Coincidence Efficiency Measurement Using 11B(p,n)11C

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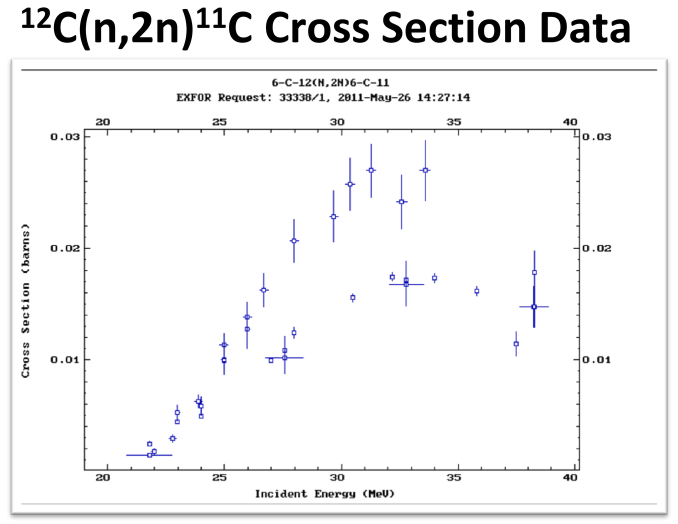
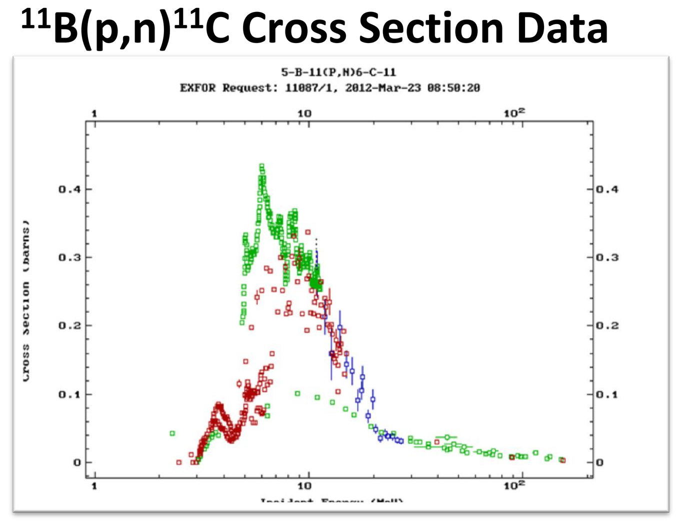
Abstract

An attempt to measure the 12C(n,2n)11C cross section for high energy neutrons in the range of 20-30 MeV was conducted using Ohio University's accelerator facility as a fast neutron source. The neutrons were incident on a graphite target and the β+ decay of the activated carbon-11 nuclei were observed in an on-axis gamma ray detector pair. To predetermine the efficiency of this gamma ray detector system, a boron-11 activation experiment was performed. Using SUNY Geneseo's 1.7 MV tandem pelletron accelerator, 3.1 MeV protons were incident upon the 11B foil inducing the 11B(p,n)11C reaction to occur at a high rate of activation. The 11C decays via β+ emission, then upon annihilation with an electron creates characteristic 511-511 keV photon pairs which were counted using coincidence methods. Since the 11B(p,n) cross section is well defined, a calculation was performed to determine the expected number of activations and later compared to the total number of decays observed in the counting system. Funded in part by a grant from the DOE through the Laboratory for Laser Energetics.

