Data Analysis (HCANA Update)

0.1 HCANA Update

0.1.1 HCANA THcHodoscope::CoarseProcess() Update

As we mentioned in the HCANA introduction, the THcHodoscope::Decode() is used to analyze the hit data and select "good" hits, preparing for further tracking-related information calculation in the CoarseTrack method. Then the track information is available for CoarseProcess() for an improved determination of scintillator paddle timing using the track information.

In the CoarseProcess method, a good hit is defined when the difference between the center of scintillator paddle and the track projection on the paddle is smaller than half of the paddle width plus a parameter (*hodo_slop*). In each plane, more than one paddle can have a good hit. The time-of-flight to each hodoscope paddle that has a good hit is calculated based on the track momentum ($\beta = p/\sqrt{p^2 + m^2}$, assuming the particle mass known), and the distance to the hodoscope paddle from the *z=0* plane (focal plane) is calculated using the focal plane track positions and angles. This time-of-flight is subtracted from each "good" hit time which gives the time at the focal plane. The average of all the time-of-flight corrected times is called the *focal plane time* and is used in the coincidence time calculation [1].

Unfortunately, the old HCANA had the track momentum calculated after CoarseProcess method. It was set to a very big value by default, which means the beta was always equal to 1. For most experiments, the particle beta is near one, so this problem had not been noticed. For our experiment, the protons in the HMS have a beta near 0.7, so using the wrong beta caused a calculated focal plane time to have a shift and an asymmetric spread in time. Since the focal plane time is used in the coincidence time calculation, this caused larger tails in the coincidence time as well. Also, we used a relatively narrow coincidence time peak cut, which means we must carefully treat the π^0 (photons) in the side peaks. It turned out that the good events

were up to 4 ns away from the coincidence peak.

In new HCANA, the track momentum is calculated before the time-of-flight determination, providing the correct beta value and focal plane time. Fig 1 are the SHMS hodoscope beta plots for two side peaks (+ 2 ns and - 2 ns) before and after the update. In the before plots, the beta for the -2 ns bin had more events in the tails of the beta spectra. They are eliminated as shown in the after plots. Fig 2 is an example of Elastic 3 W plot before and after the correction. Before, the ratios of accidentals to coincidence were about 2% and 1% in 2 ns and -2 ns bins, and about 0.9% and 0.3% in 4 and -4 ns bins. Similar fractions were found in production runs. They are larger than expected and asymmetric around the main peak. After the fix, the ratios in the 2 ns and -2 ns are about the same level at 0.7% and the 4 ns and -4ns bins have ratios about 0.2%, indicating that there are fewer true events in the side peaks. For more details on the updates, see ref [2].

