Mini Jet Production in Deep Inelastic e-p Scattering at HERA

H1 Collaboration

Abstract

The production of jets with low transverse momenta (mini jets) in deep inelastic electron-proton scattering is studied. The analyses uses data taken with the H1 detector at HERA during the years 1999 to 2000. Mini jet multiplicities are presented as a function of the transverse momentum of the leading jet, $P^*_{T,lj}$, in bins of the pseudo-rapidity of the leading jet, η^{lab}_{lj}, for three regions in Q^2. The analysis is performed separately for the inclusive jet sample, and for a dijet sample, where the second jet is required to have an azimuthal angle larger than 140 degrees with respect to the leading jet. The dijet sample is split into two samples which are enhanced in direct photon and resolved photon processes, respectively. The results are compared to various QCD based models.

1 Analysis Method

The basic concept of this analyses follows closely the one used by the CDF collaboration at the TEVATRON [1], in which case general event parameters have been investigated. In this analysis two different event samples are studied; *inclusive jet events* and *dijet events*, of which the latter constitutes a subsample of the inclusive sample. The analysis procedure is the following:

Inclusive jet sample: The leading jet is identified and reconstructed using the inclusive k_T jet algorithm in the hadronic center of mass, h.c.m., rest frame. The jet with the highest transverse momentum in h.c.m. frame, the hardest jet, is taken as the leading jet. The reconstructed jet axis defines the azimuthal angle [1] $\Delta\phi^*$=0. The region $|\Delta\phi^*| < 60°$ is defined as the 'toward region', and should contain all particles belonging to the leading jet. The angular region $|\Delta\phi^*| > 4\,140°$ is called the 'away region' and is expected to host most of the particles which are needed to provide momentum balance in the event. The transverse regions, $60° < |\phi^*| < 120°$ are those where contributions from the primary collision should be small and thus effects from underlying events should be most visible. These four regions are shown in figure 1a. Event by event a 'high activity'- and 'low activity' region is defined, depending on which region contains the most and least transverse momentum, respectively. This is illustrated in figure 1.

Dijet sample: The dijet sample includes events having at least two jets, where the two reconstructed jets are required to be almost back-to-back. The leading jet is again defining $\Delta\phi^*$=0, whereas the jet axis of the jet with the second highest transverse momentum, the sub leading jet, is required to be in the angular range $|\Delta\phi^*| > 140°$, such that it will be well inside the 'away region'. This leaves some angular space to accommodate the transverse spread of the jet within the 'away region'. A typical dijet event is shown in figure 1b.

Mini jets are jets reconstructed with the same jet algorithm as the leading jets. The average mini jet production is measured in the toward, Away, high active and low active reions as function of P_T of the leading jet .

2 Event Selection

The analysis is based on data taken with the H1 detector in $1999/2000$ using colliding positrons and protons at energies of 27.5 GeV and 920 GeV, respectively. This gives a center-of-mass energy of $\sqrt{s}$ = 319 GeV. The data collected corresponds to an integrated luminosity of 57.4 pb^{-1}.

Deep inelastic scattering (DIS) events are selected by requiring a highly energetic positron in the SPACAL calorimeter,

$$\begin{array}{rcl} E_{e'} & > & 9\text{ GeV} \\ 156° < & \theta_{e'} & < 175°, \end{array}$$

where $E_{e'}$ and $\theta_{e'}$ is the energy and polar angle of the scattered positron, respectively. The photon virtuality, Q^2, and the inelasticity, y, are determined using the electron method and must fulfill

[1] Observables in the h.c.m. frame are labeled with *.

$$
\begin{aligned}
5\ \mathrm{GeV}^2 &< Q^2 < 100\ \mathrm{GeV}^2 \\
0.1 &< y < 0.7.
\end{aligned}
$$

The invariant mass of the hadronic final state, W, is required to be higher than 200 GeV in the h.c.m. rest system, in order to enhance small x_{bj} contributions and to increase the probability of mini jet productions.

Massless jets are reconstructed by the inclusive k_T jet algorithm in its P_T weighting scheme mode, applied to combined object of tracks and calorimetric clusters in the h.c.m system to ensure a good jet reconstruction it is required that

$$
\begin{aligned}
-1.7 < \eta_j &< 2.79 \\
P^*_{T,j} &> 5\ \mathrm{GeV}.
\end{aligned}
$$

Here, the pseudo-rapidity is given by $\eta_j = -\ln(\tan(\theta_j/2))$, where θ_j is the polar angle of the jet in the lab frame, and $P^*_{T,j}$ is the transverse energy of the jet in the h.c.m. rest frame.

The inclusive jet sample consists of events that contain at least one jet, whereas the dijet sample includes events with at least two jets. The dijet sample is thus a subsample of the inclusive jet sample. For both samples the jet with the highest transverse momentum is chosen as the leading jet and in the dijet sample the sub-leading jet has to fulfill the requirement $|\Delta\phi^*_{ls}| > 140°$, where $\Delta\phi^*_{ls} = \phi^*_{lj} - \phi^*_{sj}$, and ϕ^* is the jet azimuthal angle where the labels *lj* and *sj* denote the leading and sub-leading jets, respectively.

Mini jets are required to fulfill the same η cut as the leading and sub-leading jets. However, the minimum transverse momentum of a mini jets is specified as 3 GeV both in lab and h.c.m. rest frame.

