Energy of Gamma Particles

extract from the ***Experiment Guide*** by Dr.Vladimir Vicha (IEAP CTU Prague) and Dr.Peter Žilavý (Department of Physics Education - Faculty of Mathermatics and Physics – Charles University in Prague)

This task requires a calibrated MX-10 camera.

Radionuclide ^{241}Am decays only through α-decay :

$$^{241}_{95}Am \rightarrow ^{237}_{93}Np + ^{4}_{2}He + \Delta E$$

After an alpha particle is emitted from americium nucleus, a daughter nucleus of neptunium is originated in an excited condition, and, with transition to ground energy state, it emits photons of various energies. In this process photons of energy 59.5 keV dominate and further, photons with energy of 26.3 keV are emitted in smaller amount (approximately 15 times smaller). In addition to the nucleus radiation, characteristic X-ray radiation is originated from the electron shells of neptunium, mostly with energies 14 keV to 17 kev, and also 21 keV.

Simple preview : Options : Radiation source ^{241}Am, *Measurement mode Spectrometer, Analysis type Basic, Bias 50 V, Continuous measurement checked, Integral mode unchecked, Exp. count 60, Exp. time 1 s, Min. level 0, Max level 1, Set color map Hot. Tools: - Histogram of particle properties – Energy-all frames, marker Gama.*

Procedure: Fix the MX-10 detector in the sliding bench, and choose “strainer” (position 2) as an output aperture for the radiation from the source. Bring the radiator as close to the detector chip as possible, and between the radiator and the chip insert ordinary piece of paper (it will shield alpha radiation). Start the measurement.

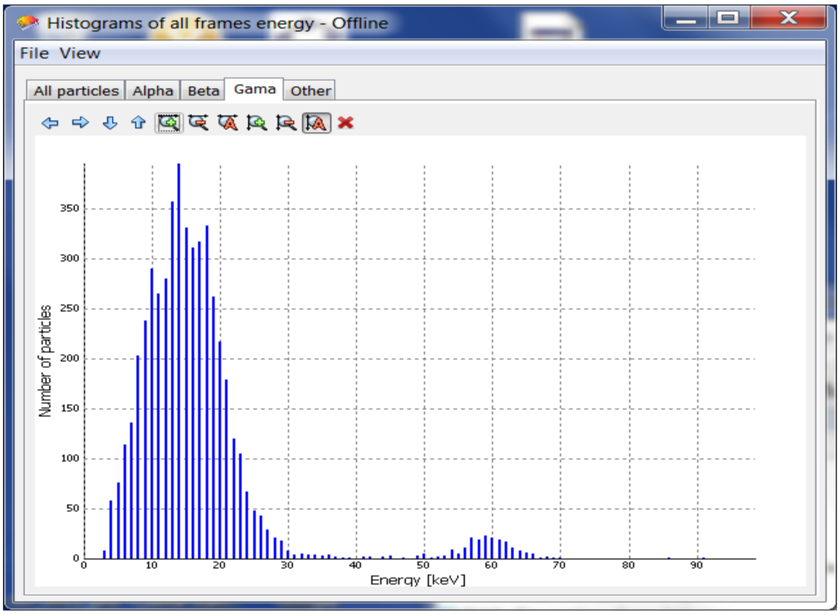

Fig.1. Energy radiation histogram of gamma source SRS ALPHA ^{241}*Am at passage through a paper during 60 s of measurement.*

Immediately after the beginning of the measurement two peaks start to show in the energy histogram, a dominant one with the maximum at approximate energy of 15 keV (characteristic X-ray radiation of neptunium), and a smaller peak with a maximum at approximate energy of 60 keV (nuclei radiation of neptunium), see Fig.1.

Visually, based on the histogram, it seems that 60 keV photons have a small distribution in the spectrum while photons with energies around 15 keV are represented considerably more.

We need to realize here that the heights of peaks are influenced by the probability of gamma photon absorption of various energies in the silicon chip whose thickness in the case of the MX-10 detector is 300 μm. The absorption probability for energy of 15 keV is 51%, while the probability for energy of 60 keV is only 2.2% (see Fig.2).

