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1. Introduction

Electron scattering is still the most precise probe of the nuclear wavefunctions. As such, the need for nuclear structure investigations with electrons remains as valuable as ever. The fact that one can measure nuclear transition densities with high precision has led to a stimulation of theoretical speculation on nuclear structure and nuclear constituents. In that spirit we have put a stronger emphasis on the quite successful theoretical programs at UNH that enables us to study what one learns from the experiments about nuclear structure. It is this part of the program that will keep the experimental nuclear structure program lively and exciting for many years to come. Similarly, the newest experimental results create a need and stimulation for the relevant improvements in the nuclear structure calculations that gives meaning to the theoretical developments.

With these theoretical studies one learns how to use the individual nucleus as a filter for certain basic nuclear structure properties so that they become accessible to the experiment. In this way we are able to get quantitative experimental results on such things as ground state correlations, nuclear core polarization, the q -dependence of the residual interaction, renormalization of the nuclear magnetic moment due to short range correlations, and many other nuclear properties.

The physics program of the nuclear physics group at the University of New Hampshire (UNH) is strongly associated with the Bates Accelerator. With changes underway at Bates towards higher energy and new experimental areas, users groups like ourselves and the group at the U. of Massachusetts have to carry a larger share in the responsibility for the nuclear structure program. As a consequence, one of us (Hersman) is making a strong commitment to upgrades in the momentum resolution and uniformity of response of the electron scattering facility.

Since beam time for nuclear structure studies at the Bates accelerator has become more scarce, we have branched out to other facilities. We have participated in and are analyzing experiments of inelastic proton scattering from ^{88}Sr at Indiana University Cyclotron Facility (IUCF), we are collaborating with J. S. McCarthy (U. of Virginia) in an experiment with approved

beam time at NIKHEF (The Netherlands), we intend to continue collaborations with Saclay (France) and the U. of Illinois, and we have started experiments at Mainz (Germany). Since the UNH nuclear physics group is still a small group, many of our experimental efforts are in collaboration with groups at the Vrije Universiteit (Amsterdam) and the Universities of Massachusetts, Illinois, Georgia, Minnesota, Indiana, and Virginia. Furthermore, we have stepped up our activities in nuclear structure calculations, and have obtained a number of powerful computer programs. Our theoretical collaborators are: J. Dubach (U. of Massachusetts) and S. Krewald (Jülich).

We are also getting involved in coincidence work at the Stanford Superconducting Accelerator, the Illinois MUSL accelerator, and the Mainz microtron. At the same time one of us (Calarco) has spent considerable time on a feasibility study of building a stretcher ring at Bates to obtain a CW beam.

The nuclear physics group has now a firm position in the graduate program at UNH. One student, J. Robb, has completed his Master's with us. Another student, S. Frolking, has joined us for his Master's thesis. T. Milliman is working with us on a PhD thesis. J. Connelly has worked with us through the summer, and we hope that he will decide to do his PhD work in our group.

2. Status of Projects

2.1. Single Arm Experiments

2.1.1. Inelastic Electron Scattering from the Pb Isotopes

The experiment has been completed for several years now. Even though many papers have come out of this effort, much of the data, containing additional information, have not yet been published. The continuing work on this project is concentrated almost entirely on finding good theoretical models for the even Pb isotopes.

In ^{208}Pb we are working on a general analysis of the data, where we try to correlate the transition strength seen in the experiment with that predicted from RPA calculations. We are in the process of incorporating several corrections into these calculations (such as the Coulomb corrections) which modify the results significantly and, thus, are essential in such a comparison. The hope is that such comparisons will help us to understand the structure of several unresolved complexes and will allow us to identify the various levels involved. Preliminary comparisons have already helped to identify several levels previously unknown.

With the new shell-model RPA (SMRPA) discussed in section 2.3.2. we have a powerful method to predict the excitation energies and transition densities of the low-lying levels in ^{204}Pb and ^{206}Pb . It is planned that this work will be carried out by S. Frolking as part of his Master's thesis. It will allow us to make a meaningful comparison to the (e,e') data for these nuclei and should lead to a publication of the experimental results.

The data for the lowest 2^+ and 4^+ levels in these nuclei have been analyzed resulting in the extraction of transition charge densities which are being compared to theoretical predictions. A short paper on that subject is in preparation (C. N. Papanicolas, et al.).

2.1.2. 180° Scattering from ^{207}Pb

This experiment is being carried out as a collaboration between C. N. Papanicolas (U. of Illinois), R. Hicks (U. of Massachusetts.), J. S. McCarthy (U. of Virginia) and UNH. The experiment is almost completed, with the remaining 76 hours of beam time scheduled for at least two additional data points. The results from the experiment are shown in Fig. 1.

Fig. 1. ^{207}Pb form factor.

With the measurement of this form factor we are sensitive to several effects. The single particle strength is due to the neutron $3p_{1/2}$ orbit only. Since this is the last neutron orbit filled, it should be most strongly affected by the softening of the Fermi surface. In addition there are strong contributions from exchange currents and nuclear core-polarization. We have several predictions for the resulting form factor. An unpublished prediction of Hamamoto that fits the data rather well is shown also in Fig. 1.

