Mini Jets in Deep Inelastic Scattering at HERA.

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For the H1 Calibration

Outline:

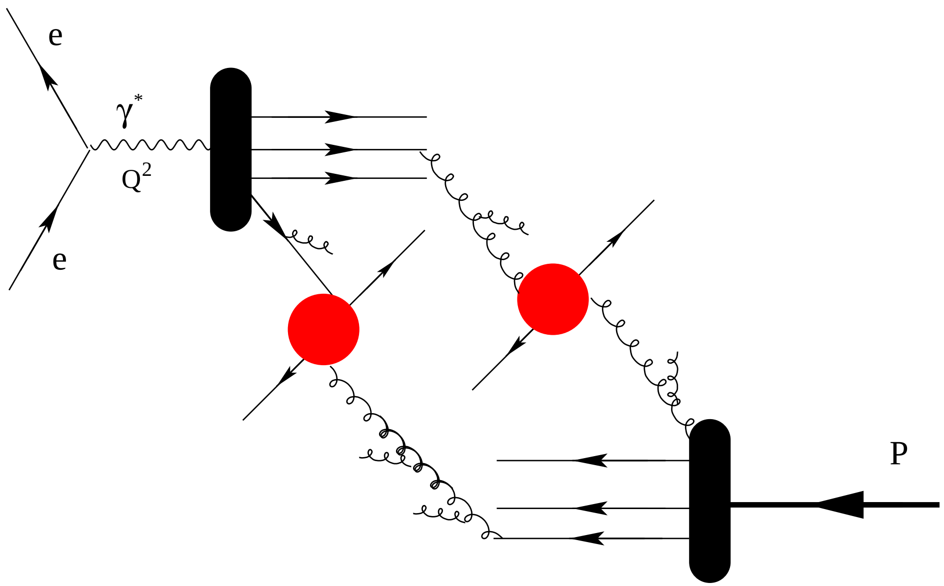
* Underlying Event.
* Motivation and Strategy.
* Selections.
* Result.
* Summary and Conclusion.

Underlying Event

* The Underlying Event (UE) consists of particles produced by additional ladder exchange.

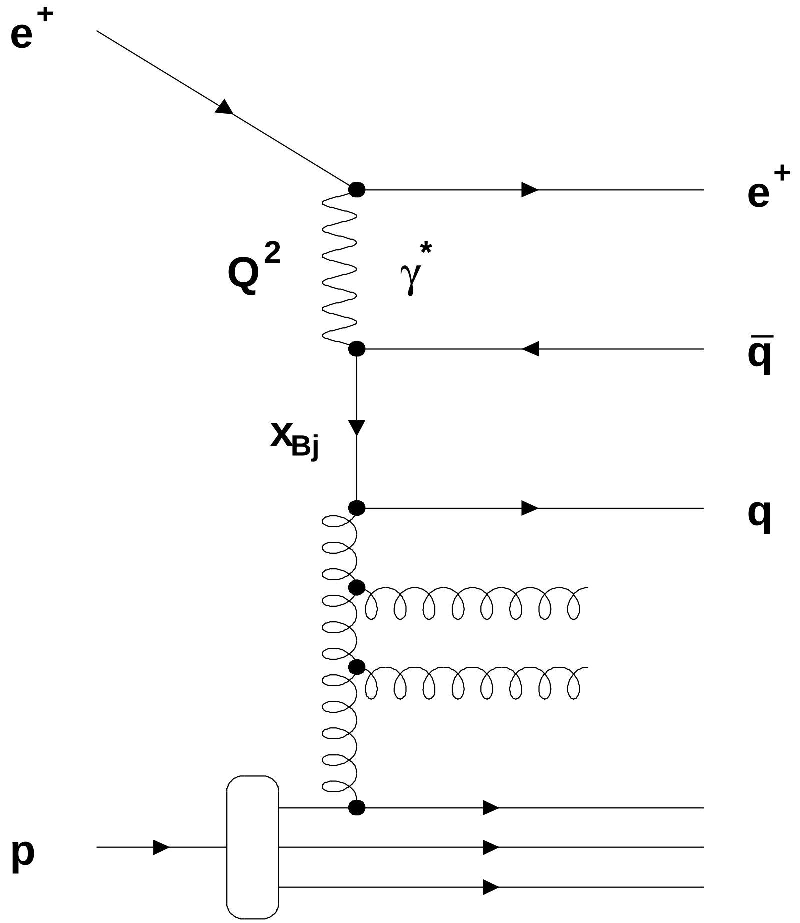
* Different treatment of UE in Monte Carlo:
  - Soft Underlying Event (SUE).
  - Multiple Interactions (MI).

* The additional emissions produced by UE may gives rise to higher production rate of jets with low transverse momenta (mini jets).



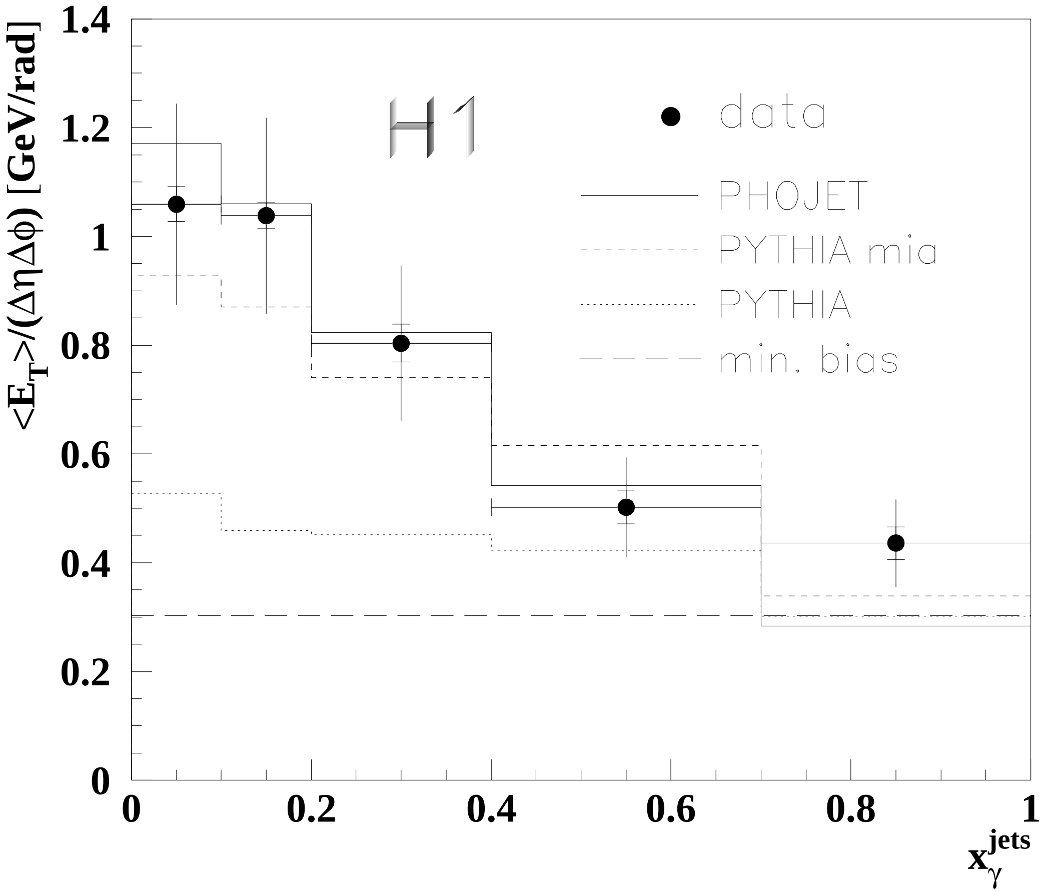
Underlying Event

* Experimentally it is hard to distinguish between contributions from underlying event and higher order processes from single ladder exchange.



