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TITLE OF PROPOSED PROJECT **ITR/AP\(PHY\): Applications for Neural-Network Techniques in Nuclear Physics Data Analysis**

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Summary

Current Medium- and High-Energy Nuclear Physics facilities produce data in such tremendous volumes that extracting all of the interesting physical quantities becomes, quite frequently, intractable. This proposal describes the implementation of a program to develop computational techniques based on neural networks to aid analyses of new data from the CLAS (CEBAF Large-Acceptance Spectrometer) at Jefferson Laboratory. These data include those obtained in several experiments performed using real photons in which the GW group has played a major role. In the context of the CLAS, the applicability of neural-network tools is manifold. The creation of intelligent filters at both the pre- and post-tracking phases of the analyses promises to reduce the CPU requirements, while drastically reducing the size of the data set in a channel-dependent manner. Furthermore, neural networks would be employed for high-level background suppression, and for signal decomposition. These methods should be generally applicable to any large particle detector system which simultaneously measures a large number of possible final states.

A multi-node CPU cluster would be progressively built up at The George Washington University Virginia Campus. In tandem with the existing large-volume data storage facility (maintained by the GW Crash Analysis Center), this cluster would provide general access to dynamically filtered CLAS event files over the internet. Users would not only be able to select a neural-network filter for a desired reaction, but also would be able to create a new one, leading to the creation of a neural-network database. This would, in turn, provide a fast and efficient way to carry out initial feasibility studies of different reaction analyses. The cluster would also serve as a distribution point and testing center for neural networks used in the higher-level tasks of background suppression and signal analysis.

Under the guidance of a postdoctoral researcher versed in both physics and computer science, four students for three months each year would collaborate to reach designated milestones. Through interaction with each other, undergraduates in both IT and Physics would gain valuable insight into the issues specific to both areas of research. The development of such analysis techniques and tools would not only stimulate significant interest from the physics community at large, but would also facilitate the analysis and publication of a wide range of original physics results.

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Applications for Neural-Network Techniques in Nuclear Physics Data Analysis

The Status Quo

In the field of modern experimental nuclear physics, the recent confluence of high-intensity continuous particle beams, advances in data-buffering techniques, and near-hermetic particle detectors has created tremendous opportunities for those seeking to carry out high-precision measurements or searches for rare events. The promise of these experiments is that the very large data sets currently being collected will contain events from many different (and possibly rare) reaction channels in sufficient numbers to be able to extract important physical properties, such as the angular and energy distributions, for these channels. For example, the CLAS detector at Jefferson Lab, with a 3π acceptance and a non-restrictive trigger, collects more than a billion triggers a week, corresponding to two Terabytes of data, and is a prototypical example of the systems designed to carry out such tasks.

The vast quantities of data involved necessarily require a commensurate investment in analysis and computational resources. In the case of the CLAS system, the basic event reconstruction alone (*i.e.*, finding charged-particle tracks) requires about 10,000 hours of (500 MHz) CPU time per billion triggers analyzed. The 20-30 billion events collected by CLAS in a single year imposes quite a challenge for data reduction and dissemination. Furthermore, the majority of these data will require a second "pass" at the basic level and several additional passes for higher level analyses (albeit with the CPU-intensive charged-particle tracking turned off). In addition, there is a comparable burden on the computing resources for the generation and analysis of simulated (Monte-Carlo) data, upon which the analysis and interpretation of all such experiments rely heavily. As a result, the task of simply converting the data to usable variables such as positions and momenta becomes monumental.

Not only is there a significant burden on the CPUs, but also on the storage/retrieval system and media. Managing hundreds of Terabytes of data imposes significant loads on the archive media and on the networking infrastructure, which in turn leads to additional overhead on the analysis-time budget.

A New Direction: FANNFARE for the Common LAN

In order to investigate a particular channel it is necessary to cleanly isolate the events of interest from those due to other reaction channels.

The problem can be addressed in two ways: (1) Expand the computing infrastructure so that the existing brute-force analysis procedures are capable of making sufficient progress, or (2) develop an efficient and reliable way to reduce significantly the amount of data subject to a full analysis. The former approach is not without its merits. It is simple enough to implement: purchase more (and faster) computers. For the latter approach, one generally sorts through the data set applying one or more tests (cuts) and retaining only those events which satisfy all cuts simultaneously, in a process is known as "filtering." The more restrictive the cuts, the greater the reduction in size for the secondary data set. The aim of this approach is to retain events from the desired channel while eliminating as much of everything else as possible. This procedure requires careful judgment when setting the applied cuts. When the variables to which the cuts are applied form peaks for the reaction channel of interest, these variables can be combined into a single variable using the method of maximum likelihood [pdg00]. This is more efficient, since it makes use of the fact that a true event is very unlikely to fall more than three standard deviations away from the nominal value for all of the independent variables simultaneously.

A further refinement of the selection process is to make use of *neural networks* (see [Lip87] for a general description). One can replace the manual selection of variables upon which these analysis (filter) cuts are made with a simple neural network capable of finding any correlations between all input variables. A form of pattern recognition, a neural network performs a multidimensional correlation analysis of the input variables creating a simple functional expression (in the form of a finite sum) used to test later input sets (each event). The neural network is "trained" using known "good" and "bad" events which generally come from a simulation but could be actual data. Once trained, the neural-network parameter set is fixed, and a test of each new event using the finite-sum expression is very fast, outputting a single value to which a simple cut may be applied.

We see four distinct stages of the CLAS data analysis procedure where neural network techniques could be usefully applied. These are (1) basic event reconstruction, (2) event filtering, (3) late-stage background suppression, and finally (4) decomposition of the signal, akin to a partial-wave analysis.

A FAst Neural-Network Filtering Algorithm for Rare Events (FANNFARE) could potentially reduce the size of a given data set by orders of magnitude. FANNFARE may, in fact, be the method of choice where rare events must be extracted from a myriad of backgrounds (*e.g.*, searches for long-lived dibaryons).

It also might be beneficial to implement a neural-network filter *before* performing the CPU-intensive track reconstruction. The dominant fraction of the CPU time used for basic CLAS event reconstruction, is spent trying to find the best track through the 30-layer, 30,000 wire drift-chamber stack. The hit pattern of the wires alone gives the initial, crude "hit-based" track, which, after fitting to the drift-time-determined hit positions, becomes a "time-based" track. The development of a neural network, not to determine the likelihood for a specific event type, but rather the likelihood that a hit-based track would successfully reconstruct to a time-based track, could lead to a significant reduction in the required CPU time at the most basic level.

CLAS event filters in use at present are typically very general, specifying only the number of neutral and charged particles. Even with a more refined set of multivariable cuts, FANNFARE may offer substantial gains. While similar for dominant channels, the relative reduction in the secondary data set would increase for rarer event topologies. A neural-network filter would give the greatest advantage for channels like $\gamma p \to (\Delta\gamma) \to p\pi^0\gamma$ in which the final-state π-p configuration is related to the kinematics of the photon radiated by the intermediate Δ and for which a rare particle was not directly detected (as in charged-kaon production). Other advantages of a neural-network filter over a traditional multivariable cut are that it automatically includes the effects of efficiency and acceptance of the detector, and could be designed to make use of built-in node elimination and thus become adept at finding the most relevant and discriminatory combinations of variables for a given reaction channel.

After the large raw data set is pared down to a manageable size during the reconstruction and filtering stage, neural networks find further application in suppression of background channels. Whereas in the initial stage the background may be composed of *many* competing channels, the second level analysis is often concerned with distinguishing the events of interest from a *single* background reaction. To this end, the neural network can be optimized and fine tuned.

We already have gained some practical experience in the use of neural networks for background suppression [Hei00] with data from the Crystal Ball experiment at Brookhaven National Laboratory (BNL). Radiative pion capture on the proton, $\pi^- p \to n\gamma$, has the smallest cross section of all reaction channels studied with the Crystal Ball in Experiments 913 and 914. We have constructed a simple two-layer neural network and trained it with Monte-Carlo simulations to distinguish between a very dominant $\pi^- p \to n\pi^0$ channel and a weak $\pi^- p \to n\gamma$ channel. When one of the π^0 decay photons is soft and goes undetected, the resolution of the Crystal Ball detector is insufficient to separate these two channels based on missing mass alone. A simple neural network was trained using seven (not fully independent) input variables: the three-momentum for each of two neutral particles and the invariant mass. In tests on the simulated data, the neural network correctly identified the channel almost 80% of the time in a kinematic region dominated by background and where standard techniques had failed. In the course of this exercise, the versatility and simplicity of neural-network applications became evident.

Finally, neural networks can play a role even in the analysis and interpretation of the events of interest. As an example, consider the CLAS data for the $p(\gamma, \pi^0\pi^0)p$ reaction, currently being analyzed by the GW group. If one presupposes that the pions were produced in a two-step process, that is, a single s-channel resonance decays by single pion emission into a daughter resonance which then decays to $p\pi^0$, then there arises an unavoidable ambiguity in assigning pions to the first and second decays. This hinders the use of a standard partial-wave decomposition. A multiple-output neural network trained with a set of possible decay chains (involving known and posited resonances) could enable the determination of the relative strength of each chain.

One can envisage eventually building up a database or library of neural-network filters available for any would-be analyst of CLAS data. The ultimate ease of use for future users could be as simple as choosing the right flag at the command line. Furthermore, it might be possible to construct a neural network general enough to handle not only one reaction channel, but a *class* of channels. For example, perhaps the same network can handle the $\gamma p \to \pi^0 p$ and $\gamma p \to \eta p$ channels simultaneously (with only the cut differing).

As leaders of the G3 collaboration (to study photoreactions on ^{3}He and ^{4}He), our group has had to assume the role of custodian for the complete data set and manage its content and analysis. With the implementation of FANNFARE, we could expand our duties to include equipping the members of the CLAS community at large with the tools necessary to identify subtle signals indicative of rare reaction channels and to provide ourselves and our collaborators with the computing means to actually extract interesting candidate events from the full data set.

To this effect, we intend to integrate the neural-network applications into an interactive browser interface accessible remotely by any member of the CLAS collaboration. We are proposing to provide remote and local users with an interactive database of known and accepted filtering functions which they can apply to any of the G3 data files stored at GW. In the eventuality that the existing functions, or combination thereof, are insufficient to identify reliably the reaction channel of interest, users will be directed to a more complex analysis level, where they will be prompted in the construction a filtering function of their own.

This second interface will invite them to generate Monte-Carlo data simulating the particular reaction channel of interest to them. Once generated, these data are to be submitted to the learning algorithm, along with a sample of real data for rejection purposes, in order to identify correlations and eventually to construct a new filtering function. The user would then be able to apply this newly created filter to the real data in view of producing a much-reduced working set of data and histograms which can be transferred over the network to his or her own machine. This new filter, if deemed successful by both the user and the database managers,would then be added to the complete library of functions. We expect that as new correlations are being identified and investigated, the database will grow rapidly at first and consequently expend sizable resources. Yet, as the project matures, we predict that this investment of resources will be greatly rewarded by our ability to identify and analyze quickly and efficiently rare and exotic nuclear reaction channels.

We emphasize the importance that the algorithms and environments described above reside and run solely on the proposed GW cluster, not only to reduce the network traffic associated with the transfer of the unusually large data files generated by CLAS (typically 20 GB), but also to ensure that the databases associated with the project can be more easily maintained.

