IBM Research

On the Calibration of Alpha Sciences Proportional Counters

Michael Gordon (gordonm@us.ibm.com)

Ken Rodbell

IBM Research
1101 Kitchawan Road
Yorktown Heights, NY 10598

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Outline

How is the discriminator set on Alpha Sciences counter and what is the alpha-particle energy associated with the setting? What is the impact of cutting out the low energy alphas from a sample?

- *Introduction*
- *Background*
- *Overview of the Alpha Sciences proportional counters*
- *Our low-energy alpha-particle source*
- *Results*
- *Conclusion*

Introduction

- *We review a technique for determining the alpha-particle energy associated with a discriminator setting.*
- *We have a low energy “thick” alpha-particle source that was developed for this work.*
- *The alpha particles from this source stop in the gas within the active volume of the detector (important for association between pulse-height analysis and alpha-particle energy).*
- *We compared the count rate of the source vs discriminator setting in the proportional counter, and the count rate of the same source with a silicon surface barrier detector to obtain an energy scale.*

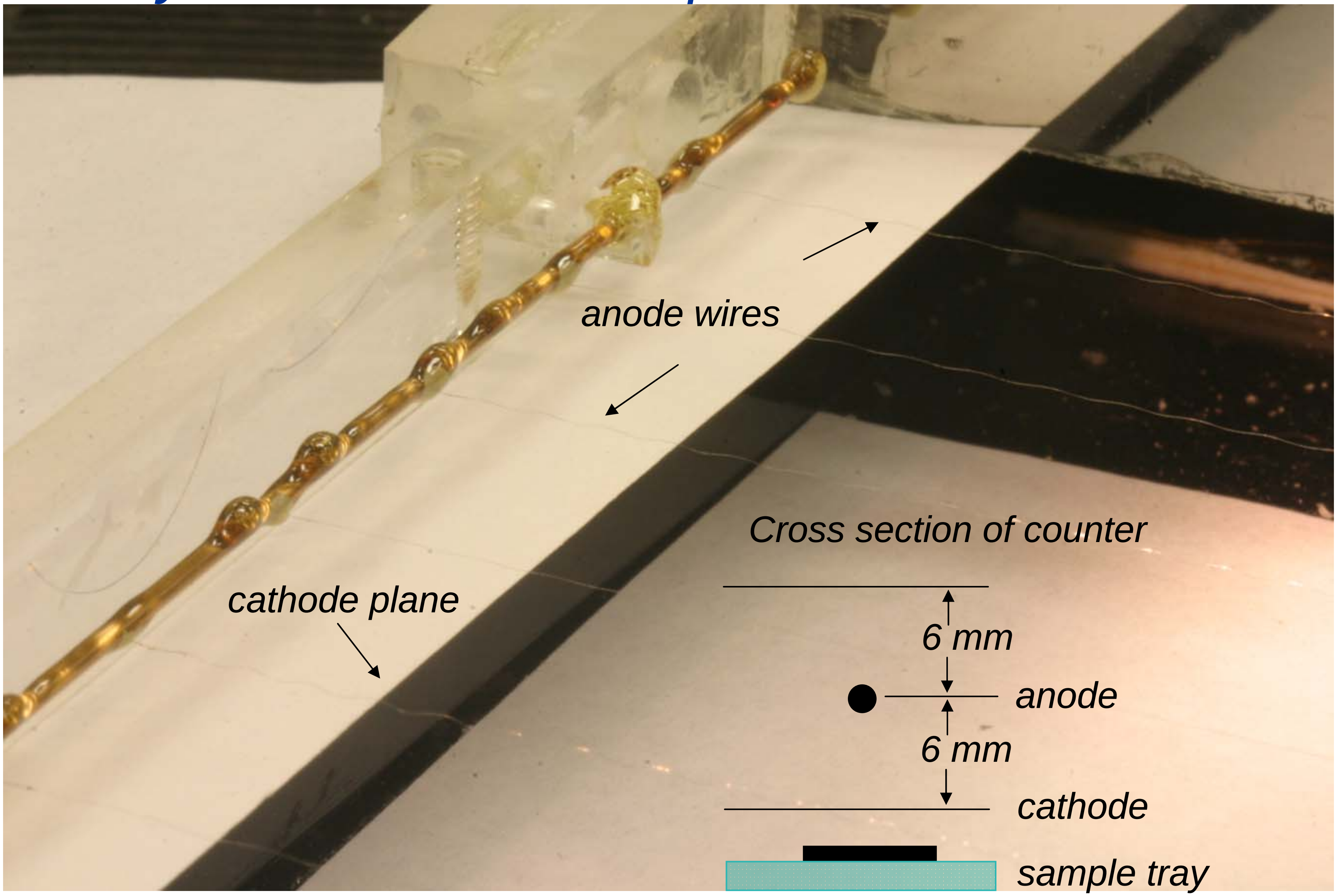
Background

- *Many labs have Alpha Sciences proportional counters*
  - *Material labs*
  - *Semiconductor labs*

- *Recently, several labs participated in a "round-robin" study of both low and ultra-low emissivity samples, "Multicenter comparison of alpha particle measurements and methods typical of semiconductor processing"**
  - *Very few constraints were placed on the measurement*
    - *No sample preparation or measurement protocol*
    - *Samples were in many pieces that could be tiled to account for different sizes of the tray/active area of the counter*
  - *There was a ~ 2X difference between the largest and smallest sample emissivity measured*
  - *It was proposed that this difference could be due to the discriminator settings on the individual detectors*
    - *Most people "assume" that the discriminators are set to 1 MeV*

