Inclusive Jet Cross Section in the Forward Region using the K_T algorithm

Pre-blessing Talk – CDF Note 7771

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Outline

→ Motivation

→ Event Selection

→ Trigger Study

→ MC simulation

- Comparison Data/MC of Raw Quantities
- Bisector Method
- Dijet Balance

→ Jet P_T Corrections

- Pile-up correction
- Average P_T^{Jet} correction

→ Unfolding

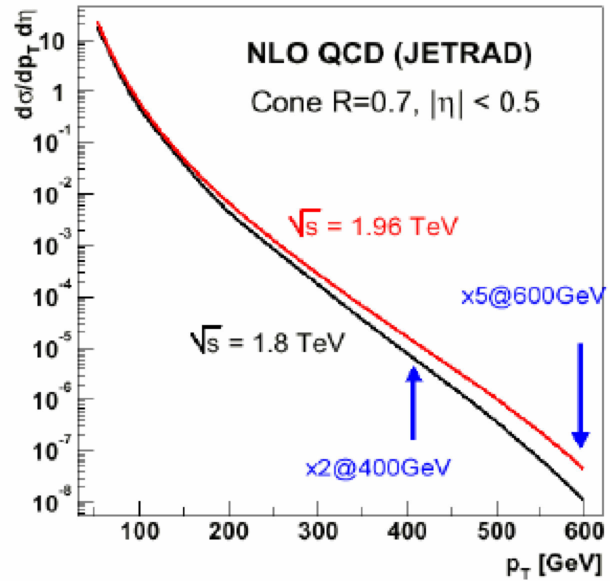
→ Systematic Uncertainties

→ NLO Calculations

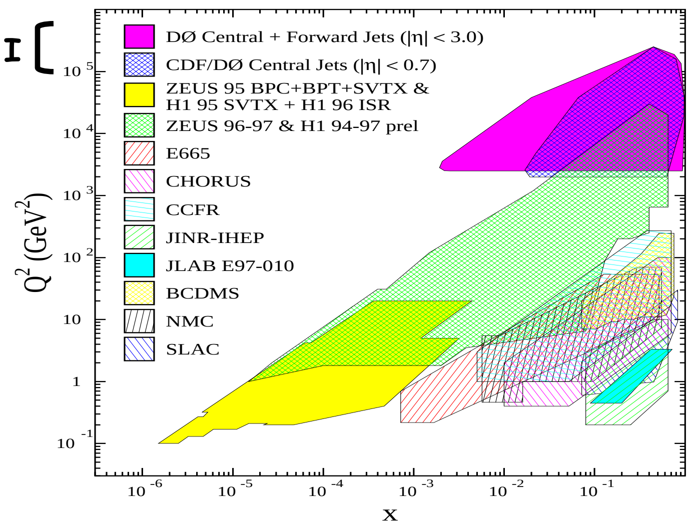
→ Results

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



RUN I



Event Selection

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

- Using v5.3.1 Data (analyzed using v5.3.3nt)
- Good Run list version 7
- Runs [155368,155742] excluded
  - Cross section drop of about ~40%

➡ $L=385\ pb^{-1}$

→ Event Selection

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

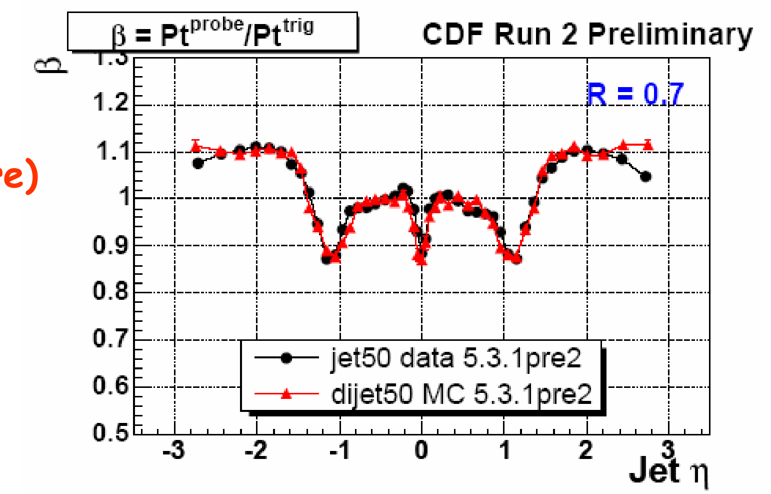
Region 1 : $|Y| < 0.1$ (90° crack)

Region 2 : $0.1 < |Y| < 0.7$ (Central Cal.) **(Not presented here)**

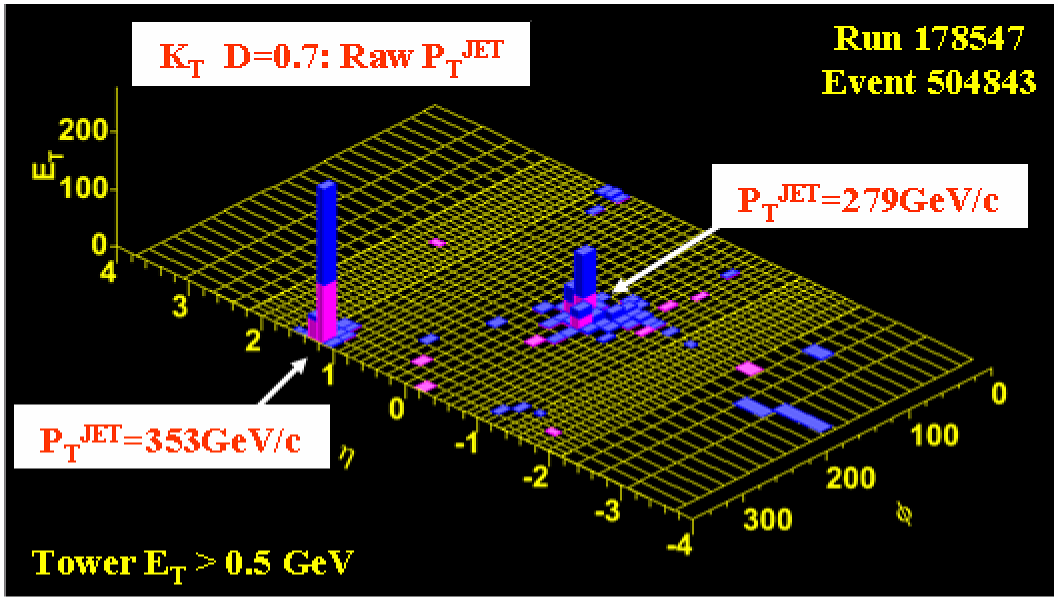
Region 3 : $0.7 < |Y| < 1.1$ (Central Cal. + 30° crack)

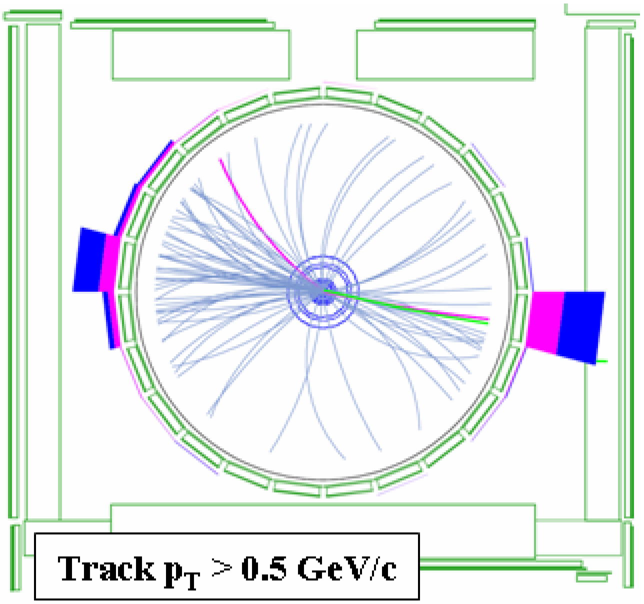
Region 4 : $1.1 < |Y| < 1.6$ (30° crack + Plug Cal.)

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



Scan of highest P_T events





$\Rightarrow$ No cosmic or beam halo related background

Trigger Study: method

→Trigger Structure

L1 →	Stw5 (pres)		Stw10 (no pres)	
L2 →	J15 (pres)	J40 (no pres)	J60 (pres)	J90 (no pres)
L3 →	J20	J50	J70	J100

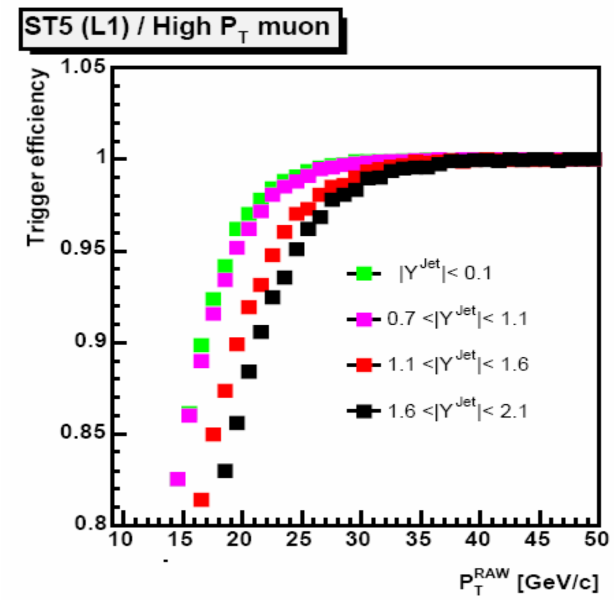
→Study the L1, L2 and L3 Trigger Efficiency from data

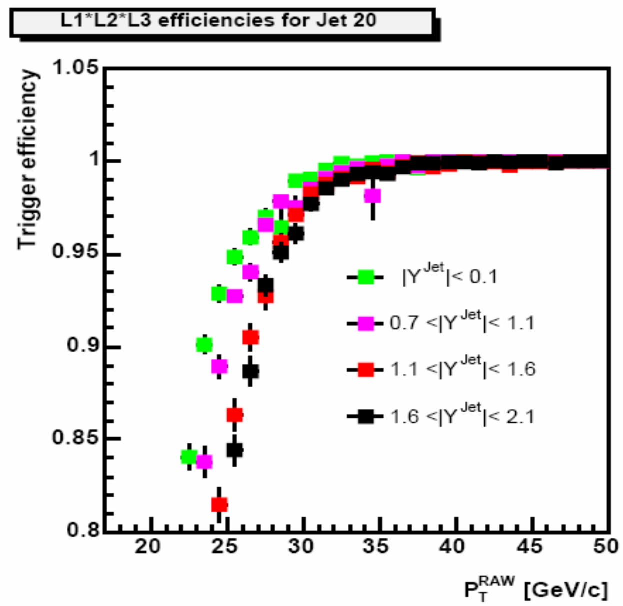
- → High P_T muons: Eff. Stw5(L1)
- → Stw5 data : Eff. J15(L2) and J20(L3)
- → Jet20 data : Eff. Stw10(L1), J40(L2) and J50(L3)
- → Jet50 data : Eff. J60(L2) and J70(L3)
- → Jet70 data : Eff. J90(L2) and J100(L3)

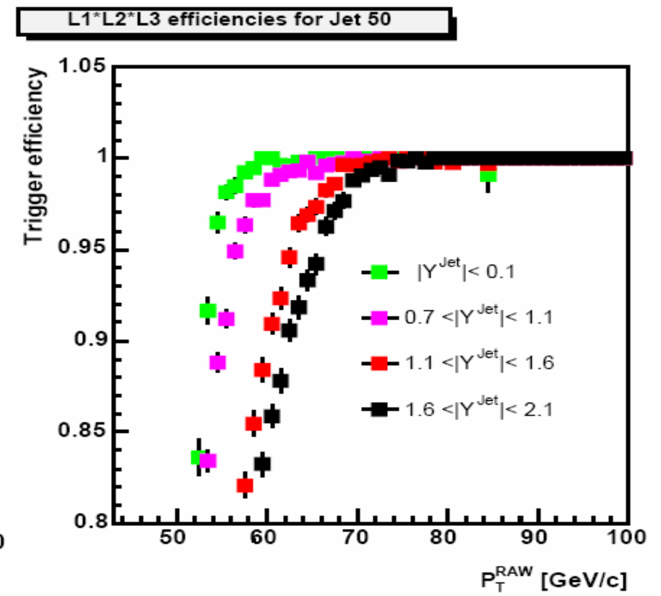
→Use data only where trigger fully efficient: thresholds defined by L1 × L2 × L3 efficiencies > 99%

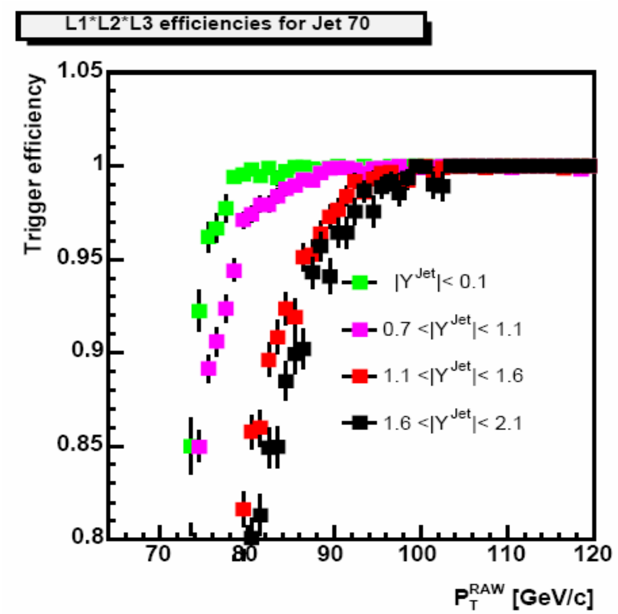
- To avoid trigger related systematic due to energy scale uncertainties, the obtain thresholds are increased by 5%

