# $N/D$ METHOD AND THE D* WIDTH

BY A. LAHIRI AND B. K. BAGCHI

Department of Theoretical Physics, Indian Association for the Cultivation of Science, Jadavpur, Calcutta*

(Received June 30, 1980)

We consider the generation of the D* by the exchange of a ρ meson in the crossed channel in an $N/D$ determinantal approach. The D* width turns out to be 56 keV.

PACS numbers: 11.50.Ec, 11.50.Ge, 12.40.Ff, 14.40.-n

The dispersion theoretic calculations had proved to be immensely popular in the sixties in ascertaining the properties of the low lying vector mesons ρ, K*, $\omega$ and $\Phi$ — the basic idea stemming from the requirement that if the ρ particle actually existed it would generate itself by a bootstrap mechanism by producing the necessary force between the pions [1]. Although the agreement with experiment has not always been remarkable, nevertheless, such calculations have given a deep insight to the basic concept of the bootstrap theory that all strongly interacting particles are bound states or resonances of one another and held by forces generated by the cross channels [2].

For heavy particles, however, not many calculations exist although an SU(4) bootstrap model was considered sometime ago [3] by Campbell Jr. The model yielded encouraging results in that single baryon exchange forces classified according to exact SU(4) gave a better mass spectrum for the charmless resonances than is obtained with SU(3) models. In this note, we pursue this idea a little further and consider the generation of the D*, the $J = 1$, $I = 1/2$ charmed particle, by the exchange of a $\varrho$ meson in the crossed channel. We find that such a generation of the D* depends on the relative sign of the $\rho D\bar{D}$ and $\pi\pi\rho$ coupling constants and once such a choice is made the ρ meson can indeed provide the necessary force in the $J = 1$, $I = 1/2$ channel of the $\pi+D \to \pi+D$ process to generate the D*. The value of the width of the D* turns out to be well within its present experimental upper limit.

Following the determinantal bootstrap approach of Zachariasen and Zemach [4] we begin by writing down the set of $N/D$ equations as follows [1, 5]:

$$m_{D^*}^2 \Gamma_{D^*} = k(m_{D^*}^2)c(m_{D^*}^2)\left[\frac{1}{\pi} P \int\limits_{(m_D+m_\pi)^2}^{\infty} ds' \frac{f(s')}{s'-m_{D^*}^2}\right]^{-1}, \tag{1}$$

* Address: Department of Theoretical Physics, Indian Association for the Cultivation of Science, Jadavpur, Calcutta 700032, India.

and

$$\frac{g_{\pi\pi\varrho}g_{\varrho D\bar{D}}}{4\pi} = -\left[\frac{m_{D*}^2 - s_0}{\pi} P \int\limits_{(m_D+m_\pi)^2}^{\infty} ds' \frac{f(s')}{s'-s_0}\right]^{-1}, \tag{2}$$

where

$$k^2(s) = \frac{1}{4s}\{s-(m_D+m_\pi)^2\}\{s-(m_D-m_\pi)^2\}, \tag{3}$$

$$c(s) = \frac{1}{16k^2(s)}\{2(s-m_D^2-m_\pi^2)+m_\varrho^2\}Q_1\left\{1+\frac{m_\varrho^2}{2k^2(s)}\right\}, \tag{4}$$

$$f(s) = \sqrt{\frac{k^2(s)}{s}}\,\frac{c(s)}{s-m_{D*}^2}, \tag{5}$$

$Q_1(x)$ is the usual Legendre function of the second kind of argument $x$ and $s_0$ is a subtraction point; the coupling constants $g_{\pi\pi\varrho}$ and $g_{\varrho D\bar{D}}$ are defined as in the Hamiltonian given by [6]

$$H = \left\{g_{\pi\pi\varrho}\vec{\pi}\times\partial_\mu\vec{\pi}+ig_{\varrho D\bar{D}}\left(\partial_\mu D^0\frac{\vec{\tau}}{2}D-D^0\frac{\vec{\tau}}{2}\partial_\mu D\right)\right\}\cdot\vec{\varrho}\mu \tag{6}$$

