Cover Letter for KLF Proposal PR12-17-001 Submission to PAC45

Response TAC Physics Report

Major modifications of the beamline

> **Q6**: The K_L flux is supposed to be measured with the Pair Spectrometer, but no simulation has been done yet. It is not obvious that the existing pair spectrometer can do the job without modifications to the magnet (the gap size) and the detector system.

A6: Our preliminary MC simulations show that the flux measurements with partial detection of decay products of KL is feasible. Additional studies to estimate the precision of the flux measurements with existing PS are under way.

Response TAC Theory Report

> **Q**: However, it is not clear that this facility can be competitive with J-PARC once J-PARC becomes operational.

A: As our Chapter **12** says: ``The proposed K_L beam intensity is similar to the proposed charged kaon beam intensity at J-PARC, so there is no reason to expect that J-PARC will do substantially better. Using different probes (K_L for JLab and K^- for J-PARC), in principle, we and J-PARC (if charged kaon beam proposal is approved) will be able to collect data for different reactions. To have full experimental information with different final states is important for coupled-channel analyses to determine hyperon parameters. The JLab and J-PARC measurements will be complementary.

(i) As $c_\tau(K^-) = 3.7$ m, while $c_\tau(K_L) = 15.4$ m, the higher rate of low-momenta kaons with a K_L beam may be an advantage.

(ii) The proposed experiment will have a KL beam with all momenta simultaneously, while J-PARC has to make many thousand different settings to scan the full range of W distributions in different reactions.

(iii) In the best-case scenario, J-PARC can start a hyperon program in 2024. In Appendix **A6**, Chapter **18**, we have presented the ability of other possible facilities as FNAL, J-PARC, Belle, BaBar, PANDA, and COMPASS to do hyperon spectroscopy. We do not see a competition factor here for two reasons:

a) some of above-mentioned facilities do not yet have secondary kaon beams;

b) even if kaon beams are approved and constructed at these facilities, a hyperon spectroscopy program will not happen before a decade from now.”

The questions about J-PARC hadron spectroscopy program will be further clarified in the talk of Shin'ya Sawada’s at the PAC meeting.

Response on ITAC Report

Physics Reach

> **Q1**: Since the initial momentum of the K_L is not known very well above 2 GeV/c from TOF (see the realistic 300 ps curve in Fig. **21**), it may be essential for high K_L momenta to detect all particles in the final state. The feasibility of inclusive measurements at higher K_L momenta will have to be determined on a case by case basis.

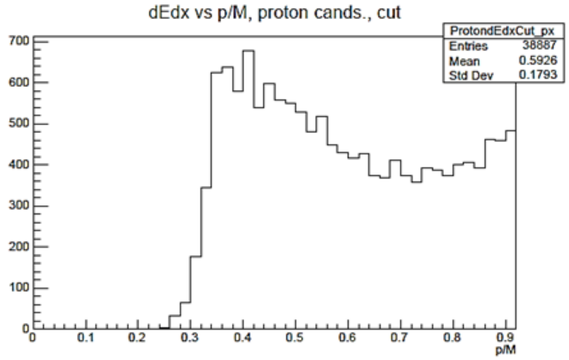
A1: Inclusive measurements make sense for the two-body final states only. There are four possible $K_Lp \rightarrow A+B$ two body reactions. All of them were carefully simulated within our proposal (see Appendix **5**, Chapter **11**). Three body final states need to be detected semi-exclusively or preferably exclusively to suppress possible backgrounds. For exclusively reconstructed events, the K_L momentum resolution is no longer a limiting factor, as shown on Fig. **22** (dashed green curve). Figures **32** and **46** further demonstrate this effect for dedicated reaction simulations.

The quoted start counter time resolution is 250 ps as shown in Fig. **23**.

> **Q2**: Simulations show that the minimum recoil proton momentum detectable with the proposed target and current GlueX detector is about 0.5 GeV/c as shown in Figure **45**. This includes the full K_L momentum spectrum as shown in Figure **16**. It is not obvious that at low initial K_L momenta the proposed measurements can be exclusive and detect the recoiling proton which is essential for

vertex reconstruction. Note that most events in Figure **37** (low t) would be undetectable in an exclusive measurement.

