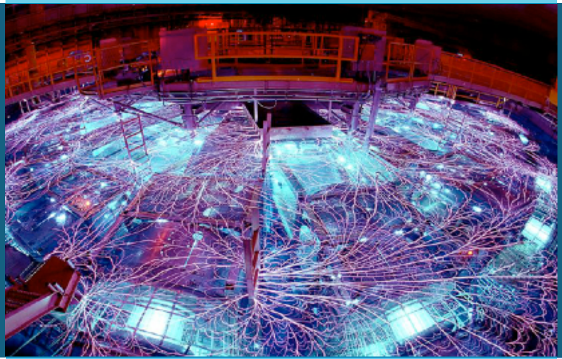
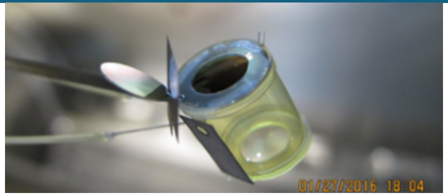
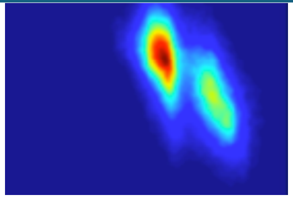
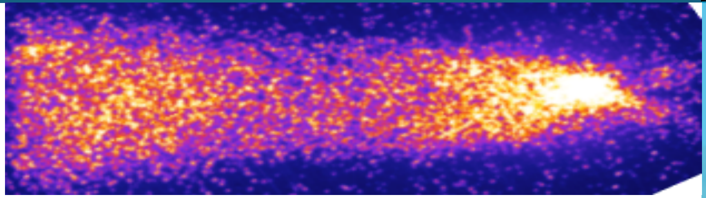
Line VISAR measurements of energy deposition for next generation MagLIF laser preheat at NIF









PRESENTED BY

Michael Glinsky

presented at 63rd Annual Meeting of the APS Division of Plasma Physics,
8 November 2021,Pittsburgh PA (paper CO05.00009)

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Contributions from:

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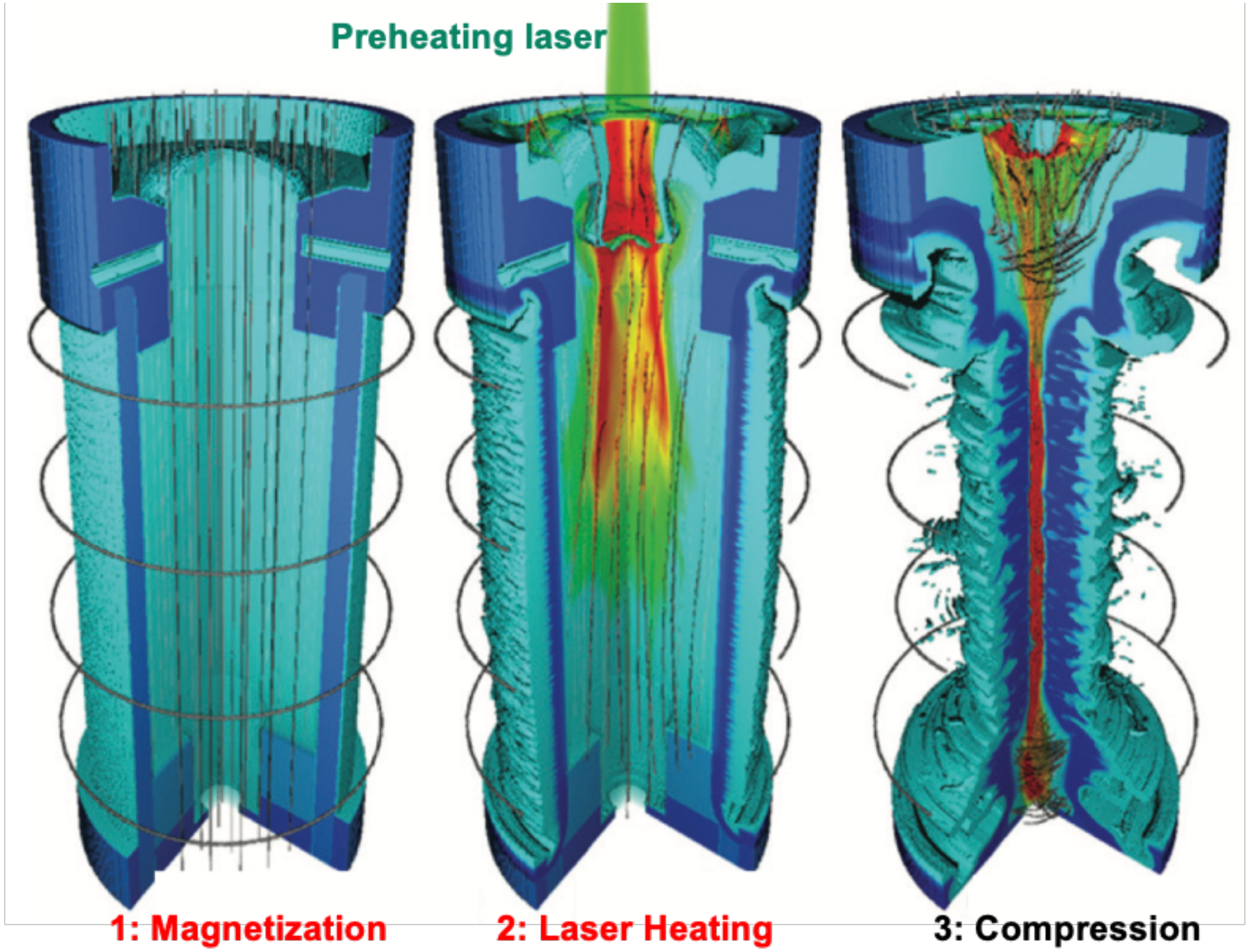
  - Matt Weis
  - Adam Harvey-Thompson
  - Kris Beckwith
- Lawrence Livermore National Laboratory
  - Brad Pollock
  - John Moody
  - Dave Strozzi

MagLIF is a magnetic direct drive ICF platform that requires coupling 20-30 kJ of laser energy into a gas pipe target

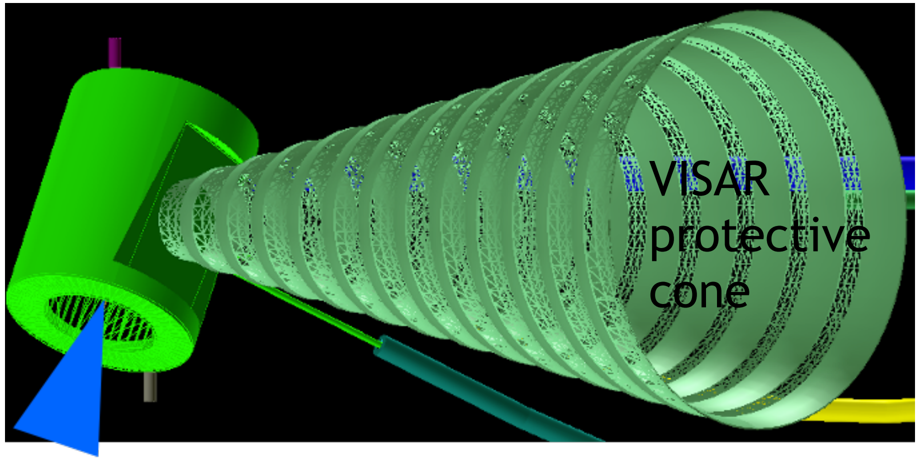
- NIF is the only facility that can drive full-scale targets at the design energy
- The intended MagLIF gas fill is 5 mg/cc D2
- NIF experiments use neopentane fills to achieve similar electron densities without the need for cryo
  - Allows for thin windows and B-fields



