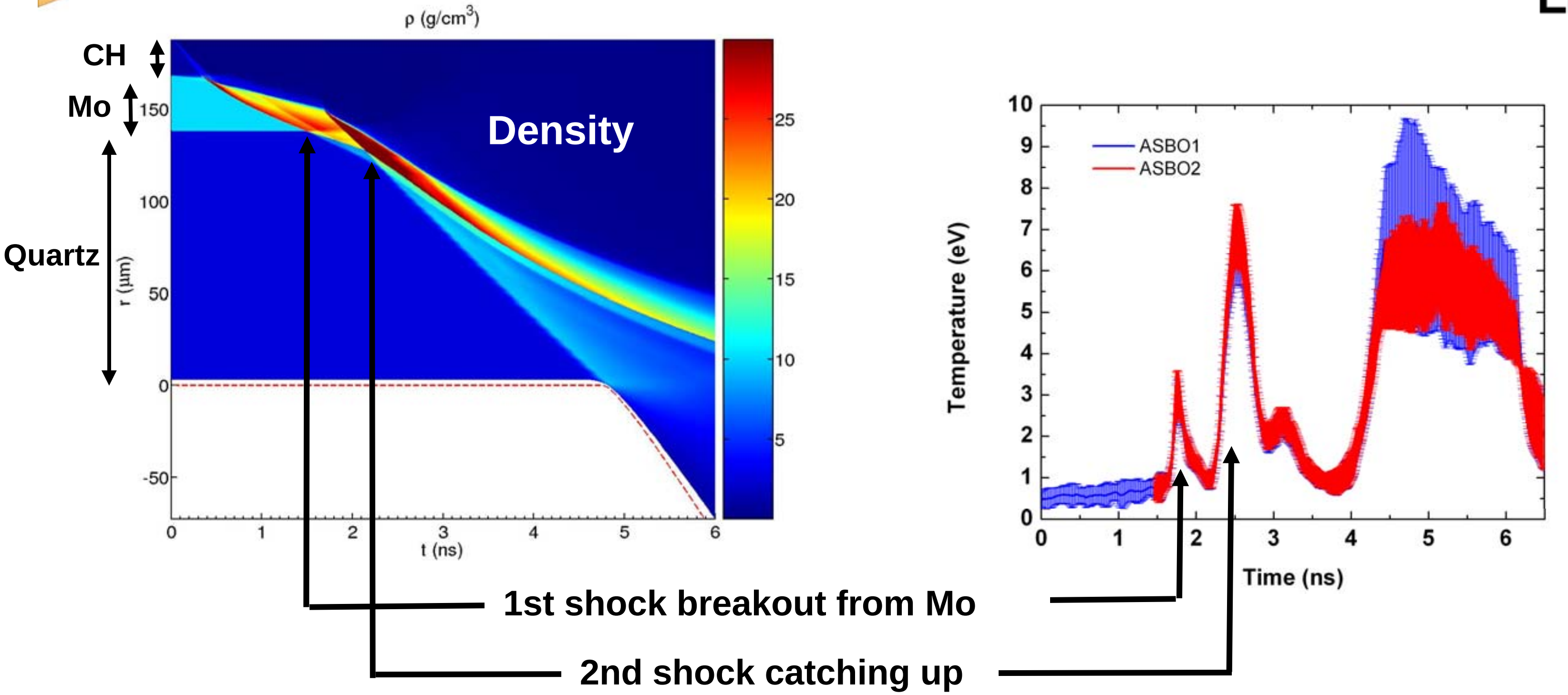
# Laser-Plasma Interaction Experiments at Shock-Ignition relevant Intensities



1st shock breakout from Mo

2nd shock catching up

**W. Theobald**
**University of Rochester**
**Laboratory for Laser Energetics**

**9th MEETING FUSION SCIENCE CENTER FOR EXTREME STATES OF MATTER**
**Lawrence Livermore National Laboratory**
**Livermore CA**
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# High intensity laser-plasma interaction experiments provide valuable backscattering, fast electron, and shock wave timing data

**Single high intensity beams interacting with imploding capsule:**

- **Up to 35% of the shock-beam laser energy is lost due to backscatter**
- **Up to 16% of the energy of the high intensity beams was converted into hot electrons of ~45 keV temperature**

**6 overlapping beams interacting a preformed plasma from planar target:**

- **The measured hot electron temperature is a factor ~3 higher (~150 keV) and conversion efficiencies are lower (~6%)**
- **The measured optical signatures of the 1st and 2nd shock waves roughly agree with 1D simulations**
- **A curved and delayed shock front at breakout indicates that 2D effects are important**

# Collaborators

**K. S. Anderson,[1] R. Betti,[1] D. Fratanduono,[1] J. A. Frenje,[2] M. Hohenberger,[1] S. Hu,[1] D. D. Meyerhofer,[1] T. C. Sangster,[1] W. Seka,[1] C. Stoeckl,[1] B. Yaakobi,[1] A. Casner,[3] X. Ribeyre,[4] and G. Schurtz[4]**

