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Laboratory for Accelerator  
Based Sciences

# Radiometric Quantities and Measurements

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**Advanced Nuclear Science and Technology Techniques Workshop**  
**18 – 22 May 2026, iThemba LABS, Cape Town, South Africa**



# Learning Outcomes

**By the end of this session the learner should be able to:**

- Calculate the range and stopping power of ionizing radiation
- Calculate the dose rates and exposures from different sources
- Estimate the shielding required for different sources
- Generate and analyse spectra
- Demonstrate the effect of energy resolution in spectrometry



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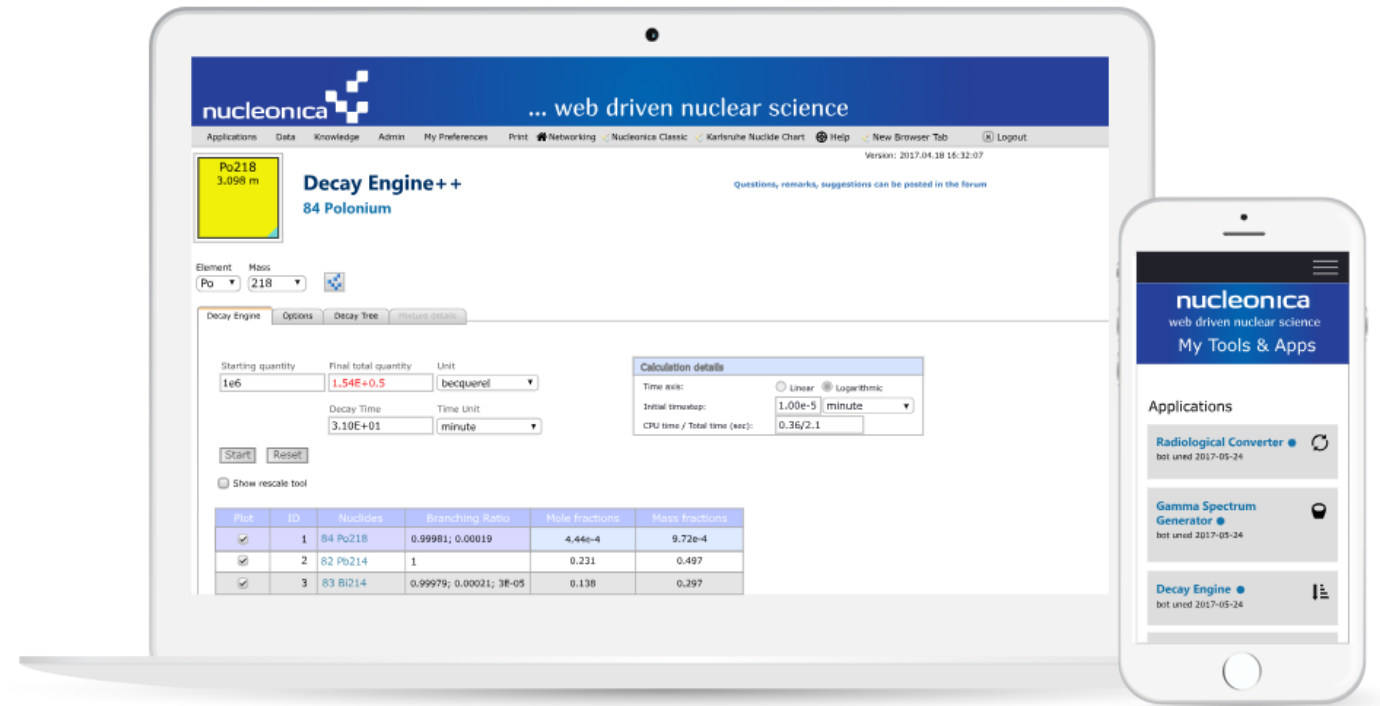
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Nucleonica is the leading online resource in the nuclear sciences

Nucleonica is the leading nuclear science applications platform for web-based calculations. It is used by thousands of science and engineering professionals in the energy, research, healthcare, defense, and education industries in more than 92 countries. In particular it is used in the following areas:

- health physics and radiation protection
- decommissioning and waste characterization
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- packaging classification for radioactive transports
- education and training





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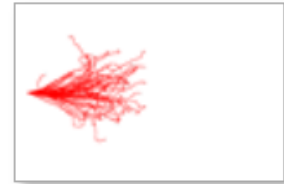
Classic

show all   last used   popular   **applications**   data   knowledge   last nuclides

Radiological Converter	Mass Activity Converter	Decay Engine	Photon Dose Rate Constants	Shield Attenuation Thicknesses	Gamma Dosimetry and Shielding H*(10)	$\beta$ Spectrum and Dose Rate	Neutron Dose Rate
Range & Stopping Power	web KORIGEN	Decay Engine for Large Nuclide Sets	Concept Repository Temperatures	e-Ship: Transport Assistant	Mixtures	Scripting	GSGLight
Gamma Spectrum Generator	Gamma Spectrum Generator Pro	Coincidence Summing Corrections	Virtual Cloud Chamber	Cambio: $\gamma$ Spectrum Conversion	WESPA: Web Spectrum Analyser	Gamma Library Pro	Gamma Library



# Range and Stopping Power



## Range & Stopping Power

Getting started

Range & Stopping Power

Table

Options

Compound Details

### Projectile

proton

Quantity

10

Unit

Energy (MeV)

Start

CPU time / Total time (sec):  
0.3750 / 0.597

### Target

Mono-element

Predefined compound

User defined compound

Solid/Liquid

Gas

Density (g/cm<sup>3</sup>)

