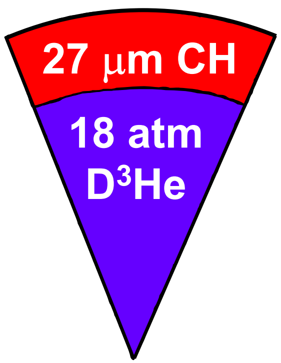
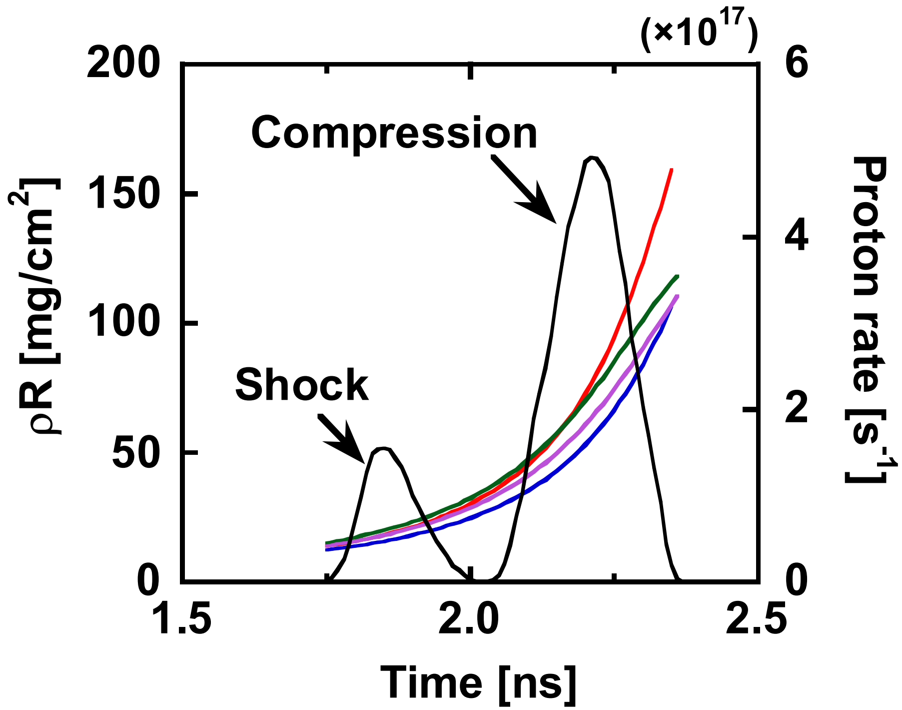
Measurements of shock timing and ρR evolution of D^3He implosions at OMEGA





Johan Frenje
MIT - Plasma Science and Fusion Center

45th Annual Meeting of the Division of Plasma Physics
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Collaborators

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Summary

Shock timing and ρR evolution of D^3He implosions have been measured at OMEGA

- D^3He burn history contains a shock component in addition to a compression history similar to that of DD neutrons.
- $T_i(t)$, shock time and shock-burn duration have been obtained and compared with 1-D calculations.
- Low-mode ρR asymmetries at shock time are amplified and mirrored at bang time, and correlated to laser drive asymmetry (for a large imposed $\ell = 1$).
- We are looking into ^3He-seeded cryogenic D_2 implosions.

Related work

Related talks and posters at this conference:

F.J. Marshall et al., CO2.005

R. Epstein et al., CO2.008

R. D Petrasso et al., CO2.009

F. H. Séguin et al., CO2.011

C. K. Li et al., CO2.012

R. Rygg et al., CO2.013

J. DeCiantis et al., CO2.015

V. Yu. Glebov et al., UP1.007

D. Wilson et al., B12.04

Recent related papers:

R. D. Petrasso et al., Phys. Rev. Letters 90 (2003) 095002.

V. A. Smalyuk et al., Phys. Rev. Letters 90 (2003) 135002.

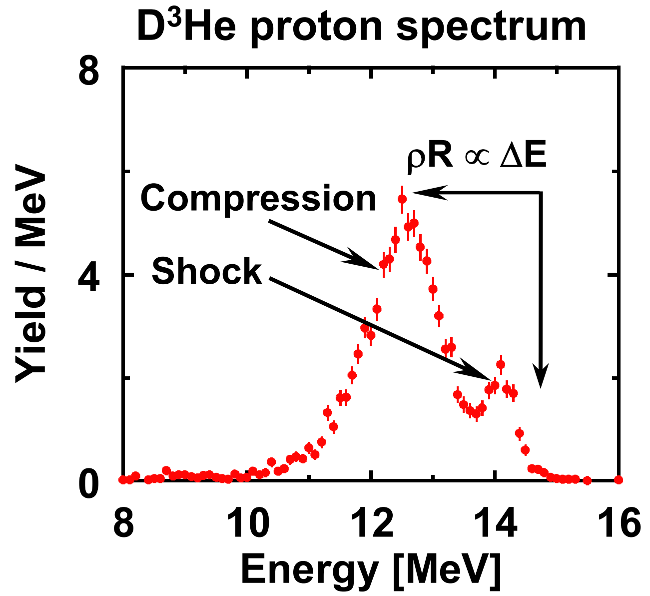
C. K. Li et al., submitted to Phys. Rev. Letters.

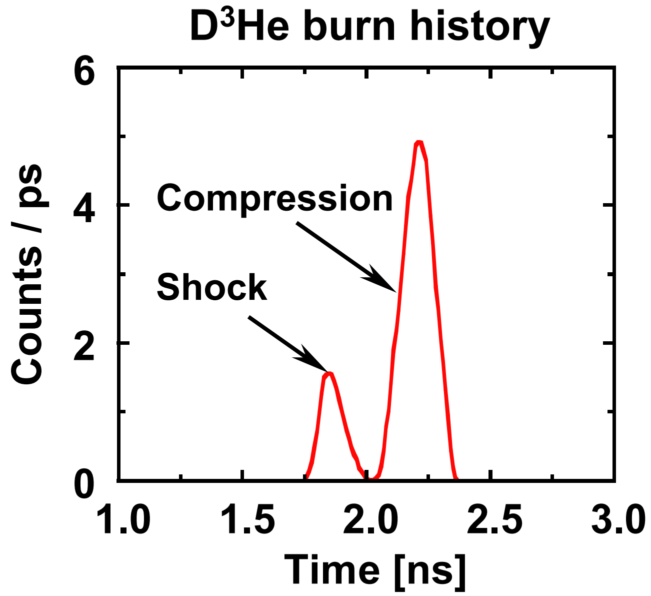
Outline

- Principle of measuring ρR evolution and D^3He burn history
- Experiments
- Effects causing time dispersion in measured D^3He burn history data
- Analysis method
- Results
- ^3He-seeded cryogenic D_2 implosions

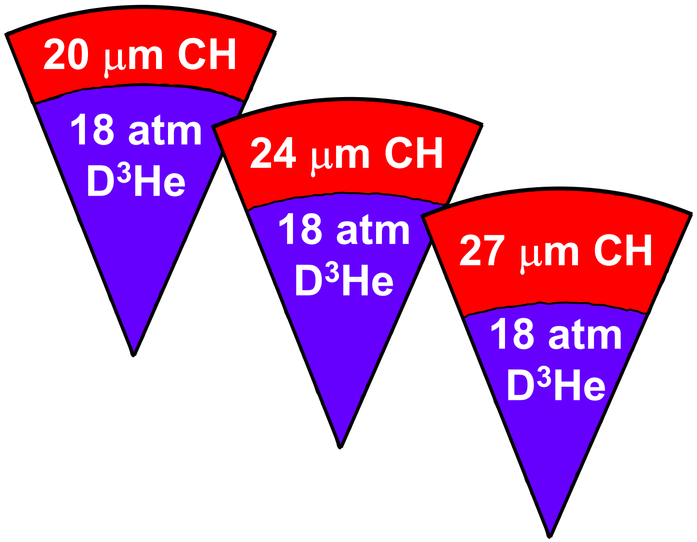
ρR(t) can be inferred from D^{3}He proton spectrum and D^{3}He burn history

D + ^{3}He → ^{4}He + p (14.7 MeV)





