Multiple Parton Interactions in PhotoProduction at HERA

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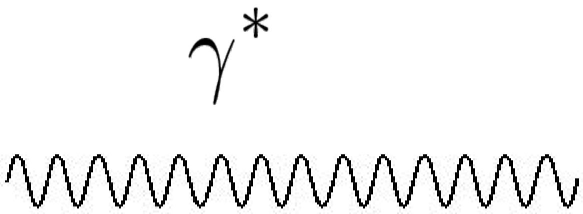
1st MPI@LHC, Perugia. 27th of October, 2008.

Introduction & Motivation

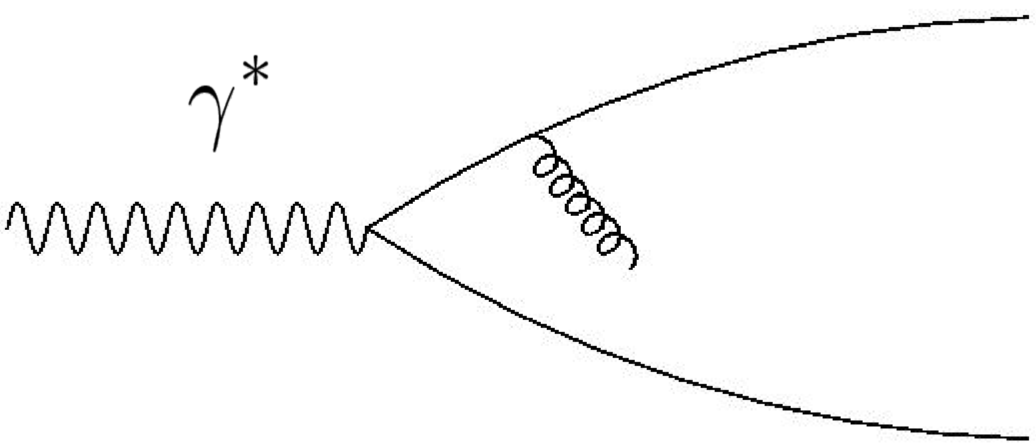
Introduction & motivation

- ✗ At high virtualities, Q^2, the photon is a point-like particle



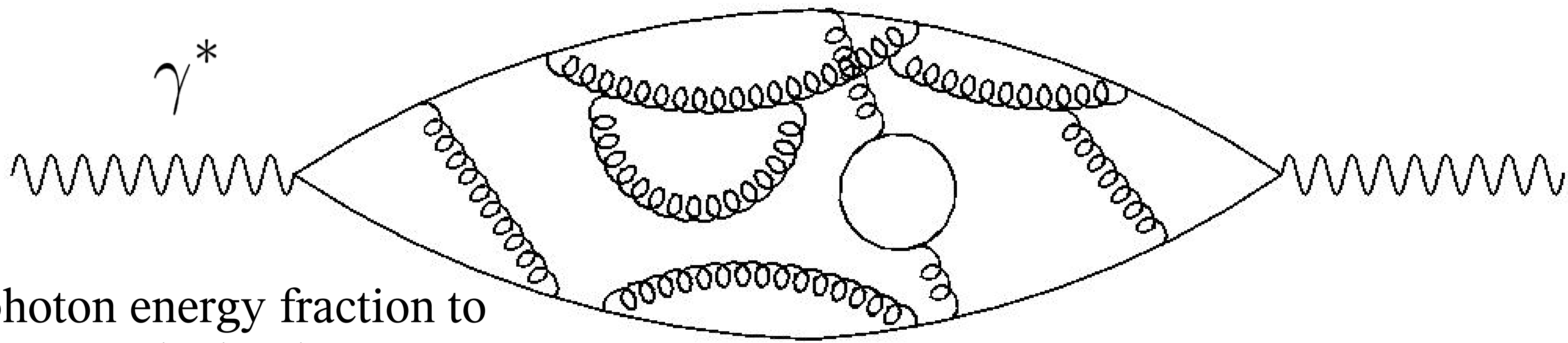
Introduction & motivation

✗ while going to lower virtualities the photon lives longer and may fluctuate into a quark-anti quark pair



Introduction & motivation

✗ in photoproduction the photon lives enough to develop a complicated hadronic structure.



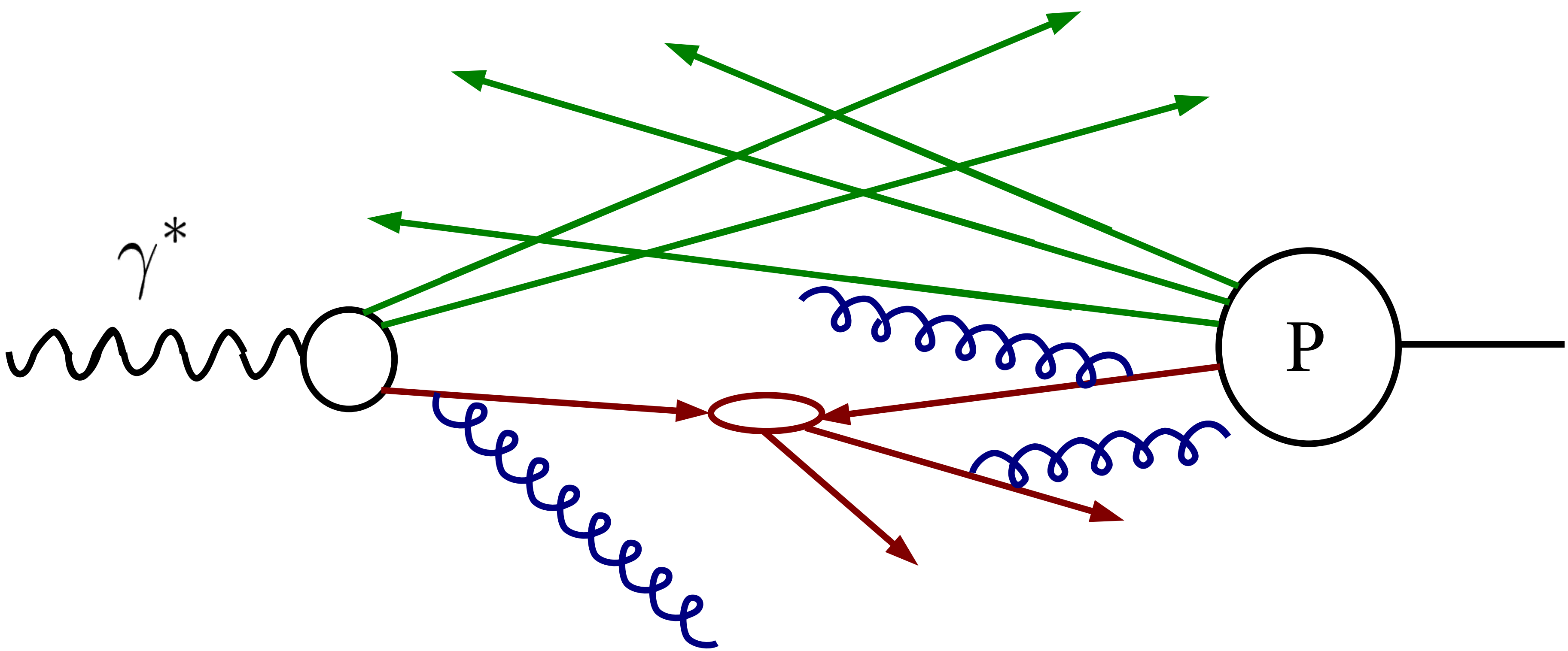
photon energy fraction to enter in the hard interaction

$$x_\gamma^{obs} = \frac{\sum_{i=1}^{N_{jets}} E_T^{jet_i} \, e^{-\eta^{jet_i}}}{2 E_\gamma}$$

- high values correspond to point-like photons
- low values correspond to resolved photons

Introduction & motivation

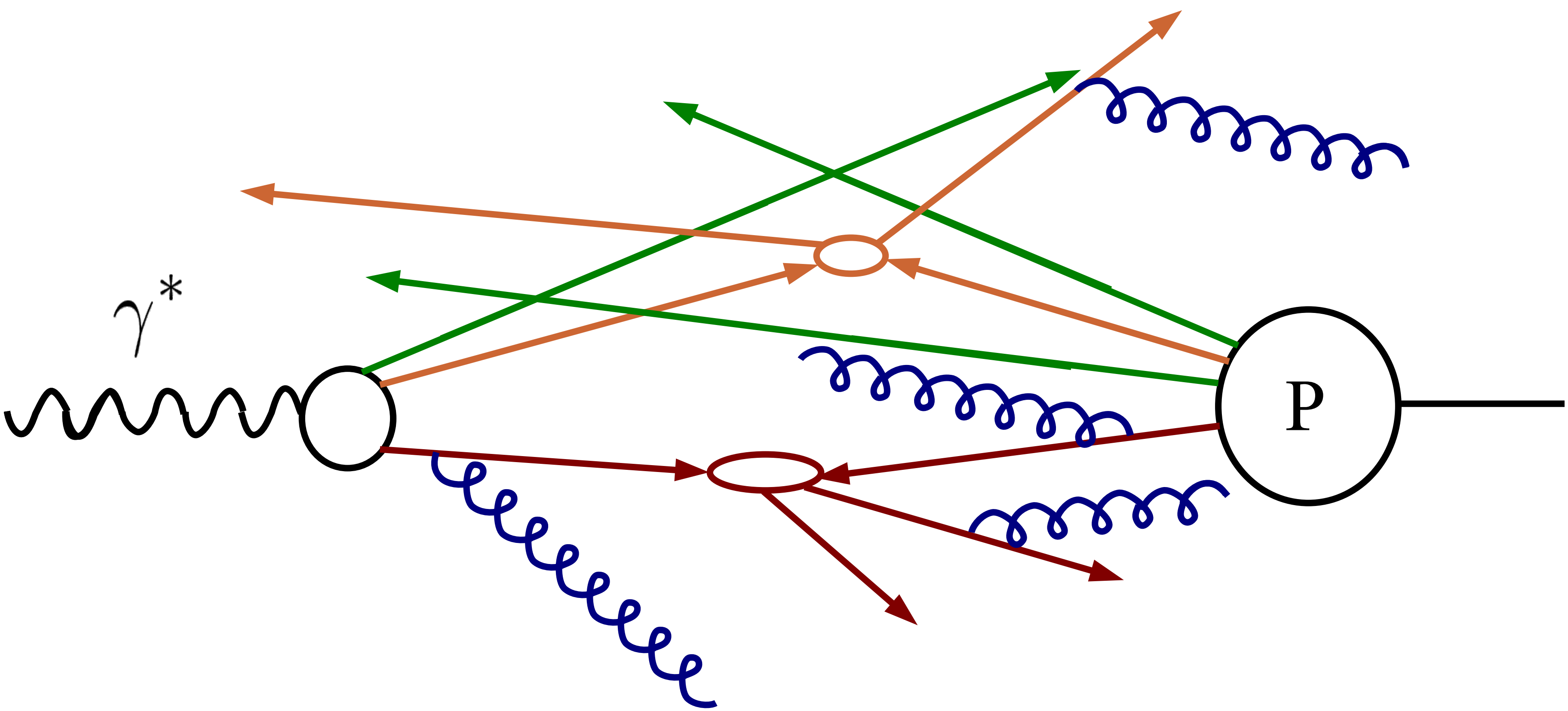
In ep we have a similar situation to the hadron-hadron collisions



