The use of borated PVT for Nuclear Material Categorization

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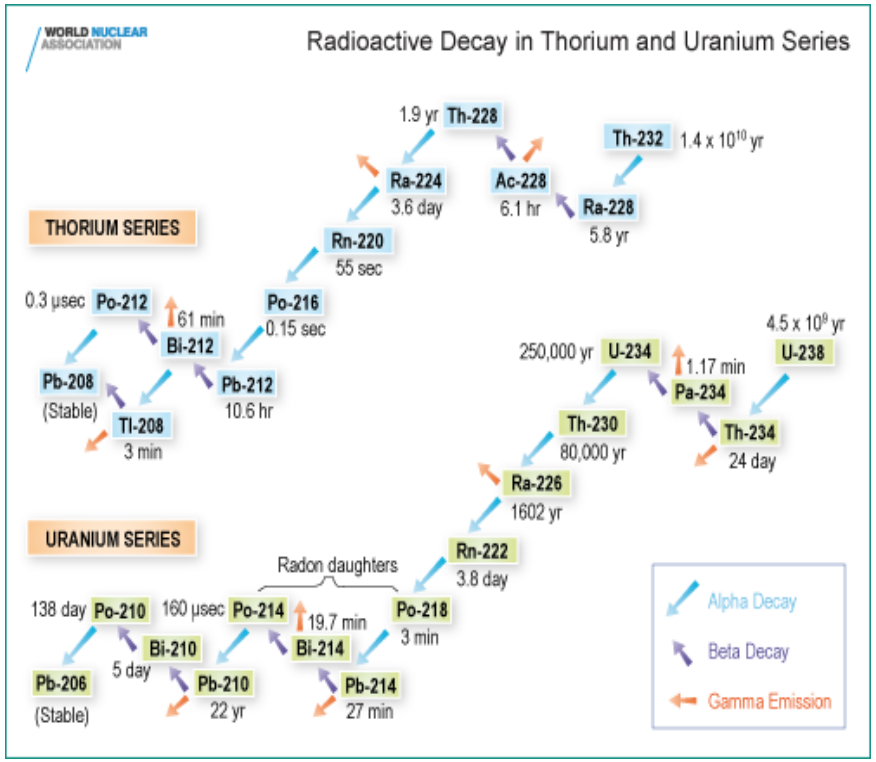
Outline

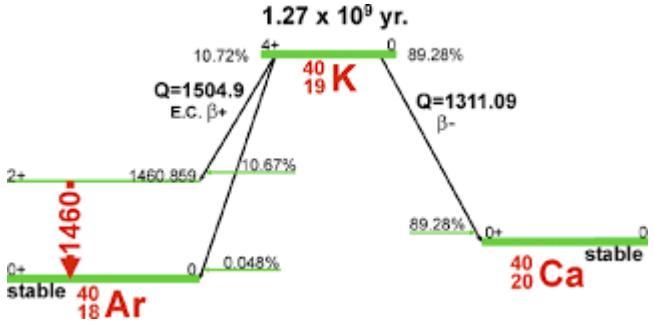
- Goals
- Background
- Materials and Methods
- Results and Discussion
- Conclusions and Future Research

Goals

- Choose parameters that best suit each spectra
- Study gamma and neutron spectra from a variety of sources and backgrounds by using a pair of borated polyvinyl toluene detectors
- Discriminate categories of nuclear material such as NORM, medical, industrial and SNM through the development of appropriate algorithms
- Tech transfer to a commercial vendor

Naturally Occurring Radioactive Materials





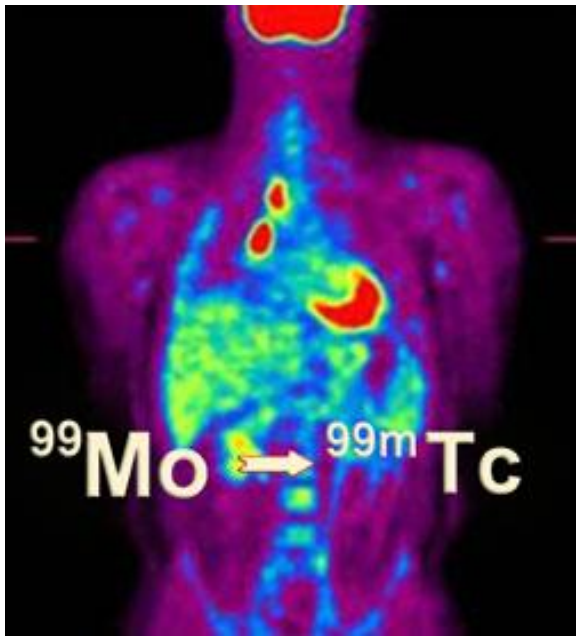
http://teachnuclear.ca/all-things-nuclear/canadas-nuclear-history/uranium-mining/uranium-mining-in-canada/

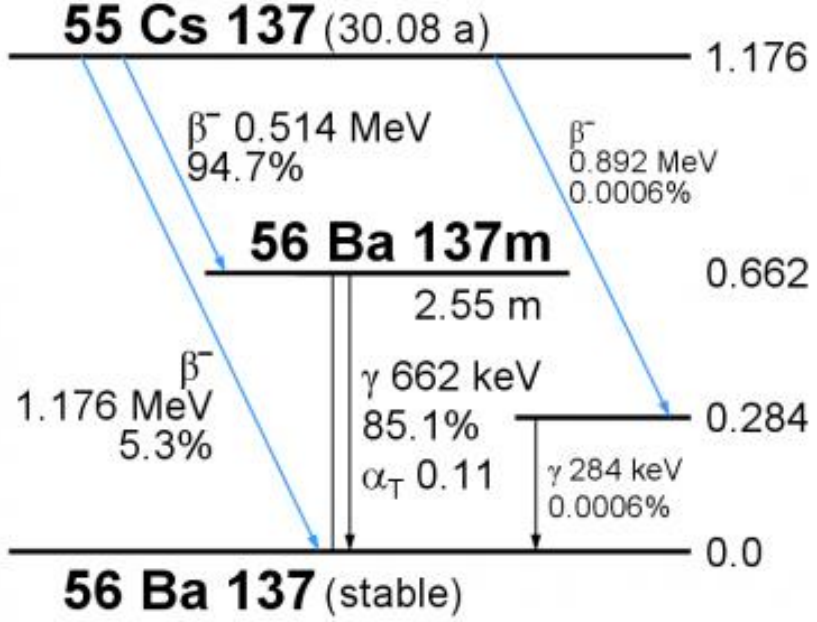
CNEC | Consortium for Nonproliferation Enabling Capabilities

U.S.NRC United States Nuclear Regulatory Commission *Protecting People and the Environment*

Department of NUCLEAR ENGINEERING

Medical and Industrial Materials





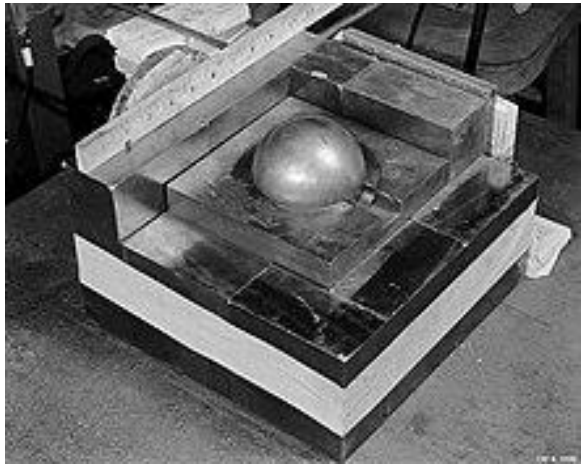
-Use of Iridium-192 for gamma radiography

http://nuclearconnect.org/wp-content/uploads/2013/11/Mo-99-imaging-250_tcm18-195733.jpg

http://irss.ca/product/sentinel-880-delta-source-projector/

http://www.world-nuclear.org/information-library/non-power-nuclear-applications/radioisotopes-research/radioisotopes-in-medicine.aspx

Special Nuclear Materials



https://upload.wikimedia.org/wikipedia/commons/thumb/d/d8/HEUraniumC.jpg/220px-HEUraniumC.jpg

https://upload.wikimedia.org/wikipedia/commons/thumb/1/13/Partially-reflected-plutonium-sphere.jpeg/220px-Partially-reflected-plutonium-sphere.jpeg

Background

- Portal Monitors are made up of plastic scintillators
- Limited to only gross counting
- False alarms often occur
- Changes with weather conditions can have an effect on the background radon progeny

https://www.scannix.com/produit/radiation-portal-monitor-model-4525-series/

Borated Polyvinyl Toluene Detector

- Plastic Scintillator with boron
- Portable
- Economical
- Sensitive to gammas and neutrons
- Total energy collected is spread over Compton continuum

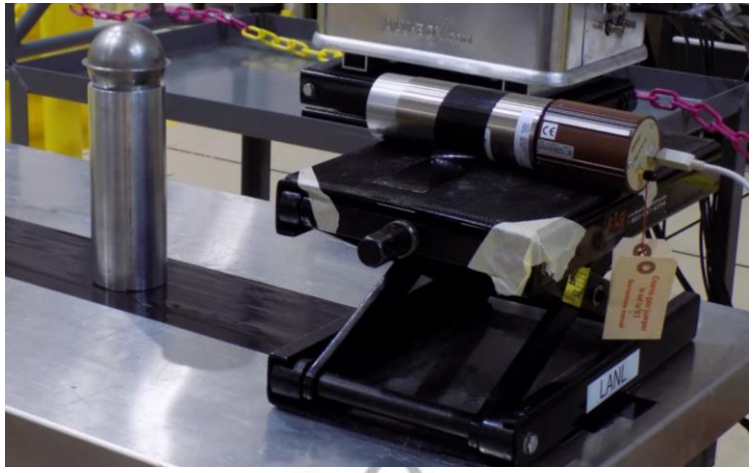
http://www.bangkokchemart.com/product/545689/9-inch-rem-ball.html

Materials

- Two borated Polyvinyl Toluene detectors
- One Ortec digibase MCA
- Standard BNC Connector
- Maestro
- Laptop
- Exempt sources of:
  - Ba-133
  - Co-60
  - Na-22
  - Am-241
  - Eu-154

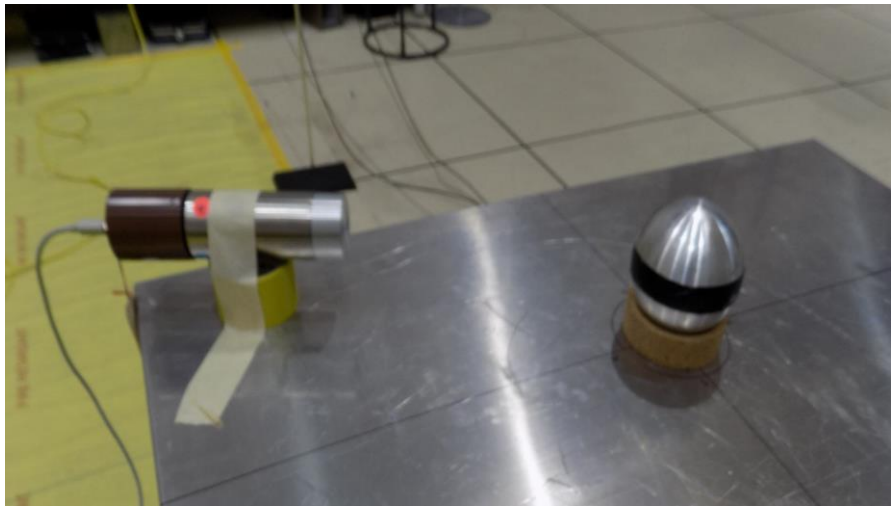
Device Assembly Facility

- Experiments at Device Assembly Facility (DAF) were held at the Nevada Test Site in summer 2018
  - Cs-137 (~20 µCi)
  - Thorium reflected Plutonium source
  - BeRP Ball with WGPu
  - Drum containing Plutonium Oxide container



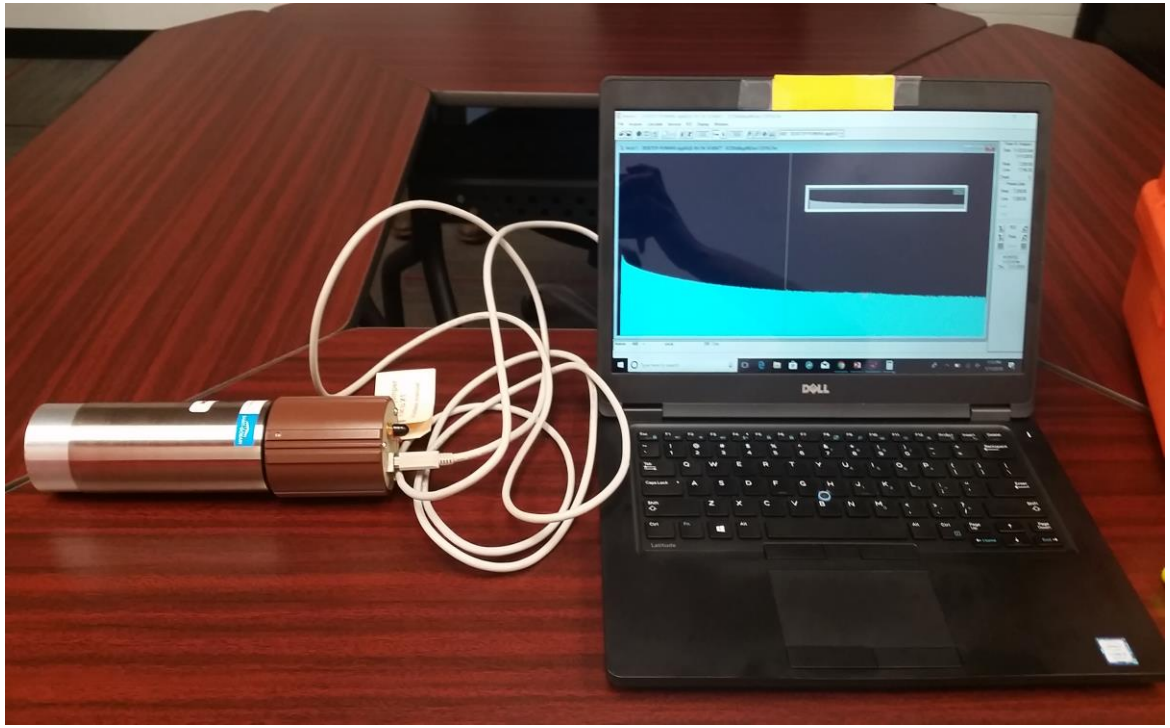
Device Assembly Facility

- Thorium reflected Plutonium source + drum containing BeRP ball with WGPu
- Plutonium oxide + drum containing BeRP ball with WGPu
- The Rocky Flats (RF) highly enriched uranium (HEU) metal shells



Methods

- About 52 experiments were done
  - 40 experiments with Ba-133, Co-60, Eu-154, Na-22, and Am- 241 sources
  - 12 experiments with background



