Multiple Parton Interactions in Photoproduction at HERA.

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Multiple Parton Interactions (MI)

Contents:

I. Introduction to MI and what has been done at HERA (by now).

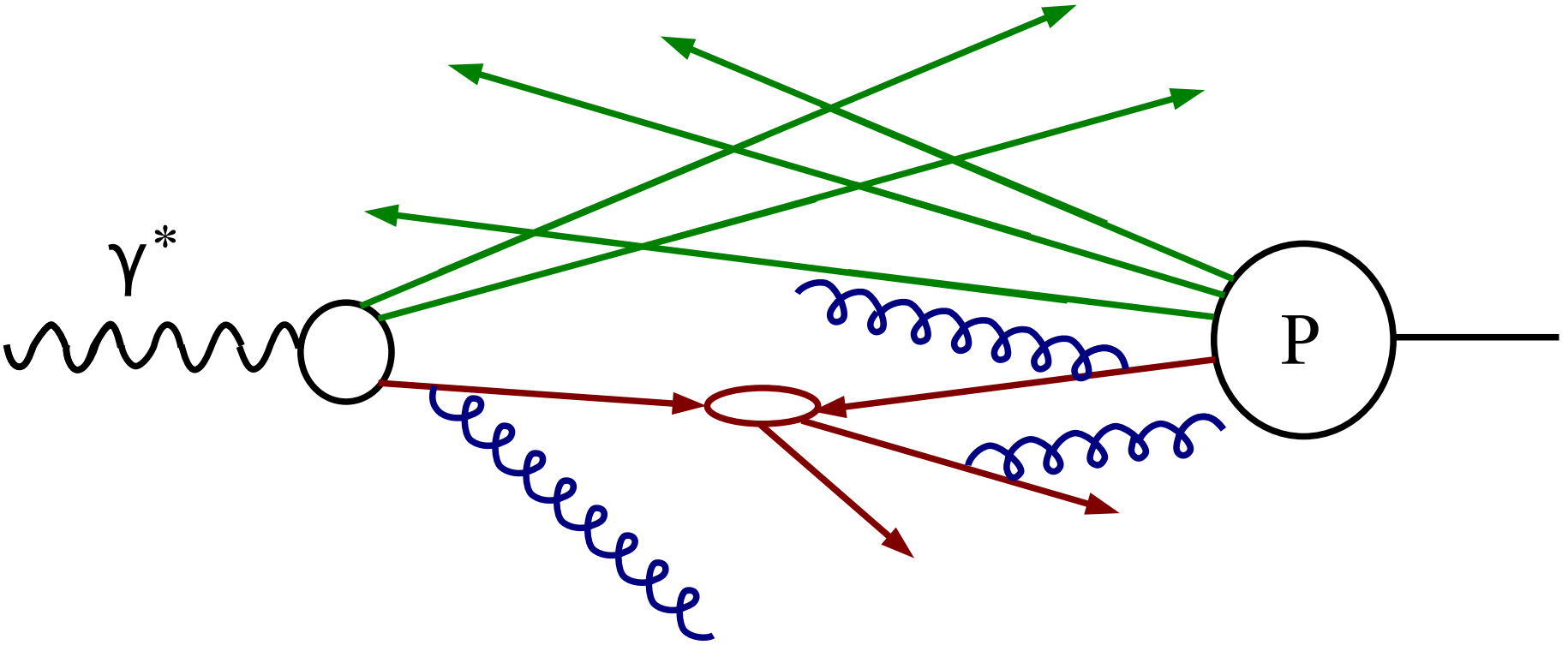
II. Some extra motivation: jet shapes.

III. What can we still measure at HERA?

Some observables like multiplicity, energy flow, as a function of φ and P_t Leading Jet

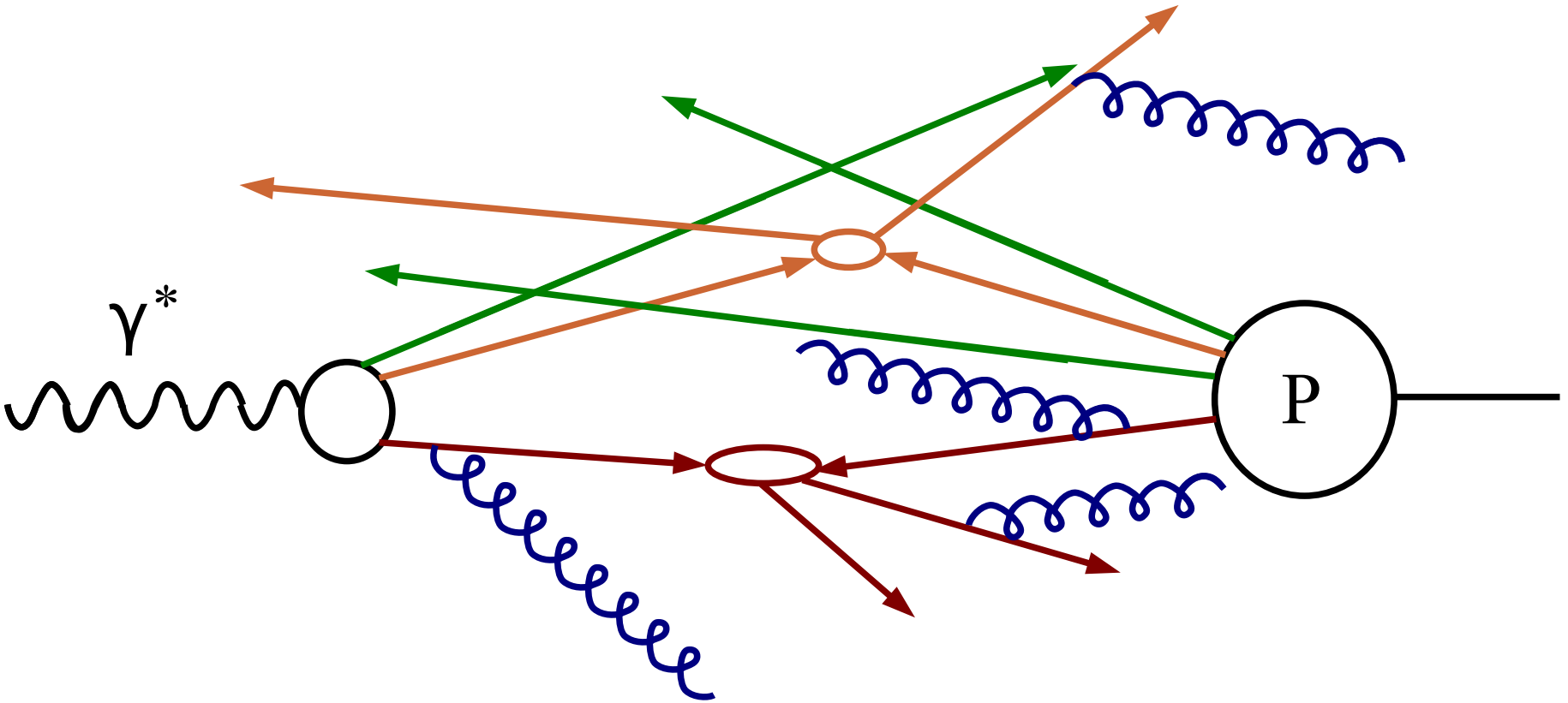
Introduction: electron-hadron collision.

- In *ep* collisions we have:



Introduction: electron-hadron collision.

- We have two remnants as in the case of hadron-hadron collisions:

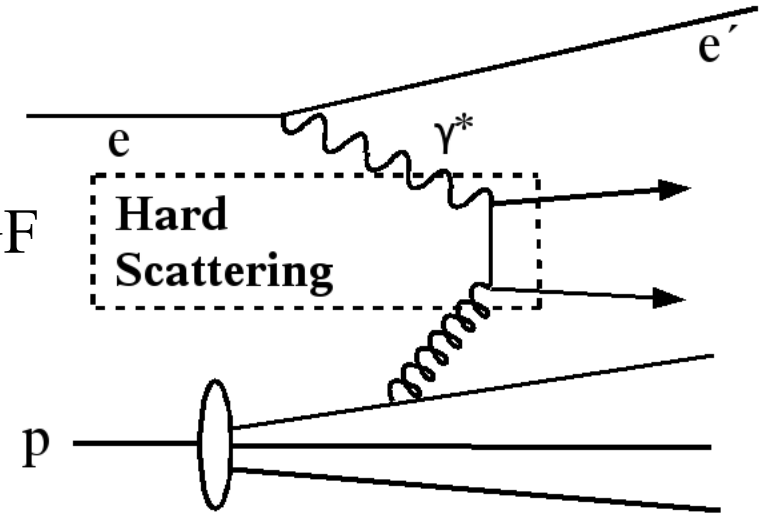


the question is how to do this....

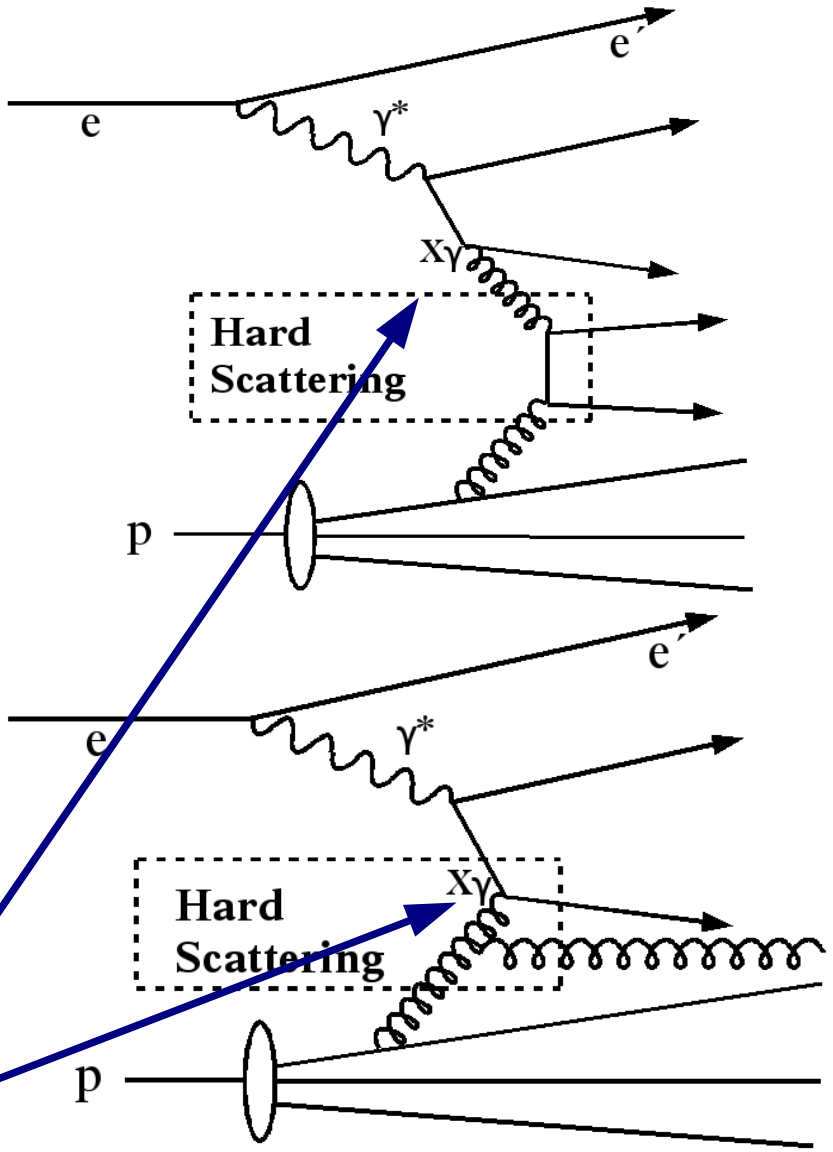
Simulation: Pythia

Three types of events are generated: BGF (direct), resolved and excitation events.

BGF



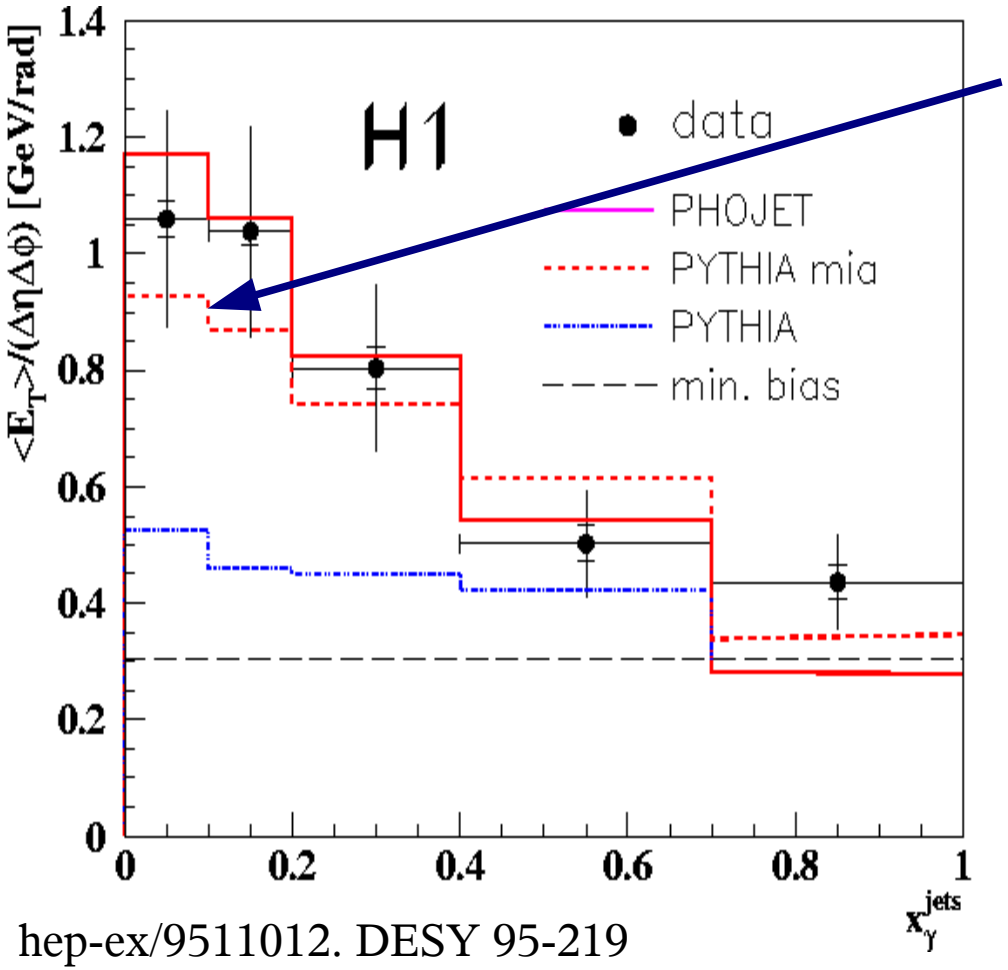
$$x_\gamma^{obs} = \frac{\sum_{h\in Jet1}(E-p_z)+\sum_{h\in Jet2}(E-p_z)}{\sum_h (E-p_z)}$$



Photon remnants like in hadron-hadron collisions

MI at HERA

HERA is a good place to test MI:



hep-ex/9511012. DESY 95-219

Already 10 years ago extra activity was needed to describe some distributions!

Two samples: dijet and charm with dijet

- Photoproduction regime (99-00 Data).
- DiJet with: $P_t > 7(6)$ GeV

  $|\eta| < 1.5$

  Kt clustering algorithm (pt weighted recom. scheme)
- Charm with dijet: one of the Jets has to contain a muon, $P_t > 2.5$ GeV.

The highest P_t Jet is the "Leading Jet"

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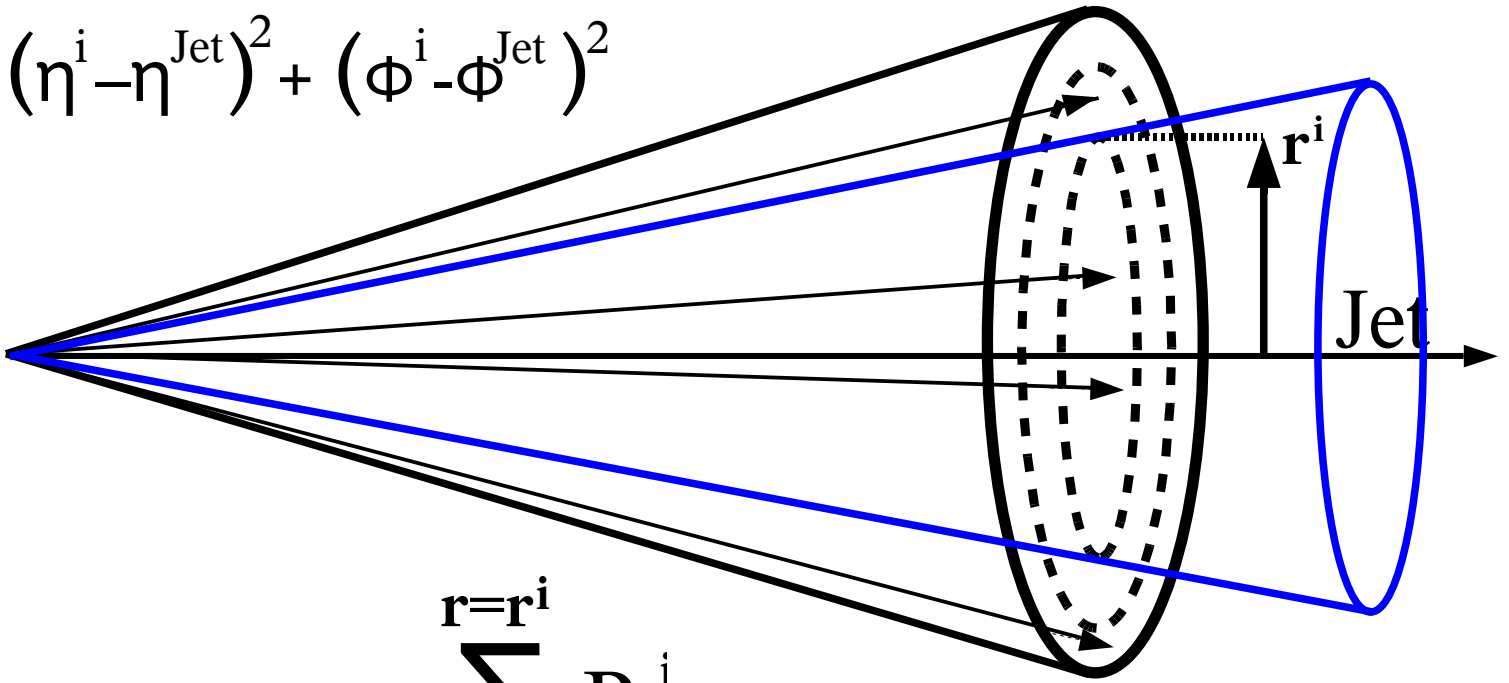
In data background is subtracted!

