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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
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January 9, 2007 through January 11, 2007

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

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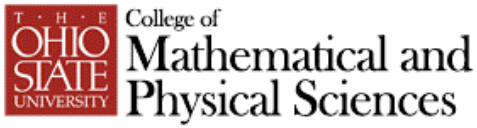

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This work was supported by the US Dept of Energy through various grants from the Office of Fusion Energy Sciences.

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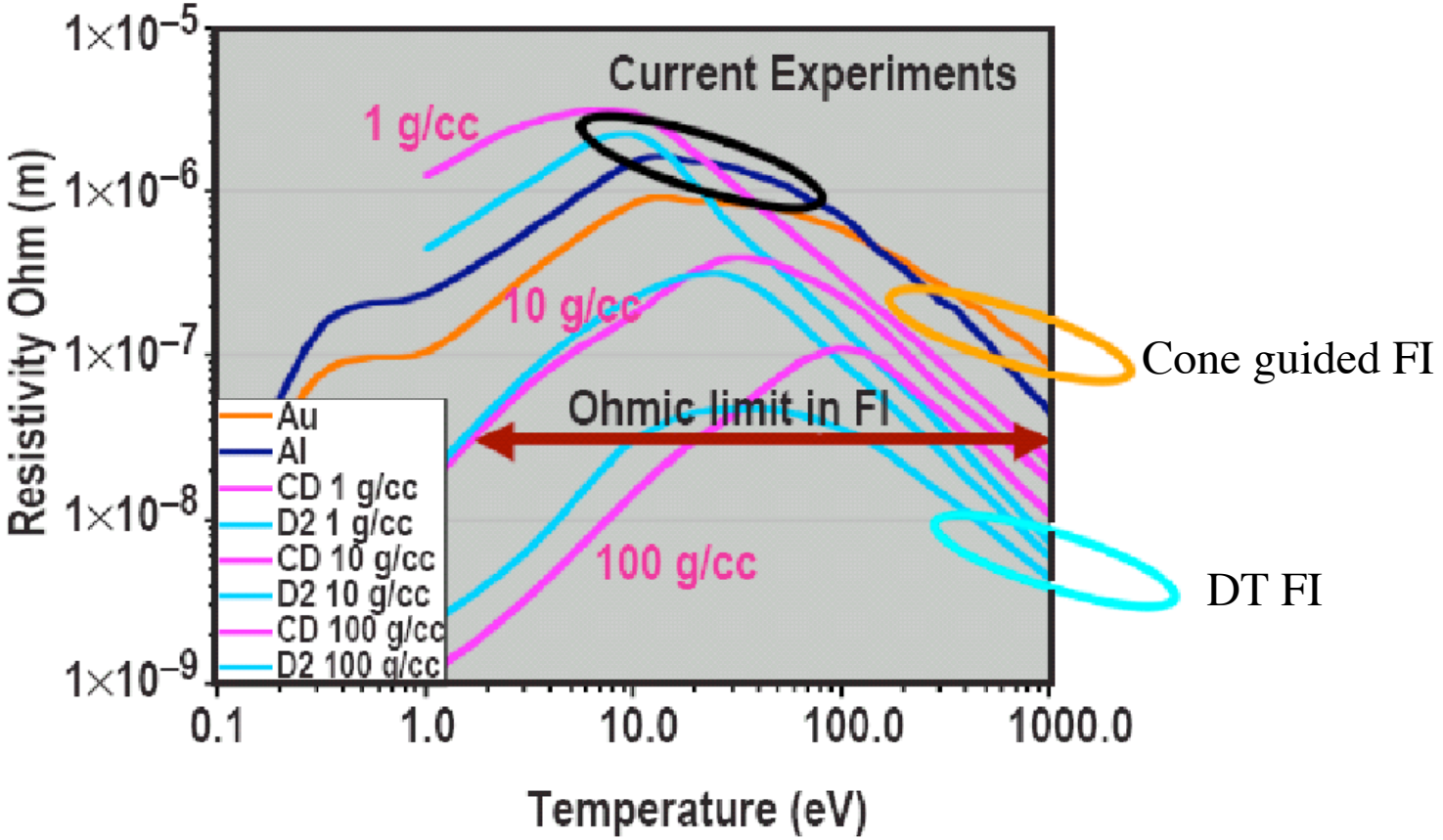
Outline

