Radiometric Quantities and Measurements

Prof. Dr. Nadir Omar Hashim

Department of Physics

Kenyatta University

hashim.nadir@ku.ac.ke

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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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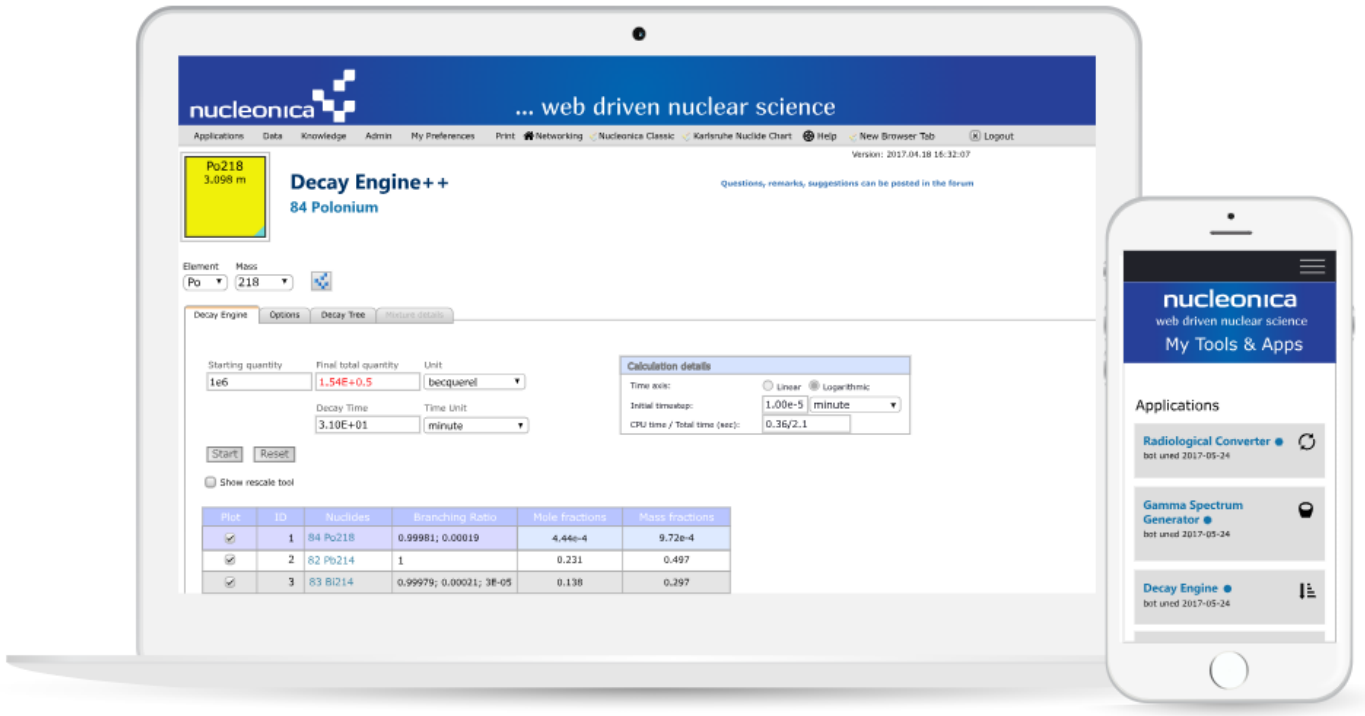
Nucleonica is the leading online resource in the nuclear sciences

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
- nuclear security, safeguards and forensics
- nuclear medicine and radiopharmaceuticals
- environmental radioactivity & radioecology
- packaging classification for radioactive transports
- education and training



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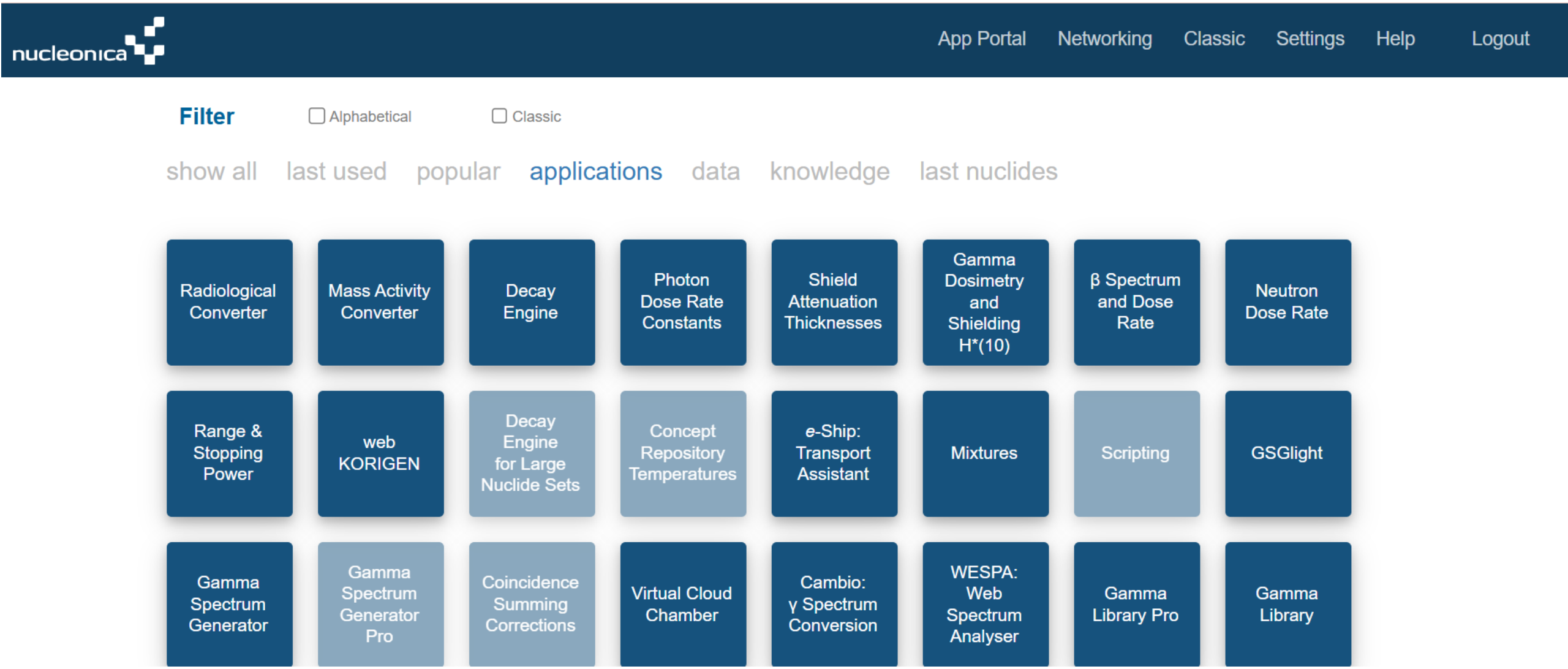
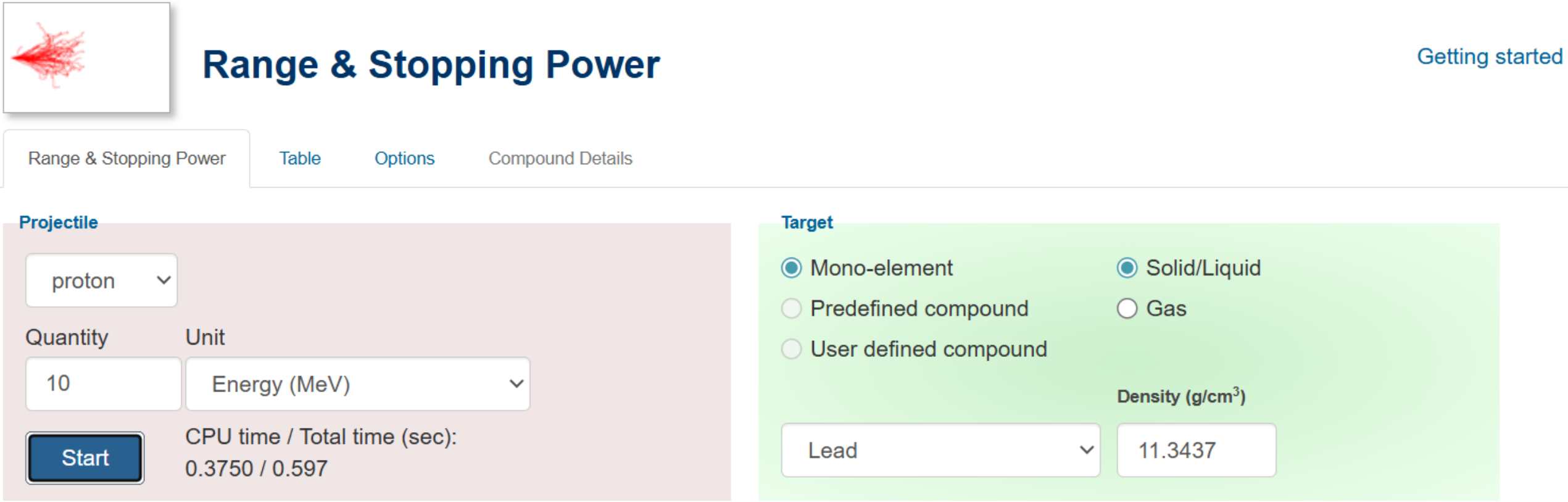
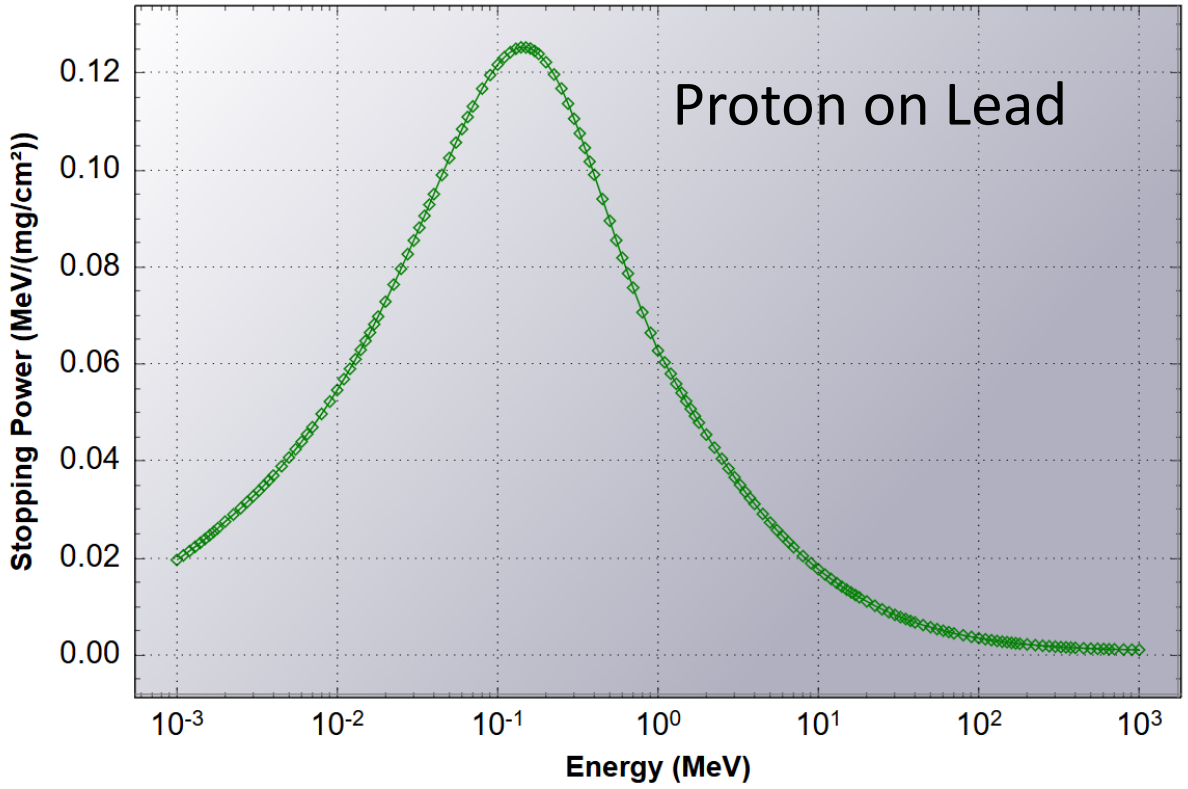


