Investigation of OMEGA Capsule Dynamics Using Shock Flash Measurements

J. Ryan Rygg et al.
MIT - PSFC

44th American Physical Society DPP Meeting
Orlando, FL, Nov 11-15, 2002

Collaborators

F.H. Séguin, J.A. Frenje, S. Kurebayashi, C.K. Li, R.D. Petrasso*, and B.E. Schwartz

Plasma Science and Fusion Center
Massachusetts Institute of Technology

J.A. Delettrez, J.M. Soures, V.Yu Glebov, V.N. Goncharov, J. P. Knauer, D.D. Meyerhofer, P.B. Radha, T.C. Sangster and C. Stoeckl

Laboratory for Laser Energetics
University of Rochester

N. Hoffman and D. Wilson

Los Alamos National Laboratory

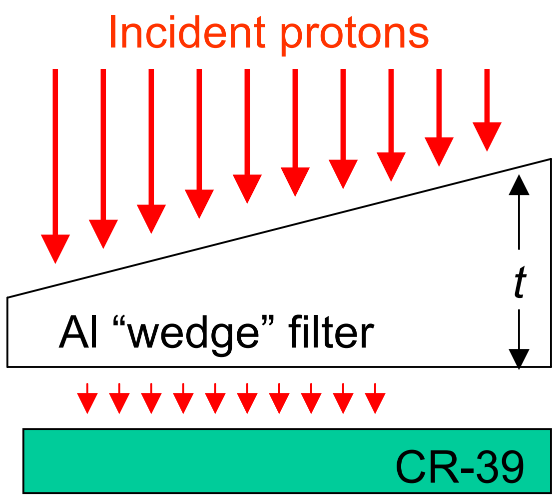
***Visiting Scientist, LLE**

Outline

- Charged particle measurements on OMEGA
- Shock and compression components of D-^{3}He proton spectrum
- Effect of capsule parameters on timing and yield
- Temperature inferred from shock measurements
- Sources of shock spectral line broadening

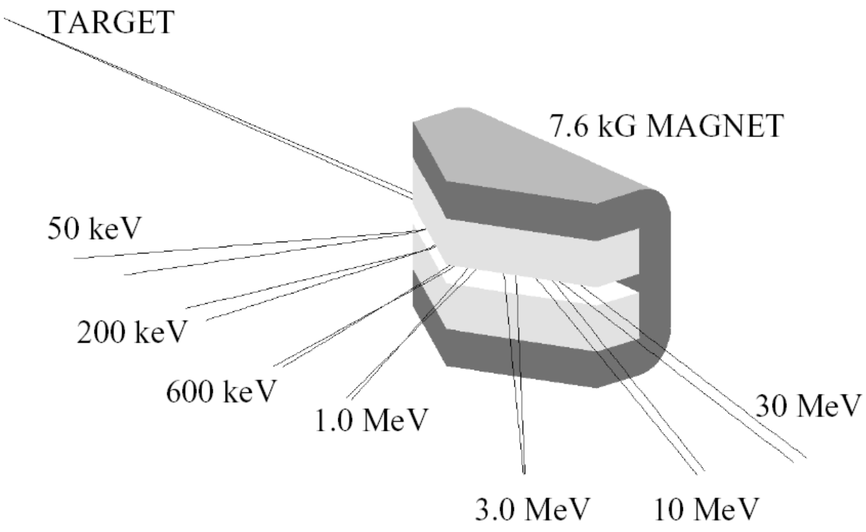
Measurements of charged particles provide spectral*, spatial and temporal information

"Wedge-Range-Filter" spectrometers (WRFs)



Particle energies identified from local thickness t and diameter of etched proton tracks in CR-39.

Magnet-based spectrometers (CPSs)

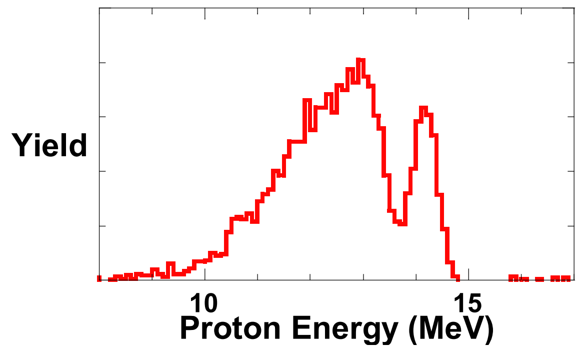


Particle energies identified from trajectories.

*F.H. Seguin et al, Rev. Sci. Instr. (to be published)

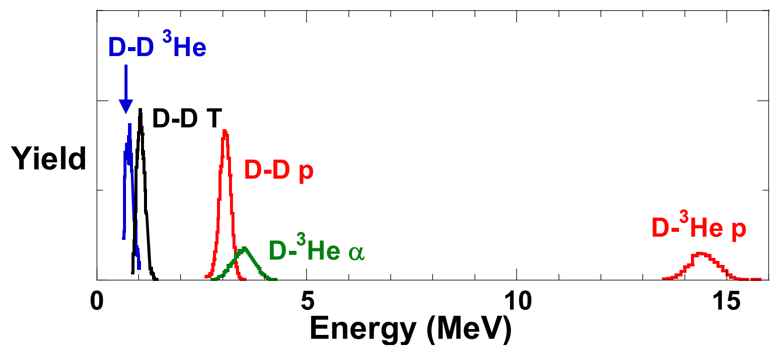
Measurements of charged particles provide spectral, spatial and temporal information

"Wedge-Range-Filter" spectrometers (WRFs)



