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# Investigating the energy balance in MagLIF preheat experiments

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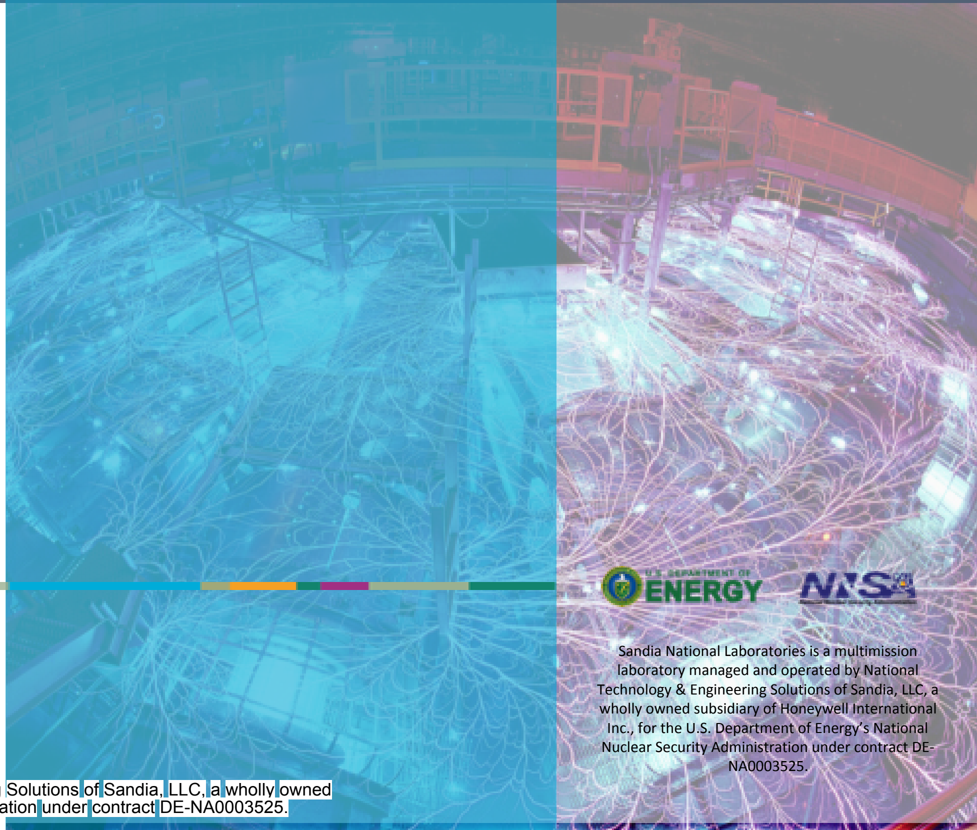
**General Atomics**





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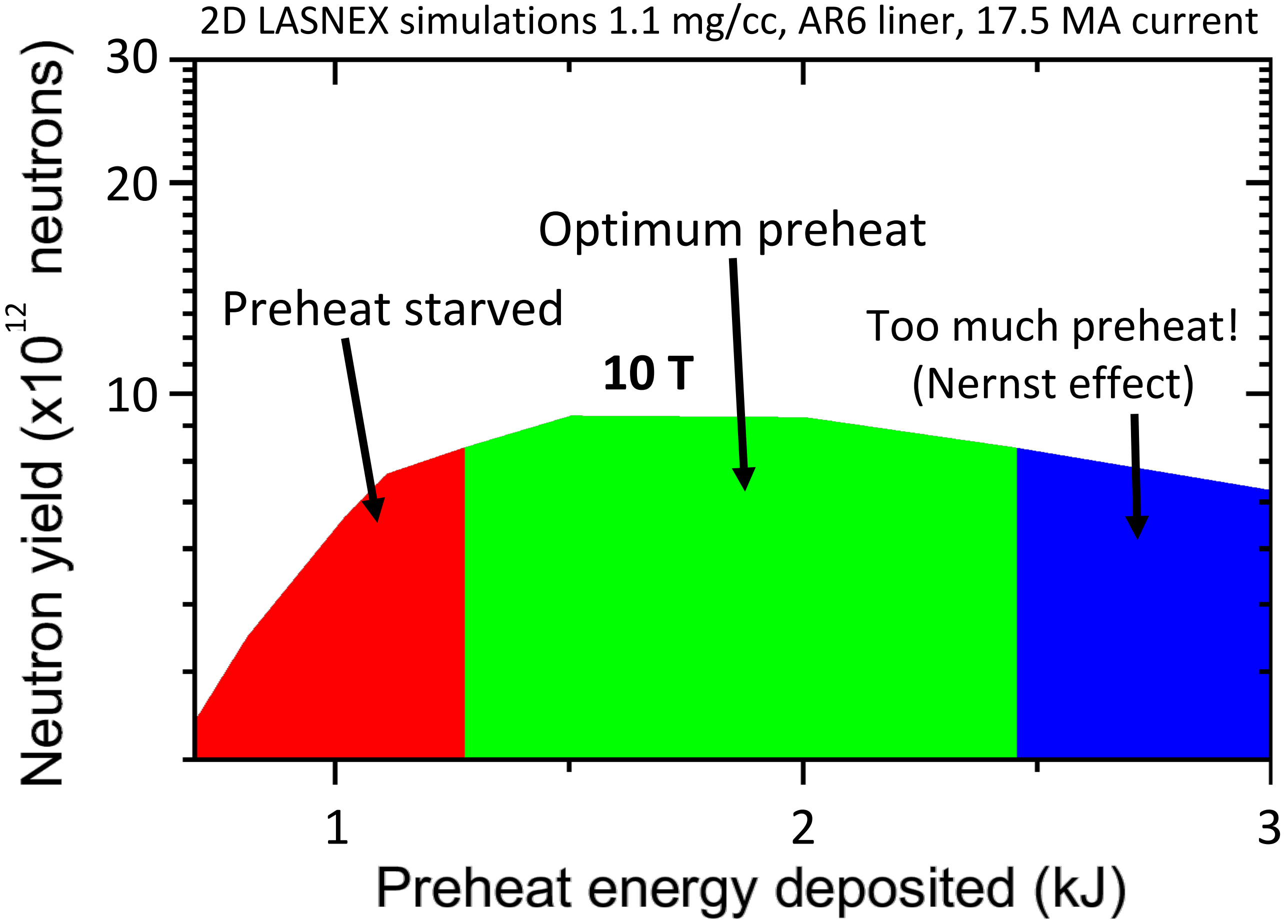
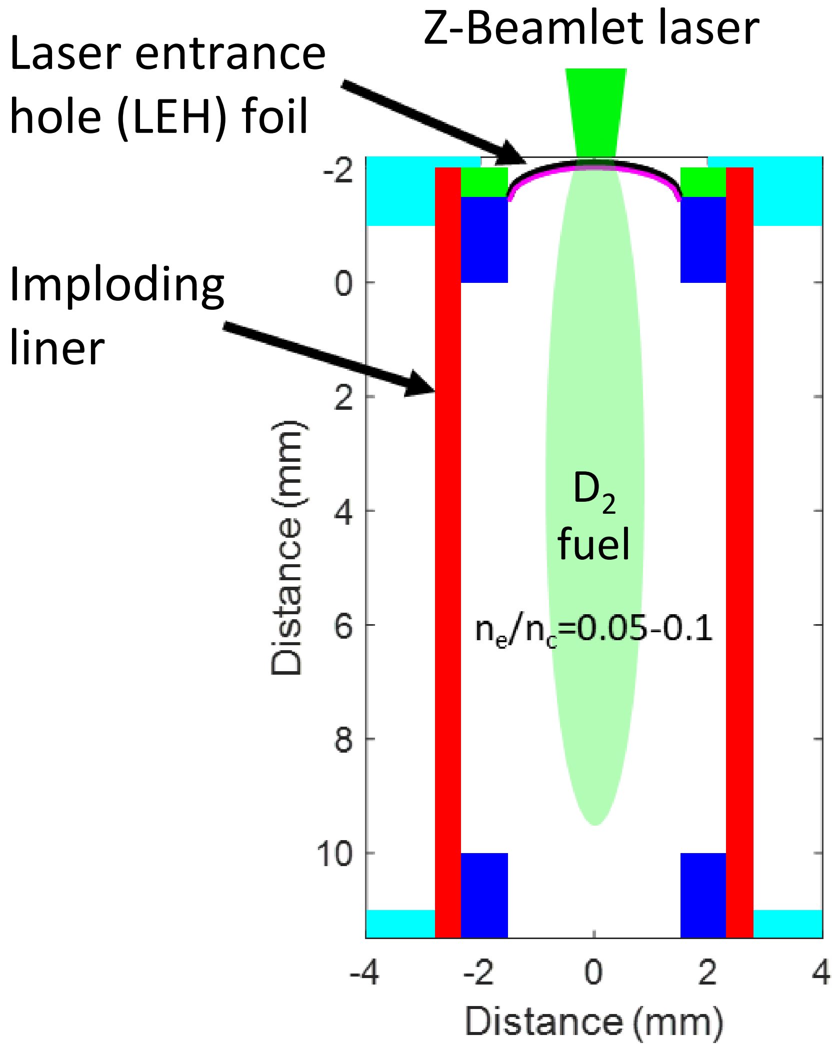
# MagLIF performance is sensitive to the preheat energy coupled

