13TeV Inclusive Jets Contact Interaction Analysis

Suman Beri[1], Suneel Dutt[2], Bipen Kotwal[2], and Harrison B. Prosper[3]

[1]Panjab University, [2]Shoolini University,
[3]Florida State University

SMP-J: Jet Analysis Meeting

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Outline

1. Introduction

2. Review: Analysis 2015 dataset ($72.5 pb^{-1}$ @ 13TeV)

3. Plans: Analysis 2016 dataset

Introduction

Goals

1. Search for new QCD-like interactions by looking in the inclusive jet spectrum for deviations from QCD predictions at high jet p_T.

2. Extend the 13TeV contact interaction analysis, based on SMP-15-007 (Eur. Phys. J. C**76** (2016) no.8, 451), to the 2016 dataset.

3. Publication before the end of 2017.

Introduction

Basic Assumption

At the LHC, the Lagrangian L can be approximated as

$$L$$

in which the $L^{(2)}$ term, which contains 4-quark dim-6 operators, can be approximated as contact interactions (CI).

Outline

1. Introduction

2. **Review: Analysis 2015 dataset ($72.5 pb^{-1}$ @ 13TeV)**

3. Plans: Analysis 2016 dataset

Analysis 2015 Dataset

Many thanks to the Inclusive Jet Group!

Sourav Dev

Giannis Flouris

Hannes Jung

Panos Kokkas

Ksenia Shchelina

and special thanks to Paolo Gunnellini who provided all the necessary details, including the observed jet p_T bin counts ($L = 71.5 pb^{-1}$).

Analysis 2015 Dataset

Experimental Input

- Inclusive jet p_T spectrum in
  $|y| < 0.5$, $638 \leq p_T \leq 2000$ GeV, anti-k_T R = 0.7 jets.

- Jet response function (JRF)

- Jet energy scale (JES) uncertainty:
  Summer15_50nsV5 for AK8PF jets

- Jet energy resolution (JER) uncertainty: 10%

Analysis 2015 Dataset

Theoretical Input

- PDFs (LHAPDF-6.1.6)

  CT14nlo, MMHT2014nlo68cl, NNPDF30_nlo_as_0118_1000

- Program to calculate QCD@NLO

  fastnlo_toolkit-2.3.1pre-1871
  InclusiveNJets_fnl5332g_v23_fix.tab

- Program to calculate CI@NLO

  CIJET-1.1

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

- Non-perturbative corrections (NP)
- Electroweak corrections (EWK)

Analysis 2015 Dataset: Models

At NLO accuracy, 4-quark interactions can be described using an effective Lagrangian of the form

$$L$$

where Λ is a mass scale, κ_i are additional free parameters, and each O_i is a sum over dim-6 operators:

$$O_{1,2} \sim \bar{u}_L \gamma_\mu u_L \; \bar{u}_L \gamma^\mu u_L$$
$$O_{3,4} \sim \bar{u}_L \gamma_\mu u_L \; \bar{u}_R \gamma^\mu u_R$$
$$O_{5,6} \sim \bar{u}_R \gamma_\mu u_R \; \bar{u}_R \gamma^\mu u_R$$

Analysis 2015 Dataset: Models

We consider the following discrete set of values for the κ parameters:

Model	η_{LL}	η_{RL}	η_{RR}
LL	± 1	0	0
RR	0	0	± 1
VV	± 1	± 1	± 1
AA	± 1	∓ 1	± 1
V-A	0	± 1	0

where $\kappa_1 = \eta_{LL}$, $\kappa_3 = 2\eta_{RL}$, $\kappa_5 = \eta_{RR}$, and $\kappa_2 = \kappa_4 = \kappa_6 = 0$.