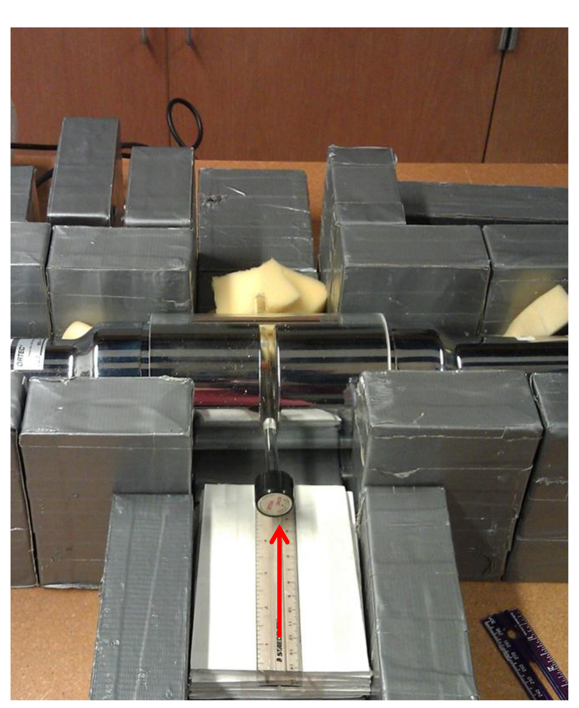
$^{12}C(n,2n)^{11}C$ Cross Section Data

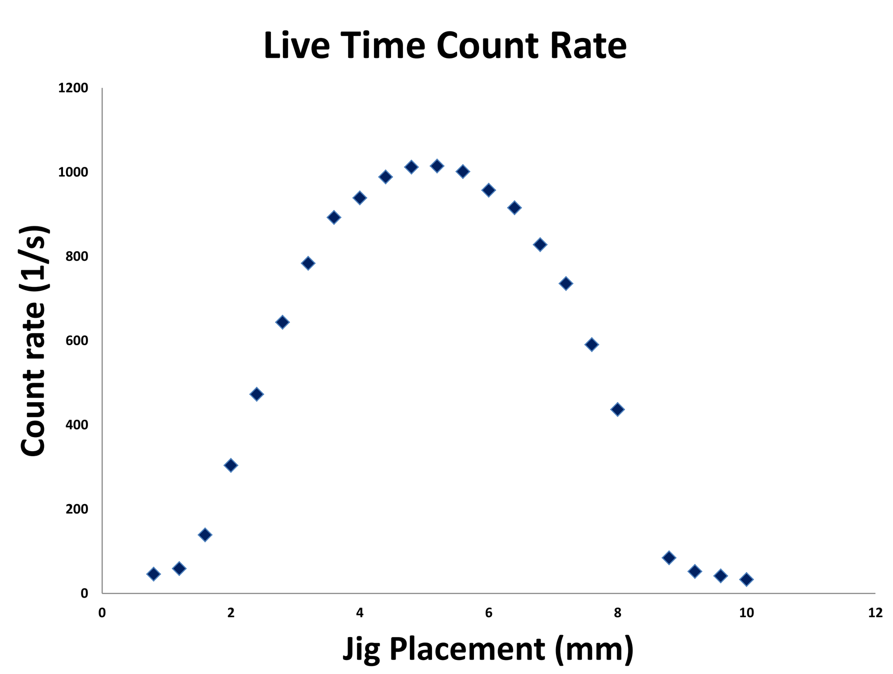


$^{11}B(p,n)^{11}C$ Cross Section Data

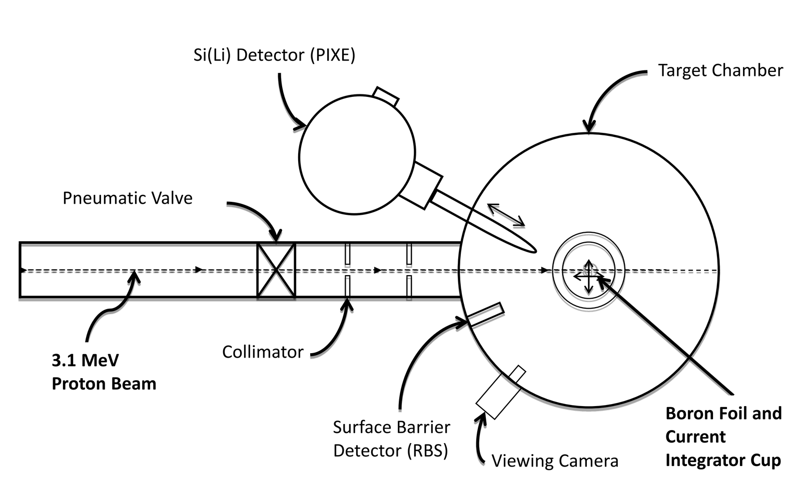


Geometric Efficiency Measurement



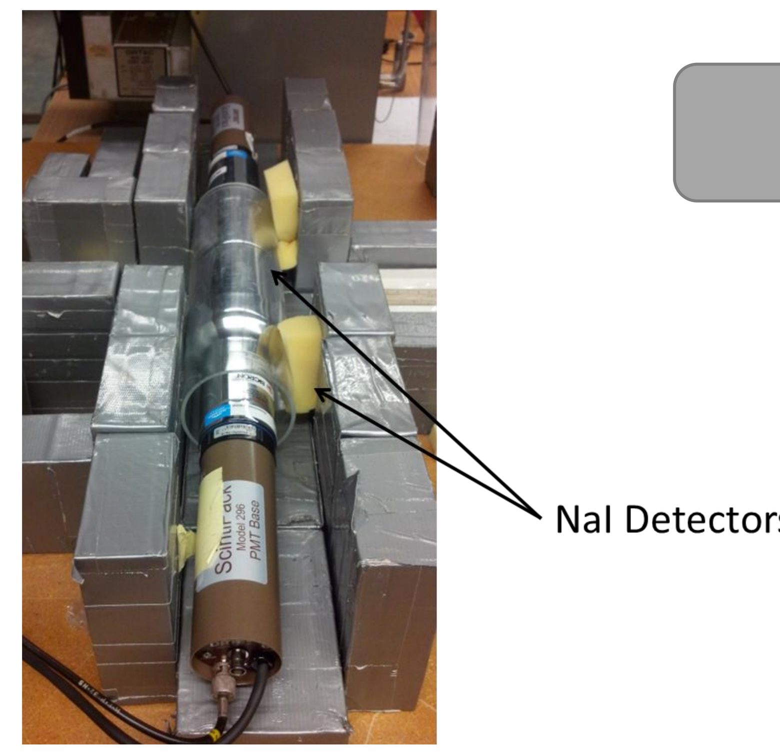


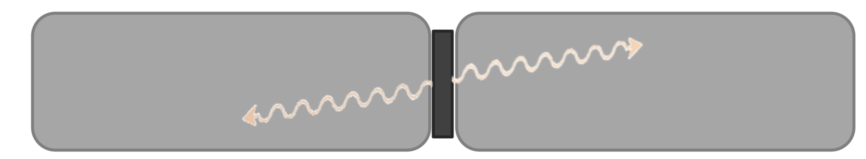
Tandem Pelletron Accelerator



(Left) A picture of the accelerator beam line. (Right) A schematic depicting the 15R beamline and end station of Geneseo's 1.7 MV tandem Pelletron accelerator for the activation of 11B.

