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N + RHO DECAY OF BARYONS

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QCD inspired constituent quark models[1,2] predict successfully baryon spectra.[3,4] In these models the ground state baryon is described as a configuration of three flux tubes meeting at a point for which the energy is minimum. The excited states appear as radial or orbital excitations of quarks into higher levels. The resulting wave functions can be tested by studying decay processes.

For mesons, viewed as quark-antiquark ($q\bar{q}$) pairs linked by a single flux tube, a mechanism for the strong decay process, consistent with the meson structure, has been proposed by Kokoski and Isgur.[5] It consists in the breaking of the tube, leading to the creation of a $q\bar{q}$ pair from the vacuum which rearranges with the spectator quarks of the decaying hadron into two new hadrons.

Recently we have generalized[6] this mechanism to the more complicated flux tube configuration of a baryon. An application to the N + π decay has proved successful. We have also shown that finite and infinite extension flux tubes give very similar results. Now, in the limit where the flux tube wave function rms radius becomes infinite one can recover[6] the quark pair creation (QPC) model.[7] In this limit the breaking amplitude γ_0 is a constant.

In this work we apply the mechanism proposed in Ref. 6 to the N + ρ decay. This application is a natural extension of the previous work. Both ρ and π are treated consistently within the same constituent quark model[3] which predicts a correct ρ-π mass difference via interactions having parameters adjusted to fit the Δ-N mass difference.

The ρ-meson wave function is given in the coordinate space by :

$$\psi(r) = f^{c}(r)\left[1 + u^{\sigma}(r)\, \vec{\sigma}_q . \vec{\sigma}_{\bar{q}}\right] \qquad (1)$$

where $f^{c}(r)$ - the central part - has been parametrized as

$$f^{c}(r) = r^{-0.2} \exp\left\{- 0.3965\, r\, W(r) - 2.1\, r^{1.5}\left[1 - W(r)\right]\right\}$$
$$W(r) = \frac{1 + \exp(- 0.15/0.05)}{1 + \exp[(r - 0.15)/0.05]} \; . \qquad (2)$$

The spin-spin correlation function u^σ is defined by

$$u^\sigma(r) = \beta_\sigma \int \frac{e^{-\mu_\sigma|\vec{r} - \vec{r}'|}}{|\vec{r} - \vec{r}'|} V_{SS'}(r')\, d^3r' \tag{3}$$

with

$$\beta_\sigma = 2\,\mathrm{GeV}^{-1}\,\mathrm{fm}^{-2} \ , \quad \mu_\sigma = 4\,\mathrm{fm}^{-1} \tag{4}$$

and

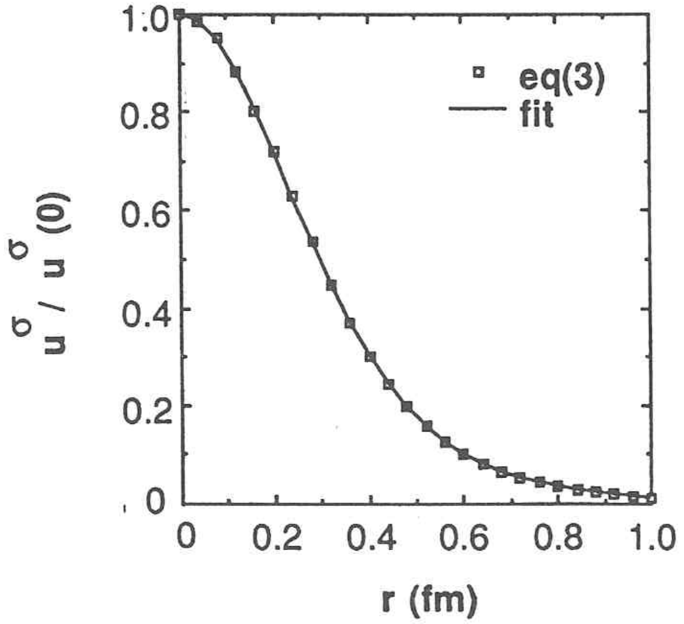
$$V_{SS} = \frac{1}{24\sqrt{\pi}\, m^2 \Lambda^3}\, e^{-(r/2\Lambda)^2} \ . \tag{5}$$

We parametrize the result of the integral (3) by an analytic expression in order to reduce the volume of the numerical computation involved by the calculation of the N + ρ width. The parametric expression is

$$u^\sigma(r) = u^\sigma(0) \exp\left\{- \gamma_2 r^2 W(r) - \gamma_{1.5} r^{1.5} [1 - W(r)]\right\}$$
$$W(r) = \frac{1 + \exp(-r_0/a)}{1 + \exp[(r - r_0)/a]} \tag{6}$$

where by fitting (see Figure) the numerical values obtained for (3) we have

$$u^\sigma(0) = 0.99743 \qquad \gamma_2 = 8.11\,\mathrm{fm}^{-2}$$
$$\gamma_{1.5} = 3.9\,\mathrm{fm}^{-1.5} \qquad r_0 = 0.47\,\mathrm{fm} \qquad a = 0.24\,\mathrm{fm} \ . \tag{7}$$



The baryon wave functions are taken from Refs. 4, 8. As the infinite extension flux tube is a very good approximation to a finite extension flux tube breaking, we calculate the transition amplitude following Eqs. (3.1)-(3.5) of Ref. 9. The breaking amplitude γ_0 is then a constant which has been fixed previously[6] to adjust the width of $\Delta \rightarrow N + \pi$. Hence, there is no free parameter in these calculations.

