Electroweak baryogenesis from dimension-six operators

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Sakharov conditions

- B-violation
- **C- and CP-violation**
- **Out-of-equilibrium physics**

Why electroweak baryogenesis?

- Physics at EW scale: testable in colliders
- CP violation: EDM experiments

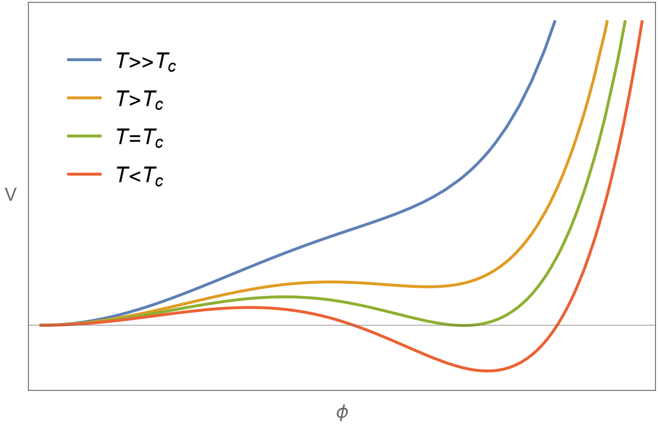
Why effective field theory?

$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \sum_i \frac{1}{\Lambda^{d_i-4}} c_i \mathcal{O}_i$$

- Model-independent
- Systematic study of all relevant dimension-six operators

Is this a suitable framework to describe electroweak baryogenesis?

First order phase transition

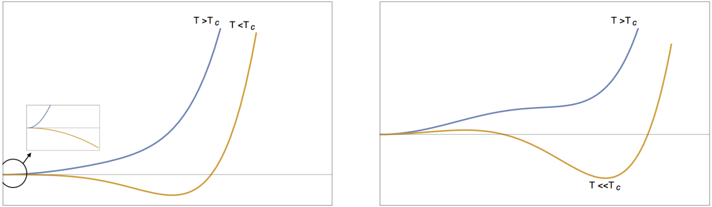


First order phase transition from dimension-six operator

- Add dimension-six operator to Higgs potential

$$V = \mu^2 \varphi^\dagger \varphi + \lambda(\varphi^\dagger \varphi)^2 + \kappa(\varphi^\dagger \varphi)^3$$

$+$ thermal corrections



κ too small

κ too large

- We take $\kappa = 2\,\text{TeV}^{-2}$ $(\Lambda \approx 0.7\,\text{TeV})$, $T_N = 88\,\text{GeV}$

CP-violating operators

- Two scenarios:

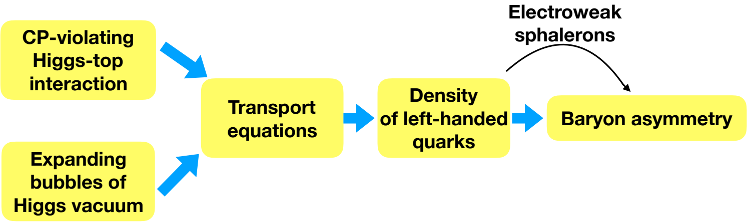
$$\mathcal{L}_{6,\mathbf{A}} = [\Lambda_{\text{CPV}}^{-2}\bar{Q}_L y_t \tilde{\varphi} t_R (\varphi^\dagger\varphi) + \text{h.c.}]$$

$$\mathcal{L}_{6,\mathbf{B}} = \alpha[\Lambda_{\text{CPV}}^{-2}\bar{Q}_L D^2 \tilde{\varphi} t_R + \text{h.c.}]$$

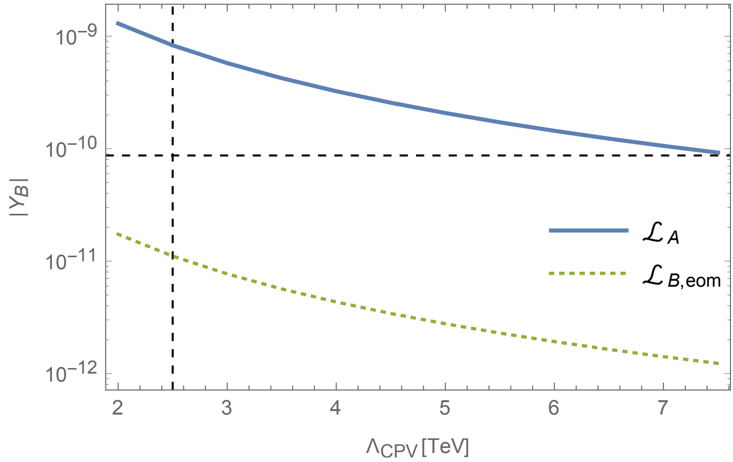
$$\overset{\text{eom}}{=} -\alpha[\Lambda_{\text{CPV}}^{-2}\bar{Q}_L \tilde{\varphi} t_R(\mu^2 + 2\lambda(\varphi^\dagger\varphi) + 3\kappa(\varphi^\dagger\varphi)^2) + \text{h.c.}]$$

