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Veneziano-like Model with $2q2\bar{q}$ Baryonium Trajectory and Elastic p-p Scattering at $90^\circ_{\text{c.m.}}$

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The $90^\circ_{\text{c.m.}}$ elastic p–p scattering in the $P_L \simeq 2\sim 6$ GeV/c region ($d\sigma/dt(90^\circ_{\text{c.m.}})$, $A_{nn}(90^\circ_{\text{c.m.}})$ and $C_{LL}(90^\circ_{\text{c.m.}})$) is discussed in a Veneziano-like model.

It is expected that studying the fixed-angle energy dependence of elastic p–p scattering at $90^\circ_{\text{c.m.}}$ is a sensitive way to know the short-range behaviour of strong interaction. In this note, we study the $90^\circ_{\text{c.m.}}$ elastic p–p scattering at $P_L \simeq 2\sim 6$ GeV/c in a dual resonance model, using a Veneziano-like representation.[1]

In order to draw duality diagrams for baryon-baryon reactions, $2q2\bar{q}$ resonances have to be introduced.[2] The $S(1936)$,[3] observed in $\bar{p}p$ system, and etc. have very narrow widths in spite of their high masses. Such narrow resonances, called "baryonium" may be $2q2\bar{q}$ resonances.

Several models for the baryonium have been proposed by some authors.[4,5,6] Here, we postulate a $2q2\bar{q}$ baryonium trajectory dual to the vector meson exchange, according to Balázs and Nicolescu.[4] They have presented two infinitely-rising baryonium trajectories, without any free parameters, using a planar self-consistent multiperipheral model with a finite-energy sum-rule constraint. One of them is dual to vector and the other to pseudo-scalar meson exchange.

It is in general not so easy to compare a Veneziano model for N–N scattering with experiments, because the strong absorptive effects from s-channel unitarity must be considered. (If the dual unitarization framework[7] is alternatively taken, calculation is too difficult to be performed.) Here, we discuss the $90^\circ_{\text{c.m.}}$ p–p scattering at $2\sim 6$ GeV/c on the viewpoint that the scattering is non-diffractive at least in the momentum range. The suppression due to the absorption is taken into account by a simple parameter modification. Our interest is put especially on the remarkable features of the scattering, a sharp change in $A_{nn}(90^\circ_{\text{c.m.}})$ near 3.5 GeV/c[8] and breaks in $d\sigma/dt(90^\circ_{c.m.})$.[9] As for the breaks of $d\sigma/dt(90^\circ_{\text{c.m.}})$ at 1.8 and 3.7 GeV/c, they are understandable by a Veneziano-like model.[10]

We take the following model amplitudes for the invariant amplitudes G_i[11] for the elastic p–p scattering:

$$G_i(s, t, u) = \mu_i(t, u)\alpha' B(t, u) + (t \Longleftrightarrow u), \qquad (i = 1, 3, 5), \tag{1}$$

where

$$\mu_1(t,u)=-\left(\frac{1}{2}G_{V\rho}^2+2G_{V\omega}^2\right)+\left(\frac{5t-2u+4m_p^2}{32m_p^2}\right)G_{T\rho}^2+\left(\frac{t-u-2m_p^2}{8m_p^2}\right)G_{V\rho}G_{T\rho}, \quad (2a)$$

$$\mu_3(t,u)=\left(\frac{1}{4}G_{V\rho}^2+G_{V\omega}^2\right)+\left(\frac{t+2u-4m_p^2}{32m_p^2}\right)G_{T\rho}^2+\frac{1}{4}G_{V\rho}G_{T\rho}, \quad (2b)$$

$$\mu_5(t,u)=\left(\frac{1}{2}G_{V\rho}^2+2G_{V\omega}^2\right)+\left(\frac{5t-2u+4m_p^2}{32m_p^2}\right)G_{T\rho}^2+\left(\frac{t-u+6m_p^2}{8m_p^2}\right)G_{V\rho}G_{T\rho}, \quad (2c)$$

and

$$B(t,u)=\frac{\Gamma(1-\alpha(t))\Gamma(j-\alpha_4(u))}{\Gamma(j+1-\alpha(t)-\alpha_4(u))}. \quad (3)$$

Here, $\alpha_4(u)$ is the $2q2\bar{q}$ baryonium trajectory dual to the EXD $\rho-A_2-\omega-f$ trajectory $\alpha(t)=\alpha't+\alpha(0)$, and j is the spin of the ground state of the $2q2\bar{q}$ trajectory.

These amplitudes, together with certain G_2 and G_4 amplitudes, are chosen to assure that poles along the $\alpha(t)$ trajectory contribute only to the $\bar{N}N$ coupled triplet amplitudes. G_2 and G_4 amplitudes, which vanish at $90^\circ_{\text{c.m.}}$, are omitted in Eq. (1).

The definitions for the $V\bar{N}N$ couplings are as usual, as in Ref. 13). The tensor coupling for the $\omega\bar{N}N$ vertex is set equal to zero.

