PROCEEDINGS OF SCIENCE

Compton scattering with tagged photons at the MAX IV Laboratory

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The Compton-scattering program at the Tagged Photon Facility at the MAX IV Laboratory is primarily focused on the extraction of the nucleon isoscalar polarizabilities from the $^{2}\mathrm{H}(\gamma,\gamma)$ reaction. In addition to deuterium, measurements have been conducted on $^{6}\mathrm{Li}$, $^{12}\mathrm{C}$, and $^{16}\mathrm{O}$ for the purposes of understanding experimental systematics. At this time, we have preliminary cross sections for $^{12}\mathrm{C}(\gamma,\gamma)$ that agree with previously published results. This is a critical first step in establishing our understanding of the absolute normalization of our experiment that is neccessary before reporting $^{2}\mathrm{H}(\gamma,\gamma)$ results.

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1. Motivation

The electric and magnetic polarizabilities (α and β, respectively) of the proton and neutron are fundamental structure constants. Measurements of these nucleon polarizabilities have been conducted for the past thirty years. Many of the studies made use of nuclear Compton scattering. Much progress has been made towards precisely extracting the proton polarizabilities [1], but the neutron values are much less well-known. A Collaboration has been established at the MAX IV Laboratory for the purpose of conducting an improved study of the ^{2}H(γ,γ) reaction and extracting more precise values of α_n and β_n. In addition to deuterium, other targets have been studied in an effort to understand the systematics of the facility.

The current world data set for deuterium Compton scattering is shown in Figure 1 [2, 3, 4]. Previous measurements suffer from large statistical and/or systematic uncertainties (*i.e.* $> 10\%$) or wide energy bins. Combined with the relatively few number of data points, these factors are responsible for the large uncertainties of α_n and β_n. The current focus is to improve on these data sets by measuring the cross section over a larger kinematic range (see Figure 1) while holding both systematic and statistical uncertainties to $\leq$10%. Additionally, measurements will be pushed above 100 MeV where the sensitivity to the polarizabilities will be even greater. Such an improvement in the world deuterium Compton scattering data set will provide a significant reduction in the uncertainty of the extraction of the neutron polarizabilities. The new data will also allow for testing the theory of the two-photon response of the nucleon, a better understanding of meson-exchange currents, and a reduction in the uncertainty of $\mathrm{M_n}$–$\mathrm{M_p}$ – calculations which are currently dominated by β_n contributions [1].

2. Experimental Conditions

The measurements presented here were carried out at the Tagged-Photon Facility (TPF) at the MAX IV Laboratory (formerly MAX-lab) [5]. The facility produces an electron beam with energies up to $\sim$200 MeV. The electron beam is directed onto a thin ($\sim$300 μm) Al radiator which produces a bremsstrahlung photon beam. The photon-tagging technique (see [6]) allows for precise determination of the energy of a bremsstrahlung photon (< 1%) by momentum analysis of the recoiling electron using the tagging magnet. The tagger focal plane also counts the number of recoil electrons which is proportional to the number of incident photons on target. The proportionality constant is a geometric scaling factor known as the tagging efficiency. The tagging spectrometer and focal plane [7] were acquired from the Saskatchewan Accelerator Laboratory.

The experimental setup is shown in Figure 2. Tagged photons which interact with the target may scatter into one of three large-volume ($\sim$50 cm ϕ $\times$ 50 cm long) segmented NaI detectors. These detectors have an energy resolution of better than 2% at energies near 100 MeV. This high detector resolution, together with the high focal-plane energy resolution, is necessary to separate elastically scattered photons from those originating from the breakup of deuterium.