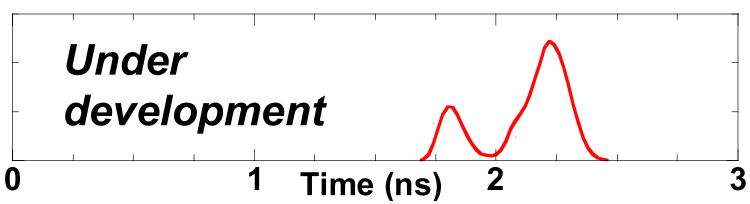
Spectra of D^{3}He p at multiple angles

Magnet-based spectrometers (CPSs)



Spectra of D^{3}He p, α and DD p, T, ^{3}He

Proton temporal diagnostic (PTD)

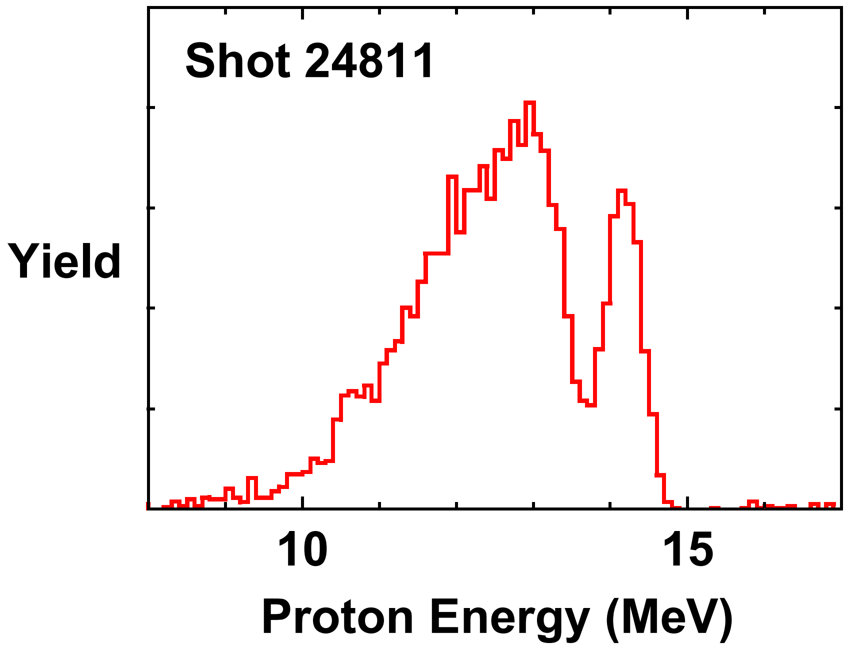


Time history of D^{3}He burn rate

Proton Core Imaging Spectrometer (PCIS)

Radial profiles of burn for DD at shock and D^{3}He at compression

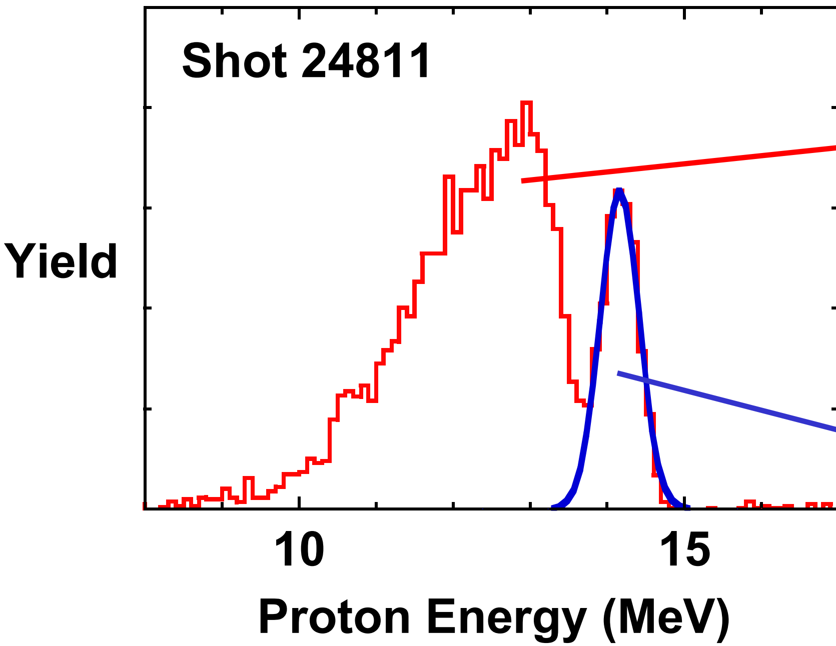
Spectra of D^{3}He protons are routinely measured on OMEGA

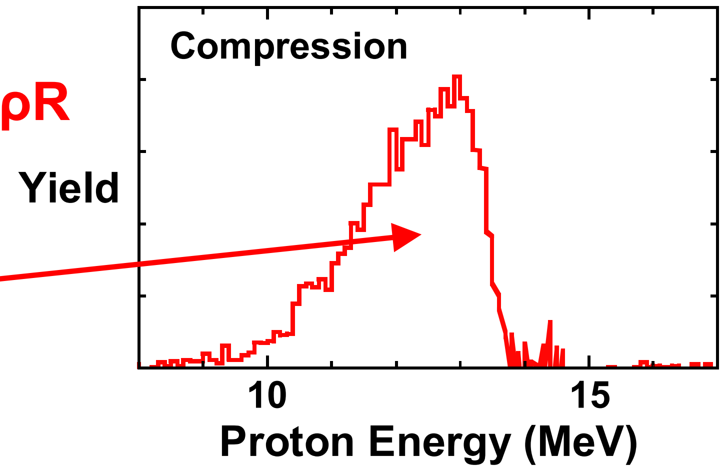


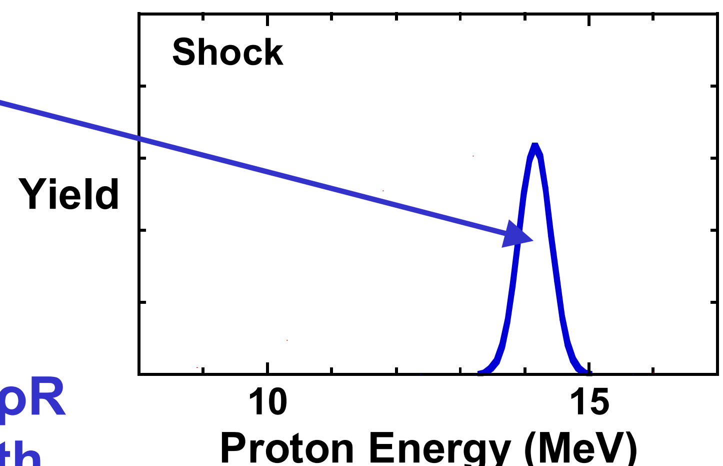
$$D + {}^3He \Rightarrow \alpha(3.6) + p(14.7)$$

