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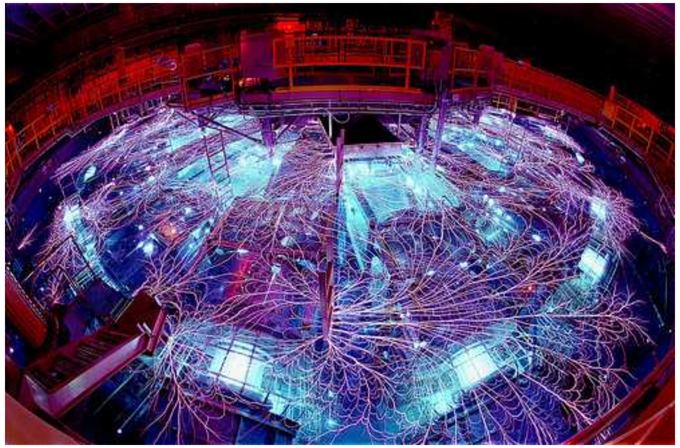

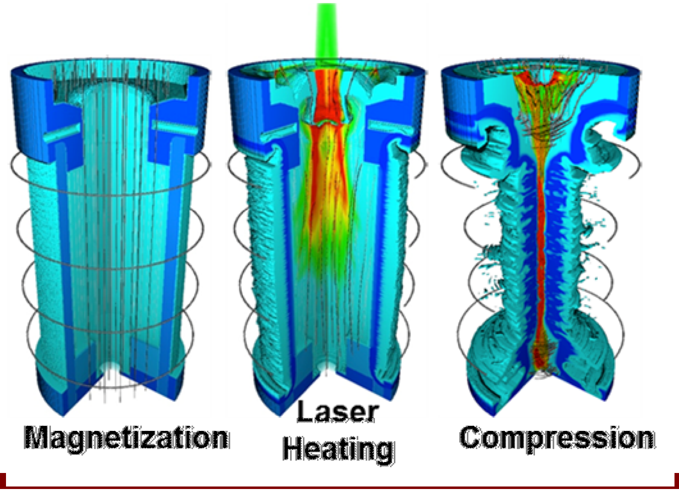

Study of fuel preheating dependence on laser wavelength and intensity for MagLIF

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CHANGING WHAT'S POSSIBLE

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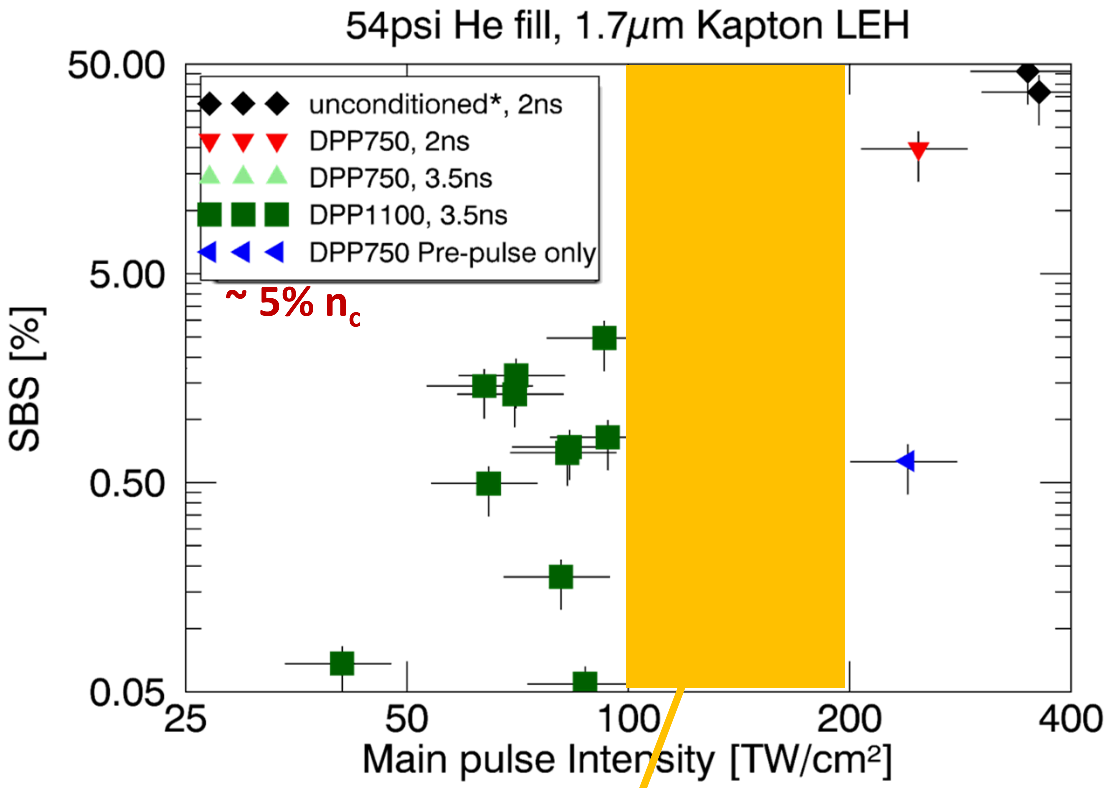
U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

Z-Beamlet (2ω) experiments have observed strong increase of laser plasma instability (LPI) with intensity

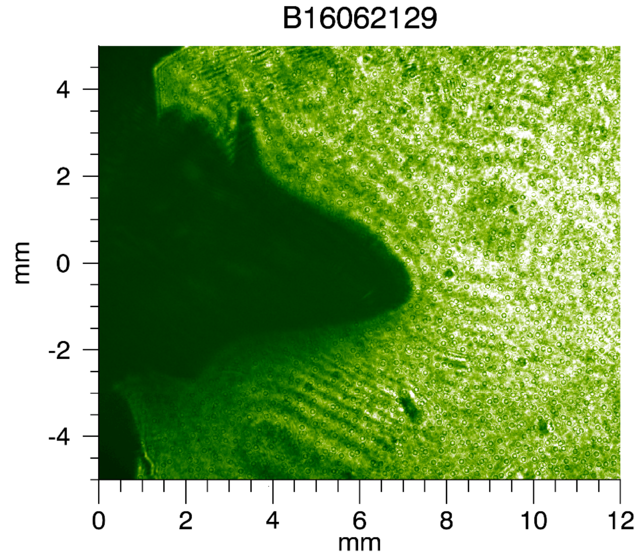
M. Geissel's talk (PO8.00004)