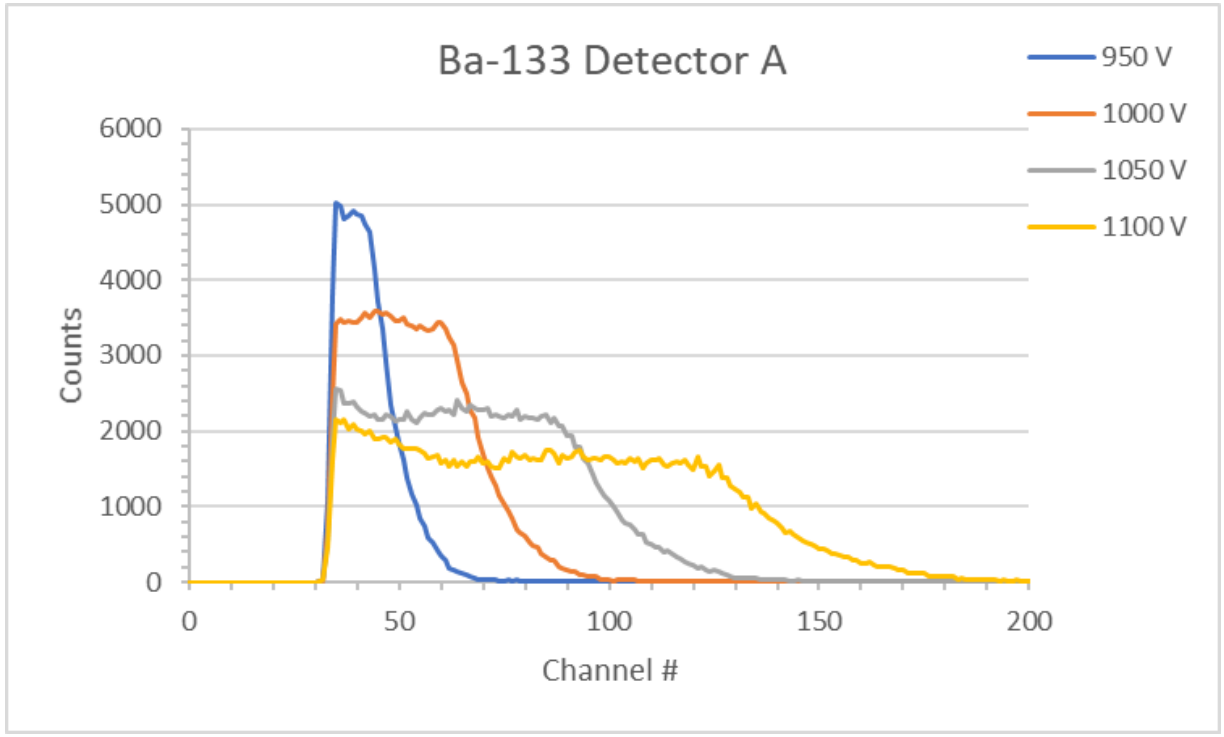
Sampling Times

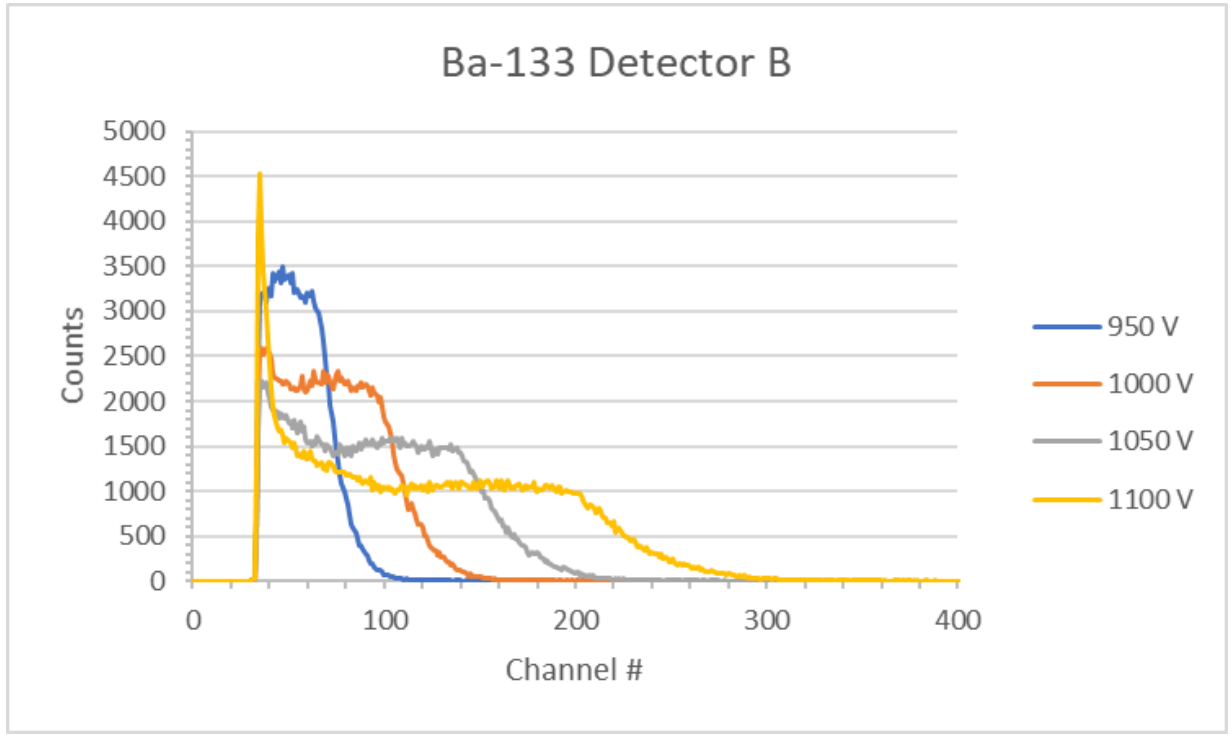
- For background:
  - 7200 seconds (2 hours)
  - 36000 seconds (10 hours)
- For sources:
  - 20 seconds
  - 20 minutes

Sampling Times for DAF

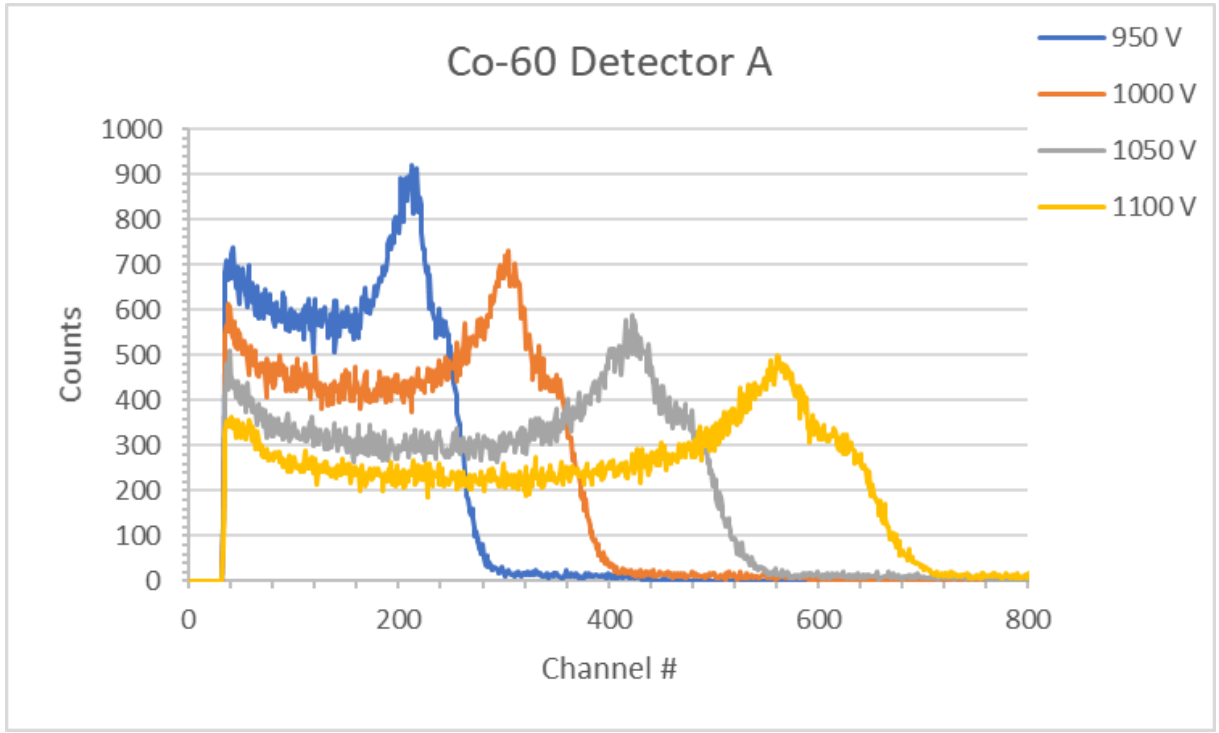
- For background:
  - 60 seconds (1 min)
  - 120 seconds (2 min)
- For sources:
  - 60 seconds (1 min)
  - 300 seconds (5 min)
  - 1800 seconds (30 min)
  - 3600 seconds (1 hr)
  - 6300 seconds (~1 hr 15 min)
- Overnight runs:
  - 12 hrs
  - ~14 hrs

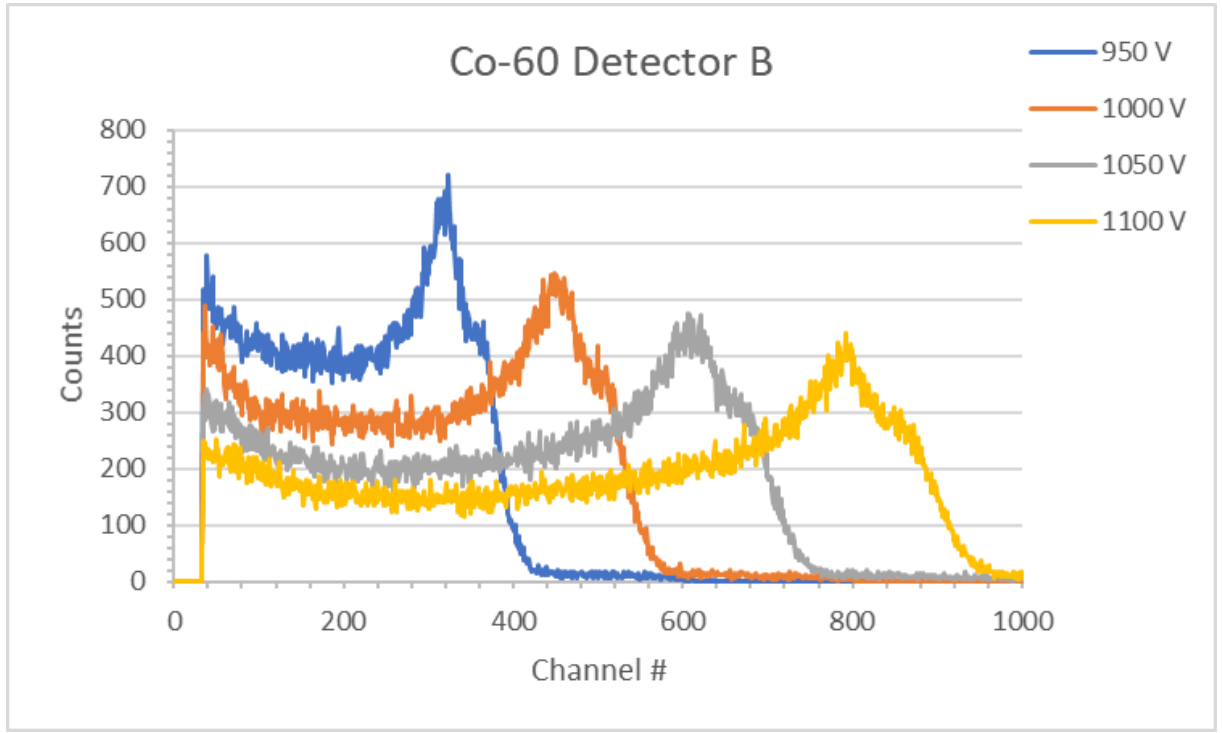
Barium-133


Ba-133 Detector A
950 V
1000 V
1050 V
1100 V
Counts
Channel #
0
1000
2000
3000
4000
5000
6000
0
50
100
150
200

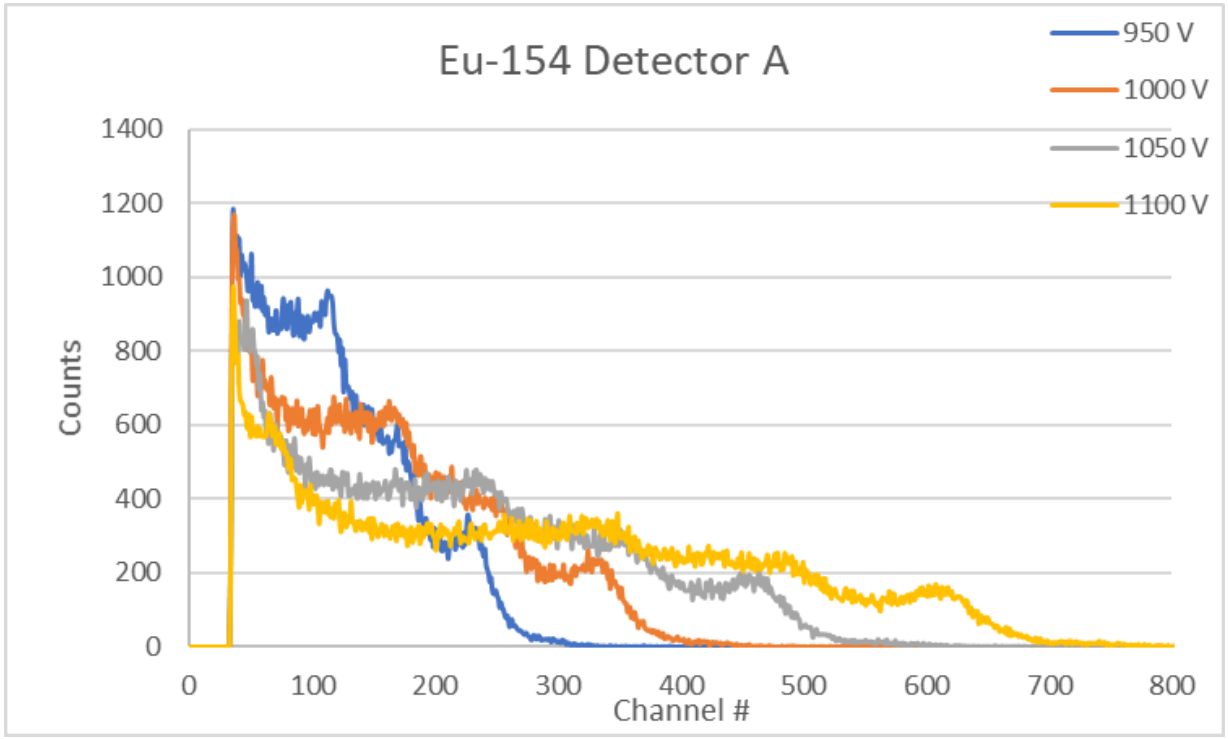

Ba-133 Detector B
950 V
1000 V
1050 V
1100 V
Counts
Channel #
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
0
100
200
300
400

