

Multiparton interactions in ep scattering at HERA

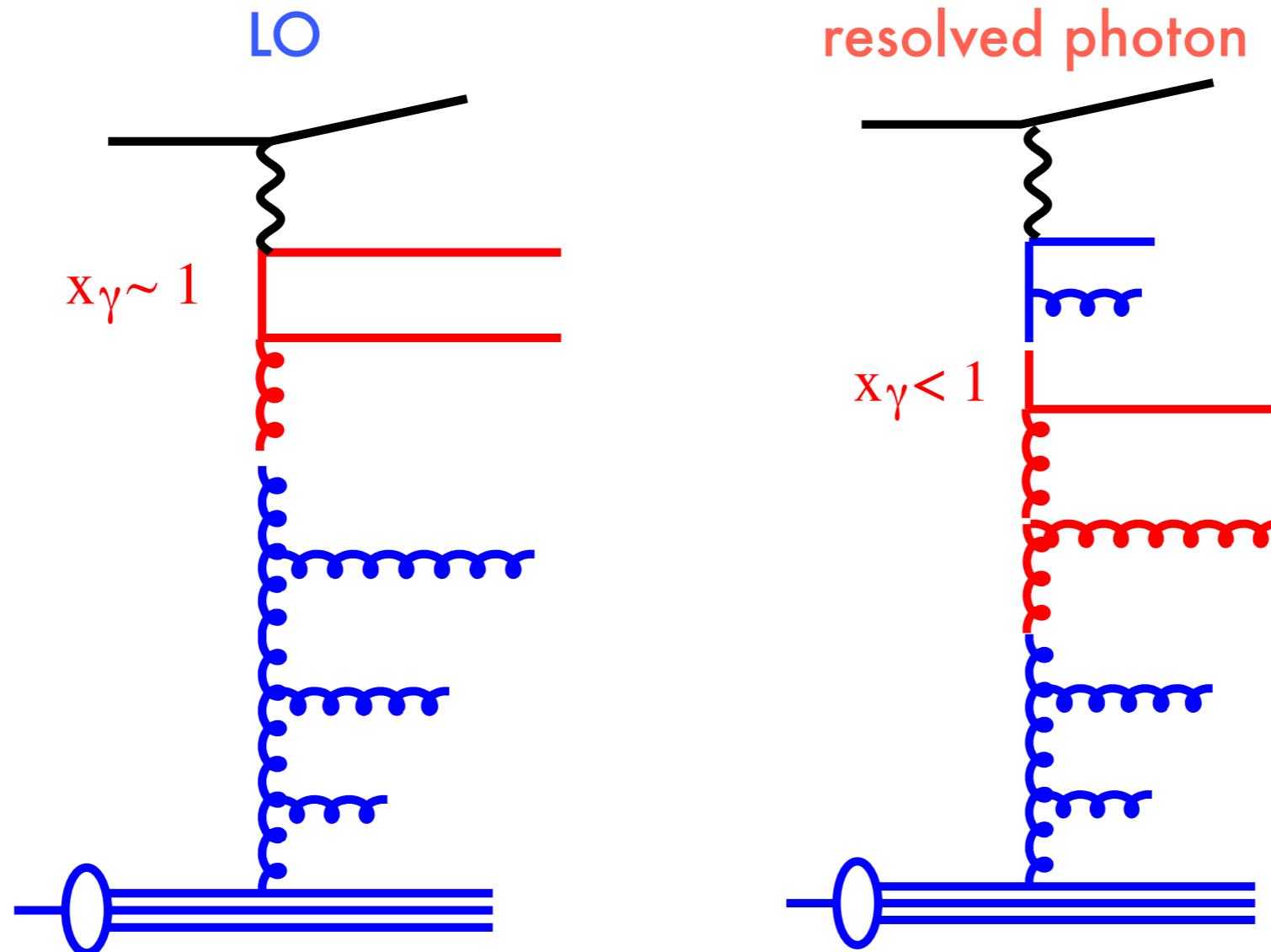
Hannes Jung (DESY, Univ. Antwerp)

on behalf of
H1 & ZEUS collaborations

- **change title to: underlying event structures in ep scattering at HERA**
- **Outline**
 - earlier HERA measurements
 - investigations of the underlying event at HERA
 - ala CDF, ATLAS & CMS
 - do we have evidence for multiparton interactions ?

Underlying event study in a clean environment

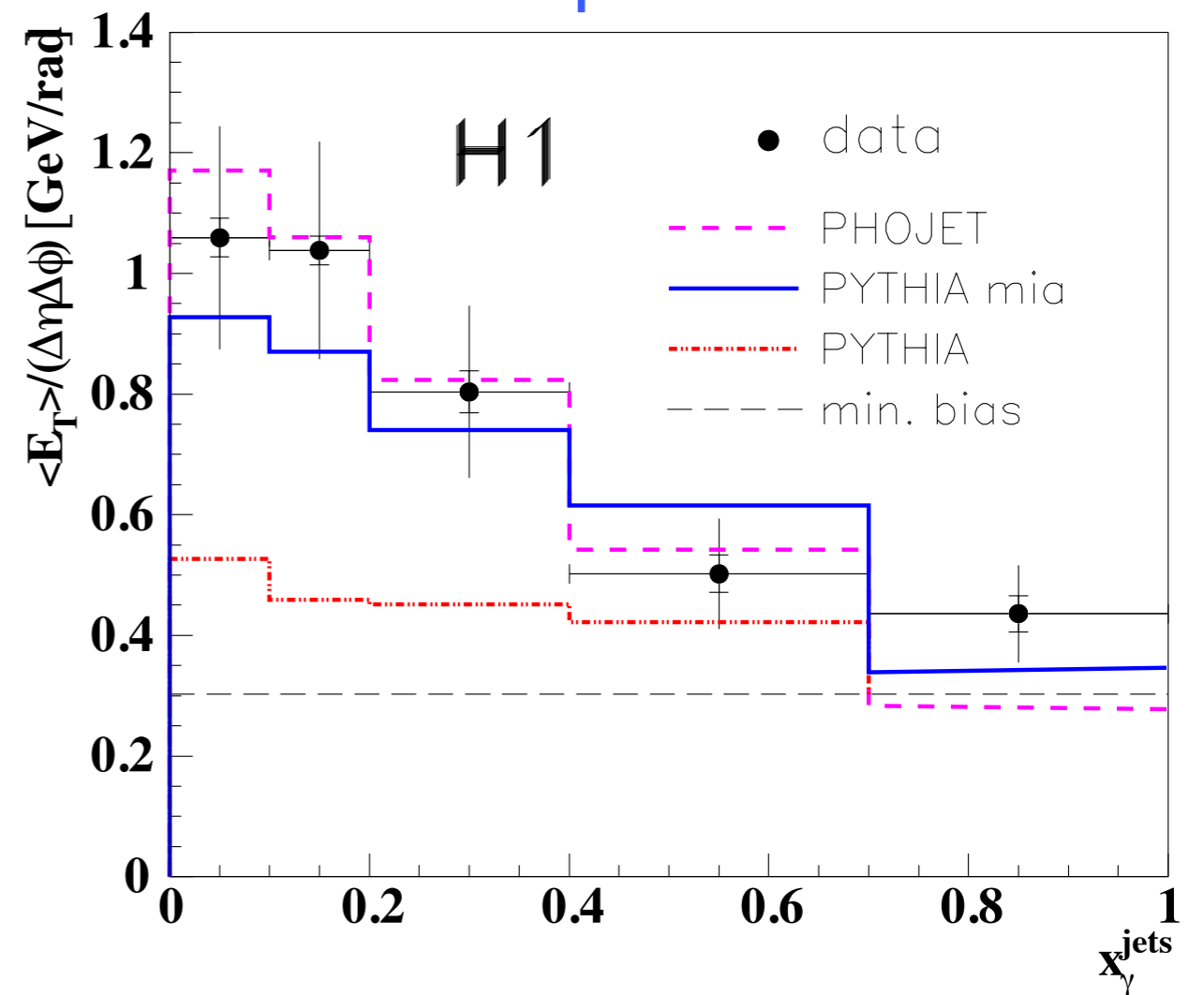
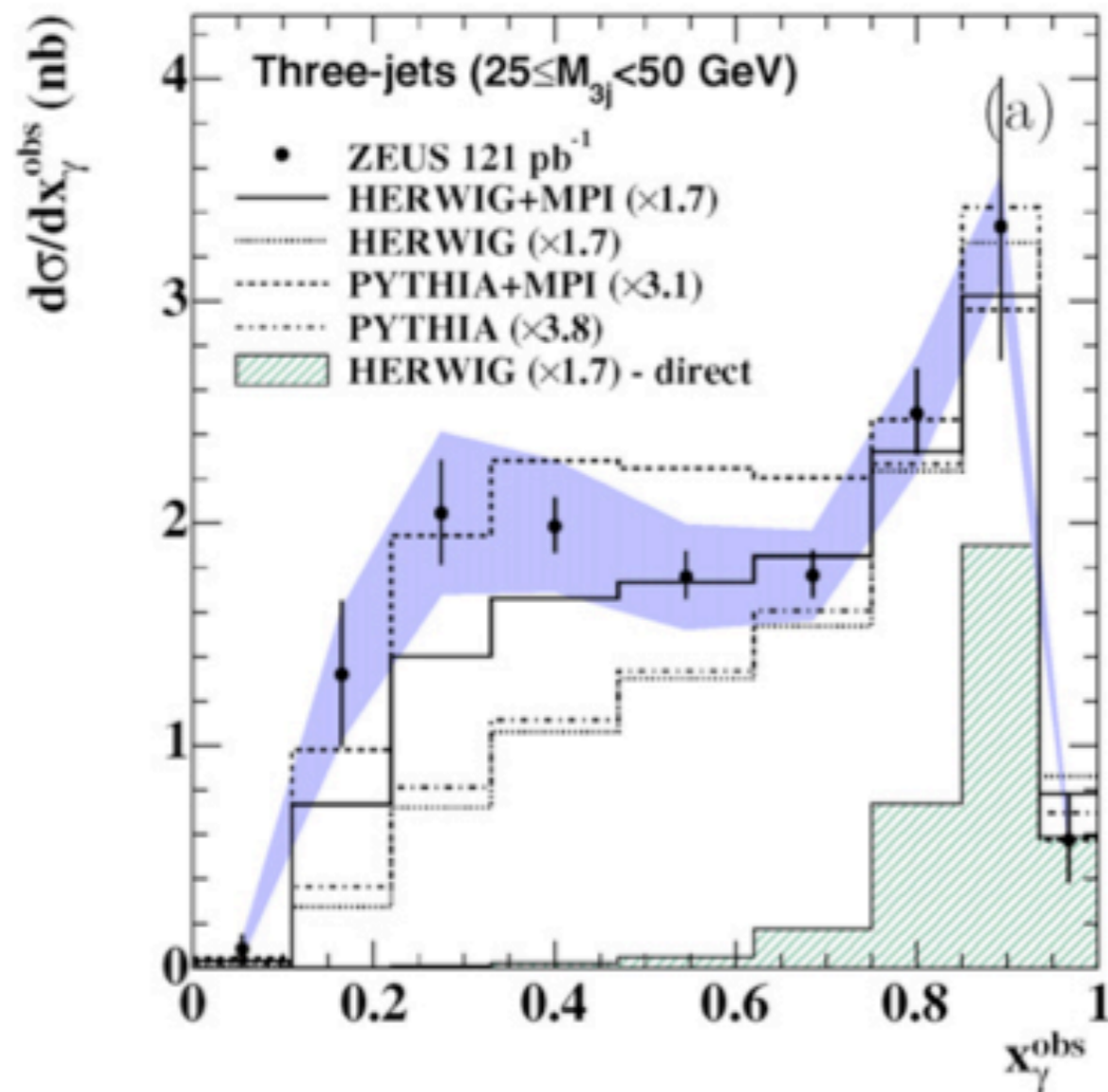
- Study of jet production and underlying event structures in ep:
 - photoproduction
 - smooth transition from pointlike to hadronlike interaction
 - DIS
 - pointlike interaction, important as benchmark checks (not reported here)



Earlier measurements

- **ZEUS:**(Nuclear Physics B 792 (2008) 1-47)
- 3 jets in photoproduction $E_T > 6$ GeV
- measurement of x_γ

- **H1:**(Z.Phys.C70:17-30,1996.)
- 2 jets in photoproduction
- measurement of energy flow outside jets