E/keV	Absorption probability/%
1	100
1,5	100
1,8	100
2	100
3	100
4	100
5	100
6	100
8	98,9
10	90,5
15	51,3
20	26,7
30	9,51
40	4,76
50	3,01
60	2,21
80	1,54
100	1,27
150	1,00
200	0,88

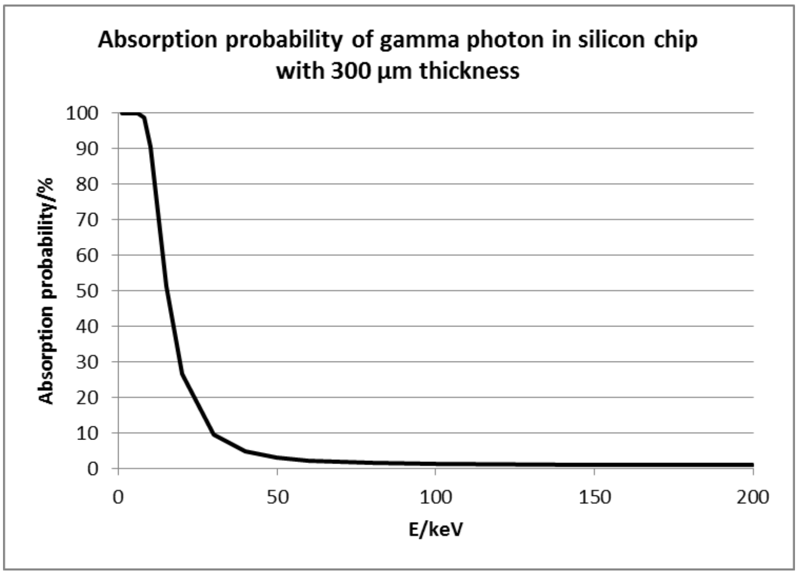

Fig.2. Absorption probability of gamma photon in silicon chip with 300 μm thickness. (Data source: http://physics.nist.gov/PhysRevData/XRayMassCoef/tab.3.html.)

The probability of absorption of particles with a given energy can be defined as a ratio of the number of particles absorbed in the chip N', to the number of all particles with the given energy impinging on the chip N_0,

$$\textit{Absorption probability} = N' / N_0 \cdot 100\%$$

From the table and graph it is obvious that probability of gamma photon absorption for small energies of units of keV is close to 100%. A significant drop in absorption happens for energies between 10 keV to 15 keV. For energies over 30 keV, the absorption already drops down to the order of ones of percent.

If we want to know the number N_0 of gamma photons impinging on the detector, we need to take into account the probability of absorption in silicon chip:

$$N_0 = N' / \textit{absorption probability}$$

where for absorption probability we substitute a decimal number from the interval (0, 1).

Because of detection efficiency, the number of photons registered by the detector *N*, is smaller than the number of absorbed photons *N*'. If we identify the number of registered photons with the number of absorbed photons (*N*=*N*'), we can calculate number of photons N_0 hitting the detector (Fig.3).

