Scintillation decay time as a function of energy for Compton electrons in NaI:Tl

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It is well known that scintillation pulse duration is shortening with decreasing of photon energy in NaI:Tl and CsI:Tl crystals [1]. It can be seen clear especially for X-rays of 5.9 keV energy, e.g. near L-edge of iodine or cesium absorption. An explanation of the effect is based on increasing of ionization density for photo- and Auger-electron [2] when these two electrons appeared simultaneously. The density of ionization increases twice or trice near K- and L-edges due to cascade formation after resonance interaction of X-rays with electron in inner shells of atom. A consequence of proposed model [3] is an independency of decay time constant (τ) as a function of Compton electrons of different energies (E_C).

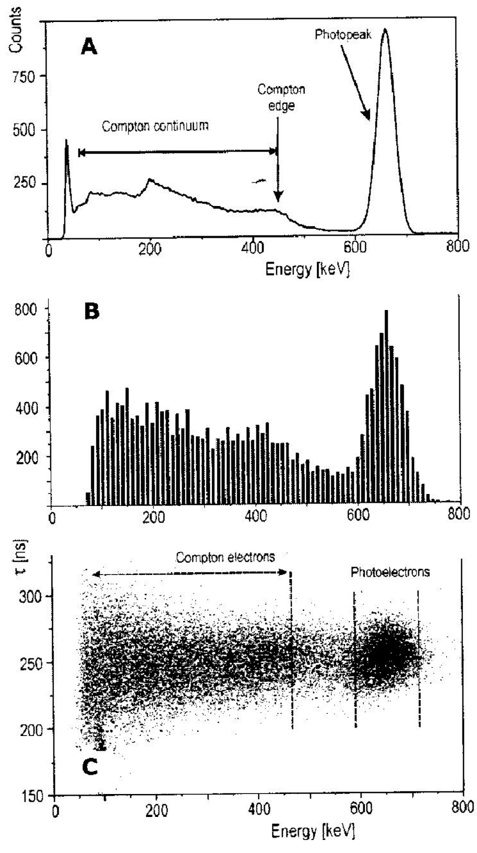

Figure 1 Pulse height spectrum (A) for NaI:Tl. Energy distributions of signal amplitude (B) and time constant (C)

In order to experimental testing of noted conclusion the dependence of scintillation decay time on Compton electrons energy is studied in a present work in comparison with events which took part in peak of full absorption.

A NaI:Tl scintillator of Ø63x63 mm size coupled to Hamamatsu R1306 photomultiplier has been investigated. Firstly, the pulse height spectrum for crystal investigated has been measured with ^{137}Cs source (the energy of gamma-rays is E_γ = 662 keV); see part "A" on Fig.1. Standard apparatuses were used for these measurements. From data of figure it is clearly seen that energy resolution at peak of full absorption (arranged near 662 keV) is equal to 6.1% and Compton edge corresponds to ~ 450 keV.

Le Croy Wave Suffer 422 oscilloscope was used for scintillation pulses recoding. An output of photomultiplier has been connected to entrance of oscilloscope via buffer multiplier. Such elements as RC-chain, filter-shaper, etc.

were not used although it common used in scintillation technique. Each pulse recoded by LCWS has been analyzed and interpolated using least square method by function:

$$F(t) = A_0 + A \exp(-t/\tau), \quad (1)$$

here A is a pulse amplitude, A_0 – afterglow, t is a time, and τ – characteristic decay time (1/e). Besides this an area under initial signal $F(t)$ curve is determined by digital integration for each recorded flash.

All recorded pulses (N = 52 000) in energy range 50 – 800 keV were divided on 800 intervals according to their amplitude. In accordance with part "A" of Fig. 1, each pulse has been assigned to energy of Compton electron. After digital analysis of signal shape the amplitude and decay time were determined for each pulse.

A distribution of number of signals with given energy versus pulse amplitude (or energy) is presented in part "B" of Fig. 1. In comparison of different parts of Fig. 1 it is clear seen that distribution of flash amplitudes on oscilloscope (part "B") well coincide with distribution of events in common pulse height spectrum (part "A"). It can be concluded that distributions on part "B" and "A" are very similar qualitatively. In spite of this similarity it is seen that quantitative difference exists between two curves. In our opinion this difference is connected with different types of excitation (^{137}Cs source was placed on top of scintillator for pulse height measurement, and from one side of crystal for oscilloscope measurements) and on a other side with big noise contribution as it can be seen on part "B" of Fig. 1. We believe that a noted noise can be significantly suppressed if an experiment will be continued in low background laboratory.

A distribution of decay time versus energy of photoelectron or Compton electron is presented on part "C" of Fig. 1. It is clear seen that decay time for Compton electrons (in the range of 50-450 keV) do not depends practically on their energy and well coincides with time constant for photoelectrons (in the range of full absorption peak).

On a base of presented results it can be concluded that scintillation decay time practically do not depends on energy of Compton electrons with E_C decreasing from 450 to 50 keV. Average value of τ_C well coincides with decay time for photoelectron which energy is arranged near 662 keV. We suppose that the reducing of the τ is caused by high density of electron-hole pairs near the K- and especially at L-edge of iodine absorption [2]. The influence of density variation on τ is typical for photoelectrons with energies close to that of the Auger electrons produced in cascade, filling the internal shells of the anion.

References:

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[2] A.V. Shkoropatenko, A.V. Kolesnikov, A.M. Kudin, et al., This issue (2013).