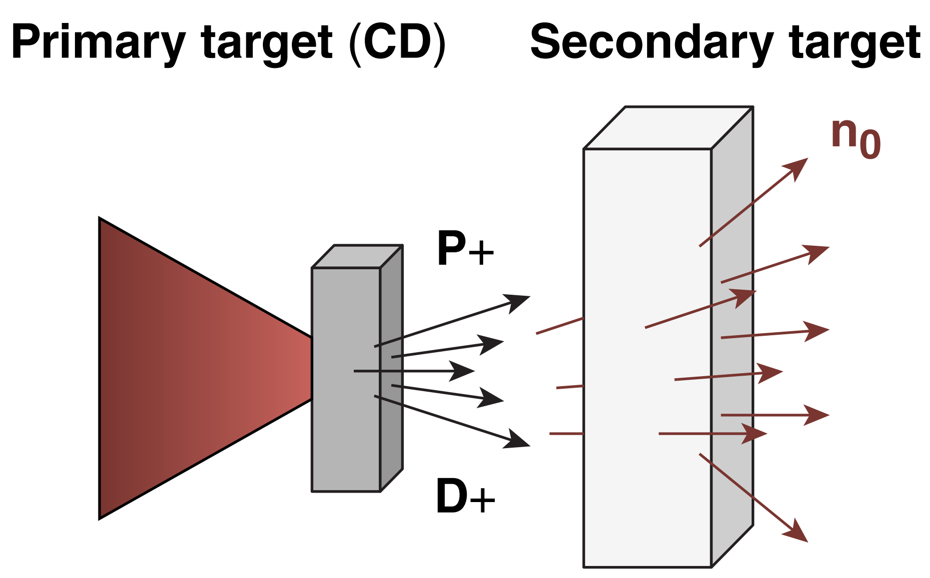
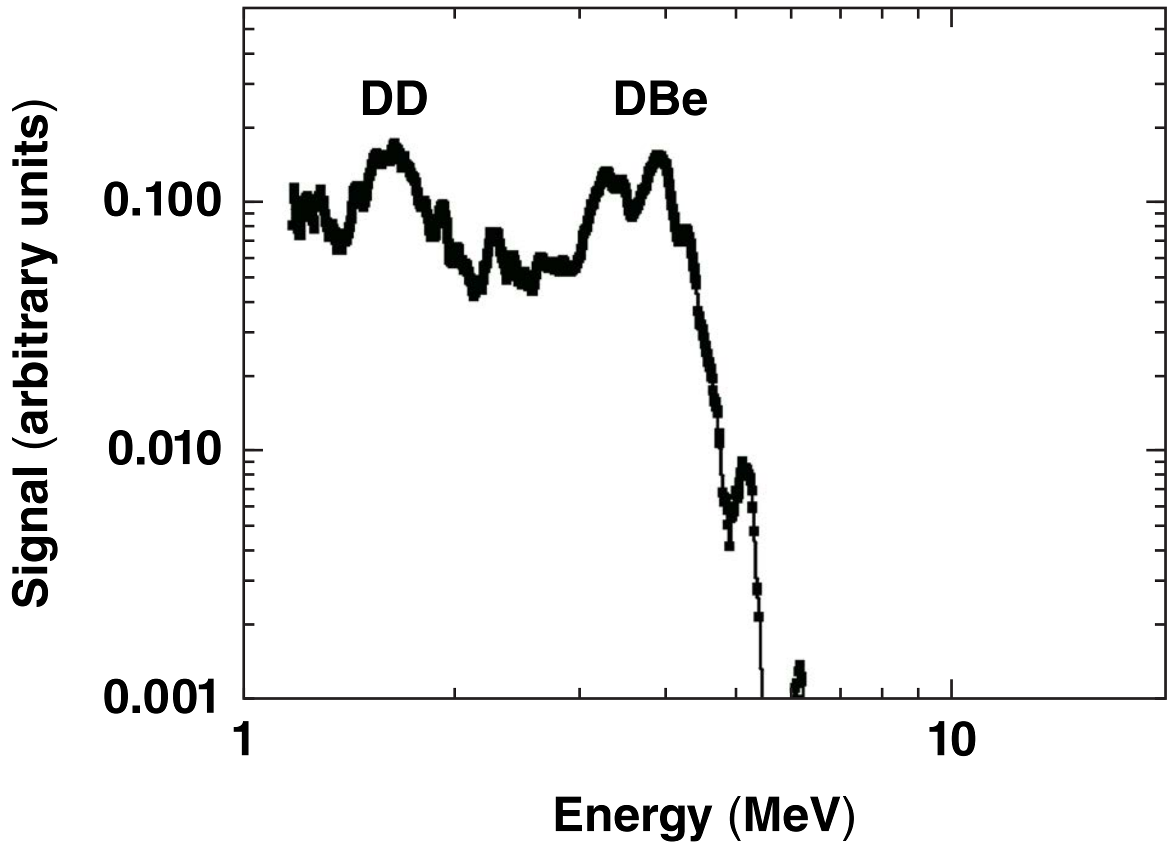
Spectroscopy of Neutrons Generated Through Nuclear Reactions in Short-Pulse Laser Experiments





