Measurement of Accelerated Ions from OMEGA Targets

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Spectral measurements were made of fast ions accelerated from targets irradiated by the OMEGA laser. A variety of proton spectra, whose maximum energies scale with laser intensity, were observed. At intensities of 1×10^{15} W/cm^2, the maximum proton energy is ~1 MeV, while the integrated energy of these protons is ~0.1% of the incident laser energy. For similar laser intensities, application of SSD has no detectable effect on the endpoint energy. In addition to protons, other accelerated ions, including various charge states of carbon, have been observed, while charged fusion products, measured simultaneously with the same spectrometers, can exhibit accelerations of several hundred keV when bang time occurs during the laser pulse. This work was performed in part at the LLE National Laser Users' Facility (NLUF) supported in part by the U.S. Department of Energy Contract Number DE-FG03-99SF21782, LLE subcontract number PO410025G, LLNL subcontract number B313975, and the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460. (Petrasso: Visiting Senior Scientist at the Laboratory for Laser Energetics, U of Rochester.)

Study of Accelerated Protons on OMEGA

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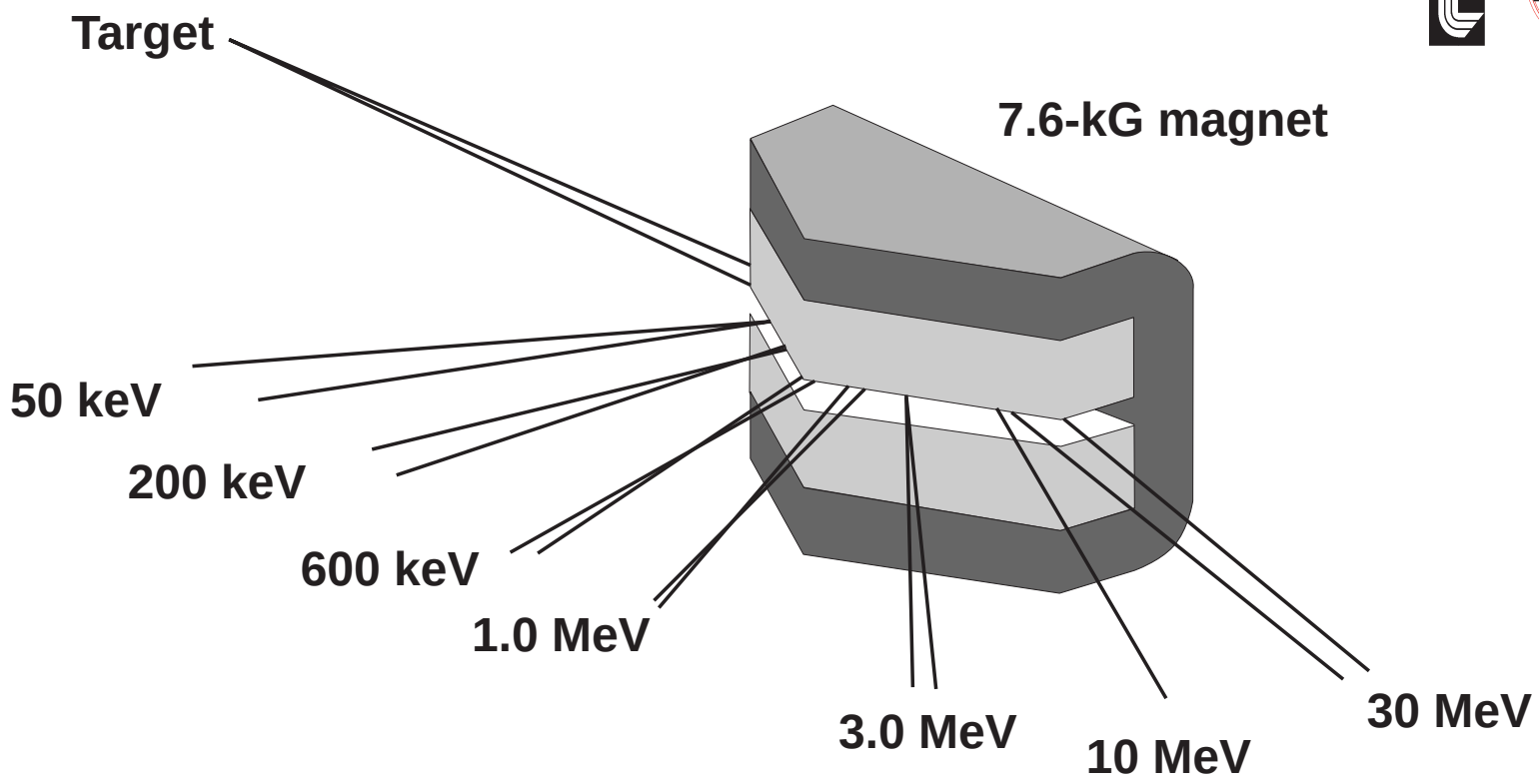
Outline

