Catching Heavy Vector Triplets with the SMEFT:

from one-loop matching to phenomenology

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arXiv:2108.01094

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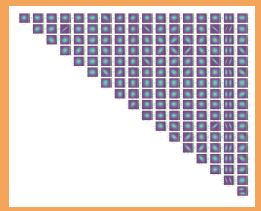
We constrain new physics along two axes: measurements and models

Model independent

Global SMEFT Fits



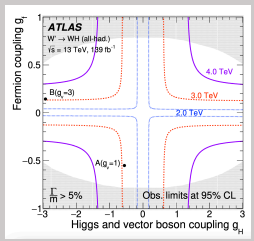
Single measurement

Constraints on new physics

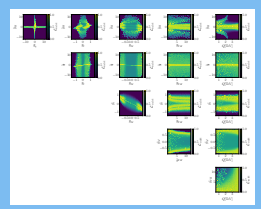
All relevant measurements

Matching

Experiments



UV Model Fits



Model dependent

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** [arXiv: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

arXiv:0907.5413, arXiv:1005.3998, arXiv:1402.4431,
arXiv:1406.7320, arXiv:1510.03443

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

arXiv:1604.03105, arXiv:1812.07587

- **Low kinematics constrain non-kinematically enhanced operators**
  - 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: arXiv:1712.06518 and **arXiv:2007.05293**
  - VV resonance search by ATLAS: **arXiv:2004.14636**

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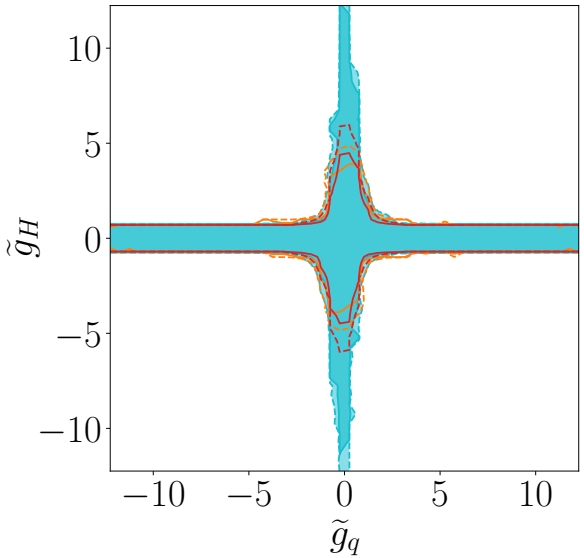
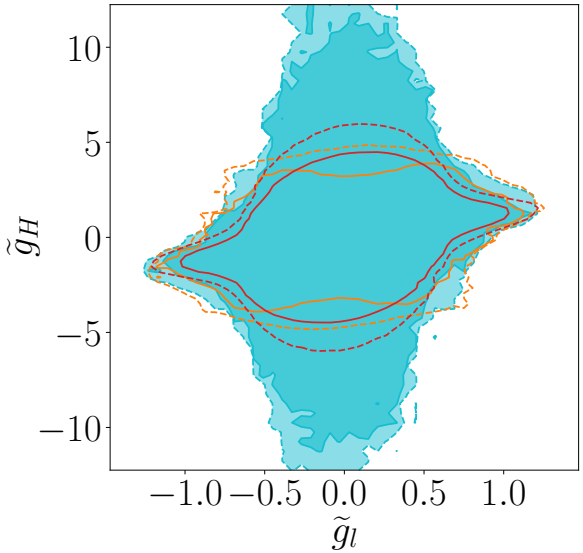
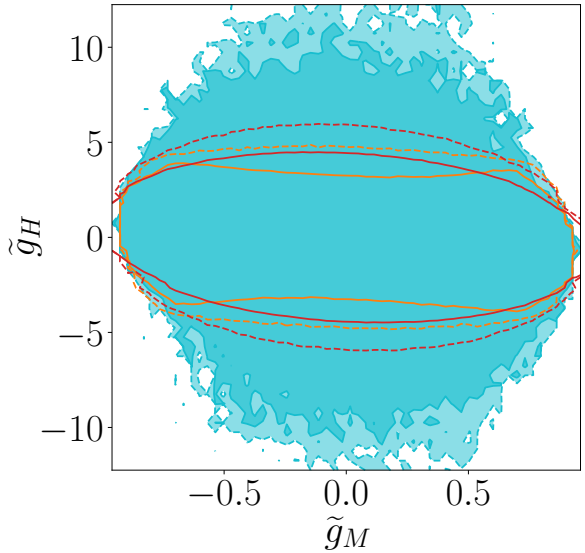
Varying the matching scale introduces (large) theoretical uncertainties

