Inclusive jet measurement with 2016 data

Overview and status of the analysis

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6 February 2020

Introduction.

Introduction

Goal

- Measurement of inclusive jet differential cross section in pp collisions with 2016 data.
- Determination of α_S and PDFs.
- Limits on contact interactions.

Status

- Framework and workflow were set up during last Autumn.
- Now investigating smoothness and correlations.
- Planning to release the analysis in time for ICHEP.

Outline

- Physics goals of the analysis
- **Test of smoothness**
- Review certain steps of the analysis
- Prospects

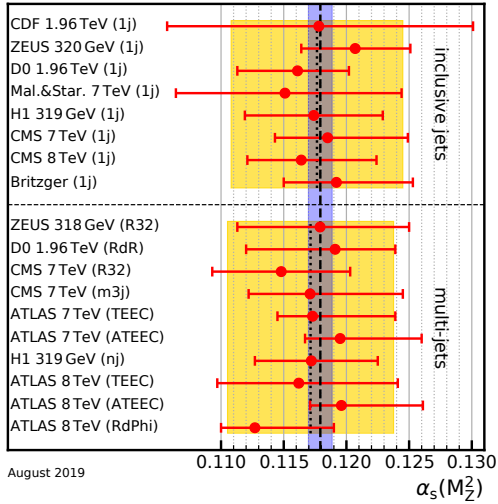
Physics.

QCD fits

Contact interactions

Current status

QCD fits

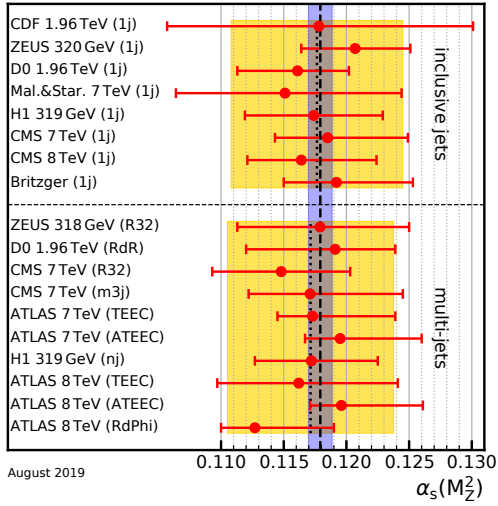


Strong coupling α_S

- Textbook measurement demonstrating *asymptotic freedom* of QCD
- Discovered in 1973 by a 22-year-old doctoral student Frank Wilczek (Nobel Prize in 2004)[a]
- Upcoming measurements will allow to reach the highest scales ever (« atto-scopy », 10^{-19} m);

[a] With D. Gross and independently by D. Politzer

QCD fits



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Note

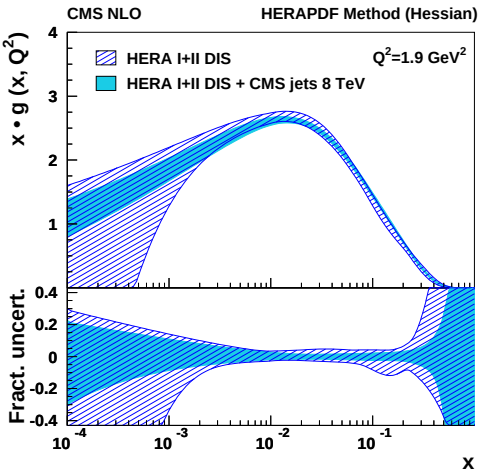
$\longrightarrow$ correlated with PDFs, so one should fit both together...

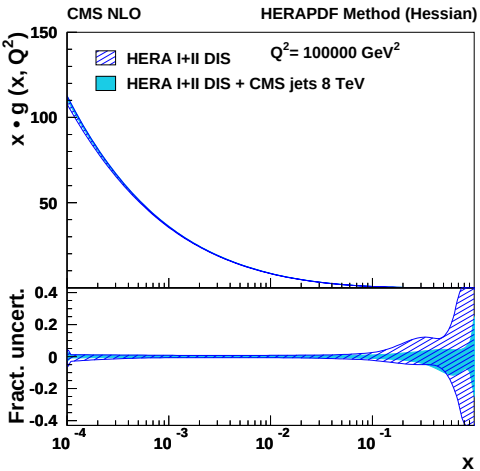
QCD fits

Extraction of PDFs

- PDFs were first measured in ep collisions at HERA.
- Improves the PDFs at high momentum fraction x and at high scale Q^2.

