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A HIGH ENERGY ANTICOINCIDENCE GAMMA RAY SPECTROMETER

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PRELIMINARY RESULTS ON "HAGAR" A HIGH ENERGY ANTICOINCIDENCE GAMMA RAY SPECTROMETER

Alessandro ZUCCHIATTI
INFN - Sezione di Genova, and
Wits-CSIR Schonland Centre, Johannesburg

1. - INTRODUCTION

Large sodium iodide crystals in association with an anticoincidence plastic scintillator shell have become a standard detection system whenever gamma ray spectroscopy has to be performed with high efficiency , large solid angle , good energy resolution and convenient cost . The technology of semiconductor detectors and of very high Z scintillating materials have begun to reduce , with their progresses , the applications of NaI in both low and high energy spectroscopy . Never the less the continuous improvements [1] on the basic design of a typical sodium odide anticoincidence spectrometer have made this instrument unrivaled in medium energy gamma spectroscopy , where semiconductor detectors cannot associate a convenient detection volume to their excellent resolution and high Z scintillators cannot provide , together with their high efficiency , a total resolution comparable to that of actual NaI detectors .

One of these scintillator spectrometers has been chosen as the basis of a research program [2] on medium energy radiative capture reactions to be performed at the National Accelerator Centre (NAC) in Faure (Republic of South Africa) , where the open sector cyclotron will provide proton beams from 27 to 200 MeV .

While the design of this particular spectrometer has been the object of a previous article [3] , we would like here to provide a schematic description of the detector system and a summary of its performances as they have been measured at the Tandem Van de Graaff EN of the Schonland Research Centre in Johannesburg , where the detector has been set for a series of low energy runs .

2. - THE SPECTROMETR DESIGN

The spectrometer consists of tree detectors : a NaI(Tl) cylinder (Ø = 23.8 cm , height = 35.6 cm) seen by seven RCA 4900 photomultipliers ; an annulus of plastic scintillator (BC408) (inner Ø = 28.86 cm , thickness = 9.84 cm , length = 61 cm) divided into six optically separated sectors each seen by two Amperex XP-2202 photomultipliers ; a front disc (Ø = 48.58 cm , thickness = 8 cm) seen by tree XP-2202 photomultipliers sitting on the disc side and spaced 120 degrees each other .

The assembly (Figure 1) is completed by a modular lead shield extending both laterally and in front for a shielding thickness of not less than 11 cm with a maximum of 25 cm in the direction of the target. Photon collimation is insured by a component of this shield which can be easily replaced if a different solid angle has to be selected . In our test runs the collimation was such that with the sodium iodide front surface positioned 120 cm away from the target , the whole back surface was spun by the reaction photons .