The highest P_t Jet is the "Leading Jet"

Observables: Jet shape

Jet Shape: average fraction of the total transverse momentum in a given cone of radius r (scalar sum).

$$r = \sqrt{(\eta^i - \eta^{Jet})^2 + (\Phi^i - \Phi^{Jet})^2}$$

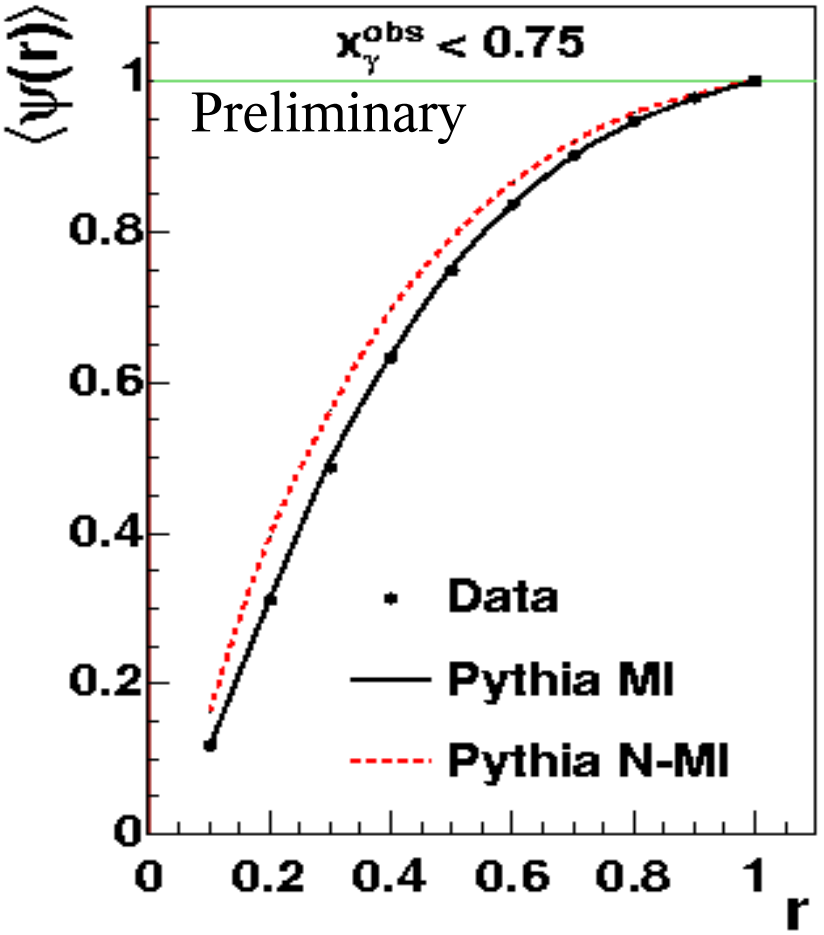


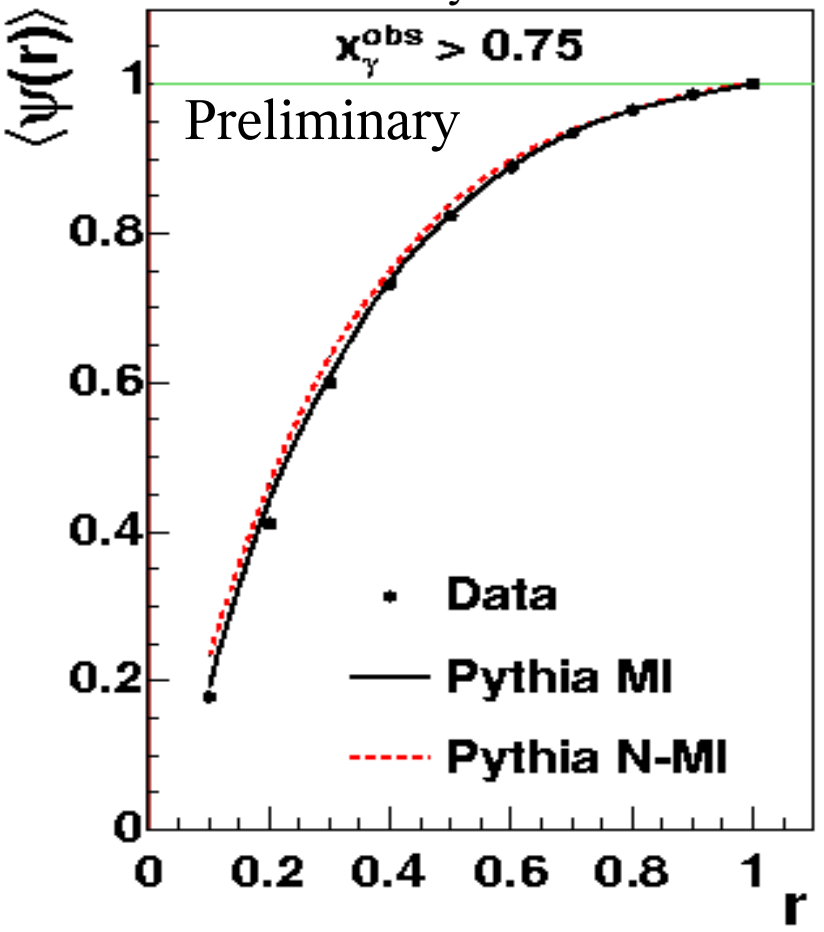
$$\langle \Psi(r) \rangle = \frac{\sum_{r=0}^{r=r^i} P_t^{\,j}}{\sum_{r=0}^{r=R} P_t^{\,j}}$$

Jet shape in dijet sample

Jet Shape: average fraction of the total transverse momentum in a given cone of radius r (scalar sum).

Desy-Thesis-2005-047

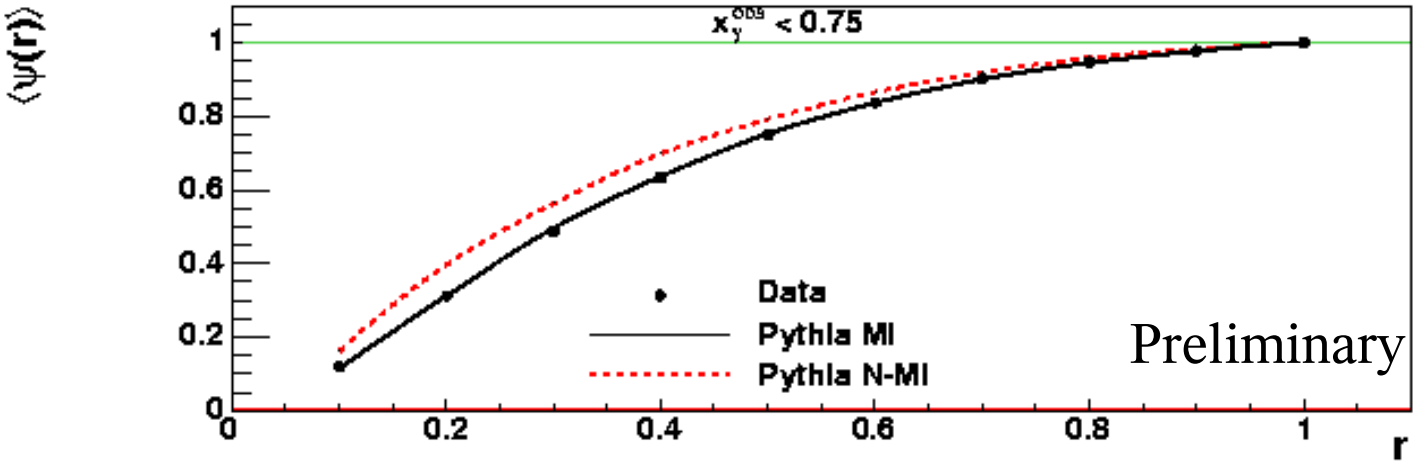


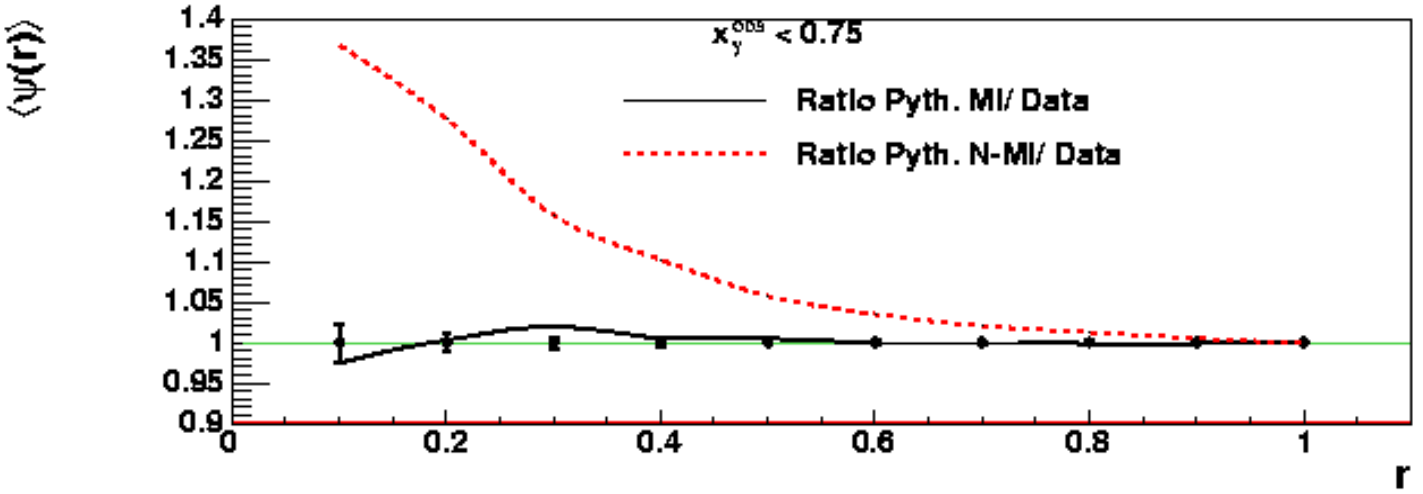


Pythia MI describes the dijet sample.

Jet shape in dijet sample

Jet Shape: average fraction of the total transverse momentum in a given cone of radius r (scalar sum).

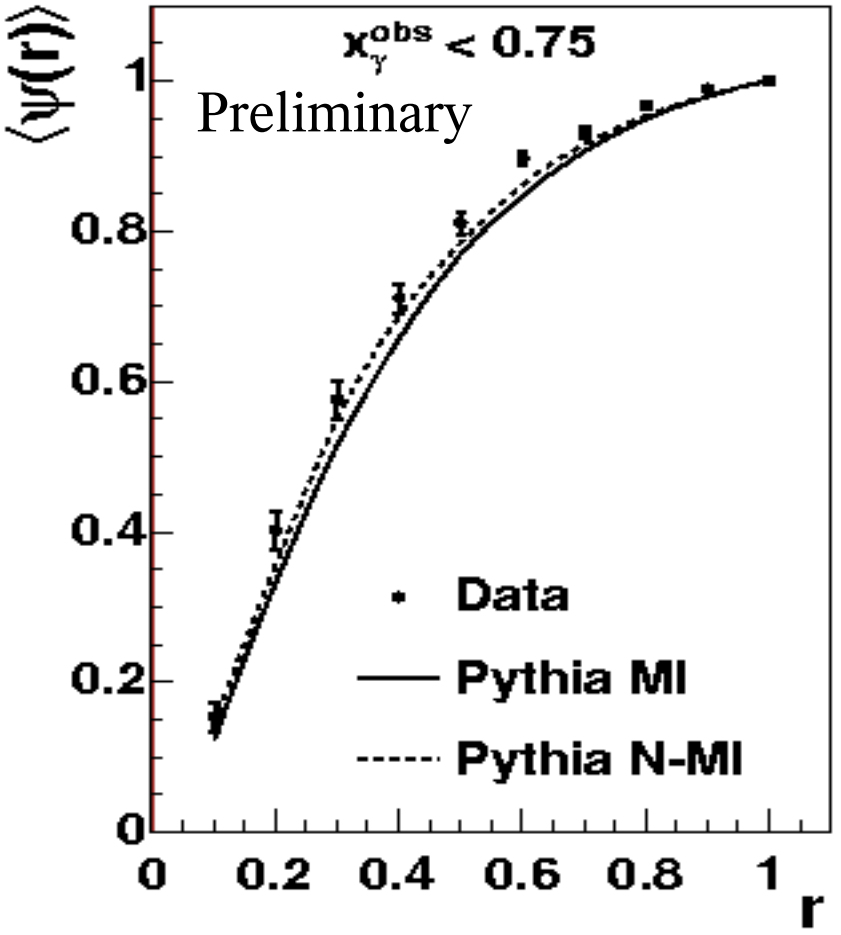


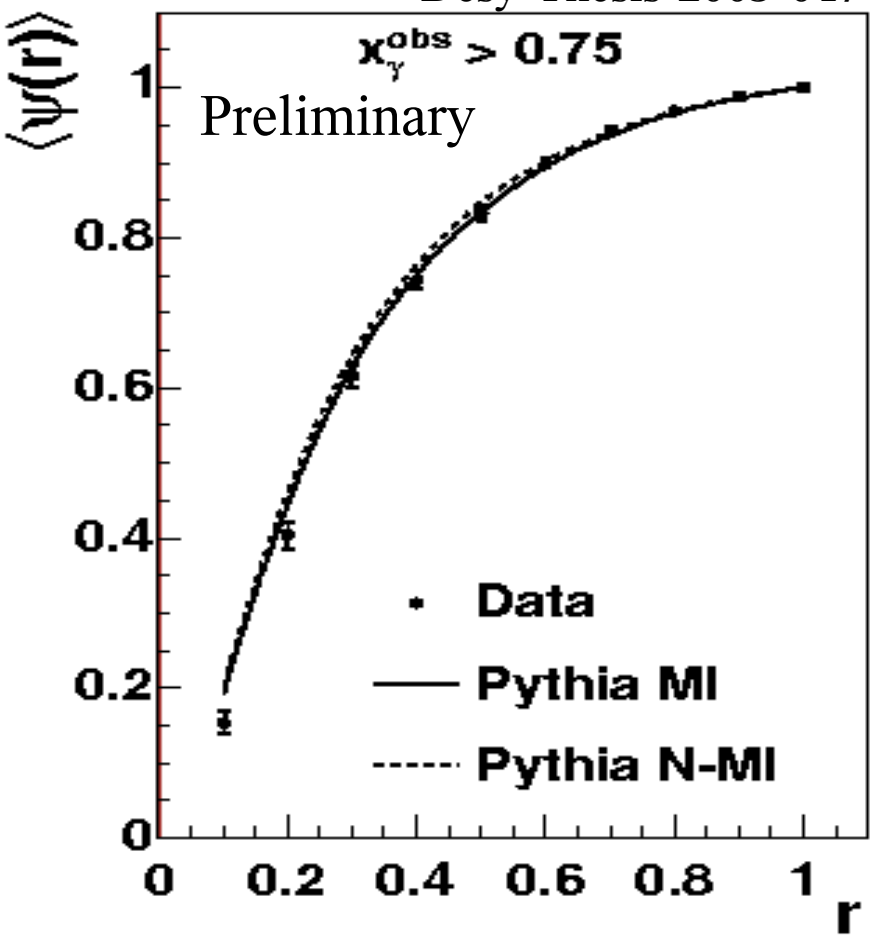


Jet shape in charm with dijet

Jet Shape: average fraction of the total transverse momentum in a given cone of radius r (scalar sum).

Desy-Thesis-2005-047





Pythia MI does not describe the charm with dijets sample.

Jet shape in charm with dijet

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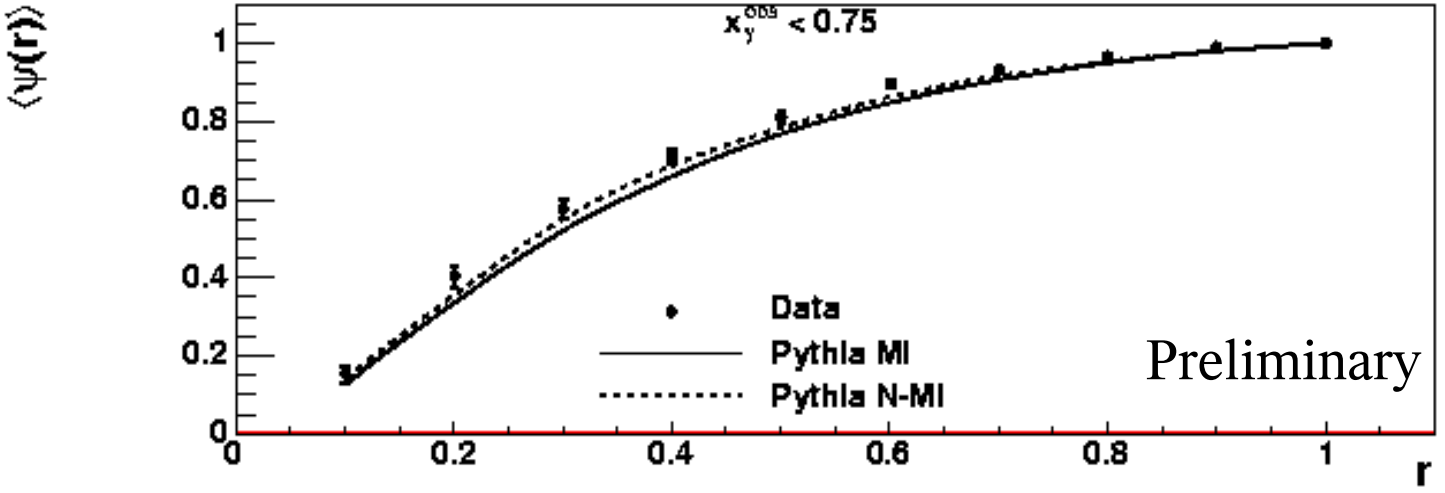
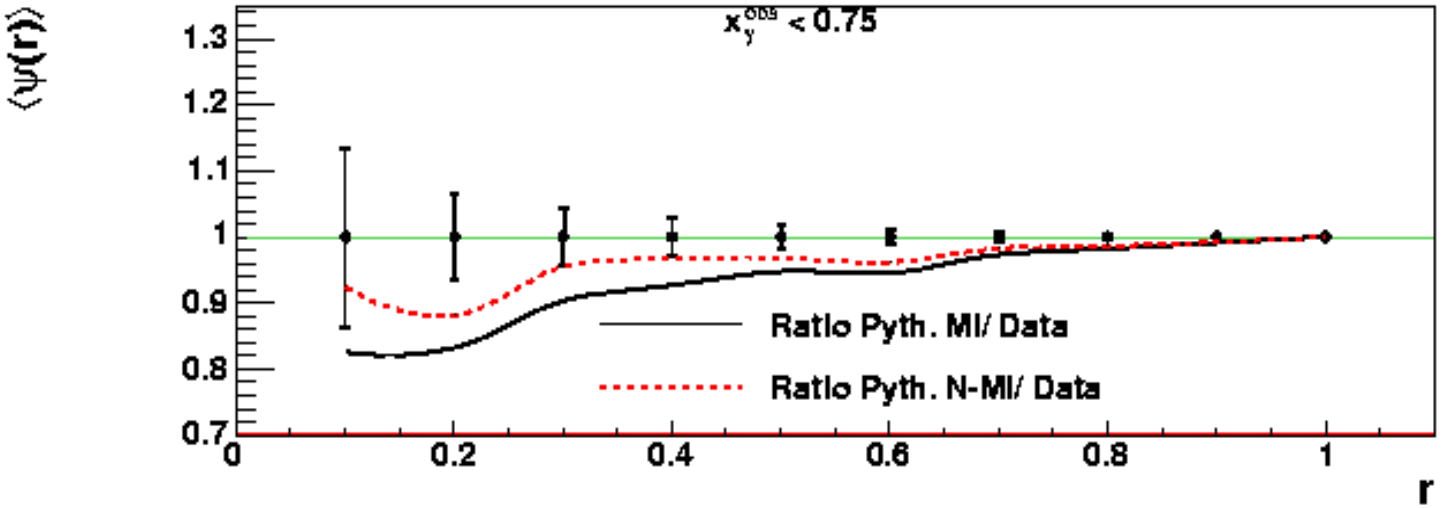