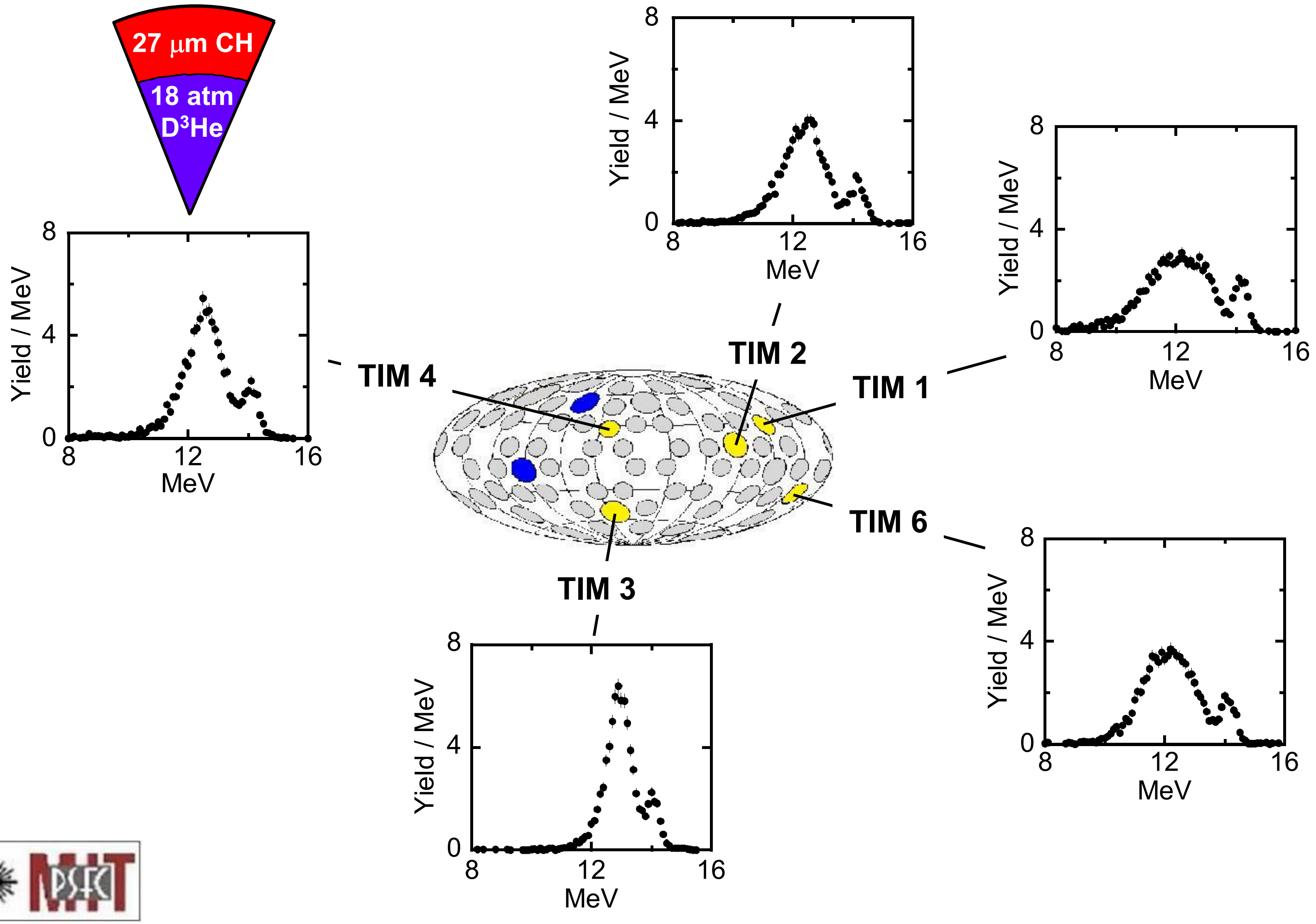
Three types of capsules were imploded



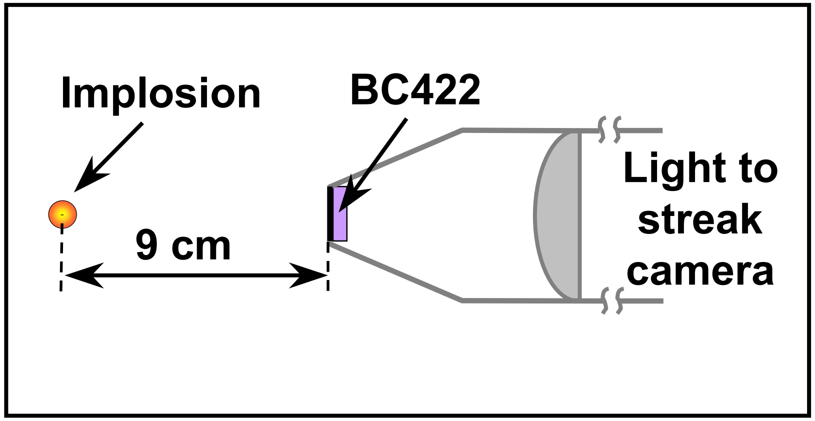
60 laser beams
23 kJ energy
1 ns square laser pulse
1 THz, 2-D SSD+PS

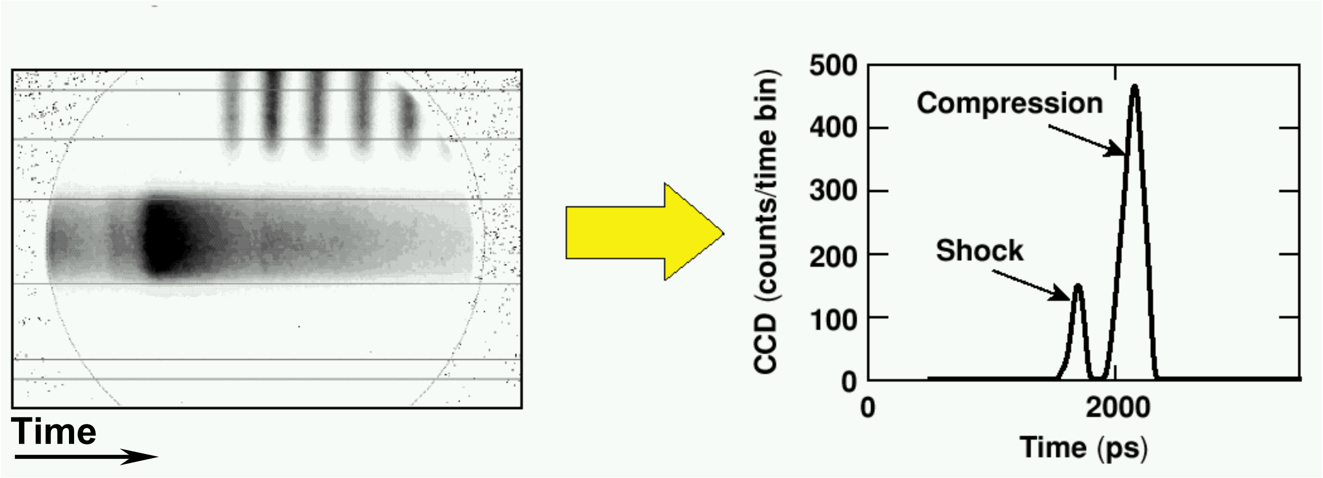
- Shock time
- Shock burn duration
- Nature of compression burn
- T_i evolution
- Evolution of ρR
- Evolution ρR asymmetries

D^3He proton spectra were simultaneously measured from different directions



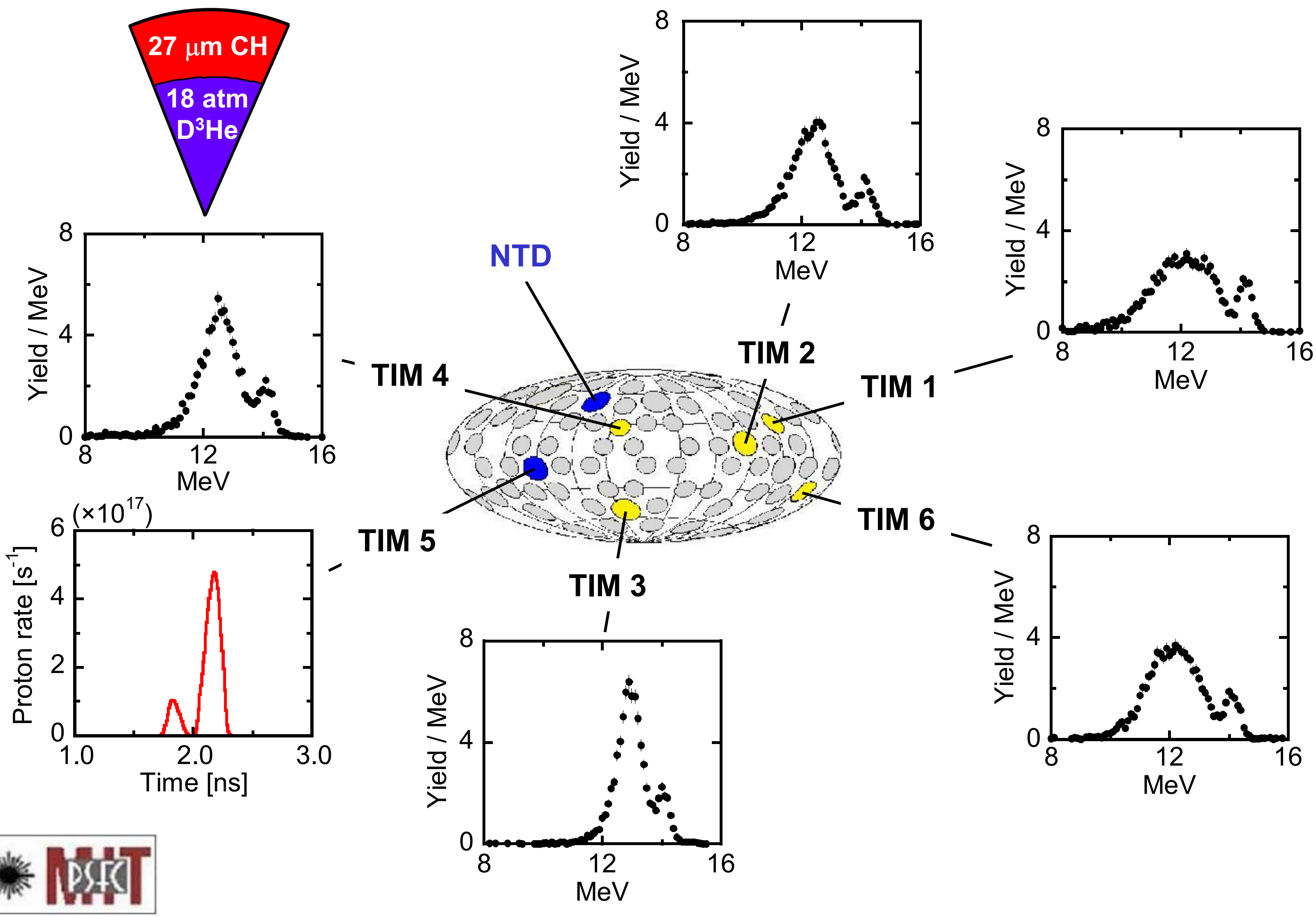
A proton temporal diagnostic (PTD) was implemented for measurements of D^3He burn history