A2: Figure **45** of the proposal shows particle identification plots for protons in two regions of the GlueX detector. For protons with $\theta < 10^0$ (upper right of Fig. **45**), the threshold is in indeed $p = 0.5$ GeV/c. However, for recoil protons produced at large polar angles the threshold for detection is $p = 0.3$ GeV/c as shown in the upper left panel of Fig. **45** and figure below of reconstructed proton p/M for the $K_Lp \rightarrow K_Sp$ reaction.



For the vertex reconstruction, for hyperons the reaction where the recoil proton is the only track originating from the primary vertex is $K_Lp \rightarrow K_Sp$. All other reactions have either a charged kaon or charged pion to tag production vertex. The $K_Lp \rightarrow K_Sp$ reaction was studied in detail, using the fully reconstructed simulations (see Appendix **5**, Chapter **17.1.1**) and as one can see from Fig. **48** (right) the reconstruction efficiency for this reaction is quite high (about 10%) even at very low W = 1.6 GeV.

As for the exclusive measurement of $K_Lp \rightarrow K\pi p$, Figure **37** shows the generated distributions for this reaction. Due to the proton reconstruction threshold at p = 300 MeV/c events with $-t < 0.1$ $(GeV/c)^2$ will not be reconstructed, however this effect was included in our estimates of the Kπ yields, which were determined from using the full reconstruction of the simulated events.

> **Q3**: The K_L beam flux is assumed to be about 3 x 10^4 kaons per second. If this estimate assumes the full momentum range of K_L as shown in Figure **16** the actual flux of "useful" K_L with momenta below 1.85 GeV/c (W = 2.17 GeV/c^2) as used in Section **11** will be about a factor of 10 smaller.

A3: The flux of 3 x 10^4 K_L/s over the full momentum range in Fig. **16** was used to estimate the yields for all the simulated reactions in the proposal. Therefore, there is no reduction in the estimated yields given in the proposal. Some of the figures in Chapter **11** are presented only for W < 2.17 GeV since there are no previous data at higher W to compare with.

> **Q4**: Will a smaller initial electron beam energy generate a more optimal K_L momentum flux distribution? The relatively large fraction of high momentum K_L in Figure **17** may not be so useful for a resonance program.

A4: As shown on Fig. **3** of the proposal, previous measurements are mostly limited to W < 2.0 GeV. However, the range 2.0 < W < 3.5 GeV studied in this proposal is almost completely unexplored and represents a truly unique aspect of the K_L facility. Significantly reducing the electron beam energy would limit the discovery potential of the proposed experiment. This will also completely limit the physics program related to K* production, where low t Mandelstam domain is very important.

> **Q5**: 200 days of beam time are requested with 100 days on Hydrogen and 100 days on Deuterium (page **52**). No simulation on physics results with a deuterium target are presented.

A5: As stated in the proposal there are no $K_L d$ measurements, thus the proposed Deuterium target data are “terra incognita”. The large discrepancy between different theoretical approaches shown in Chapter **8** further underscore the need for these measurements. While no dedicated simulations were performed for the Deuterium target, the cross sections on neutrons and protons are expected to be of similar strength. Hence, we expect similar statistical accuracy for the Deuterium target program. The nucleon spectator effects as well as the final state interaction treatments were studied in detail with the electromagnetic probes. Since the kinematics of photon and kaon induced reactions are very similar, all methods developed for photon beams with Deuterium targets can be inferred without modifications at the KLF neutron target experiment.

Compact Photon Source (CPS)

> **Q1**. The existing tagger and permanent magnet in the electron/photon beam line are part of engineering safety measures to prevent any primary electron beam from entering Hall D. Any re-design of the electron/photon beam line needs to take this into account.

Q2. The combined length of the CPS and the permanent magnet (required for safety) may exceed the space that is available between the tagger magnet and the exit photon beam pipe. Note that the tagger magnet is part of the electron vacuum beam line.

Q3. Cooling of the electron dump is essential. With 5 μA the heat load is about 60 kW. It needs to be part of the safety interlock system.

Q4. The electron beam is expected to be rastered when passing through the radiator into the beam dump. The Hall D beam line does not have any raster system. The heat dissipation in the dump depends on such a raster system.

Q5. The total weight of the CPS/electron beam dump may exceed the maximum floor loading.

