Detector comparisons

Igal Press

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1 How the graphs were normalized.

The code used to create the graphs seen in this document has been attached in the email. The histograms were normalized by multiplying their scale by the inverse of their measured KP with the code h->Scale(1/KP).

2 Setup

The Alpha source run setup isn't available as no photos were taken. The Americium source was placed underneath the detector being tested while a black garbage bag was draped over-top of the detector to limit light pollution.

Background runs were used in identical conditions to the cold neutron (CN) or ultracold neutron (UCN) runs, however the shutter was closed for the run blocking neutrons from the detector. Note that the Reuter Stokes (3He detector) is operating at 10atm.

Figure 1: The CN runs have the above setup. The detector was covered in a black garbage bag to limit light pollution and was attached directly to the CN source.. The detector was placed on-top of two jacks that kept the detector level with the source to avoid undue stress.

Figure 2: The UCN runs had the detector attached directly to the doppler shifter. Pictured: ZnS detector attached to the doppler shifter.

3 Background runs

How background runs were conducted

Background runs were conducted by closing the neutron shutter at the Japan Proton Accelerator Research Complex (J-PARC) creating a shield from incoming neutrons. These neutrons wouldn't be sensed by the detectors leaving only background sources to be measured by the detectors.

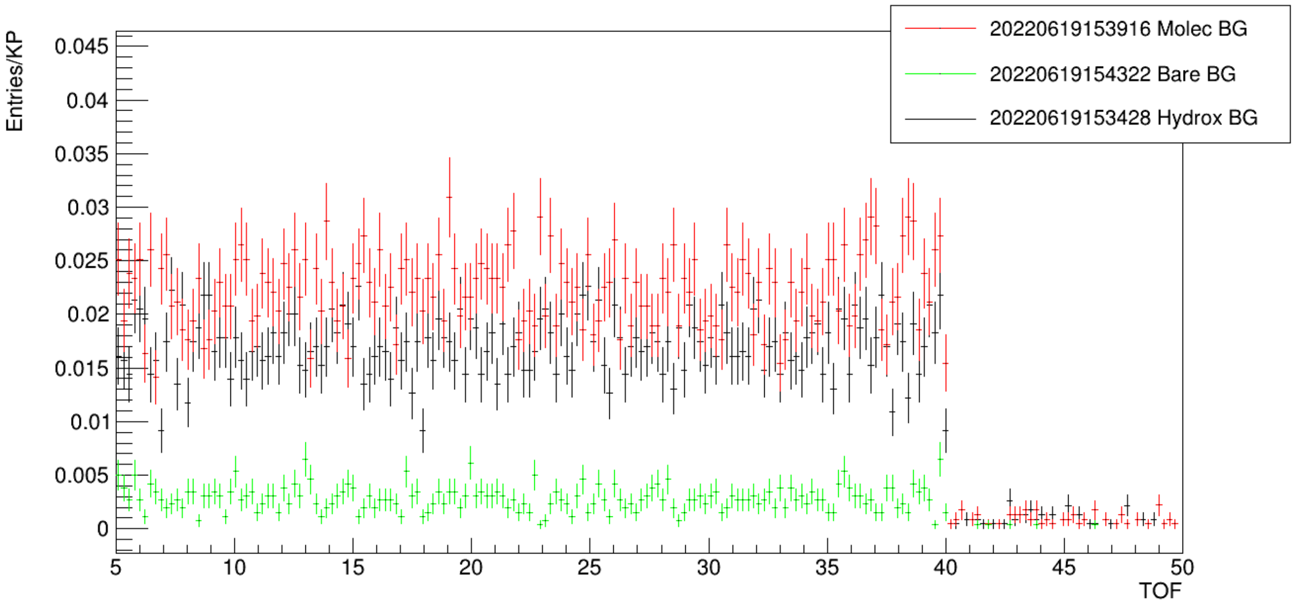

Figure 3: Cold neutron background run for the molecularly bonded, bare, and hydroxide detectors.

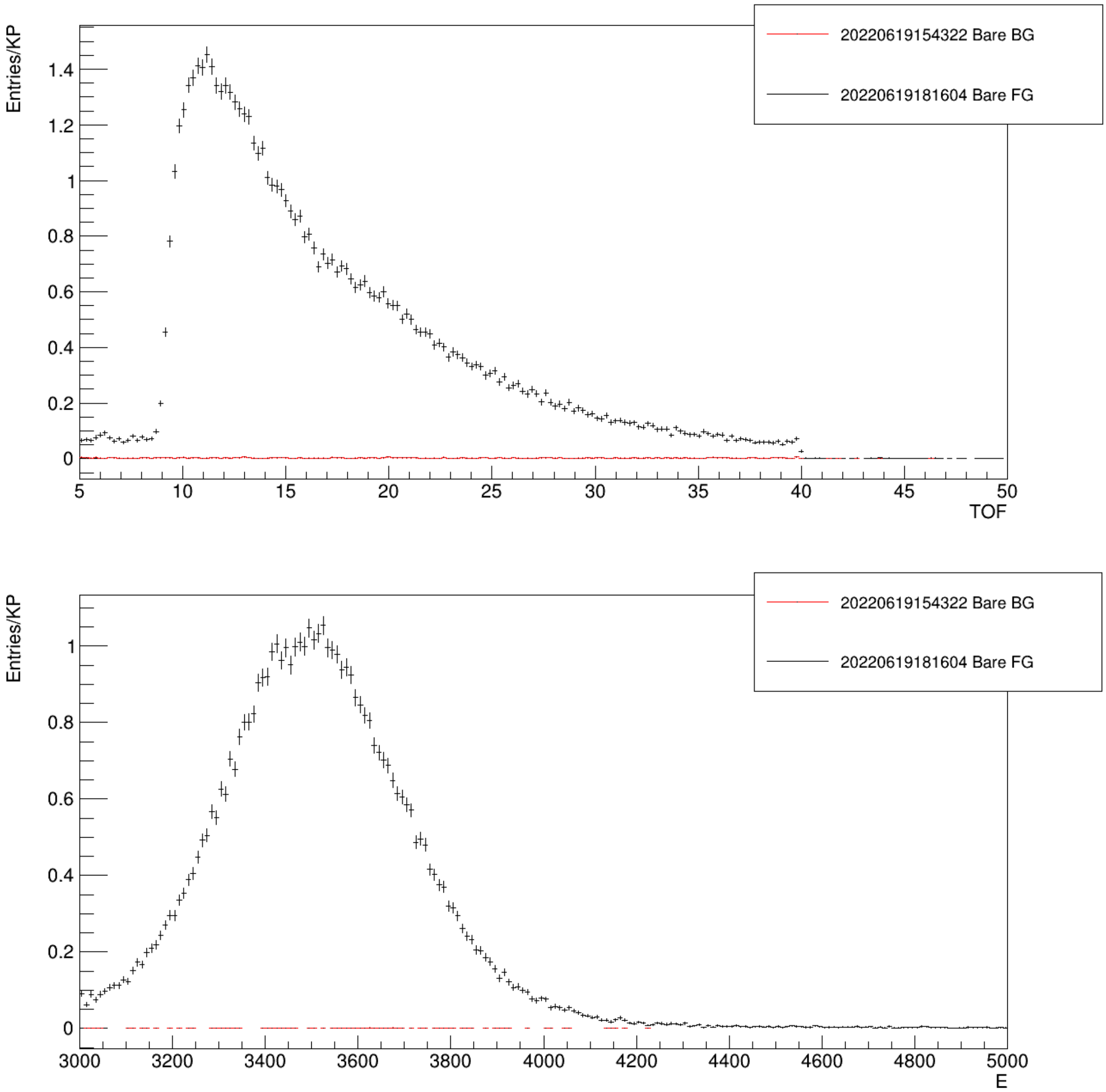

Figure 4: CN comparison between TOF of the bare detector foreground and background counts.

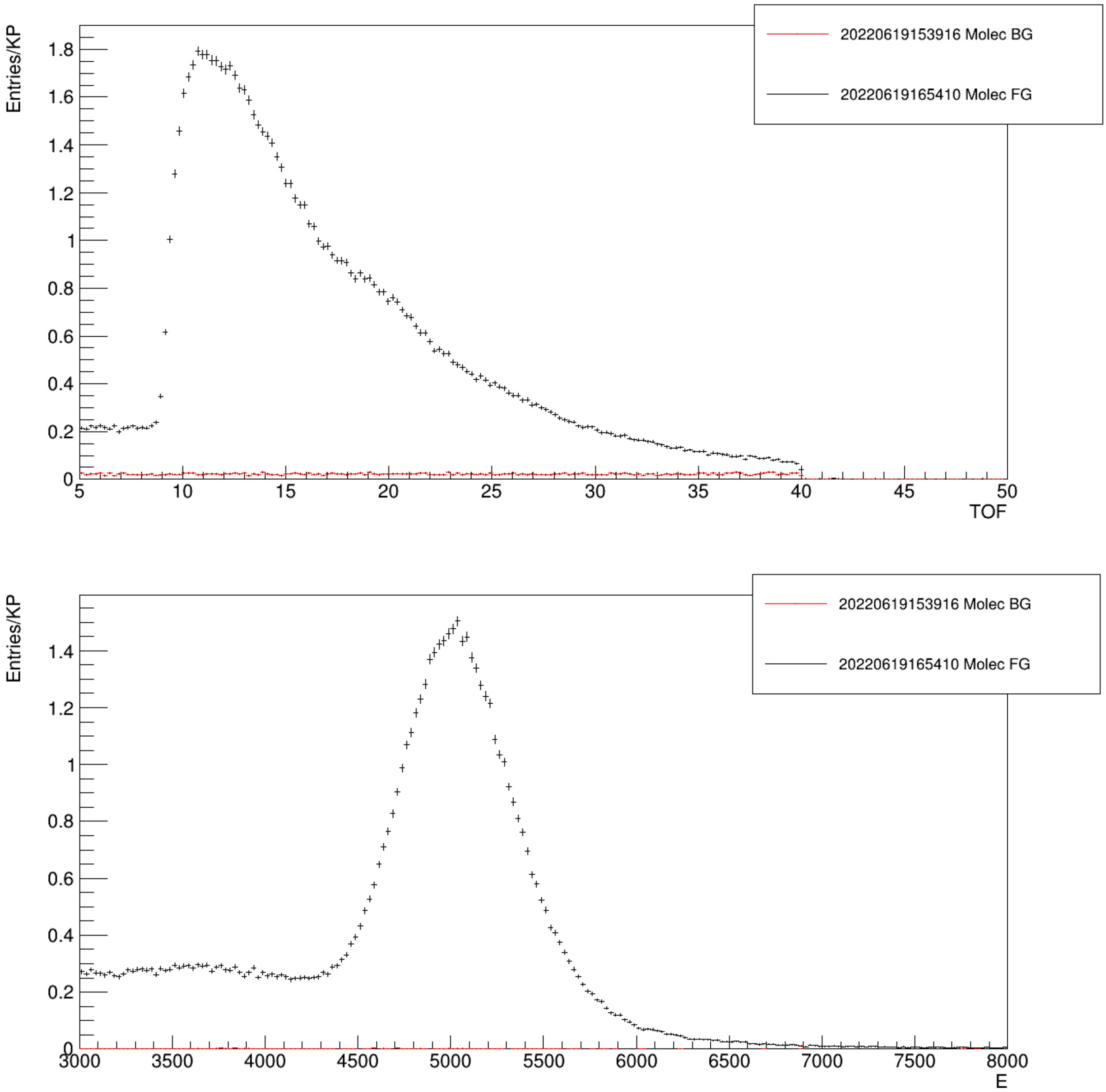

Figure 5: CN comparison between TOF and energy levels of the molecularly bonded detector foreground and background counts.

