Interpretation Errors in the SMEFT

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LPCC EFT WG Meeting

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Based on…

- 1711.07484 with Stefan Alte and Matthias König
- 1812.07575 with Stefan Alte and Matthias König
- 2007.12698 with Alyssa Horne, Jordan Pittman, Marcus Snedeker, and Joel Walker

Why should we care about uncertainties in signals?

- Neglecting or downplaying signal-function theory errors is very common in the pheno community
  - Idea being that you can clean up the calculations once we find something, but signatures won't change drastically
- Neglecting errors is never correct in precision measurements or calculations, though, and that's the business we're in

A Quote from a Model Builder

- “Whatever bound you get from your EFT, I can always write down a model that passes the test against data and violates the bound you claim to have.” – Bhaskar Dutta

Quark Compositeness

- This is an example the prevailing state-of-the-art technique for higher-dimensional operators at the LHC
  - Note that other proposals submitted aren't much different from this original technique!
- Searches originally proposed by Eichten, Lane, and Peskin in 1983, they posit some contact interaction between quarks

Compositeness Search Signal

- The quark compositeness search has kept all terms naively predicted by the dimension 6 operator $Q_{qq}^{(1)}$, including squared term
- This is strongly centrally peaked, as the interference is central and the squared term even more so
- Thus, a search in angular variables is a natural technique to distinguish it from the SM

How to build a SMEFT collider search

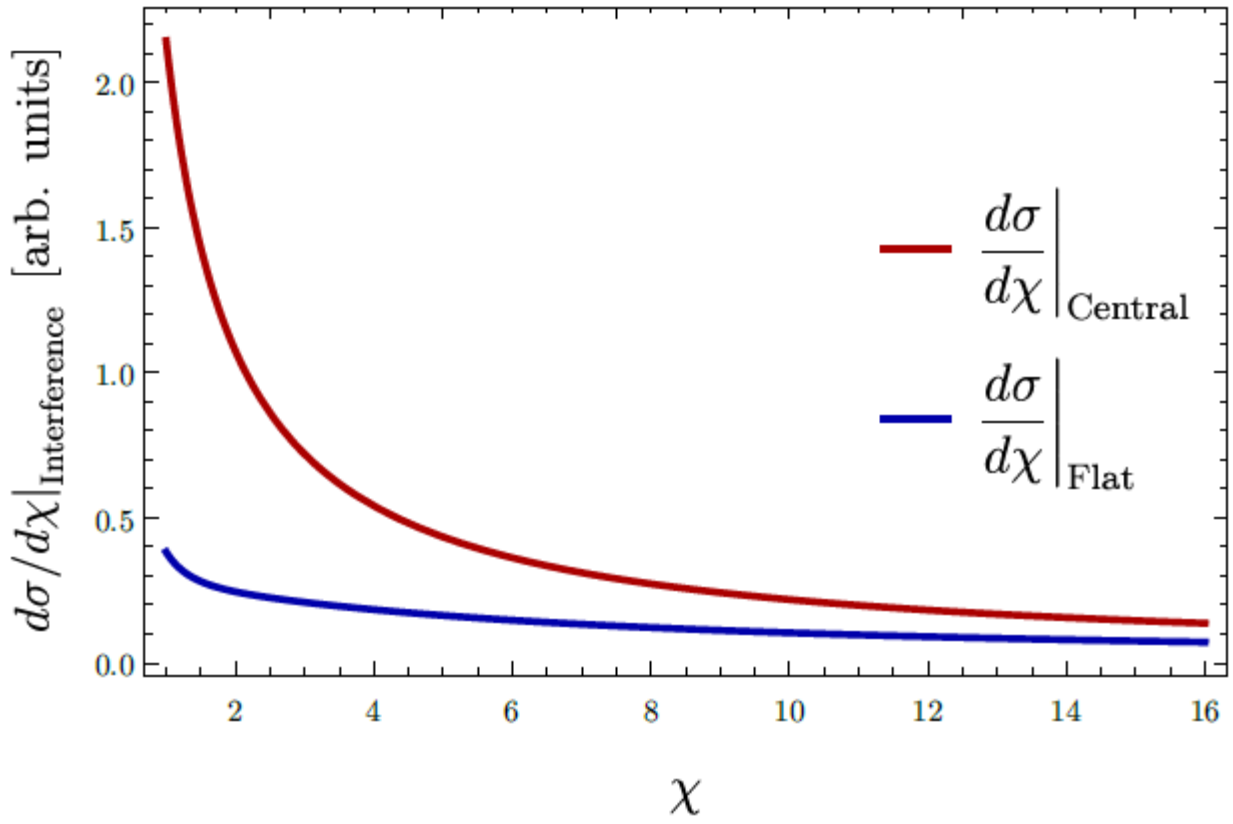
- Greatest challenge to such a search is the concern about EFT consistency; this description breaks down when the new particles are light enough
  - Ensuring EFT internal consistency is the best model-independent way of addressing this concern
  - EFT is a new perturbation series; need to estimate size of neglected contributions at next order as theory error
- Estimating next-order corrections is exactly what we normally do with scale variation!