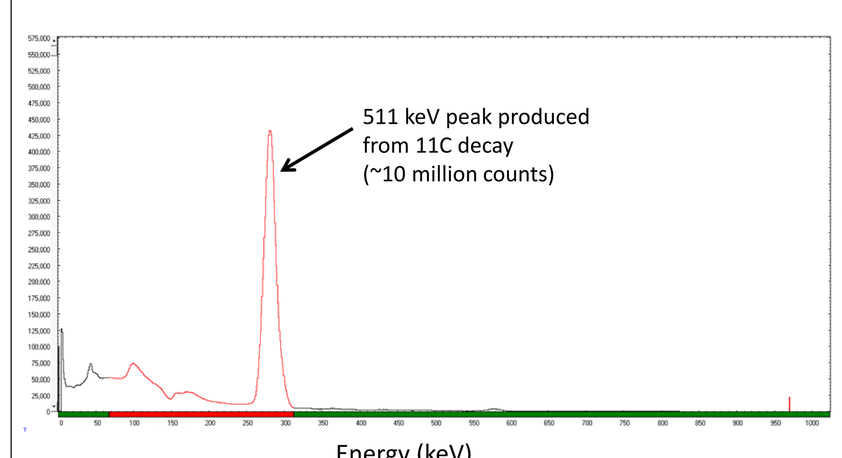
Counting Station Detector Setup

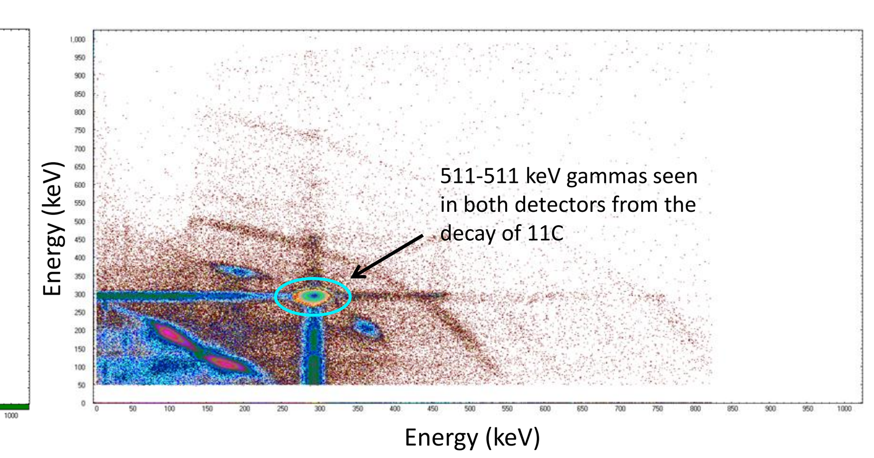


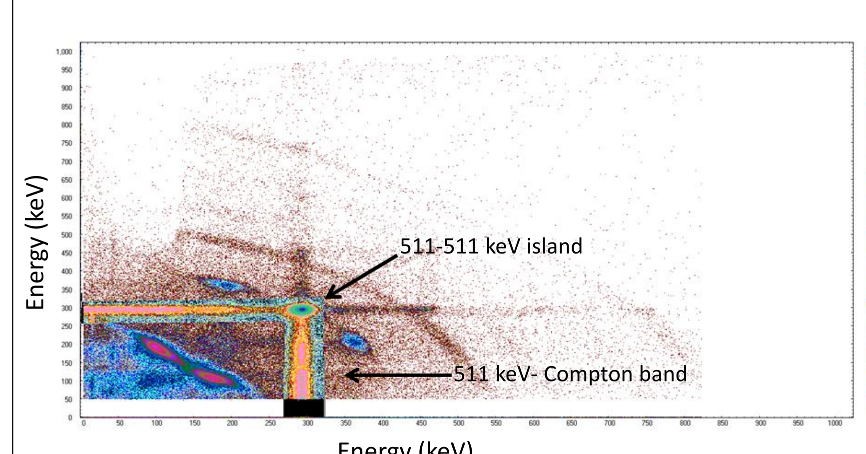


The coincident detector system consists of 2 on axis NaI detectors which were placed on either side of the activated 11B sample. The experiment successfully demonstrated that large numbers of 11C could be produced and counted using the 11B(p,n)11C reaction.