Observables: Multiplicity and Energy flow

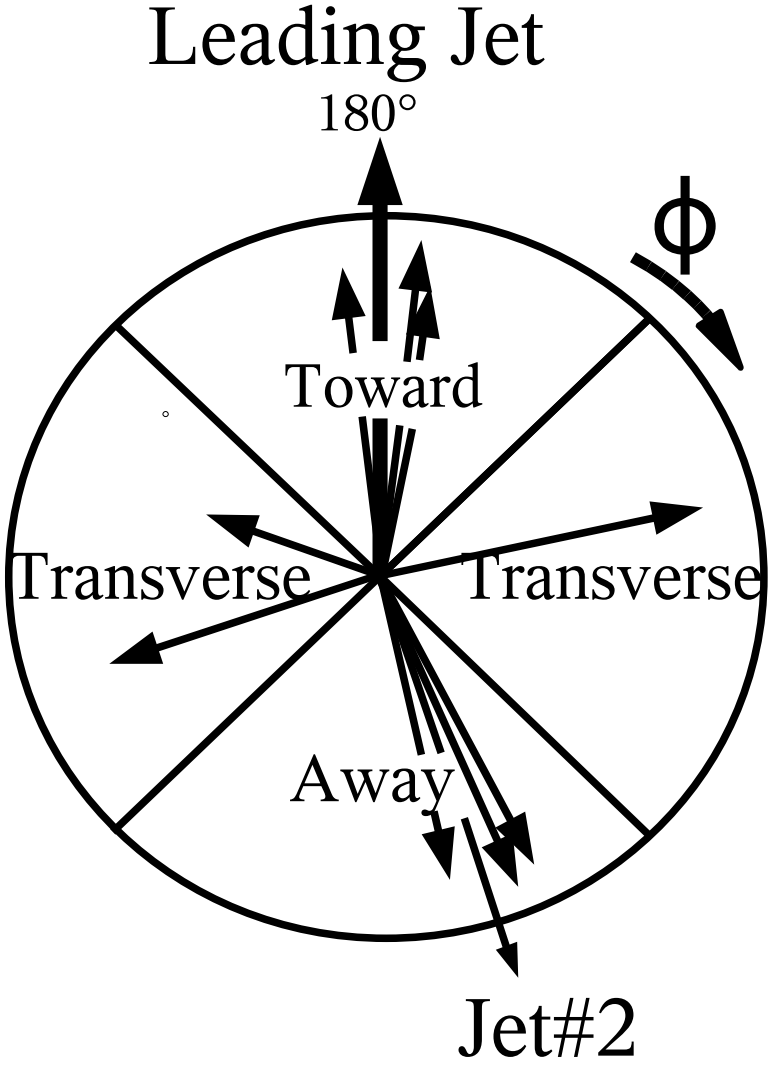
Multiplicity: average number of measured particles per event.

Energy flow: average scalar P_t sum per event.

- Charged particles:
  - with $P_t > 150$MeV and $|\eta| < 1.5$

We define three regions:

- Toward: $120° < |\varphi|$
- Transverse: $60° < |\varphi| < 120°$
- Away: $|\varphi| < 60°$



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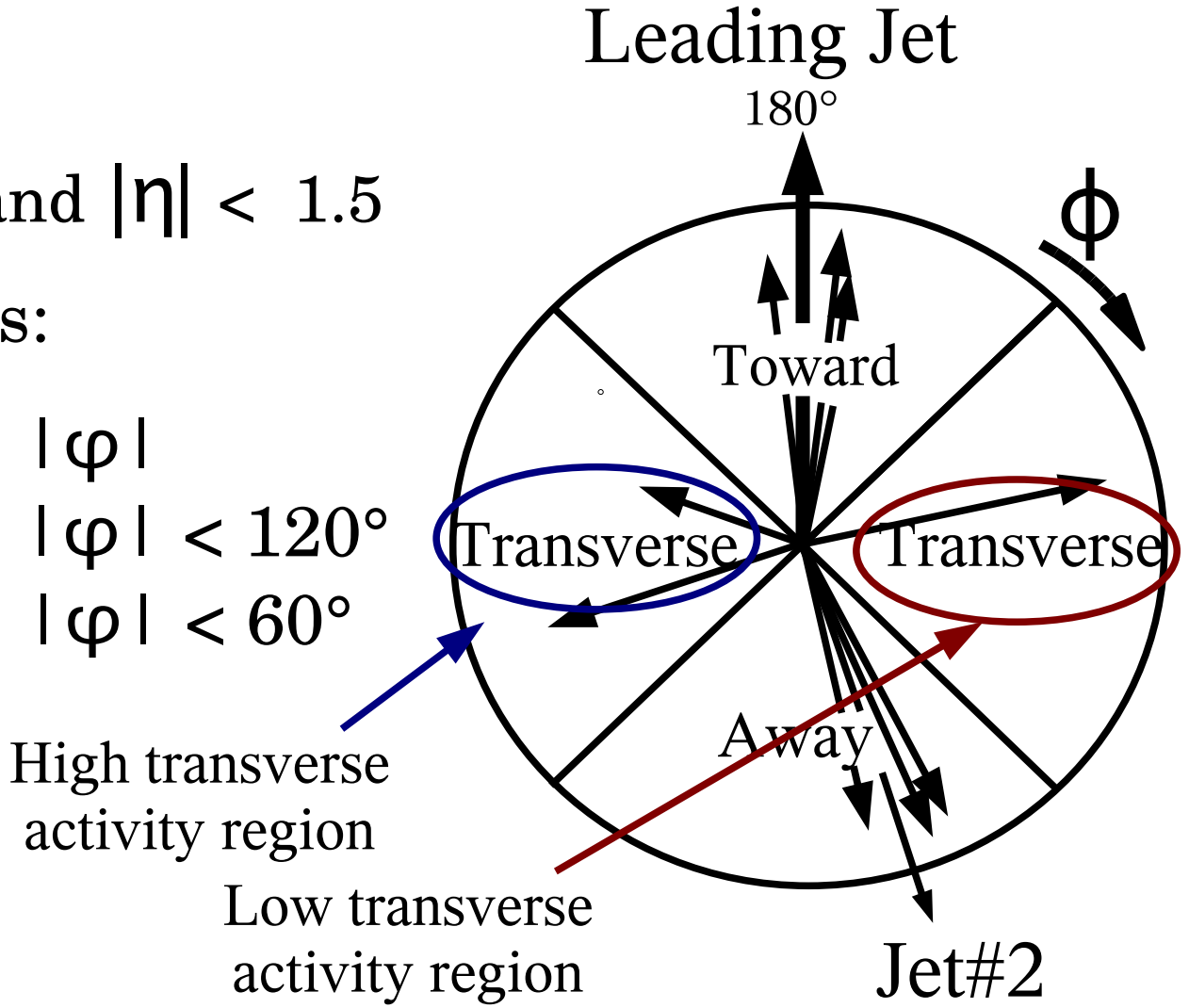
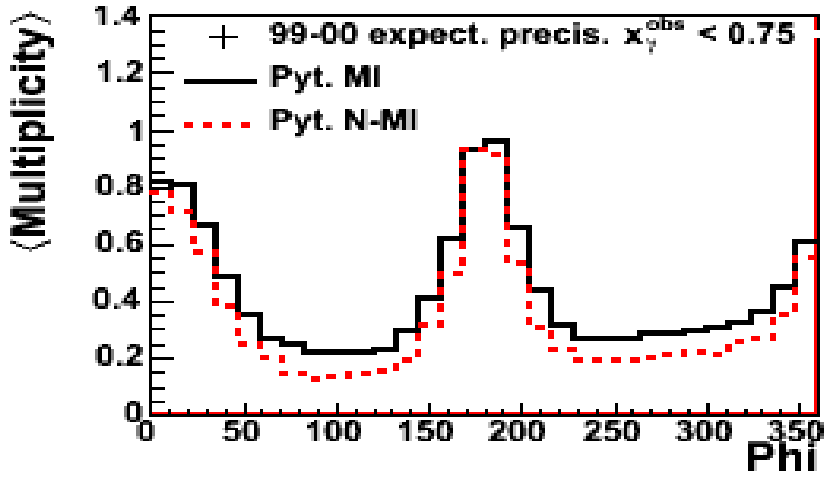
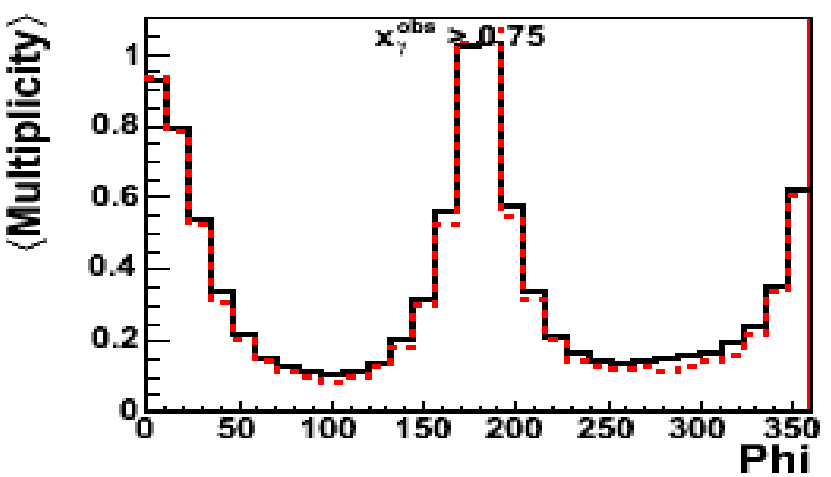
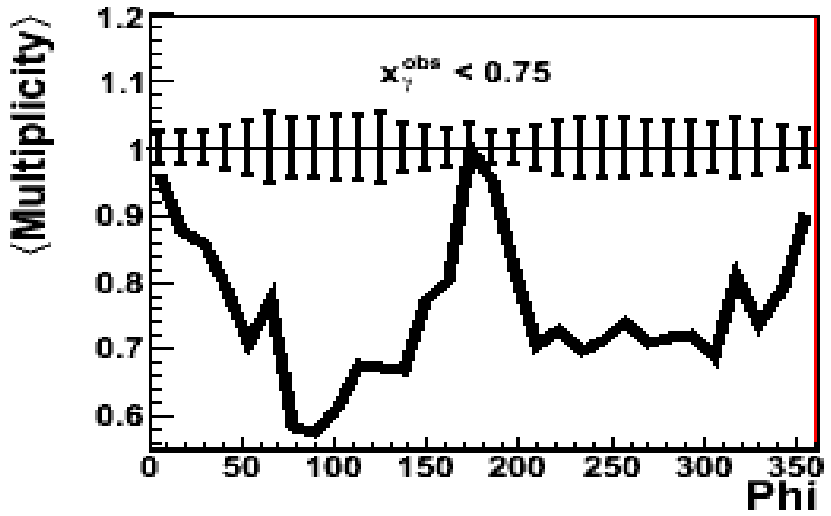


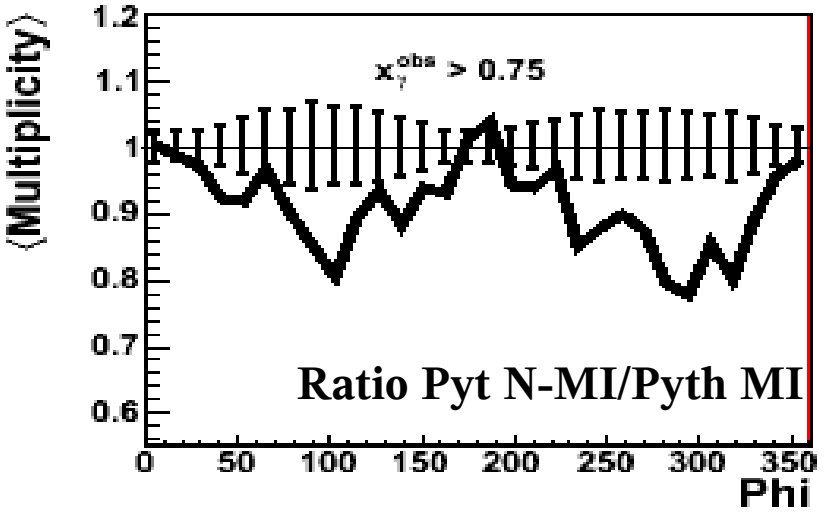
Dijet sample track multiplicity

Particle multiplicity: Average number of measured particles per event.









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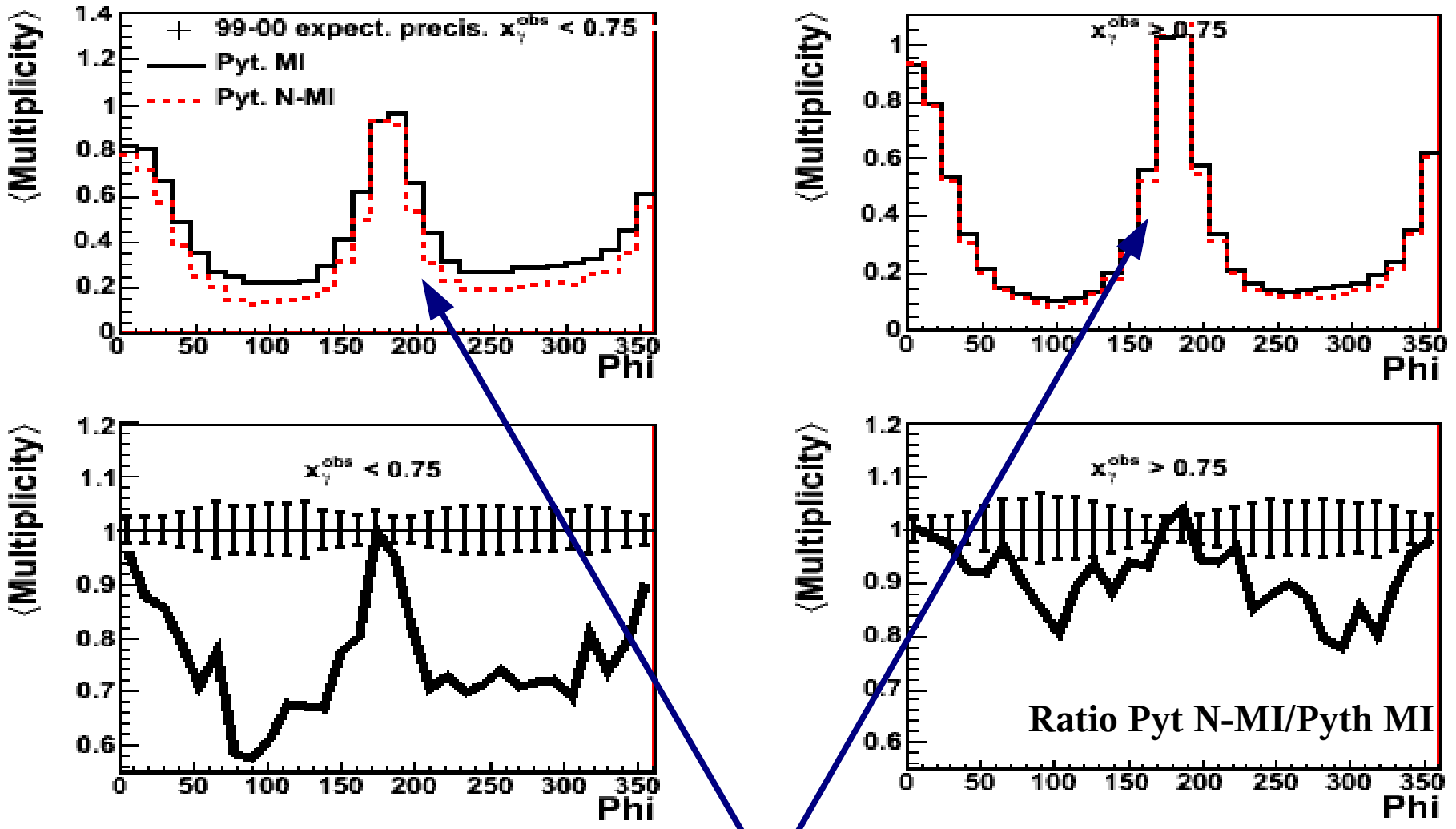

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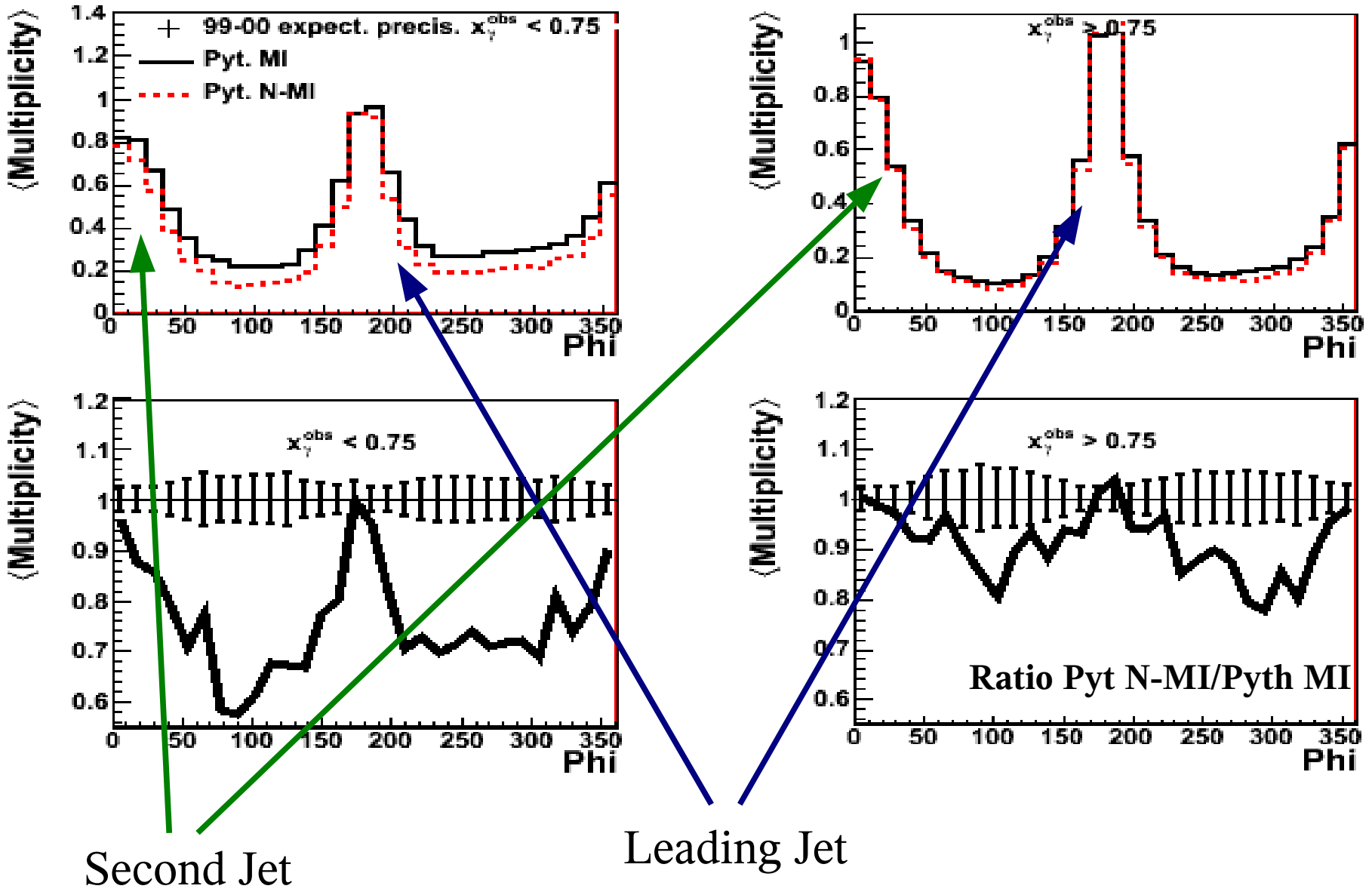