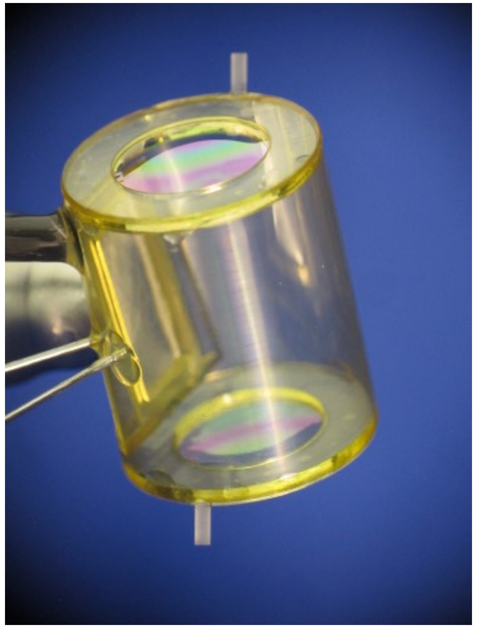
S. Slutz et. al., PoP 23, 022702, 2016, M. Gomez et. al., PRL 113, 155003, 2014

see Pollock et al. “Investigating at-scale MagLIF preheat on the NIF”, talk CO05.00007, for more details

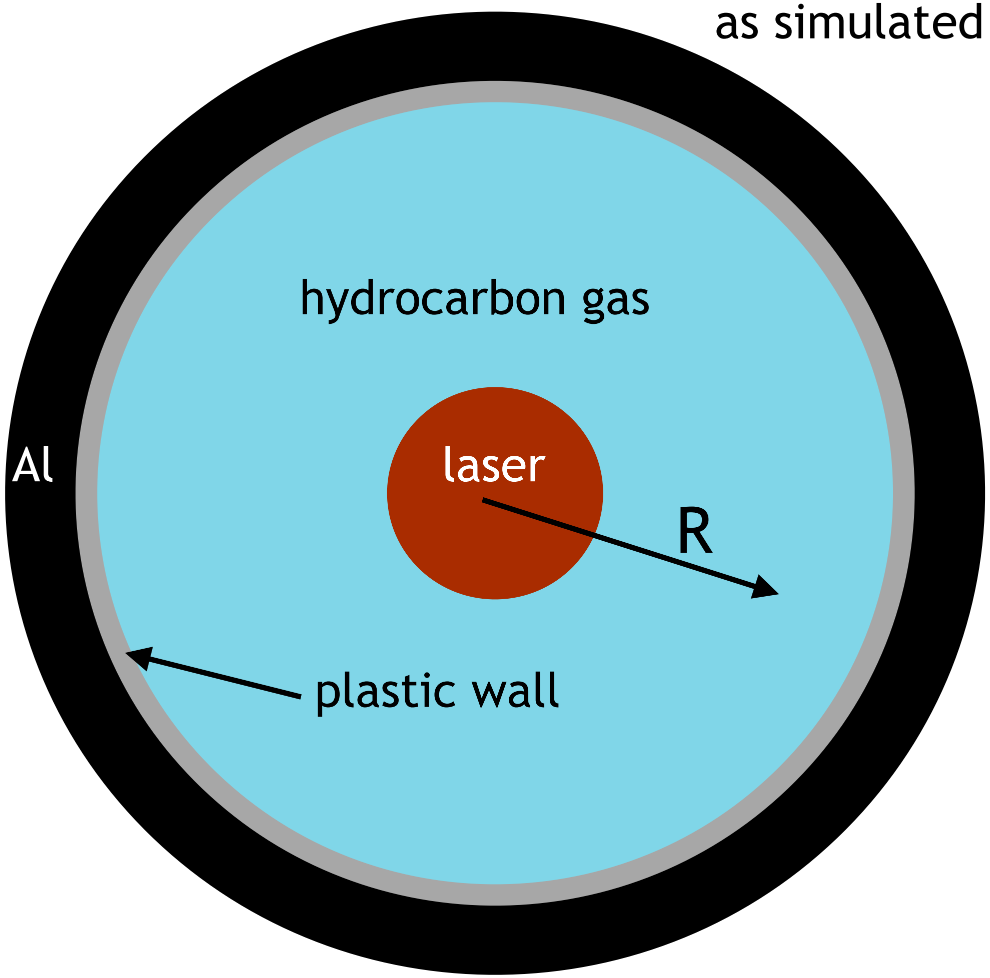
Geometry of VISAR measurement and 1D simulation



quad of NIF



as simulated in 1D



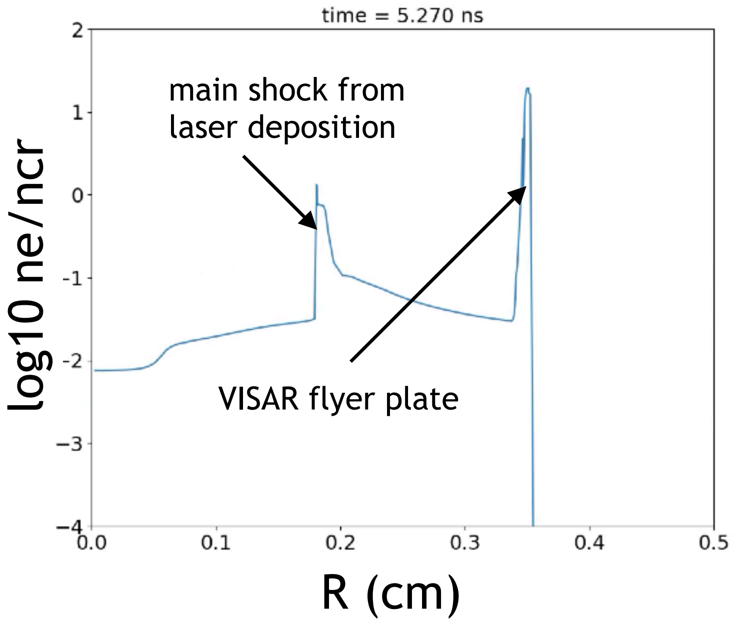
VISAR is a direct measurement of the energy deposited

