Science & Technology Facilities Council
Central Laser Facility

x-ray radiography using Laser-plasma sources.

Rob Clarke,
Sam Causer

Current Technology

- Cargo / personal

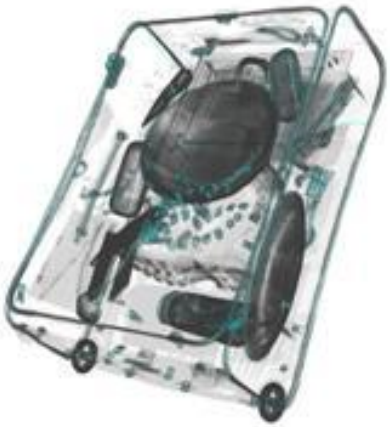
- X-ray tube, CT etc
- “low energy” x-rays < 100 keV.
- Low penetration
- Dual energy for general material identification
- X-ray diffraction for compound detection

- Truck / container

- “high energy” γ-ray / x-ray - 450keV – 6MeV x-ray or static gamma source
- Combined x-ray & neutron scanner
- Typical 10-30cm penetration (steel)

Current Technology (2)

- Current “state of the art”
- Cargo – CSIRO dual x-ray (6MeV) and neutron source. Capable of train / cargo scanning at up to 10mph. (Just won 2009 DSTO Eureka prize (Australia))
- XRD CT systems using x-ray diffraction for precise material detection.
- 3D CT scanning systems

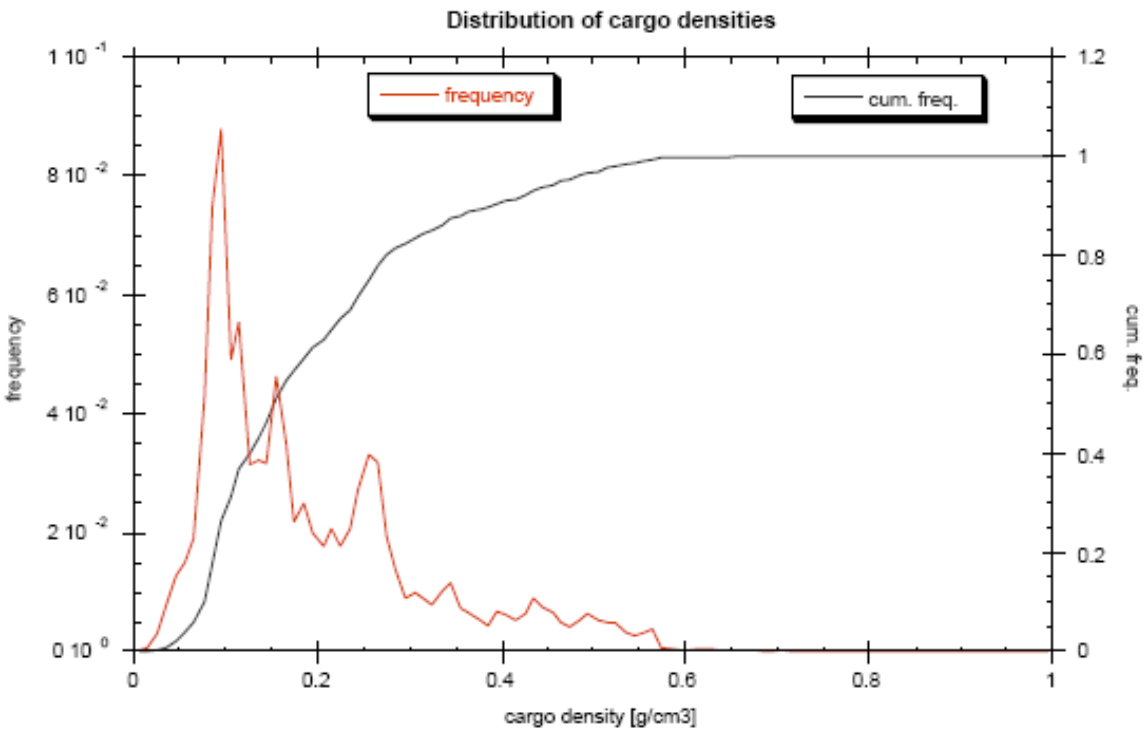


XRD 3500

GE Security

What are we looking for ?

Fig. 3. Distribution of average cargo density



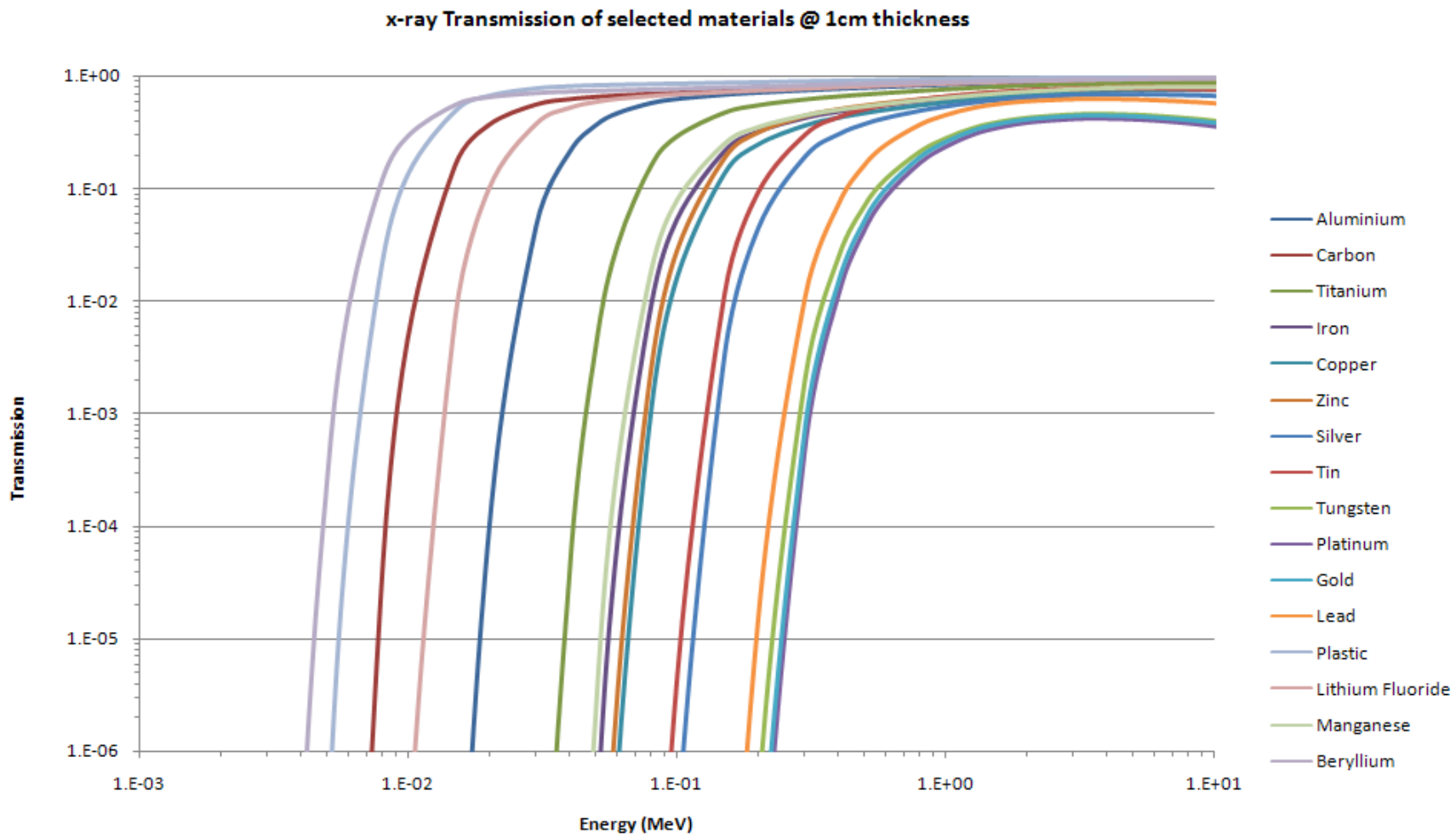
2006 IEEE Nuclear Science Symposium Conference Record N14-25
Marie-Anne Descalle, Doug Manatt, Dennis Slaughter

Typical requirement is looking for high density items within low density cargo – weapons, nuclear materials etc...