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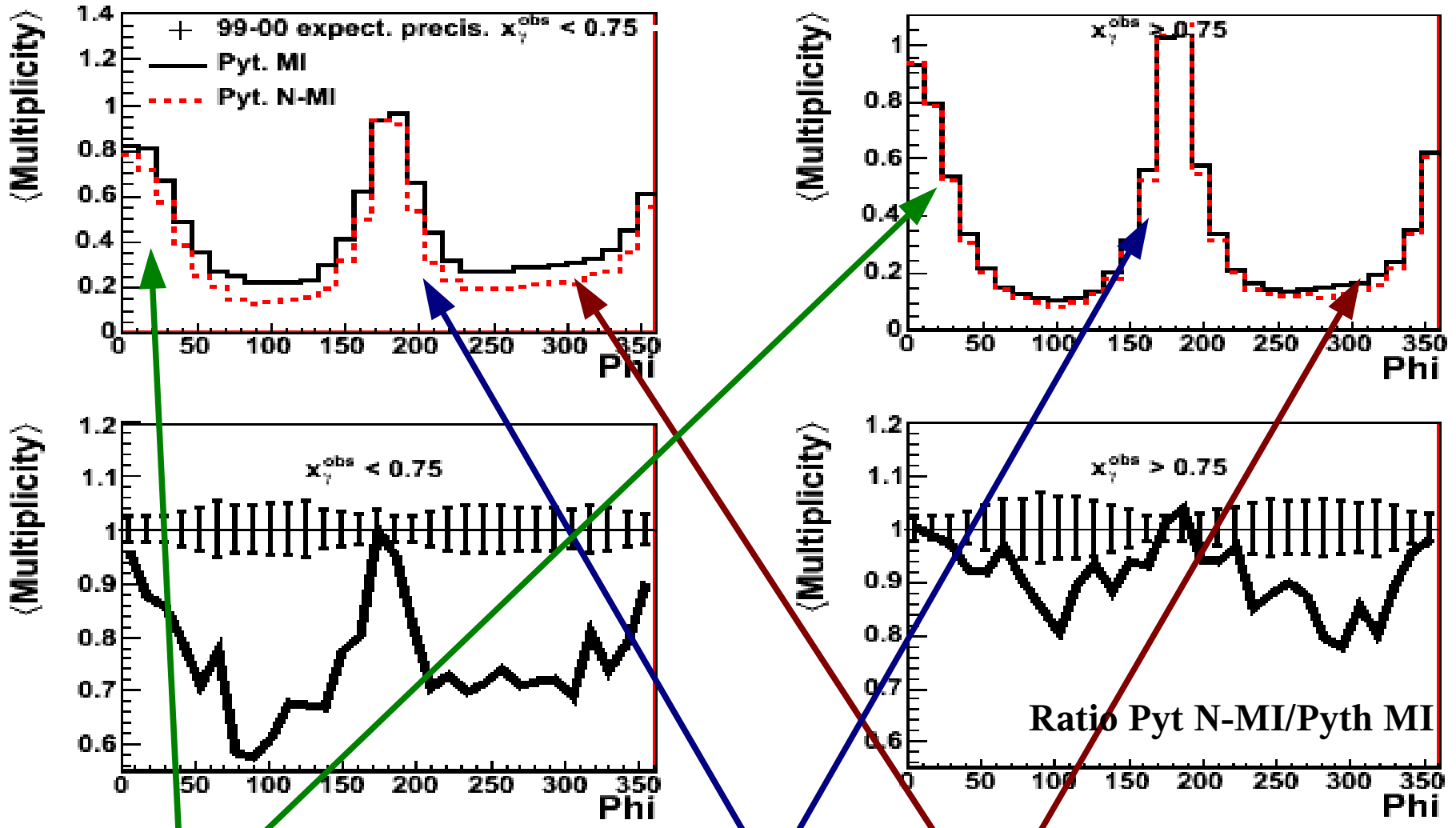

Second Jet

Leading Jet

Shoulder due to hard radiation or a 3rd Jet

Dijet sample track multiplicity

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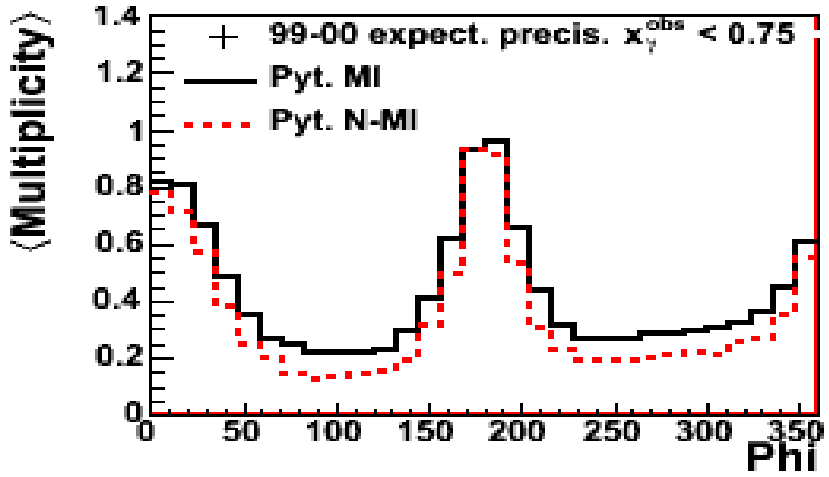

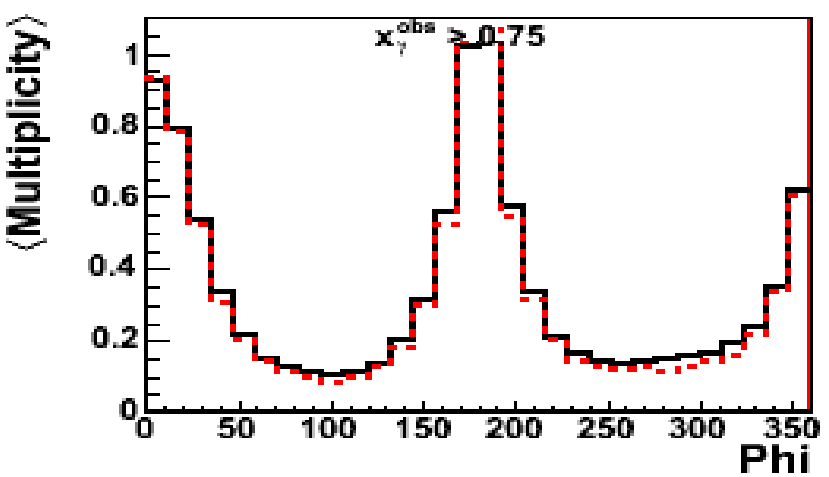

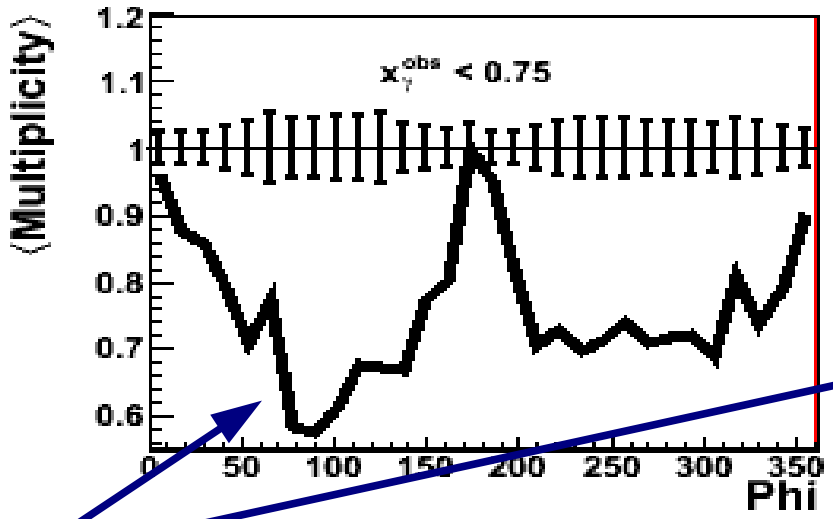

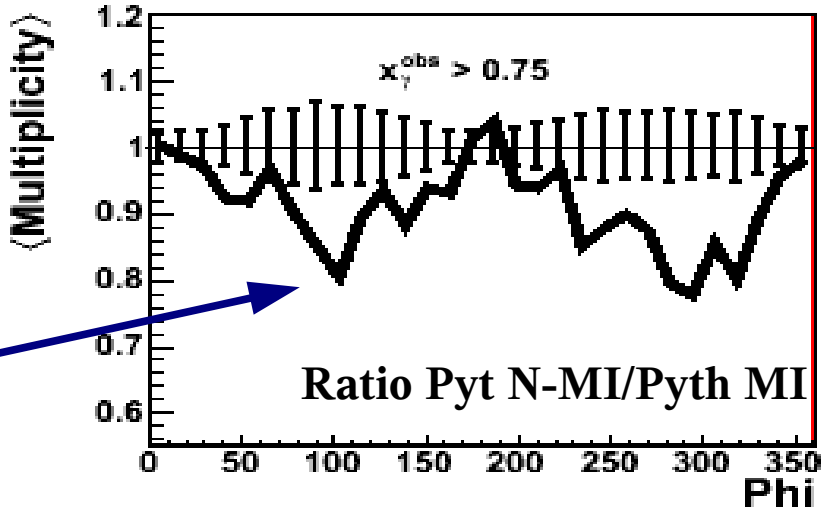

Ratio Pyth N-MI/Pyth MI

Dijet sample track multiplicity

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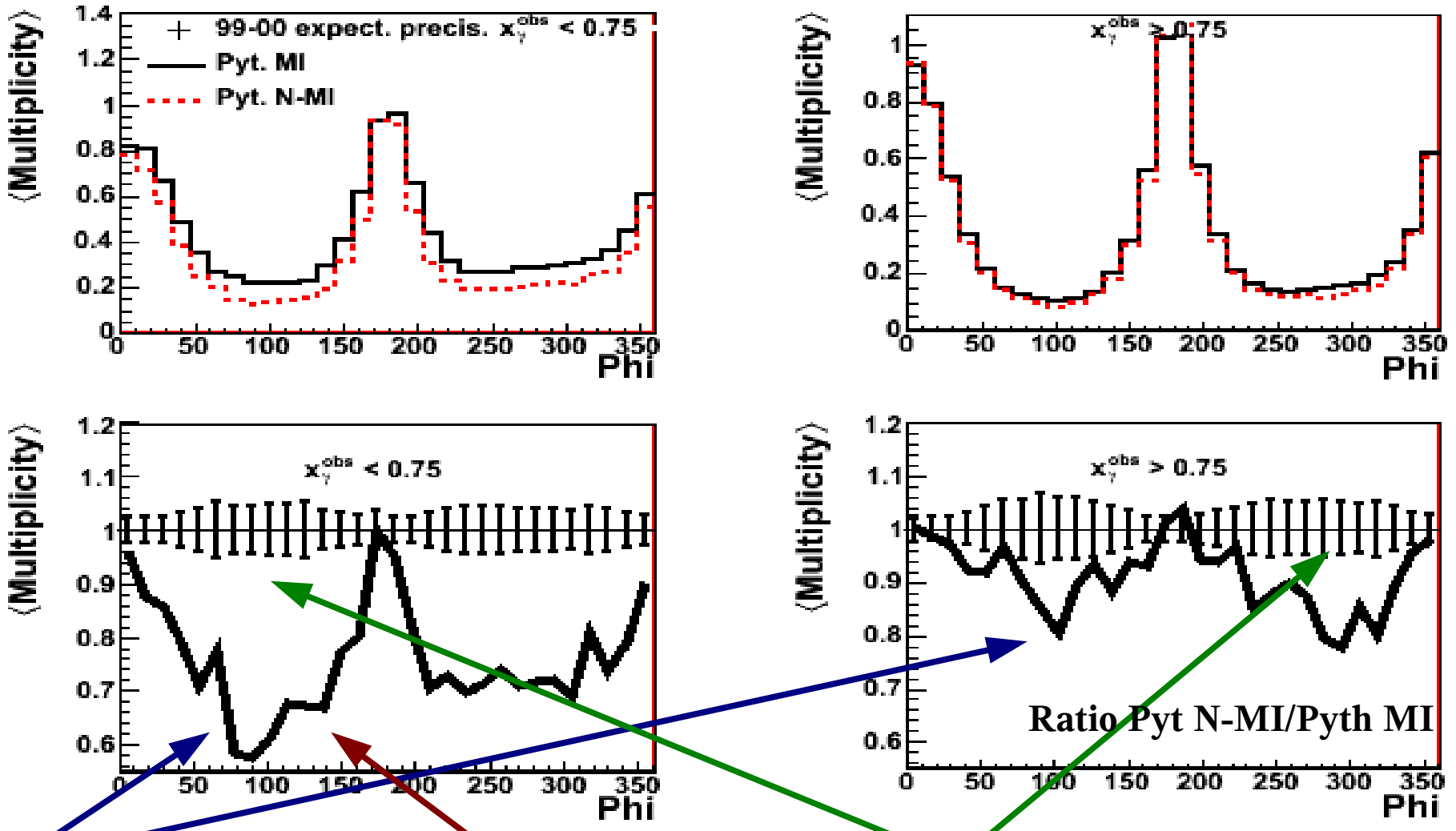

Ratio Pyth N-MI/Pyth MI

expected precision with 99-00 data

~6σ in between!

Dijet sample track multiplicity

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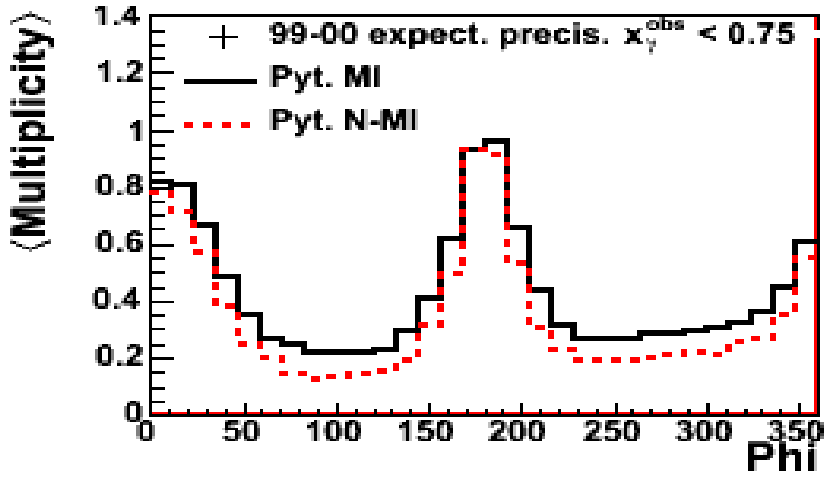
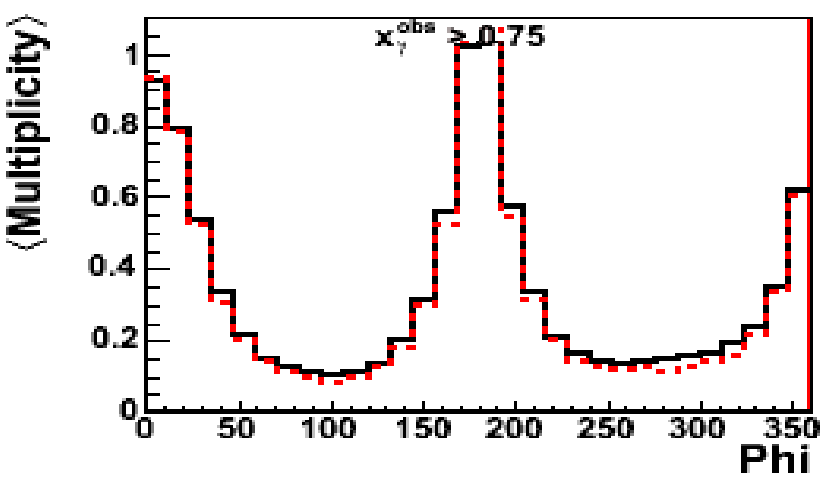
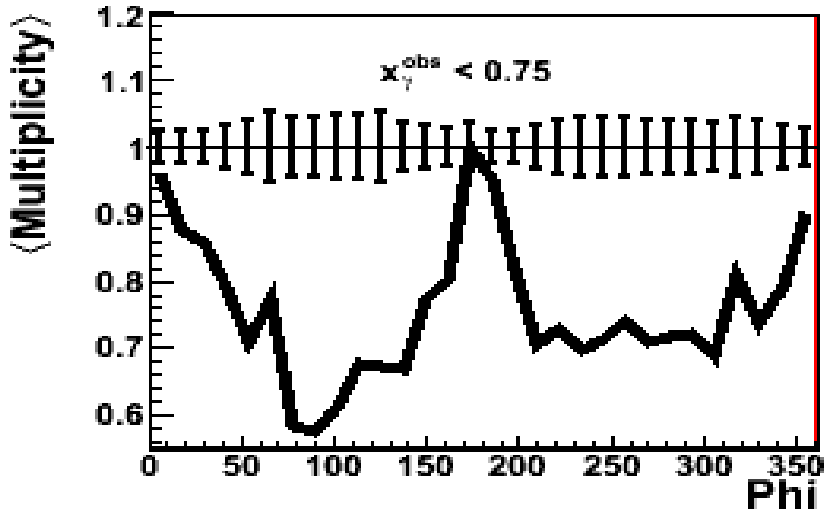
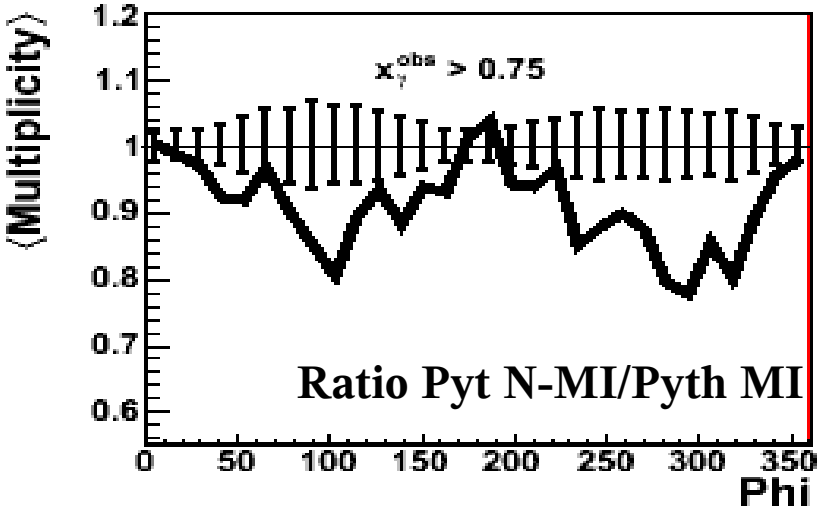