11C Decay Data

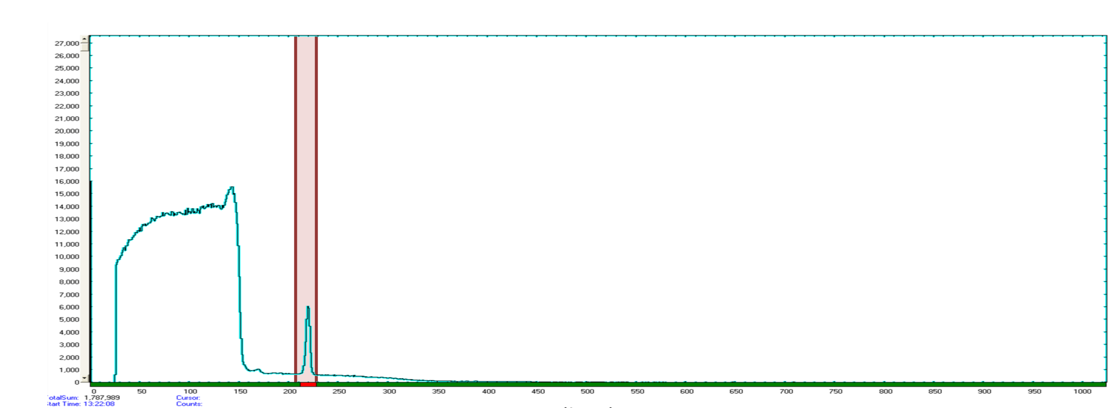


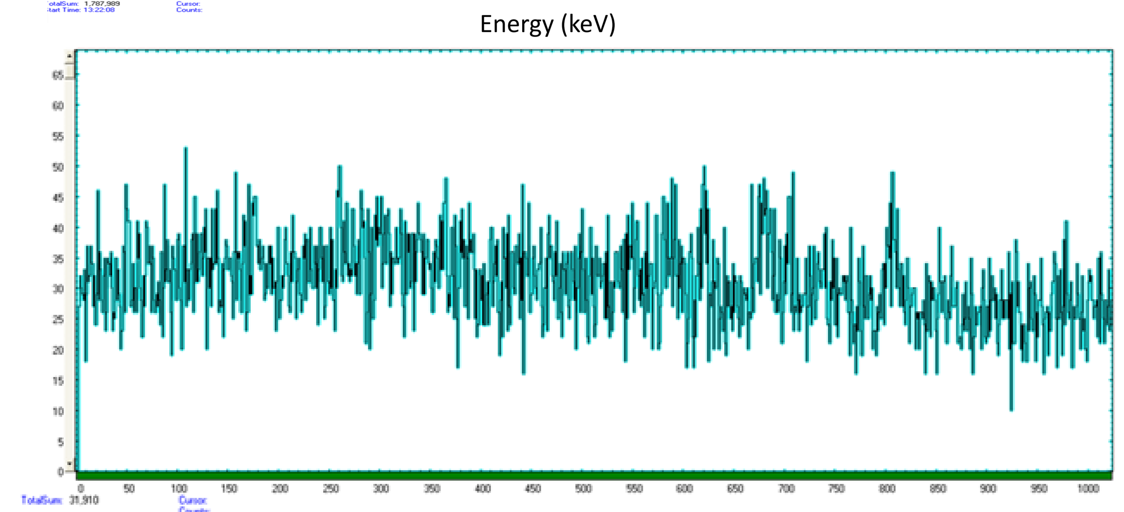


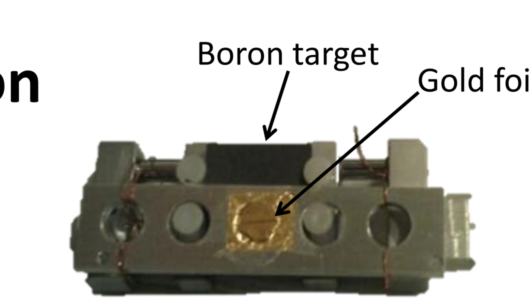


The most prominent peak in the single spectra data are the 511 keV positron annihilation gamma from the decay of 11C. Two single spectra were taken from each of the two NaI detectors, and two regions of the coincidence plot shown in the spectra were used for 11C decay analysis.