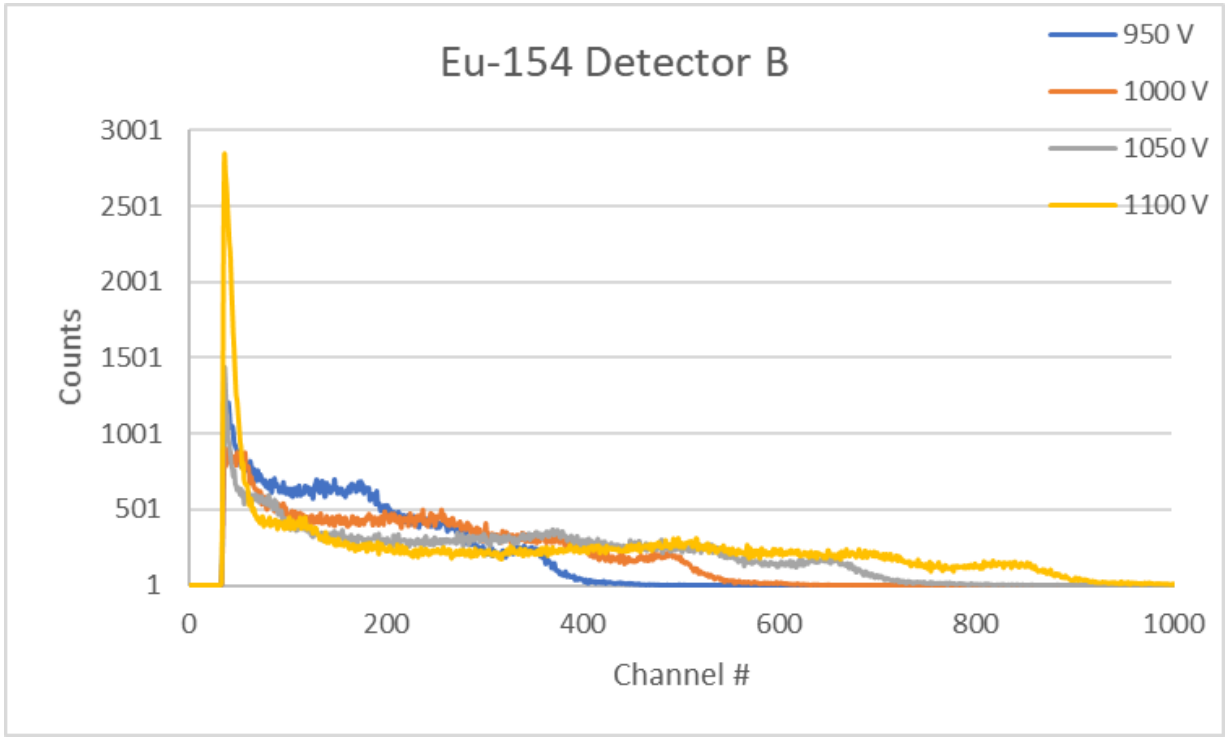
Cobolt-60


Co-60 Detector A
950 V
1000 V
1050 V
1100 V
Counts
Channel #
0
100
200
300
400
500
600
700
800
900
1000
0
200
400
600
800

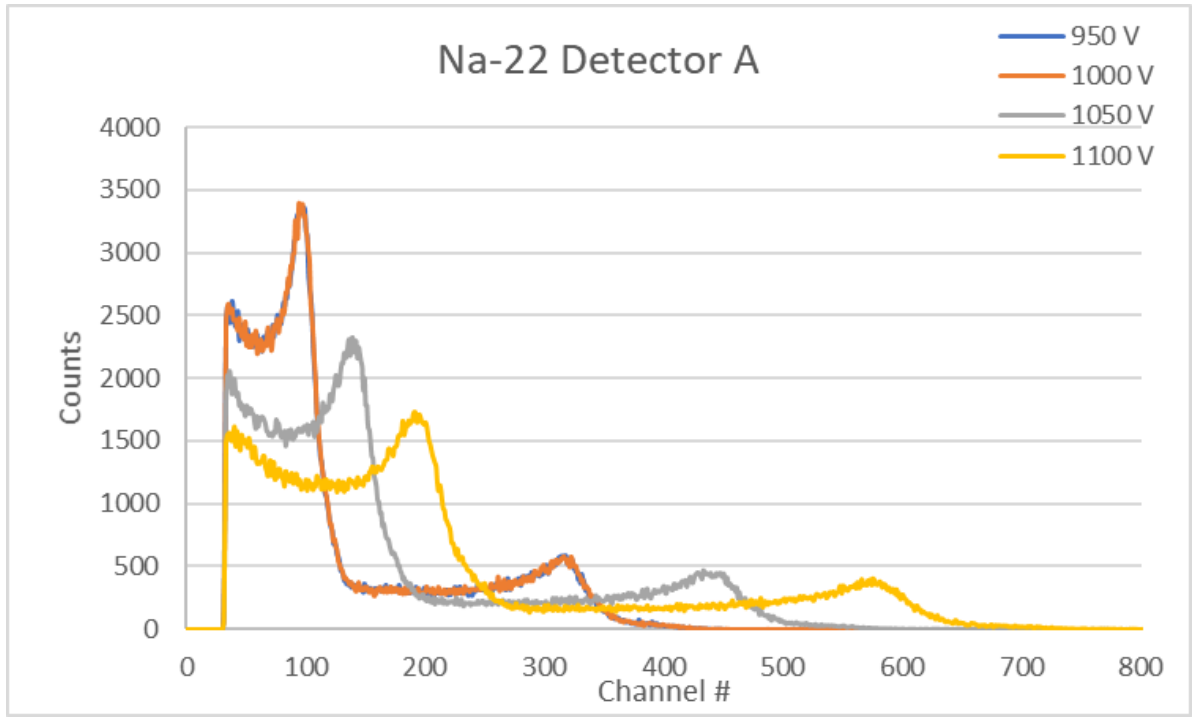

Co-60 Detector B
950 V
1000 V
1050 V
1100 V
Counts
Channel #
0
100
200
300
400
500
600
700
800
0
200
400
600
800
1000

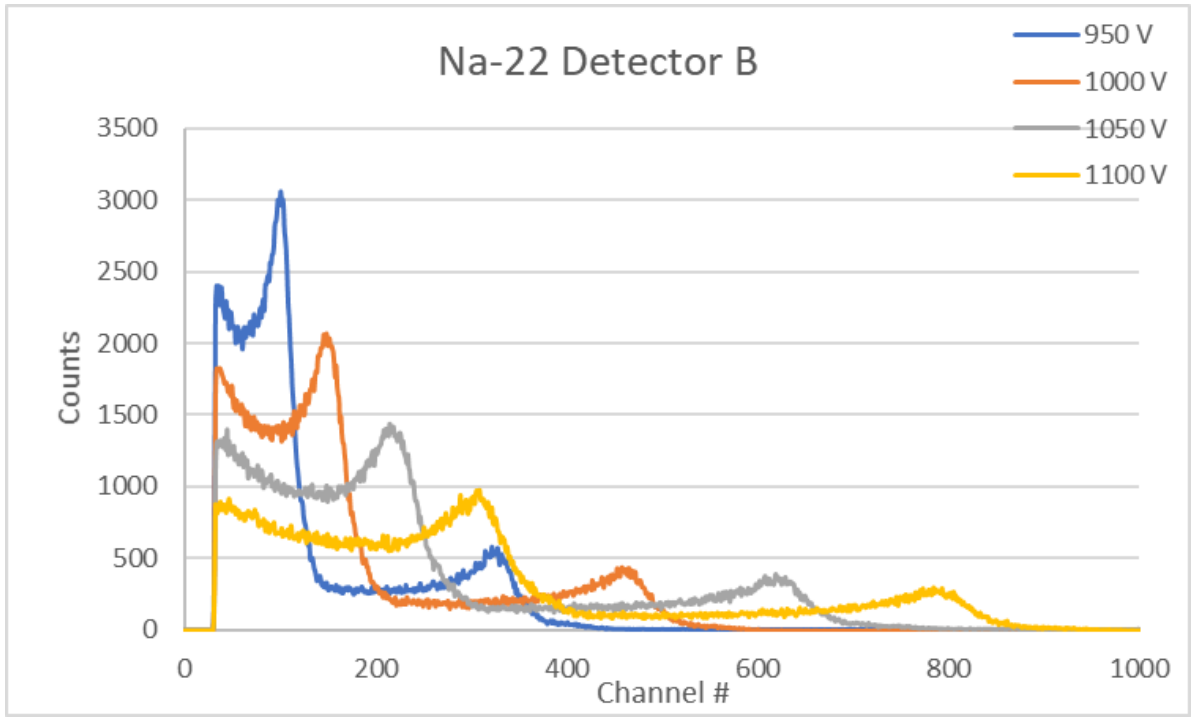
Europium-154



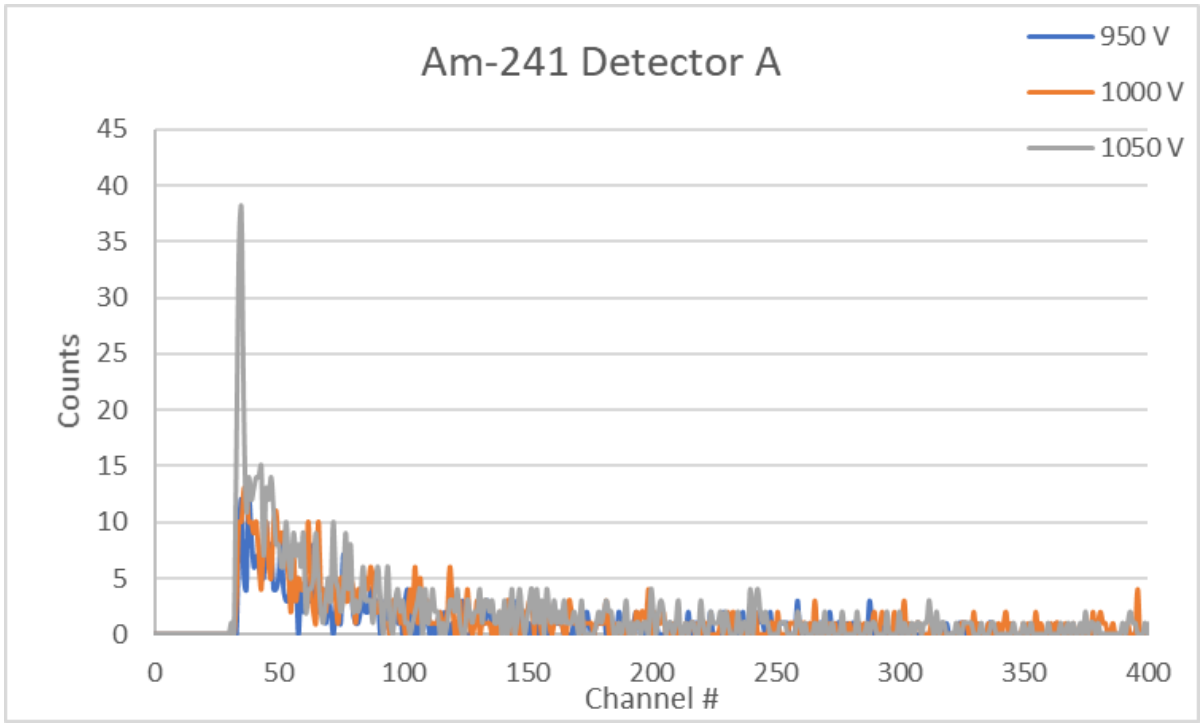


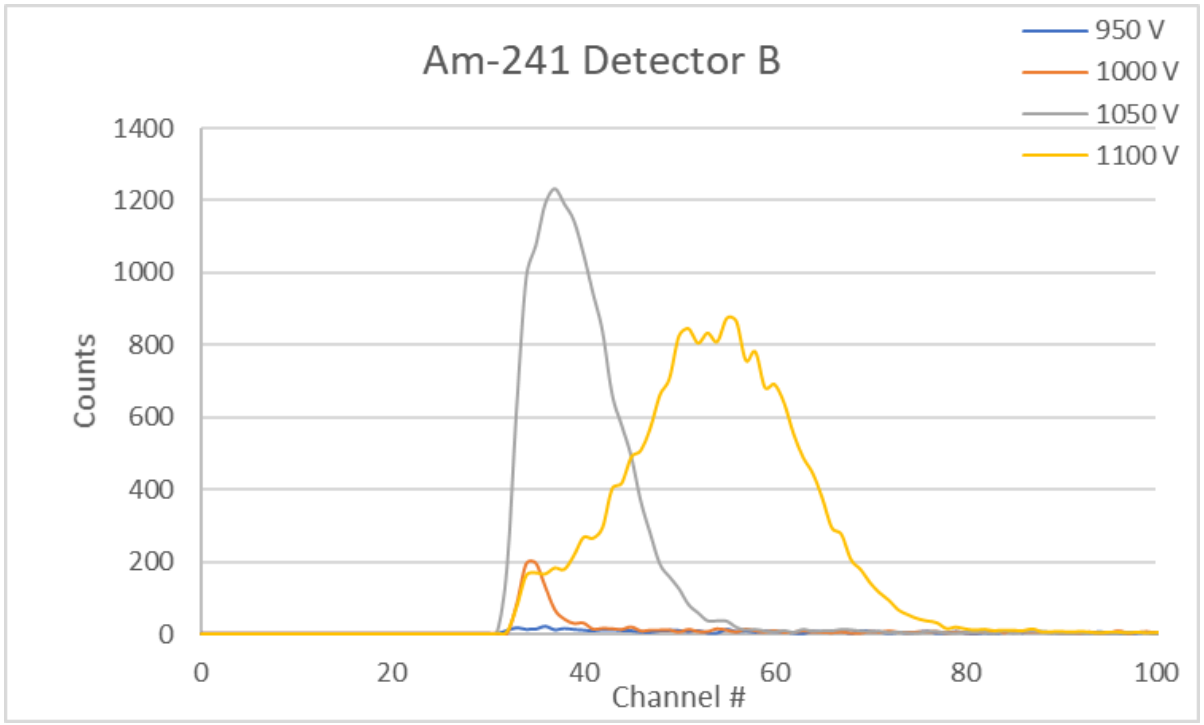
Sodium-22


Na-22 Detector A
950 V
1000 V
1050 V
1100 V
Counts
Channel #
0
500
1000
1500
2000
2500
3000
3500
4000
0
100
200
300
400
500
600
700
800