Scientific Motivation

It is vital that the application of neural-network techniques contribute to and enhance the nuclear physics efforts of the George Washington group. The foci of our physics program are (1) understanding of the strong interaction in the nuclear medium and (2) understanding the quark structure of the nucleon through its various resonant excitations. Towards the understanding of nuclear-medium effects, our emphasis is on the study of the few-body nuclei with electromagnetic probes, while our nucleon studies focus on single- and double-meson production through N^* excitation with real photons, both polarized and unpolarized.

The implementation of these novel analysis techniques must be coordinated with the physics questions in order to optimize the progress of both. For example, although single-π° photoproduction on the proton, being the single fastest counting channel, can hardly be considered rare and would probably not alone warrant the effort involved in FANNFARE, this channel can serve as a crucial testing ground for the neural-network scheme.

Few-Body Nuclei

A central theme of our experimental program is the delineation of the properties and symmetries of the short-range many-body nuclear force in the nuclear environment. Accordingly, we studied the few-body nuclei ^{3}He and ^{4}He in the experiment *Photoreactions on* ^{3}He (Jefferson Lab Experiment 93-044).

The first major objective of this experiment is to look for the nuclear three-body force in its most elementary manifestation, the three-body photodisintegration of ^{3}He at the higher photon energies available at Jefferson Lab, corresponding to reduced photon wavelengths of less than 0.1 fm. Such effects are predicted to become increasingly important at energies well above the Δ-resonance and especially for configurations where the three nucleons share the available energy equally in the final state [Fri94], [Lag88].

Another manifestation of three-body effects in a nucleus is the makeup of its ground-state wave function, and in particular, the small parts of it that become apparent only with short-wavelength probes. An example is the knockout of a pre-existing Δ (or other excited state of the nucleon) from ^{3}He, showing that for a certain fraction of the time the nucleus in its ground state exists as an NNΔ configuration. According to recent calculations [Abd90, Lag92], this probability for the ^{3}He nucleus is in the range 0.5 and 2.4%. Thus, the second objective of this experiment is to look for the direct knockout of a Δ. This is observed by examining the events in which a proton and π^+ reconstruct to the mass of the Δ^{++}.

In addition, the ^{3}He data set contains information on several other interesting reaction channels. Among these are the two-body breakup of ^{3}He and the three-body breakup of ^{4}He, coherent pion production (which leaves the residual nucleus intact), Δ production on one of the nucleons when the others are spectators, and strangeness production (kaon photoproduction) and hypernuclear excitations. Some of these reaction channels lend themselves to the study of the elementary production processes in the nuclear medium, and it is worth noting that the nuclear density of ^{3}He is intermediate between that of the deuteron and that of ^{4}He, which in turn is similar to that of heavy nuclei. Recent calculations show that quasifree nuclear pion production is sensitive to the in-medium properties of the Δ isobar, including its quadrupole component [Lee97]. These calculations have recently been extended to higher energies and show important modifications to the D13 and F15 resonances as well [Lee99]. The coherent single- and double-pion electro- and photoproduction reactions on nuclei are known to serve as viable testing grounds for resonance medium modifications [Kam97]. Accessible coherent channels using the CLAS include $\pi^+\pi^-$ production from both ^{4}He and ^{3}He as well as single π^+ production from ^{3}He (leaving ^{3}H as the residual nucleus). Since the binding energy of ^{4}He is nearly 30 MeV, it should be easy to separate the coherent two-pion production events, and further to separate those that arise from ρ^0 production. Thus, medium effects on ρ production can be studied as well.

The study of the strangeness-production channels will provide an important comparison with our similar studies on the deuteron, and should be a sensitive probe of medium effects in more tightly bound nuclei. Together, these studies will directly and quantitatively address the strength of medium effects on strange-particle production for nuclei whose binding energy varies from 1 to 7 MeV/nucleon. In particular, our group has a substantial involvement in the analysis of *Kaon Photoproduction on Deuterium* (Jefferson Lab Experiment 89-045) and *Quasifree Strangeness Production in Nuclei* (Jefferson Lab Experiment 91-014), which study nuclear-medium effects on the kaon-production process in nuclei of low density (^{2}H), intermediate density (^{3}He), and high density (^{4}He and ^{12}C).

In this study we first are investigating the photoproduction of Λ and Σ hyperons on deuterium, via the $\gamma N \to KY$ $(Y = \Sigma, \Lambda)$ reactions. Kaon photoproduction on deuterium is governed by three main mechanisms; the six elementary kaon-production reactions on the nucleon ($\gamma p \to K^+\Lambda, \gamma p \to K^+\Sigma^0, \gamma p \to K^0\Sigma^+, \gamma n \to K^+\Sigma^-, \gamma n \to K^0\Lambda, \text{and} \gamma n \to K^0\Sigma^0$), the Fermi motion of the proton and neutron inside the deuteron (the momentum distribution of nucleon momenta can be calculated using the deuteron wave function), and the interaction between the final-state hadrons. Previous experimental information exists only for the kaon photoproduction channels on the proton. Data for the neutron channels have been obtained for the *first time* in this experiment.

Also, as part of our program to study the small parts of the wave functions for few-body nuclei, we have joined with our collaborators at Genoa and Saclay to explore the probability for two-gluon exchange from the proton in the photoproduction of the ϕ meson, *Photoproduction of Vector Mesons at High t*, (Jefferson Lab Experiment 93-031). The ultimate objective is to search for a (small) hidden-color component of the ^{3}He wave function, measured by detection of a high-t ϕ meson (manifested as a $K^+ - K^-$ pair) recoiling against two protons. Here, t is the Mandelstam variable equal to the square of the 4-momentum transfer. This kind of event can be produced only by one-gluon exchange from each of the two colored three-quark objects within ^{3}He that are thereby transformed into the measured recoil protons. At low t (< 1.0 (GeV/c)^2), the photoproduction of the ϕ meson is purely diffractive, and is well described by assuming vector meson dominance (VMD). At high t, hard scattering processes are expected to dominate the cross section; assuming the strangeness content of the proton is small, two-gluon exchange is expected to dominate ϕ photoproduction. A shelf in the cross section for the $\gamma p \rightarrow \phi p$ reaction, at t greater than about 2 $(\mathrm{GeV/c})^2$, if seen in the experimental data, would provide evidence for a two-gluon exchange mechanism. This shelf has been seen, in the data obtained in 1998 in the lower-energy (4-GeV) part of this experiment, and a paper has been accepted for publication [Anc00], the first paper from the CLAS Collaboration. Additional data, at higher t, has been obtained this past year on the higher-energy (6-GeV) part.

Finally, we and our colleagues at Saclay are planning to analyze the deuterium data to set a benchmark for the study of color transparency in light nuclei. This method uses the momentum-transfer dependence, for a given recoil momentum, of the kinematic peak in the cross section for the rescattering of photoproduced hadrons by another nucleon in the nucleus as the signature for the presence (or absence) of color transparency. This effect can be large, when the scattered hadron and the scattering nucleon are almost on-shell; and the signature of the effect, the strong reduction of a peak, rather than that of a general cross-section level, should be readily apparent in the data. Moreover, when the scattered hadron is a hyperon, the experimental signature is least obscured by other reaction channels.

The Nucleon

A transition in the effective degrees of freedom (working set of "fundamental" particles) is expected as one increases the energy (or shortens the wavelength) such that the behavior of a given process can no longer be fully described by models based solely on mesons and nucleons. It is widely anticipated that in this transition-energy region and beyond, QCD-inspired models based on quark-gluon degrees of freedom will provide the basic framework for describing the interaction of strongly interacting particles.

Low-energy studies involving the exchange of light mesons have produced a wealth of information on the long-range part of the nuclear force. There remain open issues at higher energies where the production of more massive mesons can illuminate short-range nucleon dynamics.

During the past three years we have participated heavily in all of the real-photon data-taking in Hall B at Jefferson Lab. As discussed in the first part of this proposal, we now have acquired a large amount of data for meson-production reactions during the deuterium and proton target running periods. These data show great improvement over those of all previous measurements and extend them to higher photon energies. The precision measurement of differential cross sections is the first step of a program which will ultimately include precision measurements with polarized beams and targets.

In the experiment, *The Photoproduction of Pions* (Jefferson Lab Experiment 94-103), we have measured single-pion photoproduction on the proton and neutron using the CLAS and the Tagged-Photon Facility in Hall B. Tagged photons with energies between 0.36 and 3.1 GeV incident on liquid hydrogen and deuterium targets were used for protons and neutrons, respectively. Differential cross sections for the reactions $p(\gamma,\pi^0)p$, $p(\gamma,\pi^+)n$, $n(\gamma,\pi^-)p$, and $n(\gamma,\pi^0)n$ will be determined with an absolute accuracy better than 4% for the first two of these reactions and 6% for the latter two reactions. Comparison with the inverse photoproduction measurements (via detailed balance) performed at Brookhaven National Laboratory (BNL) with the Crystal Ball can provide a test of the validity of the medium corrections for the bound neutron in deuterium. To obtain such a high accuracy in *absolute* cross sections it is crucial to eliminate virtually all background events. In the case, for example, of $p(\gamma, \pi^0)p$, the approximately 15% background contamination could be eliminated with a neural network implemented in the final stage of analysis (as has been demonstrated for the BNL Crystal Ball data described above).

The cross sections extracted from these data will be analyzed to determine the photo-couplings and partial-wave amplitudes for the baryon resonances providing a crucial test of models based on nonperturbative QCD. Furthermore, couplings extracted from precision measurements can be used to test not only quark models of baryon structure and lattice-gauge calculations, but also models of the electromagnetic operator responsible for these couplings.

The double-pion photoproduction channels $p(\gamma, \pi^+\pi^-)p$, $p(\gamma, \pi^+\pi^0)n$, $p(\gamma, \pi^0\pi^0)p$ can be used to extend the study of nucleon resonances done with pion-nucleon scattering and single pion-production reactions. These channels yield information on the electromagnetic excitation and decay mechanisms of resonances, and are particularly useful for disentangling the broad and overlapping resonances at higher excitation energies, and also for exciting resonances that do not couple strongly to the pion-nucleon channel. Moreover, double π^0 production is not contaminated with background events from the $\Delta - \pi$ channel or from Born terms. At present no data exist for the $p(\gamma, \pi^0\pi^0)p$ channel above 800 MeV. By analyzing the total and differential cross sections for this reaction, we hope to better ascertain the properties of established resonances and to look for evidence of missing resonances. As discussed previously, the interpretation of the channel could be enhanced through the implementation of neural networks.

Finally, in the upcoming experiments, *Photoproduction of Vector Mesons from the Proton with Linearly Polarized Photons* (Jefferson Lab Experiments 94-109, 98-109, and 99-013), we will measure the photoproduction of vector mesons by using a beam of linearly polarized photons. The primary aims of these experiments are to delineate the spin-density matrix elements for these elementary processes and to search for new baryon resonances that are predicted to decay via the vector meson-nucleon channels. Also, measuring the beam asymmetry, Σ, as a function of t will allow one to disentangle vector-meson dominance (VMD) from other production mechanisms that give rise to the vector mesons. A drastic departure of Σ from unity at higher t will signal the onset of an OZI-evading process such as the knockout of preexisting strange quarks in the proton [Wil96].

Implementation and Integration with Our Existing Program

Additional Manpower

Due to the interdisciplinary nature (IT/Physics) of this development project, a multitude of educational opportunities become available. As the IT component evolves, the need for algorithm design and module testing (using real or simulated data) will necessarily increase.

A one-third-time post-doctoral research position will be created to oversee this project, coordinate development of the software and supervise students, and act as the System Manager for the cluster system. This in itself is a vital responsibility, providing valuable experience for a recent graduate. This person would also assist in the design and implementation of data filtering and analysis algorithms, thus providing key input (from the IT side) to a project that ultimately has utilitarian goals in nuclear physics. The integration of the post-doctoral researcher into the analysis work would give that person a completely new perspective.

