DOE/ER/40419--T2

**SELECTED PROBLEMS IN EXPERIMENTAL INTERMEDIATE
ENERGY PHYSICS**

FINAL REPORT

Technical
GRANT PERIOD: 1 FEBRUARY, 1991 – 31 JANUARY, 1994

**BILL W. MAYES
PRINCIPAL INVESTIGATOR
DEPARTMENT OF PHYSICS
(713) 743-3548**

**ED V. HUNGERFORD
PRINCIPAL INVESTIGATOR
DEPARTMENT OF PHYSICS
(713) 743-3549**

**LAWRENCE S. PINSKY
PRINCIPAL INVESTIGATOR
DEPARTMENT OF PHYSICS
(713) 743-3552**

**PREPARED FOR:
THE UNITED STATES DEPARTMENT OF ENERGY
UNDER CONTRACT NO. DE-FG05-88ER40419**

MASTER

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

I. Personnel

Personnel who will have worked in support of this contract for the period

February 1, 1991 to January 21, 1994 are listed below.

E.V. Hungerford	Professor of Physics
B.W. Mayes	Professor of Physics
L.S. Pinsky	Professor of Physics
Y.K. Chen	Research Associate
K. Lan	Research Associate
J.Zhu	Research Associate
M. Dzemidzic	Research Assistant
M. Ahmed	Research Assistant
B. Barakat	Research Assistant
P. Chen	Research Assistant
K. Johnston	Research Assistant
J. Flick	Engineer
J. Liu	Technician
Y. Lu	Technician
D. Seamon	Technician
Z. Wang	Technician
X. Yao	Technician
K. Gross	Student
R. Tully	Student
N. Tripathy	Student
D. Aguirre	Secretary
T. Kelsaw	Secretary

II. Background

A complete description of the research program of the intermediate energy group at the University of Houston may be found in previous progress reports, renewal proposals, and proposals to various accelerator advisory committees. The summaries of

activities are presented in the next section. The objectives of the research program are to:

- 1) investigate selected, forefront problems in experimental intermediate energy physics;
- 2) educate students in this field of research; and, 3) develop the instrumentation necessary to undertake this experimental program.

Generally, the research is designed to search for physical processes, which cannot be explained by conventional models of elementary interactions. As one example, we use nuclear targets where the nucleus provides a many body environment of strongly interacting particles, and where one attempts to observe the perturbation of a known interaction by this environment. Unfortunately, these effects may be masked by the complexity of the many body problem and may be difficult to observe. Therefore, experiments of this type must be carefully chosen and analyzed for deviations from more conventional models.

There were three major thrusts of the program; 1) strange particle physics, where a strange quark is embedded in the nuclear medium; 2) muon electro-weak decay, which involves a search for a violation of the standard model of the electro-weak interaction; and 3) measurement of the spin dependent structure function of the neutron and proton. During this grant period, approximately 60% of our effort has been expended on the MEGA experiment, a search for lepton number violating decay, $\mu \rightarrow e\gamma$, at the Los Alamos Meson Physics Facility, LAMPF. Approximately 20% of our effort has been devoted to strange particle physics, mainly at the Brookhaven Alternating Gradient Synchrotron, AGS, and the remaining 20% on measurement of the spin dependent structure function of the neutron and proton, SMC, at CERN. Table I. lists experiments, which were under active investigation during the grant period.

Table I. Experiments under Analysis

<u>Experiment</u>	<u>Description</u>	<u>Status</u>
AGS Exp 759	Weak Decay Modes of Hypernuclei	Paper published
AGS Exp 773	Search for an $S = -1$ Dibaryon	Paper submitted
AGS Exp 774	Search for Sigma Hypernuclei	Paper published Data under analysis
AGS Exp 798	Hypernuclei from the (π, κ) Reaction <i>Investigation</i>	Paper published
AGS Exp 828	Search for a 3 Neutron Bound State	Data under analysis
LAMPF	Pion Production at Small Angles	Paper published Paper in preparation
AGS Exp 874	K^+ Elastic and Quasifree Scattering	Data under analysis Paper published
AGS Exp 887	Do Narrow Σ Hypernuclear states exist?	Data under analysis
LAMPF Exp 969 (MEGA)	Search for $\mu \rightarrow e \gamma$	Paper published Papers in preparation Data under analysis
LAMPF Exp 1240	Measurement of the Michel Parameter, ρ	Data under analysis
CERN Exp NA47	Spin Dependent Structure Functions of The Neutron and Proton	Papers published Papers published Data under analysis

Handwritten notes:
 11. 9. 91
 Energy Physics
 June 1992
 Conference
 P. J. ...
 ...

