Applications of chirally motivated meson-baryon coupled channel model

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Meson-nucleon interactions

- hadrons (and quarks) interact through strong interaction that is in effect responsible for the nuclear force
- the pertinent quantum theory is quantum chromodynamics (QCD), but it is unperturbative at low energies due to large coupling constant
- effective field theories introduced by Weinberg in 1979 to give qualitatively correct results in situations when the application of a proper quantum field theory is difficult (if not impossible): using the most general Lagrangian that is consistent with the symmetries of the underlying theory
- chiral perturbation theory (ChPT) is the QCD effective theory at low energies, based on spontaneous chiral symmetry breaking (would be an exact QCD symmetry for massless quarks)
- the degrees of freedom are no longer quarks (and gluons) but rather hadrons (reflects quark confinement)
- our approach: describe coupled channel interactions of the meson octet with the baryon octet on the basis of the ChPT

Coupled channels meson-baryon interactions

$\bar{K}N$ system	$\pi\Lambda$	$\pi\Sigma$	$\bar{K}N$	$\eta\Lambda$	$\eta\Sigma$	$K\Xi$
ηN, $\eta' N$ system	πN	ηN	$K\Lambda$	$K\Sigma$	$\eta' N$	

strongly interacting multichannel systems with dynamically generated resonances: the $\Lambda(1405)$, just below the $K^- p$ threshold, or $N^*(1535)$ above the ηN threshold

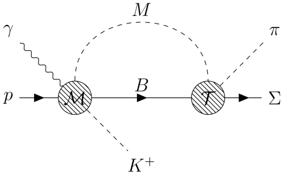
our understanding of elementary meson-nucleon interactions at low energies has impact on a broad field of physics phenomena:

- structure of hadron resonances (hadronic molecules? pentaquarks?)
- energy levels of exotic atoms (e.g. kaonic atoms)
- meson-nuclear quasi-bound states (do they exist? can they be observed?)
- few-body systems including strange hadrons
- meson-baryon correlations in high energy collisions (heavy ions, *pp*)
- equation of state of compact astrophysical objects (e.g. neutron stars)

Topic 1: meson-baryon photoproduction

We have already started with $\pi\Sigma$ photoproduction, $\gamma p \longrightarrow K^+\pi\Sigma$, a reaction in which MB rescattering is relevant in the final state. Simple model, CLAS data reproduction not quite satisfactory.

two-step process with the final state interaction of the MB pair accounted for:



- leading-order BχPT used to derive expressions for the photoproduction amplitude $\mathcal{M}$ constructed from tree level graphs (WT, Born and anomalous)
- $\pi\Sigma - \bar{K}N$ coupled channels models provide the $\mathcal{T}$ amplitudes, that describe the MB re-scattering
- task for a student - improvement of the $\mathcal{M}$ part including the contributions of vector mesons
- alternative task - similar treatment of the $\gamma p \longrightarrow \eta n/\eta' n$ process (no kaon emitted)

Topic 2: femtoscopic meson-baryon correlations

- New type of data: femtoscopic MB correlation functions measured in high energy heavy-ion or pp collisions at LHC, i.e. correlations of the out-going hadrons due to their FSI.

$$C_j(p) = \sum_i w_i \int d^3r \, S_i(r) \, |\Psi_{ji}(p,r)|^2$$

  w_i and $S_i(r)$ - statistical weights and source functions of all i-particle pairs produced initially in the high-energy collision

  $\Psi_{ji}(p,r)$ - relative wave function for the measured pair j containing information on the $i \to j$ transition

- The theoretical analysis of the $K^- p$ femtoscopic data requires a treatment of Coulomb interaction, a tricky business in the momentum space as the interaction is divergent for $p \to 0$.
- task for a student - develop a computer code to compare the calculated MB correlation functions with the available experimental data

Literature

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