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Recent work on production of hot plasmas and transport of hot electrons

F. Beg, M.H. Key, A.J. Mackinnon, A.G. Macphee, S. Lepape, P. Patel, S. C. Wilks, R.B Stephens, J. Pasley, E. Shipton, M. Wei

February 26, 2007

7th US-Japan Fast Ignition Workshop
Otsu, Japan
January 9, 2007 through January 11, 2007

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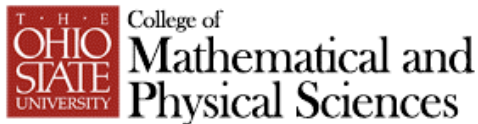
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Recent Work on Production of Hot Plasmas and Transport of Hot Electrons

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7th US-Japan Fast Ignition Workshop

Jan. 9-11, 2007

Otsu, Japan

This work was supported by the US Dept of Energy through various grants from the Office of Fusion Energy Sciences.

Collaborators



J. Pasley, E. Shipton, M. Wei



R.B. Stephens

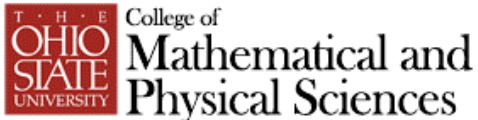
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M. H. Key, A.J. MacKinnon,
A. MacPhee, S. Lepape,
P. Patel, S. Wilks



D. Hey



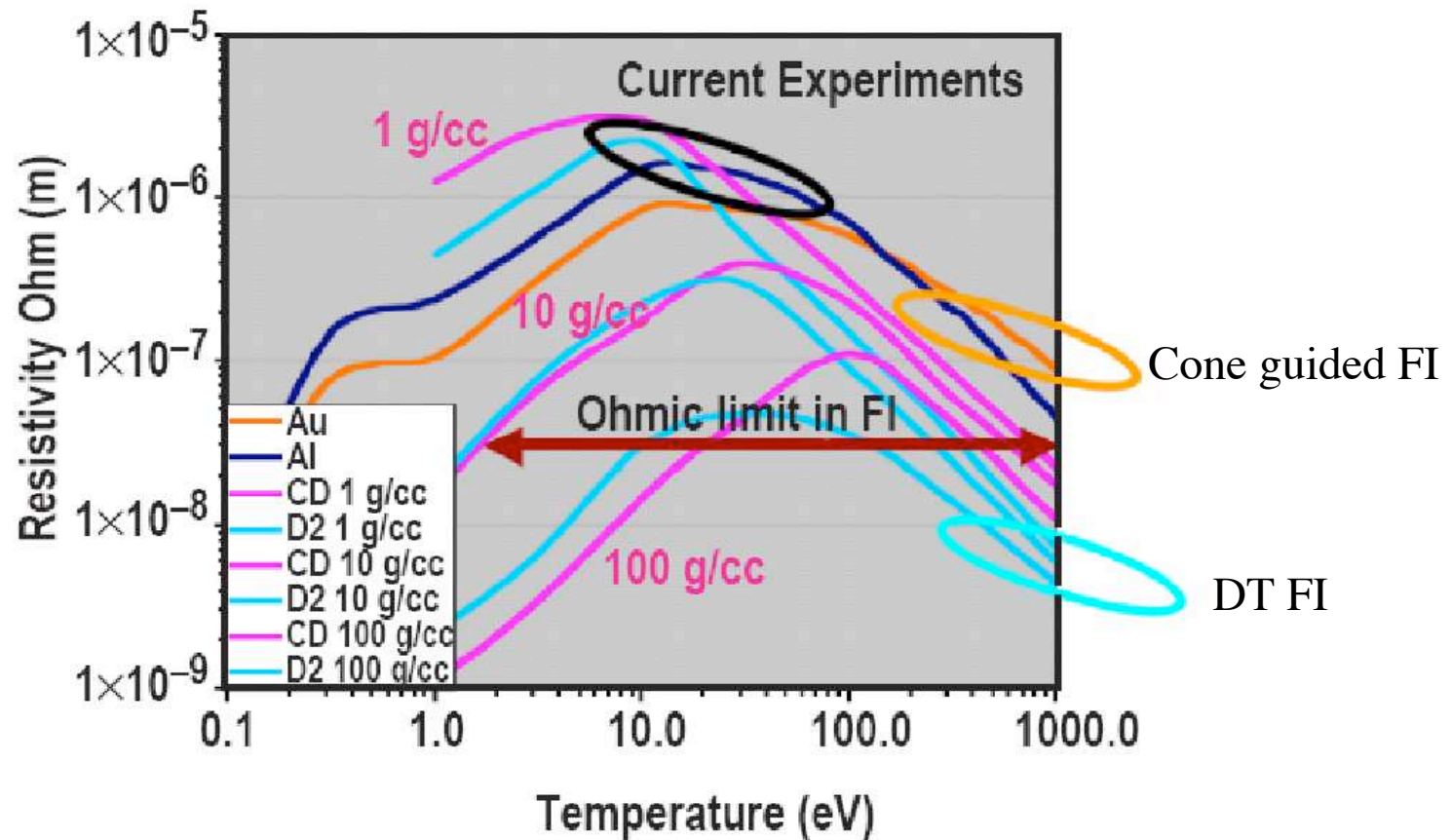
R.R. Freeman, L. Van Woerkom, D. Offerman



