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Title: LASER-PRODUCED MEV PROTONS ON TRIDENT

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Laser-Produced MeV Protons on Trident

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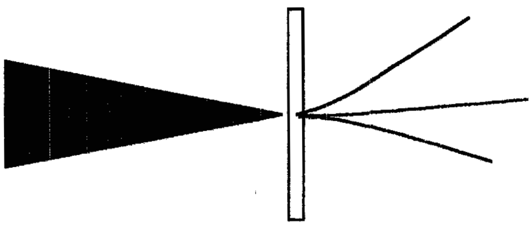
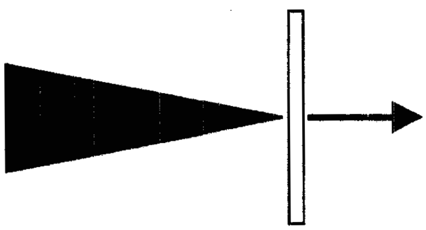
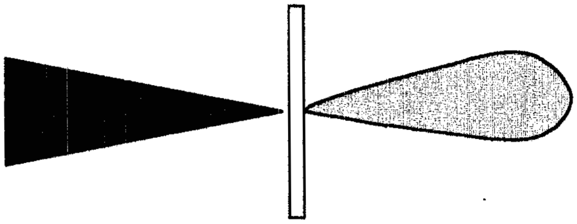


