Angular Dependance in Time-Like Compton Scattering

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Abstract

The main goal of this report is to investigate angular dependance in Time-Like Compton Scattering (TCS), using the reaction $\gamma + p_{\perp} \rightarrow e^{+} + e_{-} + p$, which consists of two sub-reactions, TCS and Bethe-Heitler process (BH), where the electron pair is coming from the photon splitting in the nuclear field. In this report, we bombard the cryo-target (Lh2, Ld2) cells with high energy photon beams. The target cells are made of aluminum 7075 alloy, whose composition is 5.6-6.1% zinc, 2.1-2.5 % magnesium,1.2-1.6% copper, and less than 0.5% of other metal, with the rest being aluminum.

This report focuses on simulations to account for the background effect and to investigate angular dependance in time-lime Compton Scattering (TCS) for the best alignment of the target. Both simulations aim to obtain best results and minimize the error caused by background effect.

Introduction

- Time-Like Compton Scattering (TCS)

Time-Like Compton Scattering (TCS) is a process that occurs in high-energy particle interactions, specifically involving the scattering of a high-energy photon off a chosen target particle. It is analogous to the Deeply Virtual Compton Scattering (DVCS), which occurs in the space-like region, where the initial photon energies is virtual.

TCS is a fundamental process in particle physics and provides insights into the structure and properties of particles, as well as the dynamics of their interactions. It is used as a tool to study the composition of hadrons, which are particles made up of quarks, such as protons and neutrons. By measuring the energy and scattering angle of the scattered photons in TCS experiments, scientists can extract information about the distribution of quarks within the target particles, which can shed light on their internal structure.

- Generalized Parton Distributions

Generalized Parton Distributions (GPDs) are theoretical objects in quantum chromodynamics (QCD), which is the theory that describes the strong nuclear force, one of the fundamental forces of nature. GPDs provide a way to describe the distribution of quarks and gluons, which are the elementary particles that make up protons, neutrons, and other hadrons, both in momentum and spatial coordinates within these particles.

GPDs are an extension of the concept of Parton Distribution Functions (PDFs), which describe the probability of finding quarks and gluons with a given momentum fraction inside a hadron. While PDFs only provide information about the longitudinal momentum of partons, GPDs incorporate information about the spatial distribution of partons as well. GPDs provide a more detailed picture of the internal structure of hadrons, revealing how quarks and gluons are distributed in momentum and spatial coordinates, and how they interact with each other.

Experiment and Methodology

In our research project, we bombard the cryo-target (Lh2, Ld2) cells with high energy photon beams. The target cells are made of aluminum 7075 alloy, whose composition is 5.6-6.1% zinc, 2.1-2.5 % magnesium,1.2-1.6% copper, and less than 0.5% of other metal, with the rest being aluminum. This report focuses on simulations to account for the background effect and to investigate angular dependance in time-lime Compton Scattering (TCS) for the best alignment of the target. Both simulations aim to obtain best results and minimize the error caused by background effect.

This overall reaction process (collision) of hitting the targets cells consists of two sub-processes to be analyzed separately – a time-lime Compton Scattering (TCS) where photons scatter off the electrons, and a Bethe-Heitler process (BH) where an electron pair is coming from the photon splitting in the nuclear field.

$$\gamma + p_{\perp} \rightarrow e^{+} + e^{-} + p$$

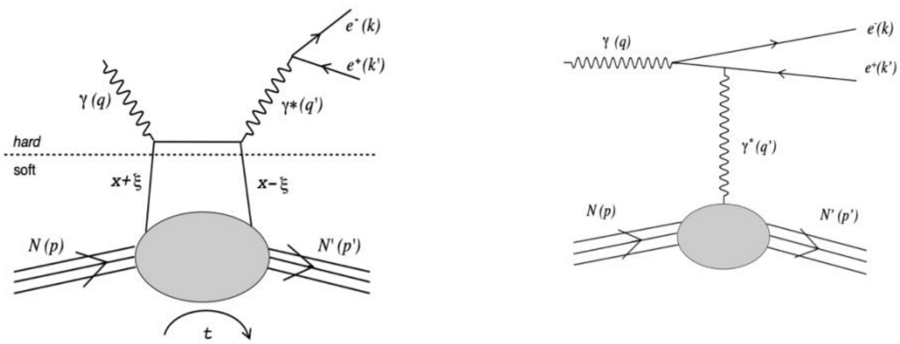


Figure 1: Left: TCS leading order and leading twist handbag diagram. The dashed line indicates the factorization between the hard QED calculable part, and the soft part, which is parametrized by GPDs. Right: Bethe-Heitler process interfering with TCS, leading order and leading twist diagram. Cross diagrams are not represented.

