Experimental Readiness Review for E12-09-109 (Proton Form Factor Ratio, GEp/GMp)
Date: April 2023, CC Rm L102

Review Committee:

- Nathan Baltzell (Computing Resources)
- Pavel Degtiarenko (Radiation)
- Sergey Furletov (GEM)
- William Gu (Electronics/DAQ/Slow Controls)
- Dave Meekins (Target)
- Bill Rainey (EHS)
- Yves Roblin (Beam Operation)
- Alexander Somov (Trigger)
- Stepan Stepanyan (Calorimeter+Coordinate Detector) Chair
- Simon Taylor (Simulations and data analysis)
- Beni Zihlmann (Polarimeter)

Observers:
Ed Folts – JLab Physics Division
Douglas Higinbotham – JLab Physics Division
Keith Welch – Radiation Control Group

Experiment E12-09-109, *Large Acceptance Proton Form Factor Ratio Measurement up to 12 GeV2 using Recoil Polarization Method*, has been approved for 45 PAC days. The experiment will measure the polarization transfer to the recoiling proton in the elastic scattering of longitudinally polarized electrons with energies up to 11 GeV from a 30 cm long liquid hydrogen target, $H(\vec{e}p \rightarrow e'\vec{p})$. It will make use of the existing Super BigBite Spectrometer (SBS) with additional GEM chambers for the polarimeter and a hadron calorimeter as a proton arm. Scattered electrons will be detected in a lead-glass calorimeter, equipped with a coordinate detector. Other standard Hall-A equipment, beamline, liquid hydrogen target, and shielding will be used as is or with some modifications.

The review committee thanks the GEp collaboration for preparing the presentations, providing ancillary information, and patiently answering our questions during the review. 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. *What is the status of the equipment required for this experiment towards operation? What is the completion/commissioning schedule and tasks? This should include:*
   a. Target and scattering chamber configuration and requirements.

   Findings: The target utilized will be the standard pivot target with 30 cm cell. A new cell block and 30 cm cell will be required and will need to be fabricated. Two flow diverter configurations have been modeled. Both will provide sufficient transverse flow to prevent excessive boiling as each design will ensure less than 5% boiling at 50 μA. The windsock flow diverter is proposed for azimuthal symmetry. These components are expected to be fabricated by the end of the calendar year (2023) and tested.

   The scattering chamber will also be the standard. A custom exit snout will be required. The exit will be diff pumped to provide isolation from the downstream vacuum space. The snout has been leak tested by the vendor.

   Tasks to complete the target work are defined, and the target system is on schedule to be ready for the run in August of 2024.

   Comments:

   - Collaboration should approve the final cell design by mid-May. This includes cell thickness and flow diverter geometry.
   - Test fit and a leak test of the new exit snout should be performed while the chamber is accessible.

   Recommendation: None~~.~~

   b. GEMs and associated electronics

   Findings: Configuration for the SBS GEM tracker system is defined - 8 GEMs in front of the analyzer and 8 in the back. All the modules but two are ready. Most have been used in previous experiments. Two modules are currently being fabricated at UVA. The operations of detectors are well understood. The observed loss of efficiency due to the voltage divider will be addressed by using the individual power supply for GEM layers. Seven new HV boars and three CAEN crates will be ordered for parallel-path HV supply on every layer. Order of new electronics is scheduled to be out in a month, and it is expected be delivered before the run starts. Existing gas systems and readout electronics in SBS will be used.

   Comments:
   - Provide details of the power consumption per channel at the nominal running conditions and consistency with HV module specs.
   - Power dissipation in the detectors, what is the estimated power dumped on GEMs? Can this be a problem?

Recommendations: None.

c. Proton Polarimeter

Findings: A single analyzer configuration is chosen for proton polarimetry. There will be 8 layers of GEM tracker in front and 8 layers in the back of the CH2 analyzer. The front tracker will define the proton kinematics and the vertex and define the incident trajectory for secondary scattering. If the tracking system is on time, the polarimeter will be ready for the experiment.

Comments: Further continue exploring use of the HCAL to select high energy protons that could potentially boost the analyzing power as much as 30%.

Recommendations: None.

d. Electromagnetic Calorimeter and associated electronics. Please discuss also the plan for lead-glass annealing during data taking and the status towards its realization.

Findings: The electromagnetic calorimeter (ECAL) consists of lead-glass modules assembled into 3x3 super-modules. All (184) super-modules are ready. Due to space constraints, the calorimeter will be assembled in the hall. The components of the calorimeter platform and frame are on hand. The assembly of the platform and the frame will be done in May. The plan is to stack modules in the frame during June-July. The heaters for annealing the modules during the run will be installed after the stacking. According to the presented schedule, ECAL will be ready for beam on time.