Ps green beam strikes a thin metal target driving off electrons

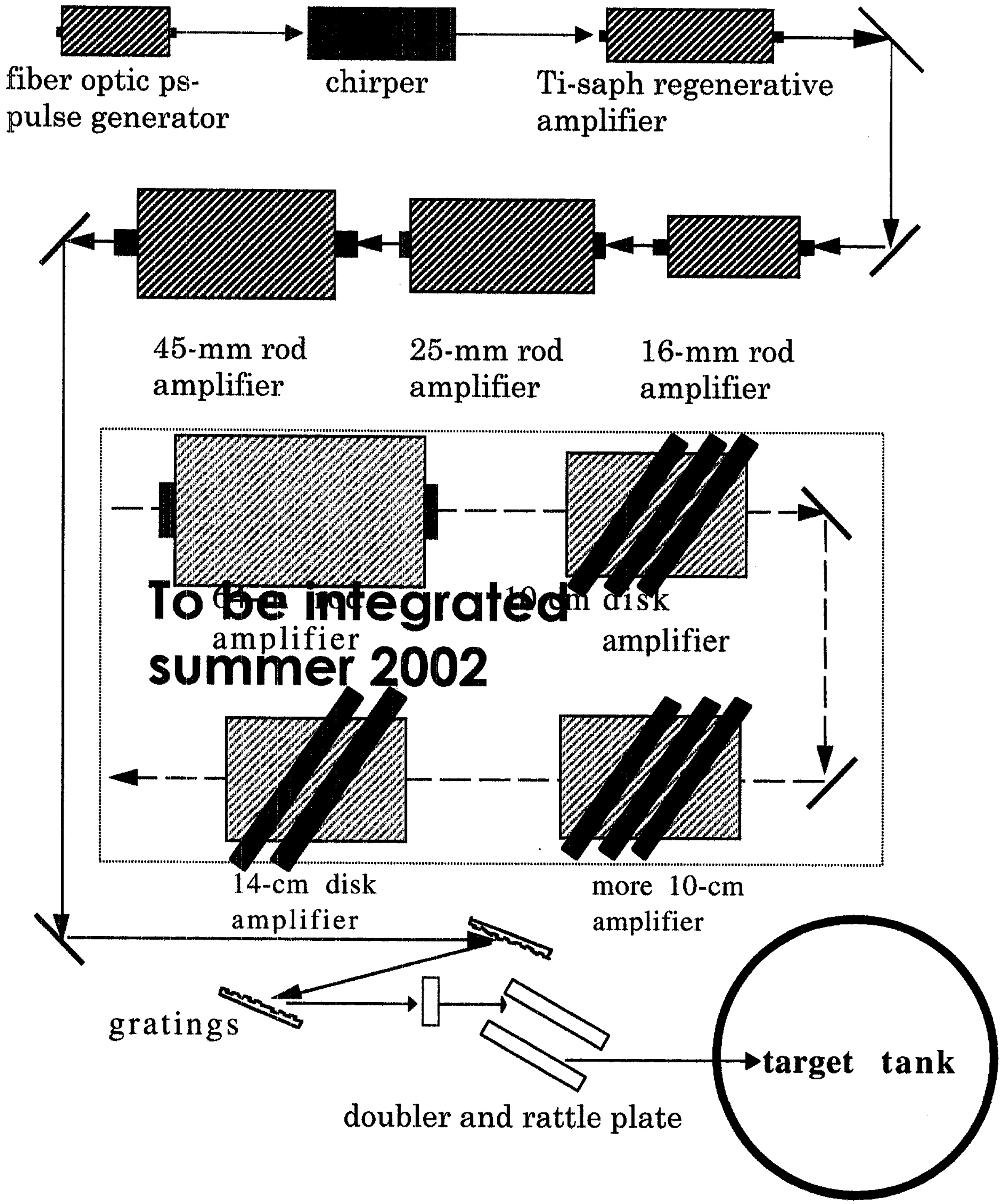


A large electric field (MV/μm) forms as the electrons leave, pulling ions from the surface.



Protons in a narrow half angle cone are accelerated up to several MeV by the field

Trident Short Pulse System



Laser Performance

$\lambda = 527$ nm
Pulse duration ~ 600 fs
Green energy >1 J
Power 1.5 ± 0.3 TW
Focal Spot ~ 2.4 μm x 2.7 μm for $1/e^2$ diameter with f/2 off-axis parabola

Target irradiance ~ 3×10^{19} W/cm^2
Pre-lase contrast 350 ps prior to the main pulse ~10^{10}