Motivation

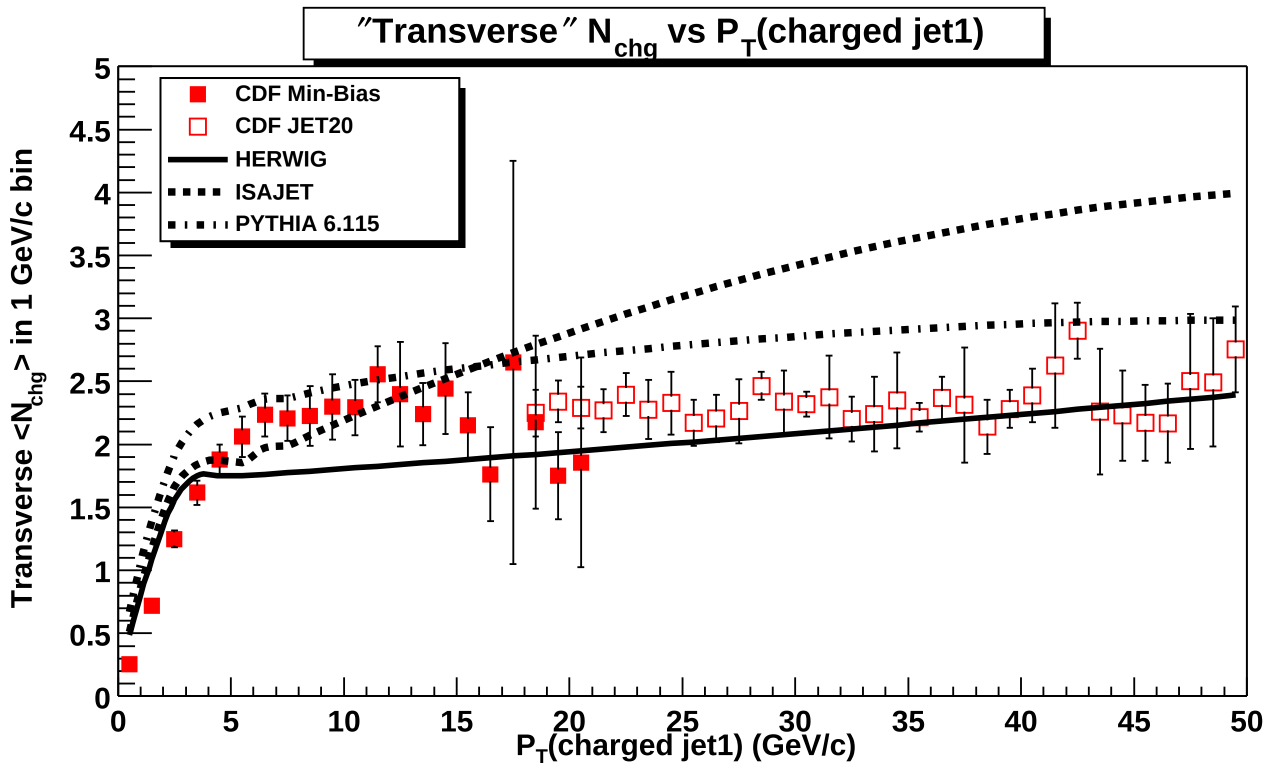
- Multiple interactions needed to describe data in photoproduction at HERA, Z. Phys. C70 (1996) 17.

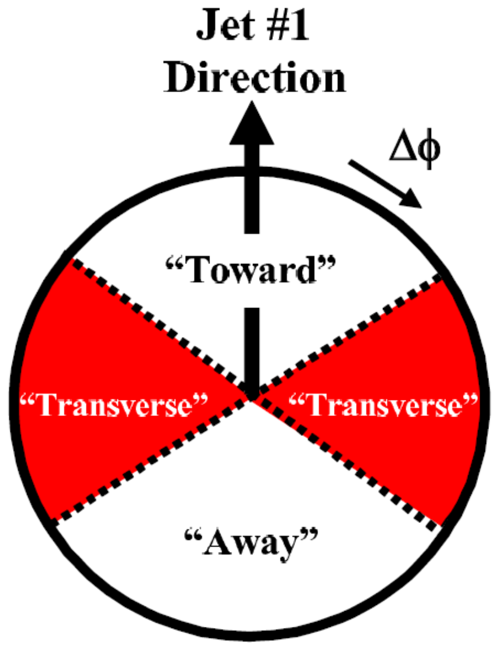


$$x_\gamma = \frac{\sum_{i=1}^{2} E_{T,i} \; e^{-\eta_i}}{2E_\gamma}$$

Motivation

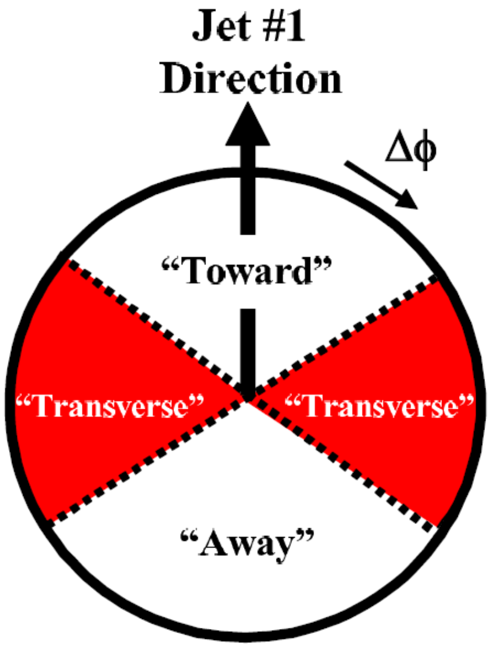
- Multiple interactions needed to describe data in photoproduction at HERA, Z. Phys. C70 (1996) 17.
- Multiple interactions needed to describe data at Tevatron, Phys. Rev. D65, 092002, (2002).

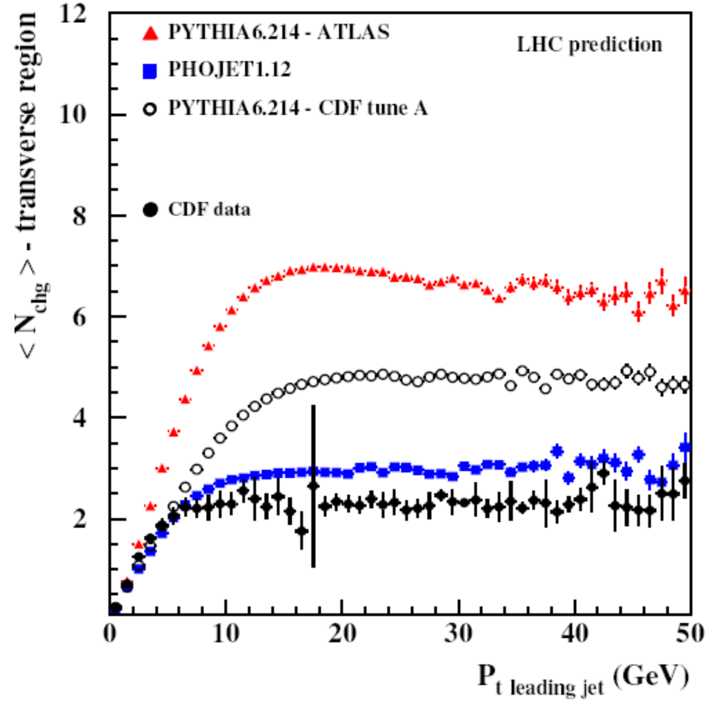


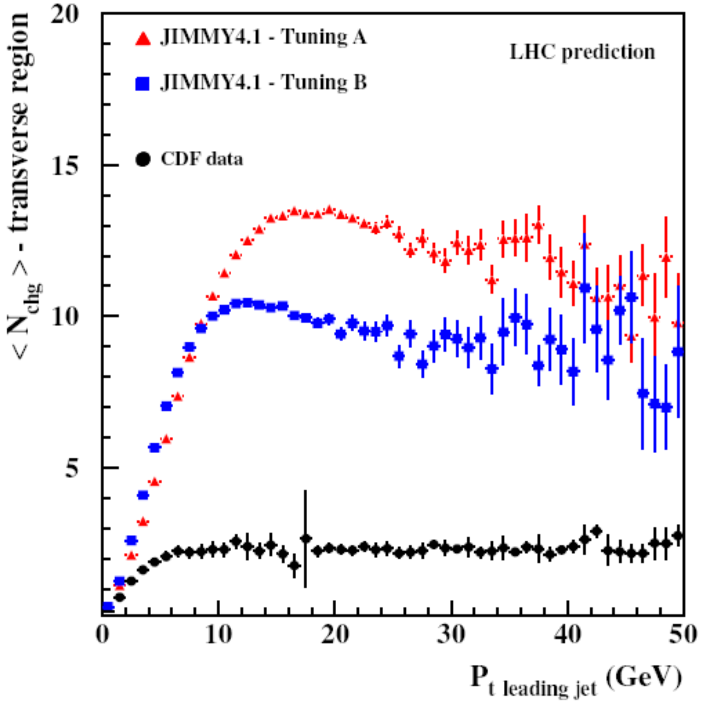


Motivation

- Multiple interactions needed to describe data in photoproduction at HERA, Z. Phys. C70 (1996) 17.
- Multiple interactions needed to describe data at Tevatron, Phys. Rev. D65, 092002, (2002).
- MC tuned to Tevatron data gives different predictions at LHC







Motivation

What about DIS? Are we sensitive to UE?

