NPS ERR Report Responses

Charge #1

Comments:

- Number of settings presented in the first talk were different from the number of settings shown in the radiation budget tables presented in the second talk.

NPS Collaboration response: the settings in the first talk are based on the tables presented in the experiment proposals, while the settings in the radiation budget may be combined and/or also list calibration targets.

  - E12-13-010/007: the number of settings in the first talk is the correct number of settings for LH2 target. The number of settings in the radiation budget table in the second talk also lists the calibration targets (Al, C), which are part of the experiment as well. These are indicated in row "cryotarget material".
  - E12-14-003/005: the number of settings in the first talk is different from the RadCon table due to combining. All settings are taken into account. RadCon set. 3/4 has beam current 45 uA which is a sum for 4B and 4C. RadCon set. 5/6 has 80/10 hours which is a sum for 4D and 4E both have current 60 uA. RadCon set. 11/12 has 180/15 hours which is a sum for 5C, 5D, and 5E, all have current 60 uA.

- It was not clear how the quoted luminosities of 10E38 cm^{-2} sec^{-1} for electron runs and 1.5x10E38 cm^{-2} sec^{-1} for photon run group experiments were calculated. Neither number can be confirmed from the numbers (beam current and target thicknesses) presented in the radiation budget tables.

NPS Collaboration response: we provide below Table 1 showing the luminosities for the photon experiments E12-14-003/005. The quoted electron-proton luminosities are consistent with the highest luminosities expected at 11 GeV. For details of the calculation please refer to section 4.3 in the PR12-14-003 proposal.

Kin	$\dot{N}_{RCS}$ $[\mu A^{-1} h^{-1}]$	N_{RCS}	δ_{stat}	I_{beam} $[\mu A]$	t [h]	$\mathcal{L}_{e-p}$ 10^{37}	$\mathcal{L}_{\gamma-p}$ 10^{36}	$\mathcal{L}_{e-N}$ 10^{37}	$\mathcal{L}_{\gamma-N}$ 10^{36}
4A	15.0	1500	0.05	5	20	1.35	1.08	3.0	2.37
4B	6.0	1300	0.05	15	20	4.1	3.24	8.9	7.11
4C	3.0	1800	0.05	30	20	8.2	6.48	17.8	14.2
4D	1.5	2500	0.05	60	30	16.4	13.0	35.6	28.4
4E	0.7	2000	0.08	60	50	16.4	13.0	35.6	28.4
5A	9.0	2400	0.05	20	15	5.5	4.32	11.9	9.47
5B	3.0	1900	0.05	30	20	8.2	6.48	17.8	14.2
5C	1.6	1800	0.05	60	20	16.4	13.0	35.6	28.4
5D	1.0	2400	0.05	60	40	16.4	13.0	35.6	28.4
5E	0.3	2200	0.08	60	120	16.4	13.0	35.6	28.4

Table 1: RCS event rate, the total number of required events for a given statistical precision, the proposed beam current and the total beam-time for each kinematic point. Also shown are the electron-proton luminosity, equivalent photon-proton luminosity, as well as the electron-nucleon and equivalent electron-nucleon luminosities.

Recommendations:

- While based on the presented NPS construction schedule and presumed time for installation it is not likely that any of the NPS run groups will be scheduled to run before the fall of 2021, it is recommended to draft a run plan for individual run groups. The order of running of different settings will matter from a radiation point of view as activation of detector components will define the time needed for switching from one setting to another (see also recommendation for Charge 7). This will directly affect beam time scheduling, floor time vs. beam run time. Priorities between the settings of individual experiments must be defined, as possibly longer changeover between settings may not allow running of every setting.

NPS Collaboration response: We provide the ordering of settings for the two run groups in Table 2 and Table 3. For the electron run group settings are ordered from high to low beam energy and from largest to smallest calorimeter angle within each of these settings. The photon run group ordering is the reverse and goes from low to high energy as calorimeter angles are generally larger and radiation impact is smaller. These orderings are beneficial from radiation point of view as there will be time for components to recover during beam energy changes.

