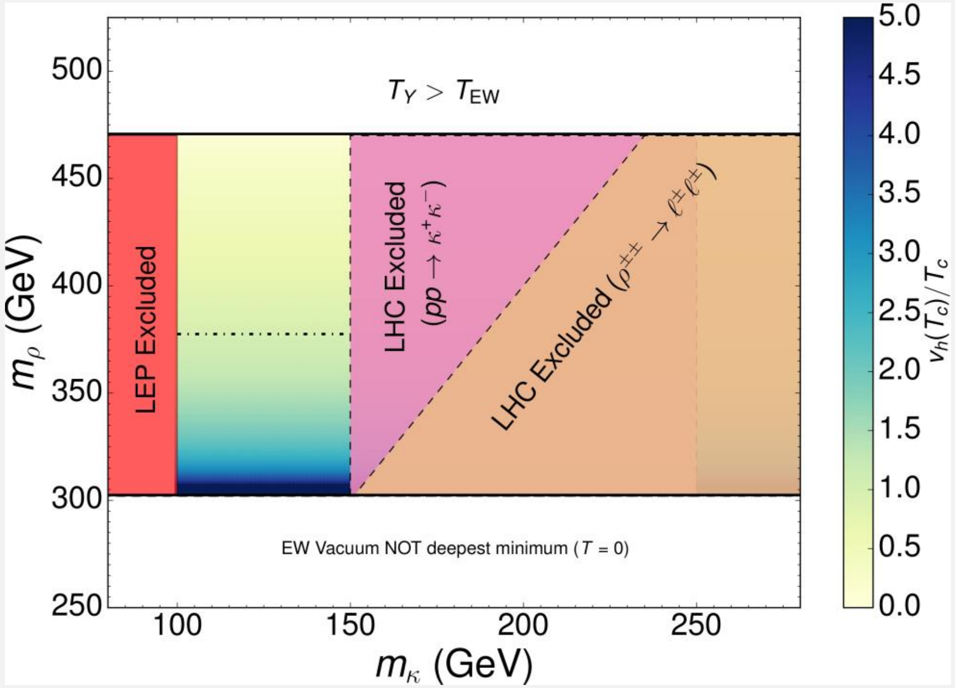
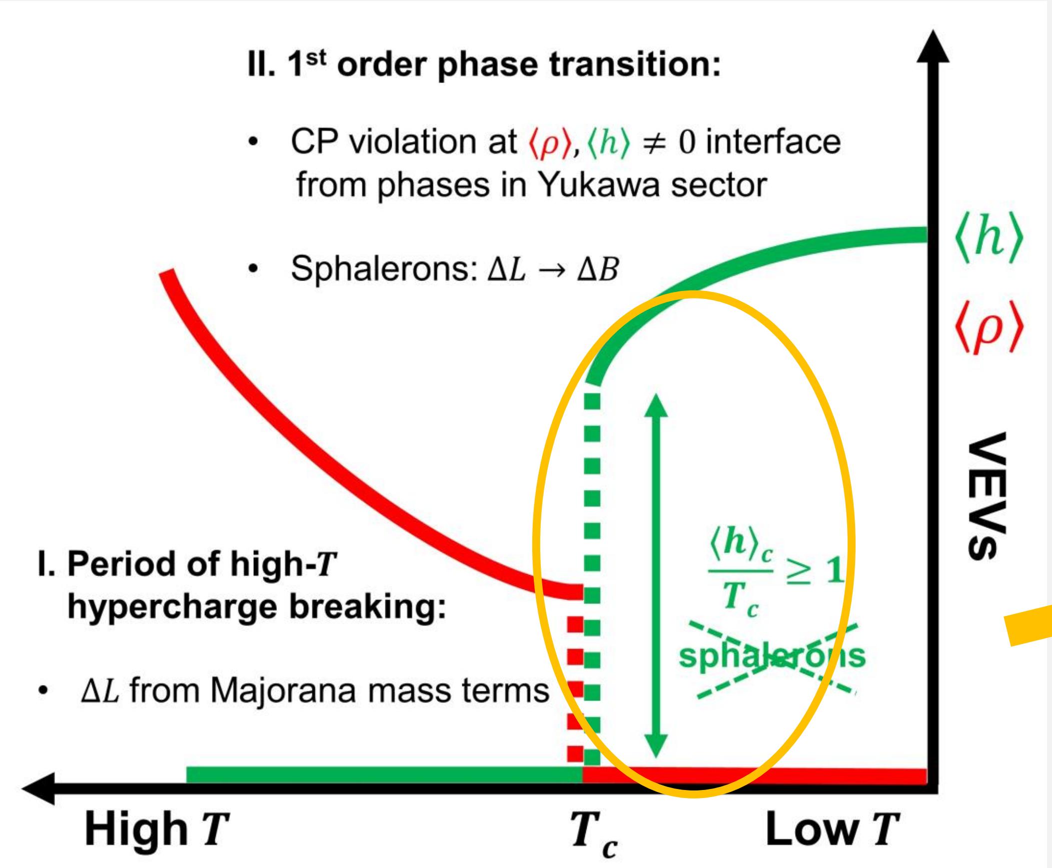