Analysis 2015 Dataset: Models

The NLO QCD+CI cross section per jet p_T bin can be written as

s

where $g = -\ln(\mu_0 \sqrt{k})$

and $\lambda = 1/\Lambda^2$

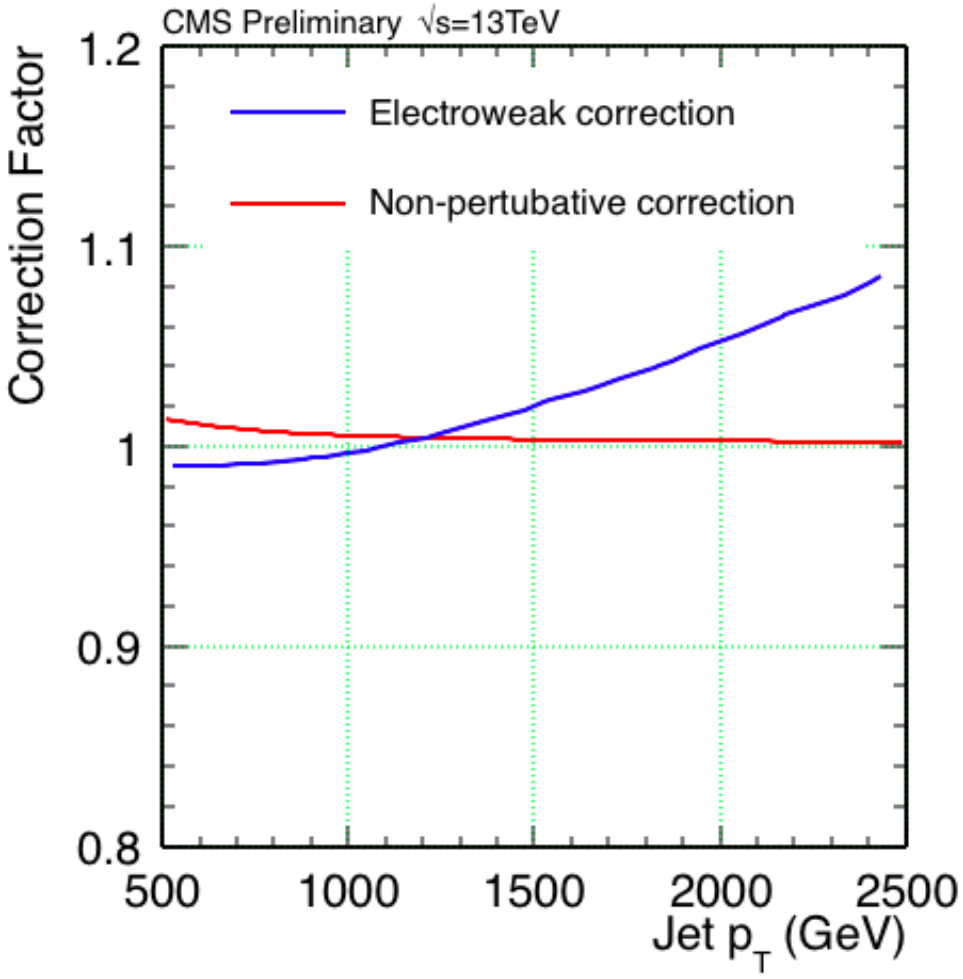
$f = \ln(\sqrt{(k / \lambda)})$

The CI term comprises

57

coefficients

2015 Dataset: NP & EWK Corrections



Analysis 2015 Dataset: Overview

1. Integrate (multinomial) likelihood $p(D|\lambda, \nu)$ over nuisance parameters ν associated with PDFs, renormalization and factorization scales, jet energy scale, and jet energy resolution. ($\lambda = 1/\Lambda^2$ and D denotes the observed counts.)

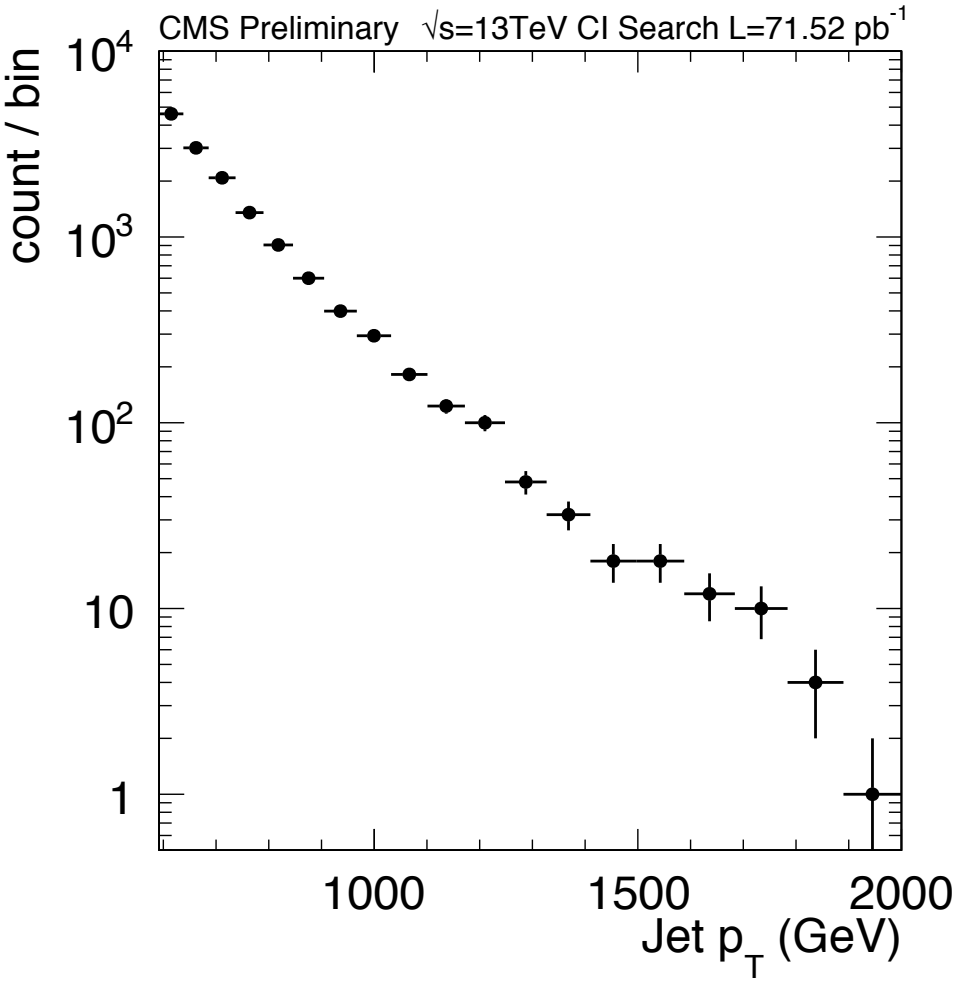
2. Compute expected limits by setting "observed" counts = expected counts

3. Compute observed limits using observed counts.

See backup for details.