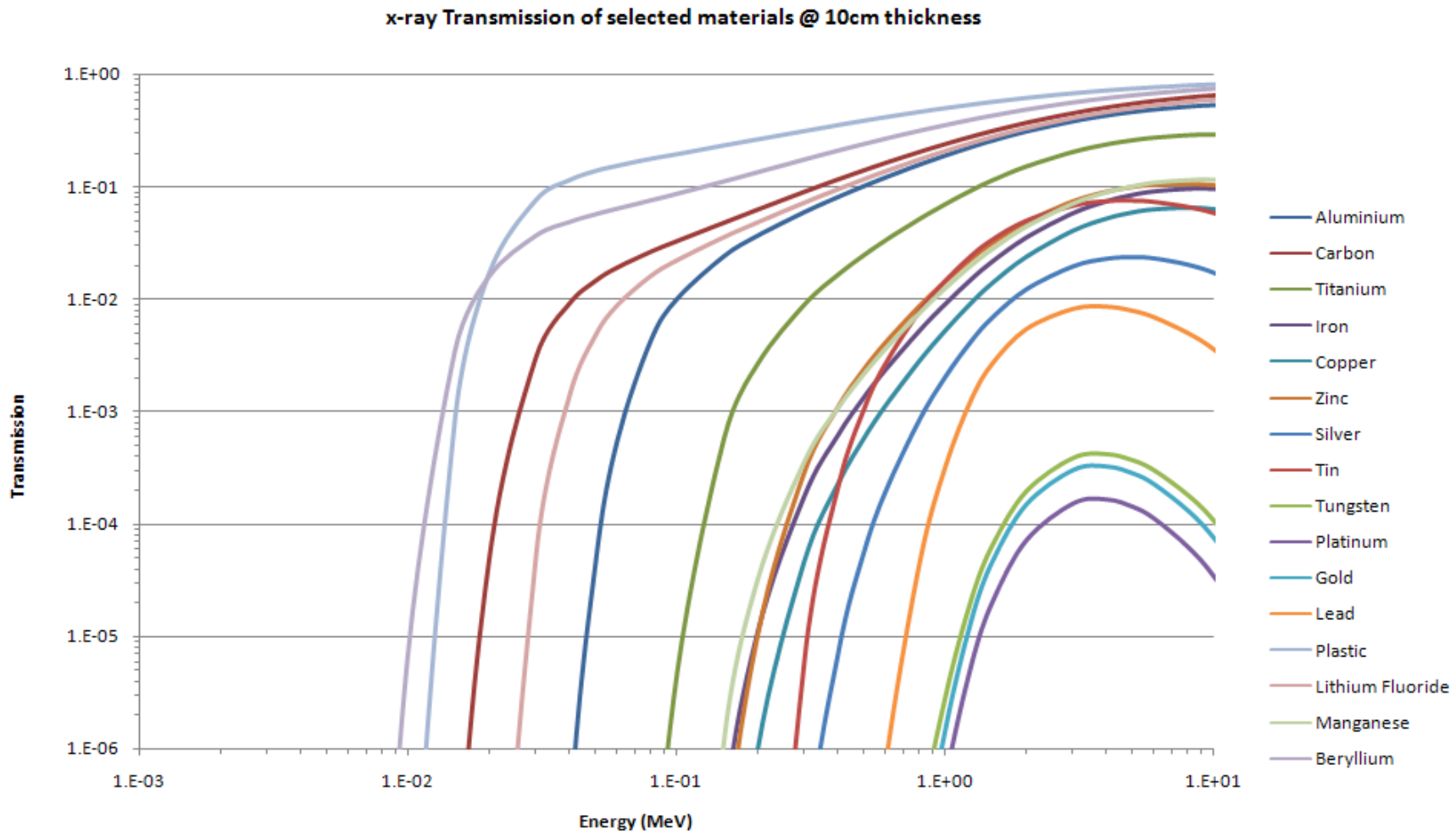
HOWEVER:

Low density materials (drugs, cigarettes etc) within high density materials need to be found too !!

1cm thick transmission Spectra



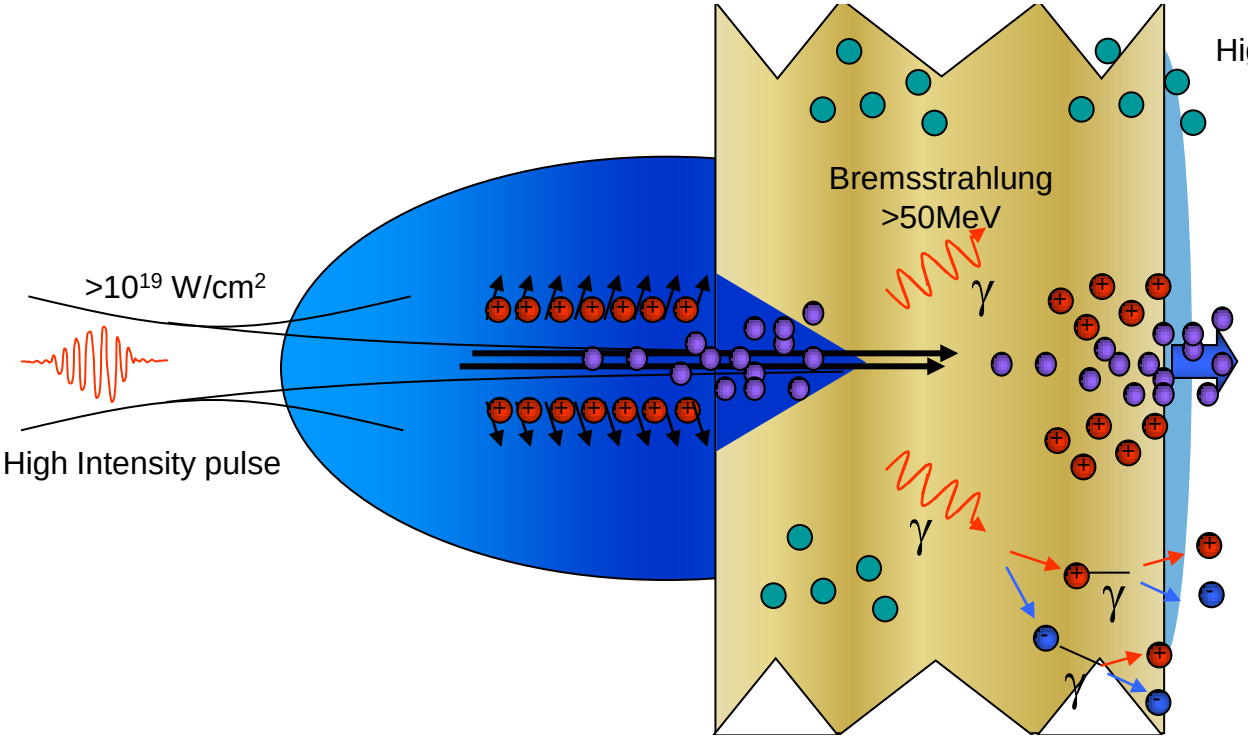
10cm thick transmission Spectra (2)



So why use a Laser?

