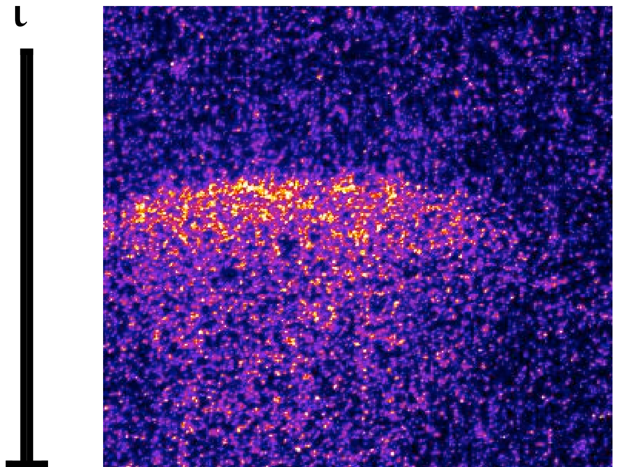
Application of short puls laser driven x-ray sources

Erik Brambrink

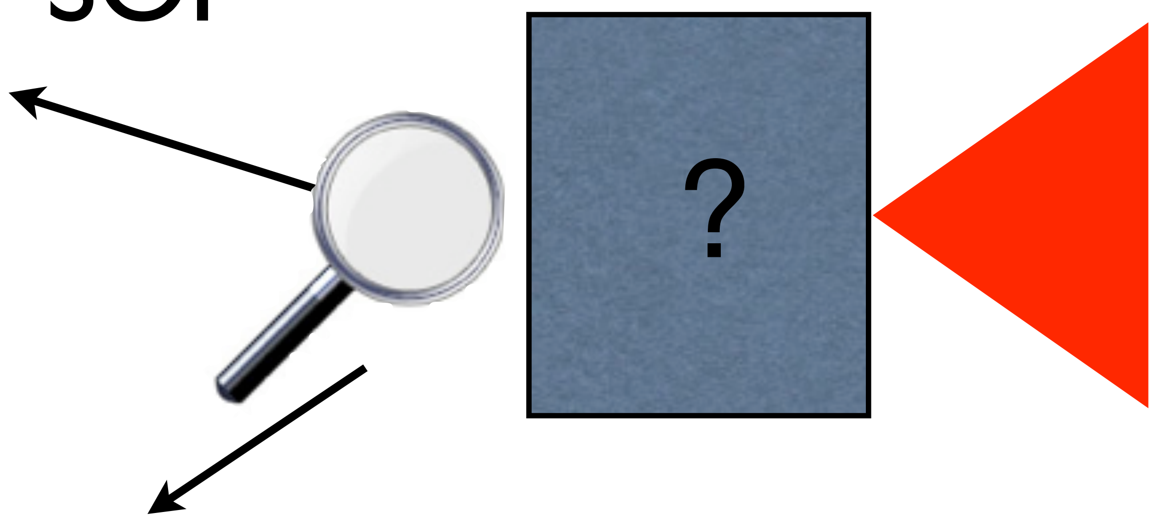
Science with high power laser and pulsed power workshop
Santa Fe, 2009

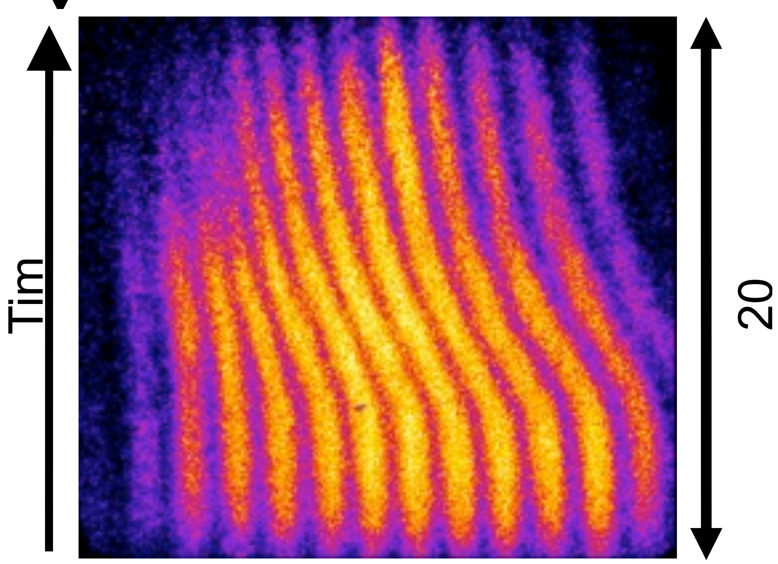
Why x-rays?

HEDP experiments are mostly based on surface diagnostics



SOP

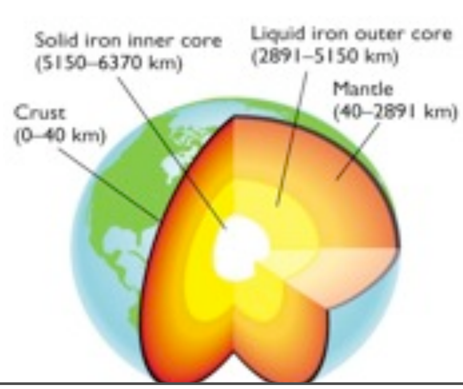




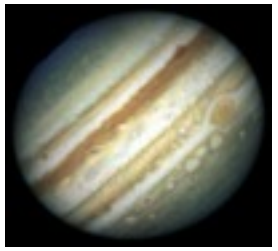
VISAR

x-rays can penetrate matter

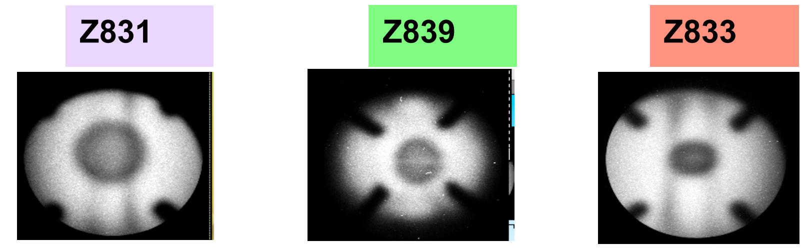
☛We can directly look inside



Important for material science, ICF, correlated plasma, etc.

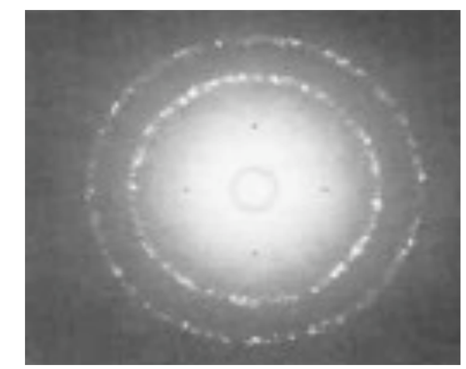


x-ray diagnostics



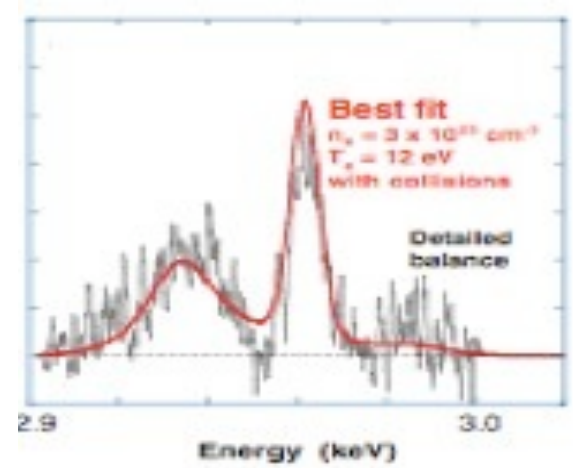
X-ray radiography

Absorption by bound electrons
→ ion density, shape



X-ray diffraction

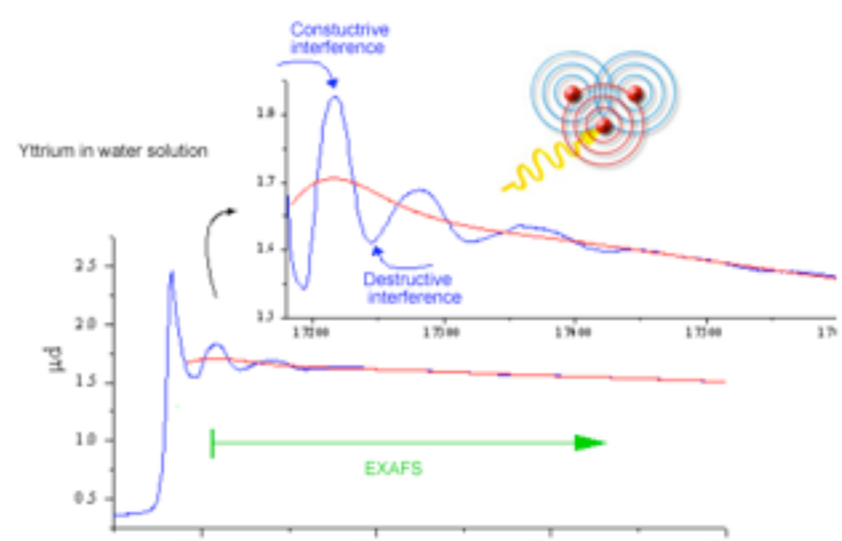
Coherent elastic scattering
→ lattice/ion structure