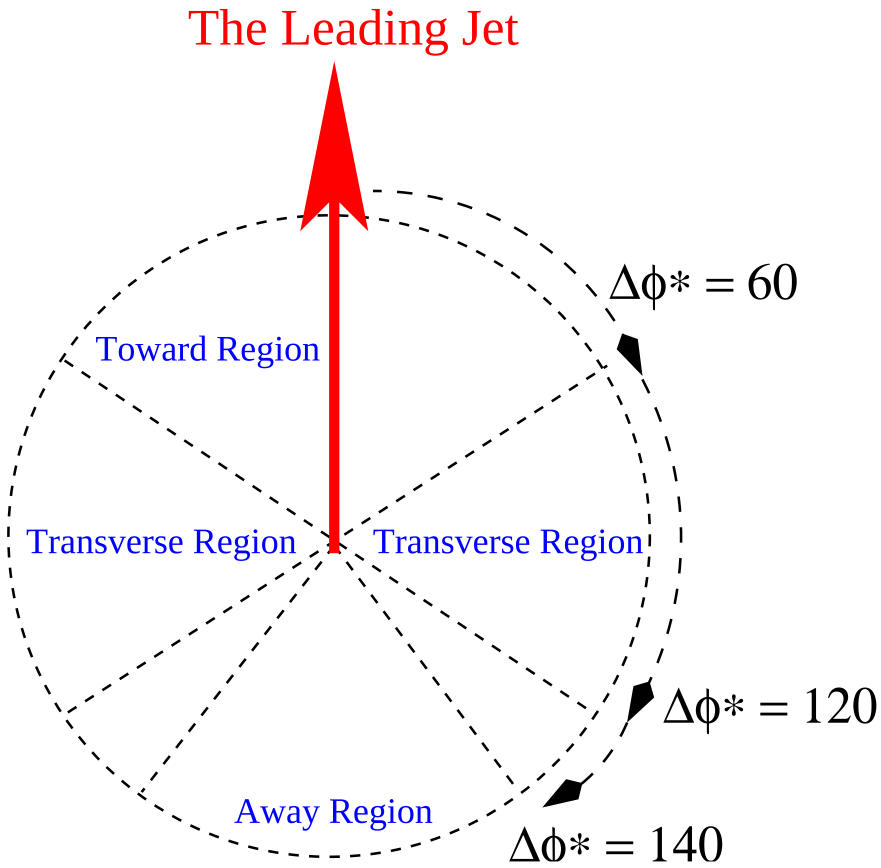
$\longrightarrow$ Measure regions expected to be sensitive to underlying event.

- Measure jets with low transverse momenta (mini jets).
- Test models commonly used in DIS.
- Test models including MI (and/or SUE) used in photoproduction.

Strategy

- Select the jet with highest P_T^* in HCM rest frame, the Leading Jet.

- Define four regions in azimuthal:
  - Toward region: $|\Delta\phi^*| < 60°$.
  - Two Transverse regions: $60° < |\Delta\phi^*| < 120°$.
  - Away region: $|\Delta\phi^*| > 140°$.

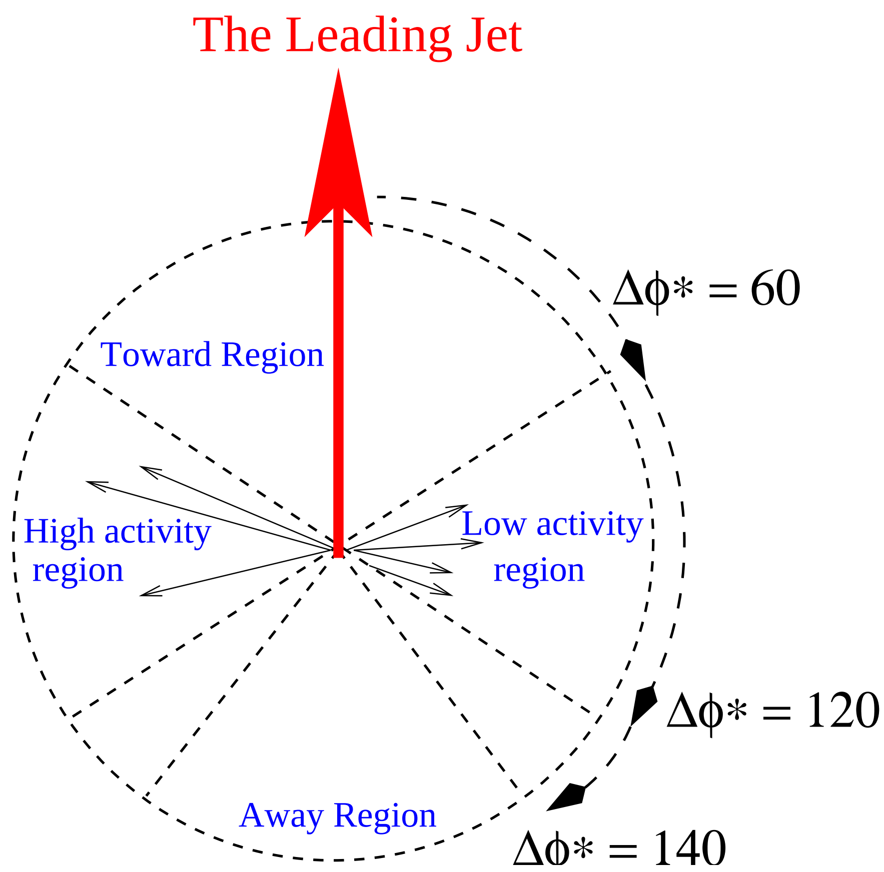


The Toward and Away regions are sensitive to the hard part of the event.