Comments:

- The type of the heaters is not defined. The heaters used to test the super module showed non-uniform heating of individual modules in the supermodule. The final heater configuration must be defined soon to test the system's performance using one or two supermodules before the full assembly.
- Since the assembly of supermodules in the frame is scheduled to proceed in parallel with other activities in the hall, collaboration should develop a backup plan in case interferences with other activities will prevent finishing the assembly as planned.
- Careful assessment of the amount of work for the fabrication of cables and how cables will be routed to the electronics must be done.

Recommendations:

- Demonstrate the new heater performance in realistic conditions. Install one of the super modules with heaters in the hall during the upcoming runs and monitor gains (like the test with the 16-channel module).
- Perform thermal simulations to show the heating pattern/load of total power consumptions. The total heat load is estimated at 20 kW max.
- Develop gain monitoring and calibration strategy and procedures.

e. Coordinate Detector and associated electronics.

Findings: CDET is a scintillator hodoscope with wavelength shifting fibers read out maPMTs. Five out six modules are ready, the last one is being commissioned now. The performance of modules, efficiency and the time resolution are within acceptable range. The magnetic shields and light-tightness are still in works and will be retrofitted after the full test in August. The final assembly of modules on the lifting frames and mounting the frames in place is planed during February-August, 2024.

Comment:

- Move the stand-alone simulation into the main GEANT4 module.
- Assess the effect of radiation on the front-end electronics and power supplies.

Recommendations: None.

f. Integration of all the above elements in the DAQ and the slow controls.

Findings: There is a general framework for the integration of detectors on proton and electron arms into the DAQ and slow controls. Very little remains to be done. A rough schedule for the completion of various tasks has been presented. Some systems will be tested during the upcoming experiments.

Comments:

Recommendation: None.

2. Have the specific equipment required by this experiment been demonstrated for readiness to operate and to achieve the scientific goals of the experiment? This includes demonstrating:

a. GEM reconstruction efficiency at high rate.

Findings: GEM reconstruction efficiency has been studied and found to be 70% at the running conditions of GEp, consistent with expectations.

Comments:

Recommendations: None.

b. *Correct estimate of the polarimeter analyzing power (to achieve science goal in the approved beam time) and its FOM.*

Findings: Analyzing power estimate for $p + CH_2$ parametrized from GEp-III data. The FOM of the single analyzer design is 15% lower than original design, but the simplicity of tracking geometry, event topology and external detector constraints should more than offset the loss.

Comments:

Recommendation: None.

3. *Are the responsibilities for carrying out each job identified, and are the manpower and other resources necessary to complete them on time in place?*

Findings: Individual systems provided a work plan and the staffing assigned to complete it. All the tasks (for GEMs, ECAL, CDET, beamline, and installation) are due to finish on August 23, 2024, but subsystems still need to provide a detailed schedule with contingency. The ownership and responsibilities for maintenance and the run-time support for each system have been identified.

Comments: Since part of the work will be done in parallel with running experiments in the hall, subsystems should prepare a plan to mitigate delays in case of interruptions.

Recommendation: Provide a detailed table with the list of remaining tasks, shared responsibilities among collaboration and staff, interdependencies between tasks and order of activities, and time needed to purchase or fabricate missing items (cables, fADCs …).

4. *Has the entire beamline, spectrometers, detector configuration been defined, including ownership, maintenance, and control during beam operations?*

Findings: The beamline, spectrometers, and detector configuration are defined. The ownership and responsibilities for maintenance and the run-time support for each system have been identified.

Comments:

Recommendations: None

5. *What is the data volume expected for this experiment? Would the experiment require large computing resources to process the collected data?*

Findings: The GEp5 DAQ configuration is defined. A raw data volume of 9.4 PB, which includes tape duplication, was presented from an estimated trigger rate of 3.0 kHz and data rate of 1.2 GB/s, which includes a safety margin of 2x over their current best estimates of 600 MB/s at 1.5 kHz. That already includes an expected factor of 3 reduction in rates via improved timing coincidence in the trigger. However, the data volume reduction options, specifically the region of interest readout, still must be studied.

It was shown that Hall A has run previously at 800 MB/s, simultaneously with halls B and D, and scicomp is aware of this projected 1.2 GB/s.

Information on data processing requirements and physics data volume was very limited and based very roughly on previous experience during GMn, while this experiment was presented to expect a factor of few more background rates and include additional GEM/tracking layers

Comments: Provide necessary information to estimate computing resources in terms of CPU hours.

Recommendations: None

6. *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: The SBS online/offline analysis software is based on the standard Hall A analysis framework and uses the ROOT-based online monitoring plots for shift workers. For simulation, the g4sbs package that reproduces observed BB GEM rate and occupancies is used. The simulation and reconstruction software are in a reasonable shape and has been used to estimate expected performance of the detector. The remaining work is in the development of software for ECal and CDet, and for SBS optics.

