Inclusive Jet Cross Section using the K_T algorithm

R. Lefèvre, M. Martínez, O. Norniella

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Outline

- Results with ~845 pb^{-1}

→ Inclusive jet Cross Section using K_T algorithm in 5 rapidity regions (|Y|<2.1)

PRL with the results in the central region based on 385 pb^{-1} submitted in December

- Review of the analysis

→ Event Selection

→ Comparison of raw quantities: new (~460 pb^{-1}) and old data (385pb^{-1})

→ Trigger Study

→ MC simulation

→ Jet P_T Corrections

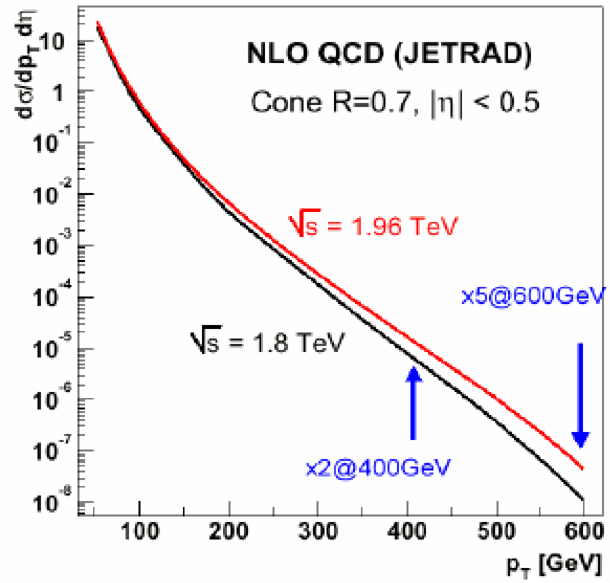
→ Unfolding

→ Systematic Uncertainties

→ NLO Calculations

Motivation

- Measure inclusive jet cross section
  - ✓ Stringent test of pQCD
    - Over 9 order of magnitude
  - ✓ Tail sensitive to New Physics and PDFs
    - Sensitivity to distances ~ 10^{-19} m
  - ✓ Measurements in the forward region allow to constrain the gluon distribution
    - Enhance sensitivity to New Physics in the central region
- K_T algorithm preferred by theory
  - ✓ Infrared/collinear safe to all order in pQCD
  - ✓ No merging/splitting feature
    - No R_{SEP} issue comparing to pQCD



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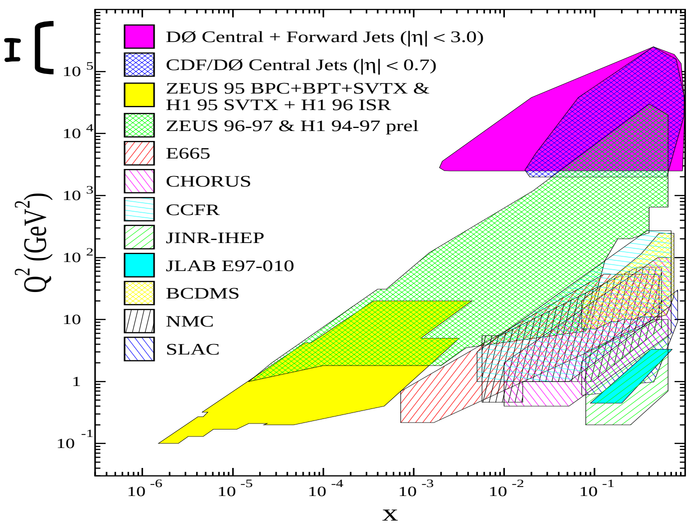


Event Selection

→ Data collected in: Jet20, Jet50, Jet70 and Jet100 datasets

- Using v5.3.1 Data (analyzed using v5.3.3nt) and v6.1.2 (Sep 2005)
- Good Run list version 10
- Runs excluded
  - [155368,155742] -> Cross Section drop of about ~40%
  - 192384, 192386 & 195452 -> change pre-scale during the run

➡ $L = 845\ pb^{-1}$

→ Event Selection

- Jets defined with K_T algorithm (D=0.7)
- Primary vertex position $|V_Z| < 60$ cm
- Missing E_T significance $E_T^{miss} / \Sigma E_T < \min(2+5/400 \cdot P_T^{jet}$ (leading jet), 7)
- Jets in different Y regions:

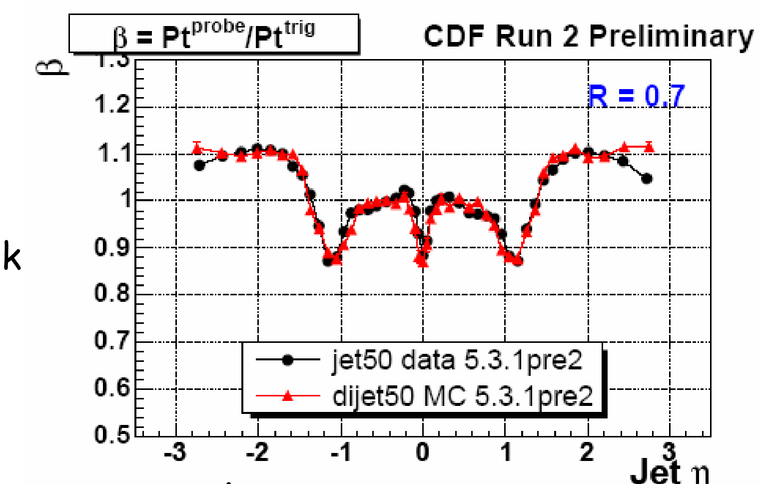
Region 1 : $|Y| < 0.1$ (90° crack)

Region 2 : $0.1 < |Y| < 0.7$ (Central Cal.)

Region 3 : $0.7 < |Y| < 1.1$ (Central Cal. + 30° crack

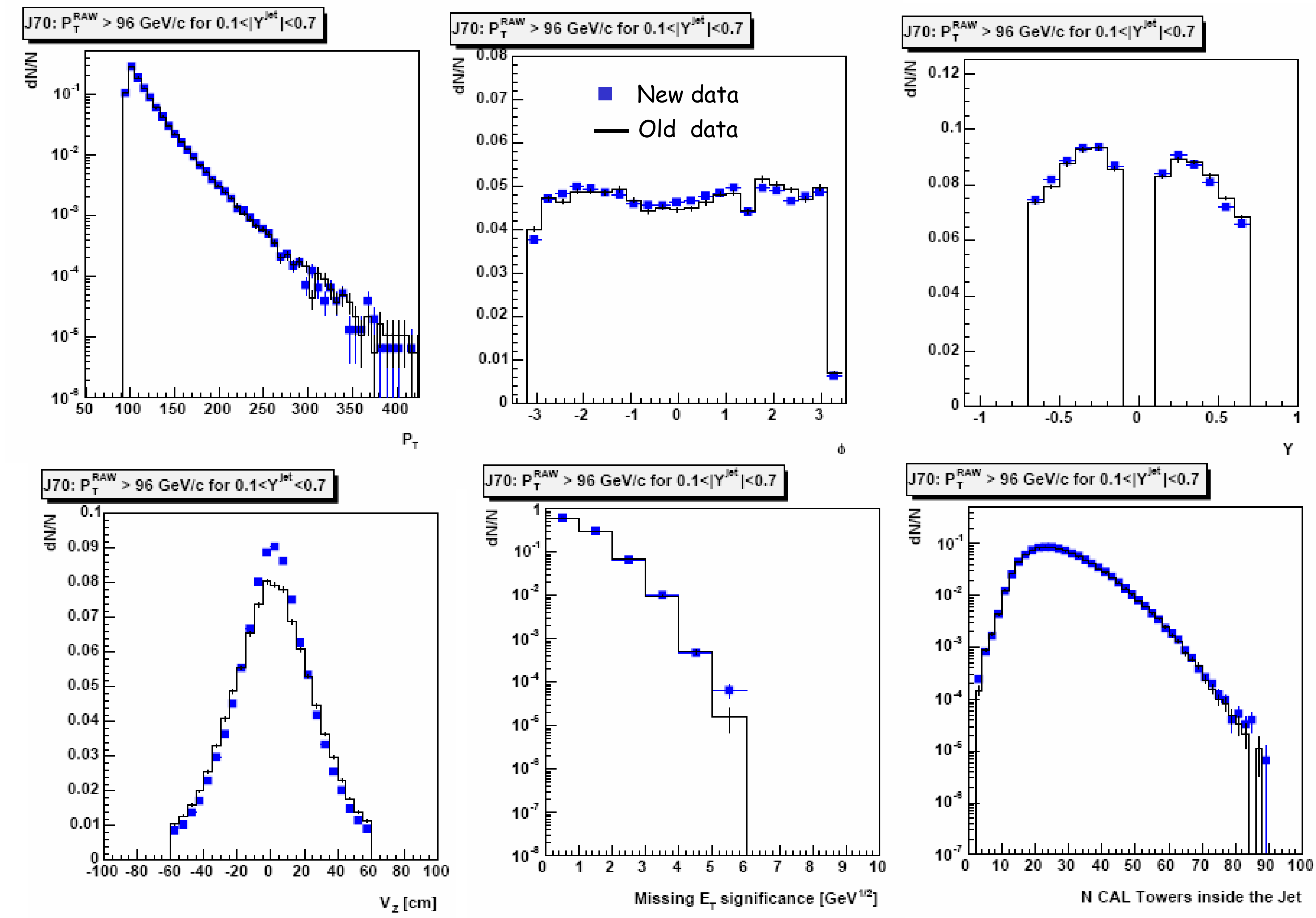
Region 4 : $1.1 < |Y| < 1.6$ (30° crack + Plug Cal.)

Region 5 : $1.6 < |Y| < 2.1$ (Plug Cal.)

