Proposal PR12-13-009
Wide-angle Compton scattering at 8 and 10 GeV photon energies
Reply to TAC Comments.

D.J. Hamilton, S. Širca and B. Wojtsekhowski

June 12, 2013

We would like to thank the TAC reviewer for his/her efforts and appreciate the comments which have helped us to reinforce the presentation of the proposal to the PAC. We carefully analyzed the reviewer's comments and provided our explanation/reply to each of them. The comments of the TAC are reproduced verbatim. The replies to these comments are given in blue.

TAC Comment 1. Significant hall engineering resources will be required for finalizing magnet design, support structures, beam line and power supplies.

Reply: We agree, and if this proposal is approved would welcome an early technical review to identify those resources (see Comment 13).

TAC Comment 2. New vertical bending magnet with a 32cm gap has been designed with integral Bdl between 0.25 to 0.6 Tm needed for different kinematics. (This is a different sweeping magnet than used for the other NPS experiments.) The front face of the magnet is located 1.1 to 2.45 meters from target at angles of 30 to 10 degrees.

Reply: We agree and feel that the proposed design will not prove to be a major technical challenge.

TAC Comment 3. A (150 kW?) power supply will be needed for the proposed magnet. If a new supply is needed, it would be beneficial to specify a supply that is compatible with the magnet for this experiment and the magnet for the other NPS experiments (PR12-13-007 and PR12- 13-010).

Reply: Indeed the supply for the proposed magnet will require around 150 kW of power.

TAC Comment 4. Removal of SHMS Horizontal Bender is necessary for installation of a sweeping magnet for γ/π^0 detector. Reinstallation should be fairly straightforward with minimal impact on SHMS optics.

Reply: As the reviewer has said, the removal and reinstallation of the SHMS horizontal bending magnet is expected to be a relatively straightforward exercise, which will not affect SHMS operation after reinstallation.

TAC Comment 5. The beamline will need to have magnetic shielding and a downstream dipole corrector. Stray fields up to 4m radius need to be accounted for when designing the beam line. Post-target correctors need careful design to avoid additional backgrounds from beam scraping.

Reply: Indeed it is important to avoid beam scraping and to minimise the effects of stray particles. We are working on this issue with Jay Benesch of the Accelerator Operations group and believe that, with magnetic shielding, the stray field integral can be reduced from $\sim$ 100 Gauss.m to $\sim$ 10 Gauss.m. With an active corrector the stray field integral can be reduced to a negligible level.

TAC Comment 6. Experience from previous the RCS experiment in Hall A was used for background, singles rate estimates and effects of radiation.

Reply: Previously in Hall-A we have made extensive comparisons between the background intensity predictions of the DINREG Monte Carlo code and actual measurements of background rates. This has been performed not only for the previous RCS experiment but also for several other experiments running at high luminosity. JLab Experiment E07-002, which sought to measure the polarization transfer components in Hall C, also provided invaluable experience, especially with the HMS. In the light of this experience we have estimated background effects for WACS in Hall-C.

TAC Comment 7. The collaboration should investigate placing the radiator further upstream so that scattering from the radiator could be shielded from the NPS and HMS.

Reply: This is a good idea. With a higher energy electron beam the bremsstrahlung cone will be more forward focused and so the increased distance to the target should not produce an unduely broad beam "spot". We believe that the radiator-to-target distance could be increased from 10 up to $\sim$ 25 cm and will investigate this more quantitatively.

TAC Comment 8. Kinematics point 5F specifies a proton momentum of 7.59 GeV/c which is above the HMS central momentum design limit of 7.3 GeV/c where the HMS has not been run before. Even if it is intended to use the large momentum bite of the HMS to reach this momentum, a short test run of the HMS near 7.3 GeV/c to study the optics and acceptance prior to the experiment would be necessary.

Reply: We have recalculated kinematic piont 5F for a proton momentum of 7.3 GeV/c. The updated kinematic settings, resolutions, background ratios and counting rates can be found in the three tables below. The net effect of this change has been to slightly reduce the beamtime required for kinematics 5F. This time will be used to perform optics studies on the HMS at this high momentum setting.

E_{in} [GeV]	θ_γ [°]	E_γ [GeV]	θ_p [°]	p_p [GeV/c]	Θ_{CM} [°]	s $[(GeV/c)^2]$	-t $[(GeV/c)^2]$	-u $[(GeV/c)^2]$
10.0	33.8	3.570	15.79	7.300	110	19.6	12.05	5.83

D_{NPS} [m]	D_{mag} [m]	$\int B \cdot dl$ [Tm]	σ_x [cm]	σ_y [cm]	e defl [cm]	N_{π^0}/N_{RCS}	$N_{ep\gamma}/N_{RCS}$
2.75	1.1	0.6	1.34	1.07	10.18	27.3	0.16

I_{beam} [μA]	R^p_{HMS} [Hz]	$R^{\pi^+}_{HMS}$ [Hz]	$R^{e^-}_{NPS}$ [Hz]	R^γ_{NPS} [Hz]	N_{RCS} $[h^{-1}]$
60	3	3	1	32	17

TAC Comment 9. It is not clear if the run time requested includes time for tune-up, spectrometer checkout or BCM calibrations.

