SAND2014-15168PE

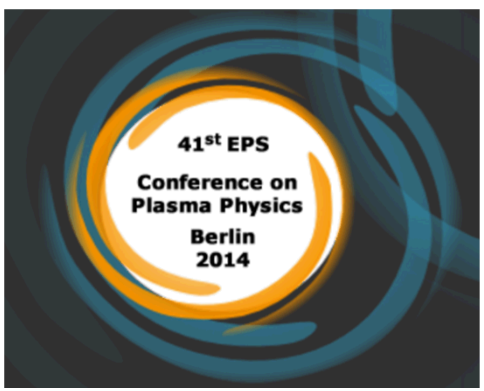
Transmission Studies for the MagLIF Laser-Entrance-Hole

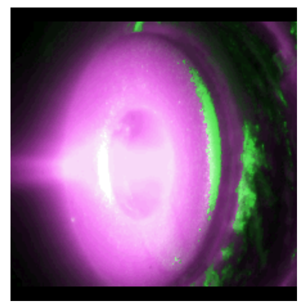
Exceptional service in the national interest

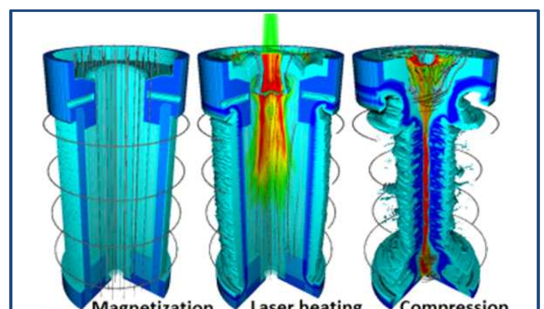
Sandia National Laboratories

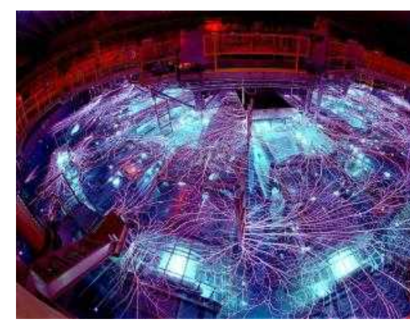
Matthias Geissel, L.E. Ruggles, A.B Sefkow, I.C. Smith, J.E. Shores, C.S. Speas, and J.L. Porter

Sandia National Laboratories
Albuquerque, NM, 87185









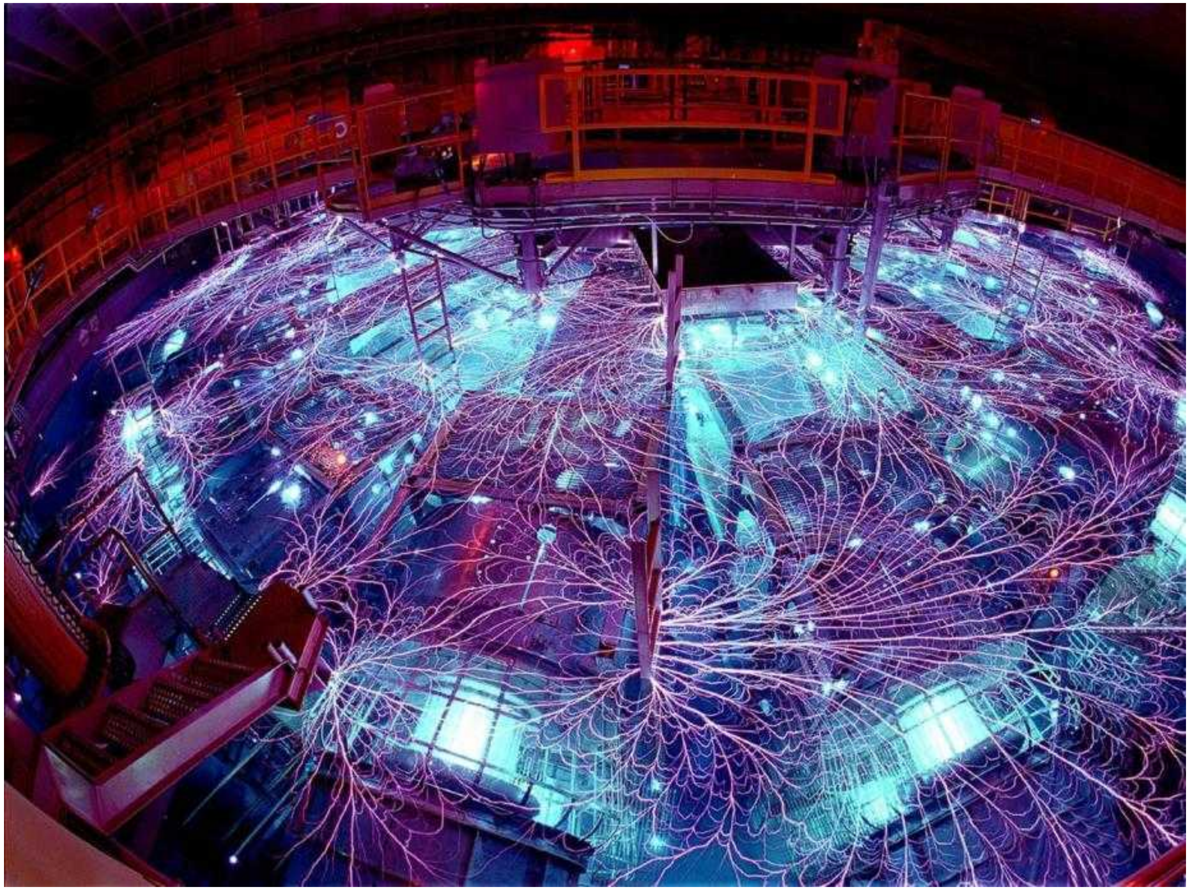
Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

SAND No. 2014–xxxxC.

ZBacklighter

The Z-Machine: Pulsed Power for HEDP

A >20 MA multi-MV discharge



World's most powerful electric device (100TW)

Can exceed 300TW/2MJ of X-ray output

Applications:

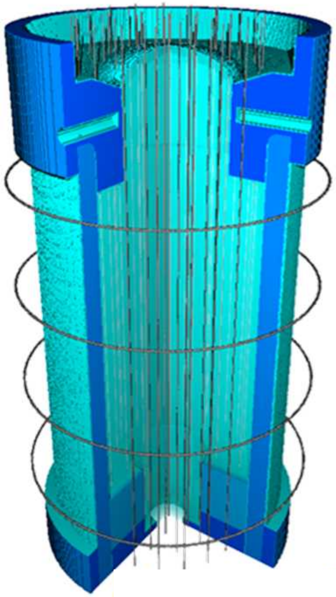
Accelerate flyer plates ('dynamic materials')

or

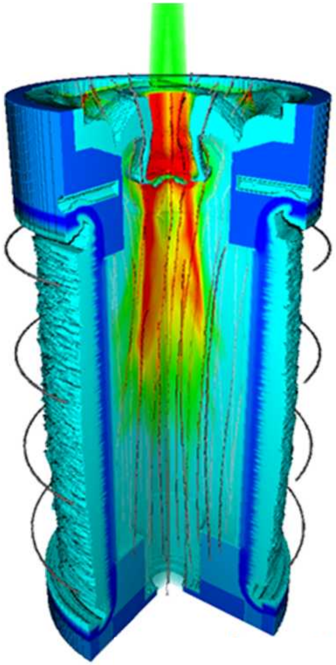
Z-Pinch implosions
(ICF, radiation source)

Motivation: Magnetized Liner Inertial Fusion:

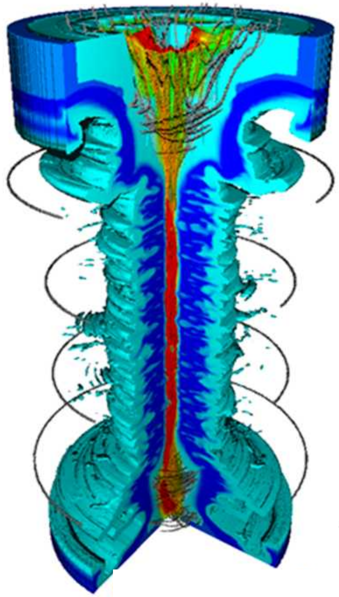
MagLIF



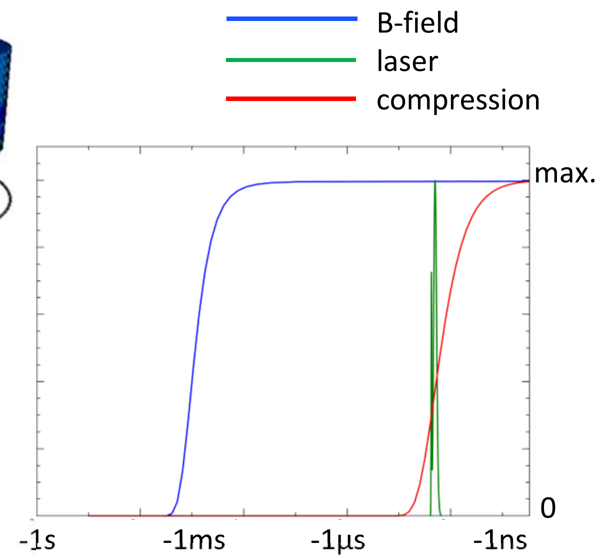
Magnetization
with external B-Field
(10-30T)

