Using the DGF-4C with scintillator detectors

DGF modules are most commonly used with semiconductor detectors for ionizing radiation. In these, the weak detector signal is sent to a charge integrating preamplifier. This arrangement allows storing the signal on a capacitor for a lengthy period of time. The step-like output from the preamplifier can then be filtered with a time constant of several microseconds, which is much longer than the original current pulse that lasted only a few hundred nanoseconds. This scheme helps to greatly suppress the electronic noise.

In scintillator detectors a photomultiplier detects the light and converts it in real time into an electric current. This current will typically decay exponentially with time. That decay constant is 230ns to 400ns in NaI depending on the dopant. The photomultiplier is a very low-noise amplifier for this current, and at the same time it is fast enough to track the light pulse in time. In scintillator detectors the energy resolution is determined and limited by the physics of the scintillation process, crystal inhomogeneities and photostatistics. With a photomultiplier as the amplifying device, electronics noise has very little impact on the energy resolution achieved by a scintillator detector. Thus, a charge integrating preamplifier is not needed in this case.

The DGF-4C recognizes this and allows integrating rapidly decaying current pulses directly without the need for an integrating preamplifier. This note describes the results obtained with a NaI-detector at XIA.

We used a cylindrical Bicron NaI(Tl) detector, measuring 1-inch thick and 1 inch in diameter. It was coupled to a Bicron phototube (PMT) and we used a base with an integrated preamplifier. The PMT was operated with positive high voltage, which means that its anode is at high potential. To couple to conventional electronics, Bicron included a charge integrating preamplifier in to the base assembly of the PMT. From the charge integrating preamplifier we removed the integrating capacitor, leaving in place the bleeding resistor. In this configuration the preamp would work as a current-to-voltage converter, tracing the scintillation light output in real time. We also had to apply some extra filtering of the incoming high voltage. A 20nF capacitor after the input resistor of 1.5MΩ provided sufficient suppression of HV-supply noise and radiative EMI into the HV-cable.

We set the DGF-4C to its lowest gain and adjusted the PMT high voltage such that the dynamic range covered by the wave form digitizer would be 800keV. We set the DGF into integrator mode (set Integrator0=1 when using channel 0) and chose an integration time of 2.4μs. In integrator mode the integration time is given by the peaking/integration time of the energy filter in the InstrumentPanel. The gap time of the energy filter was set to zero.

Figure 1 shows the complete spectrum obtained with a Cs-137 source. The broad peak at high energies is from the 662.66keV radiation and has a fwhm of 47keV or 7.1%. The peak at about 32keV is due to the two K_α-lines of Ba, which are separated by about 0.3keV. The total width of that double peak is 6keV. Note that the detection efficiency for the Ba-K_α-lines is very high. Figure 2 shows a zoom-in around the Ba-K_α-peak to highlight the fact that the trigger threshold could be set at 5.5keV---at a dynamic range of 800keV.

In conclusion, we have shown that the DGF can measure energy deposits in NaI by direct numerical, and real time integration, of the current signal from a PMT, without the need for a charge-integrating preamplifier.

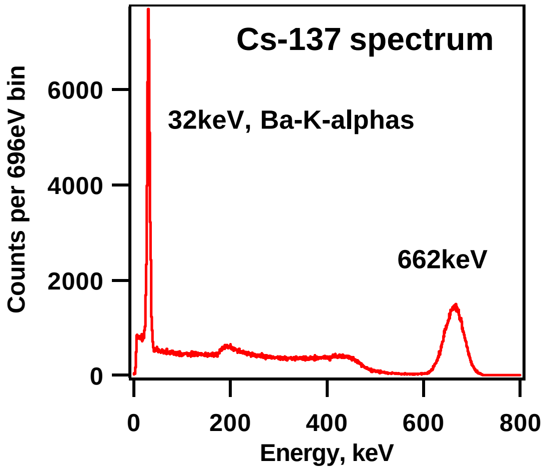

Figure 1: Cs-137 spectrum at 2000cps. The spectrum shows the Ba-K_α-double line at 32keV, the back scatter peak at around 200keV, and the 662keV line from the long-lived (T-1/2 = 2.2min) excited Ba-nucleus created by the Cs-137 decay.

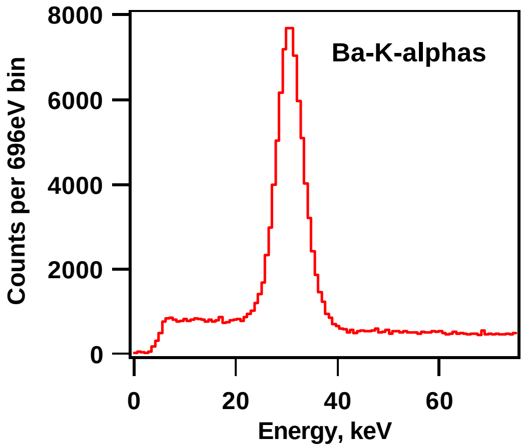

Figure 2: Low-energy part of the Cs-137 spectrum from above, highlighting the 5.5keV trigger threshold of this setup. The two barium K_α-lines are excited with comparable strengths and are separated by about 0.3keV. The fwhm of the combined peak is 6.3keV.