PHOTOPRODUCTION OF JETS AT HERA

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Recent NLO calculations for the photoproduction of one and two jets at HERA are compared to data from H1 and ZEUS. We discuss the physics potential of these measurements for constraining the photon structure, especially the quark density at large $x$, and study remaining hadronization and jet definition uncertainties.

At HERA, $ep$ scattering proceeds dominantly through the radiation of almost real photons. In a large fraction of these events, jets with large $E_T$ are produced which allows the application of perturbative QCD. In LO, one has to calculate the process $ab \to 12$, where $a$ is the photon (direct process) or a parton in the photon (resolved process), $b$ is the parton in the proton, and 1 and 2 are the two outgoing partons hadronizing into two jets. In a LO calculation one cannot produce more than two jets, and the implementation of a jet algorithm is impossible. In addition, one suffers from an artificial separation of direct and resolved processes and from large scheme and scale dependences.

In NLO, these drawbacks are remedied through the inclusion of virtual and real corrections. The singularities coming from the virtual loop integration or from the integration over soft and collinear regions of the three particle final state are regularized dimensionally and cancelled or renormalized in the $\overline{\text{MS}}$ scheme. Whereas the small cone approximation of Aurenche et al. is restricted to one-jet cross sections, the Lorentz invariant phase space slicing method used here is very flexible and can also be applied to two-jet cross sections.

We calculate cross sections for HERA conditions where the electron energy is $E_e = 26.7$ GeV and the proton energy is $E_p = 820$ GeV. The spectrum of the virtual photons is approximated by the Weizsäcker-Williams formula with $Q_{\text{max}}^2 = 4 (0.01)$ GeV$^2$ and $x_a \in [0.2; 0.85]$ ([0.25; 0.7]) for ZEUS (H1). For the proton structure functions, we choose MRS(D-) and use the corresponding $\Lambda$ value to calculate the strong coupling $\alpha_s$ in two-loop approximation with five flavors. Following the Snowmass convention, a jet is defined as a bunch of hadrons contained in a cone of radius $R = 1$ in the azimuth-rapidity plane.

We first compare our prediction\footnote{Ref.} for one-jet cross sections to H1 data\footnote{Ref.} and predictions from Aurenche et al.\footnote{Ref.} (left hand side of fig. 1), where we in-
Figure 1: One-jet cross sections in NLO: $E_T$ (top) and $\eta$ (bottom) distributions compared to H1 (left) and ZEUS (right) data.

Integrate either over $\eta$ (top) or $E_T$ (bottom). The agreement between the two calculations and theory and data is excellent for the AFG structure functions (dashed curves) except in the forward region at low $E_T$. This discrepancy vanishes after hadronization corrections (empty data points). At larger $E_T$, the effect of hadronization and the discrepancy in the forward region are reduced. The GRV photon structure function (full curves) underestimates the H1 data. However, the ZEUS data (right hand side of fig. 1) are overestimated when using the GRV structure function (full curves) except in the forward region and can be better described by the GS structure function (dashed curves).

Next, we turn to two-jet cross sections, where only ZEUS 1993 data and our predictions with NLO direct and LO resolved contributions were available so far. We compare the distribution in $\bar{\eta} = \frac{1}{2} (\eta_1 + \eta_2)$ integrated over $E_T > 6$ GeV and the difference of the two rapidities $|\eta^*| = |\eta_1 - \eta_2| < 0.5$

\textsuperscript{a}For a comparison of our predictions to ZEUS 1994 data see L. Feld’s contribution to these proceedings.
for $x_{\text{OBS}}^{\gamma} > 0.75$ using CTEQ(3M) structure functions in the proton. The ZEUS data are again overestimated by the GRV structure function (dashed and dashed-dotted curves) and adequately described by the GS structure function (dotted curve) (left hand side of fig. 2). Since we are at large $x_{\text{OBS}}^{\gamma}$, the direct process dominates with the resolved process still contributing 15% of the total cross section, and we can distinguish mainly the quark densities in the photon. Even with LO resolved contributions, the scheme dependence is cancelled as can be seen when comparing the GRV predictions in $\overline{\text{MS}}$ scheme (dashed curve) and in DIS$\gamma$ scheme (dashed-dotted curve).

An important prerequisite for pinning down the photon structure function is a good understanding of the jet final state. Here, ambiguities arise due to possible double counting of jets and restrictions in parton-parton separation. The right hand side of fig. 2 shows these uncertainties to be ±10%. They are reduced at larger $E_T$ similar to the hadronization corrections as demonstrated above for one-jet cross sections.

Finally, we present the first NLO predictions for resolved photoproduction of two jets, using again the phase space slicing method. The calculation was completed shortly after the workshop and checked with our old program in one-jet production. Fig. 3 shows the effect of the higher order contributions for $\eta$ distributions in the direct dominated region (left) and the resolved dominated region (right). As expected from one-jet production, the corrections are large and range from 40% (“direct”) to 75% (“resolved”) in the central region. Whereas they are symmetric for the latter, they increase rapidly from the backward to the forward region for $x_{\gamma}^{\text{OBS}} > 0.75$ thus improving the description of the data in the forward region.
Figure 3: Resolved two-jet cross sections in NLO and LO; $\eta$ distributions for $x_{\gamma}^{\text{OBS}} > 0.75$ (left) and $x_{\gamma}^{\text{OBS}} \in [0.3; 0.75]$ (right).

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