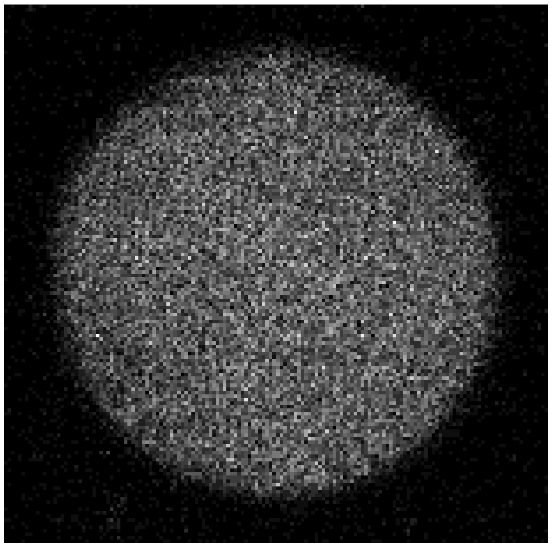
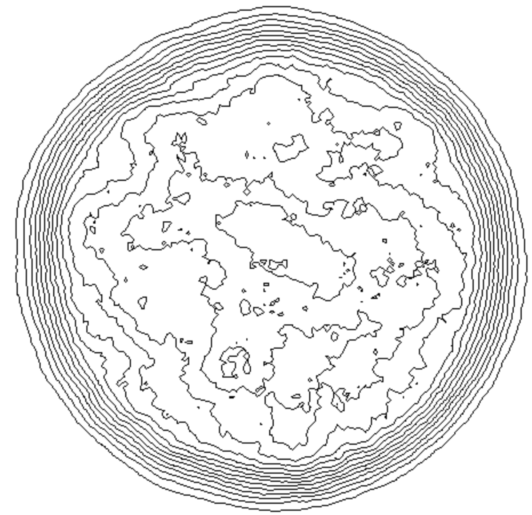
Proton Core Imaging Spectroscopy on OMEGA Implosions





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Abstract

Multiple pinhole cameras are being used to image the burn regions in implosions of both thin (~2 μm-glass) and thick (~20 μm-CH) shell capsules on OMEGA. Because the pinholes are generally much larger than the burn region, information about the proton source (i.e. size, shape, and symmetry) can be extracted from the "penumbra" of the resulting images. Capsules with D^3He and DD fills have been studied with Proton Core Imaging Spectroscopy (PCIS). For thin-shell capsules, experimental differences in the burn regions between DD and D^3He reactions will be explored, contrasted, and compared to 1-D calculations. Particularly intriguing is the situation for thick shell implosions. At first shock coalescence, the escaping charged particles sample a relatively small ρR. At bang time (a few hundred ps after shock coalescence), however, only the energetic 14.7-MeV protons escape, since they sample a much larger ρR (~70 mg/cm^2). Comparisons of the shock and compression burn regions will be made.

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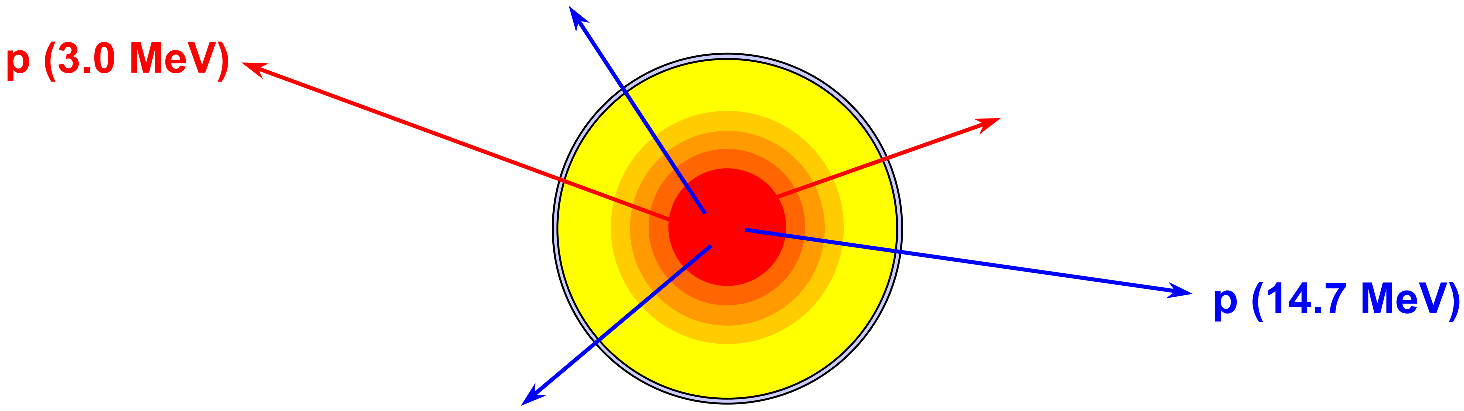
Outline

- Proton core imaging spectroscopy (PCIS) gives information about radial burn profiles of DD and D^3He reactions.
- PCIS provides radial burn profiles of DD and D^3He protons from D^3He implosions of thin and thick shell capsules at shock and bang time.
- For thin (~2μm) shell capsules, a temperature profile is inferred by comparing burn profiles of DD protons (3 MeV) and D^3He protons (14.7 MeV).
- For thick (~20μm) shell capsules, compare DD proton burn profile at shock time with D^3He burn profile at bang time.

PCIS simultaneously images protons from DD and D^3He reactions

$$D + D \rightarrow T[1.01\ MeV] + p[3.02\ MeV]$$

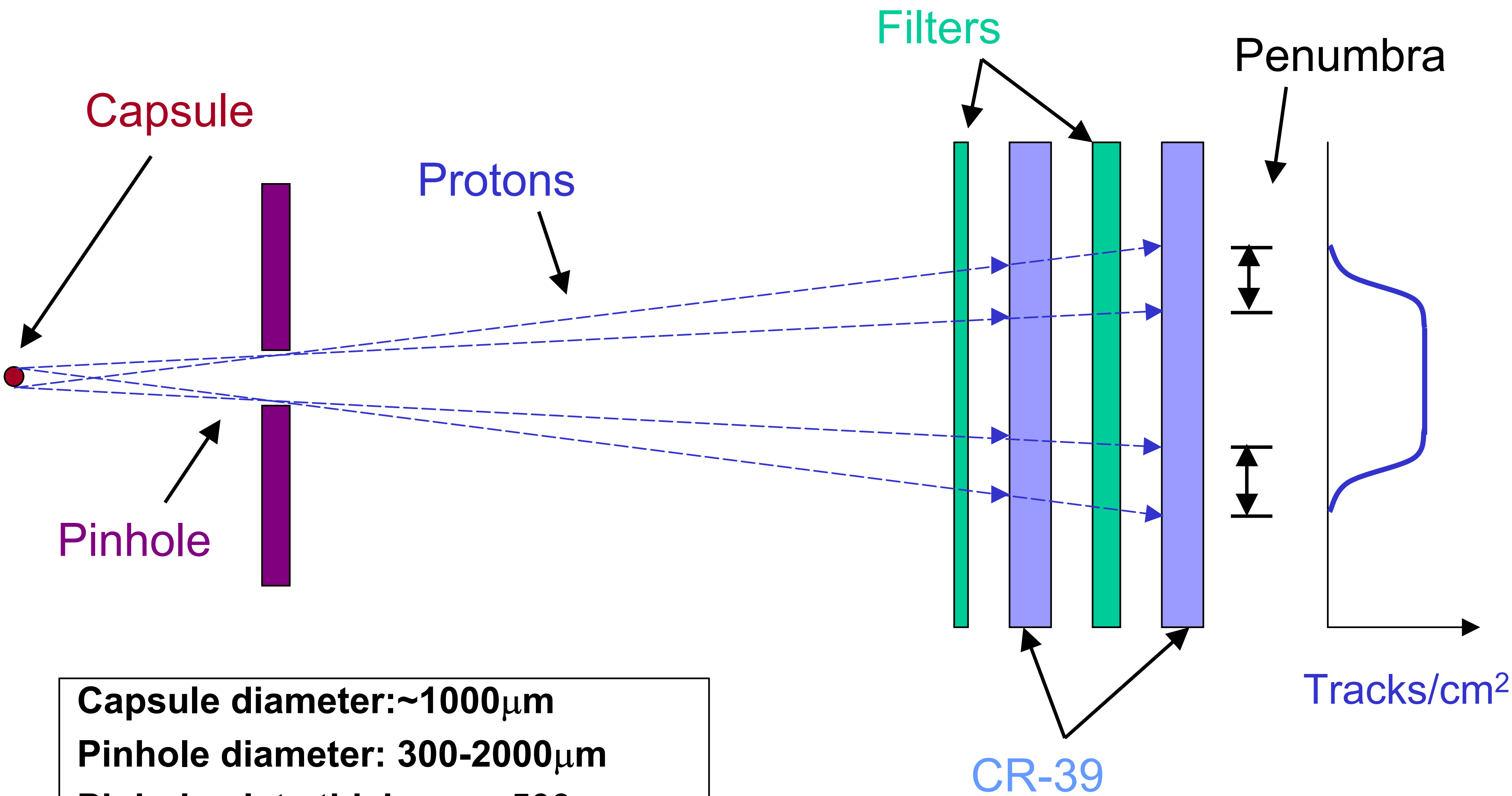
$$D + {}^3He \rightarrow \alpha[3.6\ MeV] + p[14.7\ MeV]$$



