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DEPENDENCE OF SLOPE ON MASS OF THE DIFFRACTIVELY PRODUCED $K^+\pi^+\pi^-$ SYSTEM IN THE REACTION $K^+p \rightarrow K^+\pi^+\pi^-p$ AT 4.97 GeV/c

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The method of data analysis proposed by Miettinen and Pirilä which eliminates kinematic reflections in the variation of the slope in momentum transfer distribution, as a function of diffractively produced effective mass, is applied to the reaction $K^+p \rightarrow K^+\pi^+\pi^-p$ at 4.97 GeV/c. It seems that for this reaction and at this energy, the strong rise of the slope parameter observed for low mass $K^+\pi^+\pi^-$ systems is mostly produced by kinematic effects. There is no proof that a slope-mass correlation must be explicitly present in the invariant matrix element. This does not confirm the results obtained by Miettinen and Pirilä for the reaction $pp \rightarrow n\pi^+p$ at 19 GeV/c.

In the single diffractive dissociation of the type

$$A+B \rightarrow A^*+B, \quad A^* \rightarrow X+\pi \tag{1}$$

where X is either identical with A, or decays into A and π, the broad enhancements in the effective mass of X, π system distribution were experimentally observed [1] near the threshold, i.e. when $M_{A^*} = m_X + m_\pi$. Quite reasonable theoretical descriptions of these peaks were given by models proposed by Drell, Hiida [2] and Deck [3] in which the reaction (1) goes as in Fig. 1.

The common feature of the reactions of type (1) is that peripherality in t_1 is strongest near the threshold and decreases rapidly with increasing $\sqrt{s_2}$ (mass of A^* system). The data are consistent with formula

$$\frac{d^2\sigma}{dt_1 ds_2} = f(s_2) \exp\left(b(s_2)t_1\right), \tag{2}$$

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where $b = 10-20\ \text{GeV}^{-2}$ near threshold and falls to 3—6 GeV^{-2} when $\sqrt{s_2}$ is more than 500 MeV above the threshold. There were some attempts to explain this phenomenon on the basis of the Deck model [4, 5], or double peripheral models [6, 7] as the kinematic reflection of the peripherality in t_2 due to the linear dependence between t_1 and t_2 near the threshold. Such calculations gave the variation $b(s_2)$ far weaker than that experimentally observed.

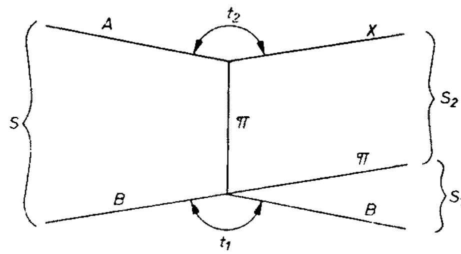

Fig. 1. One pion exchange diagram for diffractive production; s is the square of the total energy in the CMS, s_1, s_2 are squares of the final subenergies, t_1, t_2 — four-momentum transfers

Miettinen and Pirilä in their paper [8] try to prove that the strong correlation between b and s_2 must be present in the invariant matrix element and cannot be of kinematical origin. They have investigated the correlations between t_1 and t_2 by a Monte Carlo method in a double peripheral model using the matrix element

$$|M|^2 = s_1^2 e^{5t_1} e^{at_2} \tag{3}$$

and varying the peripherality in t_2 (parameter a). Even the strongest peripherality in t_2 produced a too weak dependence of b on s_2.

Miettinen and Parilä have proposed a method of data analysis, which eliminates kinematical reflections of t_2 and s_1 distributions in the $\frac{d^2\sigma}{dt_1 ds_2}$ distribution integrated over these variables. It is impossible to analyse the data in four dimensions $\frac{d^4\sigma}{dt_1 dt_2 ds_1 ds_2}$ because of limited statistics in the experiments. Instead, they have used the azimuthal

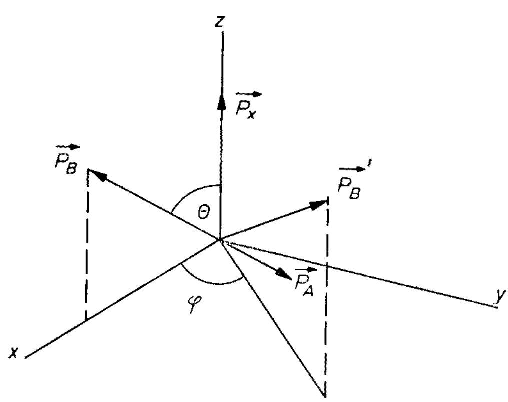

Fig. 2. The definition of the angles φ, θ in the CMS ($\vec{p}_A+\vec{p}_B = 0$).

