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Diffraction in Deep Inelastic Scattering at H1

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Abstract

The observation of large rapidity gap events in deep inelastic scattering in the range $7.5\,GeV^2 < Q^2 < 80\,GeV^2$ is reported. A successful interpretation of these data in terms of a partonic picture of electron-pomeron physics is described, and a first measurement of the structure function of diffraction, $F_2^D(x_{Bj}, Q^2)\Big|_{x_{I\!P} \leq 10^{-2}}$, is presented. A novel selection for large rapidity gap events, resulting in a less biased sample than the traditional selection requiring a large rapidity gap in the calorimeter, demonstrates that the rapidity gap may extend to $\eta \approx 6.6$ for many of these events and that they exhibit unambiguously a lower mass scale than normal DIS. A sample of 2 jet events based upon this new selection is suggestive of multi-partonic hard scattering in such deep inelastic diffraction.

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1 Large Rapidity Gaps in Deep Inelastic Scattering

An excess over the expectation of standard partonic models of deep inelastic scattering (DIS) of events with a large interval of pseudo-rapidity around the proton remnant direction almost entirely devoid of hadronic energy has been reported at HERA [1, 2], where $820\,GeV$ protons collide with $26.7\,GeV$ electrons ($\sqrt{s} = 296\,GeV$). Figure 1a shows the distribution of η_{max}, defined to be the first significant energy deposition above $400\,MeV$ found in the main liquid argon calorimeter (LAC) of H1, for a selection of low Q^2 DIS events ($7.5\,GeV^2 < Q^2 < 80\,GeV^2$) from the 1993 data, corresponding to an integrated luminosity of $271\,nb^{-1}$. A clear and significant excess of events with $\eta_{max} \ll 3.6$, the acceptance limit of the LAC, is visible over the expectation of a standard model of DIS (Django[2]).

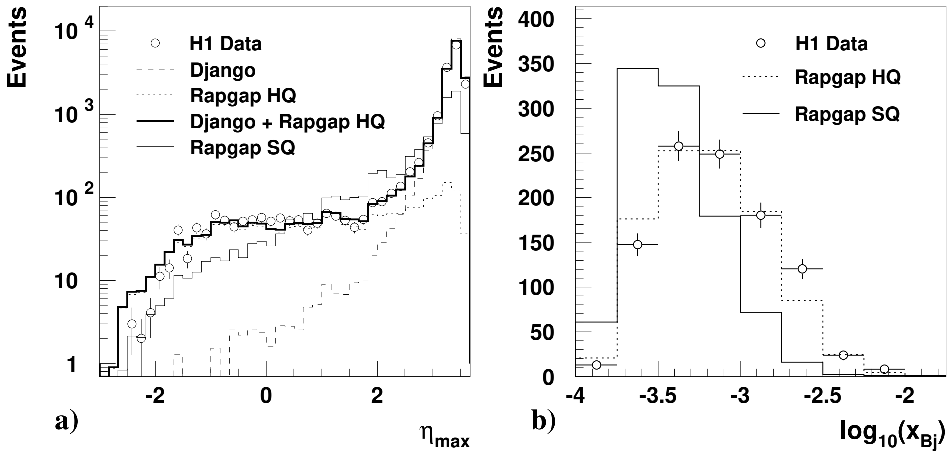

Figure 1: Distribution of η_{max} (a) for H1 data compared with RAPGAP with a hard (HQ $\propto \beta(1-\beta)$) and soft (SQ $\propto (1-\beta)^5$) for the parton density of quarks in the pomeron, $\beta q(\beta, Q_0^2)$, where β is equivalent to x_{Bj} for the electron-pomeron system. The RAPGAP component is normalised to the excess observed for $\eta_{max} < 1.8$. (b) The distribution of x_{Bj} for events with $\eta_{max} < 1.8$.

A possible explanation for these large rapidity gap (LRG) events is diffraction, where the virtual photon probes an object with no colour connection to the proton. This rapidity gap, if large enough, may be observable in the apparatus. Diffraction is anticipated to play an important rôle in low Bjorken-x physics at HERA [7, 12] where very low values of x_{Bj} down to $\sim 10^{-4}$ may be reached for values of $Q^2 > 5\,GeV^2$, providing a unique opportunity to study the structure of the diffractive exchange, the pomeron ($I\!P$).

