SAND2011-3047P

Gamma Spectroscopy

John McCulloch

Radiation Protection and Sample Diagnostics (4121)

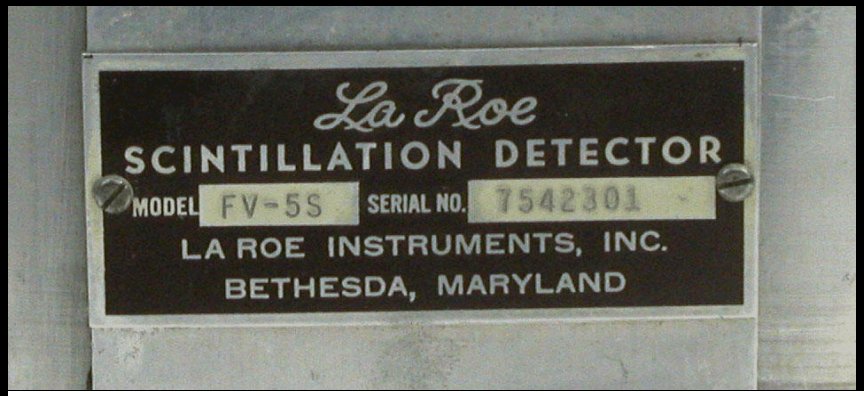
What Do These Have in Common?

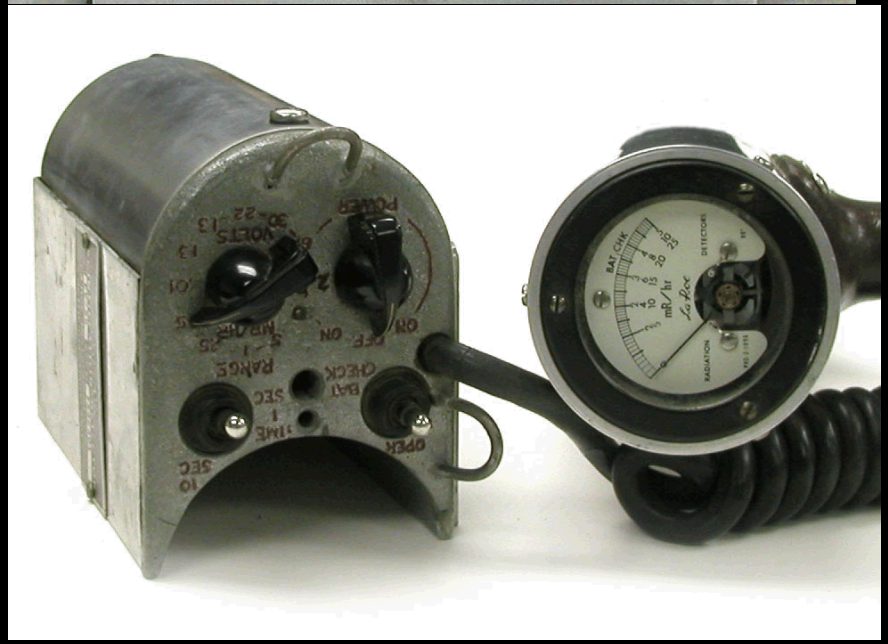
First Portable Field Instrument (1945)

Dawn of Gamma Spec

- Gammas “invisible” to all detectors
- 1948 Robert Hofstadter adds a “pinch” of Thallium Iodide to melt of NaI.
- Gamma Spec now possible
- Finds spectra for nuclides
- Identifies escape, annihilation and backscatter peaks.

Early Gamma Analysis



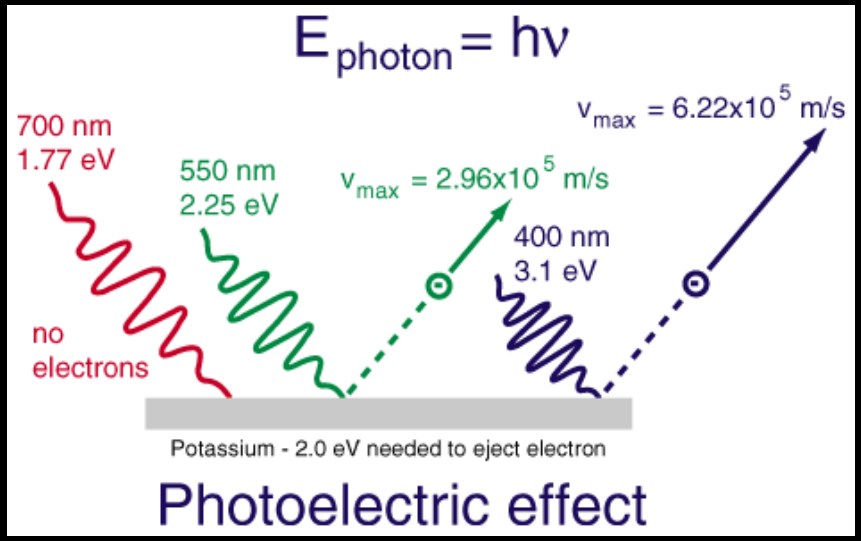


High Purity Germanium

- Allister Tavendale (1963)
- Game Changer
  - Excellent Resolution
- Li Drifted due to impurities
- MUST Keep COLD!

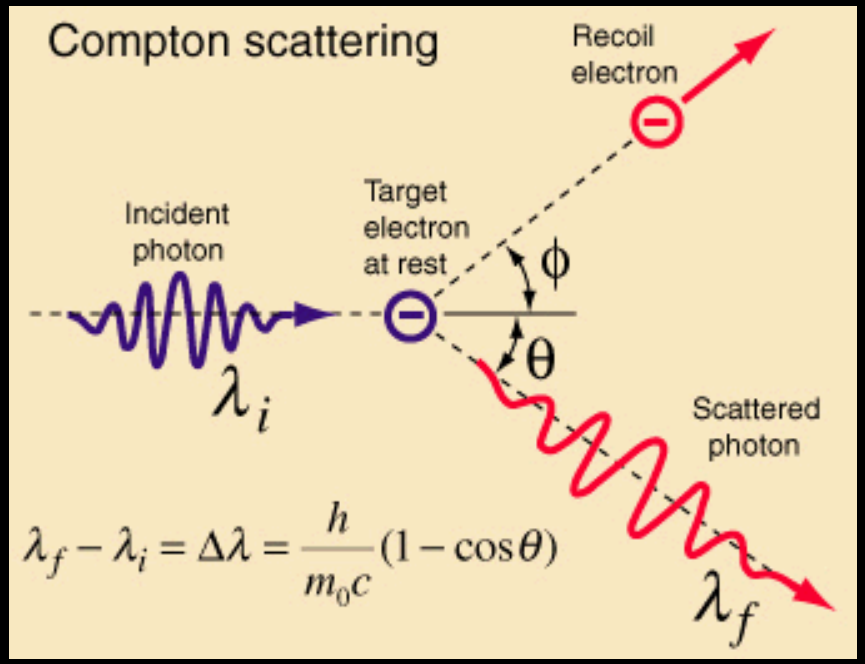
Detector Behavior – Photo Electric Effect

