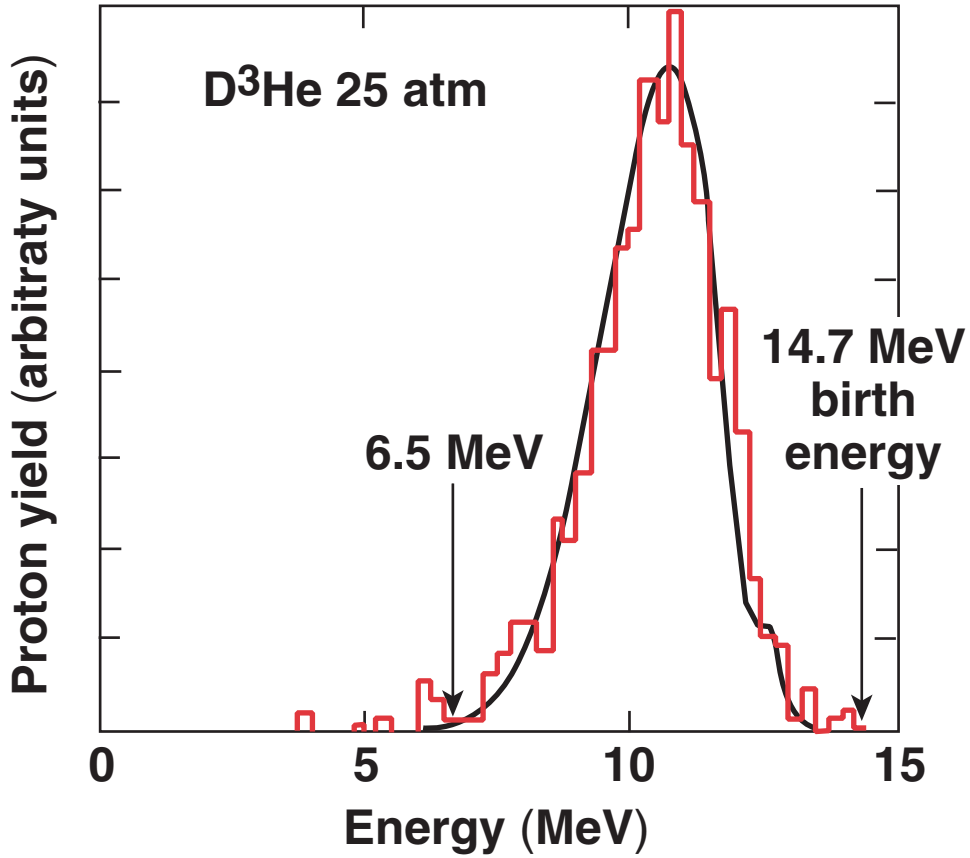
High-Areal-Density Fuel Assembly Experiments for the Fast-Ignitor Concept



$\langle \rho R \rangle_n = 0.13$ g/cm^2
$\rho R_{max} = 0.25$ g/cm^2

W. Theobald
University of Rochester
Laboratory for Laser Energetics

48th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Philadelphia, PA
30 October–3 November 2006

Summary

High areal densities of ~0.25 g/cm^2 were measured

FSC

UR LLE

- High-density and high-areal-density fuel assembly has been achieved on the OMEGA laser by imploding 40-μm-thick plastic shells with low velocity and a nearly Fermi-degenerate plasma ($\alpha \approx 1$).
- The measured proton-kinetic-energy downshifts are ~4 MeV for the spectral peak and up to ~8.7 MeV in the wings of the distribution.
- The measured proton spectra are in good agreement with calculated spectra using 1-D hydro simulations and the measured neutron production rate.
- The peak of the proton spectrum yields temporally and spatially averaged values of $\langle \rho R \rangle_n$ ~ 0.13 g/cm^2.

