YAP counting rate characterization

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Yttrium Aluminum Perovskite (YAP) scintillators are used in nuclear physics for their fast time response, and radiation hardness. They provide some pulse-shape discrimination and energy measurement. We are interested to use YAP coupled to a photomultiplier tube (PMT) as a zero-degree residue timing detector in an experiment to measure the photon strength function of ^{60}Fe and ^{58}Fe with (d,p) reactions. The YAP will see the full beam rate. For the ^{60}Fe measurement (secondary ^{59}Fe beam), we expect a rate of 2E5 particles per second. For the ^{58}Fe measurement (stable ^{57}Fe beam) the accelerator can easily provide 1E7 pps. We would like to use as much as possible, and at least 1E6 pps.

This report describes the testing of a single YAP crystal 1mm thick, ≈19 mm in diameter. The crystal was coupled with BC-630 optical grease to a Hamamatsu 1355 PMT. Voltage was supplied to the phototube electrodes with three active bases which utilize transistors to maintain the voltage on late-stage dynodes during high-rate operation. Active base #57 has a resistance from cathode to ground of 17 MOhm. Active bases #2 and #8 have 1 MOhm from cathode to ground. Each base is tested at a variety of cathode voltages. The ^{84}Kr @ 7.5 MeV/u beam was produced with the K150 cyclotron, and the beam intensity was varied. A plastic scintillator positioned away from the focal point was used to measure the relative beam rate without rate-saturating the plastic scintillator. The rate on the YAP for each beam intensity was measured.

Fig. 1 shows the rate measured on the YAP as a function of the rate measured on the plastic scintillator for five cathode voltages using base #8. For all settings, the YAP rate rises in proportion to the

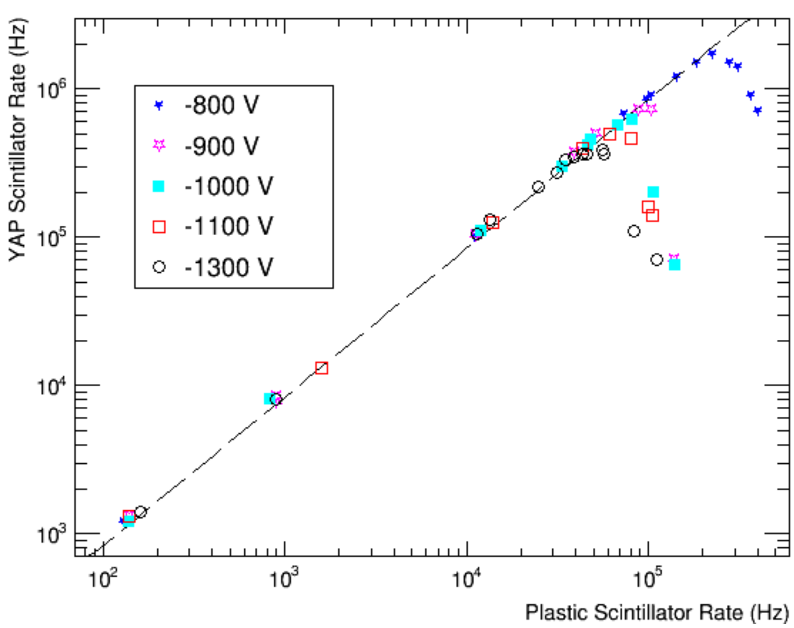

Fig. 1. Measured rate on YAP+PMT with low-resistance active base as a function of an independent detector rate proportional to the beam intensity. Lower voltage allows higher rate. The dashed line (a linear fit to the -800 V data with a y-intercept of zero) serves to guide the eye.

plastic rate until a maximum is reached, beyond which the YAP rate drops rapidly. A line with offset of 0 channels is plotted to guide the eye. For the highest cathode voltage (-1300 V), rate-saturation is reached earliest. As the cathode voltage is lowered, a higher rate is obtained before rate-saturation. At the lowest voltage (-800 V) a maximum rate of 1.7E6 pps was observed. Naturally, the pulses from the PMT become smaller as the voltage is lowered, but the rise time and fall time of the signals remain constant. At -700 V, signals from the anode were not observed.

The maximum rate observed on the YAP is plotted in Fig. 2 as a function of the cathode voltage for all three bases. For base #8, the rise in the rate with lower voltage is clear. This trend is perhaps reasonable considering that the base can only supply a certain current through the dynode chain and through the anode coupled with the fact that at lower voltage there is lower gain and thus lower current. For base #2, data was only collected at the lowest two voltages. The rates measured for #2 are similar to the rate measured for #8. The difference between #2 and #8 might be due to a difference in gain, but data at additional voltages would be needed to investigate this. Base #57 has a much lower saturation rate and does not significantly depend on the voltage in the range measured. The higher resistance in this base results in a lower current from the bias supply to the dynodes and thus the dynodes fail to maintain voltage at a moderate rate.

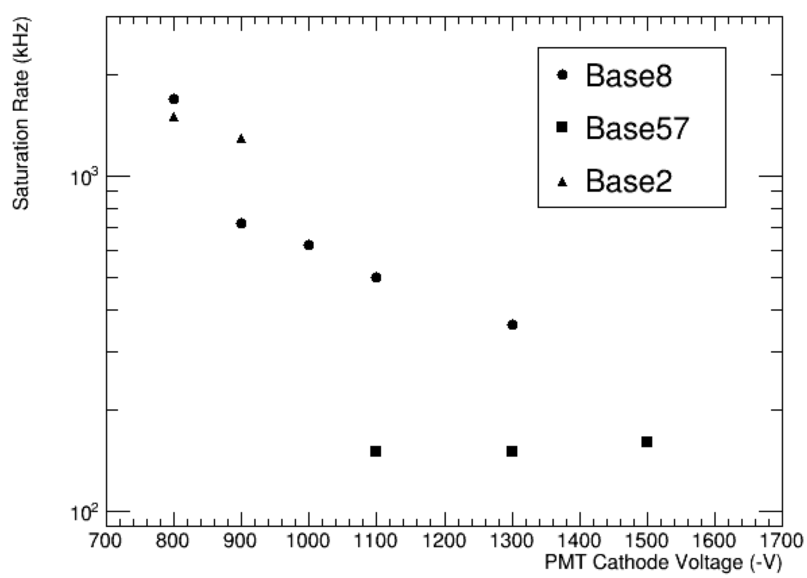

Fig. 2. Rate at which the YAP+PMT saturates as a function of voltage. Low resistance bases (#8 and #2, 1MOhm) achieve significantly higher rates than the higher resistance base (#57, 17MOhm).

The YAP itself shows no indication of degradation of performance at high rate. The low-resistance bases performed better than the high resistance base. (This is in agreement with the work of Ren et al. [1], but those authors use bases with much higher resistance, and thus get lower saturation rates.) Best performance, in terms of rate-saturation, was obtained at the lowest possible cathode voltage.

[1] P.P. Ren *et al.*, Nucl. Sci. Tech. **28**, 145 (2017).