Developing KinkFinder at ILC

Work in progress

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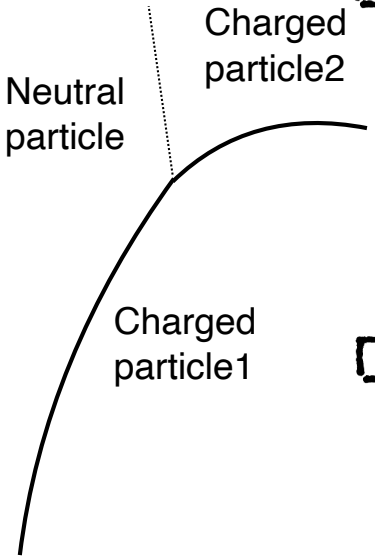
The motivation and aim of my study



What is kink?

A charged particle decays and produces an another charged particle.
Then the track bends abruptly and it is called "**kink**".

Why do I focus on kinks?

The kink is a signature of Long Lived Particles (LLPs) for New physics.

Ex. Chargino decays into a SM charged particle and a neutralino (Lightest SUSY Particle) etc…

I focus on kinks decayed inside a tracking detector, I'd like to identify kinks efficiently and accurately.

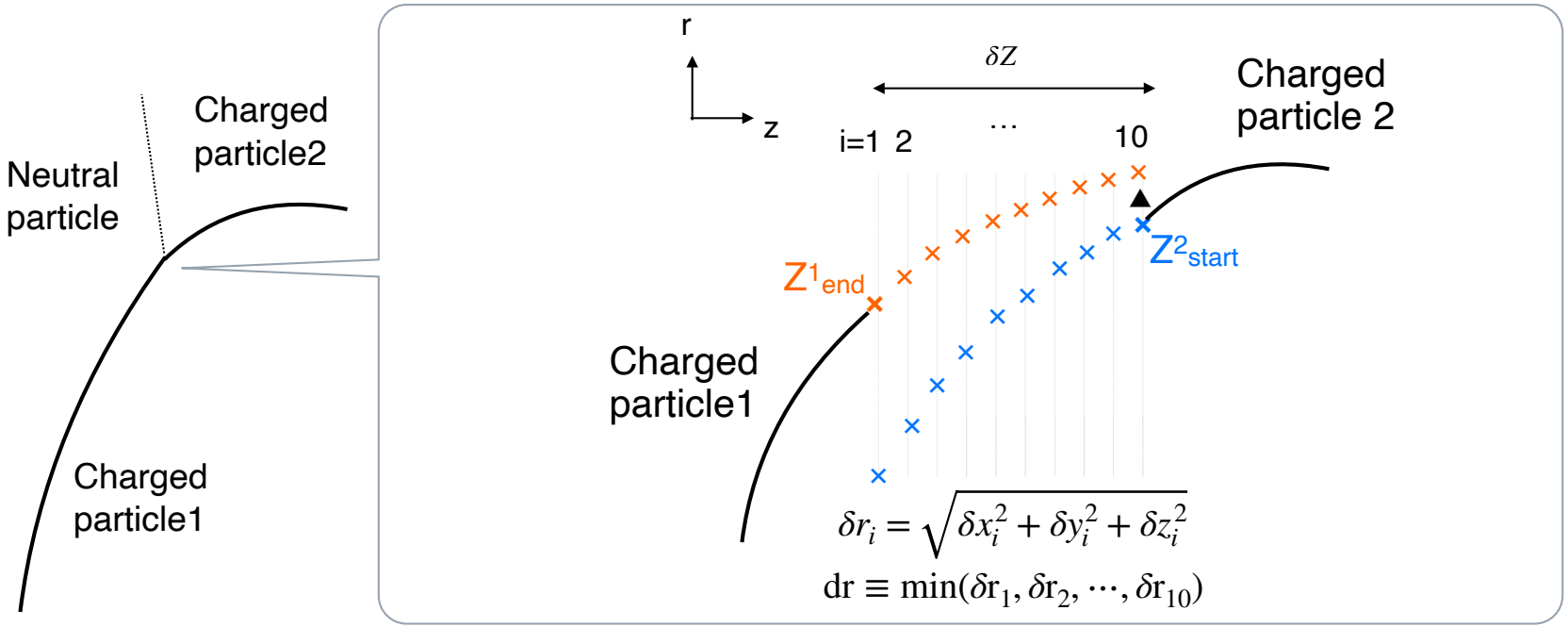
How do I identify kinks? - KinkFinder

in MarlinReco/Tracking/KinkFinder

I want to study kinks from LLPs but firstly I try to check "standard kinks" from **SM particles (eg. Kaon…)**

2 tracks with

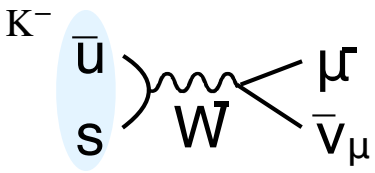
- Same sign
- Different momenta
- Small distance of closest approach



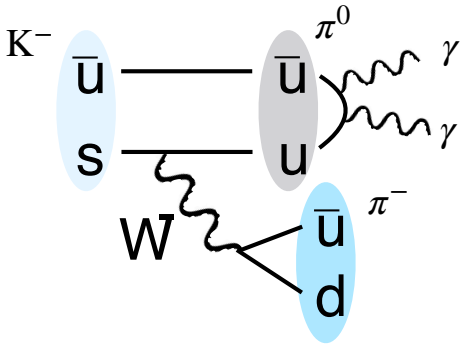
Kaon

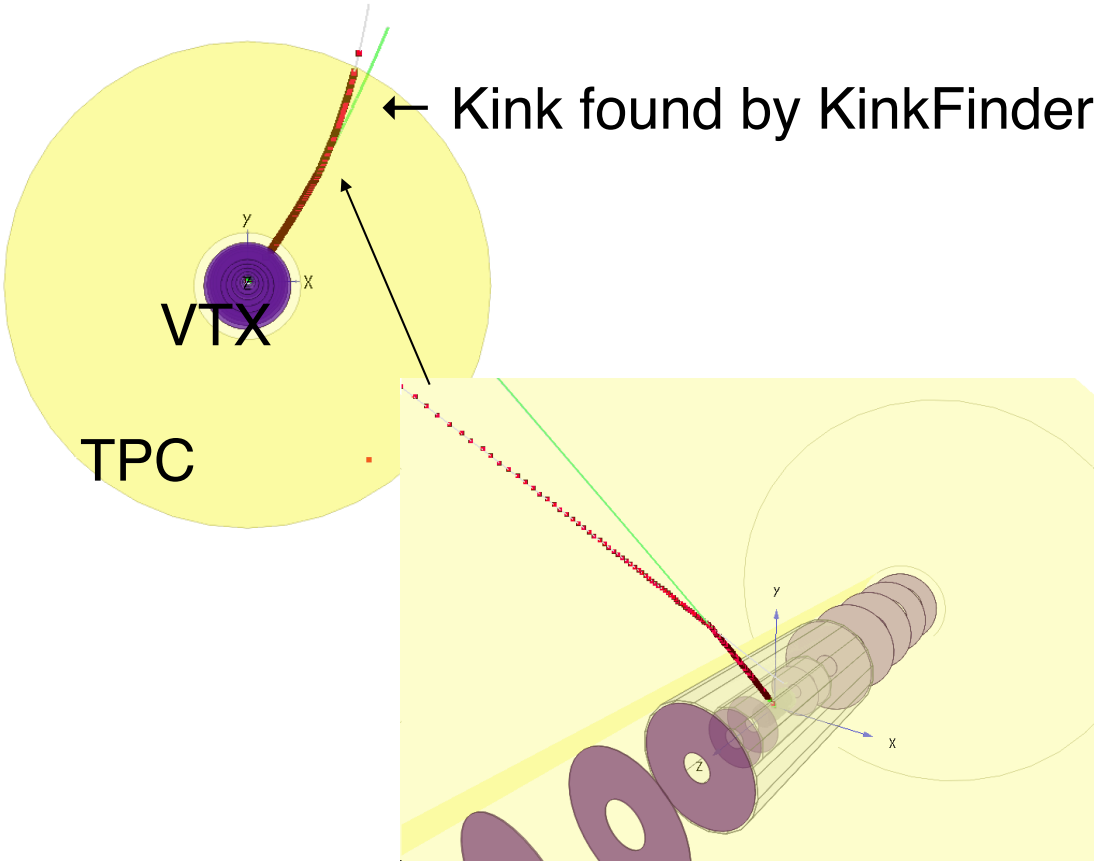
10GeV Kaons simulated and reconstructed in ILD_l5_v02 (CALOS removed)