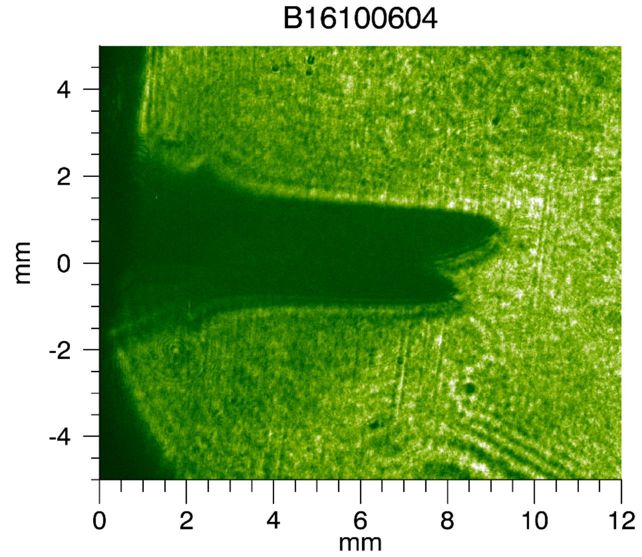
Filamentation Figure of Merit

$$\mathrm{FFOM} = \frac{I_p \lambda_0^2}{10^{13}} \left(\frac{n_e}{n_{cr}}\right)\left(\frac{3}{T_e}\right)\left(\frac{f^\#}{8}\right)^2$$

D. Froula et al., Phys. Plasmas (2007)



Focus: no Phase Plate
Pre-Pulse: 310 J
Main Pulse: 1820 J
Power: 0.9 TW



Focus: 1100 μm Phase Plate
Pre-Pulse: 60 J
Main Pulse: 850 J
Power: 0.2 TW

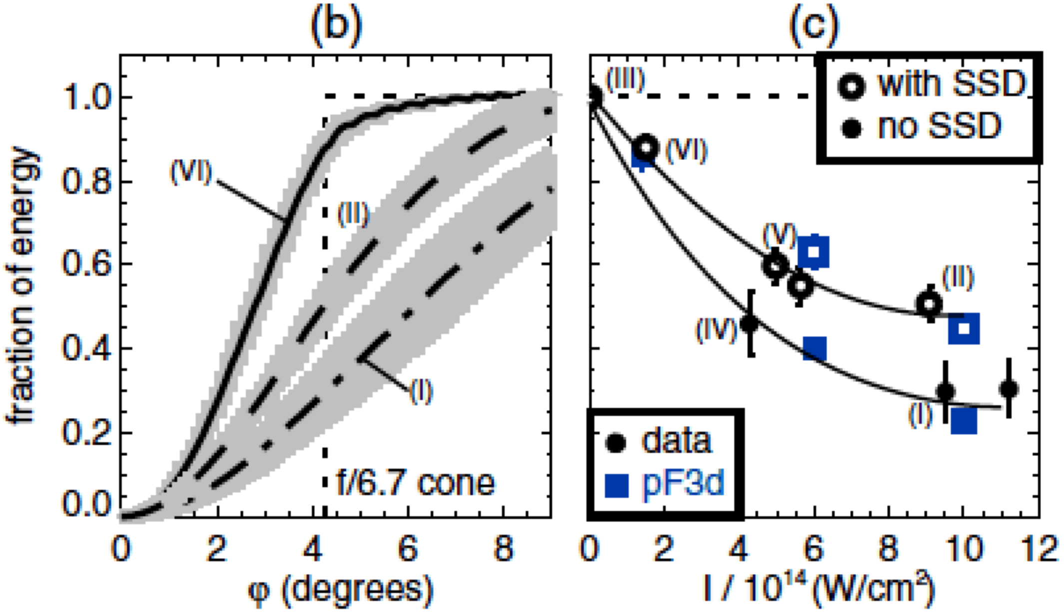
- Laser interaction with LEH and LPI need to be understood to optimize laser preheat for MagLIF

