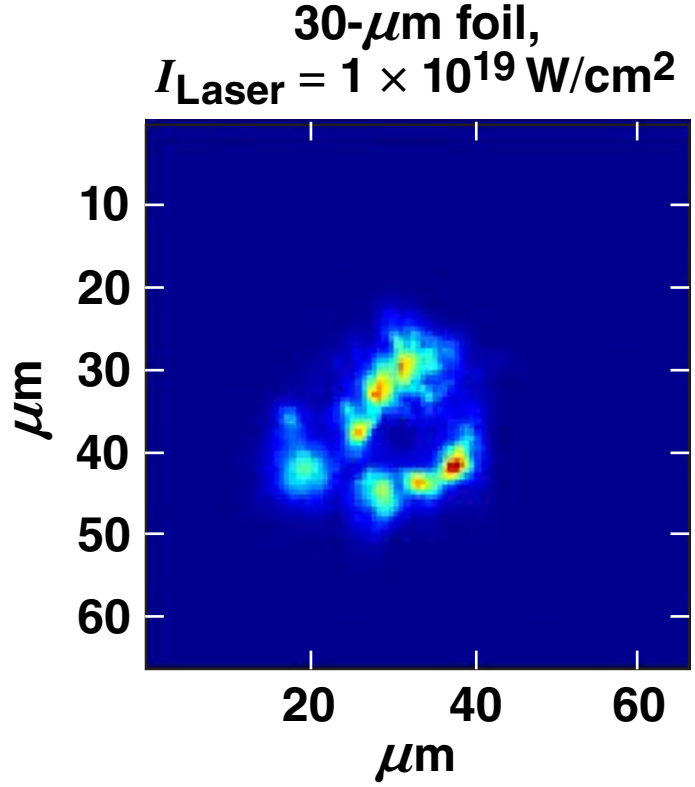
Spatially Resolved Measurements of MeV Electron-Beam Transport Using Coherent Transition Radiation



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Summary

Filamentation of high-current relativistic electron beams is diagnosed using coherent transition radiation

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- Electron-beam transport is studied by high-resolution imaging of coherent transition radiation generated in thin-foil targets.
- Experiments have been conducted on Al, Cu, Sn, and Au foil targets of varying thickness using LLE's Multi-Terrawatt (MTW) laser with intensities of ~10^{19} W/cm^2.
- Images of the target rear side show well-defined filamentary structures and ring-like patterns of the emission.
- The electron beam diverges with a half angle ~16°.
- The electron temperature of the fast-electron beam is inferred to be 1 MeV.
- At T_{hot} ~ 1-MeV velocity dispersion in the electron beam is the dominant process effecting the CTR signal.