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A nuclear physics platform using laser-generated light ions is being developed at the Laboratory for Laser Energetics (LLE)

UR LLE

- An energetic deuteron flow (E_k = 2 to 5 MeV) is created off the back surface of a primary target irradiated by a short-pulse laser (E = 1.25 keV, τ = 10 ps)
- Studies of d–d fusion, d–^{9}Be fusion processes show the expected neutron spectra
- First experiments looking at the Be^9(d, t) Be^8 neutron pickup reaction show no signature of triton production

Collaborators

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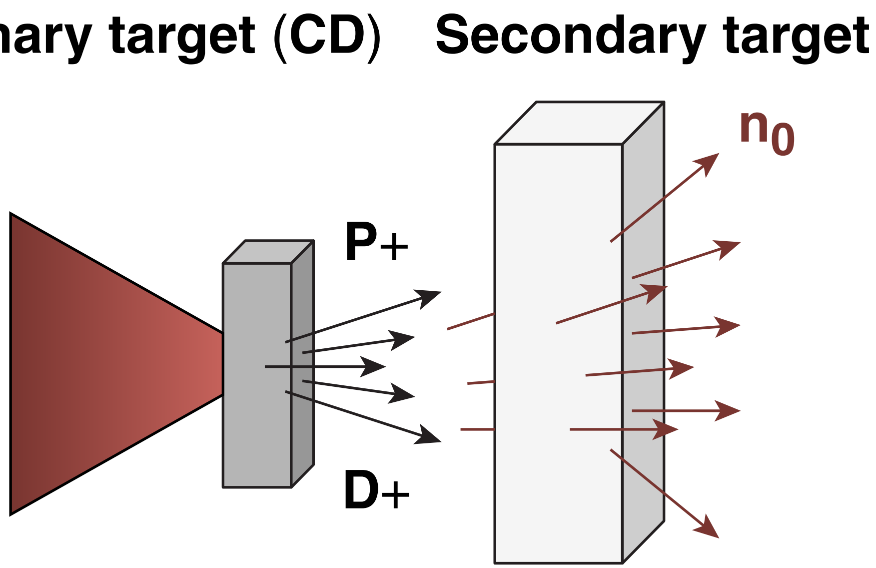
The nSpec Laboratory Basic Science (LBS) proposal studies neutron production in laser-driven, light-ion reactions



The short-pulse laser generates high-energy protons and deuterons off the primary target; nuclear reactions create neutrons in the secondary target

- CD, Be, and layered CD/Be secondary targets were used to study these reactions:
  1. Be^9 (d, t) ^8Be neutron pickup
  2. Be^9 (d, n) ^{10}B fusion/neutron stripping
  3. d (d, ^3He) n fusion
  4. d (t, α)n fusion as secondary reaction to process 1