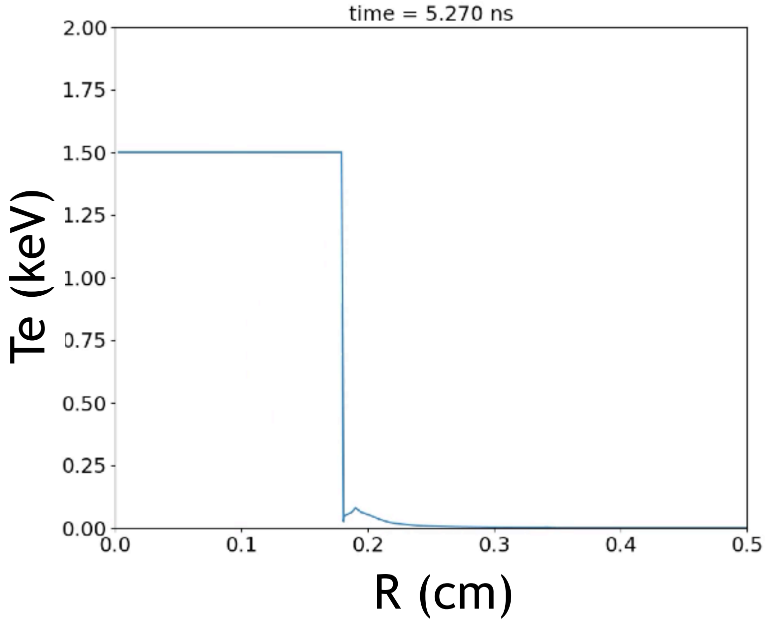
This work develops the data analysis framework to estimate the deposited energy with uncertainty

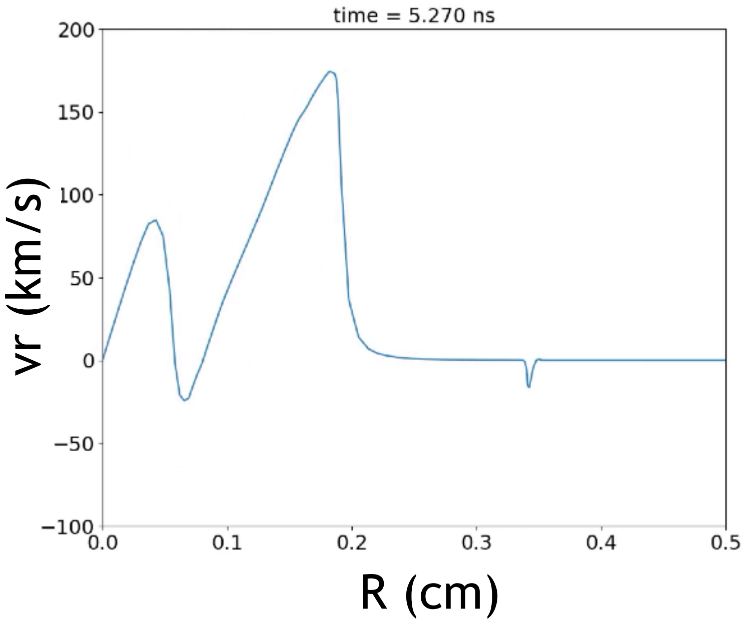
Parameters of study

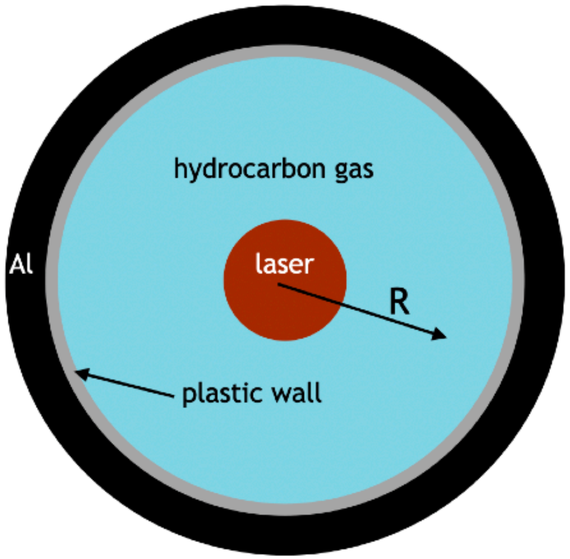
- 1D ensemble of Hydra simulations (non-LTE in gas)
- Base case of:
  - 6.94 mm inner diameter cell
  - 6 micron plastic wall with 50 micron Al flyer
  - 2.9 mg/cc hydrocarbon
- Independent parameters (4):
  - Deposition radius (800 micron base case +- 400 micron)
  - Deposition temperature (1.5 keV base case +- 0.7 keV)
  - Deposition time (10 ns base case +- 5 ns)
  - Time origin (0 ns base case, trivial +- 1.6 ns)
- Dependent parameters (3):
  - Deposited energy (kJ/cm)
  - Arrival Time of main shock (ns)
  - Delta velocity of main shock (km/s)

