Primary and Secondary D-^{3}He Proton Spectra of OMEGA Capsule Implosions

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Two charged-particle spectrometers have been used to study primary and secondary fusion protons in a recent series of experiments on OMEGA involving capsules with relatively thick (15- to 24-μm) plastic shells. From capsules filled with 3 to 10 atm of D-^{3}He, ion temperatures and total areal densities were deduced from nascent 14.7-MeV protons. Results from capsules filled with D only demonstrate that we can see secondary protons resulting from D-fusion reactions. This indicates that these secondary protons may prove useful for determining total ρR in future experiments with cryogenic DD capsules. This work was performed in part at the LLE National Laser Users' Facility (NLUF) supported in part by the U.S. Department of Energy Contract Number DE-FG03-99SF21782, LLE subcontract number PO410025G, LLNL subcontract number B313975, and the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460.

Diagnostic Use of Secondary D-^{3}He Proton Spectra for D-D OMEGA Targets

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Outline

- Why we are interested in secondary protons for studying ρR
- How measured secondary spectra are related to physical quantities
- The first high-resolution secondary proton spectrum measured with the charged-particle spectrometers (CPS's) on OMEGA
- The future: cryogenic targets and the NIF

Why are we interested in secondary protons?

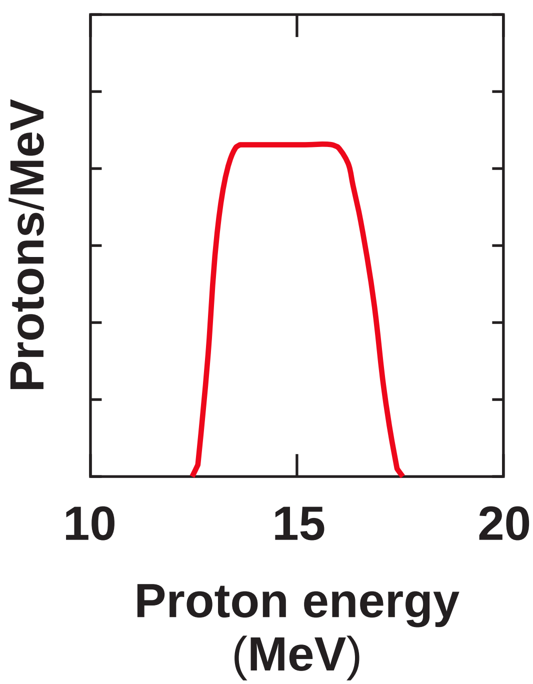
- Spectra of charged, primary fusion products have been used to study yield, Ti, and ρR of OMEGA capsules with $\rho R \leq 0.1\ g/cm^2$.
- Cryogenic experiments on OMEGA and NIF will involve D fuel and higher ρR. No charged, primary fusion products will escape.
- Secondary D-^{3}He protons (12.5 to 17.4 MeV) will escape from D capsules with relatively high ρR.
- Measurement of secondary proton yield and energy downshift gives information about
  - ρR_{total}
  - symmetry (with multiple detectors; see P. B. Radha, this conference).

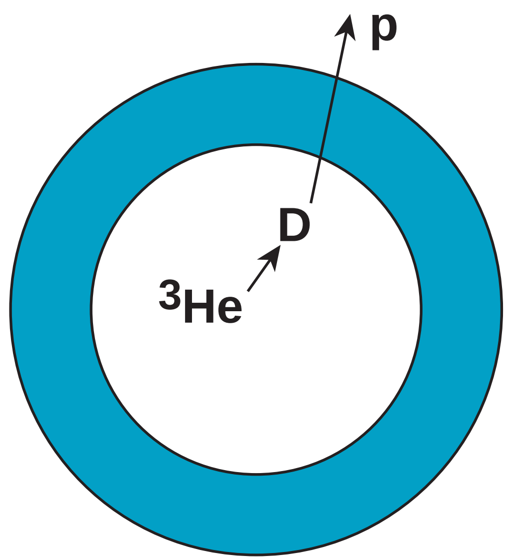
Secondary protons and their diagnostic use