The first year would be spent with the students and senior researchers learning neural-network techniques, and developing event-filtering algorithms for straightforward reaction channels. The results of these neural network algorithms would be compared with the results from traditional analysis methods to prove the efficiency and effectiveness of the neural network technique. Once both these aspects are established, the work will move on to the more difficult reaction channels, which will require the availability of additional computational facilities.

The testing phase by itself would be extensive, and the participation of undergraduate students would be ideal for this purpose. Such projects would require a basic (but not detailed) understanding of the algorithms and a grasp of the overall objective of the particular test. Undergraduates in both IT and Physics would benefit by examining the issues confronting the other discipline. The IT student needs to see the context in which the algorithmic approach is used. The Physics student gains experience in the computational aspects of the problem.

We propose to provide 4 stipends of 3 months duration for each year in the 5-year term of this proposal, for students to learn and develop the neural-network algorithms as well as parallel computational techniques.

Computer Infrastructure

In order to take advantage of the rapid improvement in computing technology we intend to distribute our hardware purchases across the term of this proposal. In the first year we would purchase a small (8 node) computing cluster, tape storage for archive purposes, and the necessary software: multi-user, multi-node compilers (C, C++, and FORTRAN), a batch queueing system, and distributed/parallel message-passing libraries. A variety of neural-network source codes are available on the public domain. For our test cases so far, we have adapted JetNet 1.1, which has been used by the high-energy particle physics community. This basic system would be sufficient to begin the development and testing of neural-network codes and implementing them on small subsets of existing data from CLAS and Crystal-Ball experiments.

In year two, we would purchase a large (1 Terabyte) disk array to provide local storage on the cluster system and additional computer nodes in years three, four and five to extend the cluster, and improve the data processing rate. By year four the system will have sufficient computer nodes that additional networking capability will also be required.

The system would be located at the GW Virginia Campus to make use of the fast-access tape library available from the GW Crash Analysis Center. This will provide sufficient storage capacity for all the raw and post-processed data for archival purposes while enabling open access with our only investment being the media costs.

Milestones

Year one

- Develop basic neural-network techniques
- Compare available neural-network software
- Further test neural-network approaches using BNL Crystal-Ball data
- Begin studies of prolific channels in CLAS data sets (*e.g.*, single-pion production)

Year two

- Develop Monte-Carlo simulations of general CLAS backgrounds (including artifact backgrounds)
- Develop a hit-based-track pre-filter for basic reconstruction
- Study the possibility of using neural networks for signal decomposition and interpretation (*e.g.*, the case of double-π^0 production) and compare with traditional fitting methods
- Test neural-network filtering for rare channels using charged-kaon production

Year three

- Design and implement a "front end" for CLAS neural-network generation
- Design and implement a standard database structure for neural networks

Year four

- Design and implement a World Wide Web interface/server for FANNFARE

Year five

- Develop a comparator for unexpected rare channels as a new method for identifying exotic reactions

Continuity of the Project

Key expertise in computational hardware, software, and data-analysis techniques resides with Co-PIs Heimberg, O'Rielly, and Niculescu, and Senior Investigator Murphy. Since the appointments of these scientists expire during the proposed lifetime of this project, we have taken the following steps to insure its continuity:

1. The senior GW faculty (PI Berman, Co-PI Feldman, and Senior Investigator Briscoe) will retain their active involvement throughout the project lifetime.

2. We anticipate that both Drs. Heimberg and O'Rielly, who were largely responsible for producing this proposal, will retain their association with GW via Adjunct appointments. We will also provide them with travel support, as necessary, from our DOE research grant.

3. We intend to hire replacements for Drs. Heimberg, Murphy, and Niculescu whose primary qualification will be significant experience in the analysis of complex nuclear physics data.

4. We intend that the postdoctoral researcher funded under this grant be employed for the life of the project, so that the stability and continuity are assured on a long-term as well as on a short-term basis.

Conclusion

We plan to implement a program to develop computational techniques based on neural networks to aid analyses of new data and put together a computational facility sufficient to handle the massive data sets we have and continue to acquire.

We believe that our nuclear physics group at The George Washington University, with its growing infrastructure, manpower, and experience, is particularly well suited to carry out such a large analysis effort. Our experimental group is one of the largest in the country that is devoted to medium-energy nuclear physics, and consists of four regular and two research faculty, three post-doctoral researchers, and six graduate students. The GW Center for Nuclear Studies also is the home for six regular and three research faculty in theoretical nuclear physics and their students.

We benefit from the facilities of our Nuclear Detector Laboratories (NDL) at both the Foggy Bottom and Virginia Campuses of GW, where the focal-plane detector array for the Tagged-Photon Facility for Hall B at Jefferson Laboratory (JLab) was built and where the goniometer for the Polarized-Photon Facility was assembled.

Furthermore, our newly formed Data Analysis Center (DAC) at the Virginia Campus has undertaken the massive tasks of compiling, correlating, and extracting quantities of physical interest, such as photocouplings and phase shifts, from the world's data with both electromagnetic and hadronic probes.

Since its inception over 15 years ago, the GW Nuclear Physics Group has been a model for student participation at all levels, including under-represented groups. The current complement of post-doctoral researchers in our group includes a woman, stationed at Jefferson Lab, and half of the 6 graduate students in the group at the moment are women. Undergraduates have had remarkable opportunities afforded by the numerous research projects involving our group. In the past few years, 5 undergraduate senior projects have been sponsored, all of which have had an IT/Physics component. In addition, the group has been able to support 2-3 summer students from outside GW for each of the past 10 summers. About a third of the undergraduates associated with our group have been women. Thus, the track record for engaging students in active research and, in particular, having a heterogeneous mix, has been excellent in the recent past.

With the present-day explosion of high-tech and computing capabilities, it is clear that science students need to be well versed in the computational aspects of their field, and the computer students benefit greatly by seeing the applications in action. The synergy between the two disciplines is critical in developing an efficient and workable product that serves its initial purpose. Moreover, that product can then be easily adapted to other new applications in other fields of study.

Results from Prior NSF Support (Gerald Feldman)

A
- NSF Award: PHY-9703049
  - Award amount: $320,000
  - Award period: September 1997 – August 2001

B Project title: Intermediate-Energy Nuclear Physics with Polarized and Unpolarized Photons

C Summary of results

1. Photodisintegration of the A = 3 Systems
   The two-body photodisintegration reactions $^3\mathrm{He}(\gamma, d)p$ and $^3\mathrm{H}(\gamma, d)n$ have been measured simultaneously using tagged photons of energy $E_\gamma = 17 - 52$ MeV at the Saskatchewan Accelerator Laboratory (SAL). These data are the first simultaneous measurements in the A = 3 systems. The primary motivation for this work is the investigation of charge symmetry in few-nucleon systems.

   Our experimental $^3\mathrm{H}/^3\mathrm{He}$ ratio is given roughly by a constant value of 1.05 ± 0.04 which is in excellent agreement with the calculations of Schadow and Sandhas over the entire energy range of the present experiment. These calculations are fully charge symmetric, so there is no evidence for any violation of charge symmetry.

   As an extension of our two-body measurements, we have performed an experiment on ^{3}He at MAX-Lab (in Lund, Sweden) in the tagged photon energy range 11 - 30 MeV. The experiment will continue in May 2001 with a run on a tritium target.

2. Triplet Photoproduction Polarimetry
   We have been working on the development and testing of a polarimeter for linearly polarized photons for the Coherent Bremstrahlung Facility in Hall B at TJNAF. The device is based on the process of triplet photoproduction, in which the incident photon produces an electron-positron pair in the Coulomb field of an atomic electron, and the azimuthal asymmetry of the recoil electron is directly related to the polarization of the incident photon. In a test run at LEGS using nearly 100% polarized photons of energy $E_\gamma = 220 - 330$ MeV. We observed a clear $\cos(2\phi)$ azimuthal angular dependence (as expected), but the maximum asymmetry was smaller than the predicted asymmetry. This reduced experimental asymmetry had been tentatively attributed to multiple scattering of the low-energy recoil electrons.

   We have developed a Monte Carlo simulation of the triplet polarimeter system in order to model the effect of multiple scattering. The simulation indicates that the idealized asymmetry expected for our geometry is significantly reduced by multiple scattering, but is still not in agreement with our measured asymmetry of 2.7%. We have recently begun a collaboration with a group of theorists from the

Ukraine who will be modeling the physics processes in a more detailed manner in an effort to understand the experimental asymmetry.

3. Compton Scattering and Nucleon Polarizability

   The data analysis for the quasi-free Compton scattering reaction $D(\gamma,\gamma' n)p$ at $E_\gamma = 236 - 260$ MeV has been completed. The scattered photon was detected in the large NaI detector BUNI from Boston University and the recoil neutron in a position-sensitive array of liquid scintillator cells. The motivation for the experiment was to make a definitive determination of the neutron polarizability. Both the neutron quasi-free (NQF) and proton quasi-free (PQF) reactions were measured simultaneously, such that the PQF cross section would serve as a test of any model-dependent assumptions in the analysis.

   The quasi-free Compton scattering cross sections were compared to the calculations of Levchuk in order to deduce a value for the neutron polarizability (and the proton polarizability, as a cross-check of the model assumptions). Using this comparison, a proton polarizability was obtained that was consistent with the results of free-proton measurements. For the neutron, we utilized the ratio of the PQF and NQF cross sections to obtain the neutron polarizability in order to minimize the effects of systematic uncertainties and model dependence in the extraction. The final results are given by: $\alpha_n = 10.8 \pm 3.2$ and $\beta_n = 4.4 \pm 3.2$. The large error bars arise because that the PQF/NQF ratio varies slowly as a function of the free parameter $\alpha_n - \beta_n$ and so a sizable range of ratio values translates into a large uncertainty in the extracted polarizabilities.

4. Photoabsorption and Photofission

   Measurements of the total photofission cross sections for actinide nuclei had previously been performed at low energies ($E_\gamma = 50 - 260$ MeV) at Saskatoon. More recently, data were obtained at higher energies ($E_\gamma = 0.4 - 3.8$ GeV) at at TJNAF.

   Our results confirm the conclusions reached in the lower-energy measurements, namely that the photofission cross section for all of the actinide nuclei is not the same. Whereas ^{238}U had previously been assumed to have a fission probability of 100%, we find that some of the cross sections (^{237}Np for example) are higher than that of ^{238}U. This conclusion could have significant implications for the "universal curve" of photoabsorption. It has been widely assumed that the cross section per nucleon is constant over a wide range of nuclei, but this interpretation could be considered questionable.

   All of the nuclei measured (including ^{232}Th, ^{237}Np, various uranium isotopes and Pb) show a variation in the photofission cross section that follows a smooth dependence on the fissility parameter Z^2/A. The relative cross sections appear to approach an asymptotic value, suggesting that the fission probability is indeed approaching unity.

5. Photoreactions on ^{3}He at TJNAF

An experiment to examine various aspects of intermediate-energy photonuclear reactions on ^{3}He was performed at TJNAF using the CLAS detector. Three general motivations for such a comprehensive study are: 1) to understand the propagation and damping of nucleon resonances in the nuclear medium, 2) to search for effects due to three-body forces, and 3) to investigate the small ΔNN configuration in the ground-state wave function of ^{3}He.

The data were obtained using tagged photons in the energy range of 1-4 GeV. Various final states have been tentatively identified using missing mass reconstruction. At the moment, the various components of the CLAS detector are in the process of being calibrated for this run. This involves the drift chambers (for track reconstruction), the time-of-flight counters (for timing information) and the electromagnetic calorimeter (for total energy information).