Collaborators

C. Stoeckl, C. Zhou*, R. Betti*, S. Roberts, V. A. Smalyuk, V. Yu. Glebov,
J. A. Delettrez, P. B. Radha, T. C. Sangster, and D. D. Meyerhofer

Laboratory for Laser Energetics
*Fusion Science Center
University of Rochester

C. K. Li and R. D. Petrasso

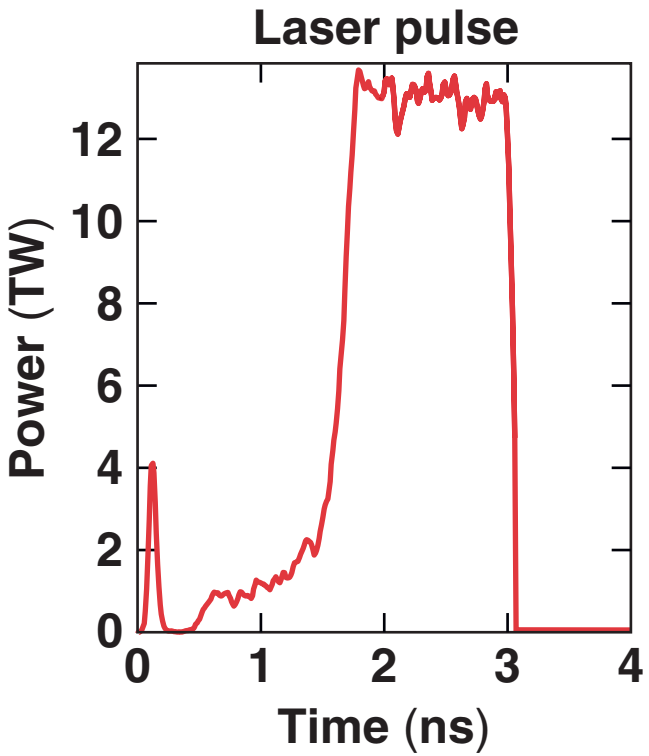
Plasma Science and Fusion Center
Massachusetts Institute of Technology

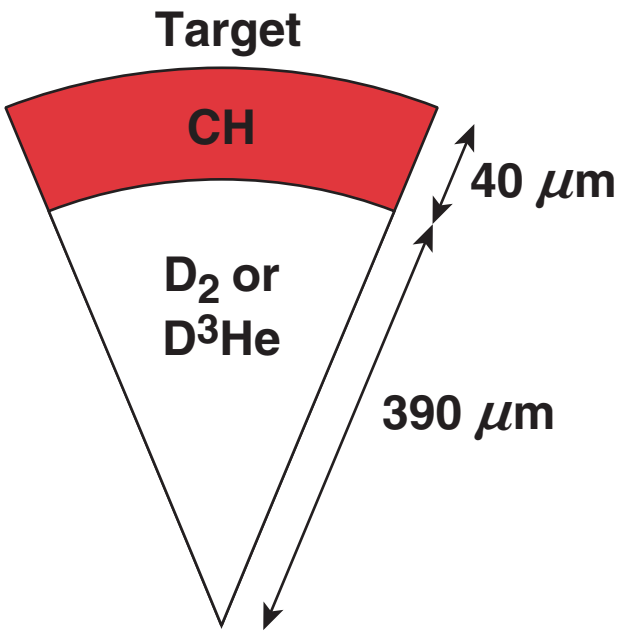
High ρR fuel assembly was achieved with thick CH shells and a low-adiabat, low-implosion velocity implosion*

