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April 1967 KFK 598

Zyklotron-Laboratorium

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G. Christaller

GESELLSCHAFT FÜR KERNFORSCHUNG M. B. H.

KARLSRUHE

NUCLEAR INSTRUMENTS AND METHODS 50 (1967) 173–176; © NORTH-HOLLAND PUBLISHING CO.

EXPERIMENTAL PEAK/TOTAL RATIOS OF A 4″×4″ NaI(Tl) CRYSTAL

G. CHRISTALLER

Cyclotron Laboratory, Karlsruhe Nuclear Research Center, Karlsruhe, Germany

Received 23 December 1966

The peak/total ratios of a 4″×4″ NaI(Tl) crystal were determined at the distances 45 cm, 30 cm, 15 cm and 7.5 cm. Neither shielding nor a collimator were used.

Since the calculated peak/total ratios mentioned in literature[1,2]) are higher throughout than the experimental data[3-5]), the peak/total ratios of a 4″×4″ crystal* were measured at various distances in an open geometry, i.e. without shielding, without collimator, with a source diameter of 3 mm. The scintillation counters were mounted on a plexiglass tube as the support; the respective distances to the walls, the floor and the ceiling being at least 1 m. Hence, the back-scattering fraction outside the detector decreased to a value below the statistical error. The crystals were encased in a copper canning to keep the background as low as possible. The fraction of quanta backscattered from the canning of the crystal was determined by the extrapolation method described by Weitkamp[6]); in addition, the scattering fraction and the absorption in the front face of the canning were considered.

* Matched-window line of the Harshaw Company.

The sample holder consisted of two thin aluminium tubes on which a plexiglass plate as a sample carrier could be moved to the desired distance. The sample proper had either been deposited on a Hostaphan foil, or it was a self-target of 20 μm thickness directly irradiated in our cyclotron. The isotopes used for measurement are listed in table 1 along with the respective energies. The activity was kept low enough for pulse pile-up and change in the amplification factor of the photomultiplier to be insignificant.