D^{3}He proton spectra can be divided into shock* and compression components

From compression component: • Yield
• Δ<E> ~ ρR



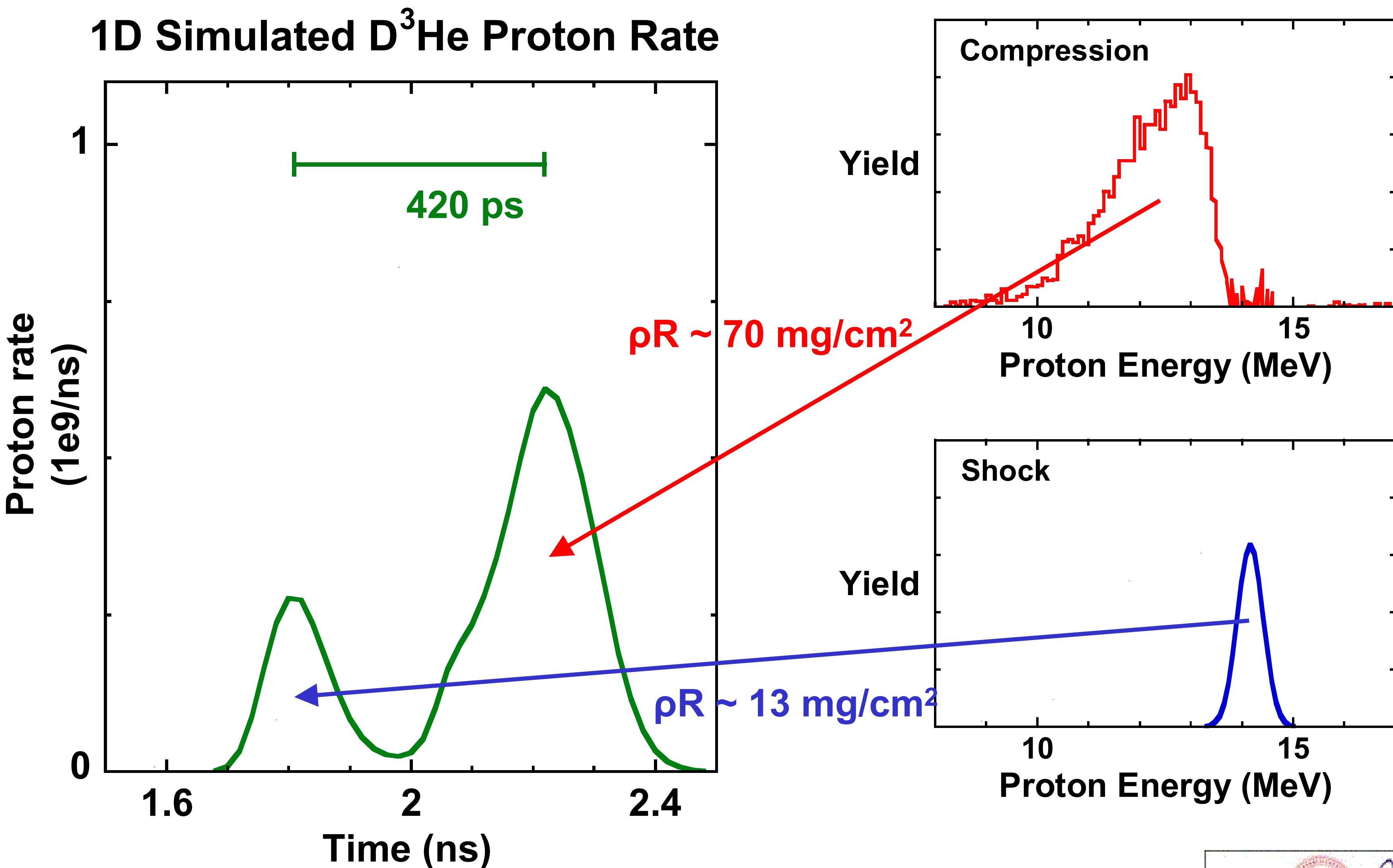




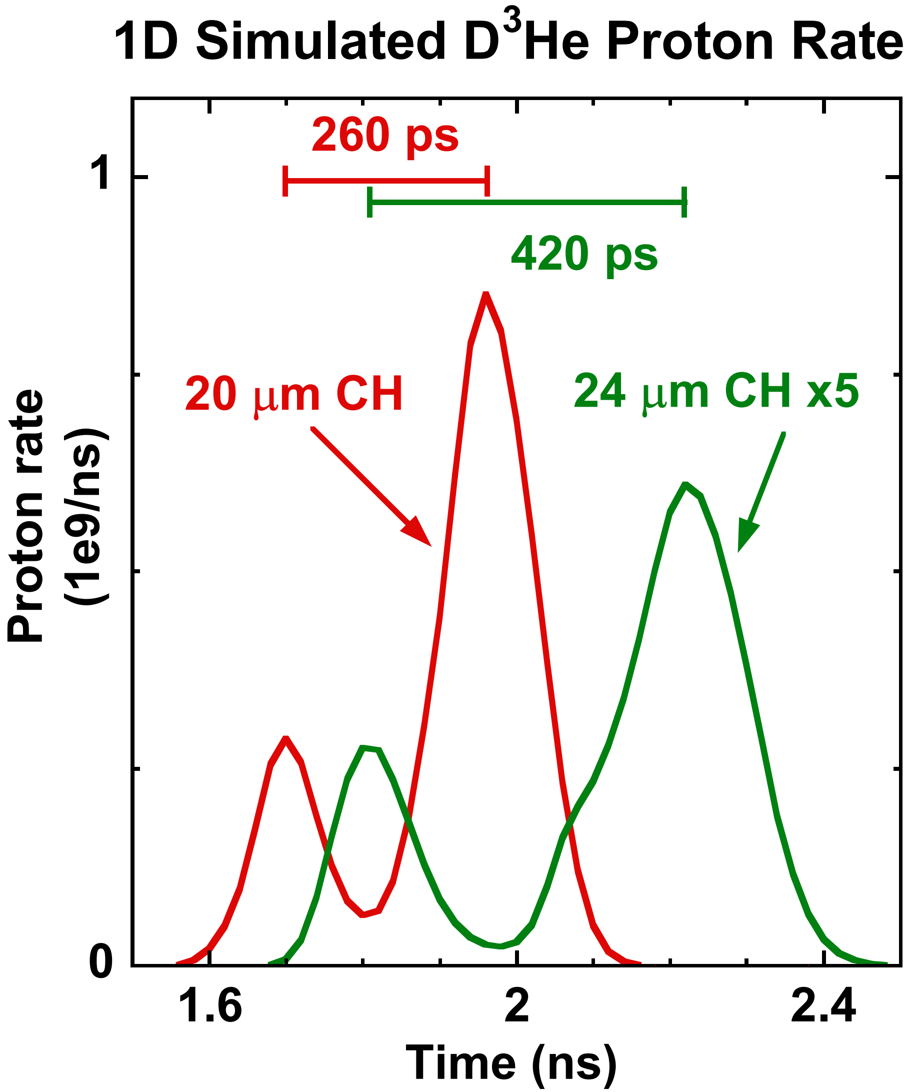
