Pramāṇa, Vol. 23, No. 1, July 1984, pp. 99–107. © Printed in India.

Recoil corrections to magnetic moments of charmed baryons in the MIT bag model

K P TEWARI and C P SINGH

Department of Physics, VSSD College, Kanpur 208002, India

MS received 29 November 1983; revised 19 April 1984

Abstract. Recoil corrections to magnetic moments of charmed baryons are studied in the MIT bag model. It is noticed that such corrections which improve the octet baryon magnetic moments have considerably significant contributions to charmed baryon's moments also.

Keywords. MIT bag model; magnetic moments; charmed baryons.

PACS No. 12·40

1. Introduction

The quark bag model (Chodos *et al* 1974a, b; De Grand *et al* 1975), where quarks are confined to some region of space (the bag) is an interesting approach to the hadron phenomenology and particularly successful in the analysis of hadron spectroscopy (Jaffe and Kiskis 1976; Ponce 1979; Hackman *et al* 1978). Since magnetic moments are useful tests for our understanding of the quark structure of hadrons they have also been extensively studied in the bag model (De Grand *et al* 1975; Barnes 1975; Allen 1975; Hackman *et al* 1978). It is found that the original bag model (Chodos *et al* 1974b; De Grand *et al* 1975) yields smaller values of the magnetic moments of the octet baryons than the experimentally observed values. The discrepancy is regarded as the shortcoming of the bag model and as such, many attempts have been made to impreve agreement between theory and experiment, *e.g.* by Hackman *et al* (1978) who added a new term $C|Nq-N\bar{q}|$ where C is a constant and $Nq(N\bar{q})$ is the number of quarks (antiquarks) to the energy of the bag on an *ad hoc* basis; by Donoghue and Johnson (1980) who incorporated the correction due to centre of mass motion, and by Theberge and Thomos (1982) who treated correction due to pion field. In a recent paper Hwang (1983) described the presence of certain recoil corrections in the study of octet baryon moments and obtained significant contribution.

The magnetic moments of charmed baryons have already been studied using symmetry consideration (Verma and Khanna 1977; Singh *et al* 1979) and in the quark model (Singh 1977; Lichtenberg 1977). In this paper, following Hwang (1983), we wish to estimate the recoil effect contribution to the charmed baryon magnetic moments in the MIT bag model.

2. Magnetic moments of baryons

In the MIT bag model (Chodos *et al* 1974; De Grand *et al* 1975) the quark wavefunction is determined by the bag radius R, the quark mass m, and the spin projections:

$$\begin{aligned}\psi(r,s) &= \frac{N}{\sqrt{4\pi}}\begin{pmatrix} U(r) \\ i\sigma\cdot\hat{r}v(r)\end{pmatrix} \quad Us, \\ & \qquad\qquad\qquad\quad \text{for } r \leqslant R \\ &= 0 \qquad\qquad\qquad\quad \text{for } r > R,\end{aligned} \tag{1}$$

where,

$$u(r) = \left(\frac{w+m}{w}\right)^{1/2} j_0(xr/R) \tag{2}$$

$$v(r) = \left(\frac{w-m}{w}\right)^{1/2} j_1(xr/R), \tag{3}$$

$$\frac{1}{N^2(x)} = R^3 j_0^2(x)\frac{2w\left(w-\dfrac{1}{R}\right)+\dfrac{m}{R}}{w(w-m)}, \tag{4}$$

with w the quark energy and x the eigen frequency determined by

$$w = [(x^2+mR)^2]^{1/2}/R, \tag{5}$$

and

$$\tan x = \frac{x}{1-mR-[(mR)^2+x^2]^{1/2}}. \tag{6}$$

The magnetic moment of a quark q of mass m confined to a bag of radius R is given by (De Grand *et al* 1975),

$$\bar{\mu}_q = \tfrac{1}{2}\textstyle\int_{\text{bag}} \mathrm{d}^3x'\bar{r}x\bar{j} \tag{7}$$

with the electromagnetic current

$$\bar{j} = e_q\psi(x')\bar{\mu}_0\psi(x') \tag{8}$$

where e_q is the charge of the quark and $\psi(x')$ is the quark wavefunction. When wavefunction given above are used (7) becomes

$$\bar{\mu}_q = \tfrac{4}{3}M_pRN^2R^3\textstyle\int_0^1 \mathrm{d}x'x'^3u(r)v(r), \tag{9}$$

with $x' \equiv r/R$ which on solving reduces to

$$\frac{R}{6}\left(\frac{4wR+2mR-3}{2wR(wR-1)+mR}\right). \tag{10}$$

Now, when recoil effects are also considered as in Hwang (1983), the operator $\bar{\mu}_0$ in the electromagnetic current has to be modified as

$$\bar{\mu}_{\text{eff}} = \bar{\sigma}\begin{pmatrix}0 & 1\\ 1 & 0\end{pmatrix} + i\frac{\bar{q}x\bar{\sigma}}{2M}\begin{pmatrix}1 & 0\\ 0 & 1\end{pmatrix} + 0(|\bar{q}|^2/M^2), \tag{11}$$

where M is the mass of baryon in question. When this operator is used and the integral (equation (7)) is solved the second term in the operator gives the recoil correction through an integral

$$\delta\mu = N^2R^3\textstyle\int_0^1 \mathrm{d}x'x'^2(u^2(r)-\tfrac{1}{3}v^2(r)). \tag{12}$$