FSC

UR LLE

$E_L \approx 20$ kJ, $\alpha \sim 1.3$, $V_i \approx 2 \times 10^7$ cm/s

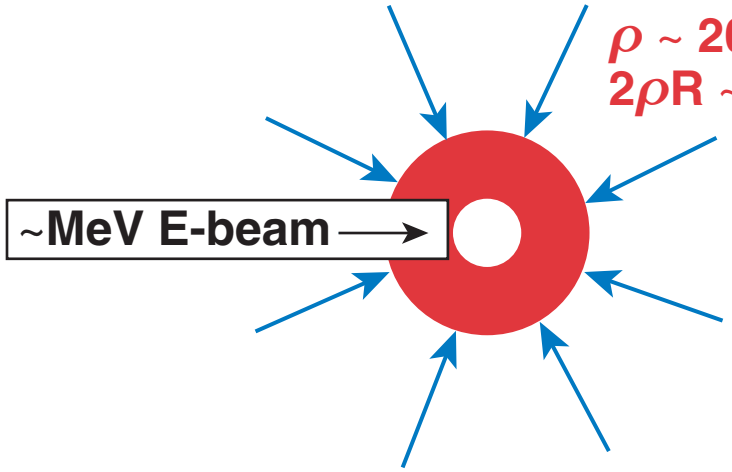




TC7384a

*C. Zhou *et al.*, BO3.0003

The areal densities are sufficient to stop MeV electrons in the plastic shell

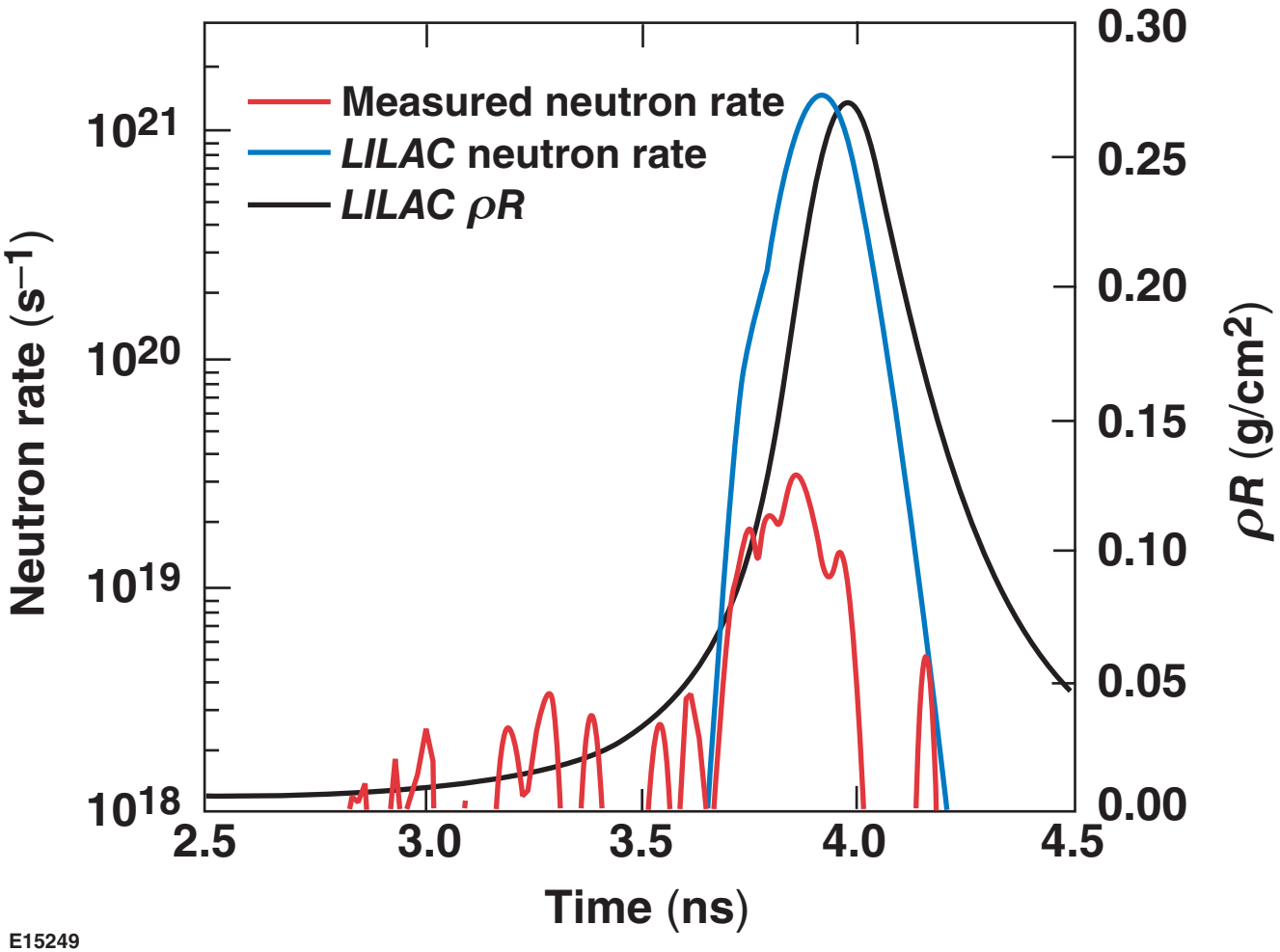


Predicted values for a 20-kJ implosion with an ideal pulse shape

Pressure (atm)	ρ (g/cc)	$2\rho R$ (g/cm^2)	E_{stop} (MeV)*
35	89.3	0.52	2.10
25	101	0.62	2.35
15	120	0.74	2.76
5	185	1.02	3.53