$\longrightarrow$ Planning to use also (already published) $t\bar{t}$ data and extract m_t along α_S and PDFs!





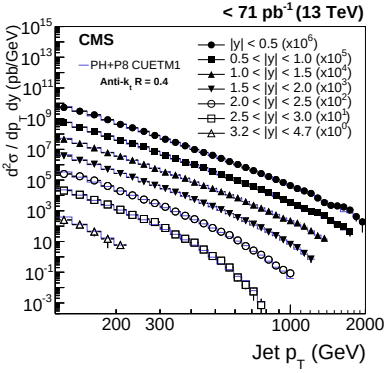
Contact interactions

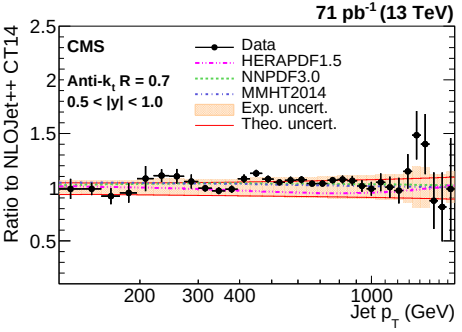
Work in progress...

Current status

Published result

Only published measurement for $\sqrt{s} = 13$ TeV performed on early data with very low luminosity [1].





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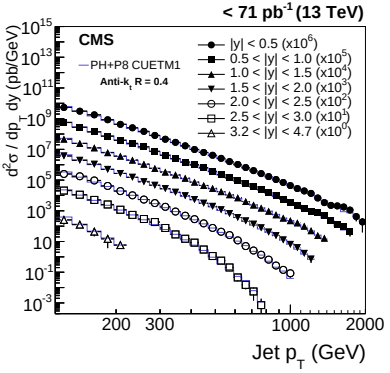

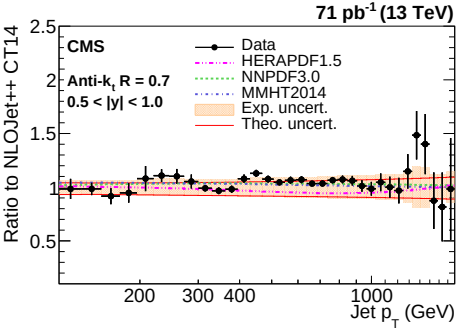

Problem

Non-statistical fluctuations in data

Current status

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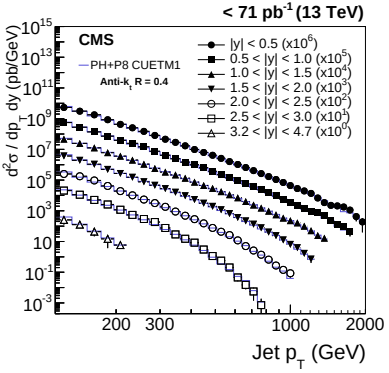

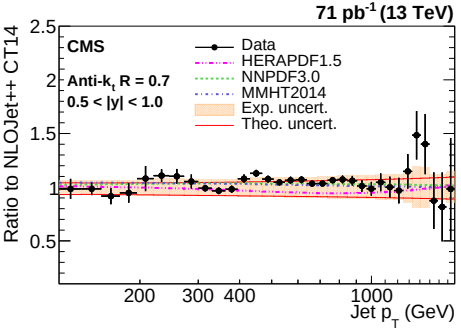

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Non-statistical fluctuations in data $\longrightarrow$ ~~α_S and PDF fit~~