- Extremely Bright source of x-rays & ultra-short pulses
    - Enable single shot (instantaneous) imaging of large areas
- Capable of VERY high energy x-rays (> 50 MeV)
- Additional sources of neutrons, protons & electrons

Laser-plasma radiation production



> 100 MeV

electrons

> 50 MeV protons

Photoelectron conversion,

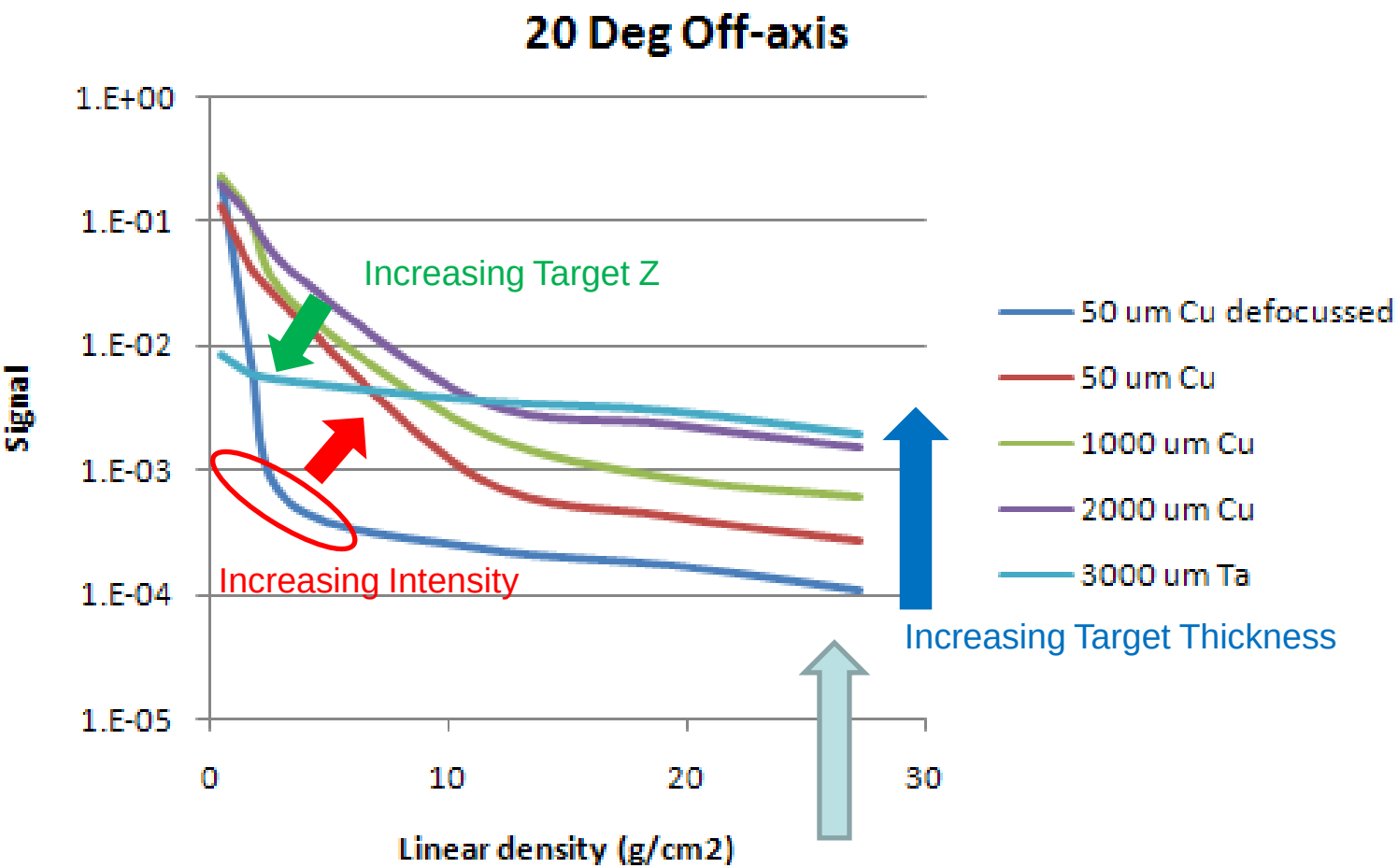
Pair production ⇨

e^+ - e^- - shower

muon, pion etc…

Laser-produced x-ray spectra (tuneability)