Fig. 4: Viable masses $(m_\kappa,\ m_\rho)$ for baryogenesis in BM1.

Baryogenesis



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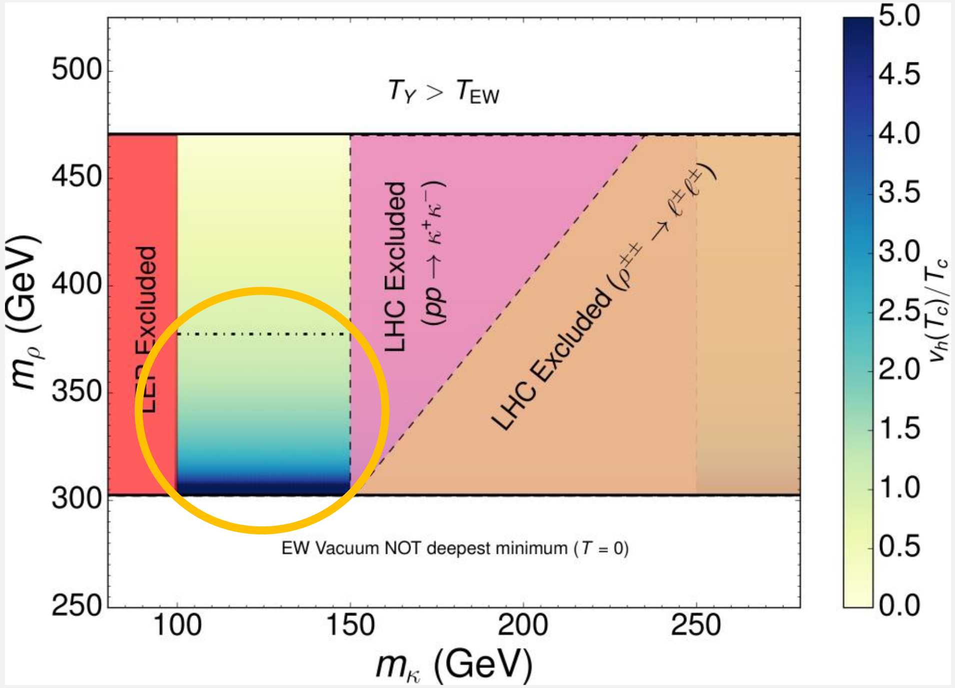