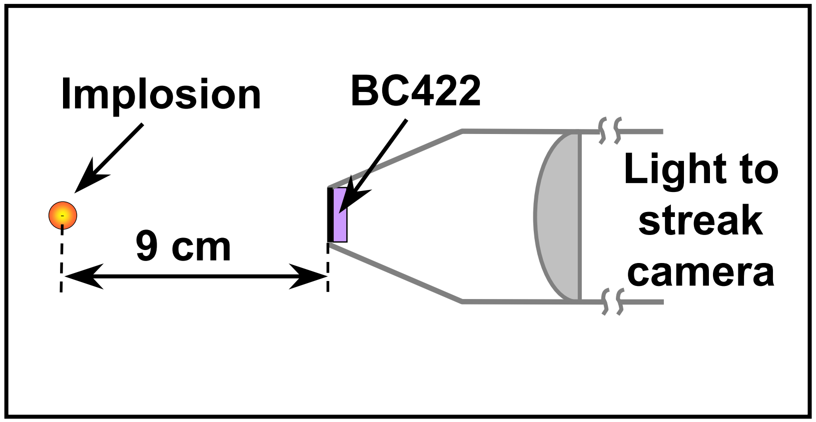


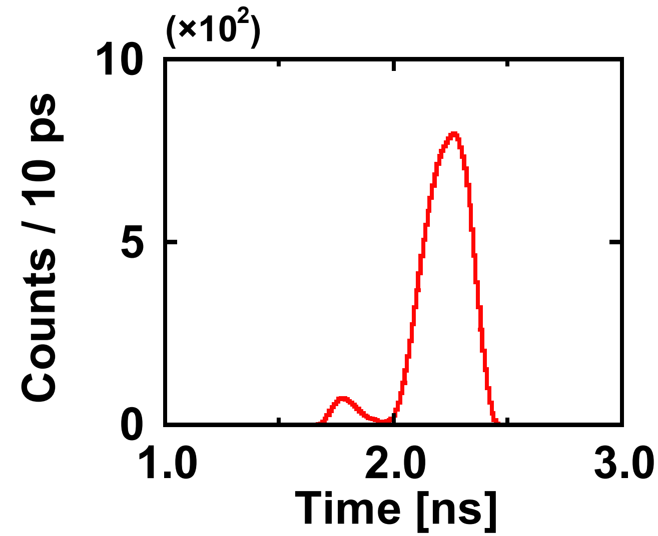
V. Yu. Glebov et al., UP1.007

D^3He burn history and D^3He proton spectra were simultaneously measured



PTD data must be corrected for time dispersion

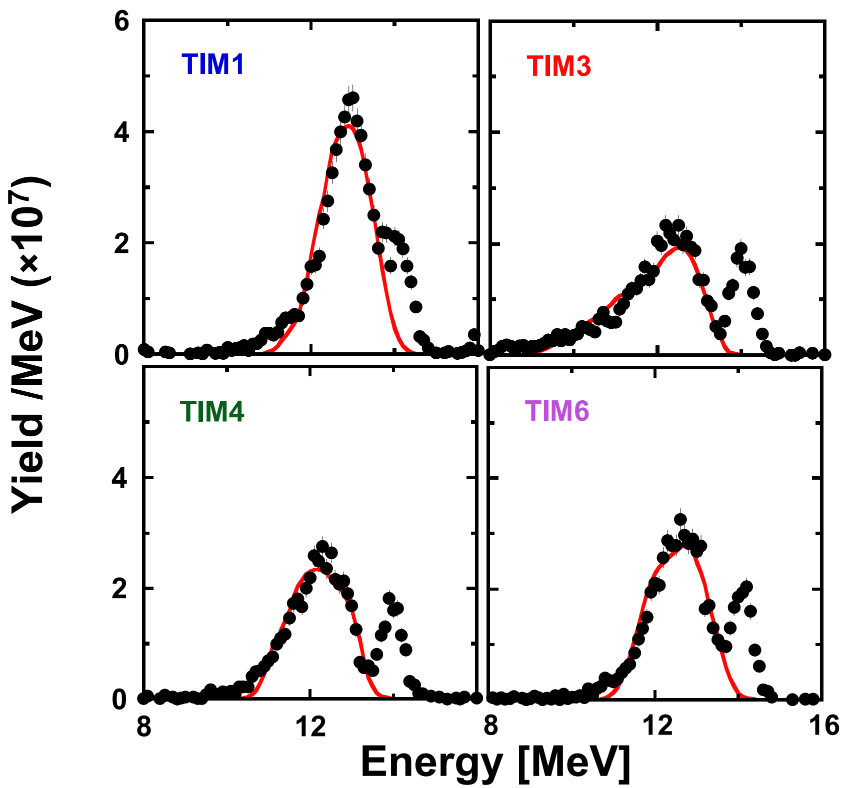


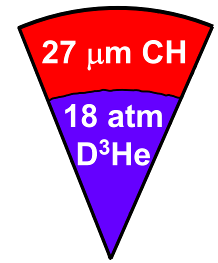


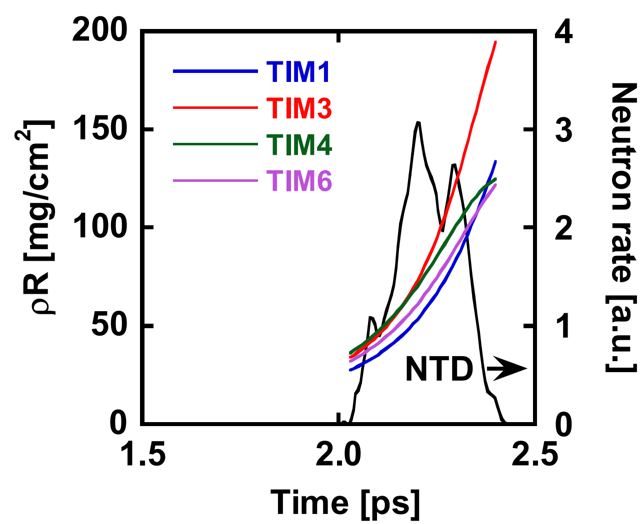
Effects causing time dispersion:

- **ρR evolution:** Needs to be determined.
- **Source and shell geometry:** From Proton Core Imaging data and X-ray imaging data.
- **Doppler broadening from $T_i(t)$:** From measurements.
- **PTD response:** From Monte-Carlo simulations.

Using DD burn history, ρR(t) was initially determined from a fit to measured D^3He-proton spectrum

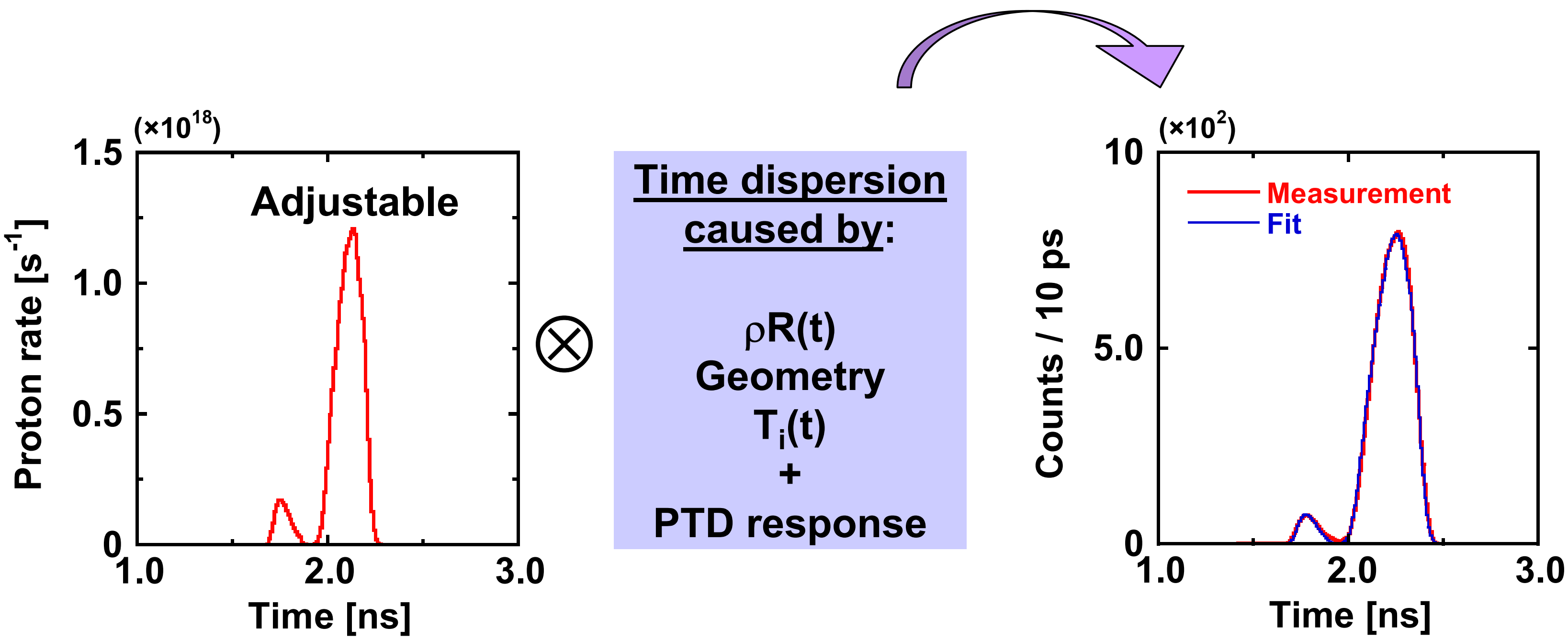






A Lorentzian function was used as a ρR(t) function in the fitting procedure.

A convolution of D^{3}He burn history and components causing time dispersion is fitted to measured PTD data



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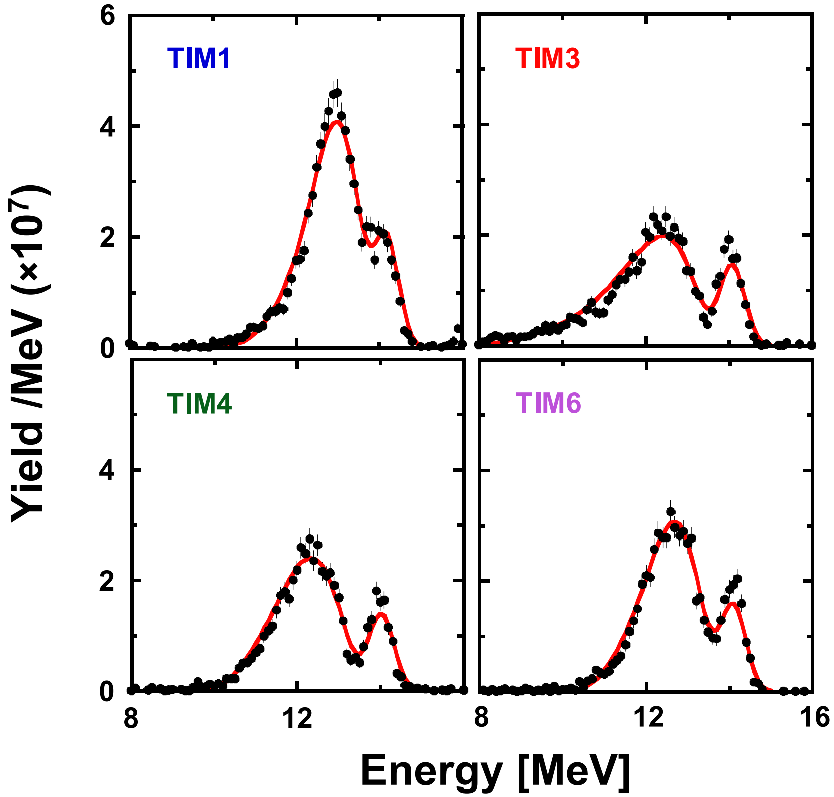
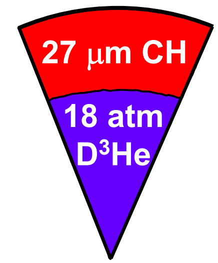
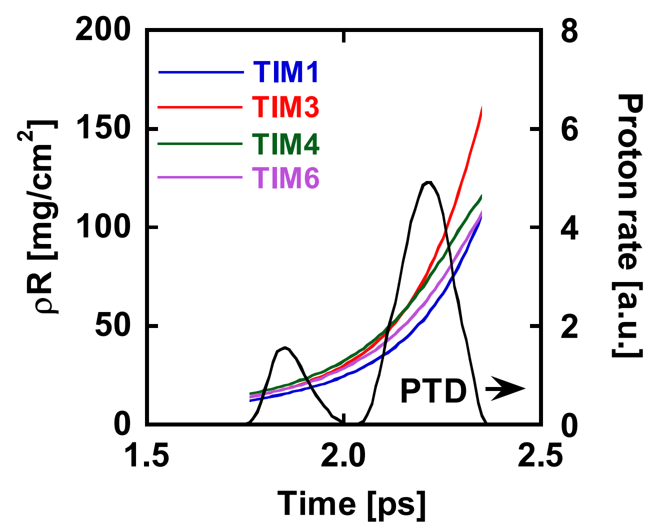
Using unfolded D^{3}He burn history, $\rho R(t)$ was finally determined from a fit to measured D^{3}He-proton spectrum

