Overview of HED Science at LLNL

Presented to OLUG

27 April 2012

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Lawrence Livermore National Laboratory

LLNL-PRES-XXXXXX

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HEDS facilities in recent use by LLNL staff

HEDS on NIF (HEDS on OMEGA covered by Postdocs/Students)

Basic Science on NIF (LBS on OMEGA covered by Postdocs/Students)

Jupiter Facility

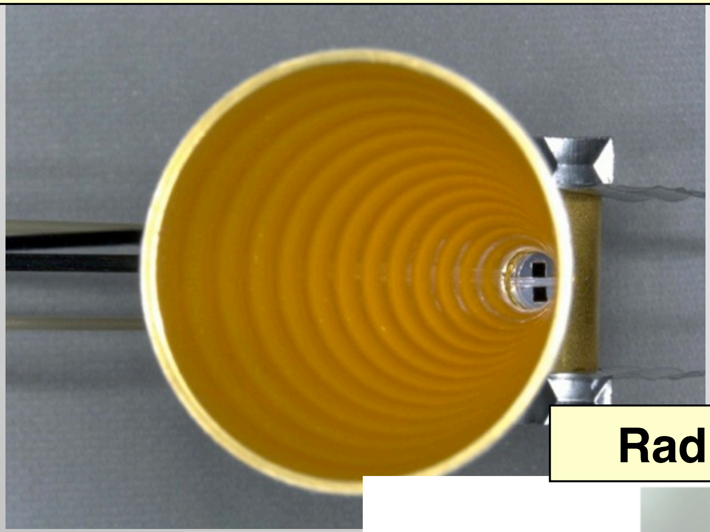
FLASH/LCLS

Nevada TWF