Strategy

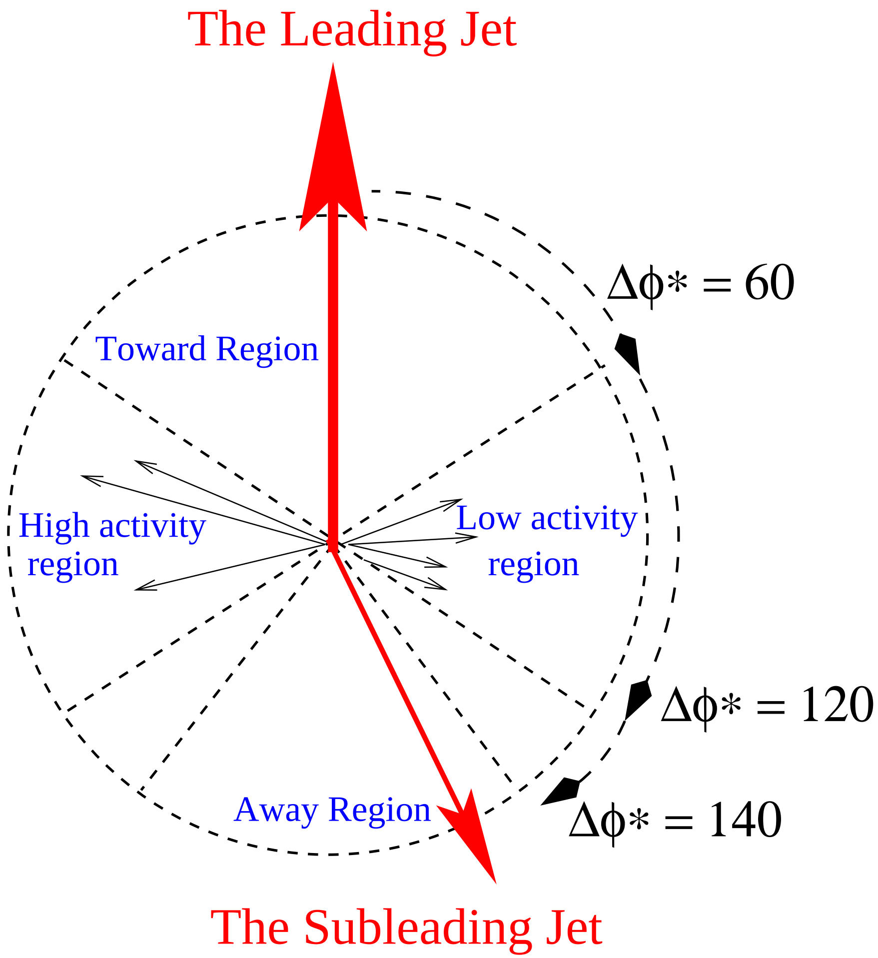
- The scalar E_T^* Sum of the particles, E_{TSum}^*, in the transverse regions is calculated for each event.

- For each event, split the two Transverse regions into a low activity region and a high activity region acording to E_{TSum}^*.



Strategy

- In addition, select a subsample, Dijet sample, where the second hardest jet, Subleading Jet, is restricted to be in the Away region.



Strategy

- Measure the average jet multiplicity in the different $\Delta\phi^*$ regions as function of P_T^* of the Leading Jet.

$$< N_{MiniJet} >= \frac{\sum_{i=1}^{N_{ev}} \quad N_{MiniJet,i}}{N_{ev}}$$

- Inclusive sample:
  - In bins of Q^2.
  - In bins of η^{lab} of the leading jet:
    - Forward region (close to the proton direction) enhanced contributions from the resolved photon processes
    - Central region less contributions from the resolved photon processes

- Dijet sample:
  - In bins of $x_\gamma = \frac{\sum_{i=1}^{2} P_{T,i}^* \; e^{\eta_i^*}}{2E_\gamma^*}$, where i=1 is the leading jet
    i=2 is the subleading jet

Selections

DIS

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

$$0.1 < y < 0.7$$

$$W > 200 \text{ GeV}$$

Jet

Inclusive sample: jet 1 (Hardest jet)

Dijet sample: jet 1,2 (Two hardest jets)

$$-1.7 < \eta_{1,2}^{lab} < 2.79$$

$$P_{T1,2} > 5 \text{ GeV}$$

$$|\phi_1^* - \phi_2^*| > 140^\circ$$

Mini jets, jets with:

$$-1.7 < \eta^{lab} < 2.79$$

$$P_T > 3 \text{ GeV}$$

The P_T cuts are applied both in HCM and Lab frame.

Jets are defined as inclusive k_t-algorithm jets (HCM).

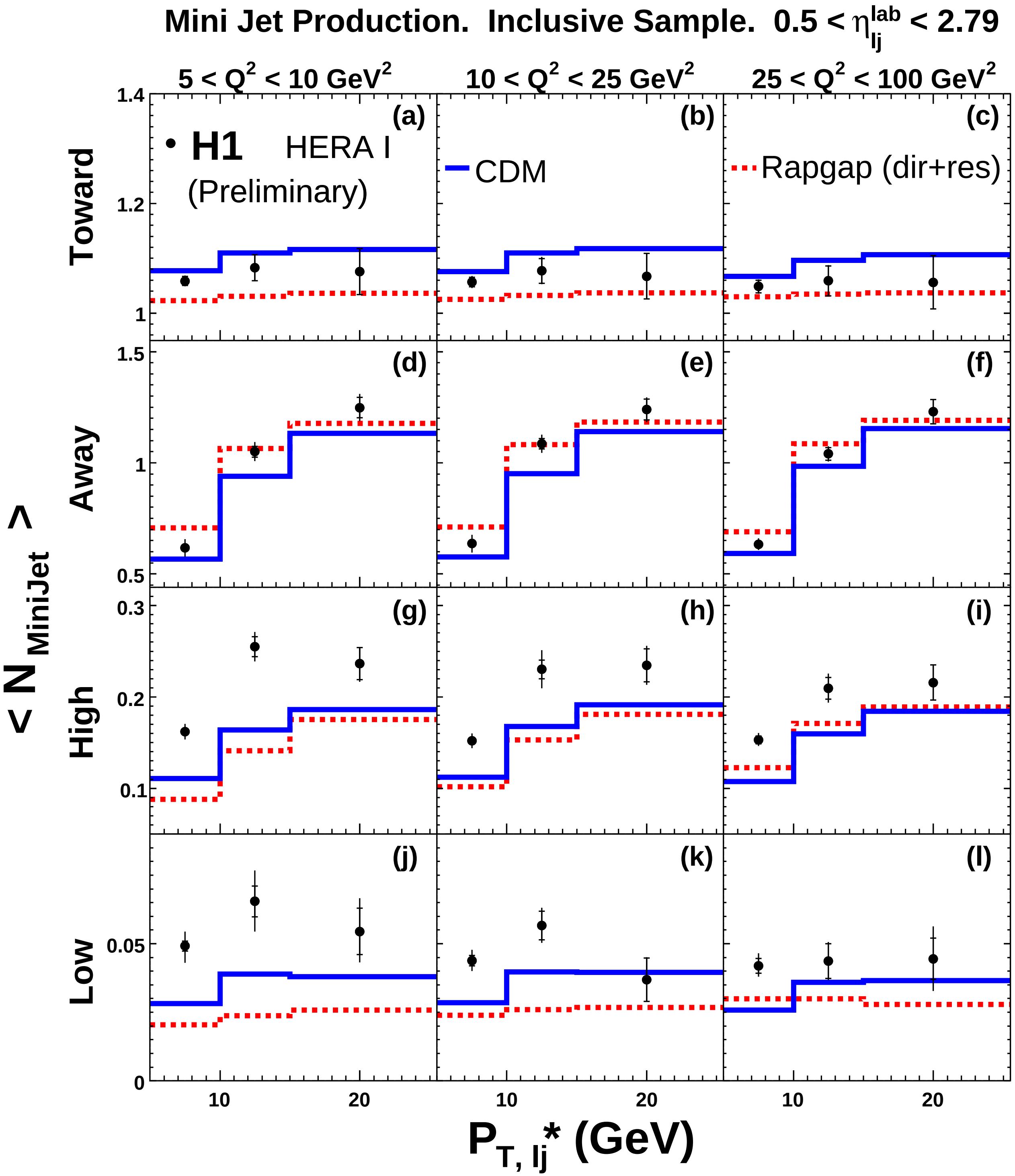
Mini Jet Production

Inclusive Sample

Forward Region:

$0.5 < \eta_{lj} < 2.79$

- √ Ok in toward and away regions
- √ MC's undershoot data in the low and high activity regions



