Catching Heavy Vector Triplets with the SMEFT:

from one-loop matching to phenomenology

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Phenomenology 2022

arXiv:2108.01094

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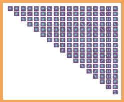
We constrain new physics along two axes: measurements and models

Global SMEFT Fits

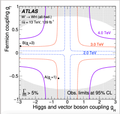


Model independent

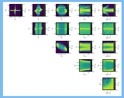
Single measurement — Constraints on new physics → All relevant measurements

Matching

Experiments



UV Model Fits



Model dependent
Heavy Vector Triplet

Today's Agenda

1. Ingredients

2. Results

3. Conclusions and Outlook

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Ingredients needed for the fit

- Fitter: **SFitter** [Lafaye, Plehn, Zerwas: hep-ph/0404282]
- Model: **Heavy Vector Triplet** $\xrightarrow{\text{matching}}$ **SMEFT (17 operators)**
- Measurements: **Higgs, Gauge and Electroweak Precision**

Our model space corresponds to parameters of the Heavy Vector Triplet model...

... and an additional nuisance parameter from the matching at 1-loop!

$$\mathcal{L}_{HVT} = \mathcal{L}_{SM} - \frac{1}{4}\widetilde{V}^{\mu\nu A}\widetilde{V}^{A}_{\mu\nu} + \frac{\widetilde{m}_V^2}{2}\widetilde{V}^{\mu A}\widetilde{V}^{A}_{\mu} - \frac{\widetilde{g}_M}{2}\widetilde{V}^{\mu\nu A}\widetilde{W}^{A}_{\mu\nu}$$
$$+ \widetilde{g}_H\widetilde{V}^{\mu A}J^{A}_{H\mu} + \widetilde{g}_l\widetilde{V}^{\mu A}J^{A}_{l\mu} + \widetilde{g}_q\widetilde{V}^{\mu A}J^{A}_{q\mu} + \frac{\widetilde{g}_{VH}}{2}|H|^2\widetilde{V}^{\mu A}\widetilde{V}^{A}_{\mu}.$$

5 UV model parameters + mass + matching scale Q

[Low, Rattazzi, Vichi: 0907.5413 | del Aguila, de Blas, Perez-Victoria: 1005.3998 | Pappadopulo, Thamm, Torre, Wulzer: 1402.4431 | Biekoetter, Knochel, Kraemer, Liu, Riva: 1406.7320 | Brehmer, Freitas, Lopez-Val, Plehn: 1510.03443]

Low and high kinematic measurements in the Higgs, Gauge and EWP sectors are included

- **Low kinematics constrain non-kinematically enhanced operators** [Butter et al.: 1604.03105 | Biekötter, Corbett, Plehn: 1812.07587]
  - Higgs measurements at LHC (275)
  - Di-boson measurements at LHC (43)
  - Electroweak Precision Observables at LEP (14)

- **High kinematics constrain kinematically enhanced operators**
  - VH resonance searches by ATLAS: 1712.06518 and **2007.05293**
  - VV resonance search by ATLAS: **2004.14636**

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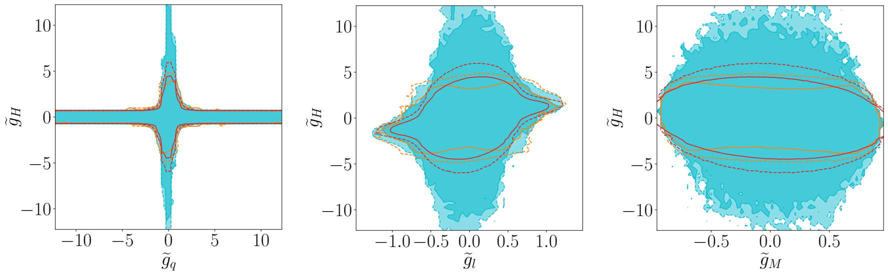
Varying the matching scale introduces (large) theoretical uncertainties

The matching scale Q should be treated as a nuisance parameter, i.e. an additional theory uncertainty.

Changes to this matching scale affect the bounds on $\widetilde{g}_H$!



Tree level matching

1-loop level matching for $Q = 4$ TeV

1-loop level matching for $Q \in [0.5, 4]$ TeV

[Other paper considering Q: Dawson, Giardino, Homiller: 2102.02823]

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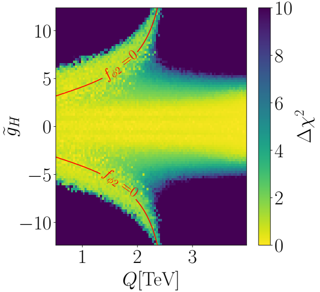
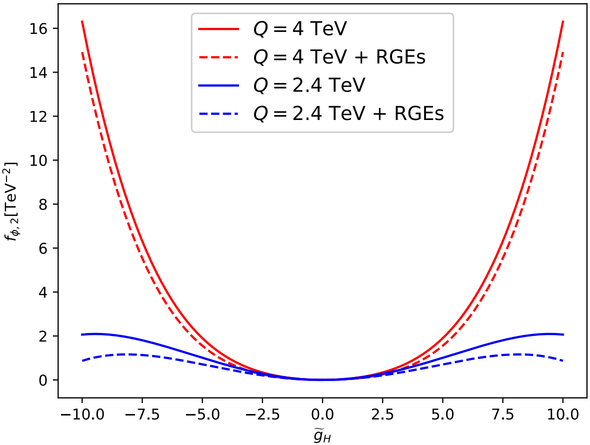


