EFT vs Top Down Approaches

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→ leads to actual **discoveries**

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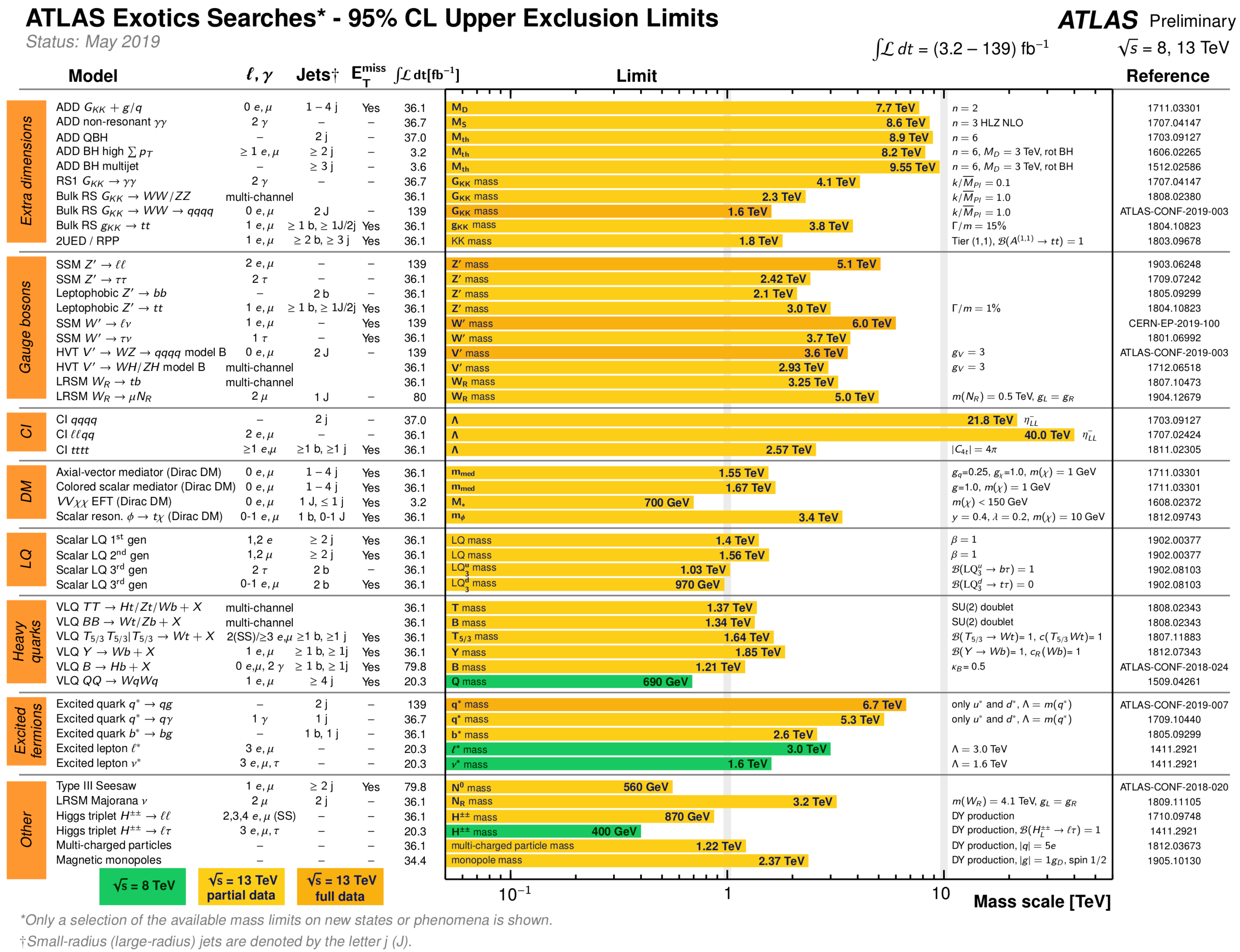
Provocative Statement:
"Direct Search" → Top Down Approach
"Indirect Search" → Effective Field Theories (EFT)

Top Down Approach

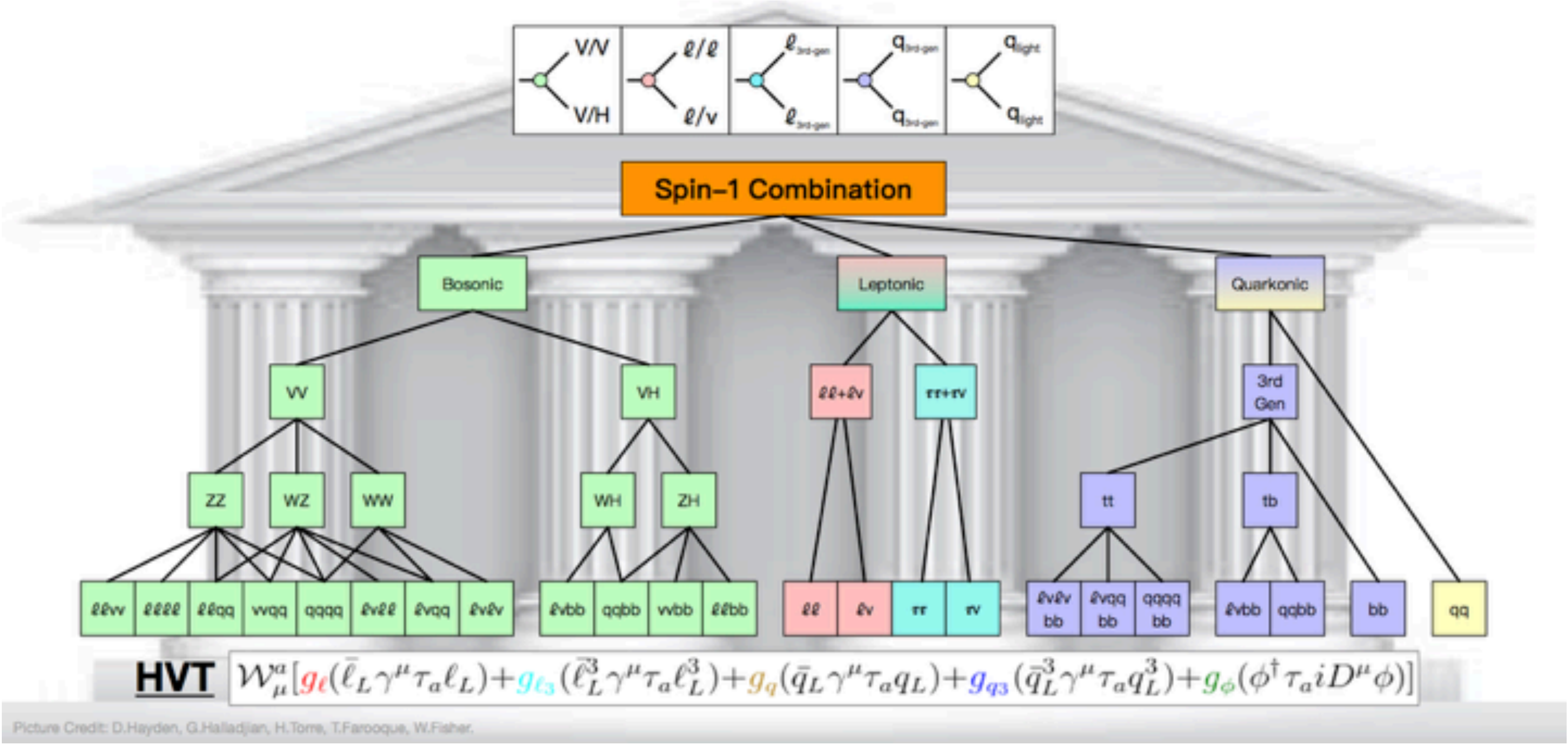


- Key Idea: If new physics is directly observable at the LHC, should be seen as a resonance or broad excess/deficit.

- LHC experiments cover many different final states with dedicated searches for specific models.

Top Down Approach

- Are efforts in both ATLAS and CMS to bring these separate searches together into a more general framework.