EFT error treatment

- The consistent application of perturbation theory is to expand the observable in a power series
  - Cross section, not amplitude
  - Think about NLO QCD – must keep only loop x tree + ISR/FSR, not loop^2
- Must include the full set of contributing operators at dim-6
  - Can be reduced to relatively few experimentally-indistinguishable linear combinations of Wilson Coefficients
- As we only have the full dim-6 contribution, everything else must be discarded from signal
  - Failing to do so is known to lead to violations of e.g. gauge symmetry
- The dim-6 squared piece can be used as a proxy for the size and behavior of the unknown total Λ^{-4} contribution
  - Note that additional operators needn't give correlated angular distribution

Dijets from EFT

$$\left.\frac{d\sigma}{d\chi}\right|_{\text{Central}} \propto -\left(c_{qq}^{(1)} + 0.61\, c_{qq}^{(3)} + 0.85\, c_{uu} + 0.15\, c_{dd} + 0.20\, c_{ud}^{(8)}\right) \qquad \left.\frac{d\sigma}{d\chi}\right|_{\text{Flat}} \propto -\left(c_{qu}^{(8)} + 0.45 c_{qd}^{(8)}\right)$$

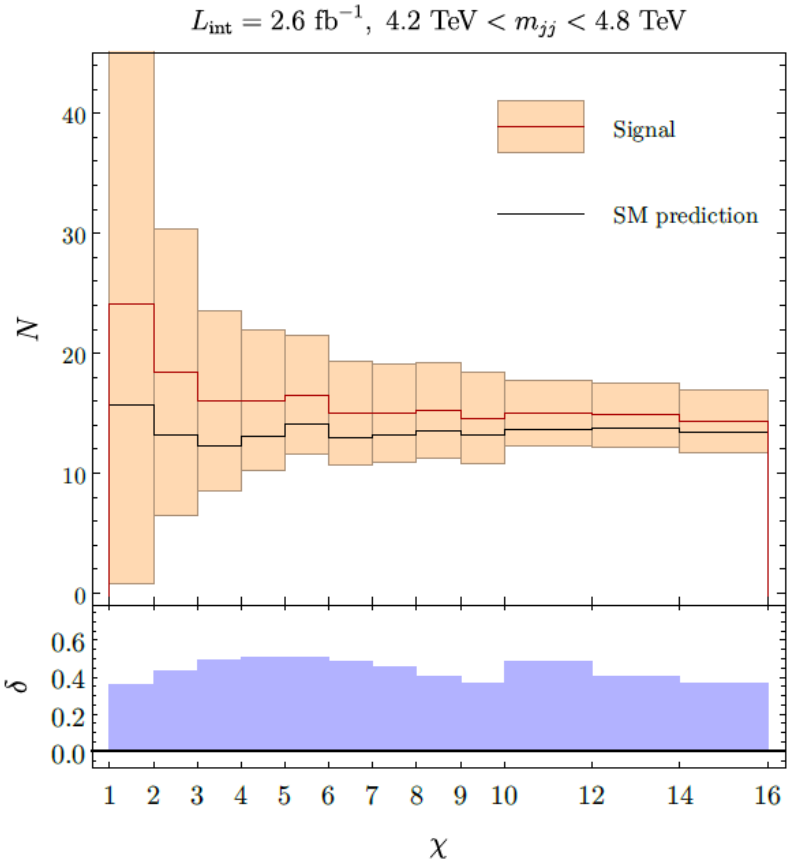


Theory Error Treatment

- Dim-8 effects are order $\frac{1}{\Lambda^4}$, signal is $\frac{1}{\Lambda^2}$
  - Dim-6-squared is also order $\frac{1}{\Lambda^4}$, can use that as a mock-up of total term of that order
- Model theory error as $\left(c_6^2 + g_{SM}^2 c_8 \sqrt{N_8}\right)\sigma_{d6^2}$
  - Uncorrelated between bins
  - We choose $c_8 = \sqrt{1 + c_6^2}$
- Sum in quadrature with other error sources

Search in Un-Normalized Distributions

- There can be large systematic differences between signal and background if we don't discard total cross-section information
- These analyses are bounded by EFT error at low χ, but statistics are important elsewhere



