Andres Ruberg, Summer Student Work Report From June 7 to June 29, 2004

Setting up and Calibrating Germanium Detector for $^{26}Al(p,g)^{27}Si$ experiment:
(Calculations and diagrams on pgs. 79 – 89 of lab notebook)

Two additional detectors were needed for this experiment. First a germanium Detector was needed in order to measure the amount of ^{26}Na contamination in the beam, which emits a prominent gamma ray at 1808.65 keV. Also there was a small amount of $^{26}Al^{*}$ (isomeric state of aluminum) in the ^{26}Al beam, which is a positron emitter. To measure the positron rate a pair of NaI detectors were set up and measured the coincident 511 keV photons emitted when the positrons interacted with matter (to be discussed later). The idea was that when the mass 26 particles were deflected onto the mass slits they would be stopped and emit their respective decay products making them available for detection.

My primary role consisted of constructing a stand for the germanium detector, assuring that it was consistently being refilled with liquid nitrogen and to perform calibration measurements and calculations.

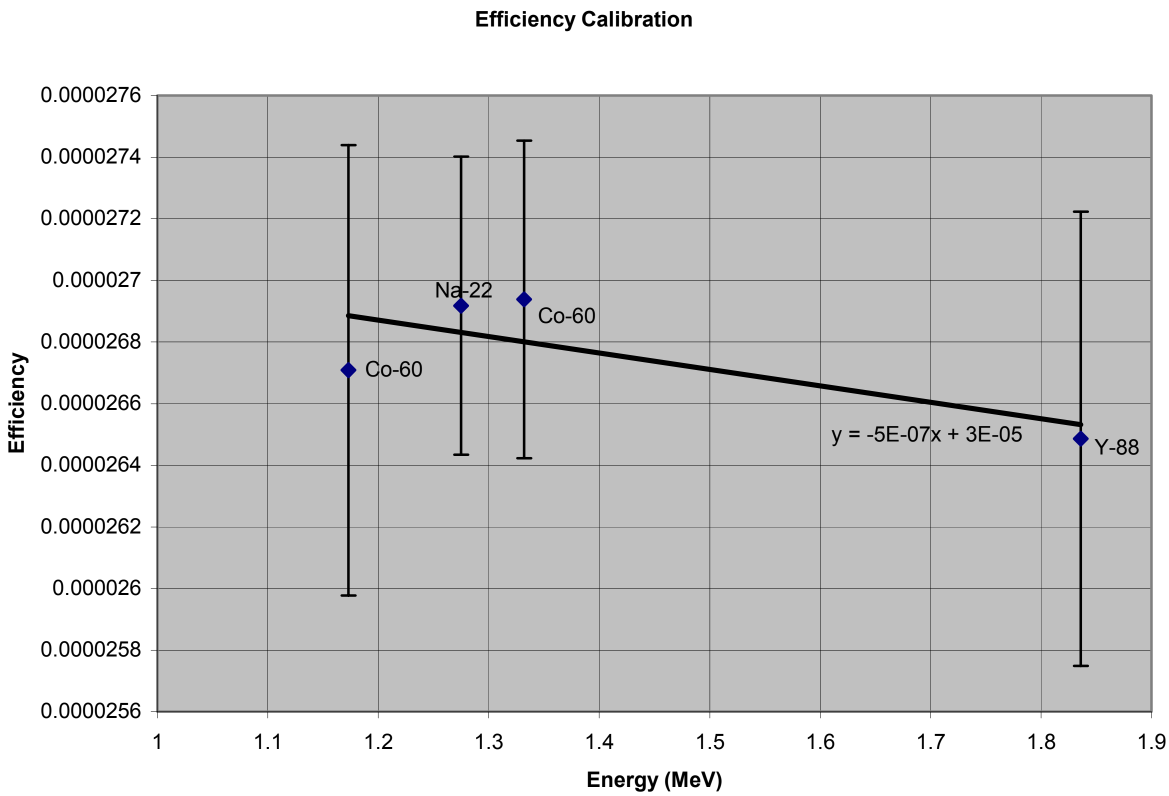
For the Ge detector an ad-hoc stand was constructed using an existing metal stand, various clamps, blocks of wood and concrete blocks (for mooring). This stand was situated such that the germanium detector was pointing through one of the holes in the concrete casing of the mass slit box and aimed towards the mass-slits upon which beam was going to be stopped, and from where the 1.809 MeV gamma rays would be emitted.