The group has been active in experiments at LAMPF, AGS, and CERN. In addition, we are preparing experimental programs at the Continuous Electron Beam Facility, CEBAF, and an upgrade of our facilities at the AGS. With regard to CEBAF, we have an approved program to explore electroproduction of strangeness. This is an extension of the program we were instrumental in developing at the AGS. However, the CEBAF program will be carried to a new level of precision by taking advantage of the expected performance of the CW electron beam at that accelerator. The research requires the development of a spectrometer system, but experiments are capable of providing resolution an order of magnitude better than currently possible at hadronic machines. The program is discussed in more detail in the next section.

Finally, we have devoted some effort to exploring techniques to upgrade and expand our facilities at the AGS. These plans are not yet completed, but we expect to submit a set of proposals to the AGS program advisory committee. These are based in part on a Letter of Intent submitted to and encouraged by the BNL PAC.

In summary, the group has been active in programs attacking a diverse range of problems at several different accelerator facilities. Emphasis on specific programs, as measured by effort expended, reflects the requirements to mount this specific experiment. Thus, MEGA has previously used substantial resources in manpower and funds. However, we expect to conclude data acquisition for MEGA as well as SMC in 1995. Future work is anticipated to be focussed at CEBAF and BNL.

III. Selected Abstracts of Current Research

This section reviews in more detail the experimental programs in which the group has been involved during the grant period.

(A) Strange Particle Physics at the AGS

The level structure of hyperons embedded in the nucleus (hypernuclei) has been under investigation by our group for some time¹. The motivation has been to sort out the hyperon-nucleon interaction in the many body system. Although hypernuclear structure is interpreted by conventional nuclear many body techniques, the underlying quark structure of the strange-nucleus interaction is just beginning to be addressed. It was suggested some time ago² that by placing a hyperon into what would otherwise be an indistinguishable sea of up and down quarks, unique configurations of the strange quark due to the interaction of the Pauli principle may provide the key to unlock the quark picture of the nucleus. For example, one would like to place a lambda deeply within the nucleus and determine the level structure with high accuracy. Changes in this structure, due to partial deconfinement of the quarks in the lambda, may occur. Alternatively a change of the size of the lambda in the nucleus may possibly be explained in terms of lambda-sigma coupling³ or perhaps three body forces⁴. This could also be connected to the significant charge symmetry breaking observed in the lambda-nucleon interaction⁵.

The best evidence that single particle Λ hypernuclear states exist in heavier nuclei comes from the analysis of the structure observed in the (π, κ) reaction on heavier nuclear targets, AGS Exp 798. This reaction populates a series of levels associated with the removal of a valence neutron, and the deposition of a Λ in one of the possible shells within the nucleus. An example⁶ is that of ^{89}Y where a $g_{7/2}$ neutron is removed and the Λ is placed in shell orbitals from the 1s to the 1g shell, Fig. 1. Fine structure within these levels cannot be seen with the current resolution, however, the centroid of the various Λ -shell orbitals as a function of the atomic mass can be fit with spin-independent Λ -

Figure 1. The hypernuclear spectrum for $^{89}_\Lambda\text{Y}$ from the (π, K) reaction. The various Λ ell orbitals are labeled.

nucleus optical potential of wood-saxon form. Fig 2. The level spacings vary smoothly as a function of A , signifying the Λ single particle behavior. However, it is not possible to simultaneously fit both the spectra of light and heavy hypernuclei with a potential linear in the nuclear density. A repulsive density dependence is needed to reduce the overbinding problem in nuclear matter⁷. Such terms are consistent with a repulsive three-body ANN interaction, and similar terms are needed in the light hypernuclear systems⁸. With this complexity the observed deeply bound Λ states are well defined.