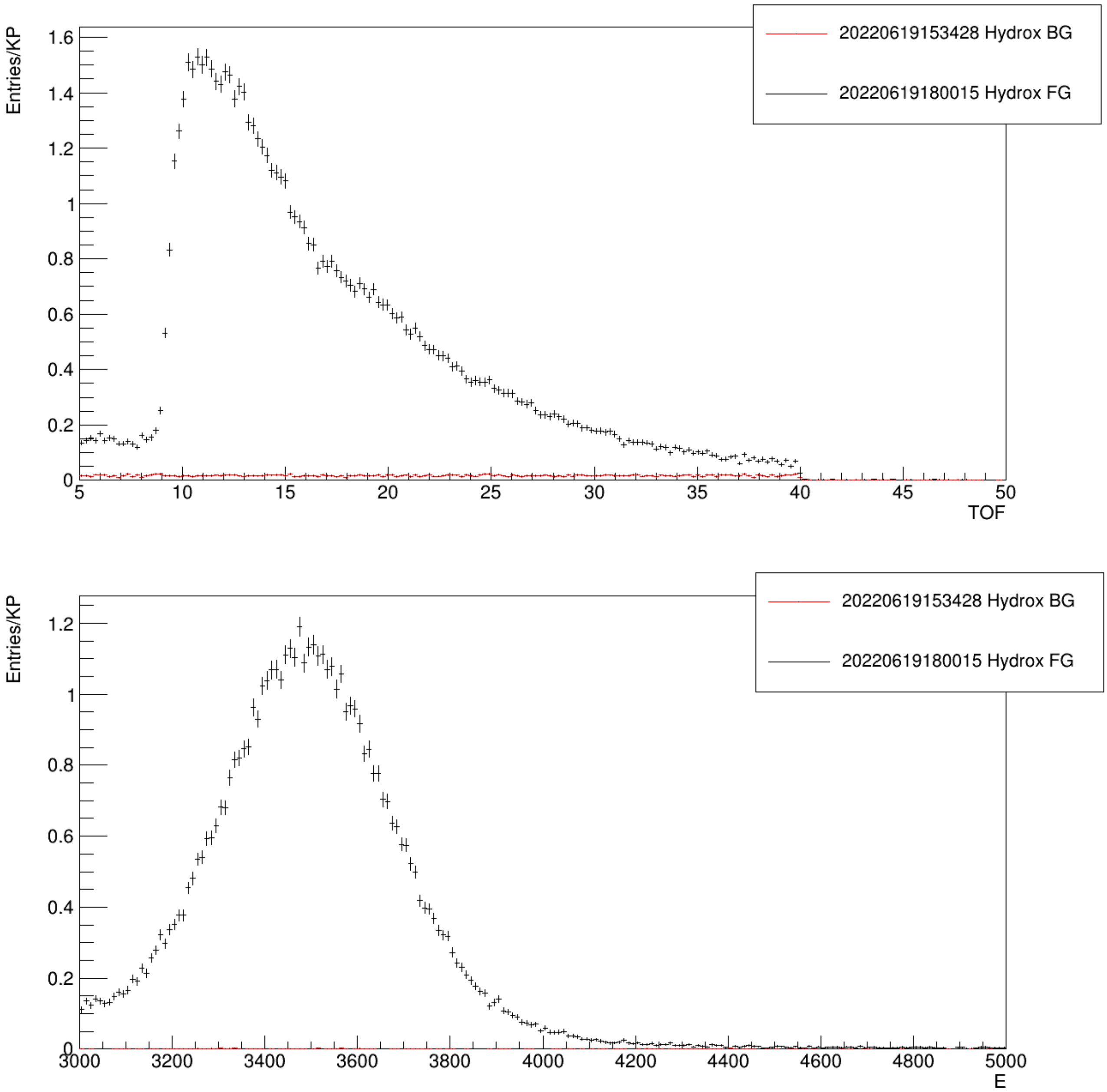

Figure 6: CN comparison between TOF and energy levels of the hydroxide detector foreground and background counts.

Section summary

We can see that in figure 3 that the amount of background detected varies by detector. The bare detector is by far the least sensitive to background radiation while the molecularly bonded and hydroxide bonded detectors are approximately equal in their detection of background radiation. This slight increase in background sensitivity is apparent when viewing figures 5 and 6 where the background radiation is visibly larger in the histograms involving the molecularly bonded and hydroxide bonded detectors than that of figure 4 with the bare detector.

4 Alpha and Cold neutron detector runs

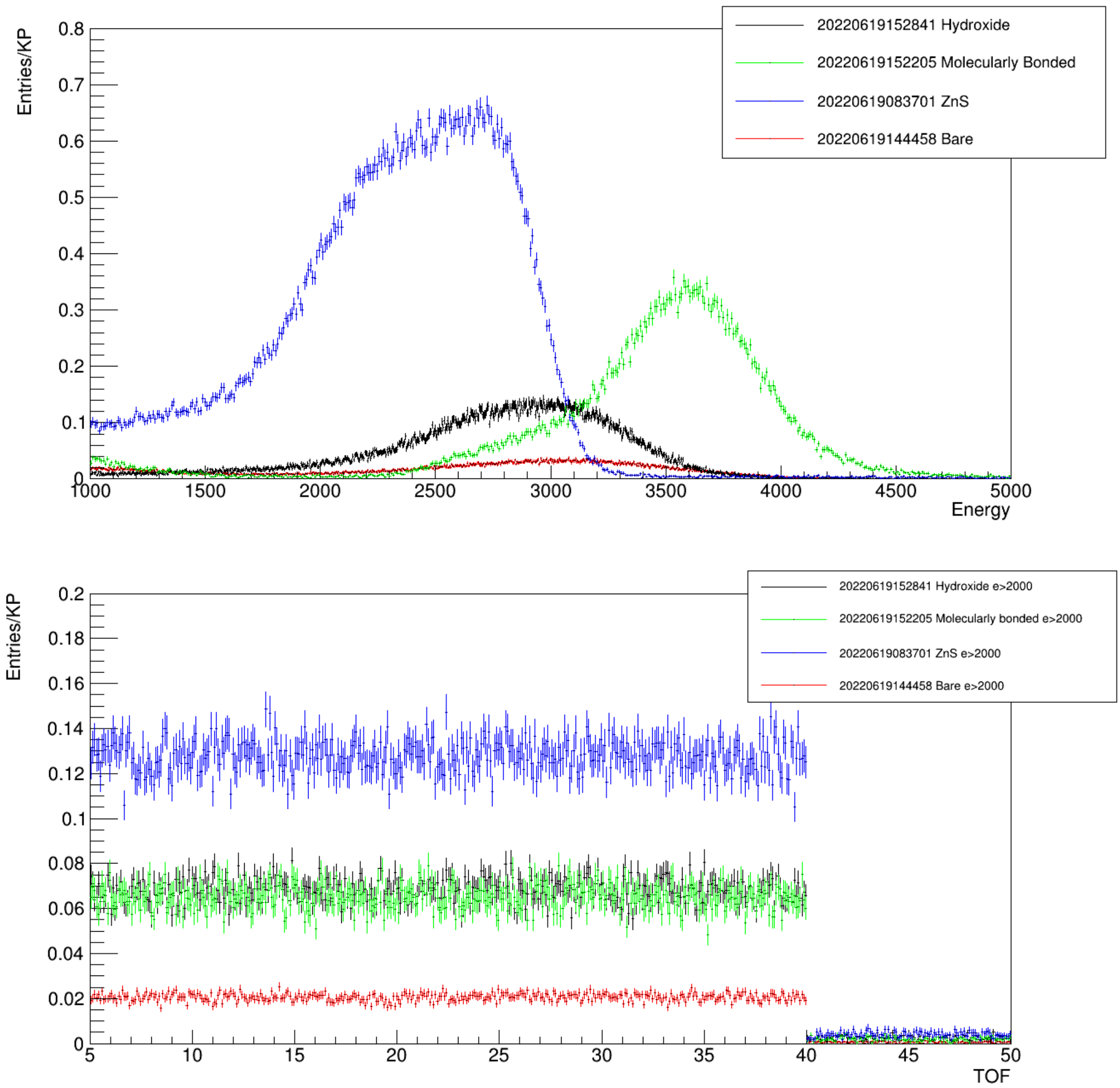

Figure 7: Alpha source runs comparing the energy spectra and TOF for the four detectors.

The ZnS detector is displayed with the highest sensitivity to the alpha particles emitted by the americium compared to the 6Li detectors. The bare detector has the lowest sensitivity to the alpha particles which is corroborated by the background measurements seen in figures 3 and 4. It's also possible to see within the TOF histogram that the hydroxide and molecularly bonded detectors are approximately equal which is also supported by figures 3 and 4.

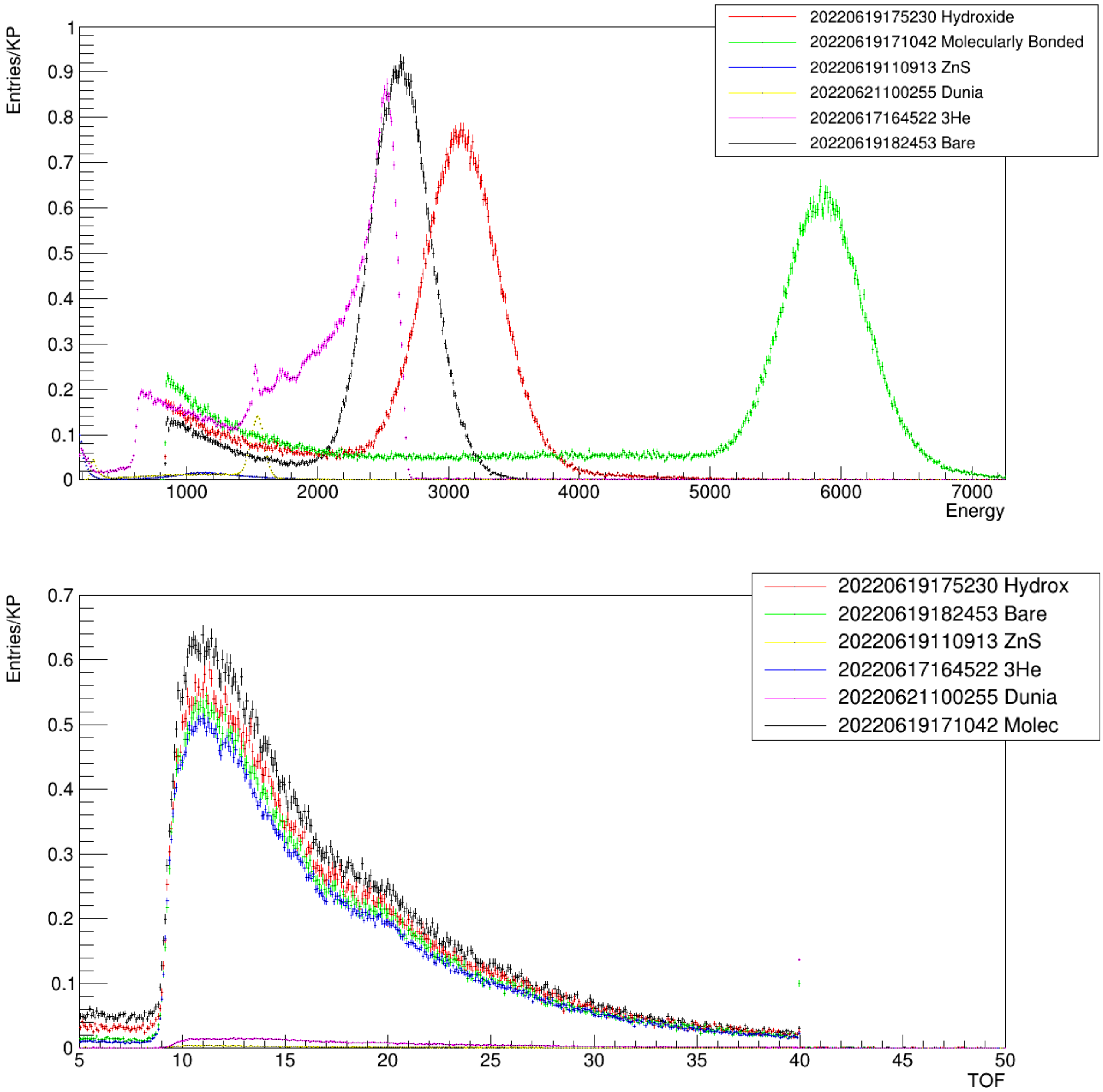

Figure 8: Cold neutron experiment comparing time of flight and energy levels for the six detectors.