Q6. Decommissioning of this dump needs to be considered at the early design stage. Taking it apart may not be possible after the experiment, and extracting the 8 m long CPS in one piece may be the only option to restore the Hall D tagger beam line.

Q7. The proposed use of Tungsten powder required additional safety measures depending on the granularity.

A: Our Proposal has a conceptual design of the CPS only. The JLab CPS Working group has considered the CPS case for Halls A/C and D in detail. Answers on all these CPS questions will be addressed in Tanja Horn's report to the PAC. The answers on **Q4** and **Q5**, in particular, are available in the PR12-17-001_TAC_Physics Report.

Electron Beam Characteristics

Q1. A 5 μA electron beam with a 15.6 MHz repetition rate as requested is not trivial. The currently installed lasers in the beam source are not capable of such a low repetition rate.

A1: Matt Poelker (polarized electron source expert at CEBAF) already noted this in a private communication:

> "…it is rather challenging to generate a 15.6 MHz repetition rate beam for the required 60 ns bunch spacing. Specifically, our fiber laser amplifiers that produce the light delivered to the photocathode become damaged at this low repetition rate. We learned this through painful experience, damaging ~ equipment that cost about $50k to replace. On the bright side, fiber amplifiers can be purchased that are designed to operate at low rep rate (i.e., higher peak power), but he just wanted to tell us that we don't presently have them. We would need to purchase some optical equipment to generate your requested bunch repetition rate. I don't know the exact cost but probably less than ~$100k. So just a speed bump, not a show-stopper."

Q2. 5 μA of beam current at 15.6 MHz repetition rate is equivalent to 160 μA of beam current at 499 MHz repetition rate in terms of the expected charge per bunch. The space charge effects will be 32^2 ~ 1000 times larger than a 160 μA beam at 499 MHz. This may require accelerator operations parameters that have not been yet achieved or shown to be compatible with the current apertures in the transport system.

A2: We've been in contact with Geoffrey Krafft (former director of CASA) regarding this issue. ``I did talk with Jay (*Jay Benesch is one of writers of ITAC Report*) on Friday morning. My understanding of our "conclusions"

[1] You are asking for beam parameters, at 12 GeV, that are beyond current experience.

[2] The charge-per-bunch for 5 μA running is actually a factor of 4 or so less than that achieved in G0.

[3] During G0 running, which was not always easy, there were occasions where enhanced halos caused beam losses that were difficult to control during the experiment. With lower charge-per-bunch these may be smaller, but they were not really understood with sufficient detail that we could reliably predict what will happen at 12 GeV as far as potential beam losses is concerned.

[4] It would be very useful, as Jay suggests, to figure out a way and plan for an injector test where 0.33 pC beam is produced and propagated up to 12 GeV (at low duty factor), so that any potential issues are understood and addressed. Matt Poelker would have to be consulted about actually performing such a test. We expect that if the proper settings in the injector can be found, propagating up to high energy may not be a serious hold up.

[5] There is no show stopper here, which may have been an impression left by the review reports. I think it is not an

> insuperable problem to develop a convincing case that a proper beam can be created.”

K_L beam source

> **Q1**. The contribution from the extended K_L source to the time resolution may become significant for the lowest K_L momenta. This should be included in any estimate of the overall time resolution and hence ΔW. A combination of Be and Carbon as K_L source may be favorable.

A1: All simulation performed for K_L proposal are done with extended K_L source. The time, momentum, and W resolution can be found on Figs. **21** & **22**. An increase of Δt seen on Fig. **21**(left) originates from the finite size of the K_L source. However, such an increase in Δt does not lead to a noticeable increase in ΔW, since t increases as well. Overall the W resolution is sufficient for all the proposed measurements over the full energy range.

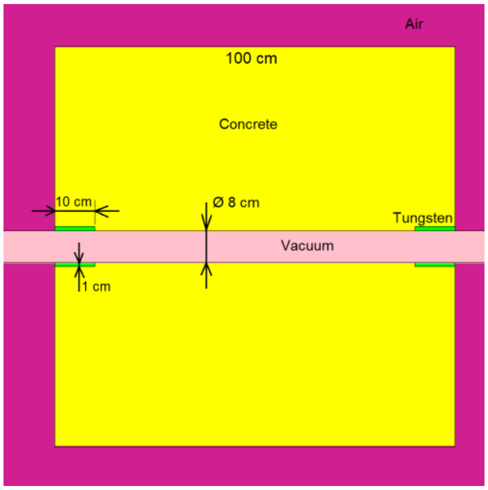
> **Q2**. Parametric timing resolutions of the start counter below the currently quoted 280 ps may not be realistic. Any improvement in this number would require a thicker start counter and will increase the minimum detectable recoil proton momentum.