Outline

- Motivation
- Two Schemes to produce hot Dense Matter
- Rad-Hydro Simulations
- Experimental Results
- Summary and Future Work

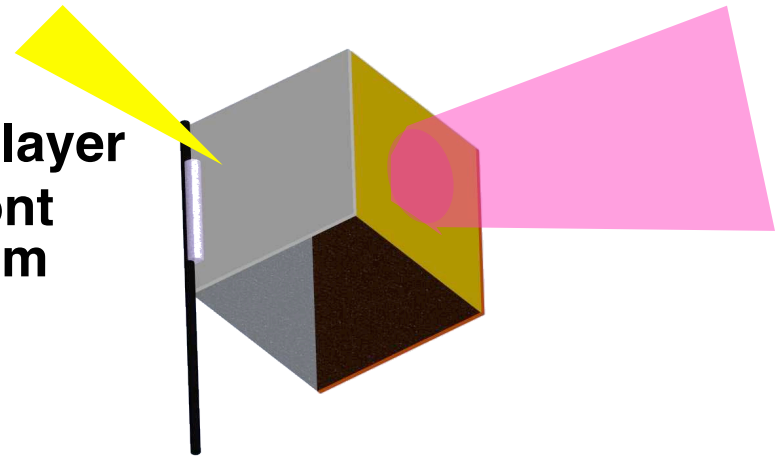
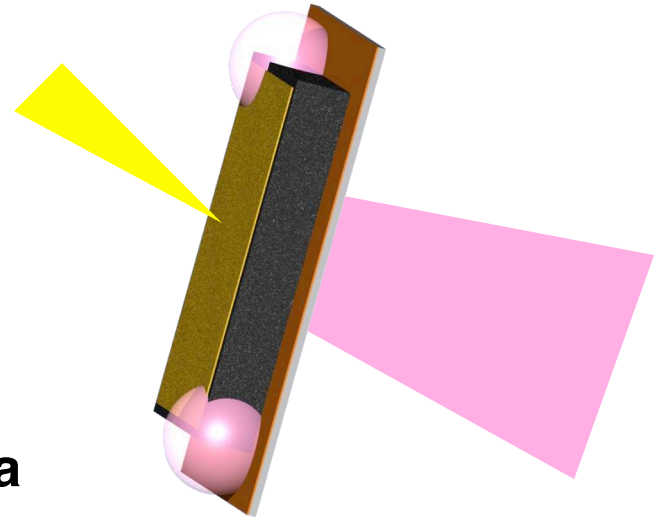
Motivation



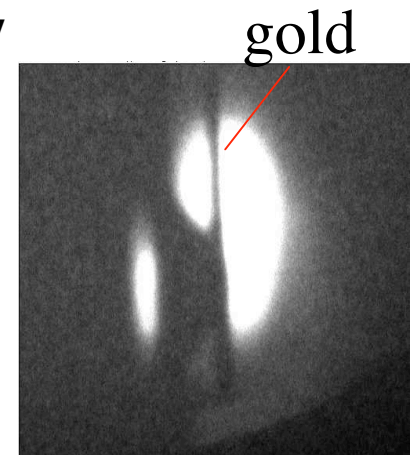
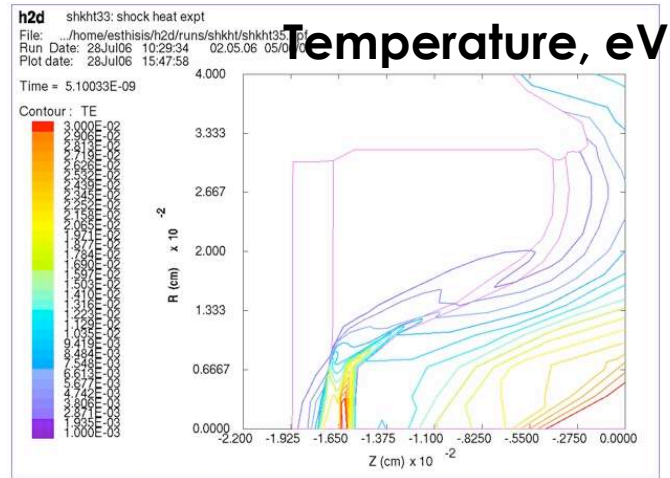
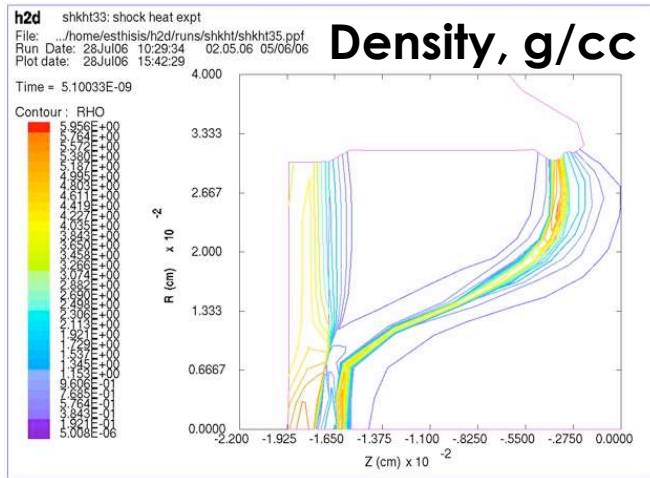
- Most experiments are performed far from FI conditions
- Electron transport in hot targets is different

