SCET BSM for Leptoquarks

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- Non-singlet: has to account for its interactions with SM particles and non-trivial renormalization of the heavy field.
- Construct an heavy field effective Lagrangian

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Heavy Scalar Effective Lagrangian

- Treat the heavy scalar momentum as: $p_\phi^\mu = M_\phi v^\mu + k_\phi^\mu$, where $v^\mu = (1, 0, 0, 0)$ and $\Delta k \sim \Lambda_{QCD}$

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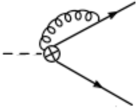

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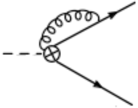

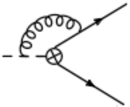

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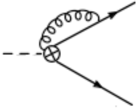

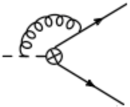

$$Z_S = 1 + \frac{C_F}{2\pi}\alpha_s\frac{1}{\epsilon}$$

Application to Leptoquarks

Scalar Leptoquark $S_1(3, 1, -\frac{1}{3})$

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Only **three** leading order operators:

$$\mathcal{L}_{SCET}^{(\lambda^2)} = C_{u\ell}^{R}\mathcal{O}_{u\ell}^{R} + C_{QL}^{L}\mathcal{O}_{QL}^{L} + C_{d\nu}^{R}\mathcal{O}_{d\nu}^{R} + h.c.$$

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$$\mathcal{O}_{u\ell}^R = \bar{u}_{R,n_1}^c \ell_{R,n_2} S_1^* + (n_1 \leftrightarrow n_2)$$
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- Effects of NP in **three** dimensionless Wilson coefficients.

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$$
\begin{aligned}
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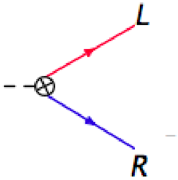
- S_1 mixes right-left handed particles



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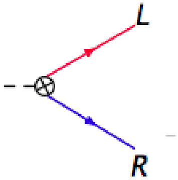
- Fermion number violated at $\mathcal{O}(\lambda^2)$



Operators for $S_1(3,1,-\frac{1}{3})$ at sub-leading order

Two jet operator-Lagrangian

$$\mathcal{L}_{SCET}^{(\lambda^3)} = \frac{1}{\Lambda}\sum_{j=1,2}\int_0^1 du \left[C_1^{(j)}{}_{Ld}^{LR}\mathcal{O}^{(j)}{}_{Ld}^{LR} + C_1^{(j)}{}_{Q\nu}^{LR}\mathcal{O}^{(j)}{}_{Q\nu}^{LR} + C_1^{(j)}{}_{d\nu}^{R}\mathcal{O}^{(j)}{}_{d\nu}^{R} \right] + \frac{1}{\Lambda} C_1^{(0)}{}_{Ld}^{LR}\mathcal{O}^{(0)}{}_{Ld}^{LR} + \frac{1}{\Lambda} C_1^{(0)}{}_{Q\nu}^{LR}\mathcal{O}^{(0)}{}_{Q\nu}^{LR} + h.c$$

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Two jet operators

$$\mathcal{O}^{(0)}{}^{LR}_{Ld} = \bar{L}_{n_1}\tilde{\Phi}^0 d_{R,n_2} S_1^* + (n_1 \leftrightarrow n_2)$$
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Two jet operators **conserve the fermion number** $\Rightarrow$ no mixing between $\mathcal{L}^{(\lambda^2)}_{SCET}$ and $\mathcal{L}^{(\lambda^3)}_{SCET}$

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3-jet operators further suppressed by the phase space!

Scalar Leptoquark $S_3(3,3,-\frac{1}{3})$

Lagrangian at leading order:

$$\mathcal{L}^{(\lambda^2)}_{SCET} = C_{3}{}^{L}_{QL}\mathcal{O}^{L}_{QL} + h.c$$

$$\mathcal{O}^{L}_{QL} = \bar{Q}^{c,a}_{L,n_1}\epsilon^{a,b}L^{b}_{L,n_2}S_3^* + (n_1 \leftrightarrow n_2)$$

+5 more operators at sub-leading order!

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  - **For leptoquark interaction both QCD and EW interactions must be included.**
- Numerically solve the above RGE to estimate the effects from the high scale M-the mass of the leptoquark

Leading order effects on the decay rates of the singlet S_1

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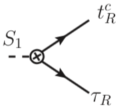

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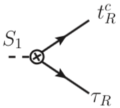

$$\frac{\Gamma(S_1 \to t^c_R \tau_R)_{resum}}{\Gamma(S_1 \to t^c_R \tau_R)_{fix}} \to \frac{|C(m_t)|^2 - |C(M_{S_1})|^2}{|C(m_t)|^2} \sim 0.19$$

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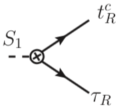

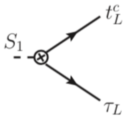

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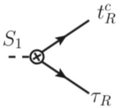

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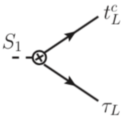

$$\frac{\Gamma(S_1 \to t_L^c \tau_L)_{resum}}{\Gamma(S_1 \to t_L^c \tau_L)_{fix}} \to \frac{|C(m_t)|^2 - |C(M_{S_1})|^2}{|C(m_t)|^2} \sim 0.25$$

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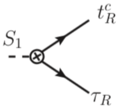

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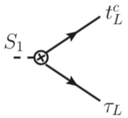

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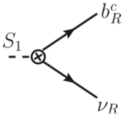

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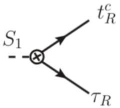

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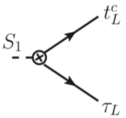

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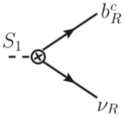

$$\frac{\Gamma(S_1 \to b_R^c \nu_R)_{resum}}{\Gamma(S_1 \to b_R^c \nu_R)_{fix}} \to \frac{|C(m_b)|^2 - |C(M_{S_1})|^2}{|C(m_b)|^2} \sim 0.92$$

Leading order effects on the decay rates of the triplet S_3

$$\mathcal{L}_{SCET}^{(\lambda^2)} = C_3{}_{QL}^{L} \mathcal{O}_{QL}^{L} + h.c$$

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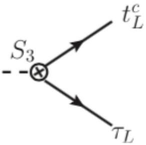

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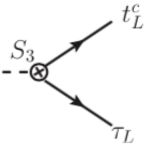

$$\frac{\Gamma(S_3 \to t_L^c \tau_L)_{resum}}{\Gamma(S_3 \to t_L^c \tau_L)_{fix}} \to \frac{|C(m_t)|^2 - |C(M_{S_1})|^2}{|C(m_t)|^2} \sim 0.12$$

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Thank you!