Oct 2009 results:
Astra Gemini 10J, 30fs
20s shot cycle

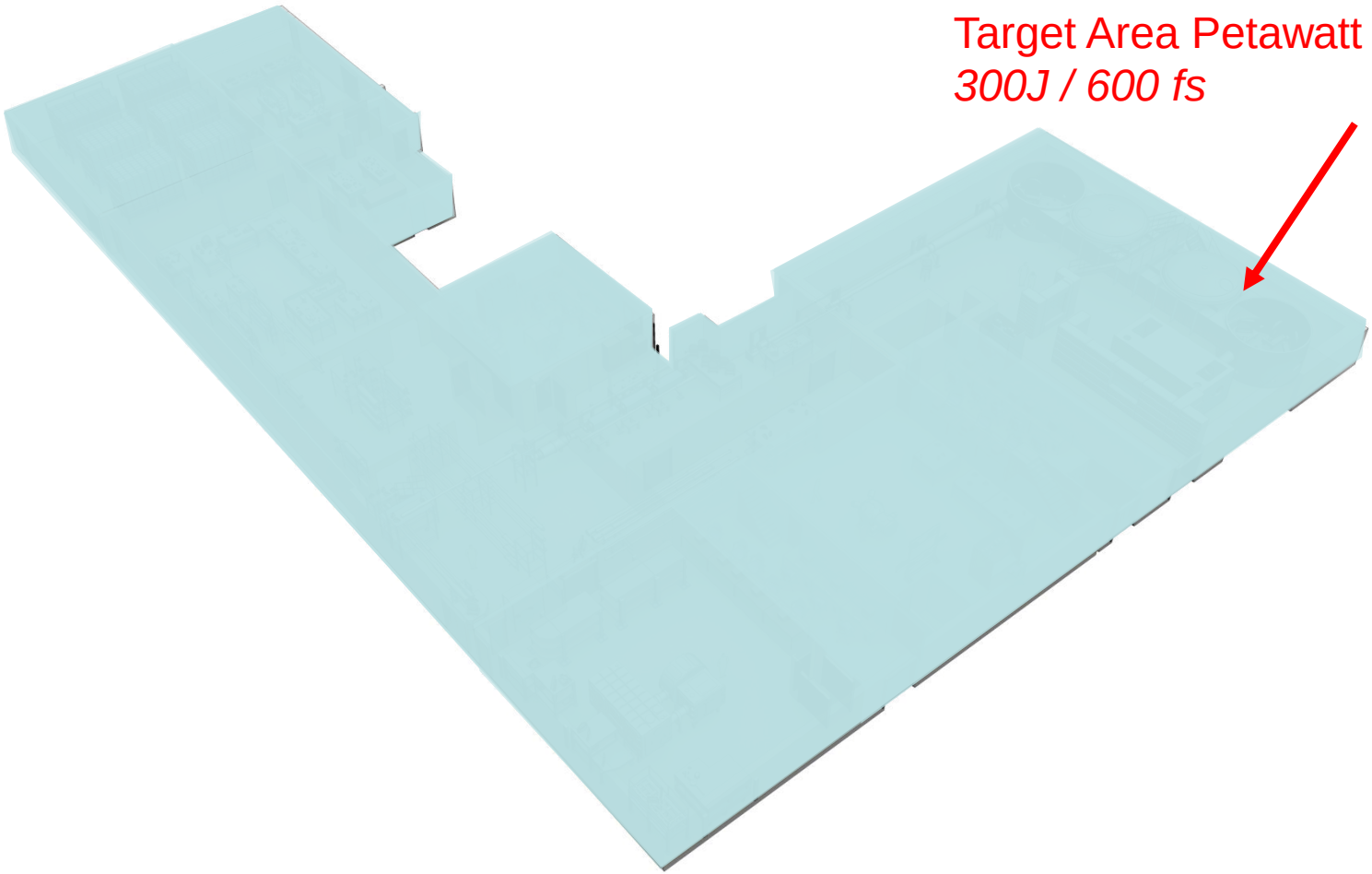


2.5cm steel + 3cm aluminium

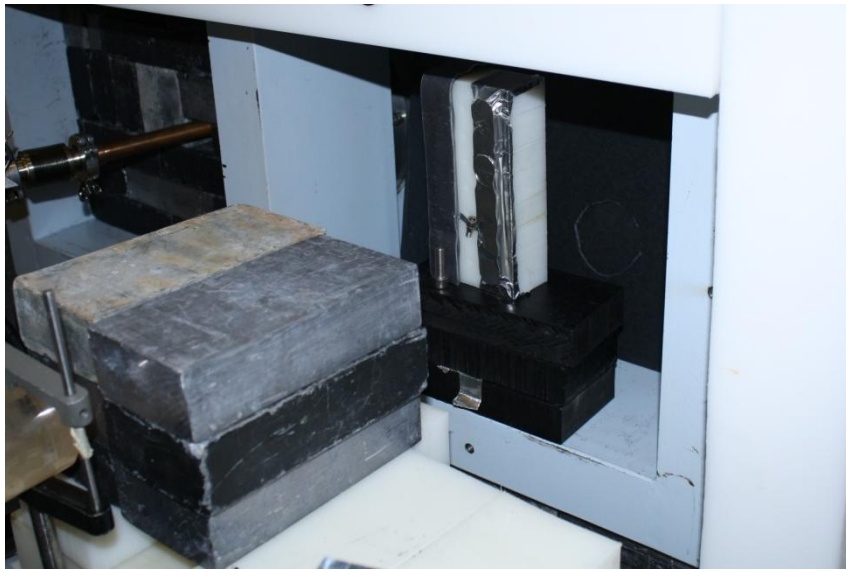
Click to edit Master title style

Experiment

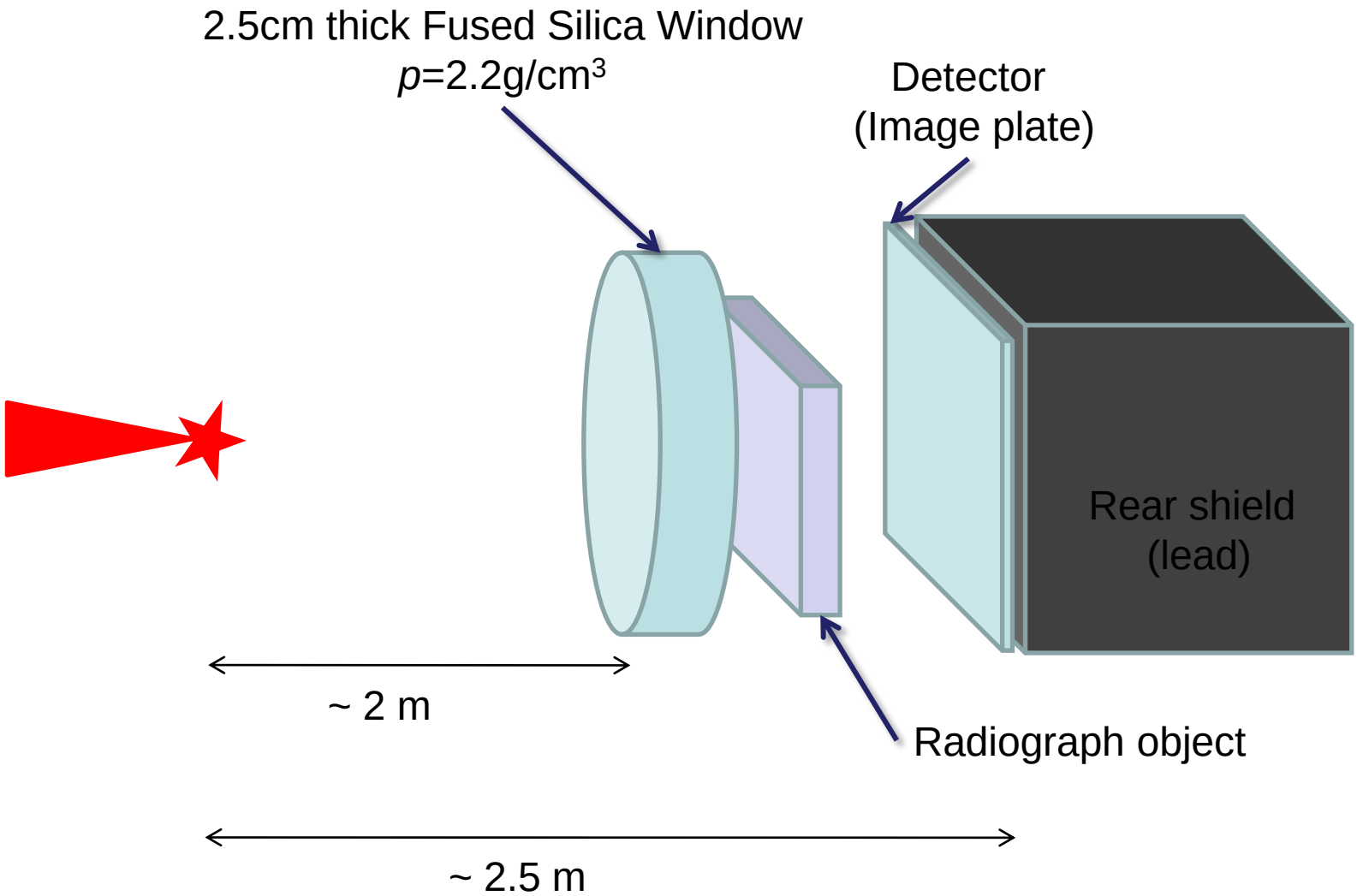
Vulcan Laser Facility



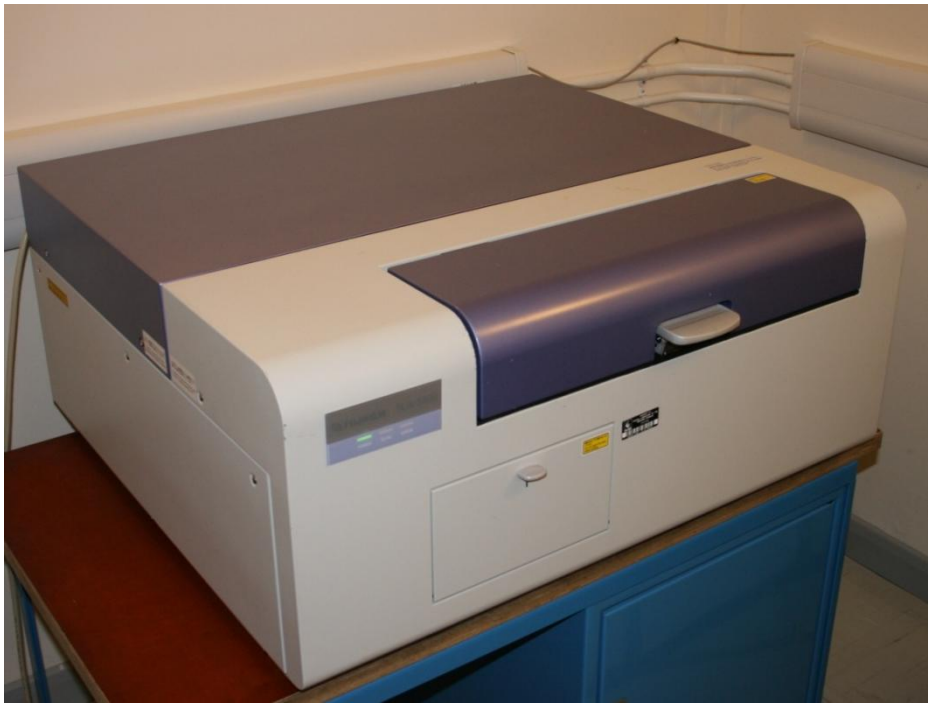
Experimental Configuration (2)



