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A. Benvenuti, P. Blasi, P. R. Maurenzig and P. Sona :

ON THE GAMMA SPECTRUM IN THE DECAY OF Ba^{133}.

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The level scheme of Cs^{133} following the decay of Ba^{133} ($T_{1/2}$ = = 7.2 y) is now well established(1). The energies of several gamma transitions, however, were determined only in a few measurements with poor energy resolution from the analysis of internal conversion electrons by means of lens spectrometers(2, 3), while the poor resolution of NaI crystals does not allow energy measurements accurate enough.

Moreover there is no agreement in the reported values for the intensity ratio of the 53 keV gamma ray to the 79-81 keV gamma cascade owing to several experimental difficulties connected with the use of NaI (Tl) crystals, namely superposition of the escape peak from the intense 79-81 keV transitions with the 53 keV gamma line, x ray - x ray summing and backscattered radiation.

A very elaborate measurement (intended to overcome the above difficulties) has recently been reported(4). This yielded a value of 0.28% for the intensity ratio of the 53 keV transition to the 79-81 keV γ cascade, which is about an order of magnitude lower than all the preceding results.

Therefore, a new analysis of the gamma spectrum of Ba^{133} with germanium detectors seemed to us worthwhile. In fact, these detectors with their high intrinsic resolution, allow pretty accurate energy determination. They afford also favourable conditions for the determination of the intensity ratio of the 53 keV line to the 79-81 keV cascade, because the escape peak of 79-81 keV lines is expected to fall far apart from the 53 keV line.

We used a lithium drifted germanium detector (1 cm^2 x 1 mm supplied by Solid State Radiations) cooled down to liquid nitrogen temperature

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(x) - Work done in the frame of the EURATOM-CNEN contract for fundamental research in nuclear physics.

TABLE I

Calibration energies (keV)

Kα -	X ray	in Tl^{203}		72,20
	γ ray	in Tl^{203} (from Hg^{203})		279,12
Kα	X ray	in Pb^{207}		74,26
	γ ray	in Pb^{207} (from Bi^{207})		569,70
	γ ray	in La^{139} (from Ce^{139})		165,84

and mounted in a vacuum chamber with facilities for changing sources in vacuum.

The gamma lines used as reference standards for energy calibration are reported in Table I; Ba^{133} was supplied by ORTEC as beta source. The position of each peak was carefully determined assuming a gaussian shape. A straight line was fitted to the calibration points in each run, by the least square method and checked by the χ^2 test. The corresponding values for the transition energies in Cs^{133} were then deduced from this straight line.

The transition energies obtained as an average of several independent runs are reported in Table II and compared with some of the previously reported results; the error quoted in our values is the standard error of the mean. A typical Ba^{133} spectrum is shown in Fig. 1. From the measured energies quoted in Table II we can assign the energies to the level scheme of Cs^{133} reported in Fig. 2.

TABLE II

Gamma ray energies (keV)

	Present work	(a)	(b)	(c)	(d)	(e)
γ_1	52,9 ± 0,1		56	53	56	54
γ_2	276,3 ± 0,2	276 ± 1	277	274	274	276
γ_3	302,6 ± 0,2	302	302	302 ± 6	302	301
γ_4	355,7 ± 0,3	355 ± 2	356,5 - 358	355 ± 7	358	356
γ_5	382,9 ± 0,4		383	380 ± 8	381	386
$\gamma_6 + \gamma_7$	80,7 ± 0,1	79 ± 1 79 ± 5	78,6 - 79	78 81	79 79	80 82

(a) - Ref. (2); (b) - Ref. (3); (c) - Ref. (6); (d) - Ref. (5); (e) - Ref. (7)

The measured energy of the $\gamma_6 + \gamma_7$ cascade should be within 0.1 keV of the γ_6 energy according to the available values of the γ_6 to γ_7 intensity ratio. Therefore the internal consistency of energy assignments in Fig. 2 is about 0.4 keV.

The intensity of the 53 keV gamma line turns out to be about 5% and surely not less than 3% of the 79-81 keV γ cascade. This lower limit does not seem to be affected by spurious effects since the high resolution of germanium detectors enables one to well separate the strong x-ray peak and to easily recognize the presence, if any, of the backscattering peak and x ray - x ray sum peak. In fact, the intensity of the last two comes out in our working conditions to be negligible.

