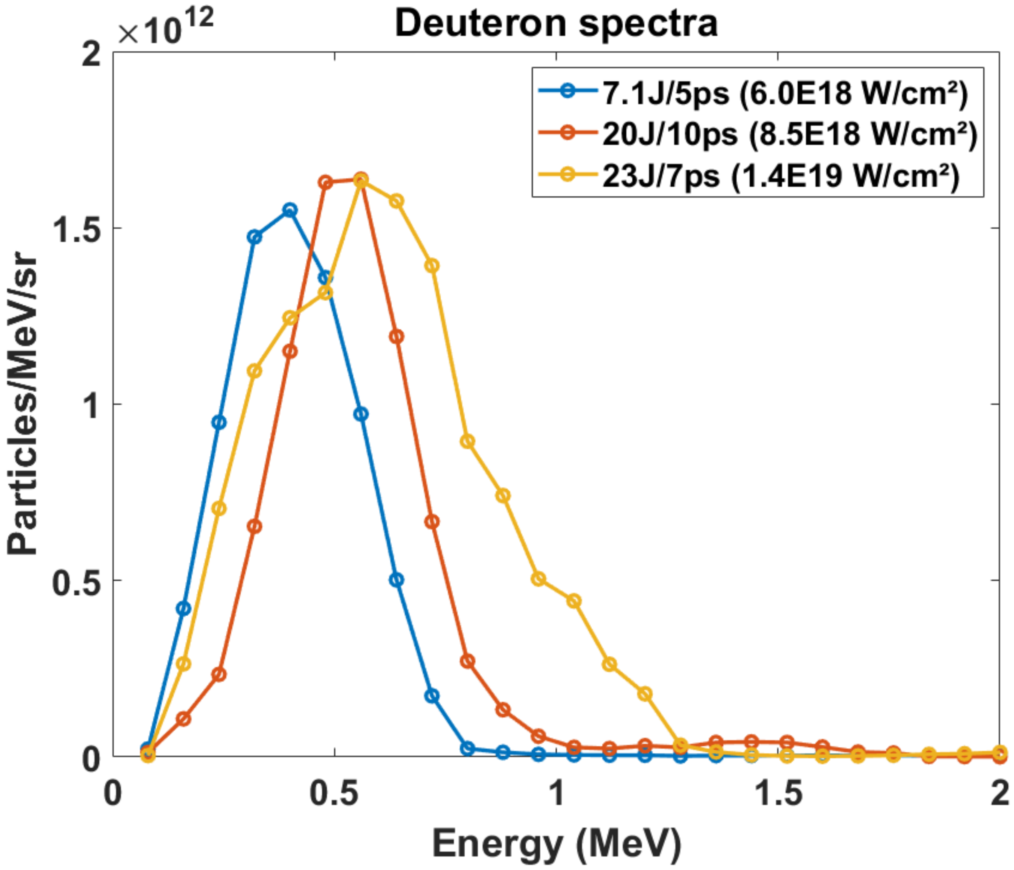
Controllable TNSA Deuteron Beams using Deuterated Titanium Targets Toward Generating a Tritium Beam



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62nd Annual Meeting of the American Physical Society Division of Plasmas Physics
9–13 November 2020

Energetic TNSA deuteron beams were generated using deuterated titanium targets

- A platform for a MeV tritium beam at the Laboratory for Laser Energetics is being developed using deuterium as surrogate
- Tritium-induced reactions like T(t, 2n)α and ${}^{6}Li$(t, p) ${}^{8}Li$ allow for the study of exotic neutron rich nuclei relevant to ab-initio nuclear structure calculations

- The deuteron yield depends only marginally on the deuteration conditions
- The deuteron spectra transition from exponential to asymmetric Gaussian with increasing laser energy
- Numerical simulations of the ion-acceleration process help to interpret these puzzling results
- Mean energies between 0.5 MeV (MTW) and 5 MeV (OMEGA EP) were observed