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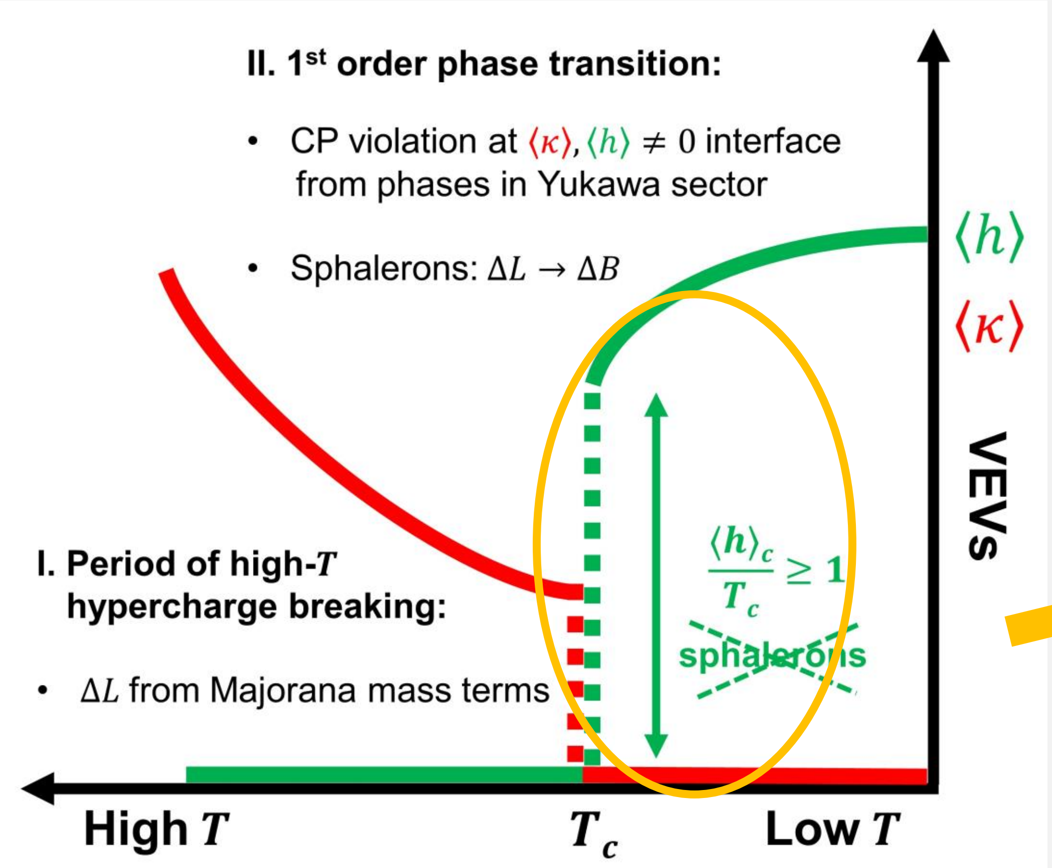

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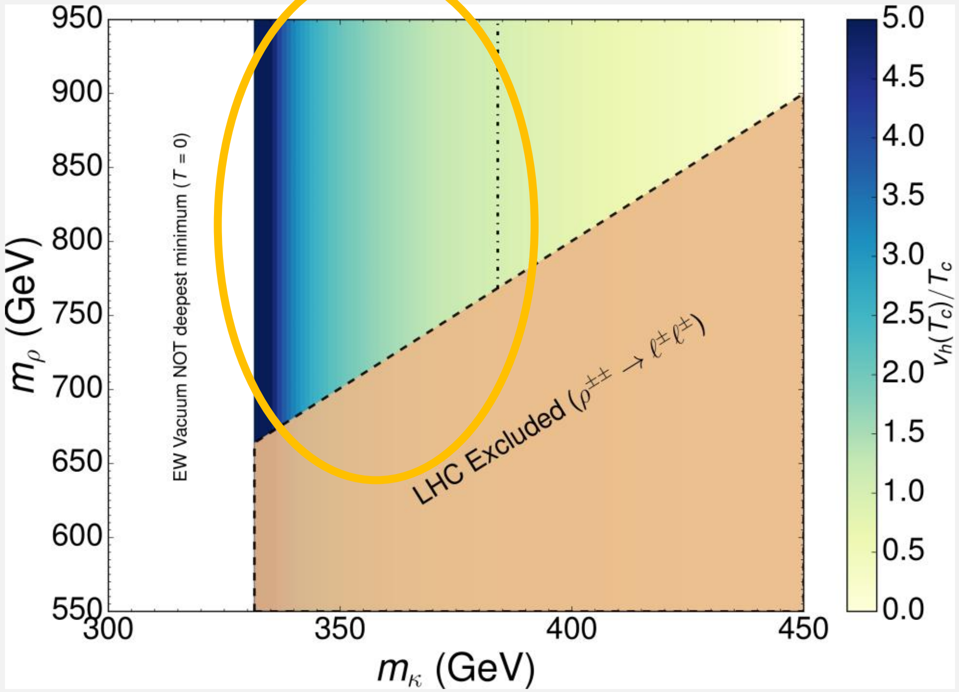
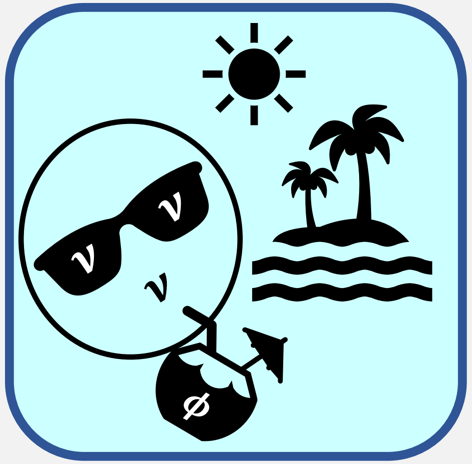
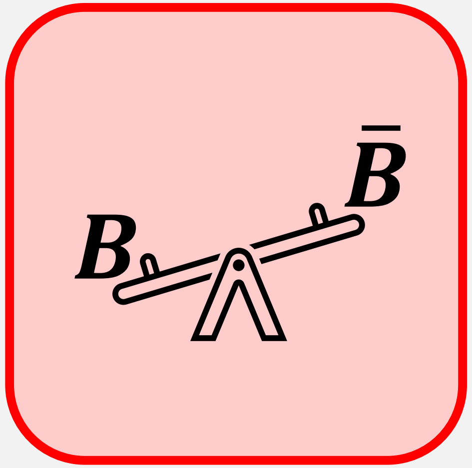


