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$\Delta\pi$ decay of baryons in a flux-tube-breaking mechanism

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Abstract. Based on the flux-tube-breaking mechanism, we have previously studied the strong decay of nonstrange baryons into the elastic and several inelastic channels. Here, we extend these studies to $\Delta\pi$ decay. We compare our results with those of Koniuk and Isgur and with recently improved experimental data. We also present results of a new and improved calculation of $N\pi$ decay and discuss the problem of resonance identification.

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1. Introduction

There is renewed interest in the study of nucleon resonances through electromagnetic probes at CEBAF [1]. These have to be complemented by the study of hadronic properties. Recently, a very extensive work by Manley and Saleski [2], hereafter MS 92, produced up-to-date information and completed previous work on the determination of resonance properties. Their work pays special attention to inelastic channels such as $\pi\Delta$, ρN, εN, πN^*,...

For more than ten years, comparison of theoretical model results for N and Δ baryon resonances properties (masses and π decay) with experimental data relied mainly on two independent sources published in 1979–1980: Carnegie Mellon-Berkeley, hereafter CMB [3] and Karlsruhe-Helsinki, hereafter KH [4], combined in the Particle Data Group (PDG) editions [5]. These studies present rather precise values for the mass and pion-nucleon partial width of nonstrange baryon resonances. However, they did not investigate other channels specifically. As a consequence, one had to rely on earlier analyses [6] in order to compare model predictions with data for these channels. These previous multichannel analyses used, as a support, elastic partial wave amplitudes from older phase shift analyses, now considered as obsolete [2].

The work of Manley and Saleski relies on the KH and CMB analyses as supports in the elastic sector. As a consequence, it becomes now possible to attempt comparison between theory and data with almost as much insight in the multichannel case as in the elastic one. Moreover, [2] provides values for the elastic channel widths and resonance masses, which confirm, complete or modify previous data. The incorporation of this analysis in the new Particle Data Group edition leads to a widening of the experimental error range on most widths.

Now that a full multichannel partial wave analysis of improved accuracy is available, it becomes more interesting to calculate $\pi\Delta$ widths. We had found the flux-tube-breaking model successful in the study of the elastic channel [7], as well as of other channels [8–10], the theoretical interest of which prompted us to study them in spite of a lesser accuracy in the data. The flux-tube-breaking mechanism is inspired by QCD [11]. It contains one parameter only, that we adjusted already on the $\Delta \to N\pi$ decay width value.

The purpose of this report is twofold. On the one side, we present original calculation of the $\pi\Delta$ decay widths based on the flux-tube-breaking model. On the other side, we review the comparison of our previous results to data in the elastic channel in the light of the work of Manley and Saleski. On the basis of these new comparisons, the identification of some resonances is discussed.

In the next section, we shall briefly describe the flux-tube model breaking mechanism. In Sect. 3, we discuss the procedure to calculate decay widths when one of the decay products, the Δ particle, is unstable. In Sect. 4, we present results for the $\Delta\pi$ decay. In Sect. 5, a review of our old $N\pi$ studies is given in the light of the most recent experimental data.

2. The flux-tube-breaking model

We start by giving a short review of the $\Delta\pi$ decay literature, which is rather restricted. First, there are the baryon decay studies of Koniuk and Isgur [12] on the basis of a point-like pseudo-scalar emission model. The above authors reduced the calculations of all transition amplitudes to four elementary ones which played the role of free parameters.

During the same period, some $\Delta\pi$ widths were calculated by Gavela et al. [13], based on the quark-pair creation (QPC) model. The point-like pseudo-scalar emission model is a limiting case of the QPC model, as discussed below. However, in the work of Gavela et al. [13], $\Delta\pi$ widths are calculated only for resonances of radial nature, namely $P_{11}(1440)$ and $P_{33}(1600)$. These studies use a harmonic confinement.