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 $Q = 4\,\text{TeV}$

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

Other paper considering Q:
arXiv:2102.02823

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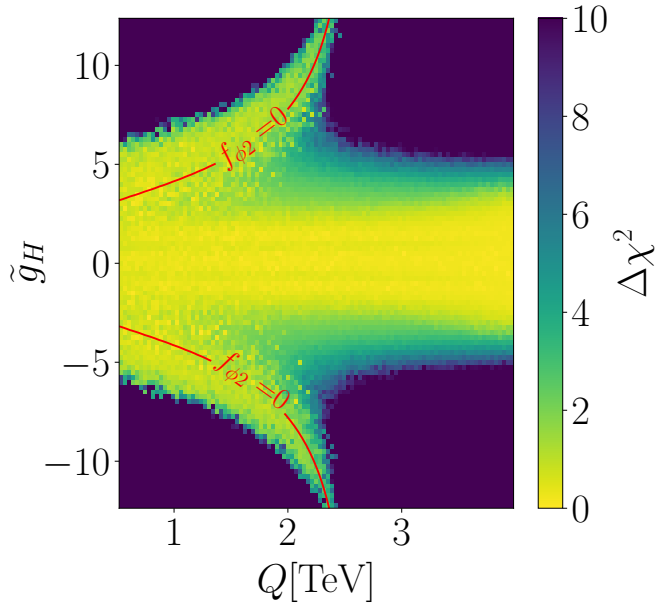
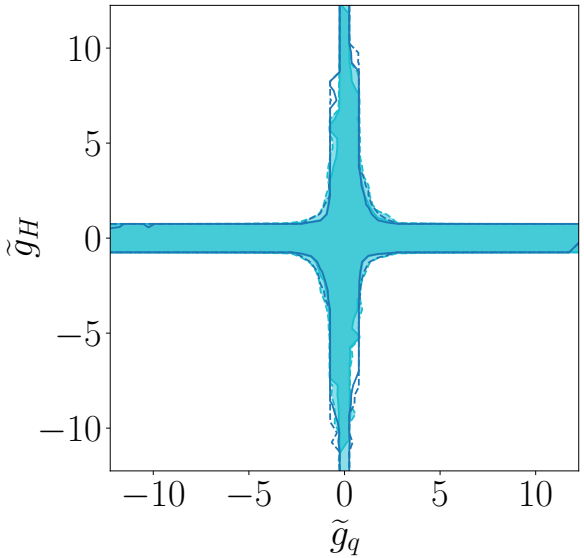


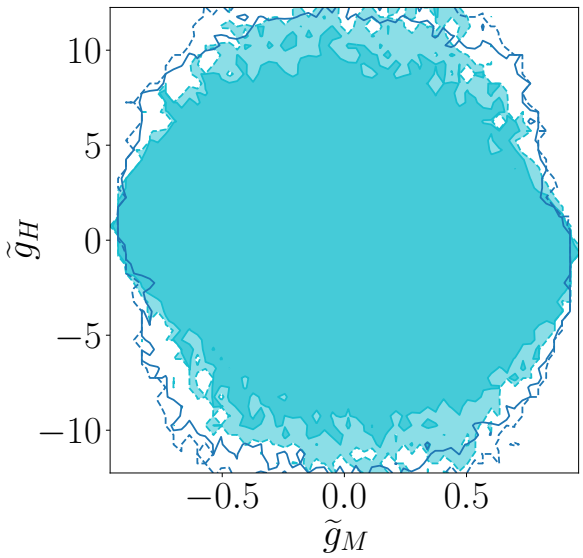
Flower due to tree-loop cancellation in $f_{\phi,2}, f_t, f_b, f_\tau$

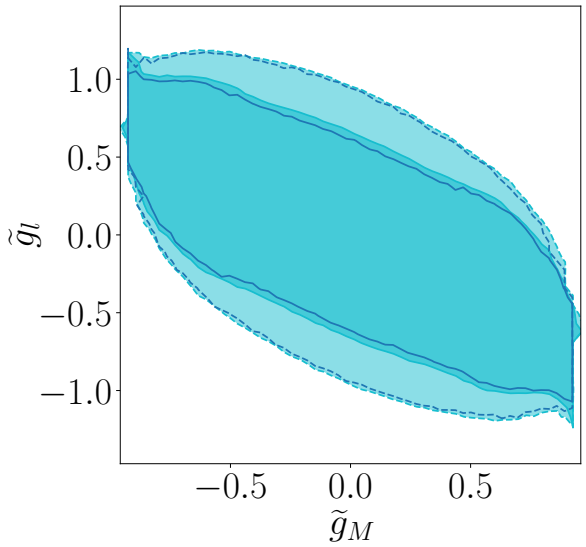
Physical mass: $m_V = \frac{\widetilde{m}_V}{\sqrt{1-\widetilde{g}_M^2}} = 4\text{TeV}$