Glenzer et al. PRL 98,065002

X-ray Thomson scattering

Inelastic scattering
→ electron density and temperature

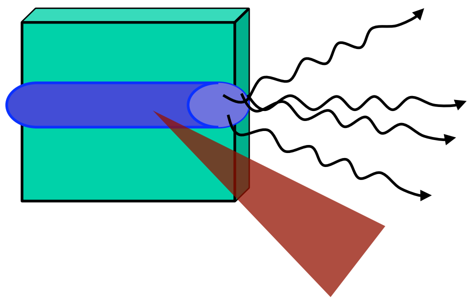


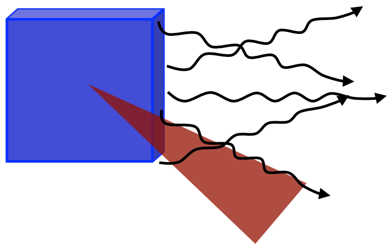
Near edge absorption spectroscopy

→ local chemistry and structure

What do we need?

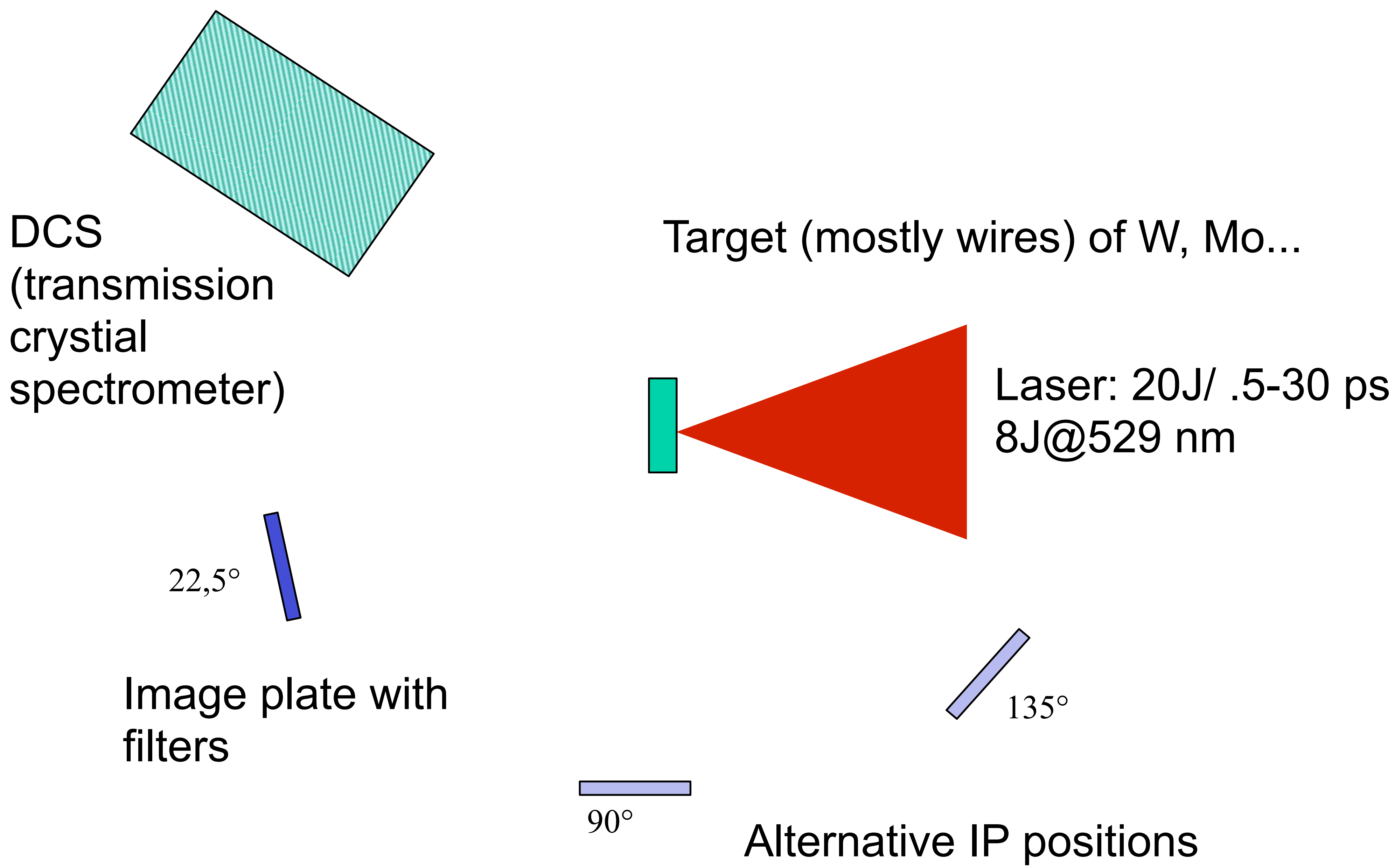
- High photon energies (5-100 keV)
  - High intensity lasers
- High temporal resolution
  - Short pulse laser
- High spatial or angular resolution
  - Target design