Experimental configuration



Detector – Image Plate

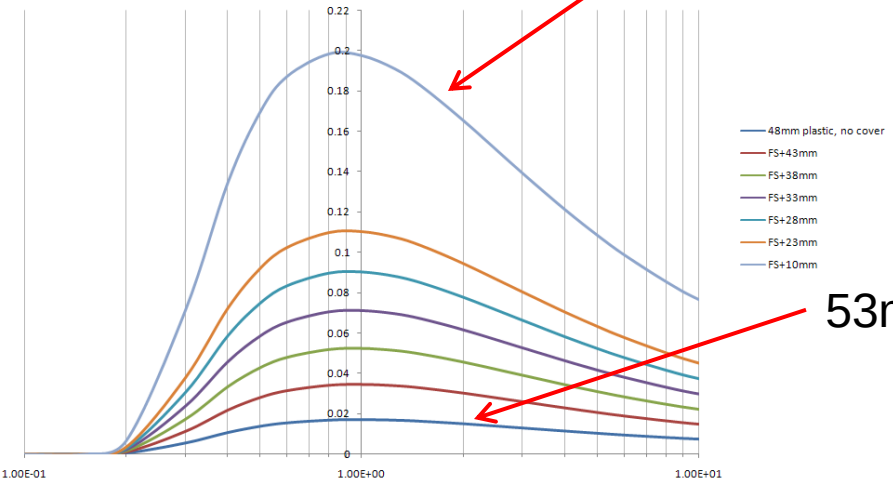


Positives:
Large area
2D
High resolution
Compact

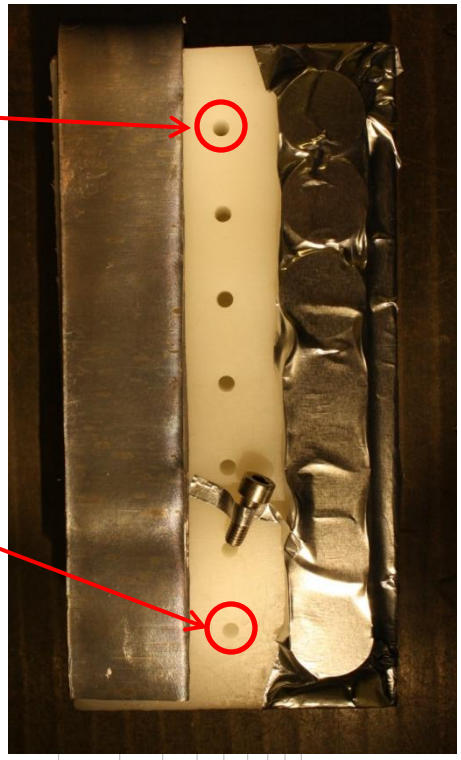
Negatives:
Low sensitivity in MeV range
Requires “reading in” – Slow.

