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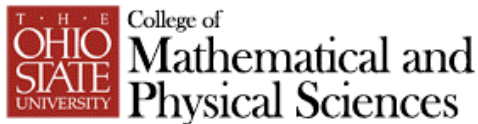
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# Recent Work on Production of Hot Plasmas and Transport of Hot Electrons

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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

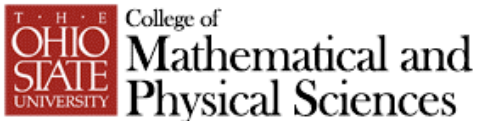
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M. H. Key, A.J. MacKinnon,  
A. MacPhee, S. Lepape,  
P. Patel, S. Wilks



D. Hey



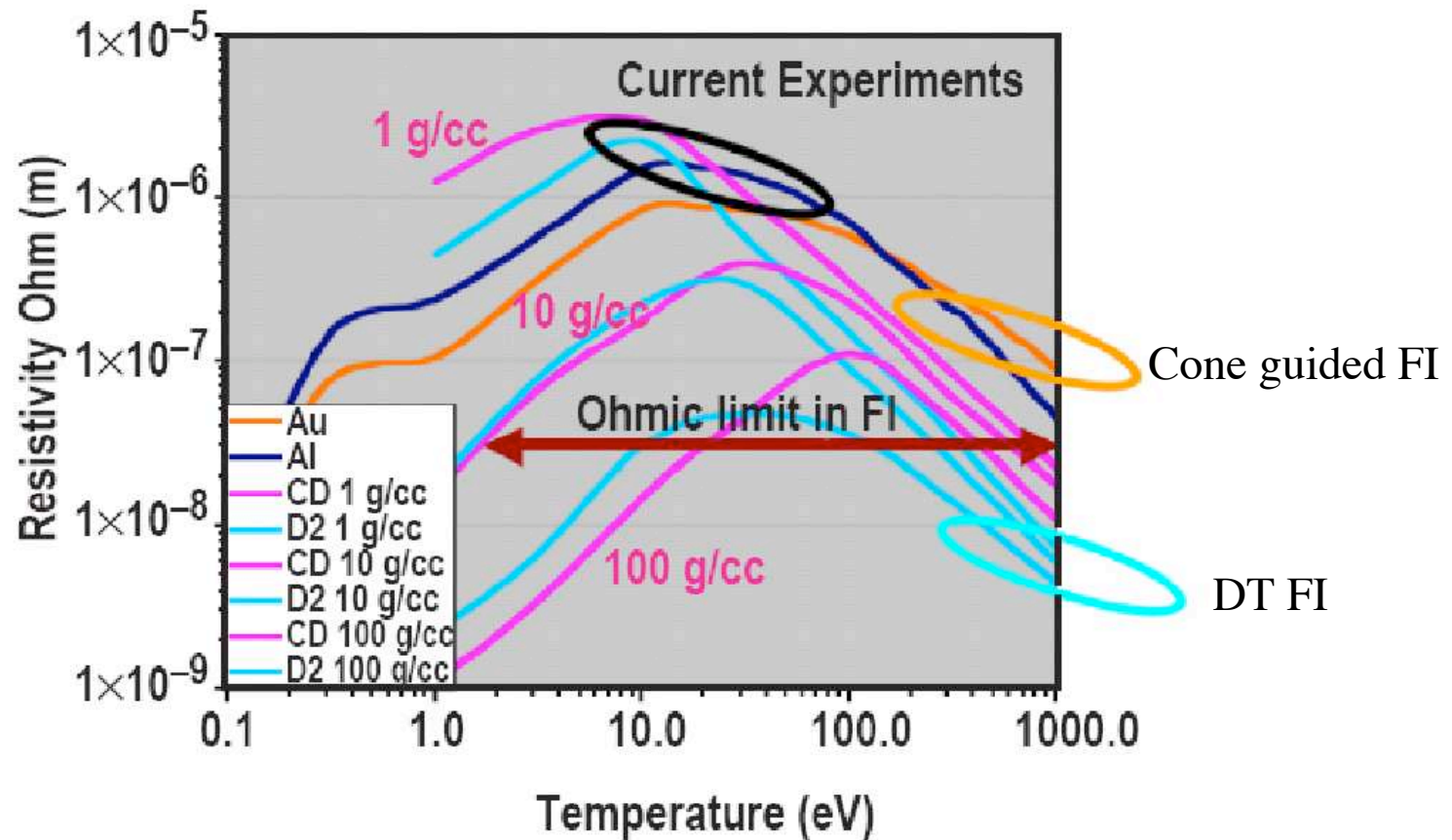
R.R. Freeman, L. Van Woerkom, D. Offerman



