Multiparton interactions in ep scattering at HERA

Hannes Jung (DESY, Univ. Antwerp)

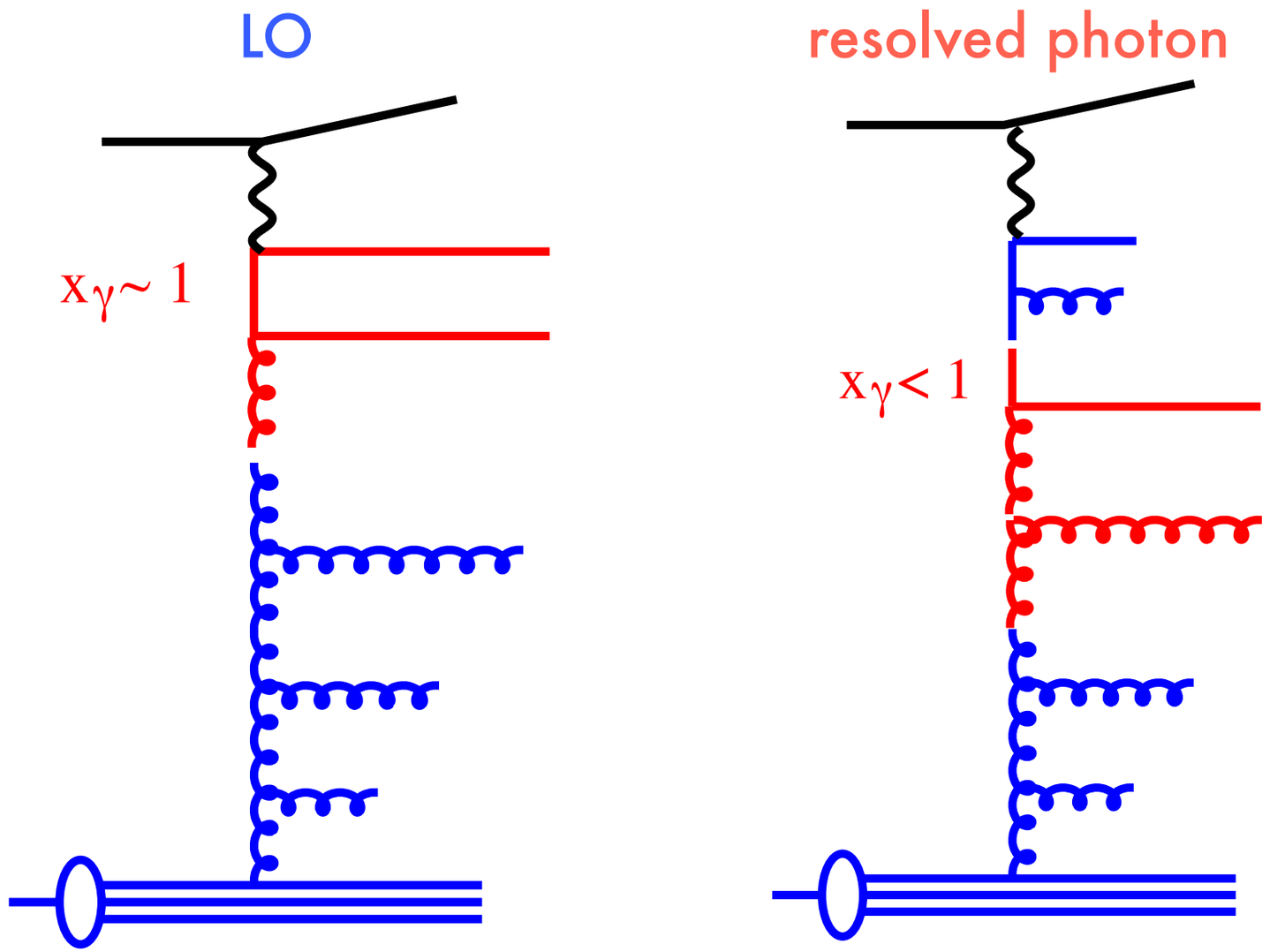
on behalf of
H1 & ZEUS collaborations

- 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

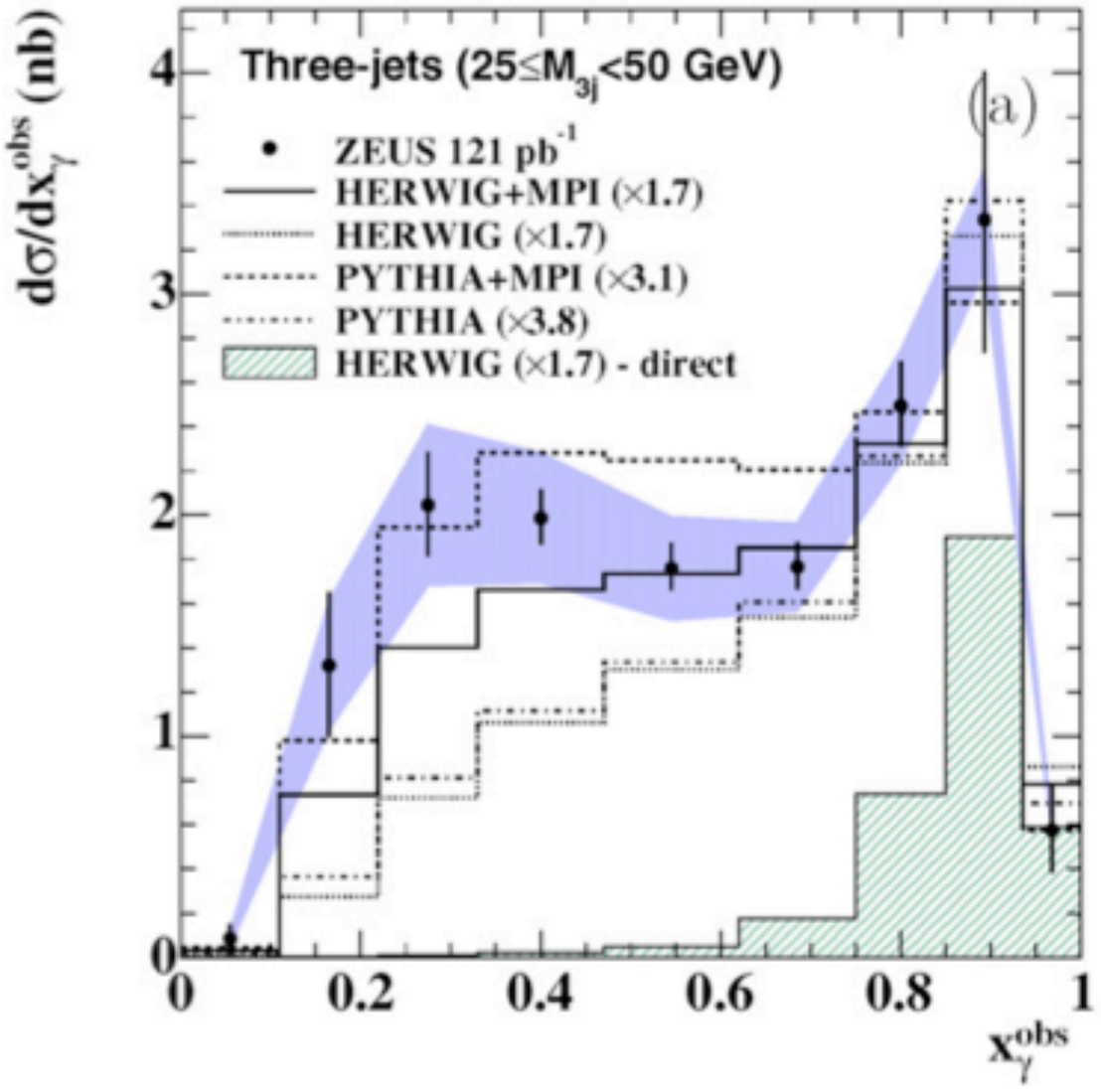
- Study of jet production and underlying event structures in ep:
  - photoproduction
    - smooth transition from pointlike to hadronlike interaction
  - DIS
    - pointlike interaction, important as benchmark checks

    (not reported here)

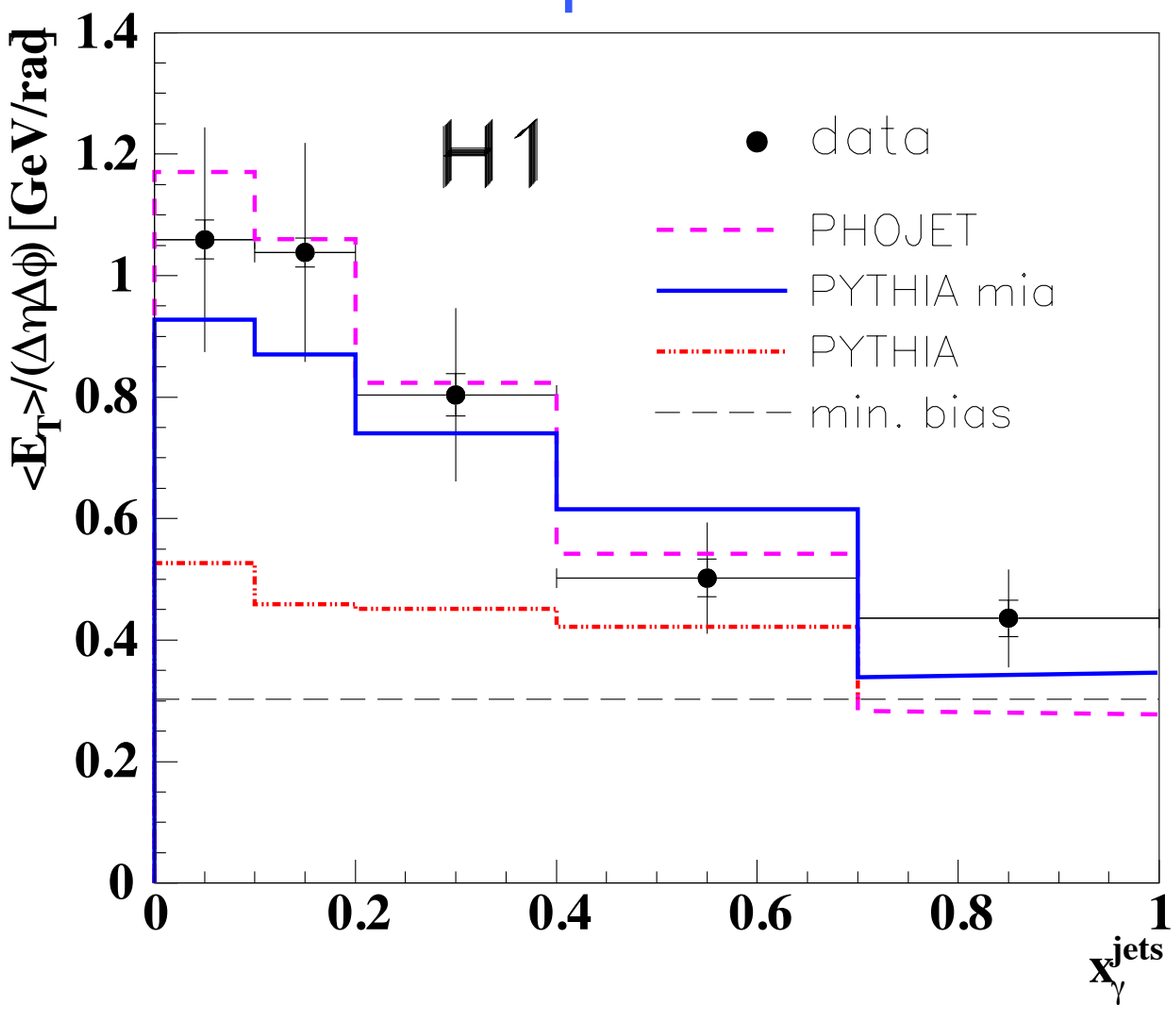


Earlier measurements

- 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

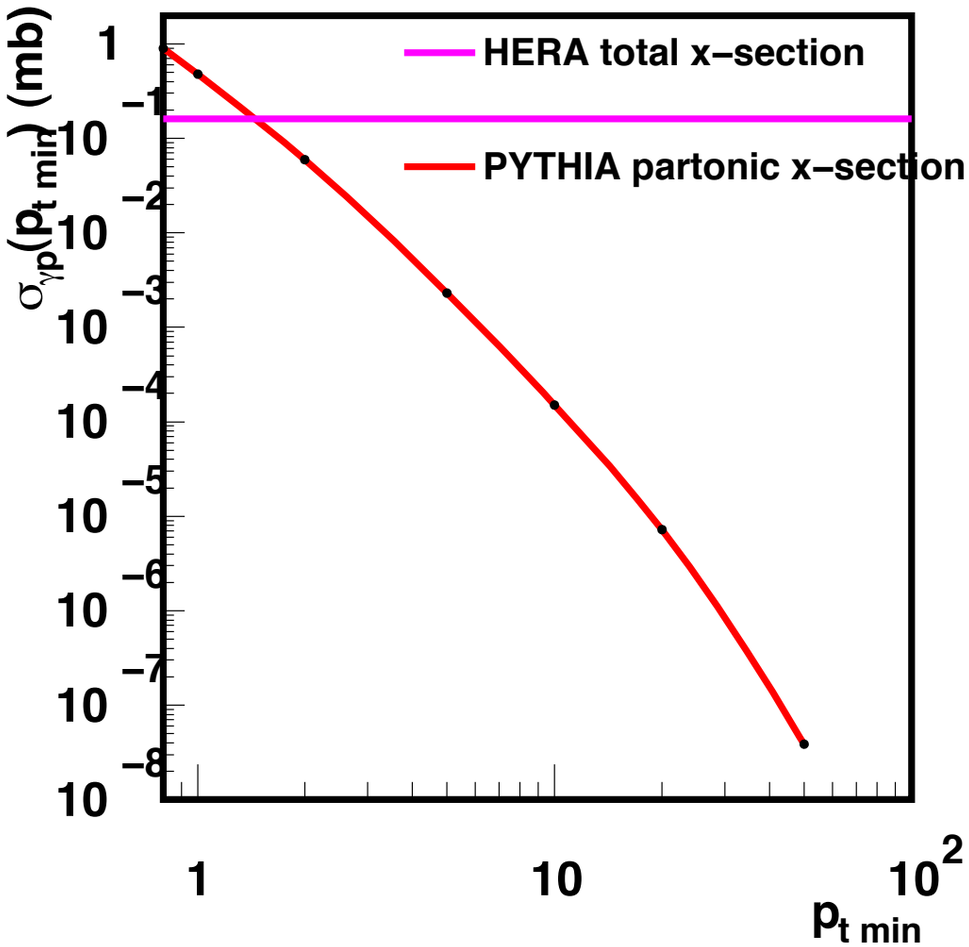


- Models including multiparton interactions come closer to measurements !

