Studies in Medium Energy Physics

Progress Report

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Narrative

University of Texas personnel for 1992-1993 include G. W. Hoffmann (Professor); R. L. Ray (Research Scientist), J. E. McDonough (post-doctoral fellow); M. J. Purcell, D. M. Read, and S. D. Worm (Graduate Students).

Our research program in Medium Energy Physics (MEP) has four 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, $p + A$ "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.

(4) Participate in the RHIC STAR detector construction project and phase in involvement in the RHIC physics program which will start taking data in the late 1990's.

Our experiments and efforts, motivated by the above objectives, are mainly conducted at the Los Alamos National Laboratory's (LANL) Clinton P. Anderson Meson Physics Facility (LAMPF), the Brookhaven National Laboratory's (BNL) Alternating Gradient Synchrotron (AGS) facility, the new Relativistic Heavy Ion Collider (RHIC) facility under construction at BNL, and at the University of Texas at Austin, where considerable shop, technical, construction, and theoretical work is done.

Presently, a total of nine projects are associated with the program. These include (1) experiments whose data taking/analysis/interpretation phases are complete and the remaining task is publication, (2) experiments whose initial data taking phases have just been completed, (3) the polarized target project, and (4) the STAR construction project which won't be finished until 1997. A detailed overview of these projects can be found in the **Addendum**.

This year, most of our experimental effort has been associated with six projects: (1) *LAMPF EXP1079*, (2) *LAMPF EXP1205*, (3) *Polarized Target Project*, (4) *AGS EXP791/871*, (5) *AGS EXP888*, and (6) *STAR SVT/software projects*.

During the 1991-1992 report period our group has authored 5 refereed journal articles, 2 published conference proceedings, 4 EXP791/871 internal reports, and 9 abstracts. Below we discuss highlights of the work done this year.

EXP1079: $p + A$ Precision Elastic Forward Angle Cross Sections. 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 $p + {}^{40}\text{Ca}$ differential cross sections in the forward-angle, Coulomb-nuclear interference region. At 500 MeV some of the differences are 15-25%. Sensitivity studies show that precision cross section data in this region would

allow us to impose important constraints on relativistic models of the virtual pair process and the scalar densities of the target nucleus. Over the past several years we developed the techniques required for a 1% experiment, and we spent a considerable amount of effort designing and building the mechanical apparatus to be used in the experiment. This year saw the first production run using this novel equipment. 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 apertures. The reference positions of the beam scanners, the target, and the slit apertures can be determined using an elaborate aligning procedure to an accuracy of about 0.001 in. Optical encoder readouts provide relative positions to an accuracy of 0.0002 in. The apparatus' many components are remotely moveable via computer control.

The initial data taking phase occurred in Summer 1992. Considerable time (about 1 month) was spent aligning the equipment and calibrating the various beam current determining devices. Physics data were taken over a 1 week period in August. Central slit settings were used that enabled precision data acquisition for the $1.75^\circ - 4.40^\circ$ angular region. Although replay of these data remains to be done, the online studies made during data acquisition lead us to believe that the final cross section data will have absolute uncertainty in the 1-2% range. It is not known at this time whether additional production runs will be needed to meet the physics goals of this experiment.

EXP1205: Precision Measurement of D_{NN} for $^{13}\text{C}(\vec{p}, \vec{p})$ at 500 MeV. Quantitative, parameter free descriptions of proton-(spin-zero)nucleus elastic scattering and inelastic excitation of natural parity, collective states, using either the relativistic or nonrelativistic models, are gradually becoming a reality.

Much less work has been done for reactions that involve spin and/or isospin transfer. These reactions are sensitive to the spin-transfer and isovector components of the NN force and to single particle aspects of nuclear structure. In general, our present understanding of spin and isospin transitions at intermediate energies is unsatisfactory and more work in this area is necessary.

A precision measurement of D_{NN} for proton elastic scattering from ^{13}C will allow important work to proceed in these studies. Specifically, such data enables new tests of relativistic and nonrelativistic models and will provide effective interaction information that complements that obtained from the elastic $\vec{p} + n$ -type polarized ^{13}C data and from $(\vec{p}, \vec{p}')$ data.

