0.1 V0 Selection

$\Lambda(\bar{\Lambda})$ and K^0_S are neutral particles which cannot be directly detected, but must instead be reconstructed through detection of their decay products, or daughters. This process is illustrated in Figure 1. In general, particles which are topologically reconstructed in this fashion are called V0 particles. The class AliFemtoV0TrackCutNSigmaFilter (which is an extension of AliFemtoV0TrackCut) is used to reconstruct the V0s.

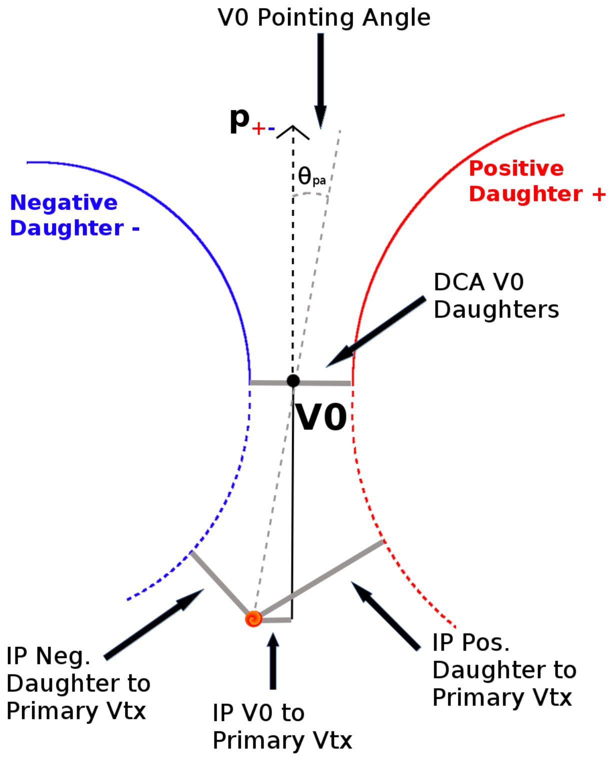


Fig. 1: V0 Reconstruction

In order to ensure a true and reliable signal, one must ensure good purity of the V0 collection. The purity of the collection is calculated as:

$$Purity = \frac{Signal}{Signal + Background} \tag{1}$$

To obtain both the signal and background, the invariant mass distribution (m_{inv}) of all V0 candidates must be constructed immediately before the final invariant mass cut. Examples of such distributions can be found in Figures 3 and 5. It is vital that the distribution be constructed immediately before the final m_{inv} cut, otherwise, it would be impossible to estimate the background. As demonstrated in Figures 3 and 5, the background is fit with a polynomial outside of the peak region of interest in order to extrapolate an estimate for the background within the region. Within the m_{inv} cut limits, the background is the region below the fit while the signal is the region above the fit.

0.1.1 Λ Reconstruction

The following cuts were used to select good Λ ($\bar{\Lambda}$) candidates:

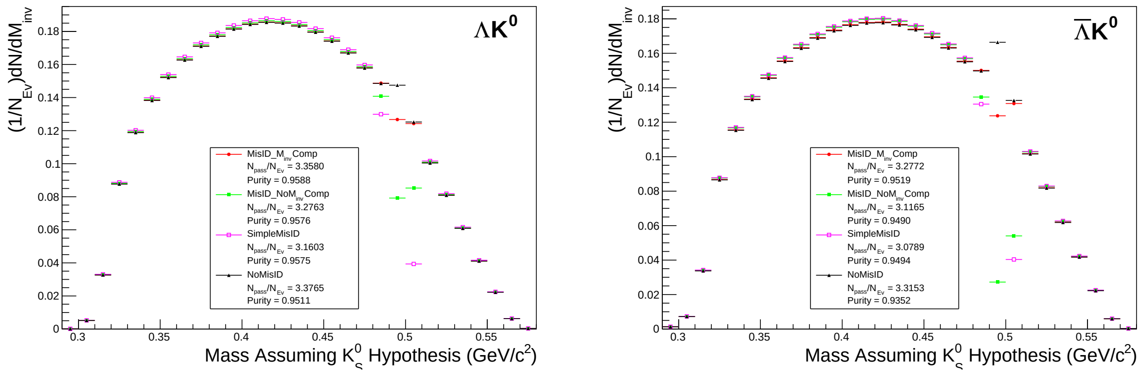
1. Daughter Particle Cuts

(a) Cuts Common to Both Daughters
   i. $|\eta| < 0.8$
   ii. SetTPCnclsDaughters(80)
   iii. SetStatusDaughters(AliESDtrack::kTPCrefit)
   iv. DCA πp Daughters < 0.4 cm
(b) Pion Specific Daughter Cuts
   i. $p_{\mathrm{T}} > 0.16$ GeV/c
   ii. DCA to prim vertex > 0.3 cm
   iii. TPC and TOF Nσ Cuts
      A. $p < 0.5$ GeV/c : N$\sigma_{\mathrm{TPC}} < 3$
      B. $p > 0.5$ GeV/c :
         – if TOF & TPC available: N$\sigma_{\mathrm{TPC}} < 3$ & N$\sigma_{\mathrm{TOF}} < 3$
         – else N$\sigma_{\mathrm{TOF}} < 3$
(c) Proton Specific Daughter Cuts
   i. $p_{\mathrm{T}} > 0.5(p)$ $[0.3(\bar{p})]$ GeV/c
   ii. DCA to prim vertex > 0.1 cm
   iii. TPC and TOF Nσ Cuts
      A. $p < 0.8$ GeV/c : N$\sigma_{\mathrm{TPC}} < 3$
      B. $p > 0.8$ GeV/c :
         – if TOF & TPC available: N$\sigma_{\mathrm{TPC}} < 3$ & N$\sigma_{\mathrm{TOF}} < 3$
         – else N$\sigma_{\mathrm{TOF}} < 3$

2. V0 Cuts
   (a) $|\eta| < 0.8$
   (b) $p_{\mathrm{T}} > 0.4$ GeV/c
   (c) $|m_{\mathrm{inv}} - m_{\mathrm{PDG}}| < 3.8$ MeV
   (d) DCA to prim. vertex < 0.5 cm
   (e) Cosine of pointing angle > 0.9993
   (f) OnFlyStatus = false
   (g) Decay Length < 60 cm
3. Shared Daughter Cut for V0 Collection
   – Iterate through V0 collection to ensure that no daughter is used in more than one V0 candidate

Figure 2a shows the mass assuming K^0_S hypothesis for the Λ collection, i.e. assume the daughters are $\pi^+\pi^-$ instead of $\pi^+\bar{p}^-$. Figure 2b is a similar plot, but is for the $\bar{\Lambda}$ collection, i.e. assume the daughters are $\pi^+\pi^-$ instead of $\pi^+\bar{p}^-$. The K^0_S contamination is visible, although not profound, in both in the slight peaks around m_{inv} = 0.497 GeV/c^2. If one simply cuts out the entire peak, good Λ particles will be lost. Ideally, the Λ selection and K^0_S misidentification cuts are selected such that the peak is removed from this plot while leaving the distribution continuous. To attempt to remove these K^0_S contaminations without throwing away good Λ and $\bar{\Lambda}$ particles, the following misidentification cuts are imposed; a $\Lambda(\bar{\Lambda})$ candidate is rejected if all of the following criteria are satisfied:

– $\left| m_{\mathrm{inv,\ K^0_S\ Hypothesis}} - m_{\mathrm{PDG,\ K^0_S}} \right| < 9.0$ MeV/c^2



(a) Mass assuming K^0_S-hypothesis for Λ collection, i.e. assume the daughters are $\pi^+\pi^-$ instead of $p^+\pi^-$.

(b) Mass assuming K^0_S-hypothesis for $\bar{\Lambda}$ collection, i.e. assume the daughters are $\pi^+\pi^-$ instead of $\pi^+\bar{p}^-$.

