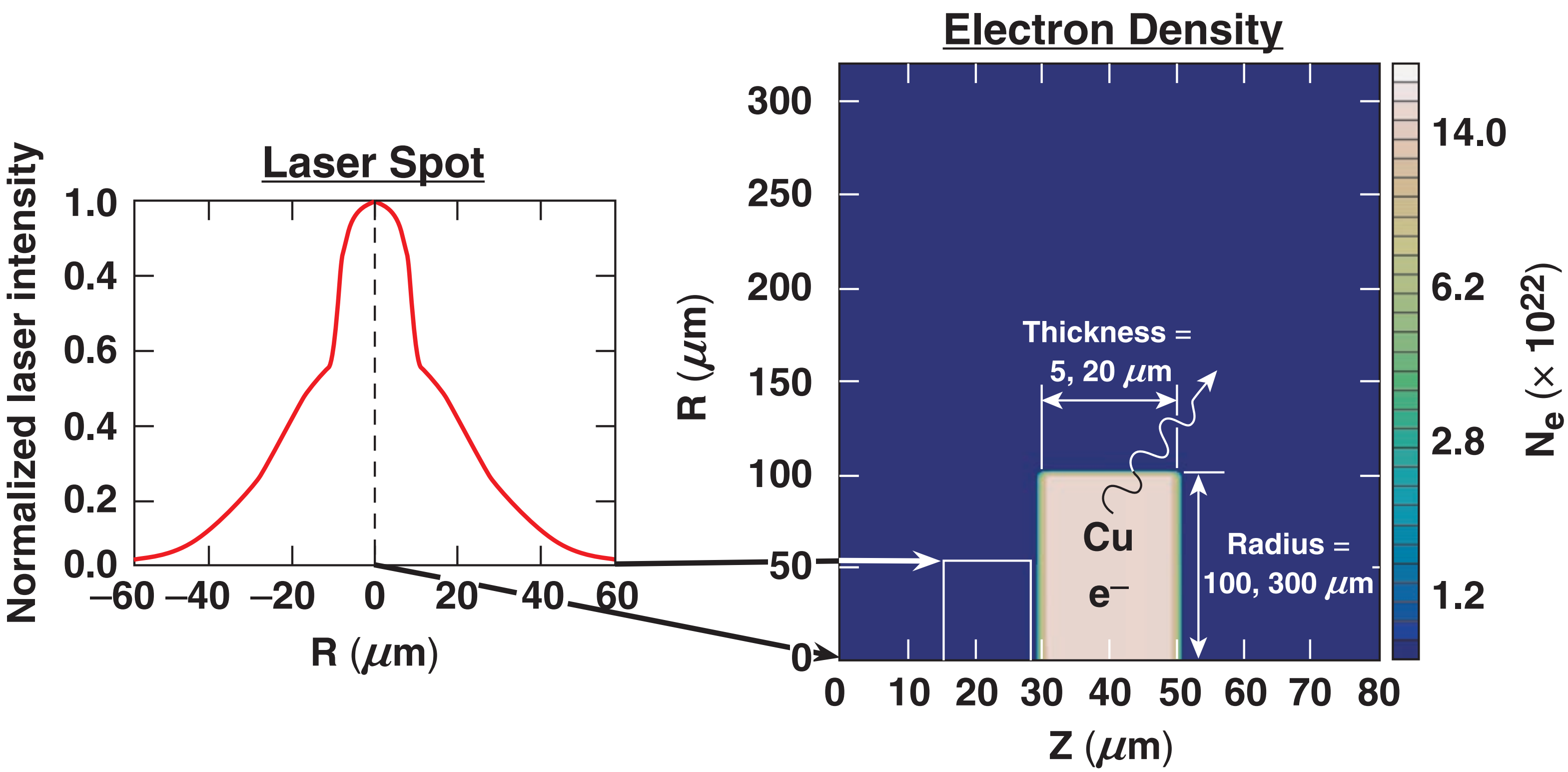
Numerical Calculations of Laser-Generated MeV Electrons and Characteristic X-Ray Production in Copper Foil Targets



