Alpha Attenuation Due to Dust Loading

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Purpose

- The purpose of this experiment was to properly correct for the attenuation of the energy of alpha particles due to dust loading on glass fiber filters used for air monitoring in facilities

Why alpha particles?

- Alpha particles were the radiation type of interest in this study because they are the most easily attenuated radioactive emission – they can be completely stopped by something as thin as a sheet of paper
- Air can also have a stopping effect on alpha particles – this is our concern

What's so special about air filters?

- These air filters are used to monitor the amount of airborne radioactivity in a specific area
- This monitored amount is used, along with other factors, to estimate a personnel radiation dose to the lungs

So, how does it work?

- These air filters are allowed to run for different sampling times at different facilities
- Once the sampling time is up, the filters are processed (ran through a radiation counter) and any showing a higher than normal activity are pulled for further inspection
- If it is found that the higher than normal activity is truly present, the personnel working in that area during the sampling time may need to go on a monitoring program to be sure that they have not received a problematic exposure

Why is this important?

- Normally, the alpha dose the is counted is corrected by 20% in order to correct for possible attenuation – this correction factor may not be accurate in all cases
- Previous studies (Luetzelschwab and Higby) have shown that dust loading may cause a counting loss by as much as:
  - 28% for samples collected weekly
  - 40% for samples counted bi-weekly
- There has not yet been a study with sufficient results to properly correct for attenuation due to dust loading on the filters
  - Although, Prior work [Broome 2005] indicated significant decreases in alpha count rate (as much as 38%) due to dust loading, especially on filters from facilities where sampling takes place over long intervals

What was my purpose?

- My purpose was to see how much dust could, hypothetically, cover the surface of the filter containing the alpha particles before more than 20% of the particles were being attenuated
- After this point of dust covering, the 20% correction factor will not cut it for an accurate representation of dose

Materials Used

- The three detectors used in this experiment were:
  - Canberra Series 5 low background gas proportional counter
  - Dual phosphor Eberline HandECount portable scaler
  - Ortec vacuum chamber with Canberra PIPS detector

  These detectors were chosen because they are the main detectors used for counting air filter samples

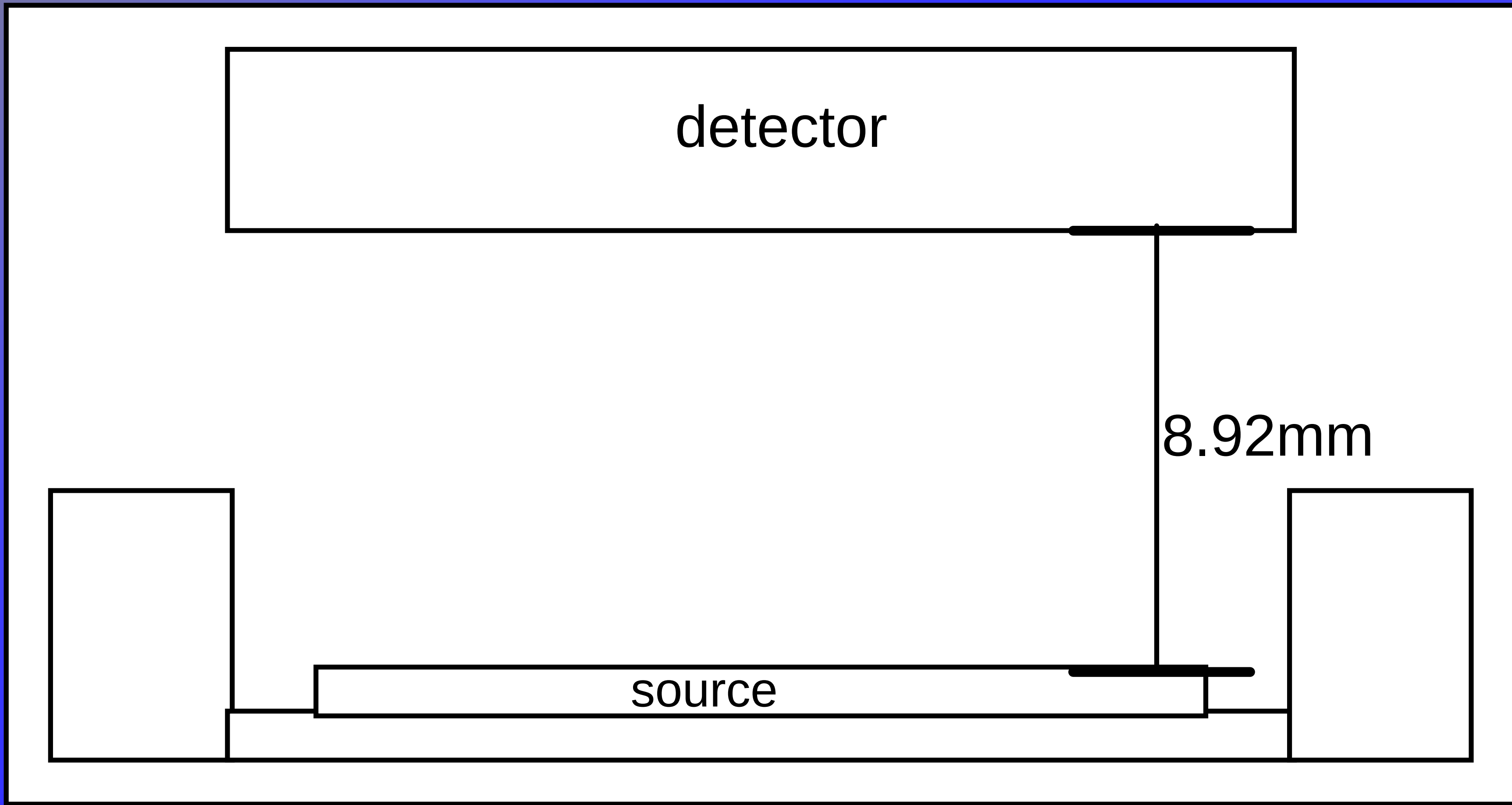
Materials Used

- An attenuator set composed of 9 attenuators of varying density thicknesses of Mylar™ ranging from $0.41 mg/cm^2$ to $3.51 mg/cm^2$ used to simulate a dust covering
- A 47mm 0.031µCi NIST traceable Americium-241 source

Canberra Series 5 Detector

- Contains gas-flow proportional and guard detector that both use P-10 gas
- Low background alpha/beta counter with beta background as low as 0.5 cpm
- 4 inches of lead shielding
- 2.25 inch detector
- Detector window density thickness is 80 $\mu g/cm^2$
- Sample lies 8.92mm from detector

