A New Approach in the Relativistic Theory of Hypernuclei

F. Ineichen, M. K. Weigel , and D. Von-Eiff [a]

[a] Institut des Sciences Nucléaires, 53, Avenue des Martyrs, F-38026 Grenoble-Cedex, France

In this investigation we study Λ, Σ, and Ξ (multi-)-hypernuclei using a density-dependent relativistic Hartree scheme (DDRH) including rearrangement effects, i.e., extending the field theory of Ref. [1] to hypernuclear systems. Thereby, from the nucleonic point of view the model is free of adjustable parameters. There remains some "phenomenology" on the hyperonic sector. However, most of the realistic meson-exchange models for the hyperon-nucleon interaction available in the literature, accounting for existing hyperon-nucleon two-bodyscattering data, rely on SU(3) constraints to fix the vertices involving strange particles. We will show that within our model satisfactory results are obtained utilizing meson-hyperon couplings close to the corresponding SU(3) values. The DDRH results for Λ hypernuclei are compared with the outcome of a purely phenomenological relativistic mean-field model including σ- and ω-self-interactions.

To summarize, we have extended the covariant density-dependent nucleonic field theory to hypernuclear systems. Within this model rearrangement self-energies in the baryonic field equations arise. In particular, quark-model arguments indicate the necessity to include ω-hyperon tensor couplings in the description.

Self-consistent solutions were obtained in the Hartree limit. The density-dependent σ- and ω-nucleon couplings were adjusted to the outcome of DBHF calculations for INM, utilizing a LDA. With the constant isovector meson-nucleon coupling, $g_{\rho N}$, fixed to the value of the corresponding OBE potential, the model, compatible with free nucleon-nucleon data, remains free of adjustable parameters on the nucleonic side. Since the solution of the INM problem within the DBHF approximation is not a unique procedure, we considered two distinct approaches from the literature as a basis for our calculations. Firstly, the results of Brockmann and Machleidt who assumed a momentum-independent nuclear self-energy and fitted the positive-self-energy matrix elements in terms of the scalar and time-like self-energy components. Secondly, the results of Huber, Weber, and Weigel who performed DBHF calculations in the full Dirac space for (a)symmetric INM.

Concerning the meson-hyperon couplings, we fixed the constant ratios $x_{\omega Y} = \Gamma_{\omega Y}/\gamma_{\omega N}, f_{\omega Y}/\Gamma_{\omega Y}$, and $x_{\rho Y} = g_{\rho Y}/g_{\rho N}(Y = \Lambda, \Sigma, \Xi)$ by SU(3) symmetry. Hence, only $x_{\sigma Y} = \Gamma_{\sigma Y}/\Gamma_{\sigma N}$ remains as a phenomenological parameter to be fitted to available experimental data. Note, that by keeping these ratios constant, the density-dependence of the meson-hyperon couplings is determined by the density-dependence of the corresponding meson-nucleon vertex. This is an *ad hoc* assumption one has to rely on as long as there are no informations on in-medium modifications of hyperon-nucleon interactions available.

We investigated single Λ-, Σ-, and Ξ-hypernuclei as well as multi-Λ hypernuclei. For all these systems, the DDRH approach including rearrangement terms is capable to reproduce, even in detail, the features of purely phenomenological relativistic mean-field calculations, but with the conceptual advantage of a parameter-free description on the nucleonic side and meson-hyperon couplings mainly based on theoretical arguments. Together with the successful description of symmetric and asymmetric INM as well as "normal" nuclei this constitutes an additional proof for the DDRH approach to be, despite its simplicity, a powerful tool for the treatment of the (hyper)nuclear structure problem.

References

[1] H. Lenske and C. Fuchs, Phys. Lett. **B345** (1995) 355
C. Fuchs, H. Lenske, and H. H. Wolter,
Phys. Rev. **C52** (1995) 3043

[2] R. Brockmann and R. Machleidt, Phys. Rev. **C42** (1990) 1965

[3] H. Huber, F. Weber, and M. K. Weigel,
Phys. Lett. **B317** (1993) 485
Phys. Rev. **C51** (1995) 1790

[4] F. Ineichen, M. K. Weigel, and D. Von-Eiff, *Nuclear Structure Calculations in the Density-Dependent Relativistic Hartree Theory* Phys. Rev. **C** (in print)