I then applied bias to the Ge detector (2500 V at about 10V/s) and loose wires were secured using duct tape. Once bias was applied I was charged with the task of making sure the detector was always full of liquid nitrogen and after doing this myself for a few days I fashioned a set of directions for filling the Ge detector with liquid nitrogen, which are now on the DRAGON website for convenient viewing.

With one of the covers removed from the mass slit box we fashioned a device using a bent piece of metal duct tape and two rulers. Samples were attached to the ends of the rulers, which we could place in near the mass slits to an accuracy of about 5 mm. Once the samples were in place (that is near the region where we expected the beam to interact with the slits) measurements were taken from the Germanium detector in order to determine its detection efficiency at various energies. The efficiency calculations involved two complications:

1. Samples obtained had incorrect radiation rates so half-life calculations had to be done using the manufacturers initial numbers in order to find the counting rate.
2. One had to consider the attenuation due to concrete, aluminum and steel, which were present (but did not affect the calibration in any significant way as we were only really concerned with the efficiency at one energy not in extrapolating a curve).

These complications were dealt with and in the end the efficiency curve shown below was obtained.



The only efficiency that was really of interest was that of the ^{88}Y sample which emitted a gamma-ray at 1.836 MeV. The efficiency we found at this energy was $(.00265 \pm .00007)\,\%$.

Learning how to construct MCP foil:

One day when nothing else needed doing I was instructed on how to cut and place MCP foils on a brass frame in preparation of the upcoming run. This consisted of carefully removing the strip of carbon foil (on glass) from a bottle then cutting it in half using a right-angled ruler and knife. I then "floated" off one half of the very thin carbon foil in a water bath, which you slowly filled with water using a pumping system and separate water container. Then I lowered the frame into the water and caught the edge of the foil, slowly pulling the frame out of the water until the foil covered the hole in the center.

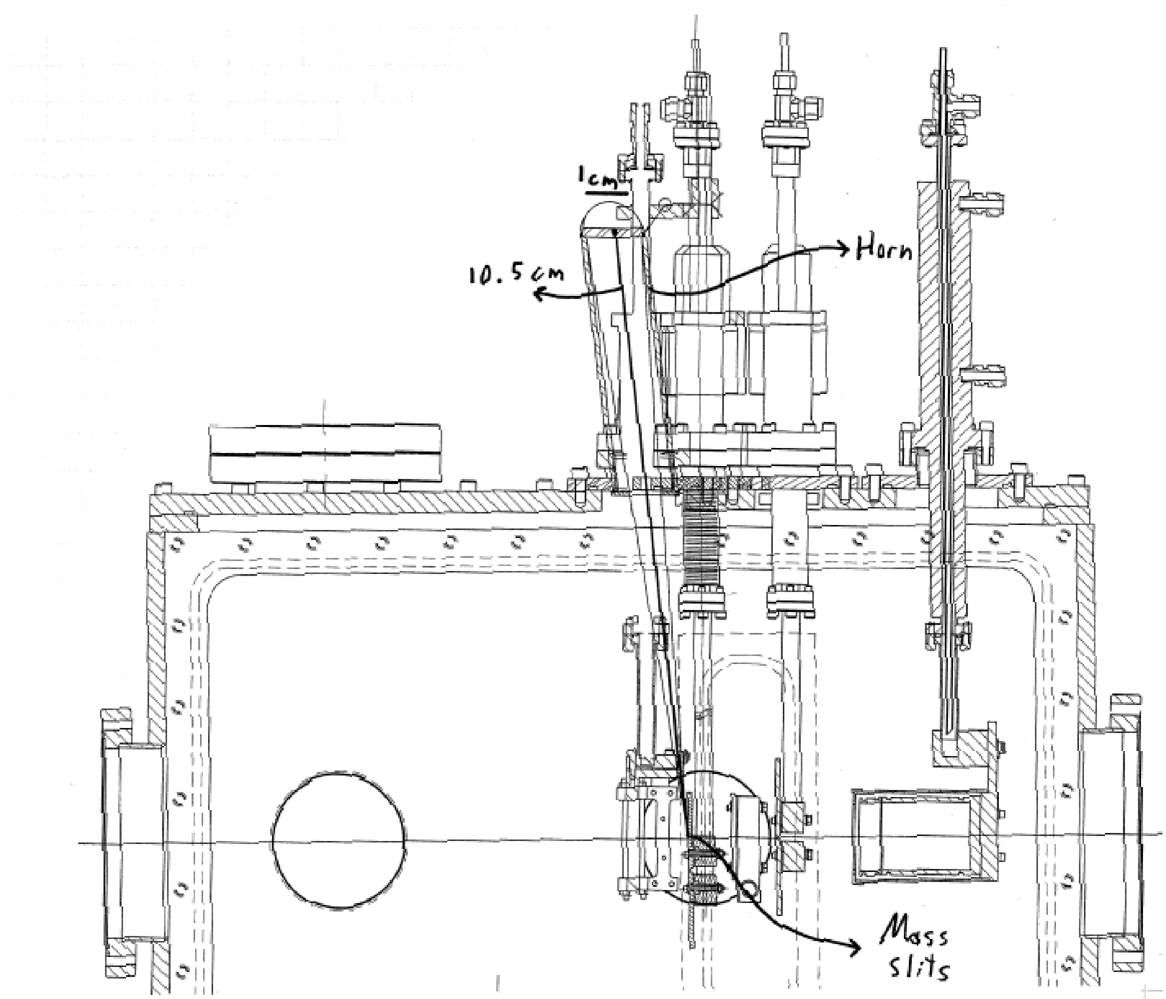
Efficiency of NaI detectors
(Calculations and diagrams available on pgs. 95 – 96 of lab notebook)