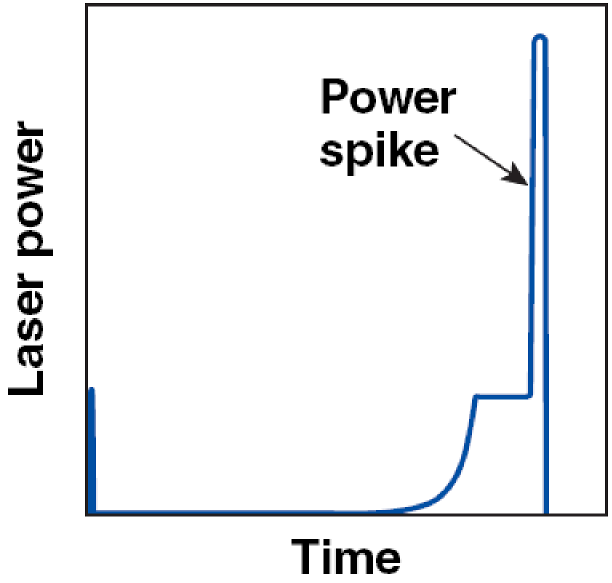
**[1]Fusion Science Center and Laboratory for Laser Energetics, Rochester, NY, USA**

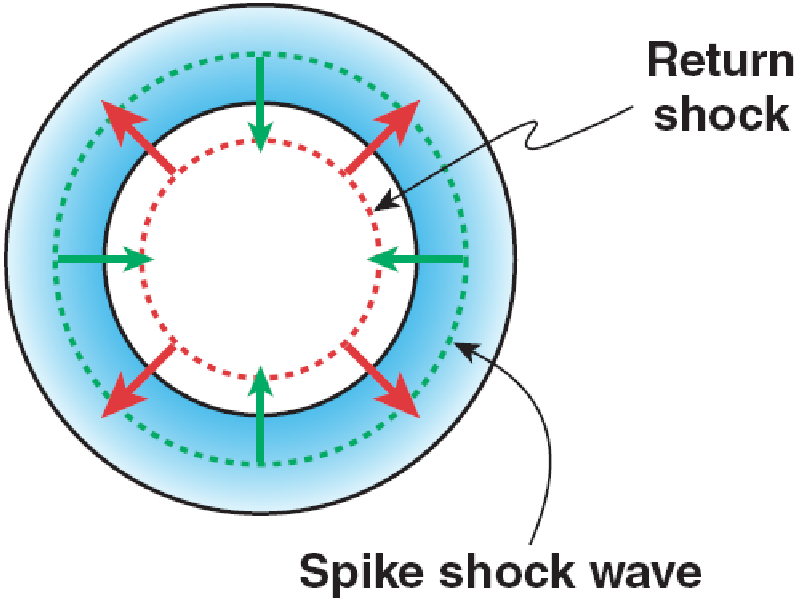
**[2]Massachusetts Institute of Technology, Cambridge, MA, USA**