Reply: We envisage the WACS experiment will run third in a series of three consecutive experiments which will use the NPS. In this case a separate tune-up, spectrometer checkout or BCM calibration would not be necessary. The table below provides a more detailed breakdown of the beamtime request than that included in the original proposal. In this table we set out the measurements we intend to make for each of the kinematic settings and the various set-up factors and configuration changes that we have assumed. For each kinematic setting, we plan to first take data on an optics target to check HMS optics and alignment, then to take data on a 10 cm LH_2 target without a radiator. These latter data are important for helping to determine the fraction of epγ events, and therefore minimizing the systematic uncertainity associated with correcting for this background. The total beam-on-target time estimate has been adjusted by an overhead factor of 1.2 in order to take into account effects such as DAQ livetime and tracking inefficiencies.

	4A	4B	4C	4D	4E	4F	4G	5A	5B	5C	5D	5E	5F
Set-up (beam & detectors)	14	-	-	-	-	-	-	10	-	-	-	-	-
Spectrometer move	-	2	2	2	2	2	2	-	2	2	2	2	2
HMS sieve slit	-	-	-	-	-	-	-	-	-	-	-	-	12
Optics target	1	1	1	1	1	1	1	1	1	1	1	1	1
No radiator	4	4	4	4	8	12	12	4	4	6	8	12	12
Production	8	18	18	27	40	60	110	12	18	42	64	110	150
Total beam-on-target	13	23	23	32	49	73	123	17	23	49	73	123	163
Adjusted beam-on-target	16	28	28	38	58	88	148	20	28	58	88	148	196
Total (hours)	**30**	**30**	**30**	**40**	**60**	**90**	**150**	**30**	**30**	**60**	**90**	**150**	**210**

TAC Comment 10. Readout instrumentation requirements will be significant (1116 channels of FADC readout, HV supply, etc.). It is not clear if the needed hardware will be integrated into the independent NPS development funding, or if JLab is expected to provide it. Note that if JLab F250 FADCs are planned then they should be considered long-lead (an additional fabrication run will likely be required). A too-long delay may result in the necessary FPGA chips being discontinued and a non-trivial board-level redesign.

Reply: The NPS is a major new piece of apparatus for 12 GeV experiments at JLab and WACS is one of several experiments which propose to use it. The procurement of all components of the detector, including readout electronics, is a general consideration for the collaboration who are building the device. The plan is to use the F250 FADC.

TAC Comment 11. Given the (potential) amount of data generated by the $>$ 1000 blocks of the NPS, additional hall resources for online data processing and storage may be required. As a benchmark, the Q-weak experiment took data at a rate on the order of 10 Mb/s – this put significant strain on hall computing resources.

Reply: The $PbWO_4$ crystals of the NPS have a pulse length of $\sim$ 30 ns, so that 16 samples ($16 \times 4 = 64$ ns) from the 250 MHz flash ADC will be sufficient to characterize the pulse form and base line. Monte Carlo simulations of the EM shower induced in the calorimeter suggest that the bulk of a shower will be contained in a 3×3 cluster of crystals. Online, a cluster will be signaled by a hit in a single crystal which exceeds a threshold of 25% of the exepcted Compton sacttered photon energy. If this and the surrounding 8 crystals are read out, a cluster will generate $9 \times 16 = 144$ data words or 288 bytes of data. If one extends the sweep of neighboring crystal to a 5×5 array, then the cluster read out will extend to 800 bytes of data. Read out the the FADCs is controlled by FPGA hardware, programmed to recognize where a hit has occurred and read out only the relevant group of FADC modules, so that the generation of large amounts of non-useful data is avoided. It is expected that the total cluster read-out will be a factor of 2 larger than this value as a result of the inclusion of auxillary words in the FADC readout, leading to a conservative estimate for the NPS event size of 2 kB.

Expected physics singles rates in the NPS for Compton scattering, ep scattering and π^0 photo production are given in Table 4 of the proposal, for a threshold corresponding to 25% of the elastic scattering peak energy. Atomic processes will produce low energy photons and electrons which will be suppressed very effectively by the 25% threshold on the trigger. The total singles trigger rates for the NPS, which is dominated by these background events, are given in Table 1 of the proposal. Since the trigger will be formed by the HMS, the maximum data throughput required will be at kinematics 5A. From experience gained during the previous Hall C WACS experiment, we expect the total HMS rate to be around a factor of 5 larger than the physics rate of 350 Hz for this kinematic point and the HMS event size to be less than 2 kB. Assuming a 4 MHz rate for the entire NPS at a 25 % threshold we therefore expect a maximum data rate of $\sim$ 6.0 MB/s, which should be well within the capabilities of the online DAQ and data storage facilities.

TAC Comment 12. Data storage and computing requirements should be specified.

Reply: The estimate given in the reply above has been made on the basis of event rates for kinematic point 5A, where they are at a maximum, both for the HMS and NPS. Point 5A takes only 30 hr of beam time and at other kinematic points the event rates are much lower. Assuming the total (HMS + NPS) data throughput does is on average 2 MB/s then 1000 hr of data taking would generate a absolute maximum of 7.2 TB of data. In modern terms this is not a huge amount of data.

TAC Comment 13. If the proposal is approved, then a review of the experiment should be scheduled early to address technical issues and identify the source of (users vs. lab) of various resources.

Reply: In common with all experiments which propose to use the NPS, there will surely be a technical review and a general identification of the sourcing of the various components of the experiment.