^{60}Fe project: barium fluoride detector recoupling

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Over the past year further re-coupling of the TAMU-ORNL BaF2 array detectors [1] were done to improve their performance. BaF2 detectors consist of two components: the BaF_2 crystal and the photomultiplier tube (PMT). These components are typically coupled using viscous silicone oil that matches the crystal's index of refraction and is transparent to UV light then wrapped with Teflon to reflect the light towards the quartz PMT window. The crystal and the PMT are then optically sealed with electrical tape to keep out ambient light. Unfortunately, we observed that over time the coupling of the crystal and the PMT degrades as silicon oil slowly leaks out from the interface. This loss of silicone oil causes a reduction in the light that enters the PMT. The loss of light has two effects, one is a degradation in the energy resolution due to lower information carrier statistics, and the second is the reduction of particle identification due to the UV fast light component of BaF_2 crystal photo response being more vulnerable to the loss of the silicon oil coupling. The loss of particle separation is a problem for BaF_2 detectors due to the presence of alpha emitting Radium isotopes mixed in with the Barium. If unidentified this alpha background would adversely affect the gamma ray spectra these detectors produce.

During the course of the November 1st 2019 test beam run a number of barium fluoride detectors showed signs of degradation in their particle separation (see Fig. 1). Some of these troubled detectors

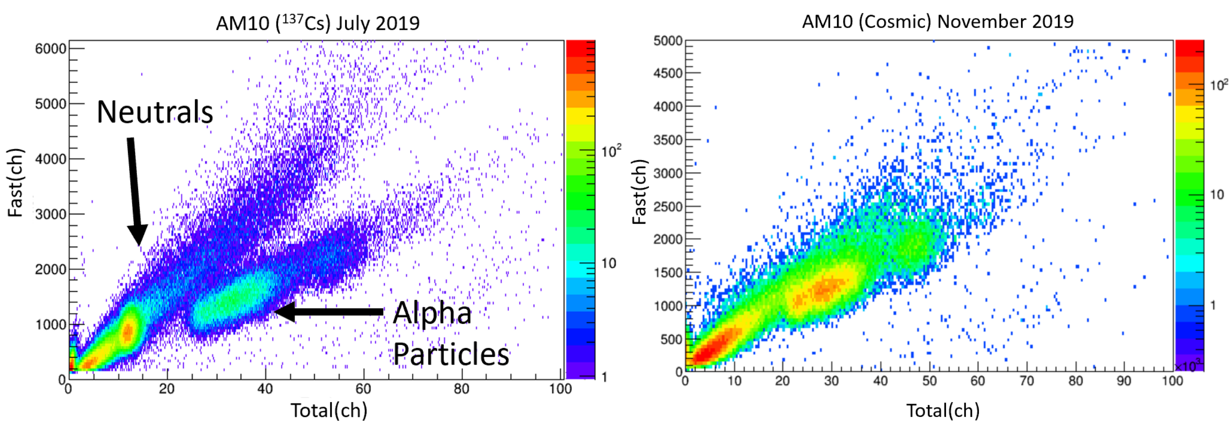

Fig. 1. Yield as a function of fast component of light output and total output. Both spectra are for detector AM10. Left) run with a ^{137}Cs source just after re-coupling in July 2019. A clear separation is seen between the alpha particles and the gamma rays. Right) cosmic spectra taken 5 months later. A clear degradation is seen in the particle identification.

were selected for recoupling. In an effort to delay the degradation of the silicone oil coupling an alternate recoupling procedure was developed. In this procedure a thick layer of RTV (Room-Temperature-Vulcanization) was placed around the contact between the PMT window and the crystal in attempt to keep the silicone oil from leaking into the surrounding Teflon. For this report, we will focus on two detectors, AM16 and AM20, which were the first two recoupled with the RTV barrier. In order to quantify the separation, the fast integral was divided by the total integral and plotted against the total integral. The total channel region above where the alpha particles first appear was chosen to project the fast/total over.