Collaborators

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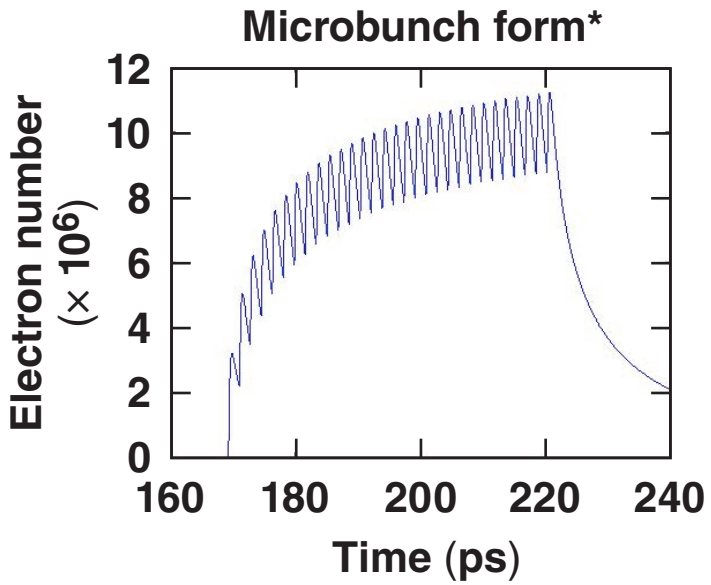
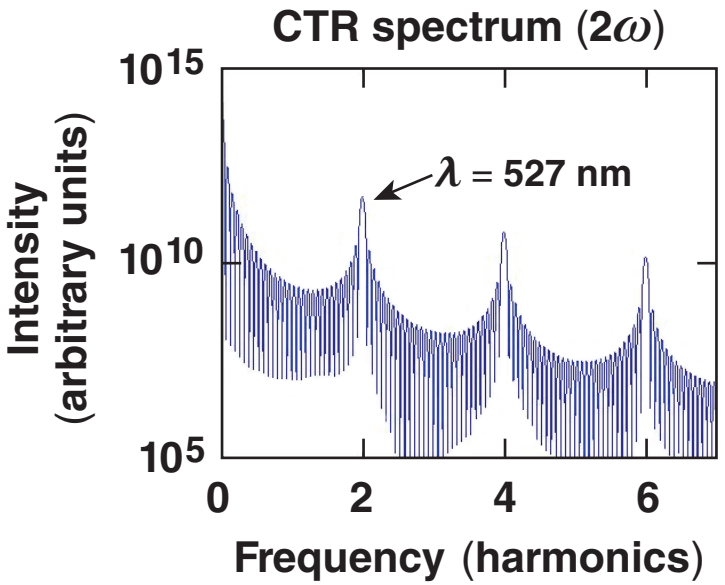
Coherent transition radiation (CTR) provides information on the dynamics of relativistic electron-beam transport

- Transition radiation (TR) is produced when electrons cross a refractive-index interface.
- CTR arises from the coherent addition of the underlying TR fields.
- The source of the coherence is traced back to the longitudinal density structure written into the electron beam by the action of the laser.





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*J. Zheng *et al.*, Phys. Plasmas 10, 2994 (2003).

A transition-radiation diagnostic provides high-resolution images of the rear-surface emission using the MTW laser

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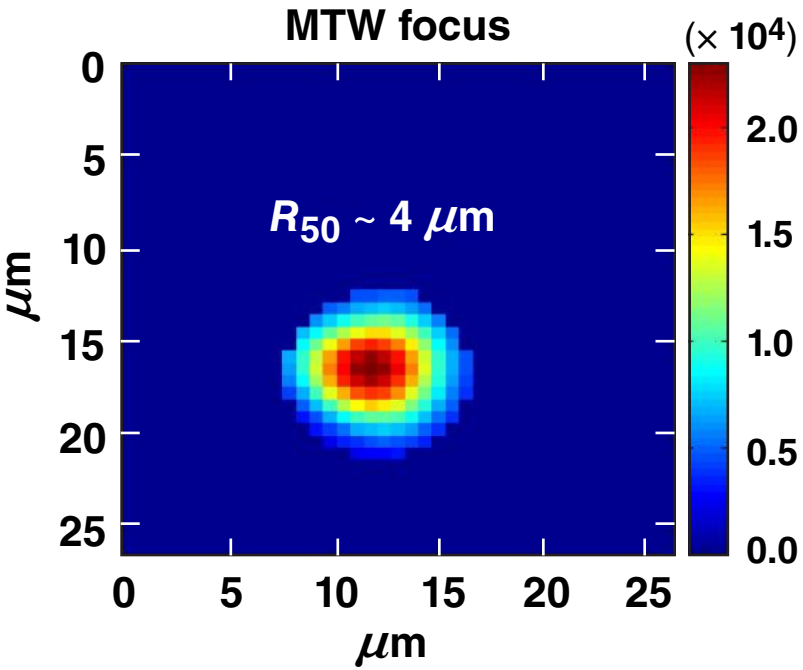
MTW Laser Parameters

