Response to Reviewer Comments - Manuscript PLB-D-25-00875

A. Smith, *et al.* [GlueX Collaboration]

July 15, 2025

Comments from reviewers are written in plain, black text. Responses from authors are written in blue.

1. Reviewer #1

General comment from referee:

This article presents a first-time measurement at energies between 6.5 and 11 GeV of the total cross section for Compton scattering off atomic electrons. The results are in good agreement with NLO QED predictions and are worth publishing in this journal. However, there are a couple of points that should be clarified and addressed before proceeding to publication:

Specific Comments:

1) When the systematic uncertainties are described, the methods employed to evaluate them are described for all contributing factors except for the systematics on the photo flux measurement, which bring the biggest contribution. The description of the method adopted to evaluate this important systematic uncertainty should be included in the text.

We added more detailed text to the first paragraph in Section 3 (Experimental Details) describing how the pair spectrometer (PS) is used to measure the photon flux, as well as how the PS acceptance was measured from special calibration data. Moreover, we added more text to the third paragraph of Section 4 (Cross-Section Results) describing the methods used for estimating the systematic uncertainty.

2) I find in general Figure 3 a bit hard to read, maybe due to the thickness of the various lines, maybe reducing it could make the figure more readable (in particular it would allow better to compare data and simulation). Anyway, in this figure the DeltaK peak doesn't appear to be centered at 0, it is shifted by about -0.3 GeV. Why? The background shape could be a reason, but by eye the peak seems shifted more than what the background, which is quite small, could cause. Is this the case for just this bin or is it a global effect?

Does this have any impact on the final results? This should be addressed. Also, still on this figure, the legend and the text indicate that the fit line is red, but it looks more orange to me, and in any case different from the color of the legend.

We reduced the thickness of the lines for the simulated signal (blue) and background (magenta) distributions, as well as for the (black) data points. The line thickness for the total fit result is kept the same, because otherwise it would be difficult to distinguish it against the black data points. As you pointed out, the color of the 'Fit' line in the figure is actually vermilion, rather than red. It is intended to be a more unambiguous option for colorblind individuals. The manuscript was edited to refer to this as an orange histogram instead.

Indeed the ΔK distribution is not peaked at zero, but this is not due to the background. In fact, both the experimental data and the simulation of Compton scattering events through our experimental setup exhibited nearly the same offset in their reconstructed ΔK distributions. This distribution is calculated according to the measured scattering angles of the two detected particles, using the two-body kinematics of Compton scattering. A bias in the reconstructed position of the scattering angle directly results in a bias to the ΔK distribution. In particular, if the scattering angles are overestimated, ΔK will be negative, and if the scattering angles are underestimated, ΔK will be positive. For particles detected near the beam hole of the Forward Calorimeter (FCAL), there is intrinsic bias in the reconstructed position that pushes the reconstructed scattering angles to larger values. As the photon beam energy increases and the distribution of Compton scattering events becomes even more forward-angle dominated, this effect becomes more noticeable. We studied the impact of this offset on the experimental results by artificially shifting the simulated ΔK distributions for the signal and background that were used as templates for the maximum-likelihood fit described in the last paragraph of Section 3. Because the offsets of the simulated distributions already were in good agreement with the experimental data, this systematic effect was estimated to be small ($< 0.3\%$). This source of systematic uncertainty was folded into the number reported for the e^+e^- background subtraction in Table 1, since this relative offset affects the fitted fraction of events identified as signal versus background. A couple of sentences were added to the second-to-last paragraph of Section 3 addressing this offset.

3) The title says "6 GeV" while it's actually 6.5 GeV everywhere else.

We updated the title of this paper to more accurately reflect the energy range of the measurment. The new title reads: "Measurement of the Total Compton Scattering Cross Section between 6.5 and 11 GeV".

4) The introduction says that this measurement is an important test for the detector performances in view of the PRIMEX-eta experiment. Do the obtained performances, in particular the systematic uncertainties on the cross section, match the expectations for PRIMEX-eta?

The estimation of systematic uncertainties for sources common to both this Compton scattering cross section measurement and the η photoproduction cross section measurement for PrimEx-*eta* are mostly consistent with expectations. The systematic uncertainty related the photon flux is around 50% larger than the original value included in the uncertainty budget for PrimEx-*eta*. However, this source of uncertainty was not predicted to be the dominant contribution to the overall uncertainty, and these result confirm that expectation.

2. Reviewer #2

General comment from referee:

This manuscript reports on new measurements of the total Compton cross section using the GlueX spectrometer in Hall D at Jefferson Lab. This work builds on previous measurements of this process in Hall B by the same collaboration. Precise measurements of the total Compton scattering cross section provide a critical test of QED, particularly at the level of NLO corrections.

The paper is well-written and a sufficient amount of details are given for the reader to understand the methods and findings. I submit below a few minor comments for the authors to address.

Specific Comments:

1) The authors emphasize repeatedly that this is the first measurement at this energy: in the title, in the abstract, in the introduction, and in the conclusion. This is unnecessary and distracting. Instead, the authors should argue why these measurements at higher energy or within this particular energy range are interesting and what their impact is with respect to our current knowledge of NLO QED corrections.