Models for underlying events

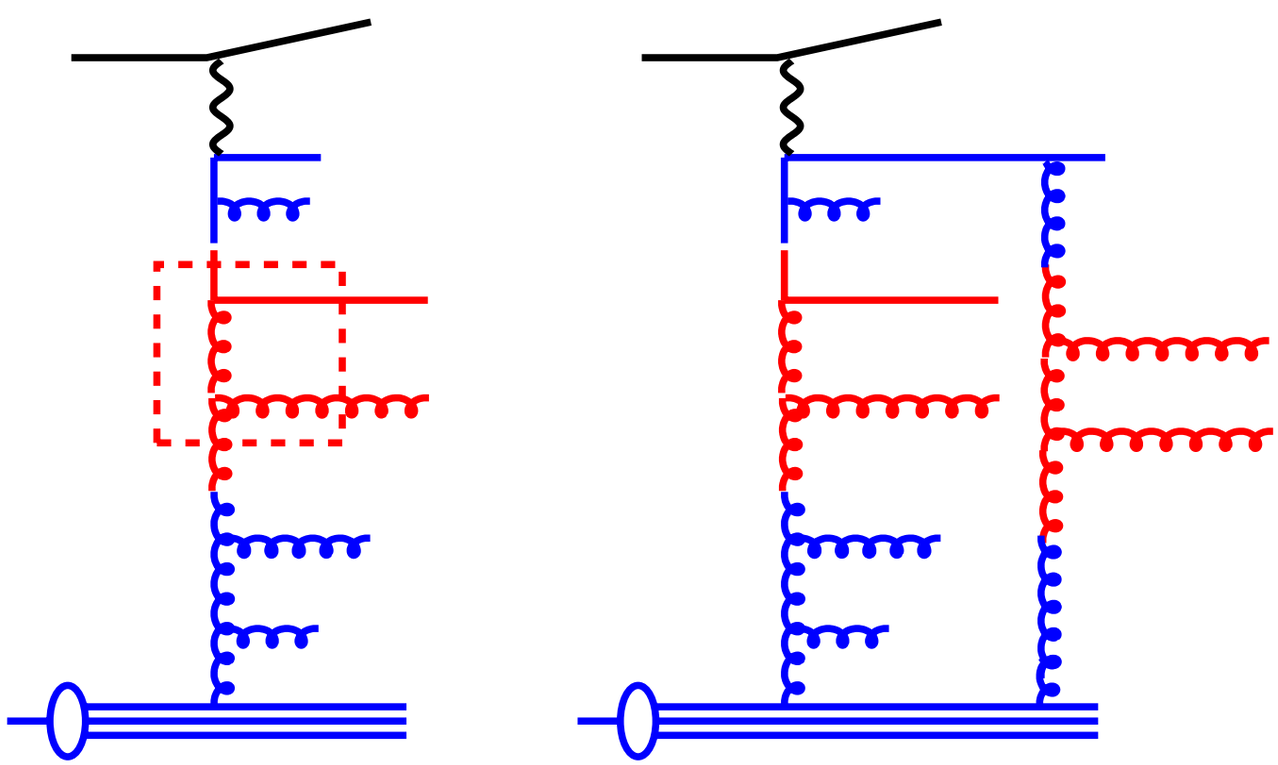
- Multiparton interaction model (a ala PYTHIA)

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



- depends on parton density
- parton evolution scheme

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



Inclusive jet x-section in γp

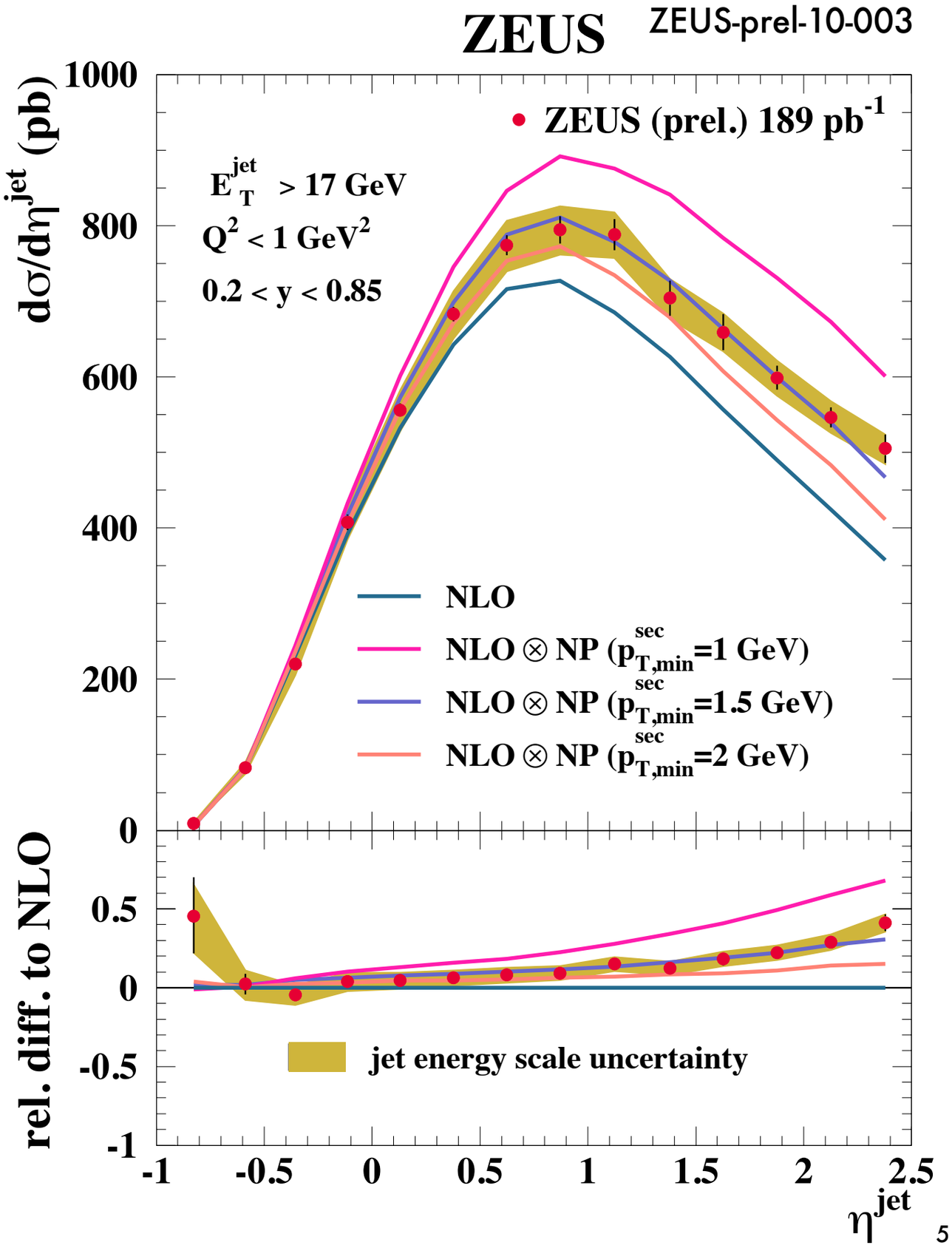
- Event selection

$$\begin{aligned} Q^2 &< 1\ \text{GeV}^2 \\ E_T^{jet} &> 17\ \text{GeV} \\ -1 < \eta^{jet} &< 2.5 \end{aligned}$$

- Non Perturbative (NP) correction determined by PYTHIA MC
- minimum pt of secondary scattering: $p_{T\,min}^{sec}$
- NP effect: $\dfrac{\sigma_{w/oMPI}^{MC}}{\sigma_{all}^{MC}}$

