JLab PAC12 Proposal Cover Sheet

This document must be received by close of business Thursday, June 26, 1997

Jefferson Lab
User Liaison Office, Mail Stop 12 B
12000 Jefferson Avenue
Newport News, VA 23606

(Choose one)

☐ New Proposal Title:

☒ Update Experiment Number: 89-019

☐ Letter-of-Intent Title:

Contact Person

Name: Ronald Gilman

Institution: Rutgers University (permanent) — temporary: MS12H, rm. C116, TJNAF

Address: P.O. Box 849

Address:

City, State, ZIP/Country: Piscataway, NJ 08855-0849

Phone: (757) 269-7011 Fax: (757) 269

E-Mail: gilman@cebaf.gov

Experimental Hall: A Days Requested for Approval: 18 (already approved)

Jefferson Lab Use Only

Receipt Date: 6/26/97

By:

PR 97-012

LAB RESOURCES LIST

JLab Proposal No.: 89-019 (For JLab ULO use only.) Date 6/26/97

List below significant resources — both equipment and human — that you are requesting from Jefferson Lab in support of mounting and executing the proposed experiment. Do not include items that will be routinely supplied to all running experiments such as the base equipment for the hall and technical support for routine operation, installation, and maintenance.

Major Installations *(either your equip. or new equip. requested from JLab)*

(none)

New Support Structures:

(none)

Data Acquisition/Reduction

Computing Resources:

(none)

New Software:

new physics analysis for espace.

Major Equipment (none)

Magnets:

Power Supplies:

Targets:

Detectors:

Electronics:

Computer Hardware:

Other:

Other:

minor installation – photon radiator

HAZARD IDENTIFICATION CHECKLIST

JLab Proposal No.: 89-019 (For CEBAF User Liaison Office use only.) Date: 6/26/97

Check all items for which there is an anticipated need.

Cryogenics	Electrical Equipment	Radioactive/Hazardous Materials
___ beamline magnets ___ analysis magnets ___ target type: ___ flow rate: ___ capacity: ___ Standard Hall A	___ cryo/electrical devices ___ capacitor banks ___ high voltage ___ exposed equipment Standard Hall A	List any radioactive or hazadorous/ toxic materials planned for use: ___ ___ ___ ___
Pressure Vessels	**Flammable Gas or Liquids**	**Other Target Materials**
___ inside diameter ___ operating pressure ___ window material ___ window thickness Standard Hall A	type: ___ flow rate: ___ capacity: ___ **Drift Chambers** type: ___ flow rate: ___ capacity: ___ Standard Hall A	___ Beryllium (Be) ___ Lithium (Li) ___ Mercury (Hg) ___ Lead (Pb) ___ Tungsten (W) ___ Uranium (U) ___ Other (list below) ___ Hall A cryotarget
Vacuum Vessels	**Radioactive Sources**	**Large Mech. Structure/System**
___ inside diameter ___ operating pressure ___ window material ___ window thickness Standard Hall A	___ permanent installation ___ temporary use type: ___ strength: ___ Standard Hall A	___ lifting devices ___ motion controllers ___ scaffolding or ___ elevated platforms Standard Hall A
Lasers	**Hazardous Materials**	**General:**
type: ___ wattage: ___ class: ___ Installation: ___ permanent ___ temporary Use: ___ calibration ___ alignment Standard Hall A	___ cyanide plating materials ___ scintillation oil (from) ___ PCBs ___ methane ___ TMAE ___ TEA ___ photographic developers ___ other (list below) ___ ___ Standard Hall A	Experiment Class: ✓ Base Equipment ___ Temp. Mod. to Base Equip. ___ Permanent Mod. to Base Equipment ___ Major New Apparatus Other: minor installation - radiator

BEAM REQUIREMENTS LIST

JLab Proposal No.: 89-019 Date: 6/26/97

Hall: A Anticipated Run Date: ASAP (mid/late 1998?) PAC Approved Days: 18

Spokesperson: R. Gilman, R. Holt, Z.E. Meziani Hall Liaison:
Phone: 269-7011
E-mail: gilman@cebaf.gov

List all combinations of anticipated targets and beam conditions required to execute the experiment. (This list will form the primary basis for the Radiation Safety Assesment Document (RSAD) calculations that must be performed for each experiment.)