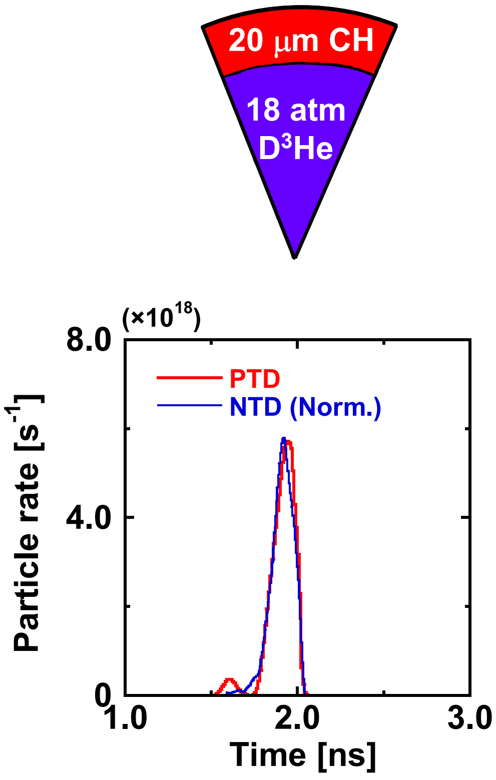


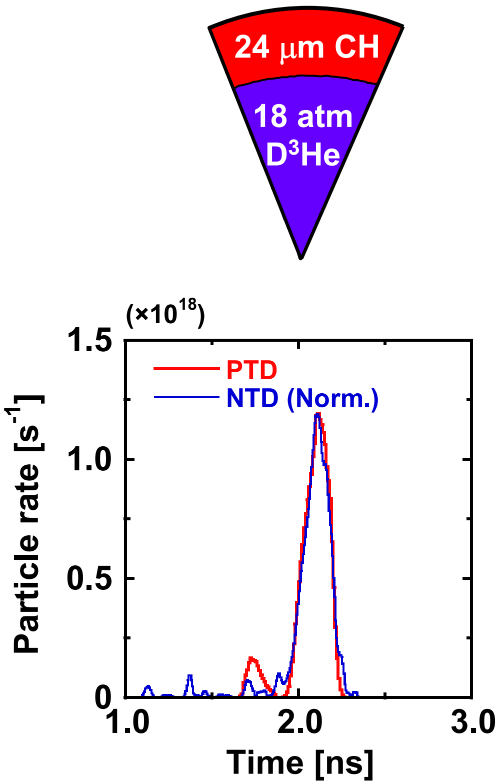


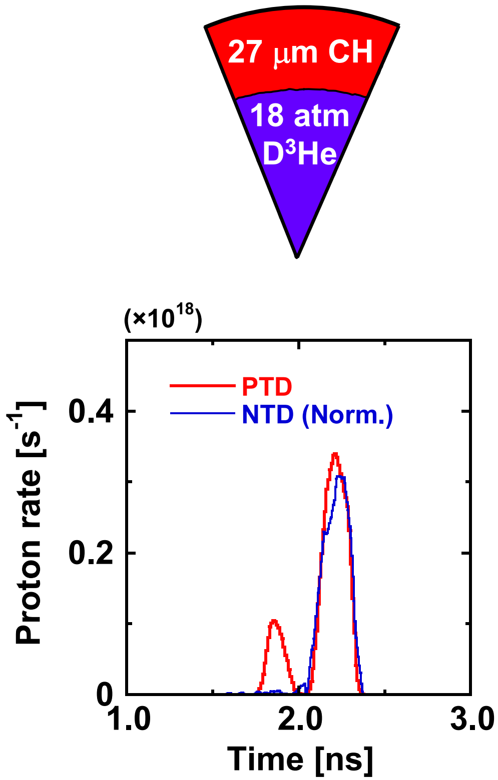


A Lorentzian function was used as a $\rho R(t)$ function in the fitting procedure.

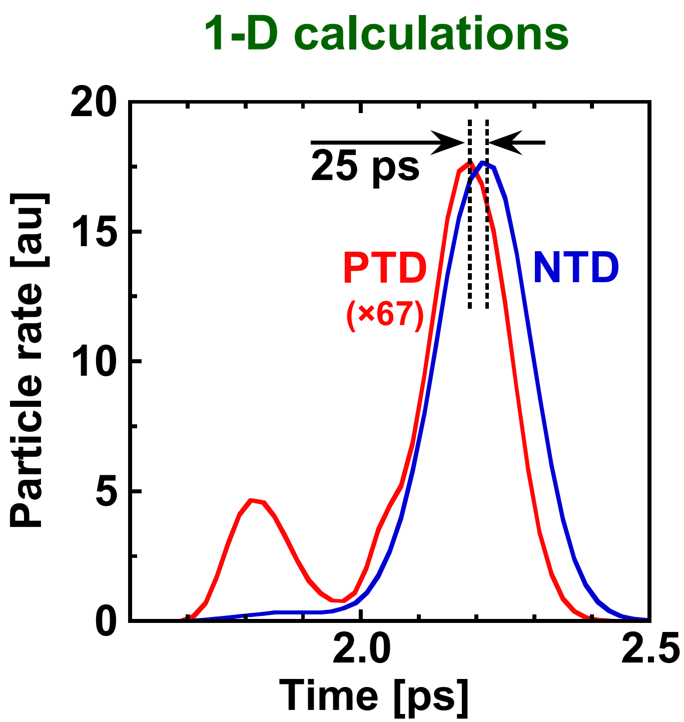
D^{3}He burn history contains a shock component in addition to a compression history similar to that of DD neutrons