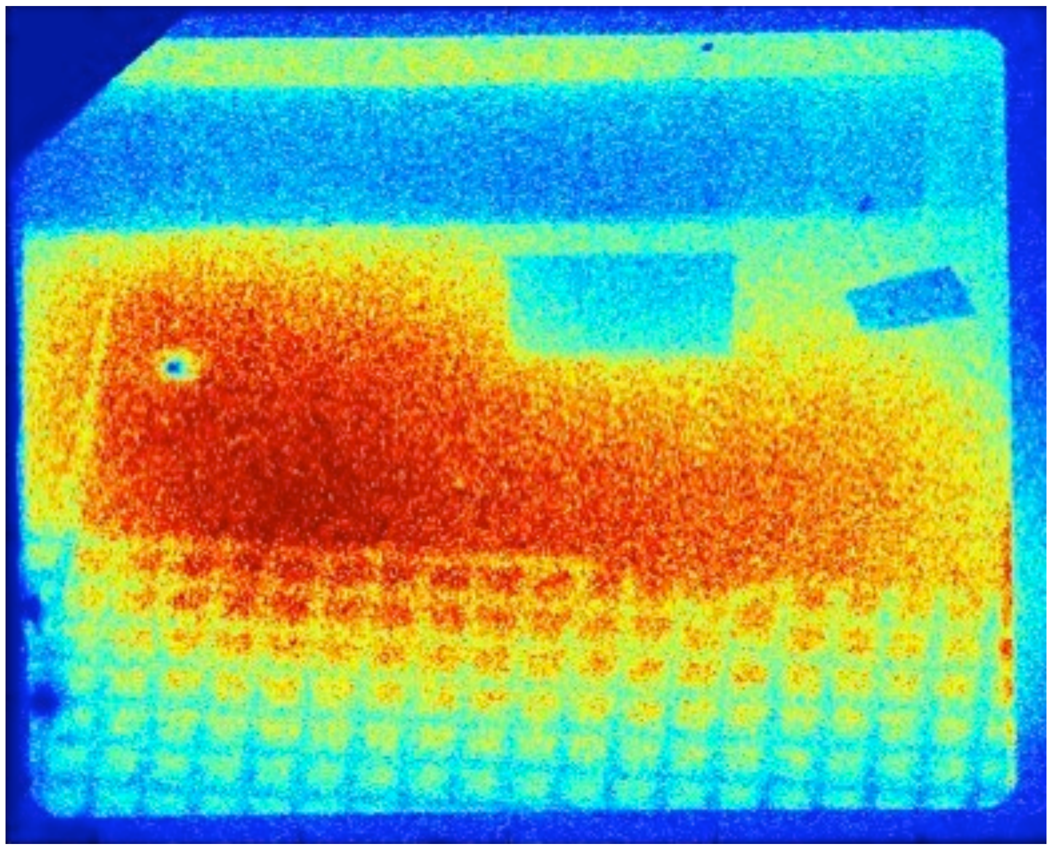


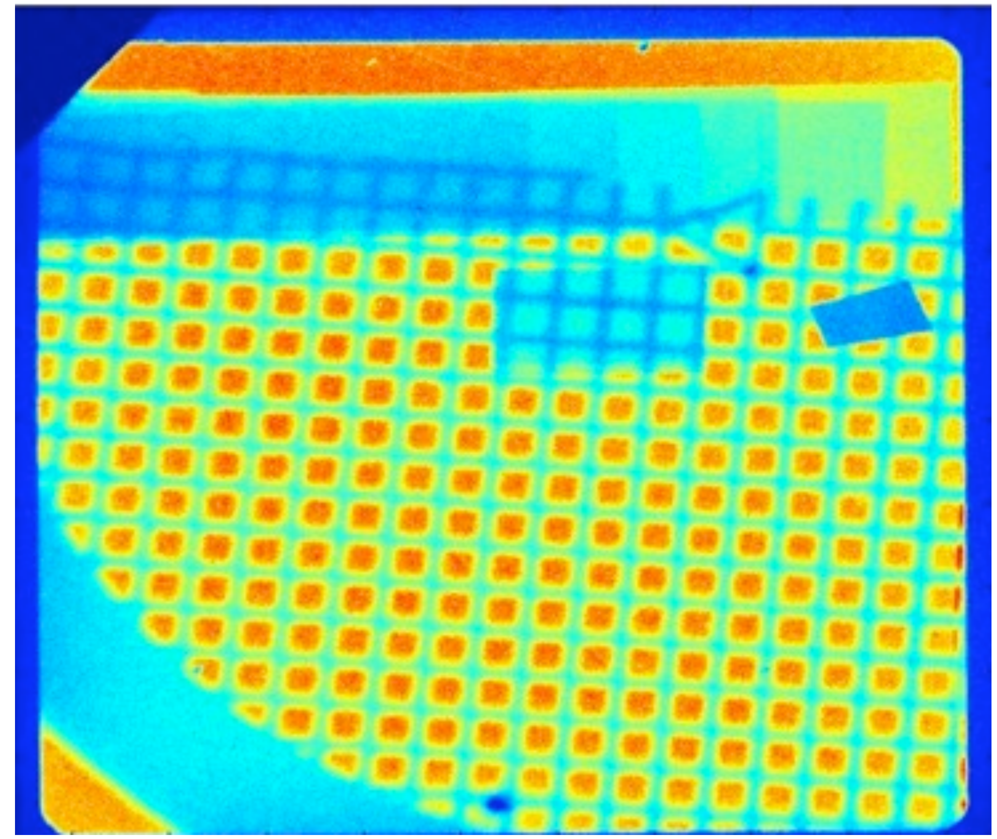
- Monochromatic or flat spectrum
  - Choice of target material, monochromators
- Large number of photons
  - High energy laser systems

