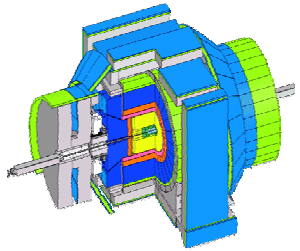


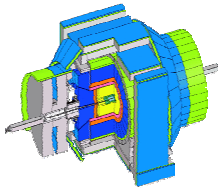
Inclusive Jet Production Cross Section using the K_T Algorithm at CDF II

Blessing Talk – CDF Note 6974

R. Lefèvre, M. Martinez, O. Norniella

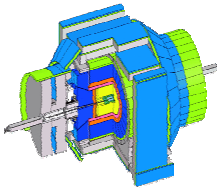
QCD Meeting, April 28th 2004

Outlook



- The K_T algorithm
- Motivation
- Event selection
- Trigger study
- Data / MC comparison of raw variables
- Jet P_T corrections
- Unfolding
- Systematic uncertainties
- Results
- Conclusions and plans

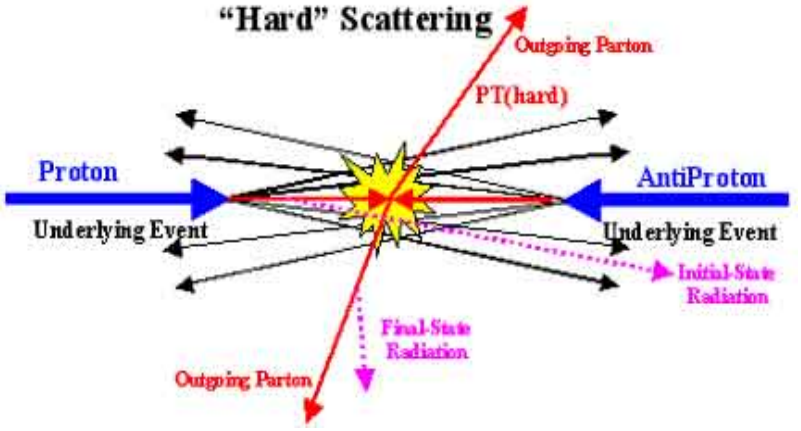
The K_T algorithm

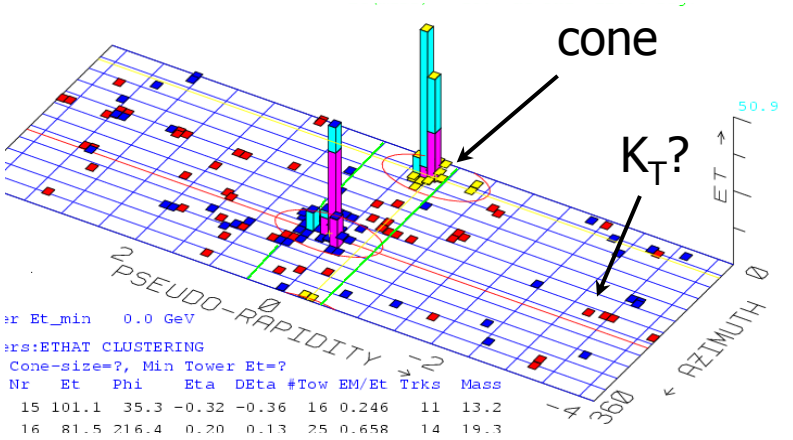


- Inclusive K_T algorithm
  - Algorithm
    - Compute for each pair (i, j) and for each particle (i)
      - $d_{ij} = \min(P_{T,i}, P_{T,j}) \frac{\Delta R^2}{D^2}$
      - $d_i = (P_{T,i})^2$
    - Starting from the smallest $\{d_{ij}, d_i\}$:
      - If d_i then i is considered to be a jet and removed from the list
      - If d_{ij} then i and j combined in a "proto-jet" (E scheme)
    - Iterate until all particles are in jets
  - P_T classification inspired by p-QCD gluon emissions
  - Infrared and Collinear safe to all orders in p-QCD
  - No merging/splitting feature: no R_{SEP} issue comparing to p-QCD
- Successfully used at LEP and HERA
- Relatively new in hadron collider
  - More difficult environment (Underlying Event, Pile-up)

Motivation

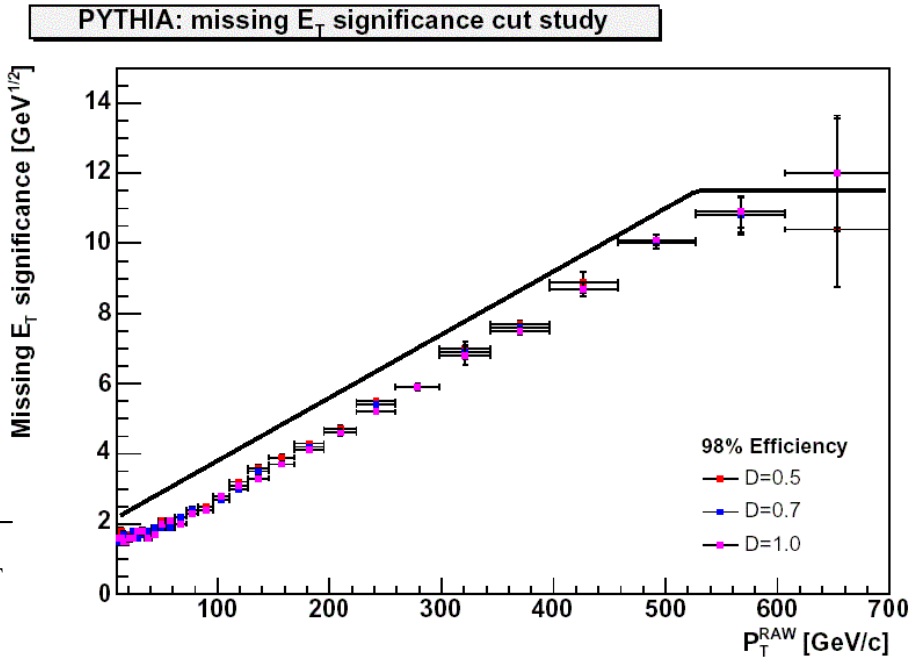
- Measure jet inclusive cross section for central jets: $0.1<|Y|<0.7$
  - Stringent test of p-QCD
    - Over 8 order of magnitudes
    - Measurement of $\alpha_S(P_T)$
  - Tail sensitive to new physic
    - Probing distances ~ 10^{-19}m
    - Run II: for $P_T > 500$GeV/c, the cross section increases of a factor ~ 3 with respect to Run I
      - $\sqrt{s} = 1.96$TeV instead of 1.80TeV
- Use the K_T algorithm: D = 0.5, 0.7 and 1.0
  - Preferred by theory
  - More sensitive to low P_T contributions than cone based algorithms?



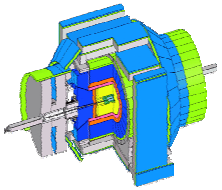


Event Selection

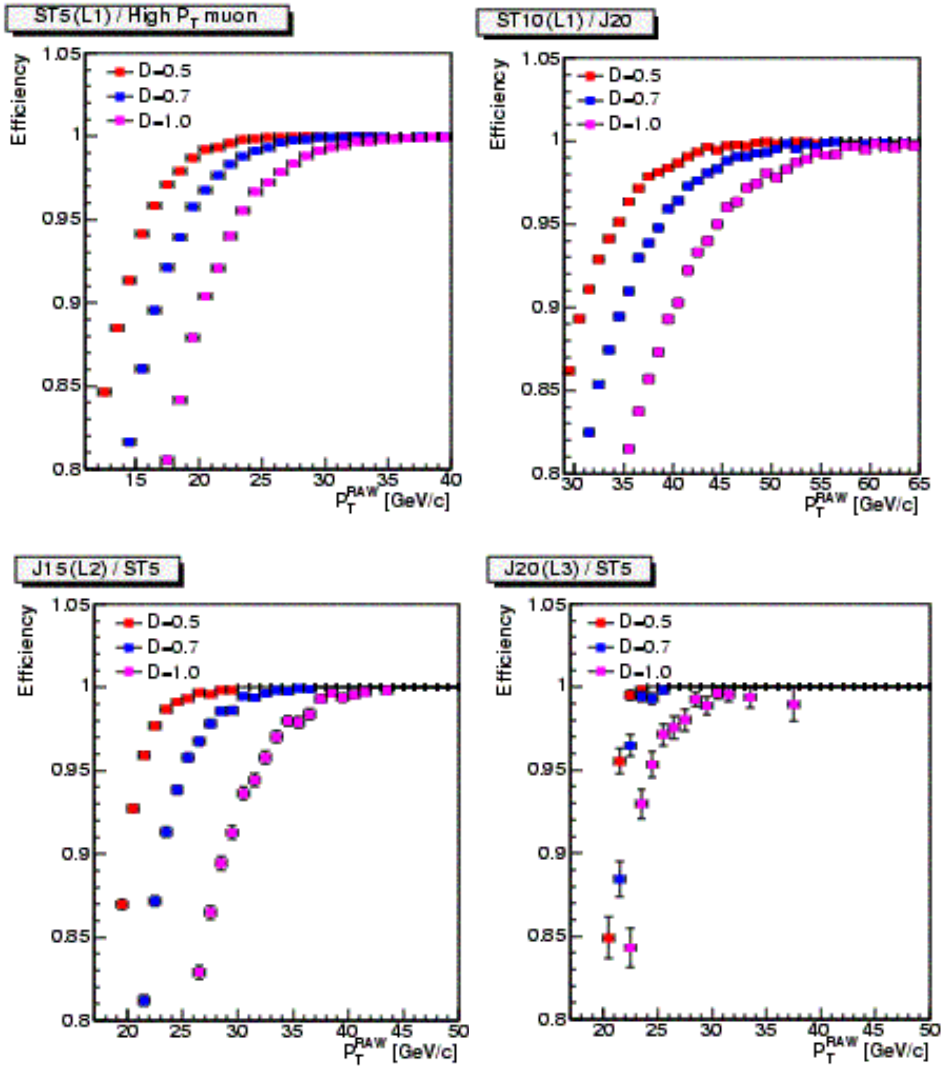
- Used MC: version 4.9.1
  - Pythia and Herwig
- Used data: datasets xxxx0c
  - ST5, J20, J50, J70 and J100 Triggers
  - V4 of QCD good run list
    - With some excluded runs
  - Integrated luminosity: 145pb^{-1}
    - 129pb^{-1} for ST5
- Cuts
  - $0.1 < |Y_{JET}| < 0.7$
  - $|V_Z| < 60$cm
    - With at least 3 associated tracks
  - Missing E_T significance: $E_T^{MIS} \Big/ \sqrt{\sum E_T}$
    - Cut function of Jet P_T



