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MEDIUM-ENERGY THEORY GROUP

PROGRESS REPORT

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Abstract

We report on research carried out during the contract period by R. A. Bryan, principal investigator, and associates R. B. Clark and B. J. VerWest. The research has centered on the nucleon-nucleon interaction at medium energies, with especial emphasis on the reaction $NN \to NN\pi$ up to 800 MeV. Elastic NN scattering near the pion production threshold has also been investigated, both through phase-shift analysis of data and theoretical interpretation of the intermediate-range force. The quasi-elastic amplitude $N\bar{N} \to \pi\pi$ for $4m_\pi^2 \leq t \leq 50m_\pi^2$ has been studied because of its bearing on the NN problem; a simple but useful model has been developed. Finally, work on the pion-photoproduction reaction $\gamma N \to \pi\Delta$ has been completed, and the close correspondence with the amplitude $NN \to NN\pi$ exploited.

In the past year much effort has gone into theoretical investigation of the nucleon-nucleon interaction at intermediate energies. We have launched a major program to calculate pion production in NN scattering from 300 to 800 MeV. This has necessitated setting up a Dirac matrix-algebra reduction code (REDUCE) on a computer to handle the formidable mathematics. We have also continued to study elastic NN scattering near the production threshold, first by reducing the experimental data themselves to phase shifts,[1,2] and second by using this knowledge of the physical S-matrix to determine the NN force at intermediate range.[3] The phase-shift analysis research has required setting up and modifying a major computer code (EDPS). Since the $N\bar{N} \to \pi\pi$ amplitude in the range $4m_\pi^2 \leq t \leq 50\, m_\pi^2$ plays a major role in our understanding of the NN interaction, we have continued expending effort to better understand this amplitude and search for reasonable analytical representations. Finally, work was completed on a model for pion-photoproduction in the reaction $\gamma N \to \pi\Delta$ (Ref. 4); the experience gained in treating this process via a vector-dominance model has been immediately applicable toward calculation of vector-meson-exchange contributions to $NN \to NN\pi$, an important correction to simple pion-exchange pion-production. We now give in more detail the results that have been achieved during the past year.

NN π Production (B. J. VerWest, R. B. Clark and R. A. Bryan)

We have begun a long-term project to study the dynamics of the reaction NN $\rightarrow$ NNπ. All of the kinematics for the three-body final state and the related cross sections have now been done along with the rechecking and recomputing of the earlier peripheral model calculations of Ferrari and Selleri, and Drechsel and Weber. These calculations are now being used as a starting point for new and more detailed calculations.

In the past year we have also been in contact with the experimental groups at LAMPF measuring pion production. There is a great deal of new data on this reaction and more to be measured in the near future. It is these new angular-distribution data that have revealed the failures of the earlier theoretical models. The groundwork for this project is now in place, and we are now beginning to study the contributions of previously omitted reaction mechanisms such as ρ-exchange in hopes of explaining these new data.

REDUCE: A Symbolic Language for Algebraic Manipulations in Particle-Physics Calculations (R. B. Clark and B. J. VerWest)

During the past year a version of the symbolic REDUCE language developed by A. C. Hearn has been implemented on the Amdahl 470. This language provides the facility to perform algebraic calculation by computer for the complex relativistic calculations involving the manipulation of Dirac matrices and spinors. The language has been used successfully for the calculations of the spinor traces for the general one-

pion-exchange contributions in the NN → NNπ problem. Presently the matrix manipulation facility of REDUCE is being utilized in the projection of the invariant production amplitudes for NN → NNπ onto the associated helicity amplitudes for this process.

Phase-Shift Analysis of Nucleon-Nucleon Scattering Data (R. A. Bryan)

We have carried out phase-shift analysis in one of the troublesome areas of nucleon-nucleon experiment, I = 0 states near 325 MeV (Ref. 1,2). Our previous analysis has been confirmed by new np D_t data taken at 325 MeV at TRIUMPF by the BASQUE group. These newly determined phase shifts are important for the understanding of the NN force at intermediate distances.

