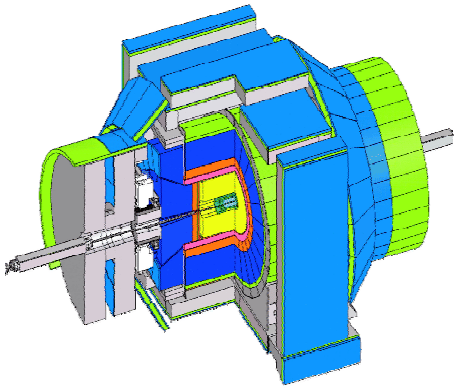
# Jet Production using the $K_T$ Algorithm



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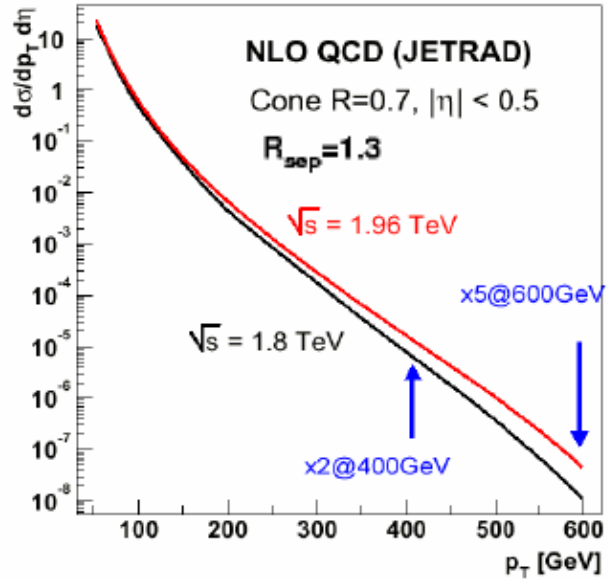
- Motivations
- Analysis
  - Trigger efficiency
  - Jet energy corrections
  - Unfolding
  - Hadronisation / UE corrections
- Plans

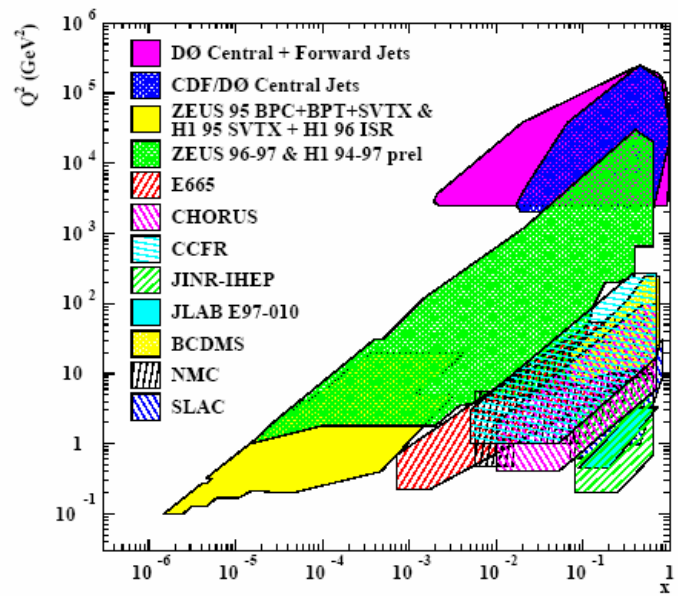
CDF Collaboration Meeting

January 21st 2005

# Motivations

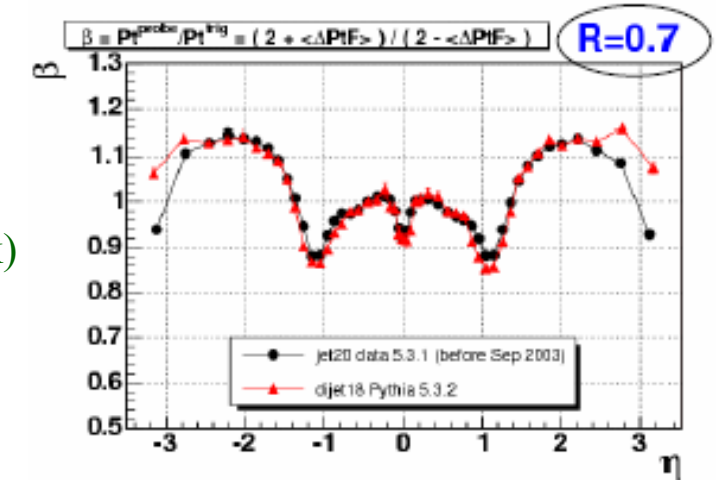
- Inclusive jet production
  - Stringent test of p-QCD
    - Over 8 order of magnitudes
  - Tail sensitive to New Physics
    - Probing distances ~ $10^{-19}$ m
    - $P_T$ reach extended by ~ 150 GeV/c with respect to run I
- Central and forward jets
  - Improve constraints on PDFs
    - Help to distinguish between New Physics and PDF effects if any excess observed for central jets
- $K_T$ preferred by theory
  - Infrared and collinear safe to all orders in p-QCD
  - No merging/splitting feature
    - No $R_{SEP}$ issue comparing to p-QCD



# Analysis

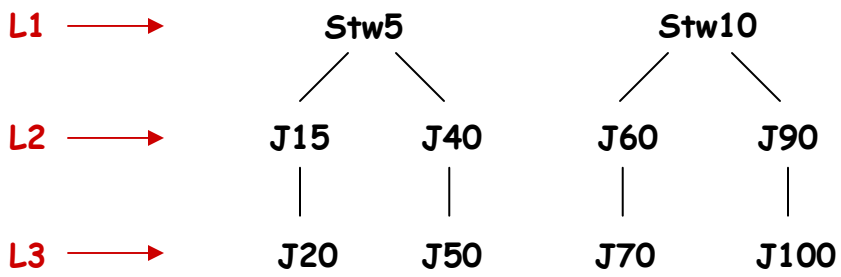
- Inclusive Jet Production using the $K_T$ algorithm
  - Central and Plug regions: 5 ≠ rapidity (Y) regions
    - Region 1: |Y| < 0.1 (90° crack)
    - Region 2: 0.1 < |Y| < 0.7 (Central Calorimeter)
    - Region 3: 0.7 < |Y| < 1.1 (Central Calorimeter + 30° crack)
    - Region 4: 1.1 < |Y| < 1.6 (30° crack + Plug Calorimeter)
    - Region 5: 1.6 < |Y| < 2.1 (Plug Calorimeter)