In the TOF histogram the molecularly bonded detector appears to be the most efficient CN detector followed by the hydroxide bonded detector and the bare detector, but when accounting for the background radiation found in figures 3 and 4 it's possible to conclude that they're all approximately equal to one another in efficiency.

CN run comparisons relative to the Dunia detector.

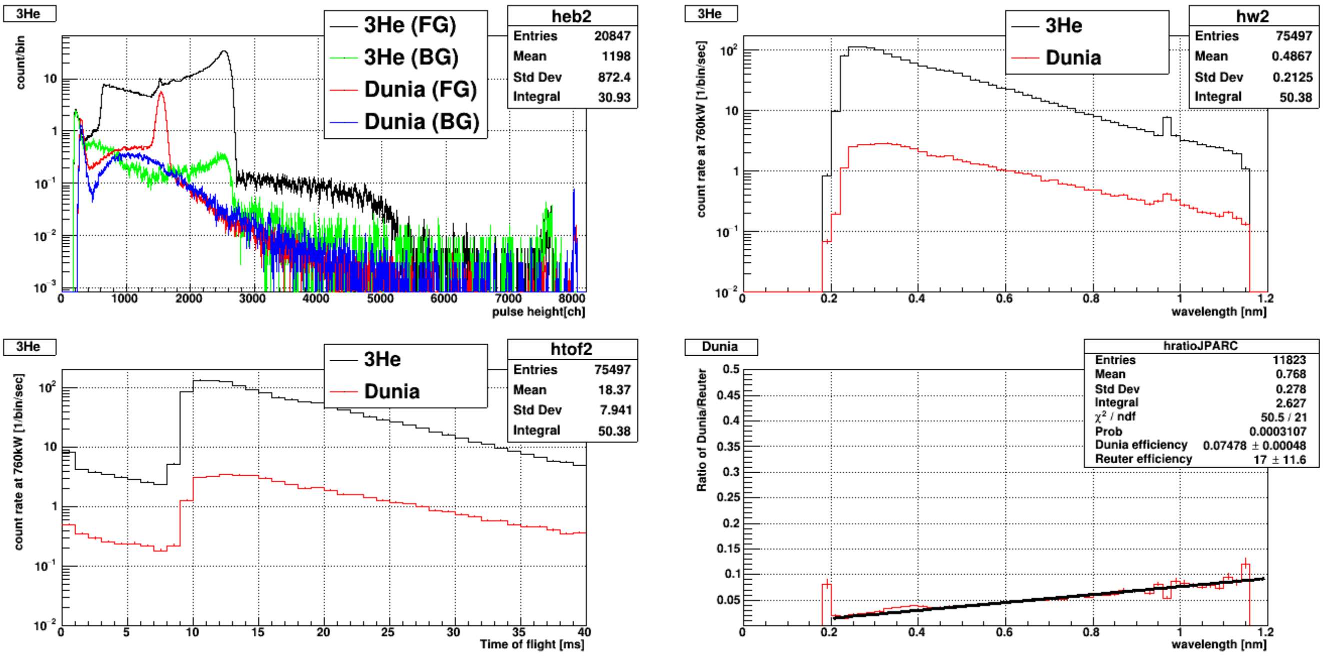

Figure 9: Efficiency of 3He compared to the Dunia detector.

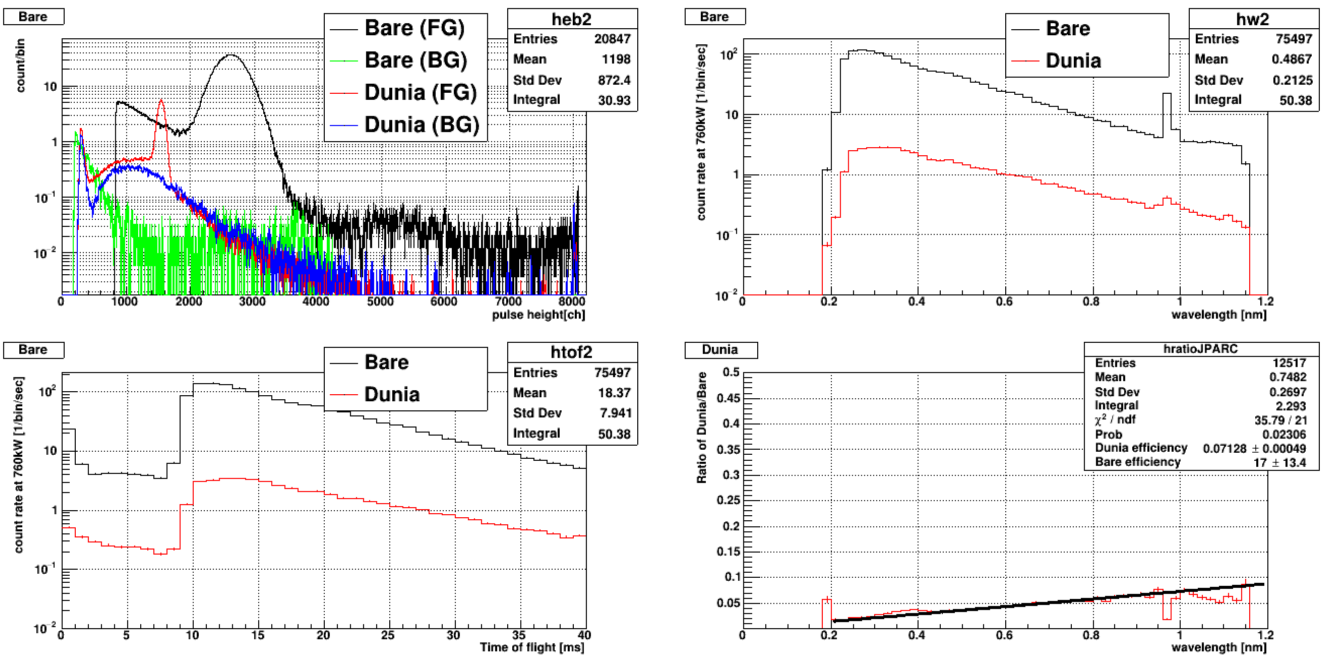

Figure 10: Efficiency of the Bare detector compared to the Dunia detector.

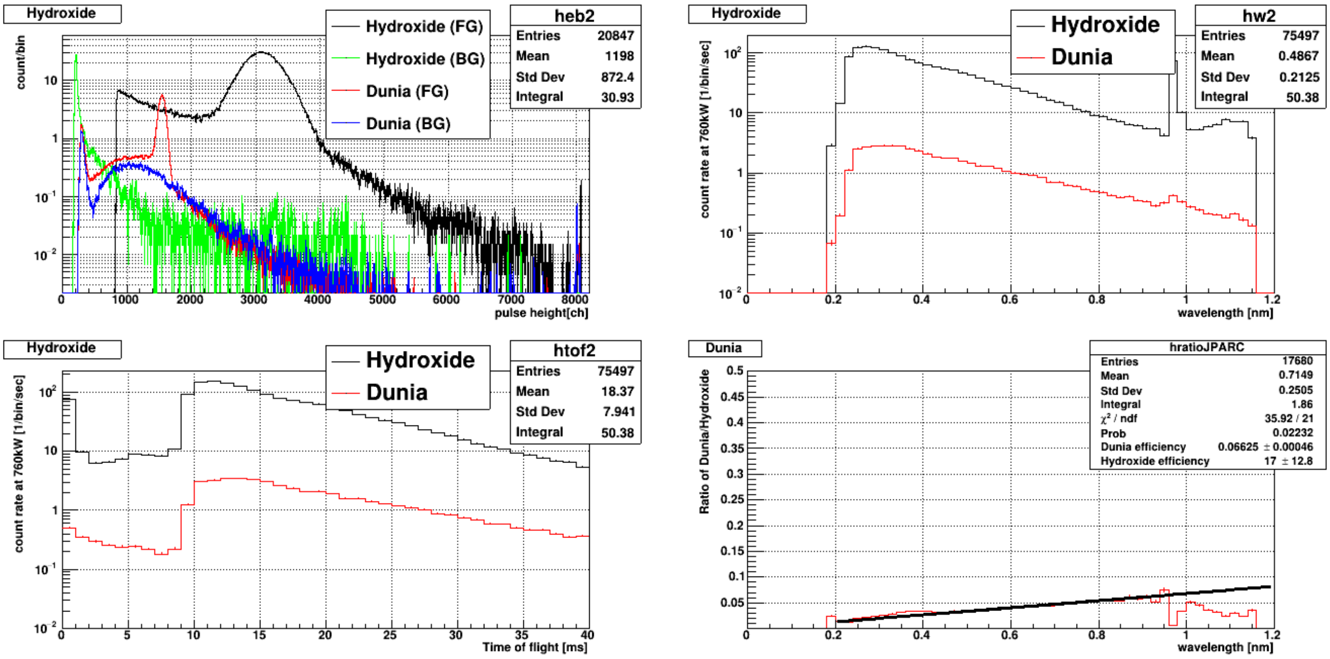

Figure 11: Efficiency of the Hydroxide detector compared to the Dunia detector.