Trigger Study: Method



- Study done for L1, L2 and L3
- Trigger Efficiency vs Jet P_T
  - Use high PT muon Trigger for ST5
  - Use ST5 for J15 and J20
  - Use J20 for ST10, J40 and J50
  - Use J50 for J60 and J70
  - Use J70 for J90 and J100

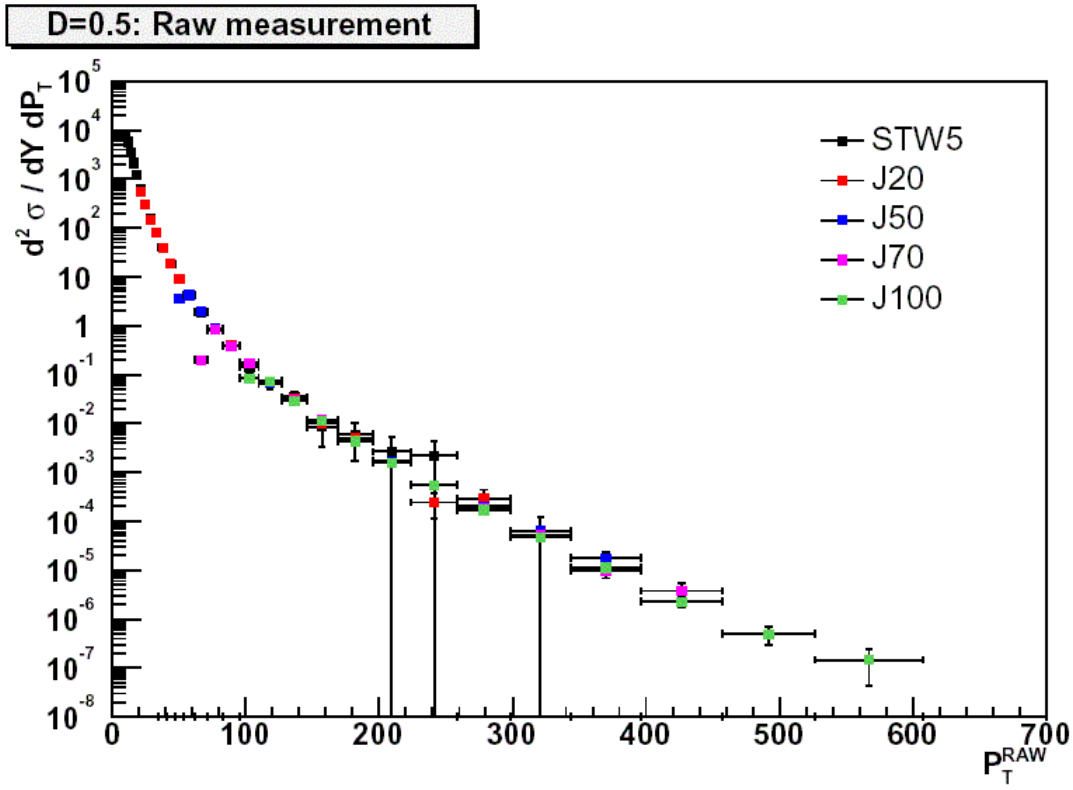


Trigger Study: Results

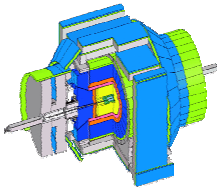
- Use data only when trigger is fully efficient
  - Minimal Jet P_T : Jet P_T for 99% Trigger Efficiency + 5%
- Check consistency at overlapping regions

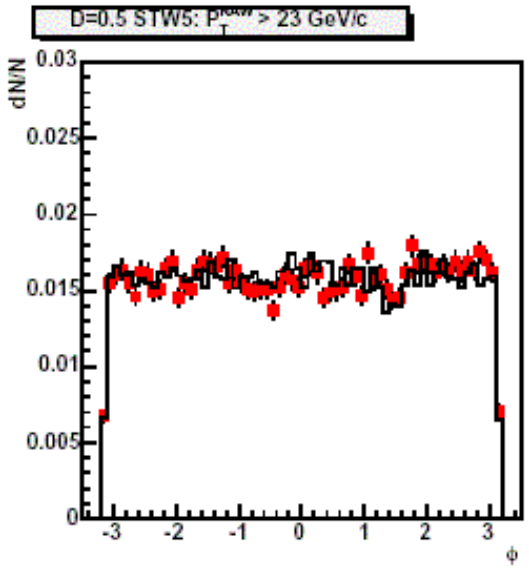
Trigger	D = 0.5 / 0.7 / 1.0
ST5	23 / 27 / 31
J20	27 / 35 / 41
J50	62 / 62 / 72
J70	83 / 96 / 96
J100	127 / 127 / 146

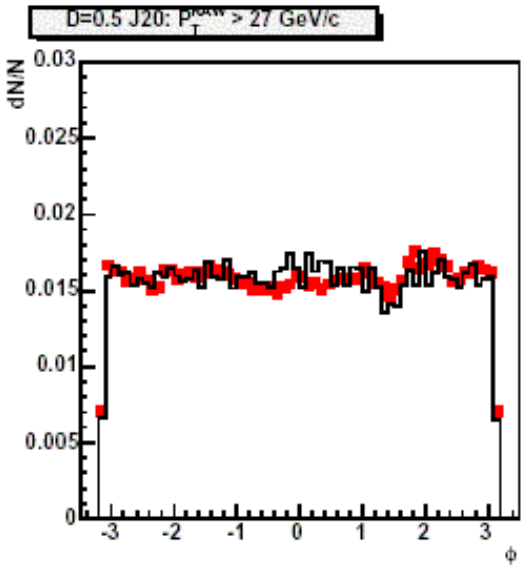
Minimal raw Jet P_T used
(taking into account chosen binning)