According to Manley and Saleski [2], the $\Delta\pi$ widths have also been calculated by Forsyth and Cutkoski [14]. They must be part of Forsyth's Ph.D. thesis [14] and they are accessible to us only through [2]. By using three different decay models, Forsyth and Cutkoski fitted masses and elastic widths of non-strange baryons in a quark harmonic shell model including $N=0$, 1, 2, 3 bands, i.e. for a larger negative parity spectrum than that of Koniuk and Isgur. In its spirit, our study is closest to that of Koniuk and Isgur, and in the comparison we discuss below, we shall quote only the results of [12].

We recall that in a previous work [15], we studied πN widths of all four-, three- and two-star resonances based on the QPC model. The decay mechanism is the same as that of Gavela et al. [13], but the mass spectrum and wave functions of baryons are derived from a Hamiltonian with linear confinement, thus giving a more realistic description of the asymptotic wave functions. In that work, we showed explicitly that a finite size emitted pion describes much better the $N\pi$ decay widths than point-like mesons do. The QPC model is a more elaborate mechanism than the pseudo-scalar emission model, being based on a non-local emission operator [13] intimately related to the finite size of the emitted meson. The model has only one parameter, the pair creation constant γ_0 which has been adjusted to reproduce the experimental $N\pi$ width of $\Delta(1232)$. The pseudo-scalar emission model can be recovered in the limit where the meson wave function becomes proportional to $\delta(\mathbf{x})$ where $\mathbf{x}$ is the quark-antiquark relative distance.

The QPC model is a limiting case of the flux-tube-breaking mechanism proposed by Kokoski and Isgur [11] to describe meson strong decay and extended by us to describe baryon strong decay [7]. The QPC model represents a flux tube of an infinite extension where the amplitude for breaking is equal to a constant (see [11]). The use of the infinite extension tube simplifies the calculations. Both for meson and baryon decays, it has been shown that an infinite extension flux tube provides a very good approximation of a finite-extension, QCD-inspired, flux tube breaking. That is why, in the present study, we use the infinite extension flux-tube-breaking mechanism, i.e. the QPC model.

As in our previous studies of $N\pi$ [7, 15], $N\rho$ [8], $N\omega$ [10] and $N(\pi\pi)_S$ [9] decays, the model has been discussed at length, here we give a brief description and a main outline of the calculations.

First, let us mention that the positive and negative parity baryon states are described as eigenstates of a Hamiltonian containing a linear confinement potential and a regularized hyperfine interaction with spin-spin and tensor terms. This interaction is diagonalized in a truncated space spanned by the $56(0^+,2^+)$, $56'(0^+)$, $70(0^+,1^-,2^+)$ and $20(1^+)$ $SU(6)$ multiplets. This means that we cover the same space as in the work of Koniuk and Isgur. Here, the spectrum and wave functions are taken from [16] and [17]. Next, the transition amplitude of the $R\to B+M$ decay in the QPC model is given by

$$\langle BM|T|R\rangle^{J_R}_{m_B m_M} = \sum_m \langle 11\, m-m|00\rangle \langle \phi_B^{m_B}\phi_M^{m_M}|\phi_R \phi_{\text{vac}}^{-m}\rangle\, I_m(R;B,M) \tag{2.1}$$

where J_R is the total angular momentum of the resonance R and m_B and m_M are the spin projection of the final state baryon B and of the meson M, respectively. The matrix element $\langle \phi_B^{m_B}\phi_M^{m_M}|\phi_R\phi_{\text{vac}}^{-m}\rangle$ contains the spin-flavour part of the wave functions, including the vacuum state ϕ_{vac}^{-m} of $J^{PC}=0^{++}$ from which a $q\bar{q}$ is created. The quantity $I_m(R;B,M)$ is a 9-dimensional integral, which contains the spatial parts ψ_R, ψ_B and ψ_M of the initial and final state baryons and a nonlocal emission operator depending of the meson relative coordinate $\mathbf{x}$. The integral I_m has the following form

$$\begin{aligned} I_m(R;B,M) &= -\left(\frac{3}{4\pi}\right)^{1/2} \frac{2^3}{(2\pi)^{3/2}} \delta(\mathbf{k}_M+\mathbf{k}_B)\gamma_0 \int d^3\rho\, d^3\lambda\, d^3x \\ &\times \psi_R[\boldsymbol{\rho}, \boldsymbol{\lambda}+(\tfrac{8}{3})^{1/2}\mathbf{x}]\, \psi_B(\boldsymbol{\rho},\boldsymbol{\lambda}) \exp\{i\mathbf{k}_M\cdot[(\tfrac{2}{3})^{1/2}\boldsymbol{\lambda}+\mathbf{x}]\} \\ &\times \varepsilon_m\cdot(\mathbf{k}_M+i\nabla_x)\,\psi_M(2\mathbf{x})\,. \end{aligned} \tag{2.2}$$