**[3]CEA, DAM, DIF, Arpajon, France**

**[4]Centre Lasers Intenses et Applications, University of Bordeaux, France**

# Shock ignition relies on a shaped laser pulse with a trailing high-intensity spike

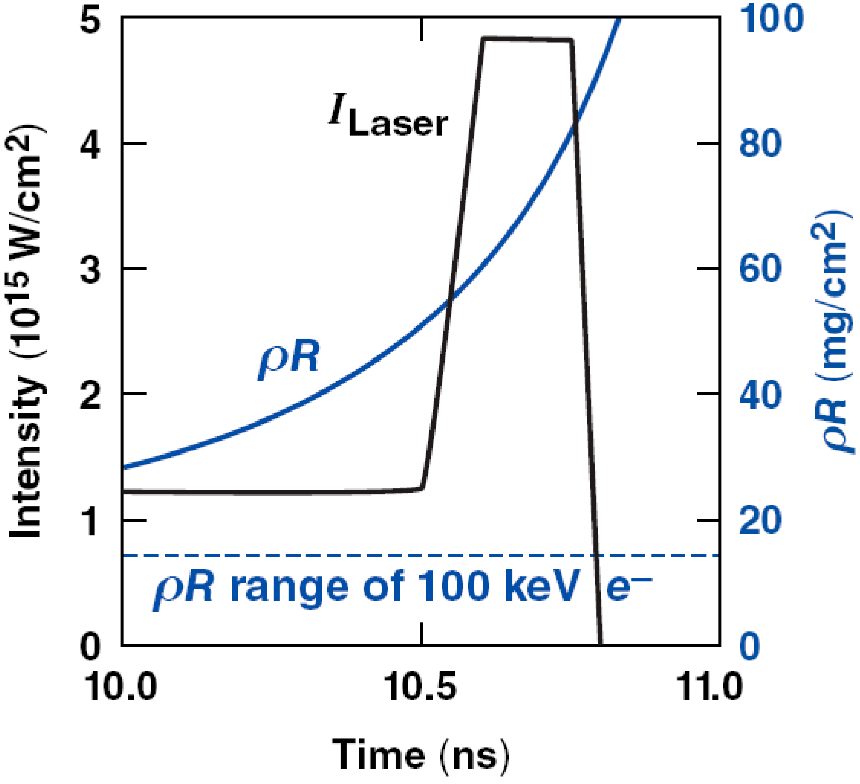


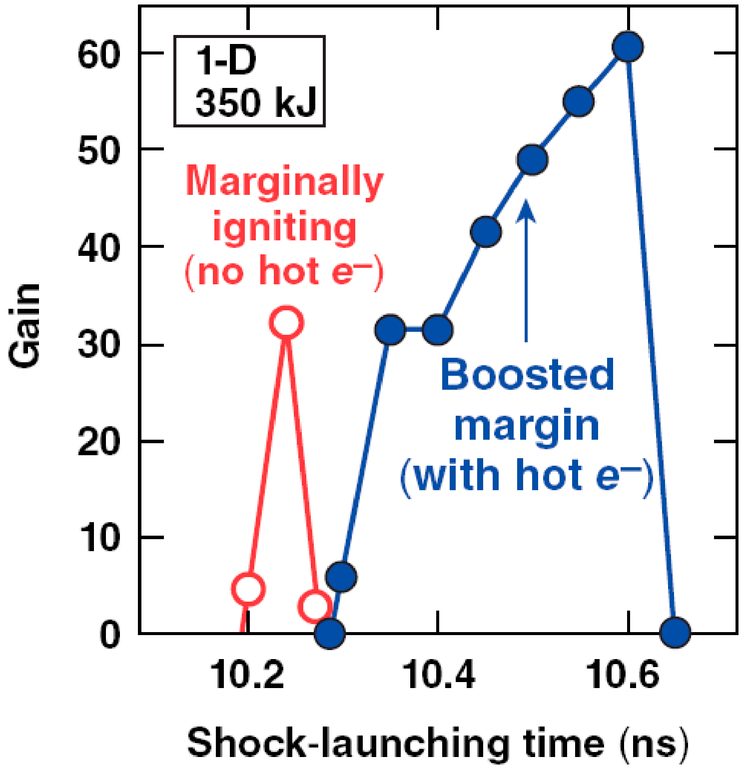


**The ignitor shock wave significantly increases its strength as it propagates through the converging shell.**

# Laser–plasma interaction during the spike pulse and hot-electron generation are important issues for shock ignition

Shock-ignition target with 350-kJ total energy





Hot e⁻ with Maxwellian $T_{hot}$ = 150 keV, $E_{hot}$ = 17% of spike energy, treated using a multigroup diffusion model*

TC7870d

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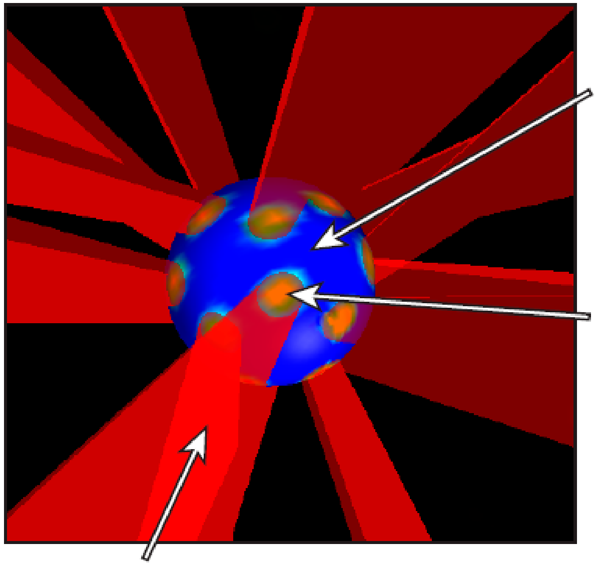
*LILAC simulations by C. D. Zhou and R. Betti

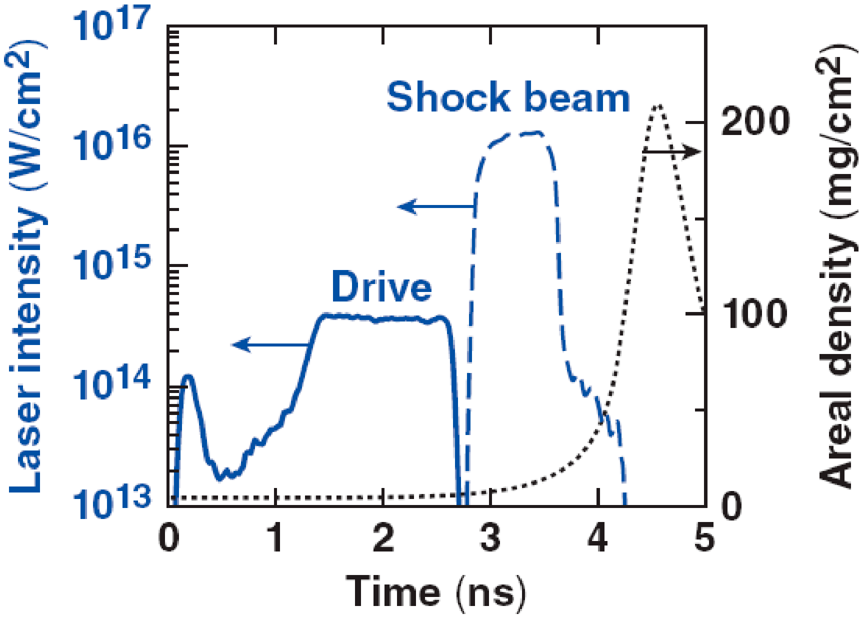
# 60 OMEGA beams were split into 40 low-intensity drive beams and 20 tightly focused, delayed beams



