Date: May 13, 2019

For Proposal for JLab PAC47

Strange Hadron Spectroscopy with Secondary K_L Beam in Hall D

Cover Letter for KLF Proposal Submission to PAC47

This Proposal follows the Proposals PR12–17–001, PR12-18-002 presented to PAC45 and PAC46, respectively. The Issues and Recommendations included in the PAC46 Final Report document read as follow:

General Issue: *There is one particular issue that we want to bring to your attention. We understand that the GlueX Collaboration enjoys a symbiosis with the Hall D staff and the Laboratory, that is rather different in character to the collaborations in the other Halls. We also realize that this symbiosis has led to an especially productive period of commissioning and initial data taking. On the other hand, it is difficult for the PAC to see the future evolution of the Hall D program, which would provide context for reviewing new proposals that are beyond the scope of the currently approved beam time.*

Therefore, we would like to suggest that the GlueX collaboration and Hall D leadership develop a vision for the future of Hall D. A brief White Paper that discusses the options and provides guidance for the PAC, would be particularly useful.

Issues: *This is potentially an exciting opportunity to continue the physics program in Hall D with an enlarged user community. However, the PAC had significant concerns about the proposal and the degree to which the proponents have critically evaluated both the technical aspects of mounting the experiment and the effects of systematic uncertainties on their results. The PAC is also concerned with the lack of awareness of competition in the international community for this science, and the impact this would have on scheduling this ambitious experiment.*

The proposal was very difficult to evaluate due to the large number of topics discussed in insufficient detail. While it has successfully established the breadth of science accessible with a high intensity KL beam, the PAC would like to see a more convincing and detailed discussion of at least a small number of highlights. For example, there were concerns regarding the theoretical difficulties in the extraction of the phase shifts from the data. The proponents should describe the physics impact (for example, how will new baryon states test lattice QCD?), and also include detailed discussion of the effects of systematic errors such as the impact of energy resolution and acceptance uncertainties on partial wave analyses. Demonstration of the amplitude extraction, using a complete detector simulation, would be necessary for approval.

As another example, we were given a clear presentation on the impact of increased statistical power (20 vs 100 days) on a phase shift analysis in πN scattering. It was, however, not clear how systematic uncertainties relevant to this experiment would impact the conclusions of that study and, given the 1% statistical errors in many bins, one would expect systematic errors to have a dominant effect. Given the dependence of many of the proposed studies on high statistics at low -t, understanding of the detector acceptance and extrapolation issues in the low -t region will be critical.

The GlueX detector and liquid target systems are well understood technically but the CPS and KL systems are both expensive and, to date, not fully fleshed out. As CPS systems are proposed for other halls, it is likely that there will be a much better understanding of the CPS design in 1-2 years, independent of this proposal. But the collaboration needs to present a more realistic view of the likely timeline and design details for an experiment of this degree of novelty and cost.

To summarize: *There are several aspects of this initiative which are attractive for a future Hall D program. However, in several respects the PAC was not convinced that the experiment/project demonstrated realism. These ranged from the clarity of the physics case and its theoretical interpretation, through the incorporation of experimental uncertainties in the analysis to the realism of the cost and schedule, and the level of commitment and strength of the collaboration.*

The KLF Collaboration believes that the current proposal addresses all of the concerns following the recommendations expressed by the PAC46:

1. **Q1**: *We would like to suggest that the GlueX collaboration and Hall D leadership develop a vision for the future of Hall D. A brief White Paper that discusses the options and provides guidance for the PAC, would be particularly useful.*

   A1: The Hall D White Paper was submitted to the JLab administration in April 2019, which includes our KLF contribution. Among other topics, the white paper clearly describes the process and timelines for mounting additional experiments with the GlueX detector.

2. **Q2**: *This is potentially an exciting opportunity to continue the physics program in Hall D with an enlarged user community. However, the PAC had significant concerns about the proposal and the degree to which the proponents have critically evaluated both the technical aspects of mounting the experiment and the effects of systematic uncertainties on their results.*

   A2: The previous proposal uses the GlueX spectrometer, along with a new photon source, target assembly, and flux monitor, for which we presented conceptual designs. For the current proposal, we have elaborated on these designs and performed more details studies of the effect of systematic uncertainties.

