The G^0 Experiment
Forward Angle Measurements

The G^0 Collaboration
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1 Overview

1.1 Introduction

This submission on the G^0 experiment has been prepared for consideration by the Jefferson Lab Program Advisory Committee. The G^0 experiment was previously approved as experiment 91-017 in December 1993 and reapproved as experiment 99-016 at the "jeopardy" review by PAC15, both with A priority. In each case 46 days of commissioning time for the experiment was approved. A great deal of progress has been made by the 20 institutions (see Table 1.1) involved in the project over the past year. The present submission requests the official allocation of 30 days of beam time for the first physics measurement.

In this experiment, the parity-violating asymmetry in elastic electron scattering from the proton will be measured at both forward and backward angles and over a range of momentum transfers from about 0.1 – 1.0 $\mathrm{GeV}^2/\mathrm{c}^2$. The primary purpose of the experiment is to separate the s quark contributions to the overall charge and magnetization densities of the nucleon using these measurements. No other proposed experiment will perform this separation directly. At backward angle we will measure quasi-elastic scattering from a deuterium target to extract the nucleon anapole moment (radiative corrections) contributions to these asymmetries. At the backward angles we will also measure the axial vector N-Δ transition form factor. A special purpose, superconducting toroidal spectrometer with large, azimuthally symmetric angular acceptance is being constructed for these measurements.

Since PAC15 many aspects of the experiment have moved from the design stage to the fabrication and assembly stages. Some important areas of progress include:

- beginning of work on high bunch charge, high polarization developments needed for the electron source,
- completion of winding and testing of the superconducting coils for the magnet, beginning of assembly of cold mass, control system design,
- completion of most of the liquid hydrogen/deuterium target,
- fabrication of North American (NA) focal plane detectors (FPDs) ready for beginning of assembly in March '00, fabrication of gain monitoring system,
- fabrication of all NA custom electronics delivery to JLab and further testing early in '00,
- completion of design, testing of cryostat exit detectors (for backward measurement),
- completion of design, beginning of fabrication of French FPDs,
- completion of design, testing of French electronics,
- standard GEANT simulation package,
- definition of on-line acquisition hardware/software, off-line analysis software; initial hardware/software test setup Summer 2000,
- background tests in Hall C.

We have also added valuable collaborators from Kentucky, Virginia Tech and Yerevan in the past year or so. The collaboration list is included as Table 1.1.

The cost and schedule for the experiment as established in the G^0 Management Plan are holding. Subsequent to PAC15, the status of the experiment was favorably reviewed by the Barish Committee (May 1999, submission and report included in the PAC17 package). At the time of writing about $2.4M of the $3.5M of the construction project has been 14 committed; the available contingencies for the remaining work are at about 26% across the project. The installation anticipated in the Management Plan is Spring ‘01, contingent on the overall schedule of the Laboratory.

We request at this time that the PAC approve 34 d (30 d for the measurement and 4 d for setup) of beam time for the forward angle asymmetry measurement. This will provide forward angle parity-violating asymmetries over the full range of momentum transfers, Q^2, from about 0.1 – 1 GeV^2/c^2. At a future date we will request approval for backward angle running.

A copy of our PAC15 proposal has been included in the PAC17 package. It includes a more detailed discussion of the physics including the relationship to other approved Jefferson Lab experiments, and a more complete description of each of the experiment subsystems. In this submission we provide a brief update of the physics, summaries of the progress on each of the experiment subsystems and conclude with the beam time request.

1.2 Physics Update

We recall that the main focus of the experiment is to separate the form factors G_E^Z and G_M^Z (neutral weak current analogs of the ordinary G_E and G_M). This will in turn allow us to determine the contributions of the strange quarks to the familiar G_E and G_M to a few percent over essentially the entire Q^2 range of 0.1 – 1 GeV^2/c^2. The expected results for these form factors are shown in Figure 1.1.

The SAMPLE and HAPPEX experiments provide some baseline information regarding the physics of these form factors. The HAPPEX collaboration has published a result for the forward angle asymmetry [An99] that is consistent with no net strange quark effect at $Q^2 = 0.47$ GeV^2/c^2. Their new results, with uncertainties roughly a factor of two smaller than those of the published result, are consistent with the previous measurement [So99]. The SAMPLE proton measurement [Sp99] at backward angles shows an asymmetry significantly smaller in magnitude than was expected. This difference is illustrated in Figure 1.2 where the contribution of strange quarks to the proton magnetic moment, G_M^s is plotted as a function of the *effective* axial current, G_A, measured in the experiment. Given the present theoretical prejudice, this measurement seems to suggest a large positive G_M^s. The preliminary SAMPLE measurements of the parity-violating asymmetry in quasi- elastic scattering from deuterium (almost completely insensitive to G_M^s), however, indicate that G_A is significantly different from the calculated value. Combining the two results suggests a smaller value of G_M^s, but a significant contribution from anapole related effects. The

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Yerevan Physics Institute				
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Table 1.1: Active participants in the G^0 collaboration († indicates contact person).