To date, seven run periods at the TPF have been used for Compton scattering experiments (see Table 1). The majority of the beam time has been dedicated to measurements of ^{2}H(γ,γ) cross sections below $\sim$120 MeV. One beam period resulted in data across pion threshold. As noted, the average photon rate per tagger channel ranges from a few hundred kHz to 1 MHz. The higher rates

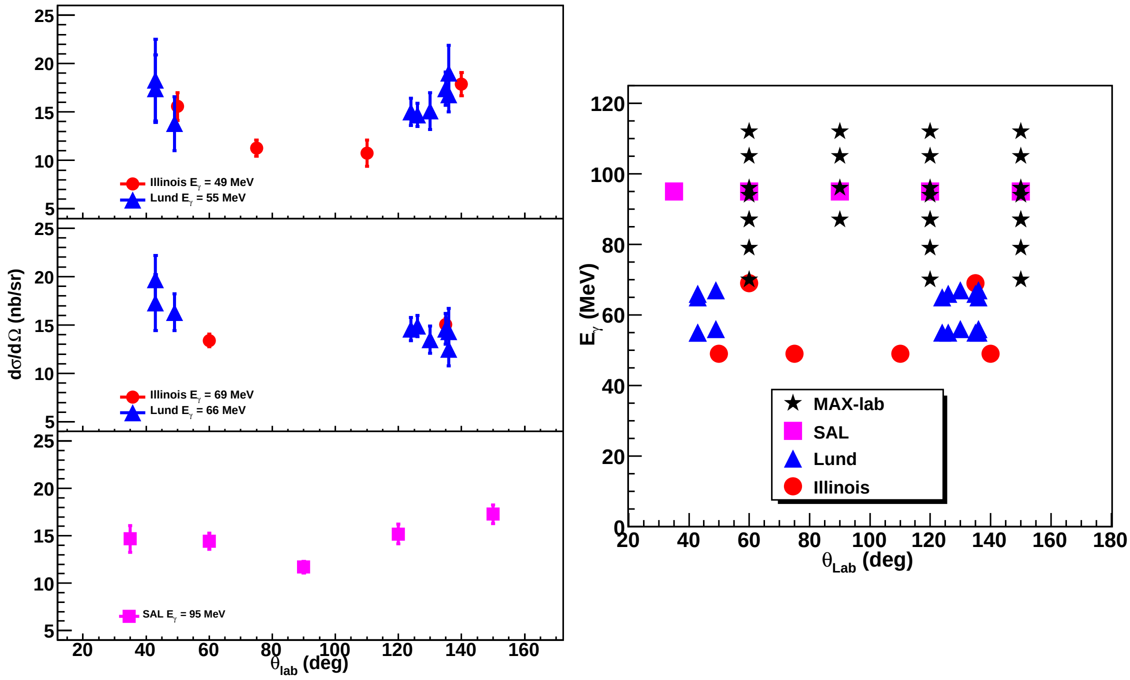

Figure 1: (Left) The current world data set for deuterium Compton scattering. (Right) The kinematic phase-space (photon energy and scattering angle) coverage of the previous deuterium Compton scattering measurements as well as the current experiment.

Run Period	Targets	Angles[deg]	E_γ [MeV]	R_{ave} [MHz]
Nov 2007	^{2}H,^{12}C	60, 120, 150	66–98	∼1.0
Sept 2008	^{16}O,^{12}C	45, 90, 135, 150	66–98	∼0.9
Nov 2008	^{2}H,^{12}C	60, 120, 150	81–116	∼1.0
Nov 2009	^{2}H,^{12}C	60, 90, 150	81–116	∼0.6
Sept 2010	^{2}H,^{12}C	60, 120, 150	81–116	∼0.7
June 2011	^{2}H,^{12}C	60, 120, 150	145–166	∼0.2
Apr 2012	^{6}Li,^{12}C	60, 120, 150	61–100	∼0.4

Table 1: Summary of the Compton scattering run periods at the TPF at the MAX IV Laboratory to date.

suffer from larger rate-dependent corrections. Data collected using the ^{12}C target are intended to provide a measure of the systematics of the experiment.