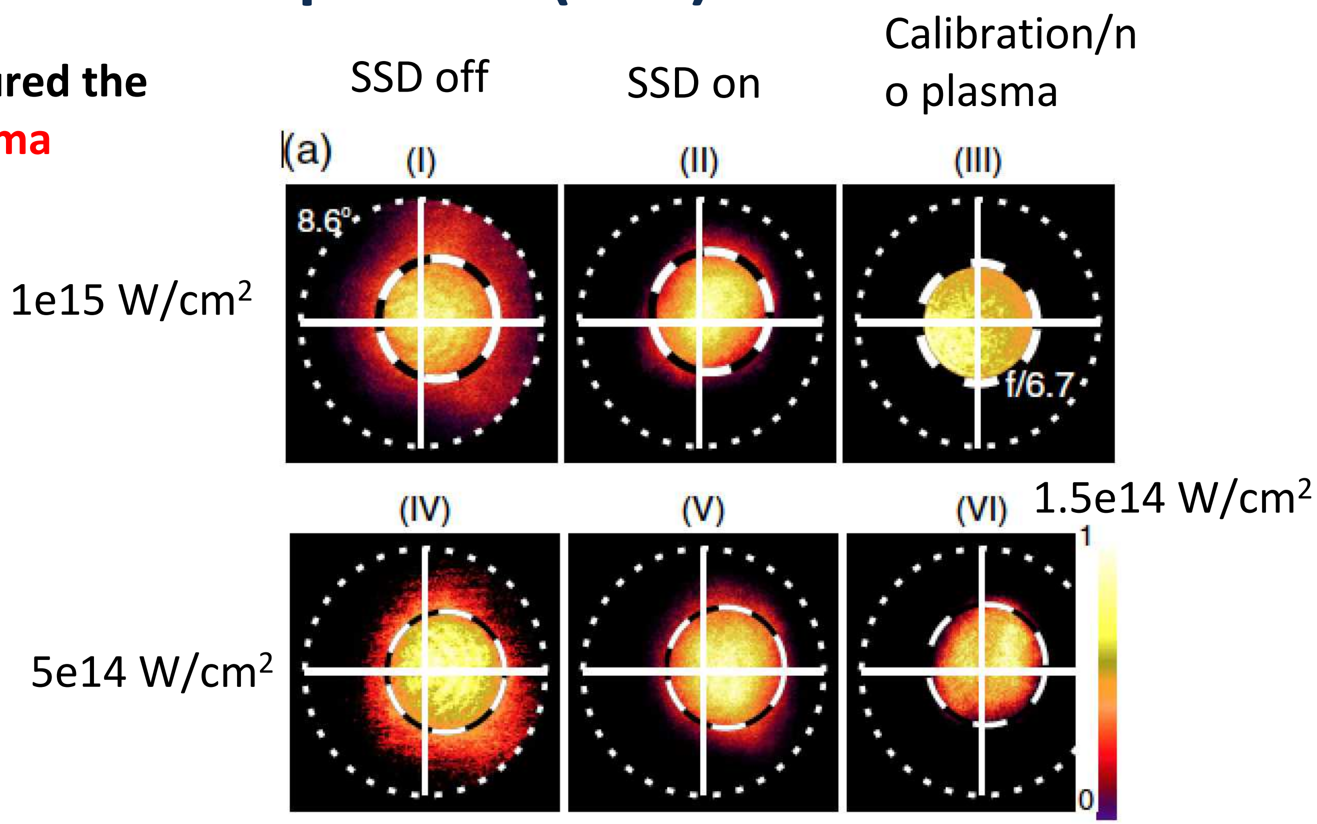
Will a 3ω beam be needed to overcome LPI? At what intensity and fuel density will LPI also become important?

Previous 2ω experiment on OMEGA showed noticeable differences in laser beam spay without smoothing by spectral dispersion (SSD)

Previous gas-bag experiments* ($0.14n_c$ CH plasma) measured the 2ω beam transmission and spray in a hot (1.8-2 keV) plasma

*C. Niemann et al, PRL (2005)





- Good beam transmission at laser intensities ≤ 2×10^{14} W/cm^2 and a strong reduction at intensities up to 10^{15} W/cm^2 due to LPI – SSD allows 2x higher intensities while keeping the beam spray constant.

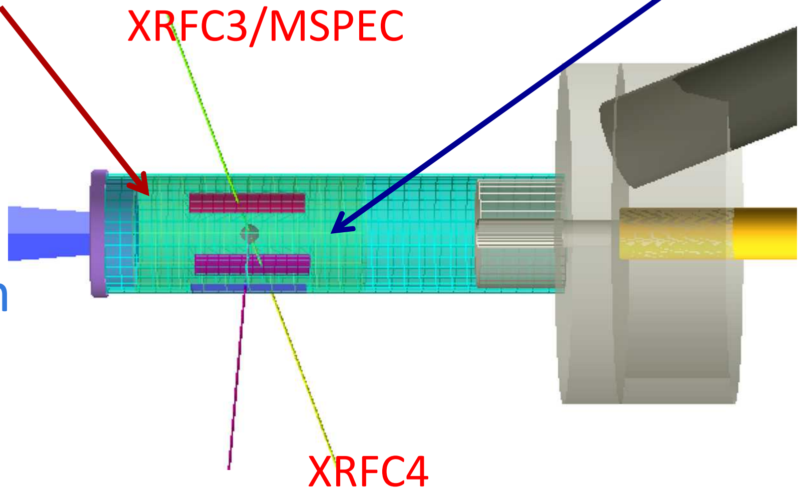
Large scale MagLIF fuel is relatively cold, more susceptible to filamentation/beam spray. Previous work were done with CH or Ar (He) plasmas. Need data with MagLIF fuel (D2 or cryo-DT) to further study LPI and preheat science.

OMEGA experiments directly compared 2ω and 3ω laser propagation and heating of D2 gas with laser intensity in the range of $1 – 5 \times 10^{14}$ W/cm²

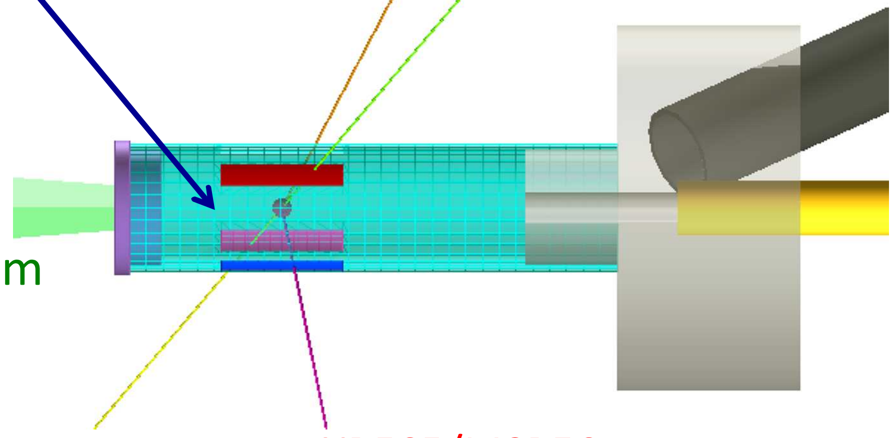
Polyimide tube:
2.1 OD, 50 µm wall, 1.82 µm thick LEH
(with 18.5 nm Ti coating facing fuel)

