
Institute of Physics of the Czech Academy of Sciences

ANS® EDUCATOR TRAINING

Unlocking the Invisible

An Introduction to Scintillators, Semiconductors, and Gamma Spectroscopy

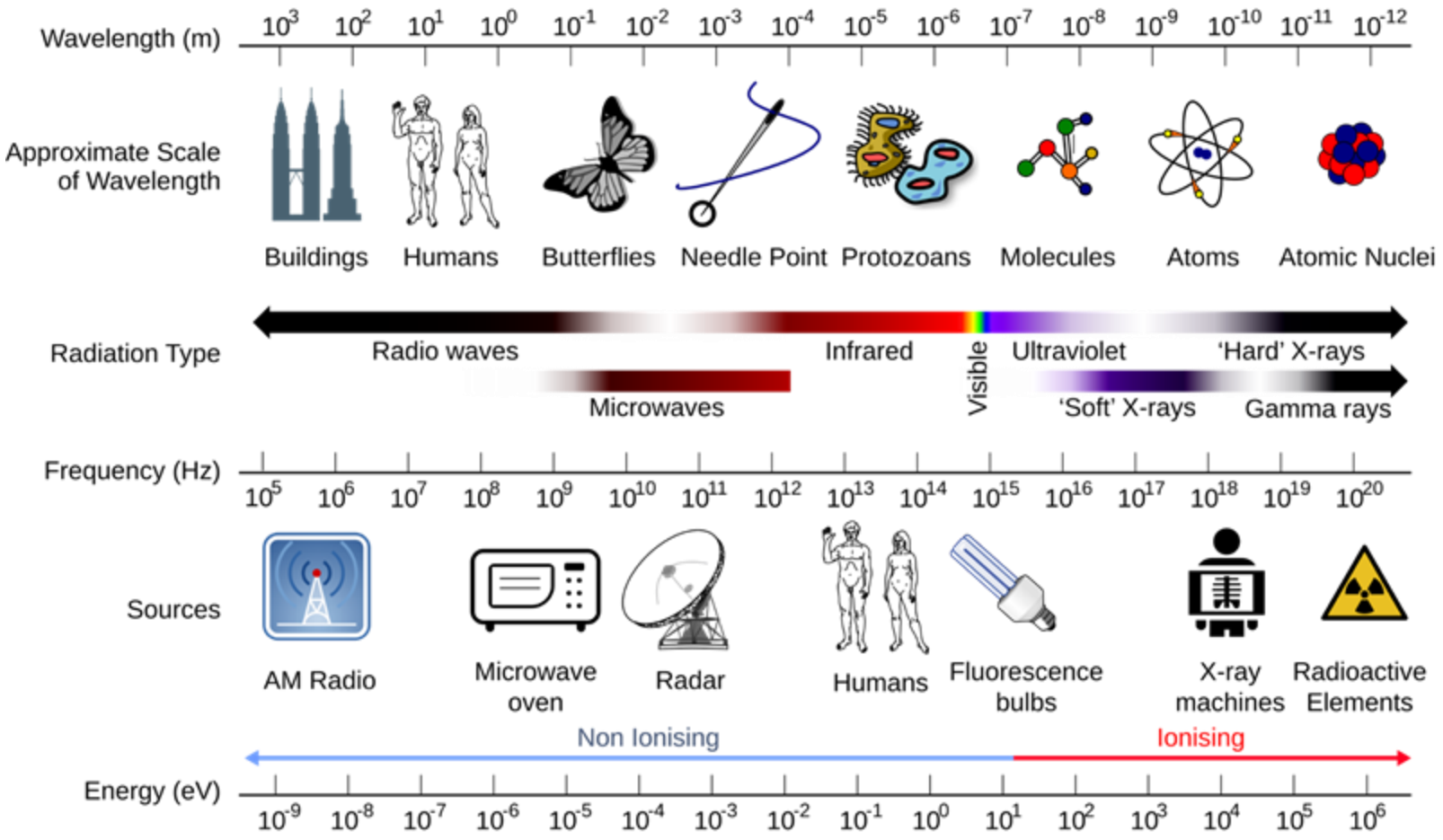
Thursday, September 19
7:00–8:00 pm ET

This event is presented by ANS in partnership with the Department of Energy, Office of Nuclear Energy.

Unlocking the Invisible: An Introduction to Scintillators, Semiconductors, and Gamma Spectroscopy

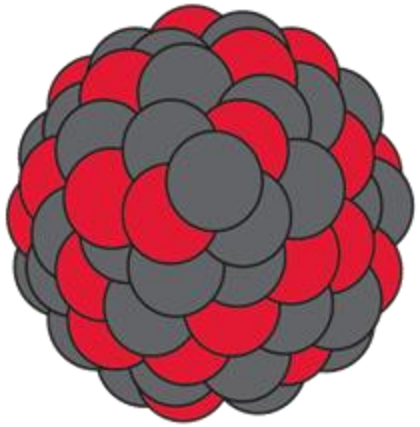
Amber Johnson
Luke Gilde
Mike Hottinger
Abby Kittel
University of Maryland
Radiation Facilities