Although I had no part in the set up of this apparatus I was given the task of calculating the efficiency of these detectors. To do this a ^{22}Na source was attached to the "horn" of

DRAGON and measurements were taken to determine what fraction of the total output the detector caught. Again, half-life calculations were done by hand to obtain the current radioactivity of the sample.
As a double check, we assumed a point source and calculated what the efficiency should have been based on solid angle. The equation used here to calculate the solid angle Ω was the standard equation for a flat detector face of radius **a** and at a distance **d** from the target in question, that formula being:

$$\Omega = 2\pi\left(1 - \frac{d}{\sqrt{d^2 + a^2}}\right) \qquad (1)$$

Due to uncertainties in measurements and distances the final efficiency of the NaI detectors was found to be $4.0 \pm 0.5\,\%$ from the horn. If one took into account the positron acceptance rate of the horn on top of this efficiency the absolute detection efficiency of $^{26}Al^{*}$ was $(2.3 \pm 0.2) \times 10^{-3}\,\%$. Below is a diagram from which we calculated the acceptance rate of the horn.

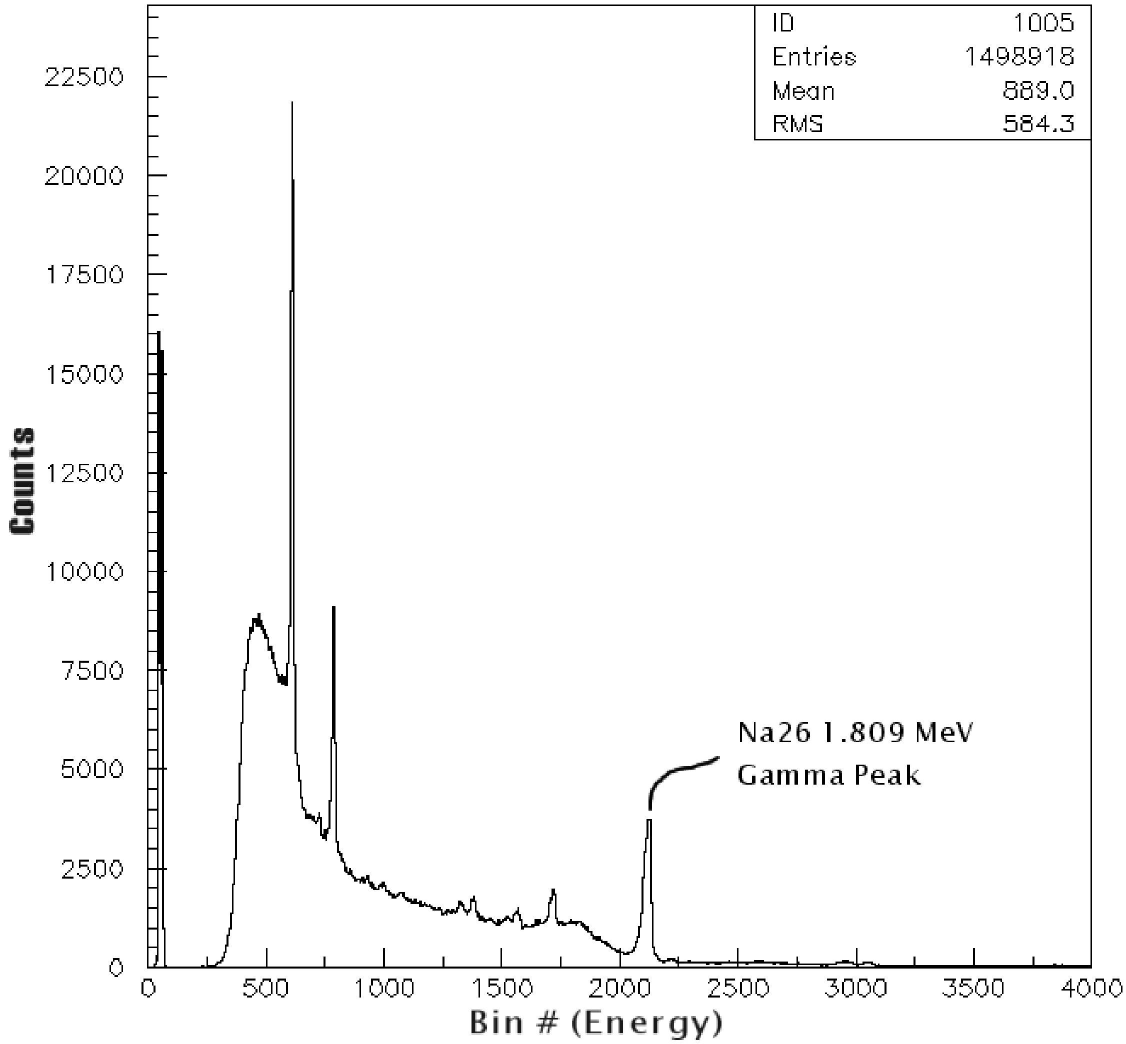


<u>Calculating Amount of $^{27}Al^*$ and ^{26}Na in the ^{26}Al beam:</u>
(Tables and calculations on pgs. 100 – 108 of lab notebook)

So with efficiency calculations finished the next step was the use the data from the detectors to figure out how much contamination we had in the beam. I used 6 runs (12583, 12584, 12585, 12601, 12581 and 12609) for this analysis, 2 of which were used solely to extract the background (runs 12581 and 12609).

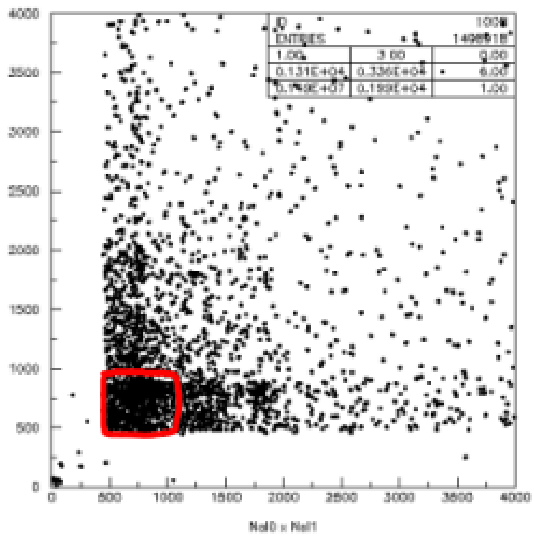
Note all the ".hbook" and ".odb" files used here can be found on IBM00 in:
/export/home/aruberg/al26pg
Also located here is an excel file where many of the calculations done are summarized.