D2 Gas
9.2 (4.1) atm with 1.25 at.% Ar for 3ω (2ω) – 0.055 n_c

3ω beam



2ω beam



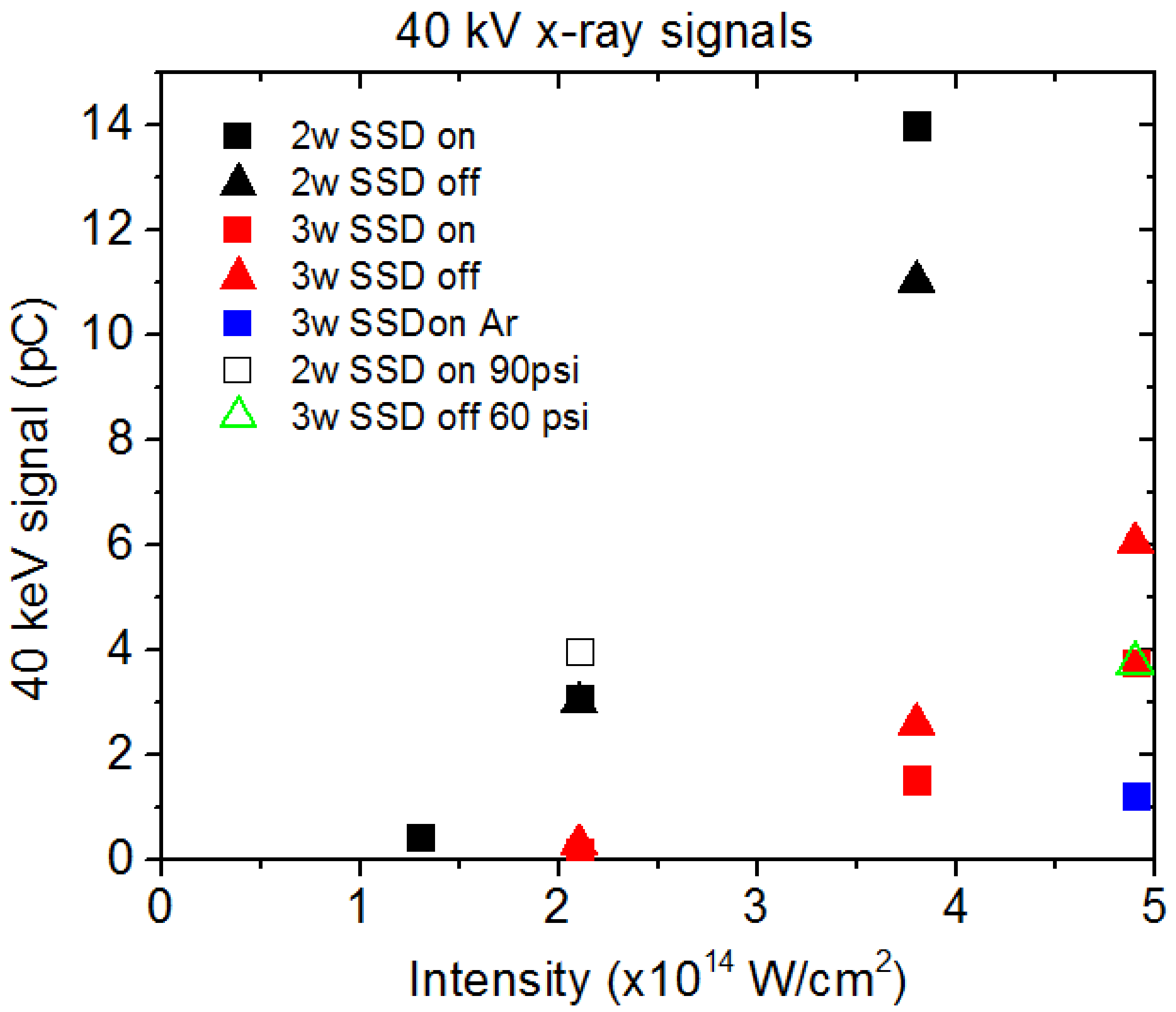
3ω (2ω) interaction beam

- up to 450 J in 1 ns and up to 285 J in 1.5 ns
- 300 µm DPP
- Intensity $1.3 – 4.9 \times 10^{14}$ W/cm²
- SSD on and off

Primary Diagnostics

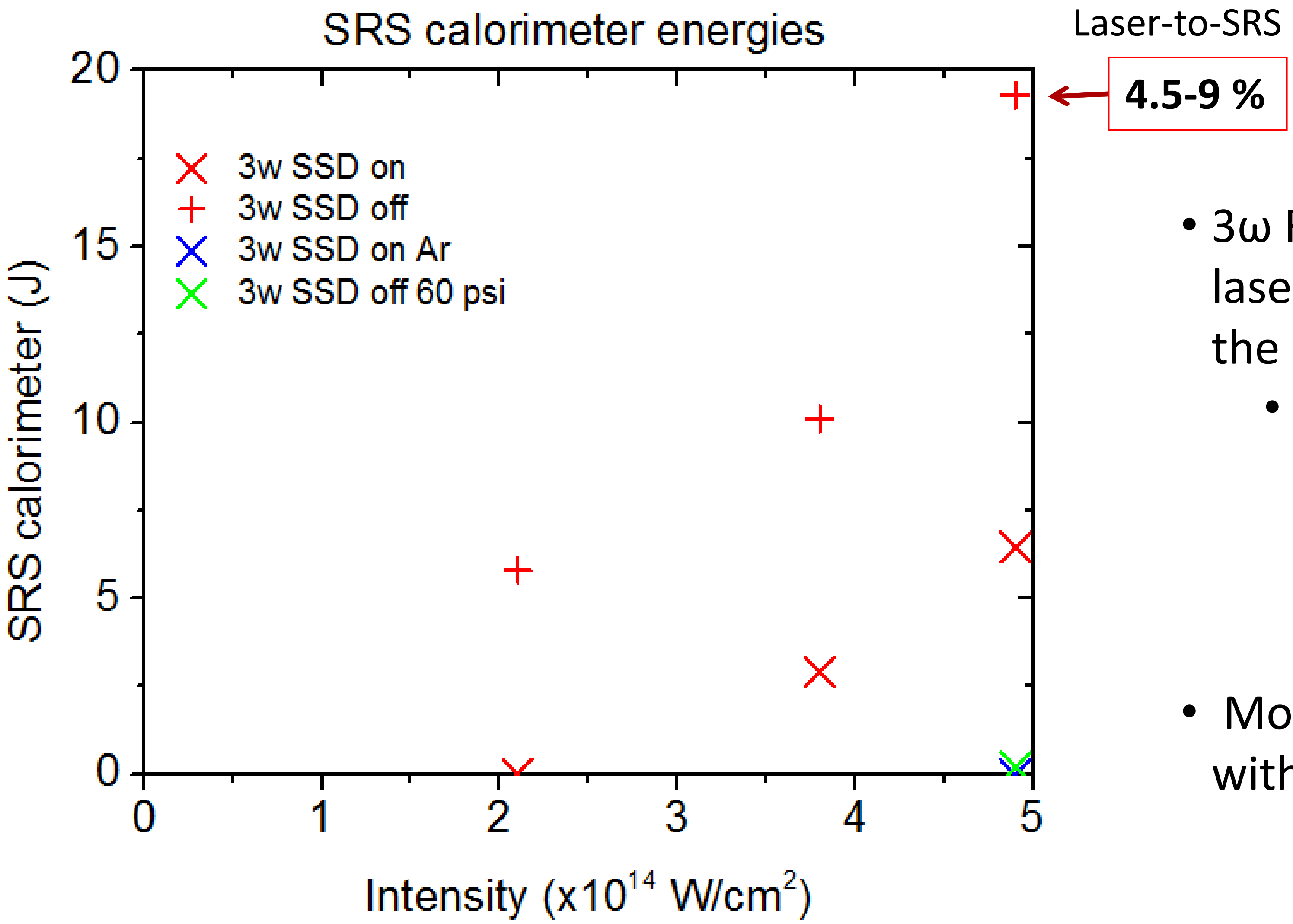
- XRFC imaged laser propagation
- HXRD monitored hard x-ray emission
- FABS characterized backscattering of the 3ω beam
- MSPEC measured Ar K-shell spectrum