Here, γ_0 is the breaking amplitude (or pair creation) constant, the only parameter of the model, ε_m is the spherical unit vector, and $\mathbf{k}_M$ and $\mathbf{k}_B$ the meson and final state baryon momenta in the resonance frame. The nonlocal character of the emission process can be seen in the $\mathbf{x}$ dependence of ψ_R. Since Δ has a spin $\frac{3}{2}$, one can observe one or two partial waves, depending whether $J_R=\frac{3}{2}$ or more (see Table 1).

Table 1. $\Delta\pi$ decay amplitudes ($\text{MeV}^{1/2}$). 1st column: resonance identification; 2nd: partial wave; 3rd: our results; 4th: [12]; 5th: Manley and Saleski [2]. An asterisk in column 1 means that the sign calculated in the $\Delta\pi$ channel is ambiguous. A double asterisk indicates that the ambiguity originates in the $N\pi$ channel calculation. An asterisk in column 5 means that the experimental sign is uncertain.

Resonance	Wave	This work	Ref. [12]	Ref. [2]
$F_{17}(1990)$	F	− 0.4(*)	− 6.0	
	H	+ 1.0		
$F_{37}(1950)$	F	+ 2.4	− 5.5	+ 7.6
	H	+ 0.9	0	
$F_{15}(1680)$	P	− 0.7	+ 2.0	− 3.6
	F	+ 0.5	− 0.7	+ 1.0

Table 1. Continued

Resonance	Wave	This work	Ref. [12]	Ref. [2]
$F_{15}(2000)$	P	+ 0.4(*)	+ 4.7	+ 7.7
	F	− 0.4(*)	− 6.5	+ 1.6(*)
3rd F_{15}	P	− 0.4	− 7.0	
	F	+ 0.3	− 4.3	
$F_{35}(1905)$	P	+ 1.1	− 3.2	− 2.0(*)
	F	+ 2.0	− 5.5	+ 1.4(*)
$F_{35}(2000)$	P	+ 3.8	+ 6.2	
	F	+ 4.3	− 1.4	+ 7.4
$P_{13}(1720)$	P	+ 1.5	+ 1.9	
	F	− 0.4(*)	− 1.0	
2nd P_{13}	P	−11.4	− 4.1	
	F	− 0.2(*)	− 1.5	
3rd P_{13}	P	+11.5	− 9.4	
	F	− 0.5(*)	− 0.7	
4th P_{13}	P	+ 2.1	− 3.4	
	F	+ 1.6	+ 9.2	
5th P_{13}	P	+ 3.5	+ 3.4	
	F	+ 0.5(*)	+ 4.5	
$P_{33}(1600)$	P	−10.2	− 8.6	+17.0
	F	− 1.2	− 0.1	
$P_{33}(1920)$	P	+ 1.9	+ 3.2	−11.2
	F	− 1.3	+ 1.4	
4th P_{33}	P		+ 0.5	
	F		− 7.7	
$P_{11}(1440)$	P	−10.0	− 2.4	+ 9.4
$P_{11}(1710)$	P	−19.2	+ 3.6	−15.3
4th P_{11}	P	10.2**	+ 3.4	− 5.3
5th P_{11}	P	+ 3.2	+ 1.8	
P_{31}	P	−11.7	+ 7.6	−13.8
$P_{31}(1910)$		+ 5.3	− 5.9	+ 4.9
$D_{15}(1675)$	D	− 2.5	− 9.3	+ 9.2
	G	− 0.1*		
$D_{13}(1520)$	S	− 3.4	+ 6.7	− 2.6
	D	+ 4.4	+ 2.5	− 4.2
$D_{13}(1700)$	S	− 0.5*	+16	+ 3.5(*)
	D	− 0.4*	− 7.7	+14.1
$D_{33}(1700)$	S	− 0.4*	−10.3	+21
	D	− 0.2*	− 6.3	+ 5
$S_{11}(1535)$	D	− 4.0	− 1.7	0
$S_{11}(1650)$	D	− 2.6	− 8.2	+ 1.7
$S_{31}(1620)$	D	− 3.3	+ 8.0	− 9.7