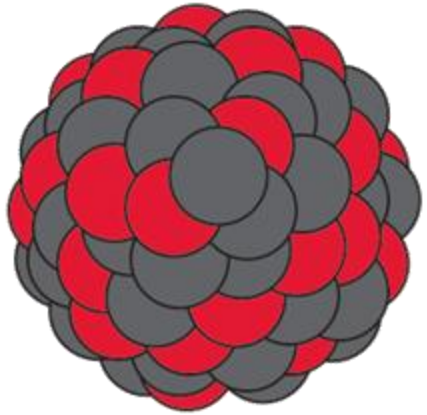
Electromagnetic Spectrum



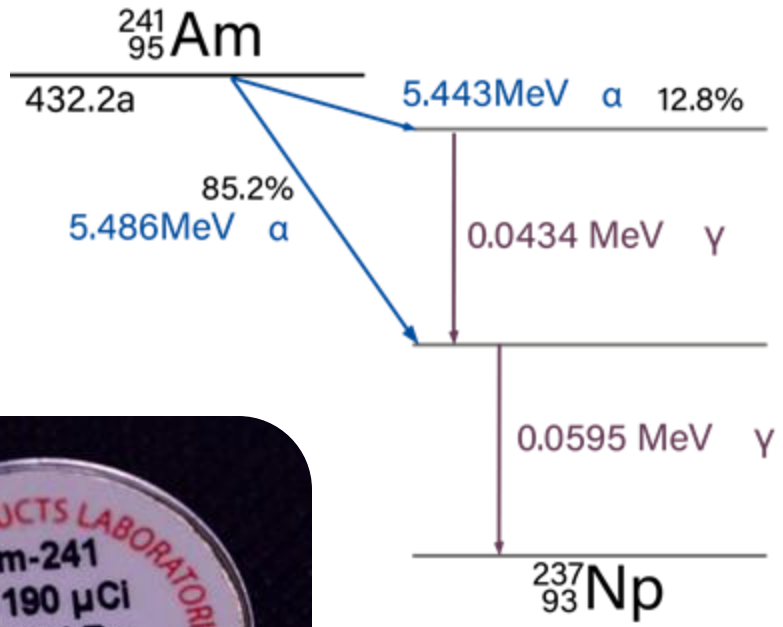
Wikimedia Commons

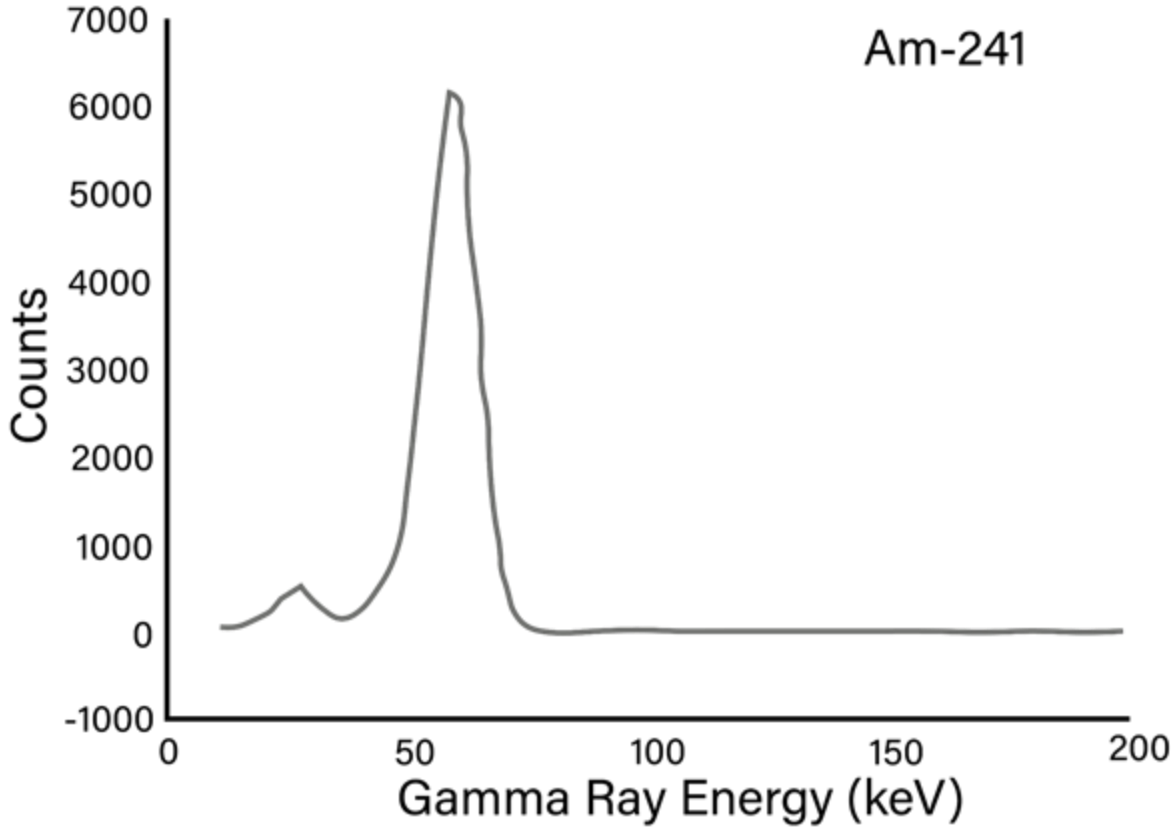
Gamma Radiation Review



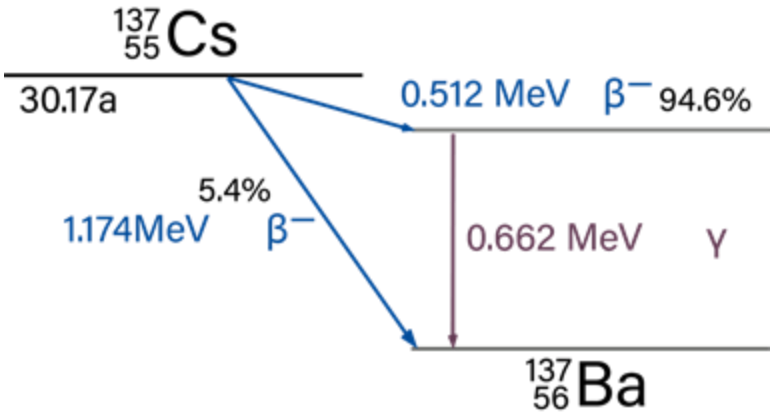


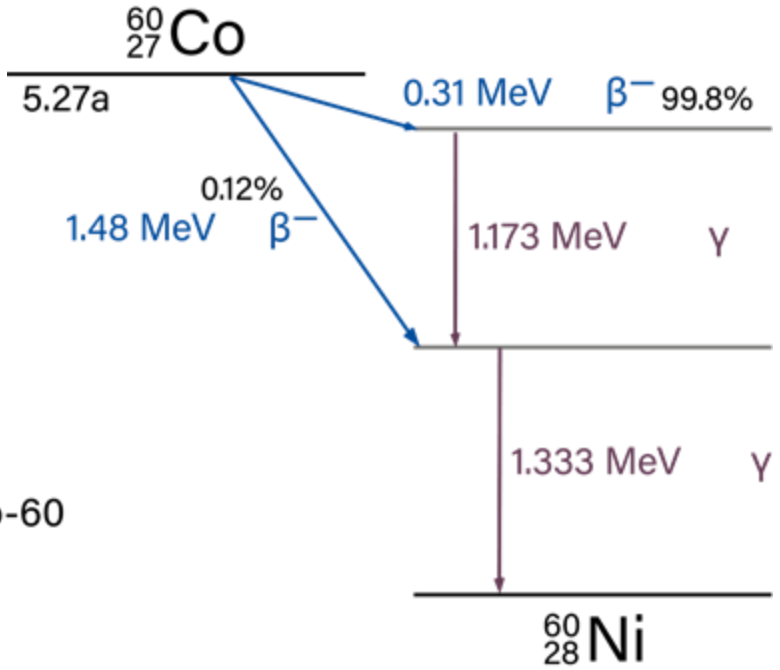
Gamma Decay Schemes - Alpha

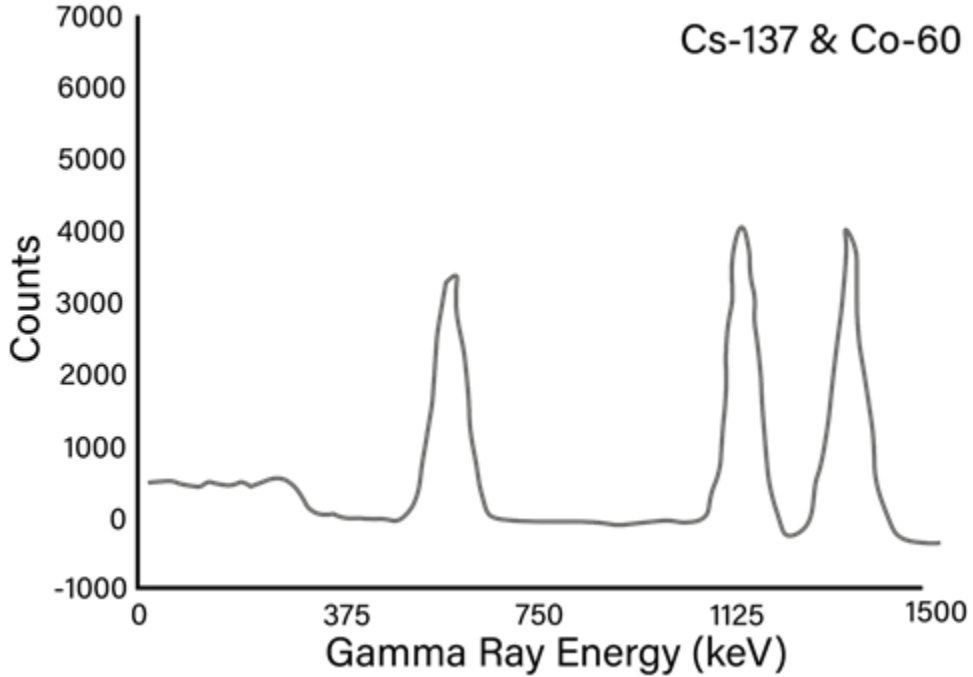


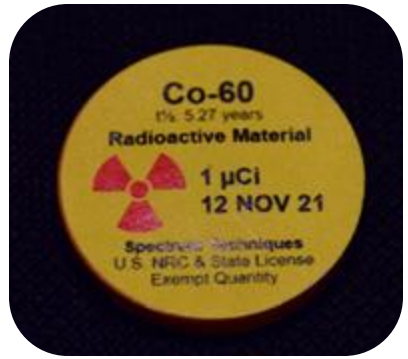