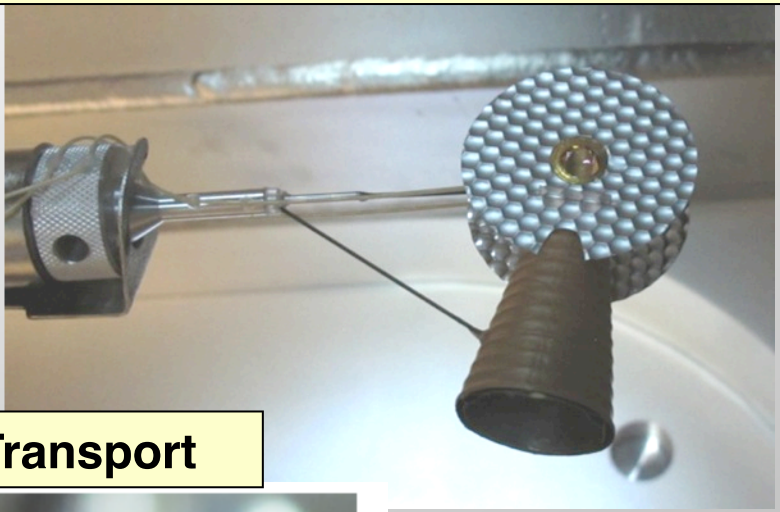
ZBL

LLNL HEDS on NIF concentrated on Radiation Transport, Material Strength

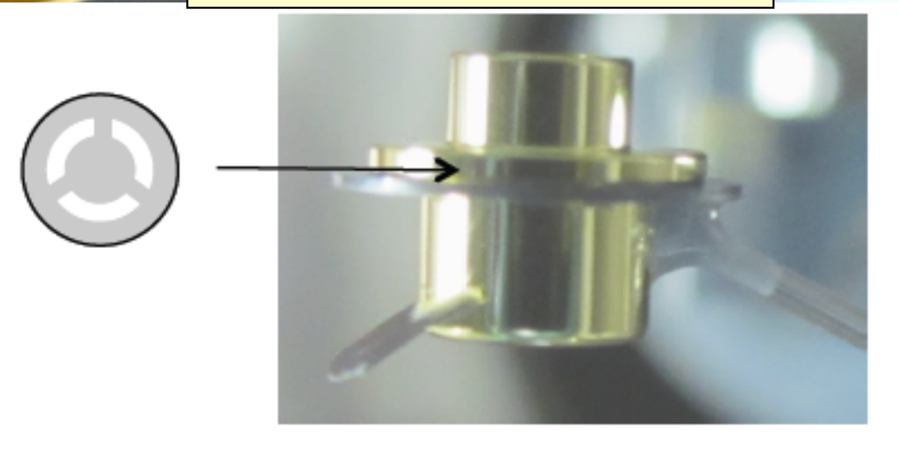
Ta EOS



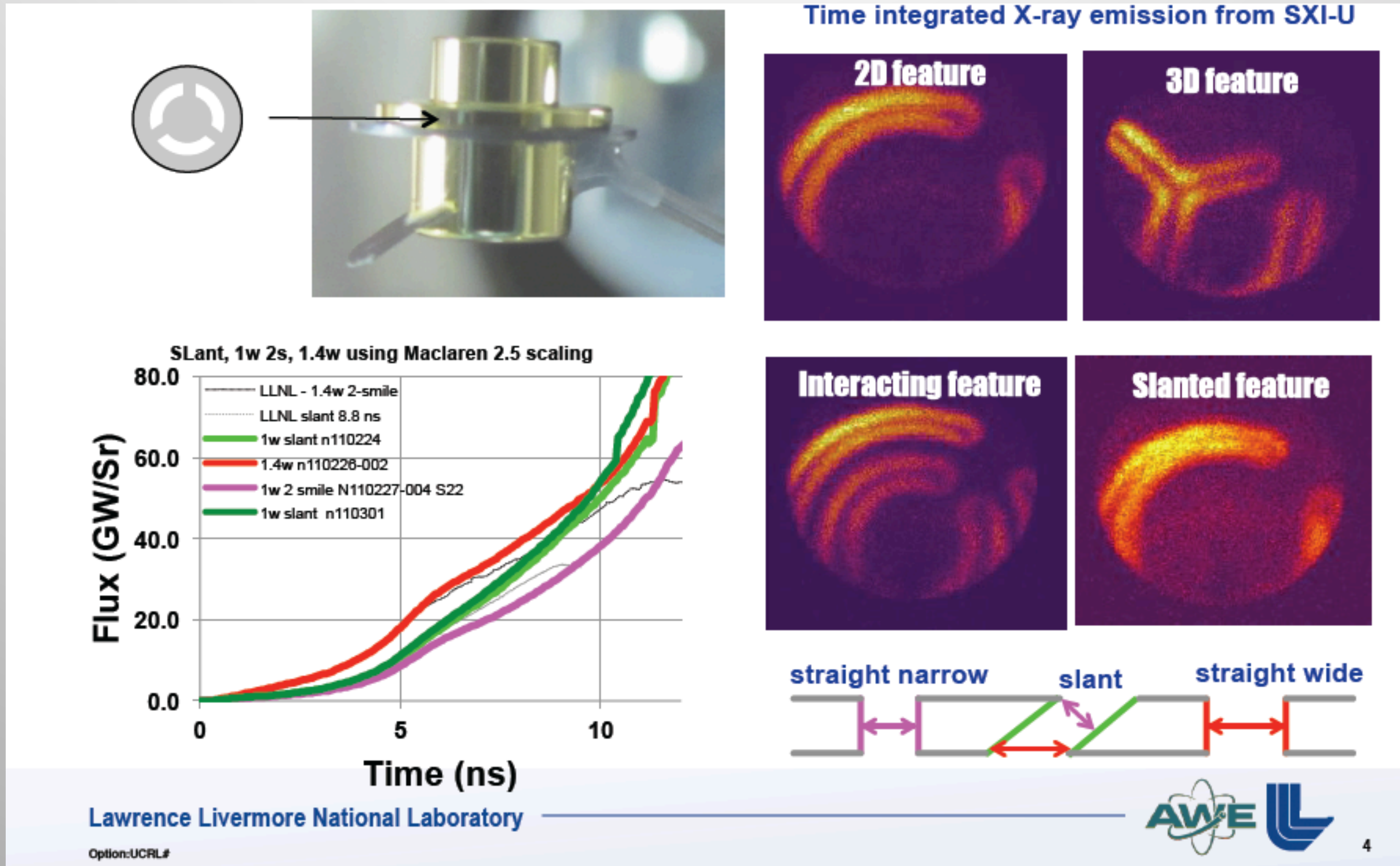
Strength Drive Characterization



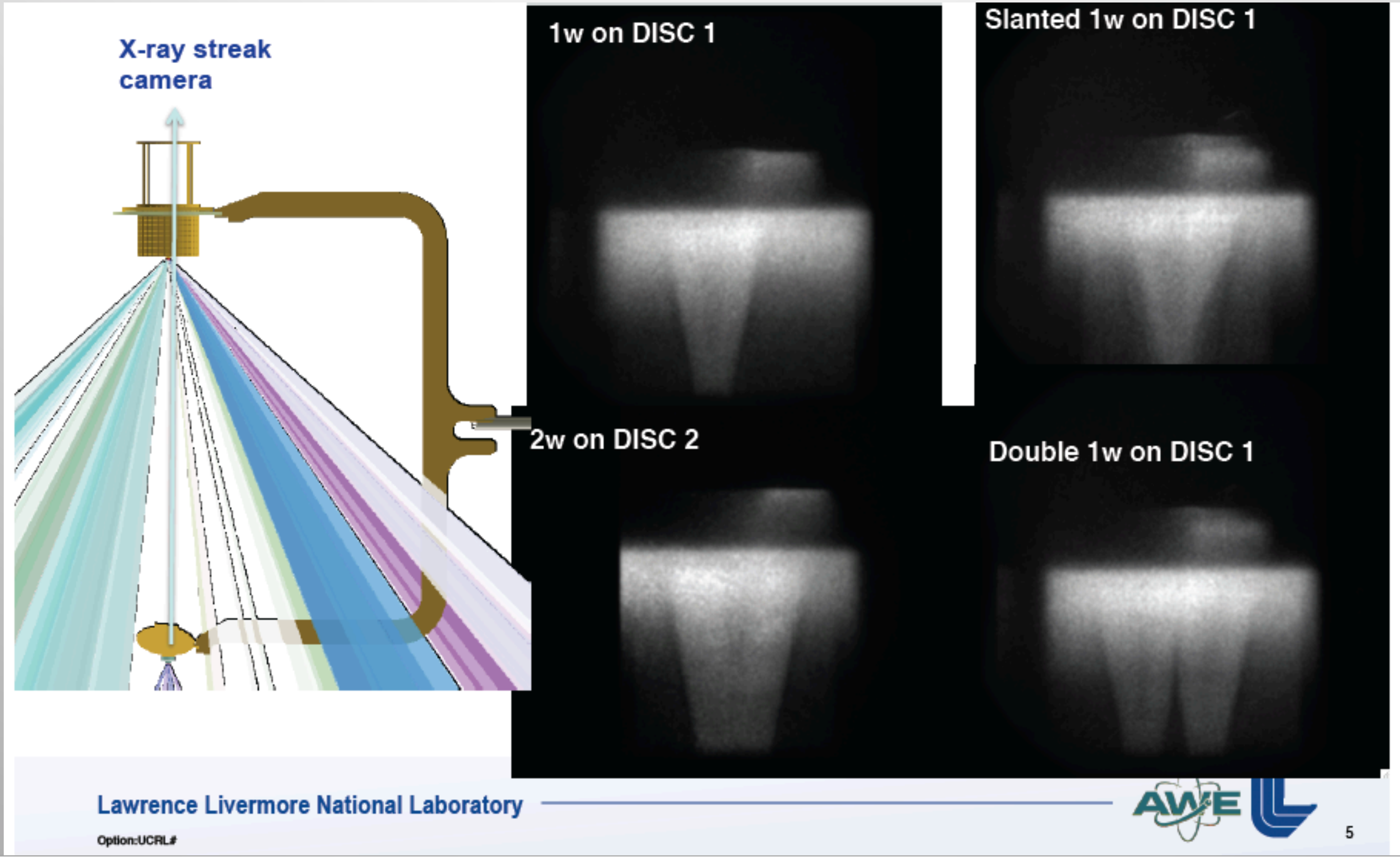
Radiation Transport



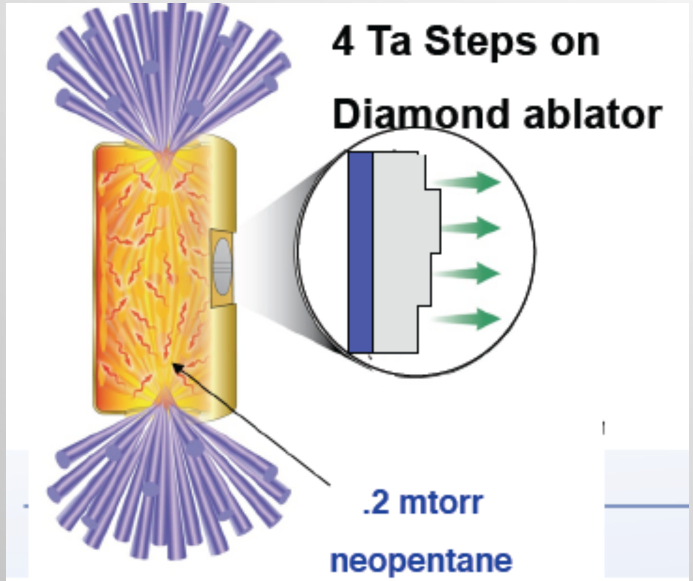
Radiation Transport calorimetry

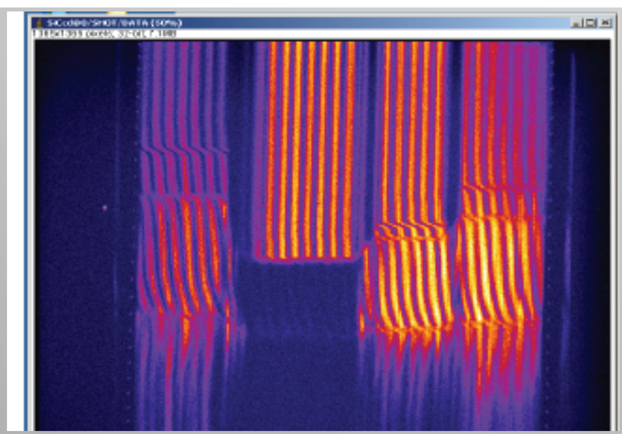


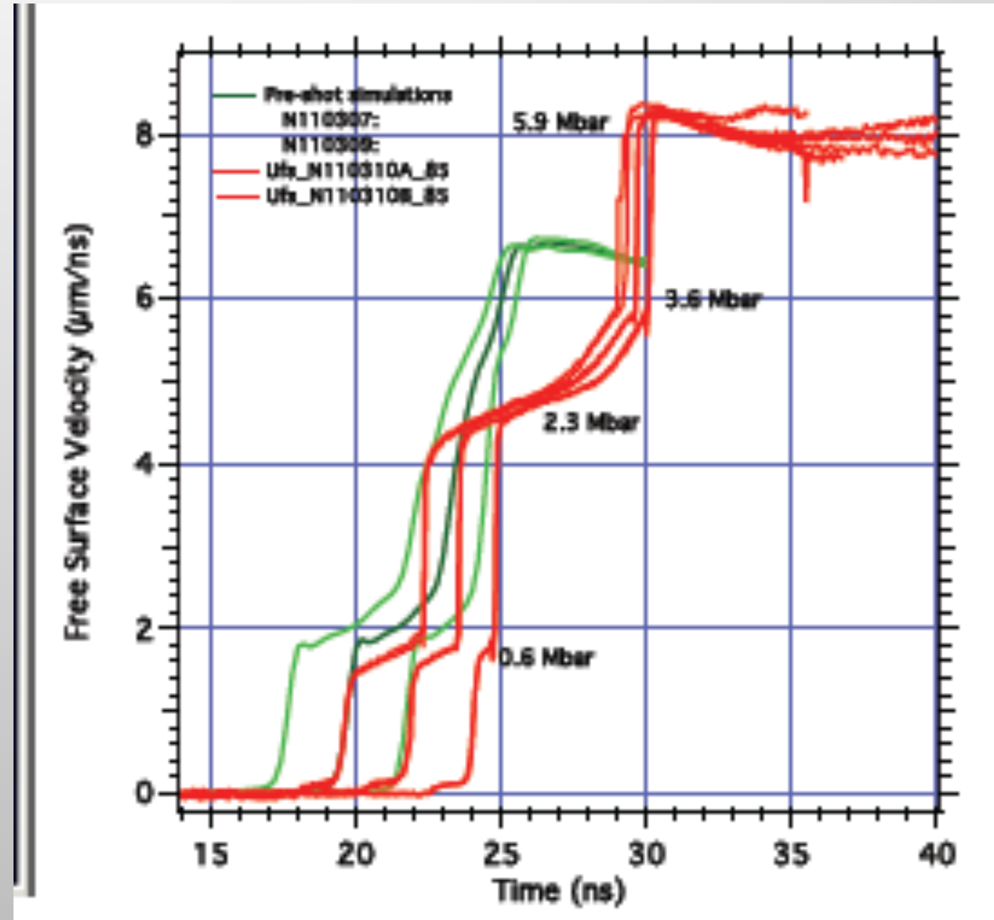
Radiation Transport Streaked Radiography



