In-medium Λ interactions and hypernuclear structure

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We study the interactions of the octet baryons in a relativistic meson exchange approach connecting free-space and in-medium interactions with those in finite (hyper)nuclei. Our approach is based on the covariant meson exchange framework. To generate the effective microscopic interaction in finite nuclei an approach using T-matrix theory with a three dimensionally reduced two-nucleon propagator is applied. In this way the same mesons with the same bare couplings are used throughout the model. The in-medium interaction is calculated in Dirac-Brueckner theory, i.e. a T-matrix calculation in infinite matter where the intermediate two-baryon propagators are Pauli-blocked and dressed by Hartree-Fock self-energies. Since a G-matrix calculation for finite nuclei is technically not feasible the density dependent relativistic hadron field theory (DDRH) is used to apply the G-matrix interactions in calculations of finite nuclei [1, 2].

DDRH theory has been extended from the use in pure isospin nuclei to hypernuclei involving the octet baryons [3, 4]. As a preparatory step to a full G-matrix calculation for the complete baryon octet an approximate treatment of the hyperon-meson vertices was obtained from a diagramatic analysis of the Dirac-Brueckner equations. It was shown [3] that the strength has to be rescaled by a factor $R_{Y\alpha}$ which can in first order be related to the free coupling constants as $R_{Y\alpha} = \frac{g_{Y\alpha}}{g_{N\alpha}}$.

Recent experimental data measured at KEK on ${}^{89}_{\Lambda}Y$ and ${}^{51}_{\Lambda}V$ [5] show a significant broadening of the single particle peaks as compared to the experimental resolution. For a description of these data we took into account also the interaction of the Λ with the high core spin. This is accomplished by self-energies $\propto \vec{I} \cdot \vec{j}$. Taking into account also the high ground state spin of the ${}^{88}Y$ and ${}^{50}V$ cores with $I^\pi = 4^+, 6^+$, respectively, we performed a refit of the data. A strong reduction of the s.o. strength compared to the simpler fit in [5] is observed being consistent with high precision measurements of the s.o. splitting in ${}^{13}_{\Lambda}C$ [6].

The fairly small s.o. splitting brings into the game the formerly already discussed $\Lambda\omega$ tensor interaction (see, e.g., [7]) which is known to affect the s.o. splitting. According to spin-flavor SU(6) the tensor and vector vertices "f and g, respectively, are related by a minus sign, leading to an almost vanishing s.o. splitting. Including the tensor interaction we performed a least squares fit of DDRH Λ single particle energies to the experimental ones with respect to the variables R_σ, R_ω and f/g (which should be 2/3, 2/3 and −1, respectively, according to SU(3)), determining for the first time the $\Lambda\omega$ tensor vertex in a microscopic model. A very strong linear correlation between R_σ and R_ω is found, induced by the spectral gross structure. The results for ${}^{51}_{\Lambda}V$ are not very significant, those for ${}^{89}_{\Lambda}Y$ seem to favor, however, a strong breaking of SU(3). R_σ and R_ω turn out to be about 1/4 and f/g approaches 0 (from the negative side). The results for DDRH and NL3 differ in details but are otherwise fully consistent. Effects which are still under investigation and might lead to minor changes are for example the influence of deformations of the nuclear core. The comparison of DDRH RMF calculations with the experimental data using our newly extracted coupling parameters is displayed in fig. 1. In ref. [8] the approach was applied to the Auger-neutron spectroscopy of hypernuclei in preparation for a proposed JLab experiment.

The accuracy of the discussed experimental data is already at the limits of what can be expected from meson spectroscopy of hypernuclei. The large uncertainties in the determination of coupling constants emphasize the need for more precise measurements provided by the new era of γ spectroscopy in hypernuclei. On the theory side it will be essential to replace the approximate treatment of the in-medium Λ interactions by a fully microscopic one. Work on such a Dirac-Brueckner G-matrix calculation is in progress.

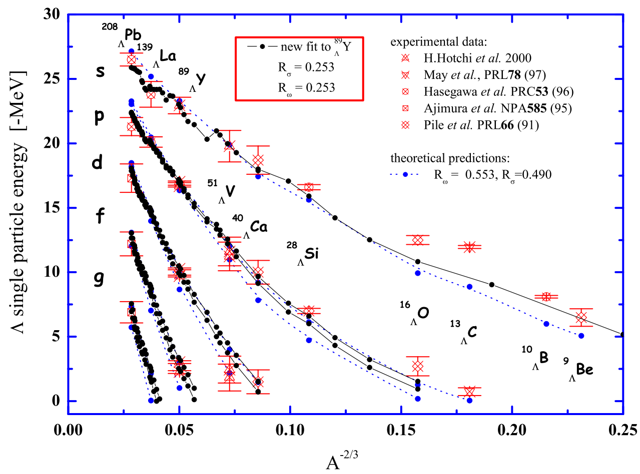

Figure 1: DDRH calculations of Λ single particle spectra compared to the world set of hypernuclear data.

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