Studies in Medium Energy Physics

Progress Report

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Narrative

University of Texas personnel for 1991-1992 include G. W. Hoffmann (Professor); R. L. Ray (Research Scientist), J. E. McDonough and A. Green (post-doctoral fellows); M. J. Purcell, D. E. Read, and S. D. Worm (Graduate Students).

Our research program in Medium Energy Physics (MEP) has three objectives:

(1) Provide precision medium energy hadron-nucleon and hadron-nucleus scattering data, as well as pragmatic, state-of-the-art analyses, to facilitate the systematic study of effective two-body interactions, to test (and possibly determine) nuclear structure, and to help study reaction mechanisms and dynamics.

(2) Conduct unique, first-of-a-kind, "exploratory" experiments whose purpose is to search for new, unexpected phenomena and new physics, and which provide data to stimulate further theoretical work.

(3) Conduct experiments that may shed light on our presently incomplete understanding of the fundamental interactions.

Our experiments, motivated by the above objectives, are conducted at the Los Alamos National Laboratory's (LANL) Clinton P. Anderson Meson Physics Facility (LAMPF) and at the Brookhaven National Laboratory's (BNL) Alternating Gradient Synchrotron (AGS) facility. Considerable shop, technical, construction, and theoretical work is done at The University of Texas in support of these experimental efforts. Presently, a total of fifteen projects are associated with the program. These range from experiments whose data taking phase was complete some time ago, and for which the work that remains is just to publish final data, to approved experiments that probably won't be scheduled for beam until 1993 and beyond. A detailed overview of these projects can be found in the **Addendum**.

This year, most of our experimental effort has been associated with three projects: (1) *LAMPF EXP1079*, (2) *the Polarized Nuclear Target project*, and (3) *AGS EXP791/871*. Our efforts were split roughly 50-50 between the efforts at LANL and BNL.

During the 1991-1992 report period our group has authored 12 refereed journal articles, 4 published conference proceedings, 7 EXP791/871 internal reports, and 5 abstracts.

Below we discuss highlights of the work done this year.

EXP1079: $p + A$ Precision Elastic Forward Angle Cross Sections. A comparison of observables predicted by scattering models which use either relativistic (RIA) or nonrelativistic (NRIA) dynamics indicates significant differences in the magnitudes of the 500-800 MeV $p + {}^{40}\text{Ca}$ and ${}^{208}\text{Pb}$ differential cross sections in the forward-angle, Coulomb-nuclear interference region. At 500 MeV some of the differences are 15-25%. Calculations indicate that precision cross section data in this region would set important constraints on relativistic models of the virtual pair process and the scalar densities of the target nucleus. The first phase of *EXP1079* was to develop the techniques required for a 1% experiment. A considerable amount of effort this year went into the design and mechanical construction of

the apparatus to be used for the production data. The system, whose components are all remotely moveable via computer control, are each mounted on an aluminum tooling plate that fits inside the HRS scattering chamber. The components consist of 4 beam scanners (an xy pair before and after the target, separated by about 30 in.), 2 high gain ($\times 1000$) ion chambers, 3 beam counting scintillators (for low intensity beams), a new target ladder, and a moveable, precision slit system made of tool steel with tapered rectangular apertures. The reference positions of the beam scanners, the target, and the slit apertures are to be determined using an elaborate aligning procedure to an accuracy of about 0.001 in. Optical encoder readouts then will give relative positions to an accuracy of 0.0002 in. Much of this apparatus was commissioned during the Summer 1991 development run and performed as expected.

Polarized Nuclear Target Project. For the past 15 years the PSI group in Switzerland headed by Mango has been developing compact refrigerators for use with the polarized target experiments performed at PSI. Such compact setups would be ideal for the programs that seem to be starting up at LAMPF with polarized nuclear targets. Because of our longer term interest in experiments which utilize polarized nuclear targets, several years ago we decided to make a copy of the PSI refrigerator to replace the LAMPF designed system. PSI provided us with a complete set of engineering drawings for the system, and are also consulting with us concerning this technically difficult project. The cryostat construction is complete, and approximately 85% of the ^3He evaporation unit has been made at this time. All components for the 70 GHz microwave system required for DNP (at a magnetic field of 2.5 T) have been acquired. We have also acquired most of the components required for the NMR system. A microvax-CAMAC controlled NMR system is modelled after that developed for *EXP955*. The 2.5 T superconducting split-coil magnet has recently been delivered by American Magnetics, Inc. The ^3He recirculation-storage-system is currently in the assembly stage. The large pumps for the ^3He main pumping system have been purchased, and the pumping package (stands, valves, plumbing, etc.,) is presently being designed. Also, construction of the ^4He transfer system is nearly finished. The construction phase of this project is projected to be complete by the end of next summer, and commissioning will begin at that time. It is reasonable to expect that a working target will be available by late 1992.