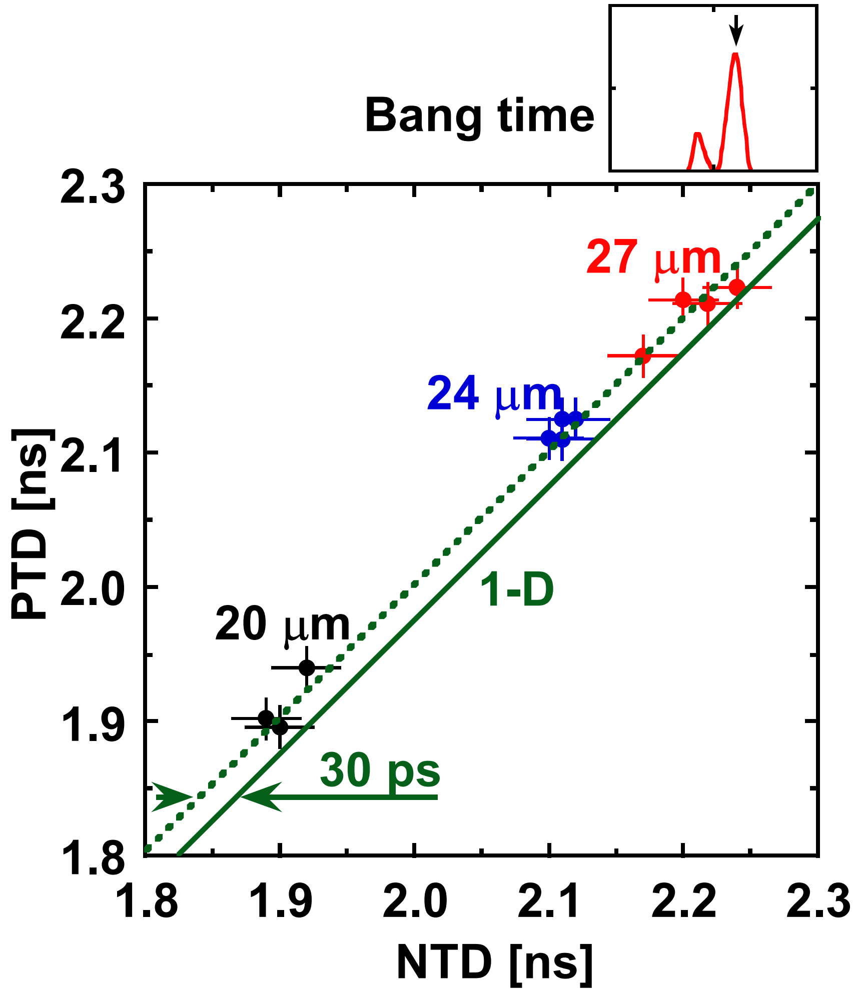




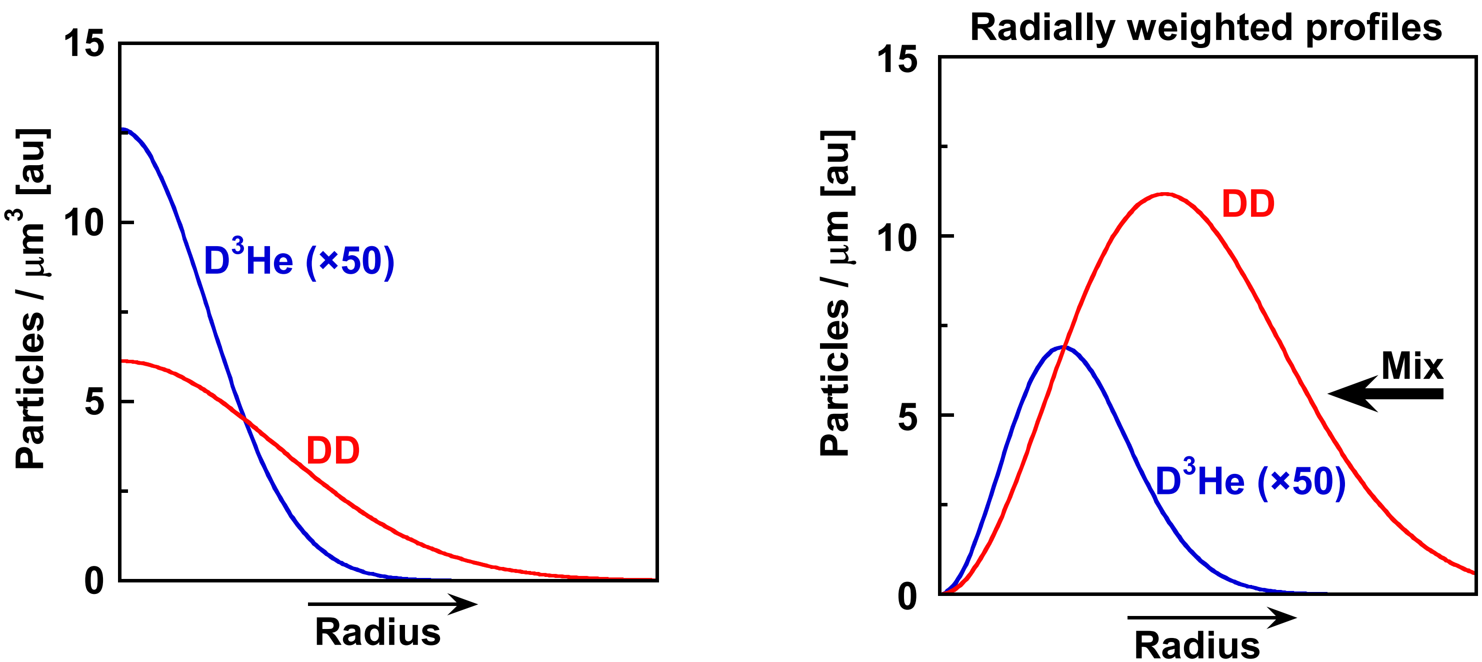


By comparing measured D^3He and DD bang times to 1-D calculations effects of mix can be addressed





Due to a broader burn profile, DD burn history is more sensitive to mix than D^3He burn history



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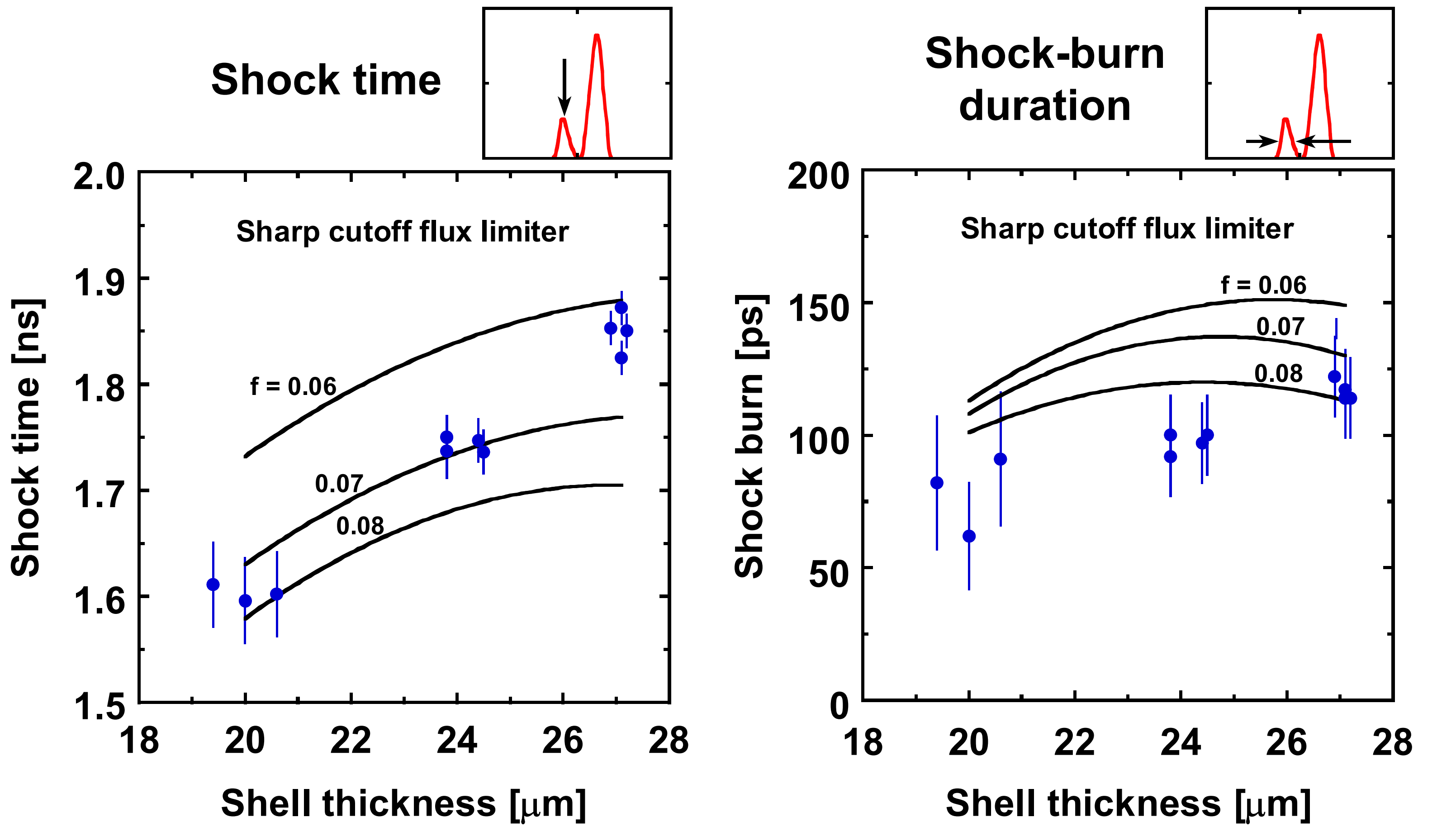
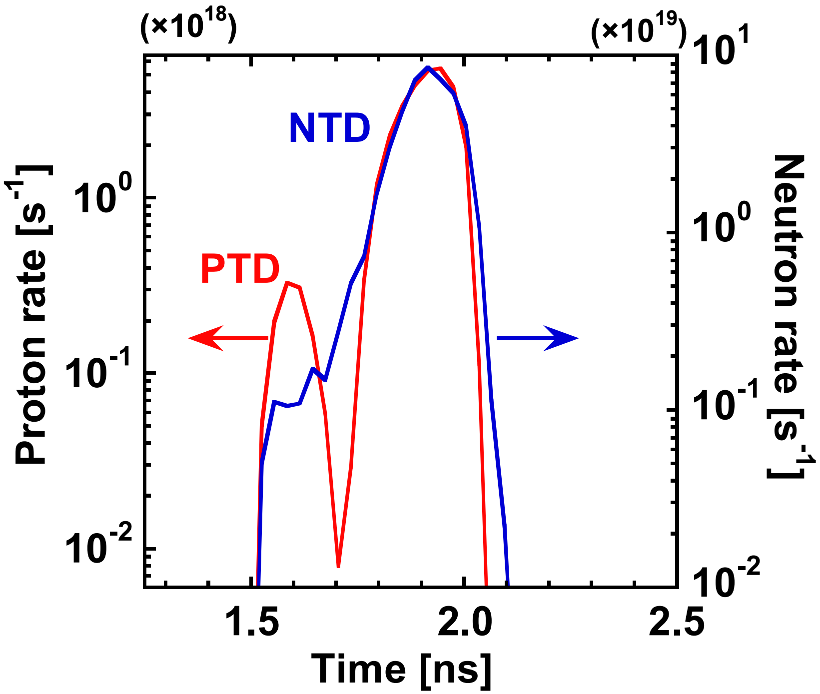
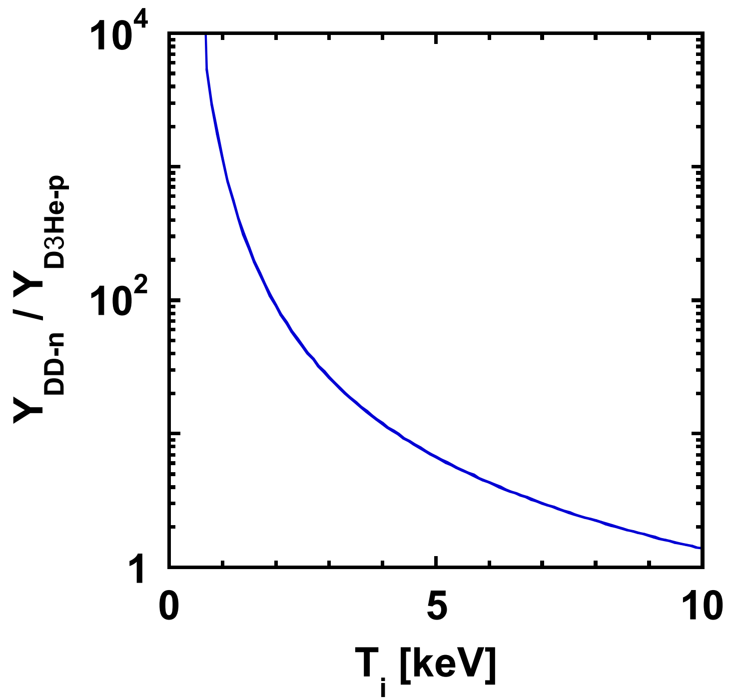
Shock time and shock-burn duration have been obtained and compared to 1-D calculations



