Multi-Detector Array for Measuring Tertiary Neutron Anisotropies in DT ICF Targets

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Experimental Goals

- Develop a diagnostic to measure DT neutron anisotropies in a ICF burn at the NIF.
- The diagnostic will be composed of eight ultrapure graphite disks used as tertiary neutron detectors strategically placed around the NIF chamber which will become activated during the burn.
- Efficiently measure the back-to-back 511 keV gamma rays created by positron decay of the radioactive 11C using eight on Axis pairs of NaI(Tl) detectors. Also to limit the number of accidental coincidences, minimize ambient background gamma ray counts, and maximize geometric counting efficiency.
- From this diagnostic determine the yield and distribution of tertiary neutrons resulting from an ICF reaction.

ICF, Graphite Activation, and Positron Annihilation

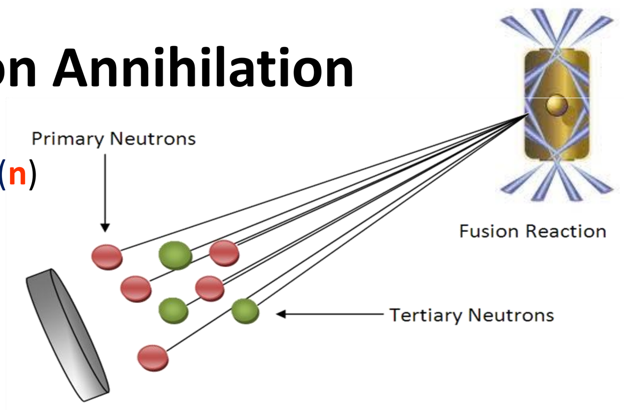
DT fuel in an ICF reaction produces 4He and a primary neutron (n)

$D_{fuel} + T_{fuel} \rightarrow \alpha + n$ Primary neutrons are roughly 14.1 MeV

$n + D_{fuel} \rightarrow n^{*} + D_{ko}$ Producing 0 – 12.5 MeV knock-ons

$D_{ko} + T_{fuel} \rightarrow \alpha + n^{**}$ Producing 12 - 30 MeV tertiary neutrons

The number of tertiary neutrons is related to $(\rho r)^2$ or ρr



Tertiary to Primary Ratio:
1 tertiary per 10E6 primaries.

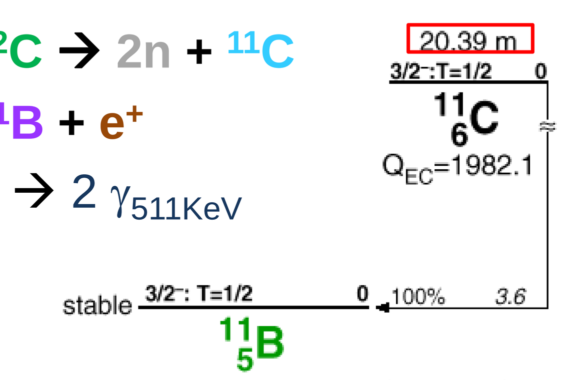
Graphite is ideal for the detection of tertiary neutrons for several reasons:

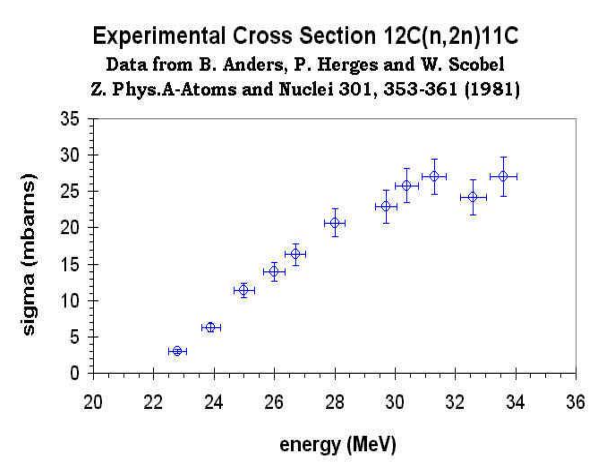
- Only tertiary neutrons from the burn contribute to the 12C(n,2n)11C reaction (insensitive to primary & scattered neutrons)
- Sensitive to the fuel density-radius product $(\rho r)^2$
- Robust, inexpensive, reusable and reliable