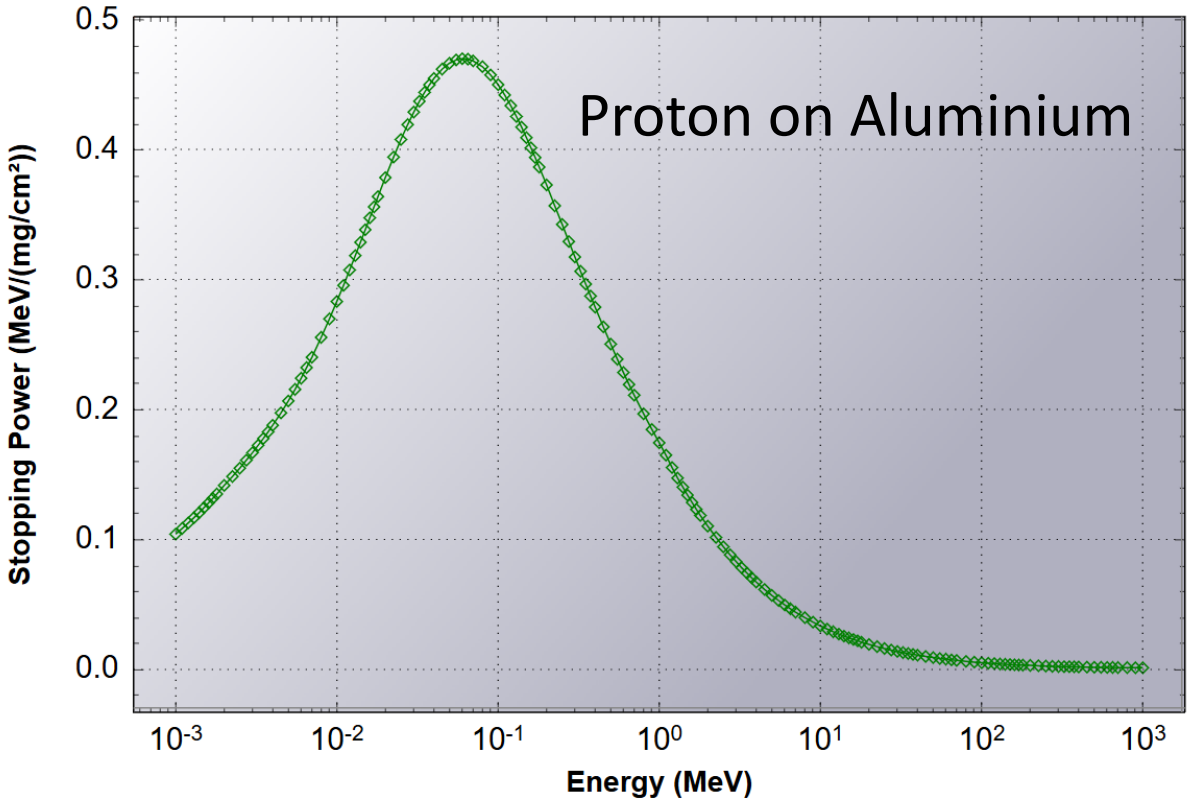
Range and Stopping Power



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

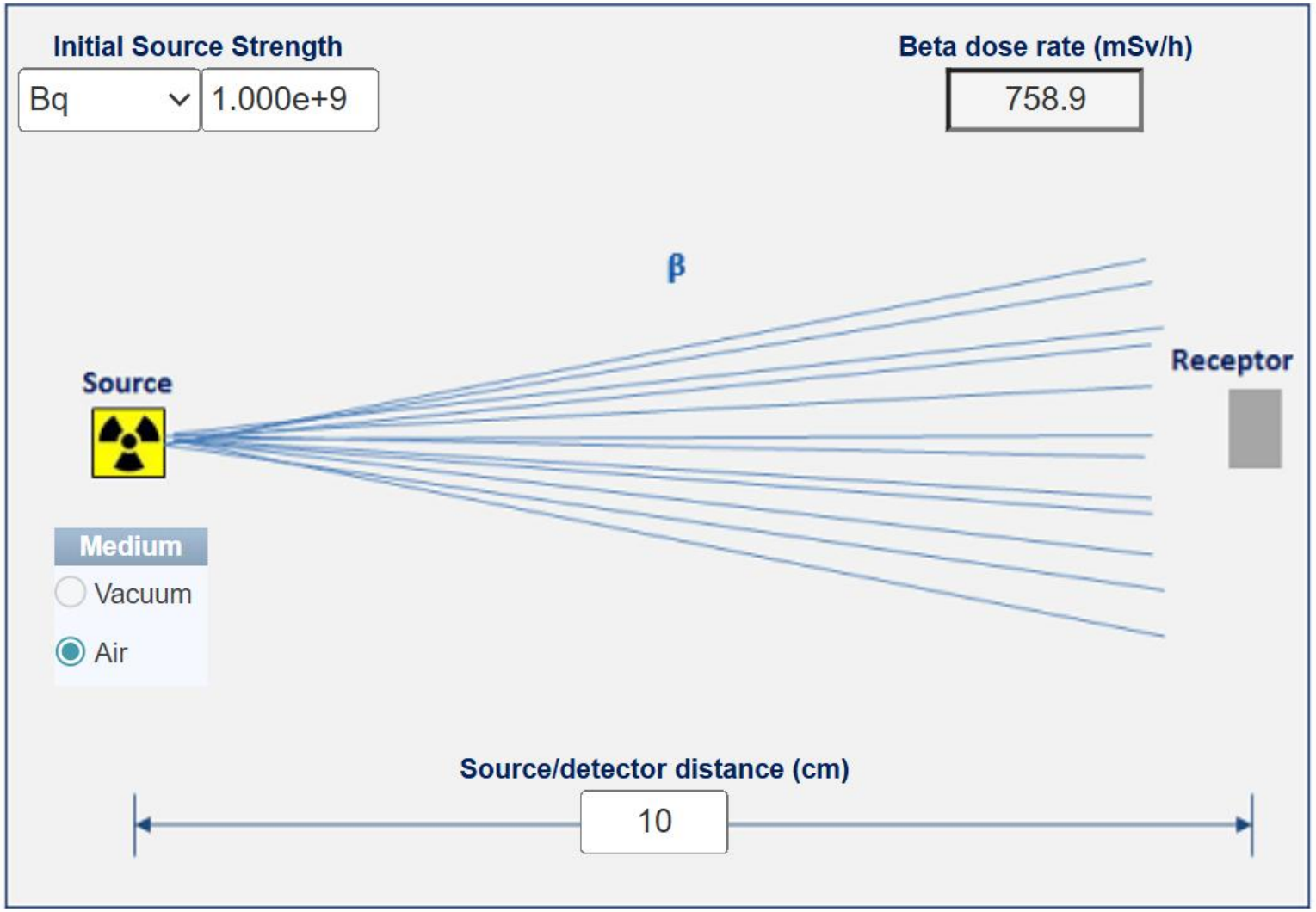
Total Stopping Power





- Tabulate the values of the range and stopping power

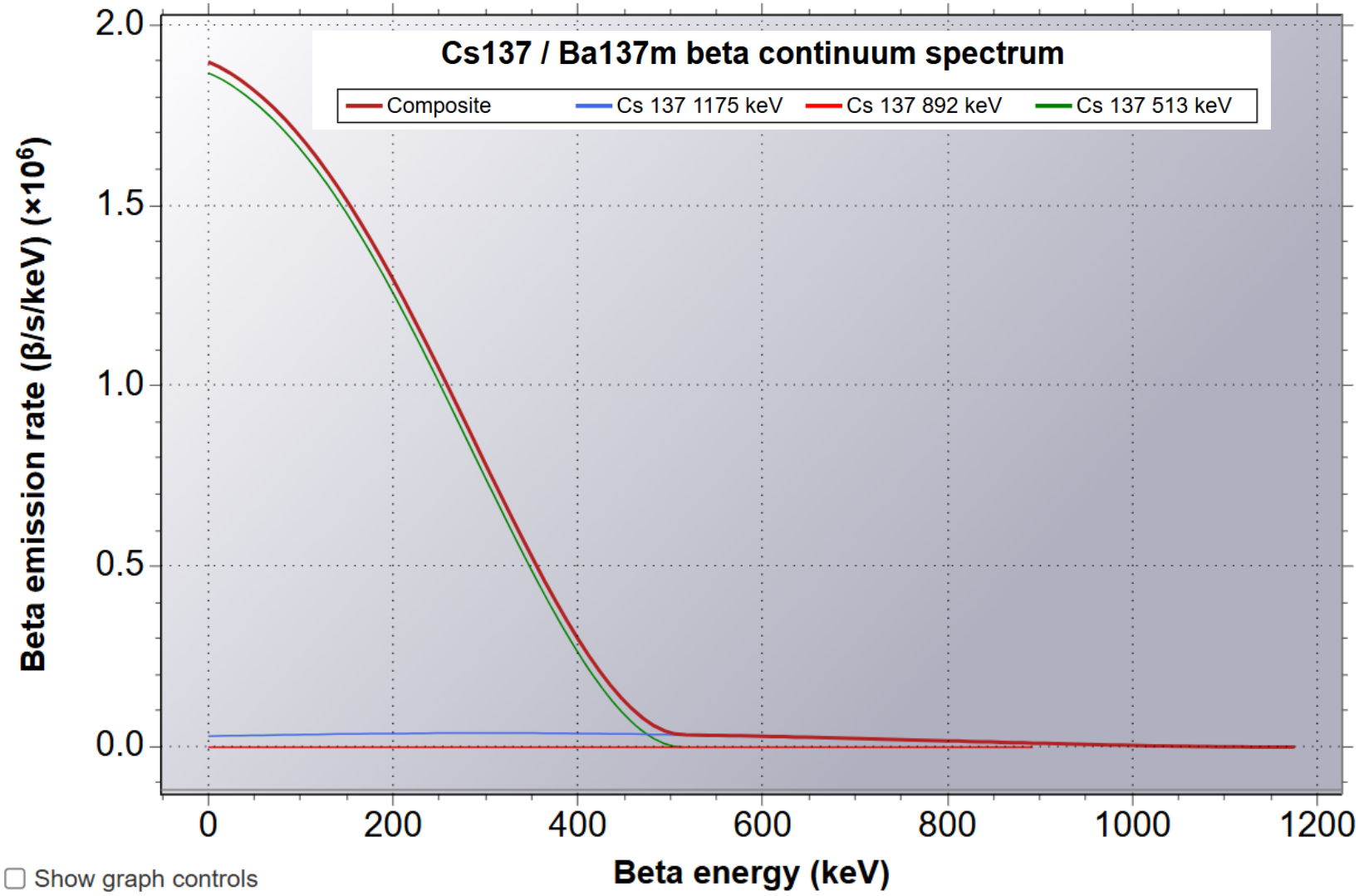
Variation of Dose Rates with Distance



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
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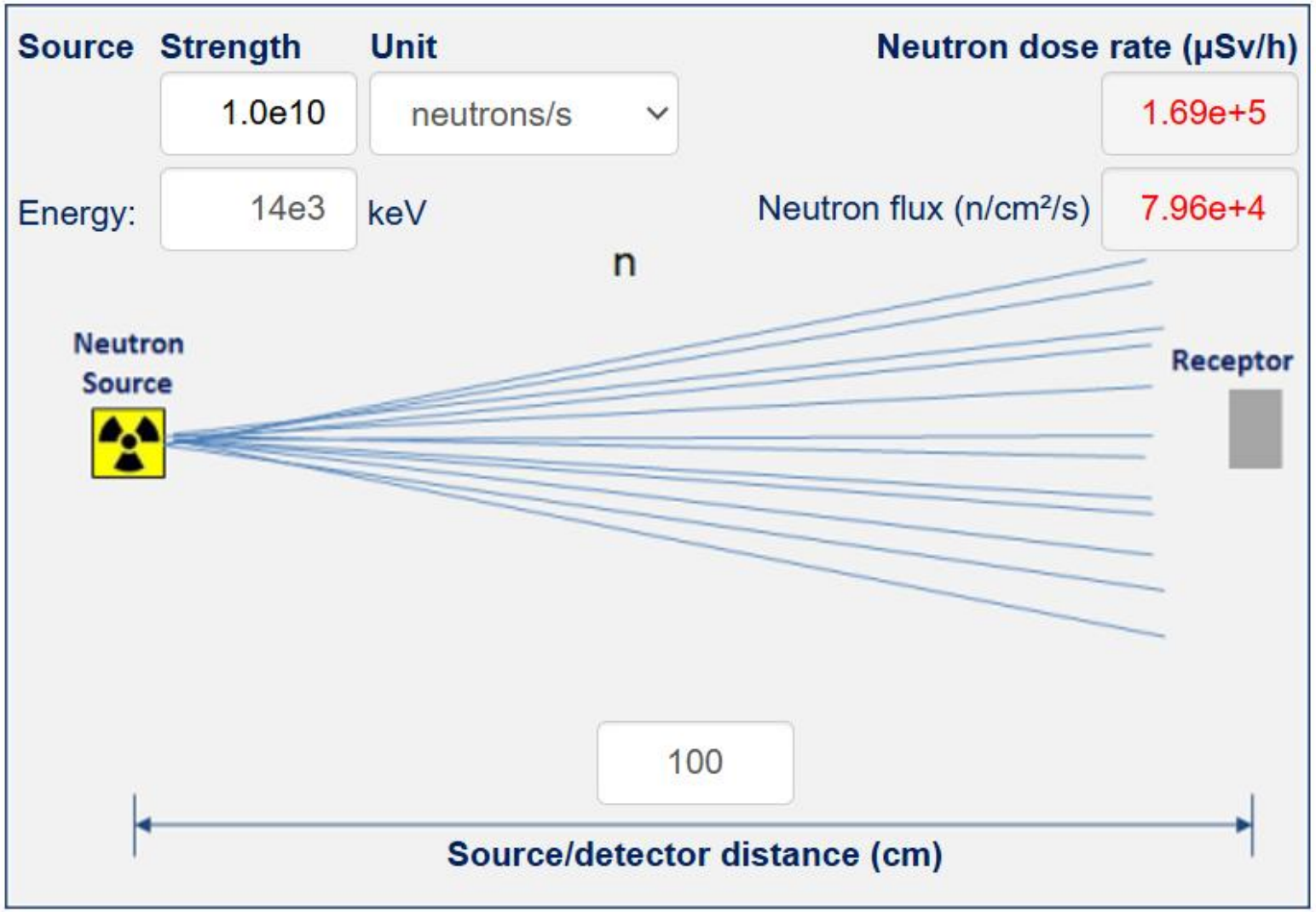
- Observe the variation of the values of the dose rates
- Observe the spectrum