Base case evolution

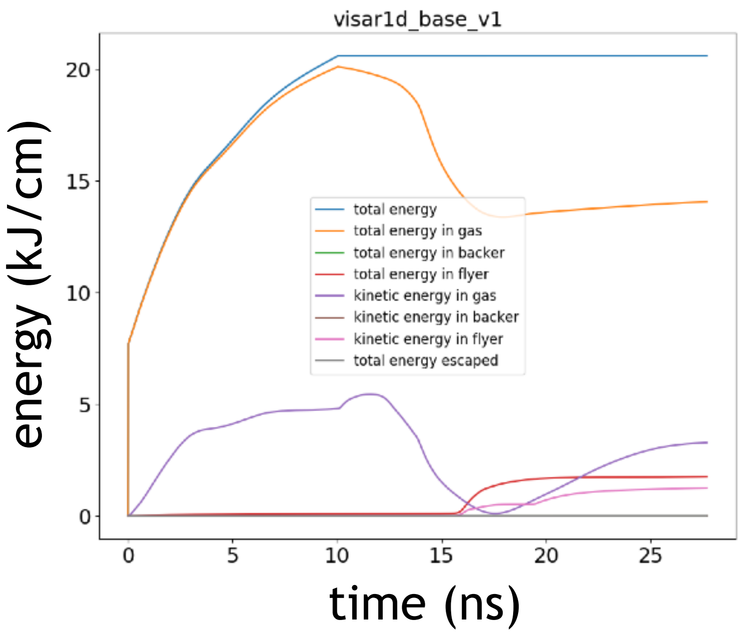


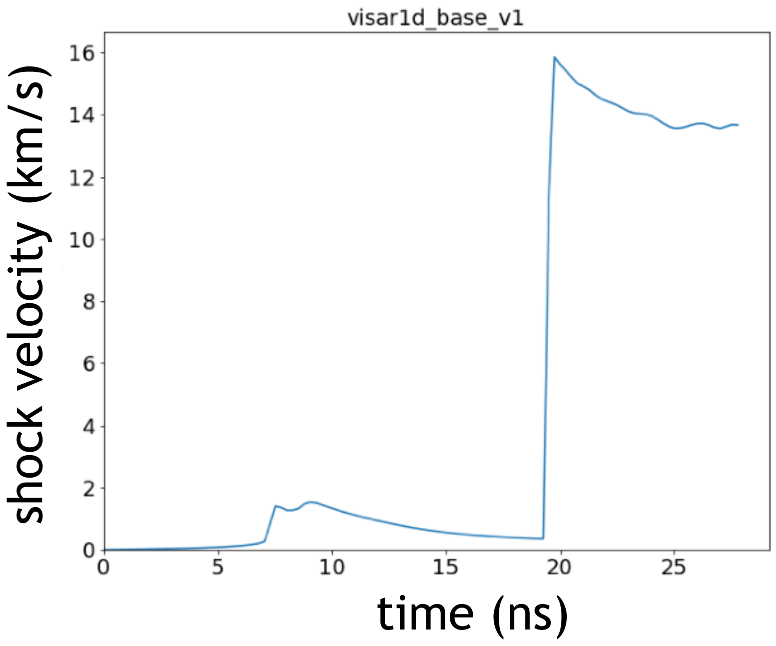


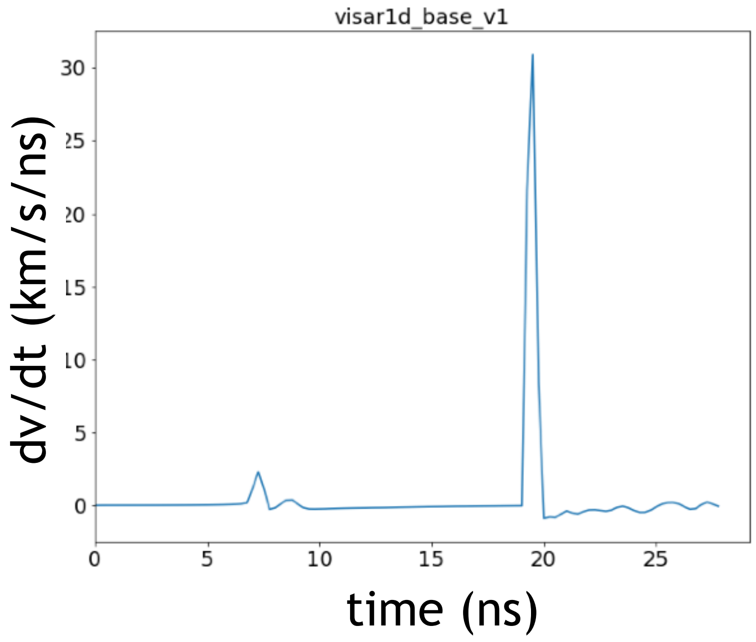




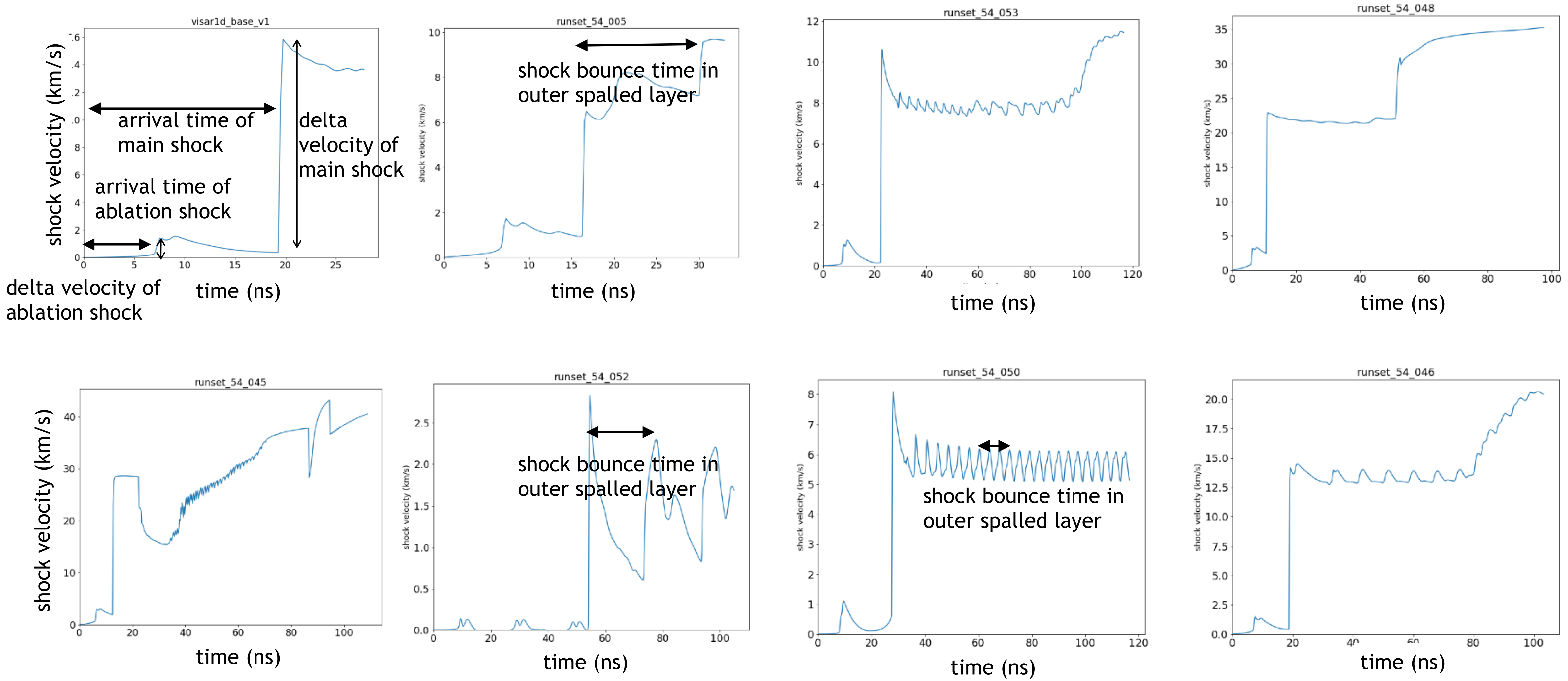
Energy and flyer interface vs. time