Condition No.	Beam Energy (MeV)	Mean Beam Current (μA)	Polarization and Other Special Requirements (e.g., time structure)	Target Material (use multiple rows for complex targets — e.g., w/windows)	Material Thickness (mg/cm^2)	Est. Beam-On Time for Cond. No. (hours)
1	845	20	—	copper	770	24
				LD_2	2250	
2	~1200	20	—	as above		24
3	1645	20	—	as above		48
4	~2000	20	—	as above		96
5	2445	20	—	as above		240

The beam energies, E_{Beam}, available are: $E_{Beam} = N \times E_{Linac}$ where N = 1, 2, 3, 4, or 5. E_{Linac} = 800 MeV, i.e., available E_{Beam} are 800, 1600, 2400, 3200, and 4000 MeV. Other energies should be arranged with the Hall Leader before listing.

Measurement of Proton Polarization in the $d(\gamma, \vec{p})n$ Reaction
Update of TJNAF E89-019

R. Gilman, Rutgers University, Contact Person
R. J. Holt, University of Illinois, Spokesperson
Z.-E. Meziani, Temple University, Spokesperson

with

L. Auerbach[1], D. Beck[2], E. Beise[3], L. Bimbot[4], P. Bosted[5], J. P. Chen[1]1, K. P. Coulter[6], B. Filippone[7], S. Freedman[8], H. Gao[9], D. F. Geesaman[9], C. Glashausser[10], J. Gomez[11], H. E. Jackson[9], C. E. Jones[9], E. Kinney[12], G. Kumbartzki[10], J. LeRose[11], S. Malov[10], J. McIntyre[10], R. D. McKeown[7], R. Michaels[11], M. A. Miller[2], R. Milner[13], S. Nanda[11], J. Napolitano[14], A. M. Nathan[2], G. G. Petratos[15], D. Potterveld[9], R. Ransome[10], P. Rutt[10], A. Saha[11], R. E. Segel[16], P. Ulmer[17], B. Zeidman[9]

[1] Temple University
[2] University of Illinois
[3] University of Maryland
[4] IPN Orsay
[5] University of Regina
[6] University of Michigan
[7] California Institute of Technology
[8] University of California at Berkeley
[9] Argonne National Laboratory
[10] Rutgers University
[11] Thomas Jefferson National Accelerator Facility
[12] University of Colorado
[13] Massachusetts Institute of Technology
[14] Rensselaer Polytechnic Institute
[15] Kent State University
[16] Northwestern University
[17] Old Dominion University

and the CEBAF Hall A Collaboration

Abstract

Cross sections for deuteron photodisintegration have been measured between 1 and 4 GeV in a series of SLAC and TJNAF experiments. The behavior at 90° center of mass is consistent with constituent counting rules; this observation is suggestive of quark substructure effects in the reaction mechanism. At more forward angles, the data are inconclusive as to the onset of this behavior.

There are currently two approved TJNAF experiments aimed at further investigation of this phenomenon. Experiment 96-003 was given A- priority by PAC 11, and is now scheduled for Hall C for this September 1997. It will measure cross sections at forward angles for photon energies up to 5.5 GeV, to determine the onset of scaling.

This update of experiment 89-019 requests that its priority be raised to A level, so that it may be run in a timely manner. The aim is to measure the proton polarization, which is expected to vanish in the scaling regime. The greater sensitivity of the polarization observables to small amplitudes in the reaction mechanism will put strict constraints on the onset of scaling and on the underlying reaction mechanism.