From shock line: • Yield
• Δ<E> ~ ρR
• line width

*R.D. Petrasso et al, Phys. Rev. Lett. (to be published)

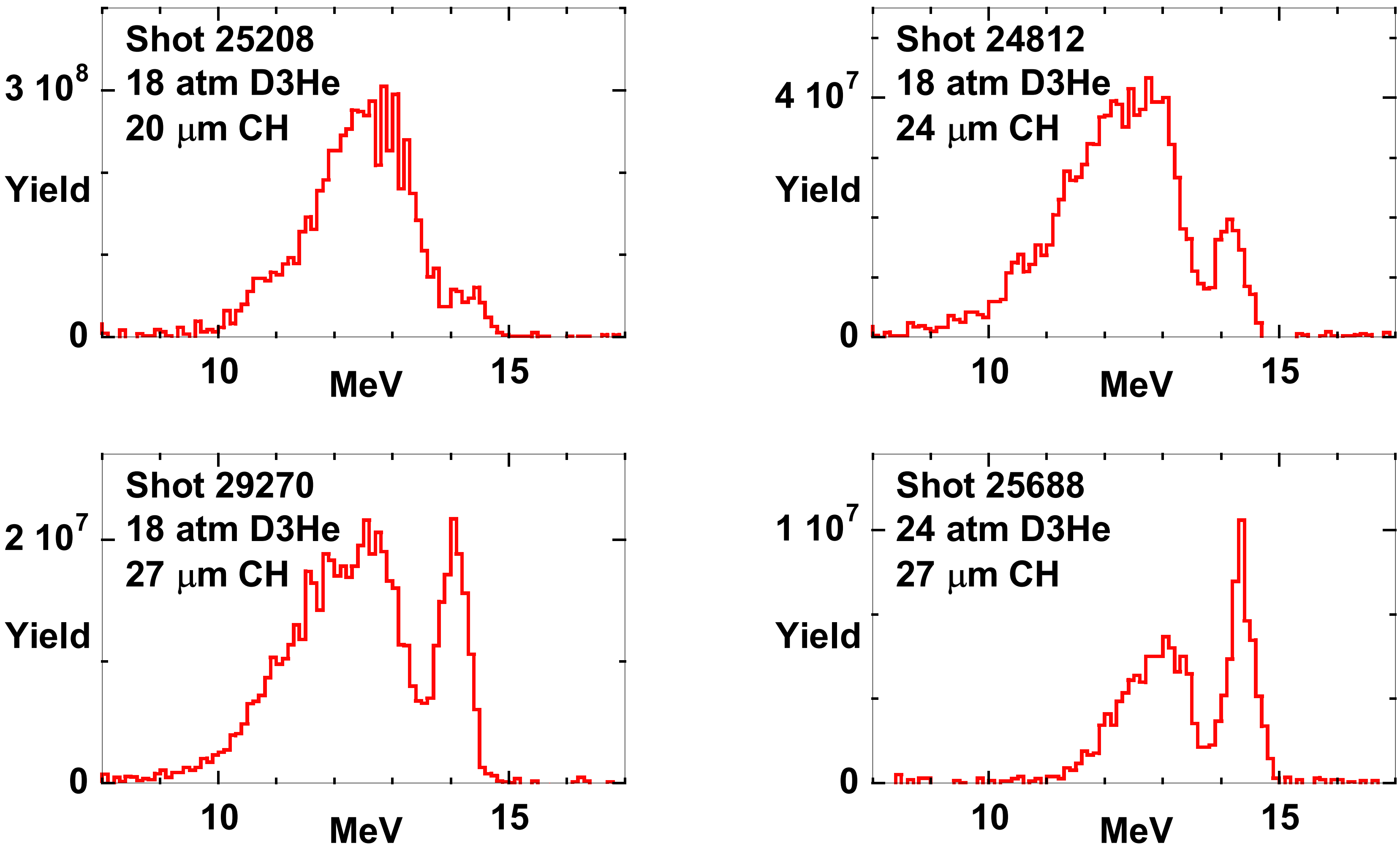
Shock and compression components occur at different times