BNL EXP791/871: Search For Very Rare K_L Decays. Typically, conservation of lepton number is violated in extensions of the Standard Model. This experiment searches for the very rare decay $K_L \rightarrow \mu e$ as well as the allowed, but suppressed decay, $K_L \rightarrow ee$. The final data set, taken in 1990, is in the final stages of analysis. Analysis of the 1989 data is complete and will be published with the 1990 data. No $K_L \rightarrow \mu e$ or $K_L \rightarrow ee$ candidates were found. The preliminary results are: $BR(K_L \rightarrow \mu e) < 7.1 \times 10^{-11}$ (1990 data), $BR(K_L \rightarrow \mu e) < 3.3 \times 10^{-11}$ (1988 - 1990 combined data), $BR(K_L \rightarrow ee) < 8.0 \times 10^{-11}$ (1990 data), and

$BR(K_L \rightarrow ee) < 4.1 \times 10^{-11}$ (1988-1990 combined data). For $K_L \rightarrow \mu\mu$ the 1989 result was: $BR(K_L \rightarrow \mu\mu) = (7.6 \pm 0.5(\text{stat.}) \pm 0.4(\text{syst.})) \times 10^{-9}$. The preliminary 1990 result is: $BR(K_L \rightarrow \mu\mu) = (6.96 \pm 0.40(\text{stat.}) \pm 0.22(\text{syst.})) \times 10^{-9}$.

EXP871 will improve upon *EXP791* by more than an order of magnitude in sensitivity and set a limit on $K_L \rightarrow \mu e$ below 2×10^{-12} if no signal is observed. At this sensitivity, we should observe several $K_L \rightarrow ee$ events. In the new experiment our present efforts concern the beam stop, or plug, that will be inserted in the upstream dipole magnet to stop the neutral beam, and an instrumented iron muon filter. The beam plug will lead to reduced rates in the detectors far downstream of the plug position; this will in turn lead to better particle identification and reduced trigger rate from events that would be rejected later. The lowest momentum at which muons were accepted in *EXP791* was 1.5 GeV/c. In the new experiment, we plan to instrument the meter of steel which follows the lead glass array with layers of scintillation counters. This will permit a lower (1 GeV/c) muon momentum threshold which will increase the acceptance by about 10%. The instrumented muon filter will also improve our ability to trigger on muons and provide good timing information on muon tracks that project into the muon rangefinder (which provides effectively no time information because drift times are long and the hits are latched). Our group has the main responsibility for this device.

The design and testing of the beam-plug was the major *EXP871* effort for our group during the last year. Optimization of the design was performed using the simulation program CALOR89. The beam-plug was extensively tested at Brookhaven during the 1991 AGS proton cycle. In addition to rate measurements using the *EXP791* detectors, we built several special detectors to measure the number and energy-spectrum of the neutrons that were produced in the plug. These detectors; Bonner spheres, liquid scintillators, and ^3He counters were used both to identify the source of drift chamber rates and also as a test of the Monte Carlo program. The major goal of the test was to measure the rates in nearby drift chambers for a well-designed beam-plug. With this information we were able to determine that *EXP871* is feasible and we will use the data obtained to design the tracking detectors.

The primary functions of the instrumented muon filter (IMF), are (1) to provide a signal to the trigger logic which indicates the passage of a parallel muon with momentum greater than 1 GeV/c, and (2) to allow determination of muon momentum in the 1 GeV/c to 1.5 GeV/c range to about 5% via range measurements in the iron. The detector was designed using GEANT and HETC and will consist of about 2 meters of iron plates, three planes of x-y scintillators, and 19 panels from the *EXP791* muon rangefinder. A depth of 46 cm of iron (plus 42 cm of PbG) is required to provide a hadronic filter while keeping high (99.8%) efficiency for 1 GeV/c muons.

Theoretical Work

We have completed a detailed review article in which nonrelativistic and relativistic scattering formalisms for nucleon-nucleus scattering were discussed and applications given for many cases of proton elastic scattering at medium energies. This review comes at a time when parameter free theoretical predictions based on nonrelativistic and relativistic dynamics are both beginning to provide reasonable descriptions of the data. In the review article we included pedagogical discussion of the theory and showed predictions for the following scattering models: (1) the nonrelativistic, density-dependent (NRDD) model, (2) the nonrelativistic full-folding model, (3) the nonrelativistic Paris-Hamburg g -matrix optical model, (4) the relativistic impulse approximation (RIA) model, and (5) the relativistic meson exchange model (IA2).

Additional work was done concerning elastic scattering from polarized nuclei. Although relativistic and nonrelativistic distorted wave Born approximation (DWBA) calculations describe the general features of the 500 MeV $\vec{p} + {}^{13}\text{C}$ A_{oon} and A_{oonn} data, they do not fit details of the smaller angle data around 20° c.m. The sensitivities of the predictions to medium corrections and shell-model configuration mixing were studied using the nonrelativistic DWBA reaction model. The new results demonstrate that medium corrections and nuclear structure effects of the type considered are unimportant for this case, at least in the forward angle region around 20° c.m. where discrepancies between theory and experiment are greatest.