1 Introduction

This experiment, 89-019, was approved by the 1993 CEBAF PAC 7 and subsequently given B priority. At that time, preliminary data for deuteron photodisintegration above 2.0 GeV beam energy were available from SLAC experiment NE-17; CEBAF experiment 89-012 was approved with A-priority, but had not yet run in Hall C.

Preliminary data are now available from E89-012, and a new experiment, 96-003, has been approved with A- priority, to continue cross section measurements to higher energies. It is appropriate at this time to request that the PAC upgrade this proposal to the same priority, so that it may be scheduled to run in a timely manner.

The importance of this polarization measurement to understanding the underlying physics in deuteron photodisintegration is widely recognized. For example, referring to this experiment, the DOE / NSF Nuclear Science Advisory Committee, in its *Nuclear Science: A Long Range Plan* (February, 1996), wrote the following:

> **At higher energies, there is already evidence that some behavior characteristic of hard QCD interactions sets in when photons are used to decompose a deuteron into a neutron and proton. Recent results from SLAC for this reaction ... reveal an energy dependence that agrees well with simple "counting rules" based on the total number of point-like constituents (here, valence quarks and the photon itself) participating in the interaction. Future experiments at CEBAF will provide crucial information on whether this behavior persists in polarization measurements.**

In his Jefferson Laboratory portrait in *Nuclear Physics News*, Vol. 6, No. 4, page 19, 1996, L. Cardman, TJNAF, discussing this experiment, wrote the following:

> **It would also be interesting to test the prediction of QCD that the polarization of the nucleon emitted in this reaction goes to zero in the "true" perturbative scaling regime. The polarization at energies below 0.75 GeV, where data do exist, is large. Measuring the polarization in the 1-4 GeV region should provide additional insights into the transition from nucleon to quark behavior.**

In the following sections, we briefly review the physics of this experiment and some experimental details.

2 Motivation

The focus of deuteron photodisintegration experiments at TJNAF is whether this basic nuclear reaction exhibits quark effects. These effects are manifested in, e.g., exclusive meson + baryon reactions in the GeV energy regime. One observation[1] is that the energy dependence of reaction cross sections follows the constituent counting rules:

$$\frac{d\sigma}{dt} \sim s^{2-n} f(\cos\theta_{cm}), \tag{1}$$

Here s and t are Mandelstam variables, and n is the number of elementary particles (quarks, photons, etc.) in the initial and final states of the reaction. Another observation[2] is the larger cross sections measured for reactions that can proceed via quark interchange, relative to those reactions that proceed via gluon exchange or other mechanisms. This observation also points to the difficulty inherent in hadronic reactions: one often finds in the quark picture that there remain multiple distinct interfering reaction mechanisms, which makes analysis difficult.

Deuteron photodisintegration is the best candidate for searching for such phenomena in a nuclear experiment. The deuteron is the lightest, and, from a theoretical standpoint, best understood nucleus. The photon is a relatively well understood probe. Experimentally, the reaction is most accessible, since an increase in the number of constituents in the reaction leads to a faster fall in cross section with energy. Furthermore, the absorption of the photon leads to large momentum transfers at relatively modest beam energies, as compared to other reactions such as elastic electron deuteron scattering.[3] Thus, one might expect to see the onset of quark phenomena at a lower incident energy.

The measurements of deuteron photodisintegration in SLAC experiments NE8 and NE17, and in TJNAF experiment 89-012, have shown that cross sections at 90° center of mass follow constituent counting rules. In Fig. 1, these data[4] are shown multiplied by s^{11}, and the apparent flatness of the cross sections is evident. In contrast, the 37° data shown do not cleanly signal the onset of scaling. In Fig. 1, several theory curves include the meson–exchange calculation of Lee[5] (solid line), the meson–exchange calculation of Laget[6] (dash dotted line at lower energies), the reduced nuclear amplitude analysis[7] (long dashed line), the asymptotic meson–exchange calculation of Nagornyi[8] (short dashed line), and a quark–gluon string calculation[9] (dash dotted line at higher energies).