Two Schemes to Produce Hot Dense Target

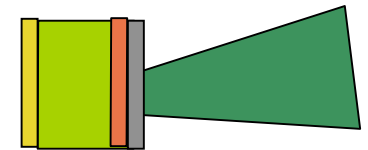
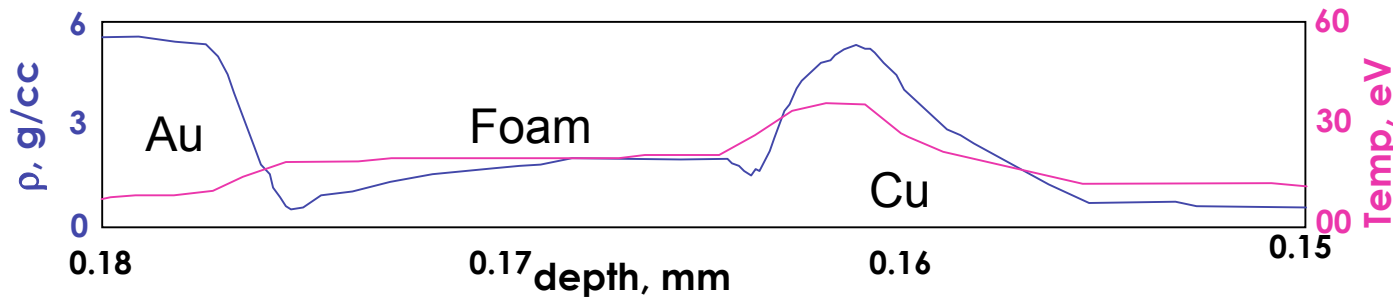
- **Shock heated**
 - Long pulse accelerates pusher plate
 - Compresses & heats foam
 - Short pulse laser interacts with gold
 - Hot electrons produced are detected by copper plate
 - ⇒ Measures electron transport into plasma
 - ⇒ Mimics the cone tip shock interaction
- **Thermal electron heated**
 - Long pulse well absorbed in thin Au layer
 - Long pulse driven thermal e^- heat front supersonically heats low-density foam
 - ⇒ Measures transport thru plasma



Shock driven experiment shows foam compression to 1 g/cc



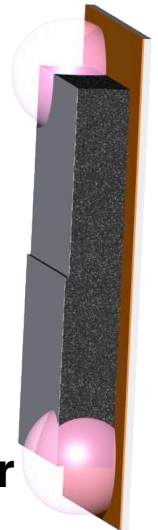
Radiograph



- Long pulse accelerates Al/Cu flyer plate
- Compresses foam to ~1 g/cc
- Shock wave penetrates Au foil on opposite side
- Electrons generated in Au cross the Au/interface and are counted in Cu