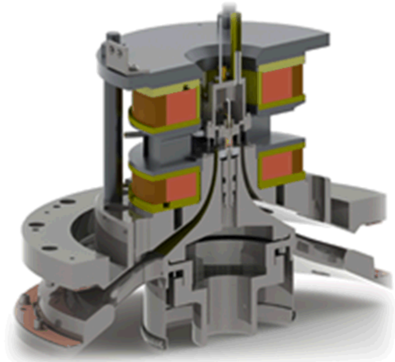


Laser heating
with Z-Beamlet
(2-6kJ @ 2-6ns)



Compression
with 'Z'





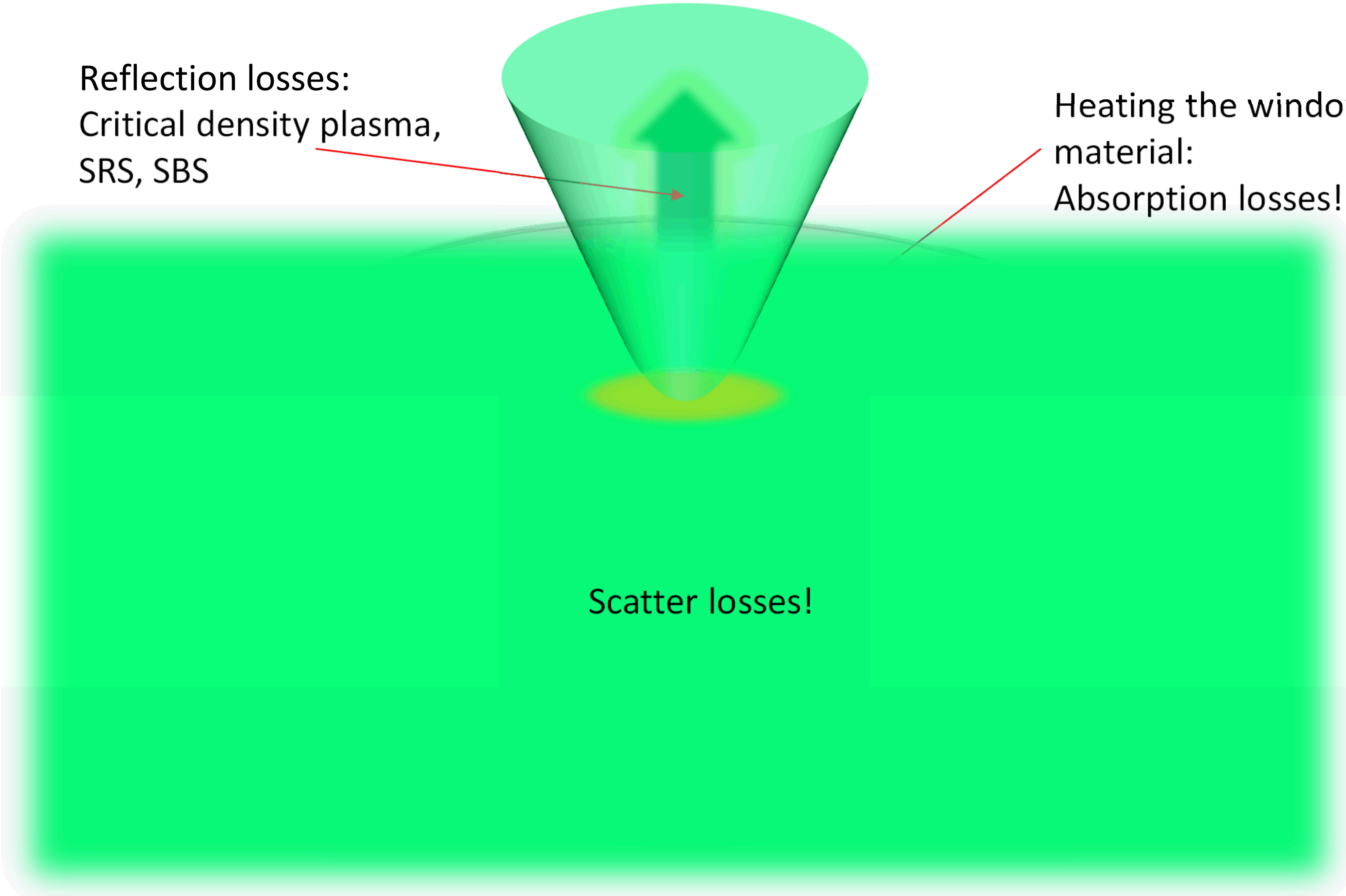
Slutz et al.: Physics of Plasmas **17**, 056303 (2010)

ZBacklighter

The Laser Entrance Window Issue

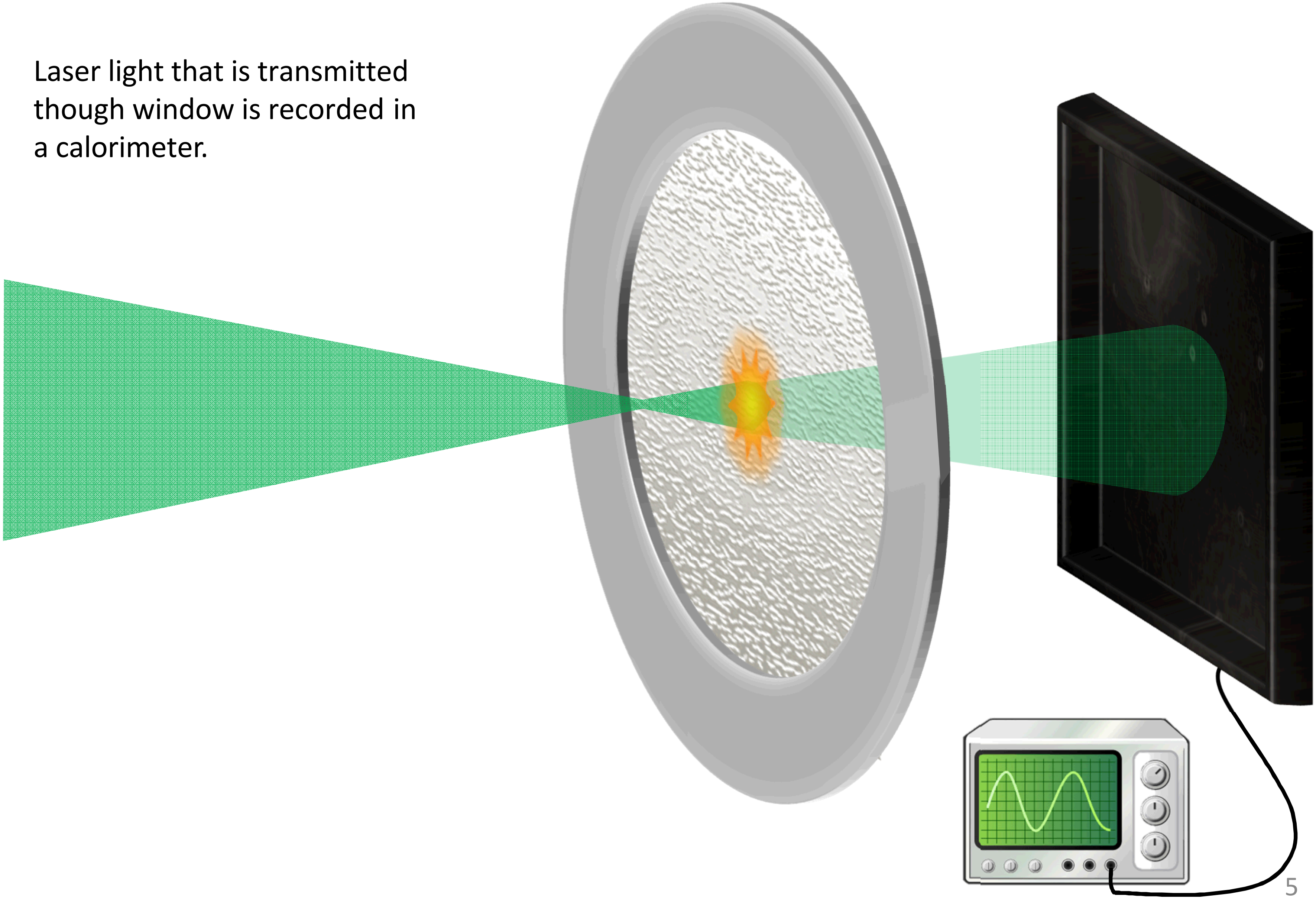
Reflection losses:
Critical density plasma,
SRS, SBS

Heating the window
material:
Absorption losses!