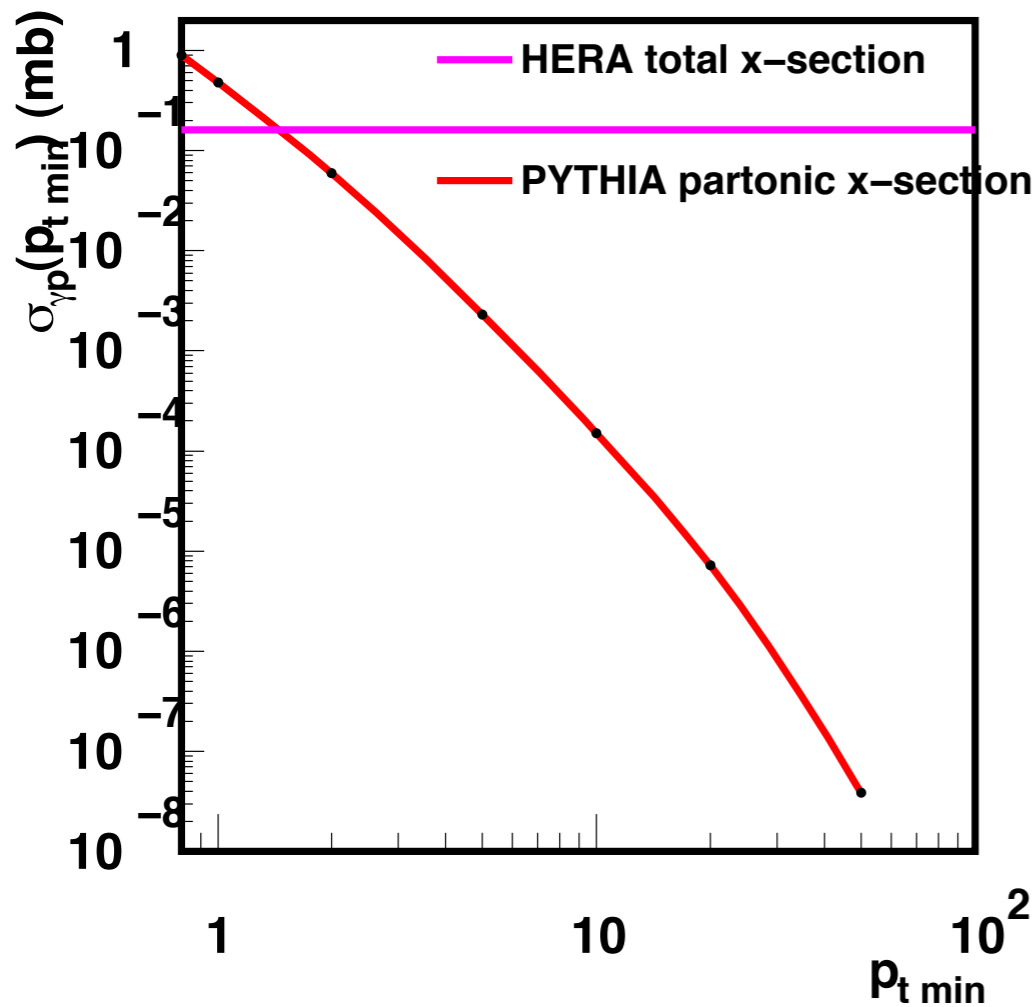


- **Models including multiparton interactions come closer to measurements !**

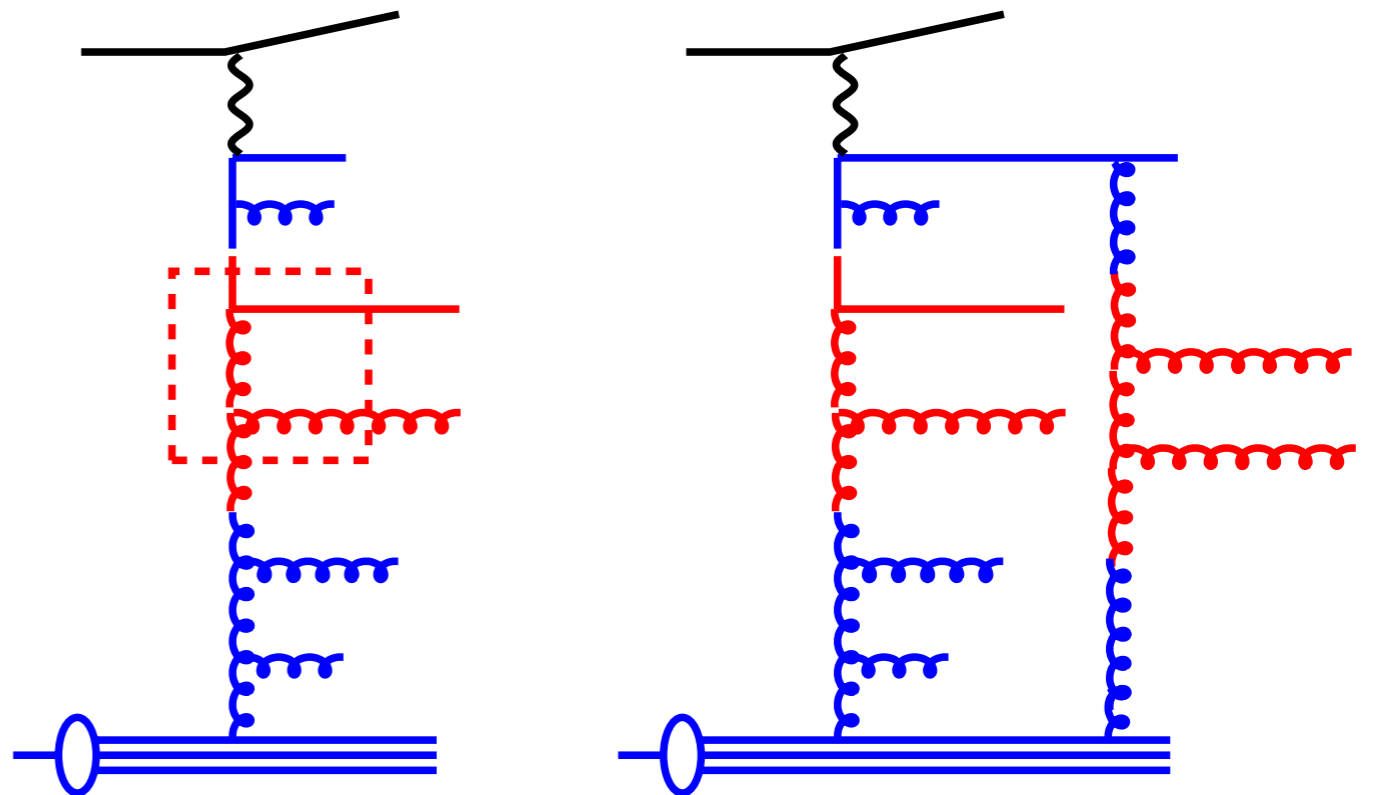
Models for underlying events

- Multiparton interaction model (a la PYTHIA)

$$\sigma_{hard}(p_{T\ min}^2) = \int_{p_{T\ min}^2} dp_T^2 \frac{d\sigma_{hard}(p_T^2)}{dp_T^2}$$



- Partonic cross section exceeds total cross section at small $p_T > 1$ GeV
- possible solution:
 - more than one partonic interaction per event !



- depends on parton density
- parton evolution scheme

Inclusive jet x-section in γp

- Event selection

$$Q^2 < 1 \text{ GeV}^2$$

$$E_T^{\text{jet}} > 17 \text{ GeV}$$

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

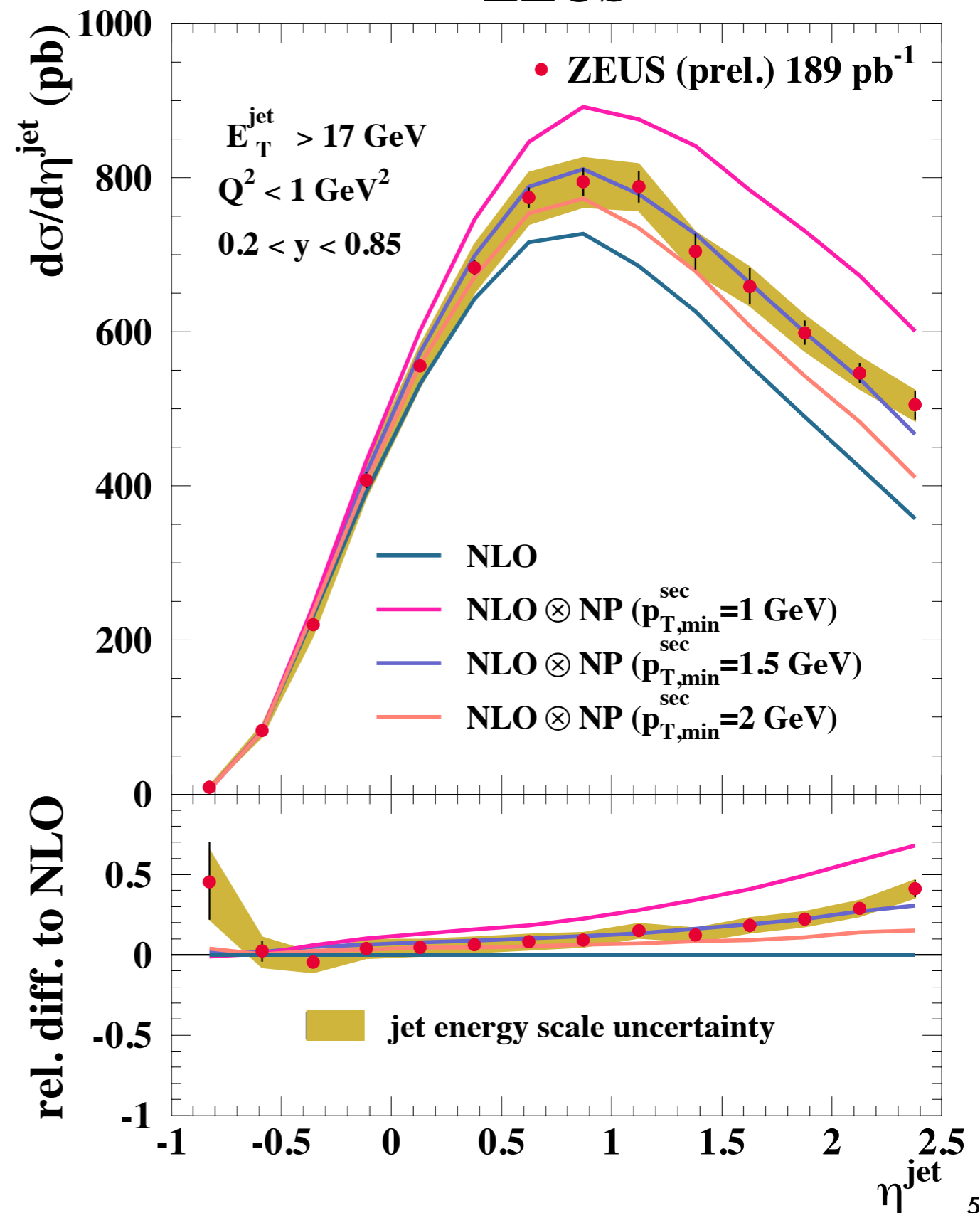
- Non Perturbative (NP) correction determined by PYTHIA MC