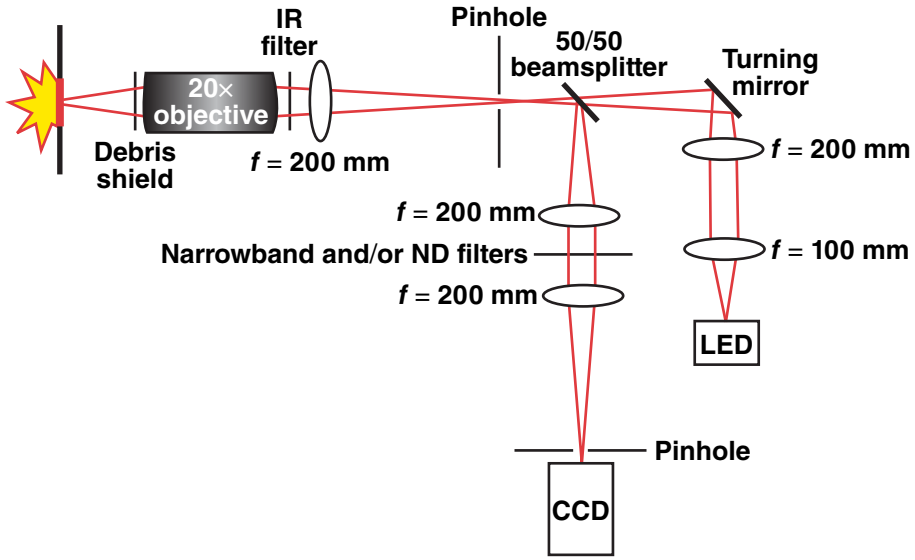
λ = 1053 nm, $\Delta\tau$ = 500 fs, E = 10 J

$\Delta\lambda$ = 24 nm about λ = 529 nm

Signal to noise ~ 10^3

Signal to background > 10^5





$R_{50} \approx 4\ \mu m \Rightarrow I_{50} \approx 2 \times 10^{19}$ W/cm^2

Depth of focus = 1.6 μm

Spatial resolution = 1.4 μm

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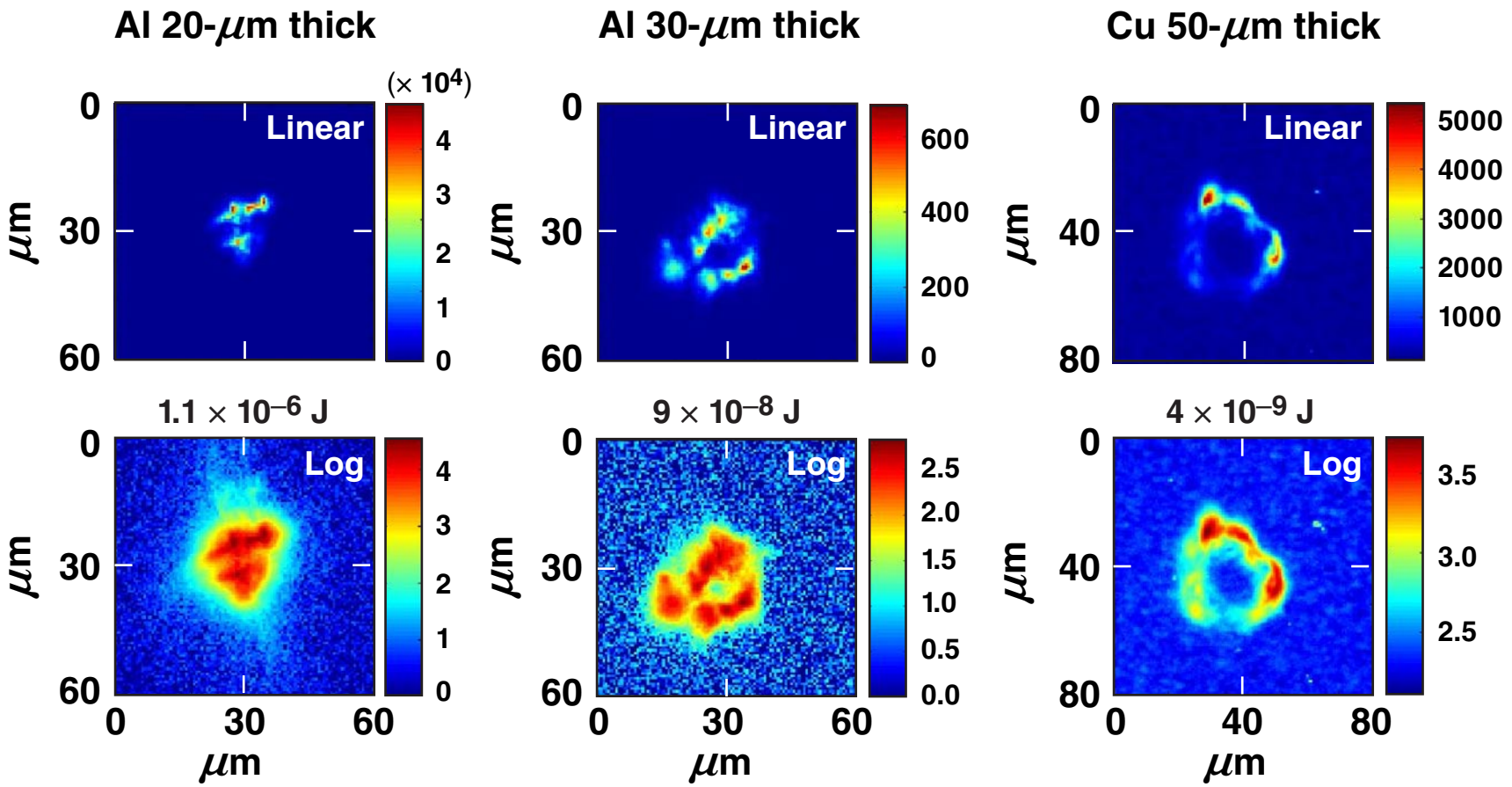
Filamentary structures are seen superimposed onto a ring-like structure