Canberra Series 5 Detector



Canberra Series 5 Detector

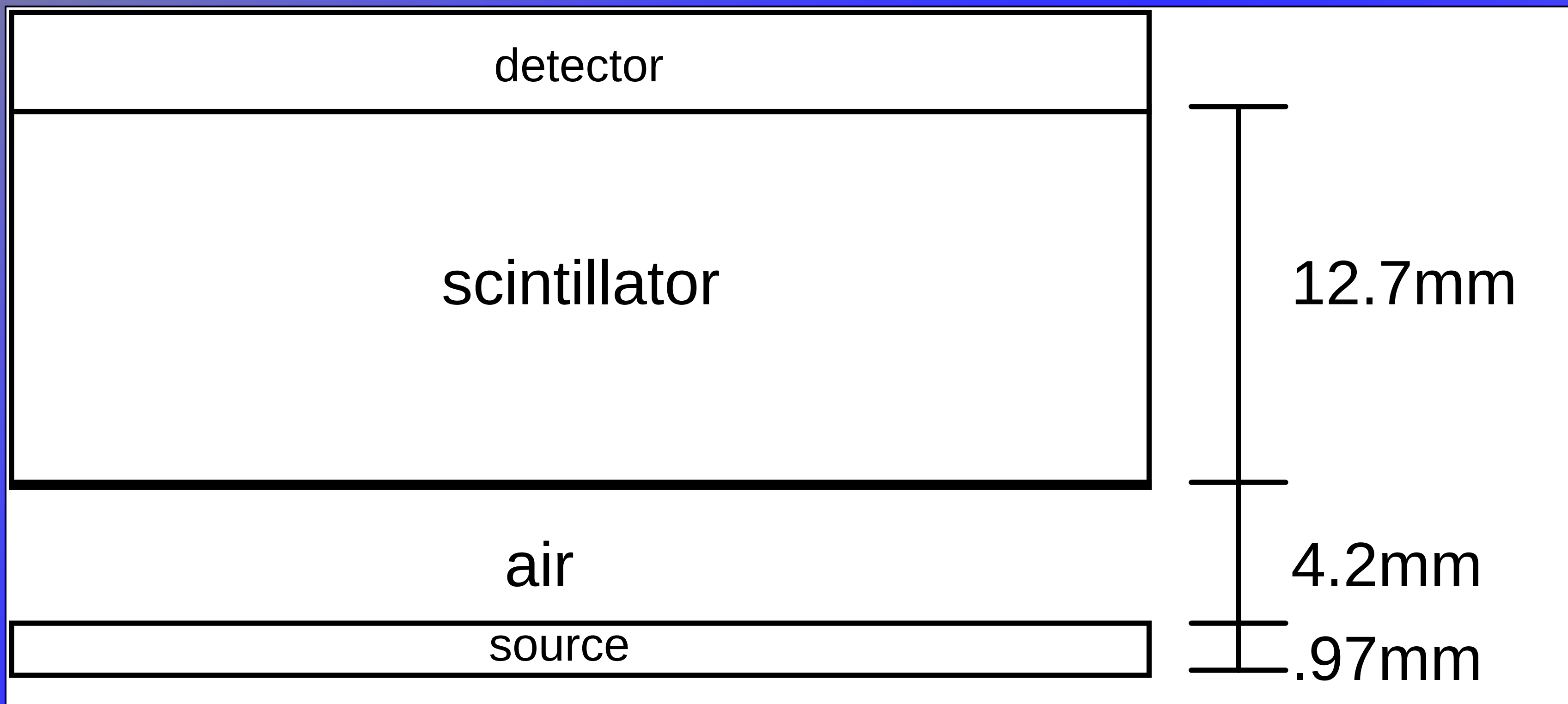
Eberline Hand$_E$Count

- 2" dual phosphor scintillation counter
- Alpha efficiency 90%
- Beta efficiency 25% to 35%
- Efficiency calculated as:

$$\alpha Efficiency = \frac{\alpha Counts - \beta\alpha CrossOver \times (\beta Counts - \beta Background) - \alpha Background}{CountTime \times \alpha EmissionRate}$$