1. $K^- \rightarrow \mu^- \nu_\mu$



2. $K^- \rightarrow \pi^- \pi^0$





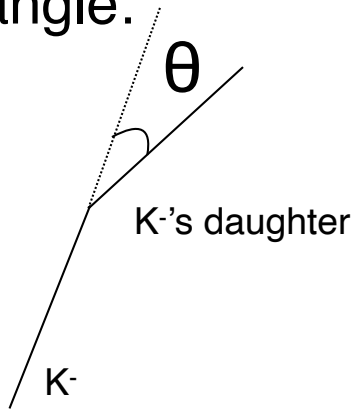
I checked the efficiency of KinkFinder.

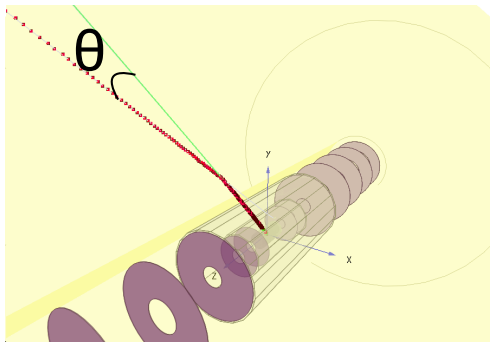
Efficiency dependence on the kink angle

Prerequisites made from **MCparticles**

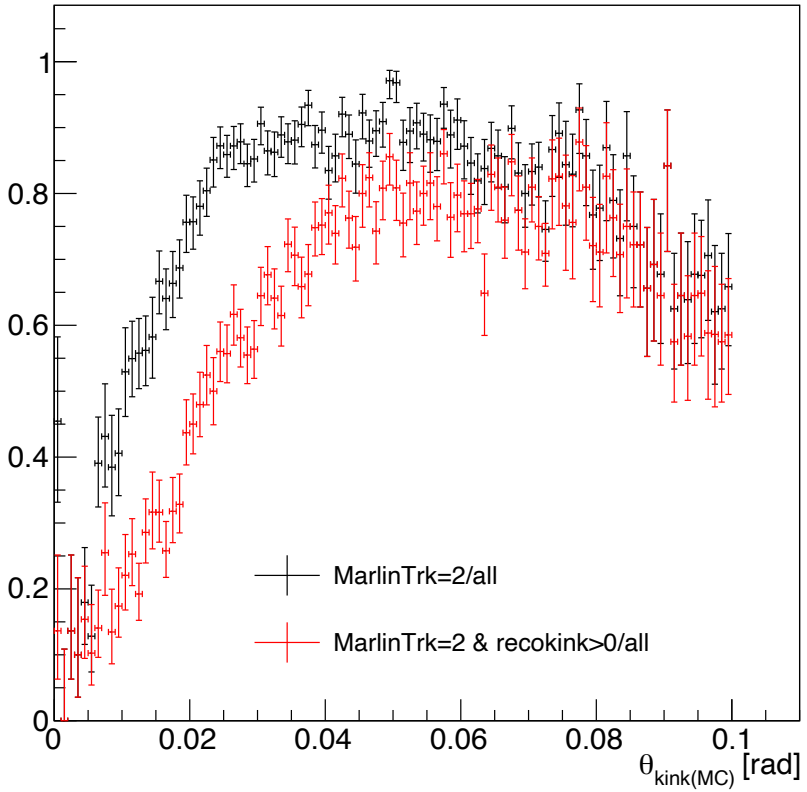
- Produced Kaon: P_K = 10 [GeV]
- Endpoint(MC) inside TPC: $329 + 100 < r < 1770 - 100\,[\mathrm{mm}]\,, |z_{max}| < 2350 - 250[\mathrm{mm}]$
- (MC) # of charged daughter of Kaon = 1

kink angle:





efficiency



all: imposing only prerequisites

Black: nTrack = 2 (tracking efficiency)
Red: nTrack =2 and Kink > 0 (tracking and KinkFinding efficiency)

KinkFinder efficiency ~ 80% ($0.04 < \theta_{kink(MC)} < 0.08$)

Efficiency dependence on the kink angle

Prerequisites made from **MCparticles**

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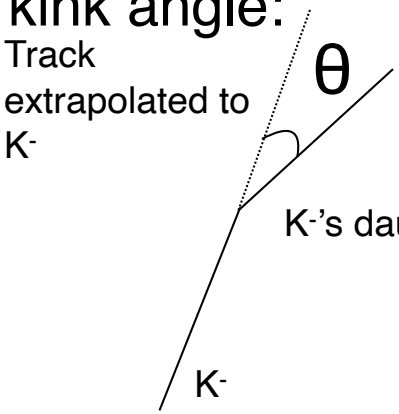
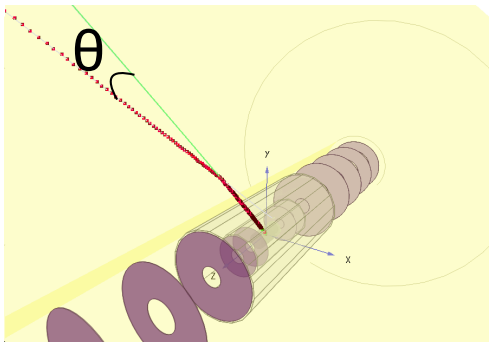
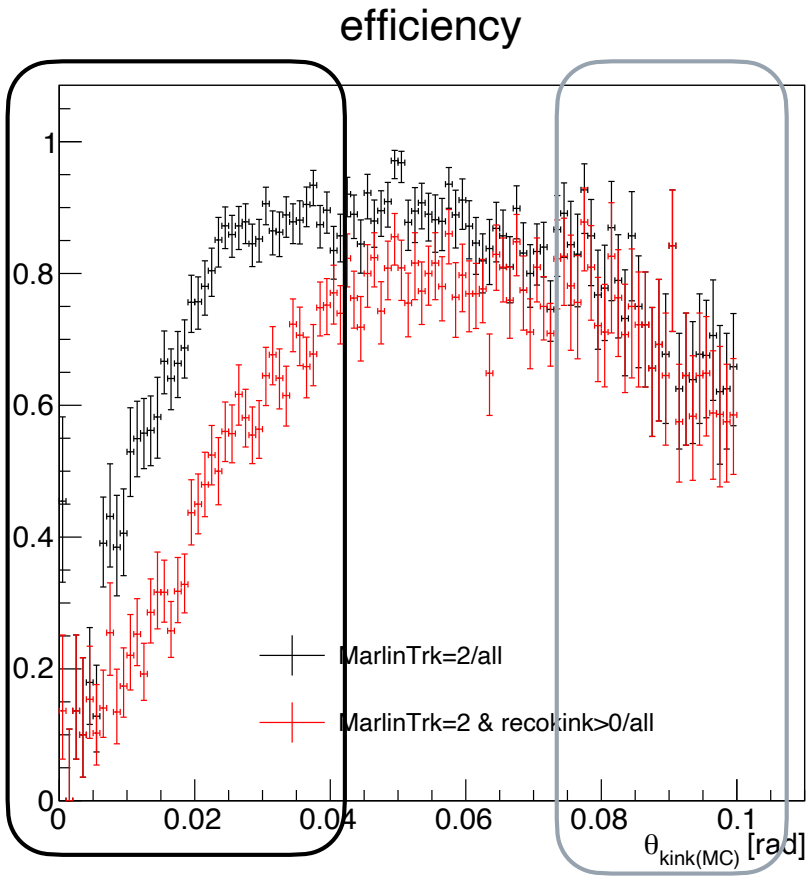
kink angle:







all: imposing only prerequisites

Black: nTrack = 2 (tracking efficiency)
Red: nTrack =2 and Kink > 0 (tracking and KinkFinding efficiency)

Reconstructed as **single** track?