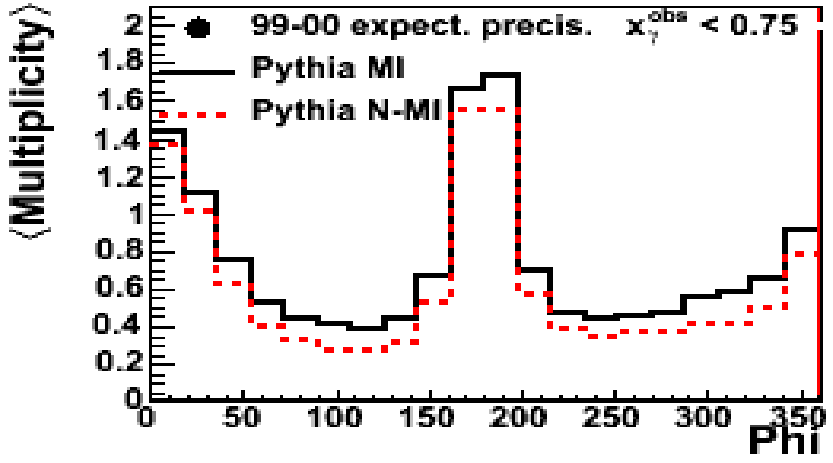


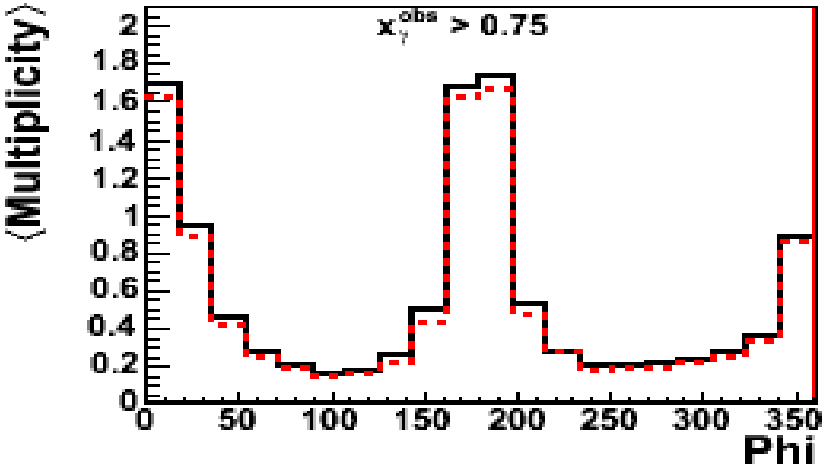


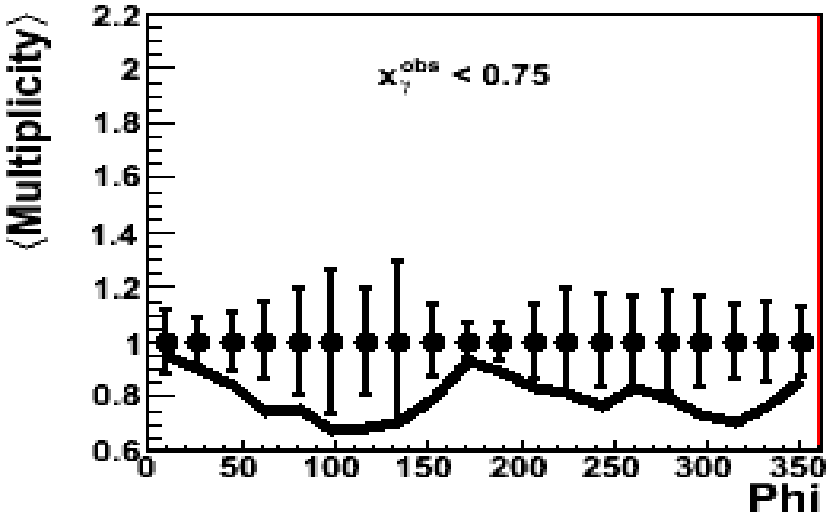
Large differences between both models!

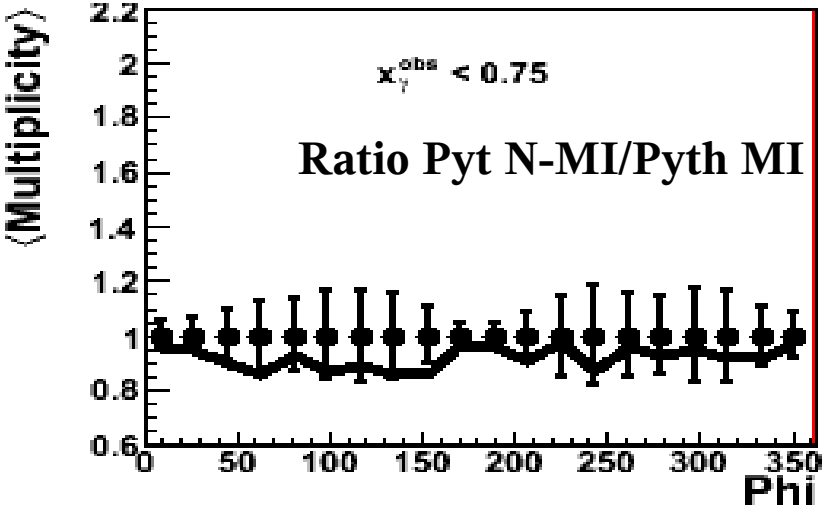
Charm with dijet track multiplicity

Particle multiplicity: Average number of measured particles per event.



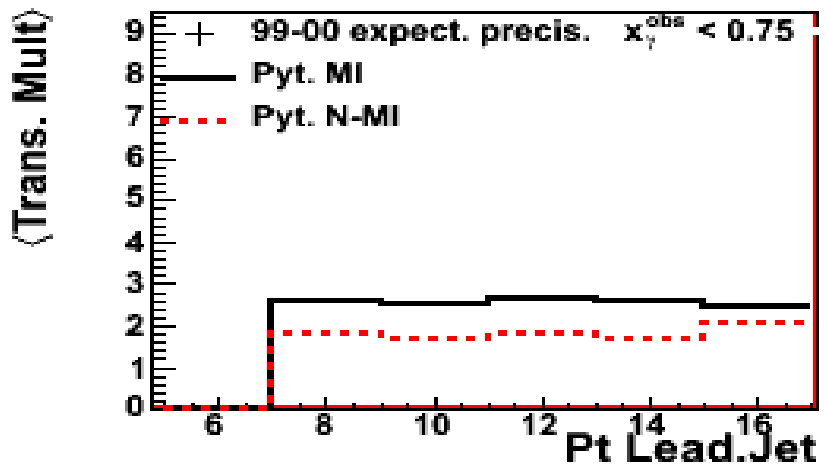


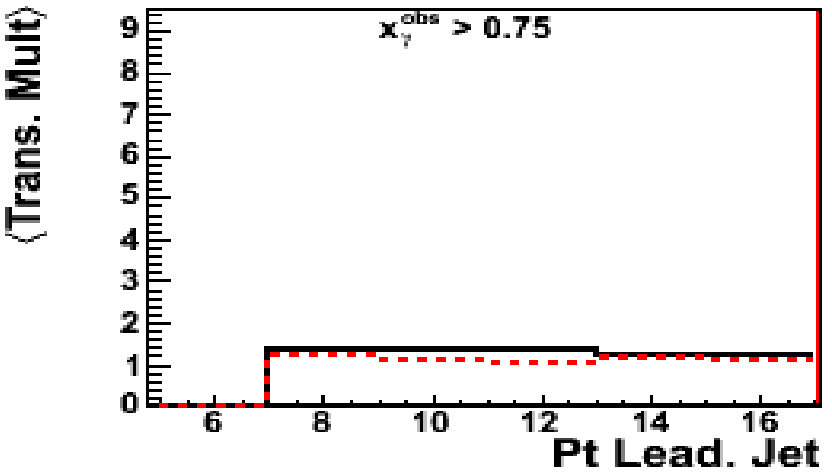


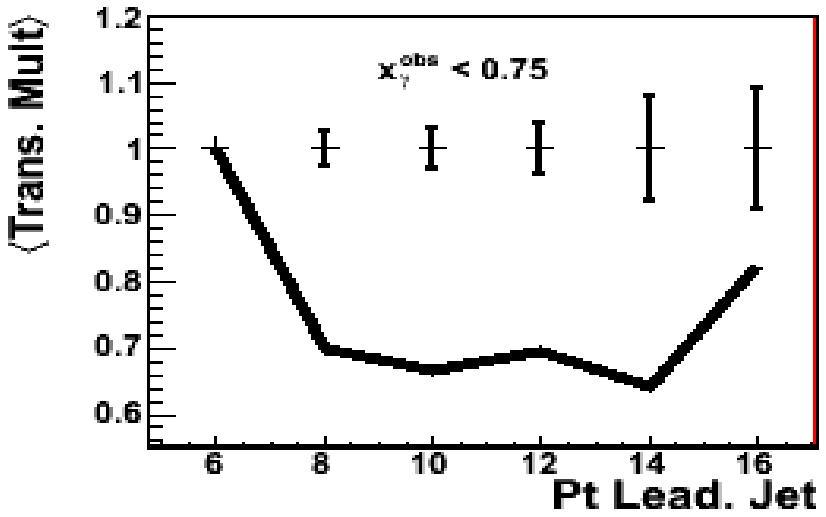


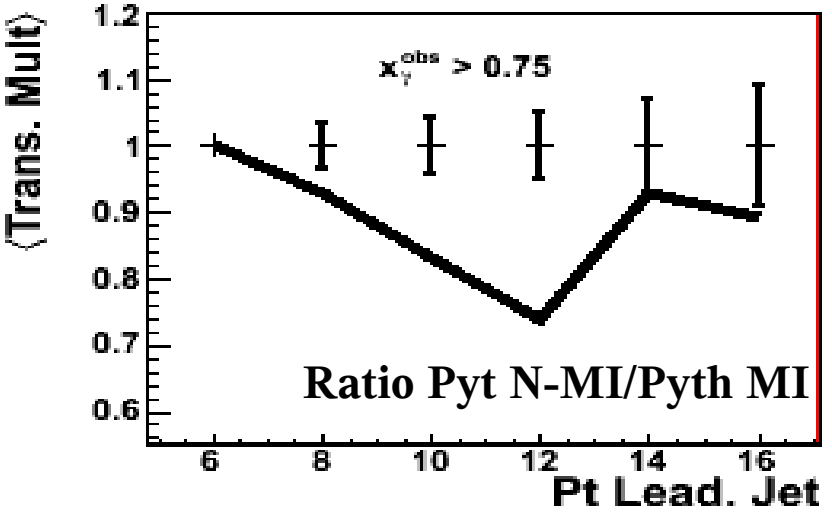
Smaller differences between both models!

Dijet track multiplicity: Transverse region



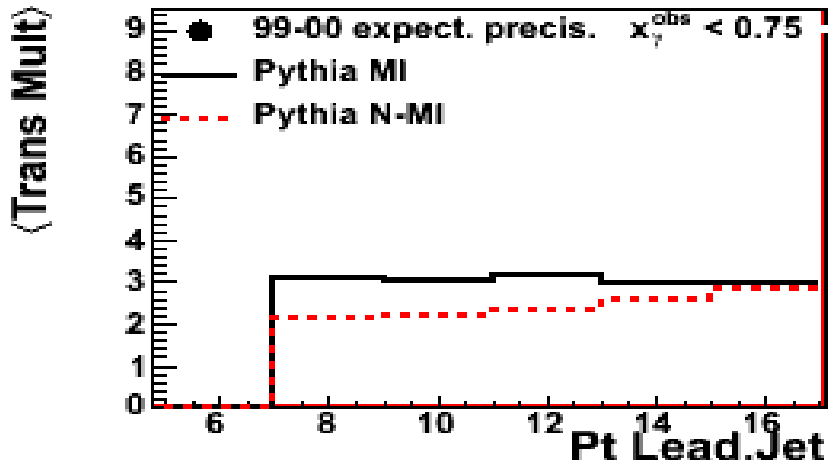


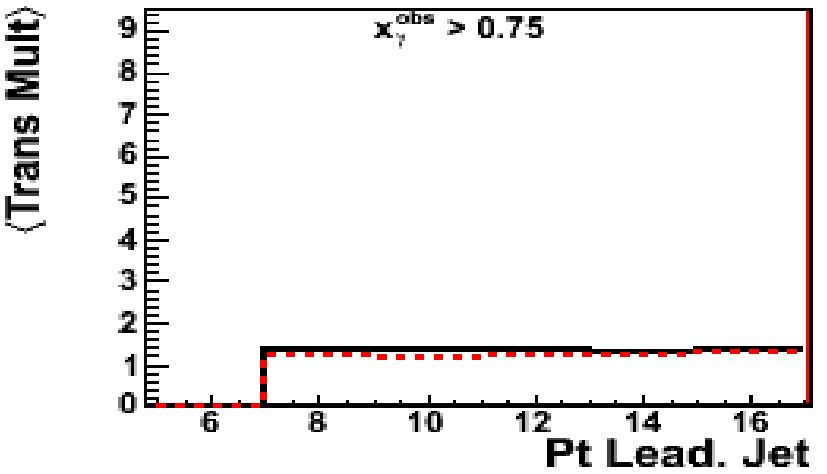


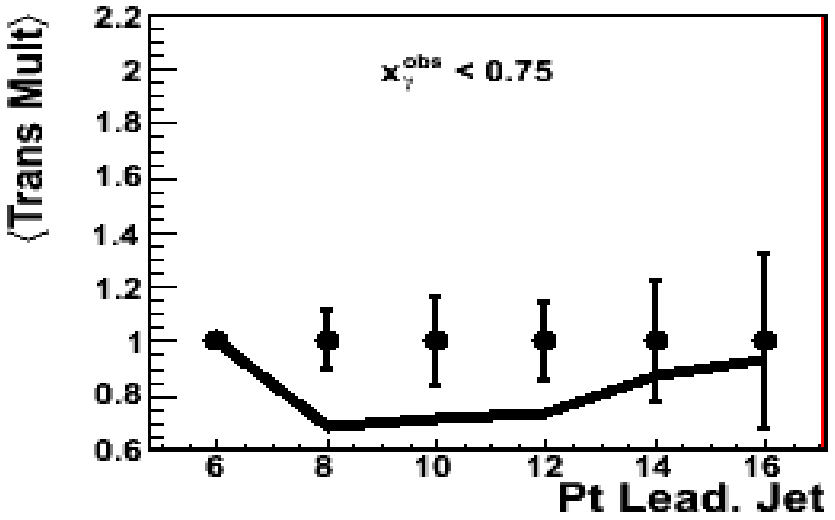


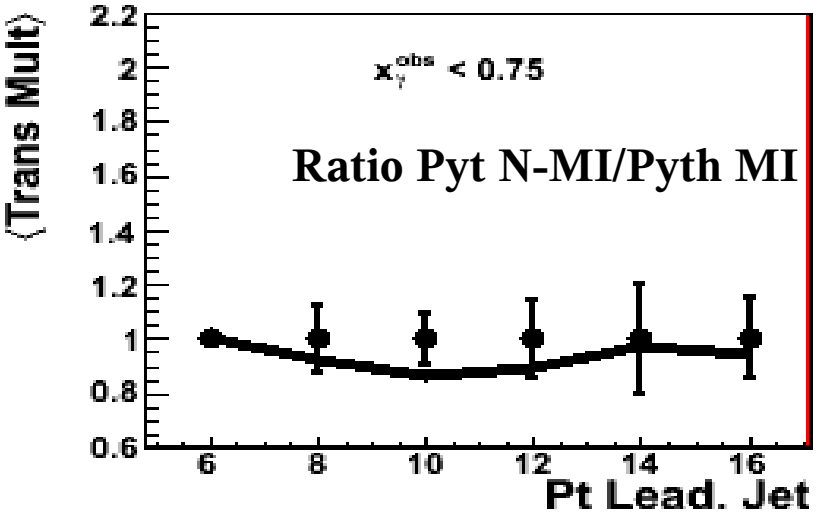
Also here large differences !

Charm with Dijet track multiplicity: Transverse region









Again smaller differences in the charm with dijets.

Summary

For the dijet sample...

- PYTHIA MI describes jet shapes.
- Differences between PYTHIA MI and PYTHIA w/o MI are very large (in the high act. transverse region around ~6σ).

For the charm with dijets sample...

- Here is PYTHIA w/o MI which describes jet shapes
- Differences between PYTHIA MI and PYTHIA w/o MI are here not so large.

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All the observables presented here can help us to understand MI and we still have a lot to learn.

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For the dijet sample...

- ✗ PYTHIA MI describes jet shapes.
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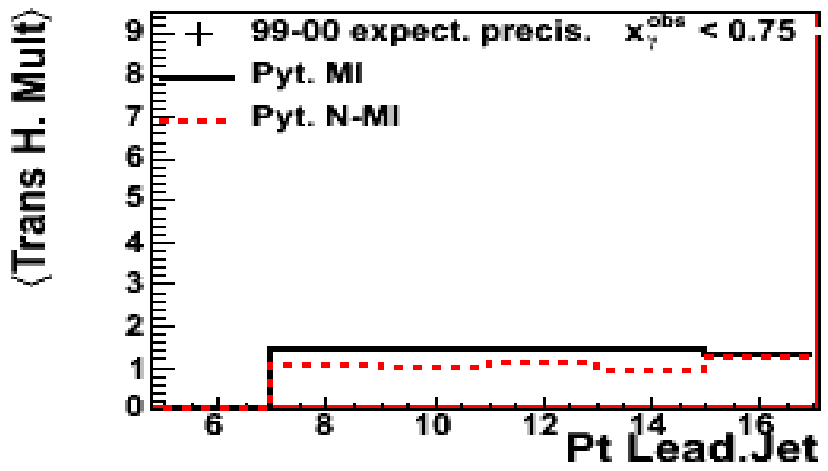
All the observables presented here can help us to understand MI and we still have a lot to learn.