- Background <=3cpm alpha and <=60cpm beta
- Source lies 4.2mm from scintillator

Eberline HandECount



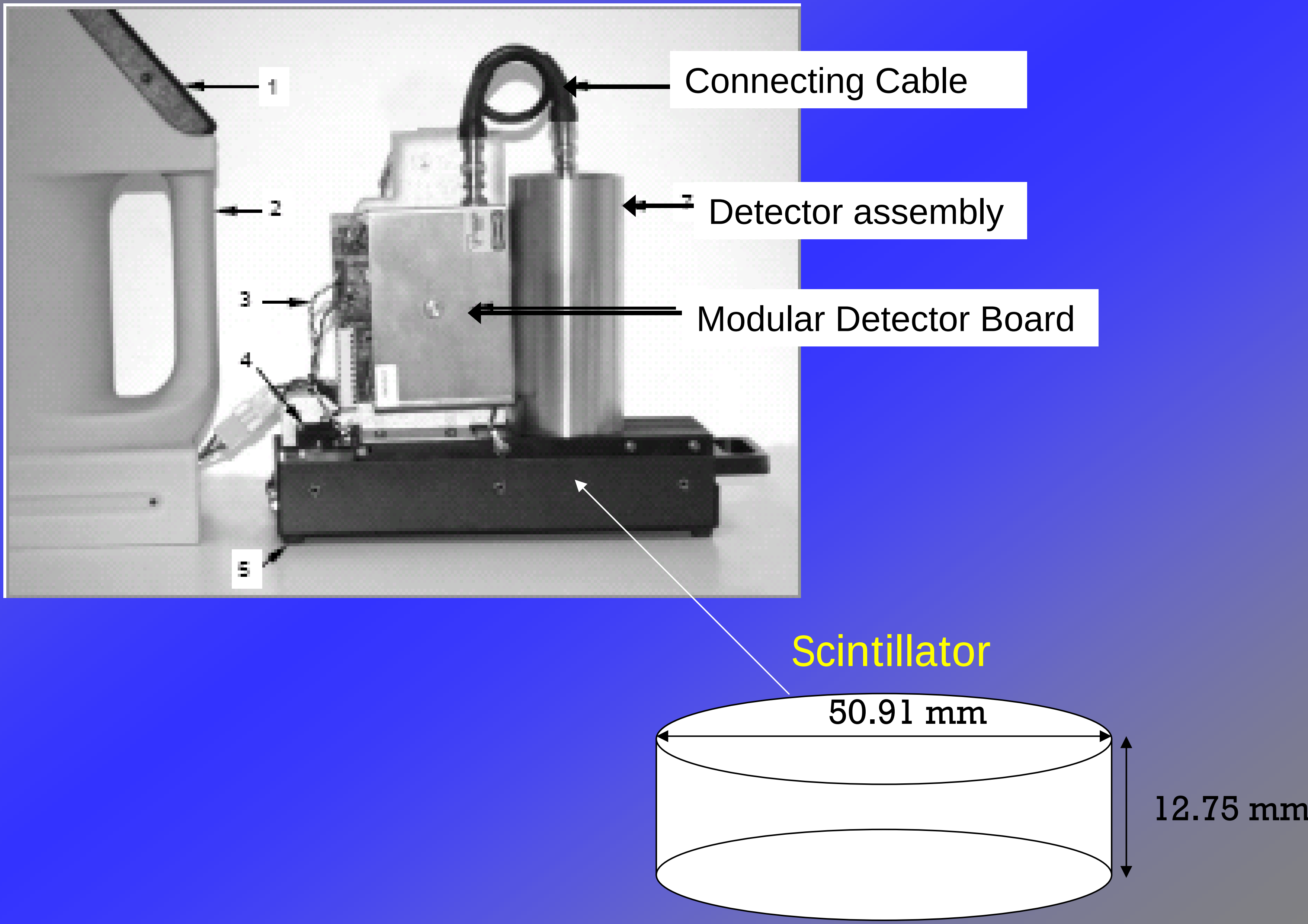
Eberline HandECount

PDA for data display

Detector housing

Drawer containing sample

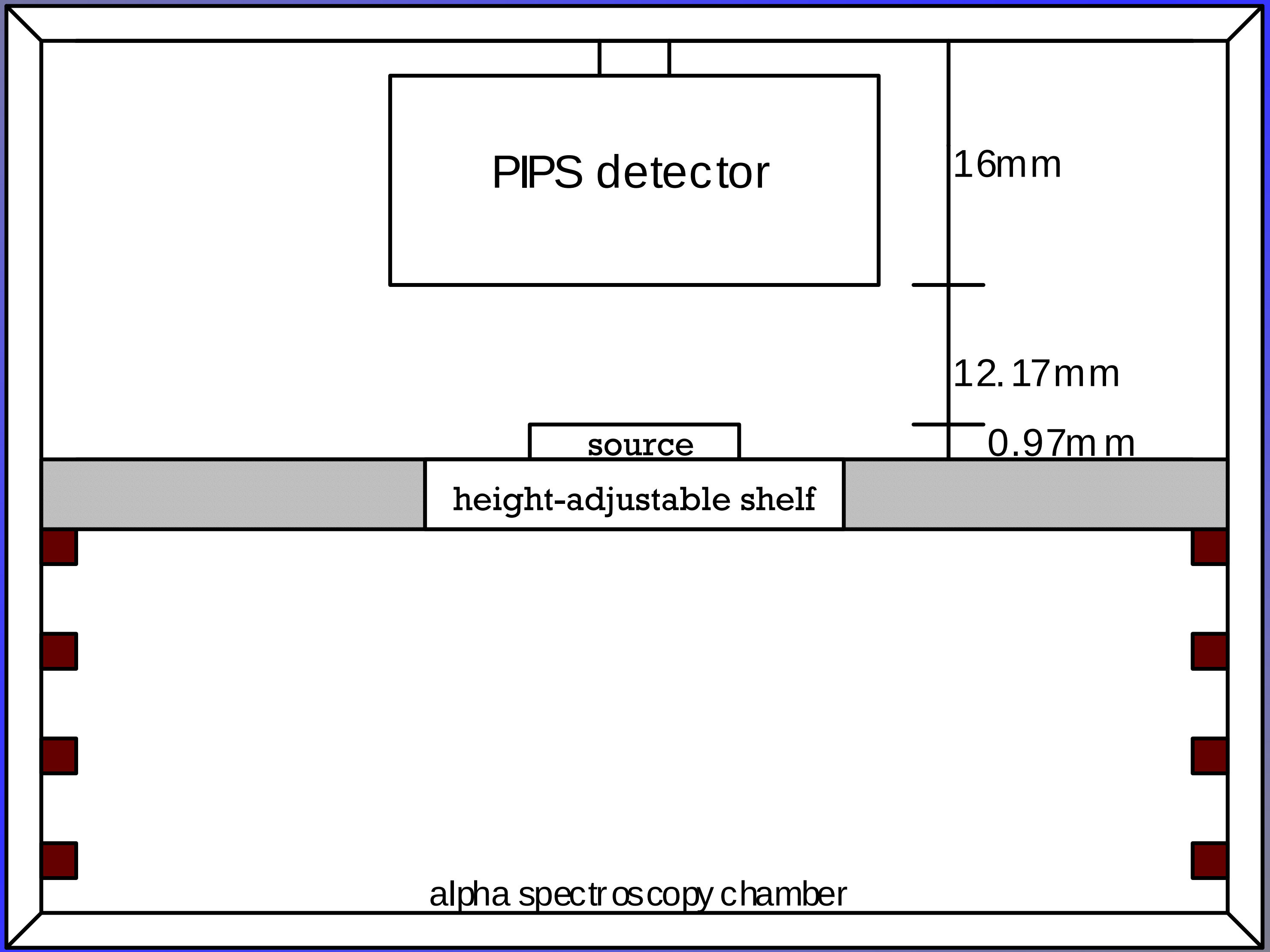
Eberline Hand$_E$Count



Alpha Spectrometer

- Composed of EG&G Ortec 808 vacuum chamber and Canberra PIPS Detector
- Chamber is evacuated using Welch Series W vacuum pump
- PIPS Detector fabricated using photolithographic techniques
- Face of detector is ion-implanted
- Detector operates at 40V
- Background count rate <0.05 counts/hr/cm^2
- Window thickness $<2 \mu m$
- Sample lies 12.17mm below bottom of detector