Sigma-nucleus interactions are not well understood despite ten years of experimental and theoretical effort⁹⁻¹⁷. In fact, much of this work has tended to cloud the issues rather than illuminate them. On the experimental side the data suffers from poor statistics, with spectra taken on different targets, at different momenta, and under different conditions. On the theoretical side considerable effort has been invested to essentially force narrow structure in the calculated results, although experimental evidence for such structure is ambiguous. Except for ^4He , no Σ -nucleus bound states are reported¹⁴, and while continuum structure exists, much of it is consistent with phase space with the addition of some amount of final state interactions¹⁵.

Our group has been involved in the attempt to settle issues concerning evidence for narrow Σ hypernuclear structure, AGS Exp 774. Since the Σ -nucleus potential is strongly spin and isospin dependent, strong conversion $\Sigma N \rightarrow \Lambda N$ occurs only in the 3S_1 : isospin-1/2 state, so that there are possible spin-isospin states in light nuclei where this strong decay mode would be suppressed¹⁶. The suppression could produce narrower than expected structure, and this process has been labeled "selectivity". Therefore, if the Σ is formed with low momentum quantum numbers of the nucleon it replaces, and since the

Figure 2. A plot of the Binding Energy of various Λ shells as a function of $A^{2/3}$. The curves are a calculation from a single density dependent Woods-Saxon potential.

nucleons in the nucleus are highly correlated, one should expect that the conversion width of some states would be suppressed.

The best targets for testing the selectivity mechanism are the s shell isotopes. P shell hypernuclei would generally produce too many levels, some broad, which would make it difficult to detect narrow structure. Experimentally stopped K^- spectra in ^4He has been interpreted as evidence for a bound $I=1/2, s=0$ state in the $A=4$ system¹⁴. Selectivity shows this state has an enhanced conversion width, but in another model calculation, the conversion width is suppressed by adding a repulsive core to the Σ -nucleus potential¹⁹.

However, with somewhat different perspective, the same data can be interpreted if both particle breakup thresholds and the isospin structure of the nuclear core are considered. In fact, the ^4He bubble chamber data, which measures the branching ratio into all sigma and lambda channels¹⁸, may very well provide the information needed to understand the data. The analysis of the final data of AGS Exp 774 is nearing completion and a paper is in preparation. This experiment investigated the (K, π) reaction on both ^3He and ^4He targets producing Σ -nucleus final states. The results are not in complete agreement with the selectivity model, but favor a model stressing the importance of Λ - Σ coupling.

More recently, an experiment, E887, was undertaken at the AGS to measure, with high statistics, the $(K^-, \pi^\pm)$ spectra to several targets in the mass region where Σ hypernuclei are expected to be formed. In particular, this experiment used ^9Be and ^6Li targets where previously Σ - hypernuclei states were reported. This experiment finds no structure in the spectra, and although broad enhancements are seen, it refutes claims of narrow Σ -hypernuclear states¹⁹. Thus the only remaining published evidence for a Σ

hypernuclear state is the bound state in $\Sigma^4\text{He}$. Experiment E774 has data on this structure and is presently under careful analysis.

Data from experiment 820 at the AGS were analyzed by a University of Houston graduate student and comprised the research for their dissertation. This experiment was a search for the lower energy member of a proposed spin 0 strange dibaryon, $s = -1$, doublet. Previously, we searched for the spin 1 state predicted to lie above the Σ -Nucleon threshold (Exp. 773). Backgrounds in Exp. 773 were high because the well known $l=0$ cusp is present at the Σ -N threshold and one must attempt to separate any structure from the shoulders of this signal.