J. Myatt
University of Rochester
Laboratory for Laser Energetics

47th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Denver, CO
24–28 October 2005

Summary

A modified version of LSP* is able to correctly compute the characteristic K-shell emission from laser irradiated foil targets without the *ad hoc* introduction of hot electron refluxing

- K_{α} photon production efficiencies have been computed for parameters relevant to recent Cu foil experiments† on the 100-TW and PW RAL systems for laser intensities in the range $I = 10^{18}$–10^{20} W/cm^2
- The computed yields depend strongly on the presence of large self-fields (B~10 MG, E~10^7 kV/cm) that create trapped and refluxing populations of hot electrons.
- Results compare favorably with the experiment in terms of the absolute yield and its dependence on laser intensity and target thickness.

*D. R. Welch *et al.*, Nucl. Instrum. Methods Res. A 464, 134 (2001).
†C. Stoeckl *et al.*, Bull. Am. Phys. Soc. 49, 1004 (2004).

Collaborators

**J. A. Delettrez, W. Theobald, M. Storm, C. Stoeckl,
A.V. Maximov, and R. W. Short**

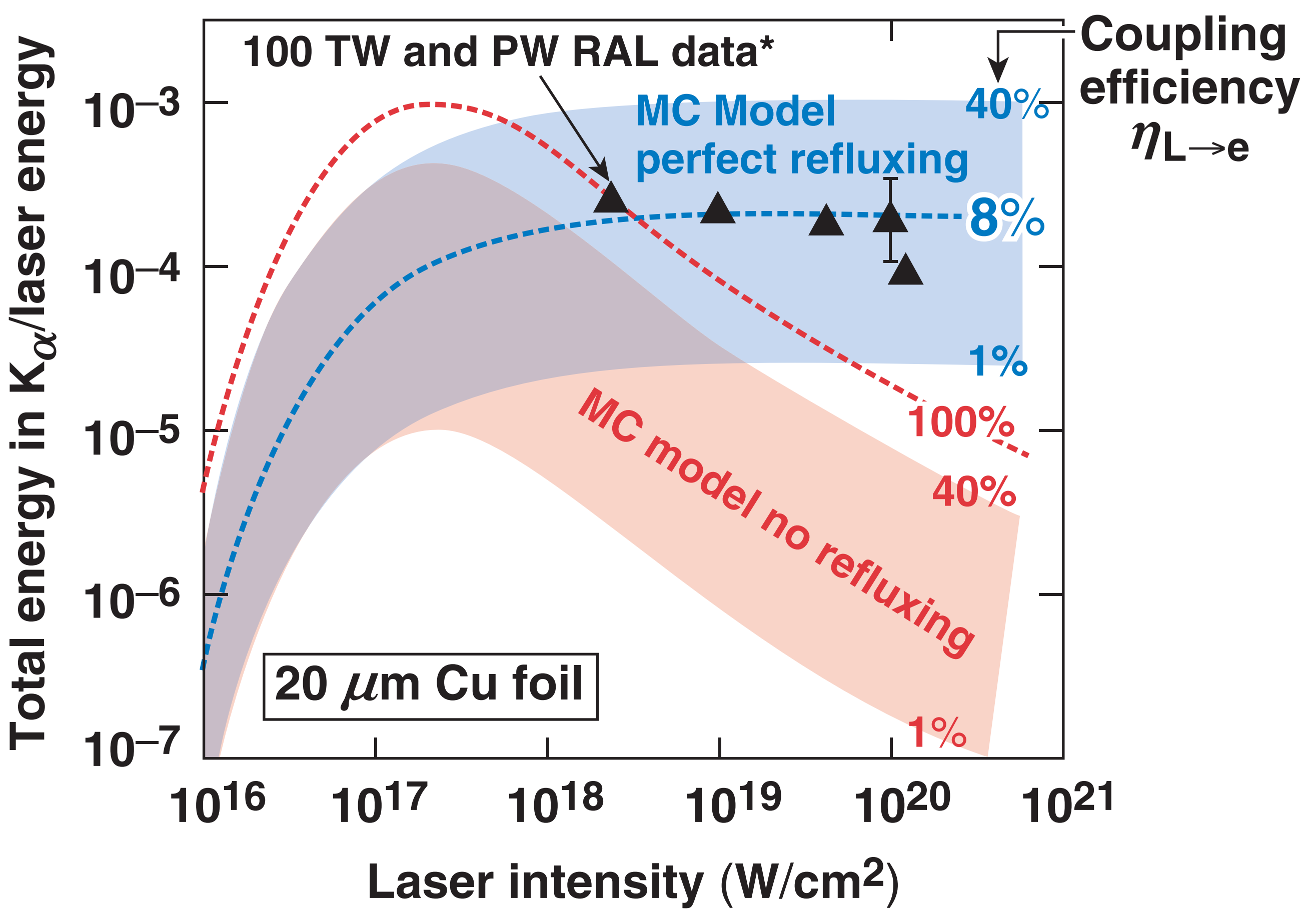
**University of Rochester
Laboratory for Laser Energetics**

