To Profile or To Marginalize: A SMEFT Case Study

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Updated SMEFT global analysis

- Updated global SMEFT analysis in Higgs and EW sector
  - Added μ Yukawa correction + chromomagnetic operator
  - Added new measurements: high invariant mass distributions + Higgs
- Using the SFitter framework for global analysis
- New ways to construct likelihoods: marginalization
  - Previously used: profiling

Where will we probably find a water molecule?

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Which object contains most likely a water molecule?

Higher marginal probability:

$$\int_T p(T|M) = \int_T \mathcal{L}(M|T)\frac{P(T)}{P(M)}$$

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Which object contains most likely a water molecule?

Higher marginal probability:

$$\int_T p(T|M) = \int_T \mathcal{L}(M|T)\frac{P(T)}{P(M)}$$

Where is the water molecule most likely located?

Higher profiled likelihood:

$$\max_T \mathcal{L}(M|T)$$

Today's Agenda

1. Profiling and marginalization
   - For the old data set
   - For the new data set
2. Comparing both data sets
3. Conclusion

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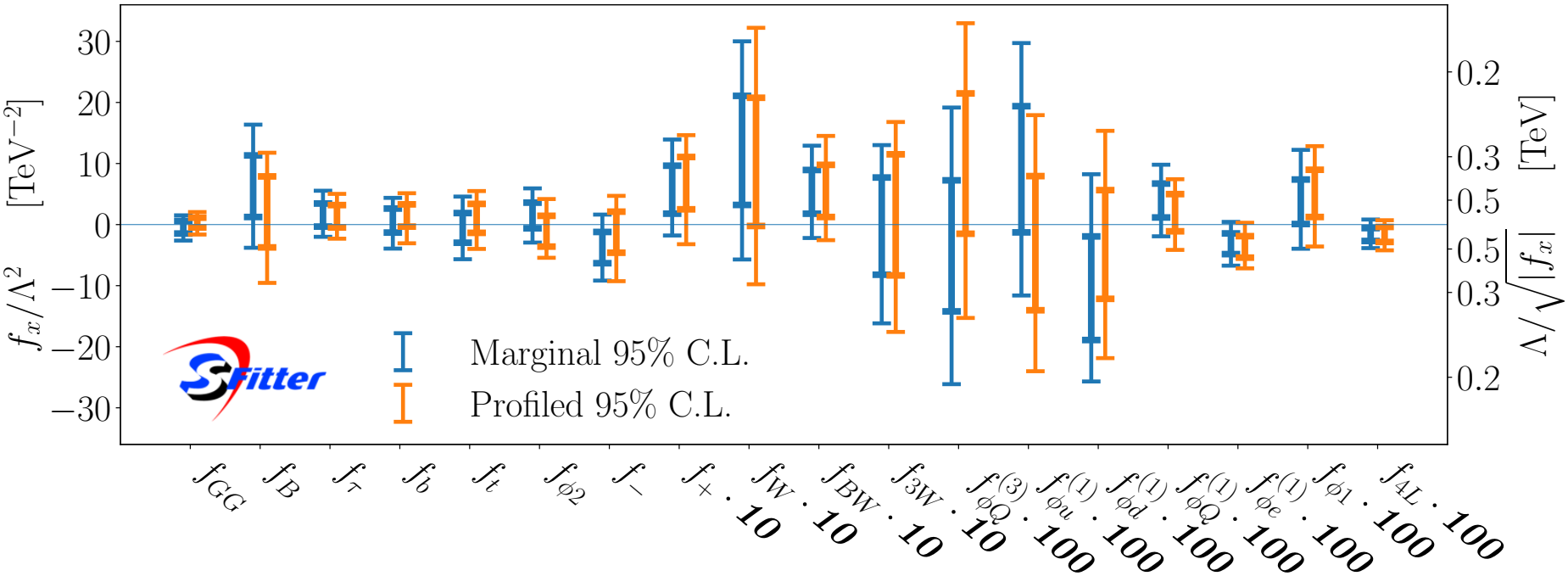
Observables included in the old data set

