OSTI

DOE/ER/40461--4

DE92 008587

THEORETICAL NUCLEAR REACTION AND STRUCTURE STUDIES USING HYPERONS AND PHOTONS

Progress Report

January 1991 - December 1991

Stephen R. Cotanch

Department of Physics

North Carolina State University

Raleigh, North Carolina 27695-8202

PREPARED FOR THE U. S. DEPARTMENT OF ENERGY
UNDER GRANT NUMBER DE-FG05-88ER40461

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

This report details research progress and results obtained during the 12 month period from January 1991 through 31 December 1991. The research project, entitled "Theoretical Nuclear Reaction and Structure Studies Using Hyperons and Photons", is supported by grant DE-FG05-88ER40461 between North Carolina State University and the United States Department of Energy. In compliance with grant requirements the Principal Investigator, Professor Stephen R. Cotanch, has conducted a research program addressing theoretical investigations of reactions involving hyperons and photons. The Principal Investigator has devoted 50% of his time during the academic year and 100% of his time in the summer. This percent effort will continue for the remaining period of the grant. The new, significant research results are briefly summarized in the following sections. Recent progress has also been discussed in the renewal/continuation grant proposal just submitted to the Department of Energy. Finally, full, detailed descriptions of completed work can be found in the project publications which are listed at the end of this progress report.

ELEMENTARY HADRON STRUCTURE

This project seeks to further the understanding of hadron structure within the framework of Quantum Chromodynamics (QCD) and QCD based models. In the last funded period several significant findings have been obtained. As detailed in our recent published paper[2,6] (at the end of this report) we (with C. R. Ji and P. L. Chung) have performed a comparative study of meson properties using our previously extended Dziembowski's model and the Hamiltonian light-front approach developed by Coester and Chung. Both models have been applied to the open flavor pseudo-scalar (π, K, D) vector (ρ K^*) and pseudo-vector (a_1) mesons and we have obtained a good description of their static properties. Major findings include: 1) both models can describe meson charge radii and decay constants but only the Hamiltonian approach can properly account for the form factor high Q^2 behavior; 2) only the extended Dziembowski's model can give a camel shaped (double-peaked) quark distribution amplitude when plotted as a fraction of the meson momentum carried by the quarks; 3) the first six moments of the meson quark distribution amplitudes computed in the Hamiltonian light-front model reproduce the basic features predicted by both lattice QCD and QCD sum-rule methods; 4) a proper spin covariant wavefunction for the a_1 meson was derived which is consistent with the Melosh transformed light cone spin wavefunction. Concerning the camel shape quark distribution amplitude for the pion, this is a controversial issue since this signature is not predicted by all QCD lattice and QCD sum-rule calculations. Further, the extended Dziembowski model can only obtain this shape using a model parameter which gives too small decay constant. While additional study is still necessary, it is clear that the Hamiltonian light-front approach is superior to the Dziembowski model. Finally, significant progress was made in developing a simple yet consistent relativistic Hamiltonian light-front model the meson spectrum in which a new method for adding the two-body confining interaction is introduced. We find it is possible to describe both the mas spectra and various electroweak meson properties. This work has been submitted for publication[6].

ELECTROMAGNETIC PRODUCTION OF STRANGENESS

This project addresses systems involving the strange quark (hyperons) and investigates hyperon electromagnetic production and radiative capture processes. During the past funding period a number of new, important research results were generated. In collaboration with R. Williams and C. R. Ji, we completed our study of the strangeness reactions $p(\gamma, K^+)Y$ and $p(K^-, \gamma)Y$ (cross sections and polarization data) for $Y = \Lambda$ and Σ[1] using our unified model based on Quantum Hadrodynamics which incorporates crossing symmetry and duality. We also extended this model to electroproduction and analyzed the world's (limited) data below 2.5 GeV. Most significantly, the model could describe the data for both Λ, $\Lambda(1405)$ and Σ production at energies up to 1 GeV above threshold. To this end we determined that the analysis is sensitive to the electromagnetic form factors and for the kaon we used the extended vector dominance prescription which provides a good description in both space-like and time-like regions. For energies beyond 1 GeV above threshold we determined that it is necessary to include higher final state partial waves (only s and p waves are included in our relativistic, Quantum Hadrodynamic model). We also extended our use of duality by including t- channel vector K*(890) and pseudovector K*(1270) mesons. This work has been submitted for publication[5]. We have also obtained preliminary results from utilizing the crossing feature of our model for the reaction $p(K^-,e^+e^-)Y$ and find that this reaction can provide important meaningful information about the kaon form factor in the time-like region.

Our results will not only impact upon CEBAF and SLAC but also the kaon factories (KEK, KAON).

