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Nucleon-Nucleon Data

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Abstract

This is the final report of a one-year, Laboratory Directed Research and Development (LDRD) project at Los Alamos National Laboratory (LANL). This work completes the determination of the nucleon-nucleon (NN) scattering amplitudes from 485 to 800 MeV. The data set is completed by the publication of two papers. These new data have a precision better than 1% and an absolute accuracy about 1%, which is generally an order of magnitude better than previous data. The NN data set is now complete and consistent. The set of spin-dependent NN-scattering amplitudes is now well determined up to 800 MeV.

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Background and Research Objectives

Nucleon-nucleon (NN) data are fundamental to nuclear physics. A precise knowledge of the NN-scattering amplitudes is an essential prerequisite for microscopic models of the nucleus. In addition, NN data are used as a fundamental test of the strong interaction, and as a basic standard for the normalization of nucleon-nucleus data.

A complete description of NN scattering at a particular angle and energy requires 10 complex scattering amplitudes. These may be derived directly from 20 independent measurements or deduced from a smaller number of measurements via a phase-shift analysis supplemented by dispersion relations.

The phase-shift approach works well at lower energies, especially near or below the pion-production threshold, where the number of orbital angular momentum states is small and the inelastic channels are negligible or confined to one resonant state. At higher energies (>500 MeV) the number of angular momentum states becomes comparable with the number of amplitudes, and the inelasticity becomes more complicated. The problem of extracting a unique solution is compounded by incorrect or inaccurate data. Consequently, more than 20 independent experiments are required.

Importance to LANL's Science and Technology Base and National R&D Needs

Neutron scattering involves both isospin-zero and isospin-one states. The isospin-one amplitudes are most easily measured via the proton-proton (pp) interaction, while the isospin-zero amplitudes must be obtained from neutron-proton (np) scattering. Thus, both pp and np data are essential for a complete understanding. The work reported here completes the measurement of both pp and np scattering.

Scientific Approach and Accomplishments

The publication "Absolute pp-Elastic Cross Sections from 492 to 793 MeV" describes the world's most accurate measurement of pp scattering, with absolute accuracy better than 1%.¹ These data have stabilized the phase-shift solutions, especially near 650 MeV where the opening of several inelastic channels gives rise to a resonance-like,

energy-dependent structure in several observables. These data complete the set of 15 pp observables and lead to a unique set of isospin-one phase shifts and amplitudes.

The publication "np-Elastic Analyzing Power at 485 and 788 MeV" describes the world's most accurate measurement of np scattering, with point-to-point precision of 0.004 and absolute accuracy of 2%.² These new data resolve a long-standing controversy on the absolute normalization of the polarized neutron beams and clarify the isospin-zero inelasticity, showing that it is coupled to a pair of delta resonances. Since 788 MeV is far below the mean energy of a pair of deltas (1380 MeV), this implies that the isospin-zero inelasticity is small near the maximum energy of the Los Alamos Neutron Science Center (LANSCE) accelerator.

Publications

1. Simon, A.J., et al., "Absolute pp-Elastic Cross Sections from 492 to 793 MeV," *Phys. Rev. C* **53**, 30 (1996).
2. McNaughton, M.W., et al., "np-Elastic Analyzing Power at 485 and 788 MeV," *Phys. Rev. C* **53**, 1092 (1996).

Figure 1. np-elastic analyzing power at 788 MeV, in comparison with the phase-shift fits of Arndt and Bugg, and previous data.

Figure 2. pp-elastic differential cross section at 492 MeV, in comparison with the phase-shift fits of Arndt and Bugg, and previous data.