DIFFRACTIVE JET PRODUCTION AT HERA*

Richard Polifka

Institute of Particle and Nuclear Physics, Charles University
V Holesovickach 2, 180 00 Prague 8, Czech Republic

(Received May 12, 2008)

The measurement of diffractive structure functions is one of the leading topics of the diffractive programme at the H1 experiment at HERA. In this study, diffraction at HERA is shortly described with special emphasis of the production of diffractive dijets and forward jets in the final state. The aim is to measure the t-dependence of the diffractive dijet cross section and to analyse a possibility of distinguishing between DGLAP and BFKL evolution equations in the low-x regime by measuring forward jets.

PACS numbers: 12.38.–t, 12.38.Aw, 12.38.Qk, 12.40.Nn

1. Diffraction at HERA

1.1. Introduction

The first extensive investigation of diffractive processes took place after the HERA[1] accelerator was started in 1992. The concept of exchange of a colorless object with vacuum quantum numbers has been developed in order to explain the measured diffractive data. Diffractive events represent about 10% of the number of neutral current events. The most clear evidence of need of a new class of processes was in the distribution in the pseudorapidity of the most forward cluster in the central calorimeter. This distribution showed, that there are processes with the so called *Large Rapidity*[2] *Gap*. This gap in rapidity is characteristic for diffractive events and it

* Presented at the School on QCD, Low-x Physics, Saturation and Diffraction, Copanello, Calabria, Italy, July 1–14, 2007.

[1] Hadron Elektron Ring Anlage, DESY (Deutsches Elektronen Synchrotron), Hamburg, Germany.

[2] Rapidity, for massless particles pseudorapidity is defined as:

$$\eta = -\log\left(\tan\frac{\theta}{2}\right).$$

means that there are no proton remnants in the forward part of the detector. The proton, which remains intact or dissociates into a very low mass system, is very weakly deflected and it escapes through the beam pipe.

Many phenomenological models have been developed to describe diffraction. The basic concept is to exchange a particle with vacuum quantum numbers between the proton and the hadronic final system. This object is called pomeron and due to its properties the rapidity gap can emerge.

1.2. Kinematics

The HERA accelerator collides electrons or positrons at energy of 27.5 GeV and protons at an energy of 820 GeV for the HERA I running period, and 920 GeV for HERA-II, respectively. This collision provides a center-of-mass energy of 300 GeV for HERA-I and 319 GeV for HERA-II. Fig. 1 defines the kinematical variables used in the diffractive processes. The meaning of the LRG is also schematically displayed in the picture. $x_{\mathbb{P}}$, the variable that is used in diffractive processes is the momentum fraction of the proton carried by the exchanged object.

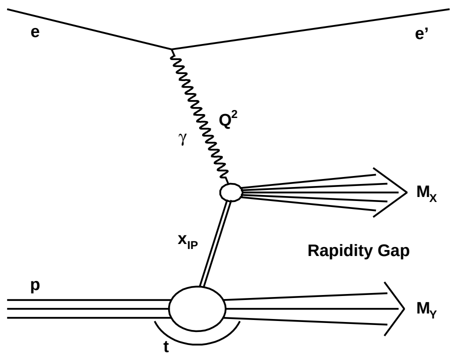

Fig. 1. Diffractive process.

In *Deep Inelastic Scattering* (DIS), the value of the four momentum squared of the virtual photon can go up to the value of $\sim 10^5$ GeV^2 for the HERA case. Therefore, a very good description of the scattered lepton is necessary.

2. The H1 detector

2.1. The central detector

The H1 detector (see [1, 2]) is one of the two 4π detectors that belongs to the DESY facility. Its size is 12m $\times$ 10m $\times$ 15m and it weights 2800 tons. It is located in an underground cavern north of the DESY site. The concept is very similar to all 4π detectors. Due to the different types and energies of the colliding particles, it is built asymmetric. The coordinate system is set that way that, looking from the centre of HERA, the protons are coming from the right and leptons from the left. The positive x axis is defined to point to the centre of the ring. The polar angle $\theta = 0$ is defined in the direction of the outgoing proton.

In the very centre of the detector there are silicon detectors to reconstruct the primary vertex. The next layer is made by multiwire proportional chambers and CJC — Central Jet Chamber required to reconstruct charged tracks. The calorimetry uses the technology of steel (hadronic part) and lead (electromagnetic part) as absorber and liquid Argon in the active region. Both parts (electromagnetic and hadronic) are more segmented in the forward region due to the largest energy flow in this region. Around the calorimetry there is a cryogenic system and a superconducting coil with a field of 1.15 T. The magnetic field allows to distinguish the charge of the particles coming from the interaction in the tracking chambers. The last layer consists of the muon chambers. The forward region is supplemented by forward muon detectors used also in diffraction as veto detectors. In the backward region there is the calorimeter designed for the identification of the scattered lepton located — the Spaghetti Calorimeter (SpaCal).