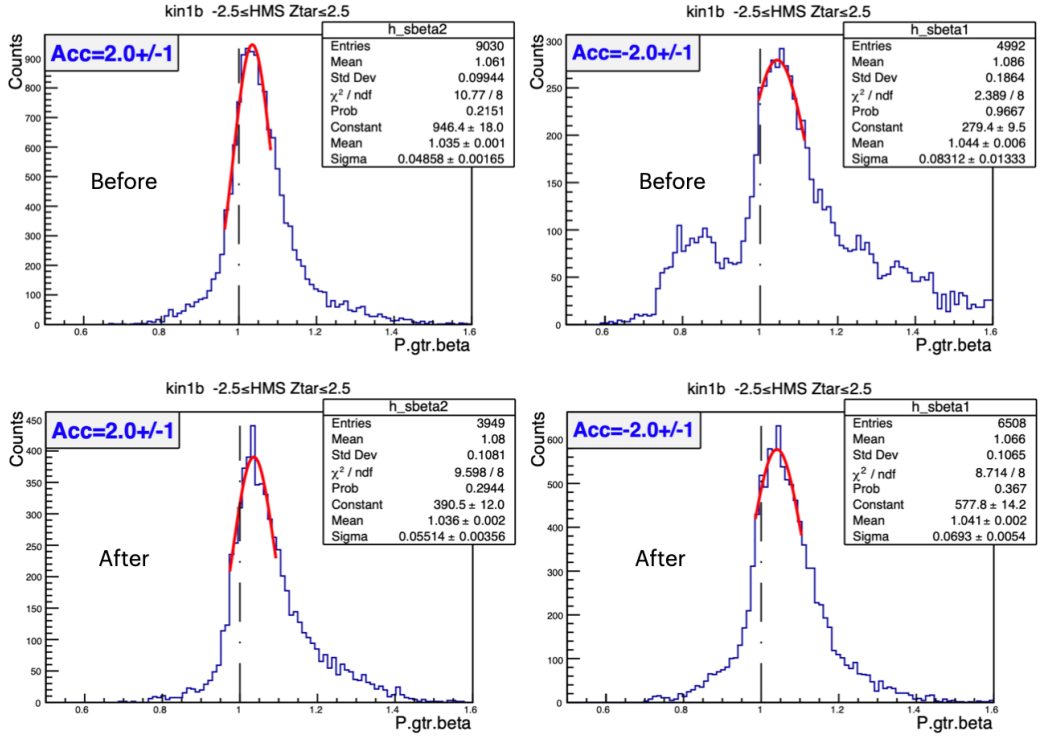

Figure 1: Kin 1b Hodoscope beta plot before and after HCANA update for 2 +/- 1 ns and -2 +/- 1 ns bins.

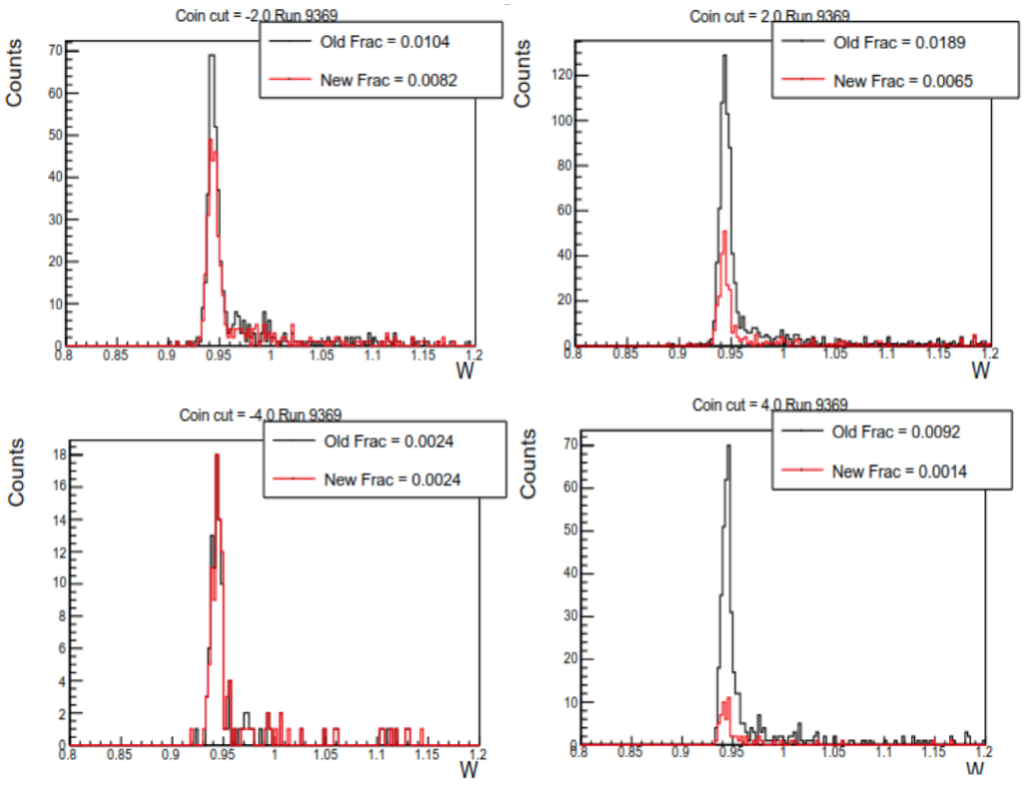

Figure 2: Comparison of events in side peaks between old and new HCANA for elastic 3. Figure Credit: Mark Jones.

0.1.2 HCANA Drift Chamber Update

The next HCANA update is on the tracking selection, which aims to find the tracks that are related with the corresponding hodoscope triggers. In each drift chamber, there are clusters of hits called "space points." The "space points" are determined from hits within a distance that is set as a parameter. HCANA loops through all possible left/right combinations of hits in the space point and does a fit for each combination, and selects the fit with lowest χ^2. The best fit is called the "stub" for that space point in the chamber. Next, the HCANA links "stubs" in the two chambers together. Specifically, the HCANA loops through all the space points in Chamber 2 to match each space point in Chamber 1. If the differences between the stub's x/y positions and dx/dz angle in Chamber1 and Chamber 2 pass certain limits, a track is formed. After matching the space points in two chambers, there can be multiple possible tracks and we need to find the one associated with the trigger. This is the "golden" track. All the possible tracks are filtered through 12 selection criteria (*pruning method*), and the track which passes all 12 is the golden track. If more than one track passes all 12 criteria, the track with the lowest χ^2 is chosen as the golden track [1][3]. Details on this step are discussed in the HCANA introduction. Next, I will discuss a bit about the HCANA update and its application on our VCS experiment in this section. For more details about the update, see ref [4].