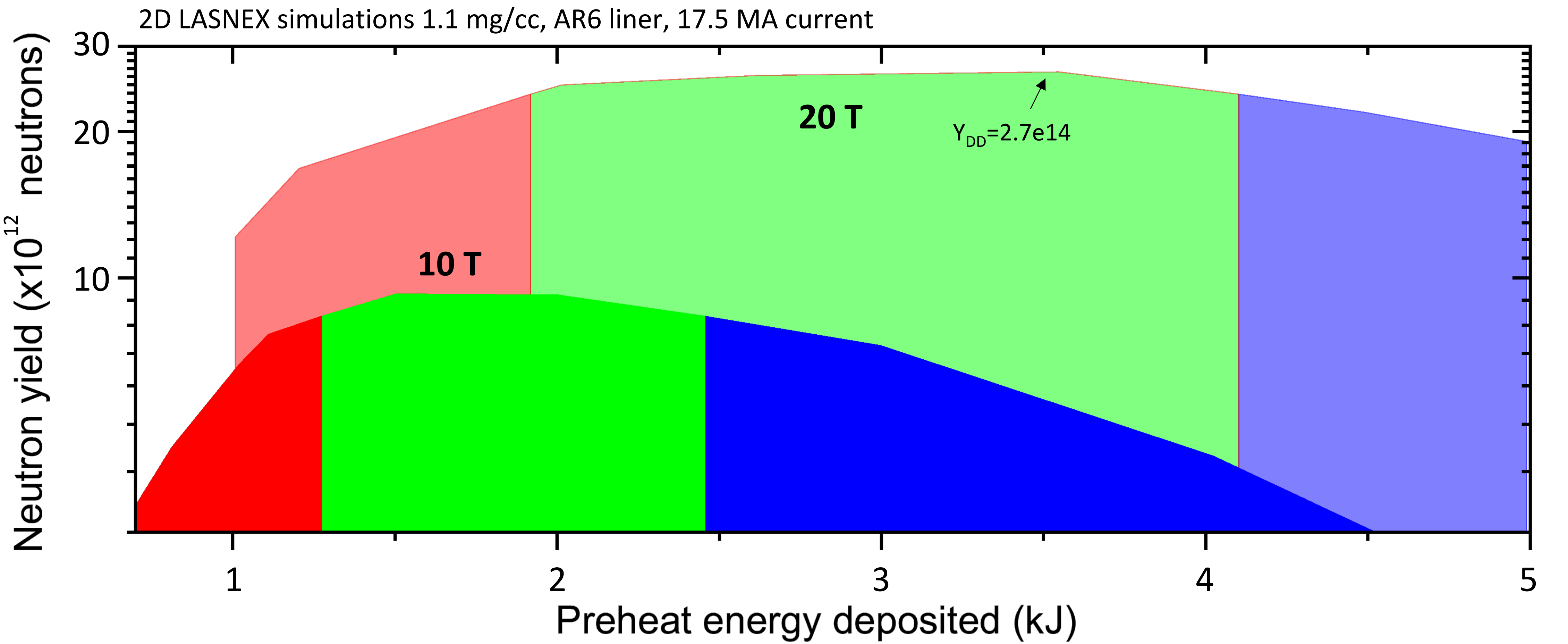



- Understanding how much preheat energy is coupled is crucial to understanding MagLIF performance

S. Slutz et al., Physics of Plasmas **25**, 112706 (2018)

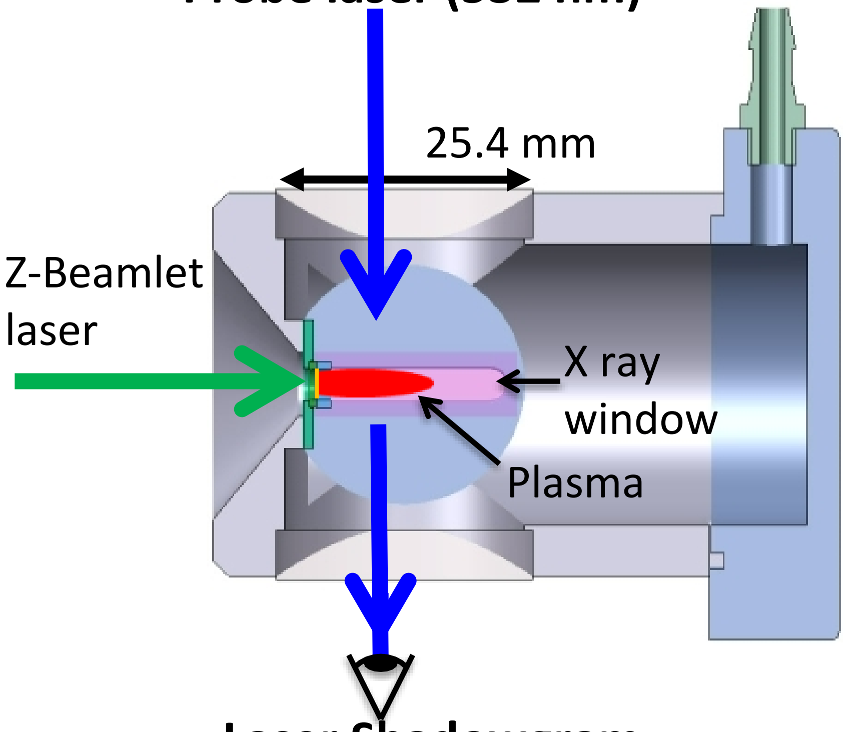
# Preheat energy needs to be increased in tandem with B field and fuel density



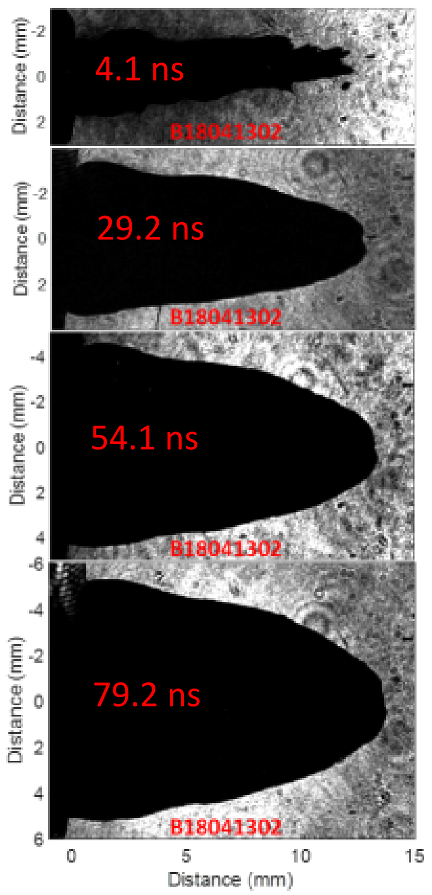

- To optimize at present MagLIF capabilities we need >2 kJ preheat

S. Slutz et al., Physics of Plasmas **25**, 112706 (2018)

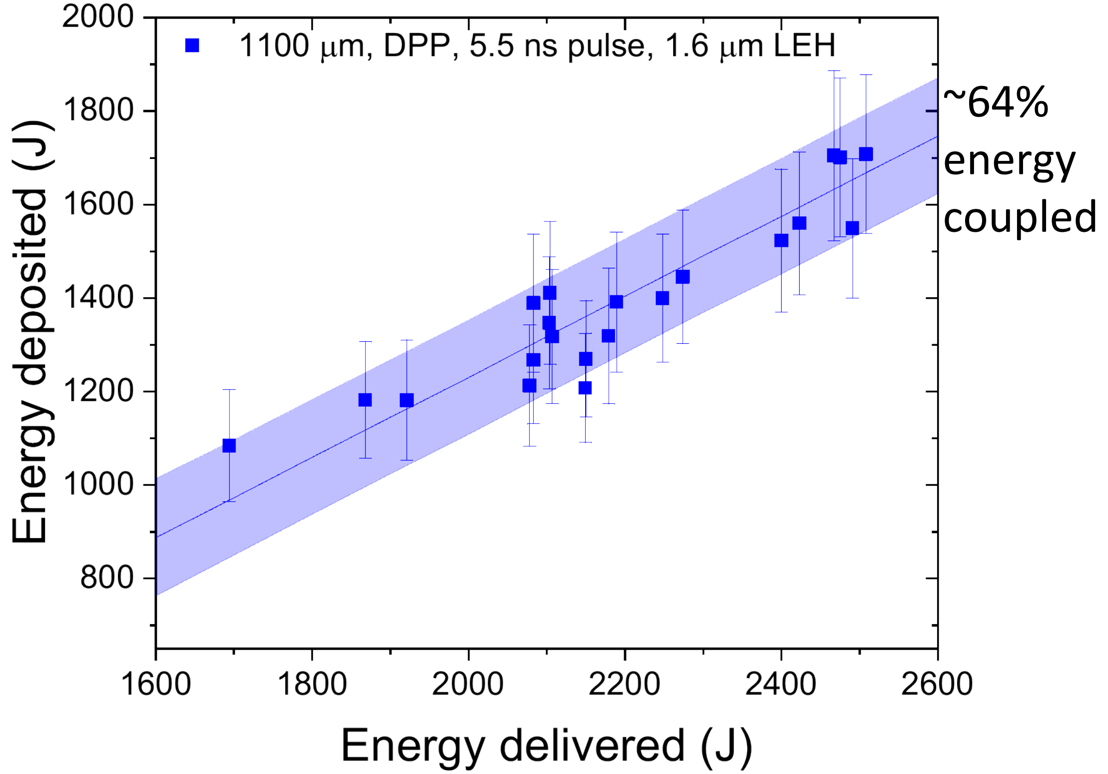
# Preheat configurations are designed in offline "Pecos" experiments




