Using SFitter to Constrain New Physics

in model independent and dependent ways

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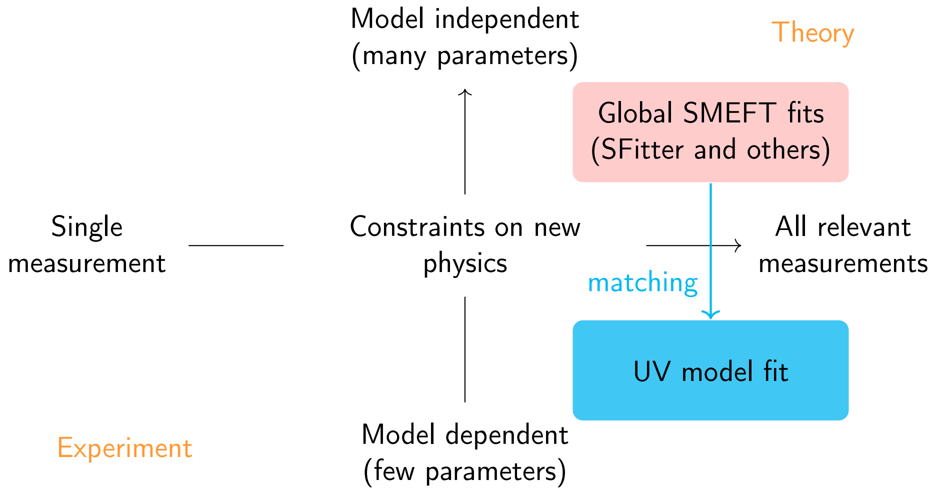
We consider two axes when constraining new physics: measurements and models



Today's Agenda

1. The Model Independent Way: Global SMEFT Fit
2. The Model Dependent Way: UV Model Fit
3. Conclusions and Future Perspectives

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The SFitter framework samples the likelihood function

- 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 theory/model is the SMEFT

Basics of EFTs

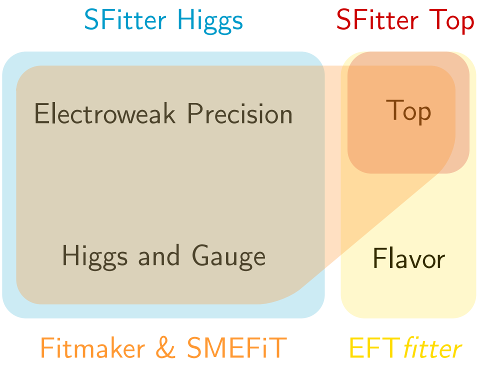
- **Assume new physics is much heavier than current phenomena.**
- Take the **same ingredients** as in the current theory: **symmetries and particle content**.
- Add **higher order operators** mediating **new interactions** between those particles which respect the symmetries.
- Operators are "classified" in an **expansion in the 1/Λ** (Λ = new physics scale) or equivalently according to their dimension.

Standard Model Effective Field Theory:

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

↑
59 operators

There are too many operators in the SMEFT, so we divide them in sectors



Obstacle to joining the two fits:

more operators
$\Rightarrow$ more CPU time.

Solution:

Bayesian approach
(work in progress)

SFitter Higgs: arXiv:1812.07587 | SFitterTop: arXiv:1910.03606
EFT*fitter*: arXiv:2012.10456 | Fitmaker: arXiv:2012.02779
SMEFiT: arXiv: 2105.00006

We specialize in careful uncertainty treatment and non-standard measurements

I. Steps to a careful uncertainty treatment:

- Consider uncertainties on signal and background measurements, SM predictions, and SMEFT Monte Carlo predictions.
- Assign to each uncertainty the correct probability distribution: **gaussian, flat, or poissonian**.
- Decide which uncertainties to **correlate** (systematic) or uncorrelate (statistical).

We specialize in careful uncertainty treatment and non-standard measurements

II. Measurements included in the SFitter Higgs fit:

- standard: Higgs searches by ATLAS and CMS, Electroweak Precision Observables by LEP,
- non-standard: Exotics or Higgs and Diboson searches by ATLAS and CMS (e.g. searches for VH and VV resonance, or $H \to \text{inv}$),
- **crucial: high kinematic distributions** constraining kinematically enhanced operators.

