Experimental Readiness Review for E12-09-016 (SBS GEn)
Dates: Oct 22, 2020, Remote
Final Report: November 30, 2020

Review Committee:
Chris Cuevas – JLab Fast Electronics Group
Pavel Degtiarenko – JLab Radiation Control Group
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Observers:
Ed Folts – JLab Physics Division
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E12-09-016, *Measurement of the Neutron Electromagnetic Form Factor Ratio* G^n_E/G^n_M *at High* Q^2, has been approved for 50 days in Hall A allowing measurement of the neutron electromagnetic form factor ratio at Q^2 values of 1.46, 3.68, 6.77 and 10.2 $(GeV/c)^2$ from semi-exclusive ^{3}He(e,e'n)pp scattering using polarized electrons incident on a polarized ^{3}He target and detecting the final state neutron in coincidence with the scattered electron. The experiment will use ``the large solid angle BigBite magnetic spectrometer, equipped with GEM-detectors for detection of the scattered electrons, together with a large area neutron detector (HCAL). An additional dipole sweeper magnet (SBS) would be employed to deflect the produced protons in order to obtain a clean neutron signal". The experiment will also use a high figure-of-merit polarized ^{3}He target with a number of improvements compared to the latest used in the Hall C A1n and d2n experiments.

The committee would like to thank the collaboration for the clear and concise presentations as well as their thorough discussion of the charge elements. The agenda and list of talks presented during the meeting is given in the Appendix.

In this report, we answer the questions posed in the charge point by point, and then provide general feedback in the form of findings, comments, and recommendations as defined here:

FINDINGS: describing the major relevant points presented to the committee or observations made during the presentations.

COMMENTS: Suggestions or other remarks that do not rise to the level for inclusion in the formal recommendations.

RECOMMENDATIONS: Describing more definite statements that must be addressed in the future.

Response to the elements of the review charge

1. Does the polarized ^{3}He system impose changes to the SBS beamline, spectrometers, or detector configuration? If so, please define these, including ownership, maintenance and control during beam operations.

FINDINGS:

- The cryotarget chamber/system will be removed and the polarized 3He target installed.
- The detector configuration will be the same as that used for the preceding experiment (SBS – GMn).
- The downstream beamline will require modest changes (change of location of the downstream correctors).
- Additional changes include installation of the BigBite magnet, positioning of the LHRS at very large angle, and implementation of a (circular) raster.
- Ownership, maintenance, and control is clearly spelled out for most components.
- Center for Advanced Studies of Accelerator (CASA) has not yet verified whether the upstream beamline can accommodate the (circular) raster and necessary beam steering.
- While the complete detector configuration was presented in Mark Jones' talk, the committee noted inconsistency concerning the removal of GEM veto plane defined in the PAC35 proposal between different presentations.

COMMENTS:

- Coordination between the experiment and OPS for control of the SBS magnet will be important so as to not adversely impact the polarized 3He target.
- Target/laser slow controls were not discussed in detail.

RECOMMENDATIONS:

- Work with Center for Advanced Studies of Accelerator (CASA) to define the final upstream beamline configuration including raster.
    - As part of this work it would be useful to develop a table of beam requirements necessary for E12-09-016. This would include:
        - intrinsic beam profile size,
        - raster (max) size and shape,
        - desired beam translation envelope (ie. what are expected beam translation limits in x and y needed to accommodate target ladder offsets, etc.

- Clarify the complete detector configuration.

2. What is the status of the equipment required for this experiment towards operation? What is the completion/commissioning schedule and tasks? In particular, provide detailed information on the high-luminosity ^{3}He target system,
   - The target(s) configuration needed, performance requirements and status.
   - The laser system configuration needed, its operation and safety (including documentation) and status.
   - The integrated system (target holders, motion mechanics, optics, enclosures, …) as expected to be used during the experiment.

FINDINGS:

- The collaboration has decades of experience developing polarized 3He targets and running them at JLab, and has produced impressive, steady improvement in these targets' figure of merit performance over that time. The goal for figure of merit for this experiment represents another incremental but significant improvement, and is achieved by increasing the beam current from 30uA to 60uA and lengthening the cell from 40cm to 60cm.

