Andres Ruberg, Summer Student Work Report up to June 7, 2004

Calculating BGO Gamma-detector efficiency:

- I was given the task of comparing the detector efficiency produced by GEANT with those produced by measurements
- In the past these efficiencies were calculated with calibration sources using their Gamma spectra but only comparing the efficiency for gamma-rays in the photopeak. My task was to compare efficiencies for data extending out as far as the second escape peak and in the case of Cesium down to ½ the photopeak energy as no pair production occurs.

In calculating the efficiency of a dragon run one requires four variables as seen in the equation

$$\varepsilon = \frac{A}{t\tau N} \qquad (1)$$

Where:
A is the area under a given gamma spectra (i.e. the number of counts in a specific energy range)
t is the time of the run in question
τ is the % of the system live time. What this represents is the fact that event analysis takes a finite amount of time therefore if one event is being analyzed as another is detected the electronics are unable to record the details of the 2nd event. The ratio of analyzed events to the total number of detector "hits" is referred to as the "live" time of the run. Most typically τ is calculated by viewing the ".ffcard" or ".odb" file associated with a given run then after some effort one finds a section labeled "scalars" where they find the variables "gammas presented" and, "gammas acquired". τ can be calculated by the equation:

$$\tau = \frac{gammas\_acquired}{gammas\_presented} \qquad (2)$$

N is the pre-determined counting rate of the sample in question. Below is a table of the sources considered in this report and their counting rates with associated errors at the time when measurements were taken:

Sample	Photopeak Energy (MeV)	Counting Rate	Error
^{137}Cs	.662	188474	4814
^{60}Co	1.33	13576	360
$^{241}Am^{9}Be$	4.44	24372	1786
$^{244}Cm^{13}C$	6.13	2618	286

(Table from Dario's Thesis)

Cesium (.662 MeV) Data Analysis
(Calculations and data available on pgs. 47 – 51 in lab notebook)

First, I calculated the efficiency found when using measurement data. The Cesium sample was located on a box between the two faces of the BGO array with the crowing detectors (1-10) removed for the duration of the measurements. This source was unfortunately non-isotropic and therefore two sets of measurements had to be analyzed, one for each detector face.

The west facing detector data (11-30 odd numbered detectors) was located on midmes01 in:

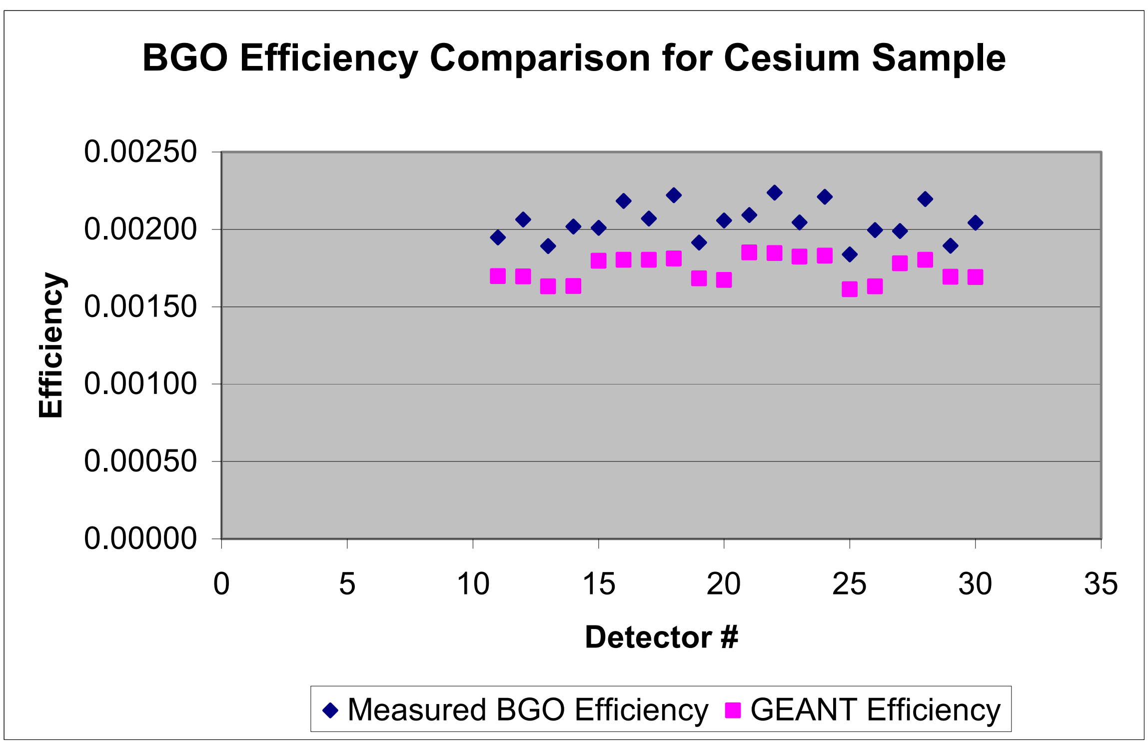
data/dragon/datad/run08157.hbook
And the east facing detector data (11-30 even numbered detectors) was located in:
data/dragon/datad/run08160.hbook

