

# Catching Heavy Vector Triplets with the SMEFT: from one-loop matching to phenomenology

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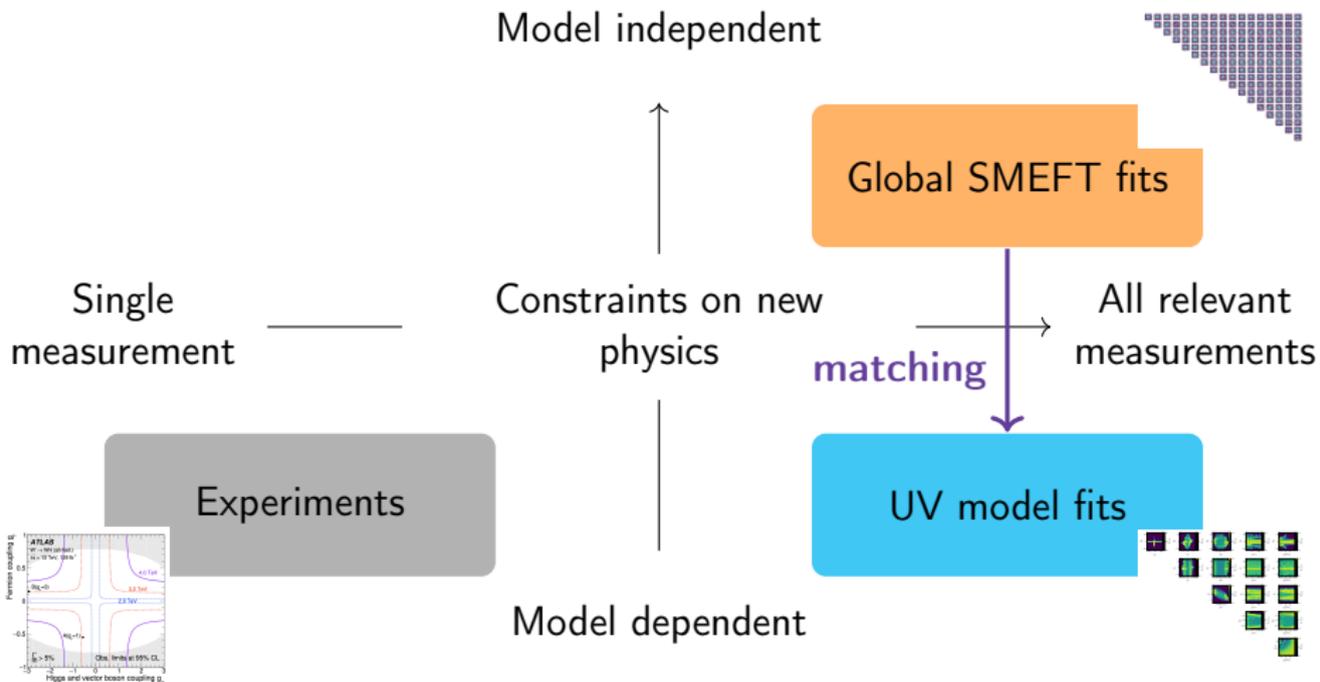
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# We constrain new physics along two axes: measurements and models



# 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!

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

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  $1/\Lambda$ :

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

↑  
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 arXiv:2108.01094.

[https://github.com/BenjaminSumm/Triplet\\_Model\\_WCs](https://github.com/BenjaminSumm/Triplet_Model_WCs)

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

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

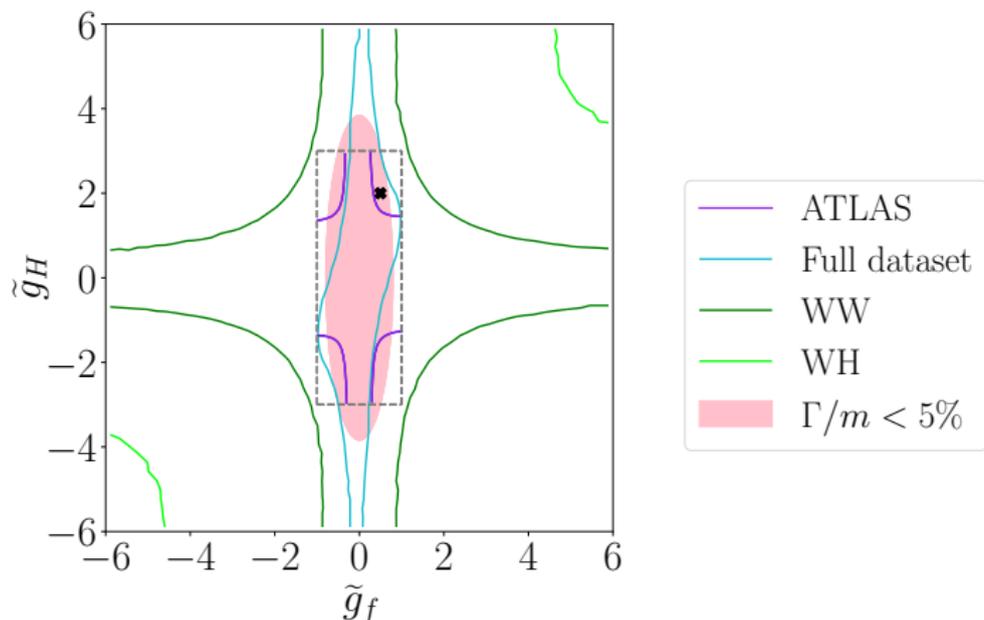
# Low and high kinematic measurements in the Higgs, Gauge and EWP sectors are included