Expected Transmission data

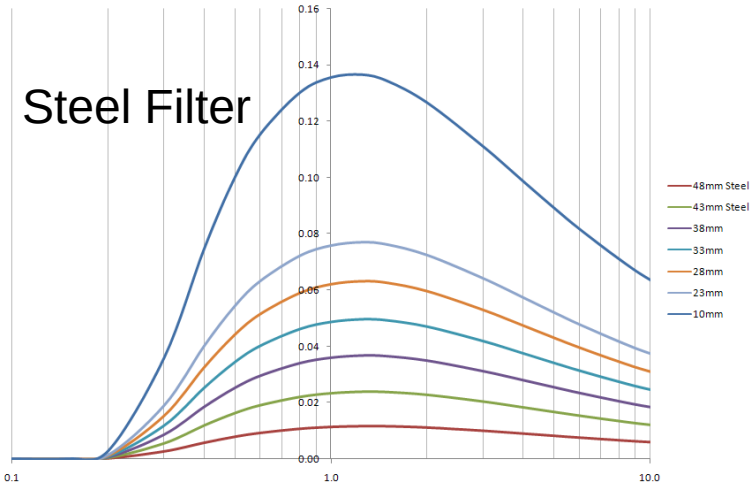
53mm block – 43mm hole



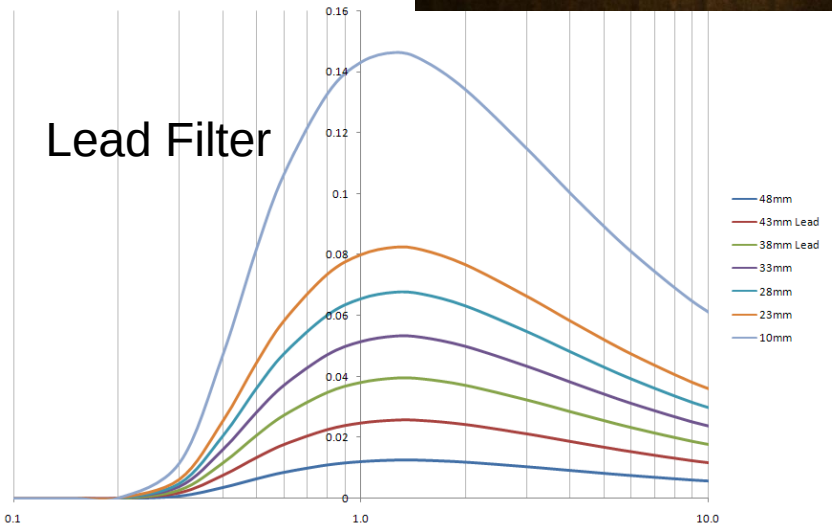
53mm block – 5mm hole



Steel Filter

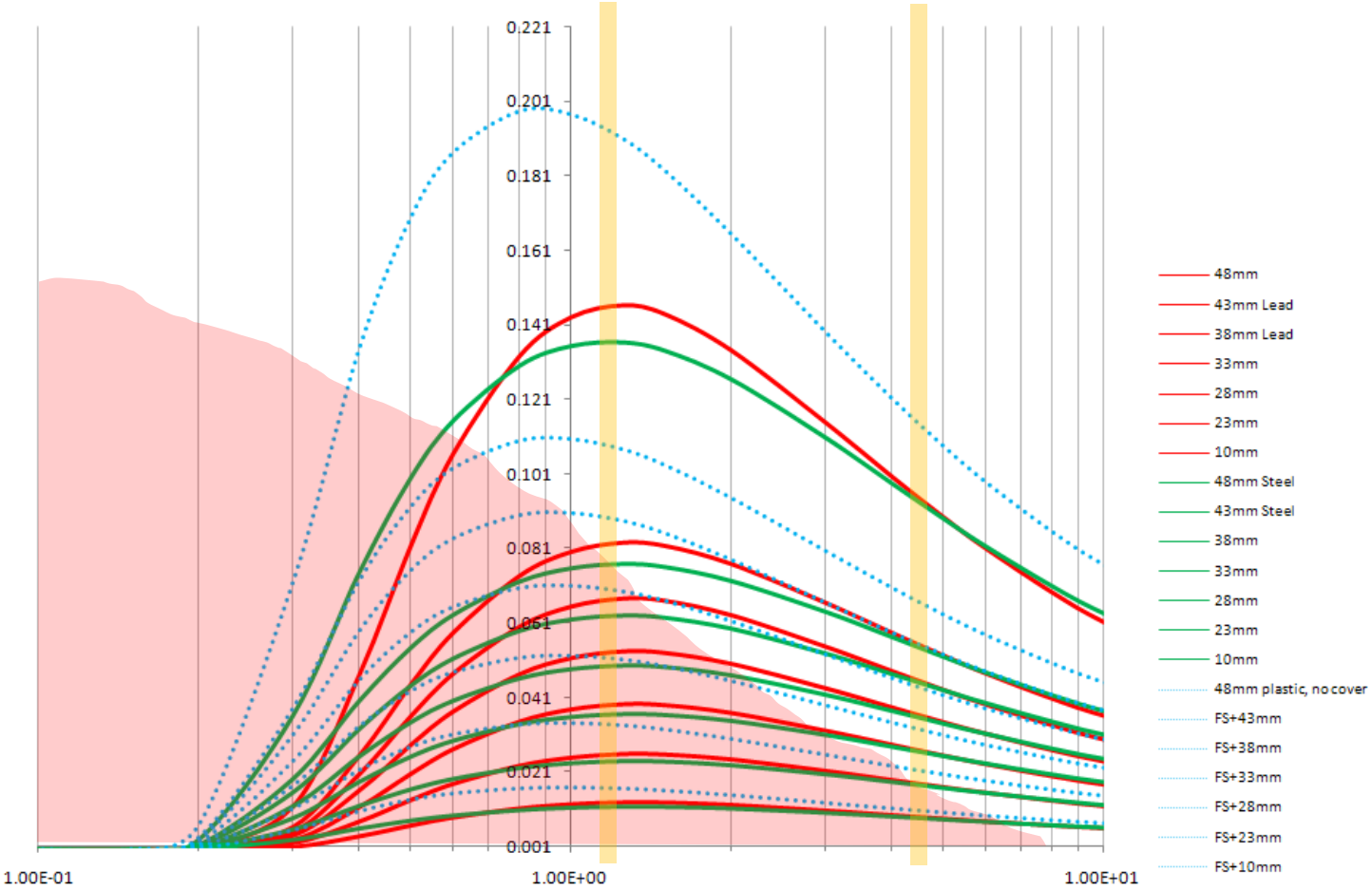


Lead Filter



Expected Transmission data (2)

Mono-energetic source – signal depends on attenuation difference.

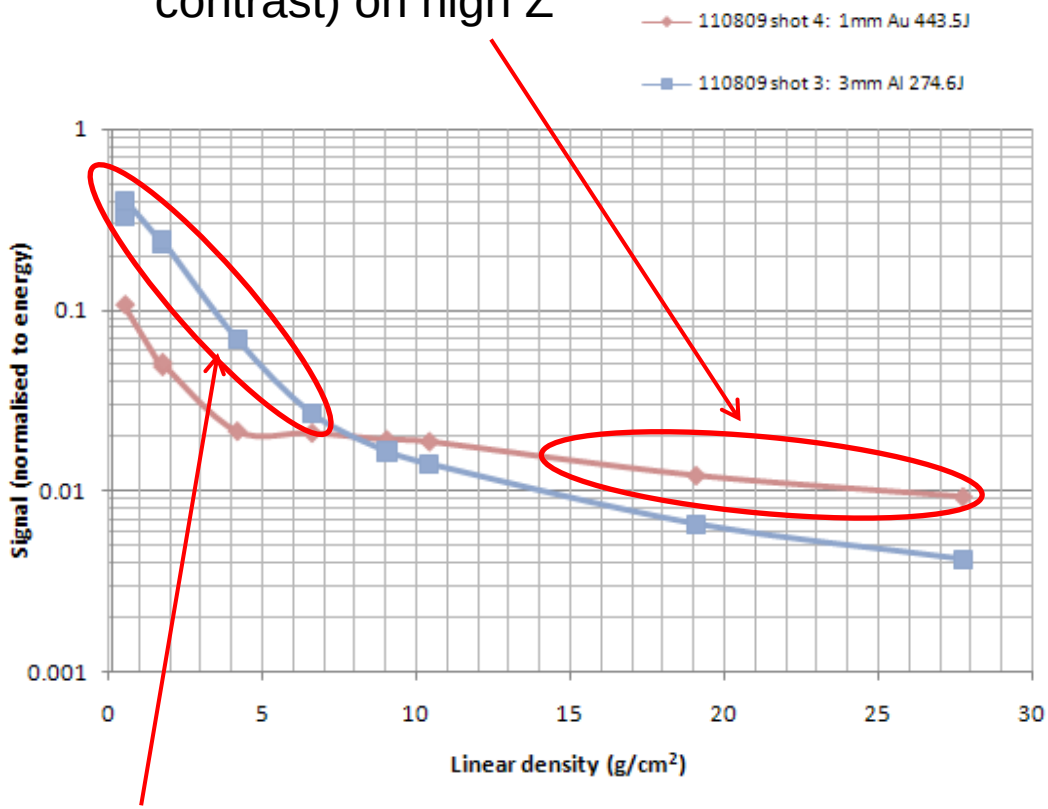


Broad Source – Signal depends on COMBINATION of attenuation and spectral transmission