As shown in Fig. 2a, detector AM16 appeared quite stable between the first two cosmic tests of its recoupling. In the last test, there appears to have a slight shift in the gamma peak. However, the BaF_2 detectors in these tests were not thermally stabilized, so it is possible this discrepancy is a thermal effect. As clearly seen in Fig. 2b, detector AM20 underwent a rapid decline in the separation between alpha particles and gamma rays, more than likely the recoupling was not stable in this case. Other detectors

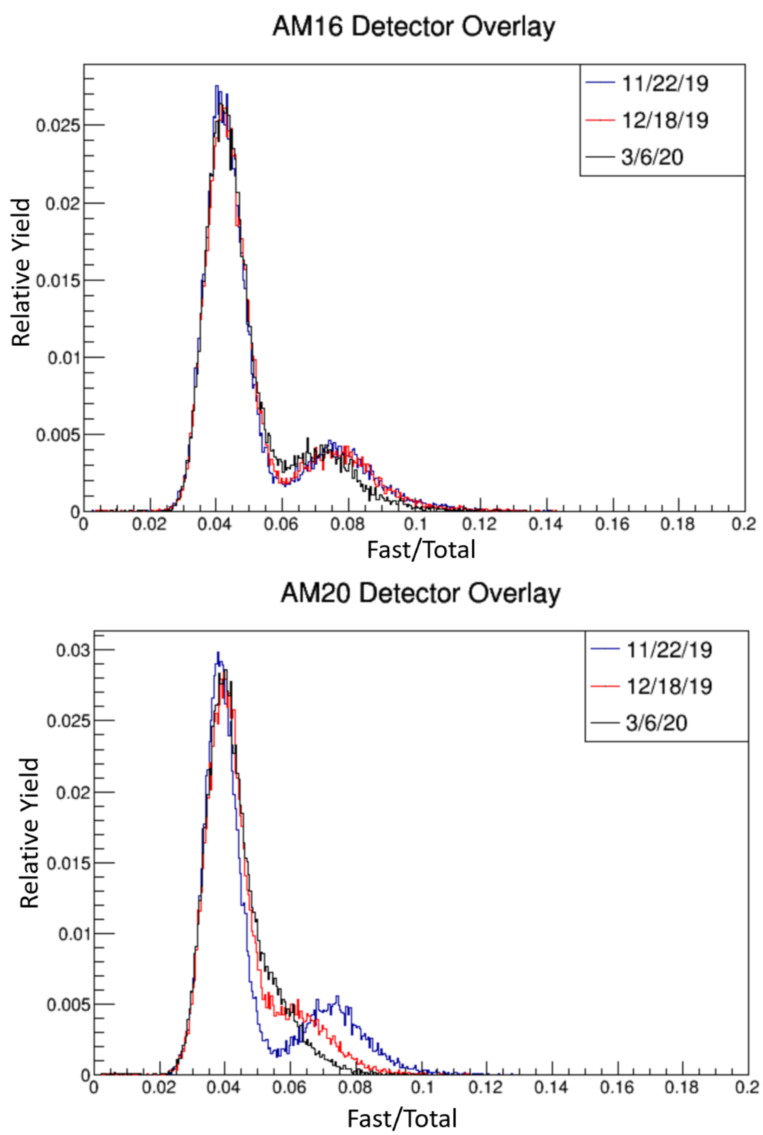

Fig. 2. a) Fast/Total projections for AM16 at different times, area normalized to one. These projections were taken starting from a total channel region of the lowest energy alpha particle seen in the first test. b) Same as panel a but for detector AM20. A clear degradation in the separation of alpha particles (left peak) and cosmic rays (right peak) were seen.

were also tested; some clearly need recoupling while others may be stable with a more thorough testing procedure. A possible reason for the failures in the barrier could be the messy nature of the barrier application around the crystal-PMT junction. A potential solution could be a Teflon ring around the interface to hold the silicon rubber in place while it is applied. Another issue with the barrier is that the RTV could react with the silicon oil, so if the RTV penetrates inside the junction before it dries up it could impair the effectiveness of the oil, thus creating a bad coupling within the most external area of the crystal-PMT junction. If this effect is not negligible, the RTV barrier technique might not be efficient but a solid, static sealing (Teflon) ring could still help to prevent the oil from leaking out.

Detectors will be tested again with active cooling to stabilize the temperature. If the changes in resolution observed can be explained by temperature variations, the coupling procedure may be working better that it seems at present. In the event that a noticeable increase in particle separation stability is not found between the barrier method and the conventional method, a return to the conventional method will be implemented for those detectors showing poor particle identification.

[1] J. Gauthier *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2018-2019), p. IV-58.