Mini Jet Production

Inclusive Sample

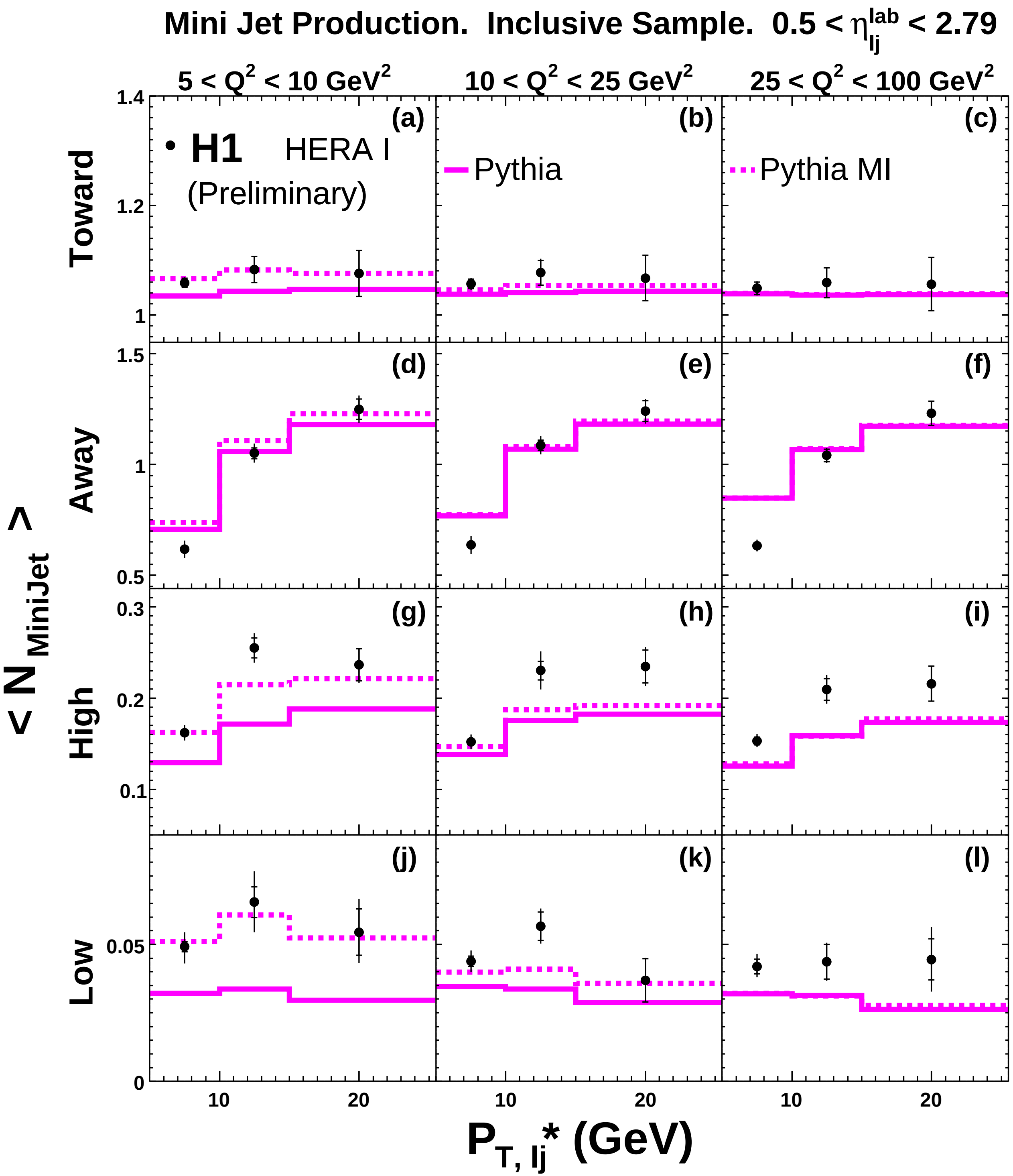
Forward Region:

$0.5 < \eta_{lj} < 2.79$

√ Ok in toward and away regions

√ Pythia MI improves the agreement with data at low Q^2

Similar results are obtained with Herwig



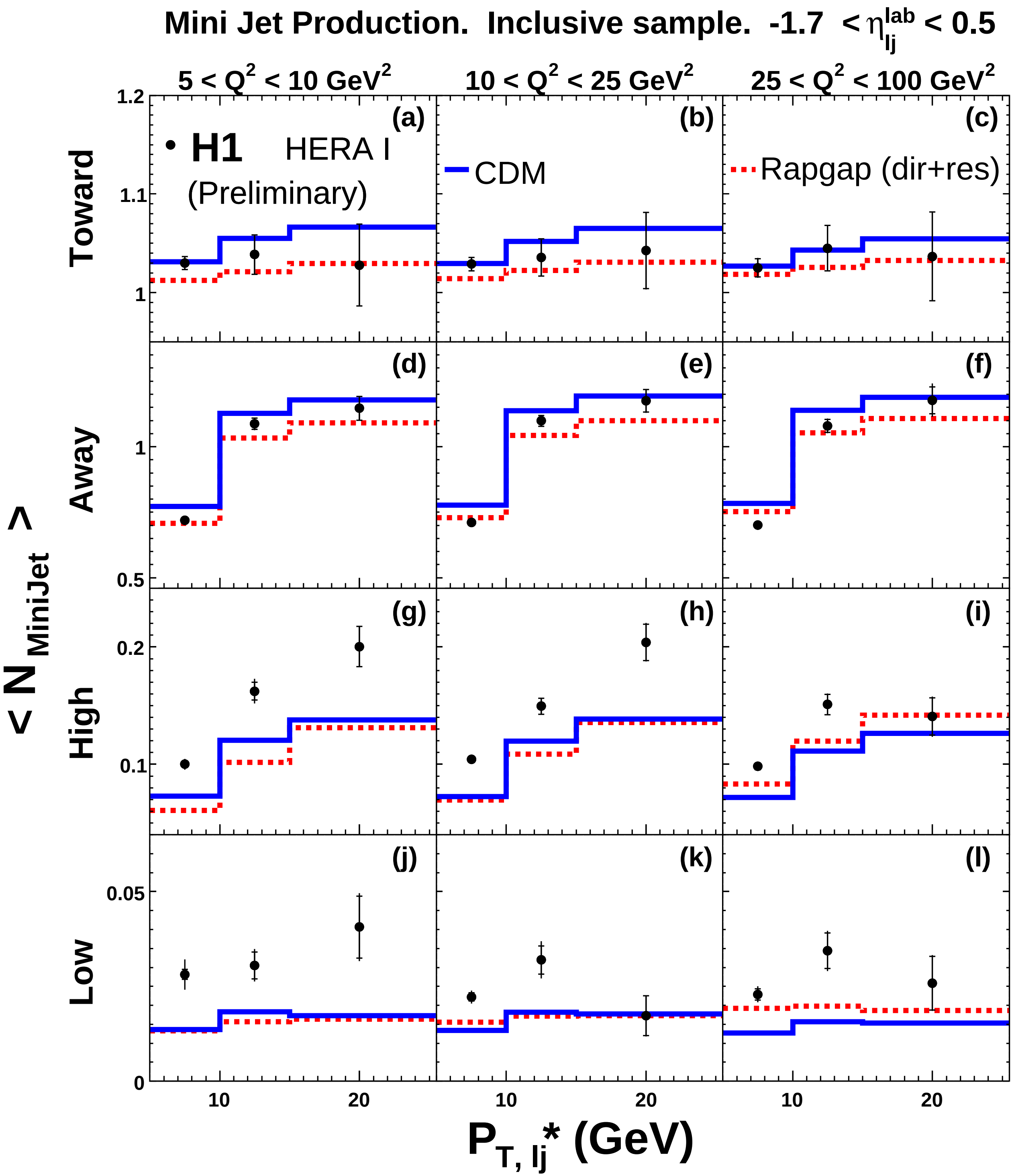
Mini Jet Production

Inclusive Sample

Central Region:

$-1.7 < \eta_{lj} < 0.5$

- √ Less activity in central region than forward region
- √ Ok in toward and away regions
- √ MC's undershoot data in the low and high activity regions



Mini Jet Production

Inclusive Sample

Central Region:

$-1.7 < \eta_{lj} < 0.5$

√ Ok in toward and away regions

√ Pythia MI improves the agreement with data at low Q^2

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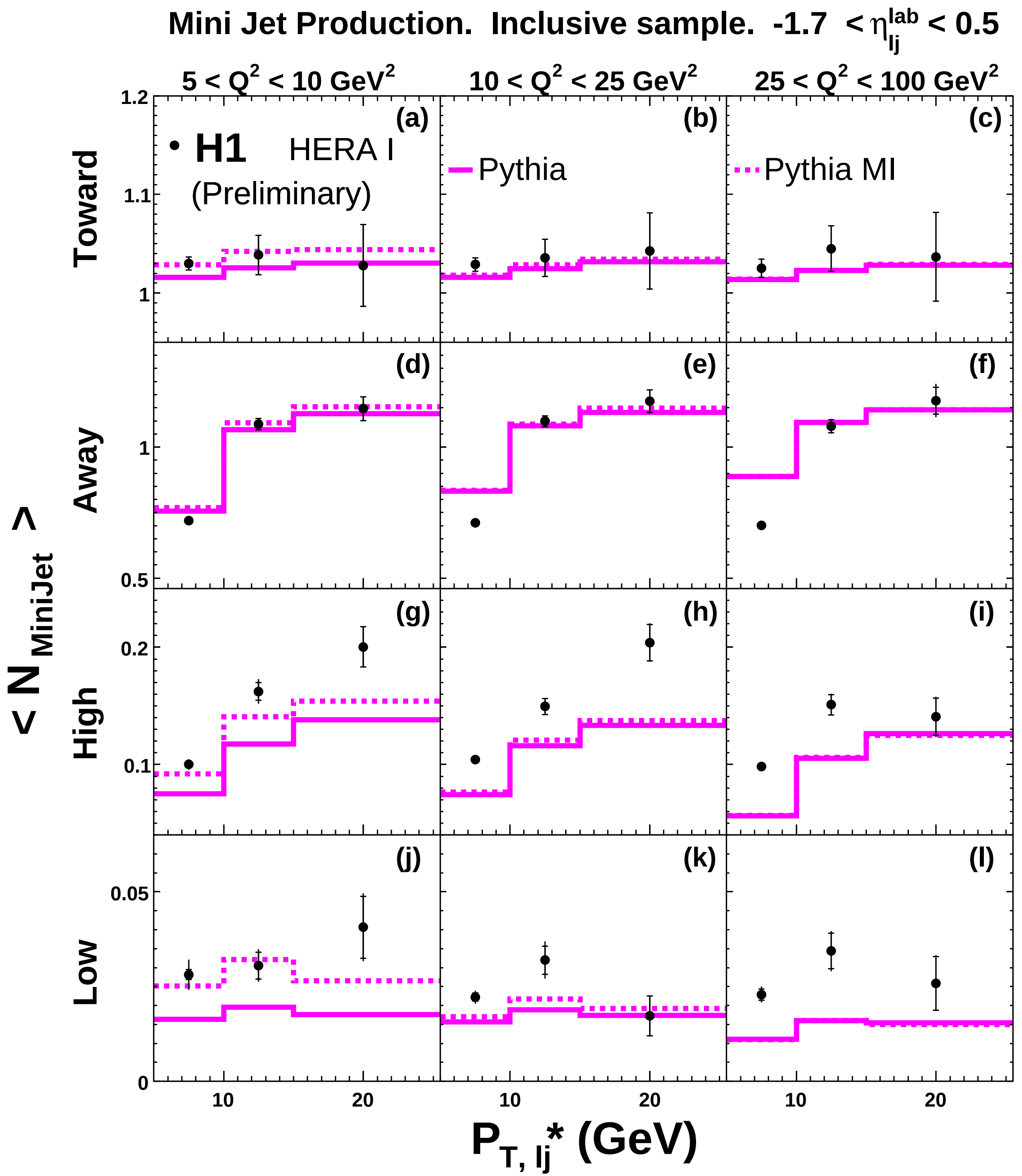
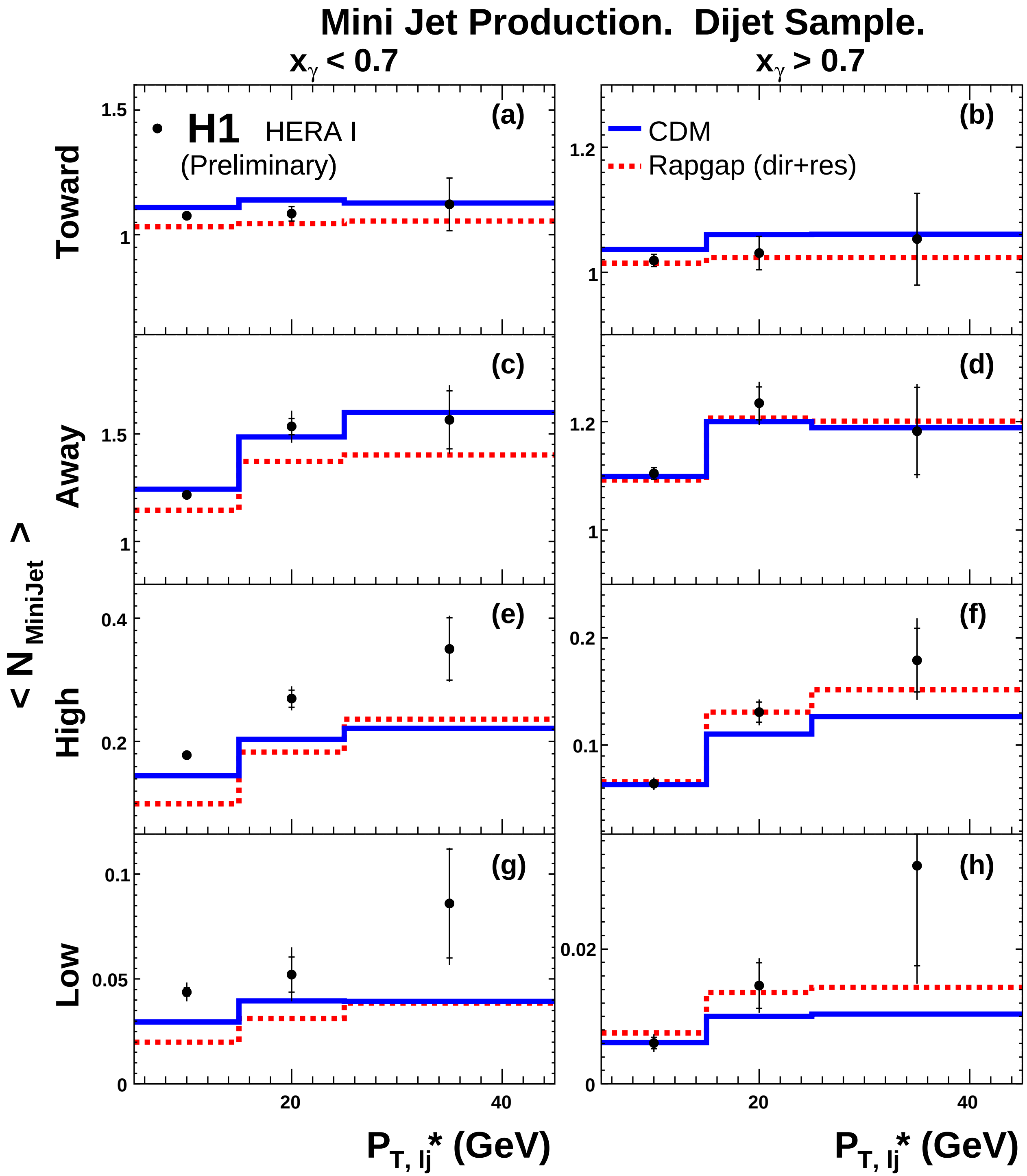


Mini Jet Production

Dijet Sample

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

- √ higher activity at low x_γ
- √ Ok in toward and away regions
- √ MC's undershoot data in the low and high activity regions