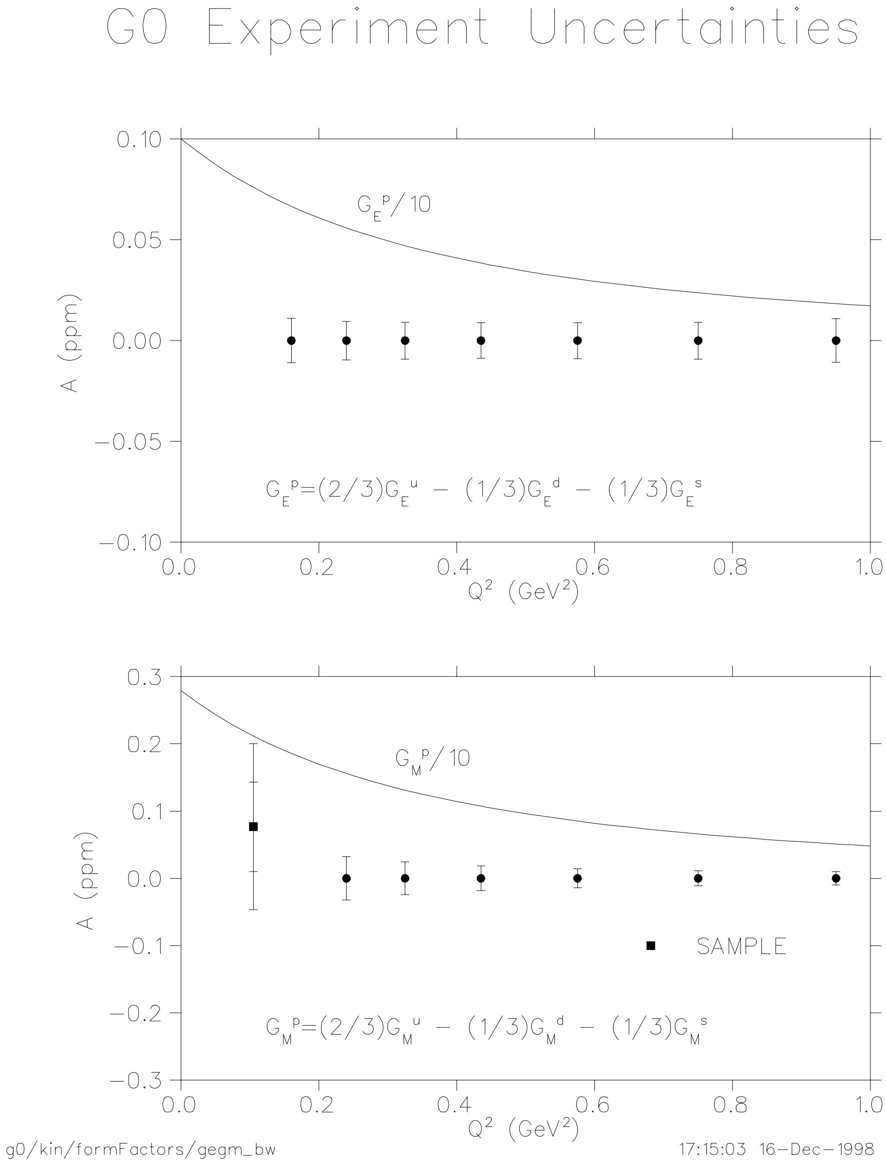

Figure 1.1: Expected results from the G^0 experiment. Overall uncertainties are plotted.

implications of the SAMPLE deuterium measurement for the HAPPEX results are not clear, not least because the Q^2 dependence of the effect is not known.

The general indications of the present experiments, therefore, are that the strange quark contributions are not a large fraction of the overall form factors. The G^0 experiment will contribute a precise separation of the form factors over a wide range of momentum transfers. These will be complemented by the expected new lattice calculations of these matrix elements by the Jefferson Lab/MIT lattice collaboration [Ne99]. It also appears that the anapole moment physics plays a surprisingly large role. We can, in principle, make measurements of the backward quasi-elastic scattering from the deuteron over the same range of momentum transfers and with similar precision; such a proposal will be made to the PAC in the near future.