- minimum p_T of secondary scattering: $p_{T, \min}^{\text{sec}}$

- NP effect: $\frac{\sigma_{w/oMPI}^{MC}}{\sigma_{all}^{MC}}$

- NP corrections can be large
 $\rightarrow 40\%$ in large η region

ZEUS ZEUS-prel-10-003



Inclusive jet x-section in γp

- Event selection

$$Q^2 < 1 \text{ GeV}^2$$

$$E_T^{jet} > 17 \text{ GeV}$$

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

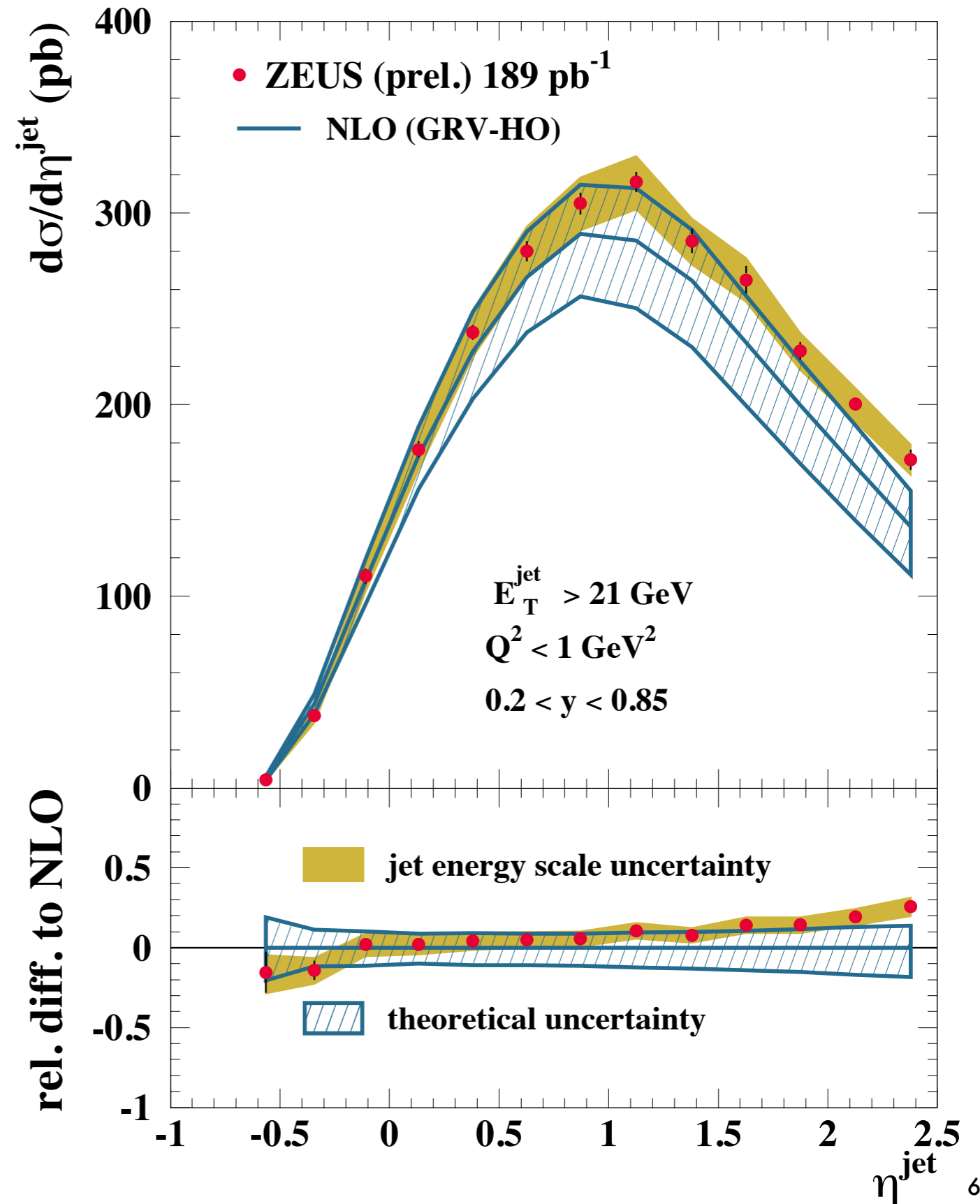
- NP correction determined by PYTHIA MC

- minimum pt of secondary scattering: $p_T^{sec} min$

- NP effect: $\frac{\sigma_{w/oMPI}^{MC}}{\sigma_{all}^{MC}}$

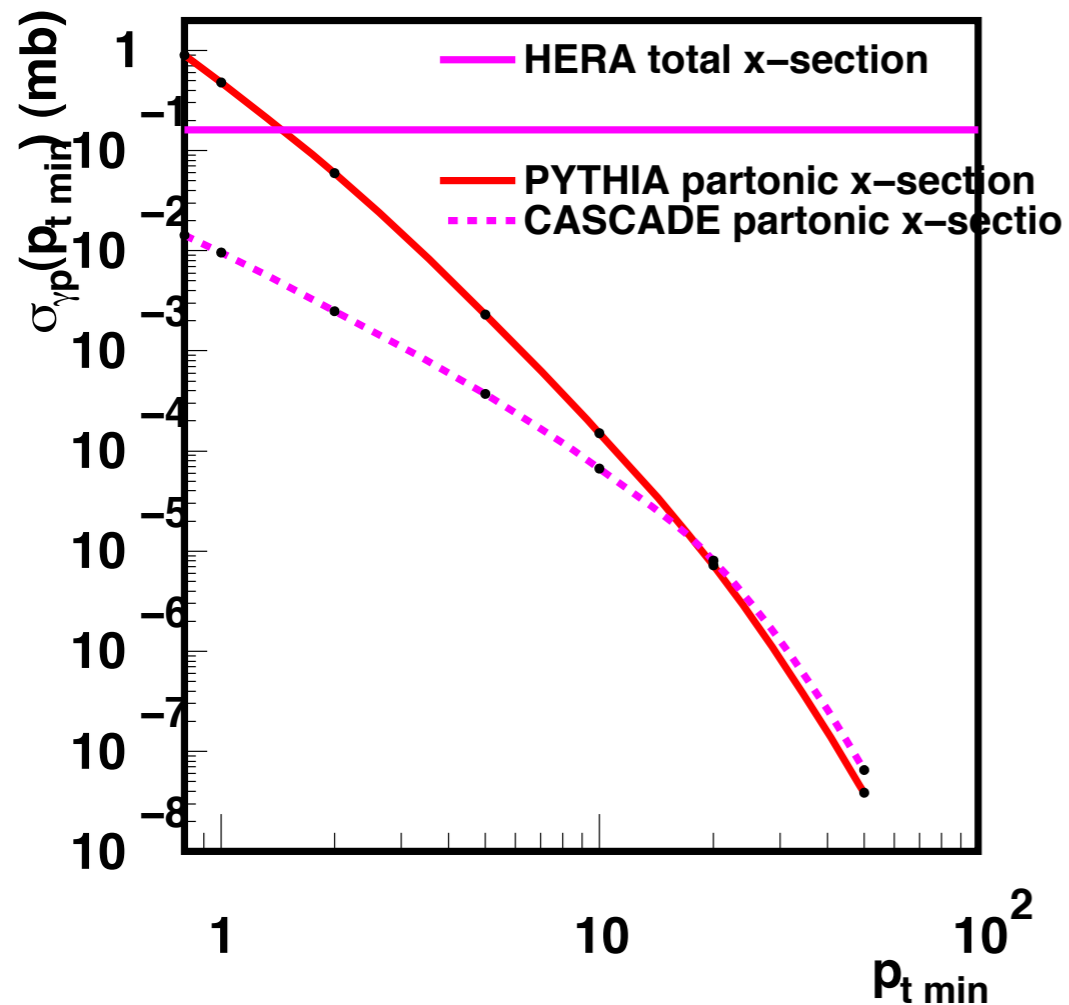
- NP corrections not needed for $E_T > 21 \text{ GeV}$

ZEUS ZEUS-prel-10-003

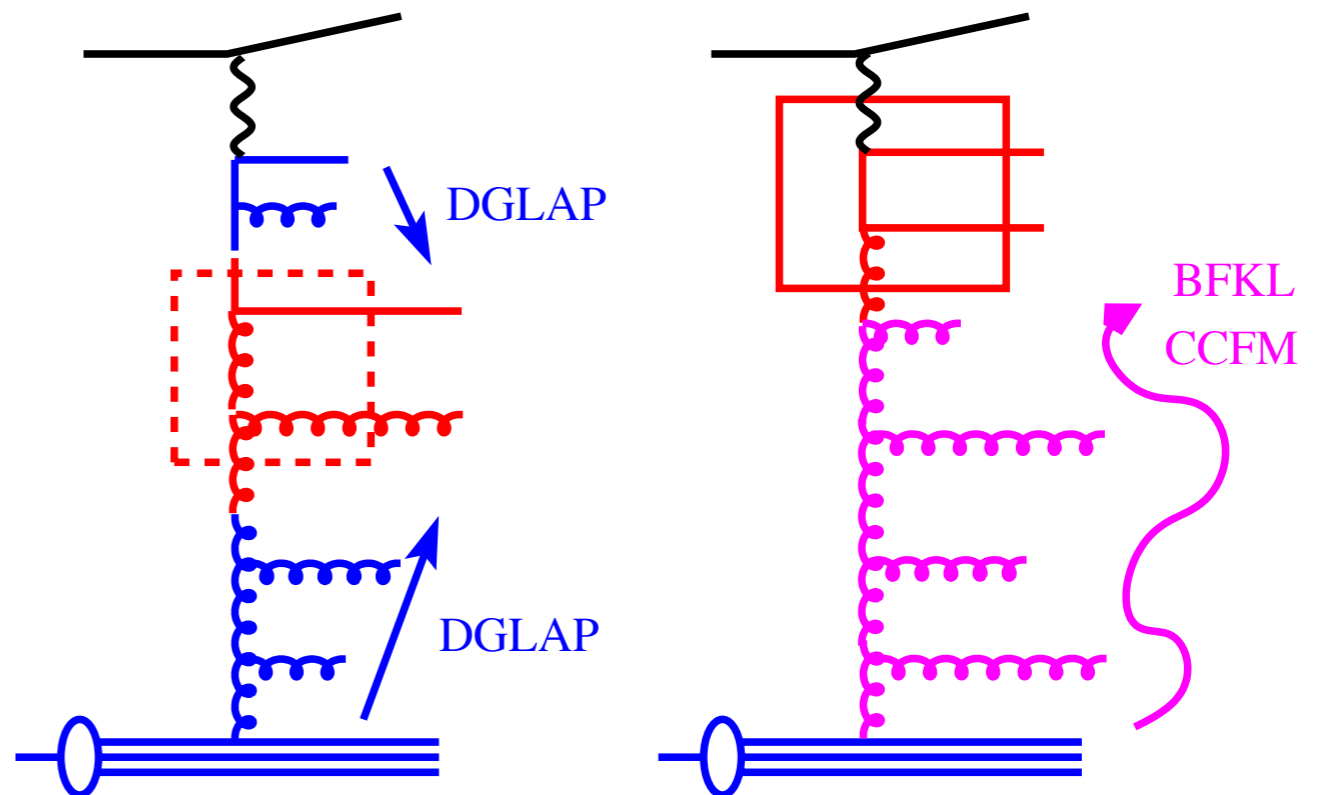


Models for underlying events

- Parton radiation ala CCFM (CASCADE)
- unordered parton radiation but also different parton densities



- Partonic cross section does not exceed total cross section at small $p_t > 1$ GeV
- ONLY one partonic interaction per event !



Underlying events in photoproduction

H1-prelim-08-036

- Event selection:

$$Q^2 < 0.01 \text{ GeV}^2$$

$$0.3 < y < 0.65$$

- **Dijets (inclusive kt - algorithm)**

$$p_T^{jet} > 5 \text{ GeV}$$

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

- **charged particles**

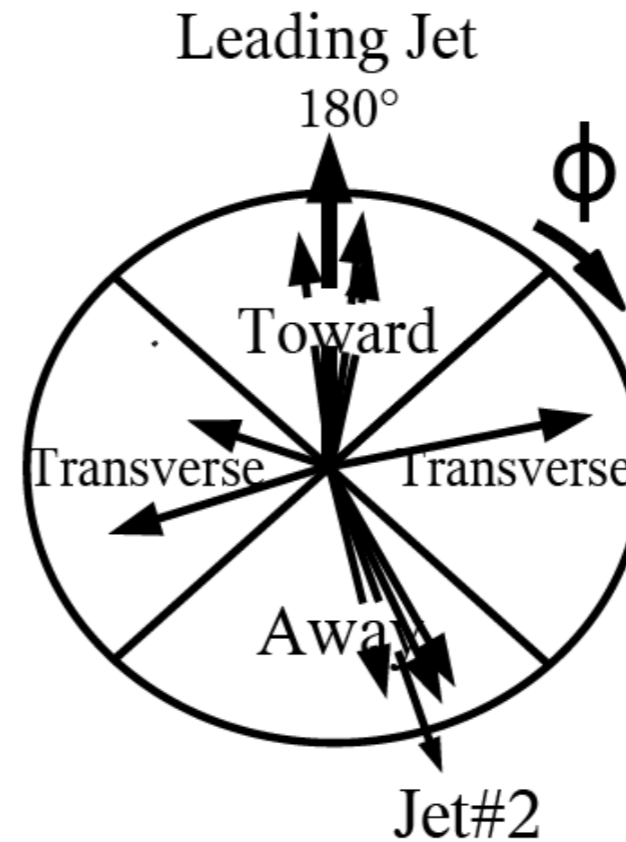
$$p_T > 0.15 \text{ GeV}$$

$$|\eta| < 1.5$$

- **high activity region:**

→ **transverse region with largest**

$$p_T^{sum} = \sum_i^{tracks} p_t^i$$



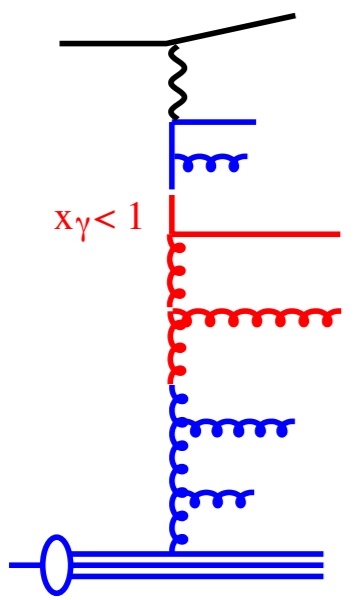
$$\mathcal{L} = 48 \text{ pb}^{-1}$$

$$E_e = 27.6 \text{ GeV}, E_p = 920 \text{ GeV}$$

- Measured charged particle spectra are unfolded to hadron level:
- **Systematics: $\sim 3\%$**
 - track finding, vertex reconstruction efficiency, nuclear interaction
 - hadronic energy scale