MEDIUM ENERGY PHOTONUCLEAR REACTIONS

Significant, interesting results have been obtained in this continuing project during the previous funding period. As detailed in recent invited talks[8] and publications[3,4], we have performed a large-scale continuum shell model calculation for (γ, p) and (p, γ) reactions at low and medium energies spanning the Δ isobar region. This is a microscopic calculation in which a realistic many-body Hamiltonian H for the A baryon system is diagonalized in a large Banach space (not Hilbert since the continuum basis states are not square integrable) spanned by products of continuum single-particle states and known bound many-body eigenfunctions of the A-1 system.The Hamiltonian contains a realistic effective interaction with finite range, spin, isospin and tensor components. The code is flexible and can accommodate a variety of two-body forces including those based on multi-boson exchange. Diagonalizing H in this space generates a large set of coupled inhomogeneous integro-differential equations in two variables (r and r' due to non-localities) to be solved, subject to appropriate scattering boundary conditions, for the unknown partial-wave scattering functions. All non-localities are retained in the radial kernels due to wavefunction antisymmetrization, Pauli blocking and exchange. Since the large number (up to 100 currently) of scattering channels rigorously account for loss of flux from the elastic channel there is no direct need for phenomenological absorption and H therefore remains Hermitian which assures proper wavefunction orthogonality that is especially important in photonuclear reactions. Further, the code rigorously respects unitary and gauge-invariance.

During the last funded period we ported and vectorized our code on the local North Carolina Cray Y-MP supercomputer (we have submitted a grant and were funded for 125 hours of time by the North Carolina Supercomputer Center). We have completed and published[3,4] calculations (without exchange currents) for the ground and first excited state in ^{12}C, which is not a closed shell nucleus, especially the 2^+ excited state. We needed to use an extended multiparticle - multihole basis for the A=11 system and included the first 5 excited states in ^{11}C and ^{11}B ($1/2^-_1$, $3/2^-_2$, $5/2^-_1$ $3/2^-_2$ $7/2^-_1$). The extended model calculation requires 48 channels for each J^π (again with a small radial mesh). Hence the calculation is tantamount to inverting a very large super matrix of the order 20,000 by 20,000 for each J^π at each energy. These calculations are still too taxing for our theory group computer (an IBM 320 reduced instruction set high speed workstation). However, with additional funding we believe we can upgrade our system to permit competitive runs with the Cray. This is important for improved productivity since we can only use the Cray at night.

In addition to ^{12}C we have also analyzed $^{16}O(\gamma, n)^{15}O$ medium energy data including Δ isobar exchange currents. We find Δ isobar effects to be quite important both above and below the Δ isobar threshold and that such effects are necessary to understand the data. We are in the process of publishing these findings. We have also performed polarization calculations for the related reaction $^{16}O(p,\gamma)^{15}N$ and based upon our results a proposal for beam time to do this experiment has been approved at the Svedberg Laboratory in Uppsala, Sweden. We are in the process of performing the Δ calculation for ^{12}C now.

PAPERS PUBLISHED IN PRESS OR SUBMITTED IN THE REPORT PERIOD

1. "Crossing and Duality Study of Λ, Σ^o, and $\Lambda(1405)$ Production by Kaon Photoproduction and Radiative Capture", R. Williams, C.-R. Ji and S. R. Cotanch, Phys. Rev. C43, 452(1991).

2. "Light-Cone Quark Model Axial Vector Meson Wavefunction", C.-R. Ji, P. L. Chung and S. R. Cotanch, Phys. Rev. D, in press (1992).

3. "The (p, γ) Reaction at Intermediate Energies", B. Höstad, E. Nilsson, J. Thun, S. Dahlgren, S. Isaksson, G. S. Adams, C. Landberg, T. Bright and S. R. Cotanch, Phys. Lett. B, in press (1992).

4. "Exclusive Radiative Proton Capture to ^{12}C" B. Höstad, S. Isaksson, E. Nilsson, J. Thun, G. S. Adams, C. Landberg, T. Bright and S. R. Cotanch,submitted to Phys. Rev. C (1992).

5. "Λ, Σ^0 and $\Lambda(1405)$ Electroproduction in a Crossing and Duality constrained Model", R. A. Williams, C.-R. Ji and S. R. Cotanch, submitted to Phys. Rev. C (1992).

6. "Relativistic Quark Model of Mesons", P. L. Chung, C.-R. Ji and S. R. Cotanch, submitted to Phys. Rev. D (1992).

INVITED PAPERS

7. "Hyperon Electromagnetic Production Studies at CEBAF", Stephen R. Cotanch, Ninth Nordic Meeting on Intermediate and High Energy Nuclear Physics, Gräftavallen, Sweden (Jan.,1991).

8. "Continuum Shell Model Approach to Medium Energy Photonuclear Reactions", Stephen R. Cotanch, Ninth Nordic Meeting on Intermediate and High Energy Nuclear Physics, Gräftavallen, Sweden (Jan., 1991).

9. "Strangeness Electromagnetic Production at CEBAF", Stephen R. Cotanch, International Workshop on Meson Production, Interaction and Decay, Cracow, Poland (May, 1991).

10. "Simple Light -Cone Quark Model Description of Meson Properties", Stephen R. Cotanch, 13th International Conference on Few Body Problems in Physics, Adelaide, Australia (Jan. 1992).

Also, there were three abstracts detailing contributed papers at several meetings. These references are available upon request.

END

DATE FILMED

4 / 02 / 92