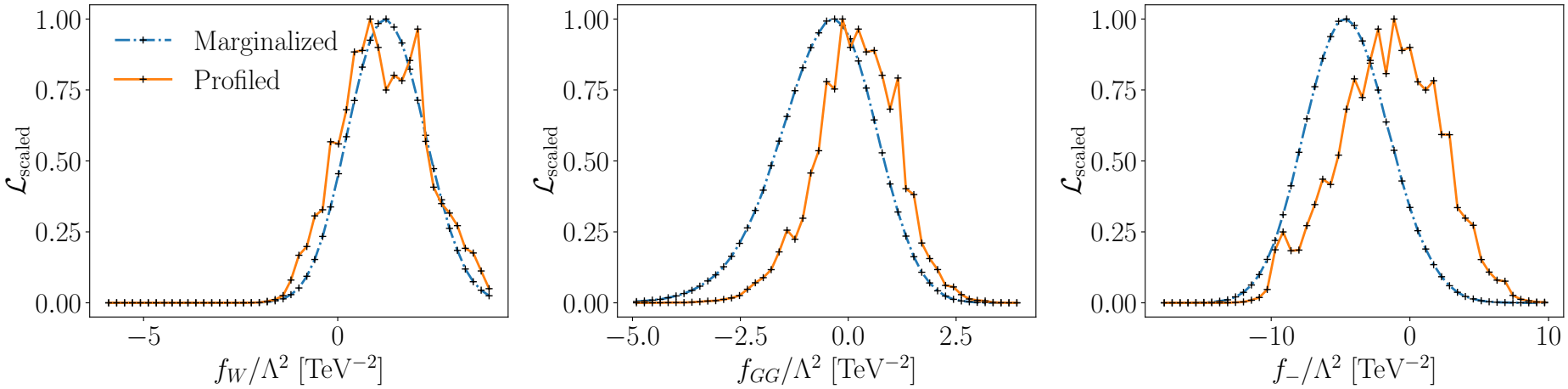
- **Low kinematics constrain non-kinematically enhanced operators** [Butter et al.: 1604.03105 | Biekötter, Corbett, Plehn: 1812.07587]
  - Higgs measurements at LHC (275)
  - Di-boson measurements at LHC (43)
  - Electroweak Precision Observables at LEP (14)

- **High kinematics constrain kinematically enhanced operators**
  - VH resonance search by ATLAS: 1712.06518

No big difference for the old data set

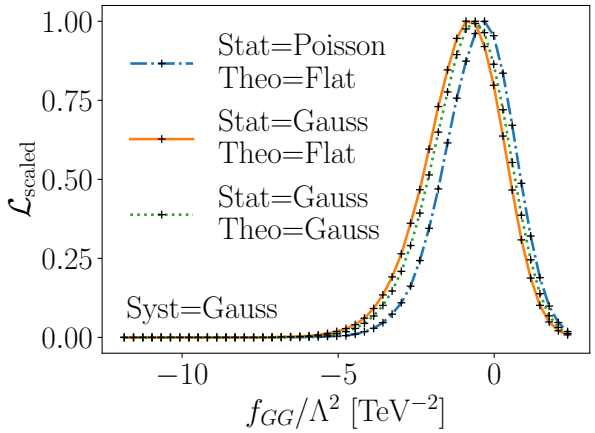


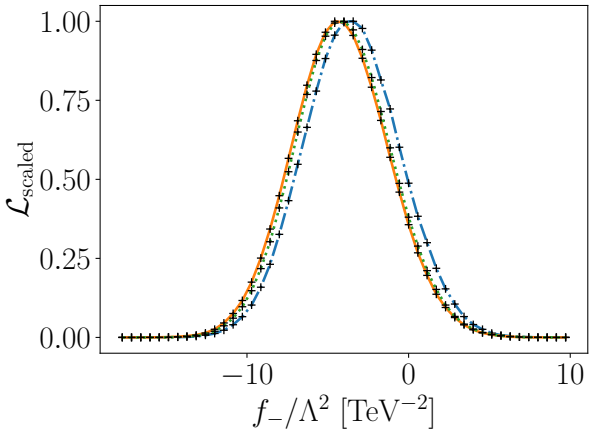
They are the same - aren't they?

