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Hypernuclear Physics as a Probe for In-Medium Flavour Dynamics

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Hypernuclear physics is a strongly developing field of research at the intersection of nuclear and hadron physics. The high potential for new discoveries is evident by considering the rather limited data base. We may expect a similar development as for exotic nuclei with the multitude of unexpected new results on isospin physics obtained in recent years by the new RIB facilities. Hypernuclear physics is the logical next step by which we obtain access at least to the dynamics of the full fundamental baryon octet. At several facilities around the world strangeness production on elementary and composite nuclear targets is studied or plans are in preparation. The experiments range from photo- and electroproduction on the nucleon to hadronic reactions also on the nucleon and on any kind of nuclear target. At the new FAIR facility a unique program is in preparation using antiprotons to produce a hitherto unseen amount of single and double Λ hypernuclei. In a later stage, highly relativistic heavy ions will be used to produce hypernuclei in fragmentation reactions. At J-PARC high energy proton beams will be a suitable tool for strangeness production on nuclear targets.

On the theoretical side, the description of these various production scenarios and the explanation of the emerging hypernuclear fragments and their spectroscopy is a highly demanding task. At Giessen, we have been following in all mentioned sectors a strictly field theoretical approach which finally will provide us with theoretically compatible and exchangeable results from the producing reaction to the spectroscopy of the final systems. Strangeness production on the nucleon by photonic and hadronic reactions is described in a Lagrangian coupled channels K-matrix approach with direct production, meson exchange and excitation of baryonic resonances and their subsequent decay into hyperon states. The resonance model is also used in pion and proton-induced reactions on the nucleon and on nuclei. Similar mechanisms are active in hypernuclear production in highly relativistic heavy ion reactions which we describe by transport theory and a statistical fragmentation model. Results for the various production reactions will be discussed.

A successful approach to the structure of hypernuclei is the Giessen DDRH theory. We obtain an ab initio approach to nuclear matter and nuclear structure by starting from a Lagrangian formulation of free space interaction. In-medium nucleon and hyperon interactions are derived by Dirac-Brueckner (DB) theory. From the solutions of the Bethe-Salpeter equation we determine density dependent coupling constants. Theoretically, this amounts to map the original Lagrangian to an effective Lagrangian with vertex functionals depending on the field operators, defined such that in mean-field approximation the DB-ladder series are exactly cancelled. The approach has given rise to a variety of phenomenological approaches exploiting the DDRH mechanism in terms of empirical parametrizations. DDRH theory describes stable and unstable isospin nuclei quite accurately on the level of a few percent or better. The same degree of accuracy is found for the existing single Λ hypernuclear data except for the lightest elements. An interesting aspect is ΛΣ0 mixing in nuclei with a strongly charge asymmetric core, leading to the dynamical distinction of mass and flavour eigenstates. Neutron star calculations show a remarkable sensitivity of the results on the nucleon and hyperon interactions. Overall, an interesting aspect is the close interdependence of the various sectors and aspects of in-medium strangeness dynamics and flavour physics.