$I_{50} \sim 1 \times 10^{19}$, normal incidence



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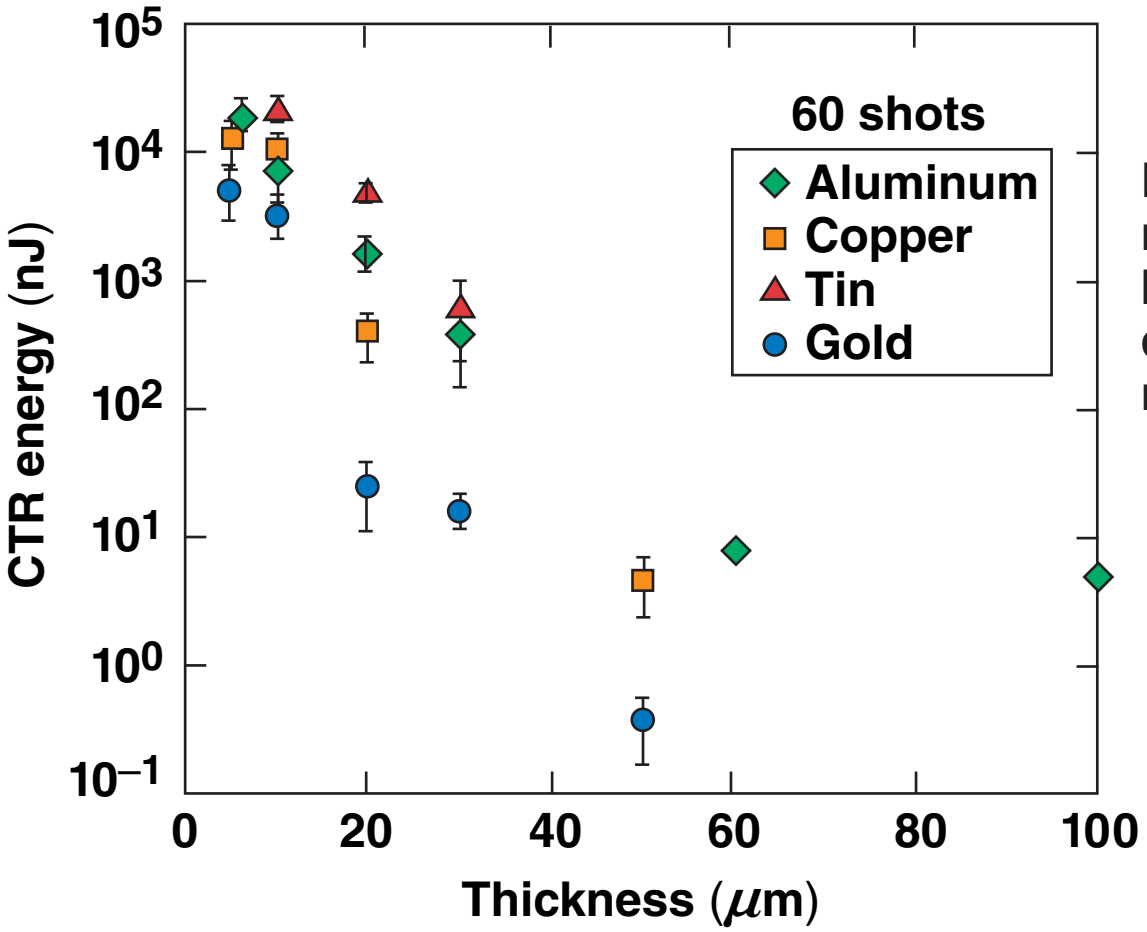
A rapid decrease in the CTR signal is observed with increasing target thickness