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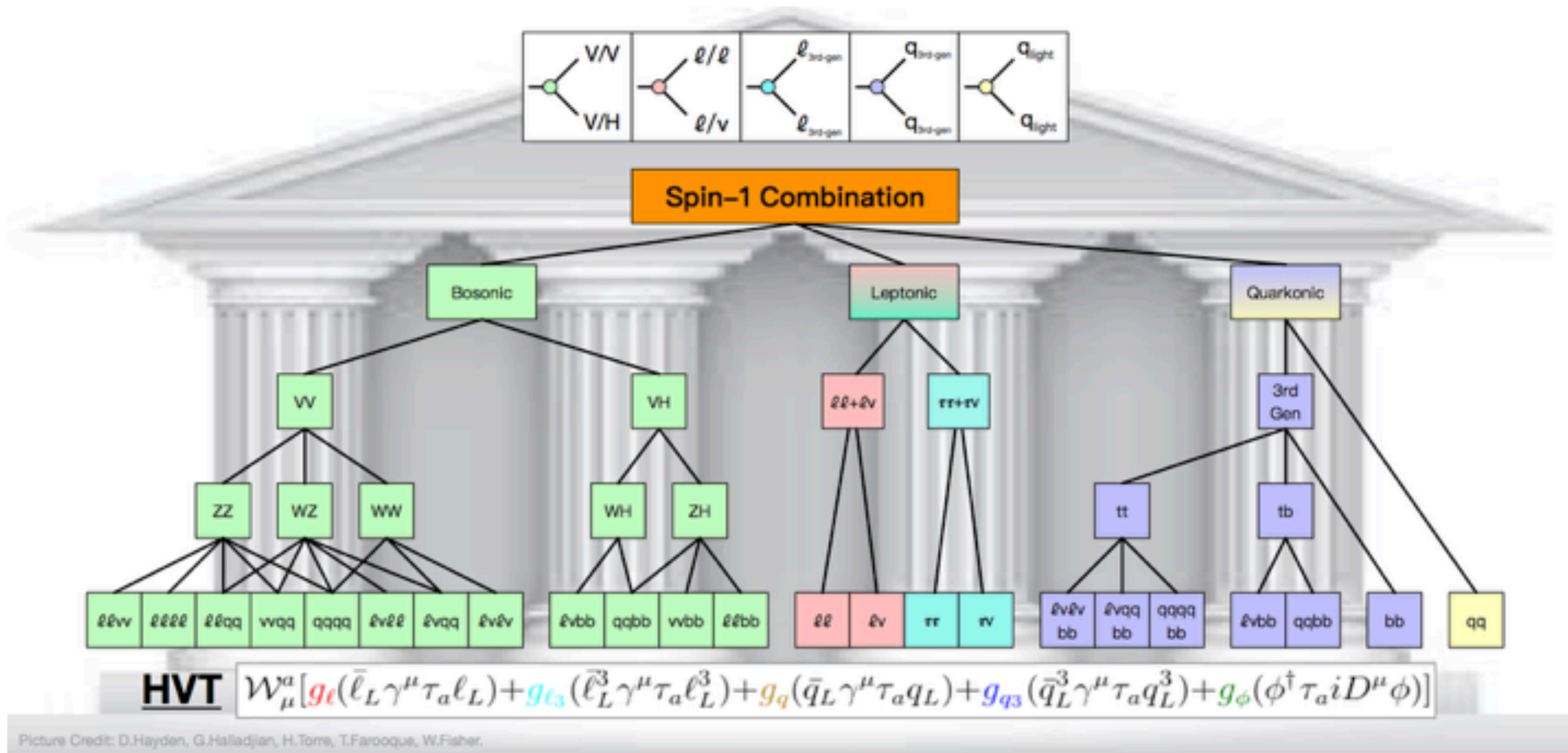
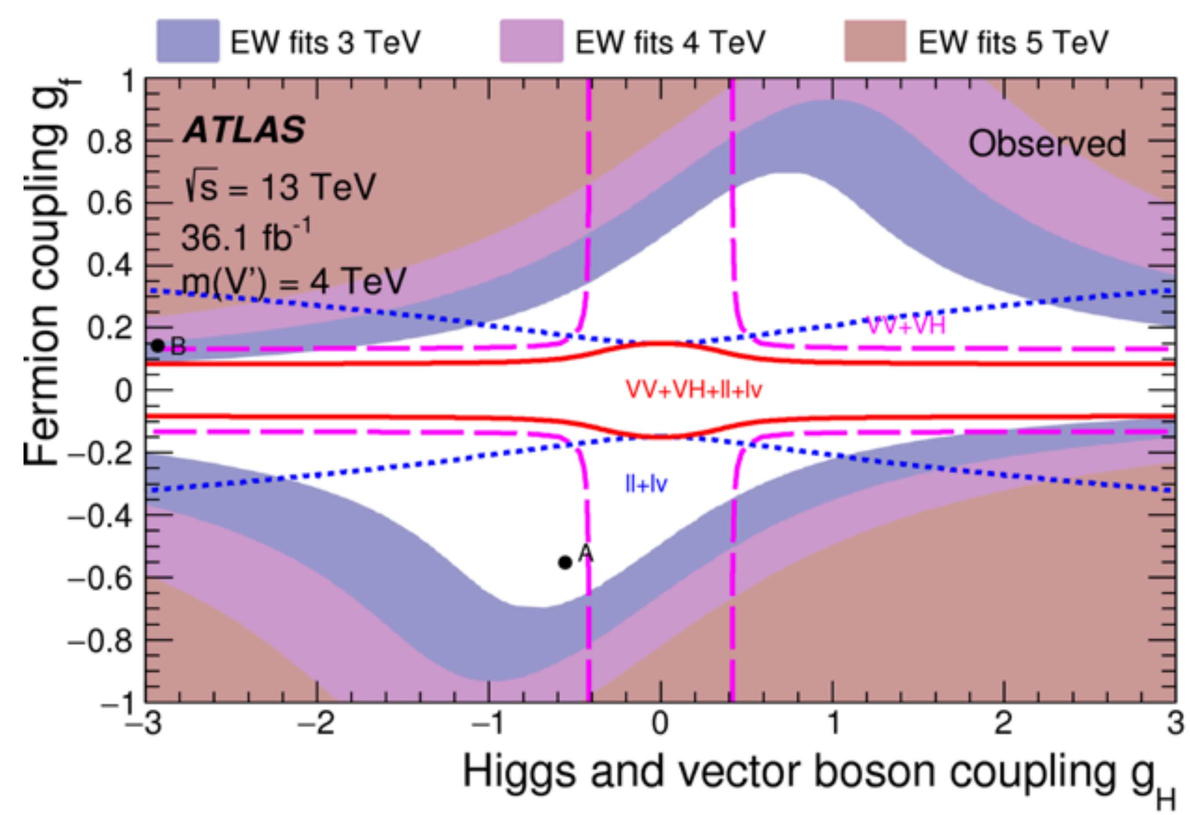


Link

- Rather than simply setting limits on xsec and mass, also make statement about SM coupling.
- Still not truly agnostic (Spin-0/2, non-resonant, complex structure)
- Searches != Precision Measurements