These files were loaded using Paw++ and then once the position of the photopeak was established I integrated all counts from ½ the photopeak energy value to a point where the counts went to essentially zero. The time of these two runs and the % system live time were both calculated from information located in the ".odb" file associated with each hbook, located in the same directory.

After analyzing the spectra of the 20 detectors of interest and calculating their efficiencies the same procedure was applied to GEANT simulations using the same sample. Again the GEANT simulation was done for the source facing both directions.

The west facing detector data was located on ibm00 in:
home/dragon/gamdet/gbox_v5_trials/gbox_mod/v12_2/data/ghex_geant6221000.hbook
And the east facing detector data was located in:
home/dragon/gamdet/gbox_v5_trials/gbox_mod/v12_2/data/ghex_geant6221001.hbook

In this case I integrated the counts as before but since this was a simulation, one did not have to account for system deadtime. In both simulations the number of events was 10,000,000 so the efficiency was just the integrated counts divided by ten million. A comparison of the results of these calculations is shown below where one can compare the efficiency of each detector as it was measured with how it was simulated in GEANT.



It is apparent that the measured data points all lie above those produced by GEANT and it almost seems as though some sort of linear scaling factor should be added to GEANT points. My thoughts were that this was due to some background effect or an effect of the beta particle, which is created during the decay reaction. After some new simulations were run it appears as though the betas could indeed be producing some low energy gammas that the GEANT simulation did not take into account.

Curium Carbon (6.13 MeV) Data Analysis
(Calculations and Data available on pgs. 52 – 59 of lab notebook)

With the Curium source I was interested in comparing the efficiencies under not only the photopeak but also under the first and second escape peaks. Also, instead of integrating under the actual data to find the number of counts in these peaks one scaled the counts under the peaks of a GEANT simulation. The idea being that the simulation can predict relative peak heights and once convolved with a Gaussian one can fit this simulation to the data. As one of the parameters in the fit one uses a "scaling factor" which is the number one has to multiply the simulated peak by to obtain the number of measured counts. This scaling factor is the one I had to multiply the photo-peak channel in the simulation by to get the number of counts under the photopeak in the data. If one assumes that the relative heights of the escape peaks are consistent throughout the measurements then this scaling parameter technique can be applied not only the photopeak data but also data as far out as the second photopeak. So this is what was done. It should be noted that in this case the crowning detectors were in place and the sample was inside the closed BGO array.

The location of the original data files that GEANT was fit to in order to calculate the scaling parameters are on midmes01:
West facing detector data
data/dragon/datad/run08188.hbook
And the east facing detector data as well as crowning detector data was located in:
data/dragon/datad/run08182.hbook

Again the associated ".odb" file is located in the same folder as the data and can be used to find the time of the run as well as the components needed to calculate the % system live time.