Tracking for very displaced 2nd track?

More particles - Kaon, Pion, Sigma, Xi

10GeV particles simulated and reconstructed in ILD_l5_v02
(CALOS removed)

Estimated **kinkmass**

What is kink mass?
which particle produced kink?

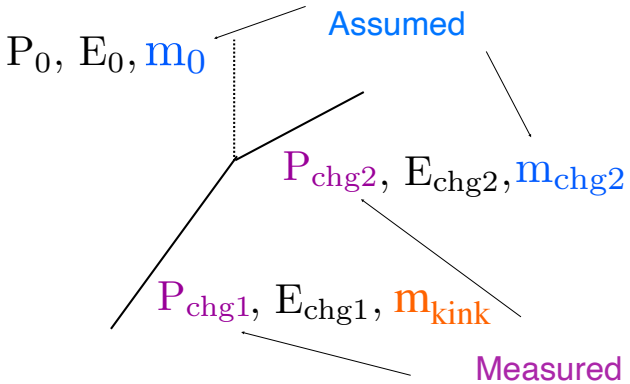


fig.Schematic of kink

Using $P_0 = P_{chg1} - P_{chg2}$, (Momentum conservation)

$$E_0 = \sqrt{P_0^2 + m_0^2} = \sqrt{(P_{chg1} - P_{chg2})^2 + m_0^2}$$

$$E_{chg2} = \sqrt{P_{chg2}^2 + m_{chg2}^2}$$ (Energy conservation)

$$m_{kink} \equiv \sqrt{(E_{chg2} + E_0)^2 - P_{chg1}^2}$$

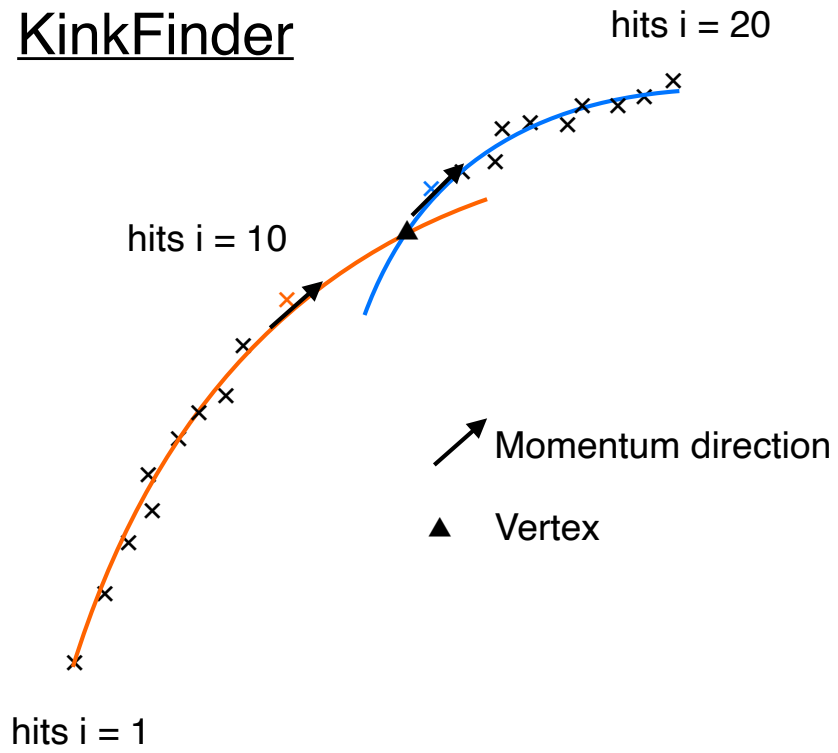
Table 1. Tested kink decay in standard kinkfinder

	m_{chg2}	m_0
$\pi^{\pm}/K^{\pm} \to \mu^{\pm}\nu$	m_{μ}	0
$K^{\pm} \to \pi\pi$	m_{π}	m_{π}
$\Sigma^{+}/\Sigma^{-} \to \pi n$	m_{π}	m_n
$\Sigma^{+} \to p\pi_0$	m_p	m_{π}
$\Xi^{-} \to \pi\Lambda$	m_{π}	m_{Λ}