Beam Current Correction

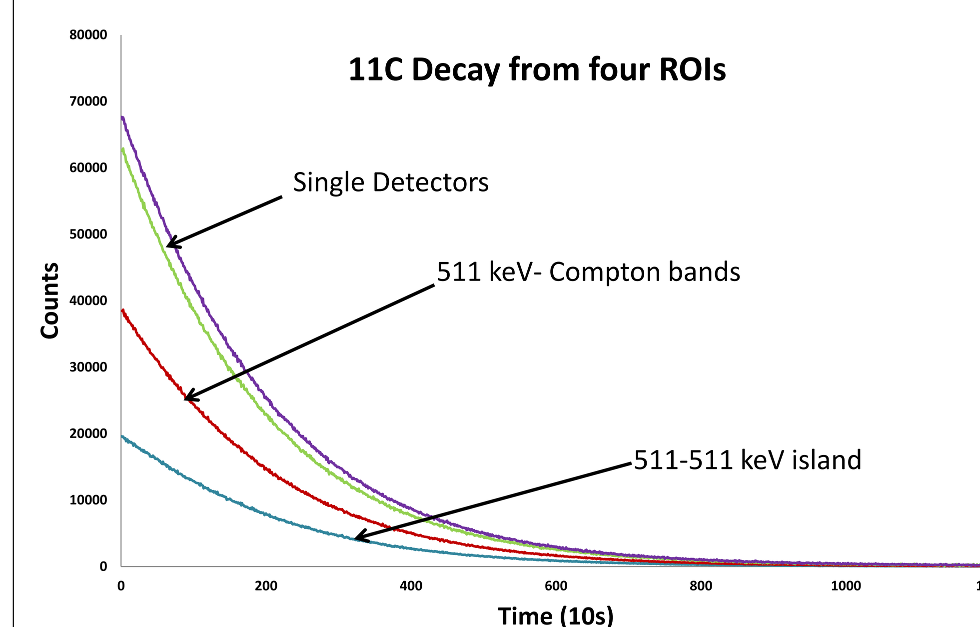






- To attain a more accurate beam current a surface barrier detector was placed at 165 degrees in the vacuum chamber
- A gold foil was placed over the boron foil
- Scattered protons seen in the surface barrier detector were used to measure Rutherford backscattering
- A time projection of the proton peak served as a proportional monitor of the beam current

