Studying Background Radiation in the Compton Polarimeter

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Abstract

Many of the experiments that run in Hall C at Jefferson Lab require a precise measurement of the electron-beam polarization. Along with the current Moller Polarimeter, a Compton Polarimeter is going to be added, which is non-destructive to the beam, allowing the polarization to be measured at the same time that data is taken. Current simulations for the Compton Polarimeter, which track the properties of the particles as they go through the magnetic chicane and into the detectors, neglect the background radiation that will be created, especially when the beam passes through a focusing aperture before it enters the optical cavity. When the beam goes through this aperture, some of the electrons in the beam halo will collide with the metal, thus creating background radiation. The focus of this project was to adapt the current Monte-Carlo-based Compton simulation to determine the perimeters as to when the background radiation produced by the beam halo will cause significant errors in the data taken in the detectors. Using Fortran, the aperture was created in the Geant3 Monte-Carlo simulation. Then, simulations of the beam halo were run, with and without the aperture, and the rates of the particles detected for both backscattering and beam halo were analyzed. It was found that the halo will not be a significant problem in the detectors, but it will be more of a problem in photon detector than the electron detector. For the backscattering and halo events to differ by a factor of ten in the photon detector, the fraction of the beam in the halo needs to be smaller than 2E-10, which is 20 times smaller than expected. This means that as long as the beam is focused, the backscattering events will dominate. Placing certain hardware thresholds on the detectors, which will cause them to only read certain energy ranges, can also improve the ratio of backscattering to halo events. These findings will allow the scientists working on the Compton Polarimeter to know the relative size of contamination coming from the beam halo background radiation. The simulation will also be useful for the design of the 12GeV Compton Polarimeter, allowing scientists to see if the size of the aperture must change as the beam's energy increases and the halo becomes worse.

The Compton Polarimeter

- The Compton Polarimeter utilizes the concepts of Compton scattering of electrons off of laser photons.
- The asymmetry of the experiment can be measured, and from this value, the beam polarization can be found.

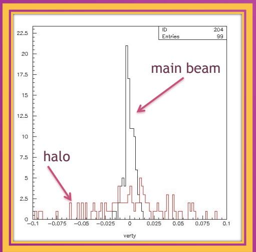

Figure 1 (above): The x-position of the main beam (black) and the hall (red)

The Beam Halo

- Type of background radiation in the Compton Polarimeter
- Some of the electrons have energy that is different from the rest of the beam and the beam Gaussian does not go to zero
- Can cause significant readings in the detectors because of a focusing aperture in the beam pipe. Because of the halo, some of the electrons may collide with the metal, causing electron scattering that is in addition to the Compton scattering.

Methods & Materials

- Current Geant3 Compton Simulation was used, which tracks particles as they go through the polarimeter
- Volume of aperture was created in the Fortran based code
- Many adjustments were made in simulation to allow for background radiation and also to make it more realistic
- Simulations (with and without aperture) of backscattering and halo were compiled and analyzed as 'hbook' files
- Main aspect that was analyzed was how much energy was being deposited into electron and photon detectors due to beam halo in comparison to backscattering
- The goal was to have the backscattering and the halo events differ by at least a factor of ten

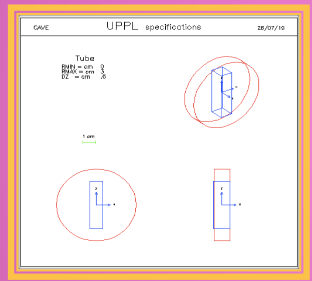

Figure 2 (above): The aperture in the simulation. First, a metal disk was made. Then, a rectangular cube of "vacuum" was placed inside the metal disk to simulate the aperture.

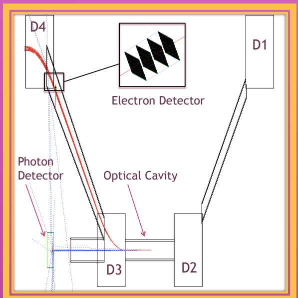

Figure 3: Compton Polarimeter with just Compton backscattering

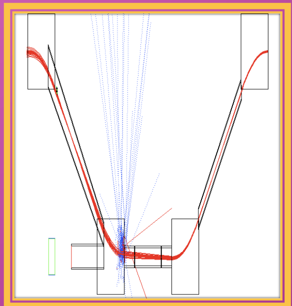

Figure 4: Compton Polarimeter with just the beam halo

Results

	No Cuts			Cut that Energy of Photon deposited 20<Eg<47 MeV (1)			Cut that Both Detectors Must Be Fired (2)			Both Cut 1 and Cut 2		
	Backscattering Rates (Hz)	Halo Rates (Hz)	BS/BH	Backscattering Rates (Hz)	Halo Rates (Hz)	BS/BH	Backscattering Rates (Hz)	Halo Rates (Hz)	BS/BH	Backscattering Rates (Hz)	Halo Rates (Hz)	BS/BH
Photon Detector (No Aperture)	105 k	1 k	105	54 k	94	580	68 k	75	902	18 k	56	317
Electron Detector (No Aperture)	69 k	3 k	24	18 k	57	317	68 k	75	902	18 k	56	317
Photon Detector (With Aperture)	107 k	11 k	7	54 k	2 k	29	69 k	1.7 k	42	17 k	430	40
Electron Detector (With Aperture)	70 k	5 k	14	17 k	430	40	69 k	1.7 k	42	17 k	430	40

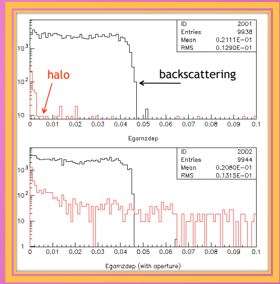

Figure 5: The energy distribution versus rates in the photon detector without the aperture (top) and with the aperture (bottom)

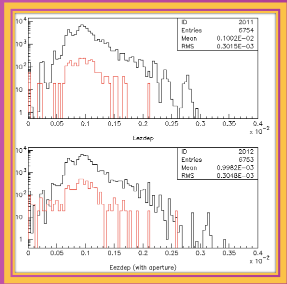

Figure 6: The energy distribution versus rates in the electron detector without the aperture (top) and with the aperture (bottom)

Conclusions

It was found that the background radiation from the beam halo will not be a significant problem, yet it will be more of a problem in the photon detector. In order for the backscattering and the beam halo events to differ by a factor of ten, the fraction of the beam (with no cuts) in the halo has to be 2E-10, which is 20 times smaller than expected. Placing cuts on the energies recorded in both detectors, which is done using hardware thresholds and software cuts, gives the optimal ratio between the backscattering and the halo. Since the ratios with these cuts are greater than ten, the fraction of the halo in the beam can be increased. Using the hardware cut eliminates events from being recorded, and thus, the scientists working on the Compton polarimeter have to decide whether it is more efficient to have all the events or eliminate as much halo as possible. In general, however, as long as the beam is focused, the backscattering will dominate the halo rates. After careful analysis, the maximum fraction of the halo in the beam to get a factor of ten difference can be as high as 8E-9.

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