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

Motivation



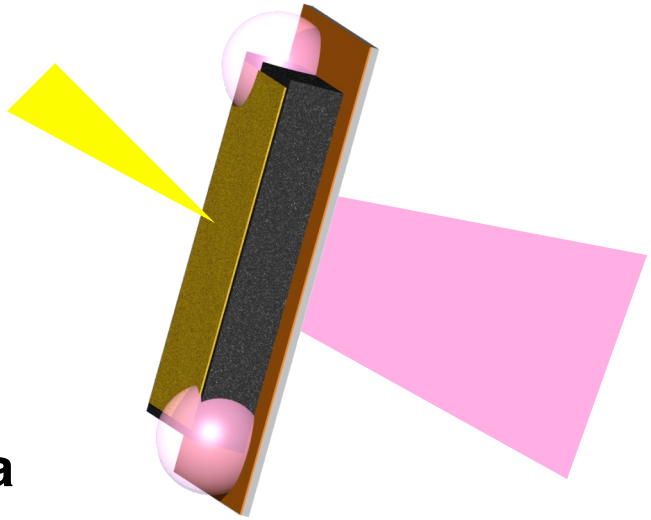
- **Most experiments are performed far from FI conditions**
- **Electron transport in hot targets is different**

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**

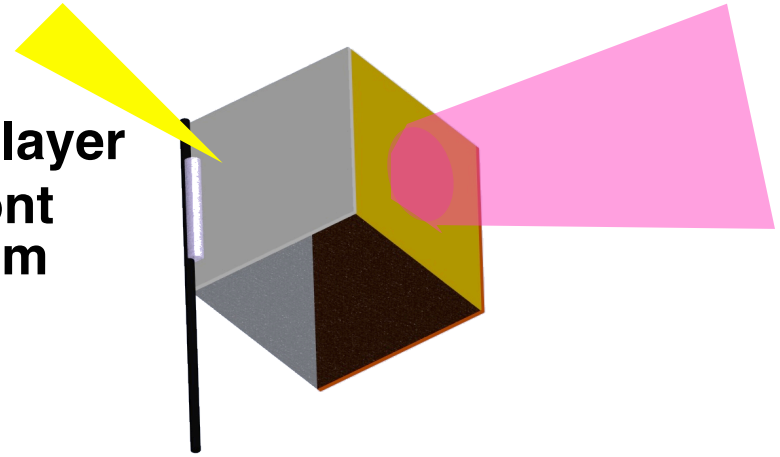
    Measures electron transport into plasma

    Mimics the cone tip shock interaction

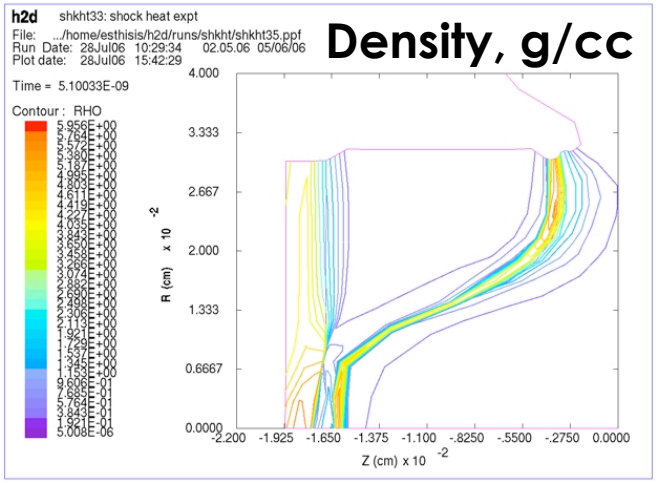


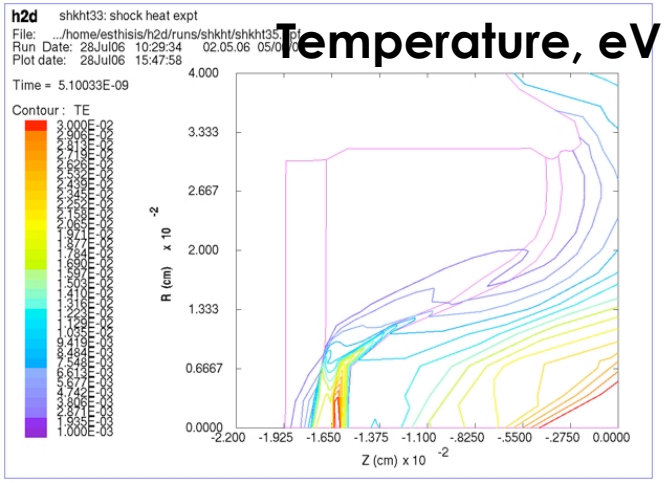
- **Thermal electron heated**
  - **Long pulse well absorbed in thin Au layer**
  - **Long pulse driven thermal e^- heat front supersonically heats low-density foam**