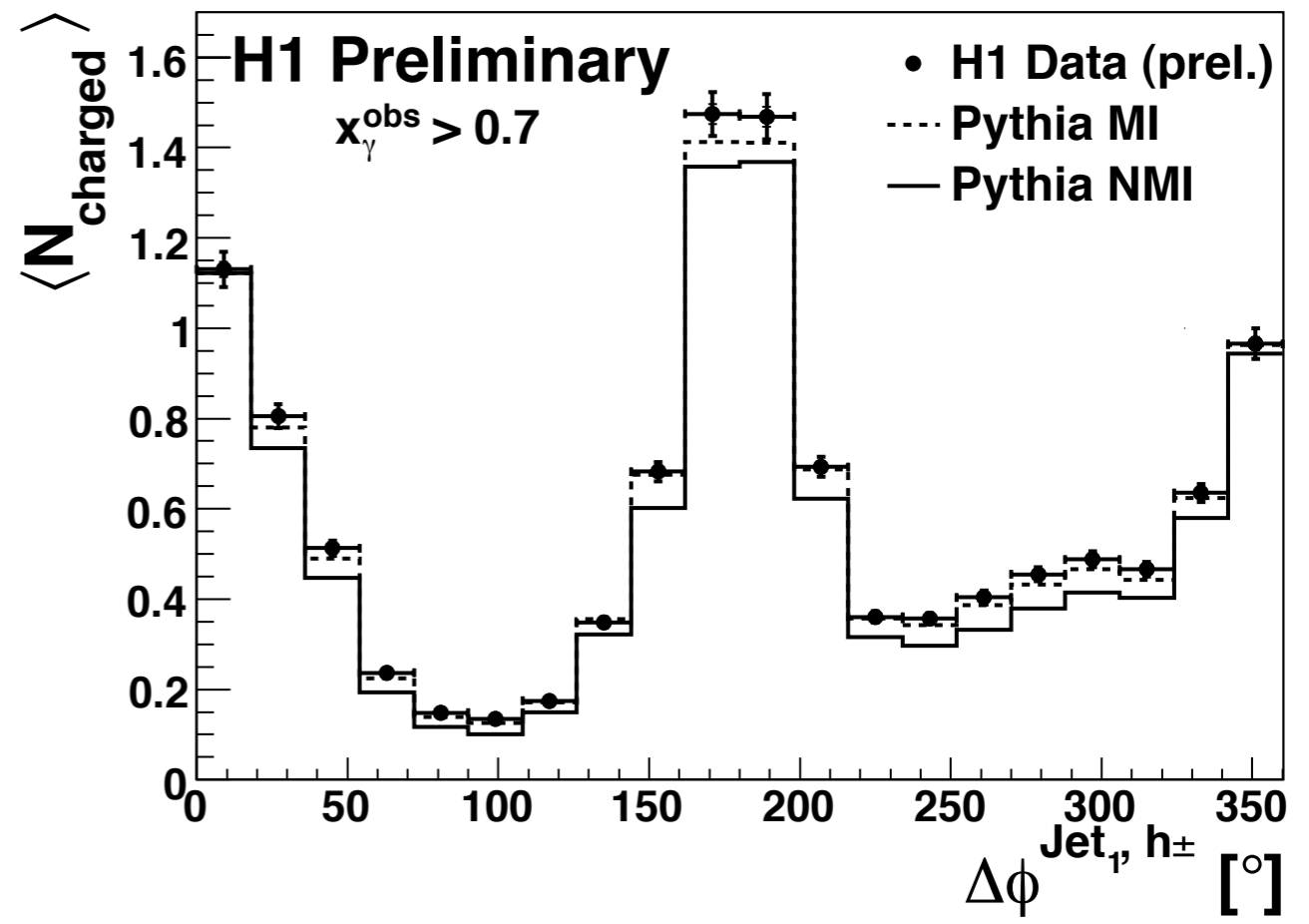
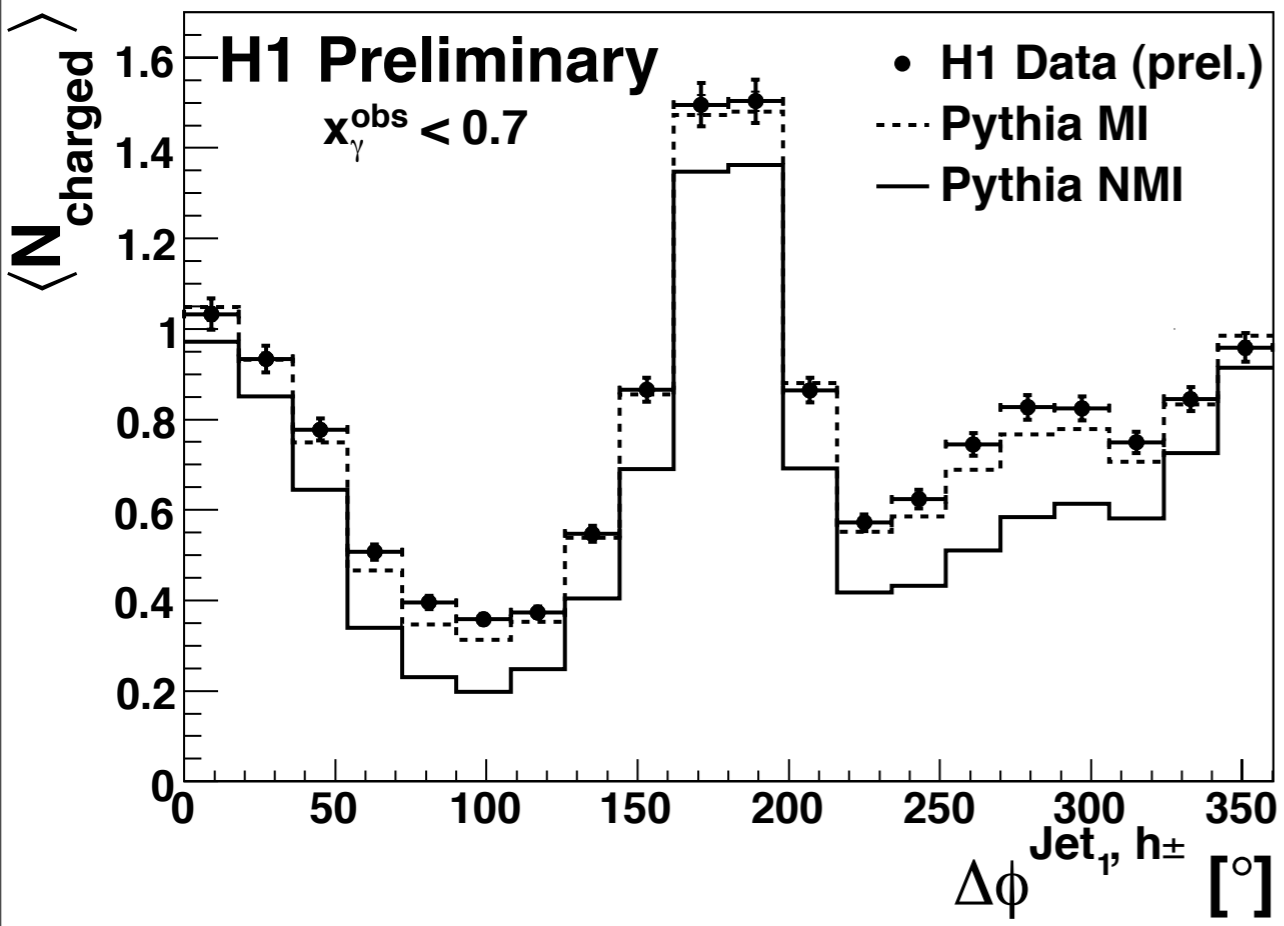
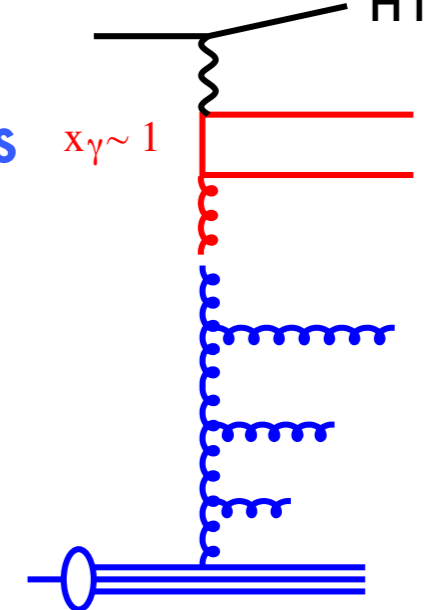
Charged particle multiplicity

H1prelim-08-036



- Separate resolved from direct processes

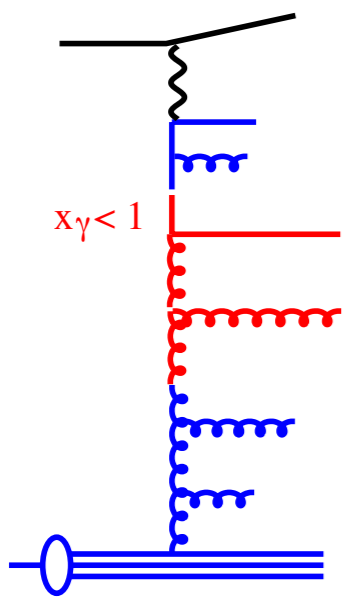
$$x_\gamma = \frac{\sum_{jets} (E - p_z)}{\sum_h (E - p_z)}$$



- Pythia simulation with multiparton interactions is closer to measurement !

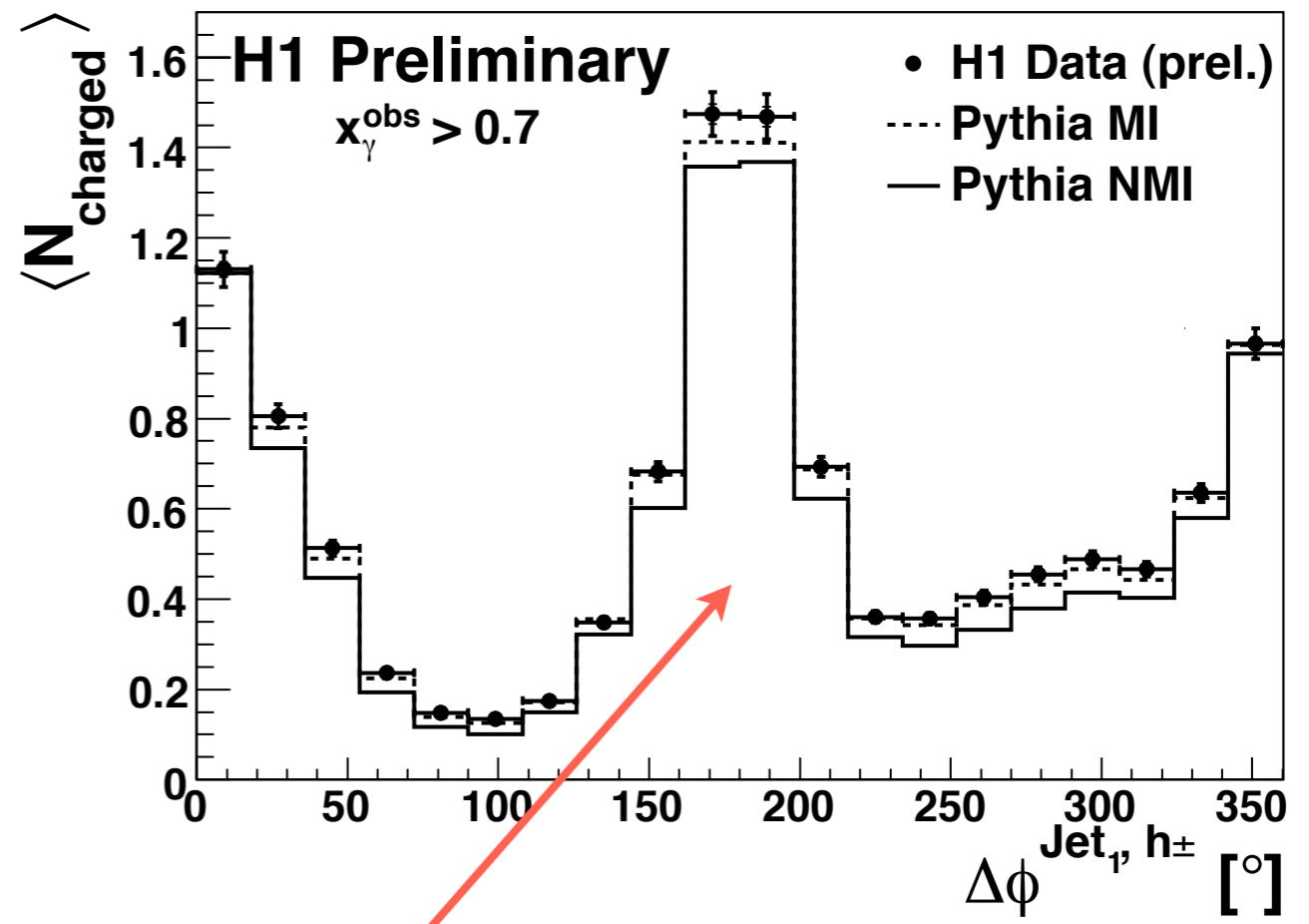
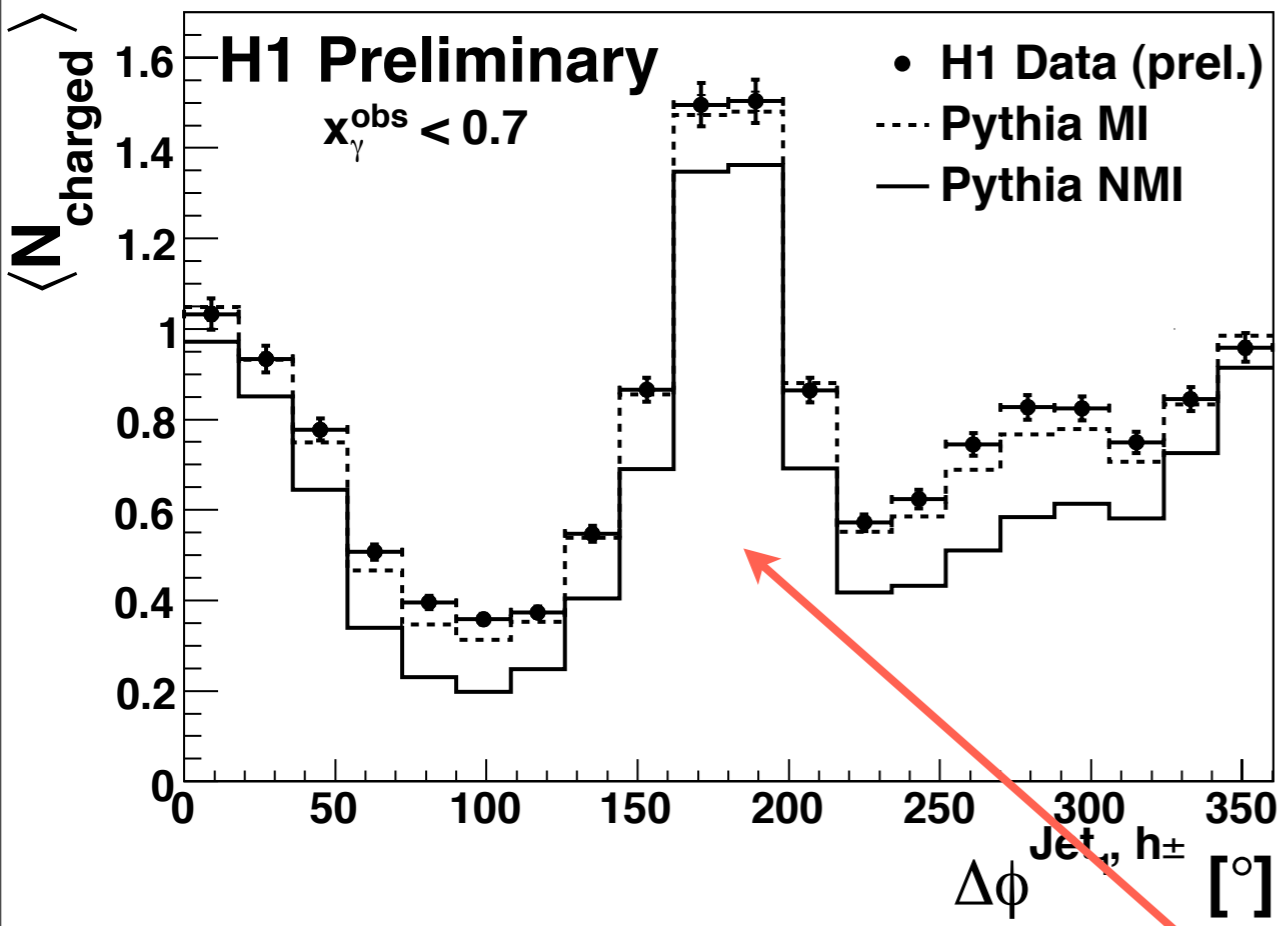
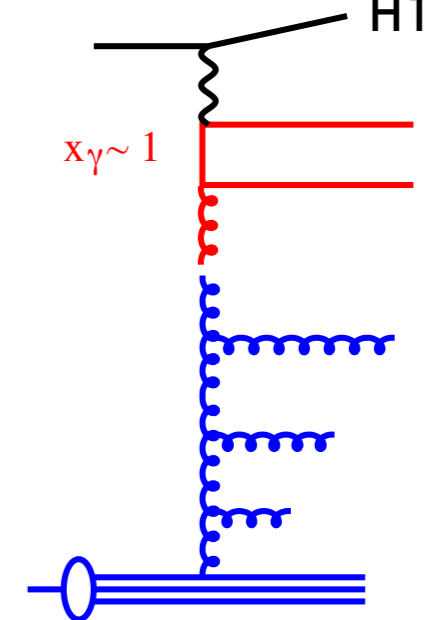
Charged particle multiplicity