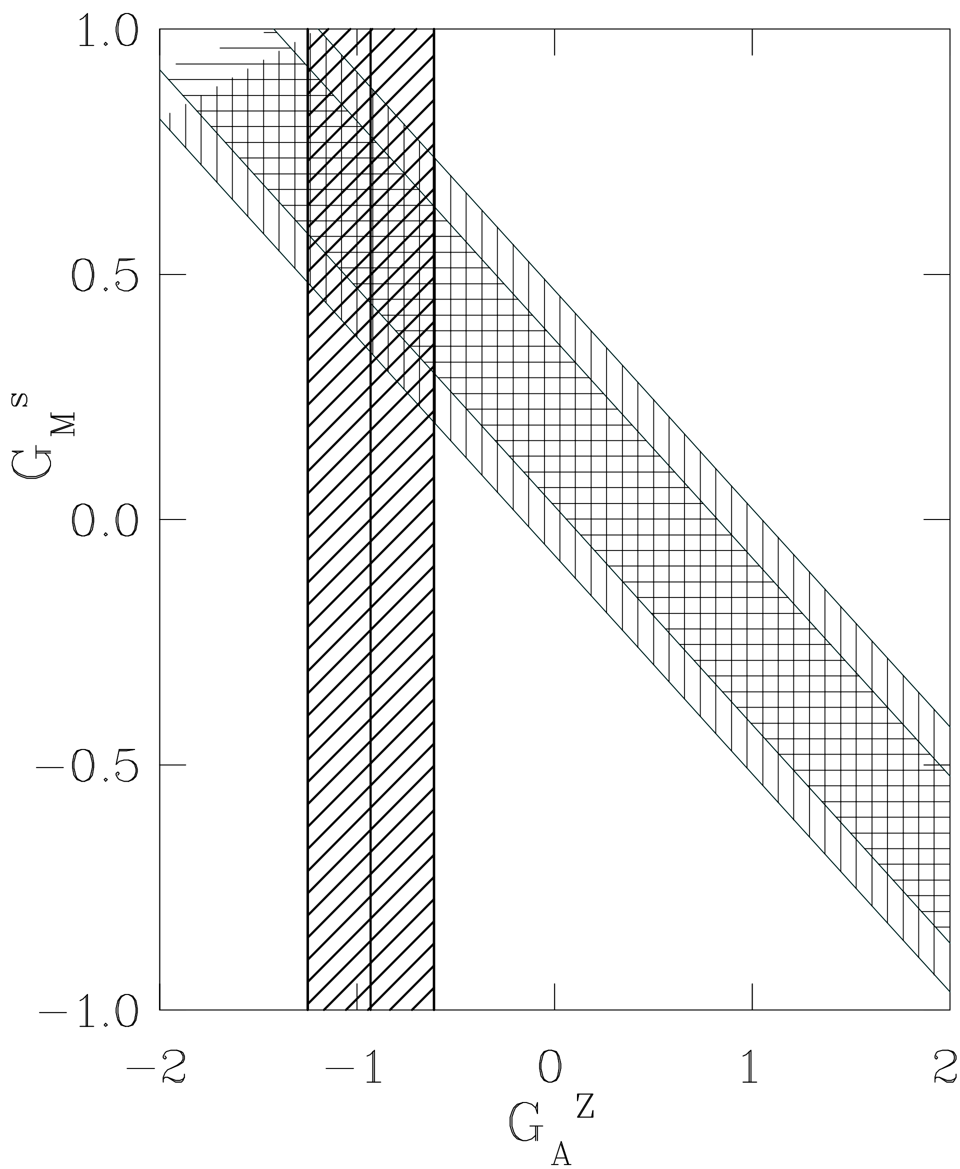

Figure 1.2: Results from the SAMPLE proton measurement [Sp99]. The s quark contribution to the magnetic moment, G_M^s is plotted vs. the effective axial current contribution to the asymmetry. The vertical band is the theoretical estimate of Musolf and Holstein [Mu94].

2 G^0 Management

The G^0 Management Plan describes the processes and procedures to be used by the Project Manager, the Spokesperson, and the Collaboration to construct, install, and execute the experiment. It includes management organization for both the construction/installation and experiment/physics branches of the project with brief job descriptions for responsible parties. The Management Plan also includes a work plan, a framework for control and oversight of subsystems, a budget with specific contingency guidelines, and a summary of the schedule and manpower resources. A final Management Plan was submitted to DOE and NSF on December 14, 1998, it was approved by the agencies and by Jefferson Lab in February 1999, and the newly committed funding was released in mid-March 1999. This marked the beginning of substantive construction work on the DOE-funded detectors, electronics, and Jefferson Lab infrastructure.

2.1 Annual Review

As part of the agreement reached by the funding agencies and JLab to support G^0, an external annual review of the project's progress will be held. The 1999 review was held in May 1999 by a committee chaired by Dr. B. Barish of Caltech.

2.2 Personnel

Since the PAC15 jeopardy proposal, there have been small changes in the membership of the G^0 collaboration. One University group (North Carolina A & T) has left to concentrate on other research, and two University groups have joined the collaboration. The University of Kentucky is contributing to the data analysis and DAQ efforts, and the Yerevan Institute is contributing to the NA FPD detector testing and assembly.

2.3 Schedule

Tracking and reporting of project status is done on a monthly basis. A list of major milestones is given in each monthly report with expected completion dates given in the G^0 Management Plan, their expected completion date if delayed, and actual completion date. To date, the magnet final design review has taken place, the Hall C layout for G^0 is complete, and bids have been awarded for both the ferris wheel and NA detector octant supports. During this fiscal quarter, it is expected that comparative testing of the Orsay and Grenoble electronics will be completed, and the NA custom electronics from Carnegie Mellon will be delivered to Jefferson Lab. Question marks are still listed under the milestone dates for delivery of the CED detectors, support structure, and related electronics to Jefferson Lab. The original schedule in the Management Plan included an accelerated fabrication schedule in order to take advantage of time available at the TRIUMF shops.

In fact the CEDs are not needed for installation until the turn-around period for backward angle measurements. Still, interface issues require that the designs be completed at this time. More CED schedule information should be available after a NA detector working group meeting in December.

Significant delays have occurred in the estimated date for delivery of the G^0 magnet to UIUC which have essentially taken up all float in that project. At present, all coil tests have been successfully completed, cold mass assembly has begun, and the cryostat vessel and endcaps are being fabricated. The delay in the target delivery to JLab shown below is driven by the delayed date for magnet/target testing at UIUC. Significant delay has also been experienced in choosing a design for the electronics for the French detector octants. This is the result of detailed prototype testing which revealed potential optimizations for both designs which are now being incorporated. Early testing showed that either choice would meet the minimum requirements for G^0. The delayed decision will affect final delivery to JLab, but will not affect the intermediate testing of electronics and detectors since prototypes will be available by Summer 2000.

Overall, the schedule for G^0 is matching that of the Management Plan to within one calendar quarter. All float has been used up for the magnet system, and for the French detectors and electronics. The NA detectors, NA electronics, and pre-installation infrastructure work in Hall C is proceeding on schedule.

2.4 Cost Performance Report

To assess the fiscal health of the G^0 project, J. Erskine at DOE recommended that we track the contingency available as a percentage of the estimated cost still needed to complete each subsystem. This resulted in Table 7.9 (DOE equipment costs) and Table 7.14 (NSF equipment costs) in the G^0 Management Plan. Each monthly progress report includes updates of these tables based on the spending information provided by the subsystem managers. These tables for the DOE and NSF portions of the G^0 project have been updated to accurately reflect the current information in the subsystem manager's reports through October 15th, 1999. The contingency available as a percentage of the estimated funds needed to complete the DOE portion of G^0 has shown a steady rise from the original 22% to the current 31%. For the NSF portion of G^0 the remaining contingency as a percent of the "Estimate to Complete" remains stable at approximately 21%. To summarize the budget situation, we are clearly still within estimates for budget and contingency for all subsystems. At this stage of the construction project, we have committed approximately $2.4M and estimate that approximately $3.5M is needed to complete the project. We are maintaining an overall project contingency of approximately 26%.