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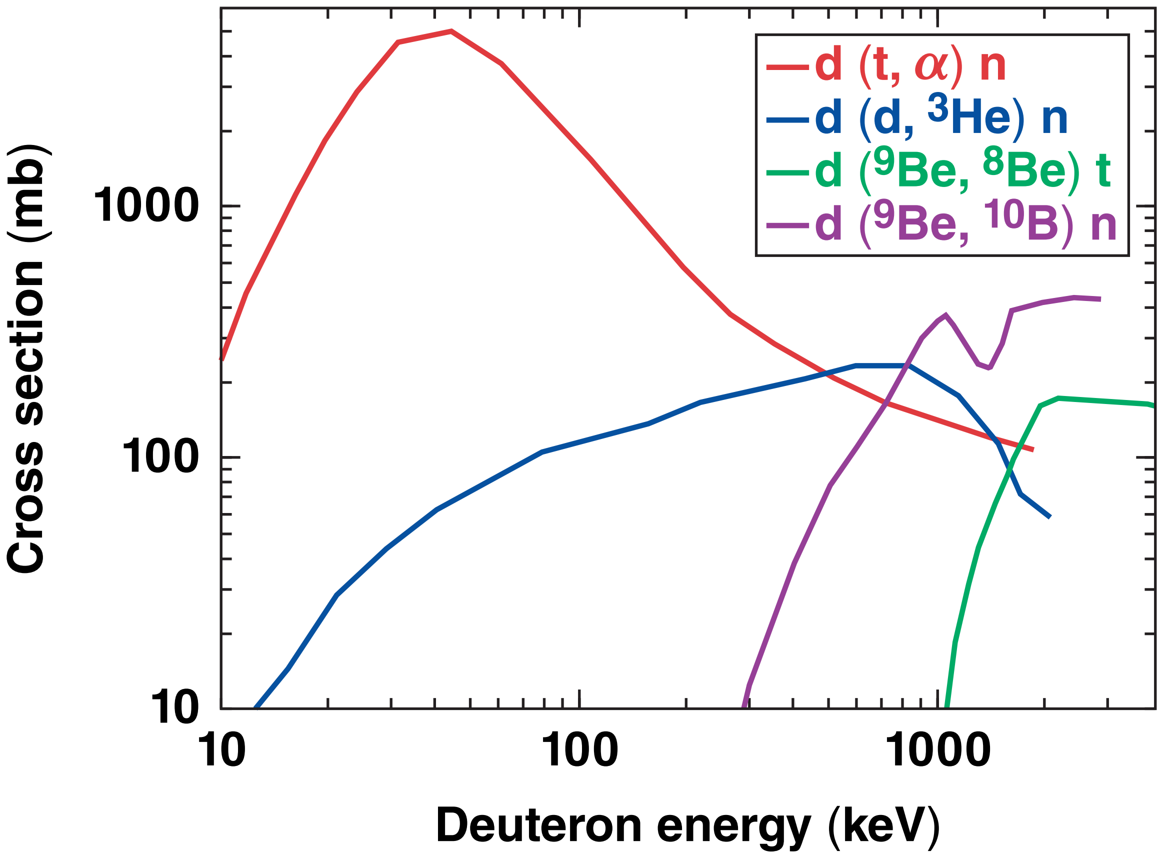
The cross sections for the deuteron reactions are comparable in the >1-MeV energy range



- The Be^9 (d, t) ^{8}Be reaction has a positive *Q* value of ~4.5 MeV
- The Be^9 (d, n) ^{10}B reaction has a positive *Q* value of ~4.3 MeV
- The d (d, ^{3}He) n reaction has a positive *Q* value of ~3.3 MeV
- The d (t, α) n reaction has a positive *Q* value of ~17.6 MeV

