Contribution ID: **27** Type: **Oral presentation**

QCD-Based Charge Symmetry Breaking Interaction and Okamoto-Nolen-Schiffer Anomaly

Thursday, 27 June 2024 09:40 (20 minutes)

An anomaly in the energy differences of mirror nuclei and isobaric analogue states (IAS), not yet well understood from a microscopic point of view, was found more than 50 years ago and is called the Okamoto-Nolen-Schiffer (ONS) anomaly. A systematic study from light to heavy nuclei within the framework of the independent-particle model found that the theoretical values of the energy difference underestimate always the experimental values by 3–9%.
A possible main source to cure the gap is the charge symmetry breaking (CSB) nuclear interaction. However, both the magnitude and the sign of the parameters in CSB interactions have not been well determined from phenomenological studie.

The aim of this study is to provide a quantum chromodynamics (QCD)-based understanding of CSB by making a quantitative link between the Skyrme-type CSB interactions and the CSB effect due to the u-d quark mass difference in QCD. A novel approach is proposed to link the CSB nuclear interaction and the low-energy constants in QCD and the density dependence of chiral condensation of $q^{-}q$ pair in the nuclear medium for the first time.

The resulting QCD- based CSB interaction is applied to resolve the ONS anomaly: the numerical results for the mirror nuclei (A = 16±1 and A = 40±1 with the isosymmetric core N = Z = A/2) with the two Skyrme EDFs show good agreement with experimental data both in sign and magnitude within the theoretical error bars. Other several possible effects on ONS anomaly were also considered in the study. Major theoretical uncertainty of the final results originates from the low-energy constants of QCD. Increasing the accuracy of these constants from the experimental data or from the lattice QCD simulations will be instrumental. The QCD-based CSB interaction discussed here would have strong impact on isospin symmetry breaking phenomena such as IAS, the super-allowed β decay in the context of Cabibbo-Kobayashi-Maskawa unitary matrix, and the mass predictions of isobar and isotriplet nuclei near the proton drip line.

Further extension of QCD-based isospin breaking forces (IBS) including the charge invariance breaking (CIB) will be discussed in the study of IAS and also hypernuclei.

Collaboration

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Session Classification: Thursday morning 1