SELECTED PROBLEMS IN EXPERIMENTAL INTERMEDIATE ENERGY

PHYSICS

PROGRESS REPORT

SEPTEMBER 1990

GRANT PERIOD: FEBRUARY 1, 1991 - JANUARY 31, 1992

UNIVERSITY OF HOUSTON

Bill W. Mayes
Principal Investigator
Department of Physics
(713) 749-2855

Ed V. Hungerford
Principal Investigator
Department of Physics
(713) 749-3843

Lawrence S. Pinsky
Principal Investigator
Department of Physics
(713) 749-3808

Prepared for the

United States Department of Energy

Under contract no. DE-AS05-76ERO-3948

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.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

I. Personnel

Personnel who will have worked in support of this contract during the period February 1, 1990 to January 31, 1991 are listed below.

E. V. Hungerford	Professor of Physics
B. W. Mayes	Professor of Physics
L. S. Pinsky	Professor of Physics
L. G. Tang	Research Associate
K. Lan	Research Associate
K. Johnston	Research Assistant
M. Dzemic	Research Assistant
B. Barakat	Research Assistant
J. Flick	Engineer
Y. Lu	Technician
X. Yao	Technician
J. Liu	Technician
R. Tully	Student
N. Tripathy	Student
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 the various accelerator advisory committees. Recent documents are

appended to this report and summaries of current research activities are listed in the next section. The objectives of this research program are to: 1) investigate 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. This includes the use of 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. For example, at long range the conventional meson exchange picture is clearly correct, however, at distances close to where the nucleons overlap, a concept of quark and gluon substructures may be more appropriate. Unfortunately, such effects may be masked by the complexity of the many body problem and may be difficult to observe. Therefore, experiments must be carefully chosen and analyzed for deviations from the 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. During this grant period, approximately 60% of our effort has been expended on the MEGA experiment at Los Alamos, a

search for lepton number violating decay, $\mu \rightarrow e \gamma$. Approximately 20% of our effort has been devoted to strange particle physics at Brookhaven and CEBAF, and the remaining 20% on the SMC experiment at CERN.

The status of our research activities is summarized in Tables I and II. Table I shows those experiments under active investigation, and Table II lists approved experiments and experiments to be undertaken by the research group.

The group has been active in the development of experimental programs at CEBAF. We are interested in the possibility of investigating hypernuclear spectroscopy with an order of magnitude better resolution than currently possible at hadronic machines. This involves the development of a beam line and spectrometer system which would provide the necessary resolution. Finally, we remain interested in the possibility of the development of a high intensity separated kaon and pion beam line in the momentum range of 1-2 GeV/c. This work includes programs at BNL, LAMPF, and KAON where such a line could be constructed.

III. Selected Abstracts of Current Research

A. Hyperon 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. However, the underlying quark structure in this interaction is just beginning to be addressed. It was suggested some time ago² that by placing a hyperon into what

Table I. Experiments under Analysis

Experiment	Description	Status
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, K) reaction	Paper published
AGS Exp 828	Search for a 3 Neutron Bound State	Data under analysis
LAMPF Exp	Pion Production at Small Angles	Paper published
		Paper in preparation

Table II. Approved Experiments

Experiment	Description	Status
LAMPF Exp 969	MEGA	Approved (running)
CERN Exp NA47	Spin Dependent Structure Functions of the Neutron and Proton	Approved (running)
CEBAF Exp 9	Spin Dependence of p shell Hypernuclei	Approved (run 1994)
BNL Exp 874	Kaon Nucleus Quasielastic and elastic scattering	Approved (run 1992)
LAMPF Exp 1240	Measurement of the Michel Parameter RHO with the Mega Position Spectrometer	Approved (run 1992)

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 also explain 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.

Experiment 820 at the AGS was mounted and completed this past year. The data is now under analysis by a University of Houston graduate student and will comprise the research for her dissertation. This experiment is 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 would 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 a ^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 $^3\text{He}(K,\pi)\text{D}_s n$, 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, is 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 from 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, π^-) spectrum as background.

The third piece of the background spectrum is due to the cusp and virtual $\Sigma N = \Lambda N$ 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.

These 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 1. 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 this past year and the data is now under analysis. The experiment will set a limit on the production of a 3 neutron bound state by using the (K, π) reaction on He.

