SEARCH FOR TACHYON'S TRACE IN THE CHARGE EXCHANGE POLARIZATION EXPERIMENTS

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Abstract

We present the results of analyses of the charge-exchange reaction $\pi^- + p \to \pi^0 + n$ with main goal to search for the tachyonic traces. Our attention is concentrated around $-t = 1(GeV/c)^2$ region, where there are specific features in t dependences of the differential cross-section. Assuming that the tachyonic resonance might also contribute to this reaction we attempt to get the estimates for its mass and lifetime. Data were analyzed in the wide momentum range 5-200 GeV/c.

The striking t-behaviors of the differential cross-section, $\frac{d\sigma(t,s)}{dt}$, and polarization, P(t), for several reactions are not yet well understood. For example, in the charge exchange exclusive reaction

$$\pi^- + p \to \pi^0 + n \tag{1}$$

there is a secondary peak in the differential cross-section around $t = -1(GeV/c)^2$ which can not be explained by only ρ-pole contribution with linear trajectory; α(t)= a + bt. Moreover one ρ-pole approach to the description of the $\frac{d\sigma(t,s)}{dt}$ immediately leads to the zero polarization, while experiments show the significant polarization effects.

Therefore one needs to use the different models like the ρ-pole + cut, ρ-pole + odderon. It is proposed in this paper to take tachyon as a resonance and by adding its amplitudes to the ρ-pole ones calculate the differential cross-section and polarization. Taking into account the many experimental data accumulated with high precision up to 200 GeV/c for $\frac{d\sigma(t,s)}{dt}$ and to 40 GeV/c for polarization it is aimed to search for tachyon trace in the charge exchange reactions on the wide base of experimental data. If tachyons are not stable, but exist as a resonance, then one can search for tachyons in the specific processes, like the reaction $\pi^- + p \to \pi^0 + n$. Therefore this is a place where one can hunt for the tachyonic pole, as usual Regge pole. As a consequence of such action the interference between the standard ρ-pole and τ-pole amplitudes arises which may explain the secondary peak and also lead to the appearance of the polarization in the above reaction.

Since 1970 several experiments measured with high accuracy the differential-cross-sections and the polarization. A complete set of the published experimental results on the differential cross-section(in mkbarn/$(GeV/c)^2$)) is presented in Fig.1 [1-6].

The following features of the data may be outlined:

1)The narrow peak around the forward direction; it is believed that this peak is entirely described by the Regge ρ-pole;

2)The minimum around $-t \approx 0.5(GeV/c)^2$ it is a result of the interference between two ρ-pole amplitudes with spin flip and spin non -flip ones.

3)The secondary peak around $-t \approx 1(GeV/c)^2$; it is not yet understood and becomes the subject for the different interpretations - several poles like ρ, ρ-prime and odderon, nonlinear ρ - trajectory plus two exponents or Regge poles and cut. None of them is gotten a firm justification. Therefore the τ(tachyons)-pole may be used also.

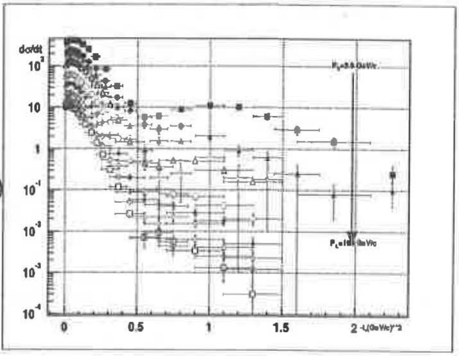

Figure 1: A complete set of the published experimental data on the differential cross-section.

As concerns of the secondary peak there is one specific feature of this peak-its position stays unchanged, when the initial energy varies. This is a very attractive point for the involvement of the τ-pole, since in this case the position of the peak $t_p \approx m_\tau^2 \approx - \mid m_\tau^2 \mid$ is negative due to the imaginary mass of tachyon. Therefore the position of the secondary peak shouldn't depend on the initial momentum.

Workable formulae for the CEX reactions

We assume that two poles, ρ and τ(tachyon), contribute in this reaction. The ρ- pole spin non-flip, $f^{\rho}_{++}(s,t)$, and spin flip, $f^{\rho}_{+-}(s,t)$, amplitudes are presented in the following way [7]:

$$f^{\rho}_{++}(s,t) = \frac{b_{++}(s/s_{0\rho})^{\alpha_\rho(t)}}{(t-4m_\rho^2)^{1/2}(t-m_\rho^2)} = \frac{ib_{++}(s/s_{0\rho})^{\alpha_\rho(t)}}{(4m_\rho^2-t)^{1/2}(m_\rho^2-t)} \quad (2)$$

$$f^{\rho}_{+-}(s,t) = \frac{ib_{+-}(s/s_{0\rho})^{\alpha_\rho(t)}}{(t-m_\rho^2)}[t(t-4m_\pi^2)]^{1/2} = -\frac{ib_{+-}(s/s_{0\rho})^{\alpha_\rho(t)}}{(m_\rho^2-t)}[t(t-4m_\pi^2)]^{1/2} \quad (3)$$

where $\alpha_\rho(t) = 0.58 + t$, and $s_{0\rho}, b_{++}, b_{+-}$ are real parameters determined by fits to experiment.