# Outline

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

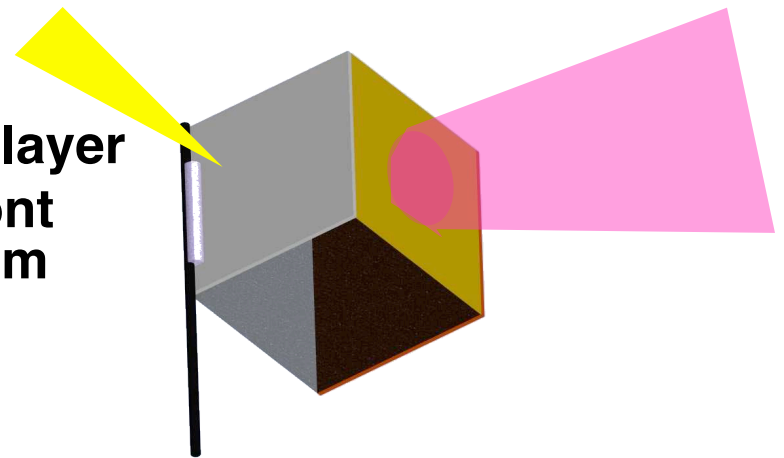
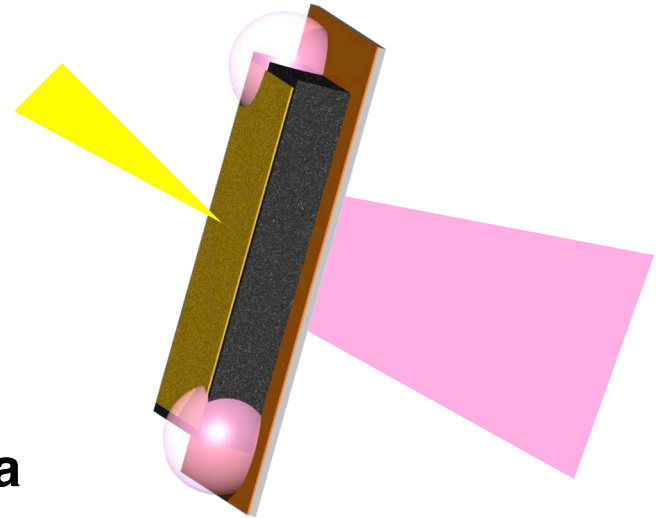
# Motivation



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

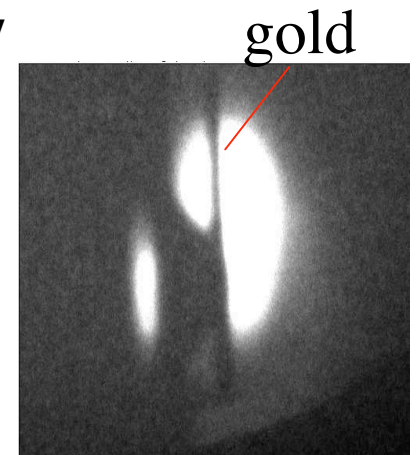
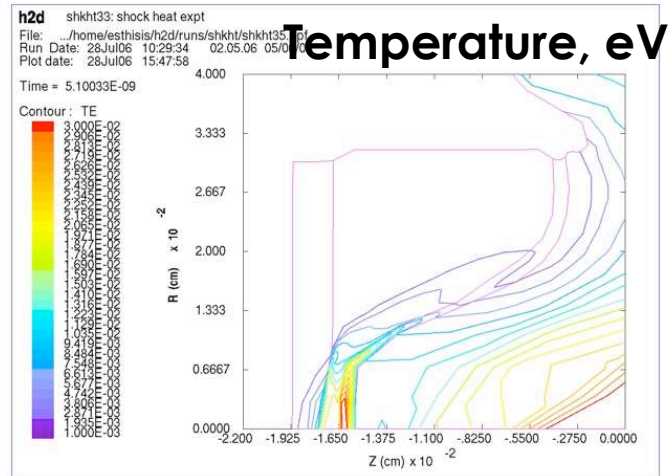
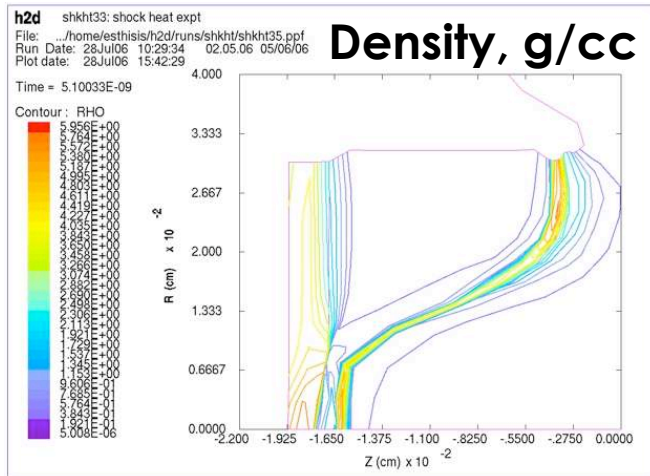
# Two Schemes to Produce Hot Dense Target