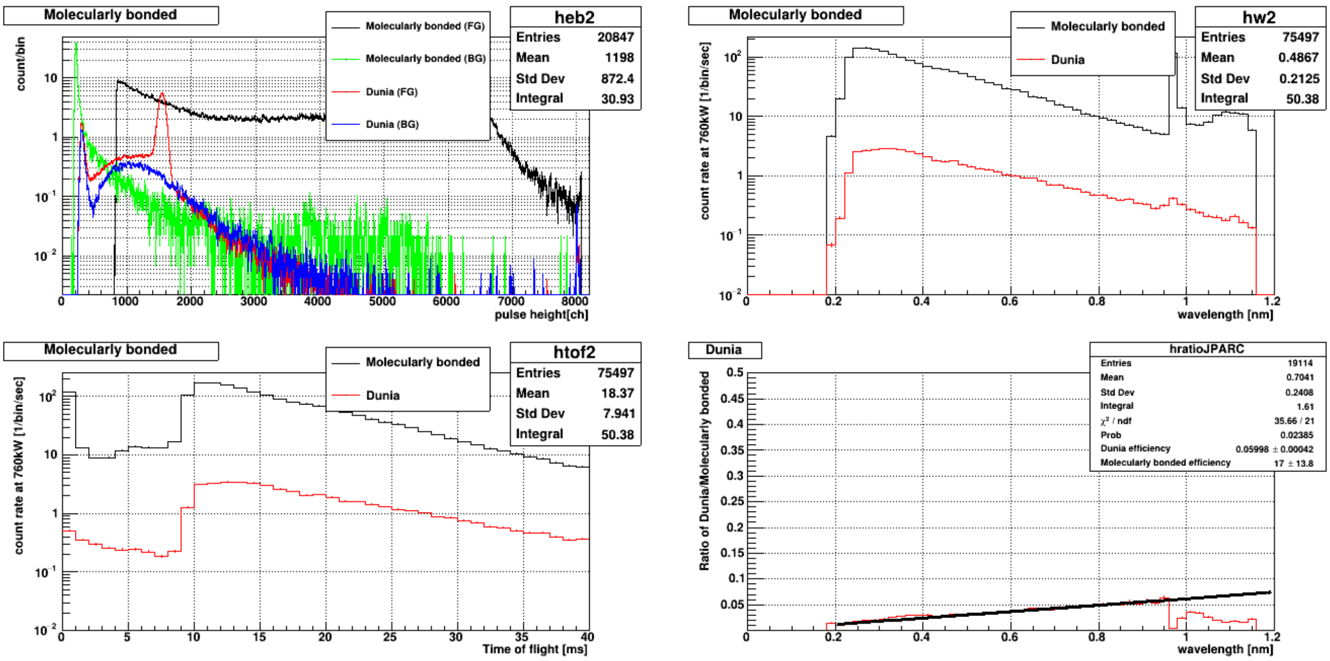

Figure 12: Efficiency of the Molecularly bonded detector compared to the Dunia detector.

5 CN run comparisons to the 3He detector.

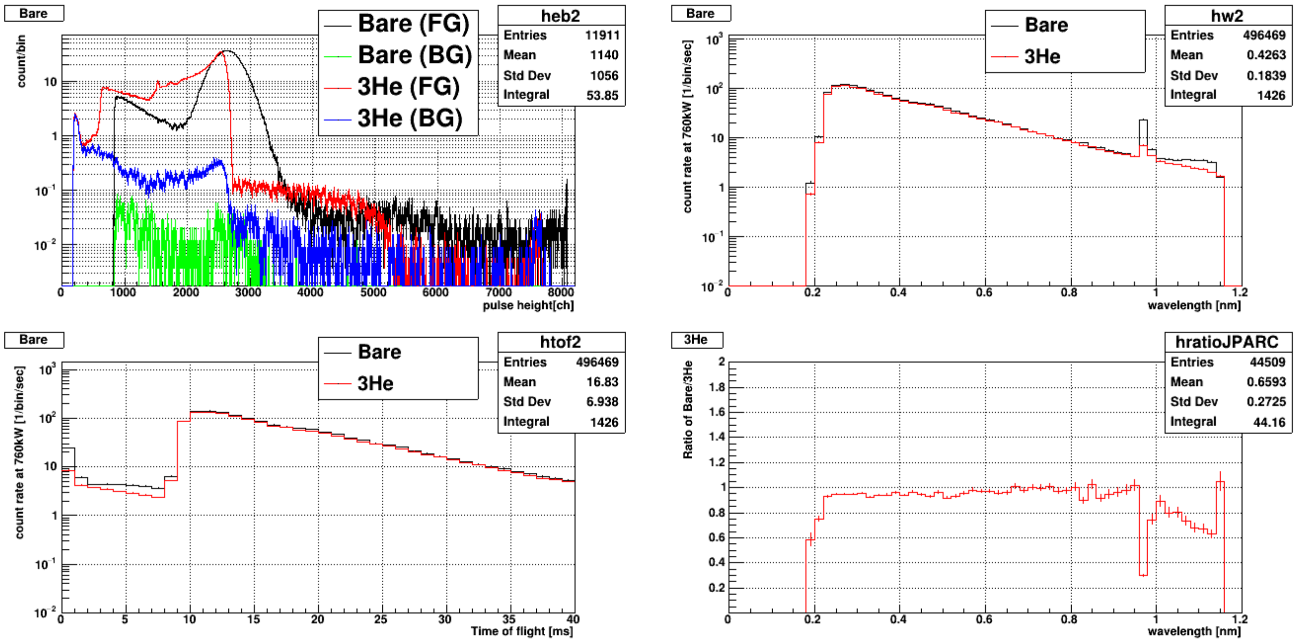

Figure 13: Efficiency of the bare detector compared to the 3He detector.

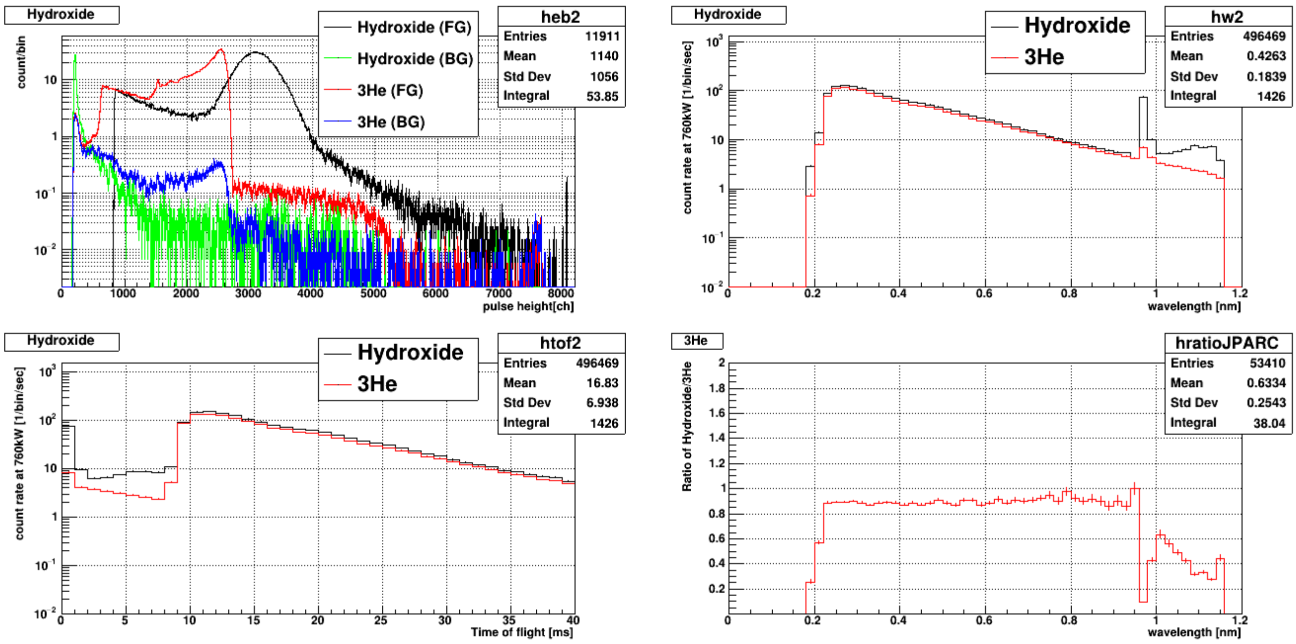

Figure 14: Efficiency of the hydroxide detector compared to the 3He detector.

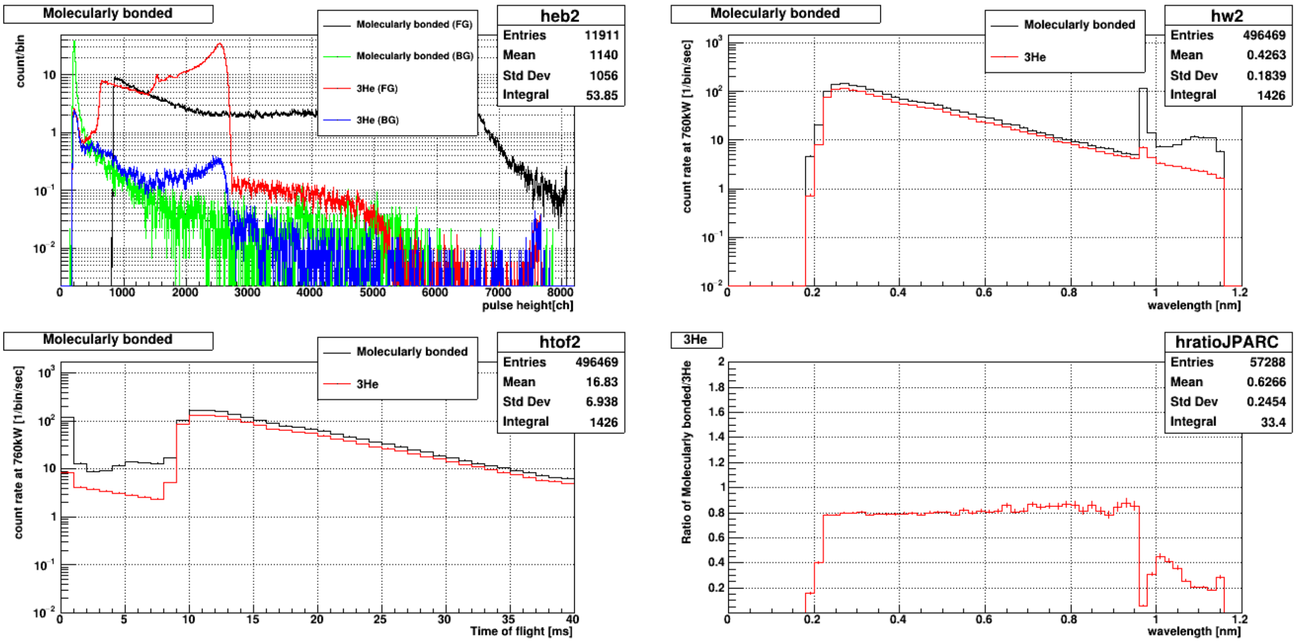

Figure 15: Efficiency of the Molecularly bonded detector compared to the 3He detector.

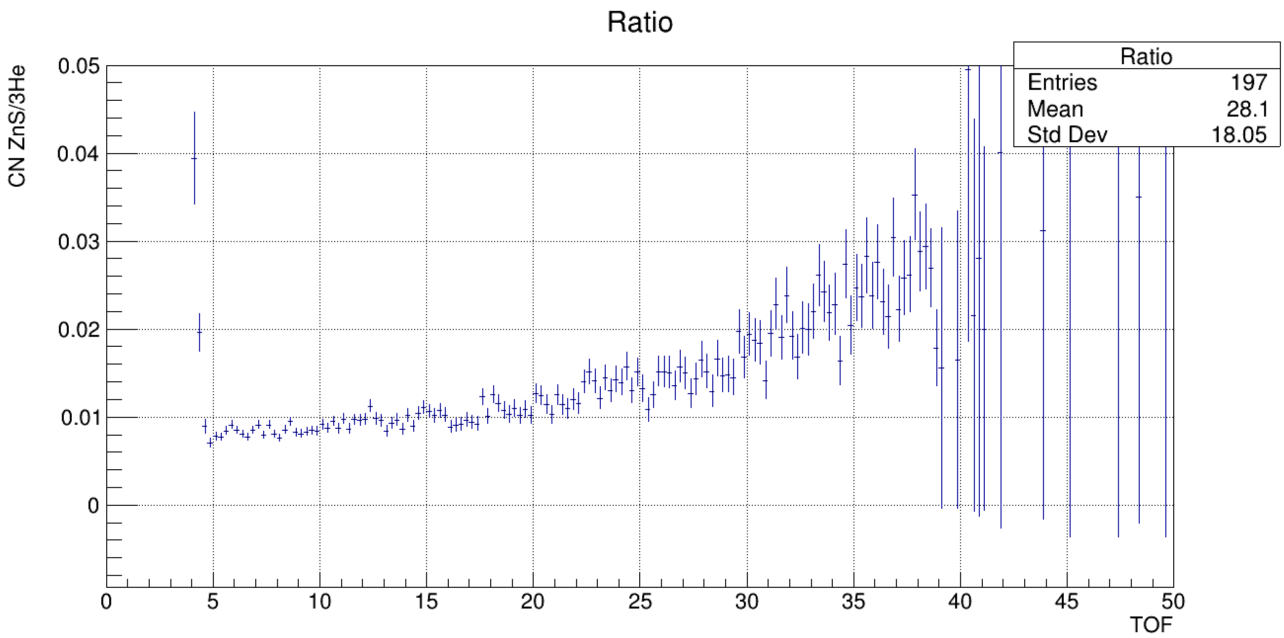

Figure 16: Efficiency of the ZnS detector compared to the 3He reference detector.