In Bethe-Heitler process, the incoming electrons scatter from the aluminum cell wall of the cryo-target, which produces the so-called background effect. The background effect needs to be subtracted from the data, and this leads to the first objective of this report – to account for the background effect using simulations.

Second objective of this report concerns with angular dependance in time-lime Compton Scattering (TCS). This report runs multiple simulations for the best alignment of the target.

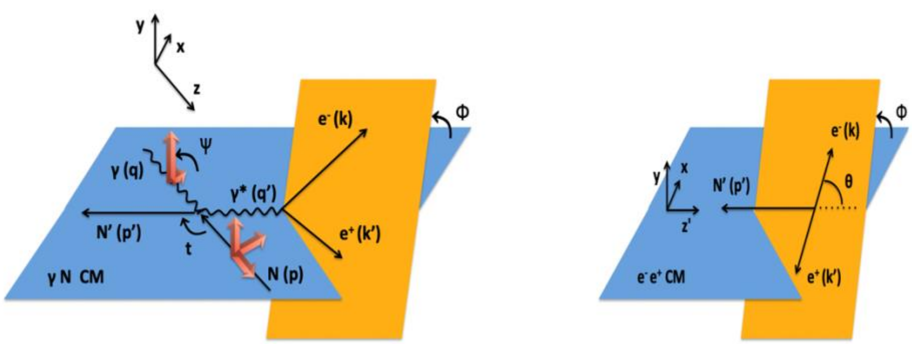
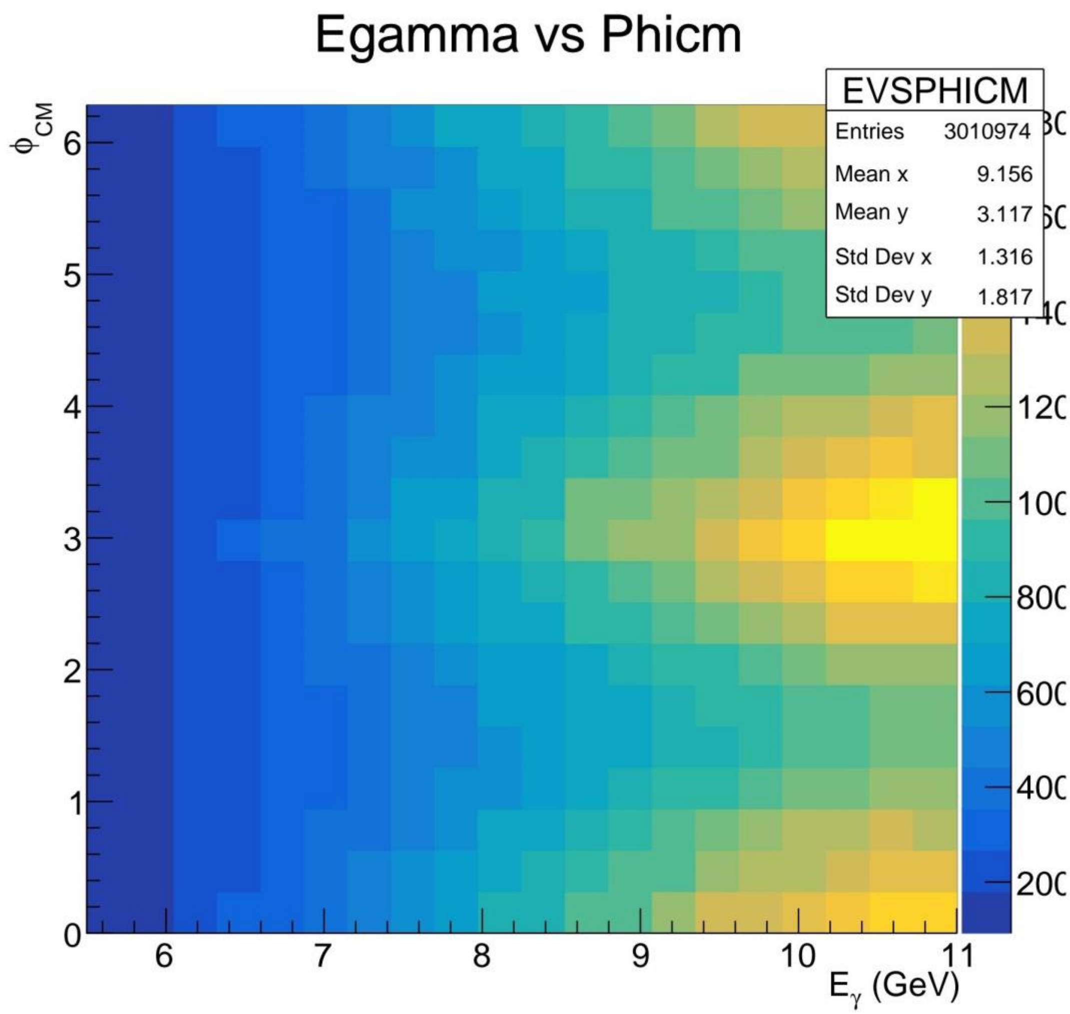