D Publications related to the work

Quasi-Free Compton Scattering from the Deuteron and Nucleon Polarizabilities
N.R. Kolb *et al.* Phys Rev Lett **85** (2000), 1388.

Photofission of Heavy Nuclei at Energies up to 4 GeV
C. Cetina *et al.* Phys Rev Lett **84** (2000), 5740.

Elastic Compton Scattering from the Deuteron and Nucleon Polarizabilities
D.L. Hornidge *et al.* Phys Rev Lett **84** (2000), 2334.

Photofission of Actinide Nuclei in the Quasideuteron and Delta Energy Regions
J.C. Sanabria *et al.* Phys Rev **C61** (2000), 034604.

Triplet Production Measurements at SAL
G. Feldman and R.E. Pywell,
Workshop on Polarized Photon Polarimetry,
CEBAF, Newport News, Virginia (June, 1998).

Charge Symmetry in the $A = 3$ System
G. Feldman *et al.* Bull Am Phys Soc **45** (2000), 36.

Triplet Polarimeter for Photons in the GeV Range
G.V. O'Rielly *et al.* Bull Am Phys Soc **45** (2000), 174.

Photofission of Heavy Nuclei at Energies up to 4 GeV
C. Cetina *et al.* Bull Am Phys Soc **45** (2000), 37.

Quasi-Free Compton Scattering from the Deuteron and Nucleon Polarizabilities
N.R. Kolb *et al.* Bull Am Phys Soc **45** (2000), 37.

Simultaneous Measurement of the Photodisintegration of ^3H and ^3He
G.V. O'Rielly *et al.* Bull Am Phys Soc **44** (1999), 1010.

References Cited

[**pdg00**] *Review of Particle Physics*, Eur. J. Phys. 1-4, 196 (2000)

[**Lip87**] R.P. Lippman, *An Introduction to Computing with Neural Nets*, IEEE ASSP Magazine, April (1987), 4-22.

[**Hei00**] P. Heimberg, *A Neural Net for Crystal-Ball Data*, GWU Nuclear Physics Seminar, Washington DC, Aug (2000)

[**Anc00**] E. Anciant *et al.*, Phys. Rev. Lett. (in press, 2000)

[**Fri94**] J.L. Friar,in Few Body 1994 (ICFBP14), p. 323 (e-print: nucl-th/9410002)

[**Lag88**] J.-M. Laget, J. Phys. **G 14**, 1445 (1988)

[**Lag92**] J.-M. Laget, in Electronuclear Physics with Internal Targets and the BLAST Detector (eds. R. Alarcon and M. Butler, World Scientific, 1992)

[**Lee97**] F.X. Lee, C. Bennhold, and L.E. Wright, Phys. Rev. C 55, 318 (1997)

[**Lee99**] F.X. Lee *et al.*, Phys. Rev. *C 60*, 034605 (1999)

[**Kam97**] S.S. Kamalov and E. Oset, Nucl. Phys. *A625*, 873 (1997)

[**Wil96**] R.A. Williams and S.R. Cotanch, Phys. Rev. Lett. *77*, 1008 (1996)

BARRY L. BERMAN

a. Education

Harvard University, Cambridge, MA	Physics	B.A. 1957
University of Illinois, Urbana, IL	Physics	M.S. 1959, Ph.D. 1963

b_1. Positions

Professor, Department of Physics, The George Washington University, (1985-present; Chairman 1993-1998; Columbian School of Arts and Sciences Distinguished Professor 1998-present)
Physicist, E Division, Lawrence Livermore National Laboratory (1963-85)
Lecturer, Department of Applied Science, University of California at Davis (1969-85)

b_2. Visiting Positions

Jefferson Lab (1999, 2000); LANL (1985, 88, 89, 91, 92); CEBAF (1991-92); LBL (1986); MIT (1982); Saclay (1980-81); Melbourne (1978); São Paulo (1977); Toronto (1970, 1975); Frankfurt (1974); Yale (1969-70)

c. Publications

(i) E. Anciant *et al*. (153 authors), *Photoproduction of Phi (1020) Mesons on the Proton at Large Momentum Transfer*, Phys. Rev. Lett. **85**, 4682 (2000)

C. Cetina, B.L. Berman, W.J. Briscoe, P.L. Cole, G. Feldman, P. Heimberg, L.Y. Murphy, S.A. Philips, J.C. Sanabria, H. Crannell, A. Longhi, D.I. Sober, and G. Ya. Kezerashvili, *Photofission of Heavy Nuclei at Energies up to 4 GeV*, Phys. Rev. Lett. **84**, 5740 (2000)

J.C. Sanabria, B.L. Berman, C. Cetina, P.L. Cole, G. Feldman, N.R. Kolb, R.E. Pywell, J.M. Vogt, V. G. Nedorezov, A.S. Sudov, and G.Ya. Kezerashvili, *Photofission of Actinide Nuclei in the Quasideuteron and Lower Part of the Delta Energy Region*, Phys. Rev. C **61**, 034604 (2000)

D.I. Sober, H. Crannell, A. Longhi, S.K. Matthews, J.T. O'Brien, B.L. Berman, W.J. Briscoe, P.L. Cole, J.P. Connelly, W.R. Dodge, L.Y. Murphy, S.A. Philips, M.K. Dugger, D. Lawrence, B.G. Ritchie, E.S. Smith, J.M. Lambert, E. Anciant, G. Audit, T. Auger, C. Marchand, M. Klusman, J. Napolitano, M.A. Khandaker, C.W. Salgado, and A.J. Sarty, *The Bremsstrahlung Tagged Photon Beam in Hall B at JLab*, Nucl. Instrum. Methods **A440**, 263 (2000)

K.S. Dhuga, B.L. Berman, W.J. Briscoe, R.W. Caress, S.K. Matthews, D.B. Barlow, B.M.K. Nefkens, C. Pillai, J.W. Price, S.J. Greene, I. Slaus, and I. Supek, *Investigation of Nuclear Charge Symmetry by Pion Elastic Scattering from ^{3}H and ^{3}He*, Phys. Rev. C **54**, 2823 (1996)

(ii) J.P. Connelly, B.L. Berman, W.J. Briscoe, K.S. Dhuga, A. Mokhtari, D. Zubanov, H.P. Blok, R. Ent, J.H. Mitchell, and L. Lapikás, *Trinucleon Cluster Knockout from ^{6}Li*, Phys. Rev. C **57**, 1569 (1998)

D. Pang, B.L. Berman, S. Chasovskikh, J.E. Rodgers, and A. Dritschilo, *Investigation of Neutron-Induced Damage in DNA by Atomic Force Microscopy: Experimental Evidence of Clustered DNA Lesions*, Radiation Research **150**, 612 (1998)

S.K. Matthews, W.J. Briscoe, C. Bennhold, B.L. Berman, R.W. Caress, K.S. Dhuga, S.N. Dragic, S.S. Kamalov, N.J. Nicholas, M.F. Taragin, L. Tiator, S.J. Greene, D.B. Barlow, B.M.K. Nefkens, C. Pillai, J.W. Price, L.D. Isenhower, M.E. Sadler, I. Slaus, and I. Supek, *Elastic Scattering of Pions from ^{3}H and ^{3}He into the Backward Hemisphere*, Phys. Rev. C **51**, 2534 (1995)

R.M.Sellers, D.M. Manley, M.M. Niboh, D.S. Weerasundara, R.A. Lindgren, B.L. Clausen, M. Farkhondeh, B.E. Norum, and B.L. Berman, *Inelastic Electron Scattering from ^{18}O at Backward Angles*, Phys. Rev. C **51**, 1926 (1995)

B.L. Berman, G.C. Anderson, W.J. Briscoe, A. Mokhtari, A.M. Petrov, M.E. Sadler, D.B. Barlow, B.M.K. Nefkens, and C. Pillai, *Inelastic Pion Scattering from ^{3}H and ^{3}He*, Phys. Rev. C **51**, 1882 (1995)

d. Synergistic Activities

Developed innovative courses in Music & Physics and Communications in Physics
Introduced term-paper assignments into all physics courses
Taught laboratory-based physics to first-, second-, and third-graders
Compiled and published database of photoneutron cross sections obtained with monoenergetic photons
Membership in 36 professional organizations and committees; referee for 20 journals; reviewer for 21 funding agencies and universities; consultant for 13 companies and laboratories

e(i). Collaborators

E. Anciant (Saclay), G. Audit (Saclay), T. Auger (Saclay), S.P. Barrow (Florida State), H.P. Blok (Vrie University), W.J. Briscoe(GWU), J.R. Calarco (New Hampshire), C. Cetina (GWU), S. Chasovskikh (Georgetown), B.L. Clausen (Loma Linda), P.L. Cole (UTEP), J.P. Connelly (Cisco), H.L. Crannell (Catholic U), P. Degtiarenko (JLab), K.S. Dhuga (GWU), W.R. Dodge (retired), A. Dritschilo (Georgetown), M.K. Dugger (Arizona State), R. Ent (JLab), M. Farkhondeh (Bates), G. Feldman (GWU), S. J. Greene (LANL), L.Sh. Grigoryan (Yerevan), P.C. Heimberg (GWU), S.D. Hobblit (BNL), D.L. Hornidge (SAL), R. Igarashi (SAL), L.D. Isenhower (ACU), R. Jones (CMU), N.M. Karlsson (Lund), G.Ya. Kezerashvili (deceased), H.F. Khachatryan (Yerevan), M.A. Khandaker (Norfolk State), F. Klein (Florida State), M. Klusman (RPI), N.R. Kolb (SAL), J.M. Lambert (retired), L. Lapikás (NIKHEF), D. Lawrence (U Mass), R.A. Lindgren (U Va), A. Longhi (Catholic U), D.S. Lowe (SAL), A.M. Mader (SAL), D.M. Manley (Kent State), C. Marchand (Saclay), S.K. Matthews (Catholic U), L.C. Maximon (GWU), J.H. Mitchell (JLab), A.R. Mkrtchyan (Yerevan), A. Mokhtari (Mashaad), L.Y. Murphy (GWU), J. Napolitano (RPI), V.G. Nedorezov (INR), B.M.K. Nefkens (UCLA), B.E. Norum (U Va), J.T. O'Brien (Catholic U), G.V. O'Rielly (GWU), D. Pang (U Wash), S.A. Philips (GWU), M.A. Piestrup (Adelphi), H. Prade (Dresden), J.W. Price (UCLA), R.E. Pywell (SAL), G.A. Retzlaff (SAL), B.G. Ritchie (Arizona State), J. Rodgers (Georgetown), J. Ruthenberg (Kent State), M. E. Sadler (ACU), C.W. Salgado (Norfolk State), J.C. Sanabria (U de los Andes), A.M. Sandorfi (BNL), A.J. Sarty (Florida State), W. Schadow (Bonn), T. Seed (U Georgia), R.M. Sellers (Kent State), D.M. Skopik (JLab), I. Slaus (RBI), E.S. Smith (JLab), D.I. Sober (Catholic U), A.S. Sudov (INR), I. Supek (RBI), B. Vidic (Georgetown), J.M. Vogt (SAL), W. Wagner (Dresden), D.V. Wiebe (SAL), D. Zubanov (Melbourne), and the other 200 or so members of the CLAS Collaboration.

e(ii). Graduate Advisor: L.J. Koester, Jr. (deceased)

e(iii). Thesis Advisor and Postgraduate-Scholar Sponsor

Thesis Advisor: C. Cetina (GWU); J.C. Sanabria (Univ. de los Andes, Bogota); D. Pang (Univ. of Washington)

Postgraduate-Scholar Sponsor: I. Niculescu (GWU); P. Heimberg (GWU); L.Y. Murphy (GWU); P.L. Cole (Univ. of Texas at El Paso); S.L. Rugari (Avenue Tech)

BIOGRAPHICAL SKETCH

Biographical Sketch: Gerald Feldman

A. Professional Preparation
Undergraduate Institution: University of Pennsylvania
Physics, Astronomy B.A. 1978
Graduate Institution: University of Washington
Physics M.S. 1981
Physics Ph.D. 1987
Postdoctoral Institution: Duke University
Nuclear Physics 1987-1990

B. Appointments
Assistant Professor, Department of Physics, The George Washington University (1996-present)
Research Scientist, Saskatchewan Accelerator Laboratory, Univ. of Saskatchewan (1990-96)
Post-Doctoral Research Associate, TUNL, Duke University (1987-90)
Research Assistant, Nuclear Physics Laboratory, University of Washington (1980-87)
Teaching Assistant, Department of Physics, University of Washington (1978-80)

C. Publications
Quasi-Free Compton Scattering from the Deuteron and Nucleon Polarizabilities
N.R. Kolb, A.W. Rauf, R. Igarashi, D.L. Hornidge, R.E. Pywell, B.J. Warkentin, E. Korkmaz, G. Feldman and G.V. O'Rielly,
Phys Rev Lett 85 (2000), 1388.