Flower due to tree-loop cancellation in $f_{\phi,2}, f_t, f_b, f_\tau$

Physical mass: $m_V = \frac{\widetilde{m}_V}{\sqrt{1-\widetilde{g}_M^2}} = 4\text{TeV}$

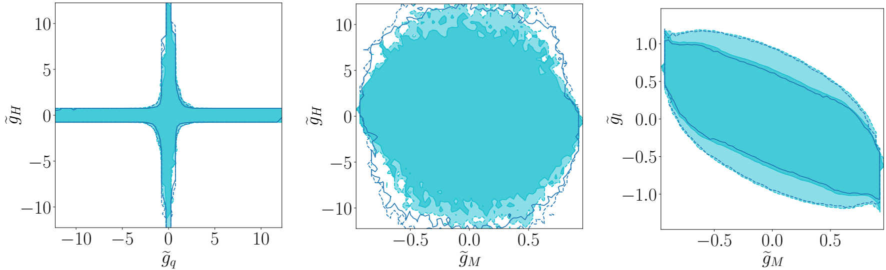
[Other paper considering Q: Dawson, Giardino, Homiller: 2102.02823]

RGEs for SMEFT parameters do not compensate for this tree-loop cancellation



RGEs for HVT parameters are not yet available in the literature.

For the HVT model, the greatest constraints come from EWPOs and not heavy resonance searches with high kinematic reach

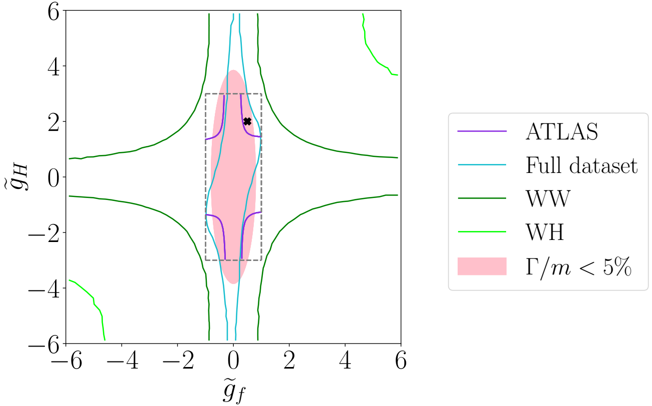


Heavy resonances searches included

Heavy resonances searches excluded

[ATLAS Collaboration: 1712.06518, 2004.14636, 2007.05293]

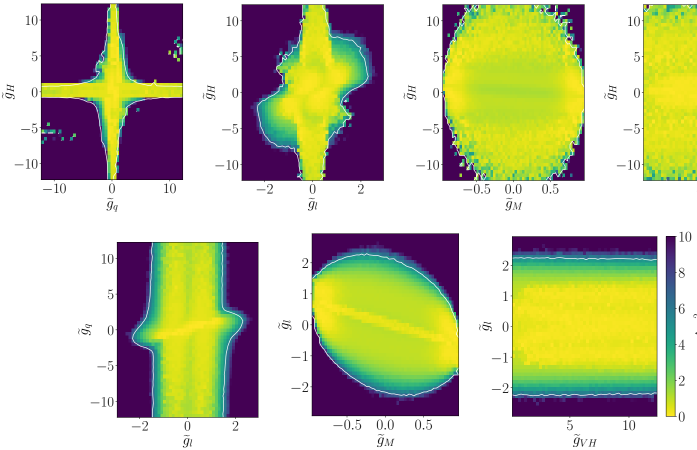
Direct searches constraints are stronger than constraints set through a SMEFT fit with the same analysis



95CL limits, physical mass: $m_V = \frac{\widetilde{m}_V}{\sqrt{1-\widetilde{g}_M^2}} = 4\text{TeV}$.

[ATLAS Collaboration: 2007.05293]

But SMEFT limits reach beyond the range of direct searches and constrain more parameters at once



We get constraints for $m_V = \frac{\widetilde{m}_V}{\sqrt{1-\widetilde{g}_M^2}} = 8\text{TeV}$, where direct resonance searches don't exist. And we fit in the full 5 parameter model space.

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SMEFT analyses and direct searches are highly complementary

- Where direct searches for heavy resonances exist, they give better constraints than the same distributions used in a SMEFT framework.

- The full SMEFT constraints are comparable to the constraints from direct searches for heavy resonances in $\widetilde{g}_H$, and stronger in $\widetilde{g}_f$, thanks to the EWPOs.

- The full SMEFT results also set constraints on all relevant UV model parameters at once and in regions beyond the reach of direct searches.

How to use global SMEFT fits to constrain a UV Model

- Use elements of an **existing SMEFT fit** (SFitter framework, SMEFT operators, measurements).
- **Match the model onto the SMEFT** at 1-loop.
- **Treat the matching scale as a nuisance parameter**, which can have big effects.

What is your preferred model?