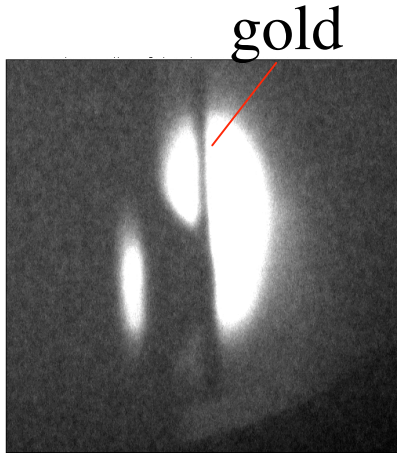
    Measures transport thru plasma



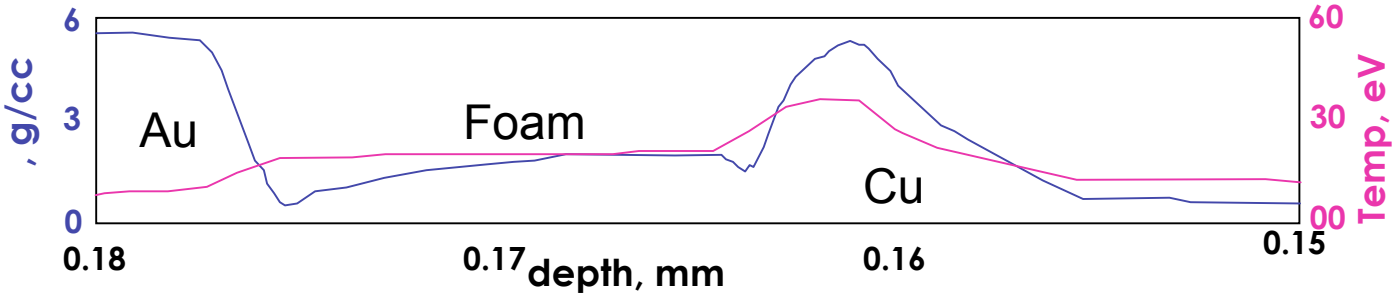
Shock driven experiment shows foam compression to 1 g/cc

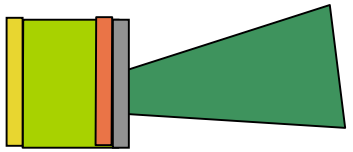






Radiograph

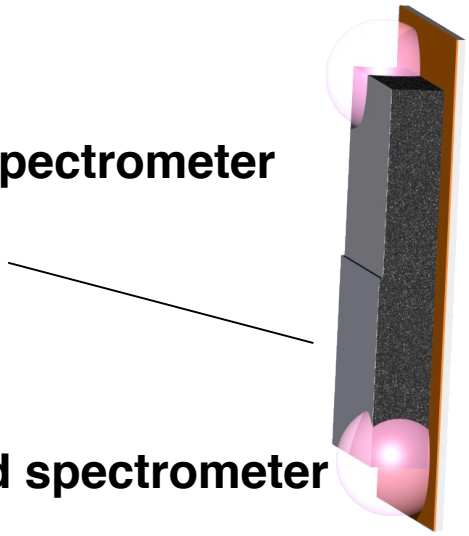




- Long pulse accelerates Al/Cu flyer plate
- Compresses foam to ~1 g/cc
- Shock wave penetrates Au foil on opposite side
- Electrons generated in Au cross the Au/interface and are counted in Cu

Various types of targets were used to understand transport

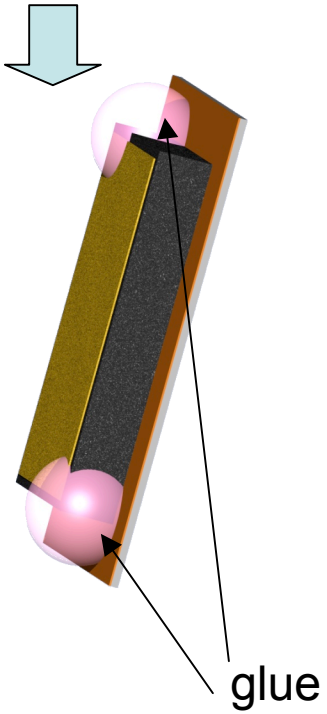
- **Au/Cu/Al - measure electron generation in Au**
  - **short pulse laser, Cu-K imager, single hit CCD and spectrometer**
- **Au/CRF/Cu/Al - measure losses in hot foam**
  - **Long pulse, check timing w backlight**
  - **Long & short pulse, Cu-K imager, single hit CCD and spectrometer**
- **Au/CH/Cu/Al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