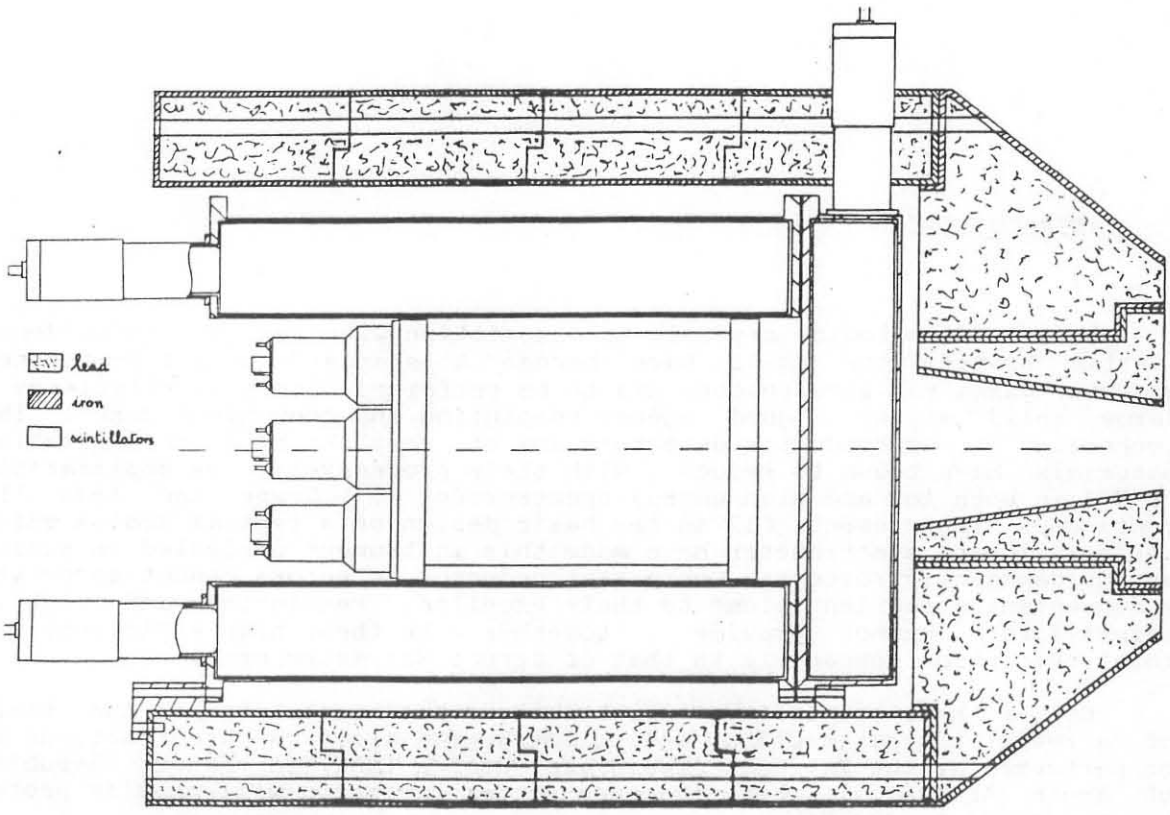

Fig. 1 - The spectrometer layout including the three scintillators and the lead shielding.

The detectors have been manufactured by Bicron Corporation , following the remarkable improvements obtained with the Brookhaven MKIII model [1] . The peculiarities of these new detectors are :

a) The NaI(Tl) is grown as a single ingot , Bicron being the builder of the largest single ingot crystals in the world . An accurate polishing of the crystal surface is made imposing uniformity contraints at 6.13 MeV (^{244}Cm-^{13}C source ; average penetration depth 8 cm) , instead than at 0.661 MeV as usually before (^{137}Cs ; penetration depth 1 cm) . The iterative polishing technique is expected to improve considerably the uniformity of light collection from any point of the crystal and therefore to improve the energy resolution of the detector .

b) The plastic shell is divided , as already said , into six optically separated sectors each seen by two photomultipliers . This insures much better light collection than that of a single annullus or a double semi-shell anticoincidence shield . The advantage is that the resolution of the entire annulus can be improved to that of a single sector allowing a more precise definition of the energy threshold in the anticoincidence detector for a more accurate rejection of events falling on the peak tail . Another advantage of this particular configuration is that the whole (annulus + disc) anticoincidence shield can be tuned for a negligible response disuniformity . This avoids square summing of the disuniformity contribution to light collection effects which remain , in practice , the sole responsible for total energy resolution .

c) Great care as to be devoted to the short and long term stability of the NaI detector and in fact we will have stabilized photomultiplier bases on the main crystal phototubes and a precision light pulser to monitor the NaI gain and the electronic chain .

3. - DETECTOR SET UP AND PERFORMANCES

The photomultipliers in the plastic annulus , and in particular the two on the same sector , were tuned for equal gain measuring the half height of the ^{137}Cs peak along the trailling edge . The disc was similarly tuned positioning the source in the centre and imposing the same overall response of one of the annulus sectors with the tree phototubes giving independently equal responses . In this way we could achieve a disuniformity over the entire (annulus + disc) anticoincidence shield of 8.6% (figure 3a) , when a collimated ^{137}Cs source was moved across 79 points of the shield inner surface . Similar results were obtained when the source was moved along the anticoincidence axis . The good uniformity was accompained by an energy resolution for a single sector of 44% for the ^{137}Cs line at 0.661 keV . This value is not as good as the best quoted value of only 20% [1] . This fact , which we tentatively ascribe to a poorer light reflection from the scintillator boundaries , is reflected partially in the actual rejection of peak tail events at 22 MeV .