Setting	NPS location	NPS angle (deg)	D_{magnet} (m)	$D_{calorimeter}$ (m)	Magnet angle (deg)	Beam energies (GeV)	Beam current (uA)	Time (hours)
7	SHMS right	21.7	1.6	3.0	5.5	11	28.0	48
11	SHMS right	19.8	1.6	3.0	5.5	11	28.0	120
12F	SHMS right	17.2	1.6	6.0	4.0 or 5.5	11	28.0	240
8E	SHMS right	16.6	1.6	3.0	5.5	11	28.0	120
3B	SHMS right	16.2	1.6	3.0	5.5	11	28.0	96
5C	SHMS right	12.4	1.6	3.0	5.5	11	28.0	72
15A	SHMS right	10.6	1.6	4.0	4.0 or 5.5	11	50.0	24
17D	SHMS right	7.9	1.6	3.0	5.5	11	50.0	120
13	SHMS right	6.3	1.6	6.0	4.0	11	11.0	24
16	SHMS right	6.3	1.6	6.0	4.0	11	11.0	24
6	SHMS right	20.2	1.6	3.0	5.5	8.8	28.0	72
10	SHMS right	17.8	1.6	3.0	5.5	8.8	28.0	24
2	SHMS right	14.7	1.6	3.0	5.5	8.8	28.0	96
4	SHMS right	10.3	1.6	4.0	4.0 or 5.5	8.8	50.0	24
14	SHMS right	9.2	1.6	4.0	4.0 or 5.5	8.8	5.0	24
9	SHMS right	13.8	1.6	3.0	5.5	6.6	28.0	120
1	SHMS right	11.7	1.6	3.0	5.5	6.6	28.0	24

Table 2: Ordering of settings for E12-13-010 and E12-13-007. Numbers correspond to E12-13-010 settings and letters to E12-13-007 settings (c.f. table III in the proposals). Calibration runs are included and are relatively short, e.g 10% of each setting time for dummy target runs. There are no priorities between the experiments. The magnet rotates about the target center. The magnet angle is defined with respect to the NPS angle (NPS Angle - Magnet angle = magnet angle to beamline). The magnet angle may have two angle settings, 4.0˚ or 5.5˚. The magnet does not have to be rotated back to 4.0˚ about the center point of the target if the NPS angle AND detector location are larger than the minimum.

Setting	NPS location	NPS angle (deg)	D_{magnet} (m)	$D_{calorimeter}$ (m)	Magnet angle (deg)	Beam energy (GeV)	Beam current (uA)	Time (hours)
4A	SHMS right	14.2	1.6	9.0	4.0 or 5.5	8.8	5	20
4B	SHMS right	17.9	1.6	7.0	4.0 or 5.5	8.8	15	20
4C	SHMS right	22.5	1.6	5.0	4.0 or 5.5	8.8	30	20
5A	SHMS right	11.0	1.6	11.0	4.0 or 5.5	11.0	20	15
5B	SHMS right	13.8	1.6	8.0	4.0 or 5.5	11.0	30	20
5C	SHMS right	16.9	1.6	7.5	4.0 or 5.5	11.0	60	20
5D	SHMS right	19.7	1.6	6.0	4.0 or 5.5	11.0	60	40
4E	SHMS left	34.0	1.4	3.0	5.5	8.8	60	50
5E	SHMS left	29.9	1.4	3.3	5.5	11.0	60	120
4D	SHMS left	26.9	1.4	3.5	5.5	8.8	60	30

Table 3: There are no priorities between E12-14-003 and E12-14-005 as the pion part is supposed to run parasitically as, in fact, was done in the previous WACS experiments. Calibration runs are included and are relatively short (5 hours each time). The magnet rotates about the target center. The magnet angle is defined with respect to the NPS angle (NPS Angle - Magnet angle = magnet angle to beamline). The magnet angle may have two angle settings, 4.0˚ or 5.5˚. The magnet does not have to be rotated back to 4.0˚ about the center point of the target if the NPS angle AND detector location are larger than the minimum.

Charge #2

Comments:

- for 2a (magnet) – Although there are power supplies that can be used for both coils of the magnet, it is advised to identify exactly which power supplies will be used early on. Some of existing (mentioned) power supplies have been reserved for other magnets/experiments

Recommendations:

- *for 2a (magnet)* – The test of the magnet in the hall to full current must be scheduled. It will require resources for installation, connecting to the power and LCW. As was discussed at the review it will be a month or more to complete this work. Therefore, it must be scheduled beforehand as with installations and running of the ongoing experiments such test will become challenging.