3. The decay width

The transition amplitudes are first converted into helicity amplitudes $M_{ls}^{J_R}$ by the Jacob-Wick formula

$$M_{ls}^{J_R}=\left(\frac{2l+1}{2J_R+1}\right)^{1/2}\sum_{m_B m_M} \times\langle ls0m|J_R m\rangle\langle s_B s_M m_B-m_M|sm\rangle \times\langle BM|T|R\rangle_{m_B m_M}^{J_R} \qquad (3.1)$$

where l and s are the relative orbital momentum and total spin of the outgoing particles. For other details, see Stassart's thesis [18]. A partial decay width in the rest frame of the resonance is defined in terms of $M_{ls}^{J_R}$ by

$$\Gamma_{ls}=\frac{1}{\pi}\frac{|M_{ls}^{J_R}|^2}{2J_R+1}\frac{kE_M E_B}{M_R} \times\langle I_B I_M I_{3B} I_{3M}|I_R I_{3R}\rangle^{-2} \qquad (3.2)$$

where $k=k_M=k_B$, E_M and E_B are the relativistic energies of the outgoing particles, and M_R the resonance mass. Our calculations were specifically made for $R\to\Delta^+ +\pi^0$. The Clebsch-Gordan coefficient $\langle I_B I_M I_{3B} I_{3M}|I_R I_{3R}\rangle$ ensures the independence of the width with respect to the charge combination considered.

The $\Delta\pi$ decay is similar in treatment with the $N\rho$ decay because one of the outgoing particles is not stable. In [8], we presented a technique which provides an appropriate threshold behaviour of the width in such cases. This technique consists in defining a partial width by integrating Γ_{ls} of (3.2) over a weighted Breit-Wigner mass distribution representing the decaying Δ particle. This procedure is required for resonances around the threshold, but it is not necessary for resonances well above the threshold, i.e. having a mass $m_R > m_\Delta + m_\pi + \Gamma_\Delta \simeq 1492$ MeV, for $m_\Delta = 1232$ MeV, $m_\pi = 140$ MeV and $\Gamma_\Delta = 120$ MeV. It is the case of all resonances discussed here, except the Roper resonance. However, due to the fact that its mass is close to 1492 MeV, the effect of the integration is small, of the order of few percents of Γ_{ls} and we neglect it.

In the following two sections, the Δ resonance is described by a wave function obtained in [16]

$$|\psi_\Delta\rangle = 0.977|56,0^+\rangle - 0.185|56',0^+\rangle - 0.088|56,2^+\rangle + 0.058|70,2^+\rangle. \qquad (3.3)$$

But, instead of the theoretical mass of 1285 MeV extracted from the spectral model, we used the experimental mass of 1232 MeV in order to ensure a correct phase space.

4. Results for $\Delta\pi$ decay

In Table 1, we present the partial wave amplitudes defined as $\Gamma_{ls}^{1/2}$ where Γ_{ls} is given by (3.2). In Table 2, we exhibit the square root of each total width given by

$$\Gamma=\sum_{ls}\Gamma_{ls} \qquad (4.1)$$

In Table 1, our results are compared to the theoretical results of Koniuk and Isgur and to the experimental values given by Manley and Saleski. The phase of each calculated partial wave amplitude is given by the product $\sigma_{\rm in}\sigma_{\rm out}$ where $\sigma_{\rm in}$ ($\sigma_{\rm out}$) is the sign of the ingoing (outgoing) amplitude. Note that in Table 2, besides the PDG92 values, the data of Manley and Saleski are also exhibited. There are two reasons for this. One is that the