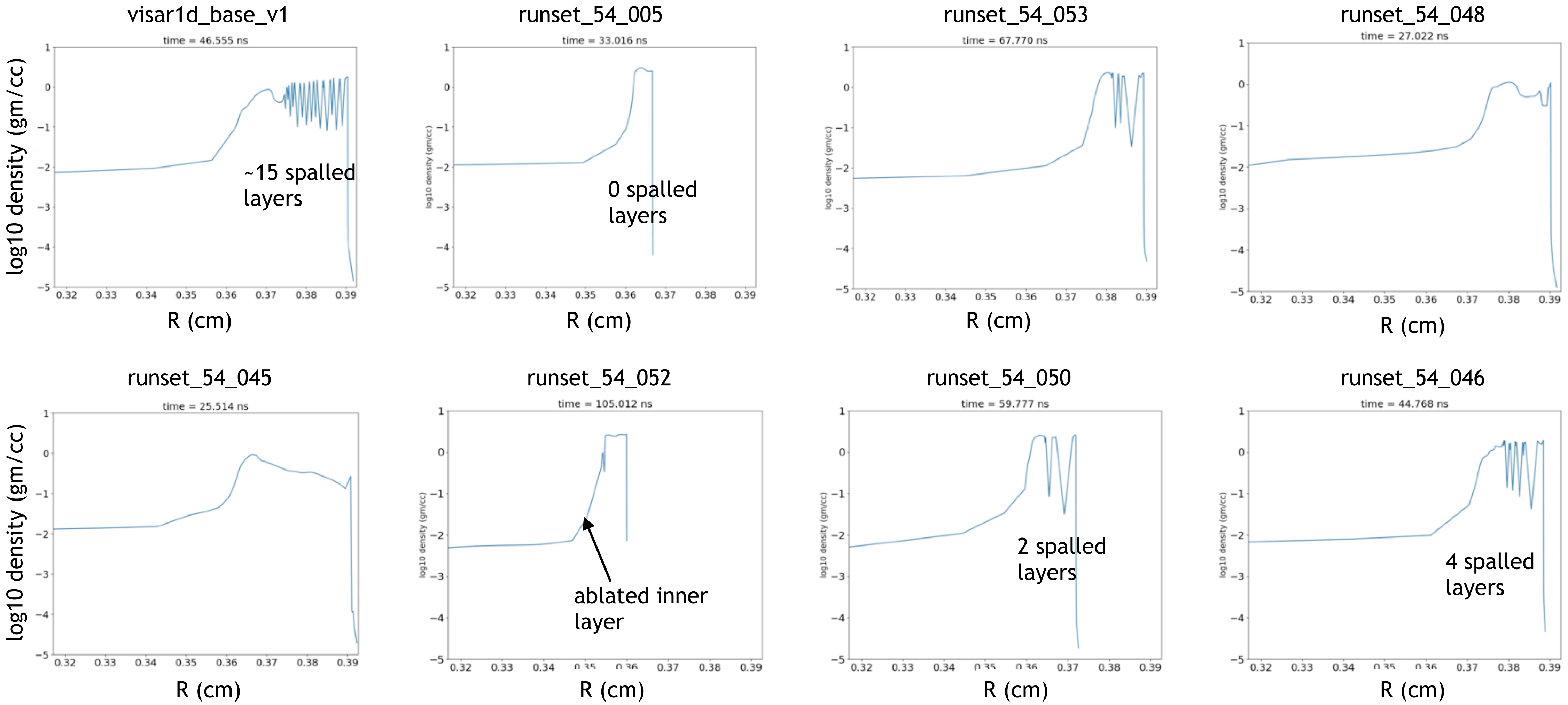




Variation in VISAR measurement

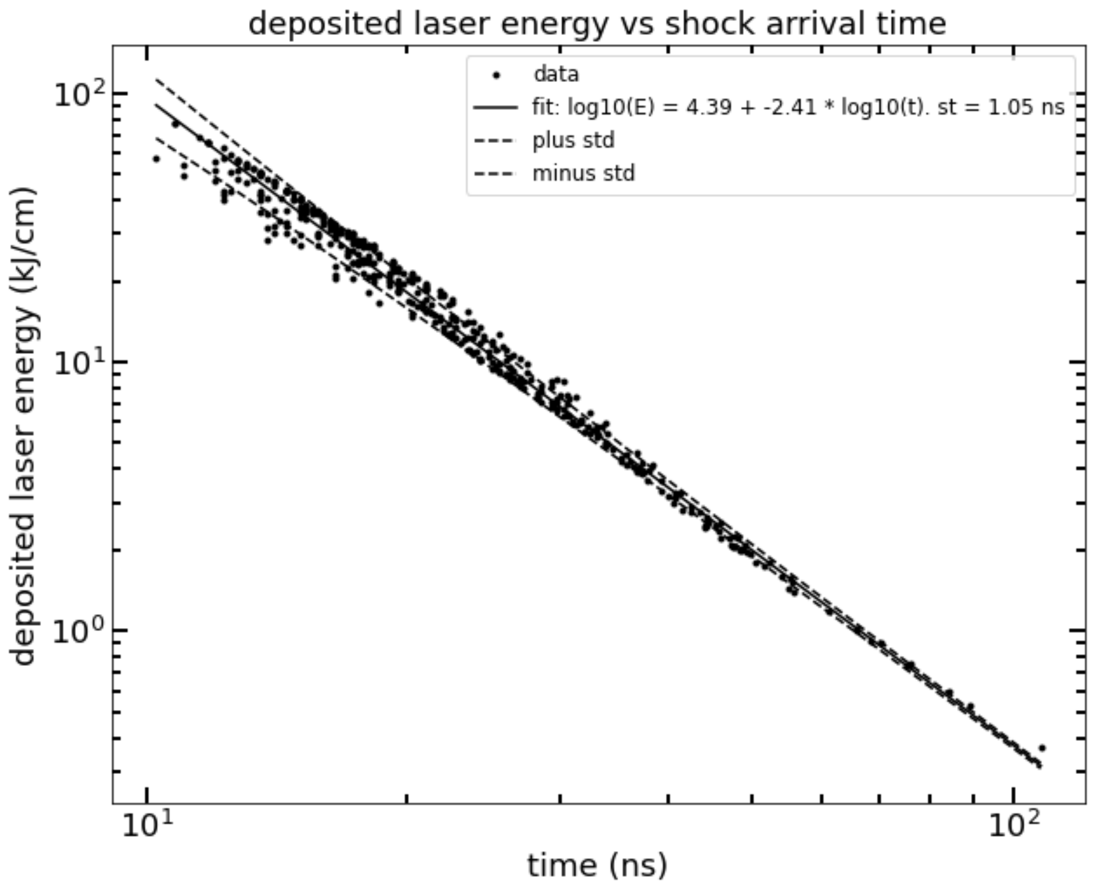


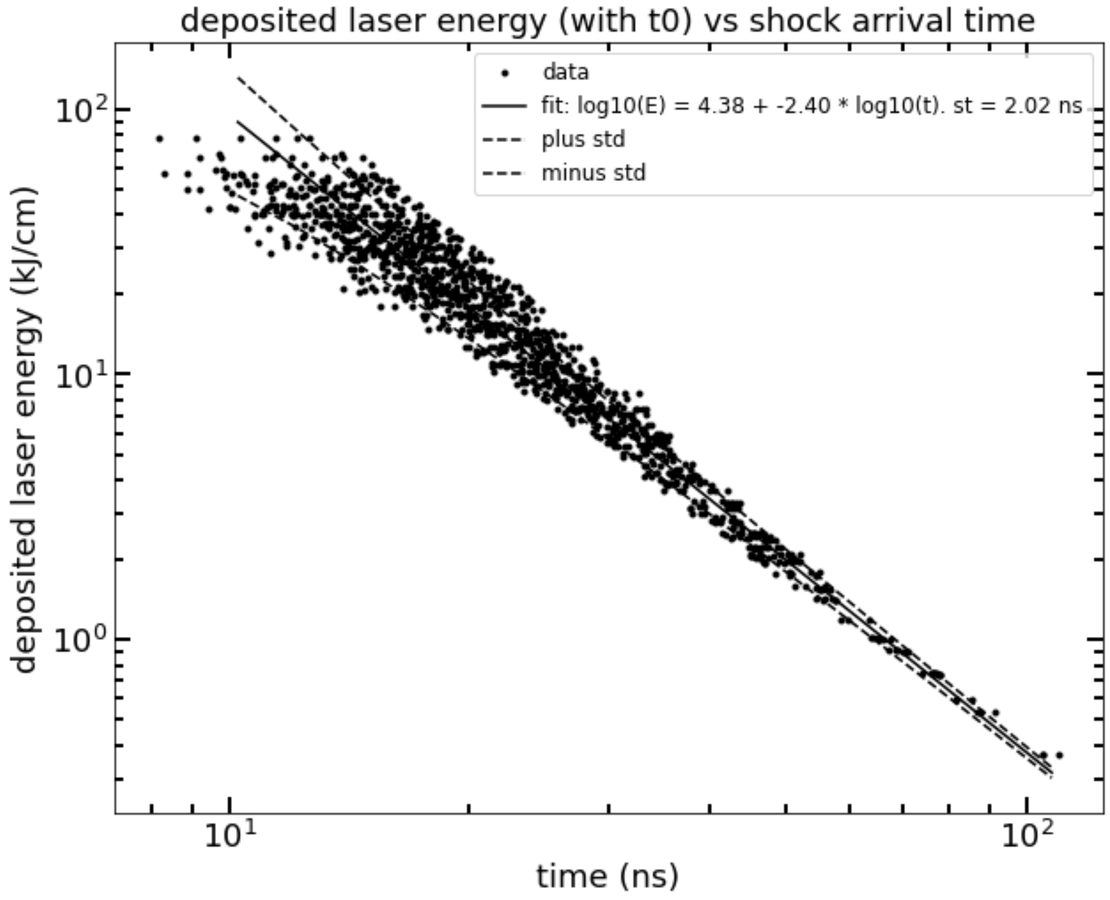
Zoom in on the flyer to see ablation of inner wall and backplane spallation