Energy of a Transmitted Laser Pulse

Laser light that is transmitted though window is recorded in a calorimeter.



ZBacklighter

Transmission Studies

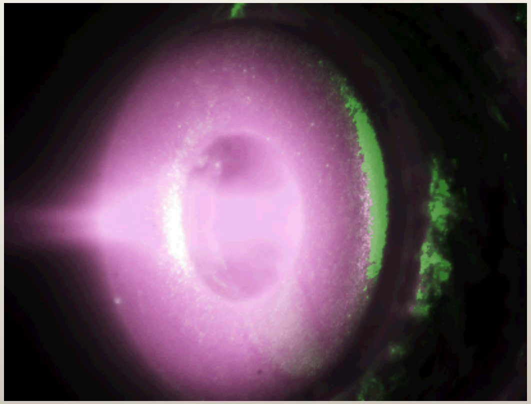
Clipping

LEH diameter	Laser spot size	Relative transmission
2 mm	1000 µm	95%
2 mm	600 µm	95%
2 mm	250 µm	94%
3 mm	600 µm	99%

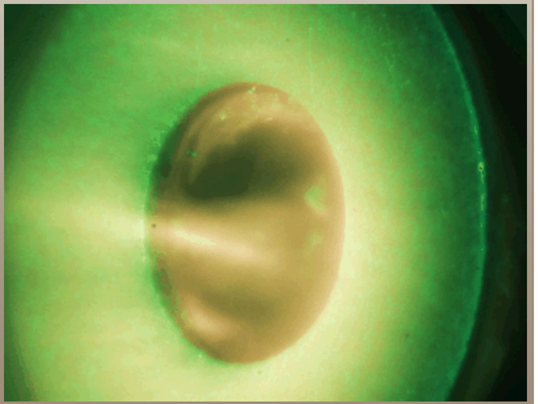
Very weak wings ablate small amounts of material from the LEH frame (washer).

The images on the right were taken at 1,000x higher sensitivity compared to foil covered laser impacts.

A: 2mm LEH
Spot Ø 250 µm



B: 3mm LEH
Spot Ø 600 µm



Penetrating a Foil

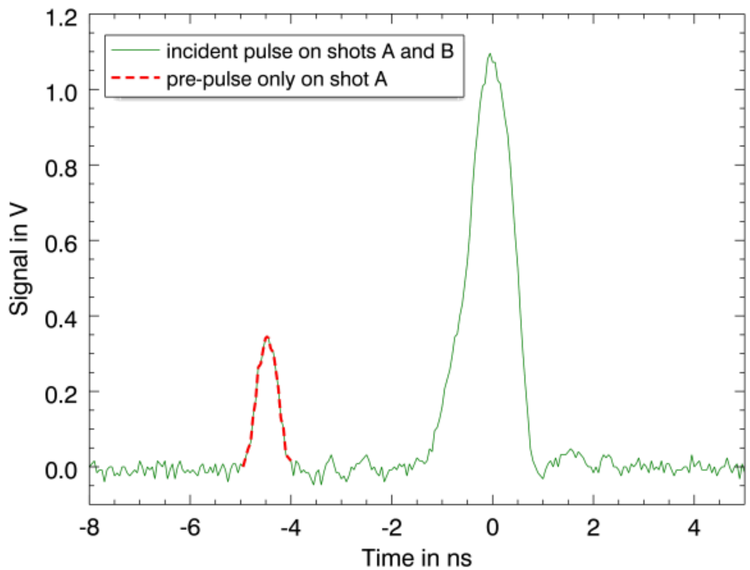
Challenges

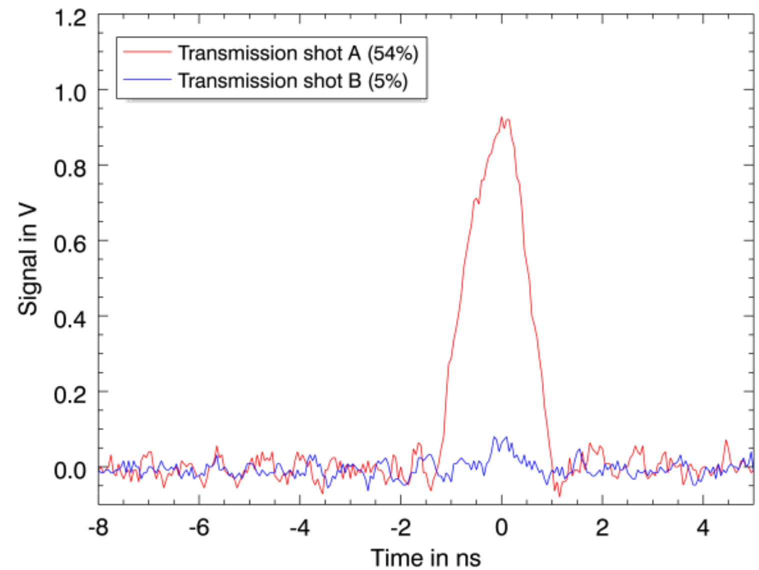
- High gas fill pressures require ‘very thick’ windows (e.g. >3 µm for 180 psig). These thicknesses are not well studied or understood.
  How can we facilitate burning through the foil?

- Our current modeling codes (Hydra, Lasnex) cannot treat the full spectrum of LPI such as SRS, SBS, TPD…
  It is known that ‘Hot Spots’ are sources for unwelcome instabilities in the plasma.
  How can we mitigate problems due to LPI? Beam smoothing?
  Is there a technique of beam smoothing with flexible spot size for the ‘discovery phase’ of the campaign?

Transmission Studies

Pre-Pulse

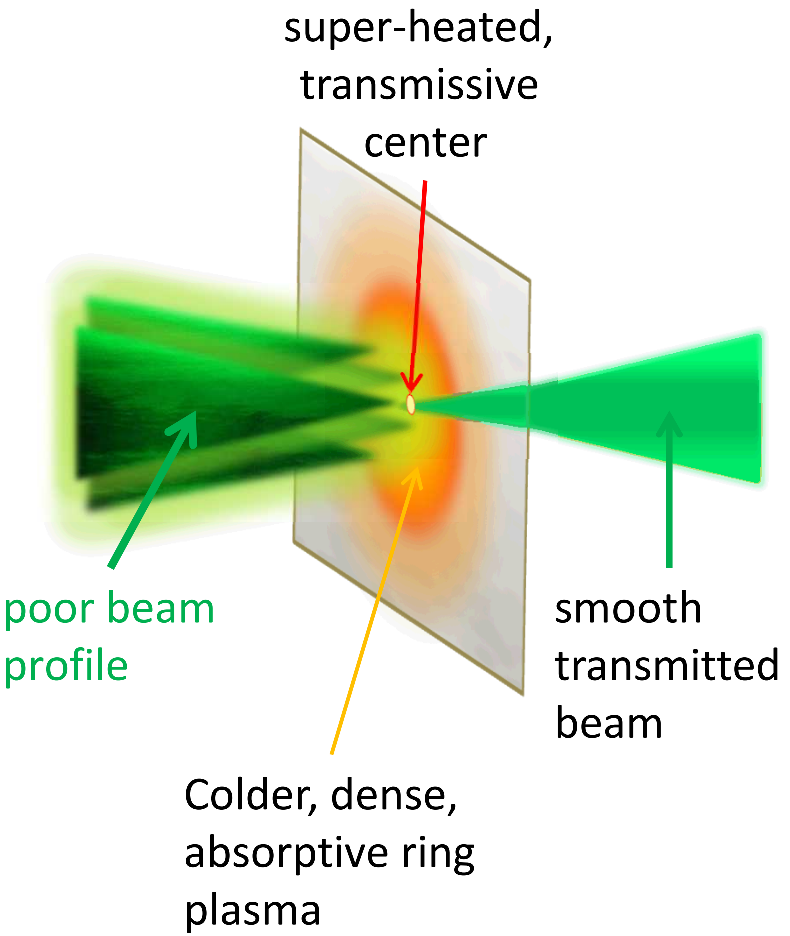




ZBacklighter

LPI: Beam Smoothing Recommended

	Random Phase Plate (RPP)	RPP + SSD (smoothing by spectral dispersion)	Sacrificial foil: Plasma Pinhole smoothing
Complexity to implement	Moderate	Very high	**Low**
Modulation (large area)	Very low	Very low	Very low
Modulation (microscopic)	High	Very low, high on ps-scale	**Very low**
Spot shape	Super-Gaussian	Super-Gaussian	**Gaussian**
Spot size	Fix	Fix	**Continuously variable**
Potential for clipping on LEH	Low	Low	**Moderate to high**
Energy investment	None	None	**Moderate**