Fig. 5: Viable masses $(m_\kappa,\ m_\rho)$ for baryogenesis in BM2.

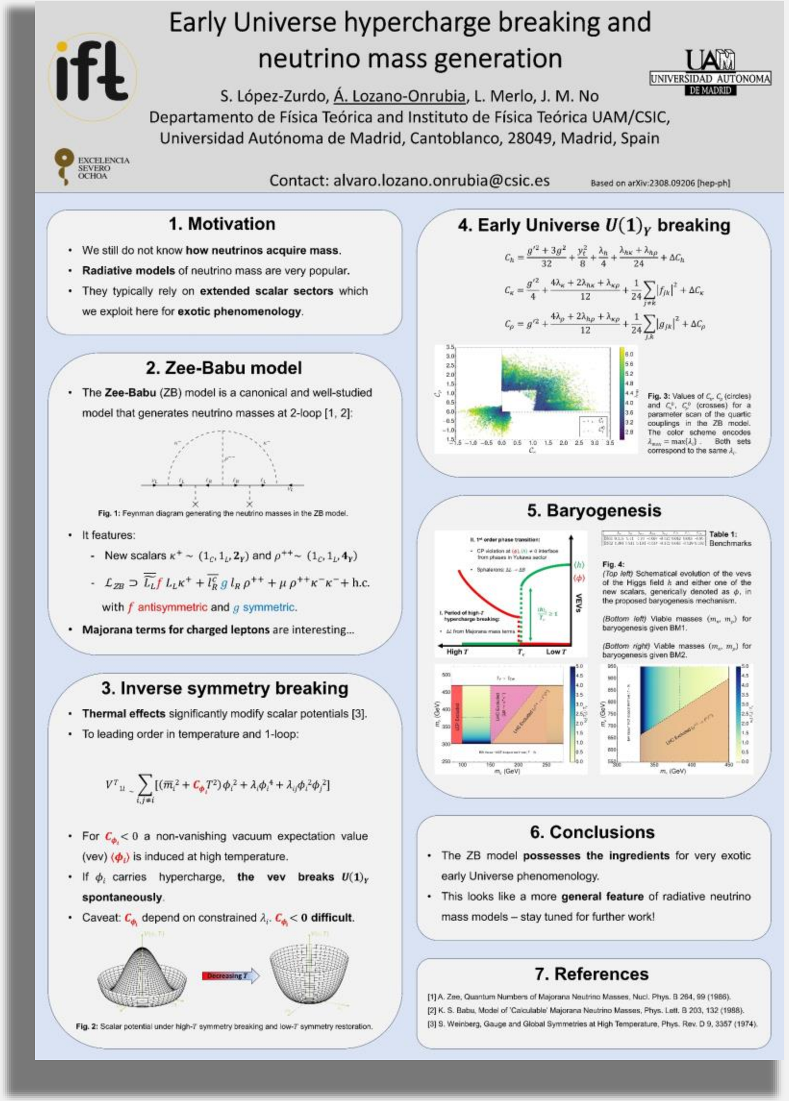
Takeaways





- ZB **possesses the ingredients** for exotic early Universe phenomenology.
- How **generic to radiative models** are these features?

Stay tuned!



Thank you!

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References

[1] A. Zee, Quantum Numbers of Majorana Neutrino Masses, Nucl. Phys. B 264, 99 (1986).

[2] K. S. Babu, Model of ’Calculable’ Majorana Neutrino Masses, Phys. Lett. B 203, 132 (1988).