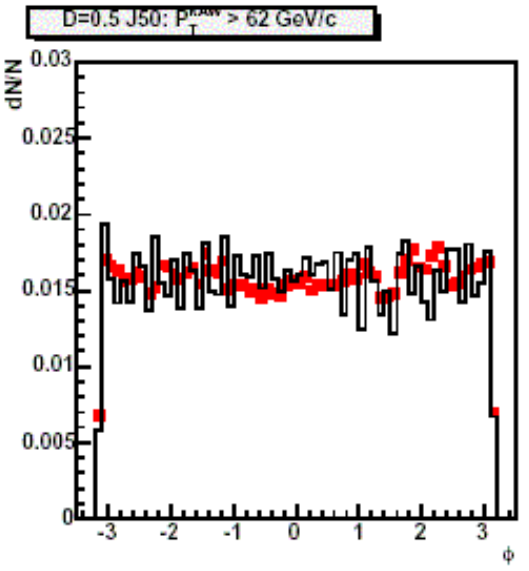


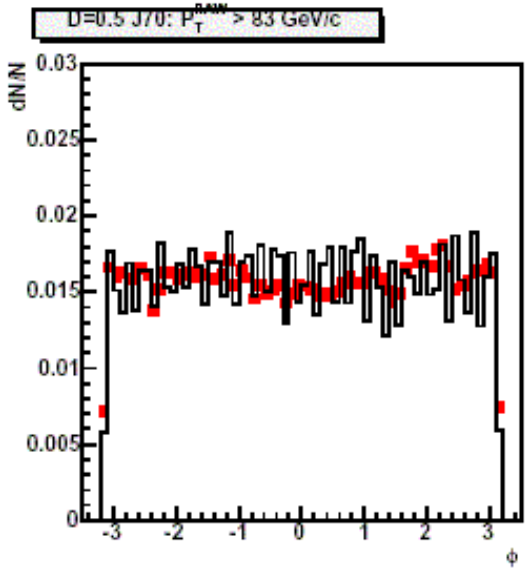
Data / MC: ϕ_{JET}

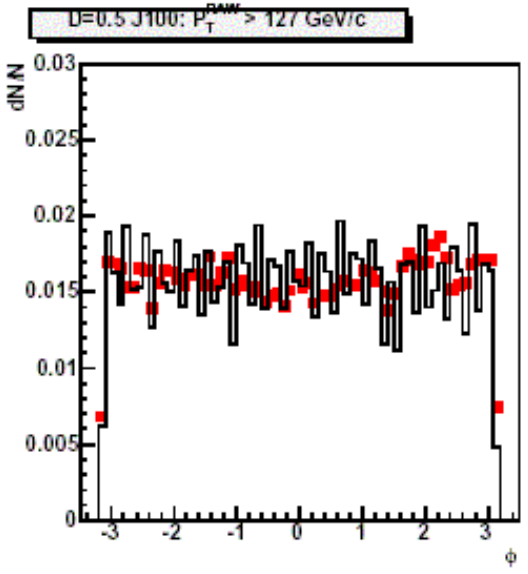




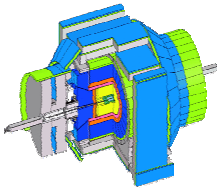


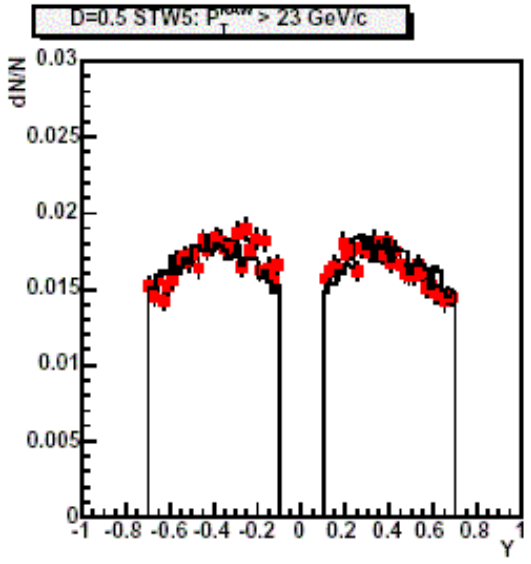


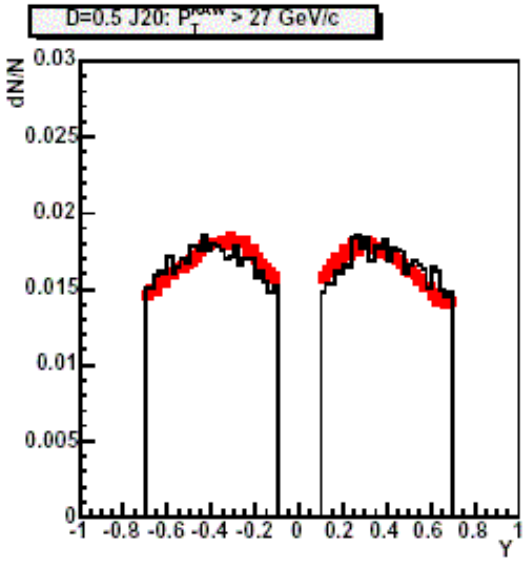


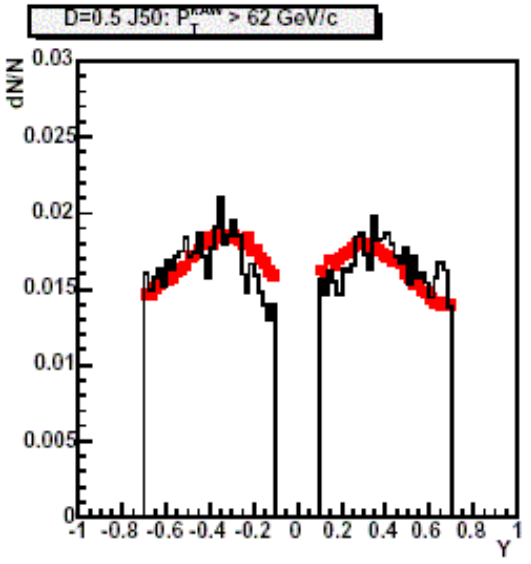


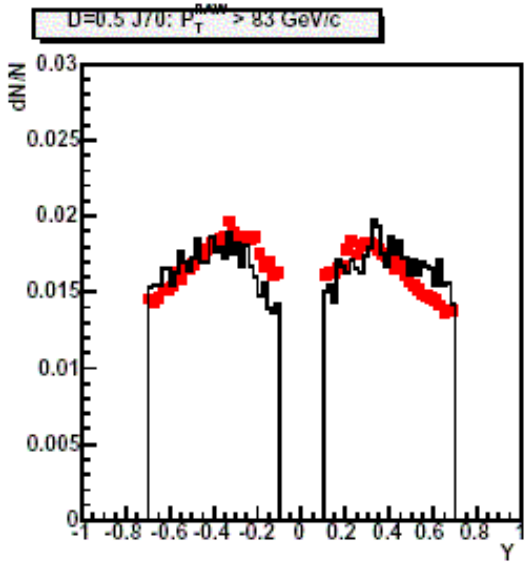
Data / MC: Y_{JET}

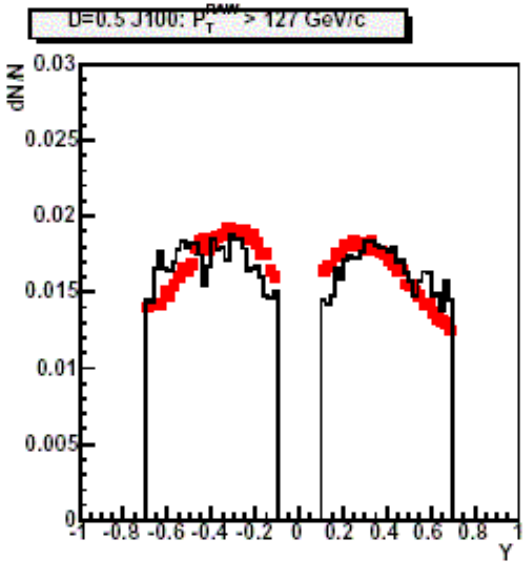



D=0.5 STW5: P_T^{RAW} > 23 GeV/c
dN/N
Y

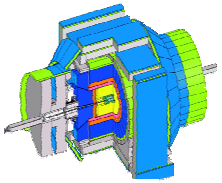

D=0.5 J20: P_T^{RAW} > 27 GeV/c
dN/N
Y

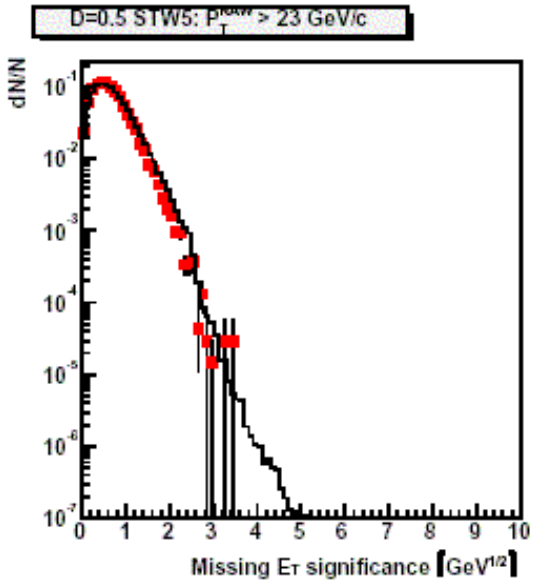

D=0.5 J50: P_T^{RAW} > 62 GeV/c
dN/N
Y

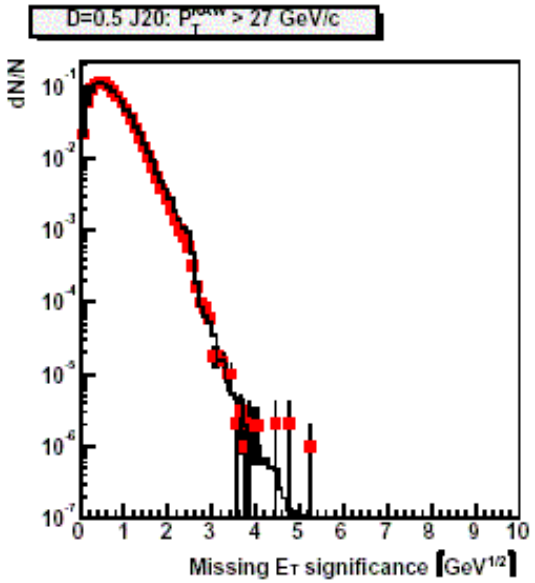

D=0.5 J70: P_T^{RAW} > 83 GeV/c
dN/N
Y

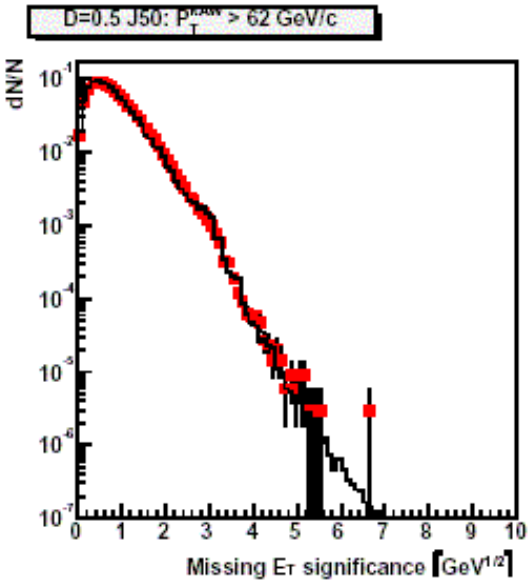

D=0.5 J100: P_T^{RAW} > 127 GeV/c
dN/N
Y

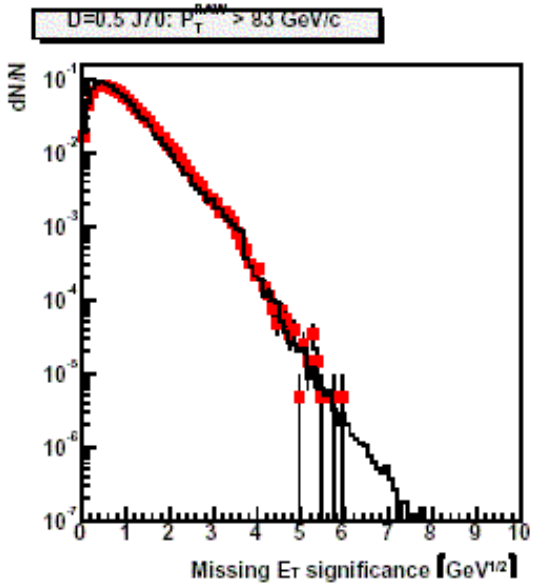
Data / MC: Missing E_T Significance

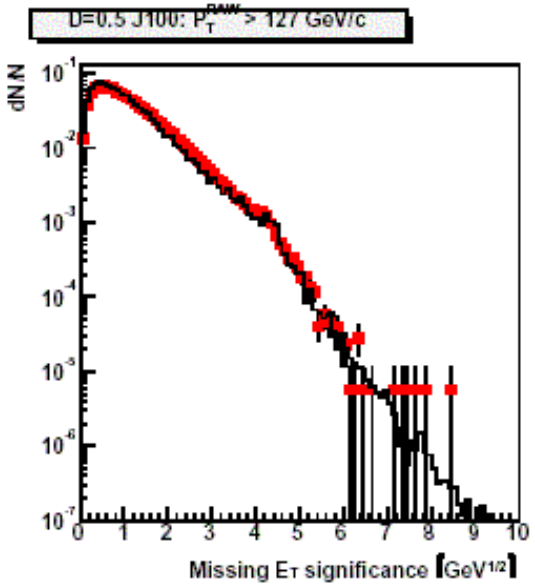




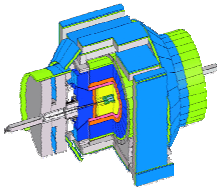


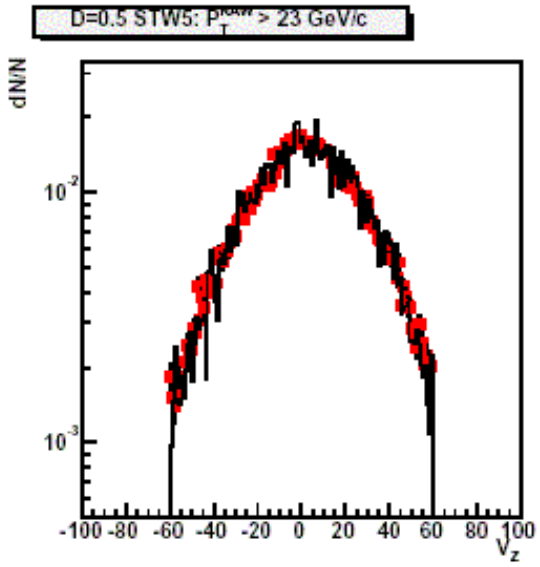


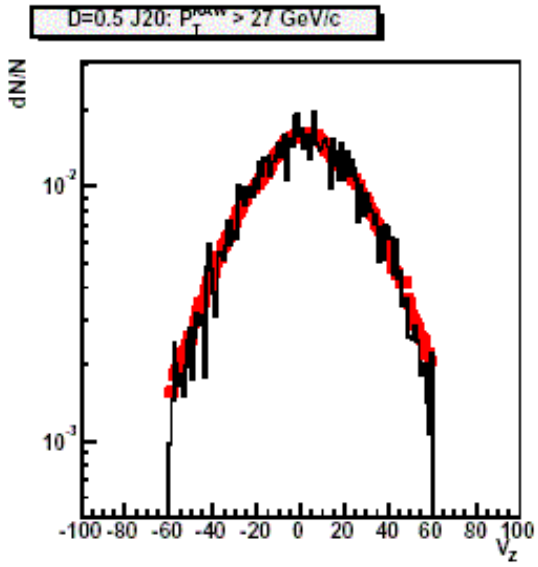


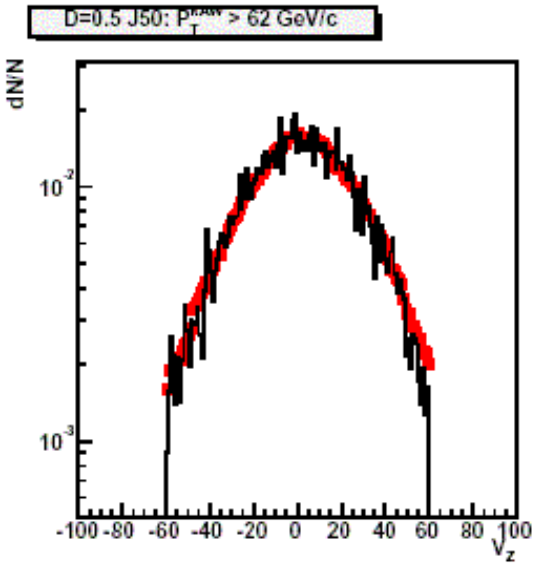


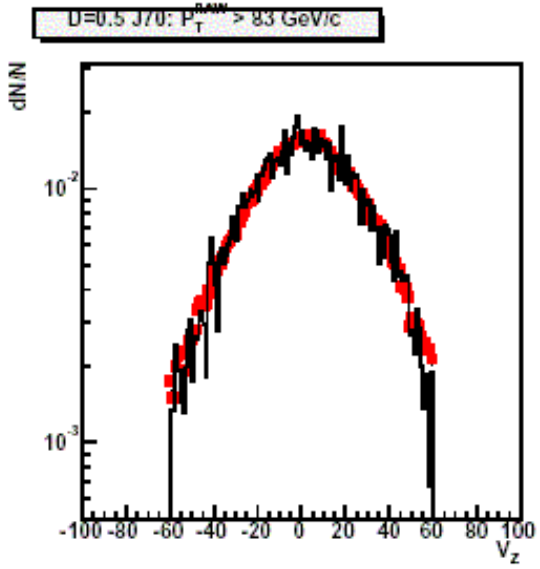
Data / MC:V_z

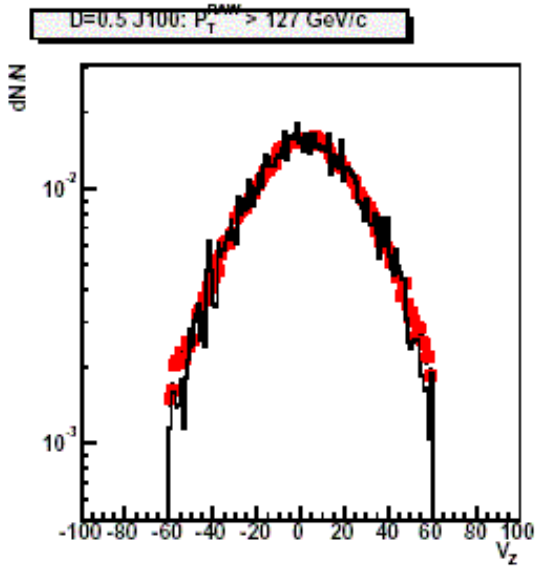



D=0.5 STW5: P_T^{RAW} > 23 GeV/c
dN/N
10^{-2}
10^{-3}
-100 -80 -60 -40 -20 0 20 40 60 80 100
V_z


D=0.5 J20: P_T^{RAW} > 27 GeV/c