The data from Exp. 820 on the other hand, should show the excitation of the $s=0$ state below the Σ -N threshold. These data comprised the phd dissertation of a University of Houston graduate student, K. Johnston. The dibaryon should have spin 0, and p wave total angular momentum lying just below the Sigma nucleon threshold. To excite this state via the (K,π) reaction, the di-proton in the ^3He target is used to obtain a spin-singlet nucleon pair. With this target, the residual neutron is regarded as a spectator to the reaction. Thus the reaction is; $^3\text{He}(k,\pi)\text{D}_s\text{n}$, where in principle at least, the neutron could also be detected. The predicted spectrum shows that the contribution from the cusp and quasifree reactions do not mask the dibaryon signal unless it is too broad or occurs too close to threshold⁷. Thus such an experiment can be more sensitive to the detection of a dibaryon.

The results of the experiment show that if a dibaryon is present it lies under the backgrounds, so at least a detailed understanding of background shapes, if not their magnitudes, are necessary. We have treated the backgrounds as arising from three

independent amplitudes added incoherently. Above threshold we assume that the background is due to the quasifree production of a proton in the He target. The shape of this background is obtained using the Σ elastic peak from the liquid hydrogen target calibration runs, with the same analysis cuts as for the ^3He target. The Σ peak from this spectrum is then spread by the Fermi momentum of a proton in ^3He as determined from a Fourier transform of a ^3He ground state wave function⁸.

Below threshold the dominant background comes from the two step lambda production on the di-proton in the ^3He target⁹. The spectrum shape is represented by the shape of the one step $^3\text{He}(K,\pi^-)$ spectrum again measured under the same experimental conditions. The assumption here is that both spectrum shapes are dominated by the interactions of the final state particles, which are the same within isospin. It is of course possible to produce a dibaryon in both reactions, but the dibaryon to background ratio for (K,π^-) reaction would be much smaller than for the two step reaction, so little is lost in treating the experimental $(K\pi^-)$ spectrum as background.

The third piece of the background spectrum is due to the cusp and virtual $\Sigma N \rightarrow \Lambda N$ conversion. This peak, as described earlier, lies near the ΣN threshold with a tail running toward lower mass. A representation of this is obtained by calculating the ΣN production amplitude using the complex scattering length expansion. This approximation is valid near threshold where the amplitude is maximal, and has been shown to give a reasonable representation of the cusp region¹⁰. The amplitude must be integrated over the unobserved neutron momenta which is treated as a spectator.

The three processes are added incoherently and fit to the data via a chi-square minimization procedure, varying the three normalization strengths. The result of this fit

is shown in Figure 3. The fit gives chi-square per degree of freedom of 1.1, so within the statistical accuracy of the data, no additional strength is needed. Thus, to a level of about $0.5 \mu\text{b/sr}$ no dibaryon signal is evident.

Exp. 828 at the AGS was also completed and the data analyzed. The experiment sets a limit on the production of a 3 neutron bound state by using the (K,π) reaction on He.

(B) Electroproduction of Hypernuclei

The unique features of CEBAF, including beam quality, as well as the properties of the electromagnetic interaction can provide information not attainable at other facilities. In particular, CEBAF offers the possibility of obtaining spectra with an order of magnitude better resolution than previously attainable. In addition, electromagnetic production of hypernuclear levels strongly populates unnatural parity states²⁷. This contrasts to hadronic production mechanisms where the spin flip amplitude is small. One should also expect (γ,K) distortion effects to be significantly less than for other reactions.

We intend to investigate electroproduction of hypernuclei, CEBAF Exp 89-09, with the ultimate goal of attaining resolution of 200 keV. This would represent an order of magnitude improvement in resolution over present experiments. The experiment will be implemented in stages. The first stages are designed to test the proposed method and the experimental apparatus. The last stage requires a high-resolution short orbit kaon spectrometer. However, it should be pointed out that even the initial stages of the experiment will yield hypernuclear spectra complementary to that taken at hadron machines and with perhaps a factor of two better resolution. Thus we anticipate that

Events in 5 MeV Bin

Figure 3. Background Subtracted Spectrum Showing no Evidence for a Dibaryon Signal

significant new physics can be addressed even before the implementation of the final spectrometer system. Our group has devoted significant effort in the design, development, and coordination of this experiment, and we would hope to mount this experiment in early 1996.