Number of target shots ~ 55
Targets: Au, 0.5 – 25 μm thick
Al, 3 – 25 μm

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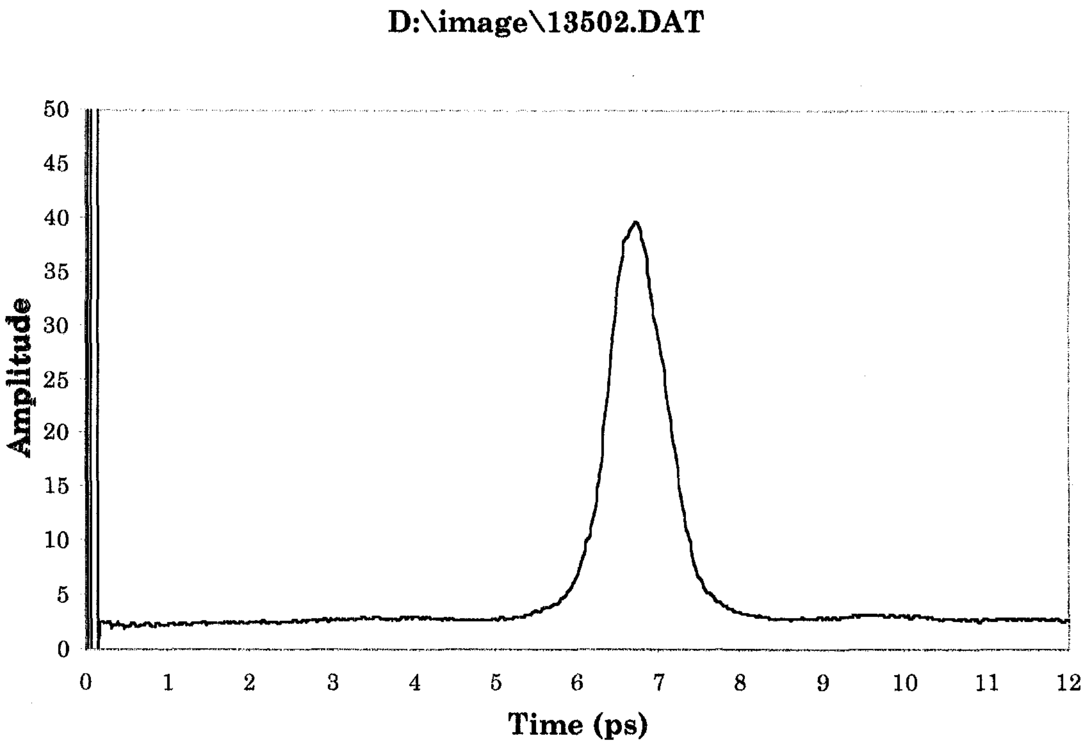
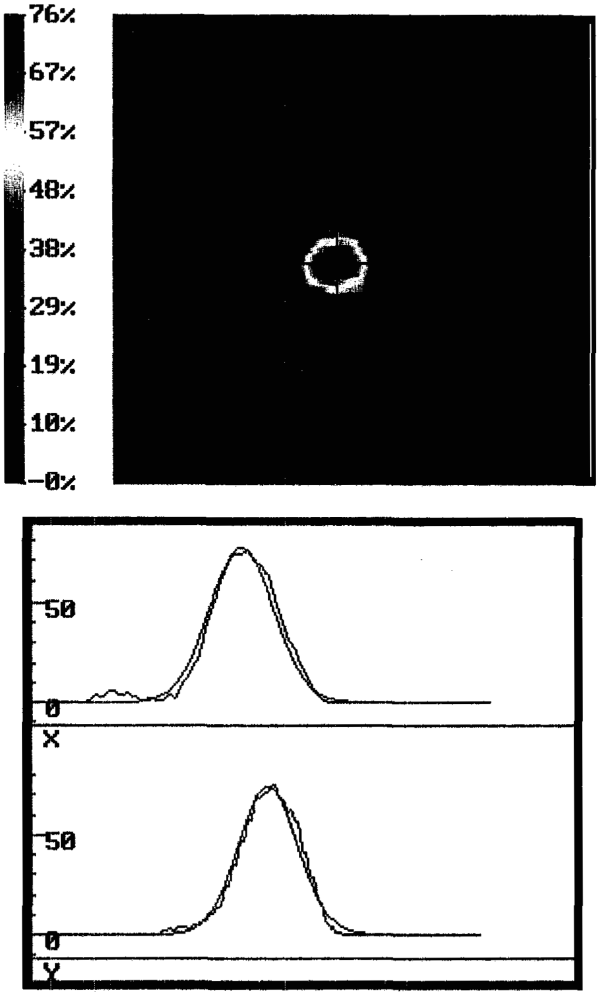
Autocorrelator Pulse Width



This typical autocorrelator trace shows a FWHM ~0.78 ps and corresponds to a pulse width of ~550 fs.

Main-pulse to prelase contrast in the green is measured to be 10^{10} at 350 ps prior to the main pulse. This is made possible by four Pockel cells, including two on the input to the regenerative amplifier, and a rattle plate for removing 1054-nm light. The 1-ω contrast at the same time is ~10^7.

