

Jety s vysokou příčnou hybností v RunII experimentu ATLAS

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Obhajoba diplomové práce

June 9, 2015

Úvod

Cíl práce

Cílem diplomové práce bylo připravit analýzu inkluzivního účinného průřezu produkce jetů a porovnat data s předpovědí next-to-leading order QCD v rámci Standard Model skupiny experimentu ATLAS pro použití po spuštění urychlovače s těžišťovou energií 13 TeV.

Osnova prezentace

- ▶ **Úvod**

Jet, Inkluzivní jet, K čemu?

- ▶ **Analýza dat**

Charakteristika dat, Rekonstrukce jetů, Unfolding.

- ▶ **Porovnání dat s předpovědí NLO QCD**

Neurčitosti v předpovědích QCD, LO vs. NLO QCD.

- ▶ **Závěr**

Why Do We Need Jets?

Gluon radiation cross section:

Divergences:

- ▶ *Infrared* ($E_k = 0$)
- ▶ *Collinear* ($\theta = 0$)

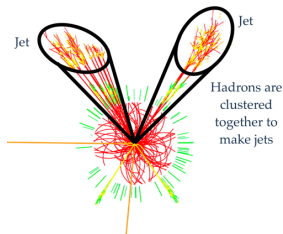
Jet: A group of collimated particles

Jet algorithm: A prescription, how particles (or other objects) are clustered into separate jets. It should fulfill

- ▶ *Infrared safety:* The presence of an additional soft particle should not affect the recombination of particles into a jet
- ▶ *Collinear safety:* Jet reconstruction should not depend on the fact, if the energy is carried by one particle, or if the particle is split into more collinear particles

q or g **CANNOT** be directly observed. Jets **CAN**

$$\sigma_{q \rightarrow qg} \sim \frac{d\theta}{|\sin \theta|} \frac{dE_k}{E_k}$$



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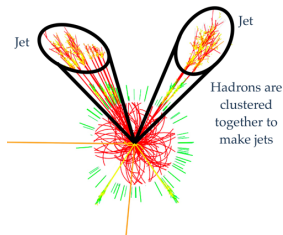
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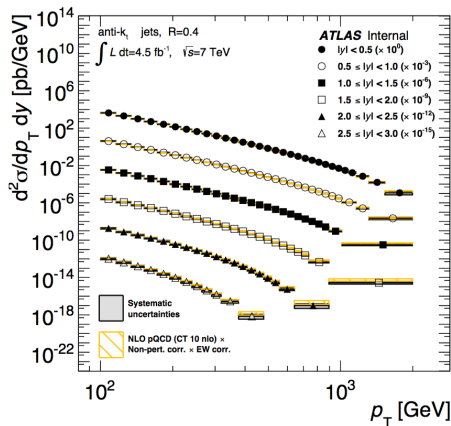
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Inclusive Jets

Inclusive Jet: $pp \rightarrow \text{jet} + \text{"anything"}$, 2012 Analysis¹:



Why Inclusive Jets?

- ▶ They Cover a *wide range of momentum transfers* ($\sim 1 \text{ GeV} - 1 \text{ TeV}$ on the LHC) \rightarrow predictions sensitive to the properties of the running coupling constant α_S
- ▶ They probe the structure of proton at *small distance scales*

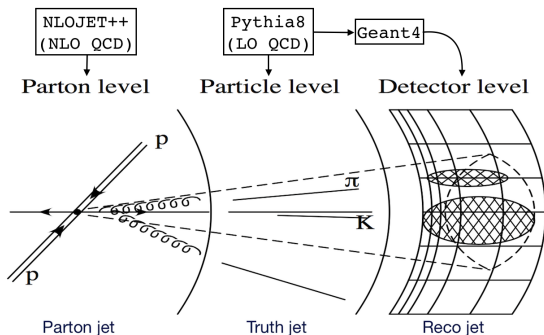
$$\lambda \sim 1/p_T \sim \text{TeV}^{-1} \sim 10^{-19} \text{ m}$$

- ▶ They contribute to our understanding of PDFs
- ▶ They *appreciate the increase in the center-of-mass energy* as no other physics process observed on hadron colliders

¹Georges Aad et al. "Measurement of inclusive jet and dijet production in pp collisions at $\sqrt{s} = 7 \text{ TeV}$ using the ATLAS detector". In: *Phys.Rev. D* 86 (2012), p. 014022. DOI: 10.1103/PhysRevD.86.014022. arXiv: 1112.6297 [hep-ex].

