# Aspects of High Scale Leptogenesis with Low-Energy Leptonic CP Violation

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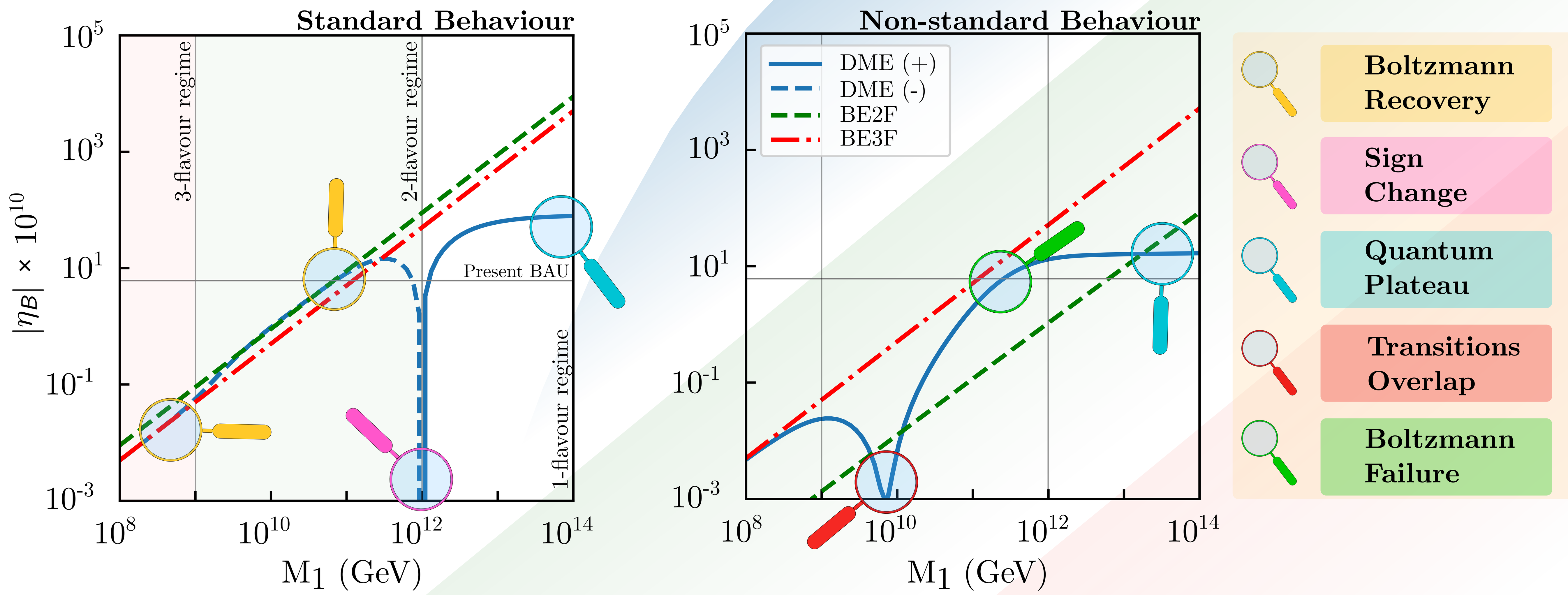
## Framework

The **type I Seesaw extension** of the Standard Model (SM) provides an elegant explanation for the **generation of the active neutrino masses** and the present **Baryon Asymmetry of the Universe** (BAU, $\eta_B$). It merely consists of adding heavy **Majorana neutrinos,** typically 3 ($N_{1,2,3}$ with masses $M_{1,2,3}$), to the SM along with **Yukawa couplings** to the Higgs and lepton doublets. The SM neutrino masses arise after the Higgs acquisituion of a non-zero vacuum expectation value, while the BAU is generated through **Leptogenesis** (LG) via the SM sphaleron conversion of an initial lepton asymmetry originated from the early **out-of-equilibrium L, C and CP violating $N_{1,2,3}$ decays** into Higgs and leptons. LG can be related to low-energy observables if the required **CP violation** is provided **solely by the phases** of the Pontecorvo-Maki-Nakagawa-Sakata (**PMNS**) neutrino mixing matrix. We studied this scenario within the following framework:

- **Hierarchical limit** with $M_3 \gg M_2 \gg M_1$ and $M_1$/GeV in the range $[10^8, 10^{14}]$;
- Normal/Inverted Hierarchical (**NH/IH**) SM neutrino mass sepctrum ($N_3$ decoupled);
- **Density Matrix Equations** (DMEs), compared to Boltzmann Equations (BEs).

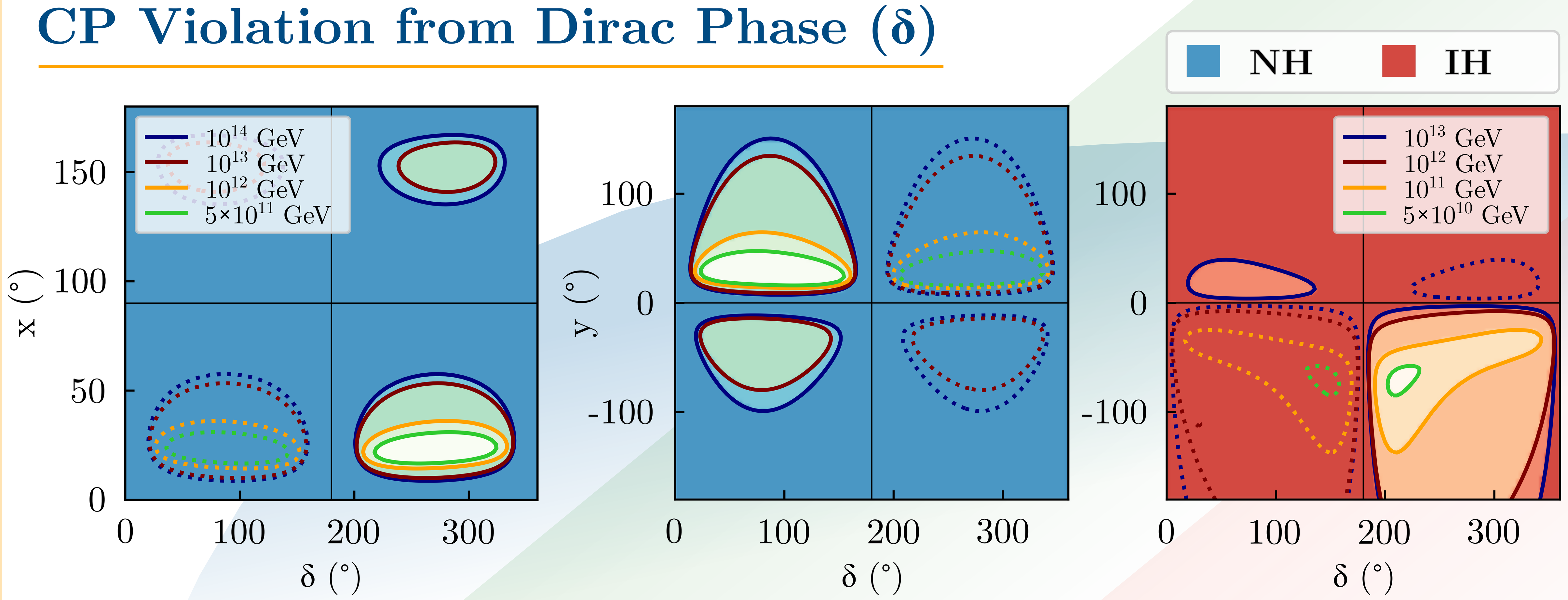
## Results

Typically, the **DMEs recover the BEs** in the 3- and 2-flavour regimes; the BAU shows a **sign change** at the 1-to-2 flavour transition ($M = 10^{12}$ GeV) in the strong wash-out regime and for vanishing initial abundance; $\eta_B$ has a **plateau** due to quantum decoherence effects above the 1-to-2 transition. However, **BEs may fail** and the **1-to-2 flavour transition** be **at M1 « $10^{12}$ GeV** and **overlap with the 2-to-3 one**.