angle φ defined in the CMS for the reaction (1) as the angle between projections of the momenta of the incoming and outgoing particle B in the plane, which is normal to the momentum of particle X (see (Fig. 2). When values of momenta and the angle θ are fixed and φ is varied, t_2 s_1, s_2 do not vary, whereas t_1 is related to φ by

$$t_1 = A(s_1, s_2, t_2)+B(s_1, s_2, t_2) \cos \varphi. \tag{4}$$

The functions A and B can be found in the literature [9]. The angle φ varies from 0 to 2π, irrespectively of the values of s_1, s_2 and t_2. So the φ distribution does not include reflections of the s_1 and t_2 distributions following from phase space.

This distribution has the form

$$P(\varphi) = C^{-1} e^{bB \cos \varphi}, \tag{5}$$

where C is the normalization constant. The parameter b is fitted by the maximum likelihood method using four dimensional data to calculate B individually for each event.

Such an analysis performed for the matrix element (3) in Ref. [8] gave a constant slope $b = 5$ GeV^{-2} independently of the peripherality in t_2. The value of b was the same as that assumed in the matrix element. This means that in this model the analysis of the φ distribution really eliminates kinematic reflections and allows us to investigate the t_1 dependence which is present in the matrix element.

In this report the analysis proposed by Miettinen and Pirilä has been performed for diffractive dissociation of K^+ on a proton target at 4.97 GeV/c. The Brussels-CERN Collaboration data [10] have been used. The sample contained 6240 unambiguous events of the reaction

$$K^+ p \to K^+ \pi^+ \pi^- p. \tag{6}$$

Single diffractive dissociation of K^+ was investigated

$$\begin{aligned} K^+ p \to\; & Q^+ + p \\ & \hookrightarrow K^*_{890} + \pi^+. \end{aligned} \tag{7}$$

The distribution $\frac{d^2\sigma}{dt_1 ds_2}$ has been made by dividing the sample into five bins in $\sqrt{s_2}$ in the Q region, i.e. for $\sqrt{s_2}$ from 1 GeV to 1.5 GeV. The bin width was 0.1 GeV. For each bin the distribution of t_1'

$$t_1' = t_1 - t_{1\,\min} \tag{8}$$

has been calculated in the range $0-0.4$ GeV^2. The upper limit was chosen to obtain good statistics and to be below the break in the so-called "diffraction peak". For each distribution the slope parameter b was fitted by minimization of χ^2. In this way the slope dependence on s_2 integrated over s_1, t_2 has been obtained. The b value rapidly decreased from 10 GeV^{-2} at $\sqrt{s_2} = 1$ GeV to 5 GeV^{-2} at $\sqrt{s_2} = 1.5$ GeV.

Similar distributions have been calculated for selected samples: with the Δ^{++} cut., i.e. for events with effective mass of $p\pi^+$ greater than 1.3 GeV and also with the K^* cut, i.e.

with effective mass of $K^+\pi^-$ between 0.84 and 0.94 GeV. These selections increased the fraction of events corresponding to the diffractive dissociation of the kaon of the type (7). The dependence $b(s_2)$ was not different from that for the non selected sample (within error limits).

Next the Miettinen and Pirilä analysis was applied. In the same bins of $\sqrt{s_2}$ the parameter b was fitted from the φ distributions by the maximum likelihood method, calculating B and limits of variation φ corresponding to $t_1 = 0$ and $t_1 = 0.4$ GeV^2 individually for each event from four-dimensional data. In this way another slope vs s_2 dependence has been obtained. This slope variation was very weak. The slope parameter b can have even constant value between 5 and 7 GeV^{-2} contrary to the steep variation obtained from $\frac{d^2N}{dt_1ds_2}$ distribution.

The dependence $b(s_2)$ obtained by the Miettinen and Pirilä method (φ distribution) for selected samples was the same, i.e. also constant (within error limits). The results of both analysis, i.e. from φ and t_1 distributions, are shown in Fig. 3.