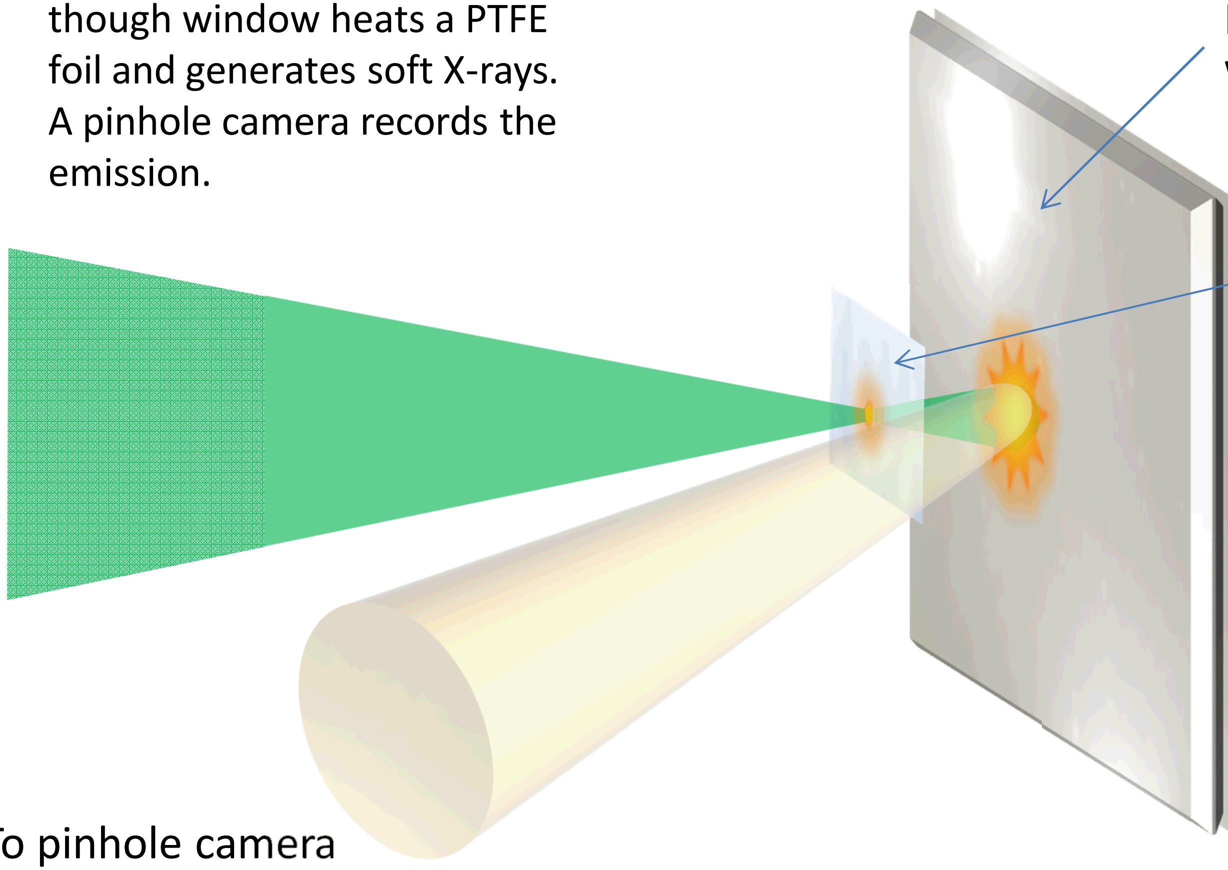


Beam Profile of a Transmitted Laser Pulse

Laser light that is transmitted though window heats a PTFE foil and generates soft X-rays. A pinhole camera records the emission.

