Baryogenesis via mesino oscillations

AKSHAY GHALSASI, DAVE MCKEEN, ANN NELSON

PHENO 2015, PITTSBURGH

Introduction to Baryogenesis

- Universe is made up of baryons $\eta = 5 \times 10^{-10}$
- Sakharov conditions

1. Baryon number violation
2. C and CP Violation
3. Departure from thermal equilibrium

- SM does not explain baryogenesis
- Need to construct minimal expansion of SM

Lagrangian and mass hierarchy

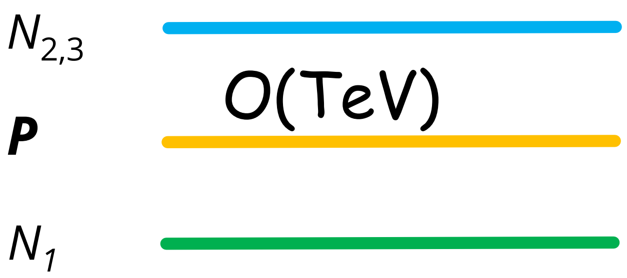
colored scalars

singlet fermions

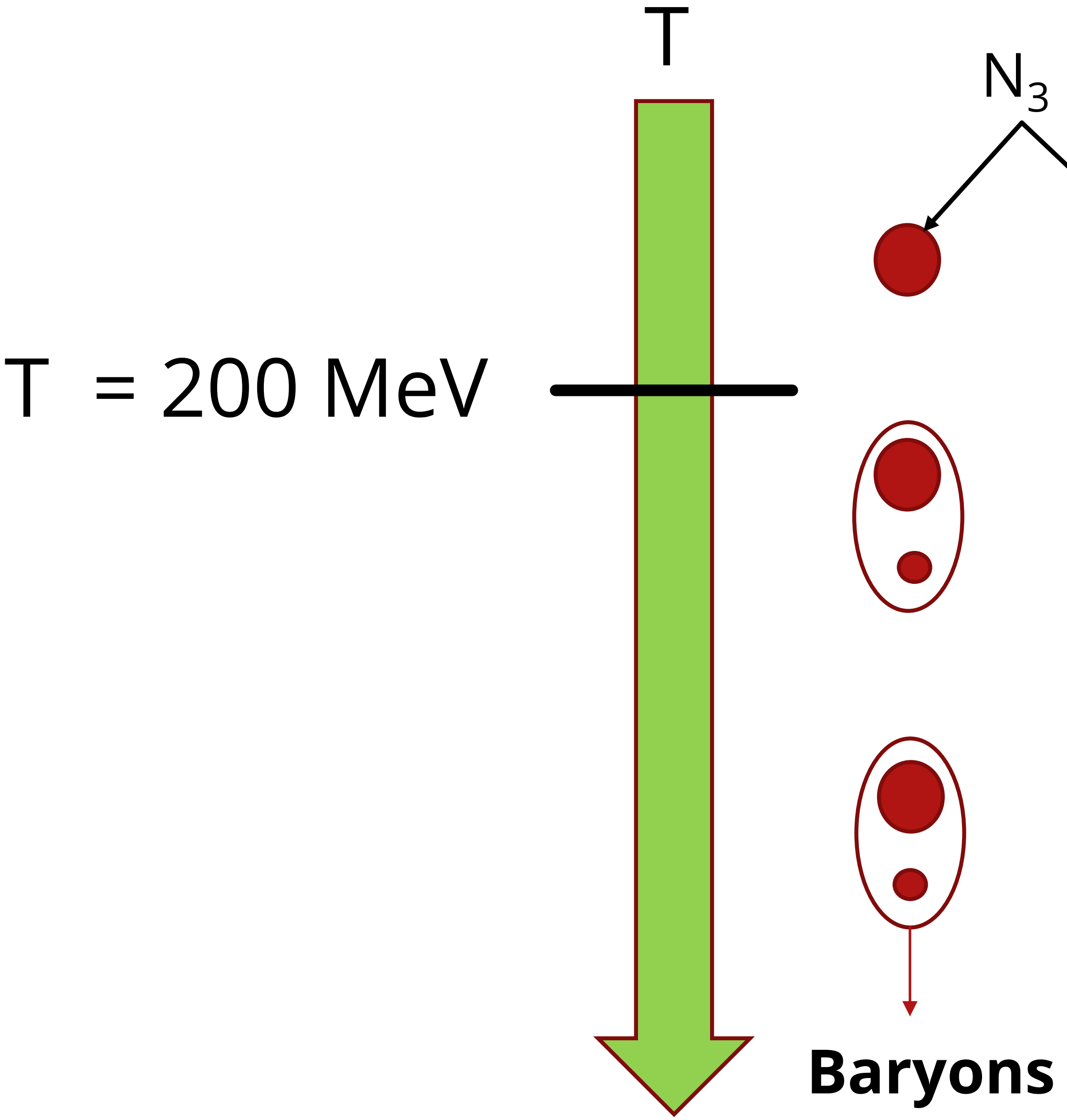
$$L = L_{SM} + y_{ij}\Phi \bar{d}_i N_j + m_{Nij} N_i N_j + \alpha_{ij}\Phi Q_i Q_j + c.c$$