TNSA: target-normal sheath acceleration
MTW: Multi-Terawatt laser

Collaborators

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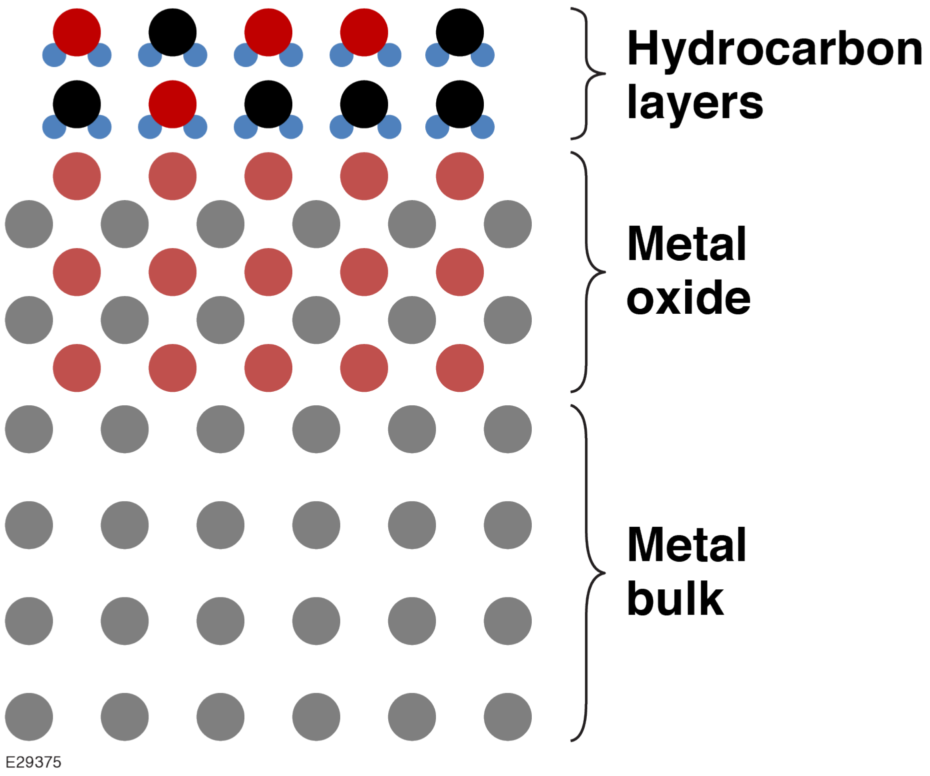
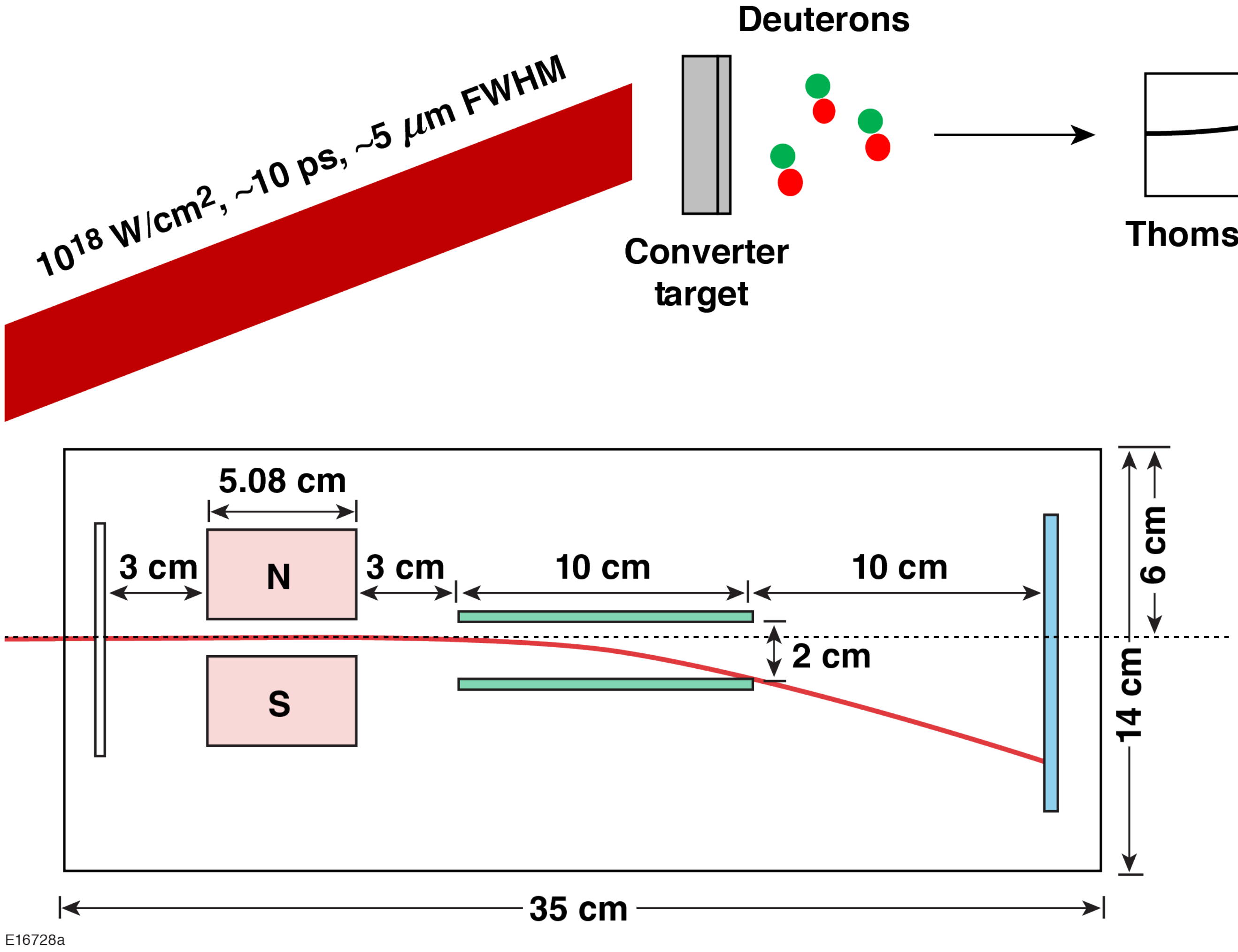
Protons in the contamination layers are isotopically exchanged with deuterium from a pure deuterium atmosphere