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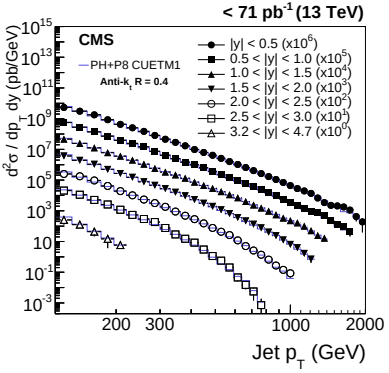

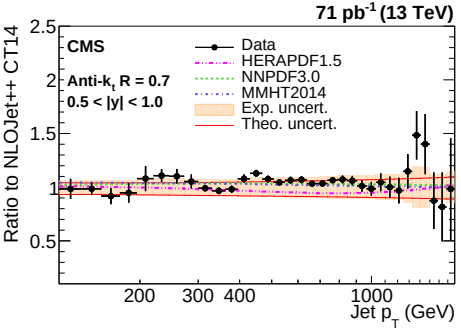

Problem

Non-statistical fluctuations in data $\longrightarrow$ ~~α_S and PDF fit~~

ATLAS data also suffer from such fluctuations...

Current status

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CMS Draft Analysis Note

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2020/01/07
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Inclusive jet production at 13 TeV with 2016 data

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We present the measurement of the double differential cross section in transverse momentum and absolute rapidity of inclusive jet production with CMS 2016 data.

Note

The inclusive jet measurement is basically the baseline of many jet measurements.

$\longrightarrow$ inclusive b jet measurement...

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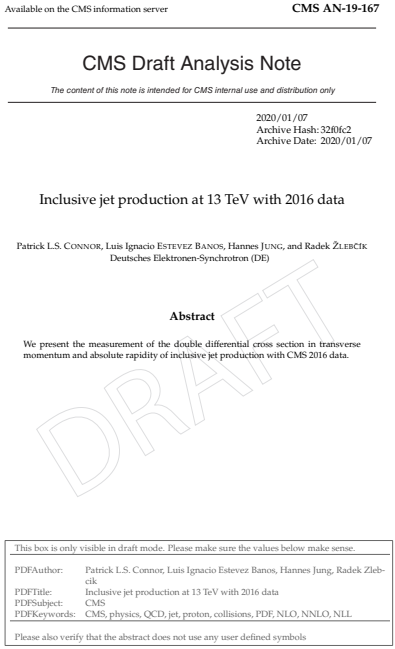

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PDFAuthor:	Patrick L.S. Connor, Luis Ignacio Estevez Banos, Hannes Jung, Radek Zlebcik
PDFTitle:	Inclusive jet production at 13 TeV with 2016 data
PDFSubject:	CMS
PDFKeywords:	CMS, physics, QCD, jet, proton, collisions, PDF, NLO, NNLO, NLL

Please also verify that the abstract does not use any user defined symbols

Note

The inclusive jet measurement is basically the baseline of many jet measurements.
$\longrightarrow$ inclusive b jet measurement...

In the next slides

- First smoothing
- Then review certain steps of the analysis
- Emphasise on the findings of the last months

Smoothness.

Problem
Chebyshev polynomials
Fit procedure
Example
Discussion

Smoothness

Bin-to-bin uncorrelated systematic uncertainties?

« Logarithmic scale can hide monsters. »

- Realised last summer when trying first QCD fits that the statistical uncertainties were not enough to describe bin-to-bin fluctuations.
- In Run-I paper, 1% uncertainties were used due to differences in trigger efficiency.

Smoothness

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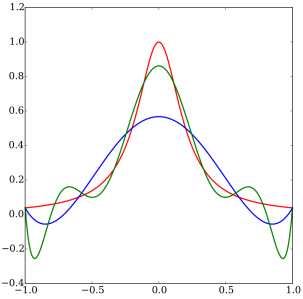


Goal

Find an analytical function to fit the spectrum in order to find non-statistical fluctuations.

Difficulties

- Runge phenomenon
- Many parameters

$\longrightarrow$ standard polynomials $\sum a_i x_i^i$ don't work well for these two reasons (at least!).