G0 Major Milestones

WBS#	Milestone	Plan Date	Status 10/15/99	Complete Date
1.3.4	Magnet Final Design Review	Q1 '99	Q3 '99	6/99
1.3.15	Magnet delivery to UIUC	Q4 '99	Q3 '00	
1.13	Magnet UIUC acceptance test complete	Q2 '00	Q1 '01	
1.3.20	Magnet delivery to JLab	Q4 '00	Q2 '01	
6.1.1.5.3	Magnet installation in Hall C	Q3 '01		
2.1.5.8	NA FPD detector assembly begins	Q2 '00		
2.1.7	NA FPD assembled/installed in octants	Q1 '01		
2.2.7	CED delivery to JLab	Q1 '01	???	
2.1.8.2	NA FPD floor testing complete	Q3 '01		
2.5.9	French FPD delivered to JLab	Q3 '01		
2.3.18	GMS installed on all NA & French FPD	Q3 '01		
2.5.11	French FPD floor testing complete	Q3 '01		
6.1.1.7.6	FPD Octants installed in Hall C	Q3 '01		
2.1.10	Integrated testing of all FPD in G0 frame	Q3 '01		
3.1.6	Comparative test of electronics solutions	Q3 '99	Q1 '00	
3.2.3	Finalize design for French electronics	Q3 '99	Q2 '00	
3.1.1.5	NA custom boards delivered to JLab	Q3 '99	Q1 '00	
3.2.4	Delivery French electronics to JLab	Q2 '00	Q4 '00	
3.1.2.8	NA commercial boards delivered to JLab	Q1 '01		
3.1.4.2	Integrated test NA elec & NA detectors	Q2 '01		
3.4	Electronics installation/testing complete	Q1 '01		
3.1.3.9	CED electronics delivered to JLab	Q1 '01	???	
4.2.4.2	Production CODA installed & running	Q2 '01		
4.1.5	Install & test slow controls at JLab	Q3 '01		
5.7	Target fabrication complete	Q1 '00	Q3 '00	
5.8.4	Target testing at UIUC complete	Q2 '00	Q1 '01	
5.9	Target delivery to JLab	Q3 '00	Q2 '01	
6.1.1.6.2	Target installation in Hall C	Q3 '01		
6.1.1.1.2	Finalize design Hall C layout	Q1 '99	Q3 '99	8/99
6.6.1.5	Award bid for octant support	Q3 '99	Q1 '00	10/99
6.6.4.5	Award bid for ferris wheel	Q3 '99	Q4 '99	9/99
6.6.3.5	Award bid for CED octant support	Q1 '00	???	
6.1.1.7.3	Ferris wheel installed	Q3 '01		
6.1.1.10	G0 installation complete	Q3 '01		

Table 2.1: Major milestones for G^0 by subsystem with expected completion date by fiscal year (FY) quarters. These form the baseline schedule for the G^0 project.

update October 15, 1999
DOE Equipment Costs:
G0 Contingency Analysis
(including Univ contributions $229k)

WBS	ITEM	Costed & Committed	Estimate To Complete (AY k$'s)	Estimated Total Cost (AY k$'s)	Available Contingency (AY k$'s)	% of Estimate To Complete
1	ISMS SC & PS	150	0	150	8	0
2	Detectors	223	90	313	41	46%
3	Electronics	149	201	350	29	14%
5	Target	0	54	54	26	48%
6	Hall C Infrastructure					
6.1	Install/ Shielding	0	403	403	86	21%
6.2	Hall C Electrical	169	348	517	96	28%
6.3	Beamline Elements	27	322	349	87	27%
6.4	Cryo Services	54	125	179	44	35%
6.5	Eng & Design	40	80	120	7	9%
6.6	Support Structures	160	192	352	132	69%
	SUBTOTAL WBS 6	450	1470	1920	452	31%
0	**G0 TOTALS**	**972**	**1815**	**2787**	**556**	**31%**

Table 2.2: An analysis of contingency that is available for completion of the DOE portion of the G^0 project. The estimates for "committed funds" and "estimate to complete" are current at the time this report is being prepared. Only DOE equipment costs are shown.

updated October 15, 1999
NSF Equipment Costs:
G0 Contingency Analysis

WBS	ITEM	Costed & Committed	Estimate To Complete (AY k$'s)	Estimated Total Cost (AY k$'s)	Available Contingency (AY k$'s)	% of Estimate To Complete
1	ISMS	1322	1650	2972	328	20%
2	Detectors	0	0	0	0	0
3	Electronics	0	0	0	0	0
5	Target	108	71	179	37	52%
6	Hall C Infrastructure	0	0	0	0	0
0	**G0 NSF TOTALS**	**1430**	**1721**	**3151**	**365**	**21%**

Table 2.3: Table 7.14 An analysis of contingency available for completion of the NSF portion of the G^0 project. The estimates for "committed funds" and "estimate to complete" are current at the time this report is being prepared. Only NSF equipment costs are shown.

3 Subsystem Descriptions and Progress

3.1 Introduction

In the following paragraphs we present a brief summary of progress in each of the main subsystems (superconducting magnet, target, detectors, electronics, infrastructure, computation, and polarized source) since the jeopardy proposal presentation in 1999.

3.2 Integrated Superconducting Magnet Subsystem

The integrated superconducting magnet system (ISMS) is the heart of the G^0 experiment. The largest component of this system is the superconducting toroid, contracted for fabrication to BWXT. The verification of its performance will be carried out using both optical means at liquid nitrogen temperature and magnet measurement at liquid helium temperature and full power. Other components, largely the responsibility of the UIUC group, include the magnet support, vacuum windows, internal collimation, and external shielding.

3.2.1 Superconducting Toroid

The magnet proper consists of eight superconducting coils cooled by four liquid helium convection circuits. The coils are housed together in a single cryostat. Liquid helium and electrical power is supplied via a cryo-reservoir mounted on top of the cryostat. The Final Design Review, including evaluation of the design of all of these components, took place in June 1999.

On the critical path to the completion of the magnet is the fabrication of the cryostat. The contractual requirement for magnetic verification of the ISMS performance has driven the design to employ materials that minimize the effect of the cryostat on external field measurements. The cylindrical part of the cryostat is thus fabricated from special chemistry ($\mu \leq 1.02$) 316L stainless steel, while the endcaps are made of aluminum. The stainless steel has been procured and checked. In fact, its permeability is smaller than our requirement, more typically 1.01. Both endcaps and cylinder are now being fabricated under subcontract to Craft Machine Works, Inc. in Hampton, Va, with an expected delivery to BWXT for integration with the cold mass in mid-March 2000.

