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Abstract. Experiments resulting in a significant neutron yield are scheduled to start in 2010 at the National Ignition Facility (NIF). A wide range of diagnostics will be used to measure several parameters of implosion such as the core and fuel shape, temperatures and densities, and neutron yield. Accurate evaluations of the neutron and gamma backgrounds are important for several diagnostics, such as the High Energy X-ray Imager (HEXRI). Several Monte-Carlo simulations were performed to identify the expected signal to background ratios at several potential locations for the HEXRI diagnostics. Gamma backgrounds were significantly reduced by using tungsten collimators. The collimators resulted in the reduction of the gamma background at the HEXRI scintillators by more than an order of magnitude during the first 40 ns following a THD shot.

1. Introduction

The National Ignition Facility (NIF) at Lawrence Livermore National Laboratory is the world's largest and most powerful laser system for inertial confinement fusion. NIF is a 192 laser beam facility that is capable of producing 1.8 MJ, 500 TW of ultraviolet light. Experiments resulting in a significant neutron yield are scheduled to start in 2010 at the NIF. Several experiments utilizing Tritium-Hydrogen-Deuterium (THD) and Deuterium-Tritium (D-T) targets are scheduled as part of the National Ignition Campaign (NIC). The THD and D-T targets have different spectrum and the THD spectrum will depend on the fraction of deuterium in the target. A wide range of diagnostics will be used to measure several parameters of implosion such as the core and fuel shape, temperatures and densities, and neutron yield. Accurate evaluations of the neutron and gamma backgrounds are important for several diagnostics, such as the High Energy X-ray Imager (HEXRI). Several sources of neutron and gamma backgrounds will impact the accuracy of the diagnostics measurements. Fusion neutrons generated by fuel burn and secondary neutrons resulting from the fusion neutrons interaction with structures present inside and outside the Target Chamber (TC) contribute to the neutron background. Inside the TC, neutrons interact with the Cryogenic Target Positioner (CRYO TARPOS), the Target Positioner (TARPOS), and three other Diagnostics Instruments Manipulators (DIM). Neutrons also interact with aluminum TC, TC concrete shield, TC port covers, and the Final Optics Assemblies (FOA). In the meantime, x-rays emitted from implosion, x-rays resulting from laser plasma interaction (LPI) of NIF beams with the hohlraum, and gamma-rays induced by neutron interactions with different structures inside and outside the TC contribute to the gamma background. A detailed model has been developed of the NIF facility and all structures inside the TC. Several Monte-Carlo simulations were performed to identify the expected signal to background (S/B) ratios at several potential locations for the HEXRI diagnostics. This paper updates and expands on our previous published work [1].

2. Computational Model

A detailed 3-D model of the NIF facility has been developed using the MCNP [2] radiation transport code. The Target Chamber (TC) is made of a 10-cm-thick aluminum wall surrounded by 40-cm of borated concrete. The TC includes, 48 indirect-drive and 24 direct-drive laser beam ports as well as 120 diagnostic ports. All diagnostic and direct-drive ports are assumed to be unshielded and only covered with ~ 2"-thick port covers made of aluminum alloy. Indirect-drive ports are connected to fully modeled Final Optics Assemblies (FOA). The Target Bay (TB) shielding walls are made of 6'-thick concrete, and the typical thickness of a concrete Switchyard wall is 3'–3". The detailed TB model used in this analysis is shown in Figure 1.

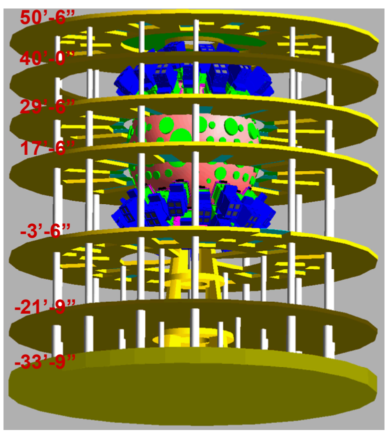

Figure 1. Target Bay model.

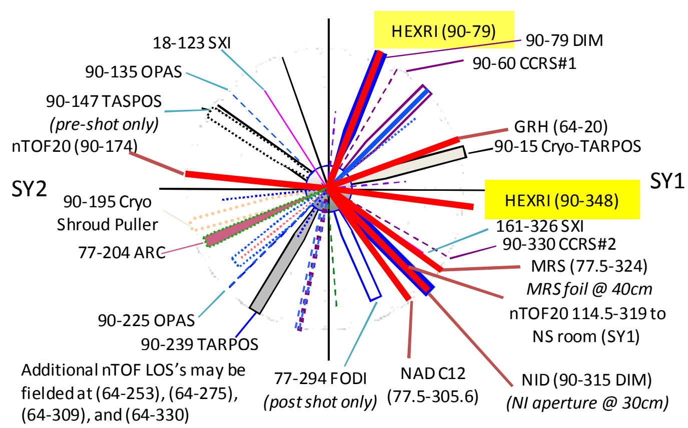

Figure 2. Potential locations of ignition/implosion diagnostics.