On evaluation this integral yields

$$\frac{1}{3}\,\frac{2(wR)^2+4(mR)(wR)-3(mR)}{2(wR)^2-2(wR)+m(R)}. \tag{13}$$

Using the well-known additivity assumption and neglecting the possibility of quark anomalous magnetic moments, the baryon magnetic moments are computed as

$$\bar{\mu}_B=\sum_i \bar{\mu}_q(m_iR)_{\text{eff}}, \tag{14}$$

i being flavour index. The μ_B value is estimated in terms of μ_q from the knowledge of the flavour and spin wavefunctions of the baryon. Denoting the combined spin and flavour wavefunctions of the quarks by $q_1q_2q_3$ we have for the magnetic moment of baryon

$$\mu_B=\langle B_{q_1q_2q_3}|\sum_i \bar{\mu}_q(m_i\,R)_{\text{eff}}|B_{q_1q_2q_3}\rangle. \tag{15}$$

Applying the above procedure, the magnetic moments are calculated and the matrix elements for various particles are given in table 1. For their numerical estimation, the baryon radius values, baryon masses and quark masses ($m_u=m_d=0$, $m_s=0{\cdot}279$ GeV and $m_c=1{\cdot}551$ GeV) are taken from Jaffe and Kiskis (1976), De Grand *et al* (1975) and the moments thus calculated are given in table 2.

Table 1. Matrix elements of baryons.

Particles	Matrix elements with recoil corrections
$J^p=1/2^+$	
p	$\frac{1}{9}\left(\mu_0^d+\frac{M_p}{M_p}\delta\mu^d\right)+\frac{8}{9}\left(\mu_0^u+\frac{M_p}{M_p}\delta\mu^u\right)$
n	$-\frac{4}{9}\left(\mu_0^d+\frac{M_p}{M_n}\delta\mu^d\right)-\frac{2}{9}\left(\mu_0^u+\frac{M_p}{M_n}\delta\mu^u\right)$
Λ	$-\frac{1}{3}\left(\mu_0^s+\frac{M_p}{M_\Lambda}\delta\mu^s\right)$
Σ^+	$\frac{8}{9}\left(\mu_0^u+\frac{M_p}{M_{\Sigma^+}}\delta\mu^u\right)+\frac{1}{9}\left(\mu_0^s+\frac{M_p}{M_{\Sigma^+}}\delta\mu^s\right)$
Σ^0	$\frac{4}{9}\left(\mu_0^u+\frac{M_p}{M_{\Sigma^0}}\delta\mu^u\right)-\frac{2}{9}\left(\mu_0^d+\frac{M_p}{M_{\Sigma^0}}\delta\mu^d\right)+\frac{1}{9}\left(\mu_0^s+\frac{M_p}{M_{\Sigma^0}}\delta\mu^s\right)$
Σ^-	$-\frac{4}{9}\left(\mu_0^d+\frac{M_p}{M_{\Sigma^-}}\delta\mu^d\right)+\frac{1}{9}\left(\mu_0^s+\frac{M_p}{M_{\Sigma^-}}\delta\mu^s\right)$
Ξ^0	$-\frac{2}{9}\left(\mu_0^u+\frac{M_p}{M_{\Xi^0}}\delta\mu^u\right)-\frac{4}{9}\left(\mu_0^s+\frac{M_p}{M_{\Xi^0}}\delta\mu^s\right)$
Ξ	$\frac{1}{9}\left(\mu_0^d+\frac{M_p}{M_{\Xi^-}}\delta\mu^d\right)-\frac{4}{9}\left(\mu_0^s+\frac{M_p}{M_{\Xi^-}}\delta\mu^s\right)$
$\Lambda\Sigma$	$-\frac{1}{3\sqrt{3}}\left(\mu_0^d+\frac{M_p}{M_\Sigma}\delta\mu^d\right)-\frac{2}{3\sqrt{3}}\left(\mu_0^u+\frac{M_p}{M_\Sigma}\delta\mu^u\right)$
Σ_c^{++}	$\frac{8}{9}\left(\mu_0^u+\frac{M_p}{M_{\Sigma_c^{++}}}\delta\mu^u\right)-\frac{2}{9}\left(\mu_0^c+\frac{M_p}{M_{\Sigma_c^{++}}}\delta\mu^c\right)$

Table 1. (*Contd.*)