Various types of targets were used to understand transport

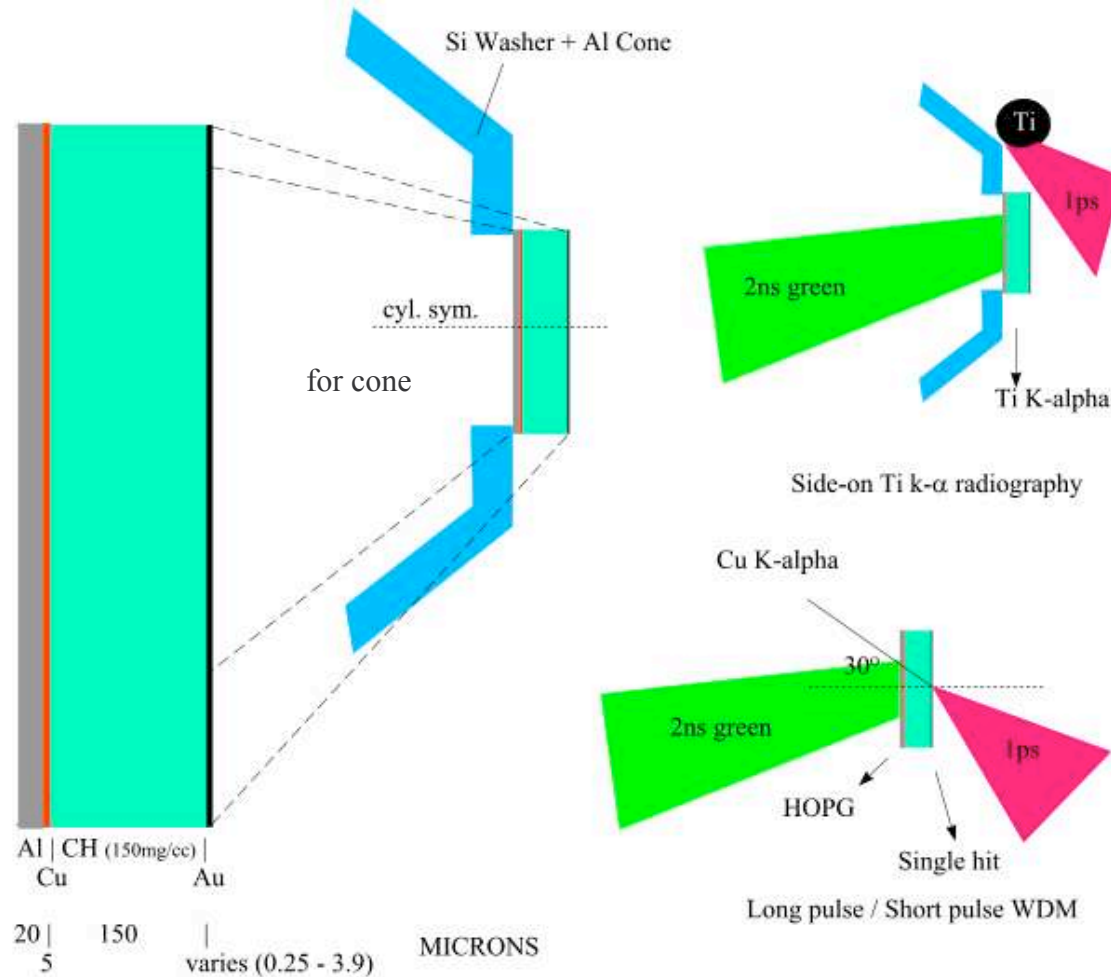
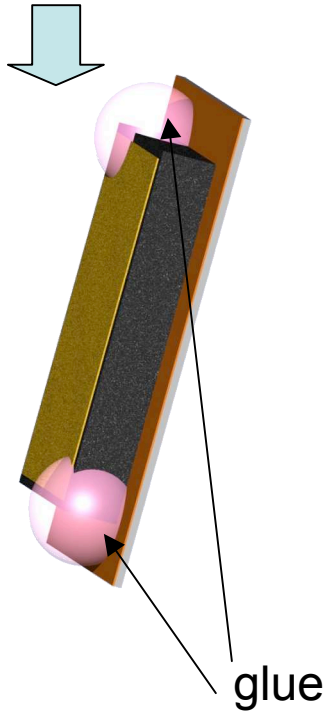
- **Au/Cu/Al** - measure electron generation in Au
 - short pulse laser, Cu-K α imager, single hit CCD and spectrometer
- **Au/CRF/Cu/Al** - measure losses in hot foam
 - Long pulse, check timing w backlight
 - Long & short pulse, Cu-K α imager, single hit CCD and spectrometer
- **Au/CH/Cu/Al** - measure losses in cold CH, same areal density
 - Long & short pulse, back-light, Cu-K α imager and spectrometer