Critical density surface

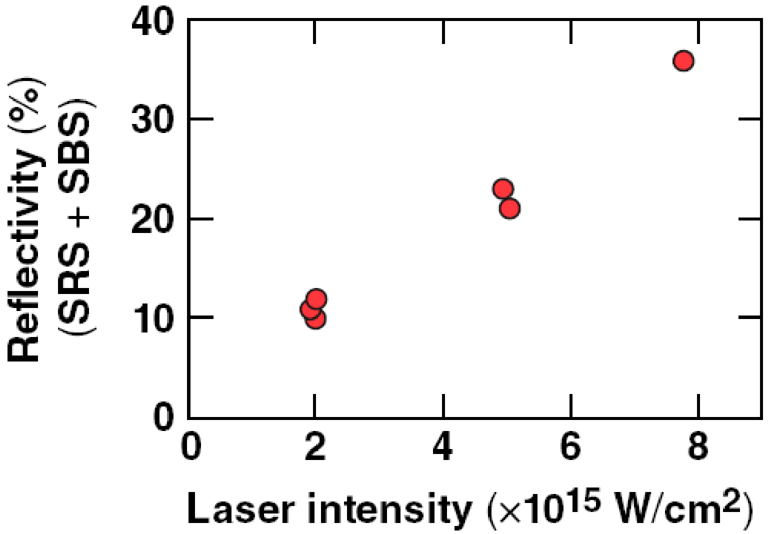
Fast electrons

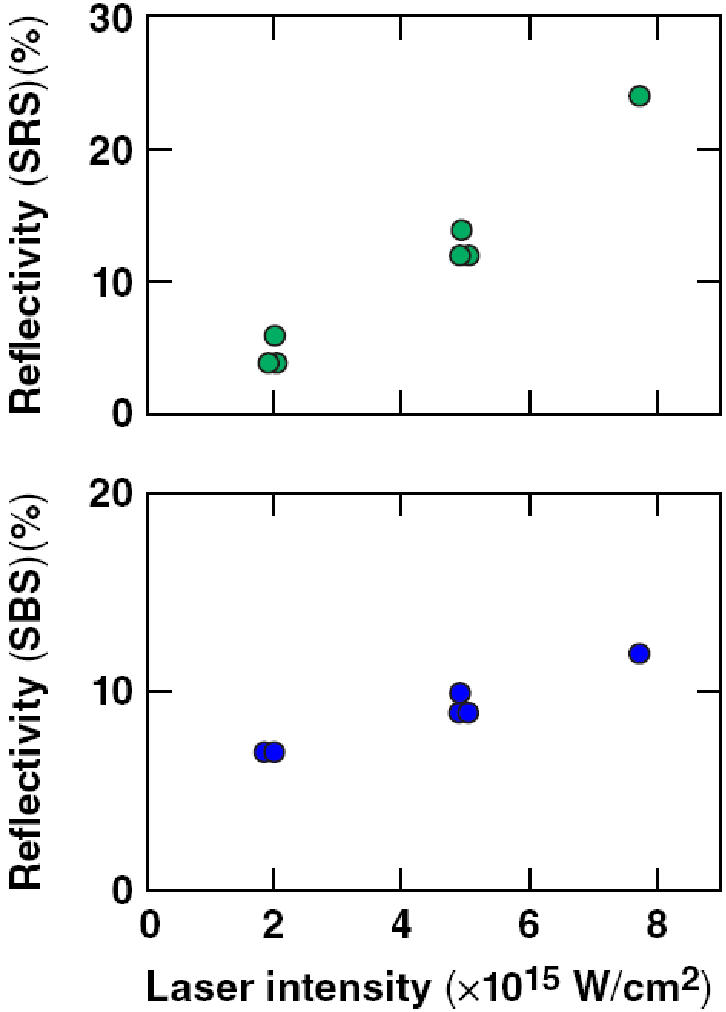
Shock beams ~$10^{16}$ W/cm$^2$



- Density scale length ~200 μm
- The delay and intensity of the tightly focused beams were varied
- Laser backscattering and hot-electron generation were studied