3 Conclusions

The folowing conclusion can be made:

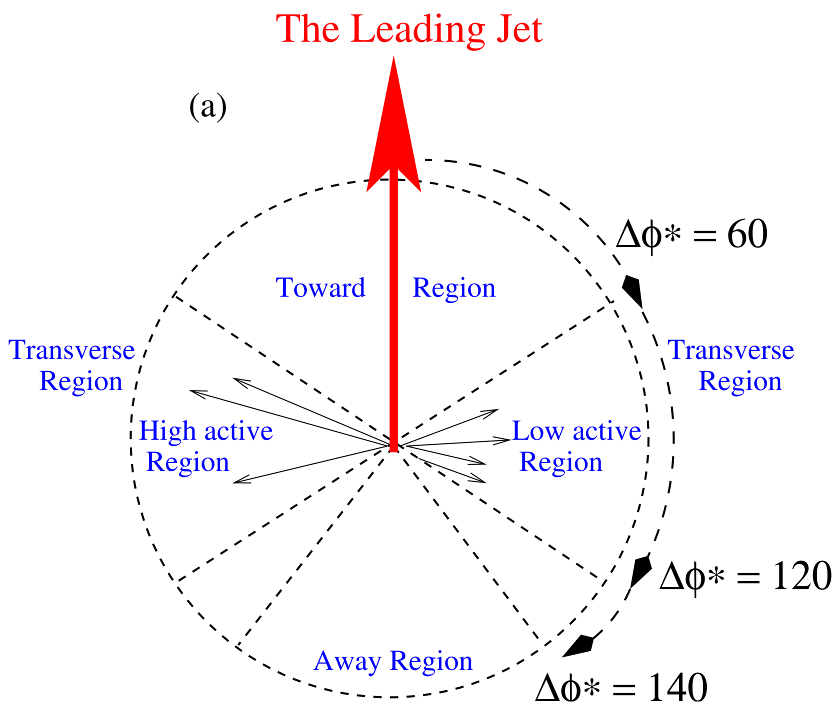
- Standard QCD Monte Carlo models with LO ME+PS fail to reproduce data in the transverse ϕ-regions $\longrightarrow$ needs more correct descriptions of higher orders or additional activity to the hadronic final state, like MI/SUE.

- Additional activity like MI (Pythia) and SUE (Herwig), 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.

References

[1] D. Acosta *et al.* [CDF Collaboration], Phys. Rev. D **65** (2002) 072005.