Figure 2 shows the NIF TC with potential locations for ignition diagnostics. The two target positioners use the (90°, 15°) and the (90°, 239°) TC ports. Two equatorial DIMs use ports (90°, 315°) and (90°, 45°), and a polar DIM uses the (0°, 0°) port. In this paper we present our evaluation of the radiation background associated with the HEXRI diagnostics. We examined the possibility of installing the HEXRI detectors outside the TC ports, namely at (90°, 79°) and (90°, 348°). As shown in Figure 2, additional diagnostics like neutron activation diagnostics (NAD), neutron imaging (NI), magnetic recoil spectrometer (MRS), gamma reaction history (GRH), and neutron-time-of-flight (nToF) will be installed at different locations inside and outside the TC. Evaluation of the radiation backgrounds associated with these diagnostics will be presented in future publications.

3. Radiation Backgrounds associated with the High Energy X-ray Imager (HEXRI) System

HEXRI goal is to record the self-emission x-rays generated in the fuel core. The HEXRI system is used to provide a sequence of two-dimensional radiographs of imploding targets. The radiographs are created by firing four beamlets of the NIF-ARC petwatt laser system on gold backlighters, and Bremsstrahlung emitted by the backlighters is used to image the target. The backlighters are installed on the (90°, 239°) target positioner (TARPOS) and located at a distance of 5 cm from the TCC. The radiographs are recorded by scintillators located outside the (90°, 79°) and (90°, 348°) TC ports at a distance of 6 m from TCC and optically relayed to a gated CCD camera.

Several sources of radiation background have an impact on the signal recorded by HEXRI. Direct neutron impact on the collected signal has been eliminated by gating the HEXRI to ≤ 40 ns. Neutrons can only travel to within 2 m from TCC during this time and do not impact the collected signal. On the other hand, two gamma background sources do interfere with the collected signal. The first gamma source is the hard x-rays generated by LPI of the NIF laser with the hohlraum. These x-rays are partially shielded by restricting the portion of the hohlraum seen by the detector by carefully placing multiple collimators near the hohlraum. The collimators are made of platinum and are placed at distances of 4 mm and 5 cm from the TCC. The second gamma source is generated by the neutrons interactions with masses in the vicinity of the target. Gammas generated (mostly through n,γ reactions) within a 2 m distance from TCC will contribute to the background signal. Contribution to the collected signal was minimized through the use of 1-cm thick conical tungsten collimators. The collimators extended from a distance of 2.5 m from the TCC to the scintellators outside the TC ports. Figure 3 shows the HEXRI detector setup.

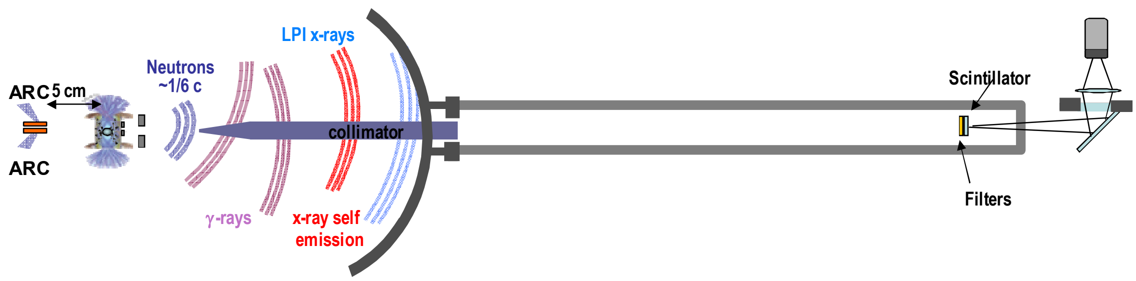

Figure 3. HEXRI detector setup.

Several models for near target chamber centre (TCC) masses were added to the NIF facility model. Photon production and neutron scattering within a two-meter radius from the TCC significantly impact the radiation backgrounds seen by the HEXRI detectors. Model for the hohlraum, the target positioners, the two equatorial DIMs, the polar DIM, MRS foil and NI collimator were included. The TC model showing the near TCC masses is shown in Figure 4. Design of the tungsten collimators was based on an evaluation of the contribution to the gamma background signal due to different near TCC masses. As shown in Figure 5, the two target positioners are the main contributors to the background signal. The tungsten collimators were designed to minimize contributions from these masses.

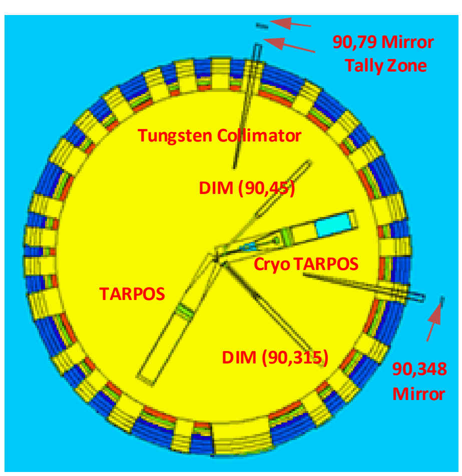

Figure 4. Masses near TCC.