Bang time

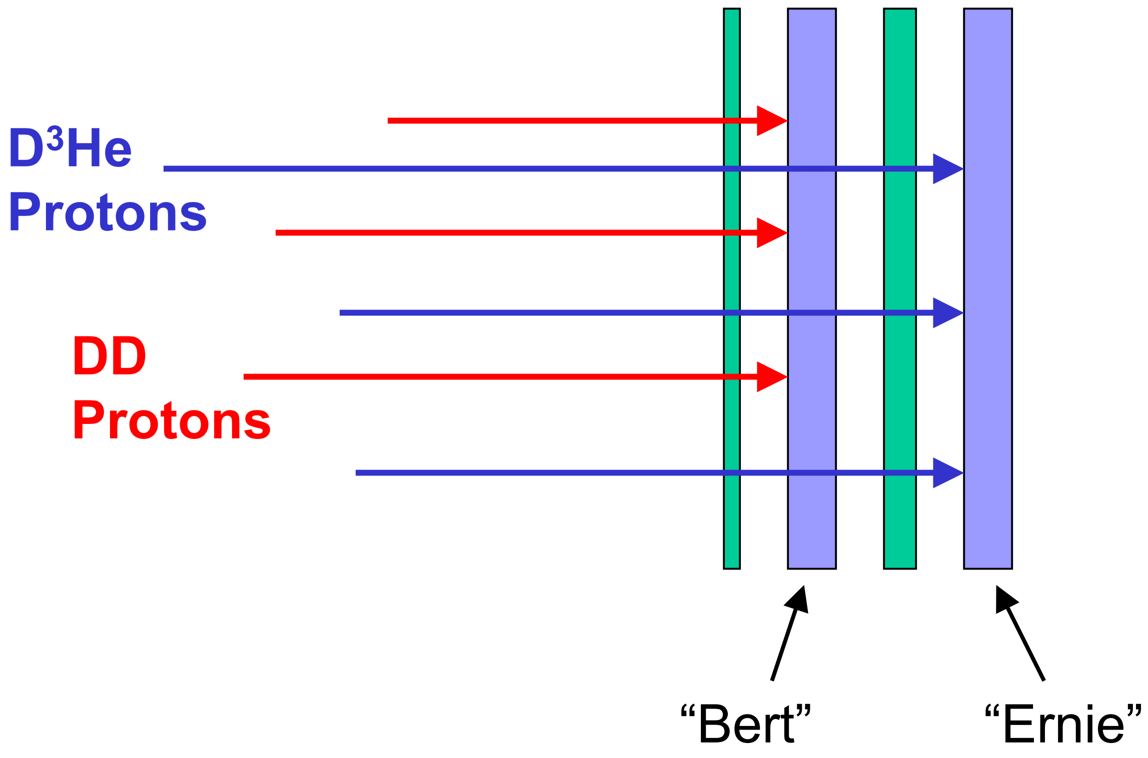
<u>D^3He(18 atm) SiO_2[2 μm]</u>

PCIS images proton emissions on to CR-39 plastic



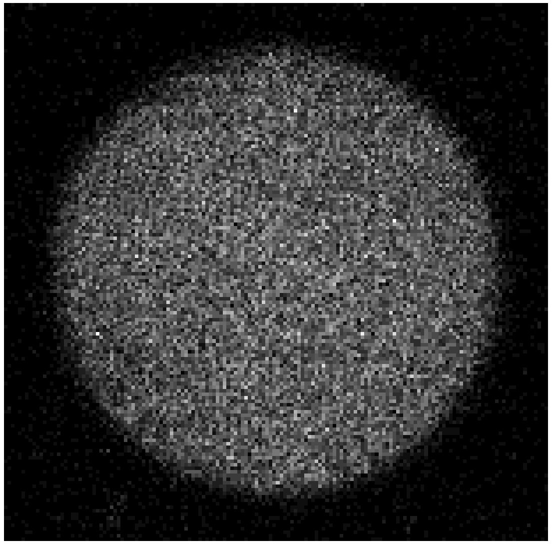
Capsule diameter:~1000μm
Pinhole diameter: 300-2000μm
Pinhole plate thickness: 500μm
Target to Pinhole distance: 3-33cm
Pinhole to CR-39 distance: 33cm

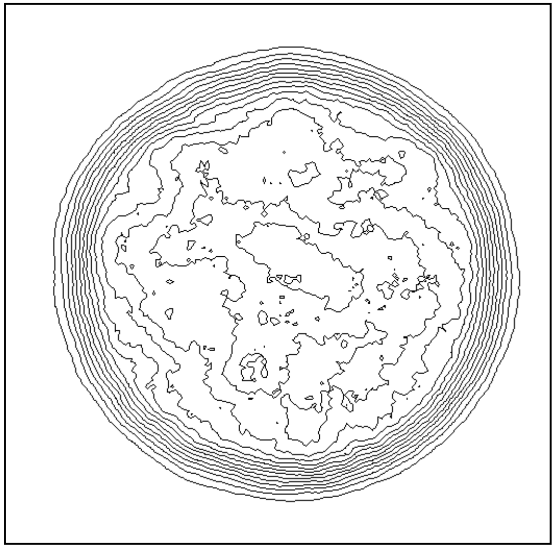
Filters are placed in front of the CR-39 to adjust which particles will be detected



Filter thickness is set so that "Bert" is sensitive to DD protons and "Ernie" is sensitive to D^3He protons

The penumbra of the image contains information about the burn profile

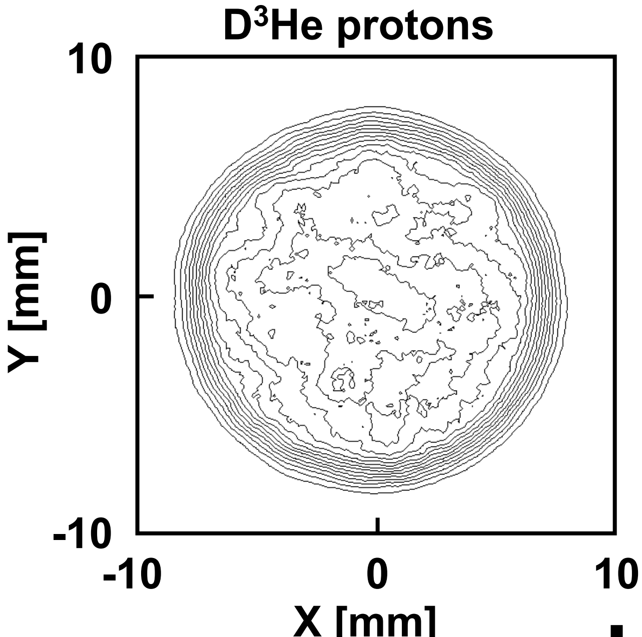




D^3He Proton tracks / cm^2
in the plane of the CR-39

(Shot 25599: D_2(6) ^3He(12) CH[20])

