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


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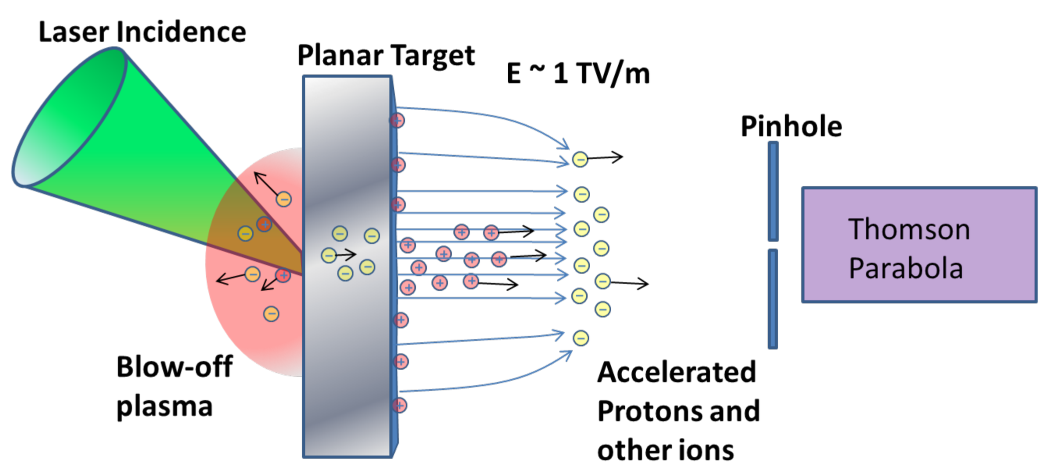
## Abstract

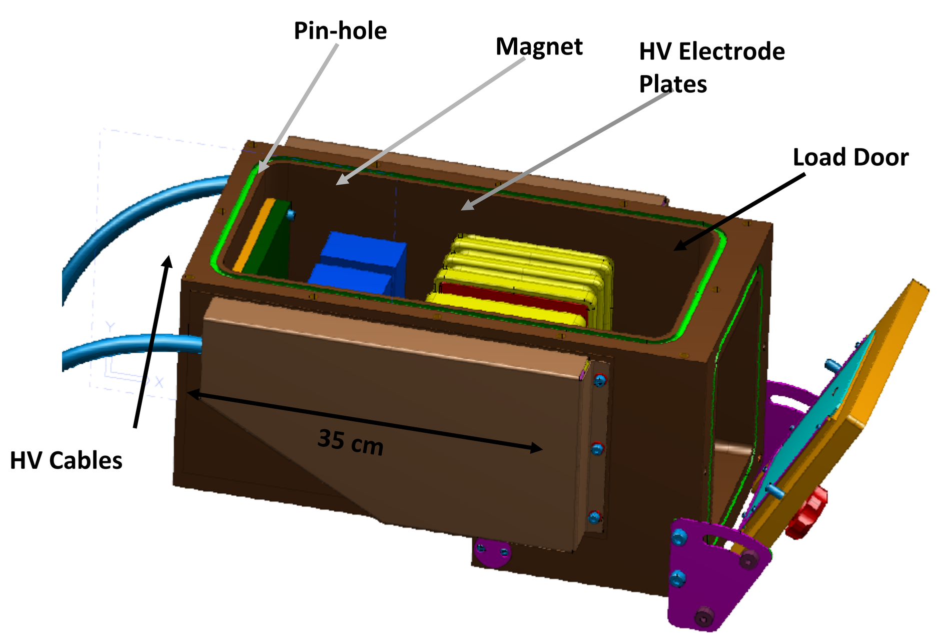

Simultaneous measurements of the energy spectrum of electrons and ions accelerated from the rear side of thin targets illuminated with ultra-intense laser light have been carried out at the Multiterawatt (MTW) laser facility at the Laboratory for Laser Energetics. The accelerated electrons and ions enter 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. Electrons, with a smaller magnetic rigidity, are deflected strongly by the magnetic field and exit the magnet at about 90 degrees to the direction they entered. An imaging plate placed on top of the permanent magnet is used to detect these electrons. A Java program has been written to analyze the resulting data. This enables the simultaneous measurement of the electron and proton energy spectrum to be determined for a particular shot. This work is funded in part by a grant from the DOE through the Laboratory for Laser Energetics.