R. P. J. Town and L. A. Cottrill

Lawrence Livermore National Laboratory

Monte Carlo (MC) models can only be made to agree with the RAL data if we allow for "refluxing"

- For exponentially distributed electrons, the best fit occurs for an 8% conversion efficiency $\eta_{L \to e}$



TC7243

*C. Stoeckl *et al.*, Bull Am. Phys. Soc. 49 1004 (2004).

The LSP model automatically describes refluxing because it self-consistently solves for EM fields

- Unlike MC, hybrid PIC includes the generation of sheath fields, anomalous stopping, resistive inhibition and collimation hot current.
- K-shell photon production efficiency is a result of the interplay between electron energy loss (dE/ds) and the energy dependence of the K-shell ionization cross section $\sigma_k(E)$.
- The LSP plasma model has been extended by using a combination of the "collisional plasma" model and ITS routines.
  - collisional slowing down and scattering*
  - produce and transport x-ray photons
- Electrons are "promoted" from the background with Wilks scaling.†

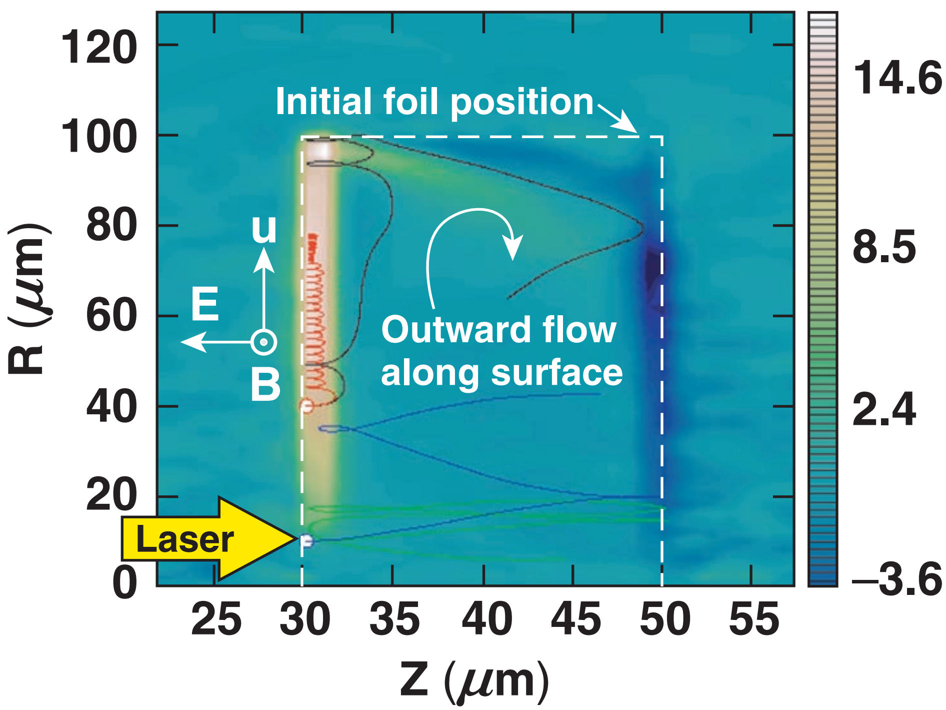
*A. Solodov *et al.*, QP1.138
†S. C. Wilks *et al.*, Phys. Rev. Lett. 69, 1383 (1992).