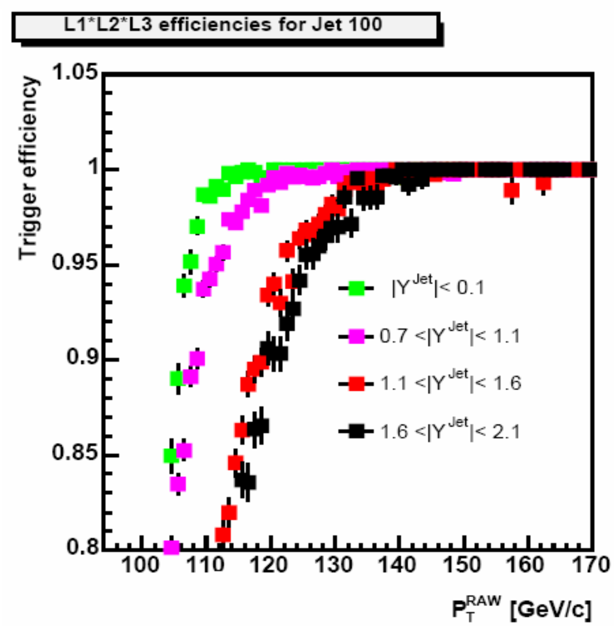
Trigger Study: results







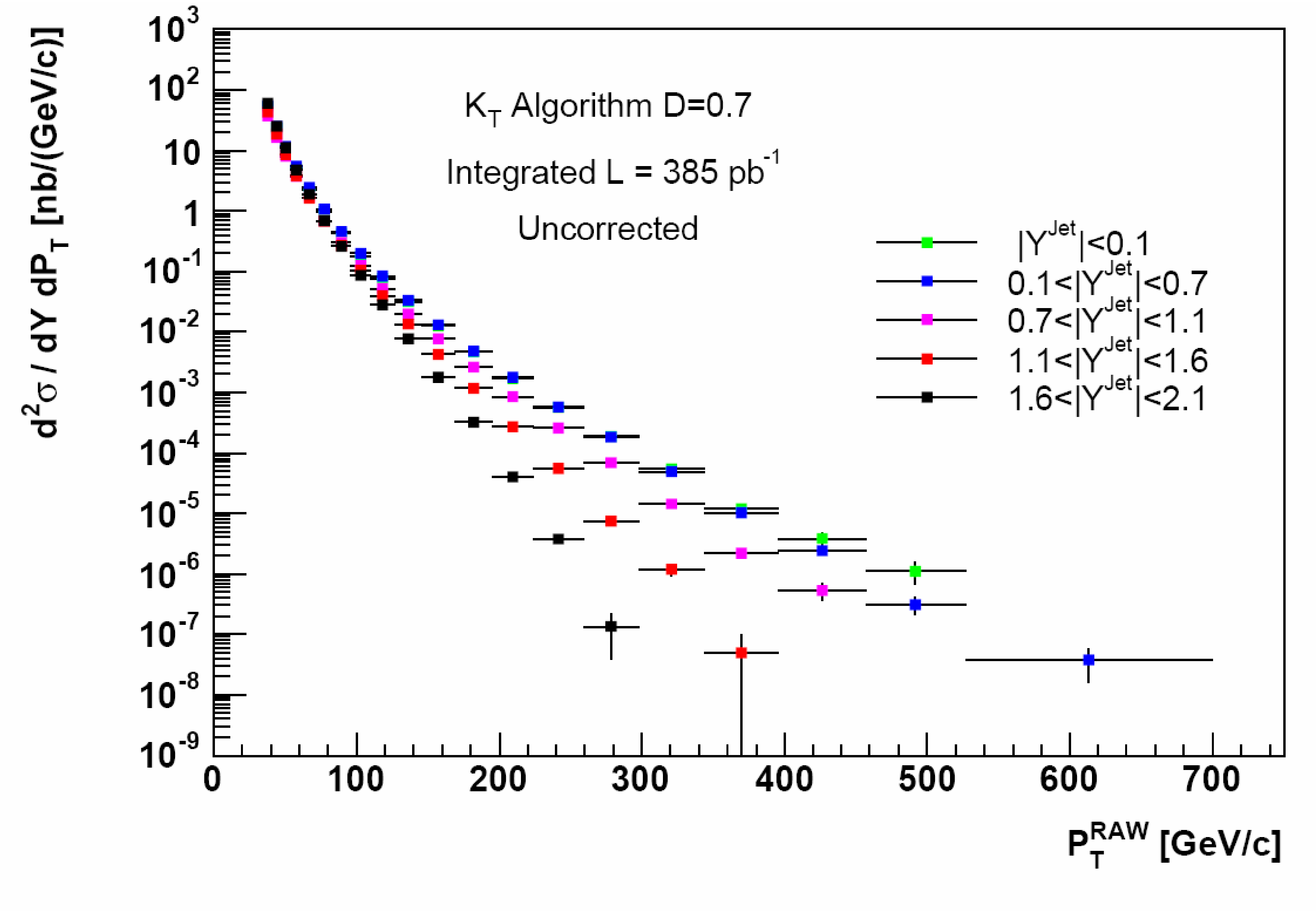




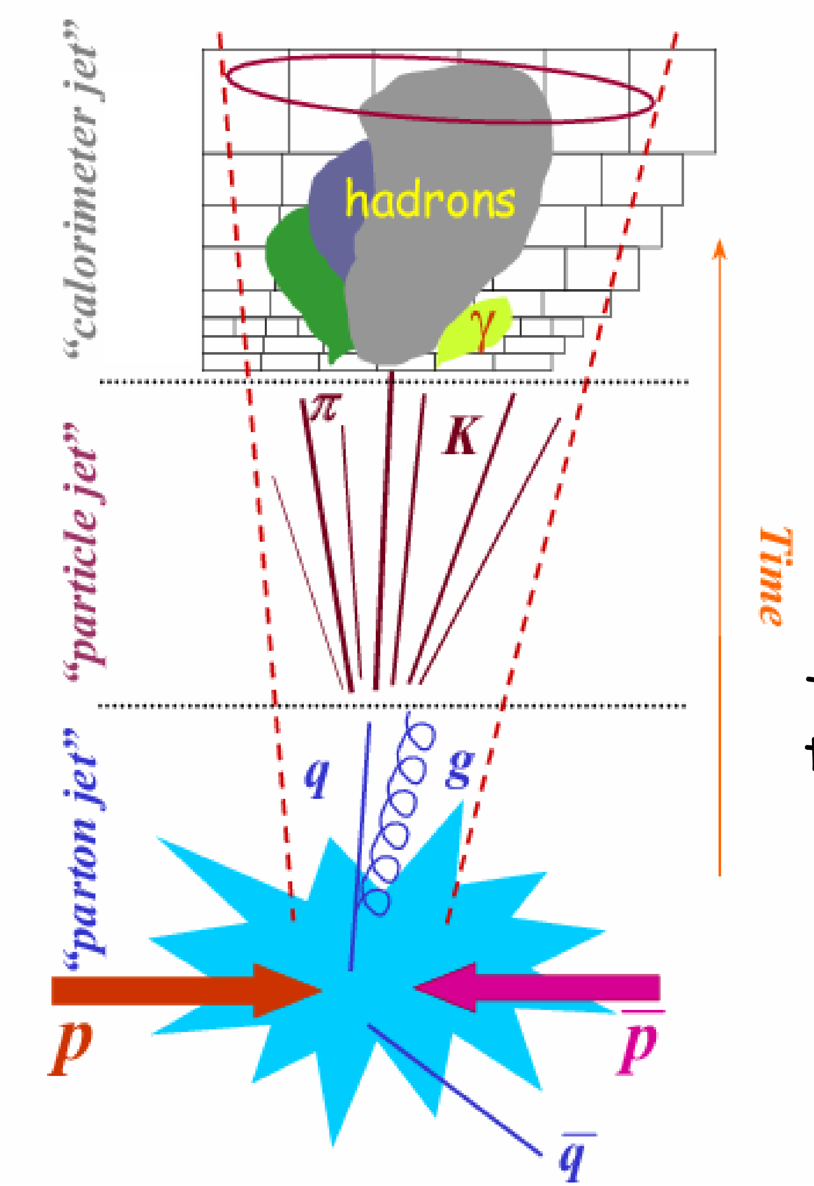
Minimum P_T^{RAW} (uncorrected P_T^{Jet}, GeV/c) for each dataset

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

Raw Cross Sections



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

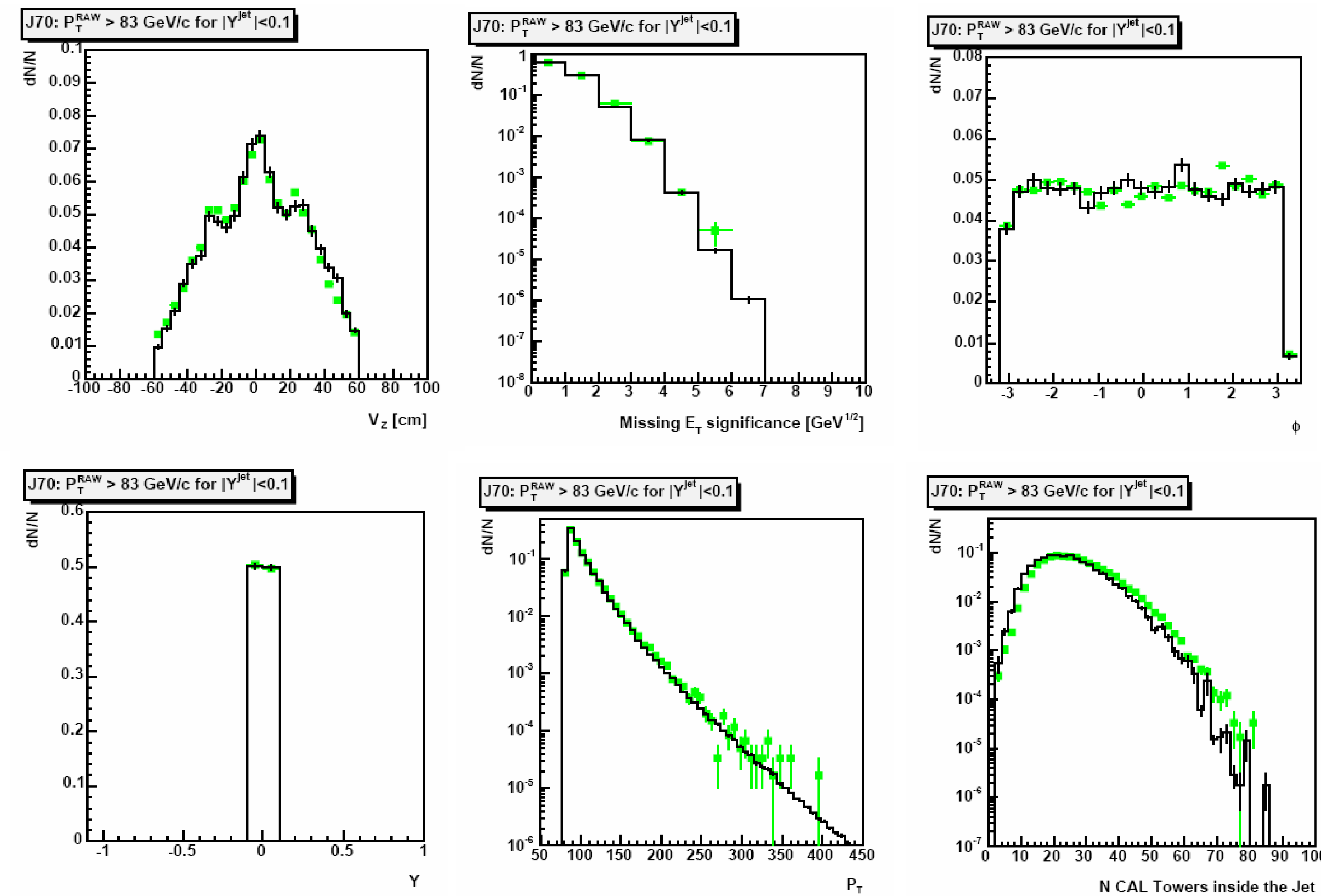
- Unfolding (MC based)

To account for smearing/resolution effects

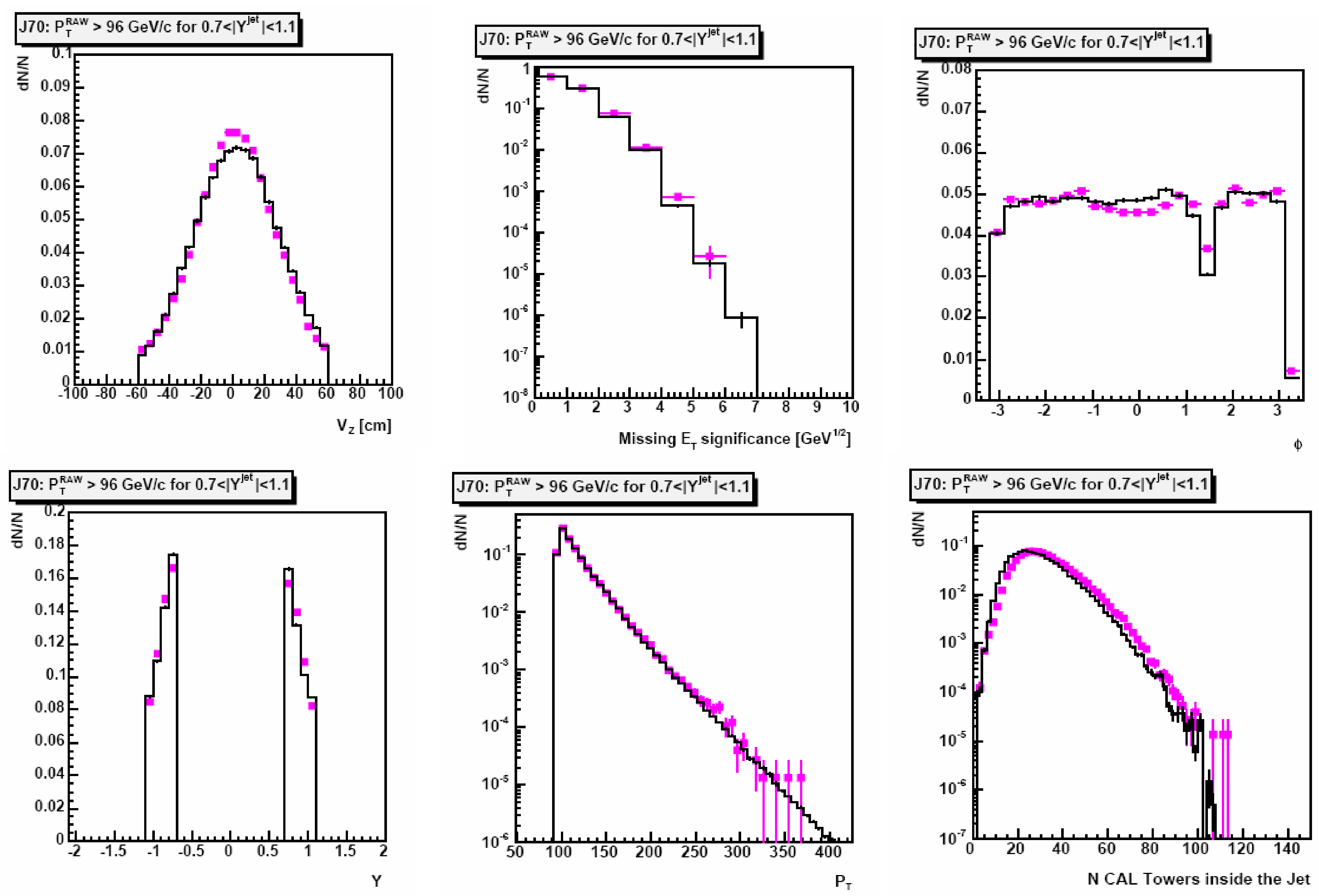
The MC simulation is good in the central part of the detector… what about the forward region?

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

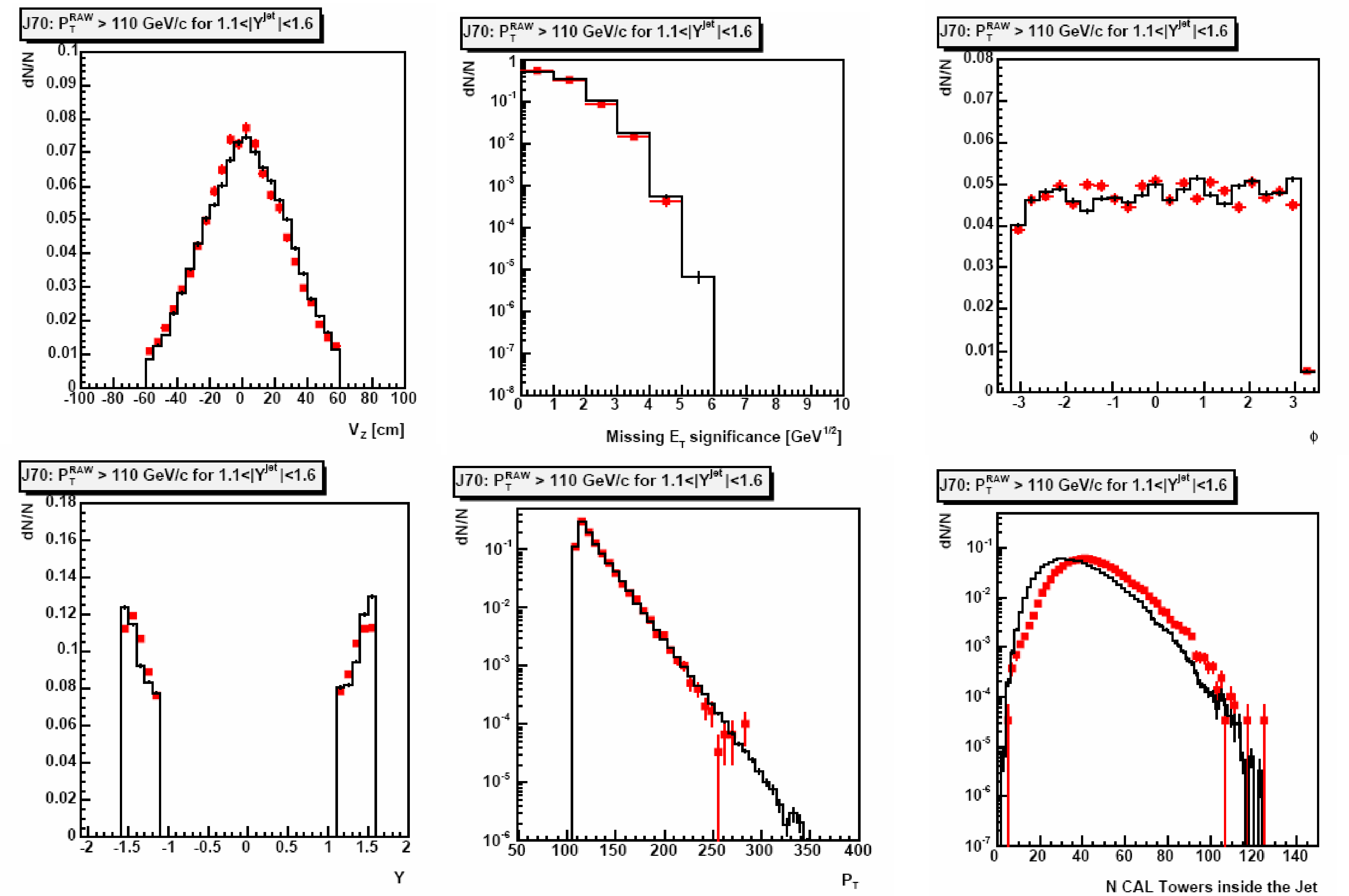
Comparison of Raw Quantities: $|Y^{jet}| < 0.1$



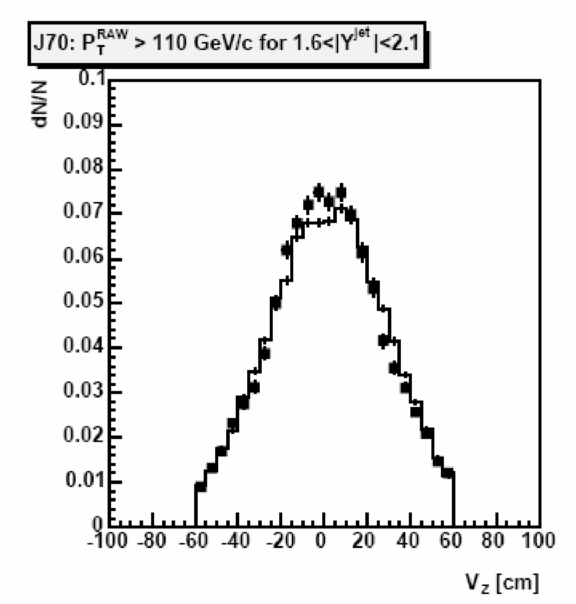
Comparison of Raw Quantities: $0.7 < |Y^{jet}| < 1.1$

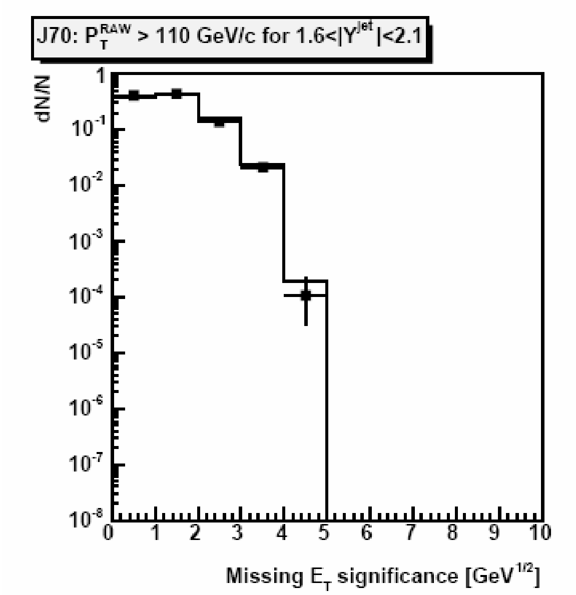


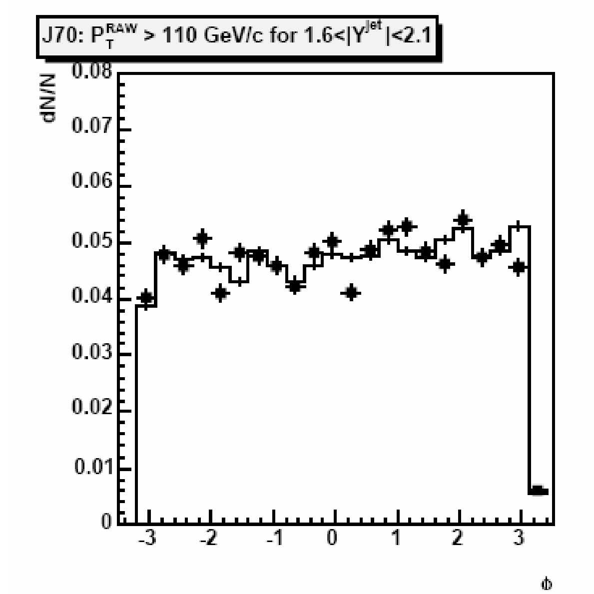
Comparison of Raw Quantities: $1.1 < |Y^{jet}| < 1.6$