Particles	Matrix elements with recoil corrections
Σ_c^+	$\frac{4}{9}\left(\mu_0^u+\frac{M_p}{M_{\Sigma_c^+}}\delta\mu^u\right)-\frac{2}{9}\left(\mu_0^d+\frac{M_p}{M_{\Sigma_c^+}}\delta\mu^d\right)-\frac{2}{9}\left(\mu_0^c+\frac{M_p}{M_{\Sigma_c^+}}\delta\mu^c\right)$
Σ_c^0	$-\frac{4}{9}\left(\mu_0^d+\frac{M_p}{M_{\Sigma_c^0}}\delta\mu^d\right)-\frac{2}{9}\left(\mu_0^c+\frac{M_p}{M_{\Sigma_c^0}}\delta\mu^c\right)$
Ξ_c^+	$\frac{4}{9}\left(\mu_0^u+\frac{M_p}{M_{\Xi_c^+}}\delta\mu^u\right)-\frac{2}{9}\left(\mu_0^s+\frac{M_p}{M_{\Xi_c^+}}\delta\mu^s\right)-\frac{2}{9}\left(\mu_0^c+\frac{M_p}{M_{\Xi_c^+}}\delta\mu^c\right)$
Ξ_c^0	$-\frac{2}{9}\left(\mu_0^d+\frac{M_p}{M_{\Xi_c^0}}\delta\mu^d\right)-\frac{2}{9}\left(\mu_0^s+\frac{M_p}{M_{\Xi_c^0}}\delta\mu^s\right)-\frac{2}{9}\left(\mu_0^c+\frac{M_p}{M_{\Xi_c^0}}\delta\mu^c\right)$
Ω_c^0	$-\frac{4}{9}\left(\mu_0^s+\frac{M_p}{M_{\Omega_c^0}}\delta\mu^s\right)-\frac{2}{9}\left(\mu_0^c+\frac{M_p}{M_{\Omega_c^0}}\delta\mu^c\right)$
Ξ_{cc}^{++}	$\frac{8}{9}\left(\mu_0^c+\frac{M_p}{M_{\Xi_{cc}^{++}}}\delta\mu^c\right)-\frac{2}{9}\left(\mu_0^u+\frac{M_p}{M_{\Xi_{cc}^{++}}}\delta\mu^u\right)$
Ξ_{cc}^+	$\frac{8}{9}\left(\mu_0^c+\frac{M_p}{M_{\Xi_{cc}^+}}\delta\mu^c\right)+\frac{1}{9}\left(\mu_0^d+\frac{M_p}{M_{\Xi_{cc}^+}}\delta\mu^d\right)$
Ω_{cc}^+	$\frac{8}{9}\left(\mu_0^c+\frac{M_p}{M_{\Omega_{cc}^+}}\delta\mu^c\right)+\frac{1}{9}\left(\mu_0^s+\frac{M_p}{M_{\Omega_{cc}^+}}\delta\mu^s\right)$
Λ_c^+	$\frac{2}{3}\left(\mu_0^c+\frac{M_p}{M_{\Lambda_c^+}}\delta\mu^c\right)$
$\Xi_c'^+$	$\frac{2}{3}\left(\mu_0^c+\frac{M_p}{M_{\Xi_c'^+}}\delta\mu^c\right)$
$\Xi_c'^0$	$\frac{2}{3}\left(\mu_0^c+\frac{M_p}{M_{\Xi_c'^0}}\delta\mu^c\right)$
$\langle\Lambda_c^+\|\Sigma_c^+\rangle$	$\frac{1}{3\sqrt{3}}\left(\mu_0^d+\frac{M_p}{M_{\Sigma_c^+}}\delta\mu^d\right)+\frac{2}{3\sqrt{3}}\left(\mu_0^u+\frac{M_p}{M_{\Sigma_c^+}}\delta\mu^u\right)$
$\langle\Xi_c'^+\|\Xi_c^+\rangle$	$\frac{2}{3\sqrt{3}}\left(\mu_0^u+\frac{M_p}{M_{\Xi_c^+}}\delta\mu^u\right)+\frac{1}{3\sqrt{3}}\left(\mu_0^s+\frac{M_p}{M_{\Xi_c^+}}\delta\mu^s\right)$
$\langle\Xi_c'^0\|\Xi_c^0\rangle$	$\frac{1}{3\sqrt{3}}\left(\mu_0^u+\frac{M_p}{M_{\Xi_c^0}}\delta\mu^u\right)-\frac{1}{3\sqrt{3}}\left(\mu_0^s+\frac{M_p}{M_{\Xi_c^0}}\delta\mu^s\right)$
$J^p=3/2^+$	
Δ^{++}	$2\left(\mu_0^u+\frac{M_p}{M_{\Delta^{++}}}\delta\mu^u\right)$
Δ^+	$\frac{4}{3}\left(\mu_0^u+\frac{M_p}{M_{\Delta^+}}\delta\mu^u\right)-\frac{1}{3}\left(\mu_0^d+\frac{M_p}{M_{\Delta^+}}\delta\mu^d\right)$
Δ^0	$\frac{2}{3}\left(\mu_0^u+\frac{M_p}{M_{\Delta^0}}\delta\mu^u\right)-\frac{2}{3}\left(\mu_0^d+\frac{M_p}{M_{\Delta^0}}\delta\mu^d\right)$
Δ^-	$-\left(\mu_0^d+\frac{M_p}{M_{\Delta^-}}\delta\mu^d\right)$
Σ^{*+}	$\frac{4}{3}\left(\mu_0^u+\frac{M_p}{M_{\Sigma^{*+}}}\delta\mu^u\right)-\frac{1}{3}\left(\mu_0^s+\frac{M_p}{M_{\Sigma^{*+}}}\delta\mu^s\right)$