TC7244

LSP calculations exhibit complex hot electron trajectories including refluxing from the foil boundaries

- Magnetic field strength and sample particle trajectories in 20 μm Cu foil.

B_θ (MGauss) at time 1.7 ps

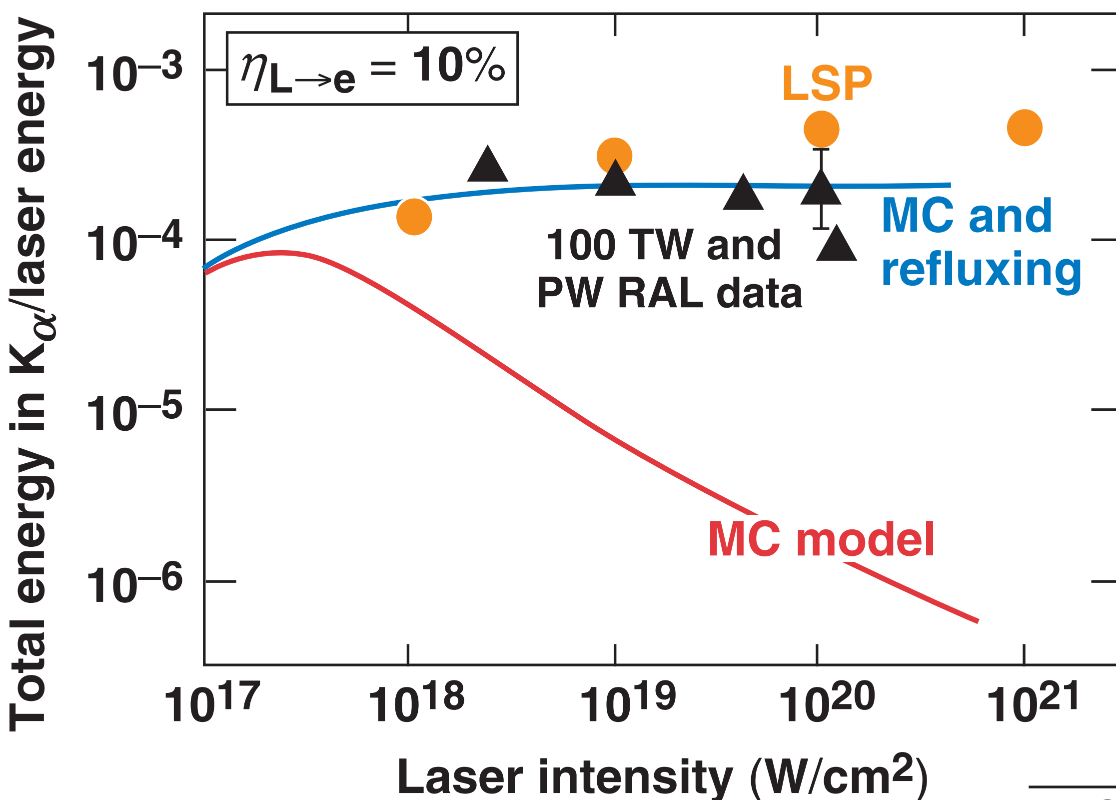


- Hot electrons flow radially outward along the target surface.
  - $U_{drift} = c\frac{ExB}{B^2}$
- Energetic electrons reflux off the sheath at the front and back surface.