# Up to 35% of the shock-beam laser energy is lost due to backscatter

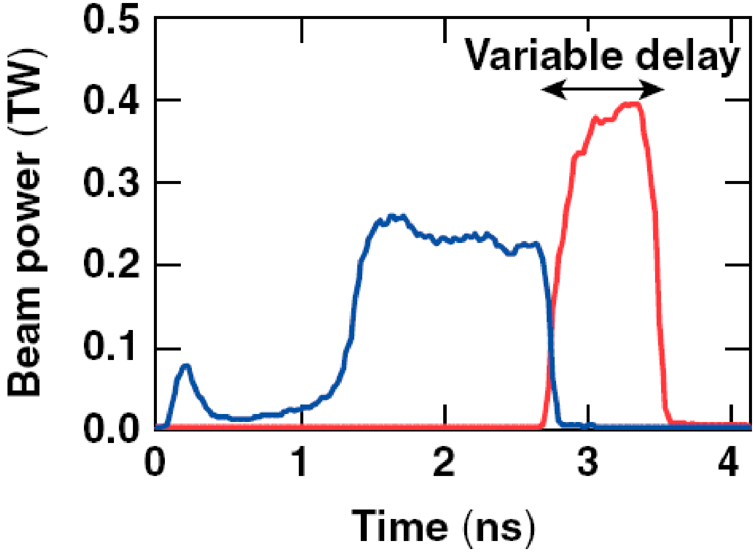


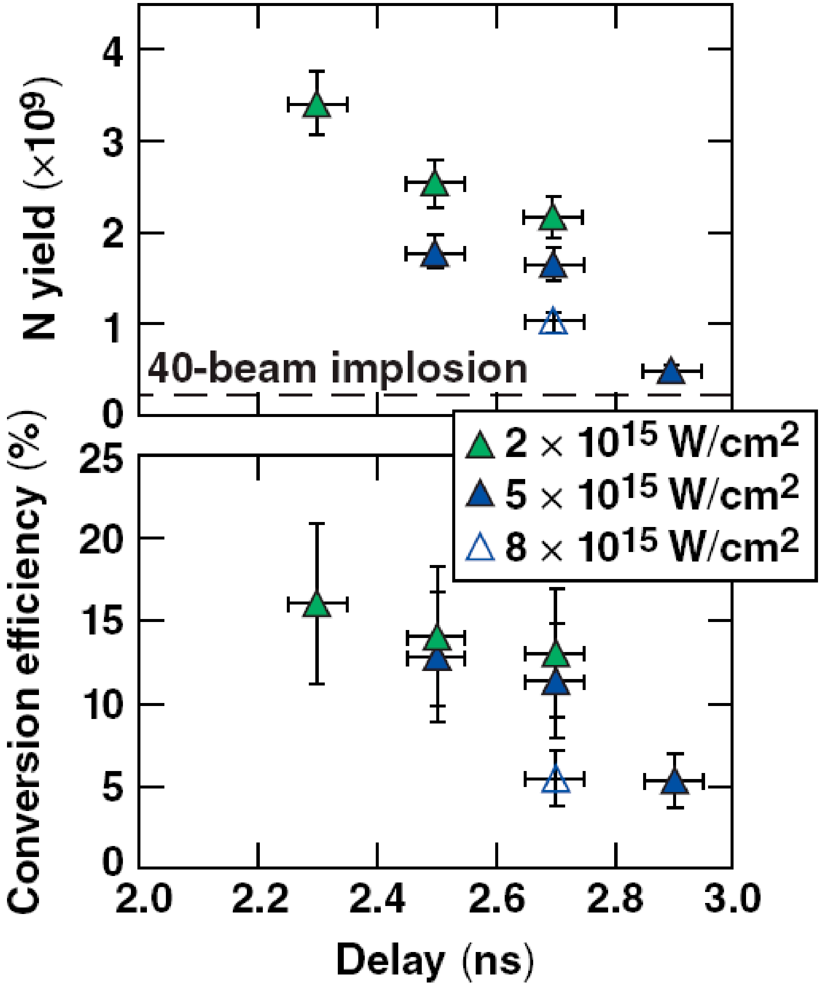


- No measurable signal of the 3/2 harmonic
- SRS dominates back reflection at highest intensity
- SBS reflection is relatively stable at ~10%

E18435

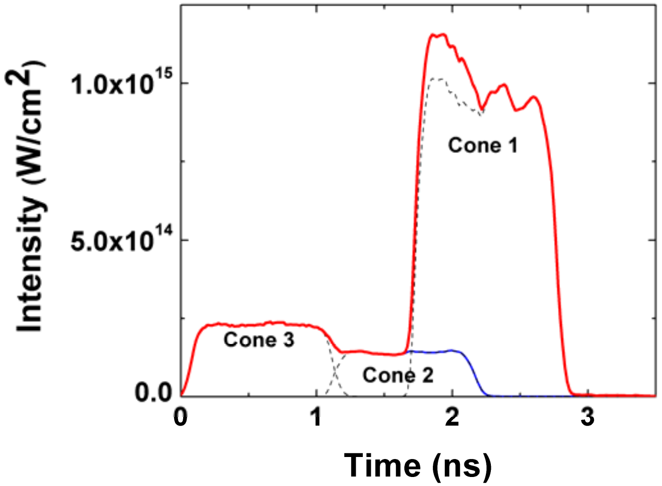
# Up to 16% of the shock-beam energy is converted into hot electrons of 45-keV temperature