Figure 2: Scheme of the TCS reaction in the nucleon-photon center of mass frame (left panel) and in the virtual photon rest frame (right panel). The momentum of incoming and outgoing nucleon, real and virtual photon, electron and positron are indicated by letters p, p', q, q', k and k', respectively. Left panel: we indicated the angle ϕ_{CM} between the lepton decay plane and the reaction plane. We also indicated by red arrows the possible orientations of the incoming photon spin (Ψ) and the target spin (ϕ_S, θ_S). Right panel: ϕ_{CM} angle is conserved in the boost from γN to γ^* C.M. frames. θ_{CM} is the angle between the lepton direction and the boost axis, defined by the γ^* direction in the γN C.M. frame.

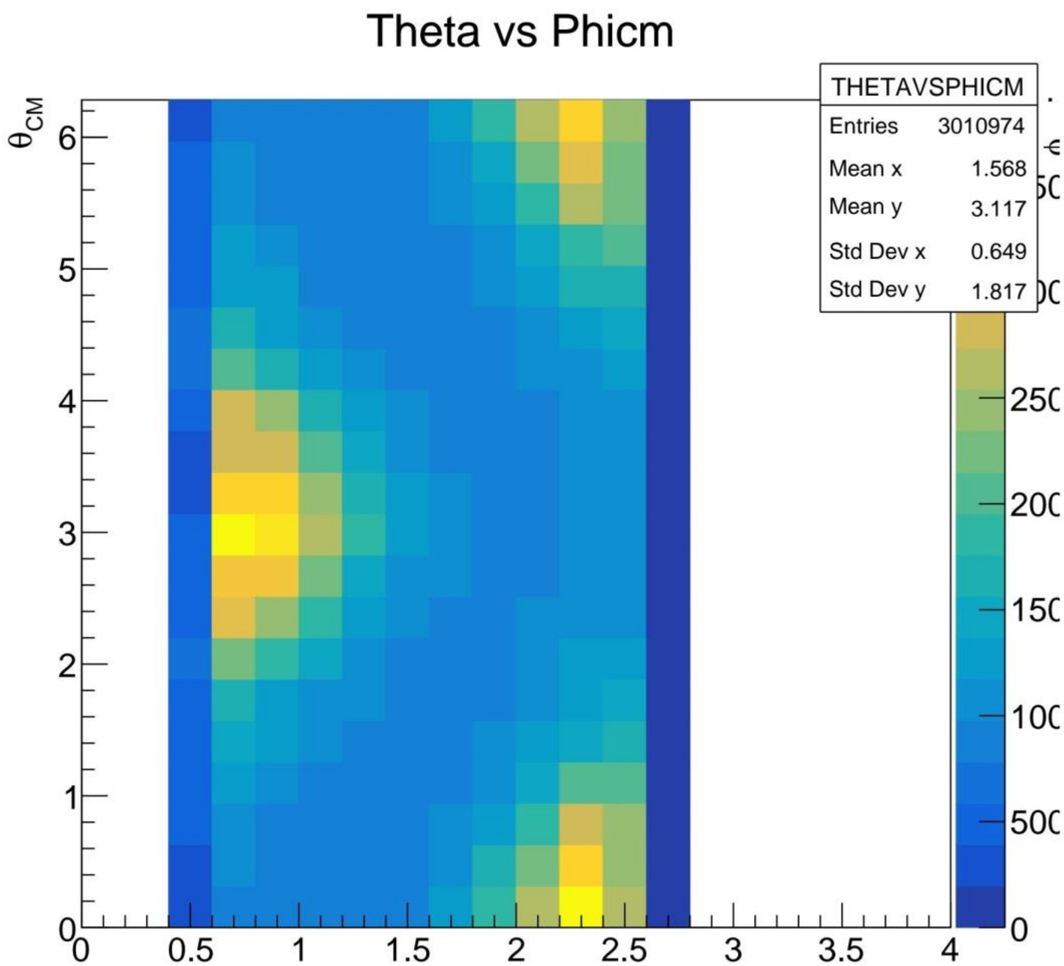
Our simulations using c++ and other programming languages investigate relationships between several scattering angles and kinematic variables, and generate probability density functions and plots that present these relationships.