The quantity D_{NN} for elastic scattering from even-even ($J^\pi = 0^+$) targets is unity, corresponding to spin-flip probability zero. For ^{13}C with ground state $J^\pi = \frac{1}{2}^-$ both $\Delta J = 0, 1$ contributions are allowed. $\Delta J = 1$ permits D_{NN} to differ from unity. Small differences from unity are expected in the region of the first diffractive minimum (about 16° laboratory angle). Theoretical work shows that, in the language of the Lorentz invariant form of the NN interaction, the spin-flip probability for this case is determined primarily by the pseudoscalar (PS) invari-

ant and to a lesser extent by the space-like tensor component. It is particularly sensitive to the choice of PS or pseudovector(PV) forms. It is also sensitive to the lower component strength of the valence wave function (for the PS form). The predicted spin-flip strength is affected somewhat by the assumptions for the core scattering amplitude, but this quantity can be tightly constrained in the analysis, since precision unpolarized $\vec{p}+^{13}\text{C}$ data exist.

The initial data taking phase of this experiment was conducted in September, 1992. Individual 50 mg/cm² ^{12}C and ^{13}C targets were sandwiched to allow data to be taken simultaneously for both nuclei. An overall HRS resolution of about 100 keV was achieved. It was crucial to the experiment to have well-resolved elastic peaks for ^{12}C and ^{13}C for accurate determination of the D_{NN} . Simultaneous $p+^{13}\text{C}$ and $p+^{12}\text{C}$ data acquisition allow systematic errors to be removed in the experiment, since $D_{NN} = 1$ for ^{12}C .

The experiment took physics data for about 1 week at one HRS central angle setting (16°). Data analysis has yet to be started, but statistics indicate that the error in the final D_{NN} (with 0.5° angle binning) will be about (± 0.02) for the data taken so far. We anticipate another production run in Summer 1993.

Polarized Nuclear Target Project. For the past 15 years the PSI group in Switzerland has been developing compact refrigerators for use with the polarized target experiments performed at PSI. A compact setup would be ideal for any $p+A$ high resolution experiment that uses a small beam spot on target. These types of experiments are done at LAMPF, TRIUMF, and IUCF. Several years ago we made the decision to build a compact polarized target for our research program. PSI provided us with a complete set of engineering drawings for the system, and has consulted with us concerning this technically difficult project. The LAMPF polarized target group is another important consultant on this project. The cryostat/evaporation unit construction is now complete, and the initial cooldown occurred, with success, in October 1992. Further work on the refrigerator awaits the delivery of a small, portable helium leak detector for diagnostics, an AC resistance bridge, and temperature sensor instrumentation. 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 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 been mounted on the refrigerator and will be cooled and energized during the next cooldown. The ^3He recirculation-storage-system has been constructed, and the large pumps for the ^3He main pumping system have been purchased. We still need to assemble the pumping package (stands, valves, plumbing, etc.). Also, construction of the ^4He transfer system is finished.

The construction phase of this project is essentially complete and the commissioning phase will begin shortly. It is reasonable to expect that a working target will be available by late 1993.

BNL EXP791/871: Search For Very Rare K_L Decays. These experiments search for the lepton-family-number violating decay $K_L \rightarrow \mu e$ as well as the allowed, but suppressed decay, $K_L \rightarrow ee$. Another suppressed decay mode, $K_L \rightarrow \mu\mu$, is measured with better precision than ever before attained. Typically, conservation of lepton number is violated in extensions of the Standard Model. The final *EXP791* 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: $BR(K_L \rightarrow \mu e) < 6.7 \times 10^{-11}$ (1990 data), $BR(K_L \rightarrow \mu e) < 3.3 \times 10^{-11}$ (1988 - 1990 combined data), $BR(K_L \rightarrow ee) < 7.7 \times 10^{-11}$ (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: $BR(K_L \rightarrow \mu\mu) = (6.86 \pm 0.37(\text{stat.}) \pm 0.22(\text{syst.})) \times 10^{-9}$.