Section summary

When accounting for background radiation in the detection process, the efficiency of the 6Li detectors seem to be operating at approximately 20x the efficiency of the dunia detector due to the fact that when taking the ratio of the dunia detector to the 6Li detectors, the efficiency operates at approximately 6±4% seen between figures 9-12.

When comparisons are made between the detectors with the 3He reference detector as seen between figures 13-15 with the 6Li detectors, you get similar results. By far the most efficient detector seems to be the bare detector when accounting for background radiation which operates at efficiencies between 95-105% of the 3He reference detector, at points being more efficient as seen between points x=0.65 through 0.7 as well as 0.85 through 0.9.

Figures 14 and 15 detail the efficiencies of the molecularly bonded and hydroxide detectors, and as expected from figures 3, 4, and 8 the detectors were calculated to be slightly less efficient than the 3He reference detector operating consistently at 90% efficiency.

Figure 16 details the efficiency of the ZnS detector and as expected when compared to figures 8, we can see that the ZnS detector operates between 0.8% and 3% the efficiency of the 3He reference detector making it a particularly inefficient CN detector.

To conclude this section it's easy to see that while the 6Li scintillating detectors are quite efficient, the bare detector operates the best of the tested detectors. With regards to the molecularly bonded and hydroxide detectors there is little to no observable difference as seen in their similarities between figures 3, 5-8, 11, 12, 14, and 15 showing that they register cold neutrons, background, and alpha particles practically identically when normalized by kp. The only difference between the two detectors with their registry of CN is the ADC channels that their individual peaks are located. The ZnS detector has also been concluded to be an inefficient ZnS detector and shouldn't be used for this purpose.

6 UCN detector run comparisons

Foreground/Background comparisons

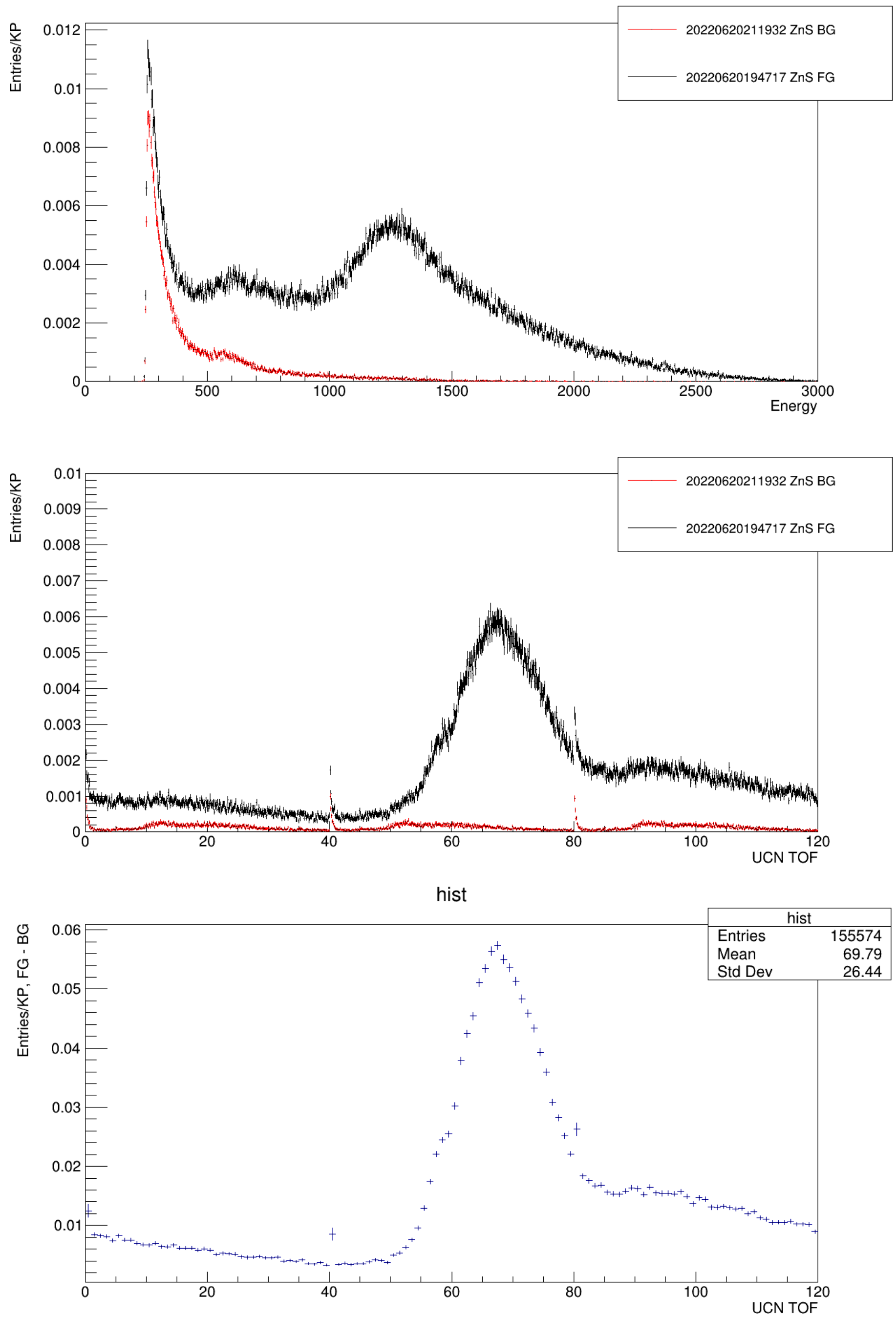

Figure 17: ZnS detector comparison between foreground and background measurements.

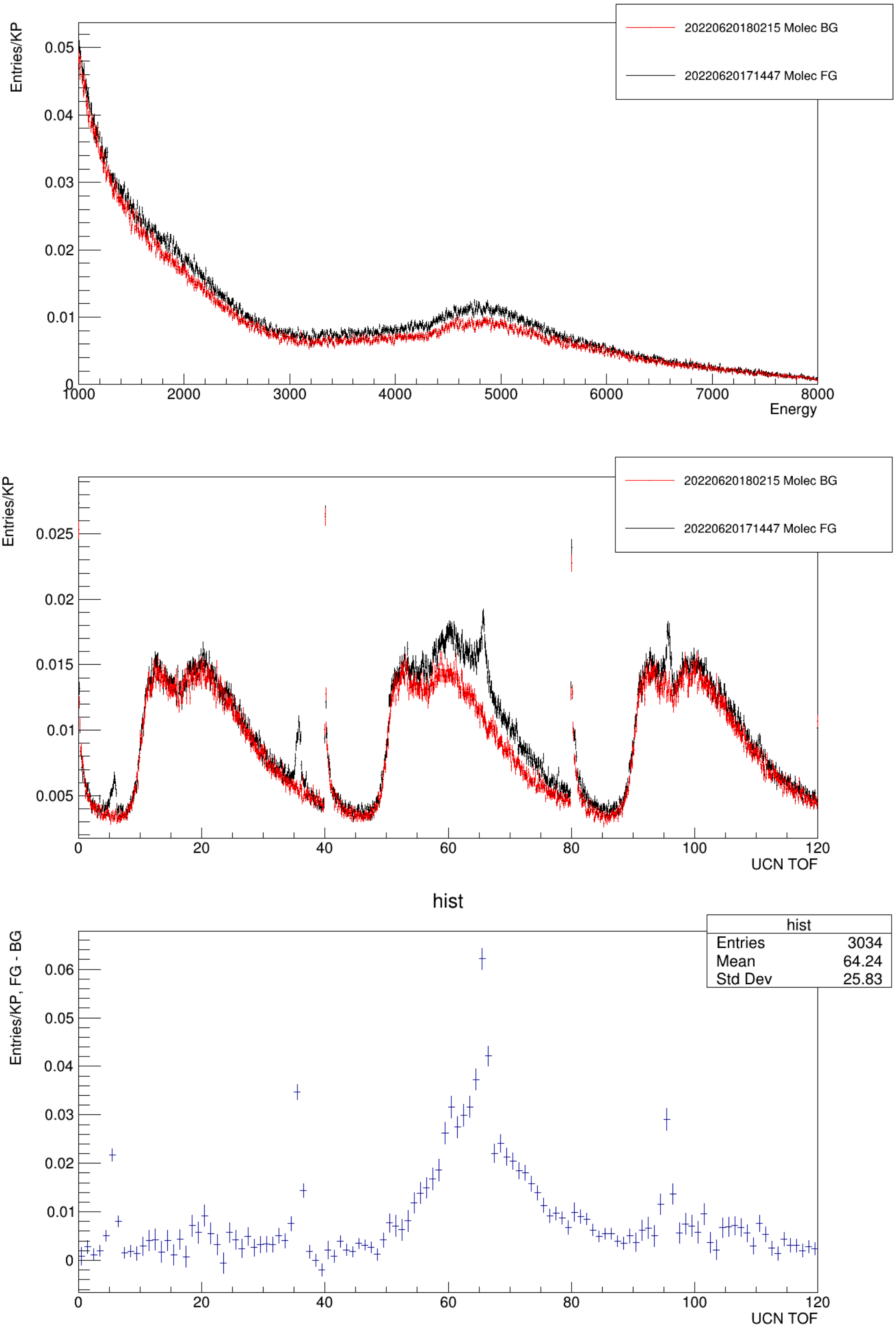

Figure 18: Molecularly bonded detector comparison between foreground and background measurements.

