## A1n/d2n ERR – Reply to Committee Final Report

A1n/d2n collaboration

May 2018

We thank the ERR committee for carefully reviewing the status of our preparation for the running of the 12 GeV A1n and d2n experiments in Hall C. In the following we will provide answers to the ERR final report dated April 4, 2018, with a focus on recommendations and comments that we feel need addressed.

The font/color coding is as follows:

black italic: committee charges c

black: committee comments and recommendations as in the final report

blue 4: answers

red: answers (work in progress)

***Charge Item 1.*** *What are the running conditions for both experiments? Please state clearly the maximum current being used and the target dimensions.*

Findings:

Both experiments will use an optically polarized 3He gas target 40 cm in length, with an approximate gas density of 12 amagat (amg). Additional measurements will be made using an array of solid targets and a “reference” gas cell filled alternately with vacuum, H2, 3He, and N2. The maximum beam current for the gas targets shall be 30 uA, and up to 60 uA for the solid targets. Both experiments will utilize the maximum beam energy available, assumed to be ≥ 10.5 GeV, with some ancillary measurements made at 2.2 GeV. As the experiments do not share kinematic settings, they cannot take data in parallel with one another. The experiments will be arranged to minimize the number of spectrometer movements. In general, the luminosity from this configuration will be significantly better than that in the original PAC30 proposals, but lower than the PAC36 updates. To compensate, the A1n experiment will reduce its proposed 2.2 GeV beam time in favor of additional statistics at its highest kinematic settings.

Comments:

1. Is it safe to do only one transverse asymmetry measurement on the ∆ resonance in Fall 2019? That is, is it safe to assume nothing in the machine will change for the Spring 2020 run?

Answer: We believe this applies to both Delta resonance and the 3He elastic runs. Yes it is necessary to repeat these measurement with 1-pass (see below) beam in the Spring 2020 run, given that there will be significant change to the target during the 2019 X’mas shutdown (target rotation and cell change).

2. Depending on the schedule, there could be a conflict between the 1-pass calibration runs of A1n and d2n and the experiment in Hall A. Can the elastic and ∆ calibrations be measured at 2-pass rather than 1-pass, without unacceptable penalty?

Answer: We carried out the calculation for both 1- and 2-pass beams. Unfortunately even at the smallest angle of 12.5 degrees, the elastic e-3He cross section drops by factor 1000 from a beam energy of 2.1 to 4.2 GeV, and the asymmetry is also smaller. This makes it impossible to carry out the elastic measurement (for which we need to measure the asymmetry to extract the product of the beam and the target polarizations PbPt, as a cross-check of the Moller and the target polarization measurements). We request 12 PAC hours (3 shifts if using a 50% beam efficiency) of beam time at 1 pass, one time each during both the Fall 2019 and the Spring 2020 run periods to carry out the elastic and the Delta resonance measurements.

In addition the optics calibration must also be done at the 1-pass energy (2-pass is possible but will take much longer time). The total beam time needed for optics calibration is xxx and yyy hours, for the Fall 2019 and Spring 2020 runs, respectively.

We understand this may mean that Hall A cannot run during the same time.

3. The factor 1.15 allocated to account for beam ramps-up, fiducial cuts, etc. seems on the low side. Ramps-up might by themselves already contribute to a 15% overhead, possibly more. Are the periodic pleedthrough measurements accounted for in the run schedule? These might be integrated with only a slight penalty into trip recovery by delaying experimental beam restoration on an occasional basis, perhaps only by tens of seconds.

Answer:

a) the 1.15 factor was used to amplify the calculated statistical error, thus it corresponds to a 30% beam time overhead effectively. We hope this is enough to cover at least the statistical loss due to beam ramp-up. Event loss due to fiducial cuts can be minimized.

b) Re “Periodic bleedthrough measurement”: We will collect data on bleedthrough. Existing data from 12 GeV runs shows up to nA level bleedthrough with the new laser system, and thus will be at the 1E-3 level. We will carry out bleedthrough measurements at the beginning of the run period, and periodic measurements depending on how significant the contamination is (varying from once per run period to possible daily measurements in the worst case). Moller will provide the sign of the bleedthrough amount that can be used for the analysis (and the polarization itself if the bleedthrough is at the percent level).