- Heinrich Hertz (1887)
- Einstein (1905)
  - Nobel Prize (1921)
- Most desirable of interactions in HPGe
- Most common for low energy photons



Detector Behavior – Compton Scattering

- Arthur Compton (1923)
  - Nobel Prize (1927)
- Demonstrates Light cannot be strictly a wave
- Occurs with mid-energy level photons
- The most common form of interaction in gamma spec



Compton Scattering - Possibilities

Electron Energy

$$E_e = h\nu - h\nu'$$

Exiting Photon Energy

$$h\nu' = \frac{h\nu}{1 + \left({}^{h\nu}/_{m_0c^2}\right) * (1 - \cos\theta)}$$

Small Scattering Angle

$$\lim_{\theta \to 0} \frac{h\nu}{1 + \left({}^{h\nu}/_{m_0c^2}\right) * (1 - \cos\theta)} = h\nu$$

Large Scattering Angle

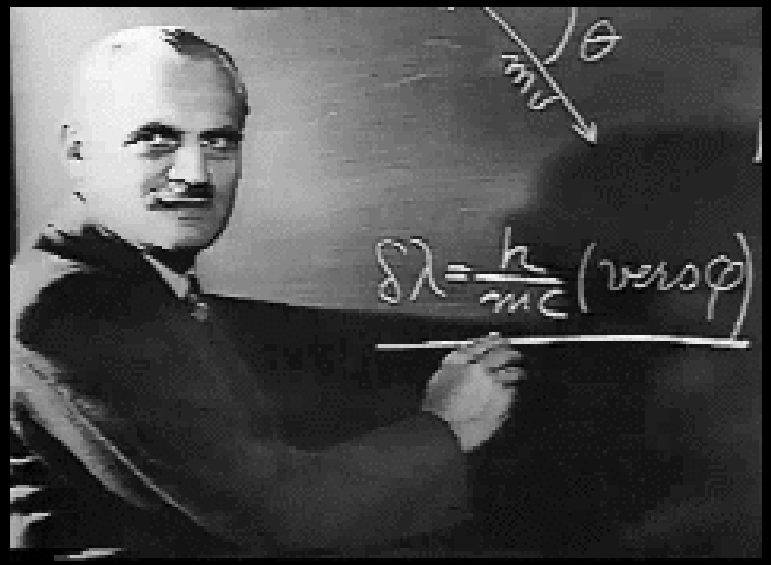
$$\lim_{\theta \to \pi} \frac{h\nu}{1 + \left({}^{h\nu}/_{m_0c^2}\right) * (1 - \cos\theta)} = \frac{h\nu}{1 + \left({}^{2h\nu}/_{m_0c^2}\right)}$$

Max Scatter Energy

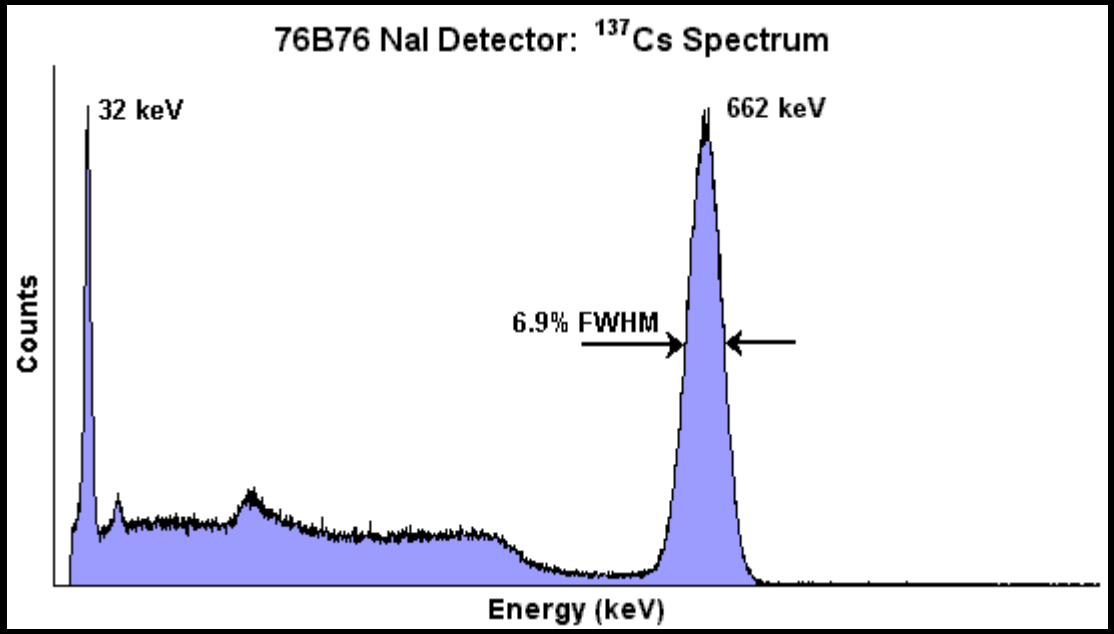
$$h\nu' = \lim_{h\nu \to \infty} \frac{h\nu}{1 + \left({}^{2h\nu}/_{m_0c^2}\right)} = \frac{m_0c^2}{2} = h\nu - 256\ keV$$

Back Scatter

- Special Case of Compton
- Photon outside detector Scatters In
- Always near 256 keV
- Peak leans left