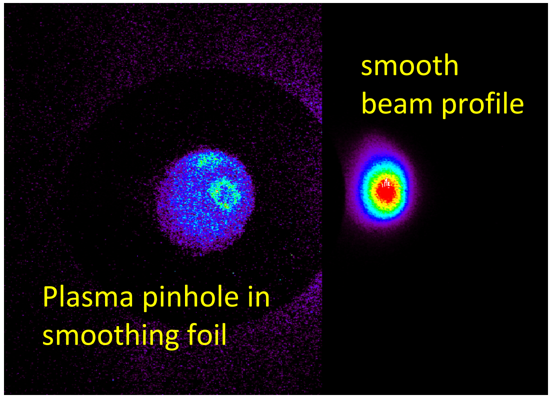
PTFE ('Teflon ™')
Witness Sample

Thin Sacrificial
Smoothing Foil
in BEST FOCUS



To pinhole camera

Measurement

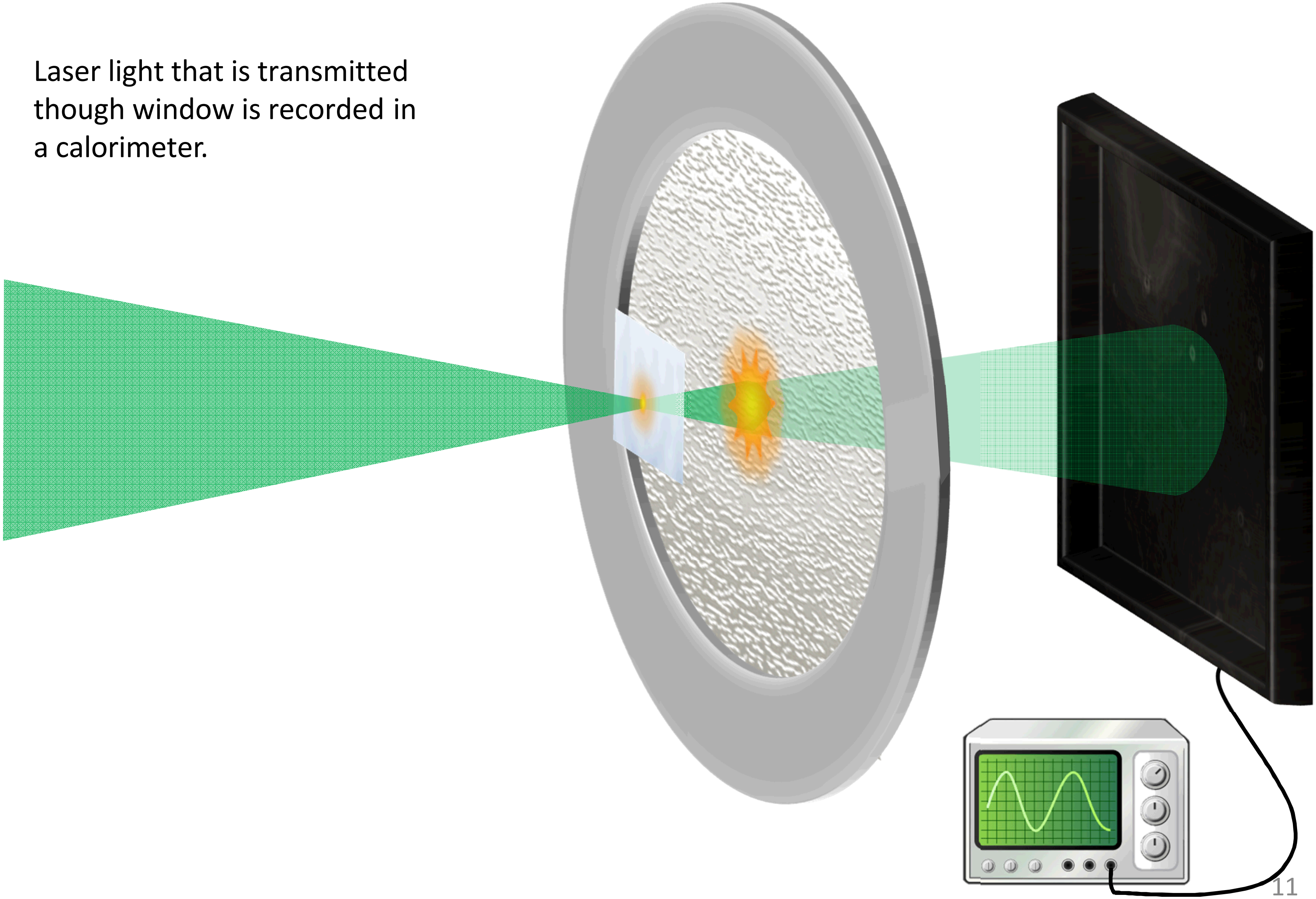


ZBacklighter

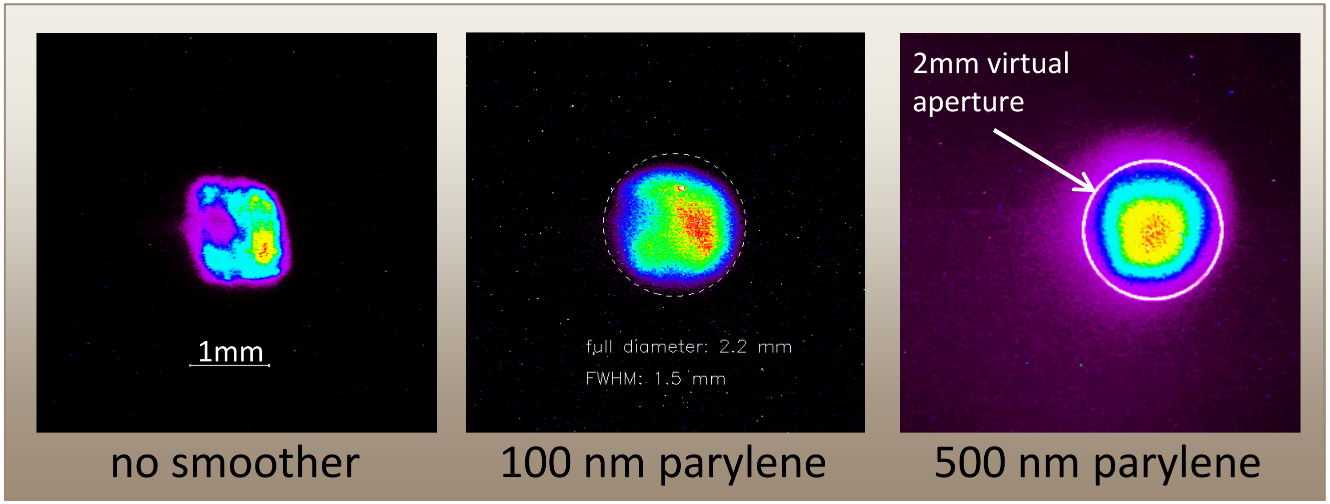
Transmitted Energy for Double Foils

Sandia National Laboratories

Laser light that is transmitted though window is recorded in a calorimeter.

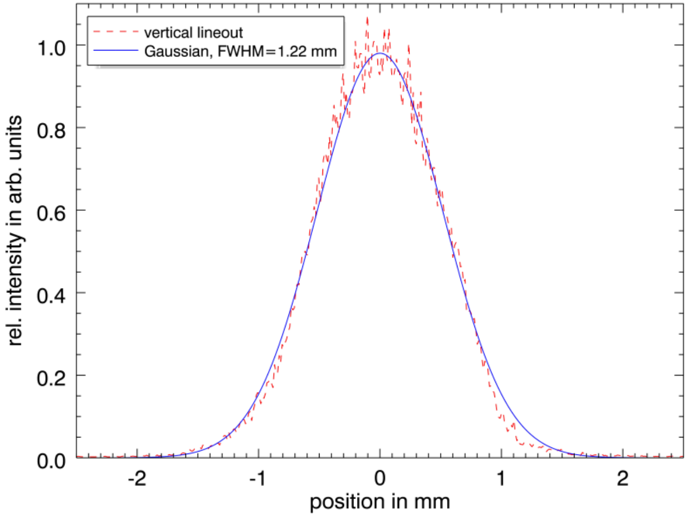


Plasma Pinhole Smoothing



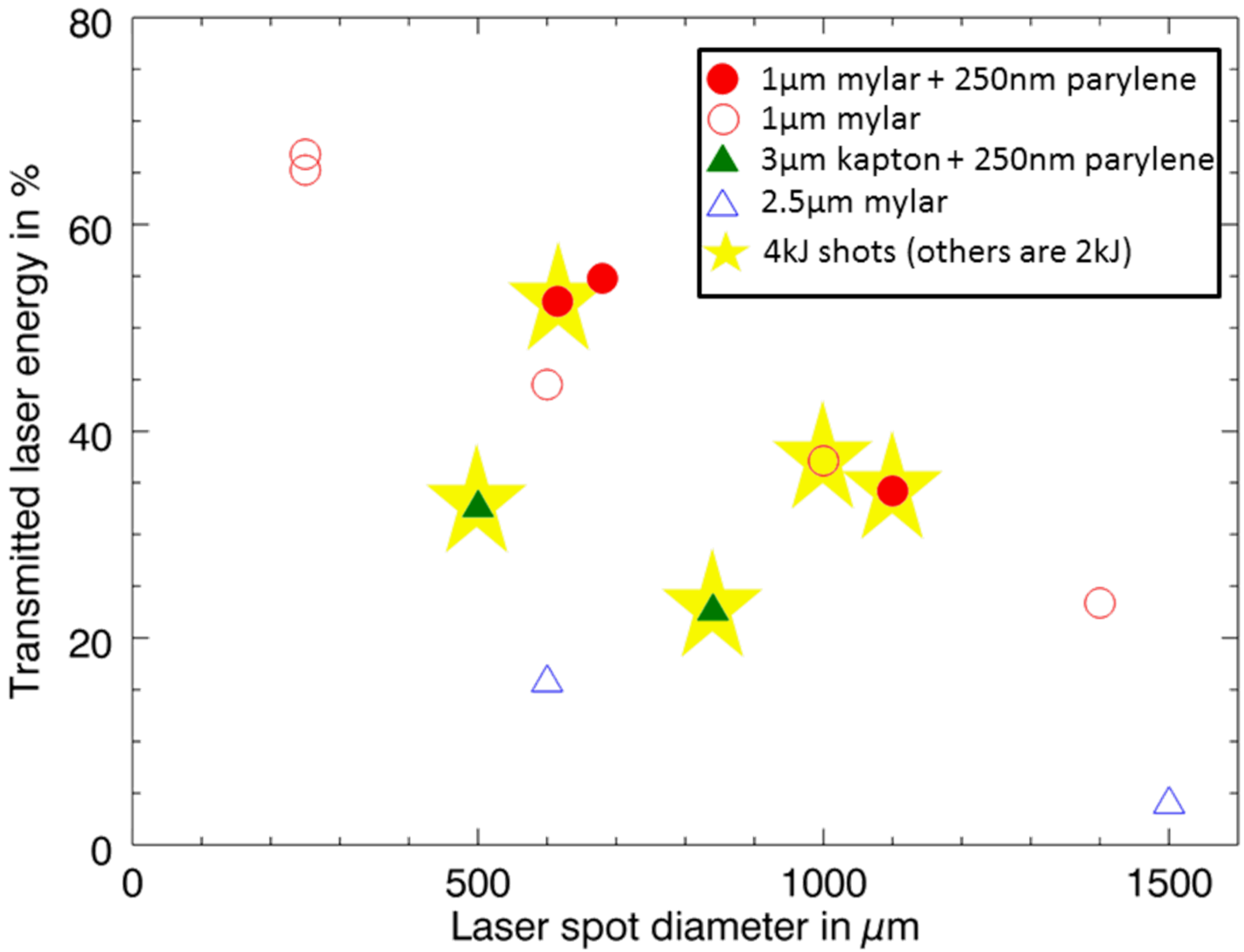
Parylene-N	Pre-pulse transmission	Main pulse transmission
0 nm	100%	100%
100 nm	90%	>90%
250 nm	50%	>80%
500 nm	9%	>80%