Alpha Spectrometer

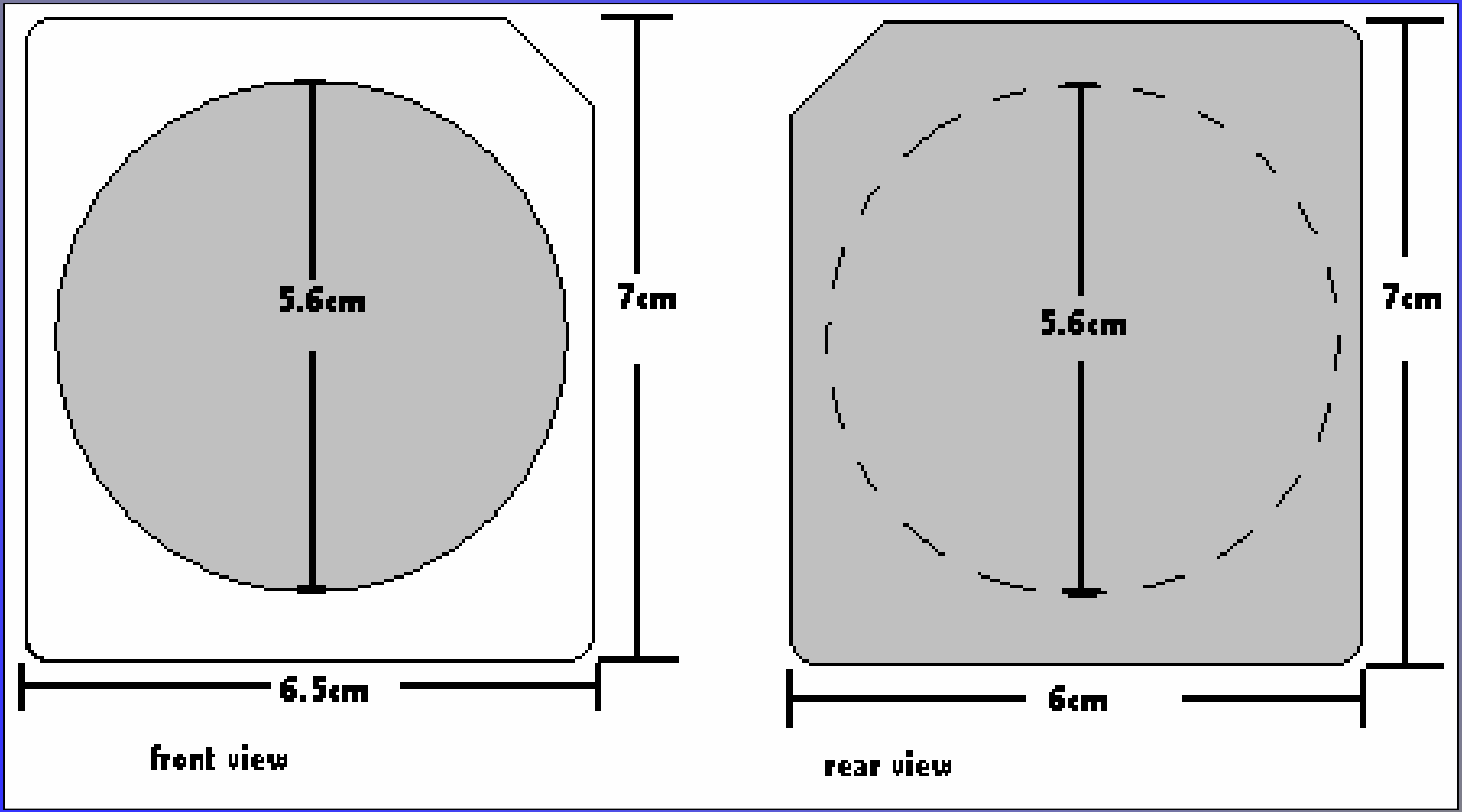


Alpha Spectrometer

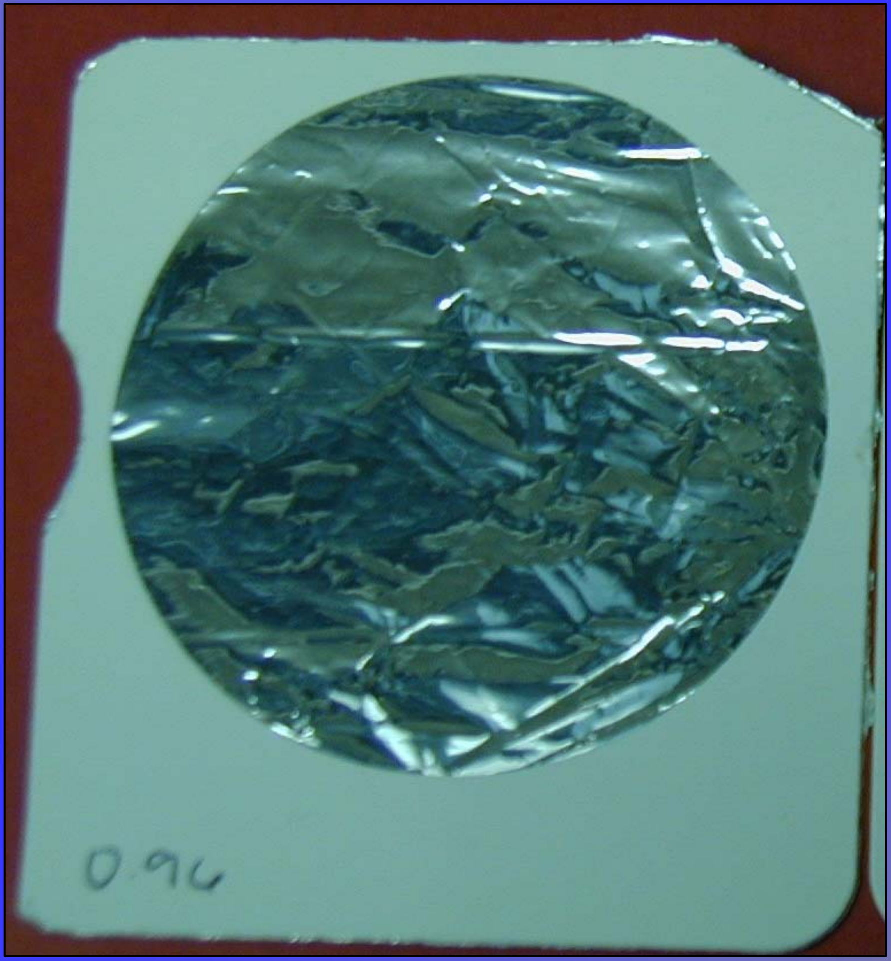
The Attenuator Set

- Attenuators were built using cards with dimensions equal to the dimensions of the cards that surround the glass fiber filters being investigated
- A 2.25” hole (slightly larger than diameter of glass fiber filters) was punched in the card
- Cards were then adhered to layers of Mylar™ of varying density thicknesses

Attenuator Set



Appearance of Attenuator



Attenuator Card

Filter Card

Method

- Background counts were obtained and recorded for each detector used everyday
- The Americium-241 source was counted for either 30 minutes or duration sufficient to acquire 10,000 counts, whichever took less time
- The count was done ten times per density thickness attenuator