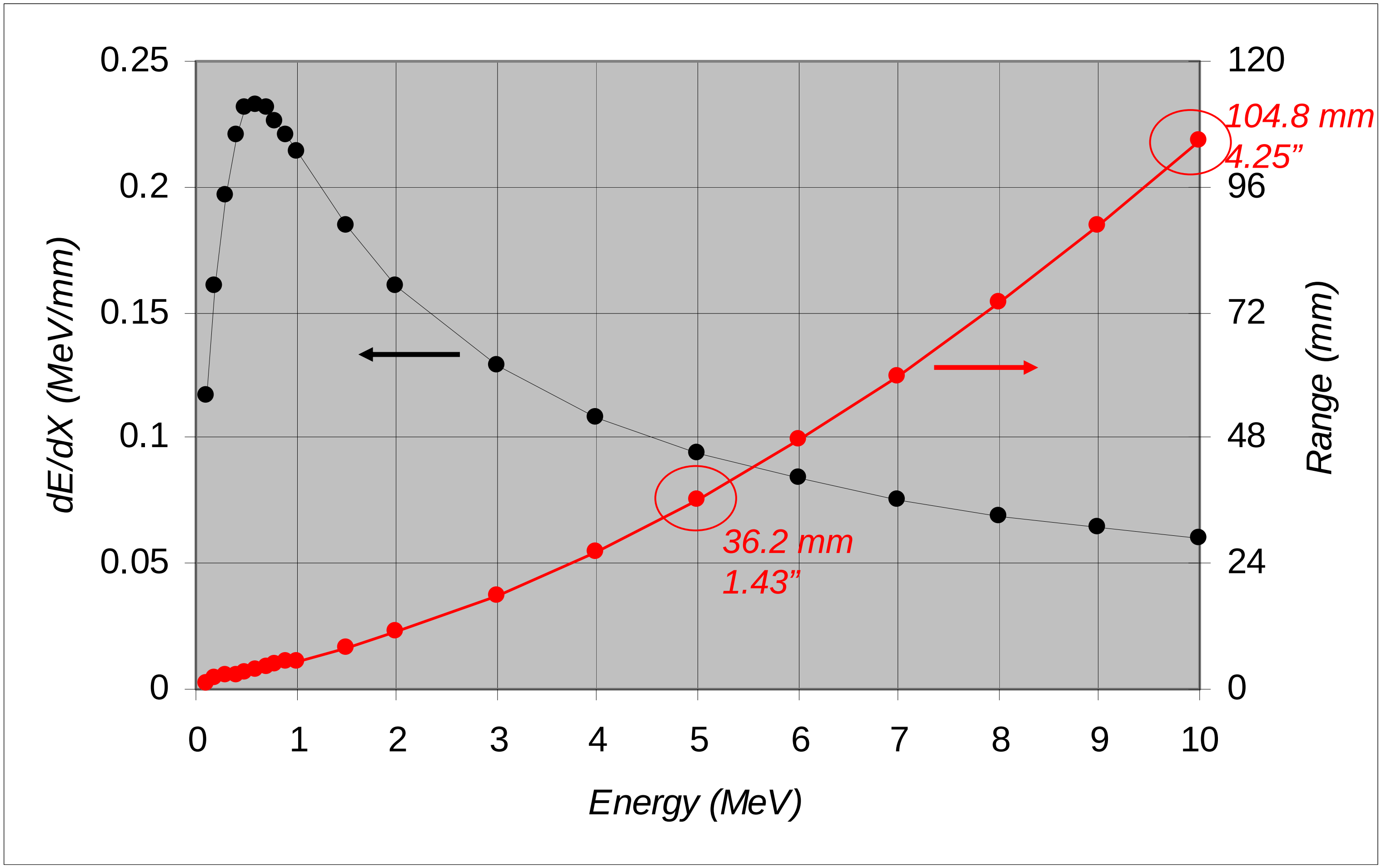
** http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5784521*

Cutaway section of an old Alpha Sciences counter

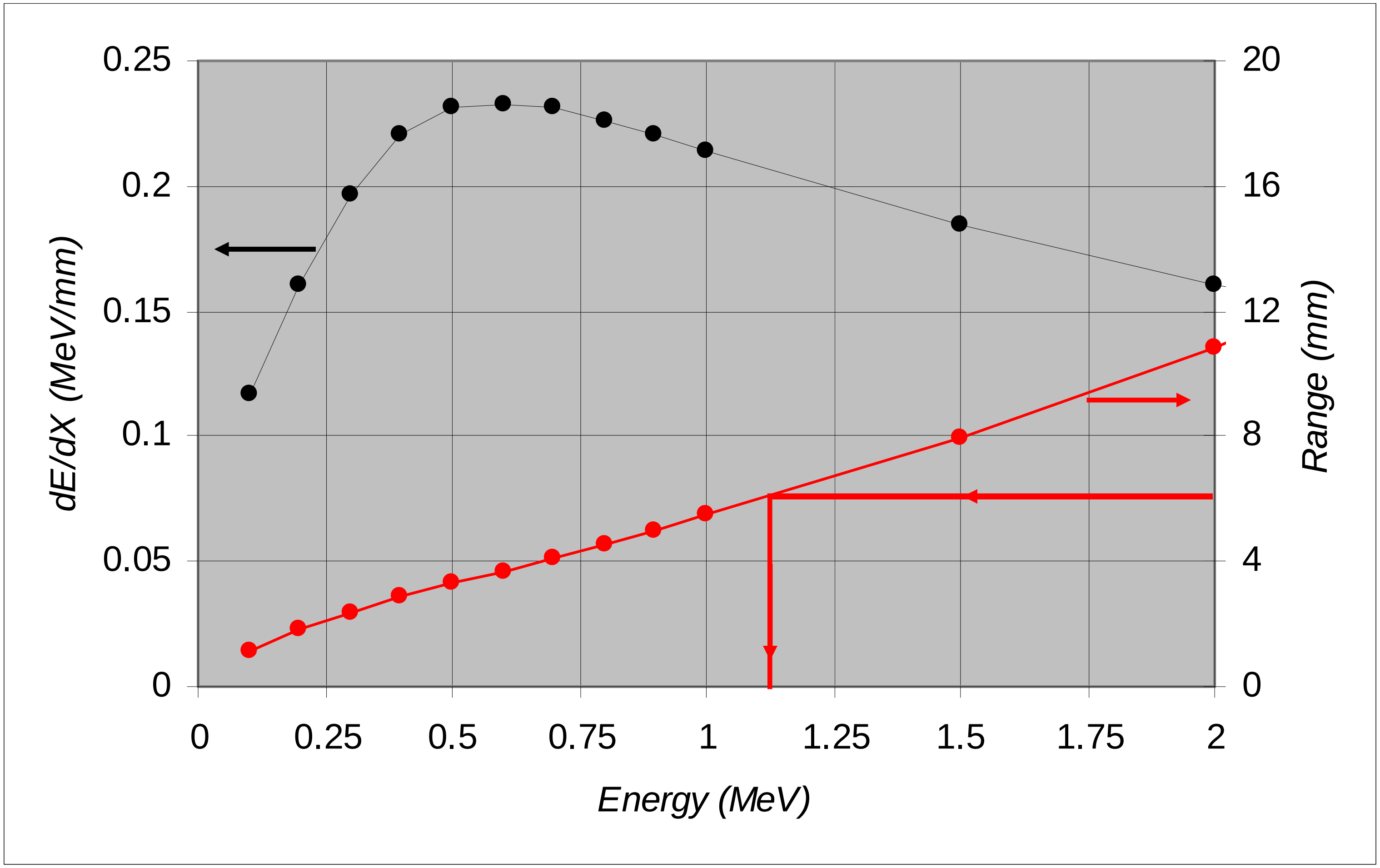


SRIM simulations of alpha-particles in Ar gas

The counter gas used is Ar/CH_4



SRIM simulations of alpha-particles in Ar gas



~1.1 MeV α-particles have a 6 mm range

<u>higher-energy alpha particle will not stop in the detector volume</u>

The low-energy α-source

- We need a low-energy α-source (so that the α's stop in the active volume in the counter)
- We made an alpha-particle source from natural Samarium since it's one of the lowest energy naturally-occurring α-particle emitter
- Sm has 3 naturally-occurring α-emitting radioactive isotopes,
  - only ^{147}Sm is important, due to the shorter ½ life compared to ^{148}Sm, or ^{149}Sm

