Response to the Theory Report on the KLF proposal
C12-19-001 submitted to the PAC48

We were very disappointed to find that the reviewers did not read the hyperon section of the PAC48 proposal, which was significantly restructured and revamped since the previous submission. The hyperon section of the theory report is a direct duplication of the PAC47 report, with the exception of the first and the last phrases. In particular, the reviewers write "*The* $\Lambda(1405)$ *is highlighted as one of the primary state(s)*", which was not true even in the PAC47 proposal. To avoid confusion, this $\Lambda(1405)$ chapter was completely removed from the main part of this proposal for PAC48, so this comment is both incorrect and obsolete. The first time you can find the $\Lambda(1405)$ in the current proposal is in Appendix 3, which does not qualify as "highlighted".
As another example, the reviewers copied the phrase "*In Fig. 6 they compare predicted experimental data that may be accessed using the* K_L *beam* ($K_L n \to K^- p$, $\overline{K}n$, $\pi\Lambda$, $\pi\Sigma$) *using two different examples of models used to determine the aforementioned pole*", however this figure was also removed from the main part of PAC48 proposal. Figure 6 of the current proposal has nothing to do with what the reviewers described but is instead related to the cascade discovery potential. This situation makes us uncomfortable in replying to anything of "theoretical" complaints. However, we have tried to do so where appropriate.

A: Comment: Within this respect, among the major points of impact are Heavy Quark Symmetry (HQS), connection to LQCD, and resolving outstanding puzzles. HQS is very well stablished and understood at this point, both formally and numerically via LQCD. This is a symmetry that works rather well in the bottom sector, reasonably well in the charmed sector, and questionably well in the strange sector. The PI's claim that "The spectrum of ⊼ hyperons also clearly has significant discovery potential with implications for heavy quark symmetry and relationships to mass splittings in charm and beauty hyperons" It is not clear what further insight would be gained with regard to this symmetry from these observations. This point is further muddled by the fact that in other parts of the proposal, the PIs argue that the experimental data may put constraints on SU(3) UChiPT, which starts from the assumption that the strange quark is massless and therefore chiral. The strange quarks are interesting in part due to the fact that they are neither approximately massless nor infinitely heavy. As a result, they might provide insight into the transition from these two regimes where reasonable theoretical approximations may be implemented. Unfortunately, this nuanced view is not adopted by the PIs.

Our response: The reviewers have overlooked the main point made in the proposal that the gradual approach to heavy quark symmetry with increasing quark mass provides an important phenomenological tool for comparing the multiplet structure in the different flavor sectors – strange, charm and bottom – in the hyperon spectra. The proposal is to exploit rather than test heavy quark symmetry.

B: Second half of the comments on hyperon spectroscopy is related to Λ(1405).

In particular, it states that: "The real part of these poles lies outside the kinematic region that will be accessed by the proposed experiment, although the pole near threshold is expected to manifest itself above threshold."

Our response: It is true that in the formation experiment the pole near the threshold will be inaccessible (the formation of any Λ even prohibited on a proton target), however in a production experiments all mass ranges will be covered and there is no kinematic constrain. In our proposal we have demonstrated in detail how these production states can be explored, using Ξ^* spectrum as an example.

Further discussion about improved techniques for the interpretation of Λ(1405) are not in the main focus of the proposed experiment. The main reason for studies of different hyperon families lies on the fact that dozens of states are missing according to CQM as well as to LQCD predictions. The unique advantage of the K_L beam is that all momenta of the incoming beam are available at once and that's why the famous SLAC LASS and Estabrooks *et al*. experiments were not able to explore hyperon production, especially in the formation process as only fixed energy incoming charged kaon beams were used in these experiments. This obvious fact escaped the attention of reviewers.

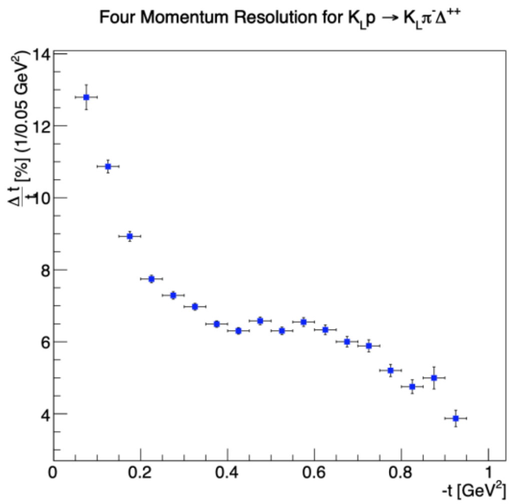
The Λ(1405) is only one small piece of information that can be obtained with the proposed K_L facility. That is why we did not even mention this state in the main part of proposal. The unique sensitivity and discovery potential of the KLF lies in Σ^* spectrum (formation) and Ξ^*(production), while in Λ^* case KLF will be competitive with existing and previous experiments. In that sense, it seems this review may have missed the forest for the trees.