The compatibility of the data with the hypothesis of diffraction is tested by comparing with RAPGAP [8], a model of diffraction in DIS based the interaction of the virtual photon with a partonic pomeron, with two extreme choices for the parton density in the pomeron. The data clearly favour a hard (HQ), rather than a soft distribution (SQ), although given the uncertainties in the unmeasured flux factor and possible acceptance effects, this preference does not constitute a precise determination. If the ansätze in the RAPGAP model are correct, then the normalisation of the Monte Carlo to the excess over expectation in the η_{max} distribution suggests that $\sim 13\%$ of the observed DIS events are attributable to diffraction in this kinematic range.

2 The Diffractive Structure Function $F_2^D(x_{Bj}, Q^2)\Big|_{x_{I\!P} \leq 10^{-2}}$

A selection of large rapidity gap events in which conventional DIS is expected to contribute less than 7% of the observed rate can be selected by the criterion $\eta_{max} < 1.8$. Figure 1b demonstrates that the data thus selected are, after the subtraction of the small remaining contribution from conventional DIS, well described by RAPGAP

[2]Django 2.1 [3] is used with the MRSH parameterisation and the colour dipole model (CDM) [4], which describe recent measurements of F_2^p [6] and energy flows [5] respectively.

HQ. Studies show that since η_{max} are strongly correlated, this selection corresponds to the limit $x_{I\!P} < 10^{-2}$, where $x_{I\!P}$ is the fraction of the proton momentum carried by the pomeron [9], in line with expectations based upon simple kinematic considerations [11]. A cross section for the diffractive cross section in DIS in the kinematic region $x_{I\!P} < 10^{-2}$ can therefore be extracted from the $\eta_{max} < 1.8$ sample, and expressed in the form of a diffractive structure function, $F_2^D(x_{Bj}, Q^2)$ following [7]. This structure function, $F_2^D(x_{Bj}, Q^2)|_{x_{I\!P} \leq 10^{-2}}$, is shown as a function of x_{Bj} and Q^2 in figures 2a and 2b respectively. Comparison of this structure function

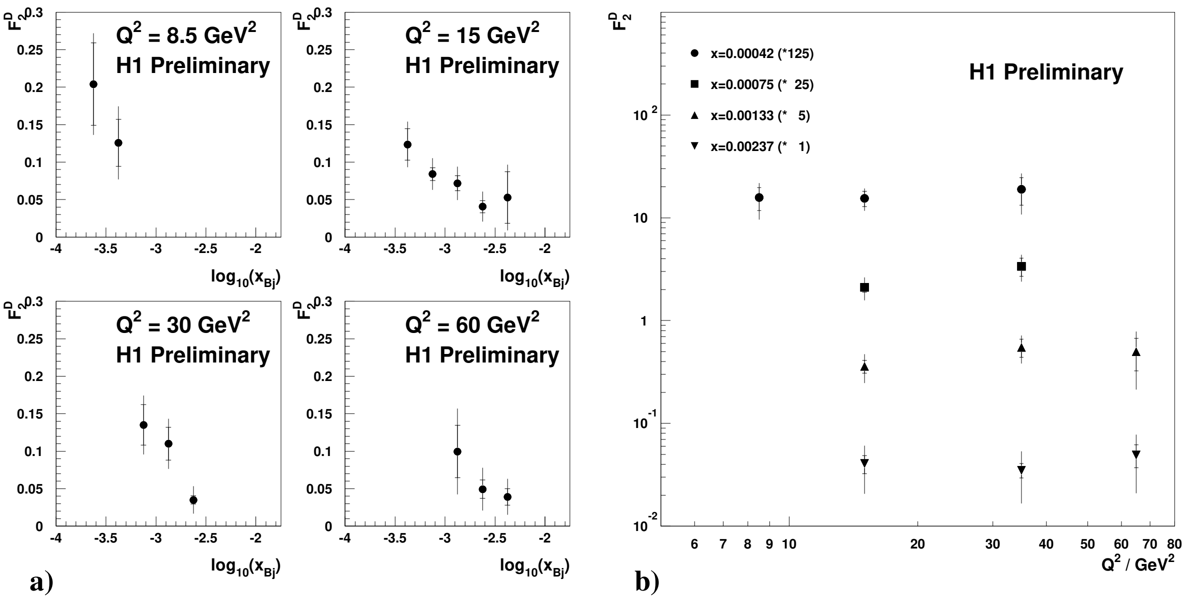

Figure 2: The diffractive struture function, $F_2^D(x_{Bj}, Q^2)\Big|_{x_{I\!P} \leq 10^{-2}}$ as a function of x_{Bj} (a) and Q^2 (b).