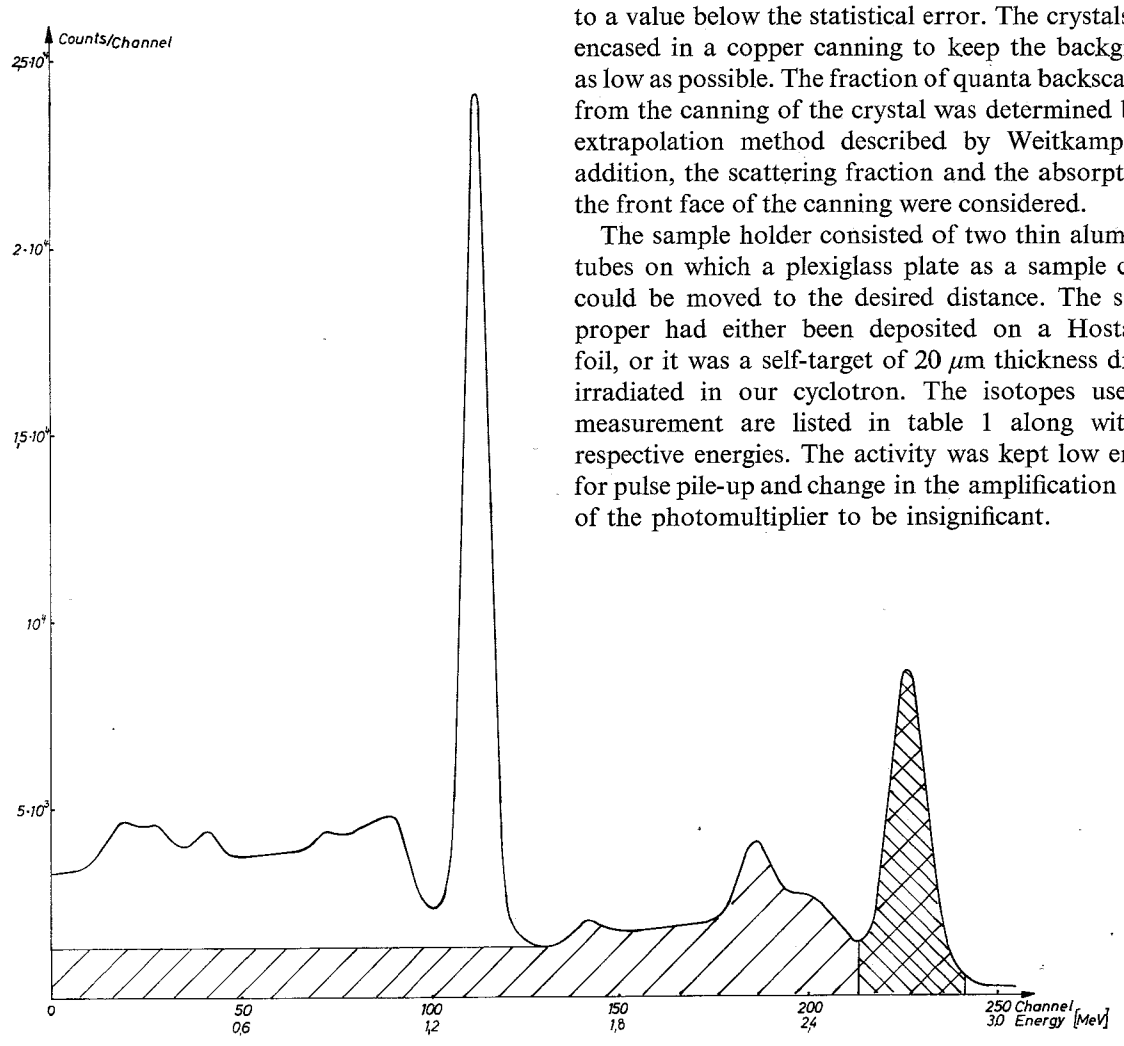

Fig. 1. γ-spectrum of ^{24}Na, measured by a 4″×4″ NaI(Tl)-crystal. Source distance 7.5 cm, no absorber, energy scale 12 keV/ch.

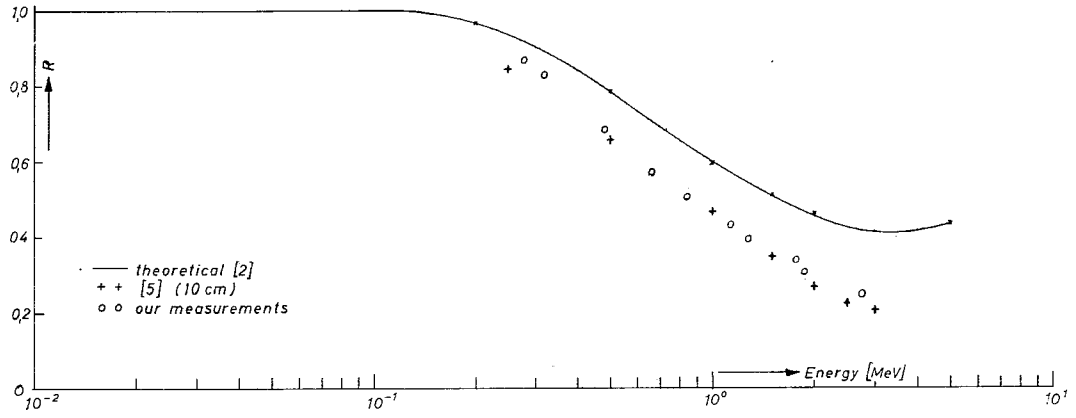

Fig. 2a. Peak/total-ratio R for a 4″×4″ NaI(T1)-crystal. Source distance: 7.5 cm.