Ta EOS reached 6 Mbar quasi-isentropically

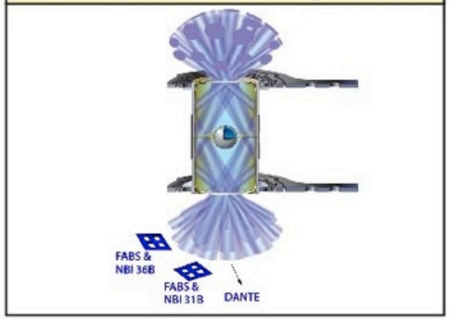




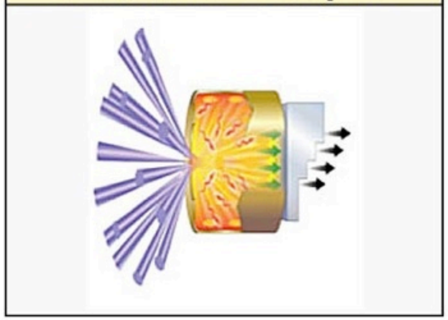


A wide variety of experimental platforms are available to NIF users

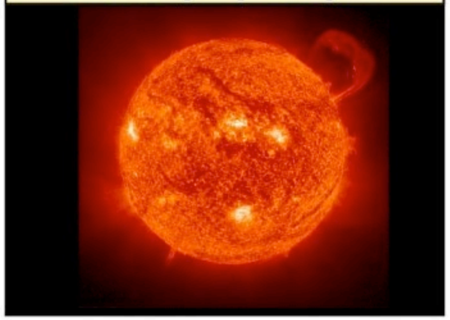
Hohlraum energetics



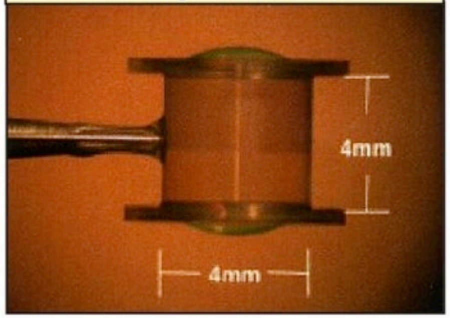
Radiation transport



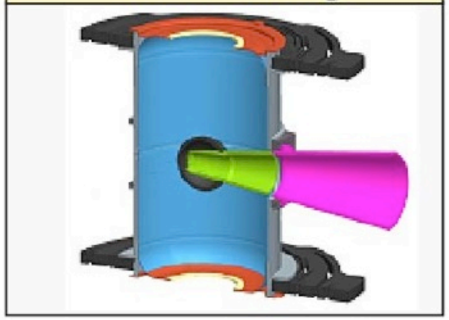
X-ray opacity



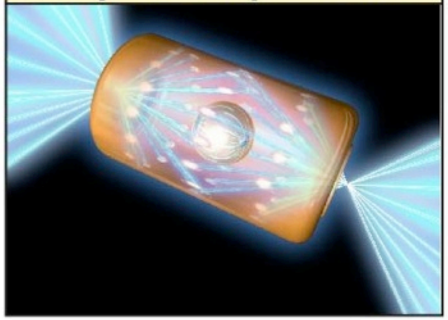
X-ray sources



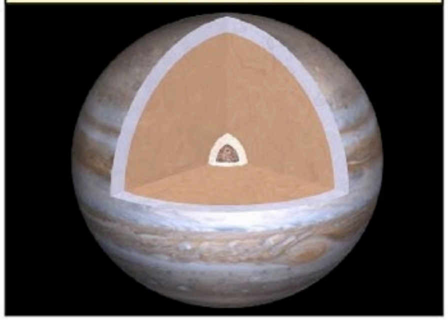
Shock timing



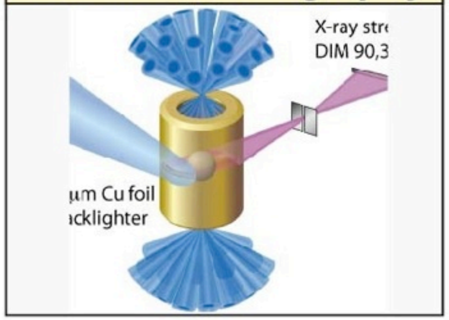
Capsule implosions



Materials



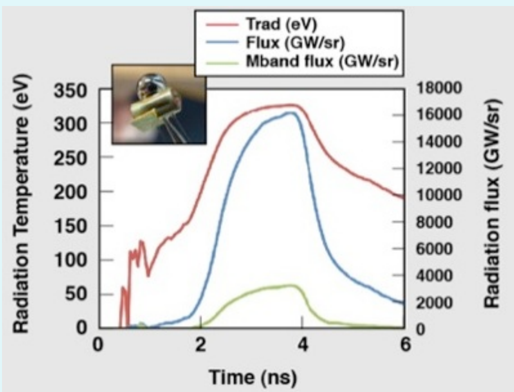
Streaked Radiography



More information at: https://lasers.llnl.gov/for_users

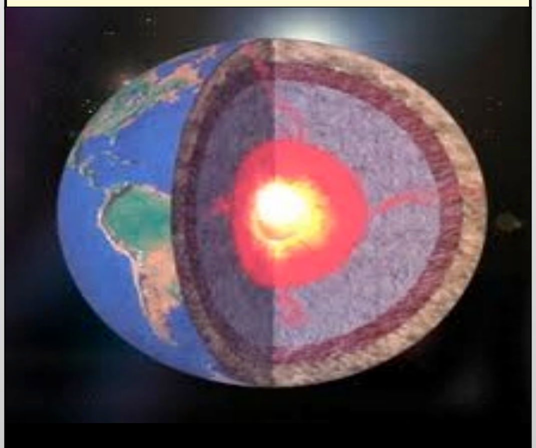
Three teams have already performed fundamental science NIF experiments

Effect of radiation on supernova hydrodynamics



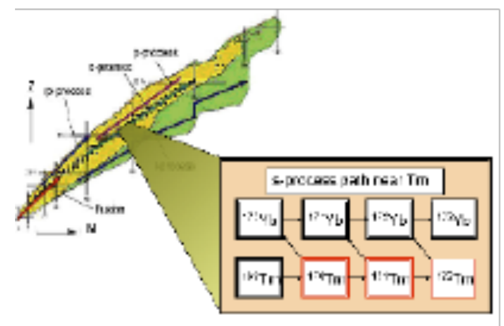
University of Michigan

C/Fe equation of state



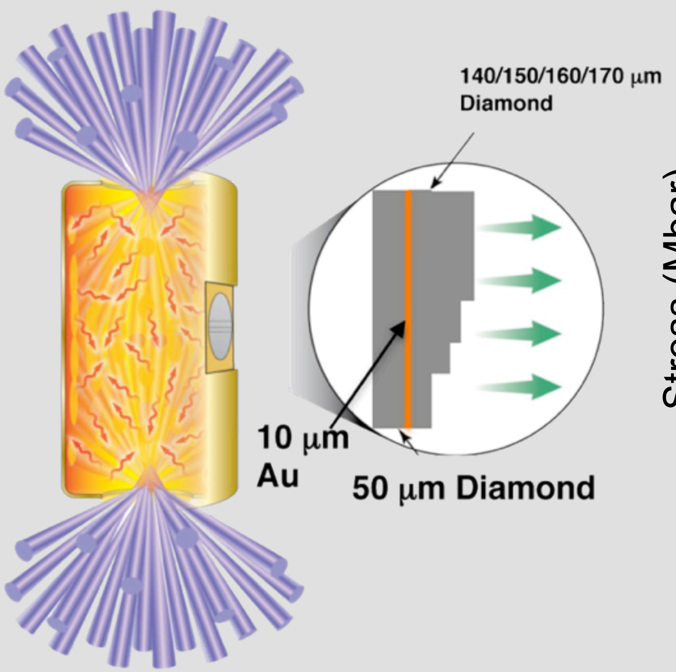
UC Berkeley; Princeton University

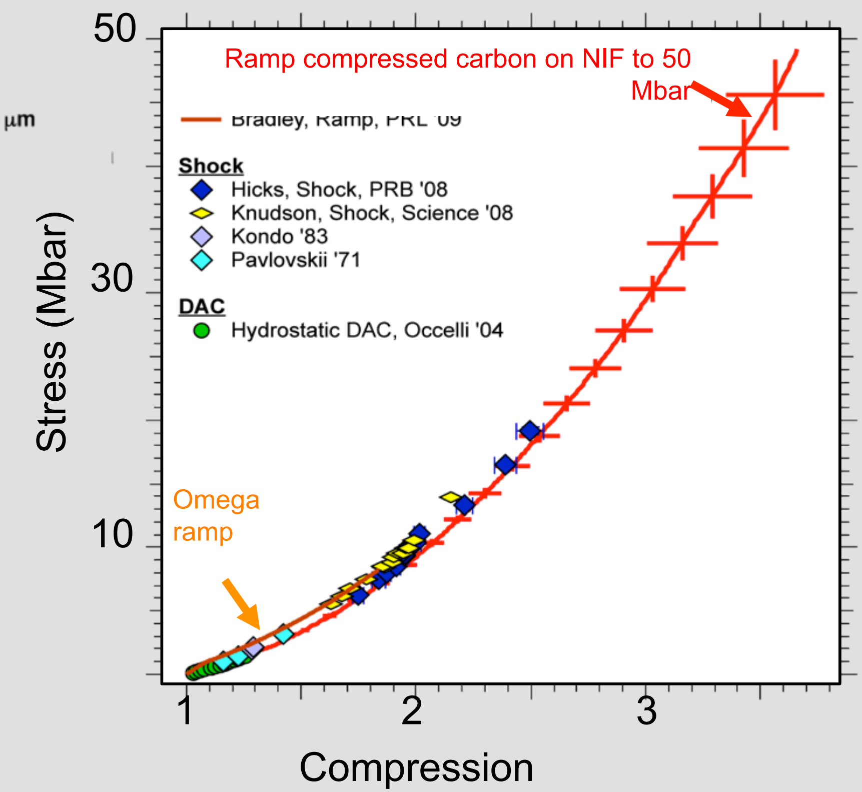
Nucleosynthesis and the s-process



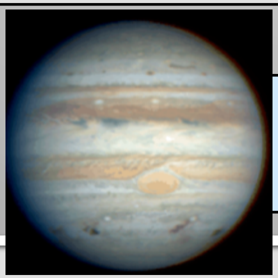
LLNL; LANL; Ohio University

NIF has been used to "shocklessly" compress carbon to 100 Mbar



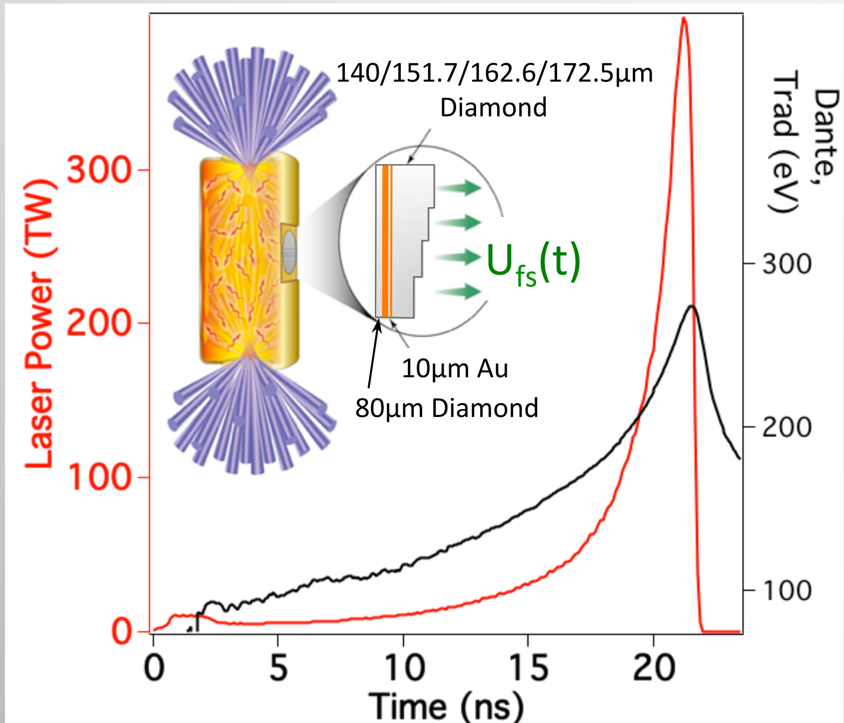


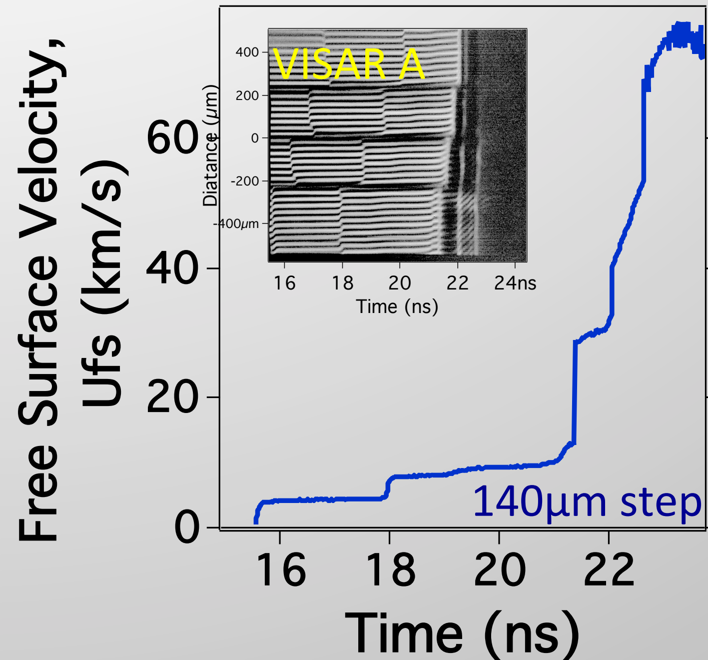
R.F. Smith, J.H. Eggert, D.G. Braun, J.R. Patterson-1, R.E. Rudd, R. Jeanloz, T.S. Duffy, J. Biener, A.E.Lazicki, A.V. Hamza, J. Wang, T. Braun, L.X. Benedict, P.M. Celliers, G.W. Collins