Table 2. Square root of total decay width in the $\Delta\pi$ channel ($\mathrm{MeV}^{1/2}$). 1st column: resonance identification; 2nd: our result; 3rd: [12]; 4th: Particle Data Group 1992 [5]; 5th: Manley and Saleski [2]; 6th: resonance status in the $\Delta\pi$ channel, from Particle Data Group 1992

Resonance	This work	Ref. [12]	PDG 92	Ref. [2]	Status in $\Delta\pi$
$F_{17}(1990)$	1.1	6.0			
$F_{37}(1950)$	2.5	5.5	$8.2^{+2.1}_{-1.6}$		****
$F_{15}(1680)$	0.9	2.1	$3.6^{+1.0}_{-1.2}$	$3.8^{+0.7}_{-0.6}$	****
$F_{15}(2000)$	0.5	8.0		8^{+9}_{-2}	*
3rd F_{15}	0.5	8.2			
$F_{35}(1905)$	2.3	6.4	<11.5	<5	**
$F_{35}(2000)$	5.7	6.4		14 ± 3	
$P_{13}(1720)$	1.6	2.1	$3.9^{+1.6}_{-1.7}$	-	*
2nd P_{13}	11.4	4.4			
3rd P_{13}	11.5	9.4			
4th P_{13}	2.6	9.8			
5th P_{13}	3.5	5.6			
$P_{33}(1600)$	10.2	8.6	$13.9^{+2.4}_{-2.7}$	17 ± 2	***
$P_{33}(1920)$	2.3	3.5		11 ± 2	**
4th P_{33}	1.9	7.7			
$P_{11}(1440)$	10.0	2.4	$9.4^{+2.2}_{-2.3}$	9.4 ± 0.8	***
$P_{11}(1710)$	19.2	3.6	$4.2^{+3.7}_{-2.0}$	15 ± 4	**
4th P_{11}	10.2	3.4		5 ± 2	
5th P_{11}	3.2	1.8			
P_{31}	11.7	7.6			
$P_{31}(1910)$	5.3	5.9	<3.7		*
$D_{15}(1675)$	2.5	9.3	$9.2^{+1.3}_{-0.7}$	9.2 ± 0.3	****
$D_{13}(1520)$	5.6	7.2	$5.2^{+1.2}_{-1.1}$	$5.0^{+0.9}_{-0.8}$	****
$D_{13}(1700)$	0.7	17.8	$6.1^{+4.2}_{-4.5}$	14 ± 6	**
$D_{33}(1700)$	0.4	12.1	11.6 ± 3.2	22 ± 6	***
$S_{11}(1535)$	4.0	1.7	<5	<1	*
$S_{11}(1650)$	2.6	8.2	<4.4	1.7 ± 0.6	***
$S_{31}(1620)$	3.3	8.0	$8.7^{+1.7}_{-1.8}$	10 ± 1	****

PDG summary table does not give any value for the one- and two-star resonances. Another is that in a few cases there is a large discrepancy between PDG 92 and MS 92, which may mean that there are still ambiguities in analyzing the data. The 9-dimensional integral (2.2) was calculated with the Monte-Carlo method. Quite often when the width was less than 1 MeV we obtained a large statistical error. The corresponding results in Table 1 are marked by an asterisk. In such cases, both the magnitude and the phase of the partial wave amplitude are ambiguous.

In detail, our results are different from those of Koniuk and Isgur, both in size and magnitude. This is normally due to the difference in the transition operator, as explained in Sect. 2. Also in many cases our mixing angles and the phase space differ from those of [12]. Concerning the 4-star resonances, our results for the $D_{13}(1520)$ resonance are in better agreement with data than those of [12], while for $F_{37}(1950)$, $F_{15}(1680)$, $D_{15}(1675)$ and $S_{31}(1620)$, our results are less in agreement with data. We recall that there is no free parameter in our model, while in [12] these resonances could have been considered in the fit of the four basic "reduced" amplitudes. However, we make better predictions than [12] for the 3-star resonances $P_{11}(1440)$ and $S_{11}(1650)$. The results for 3-star $P_{33}(1600)$ are comparable and exhibit a large width as the experiment does. For the 3-star $D_{33}(1700)$ resonance, it is difficult to make a comparison with the experiment. The experimental situation seems ambiguous to us because the $\Delta\pi$ partial width of 470 MeV seen by Manley and Saleski is much larger than the total width of Cutkoski, 280 MeV and of Höhler, 230 MeV.