The first step was to calibrate the gamma ray spectra from the Ge detector. A near-linear relationship was established between channel number and gamma energy. Once the peak of interest was located an integration using PAW++ was carried out, and this combined with the time of the run gave a "rough" counting rate. Below is the Ge PAW++ spectra:

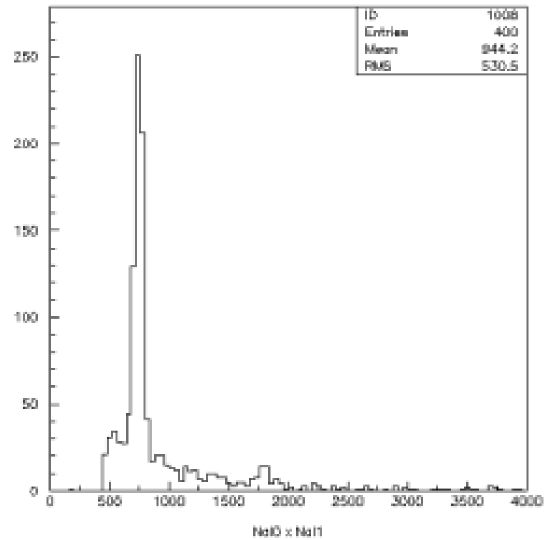


This "rough" rate was adjusted once the deadtime and detector efficiency were accounted for and the background was subtracted. Also, the charge state distribution of the ^{26}Na and $^{26}Al^*$ were taken into account. The charge state distribution for the sodium 6+ state was found in Wenjie's thesis whereas that for the aluminum 6+ state was never measured but assumed to be roughly 34% with a 4% error based on charge state distribution measurements with ^{26}Mg.

The NaI detector data analysis was very similar to that of the Ge detector except for the extraction of the "rough" counting rate. With the NaI detectors a 2d spectra was formed in PAW++ making it easy to view coincident 511 keV gammas. This did not make it easy however, to count the number of events in a given x-y range. In order to integrate the counts of interest the 2-d spectra was first copied into the PAWC viewing directory and then examined using the "view x-band" command where the x parameters were specified. This was then copied into a 1-D spectra where the integration could be carried out over the y-range of interest. The x-range integrated was between channels 640 to 820 and the y-range was 712 to 882. Below this is shown pictorially:



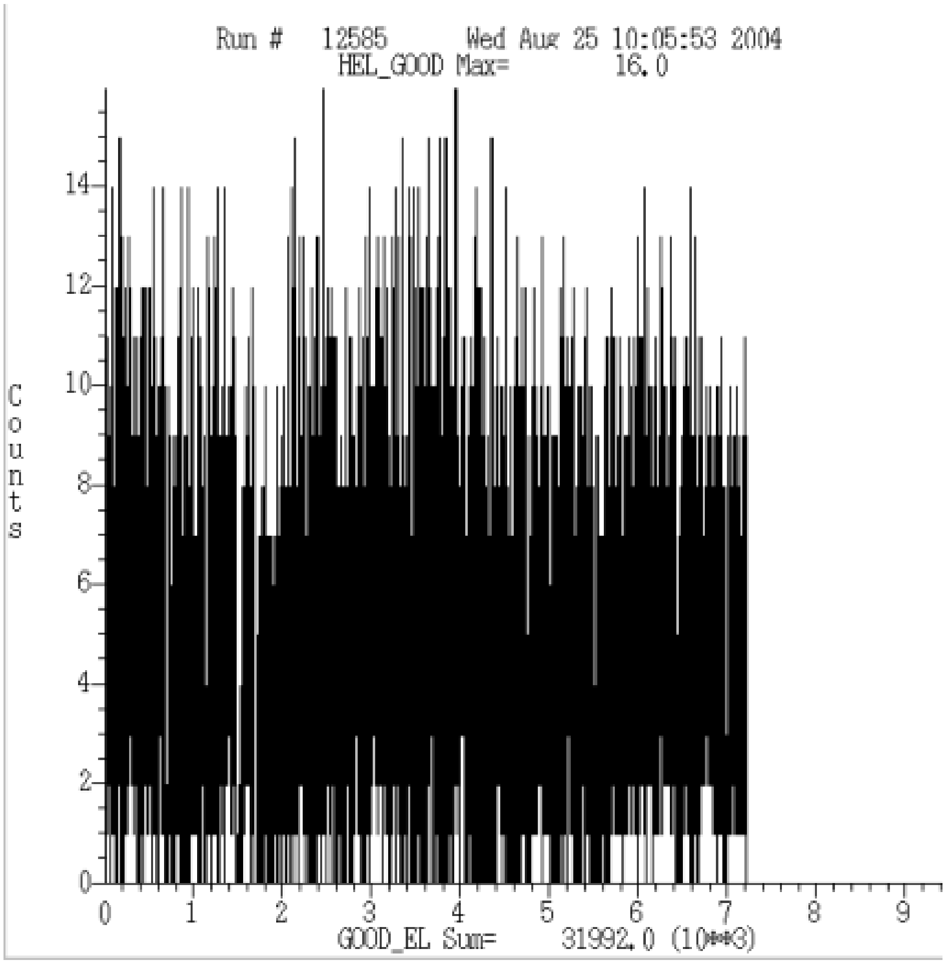
One NaI detector vs. the other
(want to integrate inside box)