Each point represents a mean value. The error bars represent standard deviations about the mean.

Fluctuations in the CTR signal indicate that the coherent part of the fast-electron beam is not characteristic of the general population.

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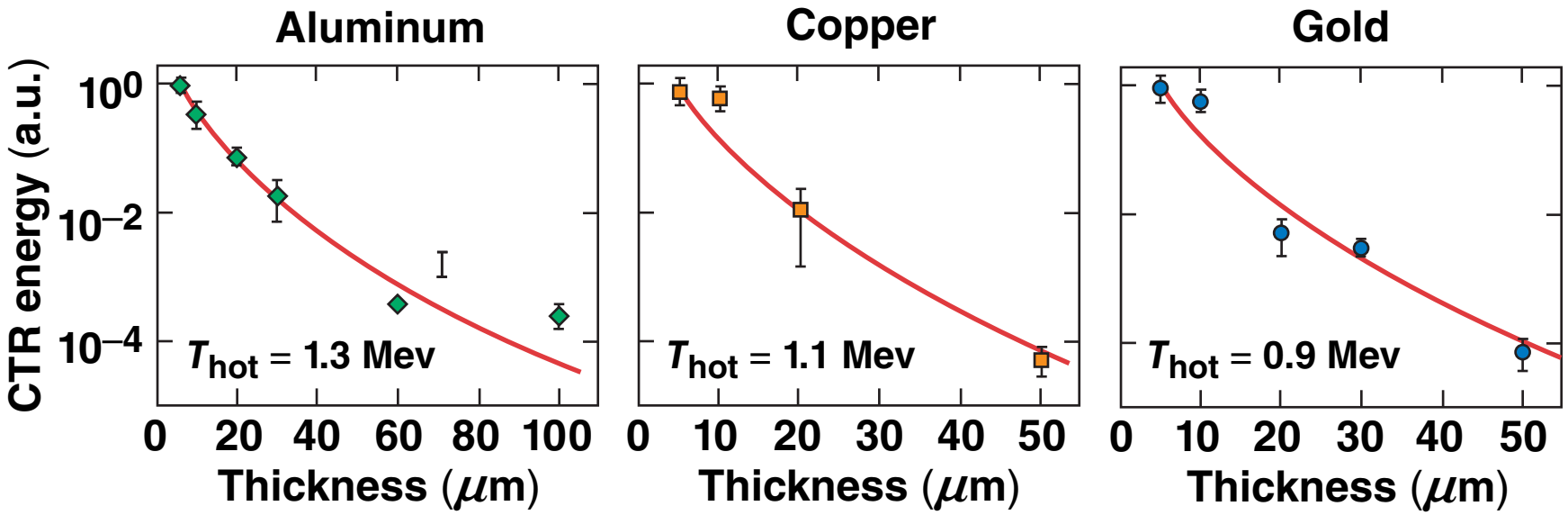
A fit has been made to a simplified analytical model to infer the electron temperature[1]