Choose best decay hypothesis using kink mass

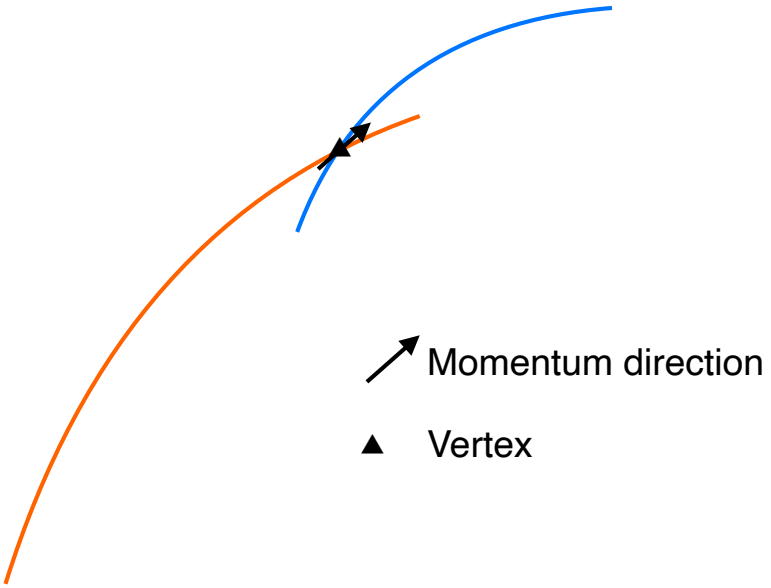
How to get momentum infomation

KinkFinder



Fit first / last 10 hits to helix
Helix momentum at last/first hits

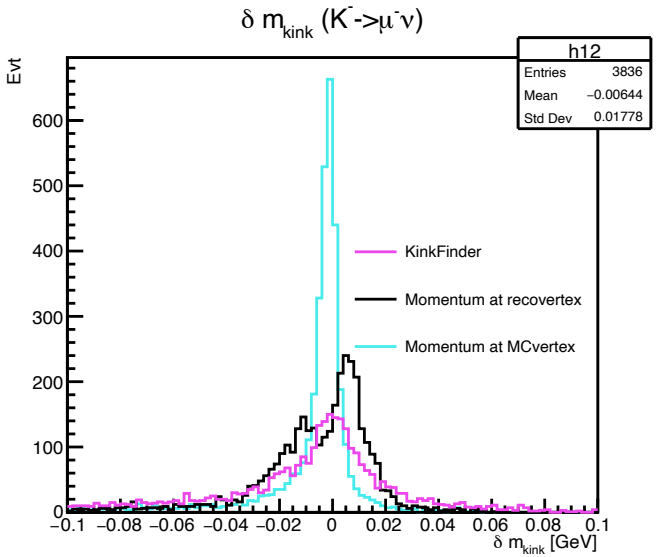
Momentum at vertex

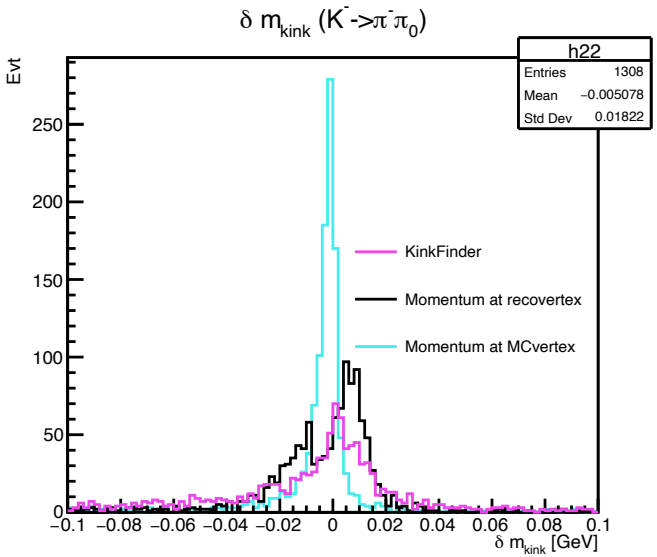


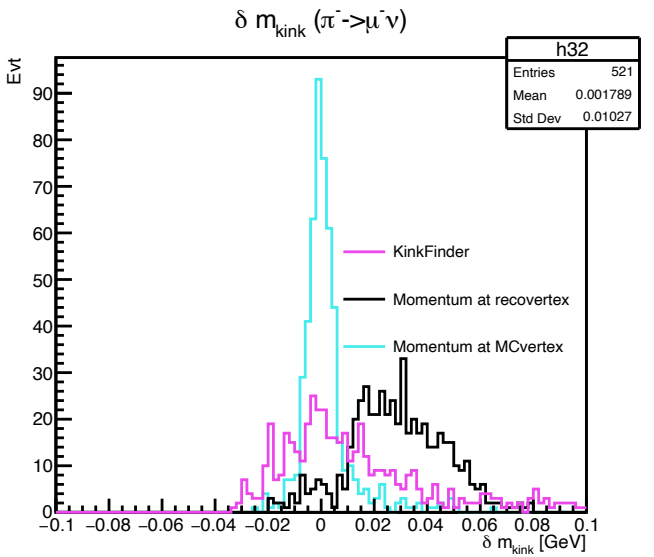
Use full track fits
trackstate momentum at
reconstructed vertex

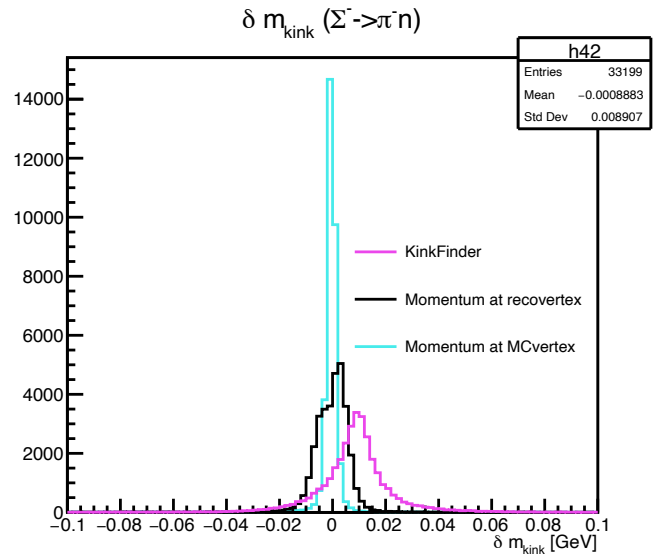
Comparison of δm distribution

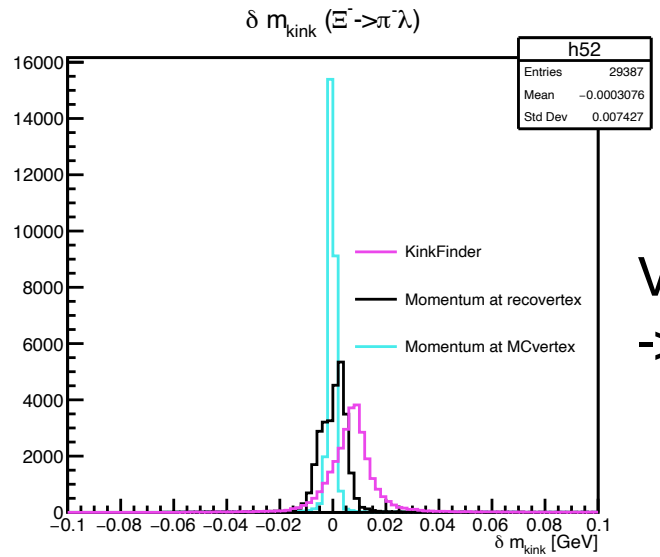
$$\delta m_{kink} \equiv m_{reco_K} - m_{true_K}$$





