Abstract:

This report documents the performance of CLEO's new secondary vertex finding package, KNVF, in the CLEO II Recompress by comparing its results to those of CLEO's tried-and-true secondary vertex finder, VFND. In addition, this note also makes some attempt to characterize the overall quality of the tracking improvements made for the Recompress through comparisons with the original compress.

1 Introduction

The pass 2 portion of the CLEO II recompress was completed in April 1997, and non-aligning, skinning, gold-planting for the k+ dauners was completed in July. Full documentation describing all the improvements made for the recompress is under construction, but only the tracking improvements are relevant for this analysis. These improvements include the introduction of a Kalman filter track-fitting algorithm [1] and new calibration for the tracking chambers.

The purpose of this document is twofold: first, to describe the performance of KNVF, CLEO's new secondary vertex finder, which was run for the first time with the CLEO II recompress, and second, to compare the recompress with the original compress using secondary vertices as a diagnostic. This analysis uses 103 pb⁻¹ of data from the K painter dataset (run 6386-63798) for both the recompressed and the original compress samples. No monte carlo is used.

This document may be regarded as a close relative to another document written by Rob Kutscshe and Anders Ryd prior to the start of the Recompress, which was never publicly released [2]. It is an excellent and thorough document, and I refer all interested readers to it.

I will present results from KNVF and VFND for $K_s$ and $\Lambda$ vertices. $\gamma$ conversions will not be discussed in this document. The $K_s$ and $\Lambda$ mass, width, and yield were monitored as a function of:

1. $\phi$ of the vertex, $\phi_X$
2. Momentum of the vertex, $P_X$
3. Radius of vertex from center of detector, $R_X$
4. $z$ direction cosine of vertex, $CZ_X$
5. Momentum of the positive daughter, $P_+$
6. $\cos(\theta)$ of the positive daughter, $\cos\theta_+$

The $K_s$ and $\Lambda$ reconstructed mass was binned in the above variables. These histograms were fit with MN_FIT's likelihood option to a line shape function made up of a double gaussian and second order Chebyshev polynomial.

KNVF is fully described elsewhere [3]. However, it is important to note when making comparisons that KNVF, by default, makes no cuts on track or vertex quality when searching for VEs; these are left up to the user. In the discussion which follows, the default VFND cuts were modified in the following way so both processors made the same cuts (or lack thereof):

1. Minimum radial distance to vertex ($R_{VMIN}$) set to 0.
2. Cut on vertex quality factor to be less than CHIMAX removed entirely.
3. Cut on RESICD of daughters for VEs inconsistent at DOCA was loosened completely.

A note about RESICD: the meaning of RESICD has changed for the recompress [4]. With the new meaning, and the cut's implementation in VFND, this cut discriminated completely against long lived VEs [beyond 12 cm]. To leave the RESICD cut untouched would have been unfair to VFND, and would have introduced a systematic into comparisons made to pre-recompress data.
4. Cut on DBCD/DCBD for daughters of candidate vertices was removed.

The V0 selection criteria used below are deliberately simple (and are not of analysis quality). This was done to avoid any systematic effects when comparing the Recompress to the original compress (lots of useful information like dEdx, time of flight, and anything having to do with tracking errors, such as track and vertex fit $\chi^2_k$, etc. all have different efficiencies in the recompress and pre-recompress data). Additionally, in order to carry out the purpose of this analysis, quantities which were cut on had to have the same meaning in KNVF and VFND for both compresses. That said, the conclusions drawn from the following analysis are not qualitatively changed when tighter selection criteria are used.

2 $K_s$

2.1 Recompress

A $K_s$ sample was selected from the KLGL = 10 events in the recompress data sample with the following criteria:
1. RBMTX $\geq$ 4 mm
2. No z-escape daughters were allowed.