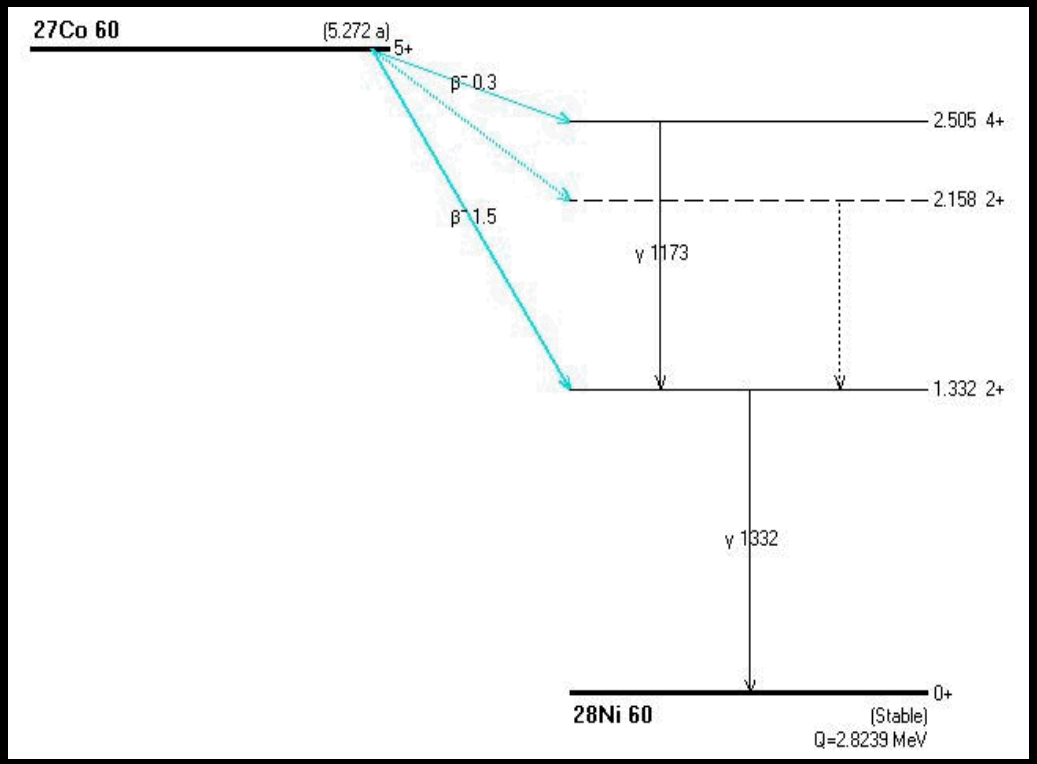


Cs-137

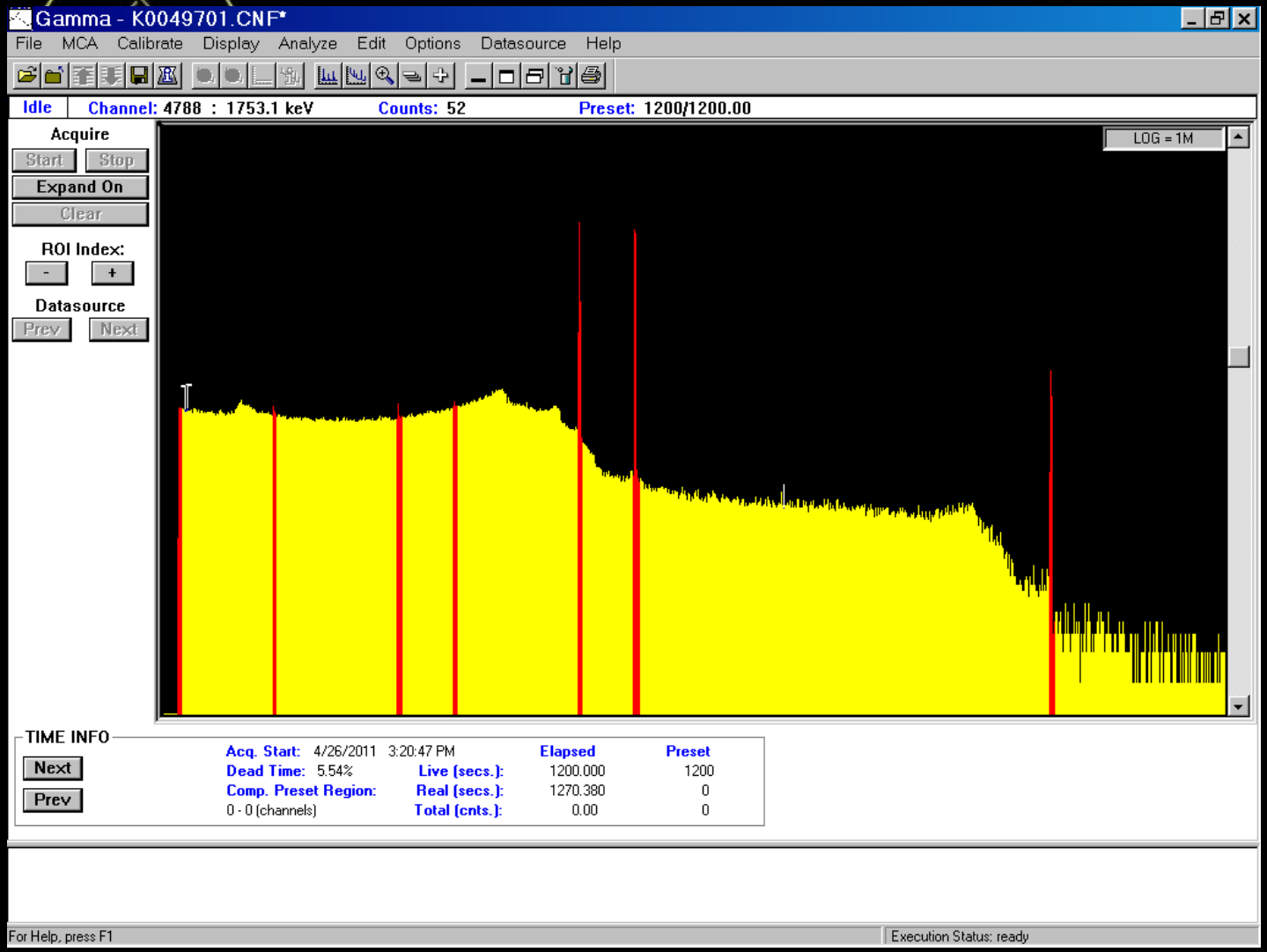

76B76 NaI Detector: ^{137}Cs Spectrum
32 keV
662 keV
6.9% FWHM
Counts
Energy (keV)

Summing

- Cascade Summing
  - Rapid Decay
  - Common
    - In certain isotopes
- Random Summing
  - High Count Rate
  - Fairly Rare
  - 511 peak
- Summing In/Out
- Creates “false” peaks