- Framework
  - Version 5.3.3nt of the code (latest Z Vertex algorithm)
  - Jet datasets xxxx0d
    - Latest calorimeter calibration (Calibration Pass 13A)
    - Version 7 of good run list
      - QCD no silicon (COT compromised period not used): 389 $pb^{-1}$
  - Version 5.3.3 of the Monte-Carlo
    - Pythia "Tune A" presented here but Herwig also considered
- Event Selection
  - Jets defined with the KT algorithm
    - D = 0.7 presented here but D= 0.5 and 1.0 also considered
  - Jets Z vertex: Quality ≥12, |Vz| < 60 cm
  - Miss $E_T$ Significance < $F(P_T^{jet}) = \min(2+0.018\times P_T^{jet},11.5)$

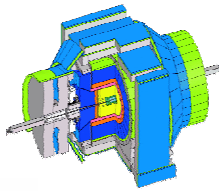
# Trigger Efficiency Study

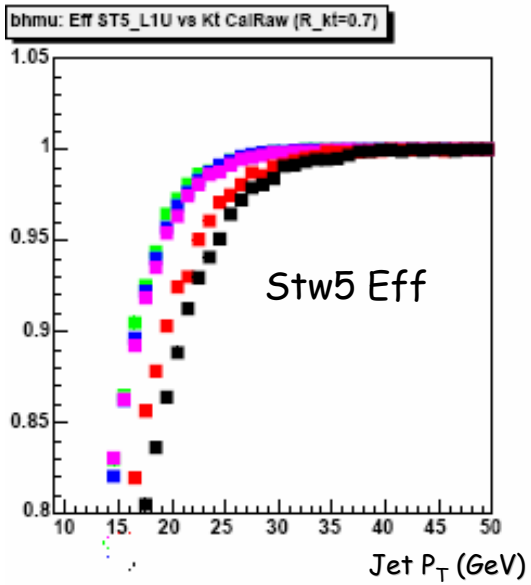
- Trigger Structure

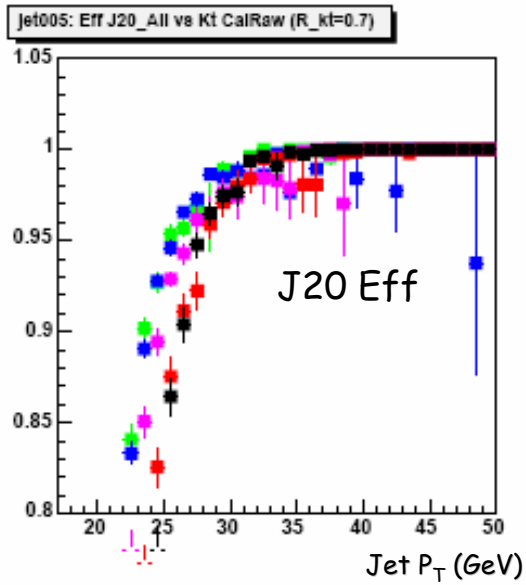


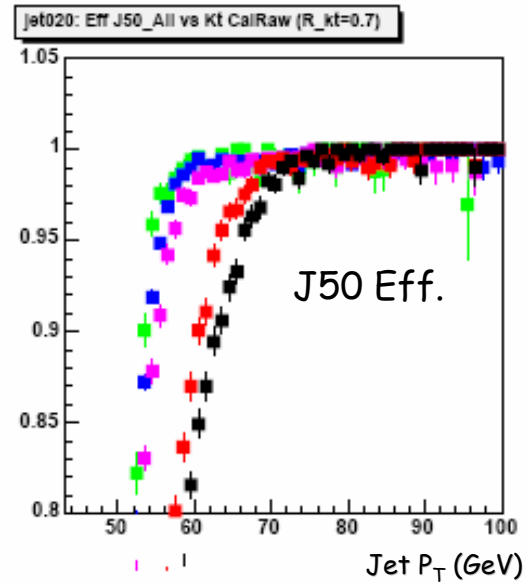

- L1, L2 and L3 trigger efficiencies extracted from data
  - High $P_T$ muons data (bhmu0d): efficiency of Stw5 (L1)
  - Stw5 data: efficiencies of J15 (L2) and J20 (L3)
  - J20 data: efficiencies of Stw10 (L1), J40 (L2) and J50 (L3)
  - J50 data: efficiencies of J60 (L2) and J70 (L3)
  - J70 data: efficiencies of J90 (L2) and J100 (L3)
- Trigger thresholds: efficiency (L1×L2×L3) ≥ 99%
  - To avoid systematics due to energy scale uncertainties, the obtained thresholds are increased by 5%

