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A CsI Detector Array for the NDTGamma Test Measurement

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Notes:
Diana Sahibnazarova won the second place in the Physical and Engineering Sciences category. Dr. Christopher Crawford was the faculty mentor.

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A CsI Detector Array for the NDTGamma Test Measurement

The NDTGamma experiment will measure the parity-violating directional asymmetry in the gamma-ray emission direction from the reaction n + D → T + γ (6.2MeV). In this reaction, the gamma rays are split into deflection and capture reactions. The capture reaction is what is being detected and observed due to the spontaneous emission of gamma rays. The process starts with gamma particles when the light flashes and produces the scintillation light. The light excites the CsI crystal and then produces light that transfers the visible light into the PMT, very fast. As the incoming photon hits the photocathode, the electrode in the PMT transfers the photoelectron to the dynodes. The dynodes are metallic pieces that are being hit with photons. The next reaction is called the photoelectric effect when the light hits the metal in the PMT and emits photoelectrons after each hit. The gamma-ray emission direction will be measured using an array of 16 CsI scintillators. The light output from each scintillator will be measured using a PMT. PMTs convert the light output from the scintillators into an electrical signal and amplify it to a detectable level for readout.

This experiment was organized based on this schematic diagram as shown in figure 1. It starts from the left with the neutron beam coming to the polarized beam, then it switches to neutron spherical array to measure the gamma-ray emission to minimize the background. The gamma-ray direction emission will be measured using an array of 16 CsI scintillators attached to Photomultiplier tubes (PMTS) with a Co-60 gamma-ray source.

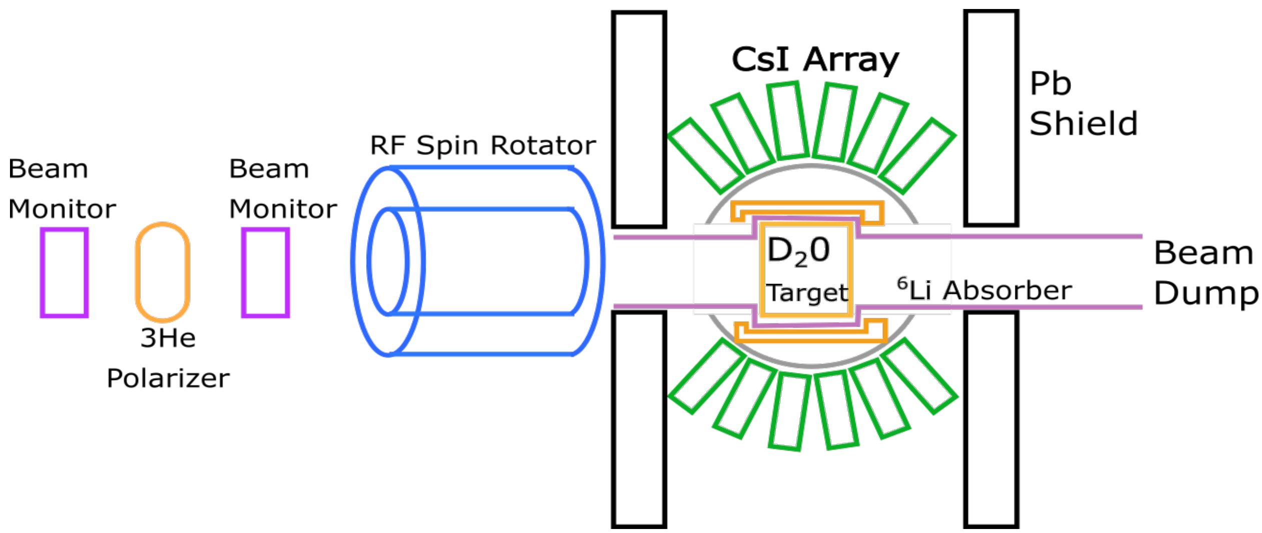


Figure 1: *NDTGamma setup*

This is a more visual interpretation of the NDTGamma experiment, the conceptual design of the experiment has a small D2O target, the target is in the middle of the shielding. The heavy water target was held in a 1 L Teflon container which has a low neutron capture cross-section. The jar was rolled up in a sheet of Li6-loaded fluorinated plastic shielding and the target assembly was suspended from the frame with aluminum wire. We also acquired data from a He-3 beam monitor upstream and a Lanthanum Bromide detector, since we were unable to use the high purity germanium detector.