Limitations

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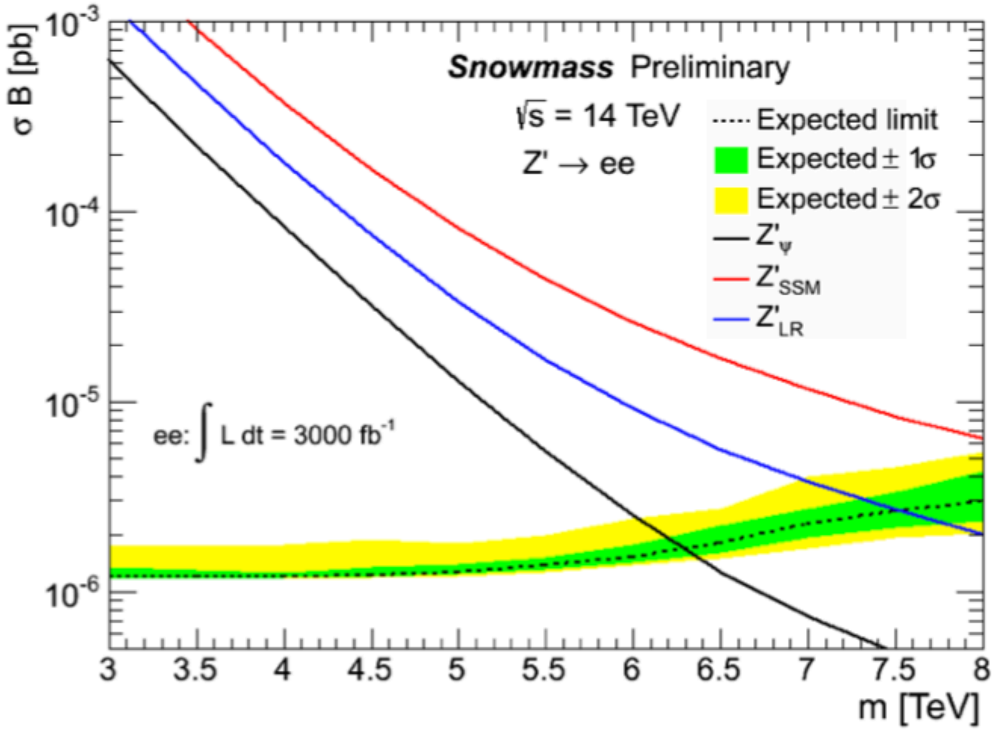

Figure 1-26. *Upper cross-section limits for the process* $q\bar{q} \rightarrow Z' \rightarrow e^+e^-$*, set at 95% CL using a Bayesian statistical interpretation given 3000* fb^{-1} *of data collected at* $\sqrt{s} = 14$ *TeV. Various signal scenarios are overlayed, with mass exclusion limits extracted at the intersection of the theory-expected lines.*

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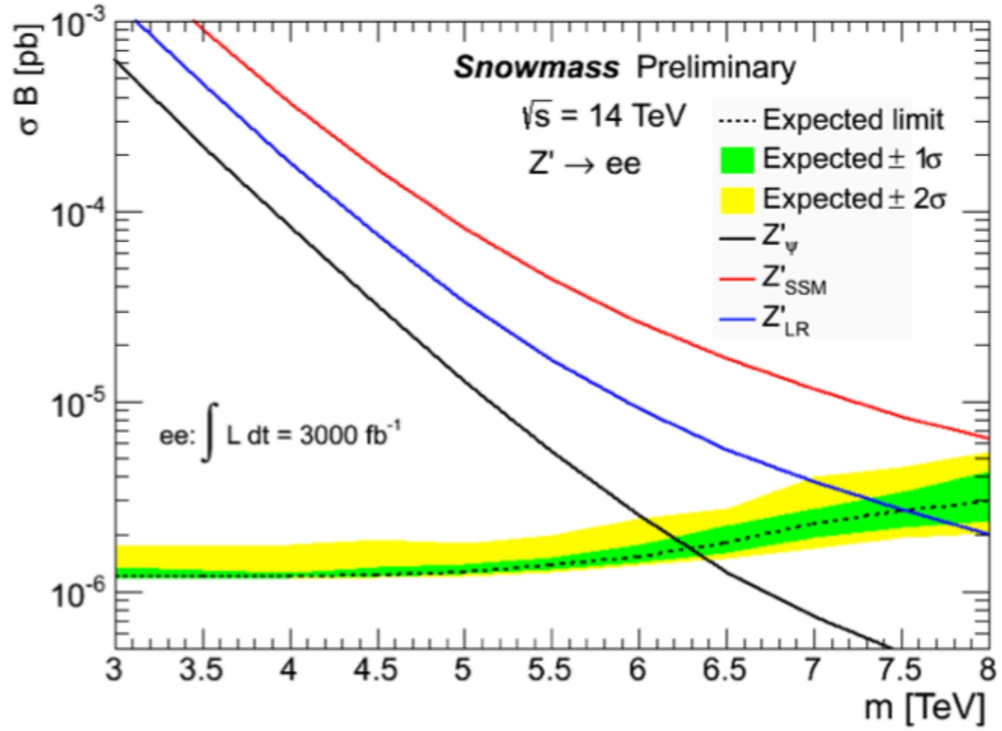

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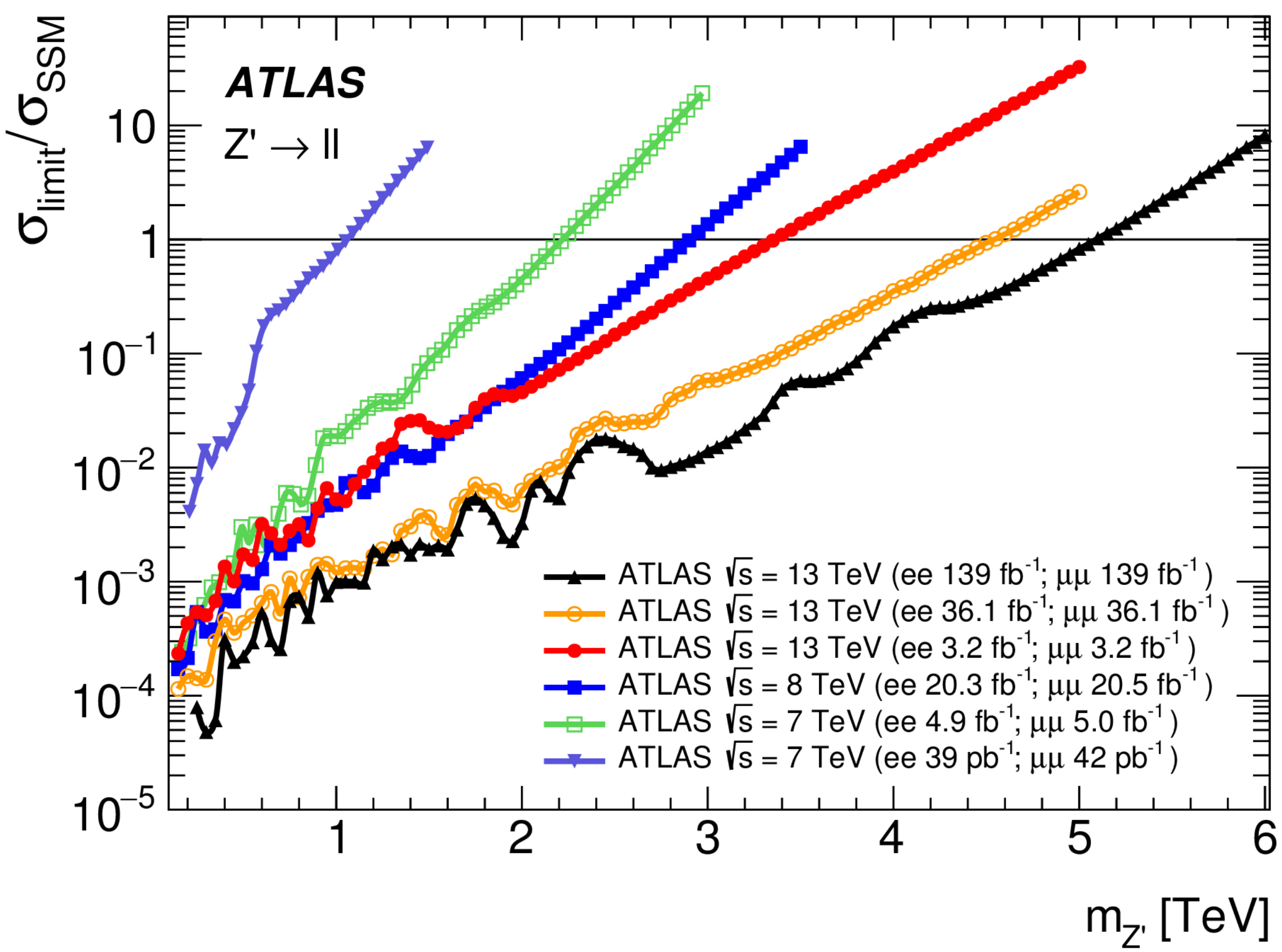