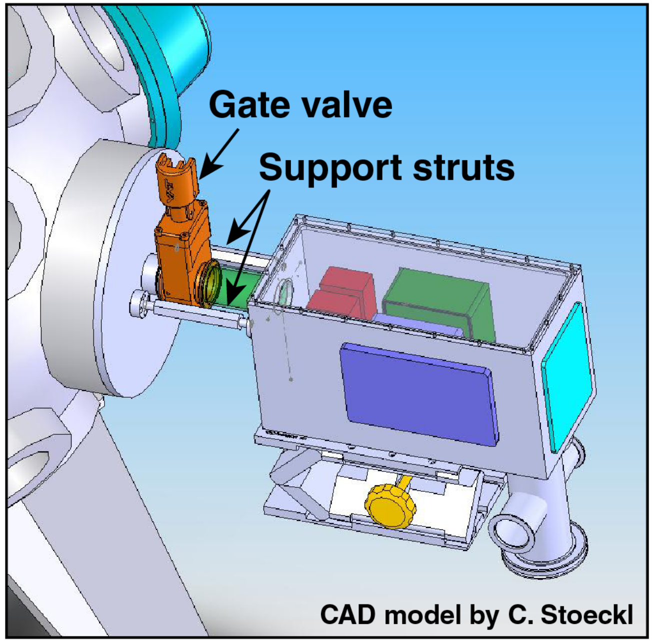


- Titanium targets are exposed to a deuterium atmosphere
- Molecular deuterium dissociates at the surface and migrates into contamination layers
- Deuterium temperature, pressure, and exposure time have only marginal impact on the deuterium yield

Targets are loaded at 900 Torr of D_2 pressure at 350ºC for 24 hours.