The cold mass is composed of eight coils interleaved between eight collimator modules. The collimators define the spectrometer acceptance and provide shielding between the target and detectors. This assembly is supported at each end of the magnet by an outer octagonal ring and an inner load-bearing hub. The entire cold mass is suspended from above, within the cryostat, by four warm-to-cold tension rods, and it is located from the below by a shear pin assembly. All parts of the cold mass and associated assembly fixtures are now complete. The collimators, provided by the UIUC group were delivered to BWXT in 1998. The coils were accepted in August 1999 following field measurements to verify correct conductor placement (at room temperature), and HiPot and impulse tests to check for turn-to-turn and turn-to-ground shorts. Cold mass assembly is now underway and projected to be complete before the cryostat is delivered.

The cryo-reservoir situated on top of the cryostat provides power and coolant to the magnet. The top plate and the helium-vapor-cooled power leads are the first ingredients required for this assembly. Both are scheduled for delivery to BWXT in December '99. The remainder of the cryo-reservoir will then be built at BWXT in parallel with the assembly of the cold mass for final integration with the cryostat in April 2000.

Important to the safe operation of the magnet is the control system. Plans for the control architecture, interlocks, signals, instrumentation, as well as quench protection circuitry will be presented and evaluated at the intermediate controls review to be scheduled in January 2000.

3.2.2 Performance Verification

The performance of the magnet design will be checked both optically and magnetically. The optical verification procedure will measure the locations of the coils and collimator modules as assembled in the cryostat vessel, at BWXT. The measurement will be made at 80° K (LN2) at which temperature most of the ultimate thermal contraction will have taken place. The purpose of the test is to identify any necessary modifications to the assembly before the magnet leaves the factory. The optical verification will employ video photogrammetry. Eight "window boxes" and associated optically-flat camera ports have been constructed to provide the three views of each magnet sector necessary to triangulate fiducial locations. The optical test is planned for May of 2000. Following the optical test, the magnet will be shipped to UIUC for magnetic verification. Shipment is scheduled for early June 2000.

The magnetic verification test is critical for establishing, under full operating conditions, that the toroid meets performance specifications. It will be carried out at UIUC with the magnet cooled by liquid helium provided by the UIUC refrigerator. Work has proceeded to bring the UIUC helium liquefier into full operation. Testing indicates that the required liquid helium production will be available. The methodology of the magnetic verification involves the precise location of zero crossings in components of the magnet field. The measurements are made external to the cryostat, just outside of the endcaps. The instrumentation for measuring zero crossings has been designed and will be fabricated and tested by the TRIUMF group. It employs precision hall probes, which are located within a $4.5 \times 4.5 \times 2$ meter volume by a computer-controlled mapping device called the "gantry". Spectrometer design studies and more recent simulation studies indicate that the probe position must be determined at the 500 μm level. All parts for the mapping system and an associated laser alignment system are currently on order. Assembly is expected to begin in February of 2000.

3.2.3 Other Associated Hardware

While not on the critical path, additional hardware is required for the completion of the ISMS. This includes, the support carriage, which was completed in mid-1997, as well as the particle-exit windows and external lead shielding.

The engineering design of the particle-exit windows is essentially complete. The windows will be made of titanium of thickness either 0.014" or 0.020". Prototype 0.020"-thick windows will be destructively tested in December 1999. Assuming that they behave as predicted, further tests will be carried out with the thinner material. The final choice of material will be based on the results of these tests. In order to prevent accidental puncture, the titanium windows will be protected, once installed on the spectrometer, by a kevlar/mylar laminate "catcher's mitt". Removable metal shutters will be employed as further protection when significant work must be carried out near the cryostat under vacuum.

An external lead collar consisting of eight segments mounted between the ribs of the downstream endcap will provide additional shielding of the detectors from the target. With the release of the aluminum head design, the design of those parts can proceed. The fabrication techniques will be those employed in the manufacture of the lead components of the collimator modules. We expect to check the fit of the external lead pieces to the cryostat during the UIUC testing phase.

3.3 Target Subsystem

Steady progress on construction of the cryogenic loop has been made since last summer and all of the machining has now been completed. We are in the process of assembling the loop with all its internal instrumentation; the heaters, temperature sensors, tachometer and pump motor. At the end of the summer we began to assemble the gas handling system for the hydrogen and helium cells. That work has been completed and we are now in the process of outfitting all the valves with sensors that will allow us to monitor their state remotely and generate warnings should the target be operating in a non-standard state. All of the hardware for the control/monitoring/interlock system has been specified, most of the commercial products have been purchased, and approximately half of the custom electronics have been completed.

Detailed specifications for the EPICS-based controls software have been provided by the University of Maryland group to the JLab Accelerator Division software support group. The main focus of the work by that group to date has been to bring all of the Hall A and Hall C device drivers up to Y2K compliance. Front panel screens are presently under development. The software group estimated that the complete software development should take 3-6 months of 1 FTE. The software is required by the summer of 2000 for tests of the target integrated with magnet at the University of Illinois.

The target service module is the vacuum vessel on the beamline directly upstream of the magnet which supports the target, houses the transverse motion mechanism, and provides gas and electrical service lines to the target cryogenic loop. We have received a design concept and a quote for the vacuum vessel and positioning/support mechanism from Thermionics Northwest. No contract has yet been executed because of funding issues, which we are currently trying to resolve so that we can proceed to build the service module and design and build the gas and electrical connections to the cryoloop.

3.4 Detector Subsystem

The construction of the G^0 detector subsystem consists of the several major components: (1) the Focal Plane Scintillators (FPD), Light Guides, and photomultiplier tubes (8 octants, each with 16 pairs of scintillators viewed from two ends), (2) the octant support structure for the FPD detector system (see also Section 3.6.6), (3) the laser-based gain monitoring system, and (4) the Cryostat Exit Detector (CED) for measuring electron scattering at backward angles (8 octants, each with 9 scintillators viewed from two ends). The effort for the first two projects is being shared by a North American component and the French component of the collaboration, each to provide 4 FPD octants and associated support.