there are remnants from the photon and the proton side

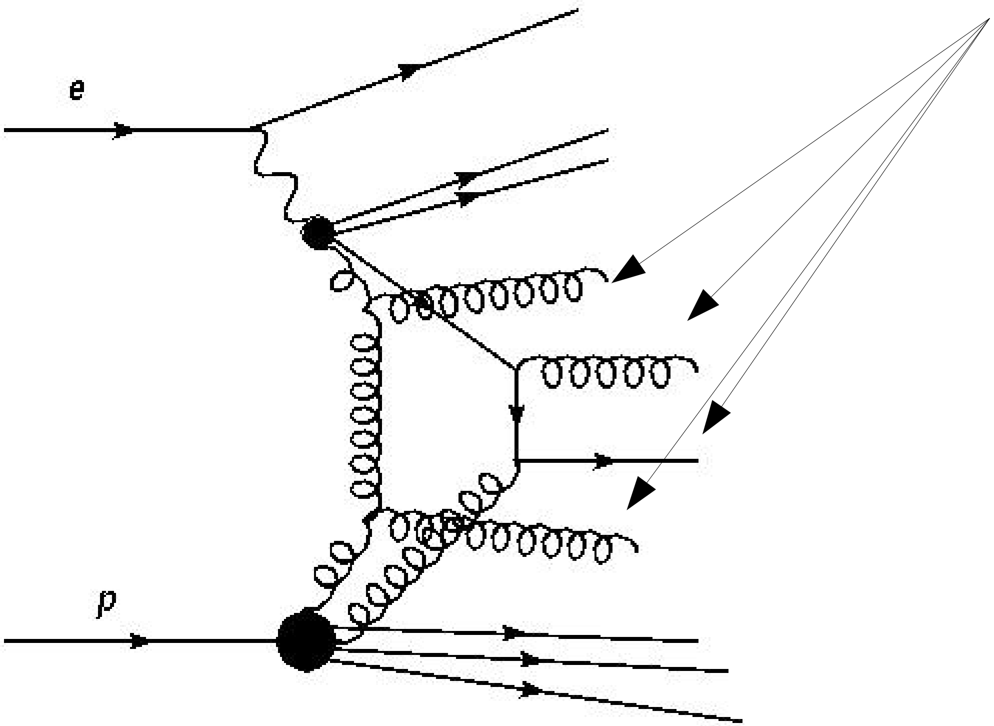
Introduction & motivation

✗ and partons from the remnants can interact



Multiple parton interactions

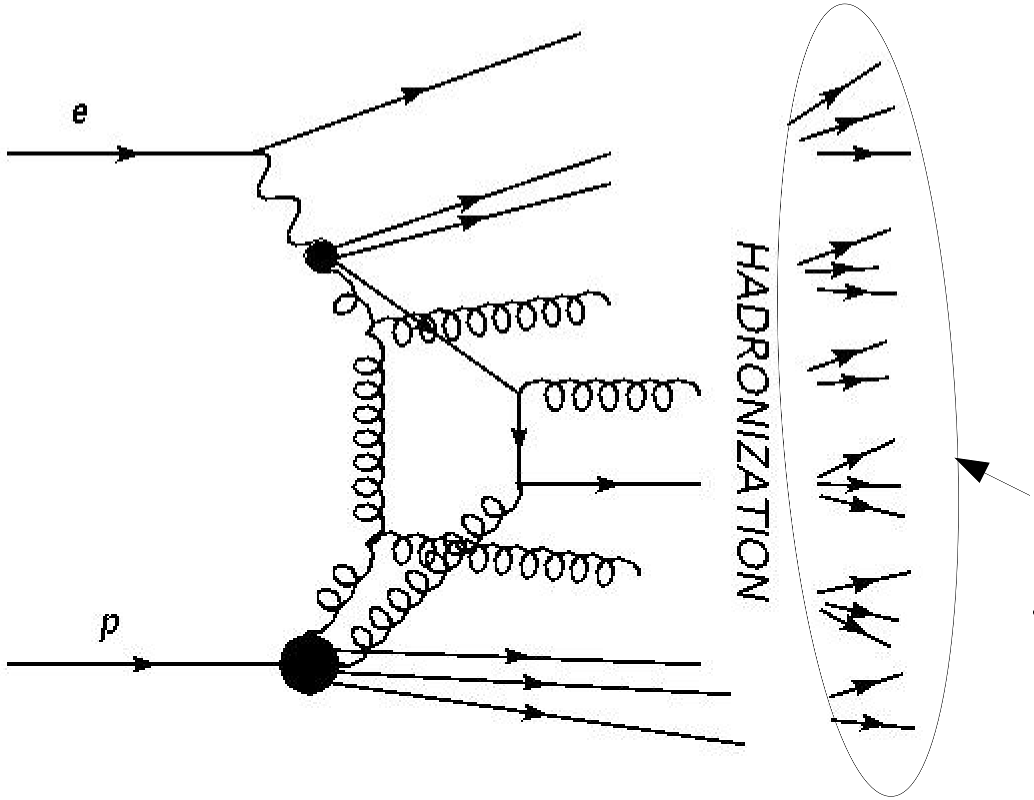
Observables:



- Hard MPI in multi jet events: three or more jets with high P_T

Multiple parton interactions

Observables:



- Hard MPI in multi jet events: three or more jets with high P_T

- Soft MPI: charged particles, low P_T jets, energy flow....

Monte Carlo

- **PYTHIA:** LO ME + DGLAP PS

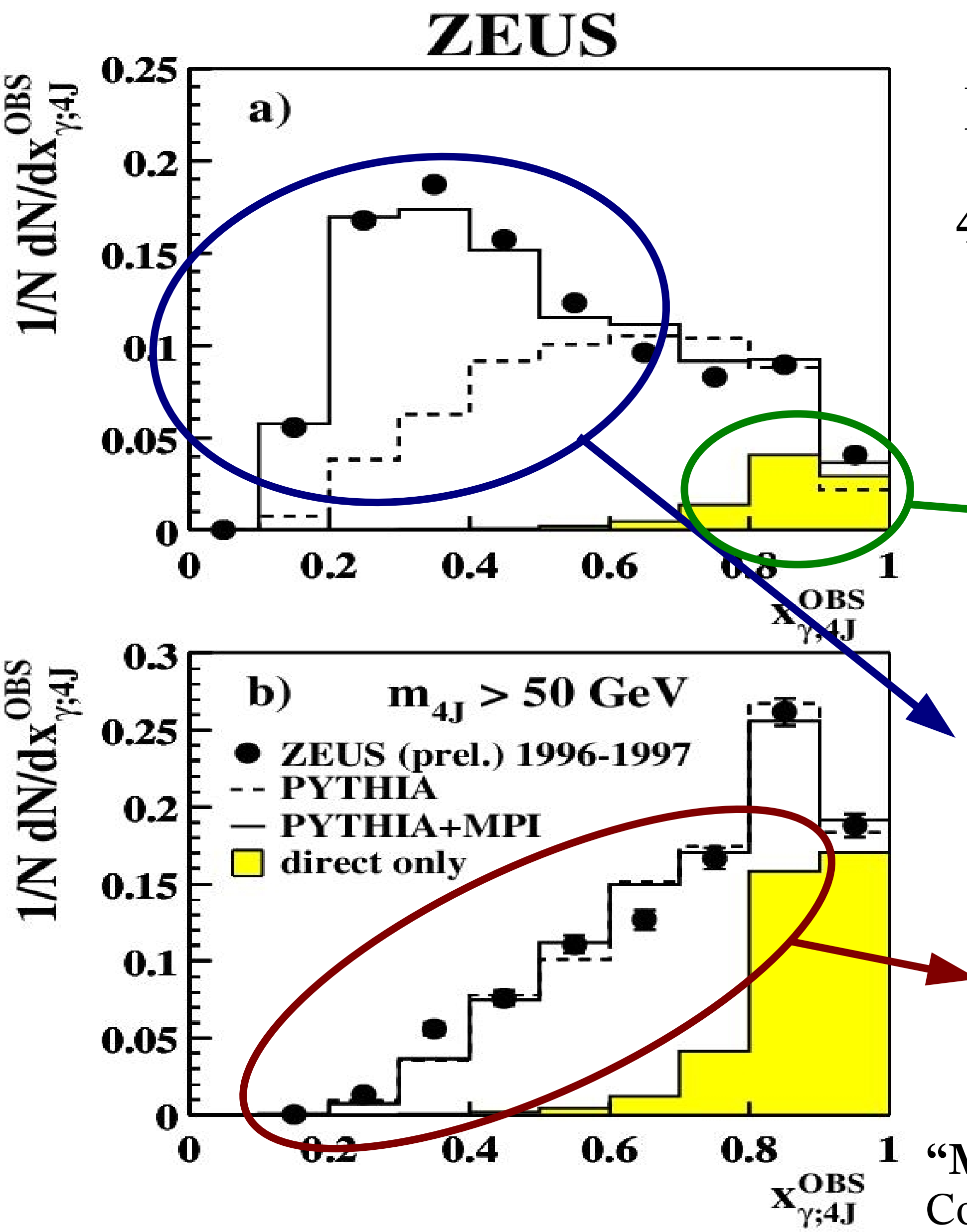
  (semi-)hard MPI + different string scenarios for hadronization
- **HERWIG:** LO ME + DGLAP PS

  MPI from JIMMY. With impact parameter dependence. Similar to PYTHIA
- **CASCADE:** off shell LO ME + CCFM PS (no resolved photon, no MPI model implemented)
- **CDM:** LO ME + PS from the Color Dipole Model(no MPI impl.)
- **RAPGAP:** LO ME + DGLAP PS (no MPI implemented)

HERA
Past

HERA present

4 jets events at ZEUS



Photoproduction $Q^2 < 1$ GeV^2

4-jet events: $E_T^{jet1,2} > 6$ GeV $E_T^{jet3,4} > 5$ GeV

$|\eta^{jets}| < 2.4$

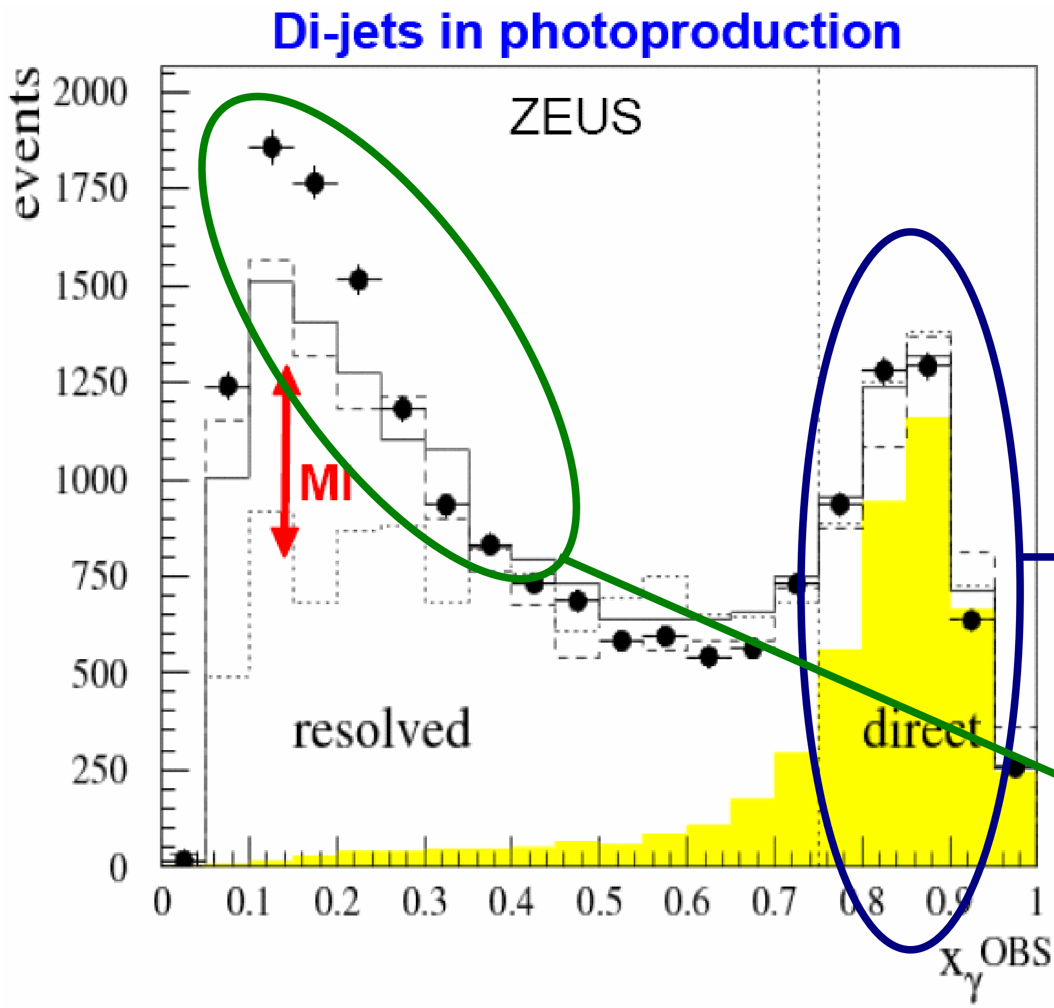
The direct photon component contributes only at high X_γ values