- NP corrections can be large

$\rightarrow 40\%$ in large η region



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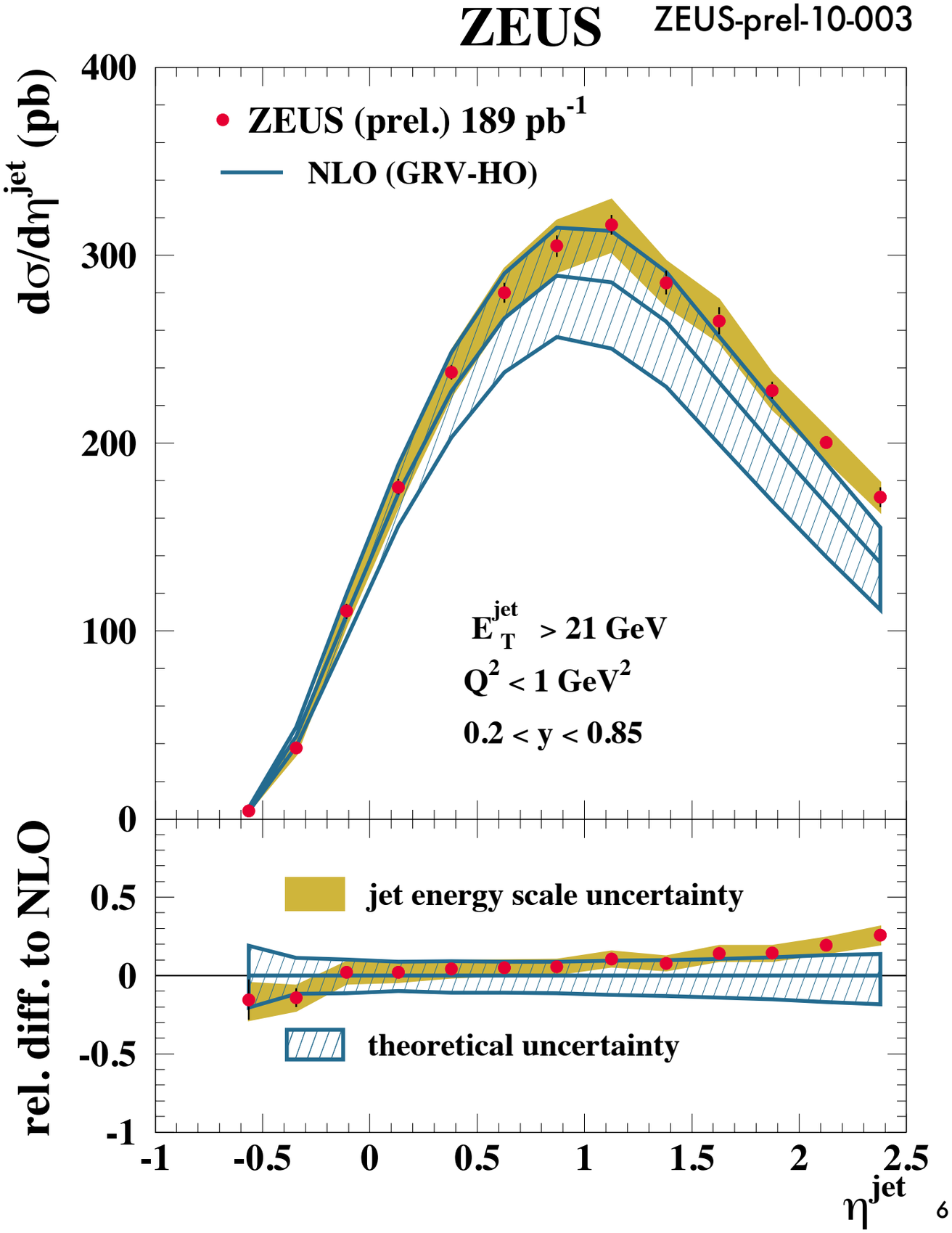
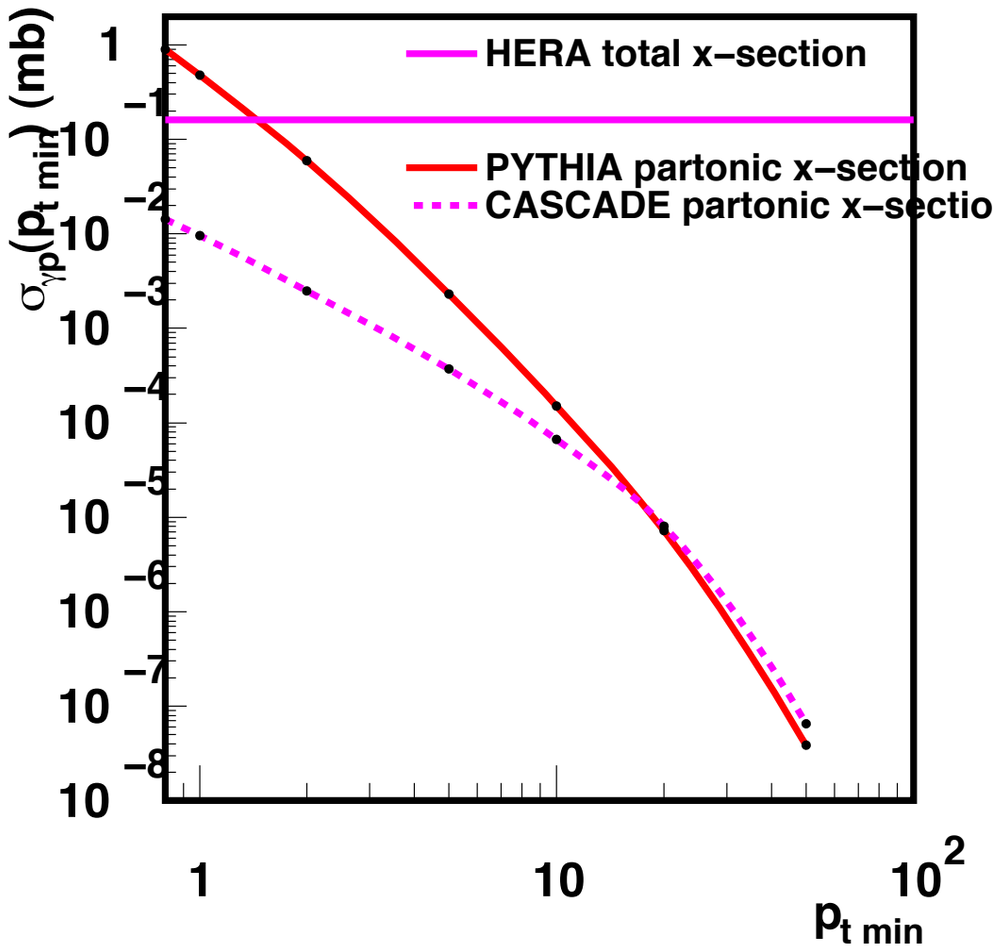
- NP corrections not needed for $E_T > 21\ \mathrm{GeV}$

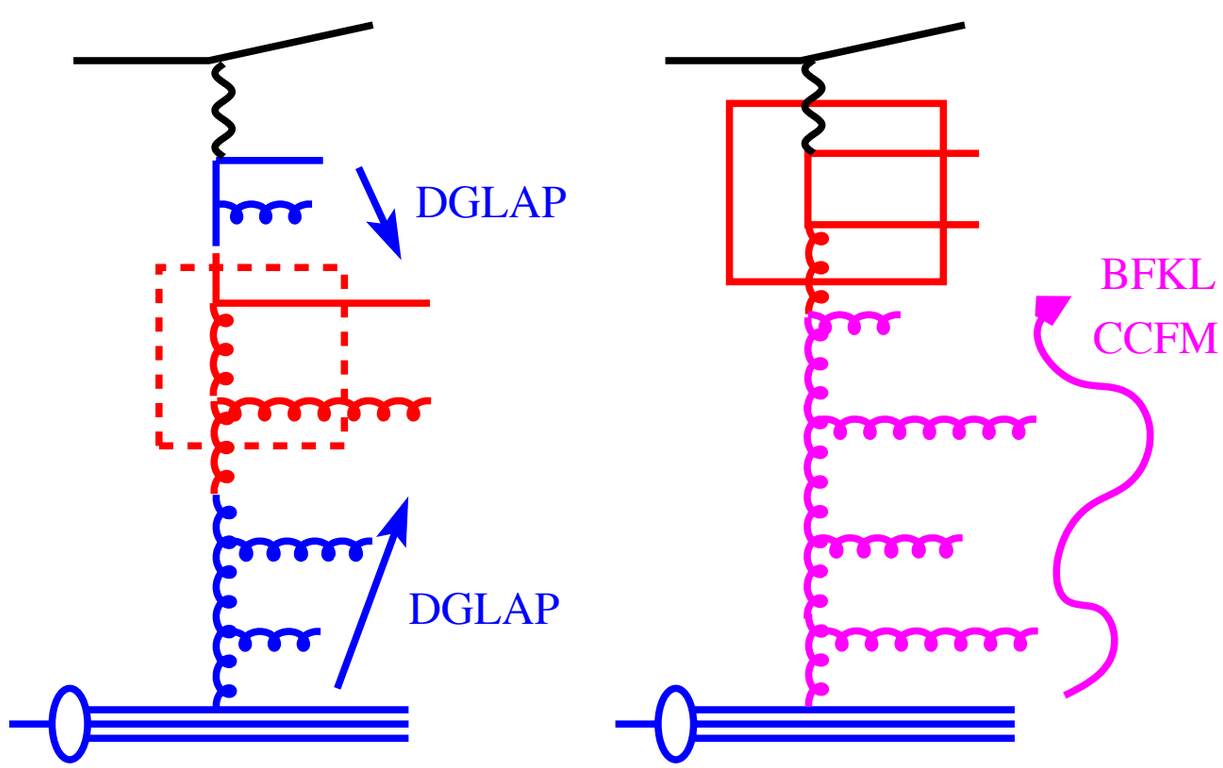


Models for underlying events

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



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



Underlying events in photoproduction

- 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

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

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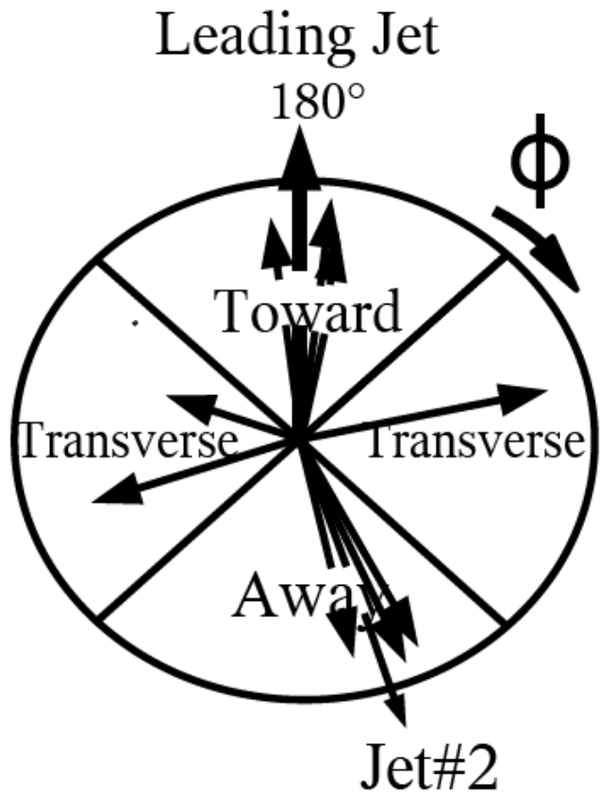
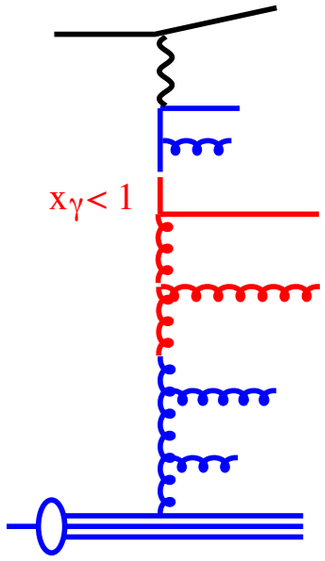


