CLAS12 Etaprime Transition Form Factor Proposal

Hadron Spectroscopy Working Group Committee Response

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Physics Motivation

Overall the committee believe the physics case for such a measurement is strong and analysis of tens of thousands of Dalitz Decays would provide a significant impact in determining the slope parameter required as input for hadronic light by light corrections.

Physics goal/motivation should be in abstract, probably first paragraph. i.e hadronic corrections for muon anomaly.

As far as we have determined, measurement of the slope parameter would ultimately be the important result of this proposal. As such this should be made clear in the abstract and the end of section 1.1.

An explanation on physically what the muon anomaly is and how it relates to the diagrams in figure 1. i.e. why it needs the hadronic corrections that this experiment is attempting to constrain in section 1.1.

It ends with too much enthusiasm. You have not made your case that there is a quantifiable connection between the g-2 QCD calculations and the proposed measurements. The most you can hope for is that “The new data will guide the theoretical improvements needed to push the QCD calculations for g-2 to have less uncertainty.”
Is there a reference to the use of this slope parameter to the HLbL calculation? It’s wiser to remove “the essential measurement needed for the HLbL contribution” unless this can be backed up with a reference. What is the relevance of the different approaches in Table 1 to the proposed measurement? Will you use these to parametrise your TFF and fit to data, or will your data replace these theoretical determinations?
There should be a clear explanation how this measurement can lead to an improvement in the Hlbl correction.

If the slope parameter is the desired outcome it should be possible, given the realistic simulation, to state an expected uncertainty in this quantity rather than just the number of Dalitz events. Again this could be reported in the abstract.

Count Rate Estimates

The committee is concerned over the method used to calculate the photon flux in section 4.2.1. The proposed measurement is the Dalitz Decay of etaprime produced in electroproduction with the scattered electron and reactions products all measured in CLAS12. As such we cannot understand why a real (untagged) bremsstrahlung photon flux is determined to calculate the expected yield. In addition we cannot find any evidence verifying this approach in the meson spectroscopy proposal as claimed. In this approach there is no scattered electron to detect in CLAS12 (essential for vertex

cut).
The referenced meson spectroscopy proposal,using quasi-real (not bremsstrahlung) photons, calculated the rate of electrons (0.4<E<4.5GeV) in the forward tagger due to hadroproduction (total cross section for all channels approximately 100ubarns) as 6.7kHz. This allows a higher rate of tagged hadron electroproduction than CLAS12 alone as the scattered electron yield is greater at small angles. (Meson section 5.5.3) This integrated the electron scattering kinematics with luminosity 10^35 and realistic Q^2 dependence over the forward tagger acceptance.
Similarly in the meson proposal the rate of electroproduction events where the electron is detected in CLAS12 (E>0.5) is given as 1.5kHz (section 5.5.2).
We can use these numbers to extrapolate to the etaprime Dalitz decay yield given an etaprime photoproduction total cross section. From reference [44] you can estimate the total cross section as very approximately 0.5ubarn (the proposers could provide a more accurate estimate). This can be compared to 100ubarn for total hadroproduction assumed in the meson proposal, i.e. a factor 200 less.
For CLAS12 electron detection number etaprime = 1.5k/200 = 7.5Hz = 50M in 80days
Dalitz Decay branch = 5x10^4 ; N(Dalitz) = 25,000
Average detection efficiency =0.05 gives 1,250 events compared to 26,000 proposed.

Section 4.4 “Realistic Yield” makes similar assumptions.

The committee note that the forward tagger would provide a further 4 times that number of events with the trigger being made by the decay e+ or e- in any case. i.e. irrespective of any coincidence the forward tagger has to make with CLAS12 for meson spectroscopy events. In addition as the photon and e+ e- must be moving very forward detection of these in the forward tagger may also help increase the acceptance. The proposers should investigate how the inclusion of the forward tagger to this proposal would help the measurement.

Of course the bremsstrahlung photoproduction will provide a significant yield of events in CLAS12 as the e- will still make a trigger. It may be possible to analyse these events, although the background will be sizeable as there is no usable vertex cut.

Measurement

It is not clear how much background might be expected with CLAS12. Is there a significant combinatorial background in the inclusive measurement? What about other final states such as eta + pi which can result in 1 photon and e+ e- from pair production detected and have a higher cross section. These points could be cleared up by the simulation and reference to g12, show the reconstructed invariant mass (inclusive and exclusive) for pure etaprime Dalitz. Include the same plot for possible background reactions using the same analysis code. There is considerable random background in the g12 data what do you expect with CLAS12 kinematics?