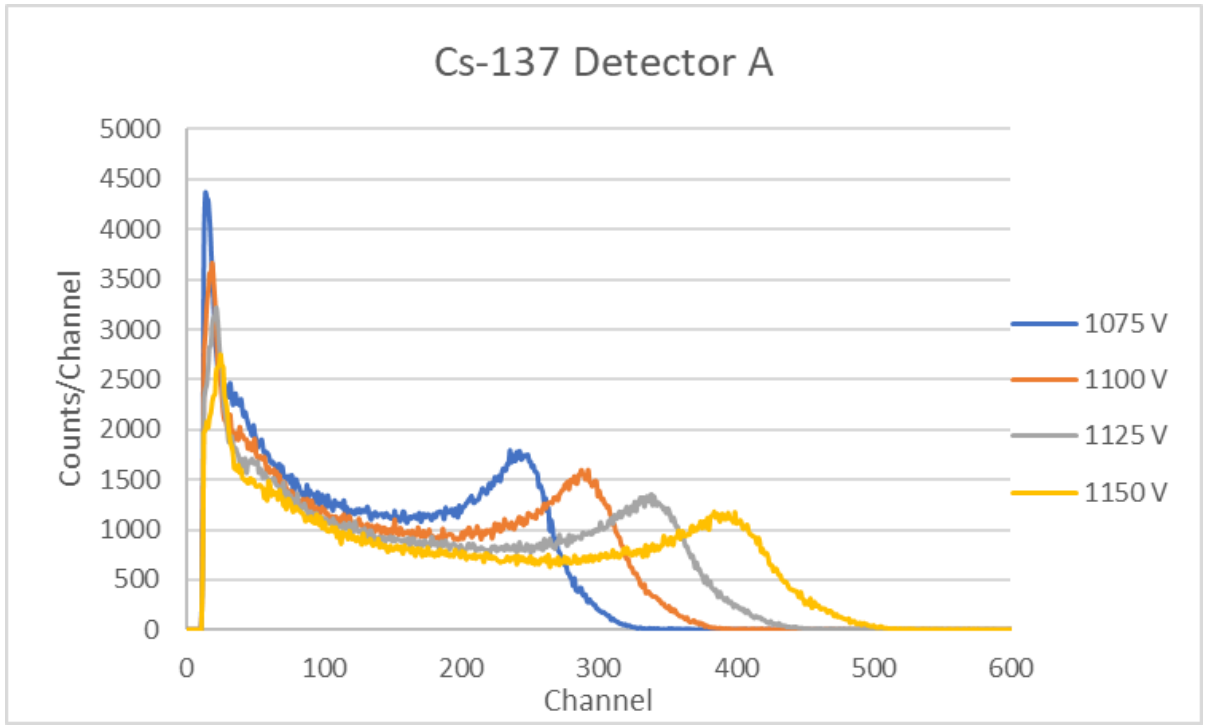

Na-22 Detector B
950 V
1000 V
1050 V
1100 V
Counts
Channel #
0
500
1000
1500
2000
2500
3000
3500
0
200
400
600
800
1000

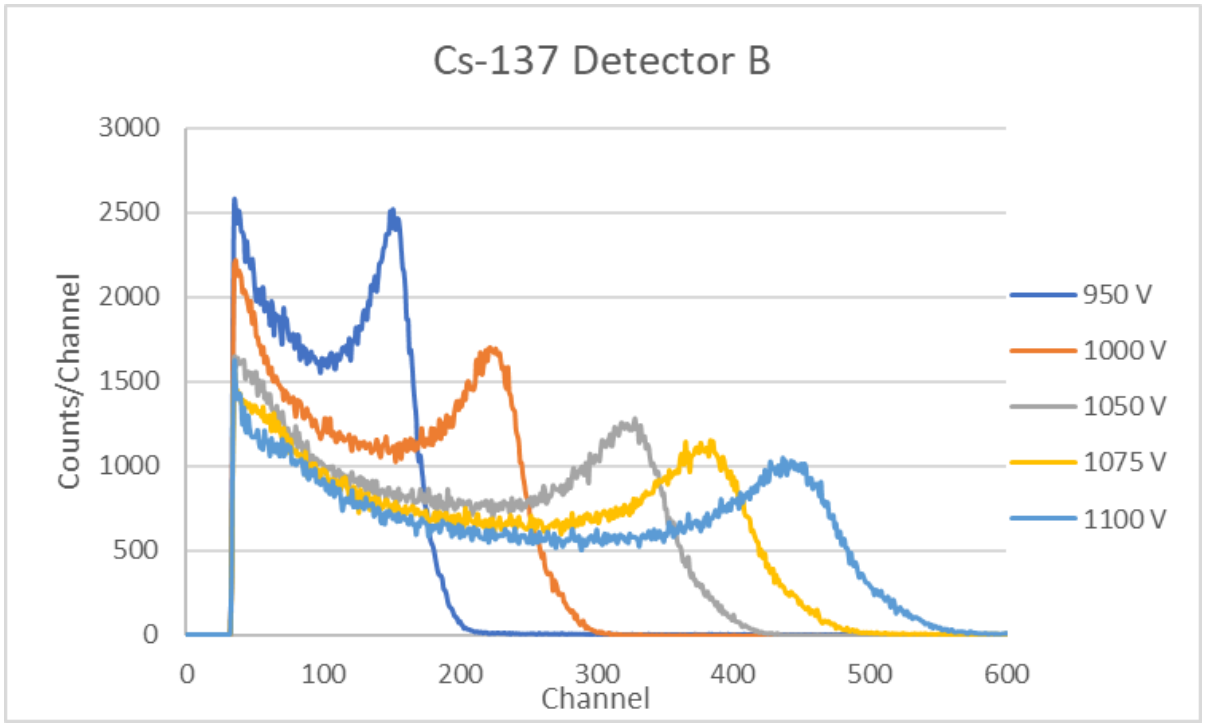
Americium-241



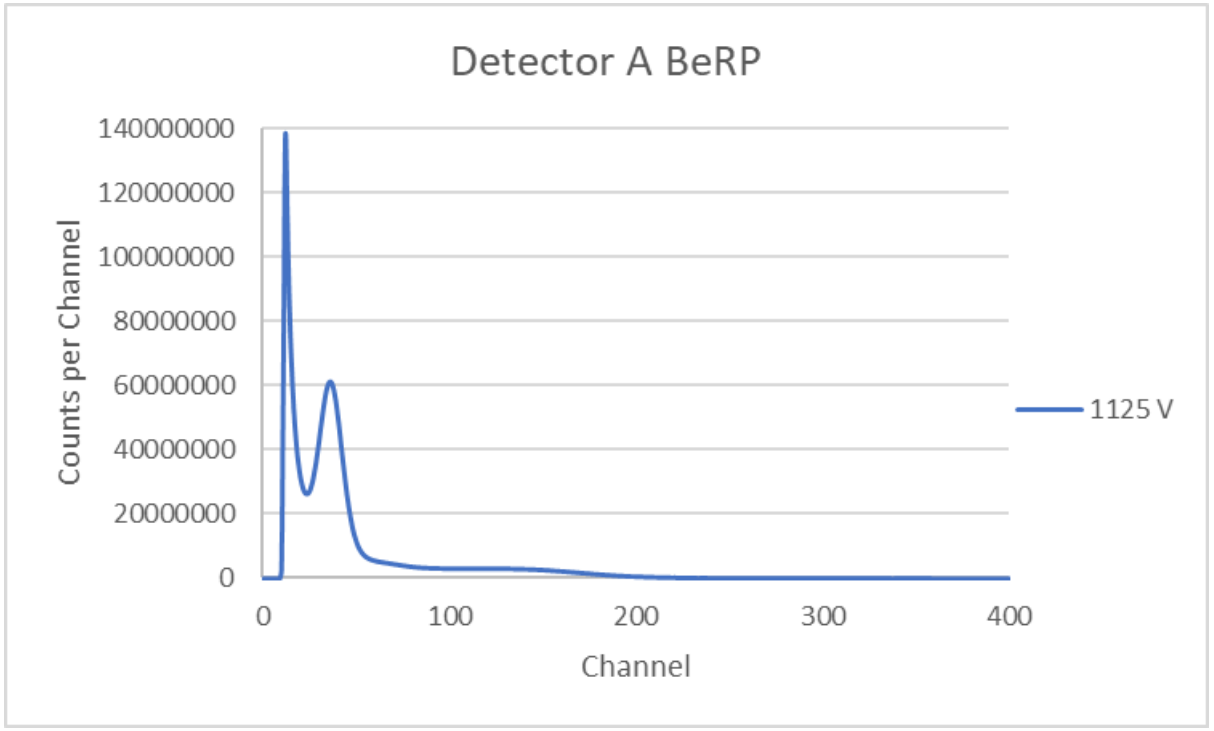


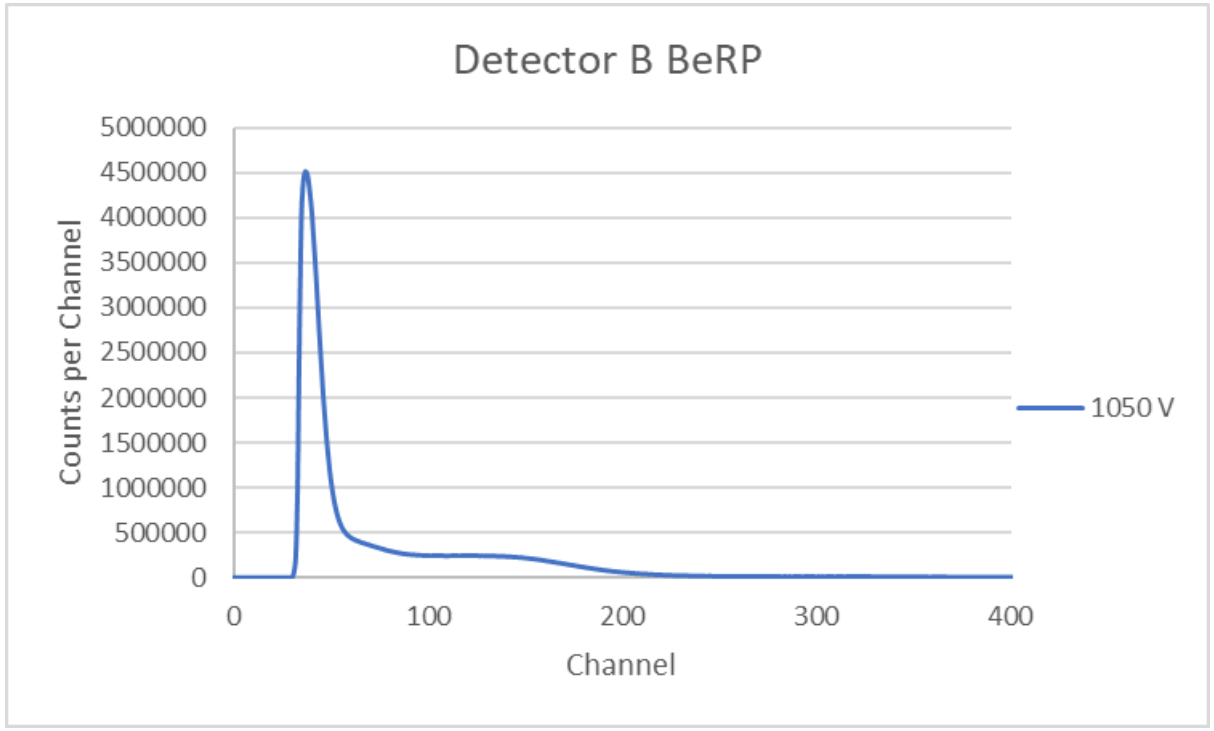
Cesium-137


Cs-137 Detector A
Counts/Channel
Channel
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
0
100
200
300
400
500
600
1075 V
1100 V
1125 V
1150 V

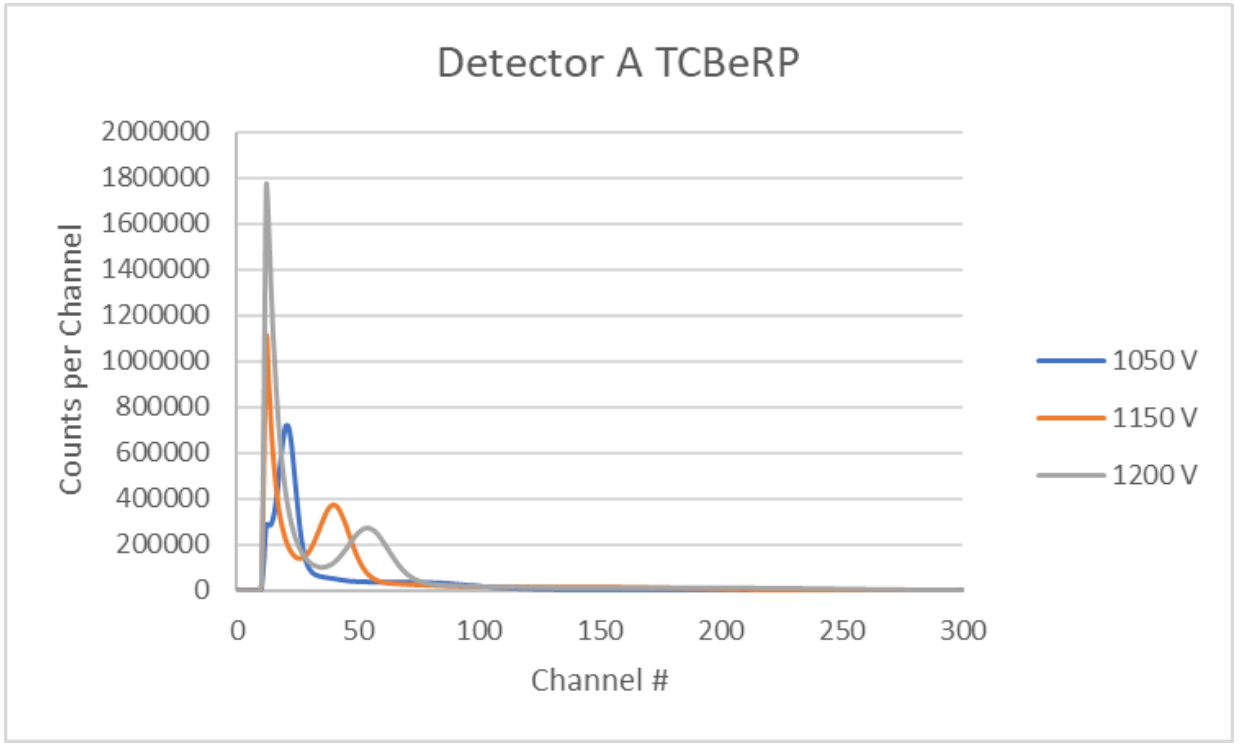

Cs-137 Detector B
Counts/Channel
Channel
0
500
1000
1500
2000
2500
3000
0
100
200
300
400
500
600
950 V
1000 V
1050 V
1075 V
1100 V