2.1.3. ^{90}Zr and $^{88}\text{Sr}(e,e')$

This experiment is a very active collaborative effort with H. P. Blok (Vrije U.), N. Hintz (U. of Minnesota), J. S. McCarthy (U. of Virginia) and C. N. Papanicolas (U. of Illinois). The data-taking was completed during the past year, and most of the levels have been analyzed. The analysis of the ^{90}Zr levels is being carried out at UNH, while the analysis of the ^{88}Sr levels is being done at Amsterdam and constitutes a major part of the PhD thesis of L. van der Bijl.

In ^{90}Zr the studies were split up into the study of the positive parity states and the negative parity states. With the positive parity states one studies the effects of the pairing that lead to partial occupations. On a more quantitative level, the analysis leads to a testing of shell model wave functions. The large spread of the observed multipolarities in ^{90}Zr is an ideal example to study the q -dependence of the spin-independent part of the residual interaction. More details of this study are being discussed in section 2.3.2. A paper on these results is in preparation.

In the negative parity transitions one finds strong transverse electric form factors. Thus for these transitions one can determine two independent densities from the experiment and from these learn much more about the microscopic form of these transitions.

For ^{88}Sr the initial interest was in the study of the low-lying positive parity excitations. A paper on the comparison of the E2 excitations in the nuclei ^{88}Sr , ^{89}Y , and ^{90}Zr has been submitted to Phys. Rev. Letters. Considerable interest exists in the excitation of the 1^+ and 3^+ states in ^{88}Sr . Our data allows us to extend the low q data from Darmstadt to $q = 2.7 \text{ fm}^{-1}$. The form factor of the 1^+ level can probably be taken as the strongest

evidence for delta-hole components in the nuclear transitions since these components modify the q -dependence of the form factor in a way that improves the agreement with the experiment. This subject was extensively discussed at the Amsterdam meeting [1] as well as most recent conferences, and thus it is in the main stream of current interest.

Another surprise was the discovery of an 8^+ state in ^{88}Sr with the configuration $(1g_{9/2})^2$. The excitation strength of this level allows one to determine the occupation probability of the $1g_{9/2}$ orbit in the nuclear ground state similar to the case of ^{90}Zr .

The results from these nuclei have stimulated a strong theoretical effort that has led to the development of the SMRPA model.

2.1.4. ^{87}Sr and ^{89}Y

The data from ^{89}Y are essentially complete. For ^{87}Sr we probably have enough data to extract the most important results from these experiments. We may find upon completion of this analysis, however, that more data are needed at high momentum transfer.

The results from the excitation of the 0.909 MeV level in ^{89}Y in comparison to the lowest 5^- excitation in ^{90}Zr have already been published. This comparison allowed for the first time a determination of the size of the ground state correlations as pointed out in several subsequent publications. The analysis of the proton hole states has been included in [2].

At the present time the analysis is concentrated on the weak-coupling aspect of these nuclei. In ^{87}Sr , the multiplets originating from the coupling of the neutron $1g_{9/2}$ hole to the collective 2^+ and 3^- core excitations have been identified already in proton scattering. We have measured the form factors for the various members of these multiplets.

In ^{89}Y we have identified the doublet from the coupling of the $2p_{1/2}$ proton to the E7 core excitation. The resulting states can be compared to the predictions using the shell model. Since the E7 core excitation is essentially a pure $1g_{9/2} (1f_{5/2})^{-1}$ ph excitation, the energies and transition strengths measured in ^{89}Y give a very good measure of the matrix elements of the residual interaction.

2.1.5. Polarized Proton Scattering from ^{88}Sr at IUCF

This project is part of a collaboration between the UNH Physics group and A. Scott, T. Baker, V. Pen Unetcha (U. of Georgia), M. Grimm (U. of Louisville), M. Whiten (Armstrong State College), and an in-house IUCF group including W. Jones, G. Emery, A. Bacher, and C. Olmer. Two nuclei, ^{89}Y and ^{88}Sr , are being measured; we have primary responsibility for ^{88}Sr .

Analysis of the data is in its early stages. Effort is being concentrated on developing compatibility between the IUCF computer and our PRIME 650 and bringing on-line at UNH suitable codes for peak-stripping and theoretical interpretation of the results. A spectrum of scattered protons is shown in Fig. 2.

Electron scattering has demonstrated that the low-lying $3/2^-$ and $5/2^-$ in ^{89}Y are due primarily to proton transitions from the $2p_{3/2}$ and the $1f_{5/2}$ orbitals to the $2p_{1/2}$ orbital, and that the first two 2^+ states in ^{88}Sr are mixtures of these two particle-hole transitions with very different resulting structures. Electron scattering has shown that the strength of the second 2^+ state has its largest contributions in the deep interior. Comparisons of the (p,p') data for these proton-rich transitions constrained to the (e,e') result will provide valuable tests of the V_{pp} part of the density-dependent G-matrix and free T-matrix forces at 200 MeV. The measurement of the 1^+ state in ^{88}Sr will provide information on the spin-flip parts of the force, which is the subject of theoretical controversy.

