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Nuclear Research with the Electromagnetic Probe

A Progress Report for the Renewal of
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Stanford University

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Nuclear Research Using the Electromagnetic Probe

I. INTRODUCTION

The project discussed in this progress report focusses on understanding the many facets and scales of strongly interacting systems using the electromagnetic probe. On one hand we are investigating the spin properties of the nucleon (proton and neutron) through its fundamental constituents (quarks and gluons). On the other hand we are studying the properties of nucleons in nuclei and the few-body systems. The E142 and the newly approved E143 experiments planned at the Stanford Linear Accelerator Center are designed to provide an answer to the mystery of the missing spin of the proton, while the new letter of intent submitted to SLAC will investigate the so called Color transparency effect related to the prediction of PQCD for the $(e,e'p)$ quasielastic process in nuclei. Our research involvement at the Continuous Electron Beam Accelerator Facility focusses in Hall A. From the technical point of view we are building the Compton polarimeter for the Hall A beam line. This device should allow a precise measurement of the electron beam polarization for several approved experiments. From the physics aspect of the project we plan to perform the transverse/longitudinal separation of the nuclear response at high momentum transfer in the quasielastic region, the photodisintegration of deuterium with the measurement of the recoil polarization of the proton and the electromagnetic form factor of few body systems. experiment .

II. PROGRESS REPORT

II.1. SLAC PROGRAM:

II.1.a High Momentum Transfer $R_{L,T}$ Response Functions of Light Nuclei. Following the study of the nucleon behavior in the nucleus and how its electromagnetic properties might change, the analysis of the NE-9 experiment on light nuclei has been completed and the results on $^3,^4\text{He}$ have been submitted for publication to Physical Review Letters. A copy of the article is included at the end of this report.

The conclusion of the study carried by the NE-9 experiment can be summarized as follows:

For medium weight nuclei the quenching of the Coulomb sum rule persists at high momentum transfer however no strong Q^2 dependence is observed. Therefore the possible modification of the nucleon electromagnetic properties in the nuclear medium seems inadequate for the interpretation of the quenching effect.

For light nuclei, and within large errors, the Coulomb sum rule seems saturated at large momentum transfer, nevertheless higher precision data are needed to have a quantitative statements about the difference between heavy and light nuclei.

II.1.b E-142, Measurement of the Spin Structure Function g_1 of the Neutron The Stanford group has taken on the the responsibility to build a set of large volume threshold gas Cerenkov counters for pion rejection. David Kawall a student at Stanford doing his thesis on this experiment has studied all the optics of the counters subsequently a construction design was performed with the help of an engineer from Lawrence Berkeley Laboratories. At this stage several parts of the counters are under construction. A set of high reflectivity mirrors were built at CERN and delivered to Stanford. The holding frames of the mirrors are under construction at the physics department's machine shop and the large volume tanks should be awarded very soon to the best bidder. A contribution to the IEEE conference in Santa-Fe has been included at the end of this report. We are also involved in the online software praparation for the experiment and the radiative correction program development. The E-142 experiment is planned to run during the fall 1992.

II.1.c E-143 Measurement of the Spin Structure Function g_1 of the Proton and Neutron

A proposal to SLAC for the measurement of the proton and the neutron spin structure functions using ammonia $^{14}\text{NH}_3$ and Deuterated ammonia $^{14}\text{ND}_3$ has been submitted to SLAC by the E-143 collaboration. This proposal was approved by the SLAC PAC in December 1991. The E-143 experiment, which will use the same detector package as the E-142 experiment, is likely to run in spring 1993. E-143 is a high precision measurement not only of the proton spin structure function but will also measure the neutron structure function by extracting it from the deuteron in the ND_3 target. It is therefore a complementary measurement to the neutron measurement of E-142 using a different target. It should allow a strong constraint on the interpretation of the neutron structure function especially for understanding the nuclear effect inherent to the use of nuclear targets as neutron targets. The proposal is included at the end of this report.

II.1.d Cu K-shell Impact Ionization by 5.1-GeV Electrons

Using a novel grazing x-ray emission method from 2.7- to 61-mg/cm² Cu foils bombarded by 5.1-GeV electrons, we have made an absolute measurement of the K-shell ionization cross section, which demonstrates directly a density effect predicted by Fermi in 1940. By determining the K x-ray yield ratio front and back layer of each target, we have verified the effect of transition radiation on the K x-ray production. This experiment was carried by the atomic and nuclear physics groups of Stanford physics department for a 24 hours beam time period at SLAC approved by B. Richter. A paper submitted to Phys. Rev. Letters describing this work is included at the end of this report.

II.1.d Measurement of the Nuclear and Momentum Transfer Dependences of Quasielastic(e,e'p) Scattering at Large Momentum Transfer

It was proposed to make a coincidence measurements of the Quasielastic (e,e'p) cross section on several nuclei in the Q^2 range of 6 to 15 (GeV/c)² using the 23 GeV linac beam and spectrometers in End station A at SLAC. These measurements at high momentum transfers focusses in the regime where PQCD should be applicable therefore the scattering process can be understood in terms of a simple counting rule arguments. The motivation for these measurements is the striking prediction

of PQCD for the $(e,e'p)$ quasielastic process in nuclei where at large momentum transfer it is expected that the elastic and inelastic final state interaction of the proton in the nuclear medium diminish considerably. The effect is called "color transparency". Observation of this effect would be an important confirmation of the applicability of PQCD to exclusive processes. A letter of intent has been submitted to the SLAC directorate and is included at the end of this report.