Blast wave expansion – energy deposited




Best performing "warm" preheat configuration




<u>"Warm" experiments have not exceeded 2 kJ with ZBL</u>

- Need to reduce losses to increase efficiency
- Energy invested in heating LEH foil
- LPI backscatter losses from LEH foil and gas

M. Geissel et al., Physics of Plasmas **25**, 022706 (2018)
A. Harvey-Thompson et al., Physics of Plasmas **26**, 032707 (2019)

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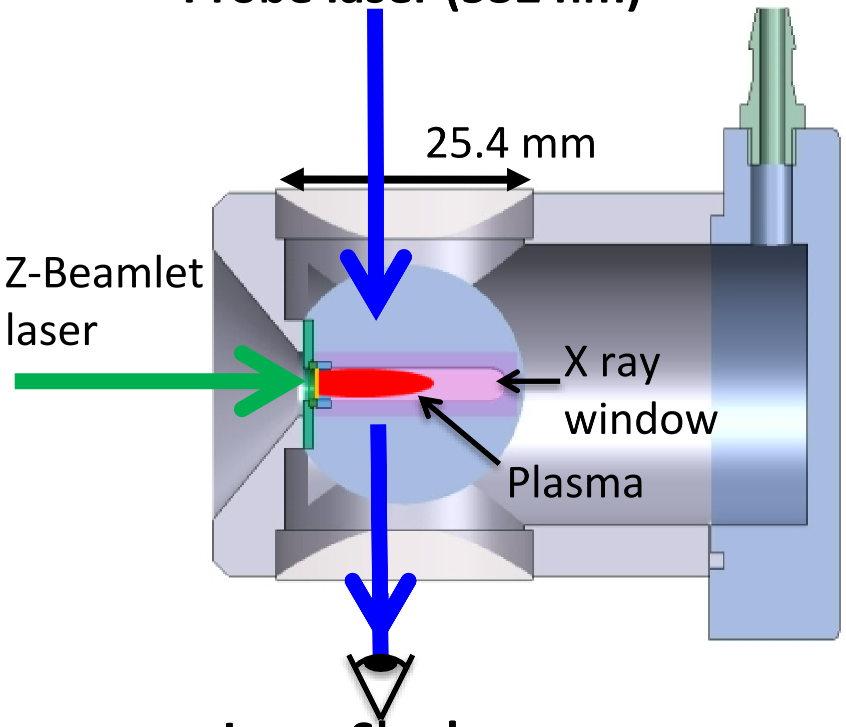


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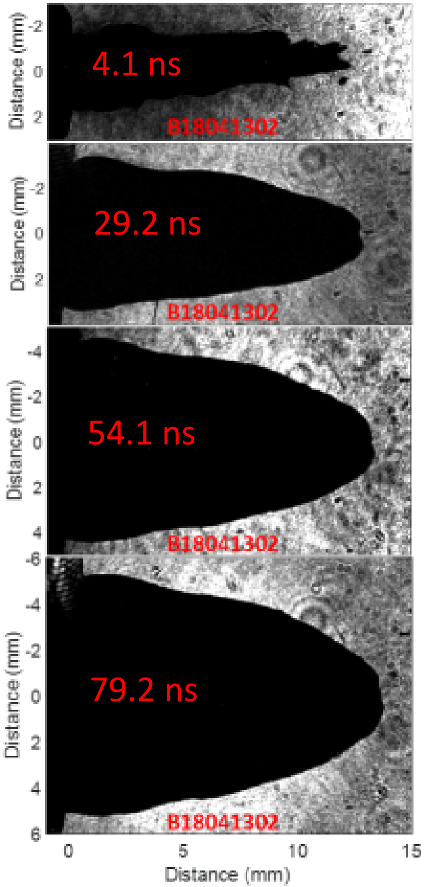


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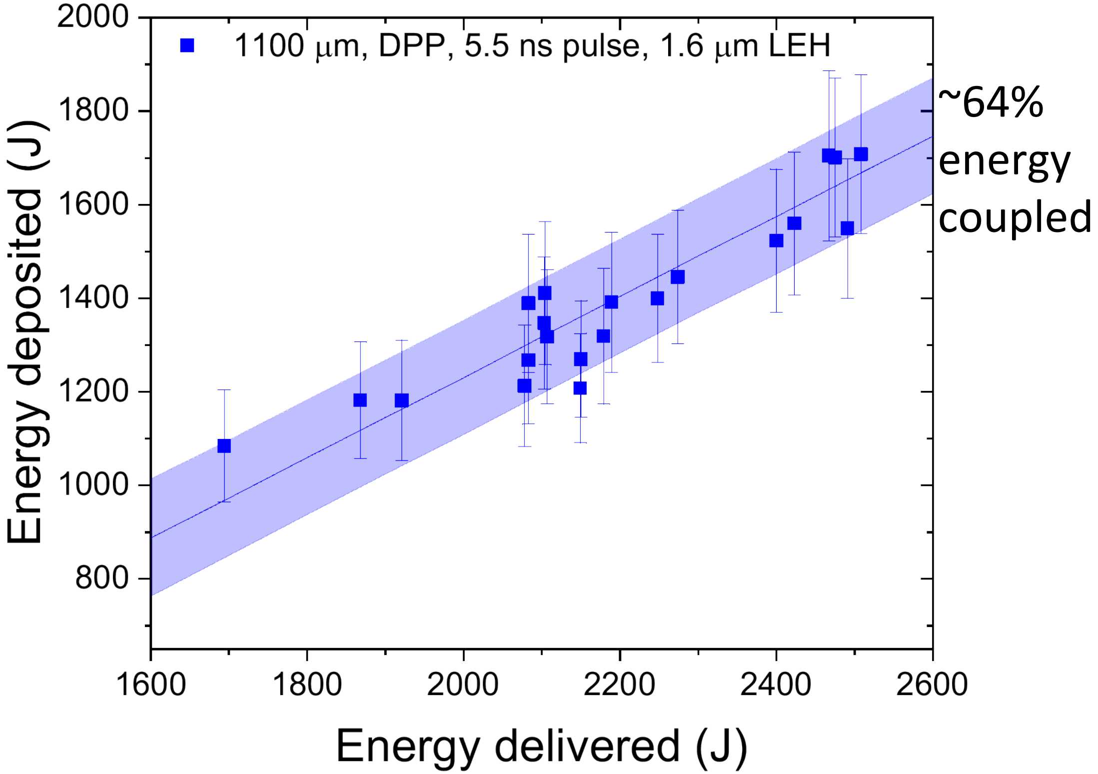


