Creation and Characterization of Warm Dense Plasmas for Transport Study of Fast Electrons

Toshinori Yabuuchi
Center for Energy Research
University of California, San Diego

This work was performed in part at the LLE NLUF, and supported by US DOE under contracts DE-FC02-04ER54789 (Fusion Science Center) and DE-FG02-05ER54834 (ACE).

2nd OMEGA Laser Facility Users Group Workshop
April 28-30, 2010 @ LLE, Rochester, NY

Collaborators

H. Sawada, M. S. Wei, F. N. Beg
University of California, San Diego

R. B. Stephens
Genetal Atomics

S. P. Regan, K. Anderson, R. Betti
Laboratory for Laser Energetics, University of Rochester

Summary

- To establish a platform for the study of fast electron transport in a warm dense plasma, plasma created in a package target is monitored using the x-ray line absorption spectroscopy.

- Aluminum doped foam package targets (200 mg/cm^3, Al atomic density of ~3-5x10^{20} /cm^3) were developed for the absorption spectroscopy.

- Cold Al K-edge was observed in both Al-doped foam and solid Al targets.

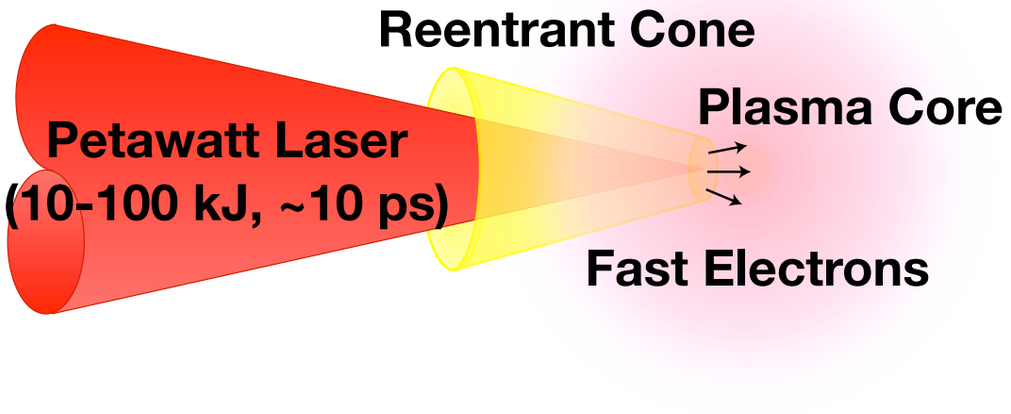
- X-ray absorption lines were recorded with a laser driven foam package.

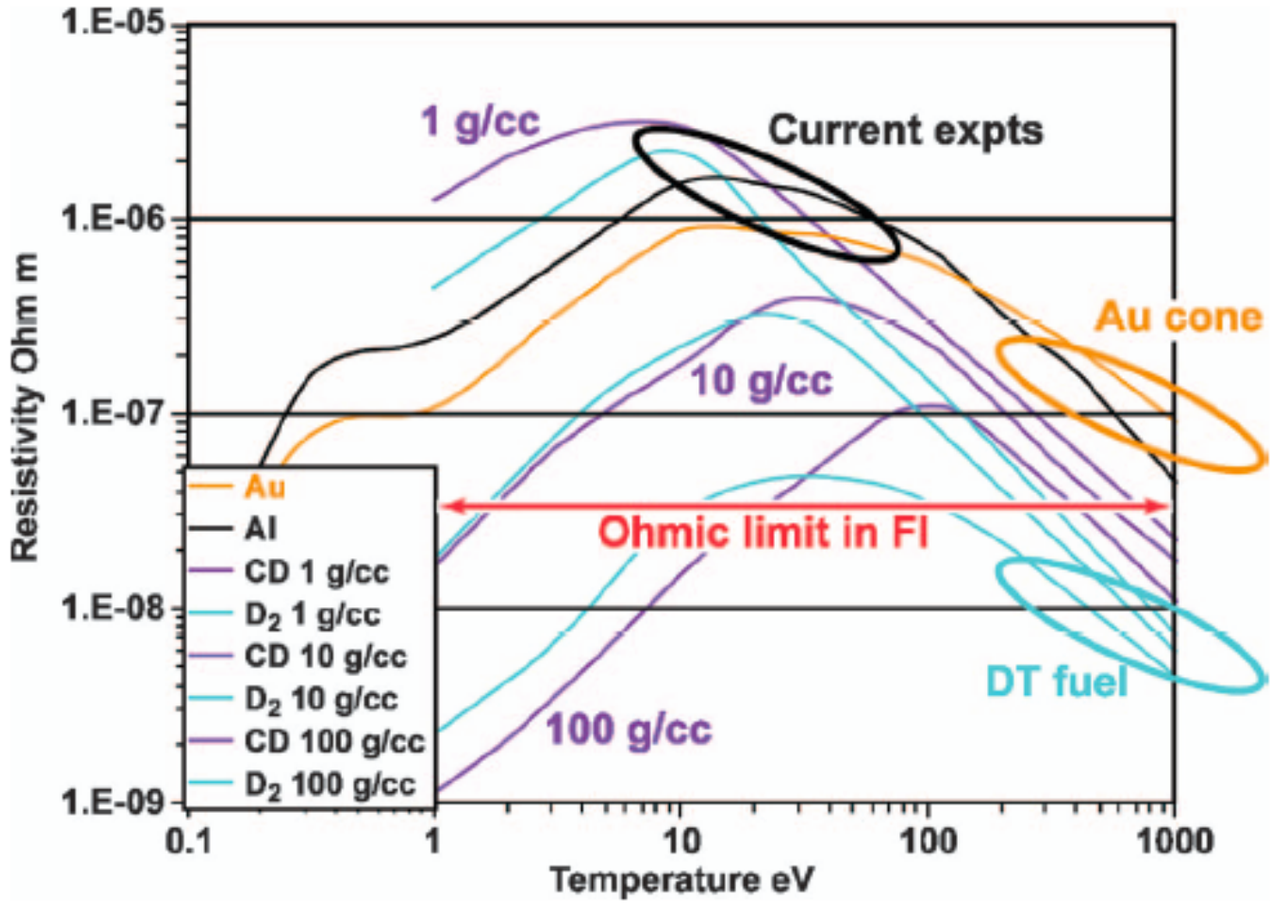
- T_e and n_e of the shocked foam targets will be inferred from the measured absorption spectra by comparing with atomic physics code.

- Fast electron transport in the characterized plasma will be studied with OMEGA EP short pulse beam in FY10.

Fast electron transport needs to be studied in warm dense plasma for fast igniton (FI).