TC7245

Reasonable agreement is obtained between experimental K_α yield and LSP yield

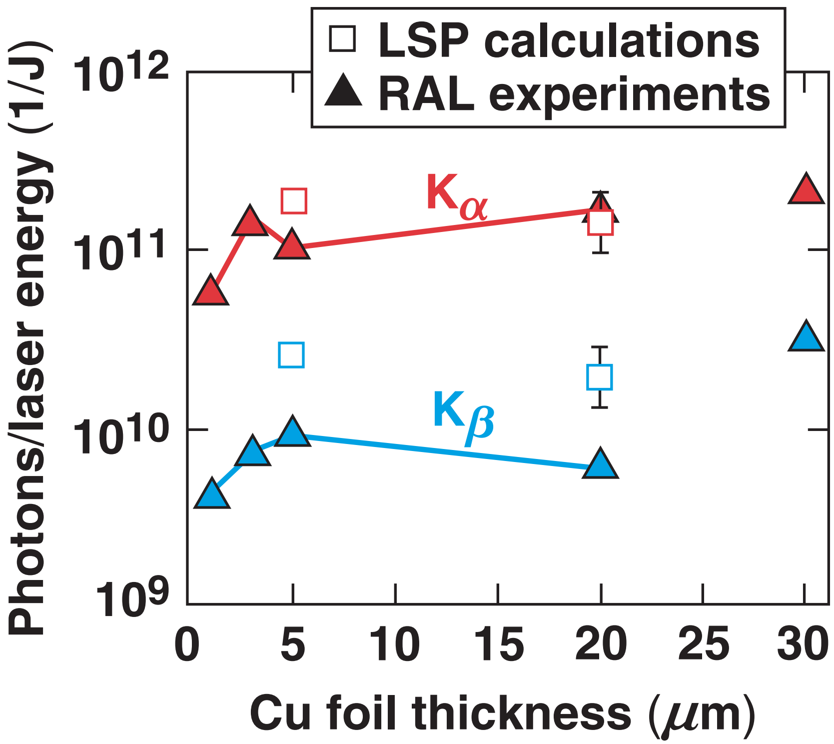
- Experimental points are a compilation of 100 TW and PW data where intensity is changed by varying beam energy (100 → 500 J) and spot size for a ~1ps pulse
- LSP collision model under-predicts stopping at high electron energy*

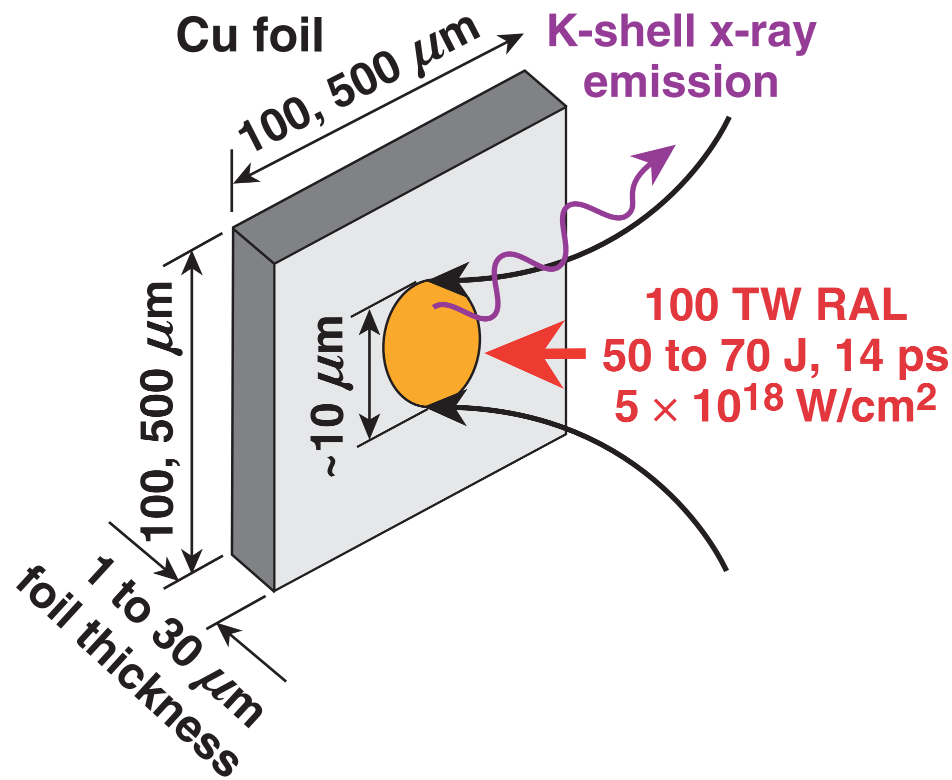


TC7246

*A. Solodov *et al.*, QP1.138

K_α yield is insensitive to target size in both experiments* and LSP calculations





TC7247

*C. Stoeckl *et al.*, Bull. Am. Phys. Soc 49 104 (2004).