Table 1. (*Contd.*)

Particles	Matrix elements with recoil corrections
Σ^{*0}	$\frac{2}{3}\left(\mu_0^u+\frac{M_p}{M_{\Sigma^{*0}}}\delta\mu^u\right)-\frac{1}{3}\left(\mu_0^d+\frac{M_p}{M_{\Sigma^{*0}}}\delta\mu^d\right)-\frac{1}{3}\left(\mu_0^s+\frac{M_p}{M_{\Sigma^{*0}}}\delta\mu^s\right)$
Σ^{*-}	$-\frac{2}{3}\left(\mu_0^d+\frac{M_p}{M_{\Sigma^{*-}}}\delta\mu^d\right)-\frac{1}{3}\left(\mu_0^s+\frac{M_p}{M_{\Sigma^{*-}}}\delta\mu^s\right)$
Ξ^{*0}	$\frac{2}{3}\left(\mu_0^u+\frac{M_p}{M_{\Xi^{*0}}}\delta\mu^u\right)-\frac{2}{3}\left(\mu_0^s+\frac{M_p}{M_{\Xi^{*0}}}\delta\mu^s\right)$
Ξ^{*-}	$-\frac{1}{3}\left(\mu_0^d+\frac{M_p}{M_{\Xi^{*-}}}\delta\mu^d\right)-\frac{2}{3}\left(\mu_0^s+\frac{M_p}{M_{\Xi^{*-}}}\delta\mu^s\right)$
Ω^-	$-\left(\mu_0^s+\frac{M_p}{M_{\Omega^-}}\delta\mu^s\right)$
Σ_c^{*++}	$\frac{4}{3}\left(\mu_0^u+\frac{M_p}{M_{\Sigma_c^{*++}}}\delta\mu^u\right)+\frac{2}{3}\left(\mu_0^c+\frac{M_p}{M_{\Sigma_c^{*++}}}\delta\mu^c\right)$
Σ_c^{*+}	$\frac{2}{3}\left(\mu_0^u+\frac{M_p}{M_{\Sigma_c^{*+}}}\delta\mu^u\right)-\frac{1}{3}\left(\mu_0^d+\frac{M_p}{M_{\Sigma_c^{*+}}}\delta\mu^d\right)+\frac{2}{3}\left(\mu_0^c+\frac{M_p}{M_{\Sigma_c^{*+}}}\delta\mu^c\right)$
Σ_c^{*0}	$-\frac{2}{3}\left(\mu_0^d+\frac{M_p}{M_{\Sigma_c^{*0}}}\delta\mu^d\right)+\frac{2}{3}\left(\mu_0^c+\frac{M_p}{M_{\Sigma_c^{*0}}}\delta\mu^c\right)$
Ξ_c^{*+}	$\frac{2}{3}\left(\mu_0^u+\frac{M_p}{M_{\Xi_c^{*+}}}\delta\mu^u\right)-\frac{1}{3}\left(\mu_0^s+\frac{M_p}{M_{\Xi_c^{*+}}}\delta\mu^s\right)+\frac{2}{3}\left(\mu_0^c+\frac{M_p}{M_{\Xi_c^{*+}}}\delta\mu^c\right)$
Ξ_c^{*0}	$-\frac{1}{3}\left(\mu_0^d+\frac{M_p}{M_{\Xi_c^{*0}}}\delta\mu^d\right)-\frac{1}{3}\left(\mu_0^s+\frac{M_p}{M_{\Xi_c^{*0}}}\delta\mu^s\right)+\frac{2}{3}\left(\mu_0^c+\frac{M_p}{M_{\Xi_c^{*0}}}\delta\mu^c\right)$
Ω_c^{*0}	$-\frac{2}{3}\left(\mu_0^s+\frac{M_p}{M_{\Omega_c^{*0}}}\delta\mu^s\right)+\frac{2}{3}\left(\mu_0^c+\frac{M_p}{M_{\Omega_c^{*0}}}\delta\mu^c\right)$
Ξ_{cc}^{*++}	$\frac{2}{3}\left(\mu_0^u+\frac{M_p}{M_{\Xi_{cc}^{*++}}}\delta\mu^u\right)+\frac{4}{3}\left(\mu_0^c+\frac{M_p}{M_{\Xi_{cc}^{*++}}}\delta\mu^c\right)$
Ξ_{cc}^{*+}	$-\frac{1}{3}\left(\mu_0^d+\frac{M_p}{M_{\Xi_{cc}^{*+}}}\delta\mu^d\right)+\frac{4}{3}\left(\mu_0^c+\frac{M_p}{M_{\Xi_{cc}^{*+}}}\delta\mu^c\right)$
Ω_{cc}^{*+}	$-\frac{1}{3}\left(\mu_0^s+\frac{M_p}{M_{\Omega_{cc}^{*+}}}\delta\mu^s\right)+\frac{4}{3}\left(\mu_0^c+\frac{M_p}{M_{\Omega_{cc}^{*+}}}\delta\mu^c\right)$
Ω_{ccc}^{*}	$2\left(\mu_0^c+\frac{M_p}{M_{\Omega_{ccc}^{*}}}\delta\mu^c\right)$
Transition element	
$\langle 1/2^+ \vert 3/2^+\rangle$	
$\langle p \vert \Delta^+\rangle$	$\frac{4\sqrt{2}}{9}\left(\mu_0^u+\frac{M_p}{M_{\Delta^+}}\delta\mu^u\right)+\frac{2\sqrt{2}}{9}\left(\mu_0^d+\frac{M_p}{M_{\Delta^+}}\delta\mu^d\right)$
$\langle n \vert \Delta^0\rangle$	$\frac{4\sqrt{2}}{9}\left(\mu_0^u+\frac{M_p}{M_{\Delta^0}}\delta\mu^u\right)+\frac{2\sqrt{2}}{9}\left(\mu_0^d+\frac{M_p}{M_{\Delta^0}}\delta\mu^d\right)$
$\langle \Sigma^+ \vert \Sigma^{*+}\rangle$	$\frac{4\sqrt{2}}{9}\left(\mu_0^u+\frac{M_p}{M_{\Sigma^{*+}}}\delta\mu^u\right)+\frac{2\sqrt{2}}{9}\left(\mu_0^s+\frac{M_p}{M_{\Sigma^{*+}}}\delta\mu^s\right)$