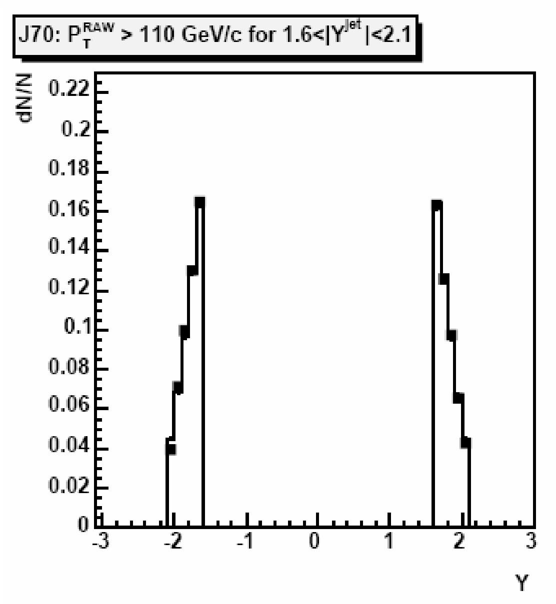


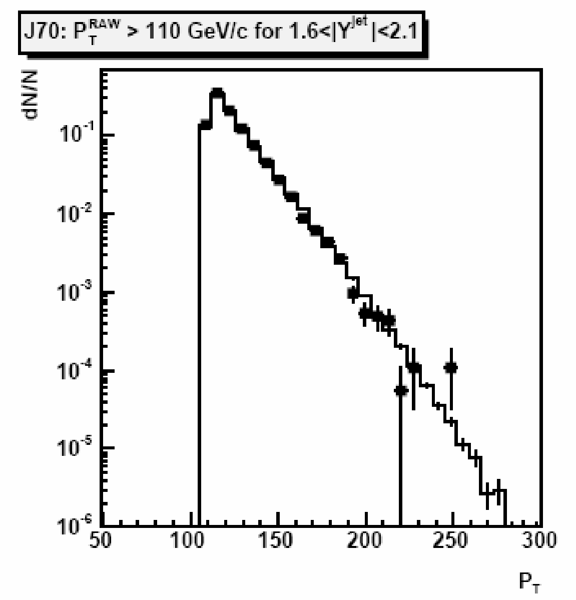
Comparison of Raw Quantities: $1.6 < |Y^{jet}| < 2.1$

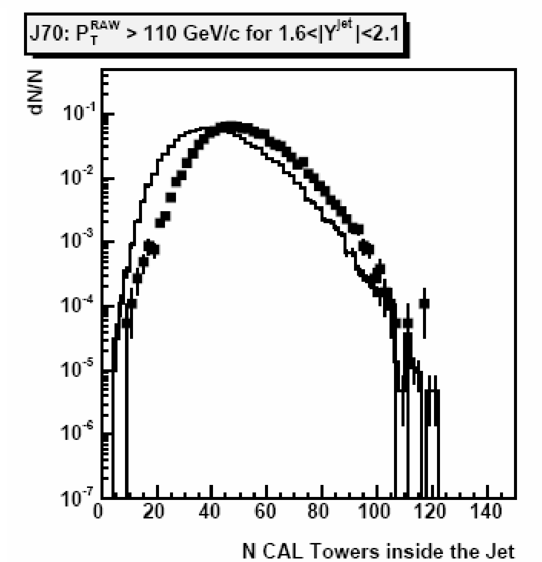












Test simulation of P_T^{Jet} reconstruction

Raw comparisons show

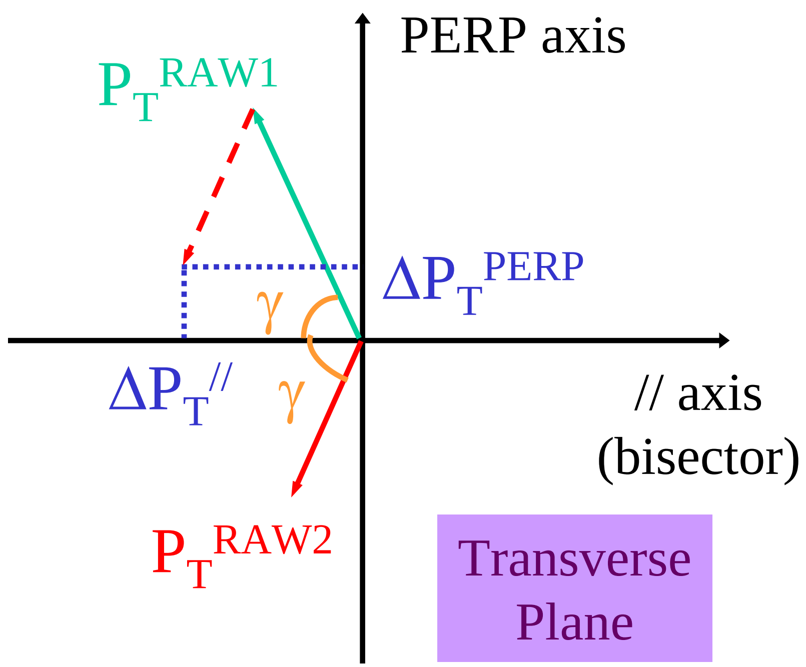
- General good agreement between Data and MC
- But MC is not perfect (Number of Towers inside jets)

- Need to test accuracy of the simulation of the P_T^{Jet} reconstruction in the MC
  - → Bisector Method -> study the resolution
  - → Dijet Balance -> understand the energy scale
- General Event Selection
  - 2 and only 2 jets with $P_T^{Jet} \geq 10$ GeV/c
  - 1 and only 1 primary vertex (|Vz| < 60cm)
  - Missing E_T significance cut applied in both jets

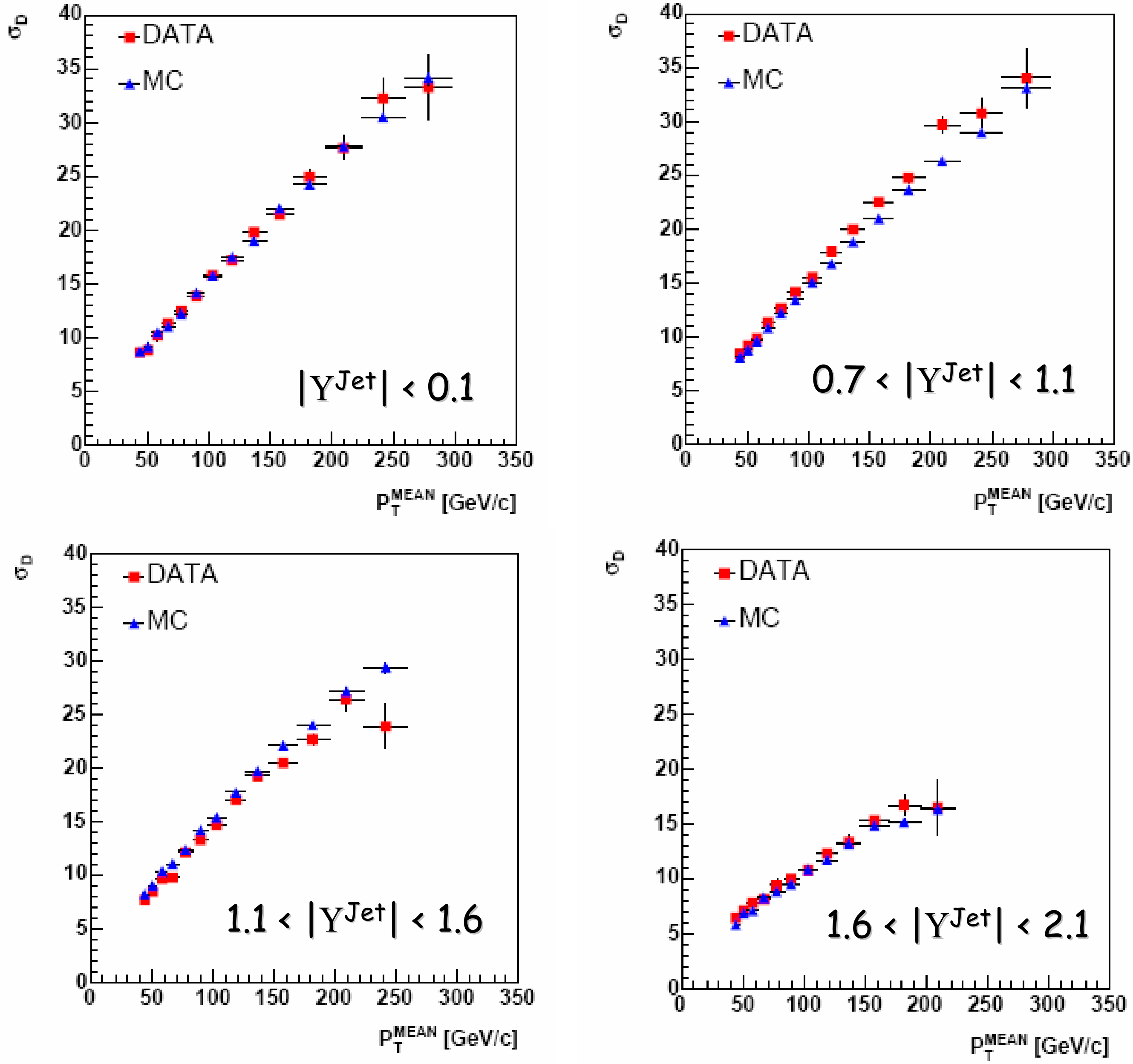
Bisector Method

- Event Selection
  - One jet (Jet 1) with $0.1 < |Y^{Jet}| < 0.7$
  - The other jet (Jet 2) with
    $|Y^{Jet}| < 0.1$; $0.7 < |Y^{Jet}| < 1.1$; $1.1 < |Y^{Jet}| < 1.6$; $1.6 < |Y^{Jet}| < 2.1$

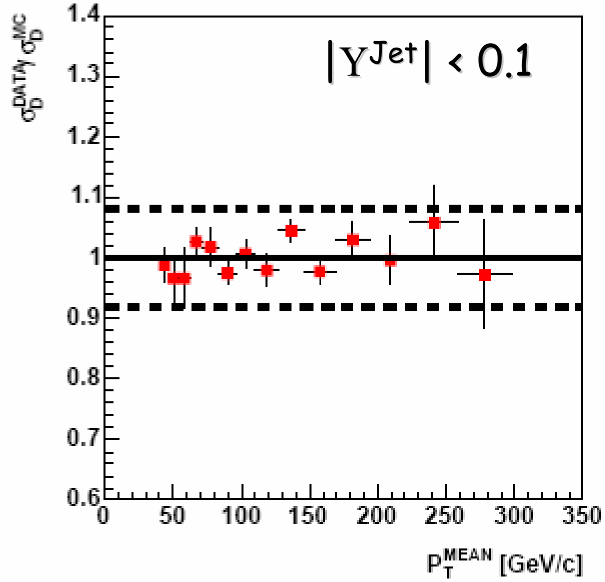
- Definitions
  - -> $P_T^{Mean} = (P_T^{Jet1} + P_T^{Jet2})/2$
  - -> $\gamma = |(\phi^{Jet1} - \phi^{Jet2})/2|$
  - -> $\Delta P_T^{//} = \pm (P_T^{Jet1} + P_T^{Jet2}) \cos(\gamma)$
  - -> $\Delta P_T^{PERP} = (P_T^{Jet1} - P_T^{Jet2}) \sin(\gamma)$
- Relevant variables (in bin of P_T^{Mean})
  - $\sigma_{//}$ = rms of $\Delta P_T^{//}$ distribution
  - σ_{PERP} = rms of ΔP_T^{PERP} distribution
  - $\sigma_D = \sqrt{(\sigma^2_{PERP} - \sigma^2_{//})}$

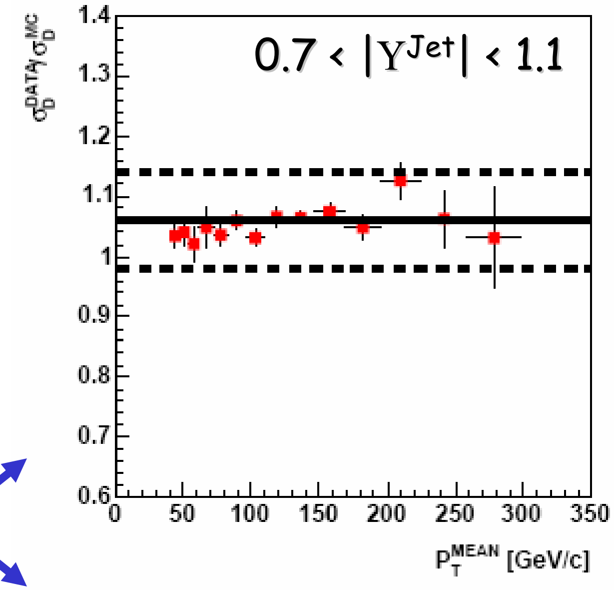


Bisector Method: σ_D in DATA and MC



Bisector Method: Data/MC



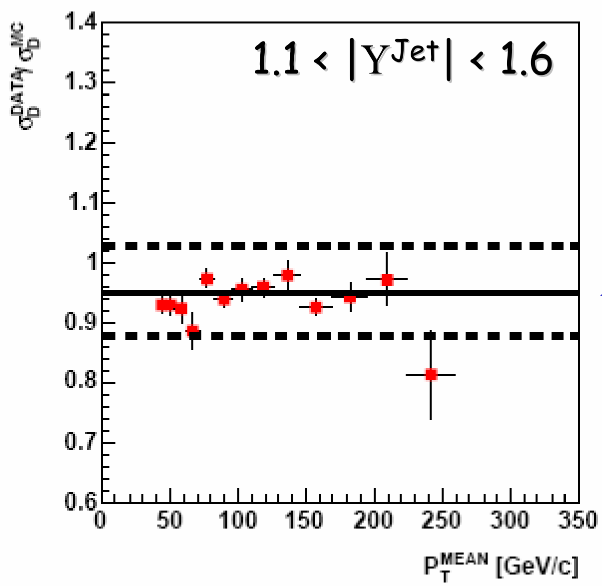


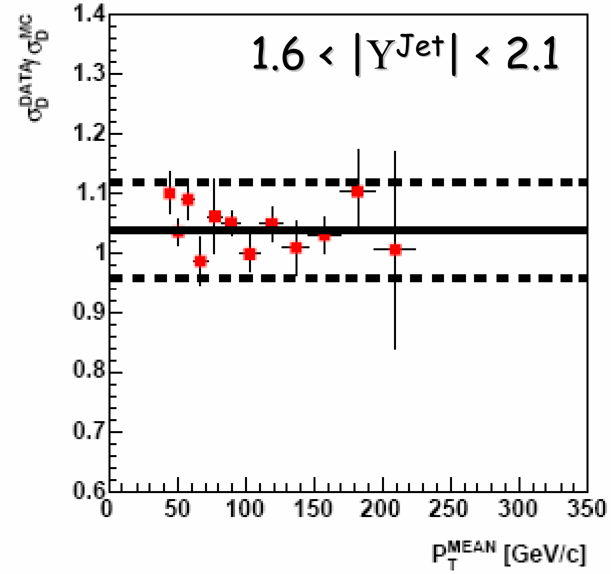
Data/MC >1

Resolution underestimated in MC

Data/MC <1

Resolution overestimated in MC

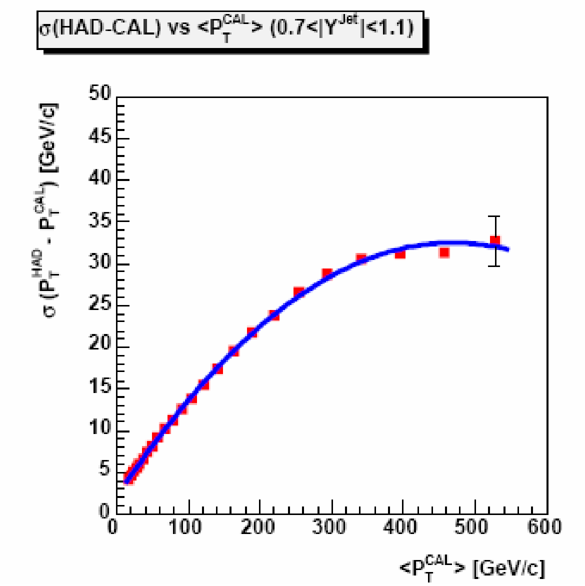




The two cases must be treated differently

Resolution Corrections (I)

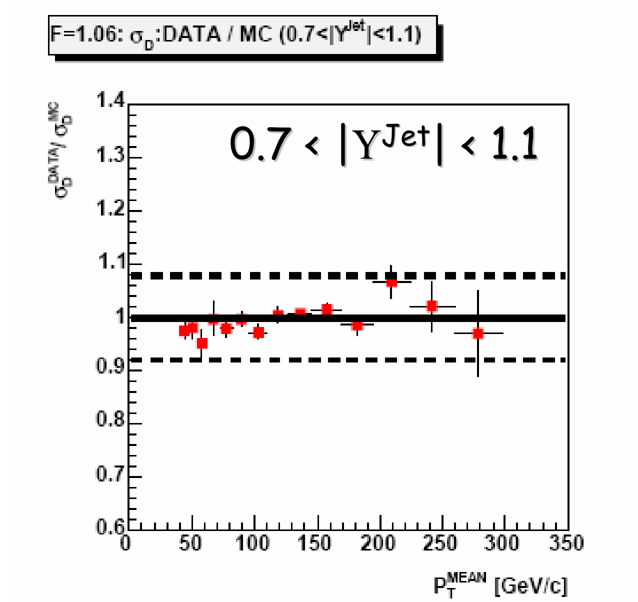
Case 1: Resolution underestimated in the MC