Aim was to produce large enough plasma to diagnose

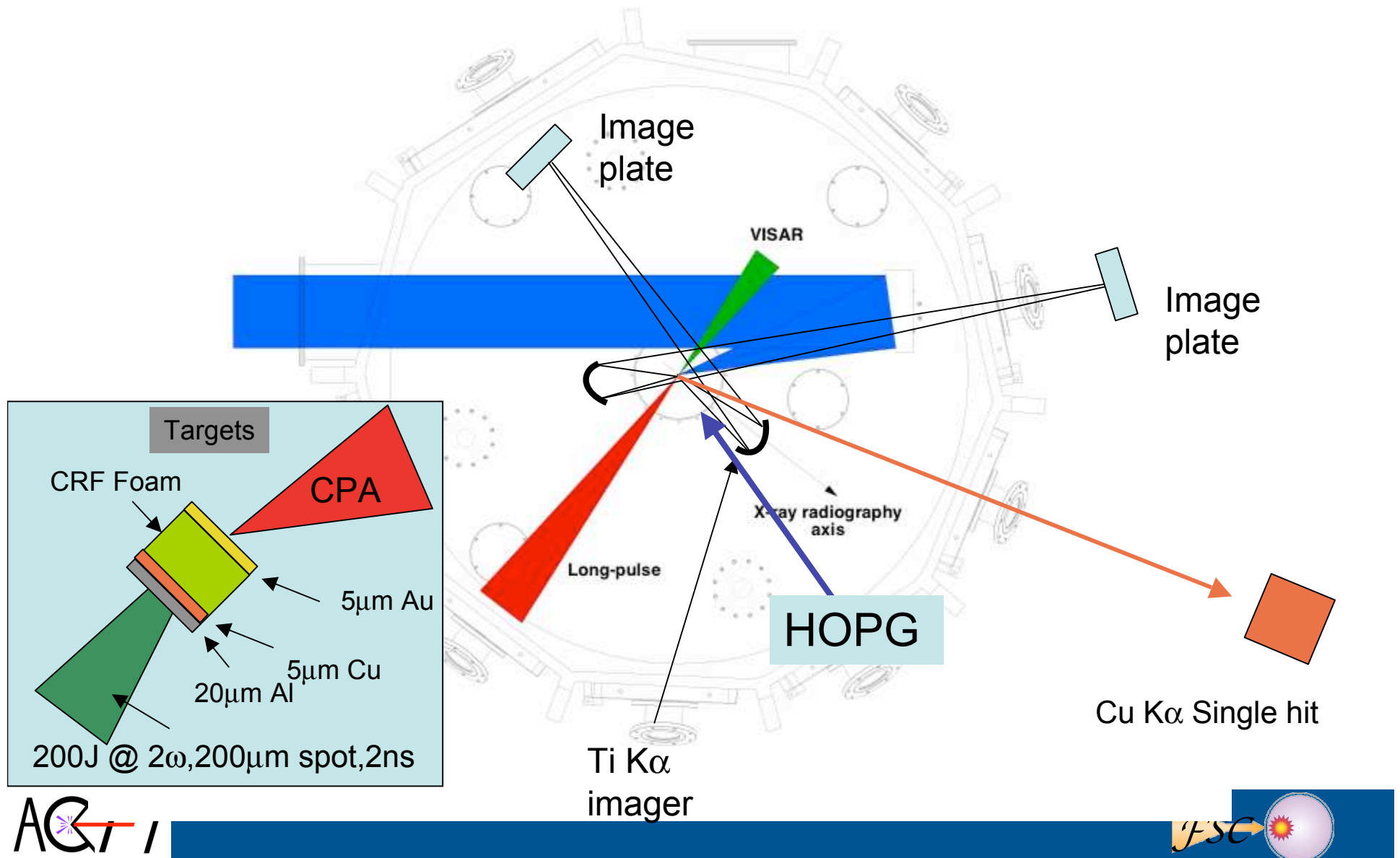
Target Schematic

Real target
Is actually
rectangular

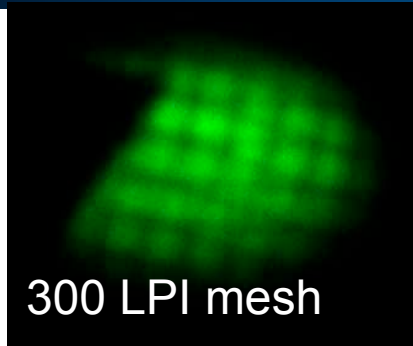


- A variety of diagnostics was used

Diagnostics



X-ray backlit images show shocked compression of foam

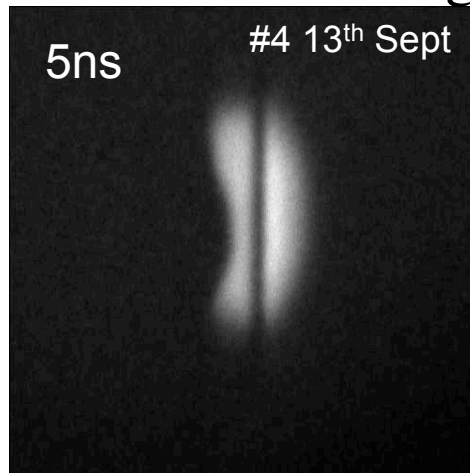
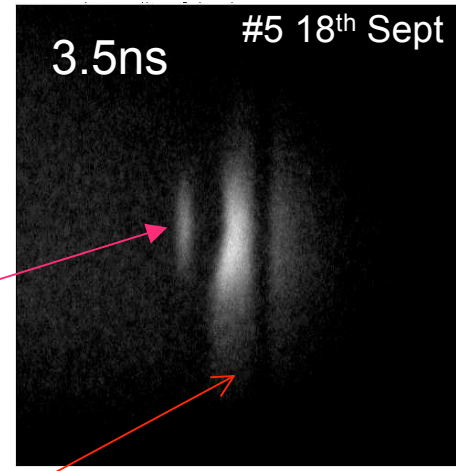
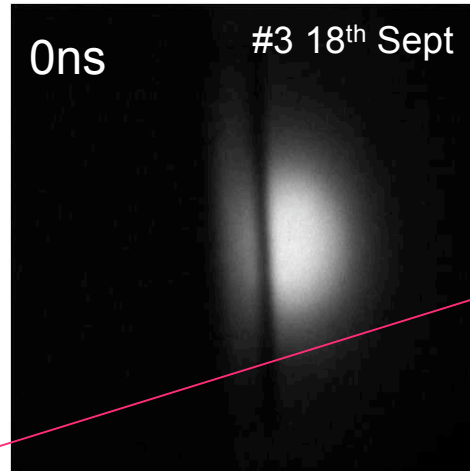


Resolution 24 microns

Bremsstrahlung from long pulse interaction.

- Radiographs show shocked compressed foam between copper and gold surface