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 preparation for 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, an instrumented iron muon filter, and the hardware trigger logic.

The design and testing of the beam-plug was a major *EXP871* effort for our group during the last two years. 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. Optimization of the design was performed using the simulation program CALOR89 and empirically during extensive tests performed at Brookhaven. 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 that 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 22 gas counters from the *EXP791* muon rangefinder. The IMF will also 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). 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. Our group has the main responsibility for this device.

The hardware trigger is one of the most important facets of the new experiment. It will provide a much greater suppression of trigger 'noise' than was possible in *EXP791* because it requires the tracks on each side of the detector to be parallel

to the beam axis. The dominant semi-leptonic K_L decay modes will not satisfy the trigger because the total transverse momentum kick of our spectrometer magnets will be tuned to force parallelism from 2-body K_L decays. The parallel trigger will include not just the trigger scintillation counters but also the particle identification counters, the Čerenkov and IMF, to further reduce trigger rates.

BNL EXP888: Search For The H Dibaryon. During the 1992 AGS proton cycle the *EXP791* detector was used to perform two complementary searches for the six-quark $uuddss$ state known as the H dibaryon. If the mass of the dibaryon is greater than twice the mass of the Λ , it will decay quickly via the strong interaction. If, however, the mass is below the $\Lambda\Lambda$ (2231 MeV/ c^2) threshold and above the $n\Lambda$ (2055 MeV/ c^2), it must decay via the weak interaction and is expected to have a lifetime similar to the lifetime of the K_L . For masses below the $n\Lambda$ threshold the lifetime is expected to be very long, since both strange quarks must decay via the weak interaction. Our two experiments are sensitive to all dibaryon lifetimes below the $\Lambda\Lambda$ threshold.

The first of these, the H-decay experiment, is very similar to *EXP791*. It searches for an $H \rightarrow X\Lambda \rightarrow p\pi^-$. Experimentally, we simply look for events with identified proton- π^- pairs that have an invariant mass equal to the Λ mass. The background from Λ 's produced at the target, which is already small since the decay region is more than 10 decay lengths from the target, can be suppressed further by requiring the reconstructed $p\pi^-$ to have a net transverse momentum.

The second dibaryon search is sensitive to lower-mass H's. It uses a series of plastic scintillators to diffractively dissociate the H. It then searches for $\Lambda\Lambda$ events by reconstructing two $p\pi^-$ pairs. The entire process is:

$$H + A \rightarrow H^* + A \rightarrow \Lambda\Lambda + A \rightarrow p\pi^- + p\pi^- + A$$

where the H^* is an excited H that can decay strongly to $\Lambda\Lambda$. The plastic scintillators serve as both the target and detector to measure the recoil energy of the target nucleus A .

RHIC-STAR Project. Recently our group joined the STAR Collaboration (Solenoidal Tracker at RHIC). The eventual goal is to use STAR at BNL's Relativistic Heavy Ion Collider (RHIC) to search for the formation of the hypothesized quark-gluon plasma (QGP) and study its properties, to temporarily produce very high density states of nuclear matter and study the properties of such systems, to study hard QCD processes which occur inside dense nuclear matter, and possibly to carry out detailed investigations of spin physics at high energies for $p + p$ collisions at center-of-momentum energies up to 500 GeV. The experimental program will include studies of $p + p$, $p + A$, and $A + A$ collisions.

The main detector components of STAR include a warm coil solenoidal magnet, a silicon vertex tracker (SVT), a time-projection chamber (TPC), an electromagnetic calorimeter (EMC), a time-of-flight system (TOF), and an external time-projection chamber (XTPC).