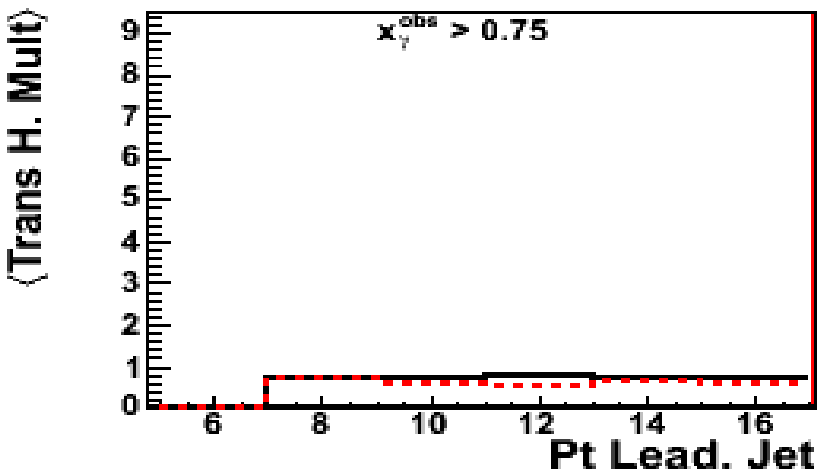
One thing is clear: we have to work harder to understand this mechanism. It is important for the LHC !!

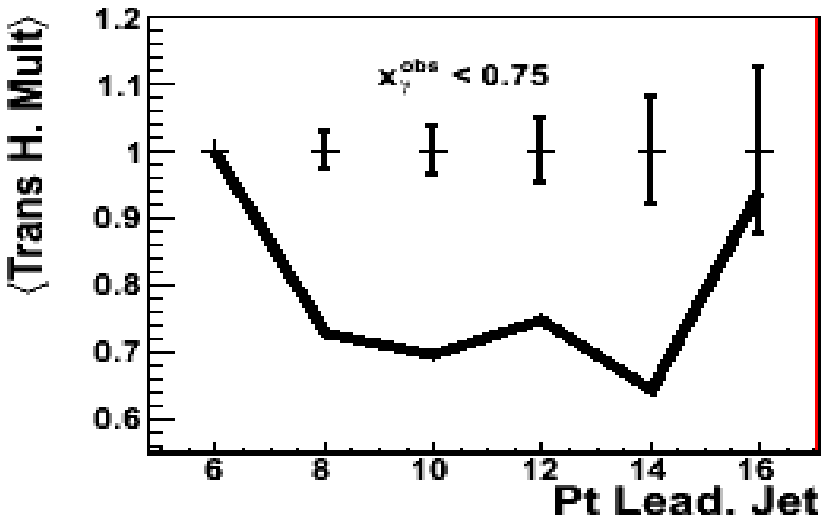
Thank you for
your attention!

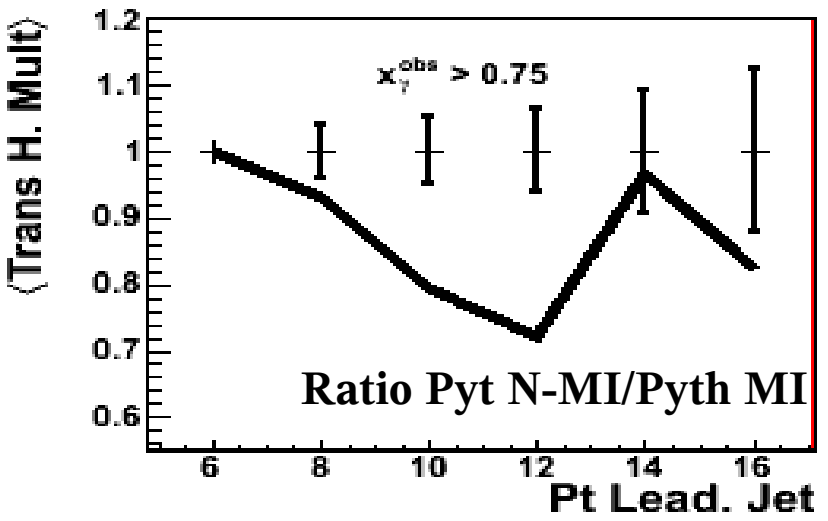
Backup

Dijet mult.: High activity transverse region



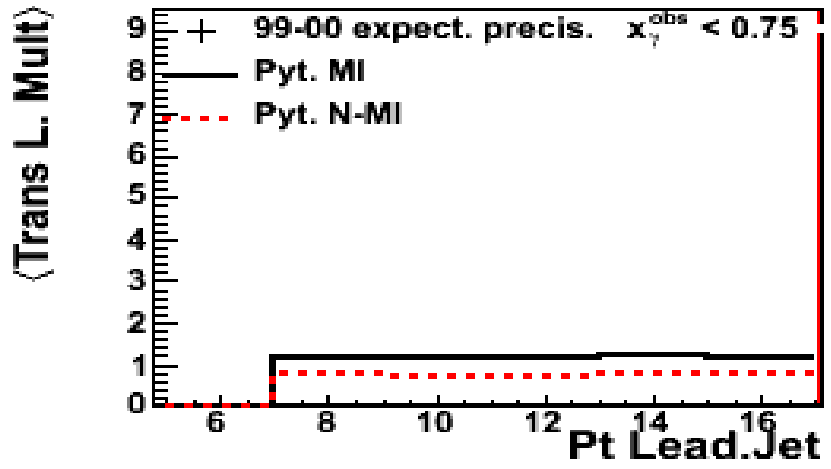


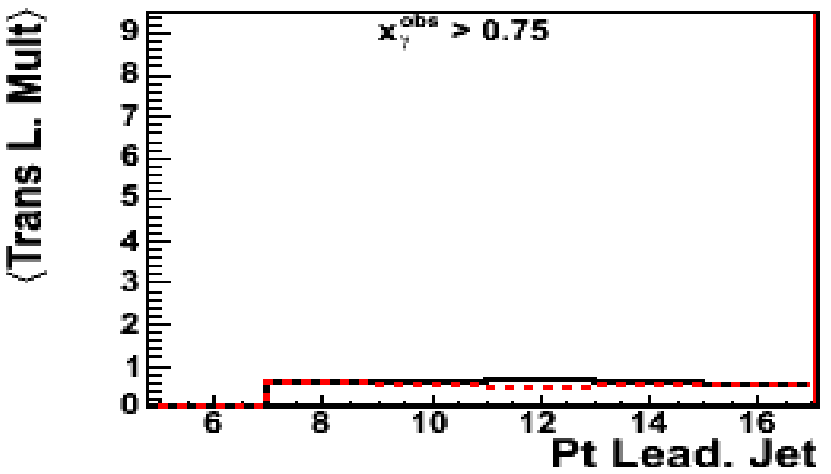


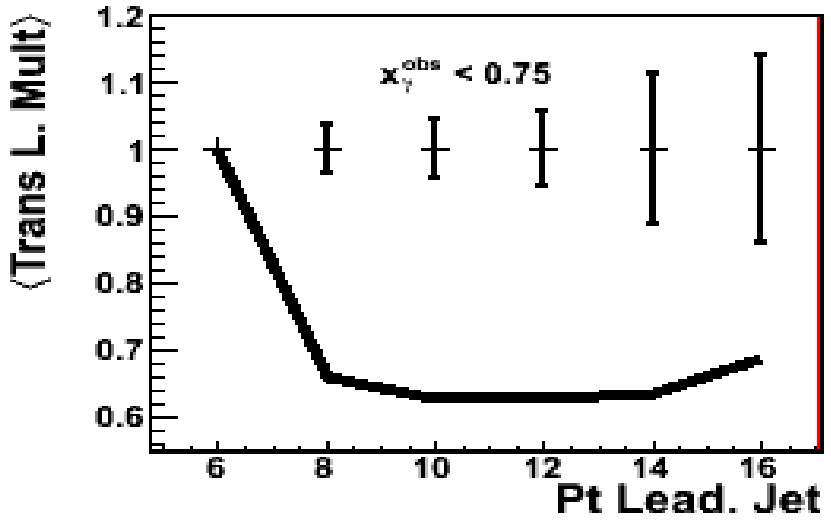


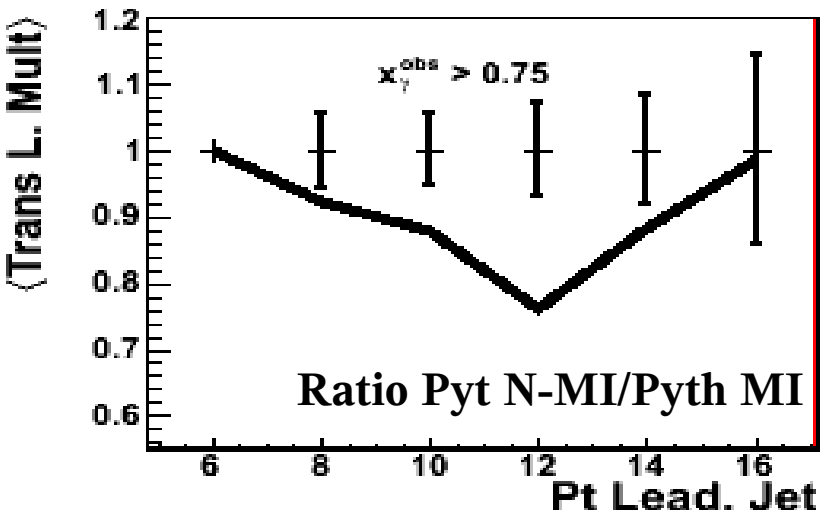
Also here large differences !

Dijet mult.: Low activity transverse region





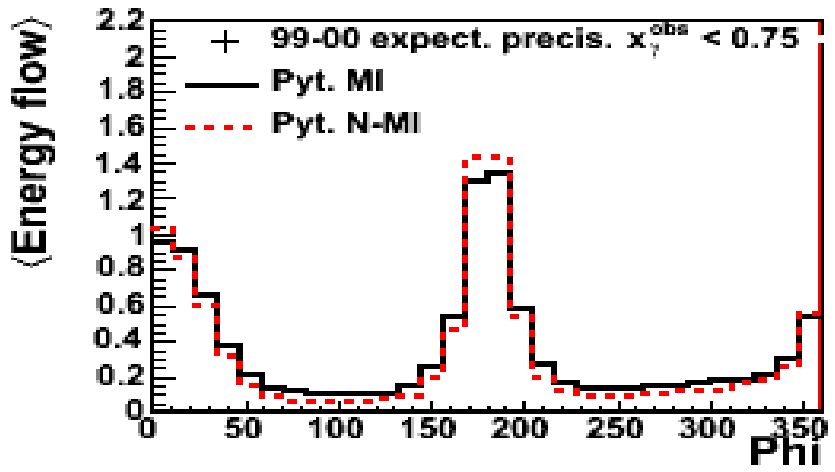


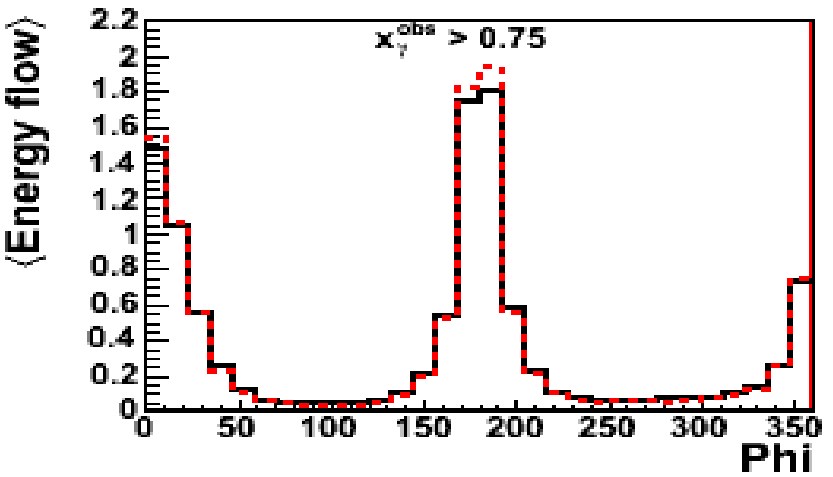


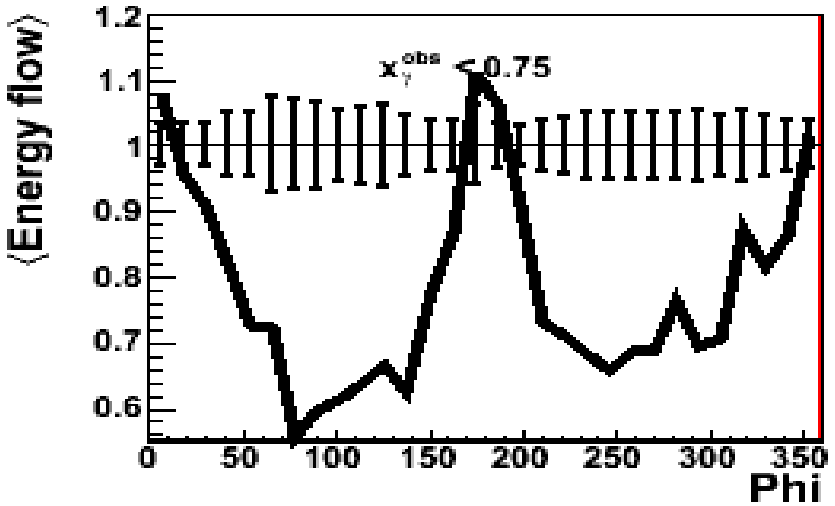
Also here large differences !

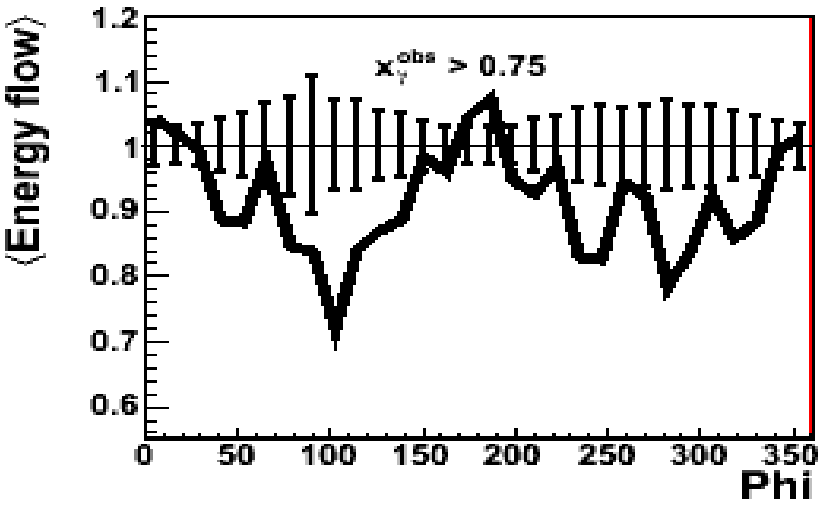
Dijet track energy flow

Energy flow: average scalar Pt sum per event.





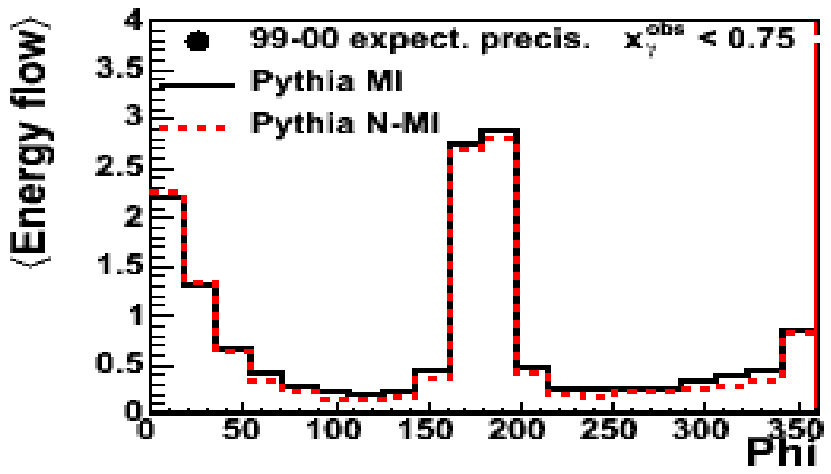


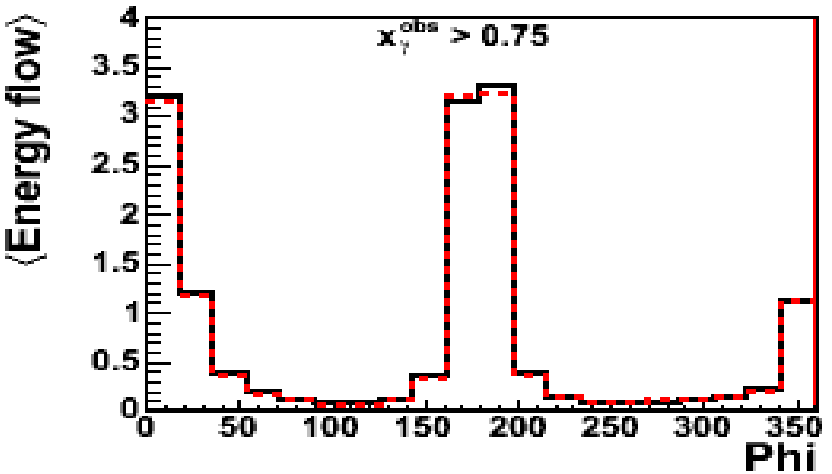


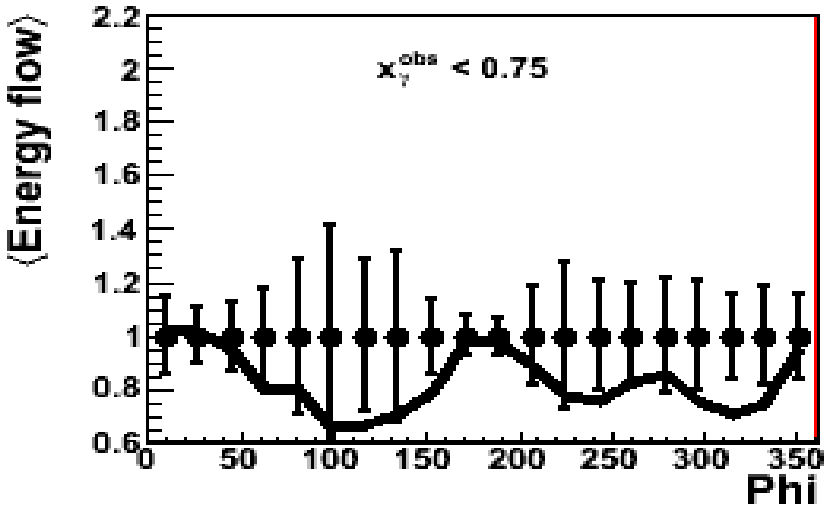
Also here large differences !