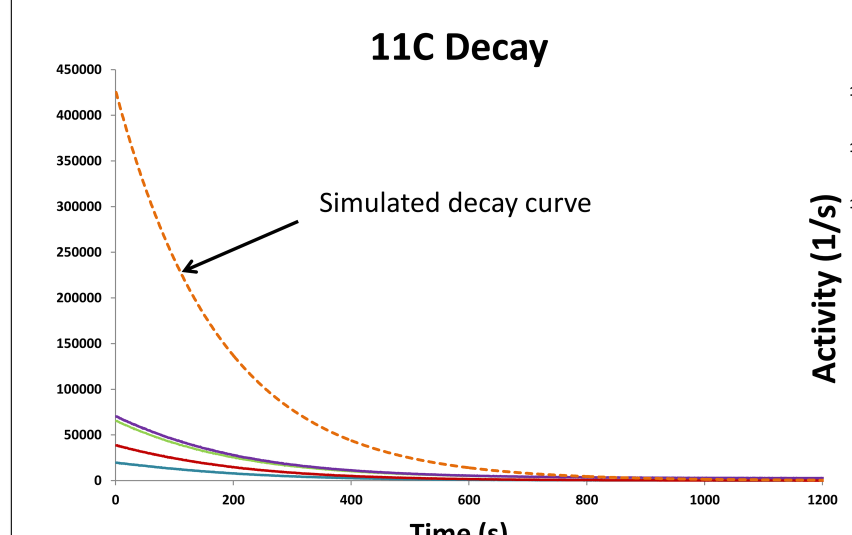
Activation Simulation and Analysis

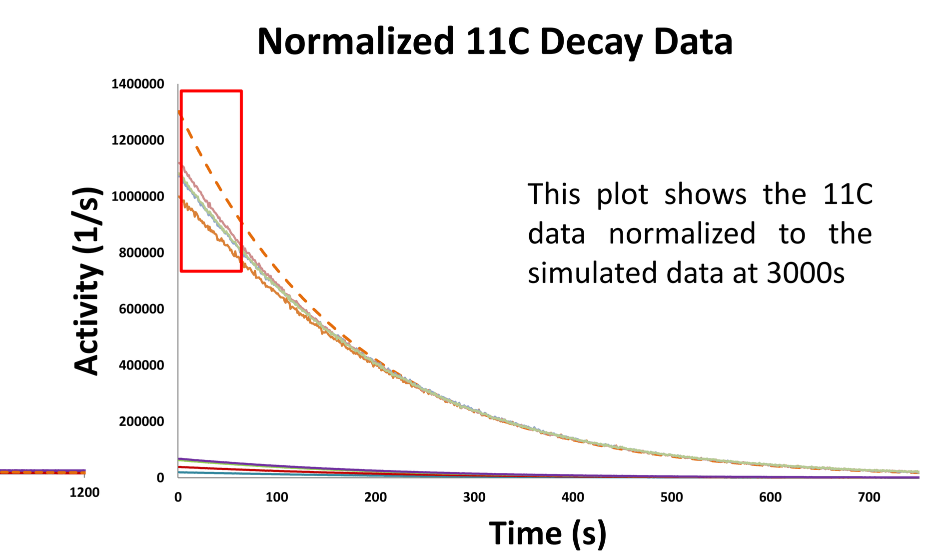


$$RR = \Phi\sigma\rho$$

$$Nuclei(t) = \frac{RR}{\lambda}(1 - e^{-\lambda t})$$

The number of activated nuclei grows exponentially over time, while taking into account the 11C that decays during the duration of activation. The activity of the sample also grows exponentially over time.