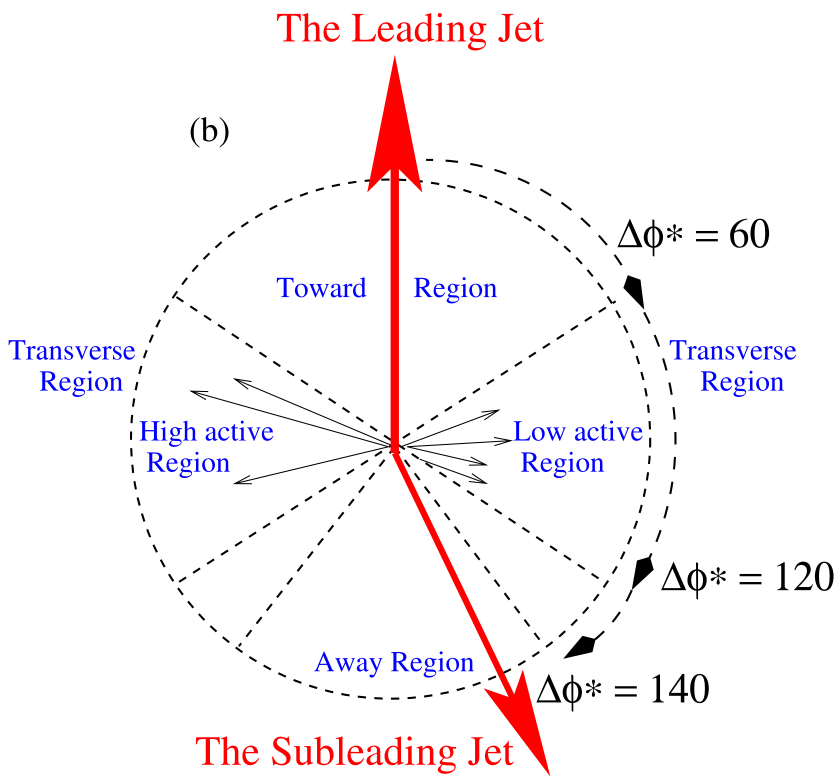


Figure 1: *The transverse regions, Toward and Away regions oriantaions.*

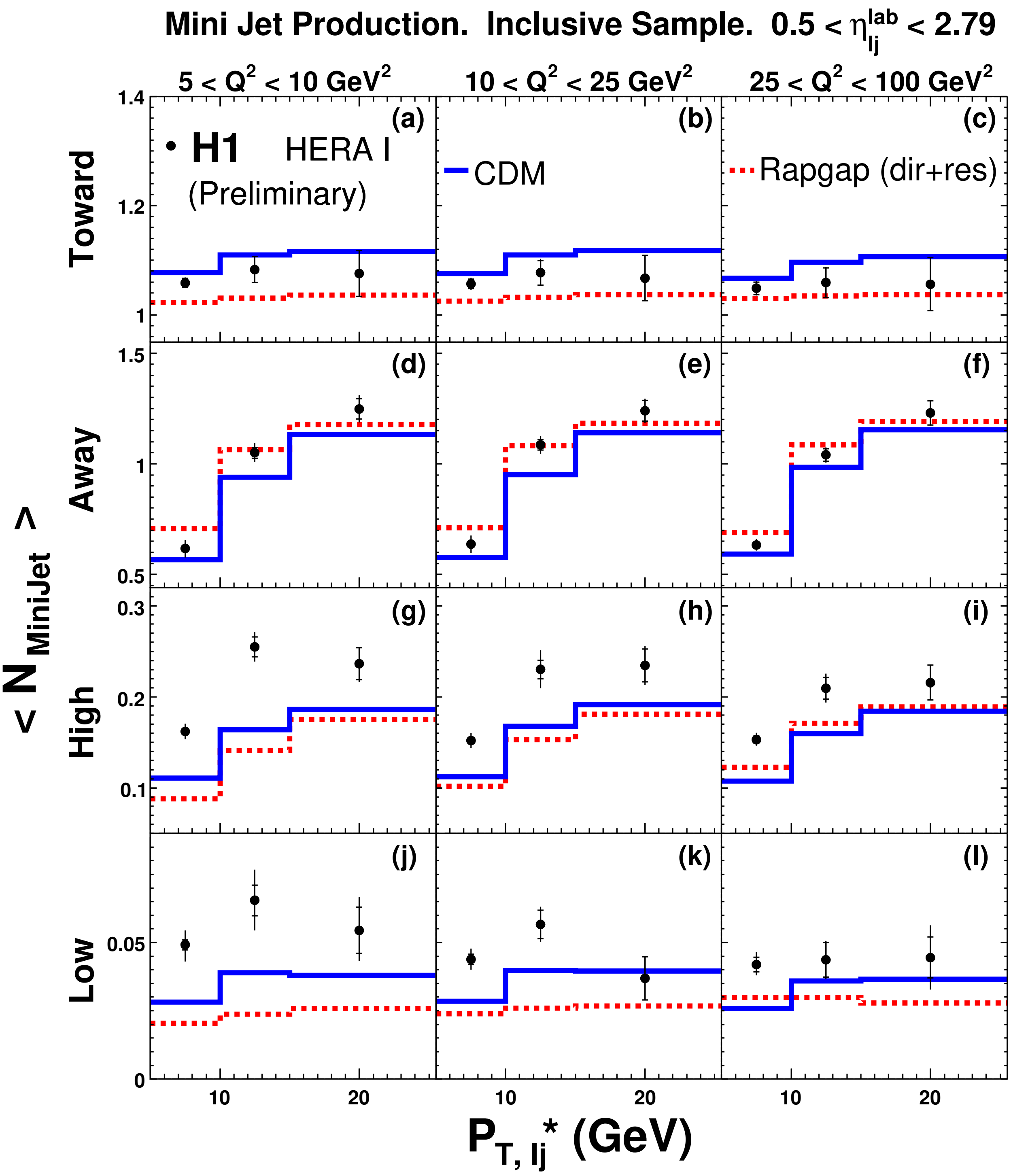


Figure 2: *The Mini jet multiplicity at the different $\Delta\phi^*$ regions in the range $0.5 < \eta_{lj}^{lab} < 2.79$ as a function of P_T of the leading jet in the h.c.m. rest frame for the inclusive sample. The data is compared with different MC with no MI.*

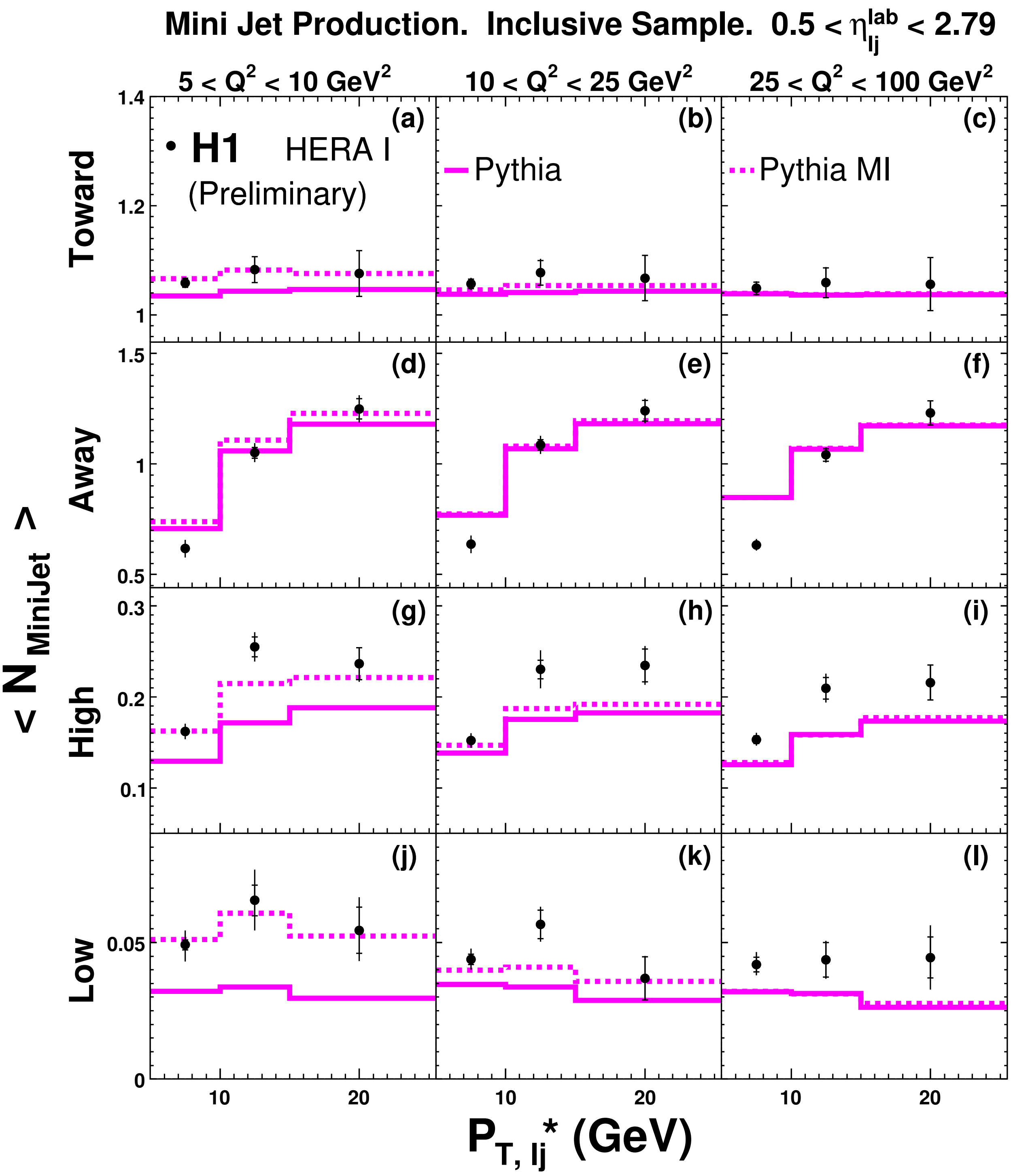


Figure 3: *The Mini jet multiplicity at the different* $\Delta\phi^*$ *regions in the range* $0.5 < \eta_{lj}^{lab} < 2.79$ *as a function of* P_T *of the leading jet in the h.c.m. rest frame for the inclusive sample. The data is compared with Pythia and Pythia MI .*