Gamma Decay Schemes - Beta





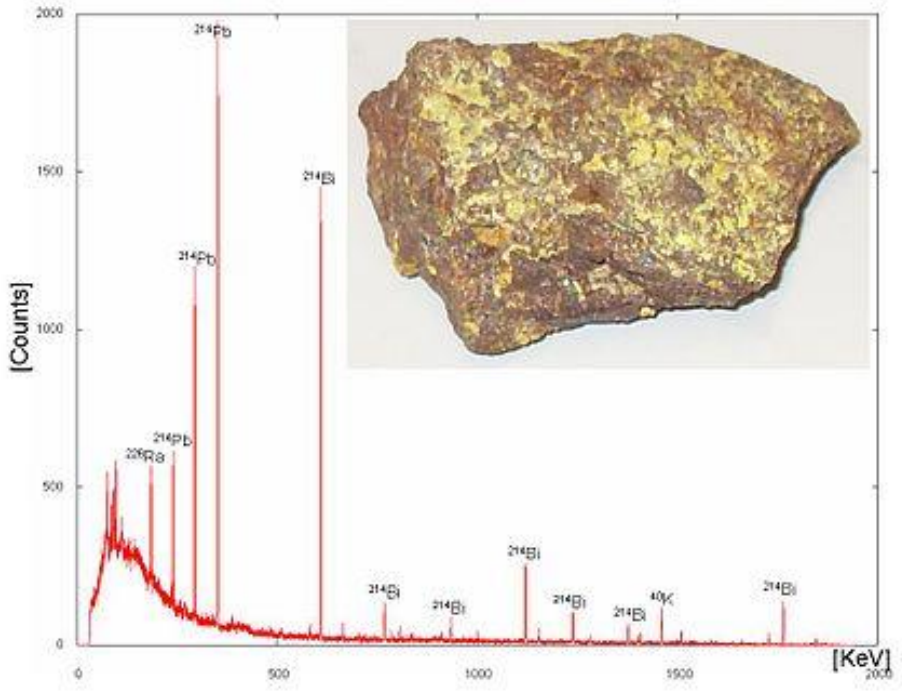




ANS
A. James Clark School of Engineering
EDUCATOR TRAINING

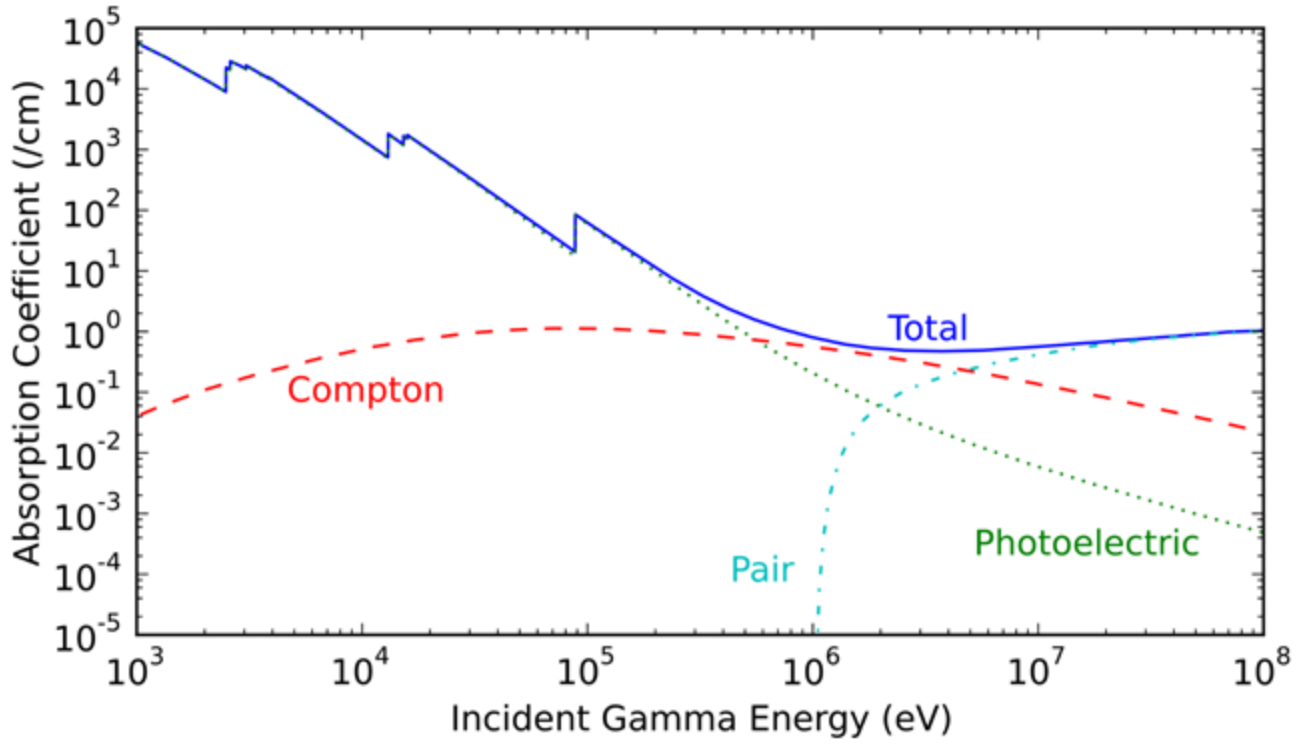
Gamma Spectrum

- Gamma rays are emitted at discrete energies
- Gamma ray energies are characteristic of a particular isotope
  - Gamma spectroscopy can be used to identify unknown isotopes!!