Hot electron generation increased with laser intensity, particularly prominent with the 2ω beam



- 2ω beam interaction produced more hot electrons than the 3ω beam
- SSD had no effect on the 2ω beam interaction
- Observed suppression of hot electrons with SSD in the 3ω shots
  - Signal was already very low
- Pure Ar plasma showed the lowest hard x-ray signal compared with the deuterium targets

Observed an increase in backscattered SRS with laser intensity from the 3ω beam interaction



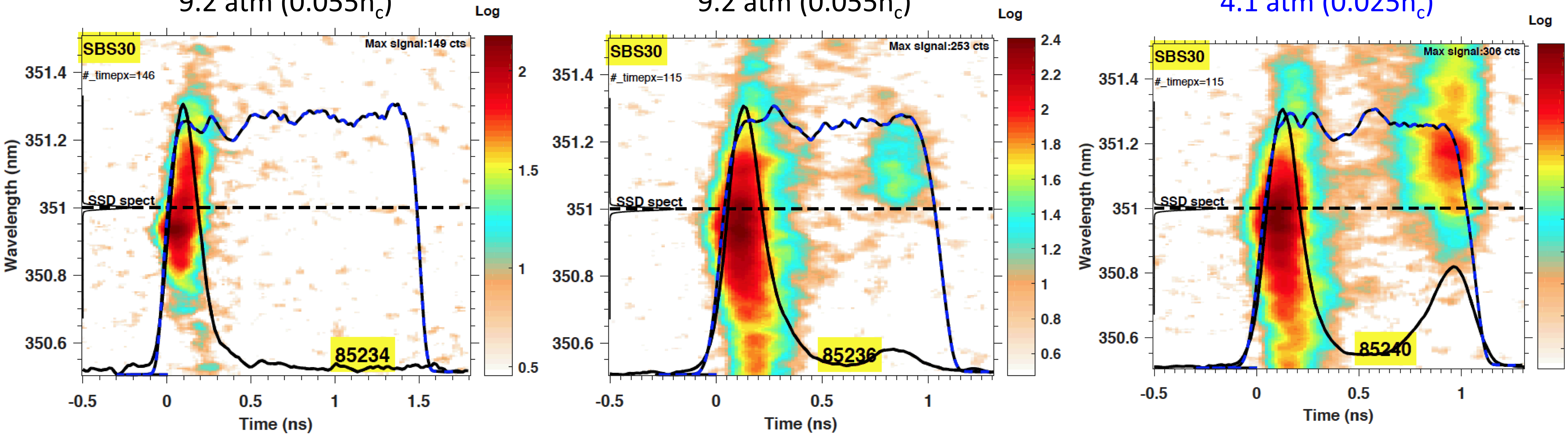
- 3ω FABS data showed increasing SRS with laser intensity, up to 4.5-9% laser energy in the backscattered SRS
  - Much stronger hard x-ray signal from the 2ω shots indicate significant amount of energy may be lost due to LPI
- More SRS when SSD was off, consistent with the hot electron hard x-ray results

SBS was generated from laser LEH interaction – increasing with laser intensity

308J, 1.5 ns, 2.2×10^{14} W/cm^2 — 9.2 atm (0.055n_c)

438J, 1 ns, 4.6×10^{14} W/cm^2 — 9.2 atm (0.055n_c)

462J, 1 ns, 4.9×10^{14} W/cm^2 — 4.1 atm (0.025n_c)