At low X_γ data can be described when including MPI

For an invariant mass of $M_{4J} > 50$ GeV the MPI contribution vanishes

"Multijets in photoproduction at HERA" XXXI International Conference of High Energy Physics, abstract 849

dijets events at ZEUS



Photoproduction $Q^2 < 4\ GeV^2$

2-jet events: $E_T^{jet1,2} > 6$ GeV

$-1.375 < \eta^{jets} < 1.875$

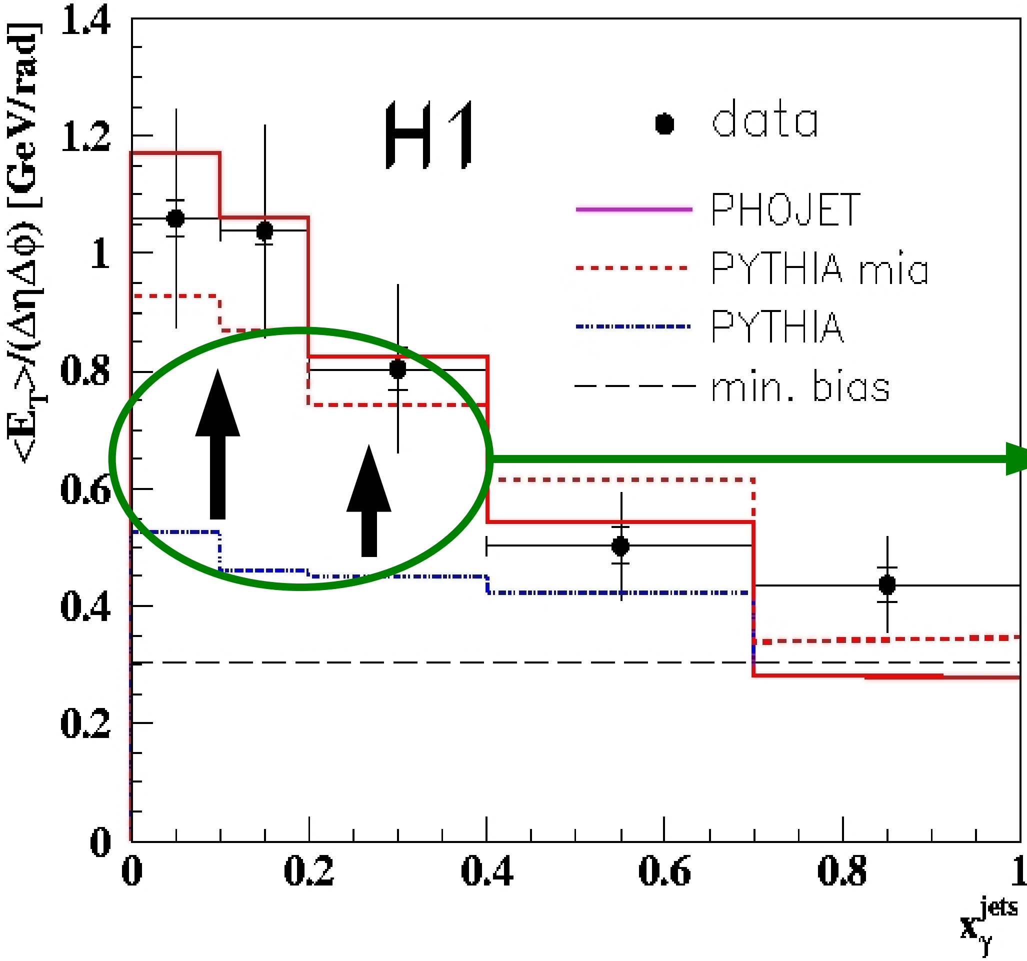
direct component – no large differences between MCs

including MPI we get a much better data description

"Dijet Cross Sections in Photoproduction at HERA"
Eur.Phys.J.C1:109-122,1998

HERA present

Energy flow outside jets at H1



Photoproduction $Q^2 < 0.01$ GeV^2

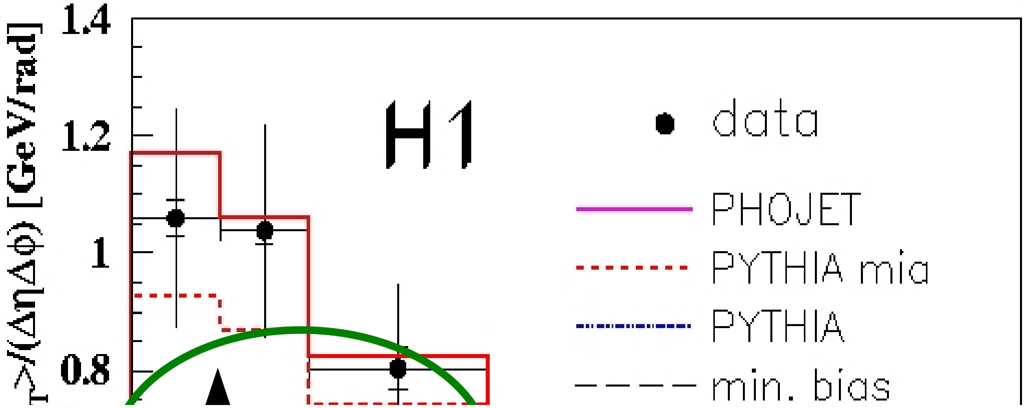
At least one jet ($E_T^{jet} > 5$ GeV

$-1 < \eta^{jet} < 2.5$)

The transverse energy density outside the jets can be described when MPI are simulated.

“Jets and Energy Flow in Photon-Proton Collisions at HERA” hep-ex/9511012

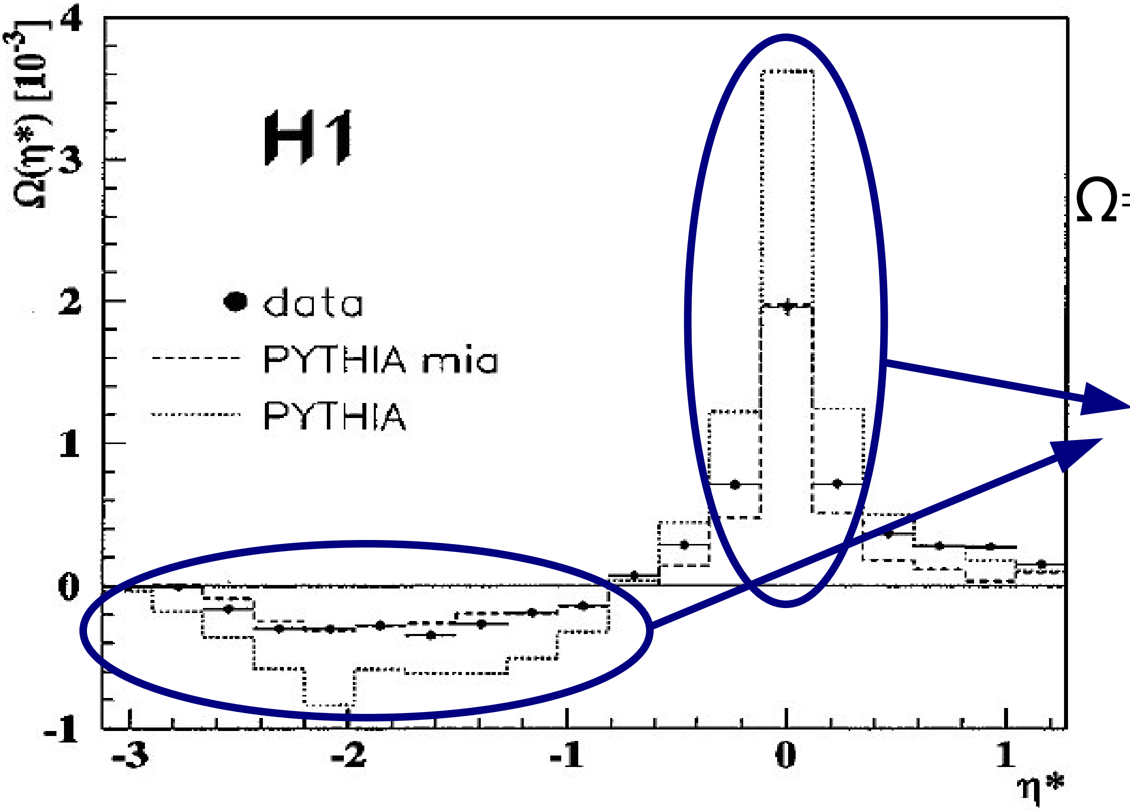
Energy flow outside jets at H1



Photoproduction $Q^2 < 0.01\ GeV^2$

High E_T sample ($E_T > 20$ GeV

$-0.8 < \eta < 3.3$)



$$\Omega = \frac{1}{N_{ev}} \sum_{i=1}^{N_{ev}} \frac{(\langle E_{T,\eta=0}\rangle - E^{i}_{T,\eta=0})(\langle E_{T,\eta}\rangle - E^{i}_{T,\eta})}{(E_T^{\,2})_i}$$