Figure 1) Background Subtracted Spectrum Showing no Evidence for a Dibaryon Signal

Exp. 774 at the AGS was completed this past year. The data from this experiment are under analysis and will comprise the phd dissertation material for one of our graduate students, M. Barakat. Previously several enhancements, identified as hypernuclei have been experimentally studied¹¹. These data were statistically inconclusive concerning narrow, and in particular bound, states of Σ nuclear systems. Because a Σ , when placed in a nuclear medium, can undergo a strong conversion $\Sigma N \rightarrow \Lambda N$, the issue turns on whether there is some mechanism by which this process can be suppressed in a nucleus. Such a mechanism, called selectivity, has been proposed¹². It uses the fact that experimentally the $\Sigma N \rightarrow \Lambda N$ reaction appears to be greatly suppressed in the spin singlet, isospin $3/2$ initial state. Therefore, if the Σ is formed with low momentum transfer on a nucleus, it can acquire the spin and orbital momentum quantum numbers of the nucleon it replaces, and since the 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. Table III gives the predicted width factors for the ΣNN and ΣNNN systems¹². There is one state in each system where the conversion width is completely suppressed. However, spin-isospin mixing in the ΣN interaction would dilute the suppression effect. In addition, the residual interaction also splits the energy levels. Thus, the $I=2$, $S=1/2$ state in ΣNN is shifted

Table III. Width Factors for ΣNN system
 Q is the width suppression factor

Width factors $Q_\alpha(T, S)$ for the ΣNN system

T	S	T_c	S_c	$Q_\alpha(T, S)$
0	$1/2$	1	0	3
1	$1/2$	0	1	$1/3$
1	$3/2$	0	1	$4/3$
1	$1/2$	1	0	2
2	$1/2$	1	0	0

Width Factors $Q_\alpha(T, S)$ for the ΣNNN System

T	S	$Q_\alpha(T, S)$
$1/2$	0	2
$1/2$	1	$14/9$
$3/2$	0	0
$3/2$	1	$8/9$

toward less binding and probably forms an unbound system since the - nuclear potential is rather shallow. On the other hand, the $I=1$, $S=1/2$ state shifts downward and the potential becomes substantially more attractive. The width of this state is suppressed by $1/3$ so it may attain a natural width of a few MeV.

On the other hand recent results with stopped K at KEK have suggested a bound Σ state in Σ^+NNN and no state in Σ^-NNN ¹³. The data have been analyzed to suggest just the opposite spin-isospin splittings of ref 11. Experiment 774 acquired data for both ^4He and ^3He target investigating both (K, π^+) and (K, π^-) reactions. Analysis of this data is just beginning, but should clearly help our understanding of these systems.

The recent experiments using the (π, K) reaction at the AGS gives significant new results (Exp.798)¹⁴. In contrast to earlier experiments using the (K, π) reaction, the results show strong reaction strength to a series of particle-hole states deeply embedded within the nucleus. A theoretical prediction of this effect shows that the reaction removes a valence neutron and replaces it with a lambda which may occupy any of the lower shell orbitals within the nucleus¹⁵. Because of the very weak lambda spin-orbit potential these states are not significantly split. This experiment clearly shows for the first time the interior shell structure of a nucleus as is illustrated by Fig. 2.

The promise of the (π, K) reaction has stimulated our interest in a facility such as PILAC (Pion Linear Accelerator) which is proposed at LAMPF¹⁶. Thus although the (π, K) elementary cross

Figure 2) (π, K) Spectra for Several Targets Showing the Particle-hole States of the Hypernuclear Spectrum

section is typically an order of magnitude below that for the (K,π) reaction, the practical counting rates to specific states for (π,K) production of hypernuclei can be larger, due to the much higher pion intensity available. Furthermore, the sizable (π,K) momentum transfer, even at 0, of the endoergic reaction favors the formation of high-spin states. An incident pion momentum of about 1 GeV/c enables one to excite members of a band in which the Λ couples to a valence neutron hole. Thus, the (π,K) reaction can be used to explore ground and excited states of the hypernucleus, and is complementary to (K,π) studies of low-spin and substitutional states and to (γ,K) production of spin-flip (unnatural parity) states¹⁷. Finally, the (π,K) reaction at nonzero angles can be used to produce polarized hypernuclei¹⁷. For a spin-zero target, this leads to negligible polarization of unnatural parity states and substantial polarization of natural parity states. Furthermore, the asymmetry of weak-decay pions in a coincidence measurement relates directly to the structure of the hypernucleus. The polarized hypernucleus may also yield magnetic moment information¹⁸.