3.4.1 North American FPD and Support

All scintillators (128 plus 2 spares per detector type) have been machined and polished and currently are being wrapped in preparation for assembly. The light guides are being fabricated at CMU. All necessary UVT strips have been diamond cut. The current schedule calls for all FPD1-8 light guides to be delivered to JLab prior to 4/1/00, with FPD9-16 due by mid-summer. The photomultiplier tubes have been in stock and tested for over a year, and the bases/housings have been completed at TRIUMF and will be delivered to JLab soon. The contract for four octant supports has been let, and they will be delivered to JLab by 2/1/00. These supports serve as the assembly jig for gluing the scintillators to the light guides. Once the octant supports have been surveyed for accuracy and tested for fit into the supporting ferris wheel, they will be moved to the JLab clean room and assembly of the first octant begun (around 3/1/00). Given the component delivery schedule and the available manpower, we do not foresee any problem completing and testing the four N.A. octants by the end of the year 2000.

3.4.2 French FPD and Support

Since the last PAC Jeopardy Proposal, significant progress has been made in the design and construction of the French detectors. First, the choice has been made to use Bicron BC408 for the scintillators. The final shapes for the scintillators have been decided, based on simulations of the proton trajectories. The required scintillator sheets have been ordered from Bicron through its European subsidiary (EURYSIS). The company that will fabricate the light guides has been identified. The choice of a company that will cut and polish the scintillators is still pending, but will be made by mid-January 2000. The design of the mechanical support for the French octant has been finalized in accordance with the NA collaborators for the integration. At present, our schedule is to deliver the last octant in JLab by June 2001, as initially planned. Procedures have been established for the transportation, survey and final assembly at JLab.

For the PMTs, all phototubes (280 Philips XP2282) have been ordered, delivered and tested. The bases developed include a x10 amplifier which has been tested and is radiation resistant. The current design of the base utilizes only Zener diodes, related to radiation concerns, and final tests of prototypes are being made. All production should be achieved by mid-year 2000.

3.4.3 Gain Monitoring System (GMS)

The stability of the gain and timing of the phototubes, as well as the transmission characteristics of the scintillator-light guide combination, will be monitored by flashing UV laser light directly onto the scintillator. The UV light is transmitted to the scintillators in all eight octants by means of light fibers. Each pair of FPD detectors will be illuminated by two fibers placed on opposite sides of the scintillators. Currently the system is nearly complete and is being tested at NMSU. The only remaining item is the construction of a masking system so as to illuminate subsets of detectors. The full system will be delivered to JLab in April of 2000.

3.4.4 Cryostat Exit Detectors (CED)

The CED construction has not yet begun, since these detectors are not needed until after the forward angle running. However, the design of the scintillators and light guides has been completed and the scintillator material purchased. Also approximately one-half of the material necessary for the light guides is on hand. These materials will be shipped to TRIUMF, and work on the construction of the scintillators and light guides will begin in the TRIUMF scintillator shop on about 1/15/00. We expect that these items will be available before the end of 2000. The necessary photomultiplier tubes for the backward measurement will be taken from the FPD system, since only one FPD detector of each pair is used for the back angle measurement. The design of the support structure has just begun.

3.5 Electronics Subsystem

Since the last PAC update, substantial progress has been made on all of the most technically challenging development projects of the electronics subsystem. Some sliding of the schedule has occurred, partly because of delays in release of funding, but the schedule remains comfortable for development of the electronics and for its testing and integration with the data acquisition system.

The designs have been finalized for all of those components of the North American electronics which were originally intended to be custom-built. (Consideration is still being given to using custom-built modules in place of the originally-planned commercial units, as described below.) The full complement of time-encoding boards has been produced, stuffed and tested, as have the peripheral modules required for time encoding. System tests have been successfully carried out to ensure that results obtained with individual prototypes also hold when many boards are in simultaneous operation. Fine-tuning is in progress to optimize uniformity of the time-encoding bins, but acceptable performance has already been achieved. A subset of the electronics is expected to be set up as a working system at JLab in early 2000.

At ISN-Grenoble, a prototype of their integrated board has been developed and the time-encoding has been successfully tested. The next generation of prototype is being produced, with improved dead-time logic and allowing head-to-head comparison of their new shift-register ASIC against the conventional components. It is anticipated that results with this prototype will allow the final design to be implemented without additional prototyping, if the ISN-Grenoble design is chosen for the French electronics.

At IPN-Orsay a prototype board for their flash-TDC based design has been produced. This has allowed experience to be gained in programming the on-board DSPs to carry out the required functions. This board has also been tested successfully. The next generation (which is expected to be the final version) is being designed with modifications to enhance monitoring of discriminated signals from individual PMTs.

Initial comparative testing indicates that both of the French designs are performing acceptably. Additional comparisons will be required in order to make the final decision of which French design should be used to read out the French octants. These tests have been somewhat delayed because limited resources make it difficult to continue development of software for the IPN-Orsay boards while comparative testing is being carried out. These comparative tests are expected to be completed early in 2000 so a final choice of design for the French electronics can be made in mid-February.

Both the North American electronics and the selected version of the French electronics will be set up at JLab over the summer of 2000 so integration and testing with the data acquisition system can be carried out.

Several spinoffs from the development of the ISN-Grenoble electronics design have benefited the implementation of the North American electronics. Development of the scaler ASIC for the integrated board has led also to the production of very economical VME scaler modules. These will now be used in place of commercial modules for capture of the information from the North American time-encoding boards. This has resulted in a substantial cost reduction for the North American electronics. A meantimer ASIC has also been developed by ISN-Grenoble. This has been tested and found to provide superior performance in several respects compared to commercially available modules. It is anticipated that the next generation of meantimer ASIC, presently being developed by ISN-Grenoble, will achieve all desired specifications. A stand-alone module will then be developed to house it for use in conjunction with the North American electronics chain. A constant fraction discriminator module is also under development. While this is a promising avenue, no prototype has yet been tested, so the decision awaits availability and testing of a first module.

3.6 Infrastructure

JLab is providing material, equipment, and services to G^0 as a part of the infrastructure of Hall C. In addition, some modifications will be required to existing equipment in the hall.