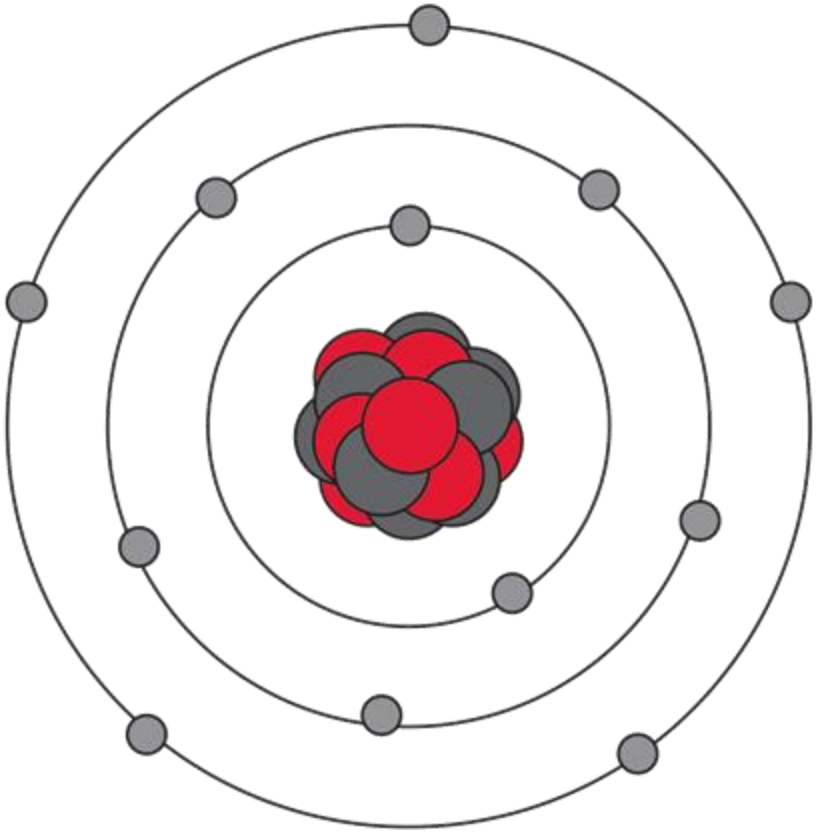
Gamma Interactions with Matter

- Photoelectric Effect
- Compton Scattering
- Pair Production

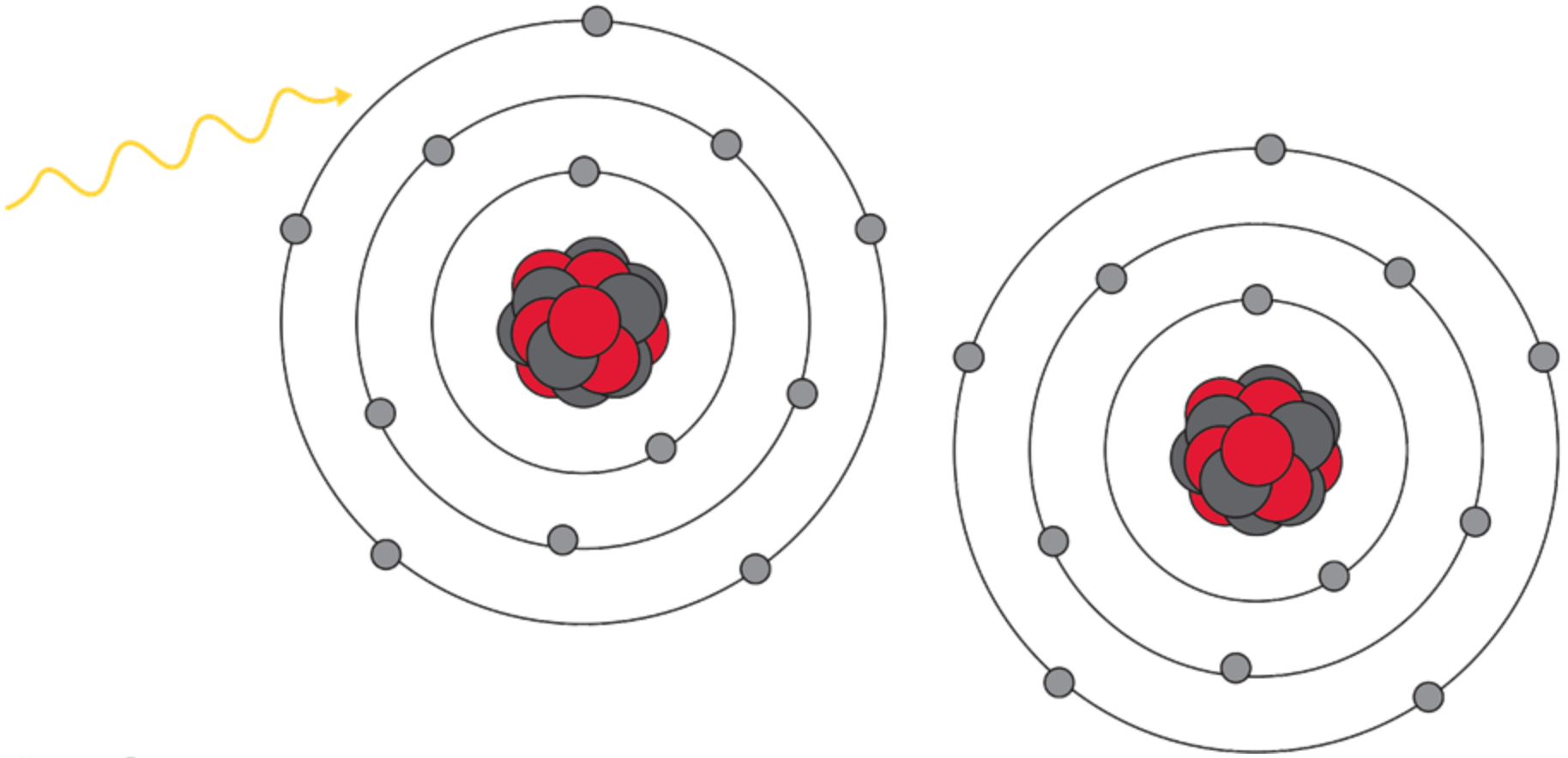


Wikimedia Commons

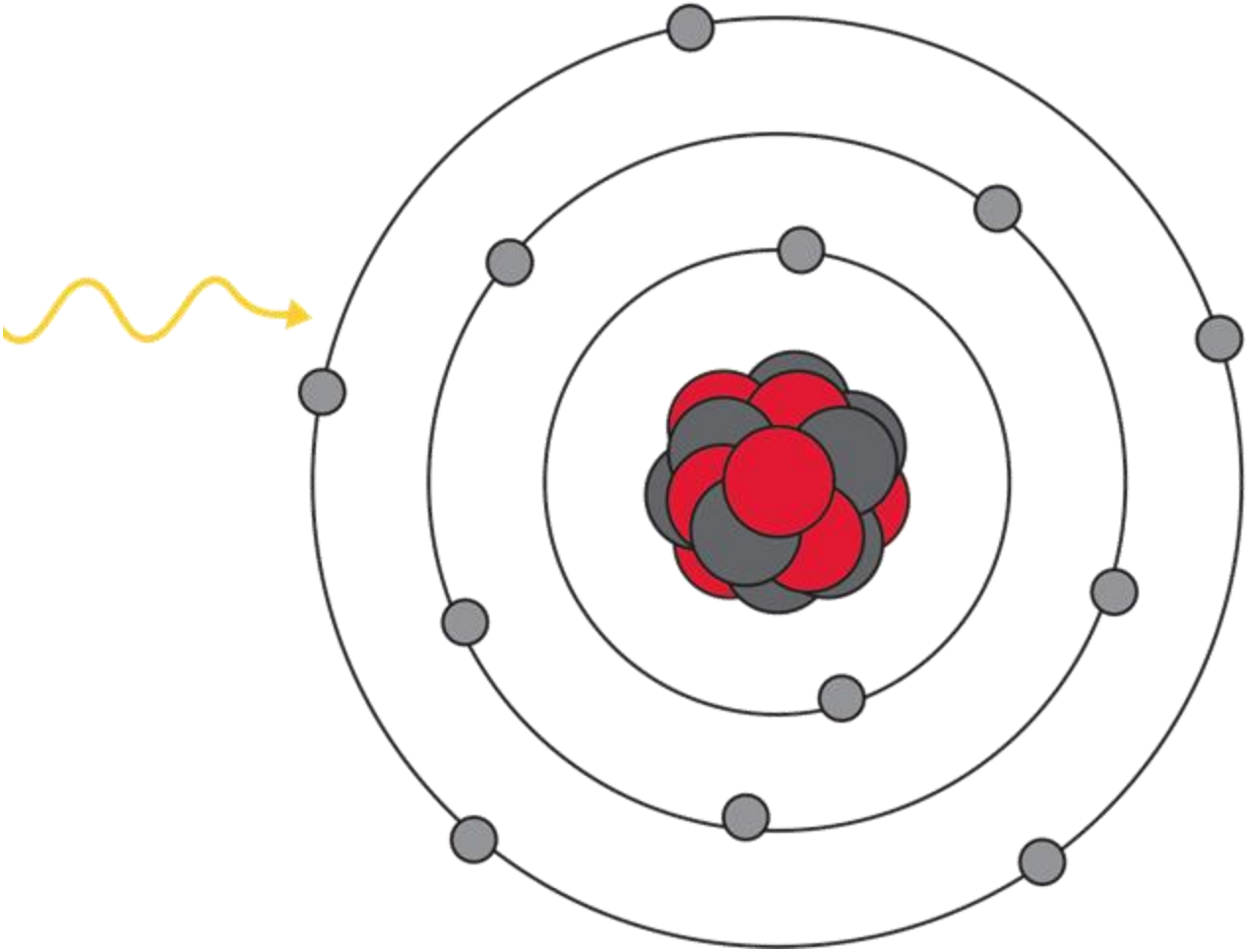
Photoelectric Effect



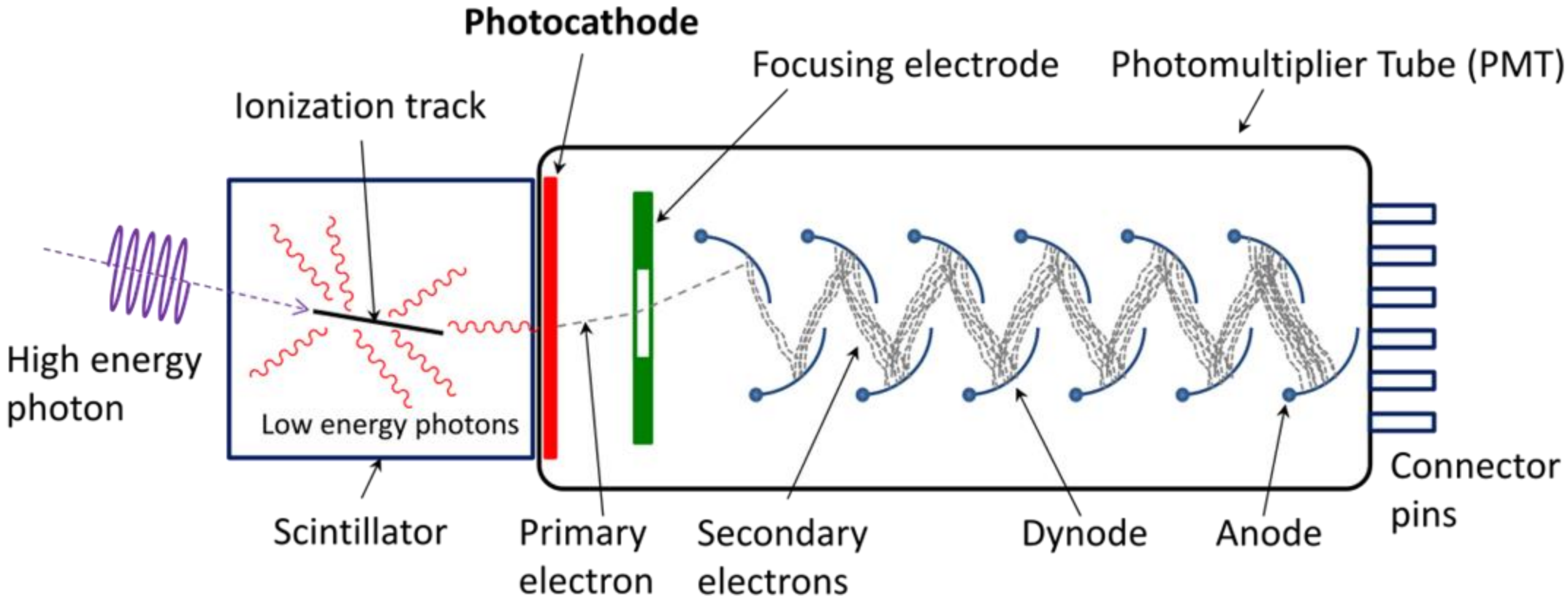
Compton Scattering



Pair Production



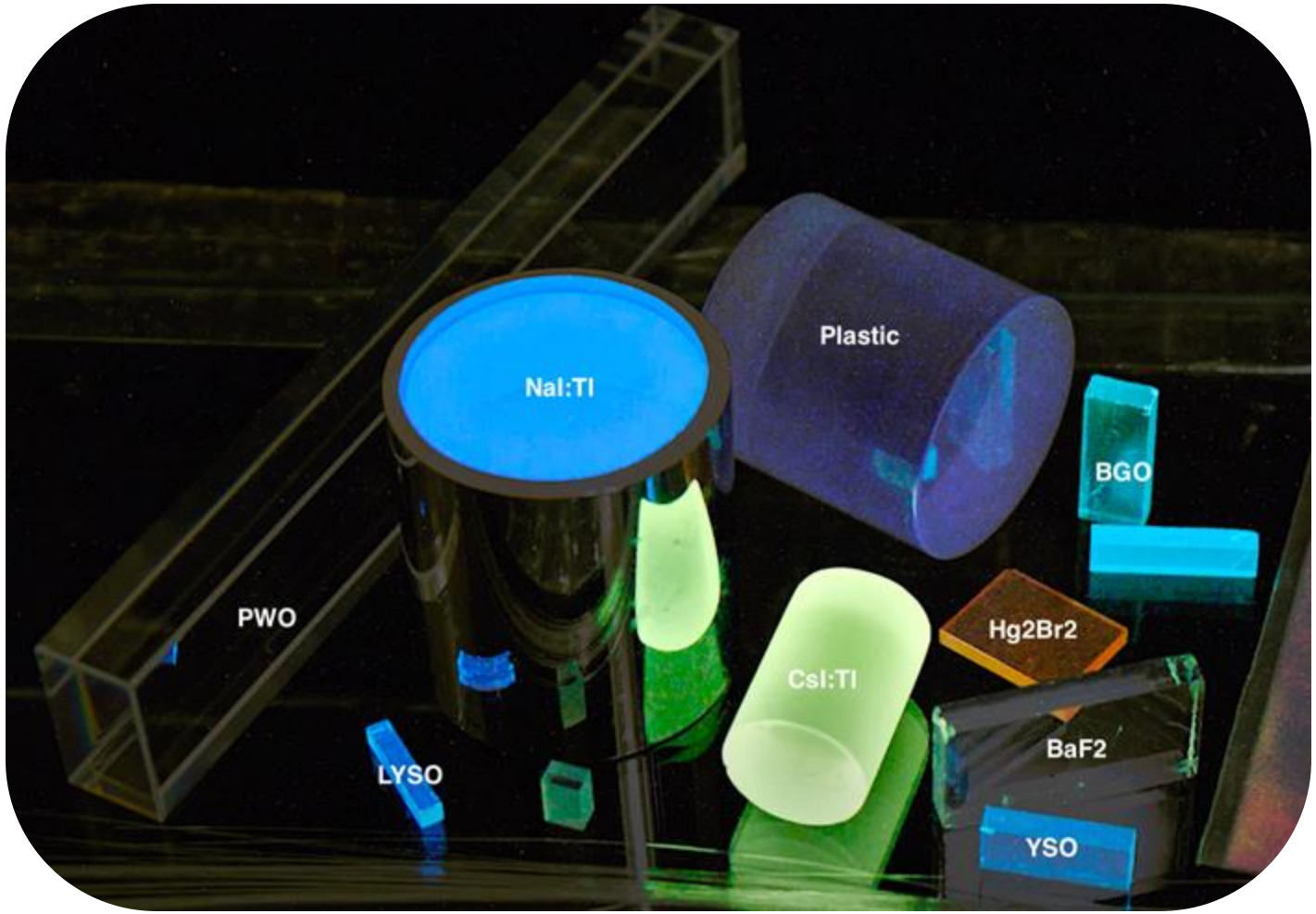
Scintillator Detectors



Wikimedia Commons

Scintillator Materials

- Many scintillator materials with different properties
  - Light Output
  - Wavelength
  - Decay Time