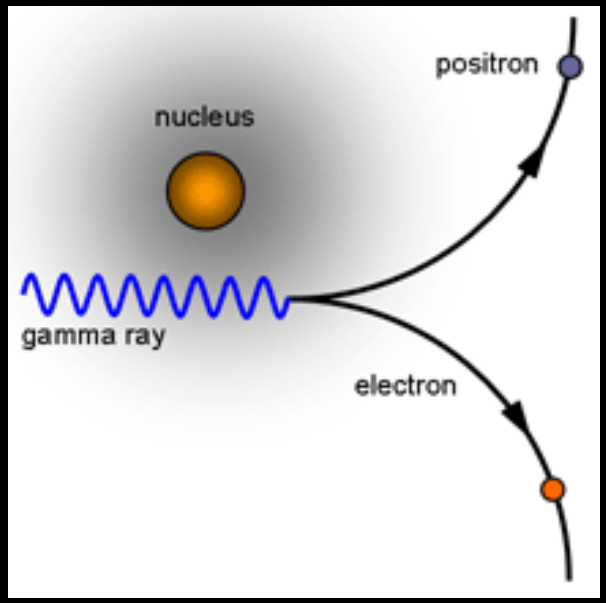


Co-60


Gamma - K0049701.CNF*
File MCA Calibrate Display Analyze Edit Options Datasource Help
Idle
Channel: 4788 : 1753.1 keV
Counts: 52
Preset: 1200/1200.00
Acquire
Start
Stop
Expand On
Clear
ROI Index:
-
+
Datasource
Prev
Next
LOG = 1M
TIME INFO
Next
Prev
Acq. Start: 4/26/2011 3:20:47 PM
Dead Time: 5.54%
Comp. Preset Region:
0 - 0 (channels)
Elapsed
Live (secs.): 1200.000
Real (secs.): 1270.380
Total (cnts.): 0.00
Preset
1200
0
0
For Help, press F1
Execution Status: ready

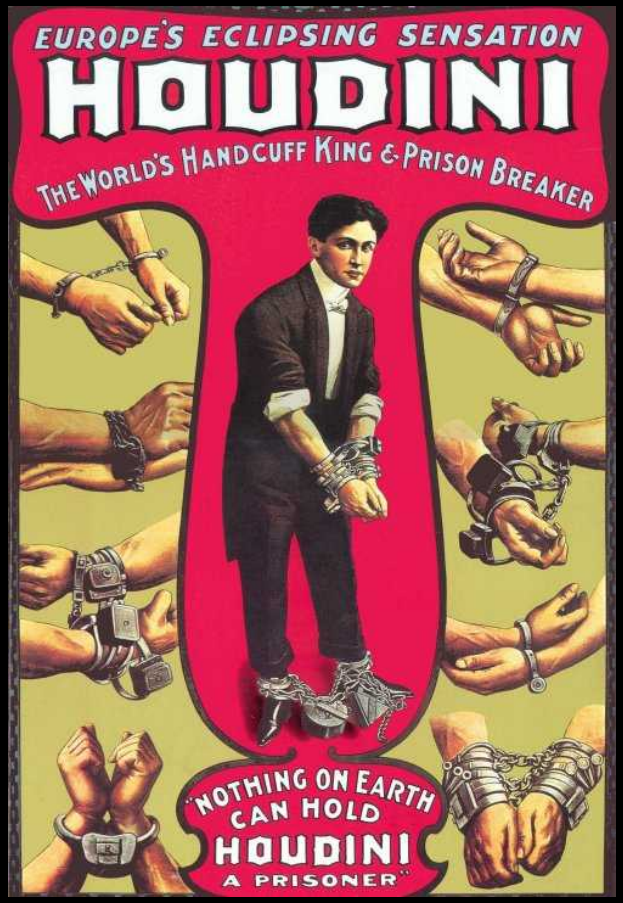
Pair Production

- Coolest form of interaction
- Discovered Patrick Blackett 1933
  - Student of Rutherford
  - Nobel Prize 1947
- Minimum Energy of 1022 keV
- Full energy deposited in 511 keV peak