- **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](https://arxiv.org/abs/1712.06518) and [arXiv:2007.05293](https://arxiv.org/abs/2007.05293)
  - VV resonance search: [arXiv:2004.14636](https://arxiv.org/abs/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

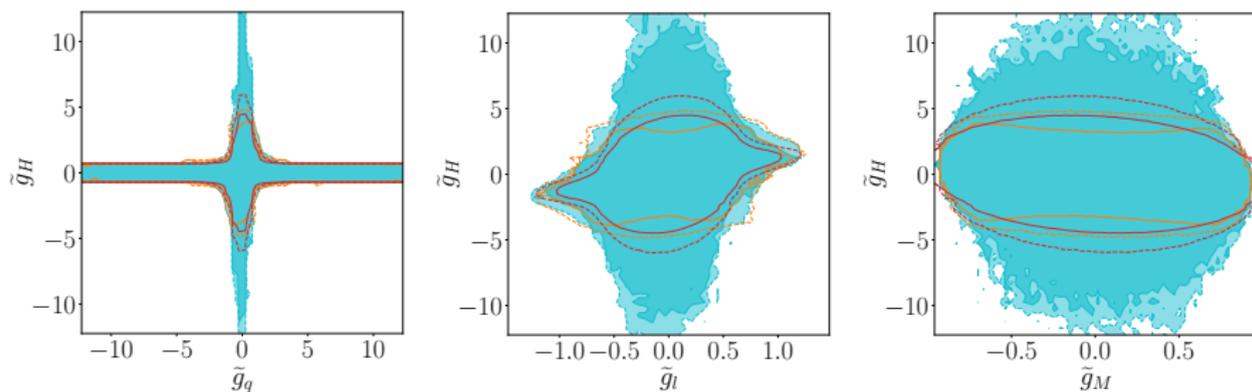


95CL limits, physical mass:  $m_V = \frac{\tilde{m}_V}{\sqrt{1-\tilde{g}_M^2}} = 4\text{TeV}$ .

# 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  $\tilde{g}_H$ !



Tree level matching

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

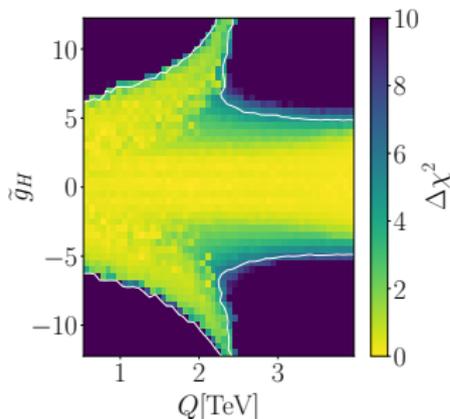
1-loop level matching for  $Q \in [0.5, 4]$  TeV

Other paper considering  $Q$ :  
arXiv:2102.02823

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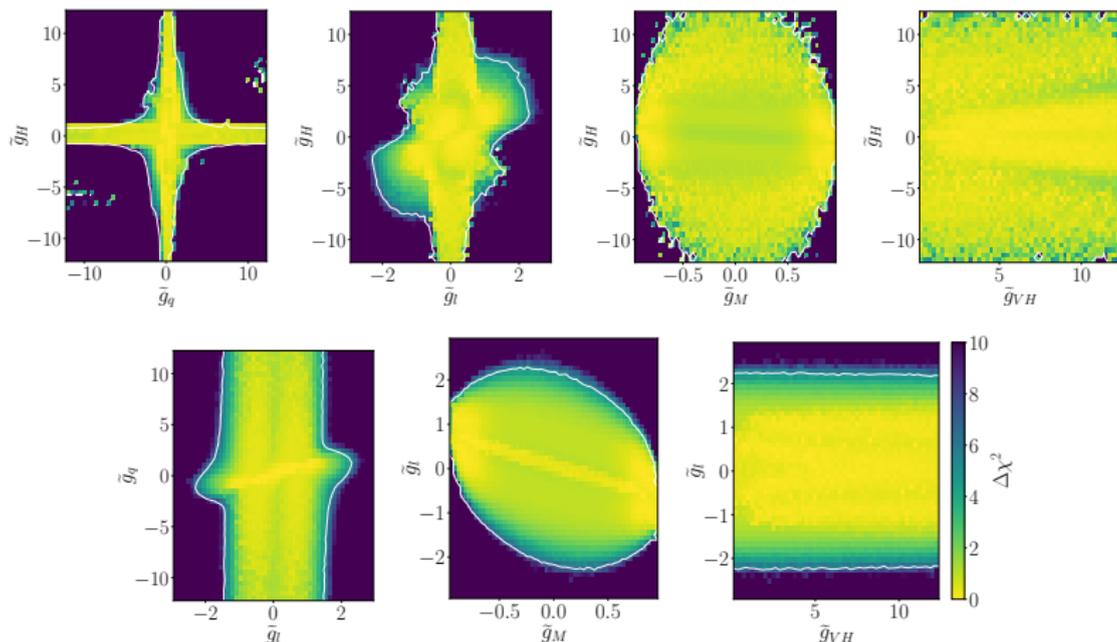


Physical mass:

$$m_V = \frac{\tilde{m}_V}{\sqrt{1 - \tilde{g}_M^2}} = 4\text{TeV}$$

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



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

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# 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?