Diffraction in Charged Current DIS

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Abstract: Following the observation of one large rapidity gap CC DIS event by ZEUS in 1994 dedicated studies were made on theoretical and experimental aspects of diffractive CC scattering. The theoretical estimate of the cross section is $\sigma^{(diff)}_{ep\to\nu X}(x_{I\!P} < 0.1) = 2.1\ ^{+1.0}_{-0.7}$ pb. Monte Carlo study shows that the signature of these events is sufficiently unique to enable good background rejection at about 35% signal efficiency. With 1 fb^{-1} of integrated HERA luminosity measurement of the diffractive CC interaction should give a significant contribution to our understanding of diffractive phenomena.

1 Introduction

Within the ZEUS sample of charged current DIS events, selected from the 1994 e^+p data, one event was found satisfying a large rapidity gap (LRG) selection as used in the NC DIS analysis [1]. This corresponds to the cross section [2]:

$$\sigma^{(LRG)}_{e^+p\to\bar{\nu}X}(Q^2 > 200GeV^2) \ = \ 0.8\ ^{+1.8}_{-0.7}(stat.) \pm 0.1(syst.)\ \text{pb}. \tag{1}$$

This event is interpreted as a diffractive charged current DIS event, where the W^+ exchange occurs between positron and pomeron. Following this observation dedicated studies were made on both theoretical and experimental aspects of diffractive CC scattering. Perspectives of precise diffractive CC DIS measurement after the planned HERA upgrade were also investigated.

2 Cross section estimate

The cross section for diffractive CC DIS can be expressed, similarly as in the case of NC DIS, in terms of the diffractive structure functions $F^{CC}_{2\,D}$ and $F^{CC}_{3\,D}$,

$$\frac{d^3\sigma^{CC}_{diff}}{d\beta dQ^2 dx_{I\!P}} = \frac{G_F^2}{4\pi}\,\frac{M_W^4}{(Q^2+M_W^2)^2}\,\frac{1}{\beta}\cdot \tag{2}$$
$$\left[(1+(1-y)^2)\,F^{CC}_{2\,D}\,(\beta,Q^2,x_{I\!P}) \ \pm \ (1-(1-y)^2)\,\beta\,F^{CC}_{3\,D}\,(\beta,Q^2,x_{I\!P})\right],$$

where $x_{I\!P}$ is the fraction of proton momentum carried by the pomeron, whereas β is the fraction of the pomeron momentum carried by the parton coupling to the W. The cross section is integrated over the undetected four-momentum transfer to the proton system.

In the studies presented here factorization of diffractive structure functions is assumed, i.e. they are decomposed into a pomeron flux factor independent of the hard scattering process and into parton distributions in the pomeron. The calculations were performed in QPM approximation, neglecting higher order QCD contributions as well as any scaling violation of diffractive structure functions.

Assuming that the pomeron contains an equal amount of up and down quarks and antiquarks the $F_{3\,D}^{CC}$ structure function vanishes and $F_{2\,D}^{CC}$ can be related to the diffractive structure function measured in NC DIS,

$$F_{2\,D}^{CC} = \frac{18}{5} F_2^D \quad . \tag{3}$$

In the following the parameterization of the ZEUS diffractive structure function measurement[1] was used,

$$F_2^{D(3)} = (1/x_{I\!P})^a \cdot b \cdot (\beta(1-\beta) + \frac{c}{2} \cdot (1-\beta)^2), \tag{4}$$

where the values of parameters fitted to data are

$$\begin{aligned} a &= 1.30 \pm 0.08\ (stat)^{+0.08}_{-0.14}\ (sys), \\ b &= 0.018 \pm 0.001\ (stat) \pm 0.005\ (sys), \\ c &= 0.57 \pm 0.12\ (stat) \pm 0.22\ (sys). \end{aligned}$$

Integration of the cross section formula 2 using relation 3 yields[1]

$$\sigma^{(diff)}_{ep\to\nu X}(x_{I\!P} < 0.1) = 2.1\ ^{+1.0}_{-0.7}\ pb. \tag{5}$$

The error on the cross section is dominated by the uncertainty in the slope parameter a, to which the cross section is very sensitive. This is shown in figure 1, together with the error band on the value of a measured by ZEUS. Precise measurement of the diffractive CC cross section can significantly constrain the description of the pomeron flux factor.

The integration of the cross section was limited to $x_{I\!P} < 0.1$, as for higher $x_{I\!P}$ diffraction is not well defined. In case of diffractive CC DIS this is a significant constraint, since, due to the W mass in the propagator term (eq. 2), the diffractive CC cross section decreases very slowly with $x_{I\!P}$, approximately like $(\frac{1}{x_{I\!P}})^{a-1}$. It also means that, in contrast to what we observe in NC diffractive scattering, the cross section is dominated by events with high M_x (invariant mass of the pomeron-W system).