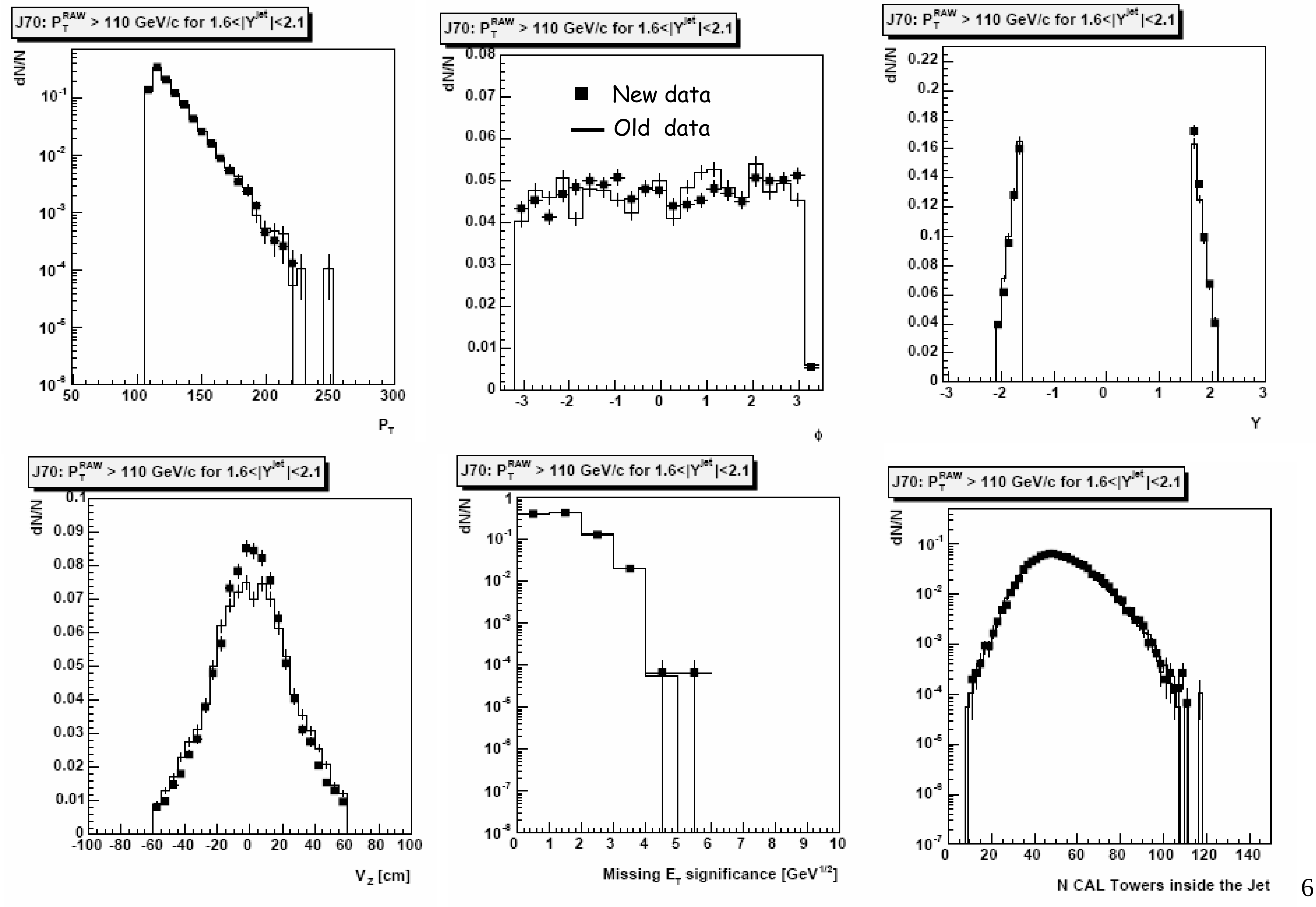


→ Pythia MC samples used to correct the measurements

Comparison of Raw Quantities: $0.1<|Y^{jet}|<0.7$

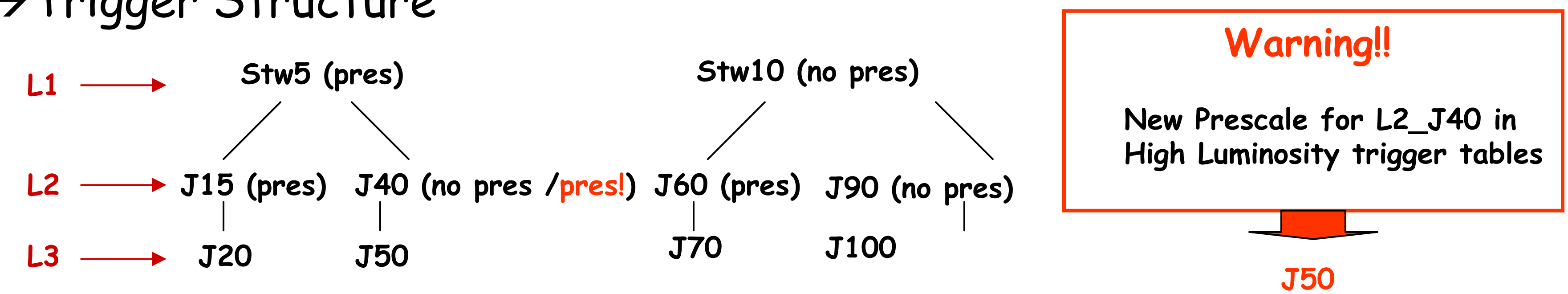


Comparison of Raw Quantities: $1.6<|Y^{jet}|<2.1$



Trigger Study

→Trigger Structure

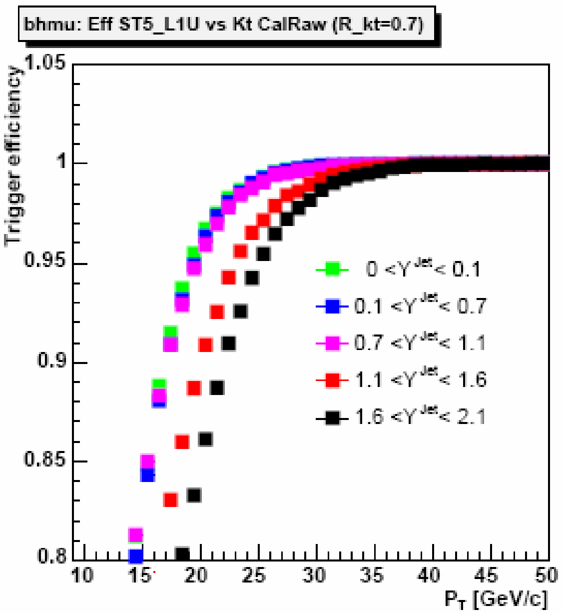


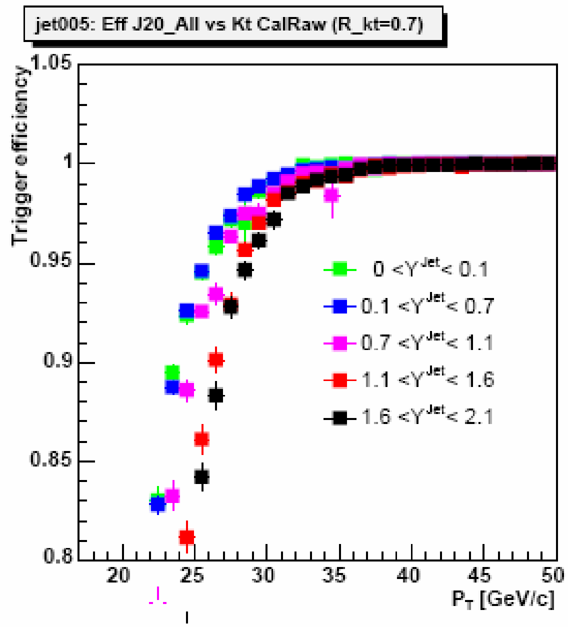
→Study the L1, L2 and L3 Trigger Efficiencies from data

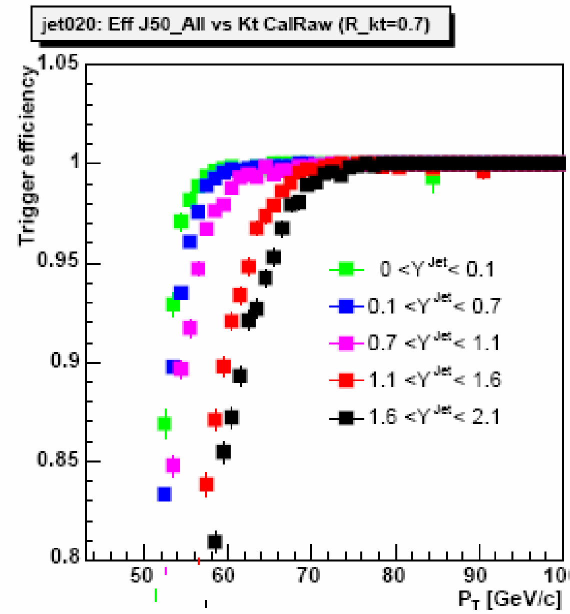
→Use data only where trigger fully efficient: thresholds defined by L1 × L2 × L3 efficiencies > 99%

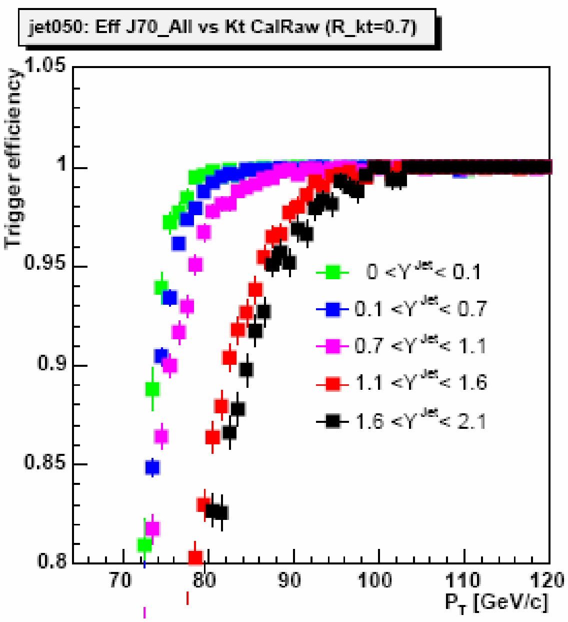
- To avoid trigger related systematic due to energy scale uncertainties, the obtain thresholds are increased by 5%

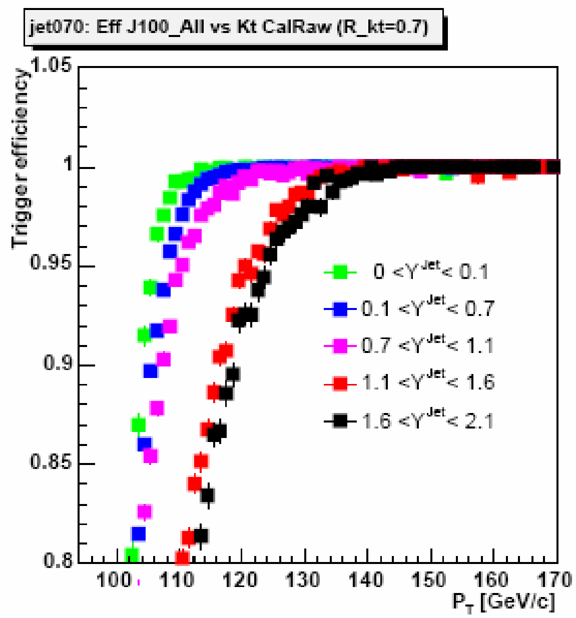
Trigger Efficiency Cuts







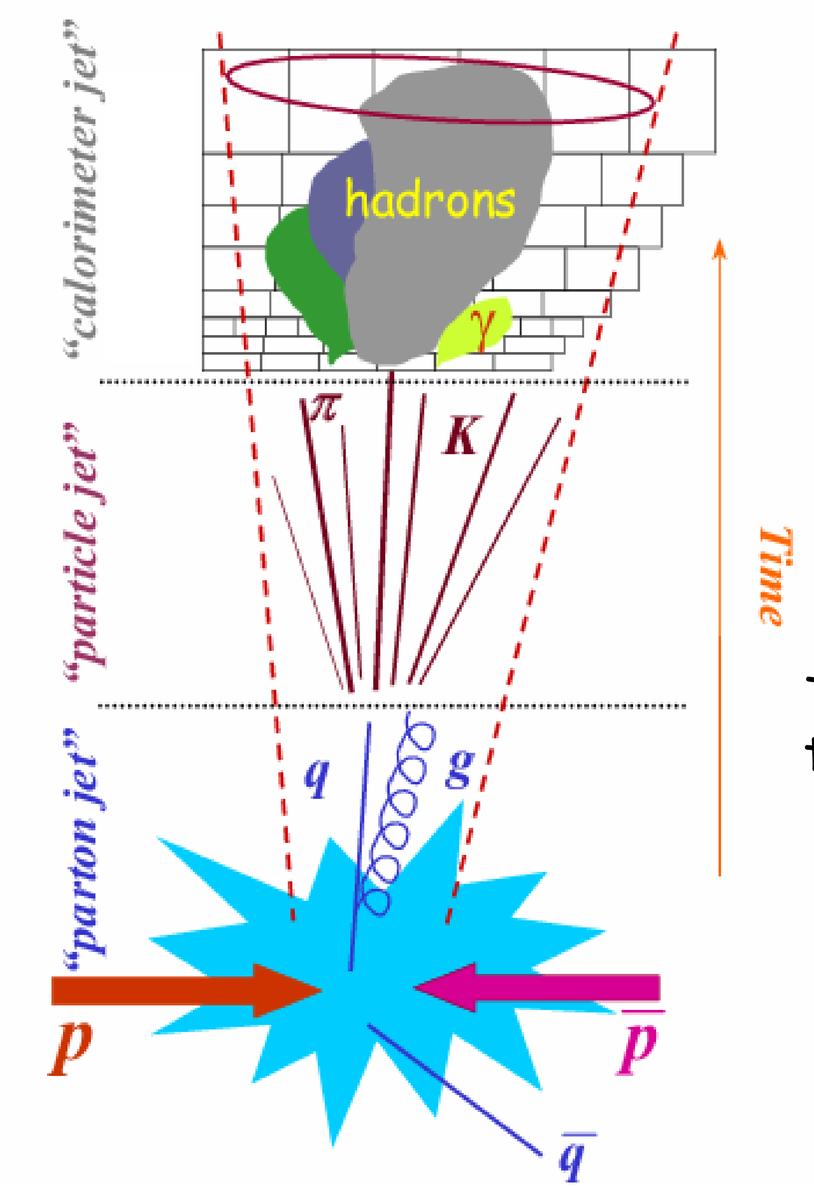




Minimum P_T^{RAW} (uncorrected P_T^{Jet}, GeV/c) for each dataset

	Rap1	Rap2	Rap3	Rap4	Rap5
Stw5	26	26	27	32	33
J20	32	32	33	34	33
J50	60	60	65	72	74
J70	81	80	91	97	101
J100	117	119	124	138	140

Corrections strategy



From calorimeter to hadron level

- Pile-up correction (data based)
- Average P_T^{Jet} correction (MC based)

To correct the average energy lost in the calorimeter

- Unfolding (MC based)

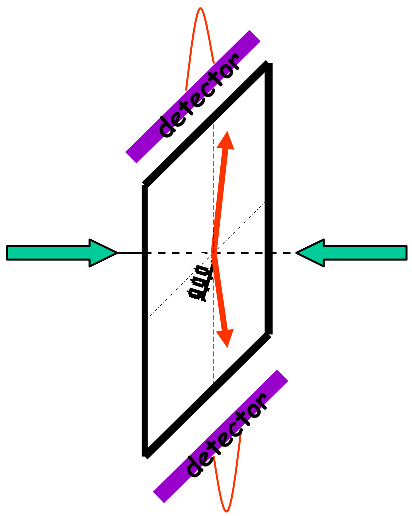
To account for smearing/resolution effects

The MC simulation is good in the central part of the detector… what about the forward region?