dN/N
10^{-2}
10^{-3}
-100 -80 -60 -40 -20 0 20 40 60 80 100
V_z

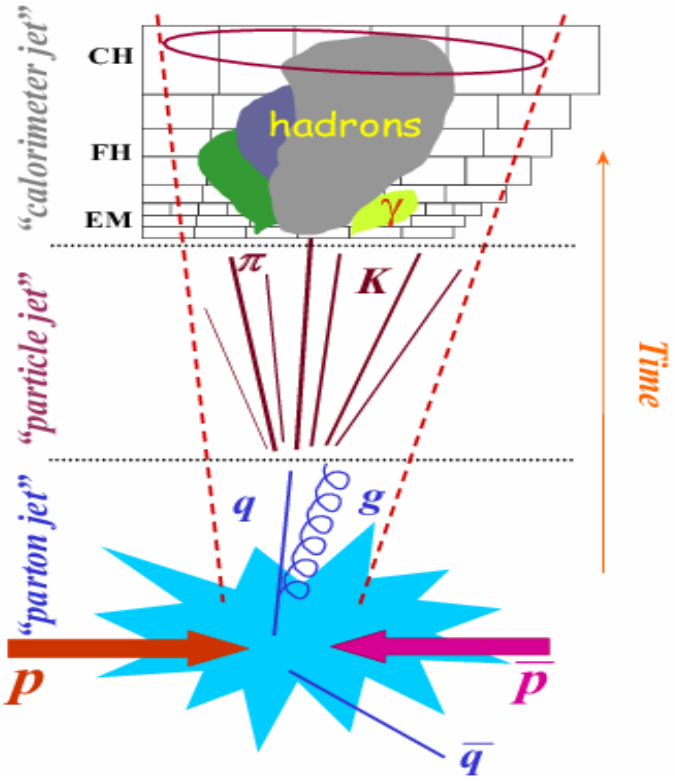

D=0.5 J50: P_T^{RAW} > 62 GeV/c
dN/N
10^{-2}
10^{-3}
-100 -80 -60 -40 -20 0 20 40 60 80 100
V_z

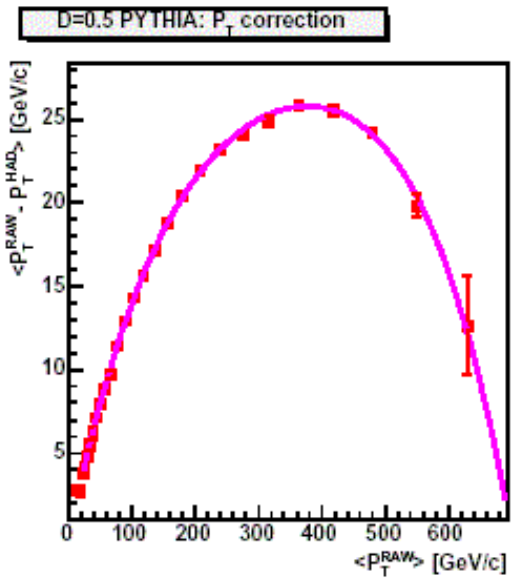

D=0.5 J70: P_T^{RAW} > 83 GeV/c
dN/N
10^{-2}
10^{-3}
-100 -80 -60 -40 -20 0 20 40 60 80 100
V_z

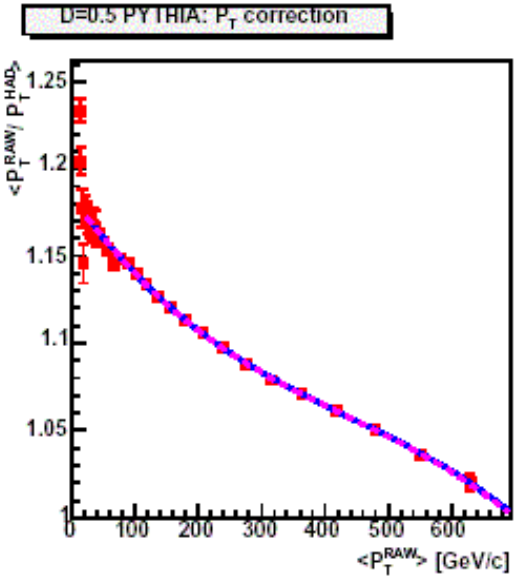

D=0.5 J100: P_T^{RAW} > 127 GeV/c
dN/N
10^{-2}
10^{-3}
-100 -80 -60 -40 -20 0 20 40 60 80 100
V_z

Jet P_T: Correction from MC

- Correction obtained from Pythia
- Clustering done at Calorimeter level and Hadron level
  - Matching Calorimeter / Hadron Jets
    - $\Delta R < D$ in ϕ–Y plan
  - $< P_T$ Raw $- P_T$ Had $>$ vs $< P_T$ Raw $>$

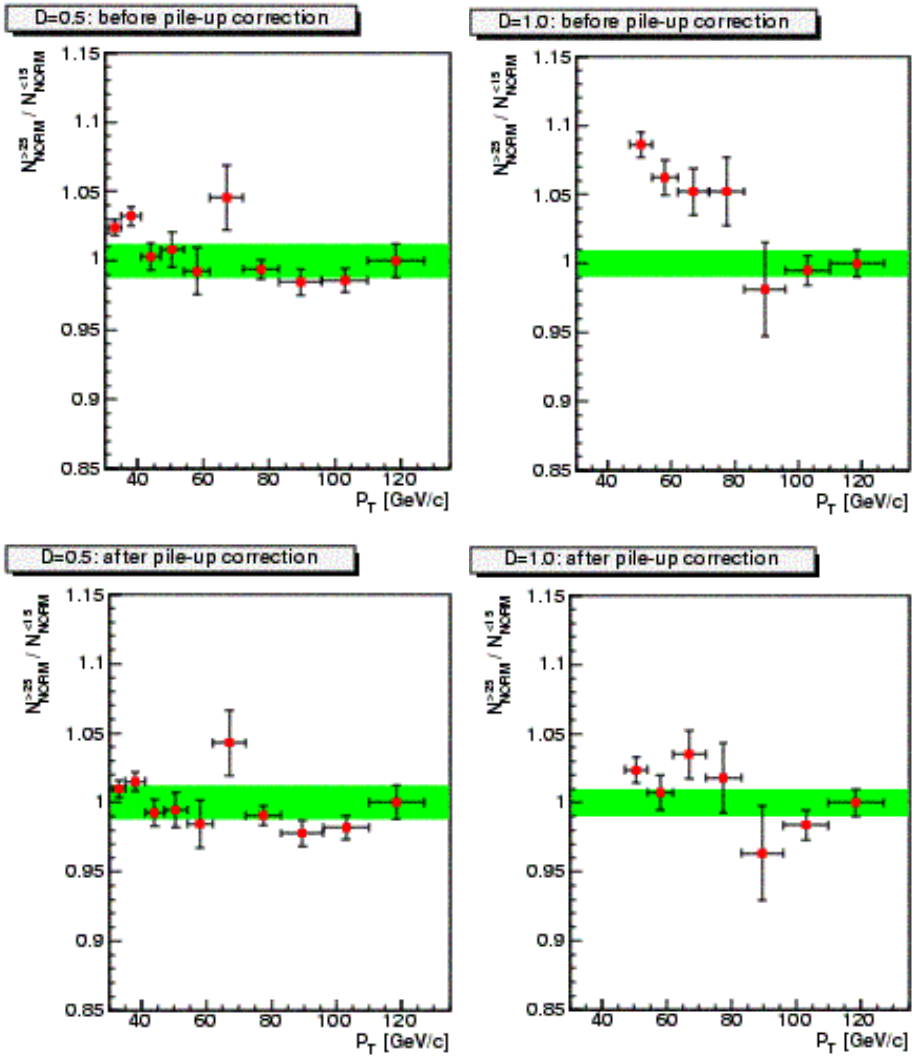






Jet P_T: Pile-up correction

- Pile-up correction
  - $-\varepsilon \times N$ additional primary vertices
    - Primary vertices of quality ≥ 12
  - ε values obtained from a dedicated study done with the cone algorithm
    - CDF Note 6239
    - 100% systematic uncertainty
    - 0.400, 0.781 and 1.581GeV/c for D = 0.5, 0.7 and 1.0 respectively
- No dependency to instantaneous luminosity after this correction
  - $L_{INST} > 25 \cdot 10^{30} cm^{-2} s^{-1}$ compared to $L_{INST} < 15 \cdot 10^{30} cm^{-2} s^{-1}$