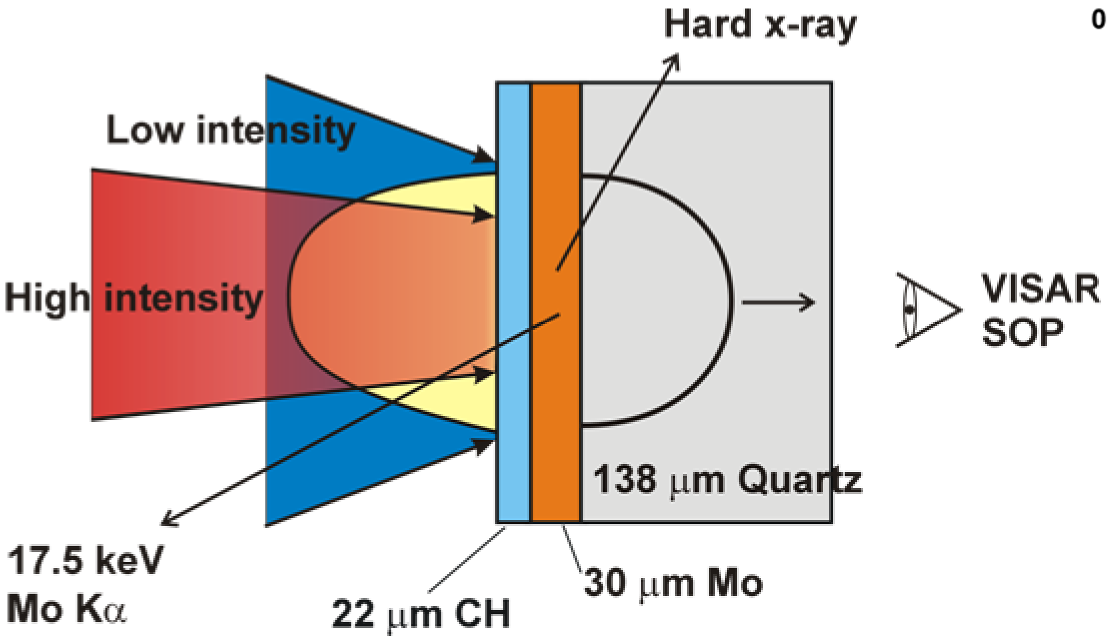




# A laser-plasma interaction experiment was performed in planar geometry with overlapping beams

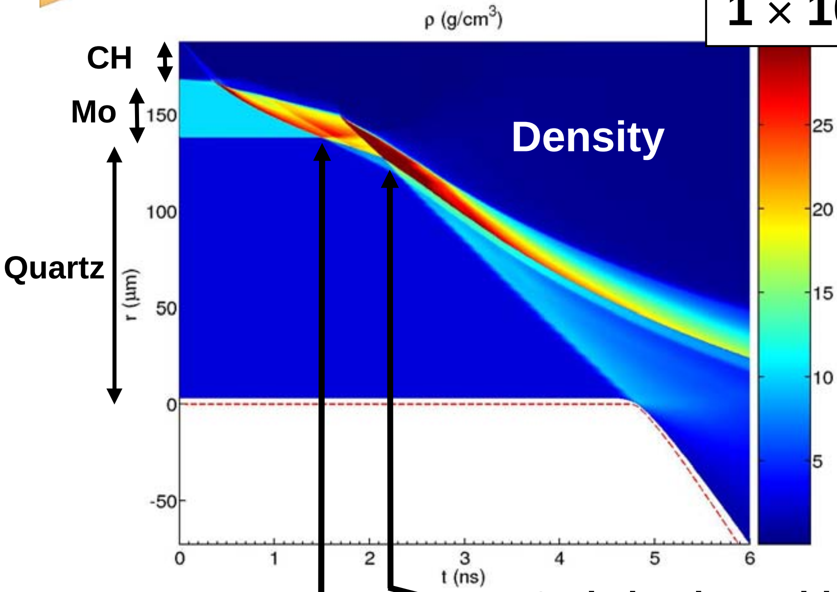
- **Pre-plasma: ~2 × $10^{14}$ W/cm$^2$**
- **Shock: ~1 - 6 × $10^{15}$ W/cm$^2$**
- **Density scale length: ~500 μm**