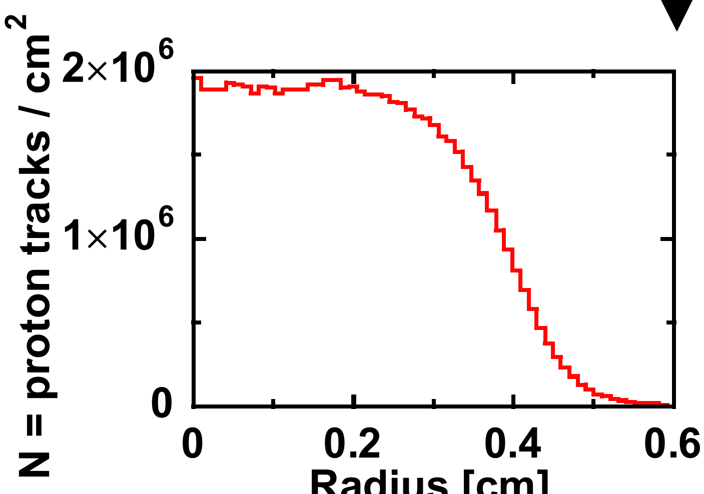
Finding the radial burn profile (part 1)



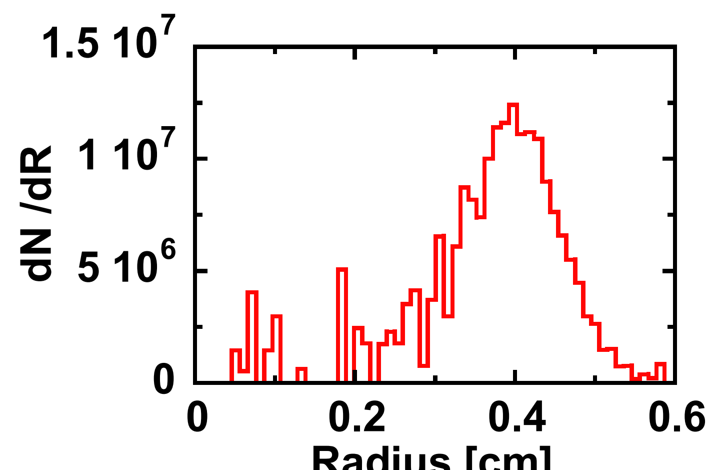
Step 1: Calculate the number of proton tracks per unit area N as a function of radius in the image plane.

Step 2: Calculate dN/dr.

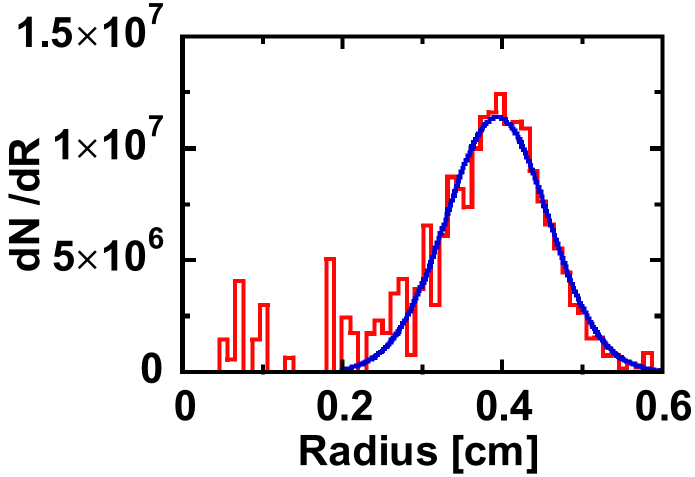
Step 1



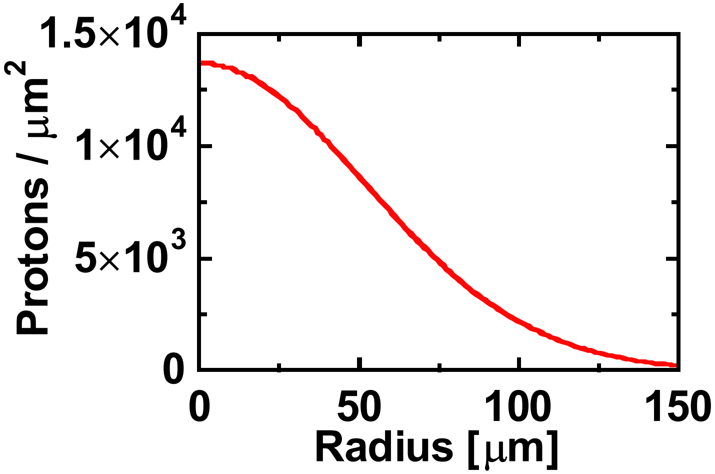
Step 2



Finding the radial burn profile (part 2)

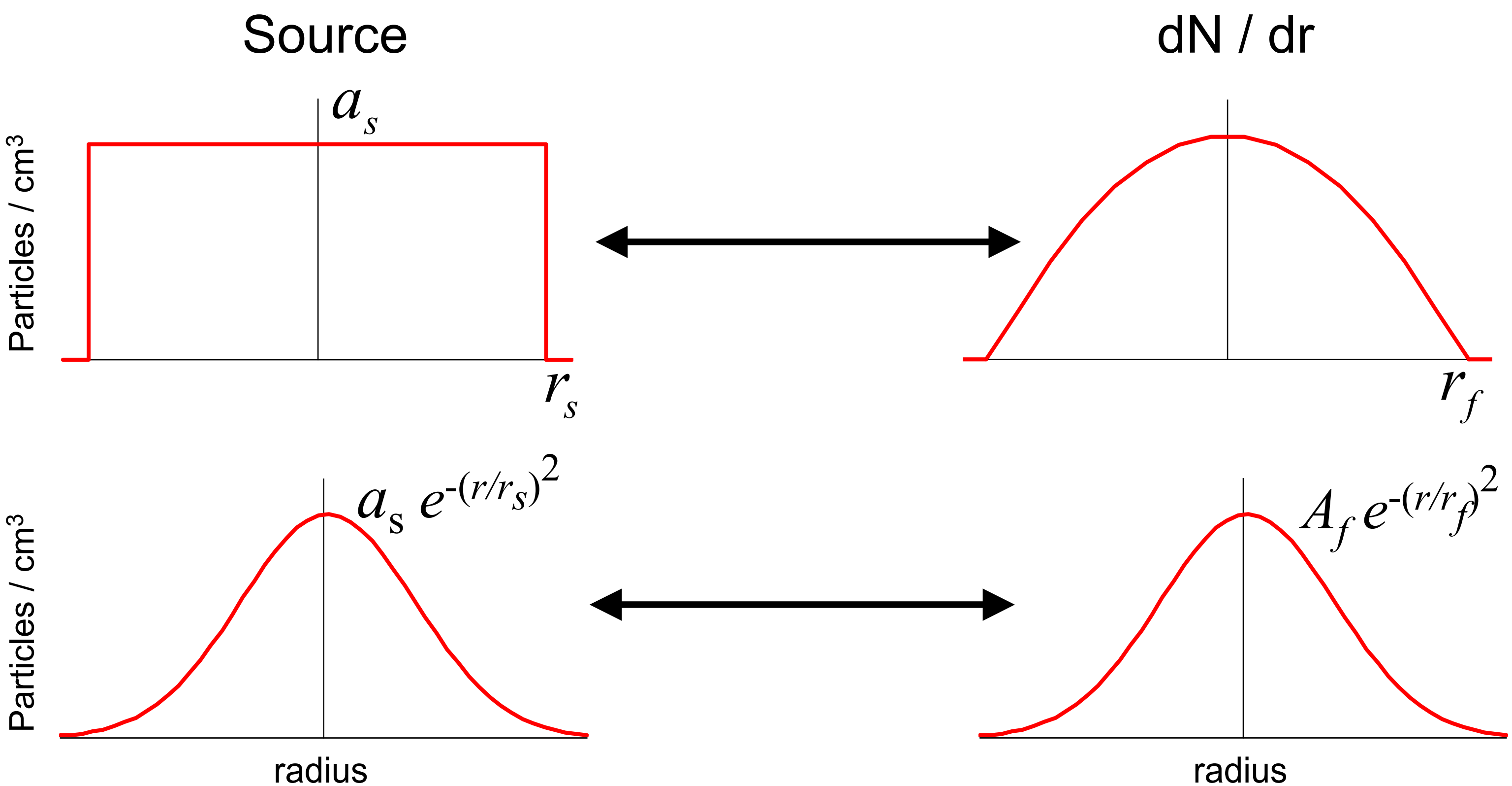


Step 3



Step 3: Use analytic inversion formula with system geometry to get radial profile of the proton emissivity in the capsule. (In this case, dN/dR is fit by a gaussian.)