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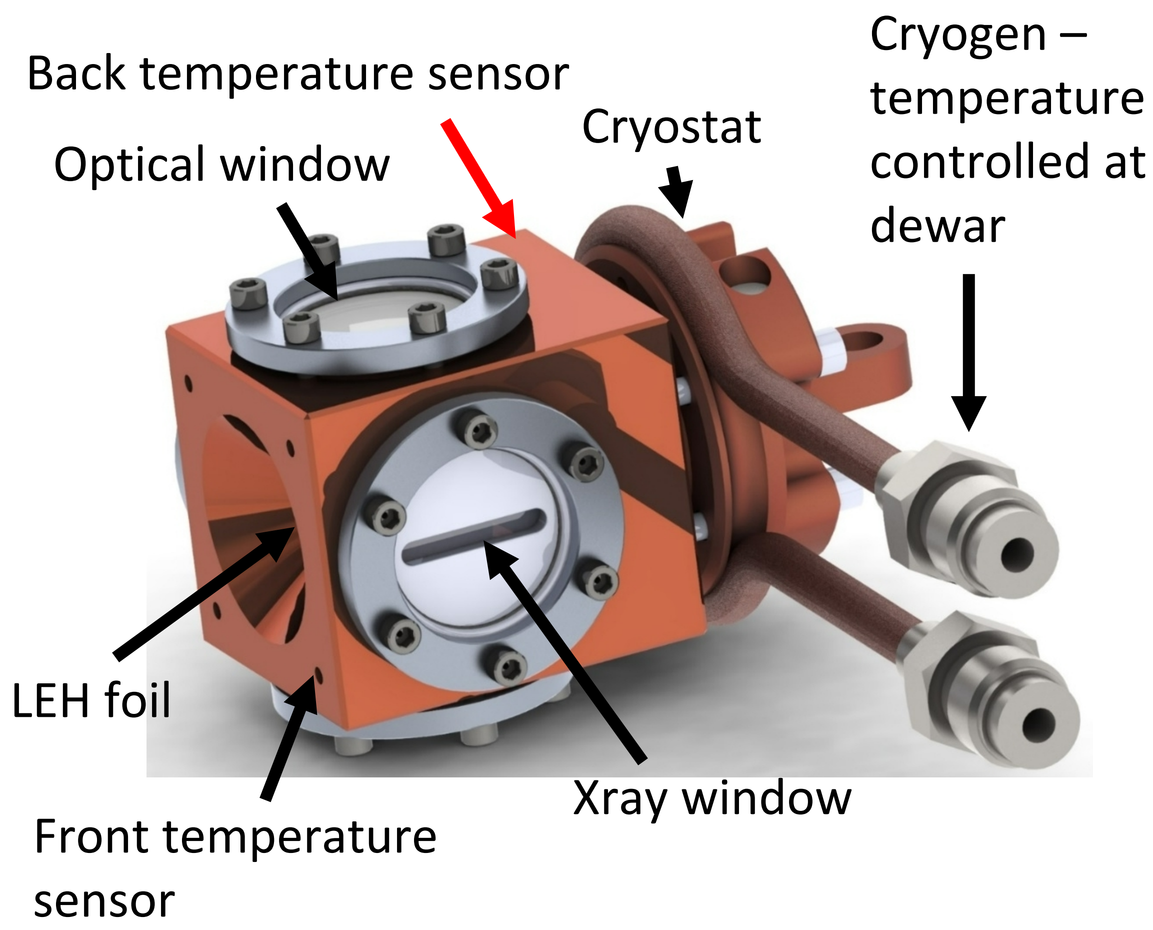
**Cryogenic cooling**

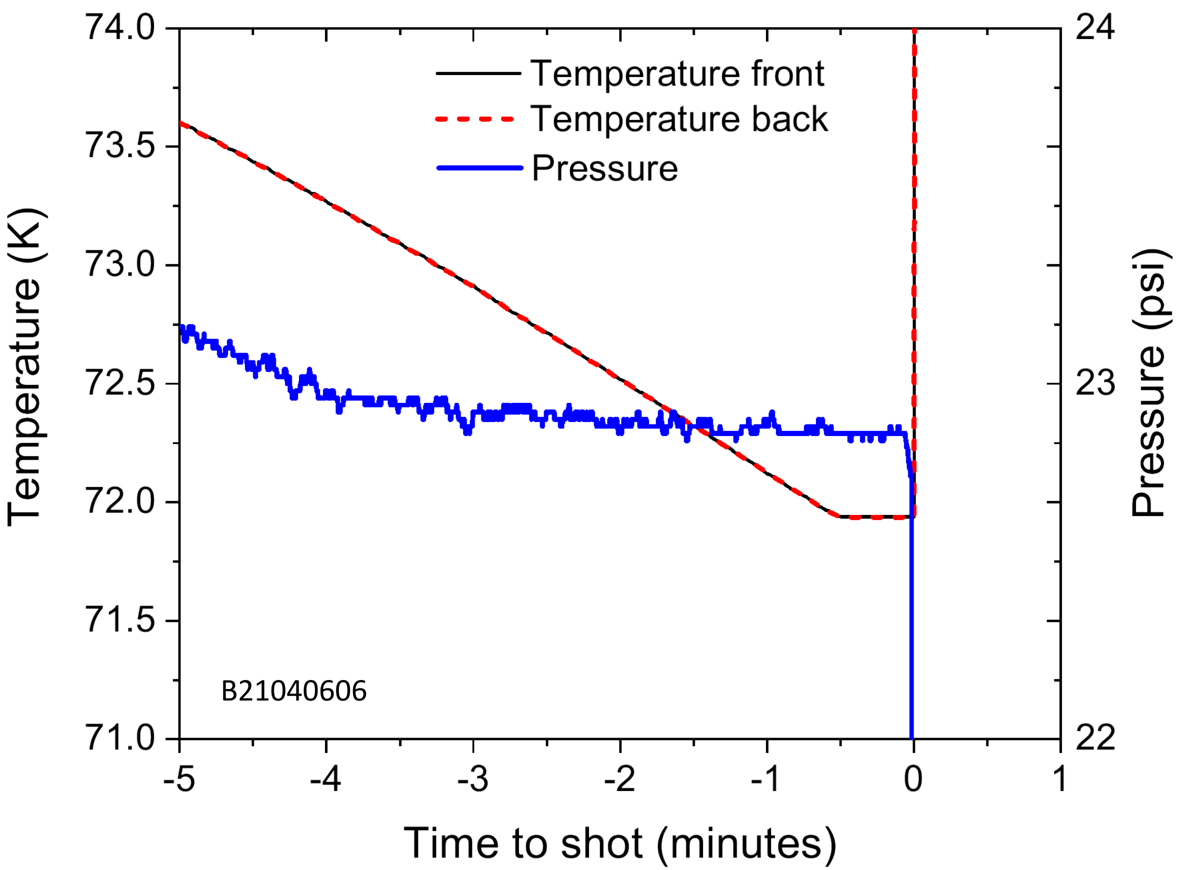
M. Geissel et al., Physics of Plasmas **25**, 022706 (2018)
A. Harvey-Thompson et al., Physics of Plasmas **26**, 032707 (2019)

# Cryogenically cooling enables lower pressures, thinner LEH foils

## Target design




## On-shot pressure and temperature



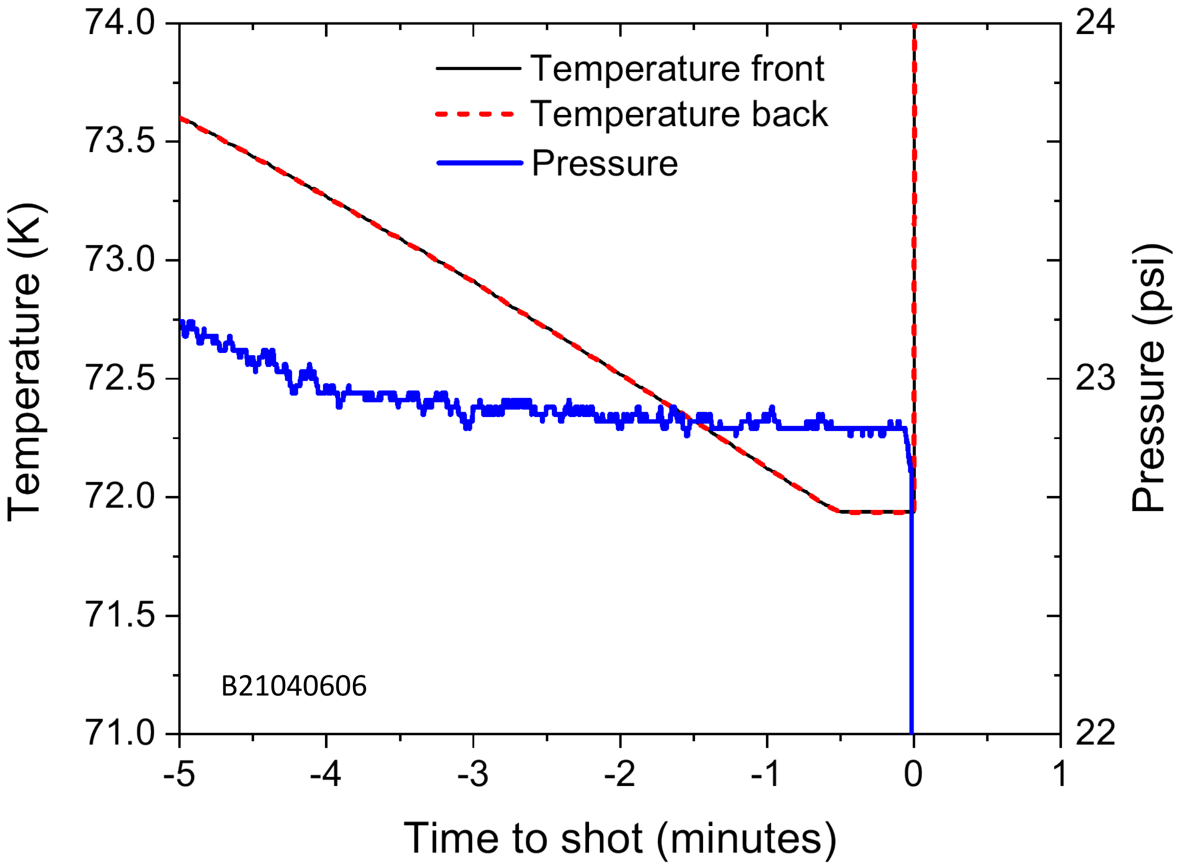

Motivated by: Weis et al., Physics of Plasmas 28, 012705 (2021)