Three Different Levels of Collision

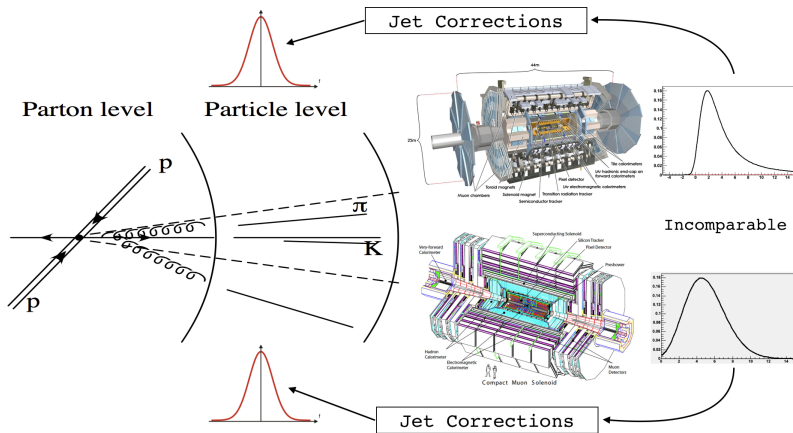
- ▶ **Parton level** - particles (q, g, \dots) created just after the collision
NLOJET++ (*NLO QCD*)
- ▶ **Particle level** - particles created by the hadronization
Events generated by PYTHIA8 (*LO QCD*)
- ▶ **Detector level** - recorded signal
Detector response obtained by GEANT4 full detector simulation



Detector causes *distortion of observables*

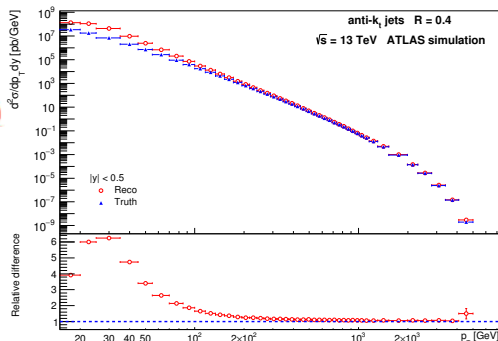
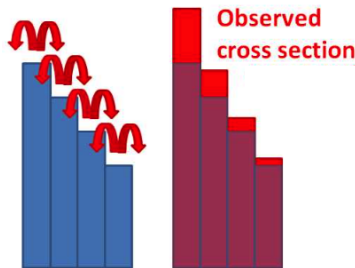
Jet Corrections

- ▶ Correct observables derived from detector to particle level by removing the detector effects
- ▶ Two main procedures - *Calibration* and *Unfolding*



Unfolding

- ▶ Final step of jet corrections
- ▶ Tries to minimize the effects of detector *finite resolution*
- ▶ *Analysis dependent*



Unfolding - Mathematical Formulation

- ▶ **I want:** $f(p_T)$ (distribution of inclusive jet p_T for $p_T \in \langle a, b \rangle$)
- ▶ From detector, **I get:** $g(x)$ (distribution of unphysical variable x)

$$g(x) = \int_a^b A(x, p_T) f(p_T) dp_T$$

- ▶ Detector smearing described by $A(x, p_T)$ (suppose, it is known)
- ▶ Complicated *integral equation* for $f(p_T)$
- ▶ Luckily $g(x)$ and $f(p_T)$ are for practical purpose discretized and in analysis, I assume $x \in \langle a, b \rangle$, $N(i) \subset \langle a, b \rangle$

$$g_i = \int_{N(i)} g(x) dx \quad , \quad f_i = \int_{N(i)} f(p_T) dp_T$$

- ▶ So the response of the detector is described by a "simple" *matrix equation*, with A being called *Transfer Matrix*

$$g = Af$$

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Unfolding

$$\text{Unfolding}(\text{detector spectrum}) \approx \text{particle spectrum}$$

Transfer matrix A_{ij} - containing the number of jets which entered detector in bin i but were reconstructed in bin j