Based on past Hall-A experience with similar physics measurements, the projected timeline for publication is 2-3 years.

Comments:

- Explore options for using AI algorithms to speed up and improve the reconstruction efficiency of GEM trackers.
- Complete simulation for data rate reduction by reading out only the region of interest in GEMs. Develop/explain the mechanism of readout sparsification.

Recommendations: None.

7. *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 equipment?*

Findings: Radiation levels have been estimated by the radiation control group using 75 μA beam current and have been found acceptable. Now that experiment will run at 50 μA, no additional shielding is required.

Comments: Thermal evaluation of the differential pump window should be done.

Recommendations:

- Dose rate evaluations in the Hall needed, both prompt and from the beam line activation to optimize access procedures and placement of the electronics.
- Estimate radiation levels behind the ECAL where you plan to install LV modules (NINO PS) and other electronics to determine if additional shielding is needed.

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

Findings: The experiment requires a polarized electron beam with a current of up to 50 μA (a decrease from the initial request of 75 μA due to a scheduling change). It will be running concurrently with Hall C and Hall B. The Wien angle will be adjusted to maximize the polarization in both Hall A and Hall B. As a result, Hall A will get a longitudinally polarized beam with polarization ranging from 83% to 87 % depending on the pass (3, 4 or 5).

Procedures for beam delivery, raster, SBS dipole and corrector setup, ion chamber, BCM calibrations, beam monitoring, and FSD system are in place and have been used in other Hall-A experiments with similar configurations. Beam commissioning procedures from the Hall-A GMn experiment will be used for GEp. While beam polarization cancels in the ratio measurement, collaboration is planning to do beam polarization measurements using the Hall-A Moller polarimeter to ensure that polarization is high (>80%) and for systematic studies.

Comments:

- Since the commissioning and setup time for the Moller polarimeter is significant, collaboration should consider dropping or reducing the beam polarization measurements at lower energies where the allotted beamtime is short. Instead, find other ways to estimate the polarization, for example, using measurements in other halls.
- For pass 3 and pass 4, the polarization will be sensitive to energy fluctuations of the main beam to the order of about 0.5 degree/10^{-4}. If a tighter energy fluctuation control is required, it is possible to request the use of the fast feedback system which would keep it within a few 10^{-5}.

Recommendation: None

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

Findings: The correct safety documentation: RSAD, ESAD, COO and OSPs have been identified and resources committed to complete these documents.

Comments: Two items appear missing in the version of the ESAD made available to the review team:

- The ESAD discussion of general hazards does not recognize work at heights. Discussions of the experimental apparatus indicated elevated work surfaces and the planned use of ladders.
- The ESAD also discusses several general hazards including electrical and pressure systems but does not discuss the important topic of hazardous energy control.

The discussion of these two items should be placed where appropriate, within the appropriate document(s).

Recommendations: None.

E12-09-109 (GEp/GMp) Readiness Review

Agenda

April 24, 2024

Thursday Morning

8:00	*Closed Session*	(30)
8:15	Remarks from Chair and Charge	Chair (10)
8:20	**Charge item 1**: Experiment plan as approved by PAC47 ([4])	Bogdan Wojtsekhowski (15+10)
8:35	**Charge Item 1, 4**: Design report including modifications to beamline, SBS and detectors([5])	Robin Wines (15+15)
9:05	**Charge Items 1b**: GEMs and associated electronics; ([6]).	Holly Szumila-Vance (15+15)
9:35	**Charge Items 1c, 2a, 2b, and 6**: The simulation and data analysis software status for the experiment, GEM reconstruction efficiency at high rate (PDF)	Andrew Puckett (25+25)
10:25	**Break**	
10:40	**Charge Item 1d**: ECAL calorimeter (**pdf**)	Donald Jones (20+20)
11:20	**Charge Item 1f and 5**: GEp experiment DAQ and Slow Controls (**pdf**)	Alex Camsonne (10+10)
11:40	**Charge Item 1f**: Trigger based on fADC ([7])	Ben Raydo (10+10)
12:00		

Afternoon

13:00	**Charge Item 7, 9**: RSAD, Safety Documents for GEp ([8])	Evaristo Cisbani (10+10)
13:20	**Charge Item 1e**: Coordinate Detector ([**pdf**])	Peter Monaghan (15+10)
13:45	**Charge Item 1a**: Target and scattering chamber configuration ([9])	S. Covrig Dusa (10+10)
14:05	**Charge Item 4**: Installation ([10])	Jessie Butler (15+15)
14:35	**Break**	
14:50	**Charge Item 8**: The beam commissioning procedures and polarimetry (pdf)	William Henry (10+10)
15:10	**Charge Item 3**: The responsibilities, manpower and other resources ([**pdf**])	Mark Jones (10+10)