The MTW laser accelerates deuterons from a deuterated Ti foil toward a Thomson parabola

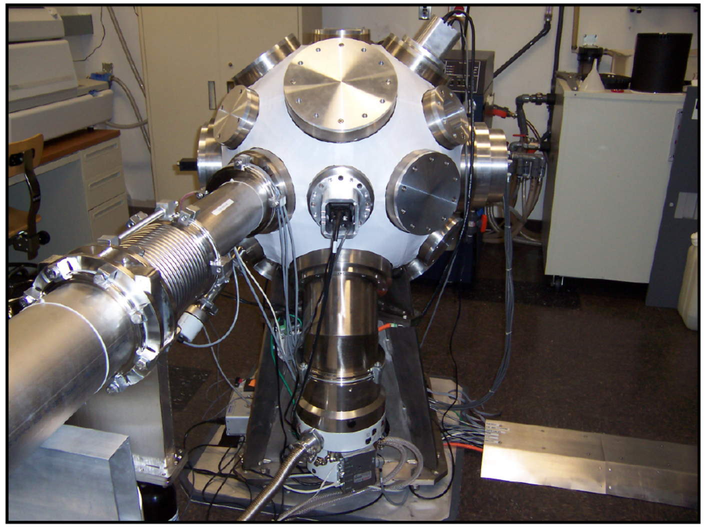




The MTW laser at LLE provides a flexible mid-scale capability for nuclear science experiments

UR LLE

Survey studies were conducted at 1, 5, 7, and 10 ps and varying energies from 1 to 23 J