Under the assumption that the data at 90° is a signature of the dominance of leading order quark diagrams, these data have led to much discussion about

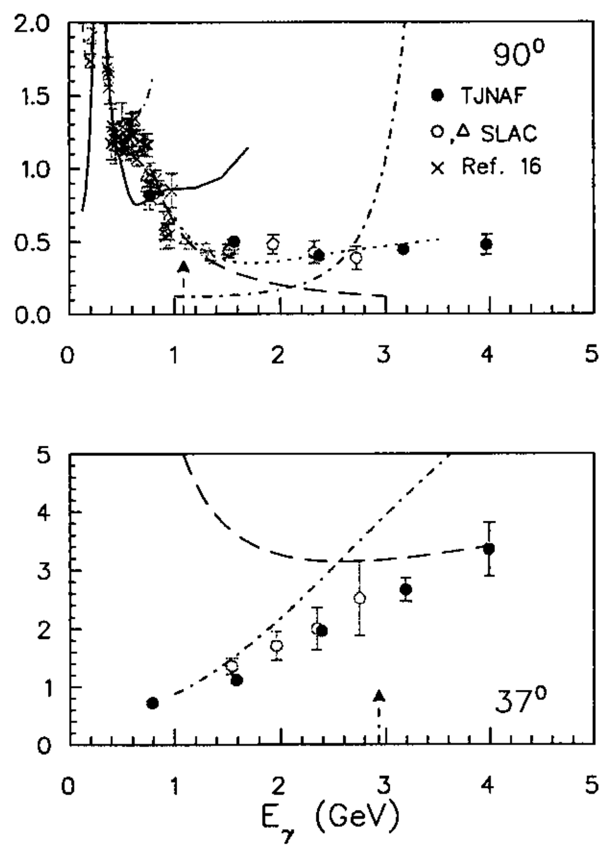

Figure 1: Cross sections for deteron photodisintegration at center of mass angles of 90^o and 37^o. The curves are described in the text.

what kinematic variable would be appropriate to characterize the onset of scaling. The arrows in Fig. 1, for example, indicate the onset of the scaling behavior at 90°, and the energy at 37° which has the same p_T. The data neither confirm nor rule out a flattening of the cross sections above this energy at 37°. Additional constraints are needed. The aim of TJNAF experiment 96-003, which was approved by PAC 11 with A- priority, is to measure forward angle cross sections. The characterization of the forward angle cross sections, in particular the observation of a scaling threshold, should lead to a better understanding of the underlying physics.

Previous measurements of exclusive reactions do not provide a clear guide as to how to characterize the onset of scaling. For pp elastic scattering, it was observed[10] for a number of scattering angles that the onset could be characterized as requiring $-t > 2.5$ GeV^2 and $s > 15$ GeV^2. In contrast, meson photoproduction data from the proton show onset of scaling at all measured angles at essentially the same photon energy. To be more precise, angular distributions for several photoreactions have been compared for 4 GeV beam energy with a higher energy, 5 or 6 GeV.[11] Over the range of common angles, about $-0.5 < \cos\theta < 0.5$, the angular distributions are consistent with $s^7 d\sigma/dt$ being constant for each reaction. However, there is no extensive set of excitation function data that allows a good determination of the onset of this behavior.

The constituent counting rules for cross sections of exclusive reactions can be derived as a consequence of perturbative QCD / QED. Two assumptions here are that one can neglect the variations of the strong coupling constant, and that nonleading order diagrams are negligible. Within this framework one can also make some simple predictions for polarization observables. Helicity conservation results both from the electromagnetic coupling, with which spin flip is suppressed at high energies, and from neglect of transverse momenta / size, which would lead to nonzero orbital angular momenta. Quark and hadron helicity conservation is a well-known expectation for high energy reactions, but *it is essentially untested in the scaling regime.* These type of measurements have been basically impossible in intermediate energy electromagnetic facilities until the construction of CEBAF. It is only now possible due to the combination of several GeV and high intensity CW beam.