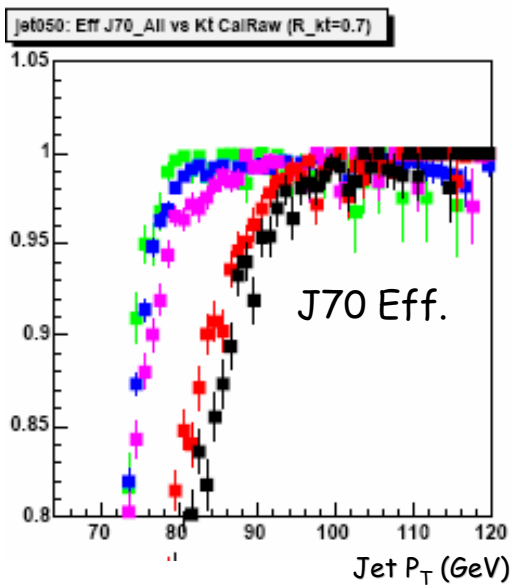
# Trigger thresholds

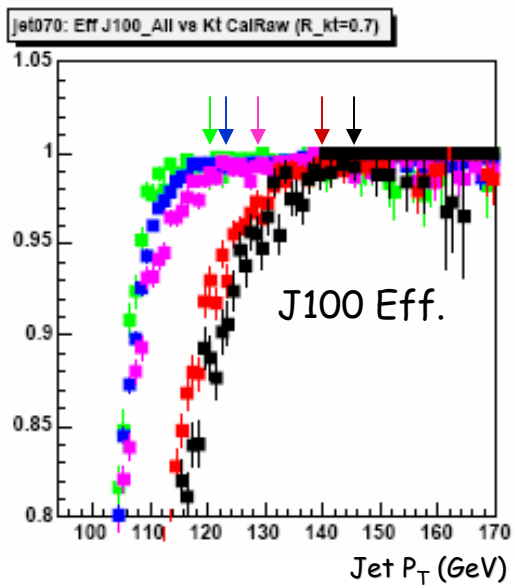




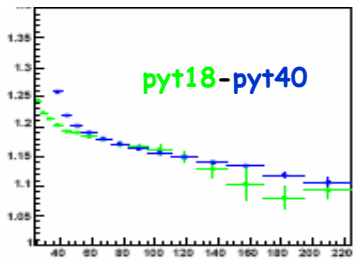

Rapidity Region 1 : $|Y| < 0.1$
Rapidity Region 2 : $0.1 < |Y| < 0.7$
Rapidity Region 3 : $0.7 < |Y| < 1.1$
Rapidity Region 4 : $1.1 < |Y| < 1.6$
Rapidity Region 5 : $1.6 < |Y| < 2.1$

| | Rap1 | Rap2 | Rap3 | Rap4 | Rap5 |
|---|---|---|---|---|---|
| Stw5 | 26 | 26 | 28 | 31 | 32 |
| J20 | 33 | 35 | 33 | 34 | 33 |
| J50 | 63 | 64 | 68 | 72 | 75 |
| J70 | 86 | 86 | 93 | 99 | 104 |
| J100 | 119 | 124 | 129 | 139 | 146 |

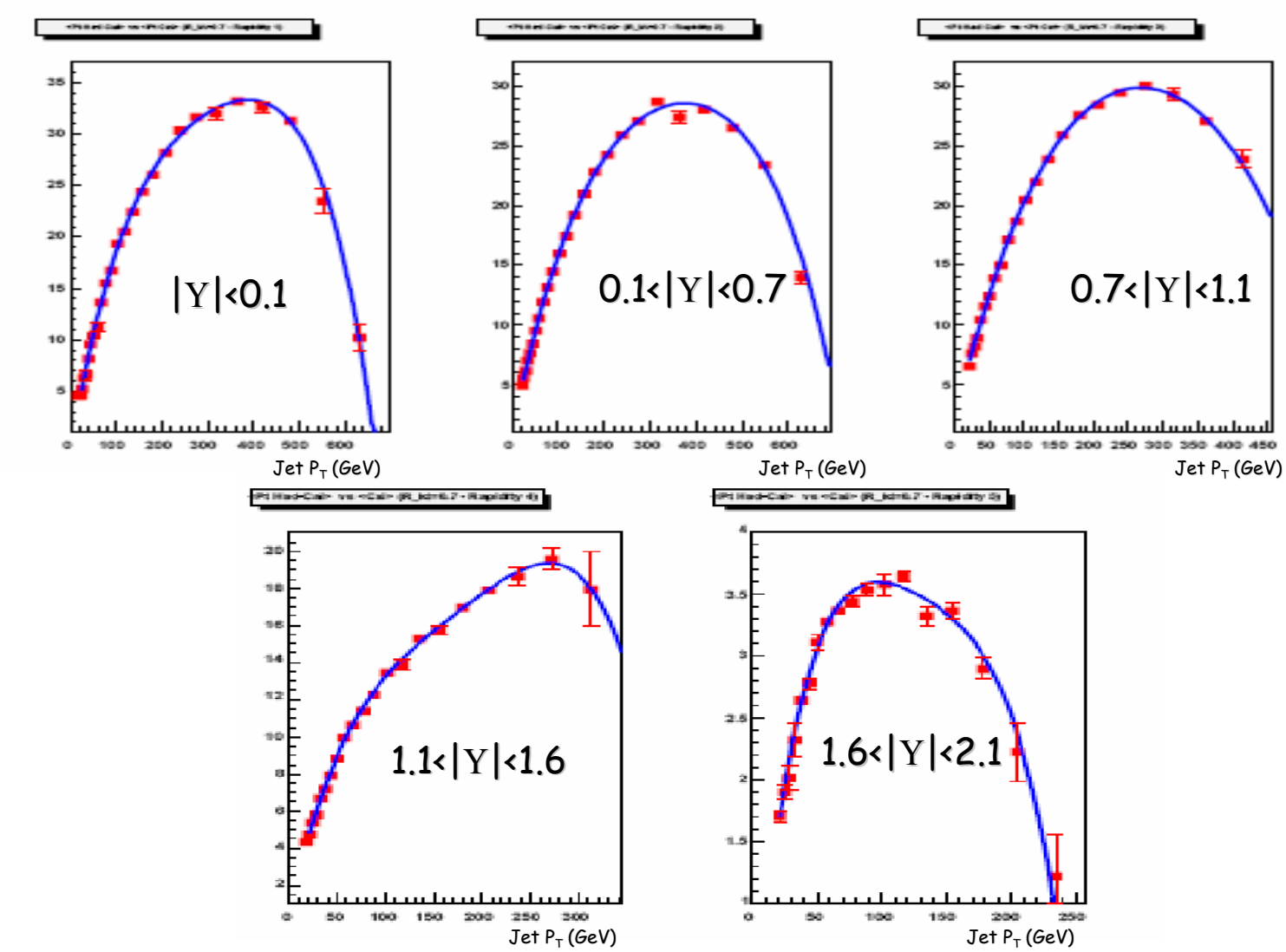
**Minimum Uncorrected Jet $P_T$ (GeV/c) for each jet dataset**

# Jet energy corrections

- Absolute correction
  - Use Pythia MC which provides a reasonably description of the data
    - Dijet balance
  - Reconstruct jets at calorimeter (CAL) and hadron (HAD) levels
    - Match CAL / HAD jets matched in the Y-$\phi$ space: $\Delta R = \sqrt{Y^2 + \phi^2} < D = 0.7$
    - Fit the correlation $<P_T^{jet}(HAD)-P_T^{jet}(CAL)>$ vs. $<P_T^{jet}(CAL)>$ for matched jets by a 4th order polynomial
      - Carefully select unbiased MC samples ($P_T^{hat}$ cut) comparing $<P_T^{jet}(HAD)/P_T^{jet}(CAL)>$ vs. $<P_T^{jet}(CAL)>$ for consecutive samples
- Pile-Up correction
  - $-\varepsilon \times N$ additional primary vertices (Quality $\geq 12$)
    - $\varepsilon = 0.928$ GeV/Vertex taken from Gene study using Midpoint
  - Need to check that jet production measurement does not depend on instantaneous luminosity after this correction
    - Normalizing $\neq$ different samples corresponding to $\neq$ instantaneous luminosity intervals using jet production measurement at high $P_T$
      - Done in the central calorimeter region / To be done in other regions



