Consistent Searches for SMEFT Effects in Non-Resonant Dijet Events

Stefan Alte, Johannes Gutenberg-Universität Mainz

Matthias König and William Shepherd

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Introduction

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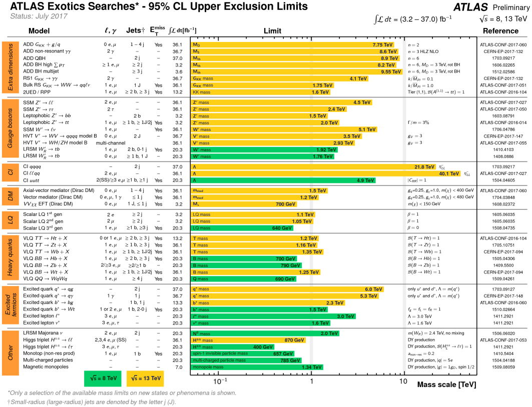
However, **NP** has **not** yet been **discovered**.



ATLAS (2017)

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In the case of the **SMEFT**, the Lagrangian is **expanded in inverse powers of the NP mass scale Λ**.

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We propose an alternative approach and **constrain SMEFT effects** in **dijet production** at the **LHC**.

"*Consistent Searches for SMEFT Effects in Non-Resonant Dijet Events*", Alte, König and Shepherd, **JHEP 1801 (2018) 094**, arXiv:1711.07484.

Dijet Production in the SMEFT

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In the **SMEFT**, the **SM Lagrangian is supplemented** by **local, higher-dimensional operators** built out of **SM fields** and respecting the **SM gauge group**.

$$\mathcal{L}_{\mathsf{SMEFT}} = \mathcal{L}_{\mathsf{SM}} + \mathcal{L}^{(5)} + \mathcal{L}^{(6)} + \mathcal{L}^{(7)} + \mathcal{L}^{(8)} + \dots ,$$

where

$$\mathcal{L}^{(i)} = \sum_{k=1}^{N_i} \frac{c_k^{(i)}}{\Lambda^{i-4}} Q_k^{(i)} .$$

Weinberg (1979); Wilczek and Zee (1979); Buchmueller and Wyler (1986); Grzadkowski et al. (2010); Abbott and Wise (1980); Lehman (2014); Lehman and Martin (2016); ...

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The **leading (non-trivial) contribution** to dijet production arises from **dimension-six operators**.

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We work in the **"Warsaw" basis**, assume **baryon-number, lepton-number and CP-conservation**. The contributing operators are:

	$Q_{qq}^{(1)}$	$(\bar{q}_p\gamma_\mu q_r)(\bar{q}_s\gamma^\mu q_t)$	$Q_{qq}^{(3)}$	$(\bar{q}_p\gamma_\mu\tau^I q_r)(\bar{q}_s\gamma^\mu\tau^I q_t)$
	Q_{uu}	$(\bar{u}_p\gamma_\mu u_r)(\bar{u}_s\gamma^\mu u_t)$	Q_{dd}	$(\bar{d}_p\gamma_\mu d_r)(\bar{d}_s\gamma^\mu d_t)$
*	$Q_{ud}^{(1)}$	$(\bar{u}_p\gamma_\mu u_r)(\bar{d}_s\gamma^\mu d_t)$	$Q_{ud}^{(8)}$	$(\bar{u}_p\gamma_\mu T^A u_r)(\bar{d}_s\gamma^\mu T^A d_t)$
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*	$Q_{qd}^{(1)}$	$(\bar{q}_p\gamma_\mu q_r)(\bar{d}_s\gamma^\mu d_t)$	$Q_{qd}^{(8)}$	$(\bar{q}_p\gamma_\mu T^A q_r)(\bar{d}_s\gamma^\mu T^A d_t)$
*	Q_G	$f^{ABC}G_\mu^{A\nu}G_\nu^{B\rho}G_\rho^{C\mu}$		

no interference

Consistency for the EFT Analysis

The **dijet cross section** in the SMEFT can be written as

$$\sigma_{\mathsf{dijet}} = \sigma_{\mathrm{SM}} + \frac{1}{\Lambda^2}\,\sigma_{\mathrm{dim6-SM}} + \frac{1}{\Lambda^4}\,\sigma_{\mathrm{dim6}} + \dots\,.$$

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Many EFT analyses pursue neither of the two options.

Our Approach

We **recast** a recent **CMS analysis** CMS (2017), where

- the **dimension-six squared** piece **is taken into account**.
- the **single-operator case** is considered.
- bounds on the **NP scale Λ** are derived.