➢ **NPS Collaboration response:** This test will be scheduled for summer/fall 2020 when a month or more will be available to complete this work.

- *for 2a (magnet)* – Question of the high pressure LCW in the hall was not clear, operating parameters of the magnet must be provided as regulation of the LCW pressure for the magnet will be needed.

➢ **NPS Collaboration response:** Table 4 lists the magnet operating parameters in Hall C.

Description	Units	Value
Field Central	T	0.52
Effective Field length	m	1.33
Current (Max)	A	990
Resistance (at operating temp)	Ohms	0.115
Voltage (Max current)	V	114
LCW flow rate at 120 psi dif. pressure	GPM	14
LCW Pressure (to obtain LCW flow)	Psig	130
Max Pressure in Hall C (+/- 20psig)	Psig	260
Return Pressure in Hall C (+/- 20 psig)	Psig	80
Temp Rise at full current and LCW flow	C	Calculated value =30
Power	kW	113

Weight	Lbf.	33,400
Conductor	mm	Luvata #6888 18x12
Water diameter	mm	8
# turns per pancake		15
Total #turns in all 8 pancakes		120
Corrector Coil (x2)		
Current (Max)	A	520
Resistance/coil (at operating temp)	Ohms	0.04
Voltage (operating 2 coils in series)	V	42
Voltage Max current (one coil)	V	21
LCW flow rate per coil (operating in parallel)	GPM	3
LCW Pressure (to obtain LCW flow)	Psig	130
Max Pressure in Hall C (+/- 20psig)	Psig	260
Return Pressure in Hall C (+/- 20 psig)	Psig	80
Temp Rise at full current and LCW flow	C	15
Power	kW	1.44
Conductor	mm	Luvata #8195 9x8
Water diameter	mm	4.775
# turns/coil		72

T*able 4: NPS Sweeper Magnet & LCW in Hall C*

- *for 2b (Calorimeter)* – Collaboration has to perform radiation hardness test of dividers and LED, perhaps can be done together with radiation hardness tests of crystals.

➢ **NPS Collaboration response:** Radiation hardness tests of the dividers have been performed during the Qweak experiment in Hall C. Doses were monitored with radiation badges and divider response tested with LEDs. No radiation damage was observed up to 150 krad. (see "New Photomultiplier Active Base for Hall C Jefferson Lab Lead Tungstate Calorimeter", V. Popov, H. Mkrtchyan, 2012 IEEE NSS/MIC/RTSD, available at: http://www.vsl.cua.edu/cua_phy/images/a/ac/NSS2012_JLAB.pdf). Crystal radiation hardness tests have been performed as part of the quality assurance procedure. Radiation studies are based on a total dose of 100 Gy (10krad). LEDs have been tested as part of our NPS prototype studies. Additional radiation studies of LEDs will be performed at IPN Orsay.

Charge #3

Comments:

- No clear proof to include amplifier with low gain as an active element of the divider was presented.

- **NPS Collaboration response:** MC studies of electromagnetic background of the NPS detector demonstrate that the PMT anode current is relatively large (40 - 110 uA) when the calorimeter is positioned at small angles and operated at high rates. The anode current may exceed the maximum current of 100 uA recommended by Hamamatsu for this type of PMT (R4125). The active base divider (see “New Photomultiplier Active Base for Hall C Jefferson Lab Lead Tungstate Calorimeter”, V. Popov, H. Mkrtchyan, 2012 IEEE NSS/MIC/RTSD, available at: http://www.vsl.cua.edu/cua_phy/images/a/ac/NSS2012_JLAB.pdf) has been developed to reduce the anode current to the level of about 10 uA. The fine tuning of the amplifier gain is being currently performed in collaboration with the Hall D group (Hall D FCAL II project).

- Calorimeter has to cover a wide energy range from 0.5 GeV to 7.6 GeV, but the linearity and resolution have been studied only for energies >3 GeV. Studies of performance must be extended to the full energy range.