1	222	1.32	4.45

*C. K. Li and R. D. Petrasso, Phys. Rev. E 70, 067401 (2004).

The DD neutron production begins as predicted and shows a 200-ps truncation, probably due to hot-spot CH–DD mixing

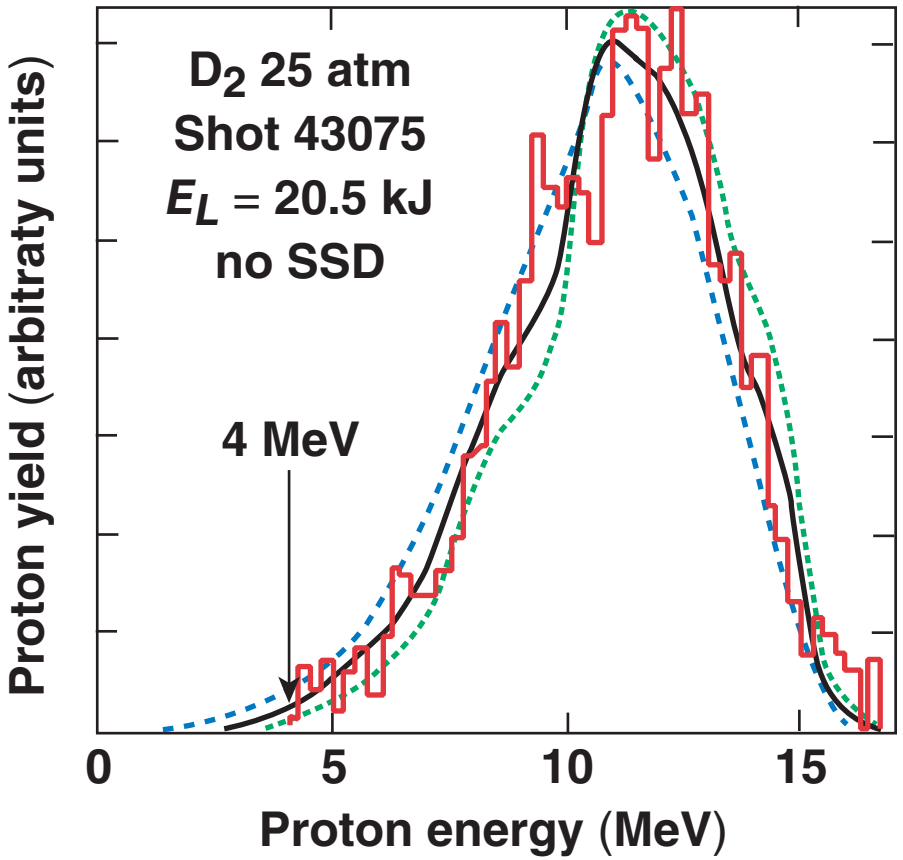


D_2 25 atm
Shot # 43075
E_L = 20.5 kJ,
no SSD

YOC = 3%

E15249

The measured[1] and reconstructed[2] downshifted secondary proton spectra are in good agreement



The reconstruction used the measured neutron rate and the simulated $\rho R(t)$.