NIF can now recreate the most extreme planetary core states in the solar system

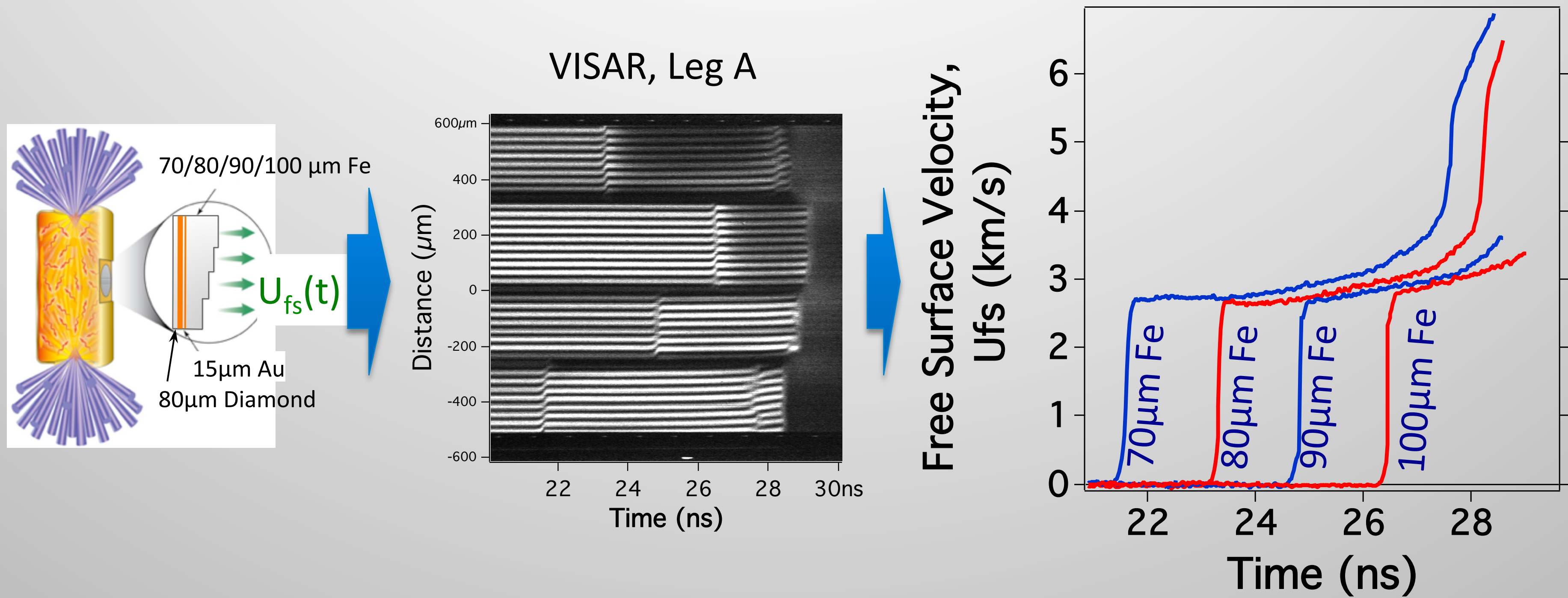
Diamond ramp compression achieved ~100 Mbar, ≈ 2x previous record





- Free surface reflectivity maintained
- Sample compressed with a series of small shocks and intermediate ramps
- EOS may be obtainable - analysis underway
- Next shot to use optimized laser pulse

First Fe ramp compression EOS experiment was conducted

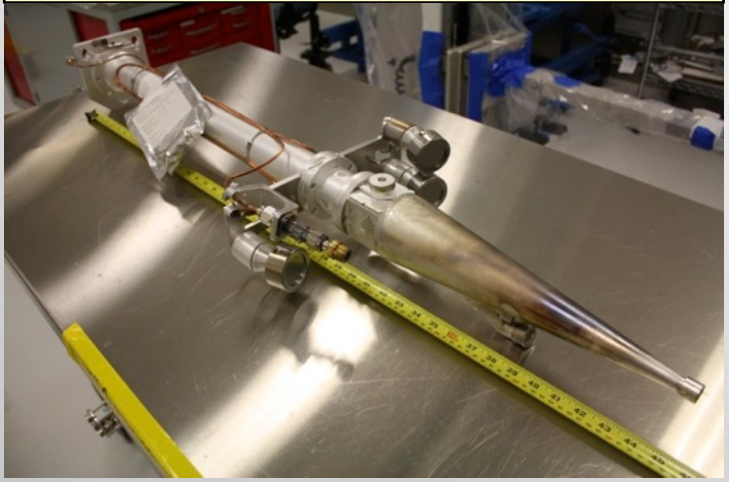


- **All 4 steps successfully compressed with steady 0.5 MBar shock**
- **Shock formed- VISAR blanked above ~ 6 km/sec (~ 2-3 MBar)**
- **Optimization of pulse shape in progress**

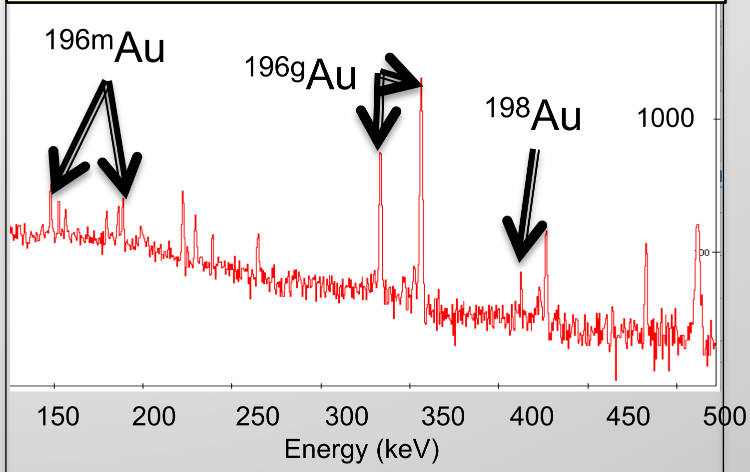
Astrophysical neutron capture observed at NIF for the 1st time:

$^{197}Au(n,\gamma)^{198}Au/^{197}Au(n,2n)^{196}Au$

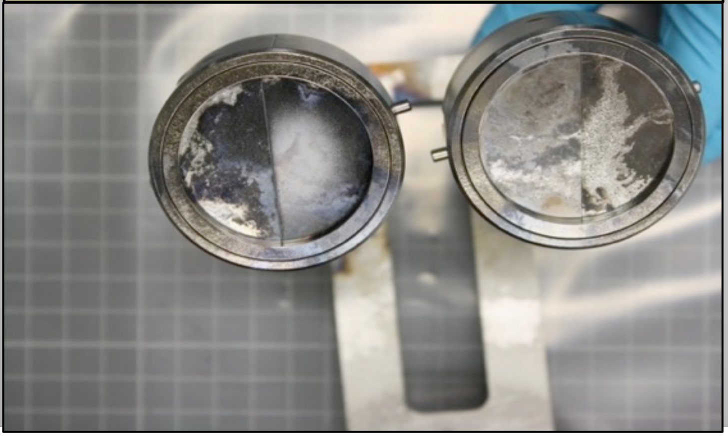
Four collectors mounted on a DIM



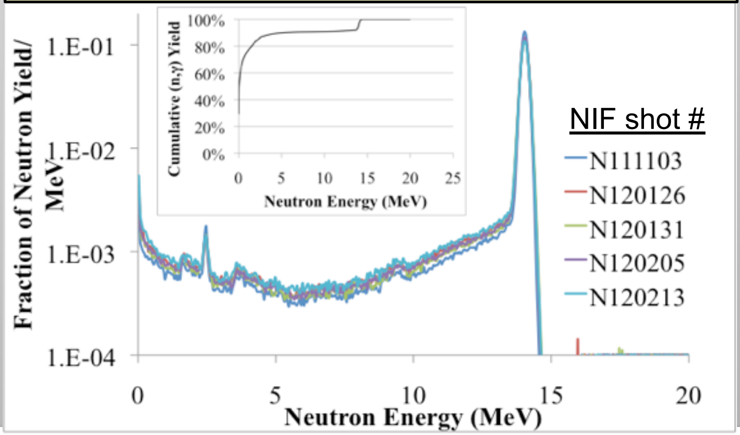
γ-decay spectra are counted in B151



Collectors are retrieved post-shot

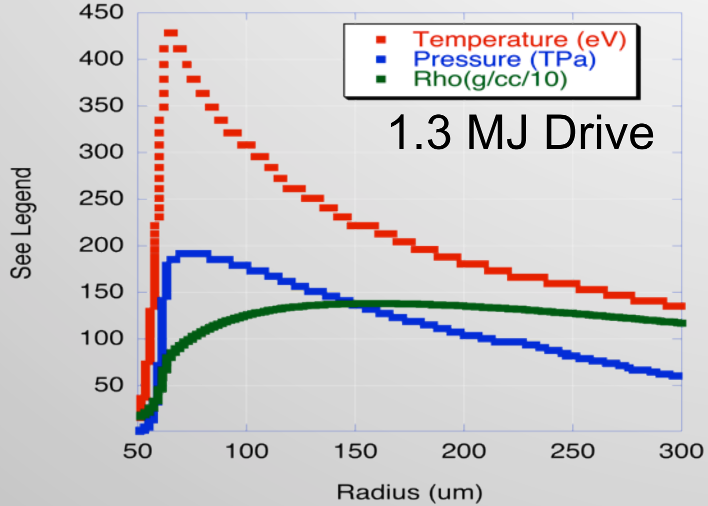


>75% of capture from E_n <700 keV

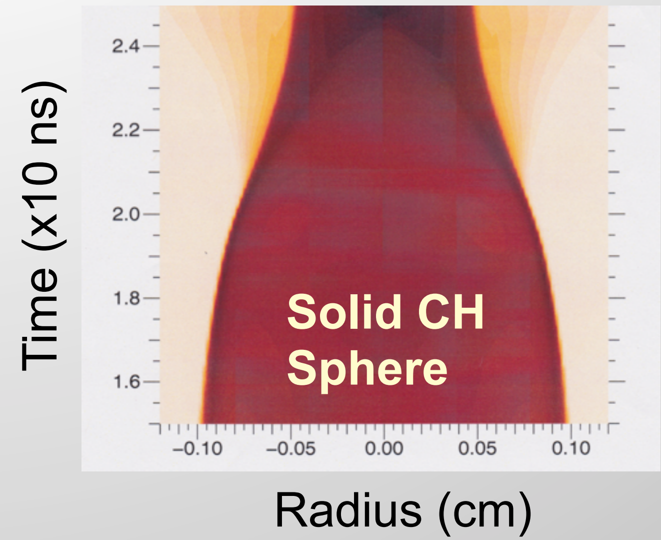


EOS of matter at > Gbar pressures

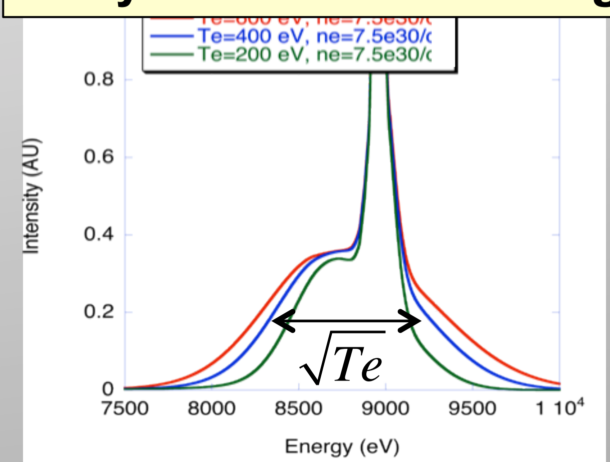
Shock compression of Solid CH Sphere



Streaked X-Ray Radiography



X-ray Thomson Scattering

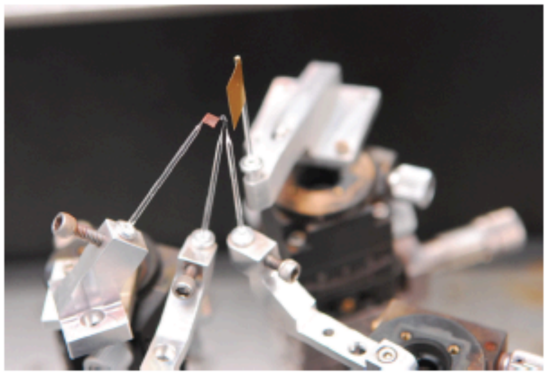


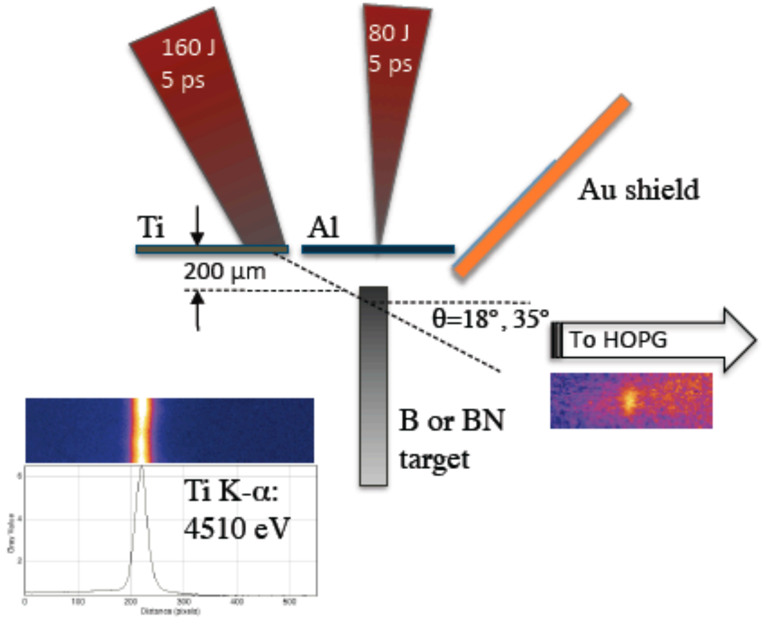
Radiography → $p = p_0 + \frac{D^2}{v_0^2}(v_0 - v)$

XRTS → Te

→ With the mass density profile, shock speeds and T_e we can constrain the EOS

B and BN Structure factor experiments at TITAN laser

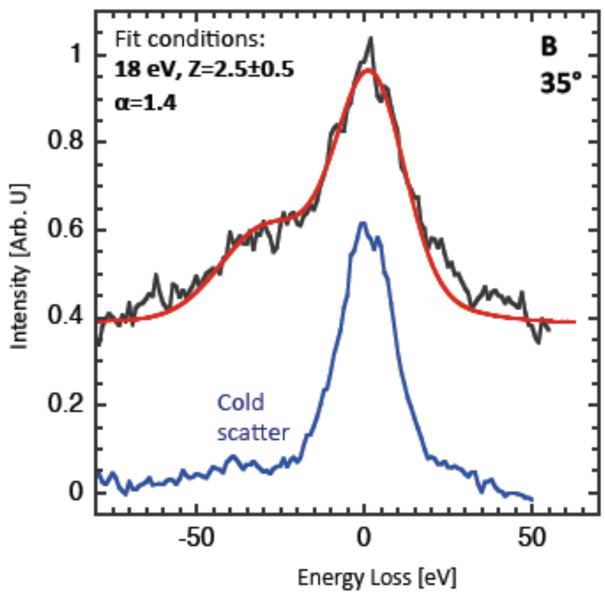




Probe is delayed 300 ps relative to heater pulse to reach thermal equilibrium

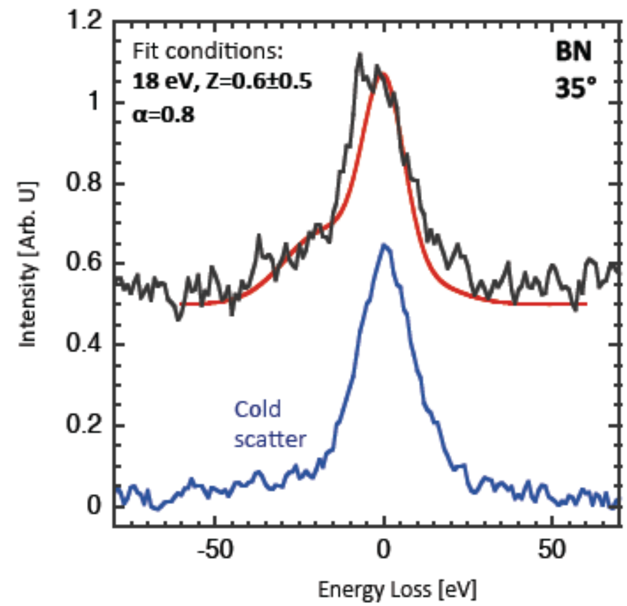
BN is ionized much less than B for same Te

Boron



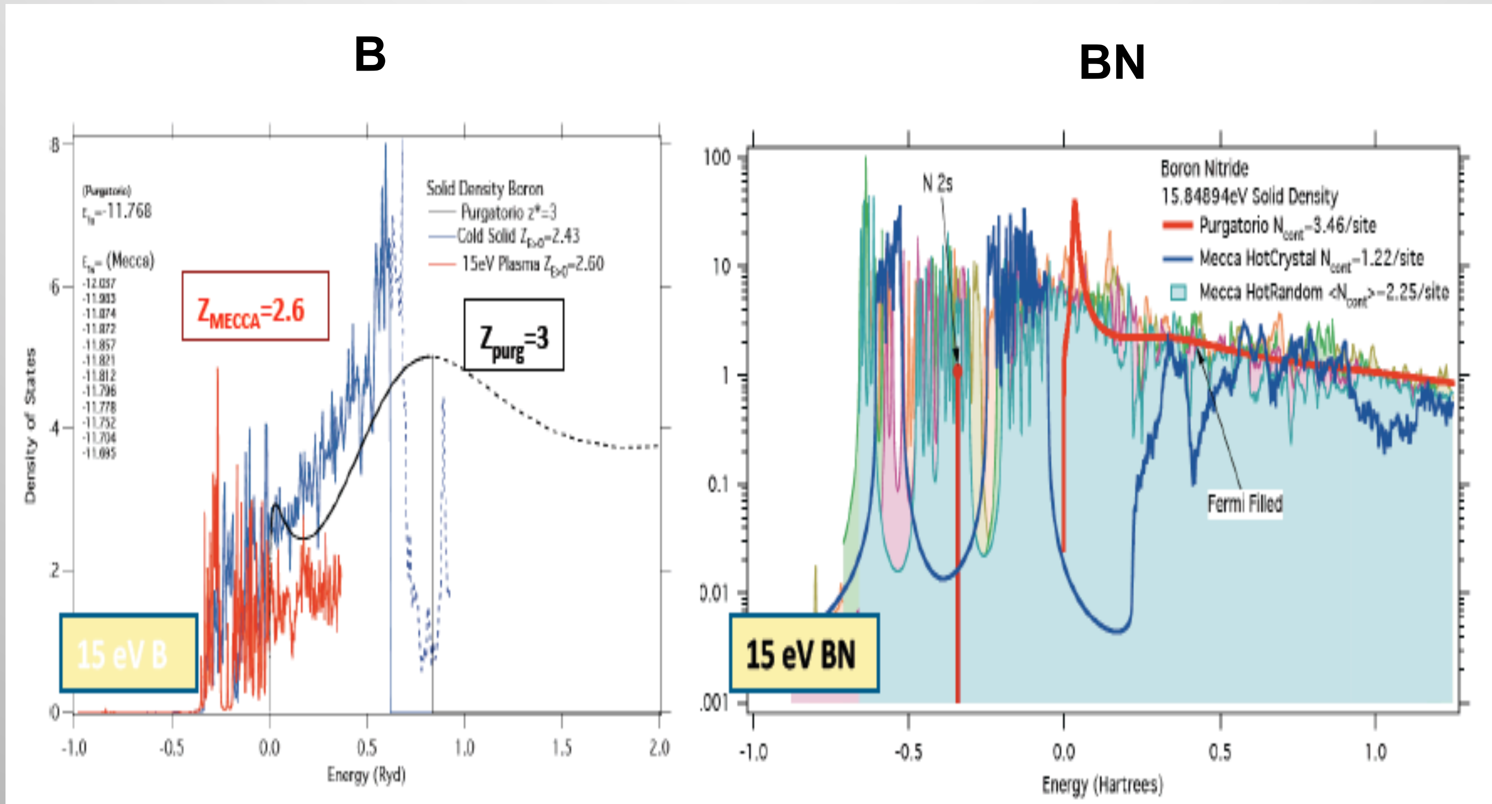
B shows strong plasmon signal corresponding to predicted levels of ionization