(C) Test of the Standard Model of Electro-weak Interactions

The acronym, MEGA, (LAMPF 969) is derived from the first letter of the branching ratio, $\mu \rightarrow e\gamma$, which is to be investigated in this experiment. The experiment is designed to be a background free measurement of this particular branching ratio to one part in 10^{13} . Presently, it appears that the experiment can achieve a limit of approximately 2×10^{13} . A measurement to this accuracy would be about a factor of 250 better than the present experimental limit²⁸. The experiment tests the standard model of electro-weak interactions, and may be interpreted in terms of a model characterized by new particles. In this measure, MEGA will raise the mass scales of new particle searches by almost an order of magnitude. MEGA is a collaborative effort of 11 institutions. The University of Houston in direct association with Texas A&M University is responsible for the construction and operation of the photon detector system.

This system consists of layers of cylindrical detectors with each layer serving as an independent pair spectrometer, and having the same geometry except for radial dimensions. The system and associated readout electronics are completed and presently operating at LAMPF. An analysis of a portion of this data will result in the phd dissertation of one of our students. The development of the detector was a significant accomplishment for our group and required the implementation of a number of new

techniques. These involved the use of large-scale carbon fiber construction, and the design of application specific IC's, ASIC, for the electronic readout.

The general layout of the MEGA detector is shown in Fig. 4. The lepton spectrometer, which is not discussed here, lies inside the pair spectrometers. A surface muon beam is brought to rest in a thin, slanted target foil, and the particles from the decays are tracked by the various detectors. The major components of a given pair spectrometer consist, from smaller to larger radius, of a scintillation barrel, a cylindrical conversion foil, a delay line for position z measurement, a turning space with drift chambers (DC), and an outer aluminum cylinder for structural support and gas seal (CAN).

The scintillation strips provide timing and some axial position information, as well as help in pattern recognition of the event. The conversion foils are composed of 0.25mm Pb supported by a carbon fiber composite cylinder, and covered with at least a 1.8mm low mass foam layer. The foam thickness provides space for annihilation radiation pairs to circle without entering the active region of the wire chambers. A typical event showing one orbit of the conversion pair is shown in Fig. 5.

The MWPC is used for pattern recognition, deconvoluting the multiplexed readout scheme, and identifying the conversion foil in which the pairs were produced. The delay line measures the axial position of a hit in the drift chamber just above it, by measuring the time difference of the induced charge as it appears at the ends of the line. The turning space and DC's provide tracking to measure the perpendicular component of the momentum of the conversion pair. The outer aluminum CAN supports the tension of the chamber wires, provides a surface for the layup of the scintillators of the next layer,

Figure 4. A schematic layout of the MEGA detector.

PHOTON ARM EVENT

Figure 5. The expected event structure for a typical conversion in the outer Pb layer.

acts as an absorber to reduce the orbital radii of pairs so that they do not overlap the initial trajectories on subsequent passes of a pair through the spectrometers, and provides an outer gas seal for the detector.

Data has been collected with sufficient statistics to reduce the branching ratio by about an order of magnitude. This data is presently under analysis. The performance of the photon detection is close to the design specification. This is demonstrated by the energy resolution of a 55 new photon obtained from a calibration using the reaction $\pi^- p \rightarrow \pi^0 n$, and detecting the two photons from π^0 decay. An angle cut on the photon opening angle of greater than 176° gives the spectrum in Fig. 6. This figure presents a resolution of better than 2 MeV FWHM.

(D) Measurement of the Nucleon Spin Structure Function

The Houston group has been a member of the Spin Muon Collaboration (SMC) experiment at CERN since its inception²⁹. The SMC is the third generation experiment to be performed on the original European Muon Collaboration (EMC) apparatus. It was motivated by the EMC measurements of the spin dependent structure function of the proton³⁰, $g_1(x)$, where x is the Feynman scaling variable. Those results were in disagreement with the predictions of the Ellis-Jaffee sum-rule³¹, the integral of $g_1(x)$ over all x . The EMC results suggested that the net contribution from the valence quarks was not sufficient to explain the spin of the proton. A further concern centered on the possible implications for the more fundamental Bjorken Sum-Rule³², which is constructed by subtracting $g_1(x)$ for the neutron from that of the proton inside the integral over all x . This has the effect of isolating the contribution to the matrix element for converting a down quark to an up quark which is known from neutron beta decay.