3 Experimental signature

In 1995 a dedicated trigger was implemented at ZEUS to select diffractive CC events. The selection is based on two basic requirements: the event should have a rapidity gap in the

[1]The assumption of equal u and d contents of the pomeron also implies that the e^-p and e^+p CC diffractive cross sections are equal.

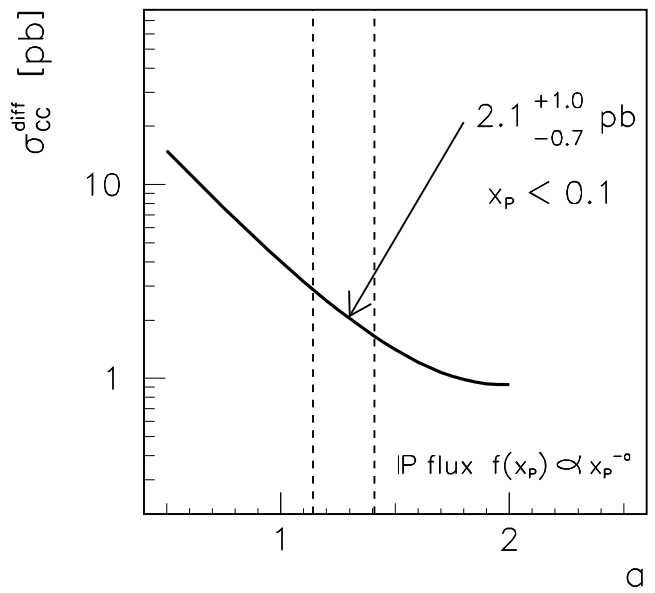

Figure 1: *Total cross section for diffractive CC scattering as a function of the pomeron slope parameter a. The arrow indicates the value of σ_{CC}^{diff} corresponding to a measured by ZEUS [1]. The vertical dashed lines indicate the quoted error on a.*

forward direction (to select diffractive events) and a significant missing transverse momentum (to select CC events).

Due to the high diffractive masses involved, the expected rapidity gap is much smaller than in diffractive NC DIS. Hence we require a minimal rapidity gap observable in the main detector, corresponding to no energy deposits in the calorimeter cells adjacent to the beam pipe hole. This cut can be slightly released, thus increasing the selection efficiency, if the contribution of nondiffractive events is additionally suppressed by use of scintillator counters placed behind the main calorimeter very close to the beam pipe. This so called Proton Remnant Tagger tags charged particles produced in the pseudorapidity interval $4.3 < \eta < 5.8$.

To select CC events it was required that there is missing transverse momentum of at least 4 GeV. Monte Carlo studies showed that both photoproduction and NC DIS background can be very efficiently suppressed by additional cuts based on the transverse momentum – p_T and the transverse energy[2] – E_T of the event, measured both in the calorimeter and in the tracking detectors:

$$\left.\frac{p_T^2}{E_T}\right|_{Calorimeter} > 3\ GeV^2$$

$$\left.\frac{p_T^2}{E_T}\right|_{Tracking} > 2\ GeV^2$$

With the additional requirement that the direction of the transverse momentum measured in the calorimeter and from the tracking detectors agree, the efficiency of the diffractive CC selection is of the order of 35% with a purity of the final sample of about 60%. Most of the background comes from non-diffractive CC DIS.

[2]The transverse energy E_T is defined as the scalar sum of the transverse momenta over all calorimeter energy deposits, or over all tracks coming from the primary vertex, respectively.

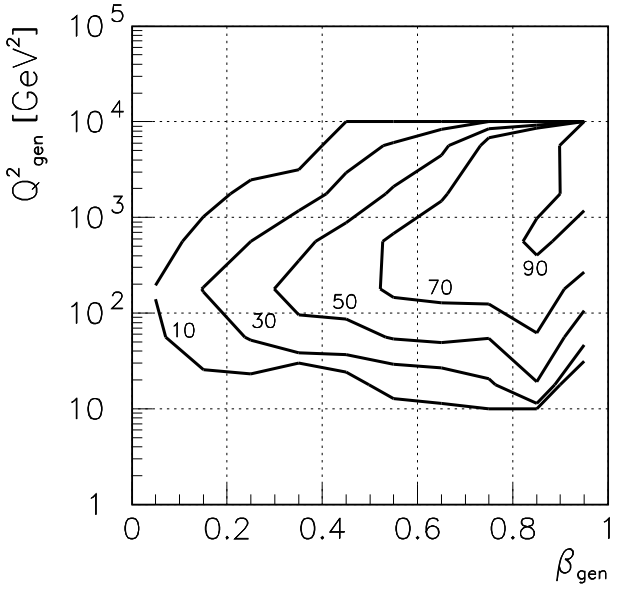

Figure 2: *Selection efficiency (indicated in percents) of diffractive CC DIS events as a function of the kinematic variables Q^2 and β.*

Figure 2 shows the efficiency of the proposed diffractive CC selection as a function of the kinematic variables Q^2 and β. The efficiency improves significantly towards high β. The proposed cuts select events in a relatively narrow Q^2 range of about $10^2 - 10^3$ GeV^2.