I test **two approaches** to the unfolding, allowing a dealing with the double binning (in p_T and y)

1. Simple unfolding

If reconstructed jet migrates to different rapidity bin, it is ignored. **8 independent** 46x46 transfer matrices, one for each rapidity bin (46 = number of p_T bins)

2. 2D unfolding

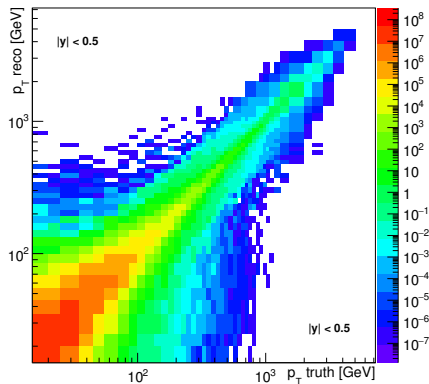
Migration to different rapidity bins allowed.

Only one 368x368 transfer matrix
(368 = 8×46)

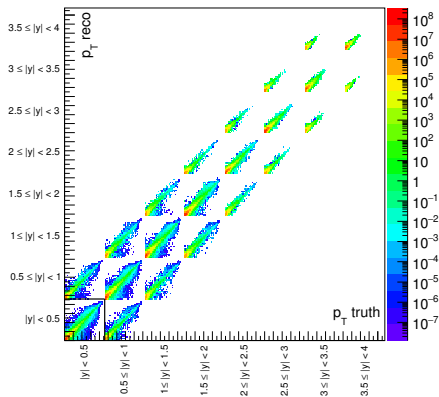


Transfer Matrices

Simple unfolding

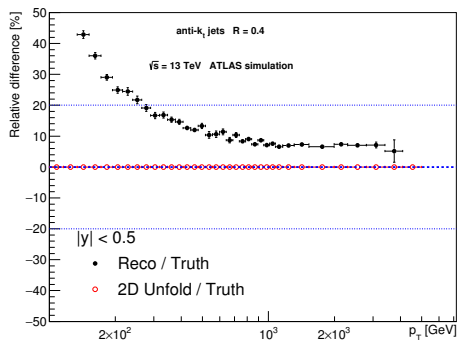


2D unfolding

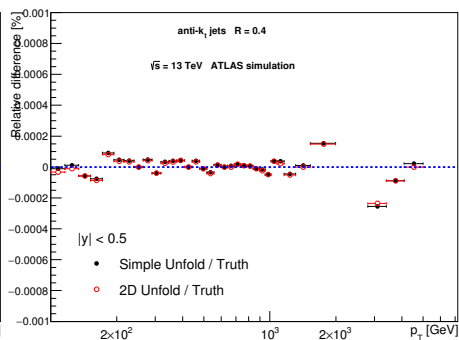


Unfolding Results

Detector (Reco) and Unfolded
vs.
Particle (Truth) Spectrum



Simple and 2D Unfolded
vs.
Particle (Truth) Spectrum



NLO QCD Prediction

- ▶ NLO QCD predictions on parton level
- ▶ *Theoretical uncertainties* which are taken into account
 - ▶ **Scale uncertainty**
Choice of renormalization and factorization scales, including neglecting the higher order terms beyond the NLO
 - ▶ α_S **uncertainty**
Because of experimental measurements of α_S
 - ▶ **PDF uncertainty**
Prediction depends on the concrete choice of a PDF
- ▶ *Other corrections* (not so significant²)
 - ▶ **Nonperturbative corrections**
Hadronization and Underlying Event corrections
 - ▶ **Electroweak corrections**
Next to the QCD processes, the electroweak processes should be assumed