Sm Isotope	α-energy (MeV)	½-life (years)	Abundance (%)	Specific activity (α/sec-g)
^{147}Sm	2.25	1.06E11	15	850
^{148}Sm	1.93	7E15	11.2	0.013
^{149}Sm	1.07	>1E16 (stable?)	13.8	

$$SA = \frac{Ln2}{T_{1/2}(\sec)} x \frac{N(atoms/mol)}{A(g/mol)}$$

http://www.nndc.bnl.gov/chart/
Chart of the Nuclides, GE, 13th ed.

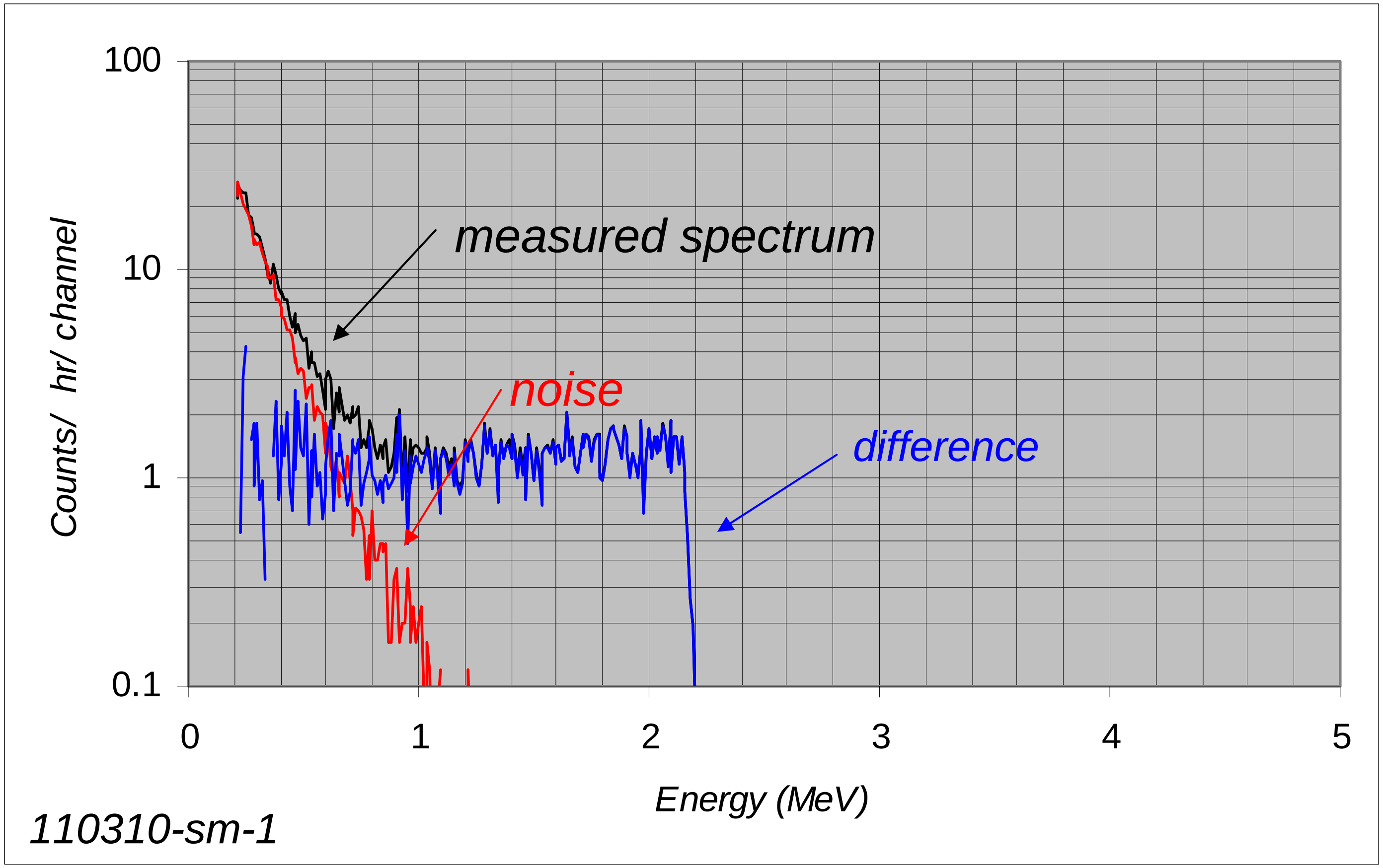
Table of natural alpha-particle emitters and their energies