- **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

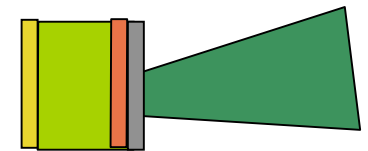
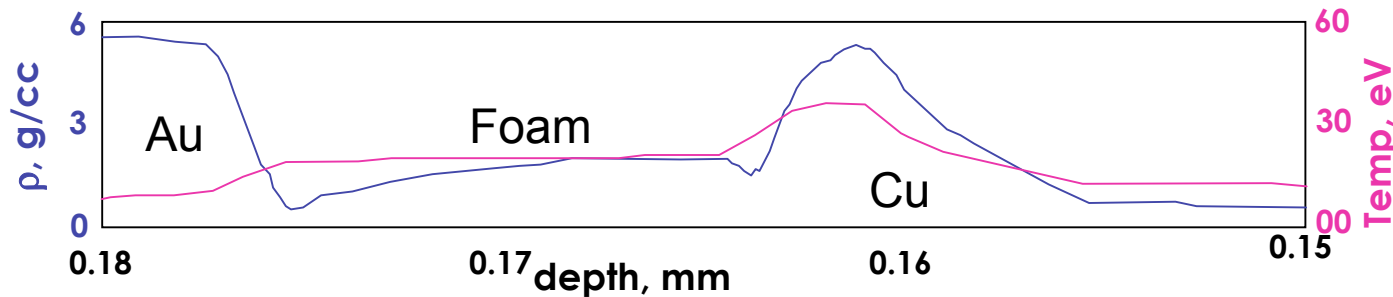