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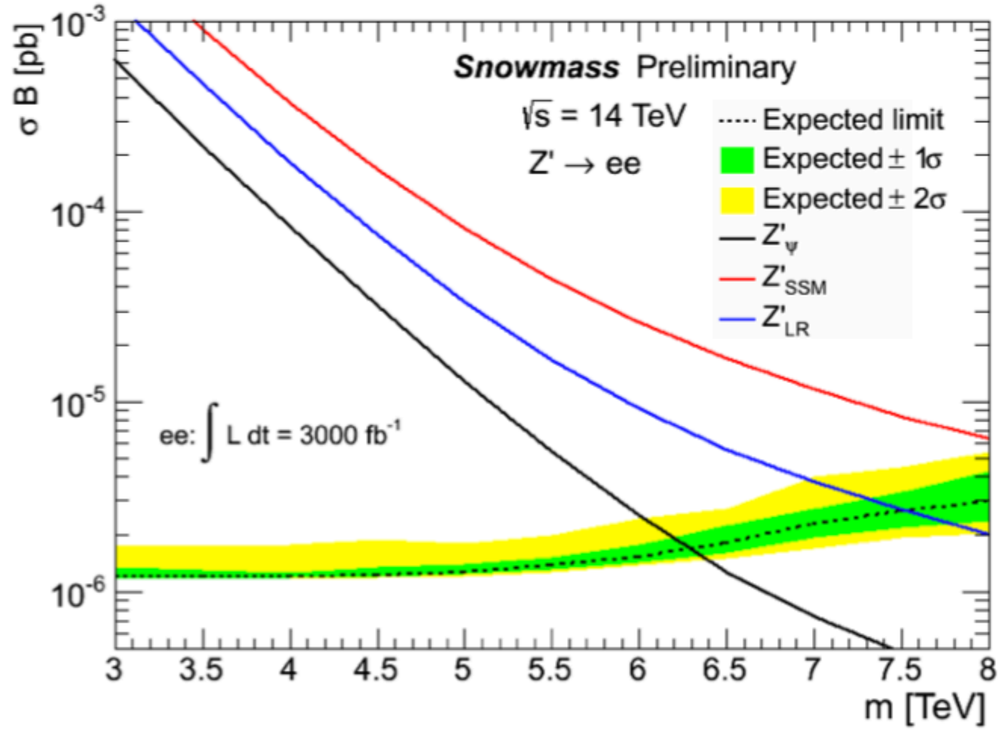

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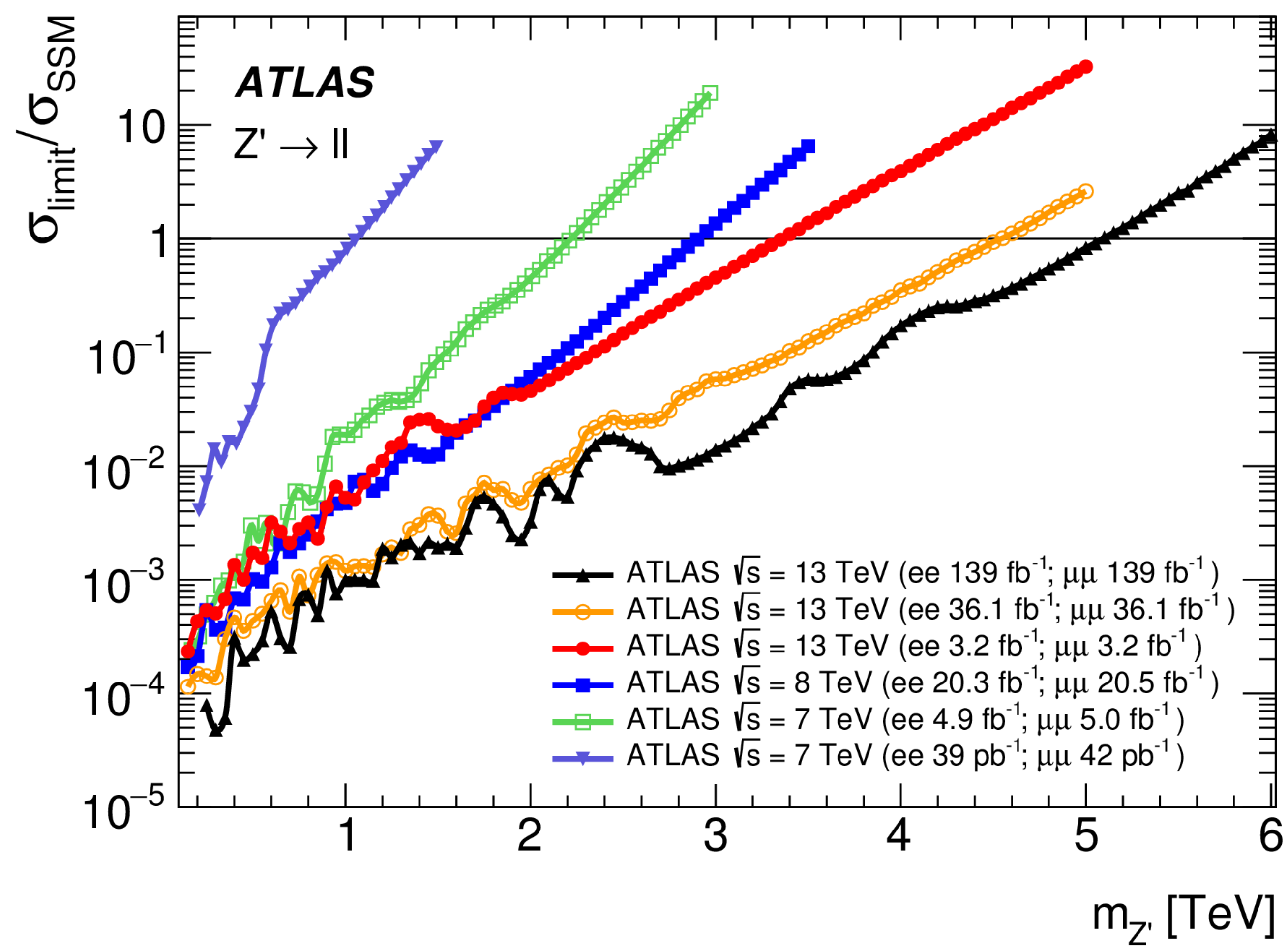
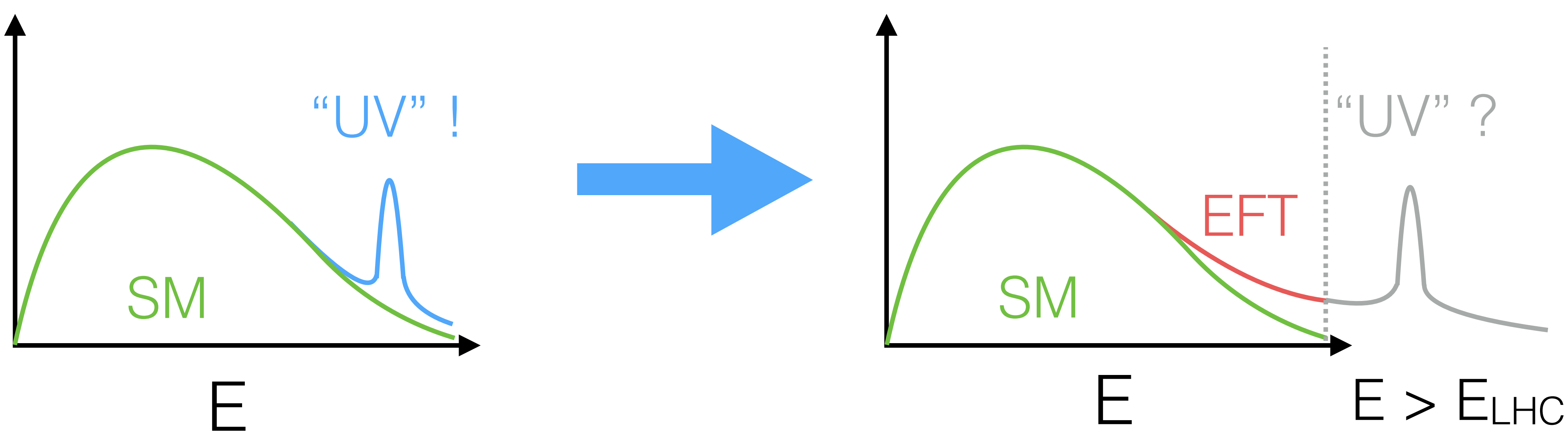


From K. Mimasu

direct searches



EFT Approach

- Key Idea: If new physics is characterized by a very large energy scale Λ (particle mass / compositeness scale / …), it's impact at the LHC can be described by an EFT.
- Pros of EFT Approach:
  - Model independent, within assumptions.
  - Do not need knowledge of UV model to make predictions.
  - Better than just anomalous couplings, as it's a full QFT.
  - Gives a systematic classification of all possible BSM effects.
  - Gives access to physics beyond LHC reach.