Table 1. (*Contd.*)

Particles	Matrix elements with recoil corrections
$\langle\Lambda\|\Sigma^{*0}\rangle$	$\frac{2\sqrt{2}}{3\sqrt{3}}\left(\mu_0^u+\frac{M_p}{M_{\Sigma^{*0}}}\delta\mu^u\right)+\frac{\sqrt{2}}{3\sqrt{3}}\left(\mu_0^d+\frac{M_p}{M_{\Sigma^{*0}}}\delta\mu^d\right)$
$\langle\Sigma^0\|\Sigma^{*0}\rangle$	$\frac{2\sqrt{2}}{9}\left(\mu_0^u+\frac{M_p}{M_{\Sigma^{*0}}}\delta\mu^u\right)-\frac{\sqrt{2}}{9}\left(\mu_0^d+\frac{M_p}{M_{\Sigma^{*0}}}\delta\mu^d\right)-\frac{2\sqrt{2}}{9}\left(\mu_0^s+\frac{M_p}{M_{\Sigma^{*0}}}\delta\mu^s\right)$
$\langle\Sigma^-\|\Sigma^{*-}\rangle$	$\frac{2\sqrt{2}}{9}\left(\mu_0^d+\frac{M_p}{M_{\Sigma^{*-}}}\delta\mu^d\right)-\frac{2\sqrt{2}}{9}\left(\mu_0^s+\frac{M_p}{M_{\Sigma^{*-}}}\delta\mu^s\right)$
$\langle\Xi^0\|\Xi^{*0}\rangle$	$\frac{4\sqrt{2}}{9}\left(\mu_0^u+\frac{M_p}{M_{\Xi^{*0}}}\delta\mu^u\right)+\frac{2\sqrt{2}}{9}\left(\mu_0^s+\frac{M_p}{M_{\Xi^{*0}}}\delta\mu^s\right)$
$\langle\Xi^-\|\Xi^{*-}\rangle$	$\frac{2\sqrt{2}}{9}\left(\mu_0^d+\frac{M_p}{M_{\Xi^{*-}}}\delta\mu^d\right)-\frac{2\sqrt{2}}{9}\left(\mu_0^s+\frac{M_p}{M_{\Xi^{*-}}}\delta\mu^s\right)$
$\langle\Sigma_c^{++}\|\Sigma_c^{*++}\rangle$	$\frac{4\sqrt{2}}{9}\left(\mu_0^u+\frac{M_p}{M_{\Sigma_c^{*++}}}\delta\mu^u\right)-\frac{4\sqrt{2}}{9}\left(\mu_0^c+\frac{M_p}{M_{\Sigma_c^{*++}}}\delta\mu^c\right)$
$\langle\Sigma_c^+\|\Sigma_c^{*+}\rangle$	$\frac{\sqrt{2}}{9}\left(\mu_0^d+\frac{M_p}{M_{\Sigma_c^{*+}}}\delta\mu^d\right)-\frac{2\sqrt{2}}{9}\left(\mu_0^u+\frac{M_p}{M_{\Sigma_c^{*+}}}\delta\mu^u\right)+\frac{4\sqrt{2}}{9}\left(\mu_0^c+\frac{M_p}{M_{\Sigma_c^{*+}}}\delta\mu^c\right)$
$\langle\Lambda_c^+\|\Sigma_c^{*+}\rangle$	$\frac{2\sqrt{2}}{3\sqrt{3}}\left(\mu_0^u+\frac{M_p}{M_{\Sigma_c^{*+}}}\delta\mu^u\right)+\frac{\sqrt{2}}{3\sqrt{3}}\left(\mu_0^d+\frac{M_p}{M_{\Sigma_c^{*+}}}\delta\mu^d\right)$