# Shock driven experiment shows foam compression to 1 g/cc



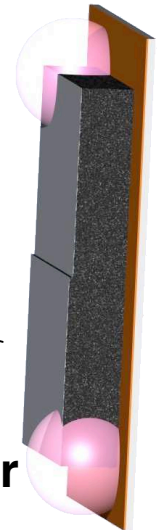
Radiograph



- 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

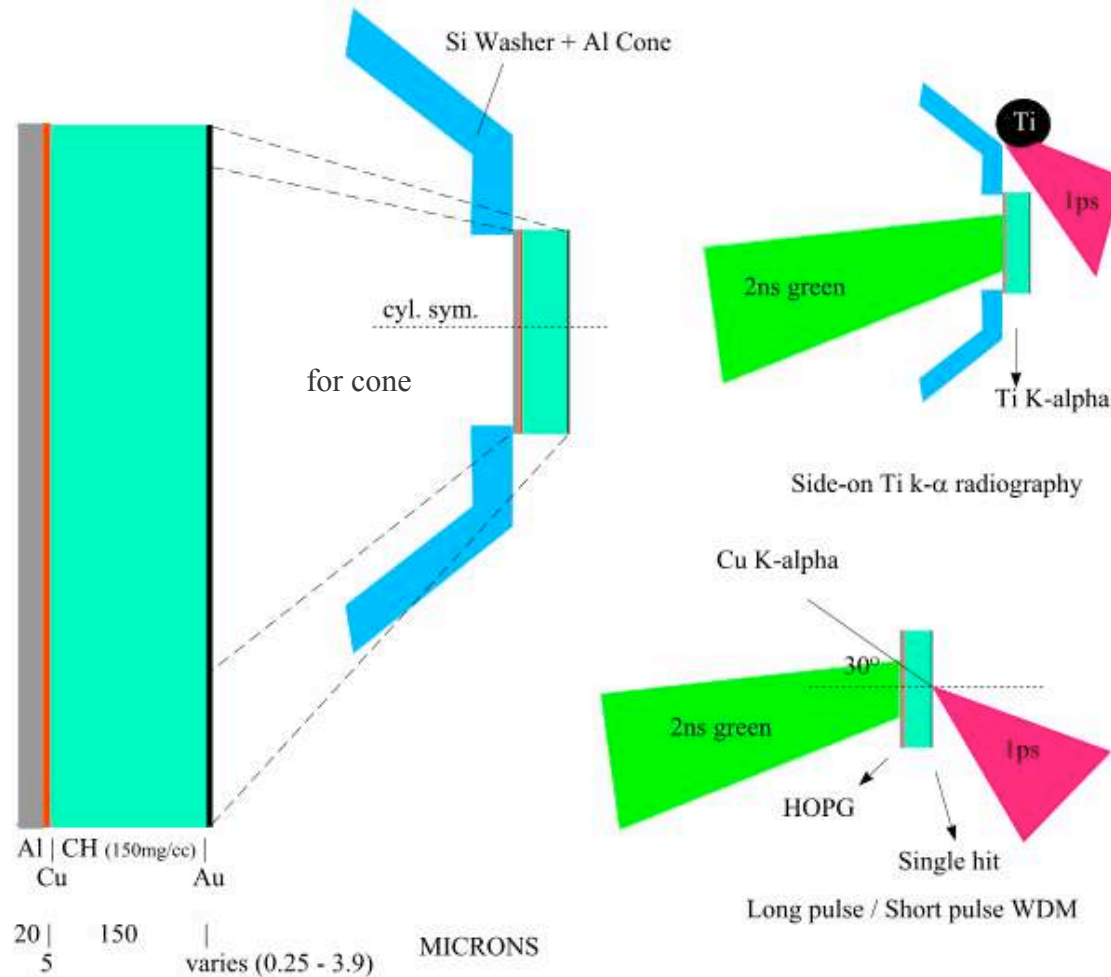
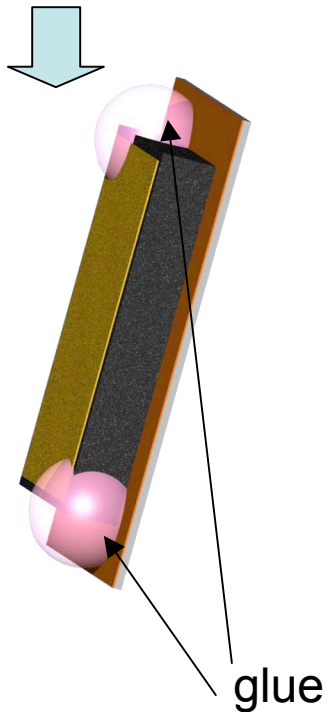
- **Au/Cu/Al** - measure electron generation in Au
  - short pulse laser, Cu-K $\alpha$  imager, single hit CCD and spectrometer
- **Au/CRF/Cu/Al** - measure losses in hot foam
  - Long pulse, check timing w backlight
  - Long & short pulse, Cu-K $\alpha$  imager, single hit CCD and spectrometer
- **Au/CH/Cu/Al**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