Laser Spot Size



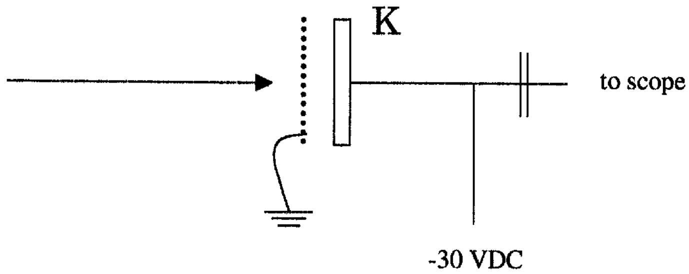
Diameters, $1/e^2$ = 2.70, 2.45 μm

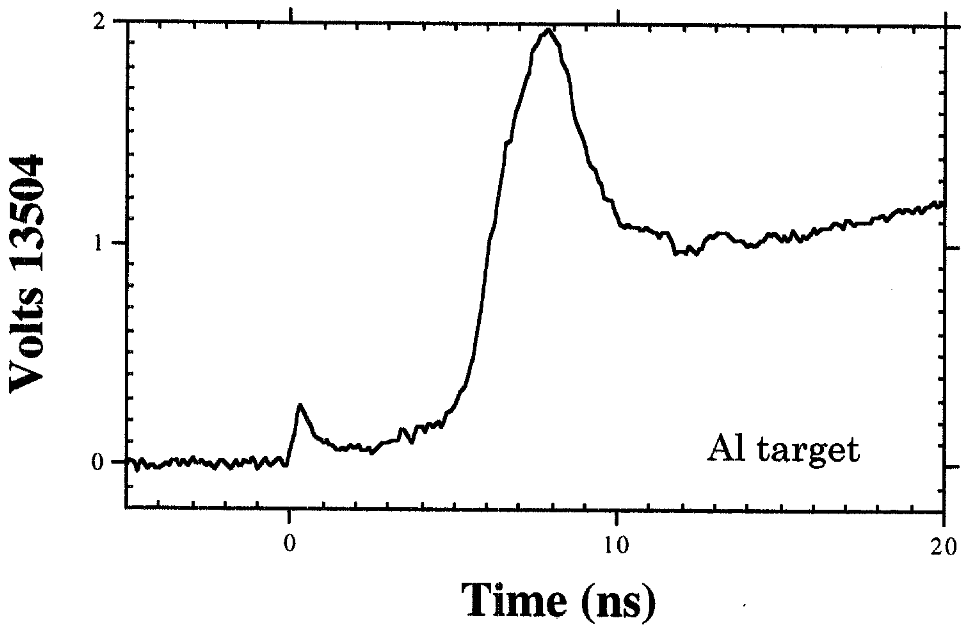
Proton Diagnostics

- Faraday cup time-of-flight detector

- CR39 nuclear particle track detectors

Faraday Cup Data

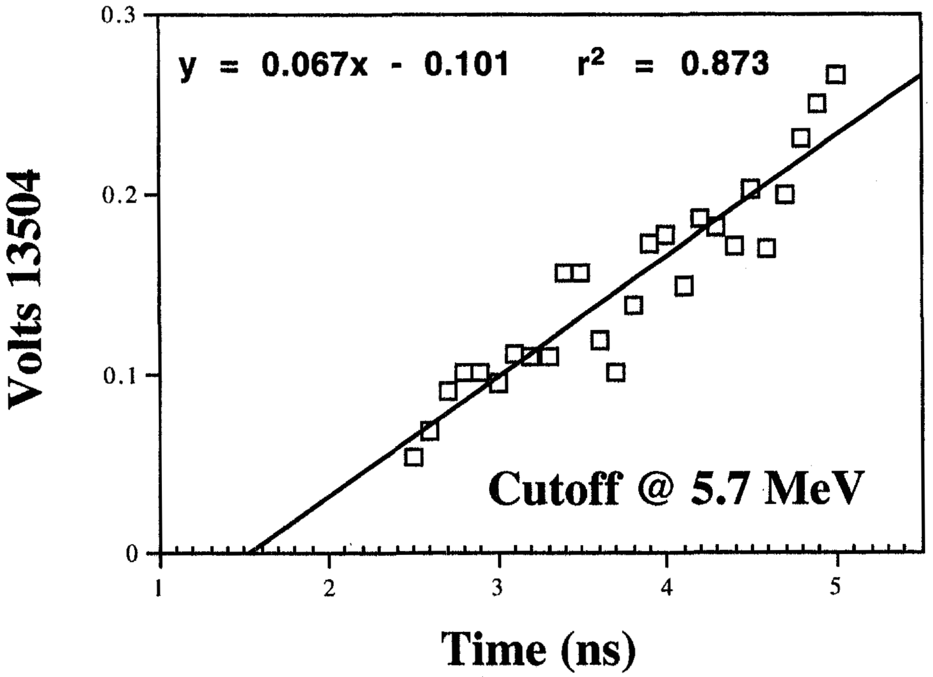




- Photoelectron current from x rays mark t = 0. The proton current beginning at 5 ns implies ~600 keV protons.
- For Au targets, the bulk cutoff energy is higher but the signal is lower by ~40X.

At the foot of the Faraday cup trace is a faster component!