H1prelim-08-036



- Separate resolved from direct processes

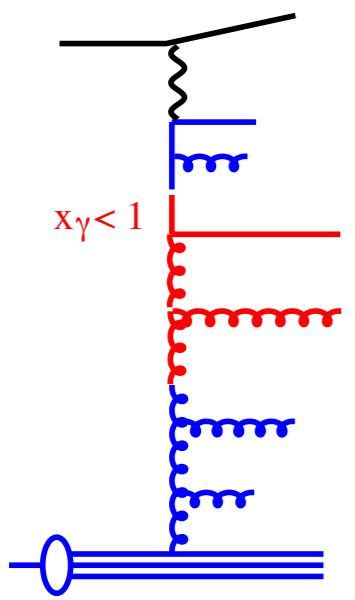
$$x_\gamma = \frac{\sum_{jets} (E - p_z)}{\sum_h (E - p_z)}$$



leading jets

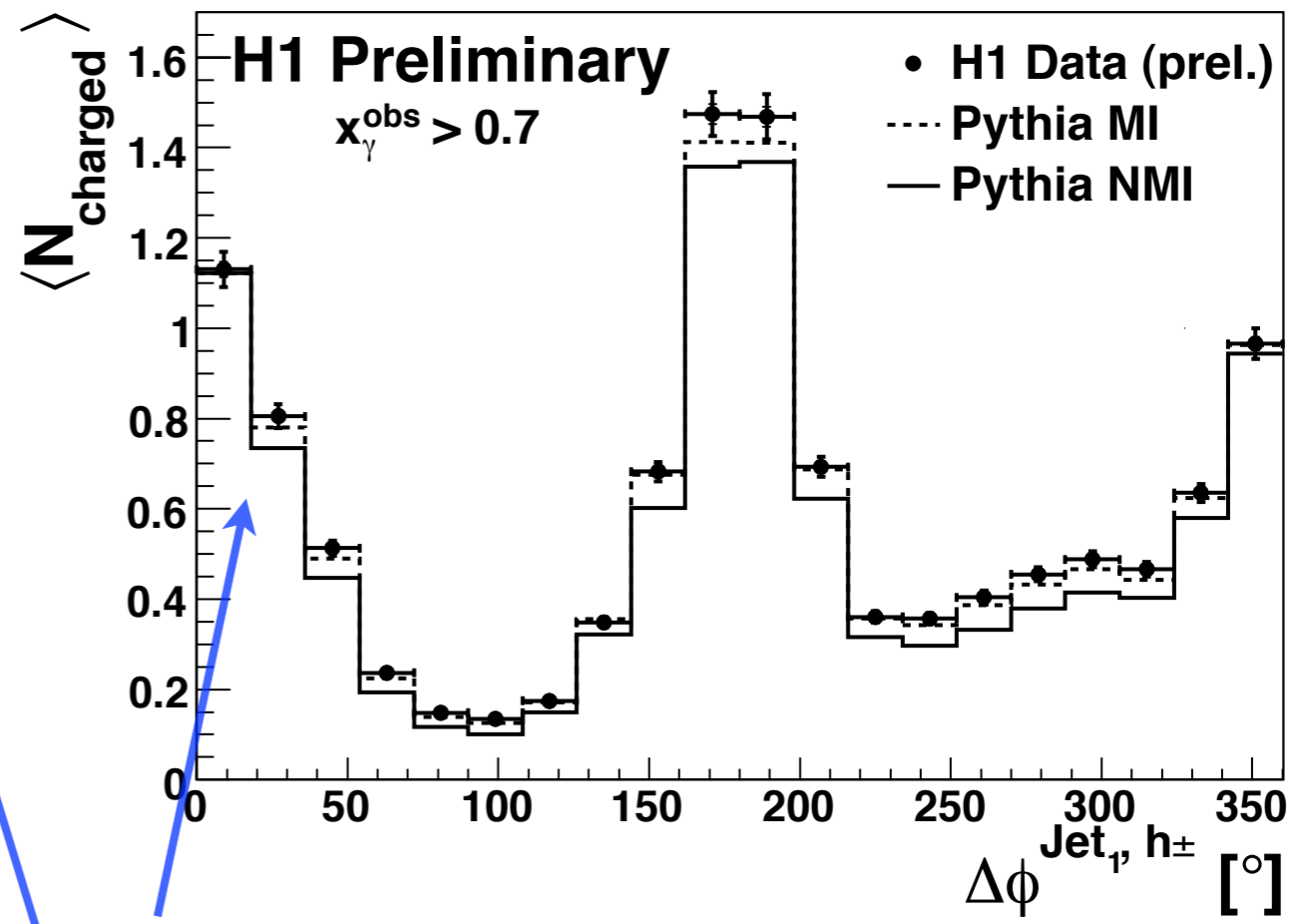
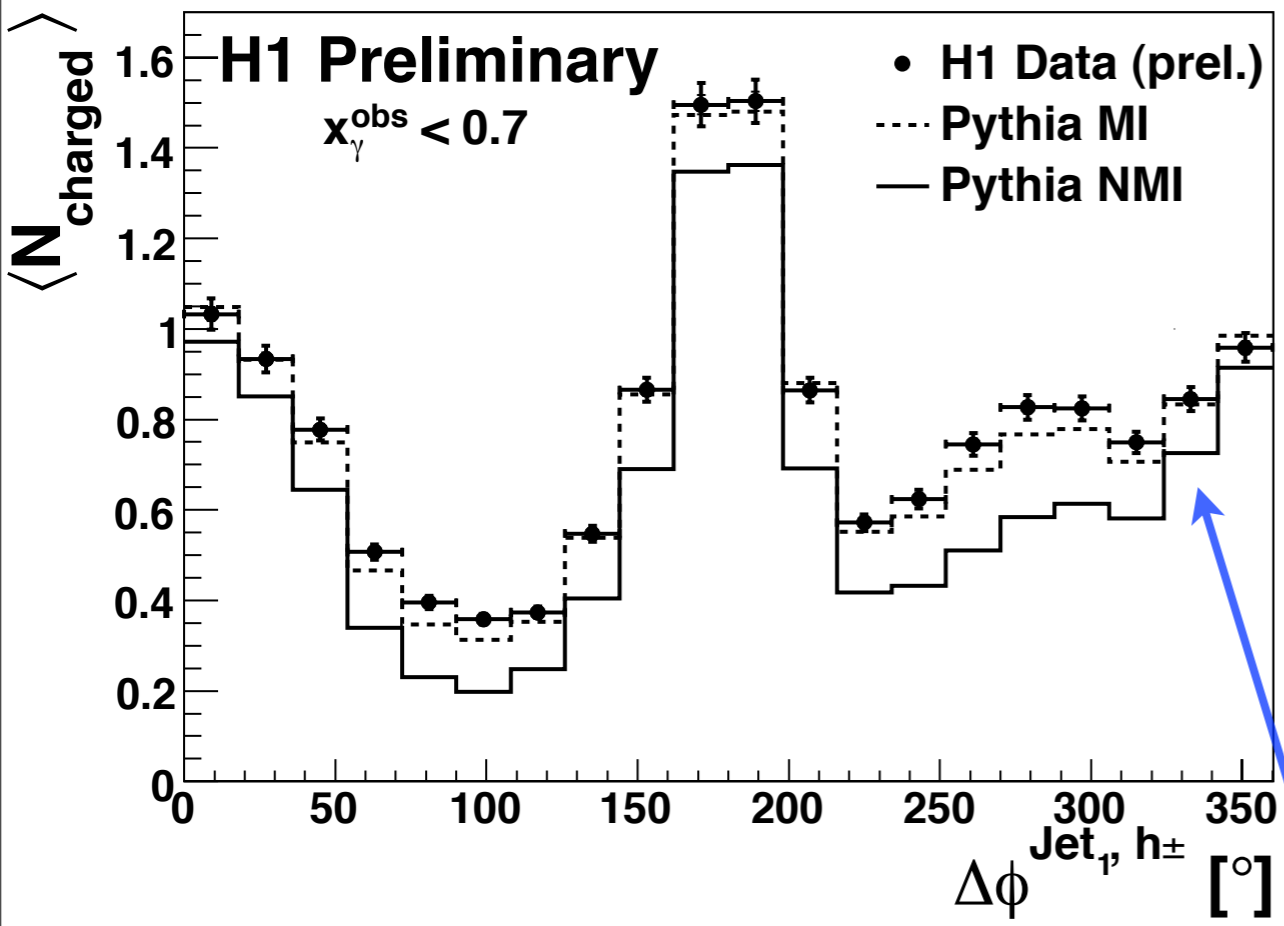
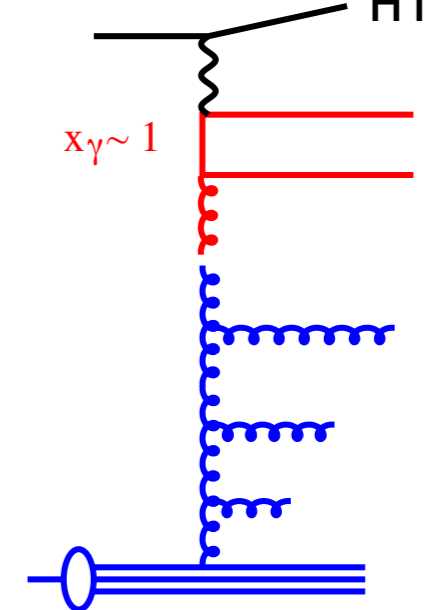
Charged particle multiplicity

H1prelim-08-036



- Separate resolved from direct processes

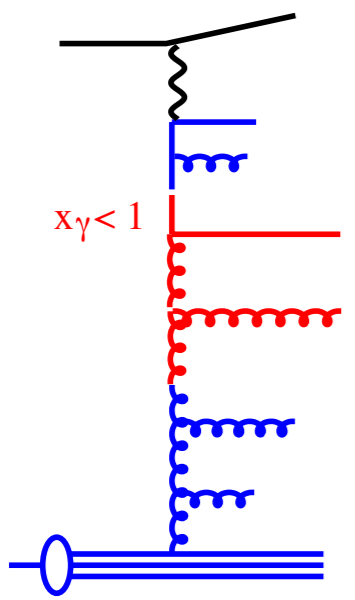
$$x_\gamma = \frac{\sum_{jets} (E - p_z)}{\sum_h (E - p_z)}$$



next to leading jets

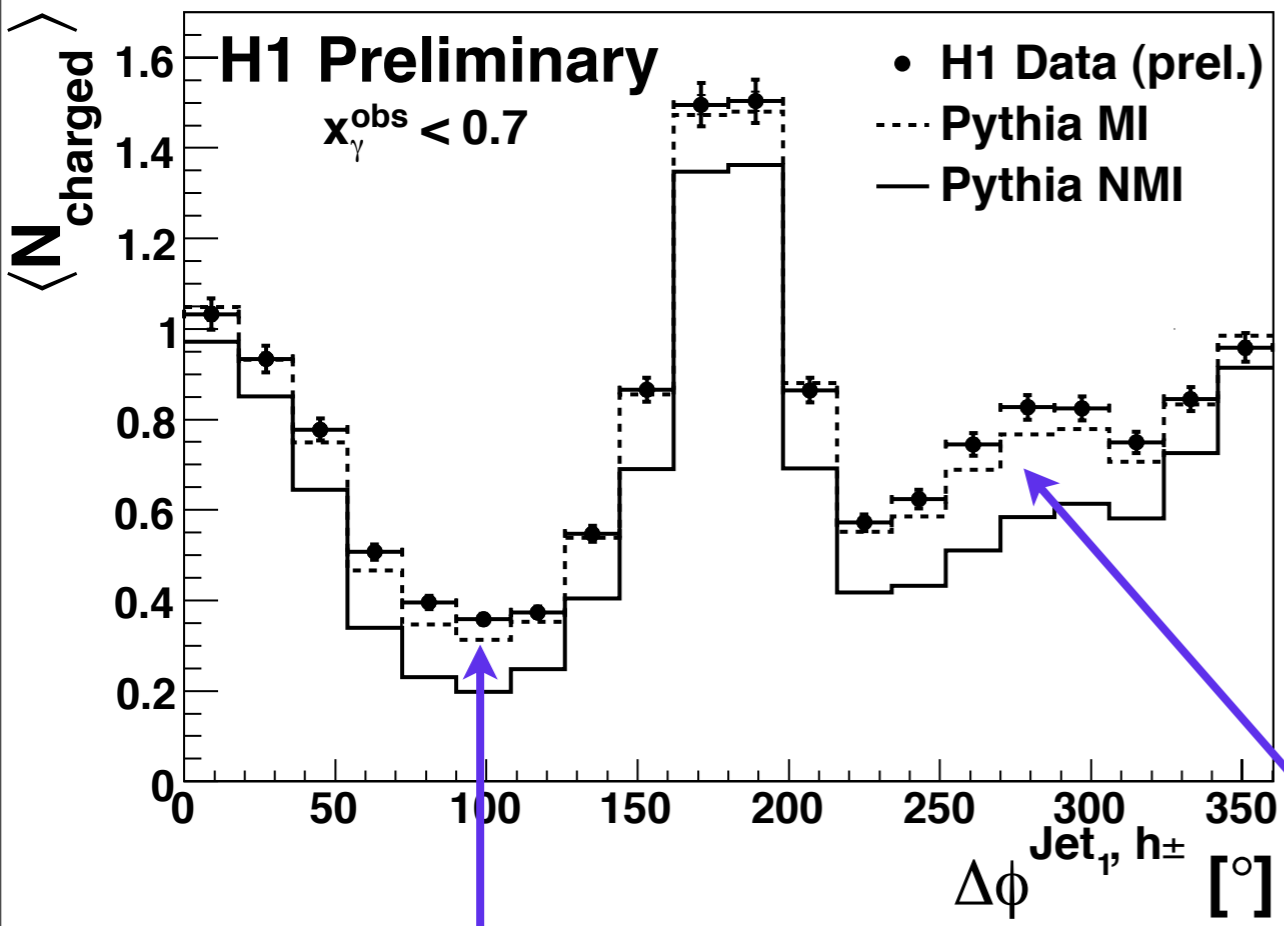
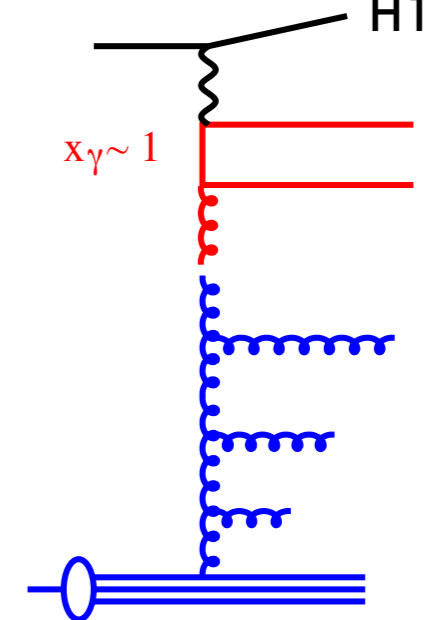
Charged particle multiplicity

