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: $\Lambda(1405)$, just below the $K^- p$ threshold, or $N^*(1535)$ above the ηN threshold

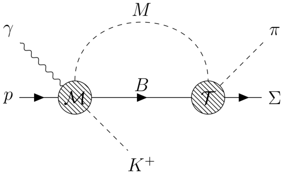
our understanding of elementary meson-nucleon interactions at low energies has impact on a broad field of physics phenomena:

- 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)

Example: meson-baryon photoproduction

$\pi\Sigma$ photoproduction in the $\gamma p \longrightarrow K^+\pi\Sigma$ reaction

Simple model: two-step process, 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
- similar treatment of the $\gamma p \longrightarrow \eta n/\eta' n$ process (no kaon emitted) is possible

Possible tasks for students

- New type of experimental 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. Their theoretical analysis requires a treatment of Coulomb interaction.
  task for a student - implement the Coulomb interaction in our *MB* models; a tricky business in the momentum space as the interaction is divergent for $p \to 0$
- Our $\pi\Sigma$ photoproduction model does not reproduce quite well the experimental data in channels combining the isoscalar and isovector contributions.
  task for a student - improve the treatment of isospin effects in our *MB* coupled channel model
- other possibilities - development of similar models for interactions of charmed hadrons or iteractions of vector mesons with baryons

Literature

general intro - *J. R. Taylor – Scattering theory, The quantum theory on nonrelativistic collisions, John Wiley & sons (1972)*

S. Weinberg - Phenomenological Lagrangians, Physica A 96, 327 (1979)

$\bar{K}N$ model - *P. C. Bruns, A. C., Nucl. Phys. A 1019, 122378 (2022)*

ηN model (no $\eta' N$) - *A. C., J. Smejkal - Nucl. Phys. A 919, 46 (2013)*

(with $\eta' N$) - *P. C. Bruns, A. C. - Nucl. Phys. A 992, 121630 (2019)*

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