Analytic inversions for two simple source functions*



$R_d \equiv$ target-CR39 dist.

$R_p \equiv$ target-pinhole dist.

$M \equiv R_d/R_p$ = magnification

$$r_s = \frac{r_f}{M}\,, \qquad a_s = 4M^3\left(\frac{R_d}{r_f}\right)^2 A_f$$

*Exact only in the limit where pinhole diameter >> source diameter, but with very little error (< 5%) for the finite pinholes used here.

Comparison between burn profiles from uniform and gaussian source functions

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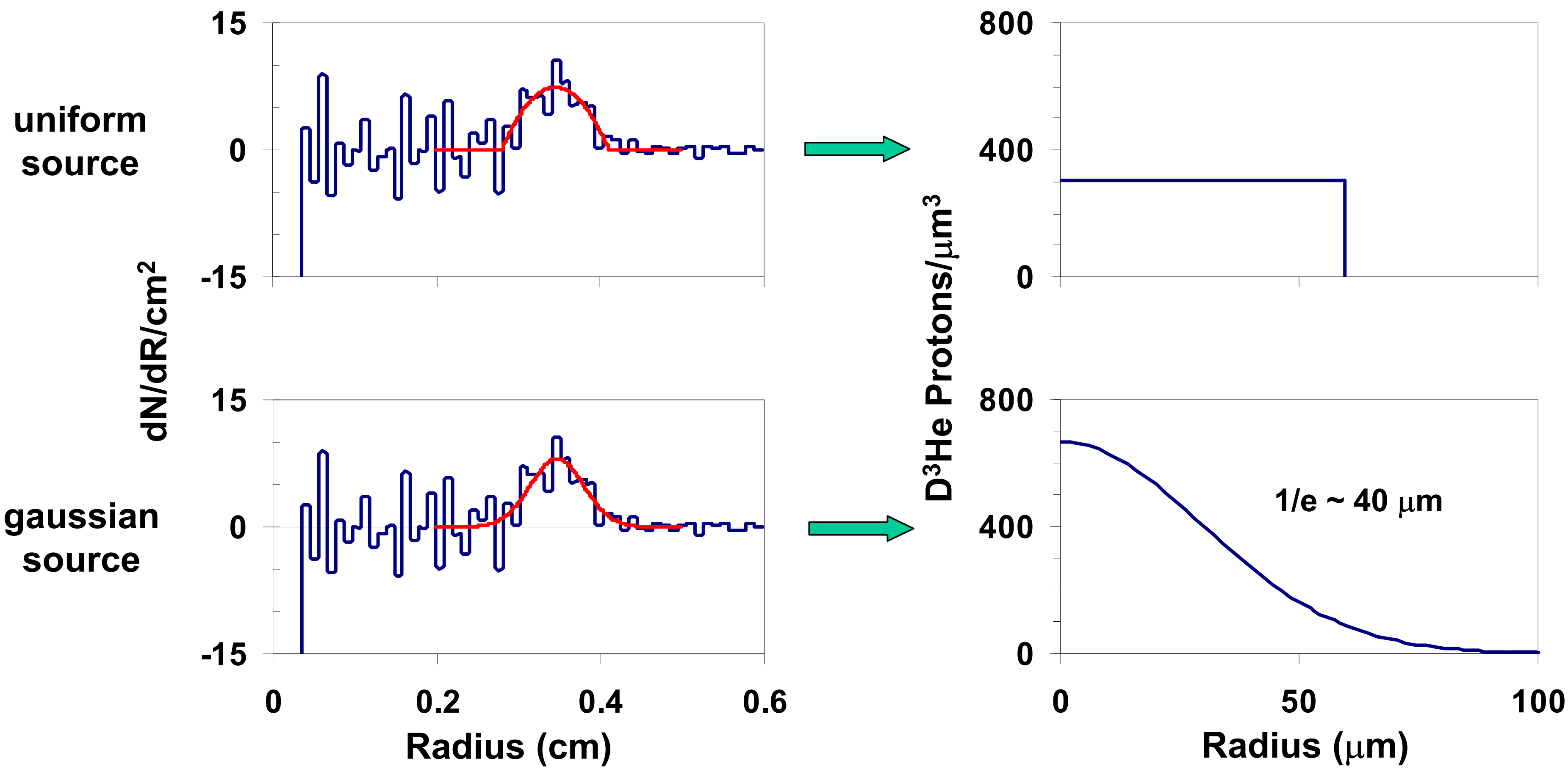
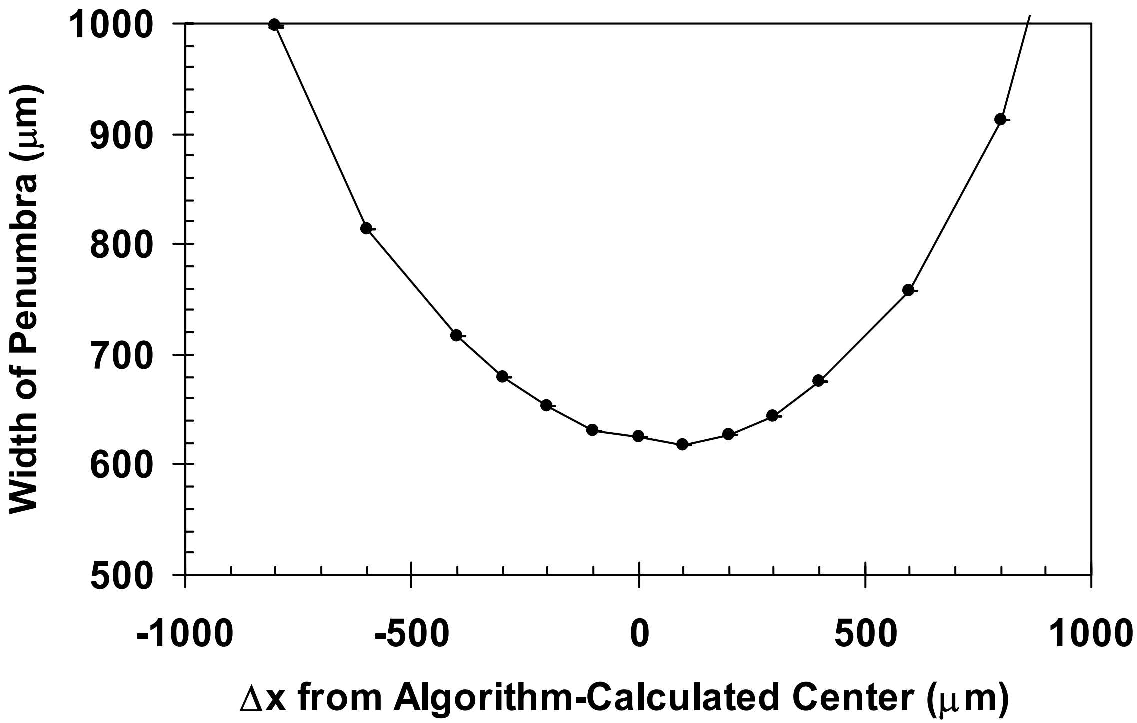
Shot 27808: D_2(6) ^{3}He(12) CH[20]