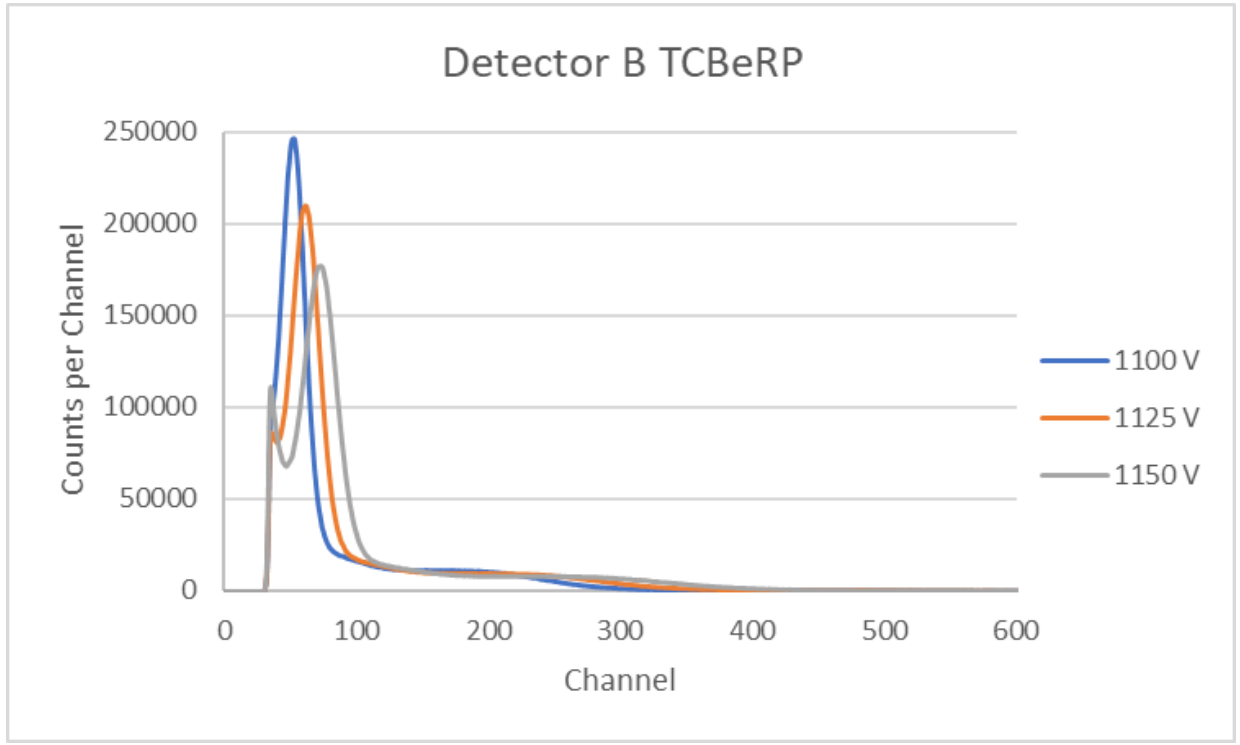
BeRP


Detector A BeRP
Counts per Channel
140000000
120000000
100000000
80000000
60000000
40000000
20000000
0
0
100
200
300
400
Channel
1125 V

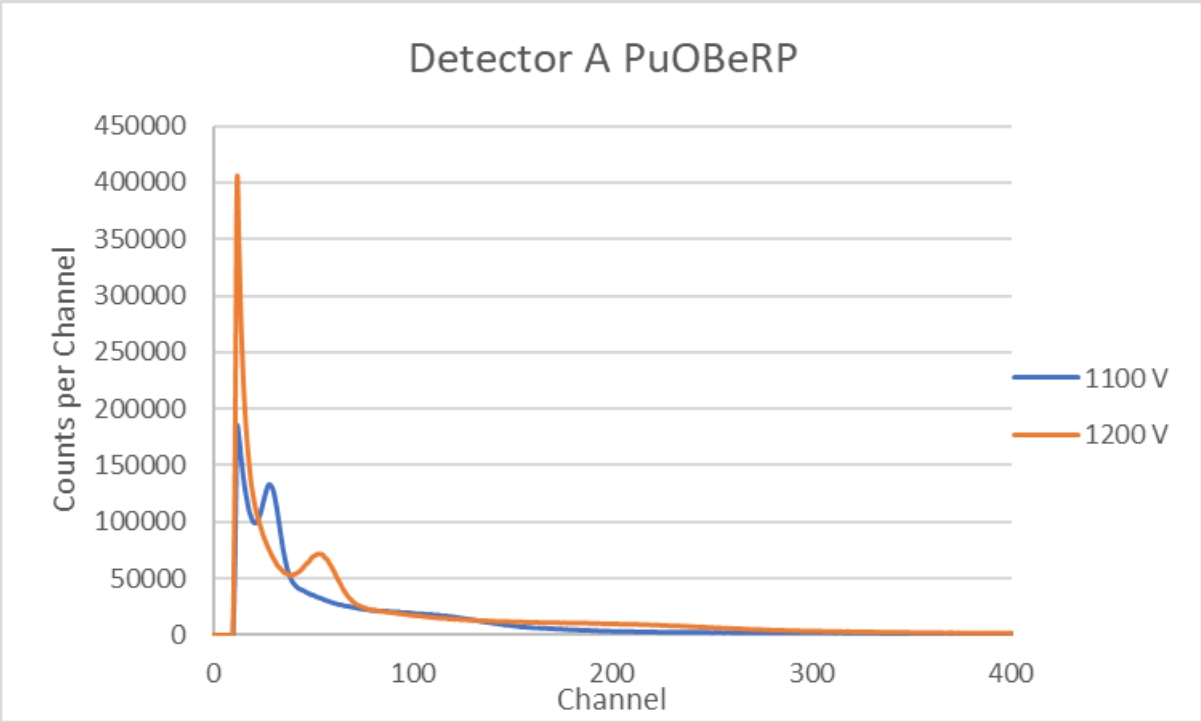

Detector B BeRP
Counts per Channel
5000000
4500000
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0
100
200
300
400
Channel
1050 V

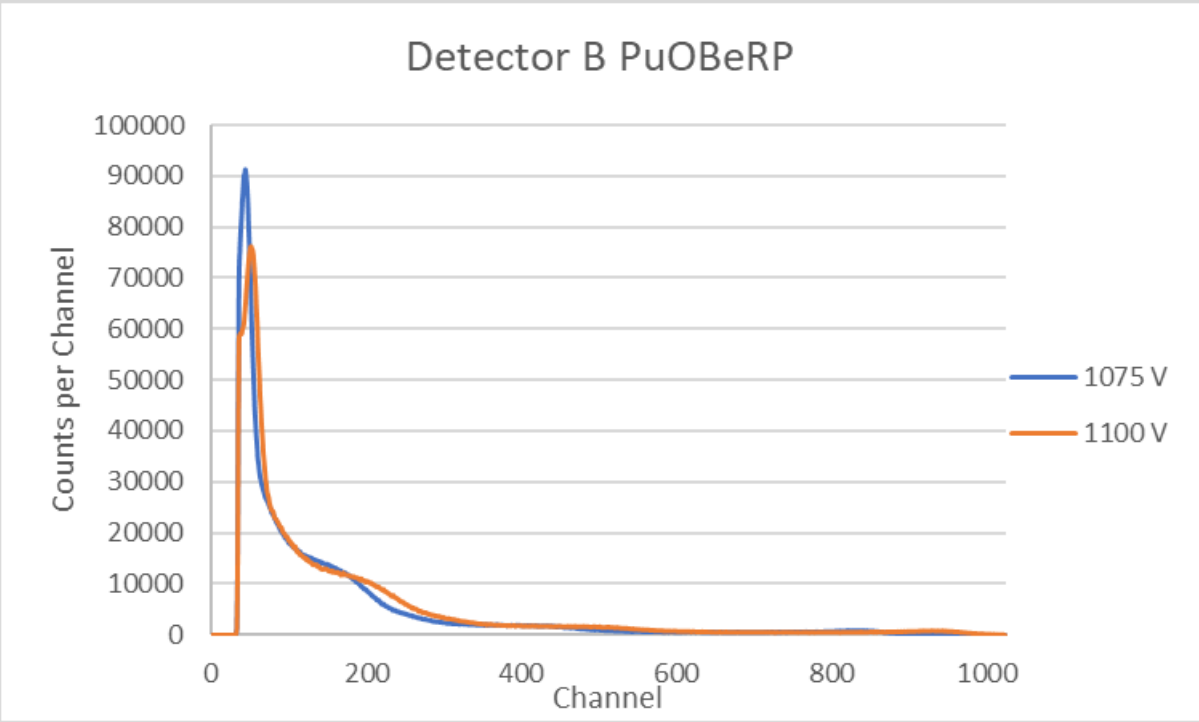
TCBeRP


Detector A TCBeRP
Counts per Channel
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
0
50
100
150
200
250
300
Channel #
1050 V
1150 V
1200 V

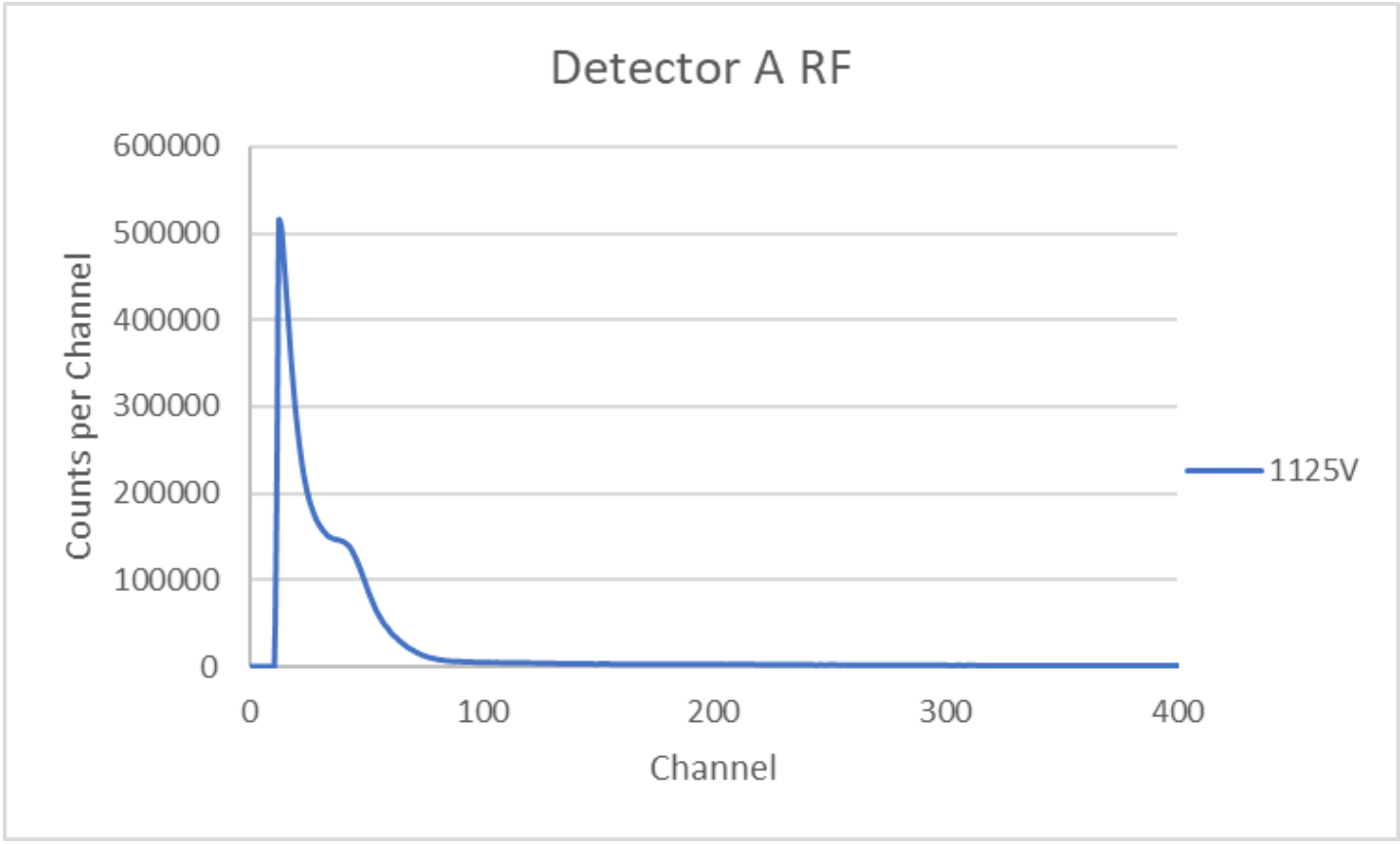

Detector B TCBeRP
Counts per Channel
250000
200000
150000
100000
50000
0
0
100
200
300
400
500
600
Channel
1100 V
1125 V
1150 V

PuOBeRP

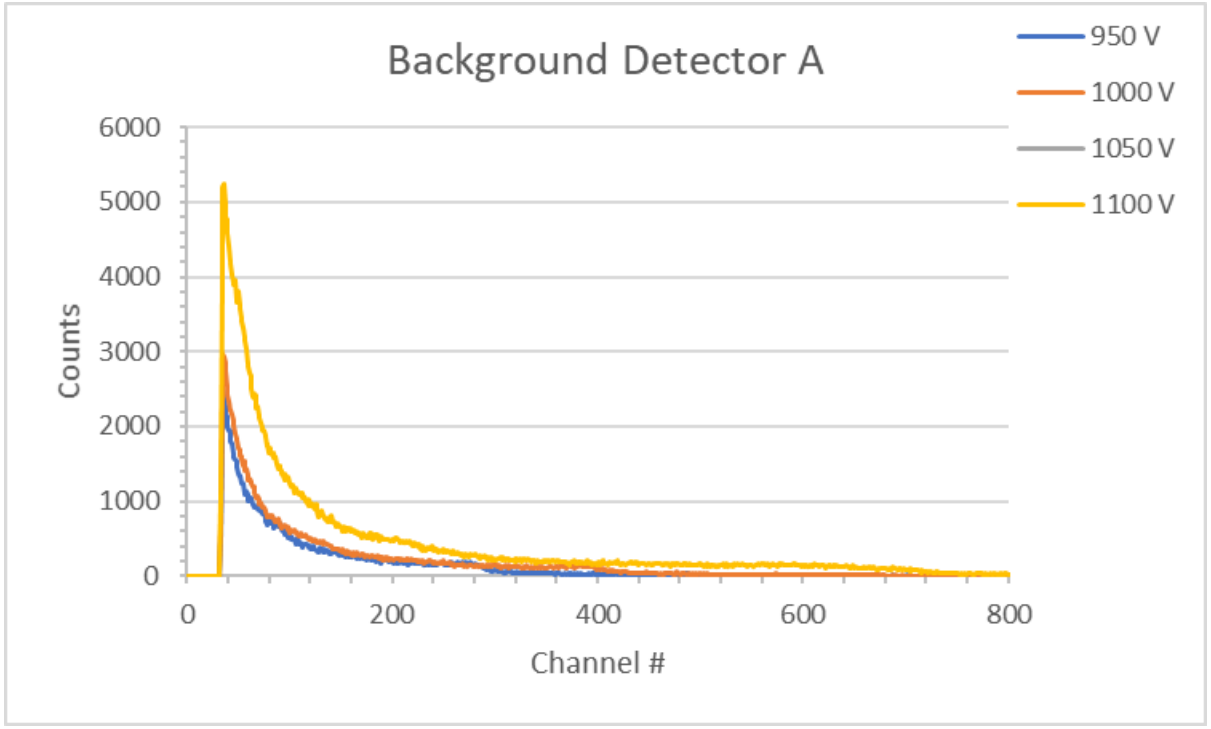

Detector A PuOBeRP
Counts per Channel
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
100
200
300
400
Channel
1100 V
1200 V