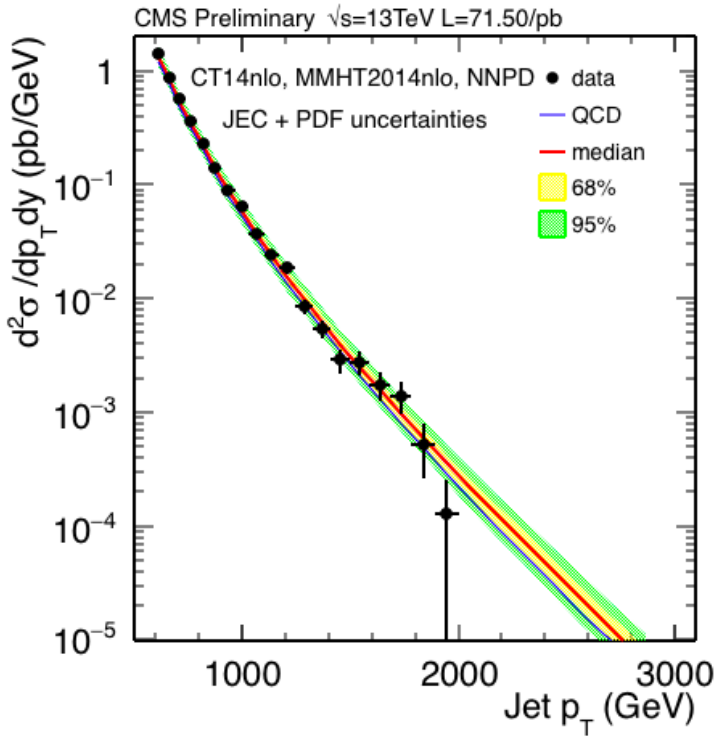
ANALYSIS 2015 DATASET:
RESULTS & LIMITS

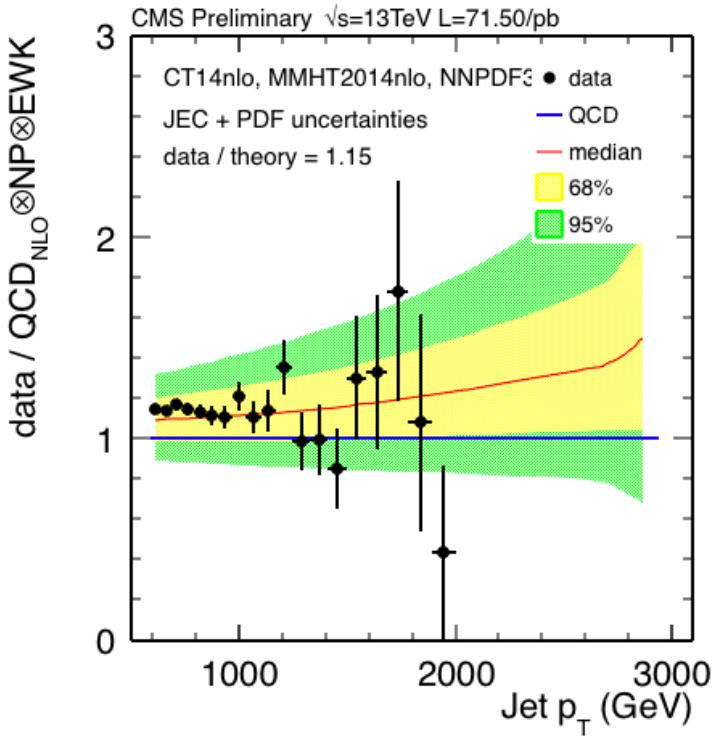
2015 Dataset: 71.52 pb^{-1} @ 13TeV



Data vs. QCD

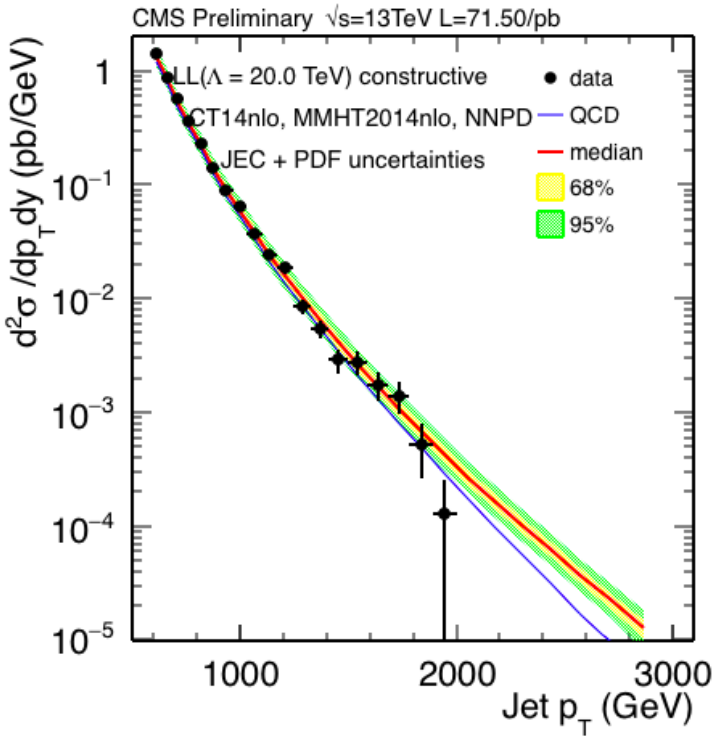
PDF + JES + JER (Summer15 V5) uncertainties

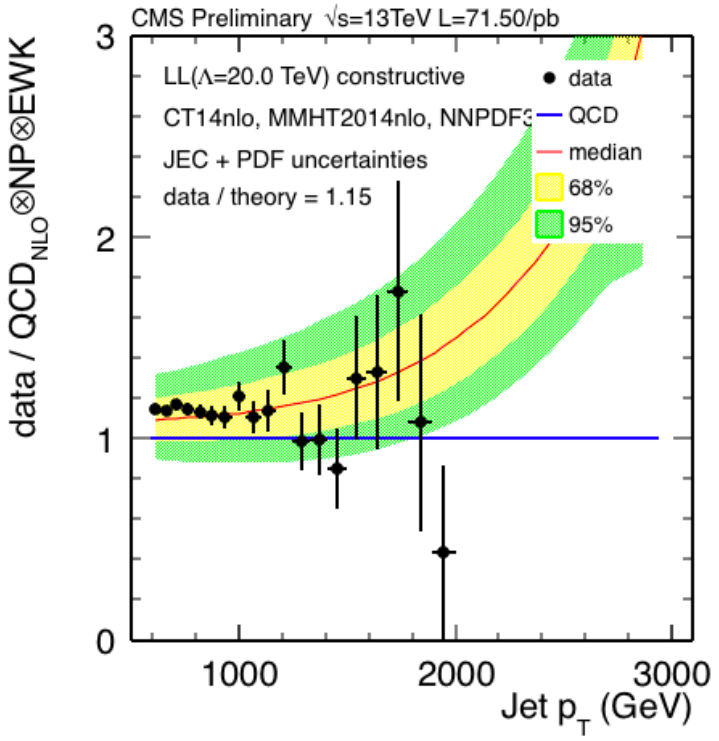




Data vs. LL Model (Λ = 20TeV)