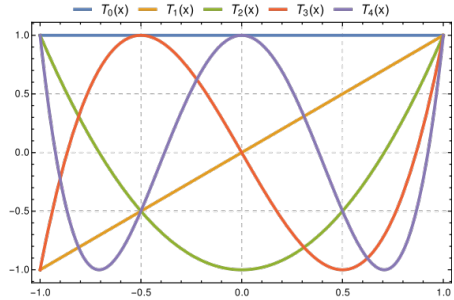
Chebyshev polynomials

Definition

$$f_n(x) = \sum_{i=0}^{n} b_i T_i(x)$$

where $T_0(x) = 1, \quad T_1(x) = x$

and $T_{n+1}(x) = 2xT_n(x) - T_{n-1}(x)$



Interesting properties

- Robust against Runge phenomenon.
- f_n is a good approximation of f_{n+1}.

Fit procedure

« Greta » fit

$$f_n(p_T) = \exp\left(\sum_{i=0}^{n} b_i T_i \left(2\frac{\log p_T / \log p_T^{\min}}{\log p_T^{\max} / \log p_T^{\min}} - 1\right)\right)$$

$\longrightarrow$ robust fit is possible with an **iterative method**:

1. guess the two first parameters from the first and last points of the spectrum;
2. add release one more parameter (assume zero), as and fit all parameters;
3. iterate until a satisfactory χ^2 is found.

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It is robust, really robust

It basically **never** fails!

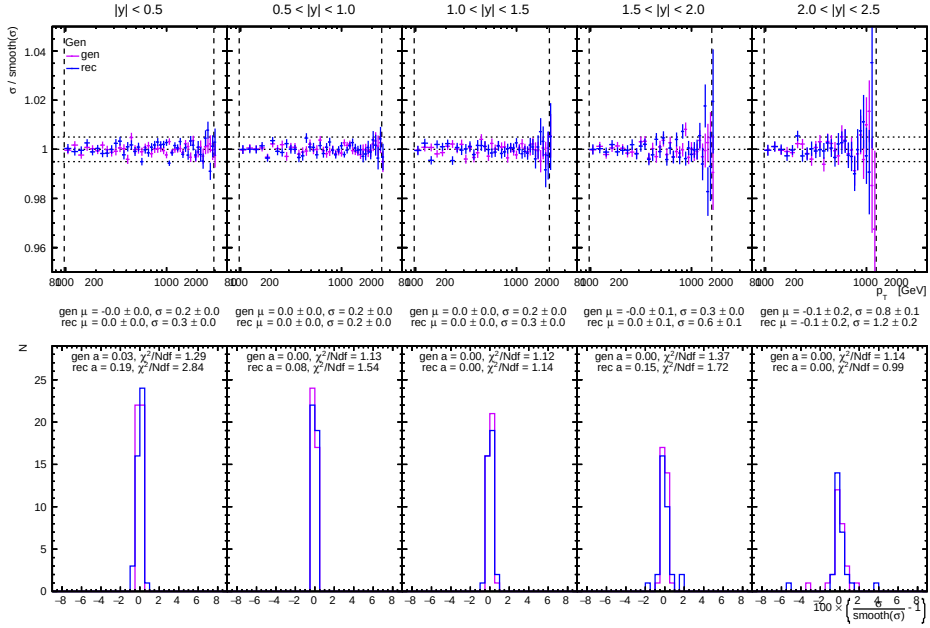
Implementation

Function itself:

- one with recursive approach (`Greta`)
- another using Template Meta-Programming (`Thunberg`)

Fitter: ...