Two things to note: (1) first shock comes from ablation of inner wall from radiation shine, (2) evolution after main shock determined by backplane spallation, material strength and failure properties, and laser power.

Ensemble for depositional energy inference using arrival time

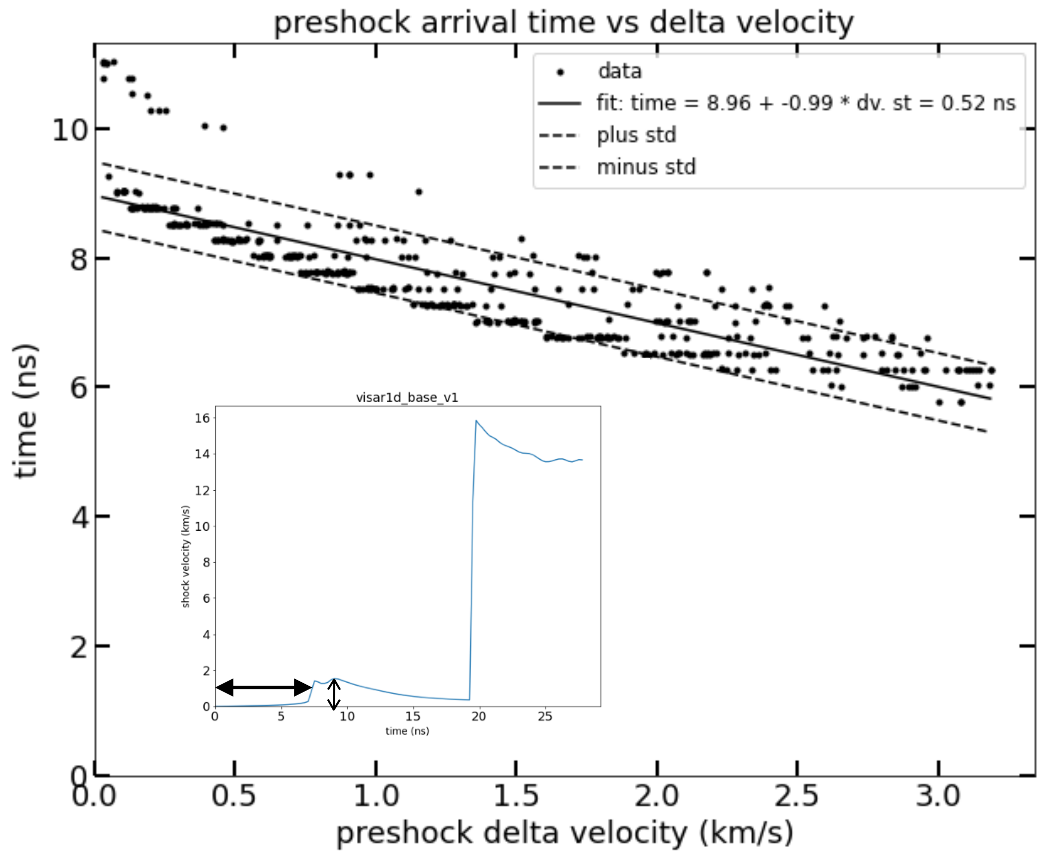


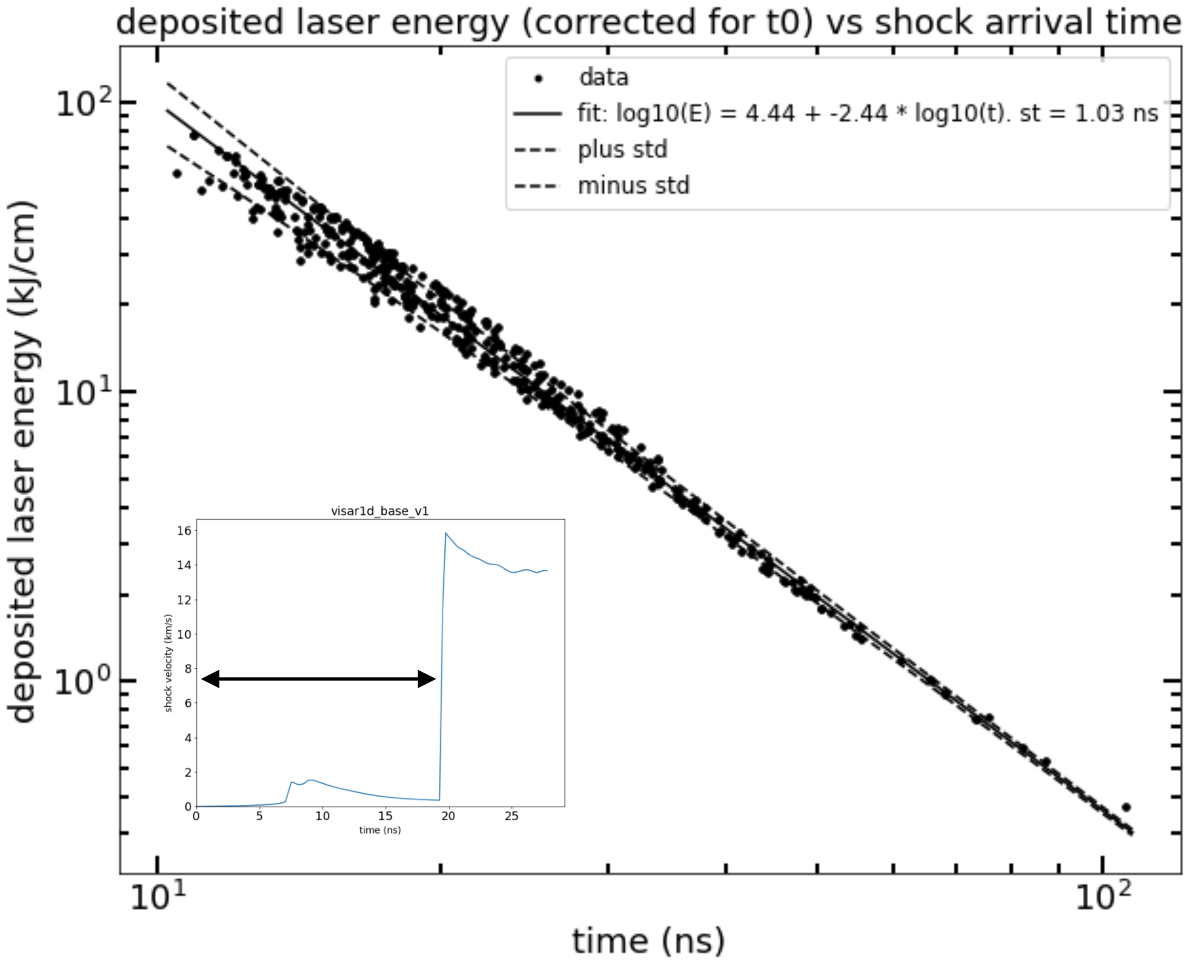


$$E = 10^a \, t^b \qquad a \approx 4.4 \qquad b \approx -2.41$$

$$\frac{\sigma_E}{E} = |b| \, \frac{\sigma_t}{t} \qquad \sigma_t \approx 1.1\,\mathrm{ns} \text{ to } 2.0\,\mathrm{ns}$$

