Timing with Thin Plastic Scintillators

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Most experiments performed with the ALADIN spectrometer have employed plastic-scintillator foils in order to measure the arrival time of beam particles. The rates of the heavy-ion beams (Xe, Au, U) were low and did not exceed 10^4/s. In these experiments, time-of-flight resolutions of less than 150 ps (FWHM) have been achieved with the ALADIN time-of-flight wall as stop detector and with a start detector consisting of a scintillator foil with a thickness between 50 μm and 100 μm, tilted by 45° with respect to the beam axis, and viewed from opposite sides by two photomultiplier (PM) tubes which were oriented 90° with respect to the beam axis.

In the most recent series of experiments during spring 1995 the conditions for beam timing were less favourable. The intended study of target fragmentation [1] required rather thin targets, consequently a minimum of material in the beam line upstream, and ^{197}Au beams with rates of the order of 10^6/s. The present report summarizes results of timing studies performed in conjunction with these experiments.

The setup consisted of scintillator foils (BC-418) of 10-μm thickness, mounted in the same way as described above and viewed by two PM tubes (Hamamatsu R2083, 51 mm diam.) at a distance of about 5 cm from the intersection point of the beam axis and the scintillator foil. Active voltage dividers were used [2]. The supply voltages were adjusted in such a way that, at the maximum beam intensities during a spill, the maximum ratings for the anode current were not exceeded.

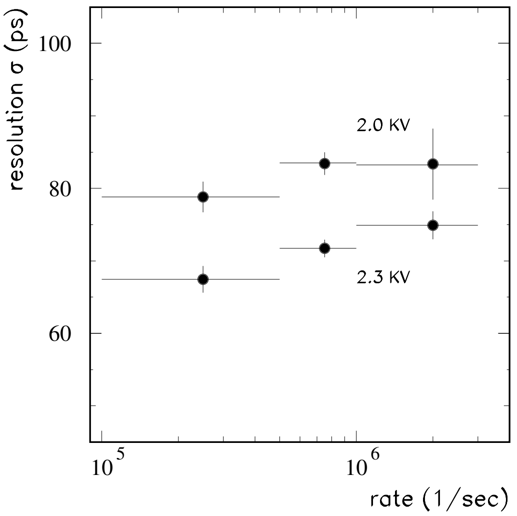

Figure 1: Time resolution (standard deviation) as a function of the rate for ^{197}Au projectiles of $E/A = 100$ MeV. The supply voltages are indicated.

The time resolutions given in Fig. 1 represent the standard deviations, divided by $\sqrt{2}$, of the time differences of the signals from the two PM tubes. Assuming that both tubes contribute equally to the observed width, this quantity represents the timing resolution of one individual tube. These results were obtained for Au beams of $E/A = 100$ MeV and rates of up to $3 \cdot 10^6$/s. The rates are momentary rates averaged over the intervals (several ms) between triggered events. The measured widths fall between 70 and 90 ps, rise weakly with increasing beam intensity, and show the expected dependence on the supply voltage. With Au beams of $E/A = 1$ GeV resolutions of 130 ps were measured (supply voltage 2.1 kV). The increased widths are consistent with an inverse square root dependence on the energy loss in the scintillator foil.

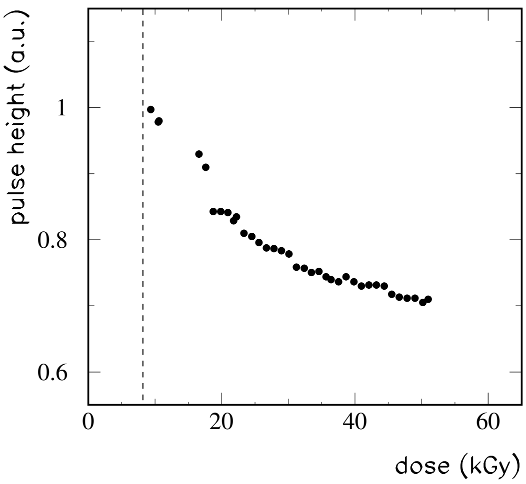

Figure 2: Mean pulse height as a function of the dose deposited by ^{197}Au projectiles of $E/A = 100$ MeV. The measurement started after the new foil had been exposed to approximately 8 kGy.

The long term behaviour of the detector was found to be dominated by the degradation of the scintillator foil. Figure 2 shows the relative pulse height as a function of the dose deposited in the scintillator foil. For the dose estimate, a homogeneous circular beam spot with a diameter of 10 mm was assumed. The total of $6 \cdot 10^9$ ^{197}Au projectiles of $E/A = 100$ MeV then corresponds to a dose of 50 kGy. With the more realistic assumption of a two-dimensional Gaussian beam profile with $\sigma = 2.5$ mm the dose delivered to the center of the beam spot is twice as large. The mean pulse height decreases first rapidly with increasing dose and then less than exponentially. However, no indications of a stabilization at a finite value were observed. The life time of the foils thus limits the use of these detectors at high rates.

Inspection of the foils after the irradiation did not reveal any visible modification of the scintillator material. They appeared indistinguishable from non-irradiated samples. In particular, no changes were found in the transmission for visible light. A thicker scintillator (BC-408) of 2-mm thickness irradiated with comparable doses exhibited colouring and a measurable reduction of the transmission for wave lengths in the range between 400 and 450 nm [3].

References

[1] T. Möhlenkamp et al., this Scientific Report.
[2] designed by H. Lotz, Universität Giessen.
[3] measurement by H. Folger, GSI.