The germanium detector on the left was prepared to measure the feasibility of the experiment for energy resolution in comparison to the CsI crystals on the right that were prepared by me. The detectors were assembled into an array with 4 layers each resting on an aluminum shelf tilted so that all 4 four detectors on the shelf pointed towards the deuterium target. The aluminum frame was designed to support lead shielding all around the front of the detector to avoid backgrounds above the faint 6.2 MeV deuterium neutron capture cross-section.

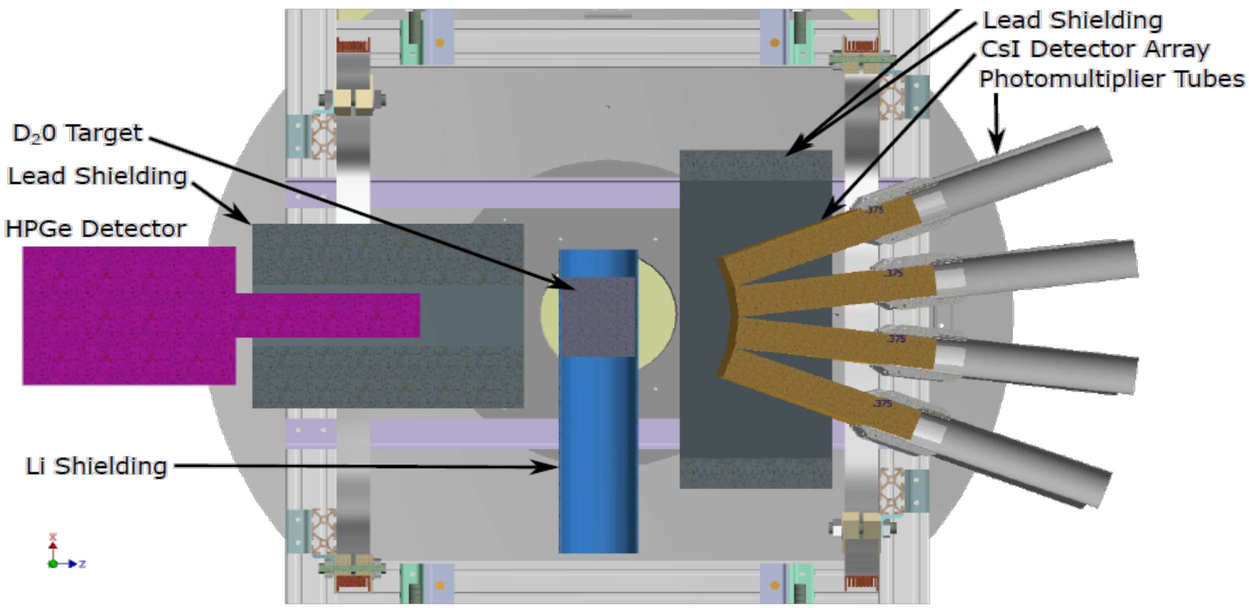
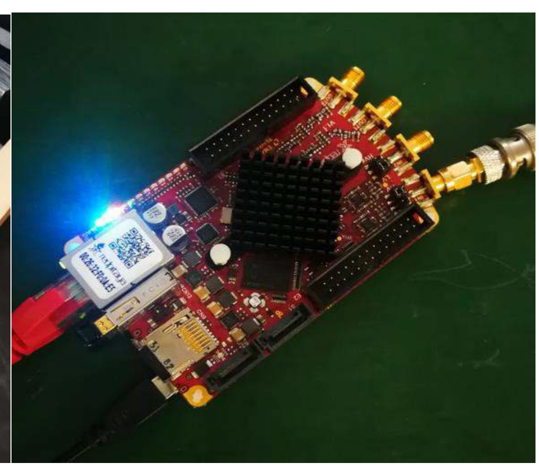