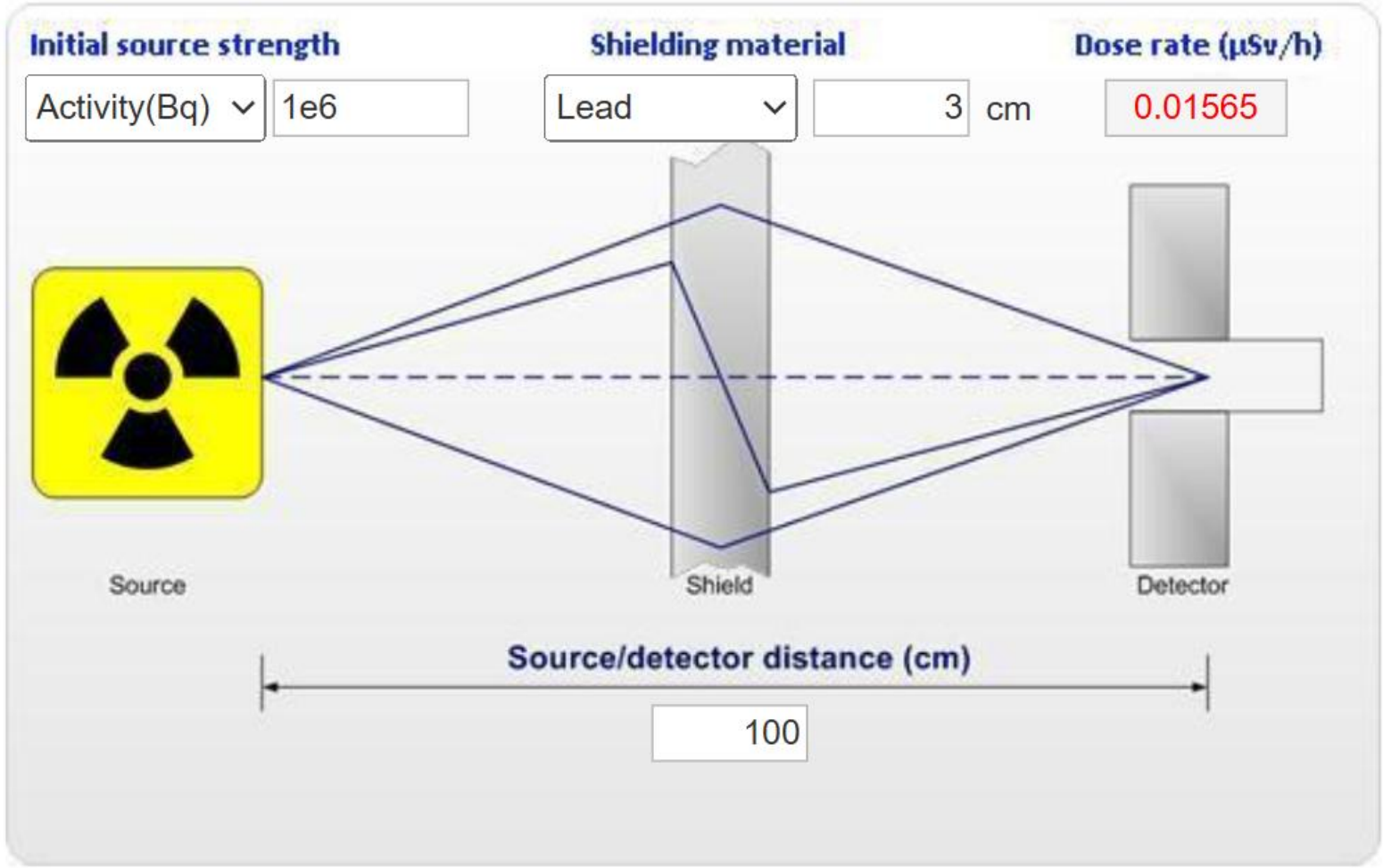
Neutron Dose Rate



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



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Exercise:

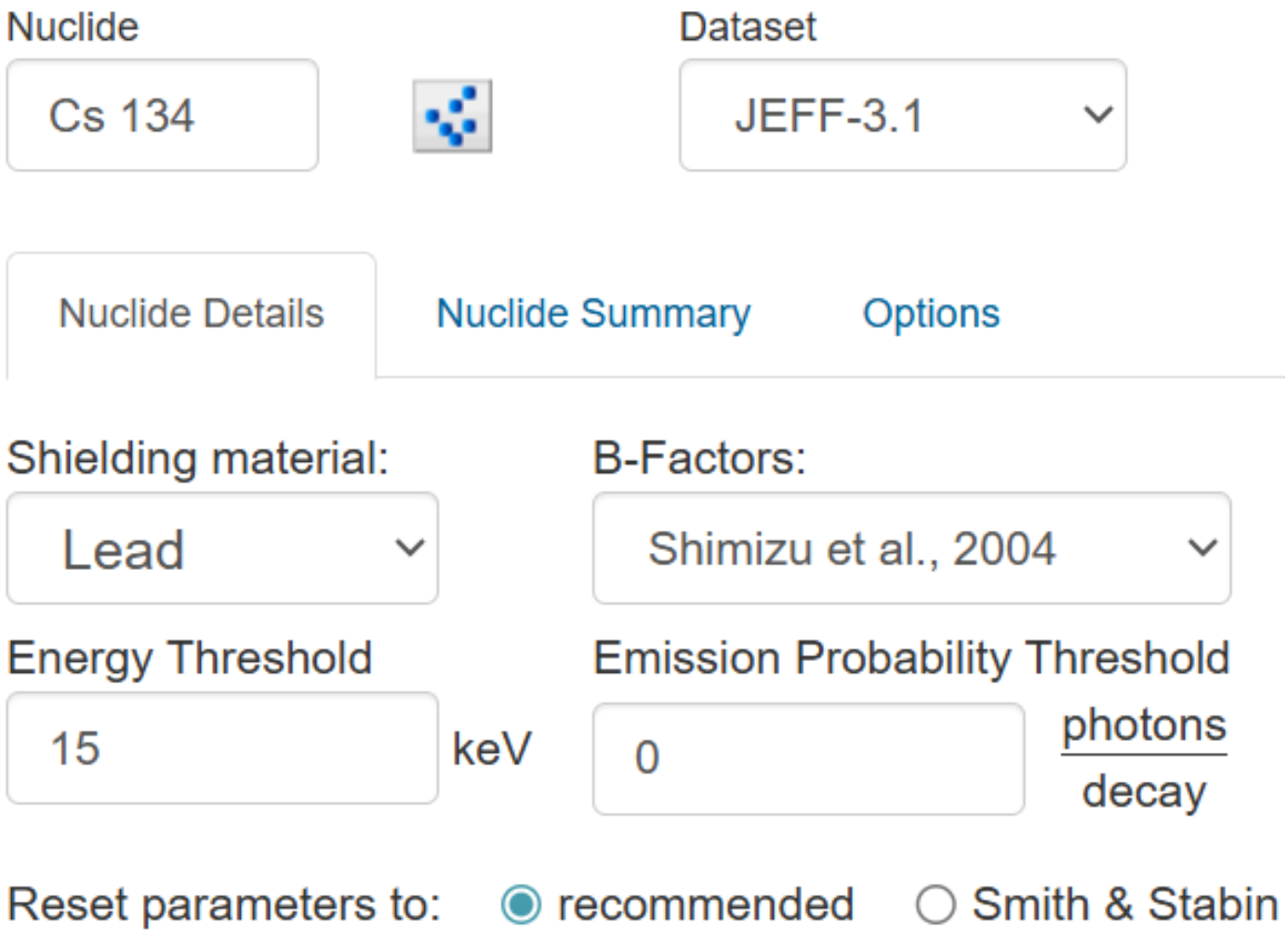
- Choose a known source and shield
- Calculate the dose rate at various source – detector distances
- Calculate the ambient dose rate
- Calculate the values of HVL and TVL

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	µSv/h
Effective Buildup factor, ANSI 6.4.3 1991	B_{eff} =	1.797	
Effective Number of Mean Free Paths	$\mu_{eff} \cdot d$ =	3.344	