In our analysis process, we found that there were excessive events in the missing mass squared below the π^0 peak, and caused an unclear separation between π^0 and photon channel, as shown in Fig 3(a) blue region. In Fig 3(b), it shows the same problem also found in elastics. Below the elastic peak, there were events have very large χ^2, for example χ^2 >100, which were caused by the bad hits in the chambers. In new HCANA, a minimum and a maximum drift time are added as parameters. If the DC time after start time correction is within the min and max time, it fills the fHits that is used for clustering. By this step, the number of junk hits is re-

duced. Second, the "stub" link method between two chambers is rewritten to reduce the number of candidate tracks that passed the matching criteria. Thirdly, a new method was written for determining the hits to include in the space point. Last, the THcDC:TrackFit() method is modified to remove the hit that has the largest residual (the difference between the fitted and measured track position at the plane).

As shown in Fig 4 (a) and (b), with new HCANA, the bump between two channels was eliminated, and the number of events that have large χ^2 at lower W in elastic 3 was largely reduced as well. Fig 5 shows the ratios of the number of events when χ^2 >100 to the total number of events before and after the HCANA update. It decreased from 8% to about 1%.

In our analysis, we use cuts at $\chi^2 > 100$, $H/P.hod.goodstarttime == 1$ (the number of planes that had good hit was no less than 3), $H/P.dc.track > 0$ (at least one track was found), and keep track of the event loss and correct for that. Eq 1 is the formula for HMS χ^2 correction factor calculation. The SHMS correction factor has the same logic.

$$fac_{\chi^2} = 1 - \frac{H.dc.track > 0 \ \& \ H.hod.goodstarttime == 1 \ \& \ H.dc.chisq > 100}{H.dc.track > 0 \ \& \ H.hod.goodstarttime == 1} \quad (1)$$

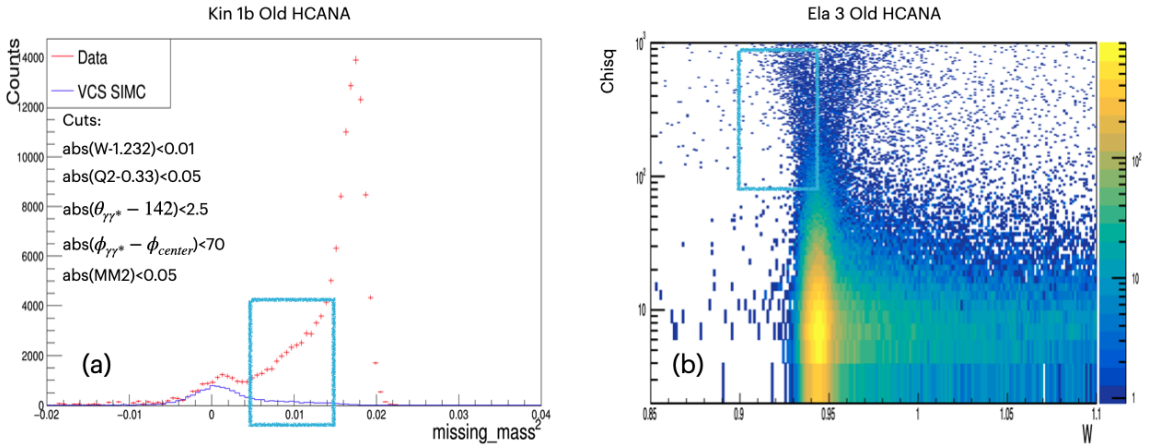

Figure 3: Plots before HCANA drift chamber update. (a) Kin 1b missing mass squared plot (b) Plot of χ^2 of the track versus W for the elastic data taken in kinematics setting 3. In MM2 plot, the blue is the VCS simulation and the red (data) γ and π^0 channels were not clearly separated. In W 2D plot, there were events that had large χ^2 below elastic peak.