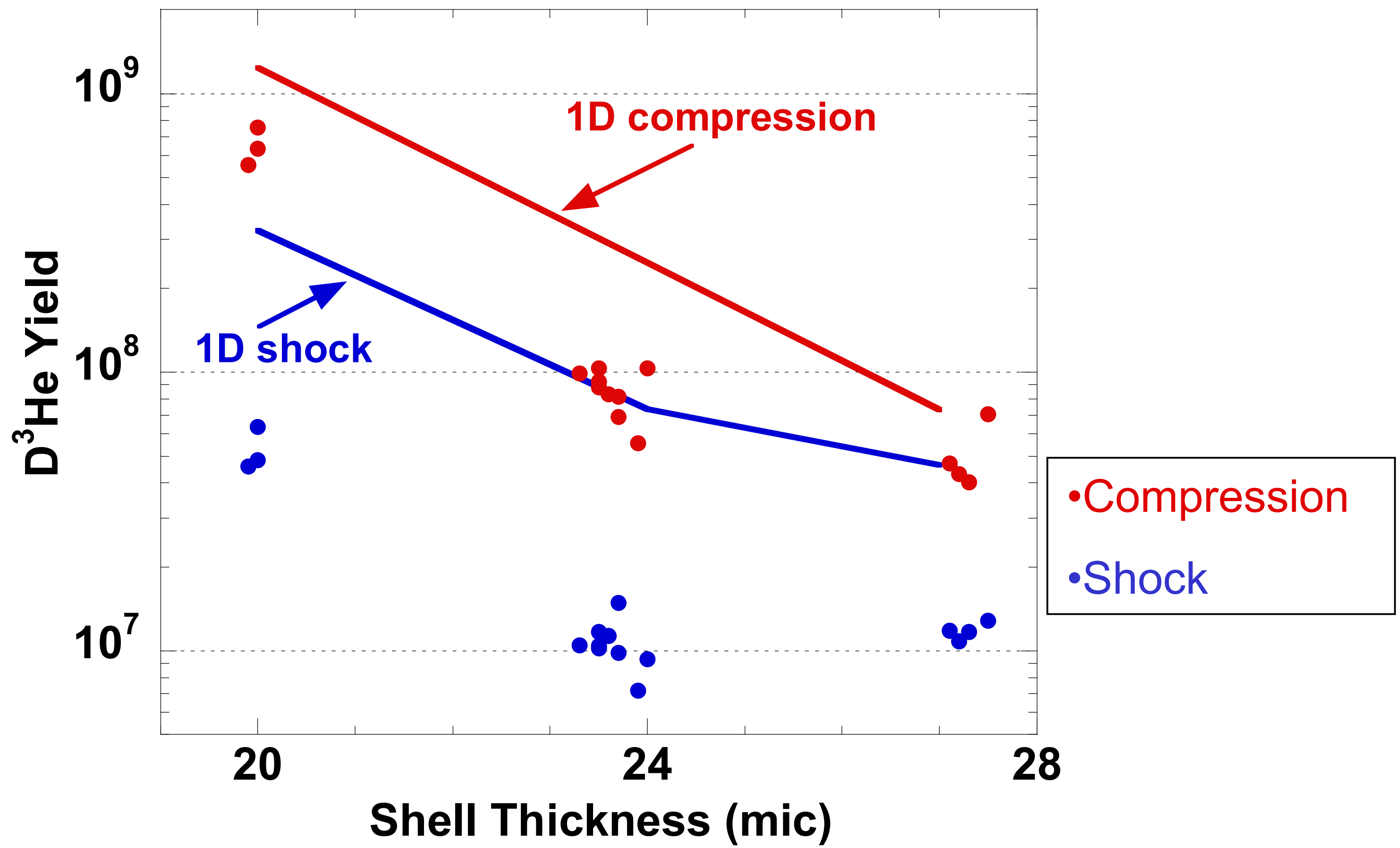
1D simulations predict a smaller interval between shock and bang time for thinner shells