$\langle\Sigma_c^0\|\Sigma_c^{*0}\rangle$	$\frac{2\sqrt{2}}{9}\left(\mu_0^d+\frac{M_p}{M_{\Sigma_c^{*0}}}\delta\mu^d\right)+\frac{4\sqrt{2}}{9}\left(\mu_0^c+\frac{M_p}{M_{\Sigma_c^{*0}}}\delta\mu^c\right)$
$\langle\Xi_c^+\|\Xi_c^{*+}\rangle$	$\frac{4\sqrt{2}}{9}\left(\mu_0^c+\frac{M_p}{M_{\Xi_c^{*+}}}\delta\mu^c\right)+\frac{\sqrt{2}}{9}\left(\mu_0^s+\frac{M_p}{M_{\Xi_c^{*+}}}\delta\mu^s\right)-\frac{2\sqrt{2}}{9}\left(\mu_0^u+\frac{M_p}{M_{\Xi_c^{*+}}}\delta\mu^u\right)$
$\langle\Xi_c^0\|\Xi_c^{*0}\rangle$	$\frac{\sqrt{2}}{9}\left(\mu_0^d+\frac{M_p}{M_{\Xi_c^{*0}}}\delta\mu^d\right)+\frac{\sqrt{2}}{9}\left(\mu_0^s+\frac{M_p}{M_{\Xi_c^{*0}}}\delta\mu^s\right)+\frac{4\sqrt{2}}{9}\left(\mu_0^c+\frac{M_p}{M_{\Xi_c^{*0}}}\delta\mu^c\right)$
$\langle\Omega_c^0\|\Omega_c^{*0}\rangle$	$\frac{2\sqrt{2}}{9}\left(\mu_0^s+\frac{M_p}{M_{\Omega_c^{*0}}}\delta\mu^s\right)+\frac{4\sqrt{2}}{9}\left(\mu_0^c+\frac{M_p}{M_{\Omega_c^{*0}}}\delta\mu^c\right)$
$\langle\Xi_{cc}^{++}\|\Xi_{cc}^{*+}\rangle$	$\frac{4\sqrt{2}}{9}\left(\mu_0^u+\frac{M_p}{M_{\Xi_{cc}^{*+}}}\delta\mu^u\right)-\frac{4\sqrt{2}}{9}\left(\mu_0^c+\frac{M_p}{M_{\Xi_{cc}^{*+}}}\delta\mu^c\right)$
$\langle\Xi_{cc}^+\|\Xi_{cc}^{*+}\rangle$	$\frac{2\sqrt{2}}{9}\left(\mu_0^d+\frac{M_p}{M_{\Xi_{cc}^{*+}}}\delta\mu^d\right)+\frac{4\sqrt{2}}{9}\left(\mu_0^c+\frac{M_p}{M_{\Xi_{cc}^{*+}}}\delta\mu^c\right)$
$\langle\Omega_{cc}^+\|\Omega_{cc}^{*+}\rangle$	$\frac{2\sqrt{2}}{9}\left(\mu_0^s+\frac{M_p}{M_{\Omega_{cc}^{*+}}}\delta\mu^s\right)+\frac{4\sqrt{2}}{9}\left(\mu_0^c+\frac{M_p}{M_{\Omega_{cc}^{*+}}}\delta\mu^c\right)$

3. Discussion

From our analysis we notice that the magnetic moments without recoil correction (table 2) are certainly much smaller than the experimental values ($\mu(\Sigma^+)$: Ankenbrandt *et al* 1983; $\mu(\Sigma^-)$: Mariner *et al* 1982; Hertzog *et al* 1983; $\mu(\Xi^0)$: Bunce *et al* 1979; $\mu(\Xi^-)$: Rameika *et al* 1984) and the inclusion of recoil corrections (table 2)

Table 2. Estimated magnetic moments of baryons.