Listing of Publications

Journal and Conference Proceedings in Print

1. W. R. Coker and L. Ray, "The Nuclear Tensor Term in the Relativistic Impulse Approximation for Proton-Nucleus Elastic Scattering," *Phys. Rev. C* **42**, 2242 (1990).
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7. S. Penttilä, J. J. Jarmer, N. Tanaka, M. L. Barlett, K. Johnson, G. W. Hoffmann, W. Kielhorn, M. Purcell, G. Burleson, A. Klein, G. Kyle, B. Brinkmoller, D. Dehnhard, Yi-Fen Yen, J. R. Comfort, and J. J. Gorgen, "LAMPF Polarized ${}^{13}\text{C}$ Targets," 9th International Symposium on High Energy Spin Physics, September 10-15, 1990, Physics, Institute, Bonn University, Bonn, Federal Republic of Germany, (Springer-Verlag, Berlin, Heidelberg, 1991), Vol. 2: Workshops, pp. 315-319.

8. J. J. G6rgen, J. R. Comfort, J. R. Tinsley, T. Averett, J. DeKorse, B. Franklin, B. G. Ritchie, G. Kyle, A. Klein, B. Berman, G. Burleson, K. Cranston, J. A. Faucett, J. J. Jarmer, J. N. Knudson, S. Penttilä, N. Tanaka, B. Brinkm6ller, D. Dehnhard, Y. F. Yen, S. Hoibraten, H. Breuer, B. S. Flanders, M. A. Khandaker, D. L. Naples, D. Zhang, M. L. Barlett, G. W. Hoffmann, and M. Purcell, "Analyzing Powers for Pion Charge Exchange on Polarized ^{13}C ," *Phys. Rev. Lett.* **66**, 2193 (1991).
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12. D. M. Alde, H. W. Baer, T. A. Carey, G. T. Garvey, A. Klein, C. Lee, M. J. Leitch, J. W. Lillberg, P. L. McGaughey, C. S. Mishra, J. M. Moss, J. C. Peng, C. N. Brown, W. E. Cooper, Y. B. Hsiung, M. R. Adams, R. Guo, D. M. Kaplan, R. L. McCarthy, G. Danner, M. J. Wang, M. L. Barlett, and G. W. Hoffmann, "Nuclear Dependence of the Production of Υ Resonances at 800 GeV," *Phys. Rev. Lett.* **66**, 2285 (1991).

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1. L. Ray, "Spin Dependent Effective Interaction for Medium Energy Nucleon-Nucleus Scattering," in the Proceedings of the International Conference on Spin and Isospin in Nuclear Interactions, Telluride, CO, edited by S. Wissink, (Plenum, New York, 1991).
2. L. Ray, "Theoretical Interpretation of Proton Scattering Results from Polarized Nuclear Targets," in the proceedings of the 4th Conference on the Intersections Between Particle and Nuclear Physics, Tucson, AZ, (American Institute of Physics, New York, 1991).
3. L. Ray, "Nuclear Structure and Medium Effects in $\vec{p}+^{13}\vec{\text{C}}$ Elastic Scattering," submitted to Phys. Rev. C (1991).
4. L. Ray, G. W. Hoffmann and W. R. Coker, "Relativistic and Nonrelativistic Descriptions of Proton-Nucleus Scattering," Physics Reports (1990), in press.

EXP791/871 KL-Memos (Internal Publications)

1. J. McDonough and M. Diwan, "Results of Beam-Plug Analysis," KL-297 (1990).
2. G. Hoffmann, J. McDonough, B. Ware and S. Worm, "Measurements of Neutron and Photon Flux from the Beam Plug," KL-337 (1991).
3. B. Ware, G. Hoffmann, J. McDonough, and S. Worm, "Bonner Spheres/BUNKI and ^3He Counter Measurements," KL-338 (1991).
4. S. D. Worm, G. W. Hoffmann, J. McDonough, and C. B. Ware, "Analysis of the Liquid Scintillator Data Taken During EXP871," KL-339 (1991).
5. J. McDonough, G. Hoffmann, B. Ware, and S. Worm, "Measurements of Photons from the Beam Plug," KL-340 (1991).
6. J. McDonough, G. Hoffmann, B. Ware, and S. Worm, "Measurements of Charged Particle Flux from the Beam Plug," KL-341 (1991).
7. G. Hoffmann, J. McDonough, B. Ware, and S. Worm, "Estimates of EXP871 Drift Chamber Rates from Texas Detector Measurements," KL-345 (1991).

Abstracts

1. L. Ray, G. W. Hoffmann and W. R. Coker, "Nonrelativistic and Relativistic Descriptions of Proton-Nucleus Scattering," Texas Section Meeting of the American Physical Society, Denton, Texas, Nov. 1-2, 1991, Bull. Am. Phys. Soc. (1991).
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