Example


|y| < 0.5
0.5 < |y| < 1.0
1.0 < |y| < 1.5
1.5 < |y| < 2.0
2.0 < |y| < 2.5
σ / smooth(σ)
Gen
gen
rec
p_T [GeV]
gen μ = -0.0 ± 0.0, σ = 0.2 ± 0.0
rec μ = 0.0 ± 0.0, σ = 0.3 ± 0.0
gen μ = 0.0 ± 0.0, σ = 0.2 ± 0.0
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rec μ = 0.0 ± 0.0, σ = 0.3 ± 0.0
gen μ = -0.0 ± 0.1, σ = 0.3 ± 0.0
rec μ = 0.0 ± 0.1, σ = 0.6 ± 0.1
gen μ = -0.1 ± 0.2, σ = 0.8 ± 0.1
rec μ = -0.1 ± 0.2, σ = 1.2 ± 0.2
N
gen a = 0.03, χ²/Ndf = 1.29
rec a = 0.19, χ²/Ndf = 2.84
gen a = 0.00, χ²/Ndf = 1.13
rec a = 0.08, χ²/Ndf = 1.54
gen a = 0.00, χ²/Ndf = 1.12
rec a = 0.00, χ²/Ndf = 1.14
gen a = 0.00, χ²/Ndf = 1.37
rec a = 0.15, χ²/Ndf = 1.72
gen a = 0.00, χ²/Ndf = 1.14
rec a = 0.00, χ²/Ndf = 0.99
100 × (σ / smooth(σ) - 1)

Discussion

Current limitations

- Using jet statistics and ignoring correlations, while it would be more correct to consider **event statistics**.
- Fitting rapidity bins separately.

$\longrightarrow$ working on it!

Analysis.

Outline
Selecta capita
Other (solved) issues

Outline

MC

- *Normalise to cross sections.*
- *Remove bad pile-up simulation.*
- **Apply JES corrections.**
- *Smear to match JER in data.*
- *Apply PU profile reweighting.*
- Apply MET filters.
- Remove hot regions.
- ~~Simulate prefiring issue.~~

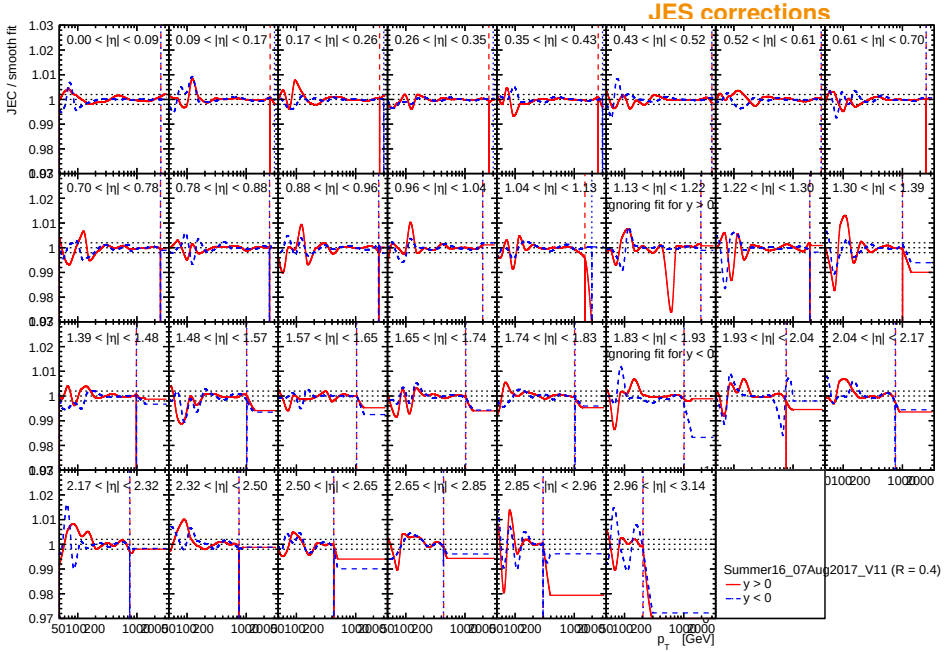
Data

- **Apply JES corrections.**
- **Combine triggers.**
- Normalise to integrated luminosity.
- Apply MET filters.
- Remove hot regions.
- Unfold.

