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EVIDENCE FOR VENEZIANO DIPS IN K^-p SCATTERING *)

R. Odorico
CERN - Geneva

A B S T R A C T

It is pointed out that $K^-p \rightarrow \bar{K}^0 n$ and K^-p elastic scatterings exhibit structure at fixed u in the low-energy region ($\lesssim 2$ GeV/c), where data of sufficient accuracy are available. No other known mechanism, besides the Veneziano model, seems to be able to account for this phenomenon.

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A peculiar feature of the Veneziano formula ¹⁾

$$\frac{\Gamma(1-\alpha(s)) \Gamma(1-\alpha(t))}{\Gamma(2-\alpha(s)-\alpha(t))} \quad (1)$$

is to predict the existence of a family of zeros at fixed u , generated by the poles of the denominator $\Gamma(2-\alpha(s)-\alpha(t)) \equiv \Gamma(u_0 + \alpha'u)$. Common phenomenological applications of the formula generally involve several beta-function terms ²⁾, thus causing some spoiling of the original Veneziano zeros. Relevance to these zeros, on the other hand, seems to be given by $\bar{p}n \rightarrow \pi^- \pi^- \pi^+$ data ^{3),4)}, whose Dalitz plot presents a characteristic hole structure which can be nicely understood in terms of them ^{*}).

In this note we want to point out the existence in $K^-p \rightarrow \bar{K}^0 n$ and K^-p elastic scattering (amplitude A) of dips with remarkably constant values of u . Since in these processes the u channel is exotic (and experimentally a steep decrease with energy is observed for the backward differential cross-section), it would be hard to relate the constancy in u of these dips to some conventional high-energy mechanism (like wrong-signature zeros or interference of Regge poles with cuts). Such dips appear, on the other hand, to be quite naturally explained by the Veneziano formula.

Because of the steep decrease with energy, the backward regions of $K^-p \rightarrow K^-p$, and $K^-p \rightarrow \bar{K}^0 n$ are not much known experimentally at high energy. A possible dip at $u \simeq -0.3$ (GeV/c)² in $K^-p \rightarrow K^-p$, with a corresponding zero in the polarization, has been pointed out by Daum et al. ⁷⁾ as being suggested by their data between

^{*}) The original proposal of Lovelace ⁵⁾ to understand such structure in terms of the Veneziano formula must somewhat be changed, however, especially in view of the features exhibited by the recently appeared data in flight ⁴⁾. Another structure for the zeros, still of the Veneziano type, seems to be at work ⁶⁾.

1.4 and 2.4 GeV/c. The data of Carrol et al.⁸⁾ with higher statistics and in the same momentum range are not able to confirm it because they do not cover the necessary angular interval. Going to lower energy the quality and the quantity of the data considerably improve, and an easy detection of the dip would be possible. In the data of Conforto et al.⁹⁾ and Armenteros et al.¹⁰⁾ below 1.2 GeV/c, however, the dip is not visible. But, since below 1.2 GeV/c it would correspond to $|t| \lesssim 1 \text{ (GeV/c)}^2$, it is possible that in this region the dip is spoiled in some way by diffraction.

$K^-p \rightarrow \bar{K}^0 n$ should present a backward structure analogous to that of K^-p elastic scattering, without possible disturbance by diffraction at low energy. In the interval 0.45 - 1.8 GeV/c this process is rather well known experimentally^{10),11)}. Plotting data against t and u , as it is done in Fig. 1, one easily recognizes that $K^-p \rightarrow \bar{K}^0 n$ differential cross-section exhibits three dips at remarkably constant values $u \simeq -0.1$, $u \simeq -0.7$, and $u \simeq -1.7 \text{ (GeV/c)}^2$. One also notices at ~ 0.850 and ~ 1.400 GeV/c, i.e., when $u \simeq -0.7$ and $u \simeq -1.7$ respectively leave the physical region, a hook structure near the forward direction, which can be interpreted as indicating a survival of the dips in the unphysical region.

In K^-p elastic scattering one can try to avoid disturbance from diffraction profiting of the fact that this mechanism seems to conserve nucleon helicity at high energy [see Gilman et al.¹²⁾ and references therein, and Ref. 13) for further evidence]. Since the amplitude A represents s channel helicity-flip at high energy, one expects, adopting the philosophy that high and low energy are linked by the analyticity properties of the invariant amplitudes, that this amplitude remains free of diffraction also at low energy^{*)}. Information on the amplitude A may be obtained from the available phase-shift analyses of K^-p scattering. A compact view of the low-energy

*) In Ref. 14), Harari and Zarmi take another attitude and explore the possibility that diffraction conserves helicity also at low energy. In our case, however, no clear structure at fixed u is observed at low energy in the helicity-flip amplitude reconstructed with phase-shifts¹⁵⁾.

behaviour of $|A|^2$, calculated from the phase-shifts of Bailey ¹⁵⁾, is presented in the perspective plot of Fig. 2 ^{*)}. One can remark the absence there of any structure at fixed t , which on the contrary is present in the differential cross-section in the same energy range, and the presence of some clear structure at fixed u . In particular a dip at $u \simeq -0.3 \text{ (GeV/c)}^2$ ($u' = u - u_{\min} \simeq -0.4$, in the considered momentum interval) is well visible until it leaves the physical region through the forward direction.