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We can constrain specific UV models by matching them onto the SMEFT

SFitter (same operators, measurements and machinery)

$+$ **Matching** of a UV model parameters onto the SMEFT coefficients

($+$ Basis rotation)

$=$ **Limits on UV model parameters** from all the measurements already included in SFitter!

OUR UV MODEL IS THE HEAVY VECTOR TRIPLET

Consider an additional vector triplet V transforming under $SU(2)_L$:

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

5 UV model parameters + **mass** + **matching scale Q** (at 1-loop)

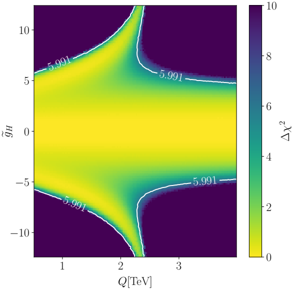
enter in **17 SMEFT coefficients inside SFitter** after matching procedure.

Matching at 1-loop using the functional matching formalism.
Benjamin Summ, arXiv: 2103.02487.

It's important to match at 1-loop and vary the matching scale

When matching at 1-loop, you must introduce a matching scale Q.

And changes to this matching scale can make a huge difference in the bounds on $\tilde{g}_H$!



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

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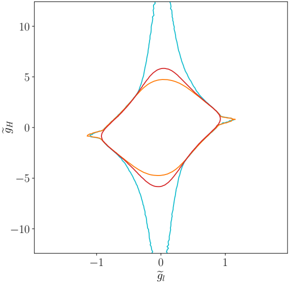

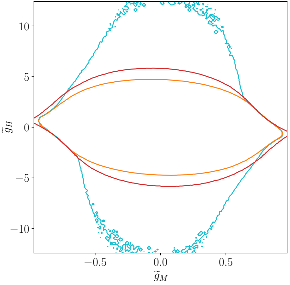

Tree level matching

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

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

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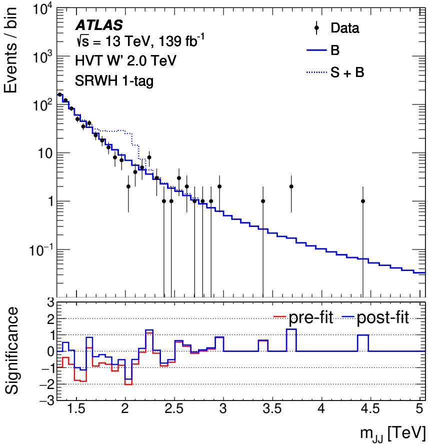
Next we include resonance searches, but use them for their high kinematic reach



arXiv: 2007.05293

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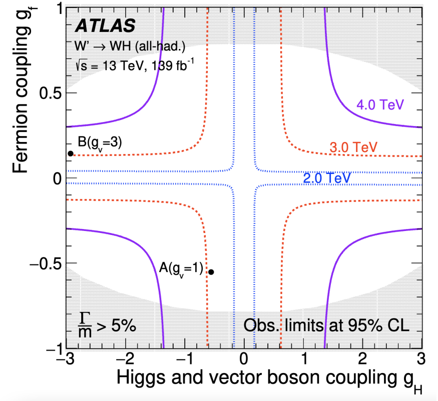

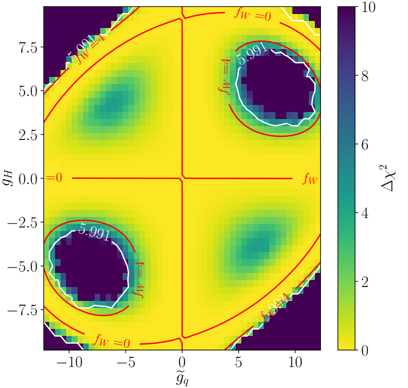

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There is more than one avenue to improve and use global SMEFT fits!

Model independent way: global SMEFT fit

- Add more operators (and sectors)
- Improve uncertainty treatment
- Add non-standard measurements
- Other: PDFs, NLO QCD, etc...

Model dependent way: UV model fit

- Match your preferred UV model onto the SMEFT at 1-loop (or more)
- Treat the matching scale as a theory uncertainty (nuisance parameter)
- Add relevant exotic searches

Thank you all for your attention.