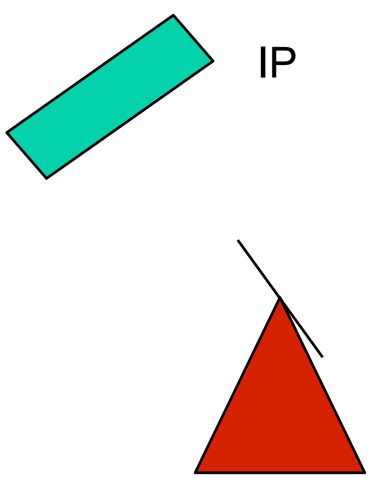
Setup for x-ray source studies



Role of the experimental geometry



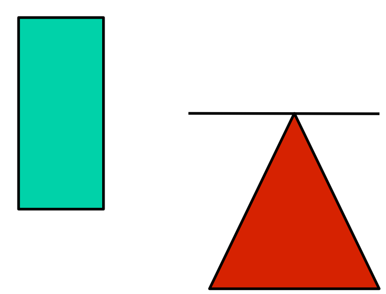




IP

oblique incidence
22,5°

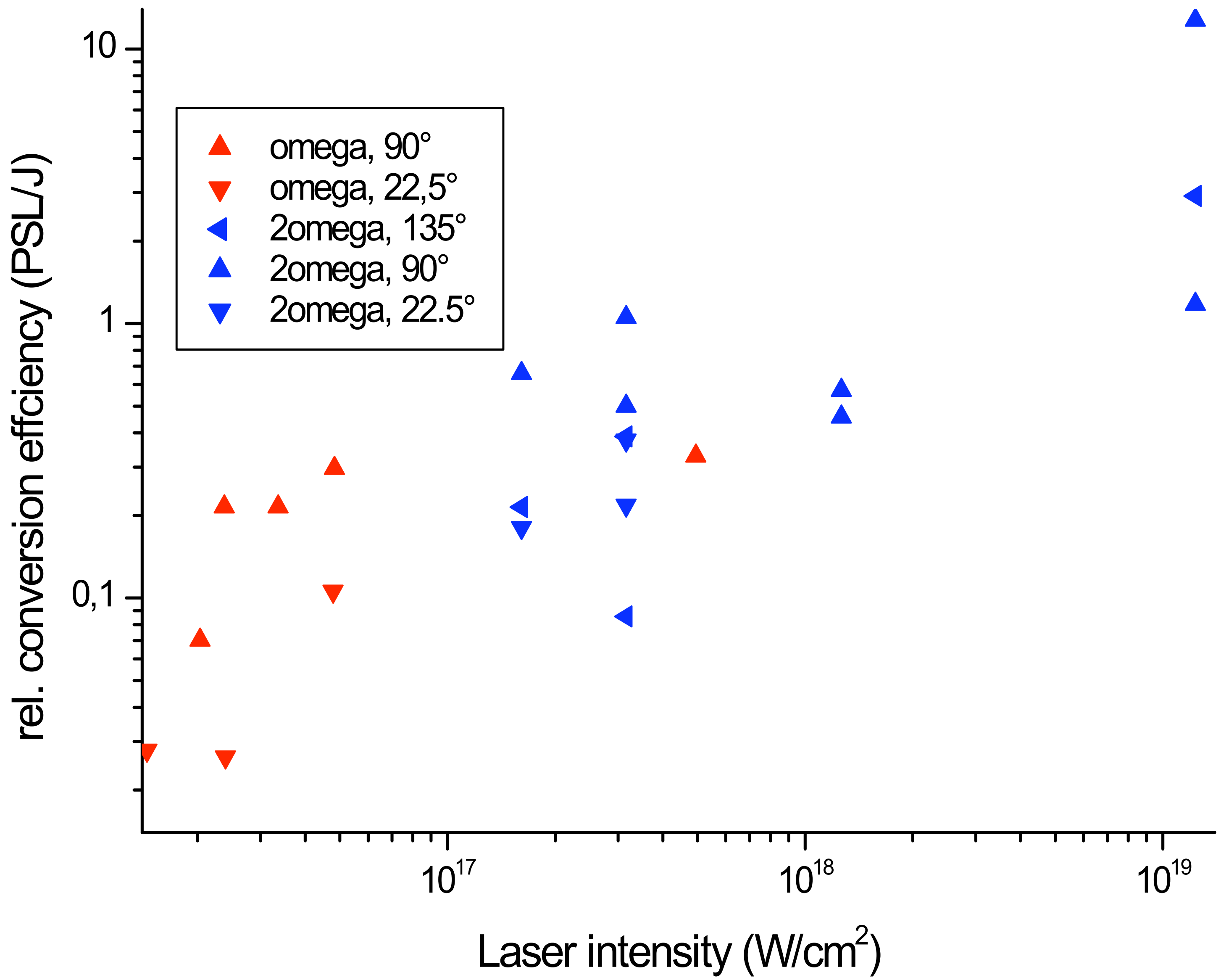
IP

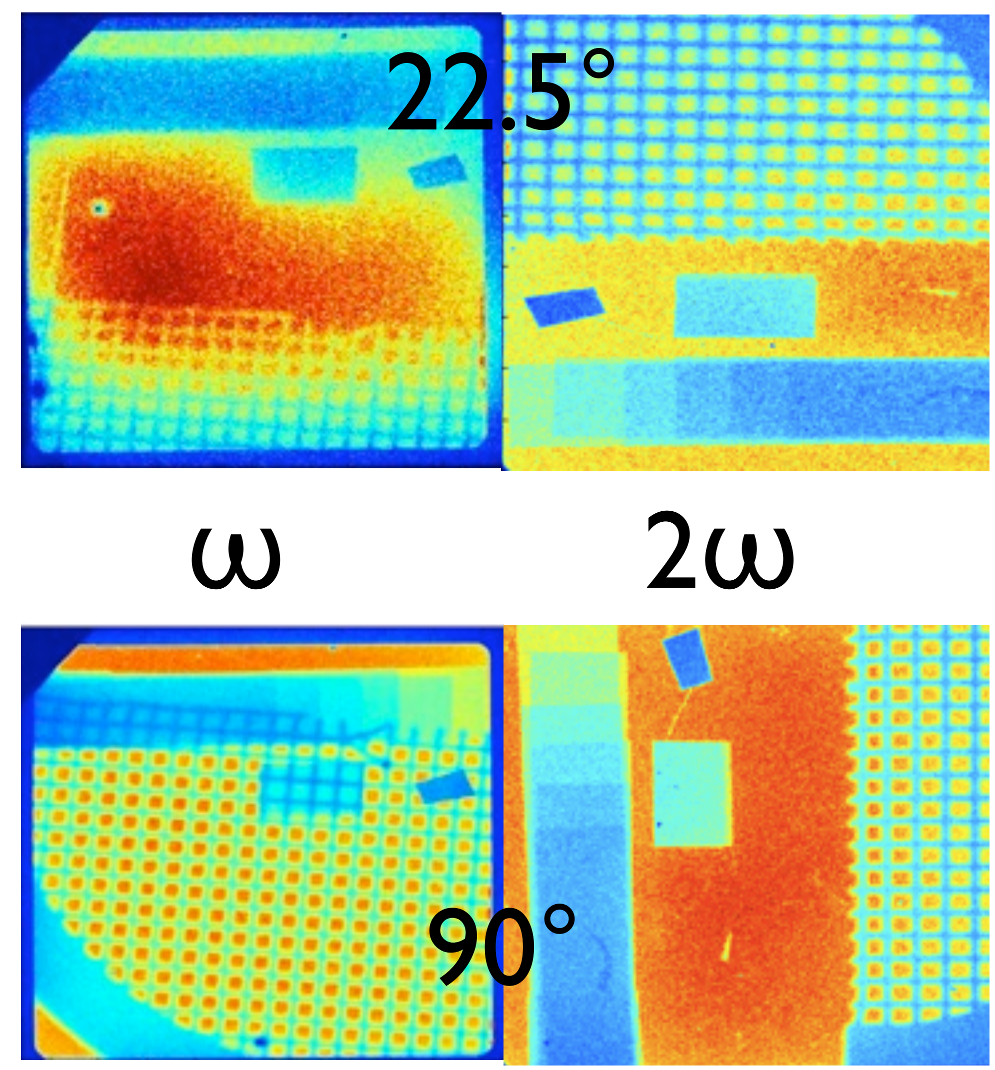


Perpendicular
incident:

Some experiments are not possible on certain installations

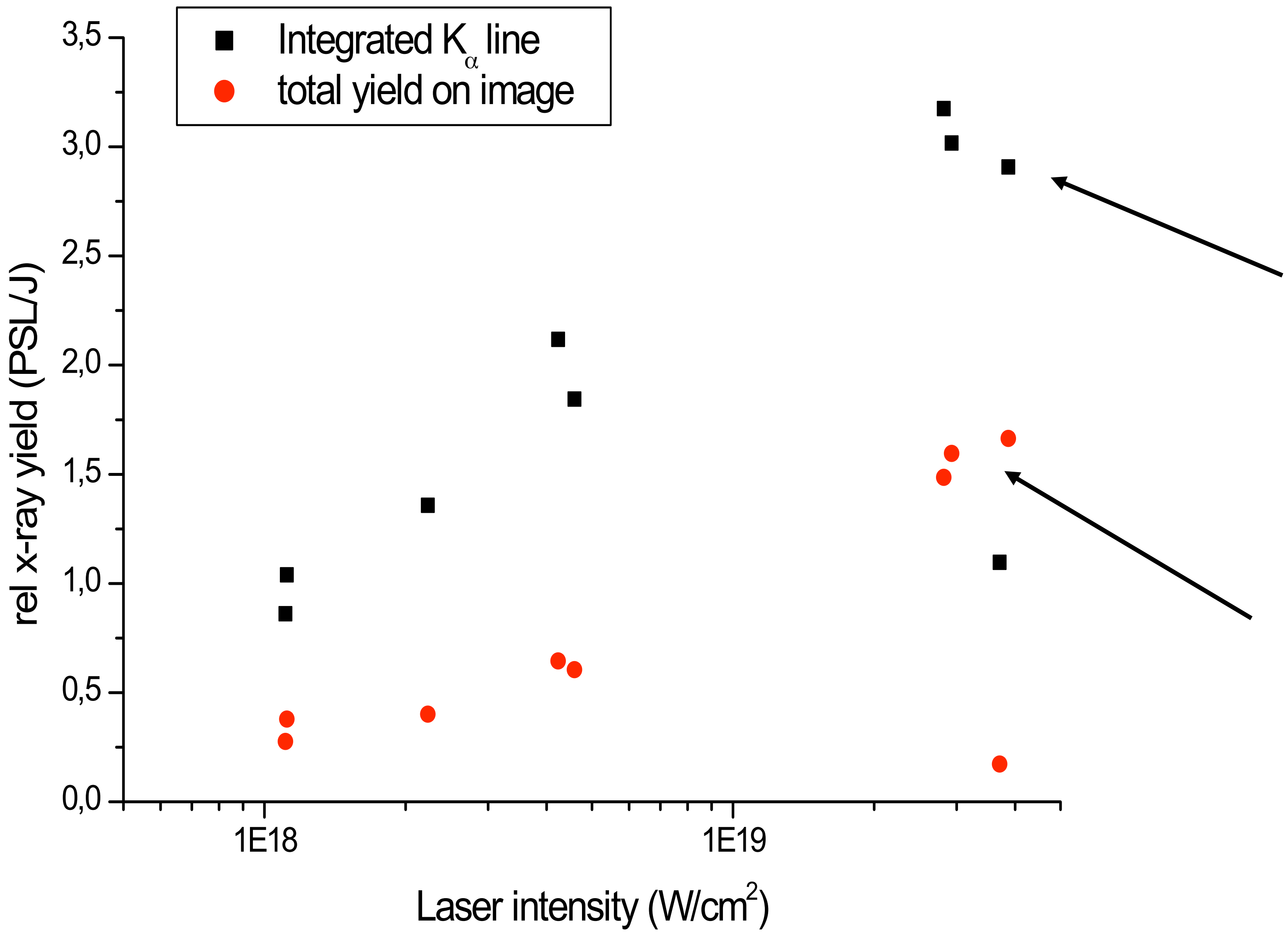
17.5 keV x-ray source

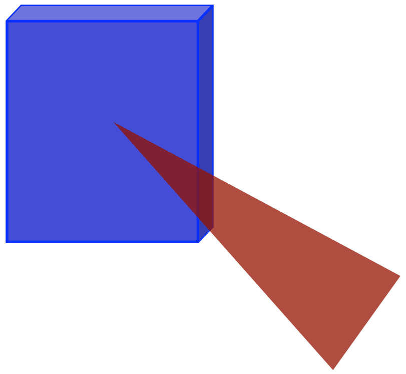


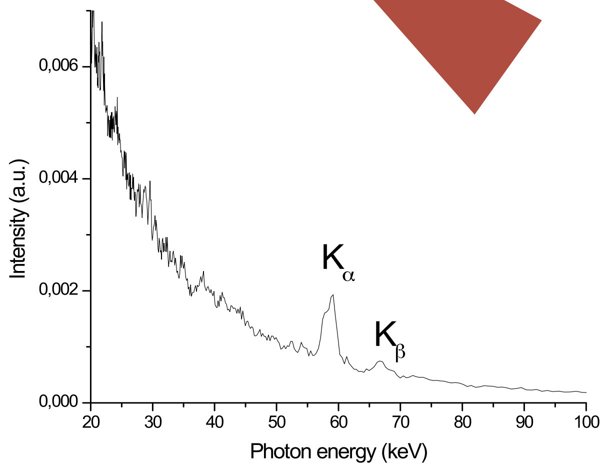


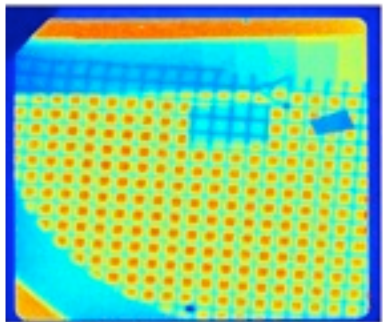
Frequency doubling can improve a lot at small incidence angles.
Effect has not been observed for higher photon energies