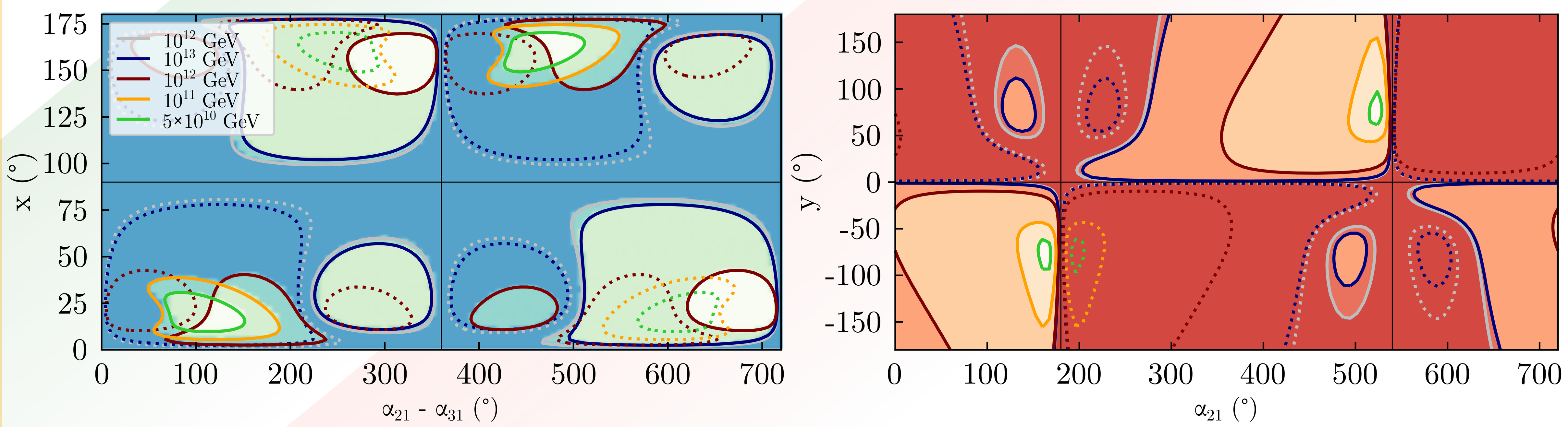

# Regions of Successful LG

## CP Violation from Dirac Phase (δ)




There is a **one-to-one relation** between the **sign of sin(δ)** and that of the **BAU**.

## CP Violation from Majorana Phases ($\alpha_{21}$ and $\alpha_{31}$)




The scenario with CP violation from Majorana phases is richer and **falsifiable**.

## Summary

The BEs are valid when either none, one or all the lepton flavours are fully decoherent, while the **DMEs**, accounting for **quantum decoherence effects**, correctly describe the 1-to-2 and 2-to-3 flavour transitional regimes. With **low-energy CP** violation only, contrarily to the BEs, the **DMEs predict the BAU** in the 1-flavour regime (**plateau**). Besides, the BEs may fail in the 2-flavour regime as well. Moreover, the **sign of the DMEs solution** strongly **depends on the mass scale** of LG. Excitingly, future **low-energy neutrino experiments** on PMNS phases can **support or severly constraint** the considered scenarios. For Dirac CP violation, there is a **1-to-1 correspondence** between the **sign of sin(δ)** and that of the **BAU.** For Majorana CP violation and NH (IH), **different** values of **$\alpha_{21}$-$\alpha_{31}$ ($\alpha_{21}$)** can select **different scenarios**.