We understand how the repetitive use of the word "first" can come off as distracting. To counter this, we removed it from the title and from the introduction when used in this context. Additionally, we re-phrased the text in the second paragraph of the introduction to emphasize the importance of this measurement for testing the NLO QED calculations not only at higher energies where the size of the corrections are predicted to increase, but also over a wider range of energies, providing a more complete test of the theory.

2) In the abstract and conclusion, a precision of 3.4% is stated. One should specify whether this refers to statistical precision, systematic precision, or maybe some (quadratic) sum of the two.

The 3.4% number represents an average value of the quadratic sum of the systematic and statistical uncertainties from each energy bin. Some extra words were added to both the abstract and conclusion to clarify this point.

3) In the introduction (4th line), it is mentioned that the LO amplitude interferes with the double Compton scattering amplitude. This cannot be the case, as the final states of these reactions are different.

You are correct that the double Compton process has a different final state and therefore cannot interfere with the LO amplitude. The loop diagrams at NLO, however, do contain the same final state and can interfere with the LO process, which leads to an infrared divergence. As discussed in Section 2 (Theoretical Background), this divergence is canceled by the inclusion of the double Compton scattering process with emission of a soft, secondary photon. The way the text was originally written implied that the double Compton process interfered with the LO process as well, so we changed the phrasing of this sentence to correct this inaccuracy.

4) The second paragraph of the introduction implicitly assumes the Compton scattering process, but does not mention it. This should be made explicit, i.e., the NLO corrections *of Compton scattering*, total cross-section measurements *of Compton scattering*, etc.

Thank you for pointing this out. We inserted the phrase "to the Compton scattering cross section" in this sentence to make the connection more explicit.

5) Typo on the 1st line of page 8 (after Fig. 3): "on change" -> "one change"?

Our apologies for the typo. "on change" was corrected to "a change".

6) Fig. 4: While within systematic uncertainties, the data show a different trend below and above 9 GeV with respect to the NLO calculations. There is no comment on this in the paper.

No conclusive explanation was determined for the observed difference in the cross section above 9 GeV. To avoid speculation, we did not make any statement about this effect. However, in the updated manuscript, we added a couple of sentences to address its existence and the possible indication of some unaccounted-for systematic effect.

One potentially relevant connection is that the energy where this effect begins aligns with the peak position in the pair spectrometer (PS) acceptance curve. The PS acceptance has a triangular shape as a function of the photon beam energy, where the peak position is defined by the strength of the magnetic field used to deflect the e^+e^- pairs. We included a figure below from an internal technical document showing the PS acceptance as a function of the beam energy, and a fit function approximating its shape. Due to the limited statistics, the acceptance (measured during dedicated low-intensity runs where a total absorption counter was inserted into the beamline) is parameterized using an analytical function. Systematic uncertainties on this parameterization were assessed by varying the fit parameters within $\pm 1\sigma$ of their nominal values, as well as using alternate parameterizations of the shape. The uncertainties on the PS acceptance were estimated from this procedure to be slightly larger at and above this peak position. Despite this connection, there is no way to unambiguously prove the observed difference in the trend of the cross section measurement with respect to the NLO calculation is related to this effect. However, the results still agree with the theoretical calculations to within our estimated systematic uncertainties, and we believe no further statement needs to be made about that fact within the scope of this paper.

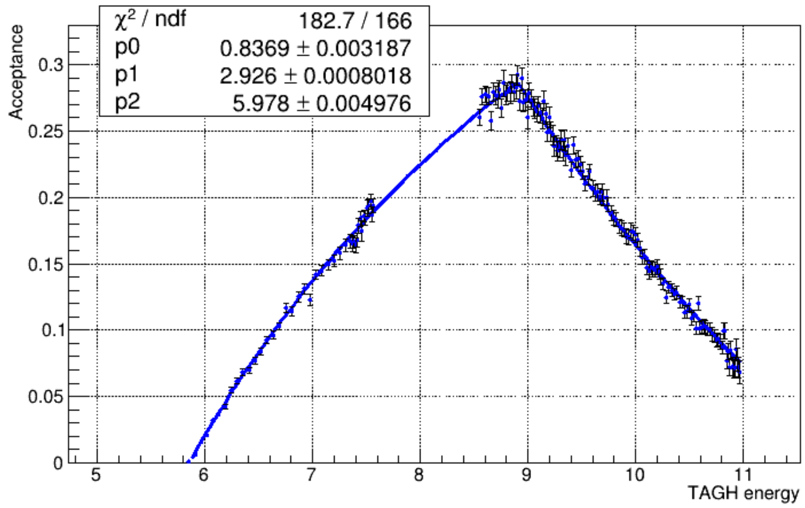

Figure 1: Pair spectrometer acceptance as a function of the photon beam energy, as measured during a dedicated TAC (Total Absorption Counter) run during the PrimEx-*eta* experiment.