Test of pinhole center-finding algorithm

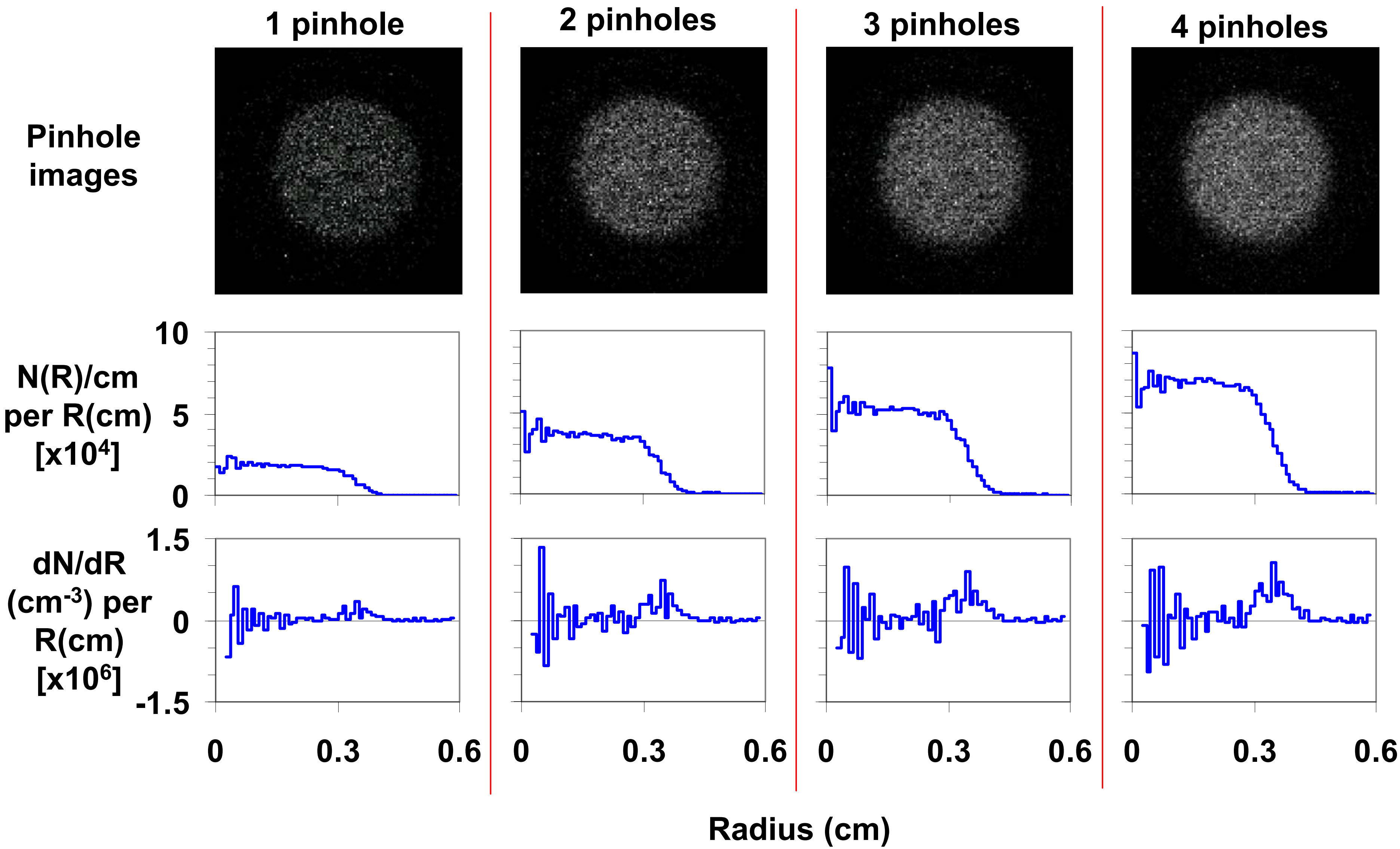
Shot 26081: D_2(6) ^{3}He(12) SiO_2[1.9]



Width calculated by default = 624.6 μm
Minimum width = 616.2 μm
(found with center displaced by dx = 100 μm, dy = -10 μm)

Error in the default values ~ 1.4%.

Summing pinhole images (shot 27808)

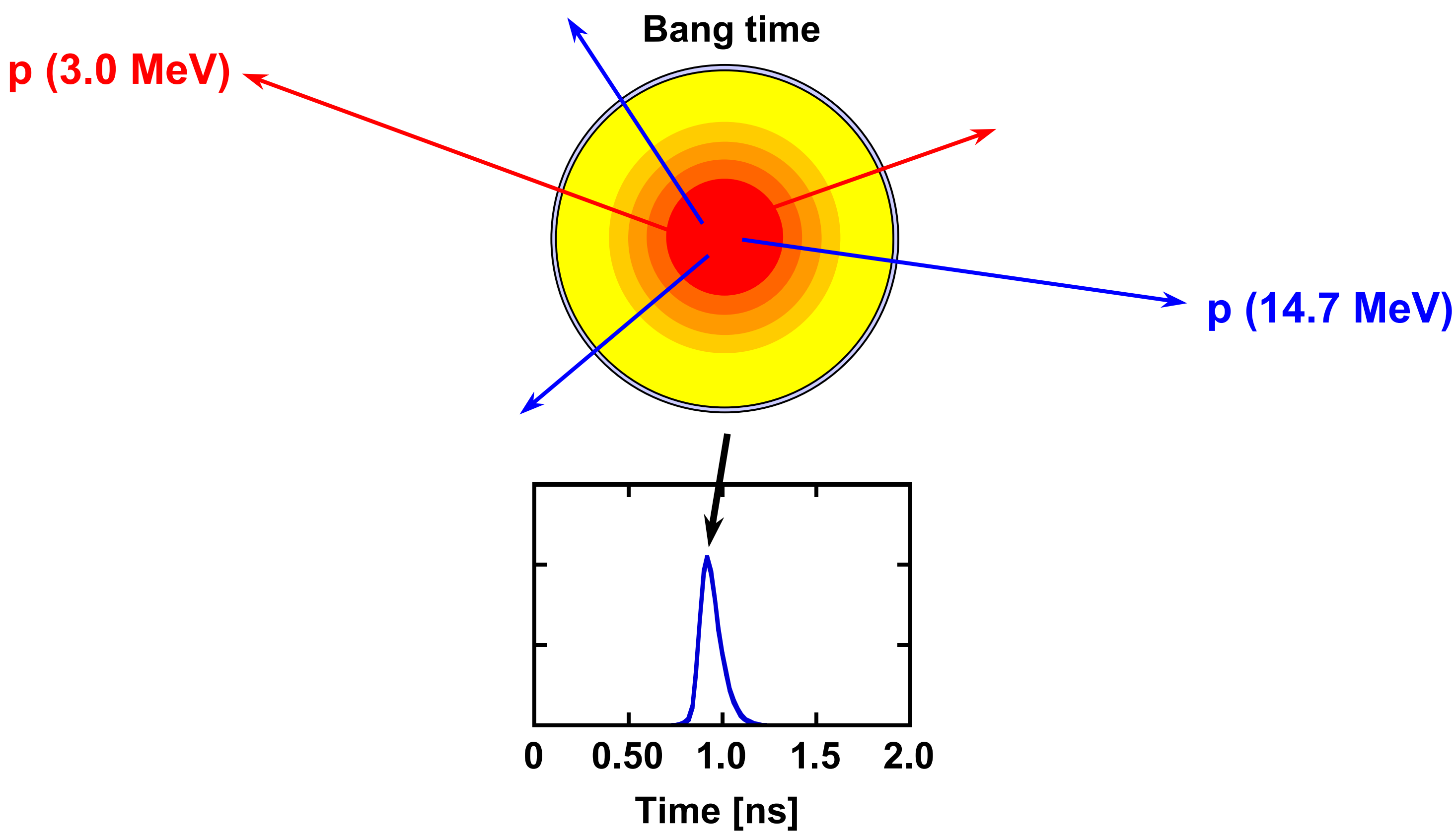


DD and D^{3}He protons are imaged for implosions of thin glass shell capsules at bang time

$$D + D \rightarrow T[1.01\ MeV] + p[3.02\ MeV]$$

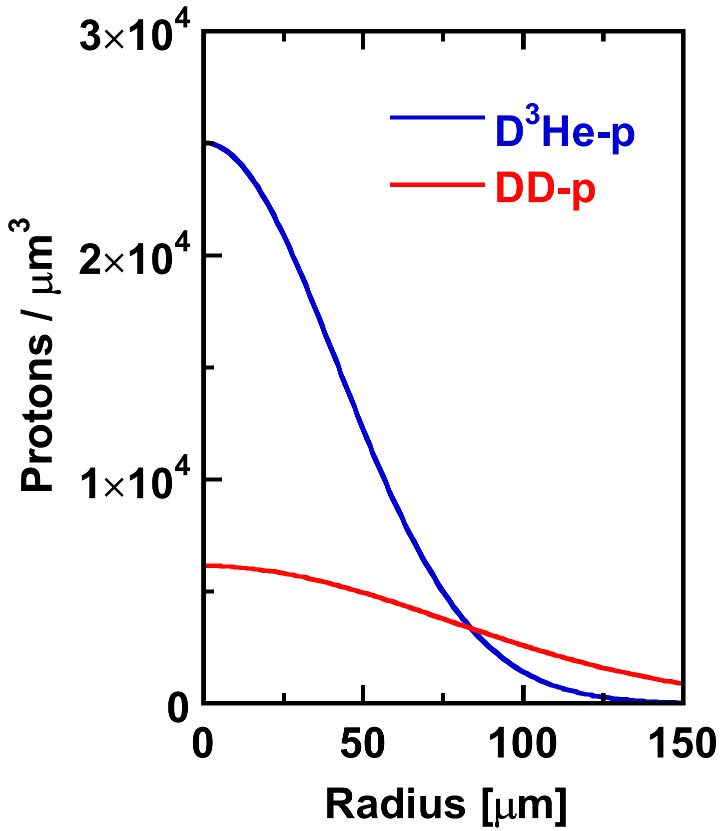
$$D + {}^3He \rightarrow \alpha[3.6\ MeV] + p[14.7\ MeV]$$