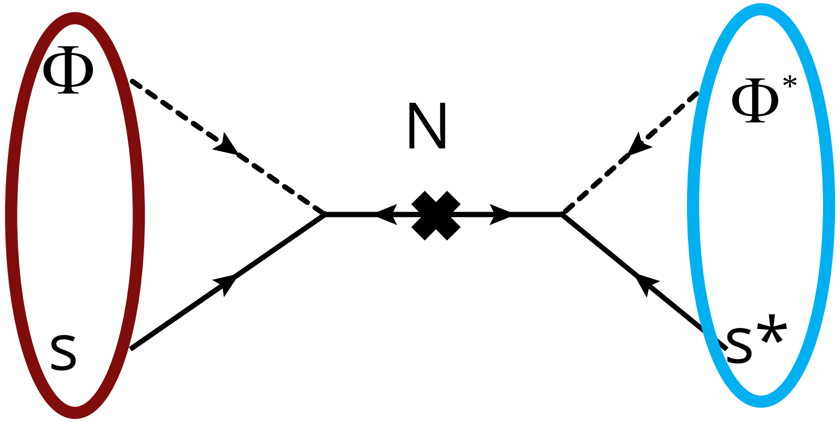
CP violation

B violation



General Idea

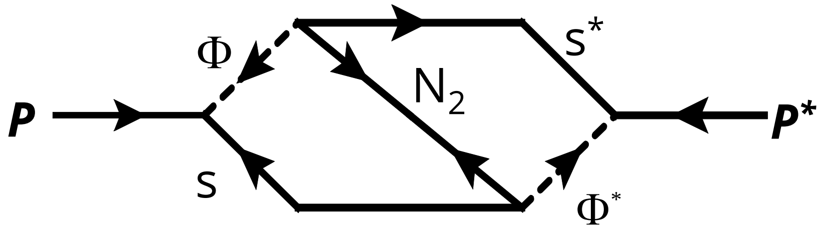


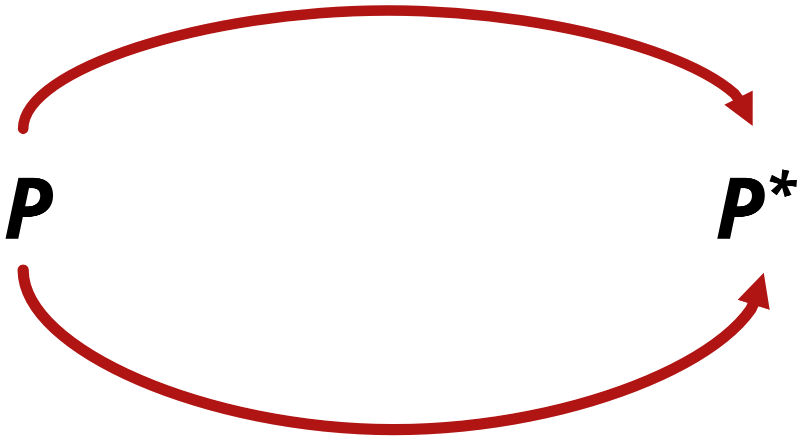


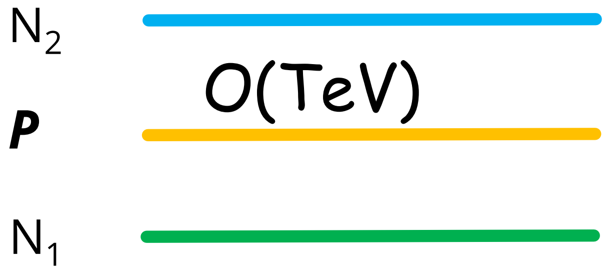
CP Violation

Oscillations

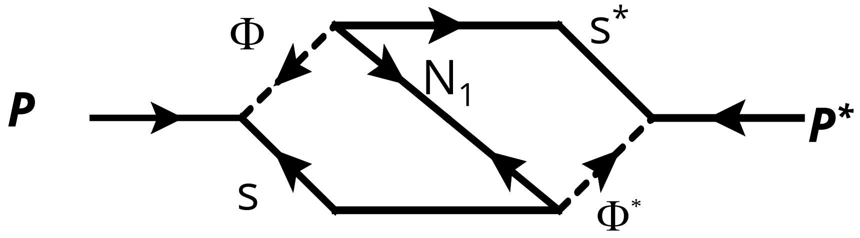
Off shell diagrams







On shell diagrams via common final states



Mesino Oscillations

- Hamiltonian without oscillations

$$H = \begin{pmatrix} M - \frac{i}{2}\Gamma & 0 \\ 0 & M - \frac{i}{2}\Gamma \end{pmatrix}$$