Data Analysis, Discussion, and Evaluation

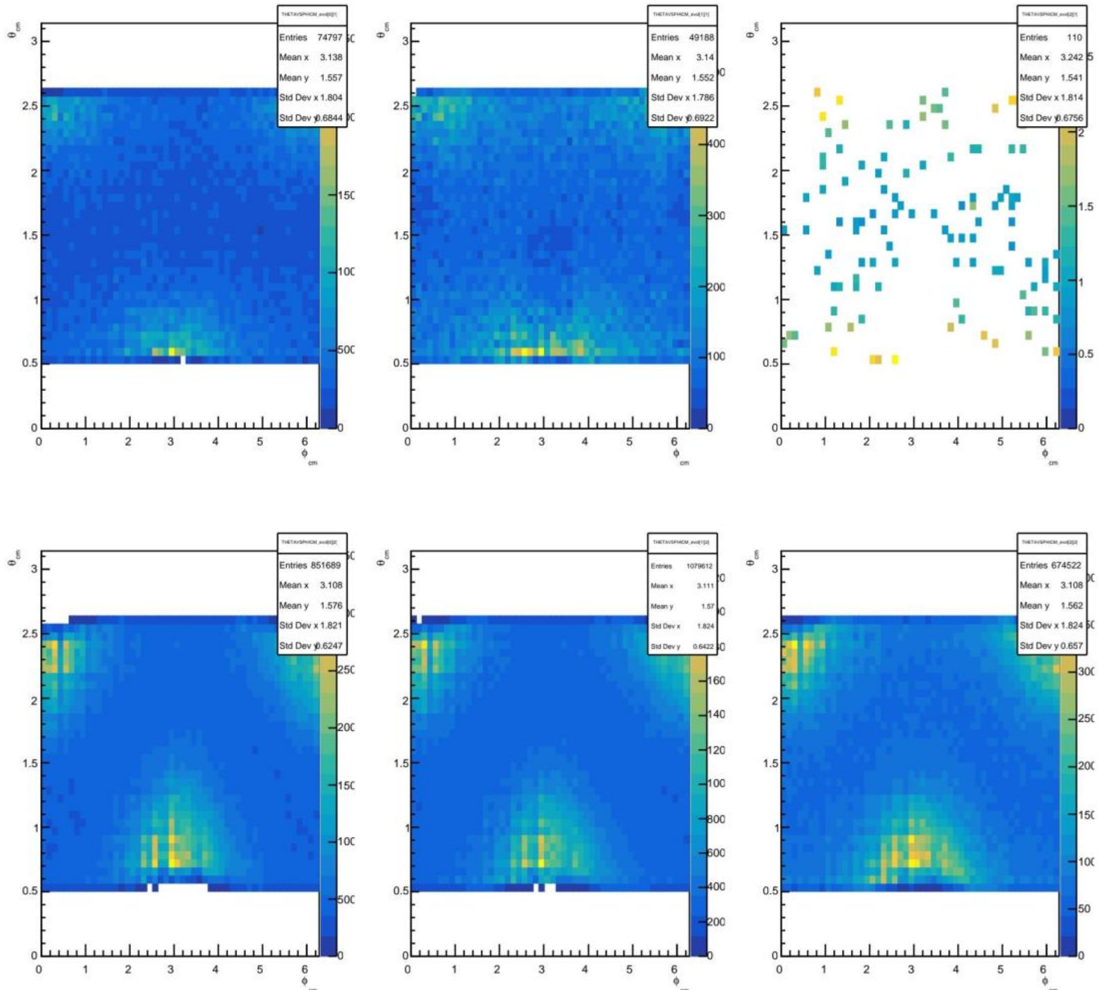
The angular dependence will be determined by using c++ to generate histograms between quantities and angles. The histogram of two variables serves as a probability distribution.



