2016 SIMP Analysis z0/tanLambda Variable

Analysis Meeting 08/22/2023

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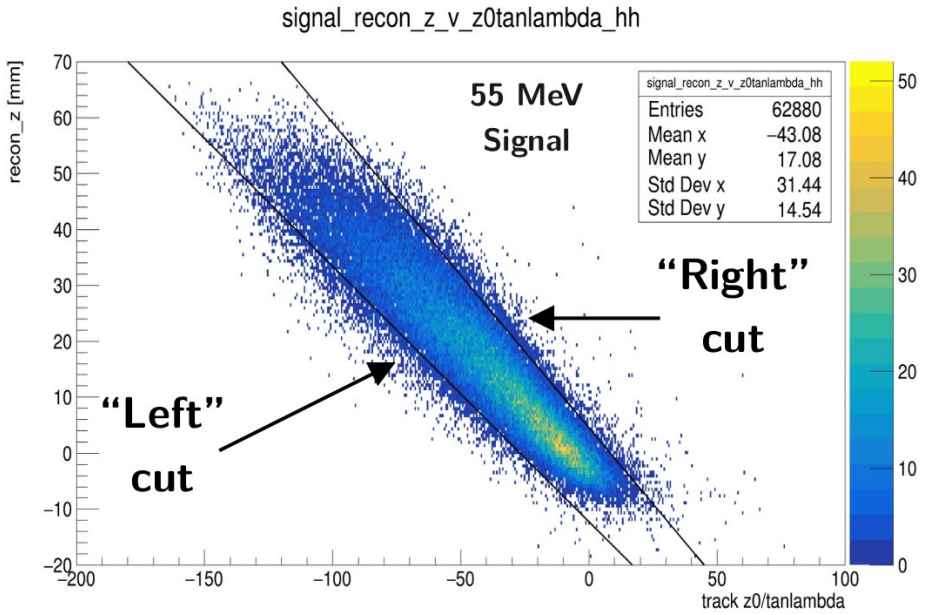
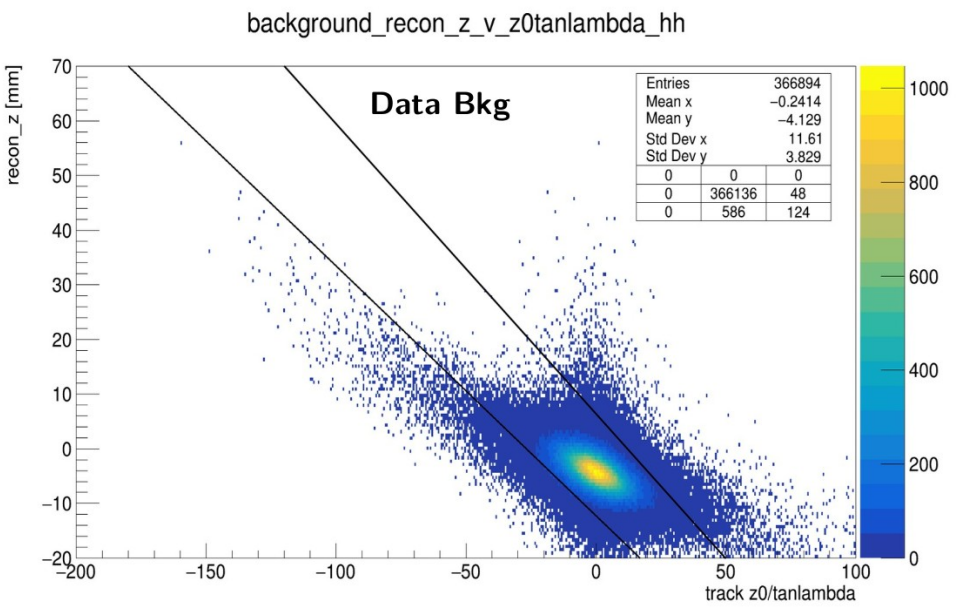
Cameron Bravo

Introduction

- Showed track z0/tan(lambda) at workshop (link) as potential new high-z cut variable
- Variable appeared to perform well compared to isolation cut and impact parameter cut
- What does this variable physically represent?
- Why does this variable look different between SIMP signal and MC
  - Workshop question: Is this due to an inelastic dm kick? $\leftarrow$ No, true for Disp A' too
- Show some prelim MC truth info (full stats are **still** hadding since yesterday)
- Using the difference of track z0/tanLambda makes this cut very simple