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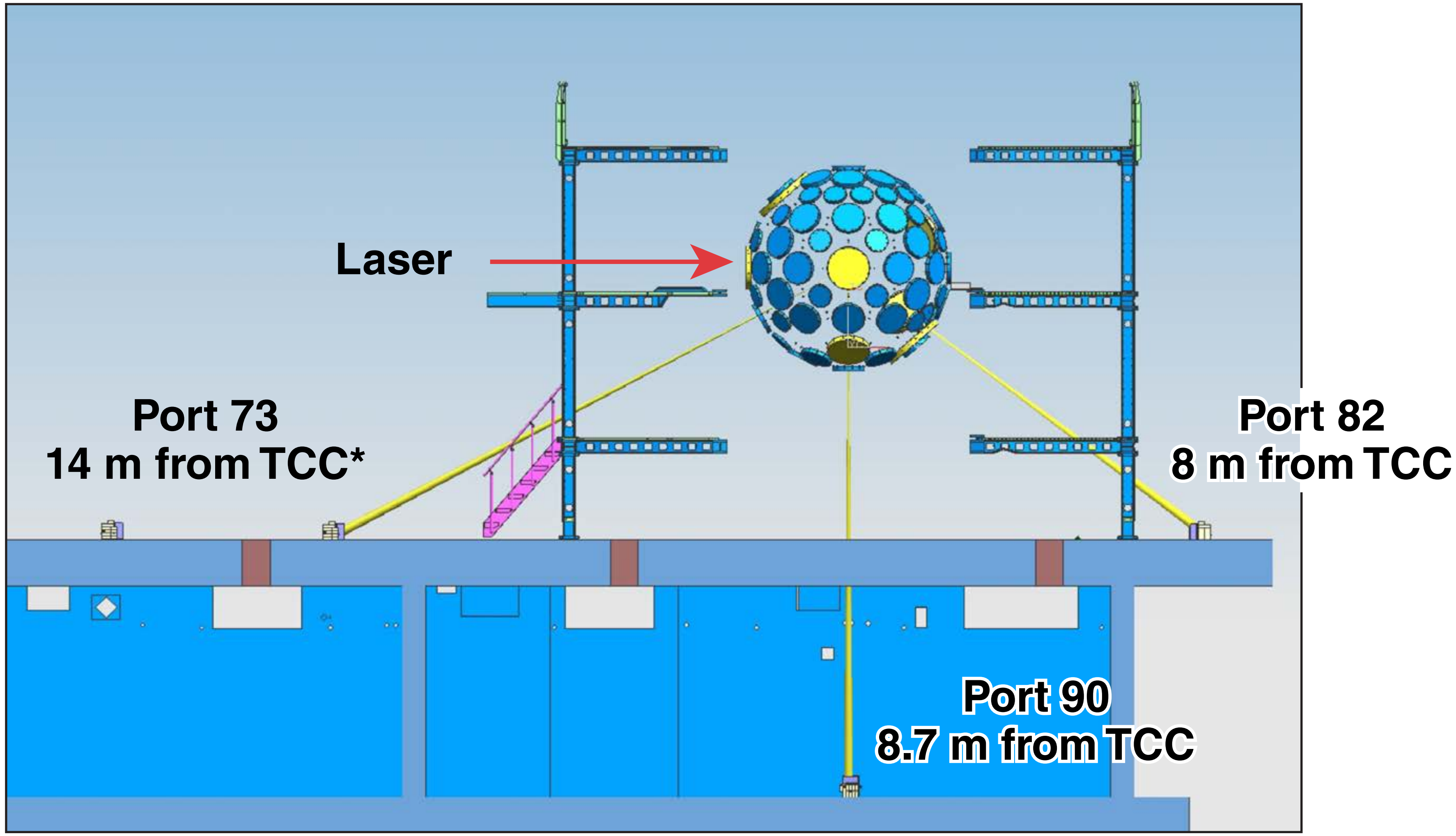
Three neutron time-of-flight (nTOF) detectors are installed on OMEGA EP at different angles to the laser direction



*TCC: target chamber center

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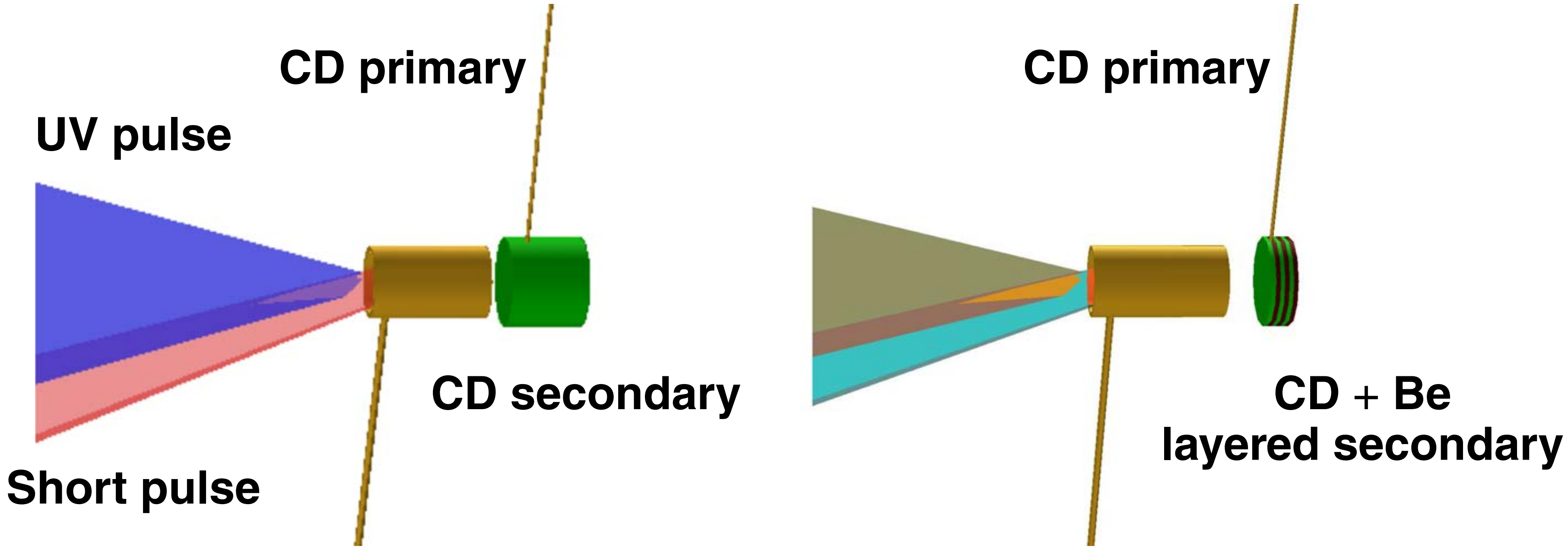
Two different secondary targets, a CD cylinder, and a stack of alternating CD and Be foils, were used



