First Demonstration of a Triton Beam Using Target Normal Sheath Acceleration

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Target normal sheath acceleration (TNSA) can generate multi-MeV triton beams with miniaturized setups

- Deuterated and tritiated targets were shot on MTW and OMEGA EP
  - 25-μm-thick titanium was tritiated by gas exposure
  - The ion beams were examined using Thomson parabolas
  - The triton beam was used for pitcher – catcher nuclear experiments

- Key discoveries
  - The ion energy spectrum can be manipulated with the laser energy
  - The world’s first TNSA triton beam contained $10^{12}$ tritons up to 10MeV and induced D–T fusion ($10^8$ DT neutrons)

MTW: Multi-Terawatt laser
Collaborators

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Motivation

Inducing $T(t, 2n)\alpha$ with a controllable beam provides a “bare-reaction” standard for ICF without plasma effects

Lasers heat outer surface

Ablating material compresses core

Nuclear reactions

ICF: inertial confinement fusion
TNSA can deliver radioactive beams that are challenging to handle for accelerators

- A 25-μm thick target contains \( \sim 10^{16} \) tritons
- The laser produces a hot (~1-MeV) electron cloud at the target rear
- The electrons accelerate a cloud (“beam”) of \( \sim 1 \times 10^{12} \) tritons
- The energy spectrum can be manipulated with the laser
Small-scale MTW experiments were conducted to guide the large-scale OMEGA/OMEGA EP deuteron and triton campaigns.
A Thomson parabola (TPIE\textsuperscript{*}) was used to resolve ions of different $q/m$ and energies.

* Cobble et al., RSI 82 (2011).
The Thomson parabola was equipped with a custom absorber* to eliminate heavy contaminants.

A custom TPIE filter effectively removed all heavy species.
Deuterium beam spectra transition from exponential to quasi-Gaussian with increasing laser energy

- Higher laser energies increase the number of deuterons in the beam
Deuterium beam spectra transition from exponential to quasi-Gaussian with increasing laser energy

• Higher laser energies increase the number of deuterons in the beam
• Low laser energies produce exponential, higher energies quasi-Gaussian spectra

Large ion populations repel so low energies are suppressed.
Deuteron and triton beam spectra are exponential with energies exceeding 10 MeV.
The world’s first TNSA triton beam contained $10^{12}$ tritons up to 10MeV and induced D–T fusion ($10^8$ DT neutrons)

OMEGA EP

Neutron spectrum

E29581

Energy (MeV)

Neutrons ($\times 10^8$ MeV)

Experiment

Gaussian fit

Geant4

$2 \times 10^{18}$ W/cm$^2$
laser pulse

$500 \times 500 \times 25$ $\mu$m$^3$
tritiated metal

$500 \times 500 \times 100$ $\mu$m$^3$
deuterated plastic

nTOF scintillator
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Advantageous kinematics produce a peaked neutron spectrum even with a broad triton spectrum.