The GEANT files that the data was compared with can be found on ibm00:
home/dragon/gamdet/gbox_v5_trials/gbox_mod/singlebgo/data2/ghex_geant61310
This simulated 10,000,000 counts.

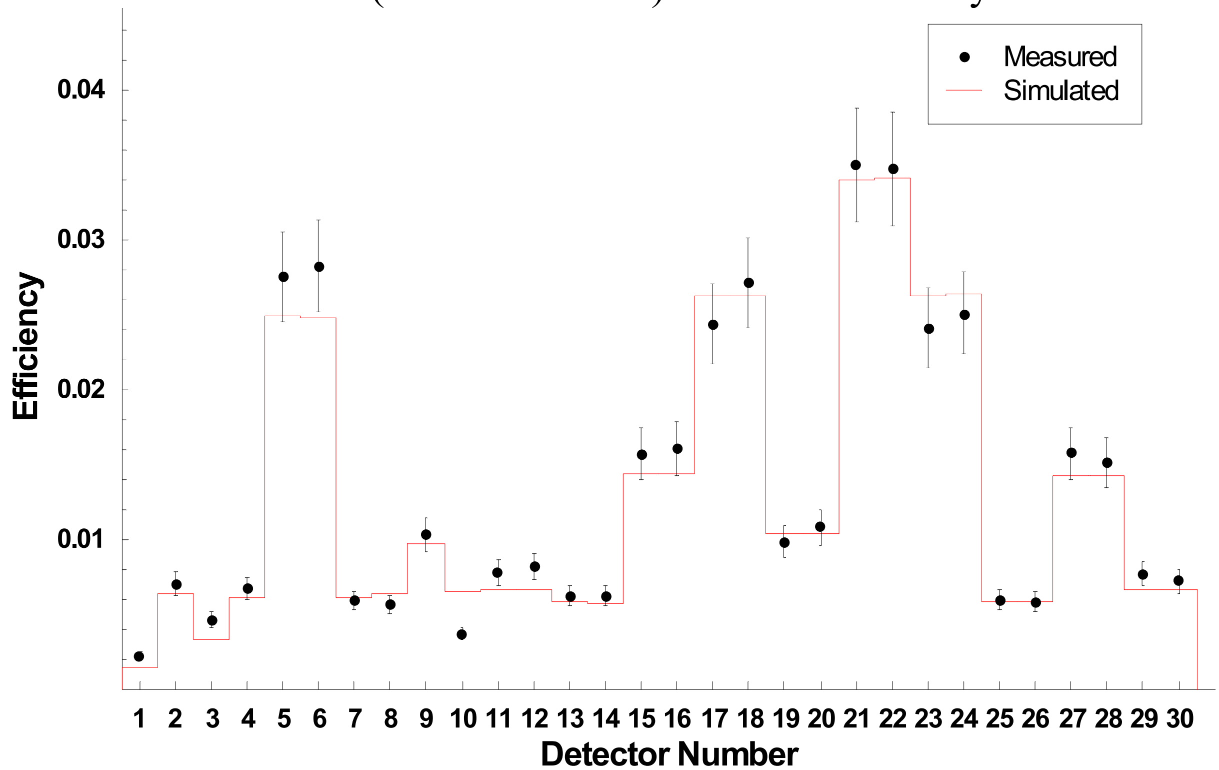
I then used Mathematica to represent my results so that I could present this data in a fashion consistent with previous work.