- High-resolution, charged-particle spectrometer on OMEGA
- Observation of fast protons ~1 MeV, 5× greater than on previous experiments at $I\lambda^2 \sim 10^{14}$ W/cm^2μm^2
- Inferred hot-electron temperatures of 10 to 25 KeV
- Total energy of protons is 0.01% to 0.4% of laser energy
- Appearance of regular spectral lines

High-resolution charged-particle spectrometer (CPS)

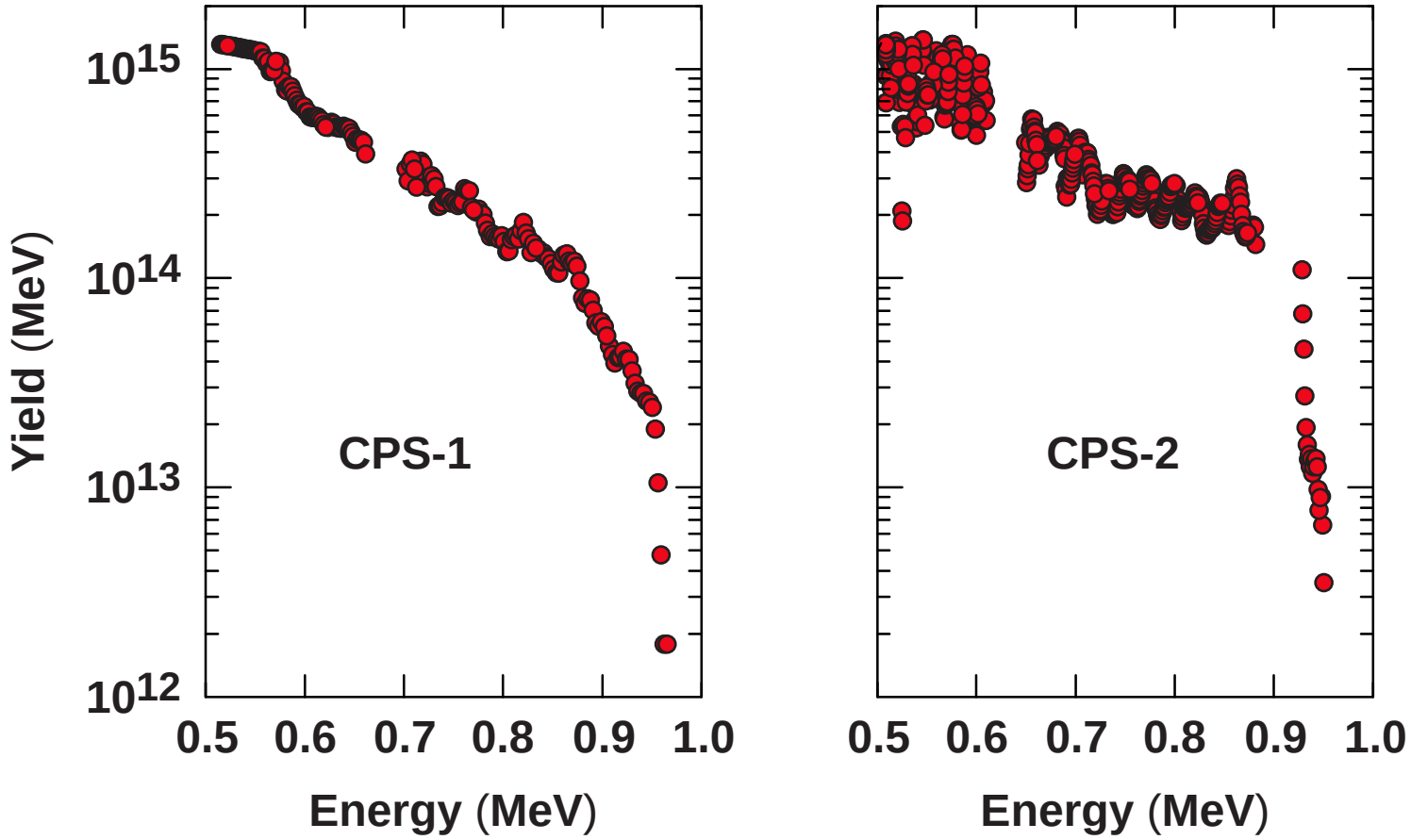