Each of the seven NaI phototubes was adjusted for the same gain when a collimated ^{60}Co source was positioned along the detector axis about 30 cm away from the front surface .Only small gain differences were necessary confirming that the photomultipliers had been factory selected for best uniformity . This type of tuning with a point like source was found practically equivalent to the tuning performed with volume distributed background radiation . The seven anodes were coupled to 93 Ohm and processed by an Ortec 113 preamplifier and a Canberra 2010 Amplifier . The single crystal resolution for the ^{137}Cs line was 7.7% and values for

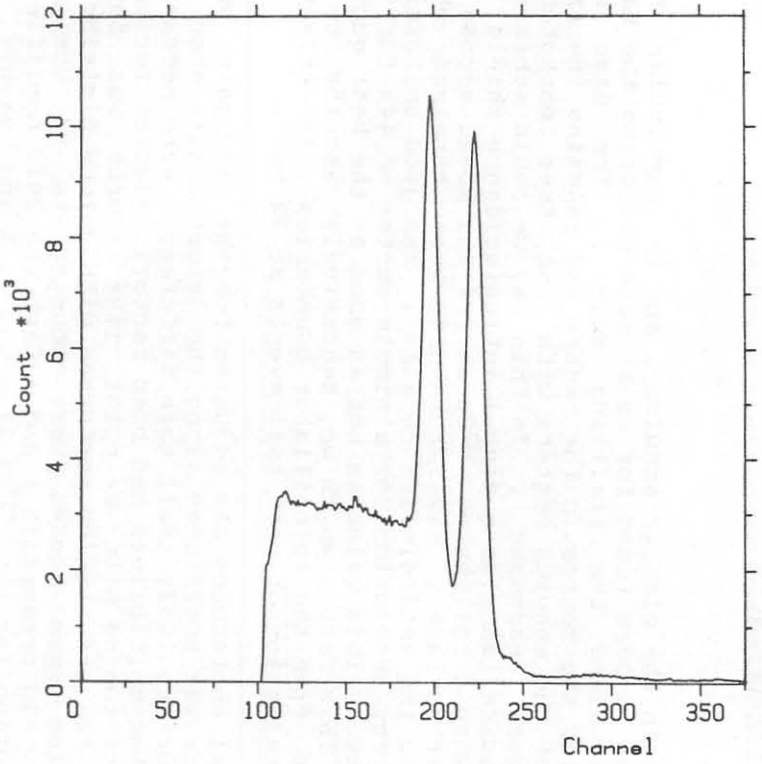

Fig. 2 - A single crystal low energy photon spectrum from a collimated ^{60}Co source.