$D + D \rightarrow n\ (2.45\ \text{MeV}) + {}^3He\ (0.82\ \text{MeV})$

${}^3He\ (0.82\ \text{MeV}) + D \rightarrow \alpha\ (6.6\text{–}1.7\ \text{MeV}) + p\ (12.5\text{–}17.4\ \text{MeV})$

Initial spectrum





Diagnostic use of measured final spectrum

- For ρR_{fuel} & 0.01 g/cm^2: yield $\Rightarrow \rho R_{fuel}$*
- For ρR_{total} & 0.5 g/cm^2: downshift $\Rightarrow \rho R_{total}$

*H. Azechi, M. D. Cable, and R. O. Stapf, Laser and Particle Beams 9, 119 (1991).

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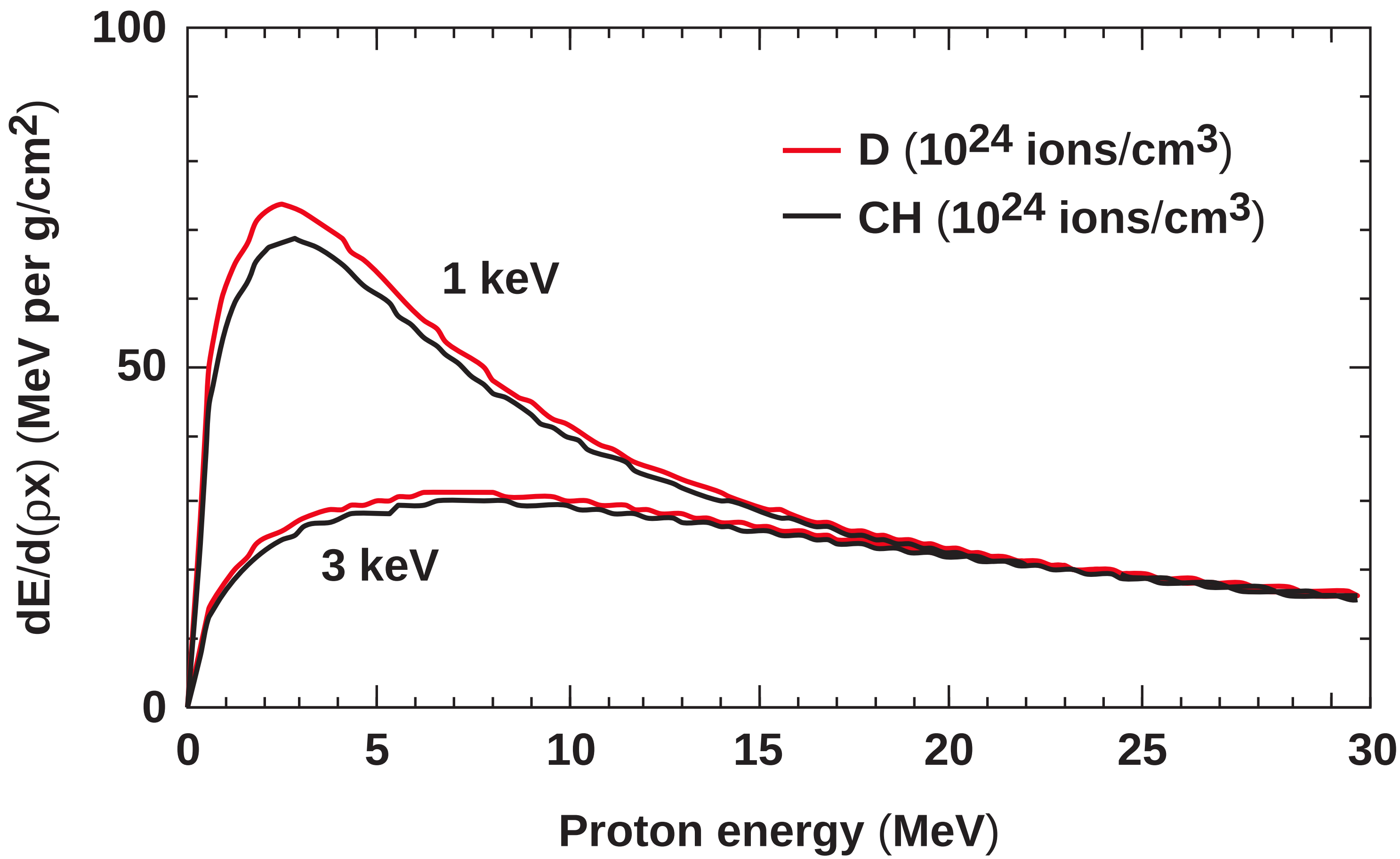
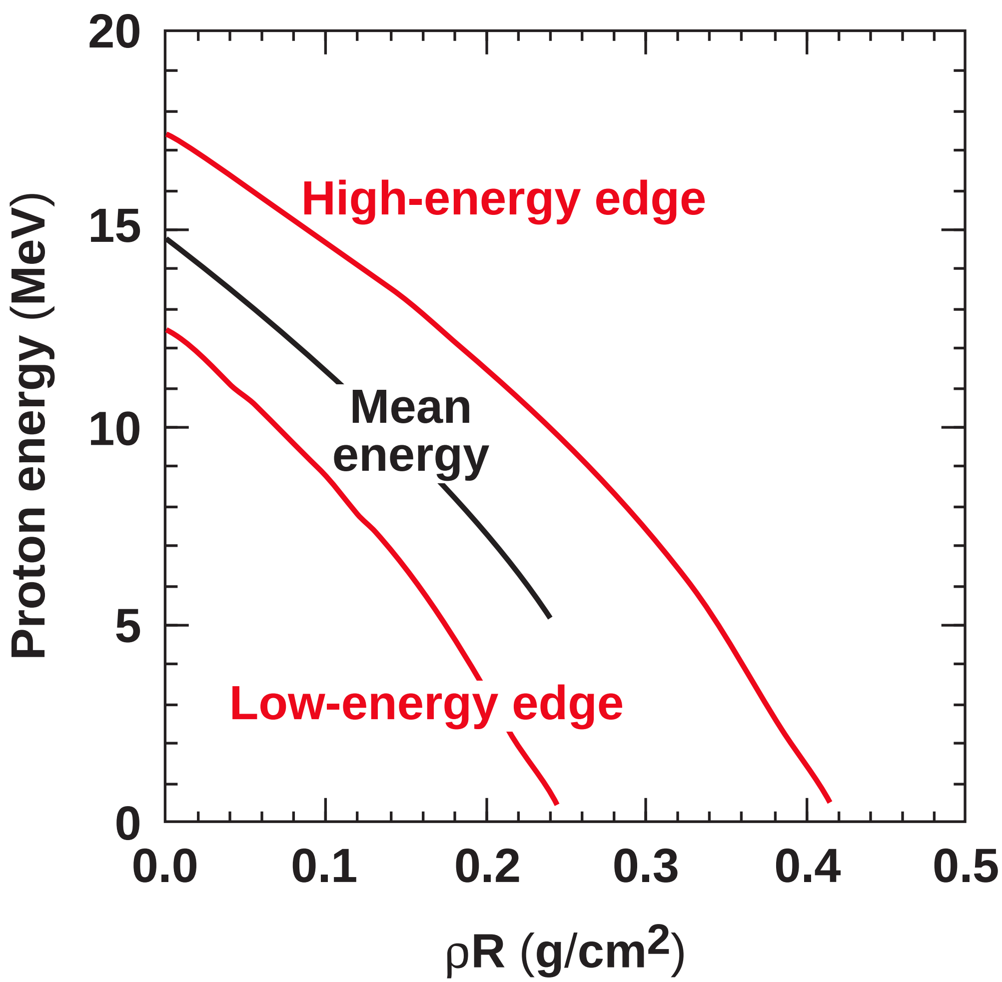
Stopping power* for protons in D fuel or CH shell



E10065

*Li and Petrasso, Phys. Rev. Lett. 70 (20), 3059 (1993).