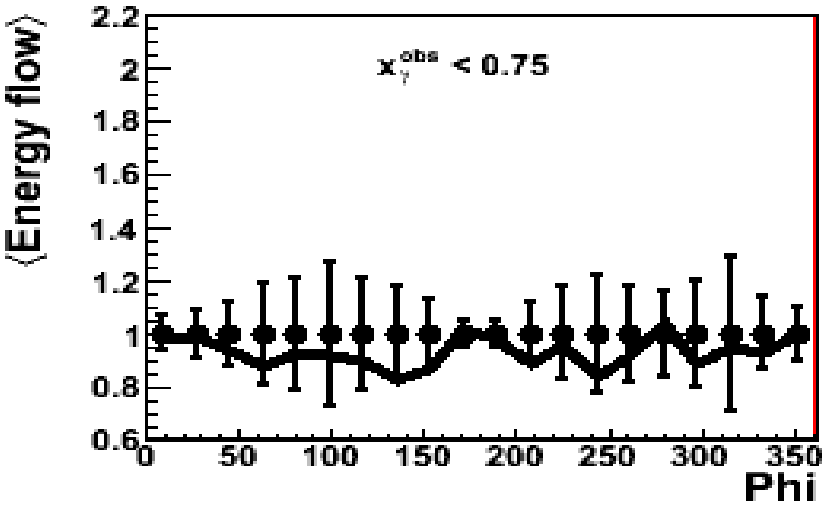
Charm with dijets track energy flow

Energy flow: average scalar Pt sum per event.



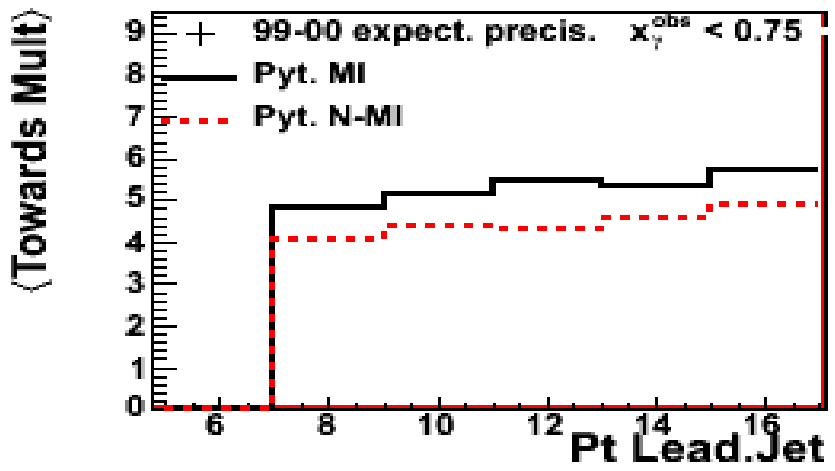


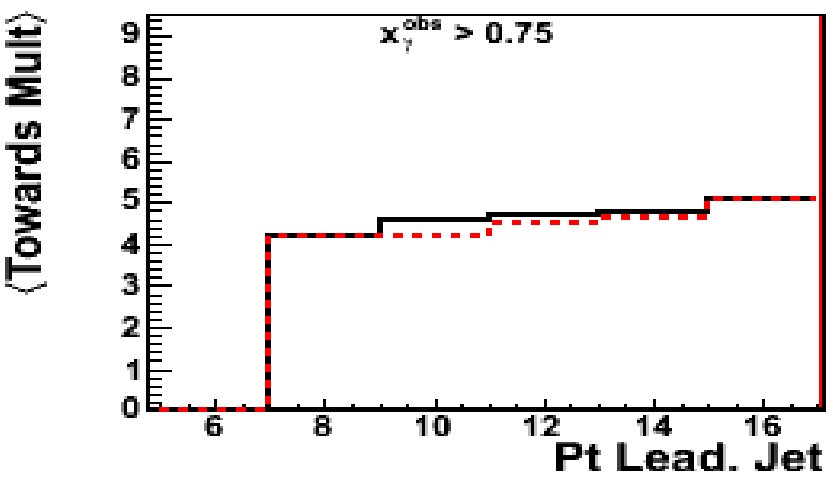


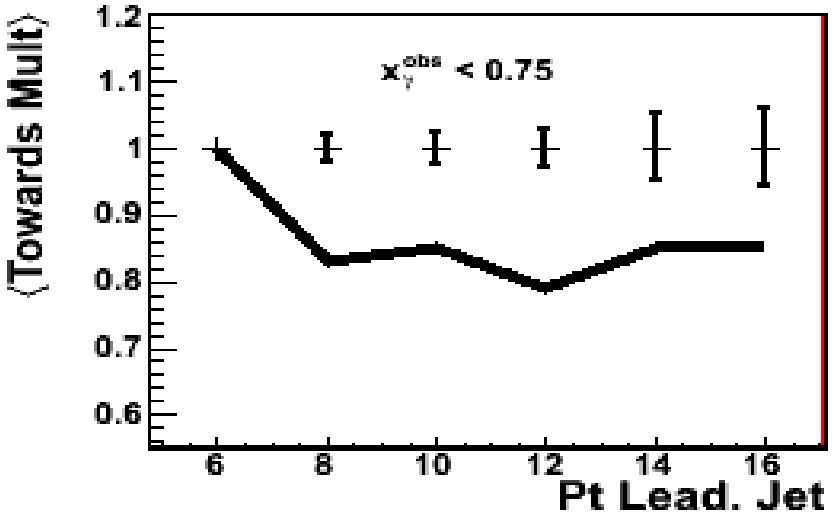


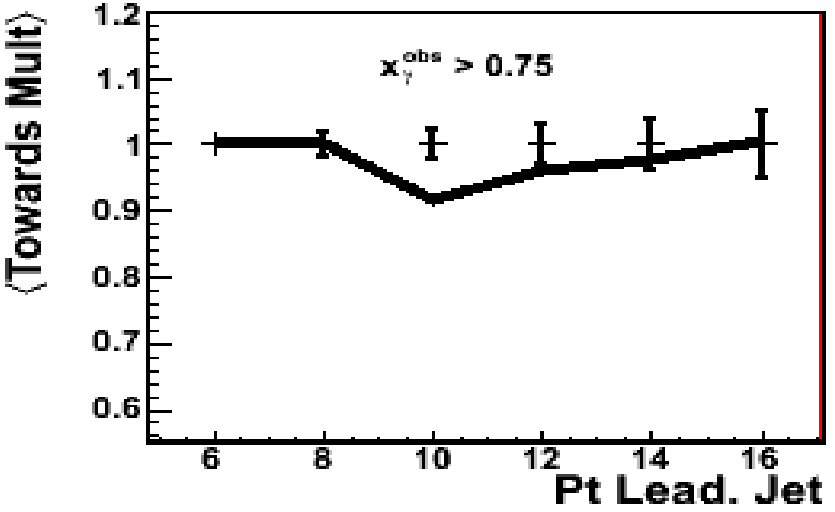
Again smaller differences between both!

Dijet track multiplicity: Toward region



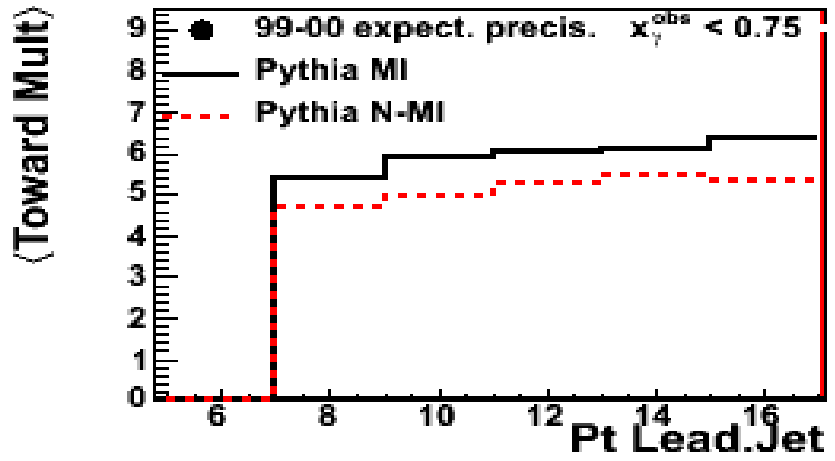


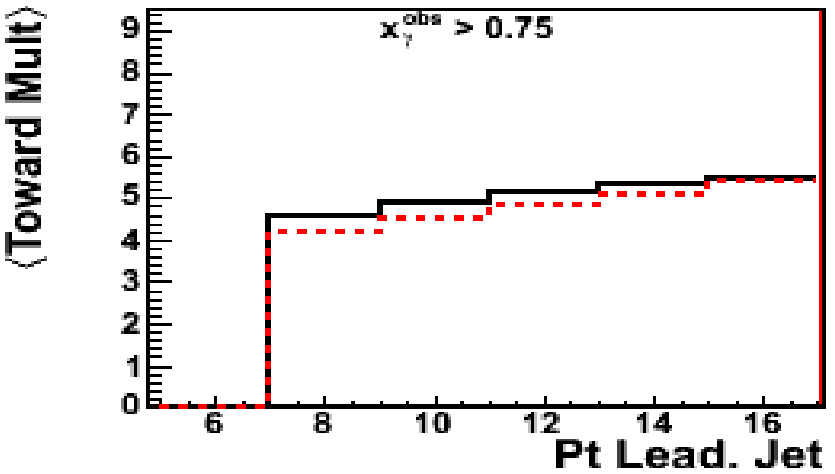


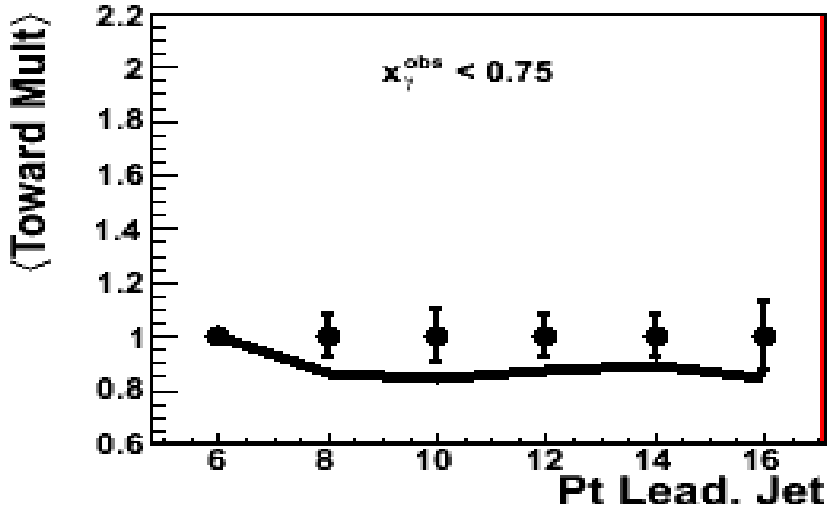


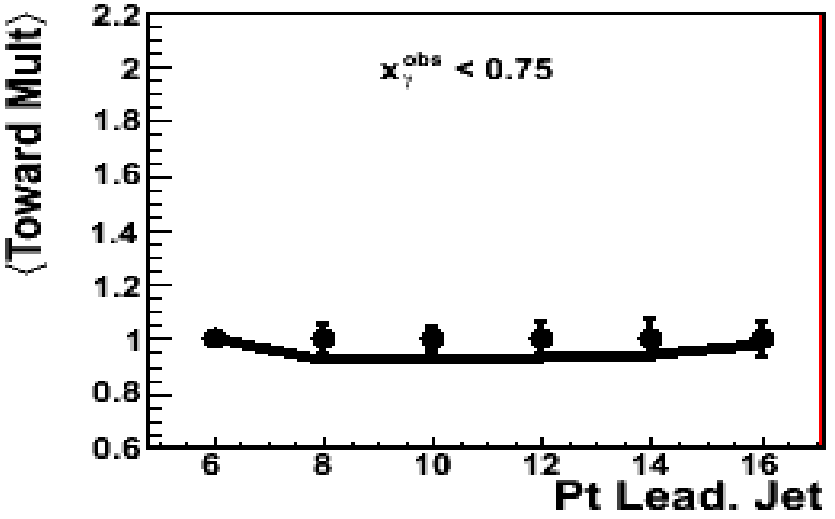
Also here large differences !

Charm with Dijet track multiplicity: Toward region



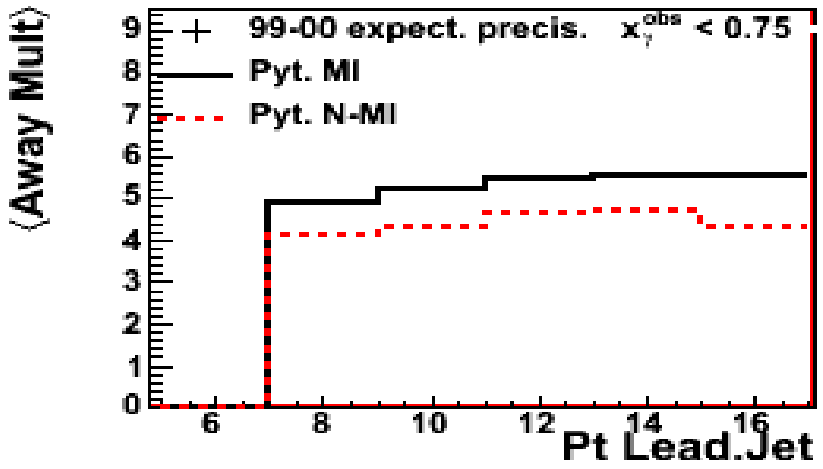


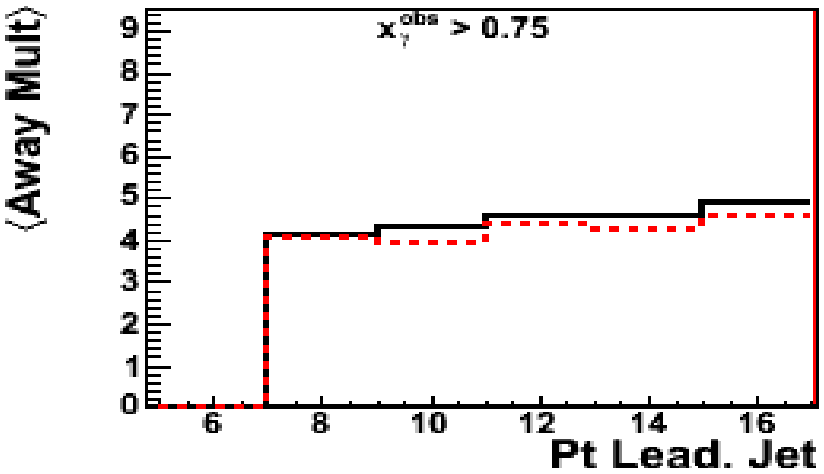


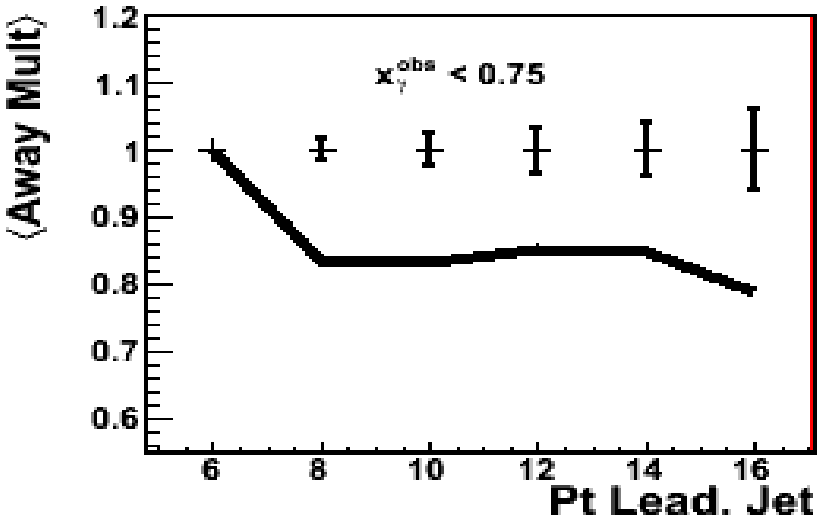


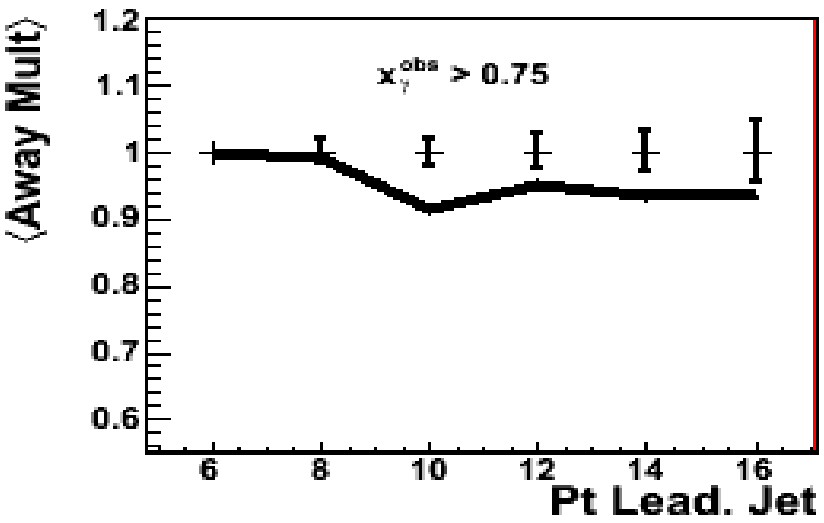
As usual for charm with dijet: no large differences.

