A New Neutron Time-of-Flight Detector for Yield and Ion-Temperature Measurements at the Omega Laser Facility

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A new neutron time-of-flight (nTOF) detector for deuterium–deuterium (D–D) fusion yield and ion-temperature measurements was designed, installed, and calibrated for the OMEGA Laser System. This detector provides an additional line of sight for D–D neutron yield and ion-temperature measurements for yields exceeding 1×10^{10} with higher precision than existing detectors. The nTOF detector consists of a 90-mm-diam, 20-mm-thick BC-422 scintillator and a gated Photek[1] photomultiplier tube (PMT240). This PMT has a 40-mm-diam photocathode, two microchannel plates, and provides a gain of up to 1×10^6. For DD measurements the PMT240 is operated at a bias voltage of –4.4 kV, corresponding to a PMT gain of 2×10^5. The PMT collects scintillating light through the 20-mm side of the scintillator without the use of a light guide. There is no lead shielding from hard x rays in order to allow the x-ray instrument response function of the detector to be easily measured. Instead, hard x-ray signals generated in implosion experiments are gated out by the PMT. The design provides a place for glass neutral-density (ND) filters between the scintillator and the PMT to avoid PMT saturation at high yields. The nTOF detector is installed in the OMEGA Target Bay along the P8A sub-port line of sight (LOS) with $\theta = 109.57°$ and $\phi = 90.00°$ (where θ and ϕ are the polar and azimuthal angles of the port in the target chamber coordinate system) at a distance of 5.3 m from the target chamber center. This detector is named P8A 5.3-m nTOF.

Until recently only two nTOF detectors on OMEGA [5.4-m nTOF (Ref. 2) located at 5.4 m from target chamber center (TCC) in sub-port H10G LOS with $\theta = 84.98°$ and $\phi = 311.76°$ and 12-m nTOFL (Ref. 3) located at 12.4 m from TCC in sub-port H8A LOS with $\theta = 87.86°$ and $\phi = 161.24°$] measured the D–D yield and ion temperature above the 2×10^{10} yield. The P8A 5.3-m nTOF detector provided an additional line of sight and increased the yield range of DD measurements on OMEGA. The P8A nTOF has a larger scintillator volume and records more neutron interactions than the other two detectors. The DD yield calibration of the P8A nTOF against the 12-m nTOFL detector is shown in Fig. 1. Only shots with yields exceeding 1×10^{10} were selected for the calibration. Figure 1(a) shows the charge of the neutron signal from P8A nTOF plotted versus the DD yield from the 12-m nTOF. The line in Fig. 1(a) is the linear fit of the data that is forced to go through the point (0,0). Figure 1(a) demonstrates a good linearity of the P8A nTOF detector signal for D–D yields up to 4×10^{11}. The data in Fig. 1 were recorded without an ND filter. When an ND filter is used there is practically no upper limit in D–D yield measurement for the P8A nTOF detector. Figure 1(b) shows the ratio of the yields from the two detectors as a function of the shot number.

Most of the LLE implosion campaigns are designed for DT yields in the range from 1×10^{13} to 1×10^{14} and recently for yields above 3×10^{14}. Therefore, the DT nTOF detectors on OMEGA were designed for such high yields. External OMEGA users, however, sometimes require DT yield measurements from 5×10^{10} to 1×10^{12}. The PMT high-voltage setting of P8A nTOF is adjusted from –4.4 kV for DD operation to –3.6 kV, corresponding to a PMT gain of 6×10^3 for the DT operation. The P8A nTOF was calibrated in DT yield against Cu activation. Figure 2(a) shows the charge of the neutron signal from P8A nTOF plotted versus the DT yield from Cu activation. The straight line in Fig. 2(a) is the linear fit of the data that is forced to go through the point (0,0). Figure 2(a) demonstrated that P8A nTOF is linear in desired DT yield range from 5×10^{10} to 1×10^{12}. Figure 2(b) shows the ratio of the yields from the two detectors as a function of shot number.