Conventions

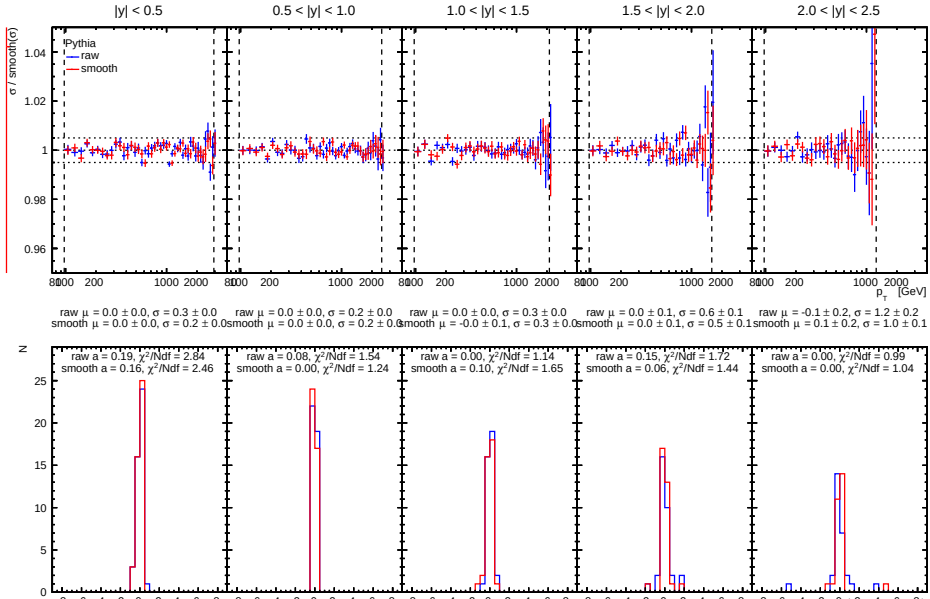
bold	test of smoothness in the next slides;
italic	improved in the last months & summarised later in the presentation;
crossed-out	probably removed for the measurement.