FI with Reentrant Cone



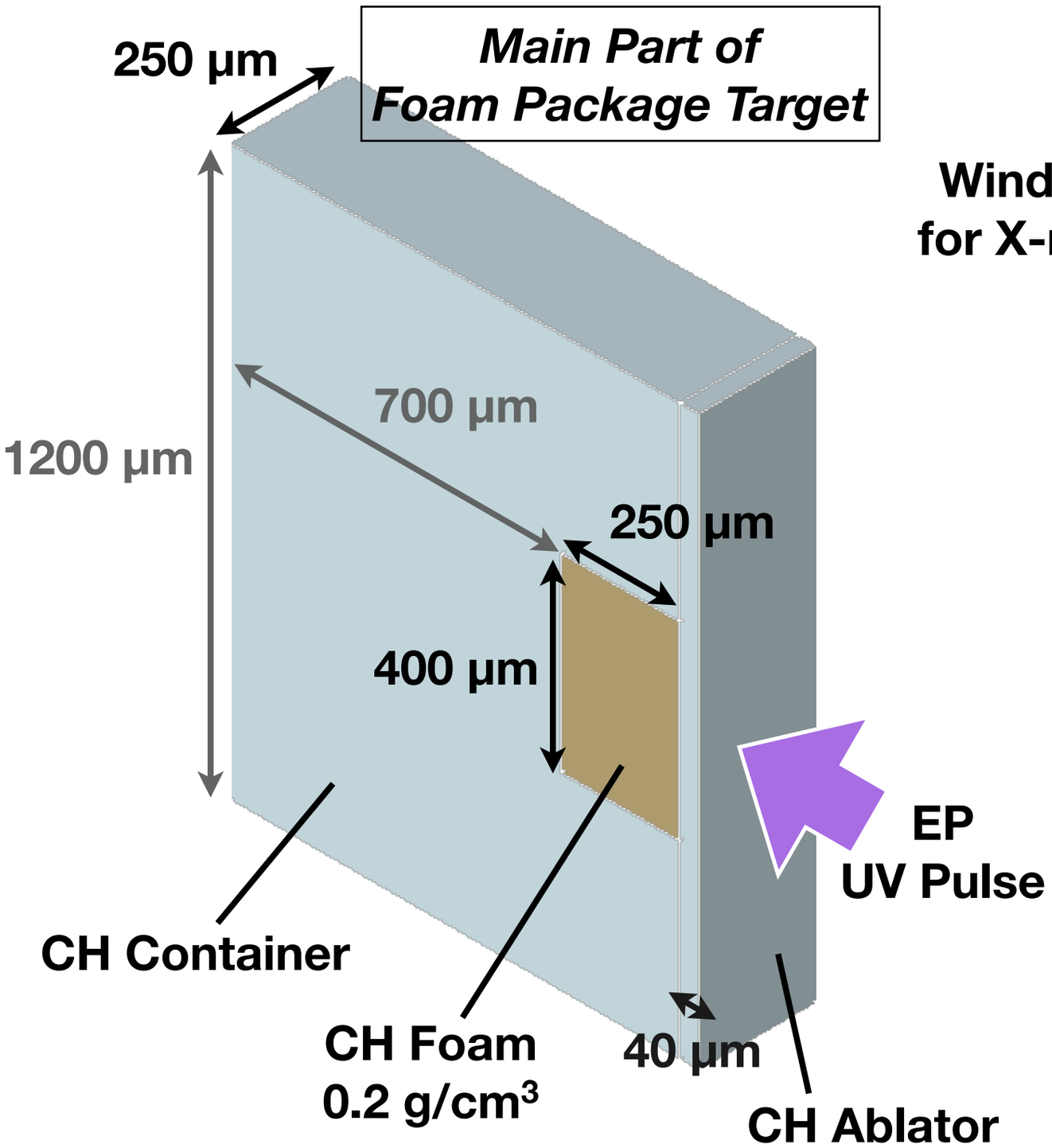


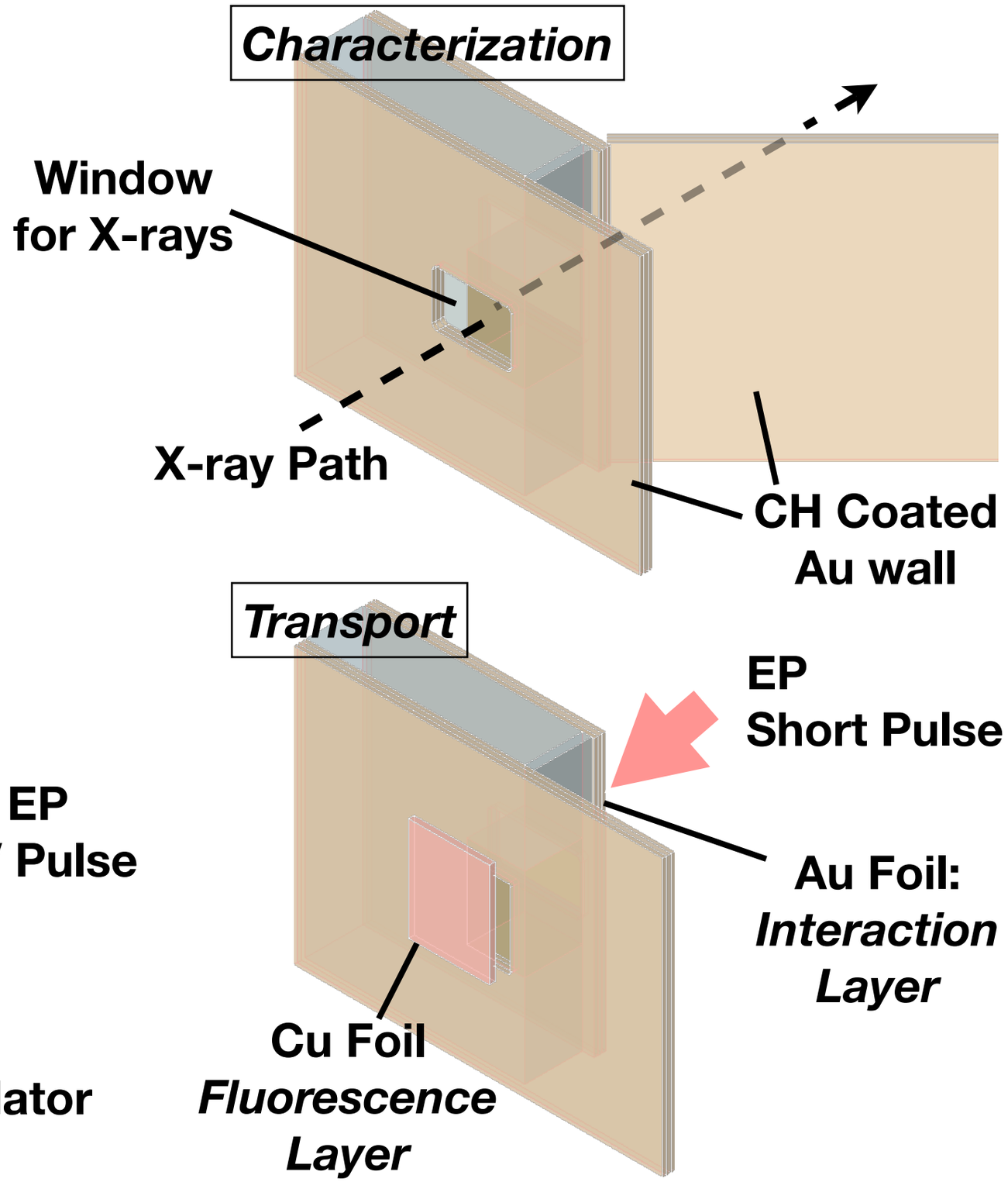
- In cone-guided FI scheme, fast electrons travel in plasma with temperature of few 100's eV - keV.
- The resistivity in hot plasma can be significantly different from the cold (room temperature), solid density target.
- Different resistivity could change the fast electron transport in the media.

Ref: M. H. Key et al., Phys. Plasmas, 14, 055502 (2007).

Foam plasma is created in container to maximize its temperature and density.