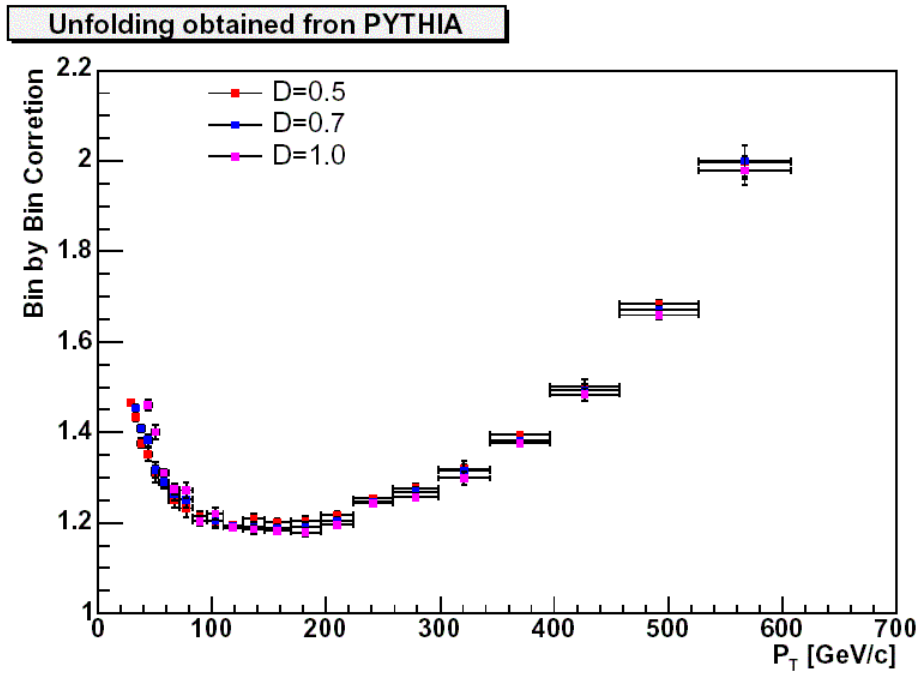


Unfolding

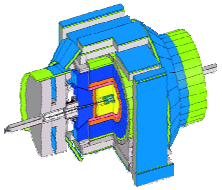
- Obtained from Pythia
  - Good agreement with data for used quantities
- Simple bin by bin correction
  - N Hadron level / N Calorimeter level (corrected Jet P_T)

Only cut on $|Y_{JET}|$

All cuts applied



Systematic uncertainties

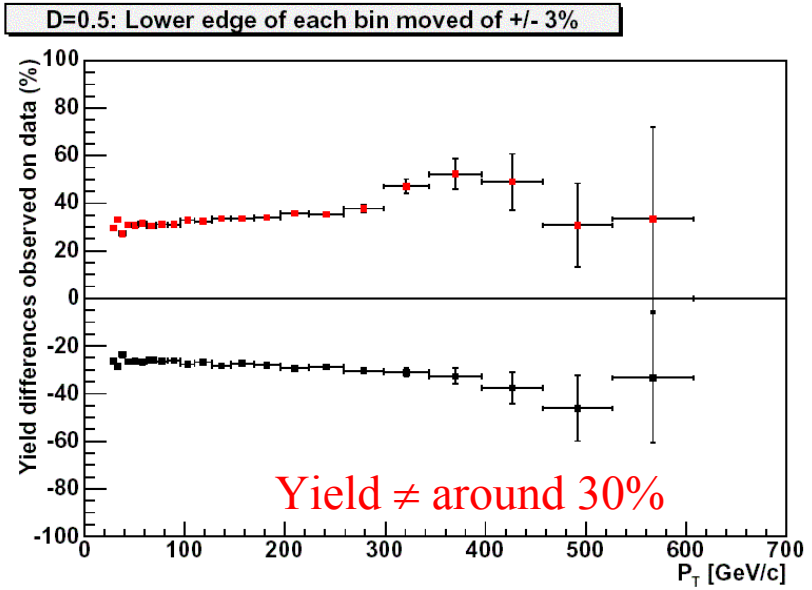


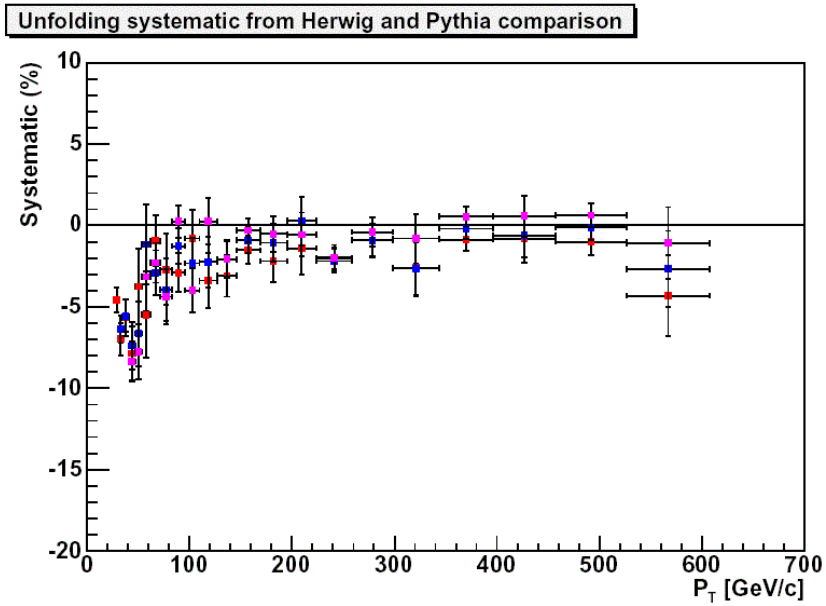
- Cuts
  - Number of tracks associated to primary vertex: ±1 track
    ⇨ effect of the order of 0.1%
  - Missing E_T significance cut:
    ±10% on missing E_T scale ⊗ ± 5% on jet energy scale
    ⇨ effect lower than 0.3%
  - $|V_Z|$ cut: ±5cm ⇨ effect lower than 1%
- Unfolding
  - MC statistics ⇨ effect lower than 2%
  - Binning: ±3% on lower edge of each bin
  - Pythia vs Herwig
- Jet P_T reconstruction
  - ±100% on pile-up correction
  - ±20% on jet energy resolution
  - ±5% on jet energy scale
    - Support by Tracking / Calorimeter comparison in Data and MC

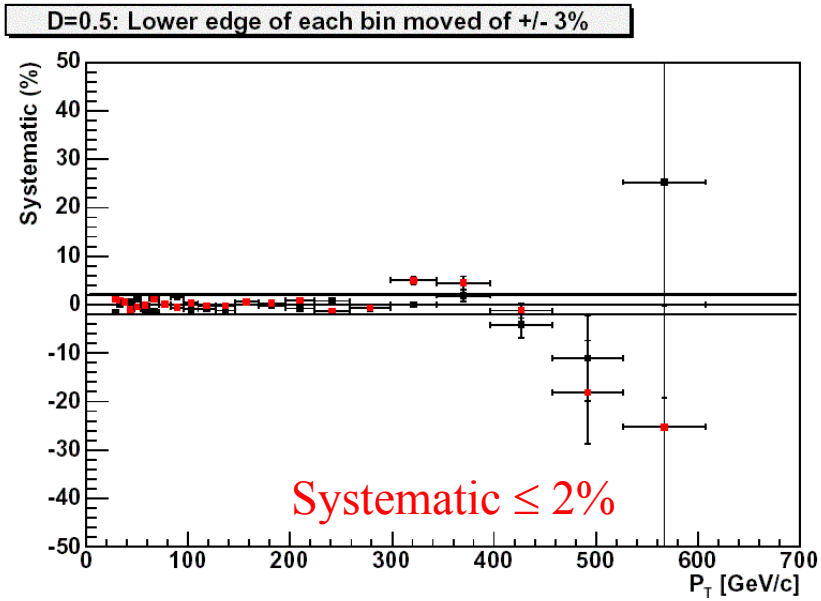
Increasing systematic

Systematic uncertainties: Unfolding

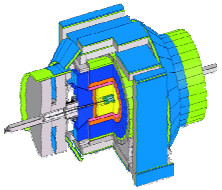
- MC statistics ⇨ effect lower than 2%
- Binning: ±3% on lower edge of each bin
- Pythia vs Herwig