ENERGY RESOLUTION FOR 55 MEV PHOTON

Figure6. The response of the photon detector to a 55 MeV photon showing the energy resolution is about 2 MeV.

The run cycle in 1993 was devoted to taking data with polarized protons using the new SMC polarized deuterium target. The goal was to check the EMC results as well as our own internal capability to extract the neutron effects from the deuteron data. The new target is considerably longer than the old EMC target and increases the useful statistics per beam particle by about a factor of 2. The present 1994 run is also using a deuterium target, but constructed of a different material.

The responsibility of our group has been to provide and maintain a set of large muon chambers now referred to as ST67. We also developed and provided 12,288 channels of front end electronics along with a completely new supporting read-out system through the CAMAC interface. The electronics has performed very well and the component failure rate has been minimal. At the present time the thresholds are running close to one half of the original design minimum. This was done to allow the STs to be operated at a lower high voltage setting in order to extend their lifetimes. The overall performance of the ST67 detector is the most stable and trouble free of any of the SMC spectrometer equipment.

All data, including our 1993 results are shown in Table II where Γ_1 , the first moment of $g_1(x)$, are compared. Summarizing the data, the proton has $\Gamma_1^p = 0.136 \pm 0.011 \pm 0.011$ ($\pm$ statistical $\pm$ systematic error) and the neutron has $\Gamma_1^n = 0.023 \pm 0.020 \pm 0.015$. This data is obtained for $Q^2 > 1 \text{ GeV}^2$. Although these data disagree with the naive Ellis-Jaffe sum rule, they are in accord with the Bjorken sum rule where we have the result $\Gamma_1^p - \Gamma_1^n = 0.19 \pm 0.05 \pm 0.04$ compared to the accepted theoretical value of 0.191 ± 0.002 .

Table II. Experiments on the spin structure function $g_1(x)$ of the nucleon (in chronological order).

Experiment	Beam	Energy (GeV)	Target	x range ($Q^2 > 1 \text{ GeV}^2$)	First Moment $\Gamma_1 = \int_0^1 g_1(x) dx$	Ref
E-80/E-130	e^-	10- 23	p(butanol)	$0.1 \leq x \leq 0.7$		[A]
EMC	μ^+	100-200	p(NH ₃)	$0.01 \leq x \leq 0.7$	$0.126 \pm 0.010 \pm 0.015^{(1)}$	[B]
SMC	μ^+	100	d(butanol)	$0.006 \leq x \leq 0.6$	$0.126 \pm 0.010 \pm 0.015$	[C]
E-142	e^-	19- 23	n(³ He)	$0.03 \leq x \leq 0.6$	-0.122 ± 0.011	[D]
SMC	μ^+	190	p(butanol)	$0.003 \leq x \leq 0.7$	$0.136 \pm 0.011 \pm 0.011$	[E]

1) Combined result of E-80, E-130 and EMC data.

- [A] SLAC E-80, M.J. Alguard, **et al.**, Phys. Rev. Lett. 37 (1976) 1261; ibid. 41 (1978) 70; Slac E-130, G. Baum et al., Phys. Rev. Lett. 51 (1983) 1135.
- [B] EMC, J. Ashman, **et al.**, Phys. Lett. B206, (1988) 364; Nucl. Phys. B328 (1989) 1.
- [C] SMC, B. Adeva, **et al.**, Phys. Let. B302 (1993) 533.
- [D] E-142, P.L. Anthony, **et al.**, Phys. Rev. Lett. 71 (1993) 959.
- [E] SMC, D. Adams, et al., Measurement of the Spin-Dependent Structure Function $g_1(x)$ of the Proton, CERN-PPE/94-57 and Phys. Lett. B, in print.

