Developing KinkFinder at ILD*

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Abstract. A study of kink reconstruction for long-lived particle search in ILD's TPC at a future Higgs factory.

1 Introduction

Many models of new physics predict charged long-lived particles (LLP). Such charged LLPs decay to another charged particle, producing a kinked track. For example, a chargino decays into a SM charged particle and a neutralino. The range of LLPs is determined by model parameters and energy. The typical tracking detector has a size of a few metres around the interaction point. In particular, the Time Projection Chamber (TPC)[1] of the International Large Detector (ILD)[2] measures more than 200 positions along the trajectory of charged particles in the range from about 30 to 200 cm from the interaction point, so that kinked tracks coming from LLPs can be measured with high sensitivity. A TPC is therefore a very powerful tool for such as LLPs. This study focuses on the reconstruction of kinks inside ILD's TPC.

2 Analysis setup

2.1 KinkFinder

The KinkFinder[3] is a Marlin[4] processor run in the ILD reconstruction chain. It uses as inputs the reconstructed tracks. The KinkFinder considers pairs of tracks with the same charge, dissimilar momenta, and for which the distance between the end of first track and the start of 2nd track is reasonably small. The distance of closest approach is calculated based on fits of the first (last) 10 hits to a helix, which are extrapolated to 10 positions between the last hit of the first track and the first hit of the 2nd track. The midpoint at minimum distance is assumed as the kink vertex position, as shown in Fig.1.

2.2 KinkFinder efficiency

10 GeV Kaons were simulated and reconstructed in the ILD_l5_v02 model. The efficiency of KinkFinder was calculated as a function of the true (Monte Carlo, MC) kink angle. The kink angle is defined as the angle between the parent and daughter track directions at the kink, as shown in Fig.2.

The efficiency is calculated for kinks which satisfy the following:

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*This work was carried out in the framework of the ILD concept group.

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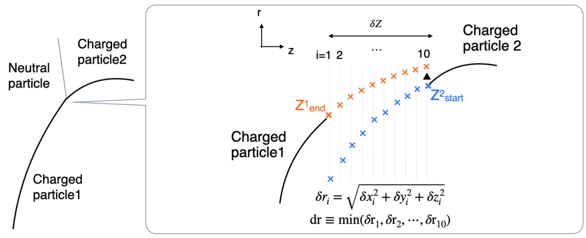


Figure 1: A schematic of the definition of kink in KinkFinder: the triangle shows the chosen vertex position.

- the Kaon decays well inside the TPC volume.: r_{in} + 100 mm $< r < r_{out} -$ 100 mm, $|z| <$ z_{max} − 250 mm, as shown in Fig.3.
- the number of charged kaon daughters is 1.

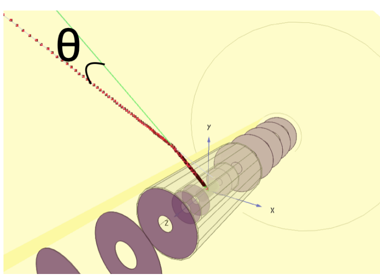


Figure 2: A schematic of definition of kink angle θ

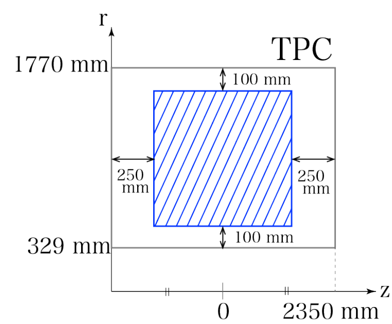


Figure 3: The 2D image for TPC area: The decay point of kaon is required within the blue shaded area to select interesting events.

Figure 4 shows that the KinkFinder efficiency is about 80% when the kink angle is between 0.04 and 0.08 [rad]. However, the efficiency is reduced where the kink angle is smaller or larger. This suggests that when the kink angle is close to 0, the two tracks are merged into a single track, and when the kink angle is close to 0.1 [rad], the efficiency is worse for the very displaced second track.

2.3 Estimation of the kink's parent particle mass

If the mass of the kink's parent particle can be accurately reconstructed, it can help to identify kinks from BSM and SM origin. Kinks produced by 10 GeV kaon, π, $\sum$, and Ξ were studied. These were again simulated and reconstructed in the ILD_l5_v02 model.

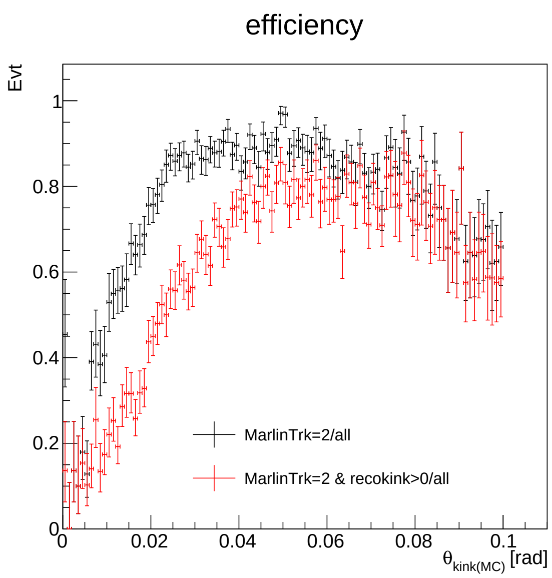


Figure 4: Efficiency dependence on the kink angle: the black points show the efficiency to reconstruct 2 tracks. The red points show the efficiency of finding a kink when the number of tracks is 2. This is a combination of track and kink finding efficiency.