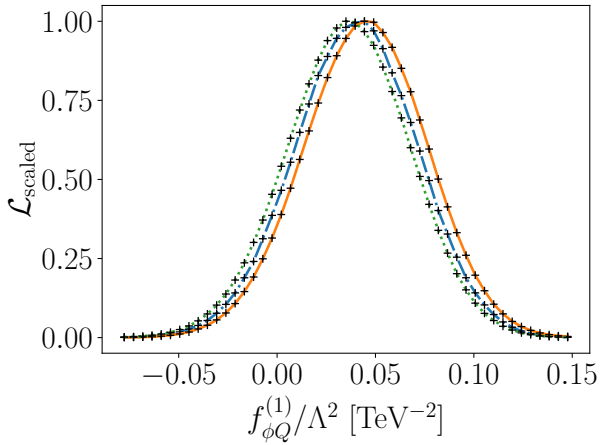


- Comparable results for both methods
- Small shifts in the peak

The rather small impact of theory uncertainites



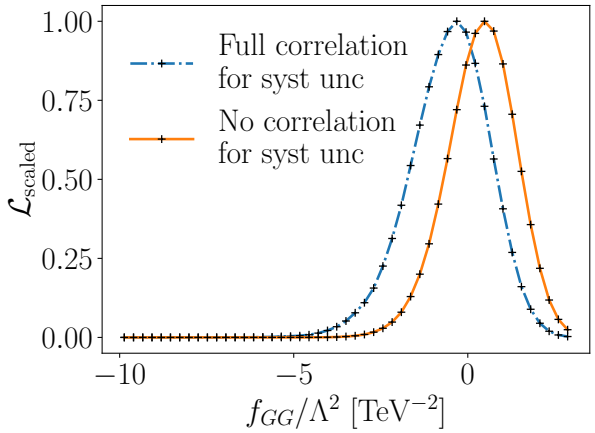


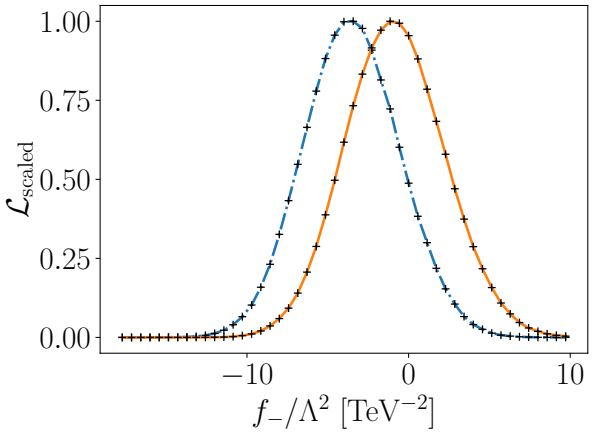


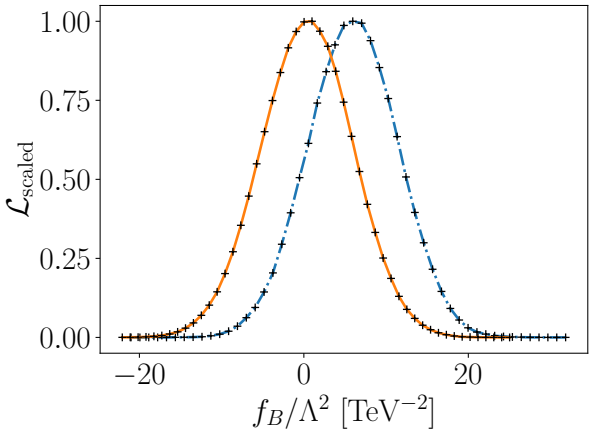
- Consider different distributions for theory and statistical uncertainties
- Systematic uncertainties are always Gaussian distributed

$\rightarrow$ Little to no impact on the overall distribution

Correlations are "game changers"







- Correlating systematic uncertainties
- Correlations have an impact on the peak

→ Responsible for shifting the distribution

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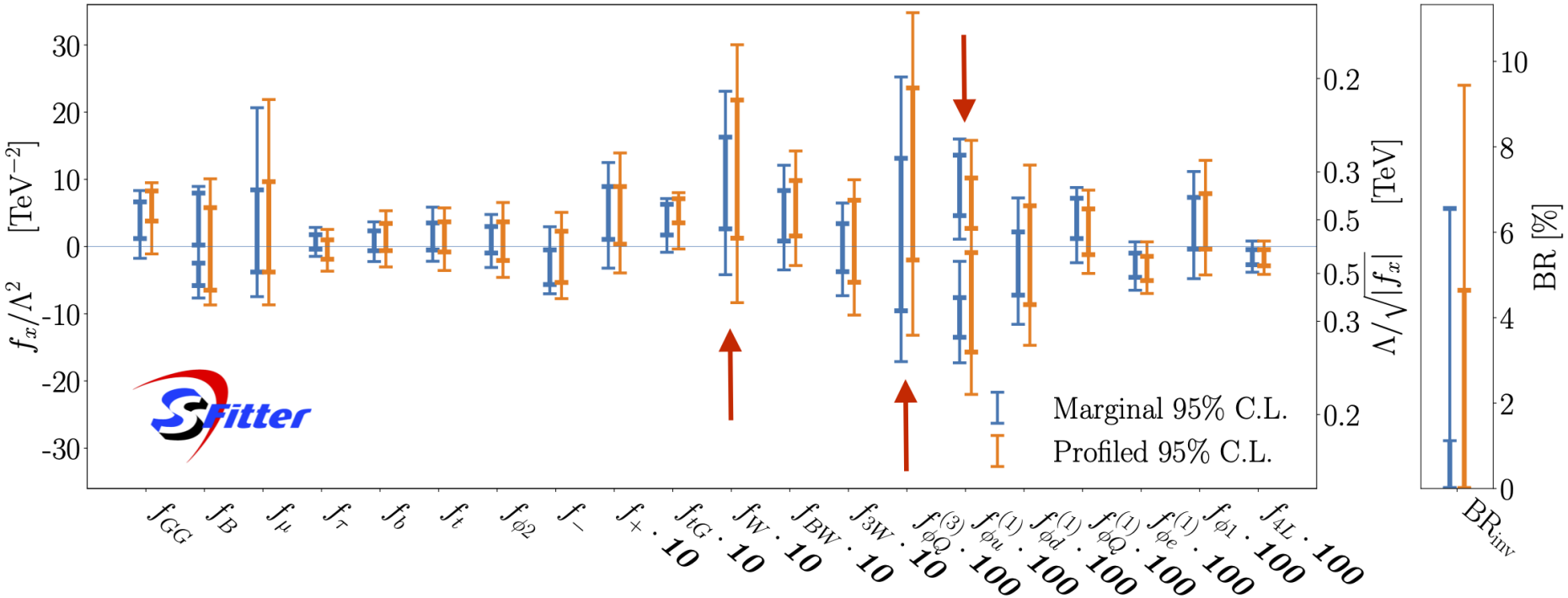
  - Higgs measurements at LHC (275) + new Higgs (36)
  - Di-boson measurements at LHC (43)
  - Electroweak Precision Observables at LEP (14)