PDF + JES + JER (Summer15 V5) uncertainties

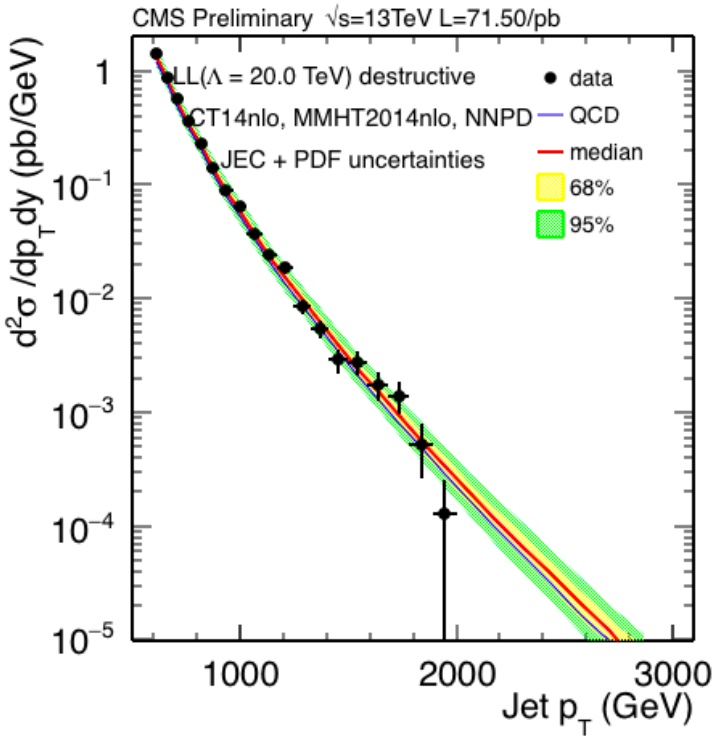


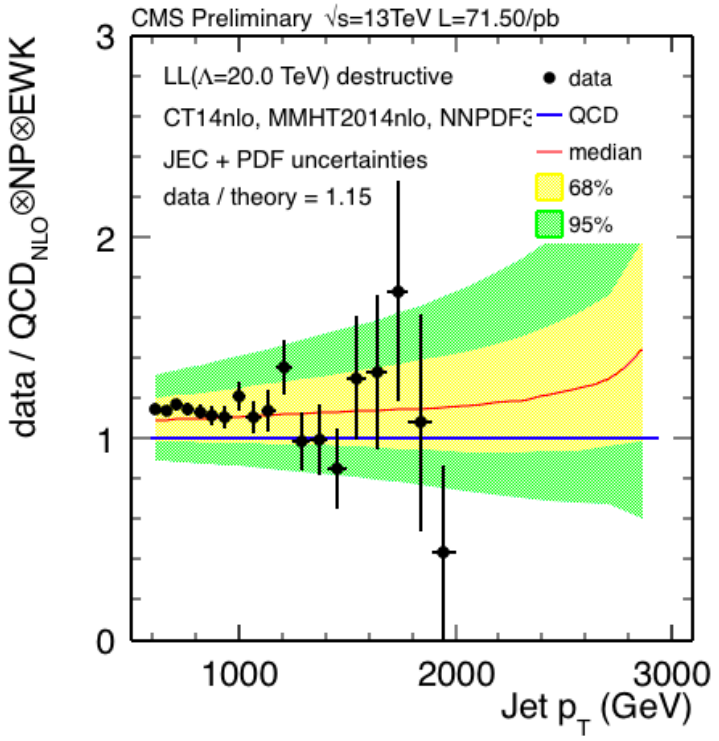


Constructive

Data vs. LL Model (Λ = 20TeV)

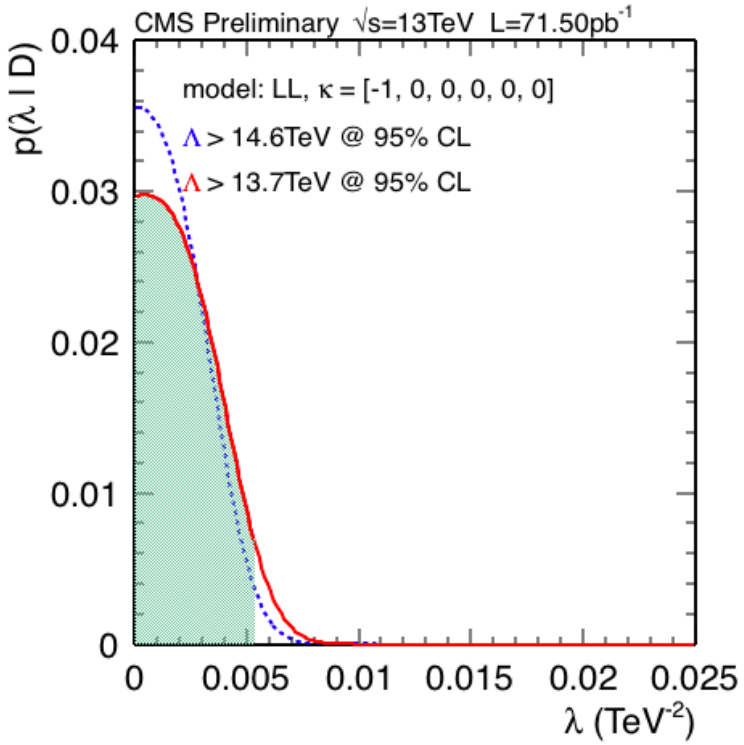
PDF + JES + JER (Summer15 V5) uncertainties