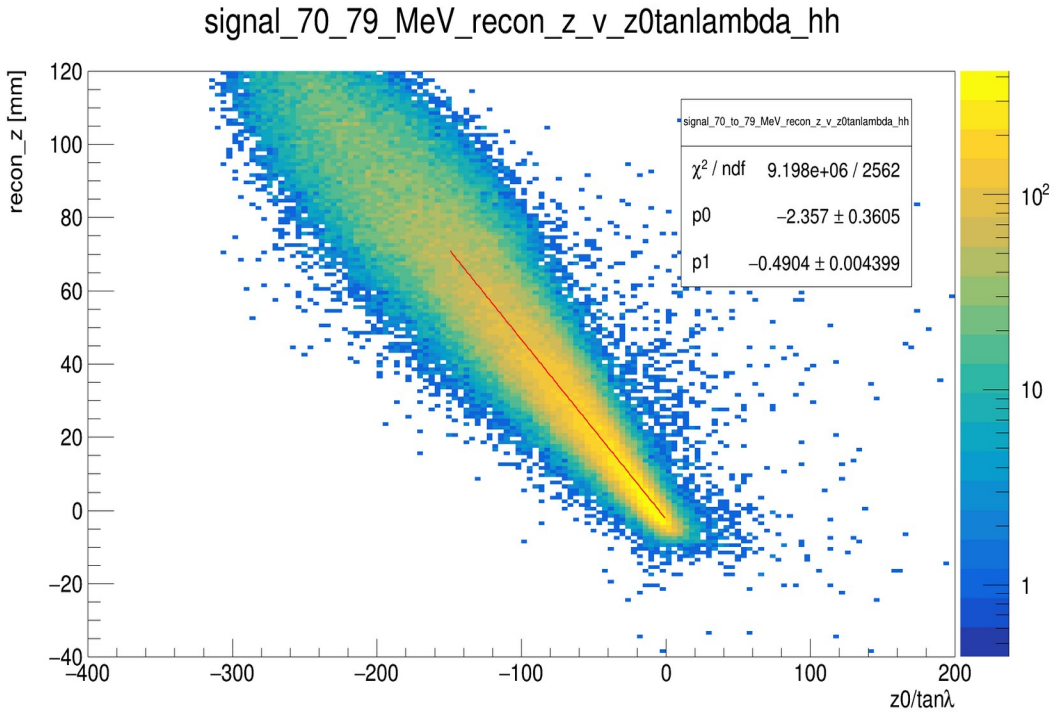
z0/tanLambda Cut Variable

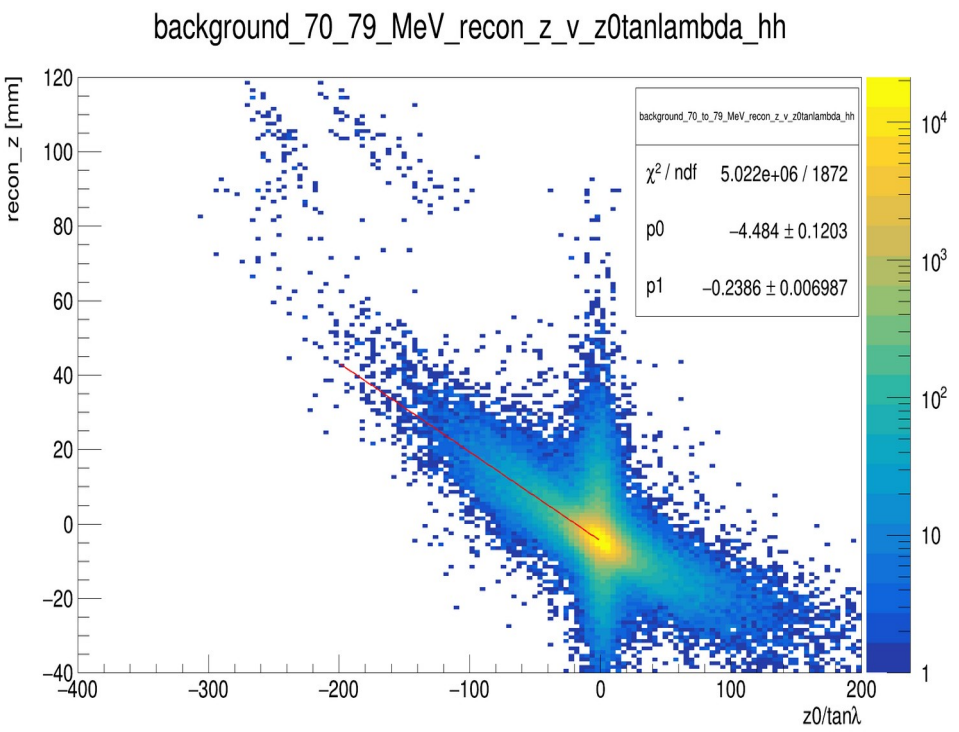




- Showed this eyeball cut at workshop **(Single mass window)**
- Plots have two entries for each vertex candidate (ele and pos track)
- Clear that many high-z background events can be cut while maintaining high signal efficiency
- Correlation in background events between tracks in central spike, and left wing
- Why is the signal distribution different than the left-wing background?
- Do these distributions change with mass?

Signal vs Background Slope

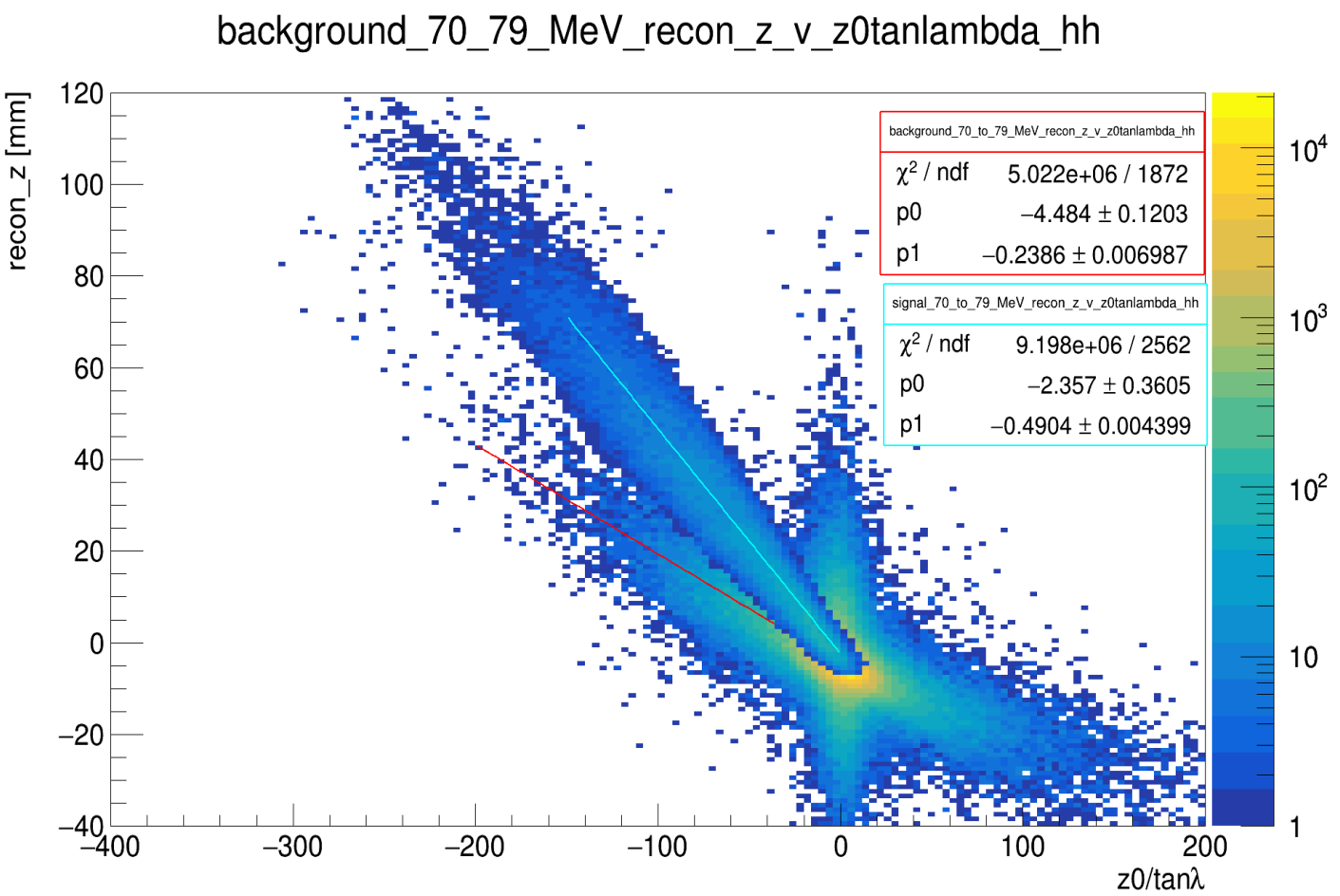




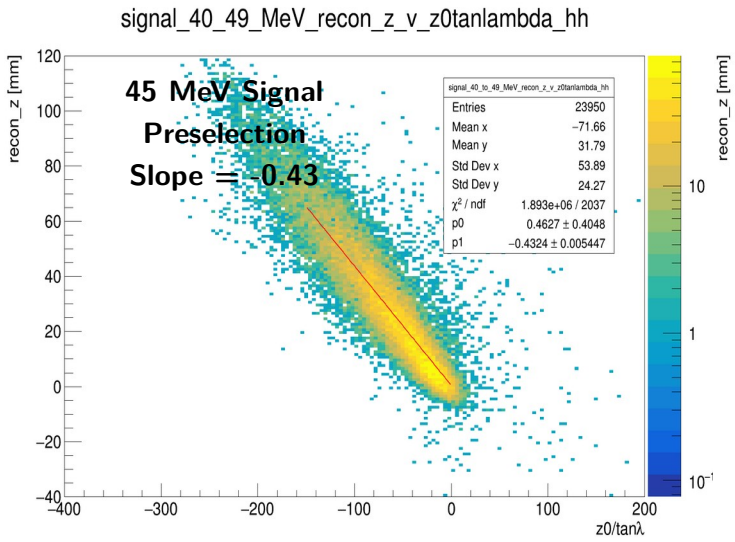
- 75 MeV SIMP+Beam and Data Sample (Preselection, no L1L1 here...just for more stats)
- Signal slope is -0.49
- Bkg left-wing slope is -0.24
- Signal slope ~ 2x Bgk
- Next slide shows plots together