A study of the positive parity transitions essentially becomes a study of core polarization as a function of angular momentum. Such a study will help in the understanding of the radial dependence of the spin independent part of the residual interaction.

2.1.6. ^{48}Ca Inelastic Electron Scattering

This experiment was initiated by J. S. McCarthy (U. of Virginia) and is the subject of the PhD thesis of J. Wise (U. of Virginia) completed this summer. The UNH group is a collaborator on this experiment.

The experiment has resulted in the determination of transition charge and current densities for many negative natural parity excitations. The data allowed the identification of several states previously unknown.

Fig. 2. ^{88}Sr proton scattering cross section.

Fig. 3. $^{238}\text{U}(e,e')$ inclusive.

Fig. 4. $^{238}\text{U}(e,e'f)$ coincidence.

Among these is an 8^- level due to the stretched neutron configuration $1g_{9/2} (1f_{7/2})^{-1}$.

Our results for the quenched strength of the currents observed in several of the transitions are quite relevant with respect to the recent claim that the quenching observed in the magnetic dipole (M1) form factor at low momentum transfer [3] is evidence for delta-hole states in this nucleus. Such an admixture would be expected to affect the low multipolarity transitions but not the high multipolarity transitions. Since our measurements show the same quenching for the M8 as that observed for the M1, it shows that this quenching is more likely produced by more conventional nuclear structure effects such as ground state correlations, core polarization, etc.

Our present activities involves some theoretical modeling for ^{48}Ca that should give us a broader basis for the understanding of our experimental results. At the same time we are preparing publications on the experimental results.

2.1.7. Electron Scattering from ^{92}Mo

This experiment has been accepted at the Bates Accelerator. We have beam time scheduled for early December 1982.

In view of the recent results from ^{90}Zr and ^{88}Sr our prime interest is in the positive parity transitions. We hope that using the SMRPA calculations we can produce agreement for the whole region of $N = 50$.

2.1.8. Electron Scattering from the Ce Isotopes

We have beam time scheduled for this experiment together with the experiment on ^{92}Mo . Since for these nuclei resolution is the most important factor in the success of the experiment, we have a strong involvement in the upgrade of the high resolution spectrometer at the Bates accelerator. W. Hersman is spending considerable time at Bates in developing the new software for the on-line data taking capability with two chambers in the focal plane. Up to now most data have been taken with only one chamber. We expect a significant improvement with the two chamber system.

2.1.9. Electron Scattering from ^{198}Hg

This experiment initiated by J. McCarthy did receive beam time at the electron accelerator at NIKHEF (Amsterdam). Presently studies at the U. of Virginia are being made to construct a rotating target containing Hg that will withstand the high beam currents. This target will be tested with natural Hg before the isotopically enriched target will be fabricated. We expect to get our first beam time for this experiment in early spring 1983.

2.1.10 ^{192}Os Experiment

One of us (W. Hersman) is involved in this experiment in collaboration with B. Shera from Los Alamos and others. Beam time at Bates for the study of ^{192}Os has been approved but scheduling has been delayed due to difficulty in obtaining enriched material for the target. Our collaborators from the U. of Georgia recently completed a study of proton scattering from ^{192}Os and have loaned us their target to obtain the complementary electron scattering data. Beam time has now been scheduled for early December.

^{192}Os lies in the region where the deformed intrinsic nuclear shape changes from prolate to oblate. Charge densities to the various levels help to understand this shape transition. In addition, the Interacting Boson Approximation makes specific predictions for this region which differ from triaxial rotor and gamma instability models. Thus this is an interesting region for a comparison.

2.2. Coincidence Experiments

The availability of high duty cycle electron accelerators makes possible detailed measurements of inelastic electron scattering to the continuum. It is now feasible to detect, in coincidence with scattered electrons, the particles emitted from the highly excited nucleus following electron scattering. Such experiments provide the cross sections and energy and angular correlations for the coupling of the highly excited nuclear states to specific final states all as a function of both energy transfer (ω)

and momentum transfer (q), and without having to subtract any radiative tail background.

There is currently considerable involvement of the UNH group in this research, and we anticipate that this activity will increase as more facilities for these types of experiments become available. J. R. Calarco has been instrumental in demonstrating the feasibility of these experiments with the pioneering work on the superconducting electron accelerator at Stanford, and has continued these studies there.

Some of this work will be continued at the Bates accelerator and at the U. of Illinois. Although the 1-2% duty factor at Bates and the low energy and intensity at Illinois make coincidence experiments difficult in general, thereby precluding a large program, certain specific experiments can be performed adequately. Specific proposals have been accepted by the Bates PAC and initial runs will be made in December 1982 and early in 1983.