- Good agreement with 2D rad-hydro simulations

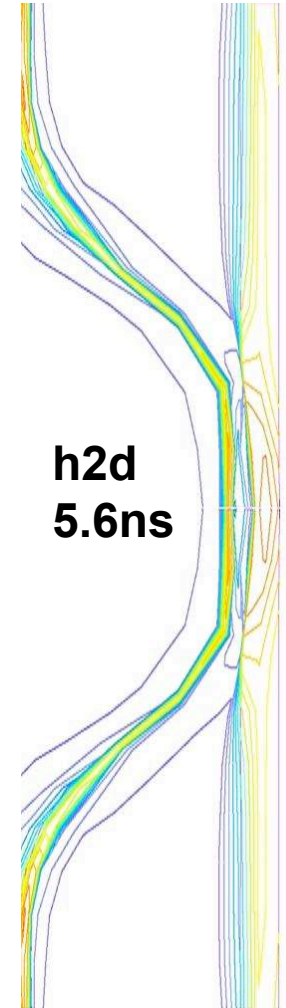


gold

Shock 55 μm into foam

Shock 90 μm into foam

200J @ 2ω , 200 μm spot, 2ns

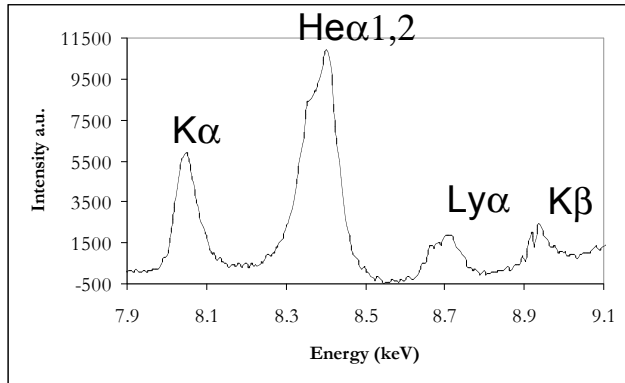


Shock heated targets

- **Timing of short pulse varied with respect to long pulse to examine transport through:**
 - **Cold Au/shocked foam**
 - **Cold Au /partially shocked foam**
 - **Shocked Au /shocked foam**

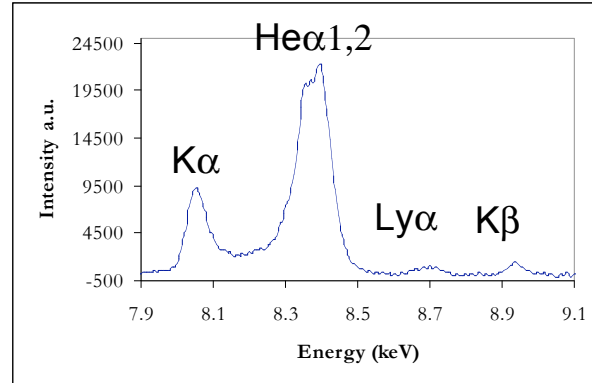
Target composition affects the electron transport

