THEORY OF PHOTON AND ELECTRON INDUCED REACTIONS

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PROGRESS REPORT, JANUARY 1992

During the first year and half of the current grant from the Department of Energy we have made considerable progress on the following aspects of the general investigation of electron and photon induced reactions: (a) photo- and electro-production of mesons; (b) Coulomb distortion effects on $(e,e'\gamma)$ and (e,e') and $(e,e'p)$ in the quasi-elastic region; (c) studies involving the relativistic shell model, and (d) quark models. We will report on each of these developments in the following sections:

(a) Photo- and Electro-Production of Mesons

Our investigation of lambda polarization in the reaction $\gamma + d \rightarrow K^+ + n + \Lambda^0$ has been completed and the work has been published¹⁾. We looked at three different lambda-neutron potentials which have been proposed by others, but which have quite different scattering lengths and effective ranges. We found that under certain reasonable kinematical conditions the exclusive reaction cross section and the polarization vary enough with the choice of potential to be useful in determining the lambda-neutron interaction. As we pointed out last year, this reaction is being actively proposed for the Large Acceptance Angle Spectrometer being planned at CEBAF²⁾.

In collaboration with C. Bennhold at TRIUMF, we have completed the extension of this calculation to study kaon photoproduction from the neutron by using the deuteron as a target. We used basic kaon photoproduction operators proposed by Bennhold³⁾, although there exist no experimental data to test them due to lack of a neutron target. We found that it is feasible to use the deuteron as a neutron target over a large kinematic region without the final state interaction of the outgoing meson and spectator nucleon causing any problems. Our paper reporting our findings has been submitted to Physical Review C. We note that all six kaon photoproduction reactions from the deuteron are scheduled for the Large Acceptance Angle Spectrometer being built at CEBAF²⁾.

We have also made considerable progress on the investigation of the role of the $\Delta(1232)$ resonance in pion photoproduction from nuclei as proposed in last year's proposal. The basic formalism, again in collaboration with Bennhold, has been worked out and the computer code for a full DWIA momentum space calculation for $A(\gamma, \pi p)B$ has been programmed. We are currently making extensive checks of the program and making preliminary comparisons with the available experimental data^{4,5}. This work will appear in the dissertation of Xiaodong Li.

References for (a)

1. X. Li and L. E. Wright, J. Phys. G **17**, 1127 (1991).
2. B. Meching, CEBAF Proposal and private communication.
3. C. Bennhold, Phys. Rev. **C38**, 1944 (1989).
4. L.D. Pham, Ph.D. Dissertation, MIT (1989) unpublished
5. P.S. Anan'in and I.B. Glavanakov, Sov. J. Nucl. Phys. **52(2)**, 205 (1991).

(b) Coulomb Distortion Effects on $(e, e'\gamma)$, (e, e') , and $(e, e'p)$

We finished our work on the inclusion of Coulomb distortion effects in $(e, e'\gamma)$ and the paper reporting these results has appeared¹⁾. We found excellent agreement with the data from an experiment performed at Mainz²⁾ on the 6.32 MeV mixed E2-M1 transition in ^{15}N and with an experiment from Illinois³⁾ on a 2^+ transition in ^{12}C . While no data is yet available from medium and heavy nuclei, our analysis indicates that it will be possible to analyse mixed transitions even with substantial Coulomb distortion effects present. Note that our calculations include the bremsstrahlung contributions which is very large near the incoming or outgoing electron directions. This work formed part of the dissertation project of Amirul Hoque who was supported by the Physics Department at Ohio University, and was done in collaboration with a former student, Indu Talwar who is now on the faculty at Geneseo (SUNY).

Many experiments have examined the inclusive reaction (e, e') in the quasi-elastic

region, and the results are invariably displayed in terms of the separated longitudinal and transverse structure functions. The reduction of many measurements at different electron energies and scattering angles, to these two functions of momentum transfer is based on an analysis using plane-wave electron approximation in lowest order, often with some compensation (use of an effective momentum transfer) to allow for the Coulomb effect on the electron wavefunctions. These analyses have found discrepancies of the order of 40-50% between calculated and measured longitudinal structure functions. There are various prescriptions for curing this which involve revision of the nucleon current operator or the treatment of the final nucleon states. At this point there is no satisfactory explanation.

Our investigation of (e,e') has concentrated on the electron-Coulomb distortion effect, which addresses the longitudinal suppression problem only peripherally, consequently we have tended to avoid such revisionist arguments. Our work, since it is carried out in configuration space rather than momentum space, sees a different aspect of the separation into longitudinal and transverse parts. In the first place, the separated currents look decidedly artificial in that their relationship to the nuclear wavefunction is non-local (they extend far outside the nuclear boundaries). In the second place, their amplitudes interfere and so are not truly separate contributions to the cross sections. At present, because we have grown mistrustful of the separation procedure we advocate a direct comparison to the cross-section data⁴). Using Our DWBA code we can calculate (e,e') cross sections in the quasi-elastic region including the electron-Coulomb effect properly. However, since this involves a sum over all nucleons (the neutron contribution must be included), it is longer than a single $(e,e'N)$ calculation by a factor equal to the number of occupied states; this is extremely time consuming for the heaviest nuclei measured such as ^{238}U although these are the ones where the Coulomb effect is most important. It is seductive to think that a modification of the plane-wave analysis, possibly one fitted to the distorted wave calculation in a given energy region, would be possible since this is so much faster, and would be especially useful if repeated calculation (as in a least-

squares fitting procedure) were to be attempted. We have looked into the procedure of Giusti and Pacati⁵⁾ and conclude that some modification is needed to agree with the DW calculation⁴⁾.