			Magnetic moments			
Particles I	R $(\mathrm{GeV})^{-1}$ II	Mass GeV III	without recoil corection IV	with recoil corection V	with variable bag pressure VI	Experimental value VII
$J^P = 1/2^+$						
P	5.00	0.938	1.90107	2.55487	2.79	2.79
n	5.00	0.938	-1.26738	-1.70325	-1.86	-1.91
Λ	4.95	1.116	-0.4843	-0.70	-0.68	-0.6138 ± 0.0047
Σ^+	4.95	1.189	1.84	2.36	2.707	2.368 ± 0.013
						2.357 ± 0.012
						2.38 ± 0.02
Σ^0	4.95	1.189	0.58	0.76	0.847	—
Σ^-	4.95	1.189	-0.68	-0.84	-1.013	-0.89 ± 0.14
						-1.11 ± 0.031
Ξ^0	4.91	1.321	-1.06	-1.41	-1.527	-1.25 ± 0.014
Ξ^-	4.91	1.321	-0.43	-0.63	-0.597	-0.69 ± 0.03
$\Lambda\Sigma$	4.95	1.189	-1.09	-1.38	-1.84	-1.82 ± 0.22
Σ_c^{++}	4.79	2.357	1.50	1.65	2.32	—
Σ_c^+	4.79	2.357	0.28	0.26	0.42	—
Σ_c^0	4.79	2.357	-0.93	-1.13	-1.40	—
Ξ_c^+	4.75	2.507	0.37	0.32	0.63	—
Ξ_c^0	4.75	2.507	0.84	-1.04	-1.24	—
Ω_c^0	4.71	2.653	-0.75	-0.94	-1.07	—
Ξ_{cc}^{++}	4.27	3.538	0.12	0.31	0.18	—
Ξ_{cc}^+	4.27	3.538	0.66	0.90	0.95	—
Ω_{cc}^+	4.25	3.690	0.62	0.86	0.87	
Λ_c^+	4.63	2.273	0.36	0.63	0.48	—
$\Xi_c'^+$	4.58	2.396	0.36	0.61	0.48	—
$\Xi_c'^0$	4.58	2.396	0.36	0.61	0.48	
$\langle \Lambda_c^+ \| \Sigma_c^+ \rangle$	4.79	2.357	1.05	1.2	—	—
$\langle \Xi_c'^+ \| \Xi_c^+ \rangle$	4.75	2.507	0.97	1.12	—	—
$\langle \Xi_c'^0 \| \Xi_c^0 \rangle$	4.75	2.507	0.08	0.07	—	—
$J^P = 3/2^+$						
Δ^{++}	5.48	1.236	4.17	5.16	5.58	4.7–6.4
Δ^+	5.48	1.236	2.08	2.58	2.79	—
Δ^0	5.48	1.236	0	0	0	—
Δ^-	5.48	1.236	-2.084	-2.58	-2.79	—
Σ^{*+}	5.43	1.385	2.24	2.65	3.04	—
Σ^{*0}	5.43	1.385	0.17	0.141	0.25	—
Σ^{*-}	5.43	1.385	-1.89	-2.37	-2.54	—
Ξ^{*0}	5.39	1.533	0.33	0.28	0.50	—
Ξ^{*-}	5.39	1.533	-1.71	-2.17	-2.29	—
Ω^-	5.35	1.672	-1.54	-1.98	-2.04	—
Σ_c^{*++}	5.12	2.48	2.97	3.54	4.10	—
Σ_c^{*+}	5.12	2.48	1.02	1.35	1.4	—

Table 2. (*Contd.*)

			Magnetic moments			
Particles I	R (GeV)$^{-1}$ II	Mass GeV III	without recoil correction IV	with recoil correction V	with variable bag pressure VI	Experimental value VII
Σ_c^{*0}	5·12	2·48	−0·93	−0·85	−1·38	—
Ξ_c^{*+}	5·07	2·603	1·16	1·46	1·65	—
Ξ_c^{*0}	5·07	2·603	−0·76	−0·71	−1·13	—
Ω_c^{*0}	5·02	2·742	−0·612	−0·57	−0·88	—
Ξ_{cc}^{*++}	4·69	3·661	1·92	2·36	2·81	—
Ξ_{cc}^{*+}	4·69	3·661	0·14	0·41	0·26	—
Ω_{cc}^{*+}	4·64	3·795	0·27	0·52	0·28	—
Ω_{ccc}^{*}	4·21	4·827	1·08	1·45	1·43	—
Transition moment						
$\langle 1/2^+ \vert 3/2^+ \rangle$						
$\langle P \vert \Delta^+ \rangle$	5·48	1·236	1·96	2·43	—	3·38
$\langle n \vert \Delta^0 \rangle$	5·48	1·236	1·96	2·43	—	—
$\langle \Sigma^+ \vert \Sigma^{*+} \rangle$	5·48	1·385	1·78	2·23	—	—
$\langle \Lambda \vert \Sigma^{*0} \rangle$	5·43	1·385	1·67	2·05	—	—
$\langle \Sigma^0 \vert \Sigma^{*0} \rangle$	5·43	1·385	0·81	1·05	—	—
$\langle \Sigma^- \vert \Sigma^{*-} \rangle$	5·43	1·385	0·16	0·13	—	—
$\langle \Xi^0 \vert \Xi^{*0} \rangle$	5·39	1·533	1·77	2·18	—	—
$\langle \Xi^- \vert \Xi^{*-} \rangle$	5·39	1·533	0·16	0·13	—	—
$\langle \Sigma_c^{++} \vert \Sigma_c^{*++} \rangle$	5·12	2·48	0·87	0·80	—	—
$\langle \Sigma_c^+ \vert \Sigma_c^{*+} \rangle$	5·12	2·48	0·04	0·23	—	—
$\langle \Lambda_c^+ \vert \Sigma_c^{*+} \rangle$	5·12	2·48	1·59	1·79	—	—
$\langle \Sigma_c^0 \vert \Sigma_c^{*0} \rangle$	5·12	2·48	0·96	1·27	—	—
$\langle \Xi_c^* \vert \Xi_c^{*+} \rangle$	5·07	2·603	−0·025	+0·16	—	—
$\langle \Xi_c^0 \vert \Xi_c^{*0} \rangle$	5·07	2·603	0·88	1·18	—	—
$\langle \Omega_c^0 \vert \Omega_c^{*0} \rangle$	5·02	2·742	0·81	1·10	—	—
$\langle \Xi_{cc}^{++} \vert \Xi_{cc}^{*+} \rangle$	4·69	3·661	0·78	0·73	—	—
$\langle \Xi_{cc}^{+} \vert \Xi_{cc}^{*+} \rangle$	4·69	3·661	0·90	1·11	—	—
$\langle \Omega_{cc}^{+} \vert \Omega_{cc}^{*+} \rangle$	4·64	3·795	0·78	0·98	—	—

