Gamma X: A 3-D Detector Array for Carbon Activation

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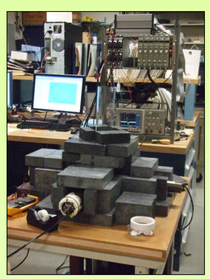
Abstract

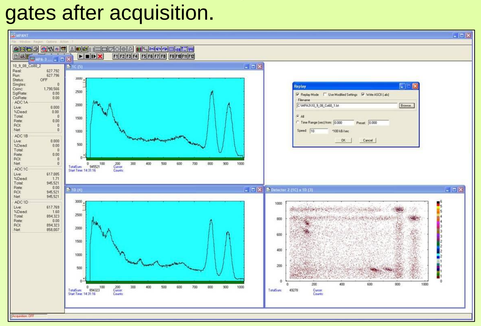
A diagnostic was developed to determine the $(\rho r)^2$ of a DT reaction via the resulting tertiary neutrons. High energy neutrons were incident upon a carbon disk which was activated via the $^{12}C(n,2n)^{11}C$ reaction then placed in a NaI detector system to record the gamma rays emitted by the ^{11}C as it decayed. The six detectors were aligned on Cartesian axes which increased the counting statistics in comparison to the previously used two detector system. To ensure a uniform calibration, copper pellets mixed with graphite powder were activated using a PuBe source prior to being placed in the center of the 6 detector system. The calibrated system was then used to count back-to-back 511 KeV gamma rays emitted from positron annihilation from the ^{11}C decay.

Capabilities of the System

Six standard NaI detectors, each with ORTEC model 296 photomultiplier tube with preamplifier and bias supply, were connected to three ORTEC 855 dual spec amplifiers. The amplifier signals were then passed though three 100 Kilo-samples/sec Wilkinson ADCs before being processed in a multi-parameter data acquisition system (Fast-ComTec MPA system). The replay function in the software allows the data to be re-analyzed in with different 2D gates after acquisition.



Detector setup at LLE with electronics connected



MPA System with replay

Detector Setup

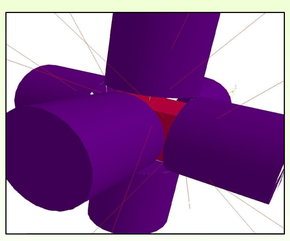
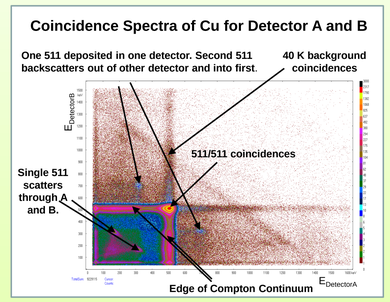


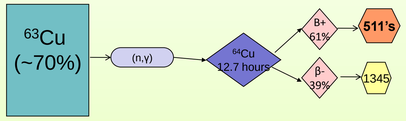
Image of detector array produced with IViPP

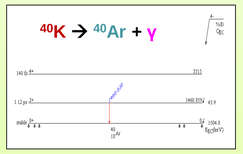
Setting up the 3-D detector array at SUNY Geneseo

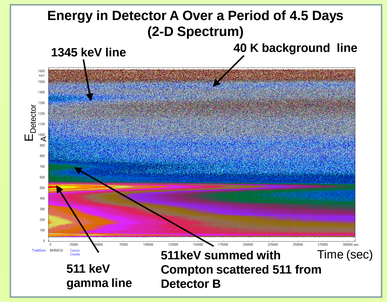
Six NaI detectors arranged on Cartesian axes with an activated source placed in the center. During acquisition, the detectors are shielded with lead to reduce background radiation due to outside sources.

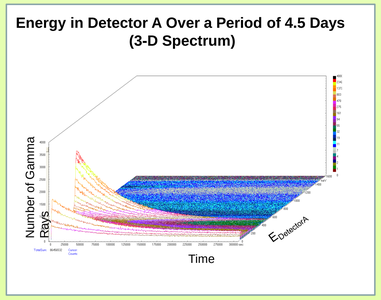
Copper & Background Radiation





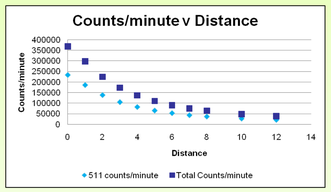






Efficiency Tests

Tests were performed using activated copper pellets in diamond dust in a four detector array to determine the efficiency of the system. A saturation test was performed to determine the effect of distance from the detector on the number of counts. The efficiency of the system was determined to be about 10%.