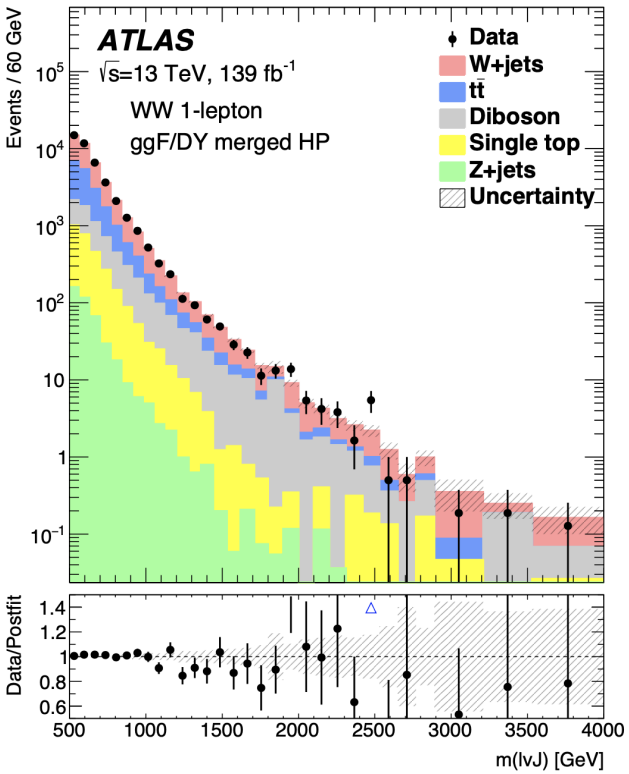
- **High kinematics constrain kinematically enhanced operators**
  - VH resonance search by ATLAS: ATLAS-CONF-2021-026 and 2007.05293
  - VV resonance search by ATLAS: 2004.14636
  - ZH resonance search by CMS: 2102.08198
  - Higgs p_T analysis by ATLAS: ATLAS-CONF-2019-029