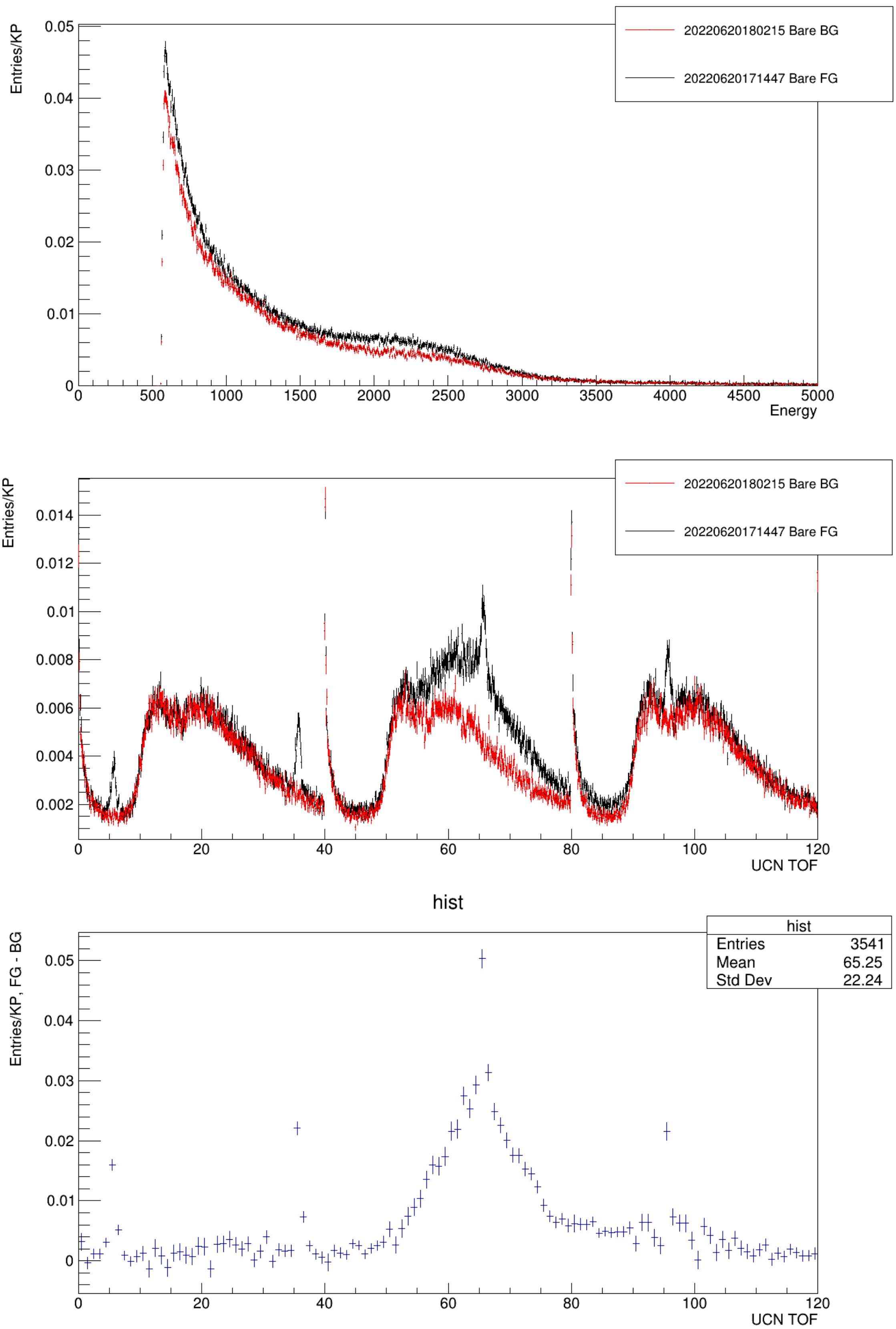

Figure 19: Bare detector comparison between foreground and background measurements.

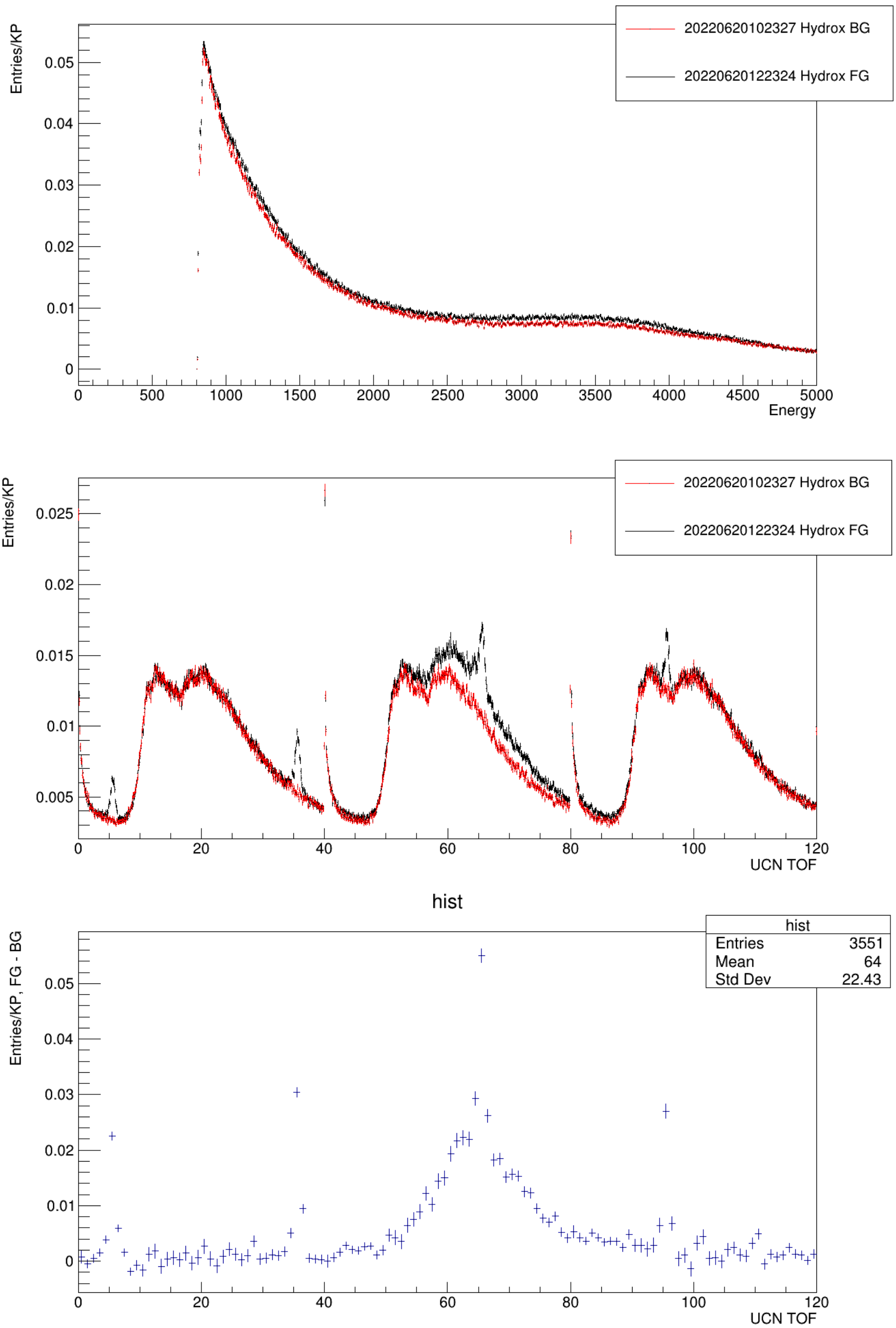

Figure 20: Hydroxide detector comparison between foreground and background measurements.

Dunia UCN Comparisons

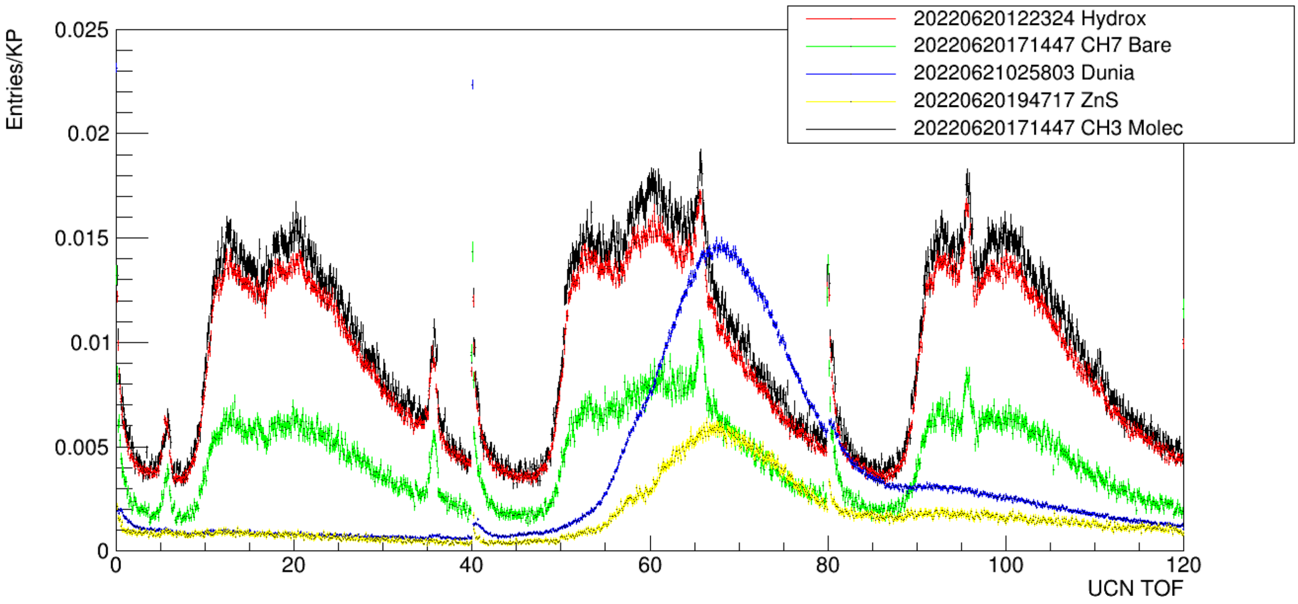

Figure 21: The five detectors foreground measurement for UCN TOF compared to eachother.