The good result we obtain for the Roper resonance, $P_{11}(1440)$, could partly be due to the better description we found for its radial wave function [17].

5. $N\pi$ decay revisited

In [7], we calculated the $N\pi$ decay widths based on the wave function (3.3) of Δ and on the theoretical mass [16] of 1285 MeV. The analysis of $\Delta\pi$ decay prompted us to

Table 3. Square root of decay width in the $N\pi$ channel ($MeV^{1/2}$). 1st column: resonance identification; 2nd: our result; 3rd: Particle Data Group 1990 [5]; 4th: Particle Data Group 1992 [5]; 5th: Manley and Saleski [2]; 6th: resonance status

Resonance	Our result	PDG 90	PDG 92	Ref. [2]	Status
$F_{17}(1990)$	1.6			$5.8^{+1.4}_{-1.8}$	**
$F_{37}(1950)$	9.7	$9.8^{+2.6}_{-2.4}$	$10.6^{+1.2}_{-0.5}$	10.7	****
$F_{15}(1680)$	11.0	$8.7^{+0.8}_{-0.9}$	9.2 ± 0.7	9.8 ± 0.3	****
$F_{15}(2000)$	2.6			$6.2^{+2.3}_{-3.8}$	**
F_{15}	<1				
$F_{35}(1905)$	3.1	$5.5^{+2.2}_{-2.0}$	5.9 ± 2.2	$2.0^{+0.7}_{-1.0}$	****
$F_{35}(2000)$	4.0			$6.4^{+1.0}_{-1.1}$	**
$P_{13}(1720)$	16.2	$5.4^{+1.7}_{-1.9}$	$4.7^{+1.6}_{-1.5}$	$7.1^{+1.0}_{-1.3}$	****
$P_{13}(1900)$	1.5			$11.4^{+1.5}_{-1.8}$	*
P_{13}	3.1				
P_{13}	2.9				
P_{13}	4.1				
$P_{33}(1232)$	input	10.7 ± 0.2	$11.0^{+0.2}_{-0.3}$	10.9 ± 0.2	****
$P_{33}(1600)$	10.9	$7.0^{+2.4}_{-1.8}$	7.8 ± 2.8	7.3 ± 0.6	***
$P_{33}(1920)$	3.5	$6.6^{+1.1}_{-1.3}$	$5.0^{+2.7}_{-2.8}$	<2.6	***
P_{33}					
$P_{11}(1440)$	16.9	$10.9^{+4.8}_{-3.2}$	$15.1^{+2.6}_{-2.9}$	$16.4^{+0.6}_{-0.7}$	****
$P_{11}(1710)$	4.0	$4.0^{+1.1}_{-1.0}$	$3.9^{+3.2}_{-1.0}$	$6.7^{+1.5}_{-1.9}$	***
$P_{11}(2000)$	<0.7			$4.1^{+1.2}_{-1.7}$	*
P_{11}	<0.6				
P_{31}	7.9			$4.9^{+1.2}_{-1.6}$	
$P_{31}(1910)$	10.0	$6.6^{+2.5}_{-1.1}$	$7.5^{+1.5}_{-2.2}$	$7.4^{+1.4}_{-1.7}$	****
$D_{15}(1675)$	7.5	$7.6^{+0.9}_{-1.1}$	$8.2^{+1.3}_{-0.7}$	8.6 ± 0.2	****
$D_{13}(1520)$	10.4	$8.3^{+0.9}_{-1.2}$	$8.1^{+0.9}_{-0.7}$	8.5 ± 0.4	****
$D_{13}(1700)$	5.3	$3.2^{+1.0}_{-1.3}$	$3.2^{+1.5}_{-1.6}$	$\leqq 3.2$	***
$D_{33}(1700)$	6.3	$6.1^{+1.6}_{-1.7}$	6.7 ± 1.2	$9^{+1.7}_{-2.1}$	****
$S_{11}(1535)$	13.5	$8.0^{+3.2}_{-2.1}$	$8.2^{+3.5}_{-2.3}$	$8.8^{+0.9}_{-1.0}$	****
$S_{11}(1650)$	10.6	$9.5^{+1.9}_{-2.1}$	$10.2^{+1.9}_{-0.9}$	12.4 ± 0.6	****
$S_{31}(1620)$	4.1	6.5 ± 1.0	6.1 ± 1.2	$3.7^{+0.8}_{-1.9}$	****