Only with MPI you can describe the Ω rapidity correlations

HERA
Present

Three and four jets events

Photoproduction: $Q^2 < 1$ GeV^2

Variable: n-jet invariant mass $M_{nj} = \sqrt{(\sum_{i=1}^{n} p_i)^2}$

with n number of jets n=3,4

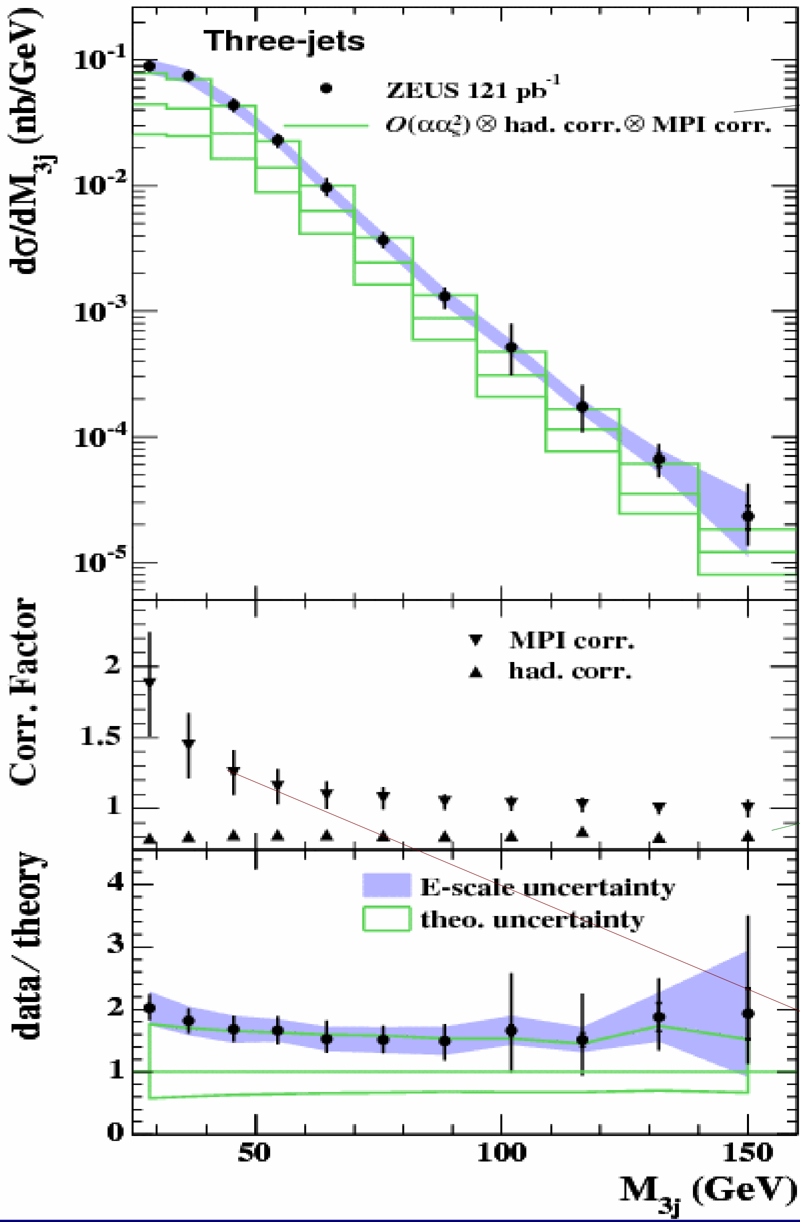
Three and four jets events: $E_T^{jets} > 6$ GeV

$|\eta^{jets}| < 2.4$

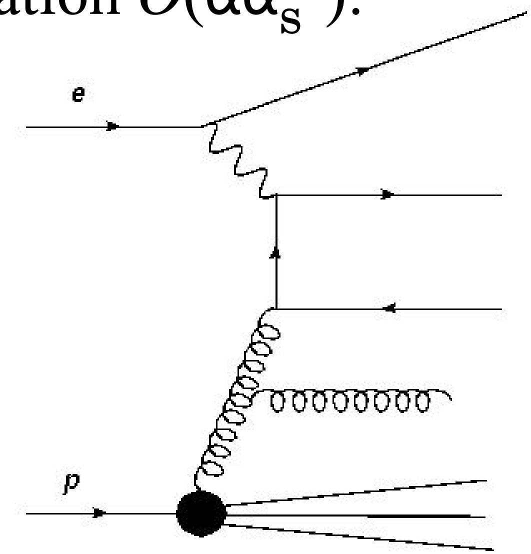
"Three- and four-jet final states in photoproduction at HERA"
Nucl.Phys.B792:1-47, 2008, ZEUS Collaboration.

HERA present: Multi jet events

Three jets events



measured 3-jet cross section compared to the LO calculation $O(\alpha\alpha_s^2)$:



\+

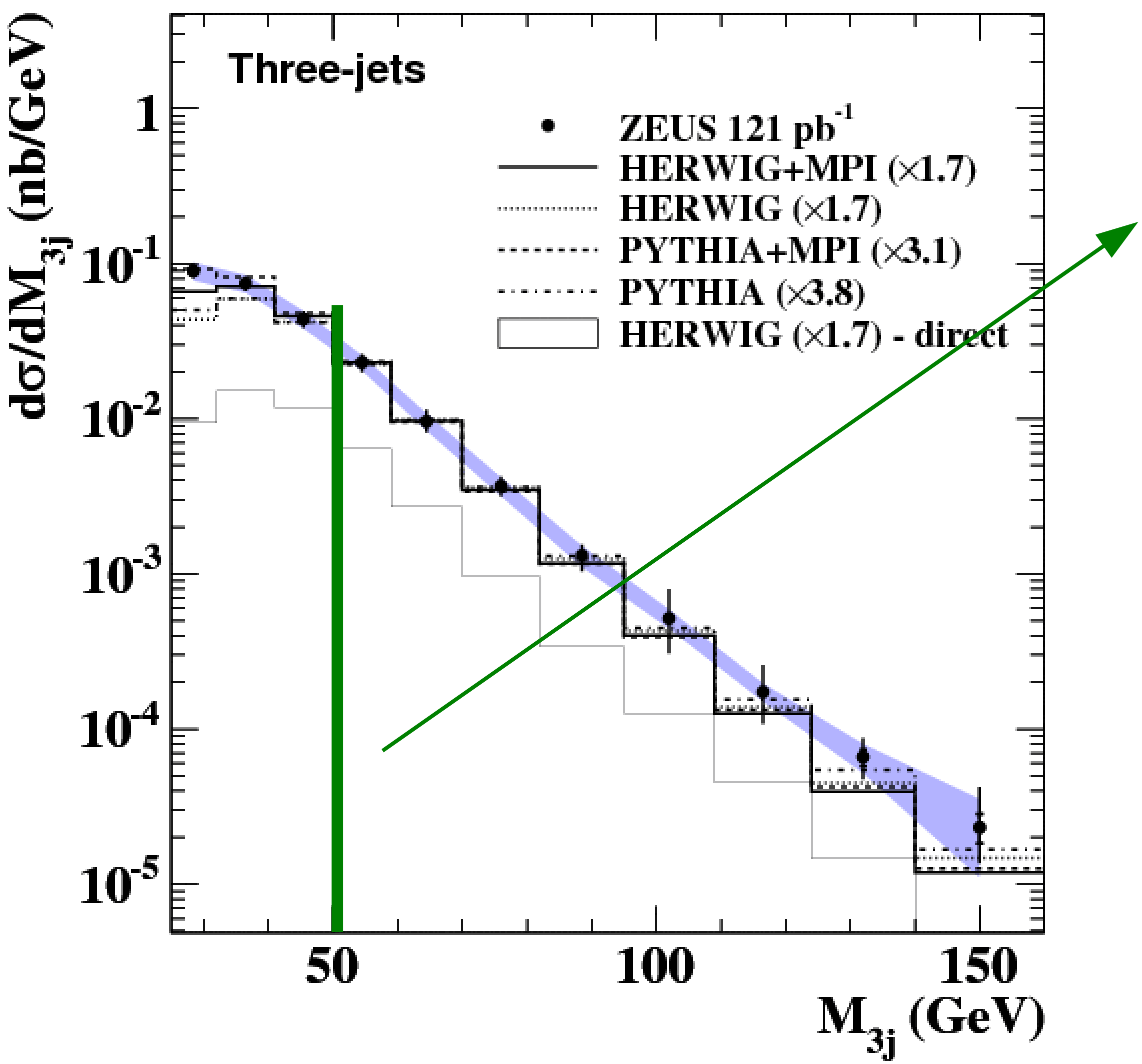
Hadronization corrections (small and constant)

\+

MPI corrections (larger and increasing with decreasing 3-jet invariant mass)

HERA present: Multi jet events

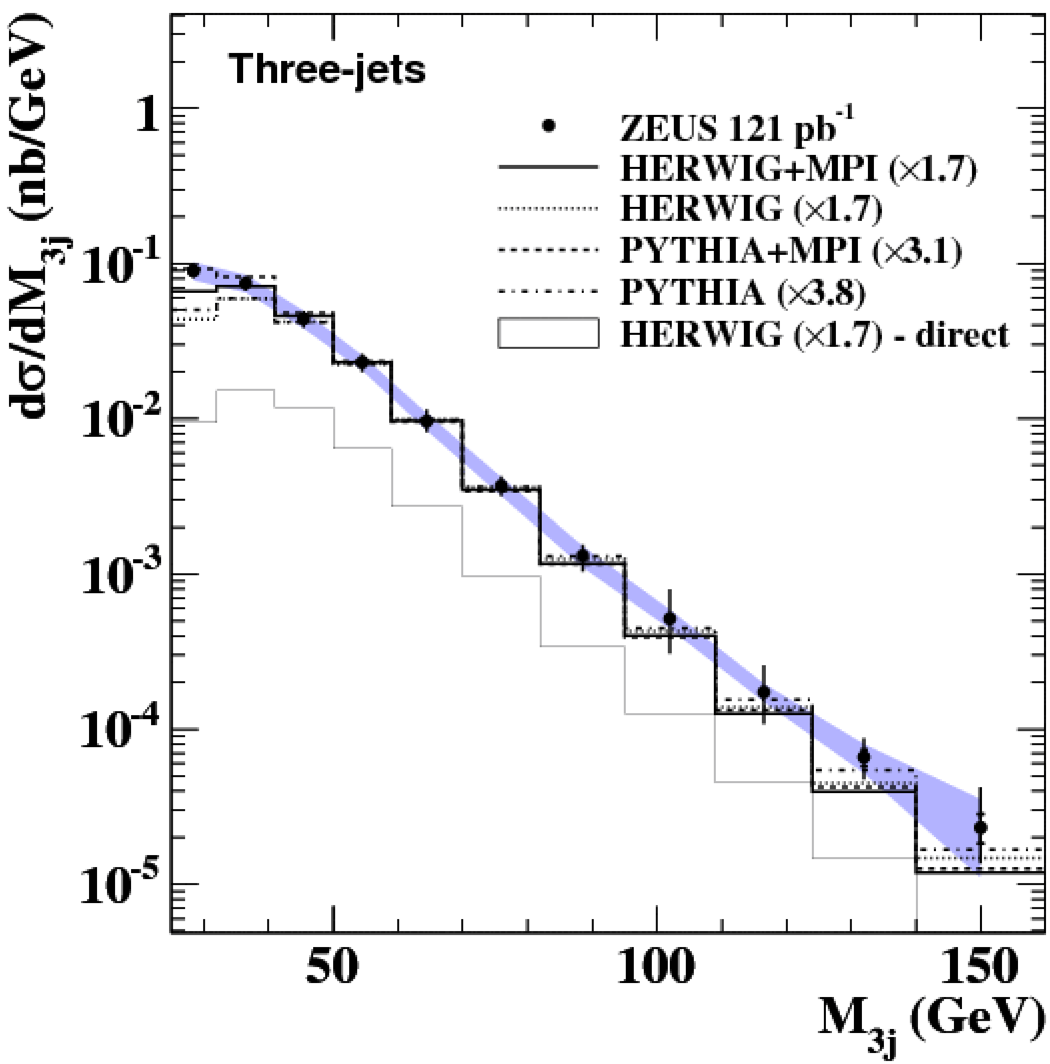
Three jets events



The Monte Carlos were normalized to the high 3-jet invariant mass ($M_{3j} > 50$ GeV)