- Measured spectrum
- *LILAC* with 1-D source size
- *LILAC* with point source
- *LILAC* averaged

8.7-MeV downshift

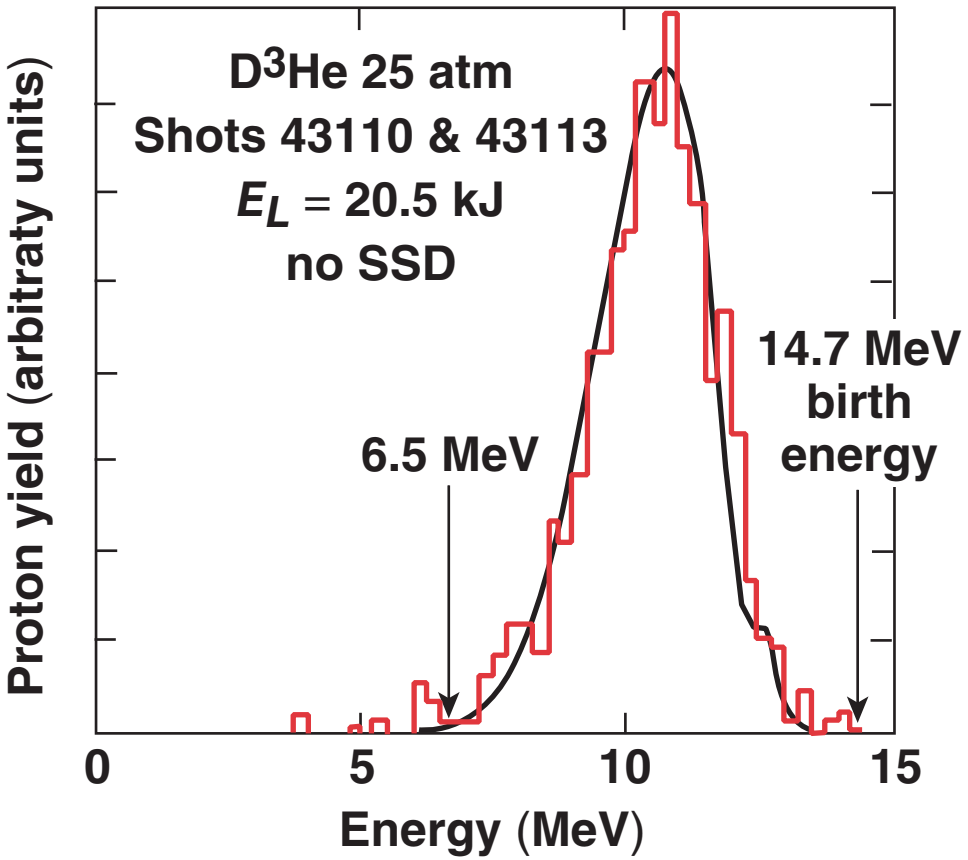
$(\rho R)_{max}$ = 0.26 g/cm^2

$\langle \rho R \rangle_n$ = 0.14 g/cm^2

[1] F. H. Séguin *et al.*, Rev. Sci. Instrum. 74, 975 (2003).
[2] P. B. Radha *et al.*, GO2.00008.

E15250

The measured[1] and reconstructed[2] downshifted primary proton spectra are in good agreement for D^{3}He implosions