No particle ID was used. The $K_s$ signal with the above cuts is shown in Figure 1, and the fits to the histograms in Figure 1 are shown in Table 1, where $\sigma_{RMS}$ is defined as

$$\sigma_{RMS} = \sqrt{\frac{A_1\sigma_1^2 + A_2\sigma_2^2}{A_1 + A_2}}$$

and $A_i$ and $\sigma_i$ are the areas and widths of the two gaussians, as in reference [2]. The quoted errors on $\sigma_{RMS}$ were calculated using the full covariance matrix returned by MINUIT. Further, in all fits the difference in the means and the ratios of the widths of the two gaussians was fixed at 0 and 2, respectively, in order to avoid convergence problems in the fits. Finally, $A_2/A_1$ had an upper limit of 0.5.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Fit results for Figure 1. The PDG mass for the $K_s$ is 497.67 $\pm$ 0.03 MeV.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\sigma_{RMS}$</td>
</tr>
<tr>
<td>VNDF</td>
<td>4.03 $\pm$ 0.03</td>
</tr>
<tr>
<td>VFND</td>
<td>4.71 $\pm$ 0.05</td>
</tr>
</tbody>
</table>

The increase in quality with KNVF is obvious from Figure 1. The characteristics indicating the increase in overall quality over an equivalent VFND - better resolution, slightly increased yield, greater significance, and mass closer to nominal - are advantages for KNVF no matter what selection criteria or fitting procedure applied. The $K_s$ candidates satisfying selection criteria from the Recompress sample, KNVF is the solid histogram VFND is the dashed. Fit results are shown in Table 1.

Plots of $K_s$ mass, width, and yield in bins of $\phi_{TX}$, $P_{TX}$, $R_{TX}$, $P_{TX}$, $\cos\theta_{TX}$, and $C_{TX}$ are shown in the appendix (Figures 5-7). One can see that KNVF outperforms VFND by wide margins in width and mass difference from nominal in almost every bin of all 6 variables. The width advantage for KNVF is primarily due to the vertex fit, and the improvement in the mass is mostly due to proper transport of the daughter track parameters and error matrix through the detector material before the vertex fit is applied. It is also worth noting that the tails of the KNVF mass distribution are consistently smaller than those of VFND, no matter how you slice and dice the mass.

The $R_{TX}$ mass distribution troubles me a bit. The structure present in this plot could imply a problem with the material description of CLEO used by the Kalman filter, or a problem with the fitter’s use of that description. But note that KNVF is much less disturbed by this problem than VFND (which is to be expected since VFND knows nothing about material); i.e., taking material into account (even despite a hypothetical error somewhere) is better than nothing. This deserves more
2.2 Recompress vs. Original Compress

In this subsection, I will investigate how much “better” recompressed data is than the original compress. This objective is a bit fuzzier than one might think, since there are many new things about the Recompress data. I shall confine myself to discussing how much “better” Recompress data is due to improvements in tracking [i.e., the Kalman Filter and new CD calibration]. Certainly, one could also ask how much “better” are the hadron skims, due to the new event classification [5] and/or any “new” runs made available from pass 2 in addition to tracking and other improvements. This is also an interesting question, though I will not discuss it in any detail here.

In order to make this comparison fairly and filter out non-tracking related improvements/differences between the two compresses, I made an event list for both data samples of KLGL = 10 events and merged them into a single, common event list (the overlap between the two). Table 2 shows the event classification differences in the two original lists for the KLGL = 10 events. Only events in the overlap event list were used when comparing the Recompress to the original compress. The mass selection criteria were otherwise unaltered from the previous subsection.

Table 2

<table>
<thead>
<tr>
<th>Data</th>
<th>Number of KLGL = 10 events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recompress</td>
<td>52,052</td>
</tr>
<tr>
<td>Pre-recompress</td>
<td>52,0835</td>
</tr>
<tr>
<td>Overlap</td>
<td>463,439</td>
</tr>
</tbody>
</table>

The track finding code changed only minutely between these two samples [although the constants were remade]. Therefore, we should expect that the number of KINCD ≥ 0 tracks (which are the only ones which KNVF and VFND consider) should not change much. Indeed, the number of KINCD ≥ 0 tracks is up by only 1.8% in the Recompress sample, and most of these are z-escapes. If one removes the z-escapes from consideration, the number of KINCD ≥ 0 tracks increased by only 0.5%.

The frequency of z-escape daughters in the overlap events was 12.5% of KINCD ≥ 0 tracks in the recompress and 11.6% in the pre-recompress. Though there is a slight difference in these fractions, z-escapes were treated differently by DUET in the two samples (they were fitted with TF3FIT in the original compress, but the track parameters of z-escapes in the Recompress are from the pattern recognition “primitive” in comparison); therefore z-escapes were cut away from both samples. In any case, removing them will not bias any mass scale or resolution conclusions since they added nothing but background to the mass distributions. Users should also ignore these tracks at analysis time.