3. Preliminary Results

The results presented here are taken from the ^{12}C data sets from 2007 and 2008. An accurate analysis of these data is essential for understanding the systematics of the TPF. The photon yield is obtained by subtracting the untagged and/or random photon background from the prompt spectrum. The photon peak is clearly evident in the missing-energy spectrum shown in Figure 3. An uncorrected cross section may be determined from this yield by normalizing to the number of

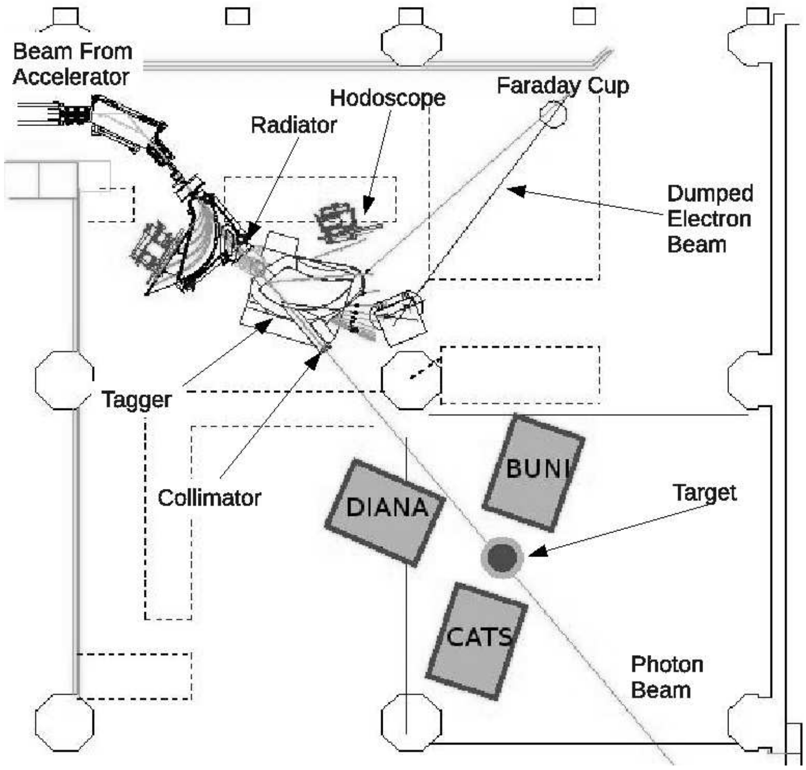

Figure 2: Experimental layout showing the locations of the focal plane, target and NaI detectors (BUNI, CATS, and DIANA) for the Compton scattering experiments.

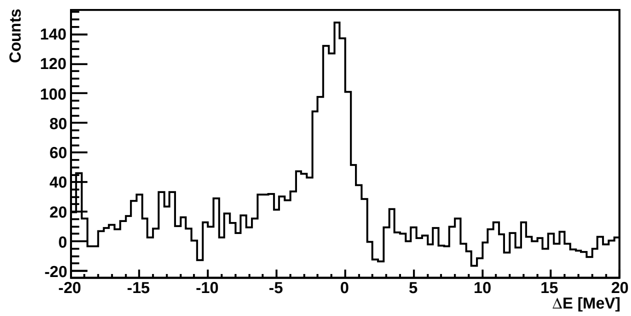

Figure 3: The background-subtracted, Compton-scattering photon peak from $^{12}C(\gamma,\gamma)$.

incident photons, target thickness, and detector acceptance. Rate-dependent corrections must then be applied.

The rate-dependent corrections are large due to high average beam rates and a low duty-factor beam (*i.e.* high instantaneous beam rates). The complex time structure of the beam (Figure 4) further complicates the analysis. Also, some of the rate-dependent corrections cannot be determined analytically. We have developed a simulation of the behavior of the focal-plane electronics that allows us to compute the rate-dependent corrections for the exact experimental conditions of the run period being analyzed [8]. The simulation does an excellent job of replicating the real beam