# Jet $P_T$ absolute corrections



# Unfolding procedure

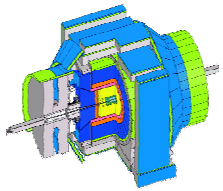
- Use Pythia MC to correct the jet spectrum back to the hadron level
  - Count bin-by-bin
    - $N_{JETS}$ at calorimeter level
      - All cuts applied: Vz, Missing $E_T$ significance, $|Y_{JET}|$
      - Use corrected jet $P_T$
    - $N_{JETS}$ at hadron level
      - No cut except $|Y_{JET}|$
  - Bin-by-bin unfolding factors

$$C\,(\text{bin i}) = \frac{N_{JETS}\ \text{hadron level (bin i)}}{N_{JETS}\ \text{calorimeter level (bin i)}}$$

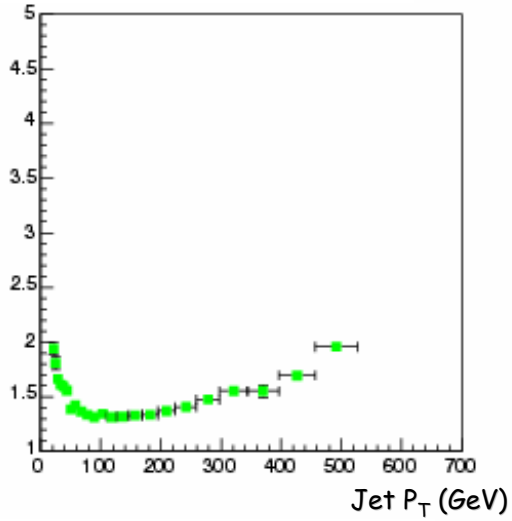
- Apply these factors bin-by-bin to the measured corrected jet PT spectrum to unfold it to the hadron level

$$N_{JETS}\ (\text{bin i})_{\ \text{DATA UNFOLDED}} = C\,(\text{bin i}) \times N_{JETS}\ (\text{bin i})_{\ \text{DATA CORRECTED } P_T}$$

