A phenomenological study of quark structure of baryons

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The study of internal structure of baryons is one of the active areas in hadronic physics as it provides valuable insight into the nonperturbative aspects of QCD. In this energy regime, chiral constituent quark model with spin-spin generated configuration mixing (χCQM$_{\rm config}$) successfully explains the "Proton spin crisis" and other related properties [1–6]. In this work, we intend to extend the applicability of the model to study the other low energy hadronic matrix elements having implications for the flavor and spin dynamics.

The analysis for the flavor distribution functions has been carried out to study the role of the non-valence sea quarks in the octet baryons. The implications of symmetry breaking have also been investigated for the scalar matrix elements, role of hidden strangeness component y_N in the meson-nucleon sigma terms ($\sigma_{\pi N}, \sigma_{KN}, \sigma_{\eta N}$), and meson-baryon sigma terms for the Σ and Ξ. The significant contribution of the strangeness component and quark sea asymmetries are consistent with the recent available experimental observations [7]. The Bjorken scaling variable x has also been phenomenologically included in the antiquark flavor distribution functions to understand its implications on the quark sea asymmetry and Gottfried integral for the octet baryons. The results strengthen the importance of quark sea at lower values of x [8].

The weak vector and axial-vector form factors are an important set of parameters for investigating the spin dynamics of baryons as they are related to the experimentally observed Bjorken and Ellis-Jaffe Sum rules. We have investigated the weak vector and axial-vector form factors for the strangeness changing as well as strangeness conserving semi-leptonic octet baryon decays. The χCQM$_{\rm config}$ is successful in explaining the weak form factors at low Q^2. The detail implications of the $SU(3)$ symmetry breaking and configuration mixing have also been investigated. It is found that the results with $SU(3)$ symmetry breaking show considerable improvement over the $SU(3)$ symmetry results when compared with the existing experimental data and also show improvement over other phenomenological models [9]. The χCQM$_{\rm config}$ has been successfully extended to determine the CKM matrix element $V_{\rm us}$ for the strangeness changing decays [10].

Since the *intrinsic* charm (IC) contribution play an important role to understand the phenomenological implications of the presence of heavy quarks in the nucleon, the magnetic moment of spin $\frac{1}{2}^+$ and spin $\frac{3}{2}^+$ low lying and charmed baryons have been calculated by including the contribution from $c\bar{c}$ fluctuations. Explicit calculations have been carried out for the contribution coming from the valence quark polarization, "quark sea" polarization, and the orbital angular momentum of the quark sea. The implications of such a model have also been studied for magnetic moments of the low lying spin $\frac{3}{2}^+ \to \frac{1}{2}^+$ and $\frac{1}{2}^+ \to \frac{1}{2}^+$ transitions as well as the transitions involving charmed baryons. The predictions of χCQM$_{\rm config}$ not only give a satisfactory fit for the baryons where experimental data is available but also show improvement over the other models. In particular, for the case of μ_p, μ_{Σ^+}, μ_{Ξ^0}, μ_Λ, Coleman-Glashow sum rule for the low lying spin $\frac{1}{2}^+$ baryons and μ_{Δ^+}, μ_{Ω^-} for the low lying spin $\frac{3}{2}^+$ baryons, we are able to achieve an excellent agreement with experimental data. For the spin $\frac{1}{2}^+$ and spin $\frac{3}{2}^+$ charmed baryon magnetic moments,

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our results are consistent with the predictions of the other phenomenological models. For the transition magnetic moments, χCQM not only gives a satisfactory fit for the low lying baryons where experimental data is available but also gives predictions for the charmed baryons [11].

Charge radii and quadrupole moments are the lowest order moments of the charge density in a low-momentum expansion, containing fundamental information about the possible size and shape, respectively. The χCQM with general parameterization (GP) method has been formulated to calculate the charge radii for octet and decuplet baryons, and quadrupole moments for the octet, decuplet, and transitions baryons. The χCQM is successful in giving a fairly good description of the charge radii and quadrupole moments. The $SU(3)$ symmetry breaking parameters pertaining to the strangeness contribution and GP parameters pertaining to the one-, two-, and three-quark contributions are found to be the key parameters in understanding the nonzero values of charge radii for the neutral octet r_n^2, $r_{\Sigma^0}^2$, $r_{\Xi^0}^2$, r_Λ^2 and decuplet baryons $r_{\Delta^0}^2$, $r_{\Sigma^{*0}}^2$, $r_{\Xi^{*0}}^2$. For the quadrupole moments, our model predicts oblate shape for the proton, neutron, and Δ^+. These results are in line with the recent experimental observations and are also comparable with other phenomenological models.

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References

[1] S. Weinberg, Physica A **96**, 327 (1979); A. Manohar and H. Georgi, Nucl. Phys. B **234**, 189 (1984).
[2] T.P. Cheng and L.F. Li, Phys. Rev. Lett. **74**, 2872 (1995); **80**, 2789 (1998); Phys. Rev. D **57**, 344 (1998).
[3] X. Song, Phys. Rev. D **57**, 4114 (1998).
[4] J. Linde, T. Ohlsson, and H. Snellman, Phys. Rev. D **57**, 452 (1998); **57**, 5916 (1998).
[5] T. Ohlsson and H. Snellman, Eur. Phys. J. C **6**, 285 (1999); **7**, 501 (1999); **12**, 271 (2000).
[6] H. Dahiya and M. Gupta, Phys. Rev. D **64**, 014013 (2001); Int. Jol. Mod. Phys. A **19**, 5027 (2004); H. Dahiya, M. Gupta, and J.M.S. Rana, Int. Jol. Mod. Phys. A **21**, 4255 (2006); Phys. Rev. D **66**, 051501(R) (2002); **67**, 114015 (2003); **78**, 014001 (2008).
[7] H. Dahiya and N. Sharma, Mod. Phys. Lett. A **26**, 279 (2011).
[8] N. Sharma and H. Dahiya, Phys. Rev. D **81**, 114003 (2010).
[9] N. Sharma, H. Dahiya, P.K. Chatley, and M. Gupta, Phys. Rev. D **79**, 077503 (2009).
[10] N. Sharma, H. Dahiya, and P.K. Chatley, Eur. Phys. J. A **44**, 125 (2010).
[11] N. Sharma, H. Dahiya, P.K. Chatley, and M. Gupta, Phys. Rev. D **81**, 073001 (2010).