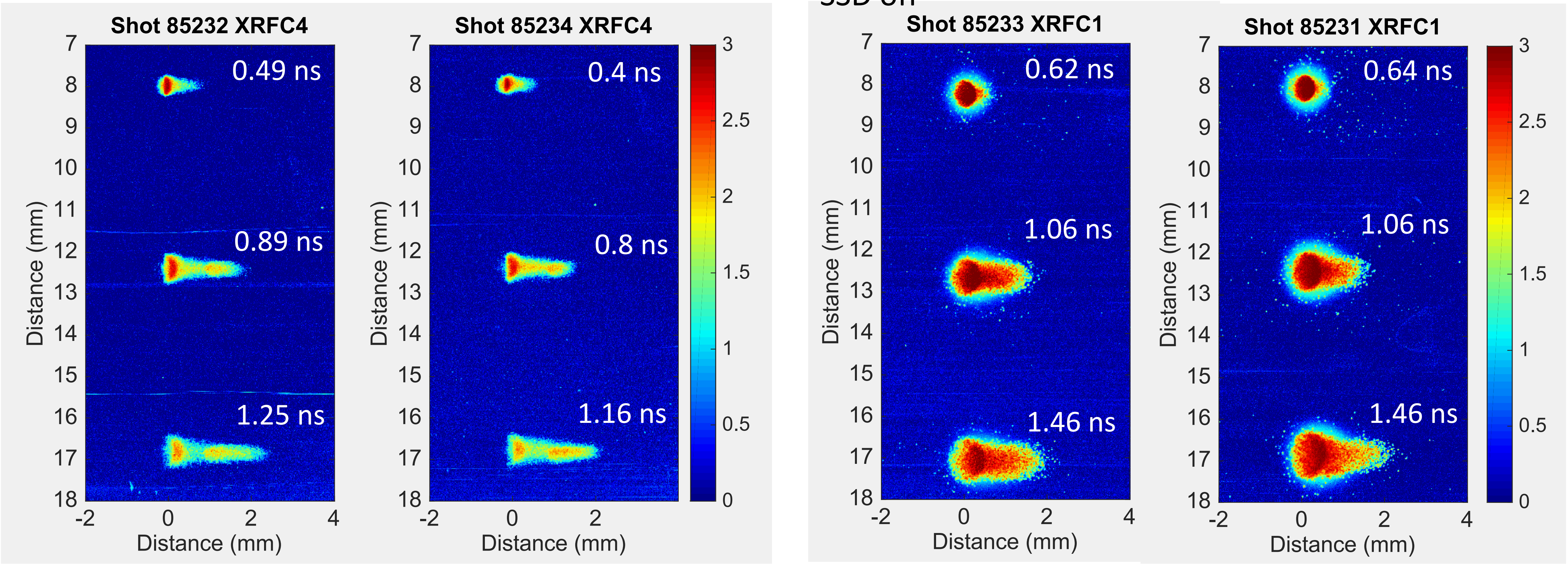


- With the same fuel density, SBS signal was doubled with 2x higher intensity
- Laser propagated over 6 mm distance in < 1 ns in the low pressure gas fill target
  - Red-shifted SBS signal observed at the end of the pulse

2ω beam propagation had a larger lateral spread than the 3ω beam

SSD on | 3ω, 1.5 ns, 2.1 × 10^{14} W/cm^2 | SSD off

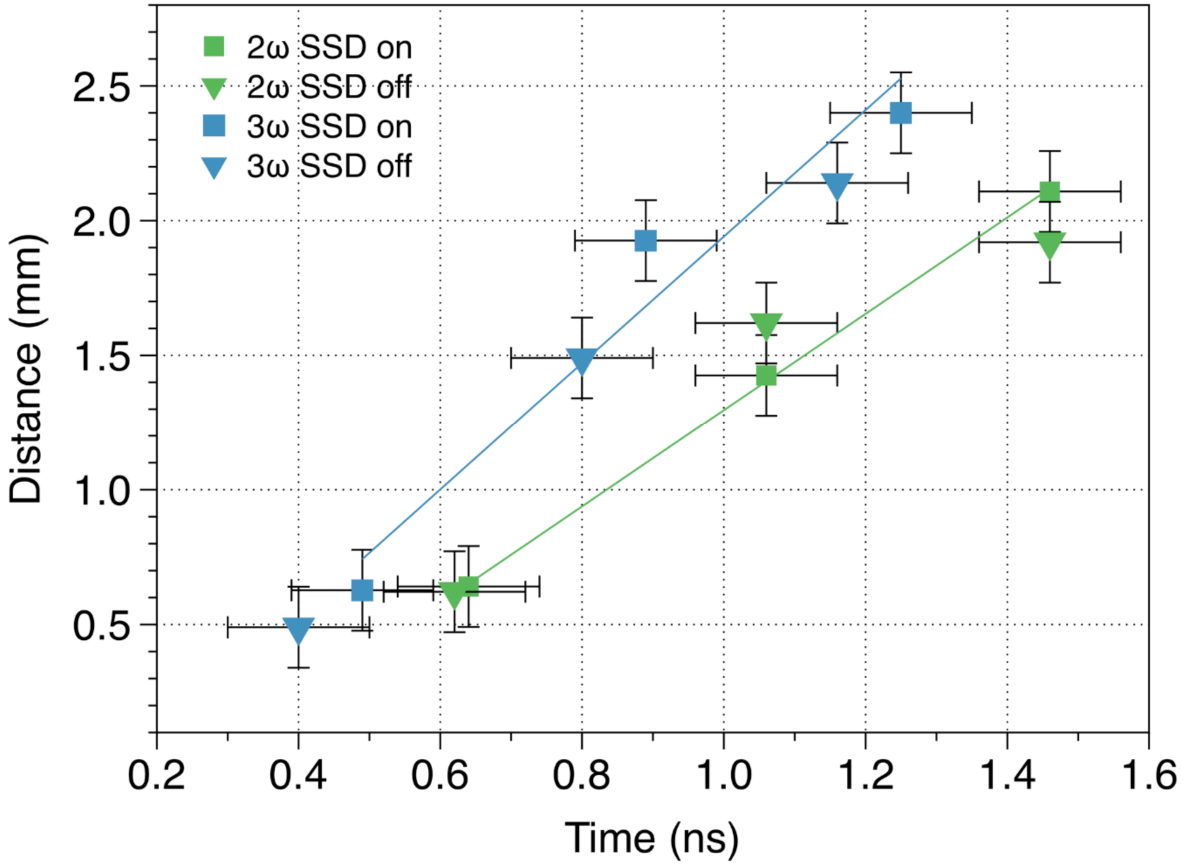
SSD off | 2ω, 1.5 ns, ~2 × 10^{14} W/cm^2 | SSD on