  - Resolution
  - Density



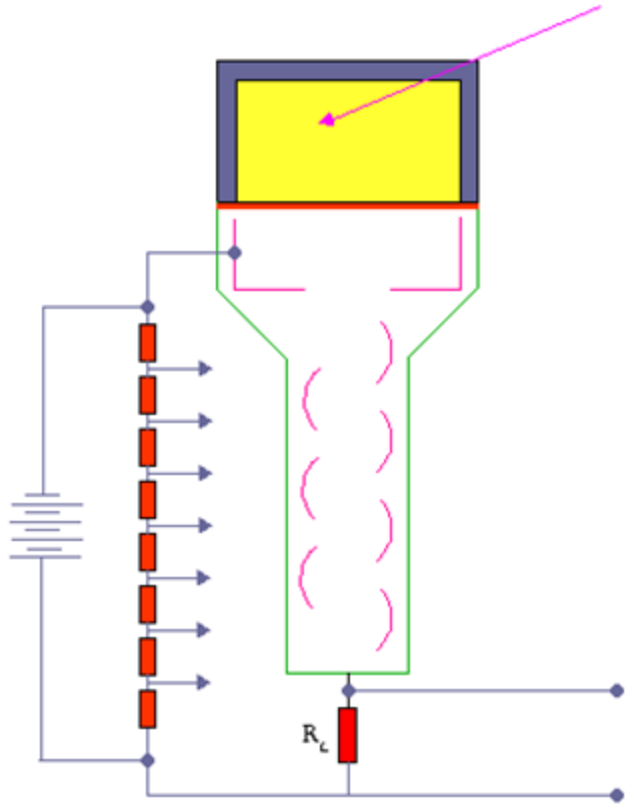
Carl Willis

Scintillator Properties

	LYSO	**NaI:Tl**	**$LaBr_3$:Ce**
Light Output	33200 Photons/MeV	38000 Photons/MeV	61000 Photons/MeV
Wavelength	420 nm	415 nm	356 nm
Decay Time	36 ns	250 ns	30 ns
Resolution	8%	7%	3%
Density	7.1 g/cc	3.7 g/cc	5.1 g/cc

Photomultipliers

- Visible light photon generates a free electron
- Electron is accelerated by a bias voltage
- Accelerated electron knocks free many more electrons to make an easily detectable signal
- SiPM or PMT