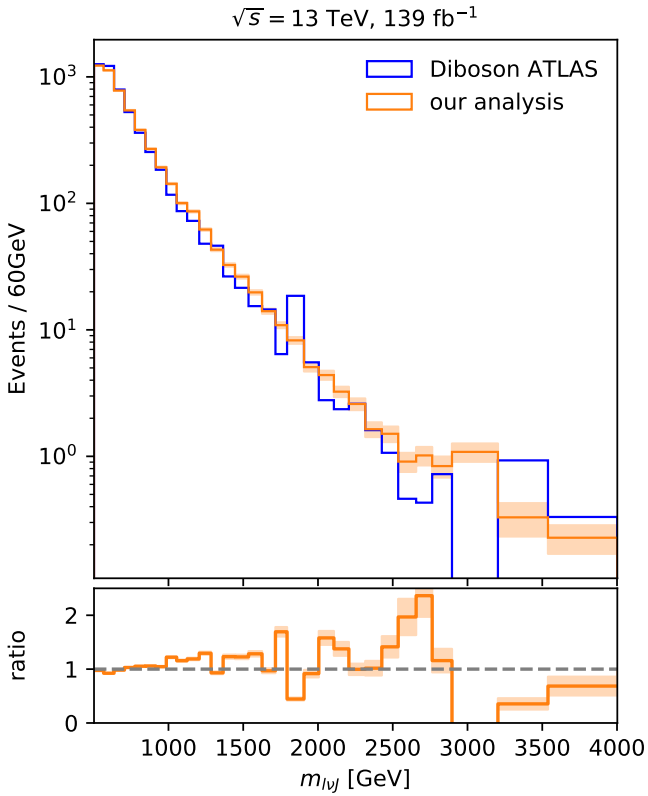
Differences for the new data set



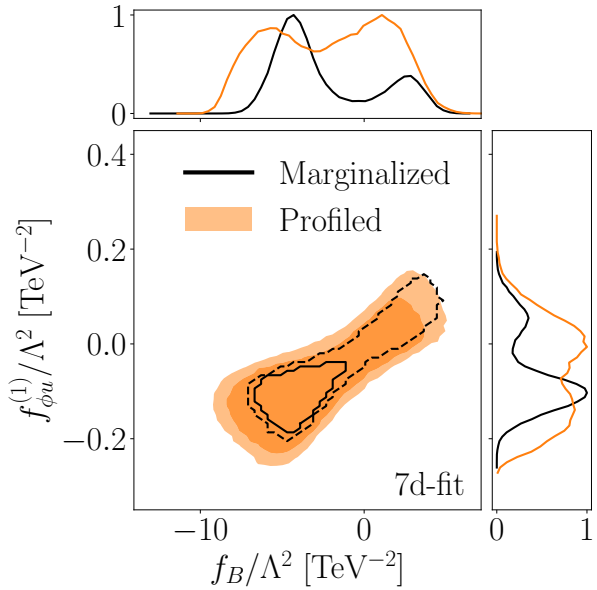
WW as one of a driving measurements

- Data set includes high kinematic distributions
- Driving measurement in linked coefficients
- Originally used for resonance searches





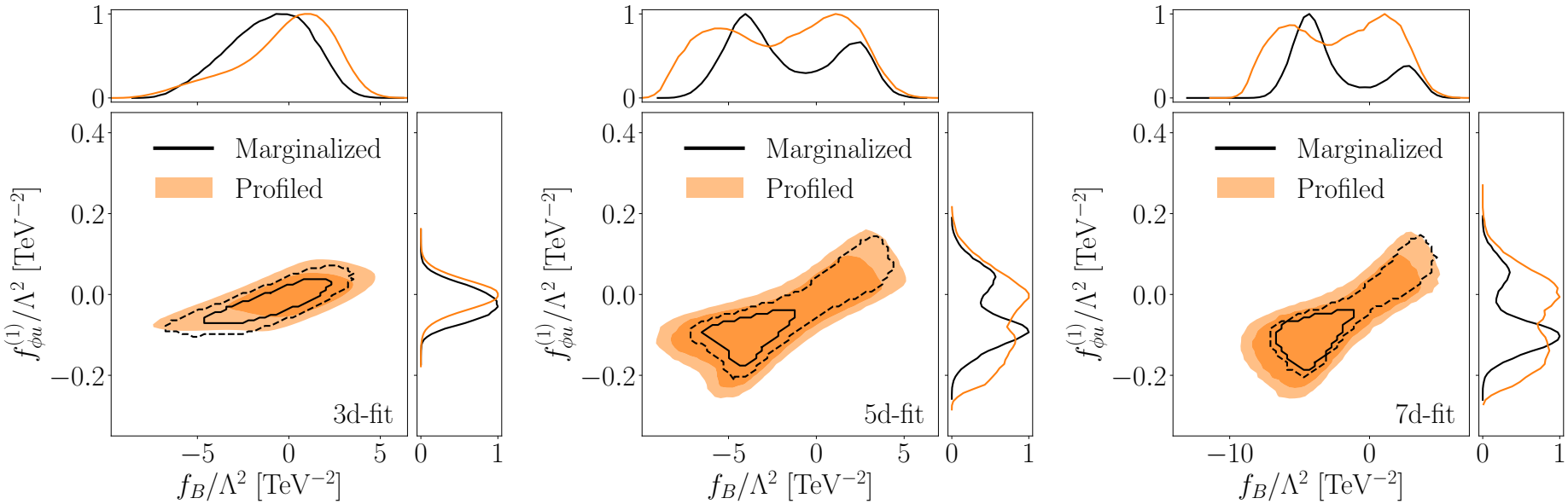
The problem with two modes



- Clear difference between both methods
- Because of the two mode structure
- Likelihood peaks are not on same level

The unexpected volume effect

- Peak structure appears with higher dimensional fits
- Need enough dimensions to accommodate underfluctuations
- More coefficients ⇒ larger volume effect
  Strengthen limits on coefficients (marginal case only)