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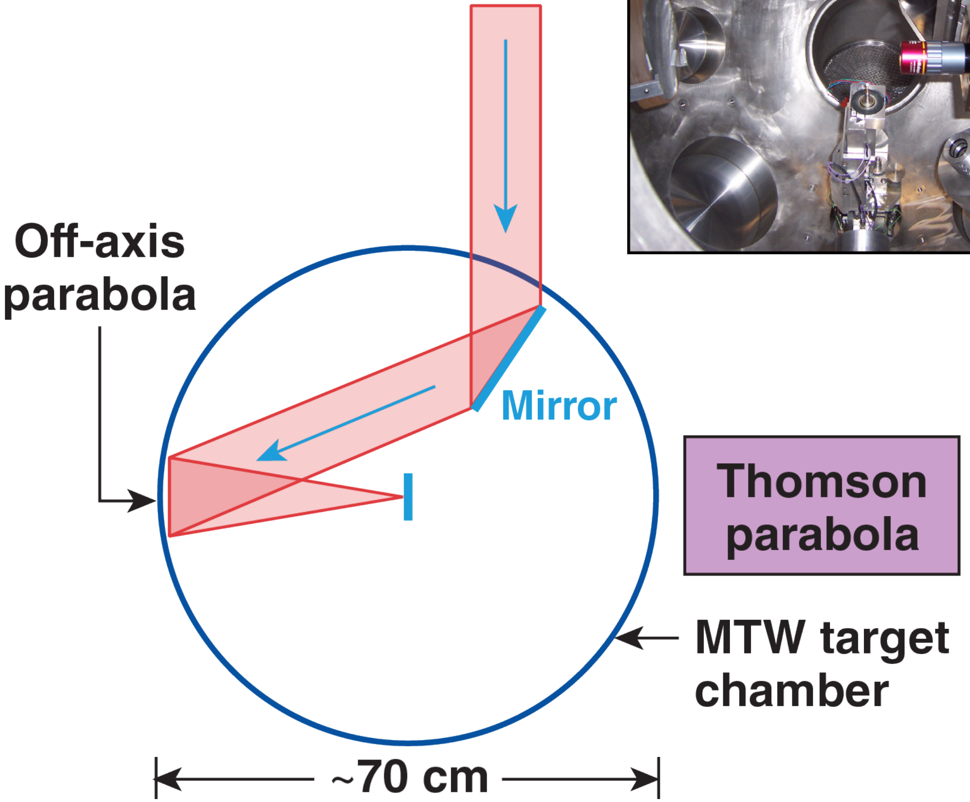