Intensity scan with flag targets



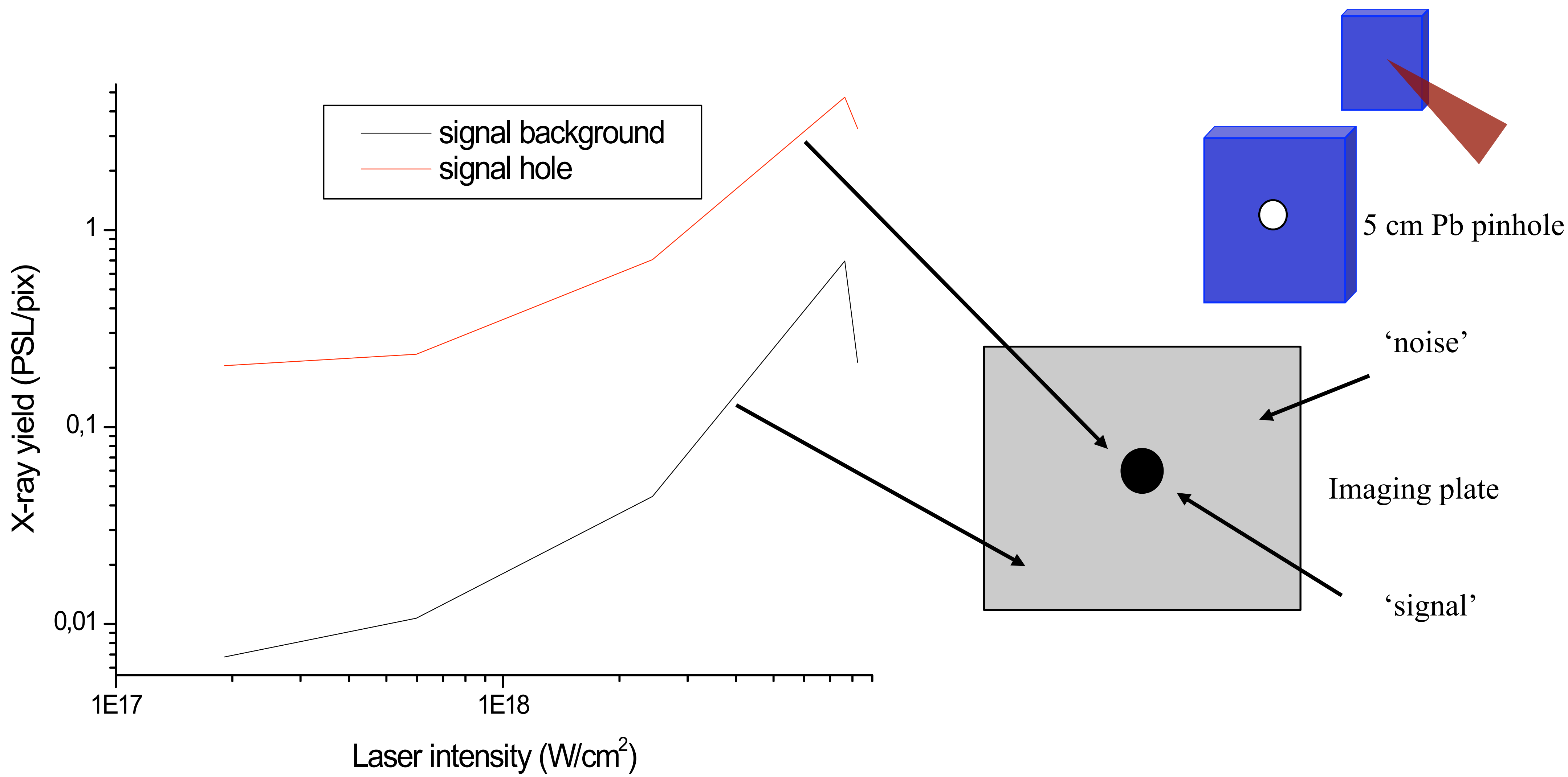






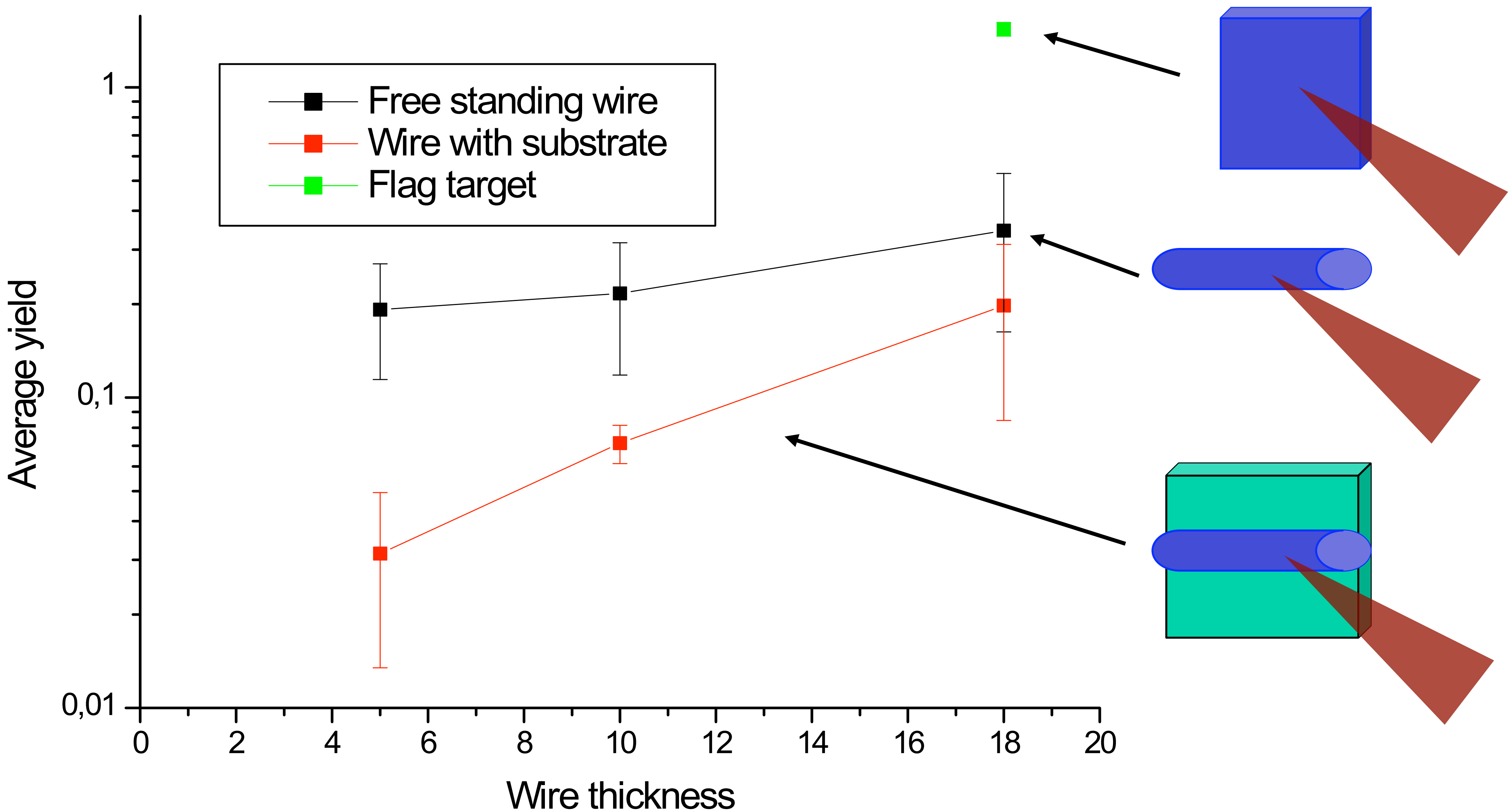
X-ray conversion efficiency increases with laser intensity for 60 keV photons. Contrary to results for lower photon energies