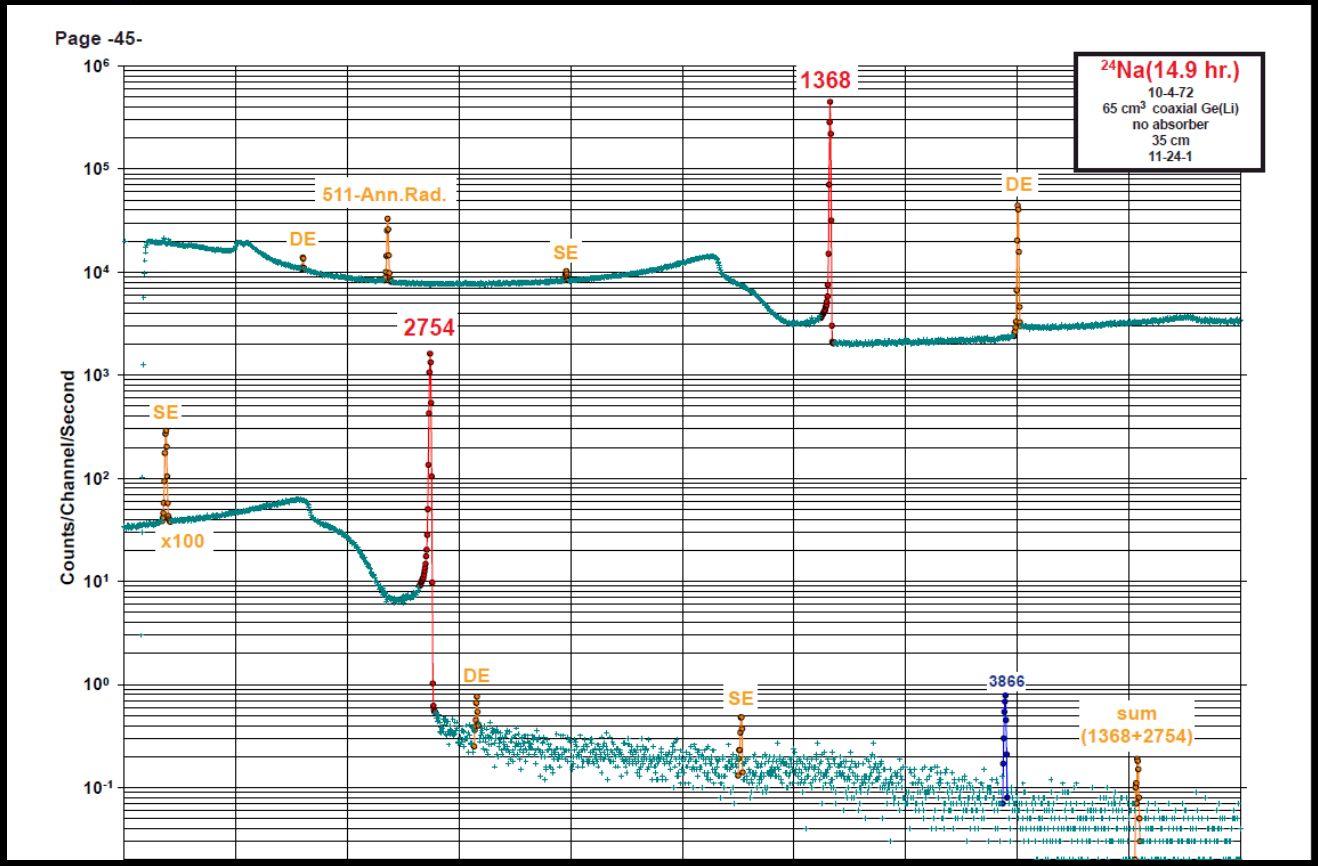


Escape Peaks

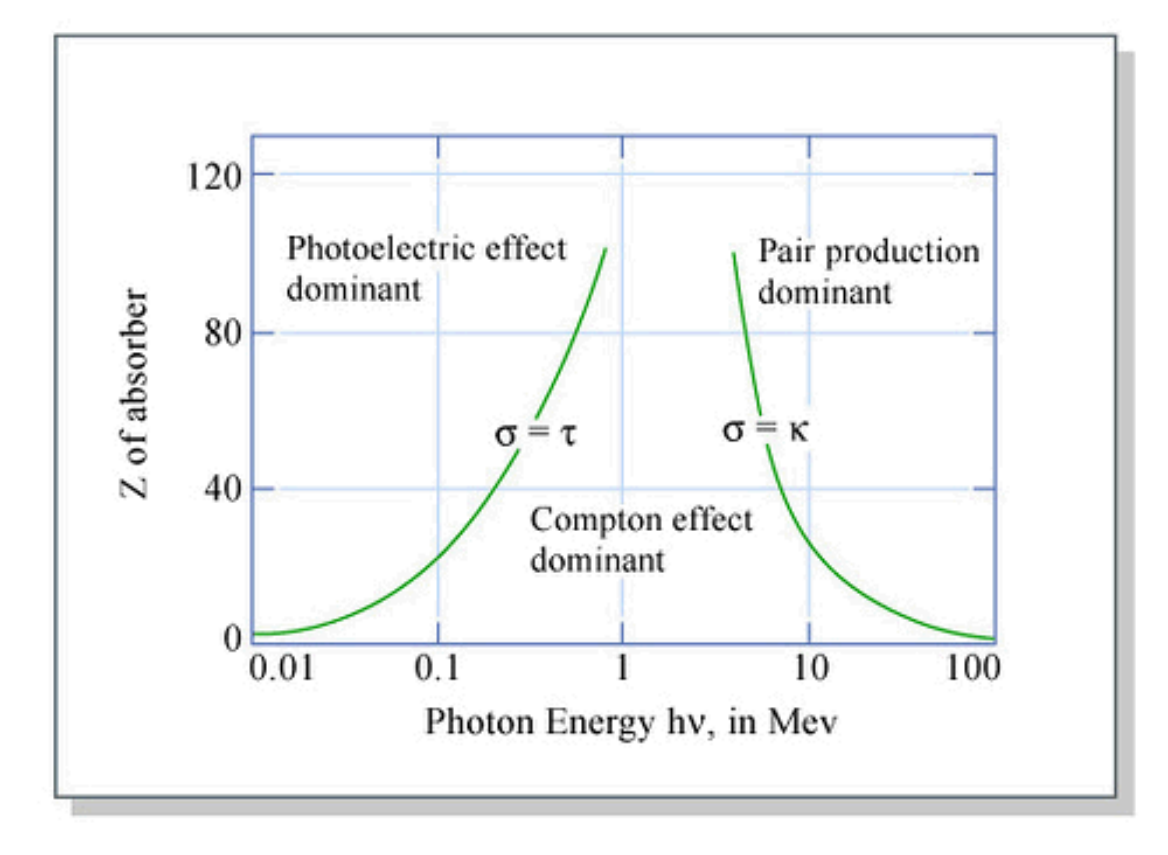
- Only for high energy photons
- Electron/Positron annihilate
- One or both 511 keV photons escape
- Peak shifted down by 511 or 1022 keV.