$g_{\pi\pi\varrho}$ may be extracted from the experimental ρ width as

$$g_{\pi\pi\varrho}^2/4\pi = \frac{12\Gamma_\varrho}{(1-4m_\pi^2/m_\varrho^2)^{3/2}m_\varrho}$$

$$\approx 2.9. \tag{7}$$

Computing the integrals in Eqs. (1) and (2) up to 20000 $m_\pi^2$ numerically and the remainder analytically, the following results have been obtained

$$\frac{1}{\pi}P\int ds'\frac{f(s')}{s'-m_{D*}^2} = 0.24\,(\mathrm{GeV})^{-2} \tag{8}$$

$$\begin{aligned}\frac{-g_{\pi\pi\varrho}g_{\varrho D\bar{D}}}{4\pi} = \left[\frac{m_{D*}^2-s_0}{\pi}P\int ds'\frac{f(s')}{s'-s_0}\right]^{-1} &= 5.3 \text{ for } s_0 = -10\,m_\pi^2,\\ &= 4.9 \text{ for } s_0 = -50\,m_\pi^2,\\ &= 4.4 \text{ for } s_0 = -100\,m_\pi^2,\\ &= 3.7 \text{ for } s_0 = -200\,m_\pi^2,\\ &= 3.2 \text{ for } s_0 = -300\,m_\pi^2,\end{aligned} \tag{9}$$

where the input masses have been taken from Particle Data Table [7] for which $k(m_{D*}^2) = 0.044$ GeV and $c(m_{D*}^2) = 1.26\times10^{-3}$.

Using Eqs. (1) and (8), $\Gamma_{D*}$ turns out to be

$$\Gamma_{D*} = 56 \text{ keV} \tag{10}$$

which is well within the present experimental upper limit of 5 MeV [7]. It may be noted that the width of the D* does not depend on the choice of the subtraction point $s_0$.

Since the integral in Eq. (9) is positive, it follows from Eq. (2) that $g_{\varrho D\bar{D}}$ must have a sign opposite to that of $g_{\pi\pi\varrho}$ which is similar to that had been observed by Diu et al. [5] for $\pi\pi\rho$ and $\rho K\bar{K}$ couplings in the K* case. However, unlike the K* case, the solution of Eq. (2) (which depends on the various locations of the subtraction points) is not alarmingly big; in fact, the magnitude of $g_{\pi\pi\varrho}\, g_{\varrho D\bar{D}}/4\pi$ comes out to be smaller than that of $g_{\pi\pi\varrho}\, g_{\varrho K\bar{K}}/4\pi$ by about a factor of 2. In this respect the results of the present scheme differ considerably from those of the K* meson. Regarding the ratio of $g_{\pi\pi\varrho}$ and $g_{\varrho D\bar{D}}$ couplings we find on using Eq. (7) that $|g_{\varrho D\bar{D}}/g_{\pi\pi\varrho}| \approx 1.1$–$1.9$ which is not too bad considering that $g_{\varrho K\bar{K}}$ had come out to be 3 or 4 times as large as $g_{\pi\pi\varrho}$ [5].

To conclude, we have reported in this letter our calculations on the one-channel treatment of the D* generation by ρ exchange. Our results may be summarised as follows:
(a) The D* width turns out to be 56 keV. It may be remarked that since this result does not depend on the choice of the subtraction point, a precise experimental value of $\Gamma_{D*}$ would enable one to determine the reasonableness of the bootstrap approach for the heavy mass resonances.
(b) The relative sign between $g_{\pi\pi\varrho}$ and $g_{\varrho D\bar{D}}$ comes out to be negative.
(c) The magnitude of $g_{\pi\pi\varrho}\, g_{\varrho D\bar{D}}/4\pi$ comes out to be smaller than $g_{\pi\pi\varrho} g_{\varrho K\bar{K}}/4\pi$ by about a factor of 2.

We are currently investigating the addition of the D* force as well as the effects of the inclusion of other channels like Dη and Dη′ — the results will be communicated at a later date [8].

We wish to thank Dr. V. P. Gautam for his kind interest in the problem and discussions. We would also like to thank C. R. Mondal for helping us with the computer programme.

## REFERENCES

[1] L. A. P. Balazs, in Lectures on Bootstrap Dynamics, Summer School of Theoretical Physics, Dalhousie 1965.
[2] G. F. Chew, F. Frautschi, *Phys. Rev. Lett.* **7**, 394 (1961).
[3] G. Campbell Jr., *Phys. Rev.* **D13**, 662 (1976).
[4] F. Zachariasen, C. Zemach, *Phys. Rev.* **128**, 849 (1962).
[5] B. Diu, J. L. Gervias, H. P. Rubinstein, *Phys. Lett.* **4**, 280 (1963).
[6] J. J. Sakurai, *Ann. Phys.* (USA) **11**, 1 (1960).
[7] Particle Data Table, *Phys. Lett.* **82B**, 1 (1978).
[8] A. Lahiry, V. P. Gautam, *Phys. Rev.* **D23** (1981) in press.