Characterizing BaF_2 Detectors for use in gamma ray detection

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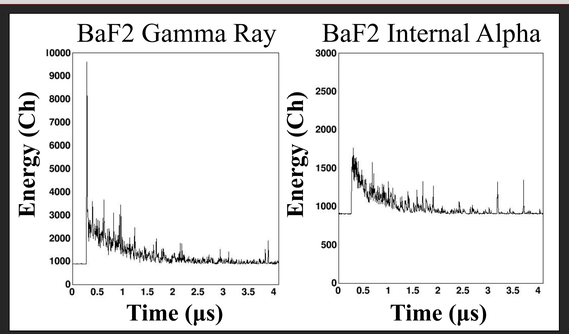
Motivation

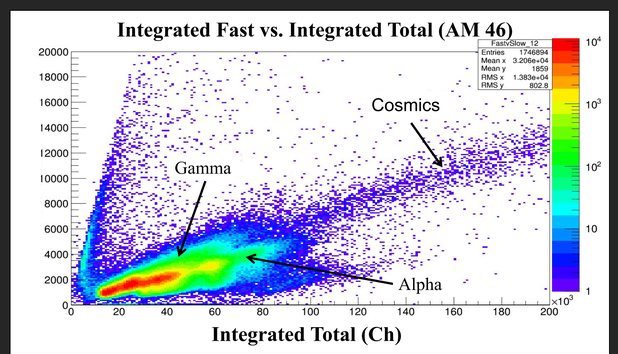
Understanding the symmetry energy in the nuclear equation of state is essential to understanding properties such as the structure of a neutron star or its gravitational collapse, leading to supernovae. It has been suggested that to better constrain the symmetry energy one can use the bremmstrahlung gamma rays emitted from the hot, dense nuclear matter in the early stages of heavy ion collisions. These gamma rays have the potential to provide a cleaner probe than the more traditional hadronic probes. To measure these bremmstrahlung photons, barium fluoride scintillation crystals were chosen for their ability to detect photons across a large energy range and for their inherent pulse shape discrimination properties.

Testing The Detectors



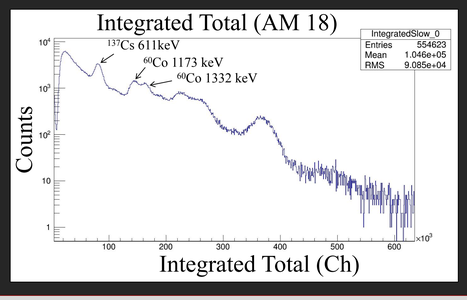
Testing:
- 15 detector batches
- 30 minute background runs
- 2 hour source runs
- Sources used
  - ^{137}Cs
  - ^{60}Co
  - ^{22}Na

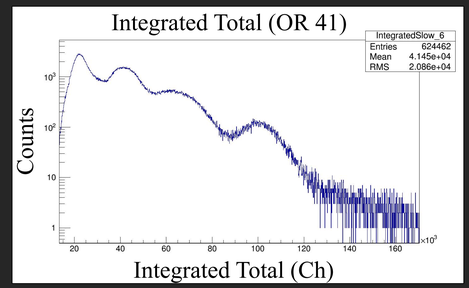
Because of BaF2's inherent pulse shape discrimination it is useful to separate the waveform into both a fast and total pulse. Because the aim of using the BaF2 detectors is to see bremmstrahlung photons it is useful to make sure that the fast and slow gates are configured to give the best possible resolution. Using a gamma ray pulse from above a fast gate of 24 ns and a total gate of 1500 ns were created. Within these gates the waveform is integrated and then used to fill a histogram. Using the pulse shape discrimination between the fast and slow responses one can determine what type of particle was detected by looking at the slope. Shown below is a Fast vs. Total histogram.



Determining The Good Detectors

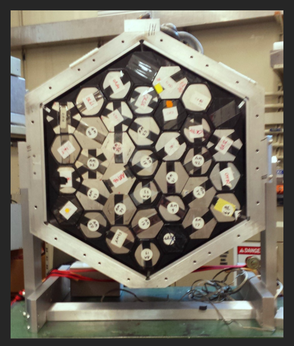
A BaF_2 detector's resolution depends on several different factors ranging from the crystal itself, to the coupling in between the crystal and the photomultiplier tube. Determining this resolution, even in a crude approximation is useful for determining our 37 best detectors. Instead of calculating an absolute resolution for all 37 detectors, the separation of the peaks in the integrated total spectra were used. In the detector AM 18 shown below, which was determined to be one of the best detectors, one can see a clear separation between certain peaks while in detector OR41 this is not clear.