# Cryogenic cooling enables lower pressures, thinner LEH foils

## Experimental parameters

| | Warm | Cryo |
|---|---|---|
| Density (mg/cc) | 1.05 | 1.05 |
| Temperature (K) | 293 | 73 |
| Pressure (psi) | 90 | 23 |
| LEH thickness (nm) | 1600 | 500 |
| LEH diameter (mm) | 2.2 | 3 |
| Spot diameter (mm) | 1.1 | 1.5 |

## On-shot pressure and temperature




- The pressure is set ahead of time and the temperature tweaked to match desired density
- Target design enables minimal temperature gradients and uncertainty → minimal density uncertainty

# Cryogenically-cooled preheat experiments demonstrated greatly improved coupling

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|---|---|---|
| Density (mg/cc) | 1.05 | 1.05 |
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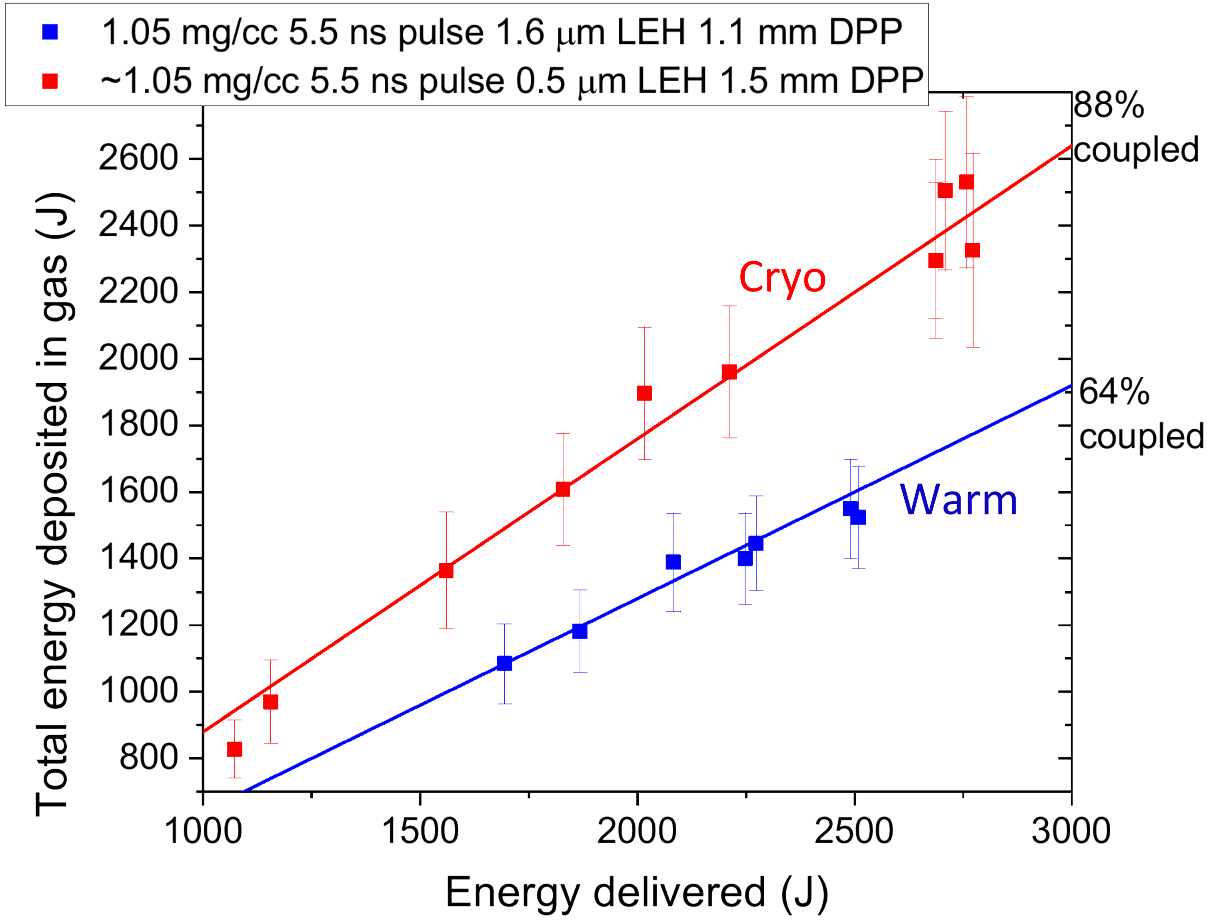
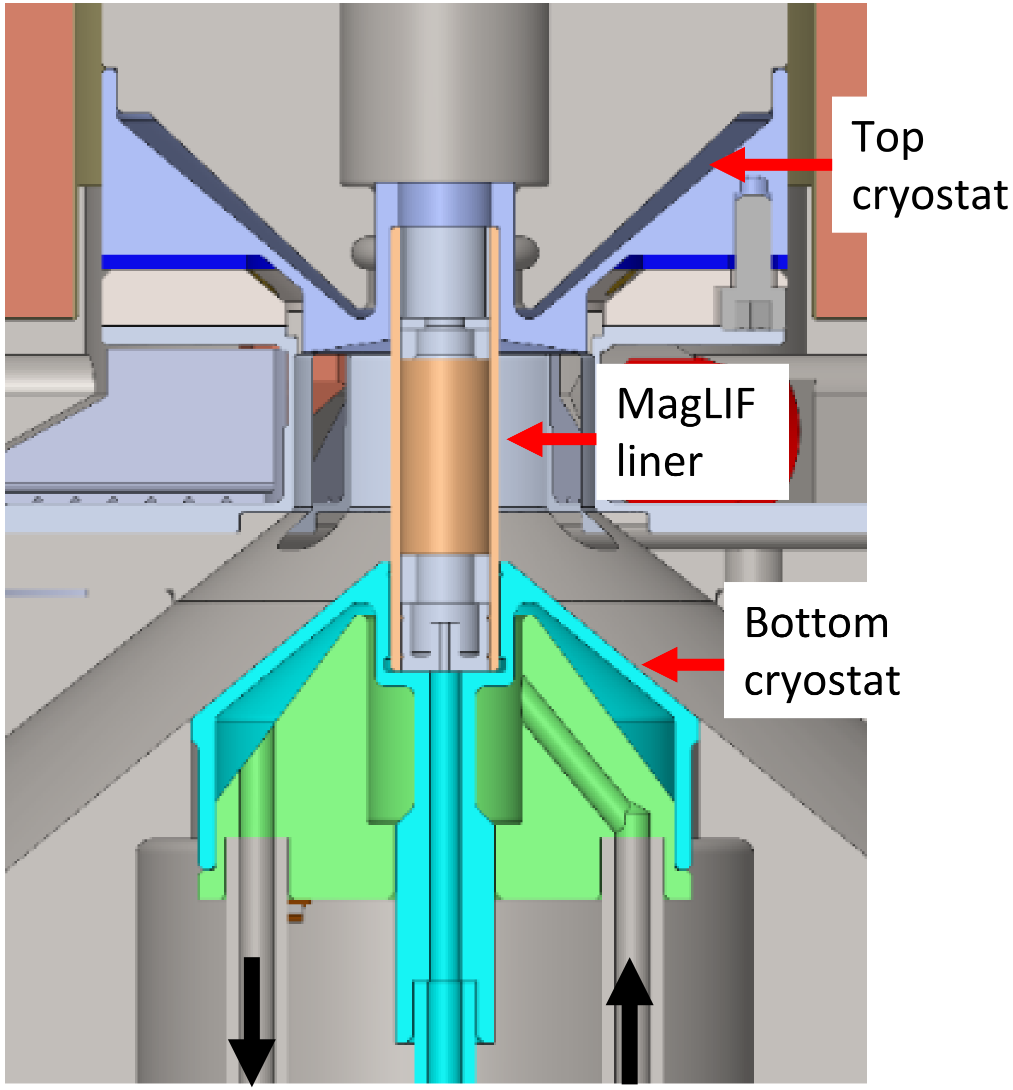
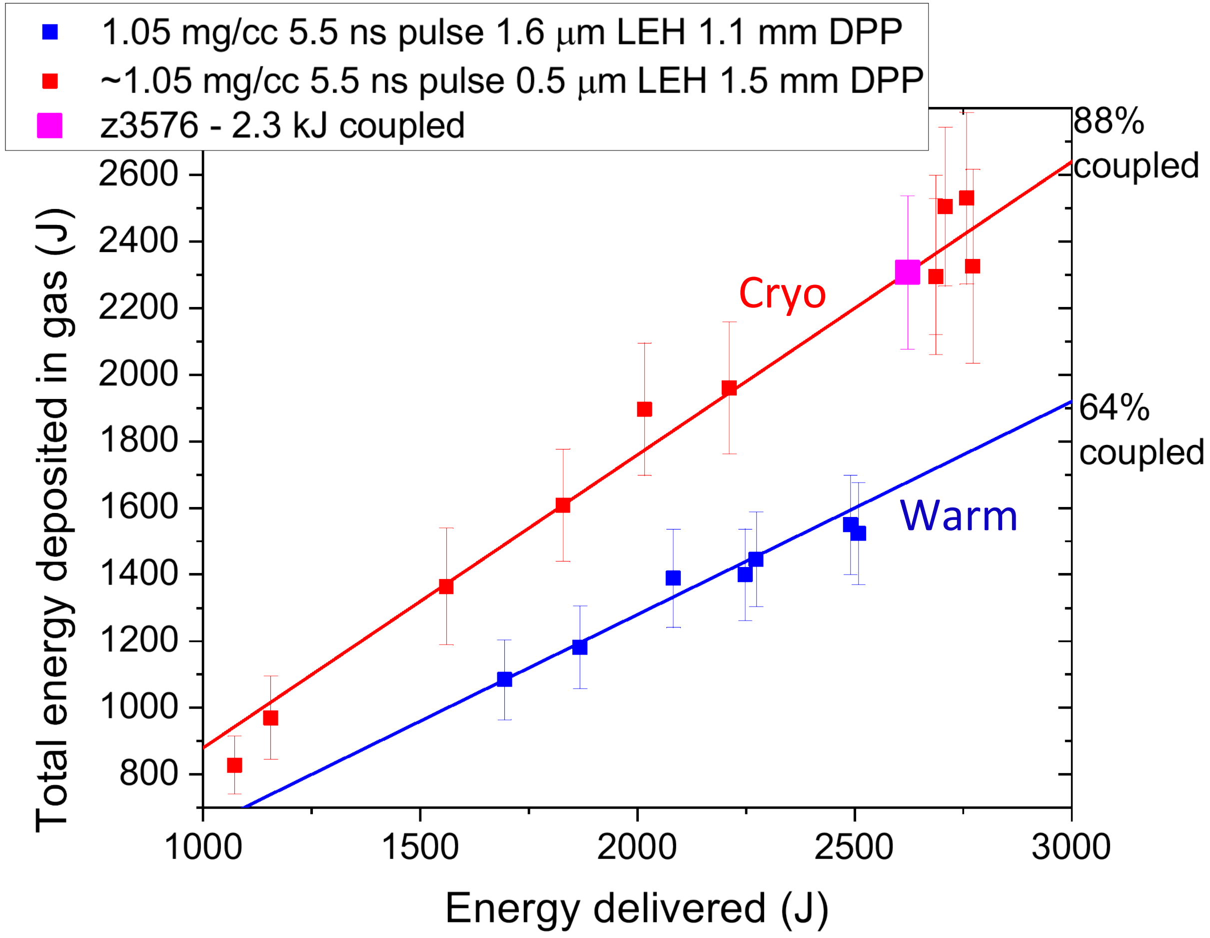