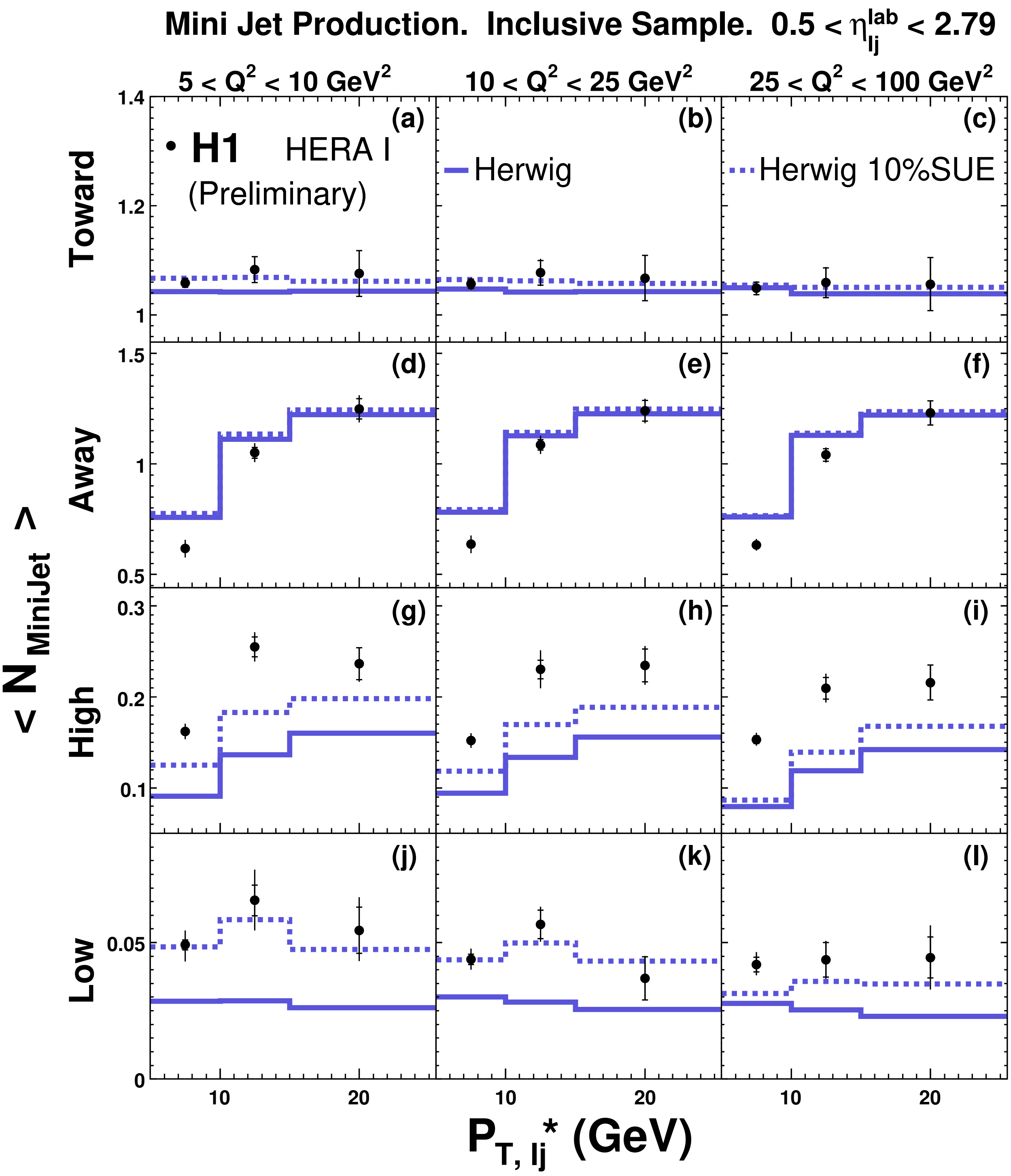


Figure 4: *The Mini jet multiplicity at the different $\Delta\phi^*$ regions in the range $0.5 < \eta_{lj}^{lab} < 2.79$ as a function of P_T of the leading jet in the h.c.m. rest frame for the inclusive sample. The data is compared with Herwig and Herwig 10%SUE .*