$$\mathcal{L} = 48\, pb^{-1}$$

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

- 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



- Separate resolved from direct processes

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

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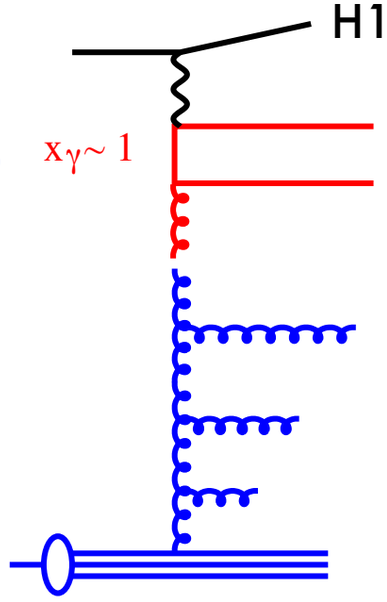
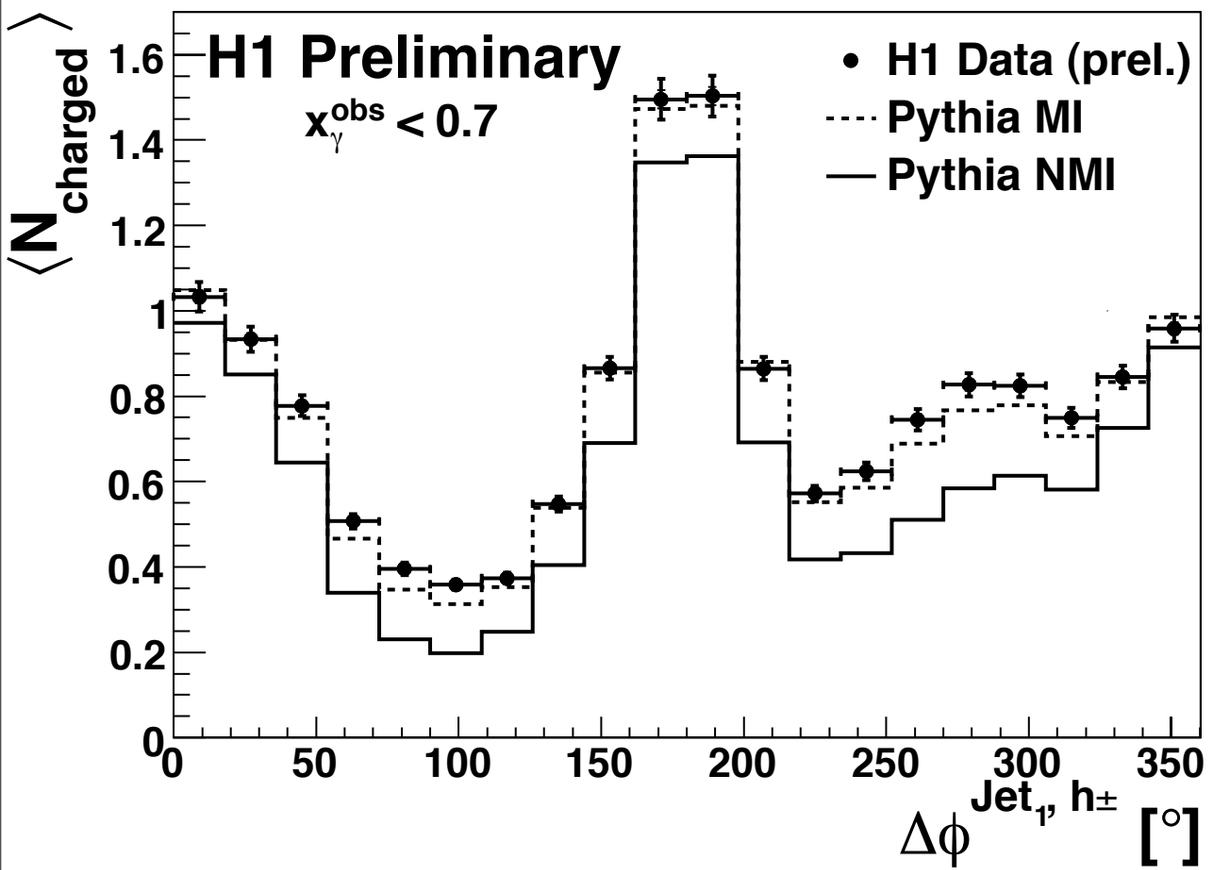
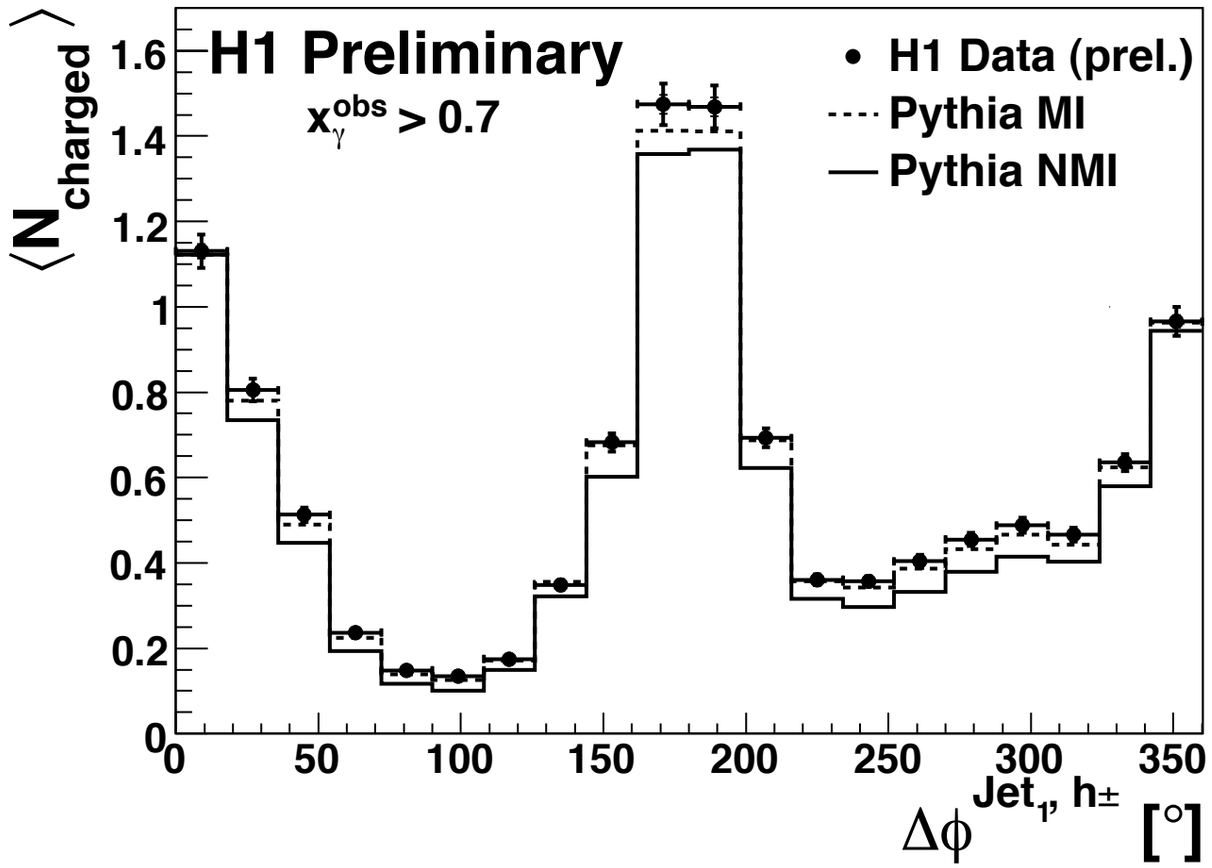
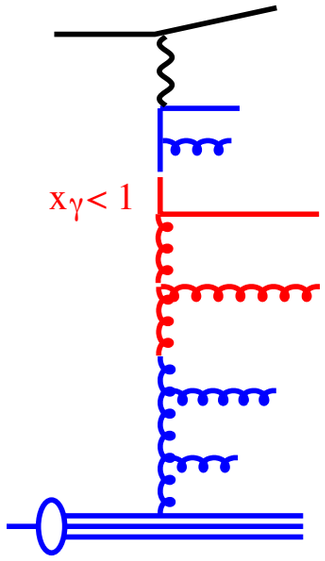






- Pythia simulation with multiparton interactions is closer to measurement !

Charged particle multiplicity



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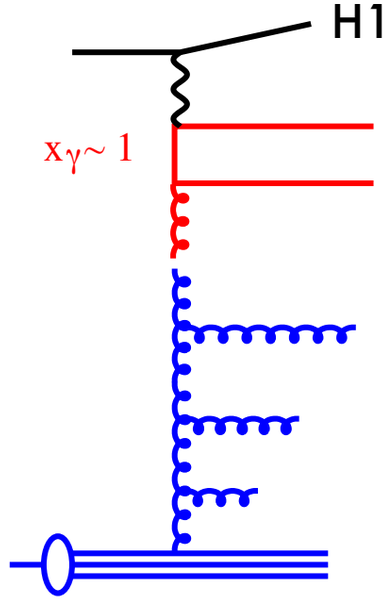
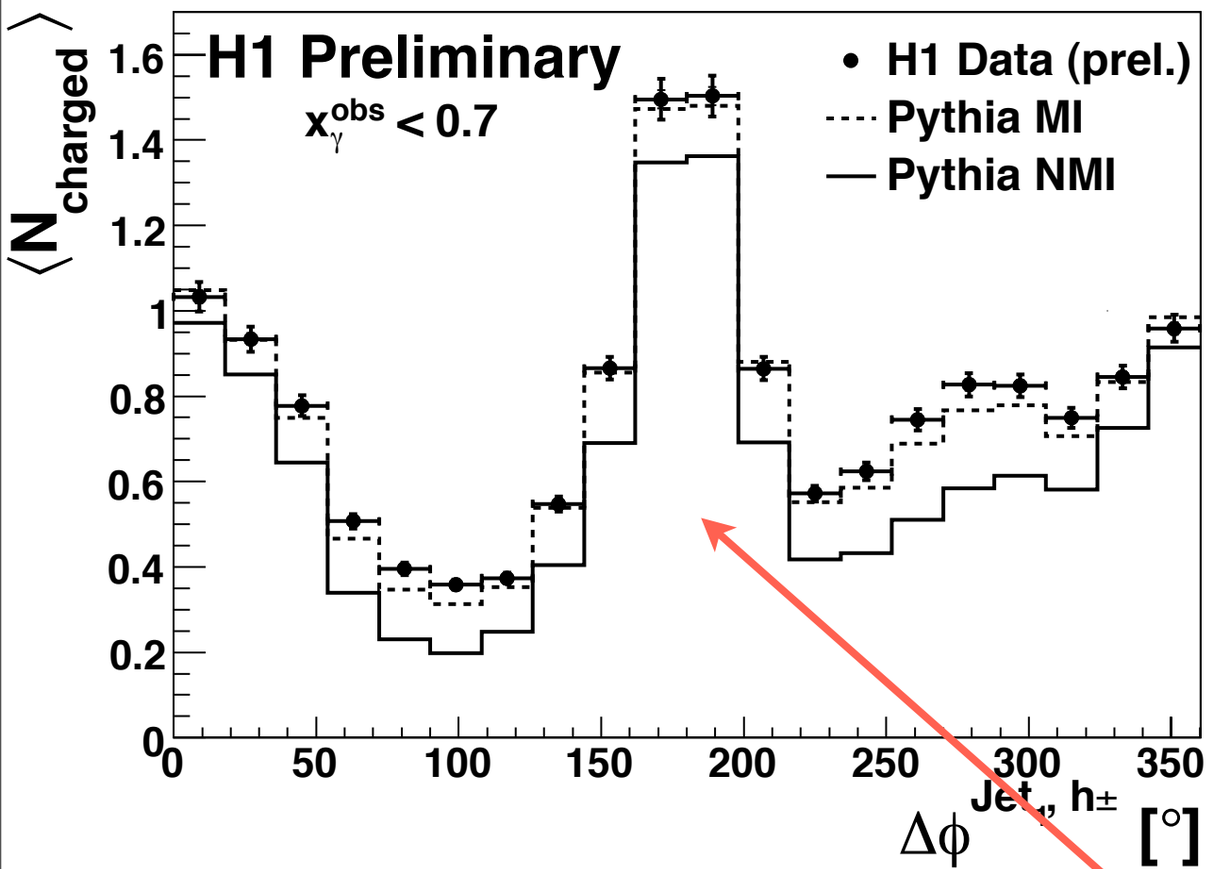
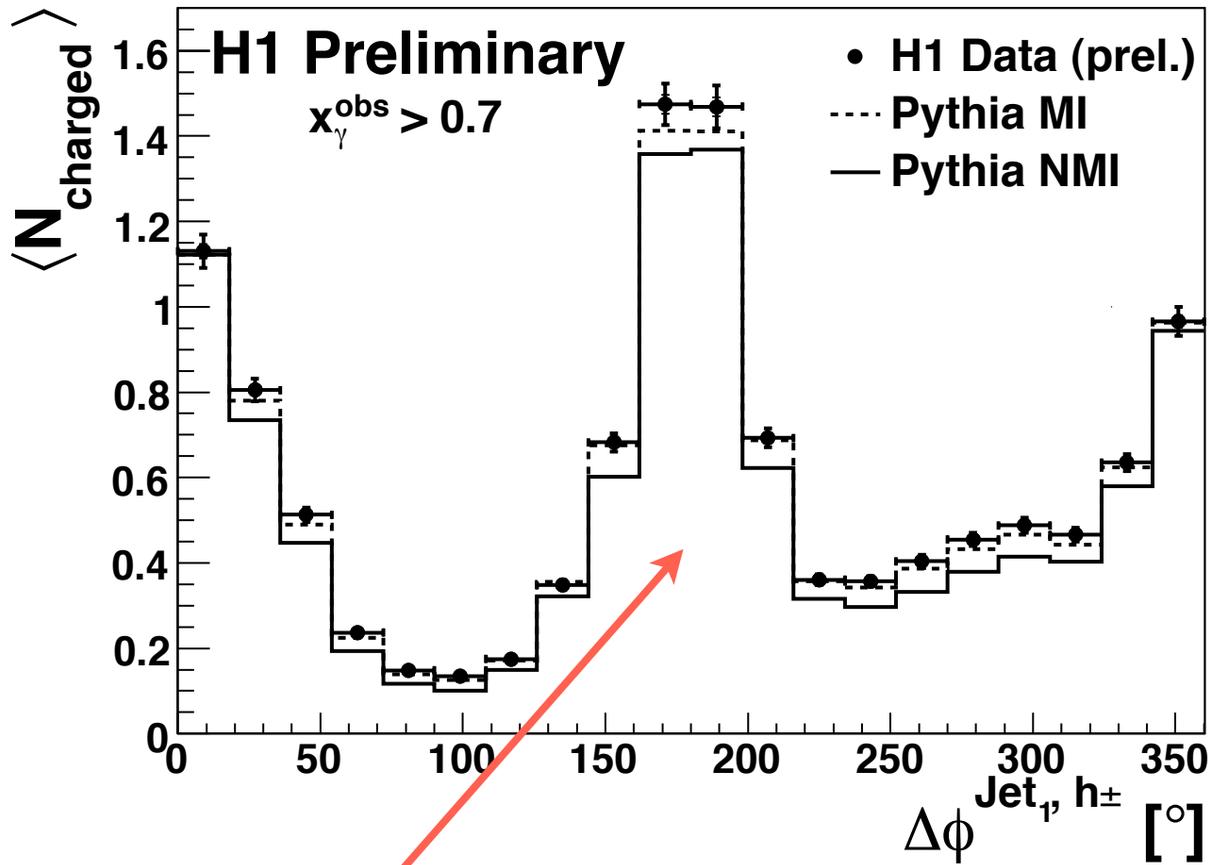
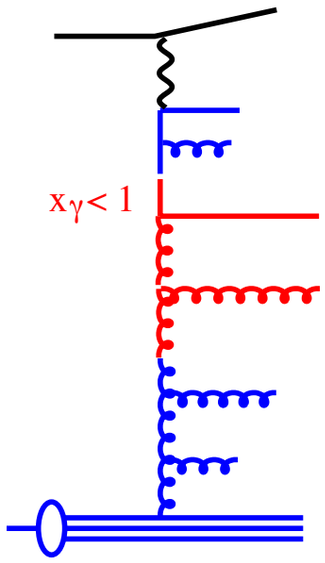