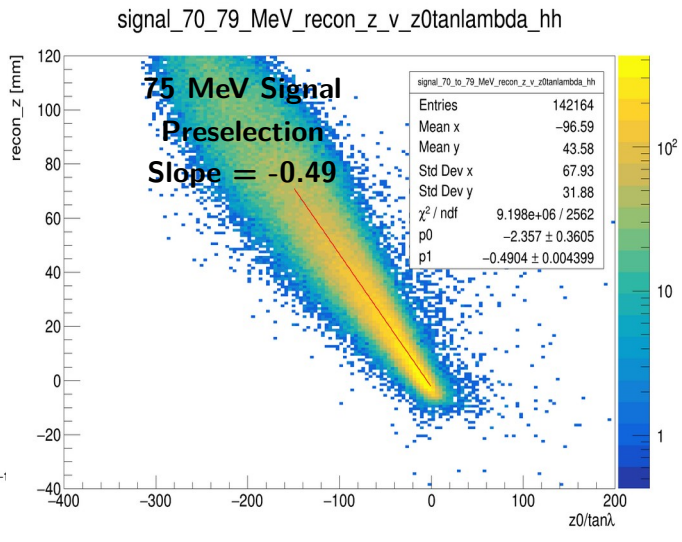
Signal vs Background Slope

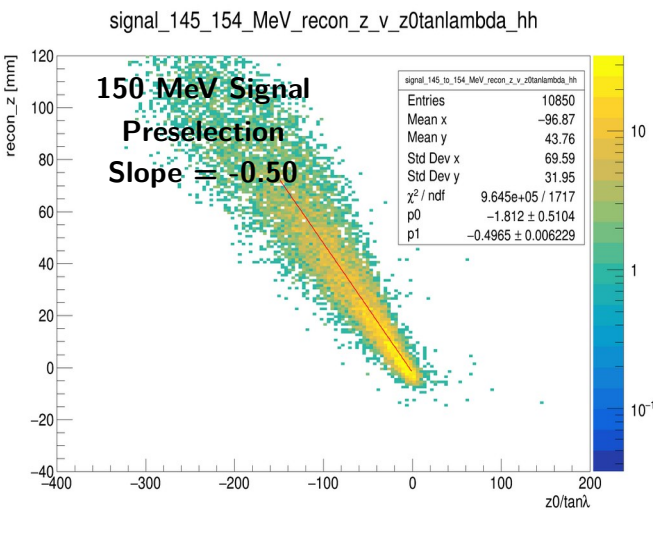
- Why are these slopes different?
- Do either slopes change with mass?
- What is the physical interpretation of this variable for truly displaced events, and for mis-reconstructed events
- What does the signal distribution look like for Displaced A's, rather than SIMPS (missing energy)

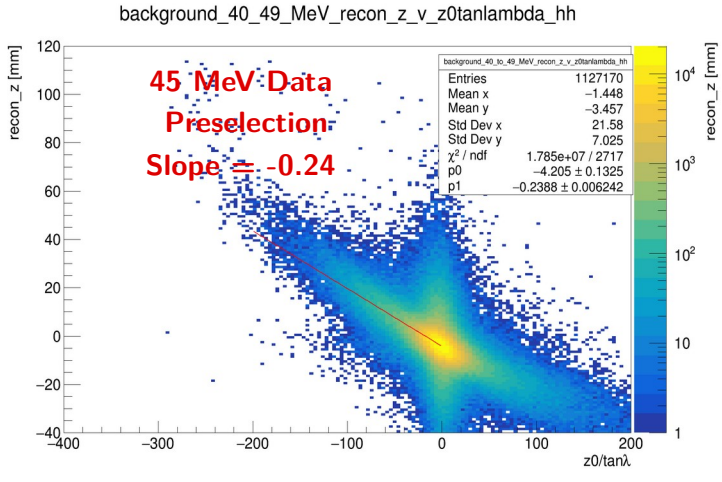


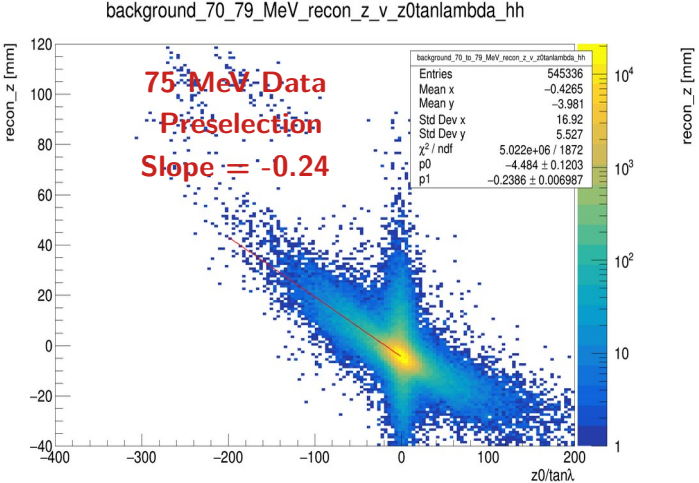
Signal vs Background Slope – Different Masses