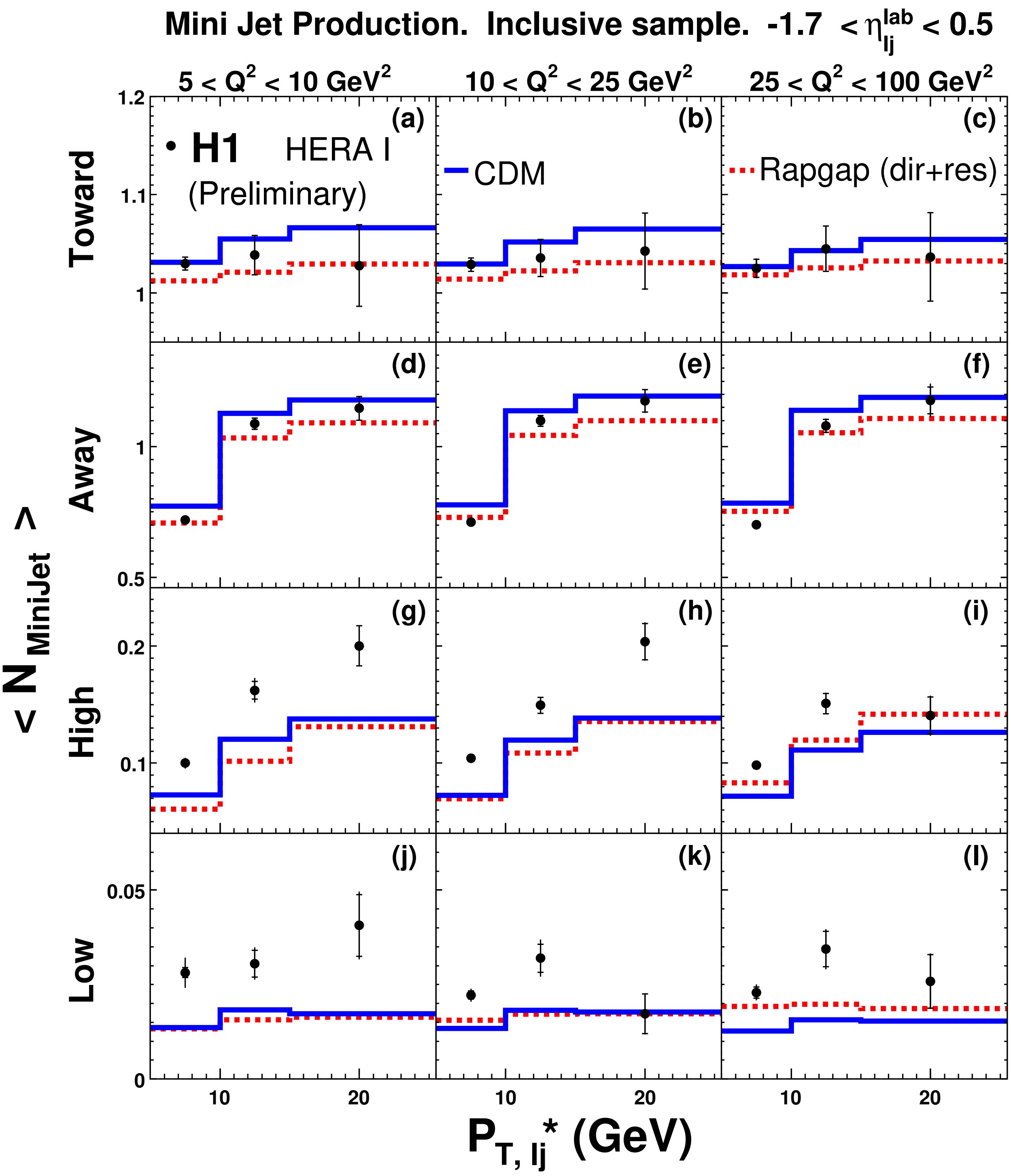


Figure 5: *The Mini jet multiplicity at the different $\Delta\phi^*$ regions in the range $-1.7 < \eta_{lj}^{lab} < 0.5$ as a function of P_T of the leading jet in the h.c.m. rest frame for the inclusive sample. The data is compared with different MC with no MI.*