leading jets

Charged particle multiplicity



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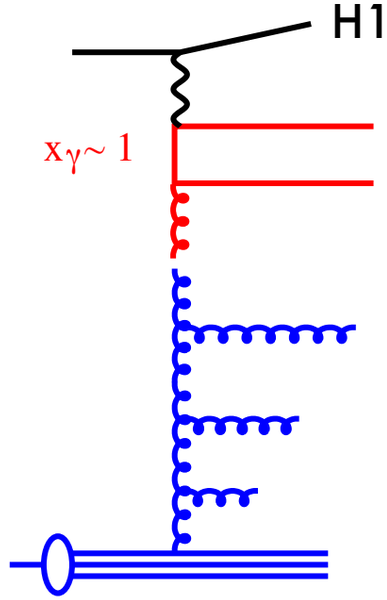
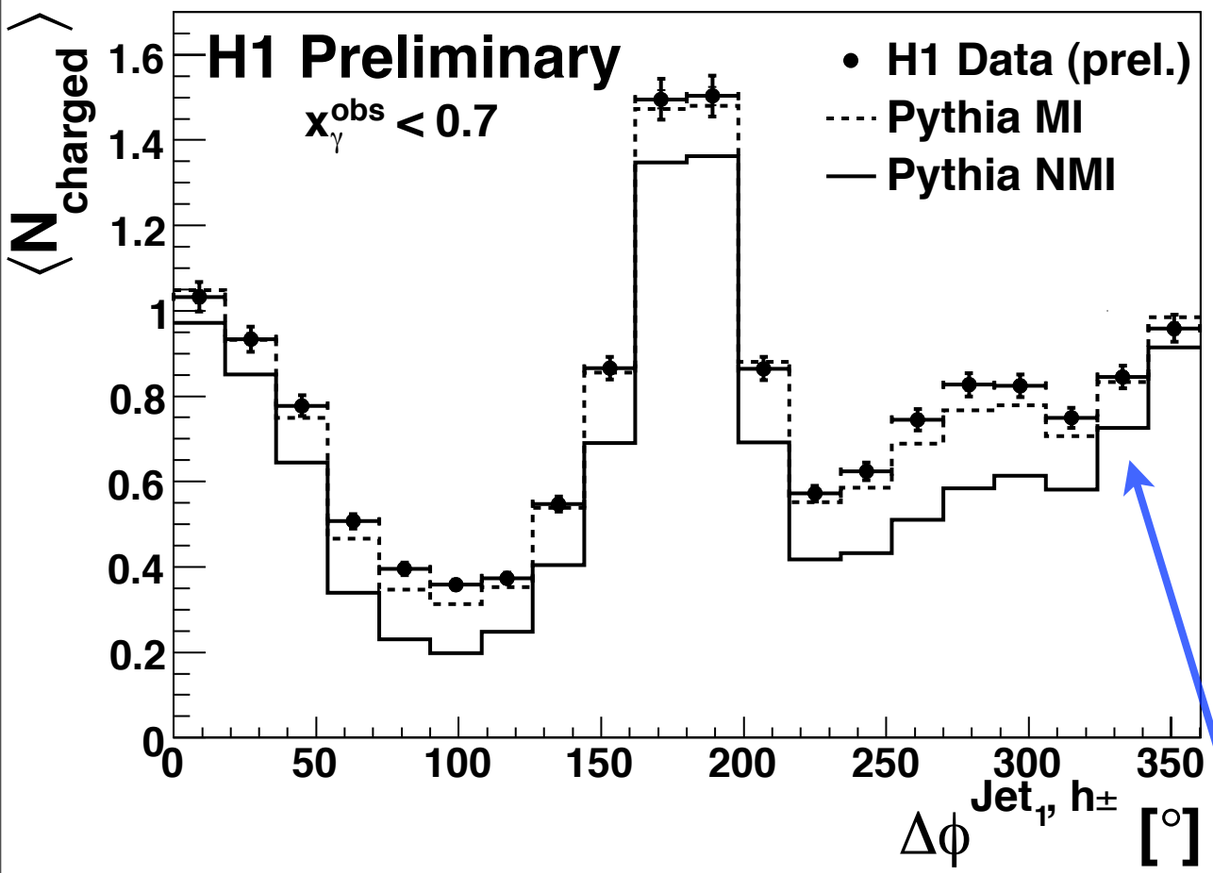
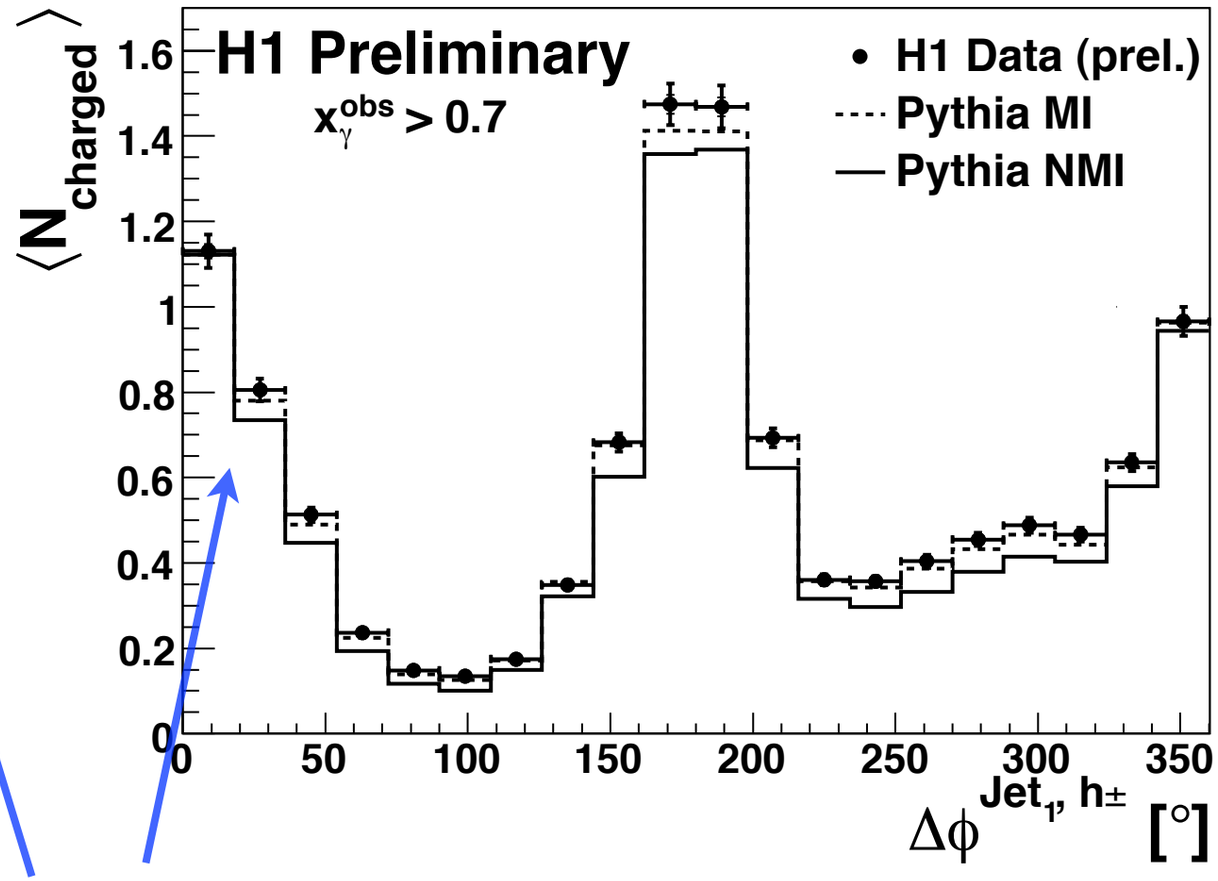
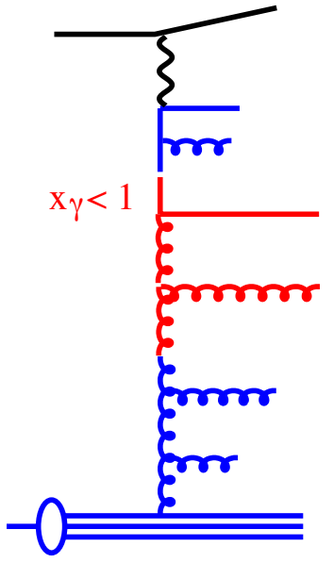






next to leading jets

Charged particle multiplicity



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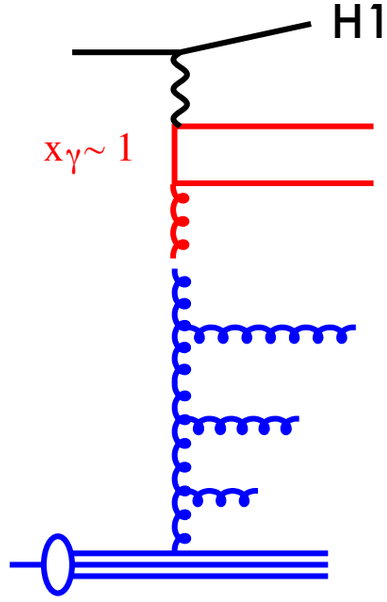