Boron Nitride

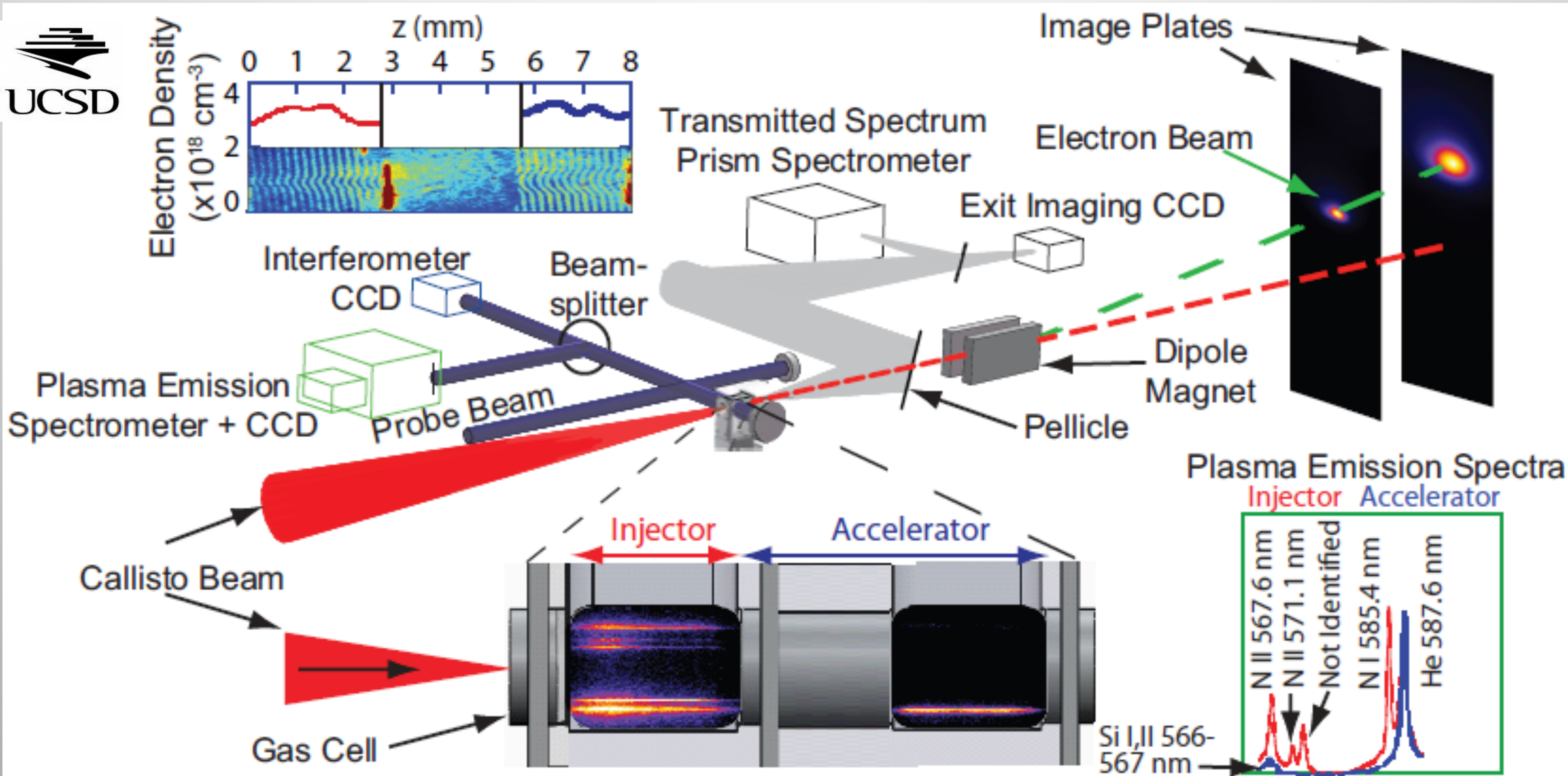


BN has a small inelastic feature – scattering has become non-collective due to very low ionization

Measured low BN ionization consistent with high T band structure



Laser Wakefield Acceleration at the Jupiter Facility (with UCSD, UCLA)



He+N

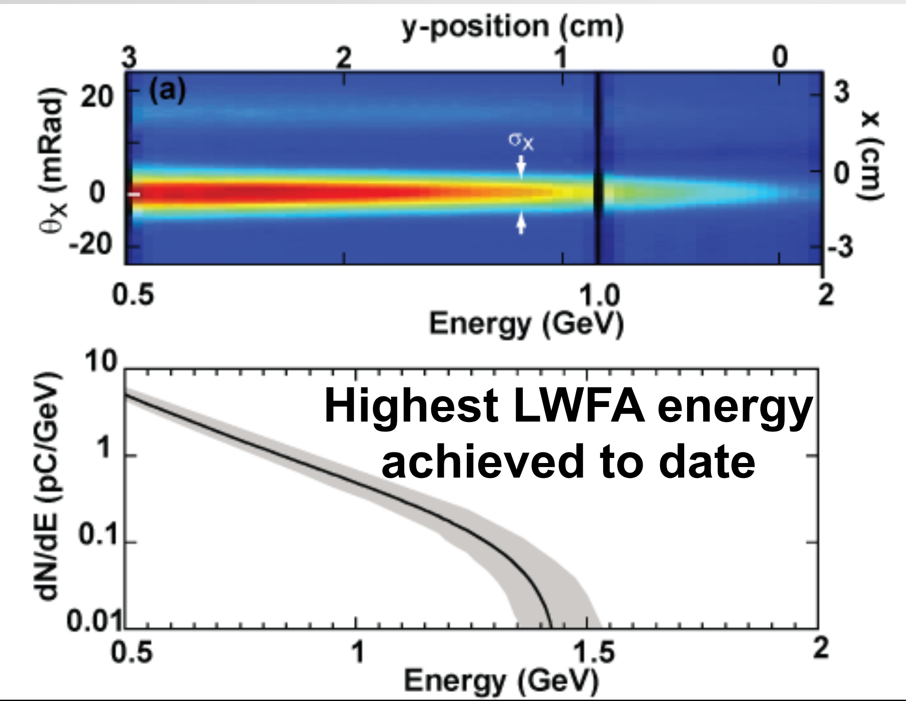
He

Reached record 1.4 GeV electron energy and 2-stage reduced energy spread

1.4 GeV electrons are produced in a 13 mm gas target

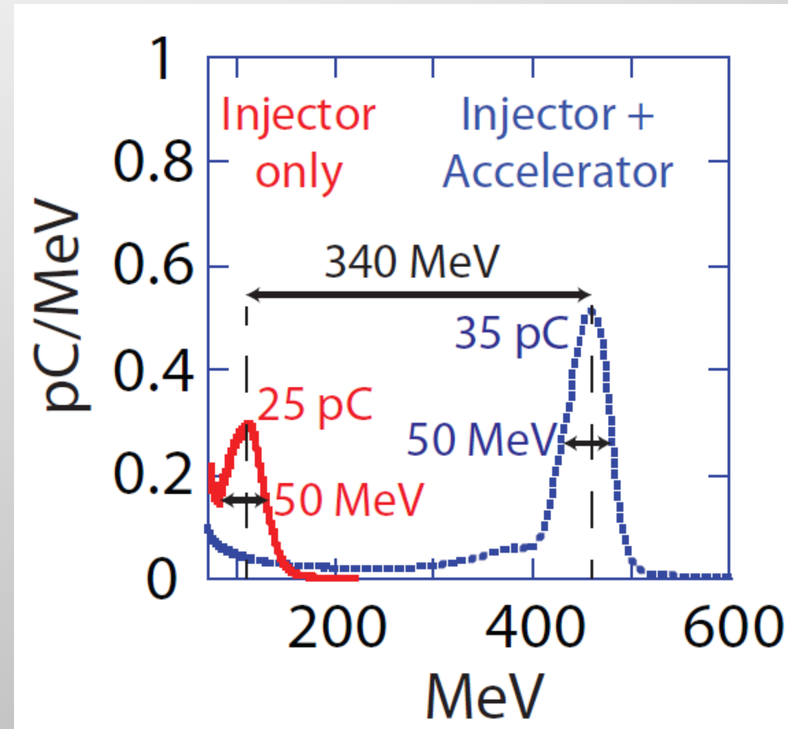
UCSD

1.3×10^{18} cm^{-3}, 1.3 cm, 3% CO_2



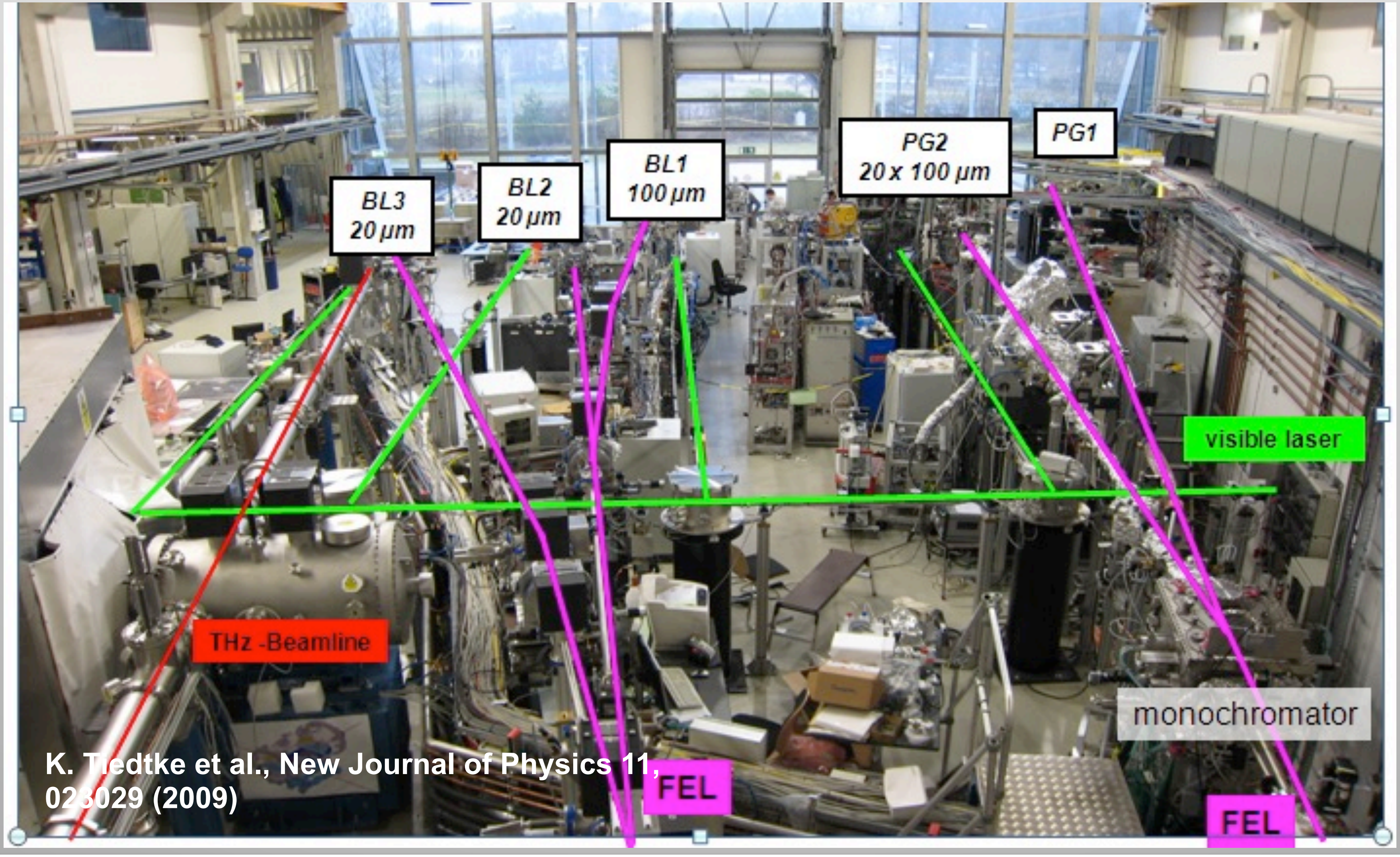
The 100% energy spread is due to the injection mechanism