But: think of the noise, too



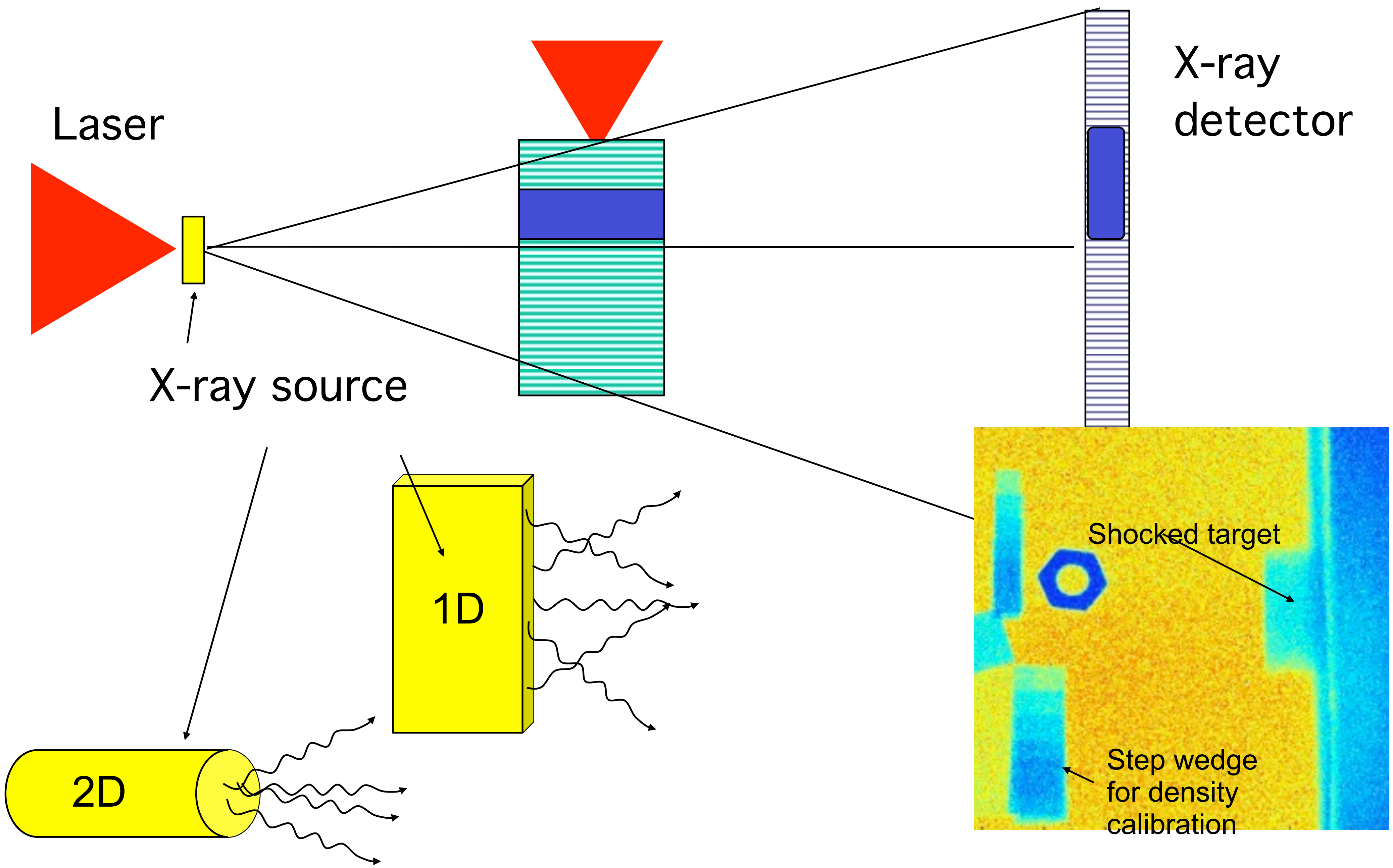
High intensities generate hard x-rays, which penetrate cms of lead (increase faster than signal). Not important for radiography, but for spectrally resolved diagnostics.

Free standing wires vs. supported

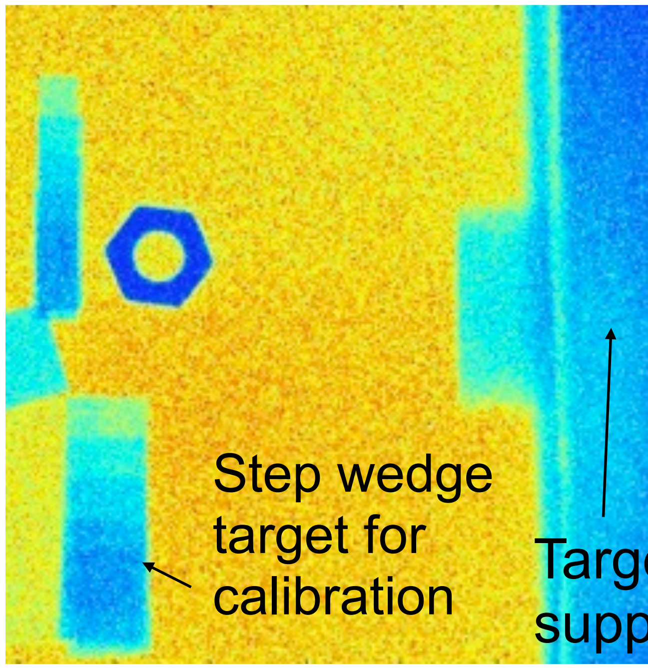


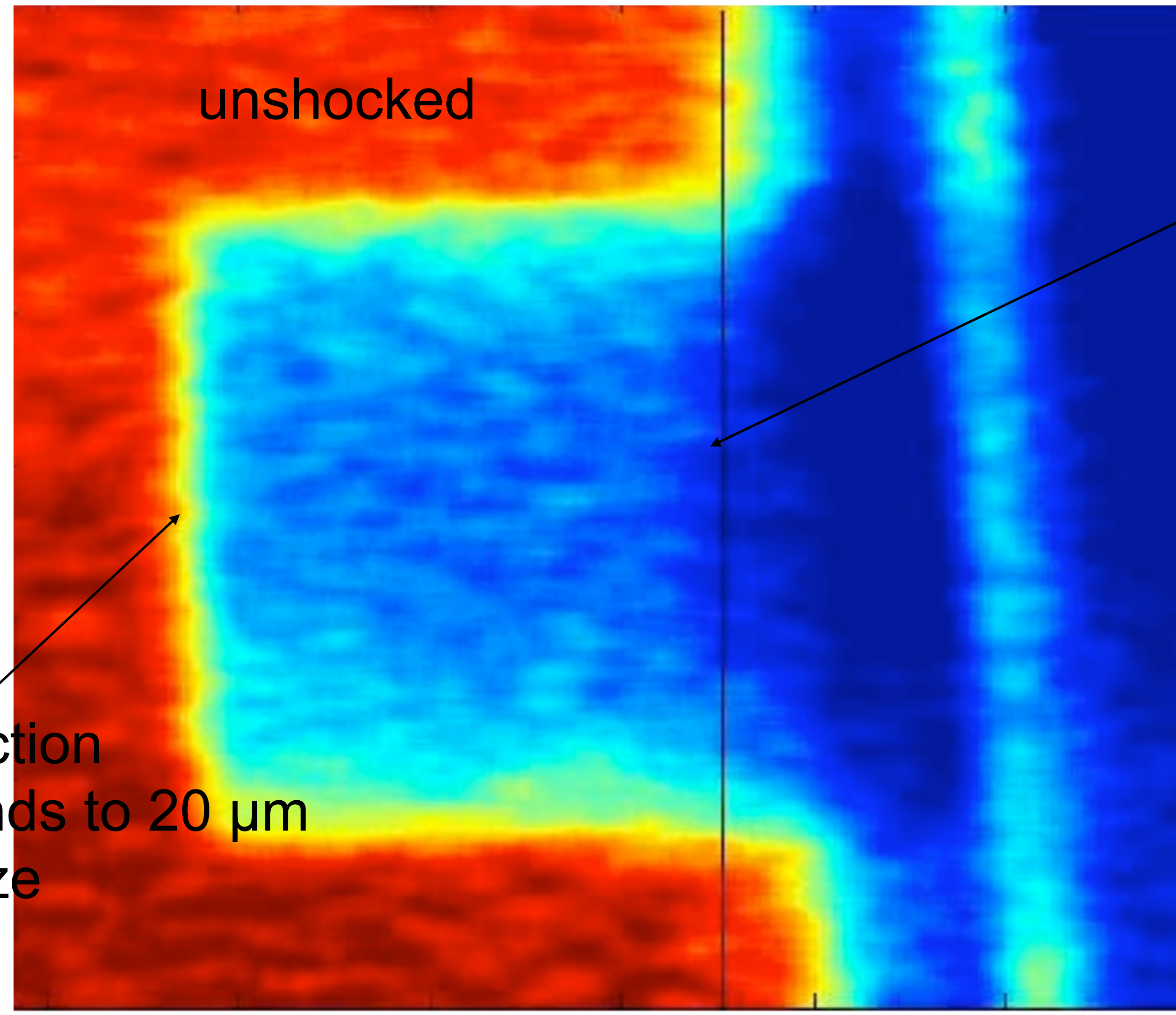
Free standing wires perform better, but pointing stability of the laser is crucial