Evolution of T_i can be inferred from the ratio of D^3He and DD burn histories





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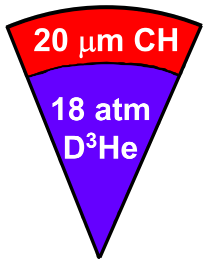
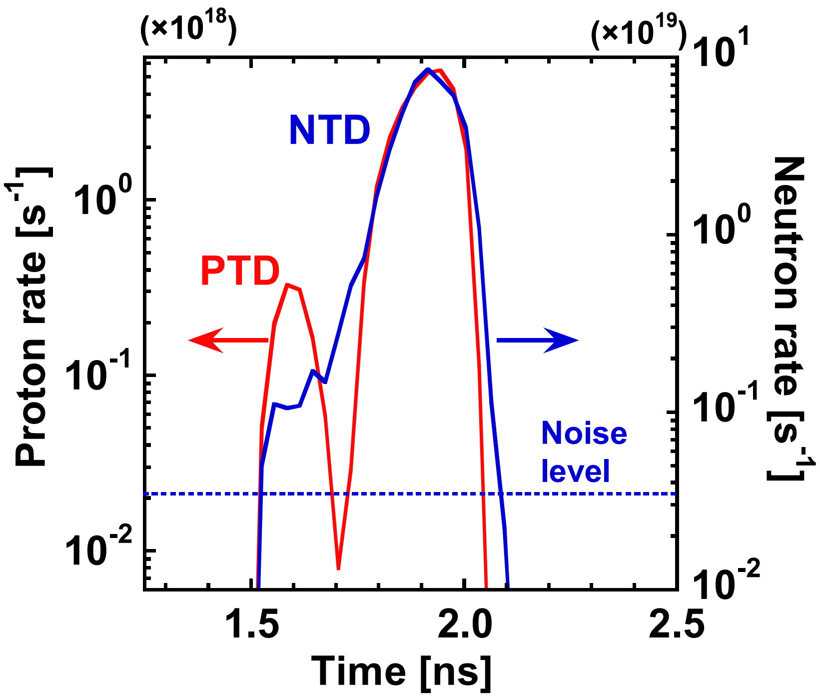
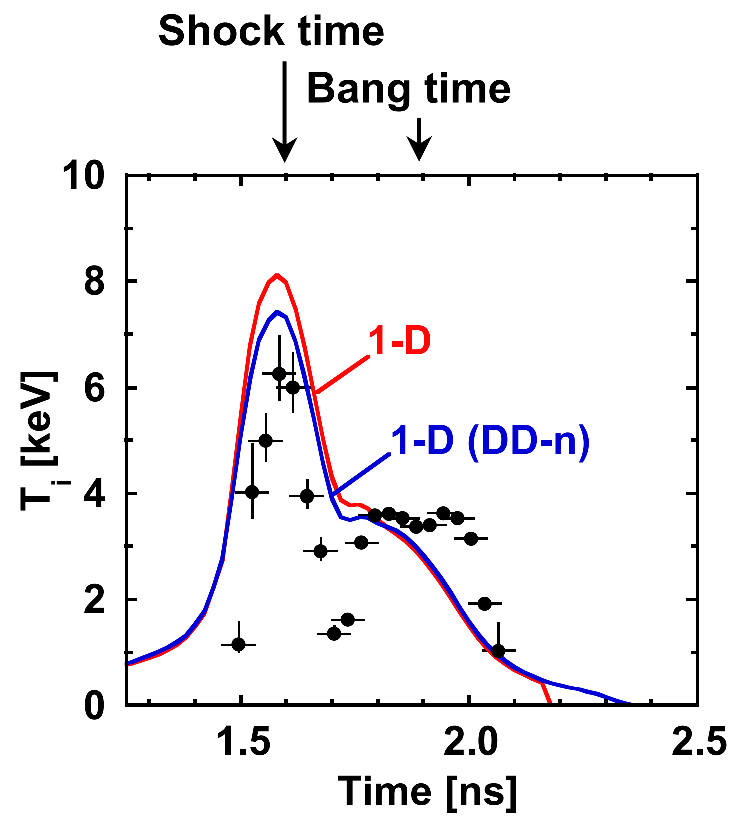
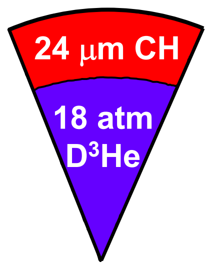
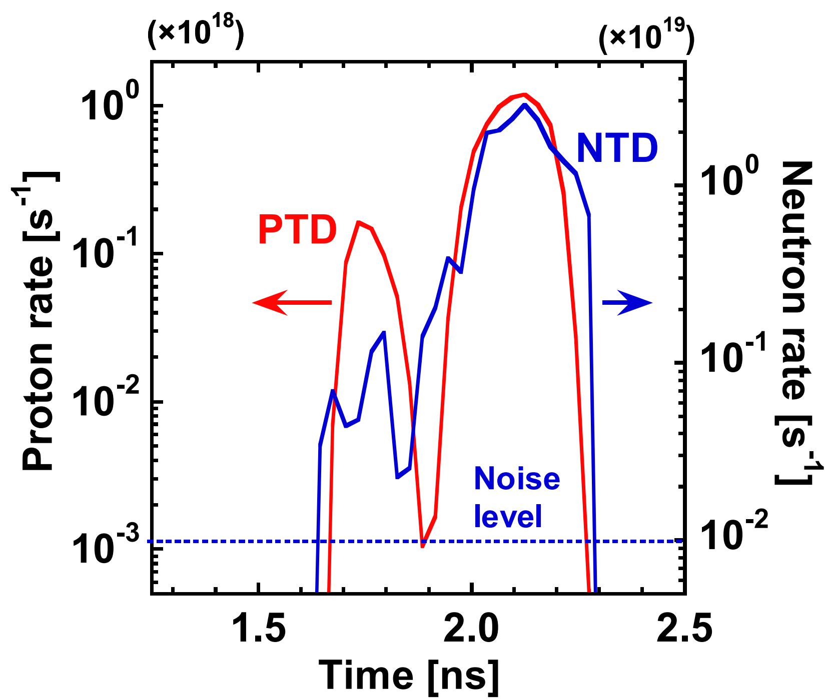


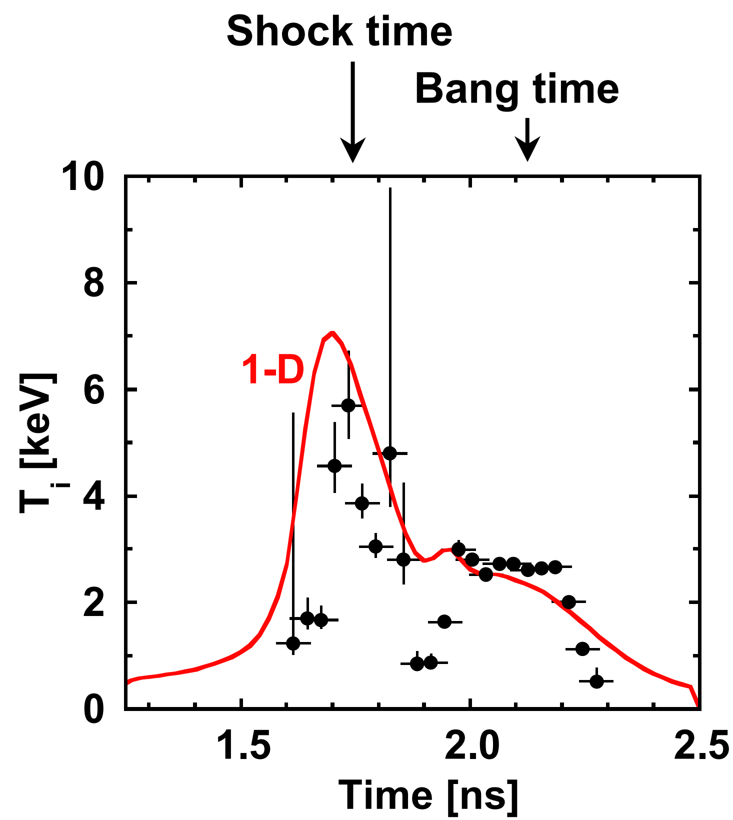




Evolution of T_i has been obtained and compared to 1-D calculations







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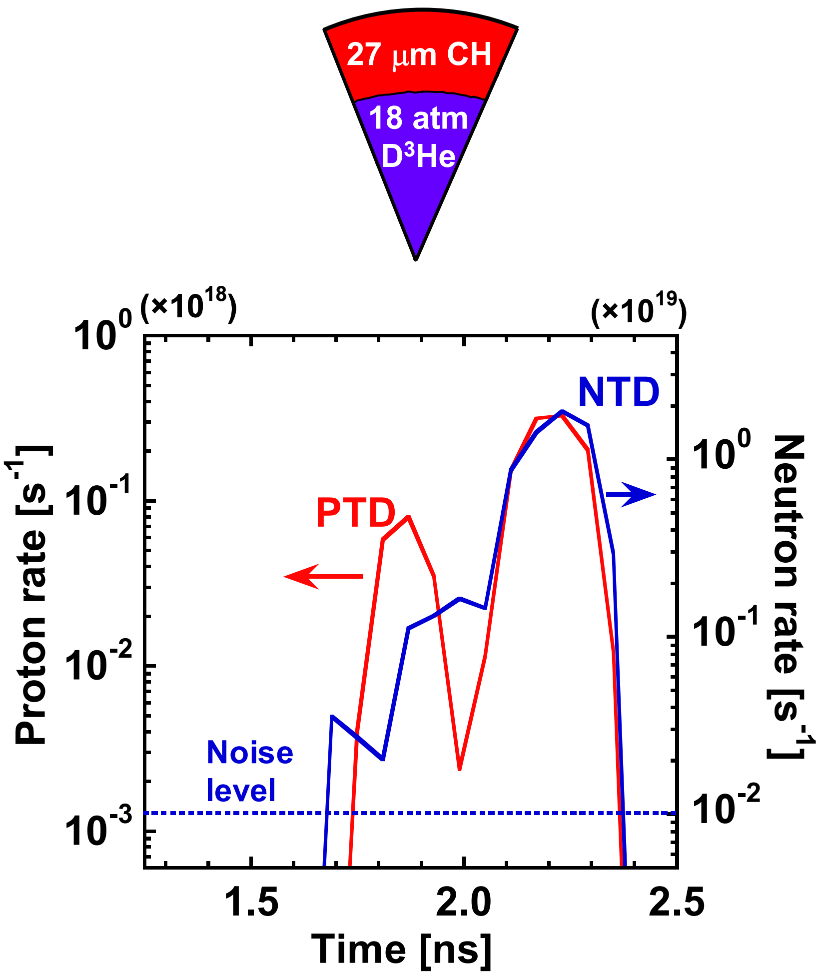
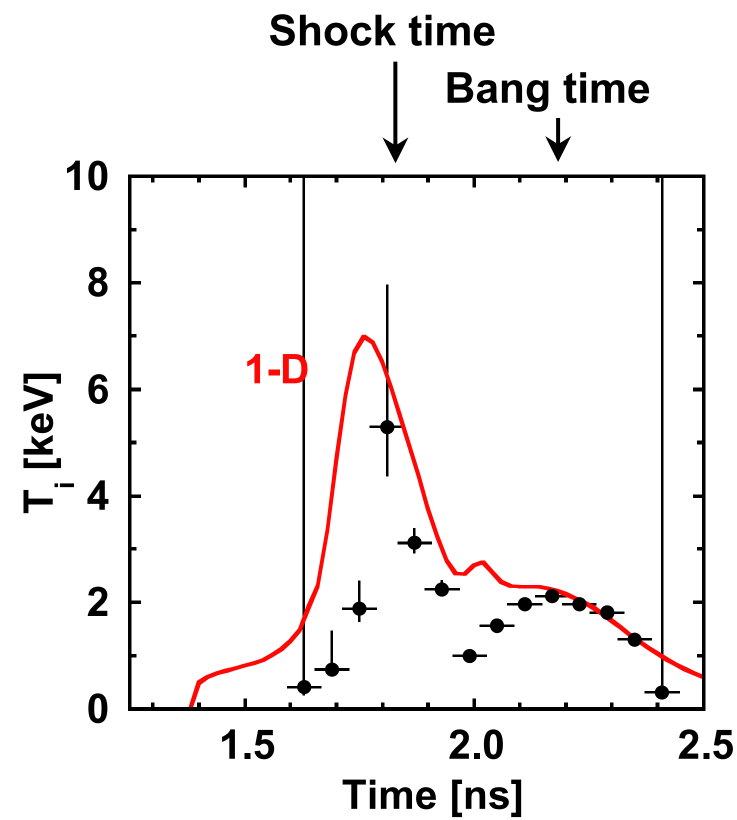
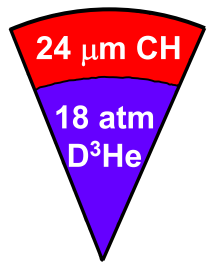
Evolution of T_i has been obtained and compared to 1-D calculations