Aim was to produce large enough plasma to diagnose

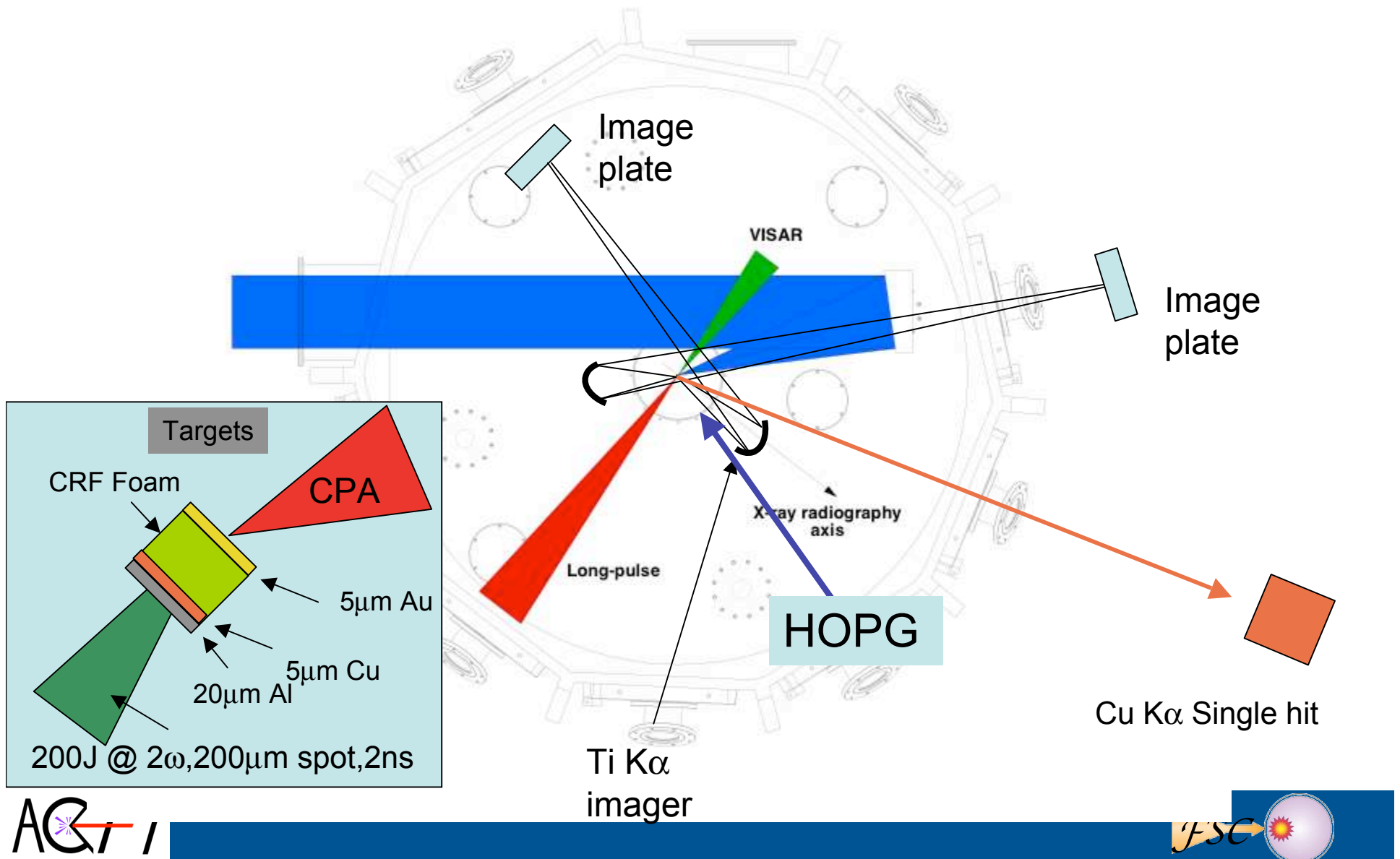
# Target Schematic

Real target  
Is actually  
rectangular

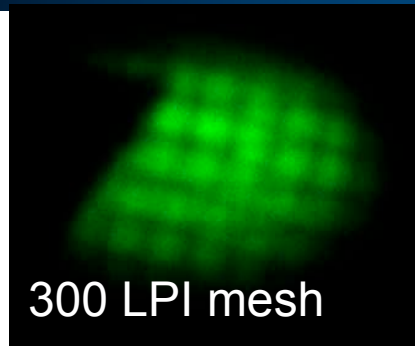


- A variety of diagnostics was used

# Diagnostics



# X-ray backlit images show shocked compression of foam



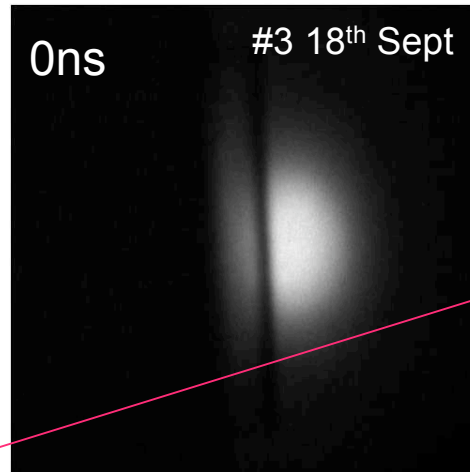
300 LPI mesh

Resolution 24 microns

Bremsstrahlung from long pulse interaction.