Digital oscilloscope data show a population of fast protons leading the slower bulk distribution. The high-energy cutoff for this superthermal tail is nearly 6 MeV.



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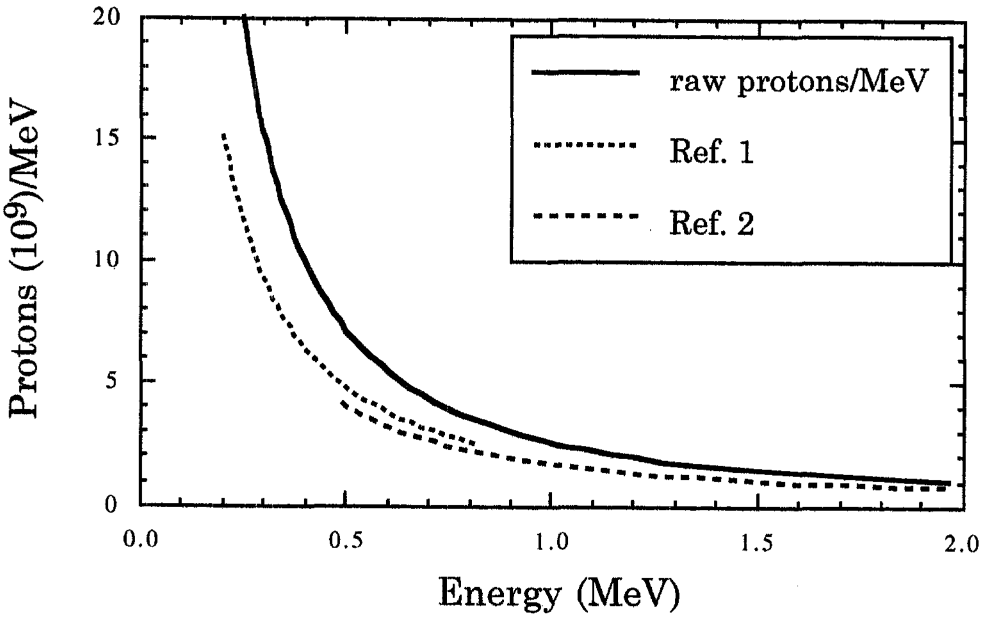
Yield Corrected for Secondary Electrons

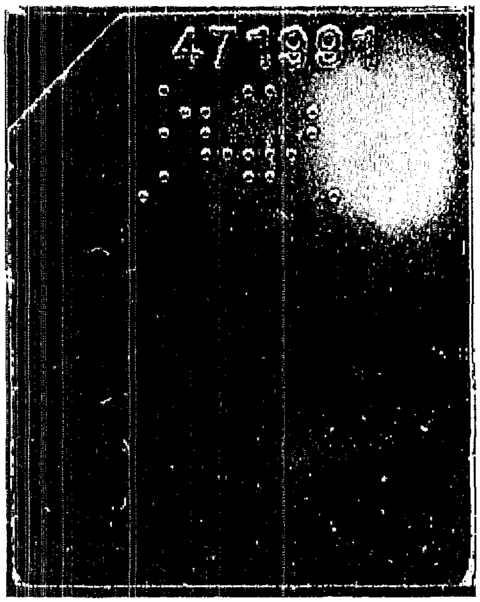


1) M. Rösler, Nucl. Instrum. Methods Phys. Res. B **115**, 278,1996.
2) E. Steinbauer, A. Schinner, and O. Benka, Nucl. Instrum. Methods Phys. Res. B **171**, 291 2000.