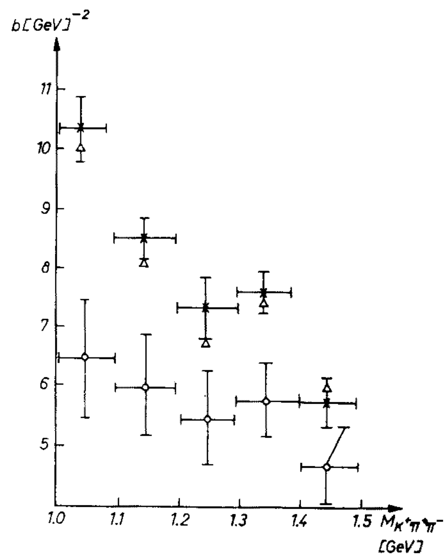

Fig. 3. The dependence of the slope parameter b on diffractively produced mass of the $K^+\pi^+\pi^-$ system in the reaction: $K^+p \to K^+\pi^+\pi^-p$ at 4.97 GeV/c: × — fit from the t_1' distributions $\left(\frac{d^2\sigma}{dt_1ds_2}\right)$ without cuts, Δ — fit from the t_1' distributions with Δ^{++} cut, ○ — fit from Miettinen and Pirilä's analysis (φ distributions)

The errors of b fitted from φ distribution are large (greater than errors from t_1 distribution) because the likelihood function

$$\ln P(b) = \sum_{i=1}^{N} -(bB_i \cos \varphi_i - \ln C_i), \tag{9}$$

where N is the number of events with t_1 smaller than 0.4 GeV^2, has a shape of a broad parabola (in the neighbourhood of the minimum). The errors of $B_i \cos \varphi_i$ estimated by a Monte Carlo method are about 10% and not so much greater than the errors in $t'_1 = t_1 - t_{1\,min}$. It follows that the value b is biased by statistical errors in both distributions φ and t'_1 in a similar way and the difference between two curves $b(s_2)$ is significant.

Conclusions

The variation of the slope parameter b with the mass $\sqrt{s_2}$ of a diffractively produced $(K\pi\pi)$ system in the reaction $K^+p \to K^+\pi^+\pi^-p$ at 5 GeV/c has been obtained in two ways. First from the integrated over t_2 and s_1 $\frac{d^2\sigma}{dt_1 ds_2}$ distribution, next by the Miettinen and Pirilä method (from φ distribution). The first analysis gave a strong dependence $b(s_2)$ contrary to the second one, in which the slope b did not depend on s_2 at all (within error limits). In spite of large errors the difference between the two curves $b(s_2)$ in both analyses is statistically significant (more than two and a half standard deviations).

Miettinen and Pirilä have obtained another result for the reaction $pp \to n\pi^+p$ at 19 GeV/c, i.e. a very good agreement of the two curves $b(s_2)$ from the t_1 and φ distributions. They say that the φ distribution does not include kinematic reflections of the t_2 and s_1 distributions, at least as long as double peripheral or isobar models are assumed, for which they proved it by Monte Carlo calculations. So they conclude that the strong dependence of b on s_2 near the threshold, which they obtained from their φ and t_1 distributions, is the real property of production dynamics and does not follow from kinematic couplings.

For the reaction $K^+p \to K^+\pi^+\pi^-p$ at 5 GeV/c the results obtained in this paper do not confirm Miettinen and Pirilä's conclusion because the analysis of the φ distribution gives no significant dependence of b on s_2 contrary to the analysis of the t_1 distribution. It seems that for this reaction and at this energy kinematic effects are essential for the relation between slope and diffractively produced mass. There is no evidence, at least on the basis of the Miettinen and Pirilä test, that this slope variation is a real property of the matrix element. Due to large errors and limited statistics the difference between the two curves $b(s_2)$ in Fig. 3 is not significant enough to claim as proved that the dependence of b on s_2 in $\frac{d^2\sigma}{dt_1 ds_2}$ is produced by the reflection of peripherality in t_2 only, as it is explained in Deck type models, it leaves, however, this possibility open.

The effect requires confirmation with better statistics and higher energy, but the explanation of the incompatibility obtained with the Miettinen and Pirilä results, only in terms of low energy and large contamination of the sample with nondiffractive events, does not seem to be satisfactory because of the small sensitivity of the effect for diffractive selections (Δ^{++} cut and K^* cut). Moreover, only the Q region in the effective mass of the $K^+\pi^+\pi^-$ system has been investigated and the momentum transfer was restricted to small values.

As a result one can say (at least on the basis of the Miettinen and Pirilä method) that kinematic effects play an important role in producing a strong rise of the slope b

near threshold (at small diffractively produced masses) in the reaction $K^+p \to K^+\pi^+\pi^-p$ at 5 GeV, and it seems that in this respect, this reaction is different from $pp \to n\pi^+p$ at 19 GeV which has been investigated by Miettinen and Pirilä.

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