4. Bearing in mind that solid targets, even cooled to cryogenic temperatures, may be melted by high beam currents. We strongly endorse a thermal analysis to determine the maximum beam current permitted for each target (see Item 2a, Recommendation 3).

Answer: Silviu has carried out thermal analysis of solid targets, this is provided in Appendix C. Meanwhile we note that JLab has plenty of experience utilizing solid targets with a wide range of conditions during the 6 GeV era. Below is a summary of commonly used solid targets that had never had melting problems:

I) carbon foil target: routinely used at up to 60 uA without raster. Our carbon is the same as previous polarized 3He experiments.

We recall that the only targets with melting problem in the past are the PREX 9% r.l. lead target (with low melting point) and the fastener of a 10% r.l. carbon target in Hall C but those are special targets that needed to be babied and we don’t use any of those.

***Charge Item 2:*** *What is the operational status/performance requirements of the equipment needed by the experiments. Precisely:*

a) 3He target – Provide the targets configuration needed, performance requirements and status

Findings:

The primary target is a polarized 3He target 40 cm in length and approximate density of 12 amg, with an average in-­‐beam polarization of 55 – 60% at a maximum current of 30 uA and ramp rate of 0.5 uA/s. The required target polarization uncertainty is ΔP/P <= 3%, and density uncertainty Δ(rho)/(rho)<= 2%. An upgraded, “Stage I” convection cell design shall be used for the experiments, comprising a glass (not metal) target cell connected to a glass optical-pumping chamber via two glass tubes. The in-beam lifetime of a cell is expected to be about 1 month. A single, prototype cell has been constructed and successfully tested. Five additional cells are

currently under production, and up to five more may be procured in the future. Sufficient 3He gas is on hand. The majority of the optical pumping equipment (lasers, magnets, etc) and electronics for target polarimetry (AFP, pNMR, Rb-­‐EPR) is also on hand, along with spares.

Comments:

1. The decision to utilize the stage-I target upgrade design for these experiments is sound and should henceforth be considered “frozen”. We remind the collaboration that any substantive changes to the target design shall require approval from JLab management.

Answer: We understand and appreciate the reminder.

2. While synchrotron radiation was negligible in the 6 GeV era, it may be far more problematic at 12 GeV. Because a vertical bending magnet is used to bring the beam to the HMS/SHMS level, low-energy polarized photons will be shined on the target cell with a different enregy spectrum from the usual Bremsstrahlung created off beam line windows. Can Jay Benesch provide the energy spectrum for a 10.5 GeV beam and its polarization? Then can its possible influence on target heating, radiation and depolarization be assessed?

Answer: Jay has done a calculation using the code (by Valeri Lebedev) to estimate the energy loss due to SR in the chicane. The results are: 15.8 keV and under half a watt (for 30uA beam), for both magnets. The vertical fans of SR will be collimated by the 22 mm inside-height beam pipe through the unpowered, 1m long horizontal bend dipole which follows. After taking into account the 30 mm ID, 4 m beam pipe which follows the magnets, about 300mW will get to the target, which is far less than the lasers which polarize it (90W).

3. Mechanical vibrations on the Hall C pivot are not known, nor there is a plan to measure/address them. They may preclude the possibility of water calibration of the NMR directly in the hall. Should they be addressed in order to retain the option of doing water calibration of the NMR directly in the hall?

Answer: Water calibration for the NMR is optional. NMR will be calibrated by both EPR and pulsed NMR in the Hall. Water calibration can be done in the target lab before running to provide a cross check of EPR. (EPR would not change from the target lab to the Hall because it depends only on temperature, which is kept the same between the two places.)

4. If the beam position fast feedback temporarily fails, what could be the amplitude of the 60 Hz beam position fluctuation on the target? What about slow beam drift? is it acceptable, remembering that the beam position may not be exactly at the center of the target, that the raster is larger than at 6 GeV while the cell diameter remains the same, and that the beam characteristic size may sometimes reach 300 microns or more? This is in the context of possibly having significant beam halo impinging on the target walls, damaging the target or at least increasing significantly the radiation damage to the cell (including the pumping chamber). Experience with Hall D feedback is that it is often found to be off, letting the beam wander at the several mm level. Will FFB be interlocked with FSD?