An EFT for BSM searches: The SMEFT

fundamental assumptions:

- new physics nearly decoupled: $\Lambda \gg (v, E)$
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Taylor expansion in canonical dimensions ($\delta = v/\Lambda$ or E/Λ):

$$\mathcal{L}_{\mathrm{SMEFT}} = \mathcal{L}_{\mathrm{SM}} + \frac{1}{\Lambda}\mathcal{L}_5 + \frac{1}{\Lambda^2}\mathcal{L}_6 + \frac{1}{\Lambda^3}\mathcal{L}_7 + \frac{1}{\Lambda^4}\mathcal{L}_8 + \ldots$$

$\mathcal{L}_n = \sum_i C_i \mathcal{O}_i^{d=n}$

C_i free parameters (Wilson coefficients)

$\mathcal{O}_i$ invariant operators that form a complete, non redundant basis

What precision is needed?

A back-of-the-envelope estimate:

on poles

$$\text{NP impact} \sim \frac{v^2 g}{M^2} = \frac{v^2}{\Lambda^2}$$

UV coupling to SM (g); mass of new resonances (M); EFT cutoff (Λ)

$$g \simeq 1 \quad M \gtrsim 2-3\ \text{TeV} \rightarrow 1\%$$

(LHC reach)

at least!

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- A parameter space reduction
- B experimental precision required

	pole observables	tails of dist.
A	remarkable	difficult (ψ^4)
B	need 1 %	ok with tens of %

Pole and tails are complementary!

Current Measurements & HL-LHC Projections

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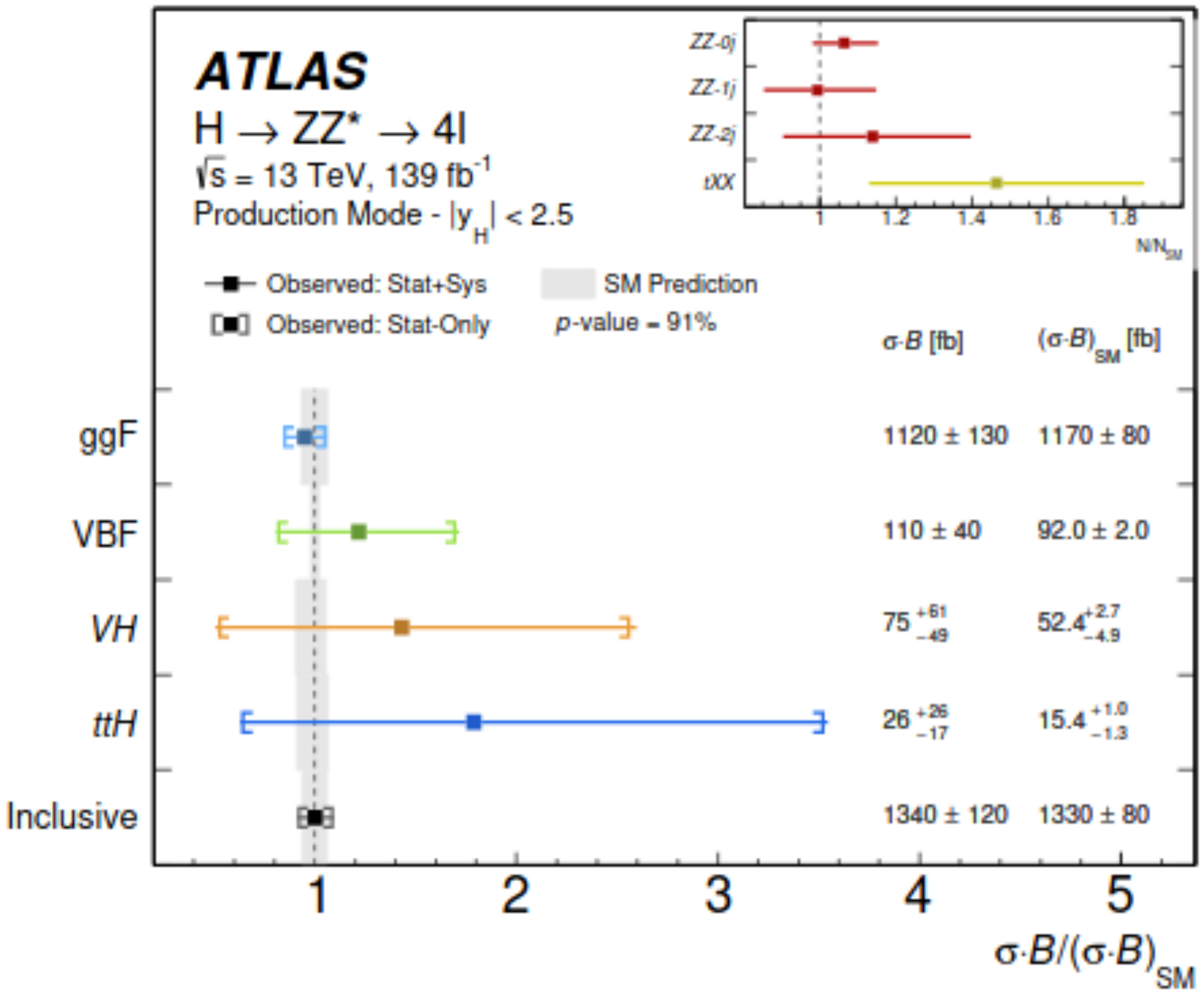