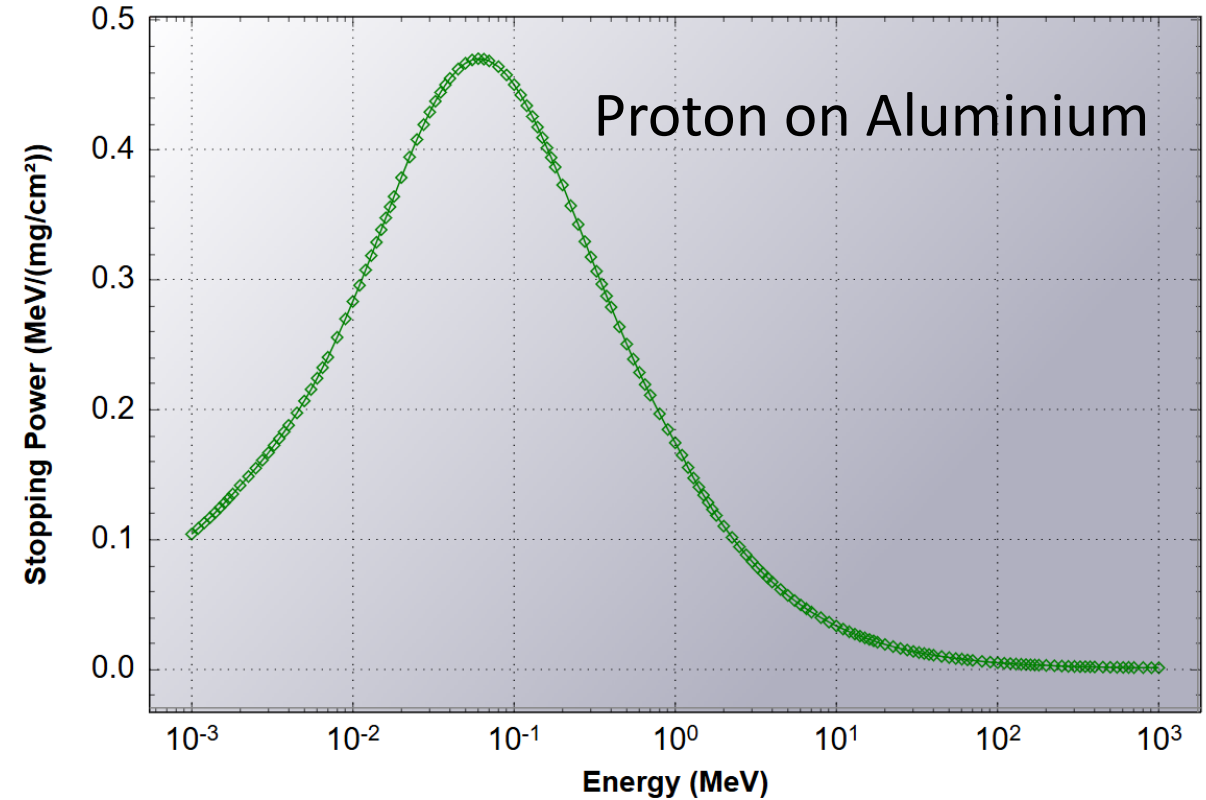
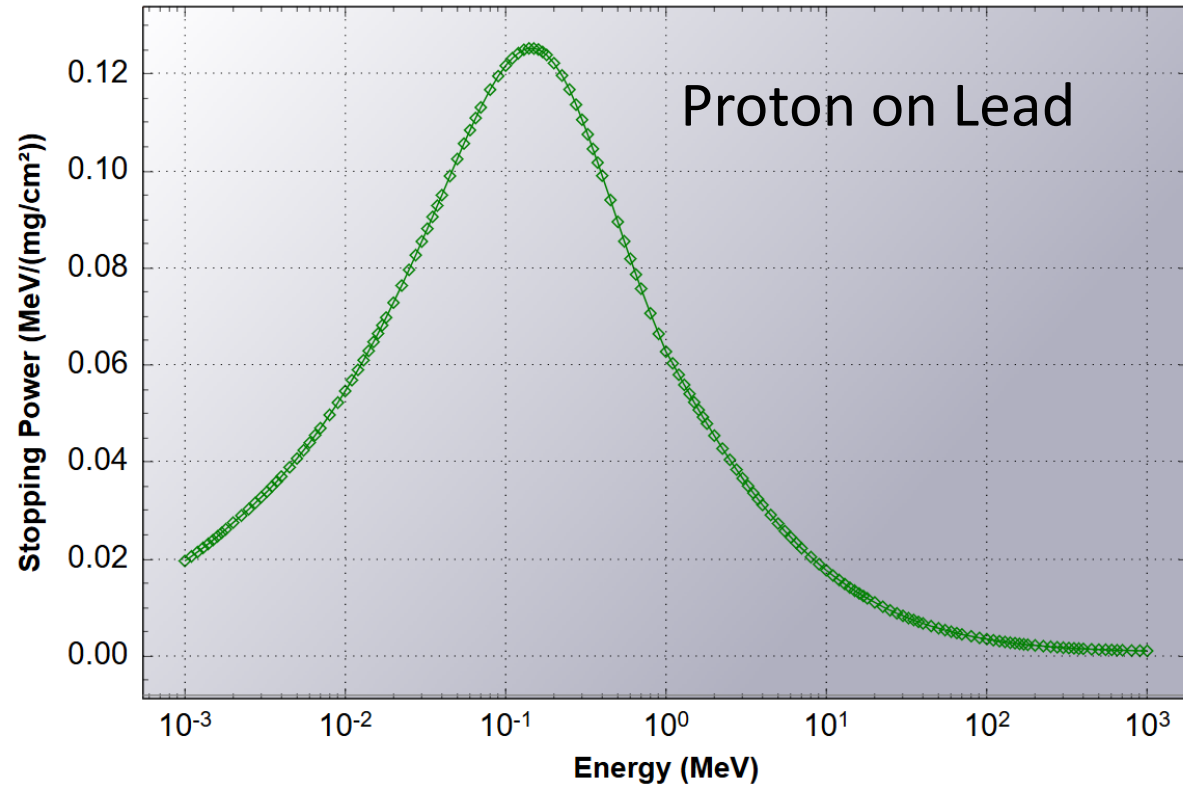
Lead