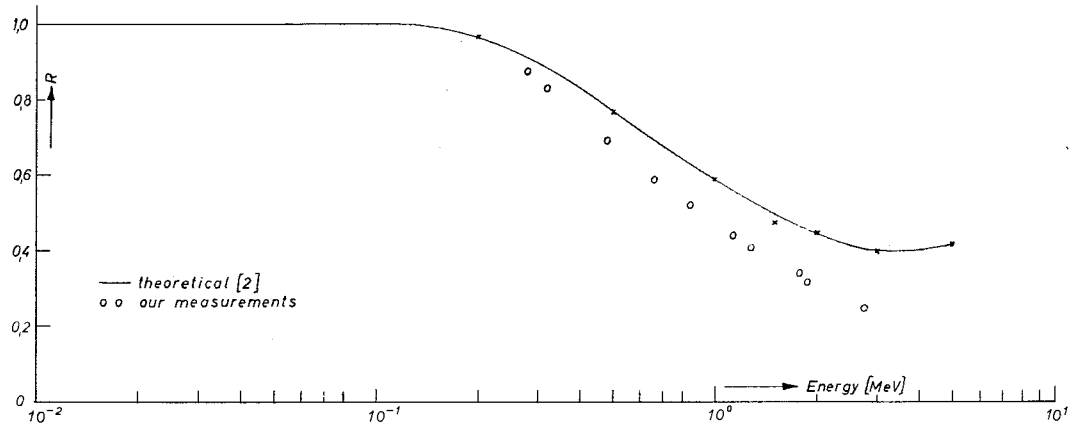

Fig. 2b. Peak/total-ratio R for a 4″×4″ NaI(T1)-crystal. Source distance: 15 cm.

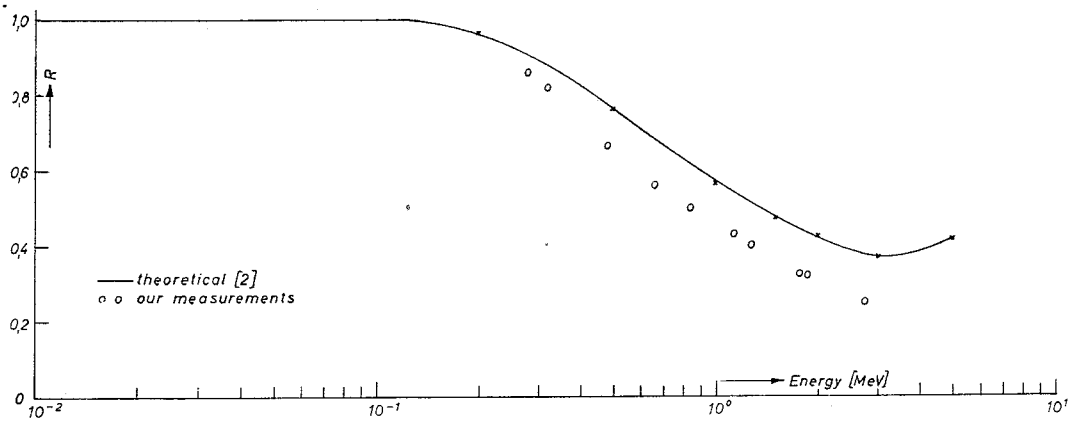

Fig. 2c. Peak/total-ratio R for 4″×4″ NaI(T1)-crystal. Source distance: 30 cm.

