Hexaquarks at CLAS12 reply

M.Bashkanov, D.P. Watts, N. Zachariou

December 2019

Abstract

Recently discovered $d^*(2380)$ hexaquark is expected to be the first particle from a SU(3) hexaquark antidecuplet. A search for heavy strange partners of the $d^*(2380)$ is a challenging task. In this analysis note we propose strategies we plan to exploit in our studies of hexaquark antidecuplet. Most promising hexaquark candidates with strangeness zero, one, two and three are identified and will be studied based on CLAS12 run group B data by the York group. Several PhD students are allocated for these studies.

1 Q&A

We want to thank the reviewers for their careful reading of our proposal. However it seems that the main goal of this proposal slipped away from reviewers attention. The document we present is not suppose to be treated as an analysis report *per se*, but as a request to analyse rg-B data to search for exotic hexaquark signals. That is why some of referees questions related to studies based on rg-B data can not be answered, since we are officially not allowed to do so. The reviewers suppose to evaluate if we are qualified enough to perform rg-B analysis, based on this proposal and give us official blessing to preform this studies. As soon as we get this allowance we will happily perform all of suggested evaluations and a lot of others. The results of these studies will be shown as analysis report different from this proposal paper. Below we had answer some of the reviewers questions, which we allowed to answer without braking the CLAS rules. We also updated the main document according to suggestions.

We can only suggest that Fig. 5 reflects the MC study of the CLAS12 detector. The information provided in the proposal is very limited and it is very weak side of this paper. We need more information how these pictures were generated and how the acceptance was calculated. Does this picture show the ability of CLAS12 to detect $d^{(2380)}$ in the $d\pi^0\pi^0$ decay mode? If so, we can say that the acceptance near the resonance mass is very low and is fast changing in this mass region. It will be very desirable to have at least the rough estimation of the d expected statistics from rg-B data set.

We have added further information to the text.

The group presented some preliminary search of ds based on the CLAS6 g13 data, attempting to study $d_s \to \Delta\Sigma^*$ decay mode. It is very good. However, there was no attempt to use the existing rg-B data set to demonstrate the CLAS12 ability to search for this resonance.

The purpose of this outline analysis request is to get an allowance to use rg-B data. Once this is approved we will of course be carrying out the analysis of rg-B data with priority. What is requested is simply not possible to do. We appreciate the calibration of rg-b is progressing well (and our group is strongly involved).

The current status of the rg-B analysis software is giving such a possibility. It is important or even necessary step in the submitting the analysis project that will determine the research activity of several PhD students.

Please see comments above. We have shown the reconstruction of this reaction is feasible with calibrated CLAS6 data. The calibration of rg-b is in progress and, because of the challenging reaction, false conclusions could be reached from analysis of small amounts of data at an early calibration stage. We do not think it is appropriate to have this as a pre-requisite to access the data. Of course this will be the major ongoing analysis project to which we will contribute to the calibration effort.

It was not clear for us why the charged kaon channel is less promising than neutral kaon channel for the ds production. We can only guess that Fig. 10 presents the simulation of the CLAS12 detector. Please provide the full description of the picture that you have presented!

We have added clearer captioning on the plots. The neutral Kaon reaction is more optimal for the studies we propose as Kaon in flight production is forbidden. This is stated in the proposal **"to suppress diagrams**

with kaon in flight production, contributing largely to a background reactions we concentrate on a process with neutral kaon in a final state". There are several background reactions with kaon in flight and Weinberg-Tomozawa type terms which exist for charged kaons, but not for the neutral. Moreover, with neutral kaon and charged d_s^+ one can have only charged particles in the final state with all of them detected (as shown in our study), with neutral d_s^0 and charged kaon it is not possible.

What kind of generator did you use for the MC simulation?

The generator was developed in York using the TGenPhaseSpace class in ROOT. In all cases (except Fig 9) it was a pure phase space with $1/q^2$ dependence for a virtual photon. For Fig.9 a full diagram simulation was implemented.

Do you have estimation of the ds mass?

Yes, on Fig.4 of the proposal you can see the mass estimation for all antidecuplet members.

We know that the track reconstruction efficiency is not 100% in CLAS12. At the rg-B luminosity the track reconstruction efficiency is around 80%. If you are going to detect 7 particles (see Fig. 10) you will have additional factor $0.8^7 = 0.2$. It means that the expected number of events will be 5 times less than calculated using acceptance presented in the picture.

The figure of acceptance has nearly nothing to do with expected number of events. The main purpose of acceptance figures is to demonstrate the smoothness of acceptance in the region of interest. We want to remind the review committee that the d_s production reaction was measured at CLAS. Yes, the luminosity related track reconstruction efficiency will be smaller than at CLAS6 days, but not by a 20%, however the CLAS12 acceptance itself is larger as well as the luminosity of rg-B outperforms g13. Even CLAS6 data allowed to set an upper limit for a d_s reaction. There is absolutely no reasons why the same things cannot be done at CLAS12 rg-B. The number of rg-B triggers is expected to be twice larger than that of g13.

What is the model that you are using to calculate background presented in Fig. 13? It was written in the capture that blue line with a maximum near 1760 MeV represents dss. Is it really so?

We assumed the same cross-sections ratio between the d_{ss} and conventional Ξ's as between the $d*(2380)$ and $N*/\Delta$'s. The statement about the 1760 MeV peak is correct: the d_{ss} is produced on two nucleons; if one take two K^+ and assumes a quasi-free production on single nucleon instead, that is exactly the picture one would see

to clarify it we have added: *Here we assumed the same suppression factor for the d_{ss} relative to conventional resonances as for the d^* relative to N^*/Δ's (~ 100 suppression). For simplicity, all known Ξ's are shown to appear with the same strength. As one can see the d_{ss} is expected to appear in the region where no Ξ contributes. If we assume a quasi-free K^+K^+ production on proton, Fig 13., the d_{ss} should appear at $M_{d_{ss}} - M_n$.*

We have the same questions and remarks for the Fig. 15 as we have for the Fig. 10.