Table 1: Tested kink decays in the standard KinkFinder

	$\mathrm{m}_{\text{charged daughter}}$	$\mathrm{m}_{\text{neutral particle}}$
$\pi^{\pm}/\mathrm{K}^{\pm} \rightarrow \mu^{\pm}\nu$	m_{μ}	0
$\mathrm{K}^{\pm} \rightarrow \pi\pi$	m_{π}	m_{π}
$\Sigma^{+}/\Sigma^{-} \rightarrow \pi\mathrm{n}$	m_{π}	m_{n}
$\Sigma^{+} \rightarrow \mathrm{p}\pi_{0}$	m_{p}	m_{π}
$\Xi^{-} \rightarrow \pi\Lambda$	m_{π}	m_{Λ}

2.3.1 Kink mass reconstruction and particle identification

The parent's mass is called kink mass, which is calculated from the momentum and energy conservation equations

$$m^2_{kink} = \left(\sqrt{P^2_{chg\,dau} + m^2_{chg\,dau}} + \sqrt{(P_{par} - P_{chg\,dau})^2 + m^2_{neu\,dau}}\right)^2 - P^2_{par} \quad (1)$$

In the TPC, we can measure the momenta of the parent and charged daughter. Calculating the kink mass requires assumed masses of the charged and neutral daughter particles, $m_{chg\,dau}, m_{neu\,dau}$. Several mass hypotheses, as shown in Tab. 1, were considered. The mass difference δm is defined as the difference between the calculated and hypothesised parent mass. The hypothesis with the smallest $|\delta m|$ was chosen.

2.3.2 How to get momentum information

In the KinkFinder, the helix is calculated using the last (first) 10 hits of the parent (daughter) track. Then the momenta are taken from the helix at last (first) hit. To improved the method, all hits were used to perform full kalman filter track fits. The momentum of this fitted track at the reconstructed vertex was used. The key difference is getting momenta at the common point in this new way.

2.3.3 How to get vertex information

Accurate vertex position is also important. In Marlin reconstruction, tracks are build from oustside to in, terminating when the track chisquare becomes too large. The vertex is therefore biased to smaller radius. A new method was developed to get vertex information. The combined track pair was cut at the hit for which the sum of both tracks' chisquare was minimum.

2.3.4 Comparison of δm distribution

The δm distributions were estimated in three scenarios: standard KinkFinder, using true MC vertex position, and using these new methods for momenta and vertex reconstruction, as illustrated in Fig. 5. Figure 6 shows the resulting δm distributuions of these three methods. A clear improvement in mass resolution is seen.

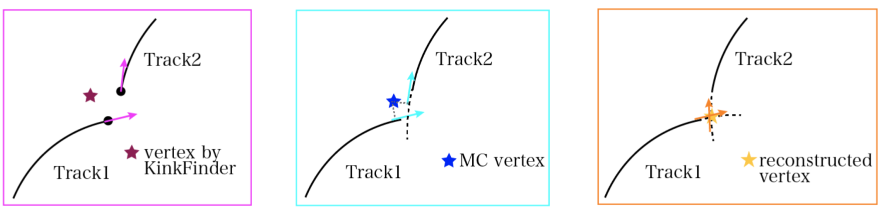
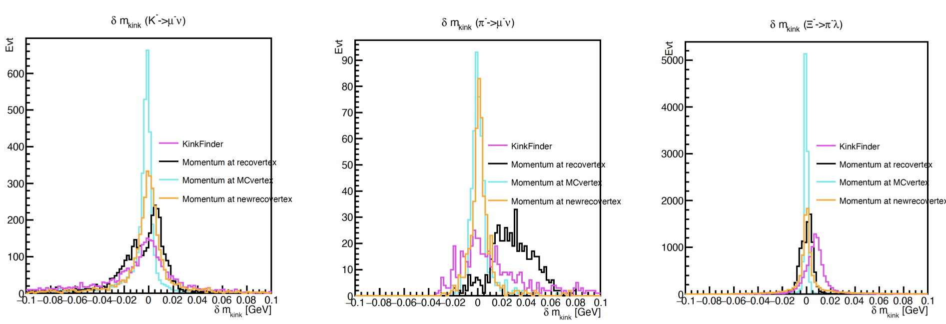


Figure 5: The respective methods to determine momentum and vertex



(a) kaon (b) kaon (c) kaon

Figure 6: Mass distribution: the colors correspond to those of the Fig. 5.

2.4 Summary

Kinked tracks are useful for LLP search. The Kinkfinder efficiency is about 80% when the kinkangle is between 0.04 and 0.08 GeV. Improved methods to reconstruct the vetex position

and momenta were developed, resulting in impoved mass resolution.
Future plans include improving the effciency at small and large kink angles, and kinematic vertex fitting, as well as studying a wider range of momenta. Finally the results will be interpreted in the context of several BSM models.

References

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