- At 88% coupling efficiency, >2 kJ energy coupling can be readily achieved with ZBL

# >2 kJ preheat energy was coupled to a cryo-cooled MagLIF experiment on Z

Integrated Z hardware

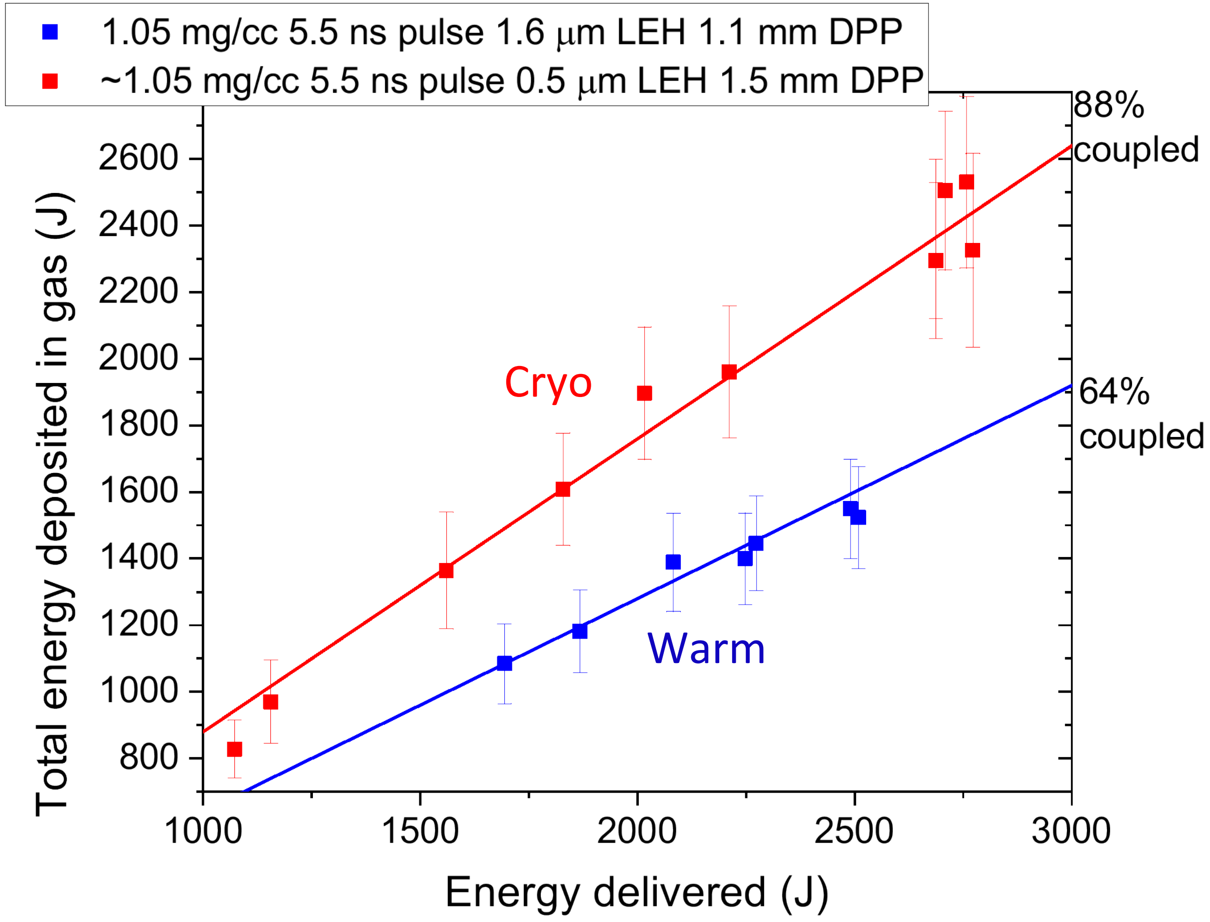



For more analysis of z3576 see P. Knapp: BI01.00004

# The cryo cooled experiments greatly outperform the warm – but why??

- Principle changes from warm to cryo:
  - Reduced LEH foil thickness from 1.6 to 0.5 µm
  - Increased spot diameter from 1.1 to 1.5 mm
- Laser interacts with less LEH mass (~59% mass of warm target) – less energy lost to foil?
- Laser intensity is ~halved due to larger spot – reduced LPI backscatter?
- Does the blast wave analysis have important sensitivities beyond coupled energy?