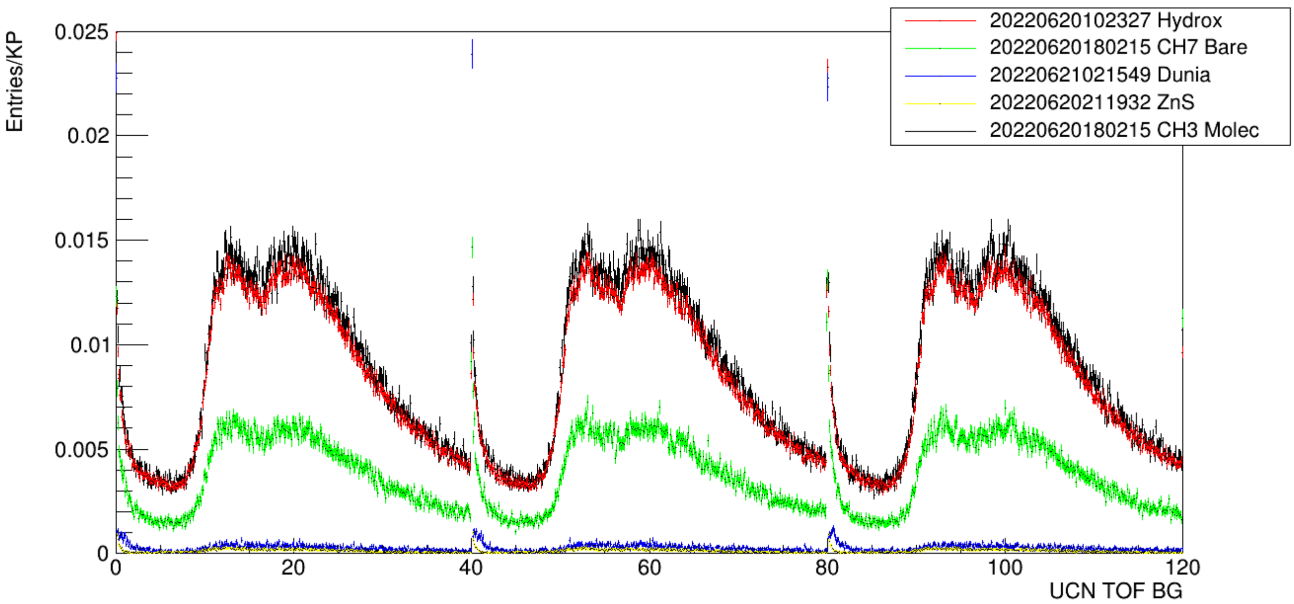

Figure 22: The five detectors background measurement for UCN TOF

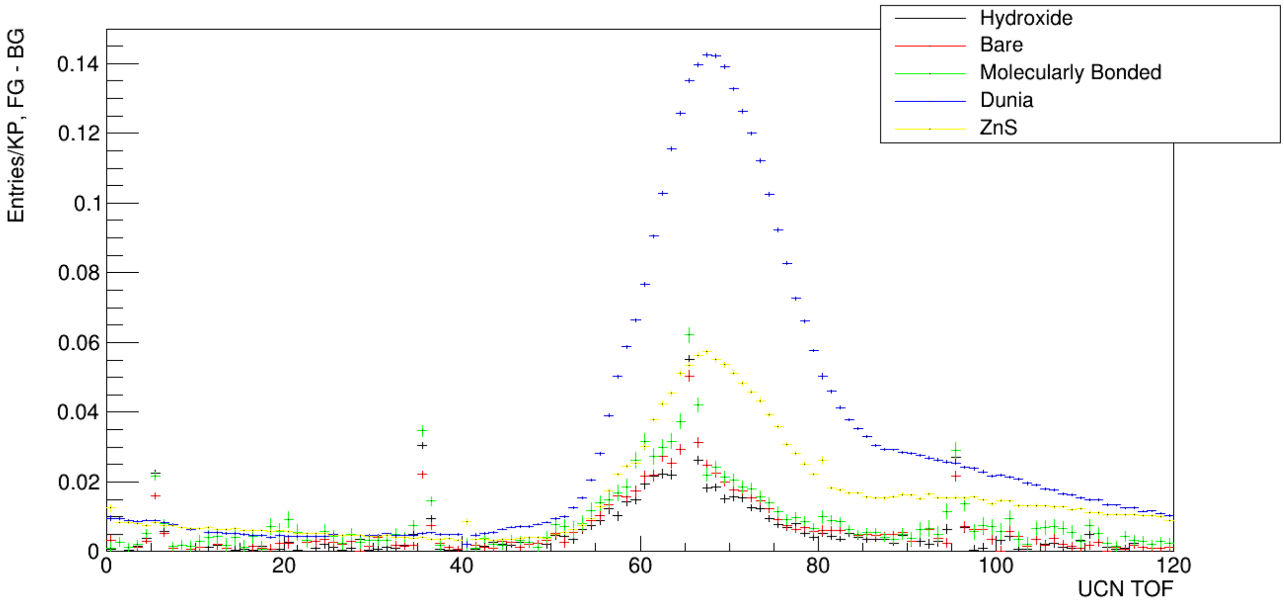

Figure 23: A comparison between the five detectors for foreground and background measurements.

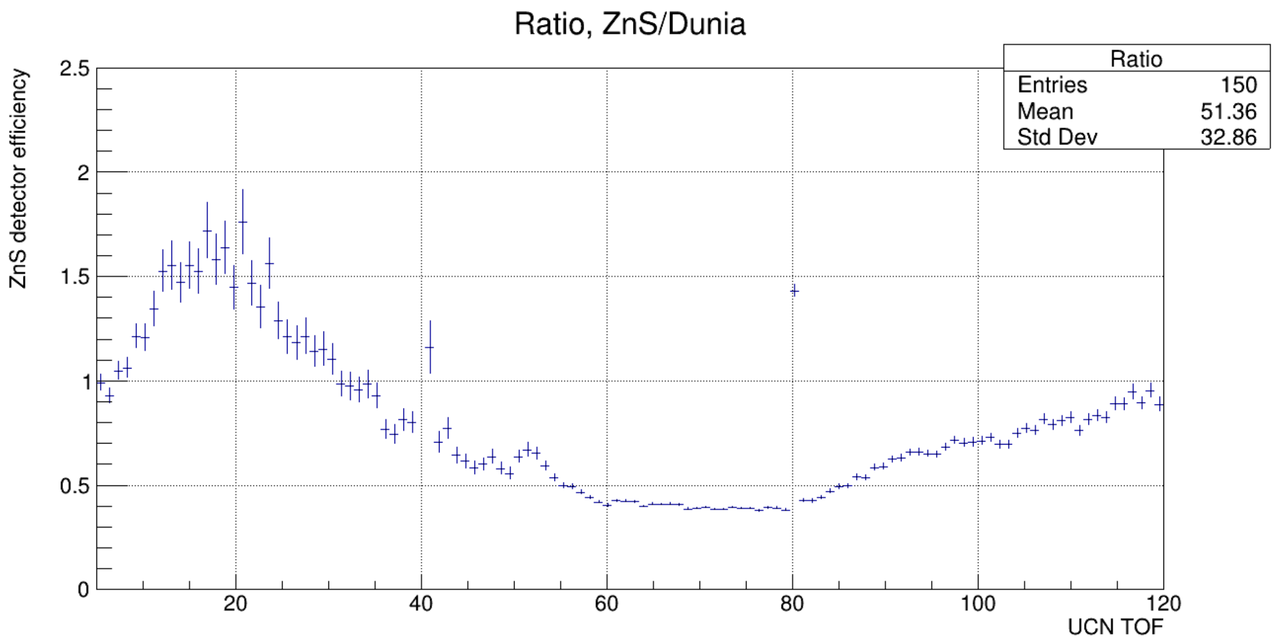

Figure 24: Ratio of the UCN time of flight for the ZnS/dunia detectors.

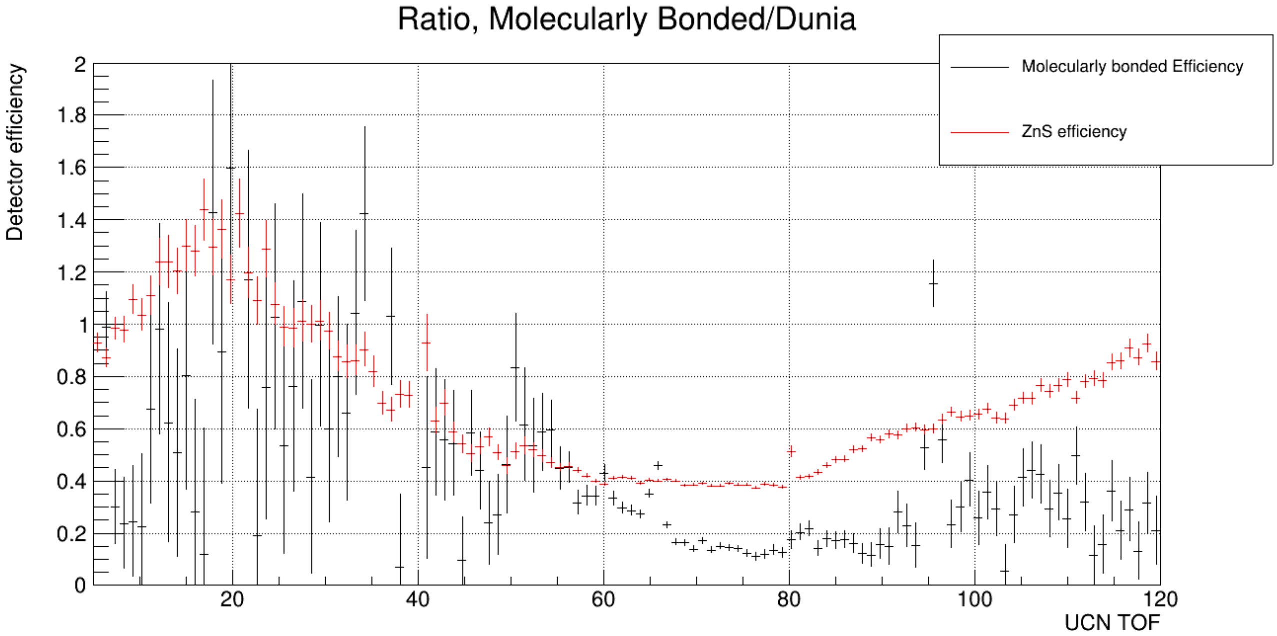

Figure 25: Ratio of the UCN time of flight for the molecularly bonded / dunia detectors.

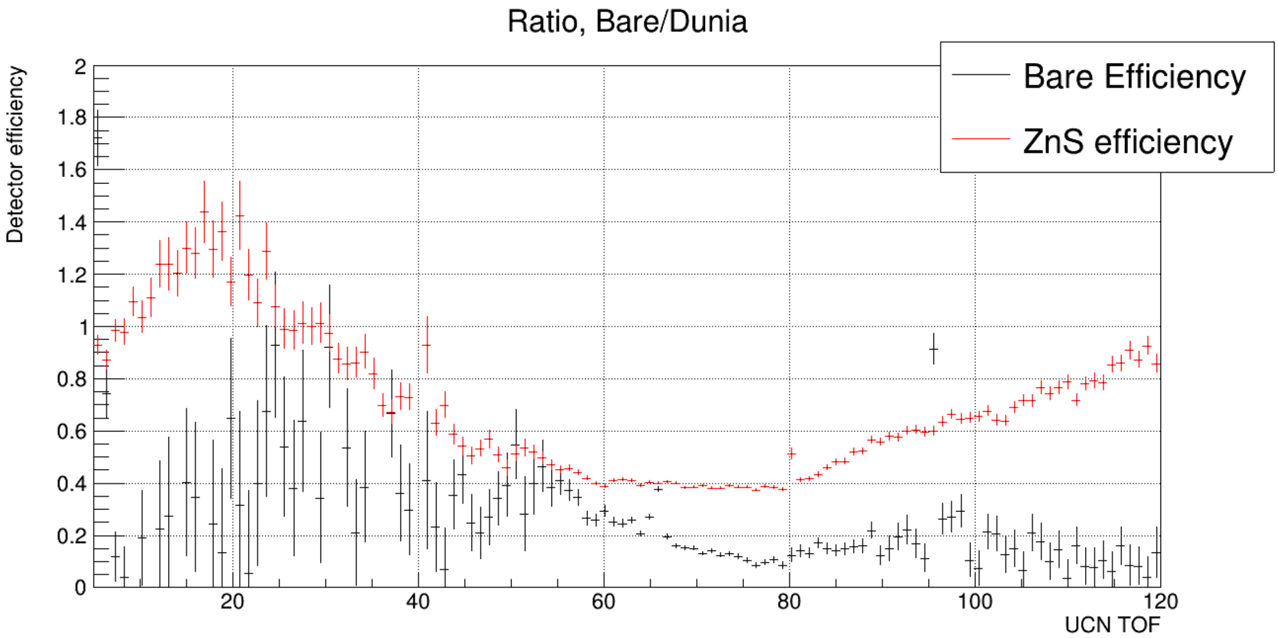

Figure 26: Ratio of the UCN time of flight for the bare/dunia detectors.