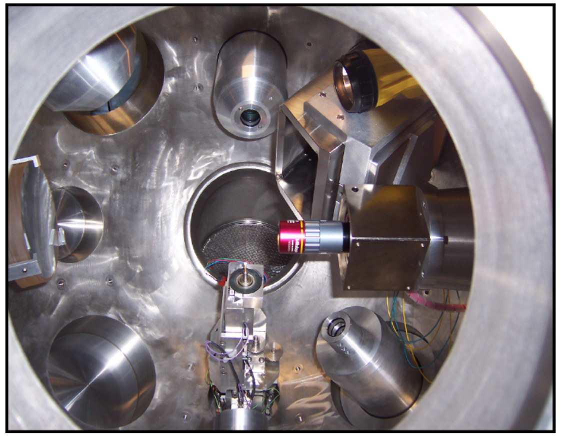
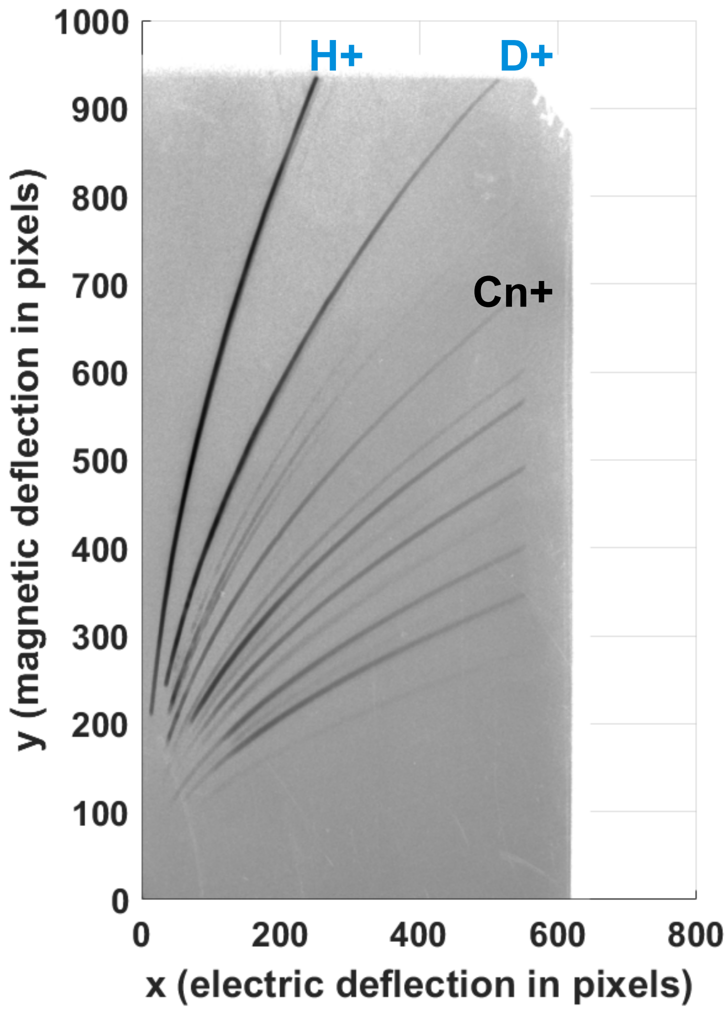
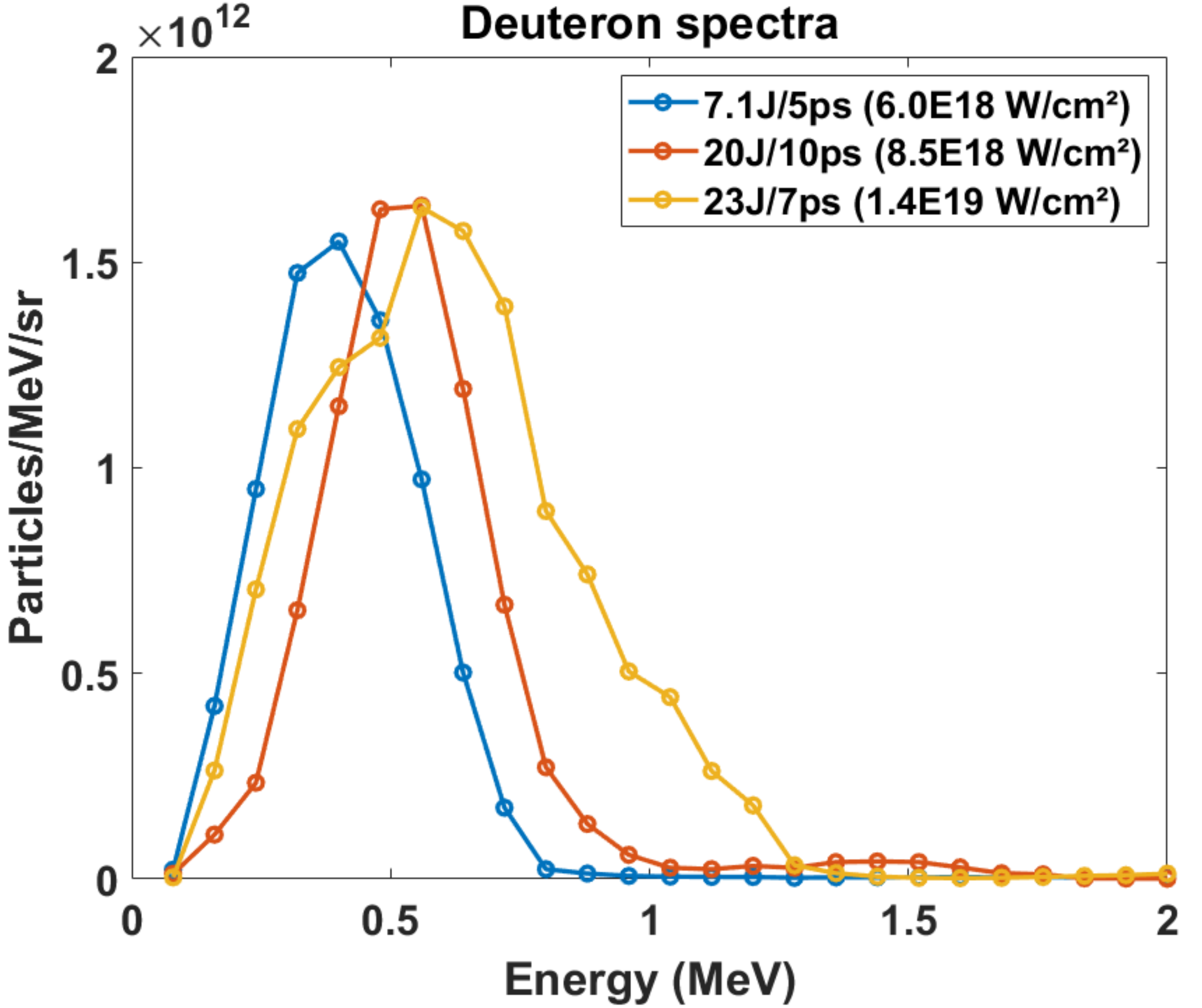