Implementing a two-stage target reduces the energy spread to <10%



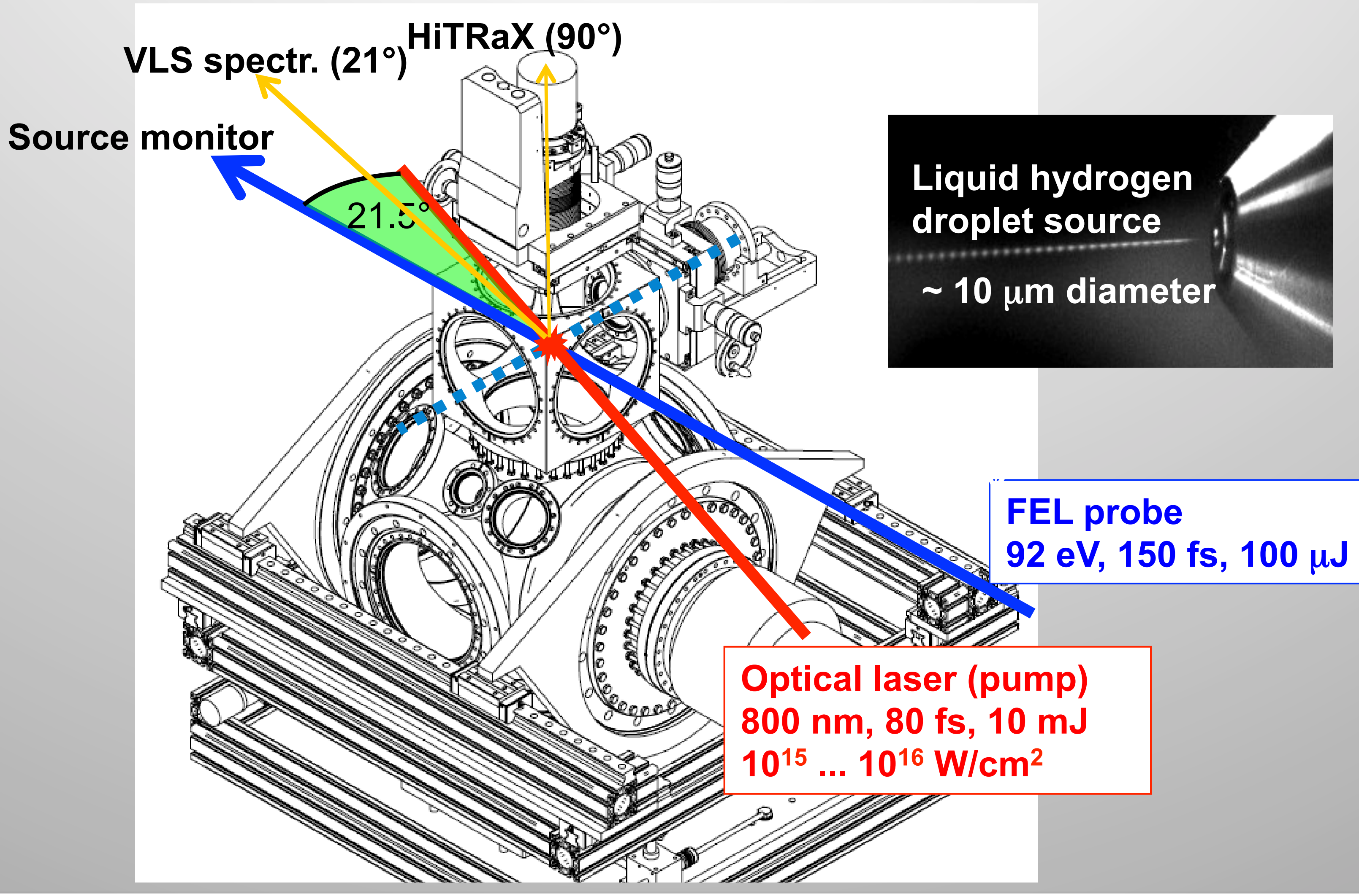
Injection is terminated at the end of the first stage

FLASH Experimental Hall, Hamburg



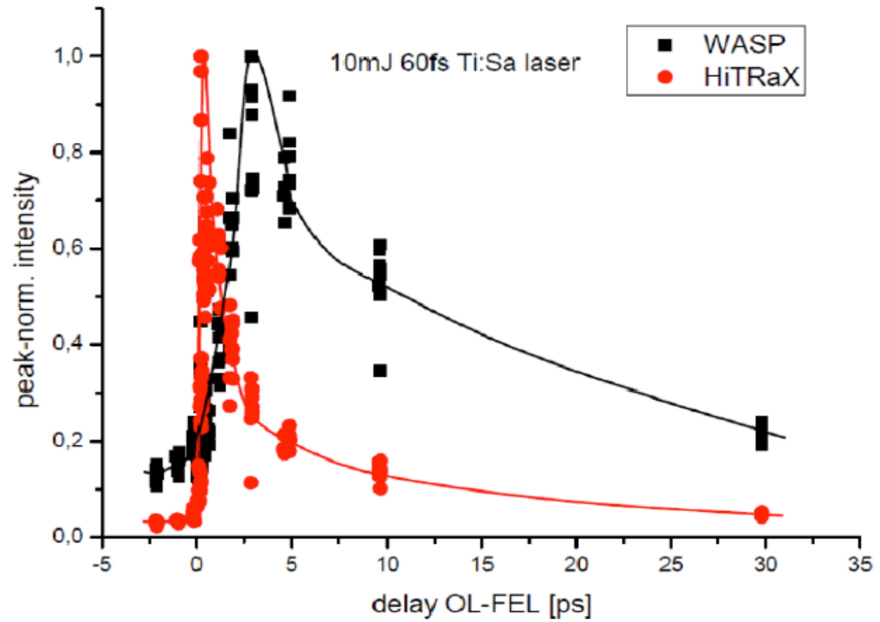
K. Tiedtke et al., New Journal of Physics 11, 023029 (2009)

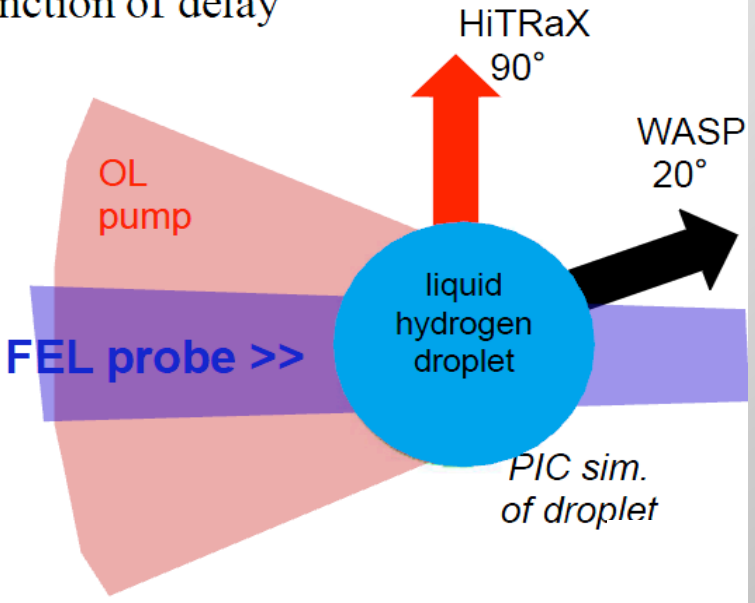
Experimental setup



FELs allow to study warm dense matter with sub-ps time resolution

Integrated Rayleigh signal (elastic scatt.) as function of delay





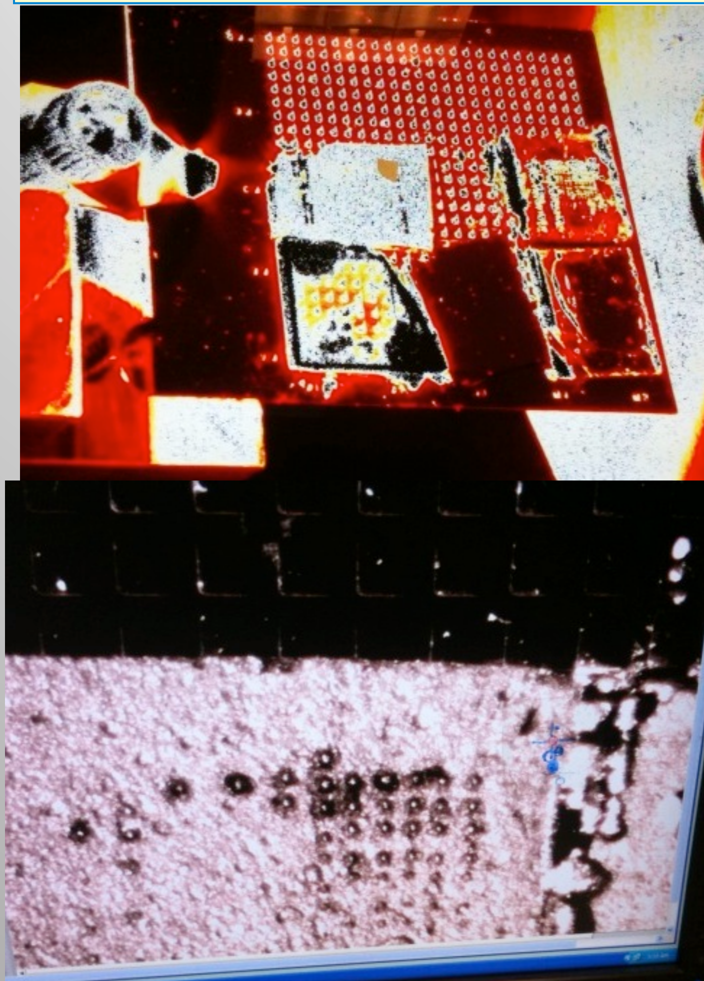
- Strong pump-probe effect in the Rayleigh scattered signal
  → electron-ion equilibration
- The two spectrometer signals peak at different times after excitation (peak at ~200 fs or ~2.5 ps)
- → possible signature of **heat wave** or **strong absorption**