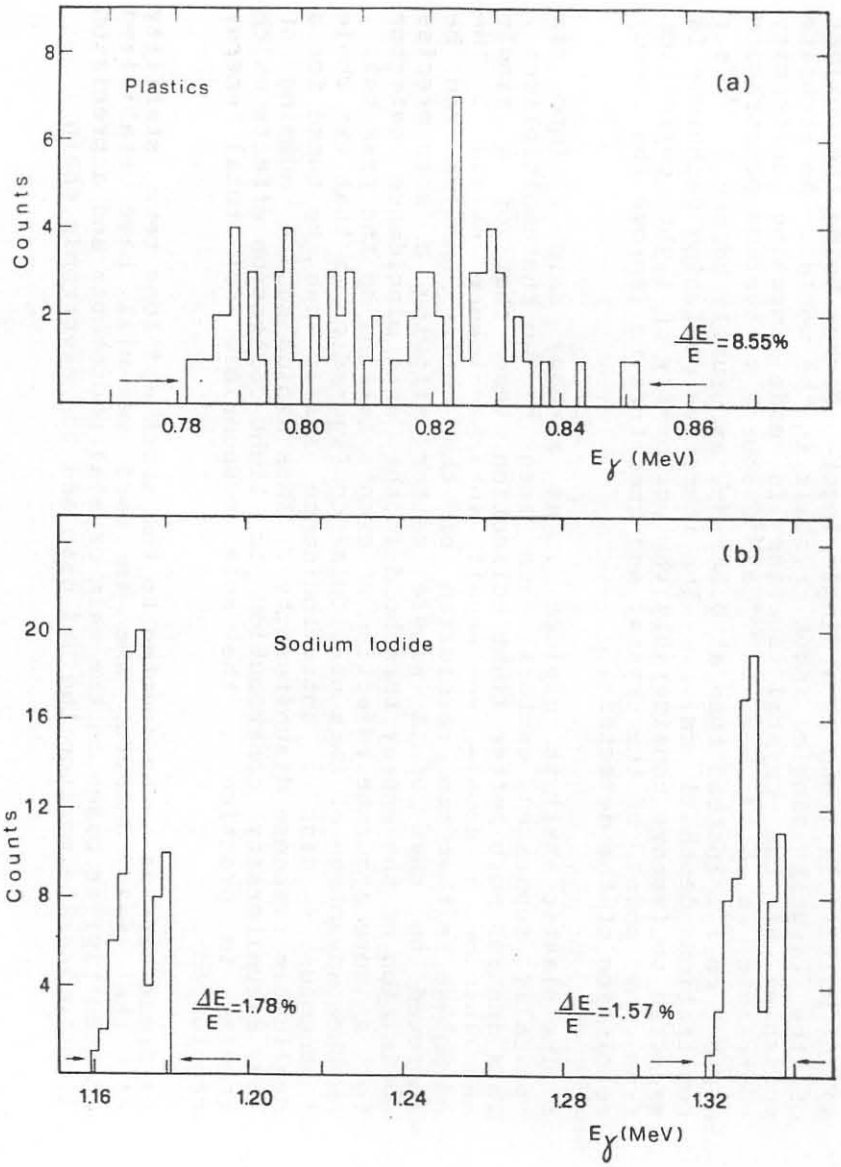

Fig. 3 - a) Uniformity histogram for the whole (annulus + + disc) anticoincidence shield as deduced from 79 points of the shield inner surface using a collimated ^{137}Cs source. b) Uniformity histogram for the NaI crystal as deduced from 79 points of the lateral and front surface using a collimated ^{60}Co source.

the two ^{60}Co lines were 5.9% and 5.3% respectively and went down to 5.7% and 5.25% in the anticoincidence set up . The adoption of a shorter (0.25 μs instead of 1 μs) amplifier shaping time resulted in a 0.1% contribution bringing the two resolutions for ^{60}Co at 5.8% and 5.4% respectively . A collimated ^{60}Co was moved across 79 points of the lateral and front NaI surfaces and the resulting overall disuniformity was of 1.78% at 1.17 MeV and 1.54% at 1.33 MeV as figure 3b shows . If we compare our results to those of reference [1] we see that both the ^{137}Cs resolution and the disuniformity are slightly larger. This is expected to affect the resolution at 22 MeV but it has already been stressed that the higher is the energy at which calibration is performed the better the results at very high energy will be .