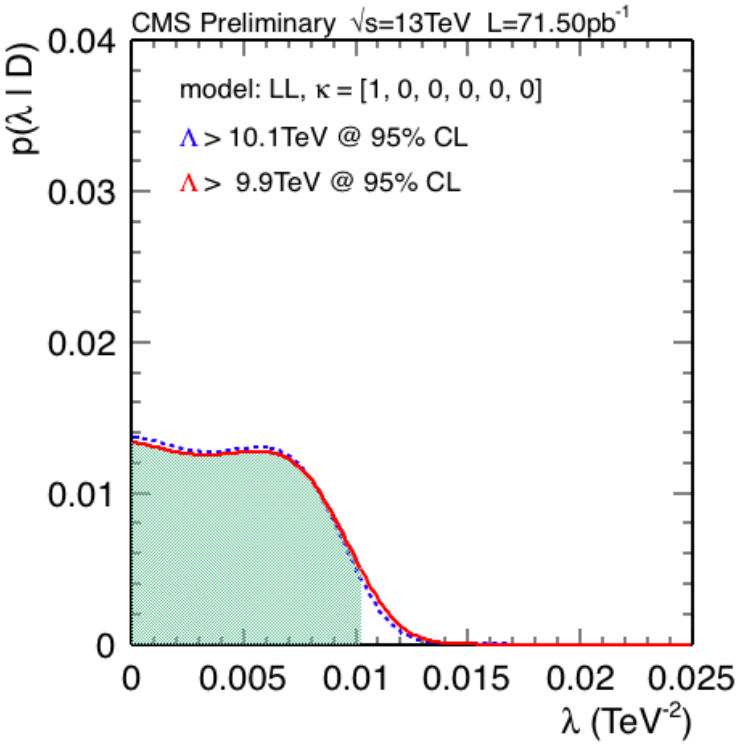




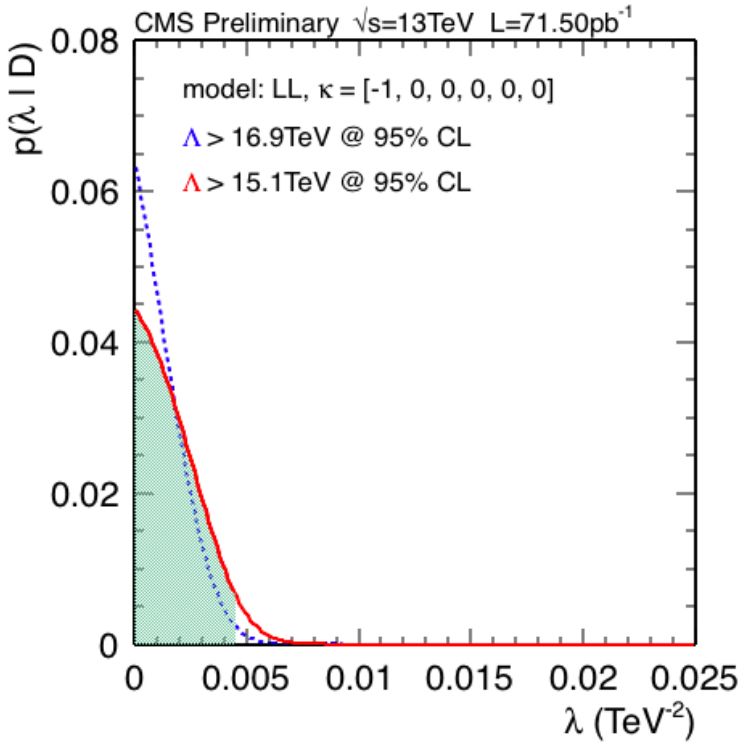
Destructive

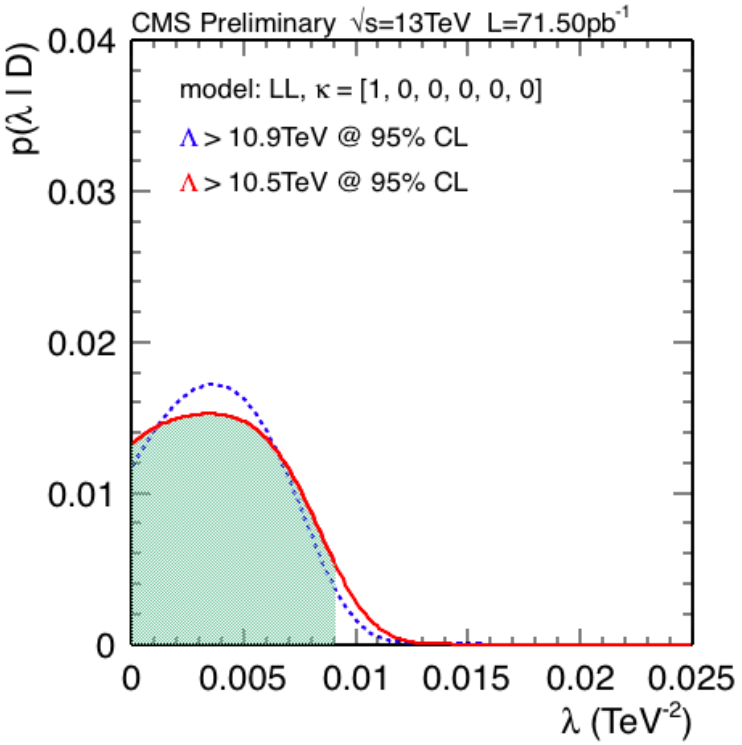
LL Limits @ 95% CL: Expected





LL Limits @ 95% CL: Observed





Limits @ 95% CL

	$L = 0.072$ fb^{-1}	$L = 2.6$ fb^{-1}
	AN-16-338	AN-15-245*
Model	**Observed (TeV)**	**Expected (TeV)**	**Expected (TeV)**
Λ^{+}(LL/RR)	10.5	9.9	12.1
Λ^{-}(LL/RR)	15.1	13.7	17.3
Λ^{+}(VV)	12.0	11.5	13.9
Λ^{-}(VV)	19.5	17.5	22.2
Λ^{+}(AA)	12.1	11.5	13.9
Λ^{-}(AA)	19.3	17.5	22.1
Λ^{+}(V-A)	8.7	8.0	9.5
Λ^{-}(V-A)	8.7	8.0	9.5

*Search for quark contact interactions and extra spatial dimensions in the dijet angular distributions at 13 TeV, AN-15-245, L. Apanasevich *et al*.