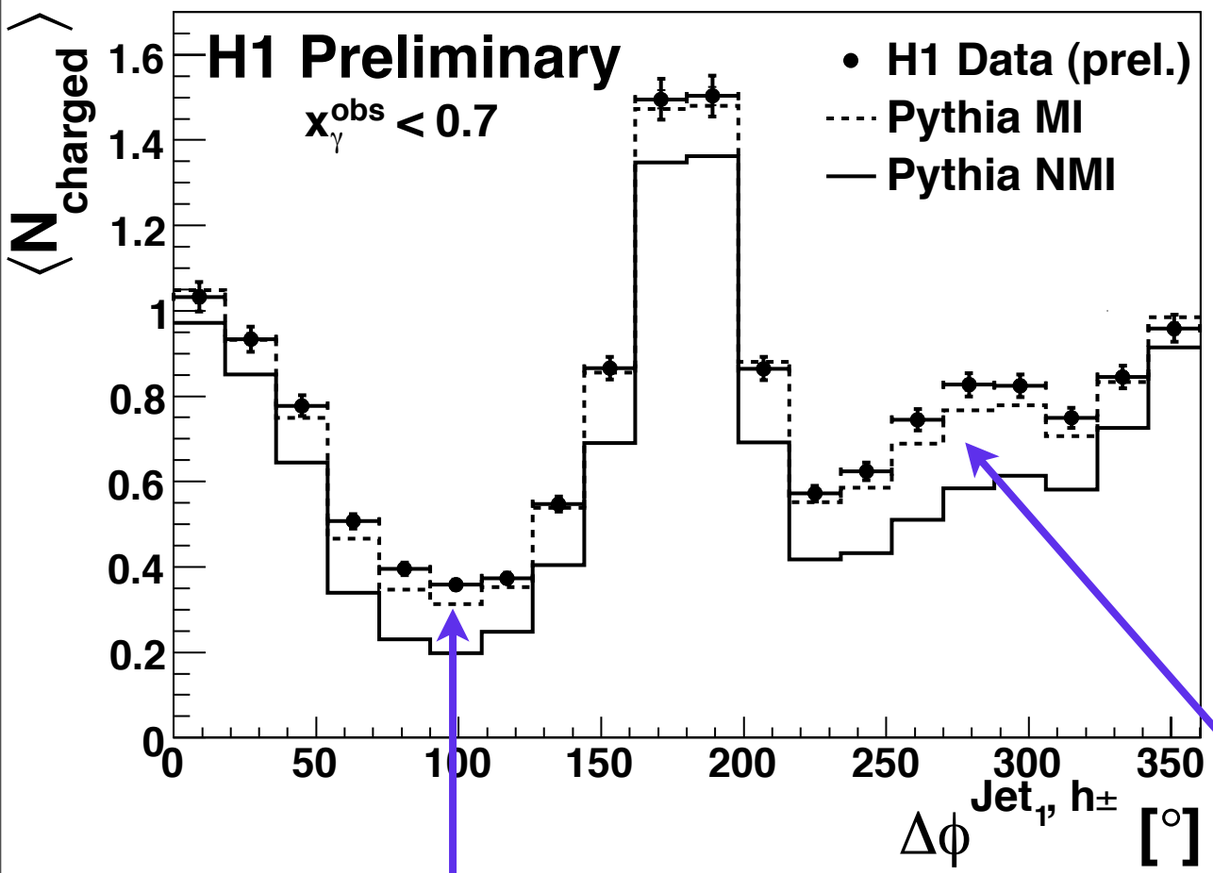

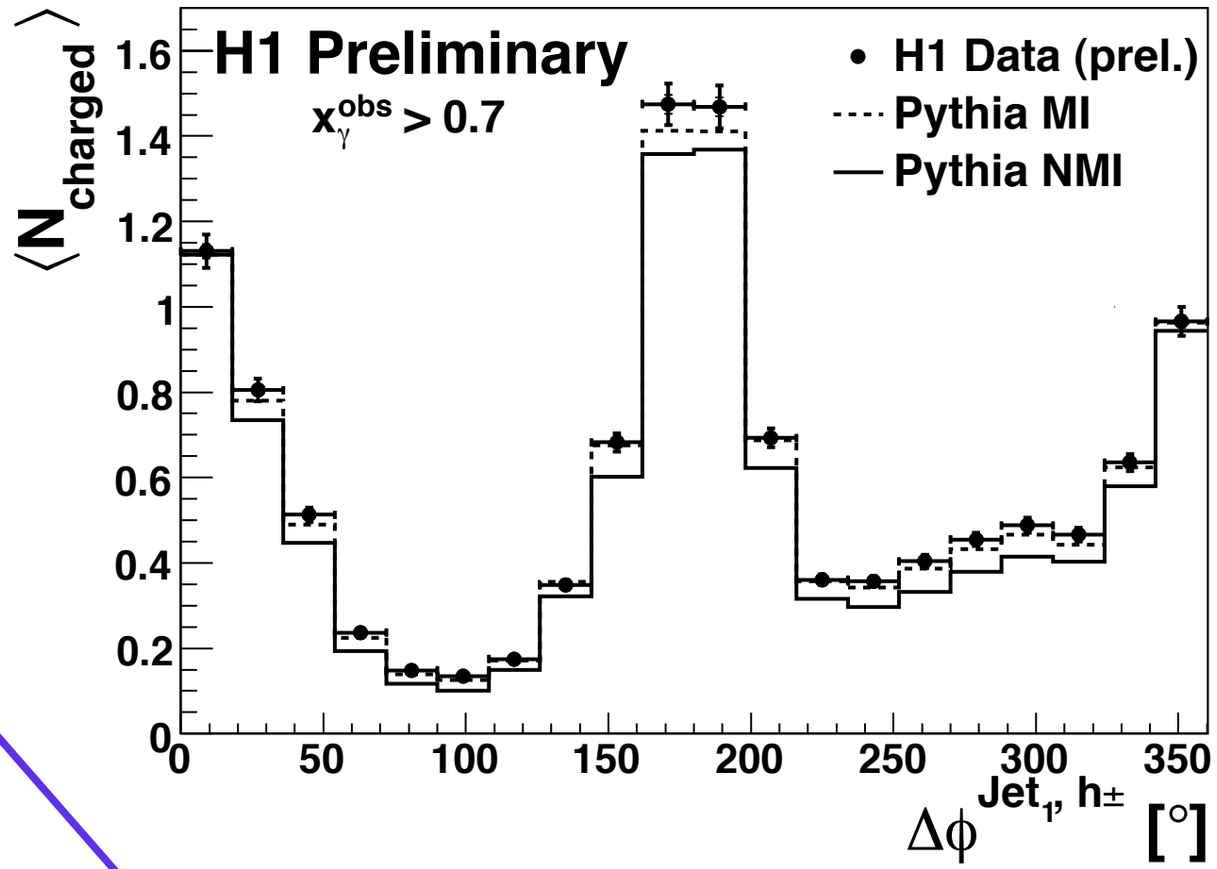

transverse low region

transverse high region

Charged particle multiplicities

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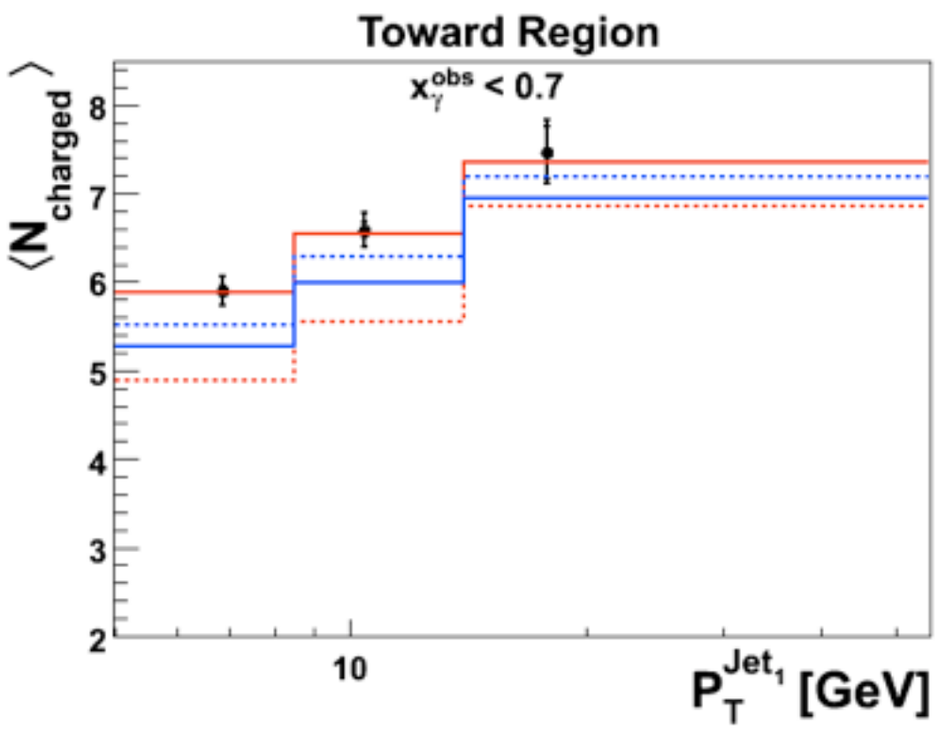

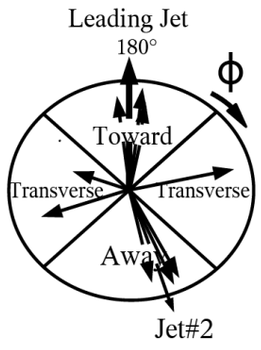

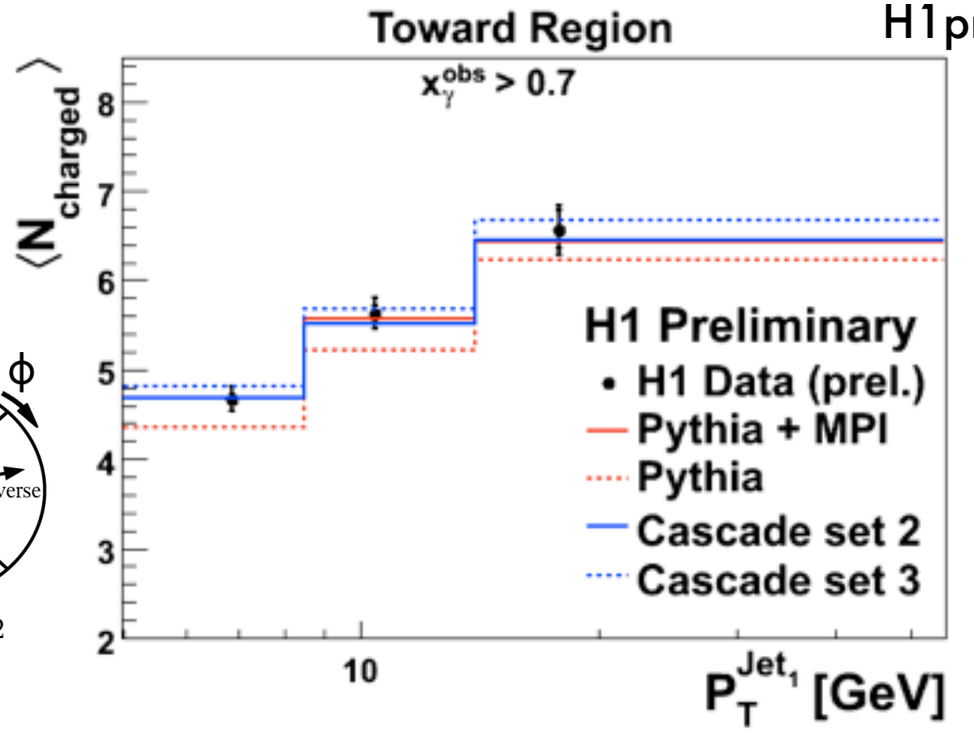

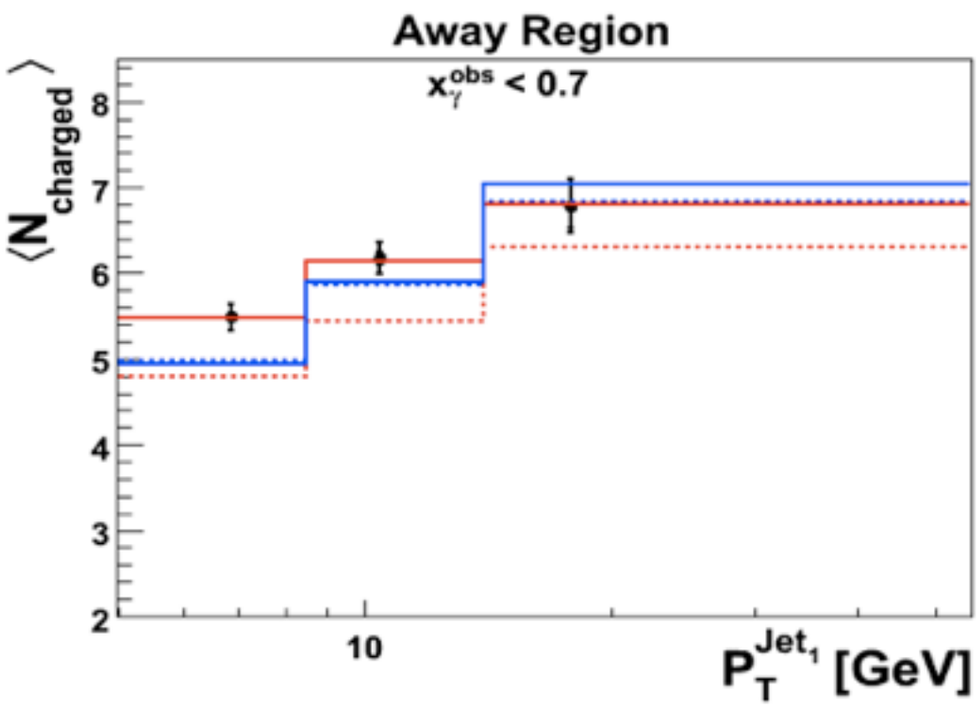

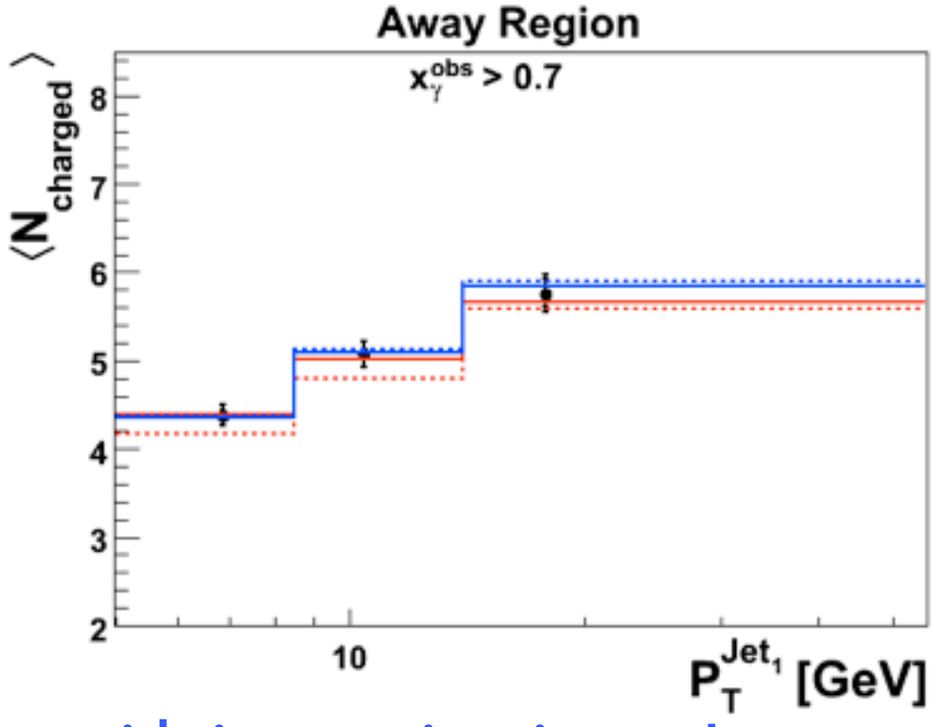

- Charged particle multiplicity increases with increasing jet pt !
- Model differences in small pt resolved photon region !