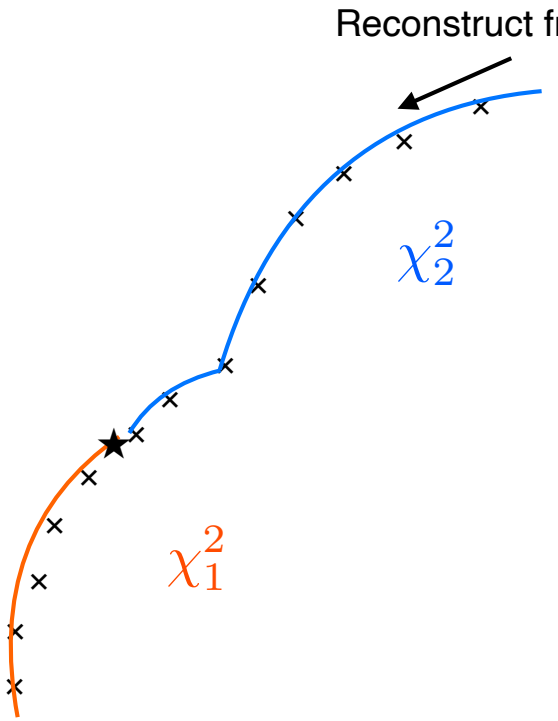


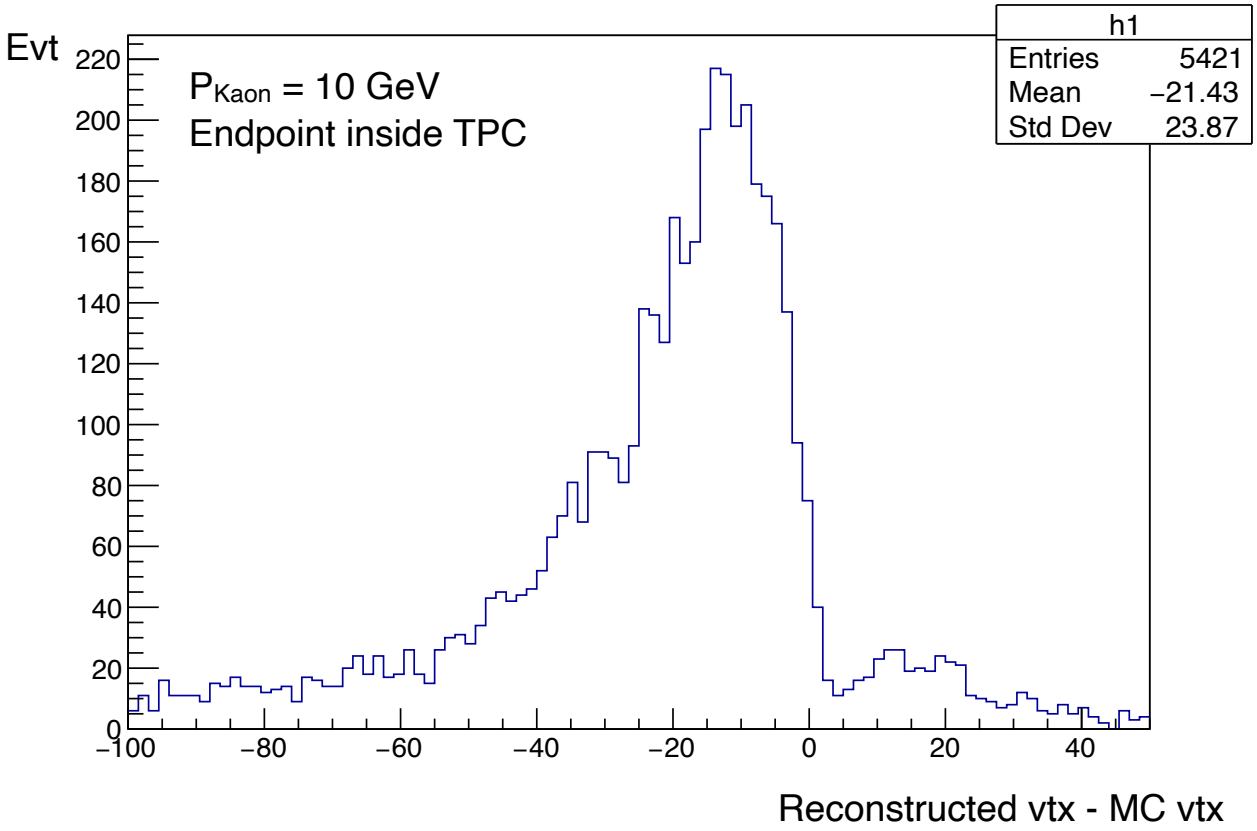




Vertex reconstruction improved
-> δm distribution is improved

Marlintrk bias at vertex

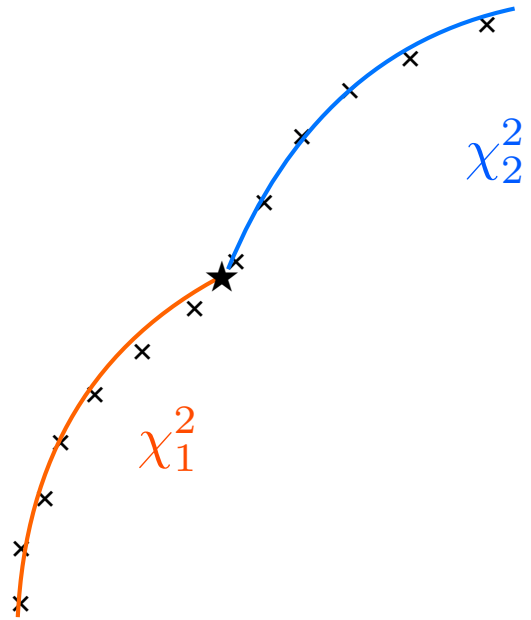




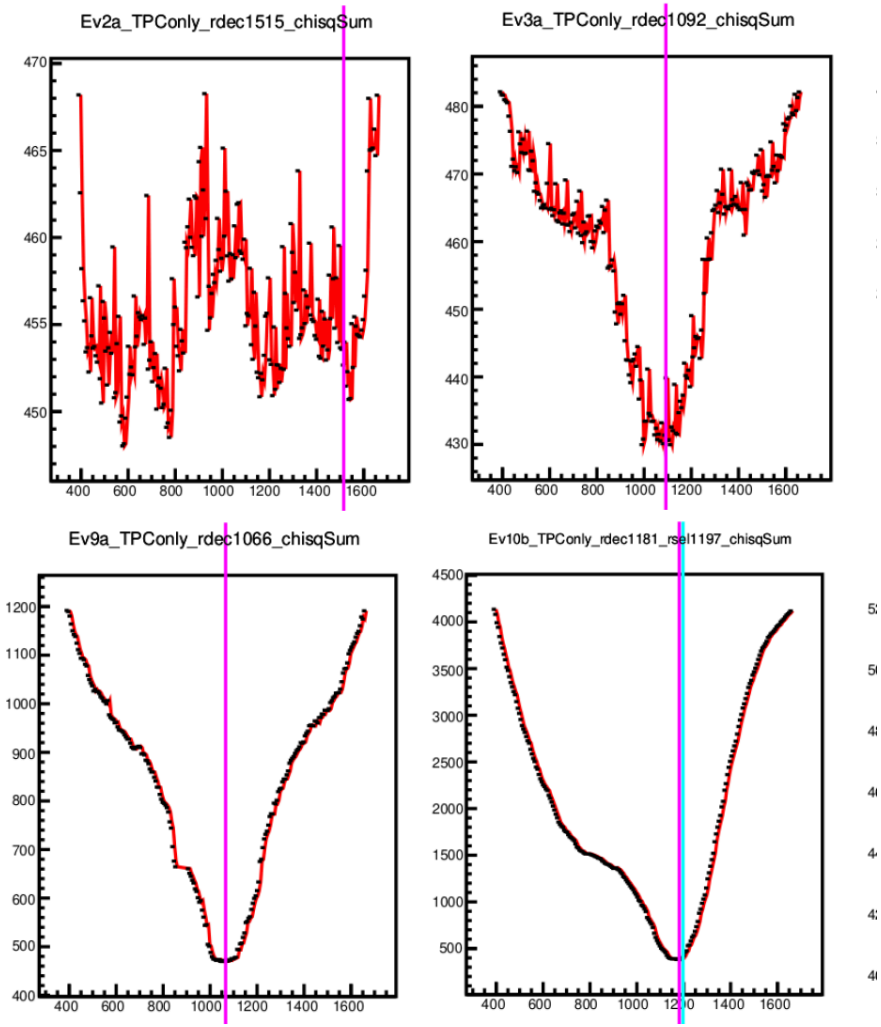
In Marlin track reconstruction, when chisq is bad, tracking is stopped.
-> vertex is bias to smaller radius.

How to get vertex infomation

New version



chiSq-trk1
+
chisq-trk2

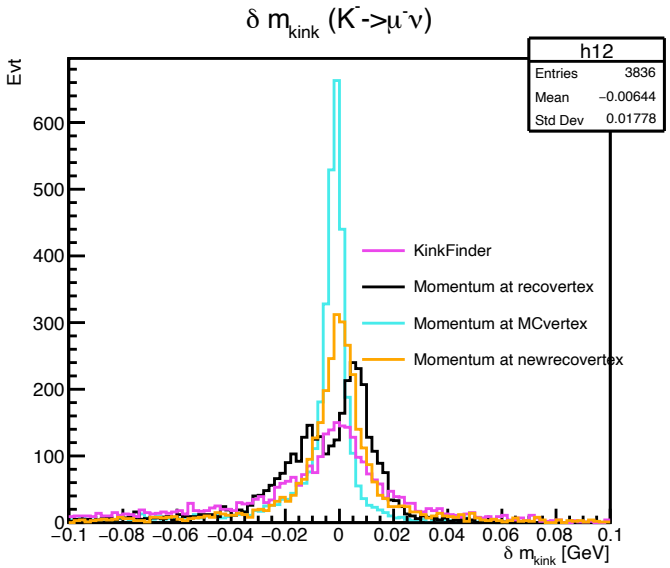


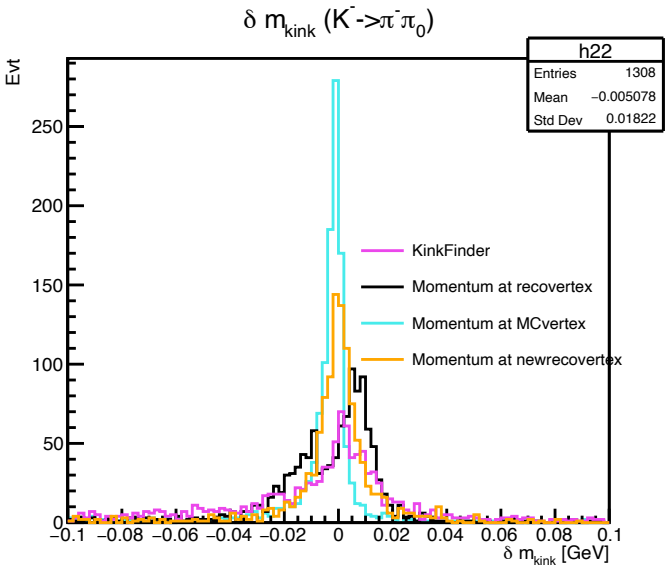
I try to cut track at every hits position, calculate $\chi_1^2 + \chi_2^2$