We put the same answer as for Fig. 10. A nicely smooth acceptance guaranty us from accidental production of bumps in the region of interest. Any events or absence of events can and will be converted into upper limits for the reaction never measured before. Provided sufficient statistics will be collected and if a clear resonance will be seen, one can further discuss a strategy of data publication. However this will be discussed with analysis report committee and have nothing to do with allowance to investigate this reaction which is the topic of this committee and this proposal.

The weak point of this proposal is absent of the preliminary study of the reactions with one, two and three kaons in the final state. It may show how clean these reactions are. In addition, we can estimate the statistics that we have in run group B.

There are no previously measured data for the reactions of interest == neither signal nor background cross-sections are known. There are no theoretical calculations on this topic either, since present day theory is unable to calculate anything reliably in this region. Any studies, except of experimental one would be just rubbish and a big waste of time. And to perform any experimental studies based on collected data we need to have an **official** allowance to conduct these studies. Before this committee would grant us such an allowance nothing can be done.

Some rg-A data analysis was presented recently from the York group. Please take a look at the Fig. 1 and 2. The situation is not very promising as for now. Even with one detected kaon the missing mass contains a significant background. The missing mass in the reaction $ep \to e'K^+K^+X$ does not show any signal from Ξ baryon at all. There is significant background below the Ξ mass.

We find it really funny that the studies which were done by M. Nicol (one of the students who performed these studies and who is asking your permission to let him study these reaction officially) are used against him. It is even more funny that the figures are quoted incorrectly. A figure 2 of your quote demonstrated issues of

Matt's code to handle extra negative pions, which is explicitly stated in the title. A reaction $ep \to eK^+K^+X$ nicely shows first two cascades even with just few runs he used and with outdated calibration constants.

The figure 18 (is it rg-A data by the way?) presents only background events.

yes

We have added "The data are from RG-A beam time" where relevant.

One of the reasons of the significant background in these reactions is kaon particle identification. Taking into account that any kaon brings a factor of 10 in comparison with pion we can estimate that K+KK+ production will be suppressed by a factor of 1000 in comparison with +++. It means that the suppression of the pion background has to be done at the level at least 103 104 that is extremely difficult. It is our guess that the situation will be even worse with the deuterium target.

We agree that the K^+ analysis would be challenging, but the other part of the statement is simply wrong. To understand it incorrectness one can select a simple $eK^+p\pi^-$ events sample which is not made by 90% of $p\pi^+\pi^-$ events. Moreover, the higher event multiplicity you have, the stronger exclusivity cuts you apply, the cleaner event sample you get. A proposed and accepted study of Ω baryon is in much worse conditions compare to this experiment. Also, an extraction of pion misidentification background is trivial and can be done in many ways: one can select a $K^+K^+\pi^+$ events and assume pions to be kaons or one can use kaon mass plot and perform a side band subtraction. To demonstrate the validity of the later method we show missing mass for the $e'K^+$ and $e'K^+K^+$ events after mass-plot side band subtraction. As one can see, pion background is fully suppressed and hyperons appeared background free. The peak on the right is a physical background. For a single K^+ production it originates from K^+K^- in-flight production, MesonEx mode, $ep \to e'pK^+K^-$. And for the K^+K^+ reactions it comes from K^+K^- production on mesonic part and $K^+\Lambda$ production on baryonic part, $ep \to e'(K^+K^-)(K^+\Lambda)$.

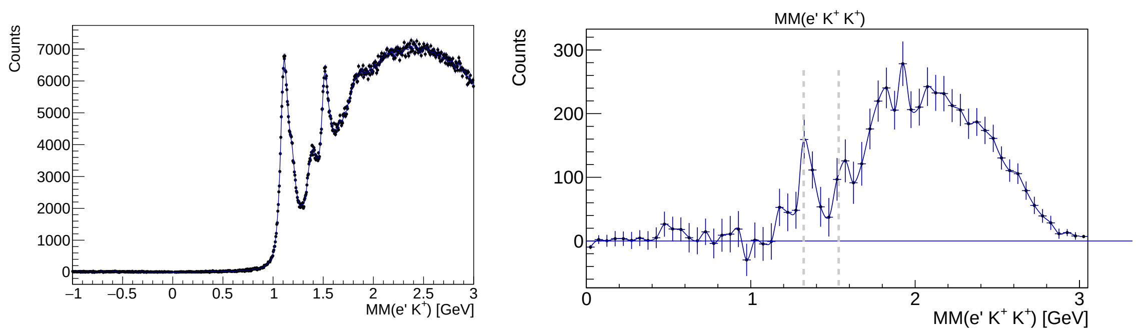

Figure 1: $e'K^+$ missing mass (left) and $e'K^+K^+$ missing mass (right) with the side band subtracted K^+ identification. The data are from RG-A beam time.

In our view it is very important to provide similar preliminary analysis of the rg-B data in advance.

That is not allowed by collaboration rules as they were explicitly expressed to us by Bryan. To perform any study of real data measured by rg-B we need an allowance by the committee.

We have also several editorial remarks.

- 1. The references are not in order. Many references are just absent, see for example Fig. 2 capture and on page 14. fixed
- 2. Reference 5 is incomplete, there is no date in it. fixed
- 3. There is no reference to Fig. 9. fixed
- 4. Page 14. No reference provided: It was shown already in Ref. ???? that a contact term is very repulsive. fixed

References

(2009). (2011).