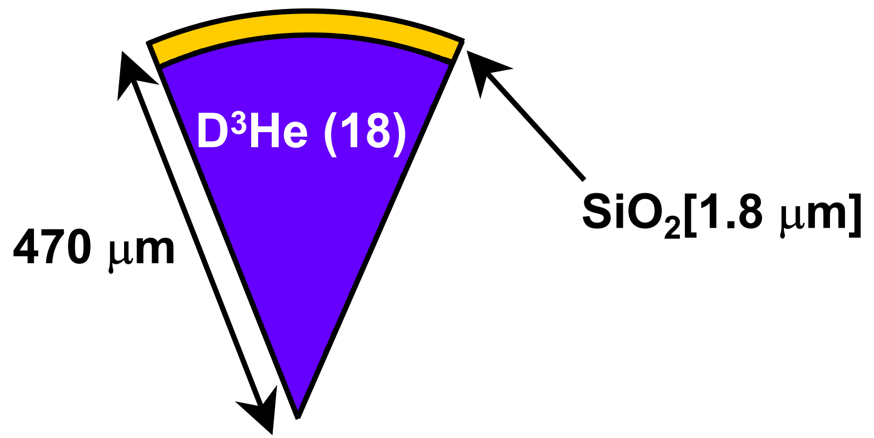
D^{3}He(18 atm) SiO_2[2 μm]



Burn profiles of DD and D^3He protons from a thin (1.8μm) glass shell D^3He implosion

Shot 27456: D_2(6) ^3He(12) SiO_2[1.8]

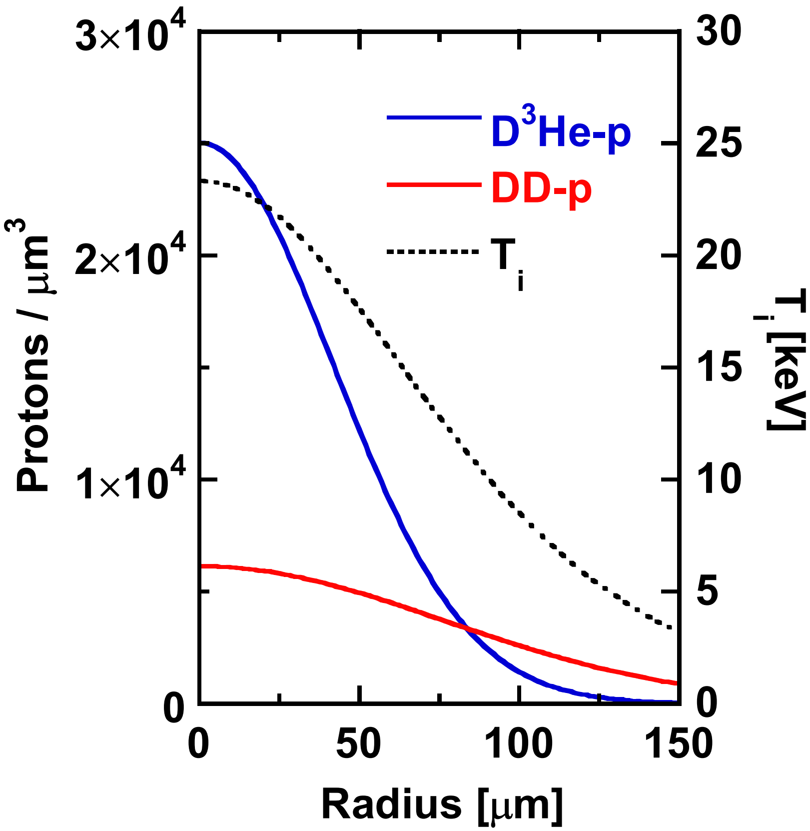


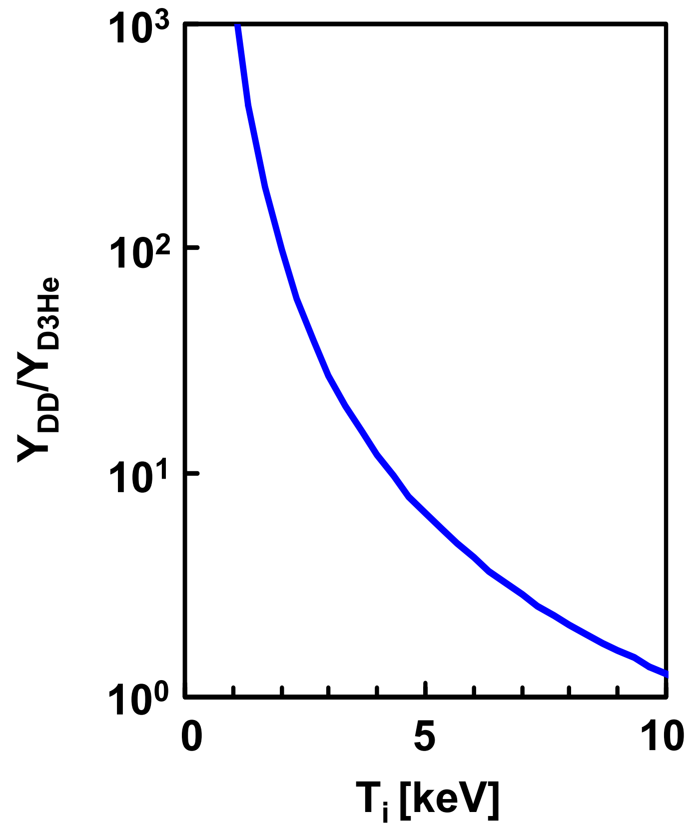


The 1/e points are at radii 60 and 110 μm

Temperature $T_i(r)$ can be inferred from the DD and D^3He proton burn profiles

Shot 27456: $D_2(6)$ $^3He(12)$ $SiO_2[1.8]$





Yield averaged temperatures compared to results from other diagnostics

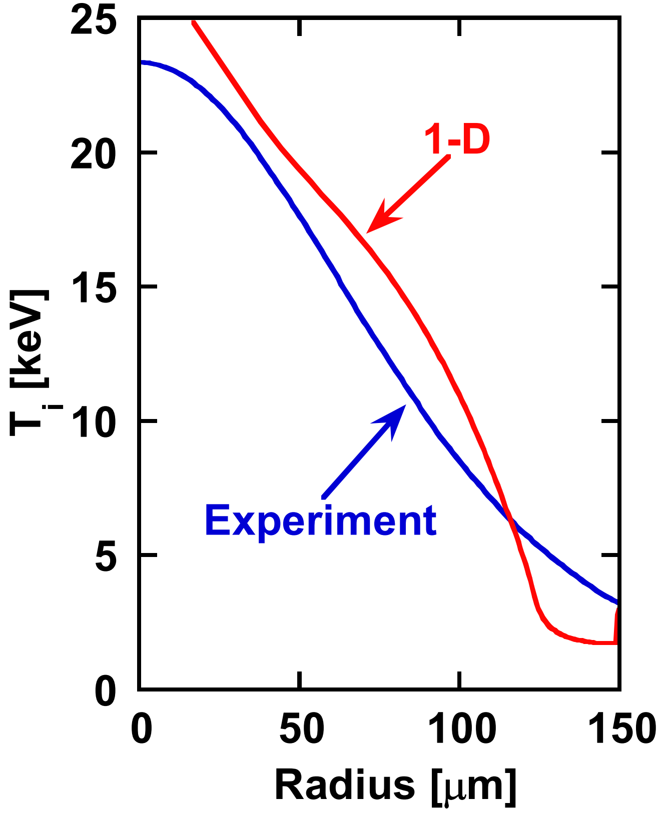
Shot 27456: D_2(6) ^{3}He(12) SiO_2[1.8]