- A small (100-J) UV pulse fired 0.5 ns before the short pulse was used to suppress p–n reactions off the front side of the target
- The calculated range of an ~5-MeV deuteron is ~100 μm in beryllium
- The Be and CD foils in the stack had a thickness of 25 μm

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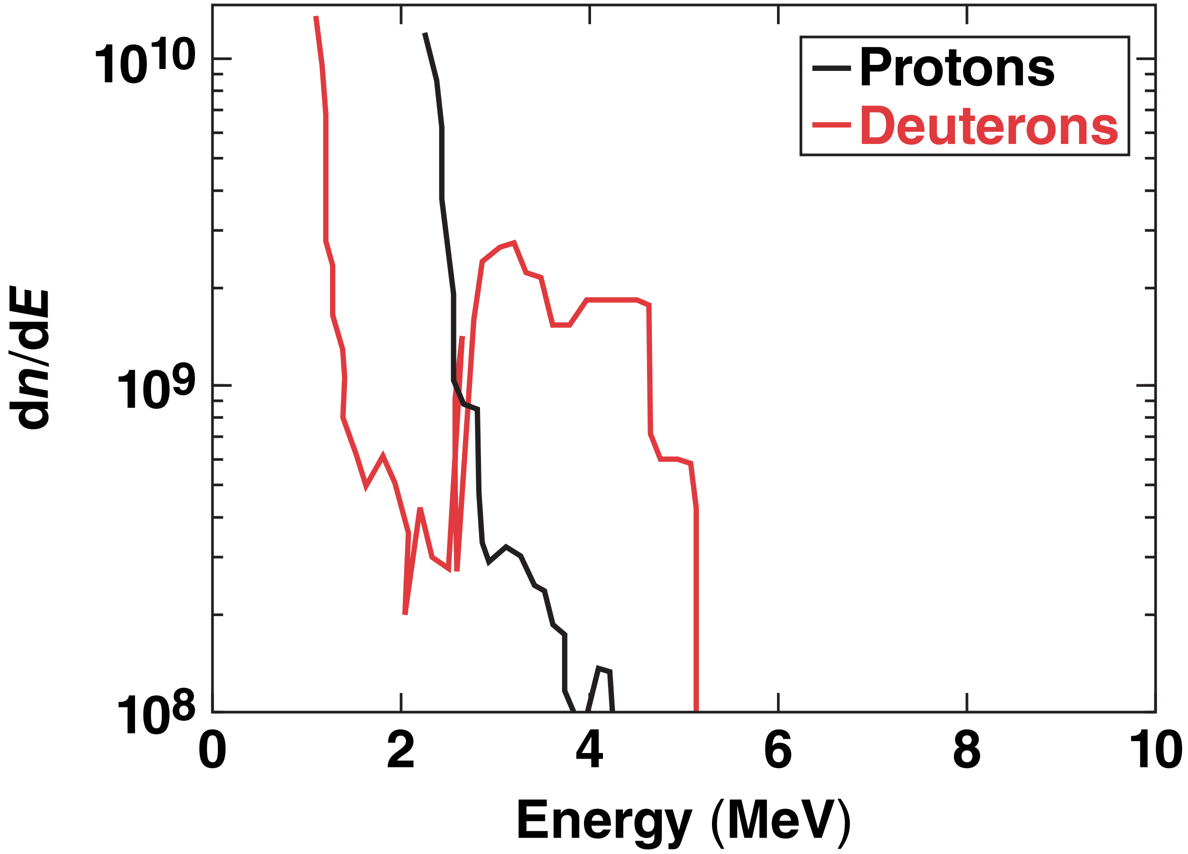
The spectrum of the ion flow off the backside of the primary target was measured using an ion spectrometer