Answer:

Re: slow beam drift:

Fast feedback (FFB) locks the position at entrance and exit to the hall arc. Slow feedback locks the position on the BPMs on the diagnostic girder. Full span variation on the A and C BPMs were measured to be +-40 microns in Y and +-25 microns in X around the set points in the slow lock in late April (see <https://logbooks.jlab.org/entry/3574638>).

Re: amplitude of the 60 Hz beam position fluctuation on the target:

BPMs are beam-synced and thus can not see 60-Hz fluctuation. The 60-Hz fluctuation in beam position was measured only in Hall D (ask AD), but no data is available for Hall C. We will measure this in Hall C in August 2018 (takes only a minute).

Re: Will FFB be interlocked with FSD?

FFB will not be locked to FSD; only beam loss indicators will. If the beam wanders enough due to hit the side of the cell due to 60 Hz, ion chambers will trip off the beams.

Re: possible beam hitting target walls and damaging the target:

With +-40 microns in Y and +-25 microns in X slow variations, a 400 micron sigma in beam size will be a problem (full halo size will be 8mm for a 3mm raster).

(a) One possible solution is to use two carbon hole targets at z=0 and -6.7cm (but it may be difficult to see the second hole) – work in progress. double holes at z=-6.7, +6.7cm will be much better. Need to make sure we can see both holes at 30 deg (with HMS 10cm y-targ acceptance).

(b) Beam steering is another problem, (Jay) it may take a while to figure out the exact steering to get through both holes.

(c) Q: can we give up the single-foil target? (single foil is used not just for optics but also for elastic carbon x-section).

Recommendations:

1. Complete a detailed thermal and stress analysis of the target entrance and exit windows under the anticipated maximum beam current and ramp rates.

Answer: Preliminary thermal and stress analysis has been performed by Silviu Covrig. Please see Appendix A.

2. Complete an analysis of the local reduction of 3He density along the path of the beam.

Answer: Preliminary thermal and stress analysis has been performed by Silviu Covrig. Please see Appendix A.

3. Provide lists of solid targets and corresponding maximum currents.

Answer – provide a summary table of target/current/raster combinations, and ideally also a sketch of the target ladder (XZ, JP).

– 30 or 60uA? – Brad?

4. Provide a list of the work remaining to prepare the 3He target for installation in Hall C, and an estimate for completion. A highly detailed, day-to-day list is **not** necessary.

Answer:

 – JP (need to include: W&M’s kappa0 is almost done, UVa’s kappa0 -- measurements will be done around September and then need to analyze the data, 2-3 months, so by end of 2018 is a reasonable estimate.)

 -- cells (update from Gordon 4/24): testing windows now but need to wait for new regulators

b) Laser system – *Provide the laser system configuration needed, the operation and safety (including documentation) and status.*

Findings:

The polarized target will utilize narrow-­‐width diode laser arrays system similar to those utilized in the most recent Hall A experiments. New lasers and optical fibers are on hand, and will provide more power to the target than in the past. Conduit for the optical fibers has been installed in Hall C.

Comments:

1. An approved Laser Operational Procedure (LOSP) is required prior to operation in Hall C.

Answer: The target OSP along with the LOSP have already been completed and submitted for approval.

2. How will the laser power density on the pumping cell compare to the 6 GeV design? To avoid more frequent target changes, efforts should be made to maintain or even lower the power density, paying mind to the increased volume of the pumping cell, and its (presumed) thicker walls.

Answer: pumping power now is 90W narrow-band laser which is the same as the 6 GeV running. Pumping chamber wall thickness should be the same, and the volume in fact increased from 1.5L (6 GeV) to 3L (12 GeV stage-I)

*c) Moller and Compton beam polarimeters - Demonstrate that polarimetry is expected to provide a precision of ΔPb/Pb < 1%. If the above elements are not already operational, what are the completion/commissioning schedules, tasks and user commitment?*

Findings:

A more relaxed requirement for the beam polarization uncertainty, ΔPb/Pb < 2%, was presented at the ERR. This is expected to be provided by semi-frequent Møller polarimetry measurements alone, as the workforce to commission and operate the Compton polarimeter will not be available (contrary to what is presented in the experimental proposals). A 12 GeV upgrade to the Hall C Møller polarimeter, along with an anticipated error budget, was presented. While the Møller has yet to be utilized since the upgrade, there are plans to commission it during the fall 2018 SIDIS run.