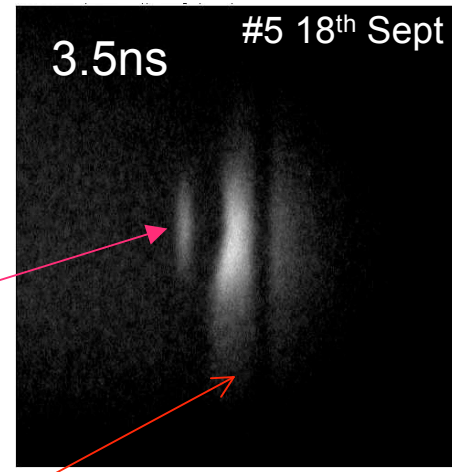
- Radiographs show shocked compressed foam between copper and gold surface

- Good agreement with 2D rad-hydro simulations



0ns

#3 18<sup>th</sup> Sept

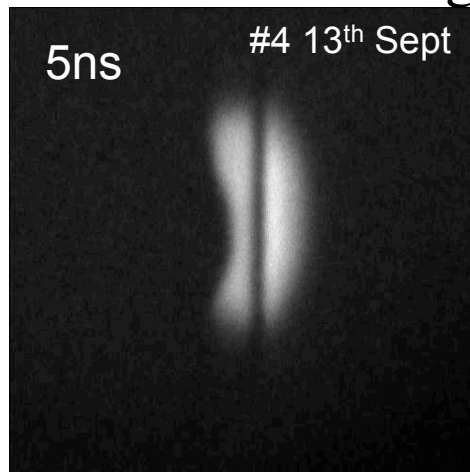


3.5ns

#5 18<sup>th</sup> Sept

gold

Shock 55  $\mu\text{m}$  into foam



5ns

#4 13<sup>th</sup> Sept

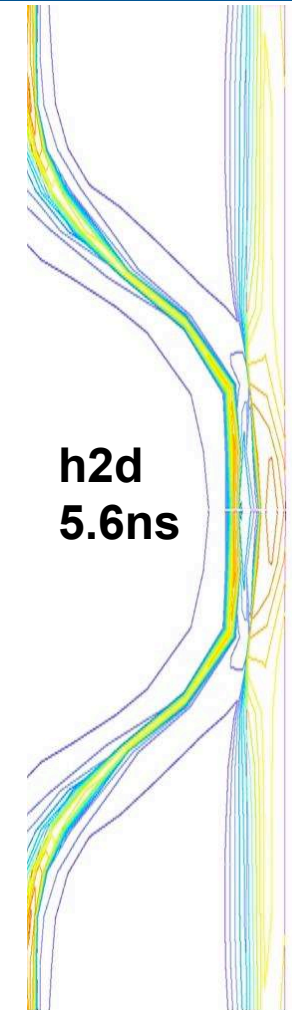
Shock 90  $\mu\text{m}$  into foam



7ns

#5 14<sup>th</sup> Sept

200J @  $2\omega$ , 200 $\mu\text{m}$  spot, 2ns



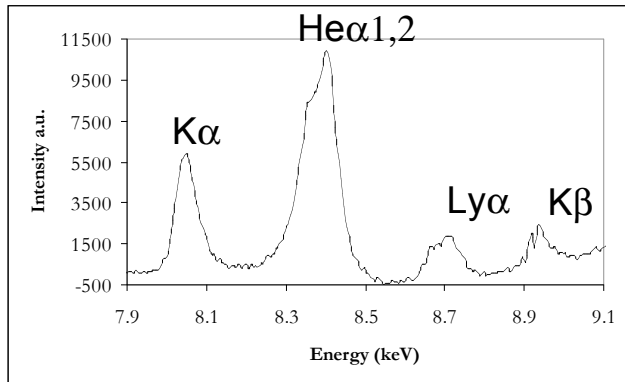
h2d  
5.6ns

## 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**

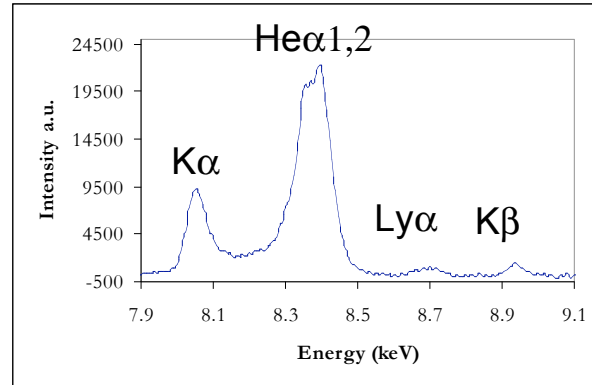
# Target composition affects the electron transport

