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Update
Scintillator Detectors

Author: N.M. Clarke

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CsI(Tl) Scintillator/Photodiode Detector

Test on the prototype detector for the new CHARISSA array

by

N. M. Clarke
School of Physics and Space Research
University of Birmingham, B15 2TT, U.K.

1. **Introduction**
At the time of writing, the detector ordered from Bicron, via Southern Scientific has not arrived, but the detector from Quartz & Silice via John Caunt Scientific was delivered about two weeks ago and has undergone a number of tests.

2. **The Q&S detector prototype**
This detector consists of a solid piece of CsI(Tl) crystal which has a front face 50mm $\times$ 50mm with an active depth of 10mm sufficent to stop about 200MeV alphas. The crystal is then tapered for a further 15mm to a 18mm $\times$ 18mm square , onto which an S3204–03 photodiode is glued. This has two pins which are soldered into a PCB on which the high-gain hybrid FET preamplifier is mounted together with a few other passive components and a ribbon cable connector. After only a few handlings, one of the pins on the diode broke off, and I had to solder it back; a recurrence of this problem was solved by putting two blobs of Araldite between the plastic surround of the diode and the PCB thus fixing the two together. The ribbon cable is 14 wires, carrying signal output, test pulse input, +12V, -12V and +30V bias; an adapter board was made to Conhex sockets to allow the detector to be used inside our test vacuum chamber, and all unused ribbons were earthed. The ribbon was about 75cm long. The test figure for the resolution for 662keV gammas measured by Q&S was 18.1%/18.9% at 4ms/2ms shaping time respectively; the 662MeV gammas yield about 20mV signals from the preamp into 1MΩ. An additional short Conhex cable was soldered onto the PCB output signal to test whether there was any difference in resolution between this output and that via the ribbon cable.

3. **Tests**

The first test were carried out in the scattering chamber of the Radial Ridge cyclotron using the 3-$\alpha-$ source (5.15,5.49,5.81 MeV). The results were not promising; the alphas were coalesced into one peak, and were scarcely resolved from the huge background of gamma rays. In addition, there seemed to be a problem with noise pickup on the long (doubly shielded!) cables from the scattering chamber, which were not present when I tested the early 18mm $\times$ 18mm detectors which had a low gain preamp with a 1000Ω output impedance. The high gain of the new preamplifier makes noise on the power lines to the preamp and pickup on signal lines important. It therefore seems likely that the main amplifiers for the scintillators will need to be as close to the preamplifiers as possible — a conclusion also reached about the 18mm detectors. It is possible that going to a high gain preamp has not significantly improved the noise problem, owing to its higher sensitivity; however it means that that we should be able to use a main amplifier with lower gain. The present detector yields a pulse of about 32mV for 5.5MeV alphas ie a gain of 5.8mV/MeV compared with about 1mV/MeV for the early 18mm detectors. This means that a 60MeV $\alpha-$ particle gives a preamp signal of about 360mV with a main amp. gain of 28, whereas the 18mm detectors gave a signal of only 60mV (down in the noise!) and required a gain of about 180 for 10V output.

The later tests were carried out in the small vacuum chamber in the relatively noise (and gamma) free environment in G7. Resolution for $\alpha-$ particles was explored as a function of type of cable on output, power supplies, bias voltage, shaping time. Spectra were recorded on a Nucleus MCA–PC with 512 channels. The same Tennelec 203BLR amplifier was used as for the orginal tests on the 18mm detectors.

There was no evidence that the resolution was better with the signal emerging via the Conhex cable than through the ribbon.

The resolution is much poorer for $\pm$15V power supplies than for $\pm$12V, and there is evidence of drifting, suggesting a warmup of the FET preamp in vacuum. Its dissipation is about 0.2W.