- **NPS Collaboration response:** The minimum energy range was limited to about 2.5 GeV by the acceptance of the Hall D tagger hodoscope (the minimum energy of the hodoscope counter is about 25% of the beam energy). The energy resolution of the prototype was found to be in a good agreement with the Hall B HyCal calorimeter in the wide energy range. Energy resolution of the HyCal calorimeter was studied in detail and satisfies NPS requirements. Linearity of the active base divider is being studied in the lab using a laser and LED light sources.

Recommendations:

- Clarify what the threshold energy for individual modules should be for required energy resolution and what the rates of each channel is expected with that thresholds.

- **NPS Collaboration response:** There will be no threshold for individual module. Only a threshold on 2x2 or 3x3 clusters will be set. Modules belonging to a cluster above threshold will be read regardless of their energy. The calorimeter will be operated at the highest rate when positioned at small angles below 10 degrees. For these runs, the beam current will be reduced, so that the maximum rate in the calorimeter will be smaller than 1 MHz per module (rates at larger angles will be negligible for the same beam current).

- Develop a commissioning plan for the calorimeter.

- **NPS Collaboration response:**
- The calorimeter commissioning will be based on our experience with commissioning the Hall A DVCS calorimeter and more recently the NPS 12x12 prototype. Steps will include HV gain and fADC baselines calibrations. Commissioning will also include elastic ep calorimeter calibration data, which are expected to be taken at each new energy, as possible. Detailed plan assuming that the calorimeter is installed.
    - checkout of the calorimeter environment: interlocks (light sensors, humidity, cooling system), HV, LED

- switch on detector voltage, check performance of calorimeter modules and readout with an LED and fadc250 scalers (perform fadc baseline calibration), collect LED data.
- perform HV scan with the LED system, obtain HV calibration curves (will be used for HV adjustment).
- collect cosmic data (may consider to install two simple scint paddles to perform initial gain equalization)
- integrate calorimeter to the trigger
- collect beam data (initial gain calibration).

Charge #4

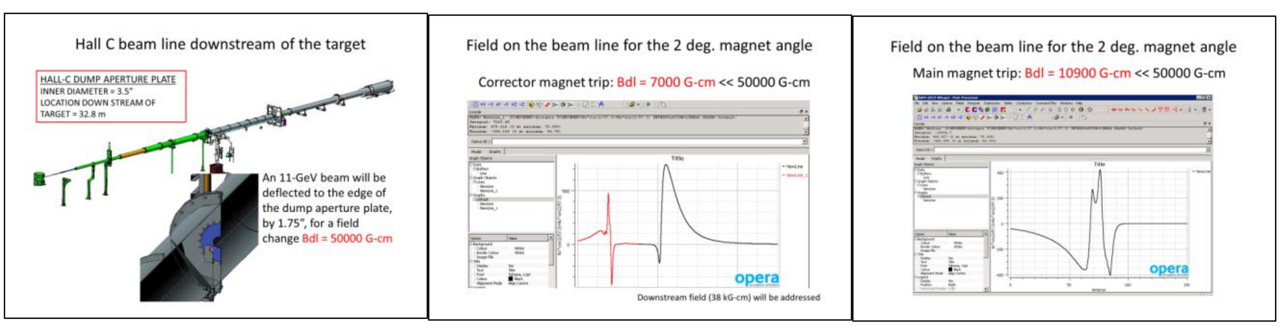
Comments:

- The electron experiments will require a polarized beam. It was not clear what will be used to measure the beam polarization, how often. From current run experience, Wein angle setting using presumed value for the beam energy is often incorrect. Depending on the degree of polarization needed, some kind of "spin dance" may be needed to set the Wein angle correct for the optimum polarization transfer.

Recommendations:

- Ownership and the controls of the sweeper magnet and the corrector coil are not clearly defined. Procedures, and who and how will control the magnet for safe operations must be provided.

➢ **NPS Collaboration response:** A magnet in the experimental hall would need to be under accelerator control if there is any impact of its field on the beam including the case of magnet trips. The impact of NPS magnet fringe fields was evaluated in detail at the ERR, the impact of corrector coil and main magnet trips is discussed here. As illustrated in the Figure below a magnet trip is not a problem. The 10kG-cm results are valid with a downstream iron pipe. The NPS magnet can be owned and controlled by Hall C, similar to SHMS magnets, with standard procedures (test plans with accelerator) when going to small angles as is done with the SHMS.