One can use this data to estimate the quark contributions to the spin of the nucleon. This results in the following contributions from the up, down and strange quarks;

$$\Delta u + \Delta d + \Delta s = 0.22 \pm 0.4;$$

With; $\Delta u = 0.80 \pm 0.04,$

$$\Delta d = -0.46 \pm 0.04,$$

$$\Delta s = -0.13 \pm 0.04.$$

The surprising aspect of this data is that the net contribution of the quark spins to the total nucleon spin is small. Further, the non-zero Δs , now widely accepted as likely, are a significant departure from the naive quark models, and from the original Ellis-Jaffe assumptions. SMC will complete data acquisition at the end of 1995.

IV. Publications

"Nonleptonic Weak Decay of $^5_\Lambda\text{He}$ and $^{12}_\Lambda\text{C}$ ", J.J. Szymansky, et al, Phys. Rev. Lett. 66, (1991) 849.

"Study of Hypernuclei by Associated Production", P.H. Pile, et al, Phys. Rev. Lett. 66, (1991) 2585.

"Hypernuclear Investigations with Energetic Pions", B.F. Gibson, and E.V. Hungerford, LANL, LA-UR-91-3969 (1991).

"Irradiation Effects on Flux Pinning and J_c in High Temperature Superconductors", J. Bechtold, et al Physica C185-189 (1991) 2211.

"Defect Size Dependence of Critical Current Density Enhancements for Irradiated $\text{Yb}_2\text{Cu}_3\text{O}_7$ ", J. Bechtold, et al, Physica C197, (1992) 199.

"Sigma-Nucleus Interactions in the $A=3,4$ Systems", M. Barakat and E.V. Hungerford, Nucl. Phys. A547 (1992) 157.

"Search for a Strangeness -1 Dibaryon below the Sigma-N Threshold", K. Johnston, et al, Phys. Rev. C46 (1992) 1573R.

"Pion Production at Small Angles", J.L. Langenbrunner, et al, LANL, LA-OR-91-1268 (1991), and Nucl. Inst. And Meth, A325 (1993) 187.

"Construction of the MEGA Photon Detector", M. Barakat, et al, Nucl. Inst. And Meth, A349 (1994) 118.

"Experimental Considerations in Electroproduction of Hypernuclei", E.V. Hungerford, Journal of Theoretical Physics (Sup), 117 (1994) 135.

"A Measurement of the Spin Dependent Structure Function, $g_1(x)$ of the Deuteron", SMC Collaboration, Phys. Lett. B302, 400 (1994).

"Combined Analysis of World Data on Nuclear Spin Structures Functions", SMC Collaboration, Phys. Lett. B320, 400, (1994).

"Measurement of the Polarization of a High Energy Muon Beam, SMC Collaboration, Nucl. Inst. Meth. A343, (1994).

V. Invited Presentations

"Search for a S-1 Dibaryon", International Conference on High Energy Physics and Nuclear Structure, Tuscon, AZ, May 1991.

"Hypernuclear Physics, CEBAF Workshop presentation, Newport News, VA June 1991.

"Hypernuclear Physics at BNL and CEBAF", Conference on Hyperon and Hypernuclear Physics with Proton Beams, Bloomington, IN, November 1991.

"A=3 Σ hypernuclei", International Conference on Hypernuclear and Strange Particle Physics, Shimoda, Japan, December 1991.

"Strange things are Happening", Seminar, Texas A&M, February, 1992.

"Hypernuclear Physics", Seminar, Trinity University, February 1992.

"Strange things are Happening", Seminar, University of Houston, February 1992.

"Strange Physics at the AGS and CEBAF", Sam Houston State University, February 1993.

"What is So New About Hypernuclear Physics?" Seminar, Duke University, February 1993.

"Strangeness in Electroproduction", CEBAF Workshop/Retreat, May 1993.

"What is So New About Hypernuclear Physics?" Seminar, Vanderbilt University, October 1993.