TABLE OF NATURAL ALPHA - PARTICLE ENERGIES

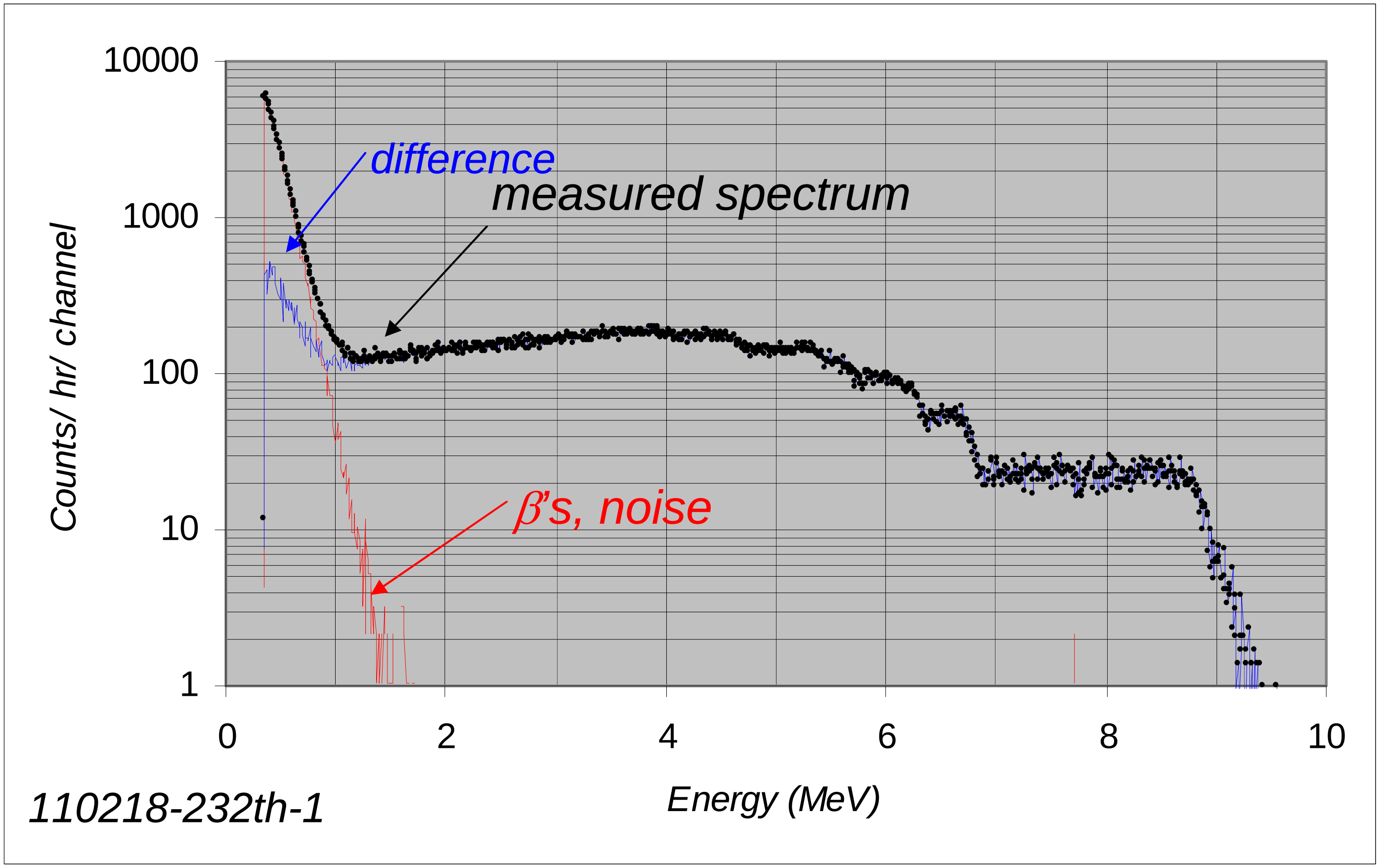
ENERGY (MeV)	MOTHER ISOTOPE	HALF-LIFE		EQUILIBRIUM ABUNDANCE	FAMILY CHAIN	COMMENTS
1.83	Nd - 144	2.4	E 15 y	24 %	none	Natural part of Nd
1.50	Ce - 142	5.	E 15 y	11 %	none	Natural part of Ce
2.14	Gd - 152	1.1	E 14 y	21 %	none	Natural part of Gd
2.23	Sm - 147	1.1	E 14 y	15 %	none	Natural part of Sm
2.50	Hf - 174	2.	E 15 y	0.2%	none	Natural part of Hf
3.18	Pt - 190	7.	E 11 y	0.01%	none	Natural part of Pt
3.83	Th - 232	1.39	E 10 y	0.2 %	Th - 232	Natural Element
3.95	Th - 232	1.39	E 10 y	23 %	Th - 232	Natural Element
4.01	Th - 232	1.39	E 10 y	73 %	Th - 232	Natural Element
4.15	U - 238	4.50	E 9 y	23 %	U - 238	Natural Element
4.20	U - 238	4.50	E 9 y	73 %	U - 238	Natural Element
4.39	U - 235	7.1	E 8 y	100%	U - 235	Natural Element
4.60	Ra - 226	1.60	E 3 y	6 %	U - 238	(2)
4.62	Th - 230	7.5	E 4 y	24 %	U - 238	
4.69	Th - 230	7.5	E 4 y	76 %	U - 238	
4.72	U - 234	2.5	E 5 y	28 %	U - 238	
4.78	U - 234	2.5	E 5 y	72 %	U - 238	(2)
4.78	Ra - 226	1.60	E 3 y	94 %	U - 238	
5.18	Th - 228	1.91	y	0.2 %	Th - 232	(1)
5.21	Th - 228	1.91	y	0.5 %	Th - 232	(1)
5.30	Po - 210	138	d	100 %	U - 238	Daughter of Pb - 210
5.34	Th - 228	1.91	y	28 %	Th - 232	(1)
5.42	Th - 228	1.91	y	71 %	Th - 232	(1)
5.45	Ra - 224	3.64	d	5 %	Th - 232	(1)
5.49	Rn - 222	3.8	d	100 %	U - 238	(2) Seeps from the Earth
5.61	Bi - 212	60.6	m	0.4 %	Th - 232	(1)
5.68	Ra - 224	3.64	d	95 %	Th - 232	(1)
5.77	Bi - 212	60.6	m	0.6 %	Th - 232	(1)
6.00	Po - 218	3.05	m	100 %	U 238	(2)
6.05	Bi - 212	60.6	m	25 %	Th - 232	(1)
6.09	Bi - 212	60.6	m	10 %	Th - 232	(1)
6.29	Rn - 220	54.5	s	100 %	Th - 232	(1)
6.78	Po - 216	0.15	s	100 %	Th - 232	(1)
7.69	Po - 214	162	us	100 %	U - 238	(2)
8.79	Po - 212	0.3	us	64 %	Th - 232	(1)