Photofission of Heavy Nuclei at Energies up to 4 GeV
C. Cetina, B.L. Berman, W.J. Briscoe, P.L. Cole, G. Feldman, P. Heimberg, L.Y. Murphy, S.A. Philips, J.C. Sanabria, Hall Crannell, A. Longhi, D.I. Sober and G.Ya. Kezerashvili,
Phys Rev Lett 84 (2000), 5740.

Elastic Compton Scattering from the Deuteron and Nucleon Polarizabilities
D.L. Hornidge, B.J. Warkentin, R. Igarashi, J.C. Bergstrom, E.L. Hallin, N.R. Kolb, R.E. Pywell, D.M. Skopik, J.M. Vogt and G. Feldman,
Phys Rev Lett 84 (2000), 2334.

Photofission of Actinide Nuclei in the Quasideuteron and Delta Energy Regions
J.C. Sanabria, B.L. Berman, C. Cetina, P.L. Cole, G. Feldman, N.R. Kolb, R.E. Pywell, J.M. Vogt, V.G. Nedorezov, A.S. Sudov and G. Ya. Kezerashvili,
Phys Rev C61 (2000), 034604.

Measurement of the gp -> npi+ Reaction Near Threshold
E. Korkmaz, N.R. Kolb, D.A. Hutcheon, G.V. O'Rielly, J.C. Bergstrom, G. Feldman, D. Jordan, A.K. Opper, R.E. Pywell, B. Sawatzky and D.M. Skopik,
Phys Rev Lett 83 (1999), 3609.

Final-State Interactions in D(gamma,pppi-) Near the Delta Resonance
M.A. Quraan, E.D. Hackett, E. Korkmaz, W.J. McDonald, A.K. Opper, N.L. Rodning, G. Feldman, N.R. Kolb, G.V. O'Rielly, R.E. Pywell and D.M. Skopik,
Phys Rev C57 (1998), 2118.

Compton Scattering, Meson Exchange and the Polarizabilities of Bound Nucleons

(This is a continuation page)

G. Feldman, K.E. Mellendorf, R.A. Eisenstein, F.J. Federspiel, G. Garino, R. Igarashi, N.R. Kolb, M.A. Lucas, B.E. MacGibbon, W.K. Mize, A.M. Nathan, R.E. Pywell and D.P. Wells,
Phys Rev C54 (1996), R2124.

3He(gamma,pp)n Cross Sections with Tagged Photons below the Delta Resonance Energy
N.R. Kolb, G. Feldman, G.V. O'Rielly, R.E. Pywell, D.M. Skopik, E.D. Hackett, M. Quraan and N.L. Rodning,
Phys Rev C54 (1996), 2175.

Reaction Mechanisms in 12C(gamma,pp) near 200 MeV
E.D. Hackett, W.J. McDonald, A.K. Opper, M.A. Quraan, N.L. Rodning, F.M. Rozon, G. Feldman, N.R. Kolb, R.E. Pywell, D.M. Skopik, D.E. Tiller, J.M. Vogt, E. Korkmaz and G.V. O'Rielly,
Phys Rev C53 (1996), R1047.

Measurement of the Electric and Magnetic Polarizabilities of the Proton
B.E. MacGibbon, G. Garino, M.A. Lucas, A.M. Nathan, G. Feldman and B. Dolbilkin,
Phys Rev C52 (1995), 2097.

D. Synergistic Activities
1) Development of an introductory physics course based on active engagement of students
2) Implementation of an electronic response system for class
3) Implementation of a web-based computer system for homework
4) Establishment of Physics Help Room as student resource facility

E. Collaborators and Affiliations
Collaborators
J.C. Bergstrom, N.R. Kolb, R.E. Pywell (Univ. of Saskatchewan)
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J.R. Calarco (Univ. of New Hampshire)
H. Crannell, D.I. Sober (Catholic University)
P. Debevec, A.M. Nathan (University of Illinois)
D.A. Hutcheon (TRIUMF)
M. Khandaker (Norfolk State Univ.)
E. Korkmaz (Univ. of Northern British Columbia)
A. Opper (Ohio University)
N. Rodning (Univ. of Alberta)
A.M. Sandorfi (Brookhaven National Lab)
B. Schroder (Lund University)
D.M. Skopik (TJNAF)

Advisors
Graduate advisor: K.A. Snover, University of Washington
Postdoctoral advisor: H.R. Weller, Duke University

Peter C. Heimberg

Professional Preparation

Texas A&M University	Physics	B.S. 1988
Northwestern University	Physics	Ph.D. 1995
Vrije Universiteit Amsterdam	Nuclear Physics	1995-1998
George Washington U.	Nuclear Physics	1998-2001

Publications

- D.L. Groep, M.F. van Batenburg, T.S. Bauer, H.P. Blok, D.J. Boersma, E. Cisbani, R. De Leo, S. Frullani, F. Garibaldi, W. Glockle, J. Golak, P. Heimberg, W.H.A. Hesselink, M. Iodice, D.G. Ireland, E. Jans, H. Kamada, L. Lapikas, G.J. Lolos, C.J.G. Onderwater, R. Perrino, A. Scott, R. Starink, M.F.M. Steenbakkers, G.M. Urciuoli, H. de Vries, L.B. Weinstein, H. Witala, *Investigation of the Exclusive* $^3He(e,e'pp)n$ *Reaction*, Phys.Rev.C63:014005,2001, e-Print Archive: nucl-ex/0008008

- H.R. Poolman, D.J. Boersma, M. Harvey, D.W. Higinbotham, I. Passchier, E. Six, R. Alarcon, P.W. van Amersfoort, T.S. Bauer, H. Boer Rookhuizen, J.F.J. van den Brand, L.D. van Buuren, H.J. Bulten, R. Ent, M. Ferro-Luzzi, D.G. Geurts, P. Heimberg, C.W. de Jager, P. Klimin, I. Koop, F. Kroes, J. van der Laan, G. Luijckx, A. Lysenko, B. Militsyn, I. Nesterenko, J. Noomen, B.E. Norum, M.J.J. van den Putte, Yu. Shatunov, J.J.M. Steijger, D. Szczerba, H. de Vries, *Experiments with Longitudinally Polarized Electrons in a Storage Ring Using a Siberian Snake*, Phys.Rev.Lett.84:3855-3858,2000

- C. Cetina, B.L. Berman, W.J. Briscoe, P.L. Cole, G. Feldman, P. Heimberg, L.Y. Murphy, S. Philips, J.C. Sanabria, Hall Crannell, A. Longhi, D.I. Sober, G.Ya. Kezerashvili, *Photofission of Heavy Nuclei at Energies up to 4-GeV*, Phys.Rev.Lett.84:5740-5743,2000, e-Print Archive: nucl-ex/0004004

- I. Passchier, R. Alarcon, T.S. Bauer, D. Boersma, J.F.J. van den Brand, L.D. van Buuren, H.J. Bulten, M. Ferro-Luzzi, P. Heimberg, D.W. Higinbotham, C.W. de Jager, S. Klous, H. Kolster, J. Lang, B.L. Militsyn, D. Nikolenko, G.J.L. Nooren, B.E. Norum, H.R. Poolman, I. Rachek, M.C. Simani, E. Six, D. Szczerba, H. de Vries, K. Wang, Z.L. Zhou, *The Charge Form-Factor of the Neutron from the Reaction* $^2\vec{H}(\vec{e},e'n)p$, Phys.Rev.Lett.82:4988-4991, 1999, e-Print Archive: nucl-ex/9907012

- P. Heimberg, R.E. Segel, F.J. Chen, K. Ackerstaff, R.D. Bent, J. Blomgren, H.O. Meyer, H. Nann, B. von Przewoski, T. Rinckel, A. Zhuravlev,

M.A. Pickar, G. Hardie, P.V. Pancella, E. Jacobsen, J.D. Brown, *Measurement of the $\vec{p}p \rightarrow d\pi^+$ Cross-section and Analyzing Power at Threshold*, Phys.Rev.Lett.77:1012-1015, 1996

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Graduate and Postdoctoral Advisors

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Professional Preparation

Bucharest University	Physics	Bachelor, 1991
Hampton University	Physics	PhD, 1999
The George Washington University	Nuclear Physics	1999-2002

Publications

1. I. Niculescu, C. Keppel, S. Liuti, G. Niculescu, *Extraction of Higher Twists from Electron-Proton Inclusive Data at Large Bjorken x*, Phys. Rev. **D60** (1999) 94001.

2. I. Niculescu, C.S. Armstrong, J. Arrington, K.A. Assamagan, O.K. Baker, C.W. Bochna, R.D. Carlini, J. Cha, C. Cothran, D.B. Day, J.A. Dunne, D. Dutta, R. Ent, B.W. Filippone, V.V. Frolov, H. Gao, D. Geesaman, P. Gueye, W. Hinton, R.J. Holt, C. Keppel, D.M. Koltenuk, D.J. Mack, D.G. Meekins, M.A. Miller, J.H. Mitchell, R.M. Mohring, G. Niculescu, J.W. Price, J. Reinhold, R.E. Segel, P. Stoler, L. Tang, B.P. Terburg, D. Van Westrum, W.F. Vulcan, S.A. Wood, C. Yan, B. Zeidman, *Evidence for Valence Quark–Hadron Duality*, Phys. Rev. Lett. 85 (2000), 1186.