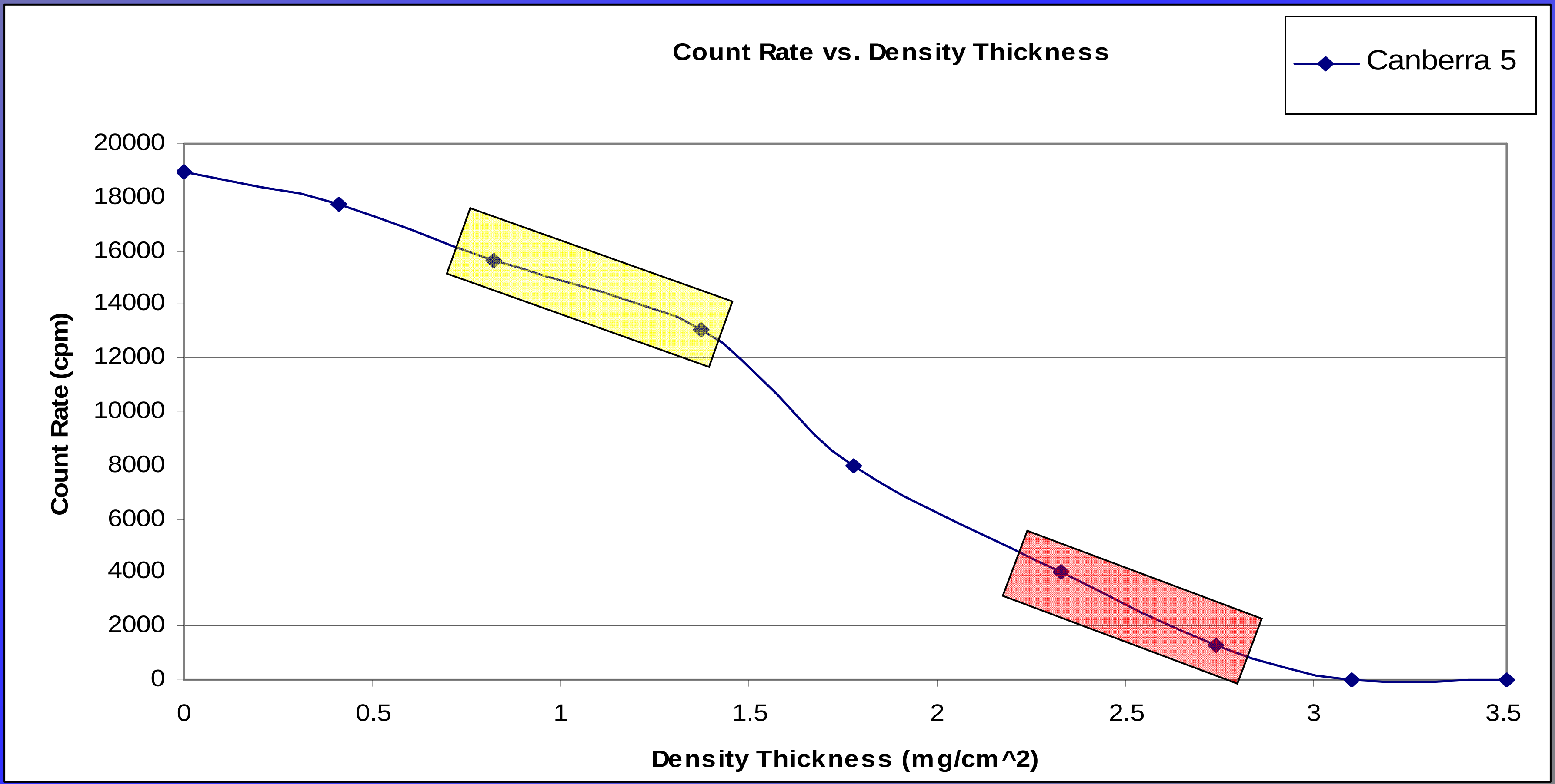
Method

- A percent deviation of no more than 6% was the data standard to ensure accuracy of counts
- The multiple counts were first taken when the source was uncovered and successively for each density thickness of Mylar™ covering
- Data was analyzed and alpha absorption curves were produced for each detector by plotting the count rate (in cpm) vs. the density thickness of the attenuating material (in mg/cm^2)