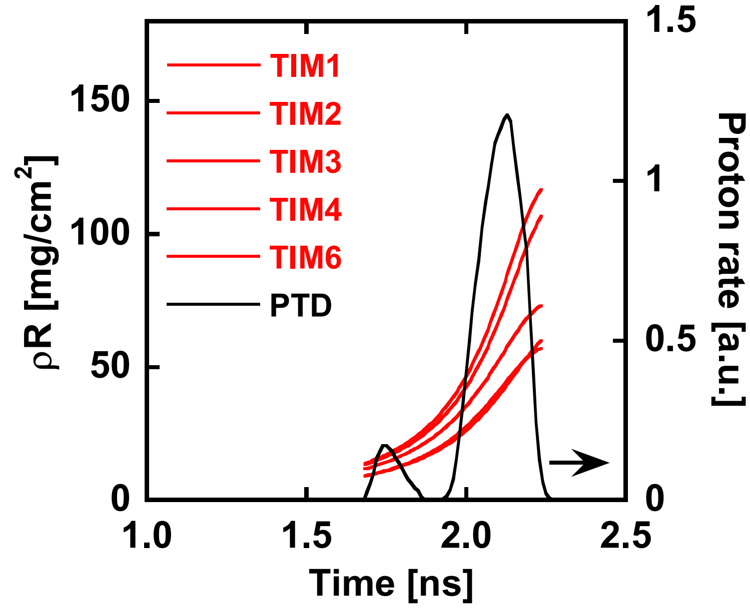




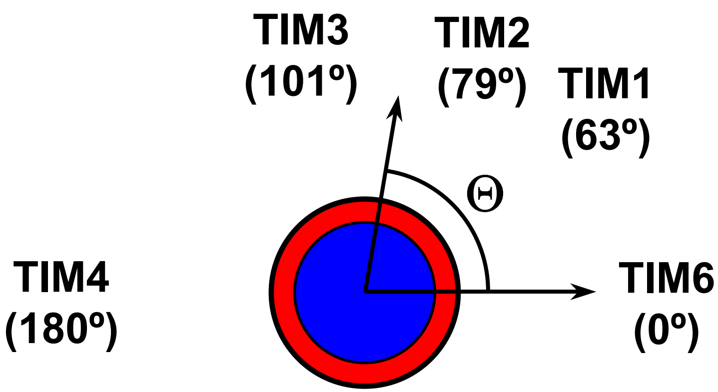
How do ρR and ρR asymmetries evolve in time?

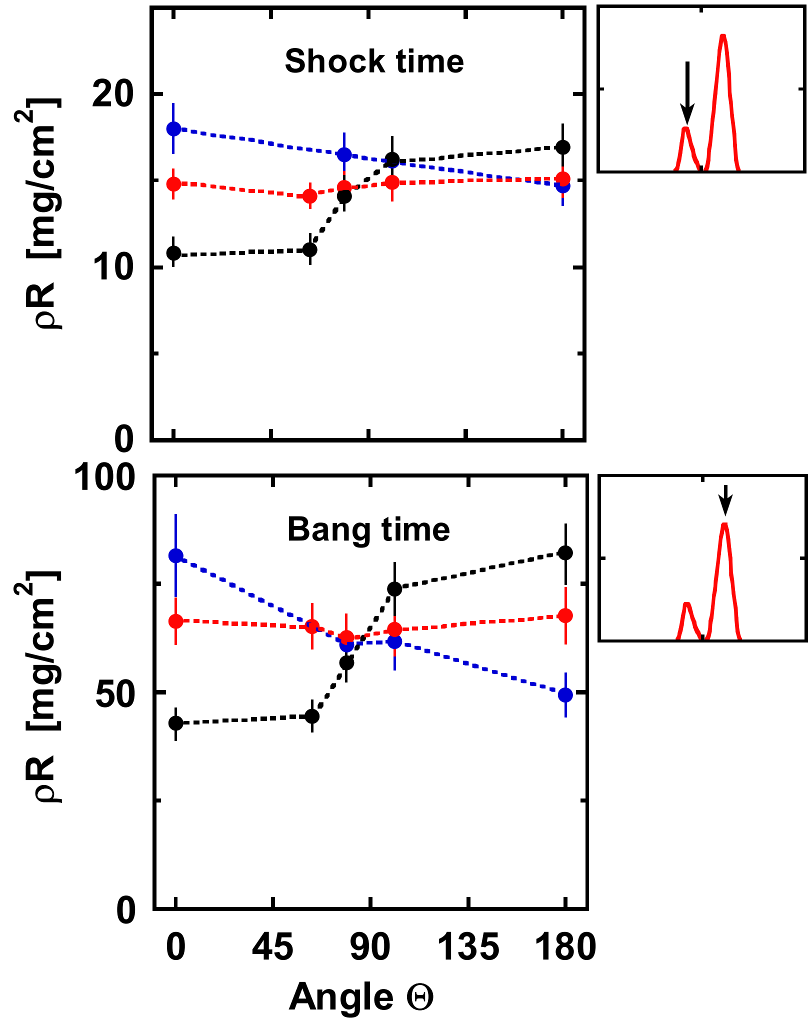


Nominally perfect implosion



Low-mode ρR asymmetry at shock time is amplified and mirrored at bang time





Low-mode ρR asymmetry is primarily driven by capsule convergence

ρR asymmetry growth $\xi(t)$ can be expressed as

$$\xi(t) = \frac{Cr(t) - 1}{Cr_s - 1}\frac{\langle \rho R(t) \rangle}{\langle \rho R \rangle_s}$$