Summary/Conclusions

A modified version of LSP* is able to correctly compute the characteristic K-shell emission from laser irradiated foil targets without the *ad hoc* introduction of hot electron refluxing

UR LLE

- K_{α} photon production efficiencies have been computed for parameters relevant to recent Cu foil experiments† on the 100-TW and PW RAL systems for laser intensities in the range $I = 10^{18}$–10^{20} W/cm^2
- The computed yields depend strongly on the presence of large self-fields (B~10 MG, E~10^7 kV/cm) that create trapped and refluxing populations of hot electrons.
- Results compare favorably with the experiment in terms of the absolute yield and its dependence on laser intensity and target thickness.

*D. R. Welch *et al.*, Nucl. Instrum. Methods Res. A 464, 134 (2001).
†C. Stoeckl *et al.*, Bull. Am. Phys. Soc. 49, 1004 (2004).

TC6973a

The k-photon yield and its dependence on laser intensity can be estimated by a simple model*

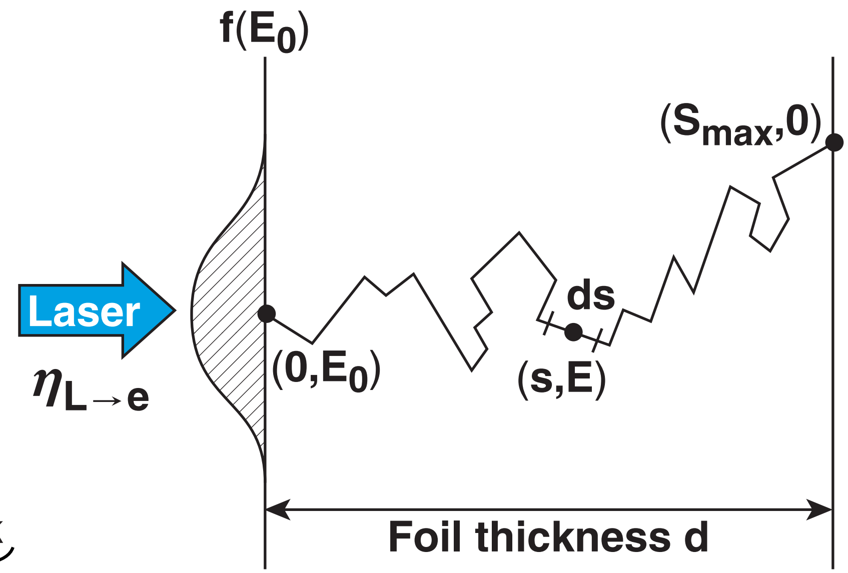
- Determine production efficiency

$$\eta_{e\to k} = \frac{t_k N_k}{\eta_{L\to e} E_L}, \; N_k = \left(N_{k,obs}/F_{obs}\right)$$

by integrating over path

$$N_k = N_e \int_0^{\infty} dE_0 f\left(E_0\right) \int_0^{S_{max}\left(E_0\right)} ds \, \underbrace{\omega_k \eta_{Cu} S_k}$$

Probability per unit path for electron with energy E(s,E) to produce a k-photon



- Energy distribution $f\left(E_0\right)$ is uncertain
  - e.g., $f(e)\,dE = \frac{1}{T} \exp\left(-E/T\right) dE$, with T related to I with Wilks scaling: $T \sim W_{osc} = 0.511\left[\left(I = I_{18}\lambda^2 \mu m/1\cdot 37\right)^{1/2} - 1\right] MeV$

*Green and Cosslett (1961).