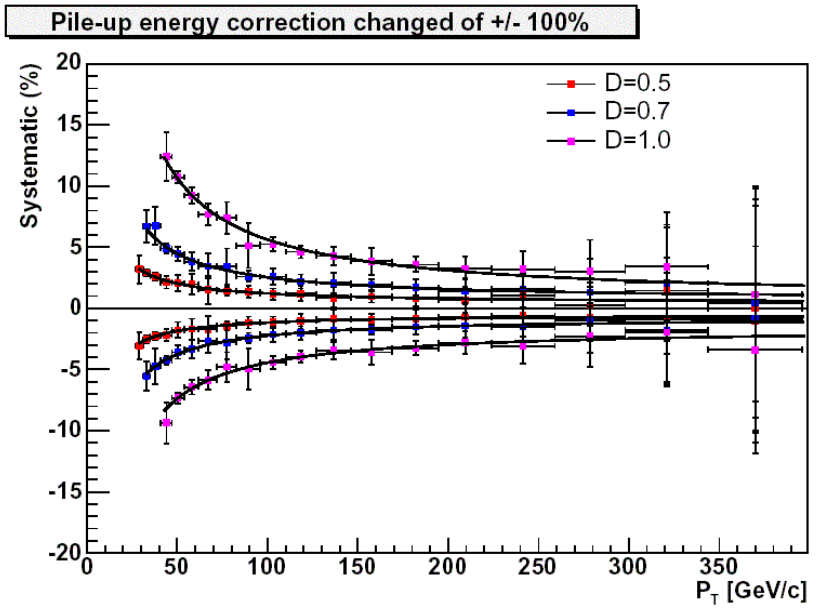


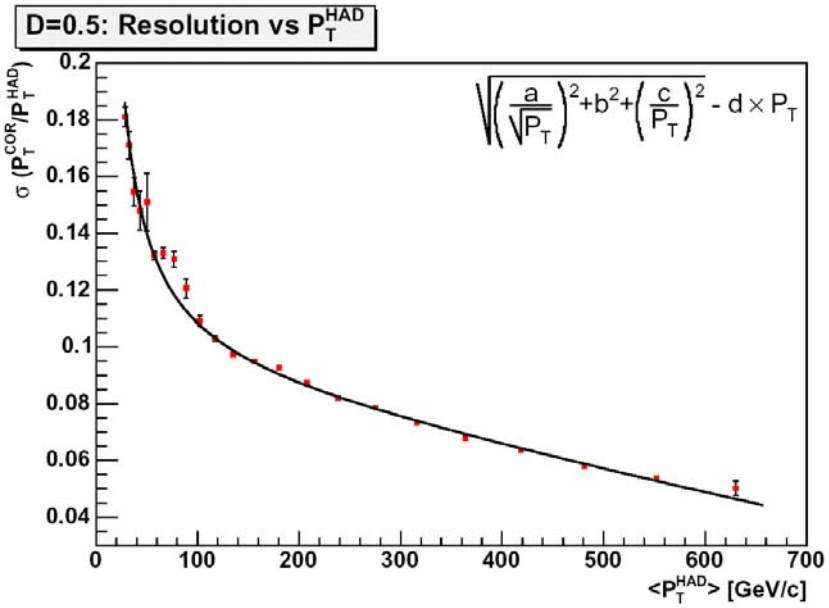


Systematic uncertainties: Jet P_T (1/2)



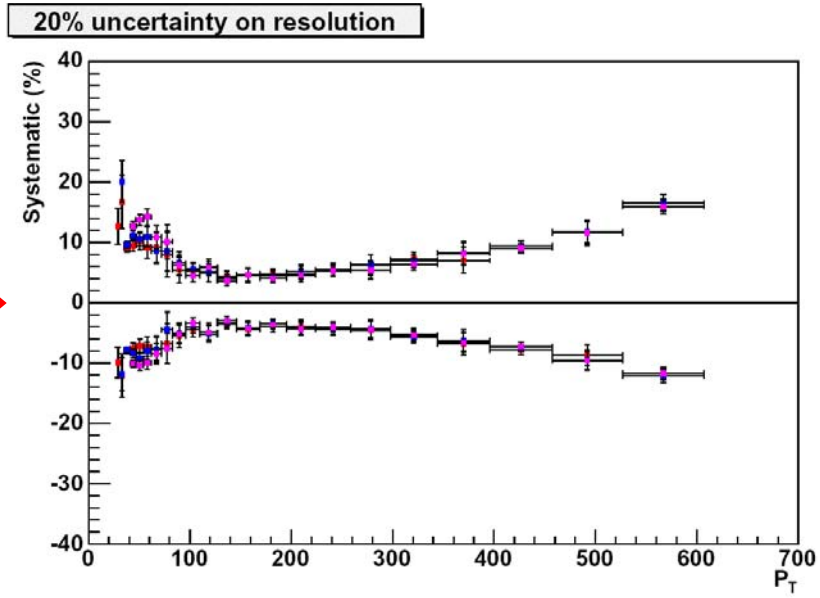
- ±100% on pile-up correction
- ±20% on jet energy resolution
  - Use Pythia and get resolution function: $\sigma(P_T)$
  - Smear P_THad distribution with Gauss [$\mu = 0$, $\sigma = \sigma(P_T)\times\alpha$] ⇨ $P_T HadS_\alpha$
  - Systematic (idem for 0.8): $(P_T Had / P_T HadS_{1.2}) / (P_T Had / P_T HadS_{1.0}) = P_T HadS_{1.0} / P_T HadS_{1.2}$



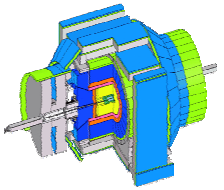


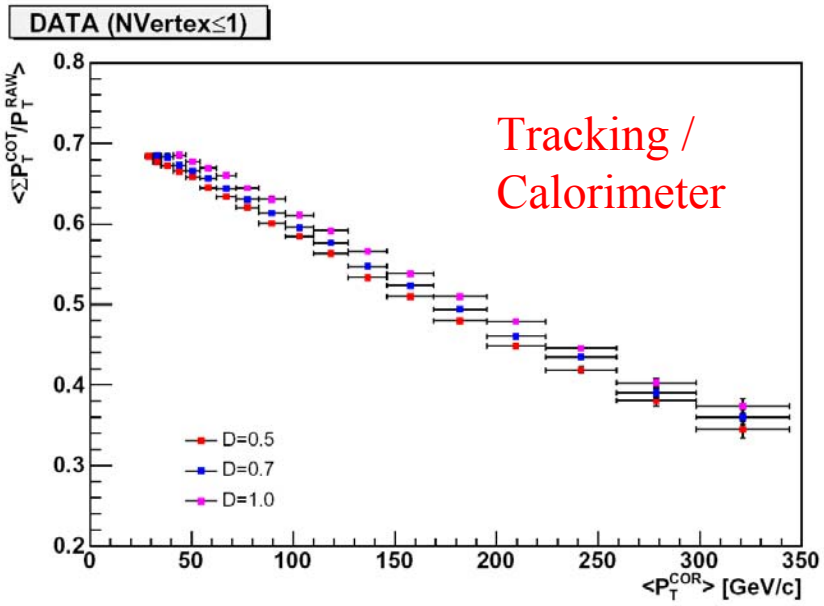
Smearing

±20%

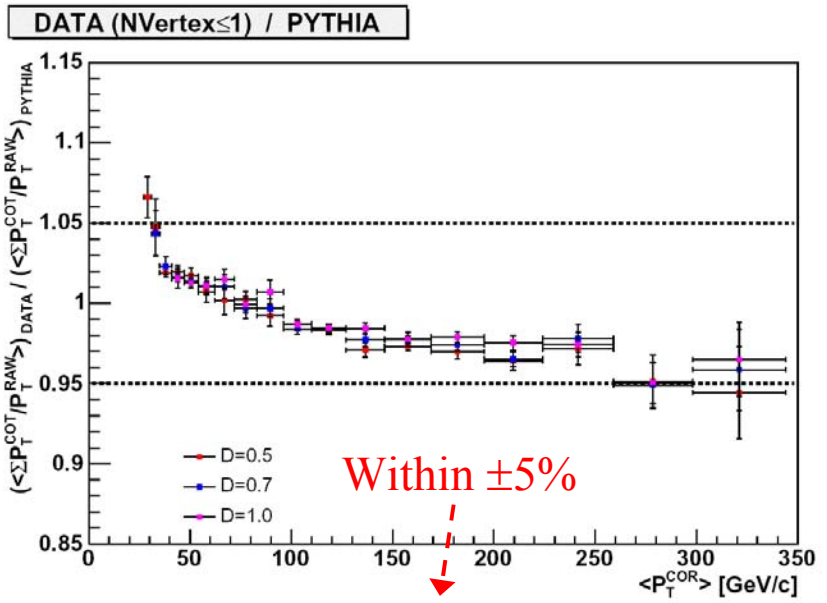


Systematic uncertainties: Jet P_T (2/2)

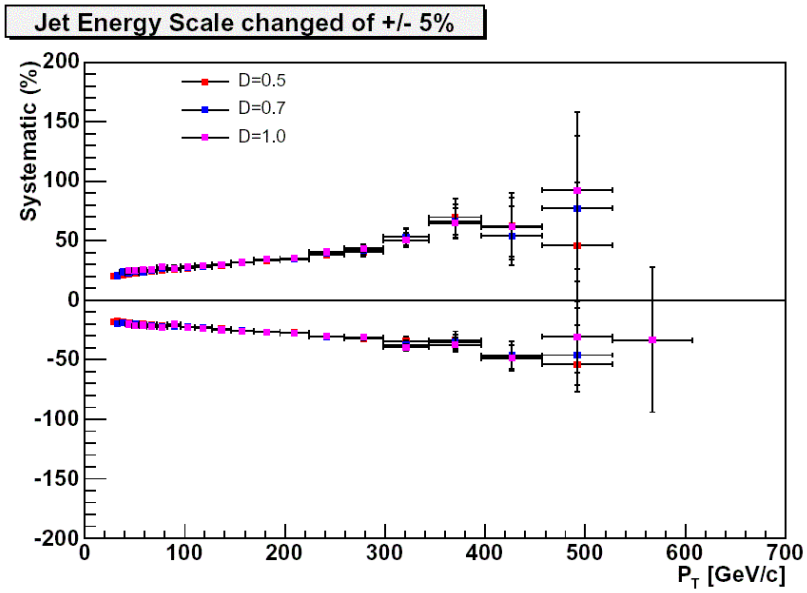




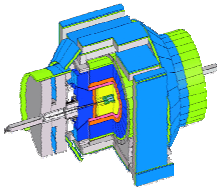
Data / MC



- Tracking / Calorimeter comparison in Data and MC
  - Scalar sum of P_T of COT tracks associated with the jet
    - $0.5\text{GeV/c} < P_T(\text{Track}) < 500\text{GeV/c}$
    - $|\eta_T| < 1.5$
    - $\Delta V_Z = |V_Z(\text{Jet}) - V_Z(\text{Track})| < 2\text{cm}$
    - $\Delta R = \sqrt{[(\phi_J - \phi_T)^2 + (Y_J - \eta_T)^2]} < D$