Slowing down of secondary protons by 3-keV D fuel and 1-keV CH shell



Downshifted spectrum can be characterized by

- **The entire spectrum ($\rho R \leq 0.2$ g/cm^2)**
- **Mean energy ($\rho R \leq 0.2$ g/cm^2)**
- **Upper-edge energy ($\rho R < 0.4$ g/cm^2)**

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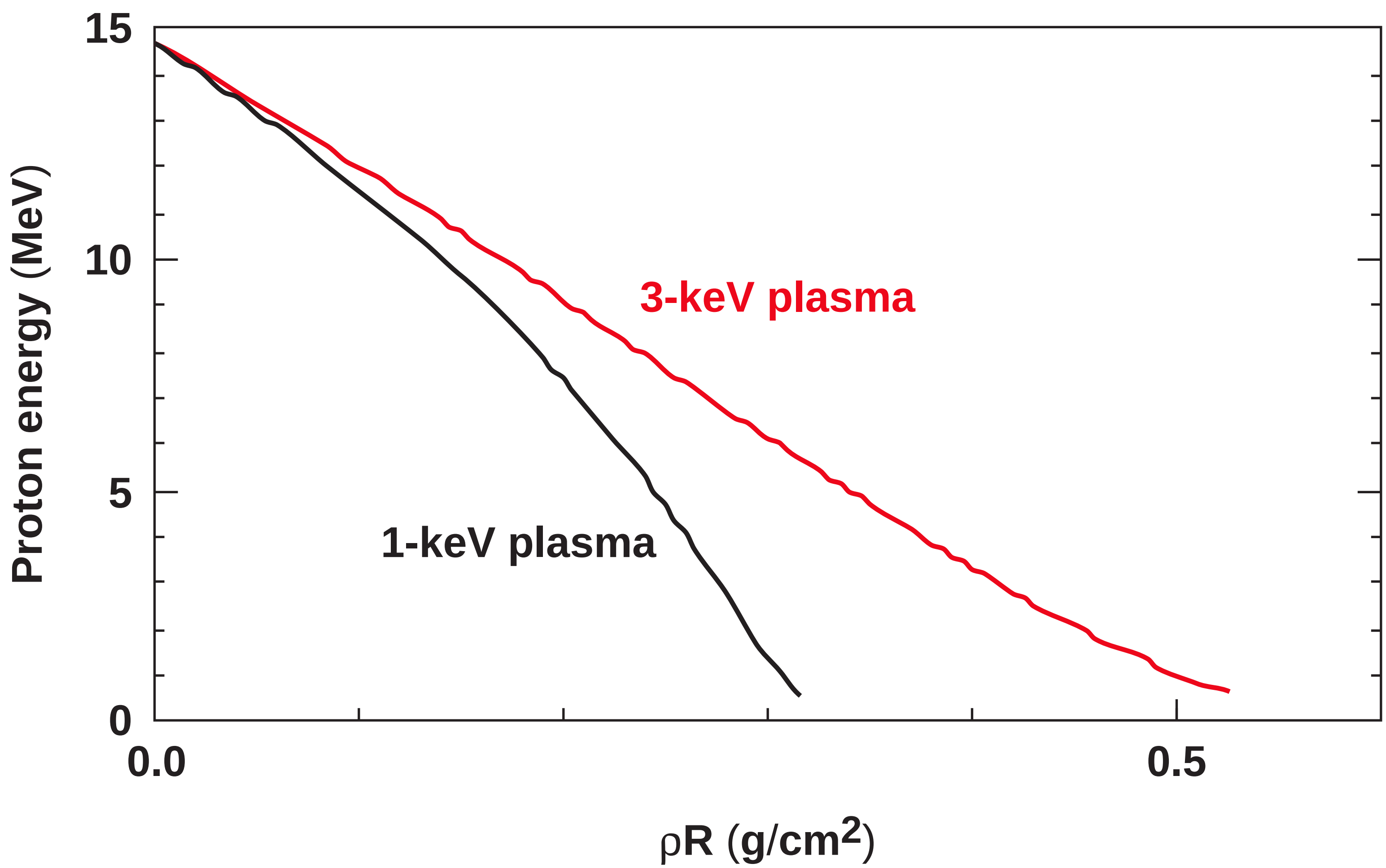
Slowing down of protons in D or CH varies with temperature



