Deviation from the Schmidt value for the magnetic moments of mirror hypernuclei with closed core+N+ Λ configuration $\left({}^{6}_{\Lambda}He, {}^{6}_{\Lambda}\mathrm{Li}, {}^{14}_{\Lambda}\mathrm{C}, {}^{14}_{\Lambda}\mathrm{N}\right)$

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Introduction

The study of nuclear structure of the hypernuclei has been carried out by various authors in either of the two complementary approaches, the shell-model or the cluster-model [1]. These authors have computed the magnetic moments of p-shell hypernuclei using well-developed cluster wavefunctions and shell-model configurations. In a later work *Tanaka* [2] has obtained the Schmidt diagram for magnetic moments of light hypernuclei with the *X-N-Y* configuration, where *X, N* and *Y* denote a nuclear core, a nucleon and a hyperon respectively, using shell model wavefuntion with good isospin. In an alternative approach *Radhey Shyam* et al [3] have considered the possibility of formation of six-quark matter by overlapping of nucleons using Hybrid Quark Model (HQM) approach. This new picture of overlapping nucleons and forming a six-quark bag can contribute significantly towards deviations of the magnetic moments from the corresponding single particle values.

In the present work we have calculated the magnetic moments of the hypernuclei in a hybrid quark model, with the configuration $X{-}N{-}\Lambda$. It is well known that the baryonic properties change inside a nuclear medium, thus the magnetic moment of Λ -hyperon well inside a six quark bag of ΛN would be different than that of the free hyperon. This can be a source of deviation of the magnetic moment values from the Schmidt limits.

As the experimental data on the magnetic moment of hypernuclei is still awaited [4], we have tried to look for the origin of this discrepancy in six-quark cluster formation effect. Our calculations are based on a Hybrid Quark Model (HQM). "In this model the nuclear matter has two phases. Two nucleons maintain their identity as long as the distance between them is greater than a certain cut of radius r_0, for distances smaller than r_0 the two baryons overlap and form a six-quark bag". Thus HQM retains the conventional meson- exchange picture at long distances and represents the effects a quantum chromodynamics (QCD) at short distances.

Formalism

In hybrid quark model, when the nucleon resides in a six-quark bag its effective magnetic moment is increased. The magnetic moments depend on the six-quark overlap probabilities and the effective magnetic moment of nucleon inside six-quark bag. The hyperon can from a six-quark bag with the core nucleons and the valence nucleons. If the average probability of the hyperon nucleon bag formation is $P^{6q}_{NN}(r_0)$ and the effective magnetic moments of hyperon inside the six-quark bag is μ'_{Λ} then magnetic moments of $X-N-\Lambda$ system are given by,

$$\mu_{Cal}=\frac{2j_N-1}{2j}\cdot\frac{2j_N+2}{2j_N+1}\mu_N-\frac{2j_N-1}{2j_N+1}\left[\left(1-P^{6q}_{\Lambda N}(r_0)\right)\mu_{\Lambda}+P^{6q}_{\Lambda N}(r_0)\mu'_{\Lambda}\right]\Big|J=j_N-\tfrac{1}{2}$$

And (1)

$$\mu_{Cal}=\mu_N+\left[\left(1-P^{6q}_{\Lambda N}(r_0)\right)\mu_{\Lambda}+P^{6q}_{\Lambda N}(r_0)\mu'_{\Lambda}\right]\Big|J=j_N+\tfrac{1}{2} \quad (2)$$

Where μ_N is the magnetic moment of the core nuclei. The experimental, Schmidt values and predicted magnetic moments of these nuclei are shown in Table 1. The predicted magnetic moments of hypernuclei have been compared with those of others work for ${}^{6}_{\Lambda}He$ and ${}^{6}_{\Lambda}\mathrm{Li}$ in Table 2.