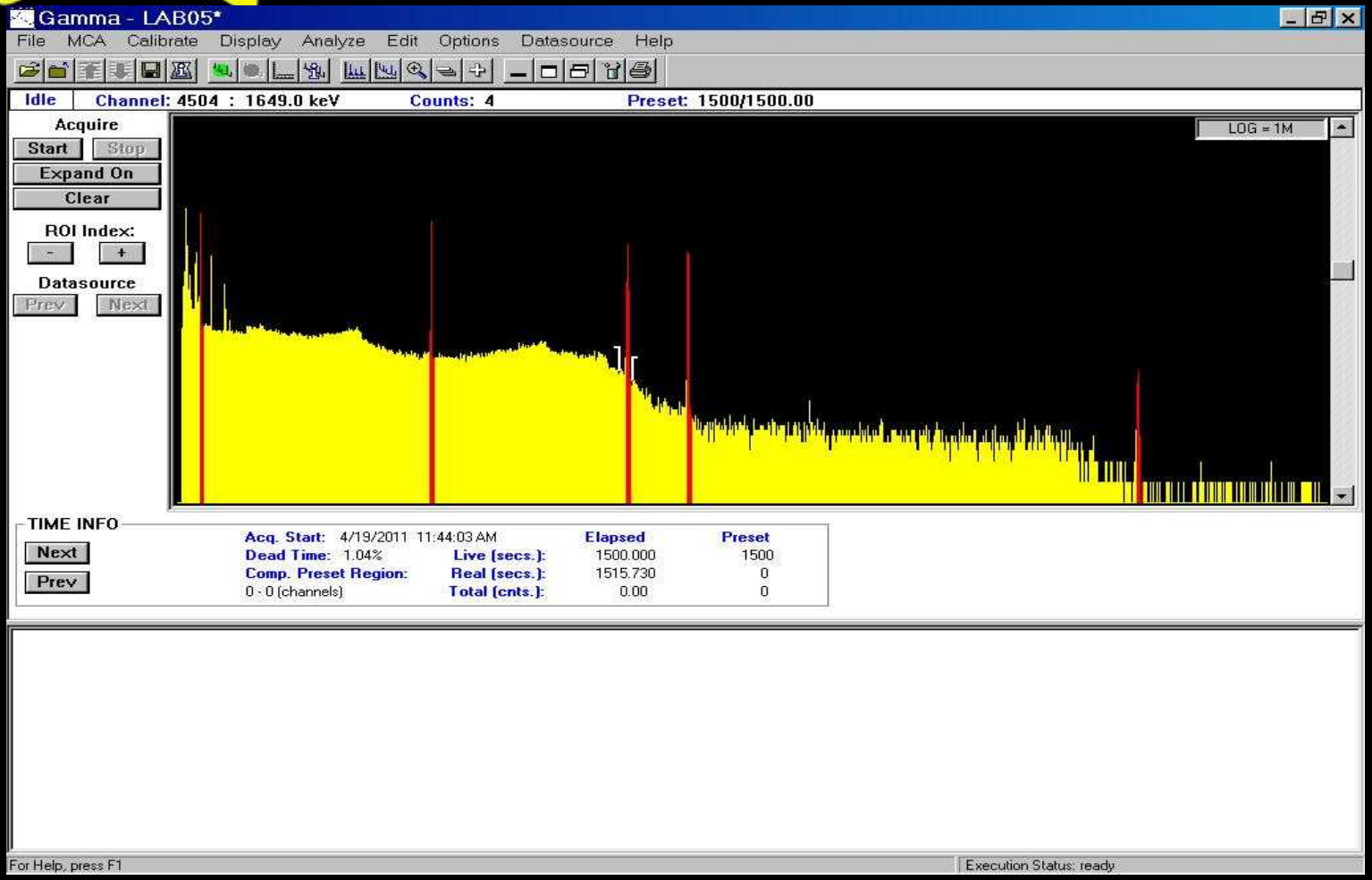
Na-24


Page -45-
^{24}Na(14.9 hr.)
10-4-72
65 cm^3 coaxial Ge(Li)
no absorber
35 cm
11-24-1
Counts/Channel/Second
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
1368
511-Ann.Rad.
DE
SE
DE
2754
SE
x100
DE
SE
3866
sum
(1368+2754)

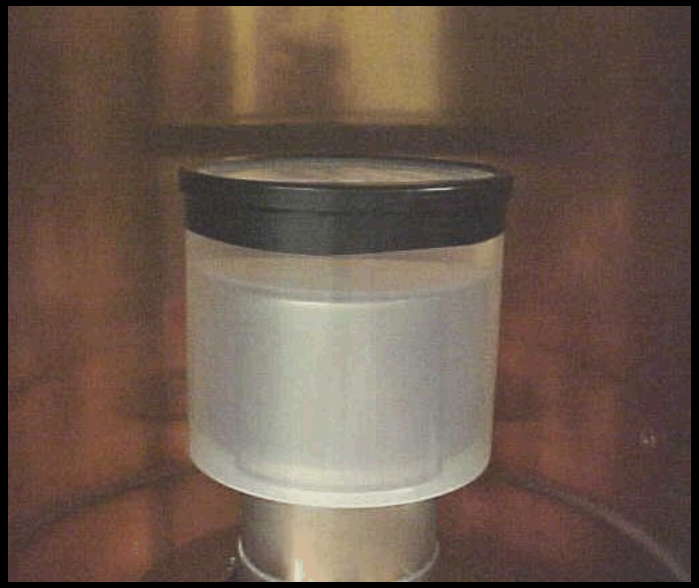
What Dominates?



Genie 2K Spectrum



Application Time



* = Primary line
NID Confidence Index Threshold : 0.40
Energy tolerance : 1.000 FWHM

Nuclide Name	Id Confid.	Energy (keV)	Eff. (Absolute)	Yield (%)	Activity (pCi/Each)	Activity Error
I-131	1.000	80.18	9.23E-002	2.62	2.87E+005	4.04E+004
		284.30	9.16E-002	6.05	3.16E+005	4.17E+004
		364.48*	7.25E-002	81.20	3.37E+005	4.40E+004
		636.97	4.31E-002	7.26	3.49E+005	4.56E+004
		722.89	3.85E-002	1.80	3.66E+005	4.84E+004
BI-212	0.517	727.17*	3.83E-002	6.65	2.79E+003	4.13E+002
		785.46	3.58E-002	1.11		
		1078.62	2.72E-002	0.54		
		1620.62	1.89E-002	1.51		