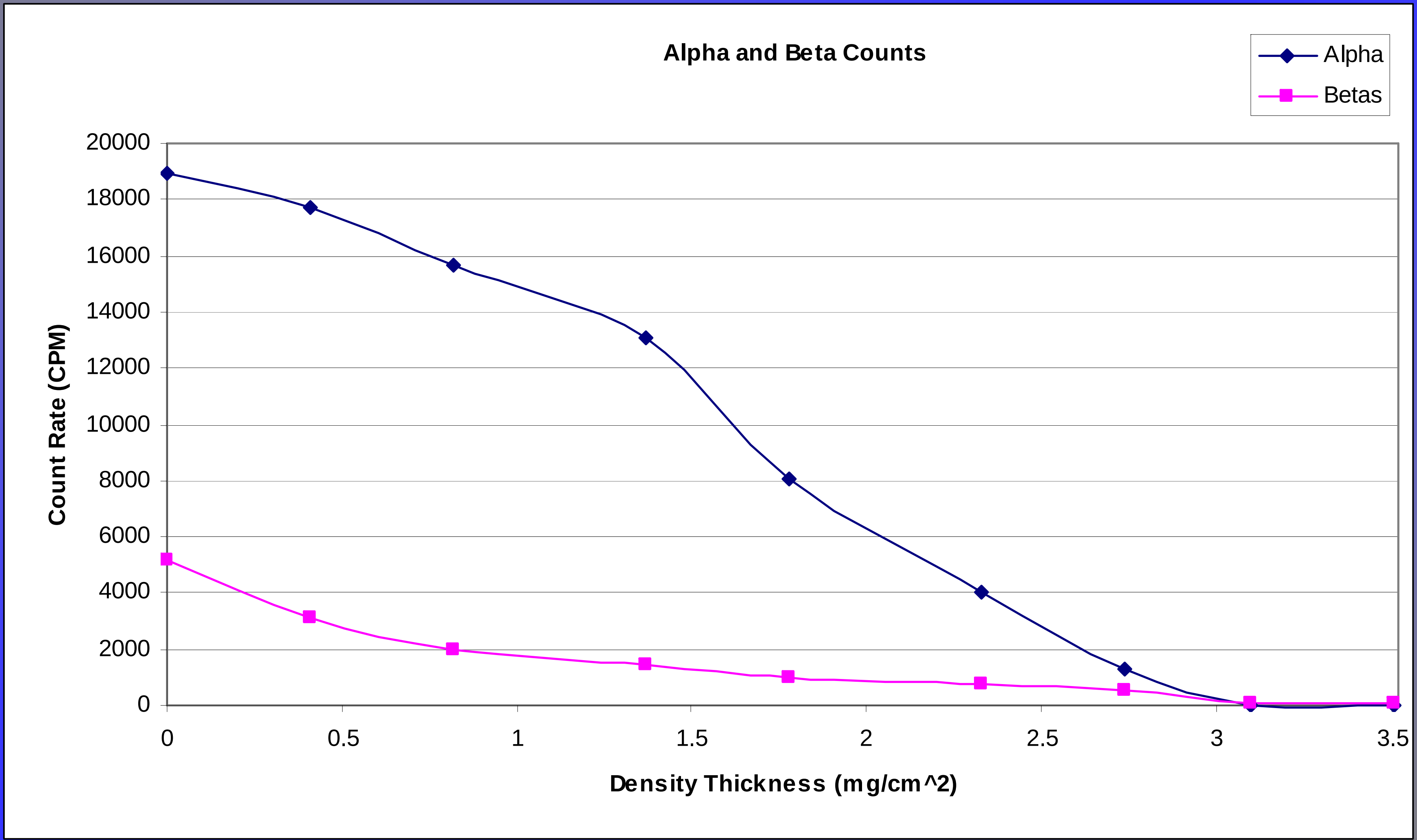
Canberra 5 Results

20% attenuation takes place between 0.82 and 1.37mg/cm^2

80% attenuation takes place between 2.33 and 2.74mg/cm^2



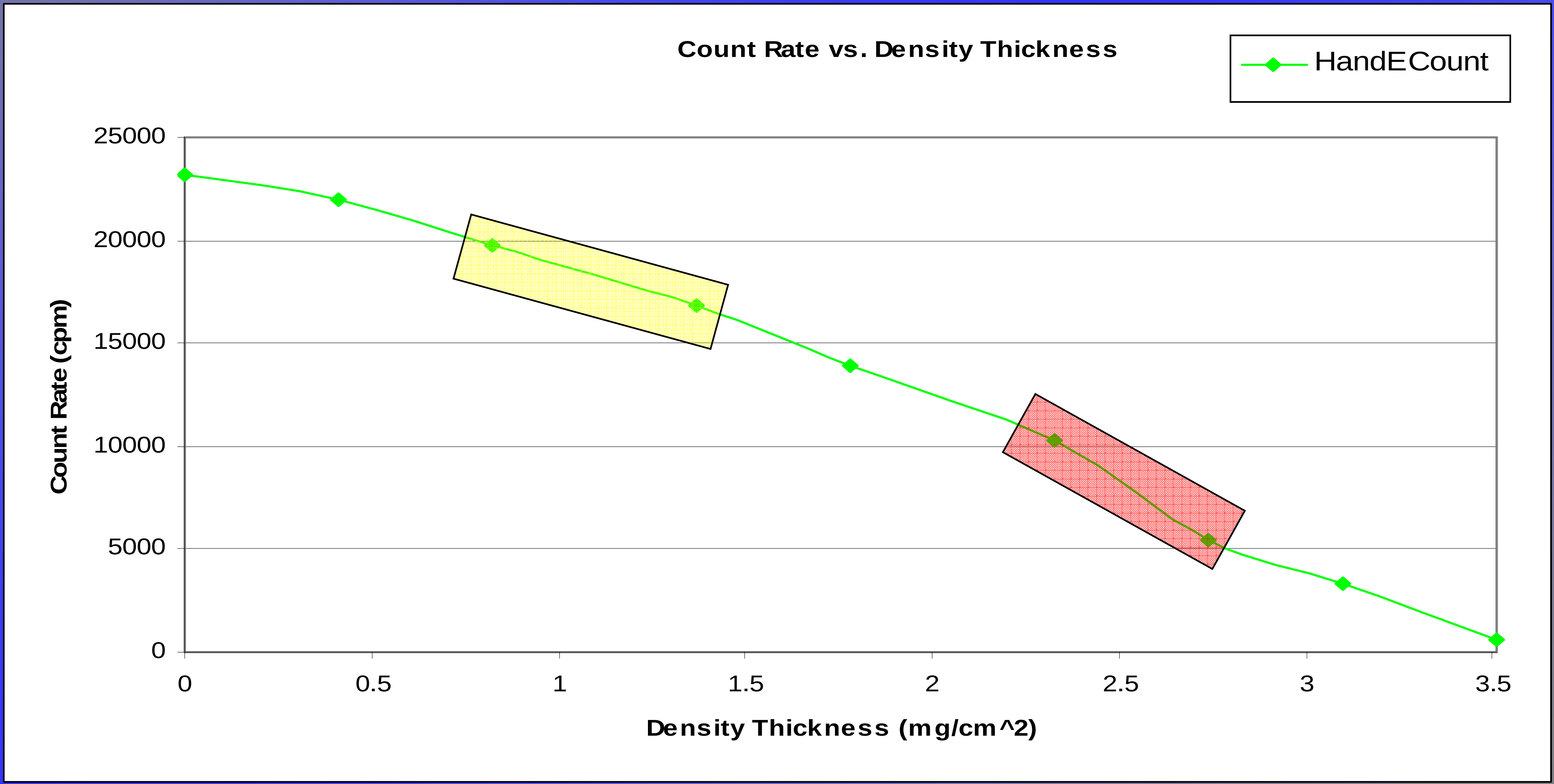
Canberra 5 Results



HandECount Results

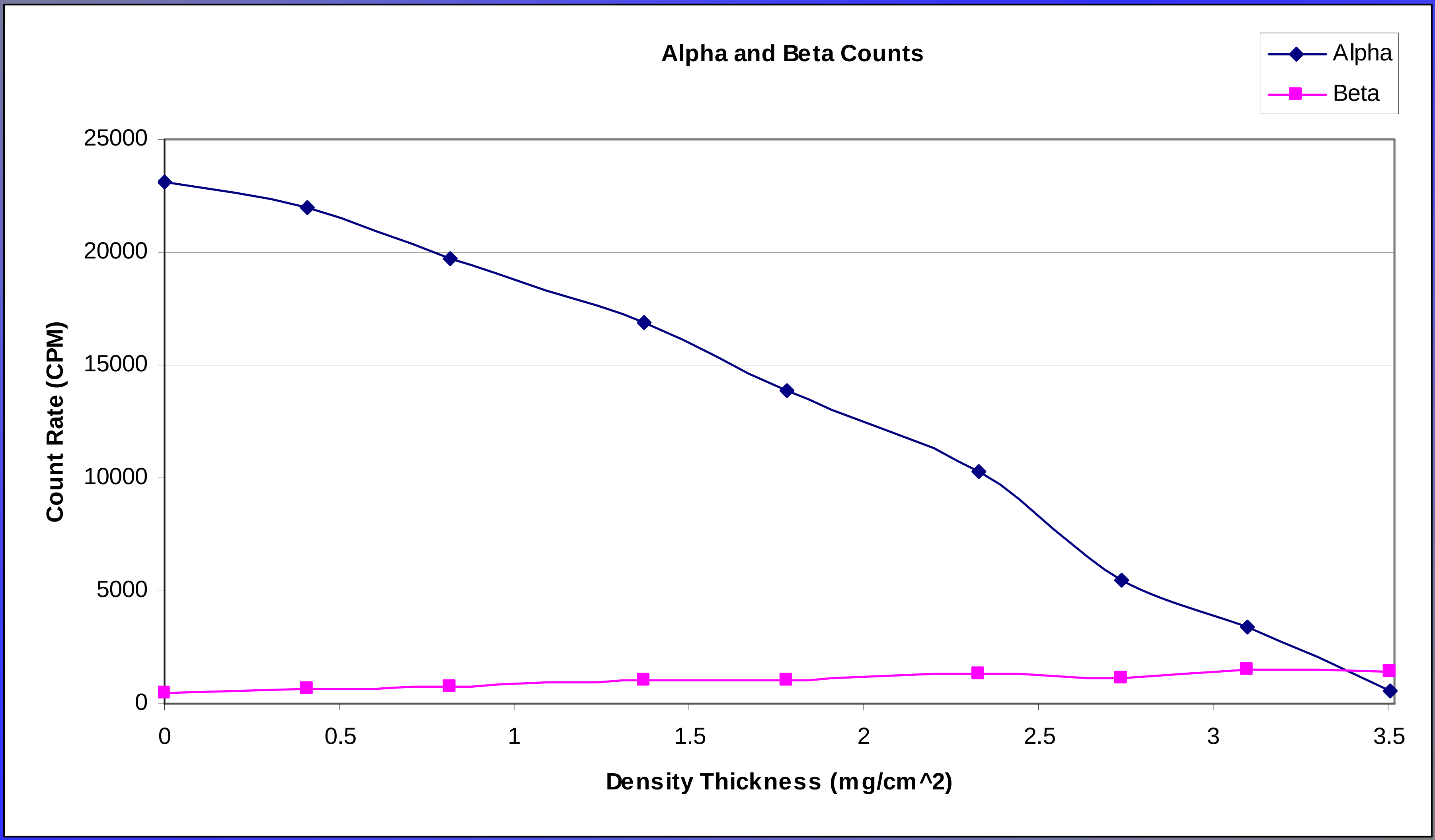
20% attenuation takes place between 0.82 and 1.37mg/cm^2