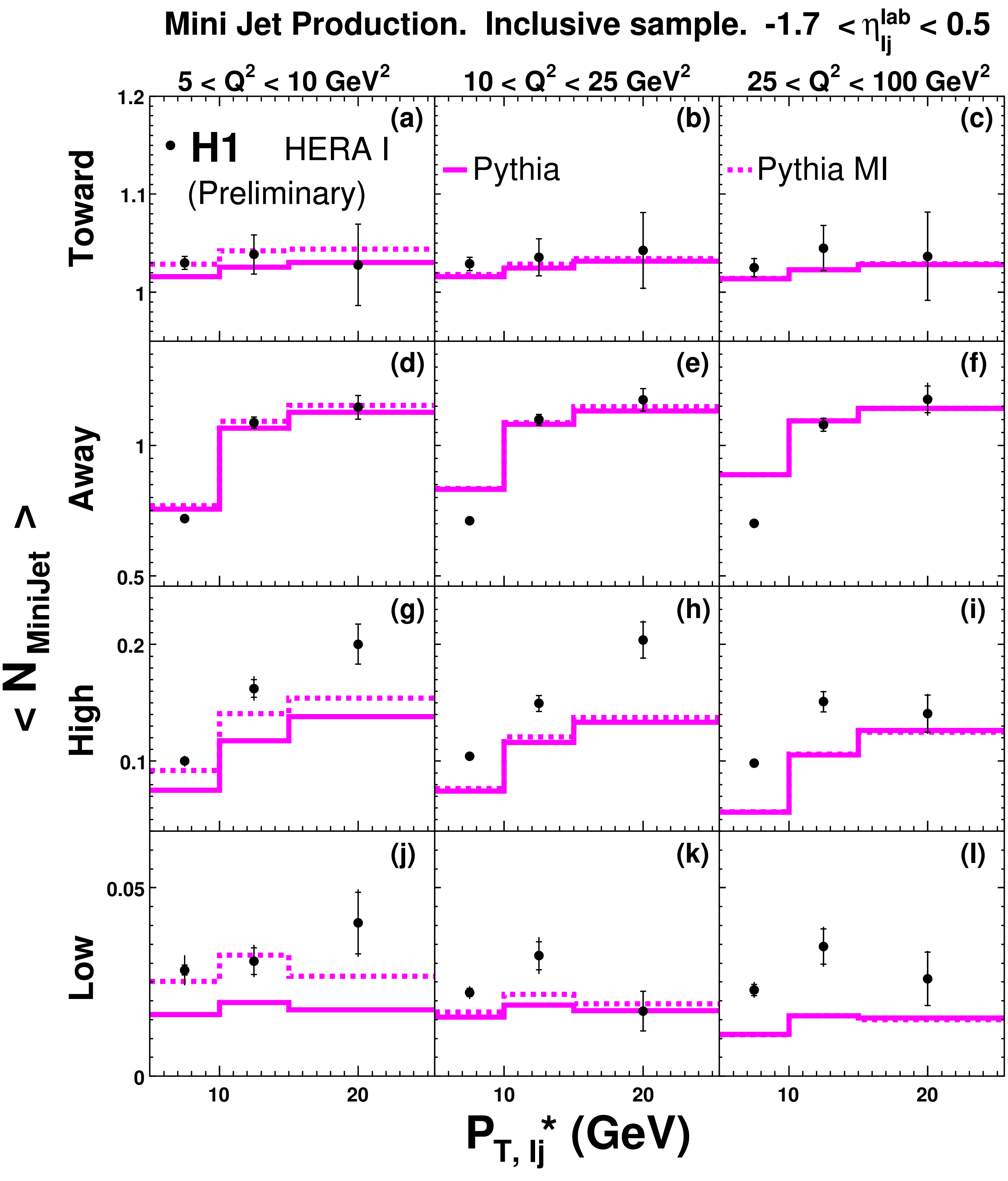


Figure 6: *The Mini jet multiplicity at the different $\Delta\phi^*$ regions in the range $-1.7 < \eta_{lj}^{lab} < 0.5$ as a function of P_T of the leading jet in the h.c.m. rest frame for the inclusive sample. The data is compared with Pythia and Pythia MI.*

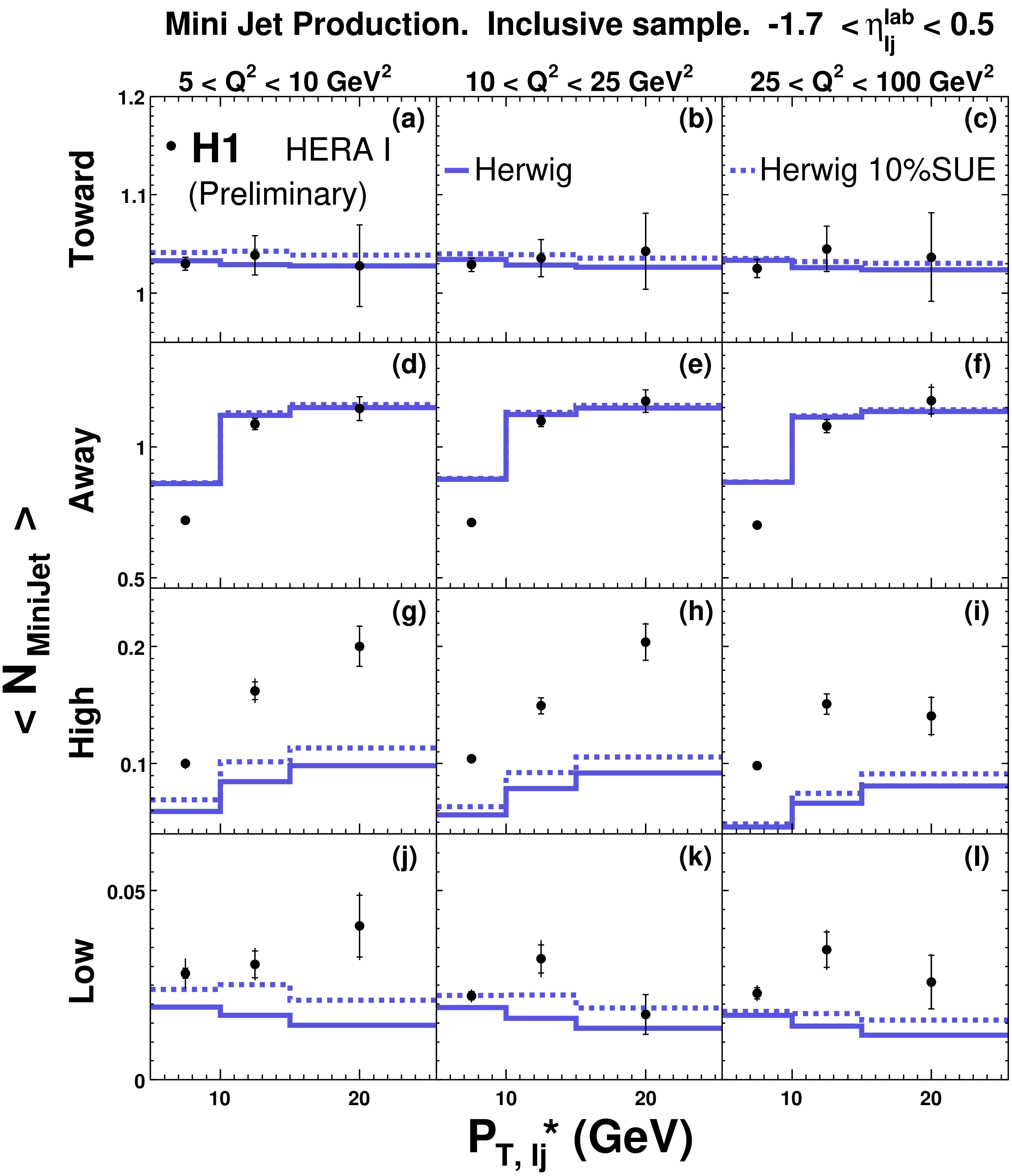


Figure 7: *The Mini jet multiplicity at the different $\Delta\phi^*$ regions in the range $-1.7 < \eta_{lj}^{lab} < 0.5$ as a function of P_T of the leading jet in the h.c.m. rest frame for the inclusive sample. The data is compared with Herwig and Herwig 10%SUE*