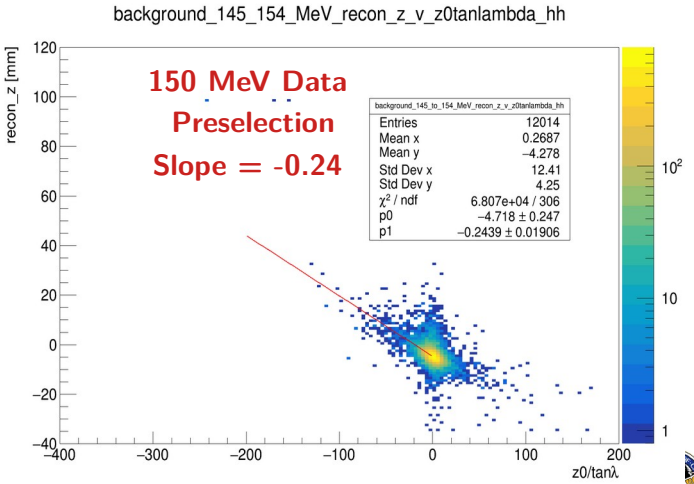








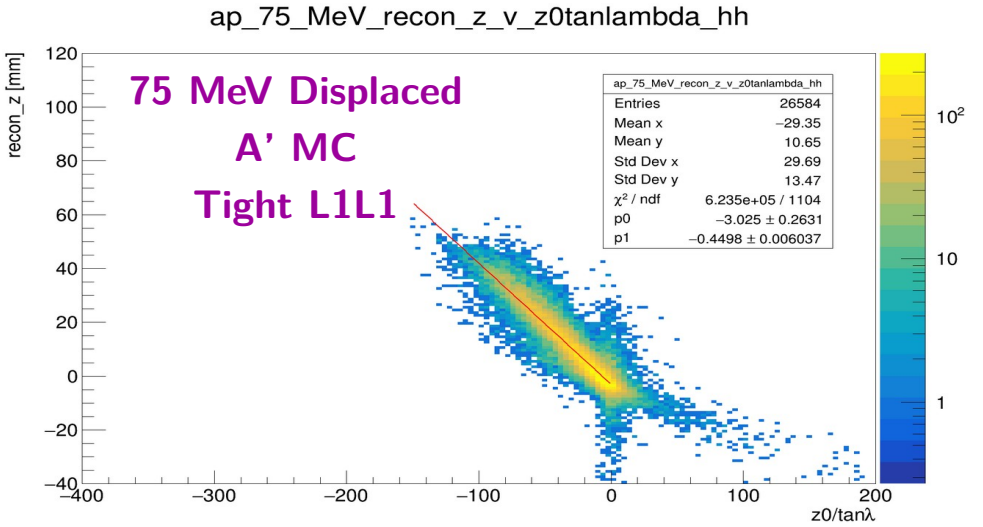


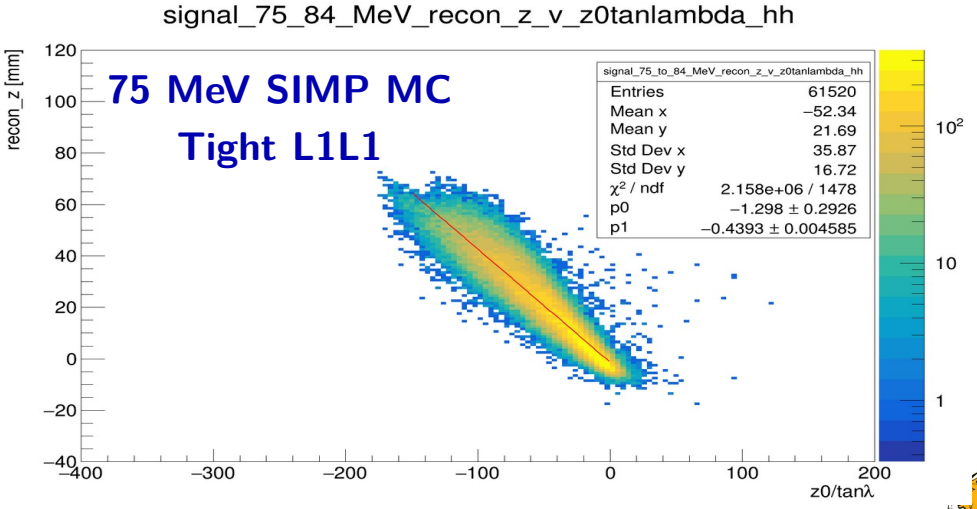


Displaced A' versus SIMPs

- **Is this ~-0.5 slope a SIMP only feature?**
  - Maybe due to the dark pion kick?

- Compare **SIMP** and **Displaced A'** MC
- **Displaced A' shows same relationship**
  - Disp A' Slope = -0.45
  - SIMP Slope = -0.44





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- **Is this ~-0.5 slope a SIMP only feature?**
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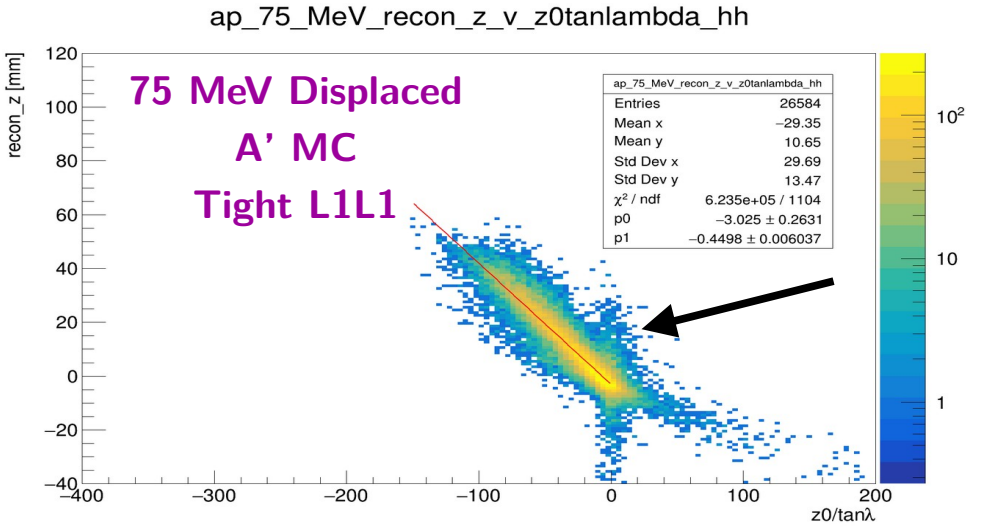
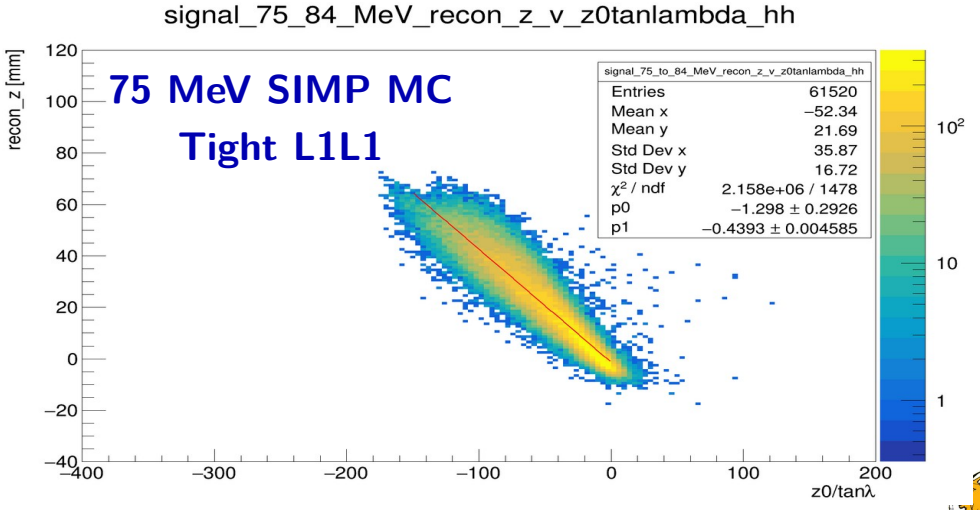
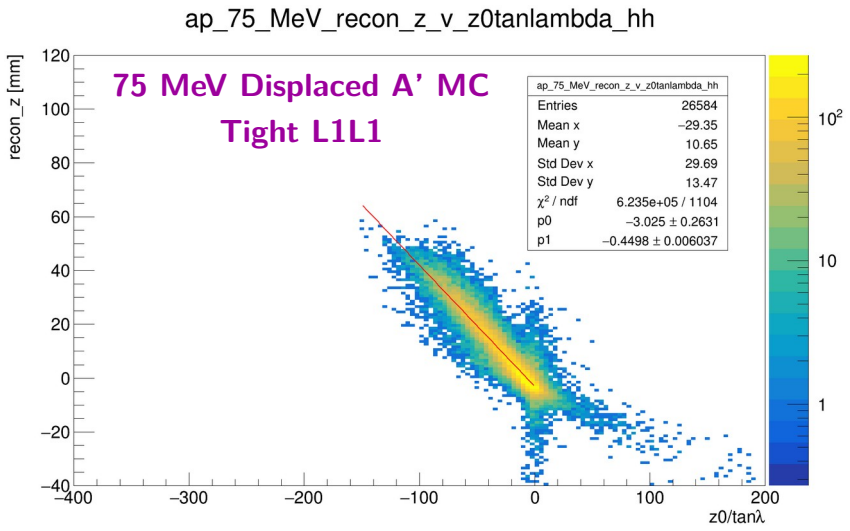
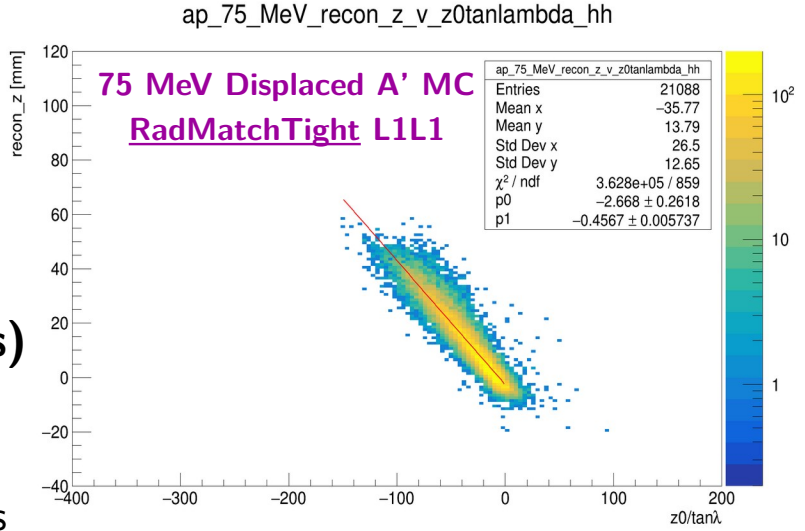
- Compare **SIMP** and **Displaced A'** MC
- **Displaced A' shows same relationship**
  - Disp A' Slope = -0.45
  - SIMP Slope = -0.44
- Quick Aside: Why do Displaced A's have a spike centered on z0/tanlambda = 0?