Plans: Analysis 2016 Dataset

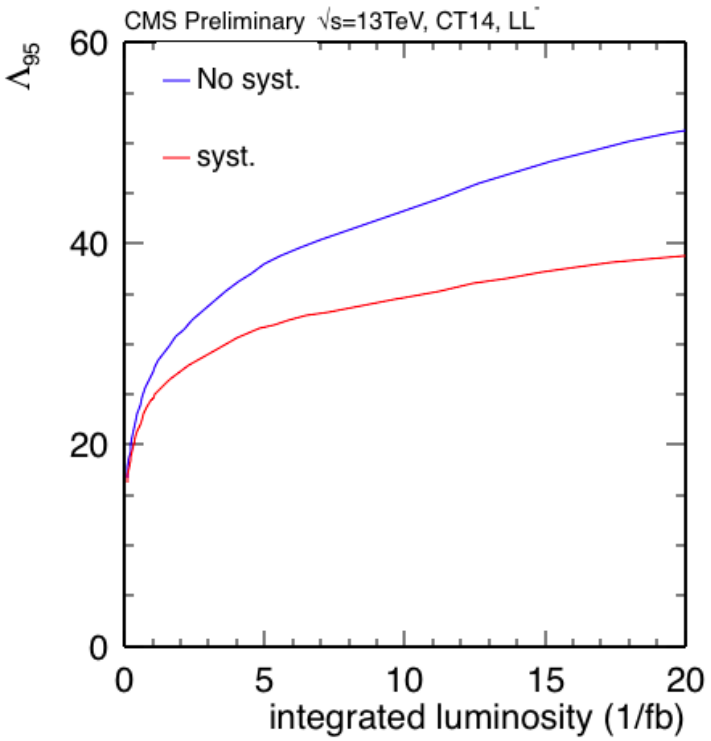
We plan to work on a publishable result using the 2016 data set.

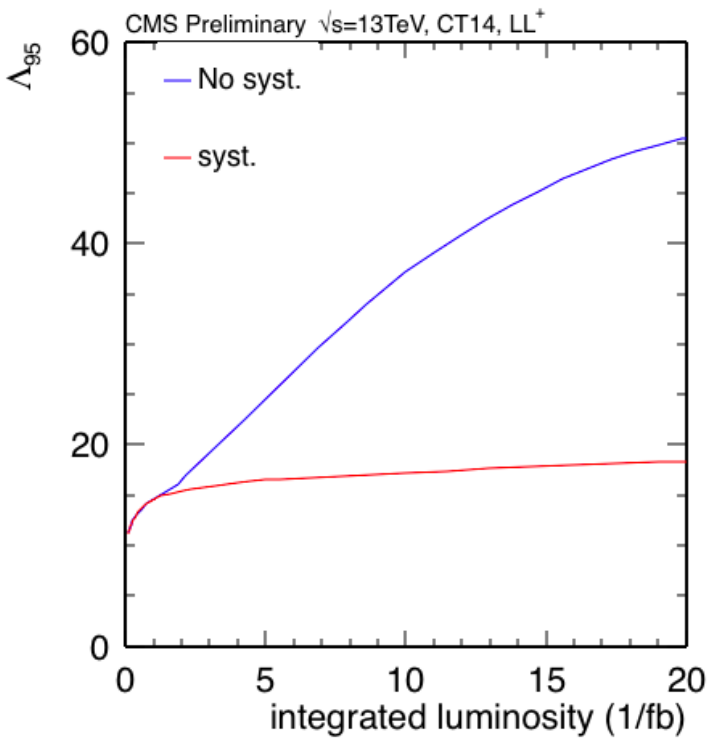
However, this only makes sense if the analysis is not severely limited by systematic uncertainties.

We've made a rough estimate for the LL model (assuming JEC uncertainties become << PDF uncertainties) using CT14.

Plans: 2016 Dataset – Λ^{95} vs. Lumi

These plots suggest that we can use up to ~ 20/fb for





constructive interference models and up to ~ 2/fb for destructive interference models with 2014 PDFs.

Plans: Analysis 2016 Dataset

1. Work with jet group on ongoing jet measurements, including the inclusive jet p_T spectrum using 2016 data.

2. Repeat analysis using 2016 inclusive jet cross section measurement. Extend p_T spectrum 2TeV.

3. Write AN/paper.

Timescale ~ 6 – 8 months (2017)

Immediate plans: work with jet group.

BACKUP

Analysis

Steps

1. For each PDF generate 200 *randomly* sampled PDF sets using hessian2replicas in LHAPDF6.1.6, except for NNPDF30_nlo for which the sample already exists.

2. For each sampled PDF set and 7 combinations of the renormalization and factorization scales, compute the QCD inclusive jet p_T spectrum (yielding 4200 spectra).

3. Repeat 2., but instead use CIJET to compute the 57 differential coefficients needed to compute the CI spectra for *arbitrary* values of κ and Λ (57 $\times$ 4200 spectra).