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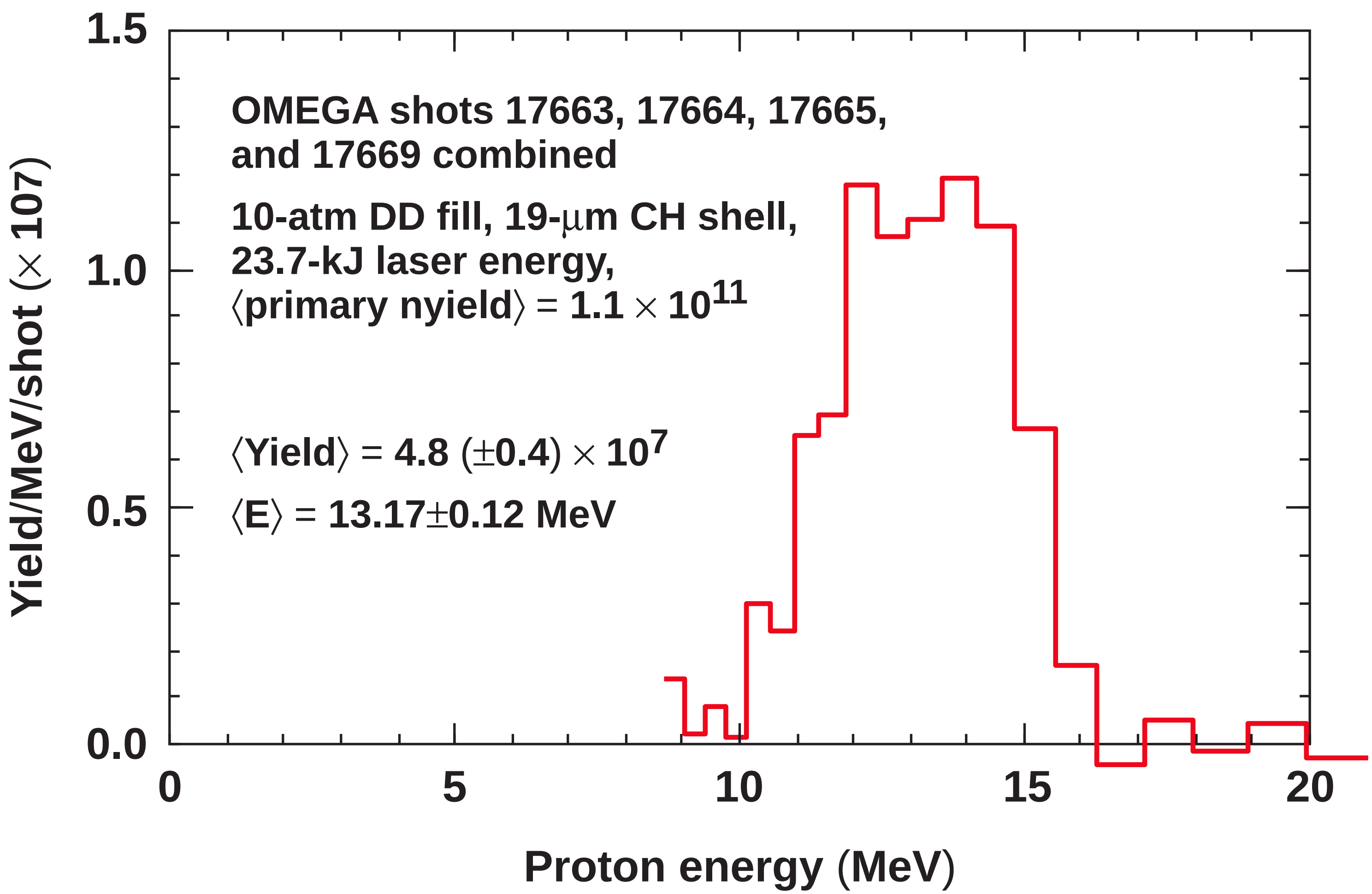
First secondary-proton spectrum measured with CPS