Lineout for 250 nm smoothing, 12 mm propagation

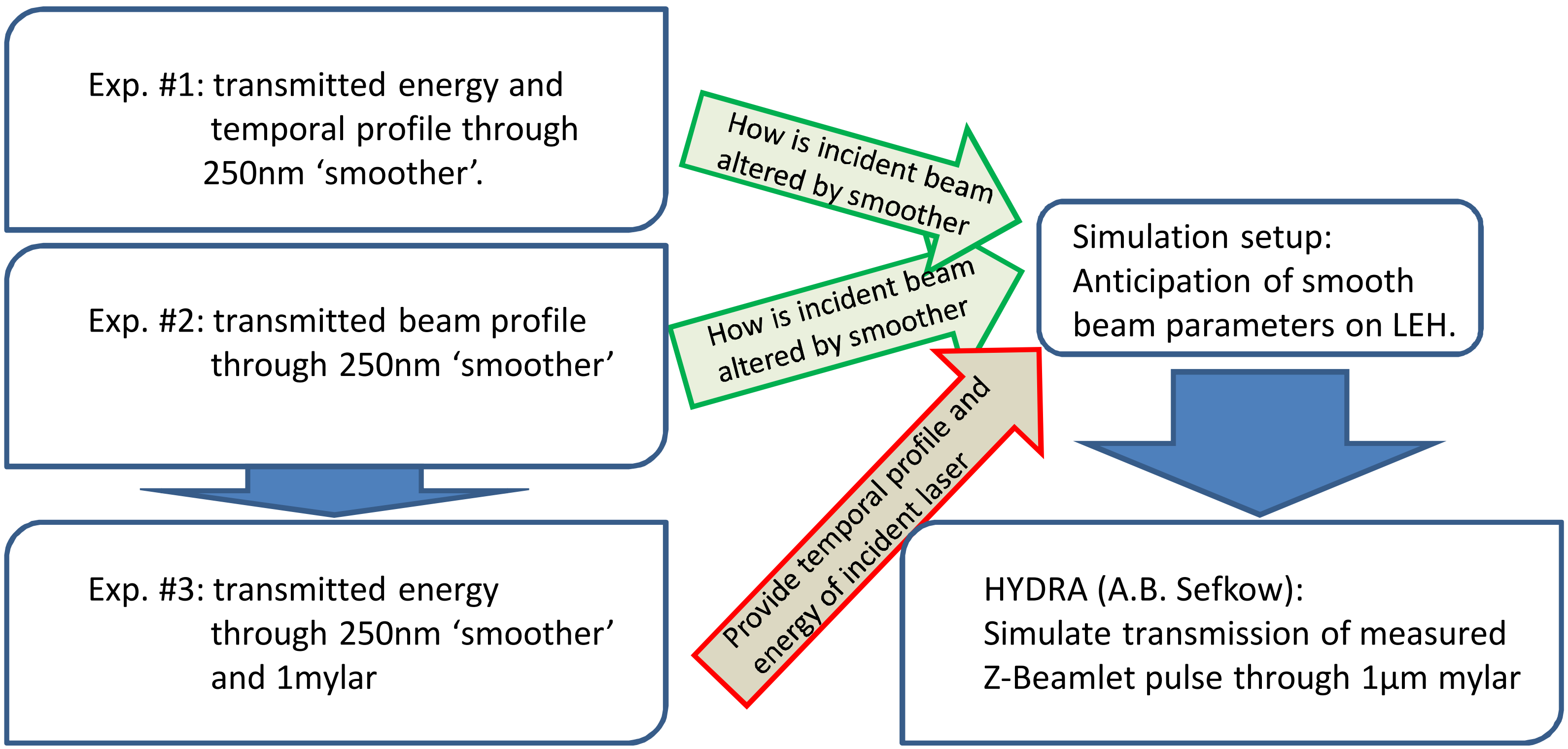


Results

Calorimeter Measurements



Experiment vs. Simulation



Total measured transmission:

E = 1227 J

Total simulated transmission:

E = 1208 J

Summary

- >50% of laser energy can be lost in LEH
- Pre-pulse is essential to transmission
- Adjustable smoothing can be achieved with sacrificial foil without additional energy loss
- Smooth beam behavior comes close to Hydra simulations

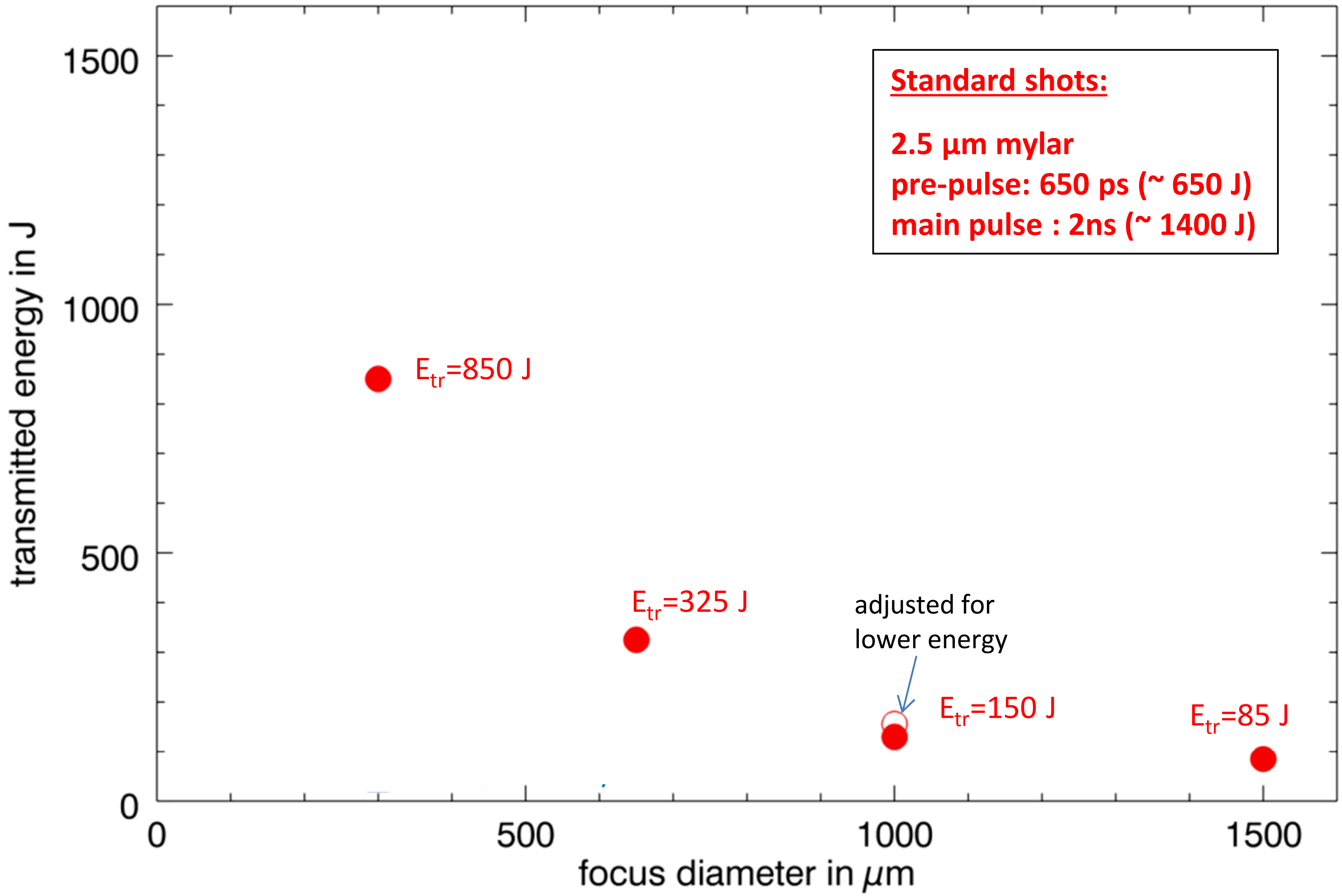
Outlook

- Increase flexibility with pre-pulse (e.g. longer separation)
- Temporal resolution for X-ray diagnostics
- Implement gas-filled target cell with/without magnetic coils ('stand-alone')