- Consists of a magnet and CR-39 nuclear track detectors.
- Automated scanning allows millions of tracks to be counted per shot.
- Two identical spectrometers are mounted on OMEGA with views 101° apart.

E10098

Fast proton spectra

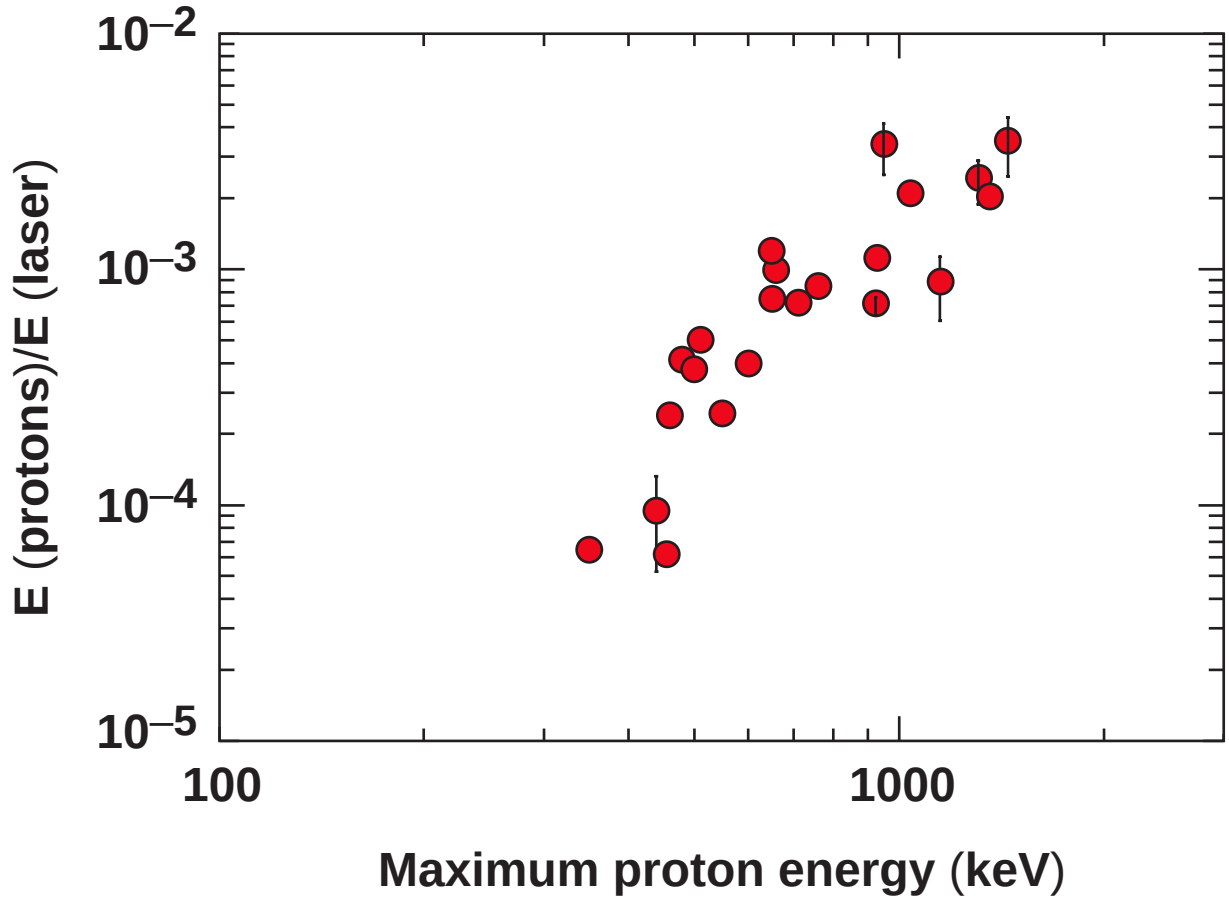
- Sharp maximum cutoff energies at 0.3 to 1.4 MeV observable on all shots.
- Both spectrometers always observe the same maximum proton energy.