3.6.1 G^0 Installation & Shielding

The planning, material, services, and labor required to install the collaboration deliverables (SMS, target, detectors, etc.) and to establish an interface to the Hall C infrastructure are covered by this task. The physical location of the G^0 experiment will be downstream of the Hall C spectrometer pivot assembly. This has the advantages of making G^0 minimally invasive to the other Hall C experimental programs and of allowing the simplest G^0 staging arrangement. Based on preliminary background radiation calculations it is also the best location for minimizing overall beam-produced backgrounds in Hall C. An effort is underway to compare and benchmark measured Hall C backgrounds with Monte-Carlo calculations. This should allow us to fine tune the experiment's beam line shielding for minimal background in the detectors.

3.6.2 Hall C Electrical

Infrastructure services and equipment related to the electrical systems of G^0 includes: 1) signal and control cables connecting the experiment to counting room patch panels (their fabrication and installation and mechanical support), additional patch panels for intermediate break-out; 2) AC power in Hall C for vacuum, cryogenic systems instrumentation, target instrumentation, gain monitoring system instrumentation, etc.; 3) high voltage supplies installed in Hall C along with cables, cable mechanical support and high voltage patch panels (if needed), and 4) the construction of a G^0 electronics and counting room with its required infrastructure including AC power, air conditioning, racks, and modular electronics crates. All H.V. and signal cables have been purchased and delivered. Installation of these cables from the counting house to the Hall C G^0 patch panel is scheduled for Jan. 2000. A "clean" design for cable distribution from the Hall C G^0 patch panel to the eight individual detector octants is currently underway. We feel that putting care and effort in this aspect of the experiment will be extremely important when it comes to system serviceability.

3.6.3 Beamline Elements

Careful measurement of the parameters of the electron beam will be necessary in order to control systematic uncertainty in the G^0 measurement. This will require beam monitors including RF cavity position/Intensity monitors and other beam position monitors (stripline, harp wire scanners). Also included in this item are electronics systems associated with the electron beam such as the raster system and the helicity readout from the polarized source in the counting room. Also included in this task is the work and material needed for the modification and adaptation of the Hall C Møller polarimeter to the needs of the G^0 experiment. Finally, mechanical modifications to the beam line, the vacuum system for the SMS, and valves to permit the isolation of the SMS are included here.

An instrumentation girder is under design which will contain the RF cavities, stripline monitors and harp wire scanners which are currently under fabrication. This self-contained girder package is very similar to the girder package currently being used in other Hall C programs. The G^0 girder package will be located upstream of the G^0 target system which is itself upstream from the magnet/detector assembly. This self-contained instrumentation girder will be removed and stored between G^0 runs. By locating G^0 downstream of the pivot and employing a dedicated beam monitoring instrumentation package G^0 will have the advantage of obtaining access to signals from three separate beam monitoring packages. Specifically, the one in the tunnel to Hall C, the package in front of the standard Hall C scattering chamber and the G^0 package. This should result in excellent monitoring of all beam properties.

3.6.4 Cryogenic Services

The G^0 SMS, the target, and the Møller polarimeter will require cryogens from the End Station Refrigerator. To accommodate G^0 the cryo distribution system must be upgraded to provide cryogens to the target and the SM. Flexible "U-Tubes" for delivery of cryogens to the SM and the target will be fabricated.

Since G^0 is located downstream of the standard Hall C pivot a satellite cryogenic "well head" will be installed near the planned G^0 location. Since this satellite "well head" will likely be used for future Hall C experiments (beyond G^0) the funds for this work are coming from the Hall C general operations budget and are not part of the scope of the G^0 experiment. This perimeter cryogenic transfer line and well head has been designed and is under fabrication by an outside vendor. Installation is schedule for spring 2000. Other miscellaneous G^0 specific (and funded) transfer lines should move from the engineering phase to the fabrication phase over the next several months.

3.6.5 Engineering and Design

This task covers the engineering and drafting effort associated with the mechanical supports, cryogenic plumbing, shielding, and other additions and modifications to the Hall C environment that are specifically required by the G^0 experiment, i.e. engineering and drafting for the other Hall C Infrastructure tasks.

3.6.6 Support Structures

This task includes all labor and material required for the fabrication and the assembly of the mechanical support of the G^0 detectors. The support consists of individual CED and FPD octant support frames, associated with the North American and the French detectors, which "plug in" to a detector superstructure (the so-called Ferris wheel). The alignment of CED and FPD octant modules is accomplished with adjustment degrees of freedom provided by the Ferris wheel. Internal alignment of scintillator elements within octant supports is established when the octant modules are assembled. Lead and borated polyethylene shielding as well as beam line material integral to the Ferris wheel support will be fabricated as part of this task. A rail system will permit the Ferris wheel to be retracted from the SMS for servicing. The Ferris wheel, base platforms, and octant support frame (aka. Detector Assembly Support Frame) to hold both the North America and French detector modules are under fabrication by outside vendors and are scheduled to arrive at JLab around Feb. 1, 2000.

The downstream placement option requires that G^0 be easily moved out of the beamline so other experiments can run in Hall C. A rail motion system is under development. This rail system is for moving the G^0 magnet and detector out of the beam line and the separation of the magnet and detector in order to allow the SOS to reach its full angular range. This system was fabricated by an outside vendor and delivery is in process. Since this is a requirement for other experiments to run easily in Hall C the cost of designing, building and installing this rail system will be absorbed by the general hall operations budget and consequently are not part of G^0's scope.

3.7 Computation

The software effort associated with the G^0 experiment has been divided into four parts: slow controls, data acquisition software, analysis, and simulations. Separate groups are focusing on the creation of software to meet the requirements of the experiment in these areas. Below is a highlight of progress since the last PAC meeting.

The NMSU group is leading the organization of the slow controls. Preliminary specifications have been drafted and details of each subsystem are now being assembled. The initial version of the slow control software will be tested at UIUC when the magnet and target tests take place.