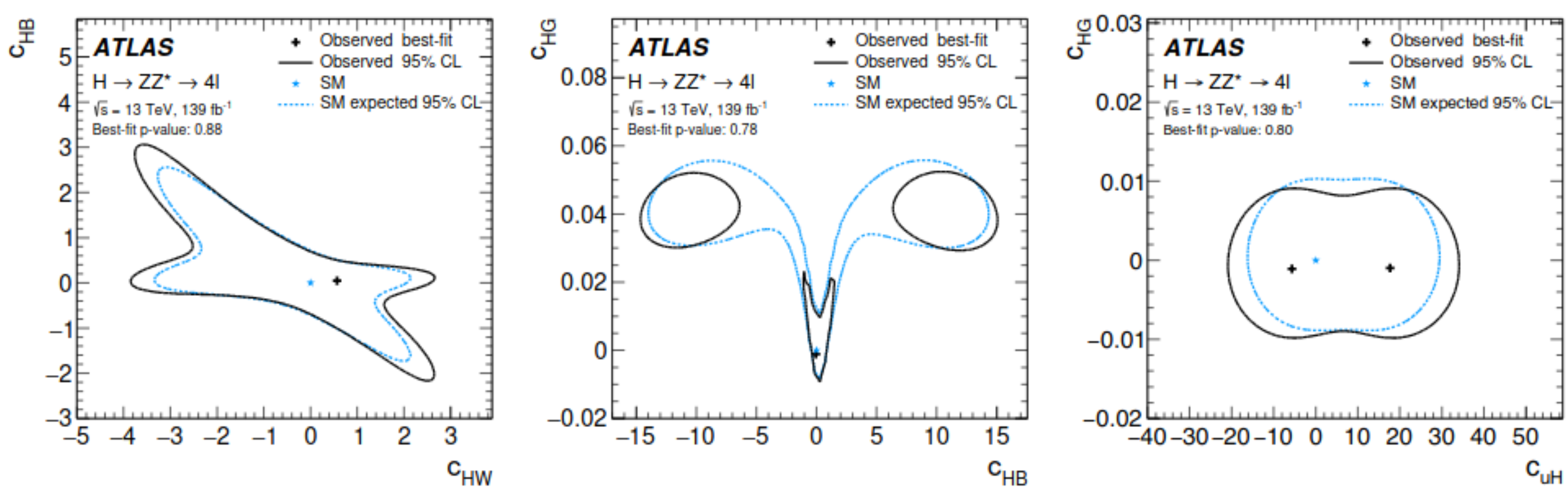

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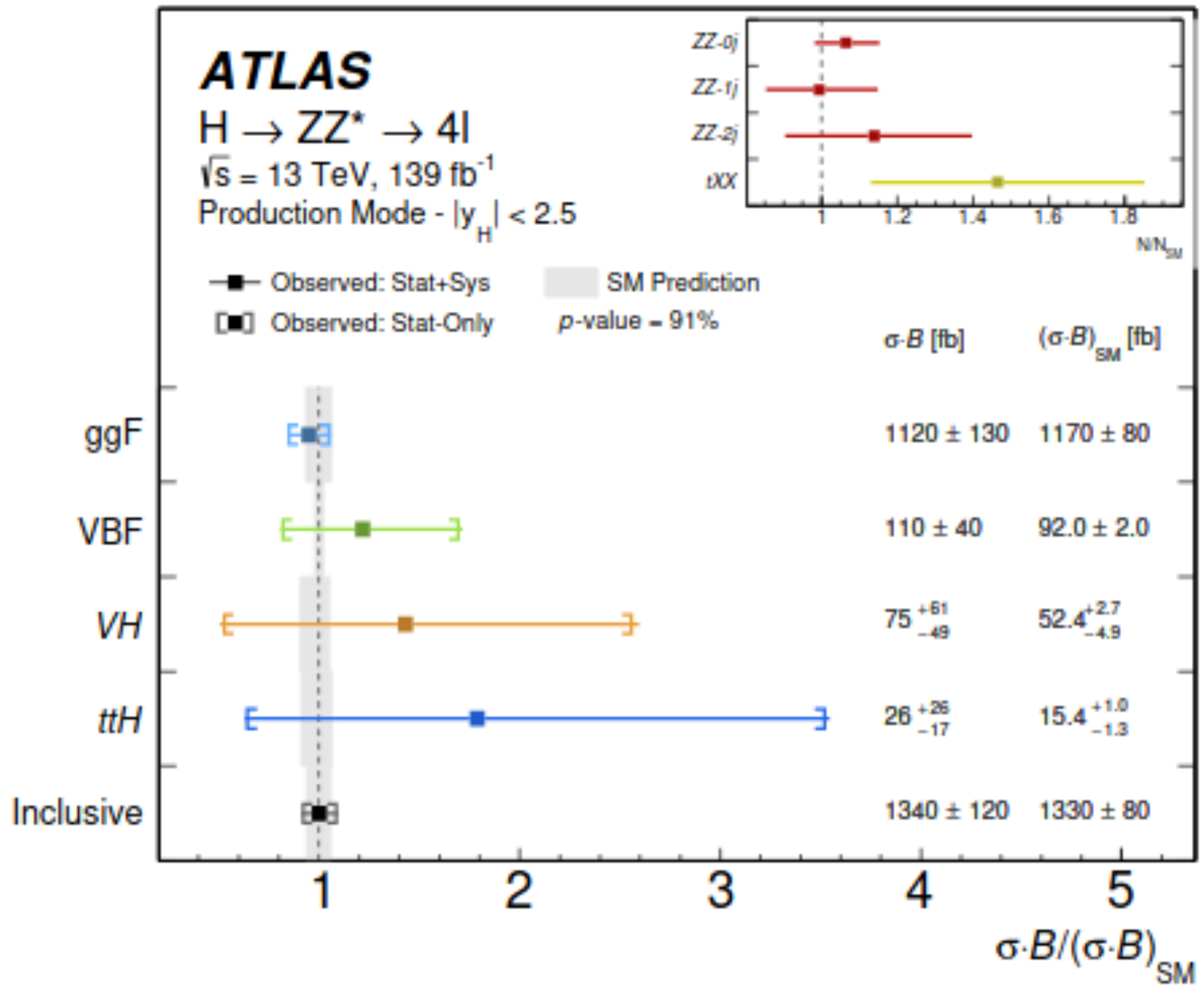

