# PR12-21-006 Reply to Reader Comments – Part 1

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This document provides answers to part 1 of PAC49 review comments of PR12-21-006, "Measurement of the Asymmetry $A_d^{e^+e^-}$ between $e^+$–$^2$H and $e^-$–$^2$H Deep Inelastic Scattering Using SoLID and PEPPo at JLab".

1. The main issue is the positron beam.

   (a) What parameters are most important properties to control, how well?

   *Answer:*

   The most important properties are how well we can control and know the difference in the beam energy, position, intrinsic size and profile between $e^+$ and $e^-$ runs. In our previous answer to theory and technical comments dated July 11th, 2021, we have addressed the beam energy difference in detail. Beam intrinsic size and profile can be monitored by frequent harp scans and their effects simulated. Beam position is monitored real-time to a few (tens?) $\mu$m precision (need confirm) and the effect on the scattering angle can be calculated to below the $10^{-5}$ level, and again can be simulated and corrected.

   (b) Proposal emphasizes importance of *equality* of beam energies. Is this a strong limitation on the lab? TAC report also mentions this. What if the consistency was 50% worse than you request? What is your estimate of how much the systematic errors would increase?

   *Answer:*

   Please see our answers to theory and technical comments dated July 11th, 2021, Section 3.2.

   (c) What is earliest time you plan to have a suitable $e^+$ beam for your experiment?

   *Answer:*

   Possibly in 2030's, we don't know. Scheduling of the experiments is considered only after they are approved.

   (d) What is the maximum time separation between e+ and e- beam running you seek?

   *Answer:*

   In our answers to theory and technical comments, we have urged the lab to consider fast switch between $e^+$ and $e^-$ runs. A separation between $e^+$ and $e^-$ running of no more than a few days, and switching every 1-2 weeks are preferred.

2. Since DIS has no sharp signal, backgrounds must be calculated (high twist, radiative corrections seem most difficult). How will those be controlled?

   *Answer:*

We have laid out some strategies regarding this issue in the proposal: We will take data with 6.6 GeV beam to better understand the background that comes into the acceptance (bin migration) due to radiative effects. Higher twist effects should be discussed separated from bin migration. For higher twists, we calculated the expected size and their impact on the measurement using two higher twist models (fits). This was described in detail in the proposal. Furthermore, we emphasize that if higher twists are unexpectedly large, we will be able to extract it using our data on $F_3^{\gamma Z}$ and iterate the process of extractions of $A^{e^+e^-}$ and $F_3^{\gamma Z}$. We have also started looking into the effect of low-$W$ background due to internal radiation using the Monte Carlo tool of [1] and obtained promising results.

3. Will you do unpolarized or single polarized DIS measurements as a cross-check?

   *Answer:*

   The proposed measurement will utilize unpolarized beam. We will extract $e^+$ and $e^-$ cross sections as cross checks, but the uncertainty will not be as good as that of the asymmetry because some systematic effects will cancel partially when asymmetries are formed. As for polarized observables, if the beam has a 20% polarization, asymmetries $A^{e^+e^-}_{LL,RR,RL,LR}$ can be formed from data. Unfortunately, they will have exactly the same systematic effects as the unpolarized $A^{e^+e^-}$ and thus cannot be used as cross checks.

4. How does this relate to other positron experiments? Why was this chosen to be first?
   *Answer:*

   It's not clear if the question is about past or future experiments, thus we will address both below.

   Historically, there has been only one measurement of the muonic $C_{3q}$, experiment NA41 at CERN. Result from and a brief overview of the CERN NA41 experiment are provided in Sections 2.2 and 2.5 of the proposal. Data from this experiment provide $2C_{3u} - C_{3d} = 1.58 \pm 0.36$, analyzed using the latest knowledge on the $C_{1,2}$. For the electron-quark $C_{3q}$, it could have been measured by facilities with positron beams, SLAC and HERMES (and HERA at higher energies). The yield ratio of positron over electron DIS scattering was measured at SLAC and was found to be consistent with zero at the 0.3% level (see [2] for the most precise measurement of a series of $e^+/e^-$ yield ratio measurements at SLAC in the 1970's). HERMES was not designed for high-precision measurements [3] and the luminosity was too low for EW physics study. Therefore, both SLAC and HERMES missed the opportunity of investigating this physics. The DIS cross sections of both $e^+p$ and $e^-p$ scattering were measured at HERA and a global fit of the $g_{A,V}$ couplings was performed, but their energy scale is too high for an isolated access to individual couplings, and the sensitivity to BSM physics is different from JLab. Additionally, the concept of low-energy effective couplings breaks down at HERA energies.

   The proposed measurement is part of the positron program being planned for JLab, but it is not the first presented to the PAC: There were two proposals (on DVCS physics) submitted to PAC 48 that require the use of a positron beam. The timing of the submission of the other positron experiments is up to their proponents.

5. What are the differences between your proposal and the existing CERN measurement? I think that comes from the fact that their beam was polarized and yours will be unpolarized.
   *Answer:*

   The CERN NA41 experiment used muon beams and the results are on the muonic $C_{3q}$. Indeed, the muon beams at CERN are "naturally polarized" because they are produced from pion decay. The $e^+e^-$ asymmetry measured at CERN thus has a contribution from

$C_{2q}$, but this contribution is small due to $C_{2q}$ being small. On the other hand, a polarized beam is not required if the physics goal is to measure the $C_{3q}$ couplings, as shown in Eqs (10) and (12) of the proposal. A short summary of experimental techniques used by NA41 was also provided in Section 2.5 of the proposal.

6. There are no model dependence (e.g. PDFs) or background subtraction components in the error budget, Table 1.

   *Answer:*

   The line items in Table 1 are what we can put as common errors to the measurement. The uncertainty due to other factors, including statistical, background correction, PDF, QED, cannot be expressed as a common factor across the full $(x, Q^2)$ coverage so they are given in figure form when possible. This information is in the texts directly above Table 1.

We noticed multiple questions regarding the status of the positron beam at JLab, systematic effects, and the timing of the measurement. We summarize this document as follows: Even though the realization of a positron beam at JLab is still some time away, there are unique reasons to propose this measurement now: First, given that it is possibly one of the most challenging experiments at JLab, its preparation will require multi-year effort in both technical and theoretical fronts and thus we must start as soon as possible. Secondly, requirement from this experiment may provide important, even determining feedback to the ongoing design of JLab's positron beam. We hope the PAC realized the physics impact of the proposed measurement in electroweak study of the Standard Model, and that the low-energy effective coupling $C_{3q}$ cannot be measured at any other facility for the foreseeable future. We hope the proposal can be approved at this time such that we can justify the multi-year effort needed to prepare for this experiment.

# References


[1] K. Charchula, G. A. Schuler and H. Spiesberger, *Combined QED and QCD radiative effects in deep inelastic lepton - proton scattering: The Monte Carlo generator DJANGO6*, *Comput. Phys. Commun.* **81** (1994) 381–402.

[2] D. L. Fancher, D. O. Caldwell, J. P. Cumalat, A. M. Eisner, T. P. McPharlin, R. J. Morrison et al., *Precision Comparison of Inelastic electron and Positron Scattering from Hydrogen*, *Phys. Rev. Lett.* **37** (1976) 1323.

[3] G. Schnell. private communication on HERMES inclusive measurements, 2021.