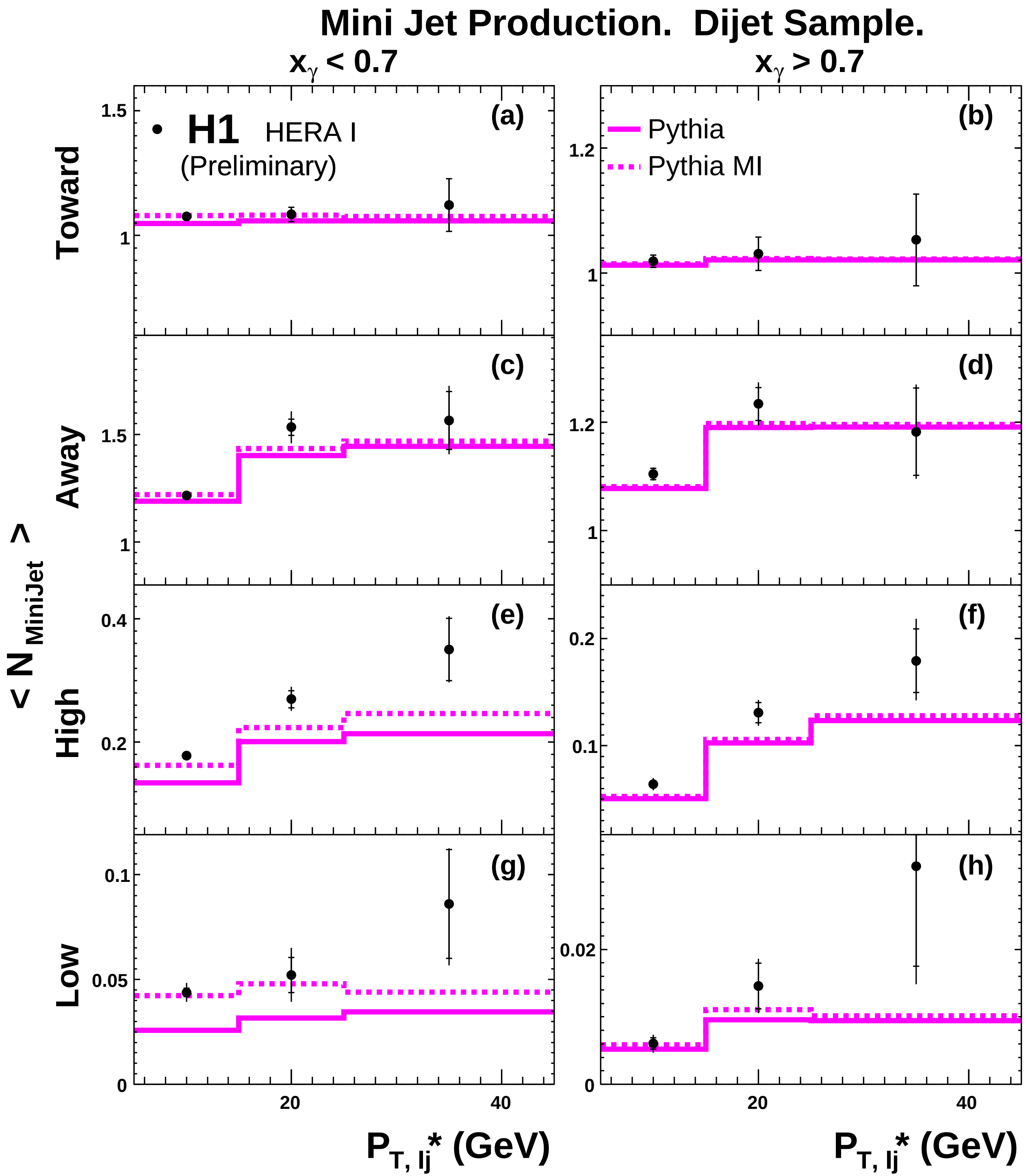
Mini Jet Production

Dijet Sample

$5 < Q^2 < 100$ GeV^2

- √ Ok in toward and away regions
- √ Pythia MI improves the agreement with data at low x_γ

Similar results are obtained with Herwig



Conclusion:

* Standard QCD Monte Carlo models with LO ME+PS fail to reproduce data in the transverse ϕ-regions $\longrightarrow$ needs more correct descriptions of higer orders or additional activity to the hadronic final state, like MI.

* Additional activity like MI (Pythia), successfully used in photoproduction, significantly improve the agreement with data at low Q^2 in the transverse regions, but fails at high Q^2.

* Due to the lack of NLO QCD calculations suitable to this analysis no conclusion from higher order contributions can be drawn.

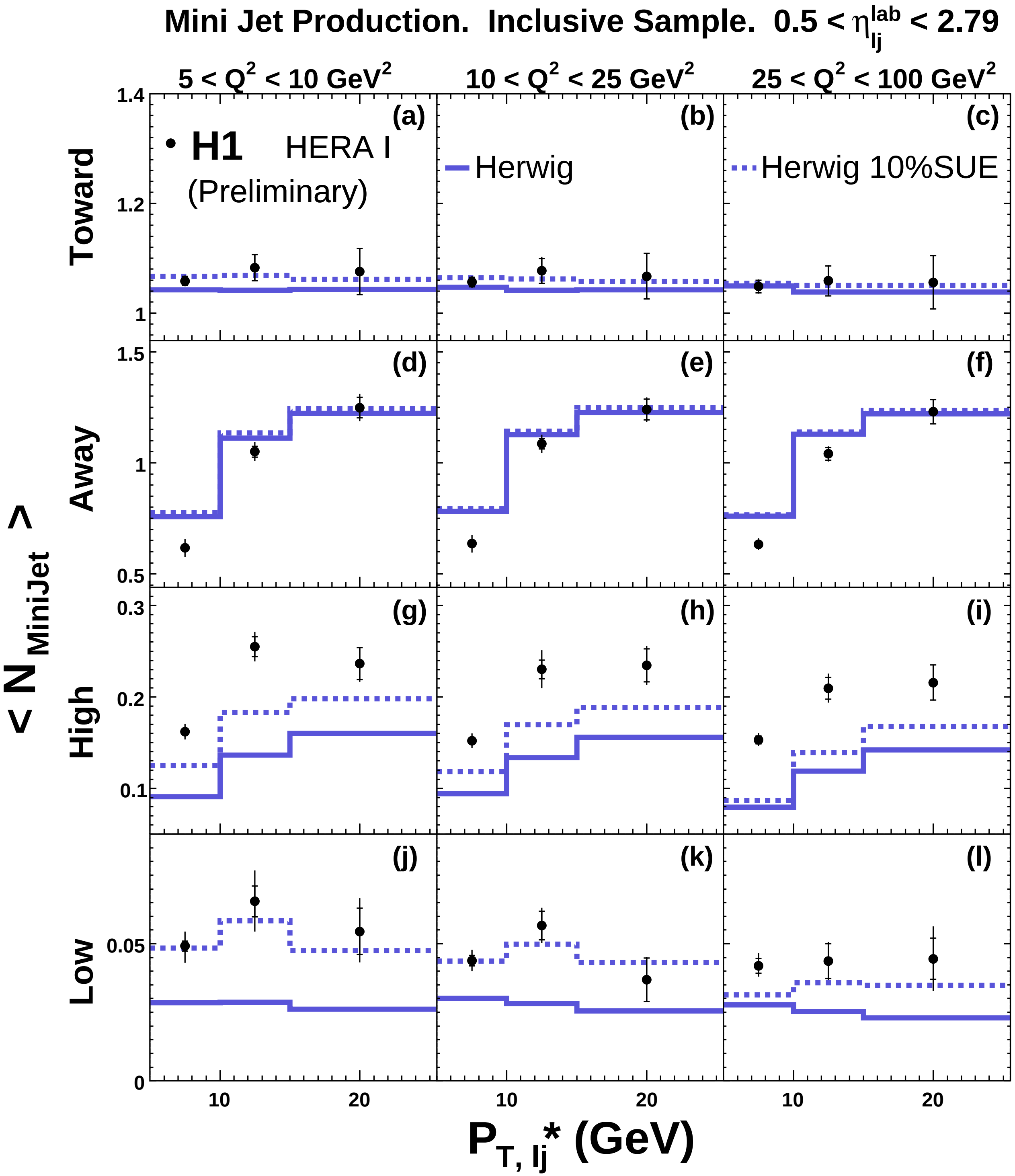
Backup Slides

Mini Jet Production

Inclusive Sample

Forward Region:

$0.5 < \eta_{lj} < 2.79$

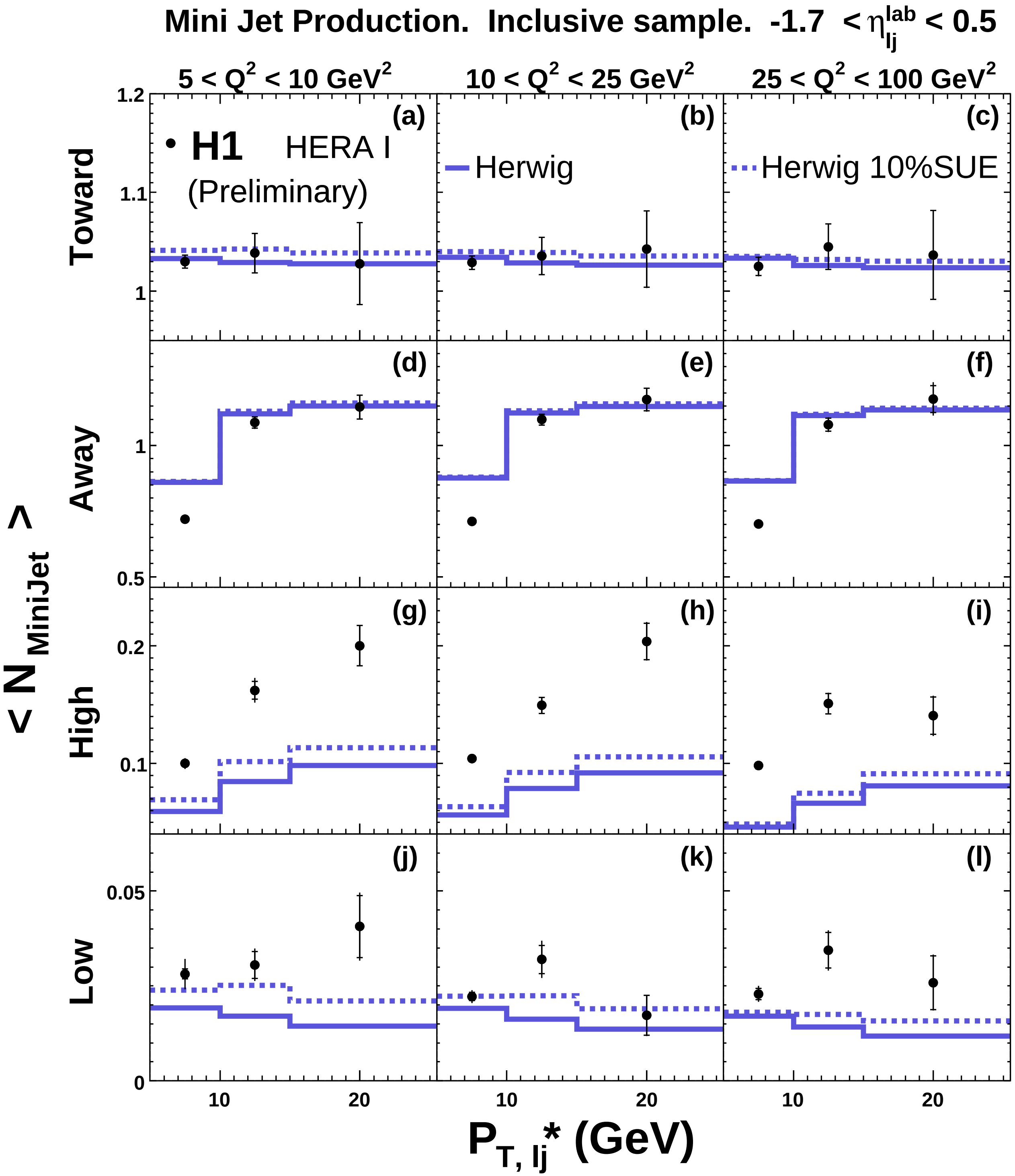


Mini Jet Production

Inclusive Sample

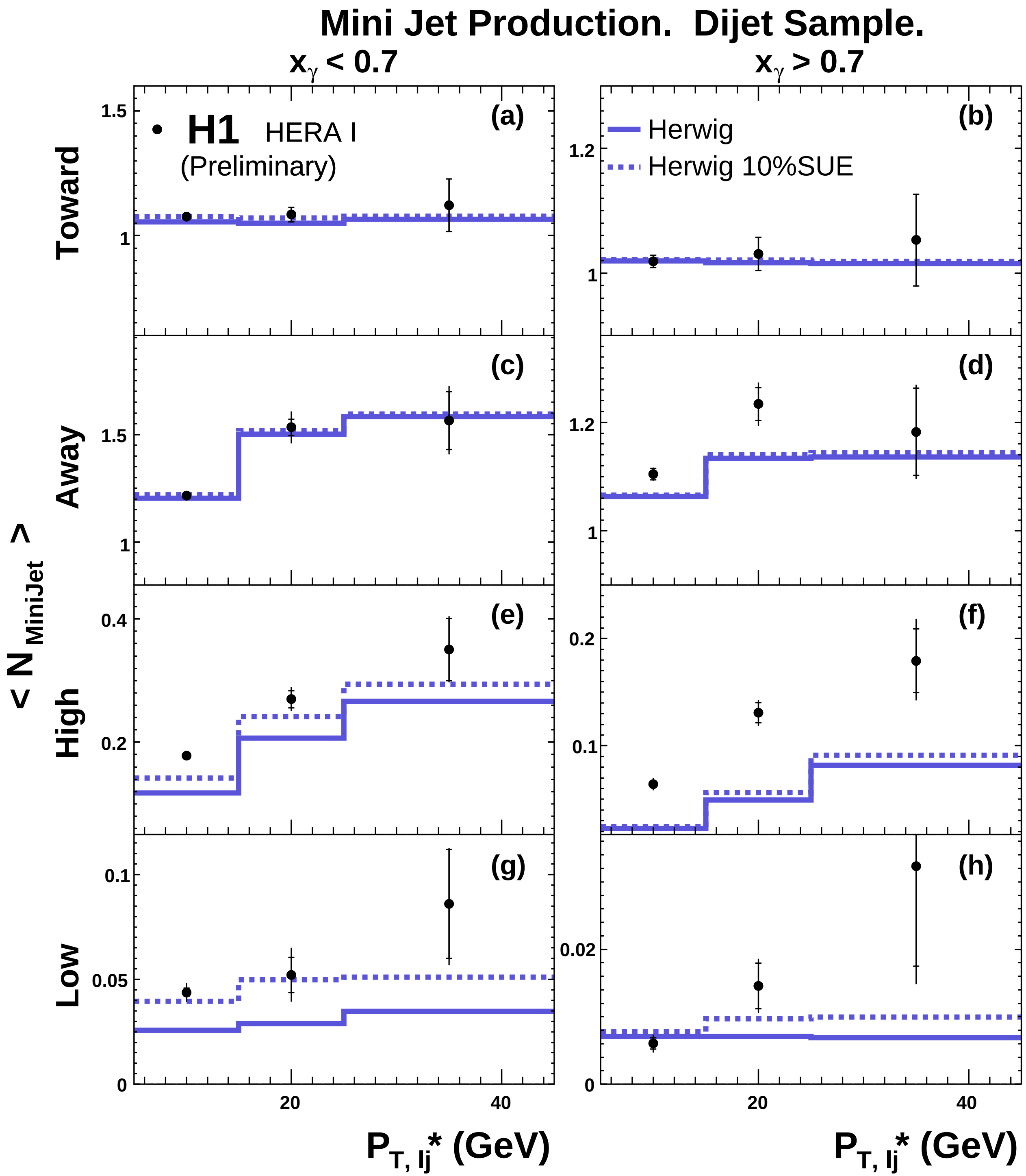
Central Region:

$-1.7 < \eta_{lj} < 0.5$



Mini Jet Production

Dijet Sample



Summary:

$< N_{MiniJet} >$ as function of P_T of the leading jet was presented.

- √ $< N_{MiniJet} >$ increase with η_{lj}^{lab} (forward jets) in the transverse regions.
- √ $< N_{MiniJet} >$ tends to decreases with Q^2 (more direct) in the transverse regions.
- √ $< N_{MiniJet} >$ decreases with x_γ (more direct).
- √ Strong correlation between $< N_{MiniJet} >$ and the leading jet P_T in the high activity region.
- √ Small correlation between $< N_{MiniJet} >$ and the leading jet P_T in the low activity region.