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

$$\boxed{\begin{array}{c} \sigma_{corr} = \sigma_{MC} \oplus \sigma_G = F \cdot \sigma_{MC} \quad \text{where } F > 1 \\ \Rightarrow \; \sigma_G = \sigma_{MC} \cdot \sqrt{(F^2 - 1)} \end{array}}$$

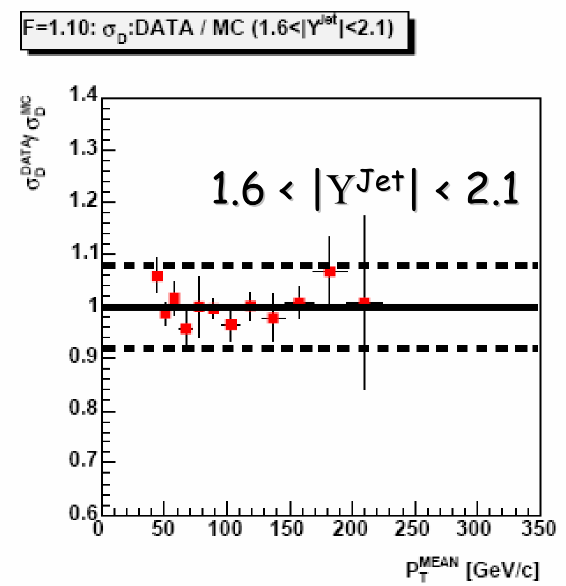
- Calculate the σ_{MC} matching CAL-HAD pair of jets $\Rightarrow \sigma\,(P_T^{HAD} - P_T^{CAL})$ vs P_T^{CAL}



- Try different values of F
- Keep the one for which $\sigma_D^{Data} = \sigma_D^{MC}$

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

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



Resolution Corrections (II)

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

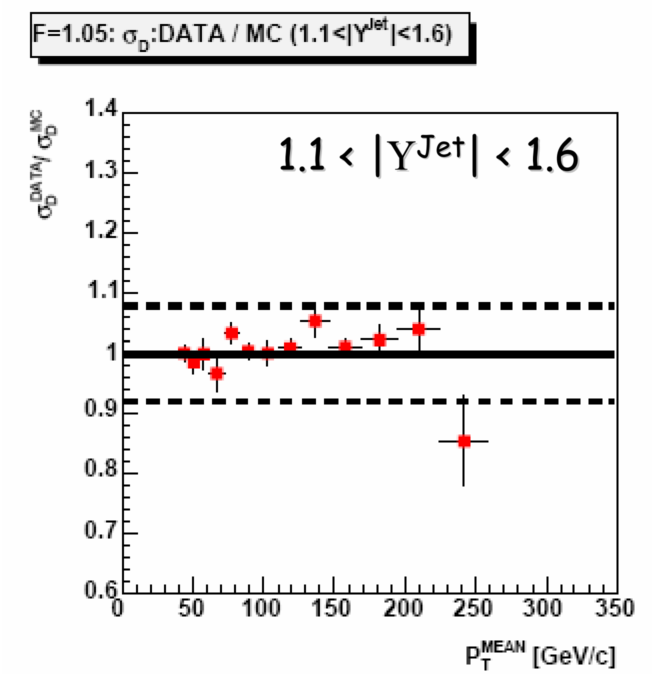
  - Smear P_T^{RAW} in the data this time (ONLY FOR THIS) using same definition of σ_G

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

- Try different values of F
- Keep the one for which $\sigma_D^{Data} = \sigma_D^{MC}$

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

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



Dijet Balance: method

After the P_T resolution has been adjusted in the MC (wherever possible)

- Event Selection

  - One jet (Trigger Jet) with $0.2 < |\eta_D| < 0.6$

  - The other jet (Probe Jet) with

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

- Definitions

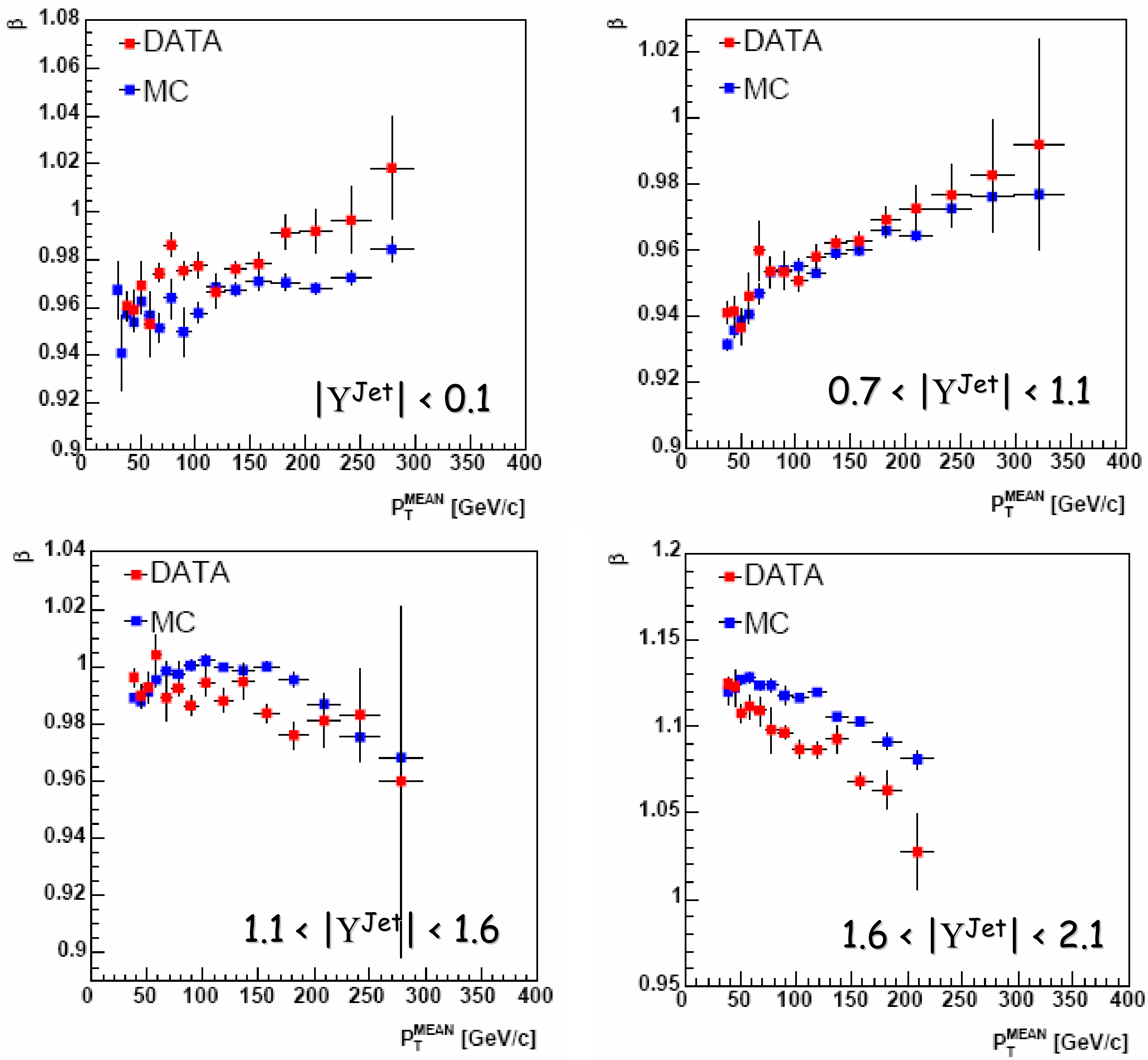
  -> $P_T^{Mean} = (P_T^{Trig} + P_T^{Prob})/2$

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

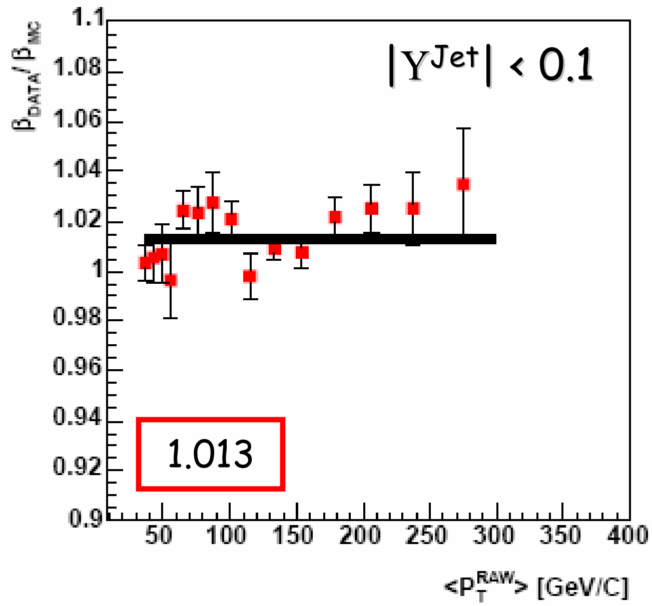
  -> In bin of P_T^{Mean} : $\beta = (2+ \langle\Delta P_T^F\rangle)/(2- \langle\Delta P_T^F\rangle)$

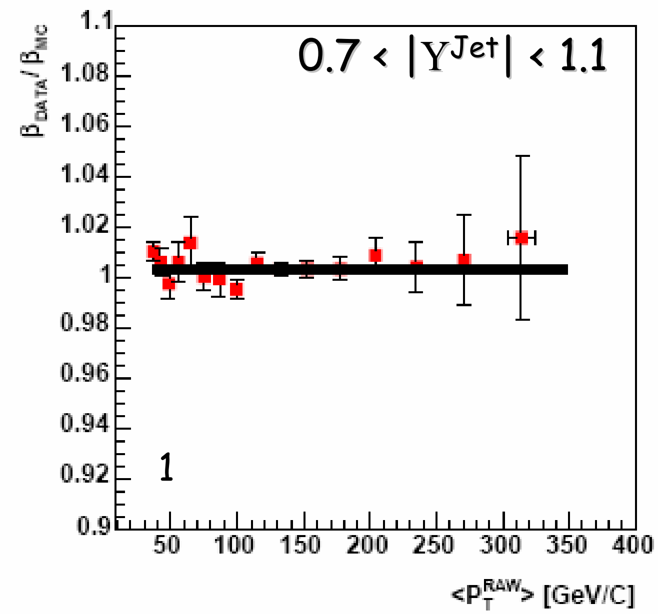
Event by event: $\beta = P_T^{Prob} / P_T^{Trig}$

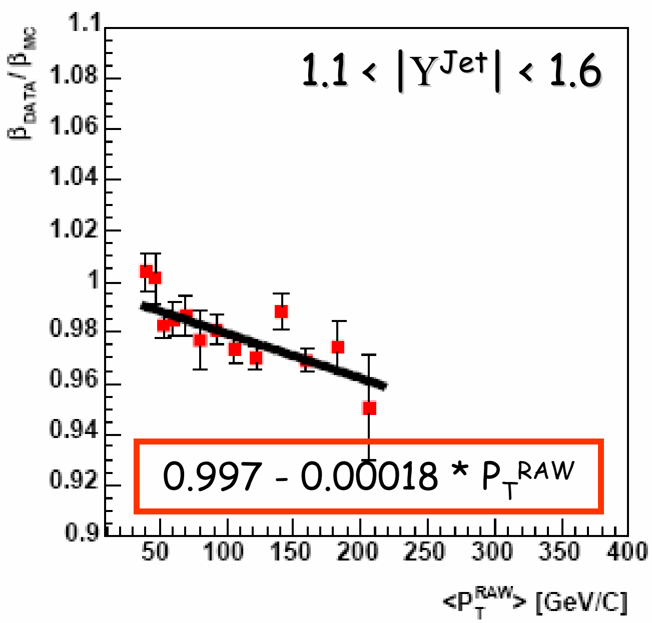
Dijet Balance: β in Data and MC

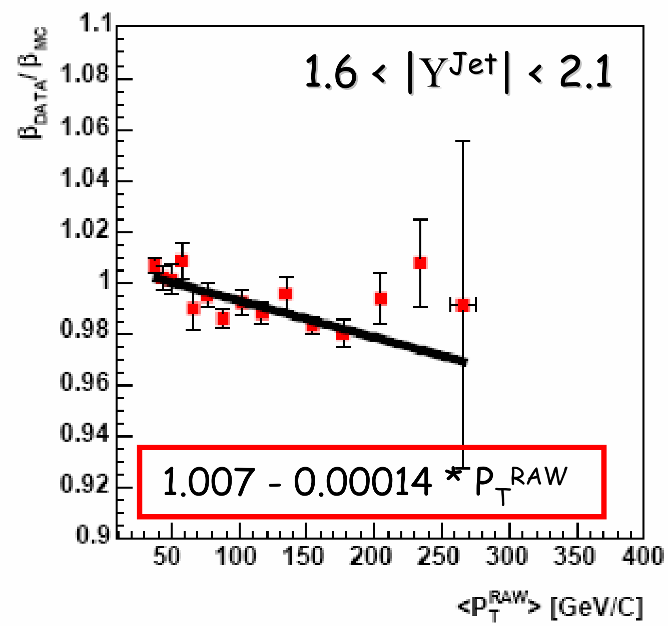


Dijet Balance: Data/MC









Pile-up correction (based on data)

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

- Shape of cross sections vs P_T^{JET} for two subsamples

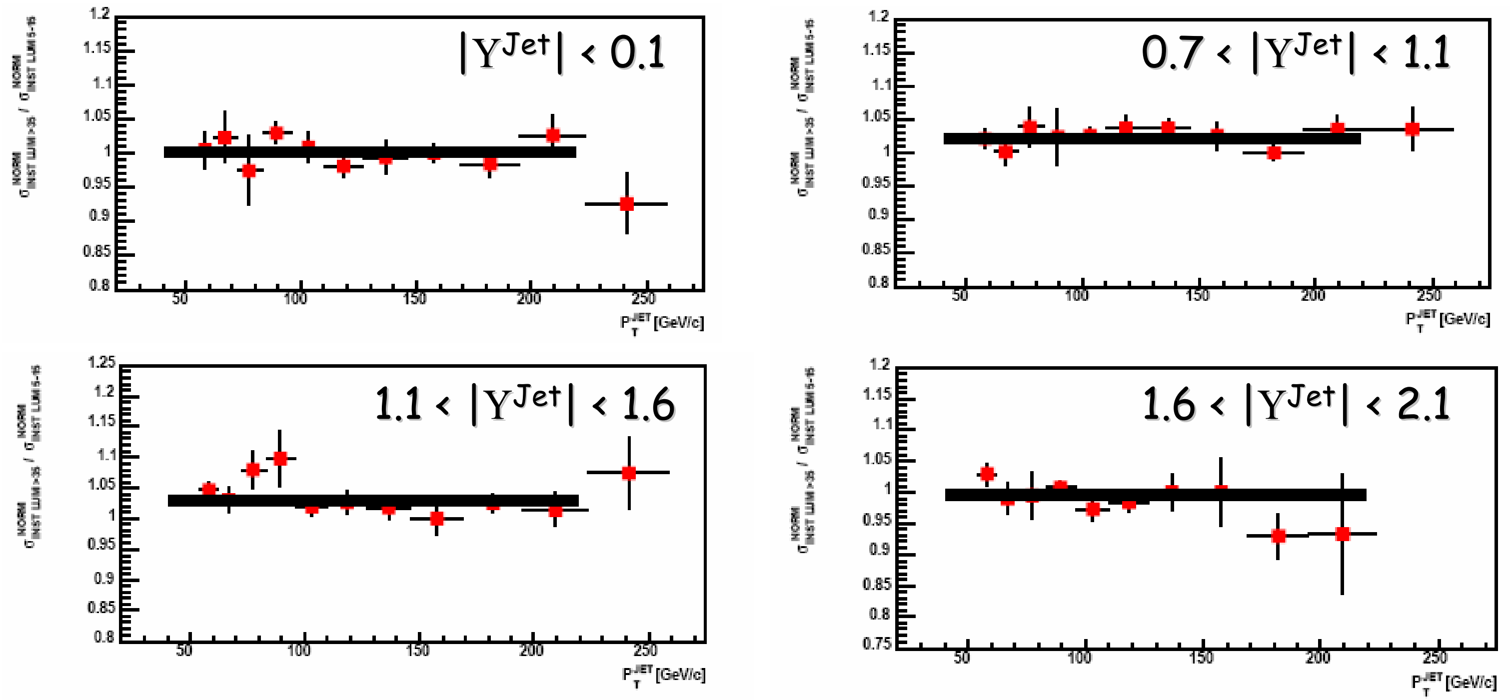
⇒ high luminosity/low luminosity normalized ratio