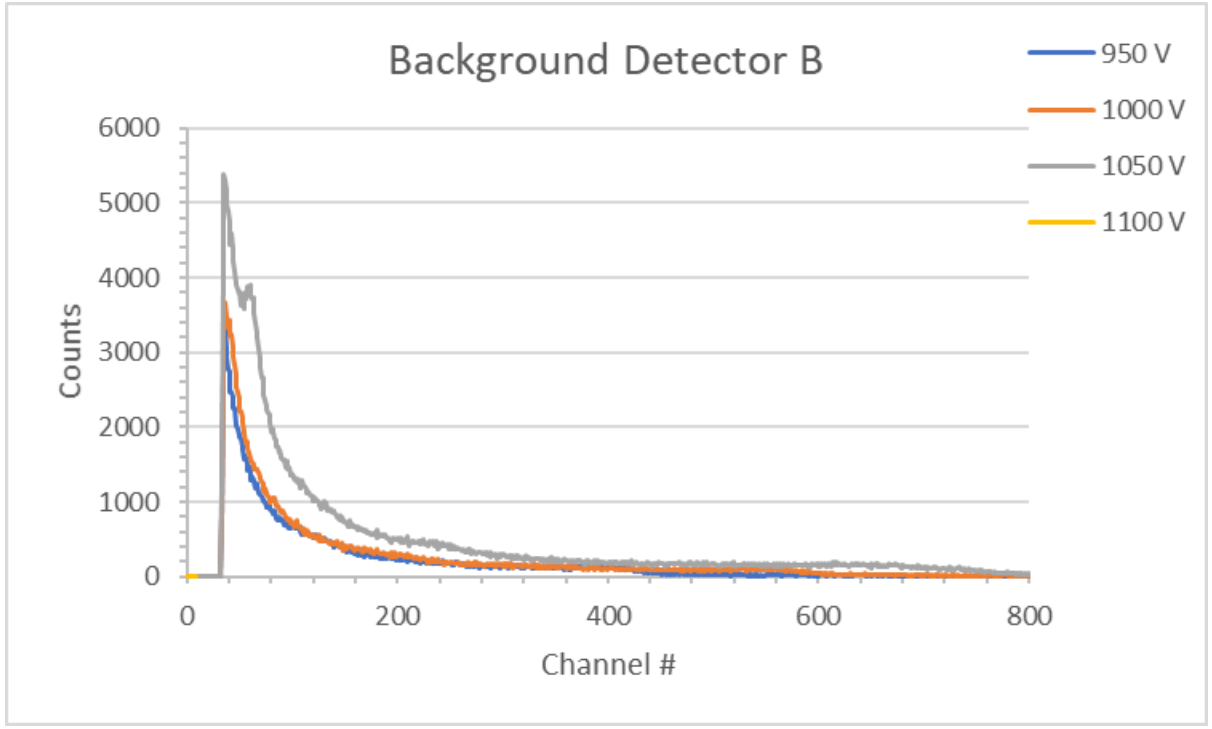

Detector B PuOBeRP
Counts per Channel
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0
200
400
600
800
1000
Channel
1075 V
1100 V

Rocky Flats

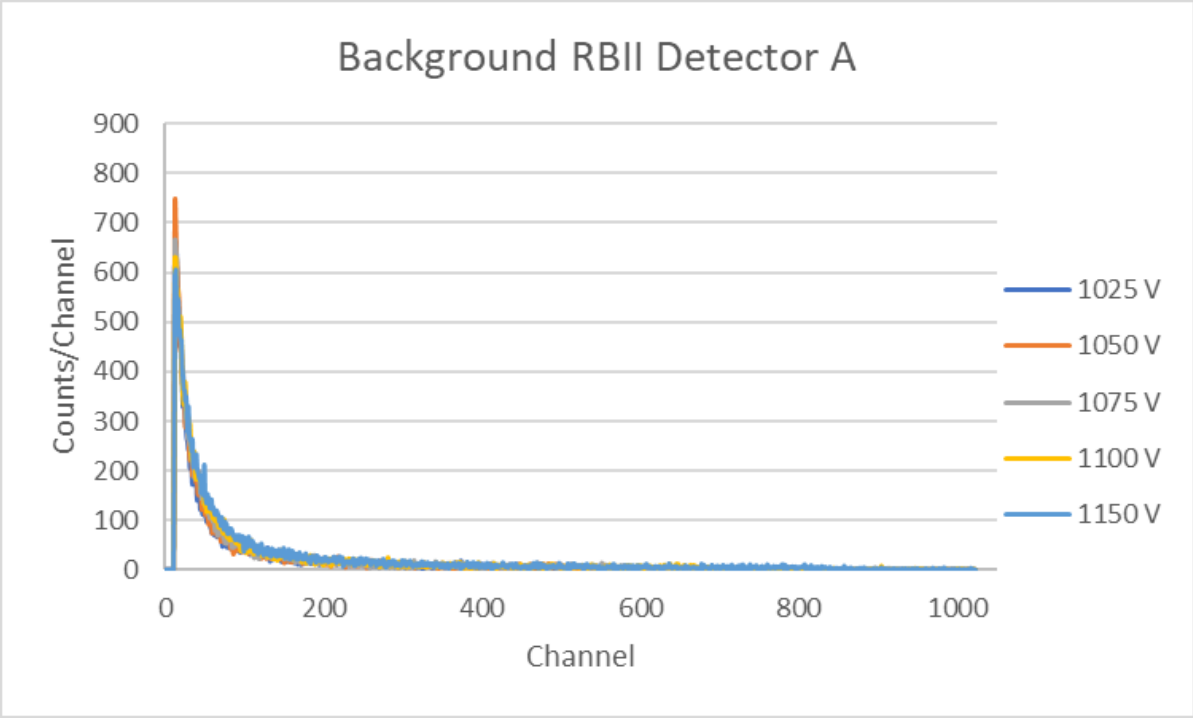

Detector A RF
600000
500000
400000
300000
200000
100000
0
Counts per Channel
0
100
200
300
400
Channel
1125V