- The high-energy end point of the ion spectrum is a strong function of the laser intensity
- The laser intensity was varied by up to a factor of 10 during the experiments

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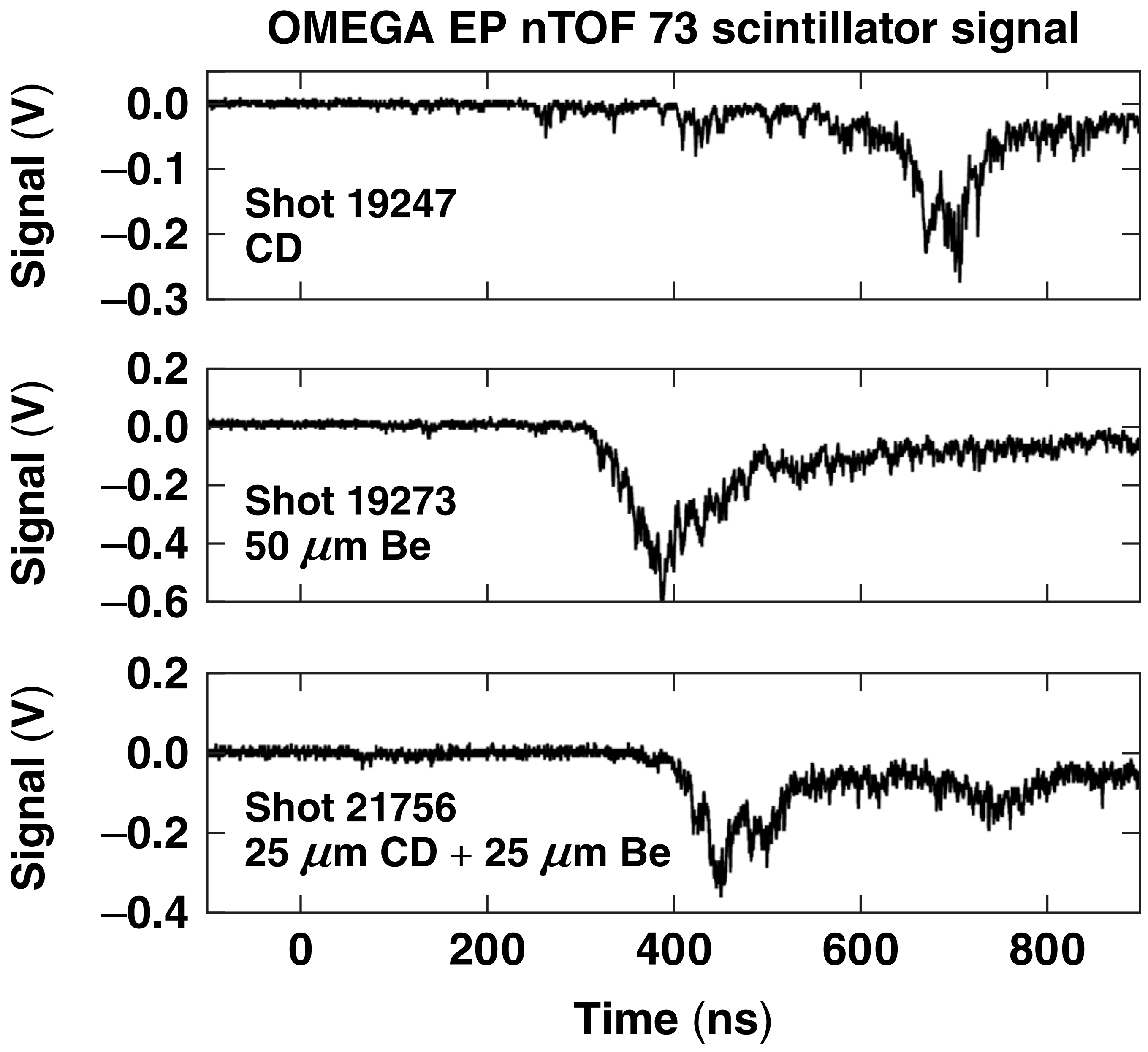
The nTOF spectrum changes significantly with the different secondary targets