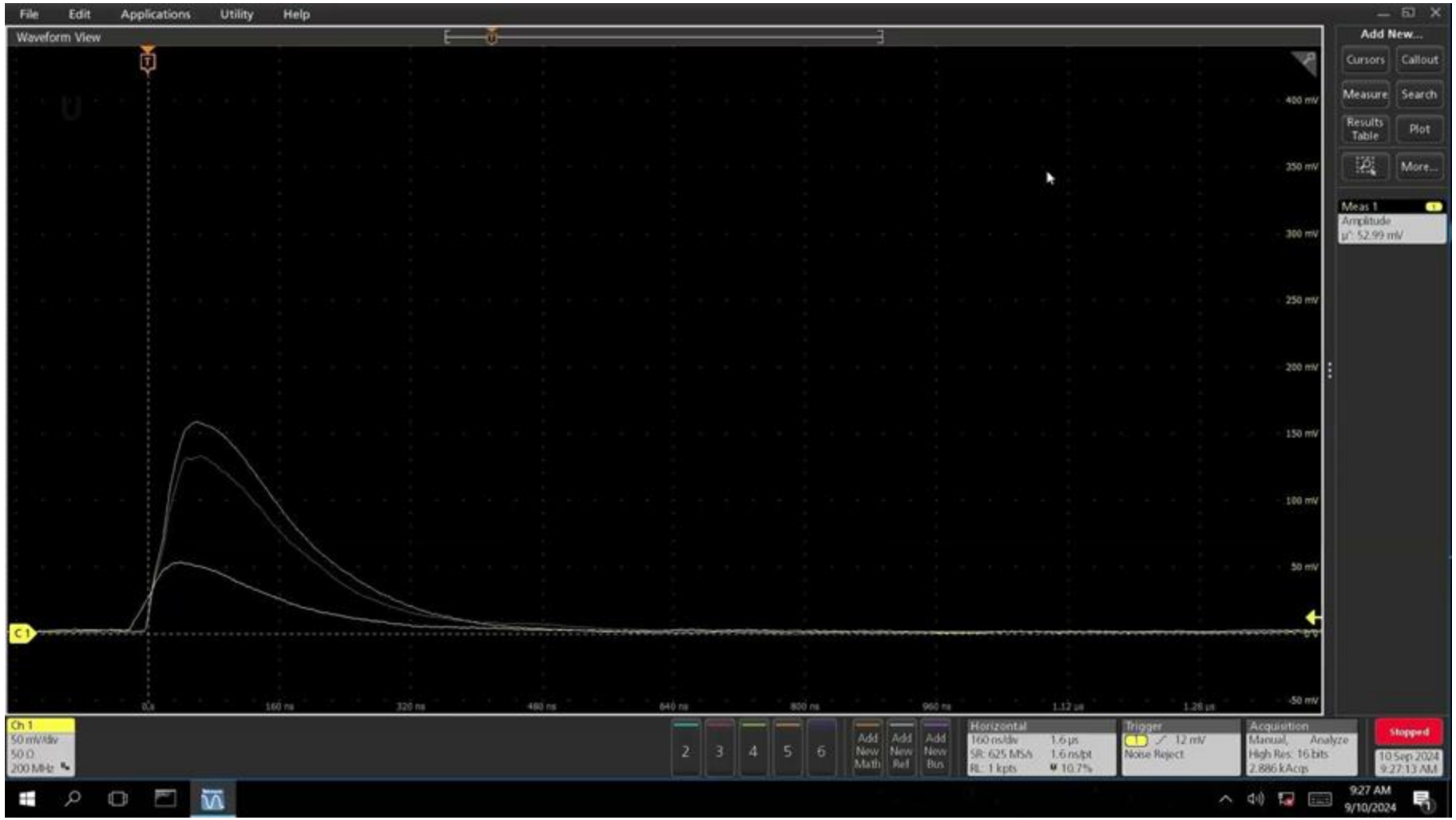
Wikimedia Commons

LYSO Scintillator

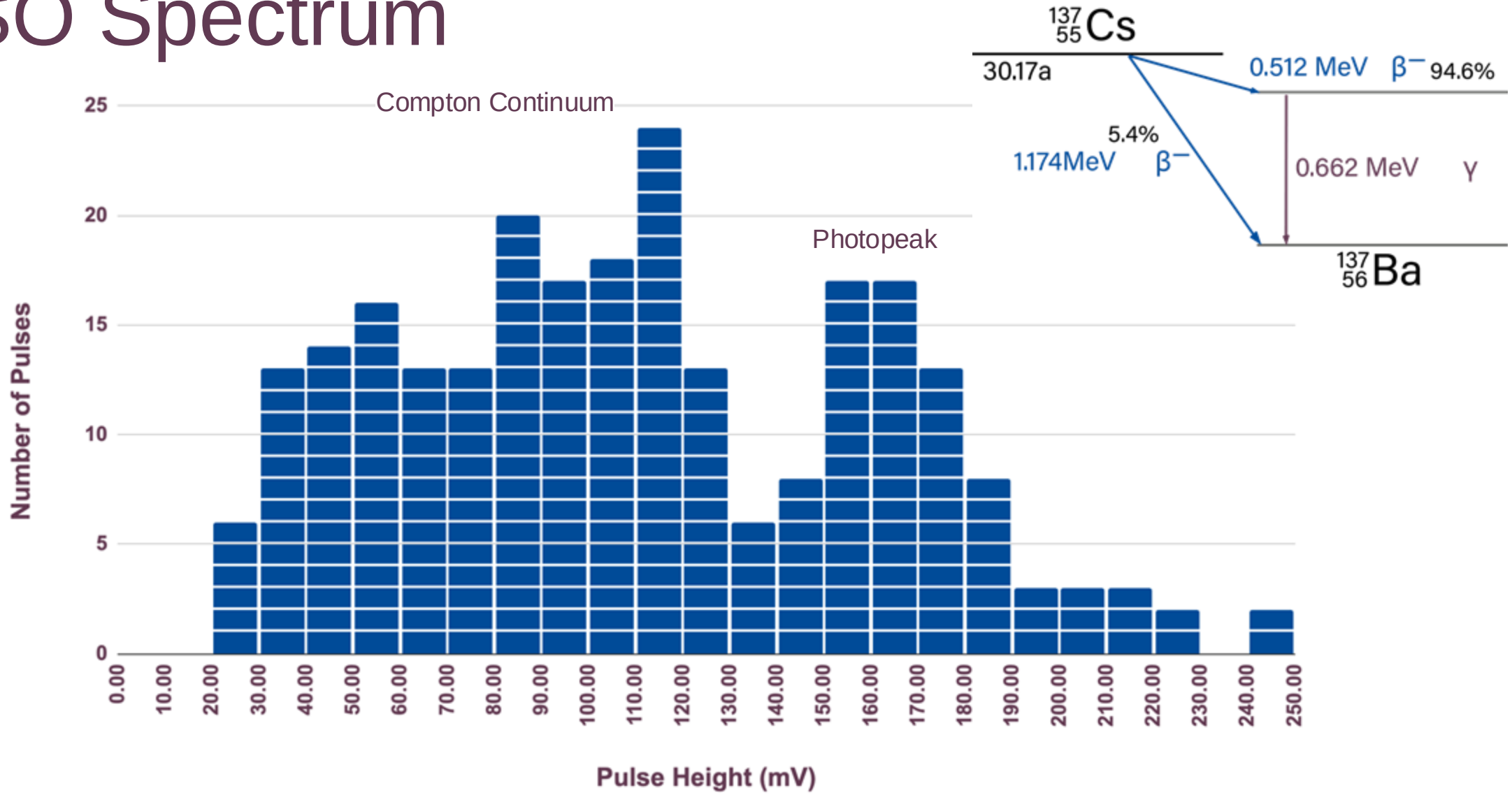
- Basic scintillation detector
  - LYSO crystal coupled to SiPM

- Oscilloscope displays pulses from the SiPM
  - Pulse heights correlate to gamma energies

LYSO Scintillator



LYSO Spectrum



Fun Fact

- The first scientific instruments launched into orbit included X-ray spectrometers and geiger counters

Jet Propulsion Laboratory

Fun Fact

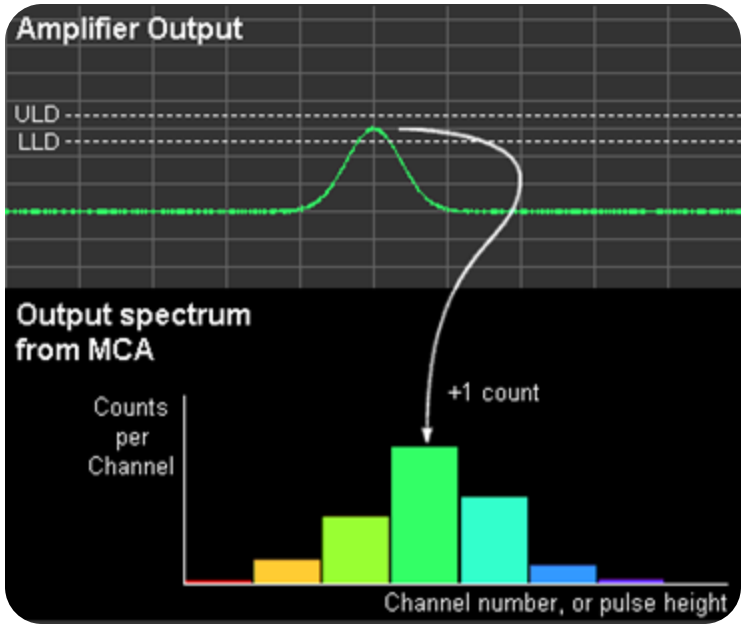
- The recent SpaceX Polaris Dawn spaceflight included scintillator based radiation monitors

SpaceX

Multi-Channel Analyzers

- MCAs can rapidly sort incoming pulses by amplitude
  - Can have many thousands of bins

- Modern MCAs contain all the power supplies, amplifiers and other components to run a detector



University of Liverpool

Mirion

Sodium Iodide Scintillator

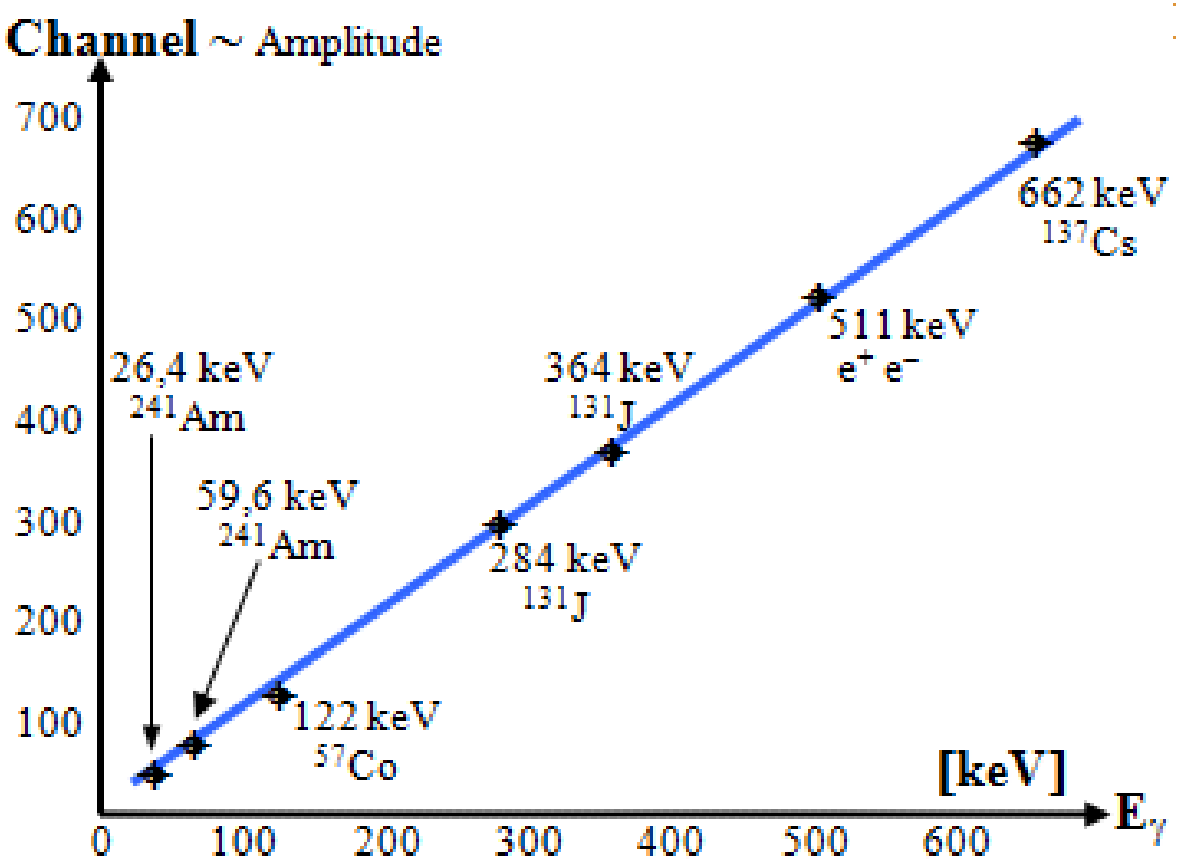
- 2” Sodium Iodide crystal coupled to photomultiplier tube
  - NaI:Tl - most common scintillator material
- Power supply, Amplifier, and MCA all incorporated into PMT base