Figure 2: *Test Setup*

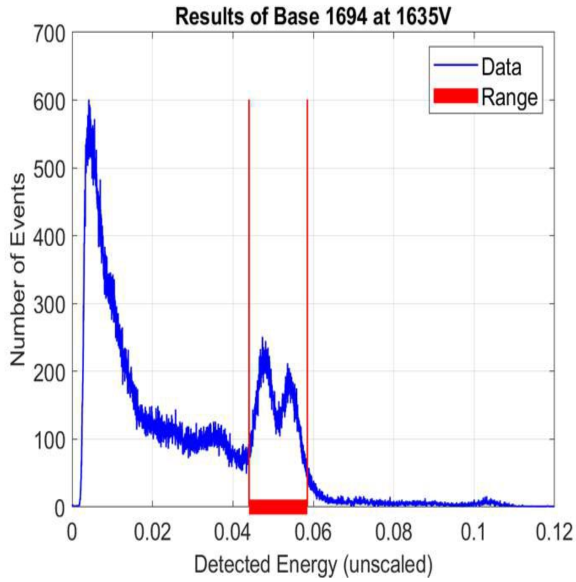
CsI scintillators were loaned to us. To couple the two together, we 3-d printed a special coupler to match the square profile of crystals to the circular cross-section of the PMT tubes. This allowed us to use the original spring-loaded tube support in the new design. Each detector was wrapped in aluminum foil and used a neoprene wrapping to make a tight fit in the coupler. The whole connection was light-tight by taping the neoprene jacket to the foil around the crystals and the PVC tubes holding the PMTs. The whole assembly was tested in a light-tight box, and then outside a black cloth was placed and slowly lifted off to see any light leaks. One of the challenges was catching the signal because many of the tubes were not very efficient, some of the bases were bad, and a special optical grease was used to make a good light connection between the crystal and the PMT.

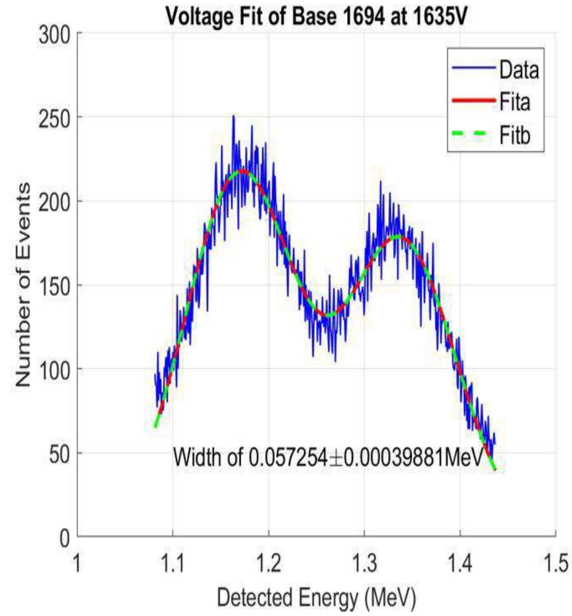
Images 1: PMT ***Image 2:*** *Test Bench Data of CsI Detectors and PMTs*

A 2-uCi Co-60 is a sealed source that was placed directly on the top of each scintillator to test both the light transparency and the energy resolution as shown in image 3. We used a $300 RedPitaya DAQ system image 4 to measure the gamma spectrum. The system was programmed with digital pulse processing to test the transparency of the crystals and the optical connection. Each crystal was tested with the same PMT and was compared to the number of counts from the Co-60 source.



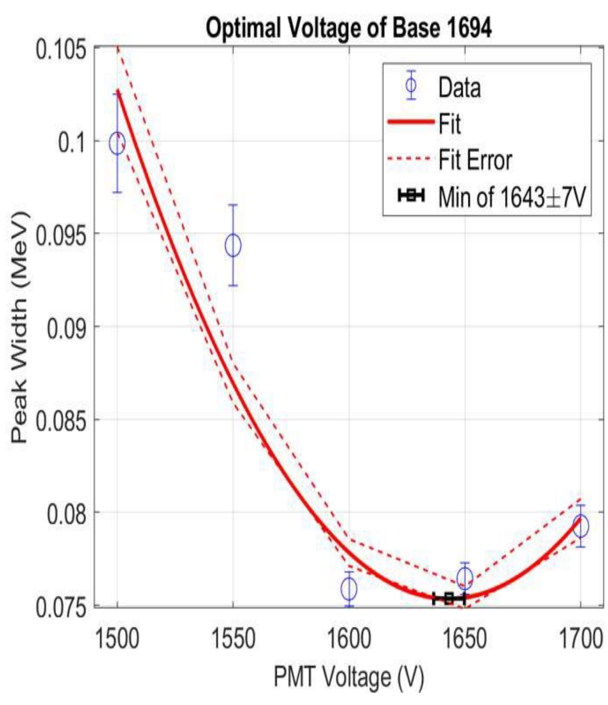
Images 3: *Co-60 source on the detectors* ***Image 4:*** *RedPitaya*