11.3437

- Calculate the range and stopping power for proton on lead and aluminium



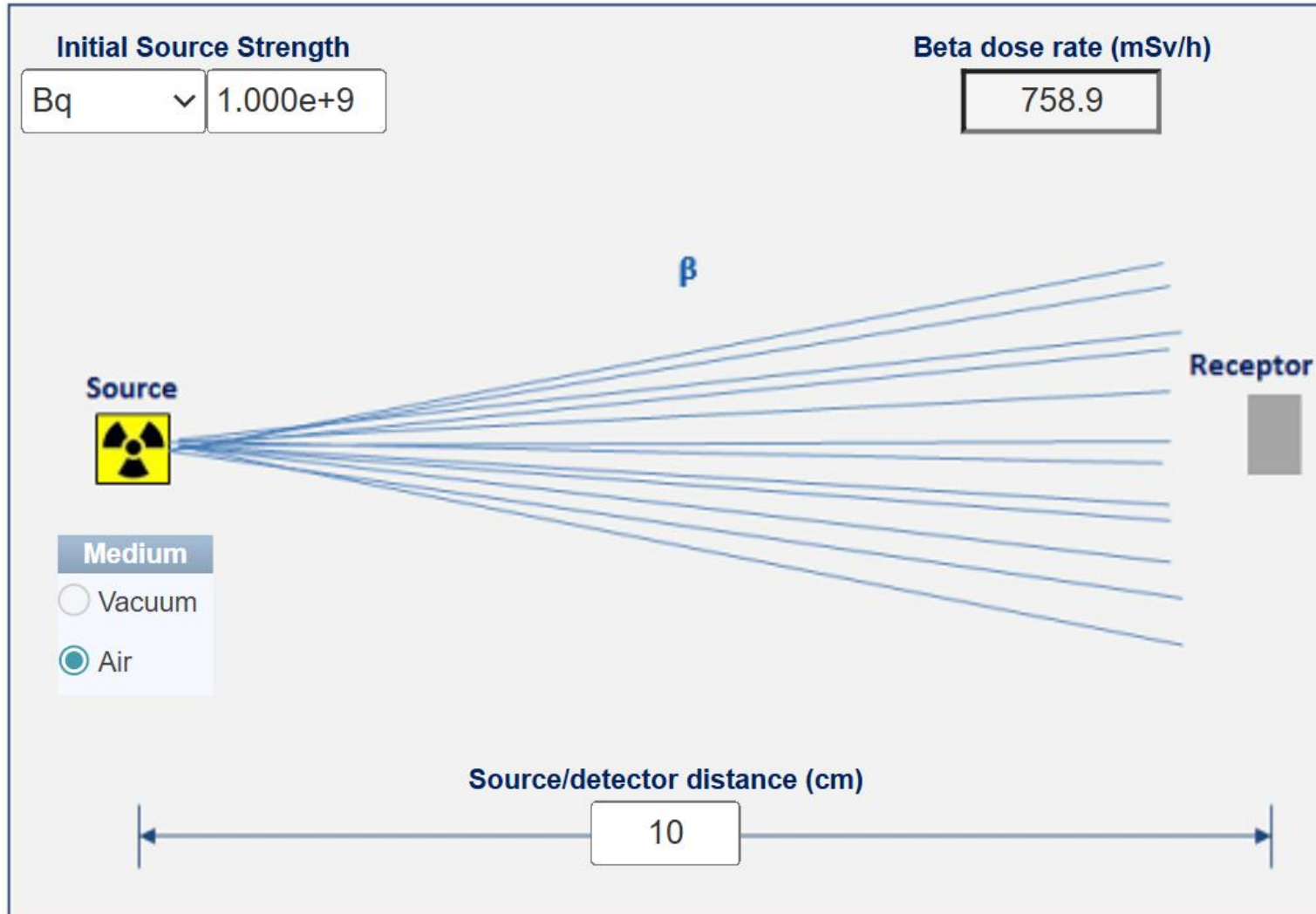
# Total Stopping Power



- Tabulate the values of the range and stopping power



# Variation of Dose Rates with Distance

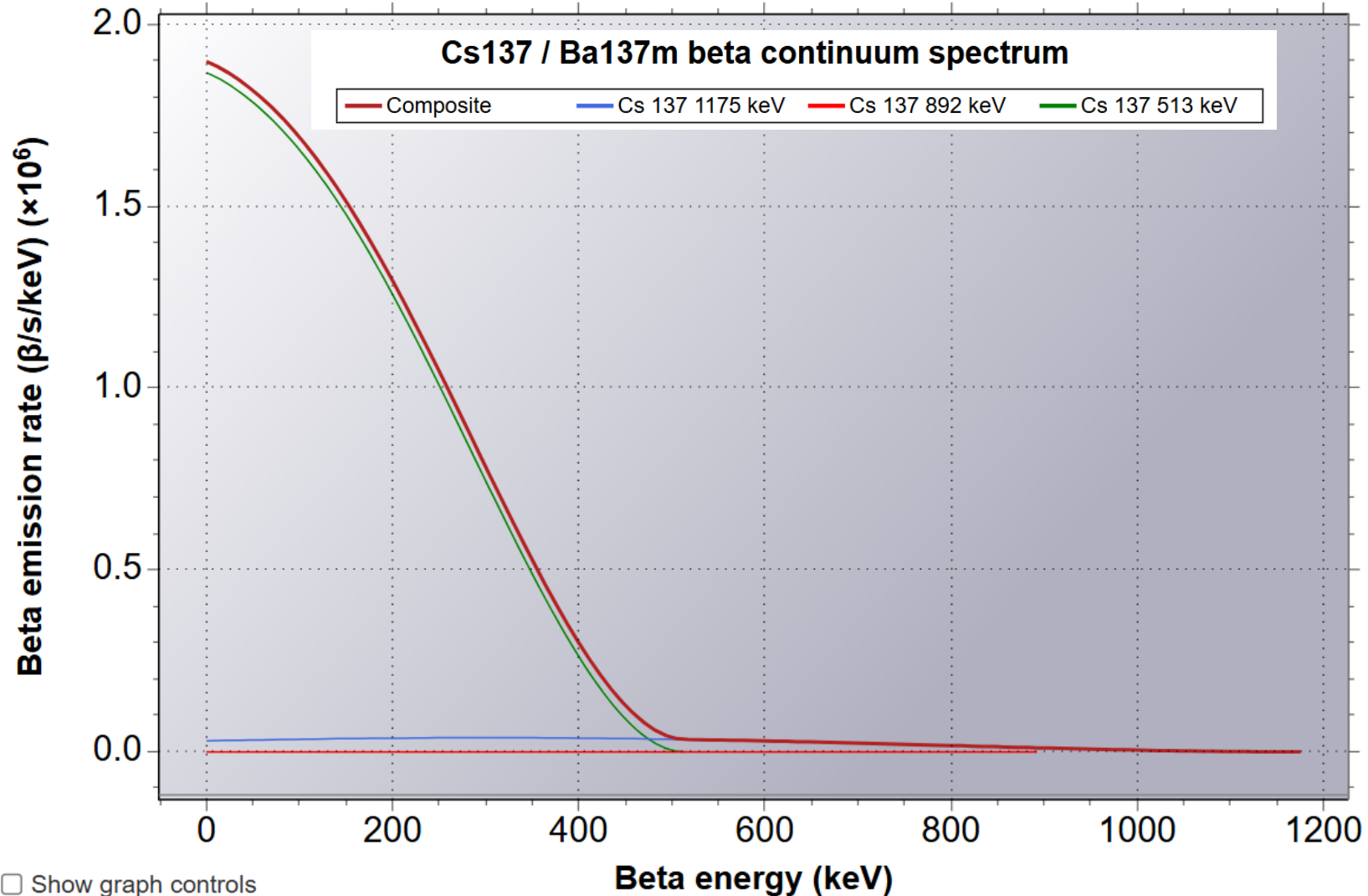


## Exercise:

- Choose a known source
- Calculate the beta dose rate at various source – detector distances
- Observe the variation of the values of the dose rates
- Observe the spectrum



# Beta Continuum Spectra

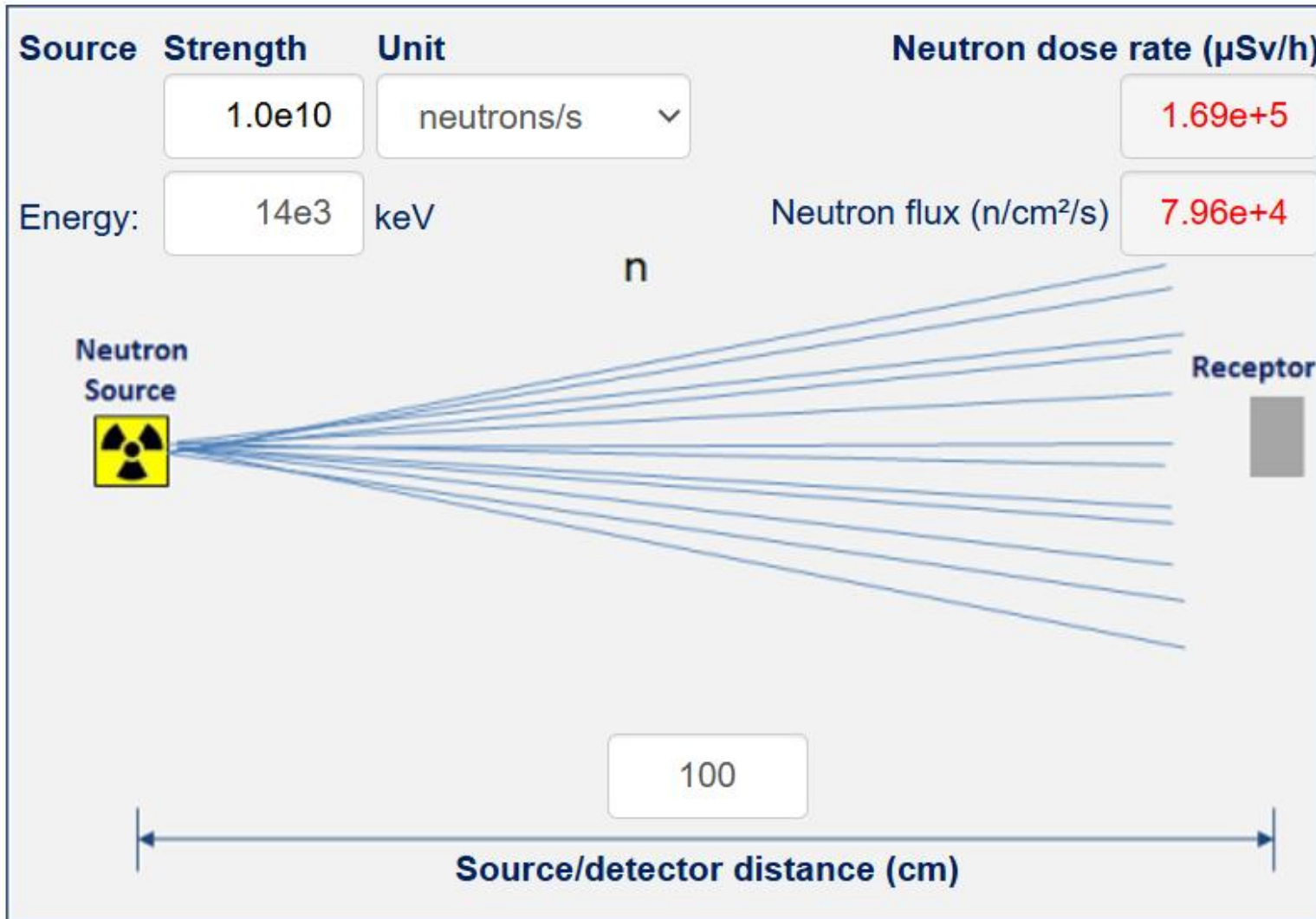


## Exercise:

- Choose a known source
- Calculate the beta dose rate at various source – detector distances
- Observe the variation of the values of the dose rates
- Observe the spectrum