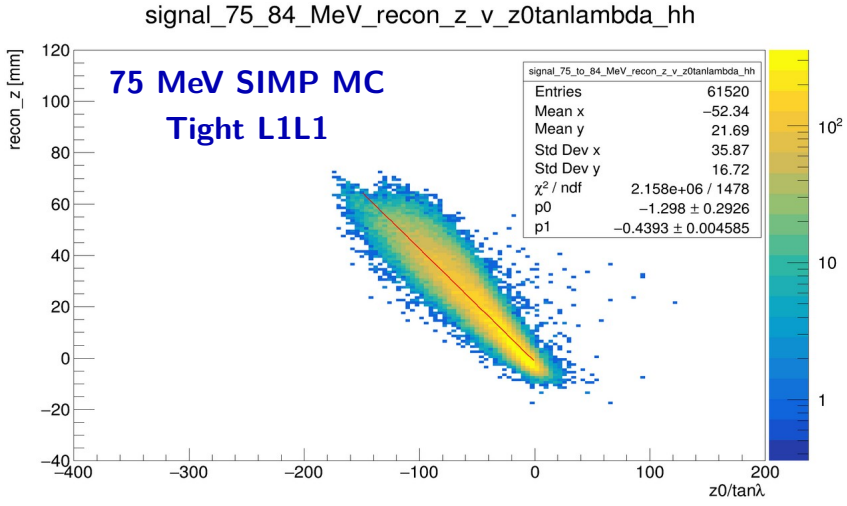
Displaced A' Recoil Electrons

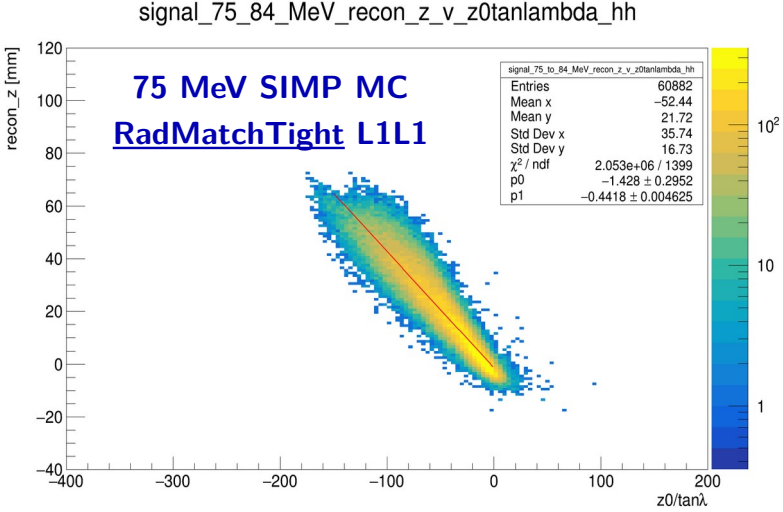




"RadMatchTight"
(No recoil electrons)

