Appendix G

Summary of PAC16 Workshop on the Physics of Nuclei (Williamsburg, Virginia, July 17, 1999)

Introduction

This was the third workshop to provide the opportunity for the Program Advisory Committee to focus on one of the five broad scientific areas that comprise the Jefferson Lab physics program. The goals of these workshops are to review the approved program in the context of recent developments, to identify the key scientific questions in the area of concentration and to suggest opportunities for future experimental work.

Vijay Pandharipande began the discussion with a summary of the key theoretical developments, recent progress and the reasonable expectation of future progress. Ingo Sick presented his views on how the experimental program at JLab could make progress on a variety of fronts. Overviews of the approved physics of nuclei experimental program were then presented by the three Hall leaders. In a round-table discussion each PAC member summarized the areas of interest and possible experiments for the laboratory.

Scientific Areas and Experiments

Electromagnetic probes have been used effectively to study nuclei for at least six decades. The capabilities of Jefferson Lab offer obvious advantages in reaching high momentum transfer to study short distance phenomena in nuclei and in coincidence experiments. In the early PAC deliberations, there was some skepticism that sufficient resolution could be obtained for many nuclear structure studies. Hall A has now achieved 2×10^{-4} resolution and it is appropriate to readdress this program. However, it is essential to consider the suggestions for further experiments in light of the large body of existing data worldwide. In many cases what is needed is a single definitive measurement that spans a significant range of several kinematic variables. Such measurements can validate the existing data set and, where problems with the reaction mechanism exist, point the way to more reliable future work.

- Testing the Standard Model of Nuclear Many Body Theory in $A > 4$ systems.

In the previous workshop on few-nucleon systems, the PAC identified as a key scientific question the testing of our standard model of nuclear physics. This standard model was defined as nuclear many-body calculations with the best current understanding of two- and three-nucleon interactions and one- and two-body electromagnetic currents. With present day computational resources, such calculations have been extended to systems of up to eight nucleons. New techniques have promise for extending calculations to $A \approx 50$.

Precise measurements of electromagnetic observables at high momentum transfer can test key assumptions in this standard model which are not well constrained by tests for systems with A = 2, 3 and 4.

⇒ High Q^2 elastic and inelastic electron scattering form factor measurements on ^{6}Li, ^{7}Li, and ^{9}Be.

(e,e'p) reactions over wide range of initial proton momenta in $6 < A < 9$.

(e,e'n) reactions to discrete states in $6 < A < 9$.

(e,e'π) reactions at high E_π to test the structure of pair currents.

- Nuclear Single Particle Structure.

  The properties of deeply bound hole states—spectroscopic strengths, positions and widths—are still only poorly known. Hypernuclei also provide an important tool for studying deeply bound states with relatively narrow widths in nuclei. While detailed knowledge of the wave functions of protons near the Fermi surface in nuclei exists, the data for neutrons is still poor.

⇒ (e,e'p) reactions to deeply bound hole states. Additional valuable information could be obtained by the detection of the nuclear decay particles.

(e,e'K^+) reactions to bound hypernuclear states.

(e,e'n) reactions to measure neutron hole states on a carefully considered choice of one light and one heavy system.

^{206}Pb –^{205}Tl comparisons at higher Q^2 to reduce the error on this textbook example of a hole state with significant density in the nuclear interior.

- Neutron Densities

  Parity violating electron scattering offers a unique quantitative probe of neutron distributions in heavy nuclei. A single, precise measurement would constrain a number of nuclear models used to describe the difference in neutron and proton density distributions. While PAC15 deferred a proposal in this area, interest remains high.

⇒ ^{208}Pb($\vec{e},e$) parity violation to measure neutron skin thickness.

- Medium Modifications of Hadrons in Nuclei.

  If the nuclear medium causes substantial modification to the internal structure of hadrons then it is quite possible that our standard model discussed in the first section will not provide a complete description of heavier nuclei. Both the currents and interactions could change in the nuclear medium. The difficulty is separating these effects from many body affects that naturally arise with three body forces and two body currents as contrasted to effects where the internal structure of the hadrons becomes important.

  ⇒ Polarization transfer measurement of G_E^P / G_M^P in A > 4 systems.

  L/T separations in (e,e'p) to discrete states

  A couple of careful studies of the Q^2 dependence of the (e,e'p) reaction to discrete states over a broad range of Q^2.

  Masses and widths of vector mesons in nuclei studied in the di-lepton decay channels.

  Bound states of ω and η mesons in nuclei.

  (e,e'π) reactions to study the properties of the pion field in nuclei, especially at high Q^2. While it is not clear how to cleanly 'count' pions in nuclei, the strong connection with meson-exchange models of the nucleon-nucleon interaction and chiral models of the nucleon suggests that both theory and experiment in the quasifree $(e,e'\pi)$ reaction should be actively pursued.

- Nucleon Correlations.

  Understanding the consequence of nucleon correlations is a must do program at JLAB, but it is still not clear what types of data are both clean enough to interpret and realistically measurable. The PAC believes the correct approach is to examine some of the results of the survey experiments that have been approved and then move decisively.

  ⇒ CLAS measurements on nuclear targets will provide an important overview of multi-nucleon reaction mechanisms.

  L/T separations in the ^{3}He(e,e'π) reaction appear to be an excellent case to study. The PAC deferred a proposal for this topic but remains enthusiastic about the possible physics insight of such a measurement.

- Hadronic Resonances in Nuclei.

This is an old problem in nuclear physics that was studied intensively for the Δ with pion beams. In many ways it is related to the search for medium modifications except well-known traditional mechanisms also can play essential roles. The PAC was not able to identify any new experiments in this area.

- Nuclei as a Length Scale or a Source of Nucleon Targets.

  Examining the nuclear dependence of a variety of electromagnetically induced reactions allows the study of hadron-nucleon final state interactions under controlled conditions. The nuclear size provides a controllable length scale to establish the elementary cross sections and coherence times at work.

  ⇒ (e,e'p) searches for color transparency.

  (e, e'V) production of vector mesons studying coherence lengths and color transparency (photon shrinkage).

  Electroproduction or photo-production of short-lived hadrons to extract the hadron-nucleon cross sections. Examples: η, J/Ψ at higher energies.

- Nuclear Response Functions in the Quasifree Region.

  There still remains controversy in the measurements of the Coulomb sum rule in L/T separations of the cross sections in (e,e') reactions as well as in the L/T separations in (e,e'p) reactions. Jefferson Lab should perform definitive studies in this area, but the demands for precision are very high. The proposers would need to convince the PAC that the methods are in hand to overcome the limitations of the past experiments in both technique (accuracy and backgrounds) and analysis (especially Coulomb and radiative corrections).

- Reaction Mechanism Studies on Nuclei.

  Unfortunately, to study much of the physics above, one needs better control of the reaction mechanisms than is currently in place. Many hints of multi-nucleon processes and excess transverse strength cloud the interpretations, even in apparently simple (e,e'p) reactions. The PAC is unlikely to approve experiments dedicated solely to tests of nuclear reaction mechanisms, however proposers are encouraged to include components of experiments focused primarily on some of the physics issues above which test key elements of the reaction mechanism that are essential for their experiments.