Strong suppression of fermionic EFT operators & custodial breaking

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Abstract

The present approach relies on the SM chiral symmetry breaking pattern $\mathbf{SU(2)_L \otimes SU(2)_R \to SU(2)_{L+R}}$ with the EW GB realized non-linearly and the Higgs as a singlet field. We assume the presence of new physics heavy states that do not couple directly to the SM fermions. This explains the strong experimental bounds on fermionic operators from colliders. We also predict a high suppression for the custodial symmetry-breaking oblique parameter T at tree level.

Resonances & the Electroweak Effective Theory

Our BSM contributions come from resonances, which do not couple to SM fermions. We propose the Lagrangian [1, 2]

$$\mathcal{L}_R = -\frac{1}{2}\langle \nabla^\lambda R_{\lambda\mu} \nabla_\sigma R^{\sigma\mu} - \frac{1}{2} M_R^2 R_{\mu\nu} R^{\mu\nu} \rangle + \langle R_{\mu\nu} \chi_R^{\mu\nu} \rangle,$$

where, for $R = V$

$$\chi_V^{\mu\nu} = \frac{F_V}{2\sqrt{2}} f_+^{\mu\nu} + \frac{\widetilde{F}_V}{2\sqrt{2}} f_-^{\mu\nu} + i \frac{G_V}{2\sqrt{2}} [u^\mu, u^\nu] + \frac{\widetilde{\lambda}_1^{hV}}{\sqrt{2}} [(\partial^\mu h)\, u^\nu - (\partial^\nu h)\, u^\mu] \,.$$

For the axial-vector resonance make the replacements $V_{\mu\nu} \to A_{\mu\nu}$, $F_V \to \widetilde{F}_A$, $\widetilde{F}_V \to F_A$, $\widetilde{\lambda}_1^{hV} \to \lambda_1^{hA}$ and $G_V \to \widetilde{G}_A$.

Integrating resonances [3] gives contributions to the Electroweak Effective Lagrangian couplings [1, 2]

$$\mathcal{L}_{EWET} = \mathcal{L}_{SM} + \sum_{m=2} \mathcal{L}^{(m)},$$

where m is the chiral order.

Resonance contribution to four-fermion contact interaction

Resonances contribution to EWET contact interaction LECs begins at chiral order $m = 4$.

The Lagrangian used to bound BSM effects in colliders [4, 5, 6] is given by

$$\mathcal{L}_{EWET} \supset \mathcal{L}_{qq} = \frac{2\pi}{\Lambda^2} \left(\eta_{\ell\ell} J_\mu^\ell J^{\ell,\mu} + \eta_{rr} J_\mu^r J^{r,\mu} + 2\eta_{r\ell} J_\mu^r J^{\ell,\mu} \right),$$

where the most stringent bound is for $\eta_{\ell\ell} = \eta_{rr} = \eta_{r\ell} = -1$.

Integrating the resonances & using Weinberg sum rules [7] we get an expression for Λ