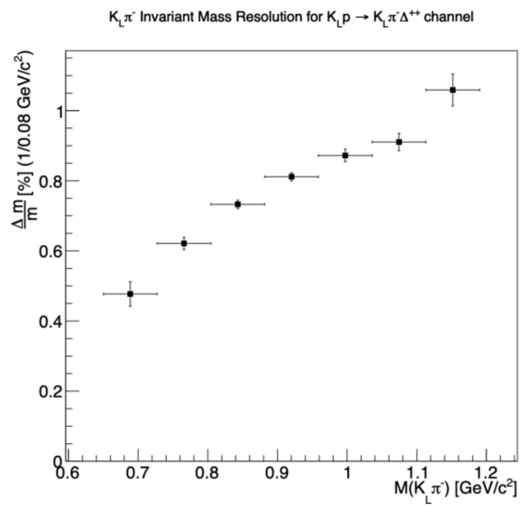
C: Second half of the report is devoted to the K-π scattering.

One notable item of progress since the last proposal, is the proposed use of Δ^{++} final states. This has the advantage over a recoiling proton, that the t-channel exchange is charged rather than neutral, potentially simplifying the modelling. In addition, it proves possible to perform isospin separation (Kπ can be produced in both I = 1/2 and 3/2) by measuring $K_Lp \rightarrow K^-\pi^0\Delta^{++}$ and $K_Lp \rightarrow K_L\pi^-\Delta^{++}$. Of course, the use of the Δ^{++} is not without its challenges, see below for comments regarding how low in |t| one can go (and hence how close to the pion pole), and the quality of resolution in the required process $K_Lp \rightarrow K_L\pi^-\Delta^{++}$ where the final state K_L is not detected.

Our response: Here we would like to answer that unfortunately the K-π mass resolution plots in the analysis note were uploaded by mistake without using kinematic fitting, which dramatically improves the resolution. The real K-π mass resolutions for all three reactions with the final state $K^+\pi^-$, $K^-\pi^0$, and $K_L\pi^-$ are below ~1% in the range of M(Kπ) <1.2 GeV.

The corresponding plots have been changed in the KLF Analysis Report (meson case) in the PAC48 wiki page of our proposal, in particular Fig 22, shown below, demonstrates the ~1% level mass resolution in the $K_L\pi^-$ final state.





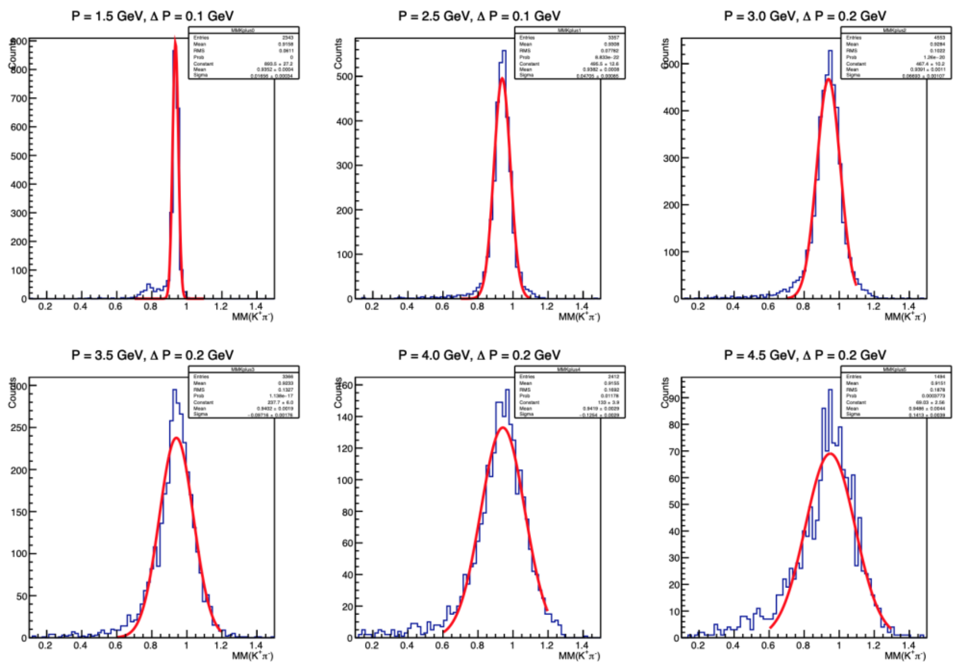
D: In the current Fig 12 what would appear to be an incredibly crude estimate of systematic error appears to have been introduced, simply an energy independent 5% systematic error added on each phase-shift point (which totally dominates the statistical error), with no suggestion as to how that originated or if is conservative or optimistic.