CD primary target

Various secondaries

Laser: 10 ps, 1250 J

100- to 140-µm focus

$\sim 10^{18}$ W/cm^2

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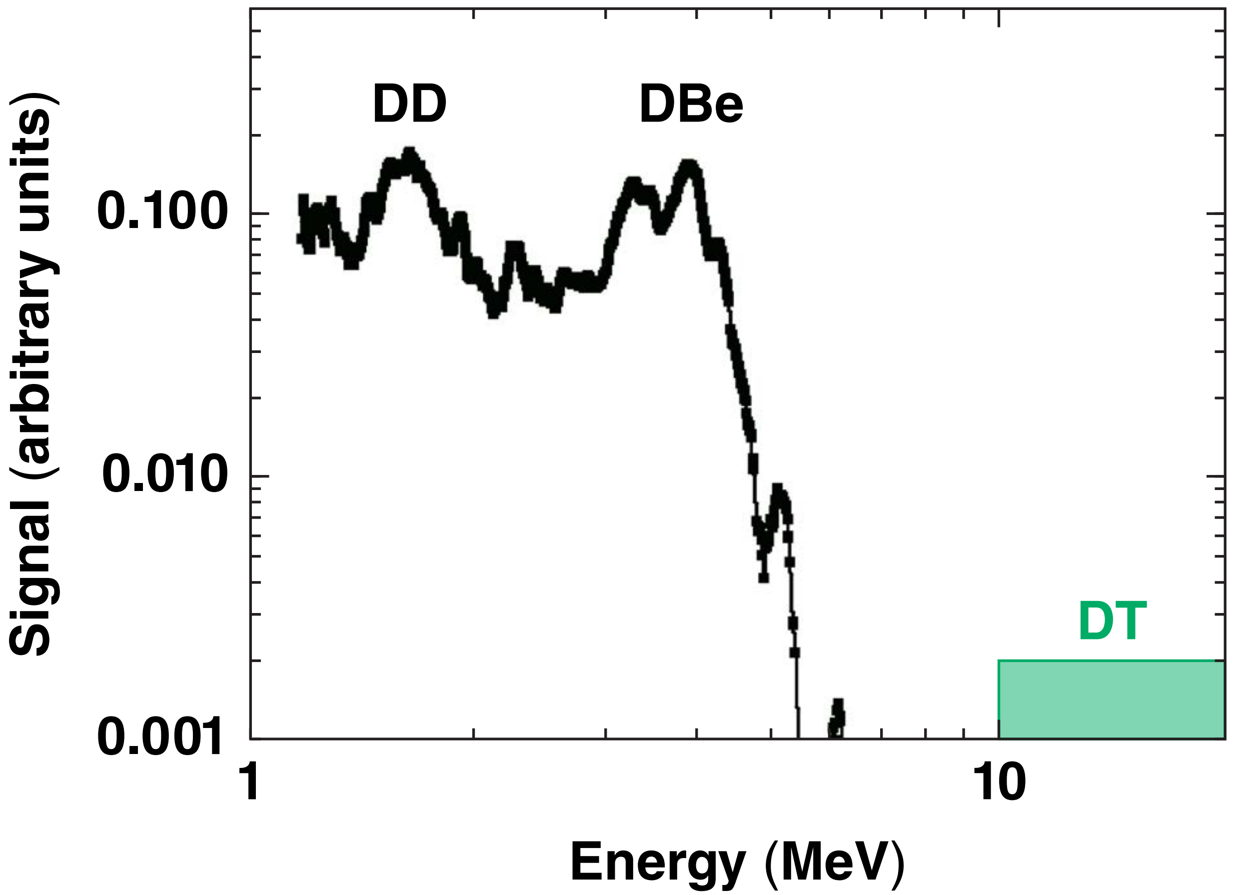
The neutron spectrum from the 25-μm CD/25-μm Be layered target shows DD and dBe neutrons



- The kinematic shift of the DD neutrons indicate a deuteron energy of ~2 to 4 MeV; the shifts of the DBe neutrons are consistent with a deuteron energy of 1 to 2 MeV
- No secondary DT fusion neutrons are seen from the Be^9 (d, t) ^{8}Be neutron pickup reaction

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A nuclear physics platform using laser-generated light ions is being developed at the Laboratory for Laser Energetics (LLE)

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