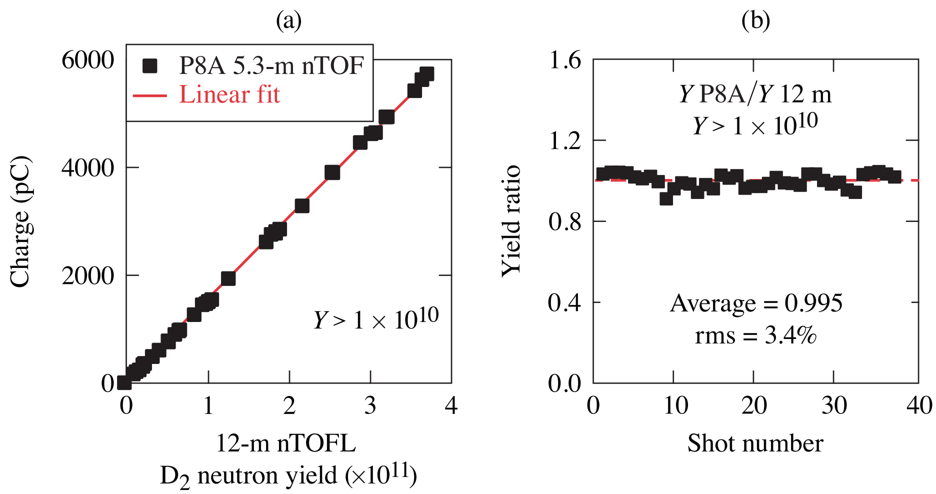

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Figure 1
(a) DD neutron calibration of P8A 5.3-m nTOF against 12-m nTOFL detector and (b) the ratio of DD yield measured by P8A 5.3-m nTOF and 12-m nTOFL detectors.

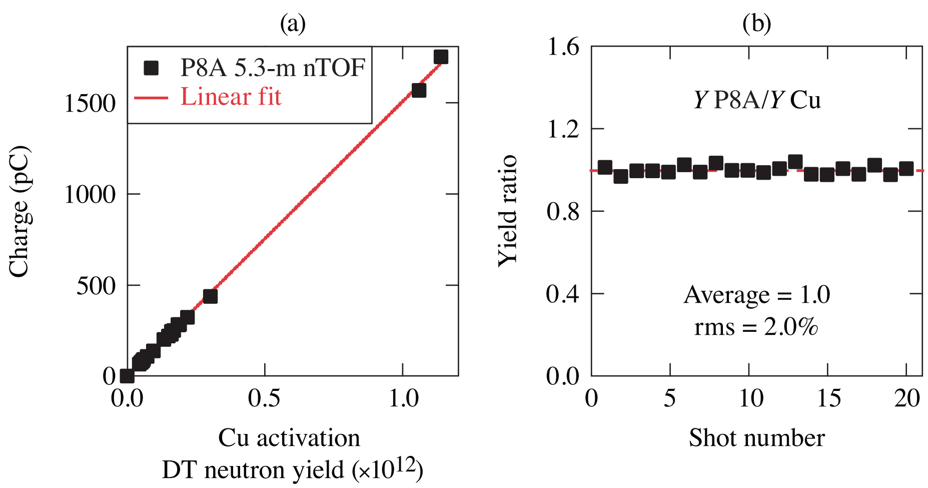

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Figure 2
(a) DT neutron calibration of P8A 5.3-m nTOF against copper activation and (b) the ratio of DT yield measured by P8A 5.3-m nTOF and copper activation.

A new nTOF detector was installed and calibrated on the OMEGA Laser System. This detector is now a standard OMEGA diagnostic for D–D yields above 1×10^{10} and DT yields from 5×10^{10} to 2×10^{12}.

This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0003856, the University of Rochester, and the New York State Energy Research and Development Authority. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. This paper describes objective technical results and analysis.

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