As compared to the $N + \pi$ decay, a new problem appears in the $N + \rho$ decay because ρ is not stable. In a first stage, the calculated width is a function of the ρ mass. The final value is obtained by a weighted average over the mass interval $[2m_\pi , (m_R - m_N)]$ where m_π, m_R and m_N are the pion, the resonance and the nuclear mass, respectively. The procedure has been explained in Ref. 10.

In the Table we exhibit the square root of the decay width $\Gamma_{N\rho}^{1/2}$ (MeV$^{1/2}$) for 29 nonstrange resonances. The first column indicates the resonances with the partial wave notation and the mass when an identification has been proposed. Columns 2 and 3 give the main component of the wave function and the theoretical mass of each resonance (Refs. 4, 8). Column 4 shows the calculated $\Gamma_{N\rho}^{1/2}$. The upper index "e" indicates when the experimental mass has been used in the calculation of the width instead of the theoretical value. This has been done whenever the predicted mass fall by more than 50 MeV off the experimental range, in order to ensure a proper phase factor, important near the threshold. The experimental $\Gamma_{N\rho}^{1/2}$ is indicated in column 5 and the last column gives the status of the resonance as seen in the $N + \rho$ decay.[11]

One can see that for 10 of the 13 resonances for which data exist the theoretical value lies in the experimental range. Therefore the agreement between theory and experiment can be qualified as very good keeping in mind that there is no free parameter. Of course for a more definite conclusion more experimental measurements are required.

Resonance	Main component	Mass	Theory	Exp.	Status
$F_{17}(1990)$	$^{4}N(70,2^{+})\frac{7}{2}^{+}$	1980	1.1	-	-
$F_{37}(1950)$	$^{4}\Delta(56,2^{+})\frac{7}{2}^{+}$	1952	4.5	< 5.8	*
$F_{15}(1680)$	$^{2}N(56,2^{+})\frac{5}{2}^{+}$	1754	4.3^{e}	4.3 ± 1.0	****
$F_{15}(2000)$	$^{2}N(70,2^{+})\frac{5}{2}^{+}$	1970	4.2	-	-
F_{15}	$^{4}N(70,2^{+})\frac{5}{2}^{+}$	2033	4.3	-	-
$F_{35}(1905)$	$^{2}\Delta(70,2^{+})\frac{5}{2}^{+}$	1962	5.1^{e}	< 12.2	*
$F_{35}(2000)$	$^{4}\Delta(56,2^{+})\frac{5}{2}^{+}$	1985	8.9	large	**
$P_{13}(1710)$	$^{2}N(56,2^{+})\frac{3}{2}^{+}$	1752	5.2	< 13.7	*
P_{13}	$^{4}N(70,0^{+})\frac{3}{2}^{+}$	1914	6.1	-	-
P_{13}	$^{4}N(70,0^{+})\frac{3}{2}^{+}$	1979	5.7	-	-
P_{13}	$^{2}N(20,1^{+})\frac{3}{2}^{+}$	1985	3.3	-	-
P_{13}	$^{2}N(20,1^{+})\frac{3}{2}^{+}$	2046	2.8	-	-
$P_{33}(1232)$	$^{4}\Delta(56,0^{+})\frac{3}{2}^{+}$	1285	0.0	-	-
$P_{33}(1600)$	$^{4}\Delta(56',0^{+})\frac{3}{2}^{+}$	1904	2.9	-	*
$P_{33}(1920)$	$^{4}\Delta(56,2^{+})\frac{3}{2}^{+}$	1964	5.2	-	-
P_{33}	$^{2}\Delta(70,2^{+})\frac{3}{2}^{+}$	1979	9.1	-	-
$P_{11}(1440)$	$^{2}N(56',0^{+})\frac{1}{2}^{+}$	1485	1.5	$5.0^{+2.2}_{-1.5}$	*
$P_{11}(1710)$	$^{2}N(70,0^{+})\frac{1}{2}^{+}$	1796	4.1^{e}	$4.7^{+2.1}_{-2.6}$	*
P_{11}	$^{4}N(70,2^{+})\frac{1}{2}^{+}$	1930	1.9	-	-
P_{11}	$^{2}N(20,1^{+})\frac{1}{2}^{+}$	2042	0.3	-	-
P_{31}	$^{2}\Delta(70,0^{+})\frac{1}{2}^{+}$	1910	17.1	-	-
$P_{31}(1710)$	$^{4}\Delta(56,2^{+})\frac{3}{2}^{+}$	1935	6.9	small	*
$D_{15}(1675)$	$^{4}N(70,1^{-})\frac{5}{2}^{-}$	1653	2.0	< 4.2	*
$D_{13}(1520)$	$^{2}N(70,1^{-})\frac{7}{2}^{-}$	1496	4.6	$5.0^{+0.9}_{-1.1}$	****
$D_{13}(1700)$	$^{4}N(70,1^{-})\frac{3}{2}^{-}$	1714	3.7	< 4.9	*
$D_{33}(1700)$	$^{2}\Delta(70,1^{-})\frac{3}{2}^{-}$	1631	4.9^{e}	< 10.2	**
$S_{11}(1535)$	$^{2}N(70,1^{-})\frac{1}{2}^{-}$	1475	1.1^{e}	~ 2.7	**
$S_{11}(1650)$	$^{4}N(70,1^{-})\frac{1}{2}^{-}$	1627	0.6	$5.1^{+2.7}_{-2.9}$	*
$S_{31}(1620)$	$^{2}N(70,1^{-})\frac{1}{2}^{-}$	1631	4.4	$4.6^{+1.1}_{-1.1}$	****

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