H. Jung, Multiparton interactions in ep scattering at HERA, ISMD 2010, Antwerp

Charged particle multiplicities

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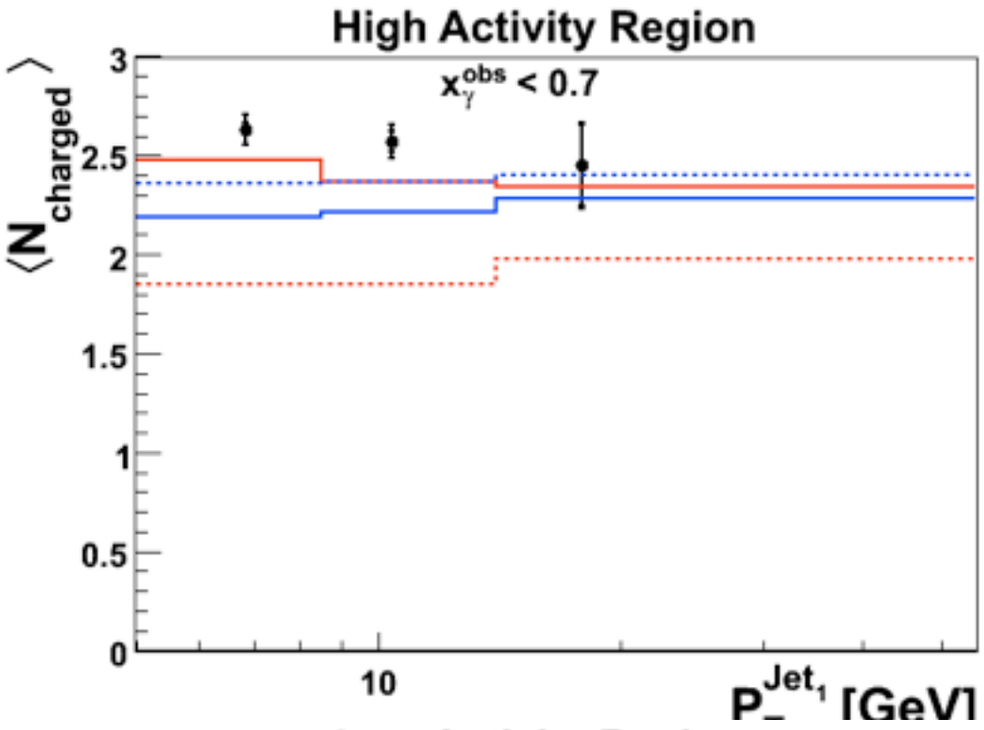

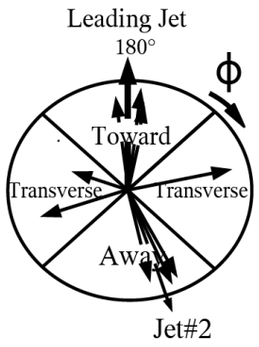

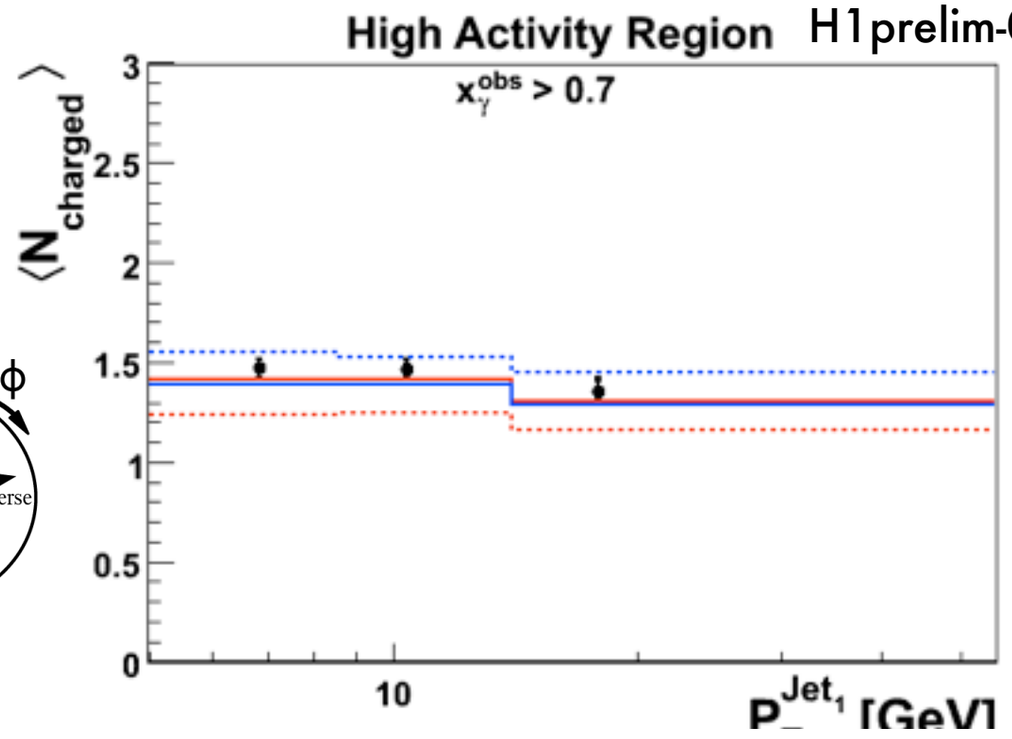

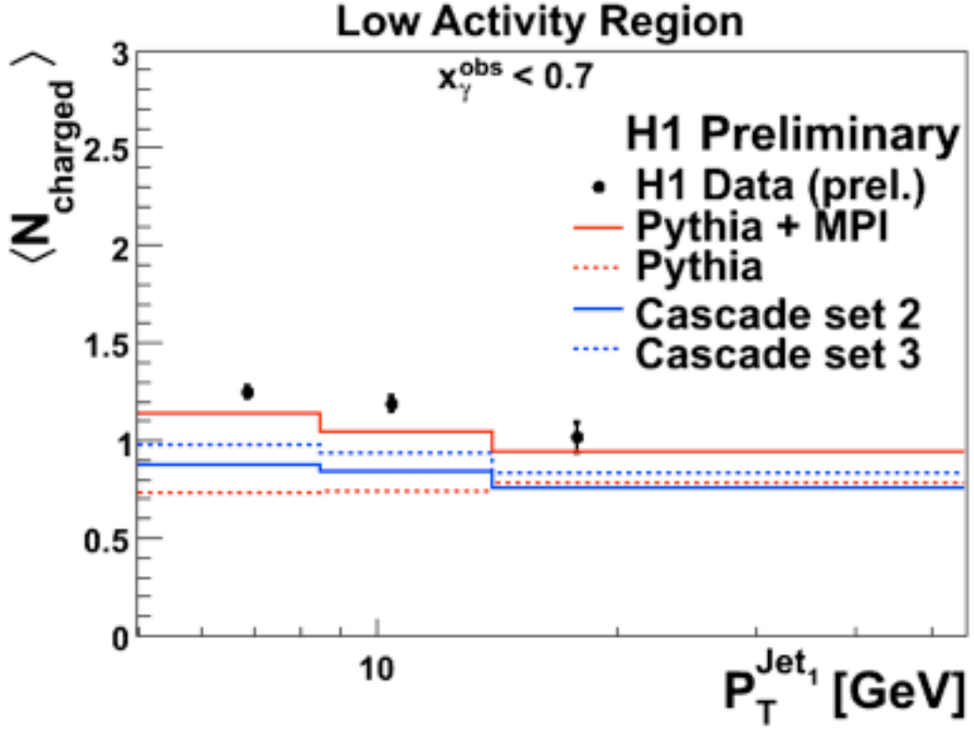

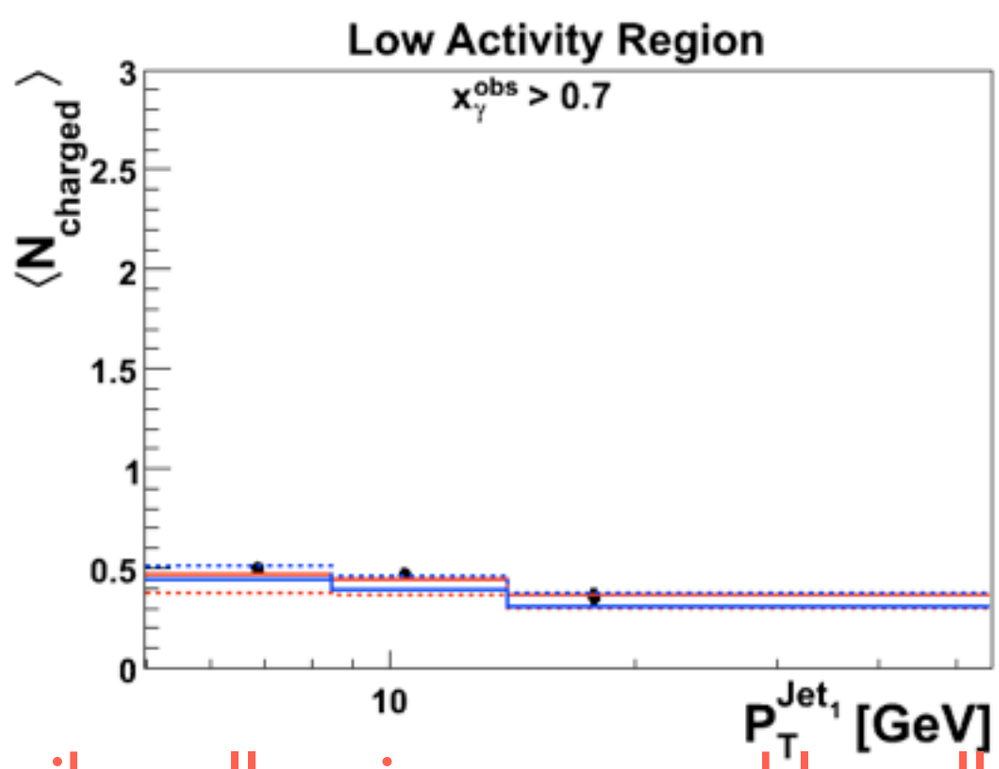

- PYTHIA with multiparton interactiondescribes all regions reasonably well
- multiparton interaction in PYTHIA needed