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We **derive** bounds for both the **fixed-Wilson** and the **fixed-scale case**.

The Multioperator Case

The search analyses the cross section **differential** in the **dijet invariant mass** $\boldsymbol{m_{jj}}$ and the **angular variable**

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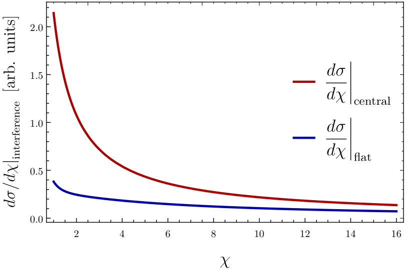

$$\frac{d\sigma}{d\chi}\Big|_{\text{central}} \propto -\left(c_{qq}^{(1)} + 0.61\, c_{qq}^{(3)} + 0.85\, c_{uu} + 0.15\, c_{dd} + 0.20\, c_{ud}^{(8)}\right)$$

$$\frac{d\sigma}{d\chi}\Big|_{\text{flat}} \propto -\left(c_{qu}^{(8)} + 0.45 c_{qd}^{(8)}\right)$$

Searches in Normalized Angular Distributions

Reproduction of the CMS Analysis

$$\left.\frac{d\sigma}{d\chi}\right|_{\text{signal}} = \left.\frac{d\sigma}{d\chi}\right|_{\text{SM}} + \frac{1}{\Lambda^2}\left.\frac{d\sigma}{d\chi}\right|_{\text{interference}} + \frac{1}{\Lambda^4}\left.\frac{d\sigma}{d\chi}\right|_{\text{BSM}} + \dots$$

for validation only!

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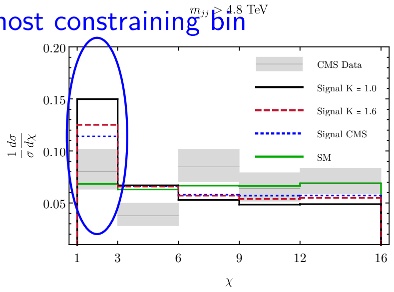
most constraining bin



	Bound on Λ [TeV]
CMS	11.5
$K = 1.0$	12.1
$K = 1.3$	11.4
$K = 1.6$	11.0

Using **LO QCD Monte-Carlo samples**, a **Chi-Squared Fit** to the CMS data results in **bounds on Λ** which **agree within $\sim$ 1 TeV** with the CMS bounds.

Truncation at Dimension-Six Interference

$$\left.\frac{d\sigma}{d\chi}\right|_{\text{signal}} = \left.\frac{d\sigma}{d\chi}\right|_{\text{SM}} + \frac{1}{\Lambda^2}\left.\frac{d\sigma}{d\chi}\right|_{\text{interference}} + \mathcal{O}\left(\frac{1}{\Lambda^4}\right)$$

$$\Delta\left.\left(\frac{d\sigma}{d\chi}\right)\right|_{\text{theo}} = \frac{1}{\Lambda^4}\left.\frac{d\sigma}{d\chi}\right|_{\text{BSM}}$$

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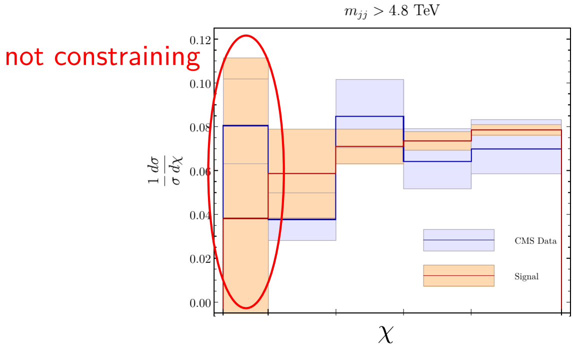

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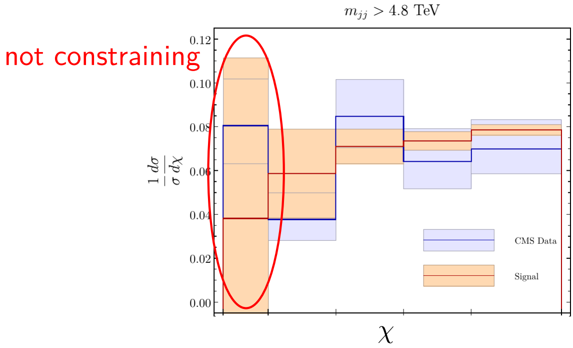

Including the new theory error, we find **no bounds on Λ**.