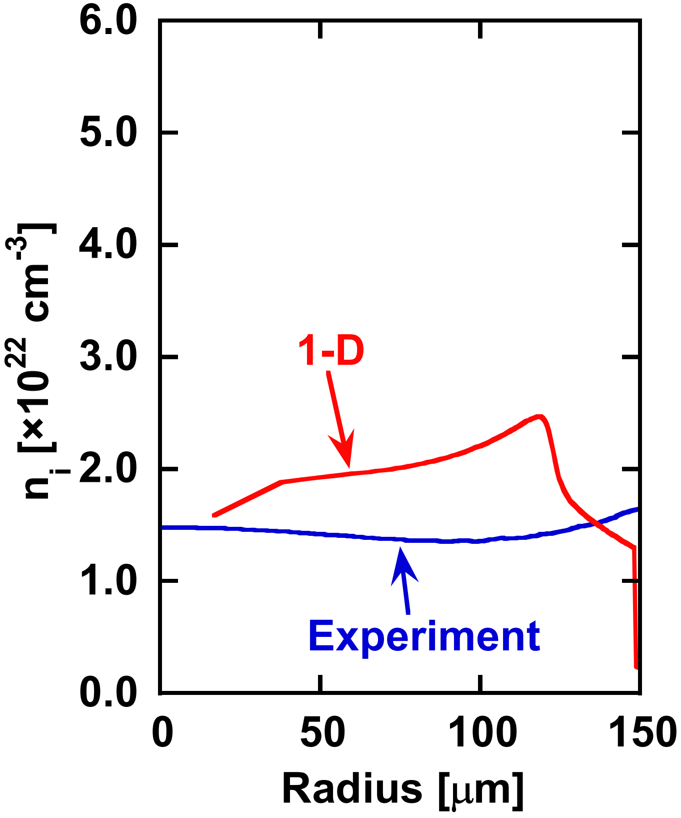
Diag.	Y_{D3He} [$\times 10^{10}$]	Y_{DD} [$\times 10^{10}$]	$\langle T_i \rangle_{D3He}$ [keV]	$\langle T_i \rangle_{DD}$ [keV]
PCIS	1.3	4.2	~ 15	~ 8
WRF	1.2	-	14	-
nTOF	-	5.0	-	~ 10

$\langle T_i \rangle$ ~ 6-7 keV
from the ratio of the total yields
Y_{DD}/Y_{D3He} determined from PCIS

Results from a thin shell capsule implosion are compared to 1-D simulations

Shot 27456: D_2(6) ^3He(12) SiO_2[1.8]





DD and D^{3}He protons from thick shell implosions are imaged at shock and bang time, respectively

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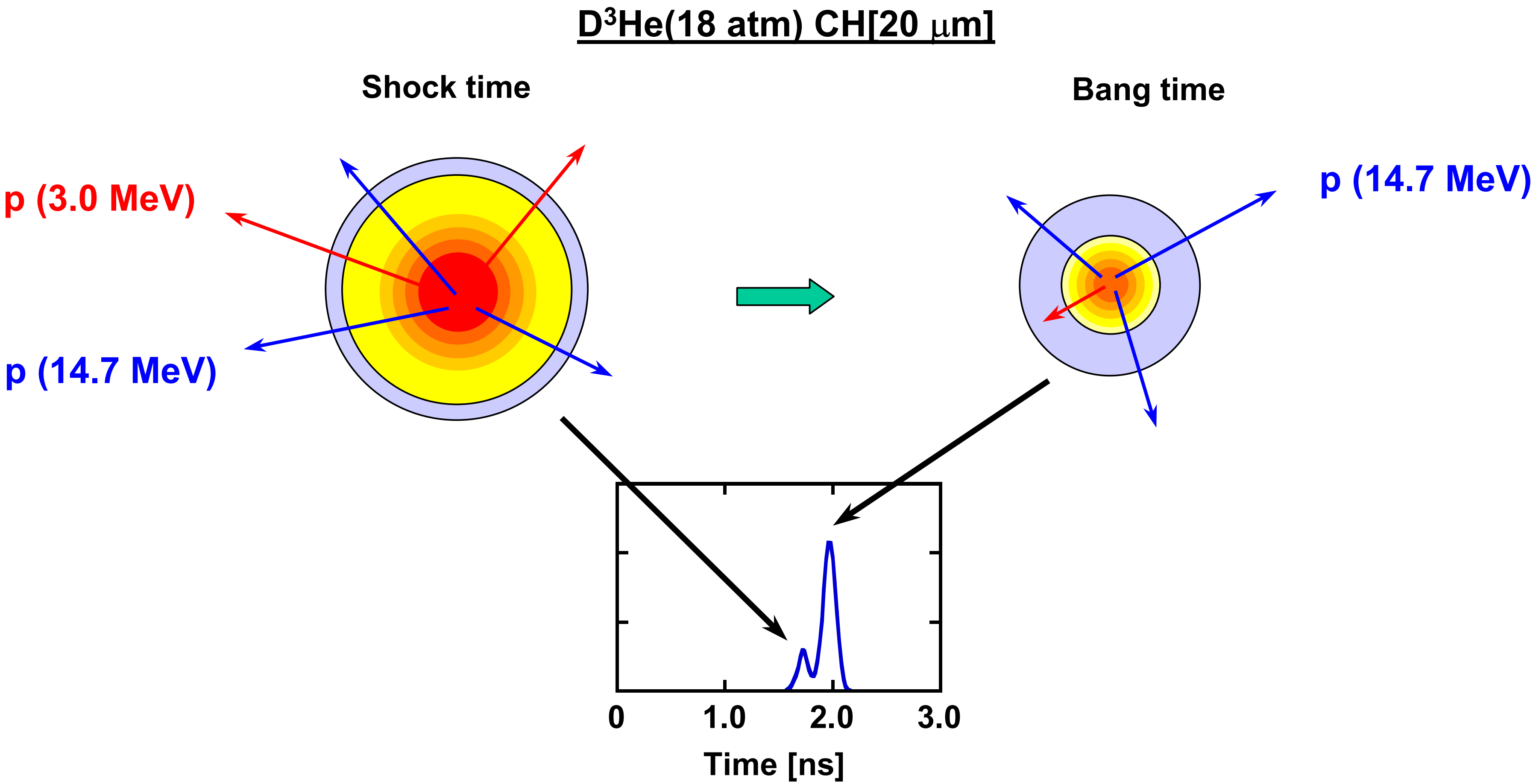
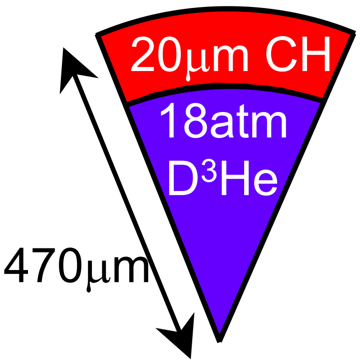
$$D + D \rightarrow T[1.01\ MeV] + p[3.02\ MeV]$$