Our group has become involved in SVT design and development efforts and also software and simulation efforts. There will be a run at TRIUMF in Spring 1993 to test the present design of the silicon drift detectors (SDD's) to be used in the SVT. Three SDD's will be placed in a pion beam and their performance (especially with respect to tracking) will be evaluated. We designed and constructed the trigger scintillator system for this test as well as the mechanical mounting/moving system for the SDD's that will allow them to be moved and precisely located in x, y, z with respect to a fixed coordinate system with respect to the trigger scintillators (the beam). The apparatus uses many of the optical encoder components of the EXP1079 setup. We have also begun software work such as setting up the STAR computer codes (both STAR specific, such as SVT and TPC trackers, and others, such as the CERN Library that will be used extensively by STAR) on our Silicon Graphics Crimson for specific tasks we have been assigned (such as SVT-TPC matching of helical trajectories). In addition we will build some of the STAR baseline detector components at Texas. One such component is the TPC test stand. We expect to have other ongoing, significant STAR construction projects at Texas, and over the next several years we expect to phase more and more into STAR so that it accounts for about 1/2 of our research effort.

Theoretical Work. Our recent theoretical work was mainly related to nucleon-nucleus reactions at medium energies and for the next year or so will continue to be directly associated with the experimental program in proton-nucleus scattering. Theoretical work associated with relativistic heavy-ion physics will commence during 1993 and will become a major focus in about a year. Theoretical projects during the past year and for the immediate future include the following: (1) A phenomenological phase shift analysis of 800 MeV $p + p \rightarrow n + X^{++}$ inclusive data in the Δ excitation region. Preliminary fits to the data (cross sections and spin observables) have been obtained and indicate that of the 16 parity invariant $NN \rightarrow N\Delta$ amplitudes the 10 which depend on rank-2 tensor spin operators are large and may be necessary in understanding Δ -excitation in nuclei. (2) Development of a low-energy NN potential model based on chiral symmetric effective Lagrangians determined from QCD. In collaboration with Dr. C. Ordonez and Mr. U. van Kolck at The University of Texas a non-local NN potential model has been developed which, in addition to the usual one-pion exchange term, contains about 70 individual spin and isospin dependent terms corresponding to two-pion exchange loops, derivative couplings, Δ intermediate states, non-static corrections, and new terms originating from the chiral symmetry of QCD. The model contains 23 parameters which are presently being fitted to the low energy NN phase shifts. (3) A calculation of medium energy proton + nucleus elastic scattering based on the full-folding optical potential model in which off-shell NN t -matrix effects, medium corrections, target nucleon correlations, and projectile - target nucleon antisymmetrization are consistently accounted for. (4) Relativistic DWBA predictions for 500 MeV $\vec{p} + {}^{13}\vec{\text{C}}$ elastic scattering based on the relativistic IA2 effective interaction.

Listing of Publications

Journal and Conference Proceedings in Print

1. L. Ray, "Spin Dependent Effective Interaction for Medium Energy Nucleon-Nucleus Scattering," in *Spin and Isospin in Nuclear Interactions*, edited by S. Wissink, C. D. Goodman, and G. E. Walker, (Plenum, New York, 1991), pages 231 - 251.
2. L. Ray, "Theoretical Interpretation of Proton Scattering Results from Polarized Nuclear Targets," in the proceedings of the 4th International Conference on the Intersections Between Particle and Nuclear Physics, AIP Conf. Proc. No. **243**, edited by W. T. H. Van Oers, (American Institute of Physics, New York, 1992), pages 939 - 942.
3. L. Ray, G. W. Hoffmann, and W. R. Coker, "Nonrelativistic and Relativistic Descriptions of Proton-Nucleus Scattering," *Physics Reports* **212**, 223-328 (1992).
4. L. Ray, "Nuclear Structure and Medium Effects in $\vec{p} + {}^{13}\text{C}$ Elastic Scattering," *Phys. Rev. C* **45**, 1394 (1992).
5. P. L. McGaughey, J. M. Moss, D. M. Alde, H. W. Baer, T. A. Carey, G. T. Garvey, A. Klein, C. Lee, M. J. Leitch, J. W. Lillberg, C. S. Mishra, 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, "Limit on the $\bar{d}/\bar{u}$ Asymmetry of the Nucleon Sea from Drell-Yan Production," *Phys. Rev. Lett.* **69**, 1726 (1992).
6. X. Y. Wu, P. Asoka-Kumar, J. S. Greenberg, S. D. Henderson, H. Huomo, K. G. Lynn, M. S. Lubell, R. Mayer, J. McDonough, B. F. Philips, and A. Vehanen, "Search for Low-Mass States in Elastic e^+e^- Scattering," *Phys. Rev. Lett.* **69**, 1729 (1992).
7. S. D. Henderson, P. Asoka-Kumar, J. S. Greenberg, K. G. Lynn, S. McCorkle, J. McDonough, B. F. Philips, and M. Weber, "Search in s Channel for Production of 1-2 MeV/ c^2 Long-Lived e^+e^- Resonances," *Phys. Rev. Lett.* **69**, 1733 (1992).