Given the opportunities which would be available with PILAC we are participating in the development of the proposed PILAC program. In addition we participated in the data collection and analysis of the measurement of pion production cross sections at small angles in order to help select the optimal pion-injection angle and momentum. This experiment was undertaken at LAMPF using the High Resolution Spectrometer (HRS) facility, and measured the absolute values of the double-differential cross sections for π^- and π^+

production from a carbon and copper targets. The data show the interesting fact that the peak of the cross section for production at zero degrees occurs for pion kinetic energy between about 300 and 350 MeV. The energy dependence is different for the cross sections; the cross section for production of negative pions with kinetic energy of 250 MeV is larger than that for 300 MeV. Because production is more likely to occur through collisions involving the neutron, the production cross section peaks at smaller pion kinetic energies.

B. Electroproduction of Hypernuclei

The physics of the strange nuclear system may address fundamental issues that should shed light on our current understanding of hadronic many body systems. These issues can be explored at CEBAF, and in fact, the features of CEBAF, including beam quality, as well as the properties of the electromagnetic interaction can provide unique information not attainable at other facilities.

However, because of the weak spin dependence of the lambda, splitting of levels within major shell orbits will be small¹⁹. A recent (π, K) reaction populating hypernuclei in heavier A targets shows strong reaction strength to a series of particle-hole states deeply embedded within the nucleus. In effect, the reaction removes a valence neutron and replaces it with a lambda in any of the lower shell orbitals within the nucleus. This series of levels may be analyzed to determine if a repulsive Pauli pressure affects the level positions, particularly in heavy systems. Although the

present fit to the data shows no evidence of unusual behavior it has been pointed out that the difference between this fit and a shift to be expected from partial quark deconfinement, would be about 1.5 MeV for the 1s shell in Pb^{20} . The expected magnitude of the shift points out that one must precisely measure the level structure of many heavy hypernuclei to extract such information.

In addition, the effective interaction potential for p shell hypernuclei predicts various level splittings, and in particular those within a give spin multiplet. This interaction predicts doublet splitting of order 100 to 200 keV. However, the parameter set is not without difficulties. High resolution data is needed to identify transition to specific levels. Present spectra using hadronic beams are limited to resolutions of about 2MeV FWHM. The quality of the beam at CEBAF offers the unique possibility of obtaining spectra with an order of magnitude better resolution.

Electromagnetic production of hypernuclear levels will strongly populate unnatural parity states²¹. This contrasts to hadronic production mechanisms where the spin flip amplitude is small. In addition, since the momentum transfer is large, one would also expect to selectively excite states of high angular momentum transfer.

In the $(e,e'K)$ reaction the minimum momentum transfer is attained when the kaon and virtual photon angle is zero. The transition form factor falls off rapidly for $t > 400 \text{ MeV}/c$, but may peak at intermediate values of t . At the peak of the elementary cross section, 1.3 GeV/c, a typical momentum transfer

for CEBAF energies is about 300 MeV/c and relatively flat as a function of kaon angle out to about 15. Kaon distortion effects have been estimated to reduce the theoretical cross sections by 10% in light systems to 60% in heavier systems²².

We have proposed an experiment at CEBAF (Exp. 9), now approved, to investigate the electromagnetic production of hypernuclear states with high resolution (200 keV). This experiment will first use the SOS spectrometer in Hall C for kaon detection and will give experimental resolutions on the order of 1 MeV.

However, we are developing a kaon spectrometer design based on the concept that resolution in the resulting hypernuclear system is to be optimized. The kaon and electron spectrometers are to be placed at forward angles ($>5^\circ$). This also allows thin samples and reduced energy loss which is also important to the resolution. At forward angles, the count rate is limited by the electron spectrometer, and one expects a relatively low hadronic background in the kaon spectrometer. This facilitates detectors employing particle identification, as well as hadronic tagging methods for background and quasi-free suppression of the resulting spectrum.