Specific X-band projection
where integration was carried out

Once the “rough” rate was established, analysis was carried out as specified above for the Ge.

Next, in order to calculate a percent contamination for the beam, I needed to find the average total beam current running through DRAGON during each run. To do this I opted to use the elastic monitor data in NOVA. An example of this data is shown below.



The files I used here and the relevant ".nbc" files where one can find these spectra can be found on ISDAQ04 in:
/export/home/aruberg

So to find the average beam current I took the total number of elastic monitor events and then divided by the time of the run to find the average elastic monitor rate for the run. I then found a correlation between elastic monitor events and beam current by comparing the initial monitor rate to the beam current measured in FC4. However, FC4 readings fluctuate often and can be fairly inaccurate so a large error was established here on the order of 20%.

Note for future data analayis: It was here that I found out run 12584 did not have beam for about half of its duration resulting in a fair bit of recalculating as not only did I have to adjust for a different run time, but a different amount of background subtraction etc.

After this was done for every run, I was ready to combine the information from all the runs to get an average amount of contamination for the ^{26}Al beam. Below are some tables summarizing the findings:

		Error			Error
Ge detection efficiency	2.65E-05	7.37E-07	% Al-26 Isomeric in 6+	34.2	4.1
NaI detection efficiency	2.27E-05	2.27E-06	% Na-26 in 6+	34.69	1.09

Run #	Time (s)	# of NaI coincidences corrected for deadtime and background	Error	Ge events also corrected	Error
12583	30971	423	21	42909	207
12584	12486	130	15	15096	123
12585	14653	209	14	24787	157
12601	4772	45	7	7130	84

	Counting Rate with charge state % and detection efficiencies taken into account			
Run #	511 keV Rate in NaI detectors	Error	Rate in Ge detector	Error
12583	1.76E+03	2.88E+02	1.51E+05	1.86E+04
12584	1.34E+03	2.60E+02	1.32E+05	1.62E+04
12585	1.84E+03	3.12E+02	1.84E+05	2.27E+04
12601	1.21E+03	2.68E+02	1.63E+05	2.00E+04

Run #	Average Current (epA)	Error	Particles/second	Error
12583	31.2	7.6	3.25E+07	7.92E+06
12584	27.6	6.7	2.88E+07	6.98E+06
12585	30.6	7.4	3.19E+07	7.71E+06
12601	33.7	8.2	3.51E+07	8.54E+06

Ok, here's the important table:

Run #	Time (s)	% Na-26	Error	% Al-26	Error
12583	30971	0.46%	0.13%	5.41315E-05	1.589E-05
12584	12486	0.46%	0.12%	4.66477E-05	1.4499E-05
12585	14653	0.58%	0.16%	5.76392E-05	1.7034E-05
12601	4772	0.46%	0.13%	3.4602E-05	1.136E-05
	Average	**0.49%**	**0.07%**	**0.0048%**	**0.0007%**
		% error	13.68%		15.39%

So there are the % contamination values for $^{26}Al^{*}$ and ^{26}Na

Some suggestions I had if more someone wanted more accurate values:

1. Do a charge state distribution for ^{26}Al

2. Do a longer background run
3. Use a different method for finding average beam current for reasons discussed earlier. Or, attempt to find a more accurate means of extracting the current from the FC reading.