Shock and compression components are strongly dependent on capsule parameters

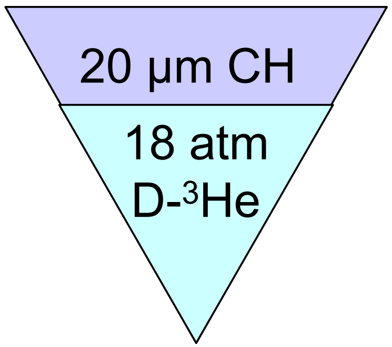


Shock and compression yields compared to 1D simulations

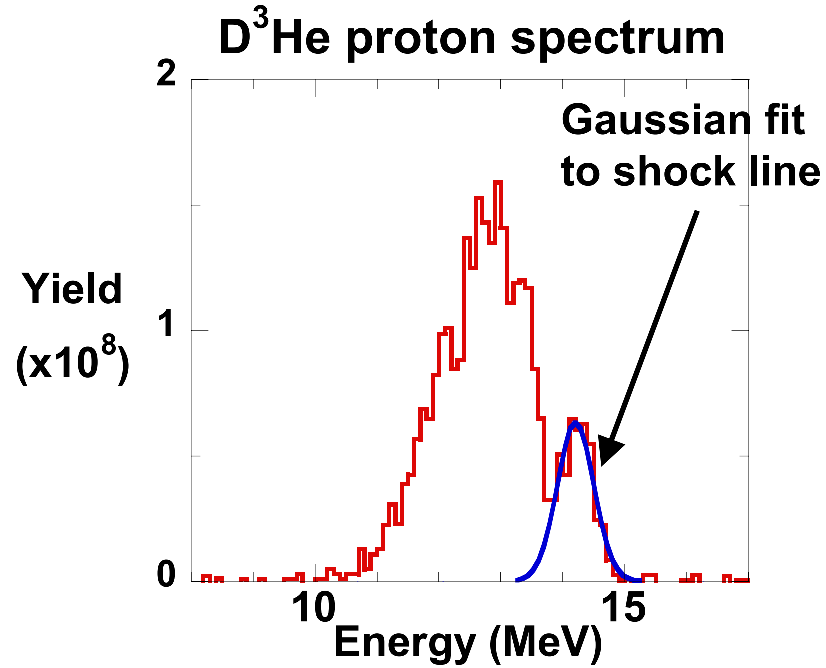


Ion temperature can be estimated assuming line width comes from doppler broadening

Shot 28925



20 kJ α501P

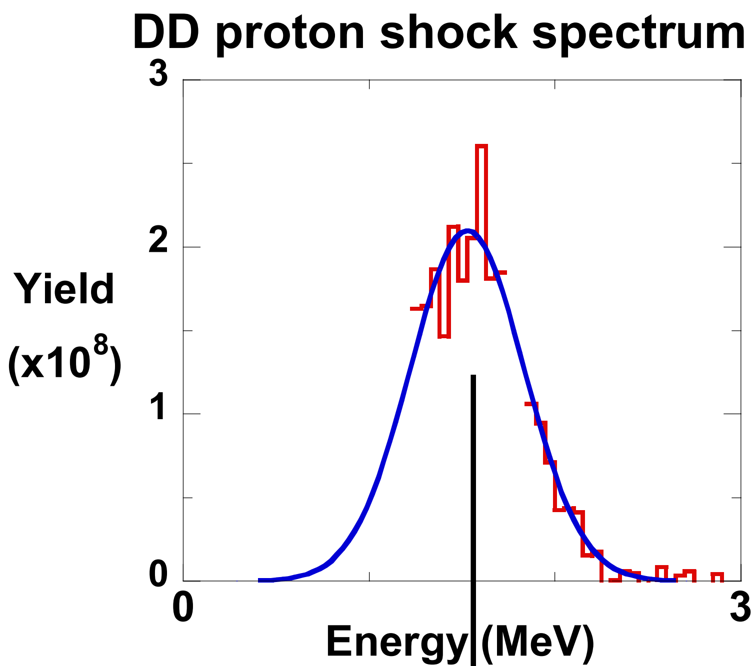


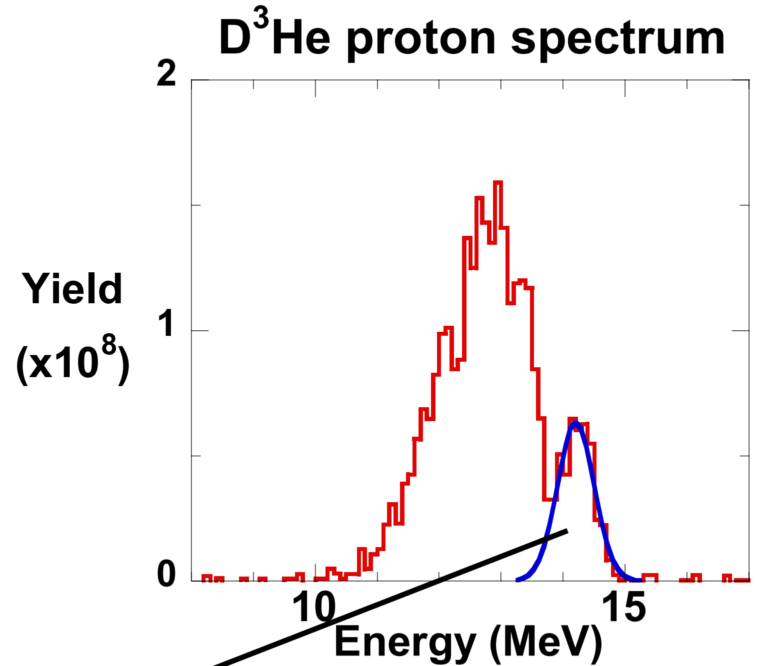
$$\sigma^2_{shock} = \sigma^2_{doppler} + \sigma^2_{instrument} + \sigma^2_{other}$$

If σ^2_{other} is neglected, derived shock temperature is:

$$\langle T_i \rangle_{width} \approx 9.8 \text{ keV}$$

Ion temperature can be estimated using yields of different nuclear reactions



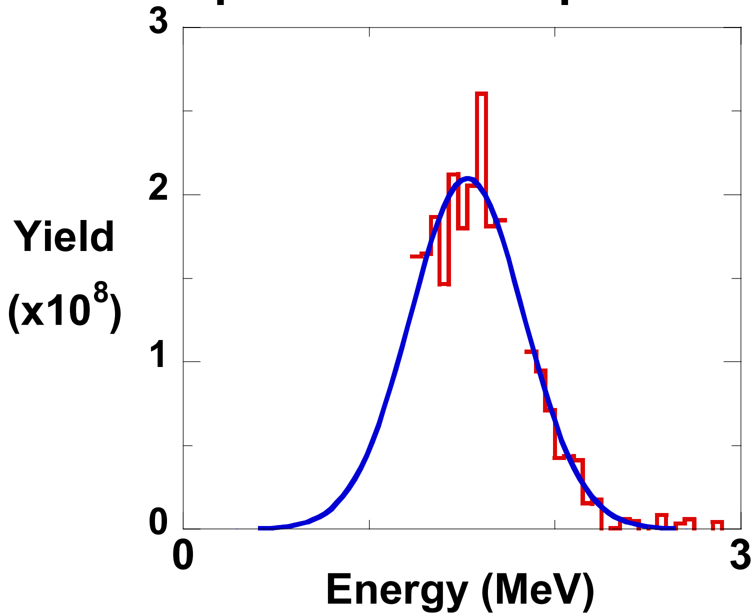


$Y_{DD} \approx 1.6e8$

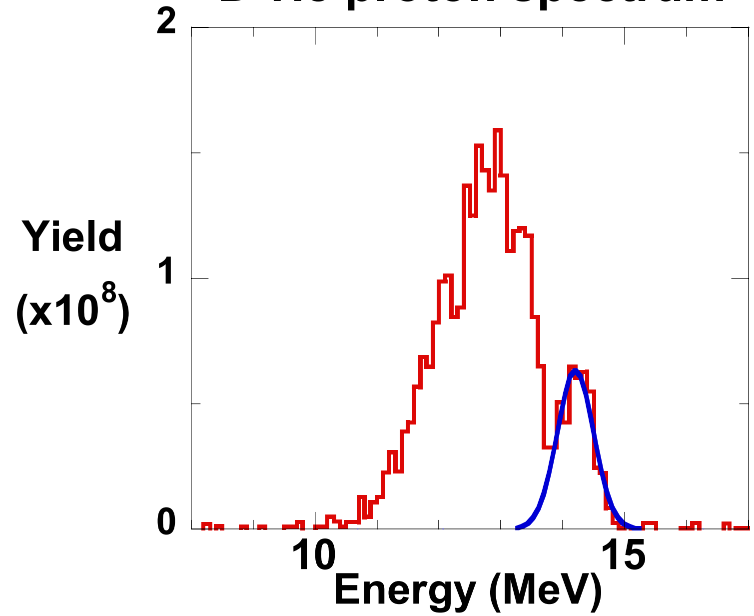
$Y_{D3He} \approx 4.9e7$

Ion temperature can be estimated using yields of different nuclear reactions

DD proton shock spectrum



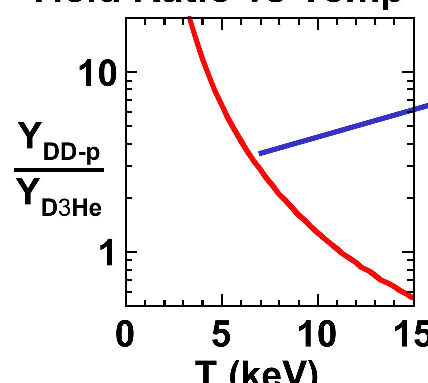
D^3He proton spectrum



Y_{DD} ≈ 1.6e8

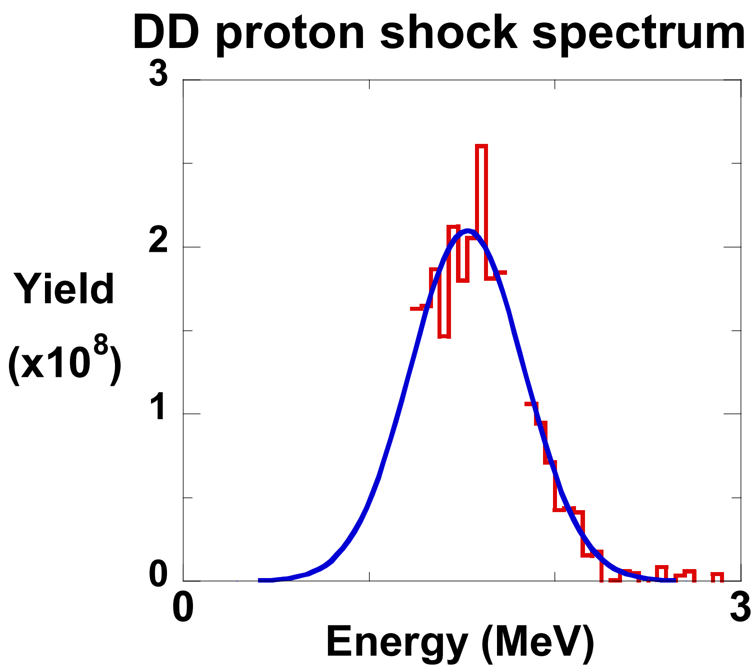
Y_{D3He} ≈ 4.9e7

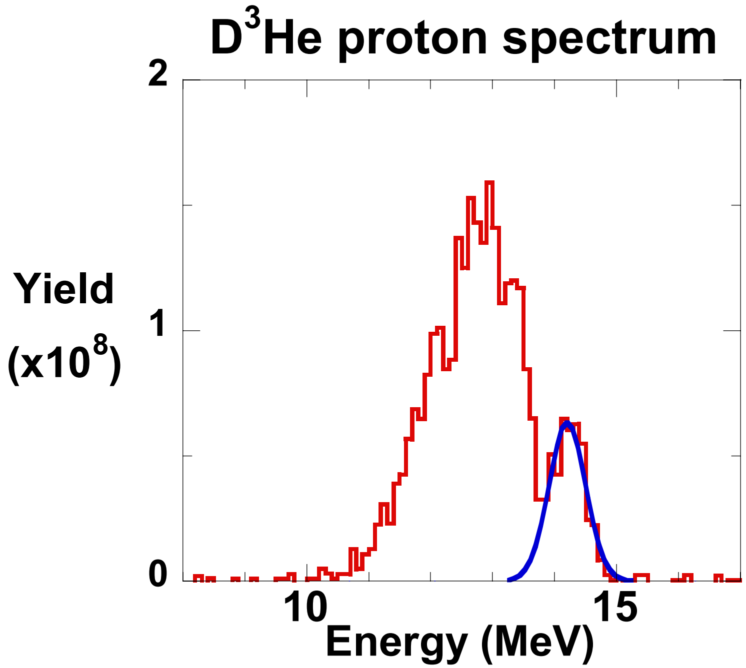
Yield Ratio vs Temp



$\langle T_i \rangle_{ratio}$ ≈ 6.6 keV

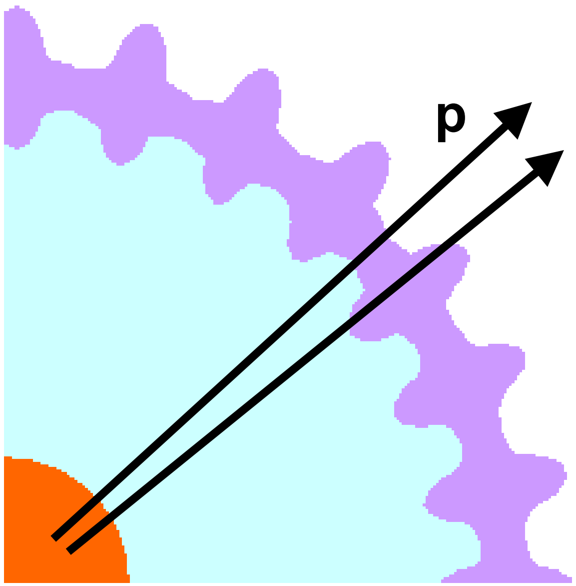
Comparison of temperatures derived from different methods





Discrepancy hints at other sources of broadening { $\langle T_i \rangle_{ratio} \approx 6.6$ keV; $\langle T_i \rangle_{width} \approx 9.8$ keV

Broadening due to high mode ρR modulations during the shock flash

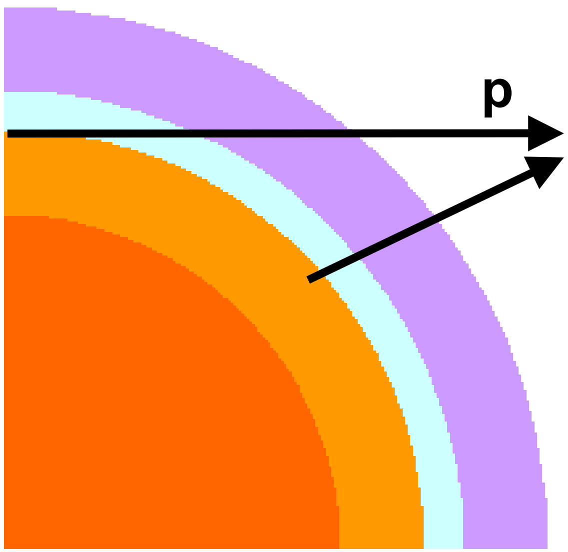


Broadening from high mode ρR variations at shock time

Temp difference constrains high mode amplitude < 40%

$\langle T_i \rangle_{ratio} \approx 6.6$ keV
$\langle T_i \rangle_{width} \approx 9.8$ keV

Broadening due to geometrical effects from a spatially extended source



Broadening from geometry effects due to spatial extent of source region