With oscillations we get off diagonal terms

$$H = \begin{pmatrix} M - \frac{i}{2}\Gamma & M_{12} - \frac{i}{2}\Gamma_{12} \\ M_{12}^{*} - \frac{i}{2}\Gamma_{12}^{*} & M - \frac{i}{2}\Gamma \end{pmatrix}$$

Mesino oscillations

- Hamiltonian has off diagonal terms, new eigenstates are

$$|P_H\rangle = p|P\rangle + q|P^*\rangle \qquad |P_L\rangle = p|P\rangle - q|P^*\rangle$$

- Assuming a state starts as P (P^*) at t = 0 then

$$\langle P^* | P(t)\rangle = \frac{p}{q} f(t) \qquad \langle P | P^*(t)\rangle = \frac{q}{p} f(t)$$

- CP violation gives $\left|\frac{p}{q}\right| \neq 1$ favoring one state over another

Maximum CP violation

- CP violation maximized for $2M_{12} = \Gamma_{12}, \theta = \frac{\pi}{2}$

$$max\left(A_{CP}\right) = \frac{\Gamma_{12}^2}{\Gamma_{12}^2 + \Gamma^2}\frac{\Gamma_{3Q}}{\Gamma}$$

baryonic Γ_{3Q}

semihadronic $\Gamma_{N_1 2Q}$

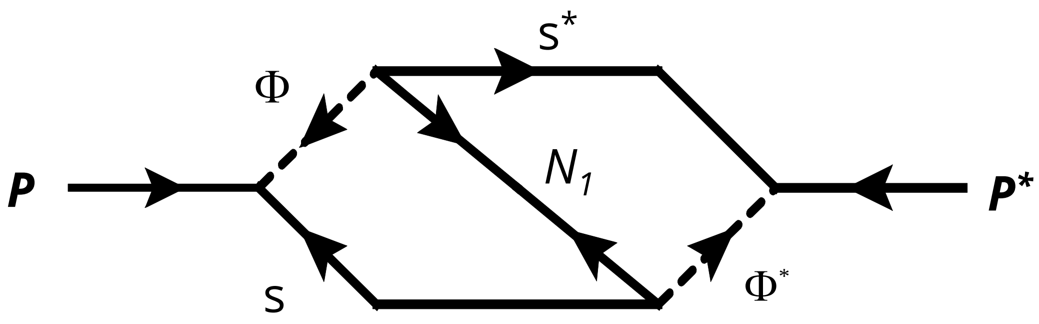
geometric

- But $max\left(\Gamma_{12}\right) = \Gamma_{N_1,2Q} \approx \frac{y_{s1}^2}{16\pi} GeV$ for $m_P - m_{N_1} \approx GeV$

- Can show that $max\left(A_{CP}\right) = \frac{\Gamma_{N_1 2Q}^2}{\Gamma_{N_1 2Q}^2 + \left(\Gamma_{N_1 2Q} + \Gamma_{3Q}\right)^2} \frac{\Gamma_{3Q}}{\Gamma_{N_1 2Q} + \Gamma_{3Q}} \approx 0.1$

- However.....

N_1 has to be fine tuned



- However if $m_P - m_{N_1} > GeV$ it suppresses Γ_{12}

$$\Gamma_{12} = max\left(\Gamma_{12}\right)\frac{(GeV)^4}{\left(m_P - m_{N_1}\right)^4}$$

- N_1 has to be fine tuned within O(GeV) of mesino
- Same holds true for N_2 to get M_{12} close to Γ_{12}

Putting it together

- Define $r = \frac{n_\phi}{n_\gamma}$ then

$$\max(\eta) = \frac{r}{10 \times 10}\left(\frac{GeV}{GeV + rm_P}\right)^{\frac{3}{4}} max\left(A_{CP}\right)$$

- For $m_P = 1TeV, r = 10^{-3}$

$$\max(\eta) = 5 \times 10^{-7}$$

Conclusions and Future Work

- This model gives us baryogenesis
- Energy scales around TeV so interesting for collider physics
- Also contributes to neutron antineutron oscillations
- Investigate the possibility of N_1 decaying further into DM