H1prelim-08-036

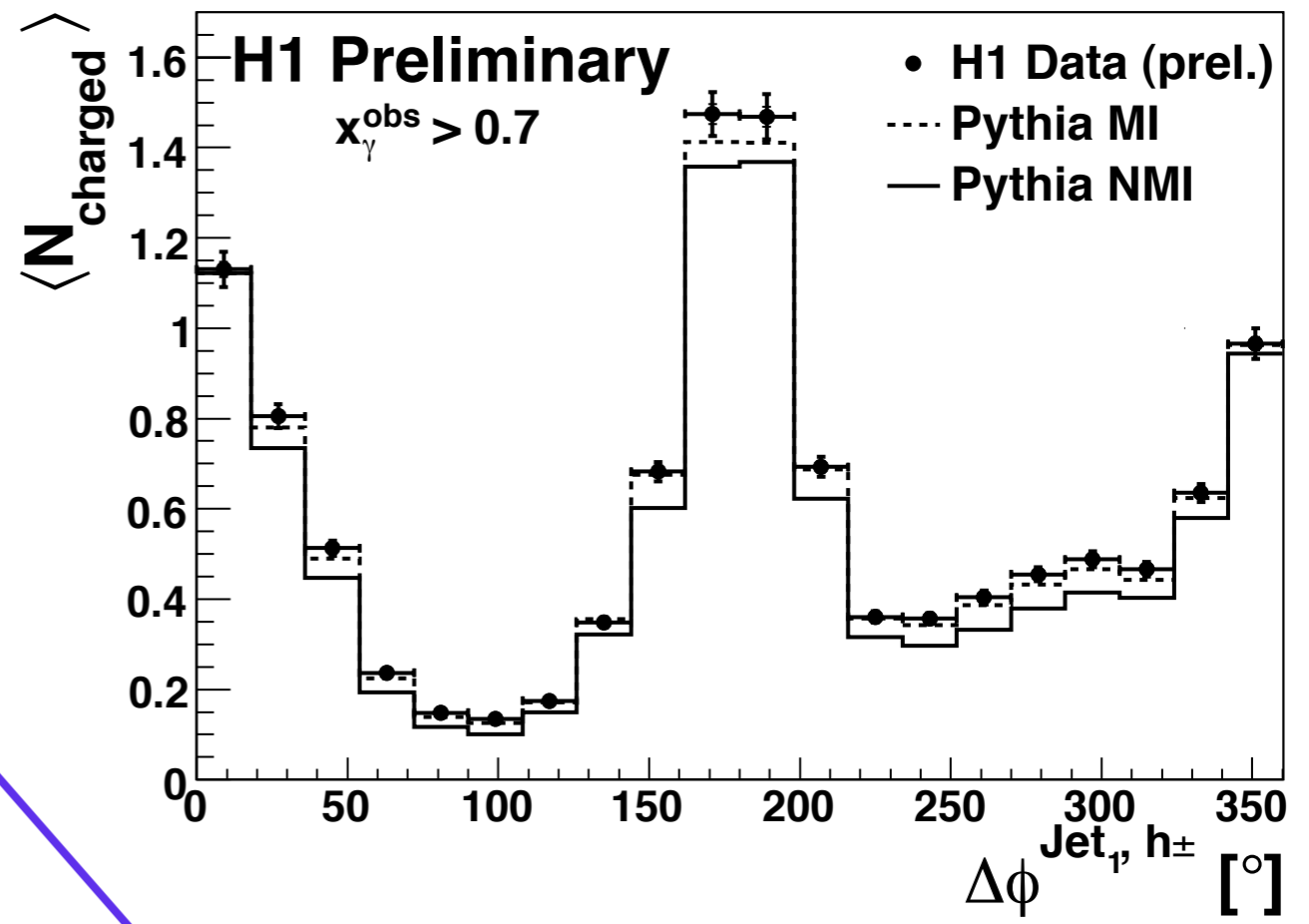


- Separate resolved from direct processes

$$x_\gamma = \frac{\sum_{jets} (E - p_z)}{\sum_h (E - p_z)}$$



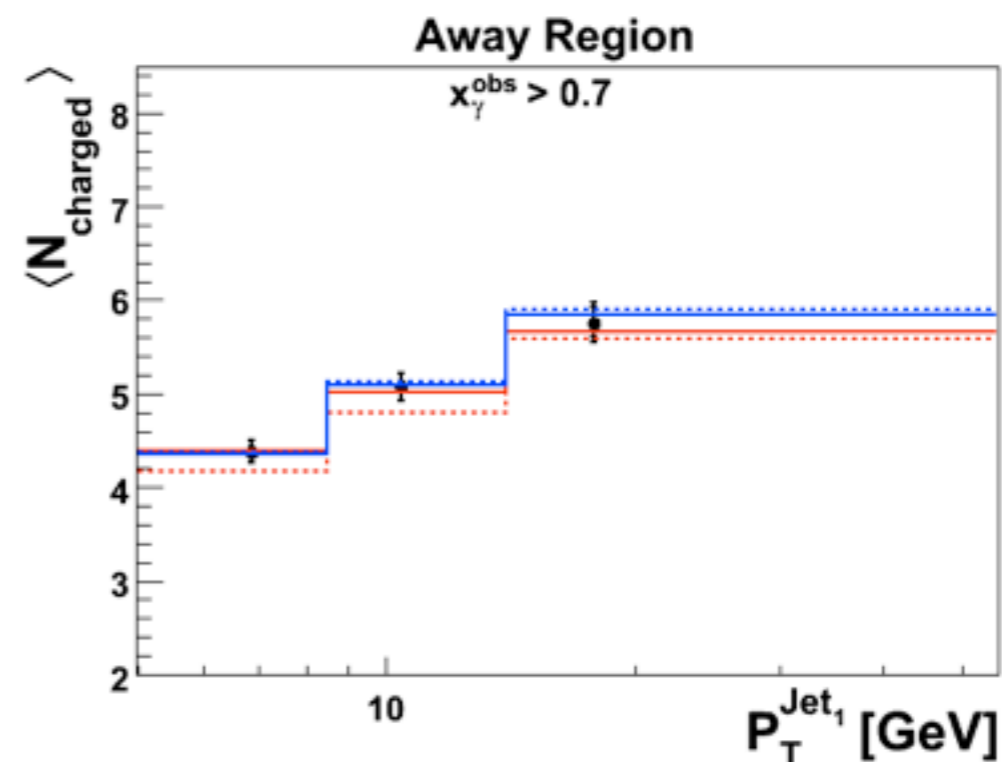
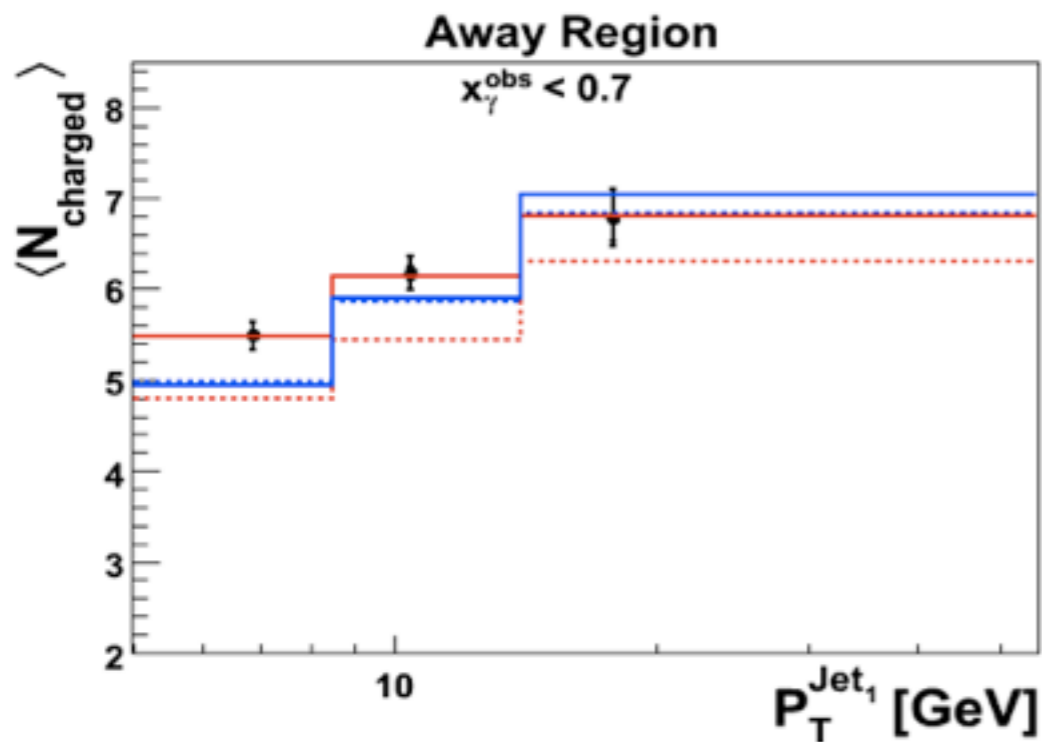
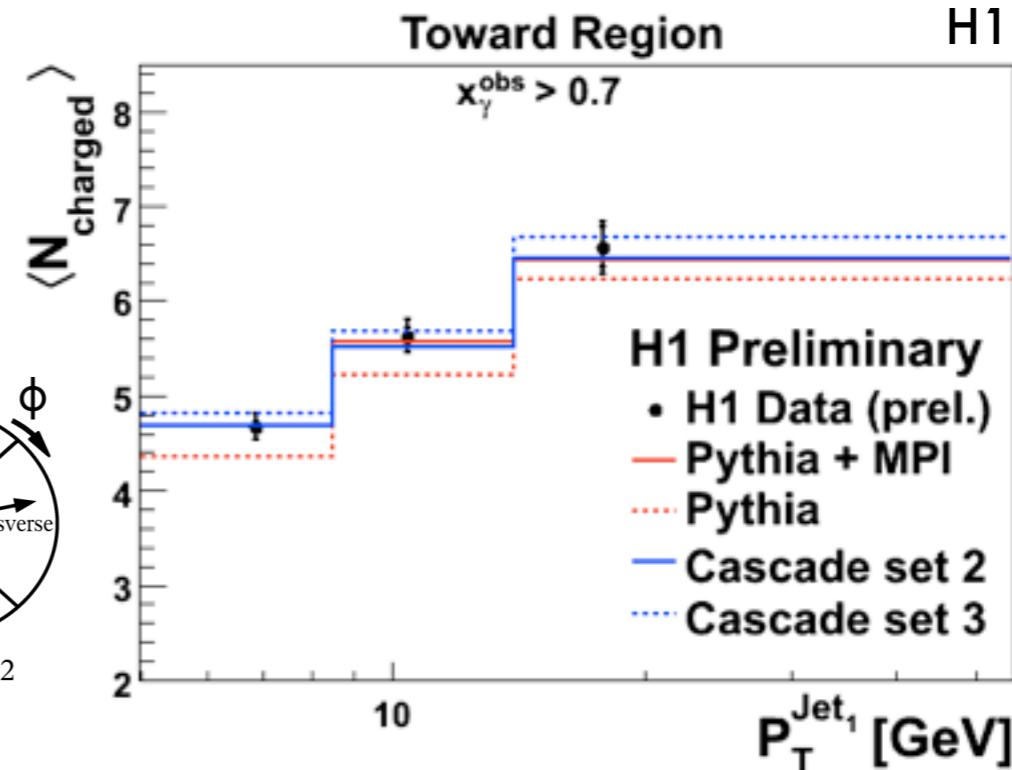
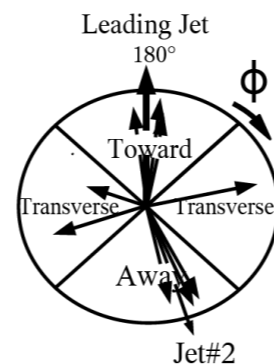
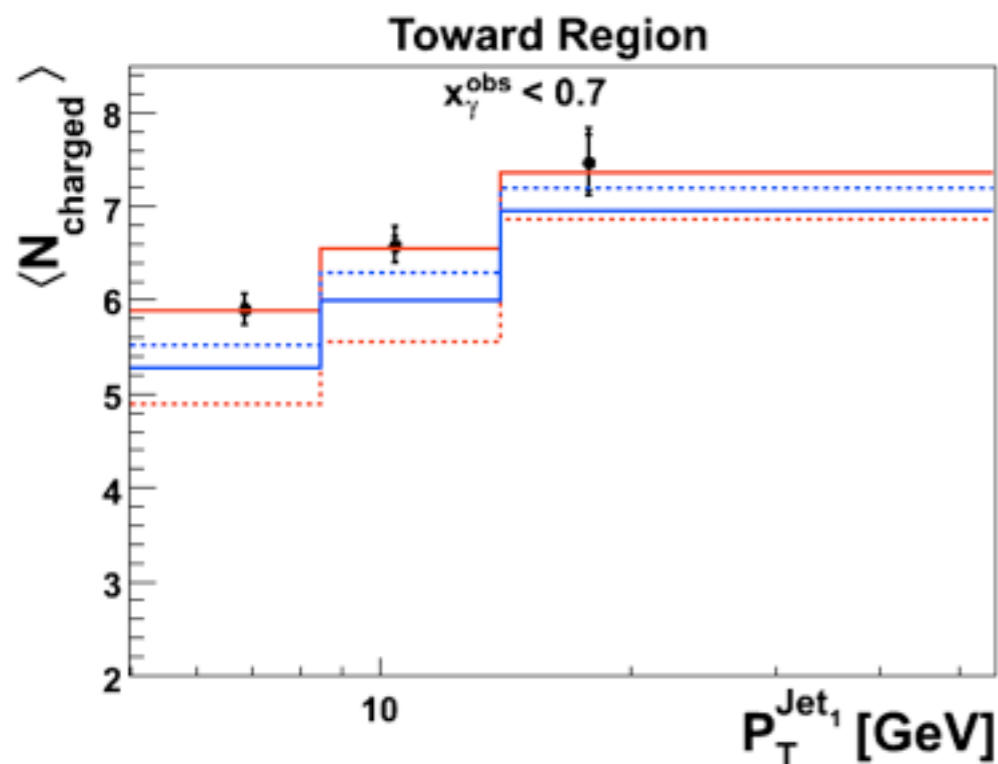
transverse low region