The calculation used an estimated proton rate and the simulated ρR evolution

Measured spectrum

Calculated spectrum

8.2-MeV downshift

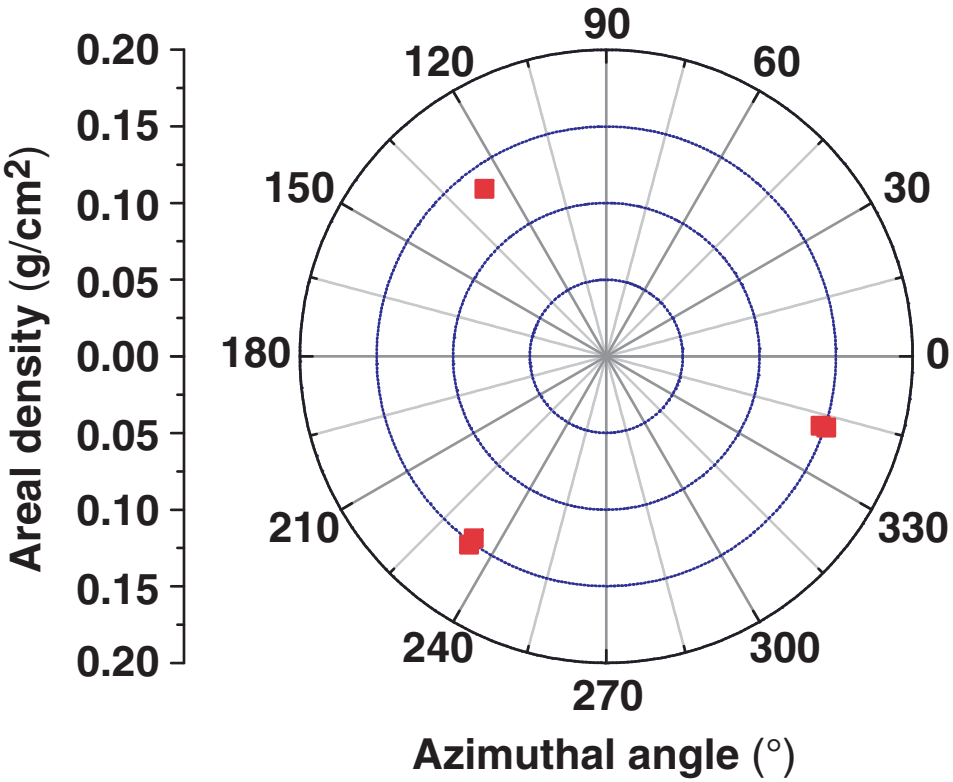
$(\rho R)_{max} = 0.25$ g/cm^2

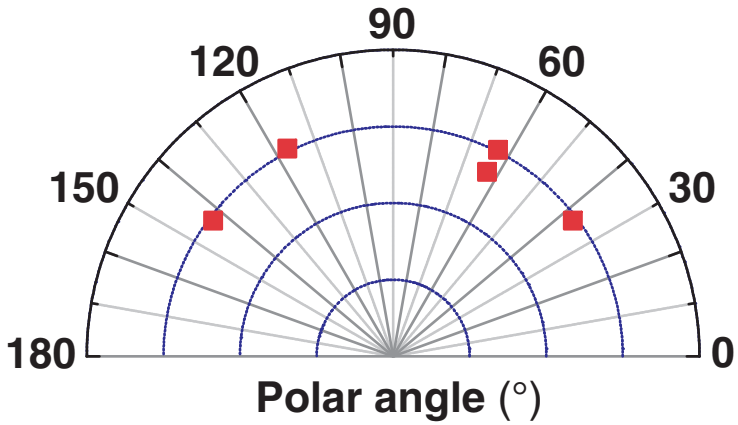
$\langle \rho R \rangle_n = 0.13$ g/cm^2

[1] F. H. Séguin *et al.*, Rev. Sci. Instrum. 74, 975 (2003).
[2] P. B. Radha *et al.*, GO2.00008.

E15251

The $\langle \rho R \rangle$ modulations are <10%, indicating that the compressed core is not significantly affected by low-mode ($\ell \leq 5$) nonuniformities