The spectrometers have been optimized to the 5th order by the program RAYTRACE. The resolution of the system as determined by Monte Carlo is better than 250 KeV FWHM. We have also investigated the detector and particle ID system that will be necessary. In particular we have obtained several pieces of Aerogel material with index of 1.05 to use as Cherenkov detectors. We have constructed

both a reflective type, using mirrors, and a diffusion type detector prototype which has the appropriate dimensions for insertion in the SOS spectrometer. These detectors are now under evaluation for use in K/π discrimination.

C. Test of the Standard Model of Electro-weak Interactions
(LAMPF 969)

The experiment acronym, MEGA, is derived from the first letter of the branching ratio, $u=e\gamma$, 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 limit²³. 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 of the photon detector.

This detector consists of 4 layers of cylindrical detectors with each layer serving as an independent detector and having the same geometry except for the radial dimensions. During the past few years, we have constructed a prototype of the smallest detector layer. It has the geometry shown in Fig. 3. The two lead

Fig 3) Geometry of Layer 1 of the MEGA Photon Detector

converters are separated by an MWPC to identify in which converter the lepton pair was produced, and the three drift chambers are used to track the conversion pair to determine the energy of the photon. In the smallest layer, there are 416 MWPC wires and 624 DC wires. Position perpendicular to the wire, albeit within the well known left-right and multiple hit ambiguities, can be determined by the drift time of the ionized charge. Position along the wire ("Z" position) is not so easily obtained. Normally stereo wires, stereo cathode readout foils, and charge division are methods of choice²⁴. In the MEGA photon detector we will use a delay line readout technique to determine "Z" position²⁵. The chambers will be constructed using low mass, high strength composite materials (carbon fibers). Tolerances require that the cylinders form perfectly cylindrical surfaces to within 100μ on a 2m diameter. This precision involves not only careful machining techniques, but it also requires constant temperature control during fabrication and operation.

Readout electronics for the detector system will use an application specific IC (ASIC) hybrid preamplifier designed by our group and manufactured by Phillips Circuit Assemblies. The amplifier/discriminator is also a hybrid ASIC. The computer interface electronics is based on FASTBUS using a CHI controller and DEC station nodes. Each node is used to filter the data before storage in a MICROVAX III and on magnetic tape. The data acquisition system is designed to operate in a high rate, high background environment, selecting only those events which satisfy

a specific track pattern. The data stream will be multiplexed (actually "or'ed") before entry into FASTBUS to reduce the number of FASTBUS channels.

1) Mechanical Construction

The geometry of the detector is shown in schematic form in Fig. 3. It is designed to detect pairs from high energy photon conversions with about 1.5% energy resolution. This requires that the conversion position is well located spatially, and that the circular orbits of the conversion leptons and dip angle of the gamma ray are well defined. Because these leptons continue to spiral in the axial magnetic field, the scintillator not only provides timing information but also introduces energy loss to reduce the probability that the leptons will cross the same wires. The proportional wire chamber between the conversion foil identifies the conversion layer so that energy loss can be removed, and is also used in the trigger to provide a cut on the energy of the gamma ray. The drift chambers are used to determine the orbits of the conversion leptons, and as input to a second stage trigger which further reduces background triggers by selecting only events having the expected pattern of the events of interest. Axial position is to be determined by signals induced on delay line placed underneath each DC/1 signal wire. A total of four cylindrical layers are to be constructed.

The structural support for the cylinders is constructed from carbon fiber composite, using room temperature epoxies. The fiber cylinders are built on machined cylindrical mandrills in layers

composed of unidirectional .006" fiber in 12" wide tape. These layers are composed from inside to outside diameter of a spiral strip, an axial strip. and a final spiral strip. The layers are then wrapped by 2" wide woven carbon tape to compress and hold the layers in place until the epoxy sets. The resulting .040" C cylinder is the structural support for the .010" Pb converter and the Al foils which form the electrostatic surfaces for the MWPC and the delay lines of the drift chamber. It is ground with a diamond grinding, wheel to dimension. Polyurethane foam sheets are epoxied to the lay up to build the cylinder up to the final outer diameter before the outer .002" Al foil is epoxied in place. This technique assured that the cylinders are strong, low mass, and stress free.

Figure 4 shows the accuracy of the cylindrical surface as measured by sampling points over the cylindrical surface. All cylinders so far constructed (to date a total of 4) have similar accuracy. This accuracy is sufficient to plateau the chambers if a 100V operational plateau for the chambers is achieved. The prototype system has shown to produce a plateau of 200 to 275 volts.