E = 25 kJ, λ = 0.35 μm, I = 10^{15} W/cm^2,
1-ns square pulse, 1-mm-diam. spherical target, 60 beams

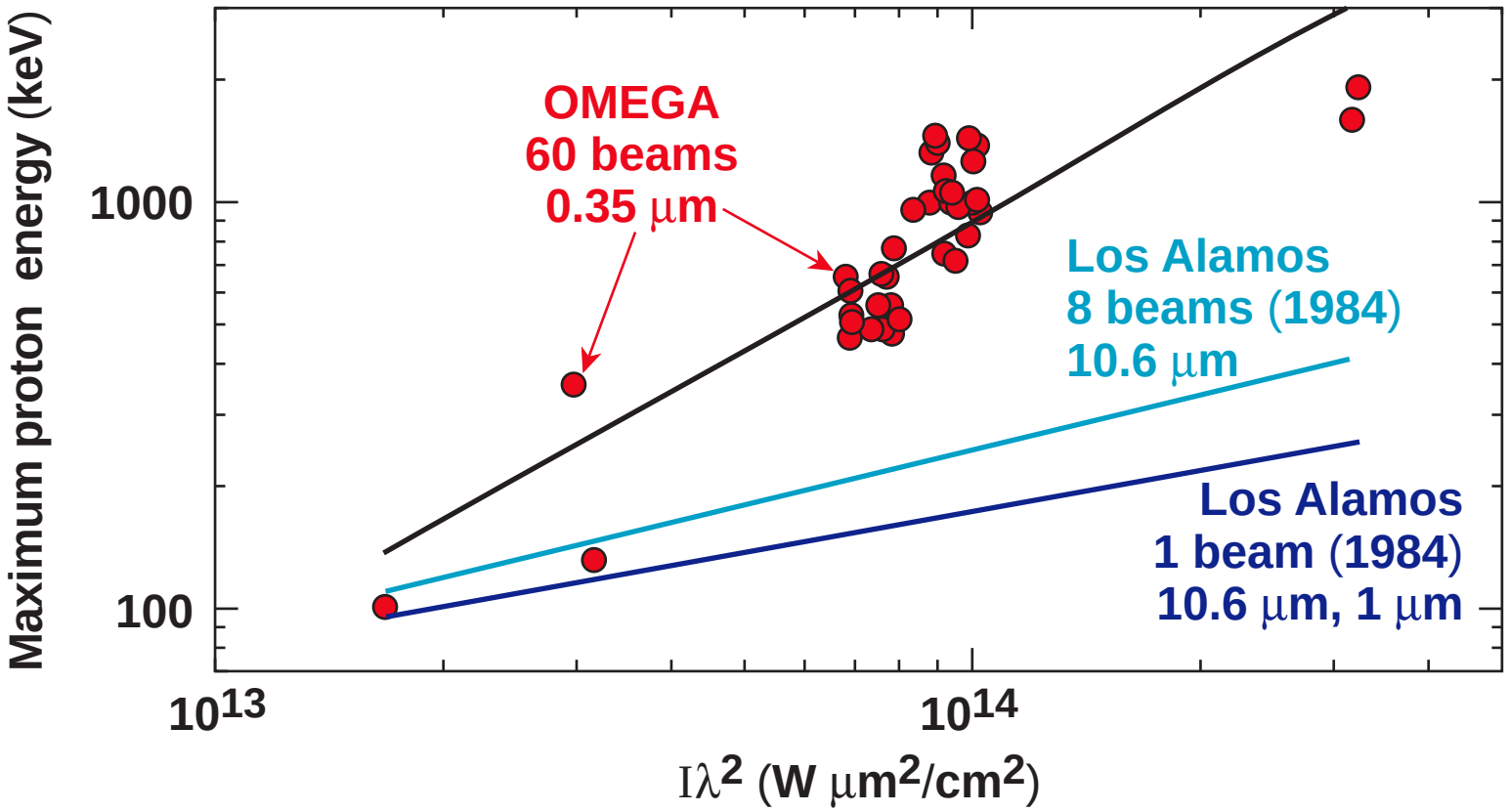
E10099

Total proton energy is 0.01% to 0.4% of laser energy