2.2. The forward spectrometer

For the purpose of diffractive physics, the detection of the outgoing protons is of extreme importance. For this purpose, the Forward Proton Spectrometer (FPS, see [3]) was built. The FPS consists of two stations: the horizontal one is located at 63 m and 80 m and the vertical one at 81 m and 90 m. Each station consists of two so called *Roman Pots*, the device that moves the detector. The active region of the detector moves up to the distance of 1 cm from the beam. Each part of the horizontal and vertical stations consists of two identical subdetectors. These two subdetectors belong to one Roman pot. Each subdetector consists of two planes inclined by ± 45 degrees with respect to the vertical pot axis. Each coordinate plane consists of five layers of 48 fibers in the horizontal stations and 20 fibers in the vertical stations, respectively. The fibers belonging to a read out plane are attached to multichannel photomultipliers. The horizontal station is able to detect protons with an energy from 800 GeV up to 920 GeV (for HERA-II) which corresponds to the maximum value of $x_{\mathbb{P}} = 0.1$.

3. Jet analysis

3.1. Dijet production

The process shown in Fig. 1 describes the interaction of the pomeron with the photon very schematically. Several processes can be involved in the $\gamma^*\mathbb{P}$ interaction. In QCD, at leading order, the photon interacts with a quark struck from the pomeron. Such a process can be used to determine the diffractive quark distribution function. On the other hand, it is not easy to determine the diffractive gluon distribution function. The dijet measurement is suitable for the extraction of the diffractive distribution function. The exchanged object emits a gluon which splits into a $q\bar{q}$ pair and the photon lately interacts with one of them. This model is called *Boson Gluon Fusion*. Such a measurement has already been provided and the diffractive gluon distribution function has been estimated [4]. The diffractive events have been selected with the LRG method. The analysis with FPS has an advantage of fixing the proton in the final state and therefore excludes all other processes like low mass proton excitations that are not detectable by the FMD detectors or standard DIS events that fake a LRG event. Last but not least, using the reconstructed outgoing proton, the t-dependence of the dijet cross section can be measured for the first time.

3.2. Forward jet production

Detecting the proton in the final state has also an other interesting advantage. When the diffractive selection is done via the reconstruction of the scattered proton and not via LRG, it is possible to investigate the diffractive final states using the activity in the forward region. The aim of measuring of the forward jets is the attempt to distinguish between DGLAP [5] and BFKL [6] evolution equations.

The DGLAP evolution equations assume a ladder of partons that is stretched between the hard process and the proton. According to DGLAP, such partons emerging from the ladder are strongly ordered in $p_{\rm t}$ in an increasing sense and weakly ordered in proton energy fractions (decreasing)[3].

$$p_{\rm t1}^2 \ll p_{\rm t2}^2 \ll \ldots \ll p_{{\rm t}n}^2 < Q^2, \qquad x_1 > x_2 > \ldots > x_n\,. \tag{1}$$

On the other hand, the BFKL approach is based on the assumption of no ordering in $p_{\rm t}$ and on the strong decreasing ordering in the momentum fraction.

$$x_1 \gg x_2 \gg \ldots \gg x_n\,. \tag{2}$$

[3] Index 1 denotes the parton emitted as first from the ladder, the index n stands for the parton entering the hard process.

The idea of distinguishing between DGLAP and BFKL is based on searching for forward jets. The selection criteria are applied on pseudorapidity of such a jet and on $p_{\rm t}^2$ ($p_{\rm t}^2 \sim Q^2$).

In the DGLAP approach, there should not be any jets going collinear with the proton with $p_{\rm t}^2 \sim Q^2$. Since BFKL does not make assumptions about $p_{\rm t}$ ordering, this region of the phase space should be suitable for the BFKL-search.

4. Summary

The aim of this paper is to discuss the measurement of diffractive dijets and forward jet events using the data taken with the FPS detector in the years 2005–2007 and an integrated luminosity of 180 pb^{-1}. At present, an extensive investigation and optimization of the selection criteria is underway.

REFERENCES

[1] I. Abt *et al.*, *Nucl. Instrum. Methods* **A386**, 310 (1997).

[2] I. Abt *et al.*, *Nucl. Instrum. Methods* **A386**, 348 (1997).

[3] P. van Esch *et al.*, *Nucl. Instrum. Methods* **A446**, 409 (2000).

[4] F.D. Aaron [H1 Collaboration], *et al.*, accepted for publication in *Eur. Phys. J.* **C** (2007).

[5] G. Altarelli, G. Parisi, *Nucl. Phys.* **B126**, 298 (1977).

[6] E.A. Kuraev, L.N. Lipatov, V.S. Fadin, *Sov. Phys. JETP* **45**, 199204 (1977).