The present plan is to have layers 1 and 2 available for data acquisition for the '92 run cycle at LAMPF and layers 3 and 4 for the '93 run cycle. Wiring of the first two layer will be in progress by October '91.

2) Electronic Readout

The signal from each drift chamber wire is passed through a grounded base preamplifier mounted on the end cap of the detector.

Figure 4) Deviation from cylindrical shape for cylinder 2 of the 2nd photon layer

This ASIC has current gain of ten, was designed at Houston, and is manufactured by Phillips Component Assemblies. Subsequent signal processing is accomplished remotely from the detector and the magnet. Separating the preamplifier from the rest of the electronics has disadvantages involving the extra cost and volume of the cable, but it does provide the necessary pipelining of the signals for later trigger processing.

After transmission, the signal feeds an amp/discriminator designed in a hybrid ASIC package. After discrimination, the signal is delayed by a delay line IC, gated by the trigger, multiplexed, and "daisy chained" through the second stage trigger to a FASTBUS TDC.

The MWPC signal is processed in a similar manner to the drift chamber signal. It passes through the preamplifier, is transmitted to the amp/discriminator, digitized, and then split, sending one signal through a gated multiplexing unit to a FASTBUS latch, and the other signal to the first stage trigger. Fig. 5 shows the block diagram of the electronics.

For plateau efficiency the drift chambers require a minimum charge collection of $>0.1\text{pc}$. This means that the chamber must operate at a gain of $>10^4$ for minimum ionizing particles.

3) Delay Line Readout

Since position resolution of 1% or better in dL/L is required, this would put severe constraints on analog electronics. Therefore, we will implement an axial position readout technique ("Z" position along a drift wire) using the difference between the

times that the induced charge appears at the ends of a delay line positioned underneath the signal wire of a drift cell. Mechanically this is easy to implement, since we must use a cylindrical foil below the sense wires in drift chamber 1, and this foil can be the delay line. Note that while stereo cathode strips could also be used, such signals would not be associated with a particular drift wire, and complicate unraveling the hit sequence. Time delays of 3ns/cm are observed in a typical delay line if the line is read differentially. A charge of 4pc, collected on the wire, is required for effective operation.

4) Software Filter

Trigger, rates, even those cut by the second stage trigger, are too high to commit to permanent storage, particularly since the event rate of interest is extremely small. Thus a software filter code is needed to further cut the data before permanent storage. This code is run in parallel on workstation nodes, simultaneously processing events as they occur. We expect on the order of 100 nodes, depending on the final configuration and the processing power of each node.

The filter code must look at each event, determine the conversion point and the projected circle trajectory of each lepton. Cuts are then applied on the energy sum, and a starting position and dip angle for the photon calculated.

D) Spin Structure Function of the Neutron

The EMC (European Muon Collaboration - NA2 at CERN) measured the spin dependent structure function $g^p(X)$ for the proton, as part of its long experimental program.²⁶ This

Figure 5) Block Diagram of MEGA Electronics

measurement extended over a broad enough range in x (nominally the fraction of the nucleon momentum carried by the struck parton), to allow the first calculation of the Ellis-Jaffe sum-rule for the proton:²⁷

$$\int g^p(x)dx = 0.189 \pm 0.005$$

The EMC result of 0.116 ± 0.009 (± 0.019 systematic) is in disagreement with the prediction of Ellis and Jaffe. There have been numerous suggestions concerning the possible causes of this disagreement.²⁸ One implication is that the spin of the proton receives almost no contribution from the spins of the valence quarks. These results are now seen as a prologue to a measurement of the far more fundamental Bjorken Sum-Rule:²⁹

$$\int (g^p(x) - g^n(x))dx = \frac{1}{6} \frac{g_A}{g_v} \left[1 + \frac{\alpha_s(Q^2)}{\pi} \dots \right] = 0.191 \pm .002$$

In the Bjorken Sum-Rule the difference between the structure functions of the proton and neutron cancels out many of the "model-dependent" features of the calculation. The result is seen as a "litmus-test" of the basic assumptions of QCD. In order to perform the first experimental evaluation of the Bjorken Sum-Rule and to measure the associated structure functions $g^p(x)$ and $g^n(x)$, (SMC - NA47 at CERN) was formed in the fall of 1988. Our group was one of the original members of the collaboration.