Results for $^{244}Cu^{13}C$ inside BGO array and compared out to 2nd escape peak

Total Measured Efficiency: $41.0 \pm 4.4\%$
Total GEANT simulation Efficiency: 39.6%

Below is a graph showing the efficiency detector-by-detector. The only error considered here was the uncertainty of the source activity:

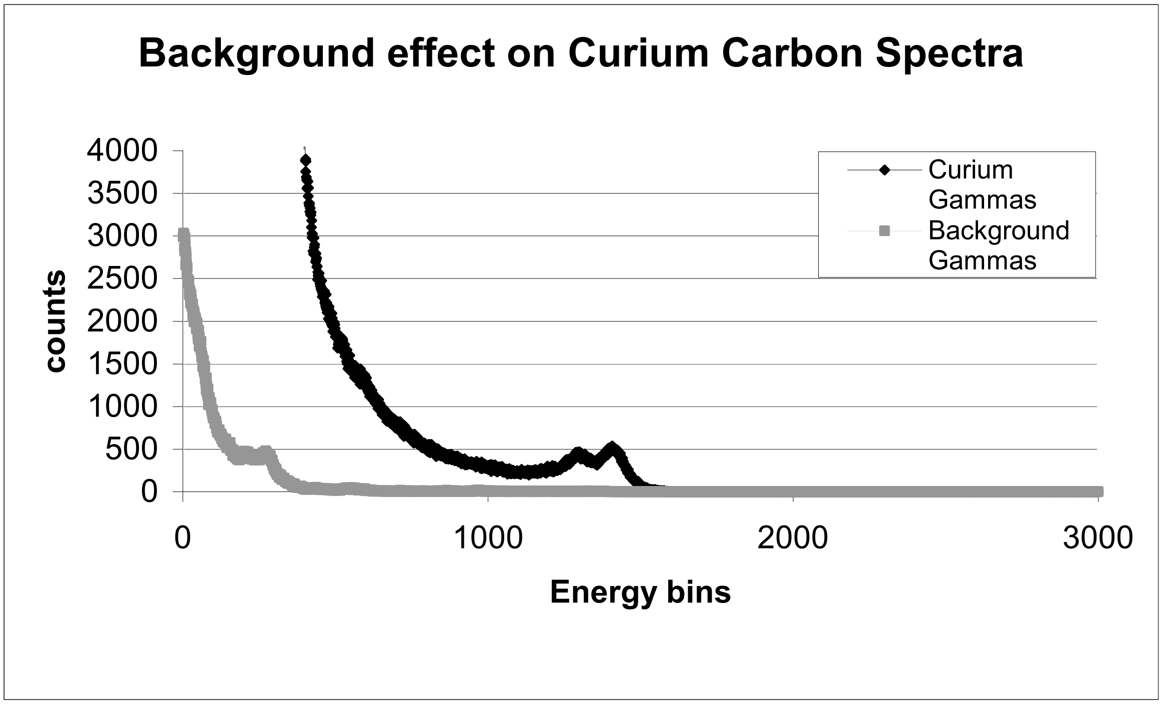
Efficiency of Simulation Vs. Efficiency of Measurement for 6.13 MeV source (Curium Carbon) Inside BGO Array



In the data there appeared to be problems with the low energy gammas data. Part of this is because a threshold was set and certain gamma inputs were suppressed. Another problem is a very distinct low energy tail not predicted by GEANT. It is thought that this tail could be due to 2 things not included in the simulation one of which was investigated by this student:

1. Background gammas
2. Gammas from neutron interactions (most likely interactions within BGO itself which would lead to a lot of low energy gammas)

It was determined that background gammas contributed very little to the overall spectra after 2 one hour runs were done one with and one without the Curium source. Below is a graph illustrating the effect of the background on the Curium spectra:



Therefore, we concluded that neutron interactions not simulated by GEANT were probably the cause of most of the observed low energy gammas.

<u>Americium Beryllium (4.44 MeV) Data Analysis</u>
(Calculations and data available on pgs. 60 – 63 of lab notebook)

This sample was analyzed the same as the Curium Carbon but the sample was on a box above the detector array and the two sides of the array were pulled apart. The original data used to find the scaling parameters can be found on ibm00:
West facing detector data:
export/home/giglio0/midmes01datad/hbooks/his08112.hbook
East facing and crown detector data:
export/home/giglio0/midmes01datad/hbooks/his08112.hbook

