Introduction
The MIT Accelerator for development of ICF diagnostics at OMEGA / OMEGA-EP and the NIF

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Summary

- The MIT accelerator generates fusion products relevant for three NIF nuclear diagnostics based on CR-39:
  - DD-n yield diagnostic
  - Wedge-range-filter Proton Spectrometer
  - MRS Neutron Spectrometer

- It is currently used to support the development and calibration of new and existing diagnostics for use at OMEGA, OMEGA-EP and the NIF.

The MIT accelerator is capable of producing fusion products and beam ions relevant for ICF diagnostics development.
Fusion products produced by the accelerator
The accelerator is capable of producing several fusion products and beam ions

Primary products (kinematics not included):

\[ \text{D} + \text{D} \rightarrow \text{T} \ (1.01 \text{ MeV}) + \text{p} \ (3.02 \text{ MeV}) \]
\[ \text{D} + \text{D} \rightarrow \text{n} \ (2.45 \text{ MeV}) + ^3\text{He} \ (0.82 \text{ MeV}) \]
\[ \text{D} + ^3\text{He} \rightarrow \alpha \ (3.6 \text{ MeV}) + \text{p} \ (14.7 \text{ MeV}) \]

Beam ions:

\[ ^1\text{D}^+ \ (<150 \text{ keV}) \]
\[ ^3\text{He}^+ \ (<150 \text{ keV}) \]
\[ ^3\text{He}^{2+} \ (<300 \text{ keV}) \]
Radioactive sources and kinematic calculations are used to characterize the energy of the fusion products.

\[ ^{226}\text{Ra source (}\alpha\text{-source)} \]

for instrument calibration

\[ ^{3}\text{He}-p \quad (14.7 \text{ MeV}) \]

\[ 120 \text{ keV} \text{ D}^+ \text{ beam on } ^{3}\text{He} \]

\[ \text{DD-t (1.0 MeV)} \]

\[ \text{DD-p (3.0 MeV)} \]

Fusion product rates up to \(~10^7/s\) are readily achieved
Kinematic effects and ranging filters are exploited to provide fusion products with a large range of energies.
Primary Objectives...
The objective with the accelerator is to design and characterize instruments for diagnosing ICF plasmas at OMEGA, OMEGA-EP...

- Capsule diameter \(~1\) mm
- A direct-drive implosion
- 60 laser beams delivering 30 kJ on capsule in \(~1\) ns
- Direct or indirect drive
...and the National Ignition Facility (NIF) at LLNL

- 192 Laser Beams delivering 1.8 MJ on capsule
- Indirect drive or direct drive
- First credible ignition experiments ~2010

Cryogenic Hohlraum (length ~ 9 mm)
Diagnostic #1: CR-39-based neutron yield detector
Compact, CR-39 based DD-n detectors have been fielded on the NIF.
The accelerator has been used to measure the CR-39 efficiency for detection of DD-neutrons at OMEGA and the NIF

Shown here is detector package for both neutron and secondary proton measurements

The detection efficiency determined from the accelerator is applied to OMEGA and NIF data

F. H. Seguin, et al. (to be submitted)
M. Manuel et al. (this session)
CR-39 has been exposed to known fluences of neutrons on the MIT accelerator.

Silicon barrier diodes (SBDs) were used to measure the associated particle fluence (3MeV protons).
Detection efficiencies were determined for different yield processing techniques.

Detection efficiencies of DD-n of order $10^{-4}$ have been determined.
Diagnostic #2: Wedge-Range-Filter (WRF) Proton Spectrometer
WRF proton spectrometers have been fielded in the polar and 90-45 DIM on the NIF
The accelerator has been used to calibrate WRF spectrometers for the measurements of D-3He protons at OMEGA and the NIF.

Aluminum (left) and Zirconia (right) WRFs have been used on the recent NIF campaign.

The WRF spectrometers have been used at OMEGA and the NIF for diagnosing $\rho R$ and $\rho R$ asymmetries in a wide range of implosions through measurements of D-3He protons.
Calibration of new WRFs and recalibration of WRFs used on the NIF have been conducted on the accelerator.

3-line calibration of Zirconia WRF

<table>
<thead>
<tr>
<th>Energy, MeV</th>
<th>Yield per MeV</th>
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<tbody>
<tr>
<td>1.0E+00</td>
<td>1.0E+00</td>
</tr>
<tr>
<td>4.0E+07</td>
<td>4.0E+07</td>
</tr>
<tr>
<td>1.2E+08</td>
<td>1.2E+08</td>
</tr>
<tr>
<td>1.6E+08</td>
<td>1.6E+08</td>
</tr>
<tr>
<td>2.0E+08</td>
<td>2.0E+08</td>
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</tbody>
</table>

Both Aluminum and Zirconia WRFs showed no significant deterioration.

Deterioration during NIF campaign

<table>
<thead>
<tr>
<th>Energy (MeV)</th>
<th>Before NIF</th>
<th>After NIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.0</td>
<td>N0911115</td>
<td>N091204</td>
</tr>
</tbody>
</table>

Both Aluminum and Zirconia WRFs showed no significant deterioration.

Incident D-He3 protons

Zirconia “wedge’
Diagnostic #3: The Magnetic Recoil Spectrometer (MRS)
An MRS is currently implemented on the NIF for measurements of the ICF-neutron spectrum.

MRS on the NIF target chamber

Cross-section of the MRS for the NIF

Graduate student Dan Casey and the NIF MRS
The MRS’ on OMEGA and the NIF are using CR-39 for detecting recoil protons or deuterons

This spectrometer measures the absolute neutron spectrum (6-30 MeV) from which $\rho R$, $T_i$, and $Y_n$ can be determined for a large range of implosions.

The coincidence counting technique (CCT) for the MRS at OMEGA was developed and optimized using the accelerator.

By applying the CCT, S/B is enhanced orders of magnitude.*

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DHe³ protons were used to test the CCT and to show that it properly subtracts background with a 200µm bulk etch.

The background region is effectively zero, showing the CCT properly subtracts the background.
Some important references...