Integrating under the blue curve, we find ~5 x 10^9 protons in the energy range 0.2 – 2 striking the cathode. This is a lower bound.

CR39 Track Detection

This piece of CR39* was etched for 16 hr in NaOH. The 10-mm bright spot in the upper right is scattered light from tracks which indicate a ~7° half angle cone of MeV protons. The target for this shot was a 5-μm Au foil.



Pits on the back surface of a double layer of CR39 indicate proton energy of 18 MeV or more.

*Jeff Hoffman and Rich McKeever of ESH-4, LANL's personal dosimetry group, supplied the CR39 and performed the processing.

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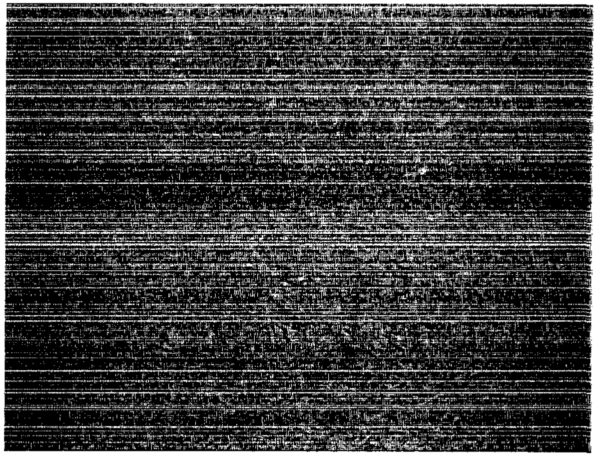
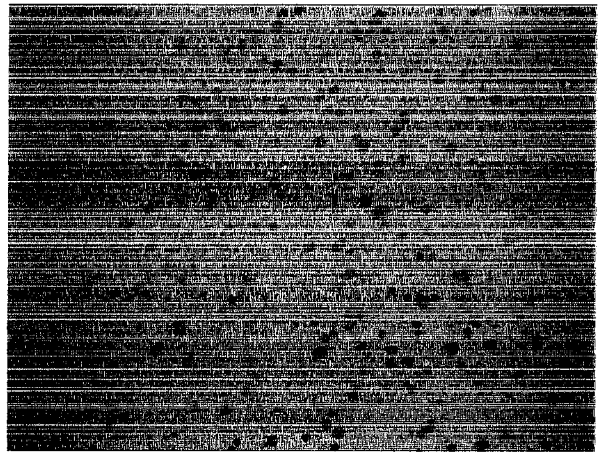
Front and Back Surface Pits