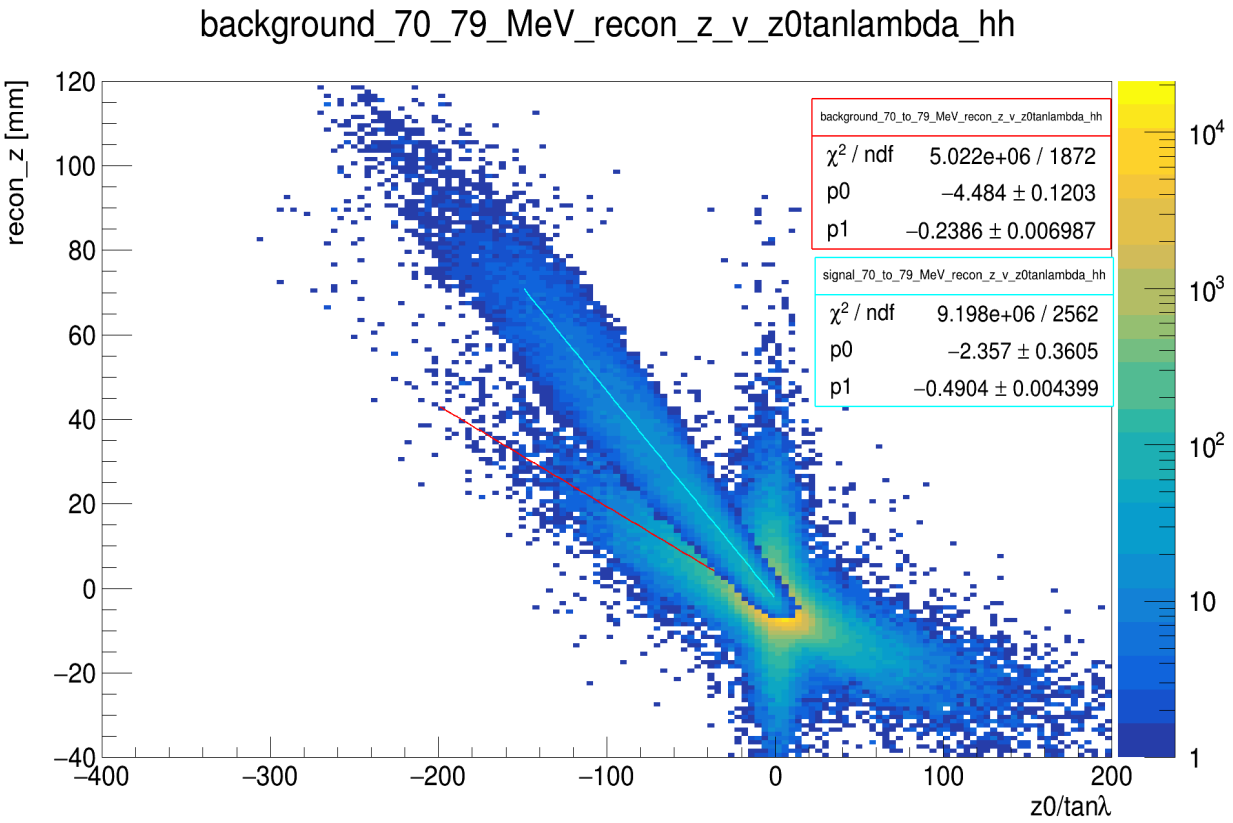
- Displaced A' Vertices occasionally use recoil electron
- Doesn't seem as frequent for SIMPs





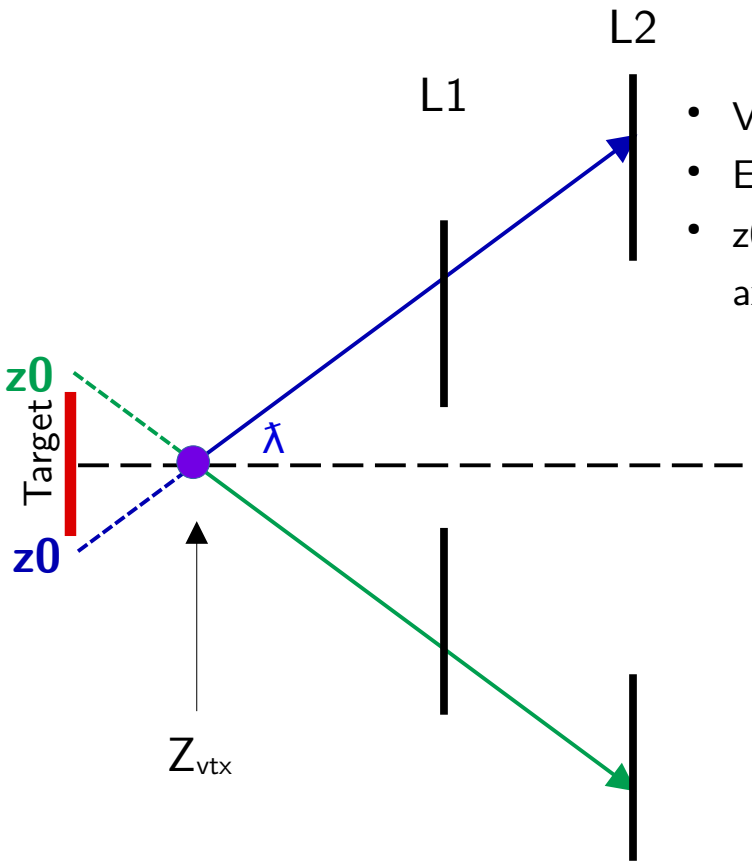
Signal vs Background Slope – Physical Interpretation

- Displaced signal has this linear correlation between z0/tanlambda and recon_z of -0.5
- Physical explanation for why background left-wing events have similar correlation, but half the slope?
- Let's look at some crude diagrams...