Discussion

We have calculated the magnetic moments of few light hyprenuclei with $X\text{–}N\text{–}\Lambda$ configuration, where X donates the nuclear core $({}^{4}He, {}^{12}C)$ using equation (1) and (2). The predicted magnetic moments of ${}^{14}_{\Lambda}C$ and ${}^{14}_{\Lambda}N$ in Table1 are obtained using experimental and Schmidt values for the magnetic moments of the core nuclei. In the case of ${}^{5}He$ and ${}^{5}Li$ as there are no experimental data; we have used Schmidt values in the formulae. The six-quark bag formation probabilities of a hyperon with the nucleons $P^{6q}_{\Lambda N}(r_0)$ needed as input in equations (1) and (2) have been calculated in both Moshinsky and Slater methods for different sets of oscillator length parameters shown in Table 1. It is well known that because of the internal quark structure the baryonic properties differ in nuclei from those in isolation. Thus the effective magnetic moment of a hyperon μ'_{Λ} inside a six-quark hyperon-nucleon bag would be different than that of a free hyperon. Assuming that μ'_{Λ} increases in direct proportionality to the size of the six-quark bag we have taken $\mu'_{\Lambda}=\frac{4}{3}\mu_{\Lambda}$

Tables

Table 1: Magnetic moments of light nuclei

Nuclei	J^{π}	$\mu_{Exp}\,(n.m.)$	$\mu_{Sch}\,(n.m.)$
${}^{5}He$	$\frac{3}{2}^{-}$	--	-1.913
${}^{5}Li$	$\frac{3}{2}^{-}$	--	3.793
${}^{13}C$	$\frac{1}{2}^{-}$	0.7024	0.6377
${}^{13}N$	$\frac{1}{2}^{-}$	-0.3222	-0.2633
Hyper-nuclei	J^{π}	$\mu_{p}\,(n.m.)$	$\mu_{sch}\,(n.m.)$
${}^{6}_{\Lambda}He$	1^{-}	--	-1.288
${}^{6}_{\Lambda}Li$	1^{-}	--	3.467
${}^{14}_{\Lambda}C$	1^{-}	0.0894	0.0247
${}^{14}_{\Lambda}N$	1^{-}	-0.9352	-0.8763

μ_{Exp} , μ_{p} and μ_{Sch} are the experimental, predicted and Schmidt values of nuclear magnetic moment respectively.

Table 2: Comparison of predicted magnetic moments of A = 6 hypernuclei with X-N-Λ configuration with others work.

$\mu(n.m.)$	${}^{6}_{\Lambda}He$		${}^{6}_{\Lambda}Li$	
	Present Work (Method)			
	Moshin-sky	Slater	Moshin-sky	Slater
I	-1.281	-1.280	3.474	3.475
II	-1.287	-1.286	3.468	3.469
III	-1.286	-1.286	3.469	3.470
	Other work			
Motoba	-1.155	-1.382	3.322	3.976
Tanaka	-1.288	-1.301	3.467	3.461

I μ'_{Λ} = - 0.817 n.m. III μ'_{Λ} = - 0.662 n.m.

II μ'_{Λ} = - 0.7445 n.m. in Λn Bag
= - 0.7686 n.m. in Λp Bag

Conclusion

In the case of ${}^{6}_{\Lambda}He$ and ${}^{6}_{\Lambda}Li$ we have observed that even a sizable variation in six-quark probability for the formation of ΛN bag from 2% to 8% makes a very small contribution towards the change in magnetic moments from the Schmidt values. The magnetic moment of hyperon dependent terms contribute only about 16% of the total magnetic moment of ${}^{6}_{\Lambda}He \sim {}^{6}_{\Lambda}Li$. For ${}^{14}_{\Lambda}$C and ${}^{14}_{\Lambda}N$ (in continuation with previous work) [5], we have predicted their magnetic moments using both Schmidt and experiment magnetic moments of core nuclei. Any departure from predicted magnetic moment from the Schmidt values can be a possible signature for the quark effects.

Reference

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