with recent measurements at HERA of that of the proton [6] demonstrates that the contribution from diffraction in the region $x_{I\!P} < 10^{-2}$ cannot, by itself, explain the steep rise observed in F_2^P at low x_{Bj}, and that there is no evidence that the Q^2 evolution of this diffractive component is any different from that of F_2^P as a whole.

3 A Novel Selection for Diffractive Events

As the $\eta_{max} < 1.8$ identifies only a component of the total contribution from diffraction, strong biases in quantities such as, M_X, the invariant mass of the hadronic final state, are inevitable. Figure 3a shows the efficiency of the η_{max} selection as a function of M_X for diffractive Monte Carlo events. This bias in M_X prevents strong conclusions being drawn from the fact that the η_{max} events exhibit a lower M_X distribution from DIS as a whole, and hinders the search for jet activity in the diffractive sample.

An alternative selection procedure has been developed, using detectors in the forward region [3] of H1 to look for large rapidity gaps closer to the proton beam direction [10]. Forward going hadronic energy in the pseudo-rapidity range $5.0 < \eta < 8$ may produce charged particles by secondary interactions in the collimators, beam pipe and adjacent material which are then detected in these forward detectors. The signals in these detectors for events in the $\eta_{max} < 1.8$ sample are consistent with diffractive processes in which the rapidity gap extends to $\eta = 6.6$ for a large fraction of the sample, and are suggestive of diffractive dissociation of the proton in $\approx 30\%$ of LRG events. A selection based upon the demand that there is no more activity in these forward detectors than is consistent with noise has a much improved acceptance in M_X, extending significantly the available phase space in which diffraction can be studied (figure 3a), and the M_X distribution obtained from

[3]The Forward Muon Detector, Plug Calorimeter and Proton Tagger are used in conjunction. The H1 detector is described in detail elsewhere [13].

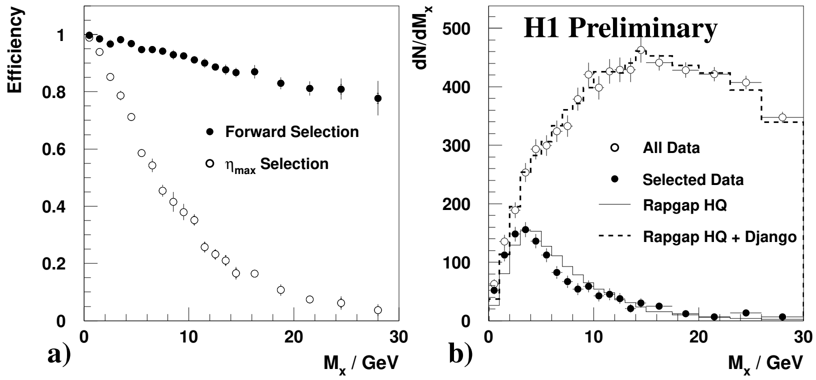

Figure 3: (a) The efficiencies for indentifying diffractive events of the Forward and η_{max} selections (see text). (b) The M_X distribution of events selected with the forward selection, corrected for backgrounds but not for acceptance, compared with the expectation from RAPGAP with a hard quark dominated pomeron (HQ).

this selection clearly demonstrates that these LRG events have a significantly lower invariant mass spectrum than that of the total DIS sample, lending support to the hypothesis of diffraction (figure 3b). In addition, this new selection enables a jet analysis to be performed, in which a total of 18 2-jet events are found, with values of E_T^{jet} between 3.5 and $12\,GeV$. In a first look, both the rate and charactersitics of these jets are well described by the RAPGAP model, assuming a hard parton density for a gluon dominated pomeron.

4 Summary

The large rapidity gap events at H1 are consistent with the presence of a diffractive component in deep inelastic scattering.

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