Radiography setup



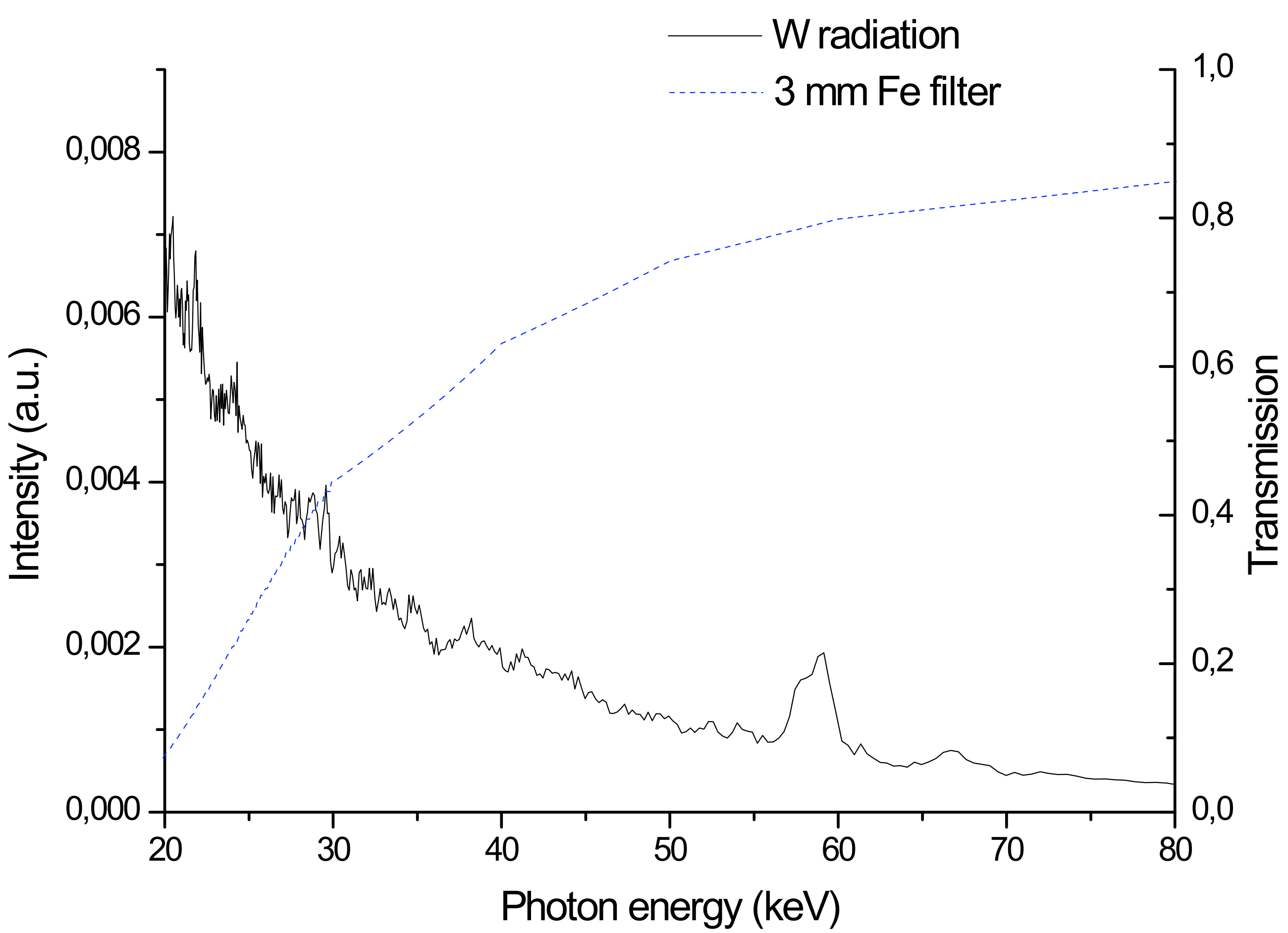
Radiography of shocked iron

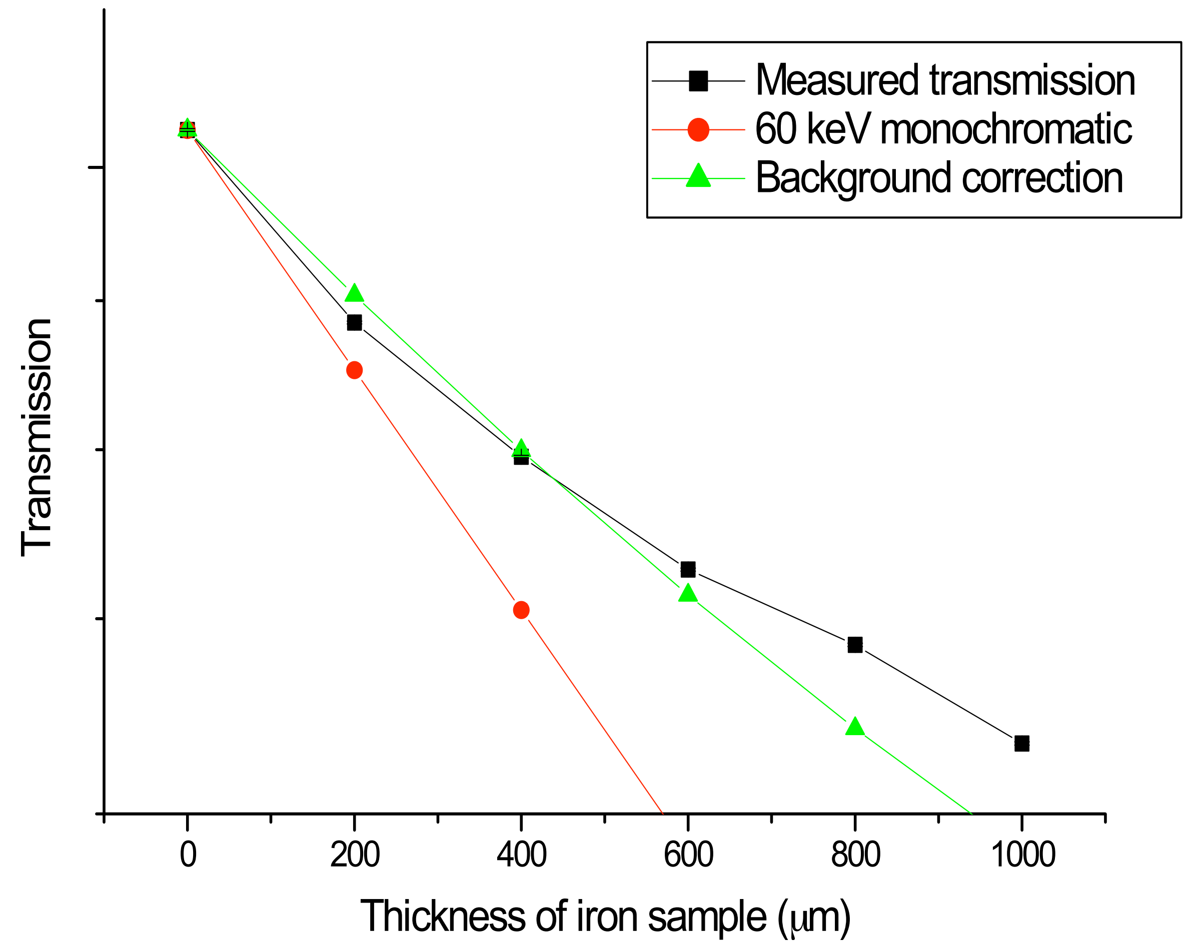




Noisy image due to low x-ray yield. Prepulse problem!