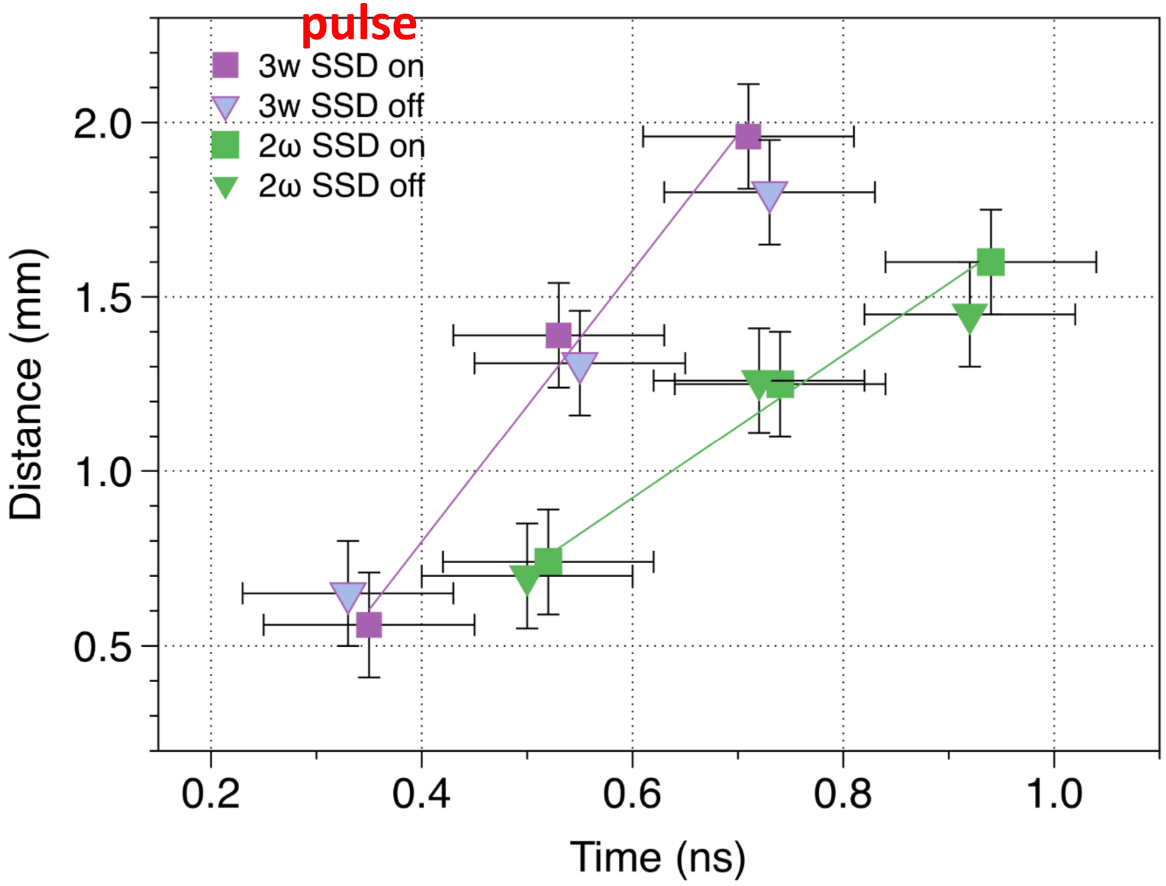
- 3ω beam propagation contained in the laser cone.
- 2ω beam interaction resulted in significant sprays, 2-3x larger than the laser spot size
- Insensitive to SSD for both 3ω and 2ω beams at this intensity – consistent with hard x-ray data

Observed slower and shorter propagation distance with the 2ω beam at both low and high intensity