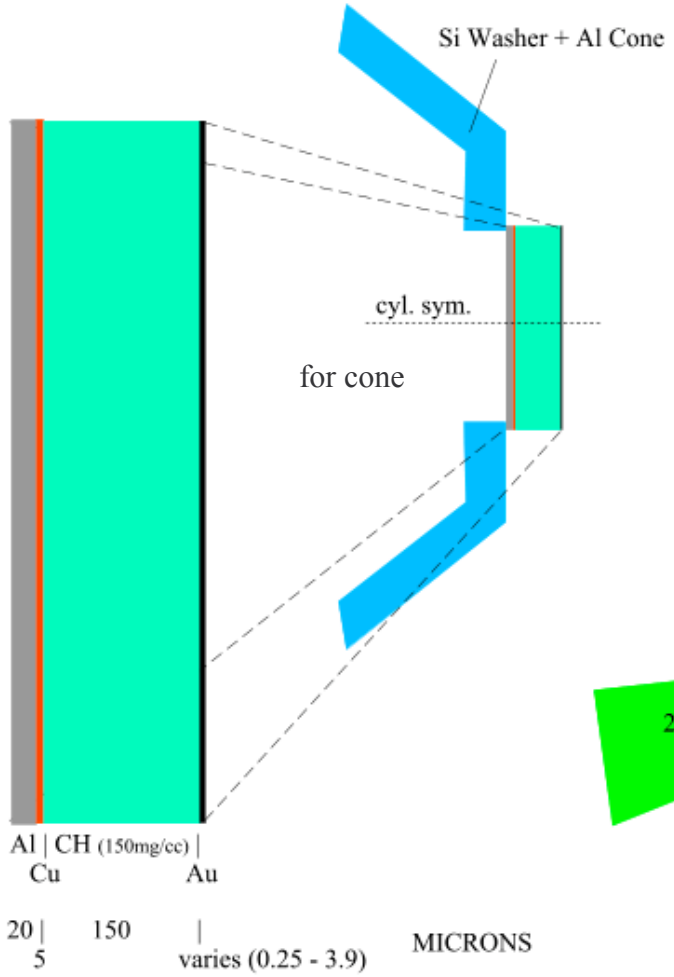


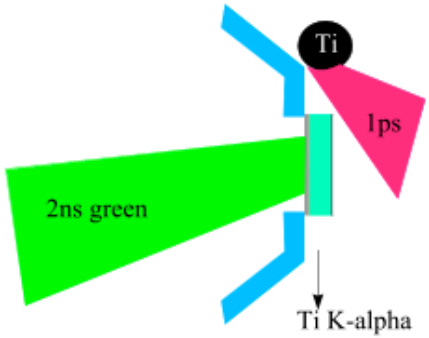
Aim was to produce large enough plasma to diagnose