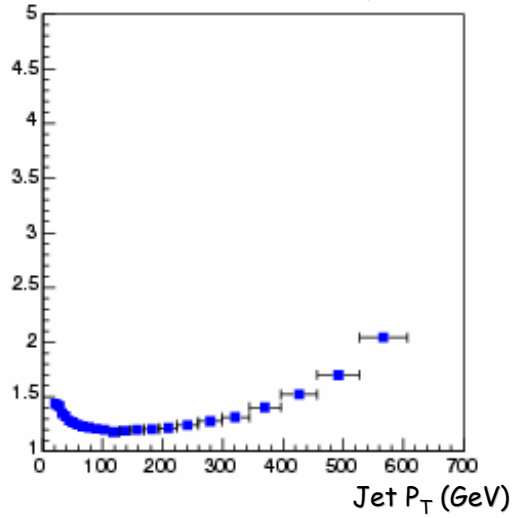
# Unfolding factors



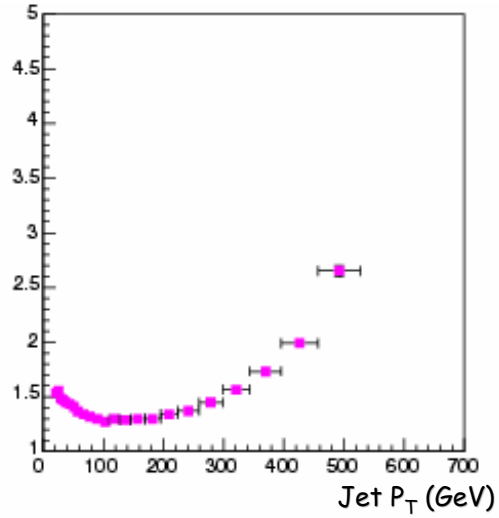
Region 1 : |Y|< 0.1



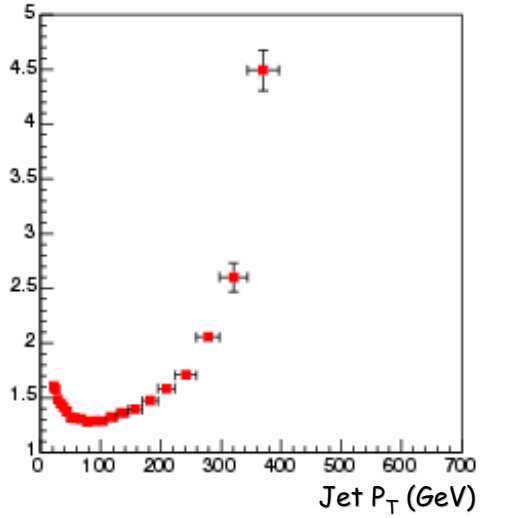

Region 2 : 0.1 < |Y|< 0.7



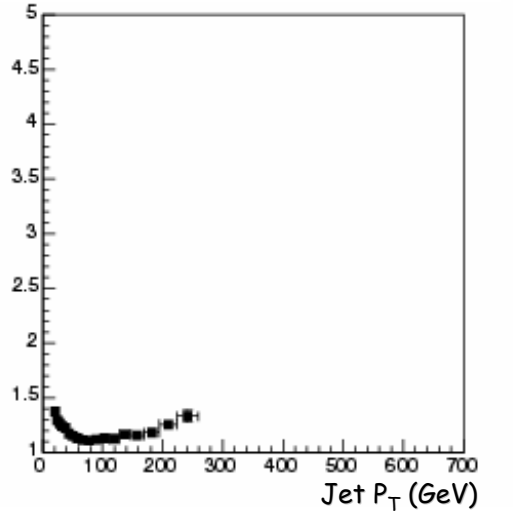

Region 3 : 0.7 < |Y|< 1.1



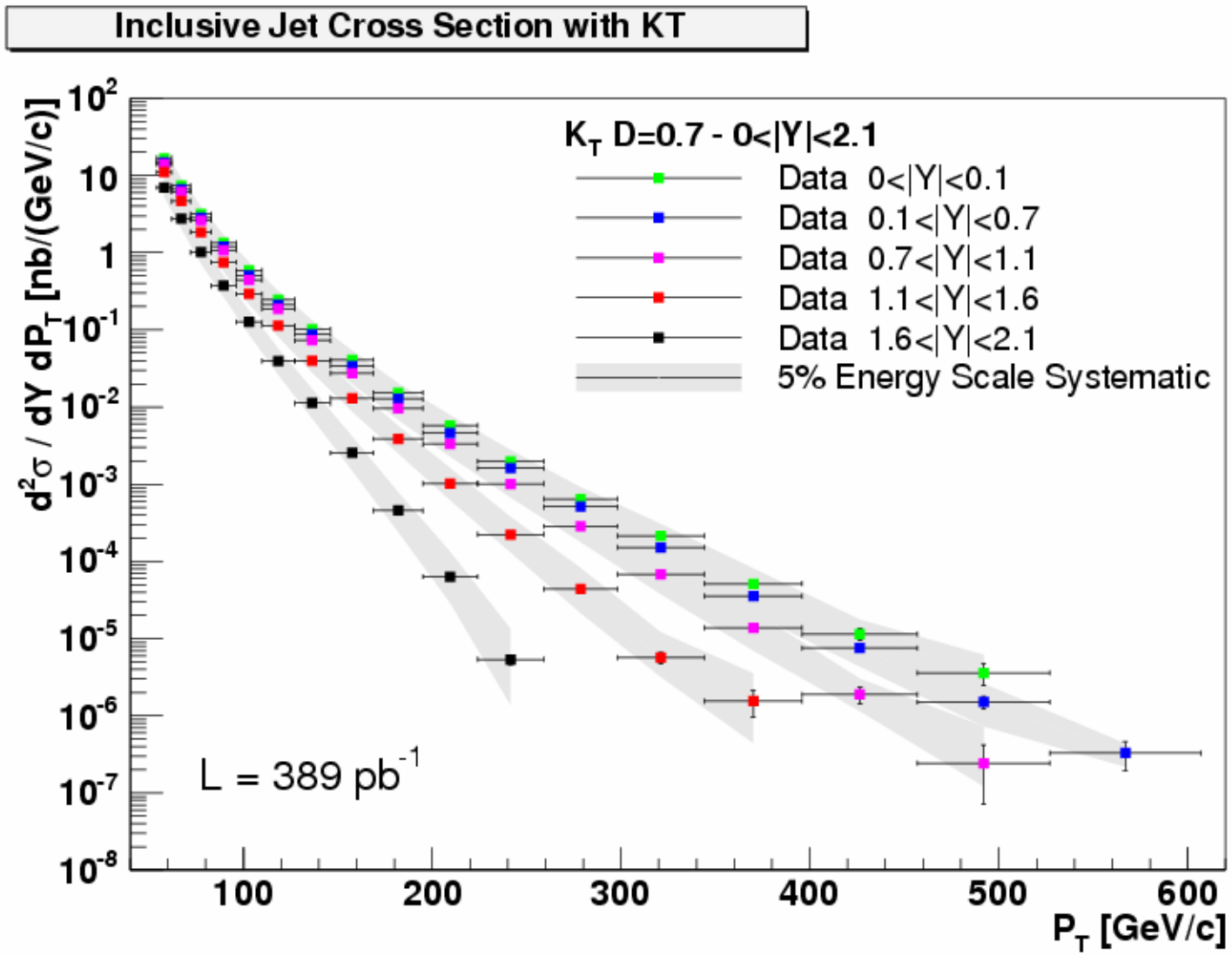

Region 4 : 1.1 < |Y|< 1.6




Region 5 : 1.6 < |Y|< 2.1

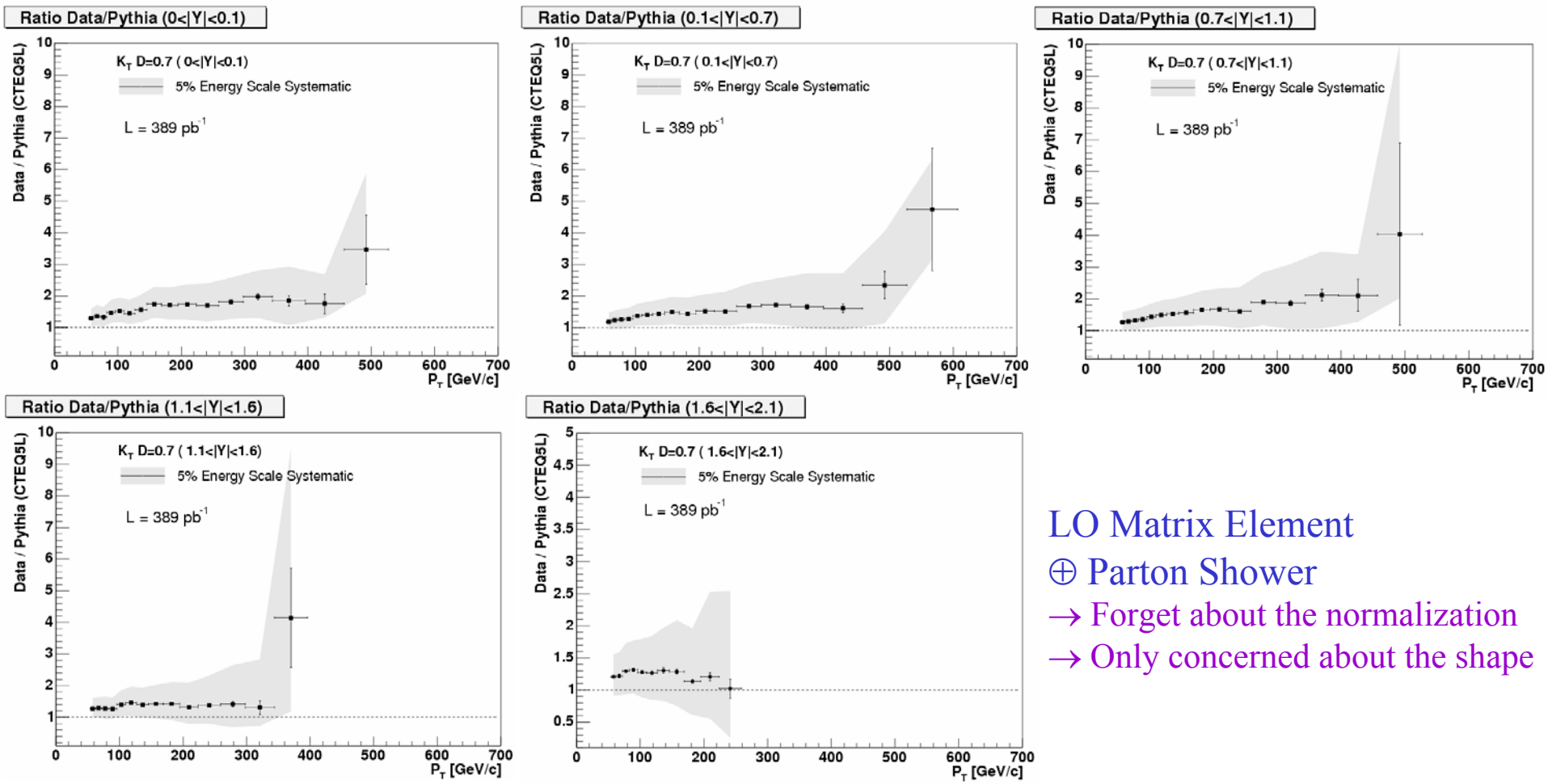


# Measured cross sections




→ Measured cross sections fully corrected to the hadron level

# Comparison to Pythia




LO Matrix Element

⊕ Parton Shower

→ Forget about the normalization

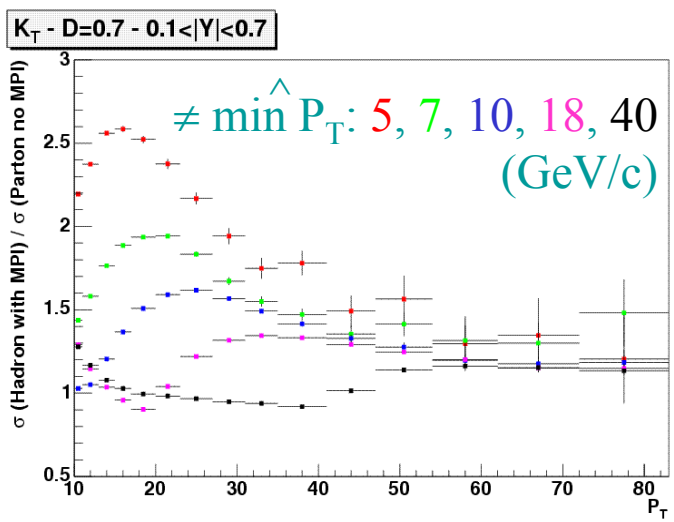
→ Only concerned about the shape