transverse high region

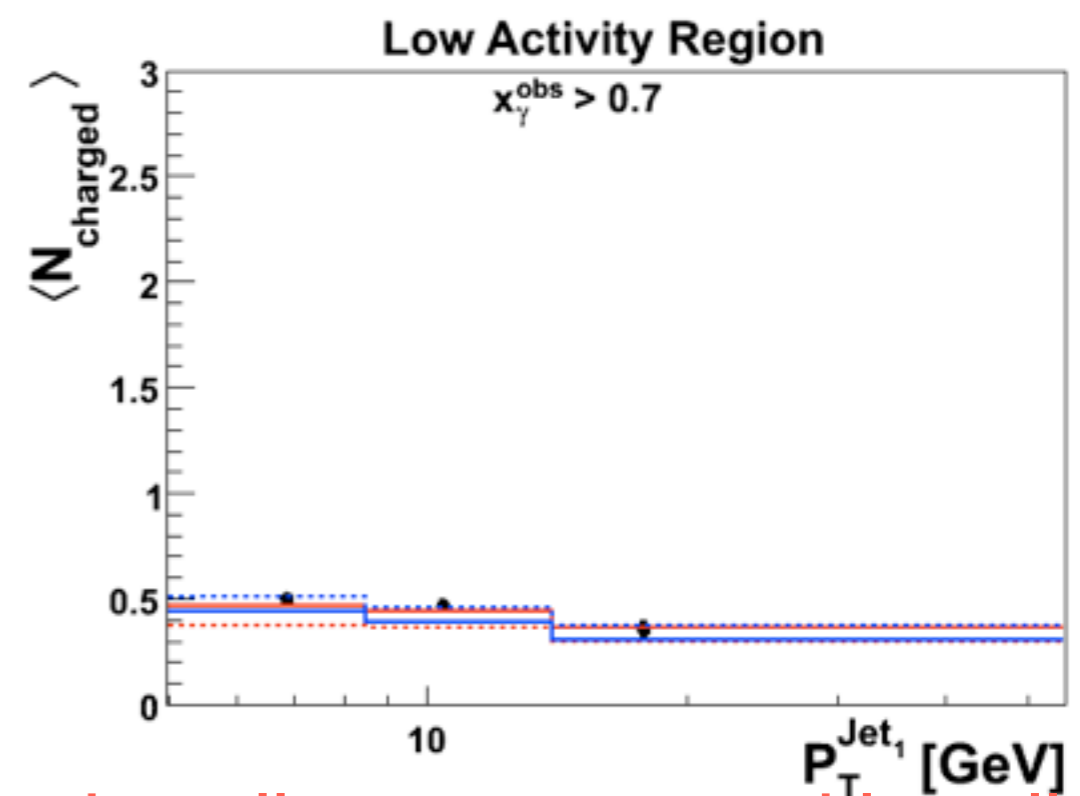
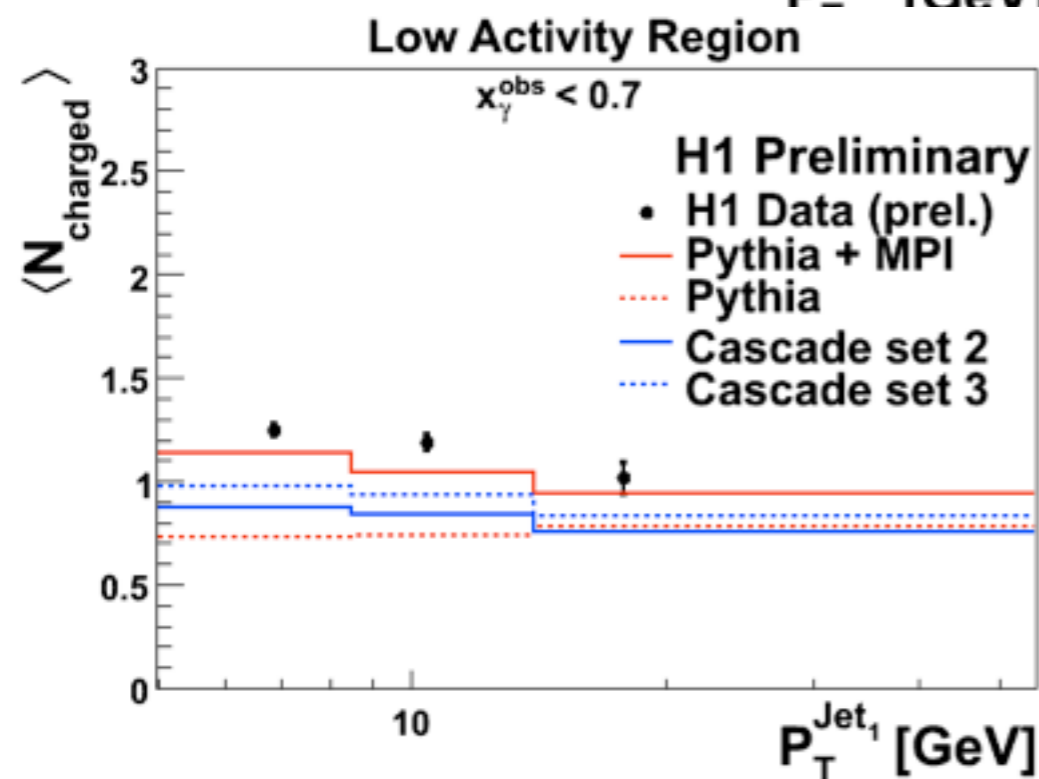
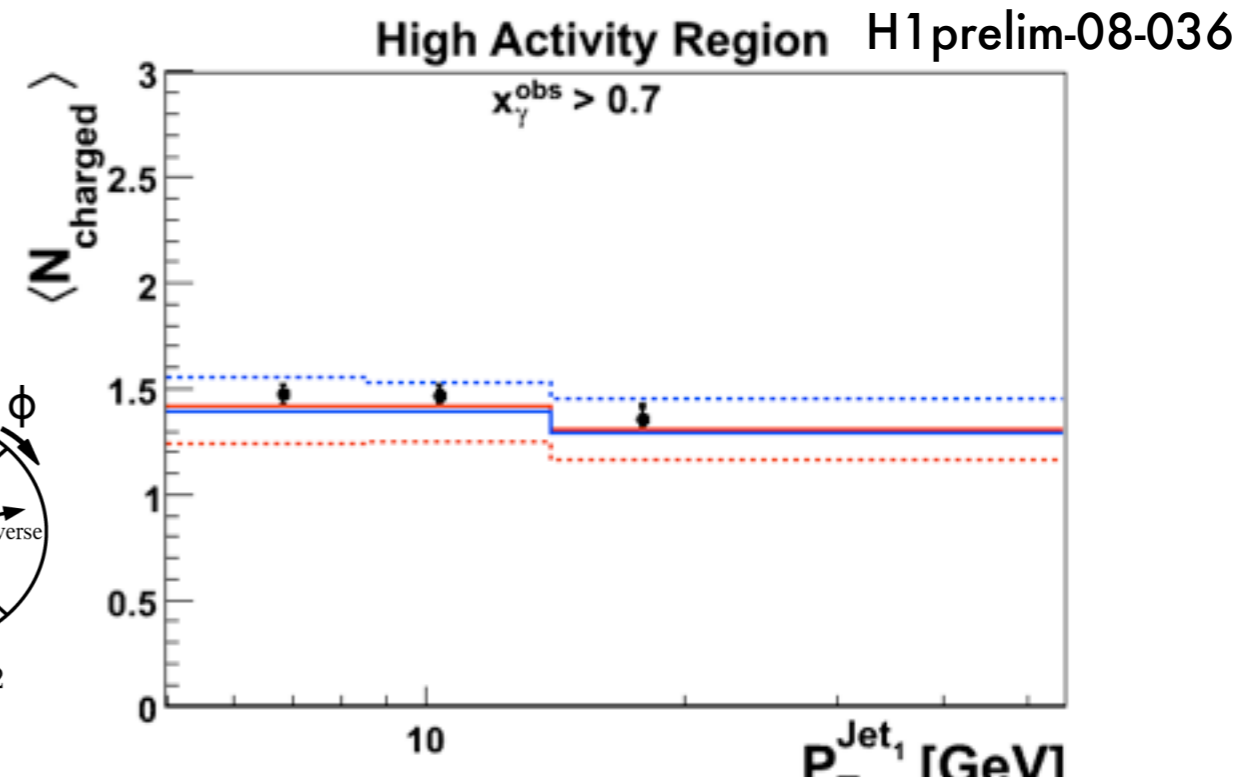
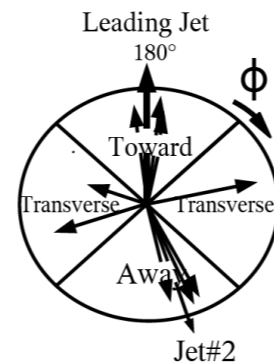
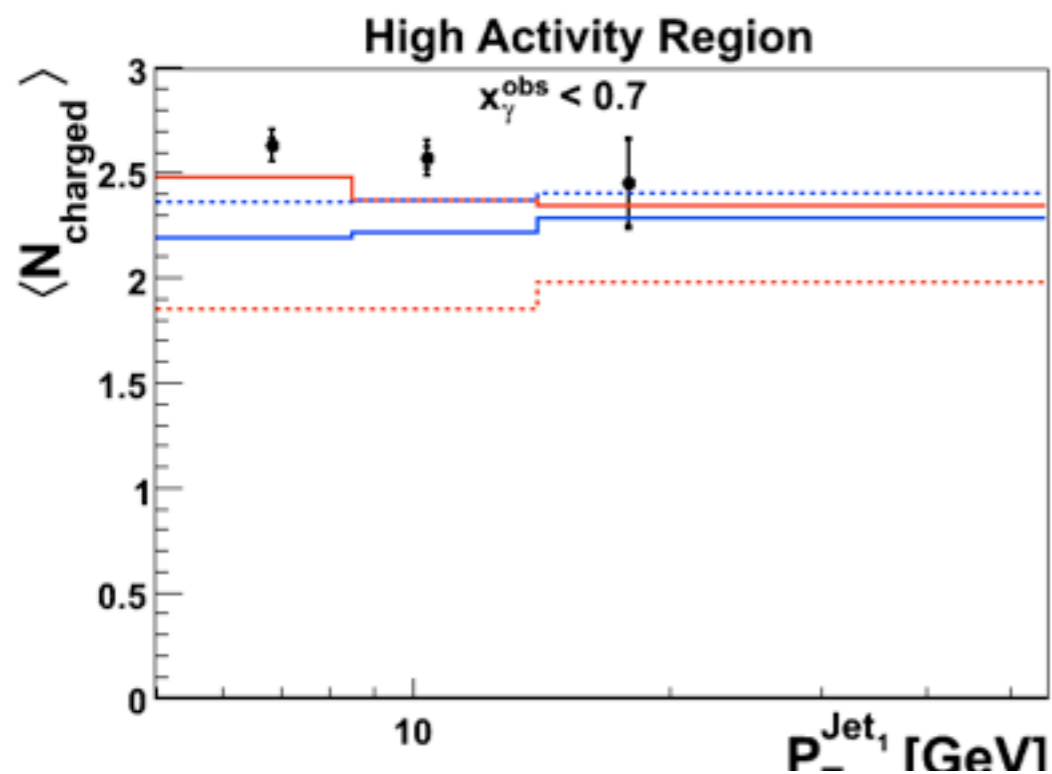
Charged particle multiplicities

H1prelim-08-036



- Charged particle multiplicity increases with increasing jet pt !
- Model differences in small pt resolved photon region !