Target Schematic

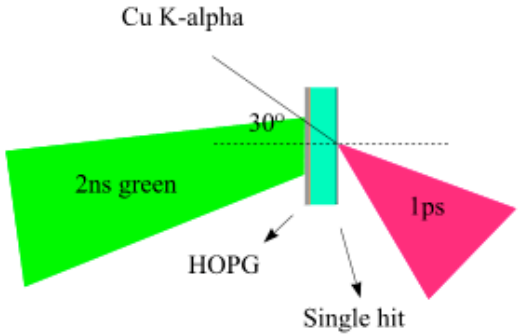
Real target
Is actually
rectangular







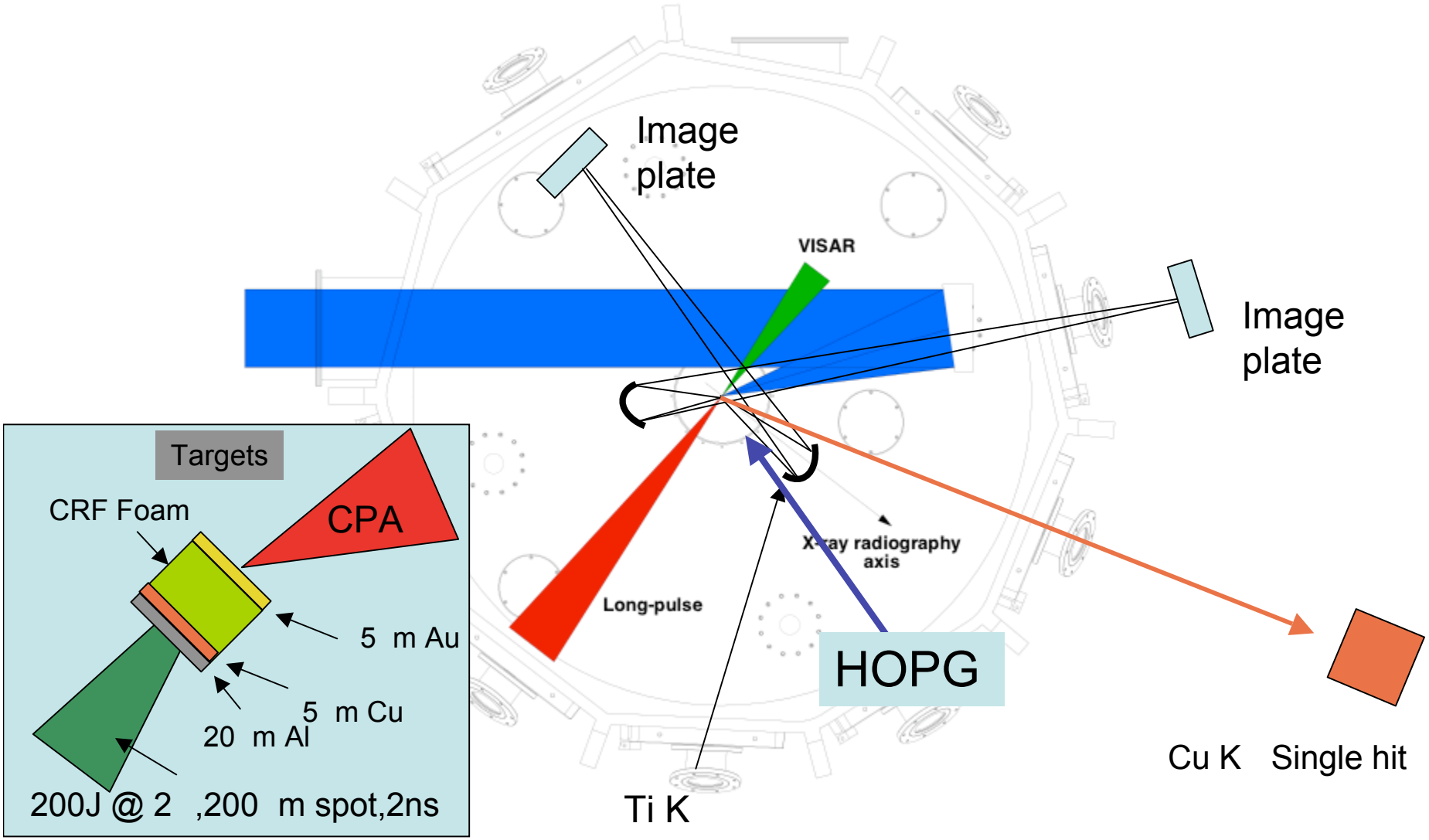
Side-on Ti k-α radiography



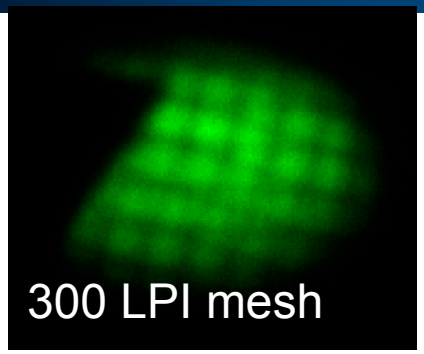
Long pulse / Short pulse WDM

- **A variety of diagnostics was used**

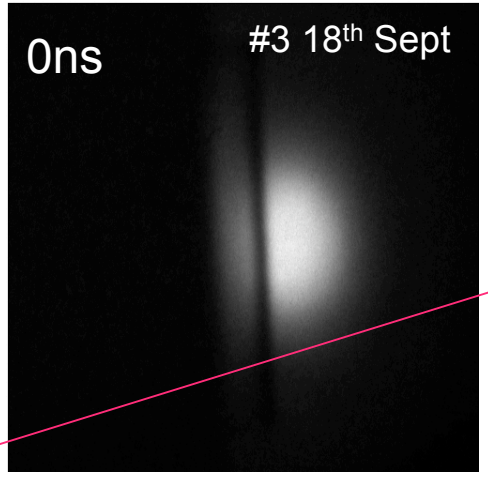
Diagnostics

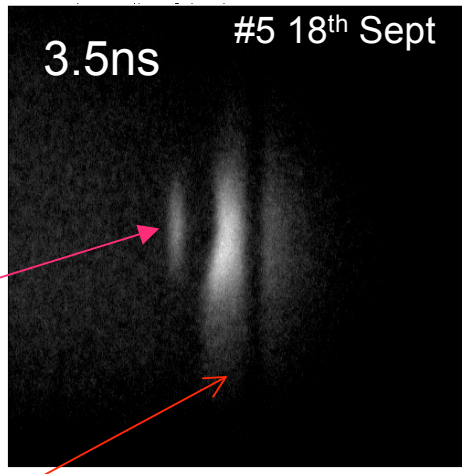


X-ray backlit images show shocked compression of foam



Resolution 24 microns

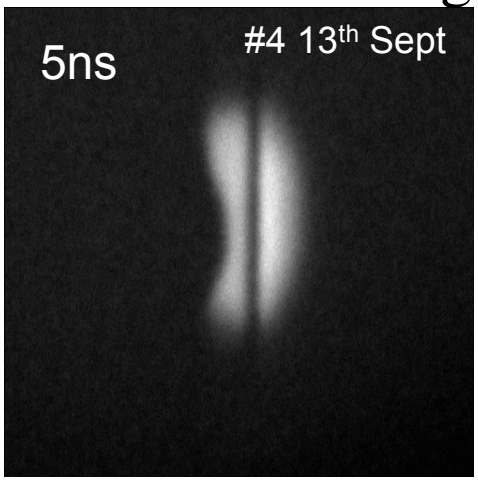




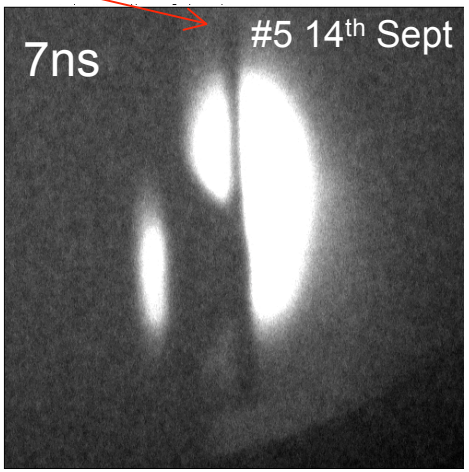