HERA present: Multi jet events

Three jets events



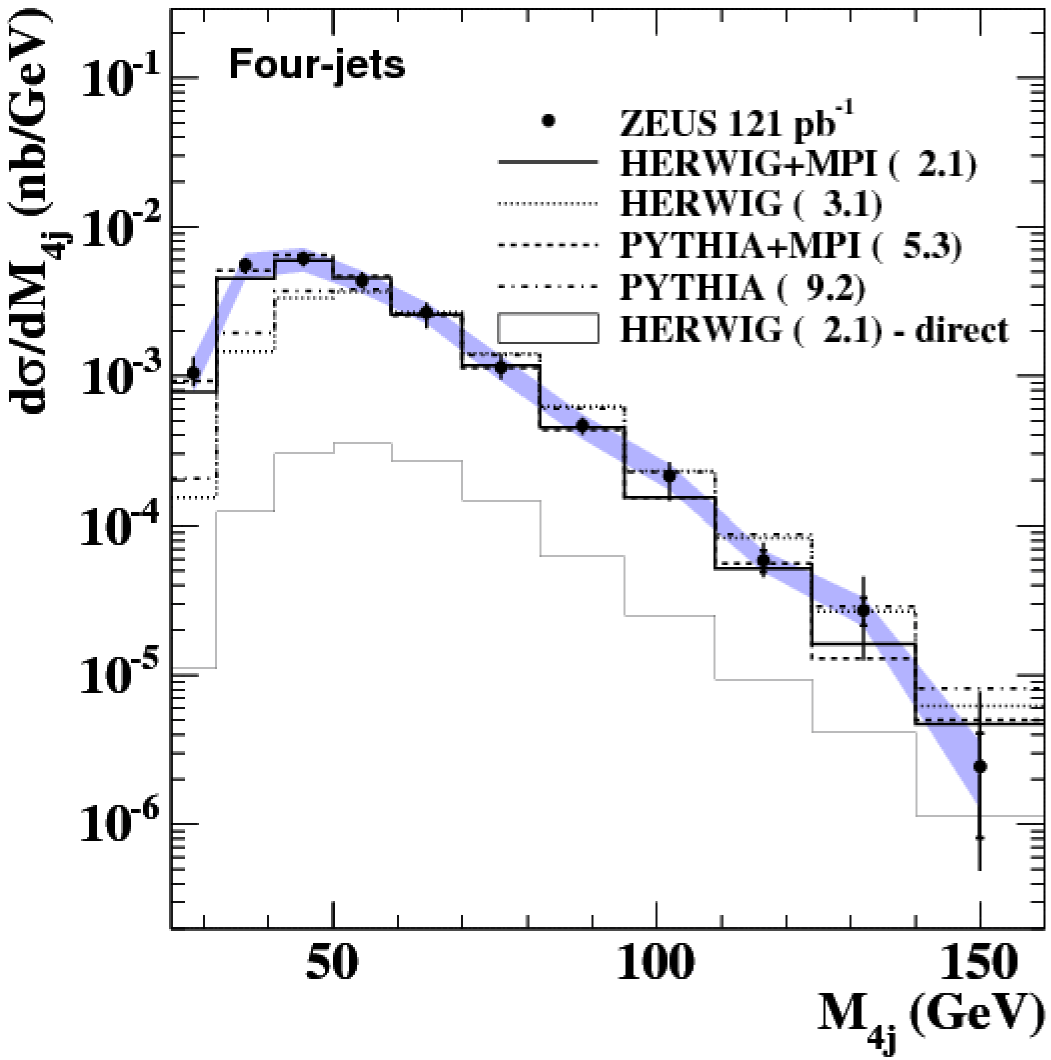
The $O(\alpha\alpha_s)$ + PS Monte Carlos cannot describe the total normalization

BUT

only if MPI are included they can describe the shape (specially the low mass region)

HERA present: Multi jet events

Four jets events



Again, the $O(\alpha\alpha_s)$ + PS Monte Carlos cannot describe the total normalization

BUT

only if MPI are included they can describe the shape.

HERA present: Multi jet events

Charged particle multiplicity

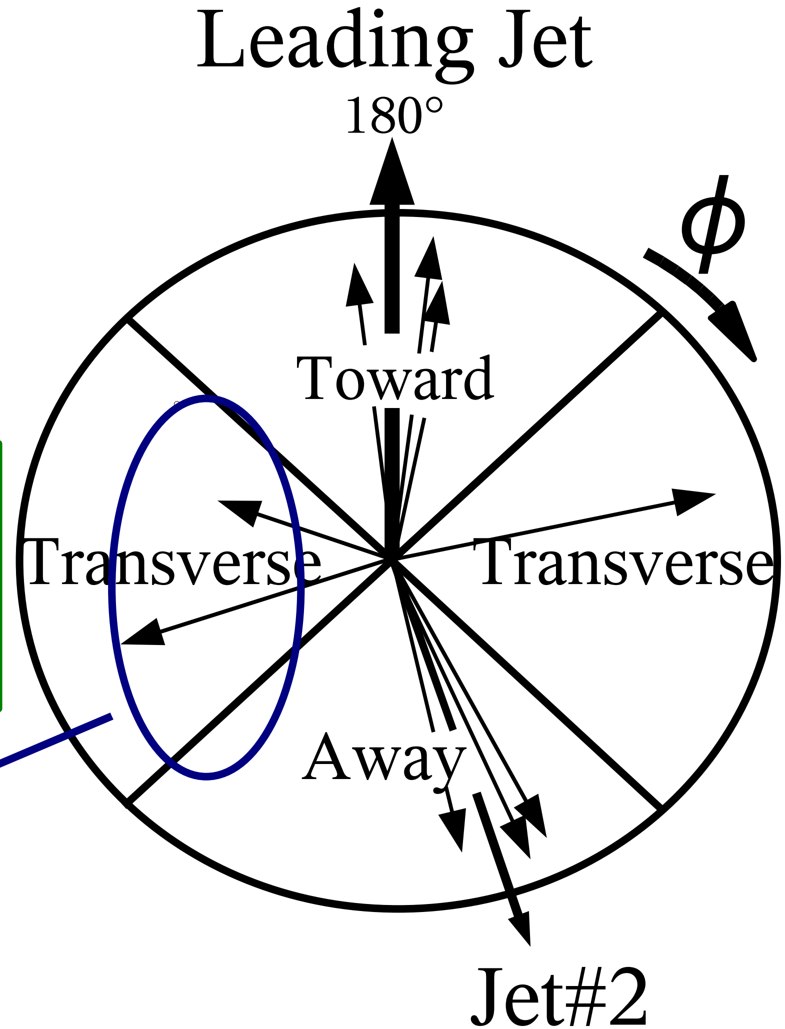
$Q^2 < 0.01\ GeV^2$

Dijet events: $P_T^{jets} > 5\ GeV$

$|\eta^{jets}| < 1.5$

Charged particles: $P_T > 150\ MeV$

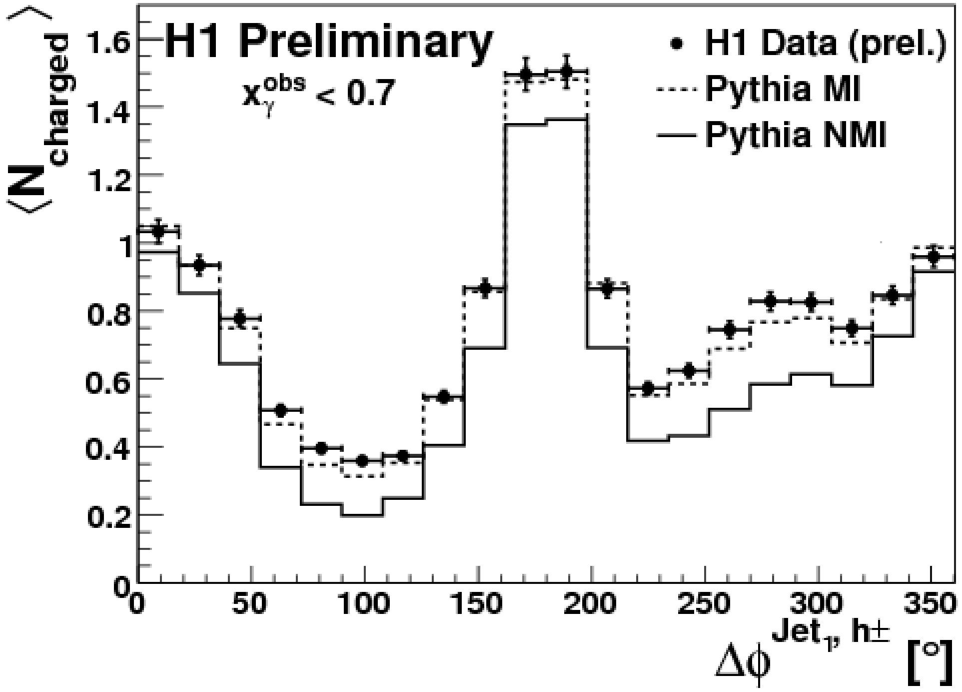
$|\eta| < 1.5$

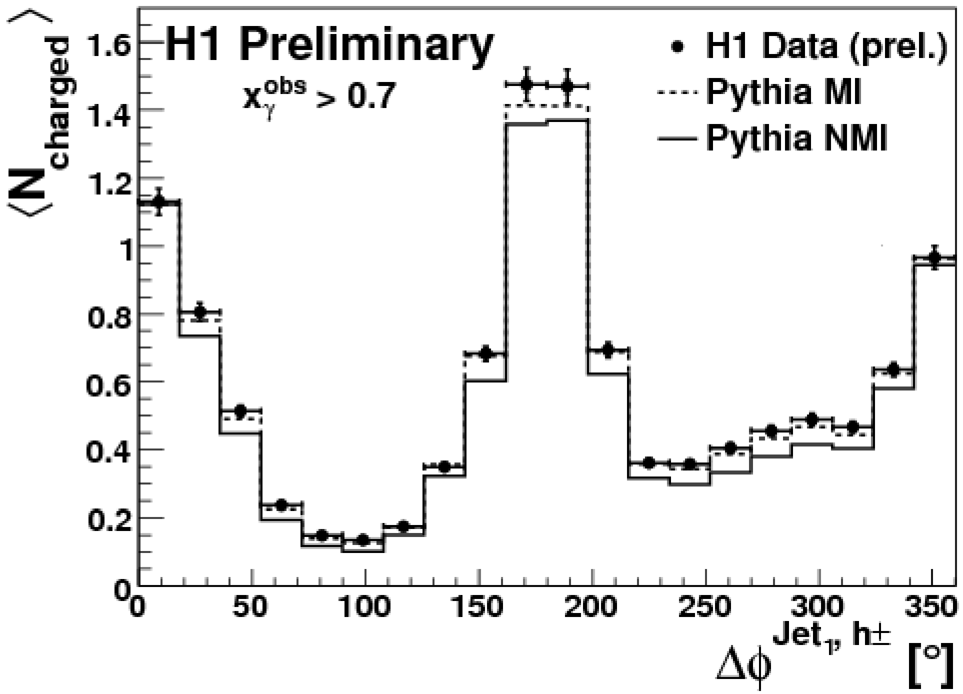


The high activity region is the transverse region hemisphere with higher $P_T^{sum} = \sum_i^{tracks} p_T^{\,i}$