Searches in Unnormalized Distributions

Signal and Theory Error

We use the **signal**

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where we switch on the **operators** $\boldsymbol{Q_{qq}^{(1)}}$ **and** $\boldsymbol{Q_{qu}^{(8)}}$.

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Our **theory error** models both the **dimension-six squared piece** and the **dimension-eight-interference piece**:

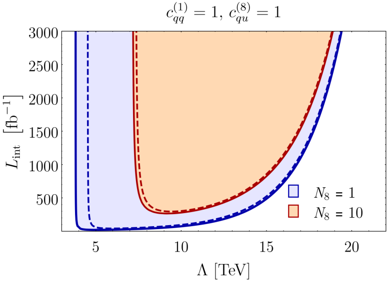
$$\Delta\sigma_{\text{theo}} = \frac{1}{\Lambda^4}\,\sigma_{\text{dim6}}\,,$$

where we **replace the squared Wilson coefficients** by

$$\Delta_{\text{theo},1} = \max\left\{c_k^2;\, g_s\, c_8\sqrt{N_8}\right\}$$

or $$\Delta_{\text{theo},2} = \sqrt{c_k^4 + \left(g_s\, c_8\sqrt{N_8}\right)^2}\,.$$

Searches in the Angular Spectrum



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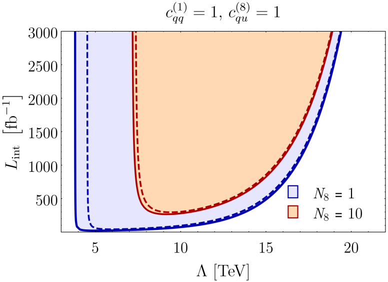
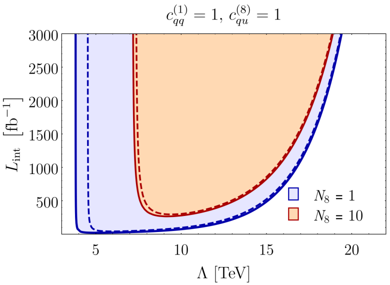


Including the **theory uncertainty**, the **bounds weaken**. **Some amount of integrated luminosity** is needed to **obtain bounds**.

Searches in the Angular Spectrum



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Above this integrated luminosity, we do **not only find a lower bound** for **Λ**, but rather an **excluded region**.

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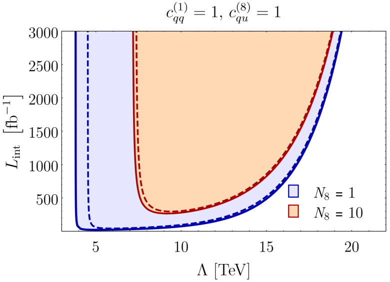

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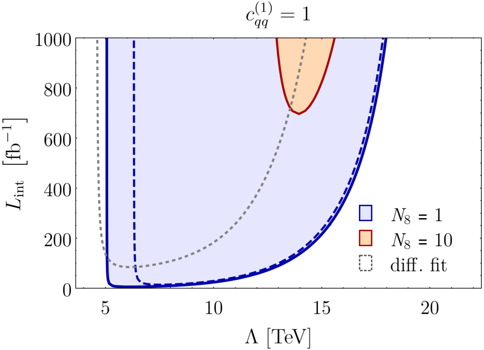
Can we do better?

Searches in the Dijet Invariant Mass Spectrum



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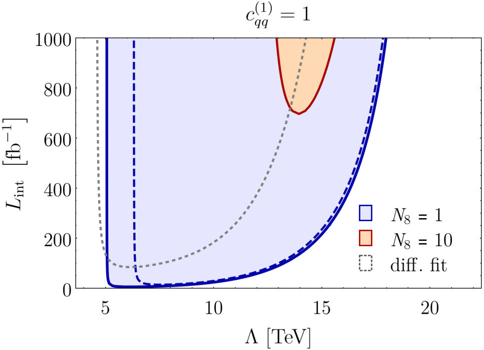

The **searches in the dijet invariant mass spectrum** yield **bounds at lower integrated luminosity** compared to the **searches in the angular spectrum**.

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The searches in **unnormalized m_{jj} distributions** reach **higher scales** at **lower integrated luminosity** compared to searches in angular spectra.

Searches in the Dijet Invariant Mass Spectrum

Besides **fixing the Wilson coefficients** and **fitting for the NP scale**, we can also **fix the NP scale** and **fit for the Wilson coefficient**.