The vertex resolution cut appears to be an important factor. Some explanation should be given as to why a 1mm resolution is a reasonable expectation for the PAC, presumably referencing the vertex detector technical report.

Why only look for the inclusive case of missing proton? The proton detection efficiency is possibly the highest of all (in CLAS12 central detector). Whereas detection of inbending e- may give a poorer acceptance.

“The lepton acceptance uncertainty is estimated to be <5% from previous CLAS measurements” This needs to be explained (i.e. how was it measured) and referenced. For your measurement it is

the acceptance as a function of M(e+e-) that is crucial, individual lepton (and photon acceptance which is not mentioned) will contribute to this but what is the uncertainty on the slope.
How does choice form factor fit function affect the extracted slope, i.e. what is the model dependence?
The background from pair production is small but in exactly the region where the slope is determined can you estimate the effect from your simulated background contribution. i.e sum the 2 histograms in fig and extract the slope parameter.
What is the expected systematic and statistical uncertainties on the slope parameter from the proposed experiment?

Simulation

It seems like significant work has been performed to verify the detection of the final state. However the section in the proposal needs improved in terms of writing (thorough proof reading) and technical details given. Don't assume PAC referees will know what EC and other detector abbreviations mean, similar GEMC and discussions of trigger. Define all abbreviations used.

In particular we would expect to see at least: reconstructed electron energy distribution, virtual photon energy and Q2, reconstructed invariant mass of (e+,e-,gamma) and missing mass (e+e-,gamma) in the inclusive case. Then detection efficiency as a function of production etaprime cos(theta_cm) or t, (cross section is highly t dependent and its exact distribution is uncertain).

If GEMC is used for the simulation it should be stated why the fastmc results are presented. Full CLAS12 reconstruction not available?

How is the scattered electron handled in the event generator? The proposal only makes reference to real photoproduction cross section and Dalitz Decay dependence. Is the vitual photon energy sample from some distribution?

The acceptance for flat and VMD is, and should be, the same as a function of M(e+e-) as it is only dependent on M(e+e-). There is no need to show both.

Figure 14 makes reference to a photon detection efficiency of 2-10%. This is not discussed in the text anywhere and has a factor 5 effect on the number of detected events! What is the origins of this factor? Why do you assume the largest value in your expected yields?

Difficult to read the numbers in Fig. 12-13 even after magnifying. There is no mention of Fig. 13 in the text.
Y-axis problems on figures 10-11, also resolution is poor, would be better to have improved figures.

Preliminary g12 results

This section requires much more technical detail on the analysis as the results are not available elsewhere for the PAC members. Refering to a technical note is not sufficient as per point 1 of the general guidelines for PAC proposals,they should be standalone, so details need to be given from ref [40,41] : In particular
What was the vertex resolution in g12? How does in compare with CLAS12?
Figure 9: Where is the background (gray) in g12 coming from? Will the author need a similar Q-factor background separation technique in this analysis?
Figure 9b What is the red histogram? Should be explained in caption/text.

The PAC committee may have no knowledge of Qfactor so if you want to present results with it you need to explain it (perhaps in appendix). It is not clear why it is used in this case, perhaps it is not a good technique as there are so few events the nearest neighbours can span a large range in M(e+e-) making the probability weight inaccurate for particular values of M(e+e-). It looks like there are only around 200 events in total so in reality all of them would be used in a fit with 200 nearest neighbours so the variation of signal to background as a function of M(e+e-) is not accounted for. It would be more appropriate to just bin and fit in ranges of M(e+e-), this would then be more straightforward for the PAC to understand.

What was the e/pi rejection factor in g12?

Assorted typos rearrangements...

In general the proposal could do with proof reading and rearrangement so that it is easier to understand for people not experts in the topic.

Section 1.3, page 5:

“In this proposal we present an experiment to study the η' meson of which decays via Dalitz decay,

$\eta \rightarrow e + e - \gamma$. The η is produced via electro-production, ...”

Typos: replace η with η' at two places in the second line.

Typo: meson of which decays ---> meson which decays

Section 2.2, page 7:

“According to that, the $\eta' \rightarrow e + e - \gamma$ the decay rate modifies as;”

Typo: the $\eta' \rightarrow e + e - \gamma$ the decay rate ---> the $\eta' \rightarrow e + e - \gamma$ decay rate

Section 2.2, page 8:

“where the virtual photon can stem from a intermediate vector mesons.”