considerably improves the values clearly showing their presence and importance. The inclusion of such corrections may even violate relations among baryon magnetic moments earlier derived from symmetry considerations (Singh *et al* 1979) and thus reduces the usefulness of those relations. Though much work has been done on other corrections to baryon magnetic moments such as arising from configuration mixing (Isgur and Karl 1980), sea quark (Donoghue and Golowich 1977), baryon mass dependence (Teese and Settles 1979; Tomozawa 1979, 1982; Singh 1981; Das and Misra 1980), pionic corrections (Theberge and Thomos 1982), and relativistic corrections (Mignani and Prosperi 1983) an overall agreement with any of the above model could not be obtained. When our results are compared with those obtained in the bag model with a variable bag pressure (Joseph and Nair 1981; Chatley 1983), it is found that they are comparable. The movement of the quarks inside the bag is mainly responsible for recoil effects and since the position of the bag surface is determined by balancing the outward field pressure against the inward bag pressure *B*, this may not be a constant parameter (as taken in the original MIT bag model, Chodos *et al* 1974, De Grand *et al* 1975) but vary according to the nature of the quarks contained inside a particular bag (as taken by Joseph and Nair 1981). This may be the reason for getting comparable results. Although at present the experimental values for charmed baryon moments are not available, our results may be useful in other studies accessible to experimental verification.

Acknowledgements

Authors are grateful to Drs M P Khanna, R Prasad and T N Trivedi for useful discussions and Prof. B S Bhargava for encouragement.

References

Allen E 1975 *Phys. Lett.* **B57** 263
Ankenbrandt C *et al* 1983 *Phys. Rev Lett.* **51** 863
Barnes T 1975 *Nucl. Phys.* **B96** 353
Bunce R *et al* 1979 *Phys. Lett.* **B86** 386
Chodos A *et al* 1974a *Phys. Rev.* **D93** 471
Chodos A *et al* 1974b *Phys. Rev.* **D10** 2599
Chatley P K 1983 *Pramana* **20** 143
Das T and Misra S P 1980 *Phys. Lett.* **B96** 165
De Grand T *et al* 1975 *Phys. Rev.* **D12** 2060
Donoghue J F and Golowich E F 1977 *Phys. Rev.* **D15** 3421
Donoghue J F and Johnson K 1980 *Phys. Rev.* **D21** 1975
Hackman R H *et al* 1978 *Phys. Rev.* **D18** 2537
Hertzog D W *et al* 1983 *Phys. Rev. Lett.* **51** 1131
Hwang W Y P 1983 *Z. Phys. C* **16** 327
Isgur N and Karl G 1980 *Phys. Rev.* **D21** 3175
Jaffe R L and Kiskis J 1976 *Phys. Rev.* **D13** 1355
Joseph K B and Nair M N S 1981 *Pramana* **16** 49
Litchenberg D B 1977 *Phys. Rev.* **D15** 3455
Mariner J P *et al* 1982 Fermi Lab. Conf. D 82/85-Expt.
Mignani R and Prosperi D 1983 *Nuovo Cimento* **75** 221
Ponce W 1979 *Phys. Rev.* **D19** 2197
Rameika R *et al* 1984 *Phys. Rev. Lett.* **52** 581
Singh C P, Verma R C and Khanna M P 1979 *Pramana* **13** 261
Singh C P 1981 *Phys Rev.* **D23** 2085
Singh L P 1977 *Phys Rev.* **D16** 158
Teese R B and Settles R 1979 *Phys. Lett.* **B87** 111
Theberge S and Thomos A W 1982 *Phys. Rev.* **D25** 284
Tomozawa Y 1979 *Phys. Rev.* **D19** 1626
Tomozawa Y 1982 *Phys. Rev.* **D25** 795
Verma R C and Khanna M P 1977 *Pramana* **8** 462