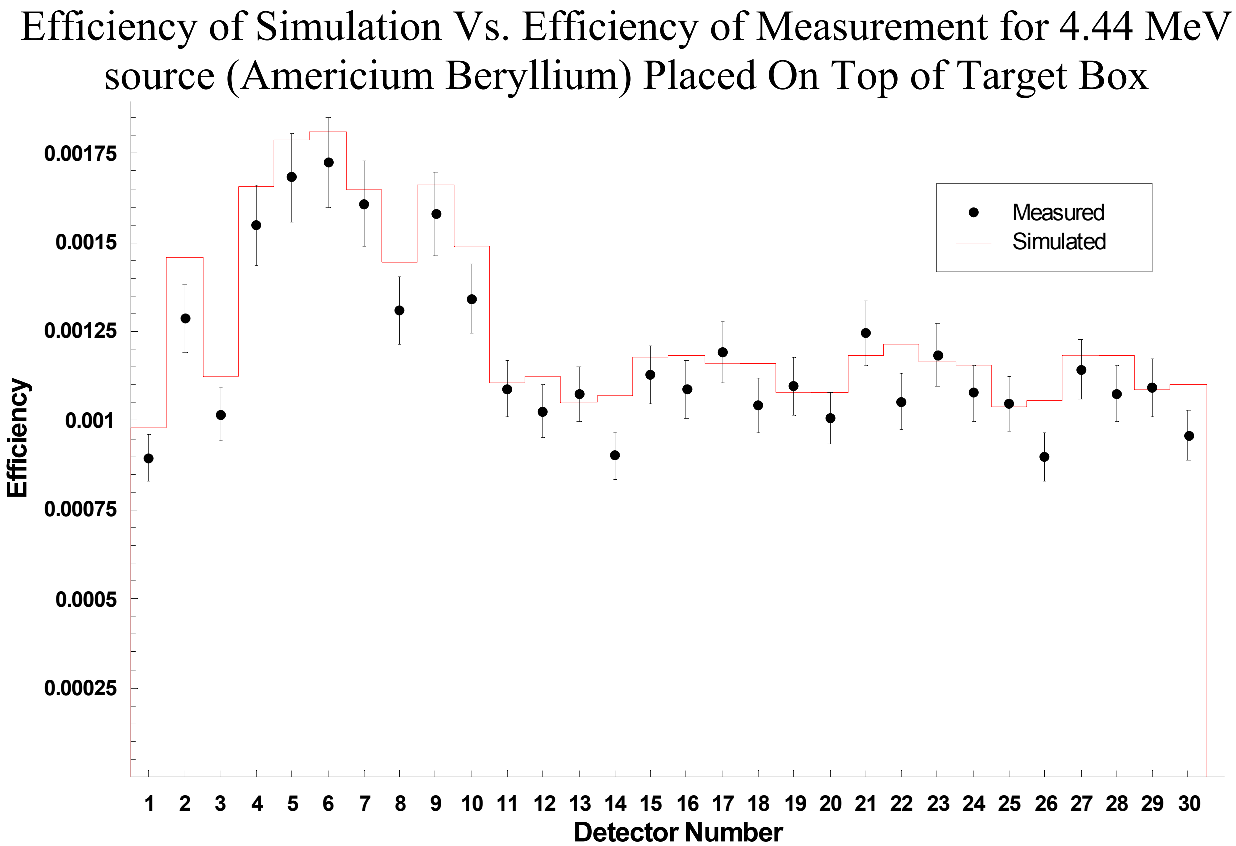
Note: “odb” files are located in same area but instead of under “hbook” folder are in the folder “odbs”.

The GEANT simulation files were located on ibm00 as well:
West facing simulation:
home/dragon/gamdet/gbox_v5_trials/gbox_mod/v12_1/data4/ghex_geant100000.hbook
And the east facing detector data as well as crowning simulation data was located in:
home/dragon/gamdet/gbox_v5_trials/gbox_mod/v12_1/data4/ghex_geant300000.hbook
Again these simulations simulated 10,000,000 events.