Low luminosity: 5 to 15 x 10^{30} $cm^{-2}s^{-1}$

High luminosity: > 35 x 10^{30} $cm^{-2}s^{-1}$

- Same study performed for the different rapidity regions used

⇒ results consistent with a single factor independent of Y^{Jet}



Average P_T^{Jet} Correction: method

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

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

→ Reconstruct jets at Calorimeter (P_T^{RAW}) and Hadron (P_T^{HAD}) level

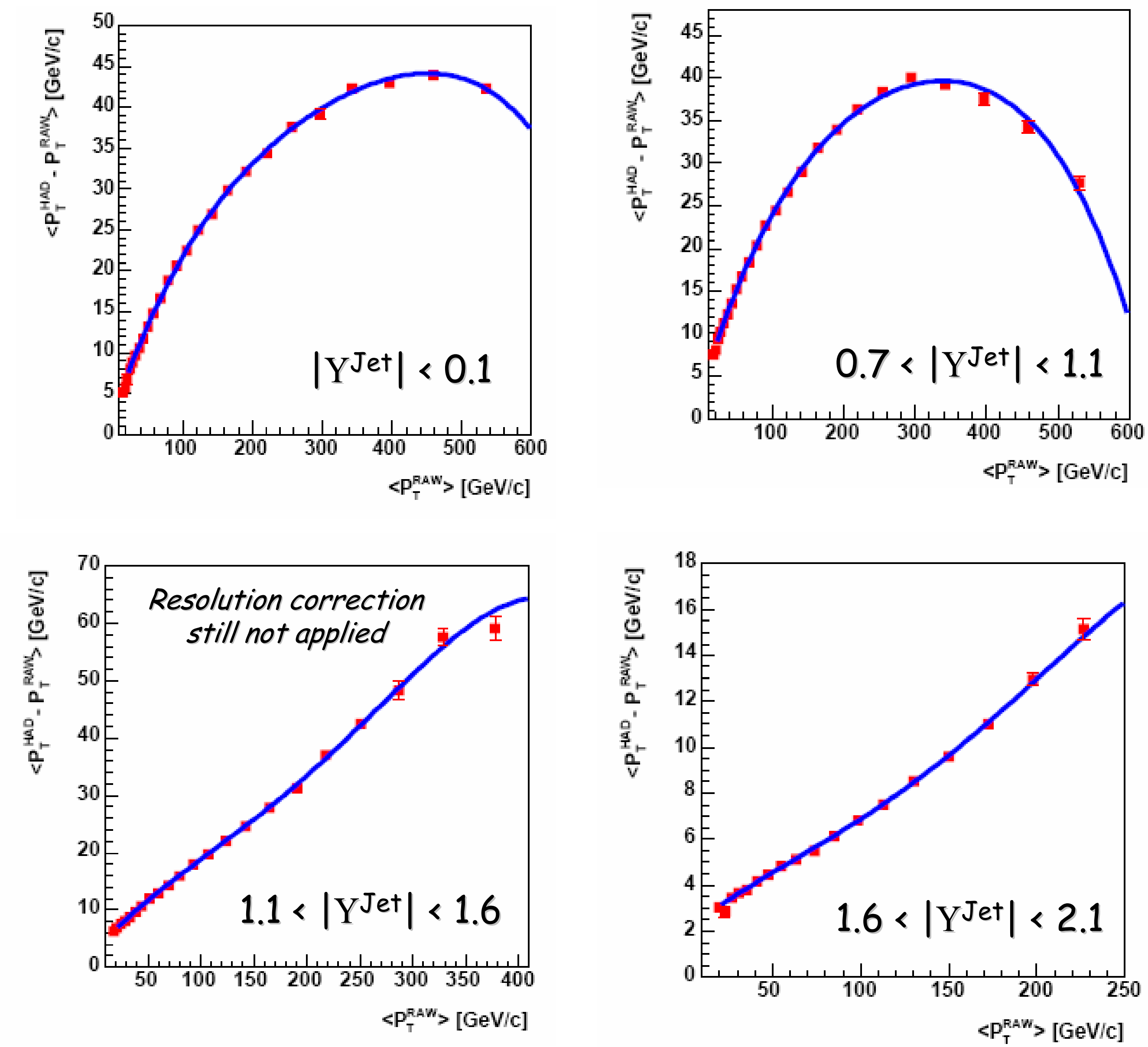
→ Match pair of CAL-HAD jets in Υ - ϕ space

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

→ The correlation $\langle P_T^{HAD} - P_T^{RAW} \rangle$ versus $\langle P_T^{RAW} \rangle$ for matched jets is reconstructed and fitted to a 4th order polinomial

- In bins of $(P_T^{HAD}+P_T^{RAW})/2$ to less bias the $P_T^{HAD}-P_T^{RAW}$ distribution

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)

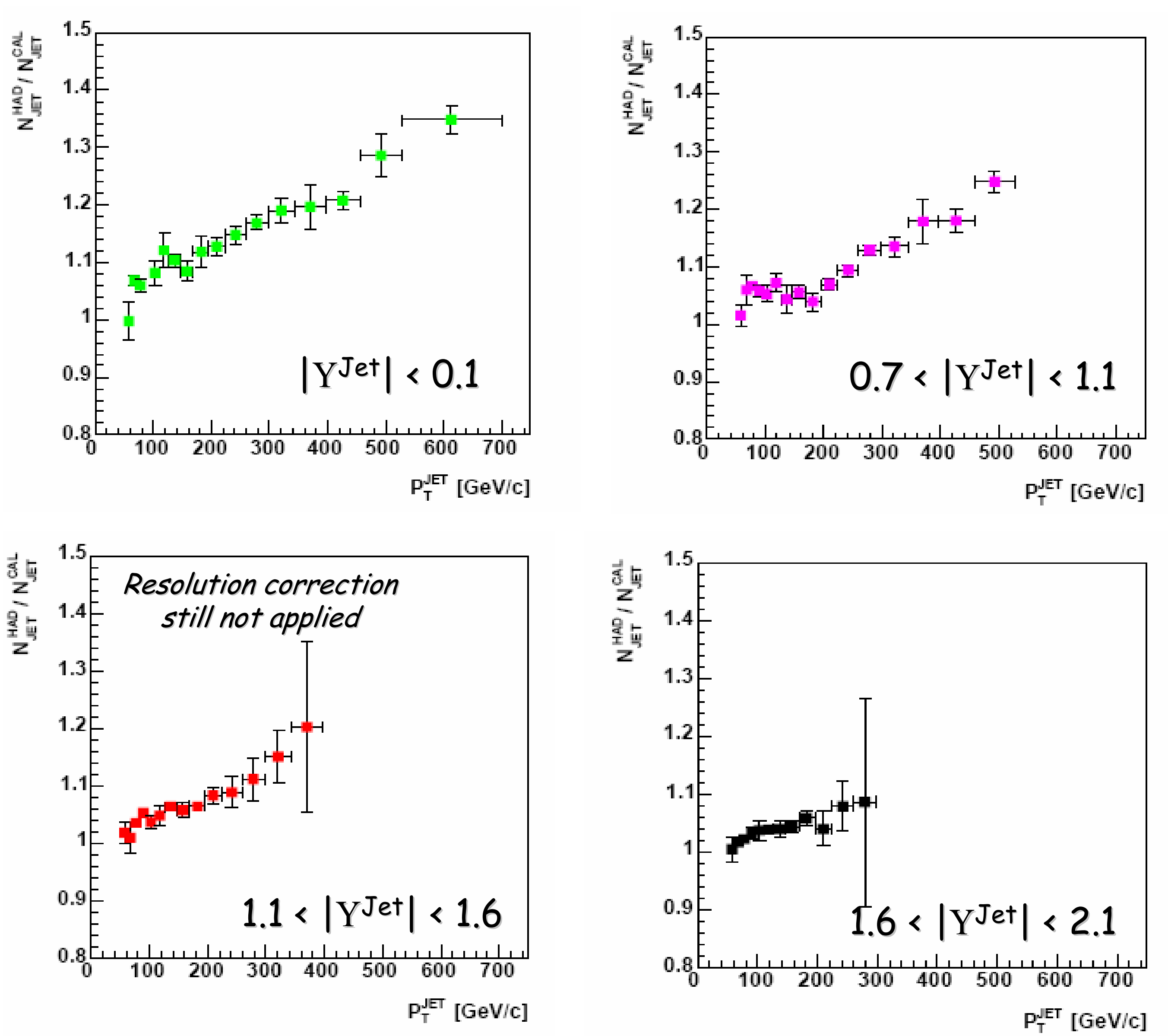
→ Bin-by-bin unfolding factors

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

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

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

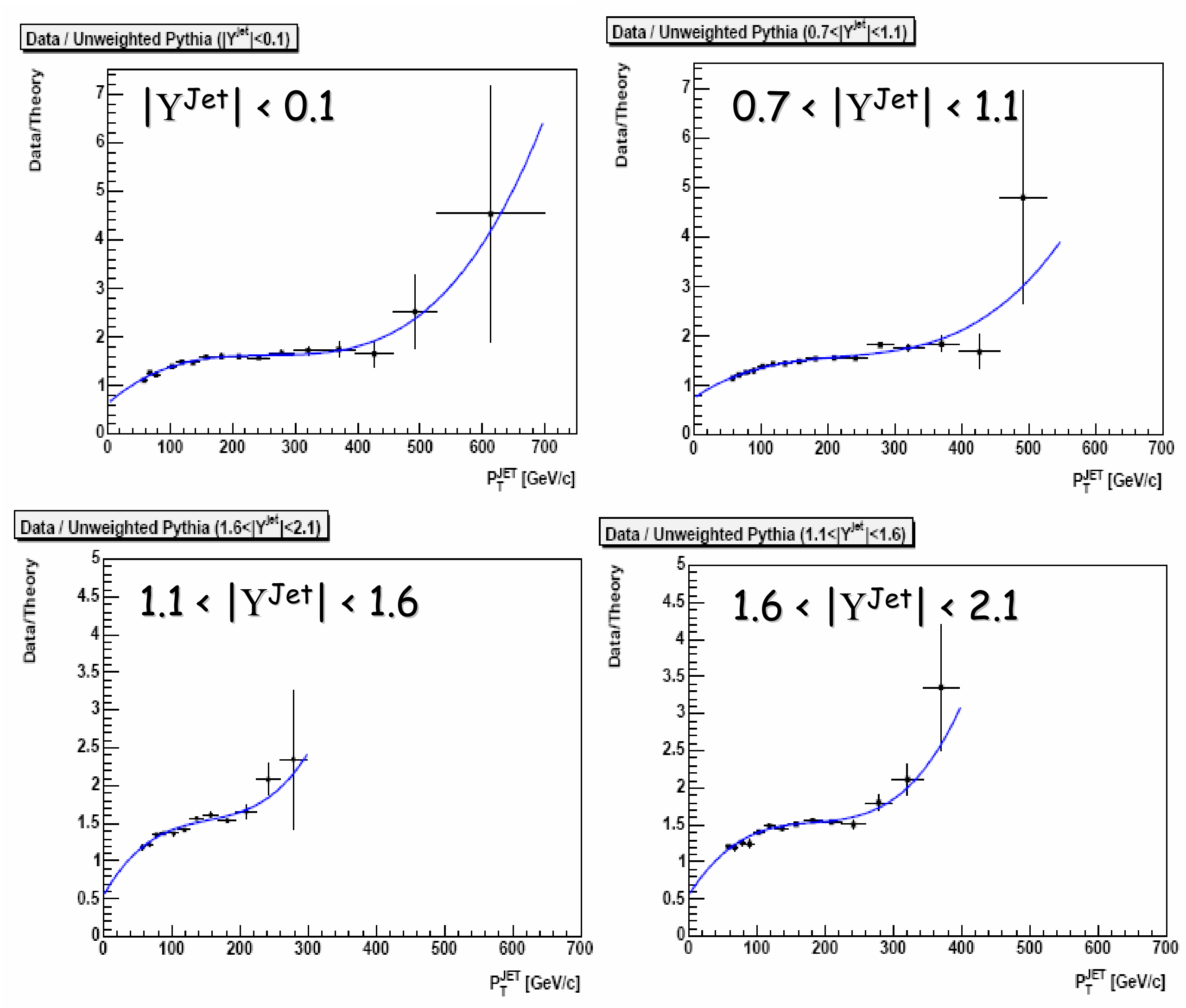
Unfolding Factors



PYTHIA- Tune A
(not reweighted)

Re-weighting Pythia

➢ To make the measurements independent of the jet P_T spectrum in the MC which is related to the PDF used



Look at ratio between data corrected to the hadon level and hadron level predictions using PYTHIA-Tune A

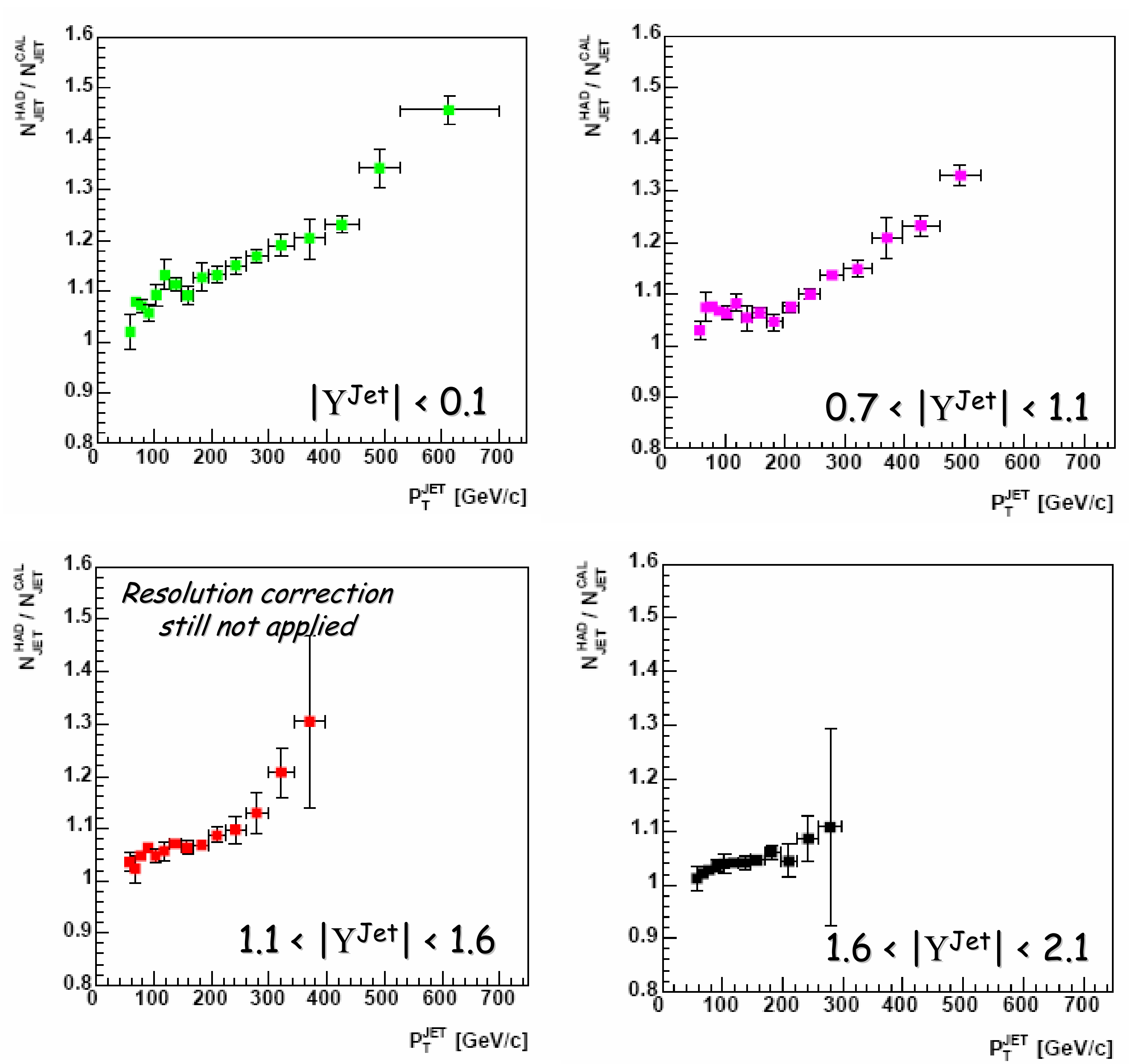
The trend at high P_T might be explained by the fact that in PYTHIA-Tune A uses CTEQ5L PDF

- Ratio Data/PYTHA vs P_T^{Jet}

- Fit by a 3rd order polynomial

- PYTHIA reweighted applying this polynomial to p_T hat

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})

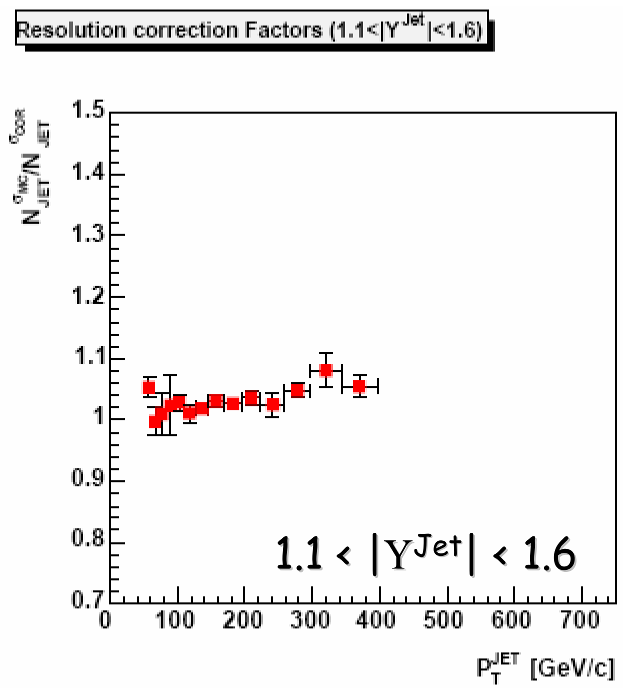
Resolution correction for case 2 ($1.1 < |Y^{Jet}| < 1.6$)

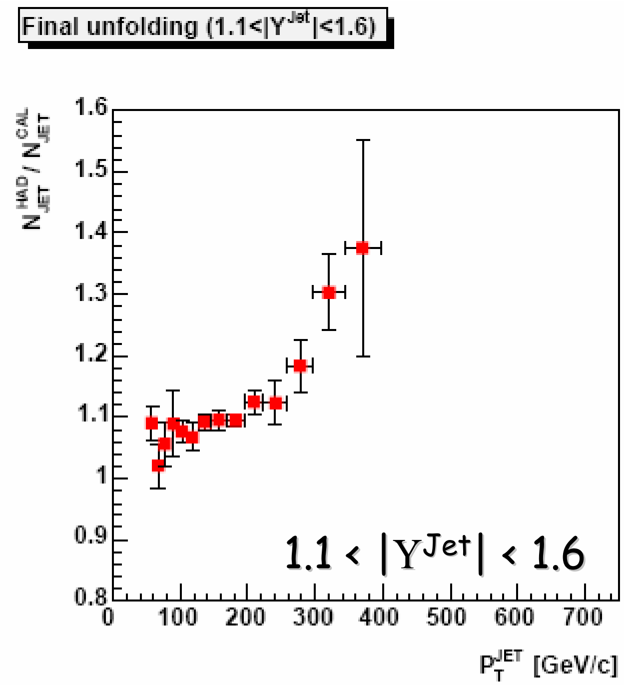
Reminder: **case 2** = Resolution overestimated in the MC

