Interference Situations in Gamma Spectrometry

Verena Kleinrath
verena.kleinrath@ec.europa.eu

2nd Advanced Training Course on Illicit Trafficking and Radiological Consequences with NUCLEONICA
Introduction

Prevention of nuclear smuggling (Illicit Trafficking)
Nuclide Identification of highest importance

Gamma Spectrometry using
an RID (Radionuclide Identification Device)

Nuclide Identification more difficult, when:
source shielded
spectra of two or more sources interfere
= Masking
Interaction of gamma rays with matter in the detector volume

transfer of photon energy to electron energy

A. **photoelectric absorption** -> photopake
   gamma photon disappears in absorber atom
   photoelectron emitted
   + characteristic x-ray or auger electron

B. **Compton scattering** -> continuum
   gamma photon scattered – some energy given to an electron, depending on angle
   all angles up to max. 180° (Compton edge)
   scattered photon escapes detection

C. pair production
   gamma energy >> 2m_e c^2
   production of positron + electron
selected effects that complicate the detector response function

peak-like distortions from the detector surroundings:

1. characteristic x-rays

2. backscattering
Areas of Interest

1. Photopeaks
2. Compton Continuum
3. Backscatter Peak

three regions of possible interferences -> three types of Masking
Resolution of Photopeaks
Ba 133 and Pu 239

Ba 133 + Pu 239

1mm lead

interferences at adjacent lines
Compton scattering within detector volume at different angles -> continuum

Comparison of different detector volumes shows different peak – continuum ratio due to escaping particles
higher initial photon energy -> lower efficiency in full energy peak

more scattering events and escapes possible -> increased continuum in relation to peak
Fertilizer (K 40) and LEU

**Gamma-Spectrum Simulated for NaI (76.2 x 76.2 mm)**

- **Nal**
  - 1001 keV
  - 767 keV

**Gamma-Spectrum Simulated for HPGe (rel. eff. 146.8%)**

- **HPGe**
  - 1001 keV
  - 767 keV

K 40 + U 238

5 mm lead

if statistical fluctuation high compared to peak height of second nuclide, peaks could disappear in continuum
The Backscatter Peak

Compton scattering in the detector surroundings

- Gamma photon Compton scattered in surrounding material
- Some energy deposited in electron there
- Gamma photon with reduced energy scattered back into detector volume
- New energy usually ~ 200 keV
- For angles greater than 120° independent on original energy
- -> Backscatter peak
The Backscatter Peak

\[ E' = \frac{E}{1 + \frac{E}{m_0c^2}(1 - \cos \beta)} \]

\[ E'_{\text{back}} \text{ for backscattering} \]
\[ \beta = 180^\circ \]
\[ m_0c^2 = 511 \text{ keV} \]

\[ E'_{\text{back}} \approx \frac{511}{2} \]

\[ E'_{\text{back}_{\text{cesium}}} = 184 \text{ keV} \]
\[ E'_{\text{back}_{\text{cobalt}}} = 210, 214 \text{ keV} \]

for great primary energies:

peak always at 255 keV or less
Cs 137 and HEU

Cs 137 + U 235

No backscattering contribution

U 235 peak at 185.7 keV clearly visible

with backscatter peak

U 235 peak hidden
Cs 137 and HEU

with high backscattering interference also in HPGe spectrum
countermeasures:

- high resolution detectors (expensive)

- full spectrum analysis or template matching

- for neutron emitters: additional neutron detection

- to detect shielding or inhomogeneities: x-ray machines

picture from G. Lasche
further recommended reading:

G. Knoll, *Radiation Detection and Measurement*

M.I. Reinhard et al., *Detection of Illicit Nuclear Materials Masked with other Gamma-Ray Emitters*

R.M. Keyser and T.R. Twomey, *Detector resolution required for accurate identification in common gamma-ray masking situations*

IAEA Nuclear Security Series No. 6, *Combating Illicit Trafficking in Nuclear and other Radioactive Material*