Comments:

1. The review committee feels that, without Compton polarimetry, achieving ΔPb/Pb<2%, will be challenging. If the Compton is truly off the table, alternative online methods for monitoring the short-term stability of beam polarization in the hall should be pursued.

Answer: 3% – Dave

2. Commissioning of the Møller polarimeter during the fall 2018 beam period is critical, and should receive high priority.

Answer: We fully agree. Moller will be used at least a few times in the Fall 2018 run. We (Dave) will make sure this happens. (test cooldown unfortunately did not happen in Spring 2018).

Recommendation:

Provide the maximum value of the beam polarization uncertainty that can be tolerated by each experiment, and demonstrate how this will be achieved.

Answer:

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

Findings:

Field gradients at the target pivot, after correction by an existing compensation-­‐coil design, are believed to be marginally acceptable for both the target’s average polarization and the loss incurred during AFP reversals of the polarization. A TOSCA model of the pivot area and with all spectrometer configurations is currently underway. This model, bolstered by a field map of the pivot area, will guide the scheme for further reduction of the field gradients.

Comments:

The committee endorses a plan to perform an in-­‐situ field map on the target pivot prior to the execution of the experiments.

Recommendation:

The TOSCA field maps with all salient features of the Hall C target pivot should be completed and a scheme to reduce the resulting target field gradients to acceptable levels should be demonstrated.

Answer: probably attach a summary as Appendix B

We find it is not necessary to address review comments and recommendations to charge items 4 and 5

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

Findings:

Ownership of the beam line components is shared between the Accelerator, Engineering, and Physics divisions and is detailed in a document link provided at the review. Hall A/C and Physics Division Support Groups have responsibilities for the detector and spectrometer systems. The experimental collaborations are responsible for the installation (with Hall C support) and operation of the polarized 3He target.

***Charge Item 5.*** *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:

With the exception of the Compton polarimeter (see item 2c), the collaborations did a good job identifying the workforce and other resources necessary to stage, operate, and analyze the experiments. If it is determined that the Compton is necessary to meet the requirements of the experiments, additional workforce (at least in part from the collaborations) will be required.

***Charge Item 6.*** *Are the beam commissioning procedures and machine protection systems sufficiently defined for this stage?*

Findings:

Jay Benesch provided a series of weblinks describing Accelerator procedures for delivering beam to Hall C, measurements of the beam energy, and set-­‐up procedures for the fast raster and ion chambers. He also reported that multiple FSD inputs are available for use with the polarized target. To avoid beam hot spots associated with a square raster pattern, the experiments will utilize a circular, fast raster with a diameter of 6 mm. This will reduce the power density on the cell’s entrance and exit windows to approximately that of the 6 GeV era experiments.

Comments:

1. Given that the target cell diameter is unchanged from the 6 GeV design, while the beam raster and intrinsic size are increasing, the cell seems somewhat more prone to damage from beam mis-steering. Careful consideration should be given to incorporating some beam position feedback into an FSD. The tritium experiments accomplish this with a combination of tight collimators upstream of the target and ion chambers surrounding it.

Answer: (Jay) As discussed above, the three one-meter dipoles provide a 22 mm square collimator of sorts ending 4.3 m upstream of the pivot. An additional collimator could be placed at the center of the superharp girder – need to followup on this, Dave/Jay? what id do we need? (target is 19mm id, maybe a 16mm id collimator – TBD? to remove the beam halo. z for superharp girder centers at about 200cm upstream from the pivot.) In the pdf attached (Appendix D) one sees ~25 cm (item 10) in the middle of the girder which could have a copper or W90Cu10 collimator placed in the spool piece. Halo wandering into that would certainly trip target ion chambers.