UCSD

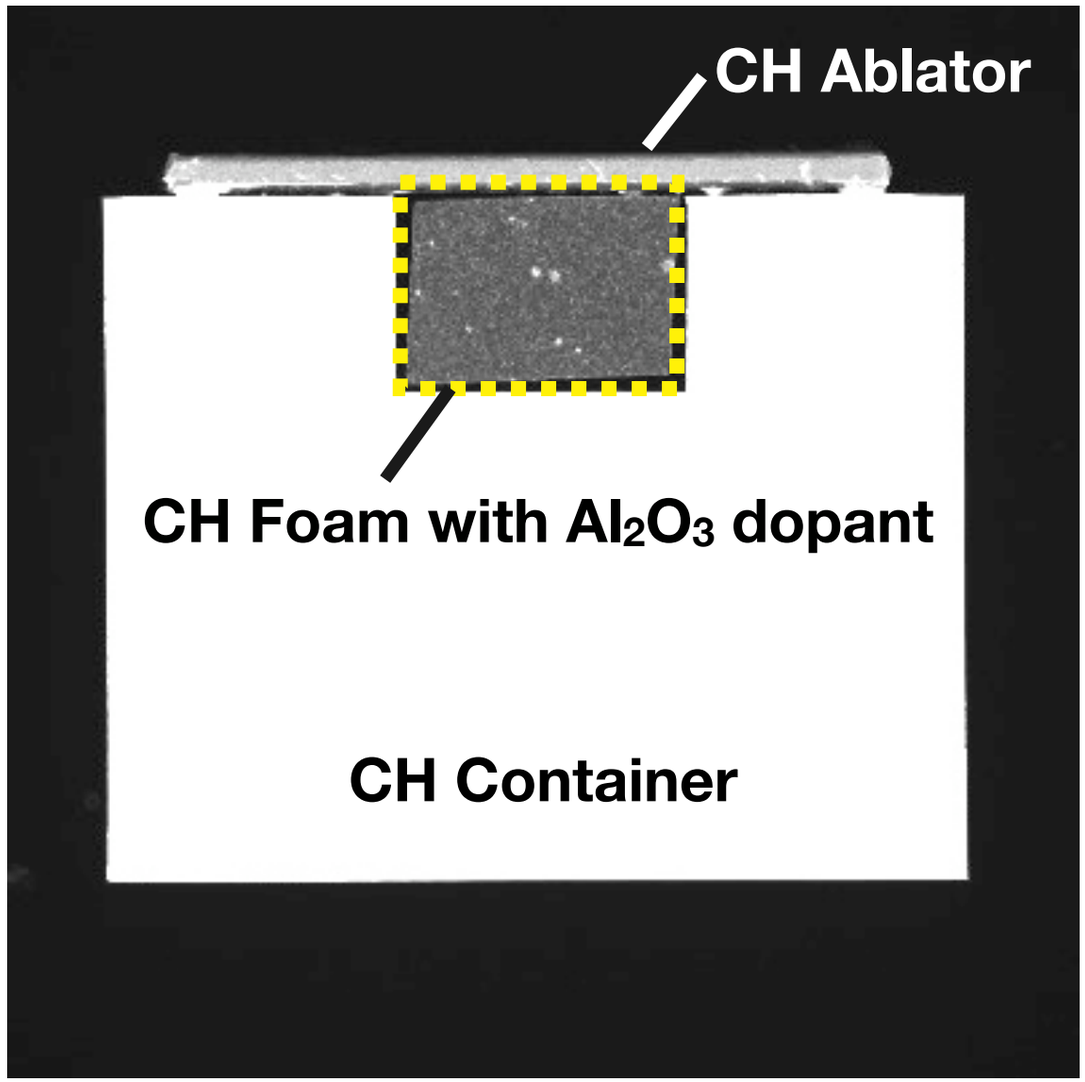




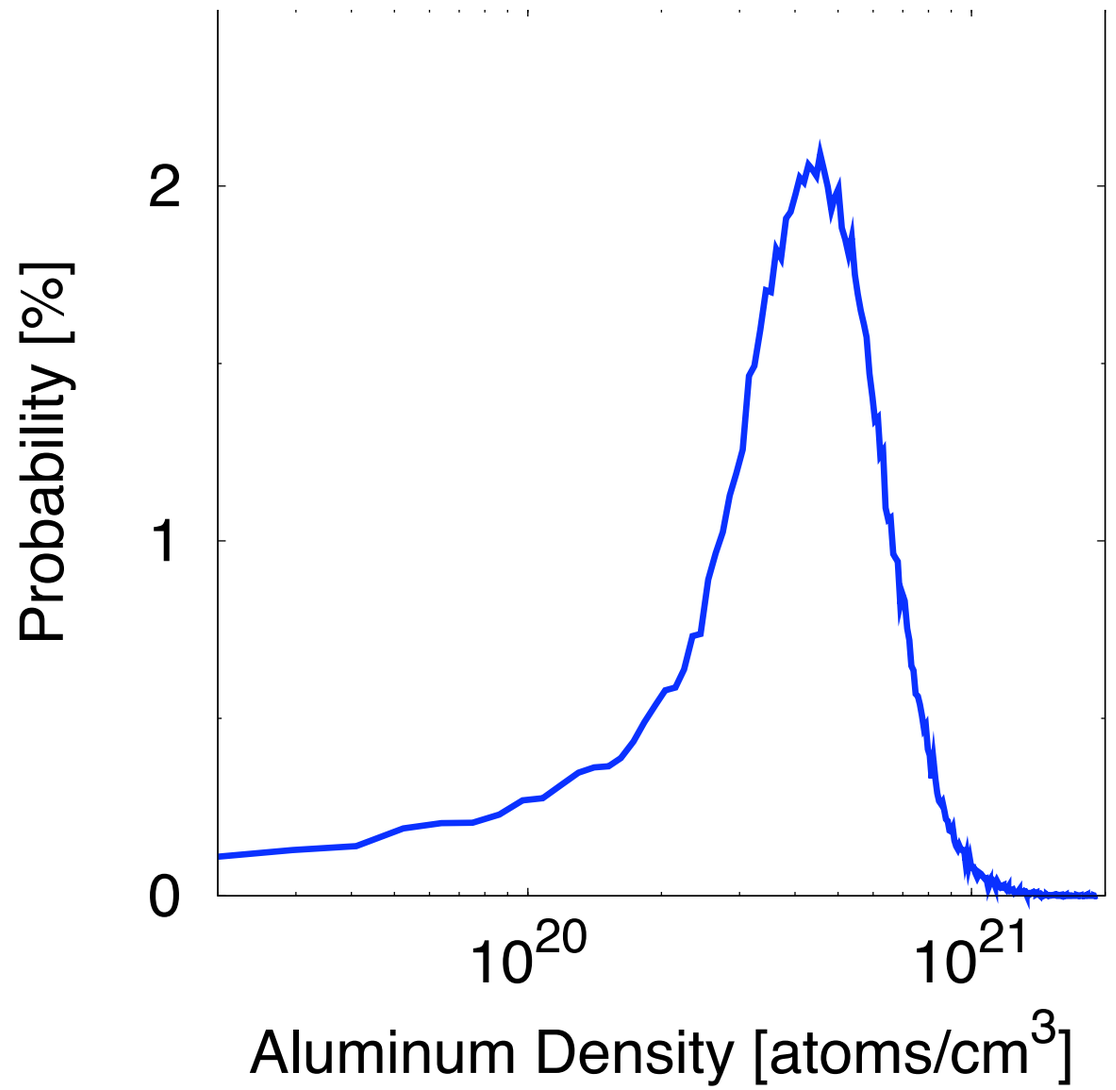
Aluminum was uniformly doped in CH foam for x-ray line absorption spectroscopy.