Practical Gamma Spectroscopy

- Energy Calibration
- Efficiency Calibration

Energy Calibration

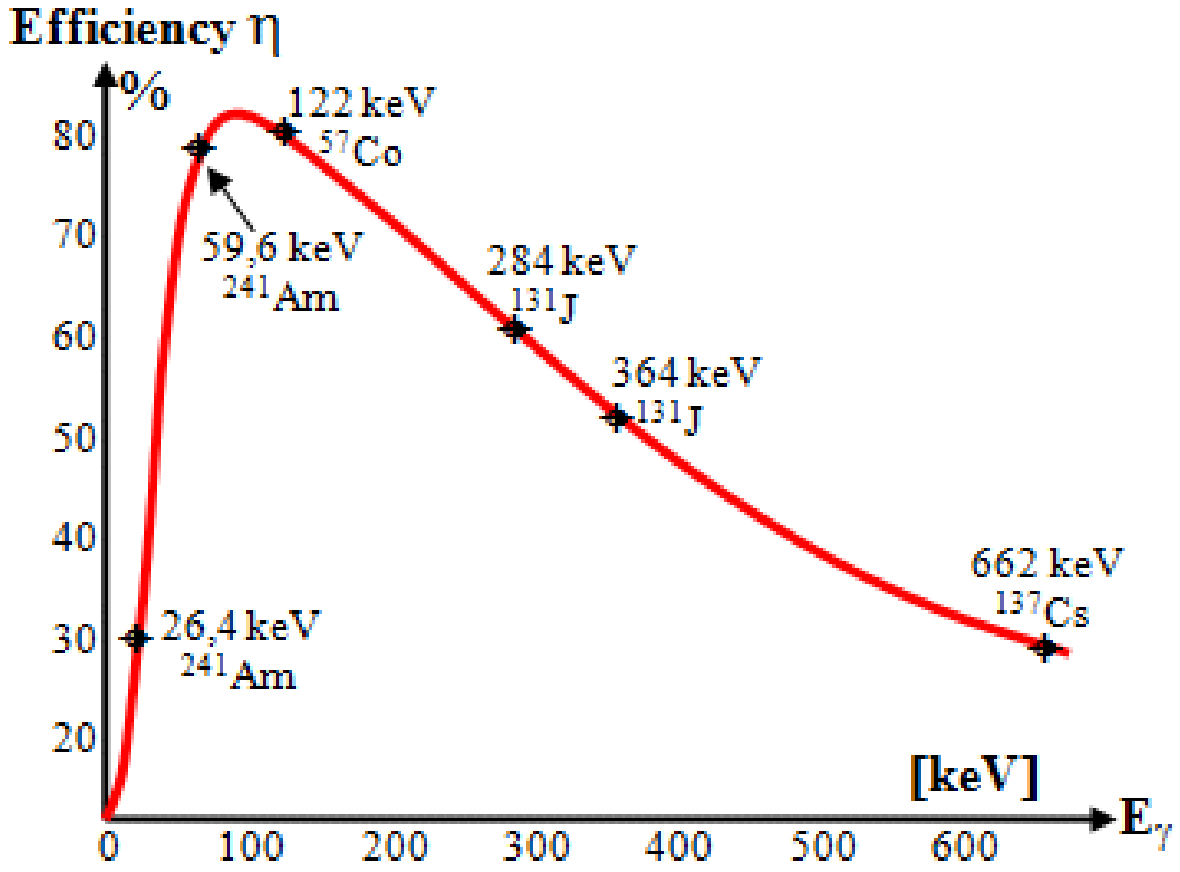
- Determine pulse height (voltage) that corresponds to gamma ray energy
- Count samples with known energies, fit energy vs. peak height



Vojtech Ullmann

Efficiency Calibration

- Detector will not capture all gamma rays emitted by the sample
- Count samples with known activities to characterize fraction of gamma rays captured



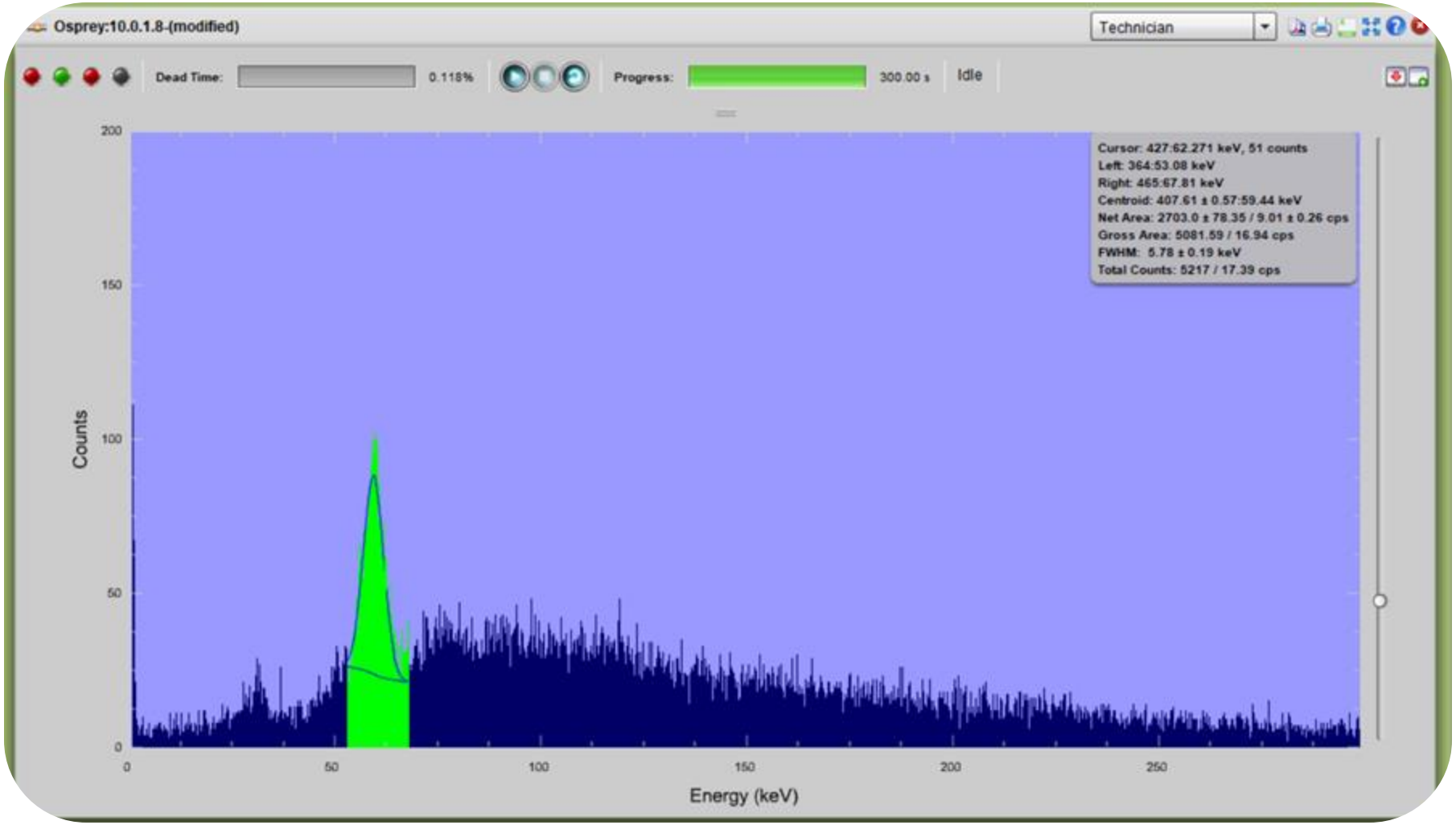
Vojtech Ullmann

Efficiency Calibration

- Efficiency = Counts in Photopeak / Photons emitted by source

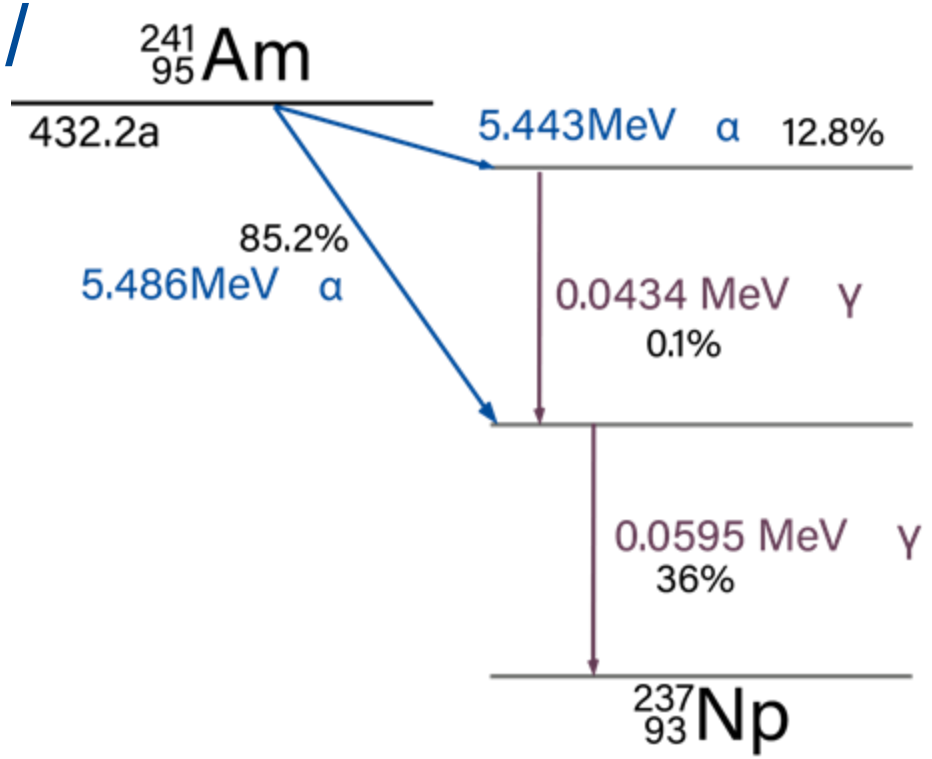
- Am-241 Source - activity of 4.403 kBq in 2013
  - Current activity = (4.403 kBq)*.5$^{(11.25/432.6)}$ = 4324 Bq