D_2 25 atm
Shot 43075
E_L = 20.5 kJ
no SSD

Summary/Conclusions

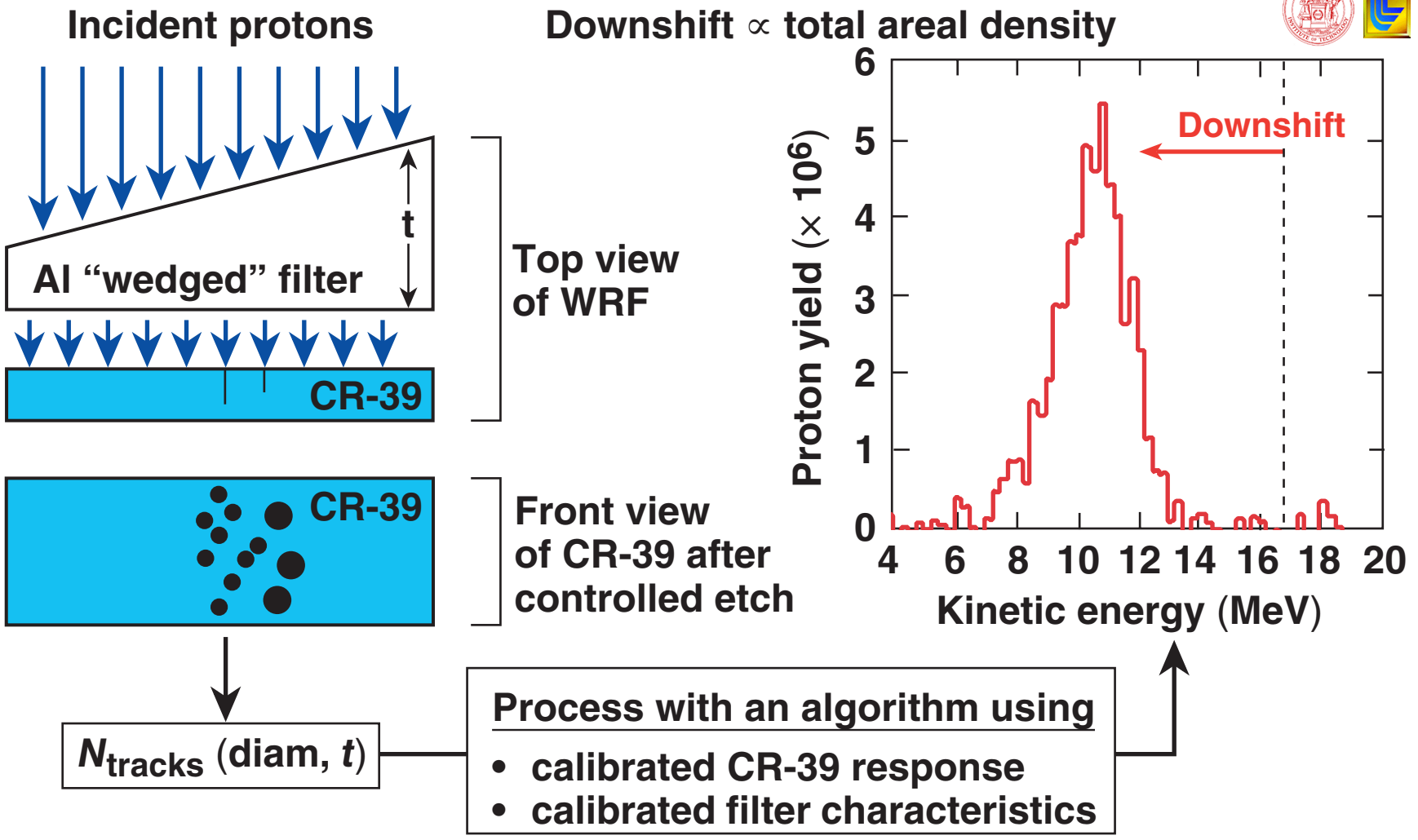
High areal densities of ~0.25 g/cm^2 were measured

FSC

UR LLE

- High-density and high-areal-density fuel assembly has been achieved on the OMEGA laser by imploding 40-μm-thick plastic shells with low velocity and a nearly Fermi-degenerate plasma ($\alpha \approx 1$).
- The measured proton-kinetic-energy downshifts are ~4 MeV for the spectral peak and up to ~8.7 MeV in the wings of the distribution.
- The measured proton spectra are in good agreement with calculated spectra using 1-D hydro simulations and the measured neutron production rate.
- The peak of the proton spectrum yields temporally and spatially averaged values of $\langle \rho R \rangle_n$ ~ 0.13 g/cm^2.

"Wedged-range-filter" spectrometers (WRF's) record the proton spectrum to measure areal density



E12685a

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

Very good agreement between measured and predicted burn-averaged areal densities is obtained

FSC

UR LLE

Shot number	Gas fill	P (atm)	Measured ρR (g/cm^2)	Burn-averaged ρR (g/cm^2)
43074	D_2	34	0.133	0.138
43075	D_2	25	0.146	0.144
43107	D_2	25	0.122	0.132
43114	D_2	25	0.128	0.112
43106	D_2	13	0.128	No NTD available
43108	D_2	13	0.129	No NTD available
43109 43112	D^3He	33	0.128	No NTD available
43110 43113	D^3He	25	0.130	No NTD available
Average			0.131	0.132

E15253