$n^{**} + {}^{12}C \rightarrow 2n + {}^{11}C$

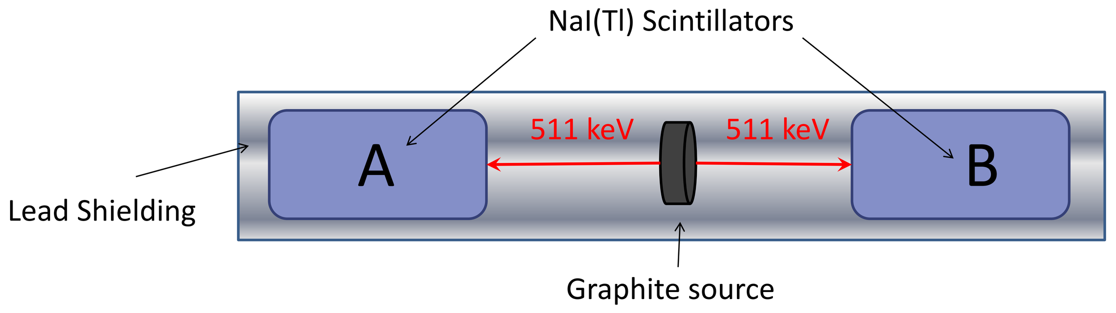
${}^{11}C \rightarrow {}^{11}B + e^{+}$

$e^{+} + e^{-} \rightarrow 2\ \gamma_{511KeV}$





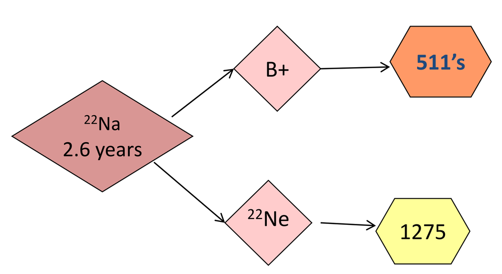
On Axis Coincidence Setup

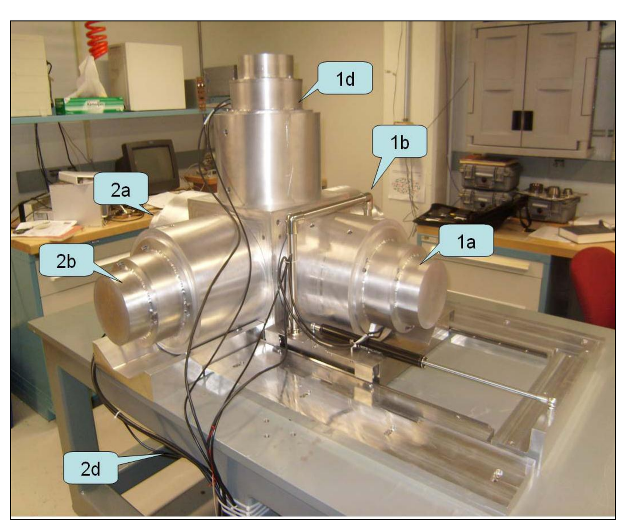


Multiple On Axis Detector Setup

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

Shielded detector setup at the Laboratory for Laser Energetics. During acquisition, a Graphite sample is placed in the center of the array.

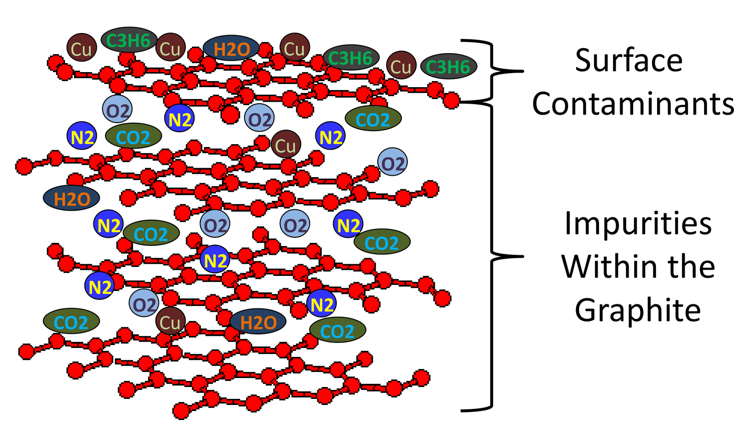




Graphite Contaminants

Graphite is very porous, air contaminants are found in its structural layers. There are also many possible surface and volumetric contaminants.