Recompress KNVF results were compared with pre-recompress VFND results of two types: with and without KNLIB energy loss corrections applied [these energy loss corrections are described elsewhere [6]]. No reasonable person would run pre-recompress analysis jobs without energy loss correcting their tracks; I only show the non-energy loss corrected results so one can see the effects of the KNLIB corrections and compare them with Kalman’s results. The results of the fits of the $K_s$ mass spectrum shown in Figure 2 are summarized in Table 3.

Table 3

<table>
<thead>
<tr>
<th>Data</th>
<th>Voecfinder</th>
<th>$\sigma_{RMS}$ (MeV)</th>
<th>Yield</th>
<th>Mass (MeV)</th>
<th>$\chi^2$/dof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recompress</td>
<td>KNVF</td>
<td>4.92 ± 0.05</td>
<td>739.46 ± 58.2</td>
<td>497.73 ± 0.02</td>
<td>1.1</td>
</tr>
<tr>
<td>Recompress</td>
<td>VFND</td>
<td>4.70 ± 0.05</td>
<td>717.00 ± 71.7</td>
<td>497.75 ± 0.02</td>
<td>1.4</td>
</tr>
<tr>
<td>Pre-recompress</td>
<td>VFND w/</td>
<td>4.98 ± 0.06</td>
<td>639.06 ± 36.8</td>
<td>497.71 ± 0.02</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>no/</td>
<td>5.80 ± 0.07</td>
<td>675.07 ± 96.5</td>
<td>495.63 ± 0.03</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Again, plots of $K_s$ mass, width, and yield in bins of $\phi, \phi_p, P_4, P_4^*, \cos \theta_3$, and $\phi/\phi_4$ can be found in the appendix (figures 8-10).

The most striking feature of Table 3 is the dramatic improvements in $\sigma_{RMS}$ and the yield - recall that these results are from the same events, Table 3 and the plots in the appendix also show the superiority of the Kalman filter’s KNVF mass over the pre-recompress energy-loss corrections applied to VFND w/ - despite the fact that the pre-recompress energy loss corrections were determined, in part, by tuning on the $K_s$ mass. It should also be noted that the old energy loss corrections look pretty good, except as a function of $\phi$. Also note the progression of errors on the width and yield - best results are obtained with KNVF in the recompress.
Figure 2. All $K_s$s satisfying selection criteria. KNVF is the solid histogram, Recompress VFND is dashed, pre-recompress VFND w/loss is the hatched, and VFND w/ no loss is dotted. Fit results are shown in Table 3.

3 A

3.1 Recompress

A selection criteria were the same as for the Recompress $K_s$ analysis, with the additional cut that the $\Lambda$ momentum be greater than 500 MeV. It should be noted that VFND does not use the proton track parameters for building $\Lambda$ candidates (it uses the pion hypothesis for all vertex hypotheses); I did not repair this for this study.

KNVF and VFND $\Lambda$ mass distributions are shown in Figure 3, and fit results are summarized in Table 4.

Figure 3. All $\Lambda$s satisfying selection criteria from the Recompress sample. KNVF is the solid histogram, VFND is the dashed. Fit results are shown in Table 4.

The signal to noise for the $\Lambda$ plots is not impressive (dEdx would clean this right up) - the backgrounds are higher, and the signal area is less. This produced some convergence problems in MINUIT. To avoid this, the ratio of the area of the wide gaussian over the total area, $A/A_t$, was fixed to 0.3 for all the lambda fits (a reasonably happy number for all distributions, though the tails are still smallest for KNVF).
Greater statistics would help, but the conclusions derived here aren’t significantly affected by the size of this data sample.

### Table 4

Fit results for Figure 3 (single gaussian and 2nd order Chebyshev). The PDG mass for the $\Lambda$ is $1115.684 \pm 0.006$ MeV.