80% attenuation takes place between 2.33 and 2.74mg/cm^2



HandECount Results

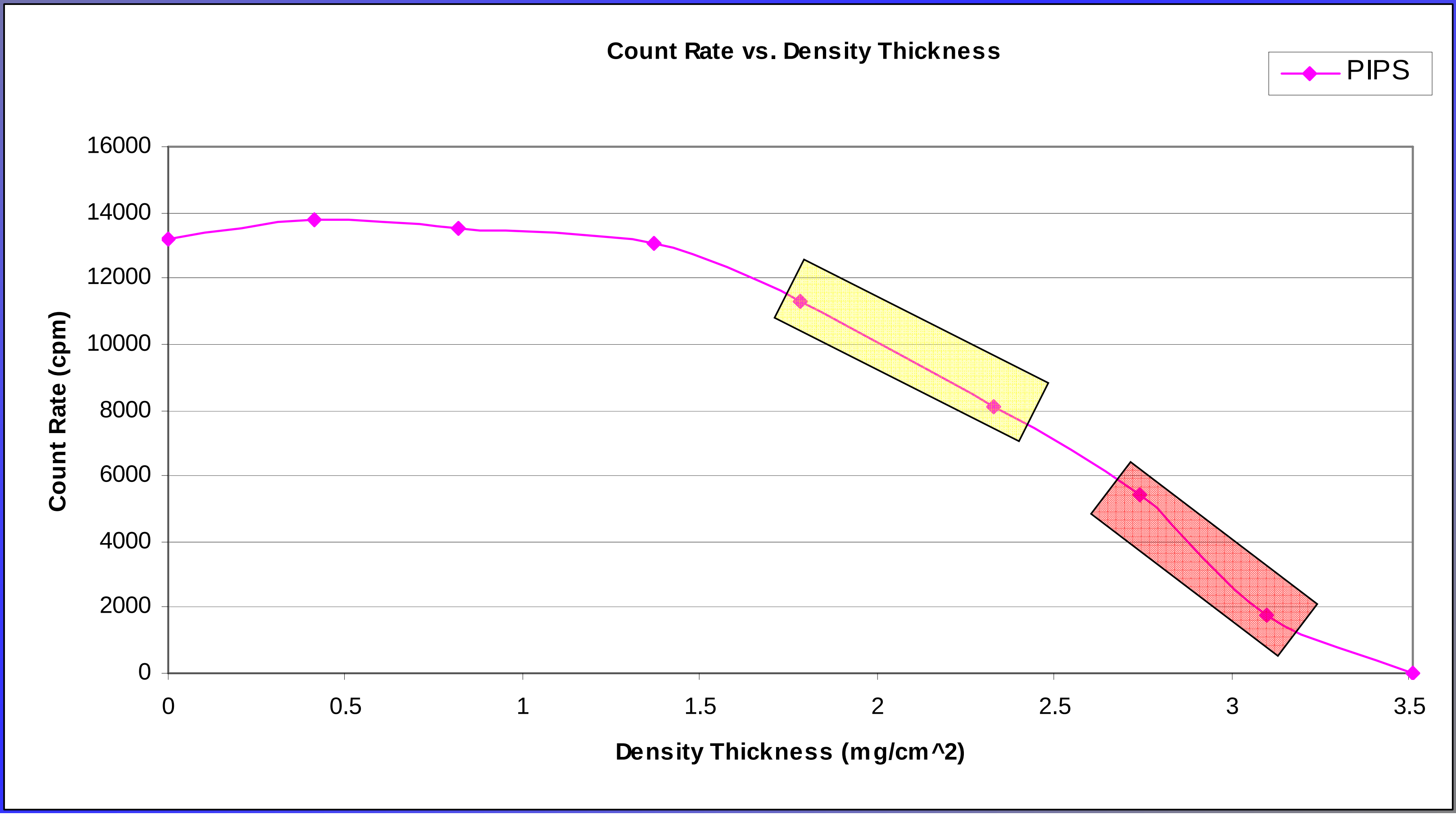
Beta counts increase as Alpha counts decrease



Alpha Spectrometer Results

20% attenuation takes place between 1.78 and 2.33mg/cm^2

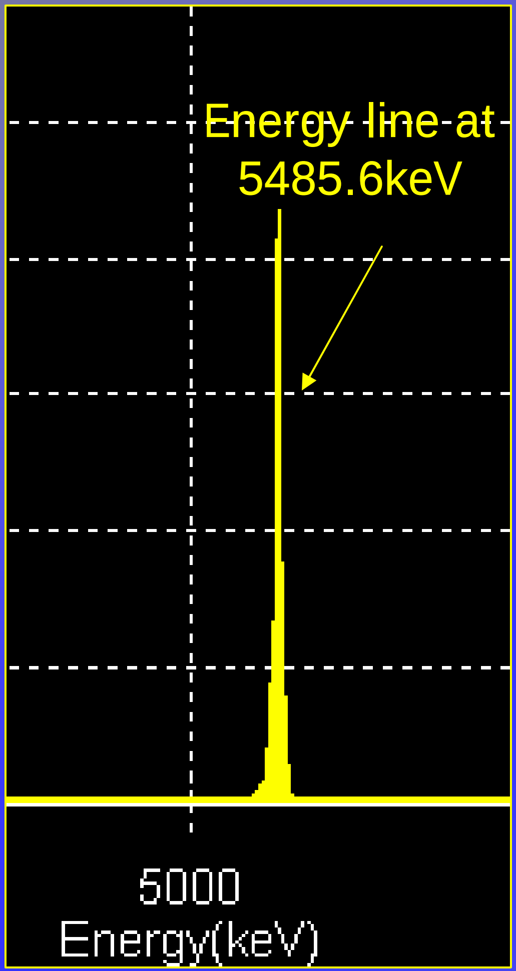
80% attenuation takes place between 2.33 and 2.74mg/cm^2