Contaminants include:	Reaction:
Nitrogen (N2)	14N(n,2n)13N
Oxygen (O2)	
Water (H2O)	12C(p,g)13N
Carbon Dioxide (CO2)	
Copper (Cu), other metals	63Cu(n,2n)62Cu
Hydrocarbons	12C(p,g)13N



Contamination by 14N, 63Cu, and other metals that have relatively high (n,2n) reaction cross sections for primary neutrons are of concern. Once activated, 13N and 63Cu will decay via positron emission with half lives on roughly the same order of magnitude as that of activated Graphite samples (11C).

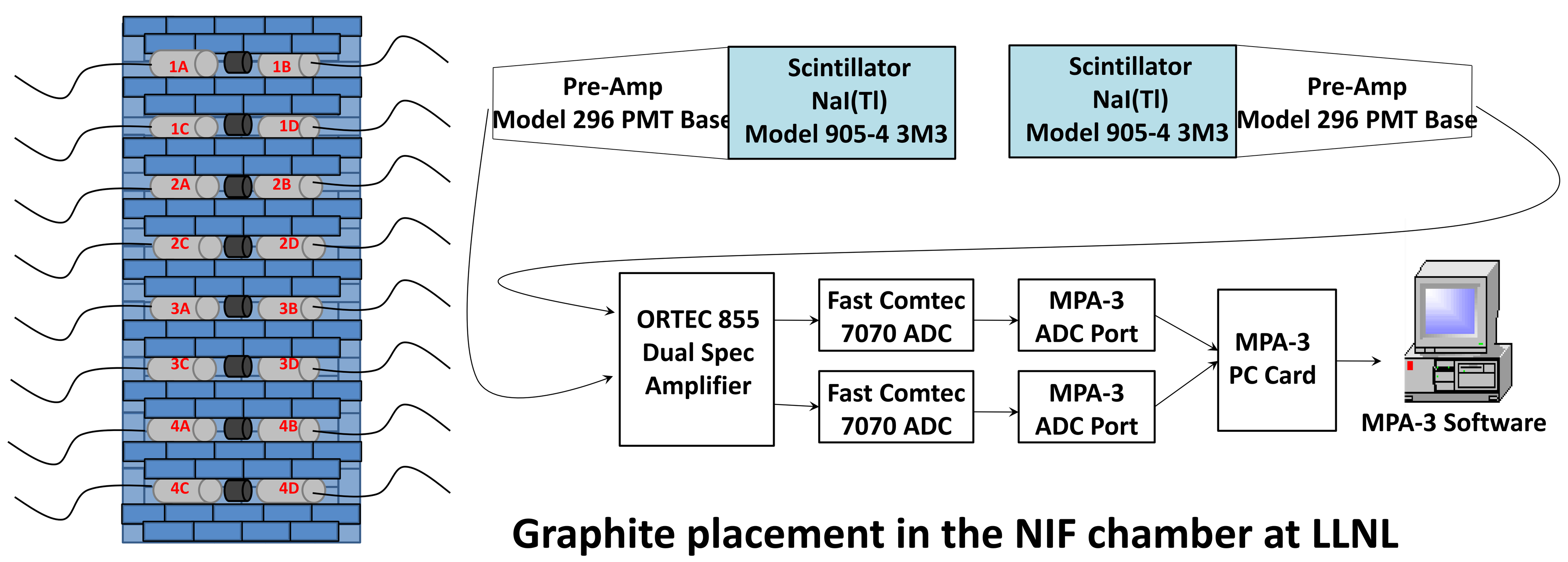
Graphite Purification

- Surface contaminants are removed with an ethanol wash.
- Internal contaminates are removed by baking the graphite at 1000 °C for 1 hour under a 20 micron vacuum, air and other volumetric contaminants like hydrocarbons are removed from the sample. Once cooled to room temperature the vacuum is backfilled with argon gas.
- The graphite is packaged in an argon environment at STP which prevents air infiltration.