3. I. Niculescu, C.S. Armstrong, J. Arrington, K.A. Assamagan, O.K. Baker, C.W. Bochna, R.D. Carlini, J. Cha, C. Cothran, D.B. Day, J.A. Dunne, D. Dutta, R. Ent, B.W. Filippone, V.V. Frolov, H. Gao, D. Geesaman, P. Gueye, W. Hinton, R. Holt, C. Keppel, D.M. Koltenuk, D.J. Mack, D.G. Meekins, M.A. Miller, J.H. Mitchell, R.M. Mohring, G. Niculescu, J.W. Price, J. Reinhold, R.E. Segel, P. Stoler, L. Tang, B.P. Terburg, D. Van Westrum, W.F. Vulcan, S.A. Wood, C. Yan, B. Zeidman, *Experimental Verification of Quark–Hadron Duality*, Phys. Rev. Lett. 85 (2000), 1182

4. R. Ent, C.E. Keppel, and I. Niculescu, *Nucleon Elastic Form Factors and Local Duality*, accepted for publication in Phys. Rev. **D62** (2000), 073008

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Biographical Sketch
Grant V.O'Rielly

A. Professional Preparation:

University of Melbourne	Physics	B.Sc. (Honours) 1986
University of Melbourne	Physics	Ph.D. 1997
University of Northern BC	Nuclear Physics	1995 - 1998
The George Washington University	Nuclear Physics	1998 - present

B. Appointments:

The George Washington University	Research Scientist	(1998 - present)
University of Northern BC	Postdoctoral Researcher	(1995 - 1998)
University of Sascatchewan	Graduate Research Assistant	(1990 - 1994)
University of Melbourne	Graduate Research Assistant	(1986 - 1989)

C. Publications:

Charge symmetry breaking in the reaction $np \rightarrow d\pi^\circ$
A.K. Opper, E.G. Auld, R.M. Churchman, C.A. Davis, R.W. Finlay, P.W. Green, L.G. Greeniaus, D.A. Hutcheon, D.V. Jordan, E.J. Korkmaz, J.A. Niskanen, G.V. O'Rielly, T. Porcelli, S.D. Reitzner, P.L. Walden and S. Yen
Nuclear Physics **A663**, 505, (2000).
Quasi-Free Compton Scattering from the Deuteron and Nucleon Polarizabilities
N.R. Kolb, A.W. Rauf, R. Igarashi, D.L. Hornidge, R.E. Pywell, B.J. Warkentin, E. Korkmaz, G. Feldman, and G.V. O'Rielly
Physical Review Letters **85**, 1388, (2000).
Measurement of the $\gamma p \rightarrow \pi^+ n$ Reaction near Threshold
E. Korkmaz, N.R. Kolb, D.A. Hutcheon, G.V. O'Rielly, J.C. Bergstrom, G. Feldman, D. Jordan, A.K. Opper, R.E. Pywell, B. Sawatzky, and D.M. Skopik
Physical Review Letters **83**, (1999)
Segmented detector for recoil neutrons in the $p(\gamma, n)\pi^+$ reaction
E. Korkmaz, G.V. O'Rielly, D.A. Hutcheon, G. Feldman, D. Jordan, N.R. Kolb, R.E. Pywell, G.A. Retzlaff, B. Sawatzky, D.M. Skopik, J.M. Vogt, E. Cairns, U. Giesen, L. Holm, A.K. Opper, F.M. Rozon, and J. Soukup
Nucl. Inst. and Methods **A431**, 446 (1999)
Inclusive Measurements of the $pp \rightarrow pn\pi^+$ reaction at 420 and 500 MeV
R.G. Pleydon, W.R. Falk, M. Benjamintz, S. Yen, P.L. Walden, D.Hutcheon, C.A. Miller, M. Hartig, K. Hicks, and G.V. O'Rielly
Physical Review C**59**, 3208 (1999).
Final State Interactions in $D(\gamma, pp\pi^-)$ Near the $\Delta(1232)$ Resonance
M.A. Quraan, E.D. Hackett, E. Korkmaz, W.J. McDonald, A.K. Opper, N.L. Rodning, G. Feldman, N.R. Kolb, G.V. O'Rielly, R.E. Pywell, and D.M. Skopik
Physical Review C**57**, 57 (1998)
Inclusive positive pion photoproduction
K.G. Fissum, H.S. Caplan, E.L. Hallin, D.M. Skopik, J.M. Vogt, M. Frodyma, D.P. Rosenzweig, D.W. Storm, G.V. O'Rielly, and K.R. Garrow
Physical Review C**53**, 1278 (1996)
Reaction mechanisms in $^{12}C(\gamma, pp)$ near 200 MeV
E.D. Hackett, W.J. McDonald, A.K. Opper, M.A. Quraan, N.L. Rodning, F.M. Rozon,

G. Feldman, N.R. Kolb, R.E. Pywell, D.M. Skopik, D. Tiller, J.M. Vogt, E. Korkmaz, and G.V. O'Rielly
Physical Review C **53**, R1047 (1996)
The response of plastic scintillator to protons and deuterons
G.V. O'Rielly, N.R. Kolb, and R.E. Pywell
Nucl. Inst. and Methods **A368**, 745 (1996)
^{3}He(γ, pd) Cross Sections with Tagged Photons below the Δ Resonance,
N.R. Kolb, E.D. Hackett, E. Korkmaz, T. Nakano, A.K. Opper, M.A, Quraan, N.L. Rodning, F.M. Rozon, J. Asai, G. Feldman, E.L. Hallin, G.V. O'Rielly, R.E. Pywell, and D.M. Skopik
Physical Review C **49**, 2586 (1994)
De-excitation γ-rays following the photodisintegration of ^{17}O
G.V. O'Rielly, D. Zubanov, and M.N. Thompson
Physical Review C **40**, 59 (1989)

D. Synergistic Activities:

- Assembled a Beowulf-type compute cluster, installed parallel computing libraries, and assisted in development of parallelized code using the cluster for calculations.
- Networked, both hardware and software installation, undergraduate teaching laboratory PCs to create a distributed queueing system used to generate Monte-Carlo simulations for nuclear physics experiments.

E. Collaborators and Other Affiliations:

i. Collaborators in past 48 months not listed above:

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Thesis: M.N. Thompson (Univ. of Melbourne) and
D.M. Skopik (Jefferson Laboratory)

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G. Feldman (George Washington Univ.)

iii. Name of graduate students (thesis) and postdoctoral scholars sponsored:

None.

Name: William J. Briscoe
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Dr William J. Briscoe received his Ph.D. from the Catholic University of America in 1978. He was Assistant Research Professor for four years at the University of California, Los Angeles. He came to GW in 1982 as Assistant Professor, was promoted to Associate Professor in 1986 and Professor in 1998. Currently, he is Special Assistant to the Dean for Computing and Information Technology, Director of the GW/JLab Data Analysis Center and Interim Director of the GW Center for Nuclear Studies. He has held Guest and Visiting Scientist positions at several international laboratories including LAMPF, TRIUMF, Saclay, NIKHEF, Bates, and currently BNL and JLab where he is co-spokesperson on experiments E909 and E103-94, respectively. As principal investigator on the GW contract with SURA, he supervised the design and construction of the focal plane detector for the Hall B Tagged Photon Facility and serves as one of the working group leaders for the Tagger Working Group. He is currently on the Executive Committees of the CLAS and Crystal Ball Collaborations. He has over 60 referred journal articles and 55 conference presentations to his credit.

B. The five publications most closely related to the proposed project are:

Real Photon Physics Experiments at JLab using the Hall B Photon Tagger**,** W.J. Briscoe, C. Cetina, and S.A. Philips, Fizika **B8**, 11, (1999).

The JLab Hall B Photon Tagger, J.T. O'Brien, H. Crannell, D.S. Sober, B.L. Berman, W.J. Briscoe, et al., Nucl. Instr. and Meth. **440/2**, 263 (2000).

Search for the CP-Forbidden Decay $\eta \rightarrow 4\pi^o$**,** S. Prakhov, C. Allgower, V. Bekrenev, E. Berger, W.J. Briscoe, M. Clajus, J. Comfort, K. Craig, D. Grosnick, G.M. Huber, D.L. Isenhower, N. Knecht 12 , D. Koetke, A. Koulbardis, N. Kozlenko, S. Kruglov, T. Kycia, G.J. Lolos, I. Lopatin, D.M. Manley, A. Marusic, R. Manweiler, S. McDonald, B.M.K. Nefkens, J. Olmsted, Z. Papandreou, D. Peaslee, J. Peterson, N. Phaisangittisakul, M. Pulver, M.E. Sadler, A. Shafi, I. Slaus , H. Spinka, S. Stanislaus, A. Starostin, H.M. Staudenmaier, I. Supek, W.B. Tippens, Phys. Rev. Lett., **84,** 4802 (2000).

Photofission of Heavy Nuclei at Energies up to 4-GeV**,** C. Cetina, B.L. Berman, W.J. Briscoe, P.L. Cole, G. Feldman, P. Heimberg, L.Y. Murphy, S. Philips, J.C. Sanabria, Hall Crannell, A. Longhi, D.I. Sober, G.Ya. Kezerashvili, Phys. Rev. Lett., **84,** 5740 (2000); and LANL E-Print **nucl-ex/0004004**.

Charge Symmetry Violations Effects in Pion Scattering off the Deuteron, V.V. Baru, A.E. Kudryavtsev, V.E. Tarasov, W.J. Briscoe, K.S. Dhuga, and I.I. Strakovsky, Phys. Rev. C **62**, 044003 (2000); LANL E-Print **nucl-th/9910011**.

Five other significant publications are:

Measurement of Neutron Detection Efficiencies in NaI using the Crystal Ball Detector, T.D.S. Stanislaus, C. Allgower, V. Bekrenev, K. Benslama, E. Berger, W.J. Briscoe, M. Clajus, J.R. Comfort, K. Craig, A. Gibson, D. Grosnick, G.M. Huber, D. Isenhower, T. Kasprzyk, N. Knecht, D.D. Koetke, A. Koulbardis, N. Kozlenko, S. Kruglov, T. Kycia, G.J. Lolos, I. Lopatin, D.M. Manley, R. Manweiler, A. Marusic, S. McDonald, B.M.K. Nefkens, J. Olmsted, Z. Papandreou, D. Peaslee, J. Peterson, N. Phaisangittisakul, M. Pulver, A.F. Ramirez, M. Sadler, A. Shafi, I. Slaus, H. Spinka, A. Starostin, H.M. Staudenmaier, I. Supek, J. Thoms, W.B. Tippens, **in press,** Nuclear Instruments and Methods, (2000).

Measurement of Charge Symmetry Breaking in the Comparison of $\pi d \rightarrow pp\eta$ *with* $\pi^- d \rightarrow nn\eta$, W.B. Tippens, V.V. Abaev, M. Batini, V. Bekrenev, W.J. Briscoe, R.E. Chrien, M. Clajus, D. Isenhower, N. Kozlenko, S. Kruglov, M. Leitch, A. Maru, T.W. Morrison, B.M.K. Nefkens, J.C. Peng, P.H. Pile, J.W. Price, M.E. Sadler, R. Sawafta, I. Slaus, H. Seyfarth, I. Supek, R.J. Sutter, A. Svarc, M.J. Wang, D.B. White, **in press** Phys. Rev. D, (2000).

Measurement of $\pi^o\pi^o$ *Production in Nuclear Matter by* π^-*s at 0.408 GeV/c*, A. Starostin, H.M. Staudenmaier, C. Allgower, V. Bekrenev, E. Berger, W.J. Briscoe, M. Clajus, J. Comfort, K. Craig, D. Grosnick, D. Isenhower, N. Knecht, D. Koetke, A. Koulbardis, N. Kozlenko, S. Kruglov, T. Kycia, G. Lolos, I. Lopatin, D.M. Manley, B. Manweiler, S. McDonald, B.M.K. Nefkens, J. Olmsted, Z. Papandreou, D. Peaslee, R.J. Peterson, N. Phaisangittisakul, S. Prakhov, M. Pulver, M. Sadler, I. Slaus, H. Spinka, S. Stanislaus, I. Supek, and W.B. Tippens, Phys. Rev. Lett., **85,** (2000).