- New metal-window cells offer the promise of improved reliability and consistency over glass cells. The metal-window cells take advantage of glass to copper and copper to aluminum electro-welding, which is expected to be robust under the radiation and thermal environment of the beam. Test cells with these metal windows have not yet resulted in the expected relaxation times, and more tests are pending. These new cells are not necessary, but preferred. Should the cell performance of the metal-window cells not be sufficient, all-glass cells can be used without decreasing the beam current by increasing the raster size. Should this be necessary, larger diameter target cells are possible to avoid clipping the cell walls.

- The laser optics system has been redesigned to improve reliability and allow laser pumping from two directions for improved polarization. The laser system can be swiveled to accommodate target angle changes. New high-power lasers will utilize new optical fibers from the counting house.

- Copper pinch-offs are being investigated to allow sealing of cells without cryogens. Properly cleaned and coated copper is expected to have a minimal effect on the polarization, particularly from the small surface area needed for the pinch-off, but in-lab tests are pending.

- Three plans were presented as paths forward for developing the target cells in preparation for the run. In "Plan A", glass and metal-windowed cells will be produced, and assuming the metal cells perform as expected, they will be used for the experiment. In "Plan B," only glass cells will be produced at room temperature using copper pinch-offs, should the metal windows not perform as expected. In

"Plan C," glass cells will be produced with traditional cryogenic fills if the copper pinch-off method be problematic.

- Cell production was slow in 2019 as expertise developed, but should be faster now with this experience. Several cells underperformed during the Hall C A1n and d2n experiments, some of which may be attributable to optics issues which have been addressed.
- Installation will take 3 to 4 months, and an additional polarized target commissioning time of 2 months without the beam is requested.
- The GEn experiment uses the same detectors that would have been used in the GMn experiment prior, and most of which is at the cosmic test stand stage at this time and will be fully commissioned at the time of GEn.
- Upgraded DAQ elements from FASTBUS to VXS which brings the backend electronics to a more modern system to be more consistent across the physics division.

COMMENTS:

- Should the proposed running schedule be followed (May 2022), there is an aggressive target development timeline to be met. Prioritize determination of "plan" ASAP. Performance assessments of test cells with metal windows and copper pinch-offs should be pursued with haste. Collaborators stressed difficulties with people-power for the target installation and preparation in previous experiments, and these people-power bottle-necks must be addressed by the collaboration.

- For A1n and d2n, the ERR committee found that the collaboration had not yet met its own target cell requirements, with only one cell within 80% of the P^2 figure of merit (FOM) from the proposals. While a number of cells were produced quickly after the ERR, the lack of cells ultimately appears to have adversely affected the achieved FOM for these experiments. The target improvements pursued for this experiment represent impressive research achievements, but have again put the collaboration in a position to produce and test novel, production-ready cells after the readiness review but before the experiment begins.

- We are convinced from the presented development and contingency plans that the target will be ready, but a detailed schedule for the development, production and testing of the new cells will help ensure the newly improved target is ready for the experiment.

- The laser safety/interlock system (in the hall) was not discussed. In the past, this was provided by the Fast Electronics Group.

- Cable routing and lengths need to be finalized as some only had a general area allocated.

- Use any lessons learned from GMn detector setup and operations.

RECOMMENDATIONS:

- Provide more specific overall target development milestone timeline to judge progress.
    - What are the guidelines for the determination of the cell types to be chosen and a timeline in which this will be done.
    - What tests will be done, on what types of cell, and by when?
    - What determines the success of a cell design (what polarization or additional relaxation time is sufficient)? June 2021 is mentioned as a decision point in a rough timeline given in the slides, but a more formal set of milestones would be useful.
    - Include milestones for production cell creation.
        - How many beam-ready cells will be needed, at what lab-measured polarization, and when will they be ready?
- Demonstrate the GEn-II experiment-required-performance full ^{3}He target on the bench that is production ready, prior to the submission of beam request.
- Complete the in-progress thermal and structural analysis of the target beam entrance and exit windows at the anticipated beam currents for the chosen cell type.
- Define final optics specifications including lasers and fibers into the hall. Complete laser fiber studies by May 15, 2021.
- Fully define target ladder configuration.
- Complete the in-progress analysis of local density reduction in the path of the beam.
- Exercise full readout chain with final detectors, cables, DAQ as early as possible.