A precise determination of the intensity of the 53 keV gamma line would require a detailed knowledge of the detector intrinsic efficiency in the 50 - 100 keV energy region and for this purpose work is in progress. Finally, no evidence has been found for the 436 keV transition reported by Gupta et al.[(3)] not even from an analysis of internal conversion electrons by means of silicon solid state detectors.

From our result assuming a value of 0,64 for the intensity ratio of the 79-81 keV γ cascade to the 355 keV line[(7)], we obtain a value of about 30 for the intensity ratio of the 355 keV γ line to the 53 keV transition.

This intensity value allows one to accept the commonly reported scheme[(8)] (see Fig. 2)[(x)] without introducing unduly large retardation or enhancement factors that would be required by the intensity ratio 560 obtained in ref. [(4)].

In fact in this scheme, even if we assume no enhancement for the pure E2 355 keV transition the retardation factor for the (pure M1) 53 keV transition becomes $\approx$ 500. Now the 53 keV transition is expected to be l forbidden if one assumes that the 436 keV and 383 keV levels are shell model s1/2 and d3/2 states. The retardation factor of 500 we have found appears quite reasonable since the well studied 81 keV transition (which is almost pure M1 l-forbidden transition) is retarded by a similar factor i.e. 400[10]).

We are grateful to Prof. M. Mandò for his constant encouragement and many helpful discussions.

(x) - γ - γ and γ - e angular correlation measurements of Subba Rao[(9)] on the 355 keV - 81 keV cascade seems to favour the spin assignment 3/2 to the 436 keV level, but the failure in observing it by Coulomb excitation, as well as the absence of a transition to the ground state with measurable intensity strongly support the spin assignment 1/2.

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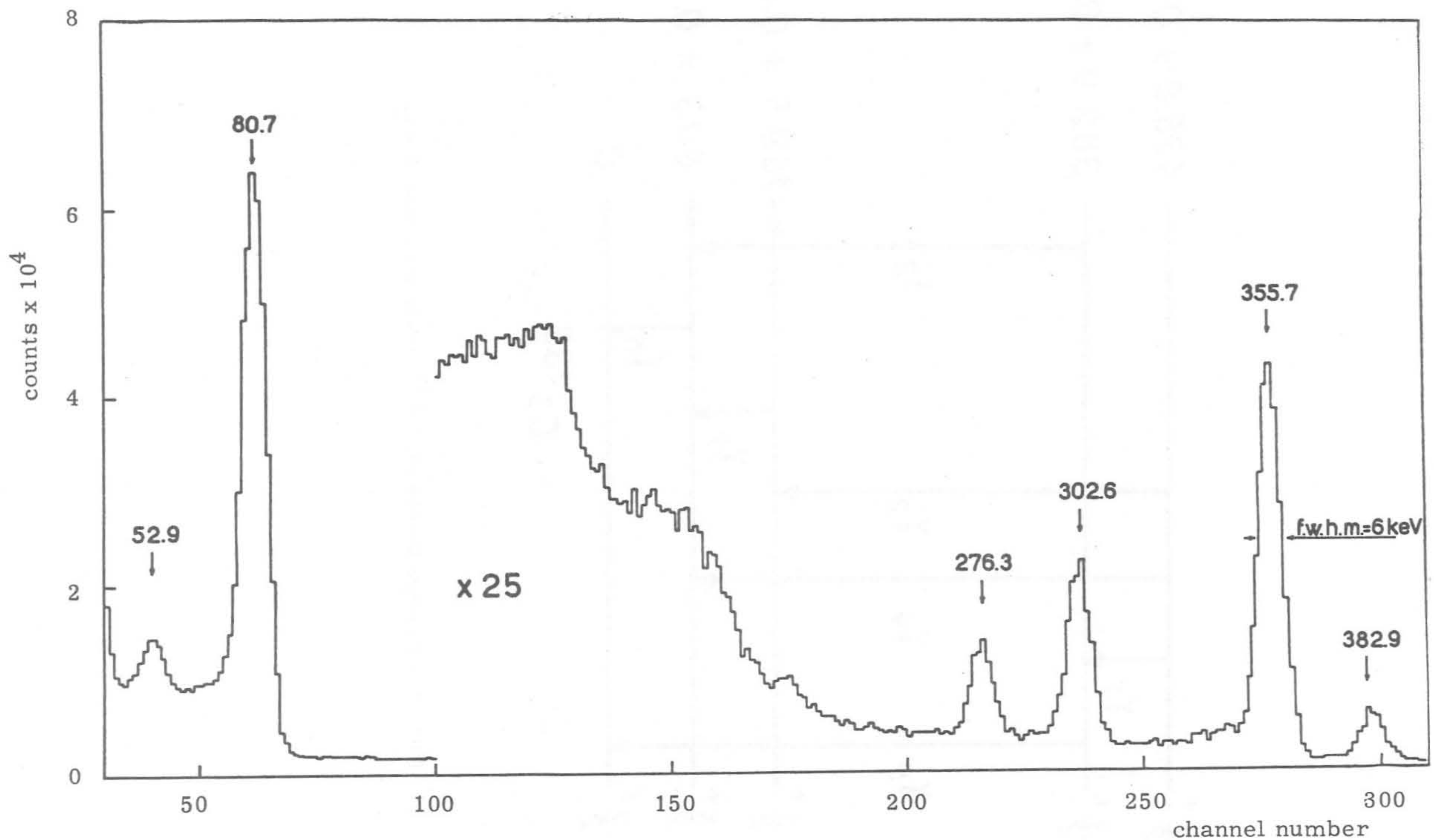