Definition of the data acquisition is nearly complete, pending a decision on which type of the French electronics will be used for the experiment. Plans are underway to implement a data acquisition test bed in the G^0 area of the Hall C counting house during the summer of 2000. The various pieces of hardware for the test setup are presently being identified. The test bed will consist of one of each of the necessary hardware to complete a North American electronics channel, from the discriminators through to the CODA workstation. A prototype module of the French electronics will be available in May 2000 and will also be incorporated into the test stand during the summer. The plan would also include having the appropriate hardware in place to read beam monitors as soon as they are available and to send helicity signals to the electronics so that parasitic beam electronics tests could be carried out. The rest of the system will then allow the possibility of either testing a single detector, or to generate fake signals to test portions of the data acquisition software.

The on-line analysis code for G^0 primarily consists of calculating asymmetries from time-of-flight histograms and then correcting the measured asymmetries for helicity correlations in the beam. Since the G^0 detector has no tracking capabilities there is no event reconstruction. Development of the first version of the analysis code is now beginning, led by the University of Kentucky group. Since the last PAC, an analysis code steering group has been established to help ensure that the interface to all aspects of the experiment is properly taken into account. The analysis code will be written in C^{++} with the ROOT graphical analysis software and with CVS for code revision control. The basic event types have been defined, and the first phase is to generate a pseudodata stream of events that can be run through the analysis code for debugging purposes. Definitions of the data stream were recently laid out for each of the three (one North American and two French) electronics systems.

At the most recent collaboration meeting it was decided that in addition to the normal 30 Hz data taking, short periods of 120 Hz data taking will be desirable. The impact on the data acquisition is minimal except in the case of the Orsay electronics which has a factor of ten larger data stream. The Orsay electronics design has been modified to accommodate this need.

The development and maintenance of standard simulation codes and their application to predict the behavior of the apparatus and to contribute to its design, is another vital computational task. In the past year, the simulation effort has increased substantially. The main focus has still been to study background production rates to help finalize the design of the detector. An accurate and fast tracking algorithm now exists, and primary event generators have been implemented. The neutron production rate (Illinois group) and detector dose rates (JLab) are presently being studied in order to determine how much shielding around the detector may be needed. Secondary event generators are in the process of being implemented, as well as spin tracking of the scattered protons.

3.8 Polarized Source

Members of the G^0 collaboration have worked together with members of the polarized source group on two issues recently: minimization of helicity-correlated beam property systematics and modeling of the polarized injector to accommodate the increased bunch charge necessary for G^0. Initial studies of helicity-correlated beam properties from the strained GaAs crystal were done along with the HAPPEX collaboration during their run in the spring of 1999. Generally it was found that the helicity-correlated position and intensity differences were larger than with the bulk GaAs crystal. They could be kept to an acceptable level by inserting a rotatable half-wave plate between the Pockels cell. Tuning this could minimize the position and intensity differences. The position differences in the injector area are generally a factor of 10-30 bigger than in the experimental hall due to the adiabatic damping of the accelerator. By making simultaneous measurements of the position differences in the injector and in Hall A, it was found that this “damping factor” could occasionally get small and a retune to carefully match the injector beam into the accelerator was necessary to keep the position differences at an acceptably small level in the hall.

After the HAPPEX run members of the G^0 collaboration and the polarized source group began a program of studying the effects of the Pockels cell on the helicity-correlated properties of the laser beam using a quadrant-segmented photodiode to measure the laser position.

A dedicated data acquisition system for this purpose was set up in the polarized source laser lab. Measurements were made with several Pockels cells alone and also with a microscope slide to "simulate" the optical analyzing power of the strained GaAs crystal surface. In addition, a potential helicity-correlated position feedback system was set up. It uses a piezoelectrically driven mirror mount to steer the laser beam in a helicity-correlated way. This can be used to compensate any helicity-correlated steering done by the Pockels cell. This system works on the laser table, but efforts will continue to minimize the helicity-correlated steering done by the Pockels cell itself and its interaction with the GaAs crystal. The piezoelectric mirror system will be tested and some other effects will be studied in two shifts of dedicated running in the injector area in late January 2000.

The other major activity involving members of G^0 and the polarized source group has been the modeling of the transport optics in the injector. G^0 will only take 1 out of every 16 microbunches. In order to maintain 40 μA beam current, a bunch charge of a factor of 6 higher than what is currently being run will be required. At this charge density, space charge effects become significant. Modeling using the in-house version of the optics code PARMELA are underway. Acceptable tunes have been found that do not require major modifications of the injection beamline. The modifications required are to enlarge two existing apertures and move an existing solenoid lens further upstream. It is important to test the code in this regime as soon as possible. That will, very likely, be possible in January 2000. The polarized source group has successfully been developing a new laser scheme involving and externally mode-locked titanium-sapphire laser. This laser will potentially have enough power to generate the G^0 bunch charge (at 499 MHz), and then tests can be performed to see if the injection line with the existing elements matches the PARMELA predictions for high bunch charge.

4 Beam Time Request

The G^0 experiment was originally designed to make a measurement of all forward angle asymmetries in a single 30 d measurement, followed by measurements of individual back angle asymmetries also in periods of 30 d. The expected results of the experiment, shown in Figure 1.1 are based on these running times.

The 46 d of approved commissioning time should, given the remarkable qualities of the beam already demonstrated in the HAPPEX measurements (stability, absence of helicity correlated effects), give us the opportunity to completely debug the spectrometer and target in operation with the beam. Indeed, a great deal of off-line testing of the subsystems is planned and in many cases has already begun.

The commissioning (see PAC15 proposal for details) will establish the baseline operation of the forward angle experiment. We assume that after commissioning activities are complete, the experiment will be rolled out and other Hall C experiments performed prior to the forward angle physics measurement. We estimate that 4 d of setup time to reestablish the operating conditions of the commissioning runs (checking target empty and target full backgrounds, symmetry of the detector and centering of the target and spectrometer relative to the beam as well as standard operational status) will be required immediately prior to the physics run.

The physics run of 30 d will involve only a single energy, 3.0 GeV, and an average beam current of nominally 40 μA with the G^0 pulse structure (one bunch every 32 ns instead of every 2 ns).

In summary, therefore, we request 34 d of beam time for the first G^0 physics run; 4 d for setup and 30 d for the physics run.

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