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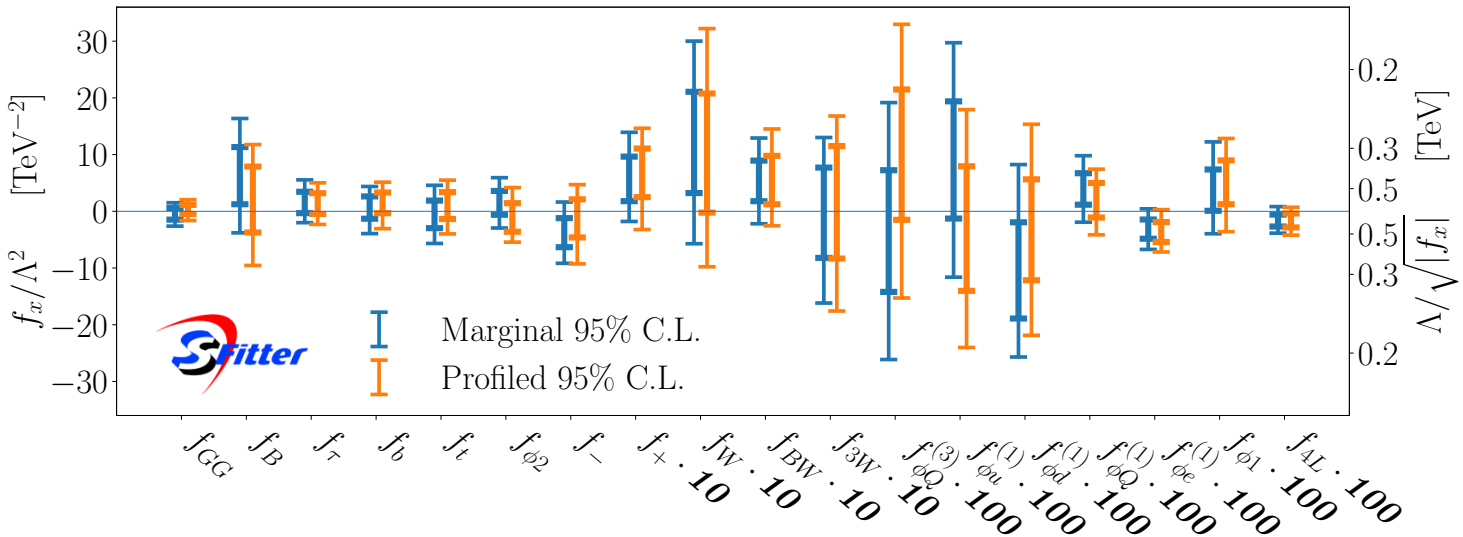
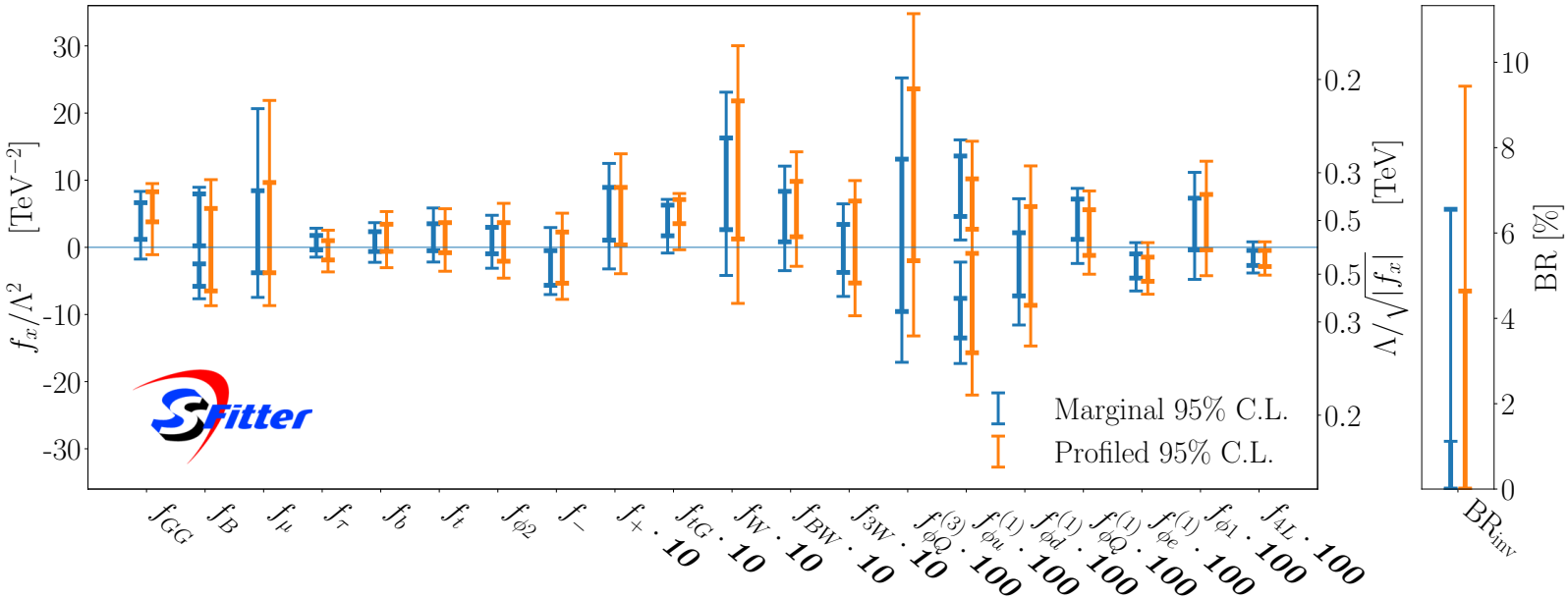
Comparing the results of both data sets