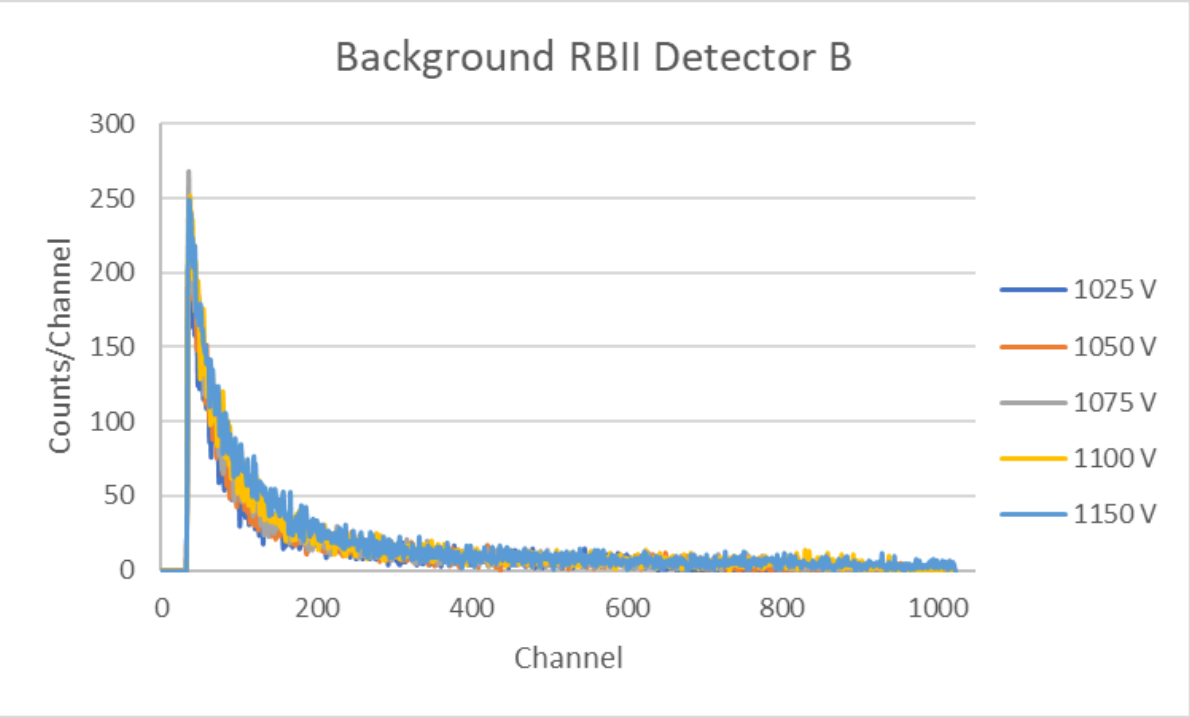
Background in Lab



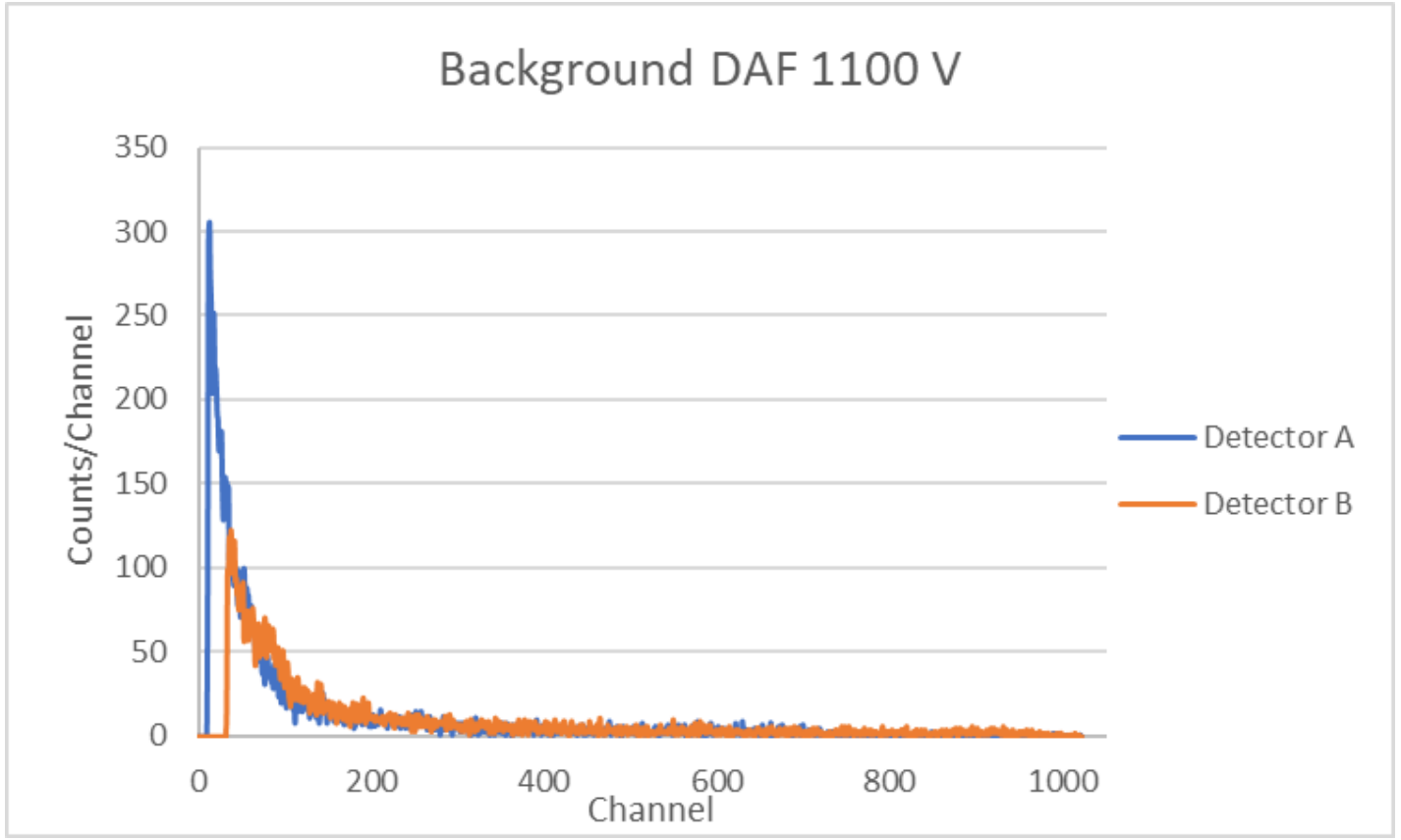


Background outside Research Building II

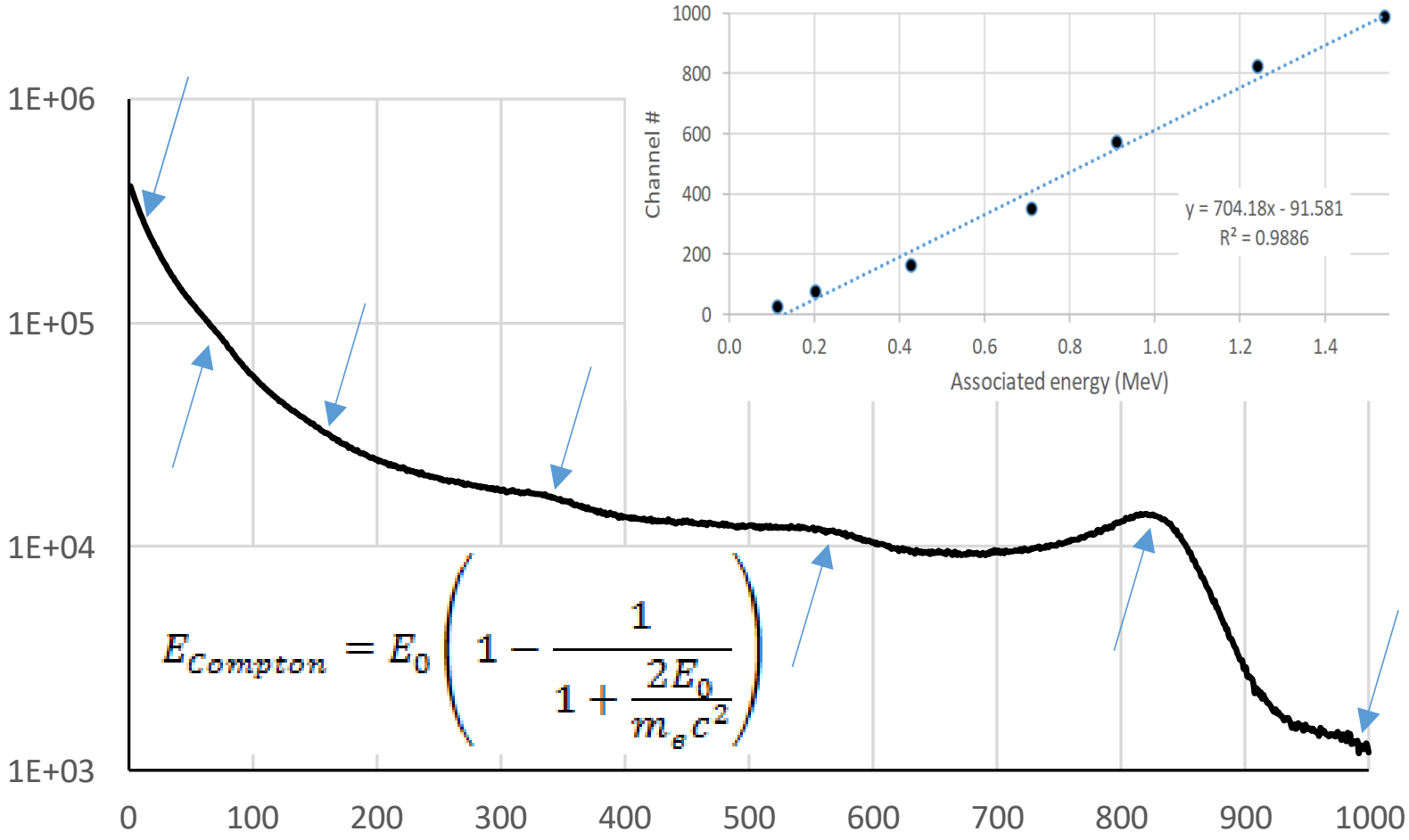


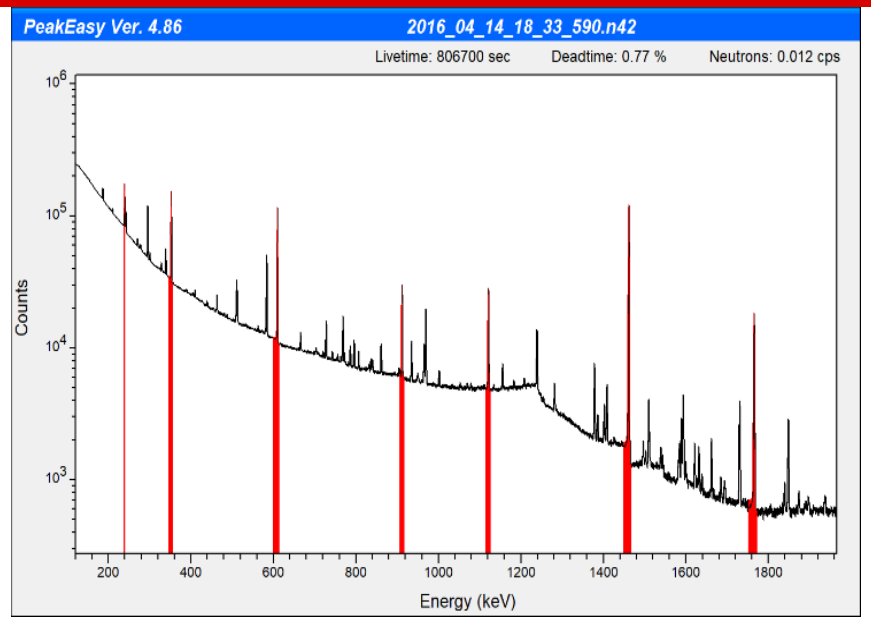


Background in DAF



Compton edge is linear with energy





7/24/2016 2:44	MeV	CE	channel #
Bi214	1.76	1.5	987
K40	1.46	1.24	823
Bi214	1.12	0.91	569
Ac228	0.91	0.71	349
Bi214	0.61	0.43	162
Pb214	0.35	0.20	75
Pb212	0.24	0.12	25

CNEC | Consortium for Nonproliferation Enabling Capabilities

U.S.NRC United States Nuclear Regulatory Commission Protecting People and the Environment

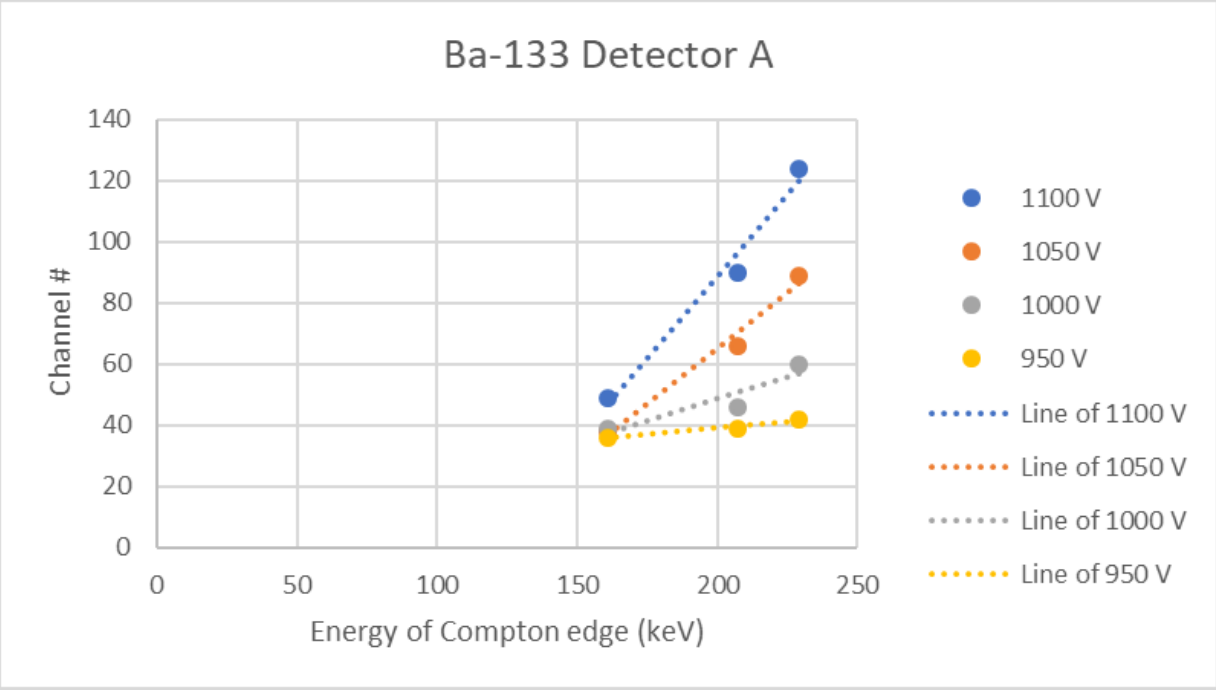
Department of NUCLEAR ENGINEERING

Compton Edge Energy

$$E_{Compton} = E_0\left(1 - \frac{1}{1 + \frac{2E_0}{m_e c^2}}\right)$$

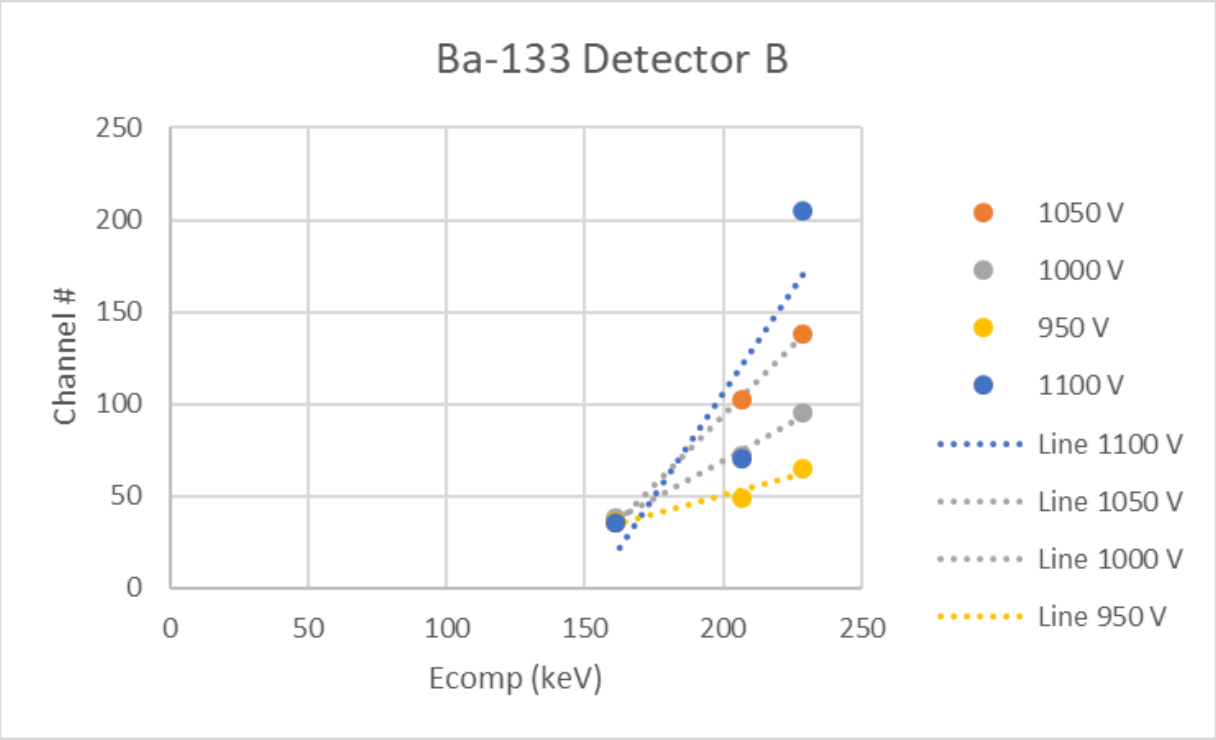
	E_o (*Gamma 1*) (KeV)	E_0 (*Gamma 2*) (KeV)	E_0 (*Gamma 3*) (KeV)	E_{Comp1} (KeV)	E_{Comp2} (KeV)	E_{Comp3} (KeV)
Barium-133	302	356	383	161	207	229
Cobalt-60	1173	1332		963	1117	
Europium-154	1004	1274	1600	800	1061	1379
Sodium-22	511	1274		340	1061	
Americium-241	60			11		
Cesium-137	662			477		

Barium-133 Detector A



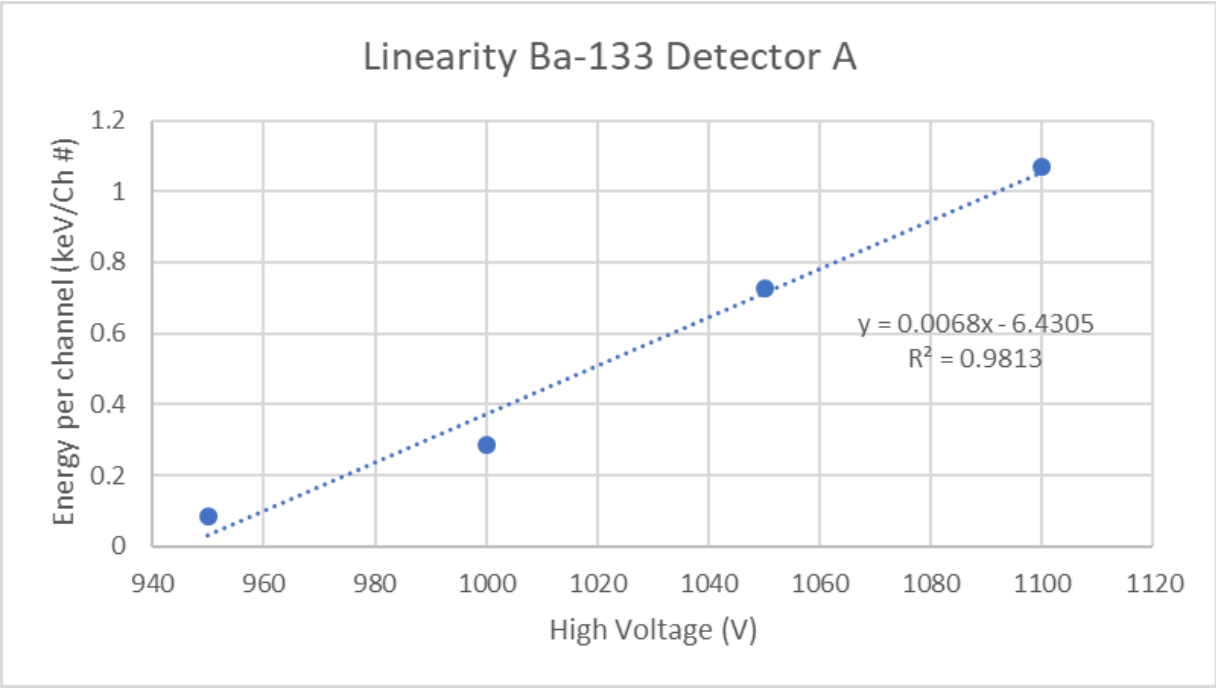
High Voltage (V)	Slope	Intercept
1100	1.0706	-125.3823
1050	0.7284	-80.6193
1000	0.2848	-8.3585
950	0.0847	22.1412