- Bisector Method -> study the resolution
- Dijet Balance -> understand the energy scale relative to central jets

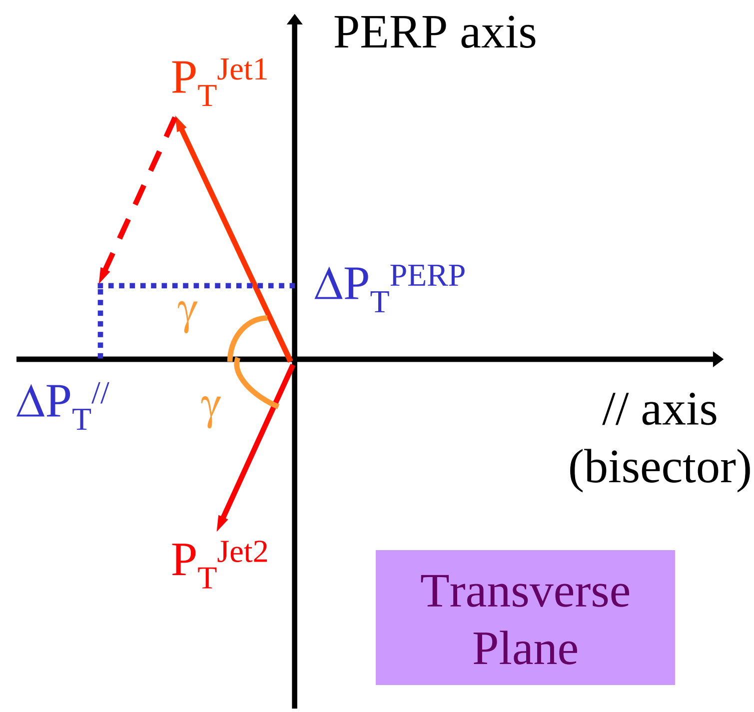
MC Studies: Bisector Method

→ To study the jet energy resolution



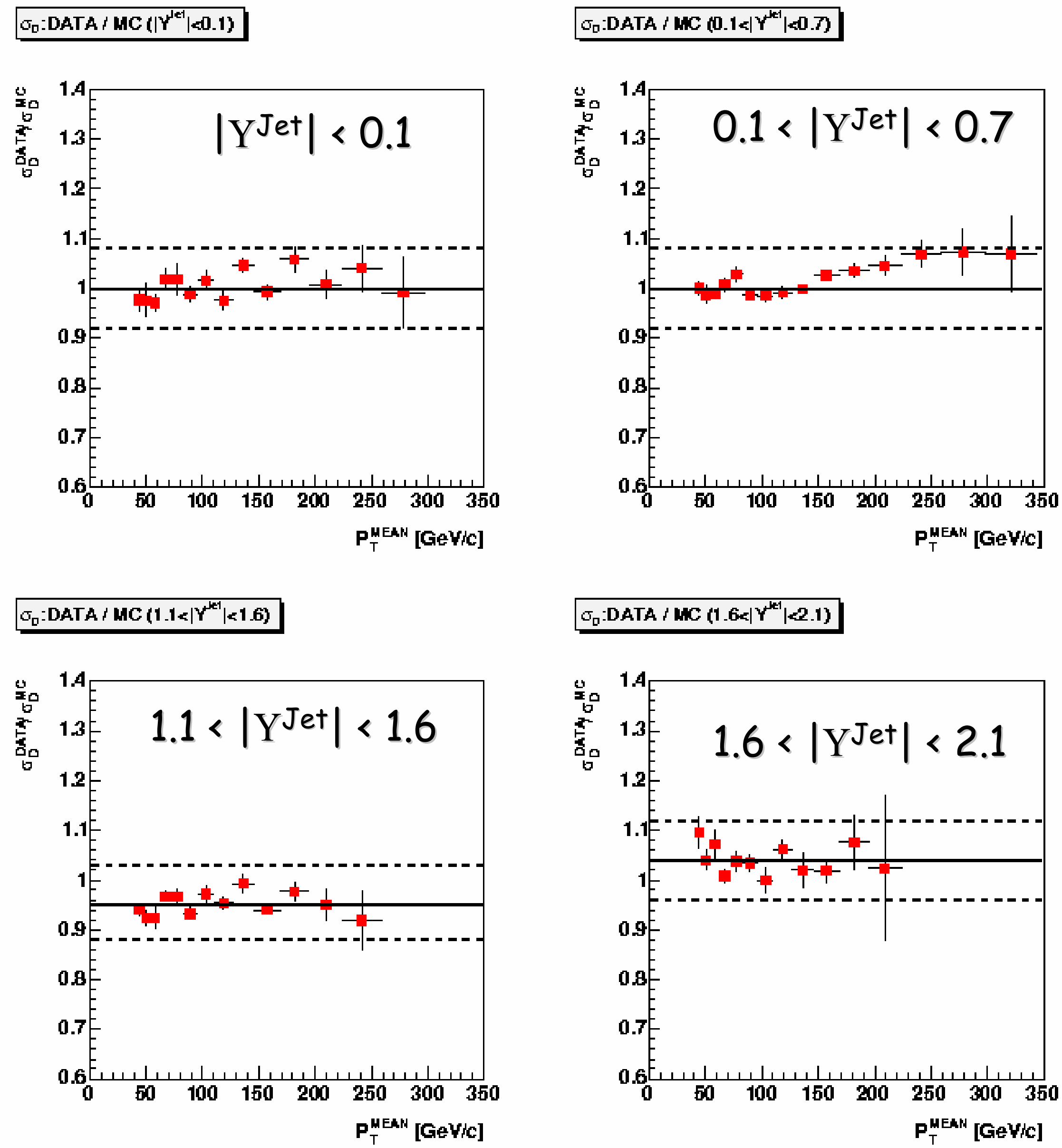
The P_T unbalance between the jets is sensitive to physic (ISR) and detector effects

- Dijet events $P_T > 10$ Gev/c
- Definitions
  - -> $\gamma = |(\phi^{Jet1} - \phi^{Jet2})/2|$
  - -> $\Delta P_T^{//} = \pm (P_T^{Jet1} + P_T^{Jet2}) \cos(\gamma)$
  - -> $\Delta P_T^{PERP} = (P_T^{Jet1} - P_T^{Jet2}) \sin(\gamma)$



- Relevant variables
  - $\sigma_{//}$ = rms of $\Delta P_T^{//}$ distribution ⇨ physics effects
  - σ_{PERP} = rms of ΔP_T^{PERP} distribution ⇨ detector + physics effects
  - $\sigma_D = \sqrt{(\sigma^2_{PERP} - \sigma^2_{//})}$

Bisector Method: Data/MC



Data/MC >1

Resolution underestimated in MC

Data/MC <1

Resolution overestimated in MC

The two cases must be treated differently

Resolution Corrections

Case 1: Resolution underestimated in the MC

- Correct the resolution by smearing P_T^{RAW} in the MC with a Gaussian $(0, \sigma_G)$:

$P_T^{RAW}{}_{Smeared} = P_T^{RAW} + \Delta P_T^{RAW}$

$$\sigma_{corr} = \sigma_{MC} \oplus \sigma_G = F \cdot \sigma_{MC} \quad \text{where } F > 1$$

$$\Rightarrow \sigma_G = \sigma_{MC} \cdot \sqrt{(F^2 - 1)}$$

$0.7 < |Y^{Jet}| < 1.1 \rightarrow F = 1.06$

$1.6 < |Y^{Jet}| < 2.1 \rightarrow F = 1.10$

Case 2: Resolution overestimated in the MC

- The method based on the smearing of P_T^{RAW} in the MC cannot be applied
- The correction will be applied later: slightly modified unfolding factors
- To know the difference between Data and MC

  - Smear P_T^{RAW} in the data this time (ONLY FOR THIS) using same definition of σ_G

$1.1 < |Y^{Jet}| < 1.6 \rightarrow F = 1.05$

⇨ Correction to apply to the resolution in the MC is 1/1.05

MC studies: Dijet Balance

→ To study the jet response relative to central calorimeter region where the MC provides a proper description of the data

Central Region: Calorimeter + Tracking

⬇

Jet Calorimeter response well understood

(within ± 2-3% energy scale)

- Dijet events $P_T > 10$ Gev/c

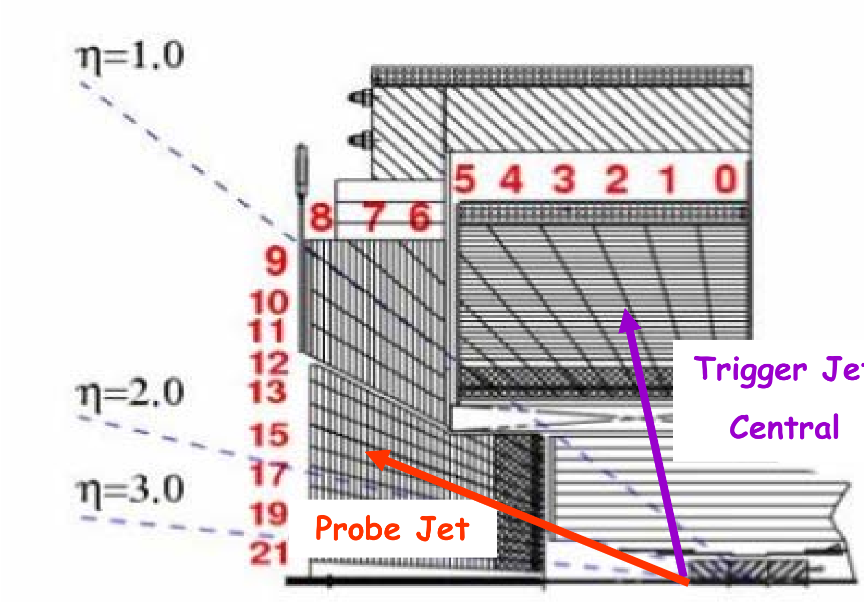
- Definitions

-> $P_T^{Mean} = (P_T^{Trig} + P_T^{Prob})/2$

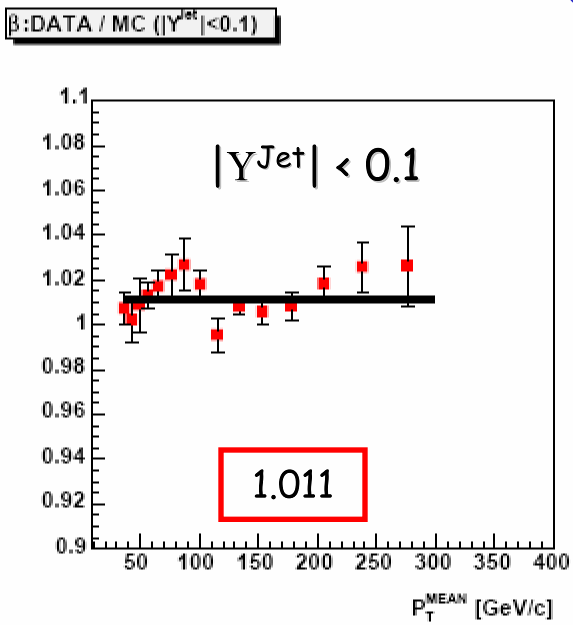
-> $\Delta P_T^F = (P_T^{Prob} - P_T^{Trig})/P_T^{Mean}$

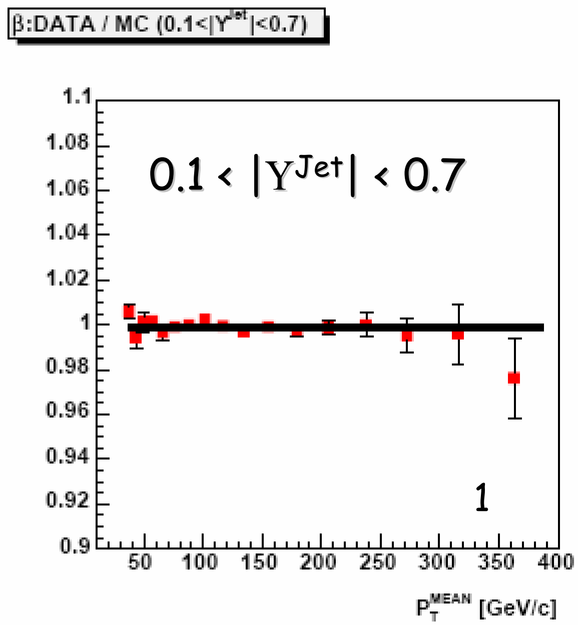
-> $\beta = (2 + \langle \Delta P_T^F \rangle)/(2 - \langle \Delta P_T^F \rangle)$

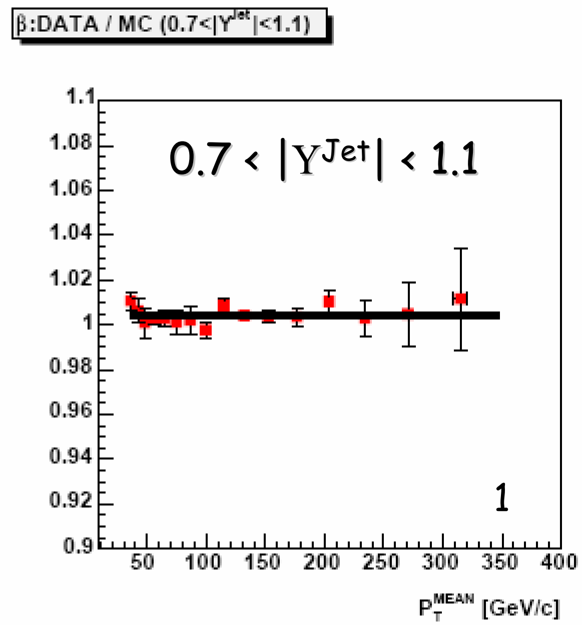
Event by event: $\beta = P_T^{Prob} / P_T^{Trig}$