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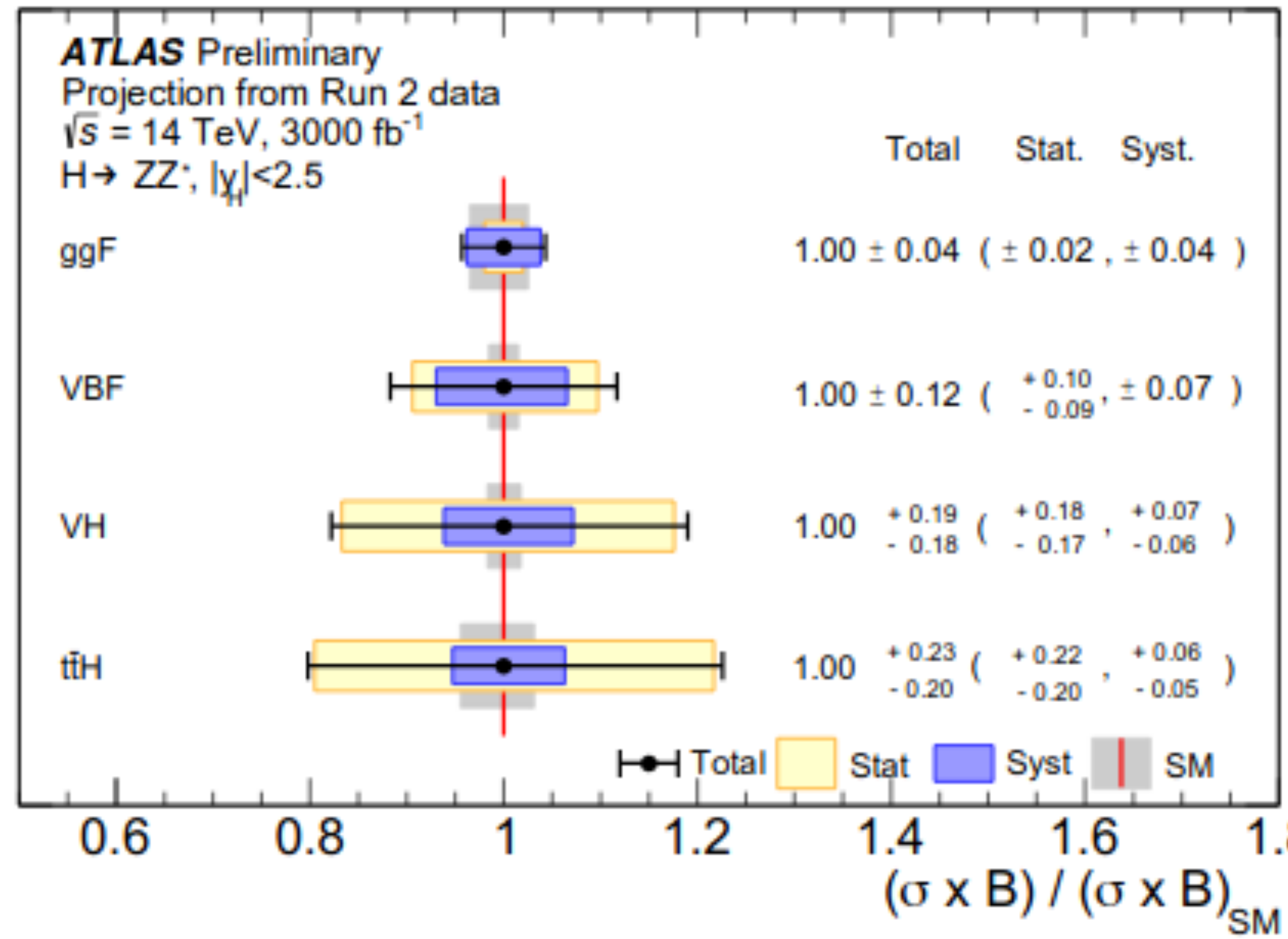
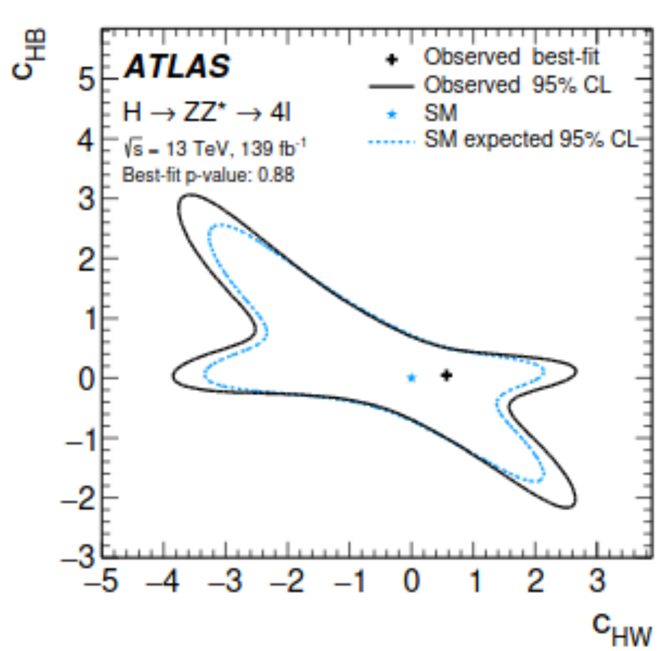
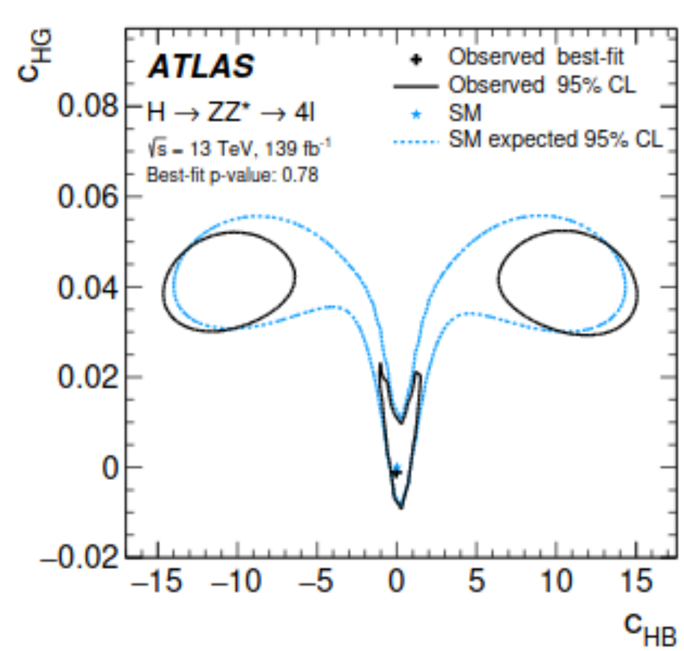
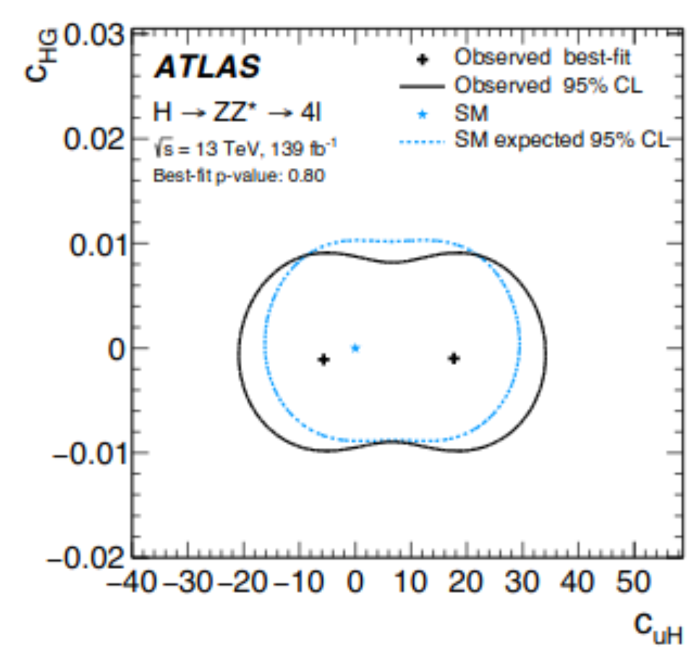
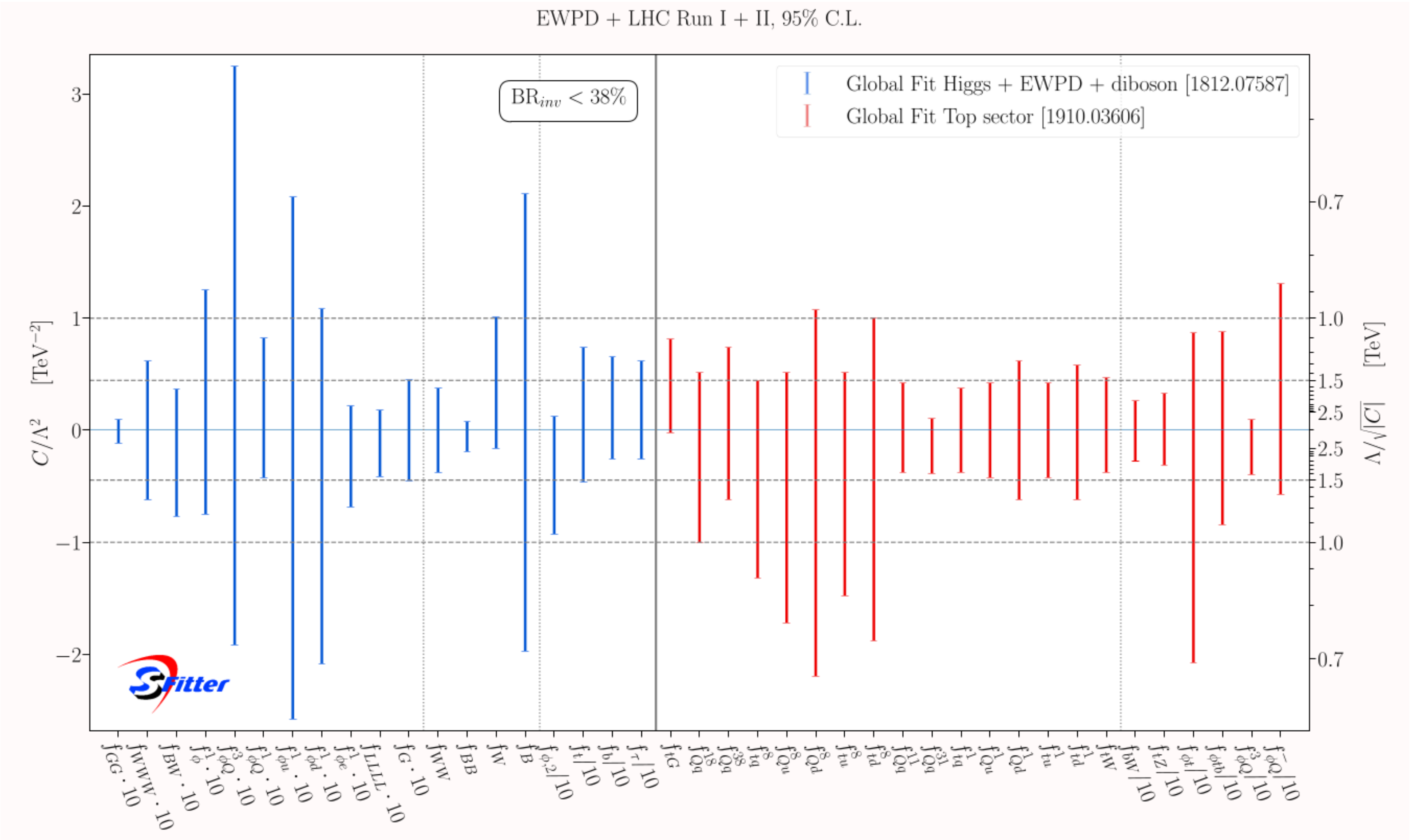