"Where is MEGA? A Search for Lepton Family Violation", Seminar, Ohio University, February 1994

"Positive Kaon Scattering and The Nuclear Medium", International Conference on Kaons and Hypernuclear Physics, Vancouver, Canada, July 1994.

"When does a Nucleon Look Like a Nucleon?" Texas Section APS, October 1994.

REFERENCES

1. M. May, *et al*, Phys. Rev. Lett. 47 (1981) 1106; 51 (1983) 2085
R.E. Chrien, *et al*, Phys. Lett. 89B (1979) 31
C. Milner, *et al*, Phys. Rev. Lett. 54 (1985) 1237
R. Grace, *et al*, Phys. Rev. Lett. 55 (1985) 1055
2. L. Biedenharn and E. V. Hungerford, Phys. Lett. 142B (1984) 232
3. A.R. Bodmer, Phys. Rev. 141 (1966) 1386
4. R.H. Dalitz, Nucl. Phys., Gordon and Breech, NY 1969
5. M. Bejidian, *et al*, Phys. Lett. 94B (1980) 480
6. P.H. Pile, *et al*, Phys. Rev. Lett. 66 (1991) 2585
7. D. J. Millener, A. Gal, and C.B. Dover, Phys. Rev. C38 (1988) 2700
8. Y. Yammato, H. Bando, and J. Zofka, Prog. Theor. Phys. 80 (1988) 757
9. R. Bertini, *et al*, Phys. Lett. 90B (1980) 395
10. H. Piekarz, *et al*, Phys. Lett. 110B (1982) 428
11. T. Yamazaki, *et al*, Phys. Lett. 54 (1985) 102
12. L. G. Tang, *et al*, Phys. Rev. C35 (1988) 846
13. C. B. Dover, D. J. Millener, and A. Gal, Phys. Rep. 184 (1989) 1
14. R.S. Hayano, *et al*, Phys. Lett. B231 (1989) 355
15. R.E. Chrien, E. V. Hungerford, and T. Kishimoto, Phys. Rev. C34 (1987) 1589
16. A. Gal and C. B. Dover, Phys. Rev. Lett. 44 (1980) 379
17. T. Haraoda and Y. Akaishi, Phys. Lett. 262B (1991) 205
18. R.H. Dalitz, D.H. Davis, and A. Deloff, Phys Lett. B236
19. Sawafta, Proceedings of the Conference on Hypernuclei and Strange Particle Physics, Vancouver, B.C., July 1994.

20. D. Marlo, et al, Phys. Rev. C25 (1982) 2619
21. P.B. Siegel, et al, Phys. Rev. C30 (1984) 1256, Phys. Rev. C31 (1985) 2184
22. G.E. Brown, et al, Phys. Rev. Lett. 60 (1989) 2723
23. X.Y. Chen, et al, Phys. Rev. C44 (1991) 2041
J. B. McClelland, et al, Phys. Rev. Lett 69 (1992) 582
24. R.J. Peterson, et al, Phys. Lett. B297 (1992) 238
25. C. M. Chen and D.J. Ernst, Phys. Rev. C45 (1992) 2019
26. L.J. Kurth, et al, Proceedings of the Conference on Hypernuclear and Strange Particle Physics, Vancouver, B.C., July 1994.
27. T.W. Donnelly and S.R. Cotanch, Proc. 10985 CEBAF Summer Study Jan. 1986
J. Adam, et al, C. Journal of Phy. 42 (1992) 1167
28. R.D. Bolton, et al, Phys. Rev. Lett. 19 (1984) 1415
29. CERN/SPSC 88-11, "Measurement of the Spin Dependent Structure Function of the Neutron and Proton", SPSC/I 169, CERN, Geneva, Switzerland, April 1988
30. EMC Collab., J. Ashman, et al, Phys. Lett B206 (1988) 364; Nucl. Phys., B328 (1989) 1
31. J. Ellis and R. Jaffe, Phys. Rev., D9 (1974) 1444; D10 (1974) 1169
32. J. D. Bjorken, Phys. Rev. 148 (1966) 1467; Phys. Rev., D1 (1970) 1376.