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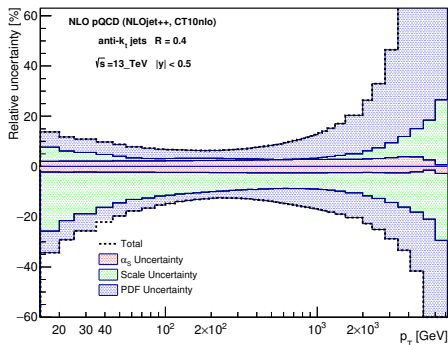
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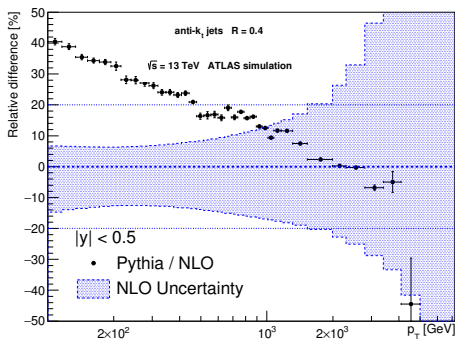
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Results

NLO Systematic Uncertainties



LO vs. NLO QCD



Thesis Conclusions

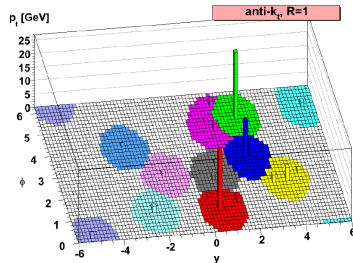
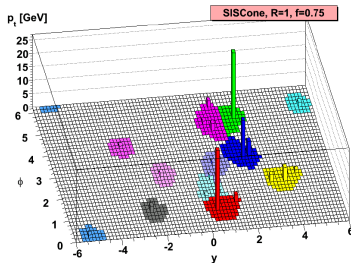
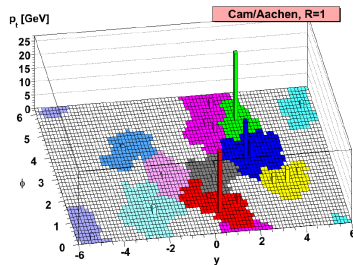
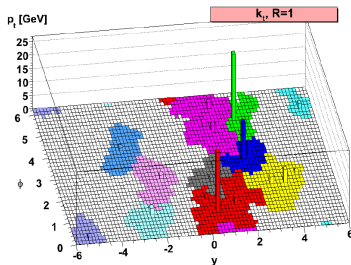
Unfolding

- ▶ Two approaches were probed
- ▶ No significant differences between these two approaches imply, for the real analysis, the **Simple Unfolding approach should be used** for its simpler implementation
- ▶ Agreement of the unfolded p_T spectra with the truth p_T spectra up to systematic error $< 10^{-3} \%$

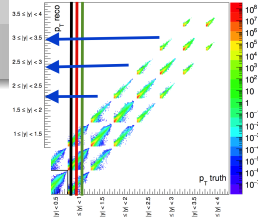
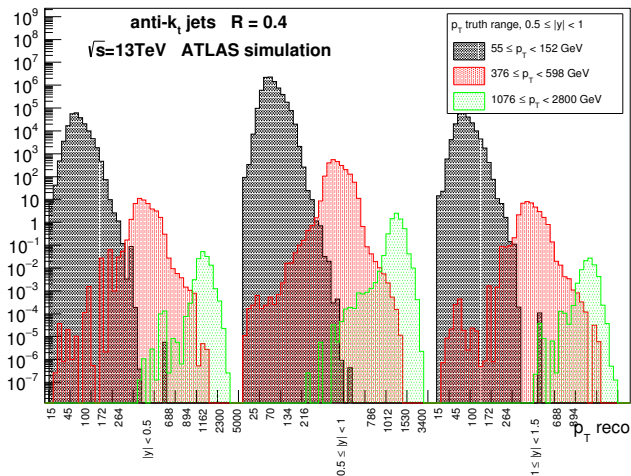
LO and NLO QCD

- ▶ **Significant differences** showing the influence of the NLO QCD processes on physical observables

Jet Clustering



Slices in Transfer Matrix of 2D Unfolding



Comparison of $\sqrt{s} = 8$ and 13 TeV