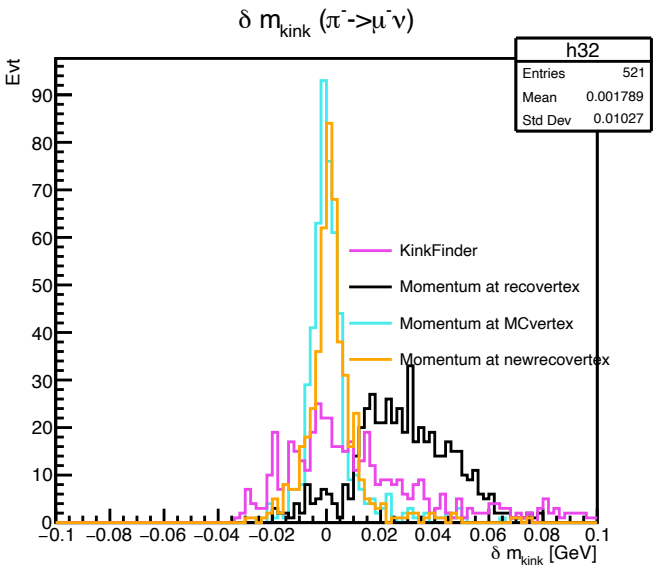
a hit corresponded to minimum $\chi_1^2 + \chi_2^2$ is assumed as a kink vertex.

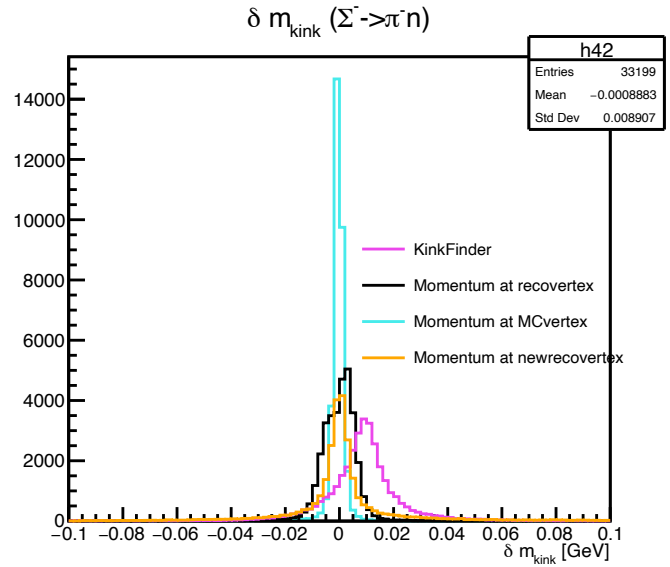
Figures by Daniel

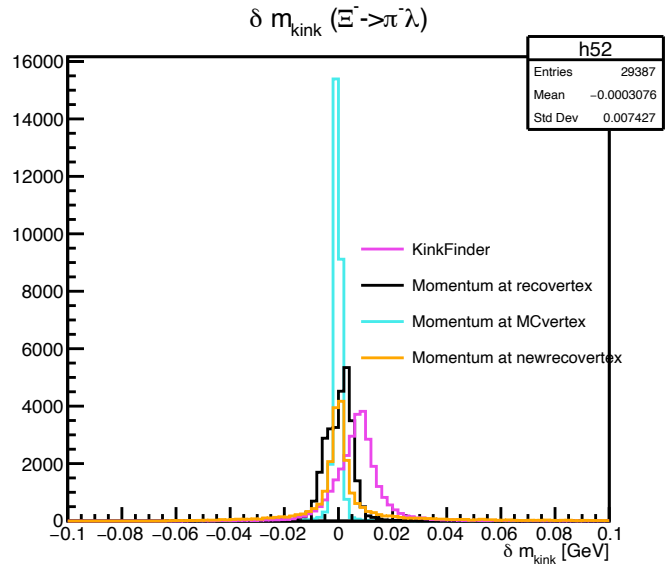
Comparison of δm distribution - new!











Improving mass resolution!

Summary

Kink is useful for LLP search!

KinkFinder efficiency is about 80% ($0.04 < \theta_{kink(MC)} < 0.08$)

Improving mass resolution
<- better vertex position
<- better track momentum at vertex

Next steps
- Fix likelihood function
- vertex fitting
- Improving efficiency at small and large kink angle

New likelihood function - try1

KinkFinder

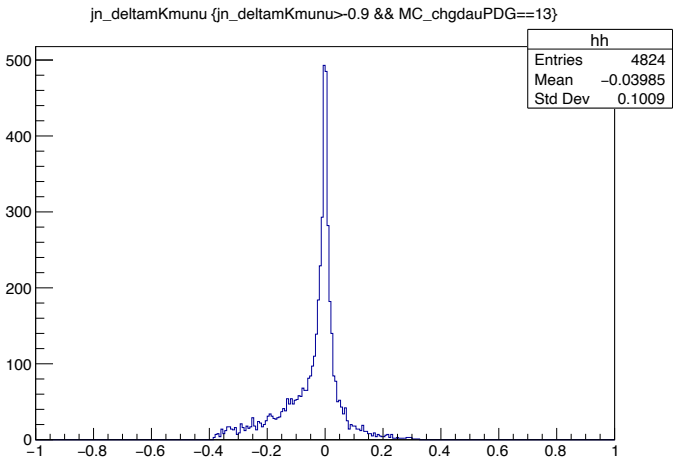
$$\text{likelihood K} \equiv 3.125 \times \delta\text{K} \times \delta\text{K} + t\text{K} \qquad \delta K \equiv \frac{|m_{kink} - m_K|}{\text{K mass resolution (0.075 [GeV])}}$$

$$\mathrm{L_K} \equiv \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{1}{2}\left(\frac{\delta m_K}{\sigma}\right)^2} \times e^{-tK}$$

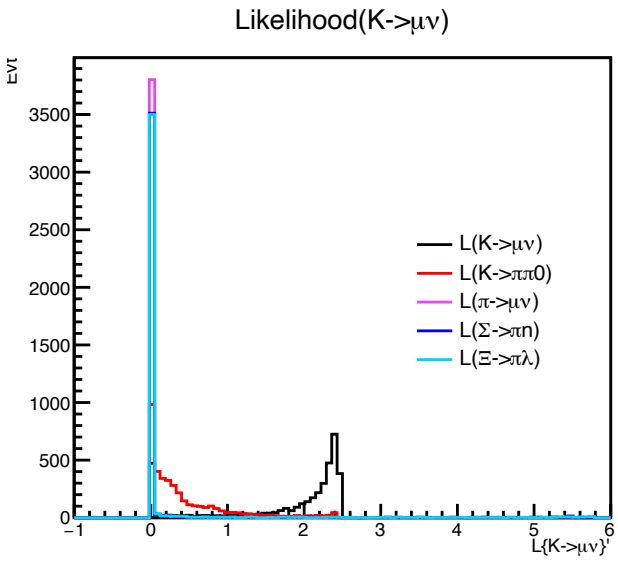
Ignoring

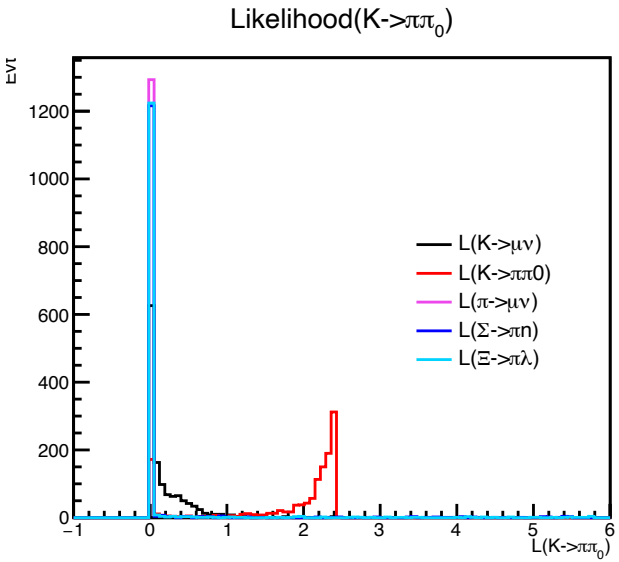
$$\delta \mathrm{m_K} \equiv \mathrm{m_{reco_K}} - \mathrm{m_{true_K}}$$