Expected Counts: *2.14E6*

Measured Counts: *212,618*

Efficiency: *9.9%*

Why Carbon?

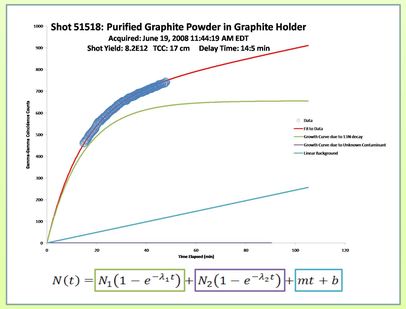
Carbon is ideal for the detection of primary and secondary neutrons for several reasons:

- Sensitive to the fuel density-radius product $(\rho r)^2$
- Insensitive to primary & scattered neutrons
- Robust, inexpensive, reusable and reliable

$$D_{ko} + T_{fuel} \rightarrow \alpha + n^{**}$$
$$n^{**} + {}^{12}C \rightarrow 2n + {}^{11}C$$
$${}^{11}C \rightarrow {}^{11}B + e^{+}$$
$$e^{+} \rightarrow 2\,\gamma_{511KeV}$$

Graphite vs. Diamond

Tests were performed to compare purified and unpurified forms of graphite and diamond powders activated in graphite and aluminum holders. The powders were activated after being inserted into the reaction chamber of the Omega Laser during a "high-yield" shot. A pair of sodium iodide detectors was used to count the number of resulting coincidence events. Each data set was fit with an exponential growth curve due to ^{13}N decay, a linear background, and the growth curve of an unknown contaminant with a long half-life



Sources of ^{13}N

- $^{14}N(n,2n)^{13}N$
- $^{27}Al(n,p)^{27}Mg \rightarrow {}^{12}C(p,\gamma)^{13}N$
- (from H_2O) $p(n,p) \rightarrow {}^{12}C(p,\gamma)^{13}N$

Sources of ^{64}Cu

- $^{65}Cu(n,2n)^{64}Cu$
- $^{63}Cu(n,\gamma)^{64}Cu$

Summary of Diamond Powder versus Graphite Powder Campaign								
					Total Number of Coincidences Projected for t_{∞}		*Background (Counts per Minute)*	
Shot #	Aerated/ Purified	Particle Size (μm)	Powder Material	Holder Material	From Nitrogen	From Copper	PreShot	PostShot
51520	Purified	74	Graphite	Graphite	442.27	0	2.5693	2.1727
51518	Purified	74	Graphite	Graphite	654.98	0	2.5604	2.3623
51527	Aerated	74	Graphite	Aluminum	1021.33	9331.8	2.2879	1.7423
51524	Aerated	74	Graphite	Graphite	1091.42	0	2.1128	3.1029
51516	Purified	0.25	Diamond	Aluminum	1674.2	9564.9	2.4001	1.3196
51305	Purified	1	Diamond	Aluminum	1851.18	1059.33	2.992	2.3369
51529	Aerated	1	Diamond	Graphite	2379.62	0	2.6098	3.091
51326	Aerated	1	Diamond	Aluminum	2421	0	2.1727	2.1553
51324	Purified	80	Diamond	Aluminum	7534.45	1993.69	2.5693	2.1727

Data acquired using graphite powder in a graphite holder had significantly less counts due to ^{13}N activation, as well as fewer counts resulting from copper contamination. Data acquired using the aluminum holders had increased amounts of ^{13}N activation as well as significant numbers of counts from activation of copper. Diamond powder overall had more counts due to ^{13}N activation.

Future Expectations

- Further explore calibration to ensure accuracy and a full understanding of the system

- Implement the Replay function to allow for further analysis of data post real-time acquisition

- Use FCM6 with activated carbon samples to determine the number of tertiary neutron activations from DT-reactions

Funded in part by the US Department of Energy through the Laboratory for Laser Energetics