Activity Determination



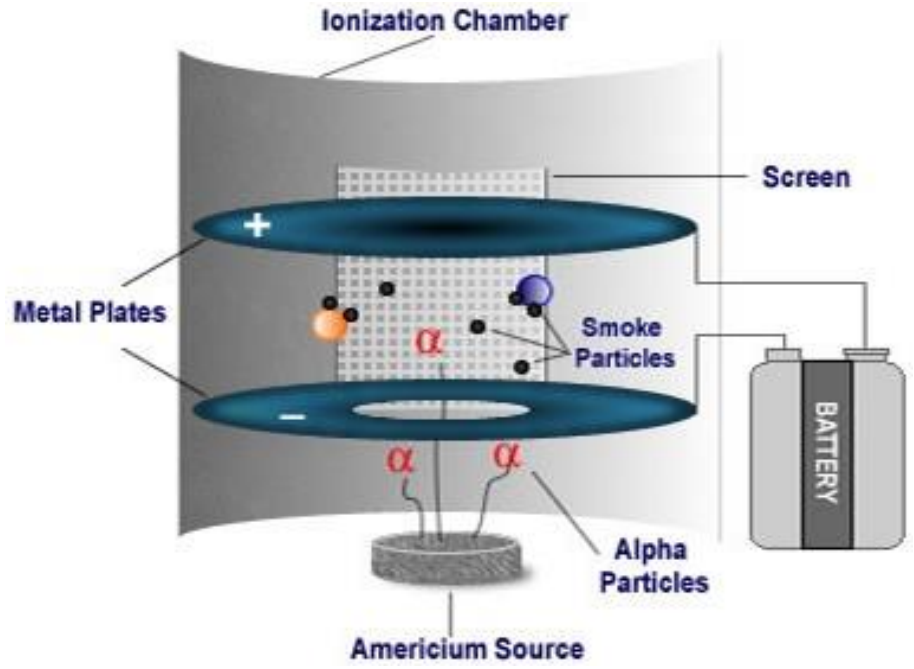
Efficiency Calibration

- 4.324 kBq * 36% = 1557 gammas / second
- 5081 Counts in photopeak / 300 seconds = 16.9 CPS
- 16.9 CPS / 1557 gamma/s = 1.1% efficient



Smoke Detector Activity Determination

- Some smoke detectors contain a small amount of Am-241 to function
- Amount can be determined by spectrometry



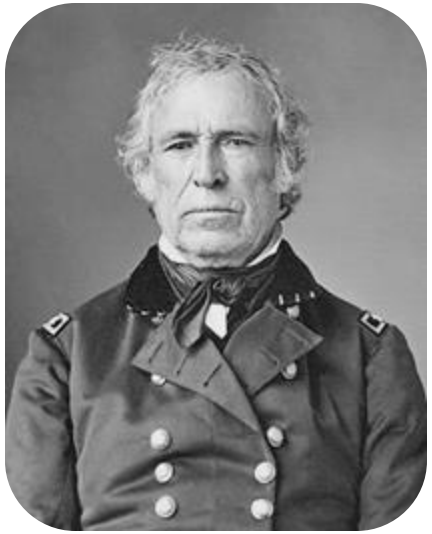
Environmental Protection Agency

Smoke Detector Activity Determination

- Some smoke detectors contain a small amount of Am-241 to function
- Amount can be determined by spectrometry

Applications of Gamma Spectroscopy

Wikimedia Commons



Wikimedia Commons

Wikimedia Commons

Wikimedia Commons

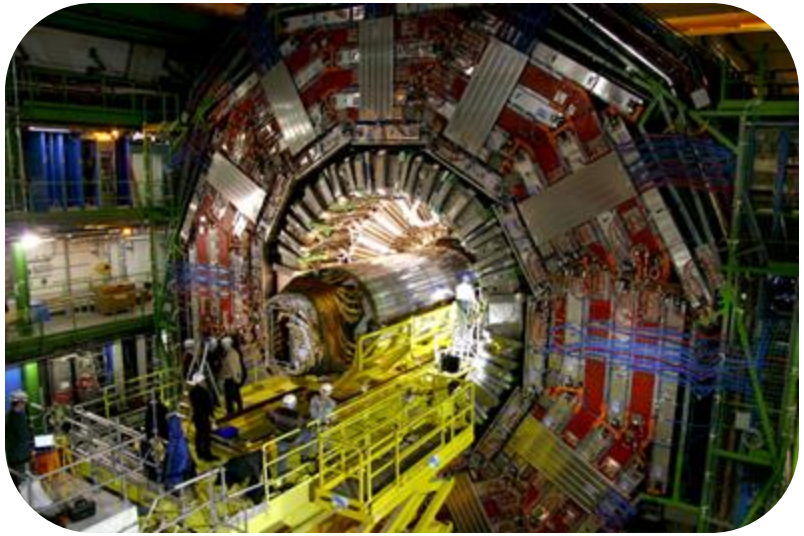
Wikimedia Commons

Scintillator Applications

Ludlum Measurements

Wikimedia Commons

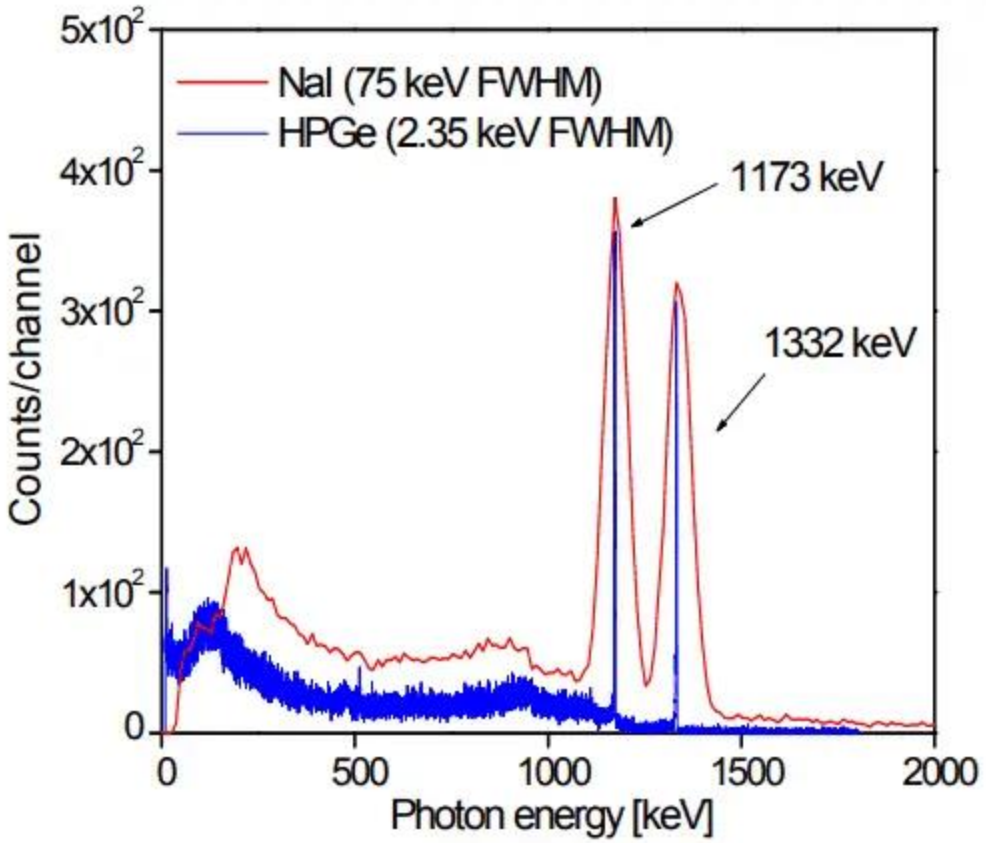
Wikimedia Commons



CERN

Semiconductor Detectors

- Better resolution
- Lower efficiency
- Require cryogenic temperatures to operate



Nuclear-Power.com

RIID

- Radioisotope Identifier Device
  - Handheld scintillation detector with MCA

- Used in the field

Questions?

- Thanks!