Shock 55 μm into foam

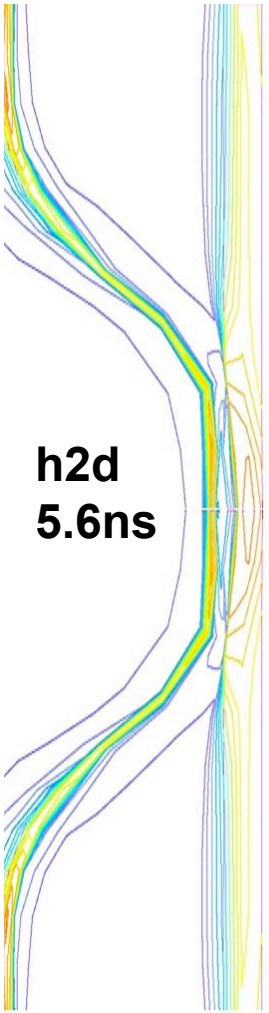
Bremsstrahlung from long pulse interaction.

gold



Shock 90 μm into foam





h2d 5.6ns

200J @ 2 ,200 m spot,2ns

- Radiographs show shocked compressed foam between copper and gold surface
- Good agreement with 2D rad-hydro simulations

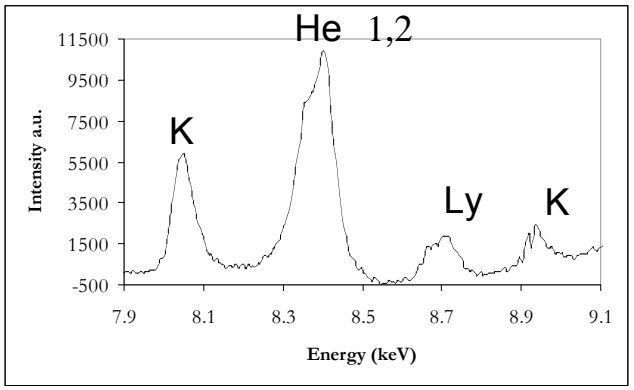
Shock heated targets

- **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**

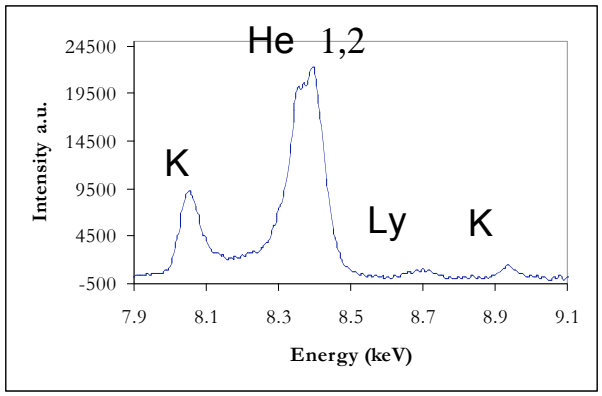
Target composition affects the electron transport