One can use parity and time reversal conservation to demonstrate that for an unpolarized initial state of deuteron photodisintegration, the only possible final state polarization is an induced polarization normal to the reaction plane. Helicity conservation in the scaling regime results in the prediction that the induced polarization vanishes. Predictions for polarization transfer, leading to longitudinal and transverse spin components, are not so simple, as the nucleon polarization depends on the wave function of the constituent quarks. In general, one expects transverse polarization to be smaller than longitudinal polarization by a factor of order $\gamma = E/m$. For deuteron photodisintegration, neither polarization transfer is expected to be large.[12]

These expectations from high energy theory contrast with what one expects from nuclear meson–baryon based theories. One can make general arguments that the cross section predictions should be similar. This is based on the observed and / or expected asymptotic behaviors of form factors, wave functions, and matrix elements. However, no parameter-free extensions of nuclear models into the GeV energy regime for deuteron photodisintegration have actually followed this behavior.

It is also *very* difficult for nuclear theories to predict zero polarization. The interference between each resonant amplitude and the background Born amplitude leads to negative spikes in predictions[6, 13] of the induced polarization for photon energies from a few hundred MeV to 1.6 GeV – see Fig. 2. Couplings to higher mass resonances are not as well understood, but resonances with relatively large couplings to the γp and γn systems are known, and should be generally expected to lead to large polarizations.

If the polarizations we propose to measure are found to be consistent with 0, it would be a striking confirmation of the picture of reactions in the GeV regime proceeding via the underlying quark degrees of freedom. If instead we see the resonance structure expected from nuclear calculations, our data lead to the question of why the cross sections agree so much better with asymptotic expectations than with actual nuclear theories. Other possibilities exist; smaller amplitudes do exist in the quark picture, but one would not expect them to lead to resonance structures in the data. While the data may be sufficient to provide a reliable conclusion of the underlying physics, our main goal must be to provide good quality data to spur theoretical efforts.

To summarize, polarization observables provide an additional test of the onset of scaling phenomena, and can help to elucidate the deuteron photodisintegration reaction mechanism in the GeV energy regime. To run this experiment in a timely manner, so that we may better understand the implications of the cross section data we have taken, we request an A level priority, as was given to the cross section experiments, to allow scheduling.

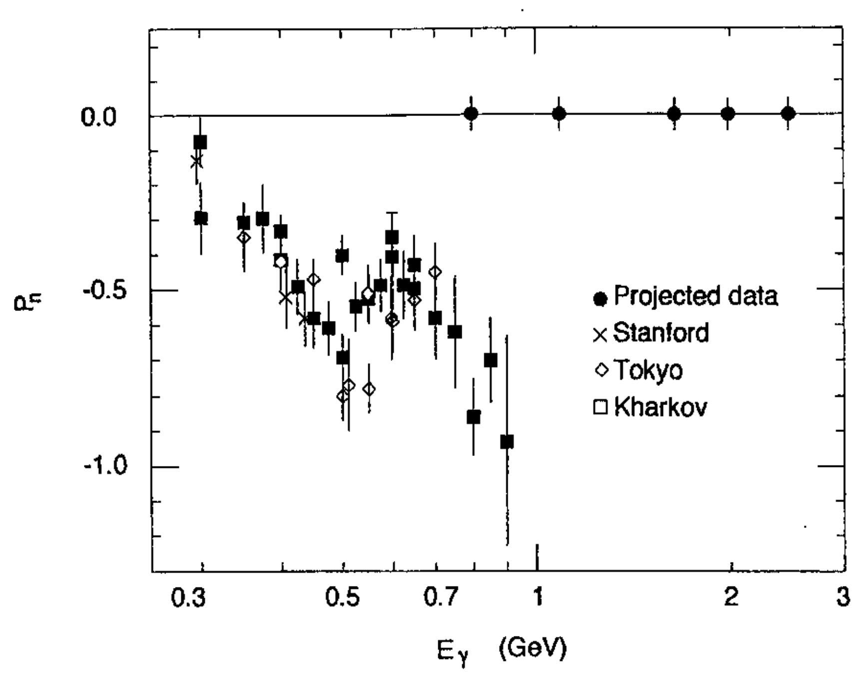

Figure 2: Recoil proton polarization data for deuteron photodisintegration at 90° center of mass. Calculations qualitatively reproduce the resonance structures seen in the data.

