Dedicated to A.B. Kaidalov’s memory

A-DEPENDENCE OF DIFFRACTION DISSOCIATION PHENOMENON IN NEUTRINO INTERACTIONS WITH NUCLEI

O.K. Egorov
Institute for Theoretical and Experimental Physics, Moscow, Russia
E-mail: egorov@itep.ru

Abstract. We present results on A-dependence of diffraction dissociation (DD) phenomenon in interactions of muonic neutrino with nuclei at various values of momentum transfer. Calculations were done within the two-gluon exchange model by Nikolaev-Zakharov-Zoller (NZZ). Comparison with experimental data obtained in interactions of muonic neutrino with photoemulsion nuclei is carried out. All data are presented as ratio of the DD cross section to the deep inelastic cross section.

Introduction

When working on analysis of electroproduction data (the experiment E-665/FNAL/) on muon interactions with xenon nuclei the theoretical group leading by N.N. Nikolaev noticed [5] that the contribution of diffractive dissociation (DD) processes on heavy nuclei can reach at definite values of kinematical variables one half of the total deep inelastic cross section. However the authors of the experiment E-665 give different values for this ratio. Namely: \( R = \sigma_{DD}/\sigma_{DIS} = 0.12 \pm 0.02 \) for \( \mu D \) and \( 0.18 \pm 0.03 \) for \( \mu Xe \) interactions [5, 8]. It is essentially less compared to the estimate of this ratio according to the NZZ model.

The experimental investigation of the diffraction dissociation phenomenon in the photo and electro production became possible only after start-up of the electron-proton accelerator HERA. In particular, investigation of this phenomenon by collaborations H1 and ZEUS is presented in papers [6, 7]. The ratio \( R \) given in these papers is \( \sigma_{DD}/\sigma_{DIS} \approx 0.1 \) being consistent with the NZZ estimate within experimental errors.

Diffractive dissociation calculation procedure

According to [1] the deep inelastic scattering (DIS) of muon neutrino on proton is described by diagram of Fig.1. The similar diagram describes the neutrino-nucleus scattering.

The diffraction dissociation process can be described with this diagram in the DD kinematics (Fig.2) when the events are characterized by large (pseudo)rapidity gap (LRG) \( \Delta \eta \) between the
Deep inelastic scattering diagram

Figure 1. Deep inelastic scattering diagram

Deep inelastic scattering diagram in the DD kinematics (dashed lines mean the diffractive exchange)

Figure 2. Deep inelastic scattering diagram in the DD kinematics (dashed lines mean the diffractive exchange)

recoil proton (nucleus) and hadrons produced due to the neutrino diffraction dissociation:

\[ \Delta \eta = \log(W^2/Q^2) = \log(1/x) - \log(M^2/Q^2) \]  

(1)

where \( W^2 \) is the squared total DIS energy, \( Q^2 \) is the squared momentum transfer to the hadron system, and \( M^2 \) is the diffractively produced hadron mass squared.

The DD calculation procedure is presented in detail in refs.[2]-[5]. The gap \( \Delta \eta \) is about to for \( W^2/Q^2 \sim 100 \) and \( M^2/Q^2 \sim 0.1 \), corresponding to the Bjorken variable \( x \) about \( \sim 0.1 \). The DD process at \( x \leq 0.1 \) is rather good described by two-gluon exchange (see [2]-[5]) as can be seen from Fig3. The quark exchange contributions (multiplied by 10 at the figure) can be neglected in first approximation.

Results and discussion

Our calculations of the A-dependence for neutrino-nucleus interactions using the NZZ model are presented at Fig.4. The ratio \( R = \sigma_{DD}/\sigma_{DIS} \) is estimated for protons, nitrogen nuclei (gelatin, a part of photoemulsion), bromine and silver nuclei. Calculation accuracy is about \( \sim 5\% \). Gluon mass is taken as 150 Mev/c\(^2\). The standard spherical form of nucleus with diffused edge is assumed (\( R = 1.1 \text{ fm} \cdot A^{1/3} \) and the Fermi momentum 250 MeV/c). We used the following experimental data for \( \nu A \) interactions. The experiment E-564 /FNAL/ gives \( \sigma_{DD}/\sigma_{DIS} = 0.29 \pm 0.09 \) [9] for AgBr crystals. Though the average \( Q^2 \) value is several times higher than 1, one can believe that calculation is consistent with the E-564 data. However more than half of this ratio is due to the incoherent DD.
Statistics in the experiment E-128 /Protvino/ is two times larger than in E-564 (670 events) but it gives only the upper bound for the ratio $\sigma_{DD}/\sigma_{DIS} \leq 0.53 \pm 0.07$ [10]. Notice that in this experiment instead of the Bjorken scaling variable $x = Q^2/2M\nu$ a new variable $x'$ is used.
which, in contrast to $x$, takes into account nonzero proton mass:

$$x' = x/(1 + m_N^2 x^2 / Q^2).$$  

(2)

Here $m_N$ is a nucleon mass and $\nu = \nu$ is energy transferred to hadrons. Comparison of $x$ and $x'$ distributions was carried out at the SCAT bubble chamber [10]. An analysis of those distributions shows that substitution $x$ to $x'$ results in about 20% increase of event number in the $0 - 0.1$ region, i.e. a number of candidates to the DD effect at freon bromide increased at 20%. This estimate is done without taking into account for lack of events at very low $x'$. So our estimate of relative contribution of the DD cross section to the deep inelastic cross section at freon bromide increases from 0.17 to 0.21 when substituting $x$ to $x'$. Account for low effectiveness of detection in small $x$ region gives the ratio 0.31. Just the similar correction resulted in so high upper bound in the experiment E-128.

**Conclusions**

In summary it is worth noting that physics at small $x$ is not so serene as it seems to the authors of [1]. In particular, it is noted in ref.[9] that the large part of the DD events are related to the noncoherent DD, i.e. those are not “white stars”. The author hopes that the OPERA experiment which has already a statistics of many thousand neutrino interactions will be able to elucidate the situation [11].

The author is grateful to his colleagues involved to the E-564 and E-128 experiments and looks forward to efforts of his OPERA colleagues in obtaining new DD estimates.

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