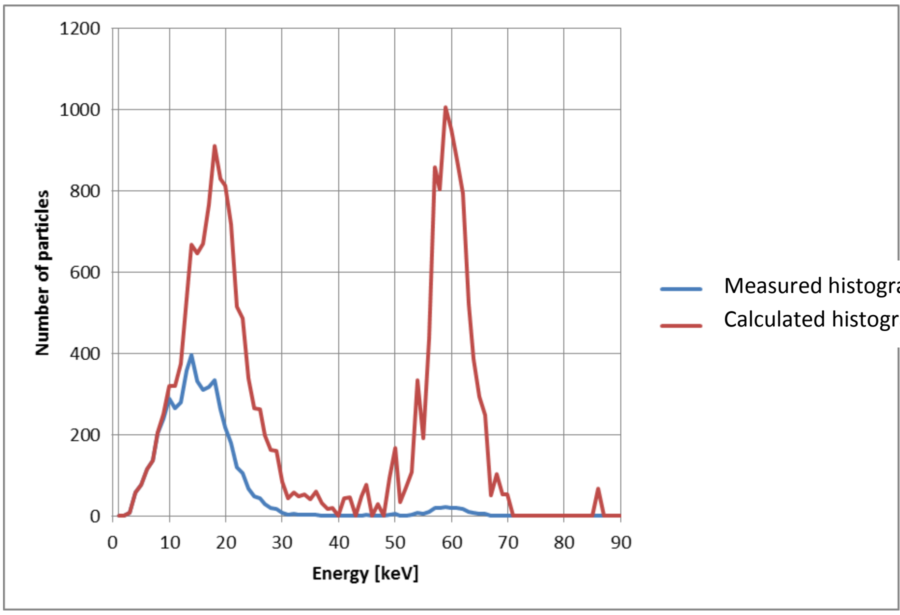

Fig.3. Gamma radiation energy – measured histogram and calculated histogram where probabilities of photon absorption in silicon chip were considered.

When the probability of absorption is considered, the 60 keV peak is greater.

Conclusion: We verified that in the spectrum of the ^{241}Am source there are two peaks, one with energy 60 keV (nuclear radiation of neptunium) and one with energy approximately 15 keV (characteristic radiation of neptunium). The peak heights are significantly affected by different absorption of gamma photons with various energies in the silicon chip of the detector. The absorption probability of gamma photons with energy of 60 keV is very small, and therefore the 60 keV peak is appreciably visible only after the influence of absorption is considered.

Note 1: Gamma photons which travel through the silicon chip can produce characteristic X-rays in other materials which the MX-10 detector contains. But in the given experiment this effect was not distinctively manifested.

Note 2 : To get better statistics, it is possible to execute a measurement with longer exposure.

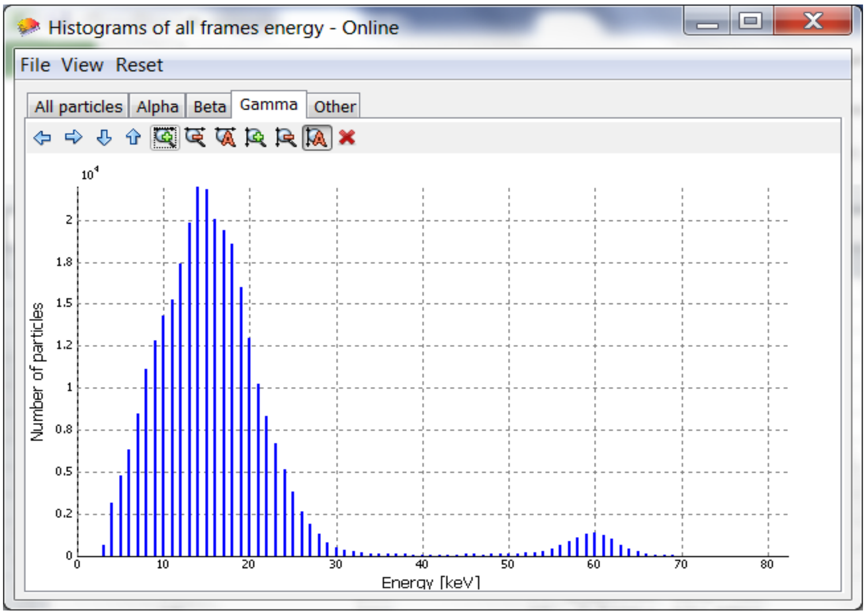

Fig.4 : *Energy histogram gamma radiation for the SRS ALFA* ^{241}*Am source at exposure of 60 min.*