Newer facilities capable of achieving both higher energies and duty factors are presently under construction at the U. of Mainz and at the National Bureau of Standards (NBS) and are expected to be available for experiments in or about June 1983 and June 1984, respectively. J. R. Calarco was invited to spend the month of May 1982 in Mainz to help plan the new generation of experiments for that facility. We anticipate that the UNH group will be strongly involved in this program. Planning for the NBS facility is less firm at this point in time. However, J. R. Calarco has been actively engaged planning the program for the 200 MeV stage which is presently under construction. Thus it is also quite clear that UNH will be carrying out experiments on the NBS 200 MeV machine when it becomes available (sometime in 1984).

2.2.1. $^{238}\text{U}(e,e'f)$ in the Giant Resonance Region

Giant resonances represent one of the most fundamental modes of nuclear excitation, that of highly collective vibrations. Thus in recent years a large number and variety of experiments have been aimed at observing these resonances and their properties, particularly in the medium to heavy nuclei where the systematics associated with nuclear hydrodynamics is expected

to dominate the intermediate structure effects associated with the coupling to the particle-hole excitation modes.

In both hadron and electron scattering, however, the observation of the resonances is difficult because of very large backgrounds. Thus the extracted properties of the giant resonances (energy, width, and strength) have large experimental uncertainties. In many cases even the spin and parity are uncertain.

In electron scattering this background can be effectively removed by demanding a coincidence with the giant resonance decay mode, because the background is primarily due to the large radiative tail from the elastic scattering. Similar coincidence measurements in hadron scattering in the medium to heavy nuclei have shown that the background in these reactions is due to real continuum excitation and there is no enhancement of the giant resonances in the $(h, h'f)$ cross sections.

In the actinide region, fission decay is an important mode of the giant resonance decay ($\sim 25\%$ in ^{238}U), the remainder being by neutron emission. Thus the ease of detecting fission fragments in comparison with neutron detection has led to a study of these nuclei by the $(e, e'f)$ reaction [4]. In addition to removing the background the fission detection provides additional information via the angular correlation and mass distribution of the fragments.

In the following subsections we briefly discuss the status and thrust of our efforts on the $^{238}\text{U}(e, e'f)$ reaction at Stanford, Bates, and Illinois.

2.2.1.1. $^{238}\text{U}(e, e'f)$ Measurements at Stanford

This program is an ongoing collaboration of J. R. Calarco with the HEPL group at Stanford and J. G. Woodworth and D. Rowley (Livermore), which was initiated when J. R. Calarco was on the staff at HEPL. The aim of this program is to measure the $^{238}\text{U}(e, e'f)$ cross section from threshold to $E_x \sim 22$ MeV over a sufficient range of q to extract the distribution of electric quadrupole (E2) or monopole (E0) strength and to estimate the contribution from higher multipoles. To this end runs were made in July-August, 1981 and February 1982 at incident energies of 80, 120, and 160 MeV and a scattering angle of 40° . An additional run is planned for November 1982 to extend the 120 and 160 MeV data to higher E_x and to obtain data

for an incident energy of 200 MeV at a scattering angle of 40° . This will probably be the last run at Stanford.

In these measurements (as well as the planned run in November) parallel plate avalanche counters [5] (PPAC) were used to detect fission fragments. These provide large solid angle (~ 200 msr each), 100% efficiency for fission fragments, and low sensitivity to electrons. The quality of the data obtained to date is shown in Figs. 3 and 4. Figure 3 shows that the inclusive (e,e') cross section throughout the giant resonance region is dominated by the elastic radiative tail. Figure 4 shows that at 80 MeV incident energy (low q) the well-known giant dipole ($E1$) peaks at $E_x = 11$ and 13 MeV dominate the coincidence cross section. Only accidental coincidences have been subtracted. At higher q this structure becomes weaker, and a concentration of strength between $E_x = 9$ and 10 MeV increases, consistent with theoretical hydrodynamic model expectations for isoscalar $E2$ strength.

We are presently analyzing these data in detail using model form factors calculated at UNH. Initial fits using the Tassie model have shown that the extracted multipole strengths are quite sensitive to the model parameters which are not well known. Low q experiments at Illinois have been analyzed to extract the $E1$ and $E2$ strengths up to $E_x \sim 12$ MeV but have relied on parameters which may be unrealistic. Presently calculations are being made using a microscopic transition density generated by the quasiparticle RPA (QRPA) code of Speth and coworkers [6]. These densities will remove the parameter ambiguity. With these data, together with the planned run at higher q (200 MeV incident energy), we expect to be able to extract the $E2$ and $E0$ strength up to $E_x \sim 20$ MeV.

2.2.1.2. $^{238}\text{U}(e,e'f)$ Measurements at Bates

A collaboration between the UNH group, C. N. Papanicolas and L. S. Cardman (U. of Illinois), and C. Barber, S. Kowlaski, and P. Sargent (MIT) has proposed to develop a facility at Bates for the purpose of studying $(e,e'f)$ on a variety of actinide nuclei including ^{238}U and at higher q . The initial proposal requested 48 hours of beam time for testing and evaluation of coincidence hardware. The initial proposal has been accepted by the PAC, and we expect to run in early 1983 using MEPS (the medium energy pion spectrometer) for electron detection and PPAC's for fission detection.