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1. M. J. Leitch, D. Alde, H. Baer, J. Boissevain, T. Carey, G. T. Garvey, R. Jeppesen, J. Kapustinsky, A. Klein, D. Lane, C. Lee, J. Lillberg, P. McGaughey, J. M. Moss, J. C. Peng, M. Brooks, G. Brown, D. Isenhowe, M. Sadler, R. Schnathorst, G. Danner, M. Wang, L. Lederman, M. Schub, C. N. Brown, W. E. Cooper, H. Glass, Y. B. Hsiung, C. S. Mishra, K. Gounder, M. R. Adams, G. Gidal, P.-M. Ho, M. Kowitt, K.-B. Luk, D. Pripstein, M. Apolinski, R. Guo, D. M. Kaplan, V. Martin, R. Preston, J. Sa, V. Tanikella, R. Childers, C. Darden, J. Wilson, R. L. McCarthy, Y.-C. Chen, G.-C. Kiang, P.-K. Teng, M. Barlett, and G. Hoffmann, "Nuclear Effects on Heavy Quark Production, Results from Fermilab Experiments E772 and E789," in the proceedings of the conference on *Quark Matter 1991*, Gatlinburg, Tennessee, November 11-15, 1991.
2. K. Arisaka, L. B. Auerbach, S. Axelrod, J. Belz, K. A. Biery, P. Buchholz, M. D. Chapman, R. D. Cousins, M. V. Diwan, M. Eckhause, J. F. Ginkel, C. Guss, A. D. Hancock, A. P. Heinson, V. L. Highland, G. W. Hoffmann, J. Horvath, G. M. Irwin, D. Joyce, T. Kaarsberg, J. R. Kane, C. J. Kenney, S. H. Kettell, W. W. Kinnison, P. Knibbe, J. Konigsberg, Y. Kuang, K. Lang, D. M. Lee, J. Margulies, C. Mathiazhagan, W. K. McFarlane, R. J. McKee, P. Melese, E. C. Milner, W. R. Molzon, D. A. Ouimette, P. J. Riley, J. L. Ritchie, P. Rubin, G. H. Sanders, A. J. Schwartz, M. Sivertz, W. E. Slater, J. Urheim, W. F. Vulcan, D. L. Wagner, R. E. Welsh, R. J. Whyley, R. G. Winter, M. T. Witkowski, S. G. Wojcicki, A. Yamashita, and H. J. Ziock, "Improved Upper Limit on the Branching Ratio $B(K_L^0 \rightarrow \mu^\pm e^\mp)$," submitted to Phys. Rev. Lett. (1992).

EXP791/871 KL-Memos (Internal Publications)

1. J. McDonough, G. Hoffmann, K. Lang, P. Riley, J. Ritchie, B. Ware, and S. Worm, "UT Austin E871 Detector Proposal," KL-369 (1991).
2. J. McDonough, "Beam-plug Monte Carlo Using CALOR89," KL-387 (1992).
3. M. Diwan, J. McDonough, and D. Ouimette, "E871 Detector Layout," KL-388 (1992).
4. J. McDonough, "Recent Communication with BNL's Instrumentation and Radiation Safety Personnel," KL-413 (1992).