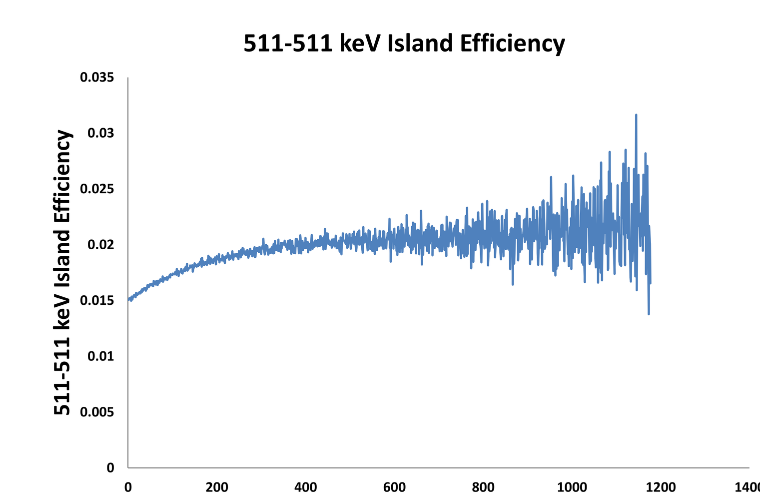


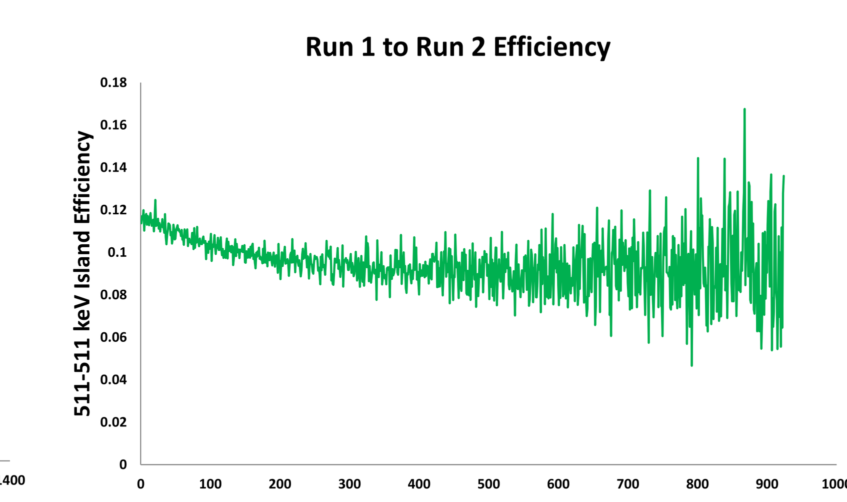


This plot shows the 11C data normalized to the simulated data at 3000s

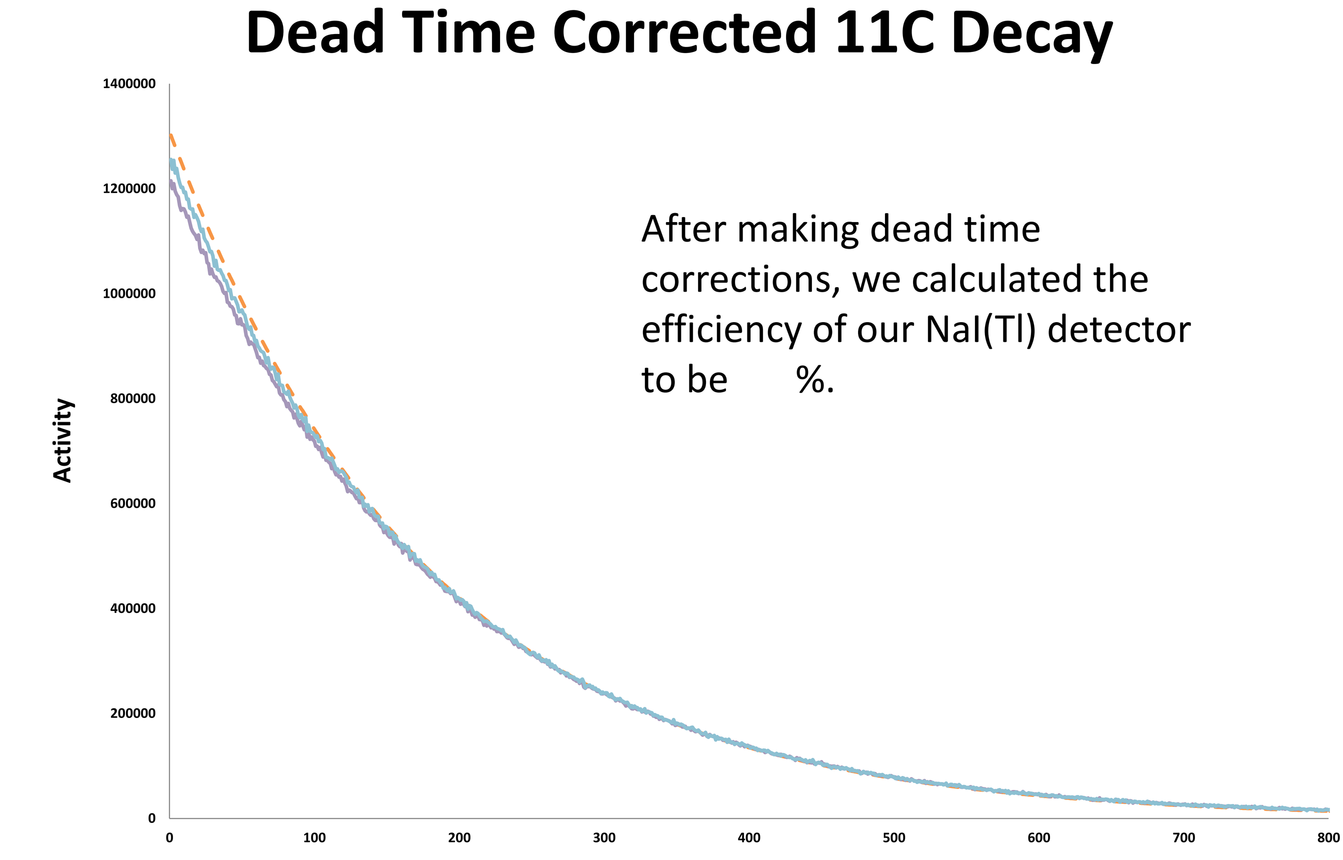
- There is a discrepancy at the earliest times but the data fits at later times after normalization
- Detector dead time was investigated as a possible explanation for this disagreement

Dead Time Investigation





Dead Time Corrected 11C Decay



After making dead time corrections, we calculated the efficiency of our NaI(Tl) detector to be %.