Source- unknown, yellowed sheet in my lab

Energy spectrum from Sm source, in vacuum

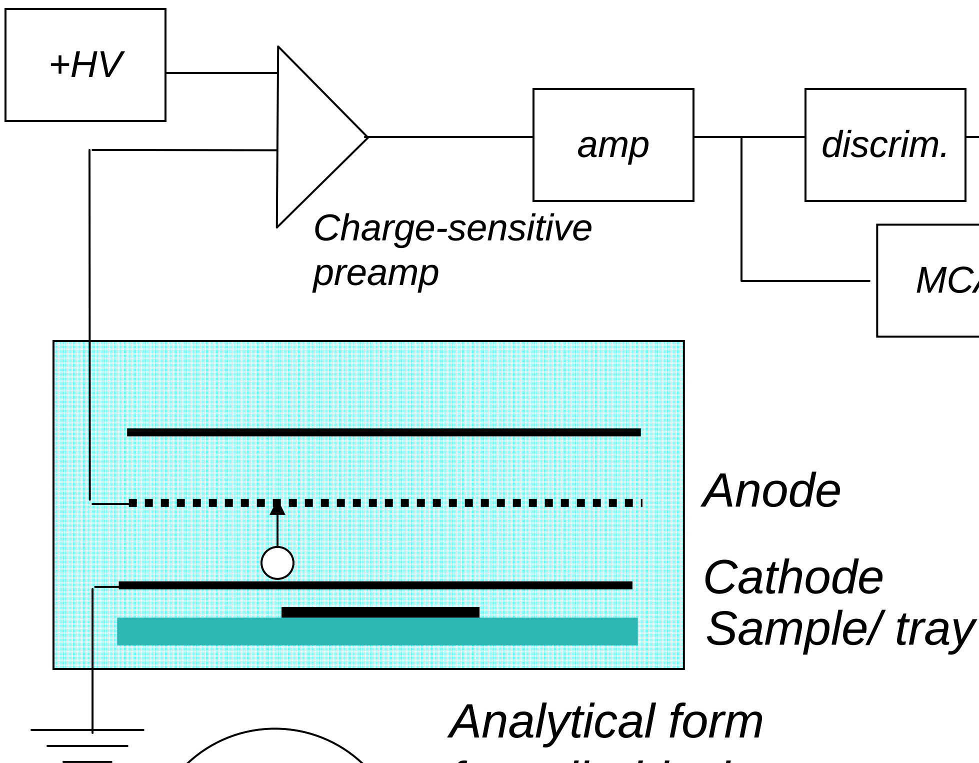


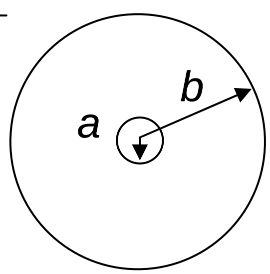
Energy spectrum from ^{232}Th source, in vacuum



Alpha Sciences counter with Ortec discrete electronics

Using off-the-shelf electronics allows for easy adjustment and repair

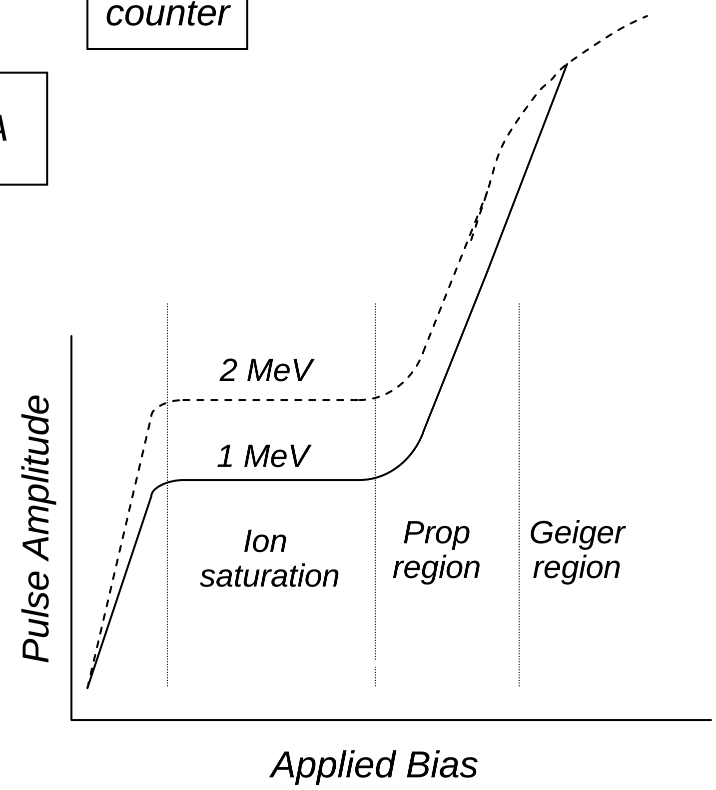




Analytical form for cylindrical geo.

$$E(r) = \frac{V}{r \ln(b/a)}$$

For r=a, V=800V, E~10^6 V/m



From Knoll

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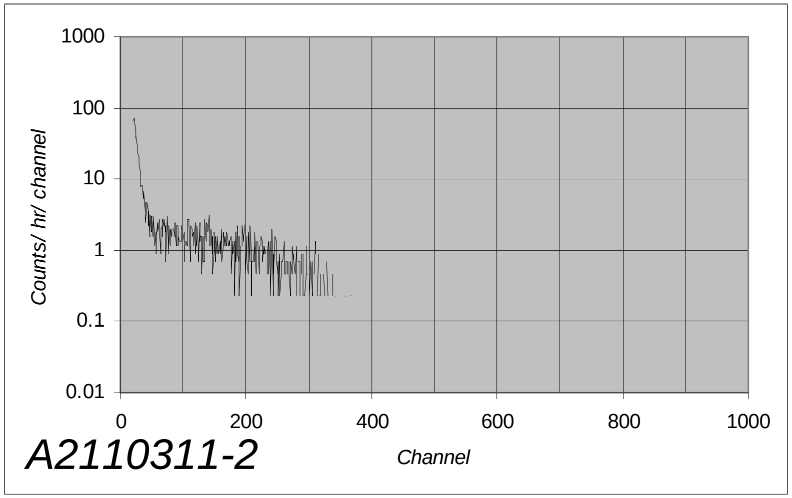
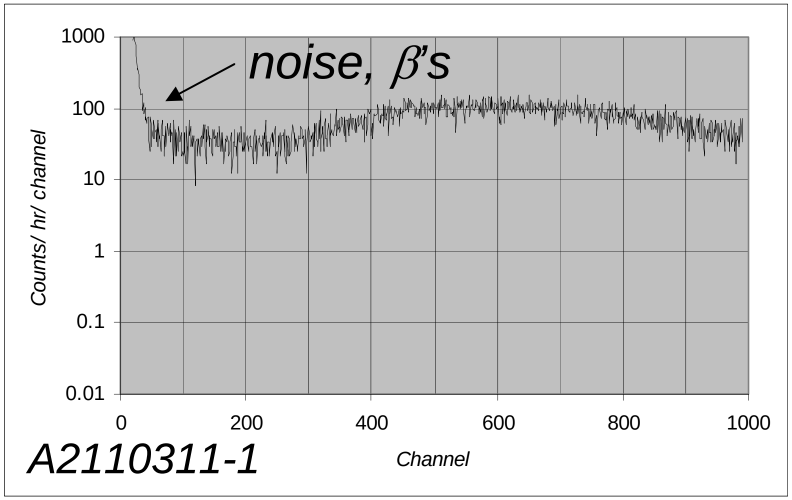
Pulse-height spectrum from sources in the Alpha Sciences counter