Setting up the Array

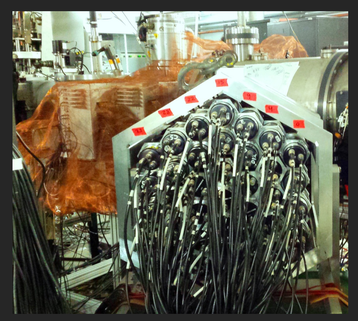
Barium Fluoride Array Front View



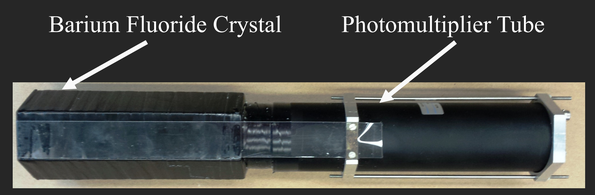
After the 37 best detectors were chosen they had to be mounted. To mount the detectors one should stack them when the mount is faced down on the floor. This will better distribute the weight of each detector. This is important because the sum total of just the detector weight is between 330 – 350 lbs. To increase efficiency of the array one should minimize the spaces between the detectors.

Once the array is set up it is moved into the cave. For the distance chosen one must decide the importance of time of flight versus solid angle coverage. Our array covered about 2% of 4π and the distance from the target was approximately 80 cm.

Barium Fluoride Array Back View



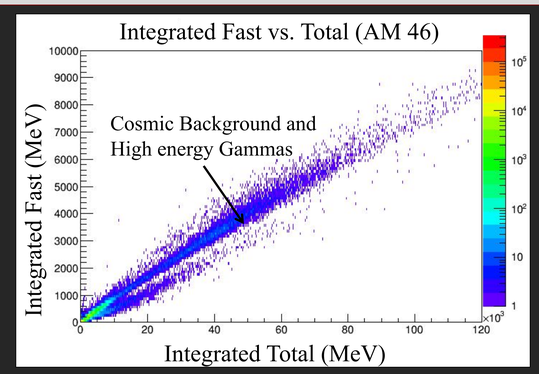
Finally when the array is positioned it is cabled to the bias supply and the two flash ADC digitizers. The array is ready for the 35 MeV $^{78}Kr^{25+}$ beam on a ^{124}Sn target.



How a Barium Fluoride Works

Barium Fluoride is useful for detection of photons because it is a high Z crystal and has nice pulse shape discrimination properties. The crystals are wrapped in Teflon tape and then subsequently wrapped with electrical tape. The Teflon provides a diffuse reflection to keep the scintillation light in. The crystal is coupled to a photomultiplier tube using silicon oil. The fast response for a gamma ray lasts around 10 ns while the fast lasts for around 1500 ns. The majority of the scintillation light is produced by ionizing radiation interacting with the crystal by either pair production, the photo-electric effect, or Compton scattering. The electrons from this interaction de-excite and in return emit photons in the UV range. Some de-excite quickly and others slowly, this is decided by the ionization density of the crystal.

Conclusion



In conclusion we were able to successfully assemble and characterize the ORNL/TAMU Barium Fluoride array. In order to successfully detect the bremmstrahlung gamma rays the cosmic events in the figure above will need to be filtered out. Use of the digitizing ADC to record the waveforms, rather than conventional electronics with QDCs, worked extremely well and gives enhanced flexibility to optimize the gating conditions off line to identify the conditions that will give the best resolution. In order to improve the resolution there are plans to recouple the BaF_2 Crystals to the PMTs. In addition to recording the entire waveforms, data was collected using charge integration of a fast and slow response which yielded higher statistics. Preliminary analysis has shown that after the cosmic rays are suppressed Bremmstrahlung photons can be measured out to approximately 40 MeV. To increase the statistics for future runs multiple 37 detector arrays will be used as well as a higher beam intensity, both increasing the solid angle coverage and the ratio of beam events to background.

Acknowledgments:
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