LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

LLNL-CONF-416019

SIMULATION OF RADIATION BACKGROUNDS ASSOCIATED WITH NUCLEAR DIAGNOSTICS IN THE NATIONAL IGNITION FACILITY

H. Khater, L. Dauffy, R. Tommasini, M. Eckart, D. Eder

August 21, 2009

The 6th International Conference on Inertial Fusion Sciences and Applications 2009
San Francisco, CA, United States
September 6, 2009 through September 11, 2009

Disclaimer

Simulation of Radiation Backgrounds Associated with Nuclear Diagnostics in the National Ignition Facility

H. Y. Khater, L. S. Dauffy, R. Tommasini, M. J. Eckart, and D. C. Eder
Lawrence Livermore National Laboratory

Abstract

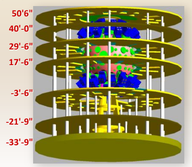
Experiments resulting in a significant neutron yield are scheduled to start in 2010 at the National Ignition Facility (NIF). Several experiments utilizing Tritium-Hydrogen-Deuterium (THD) and Deuterium-Tritium (DT) targets are scheduled as part of the National Ignition Campaign (NIC). A wide range of 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) and Neutron-Time-Of-Flight (nTOF). 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. In the meantime, X-rays emitted from the 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 ratios at several potential locations for the HEXRI and nTOF diagnostics. Gamma backgrounds associated with HEXRI were significantly reduced by using a tungsten collimator. The collimator resulted in the reduction of the gamma background at the HEXRI scintillator by more than an order of magnitude during the first 40 ns following a THD shot. The nTOF20 detectors inside the Neutron Spectrometry room are exposed to low levels of neutron and gamma background during yield shots.

Simulation of Neutron and Gamma Backgrounds for the NIF Diagnostics

- Experiments utilizing Tritium-Hydrogen-Deuterium (THD) and Deuterium-Tritium (DT) targets are scheduled as part of the National Ignition Campaign (NIC)
- 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
- The High-Energy X-Ray Imager (HEXRI) will be used on cryogenic DT implosions at NIF to provide data on the size and shape of the imploding capsules
- The neutron time-of-flight (nTOF) diagnostic will measure ion temperature, absolute and relative yields of primary and downscattered neutrons, and neutron bang time
- Following an implosion, the background from neutrons and gamma can affect the quality of HEXRI images and the nTOF detector response in terms of lowering the signal-to-background ratio

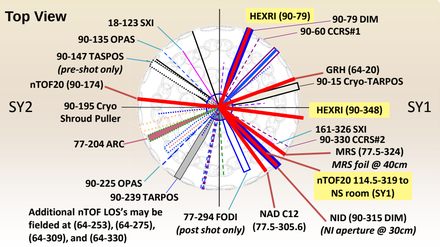
Modeling of the NIF Facility

- Radiation streaming through the Target Chamber and Target Bay (TB) wall penetrations increase the neutron and gamma backgrounds
- Target Chamber Penetrations
  - ✓ 48 indirect-drive beam ports (FOAs)
  - ✓ 24 direct-drive beam ports
  - ✓ 120 diagnostic ports
- Target Bay Wall Penetrations
  - ✓ Laser beam path in TB walls
  - ✓ 175 utility penetrations
  - ✓ 13 diagnostic penetrations

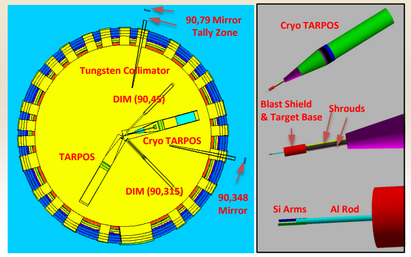


3-D Model of Target Bay

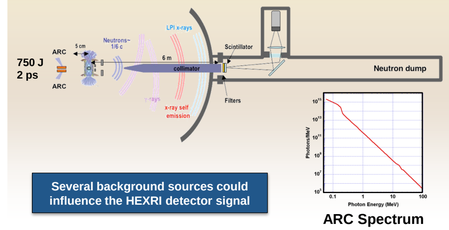
Target Chamber with Potential Locations of Ignition/Implosion Diagnostics



Modeling of Masses near TCC



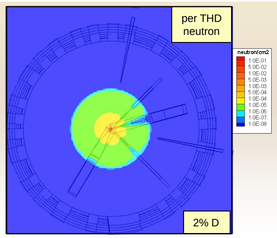
HEXRI Detector Setup



ARC Spectrum

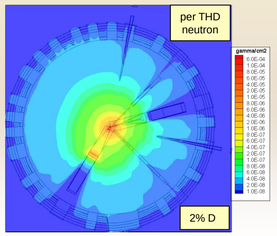
Several background sources could influence the HEXRI detector signal