HERA present: Charged particle multiplicity

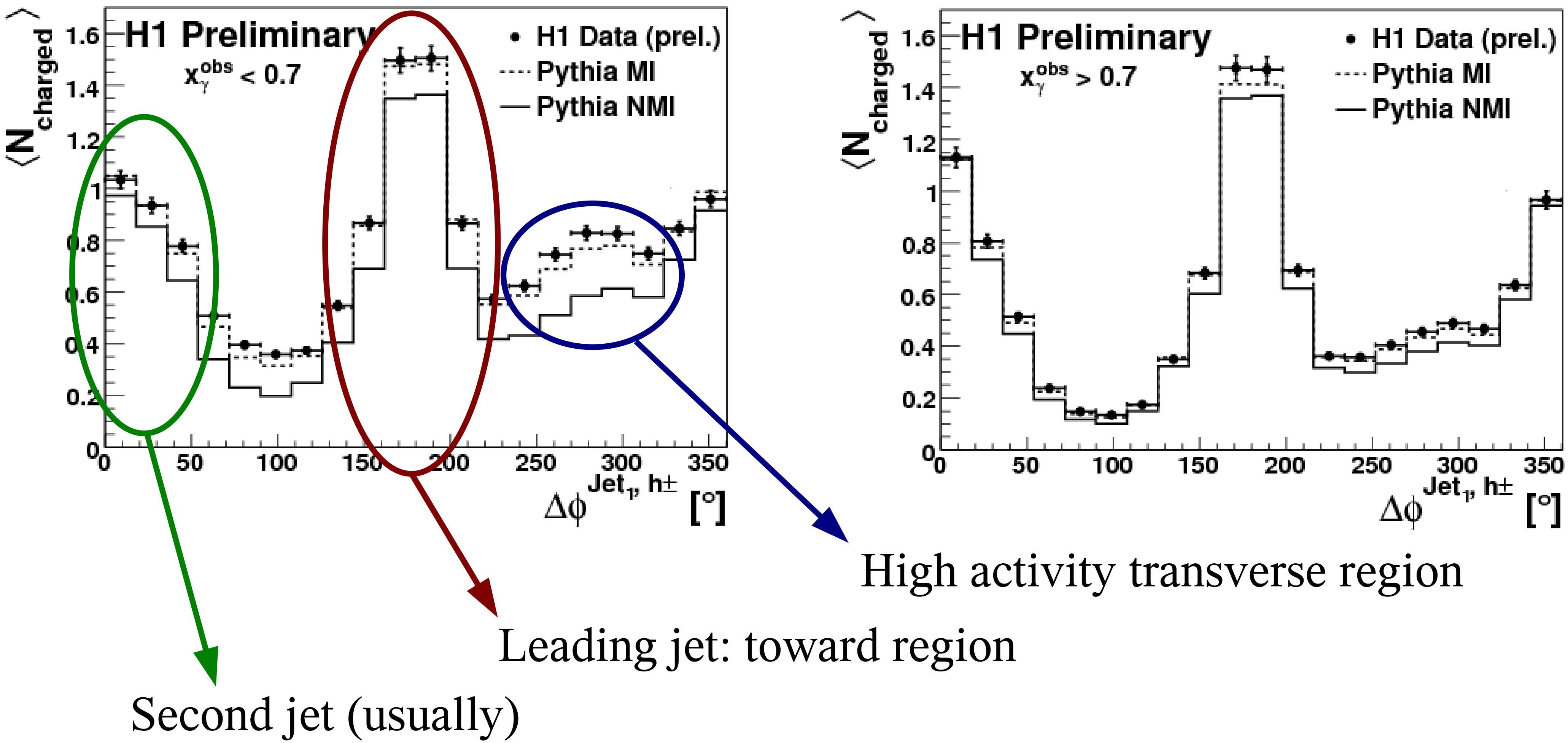
✗ Charge particle multiplicity as a function of the $\Delta\phi$ between the leading jet and the charged particles





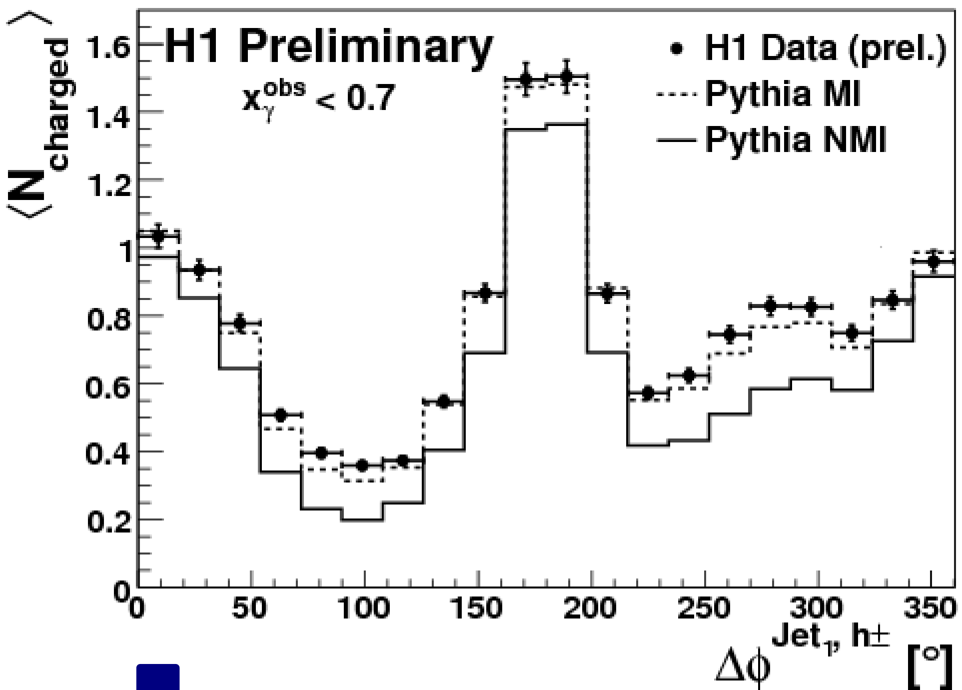
HERA present: Charged particle multiplicity

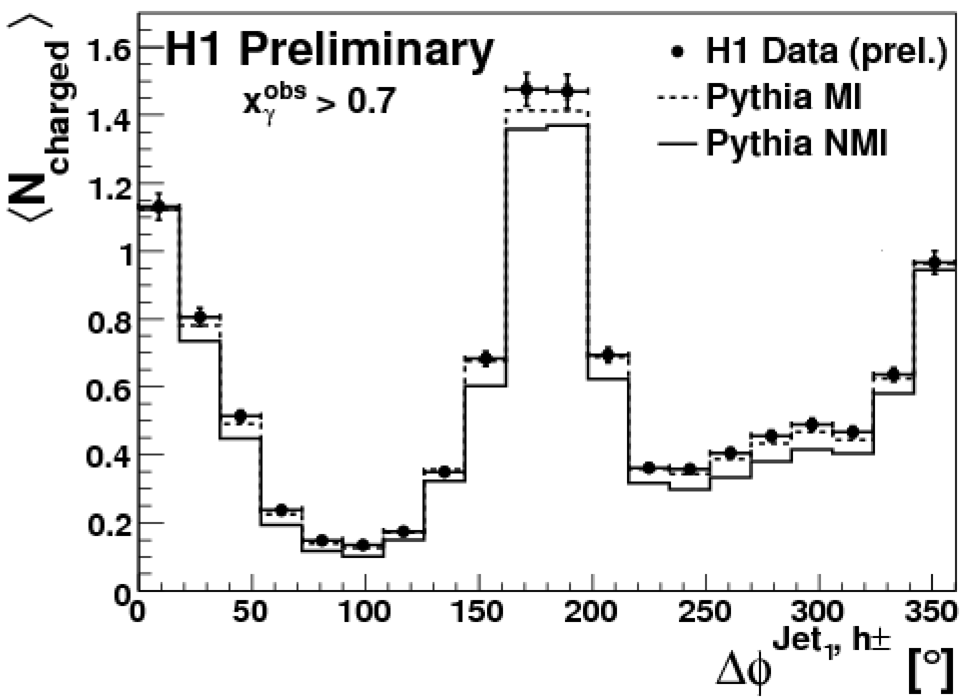
✗ Charge particle multiplicity as a function of the $\Delta\phi$ between the leading jet and the charged particles



HERA present: Charged particle multiplicity

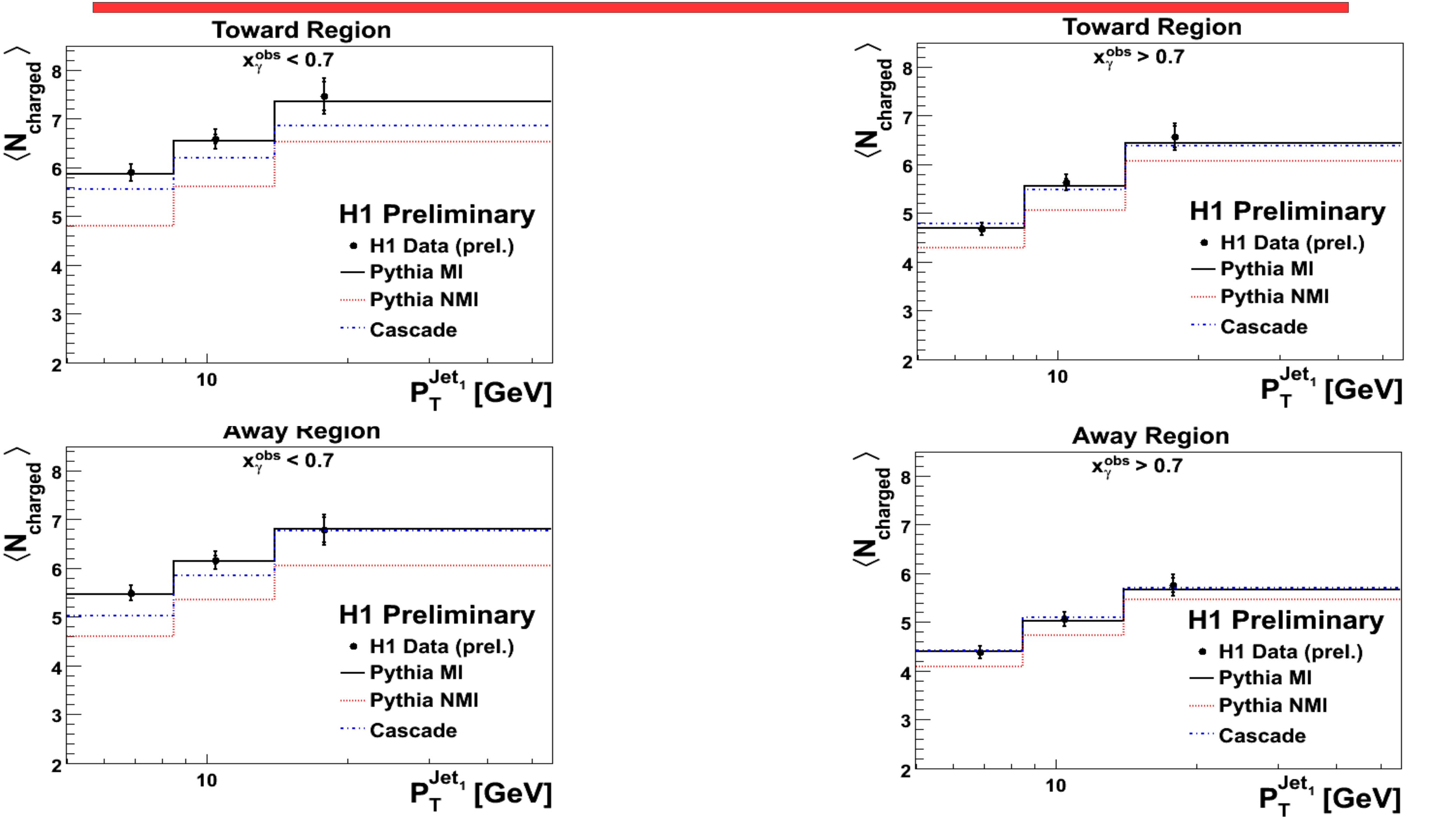
- Charge particle multiplicity as a function of the Δϕ between the leading jet and the charged particles