$$\frac{2\pi}{\Lambda^2} = \frac{m_W^4}{v^2 M_V^4} \frac{r^3+1}{r^2(r-1)},$$

where $r = M_A^2/M_V^2$. Using $\Lambda \approx 20$ TeV [4, 5, 6] we get

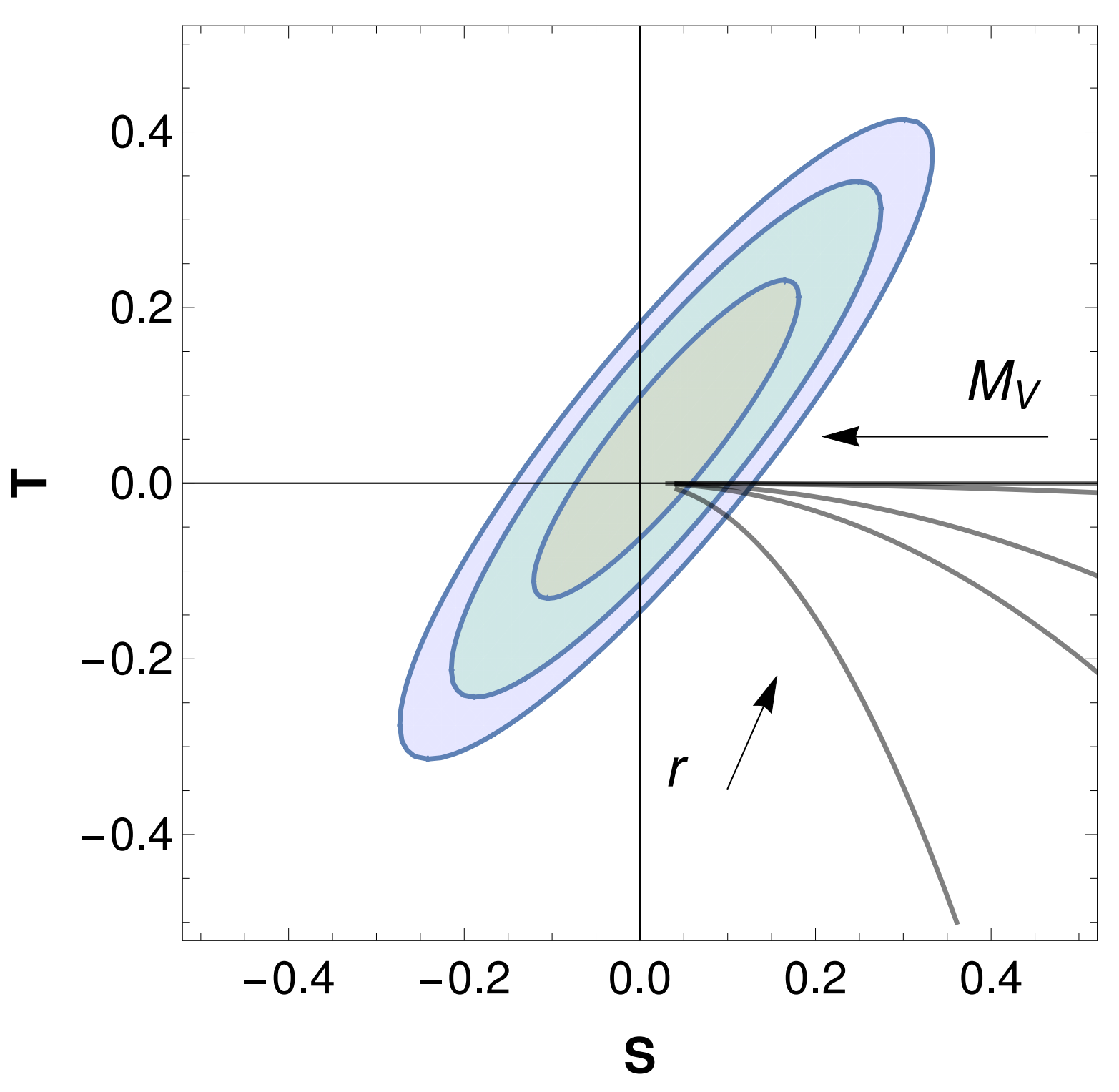
r	lower bound for M_V
$1+10^{-3}$	3.1 TeV
1.1	1.0 TeV
2	0.6 TeV
≥ 5	0.5 TeV