Many of the ambiguities associated with the analysis of the low q data will be removed by this program. First of all the availability of higher incident energy at Bates will allow the form factor to be measured at higher q where different model parameters lead to widely different predictions. Second, by varying the target nuclei the variability of the fission probability is removed.

Thus, if the initial test run is encouraging, we expect this program to run over a period of approximately two years.

2.2.1.3. $^{238}\text{U}(e,e'f)$ Measurements at Illinois

J. R. Calarco and J. Heisenberg (UNH) will be collaborating with L. S. Cardman and C. N. Papanicolas (Illinois) on measurements of $^{238}\text{U}(e,e'f)$ at Illinois at low q . The main thrust of these experiments will be to (1) make detailed high resolution measurements in the threshold region, and (2) to measure the mass distribution of the fission fragments.

The UNH group is presently designing and building a multiwire chamber for the Illinois electron spectrometer which will provide the required energy resolution. It is expected that this detector will be finished in the near future and tested during the autumn of 1982. If the test is successful we would anticipate a first run on the experiment during the winter of 1982-83.

2.2.2. $^{12}\text{C}(e,e'c)$ and $^{16}\text{O}(e,e'c)$ Giant Resonance Experiments

While the giant resonance systematics are easier to observe in the medium to heavy nuclei, the microscopic particle-hole (ph) nature of these resonances is more apparent in the light nuclei. Inclusive (ee') reactions show significant structure in the excitation functions characteristic of ph and $2p2h$ excitations. Exclusive ($e,e'x$) experiments, where x is a particle or cluster emitted in the giant resonance decay, are required to gain information on the microscopic description of these resonances. Branching ratios for the excitation of specific residual nuclear states and the angular correlation of the emitted particles will not only be characteristic of the spin and parity of the resonances but also will carry information about the microscopic structure.

Fig. 5. $^{12}\text{C}(e, e'p)$ and $^{12}\text{C}(e, e')$.

Fig. 6. $e, e'p$ angular correlation.

The pioneering work on $^{12}\text{C}(e,e'p)$ at Stanford [7] was the first experiment to show that low energy charged particles ($x = c$) could be detected with large solid angle solid state detectors close to the target of an electron beam. Data of high quality were obtained (see Fig. 5) which provided the first direct and unambiguous measurement of ^{12}C proton decay to excited states in ^{11}B . In addition angular correlations were obtained which demonstrated not only the expected dominance of the longitudinal form factor for the decay to the ground state (see Fig. 6) but also (1) a rather surprising dependence of q for the decay to the ^{11}B first excited state and (2) evidence for interference of a narrow monopole resonance near $E_x \sim 20.5$ MeV. These data are going through final analysis and two papers are in preparation for publication.

In addition some preliminary work was done on $^{16}\text{O}(e,e'\alpha)$ to (1) test any problems with the use of $^6\text{Li}_2\text{O}$ targets and (2) demonstrate the characteristic angular correlation dependence for the $J^\pi \rightarrow 0^+$ alpha decay mode. Figure 7 shows measured angular correlations for 2^+ , 0^+ and 1^- states with interference from a 2^+ background.

These results are very incomplete and a more detailed measurement at higher q are needed. A serious study of reactions such as these requires a beam energy in the range of 150-300 MeV. The accelerator at Mainz which is presently under construction is designed to reach 175 MeV. The UNH group will collaborate with G. Fricke and R. Neuhausen (Mainz), and K. T. Knöpfle and G. Wagner (Max Planck Institute of Heidelberg) on a program of experiments to measure charged particle decay ($c = p, \alpha$) from the ^{12}C and ^{16}O giant resonances using the Mainz microtron.

This program will begin shortly after the beam becomes available (June 1983). At present J. R. Calarco is working with K. T. Knöpfle on the design for a solid state detector array to be assembled at Heidelberg using components from the Stanford angular correlation set up. The Mainz group will supply their electron spectrometer and scattering chamber, and modify the logic appropriately for the coincidence experiment.

The limitation of this program will be twofold. First it will be fruitful to get to higher energies than 175 MeV. Second the Mainz electron spectrometer provides only a 5 msr solid angle with an 8% momentum bite. Both of these shortcomings will be eliminated in the program to be initiated at NBS in 1984. J. R. Calarco spent a week in June 1982 in conference

with the NBS group designing the apparatus required for (e,e'c) experiments with electrons of 200-300 MeV. This apparatus included a MEPS type 300 MeV spectrometer providing 35 msr with a 20% momentum bite. This collaboration will include the group at UNH and E. Hayward, W. Dodge, X. Maruyama (NBS) and C. C. Chang (U. of Maryland).

2.2.3. $^{12}\text{C}(\text{e},\text{e}'\text{p})$ Quasi-Elastic Scattering

J. R. Calarco will collaborate with W. Bertozzi, J. M. Finn, J. Kelly, and M. Kovash (Bates, MIT) on a proposed experiment to study $^{12}\text{C}(\text{e},\text{e}'\text{p})$ at $q = 400 \text{ MeV}/c$ for $\omega = 120$ and 200 MeV at Bates. The experiment will use the two South Hall spectrometers MEPS and OHIPS for coincidence detection of electrons and protons respectively. Beam time for a preliminary run to test feasibility has been allocated in December 1982. Instrumentation of MEPS and OHIPS is in progress at the present time.