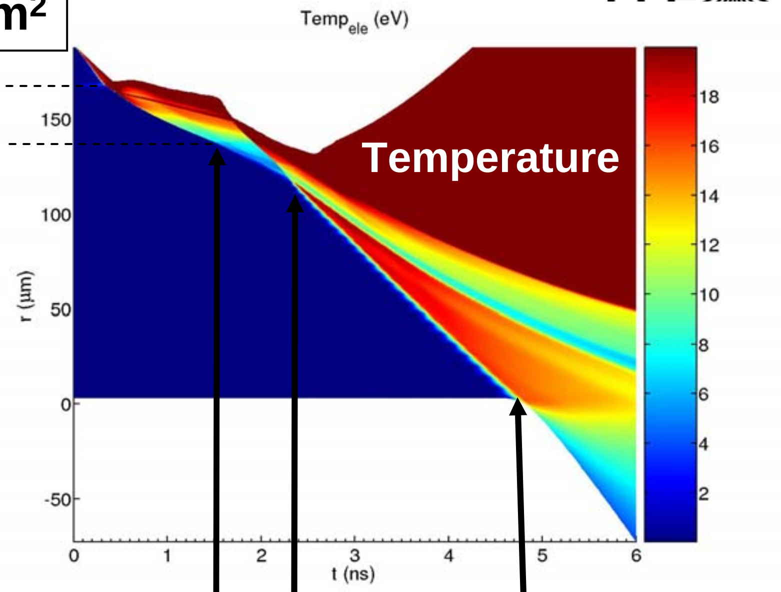




# The measured optical signatures of the 1st and 2nd shock waves roughly agree with 1D simulations with the code CHIC

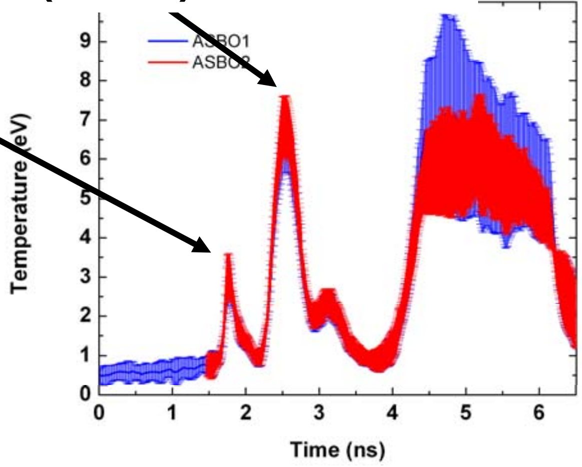
$1 \times 10^{15}$ W/cm$^2$





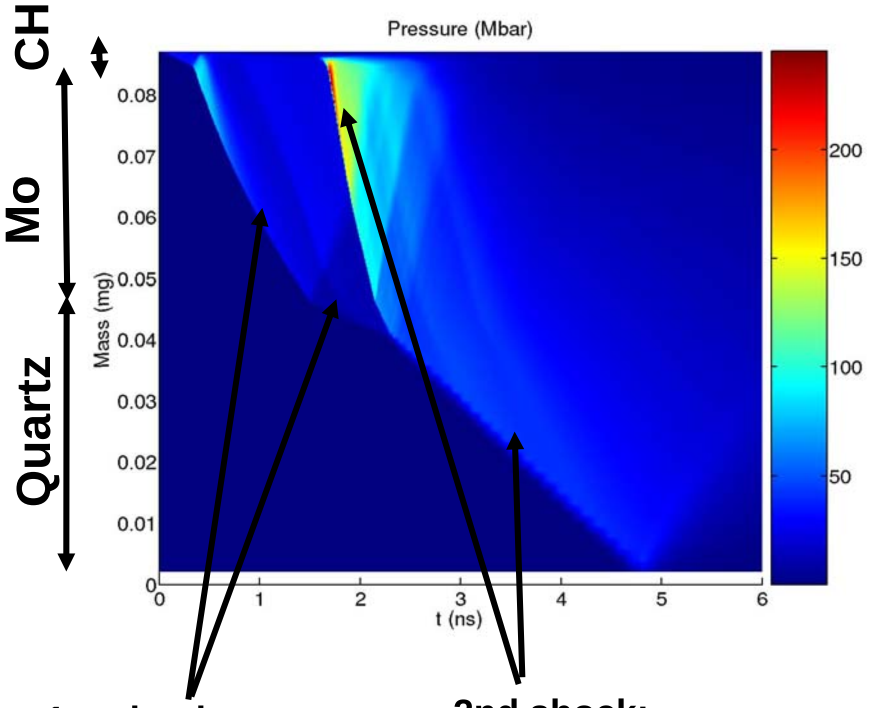
2nd shock catching up (~2.2 ns)

1st shock breakout from Mo into quartz (~1.5 ns)



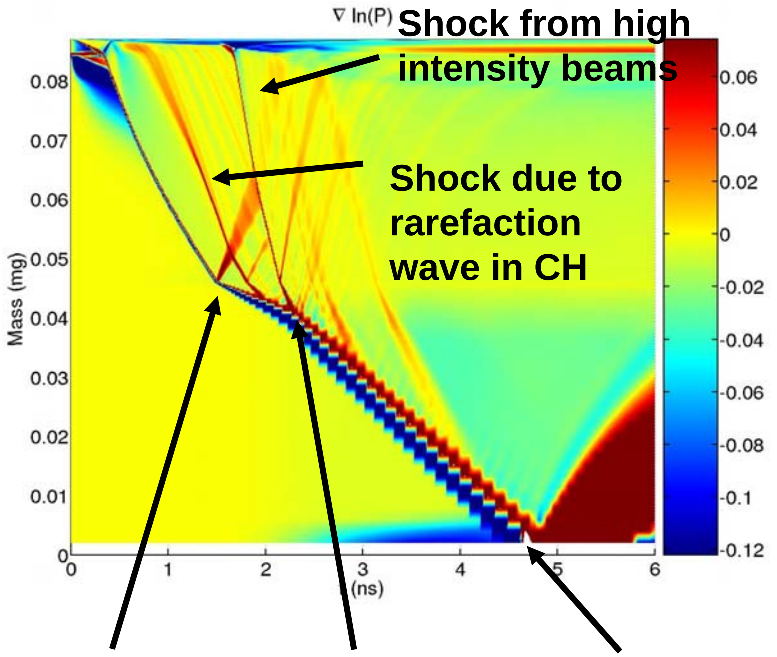
Shock breakout at rear side (~4.8 ns). Observed later in the experiment

# 1D hydrodynamic simulations predict an initial plasma pressure of ~200 Mbar for ~1×10$^{15}$ W/cm$^2$



1st shock:
~25-35 Mbar in Mo
~10 Mbar in quartz

2nd shock:
~200 Mbar in CH
~100-150 Mbar in Mo
~35-40 Mbar in quartz



Shock from high intensity beams

Shock due to rarefaction wave in CH

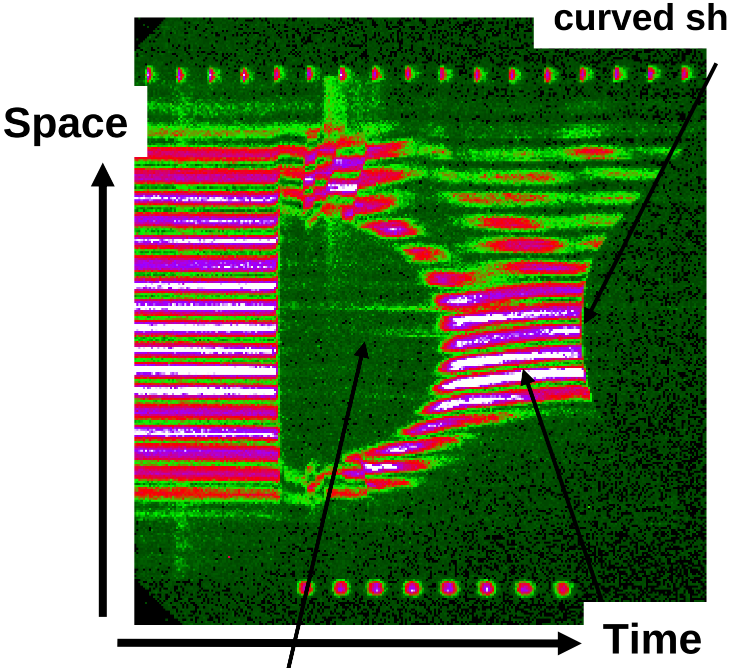
1st shock breakout from Mo into quartz (~1.5 ns)