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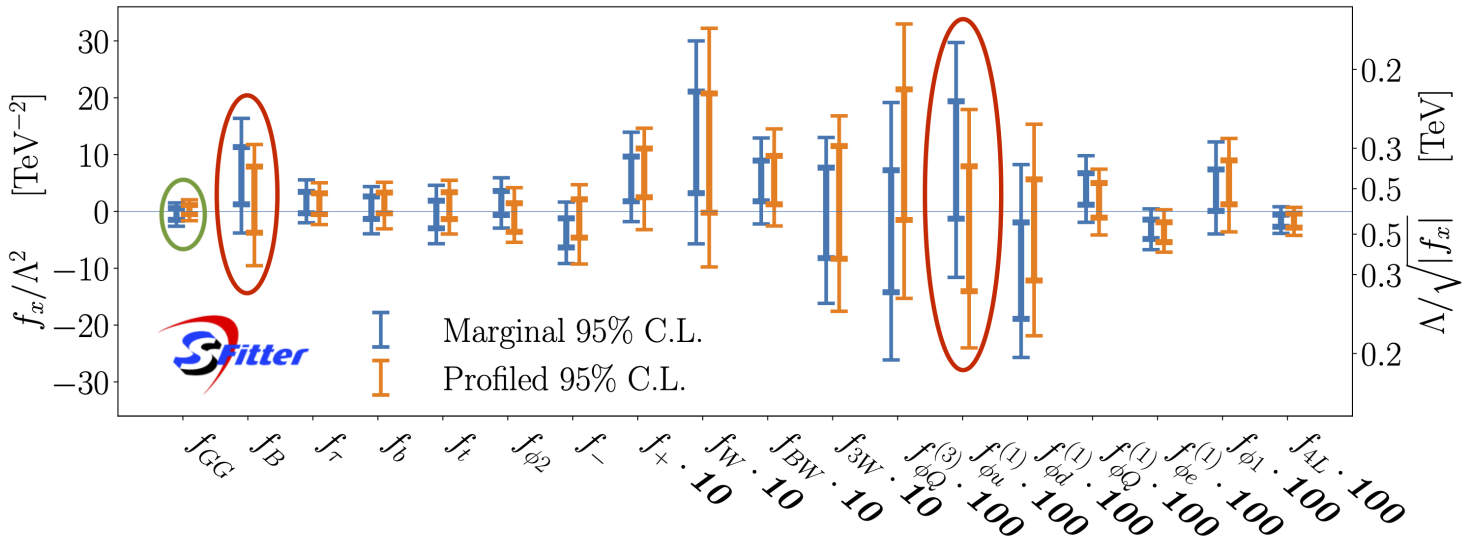