The purpose of this program is twofold. First, in the region around $\omega = 120 \text{ MeV}$, which includes the quasi-elastic peak, a separation of the transverse and longitudinal response functions will be made. Recent inclusive (e,e') results [8] have indicated an amount of longitudinal strength in this region significantly in excess of that expected from current models of the quasielastic reaction mechanism. The proposed coincidence measurement will measure the outgoing proton energy and this will be sensitive to other reaction mechanisms (meson exchange and other many body effects). Secondly, an exploration will be made in the excitation region around $\omega = 200 \text{ MeV}$, the so-called "dip" region. That there is transverse strength in this region far in excess of current predictions is well established. Again a measurement of the knocked out proton energy will help to determine whether the reaction mechanism is simple quasielastic or whether more complex mechanisms contribute significantly.

2.3. Theoretical Studies

2.3.1. Exchange Current Calculations

We have developed a method to calculate pionic exchange currents in heavy nuclei, using a Fourier-Bessel expansion. We are able to calculate

current densities in coordinate space for the long range part of the nuclear interaction potential -- the pair and pionic currents. This part of the work is now essentially complete. Our calculation can be done at all q values and for any multipolarity. We have also been working on the intermediate range part of the nuclear potential -- the delta and the rho currents. The delta currents have been computed, and have been found to be generally small, except for an unusual case of the 14^- state in ^{208}Pb , which seems to have large corrections. Recent work by Towner and Khanna [9] have shown that all these effects are of the same order of magnitude for the photon point in M1 transitions, and we would expect the same result here.

At present, our computer program applies to closed shell nuclei with simple ph excitations. The case of the closed-shell $\pm$ one nucleon would be an easy extension, and even a more complete open shell case could be considered. This work is being done by J. Dawson, R. Lambert, and J. Heisenberg, and we are in correspondence with S. Krewald (Jülich) who is independently doing a similar calculation.

2.3.2. Shell-Model RPA (SMRPA) Calculations

We now have the Glasgow shell-model code (from J. Dubach) and the Jülich RPA code (from S. Krewald) on our computer, and are able to do both shell-model and RPA calculations in the Zr region. We have recently developed a method which we call the SMRPA, in which the results of a multi-particle shell-model calculation are used in an RPA calculation to find energy levels and density distributions. The method allows the calculation of effective charges and will be discussed in a paper in preparation by J. Heisenberg and J. Dawson.

An example of this type of calculation is shown in Fig. 8 where we compare shell-model, RPA, and SMRPA calculations to experimental densities for several electric transitions in ^{90}Zr . These results, with a zero range force show that we can predict densities for the low multipolarities quite well, but over-estimate the core polarization for high multipolarities. This difficulty shows the needs for a finite range force, and we are presently investigating such forces.

Fig. 7. $e, e'\alpha$ angular correlation.

Fig. 8. SMRPA calculation for ^{90}Zr .

2.3.3. Self-Consistent RPA (SCRPA)

In collaboration with S. Krewald from Jülich we have studied ground state correlations in ^{208}Pb . There is still a large discrepancy between the measured ground state charge distribution and the best theoretical prediction based on Hartree-Fock Bogoliubov calculations with the explicit inclusion of RPA correlations. Therefore, we suspected that the RPA does not produce enough ground state correlations.

Part of that deficiency can be attributed to some intrinsic inconsistencies of the RPA method. One first assumes a sharp Fermi surface to derive the RPA equations which subsequently are being used to prove that the original assumption of a sharp Fermi surface is incorrect.

We have tried to derive a corresponding set of equations that eliminate this inconsistency. In our approach the equations of motion are evaluated for a ground state that contains 2p2h components. We then impose a self-consistency constraint requiring that the 2p2h amplitudes that result from the solutions of this equation are the same as those used for the derivation of the set of equations.

We have shown that this leads indeed to a set of equations that generates larger correlations than the RPA equations. Quantitative calculations have not yet been done.

3. Future Plans and Activities

3.1. Single Arm Experiments

The high resolution electron scattering program at UNH is now firmly established. Furthermore the dynamics and vitality of the program are such that each experiment and analysis readily suggest new and exciting directions.

We cannot, therefore, predict precisely which nuclei we would like to work on in the long range, but we can safely say that there is enough work to be completed to take several years. The previous sections, particularly section 2.1 and its subsections and 2.3 have briefly outlined our present aims. It is clear that as the experiments and theoretical studies progress on these fronts new experiments will become necessary to provide additional information to complete the picture.

Thus we anticipate that the electron scattering program at UNH will

remain vital and contribute significantly to the general understanding of nuclear structure for several years to come. At the same time we are aware that the use of other probes can contribute results which supply additional information or in some cases may even produce results which supercede those from electron scattering. We have already discussed our efforts to use the IUCF to clarify the nuclear structure of ^{88}Sr . Therefore, although we feel that electron scattering can and will provide unique detailed information concerning nuclear structure, nevertheless we will use whatever probe can provide the best answer to the appropriate question.