Fig. 2: Mass assuming K^0_S-hypothesis for V0 candidates passing all Λ (2a) and $\bar{\Lambda}$ (2b) cuts. The "NoMisID" distribution (black triangles) uses the V0 finder without any attempt to remove misidentified K^0_S. The slight peak in the "NoMisID" distribution around m_{inv} = 0.5 GeV/c^2 contains misidentified K^0_S particles in our $\Lambda(\bar{\Lambda})$ collection. "SimpleMisID" (pink squares) simply cuts out the entire peak, which throws away some good Λ and $\bar{\Lambda}$ particles. "MisID_NoM$_{\mathrm{inv}}$Comp" (green squares) uses the misidentification cut outlined in the text, but does not utilize the invariant mass comparison method. "MisID_M$_{\mathrm{inv}}$Comp" (red circles) utilizes the full misidentification methods, and is currently used for this analysis. "N$_{pass}$/N$_{ev}$" is the total number of $\Lambda(\bar{\Lambda})$ particles found, normalized by the total number of events. The purity of the collection is also listed.

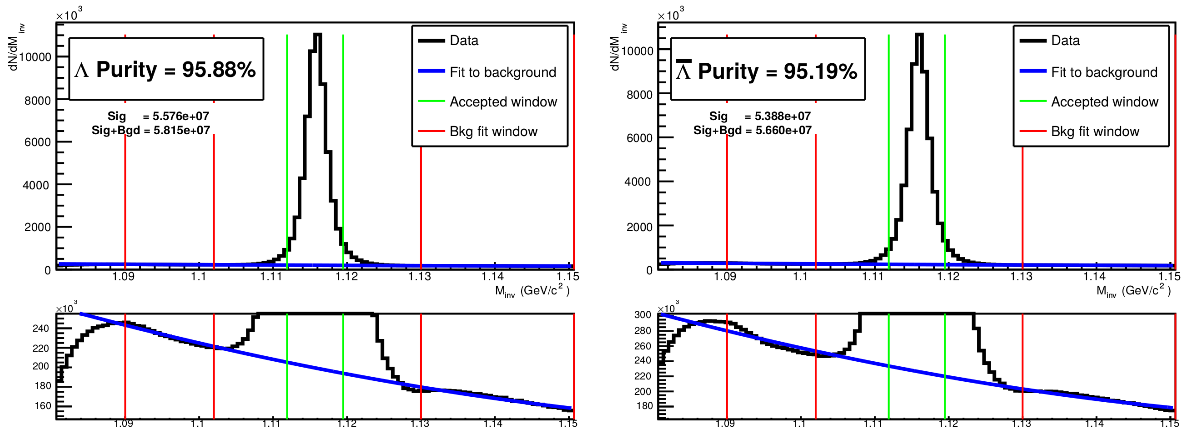
- Positive and negative daughters pass π daughter cut implemented for K^0_S reconstruction
- $\left| m_{\mathrm{inv,\ K^0_S\ Hypothesis}} - m_{\mathrm{PDG,\ K^0_S}} \right| < \left| m_{\mathrm{inv,\ \Lambda(\bar{\Lambda})\ Hypothesis}} - m_{\mathrm{PDG,\ \Lambda(\bar{\Lambda})}} \right|$

Figure 3 shows the invariant mass ($\mathrm{m_{inv}}$) distribution of all $\Lambda(\bar{\Lambda})$ candidates immediately before the final invariant mass cut. These distributions are used to calculate the collection purities. The Λ and $\bar{\Lambda}$ purities are found to be: Purity(Λ) $\approx$ Purity($\bar{\Lambda}$) $\approx$ 95%.

0.1.2 K^0_S *Reconstruction*

The following cuts were used to select good K^0_S candidates:

1. Pion Daughter Cuts
   (a) $|\eta| < 0.8$
   (b) SetTPCnclsDaughters(80)
   (c) SetStatusDaughters(AliESDtrack::kTPCrefic)
   (d) DCA $\pi^+\pi^-$ Daughters < 0.3 cm
   (e) $p_{\mathrm{T}} > 0.15$ GeV/c
   (f) DCA to prim vertex > 0.3 cm
   (g) TPC and TOF Nσ Cuts
      i. $p < 0.5$ GeV/c : N$\sigma_{\mathrm{TPC}} < 3$
      ii. $p > 0.5$ GeV/c :
         - if TOF & TPC available: N$\sigma_{\mathrm{TPC}} < 3$ & N$\sigma_{\mathrm{TOF}} < 3$
         - else N$\sigma_{\mathrm{TOF}} < 3$