Al/Cu/Au, 1ps



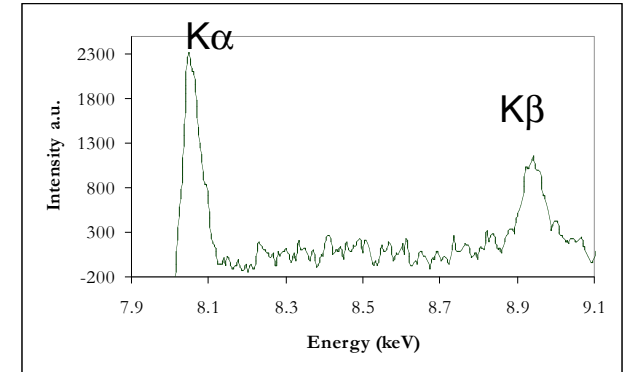
Shot 2, 7<sup>th</sup> September, 152J

Al/Cu/Au 10ps



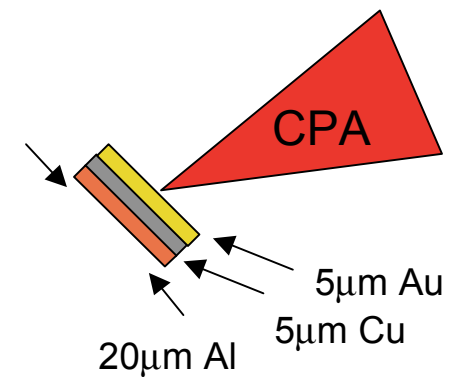
Shot 2, 6<sup>th</sup> Sept, 256J

Al/Cu/CH/Au, 1ps

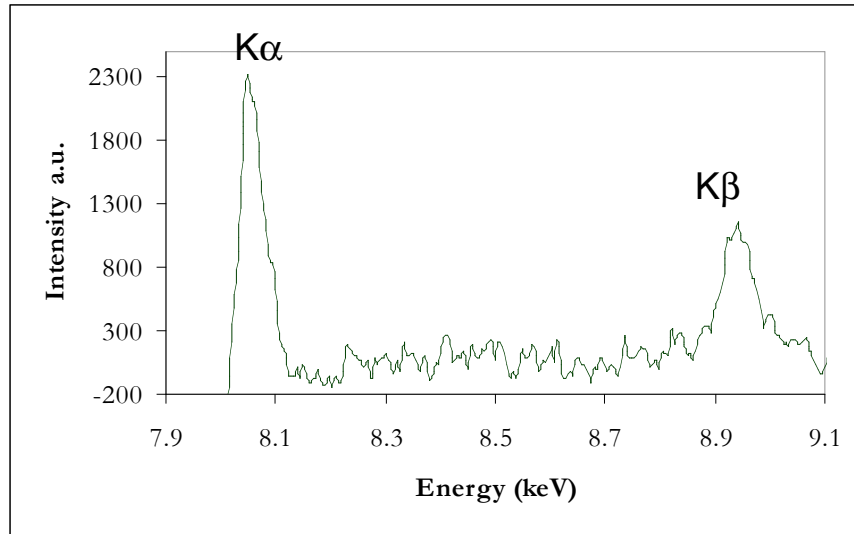


Shot 4, 6<sup>th</sup> September, 140J

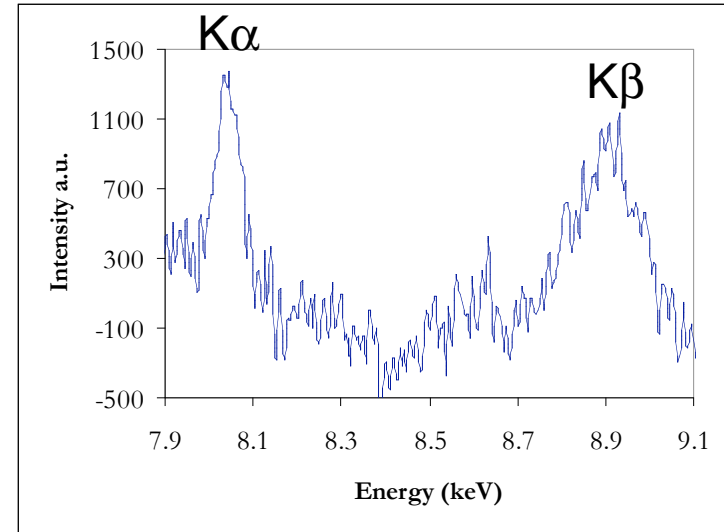
- Presence of  $\text{He}_\alpha$  shows heating of copper for both 1 and 10 ps laser pulses
- $\text{He}_\alpha$  disappears with an addition of CH in the target
- Transport is significantly different in insulator targets
- More accurate information from a single CCD camera