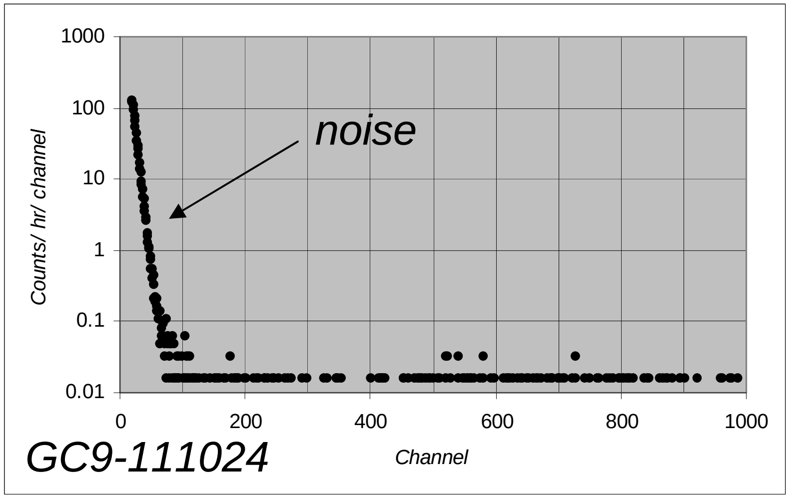
Sm source



^{232}Th source

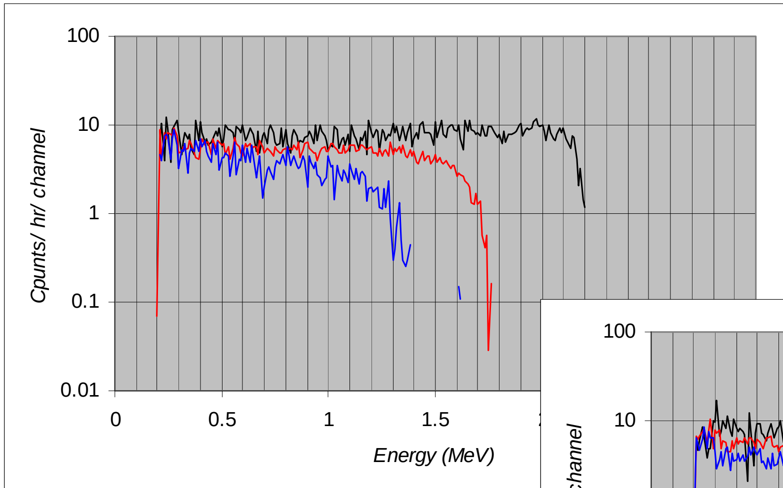


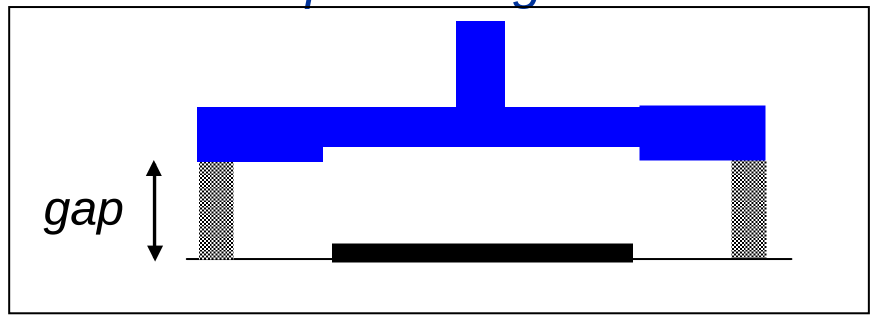
Ultra-low activity sample



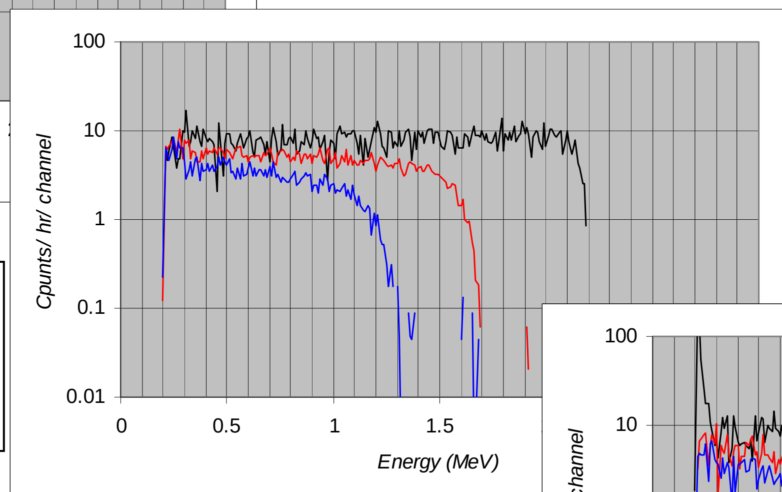
Energy spectrum of Sm source, energy loss from sample through cathode