Correcting the arrival time with the the preshock fiducial






```
for energy = 20.000 kJ/cm, error = 2.611 kJ/cm
for energy = 10.000 kJ/cm, error = 0.983 kJ/cm
for energy = 2.000 kJ/cm, error = 0.102 kJ/cm
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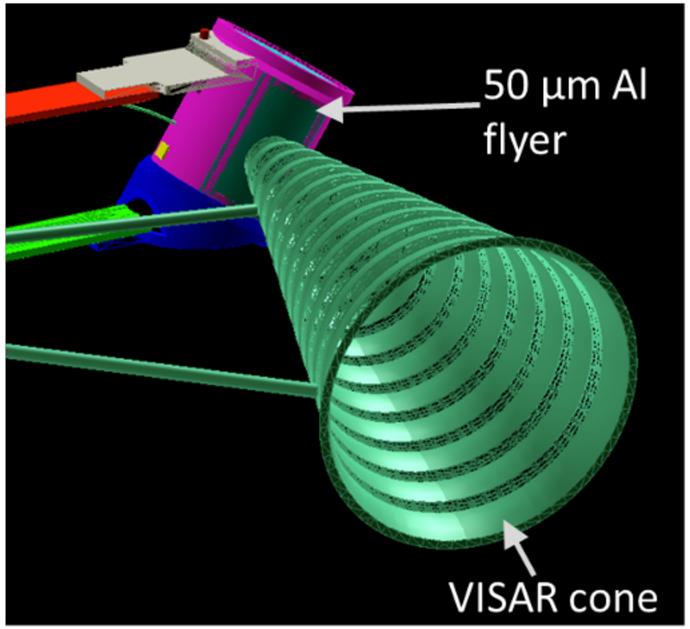
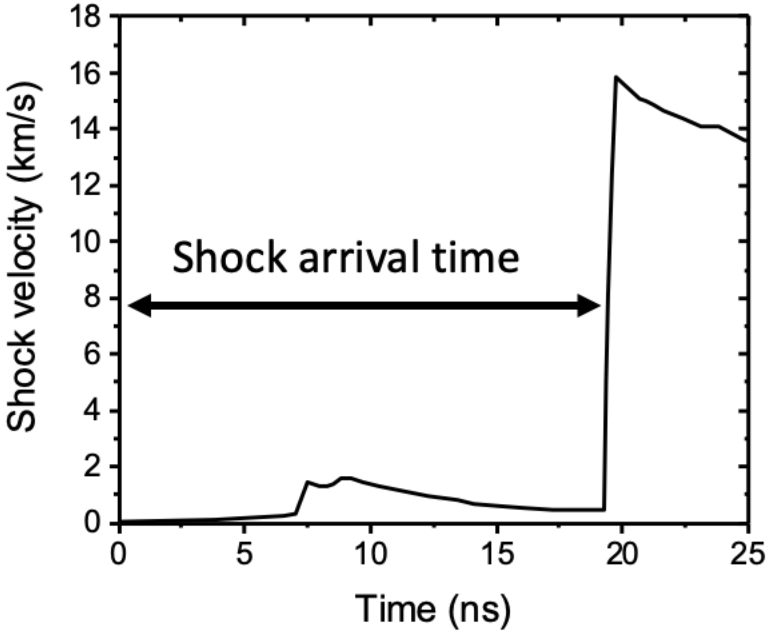
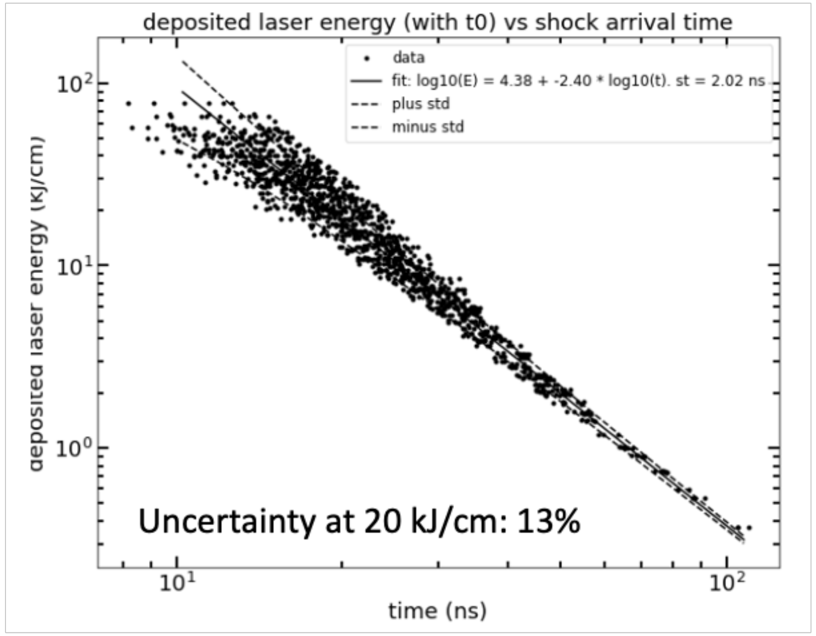
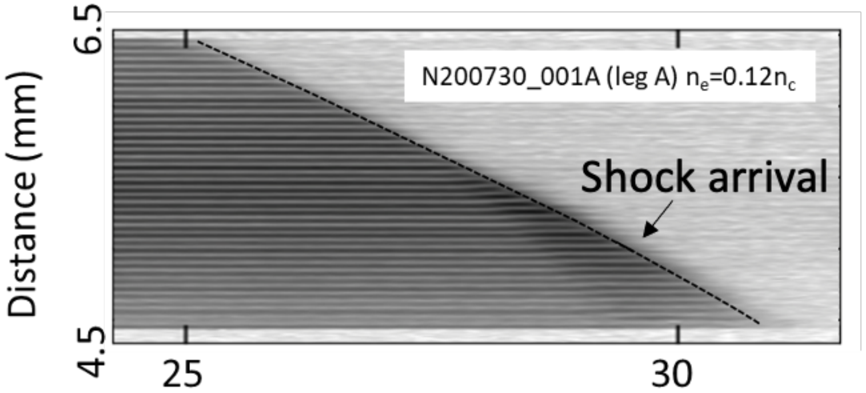
Quantitative energy deposition comparisons can be made with line VISAR





Ensemble of 400 1D simulations

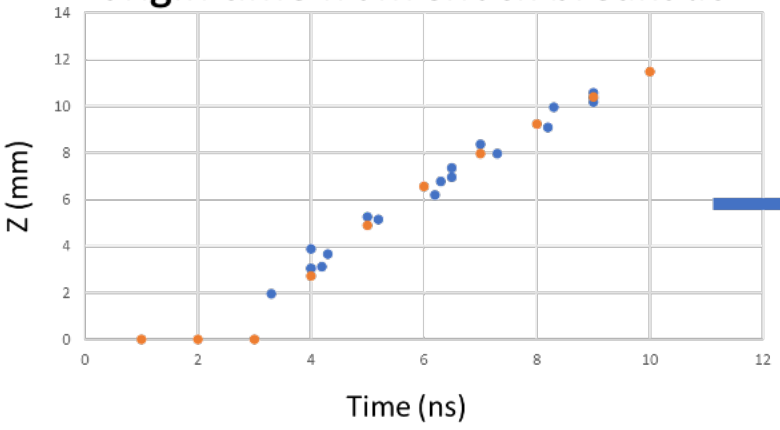


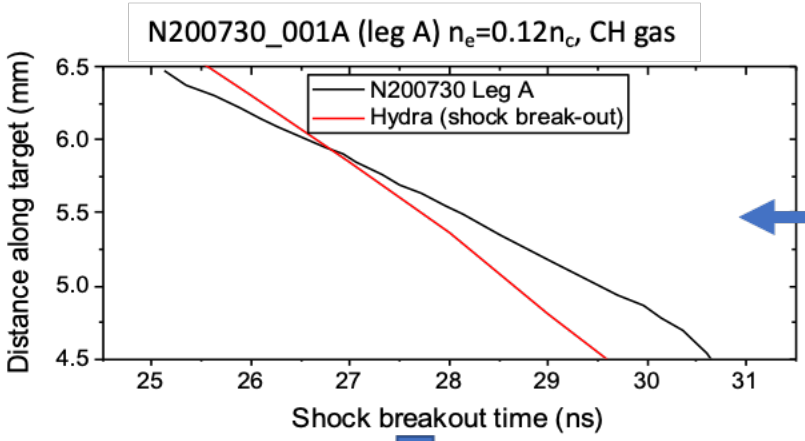


- Line VISAR measures the shock arrival time at the backside of an Al flyer
- 1D Hydra sims parameterized energy deposition, calculated velocity profiles, determined strong dependence of energy with arrival time

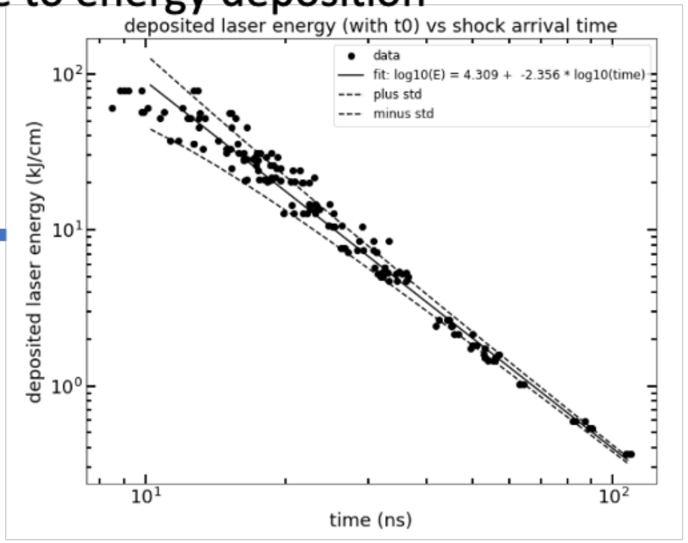
Combining information can give energy deposition

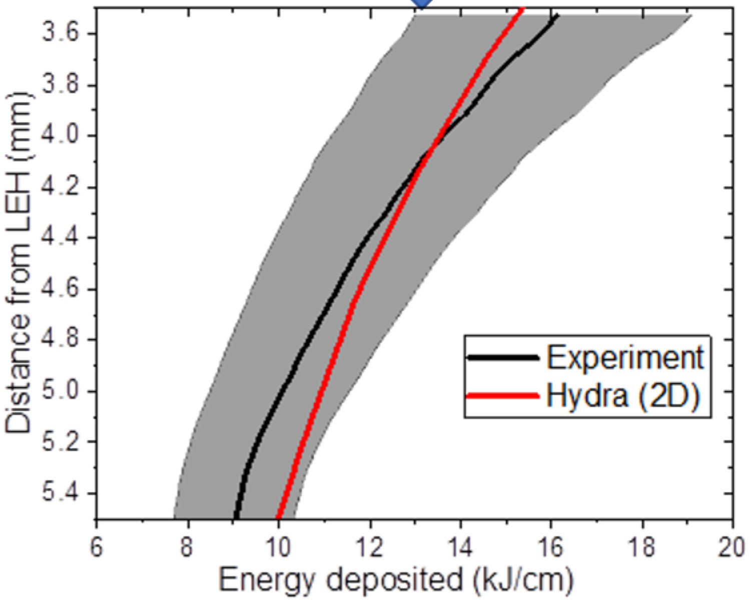
Use propagation data to subtract origin time from shock breakout





Calculate dependence of breakout time to energy deposition





Convert shock breakout time to energy per length
- Analysis is just a proof of concept at this stage

- Energy can be estimated (time only) with currently modeled configuration:
  - @ 20 kJ/cm +- 2.6 to 5.1 kJ/cm
  - @ 10 kJ/cm +- 1.0 to 1.9 kJ/cm
  - @ 2 kJ/cm +- 0.10 to 0.19 kJ/cm
- Preshock from ablation of inner wall surface, can be used as time fiducial to reduce time origin uncertainty

Forward path

- LiF (< 100 kBar) or quartz (> 1 Mbar) window to stop spallation, allowing a simpler delta velocity vs deposited energy behavior (100 kBar pressure, base case)
- High strain rate material model for Al
- Increase in radius to decrease fractional error
- Model other warm hydrocarbon surrogate density and three D2 densities
- Bayesian analysis:
  - Building a surrogate
  - Prior distribution
  - Using time and delta velocity
  - Using delta velocity profile
  - Using simple model of laser propagation for time origin estimation