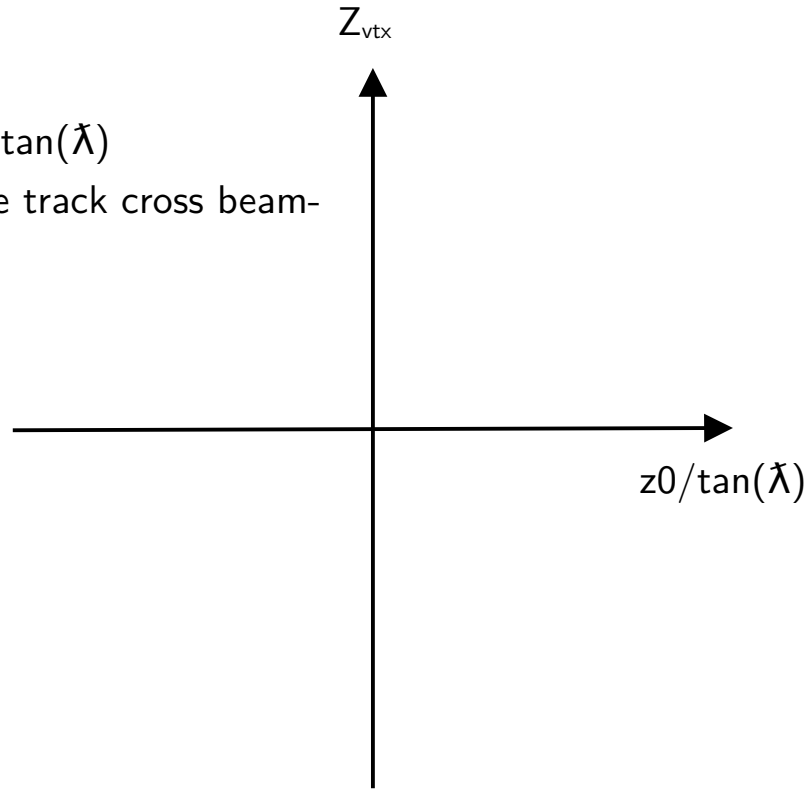


Crude Diagrams

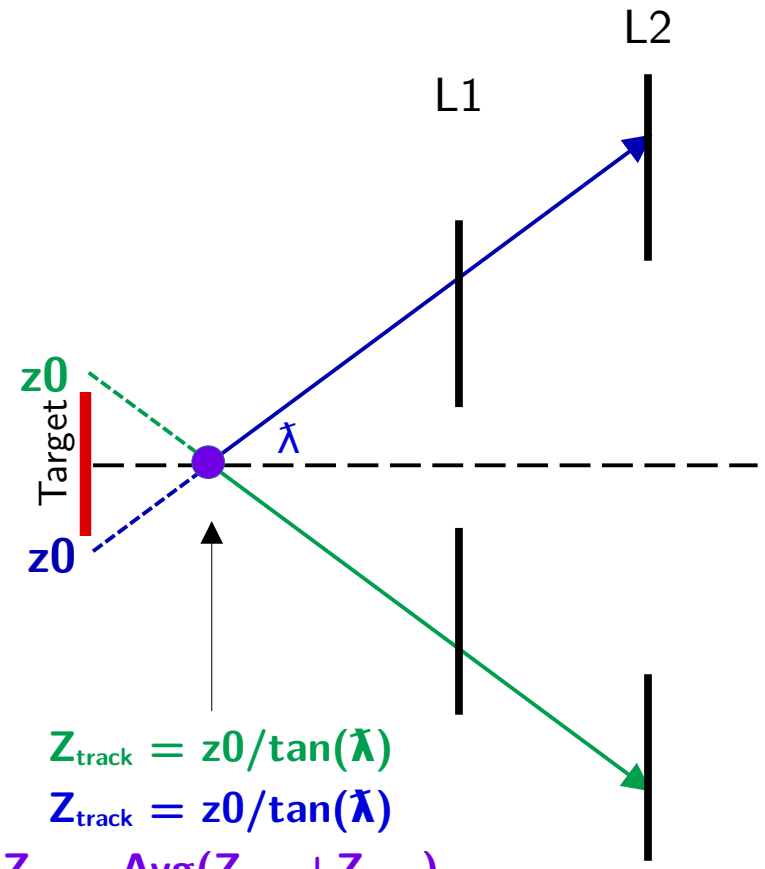
Displaced Signal - z0/tanƛ



- Vertex has Z_{vtx} position
- Each vertex track has a z0/tan(ƛ)
- z0/tan(ƛ) ~z position where track cross beam-axis