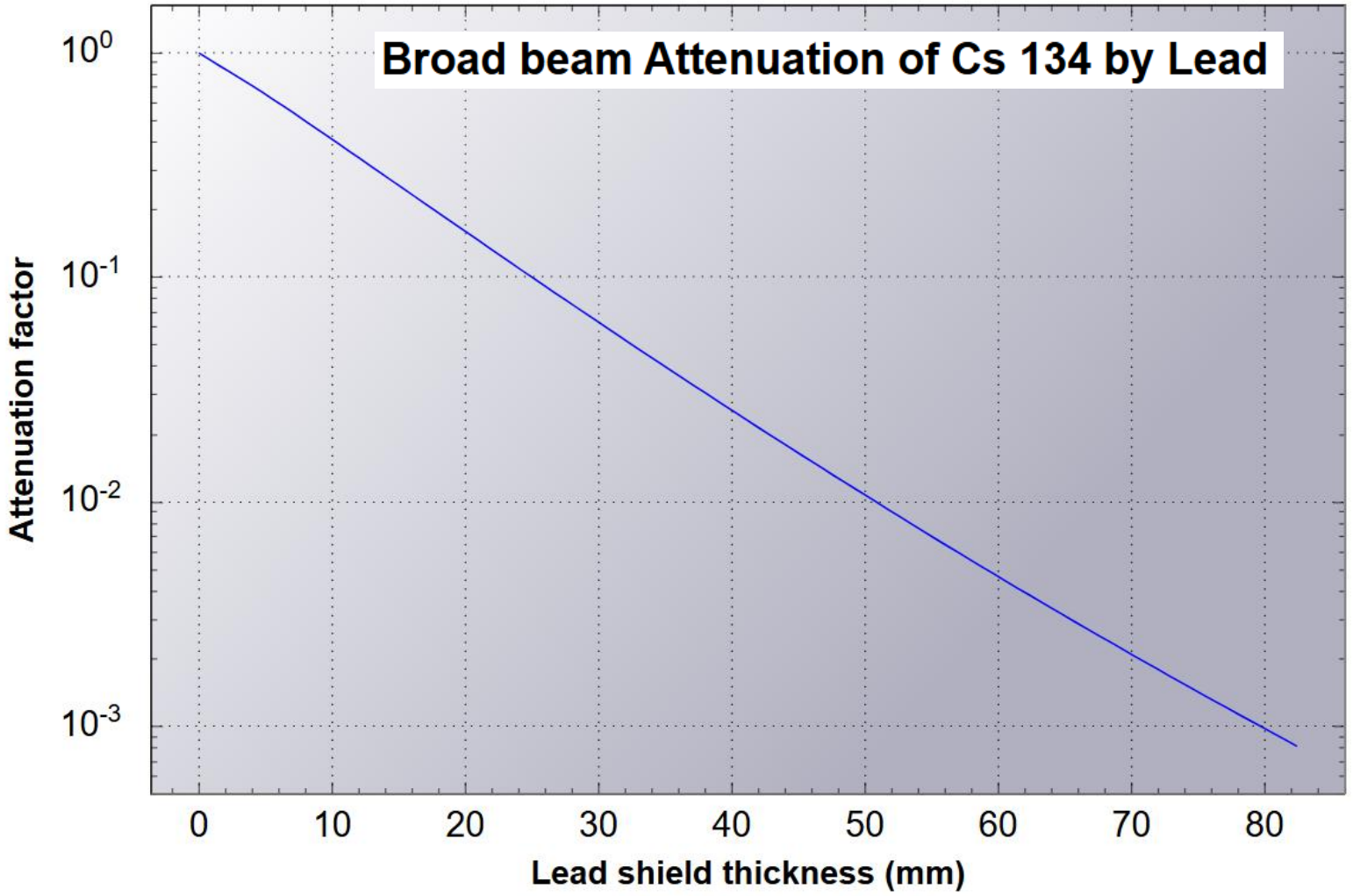
Calculation of Attenuation and Shield Thickness



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

Calculation of Attenuation and Shield Thickness



Exercise:

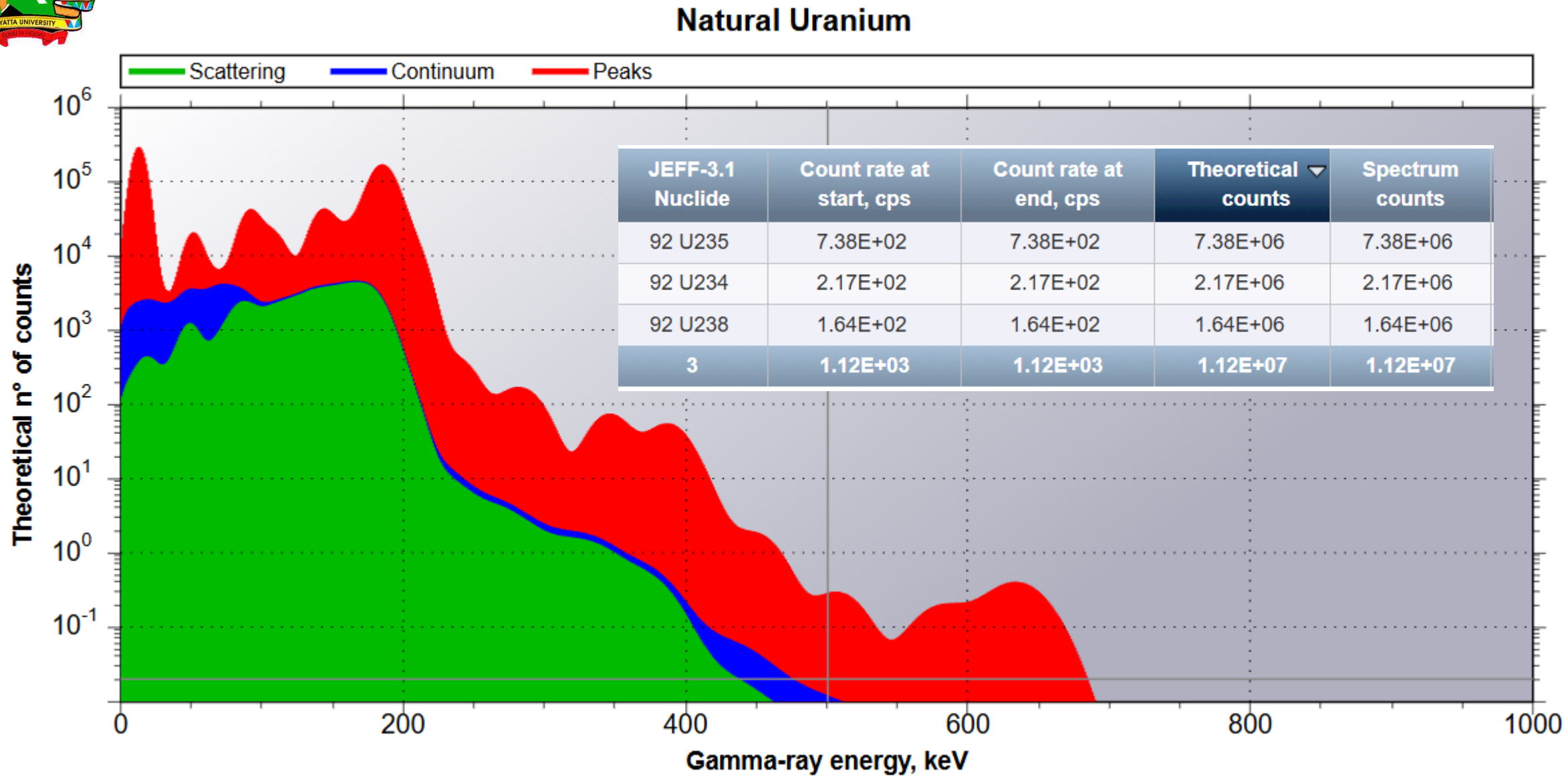
- Choose a known nuclide and shield
- Calculate the attenuation factor
- Observe the variation of the attenuation factor with shield thickness
- Calculate the values of HVL and TVL
- Repeat with a different shield material

Gamma – ray spectrum

Exercise:

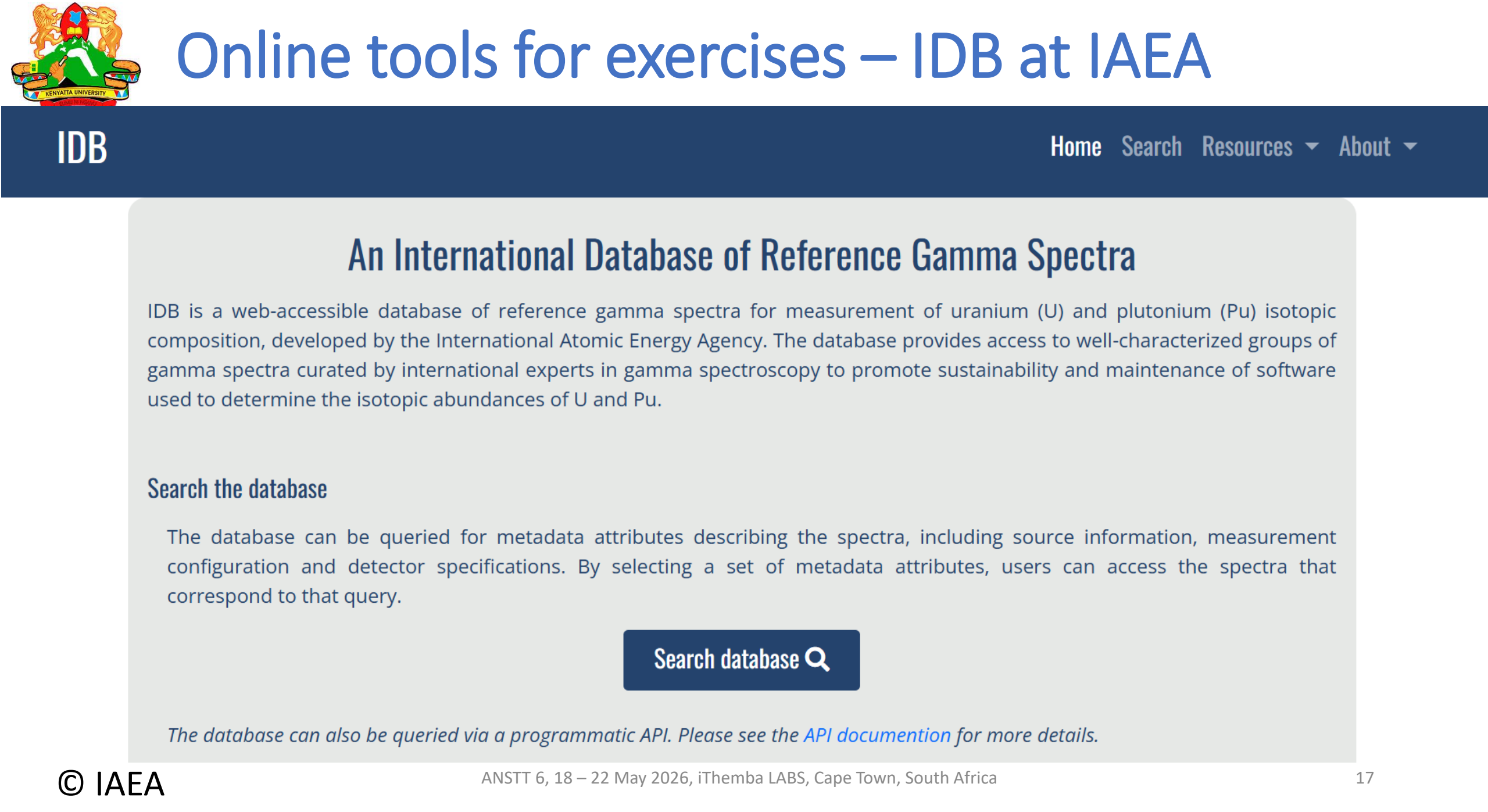
- Generate the gamma ray spectrum of natural uranium
- Indicate the following components of the spectrum:
  - Scattering
  - Continuum
  - Peaks
- Indicate the counts for each of species in natural uranium

Gamma – ray spectrum



JEFF-3.1 Nuclide	Count rate at start, cps	Count rate at end, cps	Theoretical counts	Spectrum counts
92 U235	7.38E+02	7.38E+02	7.38E+06	7.38E+06
92 U234	2.17E+02	2.17E+02	2.17E+06	2.17E+06
92 U238	1.64E+02	1.64E+02	1.64E+06	1.64E+06
3	1.12E+03	1.12E+03	1.12E+07	1.12E+07