EDPS: A Computer Code for NN Phase Shift Analysis (B. J. VerWest and R. B. Clark)

A version of the computer code EDPS from P. Signell at Michigan State University was obtained and modified to suit our computer and our specific needs. This involved changing the machine-language routines, machine-dependent features, some options and adding automatic data-plotting routines. The code was debugged and checked and is now being used productively for NN phase shift analysis.

The Nucleon-Nucleon Interaction at Intermediate Distances (R. A. Bryan)

Recent phase-shift analysis at 325 MeV (Ref. 1,2) has confirmed

earlier speculation[3] that current dispersion-theoretical nucleon-nucleon potential models overestimate the strength of the tensor potential near 1.2 - 2 F in isospin-zero states. We have shown that no allowable variation in two-pion-exchange processes is likely to restore a fit to the phase-shift data, but that heretofore-neglected three-pion-exchange, in the form of a pion-nucleon form factor, can bring about much-improved agreement.[3]

Models for $N\bar{N} \to \pi\pi$ J = 0 and 1 Helicity Amplitudes for $4m_\pi^2 \leq t \leq 50m_\pi^2$

(J. W. Durso (Mt. Holyoke), A. D. Jackson (Stony Brook) and B. J. VerWest)

Due to the importance of the process $N\bar{N} \to \pi\pi$ in the study of the NN interaction, it is mandatory that we understand the dynamics of this reaction. We have constructed models which reproduce the empirical information available for this process and bring out the important dynamical features. In particular, the relative contributions of isobar intermediate states and $\pi\pi$ rescattering in the NN interaction have been determined using this model. The full results of this calculation are now being typed for submission to Nuclear Physics A.

Amplitudes for the Reaction $\gamma N \to \pi^{\pm}\Delta$ (R. B. Clark)

Non-diffractive pion-production processes continue to be of interest not only in their own right, but also for the role they play as intermediate states in pion-production processes and in multiple-meson-exchange contributions. During the past year we have extended our earlier work on the $\gamma N \to \pi^{\pm}\Delta$ reaction (ORO-5223-04) to include model

predictions for the density matrix elements associated with the production of the Δ in various helicity states by polarized photons.[4] Comparison of the predicted density matrix elements with experimental data could provide a sensitive test of the relative phases of the background amplitude and various exchange-contributions. Unfortunately the statistics of the present experimental data are very poor so that low-χ^2 comparisons of the simple gauge-invariant model with data are obtained, but do not presently provide a definitive test of the phase relationships predicted by the model. More accurate data are required.

The principal investigator, R. A. Bryan, Professor, and the other investigators, R. B. Clark, Associate Professor, and B. J. VerWest, Assistant Professor, all of the Physics Department of Texas A&M University, have each spent about 50% of their time during the nine-month academic year on this contract. Full time is spent during the summer months as indicated in the budget.

Papers prepared for publication during contract period:

1. "Unique isospin-zero phase-shift solution for nucleon-nucleon scattering," R. A. Bryan, R. B. Clark, and B. J. VerWest (ORO-5223-08), Physics Letters B (in press).
2. "Effect of recent neutron-proton D-transfer measurements on phase-shift analysis near 325 MeV," R. A. Bryan, R. B. Clark, and B. J. VerWest (ORO-5223-09), submitted for publication to Physical Review C.
3. "Observations on the intermediate-range nuclear force predicted by recent dispersion-theoretical potentials," R. A. Bryan (ORO-5223-10), submitted for publication to Physical Review C.
4. "A simple dynamical model for $\gamma N \to \pi^{\pm}\Delta$," R. B. Clark (ORO-5223-04, revised), submitted for publication to Physical Review D.

Papers published in journals during contract period:

*5. "The πNN vertex function," J. W. Durso, A. D. Jackson, and B. J. VerWest (ORO-5223-07), Nuclear Physics A 282, 404-424 (1977).

*6. "Charmed-meson production in electron-positron annihilation," B. Humpert and R. B. Clark (ORO-5223-06), Physical Review D 16, 1327-1333 (1977).

*reported in progress report for previous year