# Neutron Dose Rate

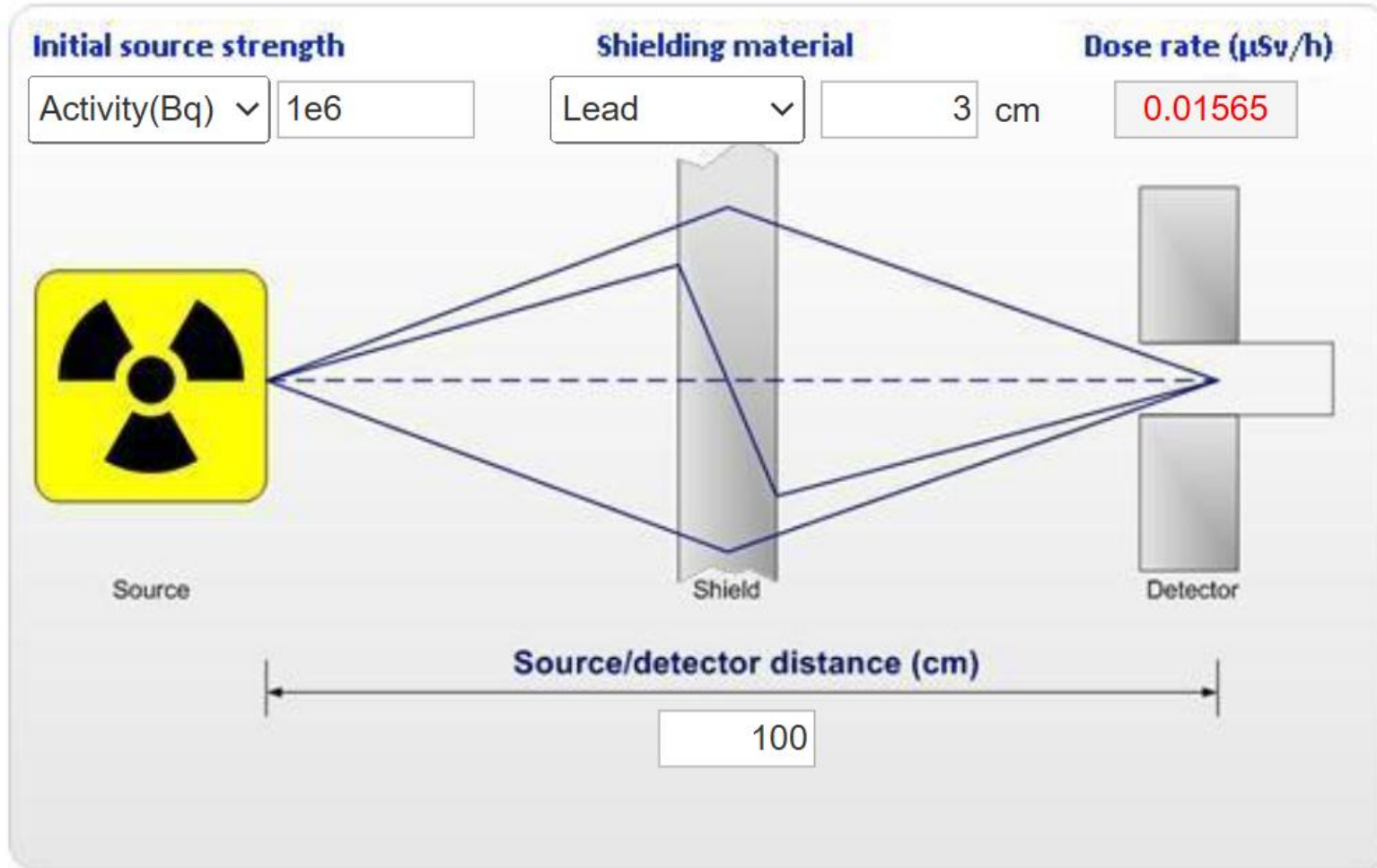


## Exercise:

- Choose a known source strength
- Calculate the neutron dose rate at various source – detector distances
- Observe the variation of the values of the dose rates
- Observe the spectrum



# Ambient Dose Rate and Shielding



## Exercise:

- Choose a known source and shield
- Calculate the dose rate at various source – detector distances
- Calculate the ambient dose rate
- Calculate the values of HVL and TVL



# Ambient Dose Rate and Shielding

\* Short-lived decay products included

ICRP-107: Cs 134	Symbol	Magnitude	Unit
Exposure Half-Value Layer Thickness, broad (narrow) beam	HVL =	0.7999 (0.5856)	cm
Exposure Tenth-Value Layer Thickness, broad (narrow) beam	TVL =	2.505 (2.016)	cm
Ambient Dose Rate	$\dot{H}^*(10) =$	0.01565	$\mu\text{Sv/h}$
Effective Buildup factor, ANSI 6.4.3 1991	$B_{\text{eff}} =$	1.797	
Effective Number of Mean Free Paths	$\mu_{\text{eff}} \cdot d =$	3.344	

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# Calculation of Attenuation and Shield Thickness

Nuclide

Cs 134



Dataset

JEFF-3.1

Nuclide Details

Nuclide Summary

Options

Shielding material:

Lead

B-Factors:

Shimizu et al., 2004

Energy Threshold

15

keV

Emission Probability Threshold

0

photons  
decay

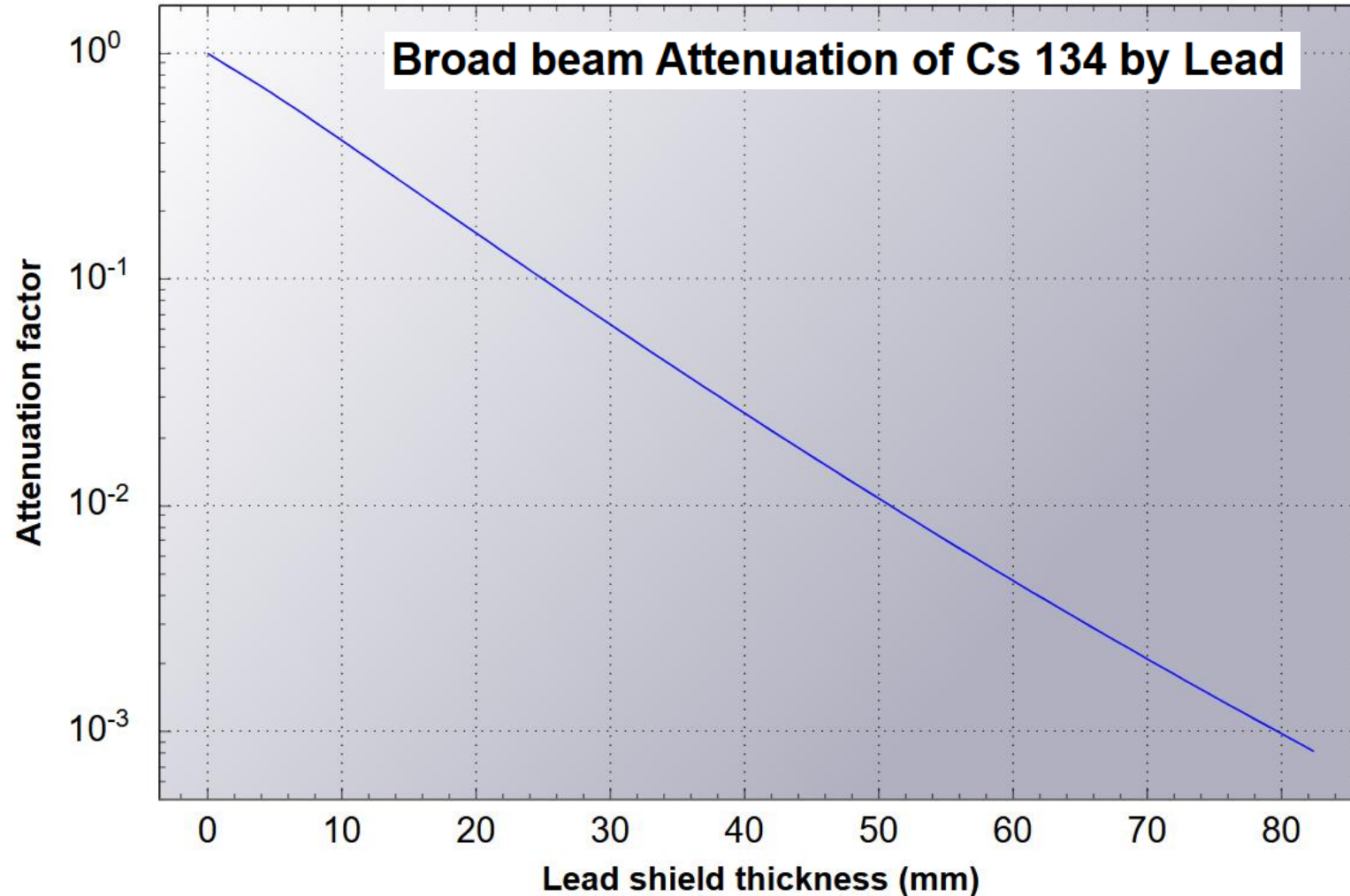
Reset parameters to:  recommended  Smith & Stabin

## Exercise:

- Choose a known nuclide and shield
- Calculate the attenuation factor
- Observe the variation of the attenuation factor with shield thickness
- Calculate the values of HVL and TVL
- Repeat with a different shield material



# Calculation of Attenuation and Shield Thickness



## Exercise:

- Choose a known nuclide and shield
- Calculate the attenuation factor
- Observe the variation of the attenuation factor with shield thickness
- Calculate the values of HVL and TVL
- Repeat with a different shield material



# Gamma – ray spectrum

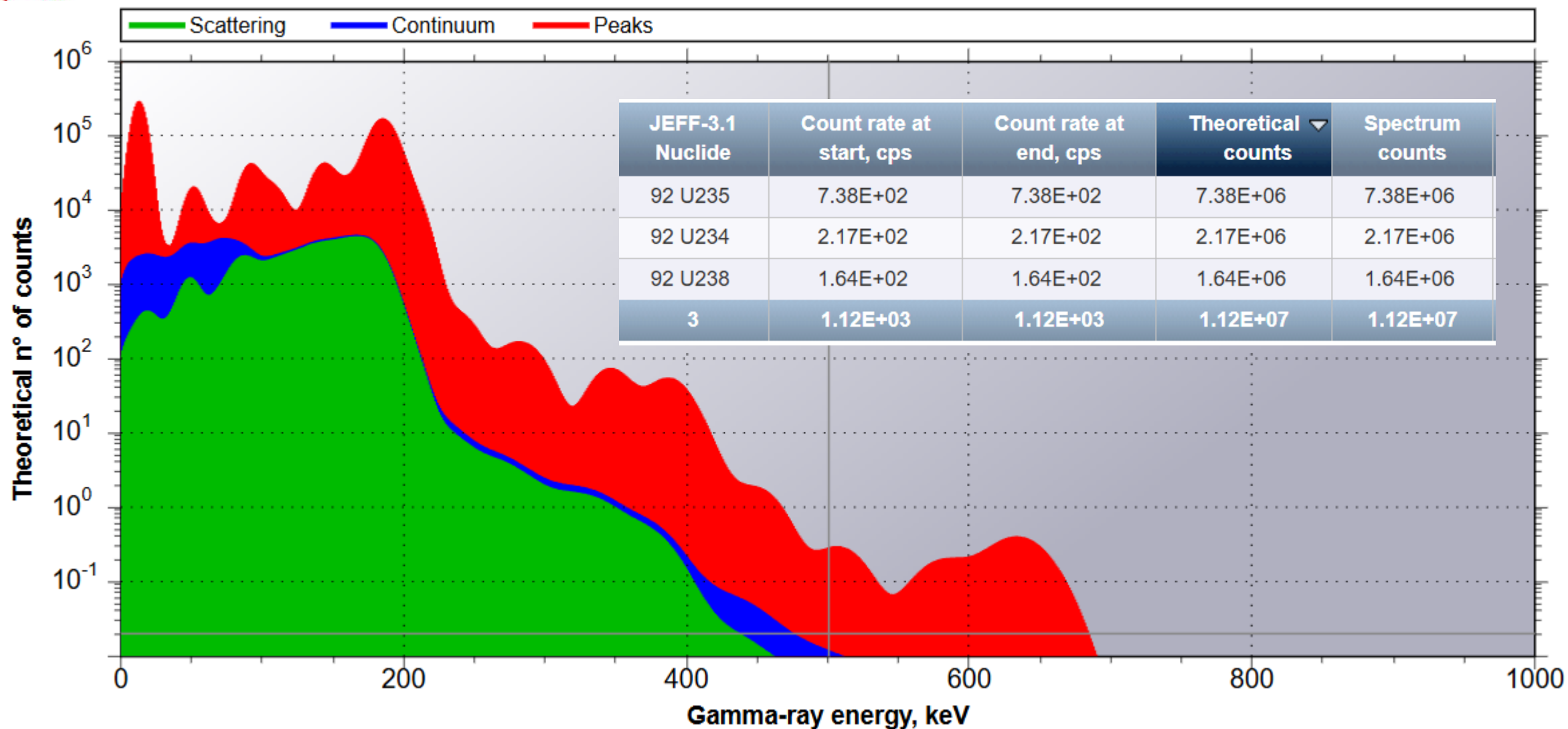
## Exercise:

- Generate the gamma ray spectrum of natural uranium
- Indicate the following components of the spectrum:
  - Scattering
  - Continuum
  - Peaks
- Indicate the counts for each of species in natural uranium



# Gamma – ray spectrum

## Natural Uranium





# Online tools for exercises – IDB at IAEA

IDB

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## An International Database of Reference Gamma Spectra

IDB is a web-accessible database of reference gamma spectra for measurement of uranium (U) and plutonium (Pu) isotopic composition, developed by the International Atomic Energy Agency. The database provides access to well-characterized groups of gamma spectra curated by international experts in gamma spectroscopy to promote sustainability and maintenance of software used to determine the isotopic abundances of U and Pu.