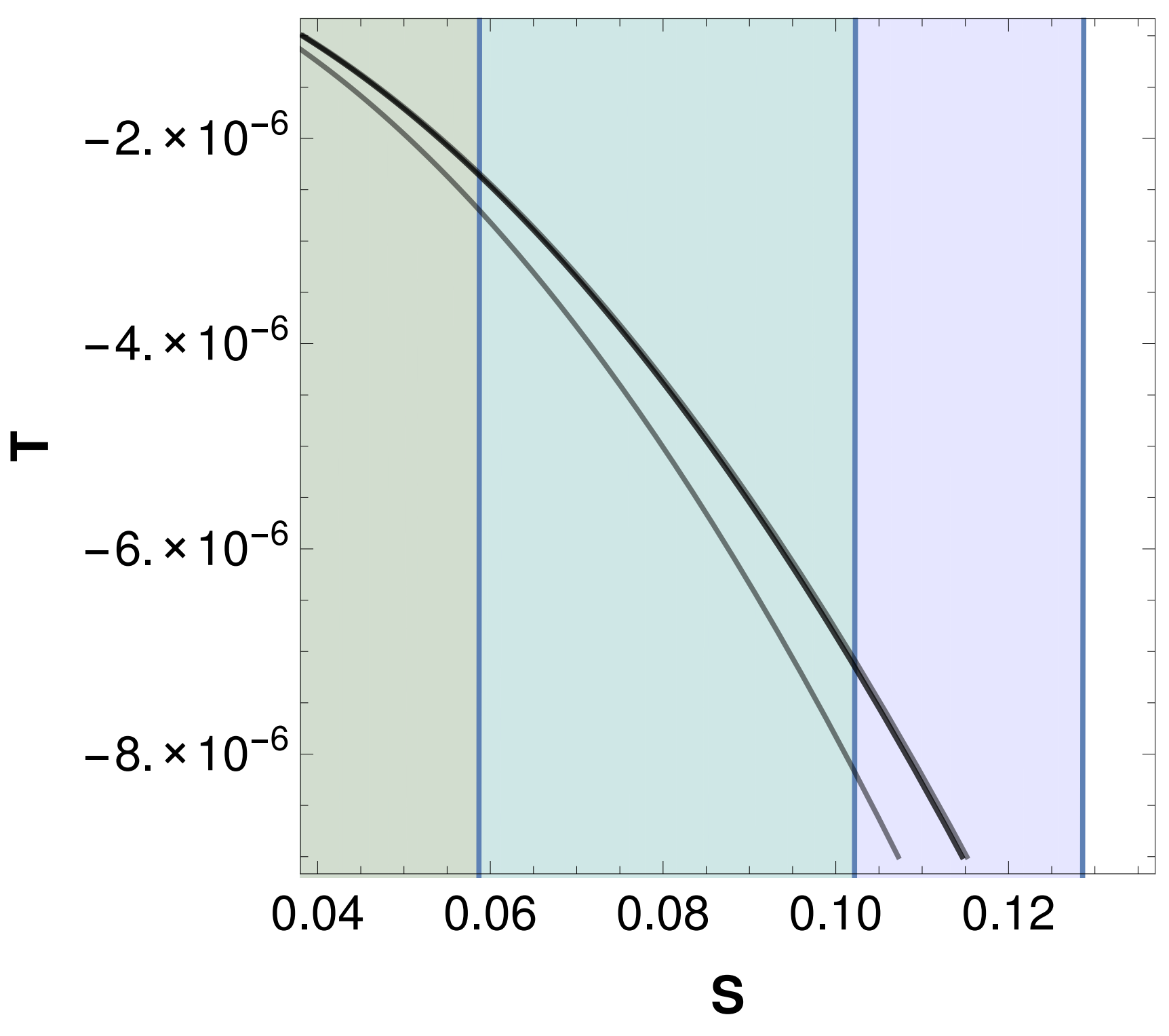
Oblique S & T parameters

A more more stringent bound is obtained from S and T [8, 9, 10], where assuming Weinberg sum rules [7] we find the tree level prediction

$$S = \frac{4\pi v^2}{M_V^2} \frac{r+1}{r}$$

$$T = -\pi \frac{v^2}{M_V^2} \frac{m_Z^2}{m_W^2} \frac{m_Z^2 - m_W^2}{M_V^2} \frac{r^3+1}{r^2(r-1)}$$





The plot on the left shows T vs S for $r - 1 = 10^{-4}, 10^{-3}, 5 \cdot 10^{-3}, 10^{-2}$ and 0.5. The one on the right for $r = 2, 3, 4$ and 5.

We give bounds on M_V for different values of r using LEP data [11].

r	lower bound for M_V	
	68%CL	95%CL
$1+10^{-3}$	5.2 TeV	4.0 TeV
1.1	5.1 TeV	3.9 TeV
2	4.5 TeV	3.4 TeV
≥ 5	3.7 TeV	2.8 TeV

Conclusions

- BSM observables involving fermionic currents can be naturally suppressed.
- Less stringent bounds on M_V are found.
- Oblique T parameter is very suppressed for $M_A > M_V$.

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