This increase in priority is justified both by the additional cross section data we have taken and are about to take, as well as by the successfull commissioning of the Hall A spectrometers, including in particular the focal plane polarimeter in the hadron arm.

3 Experimental Details

The current experiment was approved by the CEBAF PAC with B priority in 1993. The 18 days of approved beam time were to measure an excitation function for recoil polarization at 90° center of mass, for beam energies from 0.8 to 2.4 GeV, including the nonstandard energies of 1.2 and 2.0 GeV. We expect that accelerator operation above 4 GeV will be started before the experiment runs, and that some of our nonstandard energies may become standard ones. For the purposes of this proposal, it is more important to have kinematic points spaced over a wide range of beam energies than to have the exact energies proposed herein. Thus, if the standard accelerator energies change from 800 MeV up to 1000 or 1100 MeV, we may be able to change our beam energies slightly and appropriately, to ease scheduling difficulties without compromising our physics goals. We would not however make an effort to measure much above 2.4 GeV beam energy, as unfavorable spin transport and rapidly decreasing cross sections make higher energy data very time consuming.

The basic experimental technique is as follows. The electron beam strikes a radiator, producing a $0°$ bremsstrahlung photon beam with maximum energy essentially equal to the electron kinetic energy. The target, located downstream of the radiator, is irradiated by both the photons and unscattered electrons. Outgoing protons from the photodisintegration are detected in the Hall A HRS hadron spectrometer.

The Hall A spectrometers have been successfully commissioned by the collaboration with elastic scattering of 845 MeV electrons. In addition, there are measurements of singles protons, of $(e, e'p)$ coincidences, and of (e, e') at beam energies of 1.6 and 2.4 GeV. In general, the observed spectrometer perfomances are consistent with expectations:

- momentum resolution $\delta p/p \sim$ few $\times 10^{-4}$ (FWHM), over a momentum range of $\sim \pm 4.5\%$
- angular resolutions of order 1 mr, dominated by multiple scattering in windows for low energies
- horizontal target acceptance of several cm – this is not yet well mapped out at the edges, as only foil targets and the multi-"foil" waterfall target have been used – and
- spectrometer solid angle of about 6.5 msr for a point target.

The FPP working group, composed of Rutgers, William and Mary, Norfolk State University, Regina, and Georgia, has commissioned the focal plane polarimeter (FPP). We have demonstrated small false asymmetries, and measured polarizations from elastic $\vec{e}p \rightarrow e'\vec{p}$ that are consistent with calculations including the measured proton form factors, beam polarization, and spin transport. So far, essentially all work has been done with ~430 MeV protons, as our focus has been the needs of the first FPP experiment, E89-033. We will study additional proton energies, and make more detailed studies of spin transport, when we shift focus to the G_e^p measurements of E93-027, currently scheduled for spring 1998.

The only nonstandard piece of equipment is the radiator used to generate the bremsstrahlung beam. The radiator mechanism will have several foil thicknesses; we plan to use a Cu foil 6% of a radiation length thick, corresponding to ~1 mm thickness; the same thickness was used at SLAC and in Hall C. The radiator will be mounted on the rotisserie table inside the scattering chamber, with the radiator about 35 cm upstream from the pivot, well out of view of the spectrometer.