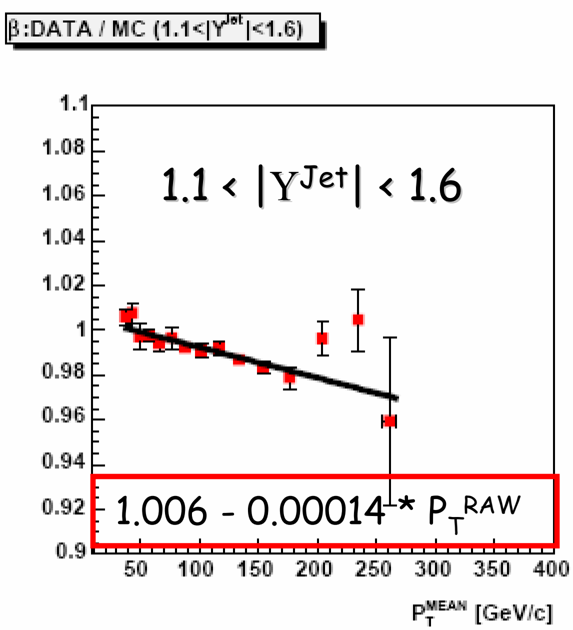


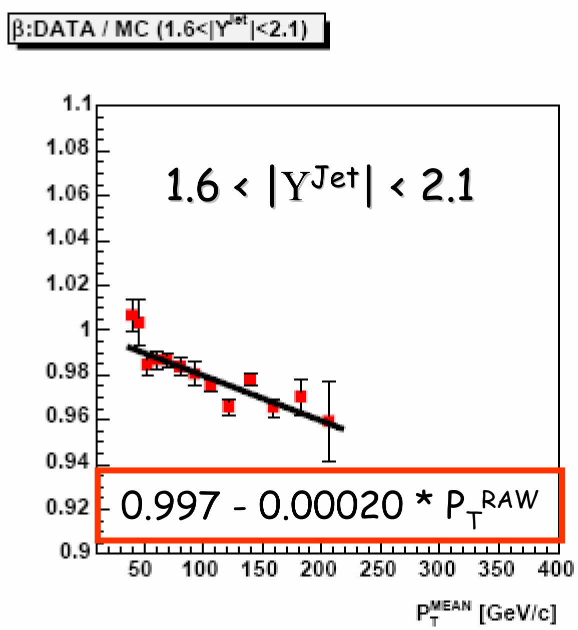
Dijet Balance: Data/MC











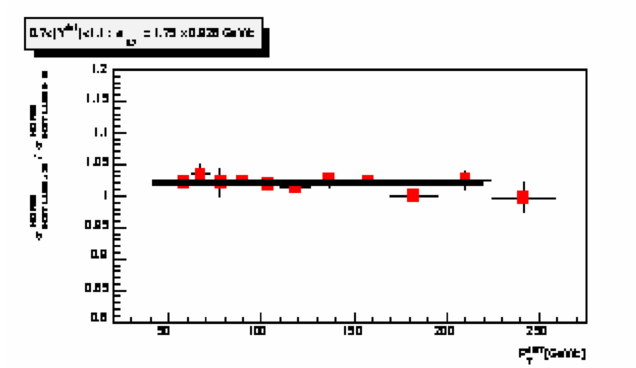
Still some work to be done in the two most forward regions

Jet P_T corrections

- Pile Corrections
  - → Correction : P_T^{RAW}(Pile-up corrected) = $P_T^{RAW} - \varepsilon_{0.7} \times (NVQ12 - 1)$
  - → $\varepsilon_{0.7}$ extracted from data for jets in the central region :

$$\varepsilon_{0.7} = 1.62\,^{+\,0.70}_{-\,0.46}\ \text{GeV/c}$$

(checked that it works in new data!)



- Use PYTHIA MC to extract the average absolute P_T^{Jet} corrections

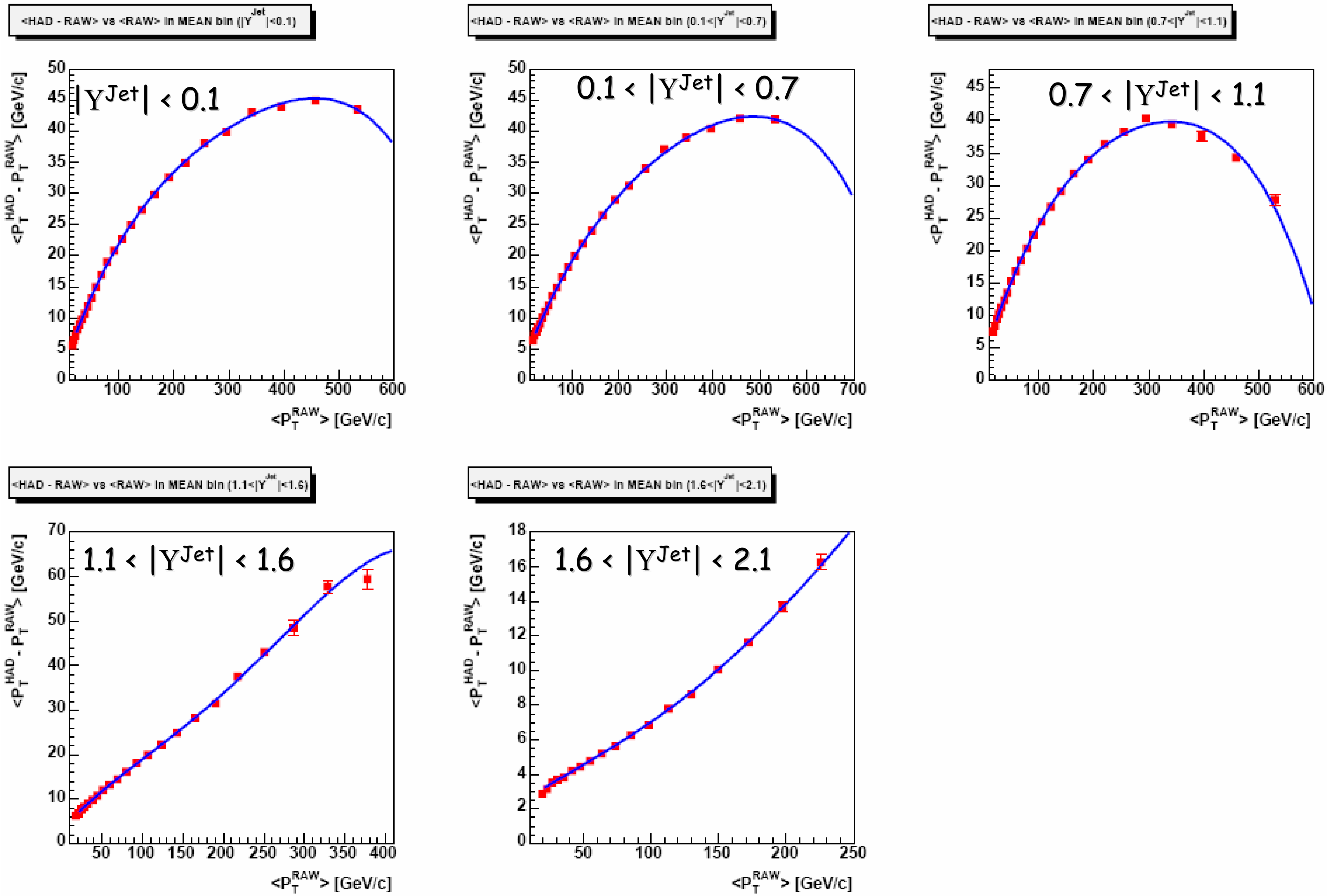
After applying corrections to the MC based on
Bisector Method and Dijet Balance studies

  - → Reconstruct jets at Calorimeter (P_T^{RAW}) and Hadron (P_T^{HAD}) level
  - → Match pair of CAL-HAD jets in Y - ϕ space

$$\Delta R = \sqrt{Y^2 + \phi^2} < 0.7$$

→ The correlation < P_T^{HAD}-P_T^{RAW}> versus <P_T^{RAW}> for matched jets is reconstructed and fitted to a 4th order polynomial

Average P_T^{Jet} Correction



Unfolding Procedure

- Use Pythia MC to correct the jet spectrum back to the hadron level

  → Count: the N_{Jet} Calorimeter level (all cuts & P_T^{Jet} corrected)

  N_{Jet} Hadron (no cuts)

  → Bin-by-bin unfolding factors

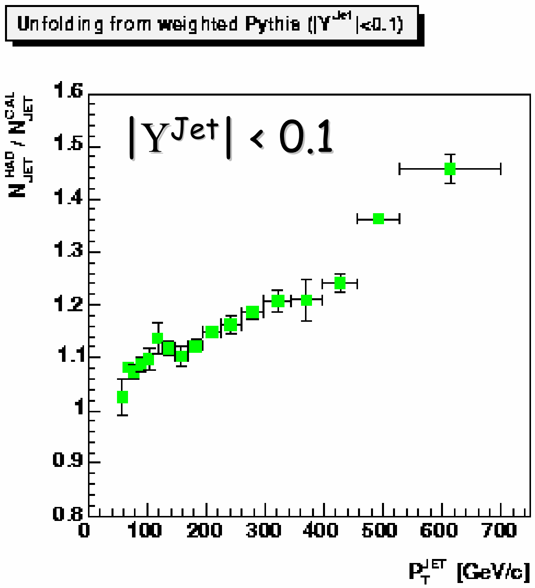
$$C_i = \frac{N_{Jet}\ \text{Hadron level}}{N_{Jet}\ \text{Calorimeter level}} \quad (P_T^{Jet}\ \text{bin } i)$$

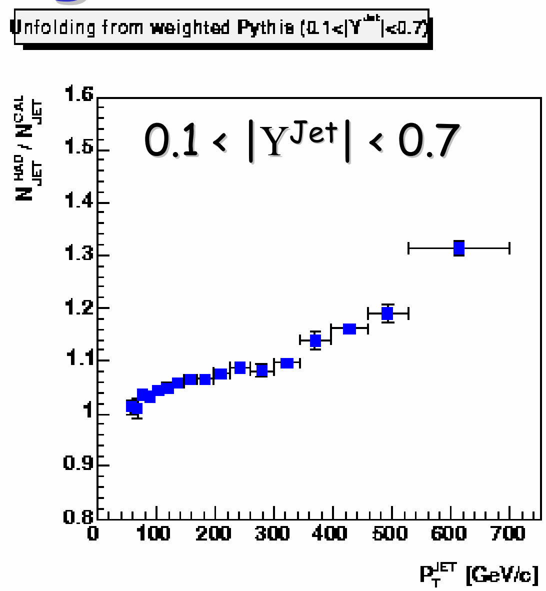
- Apply corrections factors to the measured P_T spectrum (P_T^{Jet} corrected) to unfold it to the hadron level.

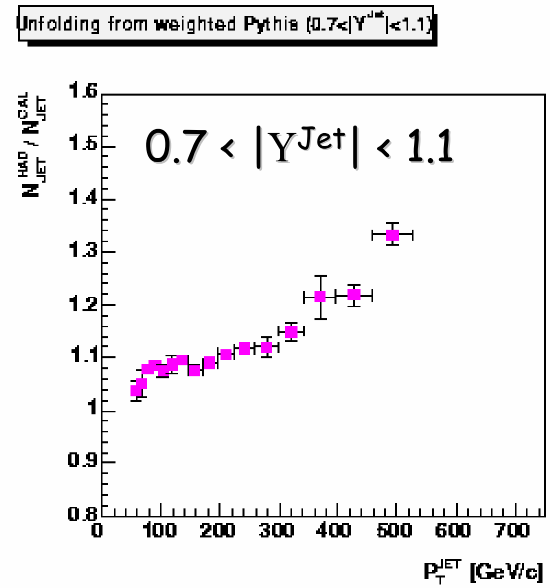
$$N_{jets}^{DATA\ UNFOLDED}\ (P_T^{Jet}\ \text{bin } i) = C_i \times N_{jets}^{DATA}\ (P_T^{Jet}\ \text{bin } i)$$

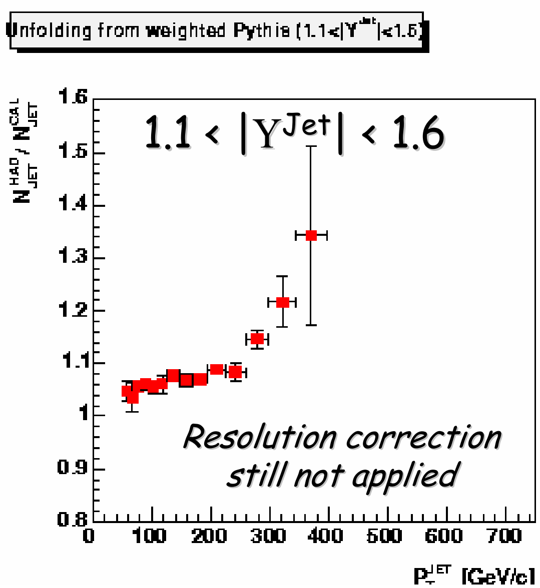
- The MC is re-weighted to make the measurements independent of the jet P_T spectrum in the MC which is related to the PDF used