Furthermore, the fit (in orange) to this data with 'systematic errors', does not account for the fact that clearly the uncertainties on these points at different m(πK) shown in Figure 12 are completely correlated, and as such the fit returns a very small uncertainty which does not reflect the (correlated) uncertainty on the data points.

Our response: The flux uncertainty does not directly translate into an uncertainty on the phase shifts. The 5% systematic error was a conservative estimate of the error on the phase shifts at the level of other systematics, such as the flux measurement uncertainty.

E: The experiment also proposes to measure Kπ in $K_Lp \rightarrow K\pi(p)$ where the recoil proton is not detected, in order to collect events at smaller values of |t|, and with improved m(πK) resolution, at the cost of needing now to model neutral exchange in which a more varied set of t-channel exchanges can be present. Further, moving away from exclusive reactions typically incurs an increases in background contributions, and this would seem particularly likely in this experiment, where the beam momentum is not known precisely – the possible backgrounds are not discussed in the proposal.

Our response: It has been simulated and shown in the supplemental note that up to $P(K_L)$ = 4.5 GeV/c the experiment can be carried out without final state proton to be detected. With this upper limit in beam momentum the proton can be separated from Δ or N* final state recoils. In the KLF Analysis Report (meson case) referenced in the proposal, the missing mass resolution determining this background separation is shown in Figure 10 (below).



F: The proposal does not describe how the recoil proton and recoil Δ^{++} data sets will be used together in the extraction of phase-shifts.

Our response: Simulation studies in the proposal have demonstrated the sufficient reconstruction of the proton and two Δ^{++} final states which provide the necessary input for isospin separation. The extraction of the separated isospin 1/2 and 3/2 phase shifts will require a simultaneous analysis of these final states, following a similar procedure to that used in previous measurements at LASS.

G: On the topic of beam energies, one issue that has not been discussed is the impact of a spread in beam energies in KLF. LASS and the earlier SLAC experiments used monochromatic beams, so their phase-shift extraction done by studying t-dependences was expressed in terms of reaction model parameters evaluated at a single beam energy. In the case of KLF, they will have a spread of beam energies, and will have to bin in p_{beam}, and do separate phase-shift extractions in each bin, with model parameters that one assumes will be p_{beam} dependent.

Our response: A model of the contributions beyond single-pion exchange which depends on beam momentum will be required to extract the elastic K-π scattering contribution. While the spread in beam energies adds another dimension to the analysis compared to previous measurements, it may also be a valuable tool to validate the models developed over a wide range of kinematics that would not be possible for a fixed energy beam. In addition, the hyperon program discussed previously will provide important input on the possible contributions from *s*-channel backgrounds at low beam momentum.

H: The use of the Δ^{++} rather than the recoil proton in the final state also complicates the phase-shift extraction as now there are multiple helicity amplitudes to deal with in a situation where the modelling is already complicated. It is not simply the case that at low |t| simple pion exchange is dominant and other processes can be neglected as demonstrated in the GlueX data on beam asymmetry in $\gamma p \rightarrow \pi^- \Delta^{++}$.

Our response: The Δ^{++} was used in the early experiment by Estabrooks *et al.* and become impossible with the LASS experiment where they presented the phase shift for the sum of 1/2 and 3/2 isospin states. The possibility of other contributions beyond single-pion exchange mechanisms in photoproduction reaction may be also present in the experiments with kaon beams be it at SLAC or with KLF. Interpreting this as insurmountable obstacle is too radical in our opinion, as it questions not only how valuable the proposed experiment will be, but also previous SLAC measurements. However, we agree that further studies and more precise experimental data will help to estimate impact of other than single pion exchange mechanism on the PWA in the elastic $K\pi$ scattering domain. Therefore, the proposed experimental program for $K\pi$ scattering is becoming even more important.

The tone of the remainder of the report that discusses issues such as previous submissions, authorship, and other editorial issues is over the top, and therefore we prefer to not respond in kind and limit our discussion to issues of physics.