Typo: remove “a”

Section 2.3, page 9:

The author does not tell what does the x variable in Equation 11 denote. I think specifying it would be nice.

Section 2.3, page 9:

“Using the ratio, $\Gamma(\eta' \rightarrow e + e - \gamma)/\Gamma(\eta' \rightarrow \gamma\gamma) = 2.13 \cdot 10 - 2$, that has been preliminary measured

by CLAS, which is consistent with [29], the probability of pair production when a photon, from the $\eta' \rightarrow \gamma\gamma$ decay, traveling though 5 cm of liquid hydrogen, H_2 , is shown in Fig. 4 as well as the number of $\eta' \rightarrow \gamma\gamma \rightarrow e + e - \gamma / 100 \eta' \rightarrow e + e - \gamma$.”

a) The sentence is too complicated. I suggest to break it into smaller sentences, specially since this is an important paragraph.b) Typo: though 5 cm of ---> through 5 cm of

Figure 4, 5:

a) Since Fig. 5 shows the contamination when a 1 mm cut is applied, it will be useful if the author can provide an equation that directly shows the probability (the y-axis) as a function of the distance traveled by the e+ e- pair. b) X-axis titles are missing in Fig. 4, 5.

Section 4.1, page 16:

Typo: The accpetance for this propose ---> The acceptance for this proposal

Section 4.1.1, page 16:

“the rate of the standard electron trigger will be 6 kHz, which the expected data acquisition (DAQ) readout rate is 10 kHz.”

Typo: which ---> while

Appendix B, Table 2 and 3:

The meaning of “upper” and “lower” should be mentioned in the Table captions in my opinion.

Abstract:

a. end of 2nd paragraph: remove “, therefore insufficient”
b. start of 3rd paragraph: “it was shown by preliminary measurements that the”
c. Remove the detail in the middle, from “The CLAS12 detector” to “will be detected”. These details belong in the text below, not the abstract.

Motivation:

d. Second paragraph: “justifies all efforts” -> “justifies the efforts”
e. Third paragraph: Reference for Lattice HPV not coming soon? Ref. [9] is too general.

History:

a. Second paragraph: add a sentence here that previous experimental results will be shown in Section 3.

Kinematics:

2.1“founded” -> “found”, and “expectation” -> “diagram”
2.2Form Factor: above Table 1, change “Tab. 1” to “Table 1”
2.3Photon Conversion:

Under Eq. (11): “preliminary measured by CLAS” -> “measured in a preliminary analysis by CLAS”

Summary: change CLAS to CLAS12. Note that even if the vertex resolution will be a few mm, the background from conversion electrons will still be very low.

Current Measurements:

change “Tab. 1” to “Table 1

Simulation

inputted -> input
Reference for GEMC?
Accpetance (spelling)

Section 1.2 Title “History” → “Dalitz Decays”

Page 5

e+e-/pi+/pi-branching rations>10^10 → ?what are you trying to say here e+e- decay rate ~10^-10 of pi+pi-? 10^10 is probably referning to rejection factor not branching ratio

Section 2 Title “Kinematics” → “Transistion Form Factors”

Page 7

Reference to Fig 3 would be better moved to P8 after equation 8 and include in text that it compares pure QED TFF with QED+VMD.

Section 2.3 Title “Photon Conversion...” ->”Background from real photon pair production”

Should some or all of Section 2.3 be moved as an extra subsection to Measurement Section?

Page 9

Para1 Remove “The process of pair production, $\gamma Z \rightarrow Ze + e^-$, occurs when a photon with $E_0 > 2m_e c^2$ converts into an electron and a positron.” repetition

Page 9

“that has been preliminary measured by CLAS, which is consistent with [29],”

Need to give a CLAS reference or just use value from [29] if it is consistent and not likely to effect the result.

.Section 2.4 Summary, just refering to section 2.3, probably not required, but Fig 7 should be moved into 2.3 (and probaby all moved into section 3). It should also be clearly stated that this is not simulated but an approximate calculation.

Page 12

last sentence suggestion “These obstacles will be mitigated with CLAS12 by the high luminosity, excellent electron identification and rejection factor of pi+pi-.”

Figure 8, Missing mass from CLEO not mentioned in the text, can probably remove this

Simulation

“The production of each particle was weighted by photo-production differential cross-sections, $d\Omega(v, \cos\theta_{cm})$, published in [44],...” should state was reference [44] is, i.e. measurements of eta' differential cross section up to ...GeV

Actually probably only need 1 of figures 12 or 13 and neither 10-11.