Al/Cu/Au, 1ps



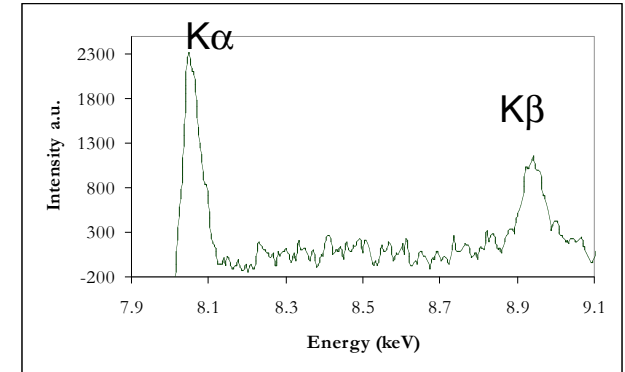
Shot 2, 7th September, 152J

Al/Cu/Au 10ps



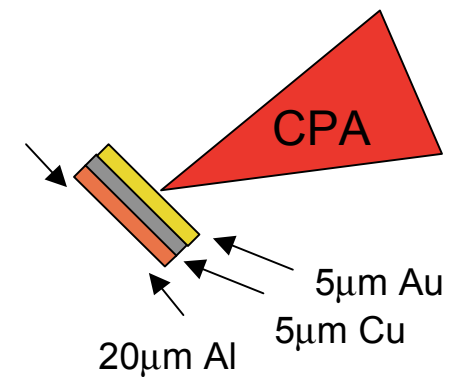
Shot 2, 6th Sept, 256J

Al/Cu/CH/Au, 1ps

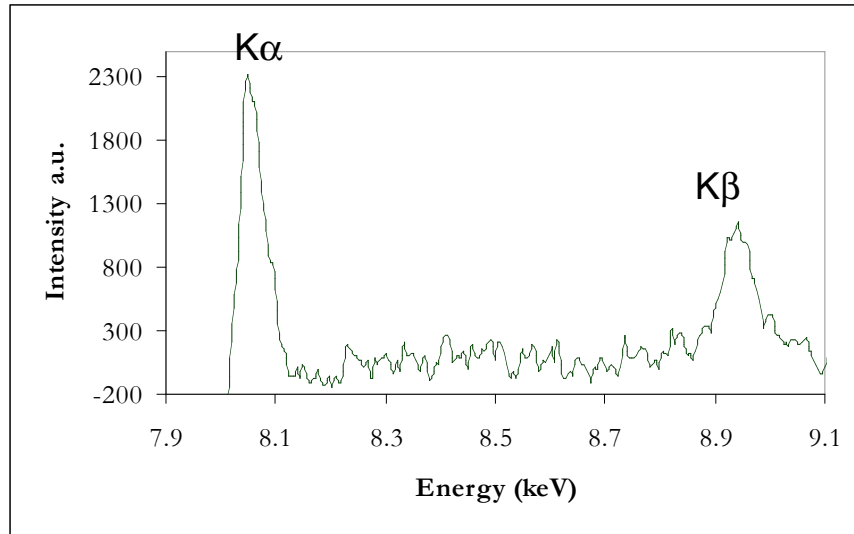


Shot 4, 6th September, 140J

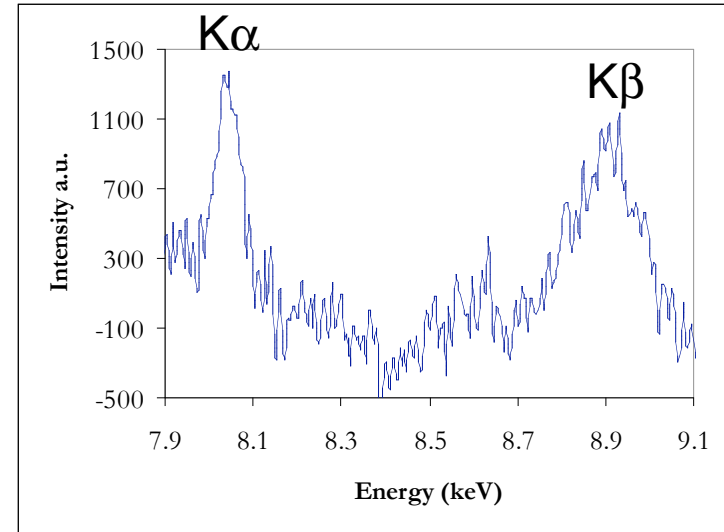
- Presence of He_α shows heating of copper for both 1 and 10 ps laser pulses
- He_α disappears with an addition of CH in the target
- Transport is significantly different in insulator targets
- More accurate information from a single CCD camera