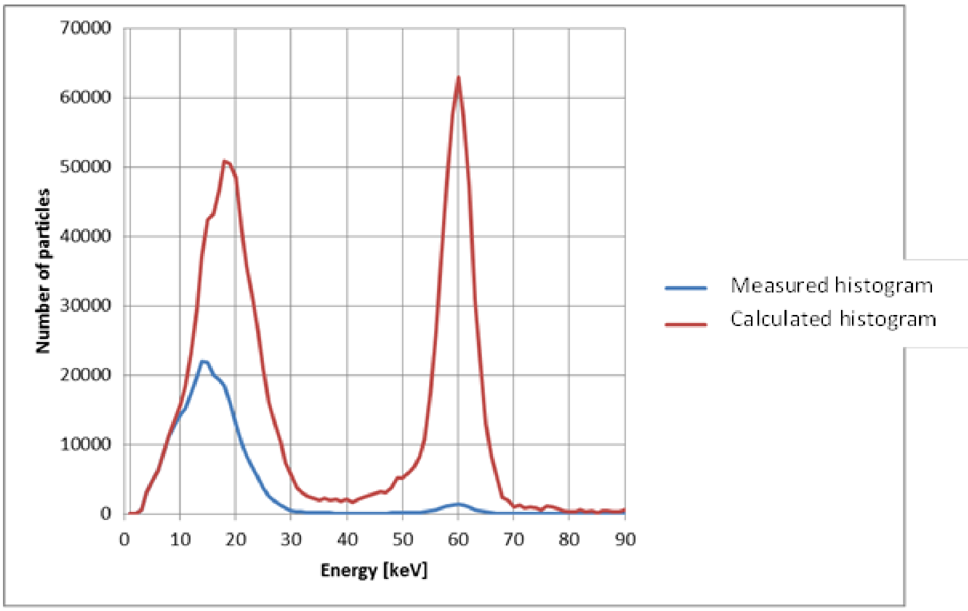

Fig.5 : *Energy of gamma radiation – measured histogram and the histogram after considering the photon absorption probability in silicon chip, at exposure of 60 minutes.*

Note 3 : To get larger statistics in the demonstration without a long waiting time, it is possible to use stronger radioactive source, for example DZZ GAMA, ^{241}Am, 300 kBq which can be obtained from the same manufacturer as in the case of SRS ^{241}Am, 9.5 kBq. These sources have identical spectra.

Instead of sixty minutes measurement with the SRS source, it is possible to obtain a smooth energy spectrum with the DZZ source in the one minute measurement (see Fig.6).

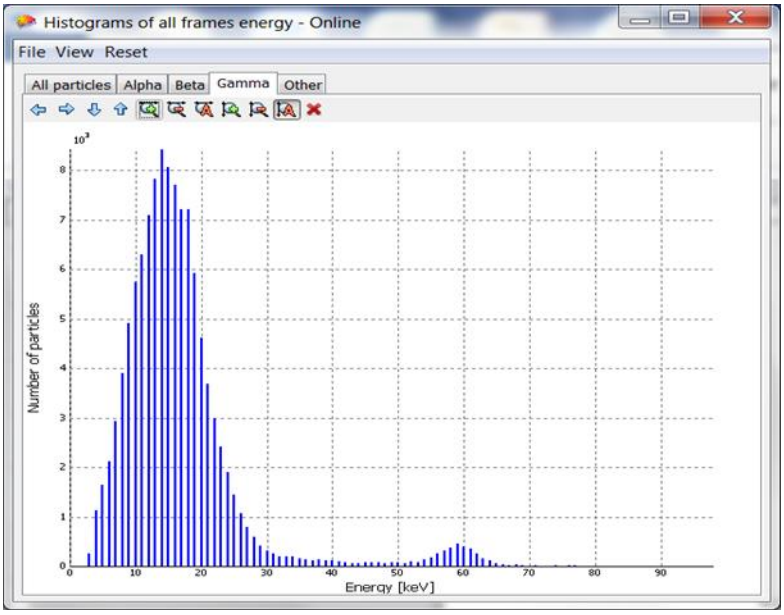

Fig.6 : Gamma radiation energy histogram for the DZZ ALFA ^{241}Am, 300 kBq source at exposure of 1 minute (240 frames [pictures] , 0.25 s each).