<table>
<thead>
<tr>
<th>Veefinder</th>
<th>$\sigma$ (MeV)</th>
<th>Yield</th>
<th>Mass (MeV)</th>
<th>$\chi^2$/dof</th>
</tr>
</thead>
<tbody>
<tr>
<td>KNVF</td>
<td>1.44 ± 0.04</td>
<td>10926 ± 260</td>
<td>1115.75 ± 0.02</td>
<td>0.8</td>
</tr>
<tr>
<td>VFND</td>
<td>1.68 ± 0.06</td>
<td>9921 ± 305</td>
<td>1116.04 ± 0.03</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Note that KNVF enjoys a significant advantage in the yield. Most of this advantage comes at low momentum, where VFND’s mistake of not using the proton track parameters is most damaging. We should expect to see the same effect at large radial distance to decay vertex, and we do.

From the summary plots in the appendix (figures 11-13), it appears that at high vertex momentum that VFND has a large improvement in the mass resolution. This is not true. In this momentum bin, the VFND mass distribution is disgusting - it will fit well to almost any width (note the drop in yield for VFND in this bin). Excluding this bin, the superiority of KNVF over VFND is again apparent in the mean and width of the mass distributions. Again, one can observe some of the same structure in the mass difference from nominal plots (material problem?).

### 3.2 Recompress vs. Original Compress

The same procedure used in the $K_s$ case was used to compare the recompress to the original compress for $\Lambda$. The overlay of the pre-recompress and recompress $\Lambda$ mass distributions is shown in Figure 4, and the fits are summarized in Table 5.

### Table 5

Fit results for Figure 4 (single gaussian and 2nd order Chebyshev). The PDG mass for the $\Lambda$ is $1115.684 \pm 0.006$ MeV.

<table>
<thead>
<tr>
<th>Data</th>
<th>Veefinder</th>
<th>$\sigma$ (MeV)</th>
<th>Yield</th>
<th>Mass (MeV)</th>
<th>$\chi^2$/dof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recompress</td>
<td>KNVF</td>
<td>1.45 ± 0.04</td>
<td>10106 ± 250</td>
<td>1115.75 ± 0.02</td>
<td>0.8</td>
</tr>
<tr>
<td>Recompress</td>
<td>VFND</td>
<td>1.71 ± 0.06</td>
<td>9251 ± 295</td>
<td>1116.03 ± 0.03</td>
<td>1.1</td>
</tr>
<tr>
<td>Pre-recompress</td>
<td>VFND w/loss</td>
<td>1.87 ± 0.08</td>
<td>8532 ± 311</td>
<td>1115.70 ± 0.04</td>
<td>1.3</td>
</tr>
<tr>
<td>Pre-recompress</td>
<td>VFND no loss</td>
<td>2.12 ± 0.10</td>
<td>8908 ± 356</td>
<td>1115.25 ± 0.04</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Figure 4. All $\Lambda$s satisfying selection criteria. KNVF is the solid histogram, Recompress VFND is dashed, pre-recompress VFND w/loss is the hatched, and VFND with no loss is dotted. Fit results are shown in Table 5.
The backgrounds in the recompress samples are consistently higher in the recompress than in the pre-recompress samples. This was also observed in [2].

Improvements in the widths of the recompress $K_s$ mass distributions are consistent with those of $K_s$. Again note the errors on the width and yield - best results are obtained with KNVF in the recompress. Figures 14-16 in the appendix show KNVF's advantage as a function of kinematical variables.

4 Conclusion

The KNVF secondary vertex finder outperforms VFND for all variables which were monitored. Advantages of KNVF over VFND include dramatically better mass resolution, greater stability of the invariant mass of a secondary vertex in relevant kinematical variables, and reduced tails in the mass spectra of secondary vertices. Preliminary CLEO II Monte Carlo studies [not presented here] with tuned recompress Monte Carlo are consistent with these conclusions. Users desiring the highest quality secondary vertex information in their analyses should therefore use KNVF Vbs.

As diagnosed by secondary vertex performance, the CLEO II recompress effort has greatly enhanced the quality of the CLEO II dataset. The Kalman filter and improved CD calibration have significantly improved mass resolutions of secondary vertices, and have increased the efficiency of finding such vertices by 10 to 15 %. Though there may be a small problem lurking in CLEO's absolute mass scale, it is certainly better than it ever was. The tracking modifications made for the CLEO II recompress, as judged by this analysis, are very successful with potential for large impact on CLEO physics analyses.