- Total proton energy is calculated for protons > 200 keV.

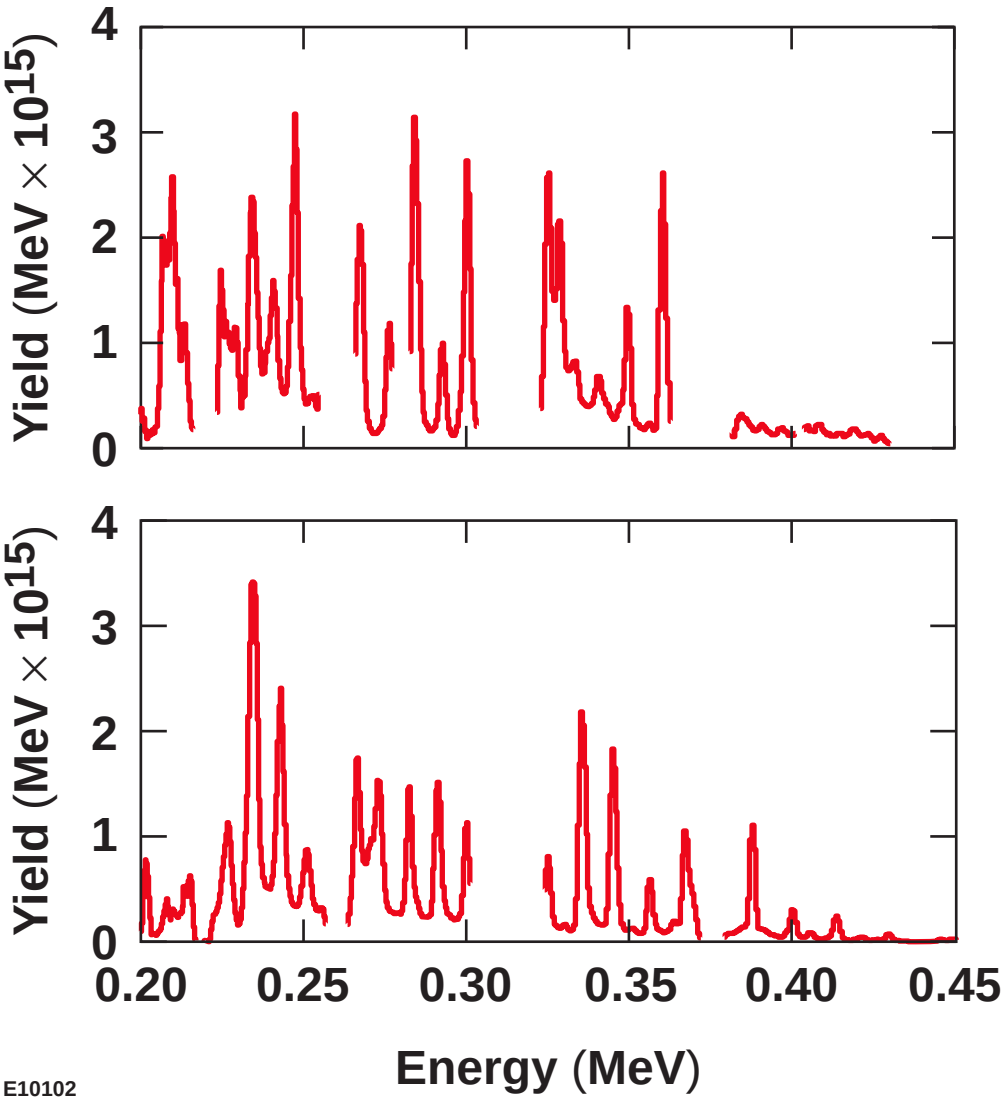
Comparison of maximum proton energy on OMEGA versus previous experiments