Status in Global Fits



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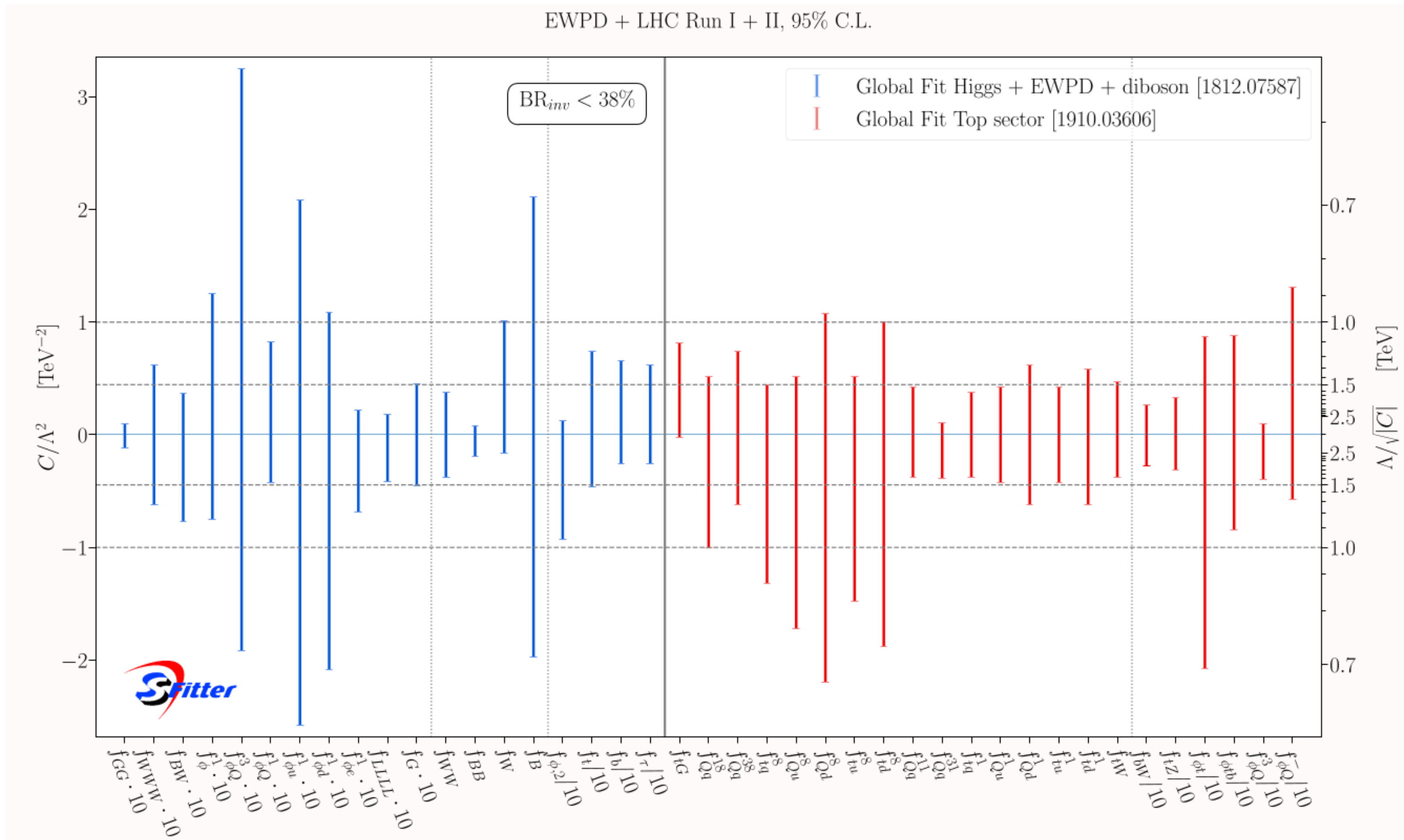

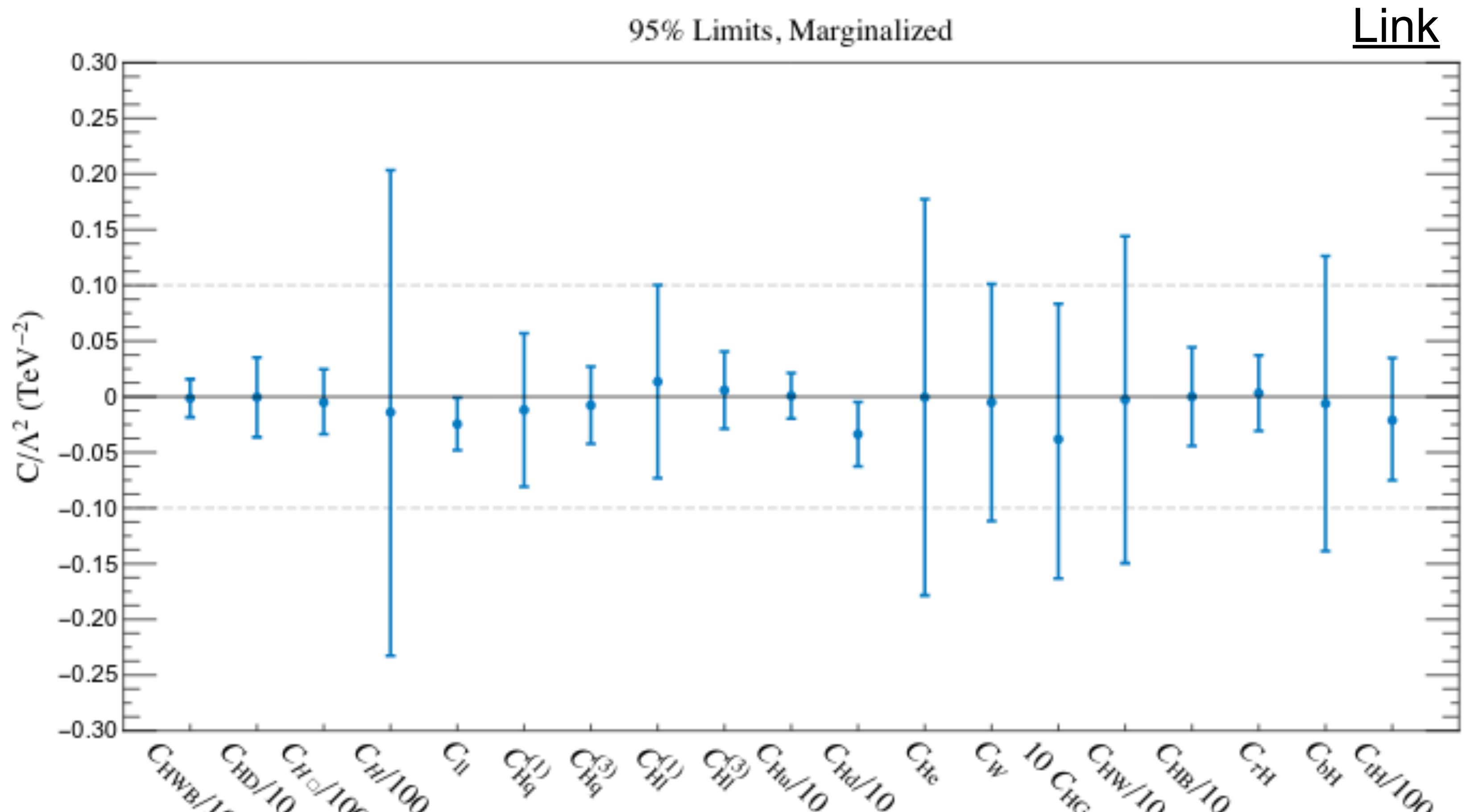

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Some Starter Questions for Discussion…

1. How does the EFT reach, in terms of new physics scale, compare to that of direct searches?

2. What is the precision needed for EFT to do better than Top Down?

   - Which measurements can realistically expect this?

3. Is there any regime where the two approaches overlap?

   - If so, how can this complementarity be best exploited?

   - Otherwise, is there a blind spot?

4. How can we better control the large theory uncertainties which limit both approaches? Is one approach more resilient?

5. Can searches performed with the Top Down approach in mind be easily cast into EFT?

   - Could be useful for where precision measurements do not exist.