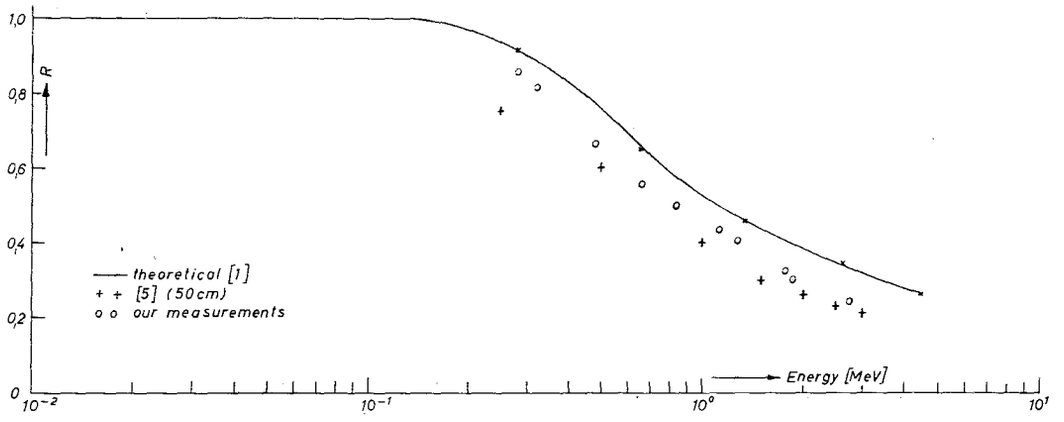

Fig. 2d. Peak/total-ratio R for a 4″×4″ NaI(Tl)-crystal. Source distance: 45 cm.

TABLE 1

Isotopes used with the respective γ-energies.

Isotope	γ-energy (MeV)	Isotope	γ-energy (MeV)
^{109}Cd	0.088	^{65}Zn	1.114
^{203}Hg	0.280	^{22}Na	1.28
^{51}Cr	0.320	^{28}Al	1.78
^{17}Be	0.478	^{88}Y	1.85
^{37}Cs	0.662	^{24}Na	2.75
^{54}Mn	0.835		

The output signal of the multiplier was fed into a Nuclear Data ND 130 AT multi-channel analyzer.

Owing to the open geometry the backscattering peak was small. However, to the extent that it was detectable it was subtracted. The pair escape peaks, if existing, were added to the total intensity, while any possibly present annihilation radiation peaks (511 keV) were subtracted. A typical example of the determination of the peak-to-total ratio is shown in fig. 1 for the γ-spectrum of ^{24}Na.

The measured peak/total ratios are indicated in figs. 2a-d for the source-crystal distances of 7.5, 15, 30, 45 cm respectively. The maximum error is $\pm 4\%$. It is composed of the statistical error ($<1\%$), the error caused by the more or less arbitrary cutoff of sections of the spectrum (e.g. backscattering peak, possibly second peak with Compton continuum, etc.) and of an uncertainty in the geometry, since the distance between the canning face and the crystal face could not be determined with great accuracy, which contributed to an increase in the error, especially for a distance between source and crystal of 7.5 cm.

As was to be expected from the experimental peak/total ratios of other authors, all our data also are below the ratios determined theoretically. The deviations are up to 60%. Leutz et al.[5]) attempted to explain this in part by the fact that in the calculations the interaction of γ-radiation with the container of the crystal was not considered. However, in our measurements the influence of the copper canning, though not of the Al_2O_3 reflector, was determined and taken into account. In addition, the absorption of the front face of the canning was also determined by the extrapolation method. The resulting corrections for the peak/total ratio were up to 12%. This is in good agreement with the differences between the measurements carried out by Leutz et al. and ours. However, this does not explain the large deviations from the data determined by theoretical methods.

Therefore, we adopted another method of checking our data. We checked the activity by means of our measured peak/total ratios for samples containing five different nuclides (^{137}Cs, ^{54}Mn, ^{65}Zn, ^{22}Na, ^{88}Y) the activities of which were accurately determined within $\pm 1\%$ by the $4\pi\beta$-γ-coincidence method. The values used for the crystal intrinsic efficiencies were those of Heath[7]).

The agreement with the activities determined by the two methods was always within the $\pm 4\%$ mentioned above.

Also the deviations in the peak/total ratio from each other for various source-crystal distances are within $\pm 4\%$ accuracy. However, a certain systematic can be recognized. Thus, the values for a source distance of 15 cm are slightly higher in almost all cases.

The author would like to thank Miss U. Martens who performed most of the measurements and made the drawings.

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