In conclusion, we can say that the data with higher statistics available at low energy confirm the existence in K^-p scattering of structure at fixed u , suggested by the more uncertain data at higher energy ⁶⁾.

The Veneziano formula accounts in a natural way for the existence of these fixed u dips. In Fig. 3, are sketched in the Mandelstam plane, the dominant t channel and s channel resonance spectra with the corresponding Veneziano zeros. The (Z_s, Z_t) resonances, not represented there for simplicity, also give a sizeable contribution. Since their masses are not quite coincident with those of the corresponding (A_α, A_γ) partners, the u positions of zeros indicated in Fig. 3 are not much significant. What one can reasonably expect is that the zeros should occur at $u \lesssim 0$ with a spacing between them approaching $\sim 1 \text{ (GeV/c)}^2$, and this seems to be in agreement with what one experimentally observes. On the other hand, because of the particular nature of u channel in the considered processes, and since the evidence for the dips remains particularly clear at the lowest energies, it is rather hard to explain their constancy in u with some conventional high-energy mechanism.

To make more understandable the success of the Veneziano formula in predicting the observed dips, one can remark that the intersection of two resonances (belonging to different channels) always generates a zero. Indeed, in order to avoid double poles, one must have near the intersection ^{**)}

^{*)} Analogous plots (for special functions) may be found in Jahnke and Emde book ¹⁶⁾.

^{**)} I want to acknowledge a conversation with G. Veneziano on this point.

$$\begin{aligned}
 (m_a^2 - s)(m_b^2 - t) F(s, t) = \\
 = b(m_a^2 - s) + a(m_b^2 - t) + O(m_a^2 - s, m_b^2 - t) \quad (2)
 \end{aligned}$$

This means that, locally, the scattering amplitude $F(s, t)$ has a zero along the line $b(m_a^2 - s) + a(m_b^2 - t) = 0$ (a and b being the residues of the two resonances at the intersection point). If these zeros, when propagating away from the intersections, must also be responsible for the angular zeros exhibited by resonances, one understands that they have to remain approximately real and to propagate onto the physical region of K^-p scattering. A possible reason why the scattering amplitude should economize zeros in this way lies in the connection between number of zeros and asymptotic behaviour. An unbalancing of the ratio (number of zeros)/(number of poles) would indeed produce a too singular asymptotic behaviour¹⁷⁾.

I would like to thank C. Lovelace for access to his data collection.

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FIGURE CAPTIONS

Figure_1 $K^-p \rightarrow \bar{K}^0 n$ angular distributions between 0.45 and 1.8 GeV/c plotted versus t and u (p_{lab} in GeV/c is indicated in each frame) (black circles : Armenteros et al. ¹⁰) ; white circles : Wohl et al. ¹¹) ; white squares : Dauber ¹¹). The solid lines are hand-drawn to guide the eye. The figure shows the existence, in the considered momentum range, of three dips at remarkable constant $u \simeq -0.1, -0.7$ and -1.7 (GeV/c)². One also observes that when the two last dips leave the physical region (~ 0.850 and ~ 1.400 GeV/c respectively), a hook structure is produced near the forward direction.

Figure_2 Perspective plot of the modulus squared of the amplitude A for K^-p elastic scattering at low energy ($p_{lab} \lesssim 1.4$ GeV/c), calculated from phase shifts ¹⁵). There are reasons to believe that this amplitude does not contain diffraction (see the text). The figure shows the existence of a dip at $u' \simeq -0.4$ (GeV/c)², corresponding to $u \simeq -0.3$ in the considered momentum range.

Figure_3 Schematic representation in the Mandelstam plane of $(\Lambda_\alpha, \Lambda_\gamma)$ hyperon resonances and t channel boson resonances appearing in K^-p elastic scattering (solid lines), with the corresponding zeros predicted by the Veneziano formula (dashed lines).

$$\frac{d\sigma}{dt} \left[\frac{\text{mb}}{(\text{GeV}/c)^2} \right]$$

FIG.1

FIG.2

FIG.3