JP: the planned target-related FSD are, target motion, cooling jets and raster. There is a concern of how to protect against beam mis-steering: Ion chamber is the standard one. One possibility to be safer than that would be using a collimator (but the one used for tritium target will not work for us because we don’t have a metal scattering chamber, a heavy collimator will be extremely difficult to mount). We can talk to people (safety and people used tritium collimator) then decide.

the other big item is the trip rate and the max current. Silviu will calculate the heat stress part, and we need jay to address the trip rate requirement.

2. It is understood that the beam energy fluctuations should be well controlled by the time the experiment runs. Nevertheless, what fluctuation is tolerable for the two experiments, keeping in mind that it will be monitored? For example, does a 10 MeV fluctuation need to be corrected, e.g. for kinematics determination purpose, or can it be ignored in the analysis? (We understand that it will be corrected for beam polarimetry, so there is no need to address this aspect in the reply.)

Answer: A good knowledge of the beam energy fluctuation is important for d2n. A fluctuation at the 10-3 level can be tolerated by the experiment. The beam energy fluctuation is less an issue for A1n.

3. Is the requirement that the beam characteristic stays below 300 um critical for the target safety? If so, should periodic harp scans be scheduled and accounted in the beam time request?

Answer:

A beam size larger than 300 microns will be a problem. We are pursuing a few options to protect the target from the possible large beam halo and mis-steering. Therefore we will carry out periodic harp scans to check the beam size. It is worth noting that such checks are part of the routine procedure after beam optics changes and extended downs. And it is usually a fast procedure so should not impact the beam time request.

Recommendations:

None. The recommendation presented at the closeout session to provide a more detailed response to this charge item is rescinded.

We find it is not necessary to address review comments and recommendations to charge items 7 through 9

***Charge Item 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 hall equipment?*

Findings:

Simulations were made using the Monte Carlo FLUKA package to estimate the radiation levels expected from a 30 uA, 11 GeV beam on a 30 cm long, 12 amg 3He target. A total of 1700 beam hours were simulated and the levels at the site boundary were found to be only 6% of JLab’s annual budget. The simulations also indicate that shielding the target electronics with a combination of lead, plastic, and steel, will reduce the neutron equivalent dose to less than 1011 MeV-­‐neutron-­‐equivalent, about two orders of magnitude below levels where electronic failures occur.

Comments:

The committee feels that the collaboration has taken this charge item seriously and has done an admirable job addressing it.

***Charge Item 8.*** *Has readiness for expedient analysis of the data been demonstrated? What is the projected timeline for the first publication?*

Findings:

Both collaborations plan to provide three graduate students for data analysis. Target operation and analysis will be shared between the collaborations. The A1n experiment, which relies only on the measurement of asymmetries is expected to be the more expedient analysis. An 18-­‐ month timeline to the first publication was presented. The d2n/g2n experiment requires extracting polarized cross sections from the data, and so will be somewhat more difficult. Here again an 18-­‐month timeline to the first publication was presented.

Comments:

Because both experiments are essentially extensions of 6 GeV measurements and because the Hall C spectrometer systems should be well understood by the time of the polarized 3He experiments, the data analysis of the experiments should progress in a relatively smooth manner.

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

Findings:

Drafts of the COO and ESAD were available for the review. Safety and operation documents for the Møller polarimeter were also available, as was an OSP for the polarized 3He target (although the related THA was not). Nor were RSAD or ERG drafts made available, either.

Comments:

At this stage of the game, the collaborations appear to be in pretty decent shape, but the reviewers remind them that all necessary paperwork must be completed before the experiments can commence.

Appendix A

polarized 3He target thermal stress study

Fig.1 Benchmarking the simulation: Simulation for the 6 GeV transversity running condition – 40cm target, 15uA beam, 3x3mm square raster, ramping rate 0.5uA/sec or 15uA/30sec. Simulated temperature agree with available data to within 5 degrees. (ths is a screenshot from 5/15/18 meeting, better figure will be provided later).



Appendix B

solid (carbon foil) target thermal stress study

Appendix C

target/SHMS field study

Appendix D

link to Jay’s drawing for the collimator-on-girder illustration will be provided here

Appendix E

link to target drawings will be provided here