3. **Q3**: *The PAC is also concerned with the lack of awareness of competition in the international community for this science, and the impact this would have on scheduling this ambitious experiment.*

   A3: The current status of relevant hadronic physics programs was given in PAC46 proposal and we have updated this evaluation in our PAC47 report. To briefly summarize the highlights, no comparable KL beam is currently planned in at least the next 10 years, with the nearest competing experiments/facilities being J-PARC, Belle II, and PANDA. Belle II and PANDA have the benefit of clean initial states, hadron decay and YY* pair production respectively, but will likely be statistically limited for the PWA needed for the firm identification and characterization of all but the narrow hyperon states. At J-PARC, the best prospects are with the charged kaon beams, with the neutral kaon beams optimized for CP-violation studies and suffering from a large duty factor. The charged kaon beams would provide data complementary to that from KLF, but there are currently only plans for studies of S=2 hyperons. It is not clear when an experiment to study S=1 hyperons might be constructed and scheduled.

   This science has been supported by a large international community. JLab supported four international workshops to discuss the physics and technical aspects of hyperon and kaon physics, including **103** talks given by top experts in the field. Our proposal was signed by **189** researchers from **62** institutions representing **18** countries around the world.

4. **Q4**: *The proposal was very difficult to evaluate due to the large number of topics discussed in insufficient detail. While it has successfully established the breadth of science accessible with a high intensity KL beam, the PAC would like to see a more convincing and detailed discussion of at least a small number of highlights. For example, there were concerns regarding the theoretical difficulties in the extraction of the phase shifts from the data. The proponents should describe the physics impact (for example, how will new baryon states test lattice QCD?), and also include detailed discussion of the effects of systematic errors such as the impact of energy resolution and acceptance uncertainties on partial wave analyses. Demonstration of the amplitude extraction, using a complete detector simulation, would be necessary for approval.*

   A4: The overarching goal of the KLF facility is the use of a KL beam that is three order of magnitude higher than that of SLAC, in order to perform scattering experiments on both proton and neutron (this, for the first time) target in order to determine differential cross sections and self-polarization of strange hyperons with the GlueX detector. This will enable precise PWA in order to determine all hyperon resonances up to 3 GeV, and to address issues in kaon spectroscopy.

   For the hyperons, the highest priority measurements are the measurement of the mass and spin-parity of a series of cascade baryons, in order to establish the lowest multiplets in their mass spectrum. This will allow us to measure several mass splittings which will provide a stringent test of heavy quark symmetry and firm benchmarks for upcoming

LQCD calculations. For illustration, we show the sensitivity for firmly establishing the poorly-known $\Xi(1820)$, $\Xi(2030)$, and $\Xi(2500)$ states. On the kaon side, the highest priority is the study of the low-mass $K\pi$ spectrum and determination of the K(800) pole position. We show the proposed run time gives us the opportunity to resolve this state once and for all.

To illustrate the sensitivity of the proposed experiment in detail, we have simulated the reaction $K_Lp \rightarrow K^+\Xi$ according to the conditions expected in Hall D, performed a PWA, and determined BW parameters for $\Sigma(1920)5/2^-$ and $\Sigma(2030)7/2^+$. These results can be compared to PDG2018 data and LQCD calculations.

5. **Q5**: *As another example, we were given a clear presentation on the impact of increased statistical power (20 vs 100 days) on a phase shift analysis in πN scattering. It was, however, not clear how systematic uncertainties relevant to this experiment would impact the conclusions of that study and, given the 1% statistical errors in many bins, one would expect systematic errors to have a dominant effect. Given the dependence of many of the proposed studies on high statistics at low -t, understanding of the detector acceptance and extrapolation issues in the low -t region will be critical.*

   A5: Our updated proposal has a special chapter addressed to systematics. Our determination of $\Sigma(1920)5/2^-$ and $\Sigma(2030)7/2^+$ parameters shows systematical uncertainties.

   The comment about small t-Mandelstam is relevant to $K\pi$ scattering. It has to be as close to the pion pole as possible. Previous measurements with LASS were done with a cut $|t|<0.2$ GeV^2. Our t range is 0.14-0.2 GeV^2, which is simulated with a full detector of GlueX and all expected results on K-pi elastic scattering and kappa studies are based on this range of t.

6. **Q6**: *The GlueX detector and liquid target systems are well understood technically but the CPS and KL systems are both expensive and, to date, not fully fleshed out. As CPS systems are proposed for other halls, it is likely that there will be a much better understanding of the CPS design in 1-2 years, independent of this proposal. But the collaboration needs to present a more realistic view of the likely timeline and design details for an experiment of this degree of novelty and cost.*

A6: We have updated the details of the KL systems and are happy to discuss any additional questions the PAC may have about them. Our estimation for the construction on new equipment is $**4.7**M (see a New Equipment document).