## Experimental Setup

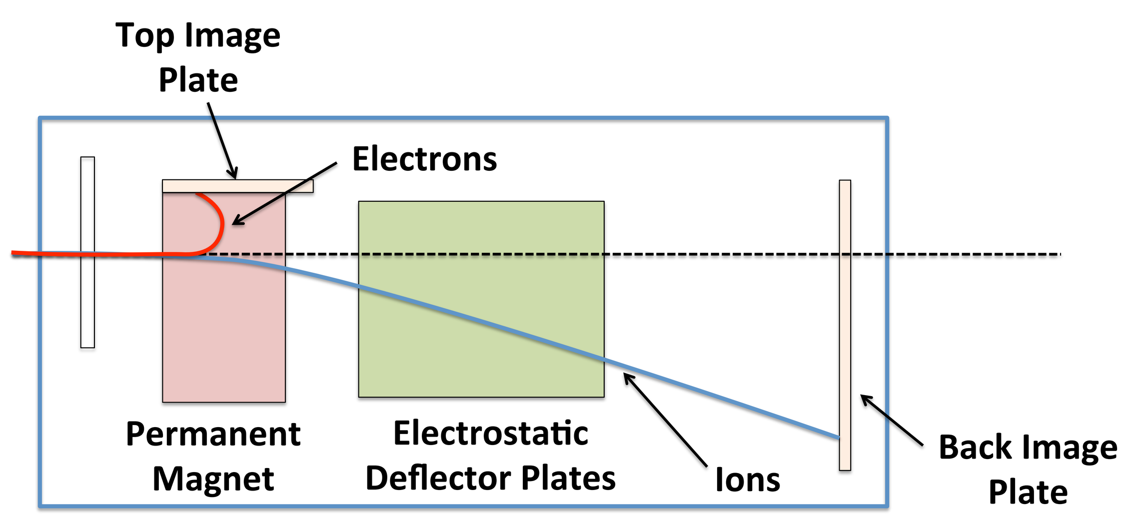
When a high intensity laser interacts with a thin metal foil, electrons and ions are ejected off of the back side of the foil at very high speeds.




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.



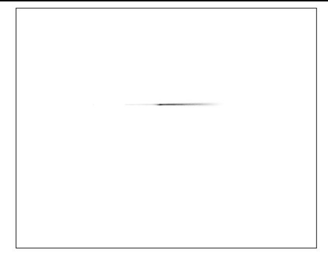

An image plate was placed on top of the magnetic field plates to intercept the electrons while another image plate was placed at the back of the Thompson Parabola to intercept the ions. A tantalum foil was placed over the image plate at the back to prevent the majority of all ions heavier than protons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



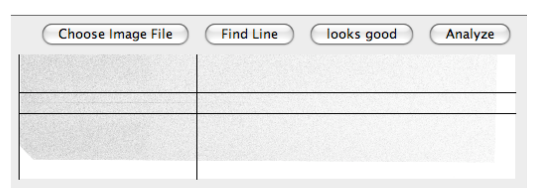

## Analysis of IPs with Java Program

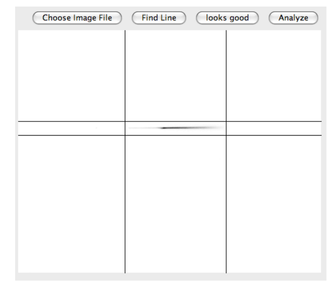
**Top Plate**

**Back Plate**



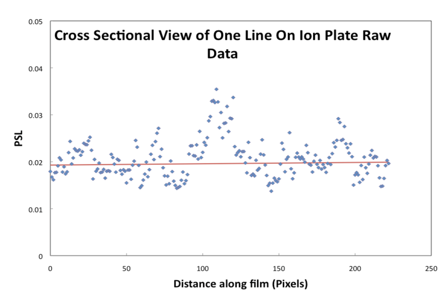
First the user opens the image file and it displays on the screen. Then the next step is for the program to find the line. The user can select a region of interest on the film with sliders to eliminate unnecessary regions of the film to get a more accurate reading of where the line is.