The τ-pole spin non-flip, $f^{\tau}_{++}(s,t)$, and spin flip, $f^{\tau}_{+-}(s,t)$, amplitudes are presented in the following way:

$$f^{\tau}_{++}(s,t) = \frac{\sqrt{8}\sigma}{(4m_\rho^2-t)^{1/2}} * \frac{\lambda_{++}\sin(\varphi)\sin(\sigma\ln z)}{\sqrt{(t+m_\tau^2)^2+\Gamma^2\mid m_\tau\mid^2}} z^{-1/2} \quad (4)$$

$$f^{\tau}_{+-}(s,t) = \sqrt{8}\sigma * \frac{\lambda_{+-}[t(t-4m_\pi^2)]^{1/2}\sin(\varphi)\sin(\sigma\ln z)}{\sqrt{(t+m_\tau^2)^2+\Gamma^2\mid m_\tau\mid^2}} z^{-1/2} \quad (5)$$

Here $z = \frac{2(s-m_p^2-m_\pi^2)+t}{[(4m_p^2-t)(4m_\pi^2-t)]^{1/2}}$, m_τ - is a tachyon mass, Γ - its width. Parameters λ_{++}, λ_{+-}, σ, m_τ and Γ are fitted to the experimental data.

Differential cross section, $\frac{d\sigma(t,s)}{dt}$, is presented by expression:

$$\frac{d\sigma(t,s)}{dt} = \frac{1}{\pi}\frac{[\mid f_{++}\mid^2 + \mid f_{+-}\mid^2]}{\Delta^2(s,m_p^2,m_\pi^2)} \tag{6}$$

Where $\Delta^2(S,M_p^2,m_\pi^2) = s^2+m_p^2+m_\pi^2-2sm_p^2-2sm_\pi^2-2m_p^2m_\pi^2$ and $f_{++} = f_{++}^{\rho}+f_{++}^{\tau}$, $f_{+-} = f_{+-}^{\rho}+f_{+-}^{\tau}$.

Results of the fit

Results of the cross-section fit are presented in fig. 2-4. The following conclusions can be made:

1) The good descriptions are obtained for specific energies

2) The second maximum region is well fitted, while the rho-region is not so well described

3) The tachyon mass is found to be around $\mid m_\tau = 1\pm0.4$ GeV, its width is $\Gamma = 0.5 \pm 0.08$ GeV which corresponds to the lifetime of the tachyon $\tau = \frac{\hbar}{\Gamma} = \frac{6.58*10^{-25}}{0.5} = 1.2*10^{-24}s$.Then the tachyon range l, can be estimated assuming that tachyon velocity u=c, $l = \tau * u = 3*10^{-14}cm$. The position of the second maximum is practically energy independent.

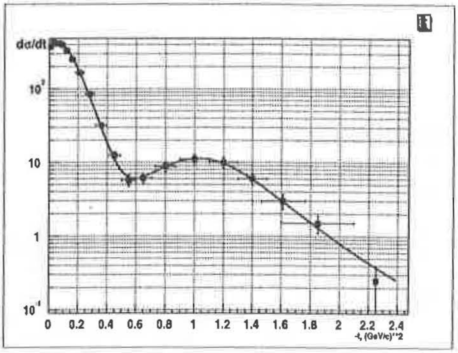

Figure 2: Result of the cross section fit at $P_L(\pi^-) = 5.9GeV/c$.

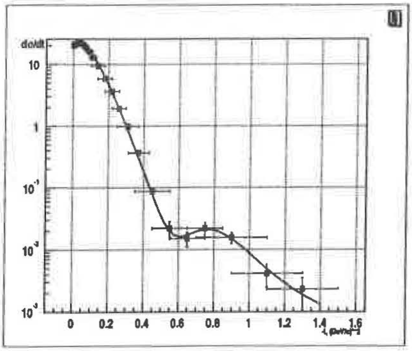

Figure 2: Result of the cross section fit at $P_L(\pi^-) = 100.7GeV/c$.

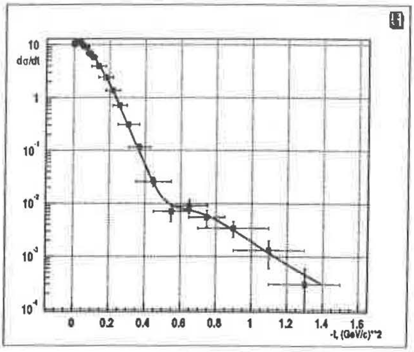

Figure 3: Result of the cross section fit at $P_L(\pi^-) = 199GeV/c$.

We compare our results with results that were obtained in paper [7]. Authors of this paper applied similar approach and gave a consistent description of the differential cross-section and polarization in the momentum region: 5.65-18.20 GeV/c for the differential cross-section and at 5.0-5.9 GeV/c for polarization. So on the base of the wider experimental data we confirm their conclusion, that tachyon pole may give a consistent description of the cross-section in the charge exchange reaction. The results of the fit to the polarization data will be discussed later.

Summary

1) The analysis of the experimental data on the reaction (1) leads to the conclusion that this reaction is an appropriate place for tracing the tachyon pole.

2) Probably accidentally the estimated tachyon mass and width are close to the results of paper [7].

3) In order to make a final decision about the existence of the tachyonic pole one needs to make the similar experiments at the higher energies and with a better precisions. We are aware that such experiments are very difficult due to the fast decrease of the differential cross section of the reaction of interest with growth of the initial energy.

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