OMEGA:
E = 8 to 30 kJ, I = 10^{14} to 10^{15} W/cm^2, λ = 0.35 μm,
0.4- and 1.0-ns square pulses, 1-mm-diam spherical targets

E10101

Some spectra show strong lines



- Intense regular lines appear on some spectra.
- It is unclear what specific experimental conditions give rise to spectral lines.
- May be associated with ion-acoustic perturbations in the expanding plasma.

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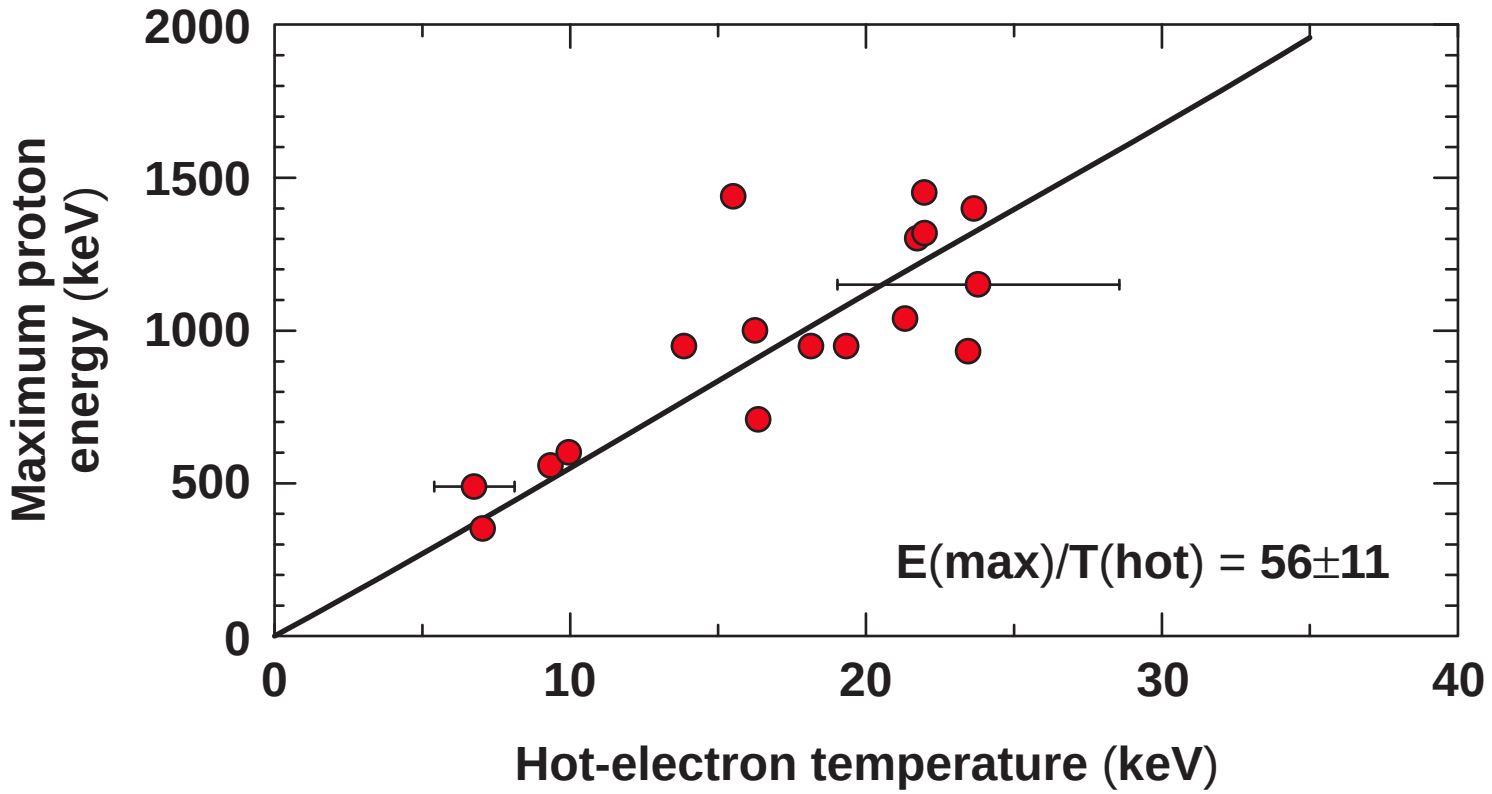
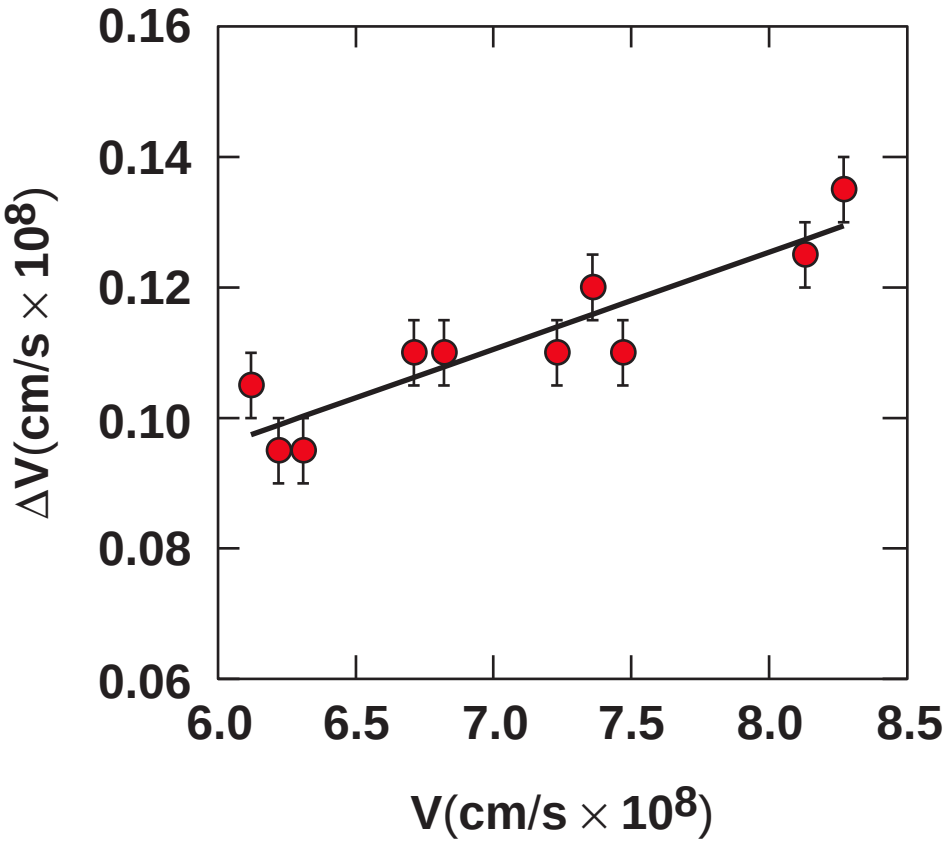
The relationship of hot-electron temperature to maximum proton energy

- Hot electron temperature is inferred from the slope of the proton velocity spectrum (self-similar plasma expansion model).
- Previous studies found E(max)/T(hot) = 66.



Tan, McCall, and Williams, Phys. Fluids 27, 296 (1984).

Spectral lines may be connected to ion-acoustic waves in the expanding plasma



- The spacing of spectral lines is observed to increase with velocity.
- Simulations show that a similar behavior is observed in ion-acoustic perturbations in the expanding plasma.
- The velocity in an expanding plasma changes with distance, so ion-acoustic perturbations distributed in space acquire different velocities.

Summary

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