- 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%





The systematic related to the application of the dijet balance before correcting for the resolution has been evaluated: ~ 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%

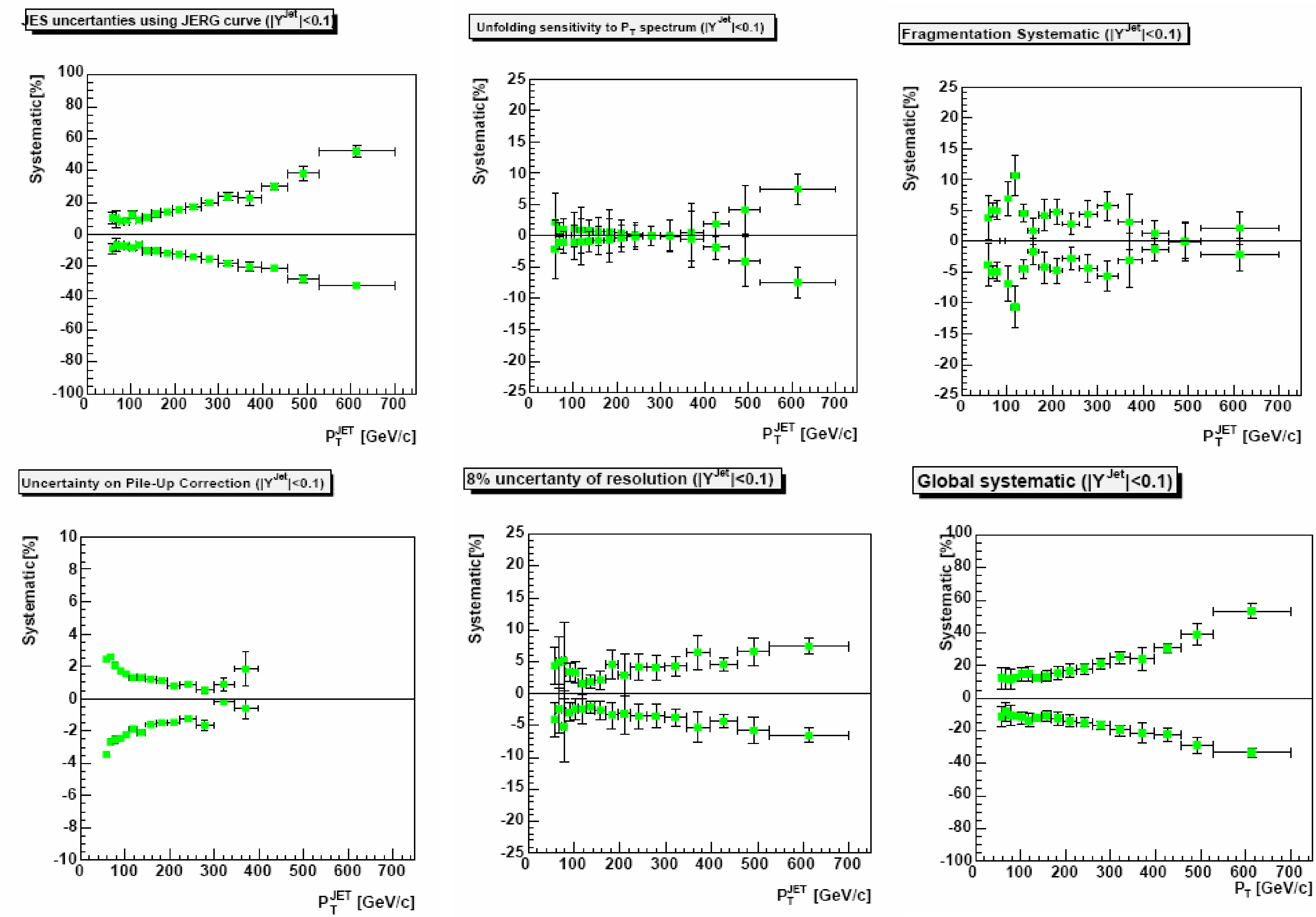
→ Missing E_T significance cut

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

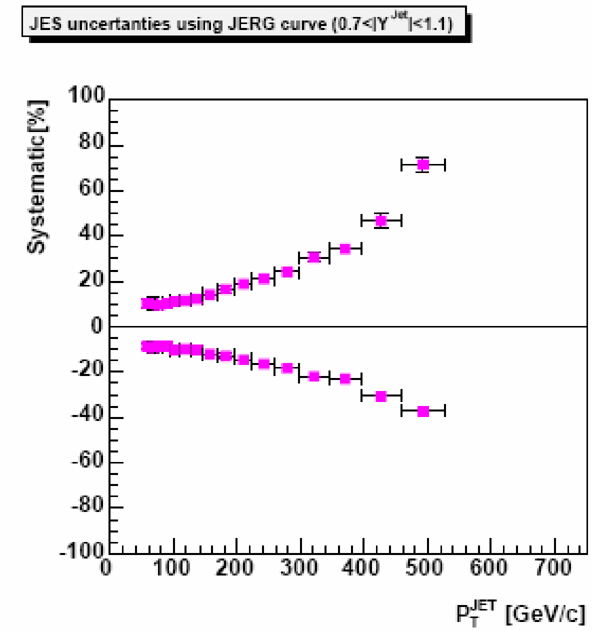
→ V_Z cut

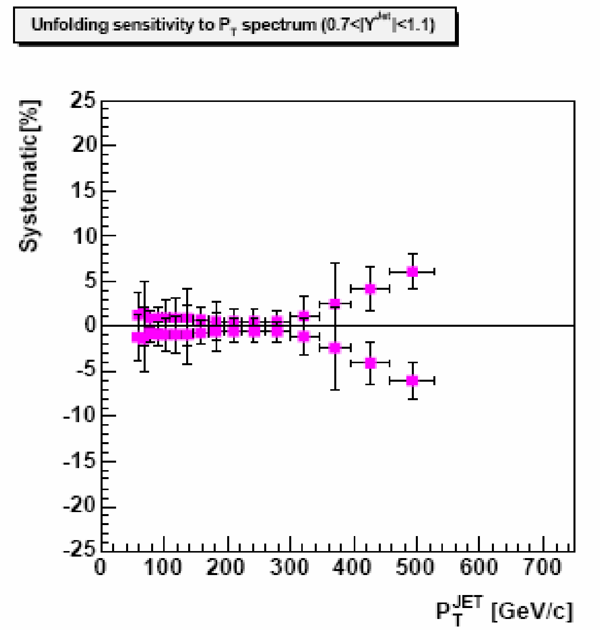
• Cut is varied by ±5cm → effect ~ 0.3%

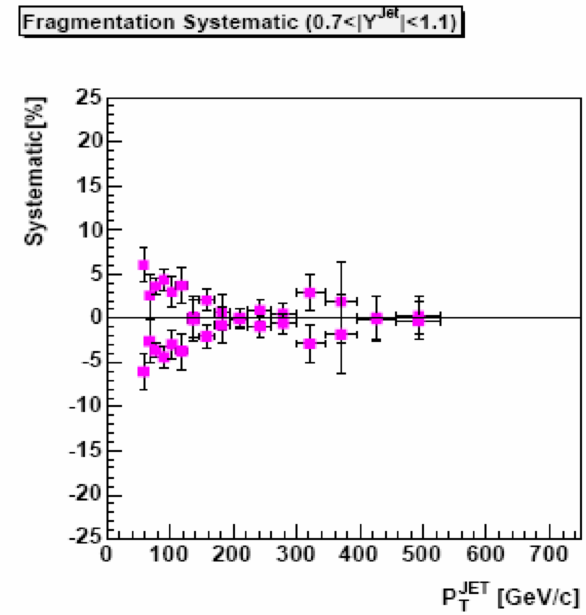
Systematic uncertainties $|Y^{jet}| < 0.1$

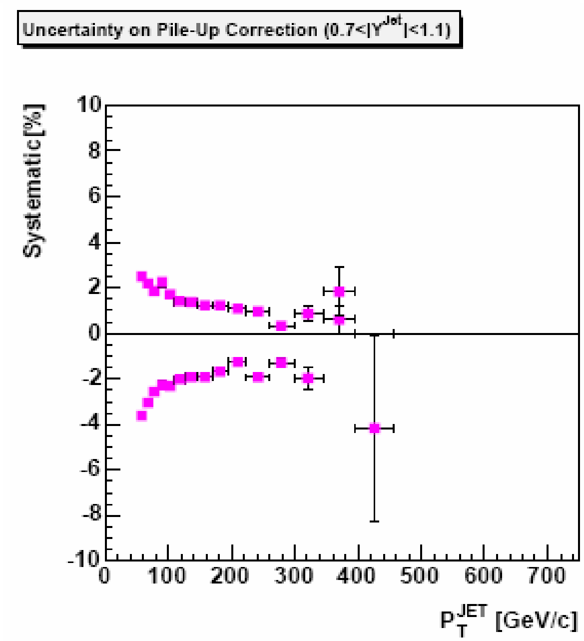


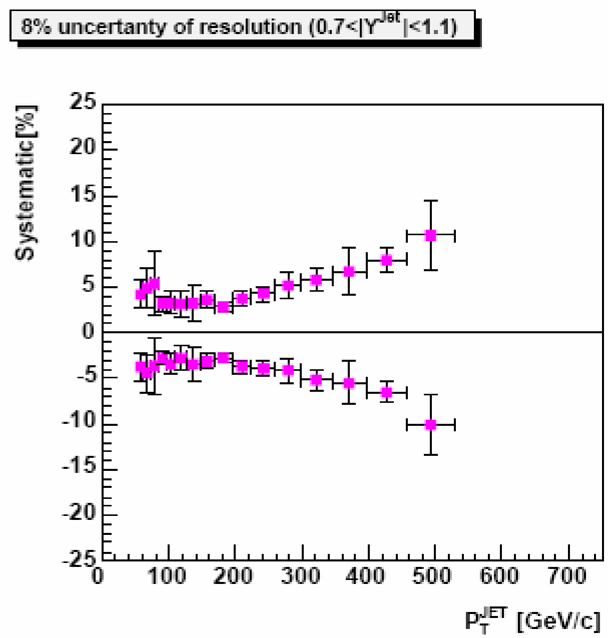
Systematic uncertainties $0.7 < |Y^{jet}| < 1.1$

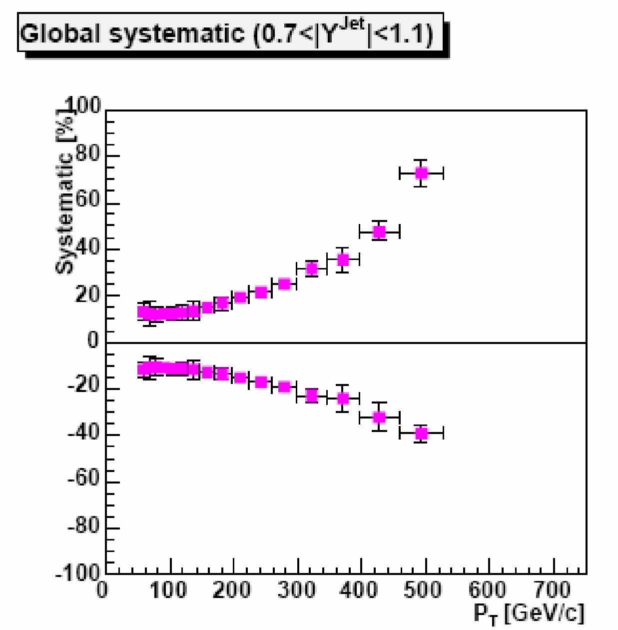




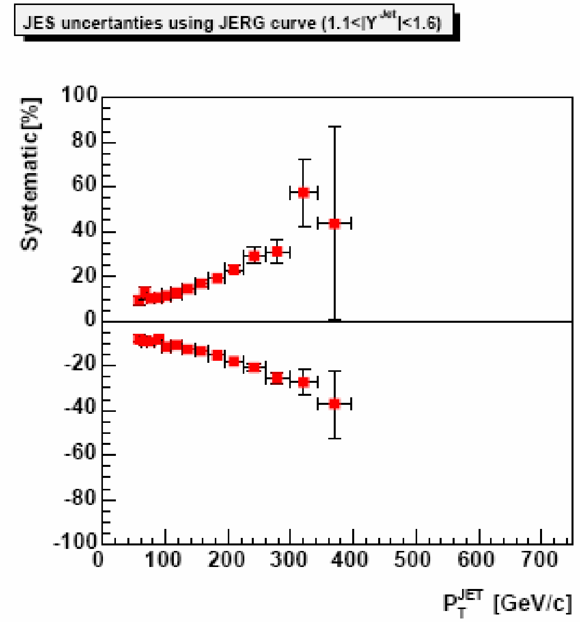


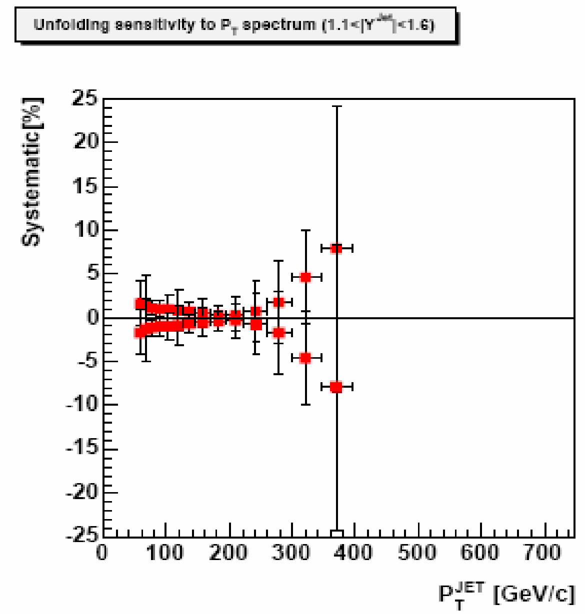


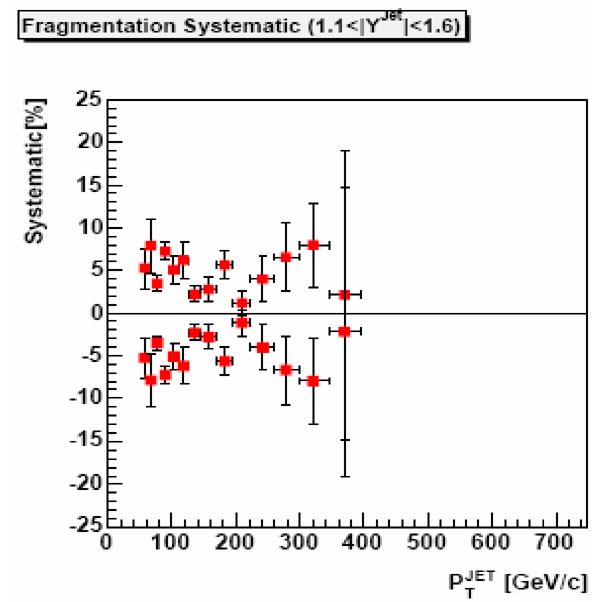


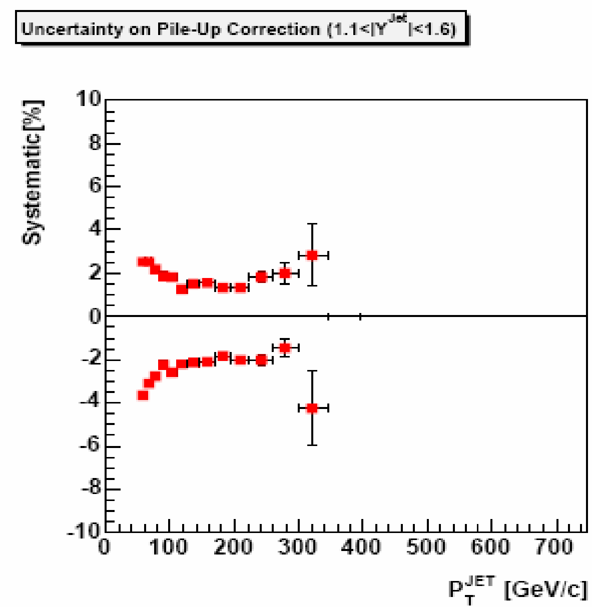


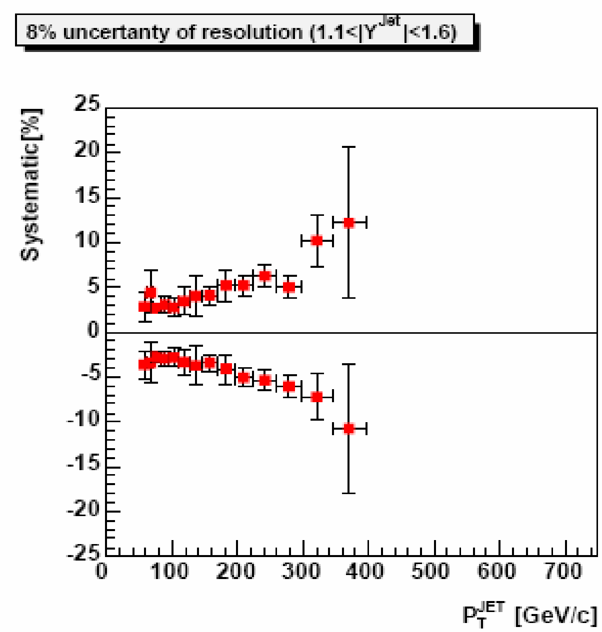
Systematic uncertainties $1.1 < |Y^{jet}| < 1.6$