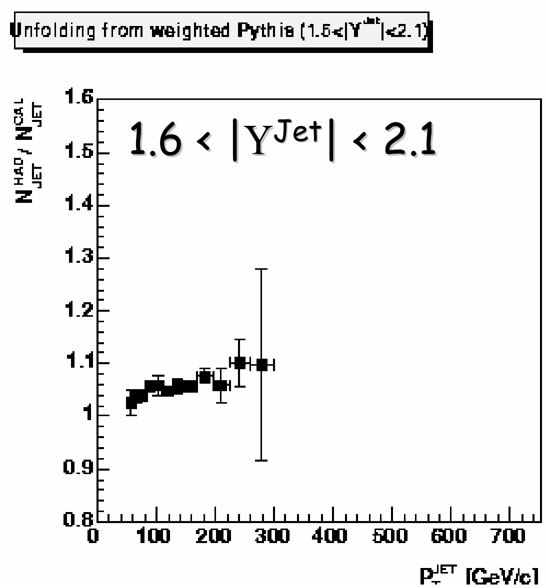
Unfolding Factors (weighted PYTHIA)











After reweighting the MC

- Unfolding factors are almost unchanged up to ~ 400 GeV/c

- Biggest changes < 10% (very high P_T^{JET})

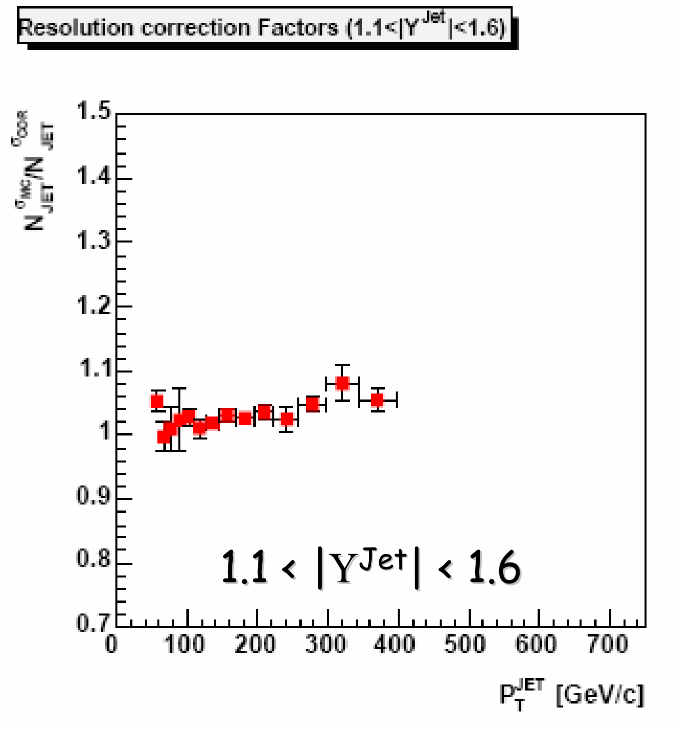
Resolution correction for case 2 ($1.1 < |Y^{Jet}| < 1.6$)

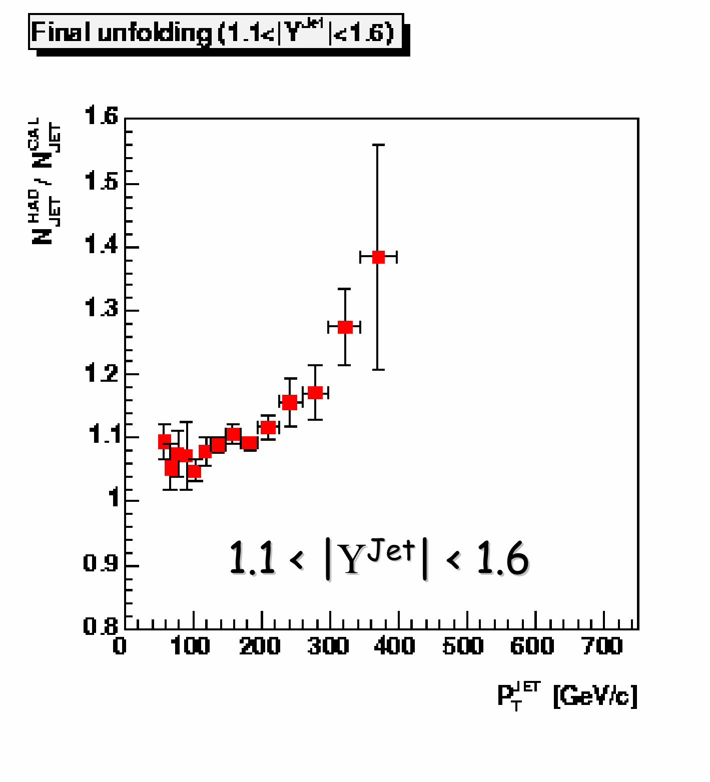
Reminder: case 2 = Resolution overestimated in the MC

- Correct the unfolding factors to take into account the discrepancy between data and MC on the jet energy resolution

- Corrections factors extracted from the ratio of the hadron level spectrum smeared by σ_{MC} and $\sigma_{corr} = \sigma_{MC} \times (1/1.05)$

$\Rightarrow$ ~ 3%





Systematic Uncertainties

→ Jet Energy Scale

• Energy scale varied in MC according to uncertainty estimated by Jet Energy and Resolution Group

→ Unfolding

• Sensitivity to P_T spectrum : ratio of unfolding factors obtained from unweighted and weighted PYTHIA
• Sensitivity to fragmentation model: ratio of unfolding factors obtained from weighted HERWIG and weighted PYTHIA

→ Jet Energy Resolution

• 8% uncertainty on the jet momentum resolution

→ Pile-Up

• Pile-up corrections are changed within uncertainties obtained on ε_D

→ P^{Jet} cut

• The lowest edge of each bin is varied by ±3% → effect ~ 2%

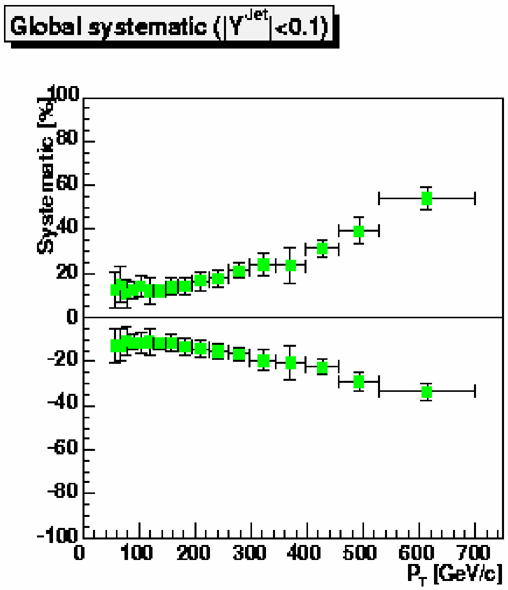
→ Missing E_T significance cut

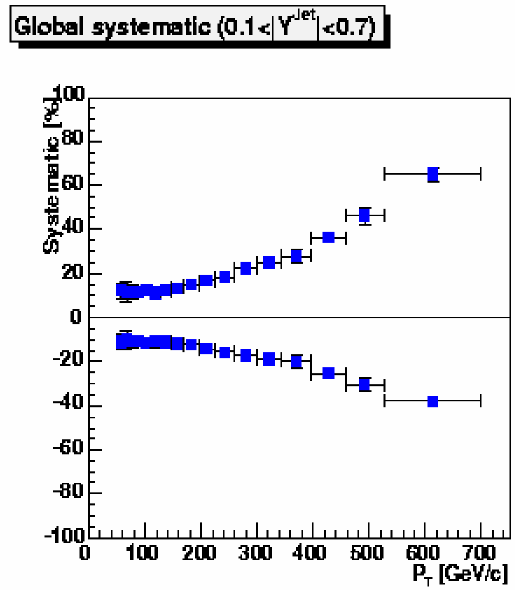
• Vary at the same time missing E_T scale by ±10% and jet energy scale by ±3% → effect < 1%

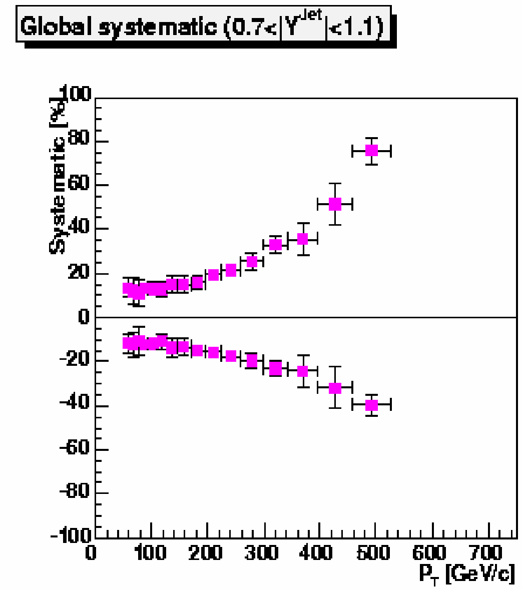
→ V_Z cut

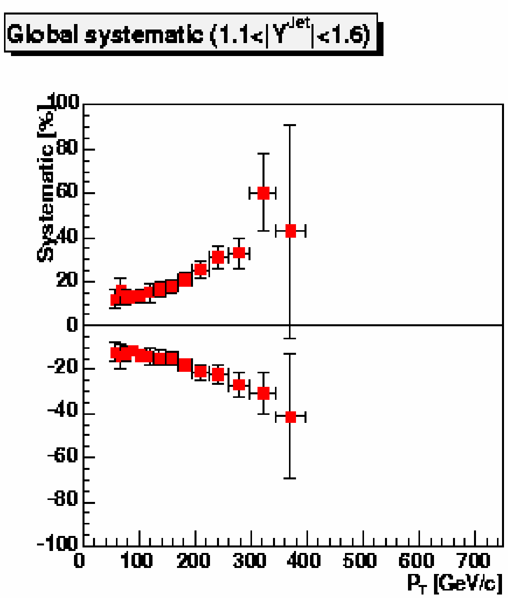
• Cut is varied by ±5cm → effect ~ 0.3%

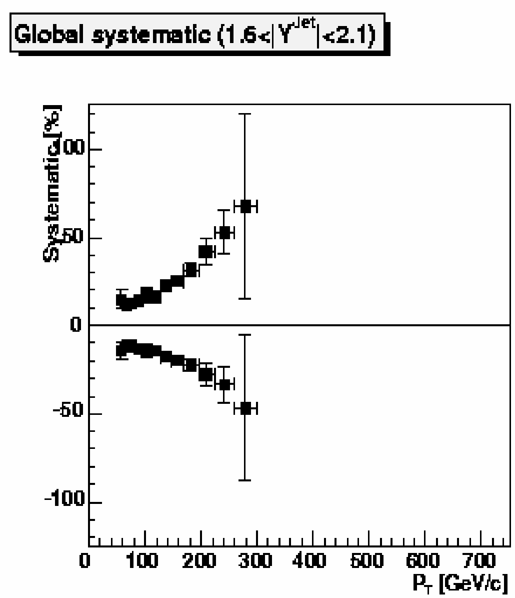
Global Systematic uncertainties











Generating MC to reduce the errors

NLO calculations

→ JETRAD CTEQ61 package

- $\mu_R = \mu_F$ = Maximum Jet $P_T/2$

- In contact with NLO++ and fastNLO authors to produce NLO predictions

→ NLO uncertanties

- Scale $\mu_R = \mu_F$ = Maximum Jet P_T

- Preliminary estimation of the uncertainties associated to the PDFs

  -Use the four sets corresponding to plus and minus deviations of eigenvectors 5 and 15

  ⇨ Eigenvector 15 related to gluon PDF which dominates the uncertainty

  - Uncertainties obtained by considering the maximal positive and negative deviations with respect to nominal set