2nd shock catching up (~2.2 ns)

Breakout at rear surface

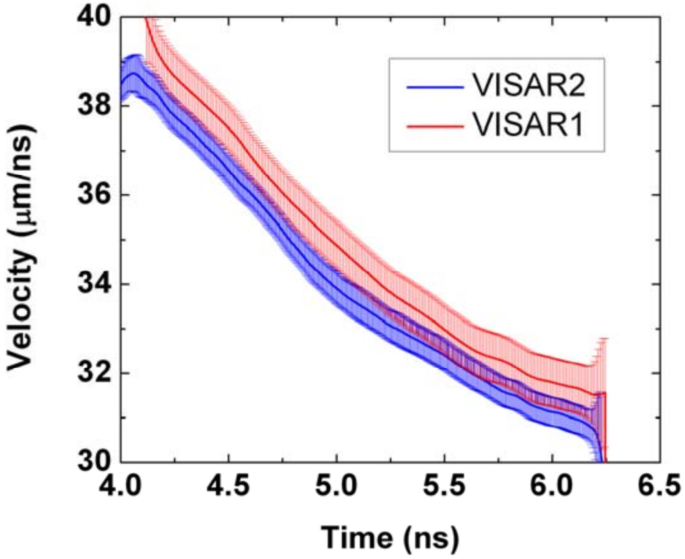
# VISAR measured a decaying, curved shock front in quartz for $1 \times 10^{15}$ W/cm$^2$

Shock breakout curved shock front



Blanking due to high intensity beams

Decaying shock

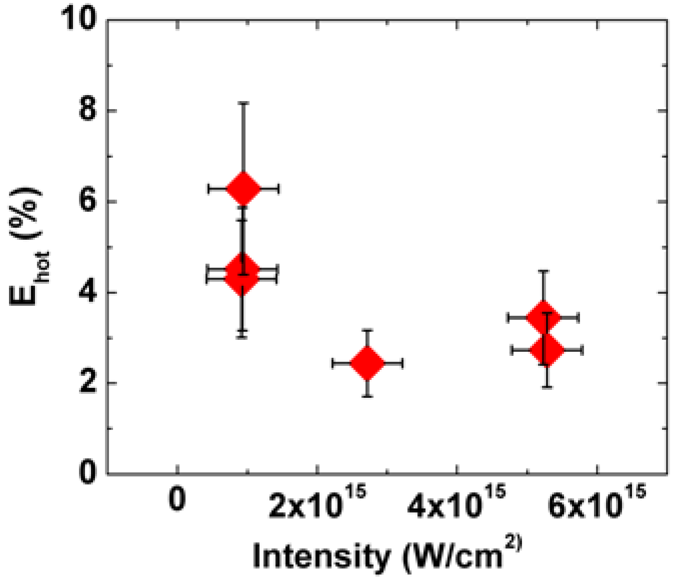


**Predicted shock velocity from 1D simulation ~47 μm/ns**

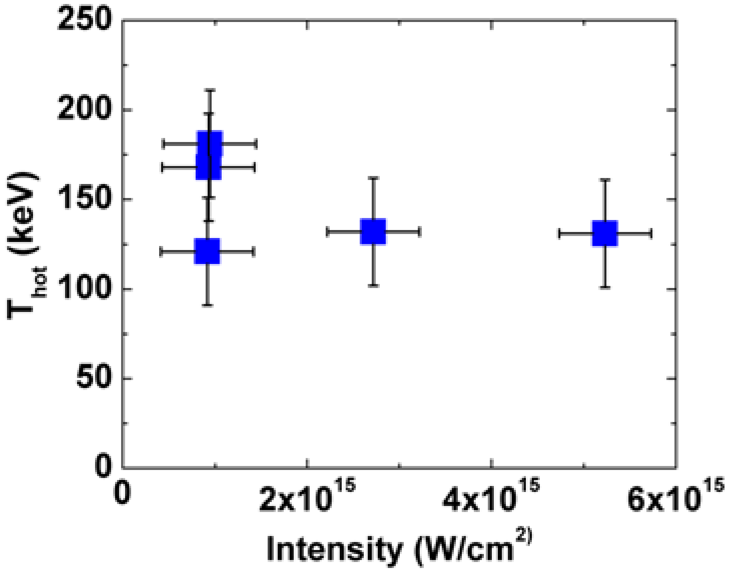
- 2D DRACO and CHIC simulations will study the shock front curvature and slowing down due to 2D effects

# Up to 6% of the high intensity laser energy is converted into hot electrons

Hot electron energy fraction versus intensity



Hot electron temperature versus intensity



- The measured hot electron temperature is a factor ~3 higher compared to spherical target experiment
- 1D LILAC simulations will be performed to study the effect of the fast electron component on the shock formation and shock propagation

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