→ Reasonable agreement of spectrum shapes

# Hadronisation / UE corrections

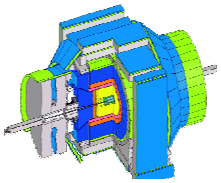
- Correct the NLO for Hadronisation and Underlying Event in order to compare to data
  - Use Pythia "Tune A": Underlying Event tuned on Run I data
    - Important statistics required: 162.5 millions events considered here
      - Pythia dijet official samples
      - Additional samples especially generated (generator level only)
- Hadronisation / UE correction factor

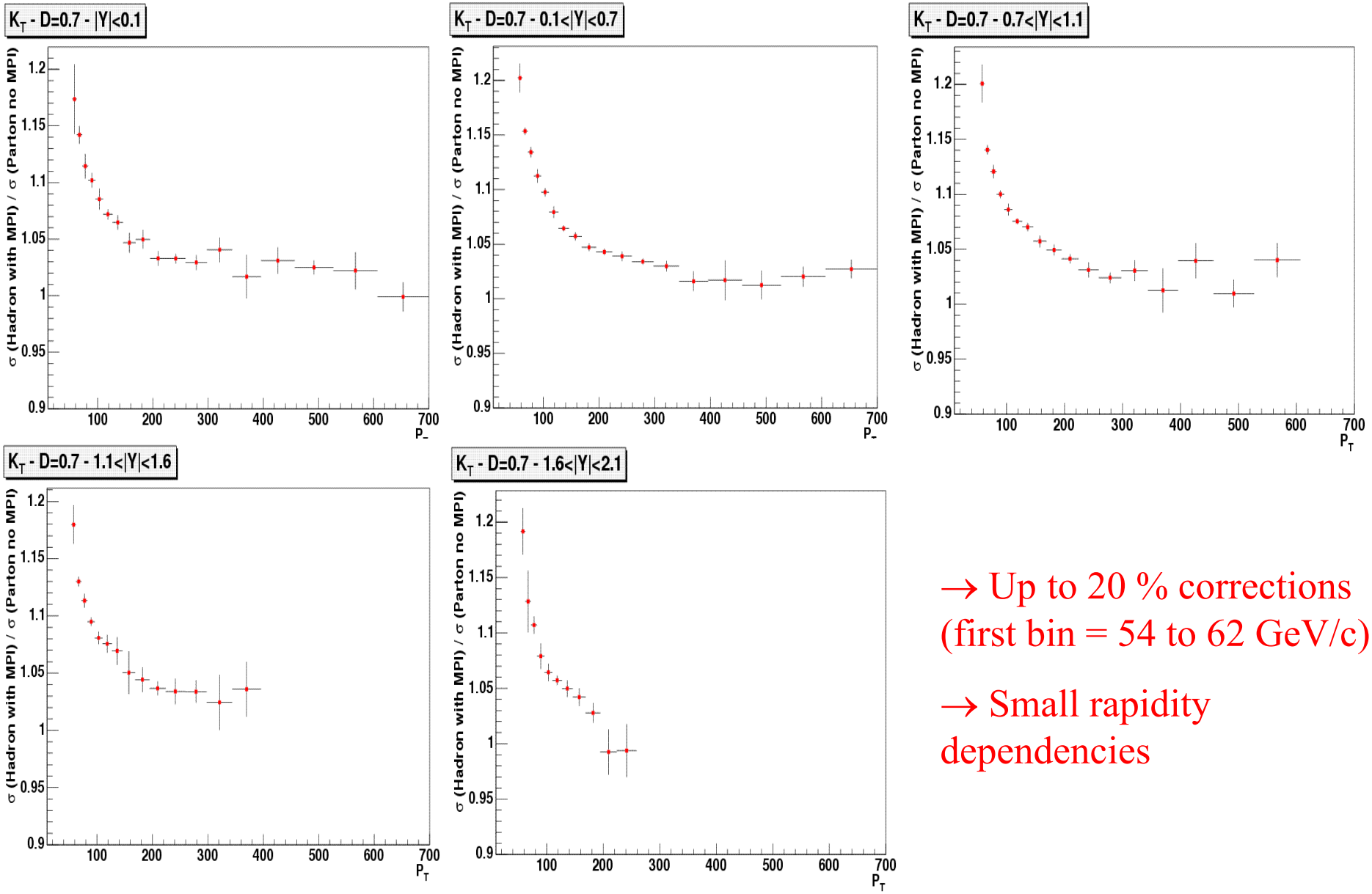
$$D\ (\text{bin i}) = \frac{\sigma\,[\text{Hadron level : Pythia Tune A with MPI}]\ (\text{bin i})}{\sigma\,[\text{Parton level : Pythia Tune A no MPI}]\ (\text{bin i})}$$