Fully shocked target shows reduction in Cu K_{α}



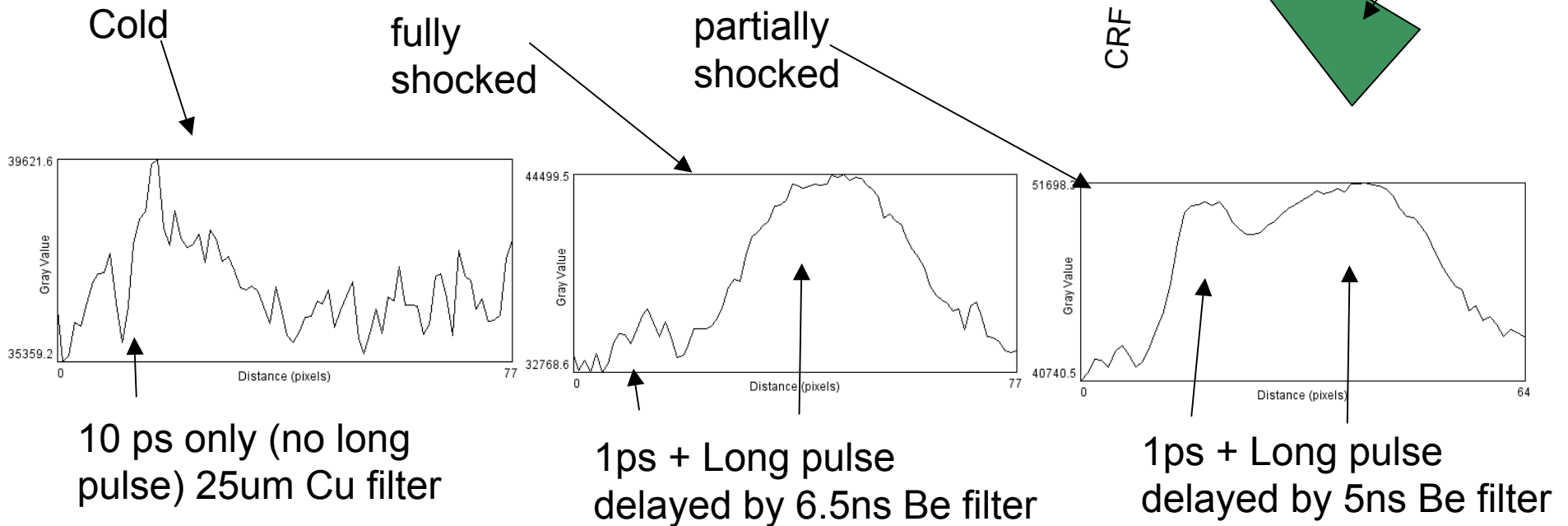
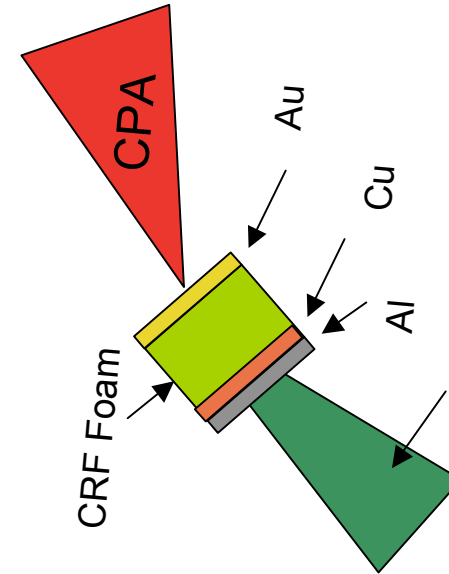
Shot 4, 6th September, 140J
Al/Cu/CH/Au, 1ps



Shot 4, 15th September, 142 J, 1 ps
Fully shocked, Delay : 6.5ns

- Reduction in copper K_{α} counts with shocked targets
- He_{α} is not observed with both plastic and shocked targets
- More careful analysis with a single hit CCD camera is required

Emission is dominated by bremsstrahlung



SUMMARY

- Experiments have been performed to produce warm dense matter with shock compression.
- Rad-hydro simulations show compression of foam to 1 g/cc and temperature of 20-25 eV. The shock timing agrees with experimental results with 200 J, 2 ns, green long pulse laser.
- Laser with a pulse length 10 ps burns through 3-4 μm gold foils
- Shocked targets show reduction in copper K_{α} counts

Future Work

- **Use of CH as ablator will reduce bremsstrahlung**
- **More shots are required for 1 and 10 ps laser pulse lengths**
- **A detailed data analysis will shed light on the physics of electron transport in warm dense matter**