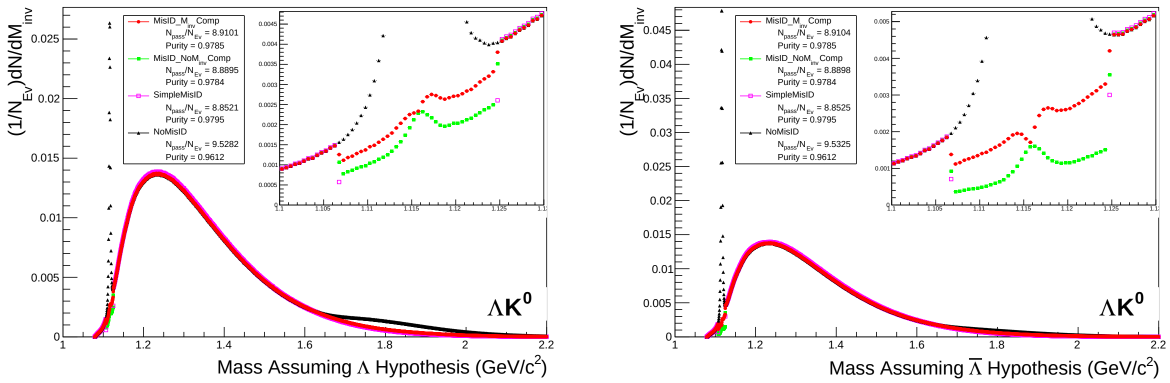
(a) Λ Purity (b) $\bar{\Lambda}$ Purity

Fig. 3: Invariant mass (m_{inv}) distribution of all Λ (a) and $\bar{\Lambda}$ (b) candidates immediately before the final invariant mass cut. The bottom figures are zoomed to show the background with fit. The vertical green lines represent the m_{inv} cuts used in the analyses, the red vertical lines delineate the region over which the background was fit, and the blue line shows the background fit. These distributions are used to calculate the collection purities, Purity(Λ) ≈ Purity($\bar{\Lambda}$) ≈ 95%.

2. K^0_S Cuts
   (a) $|\eta| < 0.8$
   (b) $p_T > 0.2$ GeV/c
   (c) $m_{PDG} - 13.677$ MeV $< m_{inv} < m_{PDG} + 2.0323$ MeV
   (d) DCA to prim. vertex < 0.3 cm
   (e) Cosine of pointing angle > 0.9993
   (f) OnFlyStatus = false
   (g) Decay Length < 30 cm
3. Shared Daughter Cut for V0 Collection
   – Iterate through V0 collection to ensure that no daughter is used in more than one V0 candidate

As can be seen in Figure 4, some misidentified Λ and $\bar{\Lambda}$ particles contaminate our K^0_S sample. Figure 4a shows the mass assuming Λ-hypothesis for the K^0_S collection, i.e. assume the daughters are $p^+\pi^-$ instead of $\pi^+\pi^-$. Figure 4b is similar, but shows the mass assuming $\bar{\Lambda}$ hypothesis for the collection, i.e. assume the daughters are $\pi^+\bar{p}^-$ instead of $\pi^+\pi^-$. The Λ contamination can be seen in 4a, and the $\bar{\Lambda}$ contamination in 4b, in the peaks around m_{inv} = 1.115 GeV/c^2. Additionally, the $\bar{\Lambda}$ contamination is visible in Figure 4a, and the Λ contamination visible in Figure 4b, in the region of excess around 1.65 $< m_{inv} <$ 2.1 GeV/c^2. This is confirmed as the number of misidentified Λ particles in the sharp peak of Figure 4a (misidentified $\bar{\Lambda}$ particles in the sharp peak of Figure 4b) approximately equals the excess found in the 1.65 $< m_{inv} <$ 2.1 GeV/c^2 region of Figure 4a (Figure 4b).