Participation in SMC by the University of Houston consists of two distinct groups. Our group (UH/DOE) has been DOE funded, whereas the group headed by Roy Weinstien (UH/NSF) has received the

majority of their funding from the NSF. The University of Houston groups have accepted a joint hardware responsibility to replace the main muon identification chambers, W6/7B, a major piece of the hardware in the existing apparatus. We are proceeding to replace these chambers with 32 4m X 4m coordinates of streamer tube arrays (16 planes of streamer tubes). The streamer tubes were chosen for several reasons. Primarily, the UH/NSF group along with the group from Northeastern University has developed a factory at the University of Houston to manufacture streamer tubes in great quantities, but also the large detector arrays one can assemble from these modular components provide by far the most cost effective muon detector available.

During the past year all 16 planes (32 coordinates) were constructed and deployed for the preliminary SMC data running from April - Sept. 1991. Our group took the major organizational responsibility during the construction phase of this project with help from our UH/NSF colleagues and from collaborators from the University of Munich. After completion of the mechanical construction our activities returned to our primary responsibility: the read-out electronics and data acquisition interface. Due to the decision to begin SMC data acquisition a year sooner than previously planned, the newly designed read-out electronics could not be available. As such, arrangements were made to borrow (for this year only) enough (marginally suitable) electronics from various sources including the L.V.D. experiment at the Gran Sasso. This has enabled us to run the system (24 coordinates fully implemental and the remaining 8, one third implemented), not only

demonstrating its fundamental efficiency, but participating in data taking which demonstrated a very dramatic improvement over the performance of the old detectors. The new electronics being developed should have an even more significant effect, both in increased efficiency and more importantly in noise reduction.

As an example of the performance of this newly commissioned detector, we can show the profiles (Figure 6) and efficiencies (Figure 7) for a typical data run. The efficiency is calculated by excluding a pair of coordinates (the 2 on either side of the same tube) and finding "good tracks" with the remaining hits. Then, one simply asks whether the excluded coordinate had a hit in the proper location. Figure 8 shows a typical track fitting "residual" plot confirming the prediction of 2.5mm (sigma) resolution from the Monte Carlo design studies.

One question of paramount importance concerns the efficiency of these detectors as a function of rate. We have found no significant fall off in efficiency at distances 8 cm or more from the beam (inside 8cm the chambers have been "deadened"). The flux at this innermost sensitive point is measured (by scintillator hodoscopes) to be on the order of $3.5-5.0 \times 10^3$ hits/cm²/sec during the 1.74 sec. spill. The fact that there is essentially no drop off at these rates in this kind of detector is remarkable and exceeds previously published results by almost an order of magnitude. A Nuclear Inst. & Methods paper on this achievement is in preparation. So far, there are very few signs of aging of the tubes, so long term survivability is quite good.

The new read-out electronics system includes the following

improvements and innovations over the prior system:

1. A delayed coincidence with experiment trigger for each (4 channel) amplifier/discriminator module separately. This allows out of time noise rejection improvement up to a factor of 10 over all previous systems.
2. A "data acknowledge" line parallel to the shift register line to eliminate the need to carefully monitor cable lengths and component separation.
3. A charge sensitive front end pre-amp section to aid in noise rejection over simple voltage discrimination.
4. A hard front-end shut-off during the shift operation to prevent accidental bleed through of large input pulses.
5. Modular threshold and low voltage power supplies allowing separate control of each parallel shift register chain.
6. Photo-optical decoupling of the signals and grounds between the "on-chamber" electronics and the read-out modules. (Readout can be CAMAC or VME. We will use CAMAC to be compatible with the existing SMC data acquisition system).
7. Complete computer control, testing, and status assesment via the read-out system.

Prototypes of this system have been built to our specifications by SGS-Thomson and C.A.E.N. We are currently

finalizing our evaluation of these prototypes and completing a list of our required design modifications. Production of the full number of required components can be accomplished in time for 1992 running.