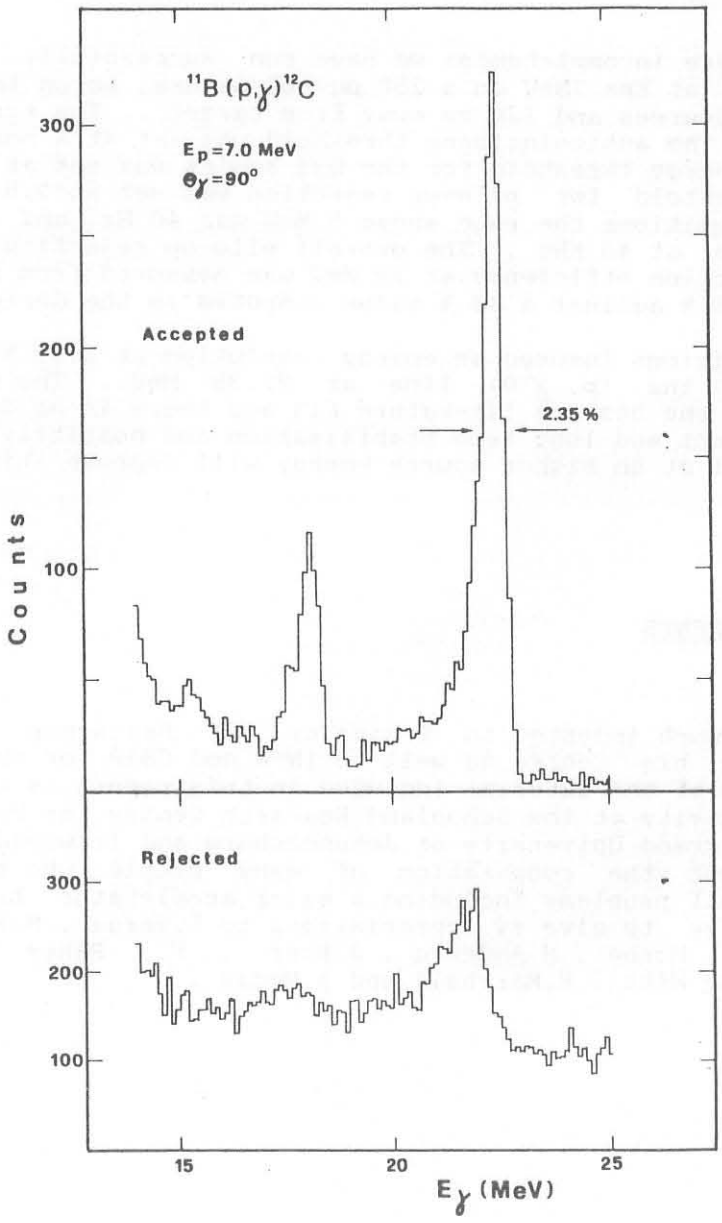

Fig. 4 - High energy photon spectrum from the $^{11}B(p,\gamma)^{12}C$ reaction at E_p = 7 MeV and θ_γ = 90 degrees. NaI-target distance = 120 cm.

It has already been underlined that the role played by the linear and logic components of the electronic chain associated to such detectors is not of second importance respect to crystal uniformity and light collection . The configuration we chose for our system has already been discussed [2] and follows closely that of a similar detector [4] . It must be reminded that the general set up is still in a developmental stage and will only be in its optimal configuration once the spectrometer is installed at NAC . In particular during these test runs no attention was devoted to gain stabilisation since it was reputed relatively unrelevant due to short collection times required for the accumulation of statistically significant high energy photon spectra . Furthermore the extremely low count rate recorded when the tandem beam pulsing (5 ns every .500 μs) was used brought the photons count rate well below the cosmics rate , making photon-neutron discrimination practically impossible.

Despite these incompleteness we have run successfully the reaction $^{11}B(p,\gamma)^{12}C$ at Ep= 7MeV on a 250 μg/cm2 natural boron target with the detector at 90 degrees and 120 cm away from target . The result is seen in figure 4 . The anticoincidene threshold was set at a nominal value of 40 keV ; the energy threshold for the NaI logics was set at 9 MeV and the NaI lower threshold for pile-up rejection was set at 0.5 MeV . In our experimental conditions the rate above 9 MeV was 40 Hz and the plastics count rate was at 40 KHz . The overall pile-up rejection was around 8% while the collection efficiency at 22 MeV was measured from the spectra in figure 4 at 46.6 % against a 43 % value computed in the design stage [3] .

These conditions insured an energy resolution at 2.35 % FWHM and 8.0 % FW1/10M for the (p,γ_0) line at 22.38 MeV . The values compare favourably with the best in literature [1] and there is no doubt that the inclusion of short and long term stabilisation and possiblly the tuning of the main crystal at an higher source energy will improve this result .

4. - ACKNOWLEDGMENTS

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