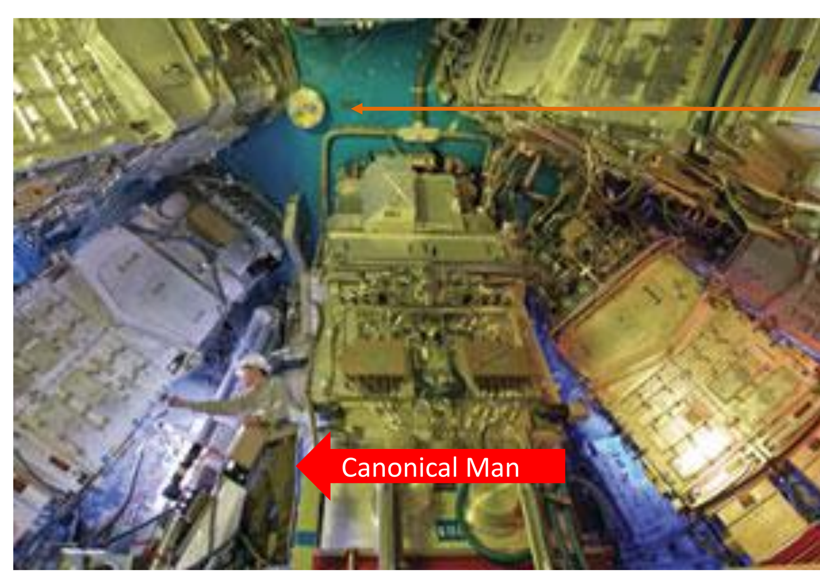
Purification oven used at the State University of New York College at Geneseo

Experimental Setup

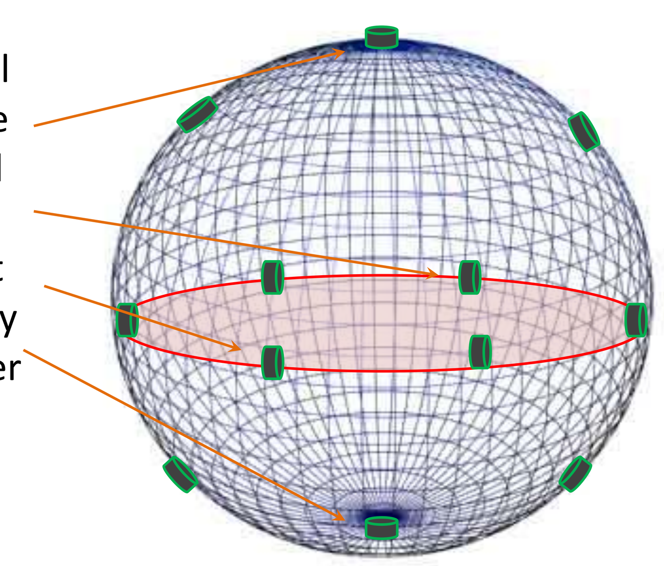
Sixteen NaI Scintillator detectors with ORTEC PMT preamps model 296 are each connected to an ORTEC 855 dual spectra amplifier. The amplifier signals are then passed through sixteen 100 kilo-samples/sec Wilkinson 7070 ADCs. Then processed in a multi-parameter data acquisition system in event mode.



Graphite placement in the NIF chamber at LLNL



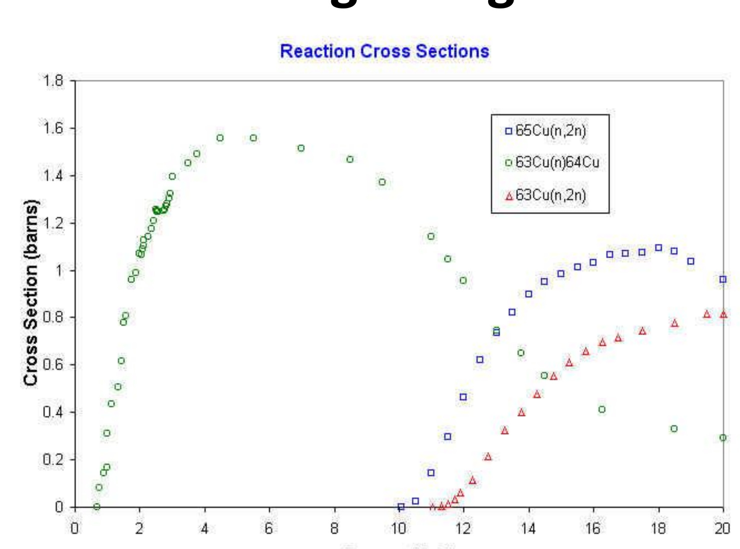
Graphite samples will be placed around the equatorial plane and polar regions of the NIF chamber on port flanges. Graphite may also be placed at other latitudes including ±45° from the equatorial plane.