Al/Cu/Au, 1ps



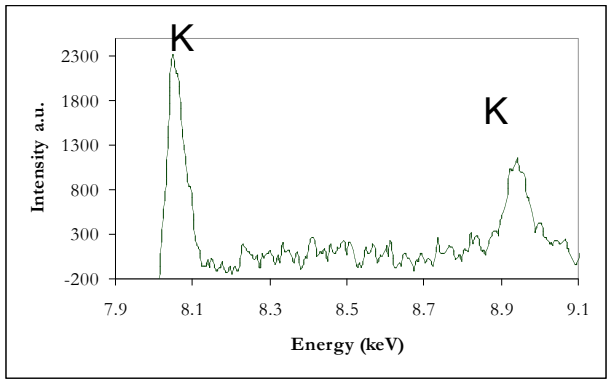
Shot 2, 7th September, 152J

Al/Cu/Au 10ps



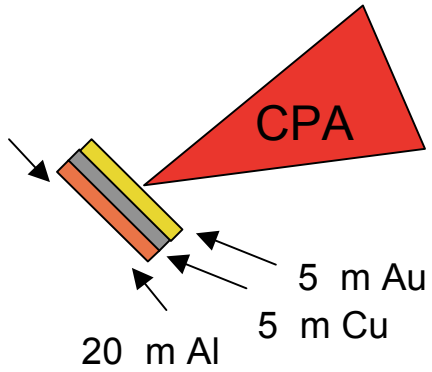
Shot 2, 6th Sept, 256J

Al/Cu/CH/Au, 1ps

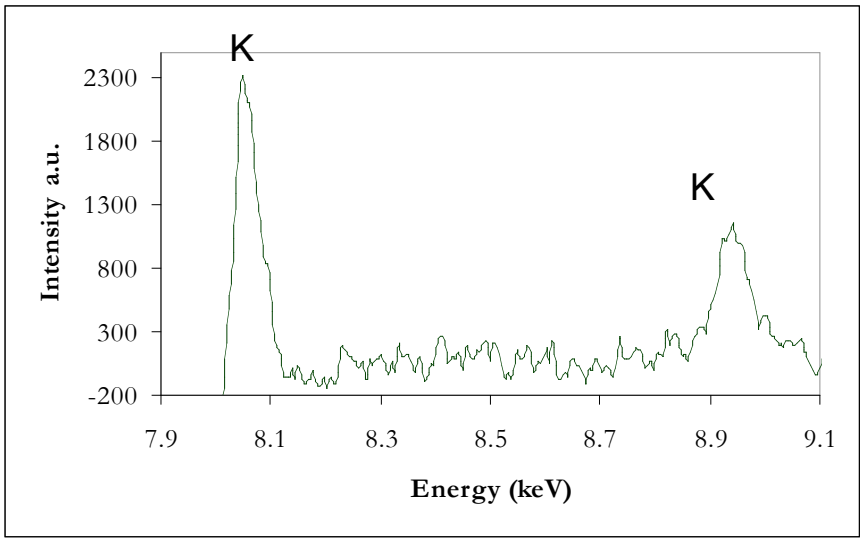


Shot 4, 6th September, 140J

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

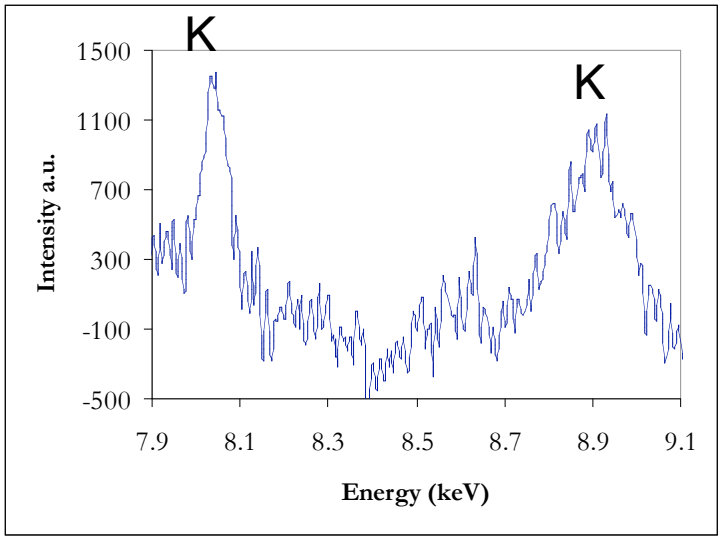


Fully shocked target shows reduction in Cu K_{alpha}



Shot 4, 6th September, 140J

Al/Cu/CH/Au, 1ps

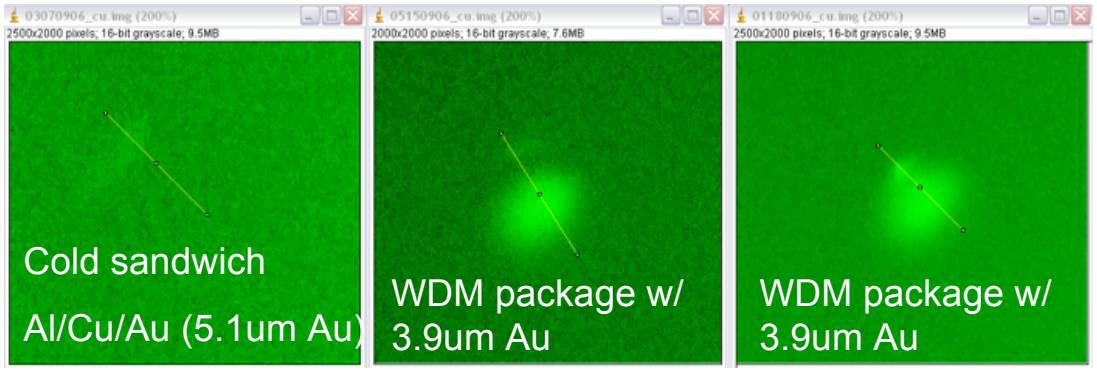


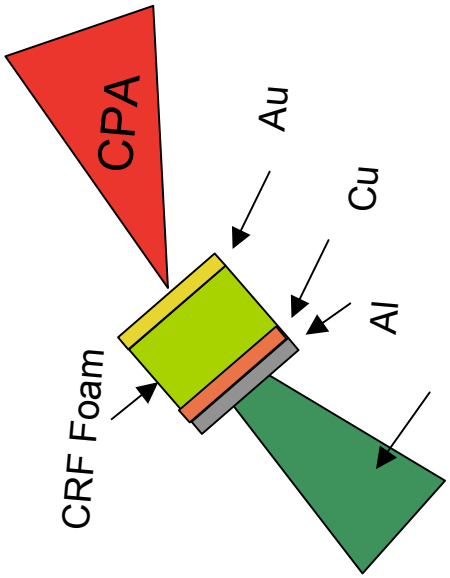
Shot 4, 15th September, 142 J, 1 ps