CI Differential Coefficients (CT14, 0)

Analysis

Steps

4. Convolve each differential spectrum, $f(p_T) = d^2F/dp_T d|y|$ (either QCD or the 57 CI coefficients),

$$f_{obs}(p_T)$$

with the jet response function R, while accounting for the uncertainty in the jet energy scale (JES) and jet energy resolution (JER), taking care to maintain the correlations across all bins and all spectra.

Analysis

Steps

5. Compute the marginal likelihood

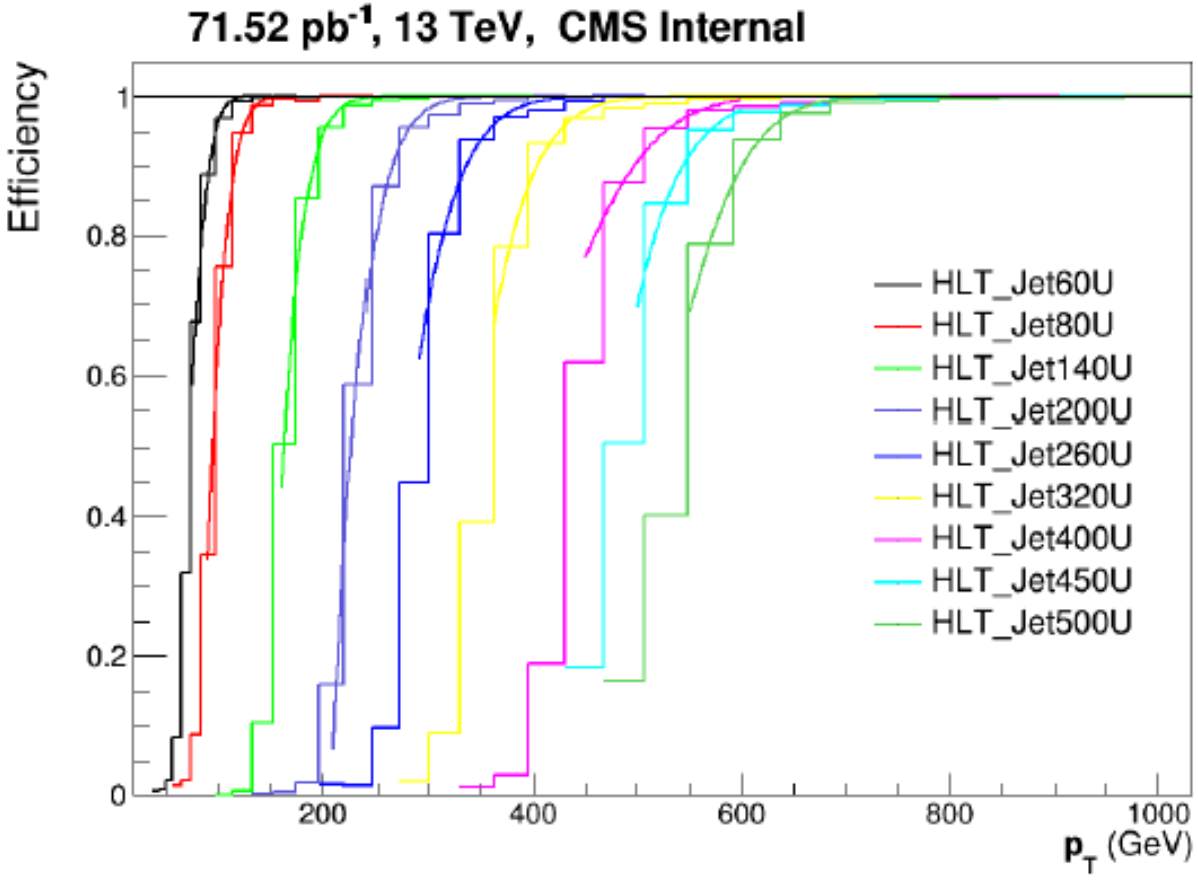
$$p(D \mid \lambda, \nu)$$

where D denotes the counts per bin, and ν denotes the JES, JER, and PDF nuisance parameters.