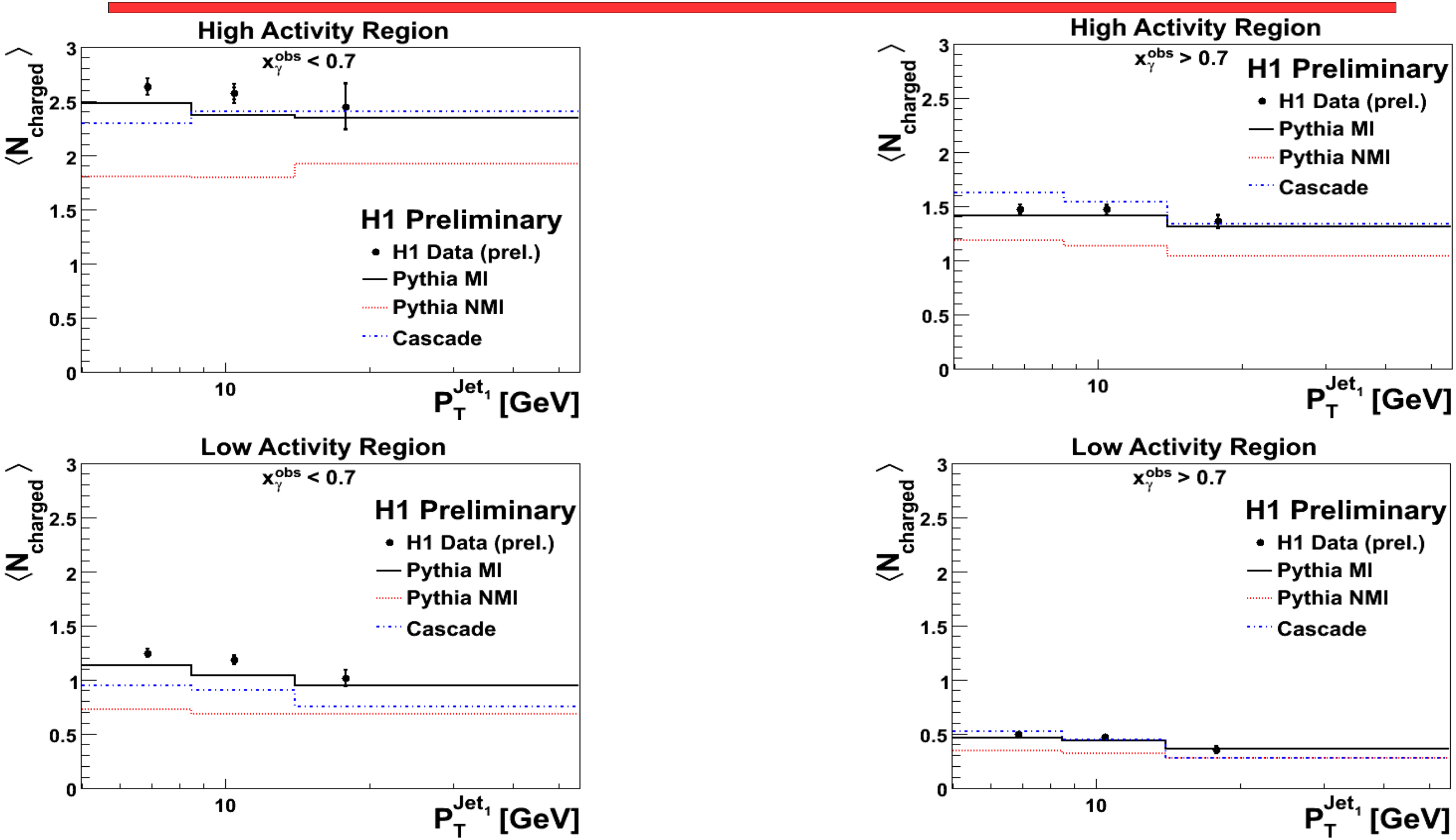
➡ It look as a pedestal over the Δϕ but...it is not so simple...

HERA present: Charged particle multiplicity



- ✗ MPI contributes more at low P_T^{Jet1} BUT not as just a pedestal since it decreases with increasing P_T^{Jet1}

HERA present: Charged particle multiplicity



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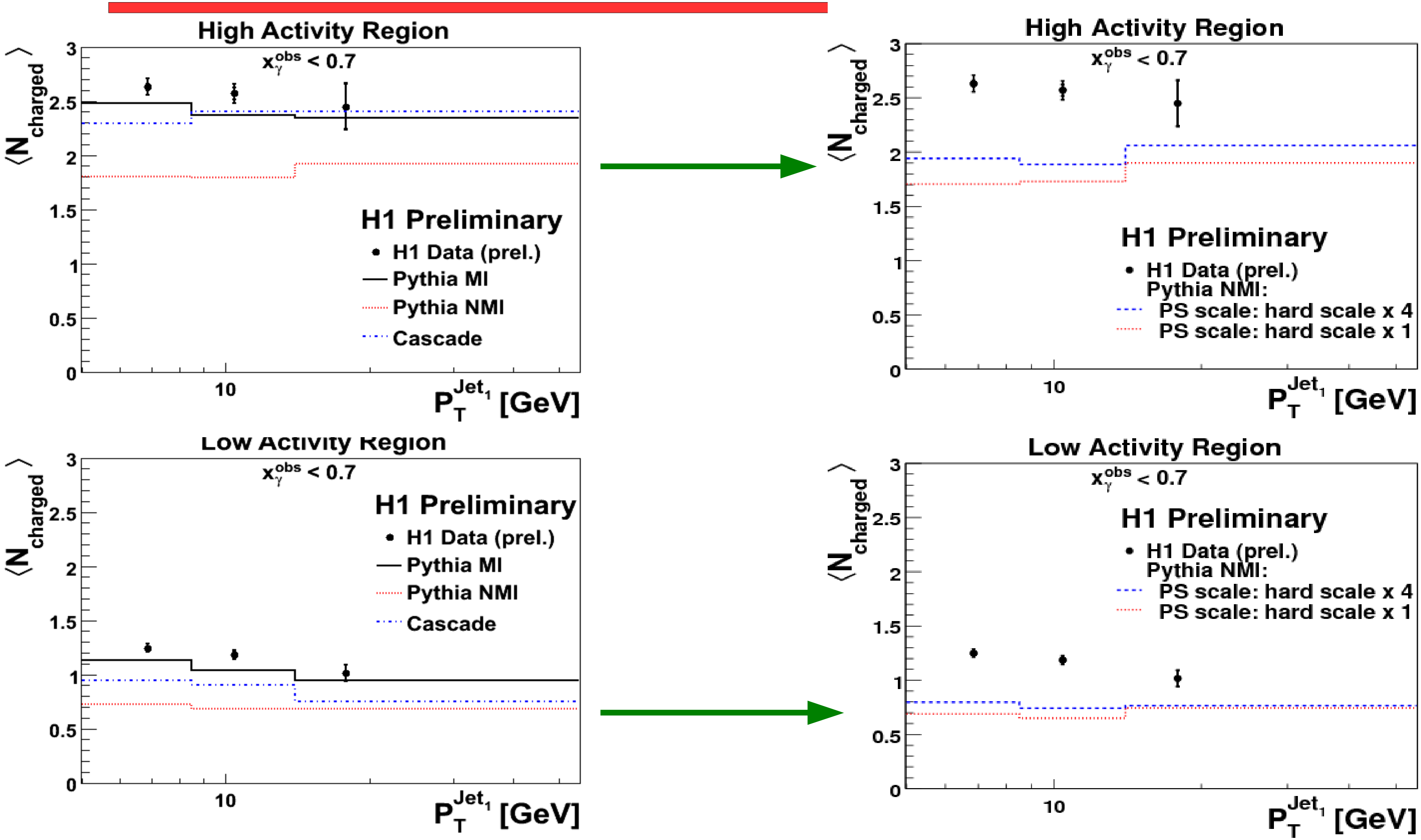

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HERA present: Multi jet events

Low E_T jets multiplicity

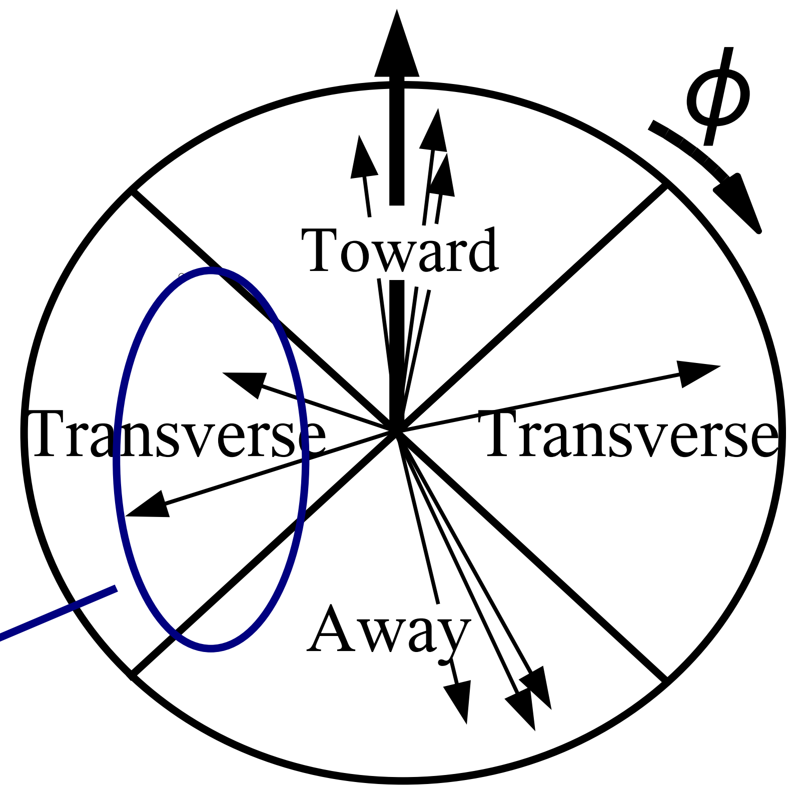
$5 < Q^2 < 100\ \mathrm{GeV}^2$

One jet events: $E_T^{jet} > 5$ GeV

$0.5 < \eta^{jet} < 2.79$

Mini-jets: $E_T > 3$ GeV

$0.5 < \eta^{jet} < 2.79$



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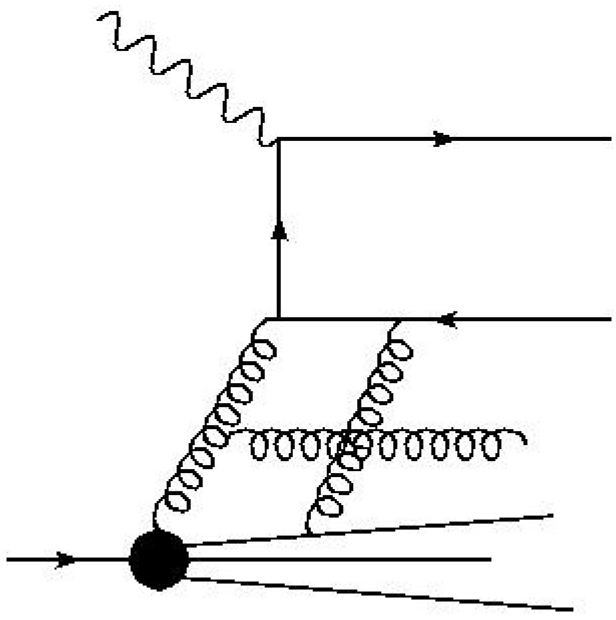
WHY?