As part of such a diverse program of nuclear structure studies, we are discussing the feasibility of searching for magnetic dipole strength in heavy nuclei using 180° inelastic positron scattering. It is in these nuclei where electron scattering studies have failed to find significant M1 strength, which has lead to a proposal that the spin-isospin mode of excitation in heavy nuclei is quenched by delta-hole coupling.

Positron scattering is expected to provide a more sensitive tool than electron scattering for such a search. This is because the Coulomb repulsion between the nucleus and the positron reduces the effective q which, in turn, increases the M1 form factor, while precisely the opposite is true for electron scattering.

The UNH group is presently carrying out detailed DWBA calculations of electron and positron scattering to M1 and M2 (magnetic quadrupole) states in ^{208}Pb in order to quantify these expectations. A collaboration is being formed with H. Crannell, L. W. Fagg, and D. Sober (Catholic U.), B. L. Berman (Livermore), and F. Buskirk at the Naval Postgraduate School (NPS) to move a 180° energy-loss mode spectrometer system designed by Fagg and presently at NPS to the Livermore linac which is the only available facility capable of producing a sufficient positron intensity. If our calculations indicate the program is feasible and the spectrometer arrangements can be made, we will construct a multiwire chamber for the spectrometer and embark on a search for M1 states in ^{208}Pb .

If such a search is successful either in finding new M1 strength or in setting more stringent upper limits on it, other nuclei will be investigated in an ongoing program.

3.2. Coincidence Experiments

In addition to the specific experiments outlined in Sec. 2.2, we anticipate that the (e,e'f) and (e,e'c) experiments will continue on other targets of interest at Mainz, NBS, and Illinois. In particular, for the (e,e'f) program, it will be important to investigate both more fissile nuclides such as ^{233}U and ^{234}U as well as less fissile nuclides such as ^{232}Th . The more fissile nuclei will allow the study of the giant resonance parameters with higher efficiency and fewer uncertainties associated with varying fission probability. The less fissile nuclei should offer a better probability of seeing a direct component.

The (e,e'c) studies will continue on other light to medium nuclei with particular interest in the 2s-1d shell, the Ni isotopes, and the Sr-Zr region. In the 2s-1d shell and in the Ni isotopes we will be principally interested in enhanced alpha emission from the giant quadrupole and monopole resonances. At the same time the proton decay will give important new information on the microscopic structure and on the isospin modes of excitation. In ^{88}Sr and ^{90}Zr , observation of the protons will allow the study of the IAR's at momentum transfers where they cannot be seen in single arm scattering.

We have proposed to Illinois that we would like to measure the cross section for $^{12}\text{C}(\text{e},\text{e}'\text{n})$ at 80 MeV in order to compare it with the $^{12}\text{C}(\text{e},\text{e}'\text{p})$ data. Discussions are underway but the details have not been resolved yet.

In the far future (~3-4 years) we hope to be carrying out a coincidence program at higher energy on the proposed stretcher ring facility at Bates or the facilities being proposed by NBS and U. of Virginia. J. R. Calarco has been actively participating in the planning for the new facilities at Bates and NBS. Our initial interest would be to continue the giant resonance studies to higher q and higher excitation energy where the interference with the quasielastic becomes important, to initiate a program on (e,e' π) to study the spin-isospin modes, and to study the s-wave pion wave function in nuclei by measuring (e,e' π) at threshold. Again, as for the single arm studies long range plans will be modified by short range results. Our program will be dictated by the physics which is interesting.

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5. Publications

5.1 Published Papers

1. "Detection of Fission Fragments by a Parallel Plate Avalanche Counter in the Presence of an Intense Electron Beam," J. D. T. Arruda-Neto, R. Avida, J. R. Calarco, K. Griffioen, D. H. H. Hoffmann, K. T. Knöpfle, K. Van Bibber, R. Westerfelt, and J. G. Woodworth, Nucl. Instr. and Meth. 190, 203 (1981).
2. "Measurement of the Effective E5 Single-Particle Transition Densities in ^{89}Y and ^{90}Zr ," O. Schwentker, J. Dawson, S. McCaffrey, J. Robb, J. Heisenberg, J. Lichtenstadt, C. N. Papanicolas, J. Wise, J. McCarthy, N. Hintz, and H. P. Blok, Physics Letters 112B, (1982), 40.
3. "Excitations of Low-Lying Natural Parity Levels in ^{108}Pb by Inelastic Electron Scattering," J. Heisenberg, J. Lichtenstadt, C. N. Papanicolas, J. McCarthy, Phys. Rev., C25 (1982) 2292.