While our primary goal is the measurement of proton polarization, we will also pay attention to systematics so that precise cross sections may be measured. The statistics obtained in the polarization measurement will allow each data point to be subdidivided into at least 10 bins with 1% statistical uncertainties. Since the relative cross sections have small systematic uncertainties, these data will also provide a statistically precise check of the s^{-11} dependence, although only over the limited range of each data point.

The radiator does contribute to background in the Hall both through increased production of low energy neutrons and increased production of high energy pions that can penetrate thick shielding. Based on estimates[14] of backgrounds at 4 GeV from these processes, the radiator will contribute perhaps a few kHz of singles rate to each scintillator in the detector stack, leading to almost no triggers. Our experience in previous measurements is that the 90°_{cm} data are clean; background problems of different sorts have been seen in both the most backward and the most forward angles.

The total amount of energy deposited in the Hall is also limited. Estimates have been made by G. Stapleton of TJNAF for the experiment.[15] In the worst kinematic point, we are close to the average annually allowed rate – that is, if we ran this data point for an entire year, the emitted background rate is estimated to be equal to the allowed limits. Averaged over the entire experiment, the rate is about an order of magnitude lower.

The Hall A cryotarget is based on the Hall C cryotarget, and should have similar performance. While the Hall A target is still under construction, operational experience in Hall C includes regular, stable running at currents of 100 μA during E94-018, the t_{20} experiment. In this experiment we plan to run currents no higher than 20 μA.

In the kinematics of this experiment, real background through the magnetic channel of the spectrometer is also not a problem. Because of the high energy of the emitted protons, single step background processes give lower momentum particles. Two-step background π are known to be small at these angles and energies – they tend to increase relative to photoprotons as one goes to larger angles. Experimentally, one assumes two body kinematics to reconstruct the incident photon energy from the measured scattered proton momentum and angle. One cuts out events corresponding to photon energies below possible π production threshold, and to events that appear to be above the bremsstrahlung endpoint. Based on our experience in these kinematics, we expect to obtain no net cross section above the endpoint, after appropriate empty target / radiator out subtractions have been made.

Spin transport is an important issue in use of the focal plane polarimeter. The estimates in this proposal use only a simple dipole approximation. The FPP working group has now worked extensively on this issue, focussing mainly on the needs of E89-033 to measure ~430 MeV protons, but also considering the more stringent needs of the G_e^p experiment. We have consistent calculations using a raytracing code, SNAKE, written by Pascal Vernin, and using the matrix formulation of the code COSY.

In the simple dipole approximation, the proton spin precesses about the dipole B field lines as the proton passes through the magnet. With a horizontal B field, leading to a vertical bend, the (horizontal) transverse spin component is unchanged, but the (horizontal) longitudinal component and the (vertical) normal component rotate by an angle

$$\chi = \frac{g_p - 2}{2} \Omega \gamma. \tag{2}$$

Here Ω is the bend angle of the spectrometer, and $\gamma = E/m$ is the Lorentz factor. Generally one measures a mixture of the longitudinal and normal components in the focal plane. In this experiment, we know $P_l = P_t = 0$, and the focal plane and target polarizations are related by:

$$P_n^{focalplane} = P_n^{target} \times \cos\chi \tag{3}$$

For our higher energy points at 90°_{cm}, spin precession changes the direction of the protons polarization by almost 180° – see Table 1 below – so that the magnitude of the polarization is essentially as large at the focal plane as at the target. Our more detailed calculations indicate that there will be a mixing of the normal component into a small transverse sideways component, which will be about an order of magnitude smaller.

The FPP measures normal and transverse spin components through the spin-orbit contribution to proton scattering from carbon. Assuming $P_t = 0$, the proton scatters in the carbon block of the FPP with an angular distribution shape $I_o(\Theta)[1 + P_n A_c(\Theta) cos(\phi)]$, where $I_o(\Theta)$ is the unpolarized angular distribution, A_c is the analyzing power of carbon, and ϕ is the azimuthal angle. The useful range in scattering angle Θ is about 5^o to 20^o, for which $A_c \approx 0.5$ near 0.2 GeV kinetic energy, and falls slowly with energy.