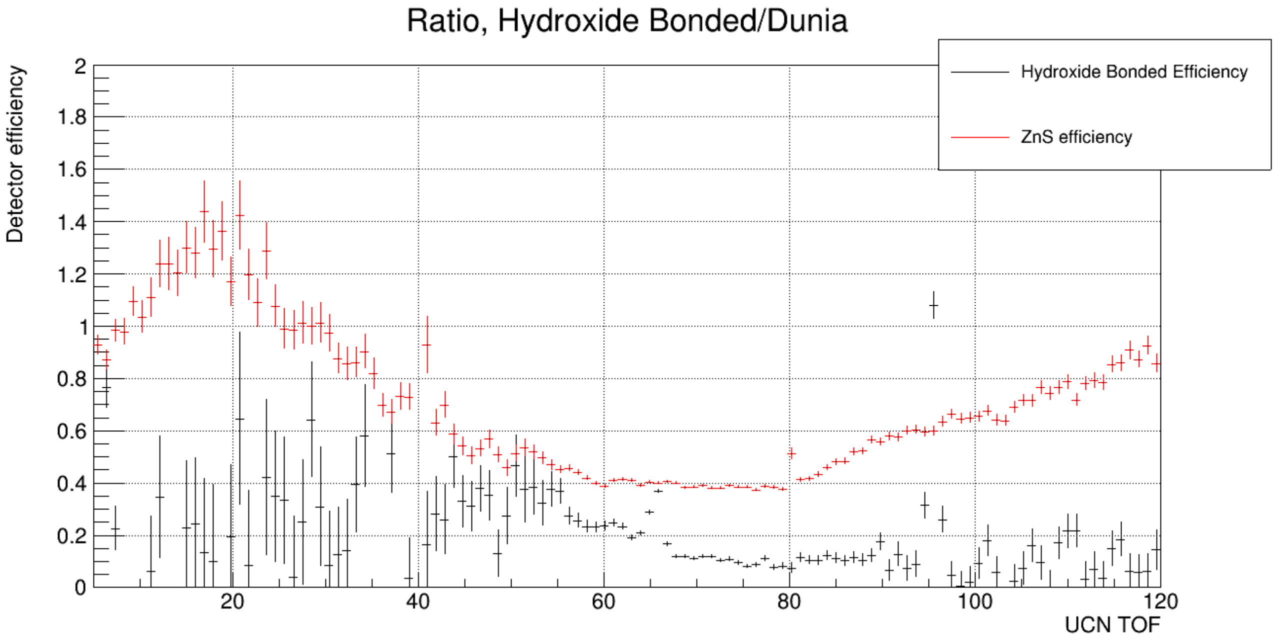

Figure 27: Ratio of the UCN time of flight for the hydroxide/dunia detectors.

UCN ZnS/6Li detector comparisons

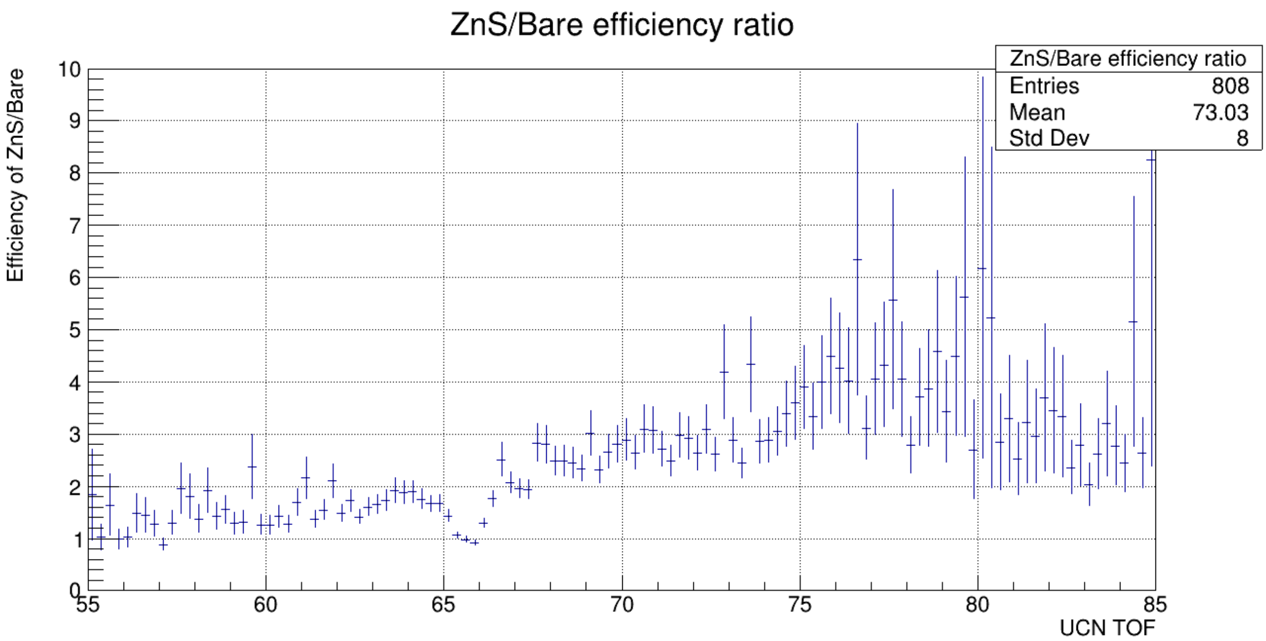

Figure 28: Efficiency of the ZnS detector compared to the bare detector

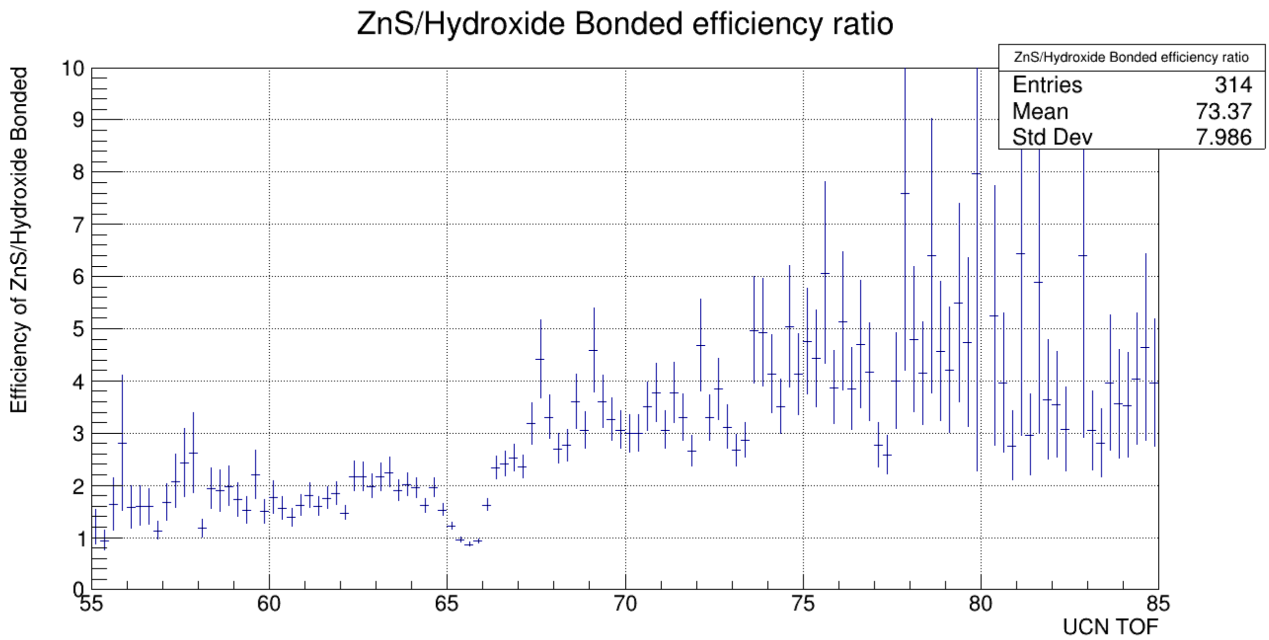

Figure 29: Efficiency of the ZnS detector compared to the hydroxide detector

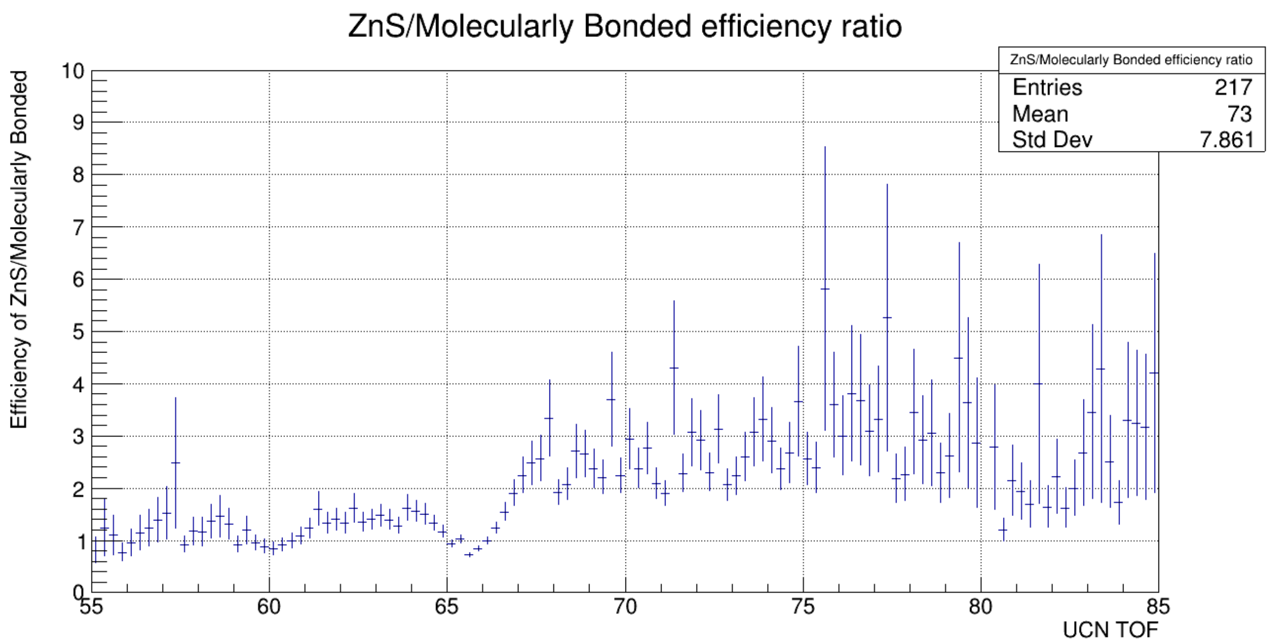

Figure 30: Efficiency of the ZnS detector compared to the molecularly bonded detector

7 Conclusion

For CN runs it appears that the 6Li detectors are relatively comparable in efficiency and approximately equal in efficiency to the 3He reference detector operating at 10atm. Being precise, it appears that the bare detector operates most efficiently when accounting for its lack of sensitivity to background radiation, and the molecularly bonded detector operates least efficiently due to its particularly high sensitivity. The dunia detector was found to be approximately 5% the efficiency of the 6Li and 3He detectors as well. The ZnS detector was particularly insensitive to CN detection and was found to operate between 0.7% and 3% the efficiency of the 3He reference detector.

For UCN runs the ZnS detector was found to be the most efficient detector by far operating at approximately 40% the efficiency of the dunia reference detector along with its insensitivity to background radiation. When compared to the 6Li detectors it was found that the ZnS detector was operating between 1-5x the efficiency relative to them depending on the bins being analyzed. The 6Li detectors were also found to be operating at approximately 10% the efficiency of the dunia reference detector making them not ideal detectors.