Online tools for exercises – IDB at IAEA

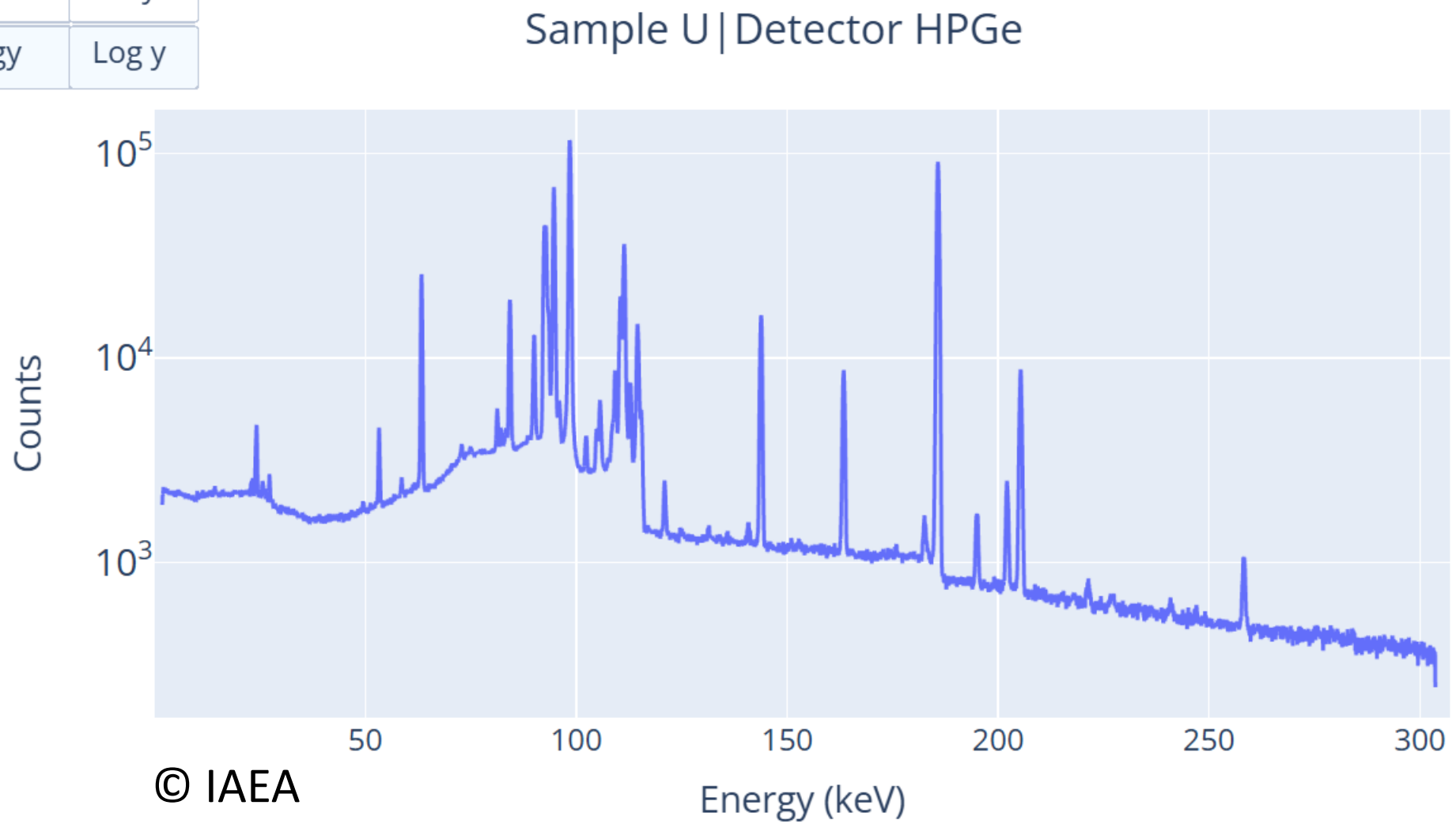


Online tools for exercises – IDB at IAEA

- 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



Online tools for exercises – IDB at IAEA