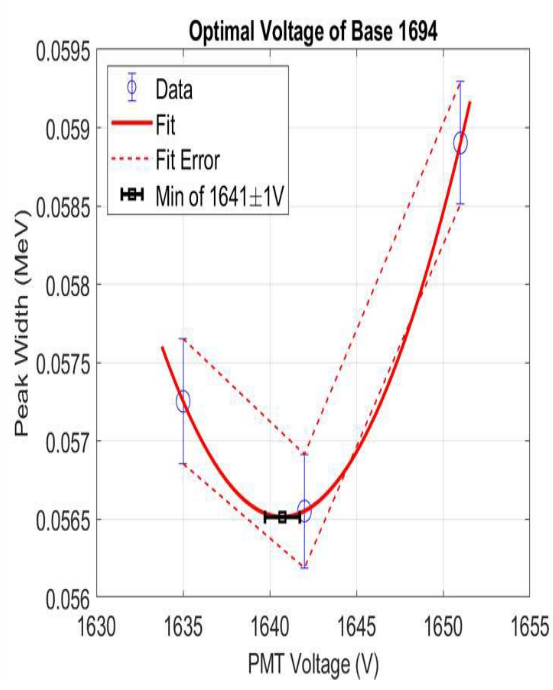




Figures 3 & 4: *Tuning the energy resolution*

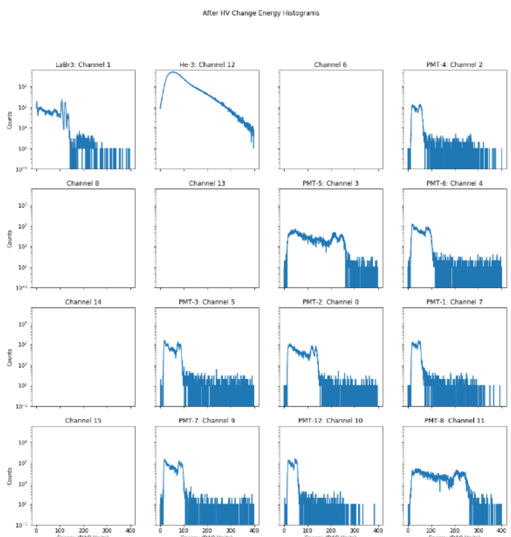
Here is the resulting spectrum from the 60-Co source for one of the good Scintillator-PMT combinations. The 1.17 and 1.33 MeV fit the peaks to a double-gaussian and used the Root Mean Square width of the distribution to tune the HV for each detector between 1500-1700 V as shown in figures 3 and 4. We also fine-tuned the parameters of the trapezoid. Low energy background is the two peaks that correspond to the gamma rays of Co 60 source as shown in figure 3. Underneath the voltage noise as you bring the voltage up, low energy events become higher within the optimal voltage range, and the least noise is being introduced to the PMT.

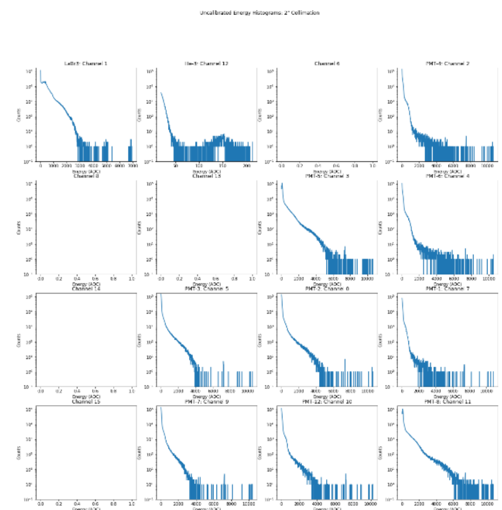




Figures 5 & 6: *High Voltage Optimization*

Fitting data points from 1500V to 1700V in increments of 50V we can find a parabola fit with the minimum of the fit being located at the optimal voltage, as shown in figure 5 on the left. The first graph of the 1643 error increment is a set of measurements that were found to be optimal where this tube was tested 3 more times than combined to the optimal voltage to the peak width with the least uncertainty. More tests were taken near where the fit says the minimum is and near the bounds of the error to see how good the optimal voltage is as shown on the right in Figure 6. Those graphs were made to find the uncertainties of the voltage leaks.





Figures** 7 & **8: *Preliminary Data*

Those are the log scale plots of area integration that were filtered out for the noise to keep the energy in terms of peak heights by using the fir method with 6 MeV as shown in figures 7 and 8. More analysis needs to be for the investigations of the of the peaks with the target and their energy activities. Figure 7 has a double peak of the energy resolution of the gamma emission, whereas figure 8 has no gamma emission and no gamma source. More analysis needs to be done in order to move further with this research.