3. Are the polarized target running configurations affected by the spectrometer fields? If yes, have the fringe field effects been properly mitigated?

FINDINGS:

- A number of detailed studies have been completed by the collaboration to study the impact of BB and SBS fringe fields on target operation. The iron shielding enclosure surrounding the target looks very promising and is expected to allow the internal magnetic field.
- The iron shielding enclosure has two plastic doors on each side of the target. The non-magnetic doors will make it possible to open them and work on the target in a laser-controlled access mode without disturbing the magnetic field characteristics. Very nice.
- The iron shield box is intended to be effectively filled with dry nitrogen (provided by the cooling jets for the glass cell and beamline windows).
    - Gas tightness will be a 'best effort' endeavor (it is not critical).

    - A venting system was mentioned to address any potential ODH issues during target accesses.
- The rigid iron shielding structure serves multiple roles. It provides magnetic shielding from the SBS and BB fields, provides a laser-light enclosure with straight forward interlock mechanisms, helps capture an inert atmosphere inside the box, and allows easy access to the target via the doors when needed. This should provide some real benefits over the prior Hall A and Hall C flexible panel approaches.
- The main holding field will be of order 20G either parallel or anti-parallel to the beam direction.
- TOSCA modeling indicates field gradients within the box should be held to well within the goal of 30 mG/cm. Simulations suggests gradients of 10 mG/cm or better should be achievable.
- Residual magnetization of the iron shield box was noted as a concern by the Collaboration. Unfortunately preliminary studies of such effects are highly dependent on details of the delivered iron, etc. and are largely impossible to simulate reliably. The Collaboration will address this through a field measurement study to be completed as part of the pre-run commissioning work.
- The larger dimensions of the GEn-II 60cm long target cell require the cell to be vertically offset slightly to allow re-use of the existing Helmholtz coils. This has been done and is reflected in the target design.
- Unlike the Hall C and earlier Hall A designs, no field-gradient "correction coils" are present in the current design. TOSCA modeling indicates that the iron shielding enclosure should make such field adjustments unnecessary. Discussions at the ERR indicated there was a possibility that similar "field spoiler" coils may actually be needed to induce additional gradient if masing is an issue. (See Recommendation below.)

COMMENTS:

- It sounded like the iron shield plates (with weights of a few 100 lbs) may need to be temporarily removed if additional access is required for Survey & Alignment or repairs/troubleshooting (only as a backup option). It would be wise to plan how this might be done after all system are installed (crane access options, etc).
- It sounds like the requested TOSCA model/maps requested in the Recommendations below may already be complete for typical and 'worst case' scenarios. It is hoped that these data are already available and can be easily recast into the plots requested below.

RECOMMENDATIONS:

- Please provide TOSCA field maps over the critical target regions (pumping chamber, transfer tubes, target cell) using up-to-date models and representative SBS and BB fields (including field clamps, accurate iron shield box model, etc).

- Plots showing the full scale of Bx, By, Bz in the regions of interest.
- Plots showing the *difference from the average* for B_x, B_y, B_z over the same regions. (These will make it easier to evaluate the gradient and general field homogeneity.)

- Please describe the target field measurement equipment (MFS system) and operational procedures/plans.
  - Provide a summary table of the magnetic field requirements and tolerances needed for target operation.
  - Describe how the necessary field measurements will be made and how long they will take, and demonstrate that the measurement tolerances will match the experimental needs in the prior table.
- Determine if field-tuning ('field spoiler') coils may be needed. If it is a possibility, then define the requirements and add needed power supplies, controls and cabling requirements to the target plan.

4. Are the responsibilities for carrying out each job identified, and are the people-power and other resources necessary to complete them on time in place?