Results

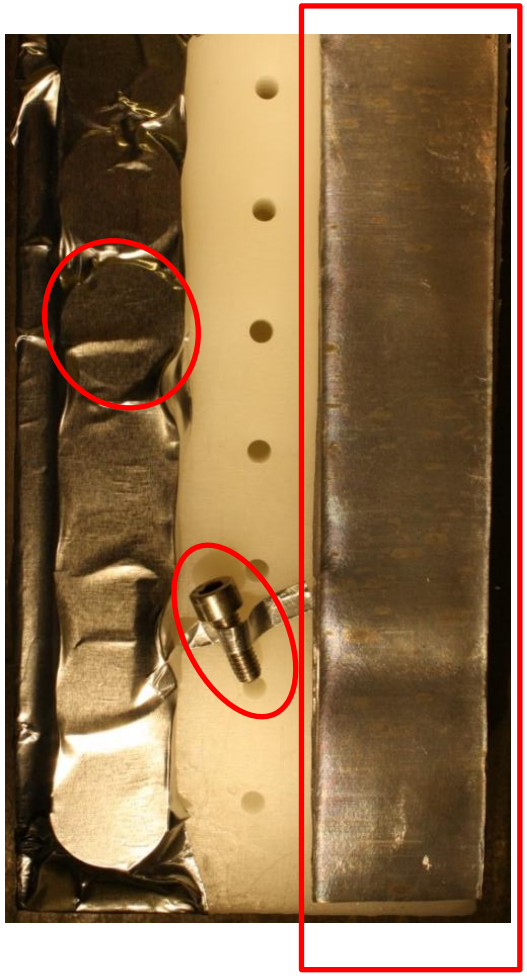
Bremmstrahlung spectra for shots

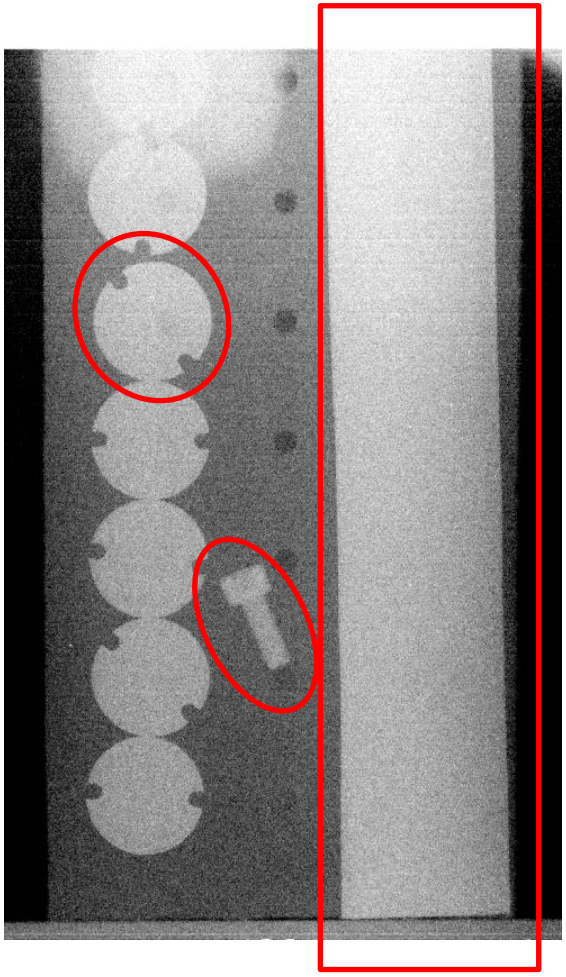
Shot 4 – Lower signal in low energy region:
Expect loer image quality but good penetration (& hence contrast) on high Z



Shot 3 – high signal in low energy region:
Expect good contrast on low Z materials, poor penetration (& hence contrast) on high Z