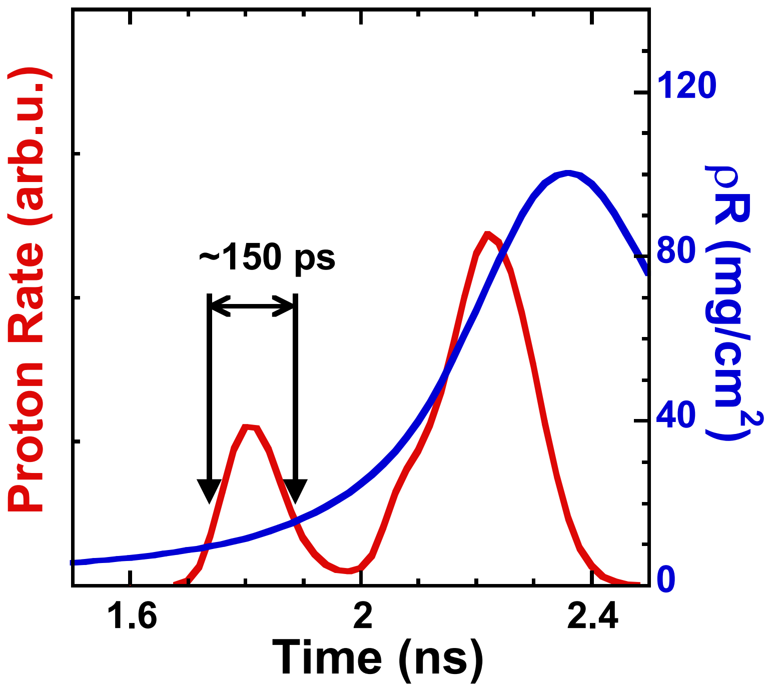
PCIS can directly measure the extent of the source region

For more on PCIS:

R. D. Petrasso *et al.*	GO2.015
B. E. Schwartz *et al.*	KP1.147

Temporal broadening due to ρR evolution over finite interval of the shock flash

1D simulated proton rate and ρR



Broadening from ρR evolution during shock flash interval

Development of PTD will enable measurement of shock width

1D simulation anticipates that:

Over ~150 ps shock interval, ρR evolves from ~10 to ~17 mg/cm^2

Summary

- ρR and yield at shock coalescence and bang time are studied using DD proton and D-^{3}He proton spectra.
- Shock and compression yields are reduced for targets with thicker shells.
- Charged particles can be used to study capsule conditions during shock coalescence, including
  - Ion temperature
  - High mode (ℓ~50) ρR modulations
  - Spatial extent
  - Temporal evolution

Future work

- Develop Proton Temporal Diagnostic (PTD) and use to directly measure the timing and width of shock flash and compression burn
- Quantify sources of shock spectral line broadening in order to investigate possible high mode (ℓ~50) ρR variations at shock time
- Investigate possible low mode (ℓ~2) ρR structure growth between shock and bang time