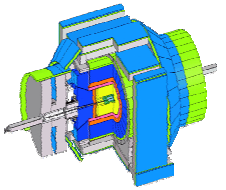


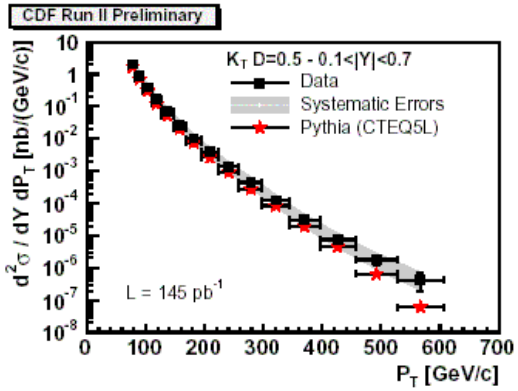
Results

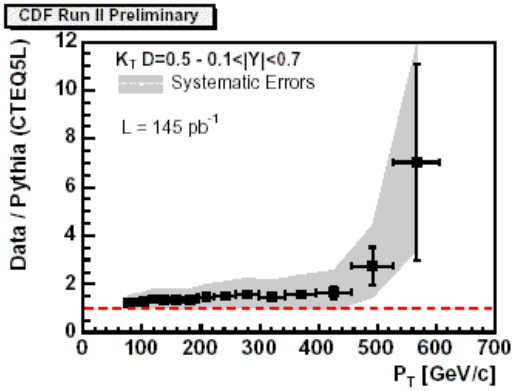


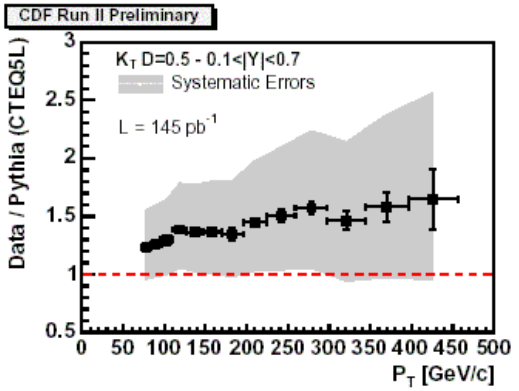
- Presented results limited to $P_T > 72 GeV/c$
  - High systematic uncertainties from "±100% on pile-up correction" and "±20% on jet energy resolution" at lower P_T
    - Further studies required to reduce them
- Comparison to Pythia and Herwig MC
  - CTEQ5L
  - LO Matrix Element ⊕ Parton Shower
    - Forget about the normalization
    - Only concerned about the shape
  - Reasonable agreement of spectrum shapes
    - No need to weight the MC for the unfolding
      - Agrees with low systematic coming from binning study, i.e. "±3% on lower edge of each bin"

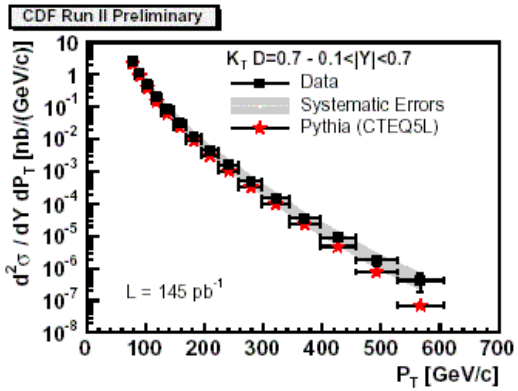
Comparison to Pythia (CTEQ5L)

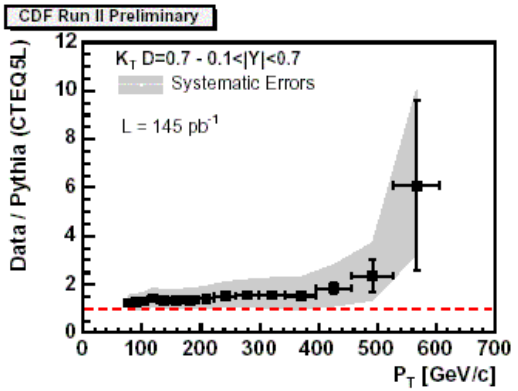


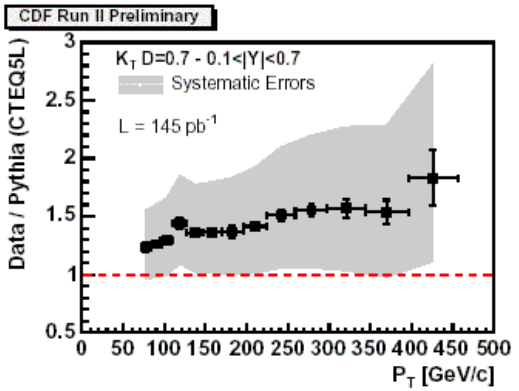


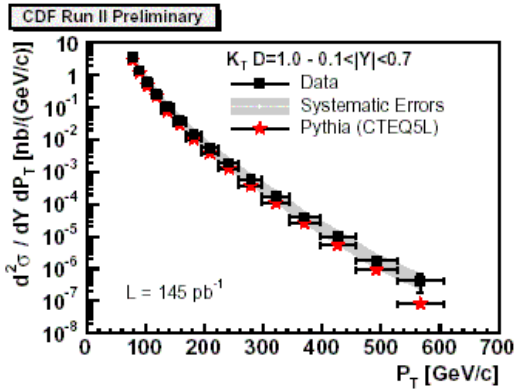


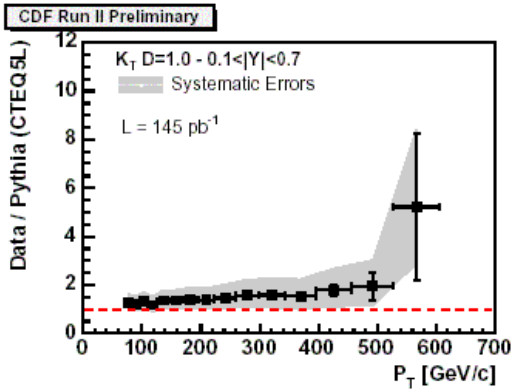


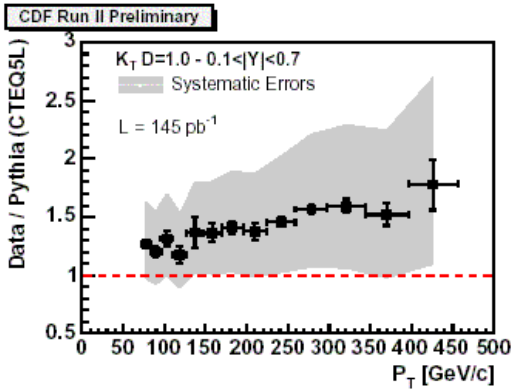




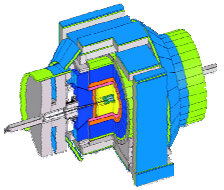


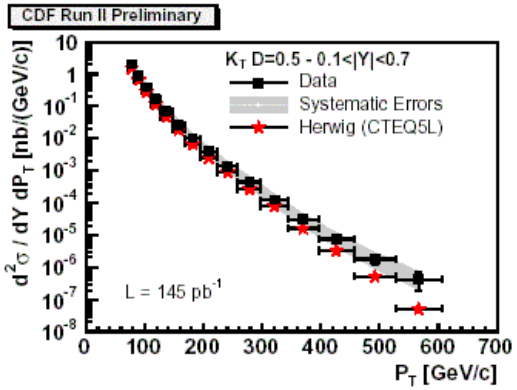


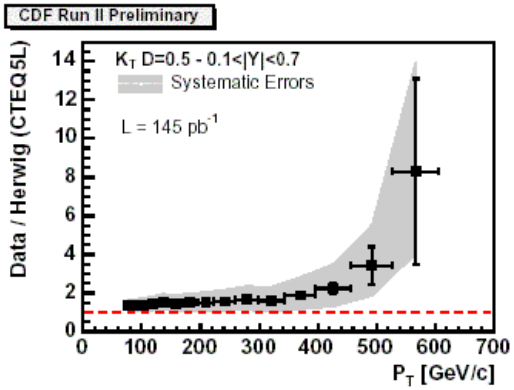


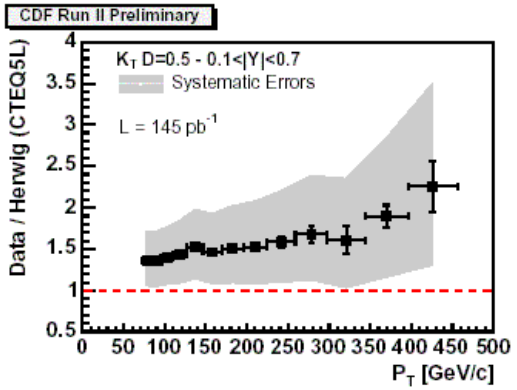


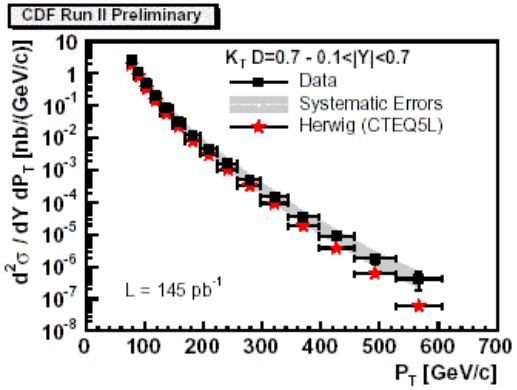
Comparison to Herwig (CTEQ5L)