The peaks around $m_{inv} = 1.115$ GeV/c^2 in Figure 4 contain both misidentified Λ ($\bar{\Lambda}$) particles and good K^0_S. If one simply cuts out the entire peak, some good K^0_S particles will be lost. Ideally, the K^0_S selection and Λ($\bar{\Lambda}$) misidentification cuts can be selected such that the peak is removed from this plot while leaving the distribution continuous. To attempt to remove these Λ and $\bar{\Lambda}$ contaminations without throwing away good K^0_S particles, the following misidentification cuts are imposed; a K^0_S candidate is rejected if all of the following criteria are satisfied (for either Λ or $\bar{\Lambda}$ hypothesis):



(a) Mass assuming Λ-hypothesis for K^0_S collection, i.e. assume the daughters are $p^+\pi^-$ instead of $\pi^+\pi^-$.

(b) Mass assuming $\bar{\Lambda}$-hypothesis for K^0_S collection, i.e. assume the daughters are $\pi^+\bar{p}^-$ instead of $\pi^+\pi^-$.

Fig. 4: Mass assuming Λ-hypothesis (4a) and $\bar{\Lambda}$-hypothesis (4b) for K^0_S collection. The "NoMisID" distribution (black triangles) uses the V0 finder without any attempt to remove misidentified Λ and $\bar{\Lambda}$. The peak in the "NoMisID" distribution around $m_{\text{inv}} = 1.115$ GeV/c^2 contains misidentified Λ (4a) and $\bar{\Lambda}$ (4b) particles in our K^0_S collection. "SimpleMisID" (pink squares) simply cuts out the entire peak, which throws away some good K^0_S particles. "MisID_NoM$_{inv}$Comp" (green squares) uses the misidentification cut outlined in the text, but does not utilize the invariant mass comparison method. "MisID_M$_{inv}$Comp" (red circles) utilizes the full misidentification methods, and is currently used for this analysis. "N$_{pass}$/N$_{ev}$" is the total number of K^0_S particles found, normalized by the total number of events. The purity of the collection is also listed. Also note, the relative excess of the "NoMisID" distribution around $1.65 < m_{\text{inv}} < 2.1$ GeV/c^2 shows misidified $\bar{\Lambda}$ (4a) and Λ (4b) particles in our K^0_S collection.

– $\left| m_{\text{inv, }\Lambda(\bar{\Lambda})\text{ Hypothesis}} - m_{\text{PDG, }\Lambda(\bar{\Lambda})} \right| < 9.0$ MeV/c^2

– Positive daughter passes $p^+(\pi^+)$ daughter cut implemented for $\Lambda(\bar{\Lambda})$ reconstruction

– Negative daughter passes $\pi^-(\bar{p}^-)$ daughter cut implemented by $\Lambda(\bar{\Lambda})$ reconstruction

– $\left| m_{\text{inv, }\Lambda(\bar{\Lambda})\text{ Hypothesis}} - m_{\text{PDG, }\Lambda(\bar{\Lambda})} \right| \;<\; \left| m_{\text{inv, K}^0_S\text{ Hypothesis}} - m_{\text{PDG, K}^0_S} \right|$