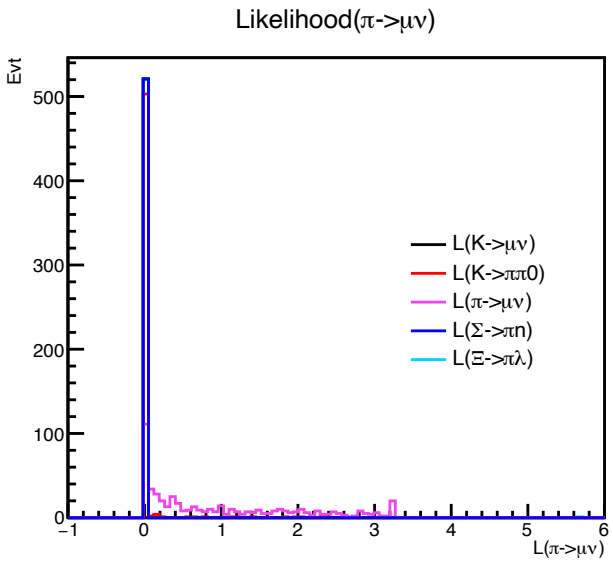
I find σ from δK', δπ', δΣ' and δΞ' distribution.
I used "RMS90".

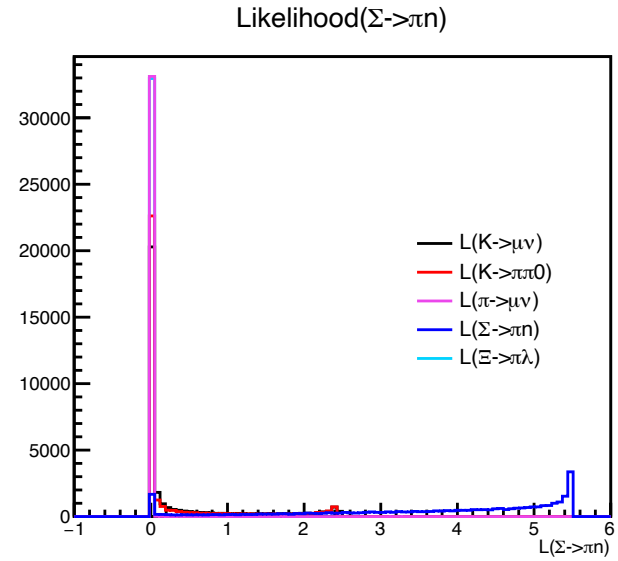


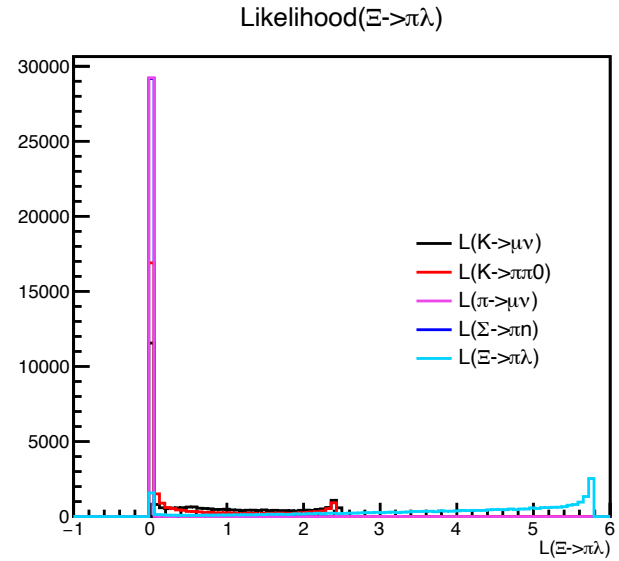
Distribution of new likelihood function









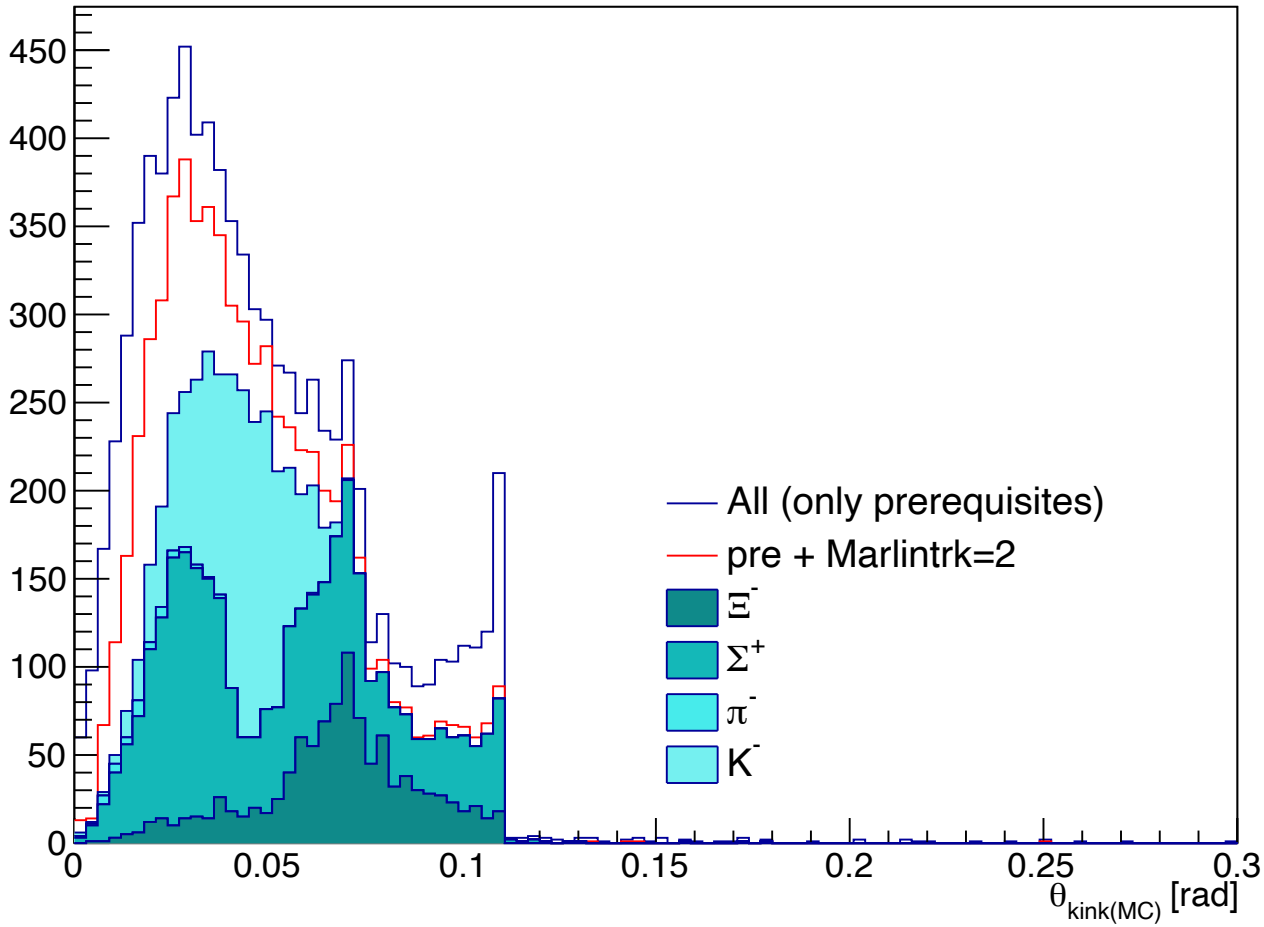


Kink angle on each pdgs - KinkFinder

Prerequisites made from **MCparticles**

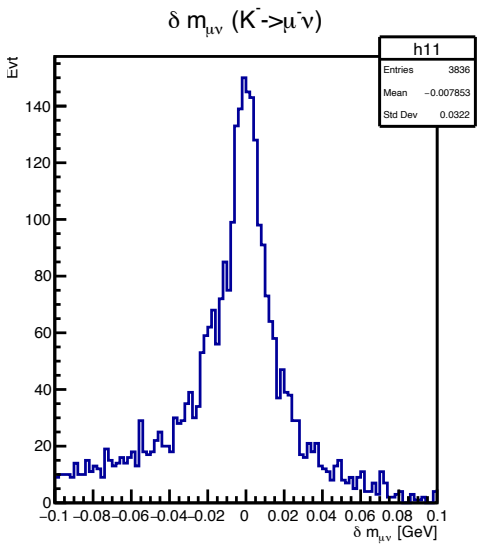
- Endpoint(MC) inside TPC: $329 + 100 < r < 1770 - 100\,[\mathrm{mm}]$ $|z_{max}| < 2350 - 250[\mathrm{mm}]$
- (MC) # of charged daughter of Kaon = 1

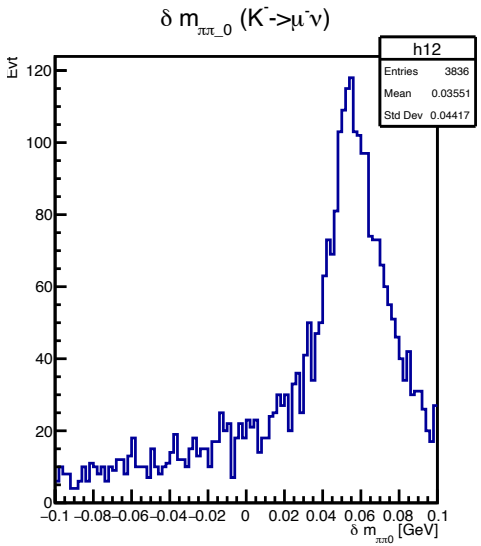