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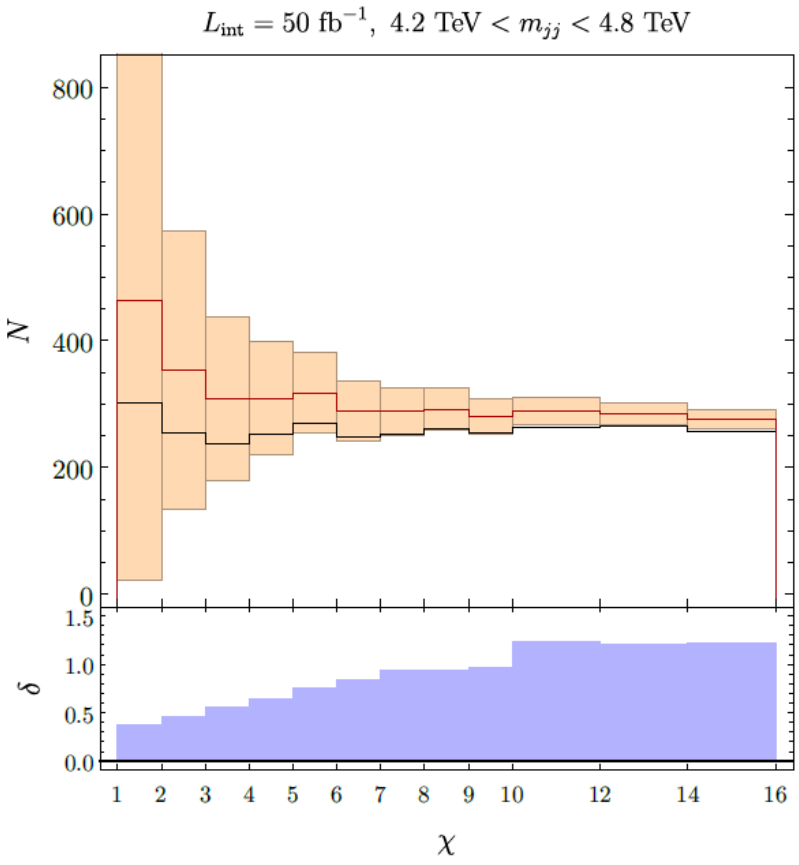
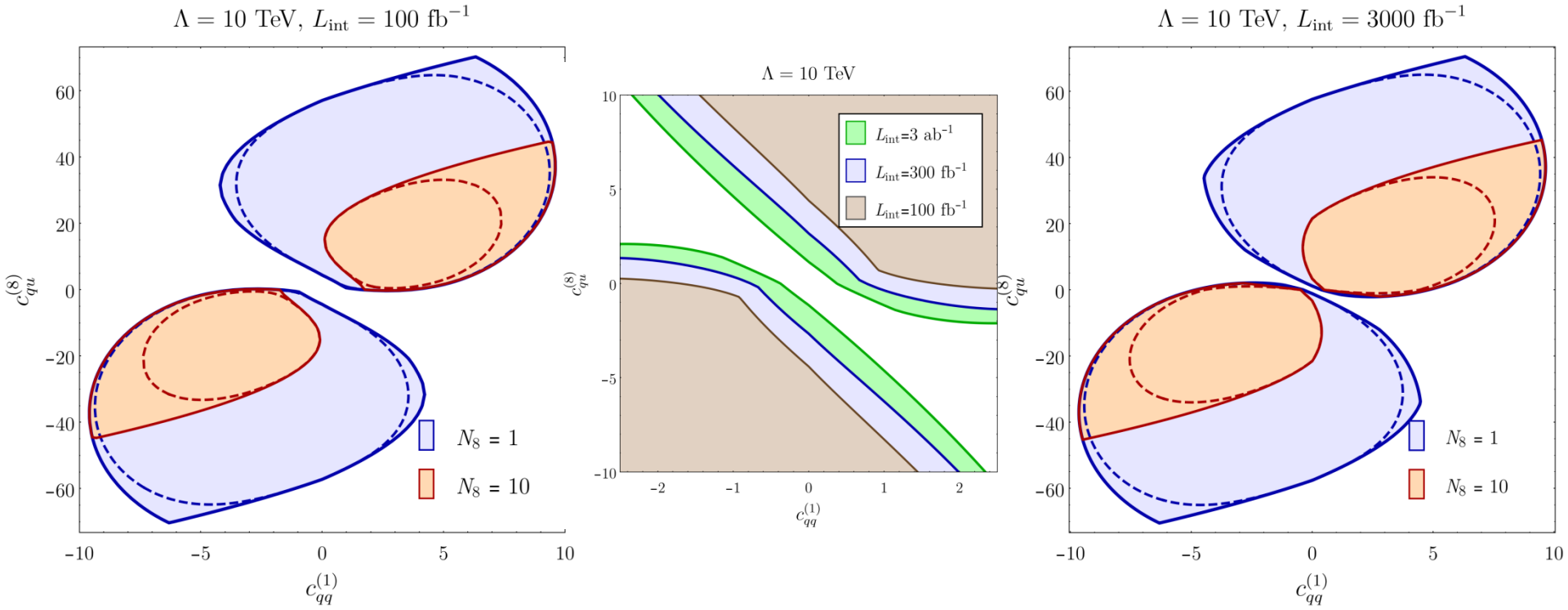


Reach: Fixed NP Scale

- For realistic N8, only a narrow angle in coupling space can be constrained



Conclusions

- A truly global analysis will be needed to properly constrain the EFT without UV assumptions
  - Developing more off-shell observables that can be consistently constrained is an important future path for this field
- EFT errors affect search design nontrivially
  - E.g. central dijets less useful than naively expected
  - Errors should be part of experimental collaboration search design
- Neglecting these errors makes our bounds useless from a new model perspective

We need to make Bhaskar wrong about this!

- "Whatever bound you get from your EFT, I can always write down a model that passes the test against data and violates the bound you claim to have." – Bhaskar Dutta

The Take-Away

- Setting some Wilson coefficients to zero does not give model-independent results
  - Linear combinations that matter to a given observable can be constructed, are generically small in number
- Neglecting these errors gets our analyses ignored by model-builders, who should be our biggest customers, so definitely stop doing that!
  - Produce results that they can't evade by utilizing an honest error estimate
  - Push back against any claim that a model can always be built to evade our EFT results

Thank You!