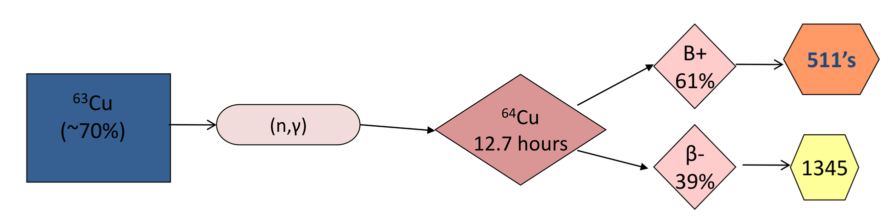
Data Acquisition

During acquisition, an activated C11 source is placed in the center of each the detector pair. The detectors are shielded with lead to reduce background radiation and accidental coincidences between off-axis pairs. Sixteen single spectra, one for each NaI detector, are acquired along with eight 2D coincidence spectra, one for each on axis pair of detectors.

Minimizing Background Data with Na-22 and Cu-64 at SUNY Geneseo



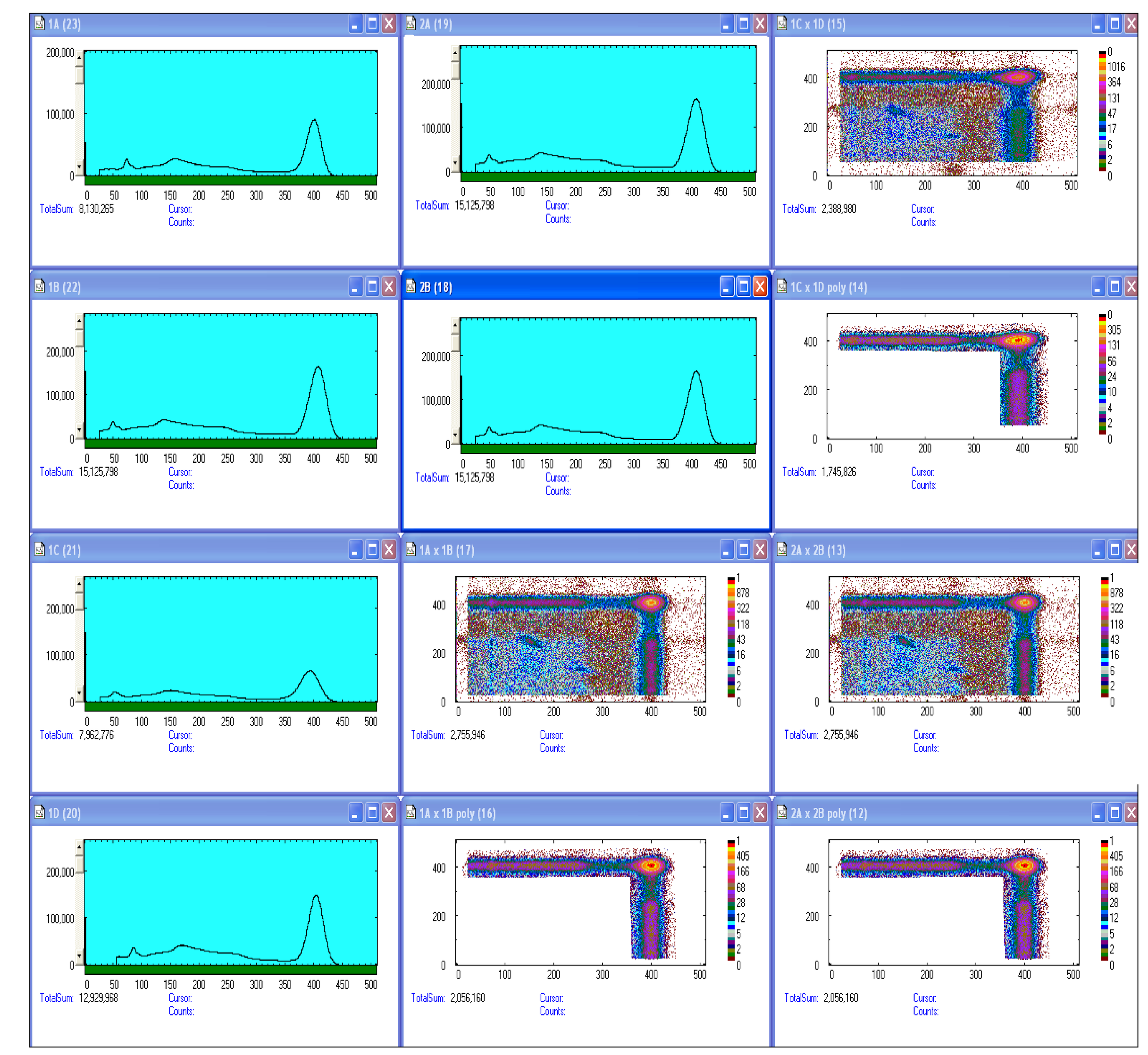
A single NaI detector pair system was used to develop the counting system and determine the effect of different lead shielding configurations about the detector pair by measuring accidental coincidences and background counts. This helped to determine the appropriate amount of lead shielding to minimize background counting.