Results:

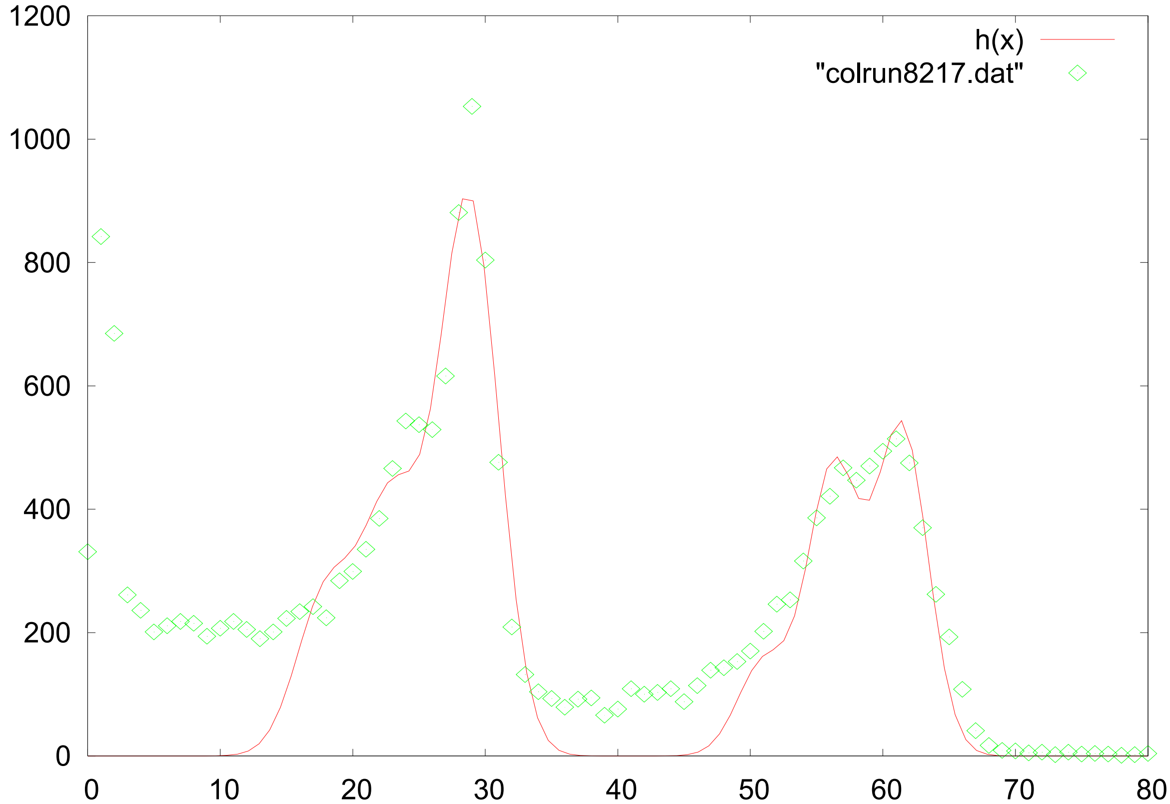
Total Measured Efficiency: $35.4 \pm 2.6\,\%$
Total GEANT simulation Efficiency: 37.6%

Below are plotted the results again in Mathematica and again with the only error being considered coming from the source activity uncertainty:



Carbon Reaction Gamma Analysis (Still in Progress)
(Early work discussed here on pgs. 68 – 70 of lab notebook)

Now attempts are going to be made to fit the $^{12}C(\alpha, \gamma)^{16}O$ reaction gamma-ray data. I will learn how the fitting was done in Dario's thesis but before that happens we plan to re-run the data through the data analysis software in order to achieve more effective binning as the current data is collected into only 125 bins resulting in poorer statistics than is possible. Below is an early 6-Gaussian fit to the current $^{12}C(\alpha, \gamma)^{16}O$ data done with gnuplot. In this fit the widths of the peaks are fixed as are the distances between the photopeaks and first and second escape peaks. This is a very preliminary fit done using only one run, with counts on the y-axis and bin number on the x-axis.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