Features within sheath accelerated proton beams

Experimental setup

**Aim:** Study of $\mathbf{j} \times \mathbf{B}$ heating using linearly or circularly polarised light at near normal incidence.

- Laser energy $\sim 54.8$ J
- Laser duration $\sim 642$ fs
- Focus (FWHM) $\sim 9.5$ um
- Intensity $\sim 8.3 \times 10^{19}$ W/cm$^2$
- $a_0 \sim 8.2$
- Incident angle $\sim 8$ deg
- Contrast ratio $\sim 10^6$
- Au foils from 10 - 100 um thick
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![Experimental setup diagram](image-url)
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Laser driven ion acceleration from solid targets

- Relativistic intensity laser
- Preplasma
- Magnetic fields
  - Hot electrons
  - ‘cold’ electron return current
  - Hole-boring and shock generation
- Electrostatic sheath field
- Refluxing electrons
- Escaping hot electrons
- Sheath field
- Sheath-accelerated ions
Target thickness scan

Increasing proton energy

100 $\mu$m

50 $\mu$m

20 $\mu$m

10 $\mu$m
More details on the multi-ring-ed structure

- Rings visible from 3 - 20 MeV

- Roughly concentric, directed around target normal.

- Central ring disappears as energy increases.

- At highest energy only the outer ring remains.
Ring radius and centroid position with energy

- Radius fluctuates slightly with proton energy.
- Centroid of rings drifts away from the laser axis at higher proton energy.

$$E = 6 \text{ MeV}$$
Ring radius and centroid position with energy

- Radius fluctuates slightly with proton energy.
- Centroid of rings drifts away from the laser axis at higher proton energy.

\[ E = 7 \text{ MeV} \]
Ring radius and centroid position with energy

- Radius fluctuates slightly with proton energy.
- Centroid of rings drifts away from the laser axis at higher proton energy.

\[ E = 8 \text{ MeV} \]
Ring radius and centroid position with energy

- Radius fluctuates slightly with proton energy.
- Centroid of rings drifts away from the laser axis at higher proton energy.

$E = 10 \text{ MeV}$
Ring radius and centroid position with energy

- Radius fluctuates slightly with proton energy.
- Centroid of rings drifts away from the laser axis at higher proton energy.

$E = 12 \text{ MeV}$
Ring radius and centroid position with energy

- Radius fluctuates slightly with proton energy.
- Centroid of rings drifts away from the laser axis at higher proton energy.

\( E = 14 \text{ MeV} \)
Ring radius and centroid position with energy

- Radius fluctuates slightly with proton energy.
- Centroid of rings drifts away from the laser axis at higher proton energy.

$E = 15 \text{ MeV}$
Ring radius and centroid position with energy
Wedged Cu targets imply rear surface proton source
Previous observations of single rings, or rings with a central beam, predominantly attributed to:

- Magnetic fields in the bulk of the target directly influencing protons accelerated from the front surface, or causing hollowing of the electron beam.

- Toroidal magnetic fields in plasma at the rear of the target.

- Filamentation
Electron recirculation modulating the rear surface field?

FIG. 1. (Color online) The two types of targets considered in this paper.
How would this modulated electron density affect the proton beam?

Simulations underway using ZEPHYRS to model evolution of electron density at rear surface for different target thicknesses.

Cowan et al., PRL, 2004
Thank you!