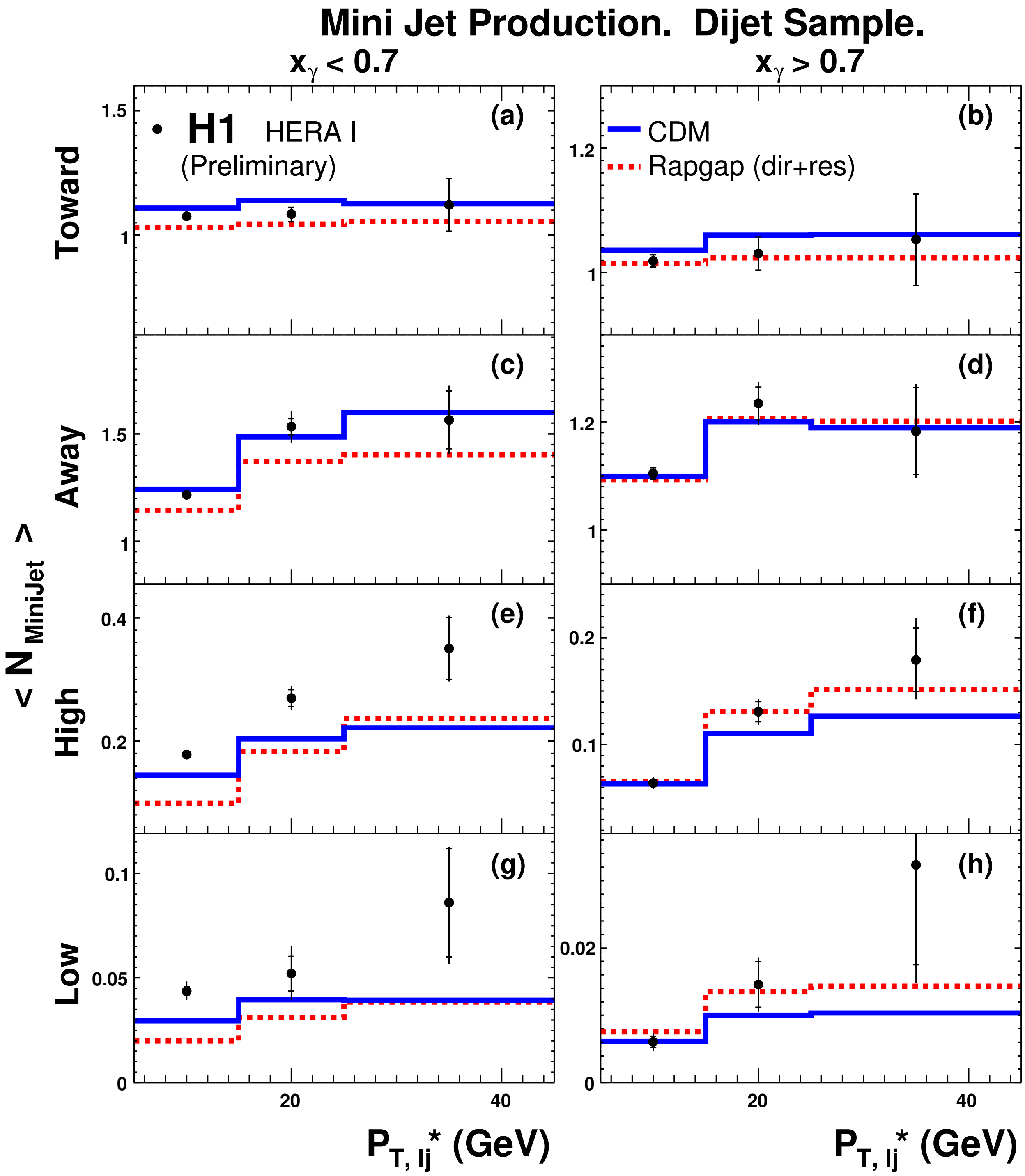


Figure 8: *The Mini jet multiplicity at the different $\Delta\phi^*$ as a unction of P_T of the leading jet in the h.c.m. rest frame for the Dijet sample. The data is compared with different MC with no MI.*