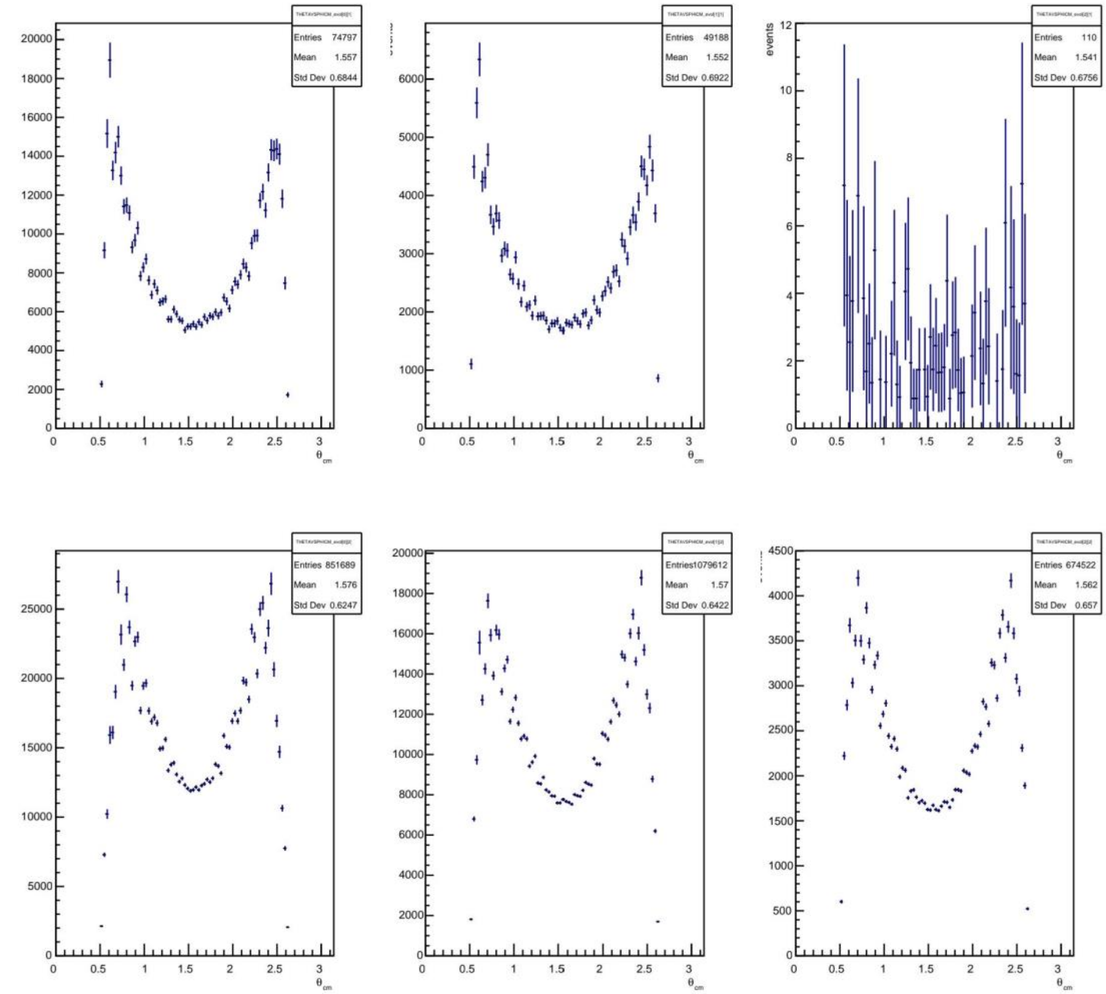
There are multiple quantities we checked; this is one of the results. In the graph, the more yellow at a certain point is, the more likely we observe the TCS. The bluer section is the opposite of yellow. The histogram above energy vs phi at center of mass frame. The histogram shows that the events is more likely to occur at nπ (n=0,1,2…). However, the energy only occurs at certain angle, it means it had limited correlations between the angle.



The two angles appeared in graph are related to the scattered particles. In the graph we observed an alternating pattern, which suggested that there are some relationships between the two angles. Therefore, we conducted a set of data analysis.



We did the same histograms but with various energy, time, and momentum. The time is from 0.05 to 0.7, energy is from 5.5 to 11, and the momentum is from 4 to 9. From the above histograms, except the third graph which showed peculiar results, the other graphs showed the angular dependence is strong.



From the histogram we can see that there are two peaks situated at right and left, which is the evolution of the two angles. From that, we can conclude the angles are strongly correlated and are complementary of each other.

Conclusion

There are limited correlations between other kinematic quantities, whereas there is a strong correlation between θ and φ and they are complementary to each other by looking at the evolution under various E,Qp2, and t. Furthermore, in TCS, there is no favored direction in which the electron pair scatters. However, the curves obtained don't show quite enough differences between them, which the experiment would have observed.

Bibliography

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