UCSD

Target Radiograph



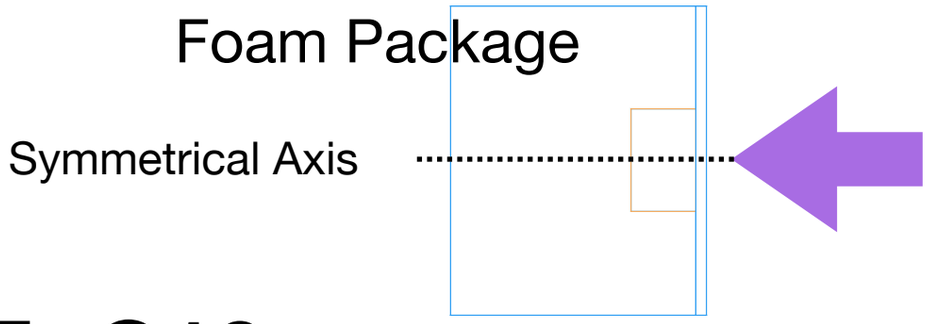
Al Density Probability in Foam



Average Density: 5.0x10^{20} /cm^3
250 μm thick foam
= 2.1 μm solid Al

Data is provided by J. Hund, GA

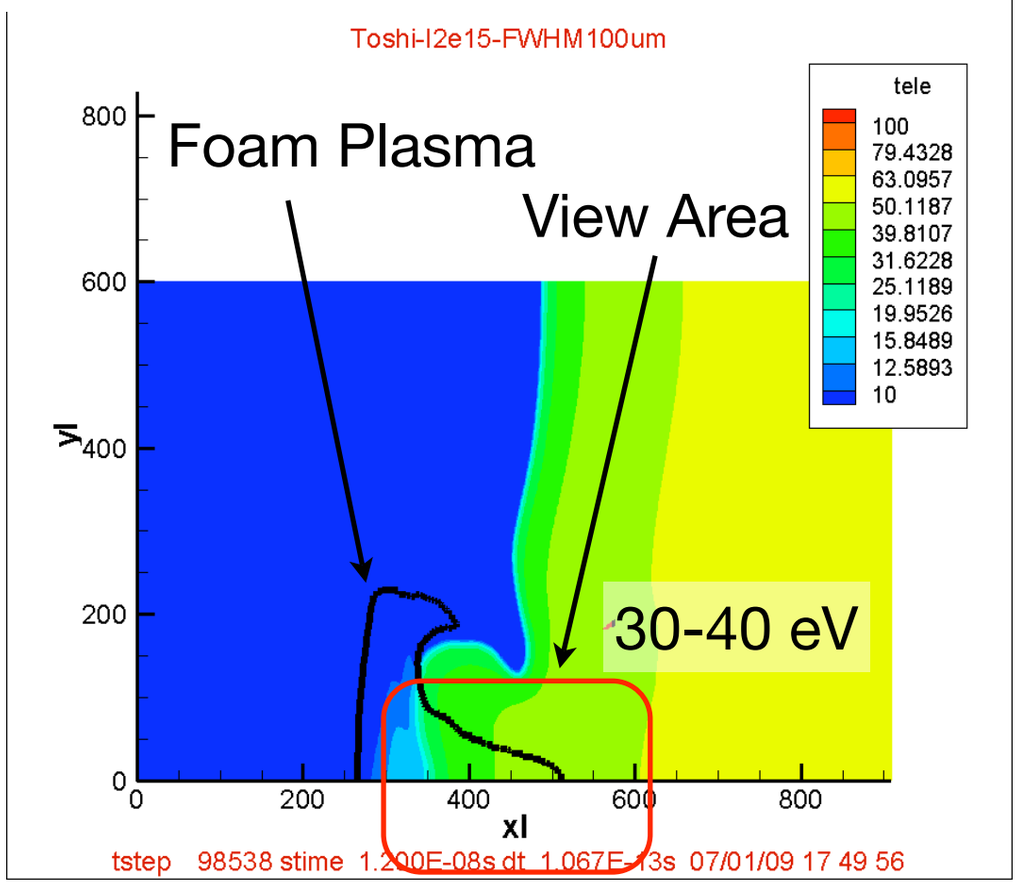
2-D hydrodynamics code DRACO shows T_e~40 eV, n_e~10^{22}/cc plasma can be created.



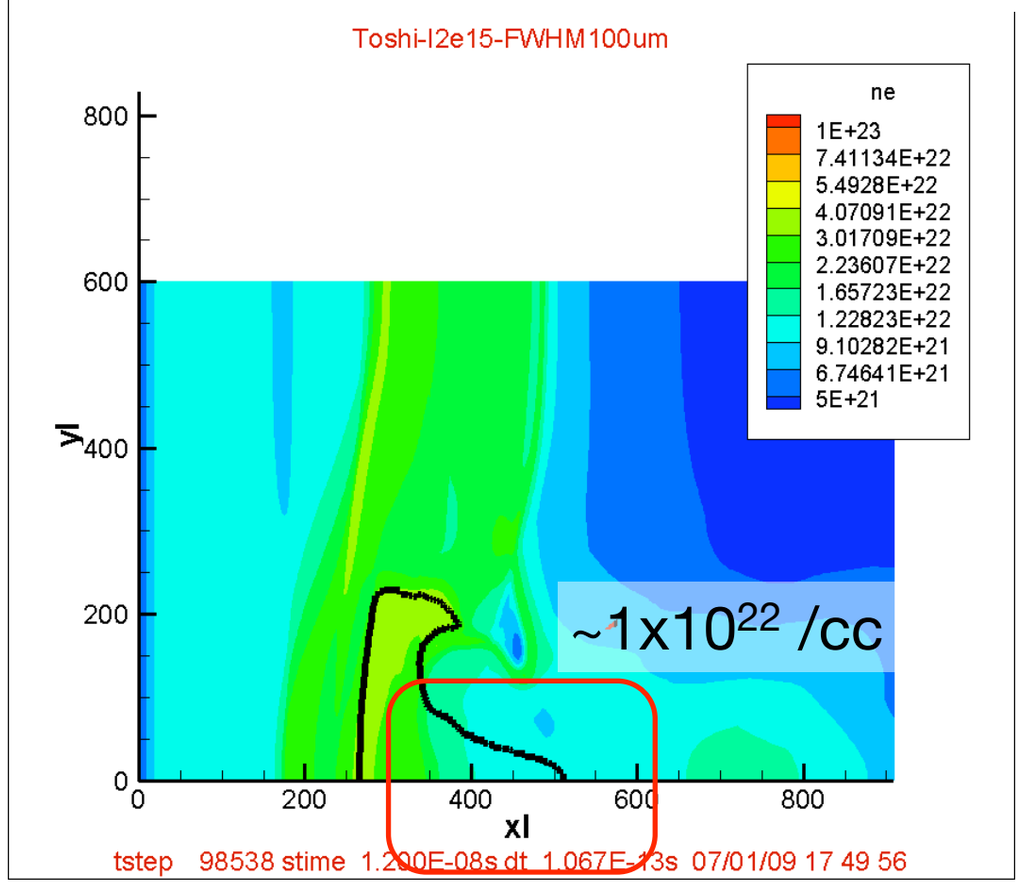
UV Pulse
I=2x10^{15} W/cm^2
3.5 ns
100 μm diam.
(with actual inc. angle)

The mass density of foam plasma is ~60 mg/cc.