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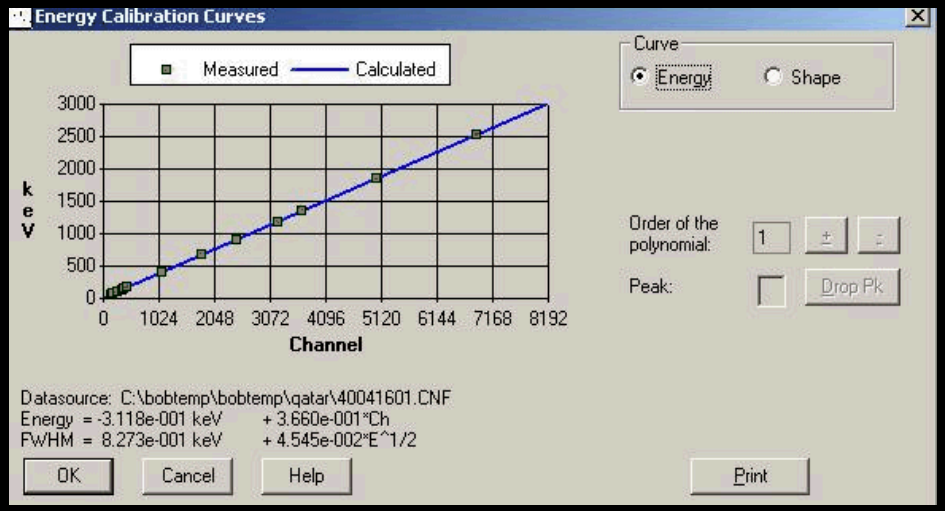
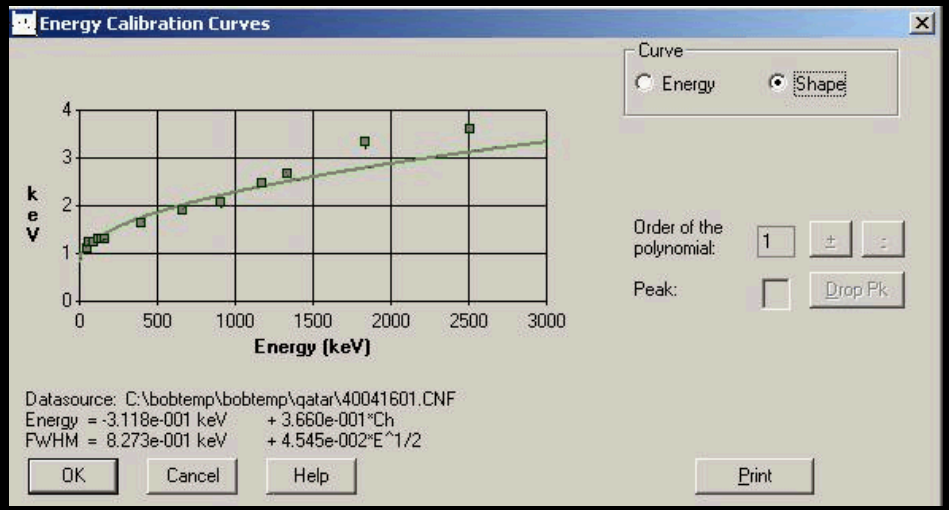
Energy Calibration