### Search the database

The database can be queried for metadata attributes describing the spectra, including source information, measurement configuration and detector specifications. By selecting a set of metadata attributes, users can access the spectra that correspond to that query.

Search database 🔍

*The database can also be queried via a programmatic API. Please see the [API documentation](#) for more details.*



# Online tools for exercises – IDB at IAEA

- ❖ Use the IAEA International Database of Reference Gamma Spectra
- ❖ Query the database for spectra of uranium measured using:
  - semi-conductor detector
  - solid scintillator detector
- ❖ Chose some consistent form of sample
- ❖ Compare the energy spectra from these detectors

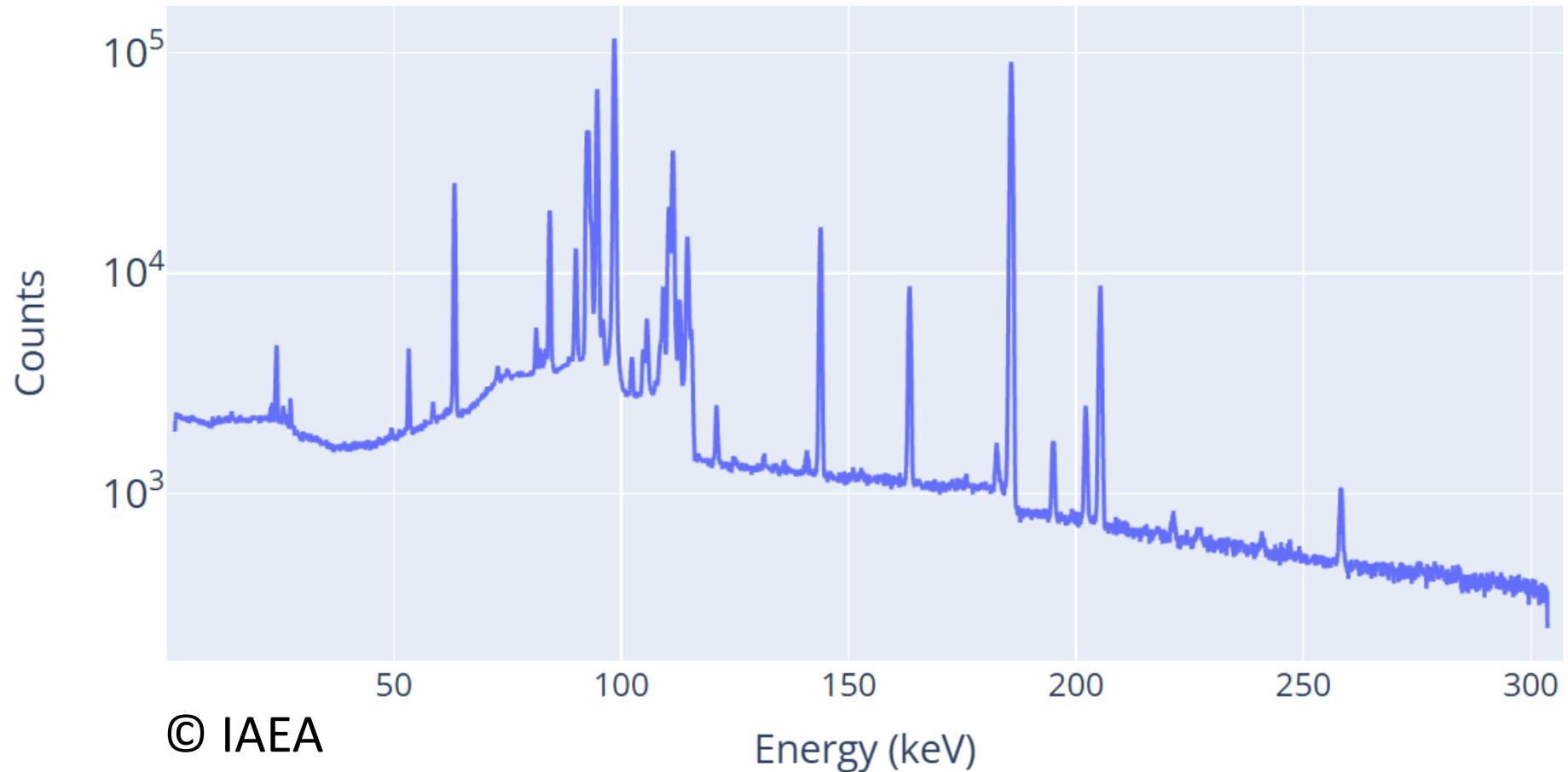


# Online tools for exercises – IDB at IAEA



Channel	Lin y
Energy	Log y

Sample U | Detector HPGe



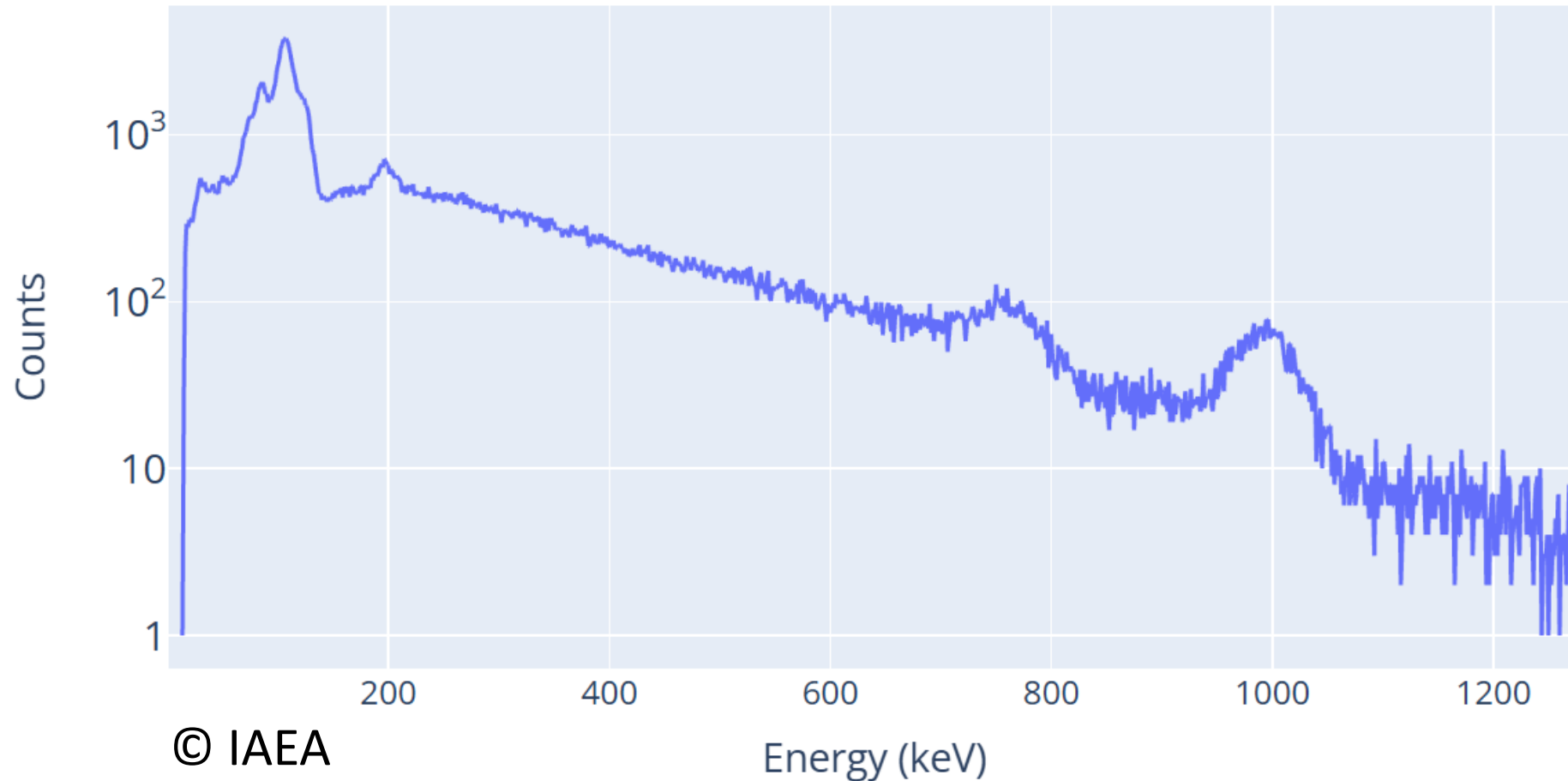
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# Online tools for exercises – IDB at IAEA