~ 2×10^{14} W/cm^2, 1.5 ns pulse

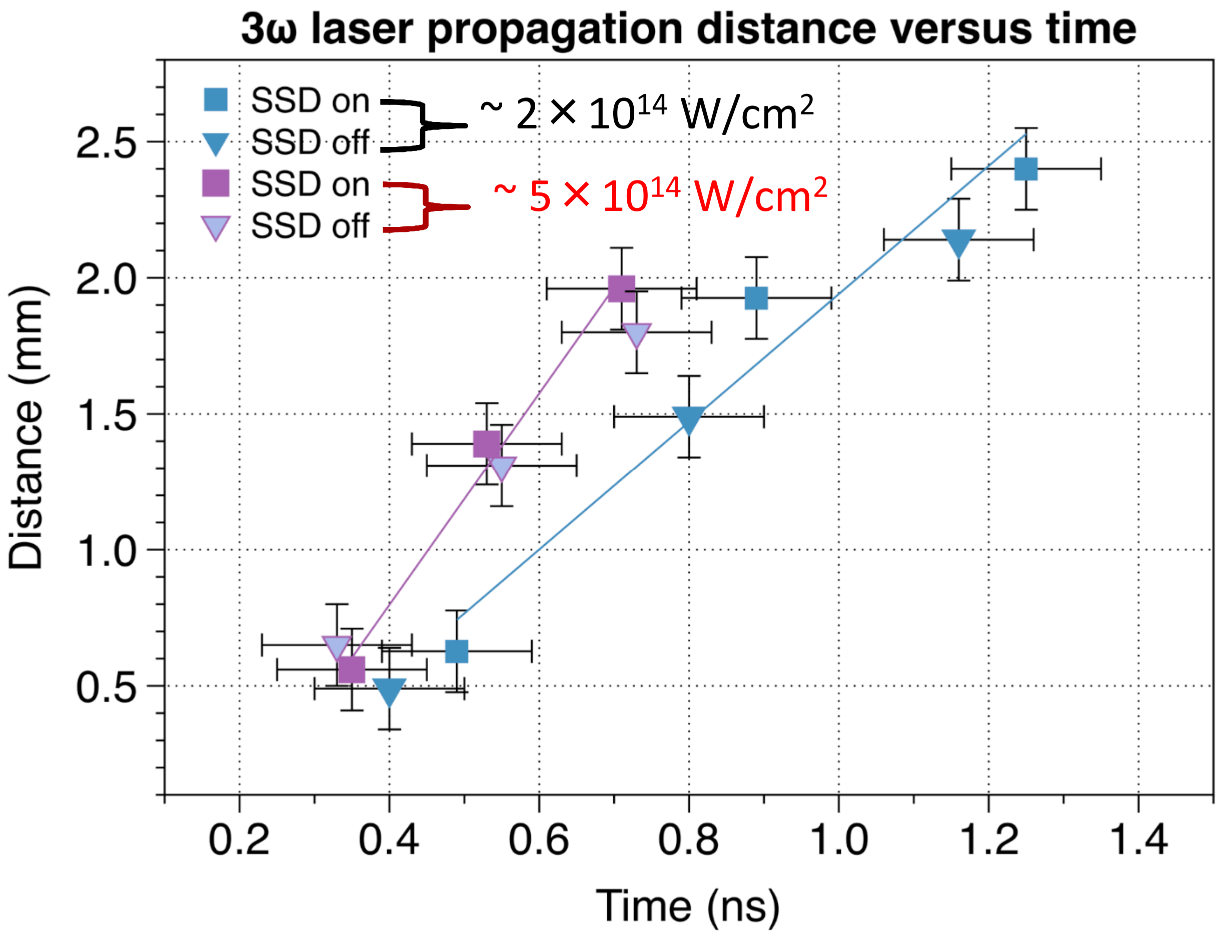


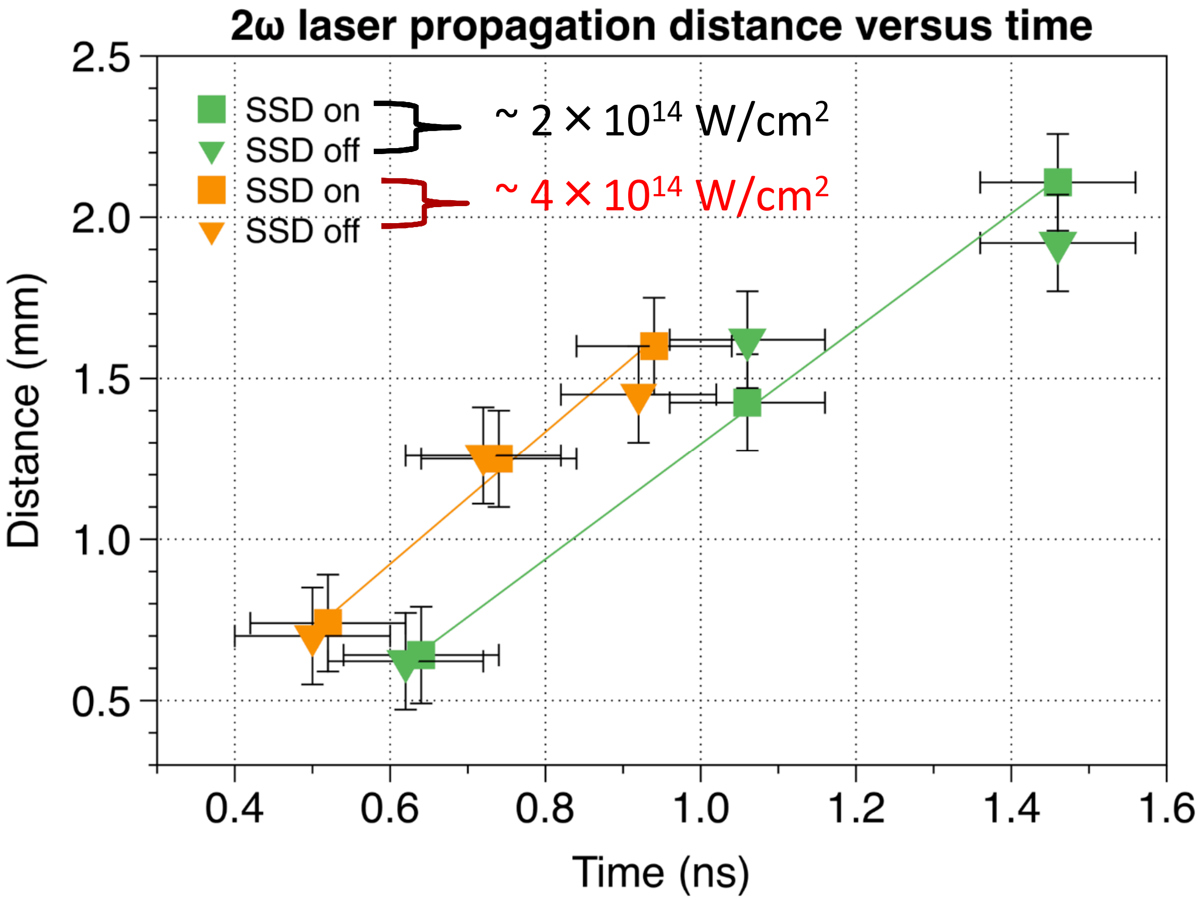
~ 4-5 $\times 10^{14}$ W/cm^2, 1 ns pulse



- SSD had little effect on the observed beam propagation distance in the intensity range investigated

2ω beam propagation velocity was not affected by 2x change in laser intensity, in contrast to the observed intensity dependence with the 3ω beam





- Significant amount of energy could already be lost due to LPI at LEH
- Data will be compared with HYDRA and pF3D modeling

Summary

- A direct comparison of 2ω and 3ω interaction and heating of underdense deuterium plasmas have been performed to examine LPI and energy deposition on laser wavelength, intensity and SSD for MagLIF preheat science
- LPI produced hot electrons increased with laser intensity, particularly from the 2ω beam interaction
  - 2ω beam produced 6x more hot electrons than the 3w beam at same laser intensity (4×10^{14} W/cm^2)
- Backscattering also increased with laser intensity – up to 9% of the 3ω beam energy were backscattered in the SRS range with laser intensity of ~5×10^{14} W/cm^2
- 2w beam propagation showed significant spray, slower and shorter propagation than the 3w beam
  - SSD had little effects on LPI from the 2w beam interaction
- Data will be compared with HYDRA and pF3D simulations