5.2 Papers Submitted for Publication

1. "E2 Transition Densities and Proton Shell Structure in ^{88}Sr , ^{89}Y , and ^{90}Zr ," O. Schwentker, J. Dawson, J. Robb, J. Heisenberg, J. Lichtenstadt, C. N. Papanicolas, J. Wise, J. McCarthy, L. T. van der Bijl, and H. P. Blok, submitted to Phys. Rev. Lett.
2. "Transverse Contributions to Natural Parity Excitations," J. Heisenberg, J. Dawson, and H. P. Blok, Proceedings of the Telluride Conference on "Spin Excitations in Nuclei," to be published.
3. "Charge and Current Transition Densities," J. Heisenberg, Proceedings of the International Conference on Nuclear Structure, Amsterdam 1982, to be published.
4. "Neutron Transition Density for the Lowest 2^+ State of ^{18}O ," J. Kelly, W. Bertozzi, T. N. Buti, J. M. Finn, F. W. Hersman, C. Hyde, M. V. Hynes, M. A. Kovash, B. Norum, J. Pekar, F. N. Rad, A. D. Bacher, G. T. Emery, C. C. Foster, W. P. Jones, D. W. Miller, B. L. Berman, W. G. Love, F. Petrovich, submitted to Phys. Rev. Lett.
5. "Implications of the Experimental Results on the Photodisintegration of ^4He ," J. R. Calarco, B. L. Berman and T. W. Donnelly, submitted to Phys. Rev. C.

5.3. Papers in Preparation

1. "Exchange Current Effects in Electron Scattering," J. Dawson, J. Heisenberg, R. Lambert.
2. "Shell Model Calculations for ^{90}Zr with the Inclusion of Effective Charge," J. Heisenberg, J. Dawson.
3. "Decay of the ^{12}C Giant Dipole Resonance from $^{12}\text{C}(e,e'p)^{11}\text{B}$ Coincidence Measurements," J. R. Calarco, J. Arruda-Neto, K. Griffioen, S. S. Hanna, D. H. H. Hoffmann, R. E. Rand, A. M. Sandorfi, K. Wienhard, and M. R. Yearian.
4. "Observation of Monopole Strength in the $^{12}\text{C}(e,e'p_0)^{11}\text{B}$ Reaction," J. R. Calarco, J. Arruda-Neto, K. Griffioen, S. S. Hanna, D. H. H. Hoffmann, R. E. Rand, K. Wienhard, and M. R. Yearian.
5. "Excitation of Positive Parity States in Electron Scattering from ^{90}Zr ," J. Heisenberg, J. Dawson, J. Robb, O. Schwentker, J. Lichtenstadt, C. N. Papanicolas, J. Wise, J. S. McCarthy, N. Hintz, H. P. Blok.

5.4. Invited Papers Presented at Meetings

1. J. R. Calarco, "(e,e'p) Experiments," Workshop on Physics with Electromagnetic Interactions, Williamsburg, VA, September 1981.
2. J. Heisenberg, "Transition Densities Measured in Recent Inelastic Electron Scattering Experiments," Washington APS Meeting, Bull. Am. Phys. Soc. 27, 546 (1982).
3. J. Heisenberg, "Transverse Contributions to Natural Parity Excitations," Telluride Conference on Spin Excitations in Nuclei, Telluride, CO, March 1981.
4. J. Heisenberg, "Charge and Current Transition Densities," International Conference on Nuclear Structure, Amsterdam, August 1981.

5.5 Abstracts of Papers Presented at Meetings

1. "Measurement of the Inclusive Electrofission Cross Section of ^{238}U at $F_e = 47, 80, \text{ and } 119 \text{ MeV}$," with K. Griffioen, et al., Bull. Am. Phys. Soc. 26, 1113 (1981).
2. "Study of the $^{238}\text{U}(e, e'f)$ for $E_x = 5 - 15 \text{ MeV}$ at $q = 0.26 \text{ and } 0.40 \text{ fm}^{-1}$," with K. Van Bibber, et al., Bull. Am. Phys. Soc. 26, 1129, (1981).
3. "The Performance of a Large Solid Angle Parallel Plate Avalanche Counter Array in Electron Scattering Experiments," with J. G. Woodworth, et al., Bull. Am. Phys. Soc. 26, 1158 (1981).
4. "Distribution of E2/E0 Strength in ^{238}U at $E_x \leq 16 \text{ MeV}$ Observed in $^{238}\text{U}(e, e'f)$," with K. Van Bibber, et al., Bull. Am. Phys. Soc. 27, 459 (1982).
5. "Inelastic Electron Scattering from Calcium 48," with J. Wise et al., Bull. Am. Phys. Soc. 27, 530 (1982).
6. "Nucleon- and Delta-hole Polarization in the Form Factor of the 1^+ State of ^{88}Sr at 3.48 MeV ," with L. T. van der Bijl, et al., ICONS, Amsterdam, August 1982.
7. "A Test of the Interacting Boson Approximation Using Electron Scattering," F. W. Hersman, et al., submitted to the October meeting of the APS.
8. "Excited States in ^{89}Y ," T. Milliman, et al., submitted to the October meeting of the APS.
9. "Shell Model Studies of the Low-Lying Nuclear Structure in the Zirconium Region," J. Dawson and J. Heisenberg, submitted to October meeting of the APS.