4 Time Estimates

Our count rate estimates for $d(\gamma, p)n$ use the measured cross sections or interpolations assuming the constituent counting rules. We assume a 15 cm (2.25 g/cm^2) liquid deuterium target, with a spectrometer y-target acceptance of 10 cm. For a point target, the solid angle is about 6 msr; for the extended target, we assume the solid angle averages to 4 msr. The beam current is 20 μA. The photon flux is calculated for a 6% radiator. We also put in a particle detection / tracking efficiency of 80%. Polarimeter efficiency and analyzing power has been estimated from the POMME data.[16]

Systematic uncertainties on the polarization are about 0.025 from false asymmetries, 0.01 from the analyzing power calibration, and 0.01 from spin transport through the spectrometer, leading to a total systematic uncertainty of 0.03. Since the spin transport causes the polarization at the target and in the focal plane to be about equal in magnitude for much of our kinematics, these uncertainties also apply to the polarization at the target. We generally aim for a statistical uncertainty of about 0.05, larger but close to the systematic uncertainty. Thus, the final uncertainties will generally be 0.05 statistical + 0.03 systematic. We will spend at least one day at each beam energy. This will result in reduced statistical uncertainties with the 6% radiator, or alternatively finer binning with the same uncertainties, and will also give us a chance to take data with a 3% radiator as a check of systematics.

The resulting time estimates are shown in Table 1. The run time given is the time needed to achieve uncertainties of ± 0.05, assuming no background. Empty target and radiator out subtractions require additional time. The days given are the total times we plan to spend at each energy, and include time for the background measurements. The extra time at lower energies will also allow checkout of the system, and studies of systematics. We do not explicity request any time for beam energy changes, as it is difficult to estimate what time will be required after another year of operational experience with the accelerator. Angle / magnet changes should require 1 – 2 hours, and will take place at the same time that we are requesting beam energy changes.

Table 1: Count rate estimate summary.

E GeV	θ deg.	p_p GeV/c	rate Hz	A_C	χ deg.	counts	run time	days
0.8	65.5	0.94	200	0.40	114	379,000	0.5	1
1.2	60.7	1.21	25	0.27	131	223,000	2.5	1
1.6	57.0	1.45	5	0.23	148	150,000	9	2
2.0	54.0	1.68	1	0.20	165	135,000	36	4
2.4	51.5	1.91	0.3	0.17	183	162,000	155	10
Total								18

5 Collaboration Background and Responsibilities

The membership of this collaboration includes many of the key individuals from the SLAC NE8 and NE17 experiments, as well as from TJNAF E89-012 and E91-003. It also includes many individuals from within the Hall A collaboration, including the Hall A staff physicists and the Rutgers University group, which was one of the two leading institutions in the design, construction, and commissioning of the polarimeter. The experiment was accepted into the Hall A collaboration. The collaboration has expertise in this physics, in the running of standard Hall A equipment, and in the use of the polarimeter. The Rutgers group is assuming responsibility for fabrication of the radiator, which will be designed and installed jointly with TJNAF.

References

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[4] In Fig. 1, TJNAF 89-012 *preliminary* data shown as filled circles; SLAC NE17 data (open circles) from J. E. Belz et al., Phys. Rev. Lett. **74**, 646 (1995); SLAC NE8 data (triangles) from J. Napolitano *et al.*, Phys. Rev. Lett. **61**, 2530 (1988), and S. J. Freedman *et al.*, Phys. Rev. **C48**, 1864 (1993); earlier data (crosses) from P. Dougan, *et al.*, Z. Physik **A276**, 55 (1976), R. Ching and C. Schaerf, Phys. Rev. **141**, 1320 (1966), H. Myers, *et al.*, Phys. Rev. **121**, 630 (1961), and J. Arends, *et al.*, Nucl. Phys. **A412**, 509 (1984).

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