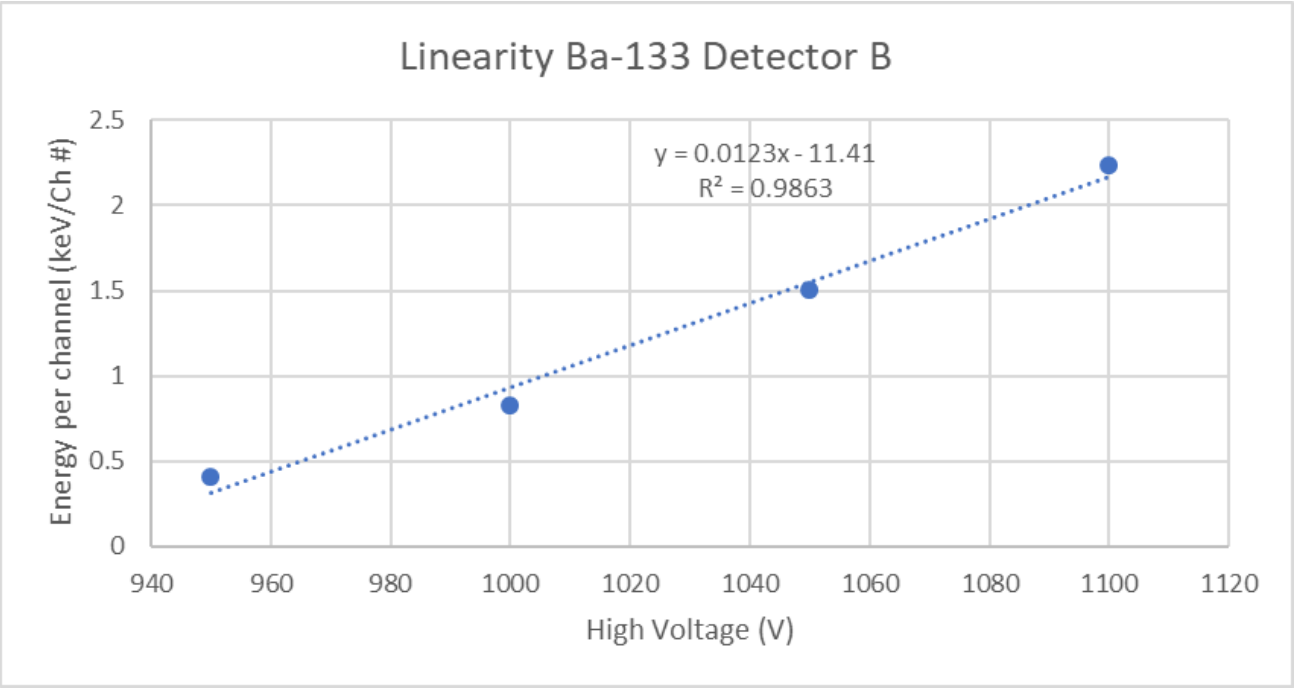
Barium-133 Detector B



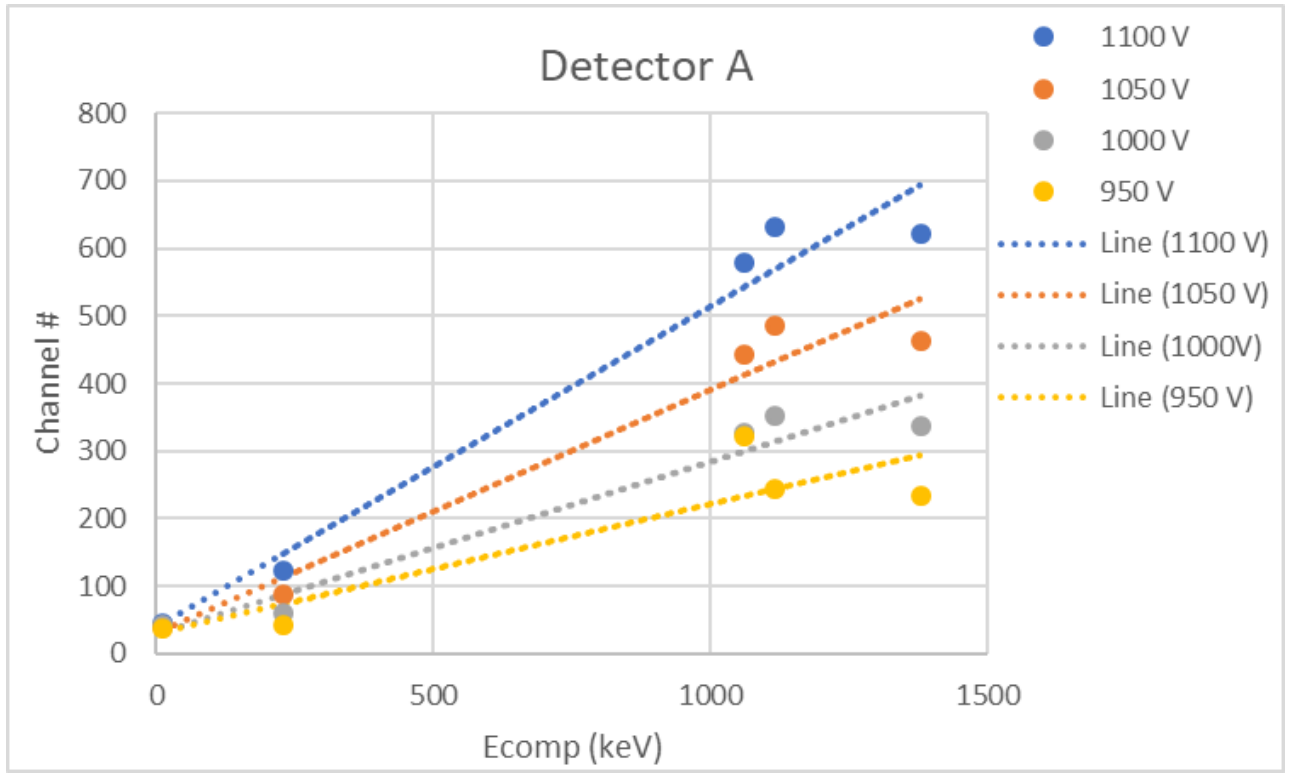
High Voltage (V)	Slope	Intercept
1100	2.2342	-341.276
1050	1.5051	-207.99
1000	0.823	-95.4615
950	0.4044	-30.4925

Linearity Barium-133



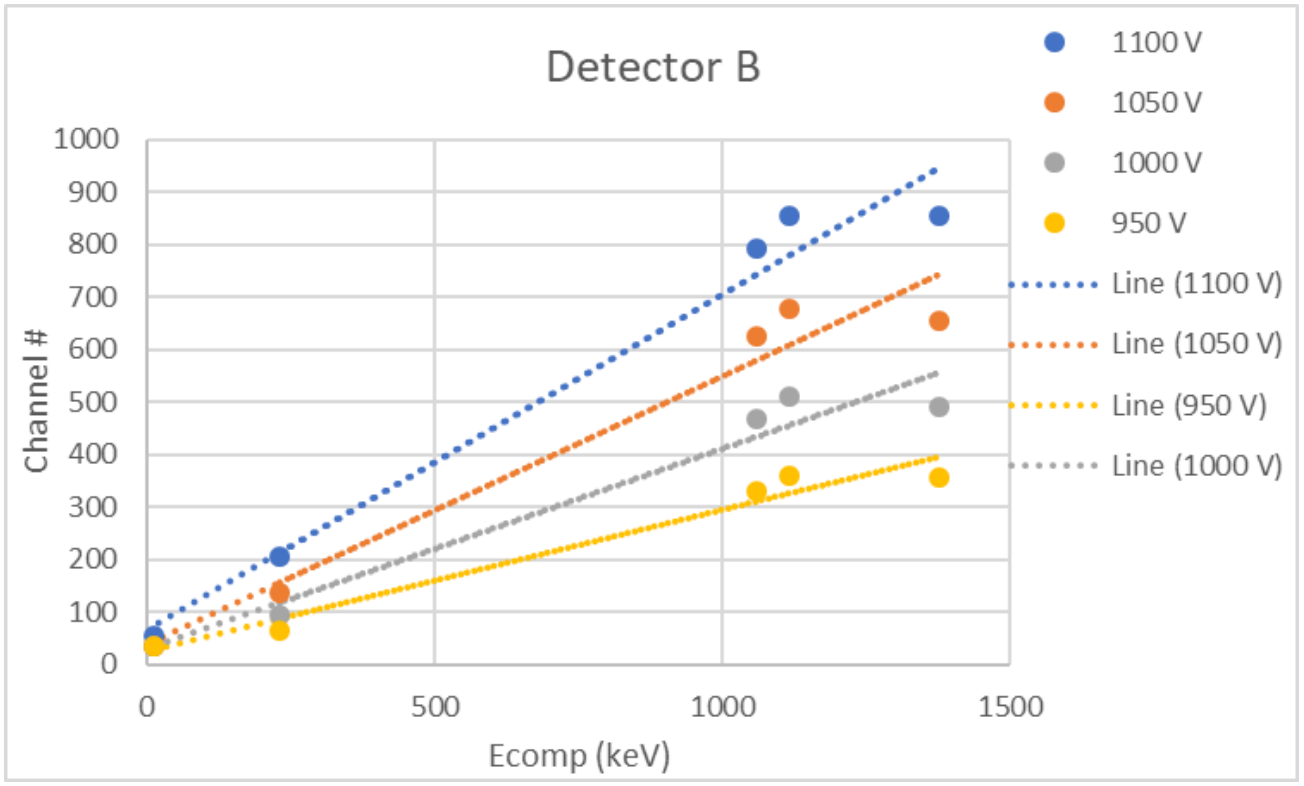


Detector A



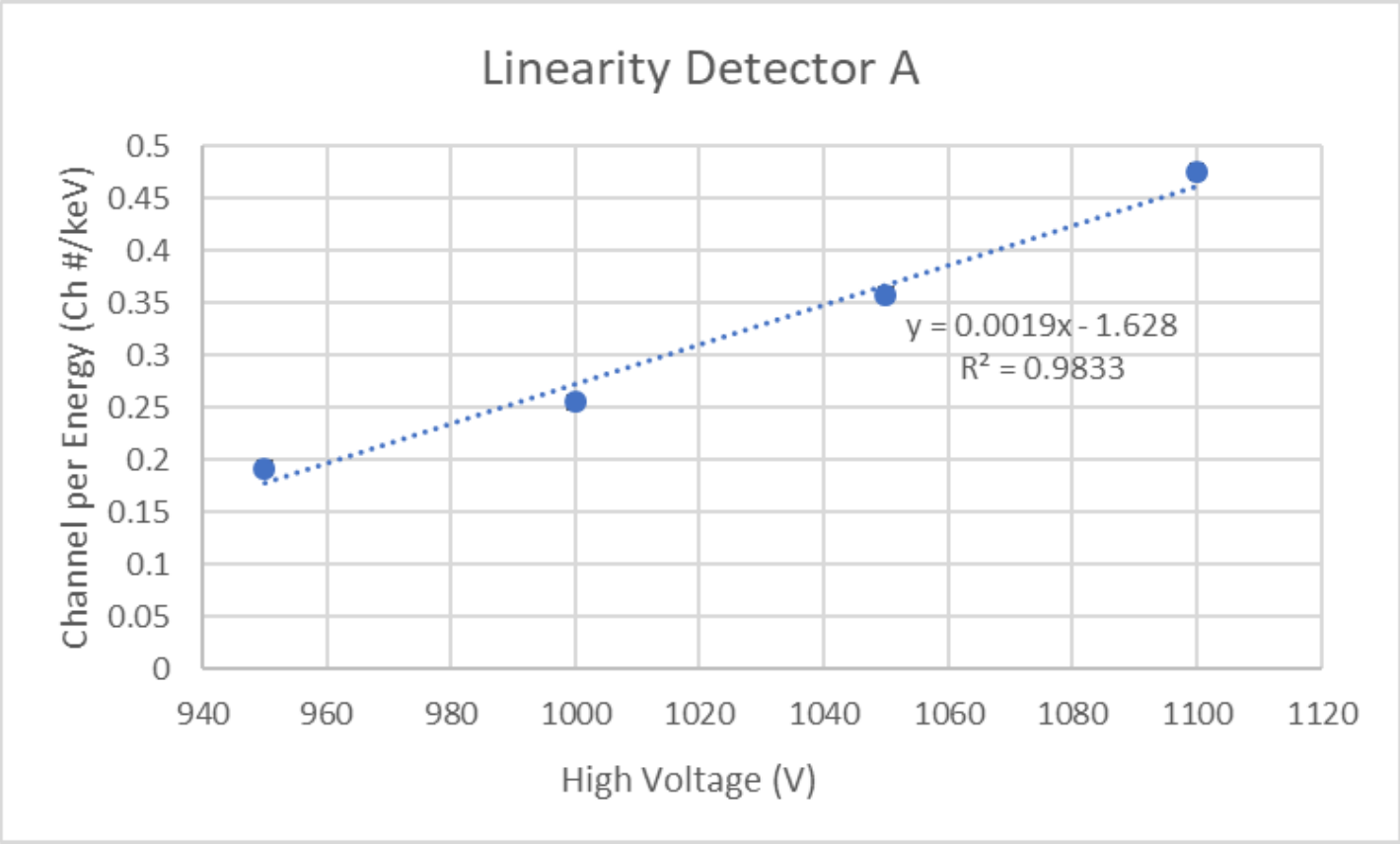
High Voltage (V)	Slope	Intercept
1100	0.4752	38.8646
1050	0.3581	31.8027
1000	0.2555	29.0998
950	0.1926	29.4686

Detector B

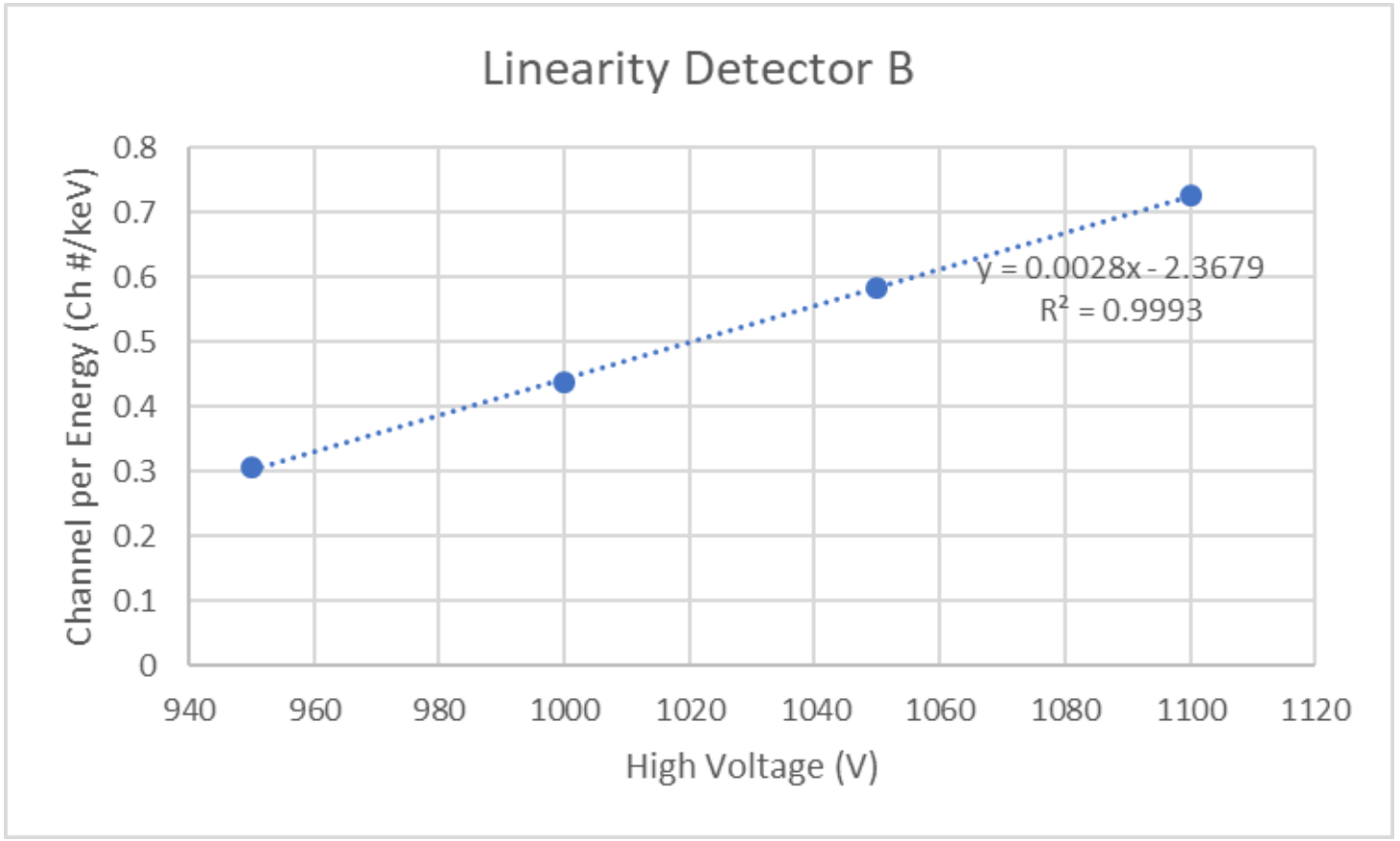


High Voltage (V)	Slope	Intercept
1100	0.727	67.1189
1050	0.5827	39.4542
1000	0.4366	29.838
950	0.3072	25.4146

Linearity of Detector A



Linearity of Detector B



Conclusions and Future Research

- Dependency on high voltage will be determined
- Sources that will be sampled:
  - K-40
- Experiments at Device Assembly Facility (DAF) held at the Nevada Test Site will continued to be analyzed

References

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Questions?

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