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.J.G. Mulder, et al, Phys. Rev. D25 (1982) 1269; D26 (1982) 3039
- 7) A.T.M. Aerts, et al, Nucl. Phys. B253 (1985) 116
- 8) T.A. Griffy and R.J. Oakes, Phys. Rev. 135B (1964) 1161
- 9) C.B. Dover, Nucleonika 25 (1980) 521
- 10) E. Morris, dissertation Oxford Univ. 1974; S.T. Brown, et al, Nucl. Phys. B47 (1972) 138; R. Koapulus and L. Rodberg, Phys. Rev. 115 (1959) 1058
- 11) R. Bertini, et al, Phys. Lett. 90B (1980) 395
H. Piekarz, et al, Phys. Lett. 110B (1982) 428
T. Yamazaki, et al, Phys. Rev. Lett. 54 (1985) 102
L.G. Tang, et al, Phys. Rev. C35 (1988) 846
R.E. Chrien, et al, Phys. Rev. C35 (1987) 1589
- 12) A. Gal and C. Dover, Phys. Rev. Lett 44 (1980) 379
- 13) R.S. Hayano, Phys. Lett. B231 (1989) 355
T. Harada and Y. Akaishi, Phys. Lett. 262B (1991) 205
- 14) P.H. Pile, et al, Phys. Rev. Lett. 66 (1991) 2585
- 15) H. Bando and T. Motoba, Prog. Theor. Phys. 76 (1986) 1321
- 16) PILAC, Los Alamos Report LA-OR-90-2230, 1990
- 17) H. Bando, T. Motoba, and J. Zofka J. Mod. Phys. A5 (1990) 1
- 18) E. Hungerford, see ref. 16
- 19) D. J. Millener, et al, Phys. Rev. C31 (1985) 499

- 20) C.B. Dover Private Communication
- 21) ref. 17; C.B. Dover and D.J. Millener, BNL 44651, May 1990
- 22) T.W. Donnelly and S.R. Cotanch, Proceedings of the 1985 CEBAF Summer Study, Jan. 1986
- 23) R.D. Bolton, et al, Phys. Rev. Lett. 19 (1984) 1415
- 24) R.D. Bolton, et al, Nucl. Inst. and Meth. A241 (1985) 52
G. Aiken, et al, SLAC-PUB-2642
H. Van der Graaf and J.P. Wagenaar, Nucl. Inst. and Meth. 217 (1983) 330
V. Radeka and P. Rehak, IEEE Nucl Sci) 25 (1978) 1
- 25) A.R. Erwin, et al, Nucl. Inst. and Meth. A237 (1985) 493
- 26) See SMC proposal submitted to DOE
- 27) J. Ellis and R. Jaffe, Phys. Rev. D9 (1974) 1444
- 28) R. Jaffe, Phys. Lett. 193B (1987) 101
- 29) J.D. Bjorken, Phys. Rev. 148 (1966) 1467, D1 (1970) 1376

PUBLICATIONS

- 1) "Nonleptonic Weak Decay of ^5He and ^{12}e " J.J. Szymansky, et al., Phys. Rev. C43 (1991) 849
- 2) "Study of Hypernuclei by Associated Production" P.H. Pile, et al, Phys. Rev. Lett. 66 (1991) 2585
- 3) "Defect Size Dependence of Critical Current Density Enhancement for Irradiated $\text{YBa}_2\text{Cu}_3\text{O}_7$ ", J. Bechtold, et al, Applied Physics Letters, to be published
- 4) "Searches for Light Strange Dibaryons", E.V. Hungerford, AIP Conference proceedings Intersections between High Energy and Nuclear Physics Tuscon Arizona, May, 1991
- 5) "Pion Production at Small Angles", J.L. Langenbrunner, et al, LANL Report, LA-OR-91-1268
- 6) "Hypernuclear Investigations with Energetic Pions", B.F. Gibson and E.V. Hungerford, LANL Report

INVITED PRESENTATIONS

- 1) "Searches for Light Strange Dibaryons" E.V. Hungerford
Intersections between High Energy Physics and Nucleon
Structure, Tuscon Arizona, May 1991
- 2) "Hypernuclear Physics", E.V. Hungerford, CEBAF, Hall C
workshop, CEBAF, June 1991
- 3) "Hypernuclear Physics at BNL and CEBAF", E.V. Hungerford,
workshop on Hyperon and Hypernuclear Physics with Proton
Beams, Indiana Nov. 1991
- 4) " $A=3$ Σ Hypernuclei", E.V. Hungerford, Hypernuclear and
Strange Particle Physics, Shimoda, Japan, Dec. 1991

END

**DATE
FILMED**

12/10/91