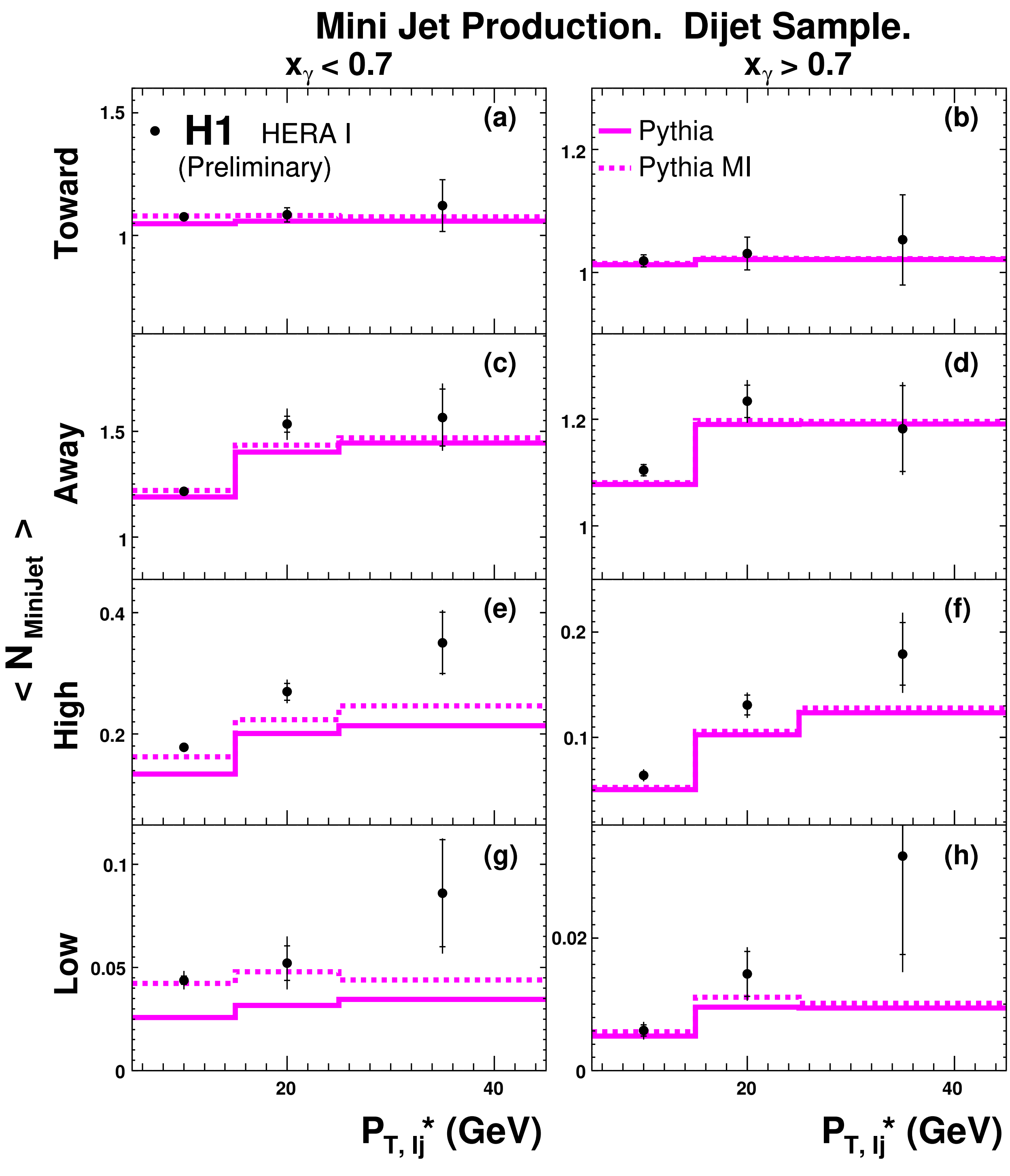


Figure 9: *The Mini jet multiplicity at the different $\Delta\phi^*$ as a function of P_T of the leading jet in the h.c.m. rest frame for the Dijet sample. The data is compared with Pythia and Pythia MI.*

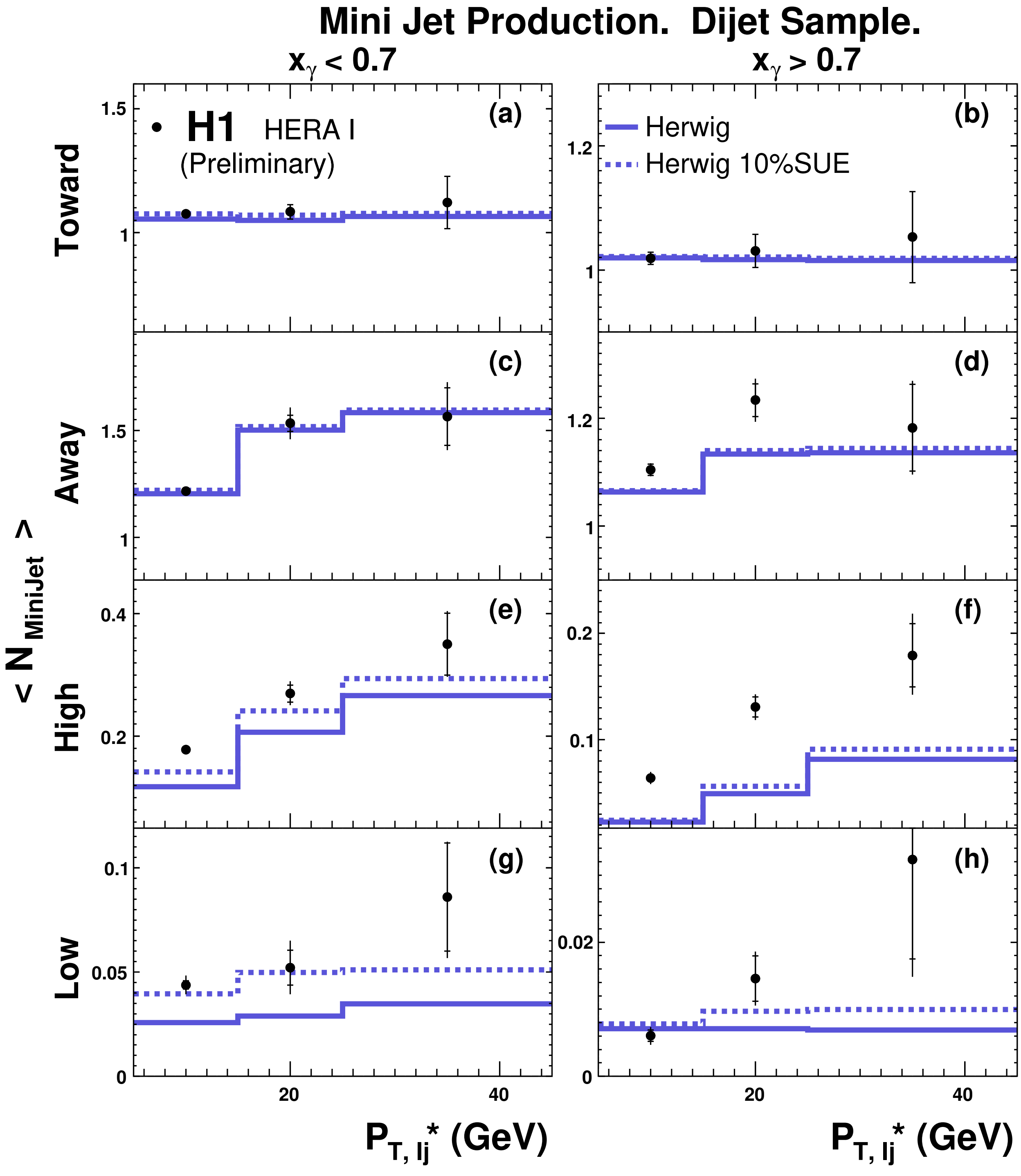


Figure 10: *The Mini jet multiplicity at the different $\Delta\phi^*$ as a function of P_T of the leading jet in the h.c.m. rest frame for the Dijet sample. The data is compared with Herwig and Herwig 10%SUE*