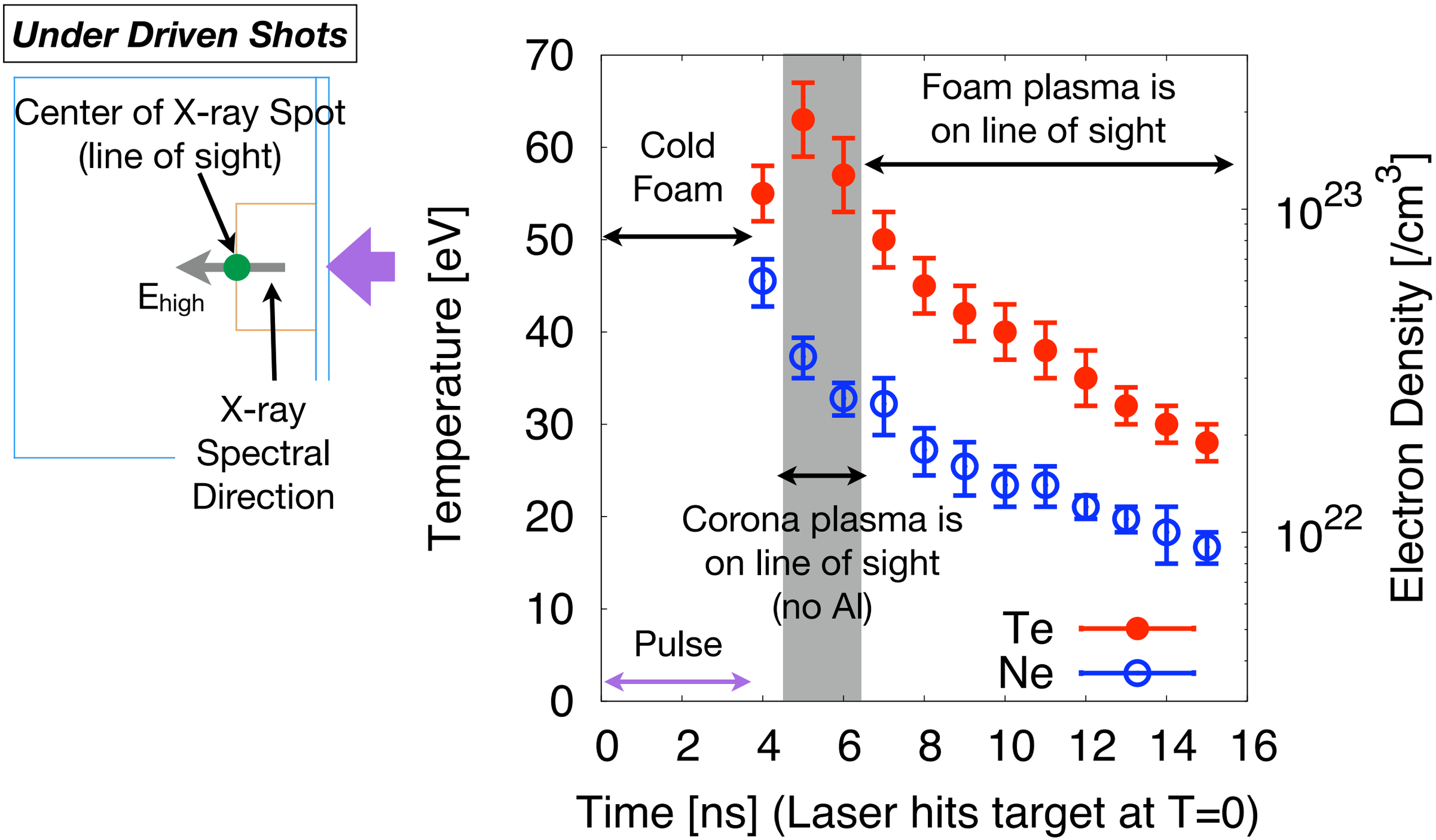
T_e @12 ns



n_e @12 ns



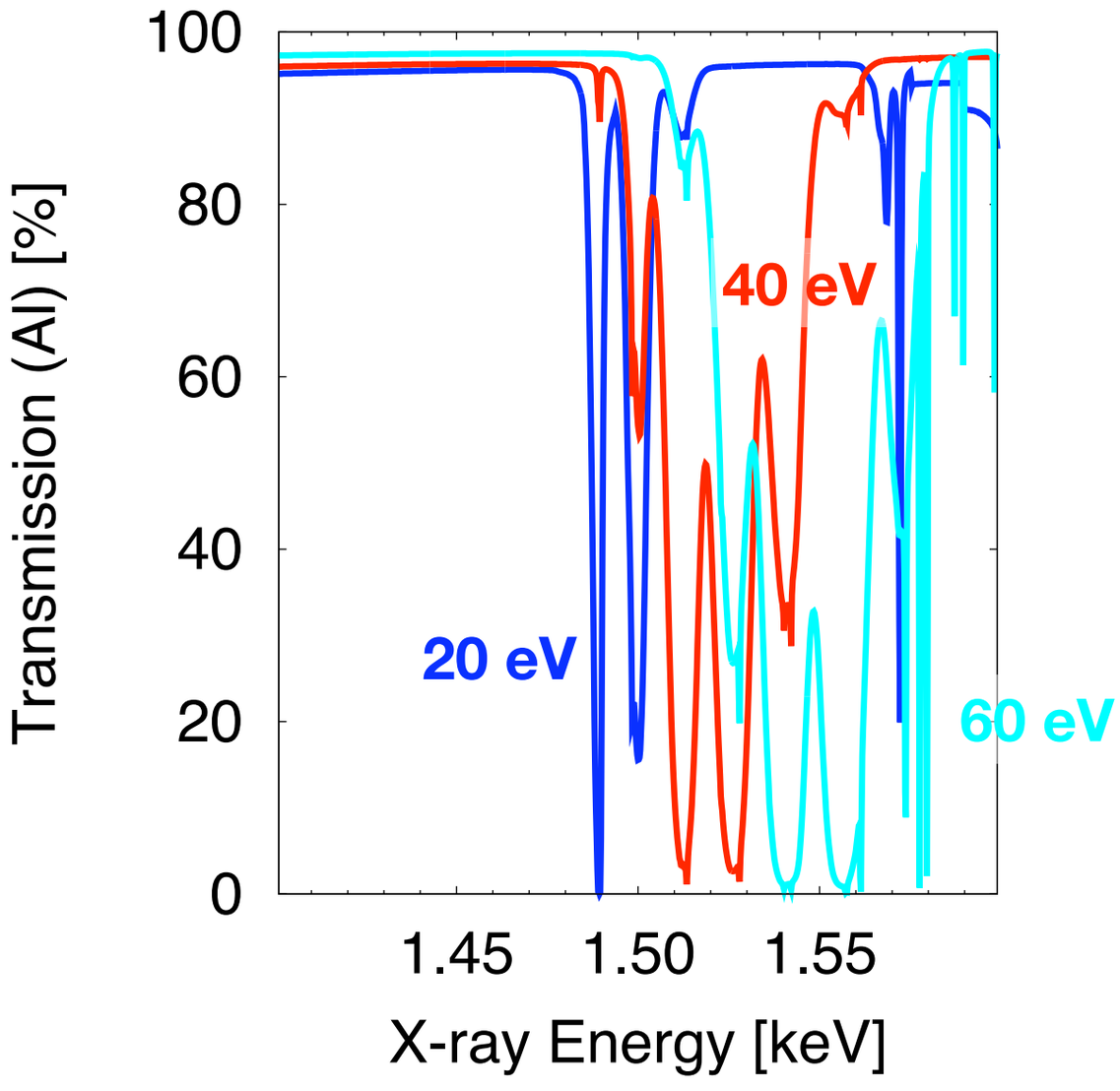
DRACO simulation predicts the plasma exist in the x-ray probe region after 4 ns.