Pion Scattering off ^{3}He and ^{3}He Nuclei in the Δ(1232) Region, W.J. Briscoe, A.E. Kudryavtsev, I.I. Strakovsky and V.E. Tarasov, **in press**, Phys. At. Nucl. (2000)

Photoproduction of ϕ(1020) Mesons on the Proton at Large Momentum Transfer, E. Anciant, T. Auger, G. Audit, M. Battaglieri, J.M. Laget, C. Marchand, G.S. Adams, M.J. Amaryan, M. Anghinol_, D. Armstrong, B. Asavapibhop, H. Avakian, S. Barrow, K. Beard, M. Bektasoglu, B.L. Berman, N. Bianchi, A. Biselli, S. Boiarinov, W.J. Briscoe, W. Brooks, V.D. Burkert, J.R. Calarco, G. Capitani, D.S. Carman, B. Carnahan, C. Cetina, P.L. Col e, A. Coleman, J. Connelly, D. Cords, P. Corvisiero, D. Crabb, H. Crannell, J. Cummings, P.V. Degtiarenko, L.C. Dennis, E. De Sanctis, R. De Vita, K.S. Dhuga, C. Djalali, G.E. Dodge, D. Doughty, P. Dragovitsch, M. Dugger, S. Dytman, Y.V. Efremenko, H. Egiyan, K.S. Egiyan, L. Elouadrhiri, L. Farhi, R.J. Feuerbach, J. Ficenec, T.A. Forest, A. Freyberger, H. Funsten, M. Gai, M. Gar¢ con, G.P. Gilfoyle, K. Giovanetti, P. Girard, K.A. Grioen, M. Guidal, V. Gyurjyan, D. Heddle, F.W. Hersman, K. Hicks, R.S. Hicks, M. Holtrop, C.E. Hyde-Wright, M.M. Ito, D. Jenkins, K. Joo, M. Khandaker, D.H. Kim, W. Kim, A. Klein, F.J. Klein, M. Klusman, M. Kossov, L.H. Kramer, S.E. Kuhn, D. Lawrence, A. Longhi, K. Loukachine, R. Magahiz, R.W. Major, J. Manak, S.K. Matthews, S. McAleer, J. McCarthy, K. McCormick, J.W.C. McNabb, B.A. Mecking, M. Mestayer, C.A. Meyer, R. Minehart, R. Miskimen, V. Muccifora, J. Mueller, L. Murphy, G.S. Mutchler, J. Napolitano, B. Niczyporuk, R.A. Niyazov, A. Opper, J.T. O'Brien, S. Philips, N. Pivnyuk, D. Pocanic, O. Pogorelko, E. Polli, B.M. Preedom, J.W. Price, L.M. Qin, B.A. Raue, A.R. Reolon, G. Riccardi, G. Ricco, M. Ripani, B.G. Ritchie, F. Ronchetti, P. Rossi, F. Roudot, D. Rowntree, P.D. Rubin, C.W. Salgado, V. Sapunenko, R.A. Schumacher, A. Sha_, Y.G. Sharabian, A. Skabelin, C. Smith, E.S. Smith, D.I. Sober, S. Stepanyan, P. Stol er, M. Taiuti, S. Taylor, D. Tedeschi, R. Thompson, M.F. Vineyard, A. Vlassov, H. Weller, L.B. Weinstein, R. Welsh, D. Weygand, S. Whisnant, M. Witkowski, E. Wolin, A. Yegneswaran, J. Yun, B. Zhang, J. Zhao, Phys. Rev. Lett., **85**, 4682 (2000); and LANL E-Print **hep-ex/0006022.**

C. Other collaborators within the last 48 month not cited above:
None

D. Names of graduate students (thesis) sponsored:

Colin J. Seftor	Ph.D.	(1988)
Nancy-Jo Nicholas	M.S.	(1991)
Scott K. Matthews	Ph.D.	(1992)
Thomas W. Morrison	Ph.D.	(2000)
Aziz Shafi	Ph.D.	(2001- in progress)

E. Names of thesis and postdoctoral advisor:
Thesis Advisor - Hall Crannell
Postdoctoral Advisor - None

A. Vitae:

Name: Luc Yves Murphy
Address: Department of Physics, The George Washington University, Washington, DC 20052

Dr. Luc Yves Murphy received his PhD from Rensselaer Polytechnic Institute in 1993. While performing his graduate research, he was stationed at the Centre d'Etudes de Saclay in France from 1991 to the completion of his thesis in 1993. While there, he worked with the Real Photon Gr oup on the analysis of data gathered with the 4-pi detector DAPHNE. His area of expertise centered on MonteCarlo simulations of various detector systems and on the theoretical mechanisms describing double pion photo production. He then stayed on at the CE Saclay as a Post Doctoral Fellow from November 1993 to November 1995. While working with Saclay, he co-authored, with JM Laget, a now widely quoted code describing the mechanisms of double pion photoproduction. His additional responsibilities then were to pave the way for the Saclay group to integrate their research effort with that of the Hall-B collaboration at Jeffers on Lab. In November 1995, he joined the GW Experimental Nuclear Physics group in Washington DC as a PostDoctoral Fellow. His ponsibilities during this appointment were to supervise the assembly and commissioning of the Hall-B Photon Tagging Spectrometer at Jefferson Lab as well as to participate in the development of the analysis codes of the CLAS. As of September 1998, he has been promoted to Associate Research Professor in Experimental Nuclear Physics at GW, where he has been able to continue his participation in a number of Hall-B projects, in particular the development of a coherent bremsstrahlung facility located on that beam line and novel approaches to computational analysis techniques. He has over a dozen publications to his credit and has given an invited talk at the Gordon Conference.

B. The Five Publications Most closely related to the Proposed project are:

1) TOTAL CROSS-SECTION MEASUREMENT FOR THE THREE DOUBLE PION PRODUCTION CHANNELS ON THE PROTON.
A. Braghieri, et al. Phys.Lett.B363:46-50,1995
2) TWO BODY PHOTODISINTEGRATION OF HE-3 BETWEEN 200-MEV AND 800-MEV.
V. Isbert, et al. Nucl.Phys.A578:525-541,1994
3) TOTAL PHOTOABSORPTION CROSS-SECTIONS FOR H-1, H-2 AND HE-3 FROM 200-MEV TO 800-MEV. M. MacCormick, et al Phys.Rev.C53:41-49,1996
4) INVARIANT MASS DISTRIBUTIONS OF THE GAMMA N --->P PI- PI0 REACTION.
A. Zabrodin, et al. Phys.Rev.C60:055201,1999
5) CONSTRUCTION UPDATE AND DRIFT VELOCITY CALIBRATION FOR THE CLAS DRIFT CHAMBER SYSTEM.
M.D. Mestayer, et al Nucl.Instrum.Meth.A367:316-320,1995

C. Other Collaborators within the past 48 months not cited above:
A.Freyberger (Jefferson Lab.), Dan Sober (Catholic University of America), Hall Crannell (Catholic University of America).

D. Name of graduate students (thesis) and postdoctoral scholars sponsored: None

E. Name of Thesis and Postdoctoral Advisor: Thesis: P. Stoler(RPI), Postdoctoral: 1) G.Audit (CE Saclay), 2) B. Berman (GW).

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION	FOR NSF USE ONLY		
George Washington University	PROPOSAL NO.	DURATION (months)	
		Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Barry L Berman	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Barry L Berman - none	0.00	0.00	0.00	$ 0	$
2. Gerald Feldman - none	0.00	0.00	0.00	0	
3. Peter Heimberg - none	0.00	0.00	0.00	0	
4. Ioana Niculescu - none	0.00	0.00	0.00	0	
5. Grant V O'Rielly - none	0.00	0.00	0.00	0	
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (5) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	4.00	0.00	0.00	24,000	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (4) UNDERGRADUATE STUDENTS				19,200	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				43,200	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				4,752	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				47,952	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) cluster compute nodes $ 19,920 magnetic media 5,000 software 7,599					
TOTAL EQUIPMENT				32,519	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				1,000	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				2,100	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				2,100	
H. TOTAL DIRECT COSTS (A THROUGH G)				83,571	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 49.0000, Base: 31852)					
TOTAL INDIRECT COSTS (F&A)				15,607	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				99,178	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 99,178	$

M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $		
PI / PD TYPED NAME & SIGNATURE* Barry L Berman	DATE	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION	
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked / Date Of Rate Sheet	Initials - ORG

SUMMARY PROPOSAL BUDGET

YEAR 2

ORGANIZATION George Washington University				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Barry L Berman				AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Barry L Berman - none	0.00	0.00	0.00	$ 0	$
2. Gerald Feldman - none	0.00	0.00	0.00	0	
3. Peter Heimberg - none	0.00	0.00	0.00	0	
4. Ioana Niculescu - none	0.00	0.00	0.00	0	
5. Grant V O'Rielly - none	0.00	0.00	0.00	0	
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (5) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	4.00	0.00	0.00	25,200	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (4) UNDERGRADUATE STUDENTS				20,160	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				45,360	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				4,990	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				50,350	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) cluster compute nodes $ 9,960 storage array 20,850					
TOTAL EQUIPMENT				30,810	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				1,000	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				1,520	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				1,520	
H. TOTAL DIRECT COSTS (A THROUGH G)				83,680	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 49.0000, Base: 32710)					
TOTAL INDIRECT COSTS (F&A)				16,028	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				99,708	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 99,708	$

M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $			
PI / PD TYPED NAME & SIGNATURE* Barry L Berman	DATE	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date Of Rate Sheet	Initials - ORG

SUMMARY PROPOSAL BUDGET — YEAR 3

	FOR NSF USE ONLY		
ORGANIZATION **George Washington University**	PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Barry L Berman**	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Barry L Berman - none	0.00	0.00	0.00	$ 0	$
2. Gerald Feldman - none	0.00	0.00	0.00	0	
3. Peter Heimberg - none	0.00	0.00	0.00	0	
4. Ioana Niculescu - none	0.00	0.00	0.00	0	
5. Grant V O'Rielly - none	0.00	0.00	0.00	0	
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (5) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	4.00	0.00	0.00	26,460	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (4) UNDERGRADUATE STUDENTS				21,168	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				47,628	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				5,239	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				52,867	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) cluster compute nodes $ 24,900 magnetic media 5,000					
TOTAL EQUIPMENT				29,900	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				0	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				1,520	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				1,520	
H. TOTAL DIRECT COSTS (A THROUGH G)				84,287	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 49.0000, Base: 33219)					
TOTAL INDIRECT COSTS (F&A)				16,277	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				100,564	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 100,564	$

M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $		
PI / PD TYPED NAME & SIGNATURE* **Barry L Berman**	DATE	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION	
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked / Date Of Rate Sheet	Initials - ORG

SUMMARY PROPOSAL BUDGET

YEAR 4

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
George Washington University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Barry L Berman

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Barry L Berman - none	0.00	0.00	0.00	$ 0	$
2. Gerald Feldman - none	0.00	0.00	0.00	0	
3. Peter Heimberg - none	0.00	0.00	0.00	0	
4. Ioana Niculescu - none	0.00	0.00	0.00	0	
5. Grant V O'Rielly - none	0.00	0.00	0.00	0	
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (5) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	4.00	0.00	0.00	27,783	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (4) UNDERGRADUATE STUDENTS				22,226	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				50,009	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				5,501	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				55,510	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) cluster compute nodes $ 19,920					
TOTAL EQUIPMENT				19,920	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				1,500	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				3,620	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				3,620	
H. TOTAL DIRECT COSTS (A THROUGH G)				80,550	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 49.0000, Base: 38404)					
TOTAL INDIRECT COSTS (F&A)				18,818	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				99,368	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 99,368	$

M. COST SHARING PROPOSED LEVEL $ 0 — AGREED LEVEL IF DIFFERENT $

PI / PD TYPED NAME & SIGNATURE*	DATE	FOR NSF USE ONLY		
Barry L Berman		INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date Of Rate Sheet	Initials - ORG

SUMMARY PROPOSAL BUDGET   YEAR 5

FOR NSF USE ONLY	
PROPOSAL NO.	DURATION (months) Proposed / Granted
AWARD NO.	