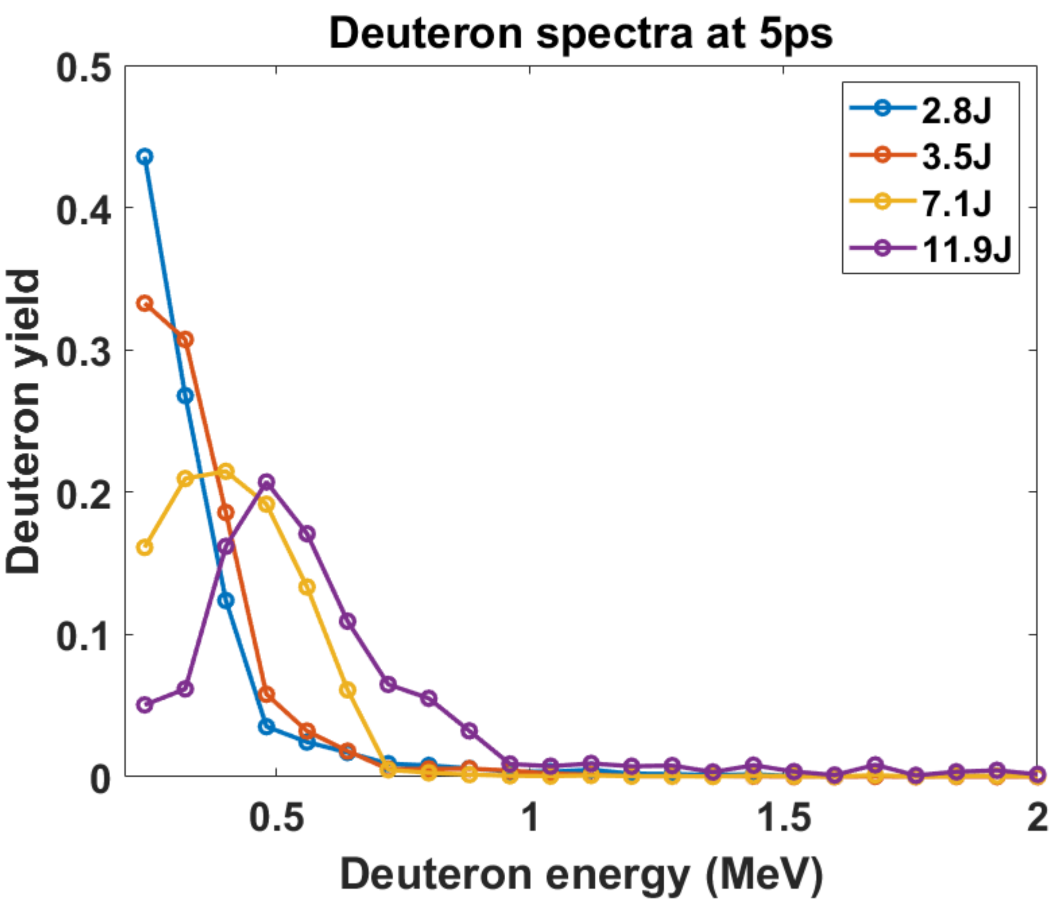


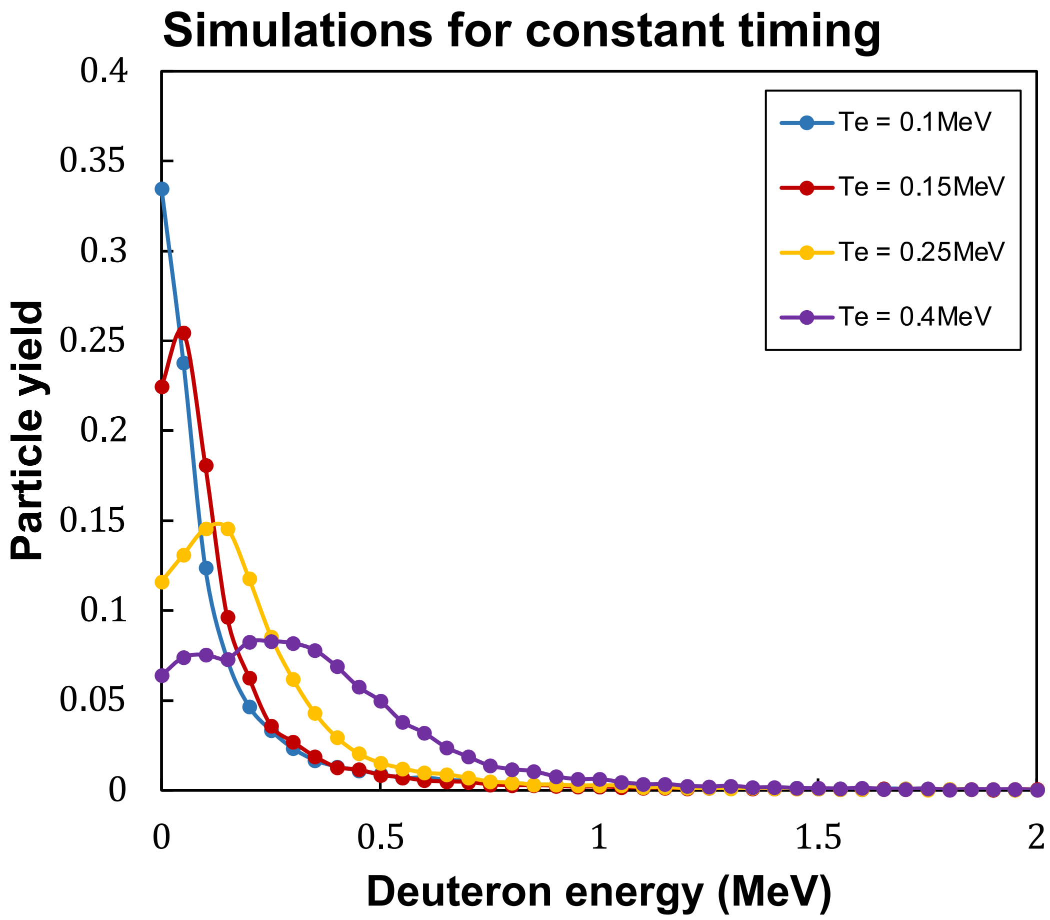
For each individual shot, the intensity is binned along each trace to obtain a spectrum