Channel	Lin y
Energy	Log y

Sample U | Detector NaI



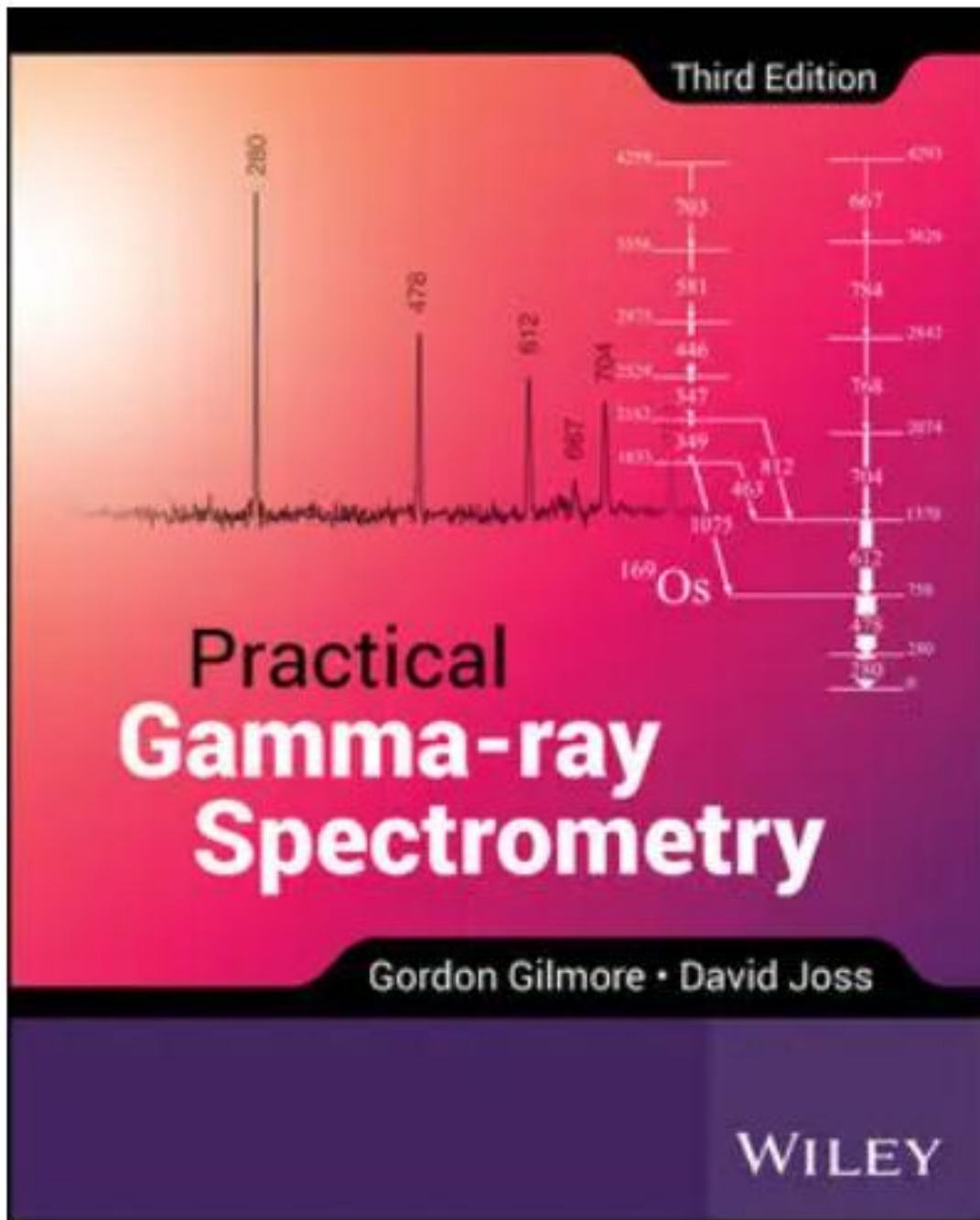
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# Summary

The following exercises were carried out during this session:

- ✓ Calculation of the range and stopping power of ionizing radiation
- ✓ Calculation of the dose rates and exposures from different sources
- ✓ Calculation of the shielding required for different sources
- ✓ Generation and analysis of spectral data
- ✓ The effect of energy resolution in spectrometry



## Further reading

Gordon Gilmore, David Joss (2024).  
Practical Gamma-ray Spectrometry,  
3rd Edition. Wiley  
ISBN: 978-1-119-89608-1



# Particle Detectors



**Claus Grupen  
and Boris Shwartz**

Second Edition

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## Further reading

Claus Grupen and Boris Shwartz (2023). Particle Detectors (Cambridge Monographs on Particle Physics, Nuclear Physics and Cosmology). Cambridge University Press.