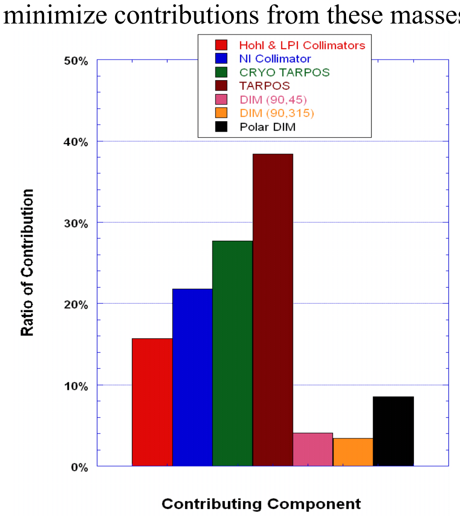

Figure 5. Contributions to background without collimators.

The radiation backgrounds were estimated for a THD target with 2% deuterium yielding a neutron yield of 2×10^{14}. Figures 6 and 7 show the neutron and gamma fluences expected during the first 40 ns following the shot, respectively. As shown in the figures, the tungsten collimators were effective in minimizing the gamma streaming through the TC ports.

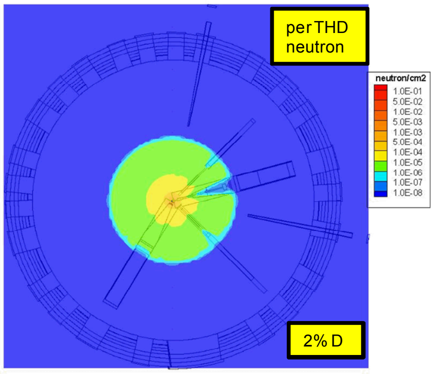

Figure 6. Neutron fluence during first 40 ns.

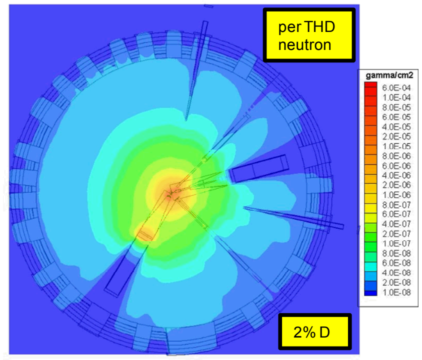

Figure 7. Gamma fluence during first 40 ns.

The impact of using the tungsten collimators on the recorded signal is further illustrated in Figure 8. The collimators were able to reduce the gamma background due to n,γ reactions by more than an order of magnitude. Finally, as shown in Figure 9, the set of collimators limited the background to signal (B/S) ratios from all sources to less than 10% of the estimated recorded signal.

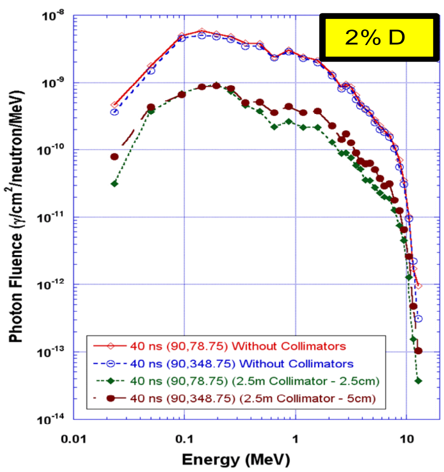

Figure 8. Gamma spectrum due to n,γ reactions.

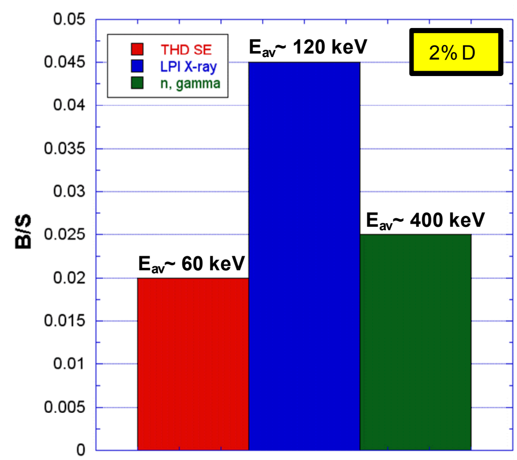

Figure 9. Gamma B/S ratio.

4. Conclusions

Detailed simulation of the radiation environment in NIF allowed for good understanding of the important issues related to performance of the HEXRI system. TARPOS and CRYO TARPOS are the largest contributors to the HEXRI gamma background. The use of tungsten collimators reduced the gamma background experienced by HEXRI detectors by more than an order of magnitude during THD shots. The current setup of the HEXRI system provides adequate reduction of radiation backgrounds.

Acknowledgement

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References

[1] L. Dauffy et al.;, "*Gamma Background Calculation for the HEXRI Diagnostics ate the National Ignition Facility,*" Journal of Physics: Conference Series 112 (2008) 032085

[2] X-5 Monte Carlo Team, "*MCNP - A General Monte Carlo N-Particle Transport Code, Version 5,*" Los Alamos National Laboratory, LA-UR-03-1987 (2005)