# Fully shocked target shows reduction in Cu $K_{\alpha}$



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

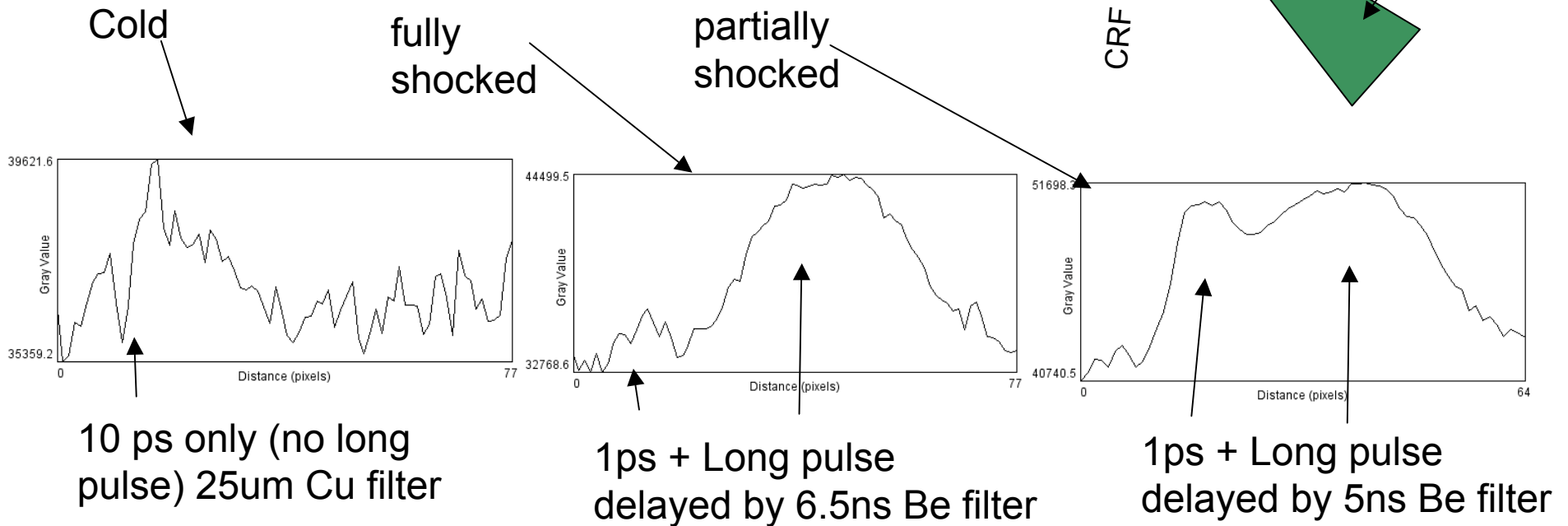
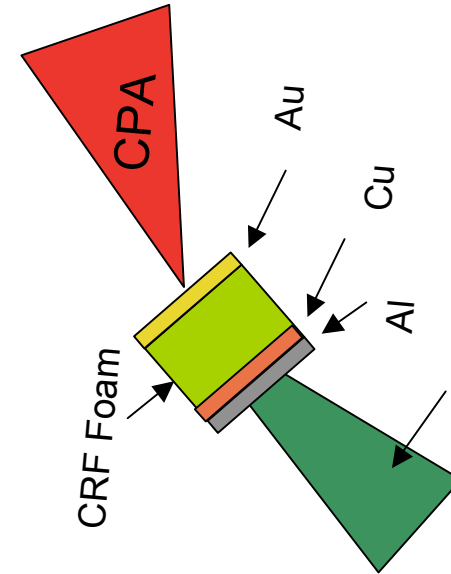


Shot 4, 15<sup>th</sup> September, 142 J, 1 ps  
Fully shocked, Delay : 6.5ns

- Reduction in copper  $K_{\alpha}$  counts with shocked targets
- $He_{\alpha}$  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  $\mu\text{m}$  gold foils
- Shocked targets show reduction in copper  $K_{\alpha}$  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**