Simultaneous measurement of ion and electron energy spectra using a Thomson parabola ion spectrometer

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Abstract

Simultaneous measurements of the energy spectrum of electrons and ions accelerated from the rear side of thin targets illuminated with ultra-intense laser light have been carried out at the Multipurpose (MTW) laser facility at the Laboratory for Laser Energetics. The accelerated electrons and ions enter a Thomson Parabola Ion Spectrometer consisting of a permanent magnet and electric field plates. The magnetic field of the spectrometer separates the ions and electrons according to their momentum-to-charge ratio. The electric field was left off for this experiment. A Fujifilm imaging plate covered with a Tantalum foil mounted at the rear of the device was used to detect the ions. The Tantalum foil allowed only the protons to hit the imaging plate.

Analysis of IPs with Java Program

Once the program finds the line, the user can then rescale the region of interest and prompt the program to calculate the line. The program then calculates the ion energy from the line and displays the results.

Electron and Ion Energy Spectra

First the pixel value on the x-axis of the raw data had to be converted into a distance. This was done using the deflection distance, which was determined using experimental data.

\[ E = \frac{qB}{mc^2} \]

where \( k = 3.34 \times 10^1 \text{ MeV} \cdot \text{amu}^{-1} \cdot \text{mm}^2 / \text{e}^2 \)

The process of converting the x-axis, y-axis was converted from PSL/pixel to PSL/MeV. PSL was then converted to number of particles using current calibration data.

Experimental Setup

A Thompson Parabola Ion spectrometer designed and built at SUNY Geneseo was used to analyze the Electrons and Ions. A Thompson Parabola consists of a set of magnetic field plates and electrical field plates that bend the ions and electrons according to their charge to mass ratio and energy. The electric field plates were left off for this experiment.

An image plate was placed on top of the magnetic field plates to intercept the electrons while another image plate was placed at the back of the Thompson Parabola to intercept the ions. A tantalum foil was placed over the image plate at the back to prevent the majority of all ions heavier than protons from hitting the image plate.

In reality, due to the background noise on the films, a single line of pixels could not be accurately examined. Instead, a wide line of pixels was averaged into one “master” line of pixels which was then analyzed. This was done to sacrifice resolution to gain accuracy. Once this “master” line of pixels was found, the background was first fit and subtracted.

Preliminary Results

First the pixel value on the x-axis of the raw data had to be converted into a distance. This was done using the deflection distance, which was determined using experimental data.

\[ E = \frac{qB}{mc^2} \]

where \( k = 3.34 \times 10^1 \text{ MeV} \cdot \text{amu}^{-1} \cdot \text{mm}^2 / \text{e}^2 \)

In the process of converting the x-axis, y-axis was converted from PSL/pixel to PSL/MeV. PSL was then converted to number of particles using current calibration data.

Future Plans

- Analysis of more image plates to determine peak proton/electron energy as a function of laser energy.
- Further development of program to analyze image plates from shots with electric field turned on.
- More accurate calculation of Electron energies.