Abstracts

1. L. Ray, G. W. Hoffmann, and W. R. Coker, "Comparison of Nonrelativistic and Relativistic Descriptions of Proton-Nucleus Elastic Scattering," General Spring Meeting of The American Physical Society, Washington, D. C., April 20 - 24, 1992, Bull Am. Phys. Soc. **37**, 901 (1992).
2. G. Hoffmann, M. Barlett, W. Kielhorn, G. Pauletta, M. Purcell, L. Ray, J. Amann, J. Jarmer, K. Jones, S. Penttilä, N. Tanaka, G. Burleson, J. Faucett, M. Gilani, G. Kyle, L. Stevens, A. Mack, D. Mihailidis, T. Averett, J. Comfort, J. Gorgen, and J. Tinsley, " A_{nn} for 500 MeV $\vec{p} + \vec{p}$ Elastic Scattering," General Spring Meeting of The American Physical Society, Washington, D. C., April 20 - 24, 1992, Bull Am. Phys. Soc. **37**, 903 (1992).
3. L. Ray, "Phenomenological Transition Amplitudes for the NN to $N\Delta$ Reaction," Fall Meeting of the Division of Nuclear Physics of the American Physical Society, Sante Fe, New Mexico, October 15 - 17, 1992, Bull. Am. Phys. Soc. **37**, 1314 (1992).
4. G. Hoffmann, W. Betts, L. Ray, D. Read, S. Thompson, J. Amann, A. Green, T. Baker, B. Storm, G. Edwards, C. Glashauser, and M. Jones, "Precision Forward Angle 500 MeV $p + A$ Elastic Differential Cross Section Measurements," Fall Meeting of the Division of Nuclear Physics of the American Physical Society, Sante Fe, New Mexico, October 15 - 17, 1992, Bull. Am. Phys. Soc. **37**, 1319 (1992).
5. K. Johnson, M. Purcell, H. Ward, A. Williams, S. Worm, B. Brinkmüller, D. Dehnhard, J. Langenbrunner, M. Palarczyk, C. Reidel, Y. Yen, G. Burleson, M. Ghossain, A. Klein, G. Kyle, S. Mukhopadhyay, M. Wang, R. Ivie, M. Kagarlis, S. Loe, M. Mackenzie, J. O'Donnell, D. Smith, M. Khandaker, M. Khayat, C. Allgower, J. Comfort, S. Greene, J. Jarmer, S. Penttila, and N. Tanaka, "Left-Right Asymmetry Measurements for Pion Scattering off Polarized ^{13}C ," Fall Meeting of the Division of Nuclear Physics of the American Physical Society, Sante Fe, New Mexico, October 15 - 17, 1992, Bull. Am. Phys. Soc. **37**, 1304 (1992).
6. S. Worm, G. Hoffmann, K. Lang, J. McDonough, P. Riley, J. Ritchie, and B. Ware, "Measurement of Neutrons, Photons, and Charged Particles from a Neutral Beam Stop," Fall Meeting of the Division of Nuclear Physics of the American Physical Society, Sante Fe, New Mexico, October 15 - 17, 1992, Bull. Am. Phys. Soc. **37**, 1306 (1992).
7. J. McDonough, G. Hoffmann, K. Lang, P. Riley, J. Ritchie, B. Ware, and S. Worm, "Beam-Plug Design for BNL E871," Fall Meeting of the Division of Nuclear Physics of the American Physical Society, Sante Fe, New Mexico, October 15 - 17, 1992, Bull. Am. Phys. Soc. **37**, 1306 (1992).

8. A. Sethi, D. N. Mihailidis, N. M. Hintz, A. Green, M. Jones, L. Rybarcyk, L. Bimbot, D. Read and S. Worm, "Inelastic Proton Scattering from Tungsten Isotopes and the IBA Model," Fall Meeting of the Division of Nuclear Physics of the American Physical Society, Sante Fe, New Mexico, October 15 - 17, 1992, Bull. Am. Phys. Soc. **37**, 1308 (1992).
9. J. McDonough, "The Design of the Beam Plug for a New $K_L \rightarrow \mu e$ Experiment," Seventh Meeting of the American Physical Society Division of Particles and Fields, Batavia, Illinois, November 10 - 14, 1992, to be published in Bull. Am. Phys. Soc.

Reprints of Publications

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