Response to ERR Charge

1. **What are the running conditions for the experiment? Please state clearly the target and beamline configurations and operation.**

We plan to run with the GlueX detector in its standard configuration using the standard diamond radiator with the coherent peak located at approximately 9 GeV (energy range 8.4 - 9.1 GeV). We are not sensitive to the exact peak energy and distribution and can run at somewhat lower initial electron beam energy and/or with a radiator producing a wider distribution.

The photon flux in the experiment constitutes about 2×10^7 photons/sec in the coherent peak region. It is 2.5 times smaller than the flux of the high-luminosity GlueX II experiment, E12-12-002, (and about 5 times smaller than the GlueX designed flux). The photon beam will be produced on a 4×10^{-4} radiation lengths (R.L) diamond radiator by an electron beam with the current of about 140 nA. The experiment will collect data using 3 targets: 7 days on 12C (7% R.L.), 4.5 days on liquid D (4.1 % R.L.), and one day liquid 4He (4 % R.L.). The experiment will also acquire calibration data using an empty target run.

The run plan of the SRC experiment is presented in Table I.

2. **What is the operational status/performance requirements of the target system needed by the experiment? If not completed, what are the completion / commissioning schedules, tasks and user commitment?**

We will run with a 30 cm-long cell that has an aluminum heat shield installed around the outside for both the deuterium and ^{4}He running (both ~4% radiation length). We will run an 8-foil carbon foil target in total 7% radiation length (each foil is 0.24 cm). The carbon foils will span the 30 cm target length.

3. **Has the spectrometer, detector configuration been defined, including ownership, maintenance and control during beam operations?**

Spectrometer and detectors will be in standard GlueX configuration.

Detector support will come from Hall D staff members. Responsible parties for each sub system have been identified and confirmed (see https://halldweb.jlab.org/level-1/manpower.pdf).

4. What is the impact of the expected neutron radiation on GlueX detector components such as the SiPMs? Is any local shielding required? Are the radiation levels expected to be generated in the hall acceptable?

Neutron background is critical for the performance of silicon photomultiplier, which are used for the instrumentation of the Barrel Calorimeter and Start Counter of the GlueX experiment. Neutron radiation results in the degradation of the SiPM performance, specifically the increase of the dark current. BCAL design allows for a factor of 5 increase of the dark noise. The start counter (ST) is less sensitive to the SiPM dark current and can be operated at least a factor of 10 larger dark noise (due to the relatively large signal amplitude > 100 pixels, and large readout thresholds applied).

During the design phase of the GlueX experiment, radiation hardness properties of SiPMs have been measured using an AmBe neutron source and beam tests in the experimental Hall A. In order to compare damage effects to Silicon caused by neutrons with different energies, it is convenient to convert the particle fluence to the equivalent fluence of 1-MeV neutrons using the so-called damage function. Radiation tests demonstrated that SiPMs with the accumulated neutron dose of 32 rem (which corresponds to the fluence of about $1.1\text{x}10^9$ n_{EQ}/cm^2) increased the dark current by about a factor of 5. Backgrounds and radiation level in Hall D were estimated using FLUKA and GEANT simulations provided by the Radiation Control group. Expected lifetimes of the BCAL and ST SiPMs of the GlueX experiment are about 8 and 5 years, respectively.

The beam photon flux of our experiment is 5 times smaller than that proposed for GlueX design. The largest neutron background will be produced on a liquid deuterium target. Recently, neutron background produced on the deuterium target was simulated by the RadCon group (Pavel Degtiarenko) using FLUKA and GEANT programs. Projected lifetime of SiPMs for runs on helium and deuterium targets are listed in the table below (neutron background produced on the C target is expected not to increase the 4He background). Degradation of the SiPM performance due to the neutron radiation, i.e., the dark current increase, is expected to be negligibly small (< 20% for the ST SiPM, where the effect is the largest) even for the deuterium target. The dark rate of SiPMs will be measured during the experiment using special runs with the random trigger; this is important for planning future experiments in Hall D.

	GlueX Design	**SRC/CT**	
	LH target	LHe_4 target	LD target
BCAL	8 years	25 years	7.7 years
ST	5 years	6.2 years	1.6 years
Run Time of our experiment		3 days	13.5 days

Table II. Expected SiPM lifetime for run conditions of the SRC/CT experiment.

Experimental Hall D was designed to handle the photon flux about two times larger than the GlueX designed flux (corresponding to 10^8 photons/sec in the energy range between 8.4 GeV and 9.1

GeV). Based on the Monte Carlo simulation, the radiation level in Hall D will not exceed the GlueX designed level. The estimated neutron dose equivalent rate in Hall D at the ceiling and walls induced by the deuterium target is conservatively estimated to be 4 - 5 times larger than the hydrogen target and therefore, should not present any issues as we run at x5 less flux. Additionally, we are coordinating with RadCon to install TLDs close to the target and implement Bonner spheres to determine the energy spectrum of the neutrons close to the target. The radiation level during run is continuously monitored by the RadCon group, specifically with the rapid access CARMs (a few detectors have been installed for the PrimEx experiment, which took data on 4He target).

5. What is the expected data rate for the experiments?

Nominal GlueX with a photon flux of $5x10^7$ photons/s has a trigger rate of about 80 kHz, 90% live time, and a corresponding data rate of 1.1 GB/s. For our experiment, we will lower the ECAL and BCAL thresholds so that we are sensitive to minimum ionizing particles, and we will include the start counter in the trigger. This configuration was tested in Feb 2020 (see https://halldweb.jlab.org/level-1/src) with the $5x10^7$ photon flux.