ORGANIZATION
George Washington University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Barry L Berman

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Barry L Berman - none	0.00	0.00	0.00	$ 0	$
2. Gerald Feldman - none	0.00	0.00	0.00	0	
3. Peter Heimberg - none	0.00	0.00	0.00	0	
4. Ioana Niculescu - none	0.00	0.00	0.00	0	
5. Grant V O'Rielly - none	0.00	0.00	0.00	0	
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (5) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	4.00	0.00	0.00	29,172	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (4) UNDERGRADUATE STUDENTS				23,338	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				52,510	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				5,776	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				58,286	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) cluster compute nodes $ 19,920					
TOTAL EQUIPMENT				19,920	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				2,000	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				1,520	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				1,520	
H. TOTAL DIRECT COSTS (A THROUGH G)				81,726	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 49.0000, Base: 38468)					
TOTAL INDIRECT COSTS (F&A)				18,849	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				100,575	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 100,575	$

M. COST SHARING PROPOSED LEVEL $ 0   AGREED LEVEL IF DIFFERENT $

PI / PD TYPED NAME & SIGNATURE*	DATE	FOR NSF USE ONLY		
Barry L Berman		INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date Of Rate Sheet	Initials - ORG

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION: George Washington University				FOR NSF USE ONLY	
				PROPOSAL NO.	DURATION (months): Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: Barry L Berman				AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Barry L Berman - none	0.00	0.00	0.00	$ 0	$
2. Gerald Feldman - none	0.00	0.00	0.00	0	
3. Peter Heimberg - none	0.00	0.00	0.00	0	
4. Ioana Niculescu - none	0.00	0.00	0.00	0	
5. Grant V O'Rielly - none	0.00	0.00	0.00	0	
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (5) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (5) POST DOCTORAL ASSOCIATES	20.00	0.00	0.00	132,615	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (20) UNDERGRADUATE STUDENTS				106,092	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				238,707	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				26,258	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				264,965	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 133,069					
TOTAL EQUIPMENT				133,069	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				5,500	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				10,280	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				10,280	
H. TOTAL DIRECT COSTS (A THROUGH G)				413,814	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				85,579	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				499,393	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 499,393	$

M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $			
PI / PD TYPED NAME & SIGNATURE*: Barry L Berman	DATE	FOR NSF USE ONLY — INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date Of Rate Sheet	Initials - ORG

Budget Justification

The following is a justification of our budget estimates for the costs associated with the proposed five-year project.

CPU nodes

The cluster compute nodes will be the latest dual-processor CPU platforms available at the time of purchase. As of October 2000, dual 800 MHz Pentium III compute nodes were available at a cost of $2490 each.

- year 1: 8 nodes for $19,920
- year 2: 4 nodes for $9,960
- year 3: 10 nodes for $24,900
- year 4: 8 nodes for $19,920
- year 5: 8 nodes for $19,920

Software

We propose to purchase a commercial suite of development software, FORTRAN, C and C++ compilers, parallel coding software libraries and batch queuing system, and cluster management tools. The cost for this software will be $7,599 in the first year, with licensing cost of $1,520 per year thereafter.

Data Storage

The large amounts of data to be processed requires a large storage array with fast access. To satisfy this requirement we propose to purchase a terabyte RAID array in year two at a cost of $20,850. In addition, we plan to purchase large capacity AIT magnetic-media tapes for archive purposes during each of the first four years.

Networking

Since the analysis of event-by-event experimental nuclear physics data is trivially parallelizable, the internode communications requirements will be satisfied with standard 100-Mbit ethernet connections and a 100-Mbit ethernet switch. A 24-port 100-Mbit ethernet switch will support all the compute nodes purchased over the course of the grant, requiring a $3,129 cost in the first year, and again in the fourth year.

Student Stipends

We wish to provide 4 Undergraduate Training Stipends of 3 months duration each at a cost of $1,600/month for the first year, to be increased by 5% in each of the following years.

- year 1: $19,200
- year 2: $20,160
- year 3: $21,168
- year 4: $22,226
- year 5: $23,338

In addition, a one-third time post-doctoral research position with a $72,000 full-time equivalent salary will be created to oversee this project, coordinate development of the software and act as system administrator for the compute cluster. For one-third time salary plus fringe benefits (at 19.8%) and indirect costs (at 49%), with 5% increase for each of the following years:

- year 1: $44,625
- year 2: $46,856
- year 3: $49,199
- year 4: $51,659
- year 5: $54,242

Notes

Fringe Benefits: FB rate of 19.8% of salaries is predetermined through from 7/1/2001 through 6/30/2002, provisional thereafter. This rate is predetermined by DHHS agreement dated 3/31/1999.

Indirect Costs: The university's on-campus F&A rate of 49% MTDC is predetermined through 6/30/2002, provisional thereafter, by DHHS agreement dated 3/31/1999.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Barry Berman**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: **A Program in Medium Energy Nuclear Physics**

Source of Support: **DOE**
Total Award Amount: $ **1,155,000** Total Award Period Covered: **01/01/01 - 12/31/03**
Location of Project: **GWU**
Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **2.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: **ITR/AP (PHY): Applications for Neural-Network Techniques in Nuclear Physics Data Analysis (This Proposal)**

Source of Support: **NSF**
Total Award Amount: $ **499,393** Total Award Period Covered: **09/01/01 - 08/31/06**
Location of Project: **The George Washington University**
Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **0.00**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: **Development of a Linearly-Polarized Photon Facility**

Source of Support: **NSF**
Total Award Amount: $ **107,200** Total Award Period Covered: **09/15/97 - 08/31/01**
Location of Project: **GWU**
Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Gerald Feldman**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Intermediate Energy Nuclear Physics with Polarized and Unpolarized Photons**

Source of Support: **NSF**

Total Award Amount: $ **320,000** Total Award Period Covered: **09/01/97 - 08/31/01**

Location of Project: **GWU**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **2.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **ITR/AP (PHY): Applications for Neural-Network Techniques in Nuclear Physics Data Analysis (This Proposal)**

Source of Support: **NSF**

Total Award Amount: $ **499,393** Total Award Period Covered: **09/01/01 - 08/31/06**

Location of Project: **The George Washington University**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

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*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Peter Heimberg**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: **A Program in Medium Energy Nuclear Physics**

Source of Support: **DOE**
Total Award Amount: $ **1,155,000** Total Award Period Covered: **01/01/01 - 12/31/03**
Location of Project: **GWU**
Person-Months Per Year Committed to the Project. Cal: **12.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: **ITR/AP (PHY): Applications for Neural-Network Techniques in Nuclear Physics Data Analysis**

Source of Support: **NSF**
Total Award Amount: $ **499,393** Total Award Period Covered: **09/01/01 - 08/31/06**
Location of Project: **The George Washington University**
Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Ioana Niculescu**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **A Program in Medium Energy Nuclear Physics**

Source of Support: **DOE, JLab (50% each)**
Total Award Amount: $ **1,155,000** Total Award Period Covered: **01/01/01 - 12/31/03**
Location of Project: **JLab**
Person-Months Per Year Committed to the Project. Cal: **12.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **ITR/AP (PHY): Applications for Neural-Network Techniques in Nuclear Physics Data Analysis**

Source of Support: **NSF**
Total Award Amount: $ **499,393** Total Award Period Covered: **09/01/01 - 08/31/06**
Location of Project: **The George Washington University**
Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Grant O'Rielly**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Intermediate Energy Nuclear Physics with Polarized and Unpolarized Photons**

Source of Support: **NSF**

Total Award Amount: $ **320,000** Total Award Period Covered: **09/01/97 - 08/31/01**

Location of Project: **GWU**

Person-Months Per Year Committed to the Project. Cal: **12.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **ITR/AP (PHY): Applications for Neural-Network Techniques in Nuclear Physics Data Analysis**

Source of Support: **NSF**

Total Award Amount: $ **499,393** Total Award Period Covered: **09/01/01 - 08/31/06**

Location of Project: **The George Washington University**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **William Briscoe**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **A Program in Medium Energy Nuclear Physics**

Source of Support: **DOE**

Total Award Amount: $ **1,155,000** Total Award Period Covered: **01/01/01 - 12/31/03**

Location of Project: **GWU**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **2.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **ITR/AP (PHY): Applications for Neural-Network Techniques in Nuclear Physics Data Analysis (This Proposal)**

Source of Support: **NSF**

Total Award Amount: $ **499,393** Total Award Period Covered: **09/01/01 - 08/31/06**

Location of Project: **The George Washington University**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **ITR/AP+IM: Research and Educational Application for High-End Parallel Processing in Biology, Chemistry, Geography and Physics**

Source of Support: **NSF**

Total Award Amount: $ **12,882,255** Total Award Period Covered: **09/01/01 - 08/31/06**

Location of Project: **The George Washington University**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **3.60** Sumr: **0.00**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Development of a Linearly-Polarized Photon Facility**

Source of Support: **NSF**

Total Award Amount: $ **107,200** Total Award Period Covered: **09/15/97 - 08/31/01**

Location of Project: **The George Washington University**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **0.00**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Data Analysis Center for Electromagnetic and Hadronic Scattering Processes**

Source of Support: **Department of Energy**

Total Award Amount: $ **219,964** Total Award Period Covered: **06/01/99 - 05/31/01**

Location of Project: **The George Washington University**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Summ: **0.00**

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*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **William Briscoe**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **A Web-Based Scientific Analysis Facility for Nuclear and Particle Physics Data**

Source of Support: **NSF**

Total Award Amount: $ **499,225** Total Award Period Covered: **07/01/01 - 06/30/05**

Location of Project: **The George Washington University**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Luc Murphy**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **A Program in Medium Energy Nuclear Physics**

Source of Support: **DOE**

Total Award Amount: $ **1,155,000** Total Award Period Covered: **01/01/01 - 12/31/03**

Location of Project: **GWU**

Person-Months Per Year Committed to the Project. Cal: **8.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **ITR/AP (PHY): Applications for Neural-Network Techniques in Nuclear Physics Data Analysis**

Source of Support: **NSF**

Total Award Amount: $ **499,393** Total Award Period Covered: **09/01/01 - 08/31/06**

Location of Project: **The George Washington University**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

FACILITIES, EQUIPMENT & OTHER RESOURCES

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. USE additional pages as necessary.

Laboratory: **Work space for hardware installation is available at our Nuclear Detector Laboratory at the GW Virginia campus.**

Clinical: **n/a**

Animal: **n/a**

Computer: **We have access to the GW CRASH Analysis Center Data Storage Silo and we possess a 10-node(20 CPU) PC cluster located at the GW Virginia campus.**

Office: **Office space for personnel is available at our Nuclear Detector Laboratory at the GW Virginia campus and in the Physics Department at the main GW Foggy Bottom campus.**

Other: ______________________

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate identifying the location and pertinent capabilities of each.

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual arrangements with other organizations.

The following George Washington University, Department of Physics personnel are involved in this project:

Dr. Barry L. Berman
Dr. Gerald Feldman
Dr. Peter Heimberg
Dr. Ioana Niculescu
Dr. Grant V. O'Reilly
Dr. William J. Briscoe
Dr. Luc Y. Murphy