EXTRAS

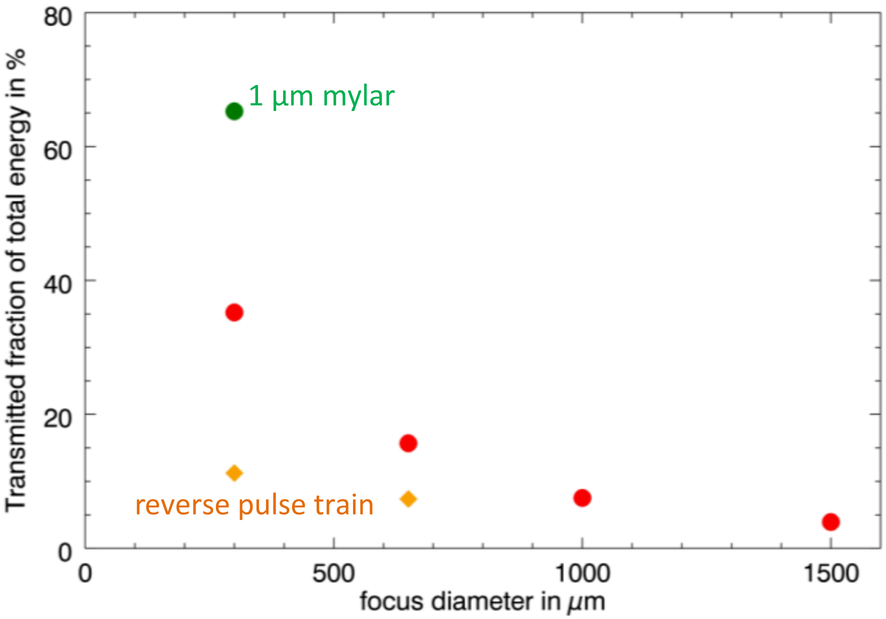
Teflon Emission Measurements

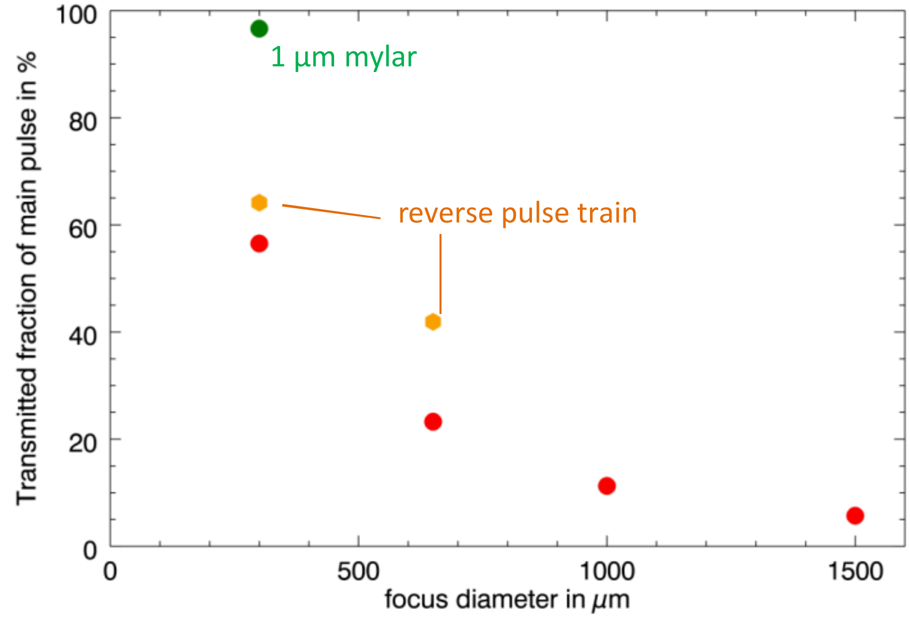
Calorimeter Measurements



Teflon Emission Measurements

Calorimeter Measurements





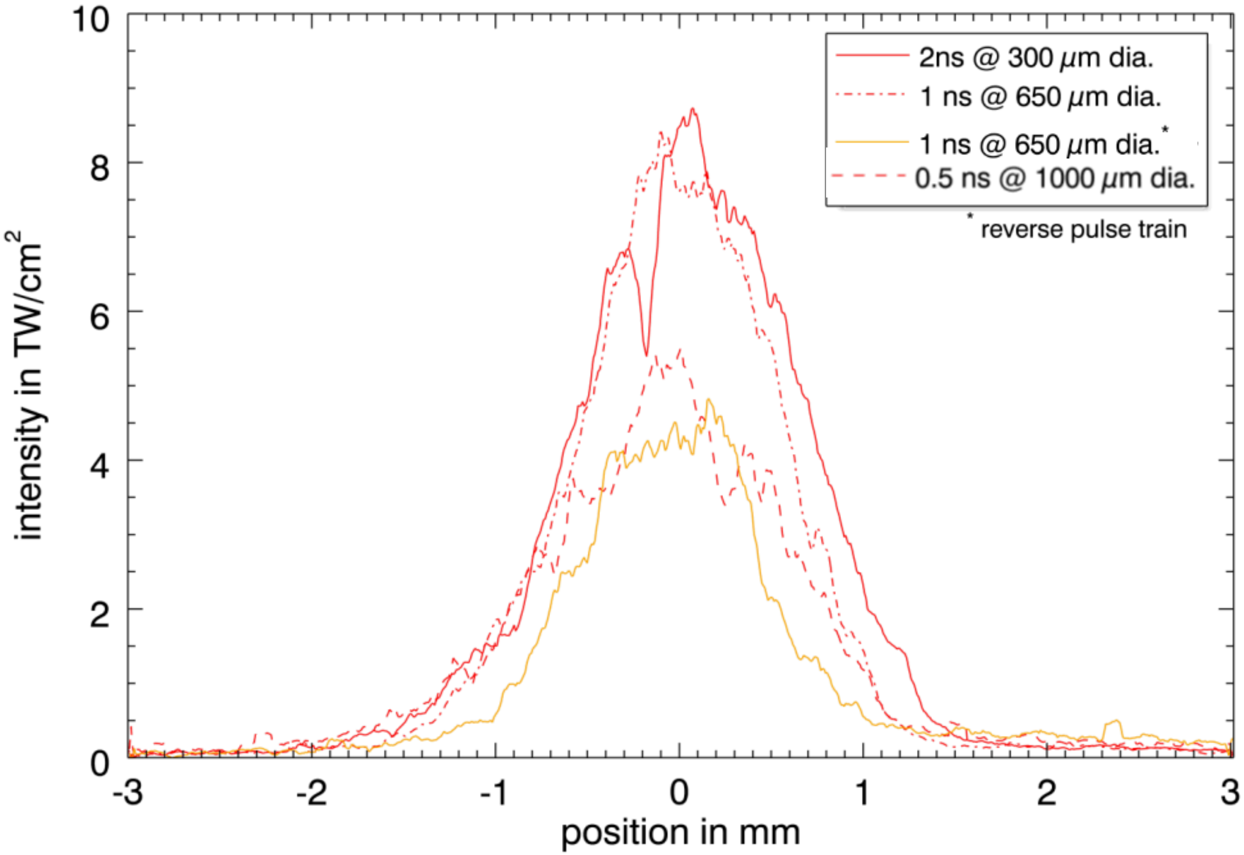
Standard shots:

2.5 µm mylar
pre-pulse: 650 ps (~ 650 J)
main pulse : 2ns (~ 1400 J)

Teflon Emission Measurements

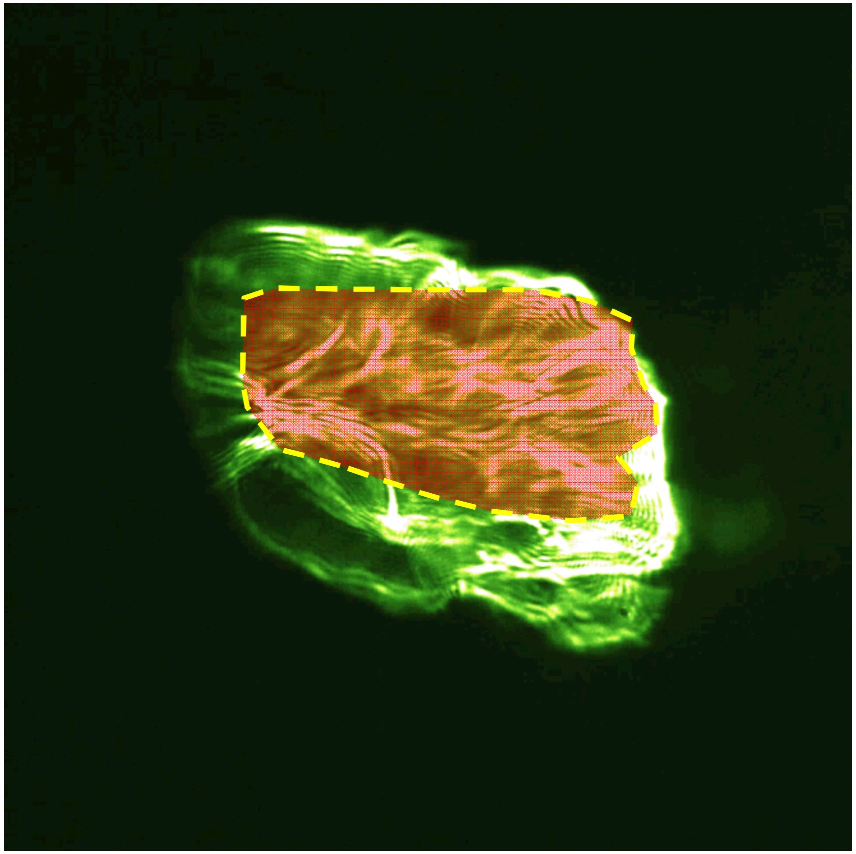
PTFE emission lineouts: Intensity 12 mm behind 2.5 µm mylar