Images – Large features



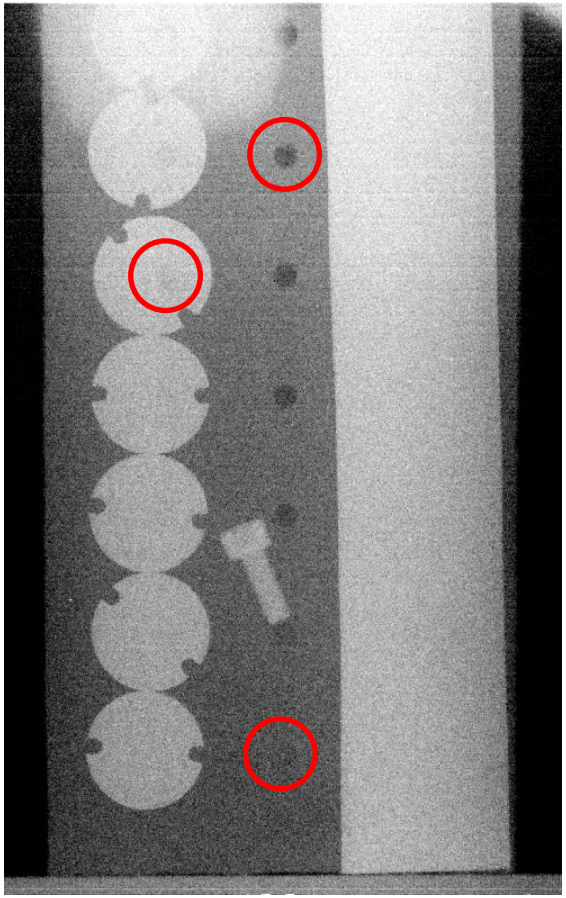


M6 bolt,

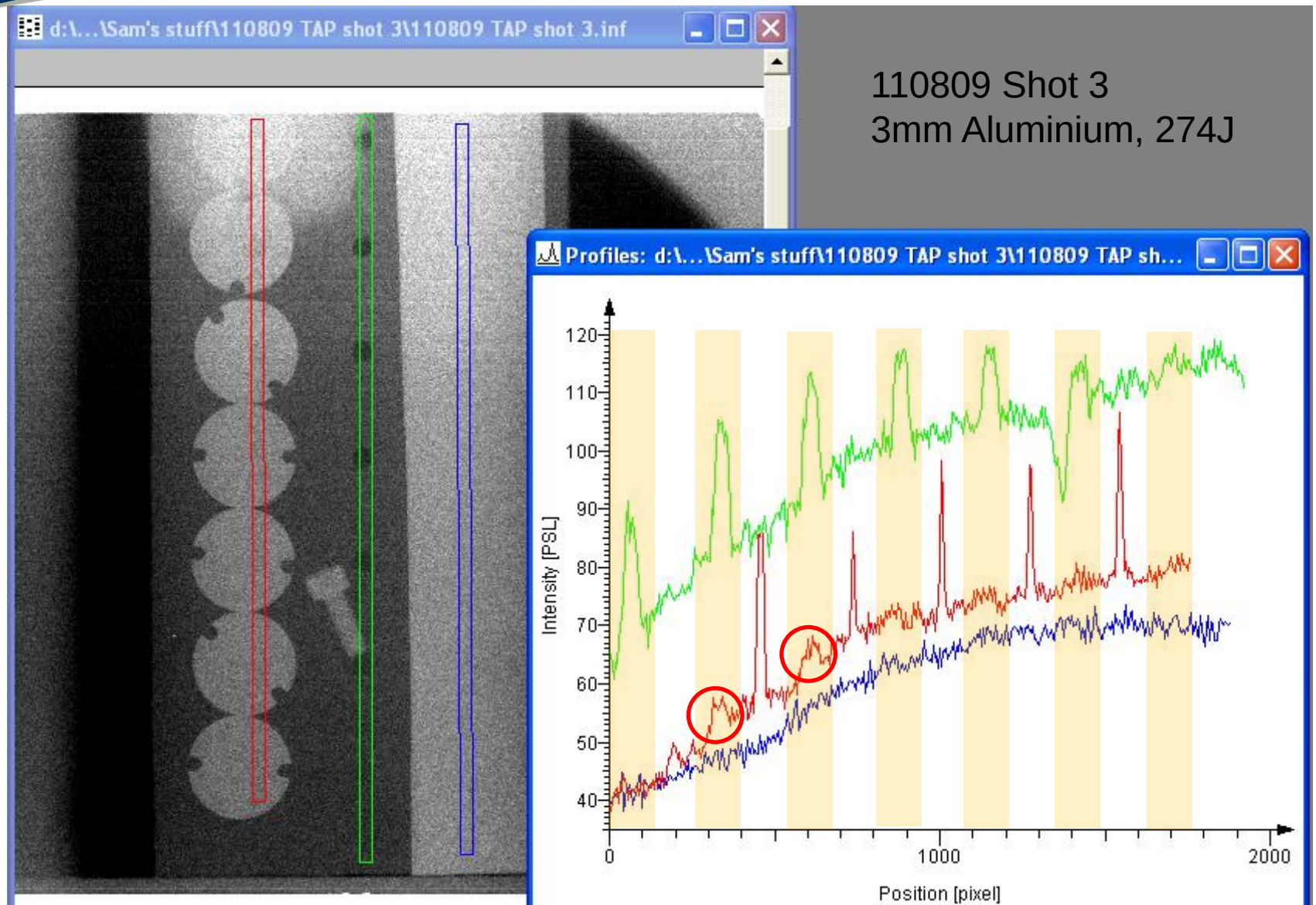
8mm thick Steel filters,

4mm lead shield

Images – Small features

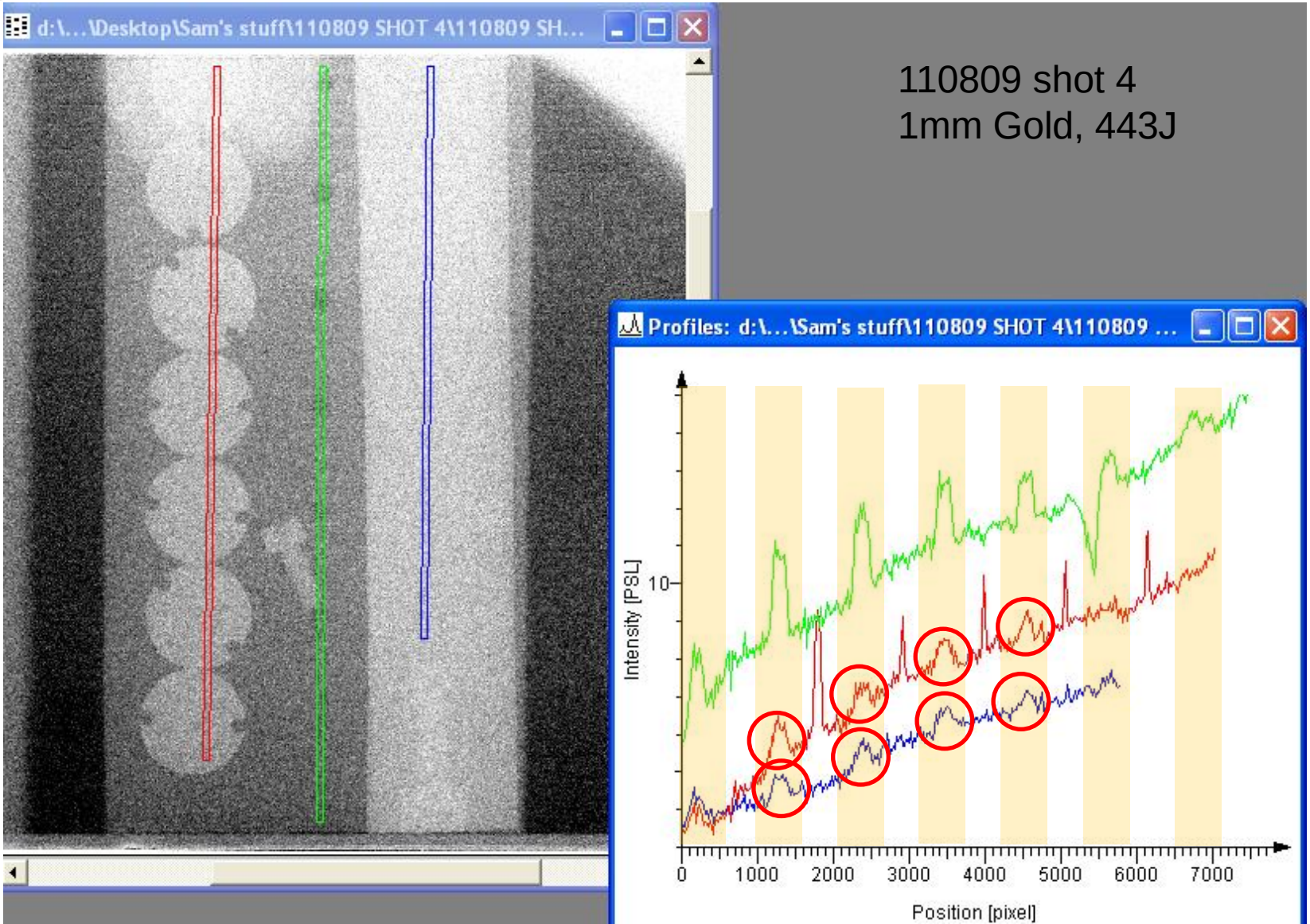


Low Z target Image – Profiling



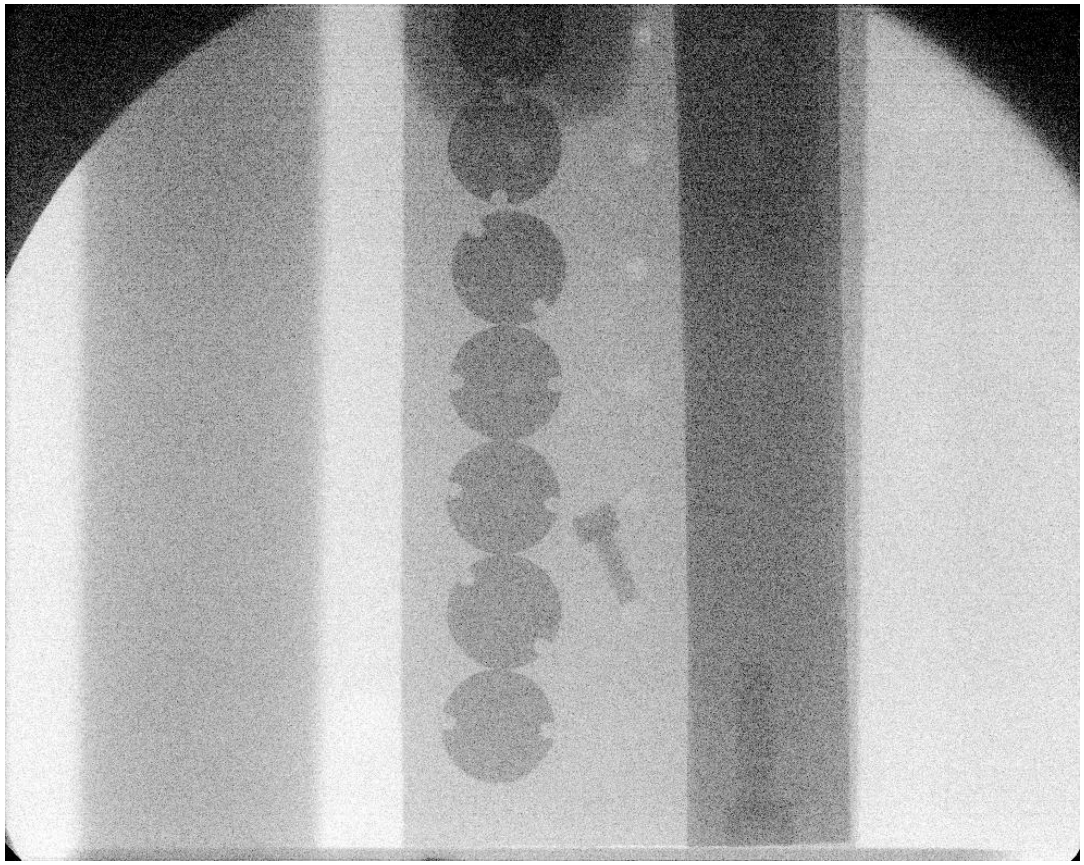
110809 Shot 3
3mm Aluminium, 274J

High Z target Image – Profiling



110809 shot 4
1mm Gold, 443J

Shot 4 Image:



Inverted image gives better contrast for human eye –

On this image you can also see:
Holes in lead and steel
Lead sheet overlaps (2*2mm)
M8 bolt behind 2.5cm glass, 5cm plastic, 4mm lead.
Can also see the Hex holes in both bolts.

Current Conclusions

Radiography of high Z materials against low Z very is effective (bulk objects) -
eg. Weaponry (eg. *Kalashnikov AK-47*) hidden within a standard Home Office “tipple” such as ½ pint Stella / sparkling water….

Able to see cm scale differences in low Z materials behind high Z materials
(not quite a potato inside an engine block)

High resolution – tests show ~250μ source size during AWE experimental tests…

Source brightness great – able to see differences *even* on Image plate detectors…

Future Work

- Need to progress to low power high rep laser system (on site)
  - But require access…
- Need to further investigate source "tuning" to both detector and objects
  - But require access…
- Investigate secondary sources – protons (small packages), neutrons, electrons… for both Imaging potential AND induced activity from γ, n and p for reactions identifying nuclear substances – (Currently do this for nuclear physics)
  - But require access…
- Need to switch to better 2D detectors with good sensitivity in the MeV region… (Scintillators, Cadmiun Tungstate, CdZT, Ge etc)
  - But require funding…