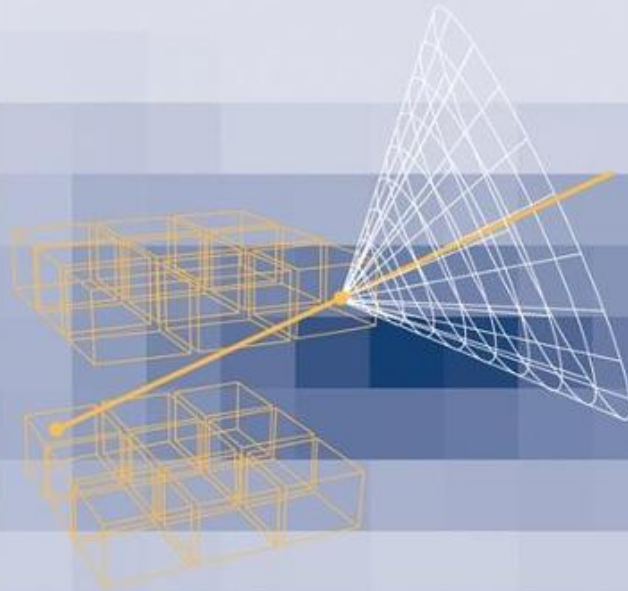
ISBN-10 : 1009401513

ISBN-13 : 978-1009401517



FOURTH  
EDITION

# RADIATION DETECTION AND MEASUREMENT



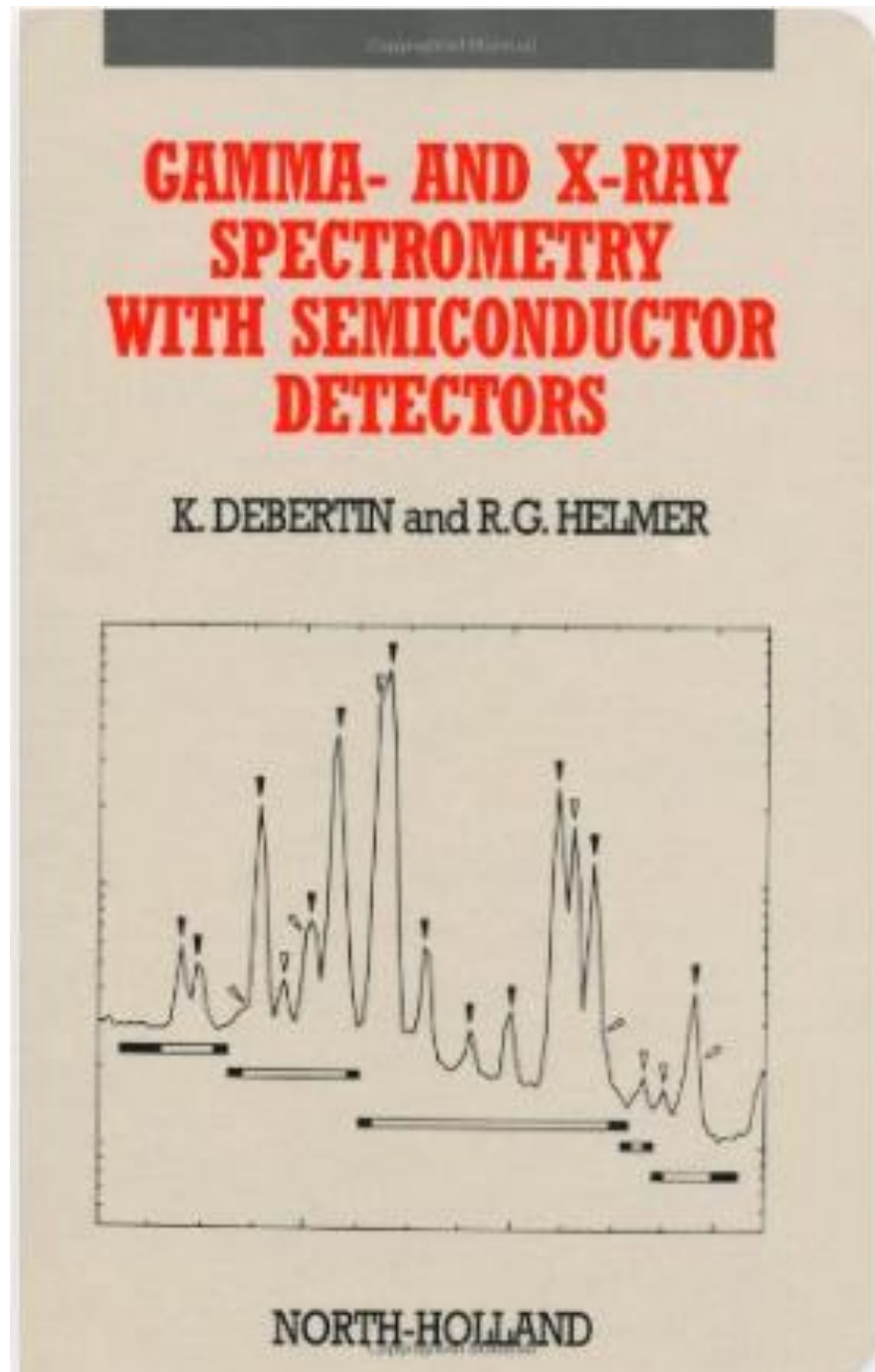
GLENN F. KNOLL

## Further reading

Glenn F. Knoll (2010). Radiation Detection and Measurement 4th Edition. Wiley.

ISBN-10 : 9780470131480

ISBN-13 : 978-0470131480



## Further reading

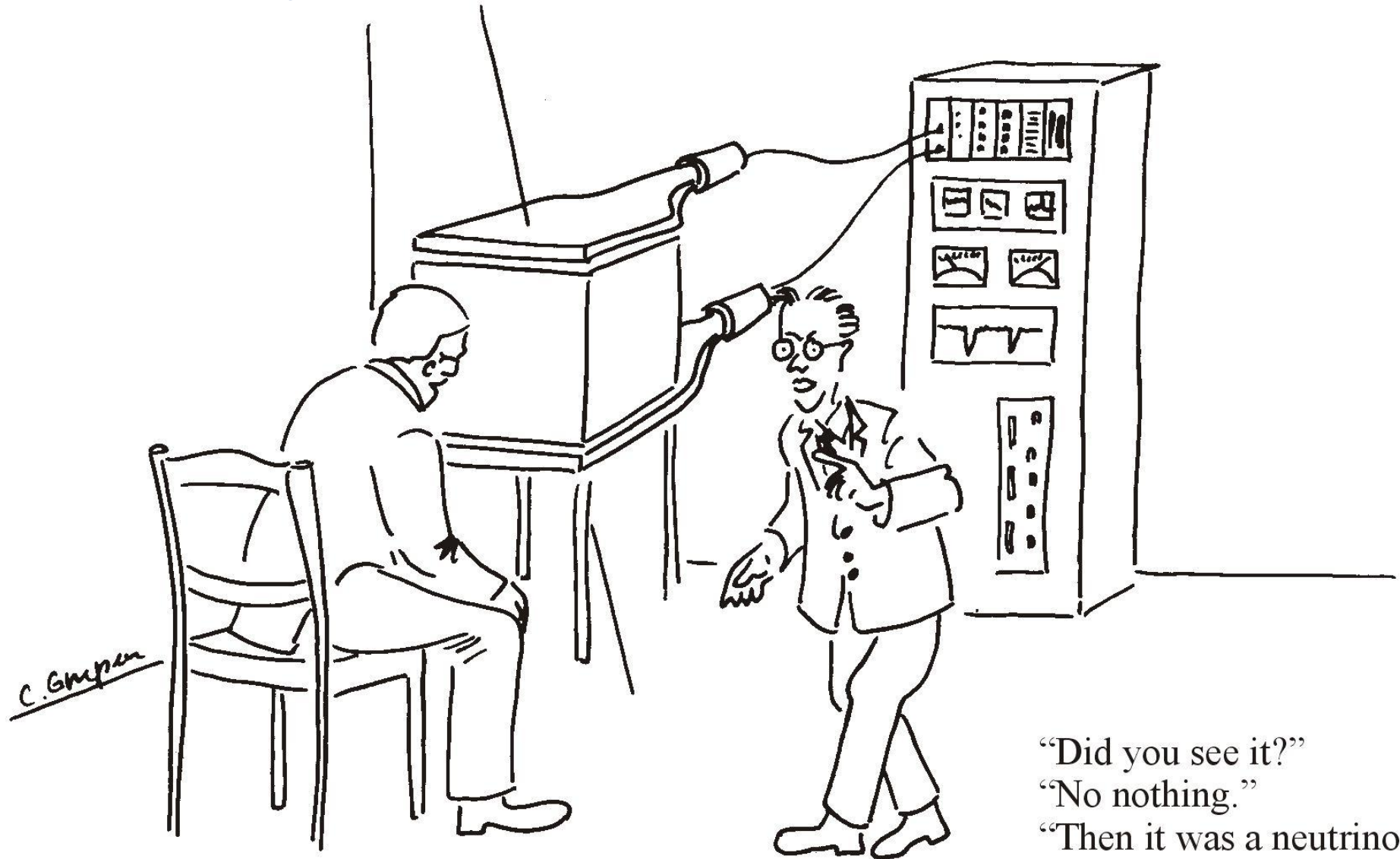
K. Debertin and R.G. Helmer (1988). Gamma- and X-Ray Spectrometry with Semiconductor Detectors. North-Holland.

ISBN-10 : 0444871071

ISBN-13 : 978-0444871077



# Thank you for the attention ...



“Did you see it?”  
“No nothing.”  
“Then it was a neutrino!”