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Quark spin coupling in baryons - revisited

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Abstract

A direct connection can be made between mixing angles in negative parity baryons and the spin coupling of constituent quarks. The mixing angles do not depend on spectral data. These angles are recalculated for gluon exchange and pion exchange between quarks. For pion exchange some values in the literature are corrected. The experimental data on mixing are very similar to those derived from gluon exchange but substantially different from the values obtained for pion exchange.

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SUMMARY

TABLE I: Summary of Results

	Coupling	Reference	Mixing Angle	$\%^4P_j$
$J^P = 3/2^-$	OPE	6, 7	$\pm 8^\circ$	2%
	OPE	this ref.	37°	36%
	OGE	3, 4 & this ref.	6°	1%
	EXP.	11	10°	3%
$J^P = 1/2^-$	OPE	6, 7	$\pm 13^\circ$	5%
	OPE	this ref.	-64.5°	81%
	OGE	3, 4 & this ref.	-32°	28%
	EXP.	11	-32°	28%

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MIXING ANGLES IN NEG. PARITY NUCLEONS

(ALL IN THE QUARK MODEL)

'CONSTITUENT' QUARKS

$$S_{total} = \frac{1}{2} \oplus \frac{1}{2} \oplus \frac{1}{2} = \begin{cases} 1/2 \\ 3/2 \end{cases}$$

NEG. PARITY $\Rightarrow$ $L = 1$ or higher for lowest states

So in the QUARK MODEL, lowest states are :

$$^2P_{1/2},\ ^2P_{3/2},\ ^4P_{1/2},\ ^4P_{3/2},\ ^4P_{5/2} \leftarrow J = L + S$$

The experimental states are in agreement with this

PHYSICAL STATES OF $J^P = 1/2^-, 3/2^-$ ARE LINEAR COMB. WHICH ARE OBTAINED FROM DECAY STUDIES: e.g.

$$\boxed{|\underset{(\pi N)}{D_{13}}(1520)\rangle = -\sin\theta_d\, |\,^4P_{3/2}\rangle_{(q^3)} + \cos\theta_d\, |\,^2P_{3/2}\rangle_{(q^3)}} \qquad \theta_d \approx 10^\circ$$

Ref 11

AND SIMILARLY FOR OTHER 3 STATES.

THE MIXINGANGLES θ_d, θ_s CAN BE COMPUTED IN QUARK MODELS IF WE KNOW INTERACTION

INTERACTIONS:

NEGLECT SPIN-ORBIT, KEEP SPIN-SPIN

$$\mathcal{H}^{(12)}_{OGE} = A\left\{\left(\frac{8\pi}{3}\right)\vec{S}_1\cdot\vec{S}_2\,\delta^3(\vec{\rho}) + (3\vec{S}_1\cdot\hat{\rho}\,\vec{S}_2\cdot\hat{\rho} - \vec{S}_1\cdot\vec{S}_2)\rho^{-3}\right\}$$

'MAGN. DIPOLE-DIPOLE'

$$\vec{\rho} = (\vec{r}_1 - \vec{r}_2)/\sqrt{2}$$

$$\mathcal{H}^{(12)}_{OPE} = B\left\{\left(-\frac{4\pi}{3}\right)\vec{S}_1\cdot\vec{S}_2\,\delta^3(\vec{\rho}) + (3\vec{S}_1\cdot\hat{\rho}\,\vec{S}_2\cdot\hat{\rho} - \vec{S}_1\cdot\vec{S}_2)\rho^{-3}\right\}\vec{\lambda}_1\cdot\vec{\lambda}_2$$

'CONTACT' 'TENSOR' (zero pion mass)

'ELEC. DIPOLE-DIPOLE'

where A, B are constants to fit spectrum.

with these forms:

"OGE": $\begin{pmatrix} 9/5 & 1/\sqrt{10} \\ 1/\sqrt{10} & -1 \end{pmatrix}\begin{pmatrix} {}^4P_{3/2} \\ {}^2P_{3/2} \end{pmatrix}$ in units $\frac{A\alpha^3}{\sqrt{\pi}}$

"OPE" $\begin{pmatrix} 14/5 & \frac{8\sqrt{10}}{3} \\ \frac{8\sqrt{10}}{3} & 7/3 \end{pmatrix}\begin{pmatrix} {}^4P_{3/2} \\ {}^2P_{3/2} \end{pmatrix}$ in units $\frac{|B|\alpha^3}{\sqrt{\pi}}$

A or |B| determine the spectrum, but the mixing angles are independent of the values of A, |B|, α

'OGE' $|3/2^-, OGE\rangle = -0.11\,|{}^4P_{3/2}\rangle + 0.99\,|{}^2P_{3/2}\rangle$ 6°

'OPE' $|3/2^-, OPE\rangle = -0.61\,|{}^4P_{3/2}\rangle + 0.79\,|{}^2P_{3/2}\rangle$ 37°

Compare Ref. 6,7 which give for 'OPE' an angle of ±8°

'EXPERIMENT' (Ref 11) has mixing angle $\theta_d \simeq 10°$

THE GAP BETWEEN 'OGE' and 'OPE' is much WIDER THAN GIVEN IN Ref 6,7, AND EXP. IS MORE UNAMBIGUOUS IN CHOOSING 'OGE'