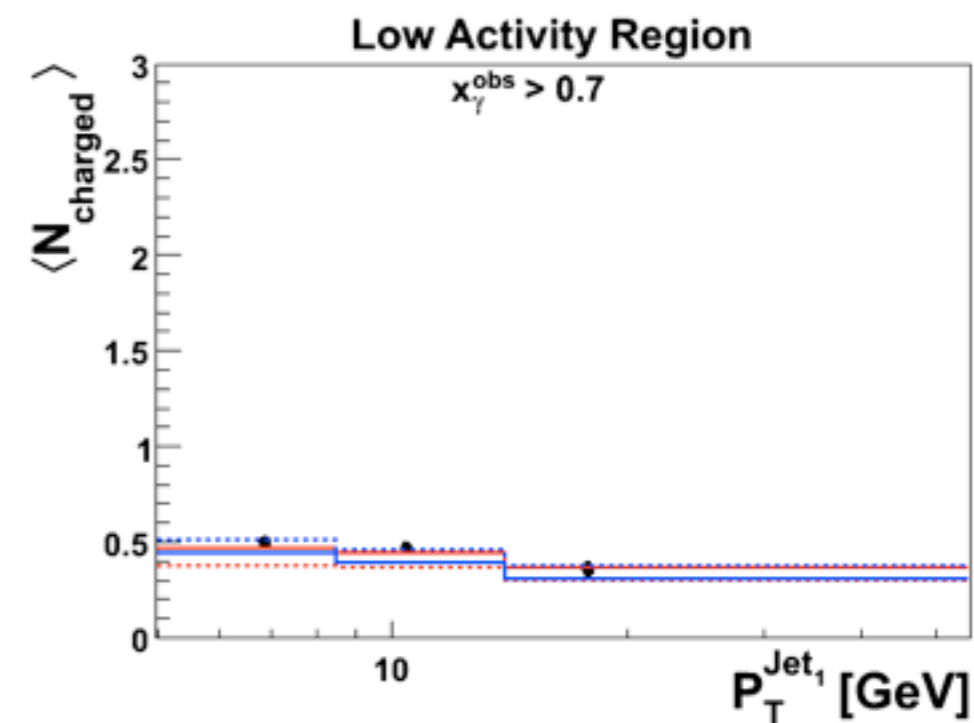
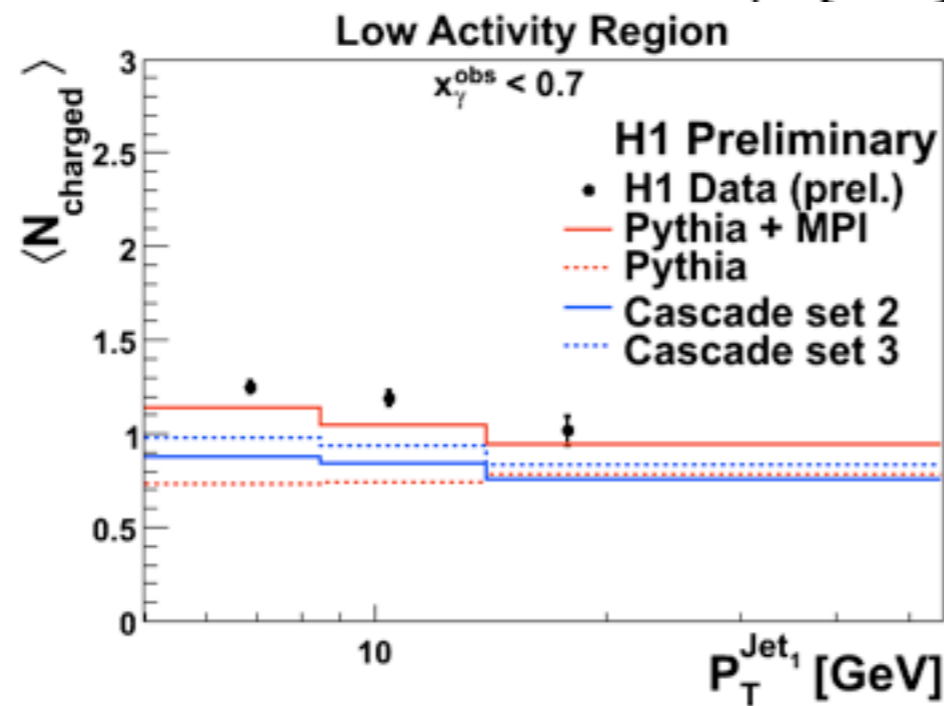
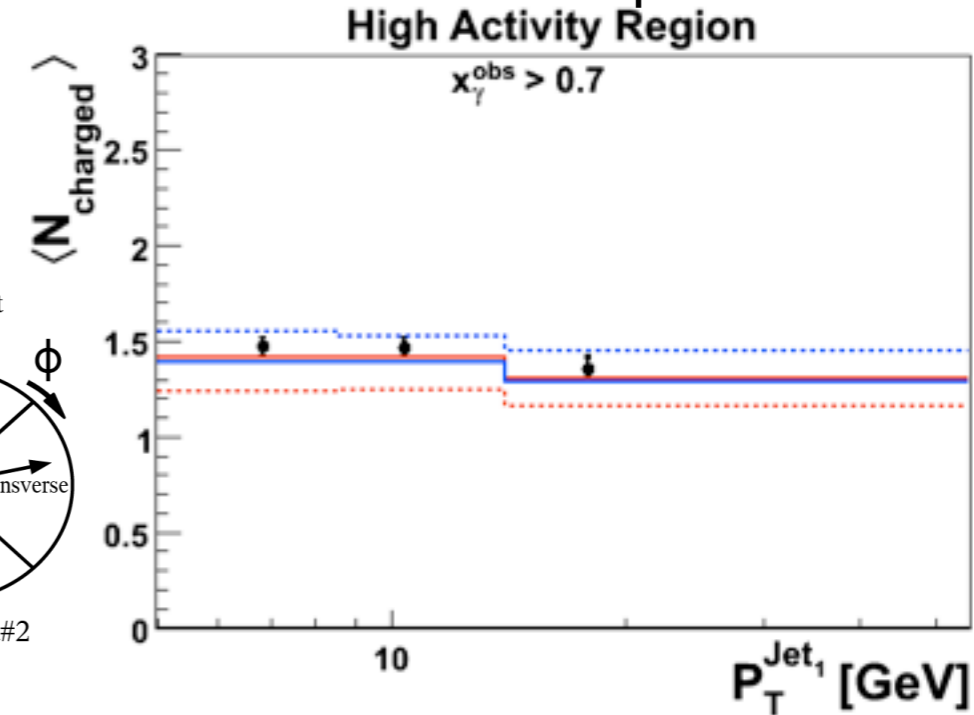
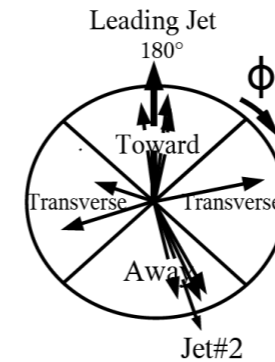
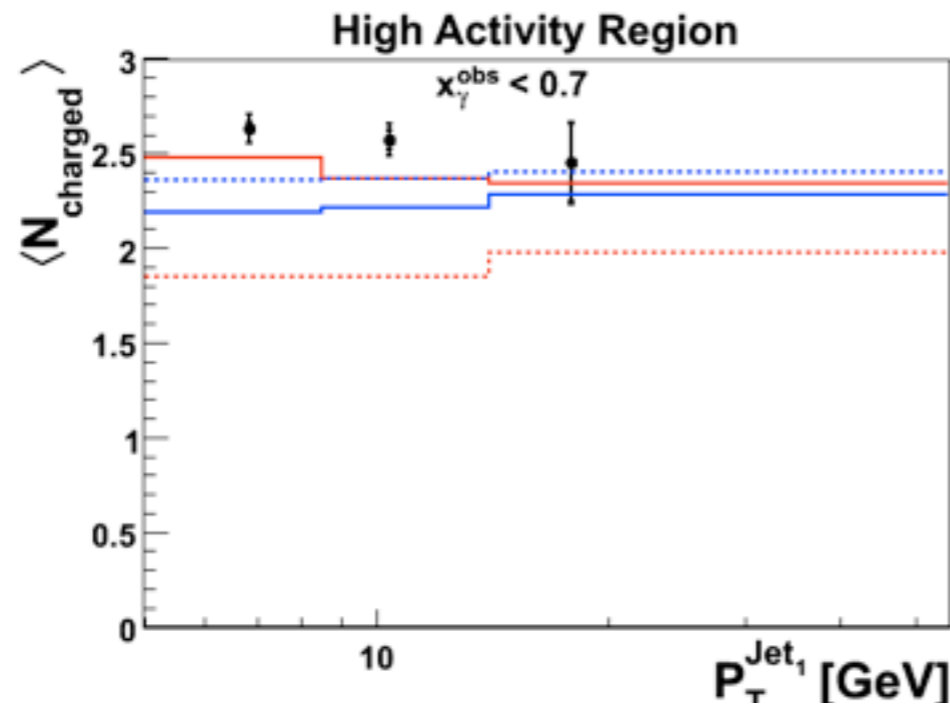
Charged particle multiplicities



- PYTHIA with multiparton interaction describes all regions reasonably well
- multiparton interaction in PYTHIA needed

charged particle multiplicities

H1prelim-08-036



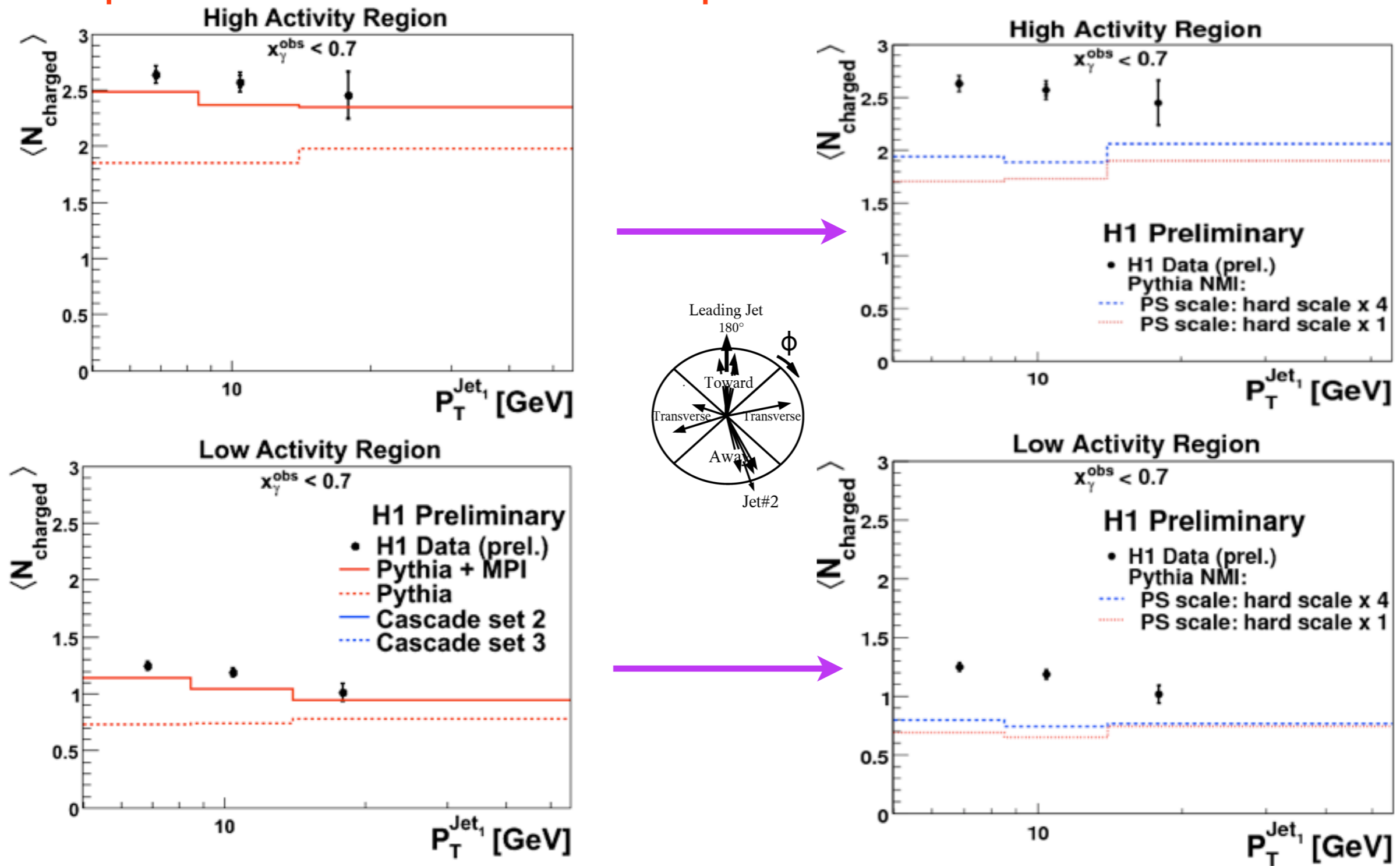
- clear difference of high and low activity region
- no clear dependence on jet pt

- CASCADE describes high x_γ region well, but is too low in low x_γ
- CASCADE has different parton shower mechanism.

Effect of parton shower

H1prelim-08-036

- Is it just an effect of the scales in the parton shower ?



- PYTHIA parton shower is not able to reproduce transverse activity !

Conclusions

- **BEWARE: corrections due to multiparton interactions can be sizeable !**
- Detailed measurements are needed !
- Underlying event structure investigated in photoproduction dijet events
- Average charged particle multiplicity in **toward** and **away** region in azimuthal plane of jets increases with jet p_t
 - reasonably well described by QCD simulations including parton shower (and multiparton interactions)
- Measured particle multiplicity in transverse region is above prediction from parton shower simulations
 - is best described including **multiparton interactions**
 - is also described with **CCFM parton shower** for $x_\gamma > 0.7$
 - but additional contributions are needed for $x_\gamma < 0.7$
 - Amount of multiparton interaction needed to describe the measurement depends strongly on **factorisation/parton shower model**
- **(Unfortunately) no unique evidence for Multiparton Interactions established at HERA !**