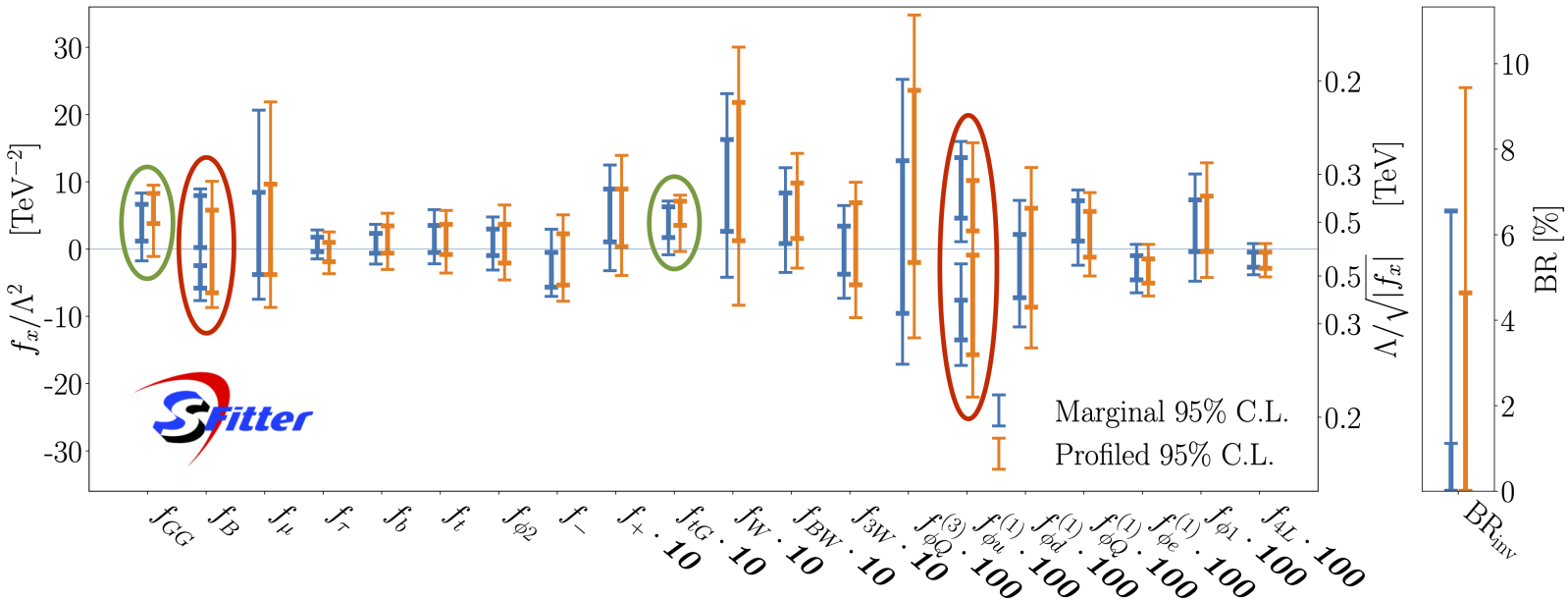

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Different methods - different questions

- Different questions $\Rightarrow$ different methods $\Rightarrow$ different results
- Choosing a method means choosing a question

$\rightarrow$ They are not the same, but you might not see it at a first look

  - Results might look similar for highly-Gaussian data set
  - Results can look completely different for another data set

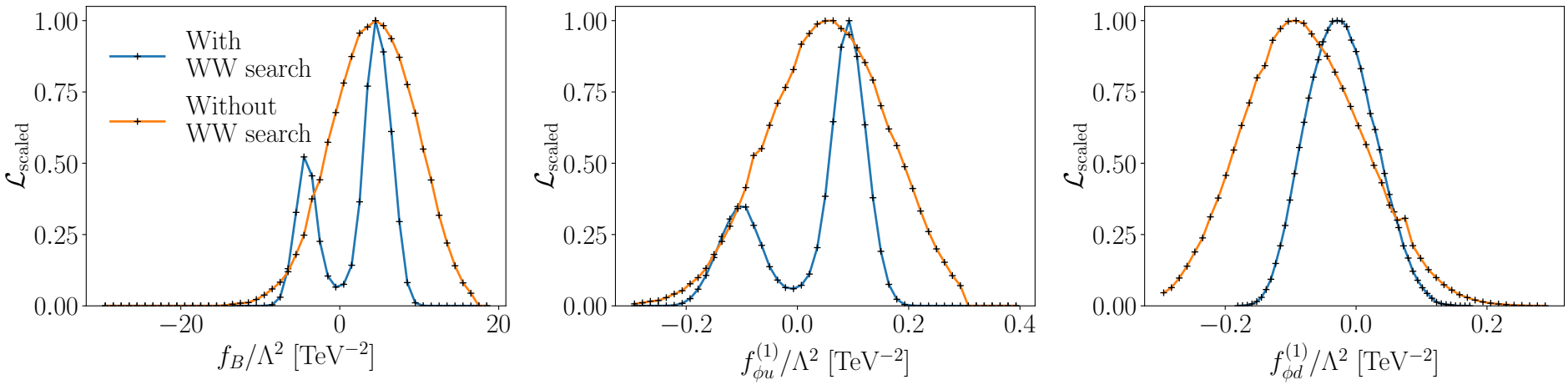
SFitter - our tool of choice

- Choose between profiling and marginalization
- Strong uncertainty treatment
- Includes high kinematic distributions

→ First SMEFT tool to combine these abilities

Backup slides

Influence of WW measurement on two modes



Interplay of f_{GG} and f_{tG}