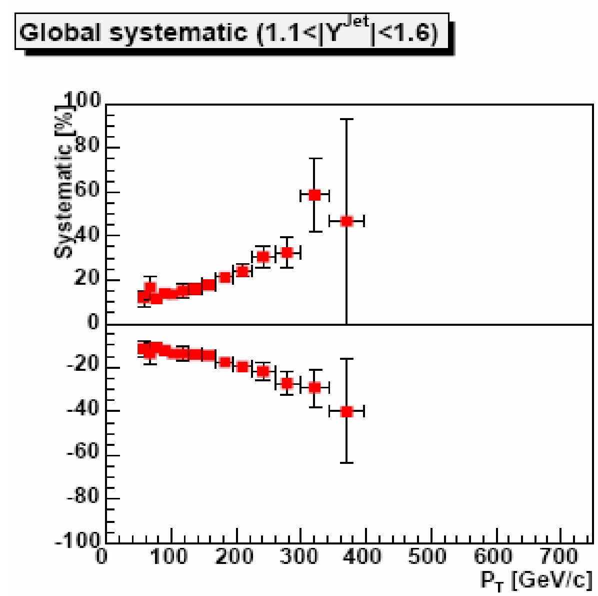




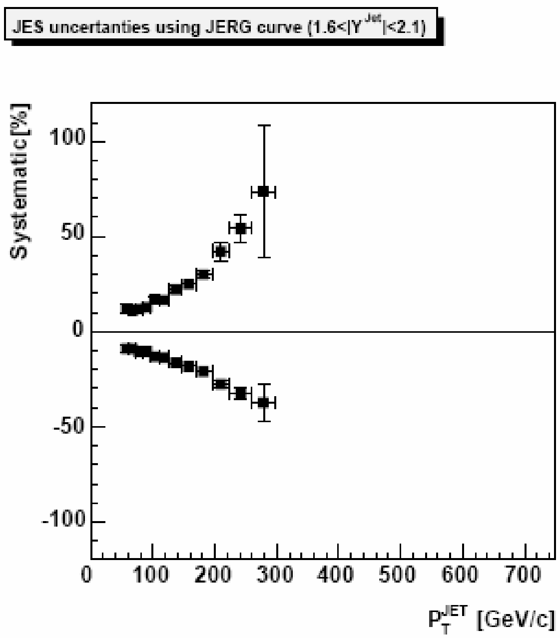


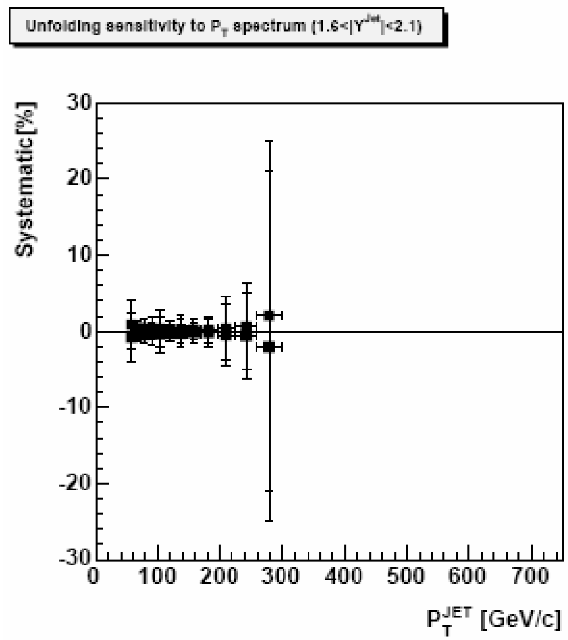


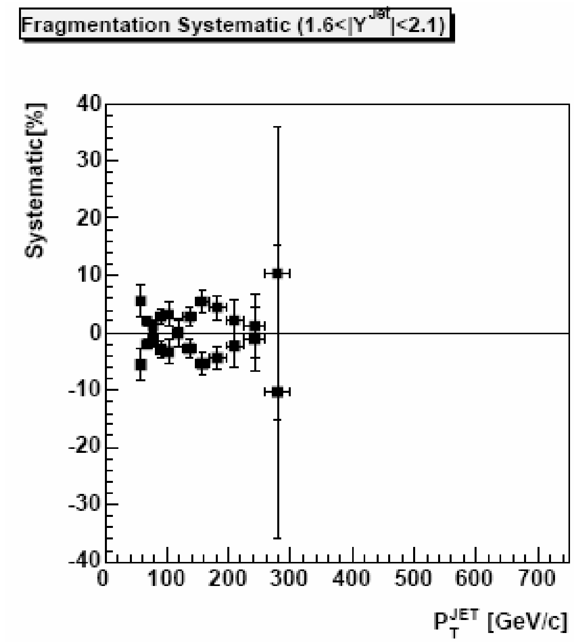


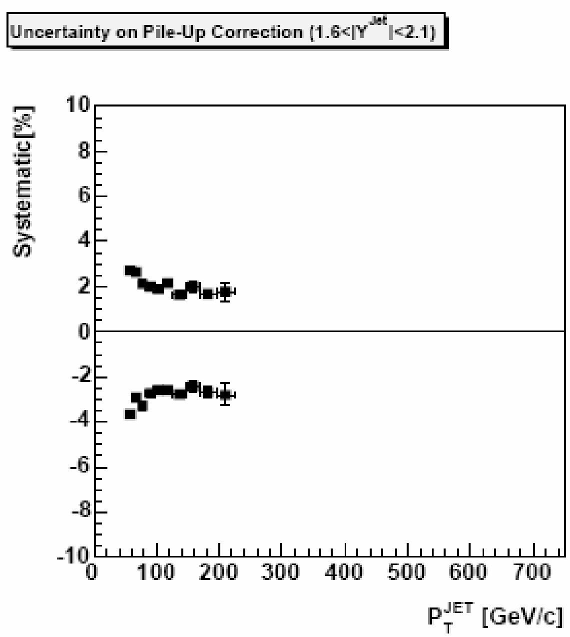


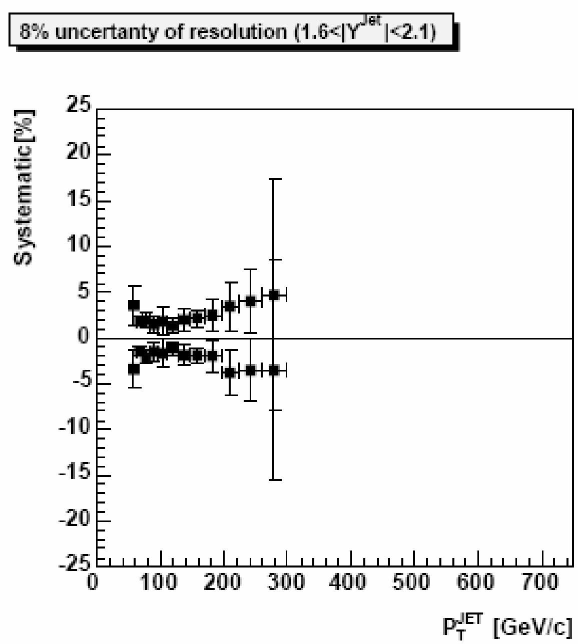
Systematic uncertainties $1.6 < |Y^{jet}| < 2.1$

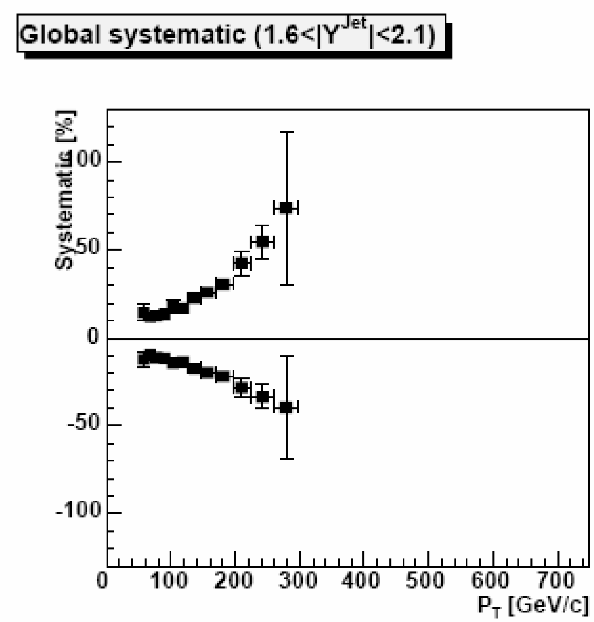












NLO calculations

→ JETRAD CTEQ61 package

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

→ 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

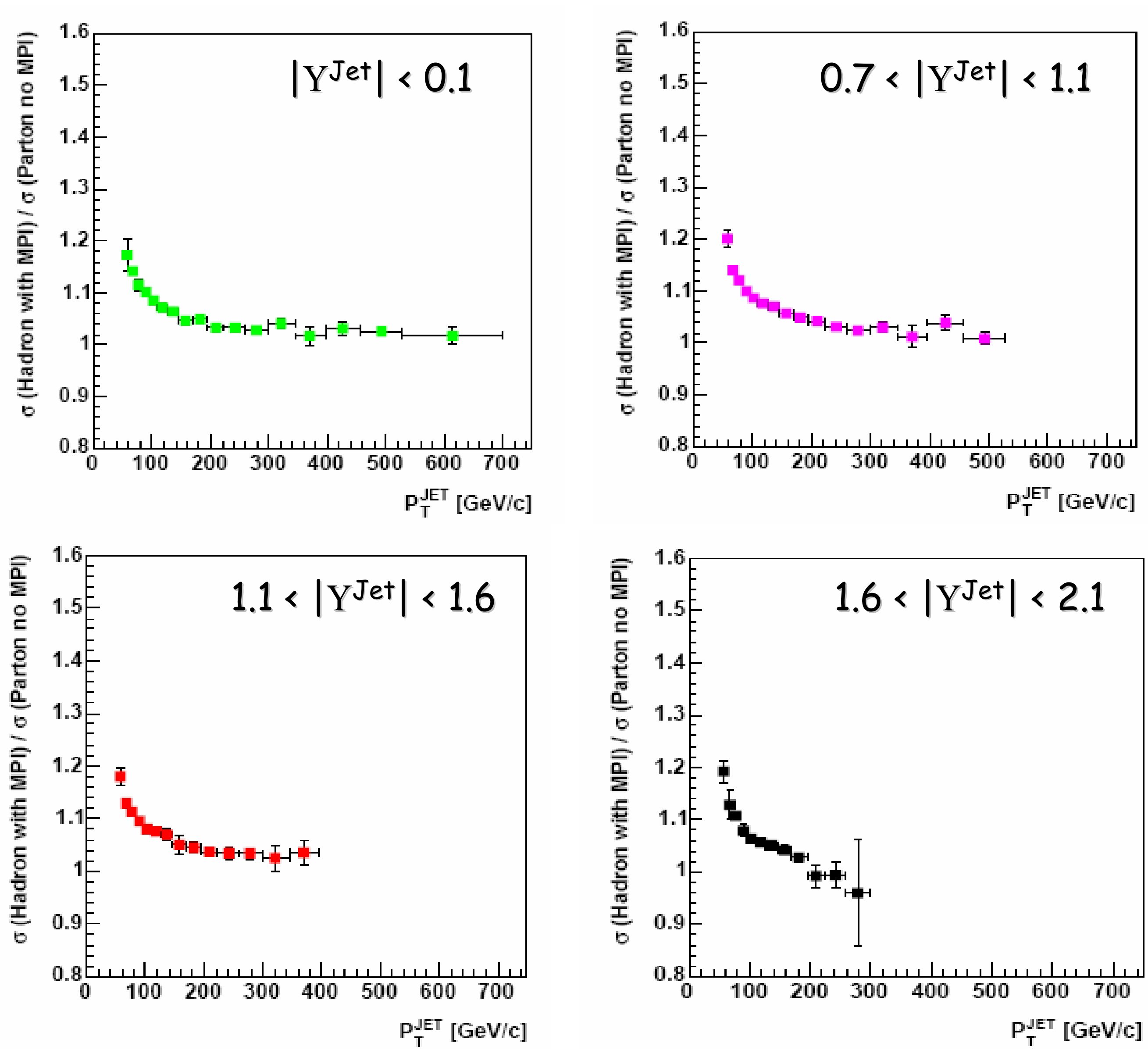
  - Final uncertainties will be computed taking into account all the 40 PDF sets and procedure as explained in hep-ph/0201195

→ UE / Hadronization corrections

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

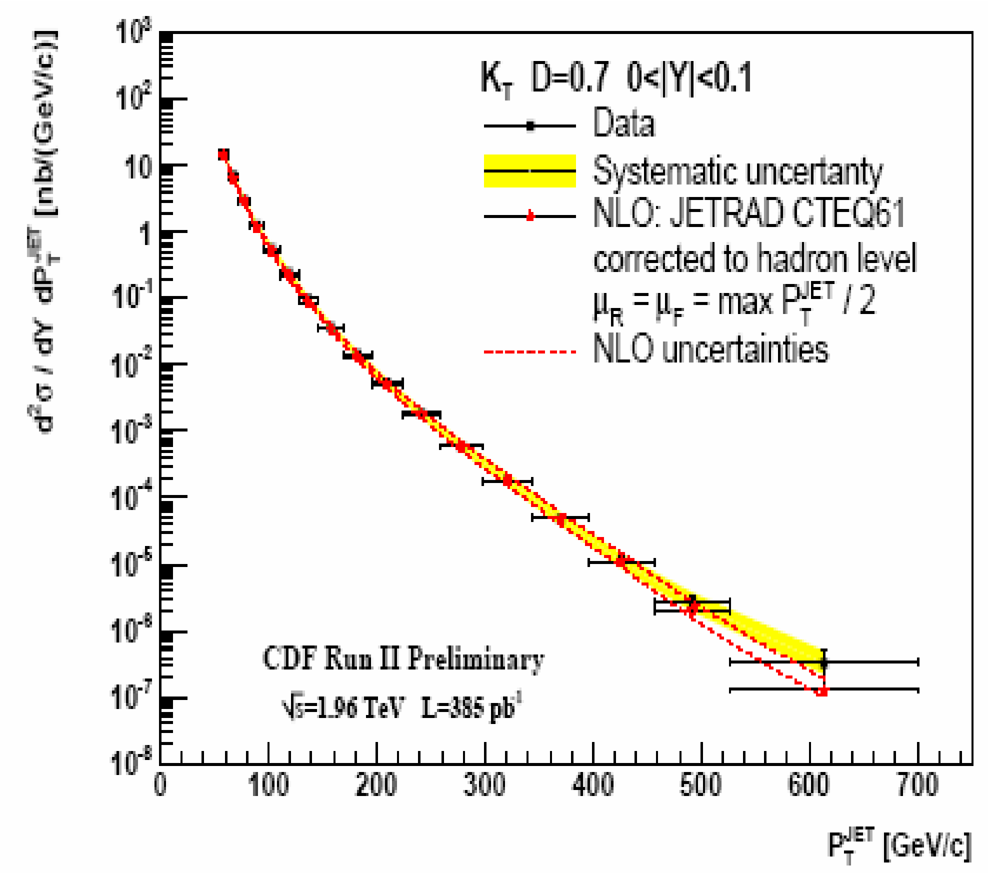
$$C_{HAD}(P_T^{Jet}, Y^{Jet}) = \frac{\sigma\text{ (Hadron Level Pythia Tune A with MPI)}}{\sigma\text{ (Parton Level Pythia Tune A no MPI)}}(P_T^{Jet}, Y^{Jet})$$

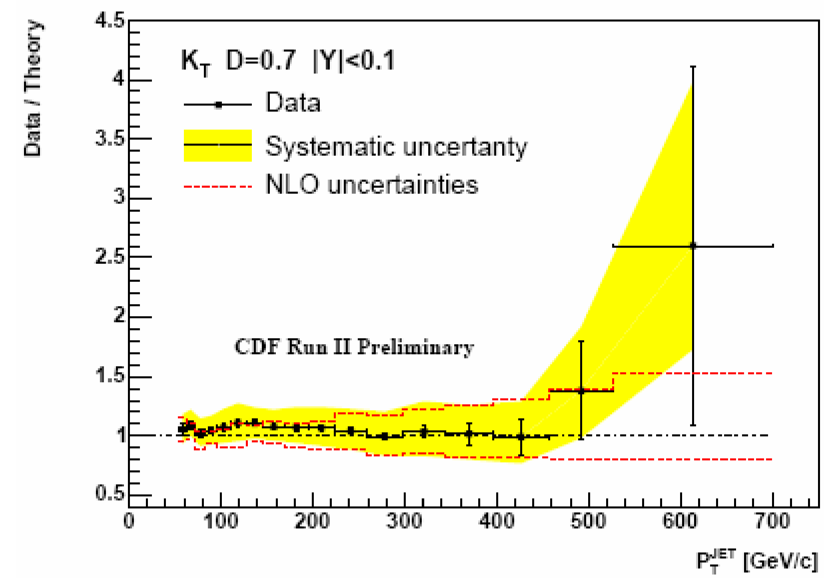
UE / Hadronization Correction

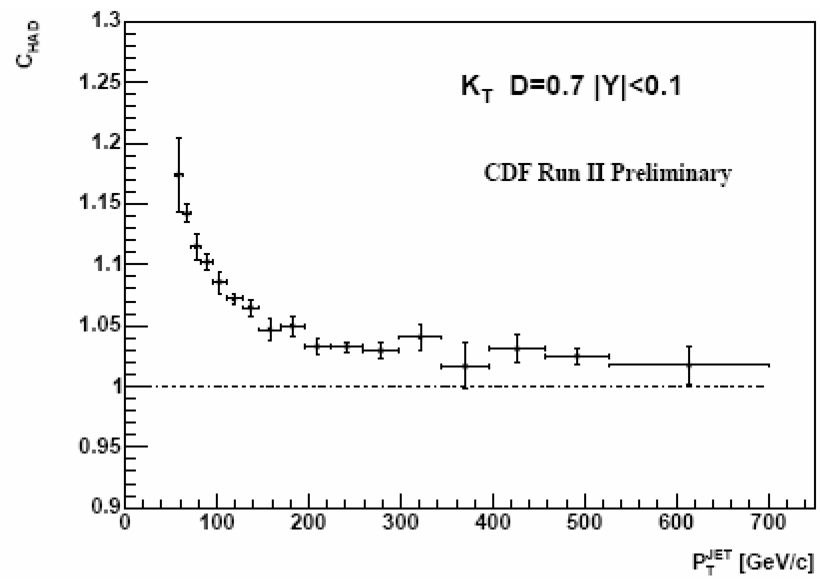


Systematic for this correction will be estimated using HERWIG (+ JIMMY eventually)

