Turkish Journal of Physics

Volume 22 | Number 7 Article 1

1-1-1998

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Tr. J. of Physics
22 (1998) , 525 – 528.

International Workshop on Linac-Ring
Type ep and γp Colliders

Observation of Events at Very High Q^2 in e^+p Collisions at HERA

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Abstract

Data collected at the e^+p collider HERA at DESY by the experiments H1 and ZEUS have allowed to probe a previously inaccessible domain of very large Q^2 in deep-inelastic ep scattering. For $Q^2 > 15000GeV^2$ both experiments see more events than expected assuming the Standard Model of deep-inelastic scattering. In this report the observed events, the theoretical expectations and their comparison are discussed.

1. Introduction

Deep-inelastic scattering (DIS) of leptons on nucleons has been an important tool for understanding nucleon structure. At the HERA collider, neutral current and charged current DIS processes are studied at a center-of-mass energy of $\sqrt{s} = 300$ GeV and at Q^2 (the negative of the square of the four-momentum transfer) exceeding M_Z^2, a kinematic region previously unexplored and probing the structure of the proton at a level of 10^{-18} m. It is also possible to search for s-channel resonances of the electron-quark system. Recently results on neutral current reactions from e^+-proton running, taken by the experiments H1 and ZEUS during the years 1994 to 1996, have been published [1],[2]. The positron beam energy was 27.5 GeV and the proton beam energy 820 GeV. The total luminosity integrated by the each of the two experiments amounts for H1 (ZEUS) to 14.19 (20.1) pb^{-1}. This report provides a brief summary of the results from both experiments. The interested reader is referred to the original publications [1],[2] for more details.

2. Event Selection and Background

The reconstruction of DIS events relies either on the measurement of the energy and angle of the scattered electron (electron-method) or the reconstruction of the angles of the scattered electron and quark (double angle method). Both techniques differ among other things in their sensitivity to initial state radiation and to the energy calibration of the calorimeter. H1 bases its analysis mainly on the electron method while ZEUS uses the double angle method.

The selection of DIS events at very high Q^2 proceeds in both experiments through very few cuts only. Genuine *ep* collisions are selected through a cut on the position of the interaction vertex. Neutral current (NC) events are required to have an isolated positron with large transverse momentum and a limited energy loss in beam direction (mainly to reject backgrounds such as photoproduction). Finally the momentum transfer Q^2 must exceed a minimum value. The resulting efficiency to select NC events is around 80% in both experiments. In H1 (ZEUS) 471 (191) events remain after applying a Q^2 cut of 2500 (5000) GeV^2, the remaining background is far less than 1 event. The selected events are strikingly clean and can neither be missed nor mis-interpreted.

3. Results

Comparing the distributions of the reconstructed events in the kinematic variables x, y, Q^2 with the Standard Model expectations one observes in general a good agreement, especially at low Q^2. However, at high Q^2, typically above 10000 GeV^2, an excess of events above expectation is observed in both experiments, as shown in Table 1. The Standard Model makes precise predictions for the cross section also for large values of Q^2. Both collaborations have estimeted the error on the Standard Model prediction due to uncertainties in the knowledge of the structure functions to be about 6.5%, and the total error on the prediction to be around 10%.

Q^2 cut (GeV^2)	H1 data	H1 NC exp	ZEUS data	ZEUS NC exp	H1+Z data	H1+Z NC exp	$P(N \geq N_{obs})$
$Q^2 > 10000$	20	18.3± 2.4	33	32.2± 2.0	53	50.5± 3.1	0.37
$Q^2 > 15000$	12	4.71± 0.76	12	8.66± 0.66	24	13.4± 1.0	0.0074
$Q^2 > 20000$	5	1.32± 0.27	5	2.76± 0.24	10	4.08± 0.36	0.010
$Q^2 > 25000$	3	0.51± 0.16	3	1.01± 0.09	6	1.52± 0.18	0.0053
$Q^2 > 30000$	2	0.23± 0.05	2	0.37± 0.04	4	0.60± 0.06	0.0035
$Q^2 > 35000$	0	0.08± 0.04	2	0.15± 0.01	2	0.23± 0.04	0.023

Table 1. Number of observed and expected events from H1 and ZEUS. For the combination, the number of observed and expected events are added and the errors are added in quadrature. The difference for the DIS expectation between H1 and ZEUS reflects the difference in integrated luminosities, the kinematic reconstruction methods, the resolution in Q^2 and the detection efficiency within the kinematic cuts. The last column gives the probability that the expected NC DIS signal fluctuates to values equal to or larger than the number of observed events, where the error on the mean expected number of events is taken into account by gaussian smearing.

The distribution of the data in x has been studied by both experiments to see if the observed deviation is clustered around some particular value of x or an equivalent mass $M = \sqrt{xs}$. This analysis has shown a certain clustering of events in H1 in a mass range around 200 GeV (or x around 0.45), whereas the excess in ZEUS occurs at larger values of x: For x>0.36 and y>0.4 H1 observes 7 events where 1.8±0.3 are expected, while

ZEUS for x>0.55 and y>0.25 finds 4 events while expecting 0.9±0.1. H1 and ZEUS have also performed a probability analysis to determine the likelihood for the largest deviation from the Standard Model by doing a large number of Monte Carlo experiments, finding in H1 (ZEUS) a probability of about 1% (6%) to obtain the observed deviation somewhere in x or M. As the largest deviation occurs in both experiments in different kinematical regions a combination of the data does not lead to a higher significance.

4. Conclusion

Deep inelastic $e + p$ scattering has been studied by the experiments H1 and ZEUS at HERA in a previously unexplored region of x and Q^2. The events found there are very clean, well reconstructed and nearly background free. The Standard Model of DIS makes precise predictions for the expected event rates, the number of observed events exceeds the prediction in both experiments. The observation discussed in this report has stimulated a large number of papers on the interpretation of the effect [3] in terms of signals of new physics like leptoquarks or supersymmetric particles. But it is clear that at present a statistical fluctuation can not be excluded. Therefore HERA has embarked on a concentrated effort to increase the integrated luminosity in the hope to shed more light on this question within the next few years.

Acknowledgement

I would like to thank the organizers of the "First International Workshop on Linac-Ring Type Electron-Proton and Gamma-Proton Collideres", held on 9-11 April 1997 in Ankara, Turkey, for their hospitality and for very interesting discussions.

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