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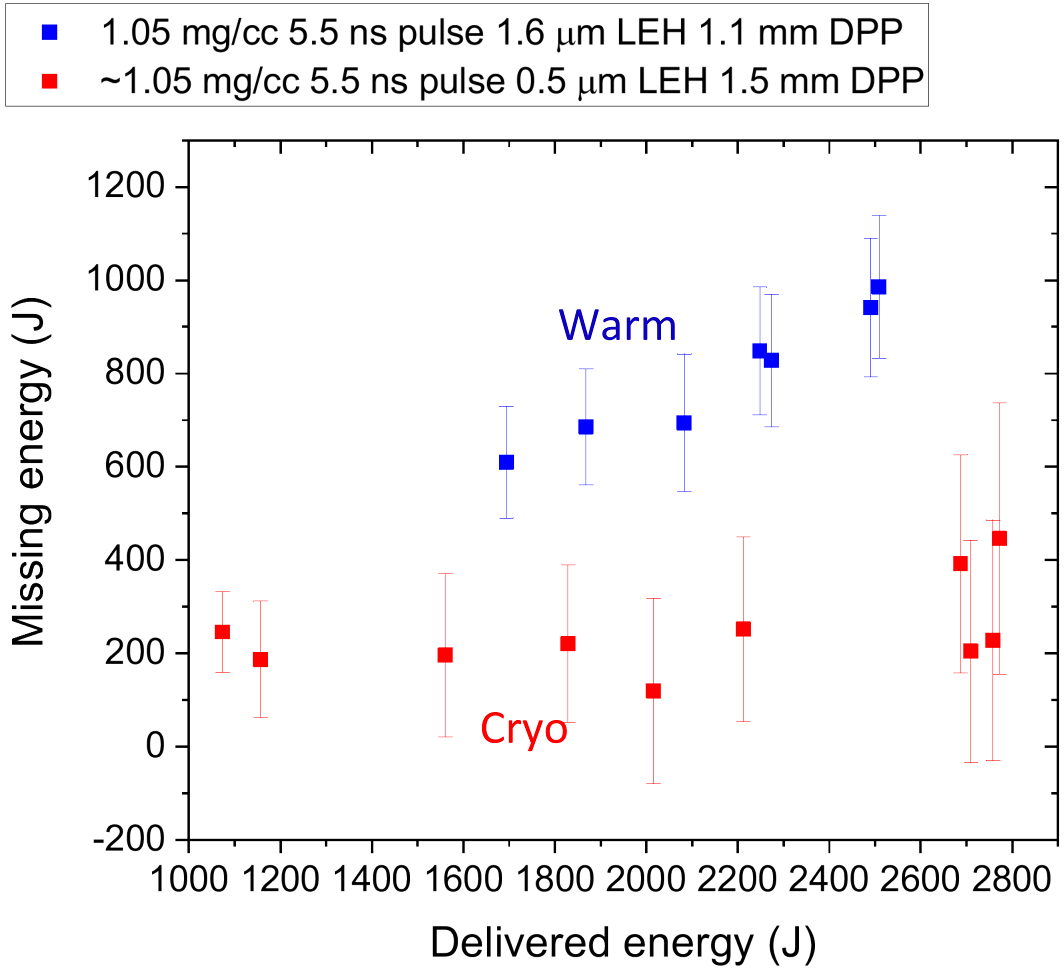

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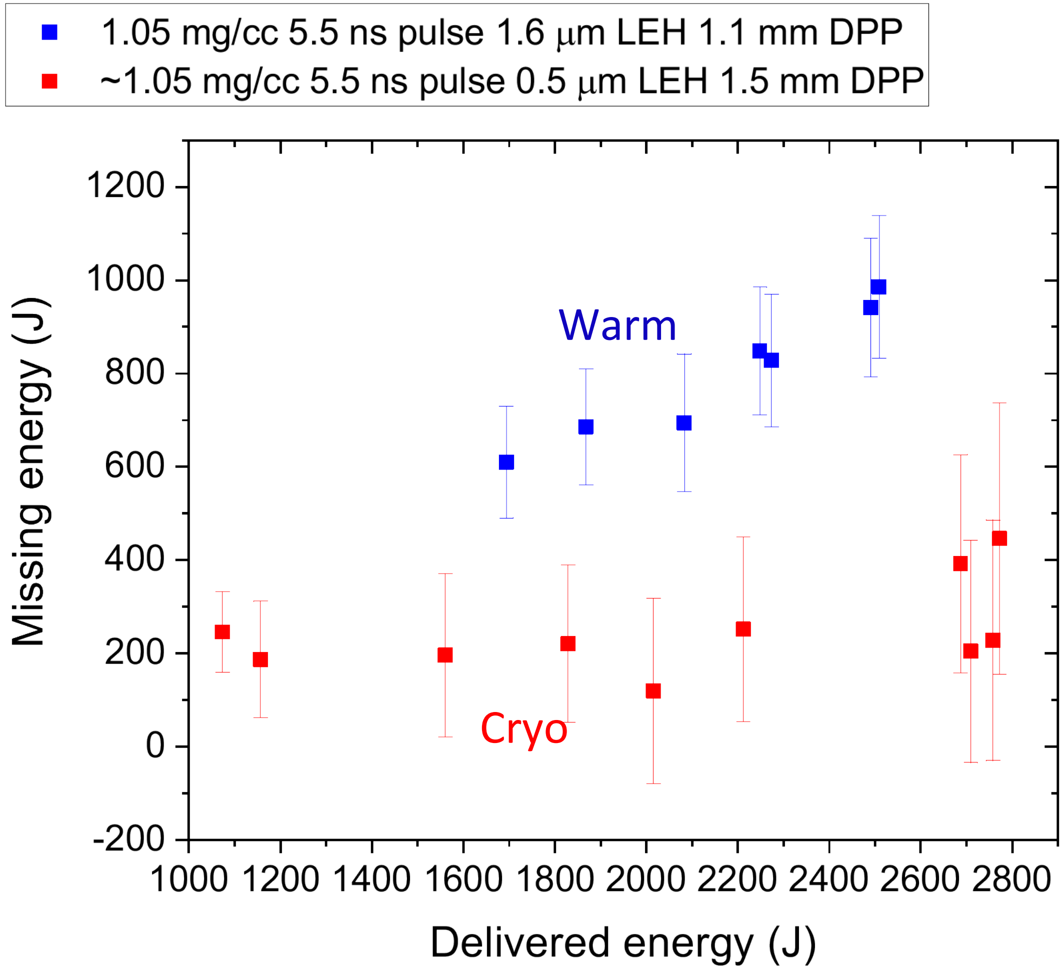
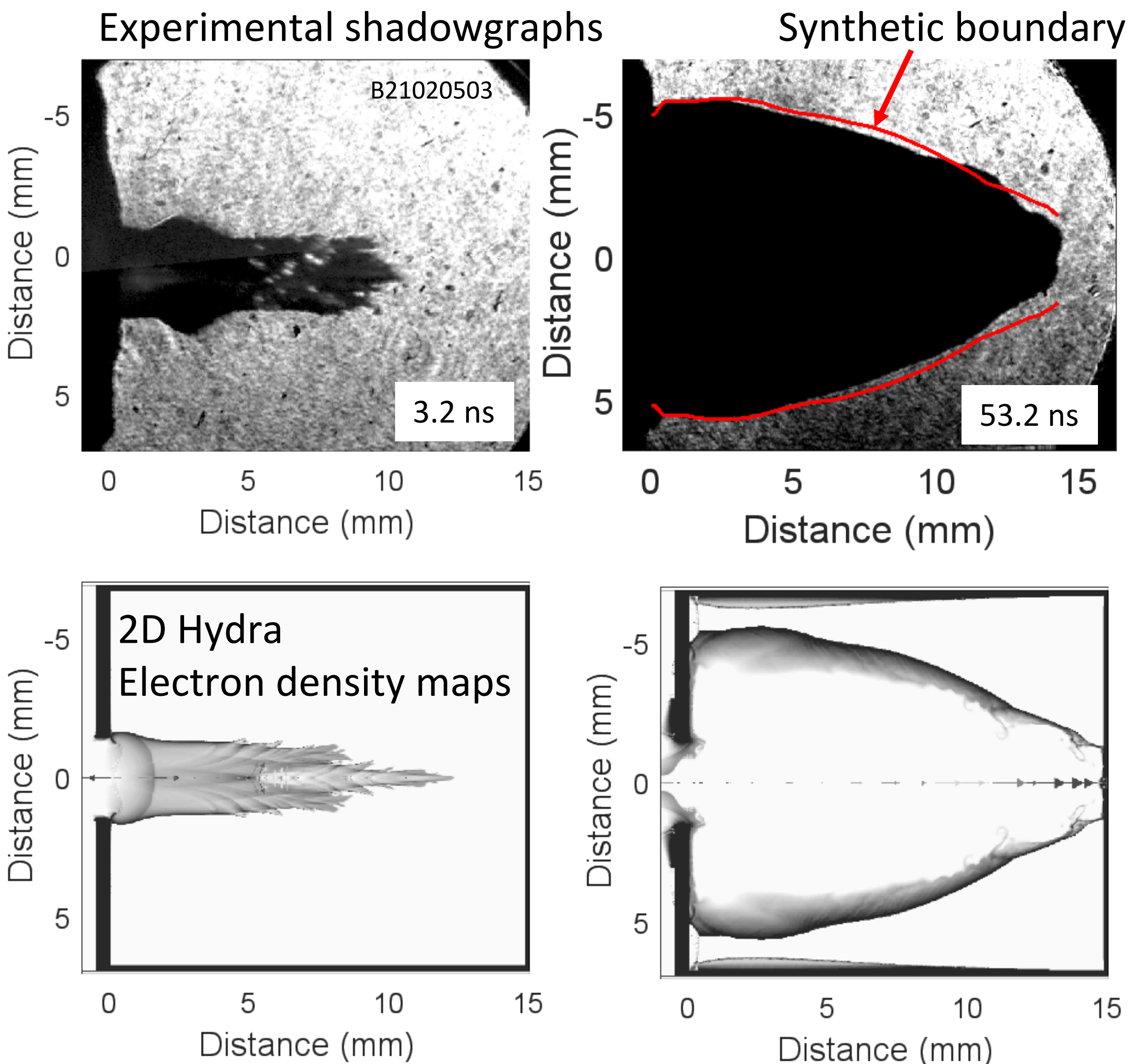
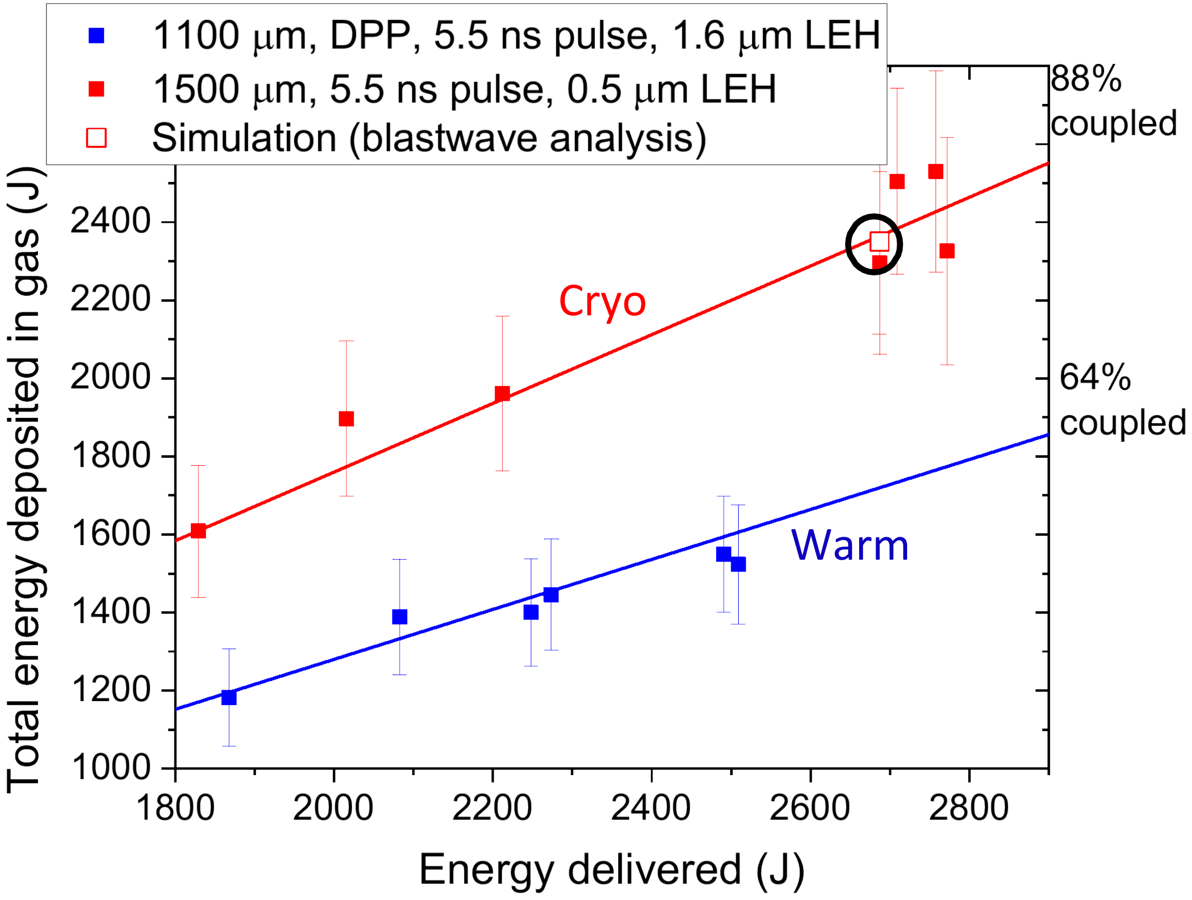
- Does the blast wave analysis have important sensitivities beyond coupled energy?
- LEH and backscatter hypotheses will be explored by M. Geissel (CO05.00006)