The pulse height as a function of bias voltage for 2ms shaping time was as follows:-

Bias (V)	Pulse-height (5.1Mev α)
10	324
15	335
20	341
25	361
30	373
35	378
40	368

This indicates that the full pulse height is reached at just over 30V bias. Tests with a single ^{241}Am source gave the following values:-

Shaping time (μs)	Resolution (%)	Pulse Height
0.25	14.5	147.4
0.5	11.6	251
1.0	11.5	328
2.0	9.4	394
4.0	9.0	427
8.0	9.8	427

Notice that the full pulse height is not reached until 4ms shaping time, where the resolution is best. However such a long time constant poses problems under high count rate situations. The resolution and pulse height are not much worse at 2ms. A long count over 4 hours gave a resolution of 10.8% for 2ms ; this indicates good stability and suggests a resolution of about 600keV (Fig. 1). However the spectra with the 3–α source indicate that the 3 peaks are just about resolved, and in the region of the $\alpha-$ peaks I obtained a dispersion of about 8.0keV/channel with a peak width of 37channels for the ^{241}Am peak - this yields about 300kev resolution (Fig. 2). This shows that the scintillator response for low energy $\alpha-$ particles is non linear, and resolution cannot be estimated from a single energy α–particle source. An extrapolation to a 55MeV $\alpha-$ particle would give about 900keV resolution, but we not know about the non-linearity over this energy range.

A test was carried out using a strong (3mCi) ^{60}Co γ–ray source near the test chamber, to examine the performance in the presence of high gamma ray flux. The gamma count rate above 0.25MeV was 15kHz. At 4ms shaping, the peaks from the 3–$\alpha-$ source are simply swamped by the pileup from the gamma rays, but can be seen much better with 2ms shaping time (Fig. 3), although the resolution is considerably worse than that obtained at low count rates. At 1ms shaping time the $\alpha-$ peaks stand well clear of the gamma background (Fig. 4), helped by the suppression of the pulse height for gammas at small time constants, although the pulse height and ultimate resolution for the alphas is worse at this shaping time. The suppression of the γ–ray pulse height at short time constants is detailed in my first report on the 18 mm detectors. Therefore it is suggested that for charged particle detection , these scintillators are operated at 2ms shaping time, unless there is a very large gamma flux, when 1ms would be better.

The last test attempted to determine the point resolution of the detector. Fig. shows the mask which was placed in front of the detectors. Seventeen 2mm holes were drilled; a 10mm spacing was used between holes on the horizontal and vertical axes and a 15mm spacing along the diagonal axes. The 3-α– source was placed in front of each hole in turn and the spectra shown in Fig.

5 obtained. Notice that every point shows a spectrum with better resolution than that obtained in Fig. 2; in some cases the resolution approaches about 150keV, and even in the corners of the detector, the resolution is maintained at about 200–250keV. However, the variation in pulse height across the detector face (shown below the Hole number) shows a variation from about 316 to 370 with a mean of 341 and mean deviation of 10 channels. Assuming these responses correspond to equal areas, then the mean deviation corresponds to about 80keV. This produces a 'flat-top' broadening which adds to the intrinsic energy resolution and produces something like the 300kev that we observe in Fig. 2. The results give us some guidance on the amount of calibration that we might need to give the array of detectors. If we are content with, say 400—500KeV accuracy on our energy calibration then a 'whole-face' calibration with an $\alpha-$ particle beam is good enough. Otherwise we might need to use the position sensitivity provided by a silicon detector to map out the pulse heights point by point across the face, and correct the response using a spline function. I should add that our first tests on 18mm crystals showed that the energy response extrapolated from a 5.5 Mev $\alpha-$ source was maintained quite well to energies of 50MeV or so, but that there are variations of about 10% or so between different light ions. Hence experiments that require precise energy calibrations for a number of light ions will need to spend time using a variety of beams to calibrate.

4. Conclusions

The overall response of the CsI(Tl) detector seems satisfactory. It provides a gain of about 6mV/MeV (CsI) which is similar to the 10mV/MeV (Si) provided by our present preamp design. The hybrid FET preamp can always be changed for a lower gain version if necessary. The energy resolution across the whole face for 5.5 MeV α–particles is about 300keV; assuming this is dominated by statistics, a "whole face" resolution of 900keV for 50MeV alphas is predicted; however the point resolution would be about 450–600keV. □