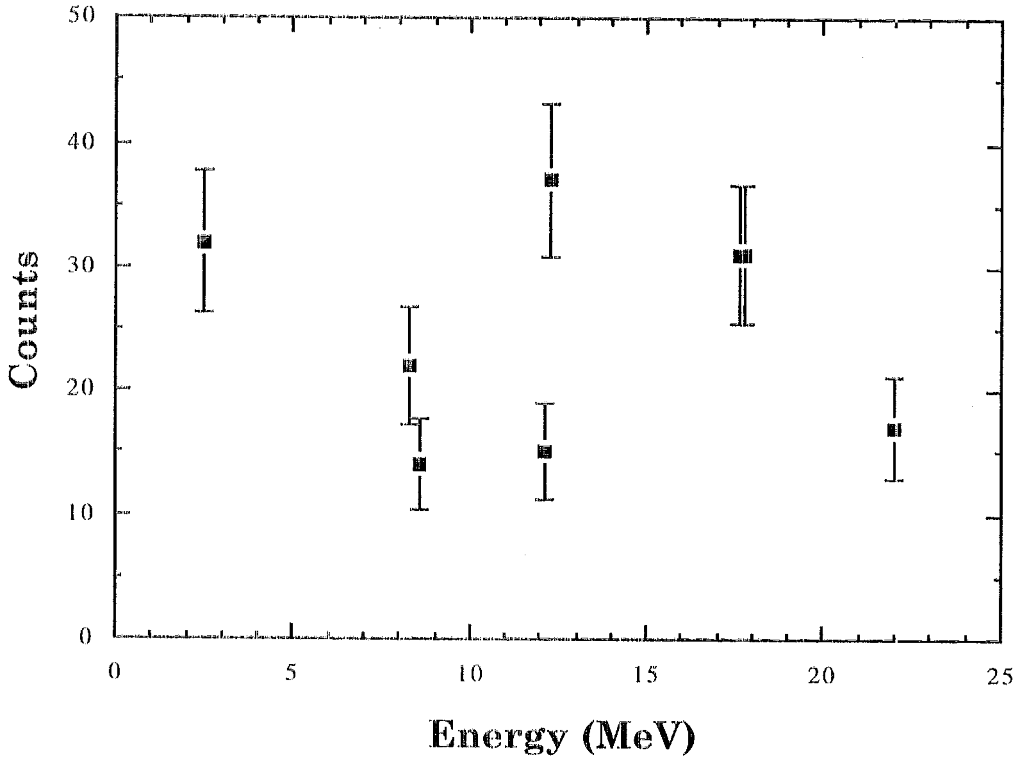
#13499
1.24 mm x
.93 mm,
5-μm Au



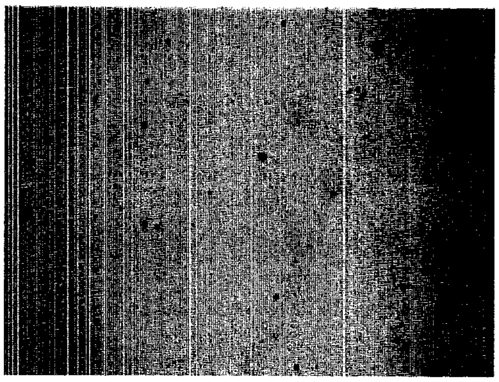
Identical region of CR39, front and back surfaces --
Rear pits ~12 MeV.

pictures taken from back
since front is so sand-blasted

CR39 Energy Spectrum

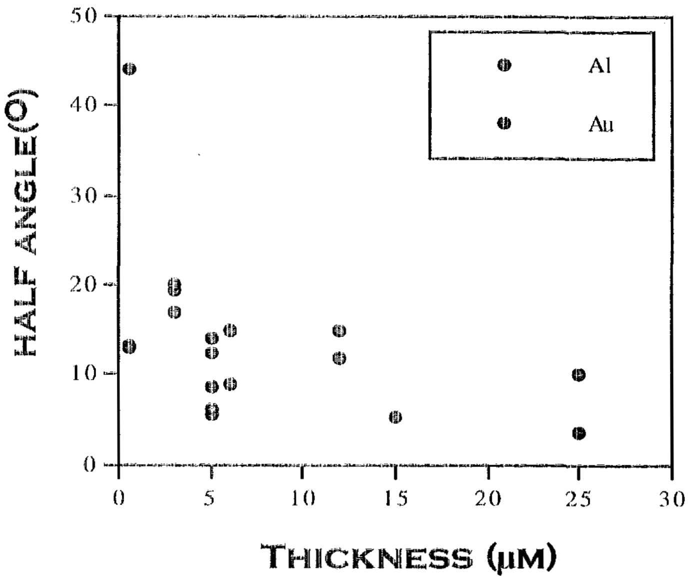


Boundaries of four pieces of CR39 represent different energies of protons penetrating through different depths of material from a 5-µm Au target.