FINDINGS:

- Estimates for scheduling activities was covered in several presentations by
  - Robin Wines
  - Gordon Cates
  - Bert Metzger
  - Mark Jones
  - Jessie Butler
  - Todd Averett
- The configuration from GMn to Gen activities were nicely presented in several talks, and top-level tables for system ownership, maintenance and operation controls were listed
- ^{3}He Target overview included significant details and discussion for the objects that comprise the 3He Target components and system. The preliminary timeline shows a start of running in May of 2022.
- Significant experience with target cells on other experiments and new techniques for metal windows was presented. Raster pattern will have to be increased to 6mm for glass at 60uA beam operations.
- Presentation from Todd Averett on Person-power and responsibilities listed the top level equipment sections for the experiment which highlighted system Owner, Maintenance responsibility, and Controls[Operation] responsibility.
- Responsibilities and scheduling were well addressed and presented during the review. The experiment will be using the standard equipment, including the ^{3}He target with the sufficient number of experts involved.

COMMENTS:

- Specific activity lists were given for the speakers listed in the findings section, and the information was more than sufficient to show that each equipment section was addressed. Discussions went off track somewhat, Raster system as an example, but this topic is well known and solutions exist. Changes to baseline must be captured in the final schedule, however.
- It would be useful assign a single point of contact from the ^{3}He target group to coordinate the target installation work with the Hall Work Coordinator.
- Request assistance from the project management group (see recommendation).

RECOMMENDATIONS:

- Create an overall spreadsheet that lists the equipment/detectors and work out detailed activities. Include resources committed for these activities and generate start-to-end [milestone] dates for these activities.
- Create a detailed detector and beamline installation plans with key milestones.

5. What is the simulation and data analysis software status for the experiment? Has readiness for expedient analysis of the data been demonstrated? What is the projected timeline for the first publication? Please provide a documented track record from previous experiments.

FINDINGS:

- Simulation and the reconstruction software are at a quite advanced stage. GEANT based software for detector response simulation includes details of the target, beamline, shielding, and detectors. There are detailed MC studies of detector performance. Studies show that the required performance in terms of momentum, position, and time resolutions will be achieved. Most of the software modules have already been used either in the analysis of beam or cosmic data.

COMMENTS:

- MC studies of electron scattering off ^{3}He exist for all kinematic points. But simulations of inelastic and quasi-elastic reactions are done separately. There are event generators on the market for simulation of the electron scattering in the full kinematic region of the experiment. Will be important to have high-statistics full simulation to assess the effectiveness of cuts for selection of quasi-elastic scattering (e'n) final states with p_t<100 MeV.

RECOMMENDATIONS:

- Demonstrate sufficient neutron-photon separation in HCAL, especially important for the highest Q^2 point where neutrons $\beta \approx 1$.

6. Are the radiation levels expected to be generated in the hall acceptable? Is any local shielding required to minimize the effects of radiation in the hall equipment?

FINDINGS:

- The Radiation Budget evaluating the dose accumulation at JLab boundary is close to be finalized. The result is acceptable and well under the alarm level for the experiment.
- Detailed geometry of the target and detectors is implemented in Geant4, the background count rates and base currents are found acceptable

COMMENTS:

- The Experiment is not expected to produce big radiological problems, however, ALARA considerations to minimize personnel irradiation should be adhered to.
- Same considerations are applied to the possible damage to electronics and materials during the run. There is no expectation for the problems, but the expected level needs to be evaluated.

RECOMMENDATIONS:

- Extend the recent GMn ALARA studies, as applicable to this Experiment, to evaluate the material activation in the vicinity of the target and around the beam line. Attention should be paid to the target surroundings and the vacuum windows. All needed planned work around the target should be scheduled in accordance with the expected radiation levels. Have a plan to address these issues.
- Use the lessons learned from the previous experiments to try to understand the sources of radioactive contamination around the target enclosure, and ways to control it. Have a plan to address this issue.

7. Are the beam commissioning procedures and machine protection systems sufficiently defined for this stage?

FINDINGS:

- The beam commissioning procedures are well defined. Machine protection systems are sufficiently defined at this stage. There is an ongoing working group reviewing and improving procedures and ensuring coordination between the experiment, accelerator operations and accelerator optics groups. This working group may make recommendations later on further improvements for the target protection.

