Search for Contact Interactions using the Inclusive Jet Production Cross Section @ 13 TeV

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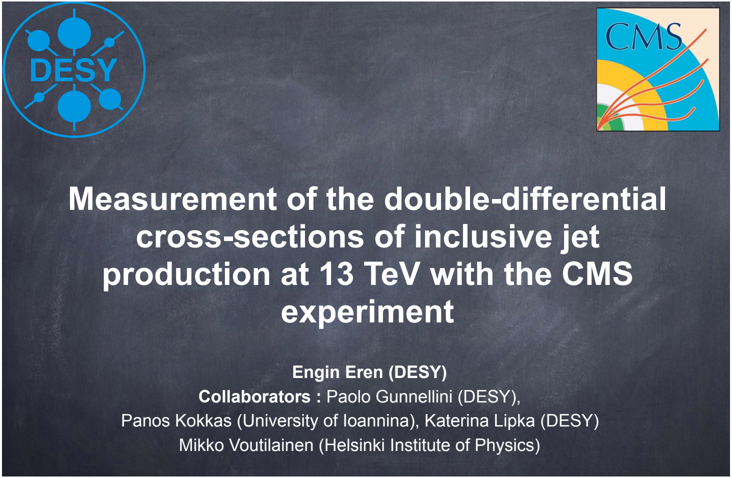
Outline

Many thanks to members of the Inclusive Jet p_T Group, and especially to Engin Eren.



Search for Contact Interactions

Look for deviations in the high-p_T tail of the inclusive jet p_T spectrum at 13 TeV from the predictions of QCD and interpret deviations as potential evidence of new QCD-like interactions that cannot be resolved at LHC energies.

Assumptions

1. At LHC energies, the Lagrangian L can be written as

$$L = L_{SM}^{(0)} + \frac{1}{\Lambda} L^{(1)} + \frac{1}{\Lambda^2} L^{(2)} + \cdots ,$$

2. with $L^{(2)}$ a sum $2\pi \sum_{i=1}^{6} \kappa_i \, O_i$ over dim-6 operators $O_{1,2} \sim \bar{\psi}_L \gamma_\mu \psi_L \, \bar{\psi}_L \gamma^\mu \psi_L$, $O_{3,4} \sim \bar{\psi}_L \gamma_\mu \psi_L \, \bar{\psi}_R \gamma^\mu \psi_R$. $O_{5,6} \sim \bar{\psi}_R \gamma_\mu \psi_R \, \bar{\psi}_R \gamma^\mu \psi_R$ that describe contact interactions (CI). κ_i are additional free parameters[1].

[1] J. Gao, Comput.Phys.Commun. 184 (2013) 2362.

Outline

Strategy

1. Given observed jet counts, N_i in M p_T bins, construct a multinomial likelihood

$$p(D \,|\, \lambda, \kappa, \nu) = \prod_{i=1}^{M} \left(\frac{\sigma_i}{\sigma}\right)^{N_i},$$

where $\lambda \equiv 1/\Lambda^2$, σ_i is the predicted cross section in the i^{th} bin, $\sigma = \sum_{i=1}^{M} \sigma_i$, and ν denotes the nuisance parameters.

2. Given a prior density $\pi(\lambda, \kappa, \nu) = \pi(\nu \,|\, \lambda, \kappa)\pi(\lambda|\kappa)\pi(\kappa)$, compute the marginal likelihood

$$p(D \,|\, \lambda, \kappa) = \int p(D \,|\, \lambda, \kappa, \nu)\pi(\nu \,|\, \lambda, \kappa)\, d\nu,$$

and then the posterior density $p(\lambda|D) \sim p(D \,|\, \lambda, \kappa)\pi(\lambda|\kappa)$ from which we estimate λ or set limits.

Cross Section The cross section per p_T bin can be written as

$$
\begin{aligned}
\sigma = \sigma_{QCD} & \\
& + \lambda \sum_{i=1}^{6} \kappa_i (b_i + a_i g + a_i f) \\
& + \lambda^2 \sum_{i=1}^{6} \kappa_i^2 (b_i + a_i g + a_i f) \\
& + \lambda^2 \sum_{i=1,3,5} \kappa_i \kappa_{i+1} (b_{ii+1} + a_{ii+1} g + a_{ii+1} f) \\
& + \lambda^2 \sum_{i=1,2,5,6} \kappa_i \kappa_4 (b_{i4} + a_{i4} g + a_{i4} f),
\end{aligned}
$$

where $f = \ln(\sqrt{k/\lambda})$ and the 57 coefficients are independent of λ^2.

[2] J. Gao, Comput.Phys.Commun. 184 (2013) 2362.

Distributions of 57 CI Coefficients

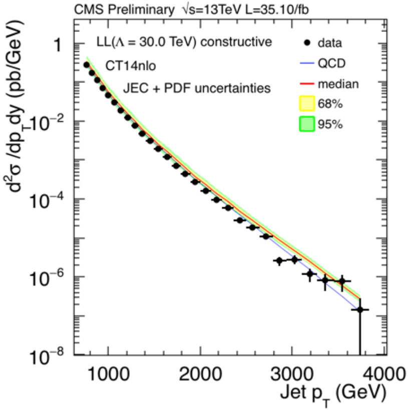
The main task is modeling the prior $\pi(\nu \mid \lambda, \kappa)$:

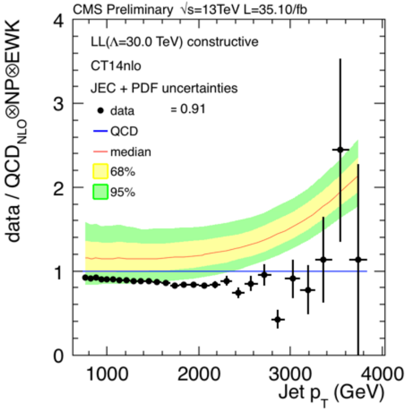
1. Use `hessian2replicas` in `LHAPDF6.1.6` to generate an ensemble of PDF sets for `CT14nlo` and `MMHT2014nlo68cl`. We also use `NNPDF30_nlo_as_0118_1000`.
2. For each PDF set, and 7 combinations of renormalization and factorization scales, use `fastnlo_toolkit-2.3.1pre-2411` to compute the QCD cross section and `CIJET1.1` to compute the 57 CI coefficients. Do this for each of M jet p_T bins.
3. Randomly select a consistent set of CI coefficients and QCD cross sections and randomly select a jet response function JRF. Convolve the 58 differential distributions with the (JRF).
4. Repeat 2 and 3 a few hundred times.

Outline

Inclusive jet spectrum at 13 TeV ($\mathcal{L} = 35.1\,\mathrm{fb}^{-1}$) compared with a $\Lambda = 30\,\mathrm{TeV}$ CI signal.

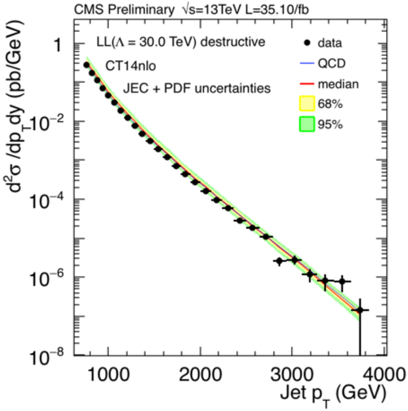
Constructive interference

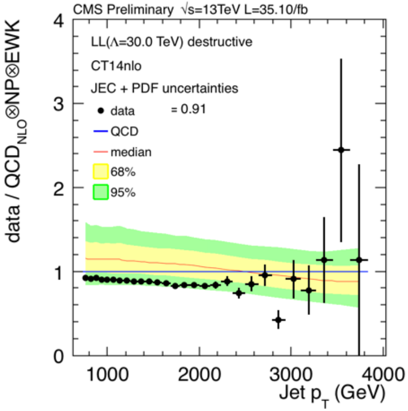




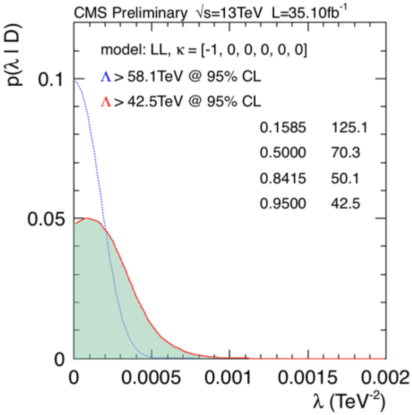
Inclusive jet spectrum at 13 TeV ($\mathcal{L} = 35.1\,\mathrm{fb}^{-1}$) compared with a $\Lambda = 30\,\mathrm{TeV}$ CI signal.

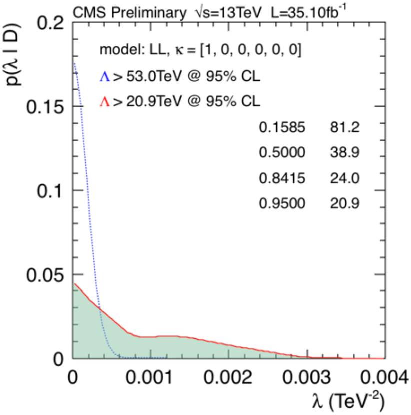
Destructive interference





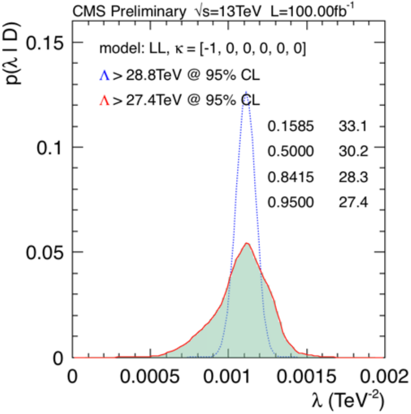
Expected limits for LL CI model
13 TeV ($\mathcal{L} = 35.1\,\mathrm{fb}^{-1}$)

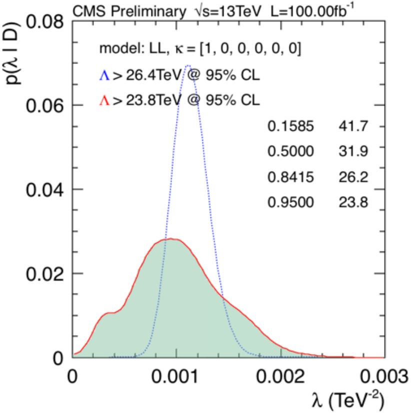




Checking the Likelihood

13 TeV ($\mathcal{L} = 100\,\mathrm{fb}^{-1}$) $\Lambda = 30\,\mathrm{TeV}$





Outline

Plans

- Complete analysis note and ask for an ARC
- Check, check, check!
- Compute expected limits for all CI models and all PDFs
- Compute observed limit
- Write paper
- Publish!