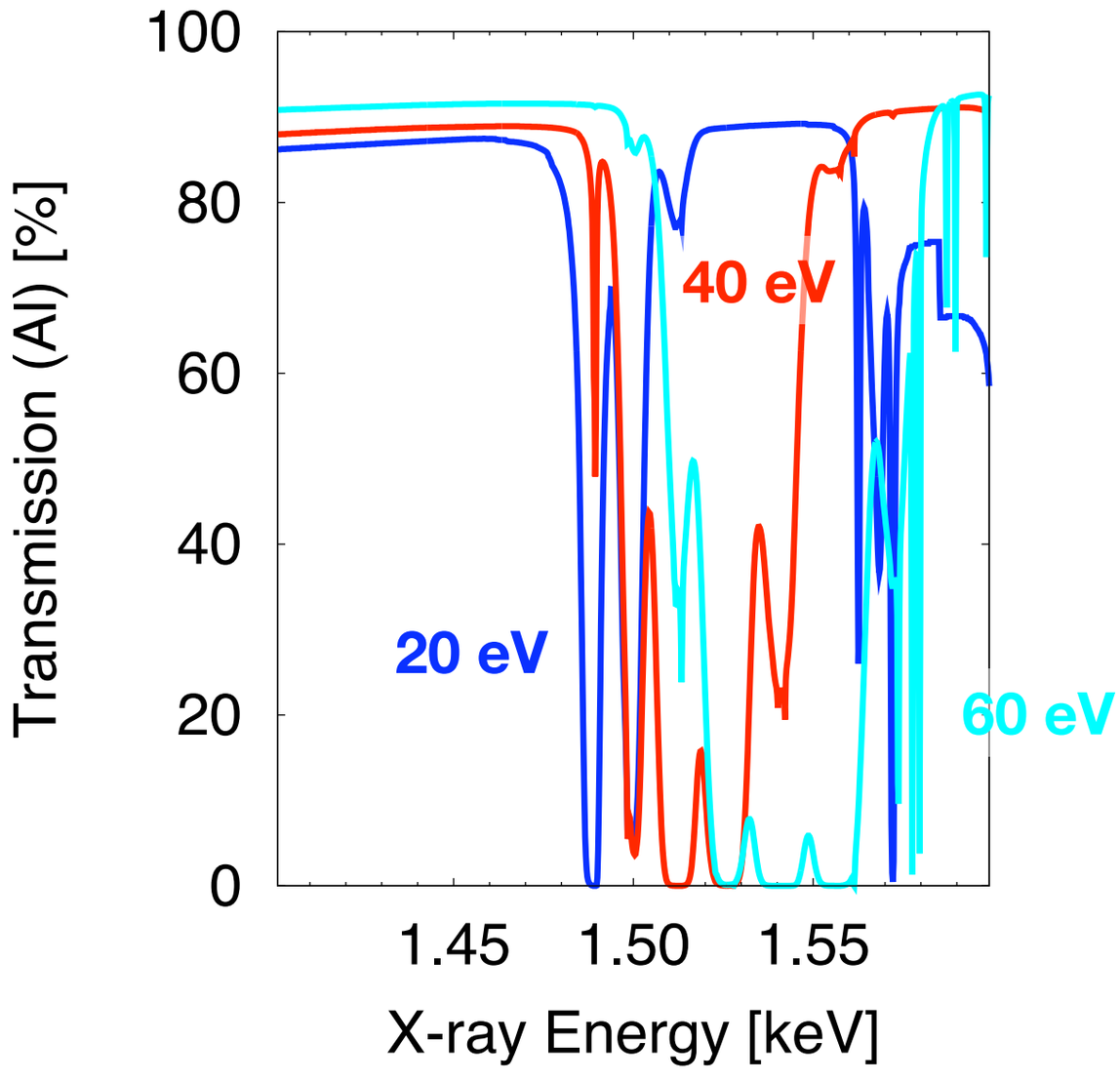
Absorption spectra of x-ray are sensitive to the plasma temperature.

UCSD

Al 1x10^{20} atoms/cm^3 in 50 mg/cm^3 CH Plasma



Al 3x10^{20} atoms/cm^3 in 100 mg/cm^3 CH Plasma



Initial Condition: ~5x10^{20} Al atoms/cc in 200 mg/cm^3 CH Foam

FLYCHK was used to estimate line absorption spectra.

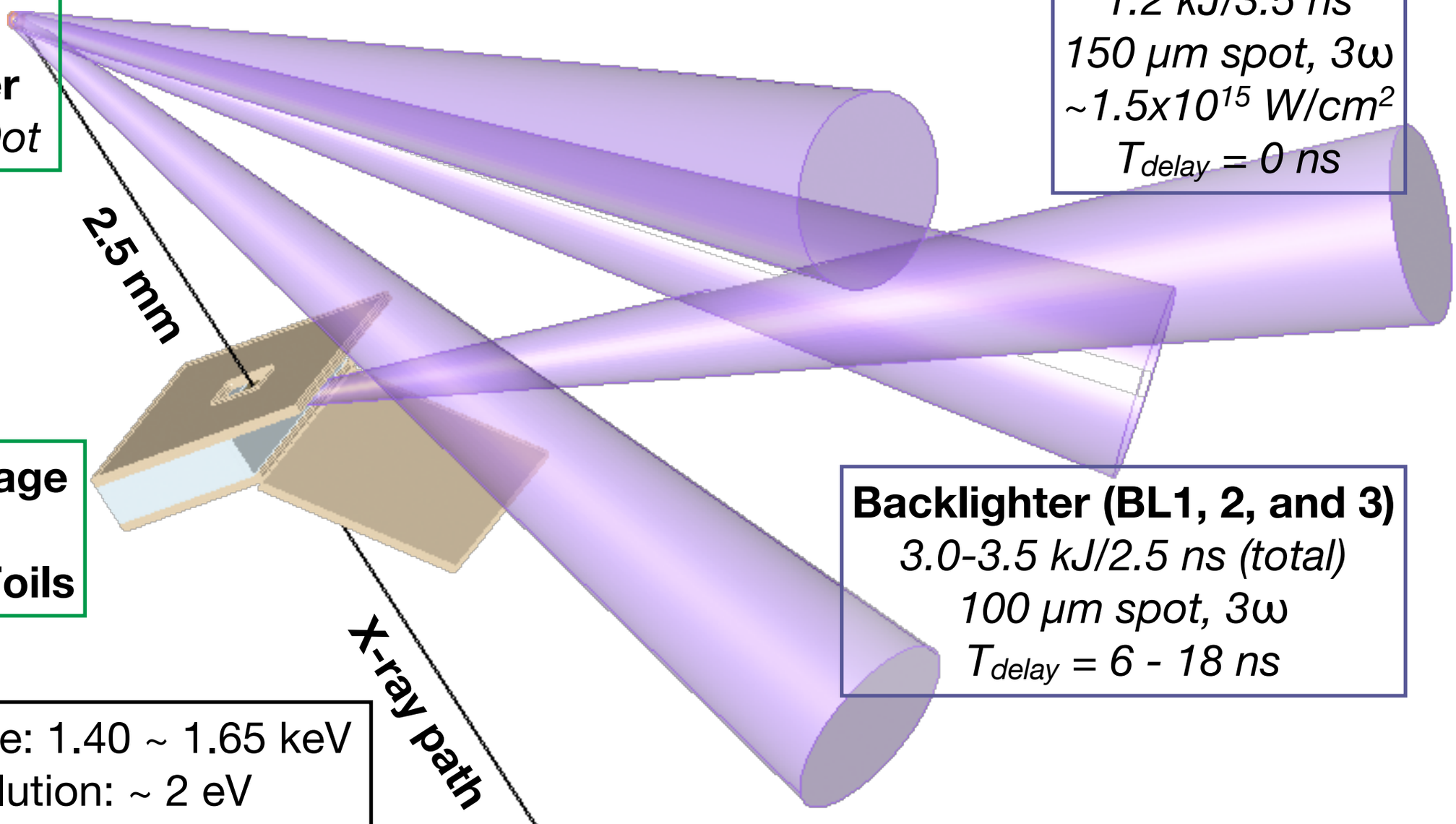
X-ray spectra though targets were measured with streaked spectrometer.