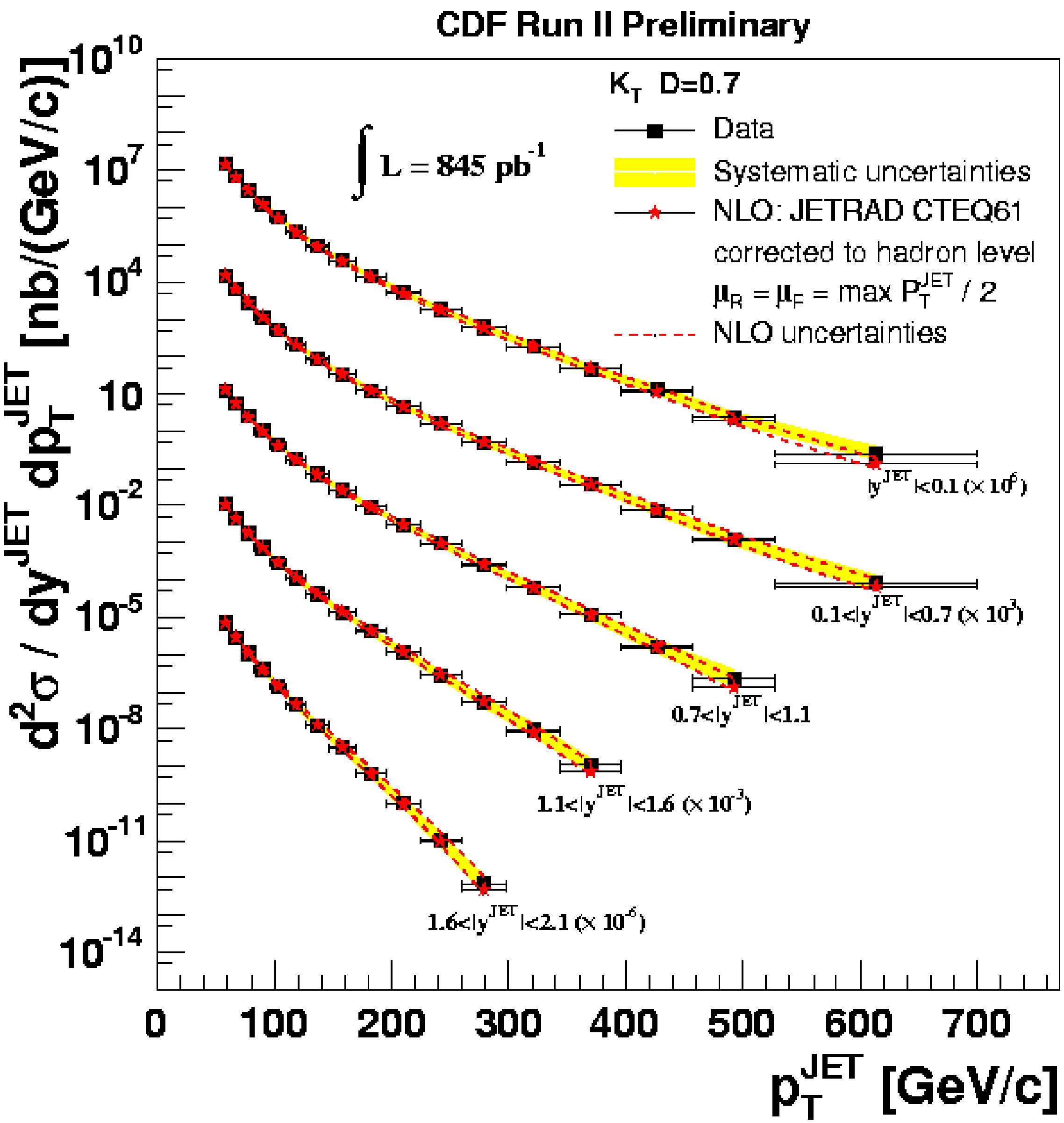
  - Final uncertainties will be computed taking into account all the 40 PDF sets

→ UE / Hadronization corrections

- Correct the NLO pQCD calculations for Underlying Event and Fragmentation in order to compare to data

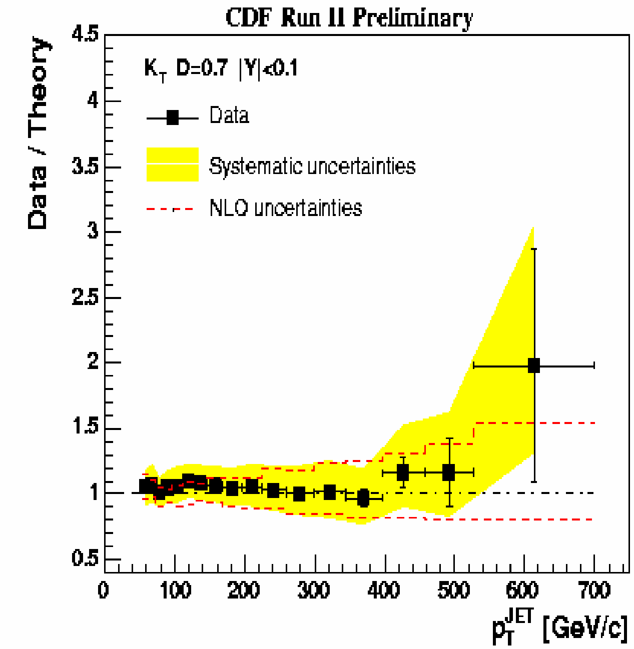
$$C_{HAD}(P_T^{Jet}, Y^{Jet}) = \frac{\sigma\text{ (Hadron Level Pythia Tune A with MPI)}}{\sigma\text{ (Parton Level Pythia Tune A no MPI)}}(P_T^{Jet}, Y^{Jet})$$