6. Compute upper limit on λ by solving

$$p(\lambda \mid D, \nu)\, d\lambda$$

Triggers



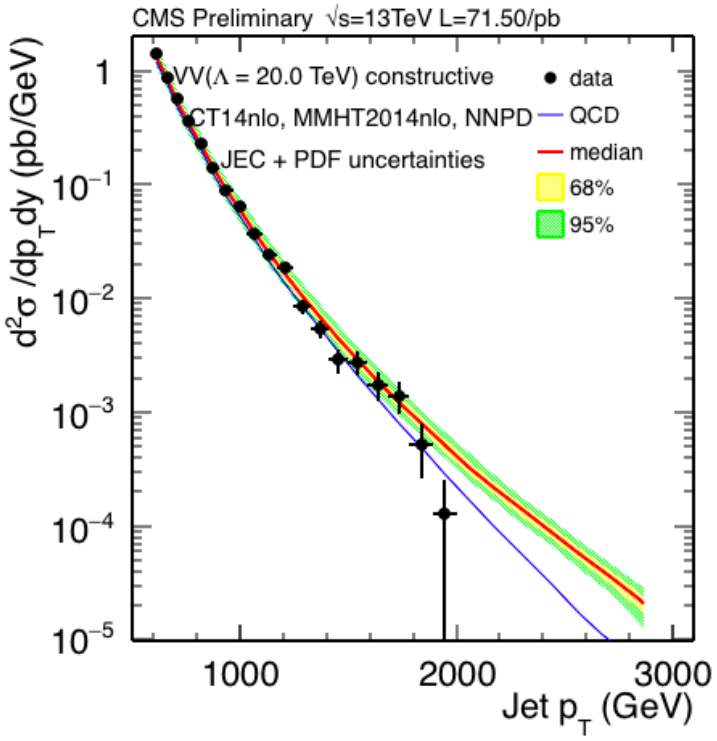
SMP-15-007

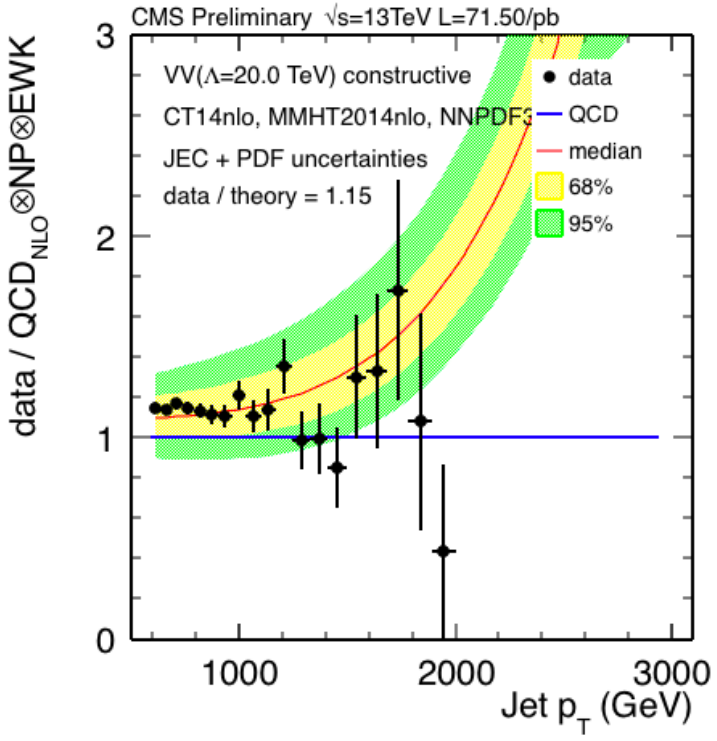
Requirement of ak7chs jet in $|\eta| < 4.7$

Trigger	Turnon
HLT60	105
HLT80	132
HLT140	220.6
HLT200	315.7
HLT260	399.8
HLT320	505.6
HLT400	602.1
HLT450	632.5

Data vs. VV Model (Λ=20TeV)

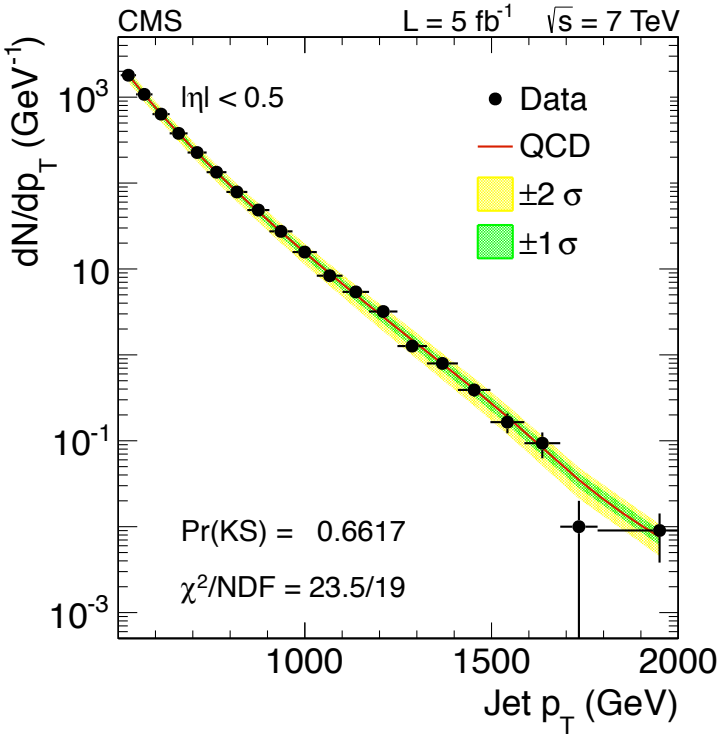
PDF + JES + JER (Summer15 V5) uncertainties

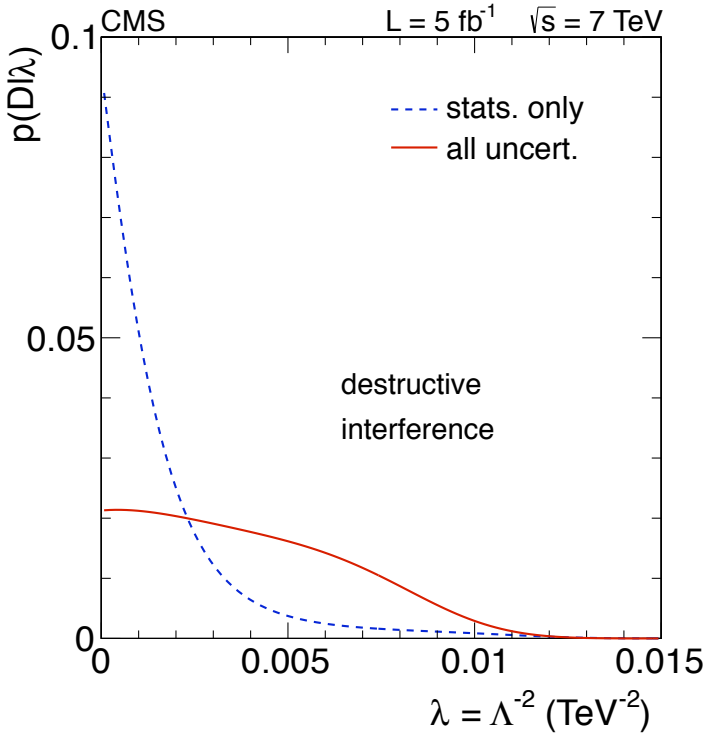




Constructive

Contact Interaction Search @ 7 TeV





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Search for contact interactions using the inclusive jet p_T spectrum in pp collisions at $\sqrt{s} = 7$ TeV

S. Chatrchyan *et al.**
(CMS Collaboration)

(Received 21 January 2013; published 26 March 2013)