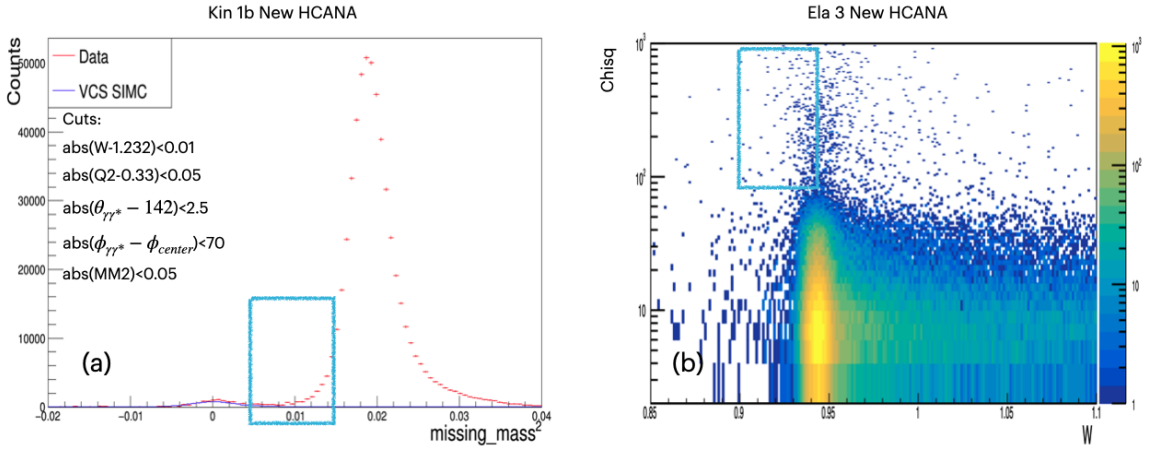

Figure 4: Plots after HCANA drift chamber update. (a) Kin 1b missing mass squared plot (b) Plot of χ^2 of the track versus W for the elastic data taken in kinematics setting 3. In MM2 plot, the data photon and π^0 channels are clearly separated. In W 2D plot, there are almost no events below elastic peak at χ^2 >100. *Note: The MM2 old HCANA plotted about a third of the Kin 1b runs and the new HCANA plot has all the runs merged together.*

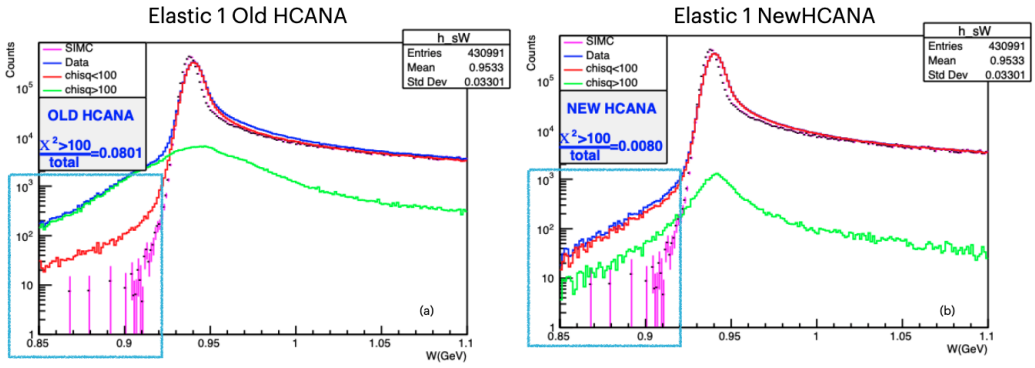

Figure 5: Elastic 1 W plots before (left) and after (right) HCANA update. Before updating, the number of events at χ^2 >100 were about 8% of total; While in the new HCANA, it dropped to less than 1%.

Bibliography

[1] Mark Jones. *Track selection in HCANA*. 2020. URL: https://hallcweb.jlab.org/DocDB/0010/001062/001/HCANA_pruning.pdf.

[2] Mark Jones. *Update to HCANA THcDC to fix problem in THcHodoscope focal plane time*. 2021. URL: https://hallcweb.jlab.org/doc-private/ShowDocument?docid=1141.

[3] Mark Jones. *private conversation*.

[4] Mark Jones. *HCANA DC Update July 2021*. 2021. URL: https://hallcweb.jlab.org/doc-private/ShowDocument?docid=1143.