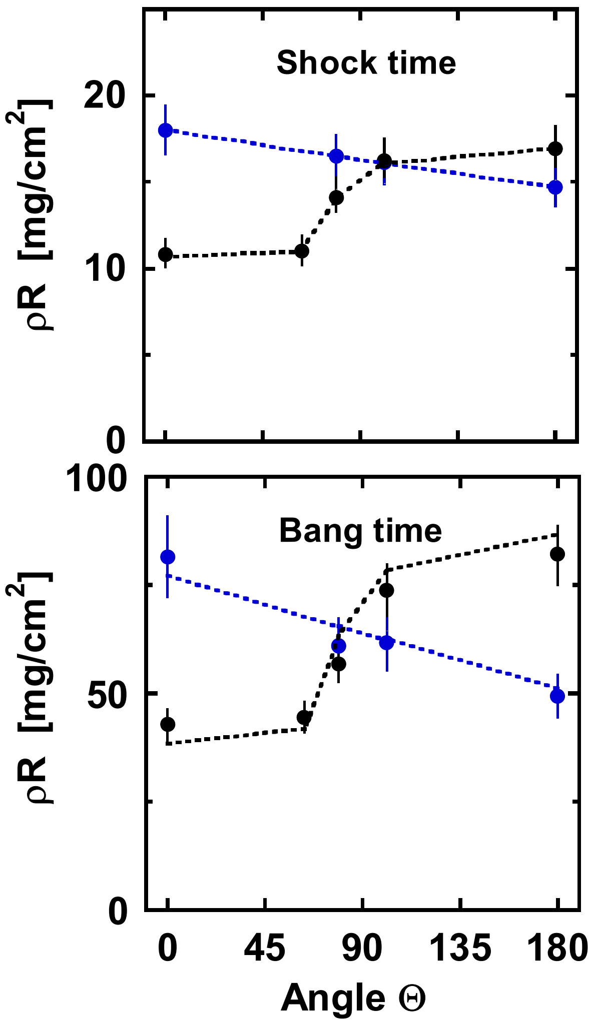
Convergence ratio Cr(t) is defined as

$$Cr(t) = \sqrt{\frac{\langle \rho R(t) \rangle}{f \rho_0 R_0}}$$

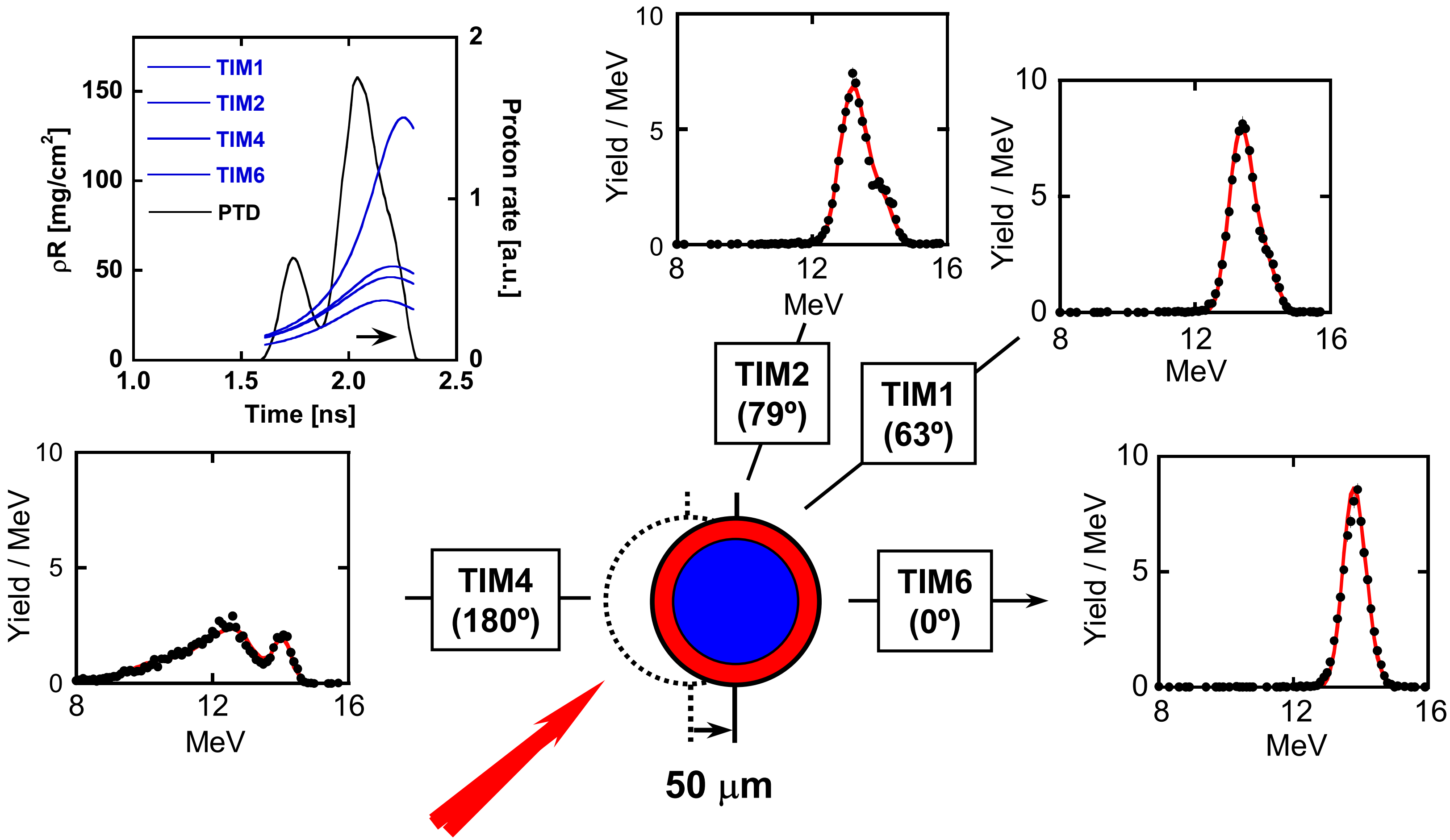
At shock time, $Cr_s \approx 5$

At bang time, $Cr_b \approx 10$

$$\xi(t) \sim 2\frac{\langle \rho R(t) \rangle}{\langle \rho R \rangle_s}$$



Is there a correlation between ρR asymmetry and laser drive asymmetry (for a large imposed ℓ = 1)?



Laser beams pointed at TCC

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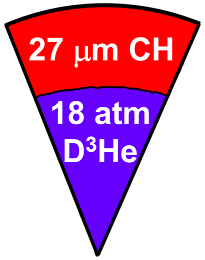
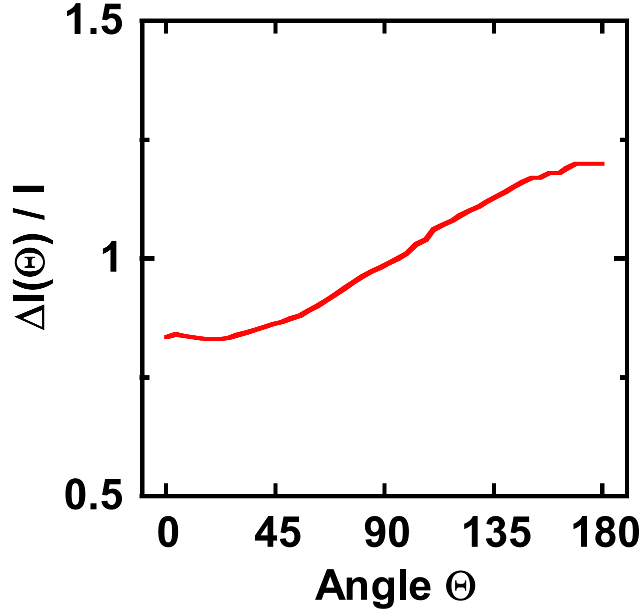
F.J. Marshall et al., CO2.005

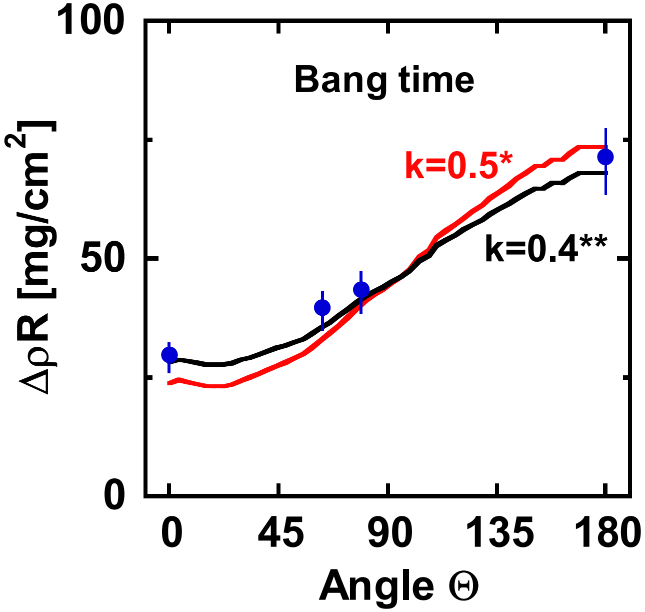
F. H. Séguin et al., CO2.011

ρR asymmetry is strongly correlated to laser drive asymmetry (for a large imposed ℓ = 1)



$$\frac{\Delta\rho R(t,\Theta)}{\langle\rho R(t)\rangle} = k[Cr(t) - 1]\frac{\Delta I(\Theta)}{\langle I\rangle}$$



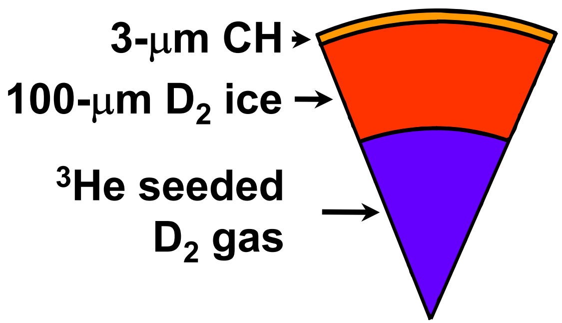


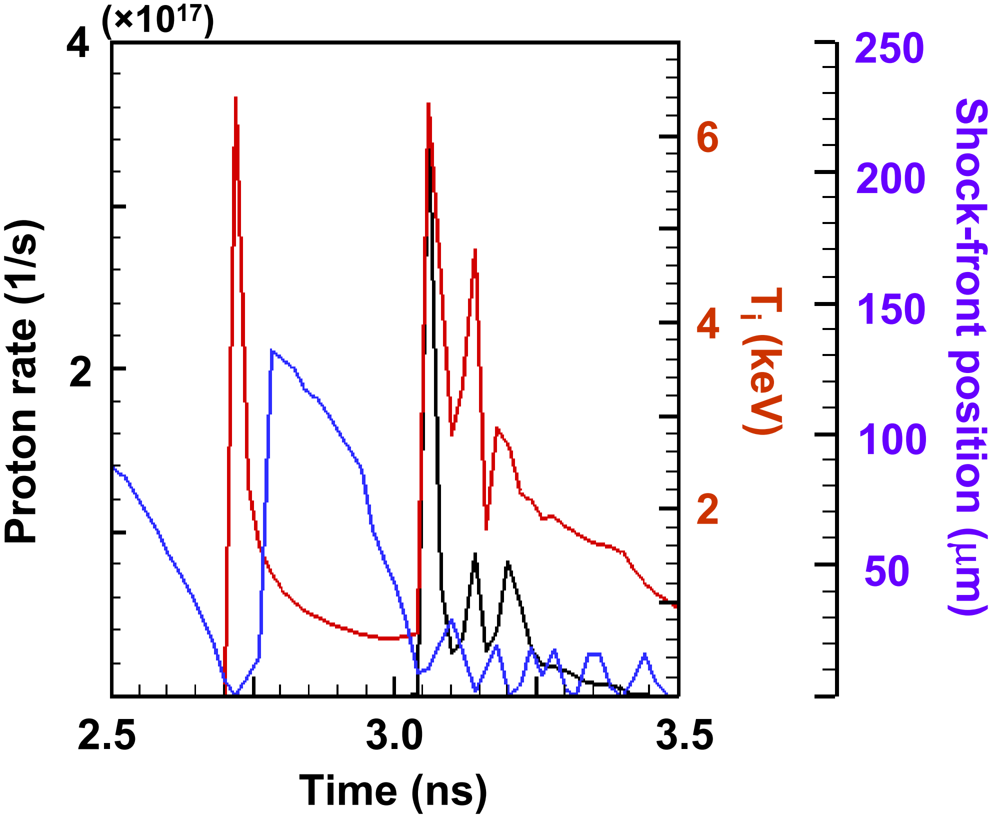
* C. K. Li et al., submitted to Phys. Rev. Letters.

** F. H. Séguin et al., CO2.011

We are looking into ^3He-seeded cryogenic D_2 implosions

α = 4 pulse





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