The tested trigger required a hit in the start counter and reduced the energy thresholds in the BCAL and FCAL to 180 and 250 MeV, respectively. These thresholds are set below the minimum ionizing particle threshold so that we accept proton and pion final states. This configuration yields a trigger rate of 78 kHz, 90% live time, and a corresponding data rate of approximately 1 GB/s (albeit at the nominal GlueX photon flux as stated above).

Our experiment will run with a photon flux of $2x10^7$, but our carbon target will be double the radiation lengths of the nominal hydrogen GlueX target. We expect that the hadronic backgrounds from the nuclear target will be smaller due to larger attenuation effects (scaling approximately as $A^{2/3}$) and the electromagnetic backgrounds should scale with the radiation length.

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

As stated in item (3) above, experts that will be responsible for each detector subsystem during data taking have been identified and confirmed.

Shifts will be covered by the experiment collaboration, which is large and adequate for running this 1 month long experiment. The experiment proposal was approved very recently and included collaborators from 14 different institutions, all indicating their willingness to participate in this experiment. The majority of these institutions have experience working with the GlueX detector. We also invite the GlueX collaboration to join in shifts and analysis.

Additionally, the groups of the core PIs leading this experiment (from MIT, GW, ODU, TAU) are large and include a total of 26 post graduate researchers (14 graduate students, 8 postdocs, and 4 PIs) that will be dedicated to help with data taking. We expect for members of our institutions working with other PIs on the GlueX experiment, as well as Hall D staff, to also participate in this experiment which will approximately double our core personnel.

Our institutions are members of the GlueX collaboration (except for TAU), and we plan to hold dedicated training sessions closer to the experiment to ensure all relevant personnel are capable of taking shifts and supporting data taking. We followed a similar strategy for the Tritium experiment, which worked very well.

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

Yes. This is all standard GlueX calibration and procedures. All basic calibrations will be done with PrimEx prior to start of experiment.

8. **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?**

Our group has a strong track record of timely publication of high-impact results. Most recently we ran the Hall A Tritium (e,e'p) experiment. We produced two letter publications from this effort, one reporting cross-section ratios in PLB less than a year after data-taking and one reporting absolute cross-sections in PRL, less than two years after data taking. We published about 8 letter publications each year (already 4 in 2020). Our work in Halls A, B, and C, as well as our experience measuring hard reactions using hadron and neutrino beams, provides us with the skills and toolsets that are needed to successfully analyze the data to be taken in this experiment.

Specifically, we will use standard GlueX calibration and software, and expect to complete the analysis within the GlueX framework. Our group already has a dedicated Monte Carlo event generator using the new Generalized Contact Formalism simulation framework. This framework was built for SRC studies by our group in collaboration with leading theoreticians and was successfully used in various previous electron scattering SRC publications [Nature 2020, PLB 2020, PRL 2019, 2xPLB 19, 2xPLB 18, …]. We recently extended this framework to describe photo-nuclear reactions, and it is fully integrated with the GlueX simulation package.

We anticipate that our first publication will be achieved within a year of data taking. This work will focus on the study of np-SRC dominance by measuring:

- $\gamma + p \rightarrow \pi^0 + p$ and $\gamma + n \rightarrow \pi^- + p$: 2 particle final state, lowest cross section
- $\gamma + p \rightarrow \rho^0 + p$ and $\gamma + n \rightarrow \rho^- + p$: 3 particle final state, highest cross section

and extracting their cross-section ratios for events with high missing-momentum. The simulations needed for the analysis of this data are already in place. To expedite the analysis we plan to utilize the forward propagation techniques we introduced in Schmidt et al., Nature (2020). Follow up works will examine branching ratio modification via measurements of cross-section ratios for different nuclei similarly to what we did in Duer et al., Nature (2018). On a longer timescale we will extract absolute cross-sections.

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

Assigned PDL is Lubomir Pentchev. Documents are initiated at
https://halldweb.jlab.org/wiki/index.php/Experiment_Readiness_Review_2020#ERR_Agenda

Condition	Scheduled Work (Activities)	Total Time	Beam Conditions
Pre-experiment	**Install C target**	**3 shifts**	**no beam**
	Disassemble beam pipe. Retract target. Remove Start Counter (ST). Remove vacuum snout. Remove GlueX cell. Mount carbon foils (survey). Attach vacuum snout. Attach ST. Target in place. Assemble beam pipe. Pump vacuum.* Ramp magnet*	1 shift assembly 1 shift for survey & align 1 shift for pumping vacuum	

Condition	Scheduled Work (Activities)	Total Time	Beam Conditions
Detector checkout		**2.5 shifts**	**140 nA**
	Establish typical tagged photon beam, check/calibrate sub-detectors, Trigger, and DAQ (some tests can be done during pumping vacuum)		
Run with C target		**7 days**	**140 nA**
Target change	**Install liquid D target**	**5 shifts**	**no beam**
	Ramp magnet down	1 shift	
	Disassemble beam pipe. Retract target. Remove ST. Remove vacuum snout. Remove carbon foils. Mount GlueX cell. Survey. Mount heat shield (needed for helium). Attach vacuum snout. Attach ST. Target in place. Assemble beam pipe. Pump vacuum*. Ramp magnet.*	1 shift assembly 1 shift for survey & alignment	
	Ramp Magnet* Pump vacuum*	1.5 shifts	

		(1 shift for pumping vacuum)	
Run with empty target		**0.5 days**	**140 nA**
Target preparation	Cool target*.	**1 shift**	
Run with D target		**4.5 days**	**140 nA**
Target change	Switch to liquid He target	**1.5 shifts**	
	Boil LD_2*. Pump D_2 from tanks. Replace with helium. Cool target*.		
Run with He target		**1 day**	**140 nA**
Total		**13 days data taking** 9.5 shifts overhead	

Table I. Run plan of the SRC/CT experiment.

(*) means Hall D can be in beam permit.