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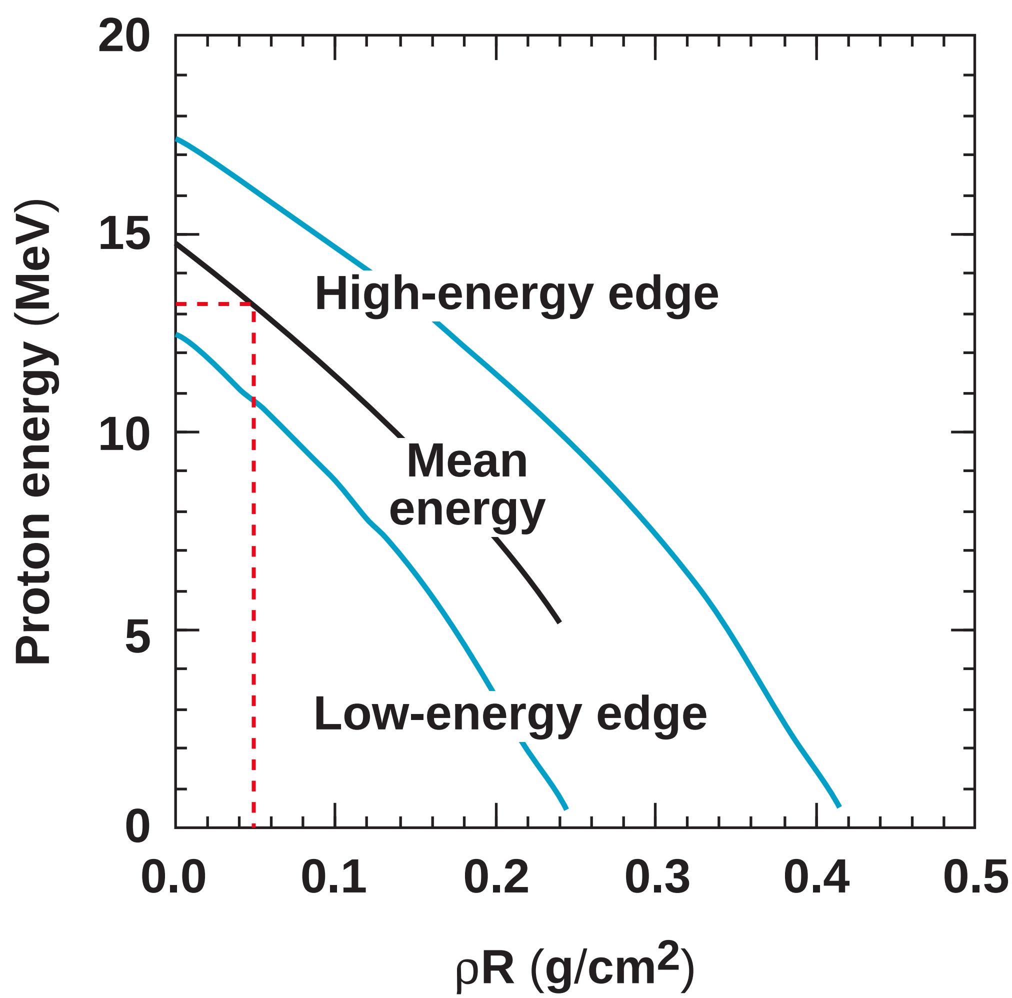
Determination of ρR_{total} from mean energy