☹ Convergence only above ~ 50 GeV/c
→ no correction provided here below

# Hadronisation / UE correction factors





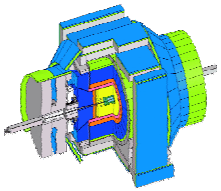

→ Up to 20 % corrections (first bin = 54 to 62 GeV/c)

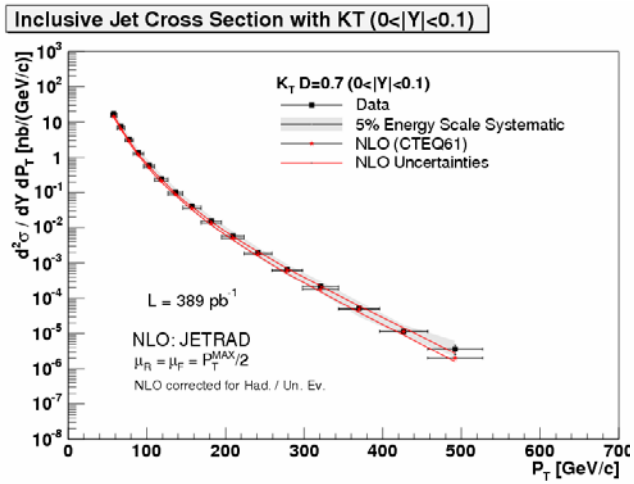
→ Small rapidity dependencies

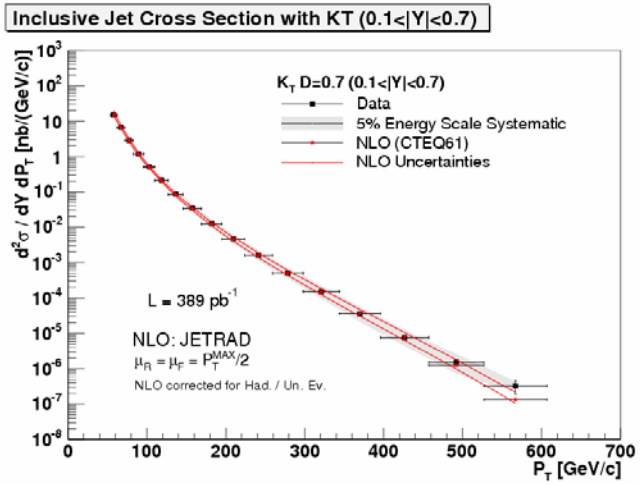
# NLO

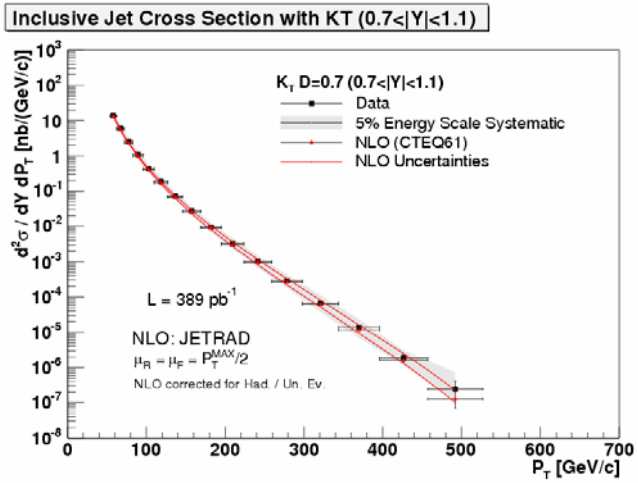
- JETRAD CTEQ61 package
  - $\mu_R = \mu_F$ = Maximum Jet $P_T$ / 2
    - K-factor (NLO / LO) ~ 1 for 70GeV/c [hep-ph/0303013]
- NLO uncertainties
  - Scale: $\mu_R = \mu_F$ = Maximum Jet $P_T$
    - Symmetric uncertainties
  - PDF
    - Asymmetric uncertainties
    - Dominates by gluon at high-x contribution
  - PDF uncertainties dominate

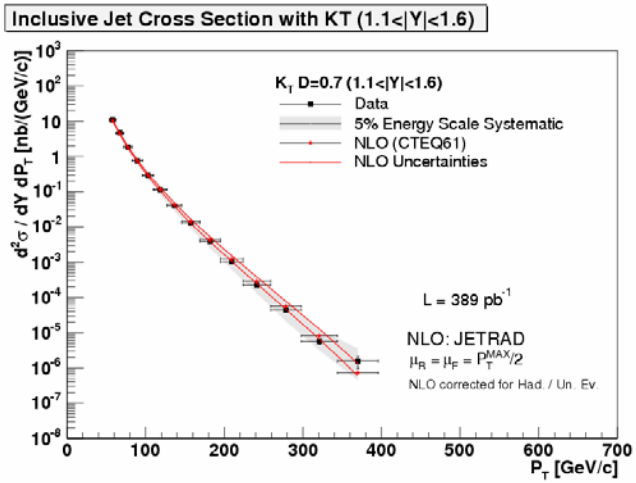
# Comparison to NLO (1/2)

