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 actually read the wrong proposal, the one from PAC47 and not from PAC48 (at least partly). In particular they write “*The* $Λ(1405)$ *is highlighted as one of the primary state(s)*”, in reality the first time the $Λ(1405)$ state mentioned is on page **59** as a sub-subsection of the 3rd Appendix, which by no means can be qualified as “highlighted”. Also the phrase “*In Fig. 6 they compare predicted experimental data that may be accessed using the* $K\_{L}$ *beam (*$K\_{L}n\rightarrow K^{-}p$*,* $\overbar{K}n$*,* $πΛ$*,*$ πΣ$*) using two different examples of models used to determine the aforementioned pole*” is wrong, since the Fig. 6. of PAC48 proposal shows discovery potential for the cascades. The figure which fits the description has number **43** on page **64** of Appendix 3, while in proposal PAC47 it was indeed Fig 6. This situation makes us very 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 study of hyperons is important as reviewers admitted: “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.”

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.

**Comment:**

”In the discussion on the ⇤(1405), the PI’s make reference to LQCD calculations in “Modern

LQCD calculations also support the view that this its structure is a KN state” and again

in “Lattice calculations based on the sequential Bayesian do, however, indicate that the multiplet may have a mainly 3-quark structure”. These so-called modern LQCD calculations

use outdated techniques that make use of uncontrolled approximations.”

**Our response:** The proposal contains a fair set of references to the most recent numerical lattice QCD calculations. It is not the task of an experimental proposal to express opinions on which set of techniques employed in those calculations are more or less up-to-date.

**B**: Second half of the comments on hyperon spectroscopy is related to L(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, however in a production experiments all mass ranges will be covered and there is no kinematic constrain.

Further discussion about improved techniques for the interpretation of L(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. Moreover, the only way to test LQCD prediction for the existence of hybrid hyperon states is to provide complete set of states that could be measured in the proposed experimental program. The unique advantage of KL beam is that all momenta of the incoming beam are available at once and that’s why famous SLAC LASS and Estabrooks *et al*. experiments were not able to explore hyperon production especially in a formation experiments as only fixed energy incoming charged kaon beams were used in these experiments. This obvious fact escaped the attention of reviewers.

In a sense that it is not constructive to not see a forest for the threes, which seems to be the case. The L(1405) is only one little piece of information that can be obtained with the proposed KL facility.

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

One notable item of progress since the last proposal, is the proposed use of D++ 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 (Kp can be produced in both I = 1/2 and 3/2) by measuring KLp🡪K-p0D++ and KLp🡪 KLp-D++. Of course, the use of the D++ 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 KLp🡪KLp-D++ where the final state KL is not detected.

**Our response**: Here we would like to answer that unfortunately the K-p mass resolution plots in the note are uploaded by a mistake. The real K-pi mass resolutions for all three reactions with the final state K+p-, K-p0, and KLp- are below ~1% in the range of M(Kp) <1.2 GeV.

The corresponding plots have been changed in the supplemental note in the PAC48 wiki page of our proposal.

The 5% systematic error is conservative estimate of the flux measurement uncertainty.

This systematic error is overall for entire M(K p) mass range and essentially affects the normalization, but not the shape of the simulated phase shift and there is no correlation of errors between the points. In addition, due to the fact that we have dramatically high statistics, this effect can be further constrained plotting the phase shift for narrow ranges of incoming beam of KL momenta.

**D**: The experiment also proposes to measure Kp in KLp🡪Kp(p) where the recoil proton is not detected, in order to collect events at smaller values of |t|, and with improved m(pK) 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(KL) =

4.5 GeV/c the experiment can be carried out without final state proton to be detected.

**E:** The proposal does not describe how the recoil proton and recoil D++ data sets will be used together in the extraction of phase-shifts.

**Our response**: The charged channel has the same Clebsch-Gordan linear expansion of isospin 1/2 and 3/2 as the reaction with K-p0D++ final state and therefore can be used in the same way along with final state with KLp-D++ to obtain phase shifts for isospin 1/2 and 3/2 separately for a different waves.

**F:** 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 pbeam, and do separate phase-shift extractions in each bin, with model parameters that one assumes will be pbeam dependent.

**Our response**: In the elastic K-p scattering the beam momenta are irrelevant, the only parameter that plays the role is the t-Mandelstam to be low to separate single pion exchange and another parameter is M(Kp).

**G:** The use of the D++ 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 gp🡪p-D++.

**Our response**: The only way, with KLF or at SLAC to get different linear combinations of isospin 1/2 and 3/2 is to use at least one reaction with D++ in the final state. That is why this separation was possible 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 than 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 will proposed experiment 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 analysis in the elastic Kp scattering domain. Therefore, the proposed experimental program for Kp scattering is becoming even more important.

The rest of the report about previous submission, number of proposal authors etc. has mentoring tone, it is rather belletristic therefore do not require the answer.