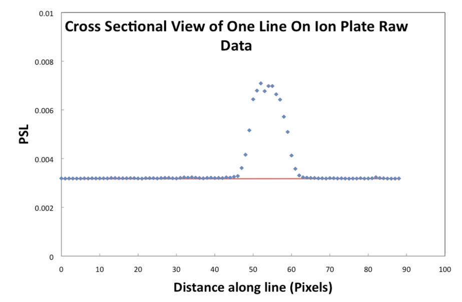


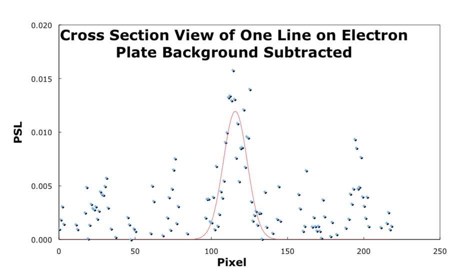
Once the program finds the line, the user can then reselect the region of interest and prompt the program to analyze the line. The program then examines one line of pixels at a time perpendicular to the line formed by the ions or electrons starting at the left most side of the region of interest selected by the user. Importantly, it only examines this line within the horizontal sliders to eliminate background. These sliders can be made parallel to the line formed by the ions or electrons after the the line is found by the program.

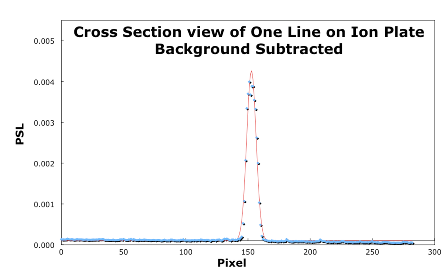

In reality, due to the background noise on the films, a single line of pixels could not be accurately examined. Instead, a wide line of pixels was averaged into one "master" line of pixels which was then analyzed. This width was 5 pixels for the proton plate and 50 pixels for the electron plate. This affectively sacrificed resolution to gain accuracy. Once this "master" line of pixels was found, the background was first fit and subtracted.



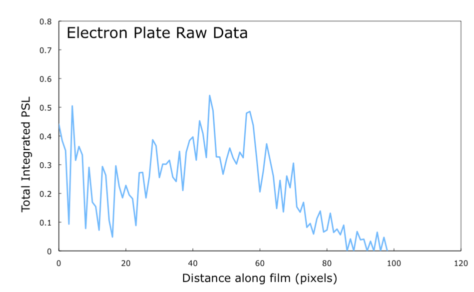



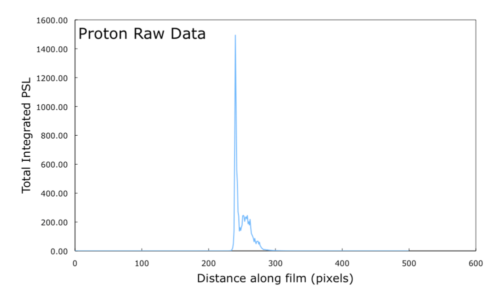

Then the line was fit with a Gaussian. This Gaussian was then integrated using the trapezoid method.




The value from the this integration was then recorded as the total integrated PSL for pixel 0. The program then moved to the right by 50 pixels for the electron plate and 5 pixels for the ion plate and repeated the process. It does this down the entire length of the region of interest selected by the user. This produces the raw data show below.




## 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 dpi of the image. Then, this distance had to be converted into an energy scale. For the electrons, a first order calculation not including fringe fields was done to determine the energy as a function of deflection distance, *x*.