Event Data Analysis

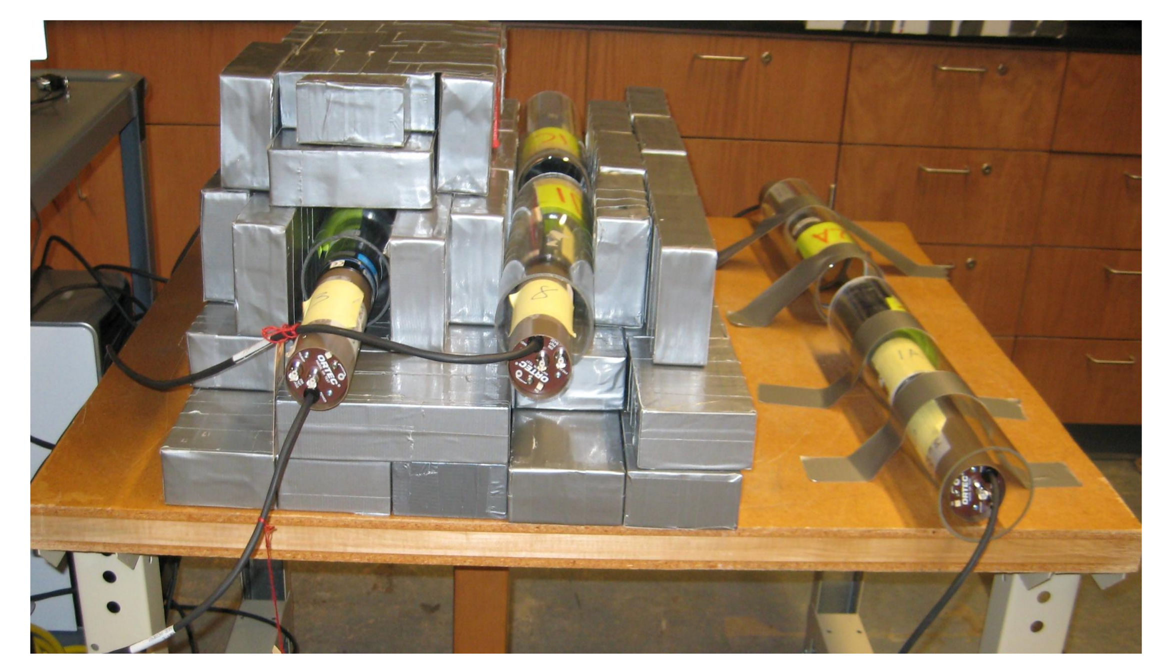
Event data can be acquired from the detector array and analyzed either on or offline. With the array offline, a more complete analysis can be made. By setting up 2D gates, single spectra can be created to determine the accidental and real coincidences in the event data.

Event Data



Multi-Detector Array at SUNY Geneseo

Three NaI detector pairs encased in lead of the 8 element array have been constructed at SUNY Geneseo. The optimal NaI detector configuration, which reduced accidental coincidences, minimized background gamma counts and maximized geometric counting efficiency, was determined with this test bench in preparation for the construction of the full 8 NaI paired detector array.



Summary

A nuclear diagnostic that is sensitive to $(\rho r)^2$ and anisotropies in the tertiary neutron distribution produced from an ICF burn at the NIF is being developed at SUNY Geneseo. Hopefully the detector array will be built, tested, calibrated and deployed at the NIF in the near future.

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