Map of Neutron Fluence during First 40 ns



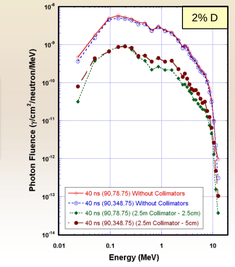
Photons generated by neutron interactions with nearby masses will have significant impact on HEXRI performance

Map of Gamma Fluence during First 40 ns



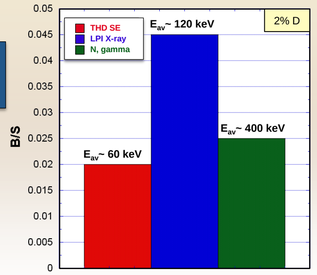
The use of collimators limited the gamma background seen by HEXRI detectors

HEXRI Gamma Spectrum due to (n,γ) Reactions



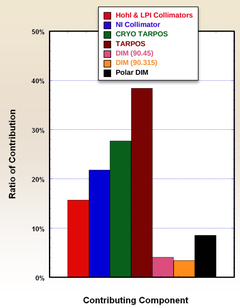
The tungsten collimators reduced the gamma background by more than an order of magnitude

Gamma Background-to-Signal Ratio (with W Collimator)



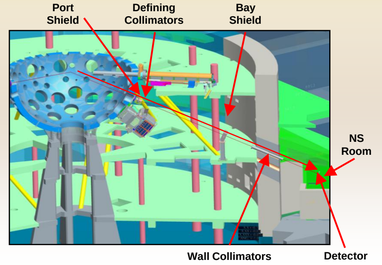
Background-to-Signal ratios are acceptable

Contribution to the Gamma Background without Collimators

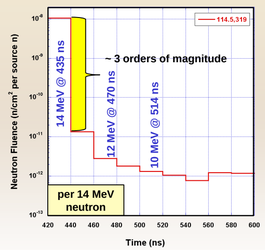


TARPOS and CRYO TARPOS are the largest contributors to the gamma background

Layout of the nTOF20 at (114.5,319)

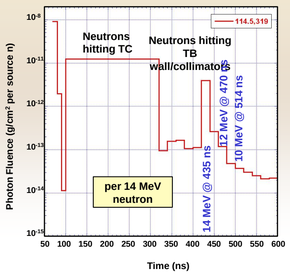


Neutron Fluence outside TB Wall at 22.32 m



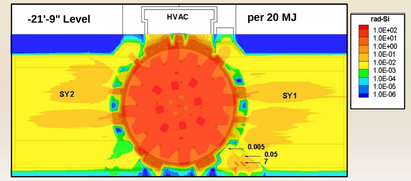
The low neutron background allows for accurate measurement by nTOF detectors

Gamma Fluence outside TB Wall at 22.32 m



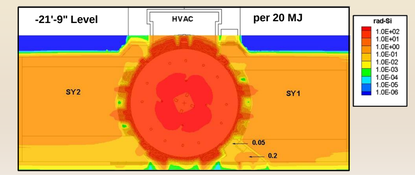
Low gamma background in the Neutron Spectrometry room at -21'-9"

Neutron Dose in the NS Room during Yield Shots



Damage to electronics racks could be minimized by careful placement of the racks inside the Neutron Spectrometry (NS) room at -21'-9"

Gamma Dose in the NS Room during Yield Shots



Gamma dose is higher than neutron dose near the Target Bay wall due to the high level of (n,©) reactions in the outer layers of the 6'-thick concrete wall

Summary

- Detailed simulation of the radiation environment in NIF allowed for good understanding of the important issues related to performance of several proposed nuclear diagnostics
- Development of models that include important details relevant to the different NIF diagnostics is underway
- Accurate simulation of neutron and gamma backgrounds are essential for success of nuclear diagnostics used during the ignition campaign
- The use of tungsten collimators reduced the gamma background experienced by HEXRI detectors by more than an order of magnitude during THD shots
- TARPOS and CRYO TARPOS are the largest contributors to the HEXRI gamma background
- The nTOF20 detectors inside the Neutron Spectrometry room at -21'-9" are exposed to low levels of neutron and gamma backgrounds during yield shots
- Careful placement of electronics racks inside the Neutron Spectrometry room will minimize their exposure to radiation background during yield shots

NIF-0809-17142 • LLNL-CONF-416019

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.