Catching Heavy Vector Triplets with the SMEFT:

from one-loop matching to phenomenology

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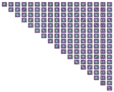
We constrain new physics along two axes: measurements and models

Model independent

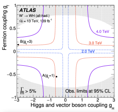


Global SMEFT fits

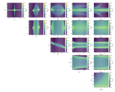
Single measurement — Constraints on new physics → All relevant measurements

matching

Experiments



UV model fits



Model dependent

Today's Agenda

1. Ingredients
2. Results
3. Conclusions and Outlook

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Ingredients needed for the fit

- Fitter: SFitter
- Model: Heavy Vector Triplet $\xrightarrow{\text{matching}}$ SMEFT (17 operators)
- Measurements: Higgs, Gauge and Electroweak Precision

The SFitter framework samples the likelihood function for a chosen model space

- What we compute: likelihood function

$$\mathcal{L}(M) = \mathcal{L}(D|M) = p(D|M)$$

- How we scan the parameter space: Markov chains

- How we measure the goodness of fit: likelihood ratio (statistical test)

$$\frac{\mathcal{L}(D|M_1)}{\mathcal{L}(D|M_2)}$$

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

We focus on specific SMEFT sectors

Higher order operators mediating **new interactions** are classified in an **expansion in 1/Λ**:

$$\mathcal{L}_{SMEFT} = \mathcal{L}_{SM}^{d\leq 4} + \frac{1}{\Lambda} c\, \mathcal{O}^{d=5} + \frac{1}{\Lambda^2} \sum c_i\, \mathcal{O}_i^{d=6} + \ldots$$

↑
59 operators, too many...

Focus on Higgs, Gauge and Electroweak Precision sectors
⇒ 17 operators / Wilson coefficients

We match the model onto the SMEFT

Matching is done at 1-loop using the functional matching formalism.
Benjamin Summ, arXiv: 2103.02487 or upcoming paper.

The matching procedure ensures that **all matrix element in the SMEFT and the HVT are equal** at $\mu = Q$.

$$\Rightarrow \quad \frac{c_i}{\Lambda^2}\left(\widetilde{g}_M, \widetilde{g}_H, \widetilde{g}_l, \widetilde{g}_q, \widetilde{g}_{VH}, \widetilde{m}_V, Q\right)$$

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

- Low kinematics constrain non-kinematically enhanced operators
  - Higgs searches by ATLAS and CMS,
  - Electroweak Precision Observables by LEP,

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

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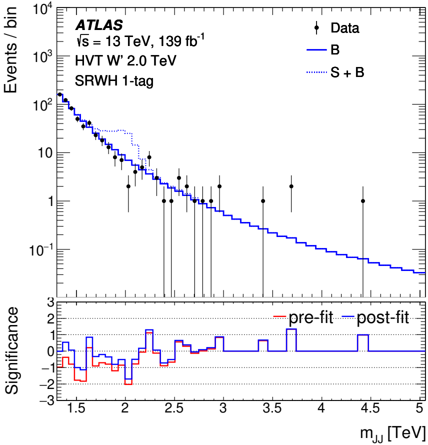
Heavy resonance searches used for their high kinematic reach are not a great source of constraints for this specific model



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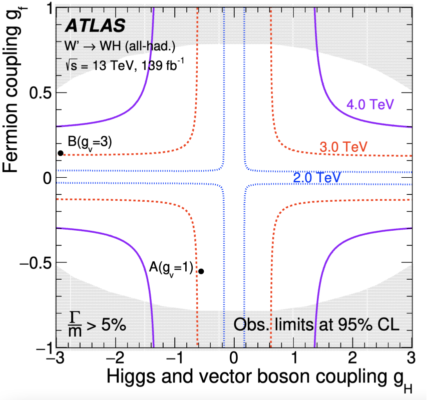

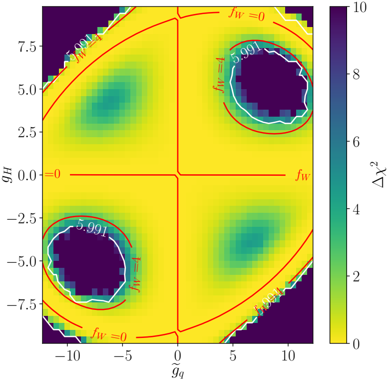

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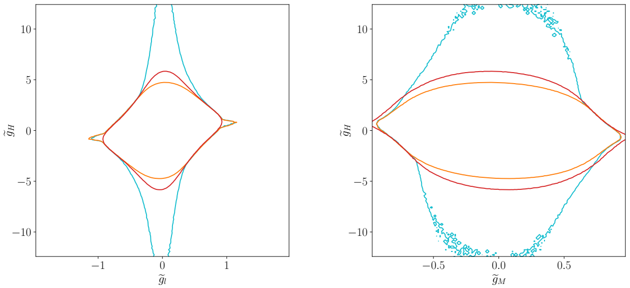
Note: all results are preliminary.

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 make 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

Note: all results are preliminary. Other paper considering Q: arXiv:2102.02823

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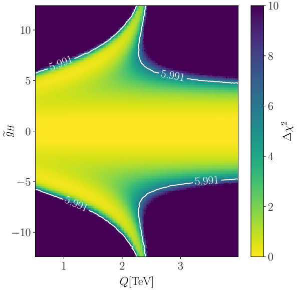

Physical mass:
$m_V = \frac{\widetilde{m}_V}{\sqrt{1-\widetilde{g}_M^2}} = 4\text{TeV}$

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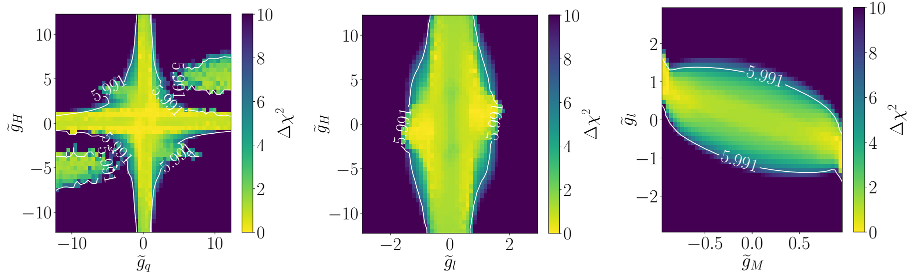
SMEFT limits reach beyond the range of direct searches and constrain more parameters at once!

We still 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 can do a fit in the full 5 parameter model space.



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Conclusions and Outlook

To catch a Heavy Vector Triplets with the SMEFT, we:

- 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.

We set constraints on the UV model parameters in regions beyond the reach of direct searches for heavy resonances.

What is your preferred model?