2.3 mm x 3.1 mm FOV

Angular Dependence on Target Thickness

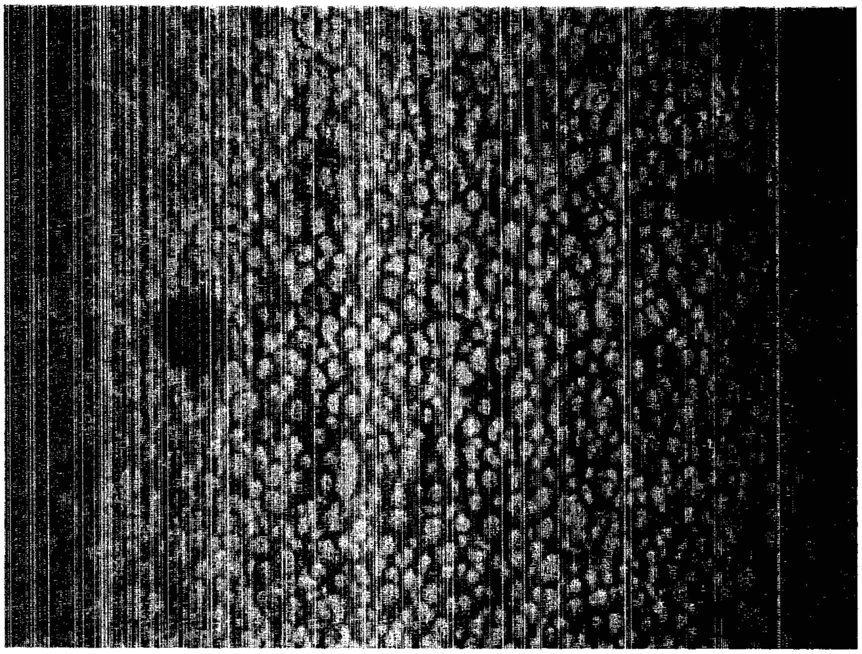


- The half angle tends to decrease as target thickness increases.

- Au targets seem to have smaller half angles than Al for the thicker targets.

- The electron transit time through the targets is much less than the laser pulse length in every case (tens of fs).

Proton Flux



305 μm x 229 μm on CR39
7.3 mRad x 5.5 mRad

- Saturation prevents good estimate from CR39

- Density of spots corresponds to 10^7 pits in a 30-mm diameter proton plume for particles with energy ~1 MeV, but what is ΔE? Rear surface (12 MeV) pits ~ 10^4.

- Are the big spots due to Al atoms?

- Integration of Faraday cup signal for Al implies proton flux (limited by size of the detector) ~5×10^9 in the range 0.2 – 2 MeV

Laser Upgrade

- The Trident Laser is being upgraded as we speak, literally, from 1.5 TW to upwards of 40 TW.

- Energy from ~1 J to 20 – 50 J
The Trident "C" beam has produced 100 J in an unchirped 0.5-ns pulse. The energy is more than adequate.

- Pulse width ~0.6 ps – same as before.

- Pulse compression in air, as before, to begin… Our B integral increase from 5 to ~7, and we expect some degradation. We note that we have focused the former to virtually the diffraction limit. Our hope is to focus to 10^{19} W/cm^2 with more energy.

- Trident would become one of the few lasers in the world with both long- and short-pulse high-energy capability at the same facility.

Summary of protons

- Narrow angle cone of MeV-class protons, slightly more narrow for Au than for Al, emerging from foils irradiated with a 1-J high-intensity ps laser

- Two component proton distribution
  Lower energy component of ~0.5 MeV
  Higher energy component of
    5-8 MeV for Al
    20 – 40 MeV for Au

- Flux of 5×10^9 protons/shot for Al
  Reduced flux (by ~40X) for Au

- New experiments expect to begin soon with a laser upgrade from 1.5 TW to >40 TW