II.2 CEBAF PROGRAM:

Our involvement at CEBAF is focussed in Hall A. During the last PAC meeting we have taken active part in two proposed experiments that have been approved or conditionally approved. One concerns the measurement of the electromagnetic form factors of the deuteron PR-026. The other is a parity violation experiment to study the strangeness content of the proton and ^4He PR-010.

II.2.a Prototype Design of the Compton Polarimeter for Hall A

We have worked on the design of the prototype beam line for the Compton polarimeter. The prototyping is done at CEBAF with financial support from CEBAF and from this grant. As a consequence of this design work, we prepared an MOU between Stanford university and CEBAF for building the Compton polarimeter. This MOU has been signed by Stanford University and CEBAF and the final decision for funds from DOE is still pending. A copy of the MOU is included in this report.

III. PLAN for RESEARCH in 92-93

We are currently preparing for the E-142 experiment run planned for next fall. Our first objective is to complete the construction of four Cerenkov Counters for this experiment. We will be testing one counter at Brookhaven National Laboratory in May 1992 for a period of five days. The counters should be ready and installed in End Station A during this summer before August 1992.

We will be preparing for E-143 since we will have to report on the next collaboration meeting about the possibility of detecting elastically scattered protons to monitor the target polarization along the beam. We will be developing the radiative correction program for the final analysis of the data.

For the CEBAF project we will be spending a large fraction of time prototyping the optical beam line and detectors for the Compton polarimeter. Different scenarios of the beam energy measurement will affect the beam line design therefore it is of paramount importance for us to closely collaborate in the scheme of the energy measurement of Hall A electron beam. As stated in our MOU with CEBAF we would finish the prototype of the optical beam line and start to design the photon and electron detector used for this polarimeter.

IV. Budget 82-93

The proposed budget for this year is covering two months summer salary of the principal investigator, a year salary of a graduate student and 20% contribution to the salary of a secretary.

The foreign travel budget include one trip to CERN to follow up on the construction of spare mirrors for the E-142, E-143 and ensure a quality control before delivery by participating in the reflectivity measurement of these mirrors.

The travel budget in the U. S. will cover the collaboration meetings at and prototype work for the Compton polarimeter performed at CEBAF.

The capital equipment part of the budget is described in a separate sheet (page 10) showing mainly two items necessary for the continuation of development of the Compton polarimeter for Hall A. It includes a CCD camera and Frame grabber needed for measuring the laser beam position and feedback for continuous monitoring of the Compton beam polarimeter. This part of the device is very important for optimizing the cross section and maintaining a constant interaction region between the laser beam and the electron beam.

IV. Publications

J.P. Chen, Z.E. Meziani, G. Boyd, L.M. Chinitz, D.B. Day, L.C. Dennis, G. Dodge, B.W. Filippone, K.L. Giovanetti, J. Jourdan, K. W. Kemper, T. Koh, W. Lorenzon, J.S. McCarthy, R.D. McKeown, R. Milner, R. Minehart, J. Morgens-
stern, J. Mougey, D.H. Potterveld, O.A. Rondon-Aramayo, R.M. Sealock L.C. Smith, S.T. Thornton, R.C. Walker, C. Woodward, "Longitudinal and Transverse Response Functions in ^{56}Fe (e,e') at Momentum transfer near 1 GeV/c", **Phys. Rev. Lett.** **66**(1991)1283.

M. Bernheim, M.K. Brussel, G.P. Capitani, J.F. Danel, E. de Sanctis, J.E. Ducret, S. Frullani, F. Garibaldi, A. Gerard, F. Ghio, H. Jackson, M. Iodice, L. Lakehal-
Ayat, J. M. Legoff, A. Magnon, C. Marchand, Z.-E. Meziani, J. Morgens-
stern, P. Vernin, and A. Zghiche "A Study of the Electrodissintegration Reaction $^4\text{He}(e,e'p)^3\text{He}$ with Transverse Longitudinal Separation" submitted for publication to **Nucl. Phys. A** (1991)

Z.E. Meziani, "Quasi-Elastic electron scattering at High 2Q and the Coulomb sum Rule" 4th Conference on the Intersections between Particle and Nuclear Physics May 24-29, 1991,

Z.E. Meziani, J. P. Chen, D. Beck, G. Boyd, L.M. Chinitz, D.B. Day, L.C. Dennis, G. Dodge, B.W. Filippone, K.L. Giovanetti, J. Jourdan, K. W. Kemper, T. Koh, W. Lorenzon, J.S. McCarthy, R.D. McKeown, R. Milner, R. Minehart, J. Morgens-
stern, J. Mougey, D.H. Potterveld, O.A. Rondon-Aramayo, R.M. Sealock L.C. Smith, S.T. Thornton, R.C. Walker, and C. Woodward, "High Momentum Trans-
fer $R_{T,L}$ Inclusive Response Functions for in $^3,^4\text{He}$ (e,e') submitted to **Phys. Rev. Lett.** (1992)

W.E. Meyerhof, D.G. Jensen, D. M. Kawai, S. Kuhn, D.W. Spooner, Z.-E. Meziani, D.N. Faust "Cu K-shell Impact Ionization by 5.1 GeV electrons" sub-
mitted to **Phys. Rev. Lett.** (1992)