

Bootstrapping Two-Nucleon Effective Field Theories

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Abstract. This work presents a rigorous evaluation of theoretical and statistical consistency in Two-Nucleon (NN) Effective Field Theories (EFTs) by combining the exact N/D method with a robust bootstrap fitting methodology. Standard implementations of Chiral EFT (χ EFT) rely on the Lippmann-Schwinger equation to iterate regularized potentials, an approach that frequently introduces fixed-cutoff artifacts and complicates non-perturbative renormalization when dealing with highly singular attractive forces at short distances. To address these limitations, we implement the analytical N/D method, which separates the scattering amplitude into a numerator (N) and a denominator (D), encoding the left-hand and right-hand cuts respectively. By incorporating multiple subtractions into the dispersion relations, short-range information is mapped directly to Effective Range Expansion (ERE) parameters: scattering length (a), effective range (r) and shape parameter (v_2), effectively bypassing explicit ultraviolet (UV) regulators and eliminating cutoff-dependent distortions.

The stability and convergence of this framework are scrutinized in two phases. First, a controlled toy model featuring regular and singular potentials is constructed to establish the validity limits of Leading Order (LO) and Next-to-Leading Order (NLO) descriptions. By generating 2,000 synthetic bootstrap experiments under Gaussian noise, we perform a precise residual analysis ensuring that the extracted χ^2/dof behaves consistently as a statistical distribution close to unity. Second, the framework is validated against real-world physical scattering data, targeting the 1S_0 partial wave from the high-precision Granada np database. The statistical bootstrap analysis reveals that while the LO description breaks down rapidly beyond momenta of $k \approx 150\text{--}175$ MeV, the explicit inclusion of NLO chiral forces systematically extends the range of statistical consistency up to $k_{\text{max}} \approx 250$ MeV. Furthermore, the N/D approach yields highly stable extrapolations up to 400 MeV, demonstrating that combining exact dispersive methods with bootstrap criteria provides a powerful, regulator-independent tool for quantifying theoretical uncertainties in nuclear interactions.