Using our DWBA code for (e,e'p) we get excellent agreement with data on the nucleus ^{40}Ca and ^{208}Pb and, furthermore we find spectroscopic factors generally in agreement with those obtained by other probes⁶⁾.

In our analysis we have confined ourselves to relativistic Hartree states for the bound proton, and to the relativistic global optical model for the free proton. We are interested in the sensitivity of our results to changes in these assumptions, including the change from relativistic to non-relativistic descriptions. Preliminary results⁷⁾ using phase-shift equivalent optical potentials, show how the change depends on the 'missing' momentum p_m , being almost negligible at the quasi-elastic value.

References for (b)

1. Indu Talwar, Amirul Hoque, L. E. Wright, Phys. Rev. C44, 2694 (1991).
2. Rainer Nick, diploma, University of Mainz, 1988.
3. C. N. Papanicolas et al., Phys. Rev. Lett. **54**, 26 (1985).
4. Yanhe Jin, D.S. Onley, and L.E. Wright, (e,e') to appear in Phys. Rev. C.
5. C. Giusti and F.D. Pacati, Nucl. Phys. **A473**, 717 (1987).
6. Yanhe Jin, D.S. Onley and L. E. Wright, (e,e'p) to appear in Phys. Rev. C.
7. D. S. Onley, Talk at the VIII Seminar on Electromagnetic Interactions of Nuclei at Low and Medium Energies, Moscow, December 2-5, 1991.

(c) Relativistic Shell Model Studies

We have a working relativistic Hartree-Fock program which is sufficiently general that we can consider deformed shapes, odd-A states etc. We also have a Hartree code which admits non-axial deformation of the nucleus. In these calculations the basic Lagrangian is an extension of the σ - ω model which couples the

nucleons to four meson fields $\sigma, \omega, \pi, \rho$ as well as to the electromagnetic field. The contributions of the isovector mesons are most noticeable in the exchange terms of the Hartree Fock calculation (in fact the value of including them in the Hartree calculation is somewhat unclear). A study of the effects of retardation of the meson propagators in the Hartree-Fock calculation has been published ¹⁾ which shows, as one would expect, that the π is most effected (being the lowest mass meson) and that the effect increases with nuclear mass (because the energy difference between the exchanging pair of states can be larger). We have also published²⁾ a study of an interesting alternative (derivative) type coupling of the nucleon to the σ , originally proposed for bulk nuclear matter. Here we found results for finite nuclei were unsatisfactory (the spin-orbit coupling is too small).

We have made progress with a study of the effect of tensor coupling on deformed nuclei, in particular including the tensor coupling to the ρ . In Hartree Fock calculations the exchange terms enable the ρ to couple to the proton and neutron densities individually (not just to their difference, as in the Hartree calculation) and so large contributions are found considering that the tensor coupling of the ρ is rather strong. However we find disagreement with the only comparable calculation³⁾ and we are attempting to resolve this before we publish.

The calculations on potentially non-axially deformed states have turned up no seriously non-axial ground states in the s-d shell. We have found small non-axial effects but we are not yet certain that these are truly reproducible. We have done some calculations in the shell where we are particularly interested in the role of the pairing terms which are usually added - they are not present in the mean-field hamiltonian. Non-axial shapes reportedly occur⁴⁾ in this mass region.

References for (c)

1. J-K. Zhang and D. S. Onley, Phys.Rev. **C44** 2230 (1991).
2. J-K. Zhang and D. S. Onley, Phys.Rev. **C44** 1915 (1991).
3. P. G. Blunden in Relativistic Nuclear Many-Body Physics (World Scientific, Singapore 1989) p265.
4. S. S. L. Ooi et al Phys.Rev. **C34** 1153 (1986); J. A. Sheikh et al.

Phys.Rev.Lett. **64**, 376 (1990); C. J. Lister et al. Phys.Rev. **C42** 1191 (1990)

(d) Quark Models

We are still investigating photoproduction of mesons, directly and via nucleon resonances, using an extension of the constituent quark model (see original proposal). The model has a mixture of relativistic and non-relativistic elements; non-relativistic in that the quark motion is according to the non-relativistic Schrödinger equation, and relativistic in that the quark excitation energies must be included in the mass and particle-antiparticle production is allowed. We are in the process of comparing with phenomenological models in the non-relativistic limit.

A simple model of a decaying system has been introduced¹⁾ which enables us to study its representation for strong as well as weak (perturbative) decay interactions. For particles which decay by strong interactions (Δ for example) the behaviour appears to be dominated by a cut term rather than a pole term in the complex energy plane.

References for (d)

1. D. S. Onley and A. Kumar, Am.J.Phys. (to be published March 1992).

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