2 mm gap

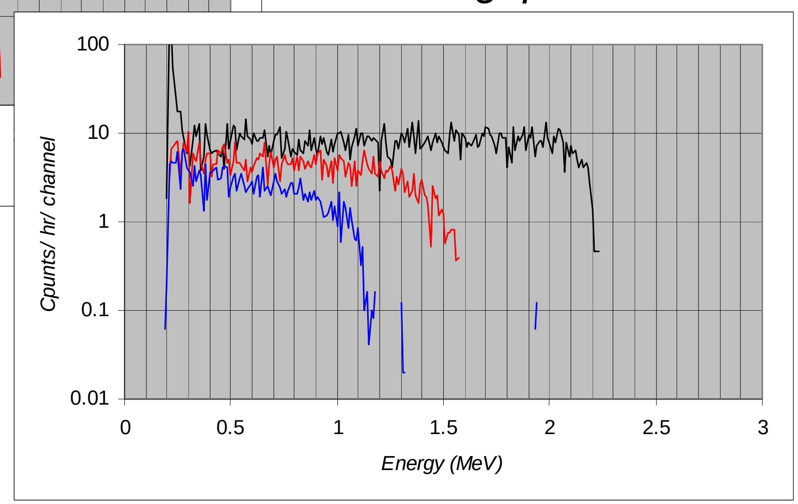




2.5 mm gap



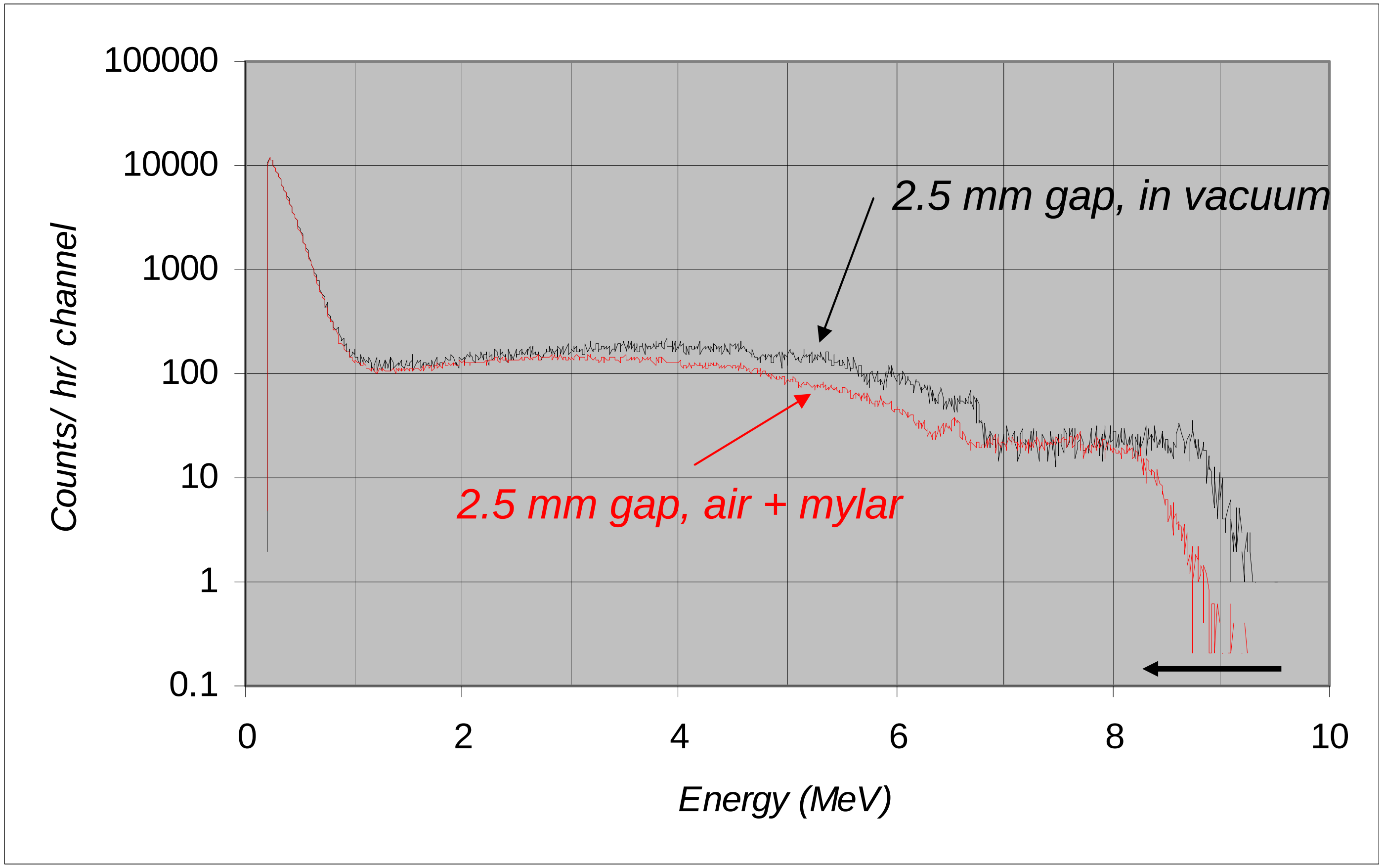
3 mm gap



~1 MeV energy loss in air and mylar- before α's reach active area

- *vacuum*
- *air*
- *air + mylar*

Energy spectrum of ^{232}Th source, energy loss from sample through cathode



Passage of the alphas in the gap and mylar causes reduction in maximum energy and in the flux

Results

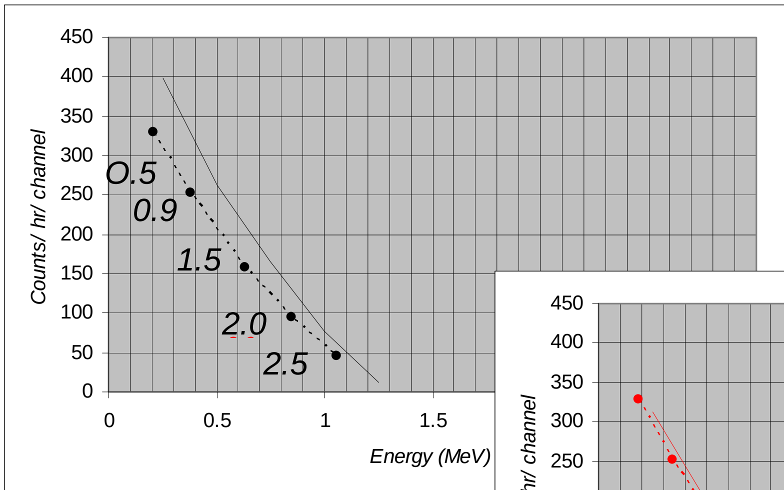
- *Integrate the measured alpha particle energy spectrum from the samarium source, using the silicon detector, above a given threshold (eg E>0.25 MeV, E>0.5 MeV, E>0.75 MeV and E>1.0 MeV)*
- *Repeat integration for each of the source-to-detector gaps*
- *Plot the resulting integrated count rate vs energy*
- *Integrate the count rate for the Alpha Sciences counter above a given ADC voltage threshold (eg V>0.5V, V>0.9V, V>1.5V,V >2.0V) using the discrete electronics*
- *We can correlate the pulse height with energy- given the MCA spectrum from the Alpha Sciences counter, and the maximum energy in the alpha particle energy spectra*