UCSD

OMEGA EP

X-ray Backlighter
80 μm Sm Dot

Driver (BL4)
1.2 kJ/3.5 ns
150 μm spot, 3ω
~1.5x10^{15} W/cm^2
T_{delay} = 0 ns



Foam Package or Reference Foils

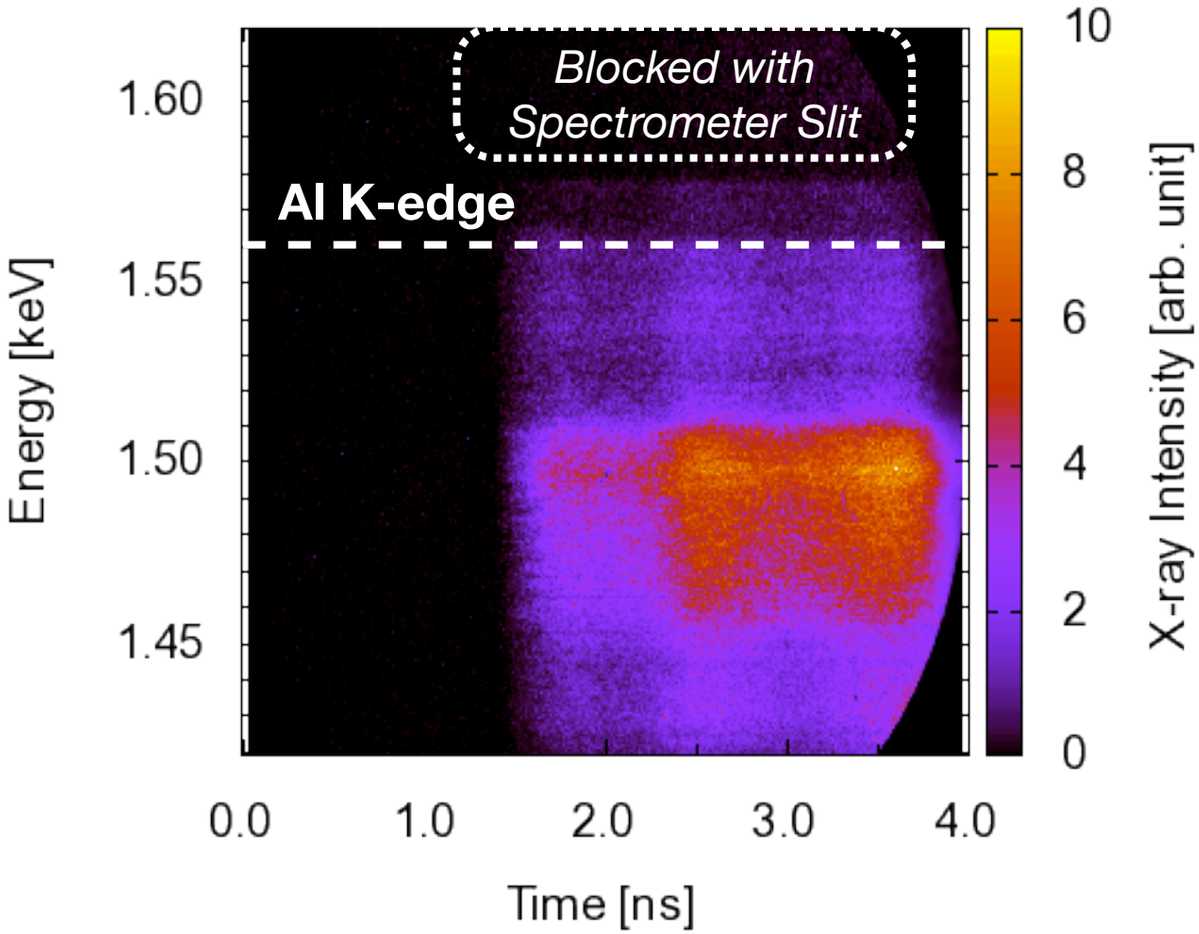
Backlighter (BL1, 2, and 3)
3.0-3.5 kJ/2.5 ns (total)
100 μm spot, 3ω
T_{delay} = 6 - 18 ns

Energy Range: 1.40 ~ 1.65 keV
Energy Resolution: ~ 2 eV
Time Window: 4 ns
Temporal Resolution: ~ 60 ps

SSCA Streaked Spectrometer (TIM13)

Al cold K-edge was observed in both undriven Al-doped foam and solid Al targets.

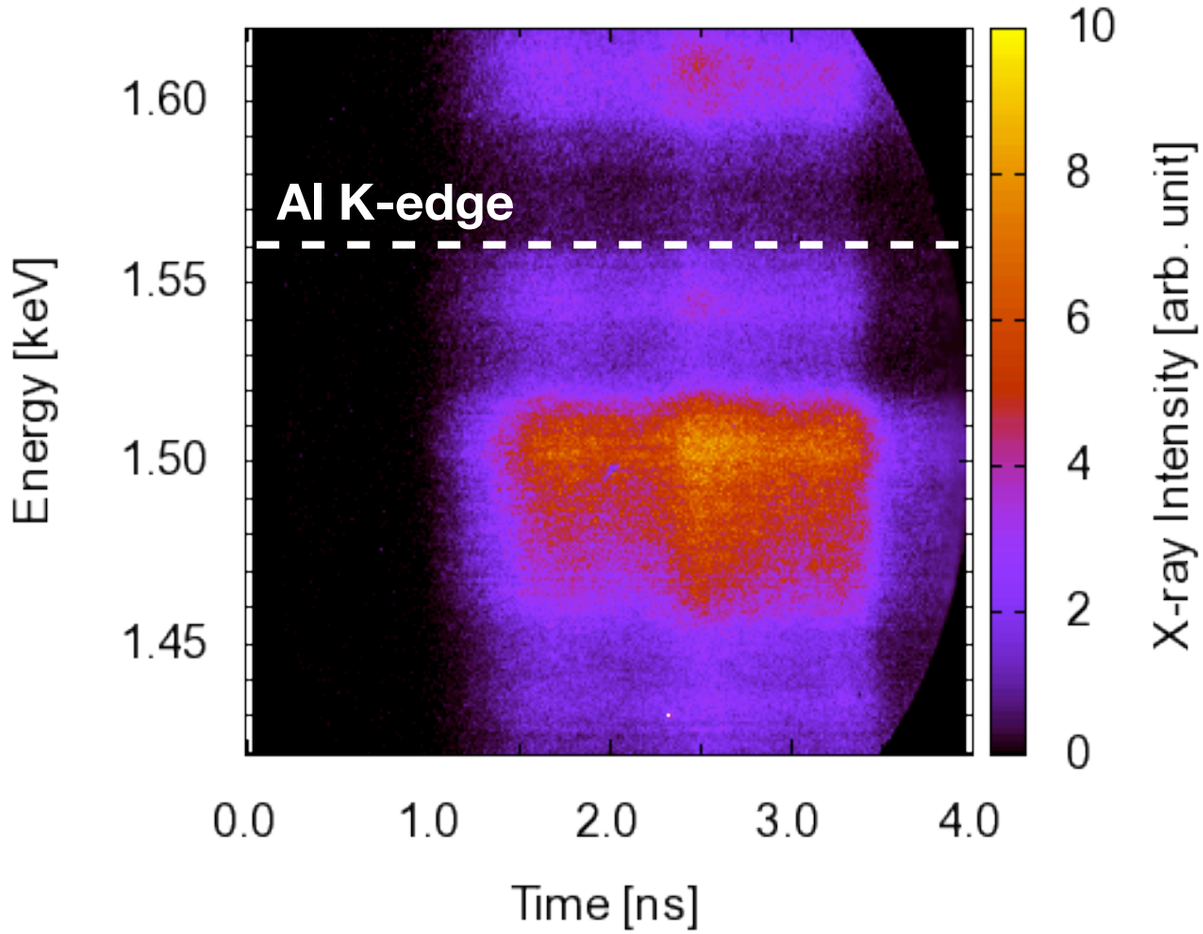
#7320: Undriven Foam



Foam: 250 μm thick, 200 mg/cm^3
(Equiv. 50 μm Solid CH)

Doped Al: 5.0x10^{20} atoms/cm^3
(Equiv. 2.1 μm Solid Al)