Fully shocked, Delay : 6.5ns

- **Reduction in copper K_{alpha} counts with shocked targets**
- **He 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

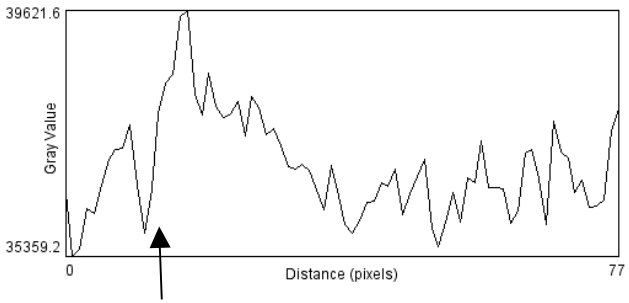




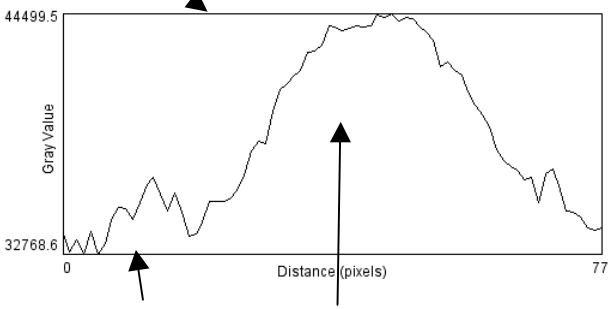
Cold

fully shocked

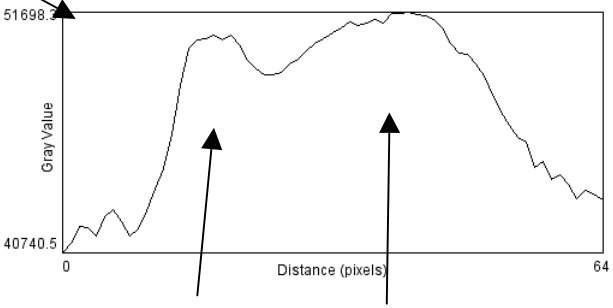
partially shocked



10 ps only (no long pulse) 25um Cu filter



1ps + Long pulse delayed by 6.5ns Be filter



1ps + Long pulse delayed by 5ns Be filter

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_{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