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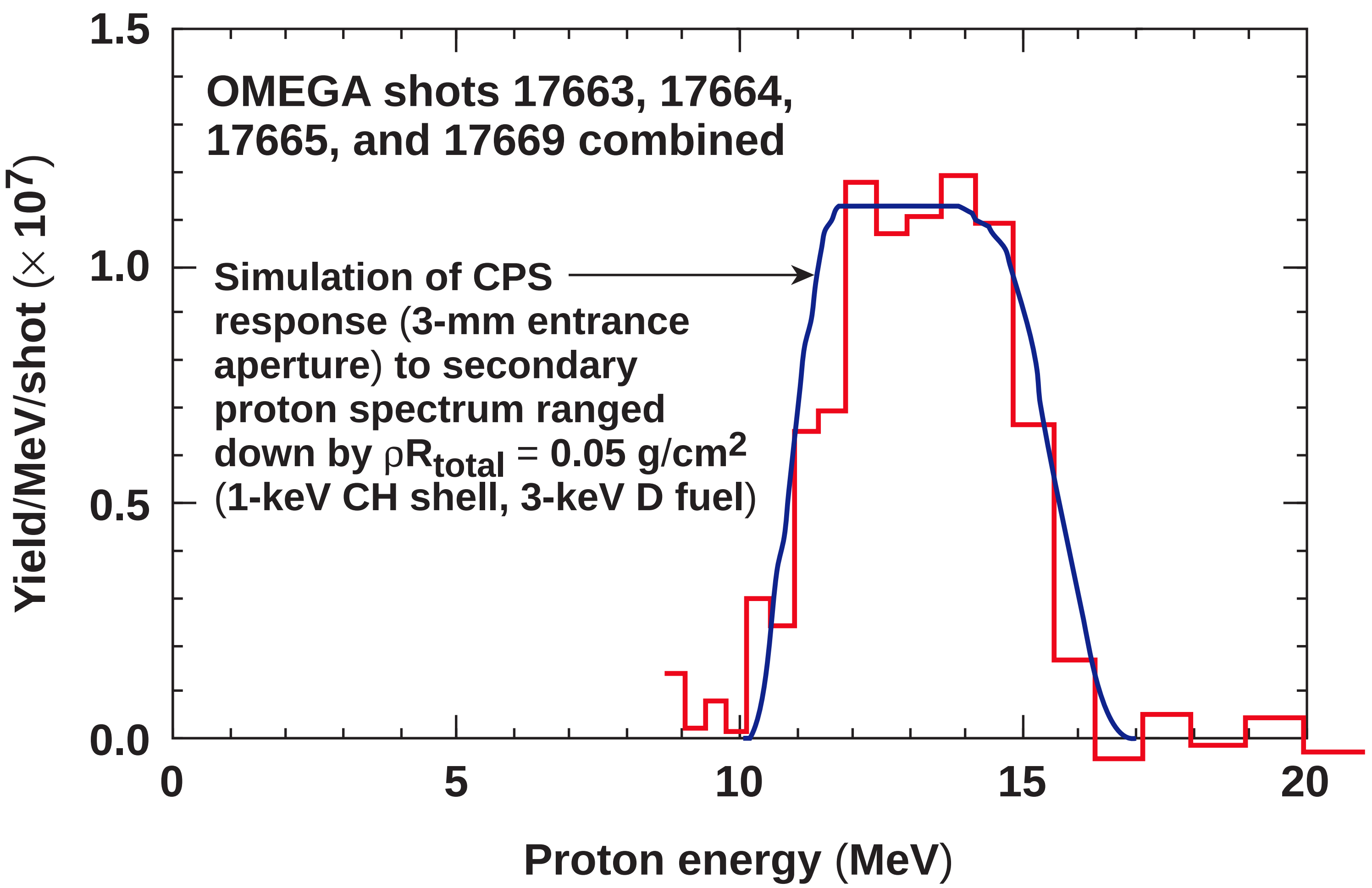
Comparison of data with simulation