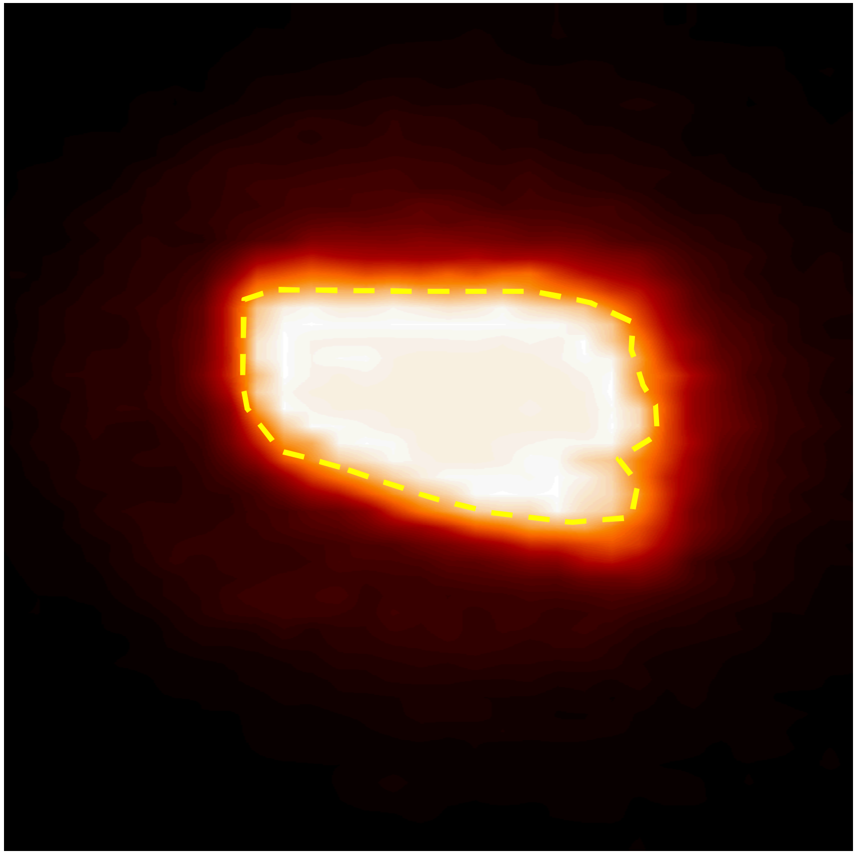
(135 µm box average for noise suppression)



Feature comparison

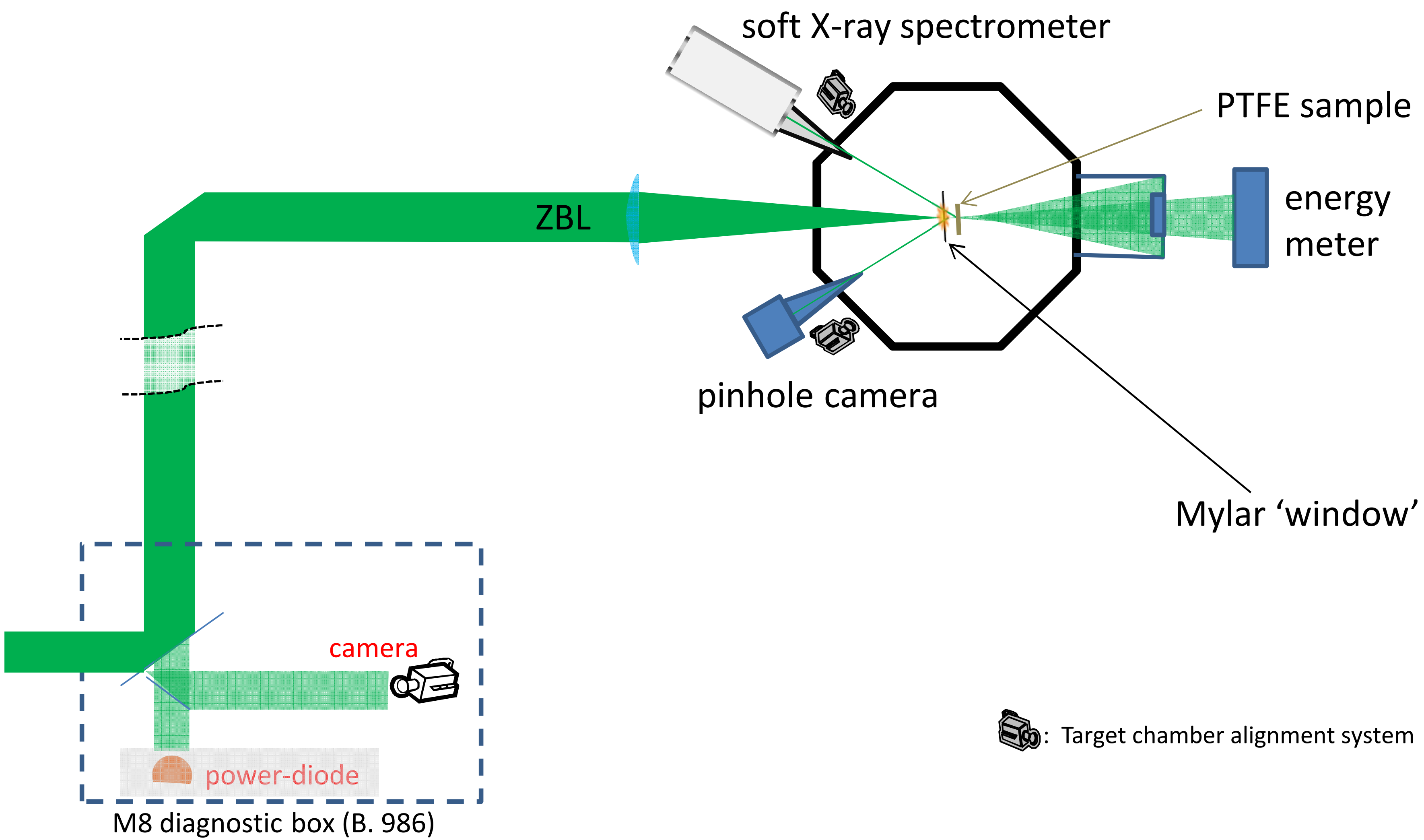
Probe beam vs. pinhole image



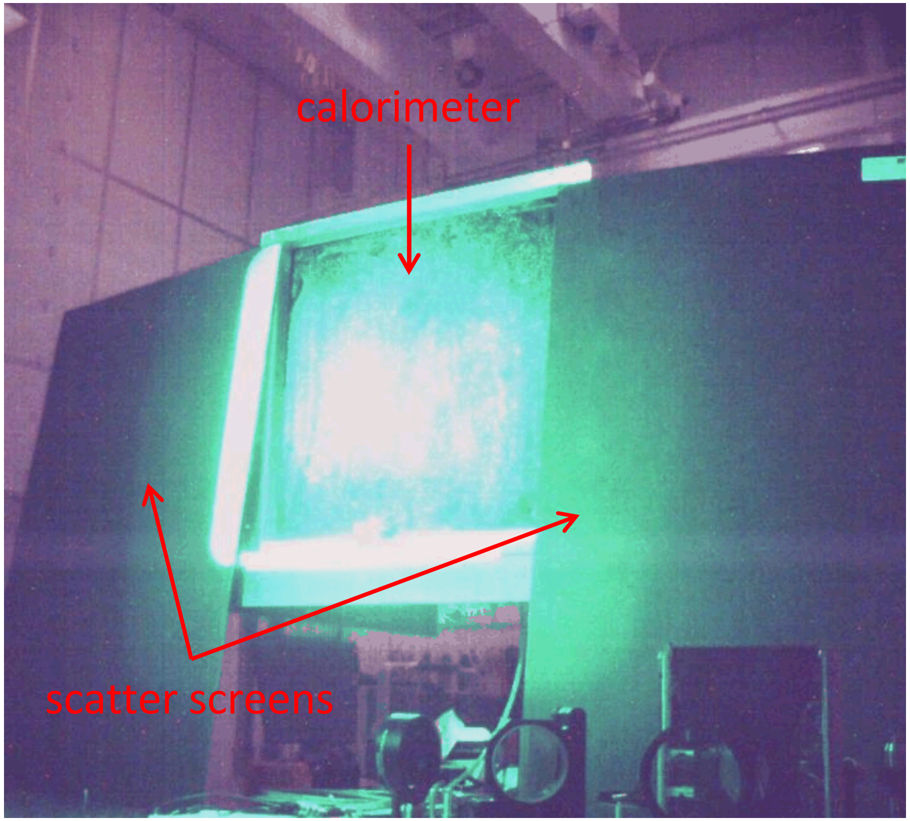


First Results on LEH Transmission Studies

SETUP



Calorimeter Measurements



Calorimeter:

~ 40 cm x 40 cm

8”1” behind target

Beam should be ~ 28 cm x 28 cm

Beam overfills and clips on exit window.

Beam has ‘Gaussian’ center.

Green scatter from chamber creates wide pedestal.