Selecta capita



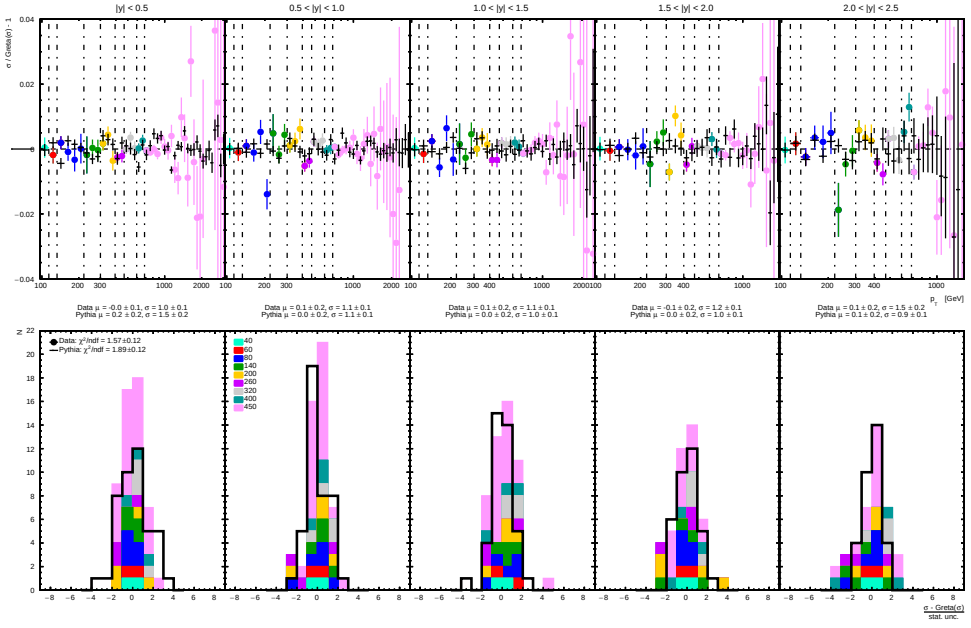
Selecta capita

JES corrections



Selecta capita

Trigger strategy



Selecta capita

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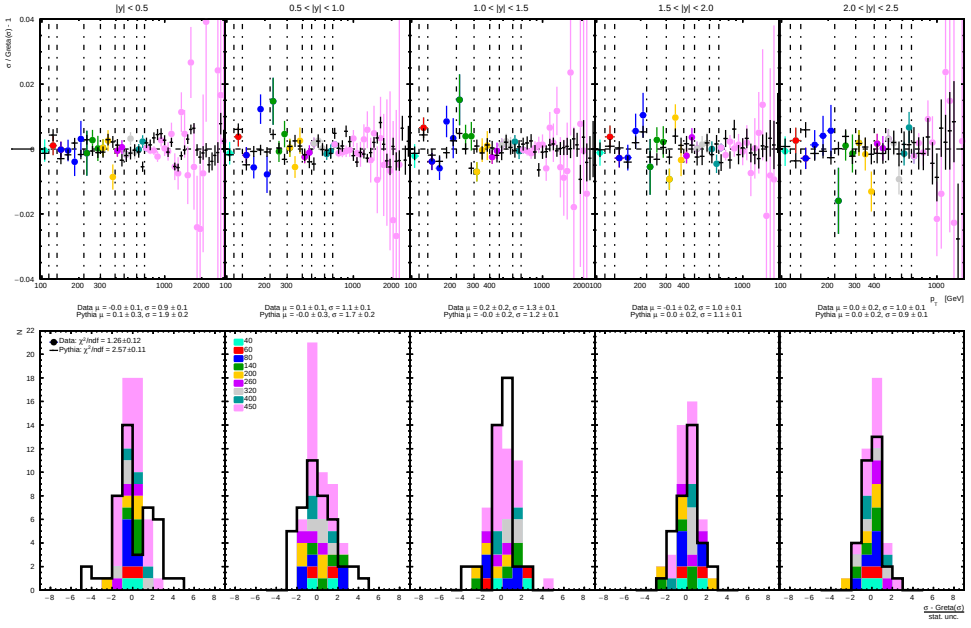

Other (solved) issues

Short list

MC cross sections values should be taken from XSDB...

PU *staub* more sophisticated way(s) than traditional cut p_T^{rec} vs. $\hat{p}_T$ (different for flat and binned samples)

JER difference between resolutions from JetMET and resolutions from MC samples after smearing with SFs from JetMET at high p_T in $1.5 < |y| < 2.0$.

PU profile reweighting if following the approach with effective luminosities, careful with generator-level spectrum (not a problem if you go for prescales)

Note

Happy to share code / knowledge!

Summary & Prospects.

Summary & Prospects

Summary

- Goals of the ongoing analysis.
- Test of smoothness with Chebyshev polynomials.
- Overview of the analysis, focussing on smoothness.
- Outline of the recent findings.

Prospects

- Confirm smoothness of the spectrum with 2D fits accounting for correlations.
- In any case, define uncertainty on trigger, uncorrelated among rapidity bins.
- If successful, deliver new tables in JetMET format.
- (Investigate 2D unfolding in order to have proper description of correlations among rapidity bins.)
- Deliver tables to Toni & Katerina to proceed to QCD fits (AK7 only).

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Thank you for your attention!

Back-up.

Glossary I

ATLAS A Toroidal LHC ApparatuS. 9–12

HERA *Hadron-Elektron-RingAnlage*. 7

JER Jet Energy Resolution. 24, 29

JES Jet Energy Scale. 24

MC Monte Carlo. 29

MET Missing Transverse Energy. 24

PDF Parton Distribution Function. 3, 5–7, 9–12

PU pile-up. 24, 29

QCD Quantum Chromodynamics. 5, 6, 16, 17, 31, 32

SF Scale Factor. 29

XSDB Cross sections Data Base. 29

References I


Vardan Khachatryan et al. "Measurement of the double-differential inclusive jet cross section in proton–proton collisions at $\sqrt{s} = 13\,\text{TeV}$". In: *Eur. Phys. J.* C76.8 (2016), p. 451. DOI: 10.1140/epjc/s10052-016-4286-3. arXiv: 1605.04436 [hep-ex].