# 2D Hydra simulations compare well with cryo shadowgraphy data

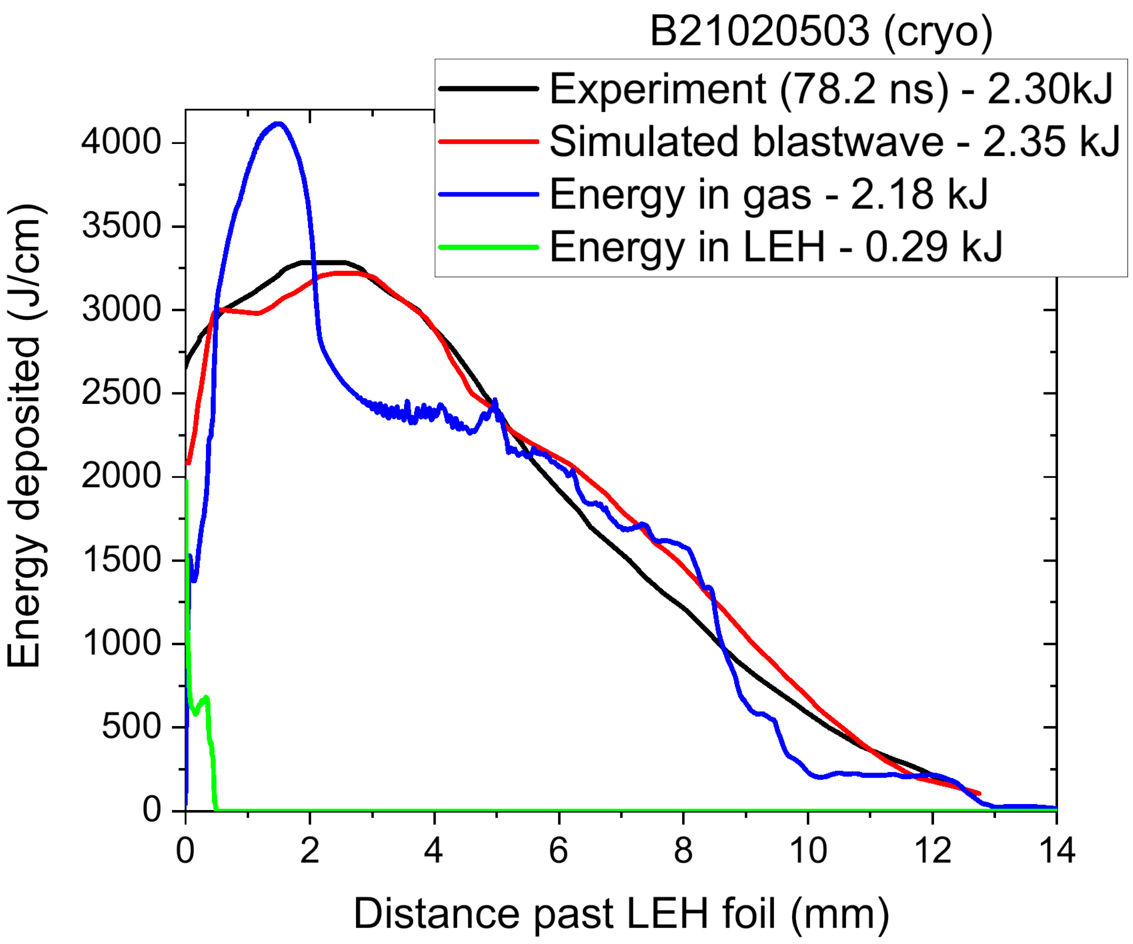


# The energy "seen" by the blast wave is not just inverse Bremss. deposition in the $D_2$

- At the end of the laser pulse, for z>0:
  - Energy in gas < energy inferred from blast wave
  - Energy in LEH+gas > energy inferred from blast wave
- The energy balance is dynamic – e.g. foil material is ejected in simulations later in time
- The energy inference is complex and includes contributions from the LEH foil material
  - Remember for laser-gate (B. Galloway CO05.00005) and thicker-foil targets (M. Geissel CO05.00006)!
- But… simulations suggest the blast wave is capturing energy deposition in these targets
- The effects do not explain the discrepancy between warm and cryo targets – must be LEH or LPI!

Energetics at end of laser pulse




Other dependencies discussed in A. Harvey-Thompson et al., Physics of Plasmas 26, 032707 (2019)

# Summary

- Increasing MagLIF performance requires increased preheat energies beyond 2 kJ
- Cryogenically-cooled MagLIF targets have dramatically increased the coupling efficiency
  - >2 kJ preheat energy was coupled in z3576
  - Laser-gate may also enable performance increases (see next talk B. Galloway CO05.00005)
- We are working to understand the improvement in energy coupling
  - Assumptions in the blast wave analysis do not seem to be a major contribution – we are measuring the coupled energy
  - Other possibilities are losses to the LEH foil and LPI backscatter – see talk by M. Geissel (CO05.00006)
  - Spoiler alert – we think SRS backscatter in the warm targets explains the energy difference