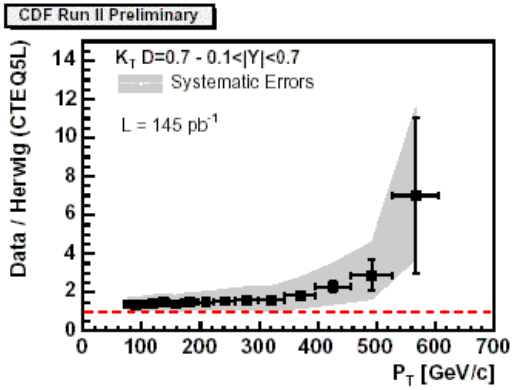


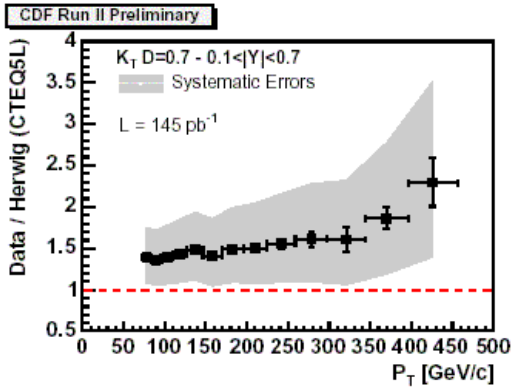


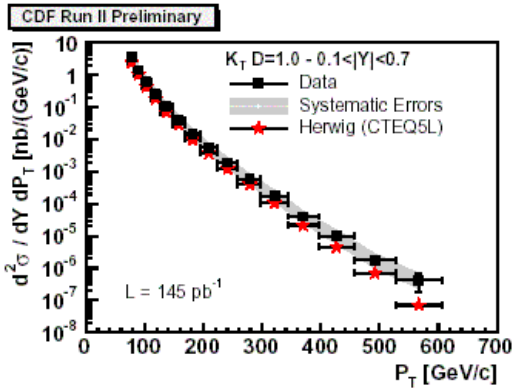


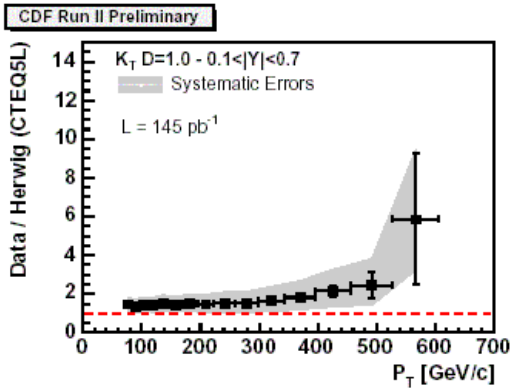


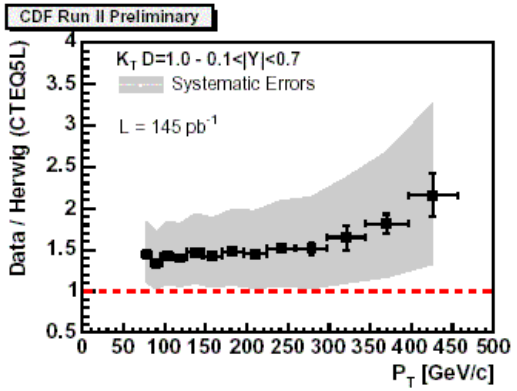






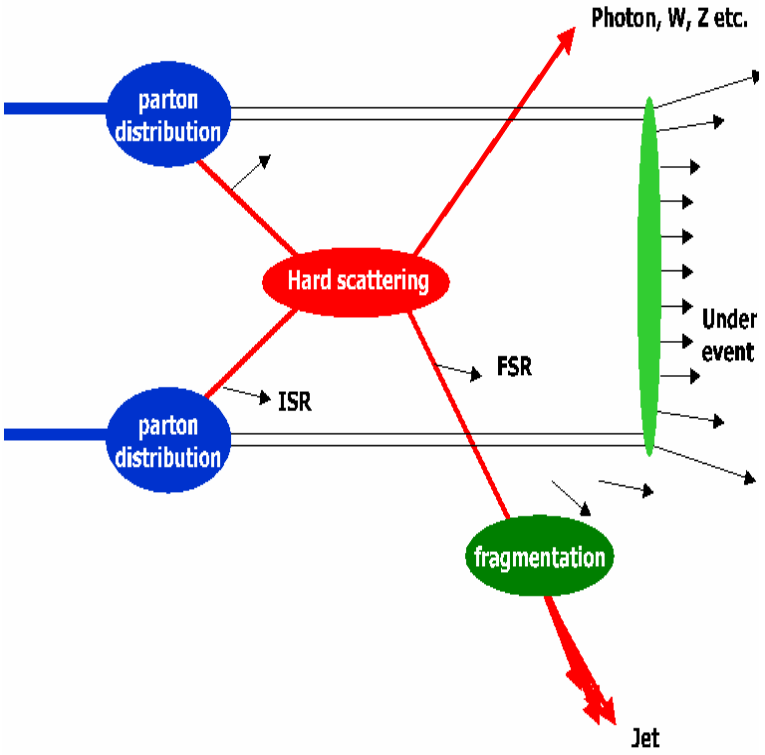




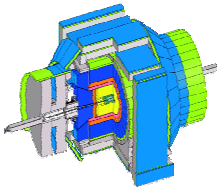


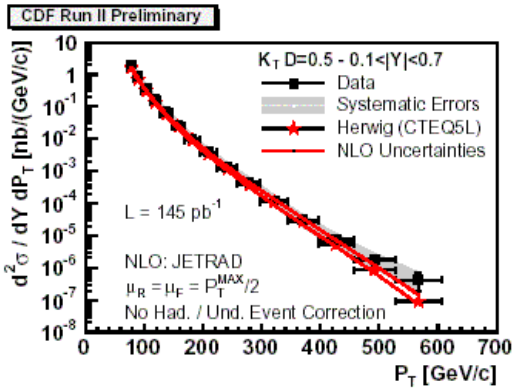
Comparison to NLO

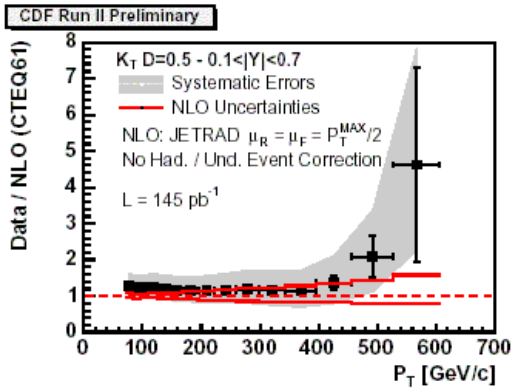
- JETRAD CTEQ61 package
  - $\mu_R = \mu_F$ = Maximum Jet P_T / 2
- NLO uncertainties
  - Scale: $\mu_R = \mu_F$ = Maximum Jet P_T
    - Symmetric uncertainties
  - PDF: sets 5 and 15 used
    - Set 5 dominates at low P_T,
      Set 15 dominates at high P_T
    - Asymmetric uncertainties
  - PDF uncertainties dominate
- Warning
  - For the moment, NLO is not corrected for hadronisation
    - i.e. Underlying Event, Parton Shower and Fragmentation
  - Explains rising of Data / NLO ratios going to low P_T
    - Effect not seen in Pythia and Herwig comparisons
    - Effect increases with the size of the jets (D parameter)

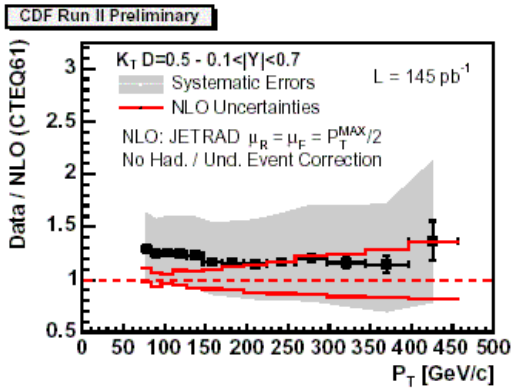


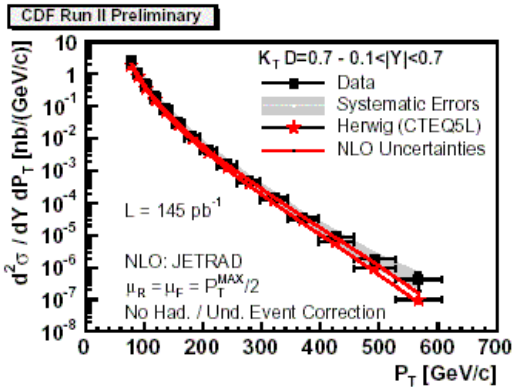
Comparison to NLO (CTEQ61)

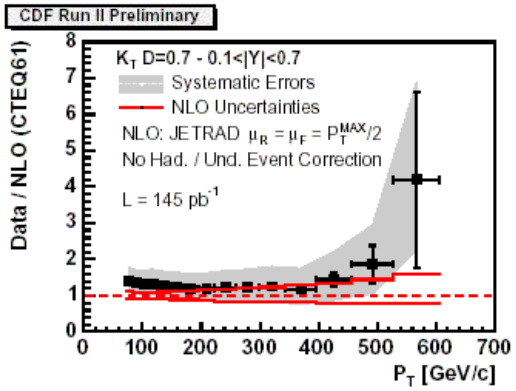


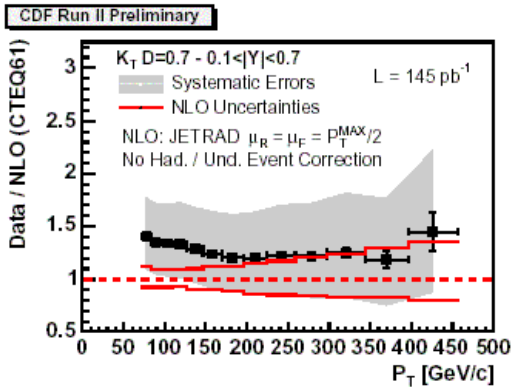


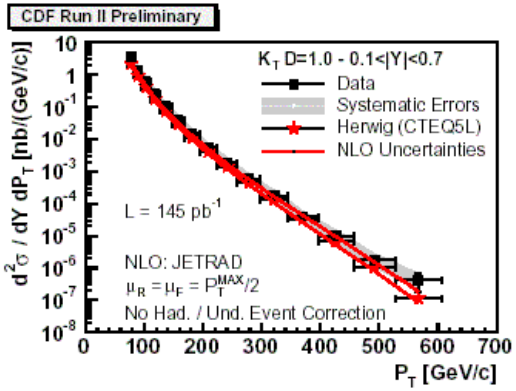


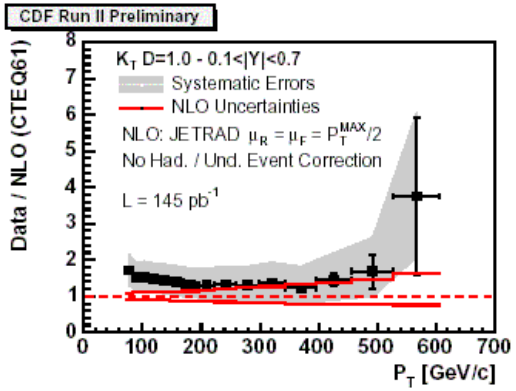


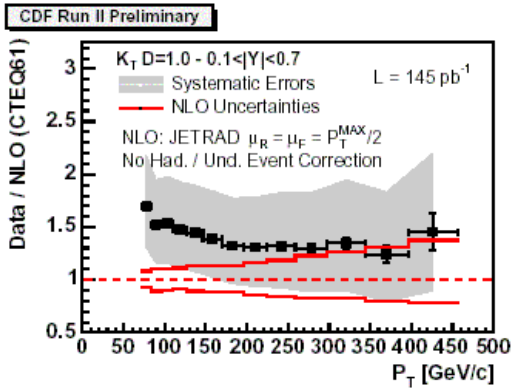




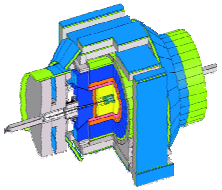








Conclusions and plans



- Conclusions
  - Jet inclusive cross section measured for central jets ($0.1<|Y|<0.7$) using the K_T Algorithm (D = 0.5, 0.7 and 1.0) for $P_T > 72$GeV/c
  - Comparison to Pythia and Herwig MC (LO Matrix Element)
    - Reasonable agreement of spectrum shapes
  - Comparison to NLO
    - Reasonable agreement taking into the fact that the NLO is not corrected for hadronisation (explains rising of Data / NLO ratios going to low P_T)
- Plans
  - Move to 5.3.1 version of MC and data
  - More detailed studies of
    - Resolution uncertainty and pile-up correction before going to lower P_T
    - Energy scale to decrease the systematic uncertainties
  - Correct NLO for hadronisation
    - Compare MC with or without: Underlying Event, Fragmentation …
  - Goal: final results and PRL by Moriond 2005