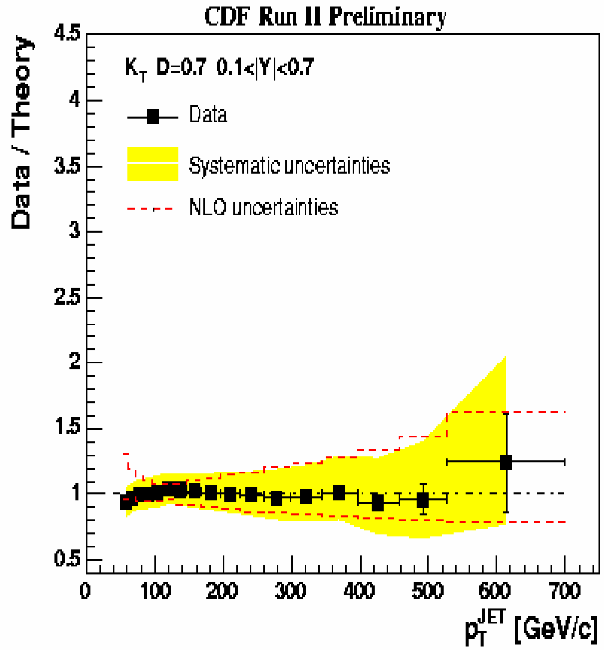
Results $|y^{Jet}| < 2.1$

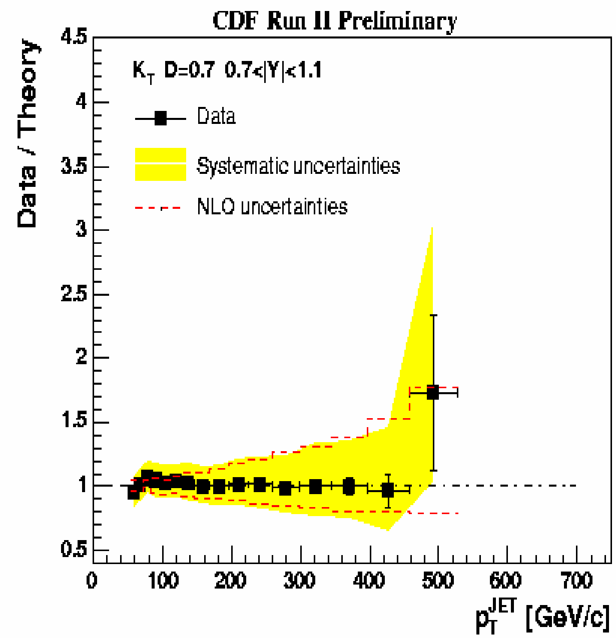


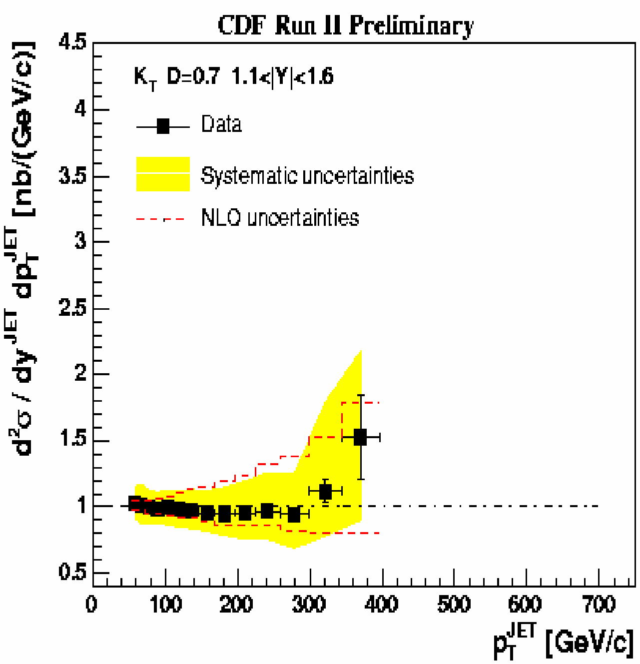
Good agreement with NLO

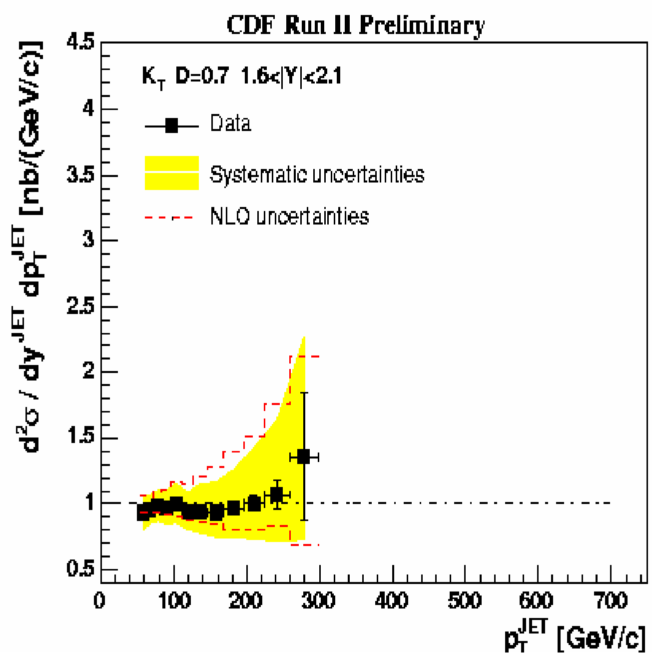
Results: Data/NLO



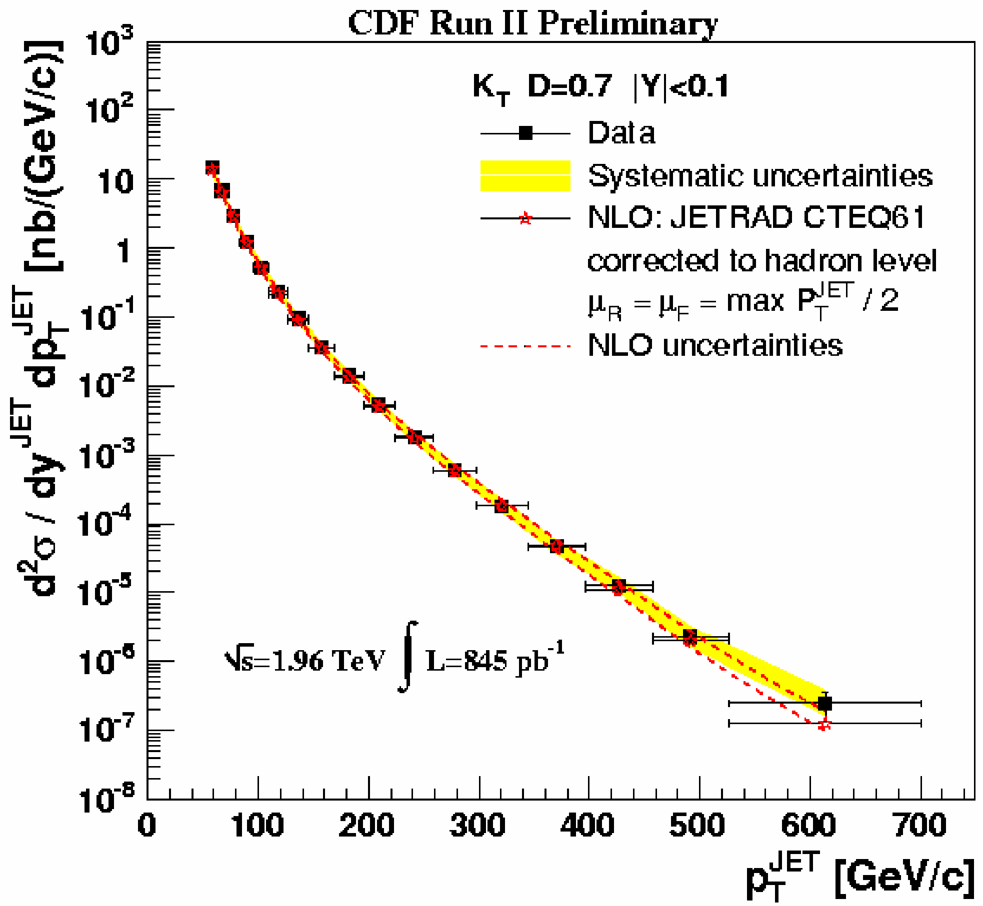


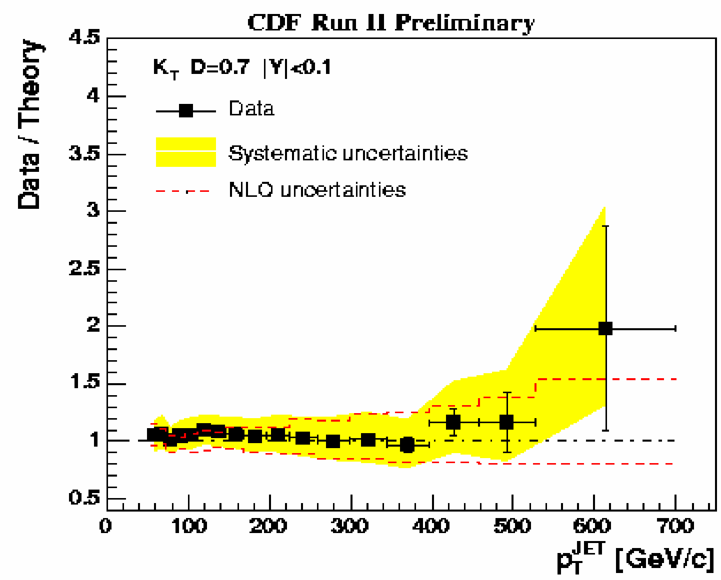


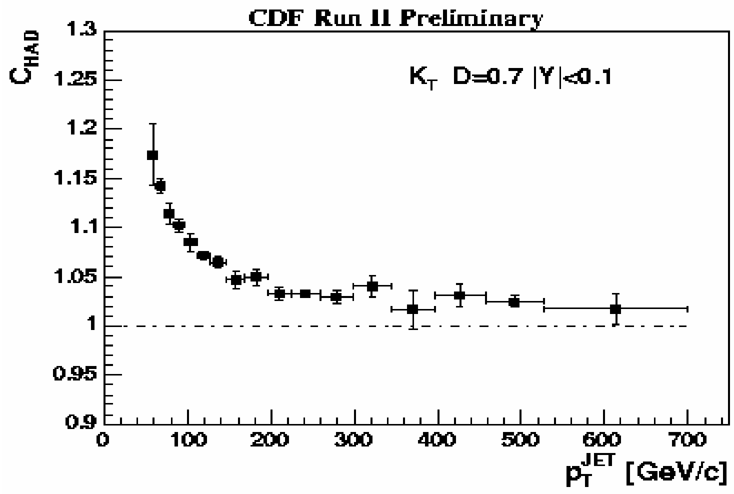




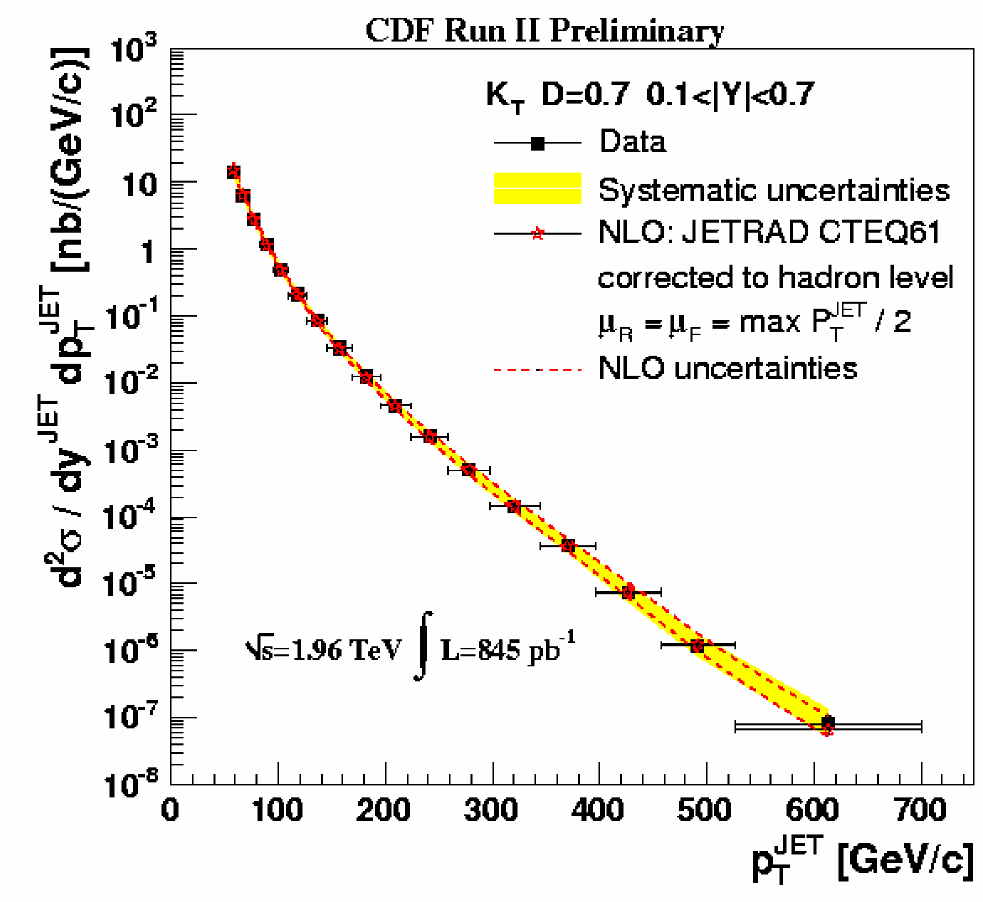
Results: $|Y^{jet}| < 0.1$

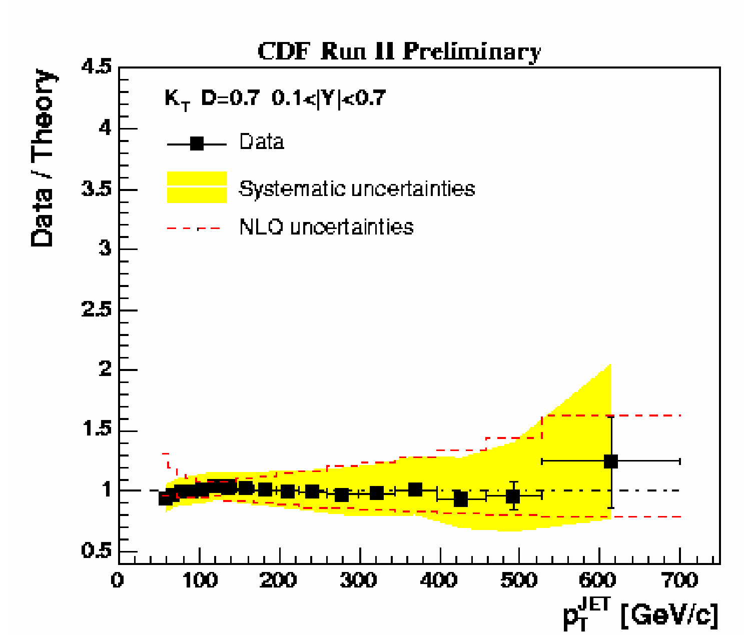


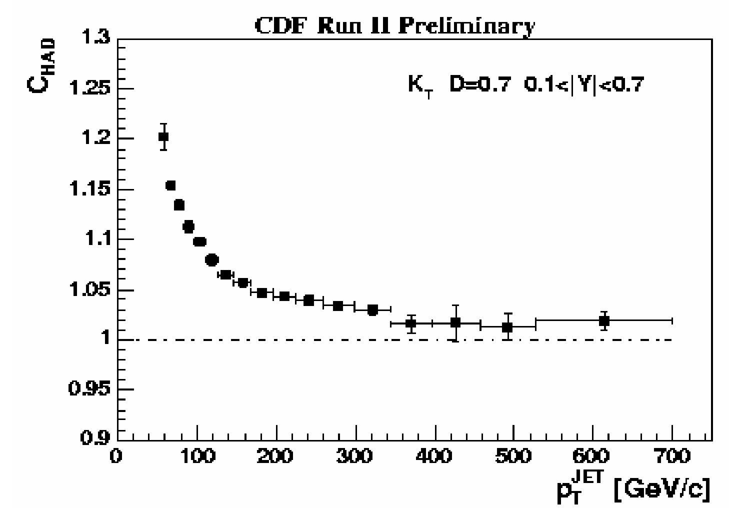




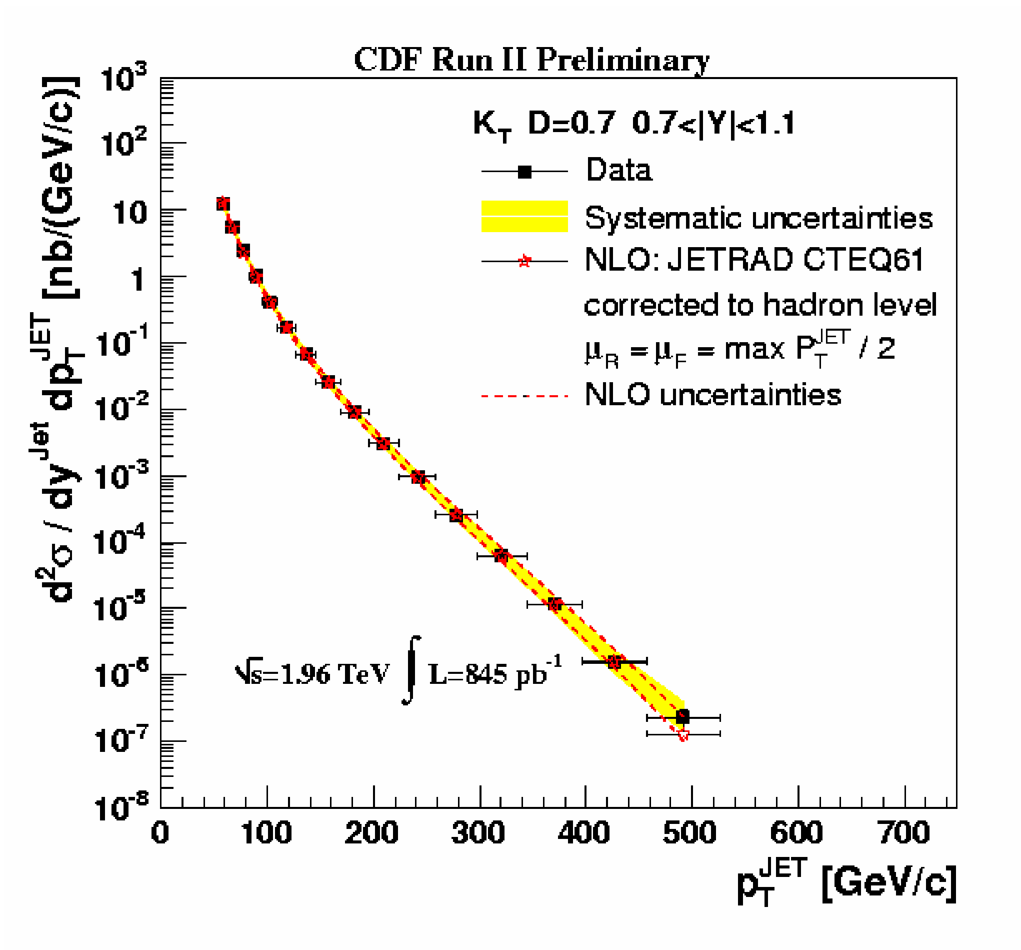
Results: 0.1 < |Y jet| < 0.7

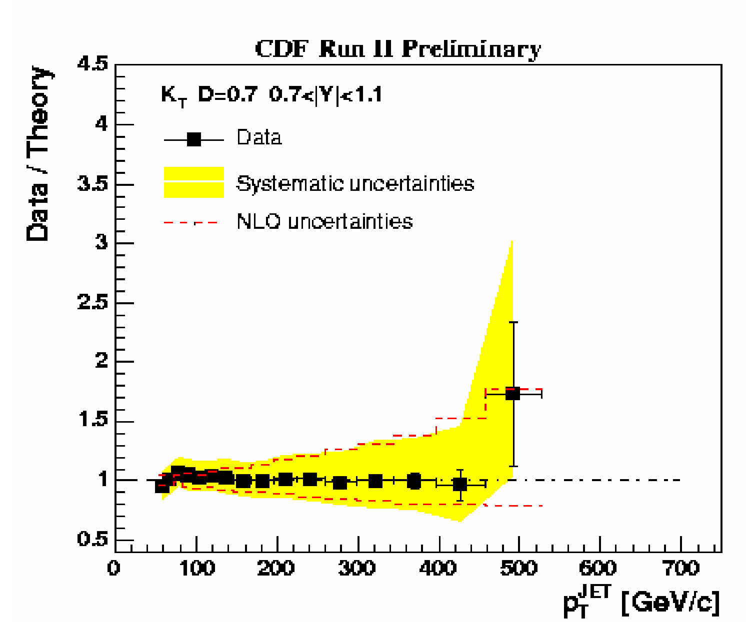


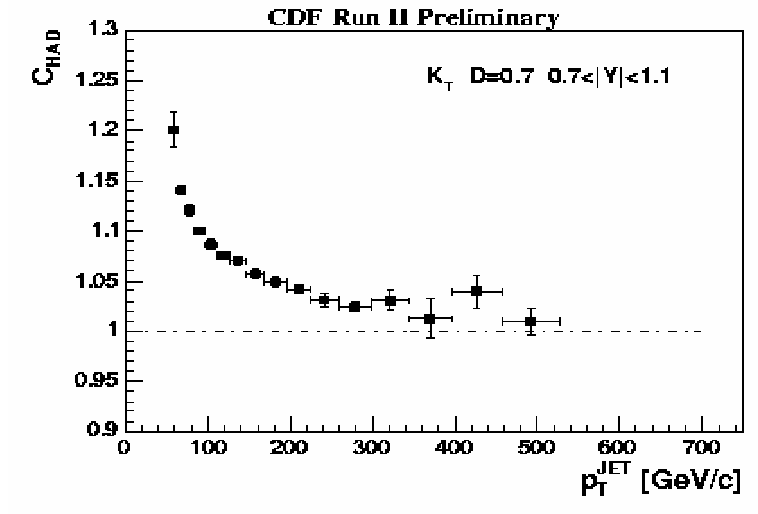




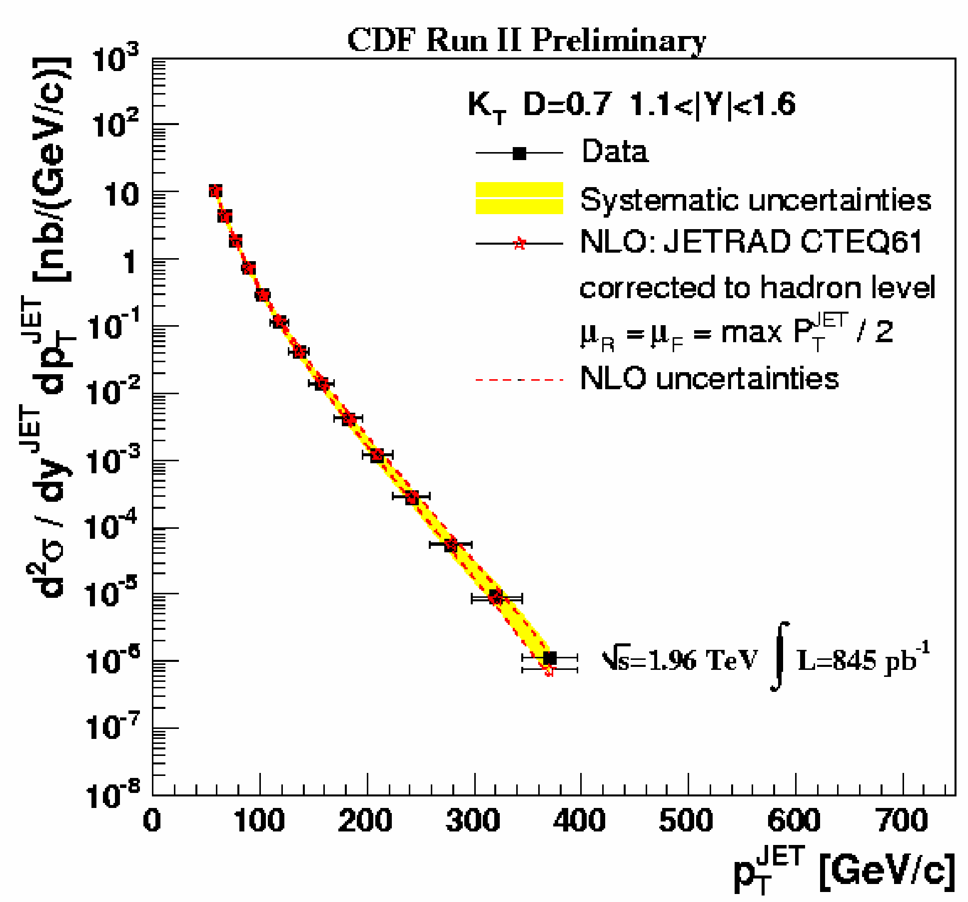
Results: 0.7 < |Y jet| < 1.1

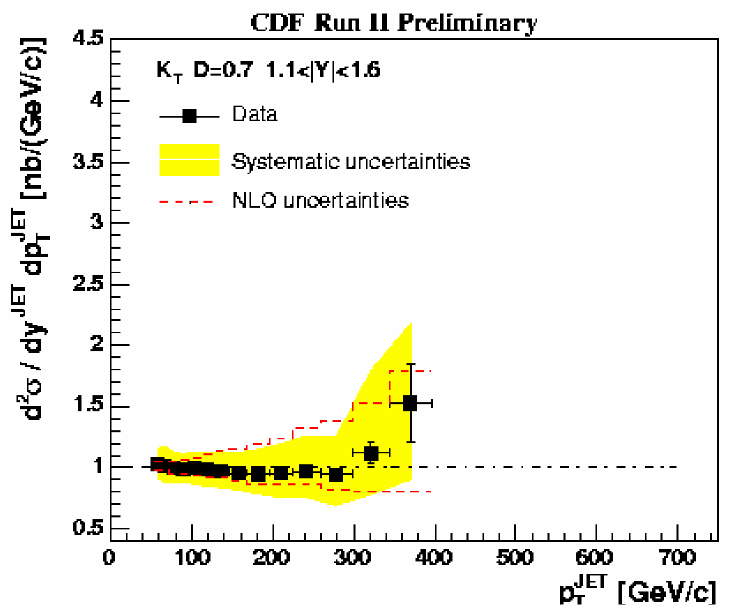


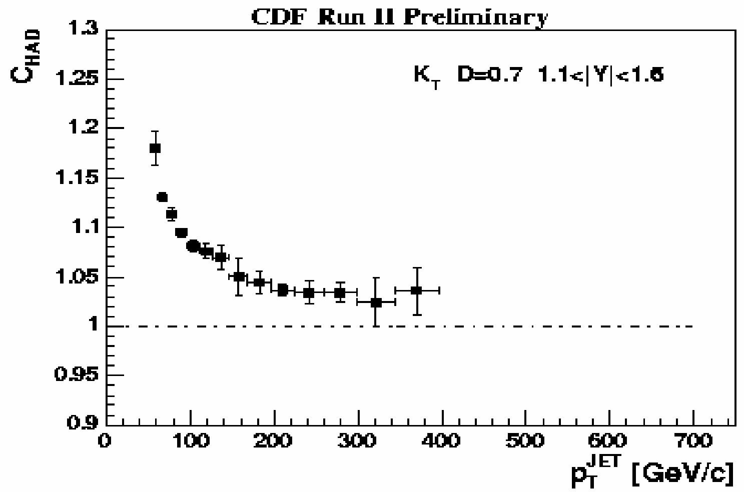