- Each pdg plots are imposed Marlintrk = 2 and reconstructed kink exists

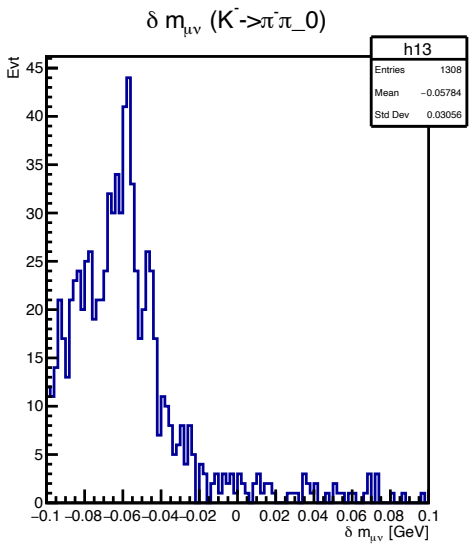


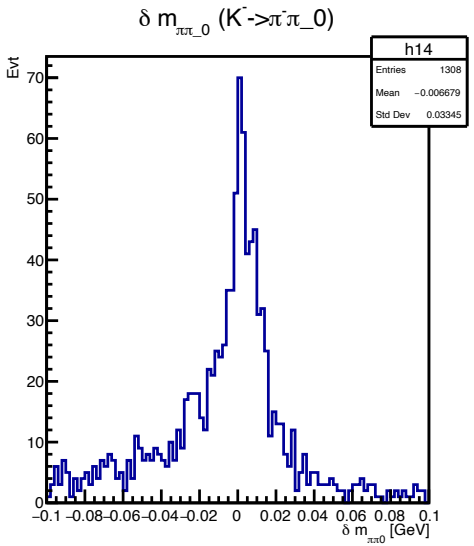
In Kaon samples, many kinks are misidentified

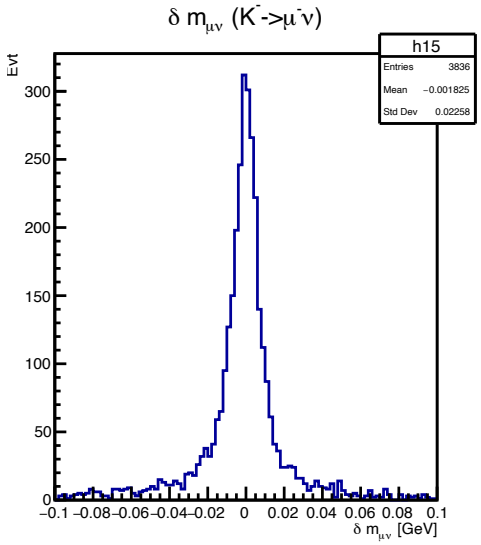
KinkFinder vs New - δm distribution (Kaon)

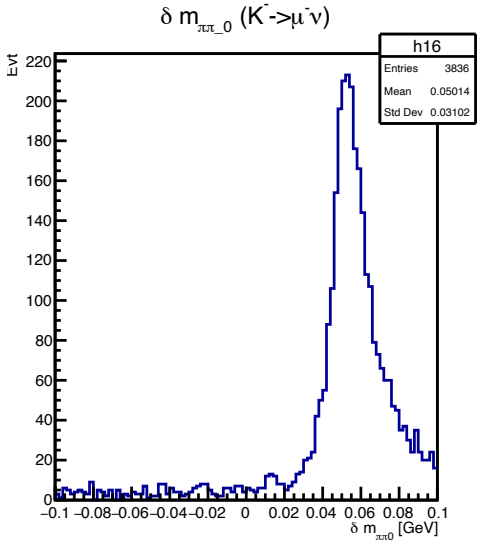


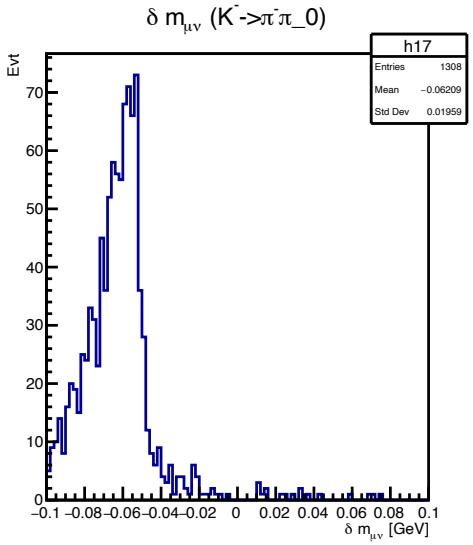












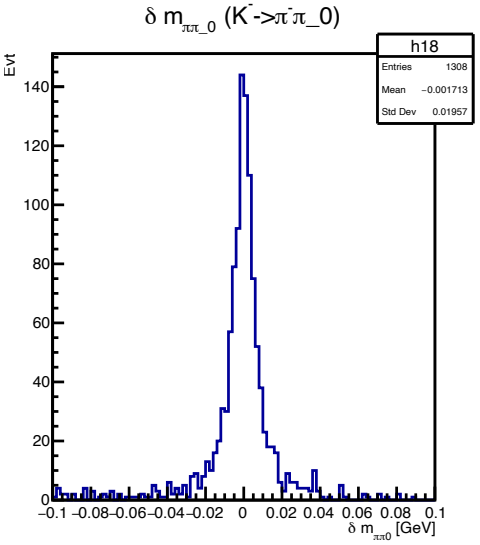


Table: sigma by RMS 90 - New

	Sigma	Error of sigma
K-> munu	0.012136338	0.00015802845
K->pipi0	0.0088005273	0.00019342986
Pi->munu	0.0057965286	0.00019430008
Si->pin	0.0093852586	4.3146168E-05
Xi->pilamda	0.0078814737	3.9757787E-05