Results

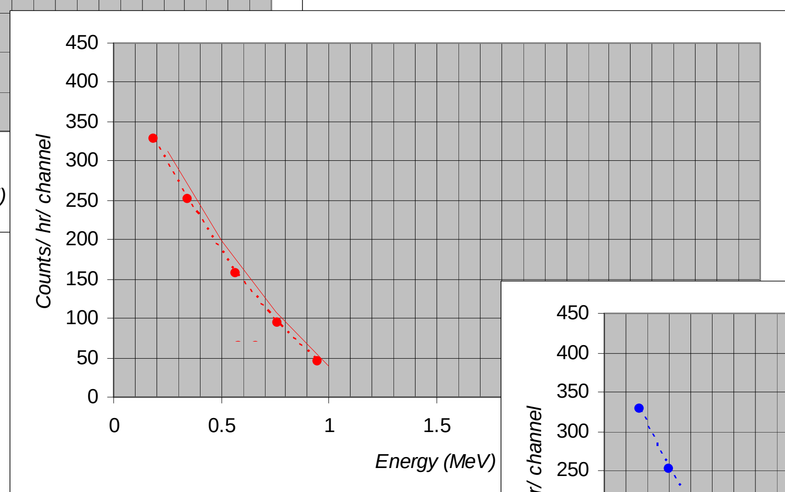
——— *Si detector data*

············ *gas counter data*

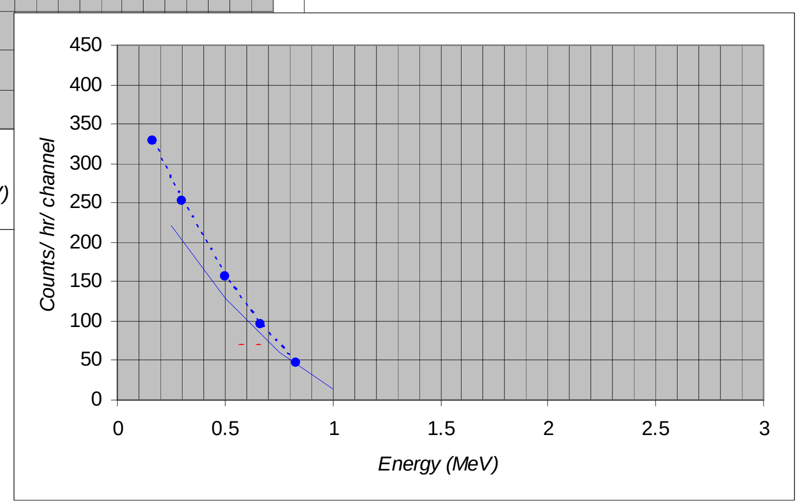
2 mm gap



2.5 mm gap



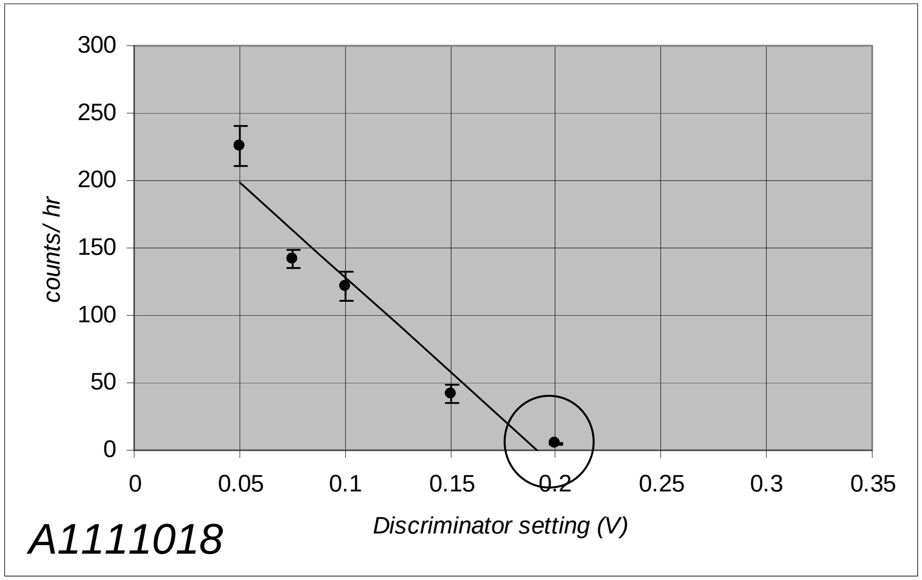
3 mm gap



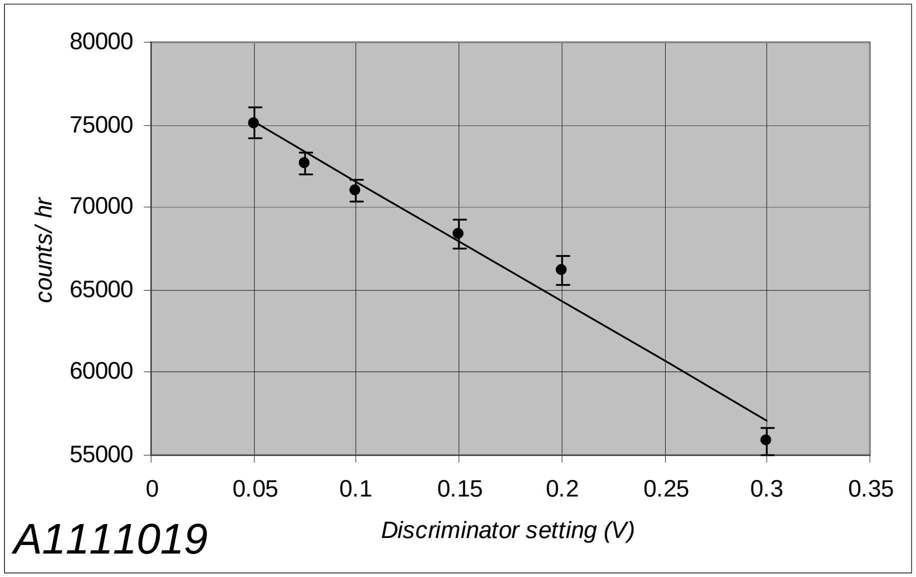
- *data from Si detector "fits" the gas counter data with a ~2.5 mm gap*
- *0 count rate with this source is ~1-1.3 MeV*

Response of Alpha Sciences counter, original electronics

Sm source



Th source



Zero count rate corresponds to a total energy loss of 2.25 MeV

Raising the discriminator level lowers the detection efficiency (lowers the count rate) for a thick source

The slope of count rate vs discriminator setting, and the discriminator setting where the count rate goes to zero, will depend on the amplifier gain

Conclusion

- *We have shown the energy spectrum from a low-energy Sm α-particle source.*

- *There is an appreciable energy-loss of low-energy α's before they reach the active gas volume in the Alpha Sciences counters.*

- *While the discriminator can be set higher to reduce the background count rate, it cuts out the detection of low-energy α's.*

- *The efficiency of detection in these counters is energy-dependent.*

- *What energy α's are really important for samples that we measure?*

- *What is the α-particle energy associated with the discriminator setting on your Alpha Sciences counters?*