Now, we discuss $d\sigma/dt(90^\circ_{\text{c.m.}})$, $A_{nn}(90^\circ_{\text{c.m.}})$ and $C_{LL}(90^\circ_{\text{c.m.}})$. These observables are related to the amplitudes in Eq. (1) as

$$d\sigma/dt(90^\circ_{c.m.})=\frac{\pi}{p^2}\sigma_0(90^\circ_{\text{c.m.}}), \quad (4a)$$

$$\sigma_0(90^\circ_{\text{c.m.}})=\frac{1}{4E^2}[(E^2\bar{G}_1+m_p^2\bar{G}_3)^2+(p^2\bar{G}_3)^2+(p^2\bar{G}_5)^2], \quad (4b)$$

$$A_{nn}(90^\circ_{\text{c.m.}})\sigma_0(90^\circ_{\text{c.m.}})=\frac{1}{4E^2}[-(E^2\bar{G}_1+m_p^2\bar{G}_3)^2+(p^2\bar{G}_3)^2+(p^2\bar{G}_5)^2], \quad (4c)$$

$$C_{LL}(90^\circ_{\text{c.m.}})\sigma_0(90^\circ_{\text{o.m.}})=\frac{1}{4E^2}[-(E^2\bar{G}_1+m_p^2\bar{G}_3)^2+(p^2\bar{G}_3)^2-(p^2\bar{G}_5)^2], \quad (4d)$$

where $\bar{G}_i=G_i(90^\circ_{\text{c.m.}})$, $E^2=p^2+m_p^2$ and p^2 is the squared c.m. momentum of proton. The suppression due to the absorption is considered by multiplying the amplitudes μ_i by a factor c $(0<c<1)$,

$$\mu_i \longrightarrow c\mu_i. \quad (5)$$

In Figs. 1, 2 and 3, the present model is compared with experiments,[8,12,14] taking $\alpha_4(u)$ etc. as

$$j=1, \quad \alpha_4(u)=0.7u-0.8,^{4)}$$

$$\mu_1(90^\circ_{\text{c.m.}})=11.0-10.7p^2, \quad \mu_3(90^\circ_{\text{c.m.}})=-8.2-10.7p^2, \quad (6)$$

$$\mu_5(90^\circ_{\text{c.m.}})=15.5-10.7p^2, \quad c=0.649.$$

$\mu_i(90^\circ_{\text{c.m.}})$ in Eq. (6) are near to those given by coupling constants[13] from low-energy NN data. It is noted that the quantities $(d\sigma/dt)_{\uparrow\uparrow}$ and $(d\sigma/dt)_{\uparrow\downarrow}$ in Fig. 2 are related to $d\sigma/dt$ and A_{nn} in Eq. (4) as

$$(d\sigma/dt)_{\uparrow\uparrow}=(d\sigma/dt)(1+A_{nn}), \quad (d\sigma/dt)_{\uparrow\downarrow}=(d\sigma/dt)(1-A_{nn}). \quad (7)$$

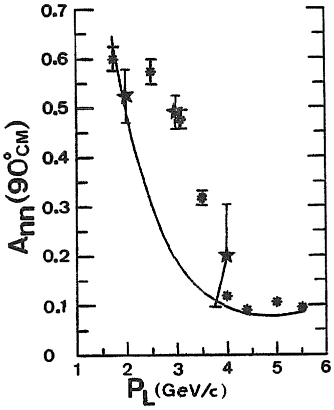

Fig. 1. Experiments[8,12] for $A_{nn}(90^\circ_{\text{c.m.}})$ and a theoretical curve.

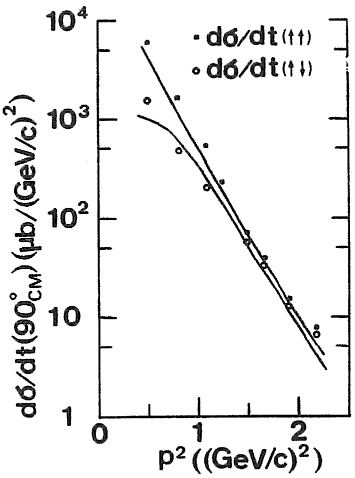

Fig. 2. Two independent pure-initial-spin differential cross sections $(d\sigma/dt)_{\uparrow\uparrow}$ and $(d\sigma/dt)_{\uparrow\downarrow}$,[8] and theoretical curves.

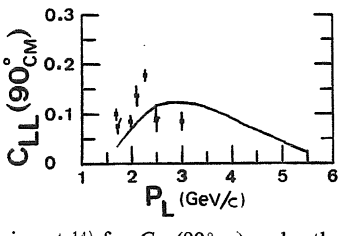

Fig. 3. Experiments[14] for $C_{LL}(90^\circ_{\text{c.m.}})$ and a theoretical curve.

There is found no theoretical understanding for the observed sharp change in $A_{nn}(90^\circ_{\text{c.m.}})$ at around 3.5 GeV/c. Here, we want to stress that the sharp change may be due to the exchange of the $\rho-A_2-\omega-f$ trajectory, as suggested by the present model.

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