4 Perspectives

With the proposed upgrade schedule, HERA should be able to deliver about 1000 pb^{-1} of luminosity until the year 2005. This would open a wide range of possibilities in studying diffractive CC interactions. Figure 3 shows the expected number of events observed after selection cuts, as a function of the kinematic variables Q^2 and β. The total cross section could be measured with precision of the order of 5%, which corresponds to an error on the pomeron flux parameter a of the order of 2%. This measurement will be very sensitive to the pomeron flux description at high $x_{I\!P}$ as well as to the assumed factorization of the diffractive cross section itself.

With 1000 pb^{-1} of data also the measurement of the differential cross section becomes possible. The cross section in β can be measured with 20–30% statistical error, as shown in figure 4. Although the diffractive CC DIS events populate (after selection cuts) a relatively narrow Q^2 range, this measurement can be used to test the evolution of the diffractive structure function, when compared to low Q^2 NC DIS results.

High statistics of diffractive CC events should also allow a precise jet rates study. The fraction of two jet events should be sensitive to the gluon contents of the pomeron, as they are expected to result from the W-gluon fusion.

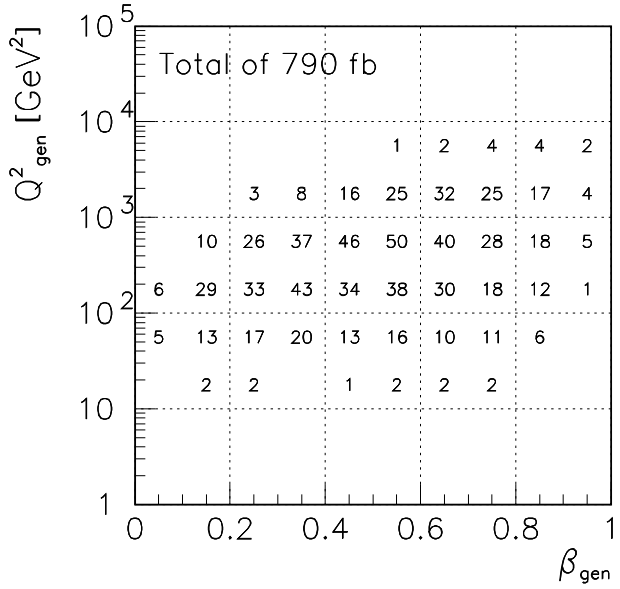

Figure 3: *Cross section in fb, after selection cuts, for diffractive CC DIS in bins of the kinematic variables Q^2 and β. The values correspond to the expected number of events for an integrated HERA luminosity of 1000pb^{-1}.*

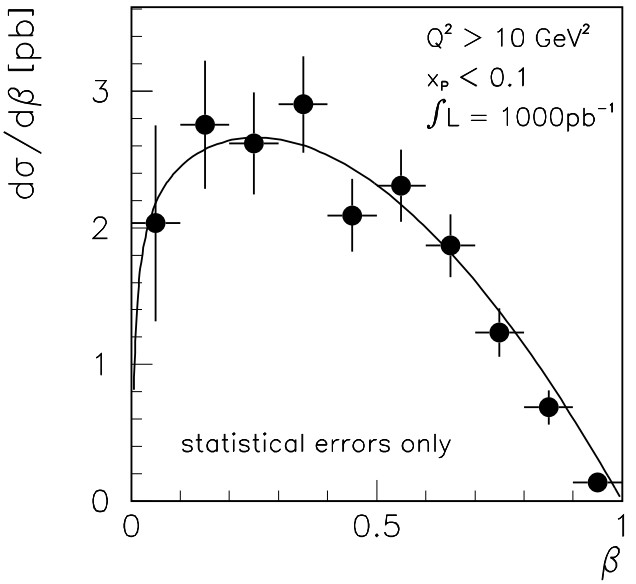

Figure 4: *Measured differential cross section for diffractive CC DIS as a function of β. Only statistical errors are shown, corresponding to an integrated HERA luminosity of 1000pb^{-1}.*

5 HERA upgrade

Results presented in the previous section were obtained with the assumption that the efficiency for the diffractive CC event selection after the HERA upgrade will remain the same as before. Using the Monte Carlo simulation it was checked that the proposed HERA and detector modifications should not have much influence on the measurement of CC events in the ZEUS detector. However, the proposed modification of the HERA magnet system is incompatible

with the present design of the Proton Remnant Tagger. It is not clear at the moment if the installation of new tagging device will be possible, nor if its efficiency in vetoing nondiffractive events will be compatible to the present design. If the proton remnant can not be tagged, stronger selection cuts will have to be applied in the central detector, resulting in the reduction of selection efficiency by a factor of about 2.

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References

[1] ZEUS Collaboration; M.Derrick *et al.*, *Z. Phys.* C **68**, 569 (1995).

[2] ZEUS Collaboration; M.Derrick *et al.*, DESY 96-104,
submitted to *Z. Phys.* C.

[3] J.Terron, see materials contributed to this workshop.