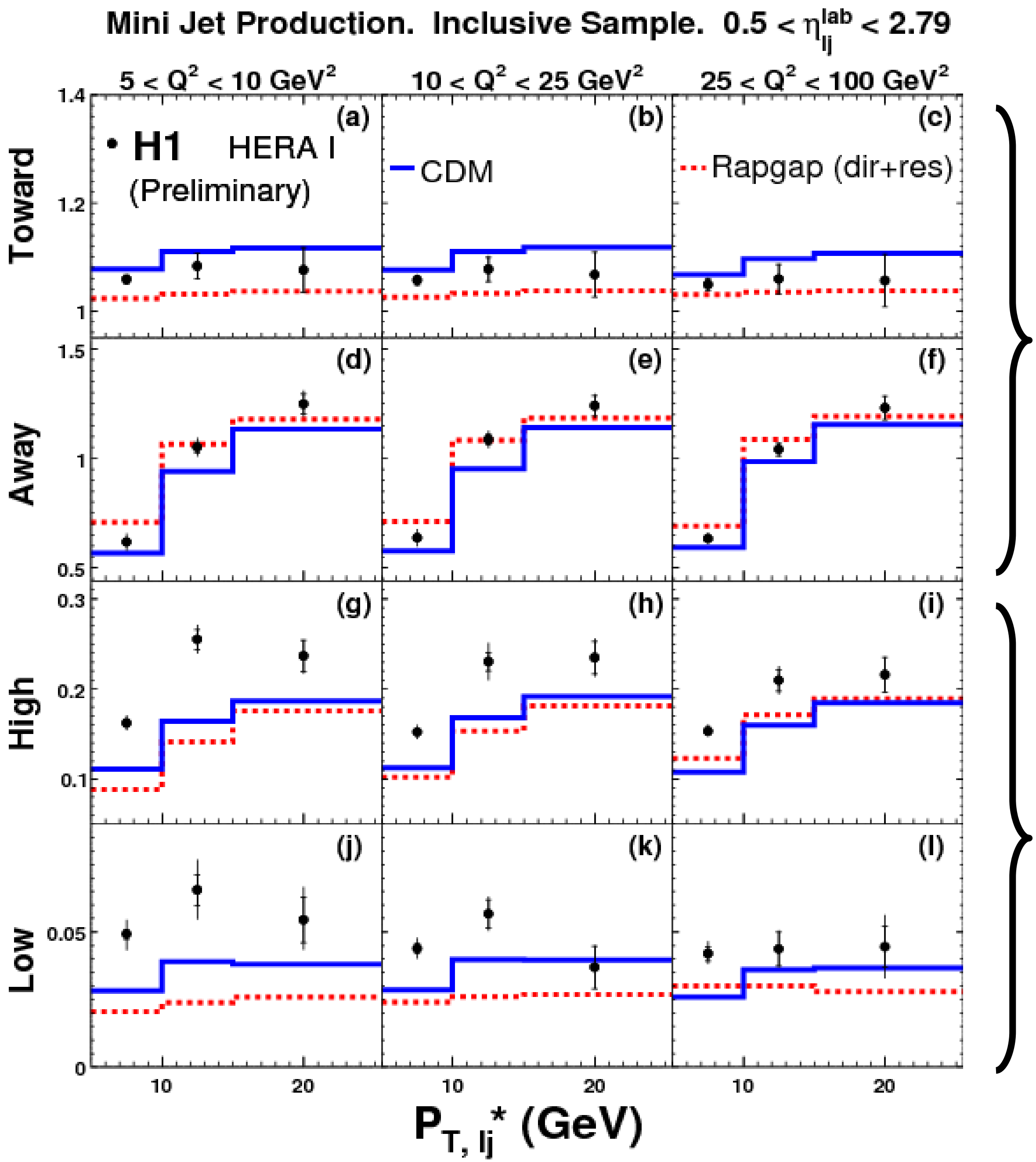
Study the effect of MPI as $Q^2 \nearrow$

AND



interactions between the hard scattering and the proton remnant

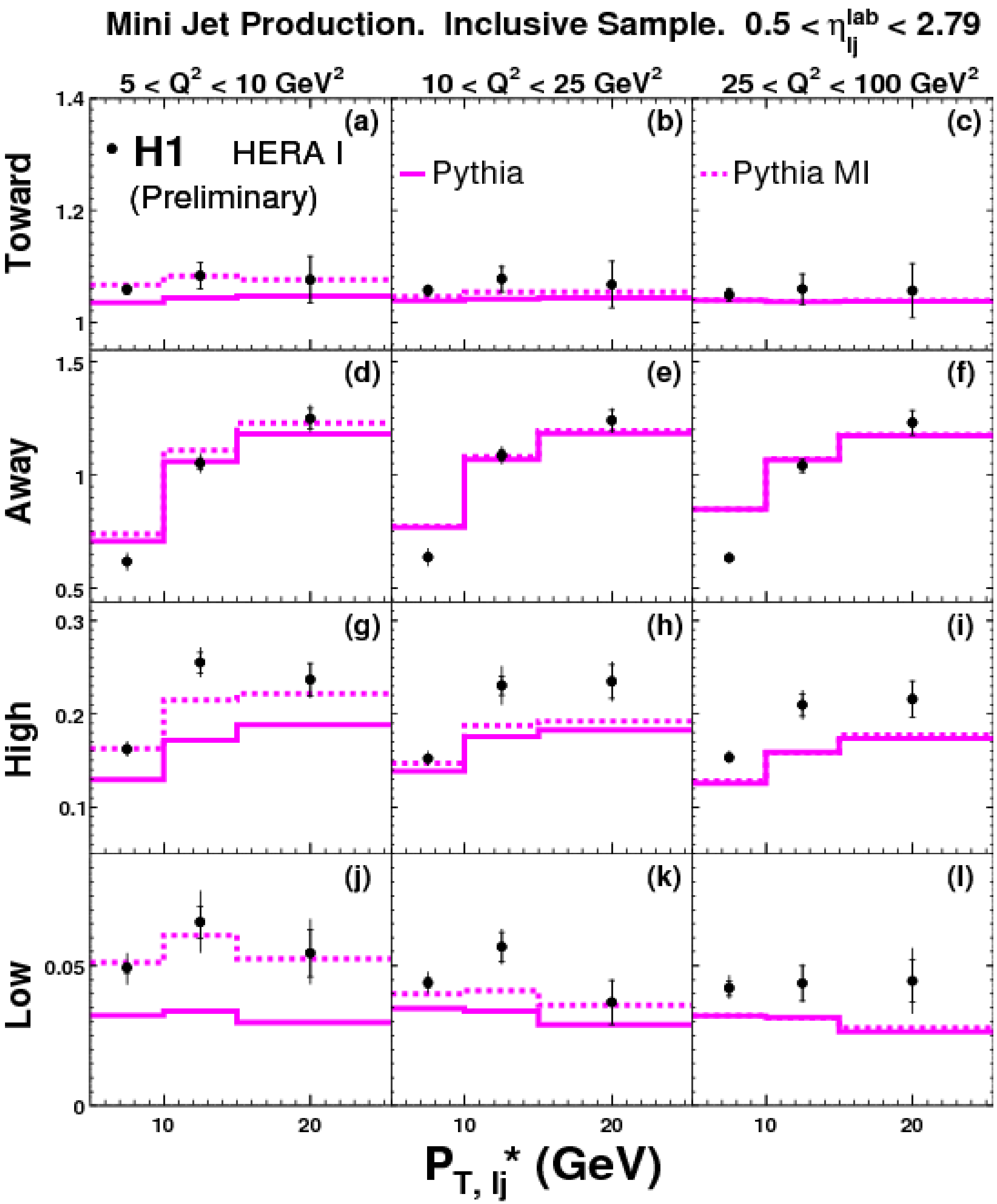
HERA present: Multi jet events



Toward and away regions are described by MC without MPI

MC underestimate the number of mini jets in the transverse regions

HERA present: Multi jet events



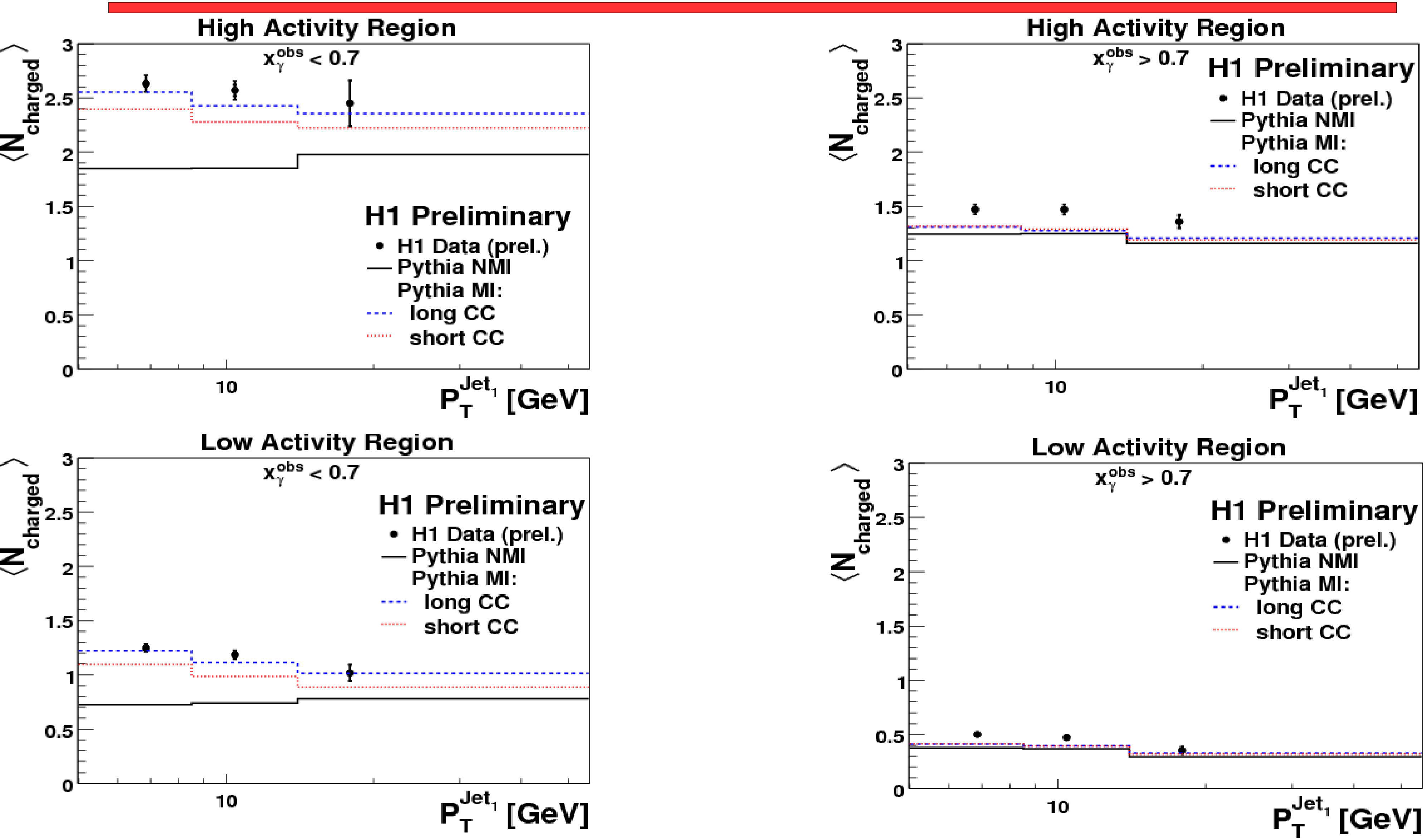
Including MPI we describe better the low Q^2 regions but without resolved photons there is no MPI in MC

Summary and outlook

- Hard MPI:
  - Multijet photoproduction
    - 3-jet cross section not described alone with $O(\alpha\alpha_s^2)$. MPI are needed
    - In 4-jet events the contribution from MPI is even larger
- Soft MPI:
  - Charged particle multiplicity in photoproduction
    - Charged particle multiplicity outside the hard interaction not described without MPI (although CASCADE…)
    - Minijets in photoproduciton can provide supplementary information
  - Minijet production in at low Q^2
    - Including MPI improves the description where the resolved photon still contributes
    - Need to improve MC: improve PS (CASCADE) and MPI?

Thanks for your attention

HERA present: Charged particle multiplicity



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