- ENERGY CALIBRATION
  - E = b + m*ch
  - Energy response is very linear



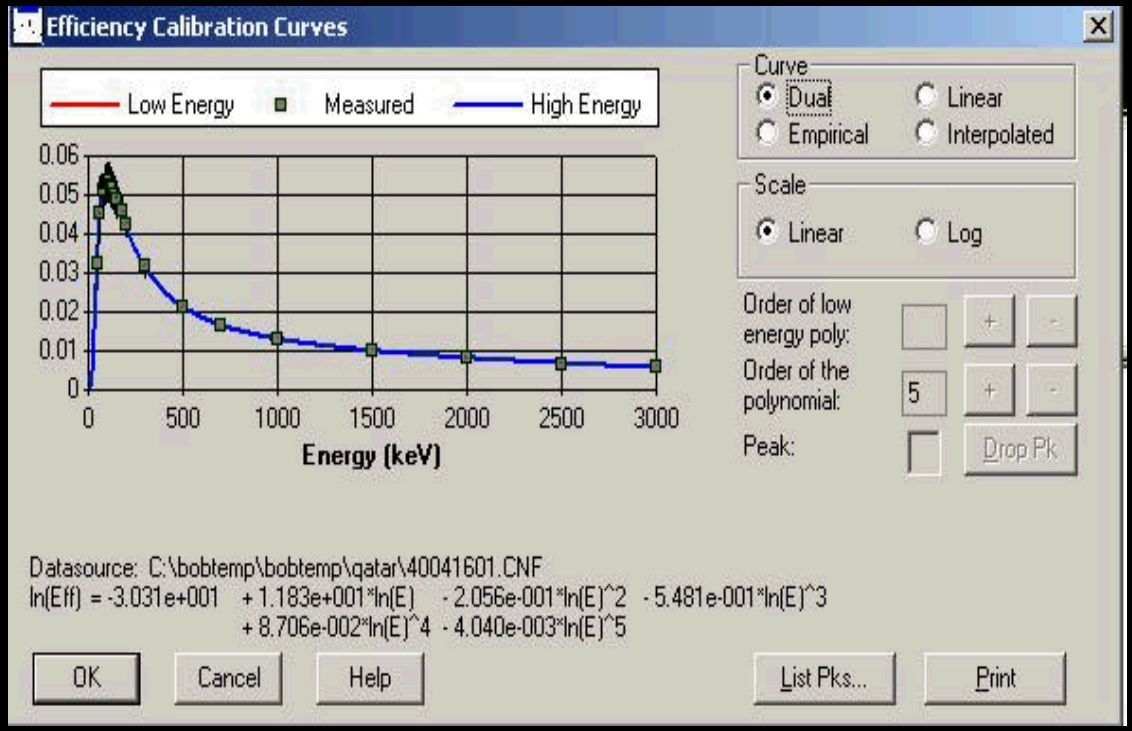
Shape Calibration

- SHAPE CALIBRATION
  - FWHM
  - Peaks broaden with root of energy



Efficiency Calibration

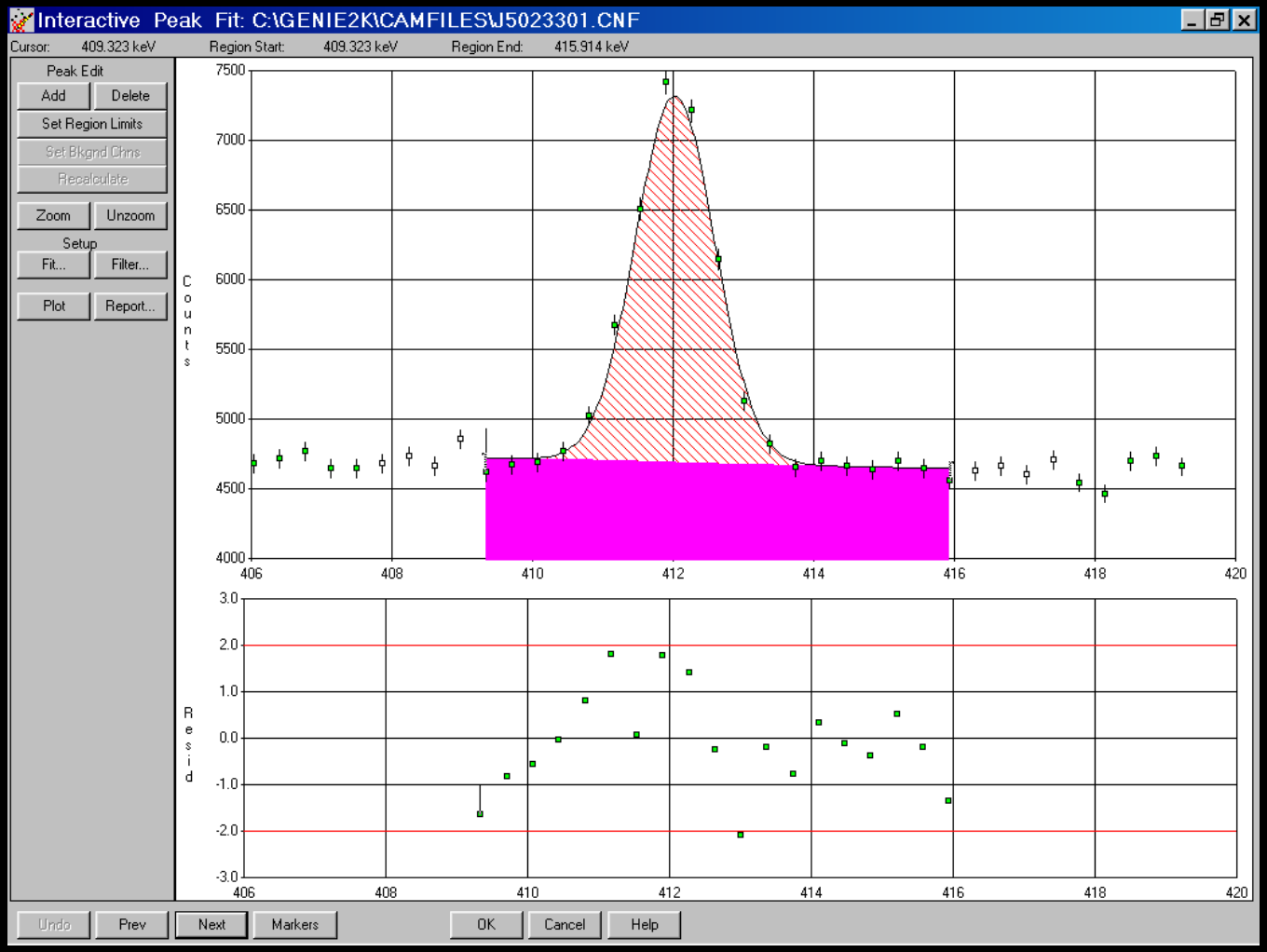
- Factors That Affect Efficiency
- Geometry
  - Size
  - Shape
  - Distance
- Density
  - Material
  - Atomic Number
  - Packaging



RPSD Calibrated Geometries

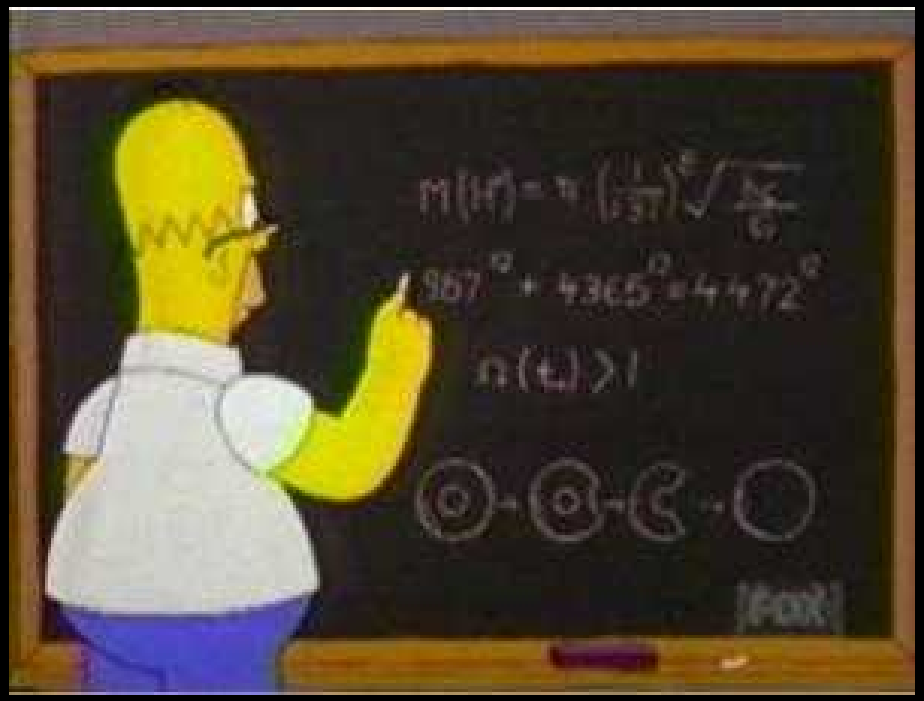
- Point Source
- Point Source 5 cm off detector face
- 1 inch Air Filter
- 2 inch Air Filter
- 2 inch Air Filter in Marinelli
- Carbon Cartridge Air Filter
- 4 x 5 Inch Air Filter
- Soil 250 mL Jar
- Liquid 250 mL Jar
- Low Density 250 mL Jar
- Soil 500 mL Marinelli
- Liquid 500 mL Marinelli
- Low Density 500 mL Marinelli
- LSC Vial
- Four Varieties of Drums
- ISOCS Capability (As Needed)

Identifying and Quantifying Peaks



Background Subtraction

- Monthly Background
- Long Count Time
- Count Rate Subtracted from each applicable peak



Fun Background Fact

- Beryllium
- Be-7 Occurs in BG forms from spallation in atmosphere
- Many Unique Properties/Attributes

Isotope Identification

- Peak Centroid Compared to User Defined Library
- Abundances cross checked
- Confidence Level Assigned
- Not Perfect!
- Needs a Human to Review!

Unidentified Peaks

- Very Valuable Information!
- Peaks that didn’t fit algorithm
- Helps user identify potentially missed nuclides

Results

- 8 Nobel Prizes (at least)
- 100 min count time
- 3 Sec computer time
- 10 -100 min analyst time
- 10-15 pages of paper
- Results FINALLY!

Some Thoughts on Uranium

- Naturally Occurring
- If U-235 is present in spectrum possibly enriched
  - Above 15% enriched probably won't see U-238
- U-235 frequently mis-identified with Ra-226
  - They share a line at 186 keV
- Most of activity belongs to U-234
- ASK QUESTIONS of RPSD!

What is Gamma Spec Good For?

- Identifying unknown nuclides
- Quantifying individual isotopes
- Little or no sample prep time
- “Looking” into containers
- ISOCS

Limitations of Gamma Spec

- Long Count Times
- Low Efficiency
- Expensive
- Can’t identify pure beta/alpha emitters
- Limitations on detection of many heavy isotopes (Pu, Cm, Np, Th)