- The model accounts for only the effects of velocity dispersion of the beam.
- The estimated current ~1 MA $\approx$ 20$\times$ the Alfven limit.

The fall off in CTR is in agreement with the model for T_{hot} = 1.1±0.2 MeV.

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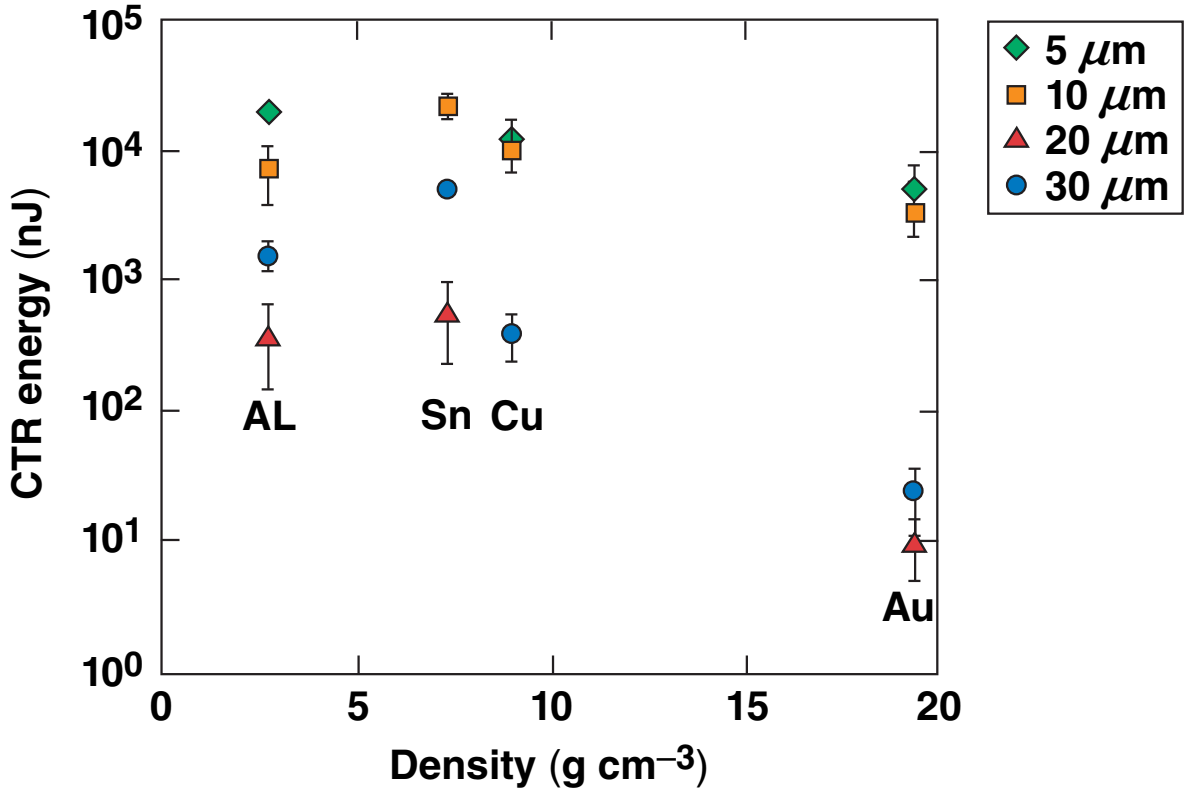
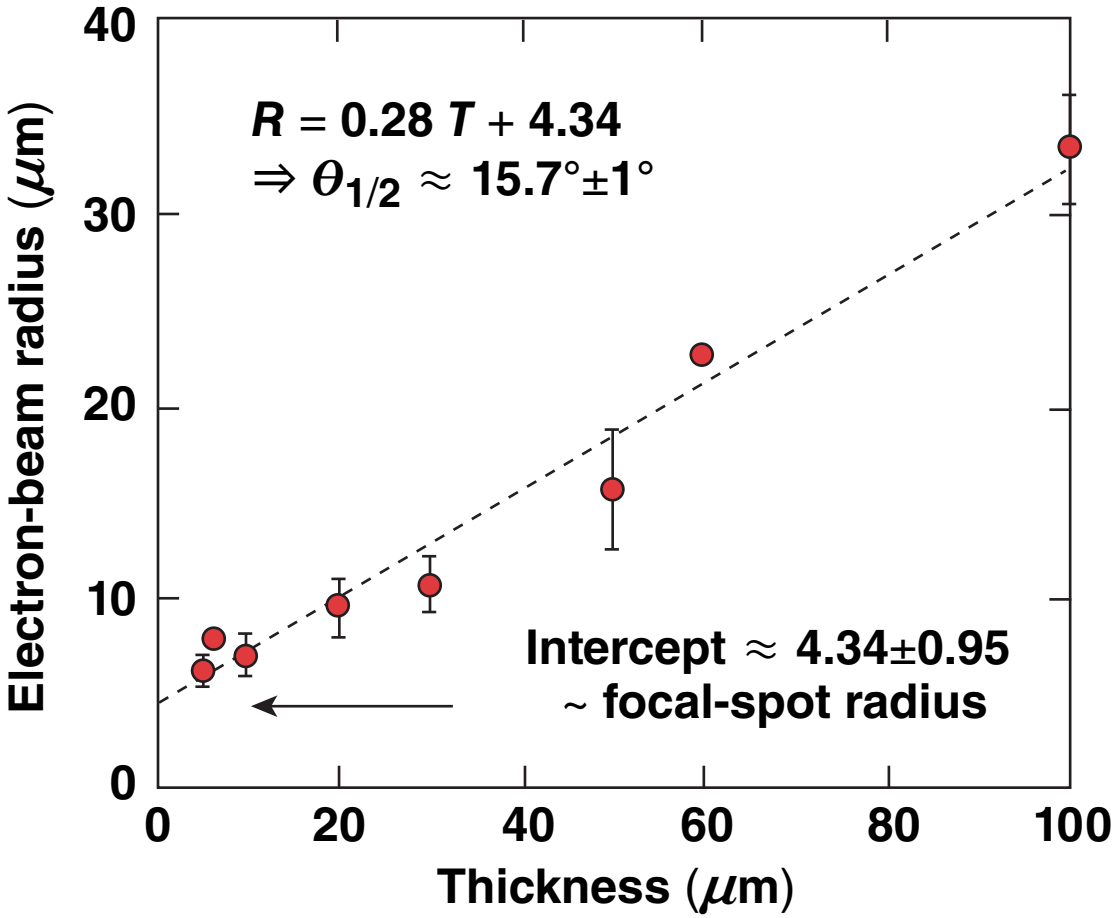
[1] J. Zheng *et al.*, Phys. Plasmas 10, 2994 (2003).

A reduction of the CTR signal with increasing target density indicates collisional effects



At T_{hot} ~1 MeV, velocity dispersion is the dominant process affecting the integrated energy in the CTR signal.

Averaged over all metals the observed electron-beam divergence is of the order of 16°



Evidence exists that the coherent part of the fast-electron beam propagates with lower divergence than the incoherent part.[1,2]

An ability to increase the energy into the coherent part of the beam would be useful for directing fast-ignition electrons.

[1]J. Santos *et al.*, Phys. Rev. Lett. 89, 025001 (2002).
[2]H. Popescu, Phys. Plasmas 12, 063106 (2005).

Summary/Conclusions

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