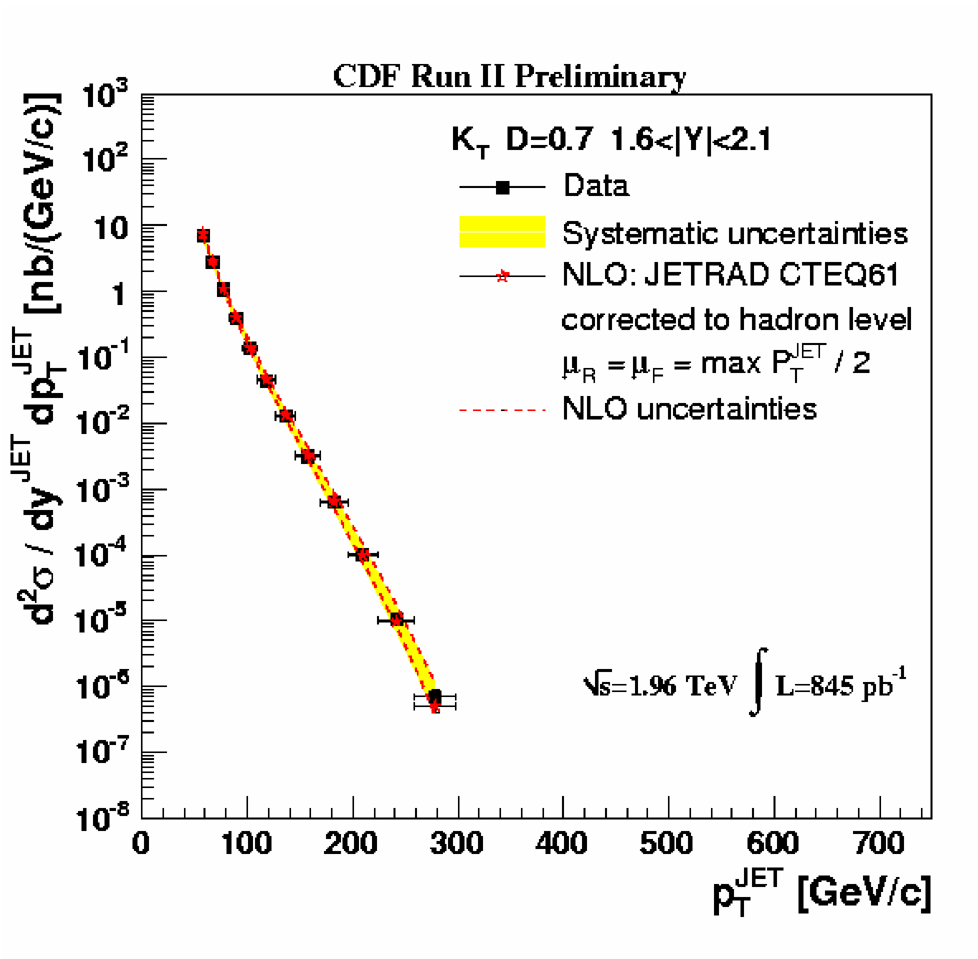
Results: 1.1 < |Y jet| < 1.6

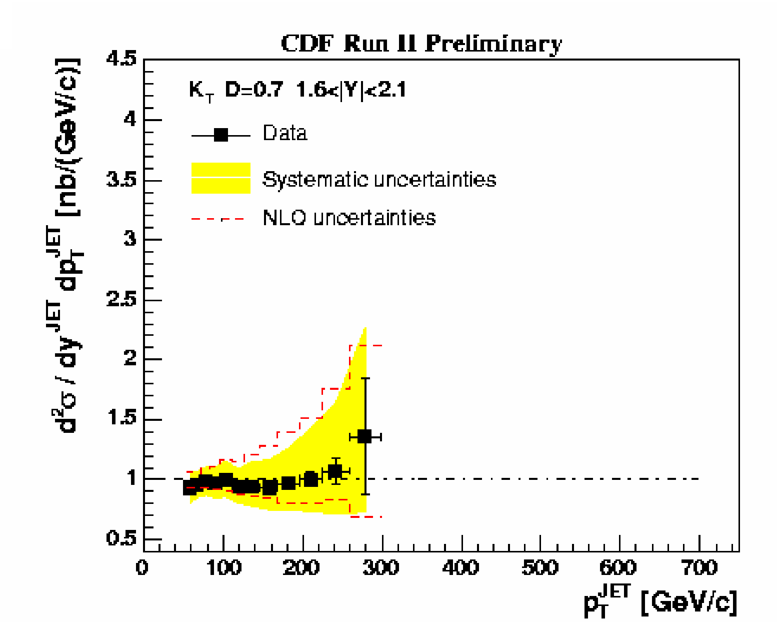


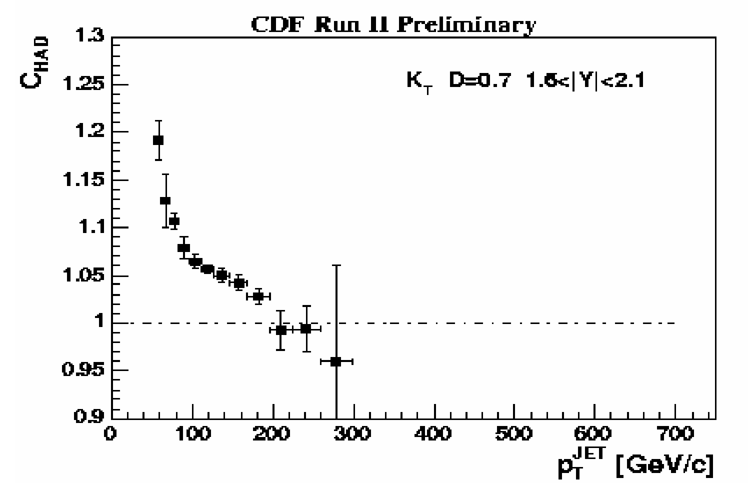




Results: 1.6 < |Y jet| < 2.1







Summary and plans

Inclusive jet cross section measured using 845 pb^{-1} of CDF RunII data for jets with $P_T \geq 54$ GeV/c in five rapidity regions:

$|Y^{Jet}| < 0.1$; $0.1 < |Y^{Jet}| < 0.7$; $0.7 < |Y^{Jet}| < 1.1$; $1.1 < |Y^{Jet}| < 1.6$; $1.6 < |Y^{Jet}| < 2.1$

- Using the K_T algorithm
- Fully corrected to the hadron level
- Good agreement with theory, NLO pQCD corrected for UE / Hadronization

Final results (final theoretical uncertainties) for winter conferences

- Preblessing Feb 10 (or Feb 17)
- Blessing Feb 27 (or Mar 3)
- Already starting the preparation of PRD

…and then…write my thesis