FIG. 1 - Gamma-ray spectrum of Ba^{133} observed with 1 cm^2 x 1 mm germanium lithium drift detector. -

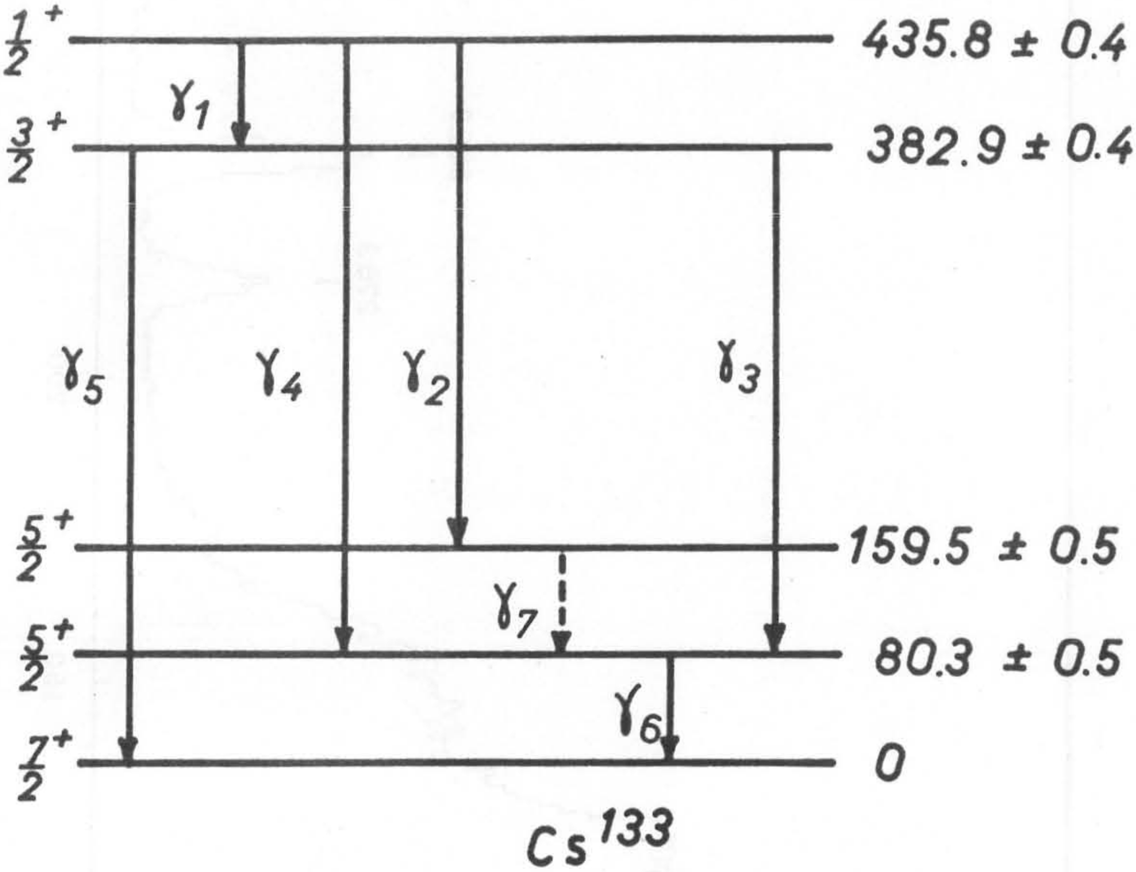

FIG. 2 - Energy levels of Cs^{133} based on present data. -