Strong decay channels for $N^*(1535)$ Baryon

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Introduction

The findings of baryon resonance decays offer important assistance for placing the resonances in the correct places within different symmetry schemes. The right isotopic spin assignment is likely to be implied by the experimental branching ratio into distinct charge states of particles produced by the decay, whereas phenomenological coupling constants can be extracted from the experimental decay widths.

Our earlier work has been targeted towards establishing the resonance spectra for higher states using a non-relativistic hypercentral Constituent Quark Model (hCQM) [1–5]. This model has been subjected to different potential terms as well as higher order correction terms to improve upon the hyperfine splittings. This allowed us to have data sets with all possible spin parity which have been compared with other models as well as experimental available states. Also, Juhi et al. has applied Regge Phenomenology for the resonance specta study [6].

The Hamiltonian on incorporating all the terms in potential appears to be,

$$H = \frac{P^2}{2m} + V(x) + V_{SD}(x) + \frac{1}{m}V^1(x) + \frac{1}{m^2}V^2(x) \quad (1)$$

Using the calculated masses for all light octet, decuplet baryons, the second step to the study of various decay properties. The magnetic moment and radiative decay widths have been explored for few channels.

Incorporating the recent additions,nearly 15 four star, 4 three star and many other experimental status have been explored with the values ranging from $J = \frac{1}{2}$ to $J = \frac{13}{2}$ and still many states are awaited of confirmation of existence as listed by Particle Data Group (PDG) [7].

Background for Strong decay channels

The pion decay channels have been dominantly observed in almost all the N^* states. However, there are other meson exchange resulting in the decay of N with mesons η, ρ, ω etc. Riska et al. have implemented chiral quark model to describe pion to nucleon coupling constant [8]. Experiments have shown a significant coupling of $N^*(1535)$ to ηN channel [9]. Also, naive quark model has shown that η meson may have strange quark component. This has lead to inclination towards details of possible hidden component in η channel for N(1535).

Quark models describe form factors as valence quark degree of freedom whereas chiral models suggest meson cloud effects for baryon meson resonances. Transition form factors have been calculated with various models as in coupled channel model [10], Ads/QCD [11], light front quark model, covariant model [12], holographic QCD [13], etc. Studies have looked for electromagnetic transition leading to N(1535) state as $\gamma N^* \rightarrow N(1535)$. It has been deduced that there seems to be some $s\bar{s}$ component in N(1535) state which makes a key element to explore more.

In last two decades, experiments namely ELSA, GRAAL, JLab, MAMI, etc have collected large data samples for nucleon resonances. Not only these, upcoming exper-

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iments like PANDA are focused for light baryon studies including strange sector [14, 15]. These are the leading factors to study nucleon sector in every possible way as it might provide us the insight of nature of QCD in confinement domain. $N^*(1535)$ Dalitz decay has been recently studied at HADES experiment [16].

Results and Discussion

In constituent quark model, $\mathrm{N}(1535)\frac{1}{2}^-$ is considered to be mixed state of $P^2\frac{1}{2}-$ and $P^4\frac{1}{2}-$. Also, the ratio to decay widths $N(1535) \rightarrow N\eta$ and that of $N(1535) \rightarrow N\pi$ is found to be in the range 0.82-1.71. This signifies that $N\eta$ channel is equally dominant.

An and Zao have studied this channel for 1535 with three and five quark component [17]. The lagrangian for the chiral quark model will give the coupling for baryons to light pseudoscalar mesons.

$$\mathrm{d}\Gamma_{N^*(1535)\rightarrow N\eta} = \frac{1}{16\pi^2}\frac{E' + m_N}{m^*}\left|\boldsymbol{k}_\eta\right|\left|T^{(\eta)}\right|^2 \mathrm{d}\Omega \tag{2}$$

The final form above gives the partial decay width for $N^*(1535) \rightarrow N\eta$ channel. where, $E^{'}$ is the energy of the final nucleon and k is momentum.

$$E^{'} = \frac{m^{*2} - m_\eta^2 + m_N^2}{2m^*} \tag{3}$$

$$k = \frac{\sqrt{[m^{*2} - (m_N + m_\eta)^2][m^{*2} - (m_N - m_\eta)^2]}}{2m^*} \tag{4}$$

However, in our earlier work, the resonance mass for 1535 state is obtained to be 1523 MeV. So, an attempt has been made to obtain the decay width for our results while using the coupling constants already obtained in the mentioned article and experimental data. Here, the mass of η meson is 547 MeV.

The partial decay width result for resonance predicted with hCQM using linear potential term and other order of correction terms yielding 1523 MeV is obtained to be 43.718. The results from extended chiral model have been 50.7 which is quite near to our prediction using the same formalism.

Thus, this study is just a starting point towards looking for all possible strong decay channels which allow us to better understand the nature of a given resonance. The theoretical models developed form the base for experimental studies and vice versa.

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