Charge #5

Comments:

- Responsible groups/individuals are identified for all mission critical jobs. Manpower is adequate, most resources are defined for completion of the project.

Recommendations:

- While software tasks for integration of the NPS into Hall-C offline analysis software framework are few and should not take too long to complete, identifying people who will work on these tasks must be done soon.

➢ **NPS Collaboration response:** List of tasks for integration of NPS into Hall-C offline software and people who will work on these tasks:
  - Modify existing libraries to accommodate NPS (HS Ko/IPNO) – DONE, available on github
  - Implement DVCS libraries into hcana (G. Niculescu/JMU, S. Wood/JLab)
  - fADC/ARS trigger decoding (JLab personnel, A. Camsonne)
  - Multi-pulse fitting (JLab personnel, A. Camsonne)
  - Clustering (JLab personnel, A. Camsonne)

Charge #7

Comments:

- RadCon department assistance will probably be needed to conduct/review some of the simulations. This should be coordinated with RCD as soon as possible.

➢ **NPS Collaboration response:** Simulations have been performed in 2012/13 and have been checked with Pavel D. from the RadCon department.

- Final boundary dose estimates should be calculated taking the radiator into account.

Recommendations:

- Activation levels should be modeled to evaluate residual dose rate fields. Results of this simulation will help with:
  - decisions on the sequencing of the different configurations
  - final design of sweeping magnet support hardware; if the magnet is in a high radiation area, effort should be given to enhancing the hardware to reduce the amount of hands-on manipulation needed.
  - decisions to apply local shielding at the radiator or elsewhere for ALARA.
- Simulation was done and estimates were calculated for the integrated dose on the crystals. Specific simulations to evaluate the radiation dose to the calorimeter electronics should be conducted.

➢ **NPS Collaboration response:** Extensive radiation background simulations studies were completed in 2013. A detailed description of our studies can be found in our Neutral Particle Spectrometer Facility in Hall C document submitted to PAC40 (available here: https://hallcweb.jlab.org/experiments/PAC40/NPS/nps.pdf). The document includes dose rate calculations at the crystal locations. Background rates strongly depend on the angle. Rates at angles larger than 20 degrees are negligible compared to angles below 20 degrees. Radiation dose estimates to the calorimeter electronics are being conducted at IPN-Orsay. Preliminary results show much smaller doses than to the crystals. FLUKA can be used for activation level estimates. Lorenzo Zana from the Radcon department is conducting these studies in collaboration with the NPS collaboration.

Charge #8

Comments:

- As NPS will remain in the Hall C equipment portfolio and may be used by other experiments in the future, it would be advisable to have well defined procedures and prescriptions for performing simulations of charged and neutral particles with the integrated use of simC and of the GEANT4 simulation of the NPS calorimeter.
- Even though the work involved is relatively limited, it is advisable to assign task for the remaining software development tasks and define a timeline to have the work completed by early next year and have sufficient time for tests and possible upgrades before the tools will be needed.
- The GEANT4 simulation of the calorimeter will be crucial to tune the reconstruction algorithms for neutral particles, determine acceptance and efficiency. Any remaining work to tune the simulations make this tool accessible to users should be completed as soon as possible. This will also be crucial to simulate the trigger readout: at this end, full simulation of the pulse shape, fADC sampling and FPGA algorithm will be necessary.

Recommendations:

- Define/present a plan for developing software for simulation of the NPS trigger and complete its validation during the NPS calorimeter commissioning

NPS Collaboration response: Some level of NPS (VTP) trigger validation would be provided by the 'LED group' triggering feature in the (to be finalized) LED control board specification, and then eventually a random trigger with beam. For the trigger simulation software, we will implement a basic NPS trigger in GEANT4 with different thresholds to determine the inefficiency due to dead time. This study would entail running GEANT4 and then do all the sums of 3x3 and take block from one cluster. One could hide a DVCS event and see if we lose the event or not. It could be interesting to look at 2x2, 3x3, 4x4 to see effect of background on trigger rates too.

Charge #9

Comments:

- NPS part is missing from ESAD (just started to implement).
- No RSAD ready yet, but preliminary boundary dose calculations are complete.
- A list of new OSPs has been presented, most are in motion but not complete yet. Having OSPs approved in advance will ensure that no safety issues with running the detector and or performing the task.