H. Jung, Multiparton interactions in ep scattering at HERA, ISMD 2010, Antwerp

charged particle multiplicities

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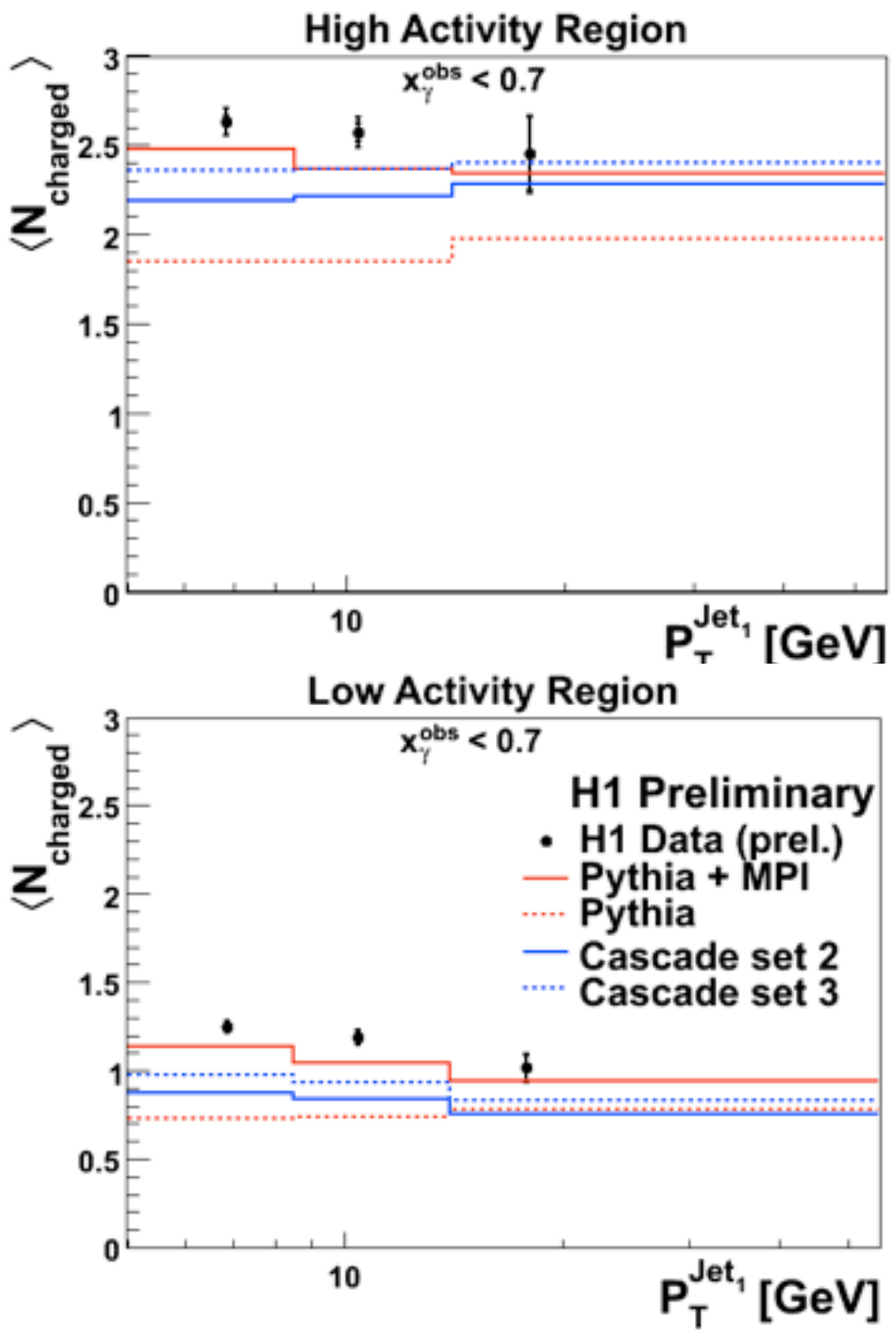
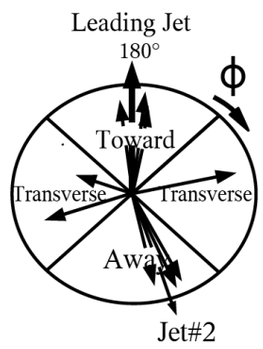
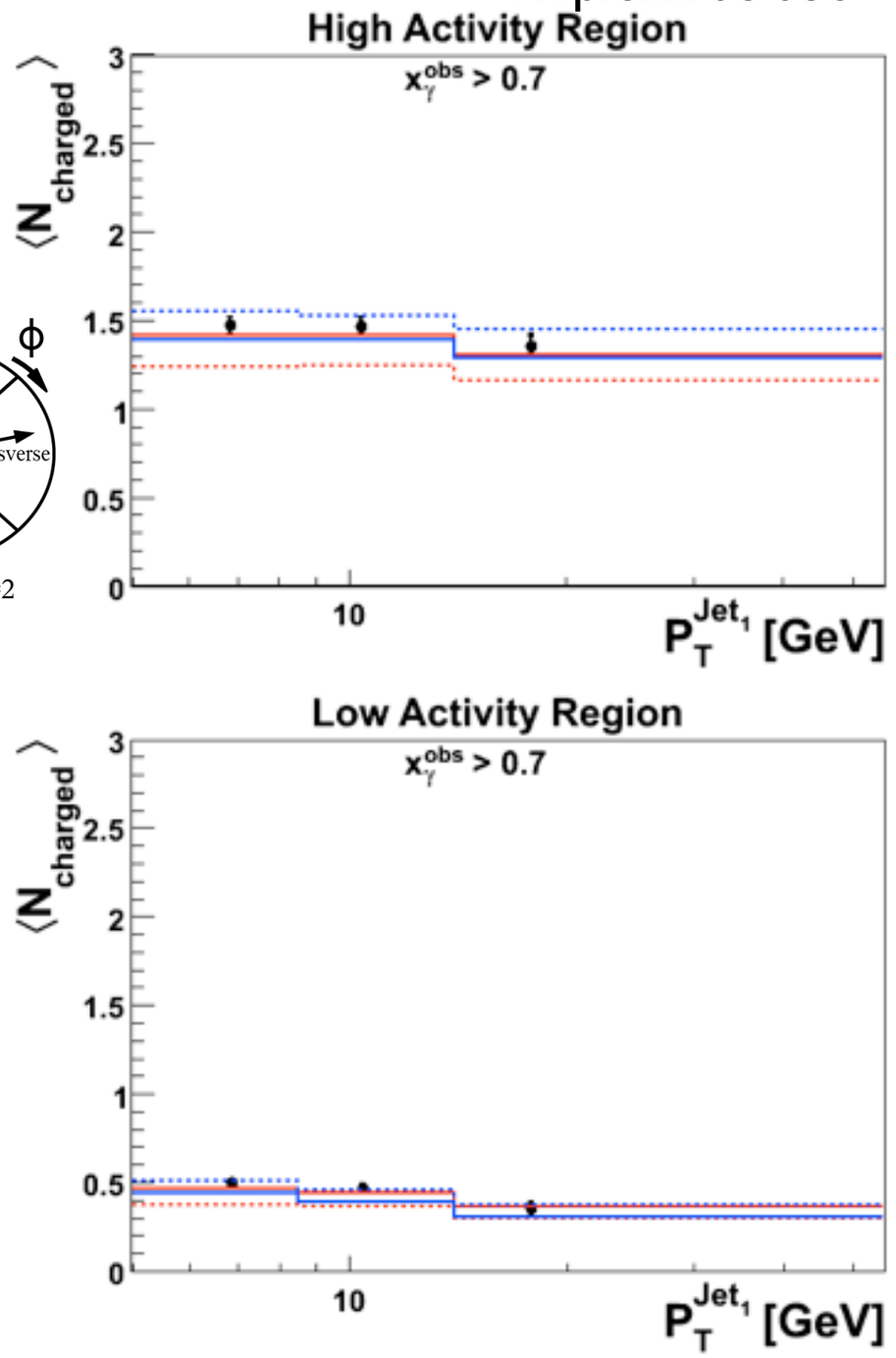
- clear difference of high and low activity region
- no clear dependence on jet pt







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

Effect of parton shower

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

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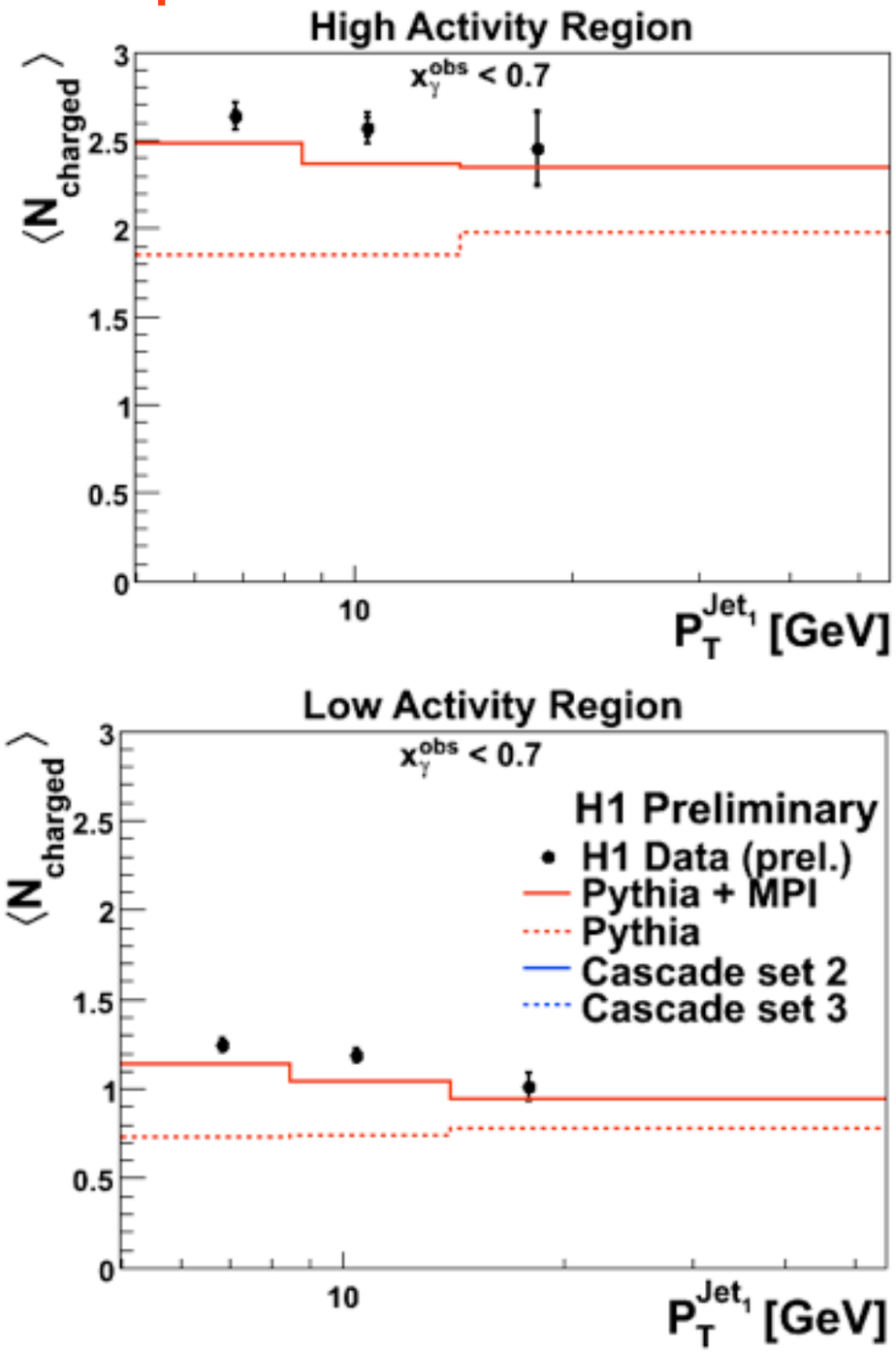

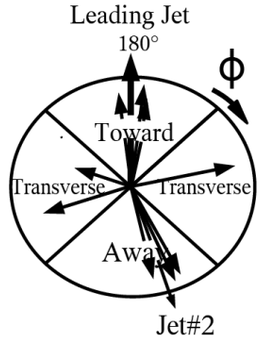

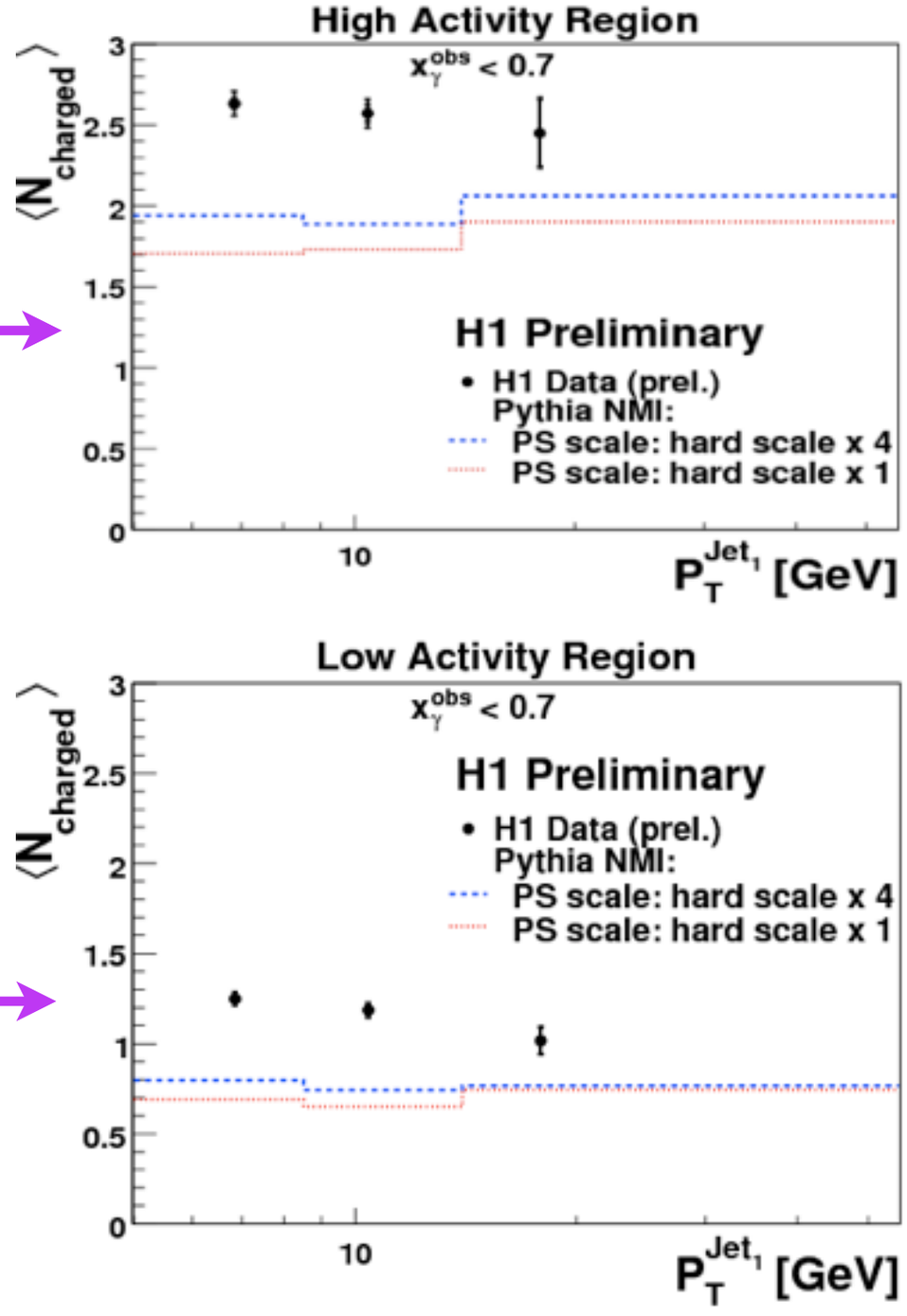

- PYTHIA parton shower is not able to reproduce transverse activity !

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 pt
  - reasonably well described by QCD simulations including parton shower (and multiparton interactions)
- Measured particle multiplicity in transverse region is above prediction form 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 !