References


Appendix

Here I'll put some summary and plots detailing the performance of KNVF and VFND, for recompress and pre-recompress data. In the plots which follow, the mass difference from nominal and the width are given in MeV.

Table 6

Key to figures in the appendix.

<table>
<thead>
<tr>
<th>Figures</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-7</td>
<td>Recompress $K_s$ yield, mass and width as functions of $\phi_{TX}$, $P_{TX}$, $R_{TX}$, CZ$<em>{TX}$, $P</em>+$, and $\cos\theta_+$</td>
</tr>
<tr>
<td>8-10</td>
<td>Recompress and pre-recompress $K_s$ yield, mass, and width from a common event list as functions of $\phi_{TX}$, $P_{TX}$, $R_{TX}$, CZ$<em>{TX}$, $P</em>+$, and $\cos\theta_+$</td>
</tr>
<tr>
<td>11-13</td>
<td>Recompress $A$ yield, mass and width as functions of $\phi_{TX}$, $P_{TX}$, $R_{TX}$, CZ$<em>{TX}$, $P</em>+$, and $\cos\theta_+$</td>
</tr>
<tr>
<td>14-16</td>
<td>Recompress and pre-recompress $A$ yield, mass, and width from a common event list as functions of $\phi_{TX}$, $P_{TX}$, $R_{TX}$, CZ$<em>{TX}$, $P</em>+$, and $\cos\theta_+$</td>
</tr>
</tbody>
</table>
Figure 5. $K_s$ yield, mass, and width as functions of $\phi_{TX}$ and $P_{TX}$. KNVF is the solid squares, VFND is the open triangles.

Figure 6. $K_s$ yield, mass, and width as functions of $R_{TX}$ and $CZ_{TX}$. KNVF is the solid squares, VFND is the open triangles.
Figure 7. $K_\pi$ yield, mass, and width as functions of $P_+$ and $\cos\theta_+$. KNVF is the solid squares, VFND is the open triangles.

Figure 8. $K_\pi$ yield, mass, and width as functions of $\phi_{TX}$ and $P_{TX}$. KNVF on recompress is the solid squares, pre-recompress VFND with KNLIB energy loss correction is the open triangles, and pre-recompress VFND with no energy loss correction is the open circles (some of which are off scale).
Figure 9. $K_s$ yield, mass, and width as functions of $R_{TX}$ and $CZ_{TX}$. KNVF on recompress is the solid squares, pre-recompress VFND with KNLIB energy loss correction is the open triangles, and pre-recompress VFND with no energy loss correction is the open circles (some of which are off scale).

Figure 10. $K_s$ yield, mass, and width as functions of $P_+$ and $\cos \theta_+$. KNVF on recompress is the solid squares, pre-recompress VFND with KNLIB energy loss correction is the open triangles, and pre-recompress VFND with no energy loss correction is the open circles (some of which are off scale).
Figure 11. A yield, mass, and width as functions of $\phi_{TX}$ and $P_{TX}$. KNVF is the solid squares, VFND is the open triangles.

Figure 12. A yield, mass, and width as functions of $R_{TX}$ and $CZ_{TX}$. KNVF is the solid squares, VFND is the open triangles.
Figure 13. A yield, mass, and width as functions of $P_+$ and $\cos\theta_+$. KNVF is the solid squares, VFND is the open triangles.

Figure 14. A yield, mass, and width as functions of $\phi_{TX}$ and $P_{TX}$. KNVF on recompress is the solid squares, post-recompress VFND with KNLIB energy loss correction is the open triangles, and post-recompress VFND with no energy loss correction is the open circles (some of which are off scale).
Figure 15. A yield, mass, and width as functions of $R_{TX}$ and $CZ_{TX}$. KNVF on recompress is the solid squares, pre-recompress VFND with KNLIB energy loss correction is the open triangles, and pre-recompress VFND with no energy loss correction is the open circles.

Figure 16. A yield, mass, and width as functions of $P_{+}$ and $\cos \theta_{+}$. KNVF on recompress is the solid squares, pre-recompress VFND with KNLIB energy loss correction is the open triangles, and pre-recompress VFND with no energy loss correction is the open circles (some of which are off scale).