Optimization of Neutron Activation of Carbon at the NIF

S. Padalino, D. Polsin, M. Russ, State University of New York at Geneseo
C. Sangster Laboratory of Laser Energetics, University of Rochester

Goals
- To determine the lower limit on the tertiary yield measurement for the carbon activation diagnostic.
- Examine the geometric and attenuation losses in the activation diagnostic at the NIF chamber
- A verification of MCNPX calculations
- A study of the published $^{12}$C(n,2n) cross sections in the 20 to 30 MeV energy range

Approach
- A finite element calculation was performed to set the lower limit on the sensitivity of the activation diagnostic
- A verification of MCNPX calculations

Carbon Activation and Positron Annihilation

$^{12}$C(n,2n)$^{11}$C reaction (insensitive to primary & scattered neutrons)

- Tertiary Neutrons
- Robust, inexpensive, reusable and reliable

Carbon is ideal for the detection of primary and secondary neutrons for several reasons:
- Only tertiary neutrons from the burn contribute to the $^{12}$C(n,2n)$^{11}$C reaction (insensitive to primary & scattered neutrons)
- Sensitive to the fuel density-radius product ($\rho$)$^2$
- Robust, inexpensive, reusable and reliable

LLE Detector Setup

The six NaI detectors are arranged on Cartesian axis. The detectors are shielded with lead to reduce ambient background radiation.

Angular Distributions of Neutrons

Tertiary to Primary Ratio: 1 tertiary per 1,000,000 primary's

- The angular distributions of elastically scattered neutrons shows that it is unlikely for neutrons to be scattered at angles greater than 60 degrees.
- Neutrons with an energy less than 20.3 MeV do not play a role in the activation of Carbon.
- Very few neutrons are produced greater than 27 MeV in an ICF reaction.

Other Related Cross Section Data

$^{12}$C(n,elastic) vs. energy (MeV)

- For our calculation, we only care about the energy range from 20.3 MeV to 30 MeV. We have estimated the cross section value to be constant over this range, 1.0 barns.

$^{12}$C(n,tot) vs. energy (MeV)

- For our calculation, we only care about the energy range from 20.3 MeV to 30 MeV. We have estimated the cross section value to be constant over this range, 1.0 barns.

MCNPX Analysis

The following neutron energy spectrum was used in the MCNPX input file. The graph below is the cross section file used, which is library 6000.66 for natural carbon, but more importantly includes data from 20.3 MeV to 30 MeV. The input geometry file and the PTRAC data were displayed using iViPP software.

MCNPX and iViPP Analysis

Using the visualization program iViPP, which is capable of displaying neutron trajectories using the MCNP PTRAC files, we manually determined the activation for 1 mm slices of graphite, using disk selectors and determining the flux of neutrons through successive planes. In the image to the right, we have placed a disk selector in the center of the graphite cylinder. The black tracks are the neutrons passing through the plane of the graphite, while the red are the tracks of the neutrons which have scattered from the graphite.

Conclusion

Using the fluences from iViPP, we were able to calculate the activation of the graphite from the MCNPX data and compare it to the calculated finite element activation.