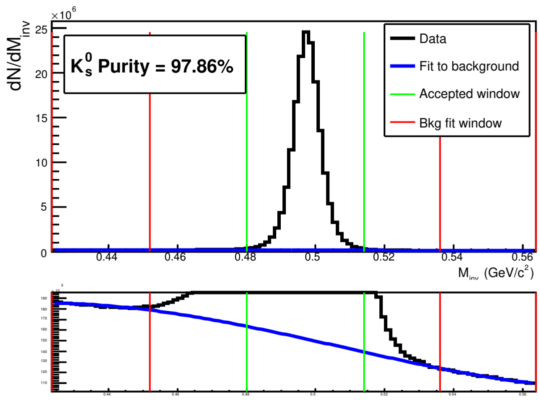


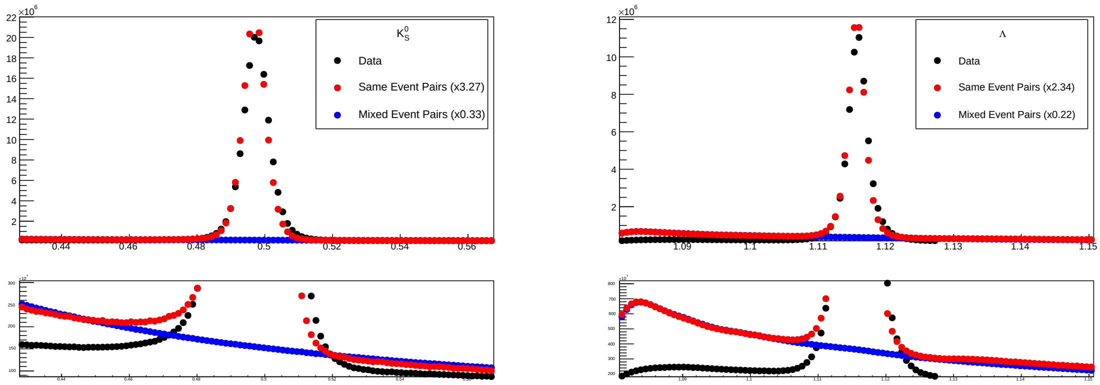
Fig. 5: Invariant mass (m_{inv}) distribution of all K^0_S candidates immediately before the final invariant mass cut. The bottom figure is zoomed to show the background with fit. The vertical green lines represent the m_{inv} cut used in the analyses, the red vertical lines delineate the region over which the background was fit, and the blue line shows the background fit. This distribution is used to calculate the collection purity, Purity(K^0_S) $\approx 98\%$.

0.1.3 V0 Purity Background Estimation

As previously stated, the backgrounds in the m_{inv} distributions are fit with a polynomial outside of the final cut region in an attempt to estimate the background within the cut region. As this estimation of the background under the mass peak is vital in our estimation of our V0 purity, it is important for us to ensure that our estimation is accurate. More specifically, it is necessary that we ensure the background is well described by a polynomial fit within the cut region.

To better understand our background, we studied V0 candidates reconstructed with daughters from different events. These mixed-event V0s certainly do not represent real, physical V0s (a single V0 cannot have daughters living in two different events!), but rather represents a large portion of the background creeping into our analysis.

The standard AliFemto framework is not equipped to handle this situation, as most are not interested in these fake-V0s. Therefore, we built the AliFemtoV0PurityBgdEstimator class. In addition to finding fake-V0s using mixed-event daughters, we also used our AliFemtoV0PurityBgdEstimator class to find real-V0s using same-event daughters. The purpose here was to compare our simple V0 finder (in AliFemtoV0PurityBgdEstimator) to the established V0 finder used in standard AliFemto analyses.



(a) K^0_S (b) Λ

Fig. 6: V0 Purity Background Estimation. The black points, marked "Data", correspond to real V0s found using the standard V0-finder (i.e. the V0s used in my analyses). The red points, marked "Same Event Pairs", show real V0s reconstructed with our personal V0-finder in AliFemtoV0PurityBgdEstimator. These data are scaled by a factor (listed in the legend) to match their $Signal + Background$ value in the cut region with that of the data. The blue points, marked "Mixed Event Pairs", show fake-V0s reconstructed with our personal V0-finder using mixed-event daughters. The blue points are scaled by a factor (listed in the legend) to closely match the red points in the side-band region.

Figure 6 shows the results of our study. In the figures, the black points, marked "Data", correspond to V0s found using the standard V0-finder, and to the V0s used in my analyses. The red points show real V0s reconstructed with our personal V0-finder (in AliFemtoV0PurityBgdEstimator) using same-event daughters, and the blue points show fake-V0s reconstructed with our personal V0-finder using mixed-event daughters. Both the red and blue points have been scaled by different factors (listed in the figure's legends) to nicely align all three data on a single plot.

Figure 6 shows that our personal V0-finder does a good, but not perfect, job of matching the shape of the m_{inv} plots obtained from the data. The scale factor listed in the legend reveals that we are only finding 1/3 - 1/2 of the V0s found by the standard V0-finder. These two points are not of concern, as our purpose here was to gain a sense of the broad shape of the background. It is revealed in Fig. 6, when studying the red and blue points, that the background distribution within the mass peak region is simply a smooth connection of the backgrounds outside of the cut region. Therefore, our method of fitting the background outside of the cut region, fitting with a smooth polynomial, and extrapolating to the cut region is justified.