Dijet track multiplicity: Away region



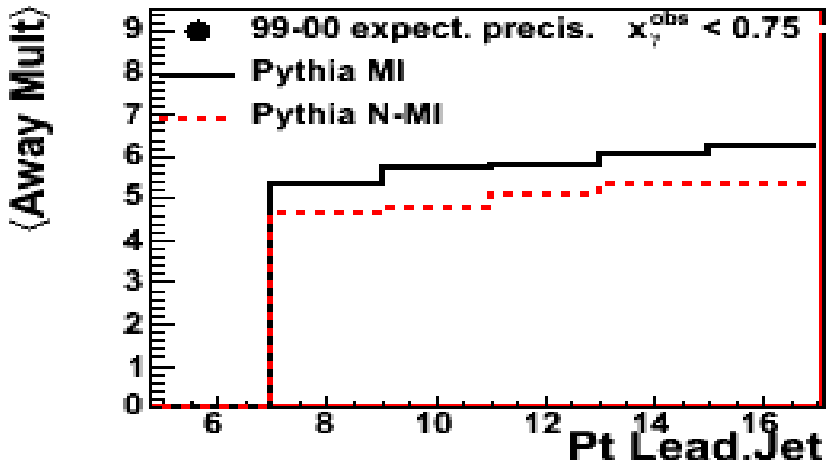


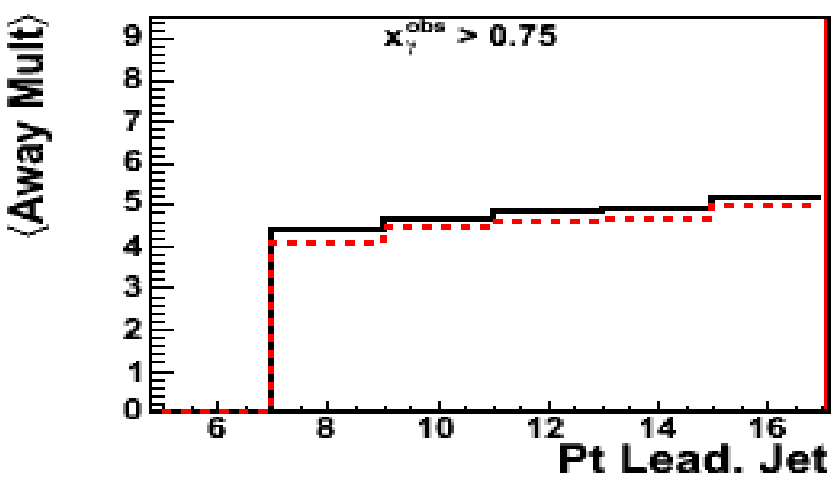


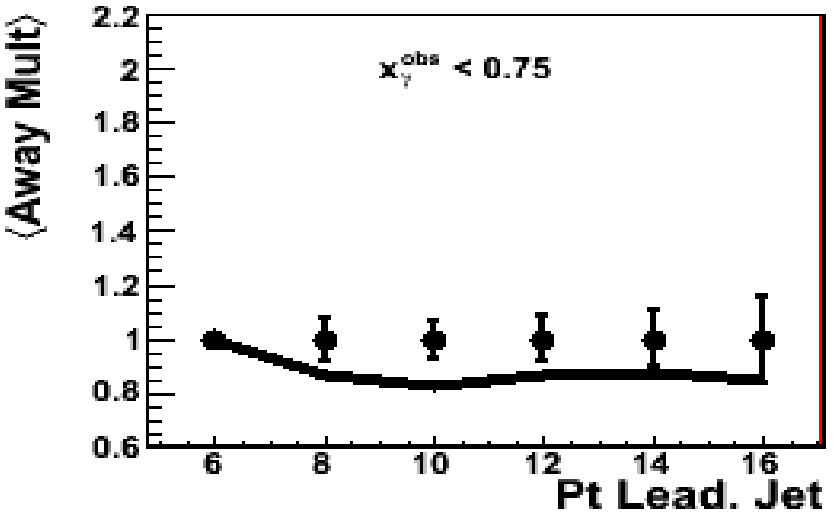


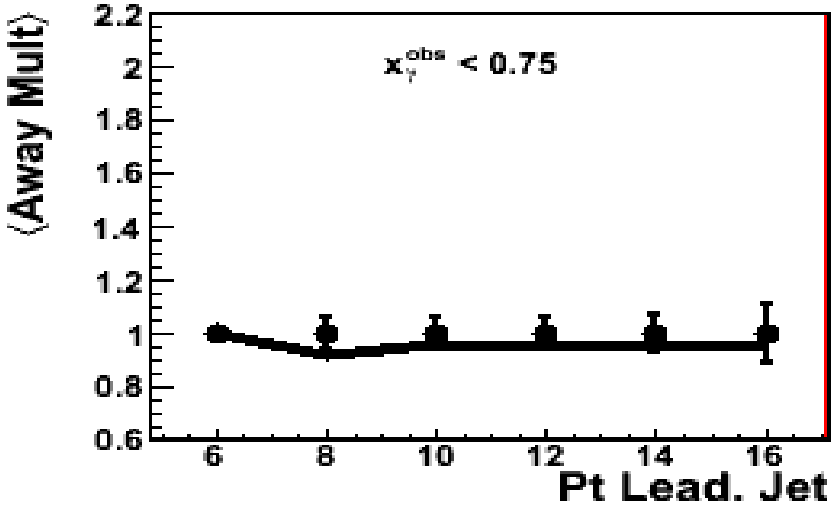
Also here large differences !

Charm with Dijet track multiplicity: Away region









As usual for charm with dijet: no large differences.

Pythia MI Model.

Parameter values used in Pythia:

- PARP 67: set to 4 (default 1). Scale factor that governs the amount of initial-state radiation
- MSTP 82: set to 1. Same MI probability in all events. Abrupt Ptmin cut-off.
- PARP 82: set to 1.20GeV (default 1.55GeV). Regularization scale. Cut-off for MI.
- MSTP 93: set to 5 (default 1). Primordial K_t distribution in photon $dK^2_t/(K^2_{t0} + K^2_t)$
- PARP 99: set to 0.6GeV (default 0.4GeV). K^2_{t0} value in MSTP93
- PARP 100: set to 5GeV (default 2GeV). Upper cut-off for primordial K_t distribution.

Dijet sample selection

- Data: 1999-00 (subtrigger s83)
  - Electron tagger ET33: photoproduction ($Q^2<0.01 GeV^2$)
  - $0.3 < y < 0.65$ (from the scattered electron).
- DiJet sample with: $P_t > 7(6)$ GeV

$$|\eta| < 1.5$$

Charm with dijet sample selection

- Data: 1999-00 (subtriggers s19 & s22)
  - Photoproduction ($Q^2 < 1GeV^2$)
  - $0.2 < y < 0.8$
- DiJet sample with: $P_t > 7(6)$ GeV

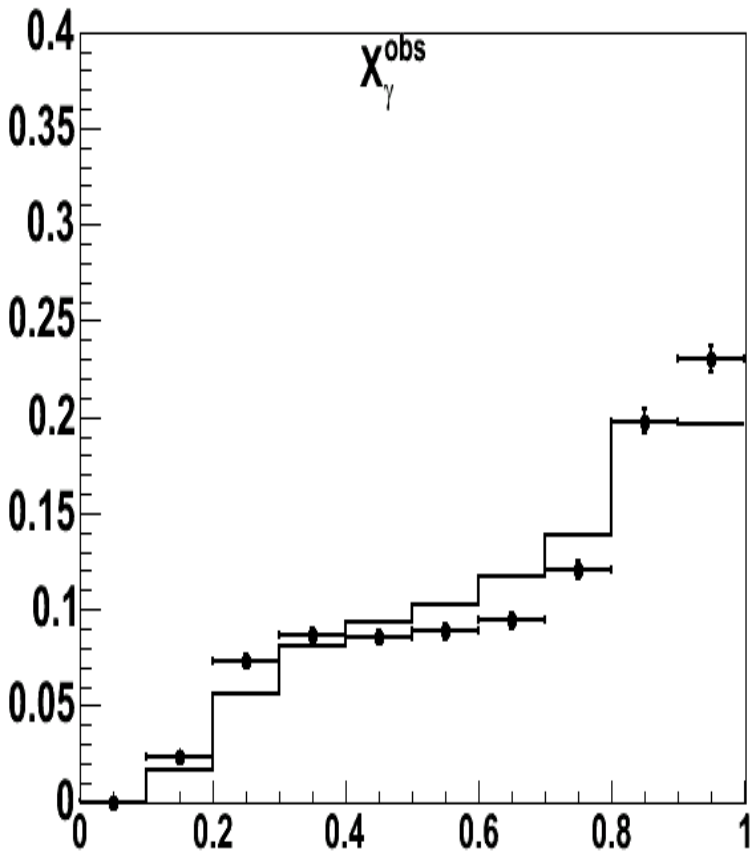
  $|\eta| < 1.5$
- Muon with $P_t > 2.5$ GeV and $|\eta| < 1.5$ in one of the Jets.
  - pt rel < 1.0 GeV
  - -0.1< impact parameter < 0.15
    - fake (18%) and beauty (11%) fractions ➡ subtracted!

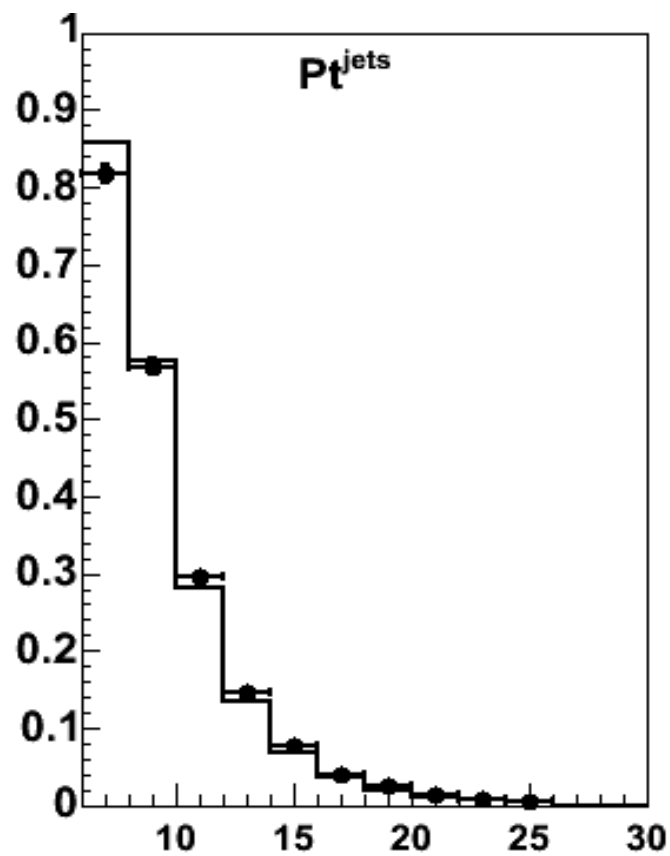
Particle selection

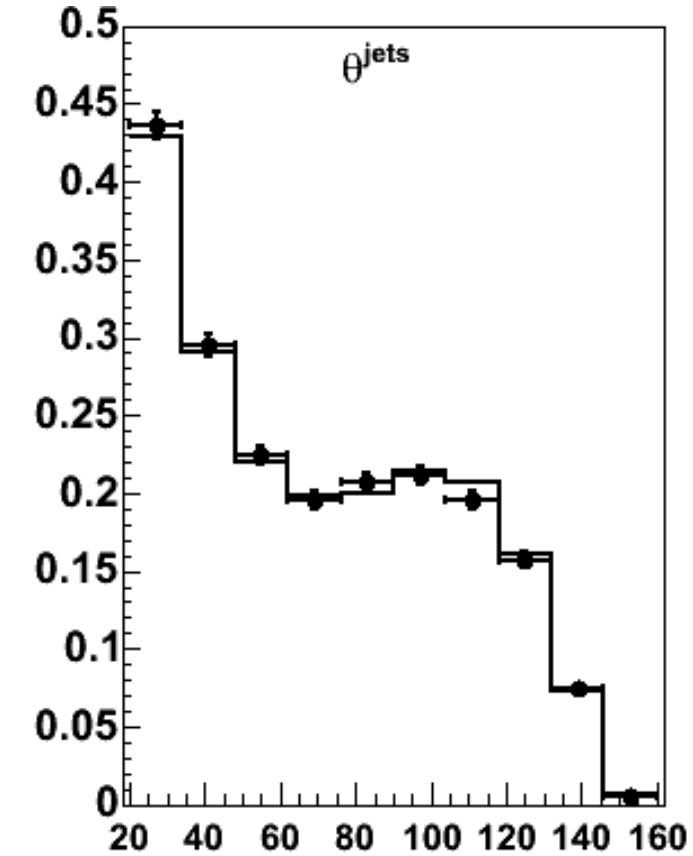
- Charged particles:
  - Primary vertex fitted tracks.
  - with $P_t > 150$MeV and $|\eta| < 1.5$
  - Radius length > 10cm
  - Start Radius < 30 cm
  - $|Z_{dca} - Z_{\circ}| < 20$ cm
  - $|dca \sin \Theta| < 1$ cm
    - P_t : ± 20 MeV
    - $|\eta|$: ± 0.2
    - Radius length +10 – 5 cm

Dijet sample control plots (some)

Pythia MI describes control plots pretty well:

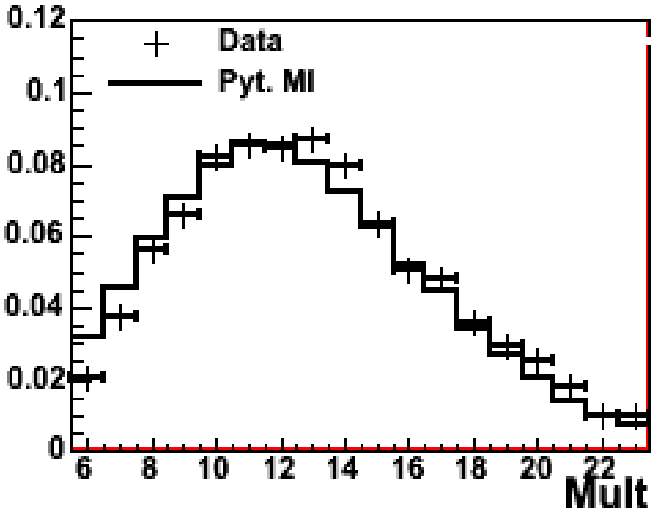


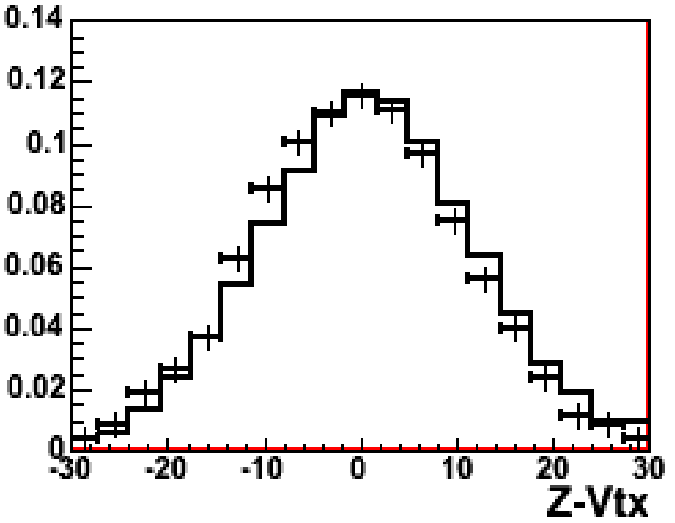


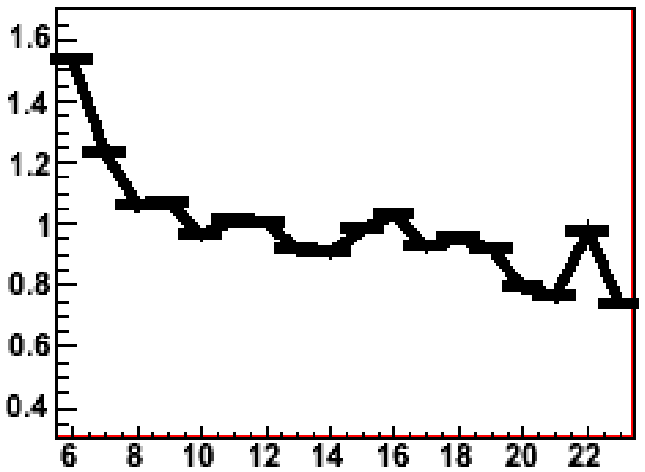


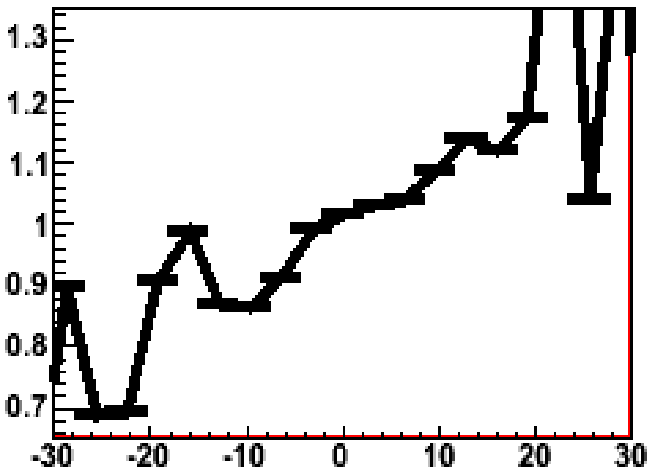
Dijet sample control plots (some)

Pythia MI describes control plots pretty well:



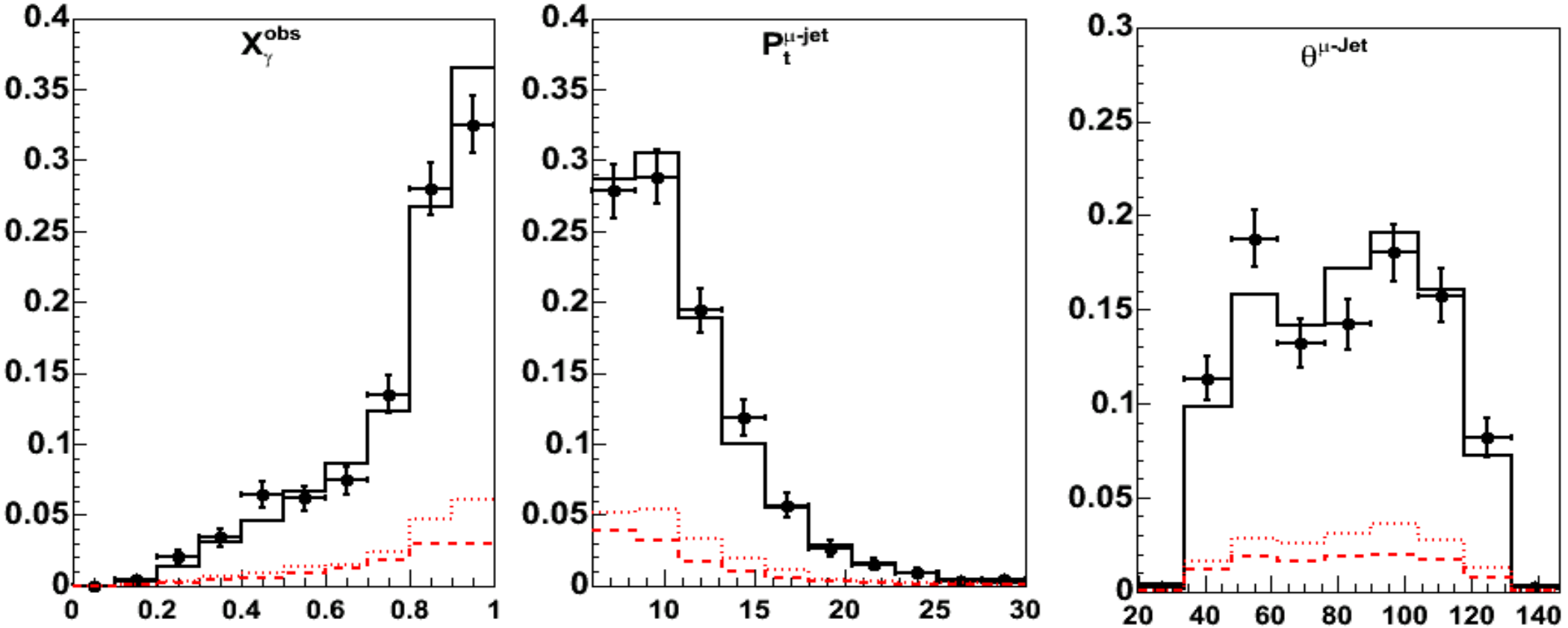






Charm with dijets sample control plots (some)

Pythia MI describes control plots pretty well:



Charm with dijets sample control plots (some)