COMMENTS:

- Consider using the Geant4 model to determine whether there is an optimal position for ion chambers to be sensitive to scraping on the ^{3}He target walls during beam delivery.
- Define
  - beam polarization,
  - trip rate assumptions/requirements,
  - beam ramp rate specifications.

RECOMMENDATIONS:

- The choice of the raster pattern needs to be motivated. Whether one has to use a circular or square raster will affect the optics configuration of the beamline. Likewise, there is an upper limit on the raster size beyond which it may become difficult to deliver beam without scraping on the long ^{3}He target.

- The target alignment procedure with beam needs to be detailed in an OPS procedure. This also should include a description on how operations will ensure the beam alignment stays within tolerances during beam delivery.

- The experimenters have a plan for commissioning the SBS correctors and studying the effect of the stray field on beam delivery. A formal procedure needs to be developed with operations to eliminate ambiguities and miscommunications between MCC and the Hall A control rooms.

- Develop a solution allowing for centering the beam on target with the required raster pattern along with any specialized targets on the target ladder.

8. What is the status of the specific documentation and procedures (COO, ESAD, RSAD, ERG, OSP's, operation manuals, etc.) to run the experiments?

FINDINGS:

- None

COMMENTS:

- Continue to work with Physics Division Safety Officer (Ed Folts) and ESH Physics Division Liaison (Bert Manzlak) to complete the expected Safety Documentation (COO, ESAD, RSAD, ERG, OSPs and LOSP).

RECOMMENDATIONS:

- Have a physics liaison assigned and complete full set of safety documents (COO, ERG, ESAD, RSAD) for E12-09-016.

- Identify necessary work control documents required (Operational Safety Procedure), using the laboratory's format found in Chapter 3310 Operational Safety Procedure (OSP) 3310 Operational Safety Procedure (OSP) Program
  https://www.jlab.org/ehs/ehsmanual/manual/3310.htm
  Chapter 6410 Appendix T1 Laser Operational Safety Procedure (LOSP)
  https://www.jlab.org/ehs/ehsmanual/6410T1.htm

Agenda

Thursday Morning		
8:00	*Closed Session*	(20)
8:20	Remarks from Chair and Charge	H. Gao (10)
8:30	Experiment Overview (pdf)	Bogdan Wojtsekhowski (10+10)
8:50	**Charge Item 1**: Design report (non-target) including modifications to beamline, SBS and detectors to accommodate polarized target (ppt , pdf)	Robin Wines (20+10)
9:20	**Charge Items 2, 3**: Target overview, configuration, performance requirement. Subsystems, including cells and lasers, lessons learned and timeline (pdf)	Gordon Cates (40+20)
10:20	**Break**	(15)
10:35	**Charge Item 2 (target)**: Integrated System-Target Design and Fabrication (ppt , pdf) Supplemental: Assembly and Drawings (link in pdf) (xls , pdf)	Bert Metzger (20+10)
11:05	**Charge Item 3**: Effect of Spectrometer fields, Magnetic Shielding and Simulation (pdf)	Vladimir Nelyubin (20+10)
11:35	**Charge Item 2 (non-target)**: Status of the equipment required for this experiment. Completion, commissioning. (ppt , pdf)	Mark Jones (30+10)
12:15	**Lunch**	(45)
Afternoon Session		
13:00	**Charge Items 1, 2, 4**: Equipment ownership, maintenance, control. Installation plans, timeline (pdf)	Jessie Butler (20+10)
13:30	**Charge Item 5**: Data Analysis & Simulation, Software Status, time to 1st publication (pdf)	Andrew Puckett (20+10)
14:00	**Charge Item 6**: Radiation and Shielding (pdf)	Eric Fuchey (20+10)
14:30	**Charge Item 7**: Beam Commissioning and Machine Protections Systems (pdf)	David Flay (20+10)
15:00	**Charge Item 4**: Personpower and responsibilities (ppt , pdf)	Todd Averett (20+10)

15:30	**Charge Item 8**: Safety Documents, target and non-target (in previous pdf)	Todd Averett (15+5)
15:50	**Break**	(10)
16:00	Closed Session	(90)
17:30	**Closeout**	