- **A** and **B** give identical contribution to EDMs
- **A** and **B** give identical baryon asymmetry up to dim-8 effects

Electroweak baryogenesis in a nutshell

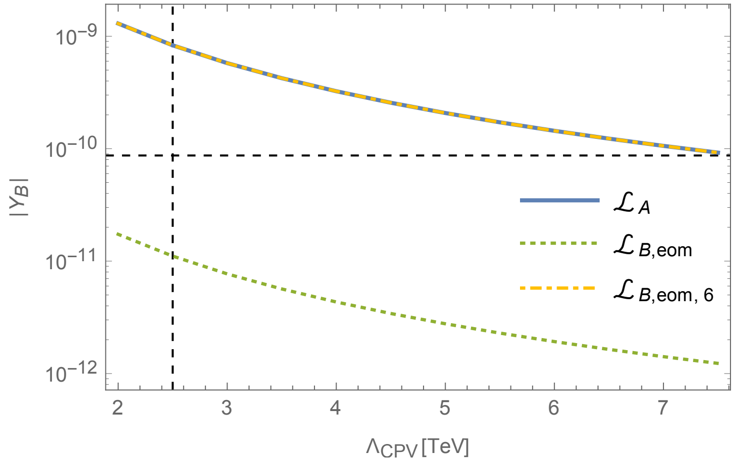


Results



10^{-9}
10^{-10}
10^{-11}
10^{-12}
$|Y_B|$
$\mathcal{L}_A$
$\mathcal{L}_{B,\mathrm{eom}}$
2
3
4
5
6
7
Λ_{CPV} [TeV]

Importance of dimension-eight effects



Implications

- Finite-temperature and dimension-eight effects can not be ignored
- Effective field theory description breaks down

Possible solutions

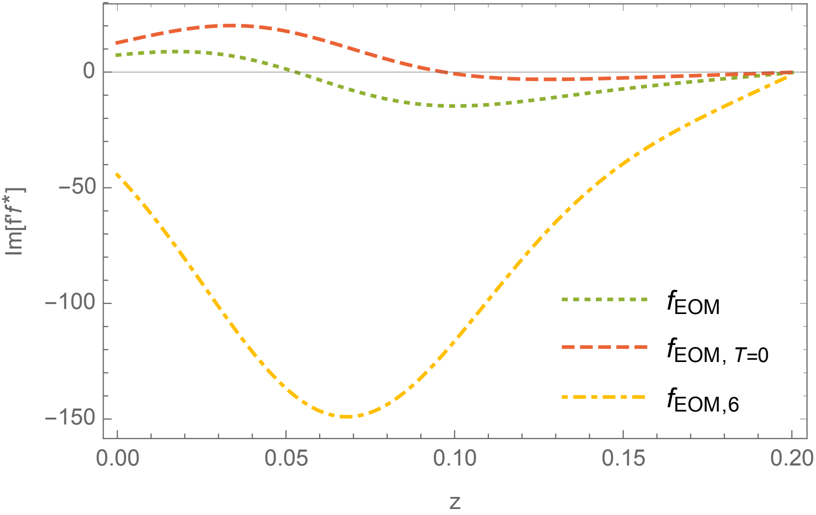
Can use EFT in the CPV sector, but not to obtain the EW phase transition

- Use UV-complete model
- Describe the bubble profile phenomenologically

Summary & conclusions

- Dimension-six operators
  - $\kappa(\varphi^\dagger\varphi)^3$ for first order phase transition
  - CP-violating Higgs-top interactions
- Dimension-eight effects can not be neglected in the computation of the baryon asymmetry
- Effective field theory description breaks down

Source term



Importance of finite T and dimension 8 effects