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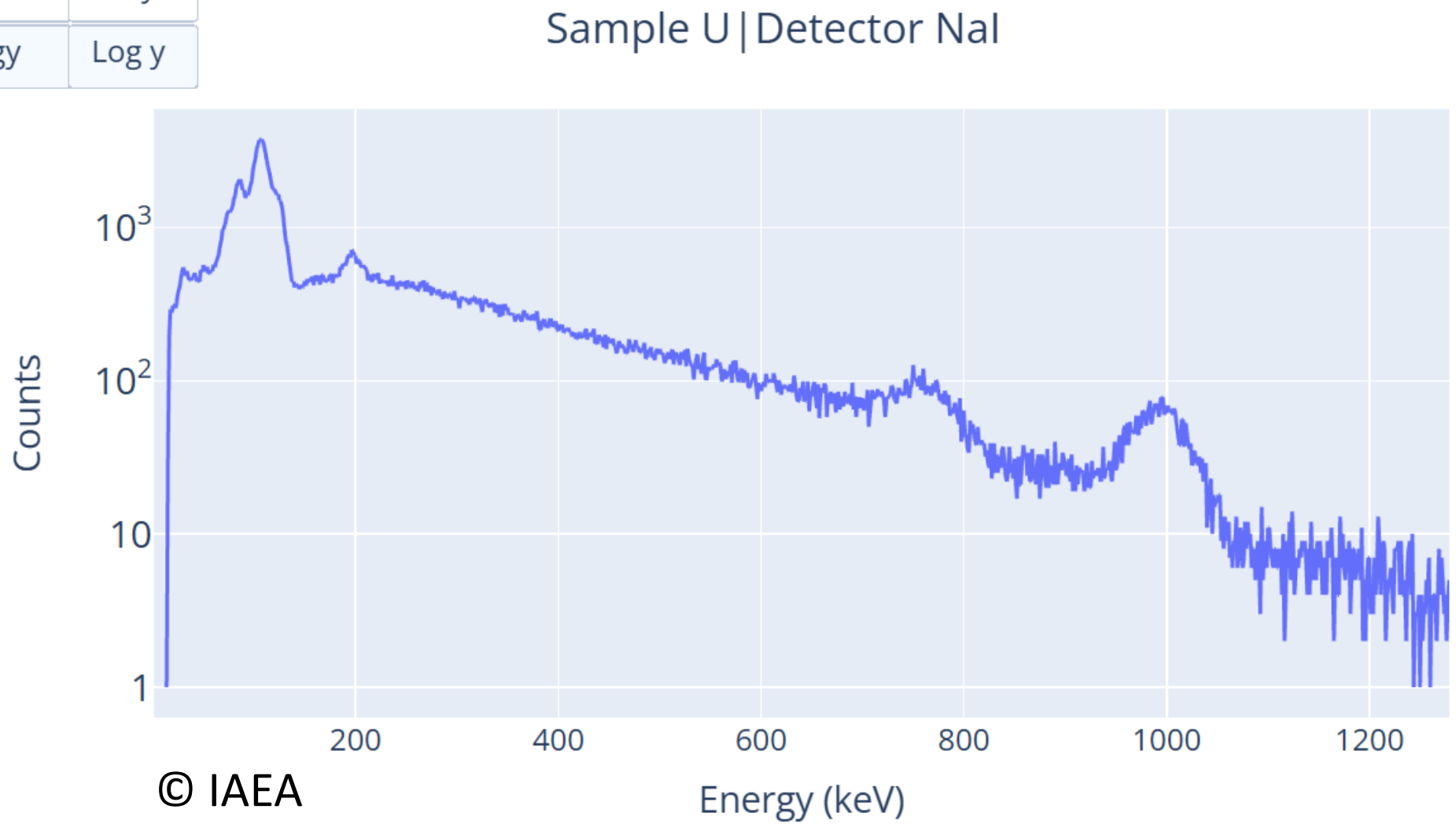
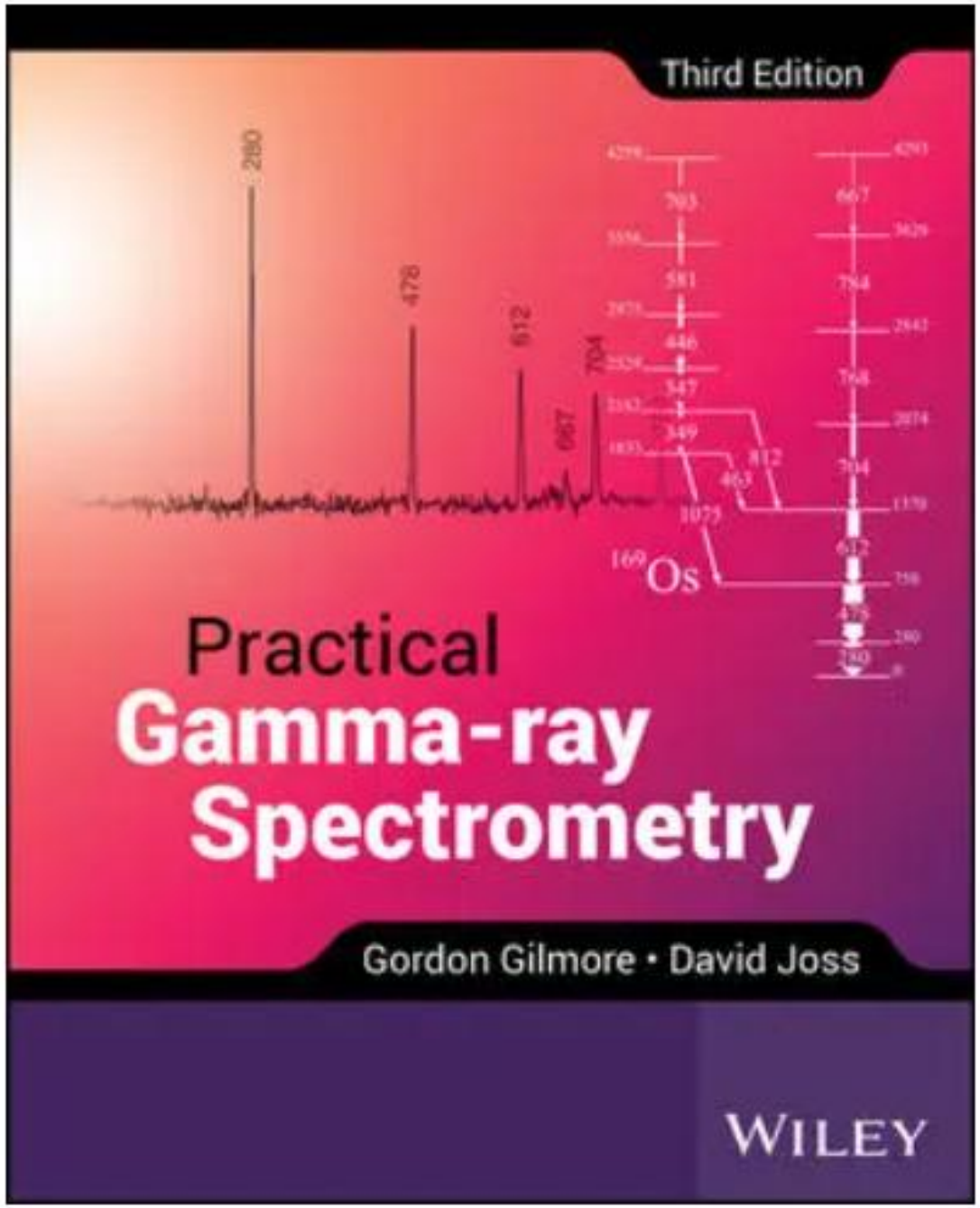


Summary

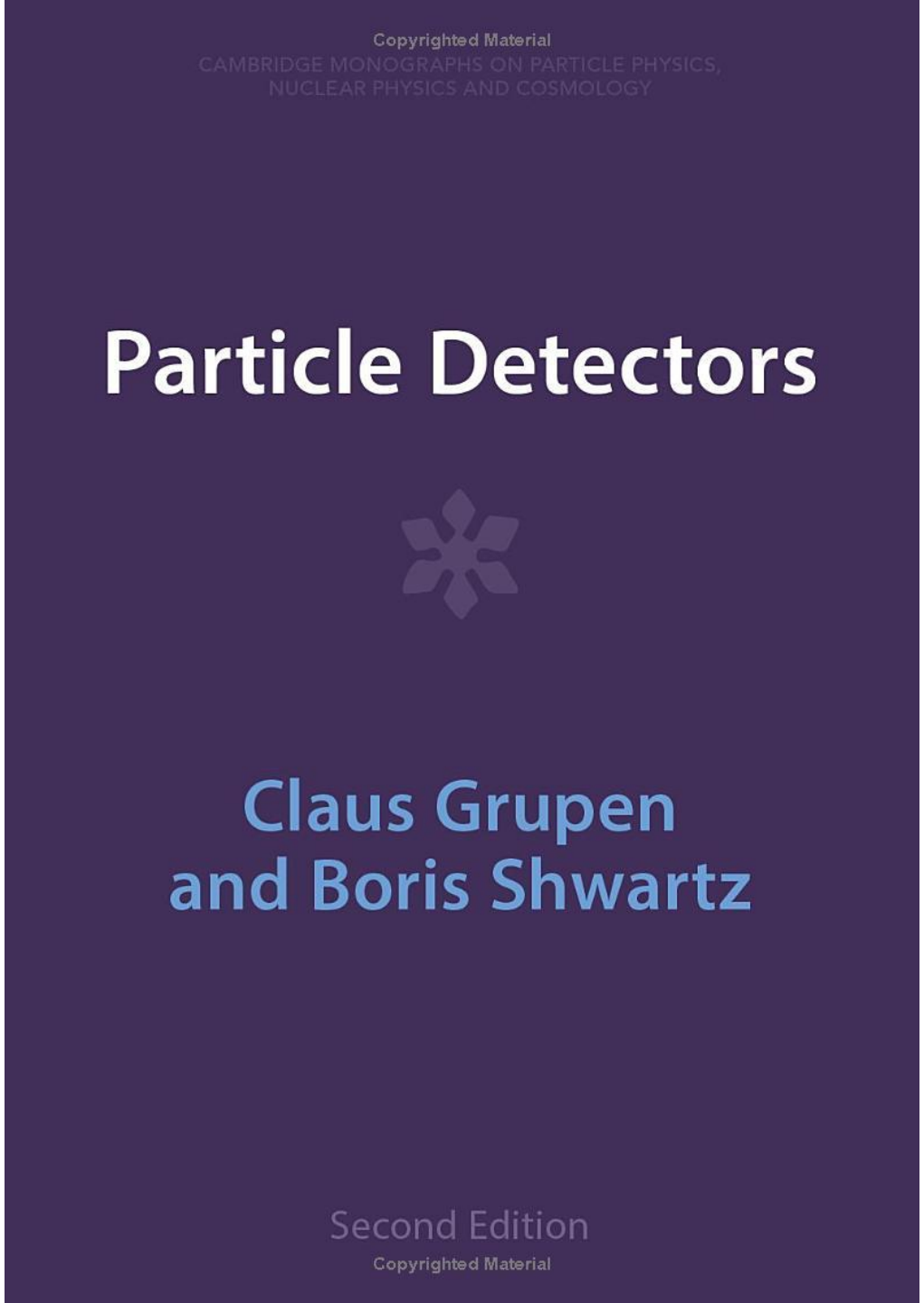
The following exercises were carried out during this session:

- ✓ 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



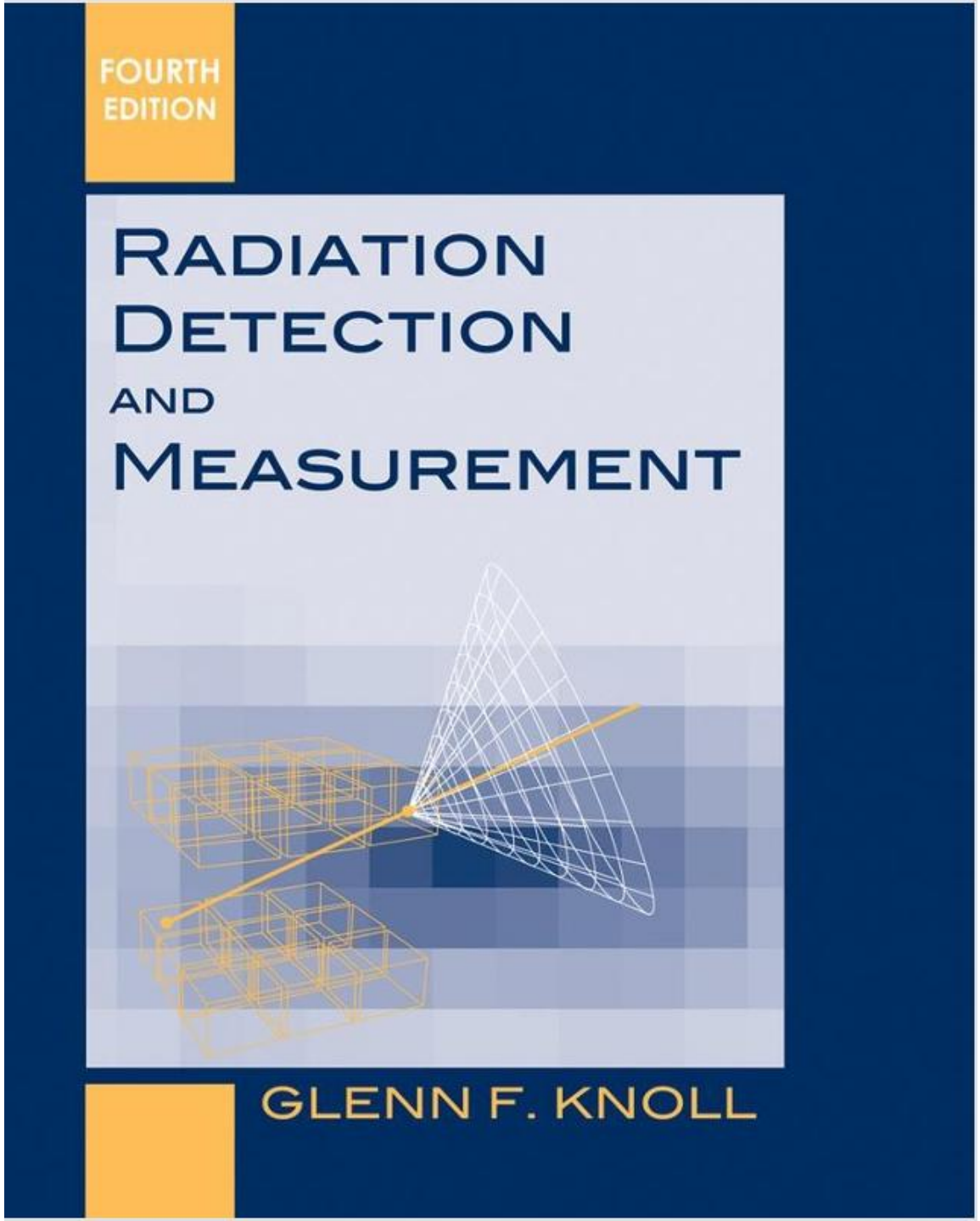
Further reading

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



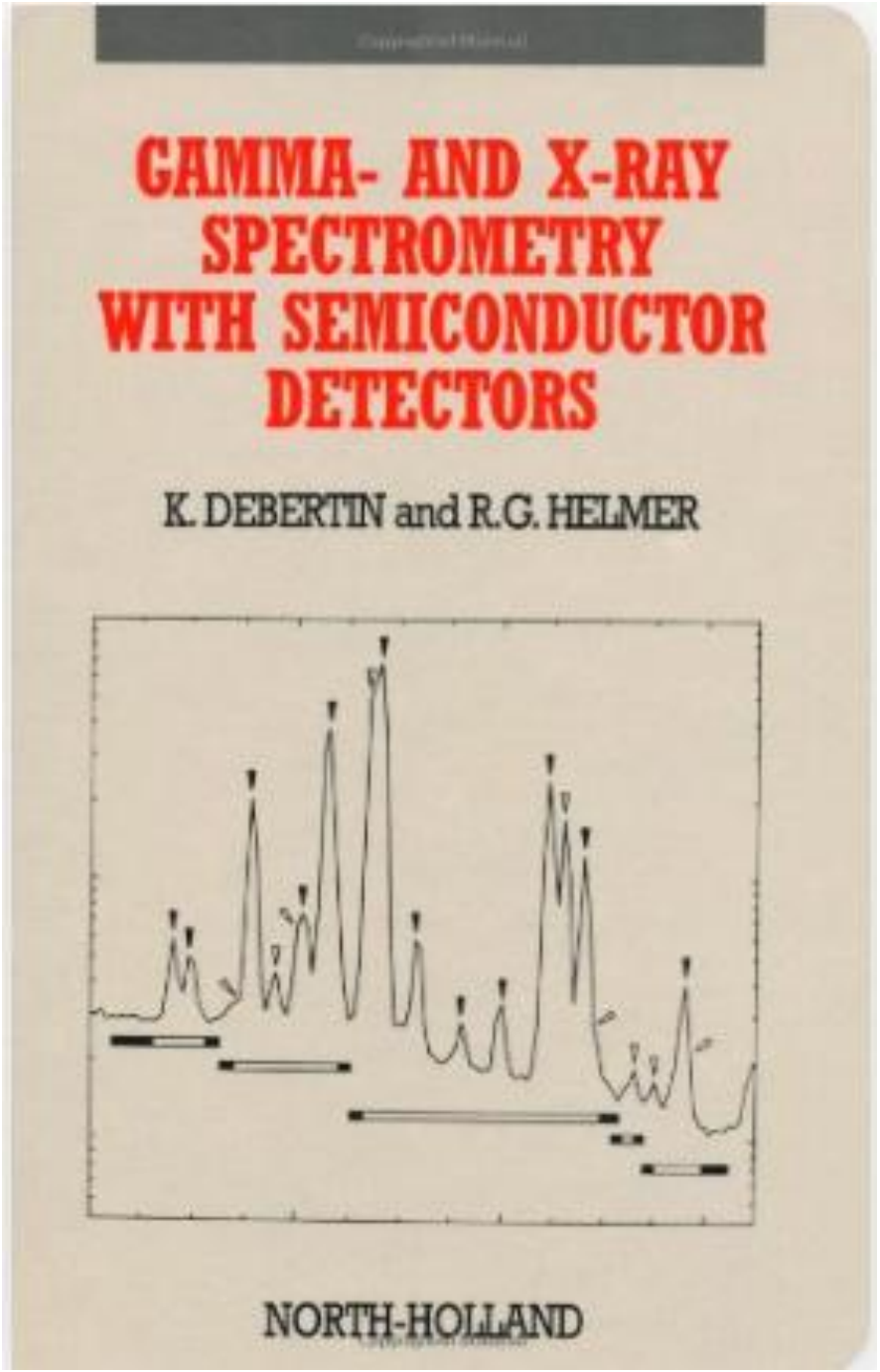
Further reading

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



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 …