$$E = \sqrt{\left(\frac{x^2+y^2}{2y}\right)^2 q^2B^2c^2 + m^2c^4} - mc^2$$

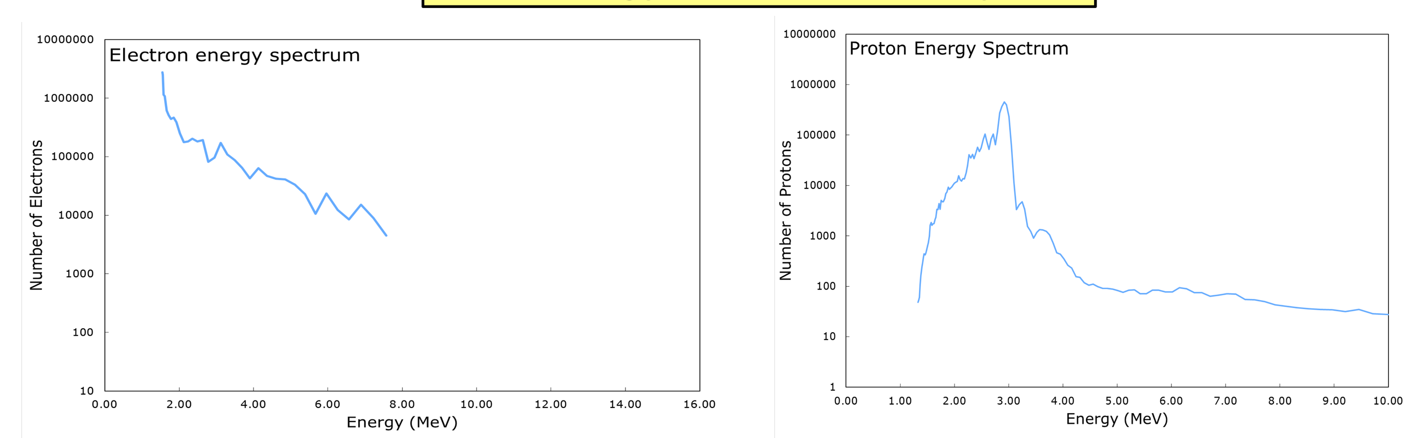
For the protons, energy as a function deflection distance *x* was determined using experimental data.

$$E = k\frac{q^2}{mx^2} \qquad \text{where} \quad k = 3.34\times10^3\,\text{MeV}\cdot\text{amu}\cdot\text{mm}^2/e^2$$

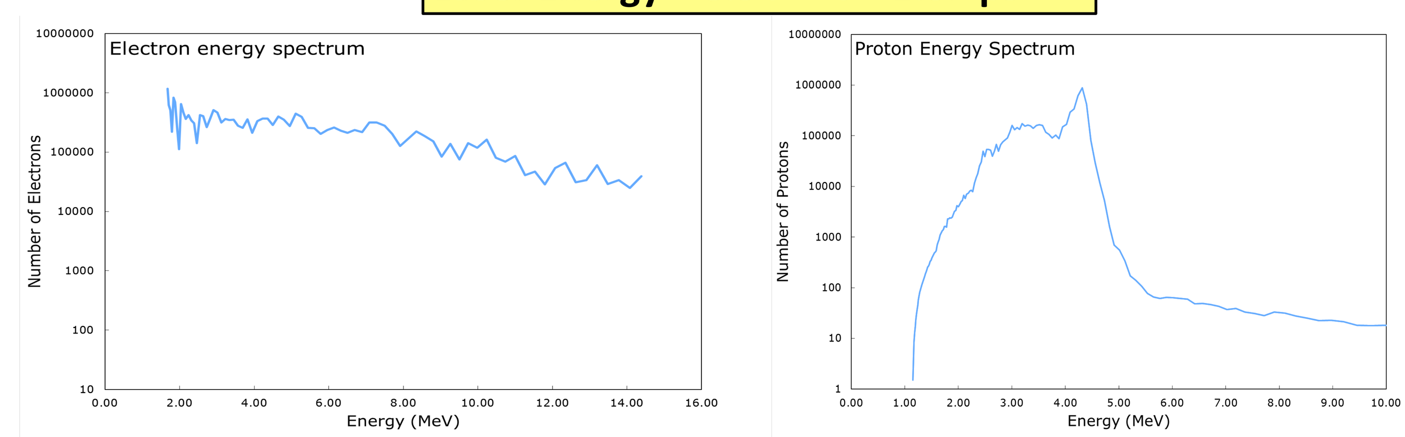
In the process of converting the *x*-axis, the *y*-axis was converted from PSL/pixel to PSL/MeV. PSL was then converted to number of particles using current calibration data.

## Preliminary Results

**Laser Energy = 7.1 J τ = 1.04 ps**




**Laser Energy = 8.9 J τ = 1.07 ps**




## 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.