TNSA experiments at constant pulse duration but increasing energy show the formation of a peak





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Backup

Boundary conditions for constant laser pulse durations but varying energies

- The ions are accelerated by n_e electrons with an exponential energy distribution of temperature T_e

- To first order, T_e equals the ponderomotive potential,

$$T_e = \frac{e^2}{4m_e\omega^2}E^2 = \frac{e^2}{4m_e\omega^2}\frac{2I}{\epsilon_0 c}$$

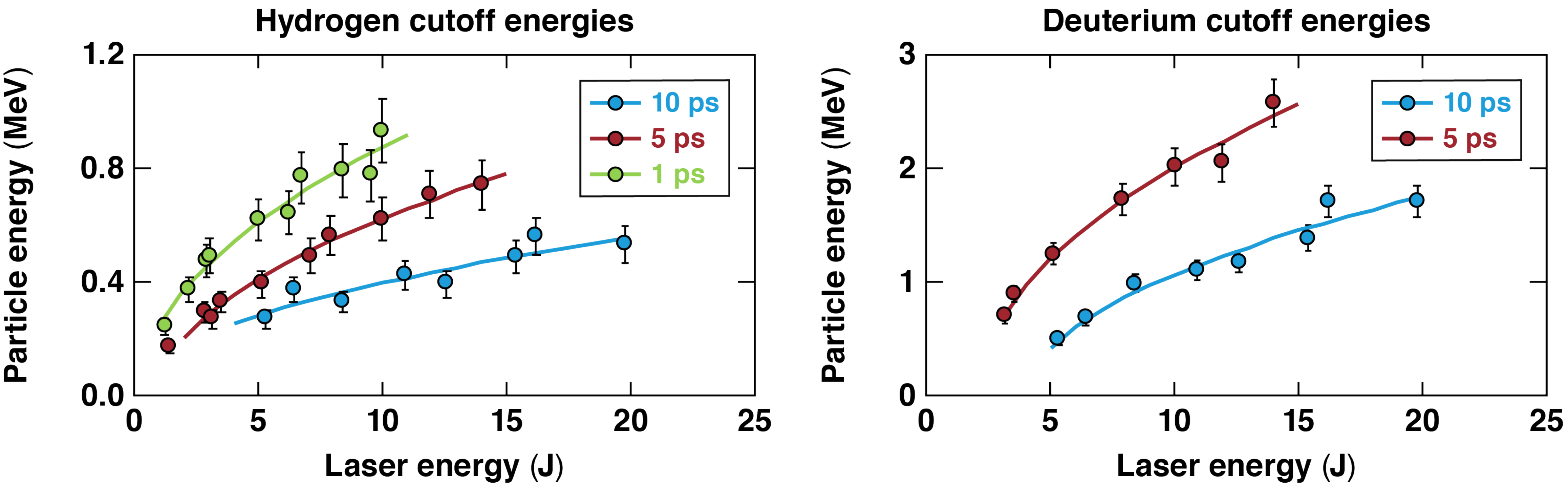
- To first order, n_e equals the laser energy divided by the average electron energy,

$$n_e = \eta\frac{E_{laser}}{T_e} **$$

- Combining equations reveals that n_e depends only on laser pulse duration and spot size
- $\rightarrow$ Varying only E_{laser} should increase T_e but leave n_e constant

** efficiency η changes from ~10% - 15% in our ROI

The highest observed ion energy was determined and related to the laser energy



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A fit to $\sqrt{E}$ reproduces the cutoff energies of hydrogen and deuterium very well, as observed by other authors.*

*E. L. Clark *et al.*, Phys. Rev. Lett. 85, 1654 (2000).