Courtesy of U. Zastrau

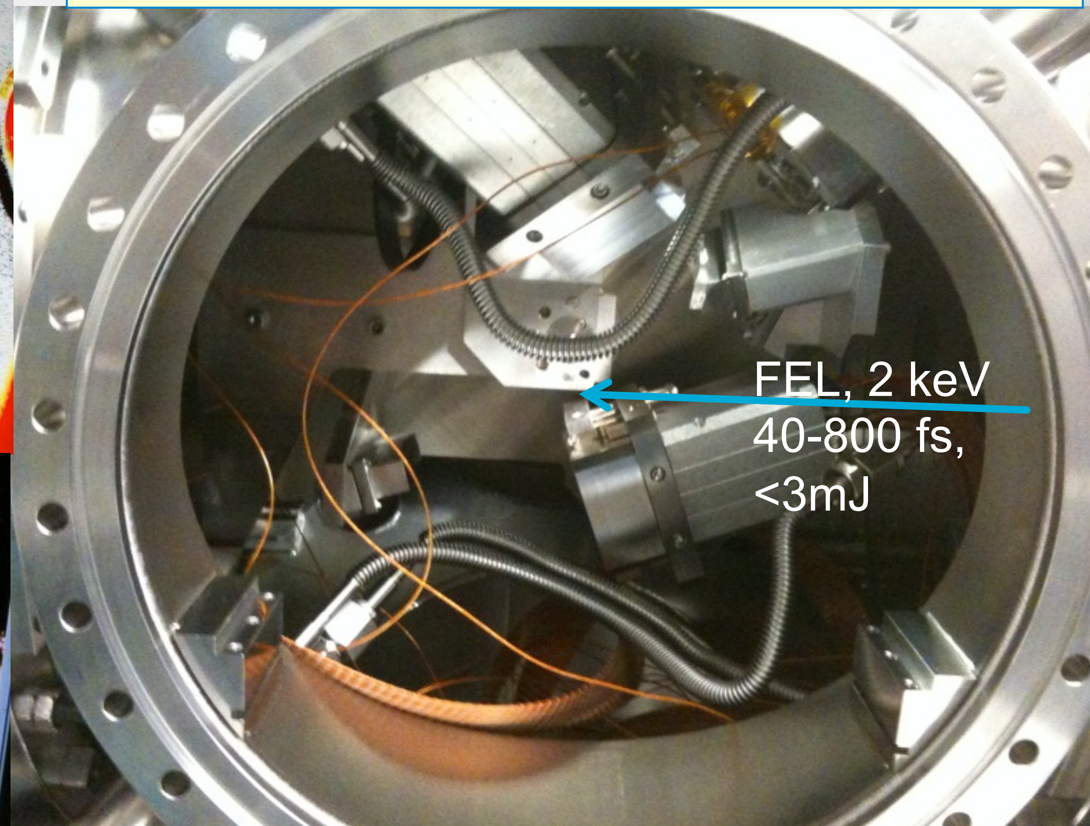
Isochoric heating of graphite at sub-ps Stanford LCLS FEL

S Hau-Riege, A Graf, T Doeppner, S Glenzer et al.

Target views



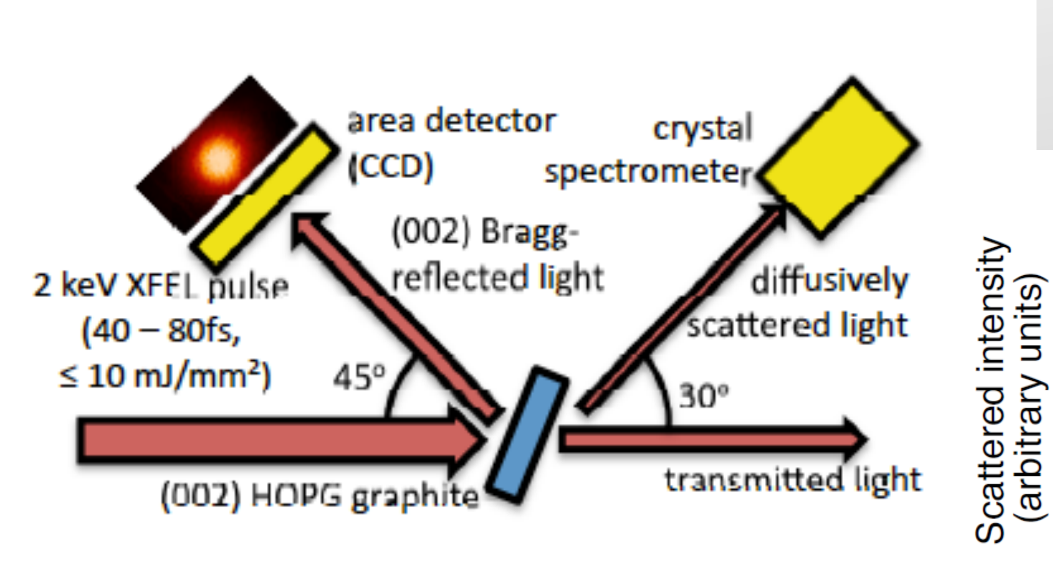
Target chamber



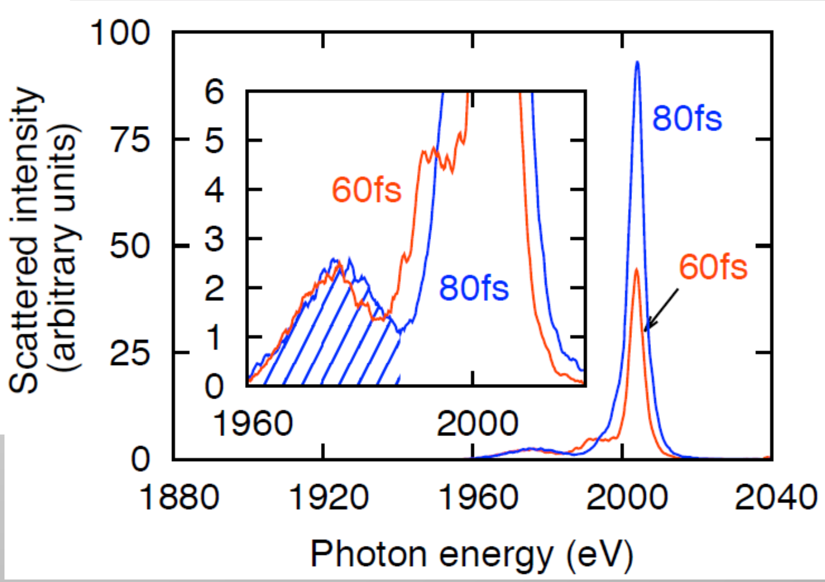
S Hau-Riege, accepted, PRL (2012)

Bragg vs Rayleigh scatter for inferring graphite ion temperature

Experimental Setup



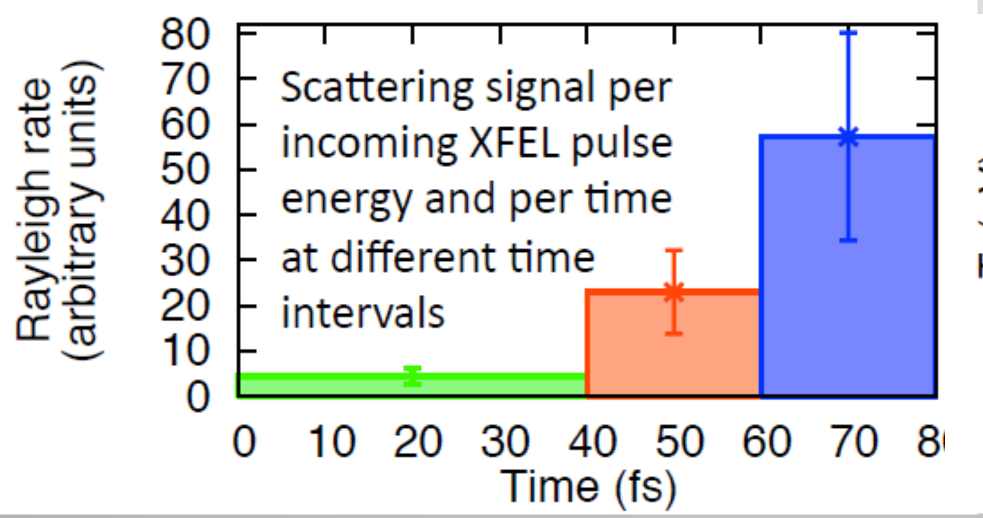
Diffuse Scatter showing Pulse Length Dependence

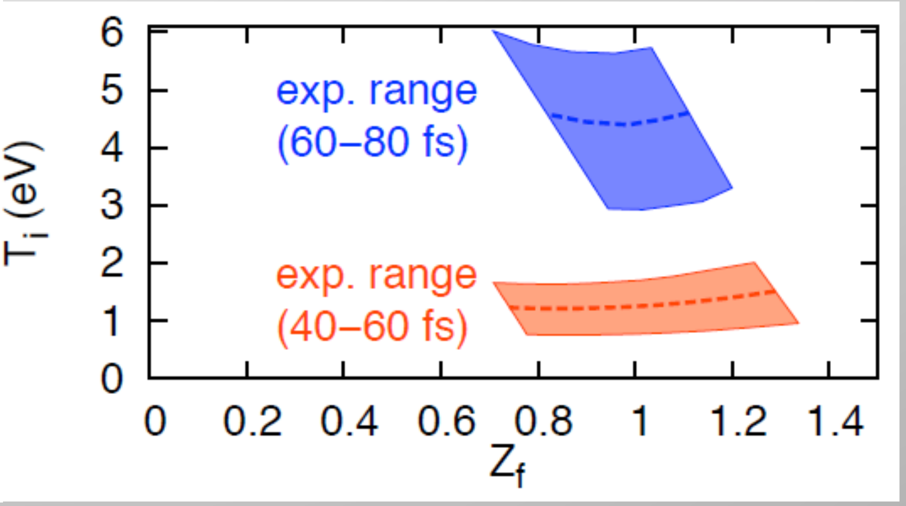


S Hau-Riege et al., accepted, PRL (2012)

Rayleigh scattering strongly increases in time due to lattice destruction and ionization, faster than expected

We infer ion heating up to 5 eV in graphite within a 80 fs long XFEL pulse at 2 keV photon energy





S Hau-Riege et al., accepted ,PRL (2012)

HEDS Scientists in multiple directorates are now colocated in one building (B481)

NIF	Target Physics
Physical and Life Sciences	EOS Radiative Properties Fusion Energy

- Includes ≈ 20 Postdoctoral Researchers, 10 Students, 10 Participating Guests, and offices for Scientists from LANL, SNL, OMEGA, MIT

- Also in close proximity to target design scientists in B381

- We are always looking for creative, motivated early-careeer scientists

Lawrence Livermore National Laboratory