Other paper considering Q: arXiv:2102.02823

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





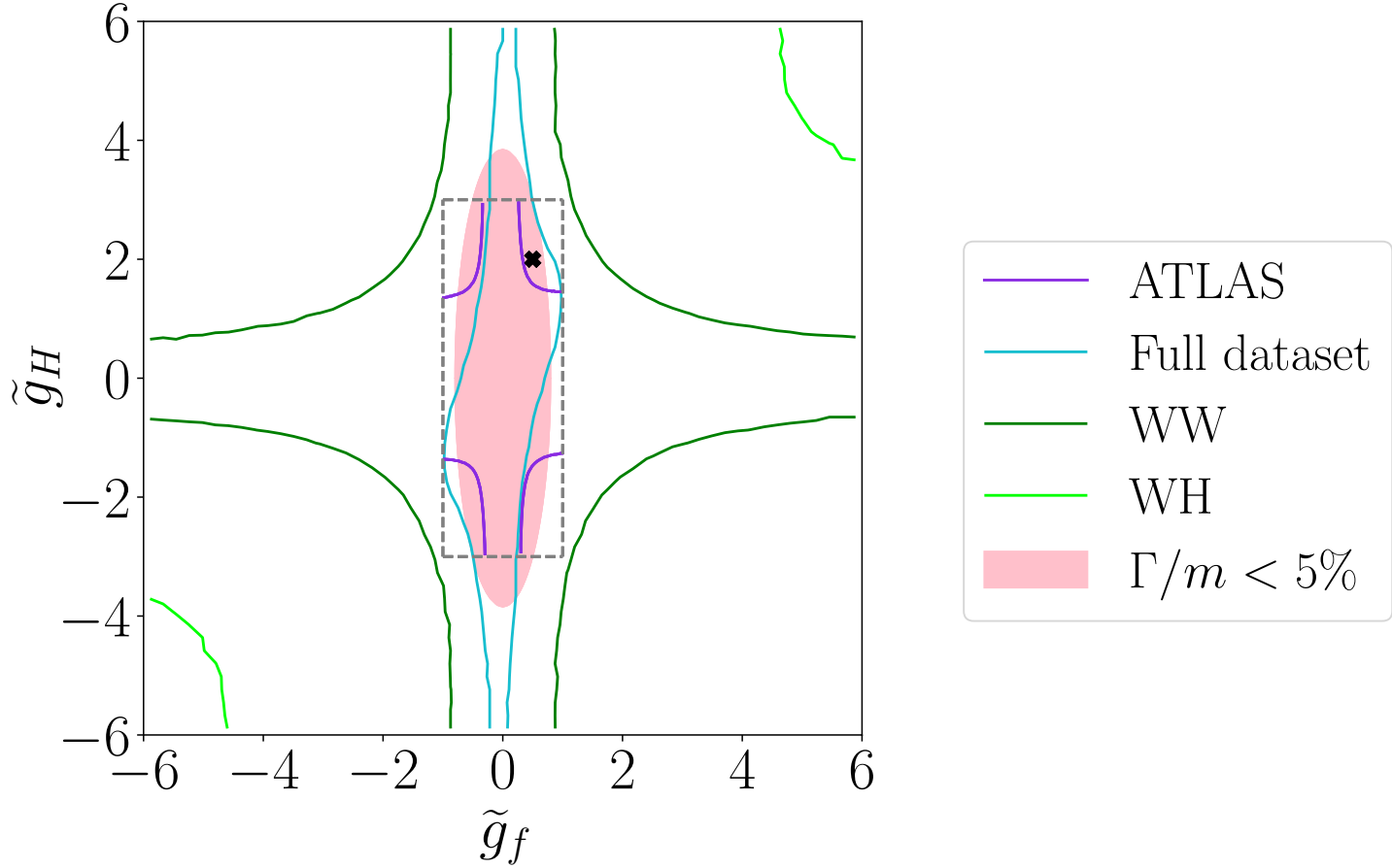


Heavy resonances searches included

Heavy resonances searches excluded

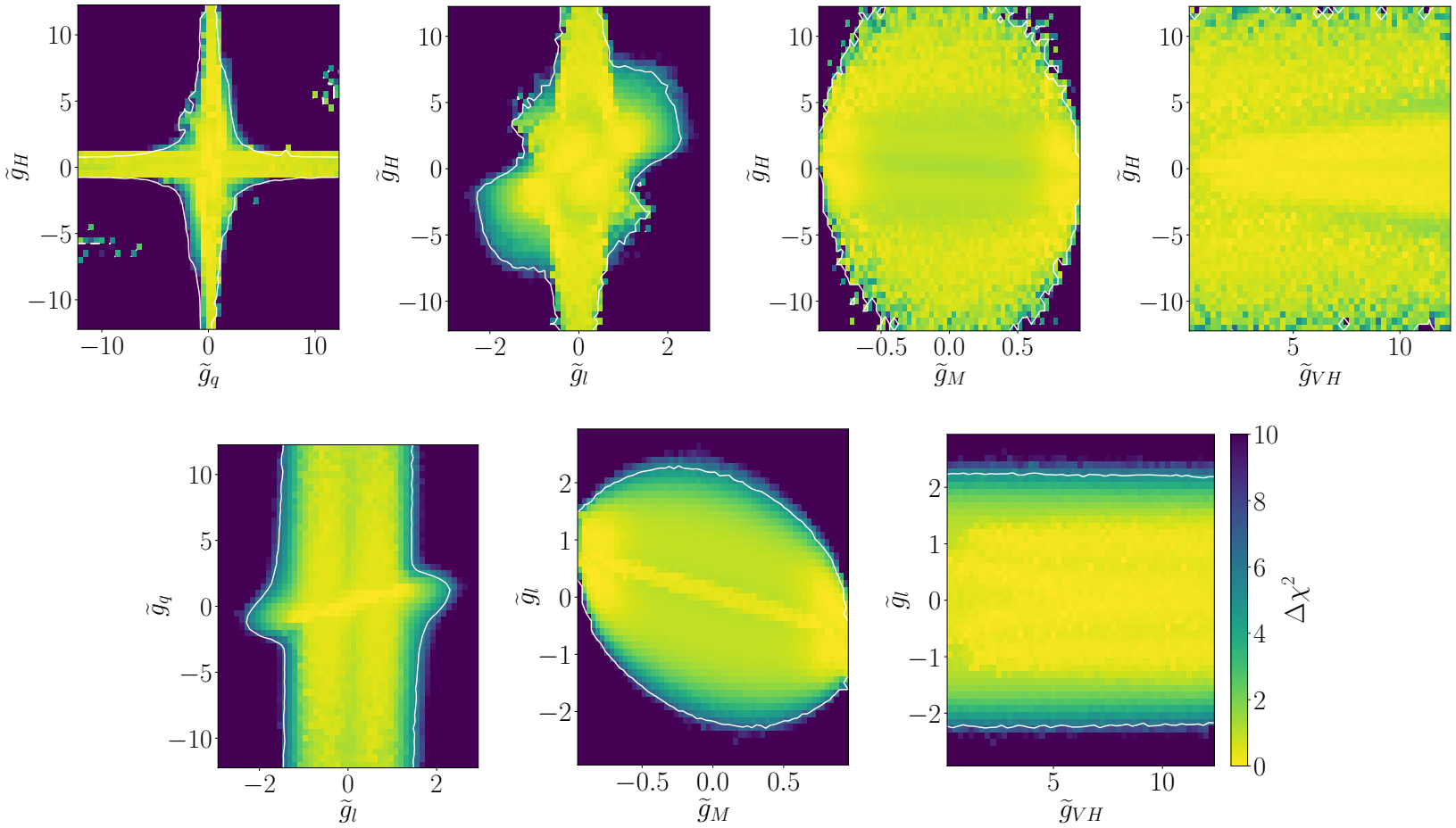
arXiv:1712.06518, arXiv:2007.05293, arXiv:2004.14636

In the range where direct searches exist, they are more powerful than constraints set through a global SMEFT analysis



95CL limits, physical mass: $m_V = \frac{\widetilde{m}_V}{\sqrt{1-\widetilde{g}_M^2}} = 4\text{TeV}.$ arXiv:2007.05293

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



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

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SMEFT analyses and direct searches are highly complementary

- Where **direct searches** for heavy resonances exist, they give the **best constraints**.

- While the **SMEFT** results, set **constraints** on all relevant UV model parameters in regions **beyond the reach of direct searches**, taking into account all relevant measurements.

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?