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HIGHLIGHTS ON DEEP INELASTIC SCATTERING
AT HERA

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Highlights on deep inelastic scattering at HERA *

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1. Introduction

The new collider HERA, located at DESY, Hamburg, between electrons (positrons) and protons of respectively 27.5 and 820 GeV has provided new interesting results in quantum chromodynamics at low x , where x is the momentum fraction of the interacting parton in the Feynman parton model. We will describe the new results concerning the measurement of the proton structure functions obtained by the H1 and ZEUS collaborations at very low Q^2 , the transferred energy squared between the electron and the interacting quark. We will then discuss some new interesting events where there is no deposition of energy in the proton direction. We finally present the new very high Q^2 events observed by both collaborations. This short review represents only a small part of the results obtained by both collaborations.

2. Measurement of the proton structure function

The measurement of the proton structure function has always been of great importance for the understanding of the quark and gluon structure of the proton. In the continuity of the previous fixed target experiments, HERA allows the measurement of the proton structure function in a very wide kinematical domain (a gain of almost two orders of magnitude is reached compared with the previous fixed target experiments): $3 \cdot 10^{-5} < x < 0.3$, and $0.15 < Q^2 < 5000 \text{ GeV}^2$.

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In figures 1a and 1b are shown the new results obtained at low Q^2 by both collaborations [2], as well as the results obtained by the fixed target experiment NMC. It is seen that the rise of F_2 observed at low x for higher values of Q^2 [2] is still valid in this new domain even if it is attenuated. The measurements are compared with parametrizations motivated by Regge theory relating the structure function to Reggeon exchange amplitudes. These Regge parametrizations successfully describe the slow rise of the total cross section with energy in hadron-hadron and γp interactions. We can see that these models can give a correct description of the data only at very low Q^2 . On the other hand, some QCD inspired models like GRV (based on the Dokshitzer Gribov Lipatov Altarelli Parisi evolution equation starting at very low scale) can describe the data at higher Q^2 but fail completely when Q^2 decreases. This new low Q^2 domain is thus the intermediate region between photoproduction where Regge theories apply and the standard deep inelastic scattering region where perturbative QCD can be used.

Another important result on the proton structure functions obtained by the H1 and ZEUS experiments is the analysis of the charm content of the proton. For $8.10^{-4} < x < 8.10^{-3}$, it could be shown that the charm fraction of the proton structure function $F_2^{c\bar{c}}/F_2$ is equal to $0.237 \pm 0.021^{+0.043}_{-0.039}$, and that $F_2^{c\bar{c}}$ increases steeply with decreasing x .

3. Diffraction at HERA

The data taken in 1992 by the H1 and ZEUS experiments showed some new interesting events with an interval of rapidity around the incident proton direction devoid of any hadronic activity. This means that a colourless exchange ("pomeron") must have occurred since there is no colour connection between the remnant proton and the struck quark.

For the first time at HERA, the statistics obtained in 1994 allowed a measurement of the proton diffractive structure function defined in analogy to the standard proton structure function in a wide kinematical domain. In order to describe the exchange of a colourless object, we need two more kinematical variables to determine the kinematics of the event: Q^2 as before, t the Mandelstam variable, β , the momentum fraction of the colourless exchanged object, and $x_p = x/\beta$. x_p is the momentum fraction of the parton inside this object if we assume it has a partonic structure. The obtained results from the H1 experiment are shown in figure 2 [4]. In a Regge interpretation, the x_p dependence can be factorised out from the β and Q^2 dependence. The x_p -term is assumed to describe a reggeon flux associated with the proton (expected to be of the form $F_2^{D(3)} \sim 1/x_p^n$), and the β and Q^2 dependence the structure function of the colourless exchanged object. Experimentally this factorisation breaks out, and there is a clear dependence of n as a function of β , but not as a function of Q^2 . A natural interpretation of this result is that we need two separate factorisable components which contribute to the cross section. In this case, there

Fig. 1. — Measurement of the proton structure function F_2 from the H1 and ZEUS collaborations at very low Q^2 compared with the fixed target experiments data from NMC, E665, the data are compared with some Regge inspired models (DL, Donnachie Landshoff), or based on perturbative QCD (GRV Glück, Reya, Vogt)

is a contribution to the measured cross section from sub-leading trajectories which may be identified with the exchange of quantum numbers corresponding to physical meson states. The leading trajectory would be the pomeron, and the next-leading exchanges the trajectories with the quantum numbers of the ρ , ω , a_2 , and f_2 mesons. An experimental fit assuming these contributions has been successfully performed by the H1 collaboration. Another possibility also leading to two components would be to use an unified description of total and diffractive structure functions in the framework of the dipole model of the hard BFKL pomeron [1].

4. High Q^2 events

As we noticed before, it is possible to reach very high values of Q^2 at HERA up to 35000 GeV^2 . It is then possible to count the number of events above a given Q^2 threshold and to compare it with the predictions of the standard model. The H1 experiment [3] observes 12 neutral current candidate events for $Q^2 > 15000 \text{ GeV}^2$ where the expectation from the standard model is $N_{DIS} = 1.77 \pm 0.76$ events. The probability $P(N \geq N_{obs})$ that the DIS model signal fluctuates to $N \geq N_{obs}$ in a random set of experiments is $6 \cdot 10^{-3}$. The ZEUS collaboration [3] has also reported for an excess: for $Q^2 > 35000 \text{ GeV}^2$ (resp. $x > 0.55$ and $y > 0.25$), they observe 2 (resp. 4) events whereas the standard model expectations are 0.145 ± 0.013 (resp. 0.91 ± 0.08), which corresponds to a probability $P(N \geq N_{obs})$ of $6 \cdot 10^{-2}$ (resp. $7 \cdot 10^{-3}$). This excess of events is very interesting and more statistics is needed to say if this is a discovery of a phenomenon beyond the standard model.

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Fig. 2. — Measurement of the diffractive structure function, the result of the phenomenological fit in which two separately factorisable components contribute to the cross section is also shown