Source is not monochromatic

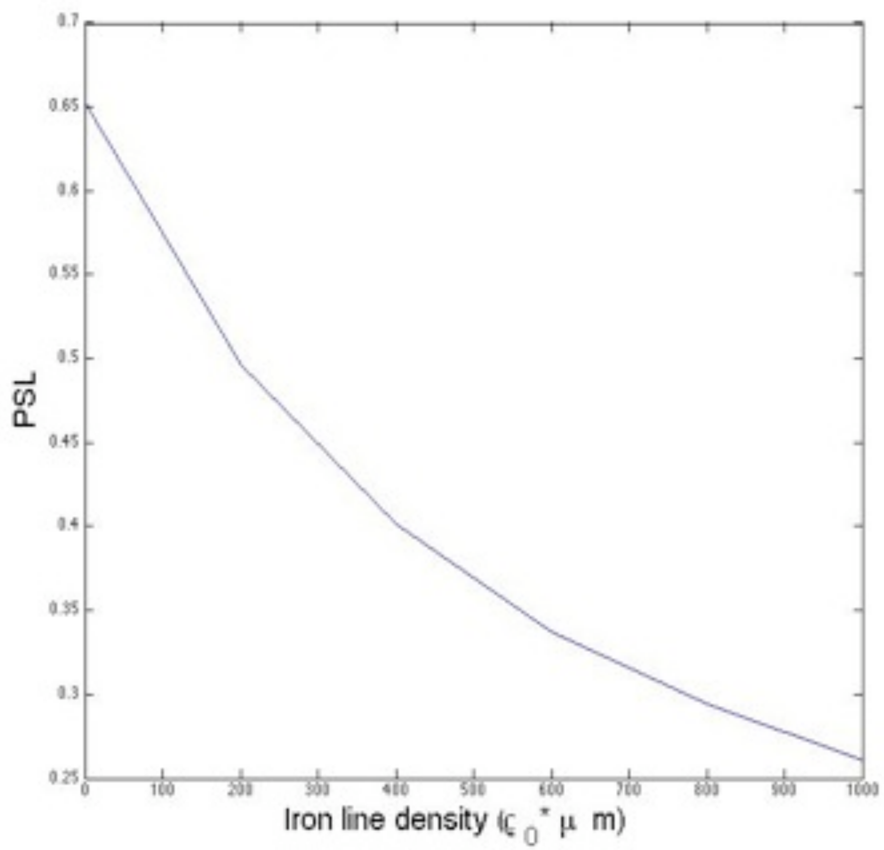


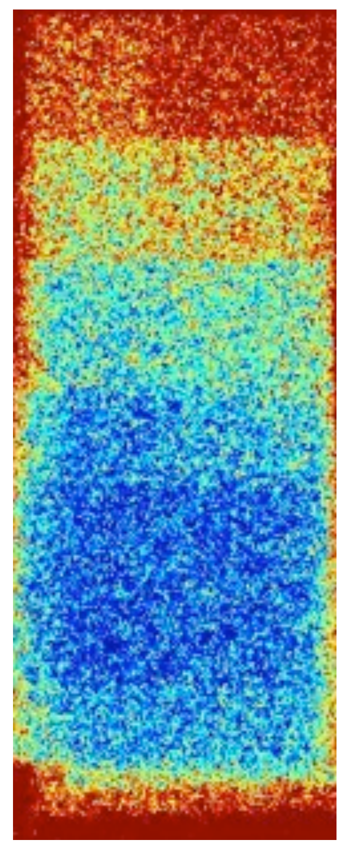


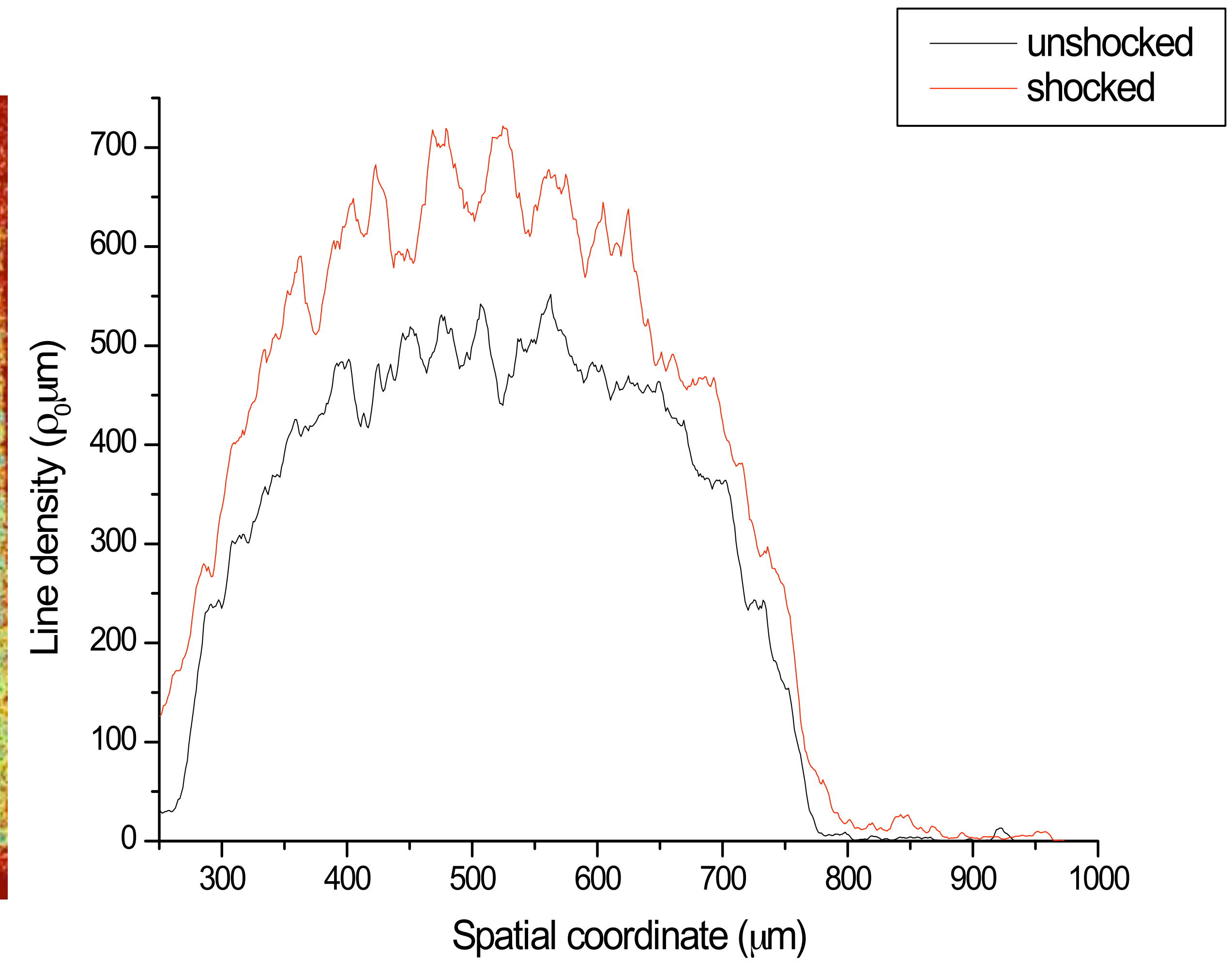
Contributions of continuum radiation and energetic x-rays are too strong to be neglected ☹

But nevertheless...

Calibrating the line density on shot allows analysis







In this experiment, precision was limited to 5-8%, but with a proper x-ray source, 1% is possible!

What do we have to study?

Best laser parameters

depends on x-ray energy?
influence of the preplasma?

Target optimization

compromise between efficiency and experimental demands
Implications for laser design (e.g. pointing stability)

Detector shielding

Is there something like an ideal shielding?
What parameters to put in a radiation protection calculation?

Geometry of the setup

Incidence angle and detector position can play an important role
Laser geometry is mostly difficult to change

Experimental and theoretical approach necessary