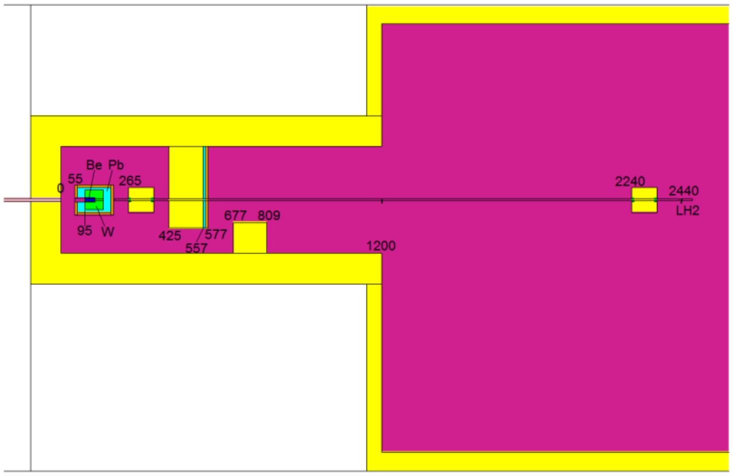
A2: The quoted start counter time resolution is 250 ps as shown in Fig. **23**. Possible paths towards reducing the time resolution of the time resolution of the start counter and utilizing other components of the GlueX detector to reduce the overall K_L momentum resolution are outlined in Section **10.1.6.**

Fortunately, we do not have a high sensitivity to the ΔW resolution because our goal is not a bump hunting. As we presented in the proposal, our goal is to study the hyperon properties through PWA with new JLab and J-PARC data.

> **Q3**. There is no information about the two collimators that are shown as part of the K_L beam line right after the sweeper magnet and upstream of the GlueX detector (Figs. **14** & **20**). This second collimator is directly competing with the LH target for space on the upstream platform. No information about the collimator material, its dimensions, bore diameter and weight are available. This is important to determine the floor load, in particular on the upstream detector platform.

A3: Collimator C1 is a part of the current Hall D photon beam line while collimator C2 is the same. Material for both collimators is concrete with small tungsten components. Sizes are given on left figure below (view from top). The highest above floor is 340 cm. The location of both collimators shown on right figure (view from top).





Q4. A simulation of K_L and other particle fluxes as a function of radius is not available. It is important to know the fluxes at the detectors as well as the target. The CDC straws would be very unhappy if they see a high muon flux along their lengths. We need these numbers to estimate the radiation damage to the BCAL SiPMTs as well.

A4: The flux of muons on GlueX has been simulated and it came to the number 200 muons/s/cm^2 on GlueX setup which cannot be considered high enough to consider them to be source of radiation damage.

LH/LD Target

Q1. The requested 6 cm diameter LH/LD target is a substantial increase in the transverse target thickness as compared to the nominal GlueX target. This will have an adverse effect on the average minimum detectable recoil momentum of the proton.

A1: The addition of 2 cm of LH_2 is equivalent to 1 mm of scintillator material, which is 1/3 of the start counter thickness. So while the larger diameter target does increase the material budget, it is not expected to limit the proposed measurements.

Q2. The use of a deuterium target may increase the neutron radiation dose in the Hall considerably, not only with regard to the total radiation dose at the site boundary but due to the adverse effect low energy neutron radiation has on the SiPMs that are the basis of the start counter readout and the Barrel Calorimeter readout.

A2: The main neutron dose originates from the K_L production target and was simulated in detail (see Chapter **10.1.4**). Secondary neutron production on deuterium target is several orders of magnitude smaller than the direct neutron flux from the K_L production target and can be neglected.

We made our calculations for neutrons from the K_L production target (see Chapter **10.1.4.3** and Appendix **A4**, Chapter **16**) using the MCNP6 N-Particle (MCNP) Transport code which is standard for national laboratories. Overall the neutron flux is tolerable.