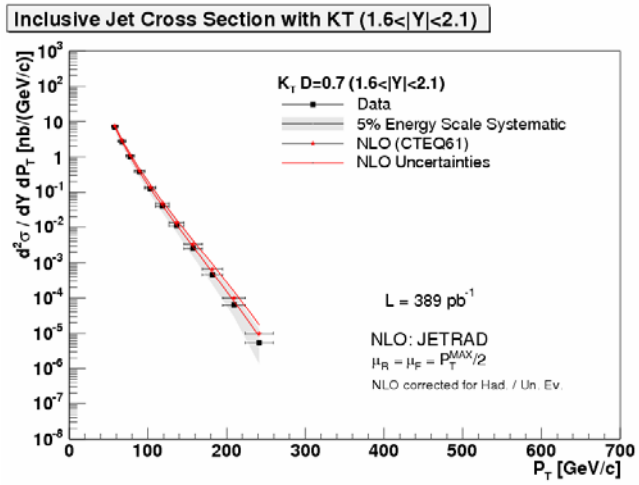




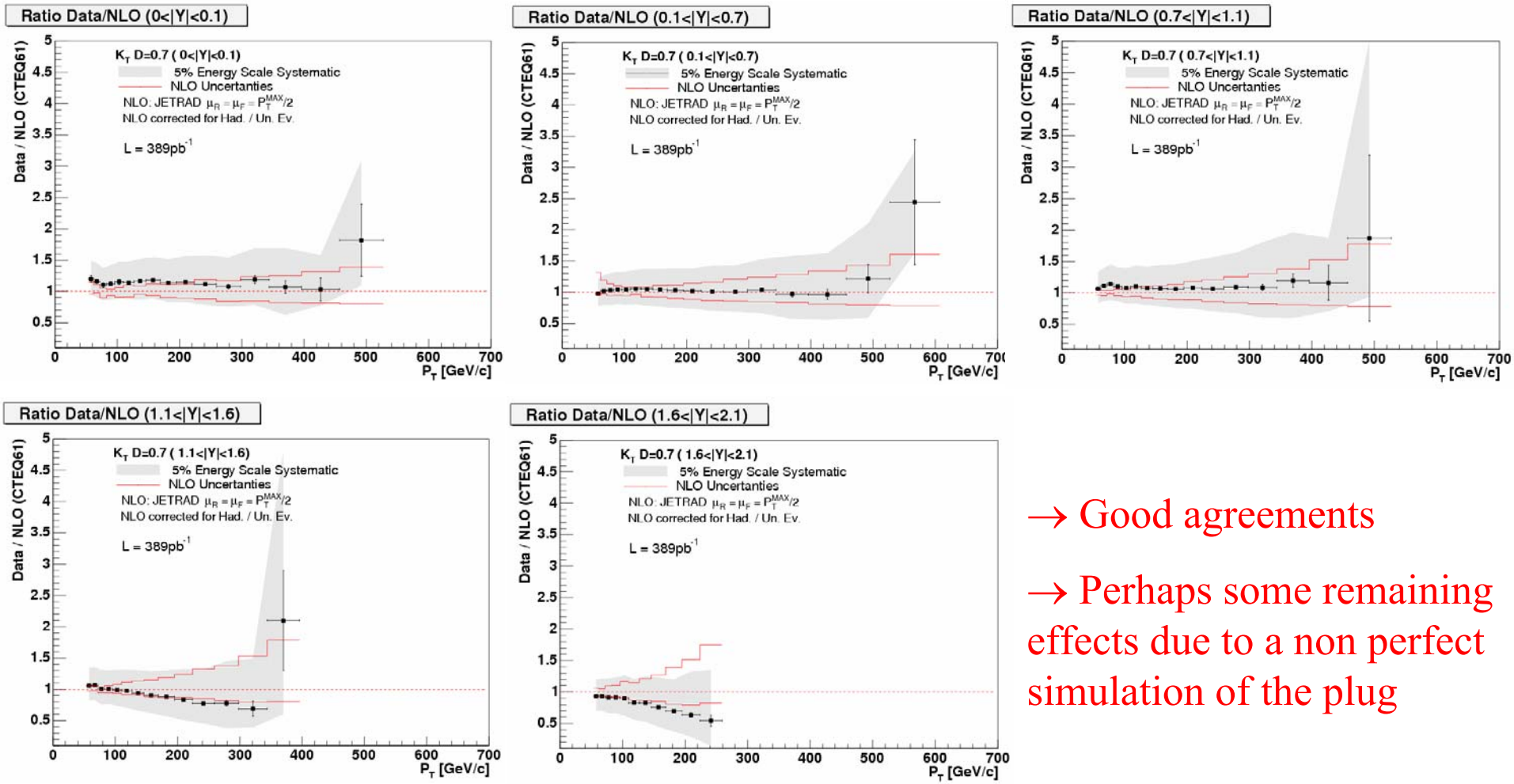



# Comparison to NLO (2/2)




→ Good agreements

→ Perhaps some remaining effects due to a non perfect simulation of the plug

# Plans (1/2)

- Reduce the systematics
  - Jet energy scale: 5% used now → 3% or less may be achievable
    - Central: use tracking as a reference
      - $P_T$ sum of the COT tracks inside the jet: $[COT/CAL]_{DATA}$ / $[COT/CAL]_{MC}$
    - Plug: dijet balance
      - Other idea: dijet balance using tracking for the trigger jet
  - Resolution: 20% used now → 10% or less may be achievable
    - Will use the bisector method on the dijet balance to check how well the MC describes the resolution
  - Pile-up: 100% used now → 50% or less may be achievable
    - 3 complementary ways
      - Compare $K_T$ jets to JetClu / MidPoint ones vs. Number of primary vertices
      - Look at luminosity dependencies
      - Make use of Pythia MC with Pile-Up events

# Plans (2/2)

- Unfolding
  - Unfold with Herwig instead of Pythia
    - Still using Pythia absolute jet energy corrections
      - Take into account any ≠ in calorimeter response functions between Pythia and Herwig (≠ in $P_T$ spectrum of the particles inside the jets)
  - Also to be done
    - Reweigh the MC to get the shape of the cross section right
      - See the effect on the unfolding
      - Make measurement independent of the knowledge of the PDF already in the MC
    - Check difference between matrix inversion and bin by bin unfolding
- Put limits on compositeness

→ Bless preliminary results around middle of February

→ Ready for GP by summer