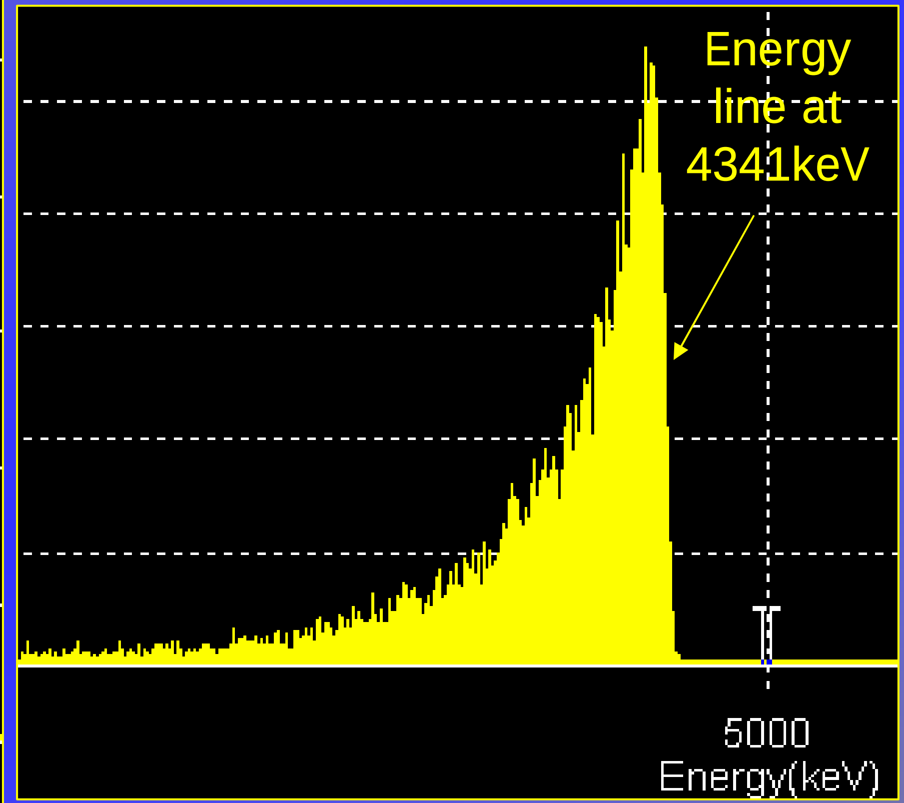
Alpha Spectrometer Results

Actual Americium-241 peak occurs at 5486keV

0 attenuation

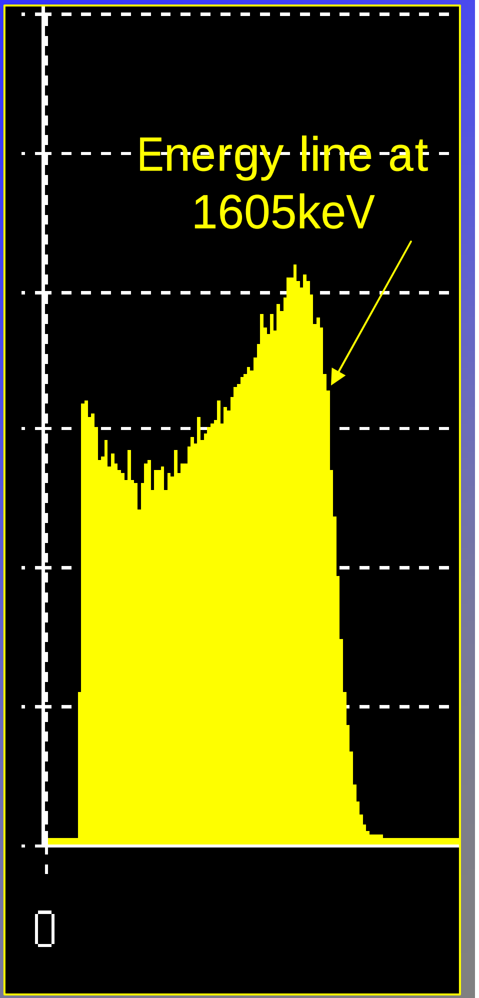


$1.37 mg/cm^2$ attenuation

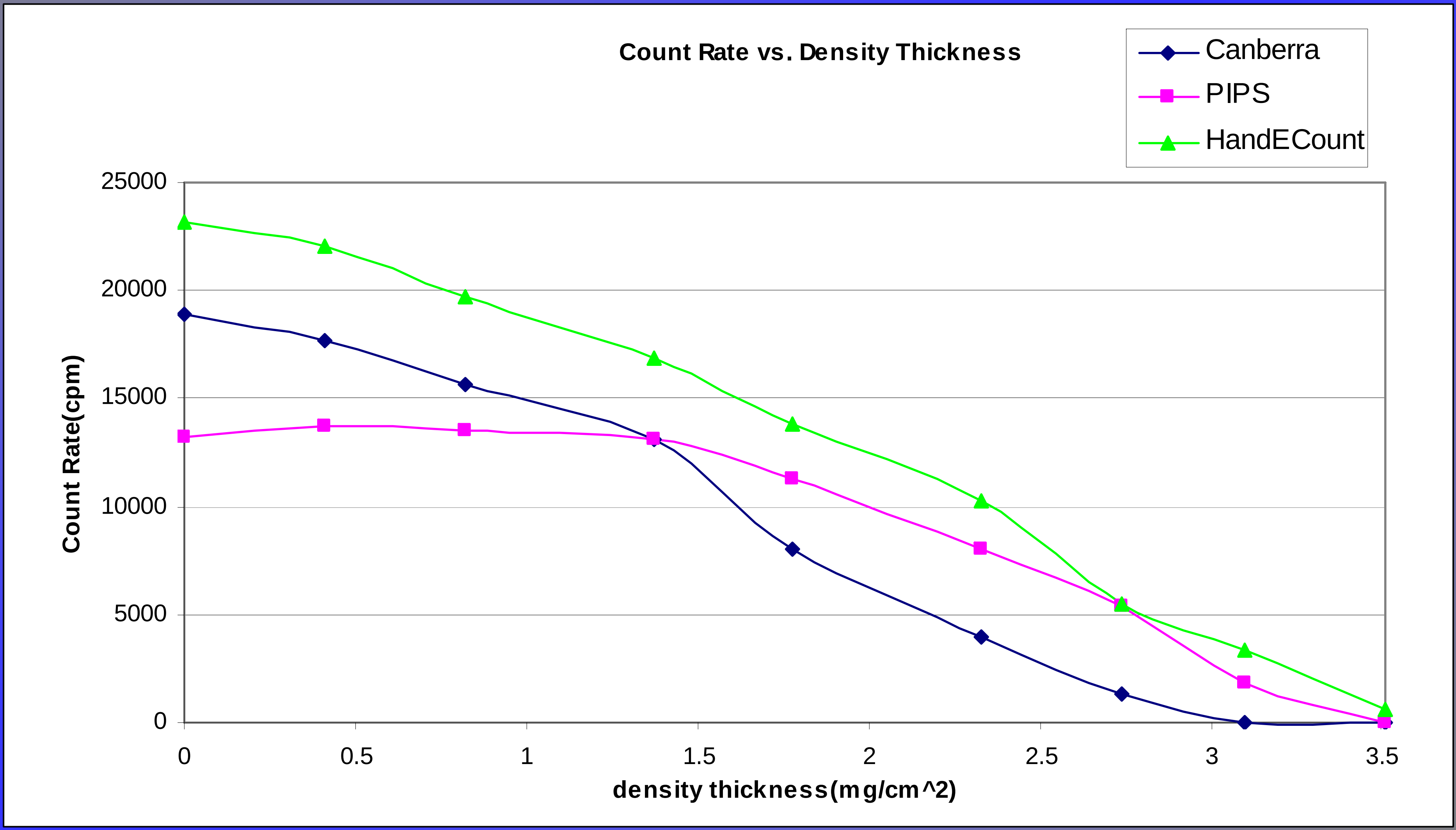


*Resolution is greatly decreased

$3.51 mg/cm^2$ attenuation



Results



Count Rate vs. Density Thickness
Canberra
PIPS
HandECount
25000
20000
15000
10000
5000
0
Count Rate(cpm)
0
0.5
1
1.5
2
2.5
3
3.5
density thickness(mg/cm^2)

Results

- Counts without attenuation are varied due to the distance from the source to the detector
- These distances are 4.2, 8.92 and 12.17mm
- As expected, the number of counts is inversely proportional to the distance between source and detector
- This is due to the range of an alpha in air, given by:

$$R_a = 1.24E - 2.62$$

where:

E is alpha particle energy in MeV

R_a is the range of the alpha particle in cm

Future Studies

- Facilities will perform dust loading studies in order to determine the proper sampling periods, so that it will be unlikely that there will be attenuation greater than is corrected for.

References

- Higby, D.P. *Effects of Particle Size and Velocity on Burial Depth of Airborne Particles in Glass Fiber Filters*, PNL-5278, Pacific Northwest Laboratory, Richland, WA, 1984.
- Luetzelschwab, J.W., C. Storey, K. Zraly, and D. Dussinger, *Self Absorption of Alpha and Beta Particles in a Fiberglass Filter*, Health Physics, 79:425-430; 2000.
- Broome, M.A. *Defense Waste Processing Facility (DWPF) Air Sample Dust-Loading Study*, CBU-WSP-2005-00065, Savannah River Site, Aiken, SC, 2005.
- Hadlock, D.J. *Workplace Air Monitoring Technical Basis Manual*, WSRC-IM-2001-00025, Revision 1, 2005.

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