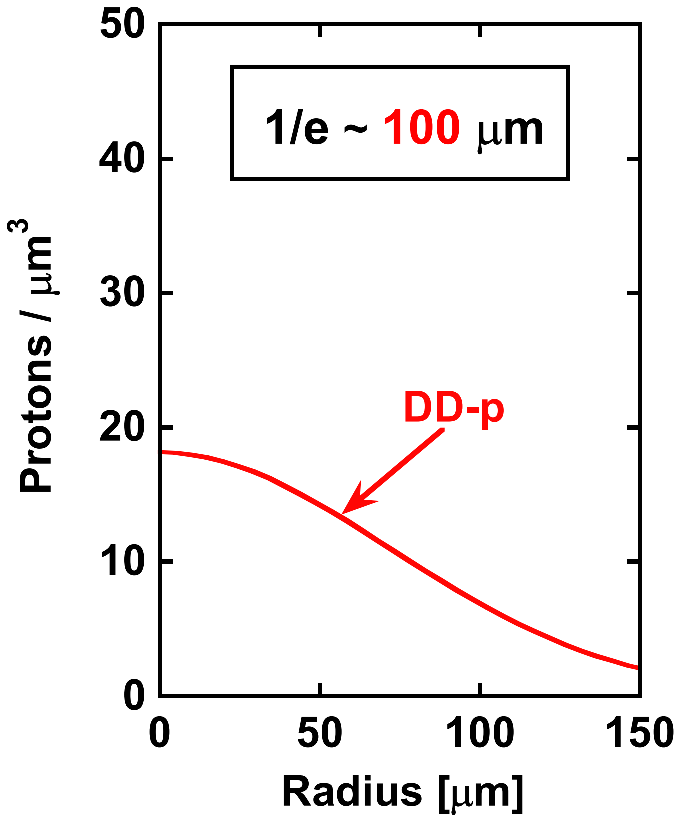
$$D + {}^3He \rightarrow \alpha[3.6\ MeV] + p[14.7\ MeV]$$



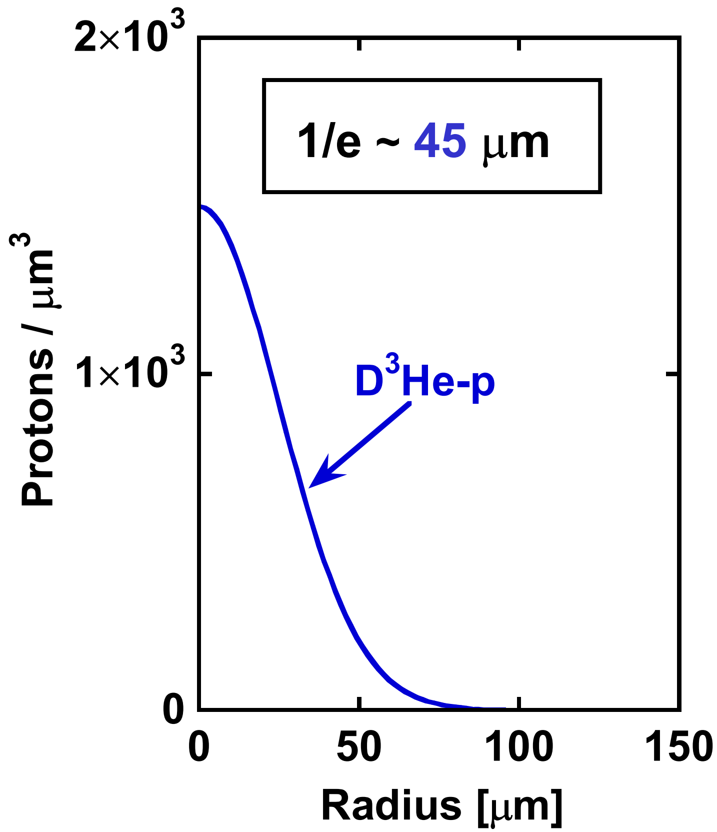
Burn profiles of DD and D^{3}He protons from a thick (20μm) CH-shell D^{3}He implosion



Shot 27806: D_2(6) ^{3}He(12) CH[20]

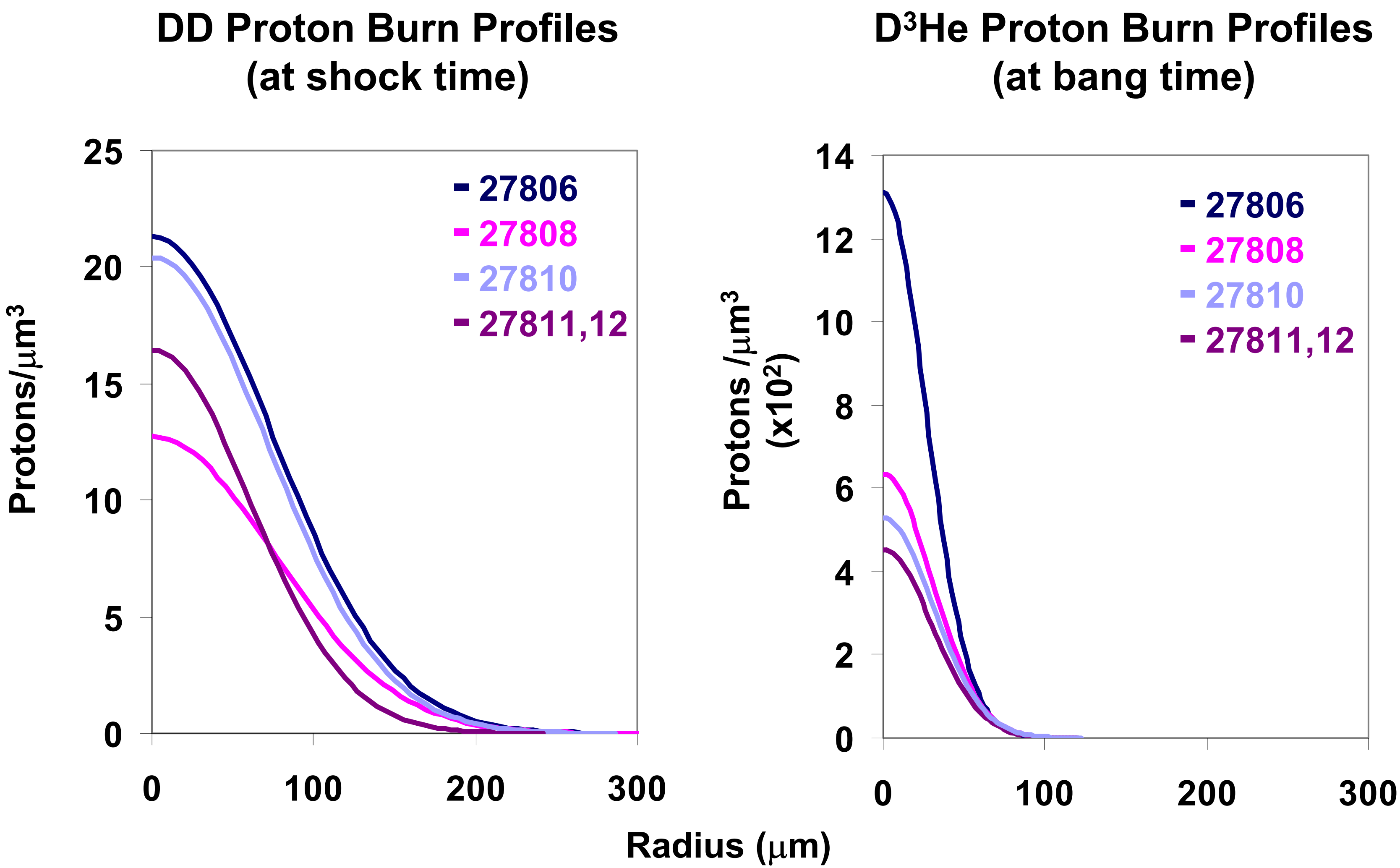


at shock time



at bang time

Burn profiles of DD and D^3He protons from several thick shell capsule implosions



Yield comparison of all thick shell profiles

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	Bert		Ernie		
Shot #	Y_{DD} PCIS ($\times 10^8$)	1/e point	Y_{D3He} PCIS ($\times 10^8$)	Y_{D3He} WRF ($\times 10^8$)	1/e point
27806	1.3	100	3.7	3.7	45
27808	0.9	110	2.7	2.2	40
27810	1.2	110	2.4	1.8	45
27811,12*	1.2	80	1.9	1.9	40

*PCIS summed over two shots.
Yields for this data are normalized.

Summary

- With Proton Core Imaging Spectroscopy (PCIS), the first burn profiles of DD and D^3He reactions have been obtained of thin- and thick-shell implosions

- $T_i(r)$ and $n_i(r)$ profiles have been inferred for thin-shell implosions and compared to 1-D simulations

- Burn profiles of DD and D^3He reactions at shock coalescence and at bang time have been measured for thick shell implosions.

Future Work

- Optimize PCIS instrumentation.
- Begin to build up a data base of images, and establish the range of PCIS applicability.
- Compare PCIS to x-ray and neutron images.
- Compare PCIS to 1-D and 2-D simulated images.
- Investigate asymmetries in burn region, and develop algorithms to treat asymmetries.
- Obtain orthogonal images.