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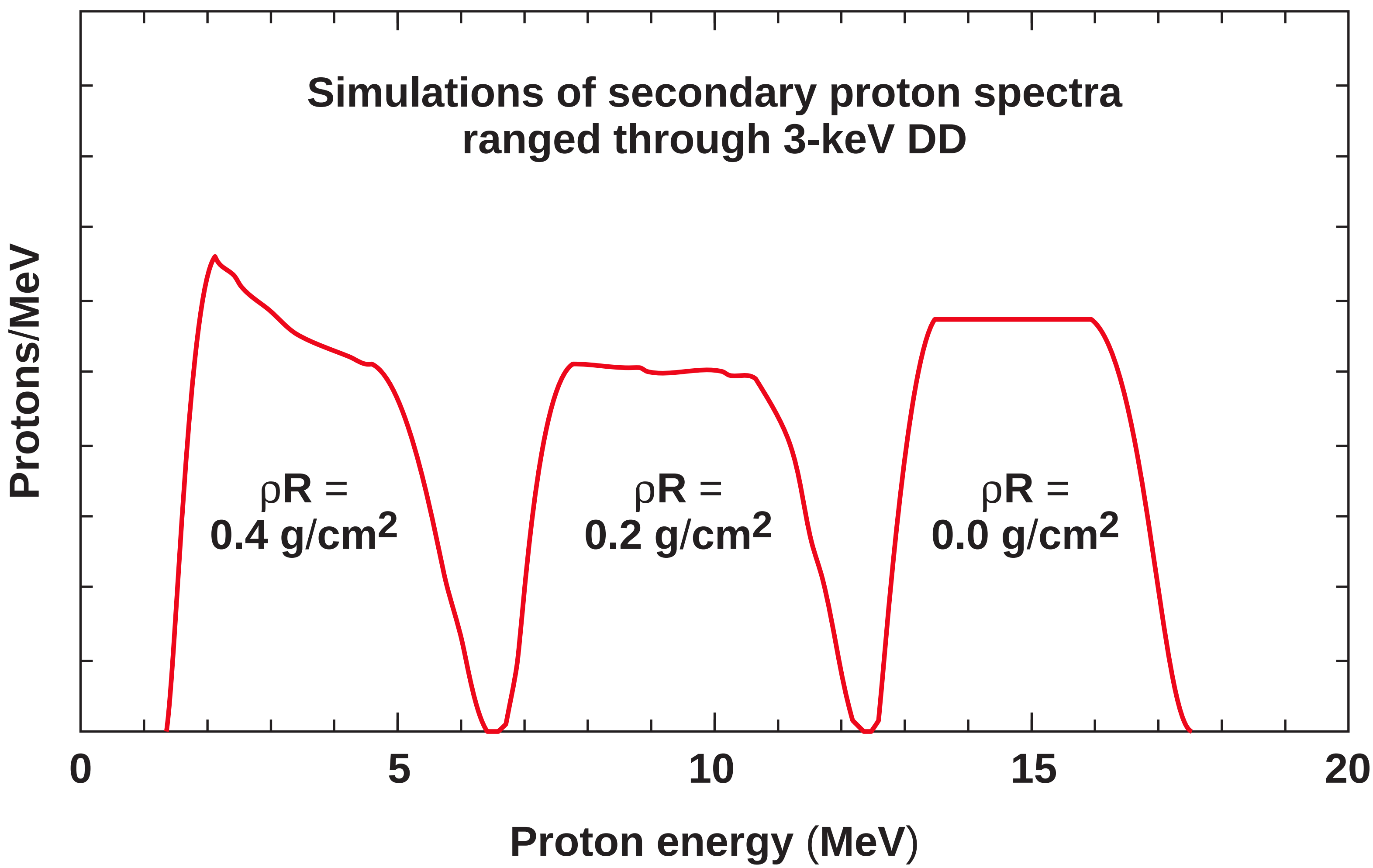
Cryogenic targets may have higher ρR, higher yield



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Conclusions

- We can accurately measure the secondary proton spectrum.
- The energy downshift of the spectrum is directly related to ρR.
- Yield and downshift carry information about symmetry (with multiple spectrometers).
- For cryogenic D-D capsules, secondary spectra could be usable for ρR as high as 0.4 to 0.6 g/cm^2 (3-keV plasma).