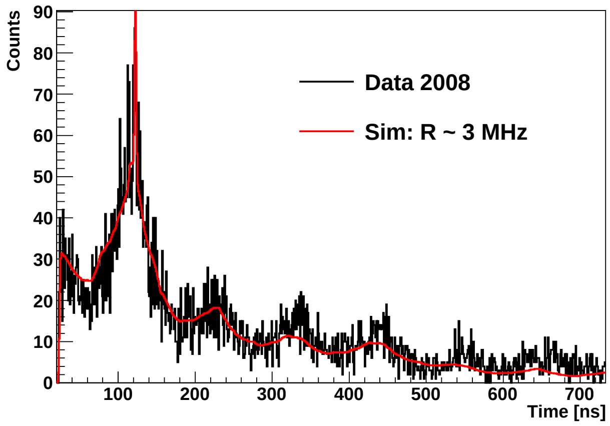

Figure 4: The time profile of the beam at MAX-lab. The black spectrum is taken from scattering data. The red is the output from the simulation. See Ref. [8] for details.

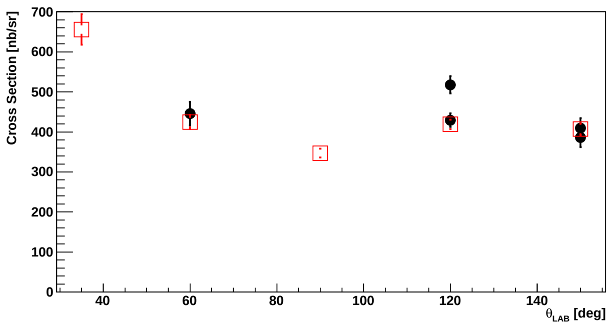

Figure 5: Preliminary ^{12}C cross sections (circles) for this measurement at 86 MeV from 2007 and 2008. Results from Warkentin *et al.* [9] are also shown (squares). The 2007 data set did not have a suitable measurement at 60° due to an improper veto.

structure in these data (Figure 4).

Preliminary differential cross sections for ^{12}C are shown in Figure 5. The agreement with previously published results is excellent. We believe that the systematics of the TPF at MAX-lab are well-understood.

4. Future Goals

Our immediate goals are to publish the ^{12}C cross sections for the 2007 and 2008 run periods. The analysis of the ^{2}H(γ,γ) will be completed shortly thereafter. Analysis of the 2009 and 2010 ^{2}H(γ,γ) data is progressing at the University of Kentucky. A longer-term goal is to obtain more data in the pion-threshold region in order to extract polarizabilities at these energies.

References

[1] H.W. Griesshammer, J.A. McGovern, D.R. Phillips, and G. Feldman, *Using Effective Field Theory to analyse low-energy Compton scattering data from protons and light nuclei*, *Prog. Part. Nucl. Phys.* **67** 841 (2012) [nucl-th/1203.6834].

[2] M.A. Lucas, Ph. D. Thesis, University of Illinois (unpublished) (1994).

[3] D.H. Hornidge *et al.*, *Elastic Compton scattering from the deuteron and nucleon polarizabilities*, *Phys. Rev. Lett.* **84** 2334 (2000).

[4] M. Lundin *et al.*, *Compton scattering from the deuteron and extracted neutron polarizabilities*, *Phys. Rev. Lett.* **90** 192501 (2003).

[5] J.-O. Adler *et al.*, *The Upgraded Tagging Facility at the MAX IV Laboratory*, Submitted to *Nucl. Inst. Meth.* **A** (2012).

[6] J.-O. Adler *et al.*, *A broad range tagging spectrometer for the MAX-laboratory*, *Nucl. Inst. Meth.* **A388** 17 (1997).

[7] J.M. Vogt *et al.*, *The Photon Tagging Facility at the Saskatchewan-Accelerator-Laboratory*, *Nucl. Instr. and Meth.* **A339** 425 (1994).

[8] L.S. Myers *et al.*, *Monte Carlo Simulation of the Photon-Tagger Focal-Plane Electronics at the MAX IV Laboratory*, Submitted to *Nucl. Instr. and Meth.* **A** (2013) [physics.ins-det/1303.4013].

[9] B.J. Warkentin *et al.*, *Nuclear Compton scattering from ^{12}C and bound-nucleon polarizabilities*, *Phys. Rev.* **C64** 014603 (2001).