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

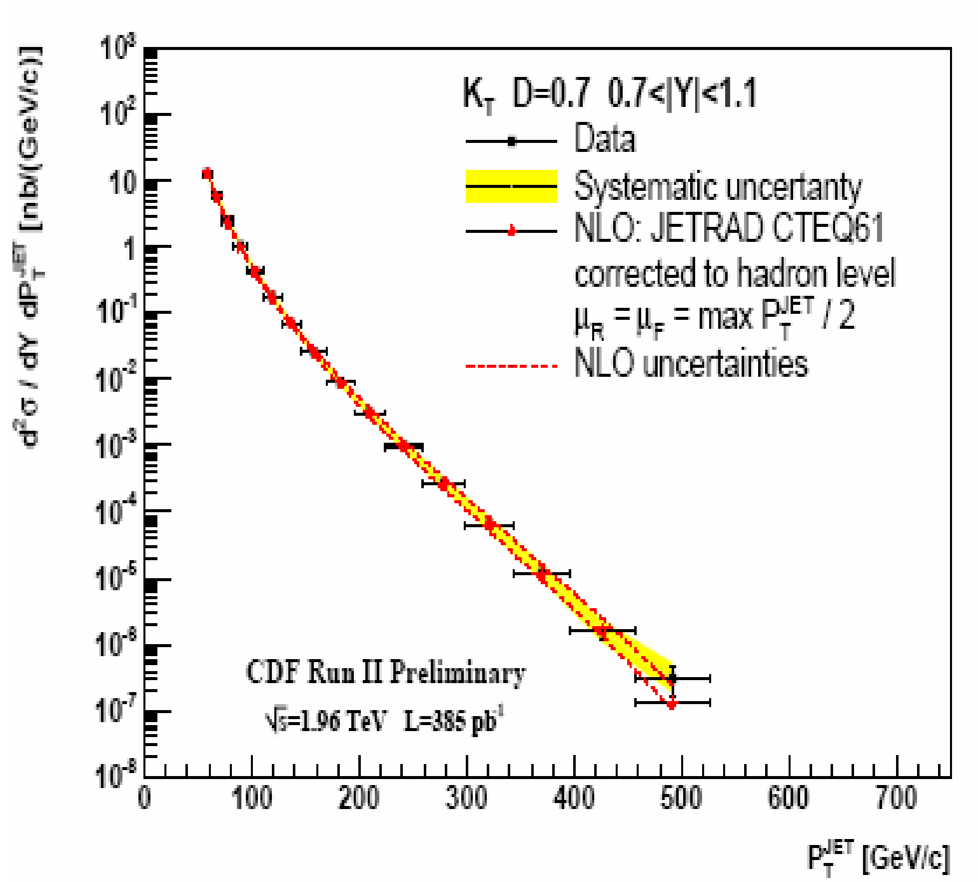


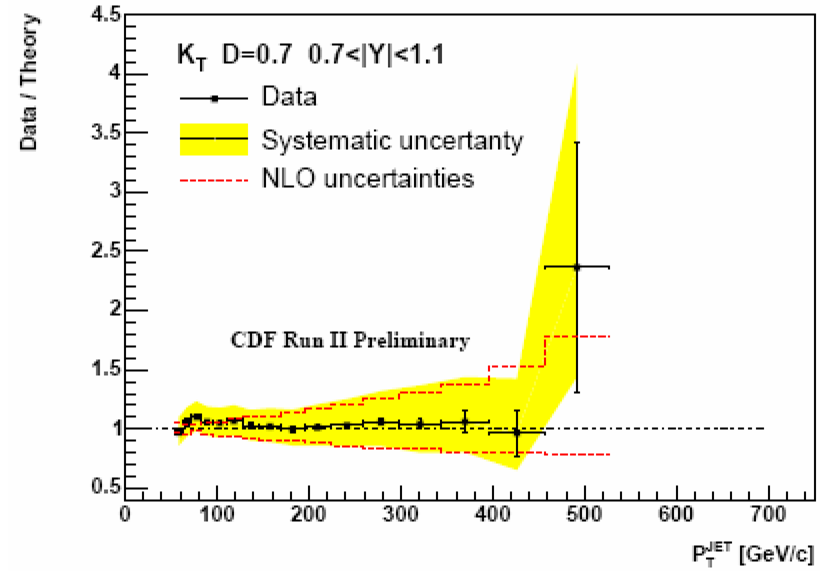


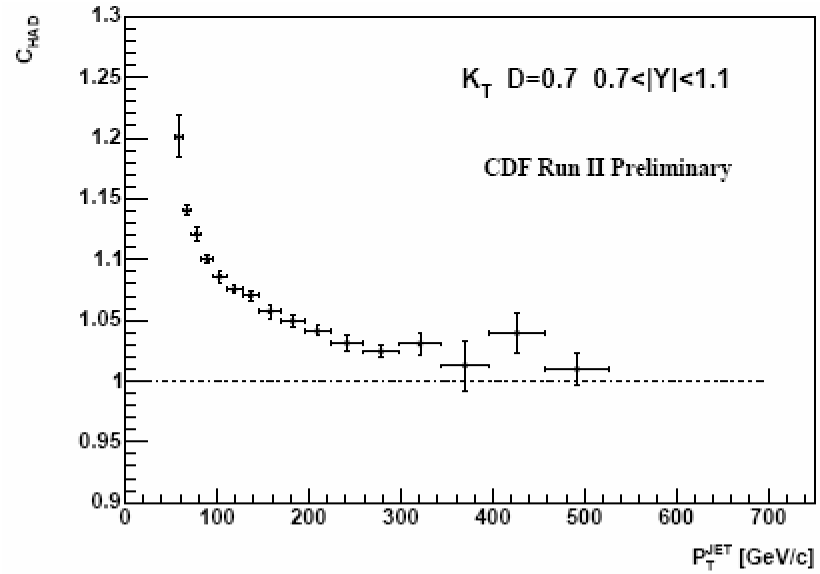


For blessing

Results: 0.7 < |Y jet| < 1.1

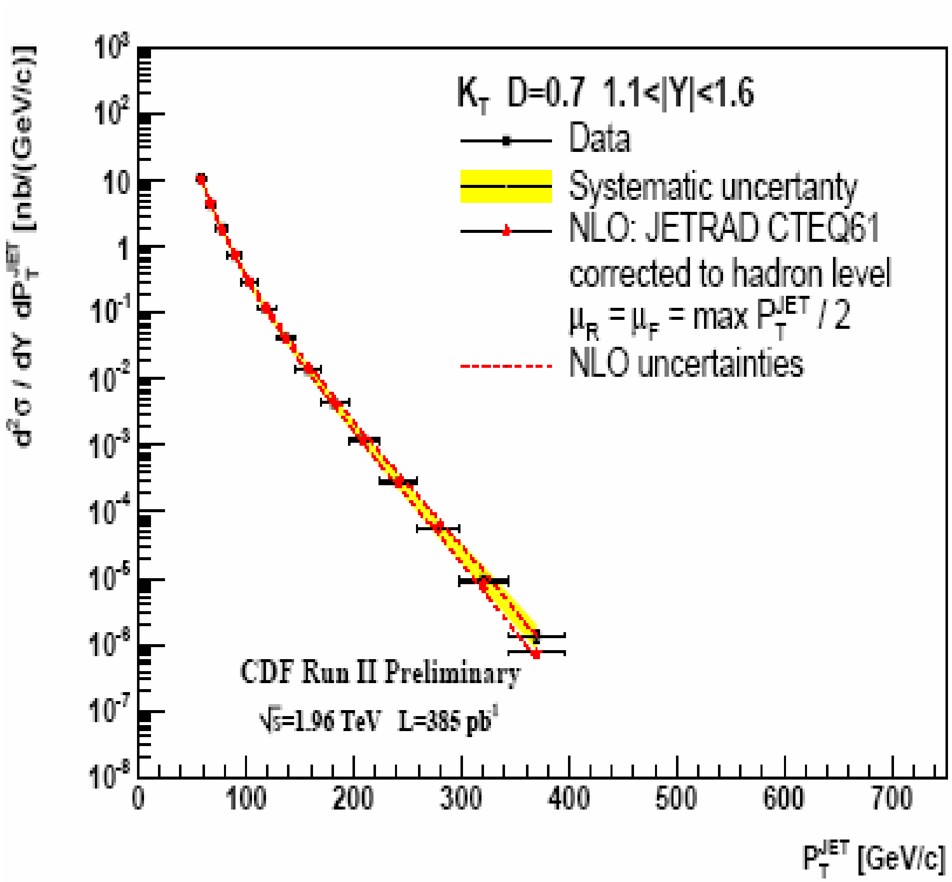


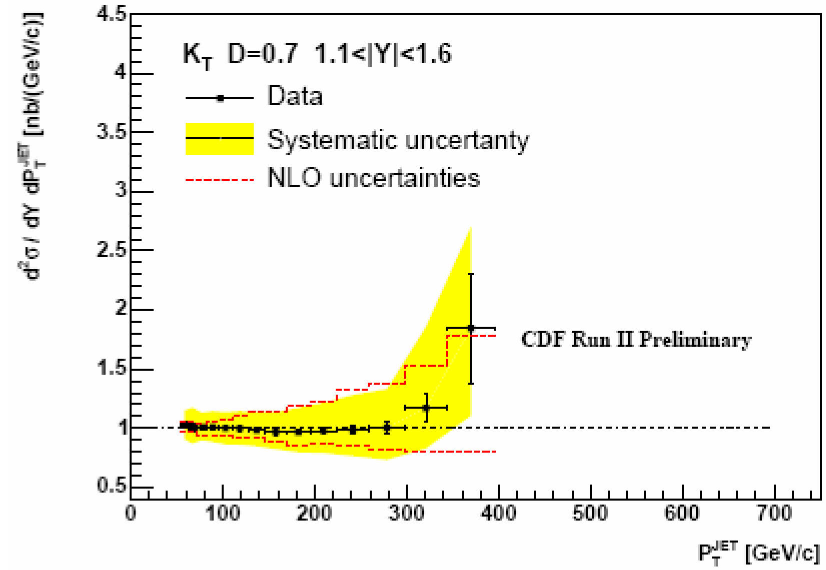


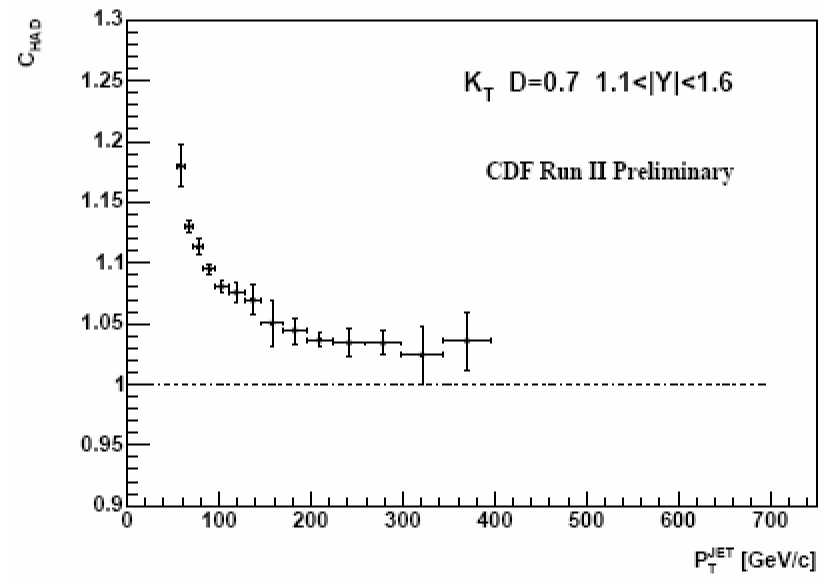


For blessing

Results: 1.1 < |Y jet| < 1.6

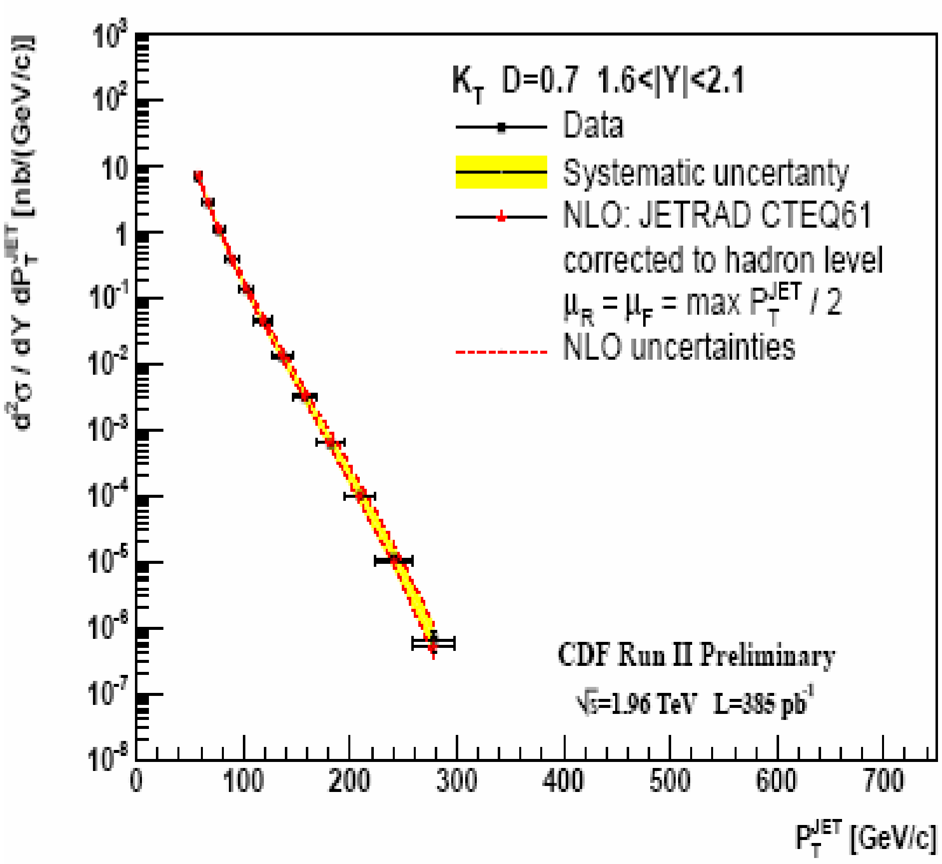


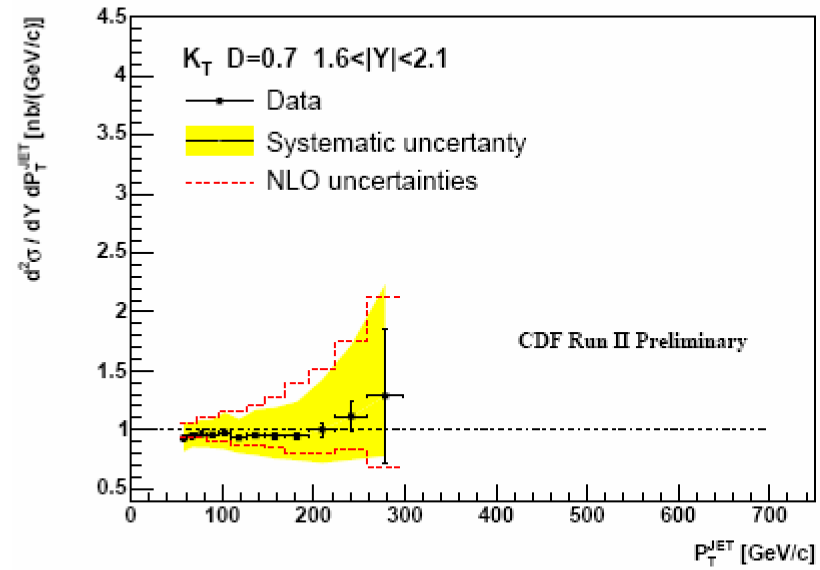


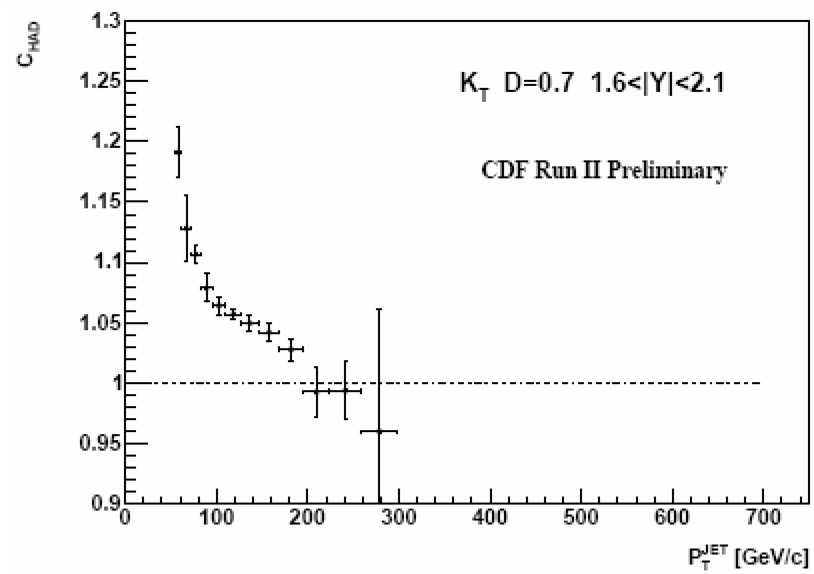


For blessing

Results: $1.6 < |Y^{jet}| < 2.1$







For blessing

Summary and plans

Inclusive jet cross section measured using 385 pb^{-1} of CDF RunII data for jets with $P_T \geq 54$ GeV/c in four rapidity regions:

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

- Using the K_T algorithm
- Fully corrected to the hadron level
- Good agreement with theory, NLO pQCD corrected for UE / Hadronization
- Complement previous measurements for central K_T jets, $0.1 < |Y^{Jet}| < 0.7$

Final results (final theoretical uncertainties) in a couple of months

- Start preparation of PRD
- Request Godparent Committee
  - May be the same Committee than for the central K_T jets PRL