recalculate the $N\pi$ decay width based on the experimental mass $m_\Delta = 1232$ MeV. This brings a change in the phase space which amounts to a renormalization of the pair creation constant γ_0 of (2.2) in order to fit correctly the $\Delta \to N\pi$ width. In Table 3, we present these new results for $N\pi$ widths together with experimental data of PDG 90, PDG 92 and MS 92. One can see that there is a change in the PDG data from 90 to 92; in particular, the Roper resonance acquired a larger width (close to Manley and Saleski's value), which brought our value to a very good agreement with the experiment. Also, for the $S_{31}(1620)$ there is a substantial improvement and our result agrees very well with the MS 92 value. In the F_{35} channel, MS 92 finds two resonances, while PDG presents results for $F_{35}(1905)$ only. Our values are in a fairly good agreement with MS 92 in this case. The P_{31} channel raises the problem of identification of the resonances. Our model predicts two resonances of comparable mass 1910 MeV and 1935 MeV, both consistent with the well-established $P_{31}(1910)$ resonance. Our calculation of the $N\rho$ decay widths [18] indicated a better agreement with data if the second resonance in the sector, of mass 1935 MeV and main component $^4\Delta(56,2^+)\frac{1}{2}^+$ is identified as the $P_{31}(1910)$ resonance. Such interpretation is consistent with $N\pi$ results too, as can be seen from Table 3. In an overall view, one can see that there is a general agreement of our results with the data, except for one case, the $P_{13}(1720)$ resonance, where the $N\pi$ width is too large.

The total widths given by MS 92 for $P_{13}(1720)$ and $P_{13}(1900)$ are 380 MeV and 500 MeV, respectively. This indicates that these two resonances overlap quite strongly and a new analysis of data seems desirable. However, it is interesting to find out that our previously calculated $(\Gamma_{p\frac{1}{2}})^{1/2}$ partial wave amplitude for the $N\omega$ decay of the $P_{13}(1900)$ resonance has a value of 11.5 $\mathrm{MeV}^{1/2}$ in good agreement with MS 92 value of 12.3 $\mathrm{MeV}^{1/2}$ extracted from Table II of [2].

6. Summary

We have calculated the decay width of nonstrange baryon resonances into the $\Delta\pi$ channel and reviewed our previous calculations of the $N\pi$ channel. In both calculations, the flux-tube-breaking mechanism in the limiting case of an infinite extension flux tube has been used. In this limit, the quark pair creation model is recovered. Another common point of the two calculations is the description of the $\Delta(1232)$ resonance. The wave function is given by (3.3) which results from the diagonalization of a hamiltonian containing linear confinement but for the mass we take the experimental value in order to describe the phase space correctly. This leads to a readjustment of the only parameter γ_0 of the model. The resulting $N\pi$ widths turned out to get much closer to the latest PDG data. Based on the same value of γ_0, we calculated the $\Delta\pi$ widths and compared them to the theoretical results of Koniuk and Isgur and the experimental results of PDG 92 and the detailed experimental values of Manley and Salesky. Our results are generally different from those of Koniuk and Isgur either due to the decay mechanism or to a different description of the decaying resonances. We get good agreement with the data for some resonances and, in particular, for $P_{11}(1440)$. The PDG 92 edition and Manley and Salesky are sometimes contradictory. For example, for $P_{11}(1710)$, we are close to Manley and Salesky's value, but disagree with PDG 92.

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