#7321: Solid Al Foil



50 μm thick solid CH

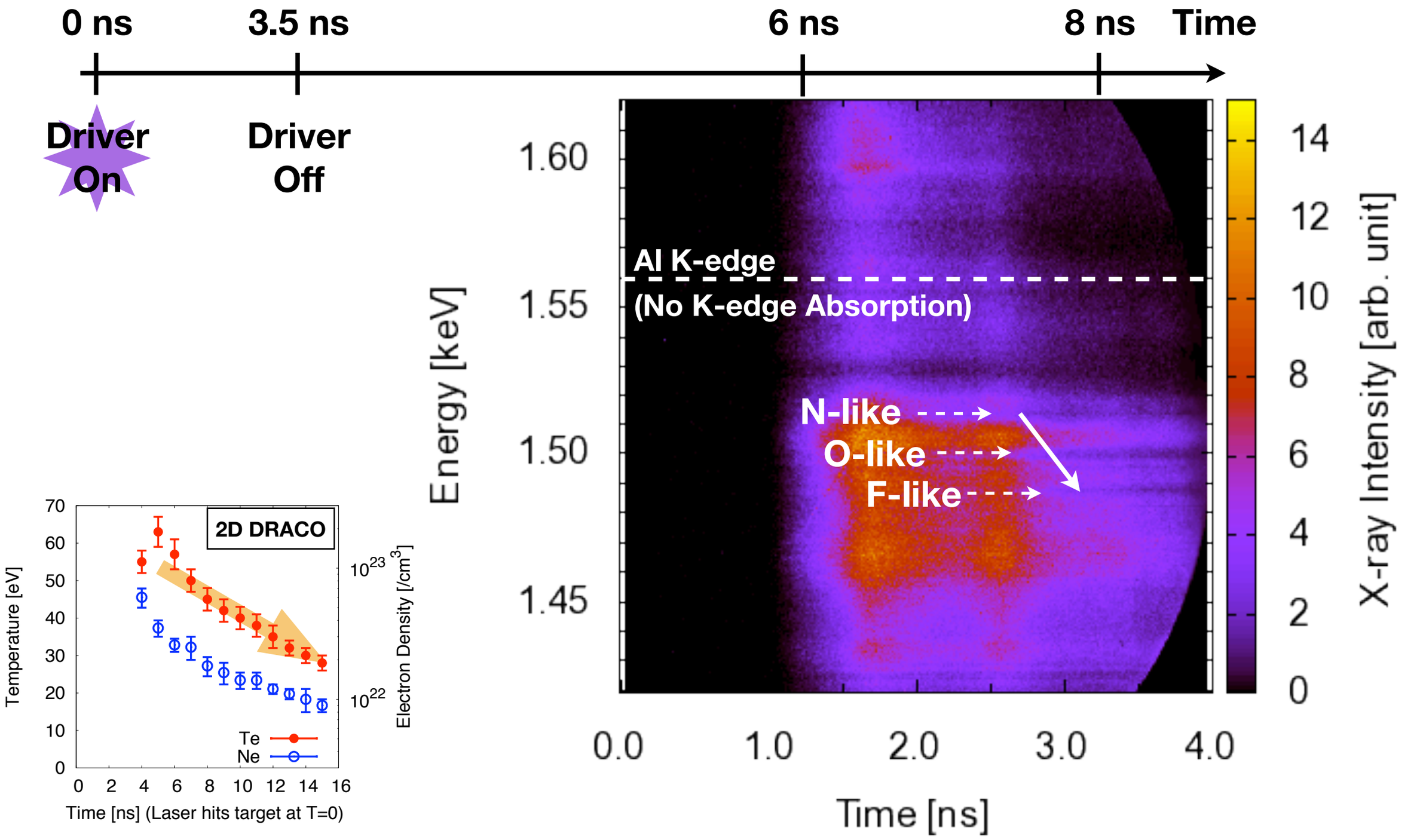
with

2 μm thick solid Al

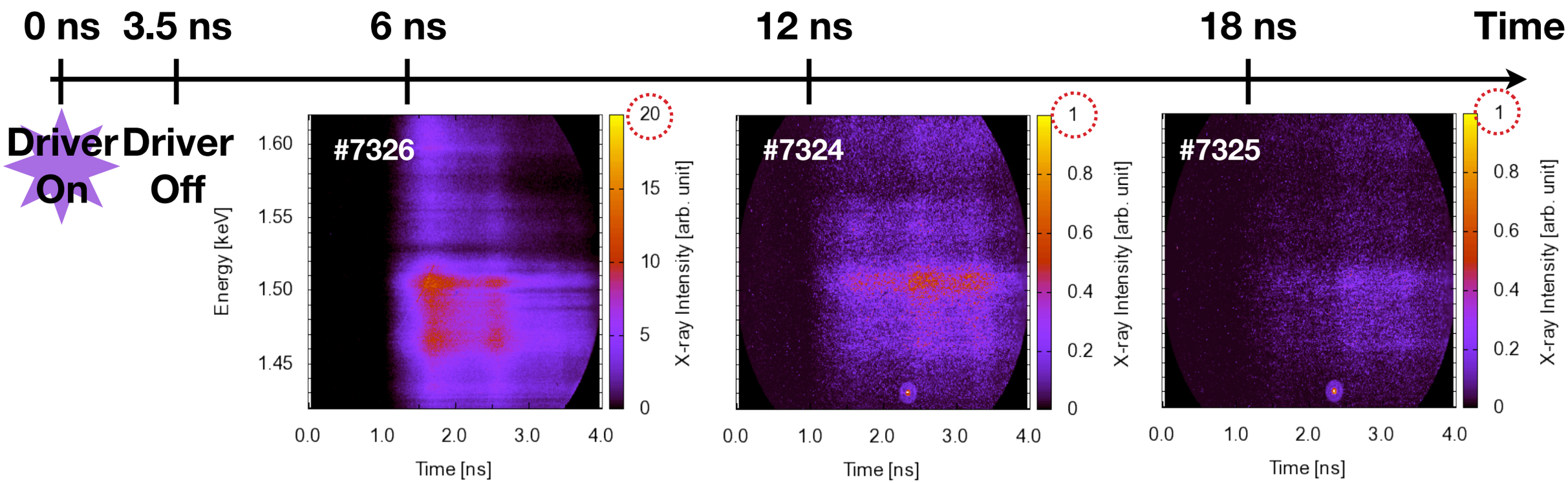
Absorption lines were observed at ~8 ns indicating temperature reduction in time.

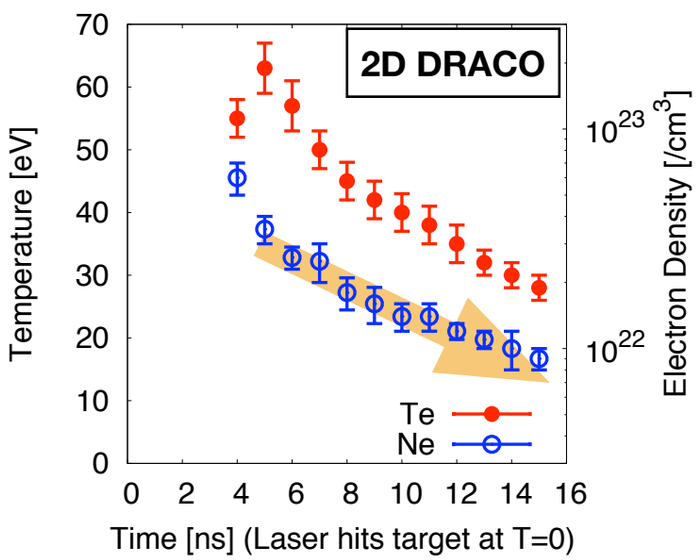
#7326: Driven Foam (Backgliht Delay: 6 ns)

Doped Al: 3.4x10^{20} atoms/cm^3



Intensity of the backlighter x-ray attenuated by the driven target decreased in time.





- The foam plasma density should decrease in time after the pules is off, which cannot explain this trend.
- It is most likely that the x-ray windows were infilled by high density plasma from the walls (CH coated Au).

Future Experiment

e-transport will be studied in characterized plasma with Cu K-shell x-ray diagnostics.

OMEGA EP