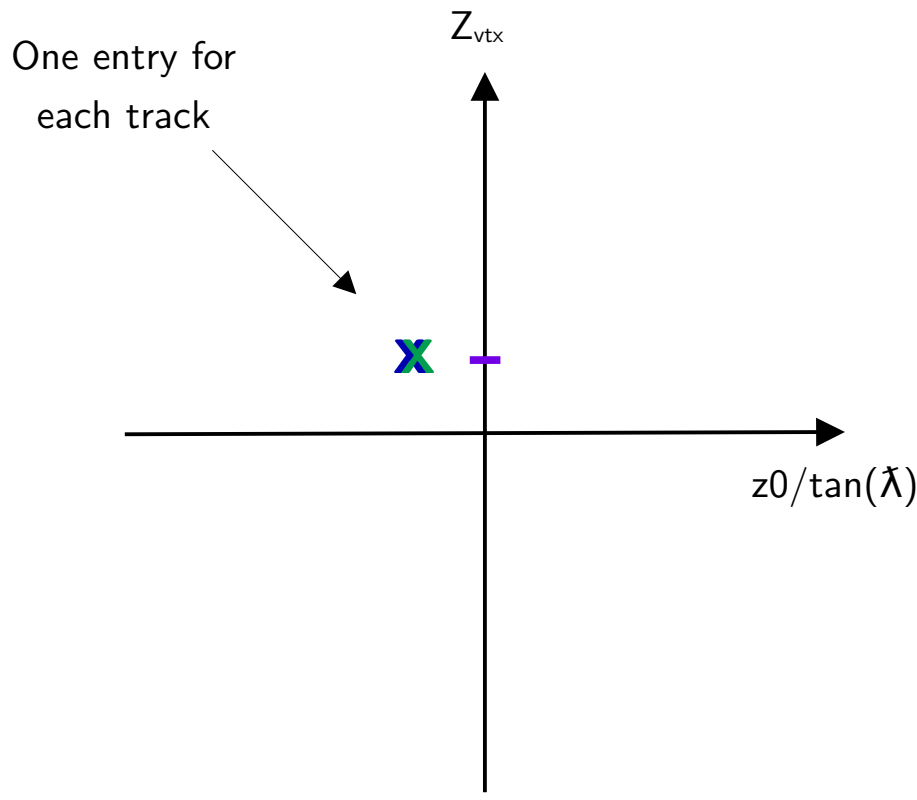
Displaced Signal - z0/tanƛ



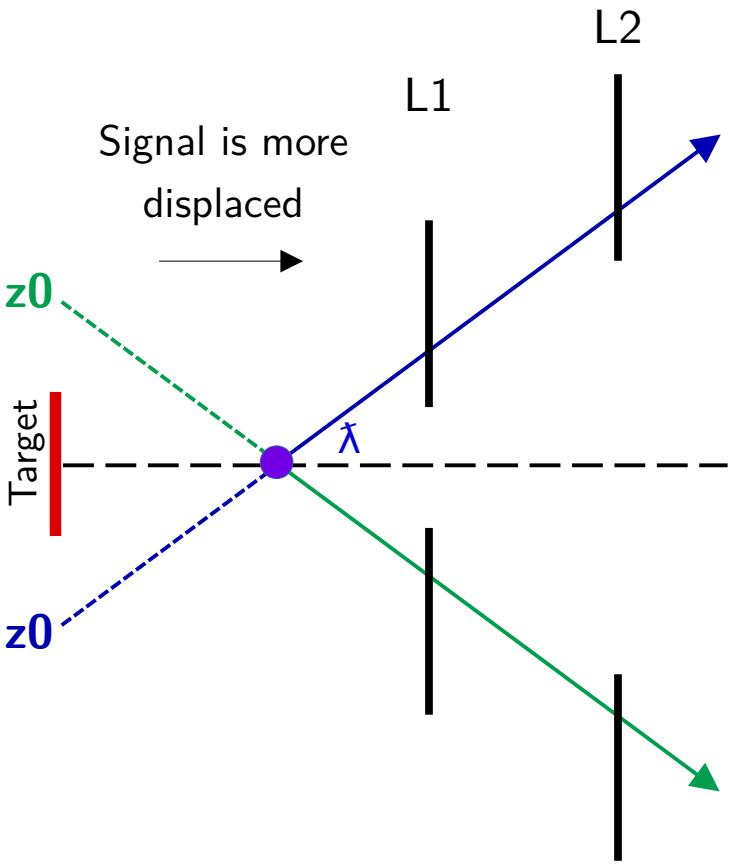
$Z_{track} = z0/\tan(ƛ)$

$Z_{track} = z0/\tan(ƛ)$

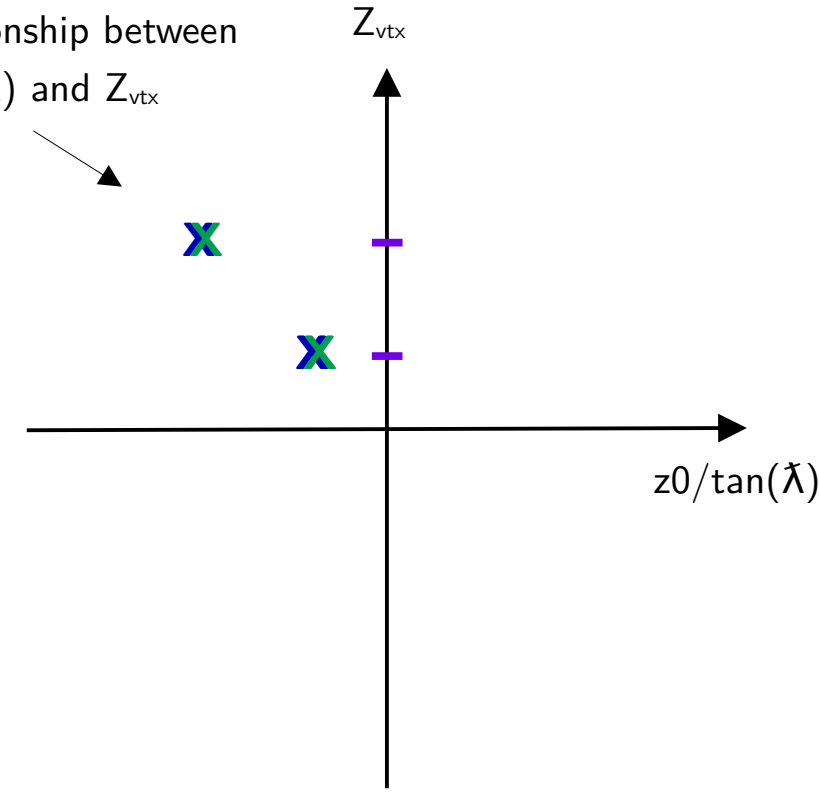
$Z_{vtx} \sim Avg(Z_{track}+Z_{track})$



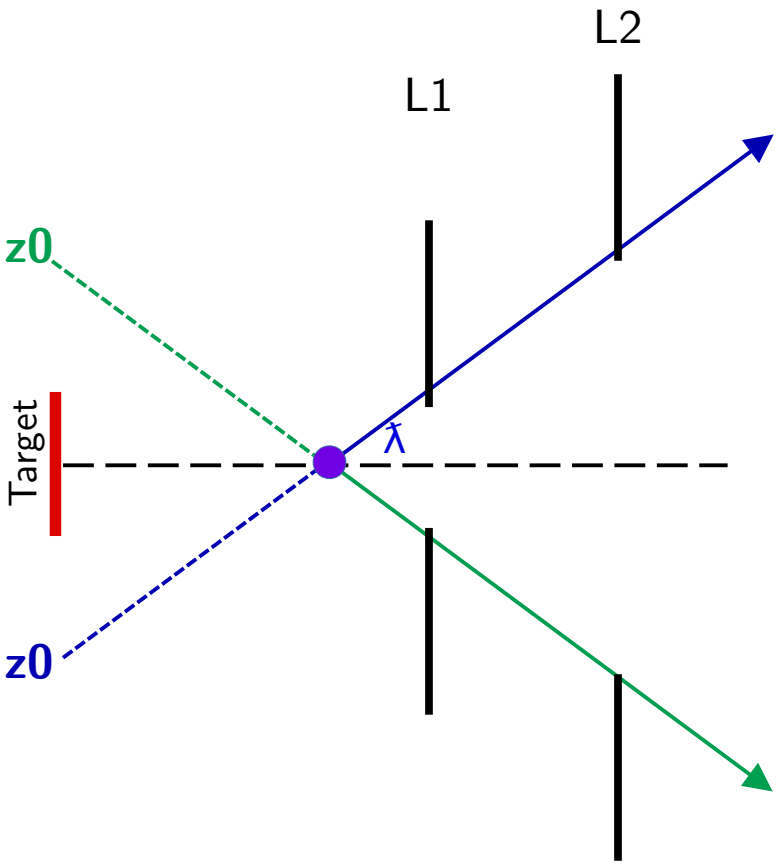
Displaced Signal - z0/tanƛ

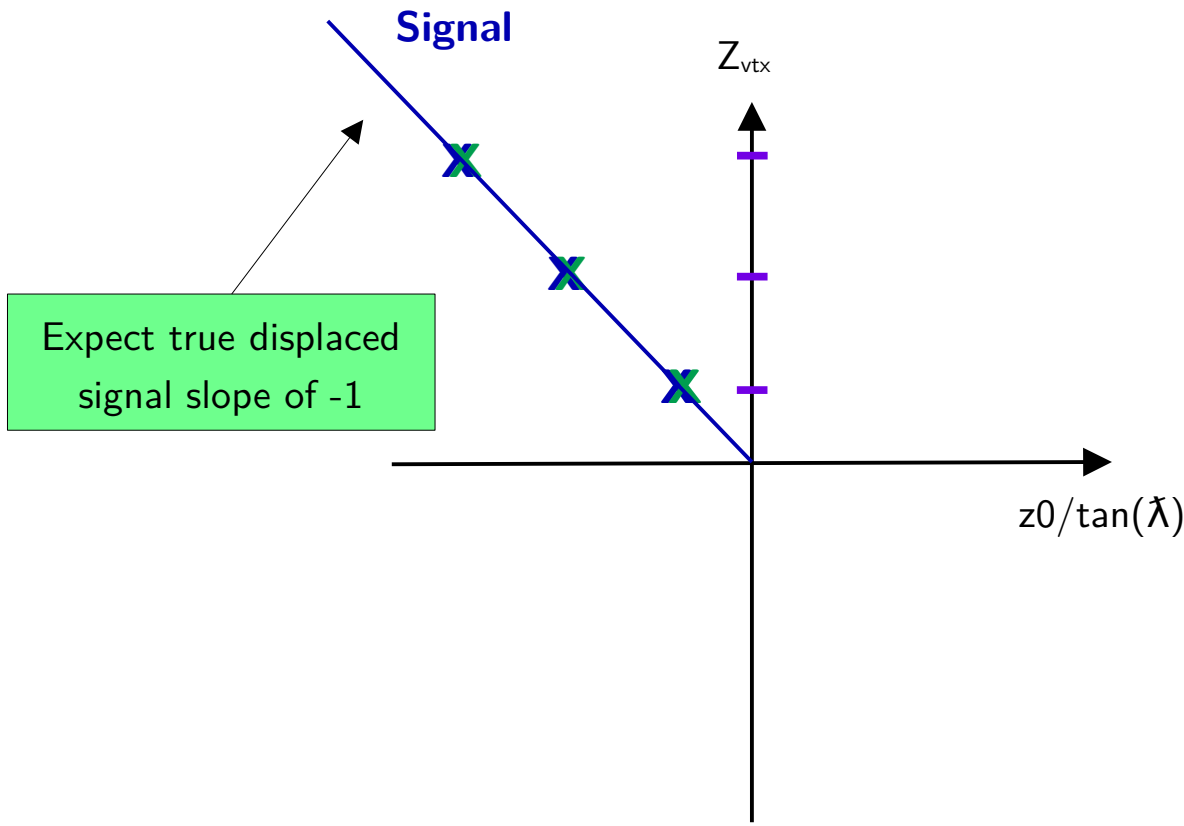


Linear relationship between
z0/tan(ƛ) and Z_{vtx}

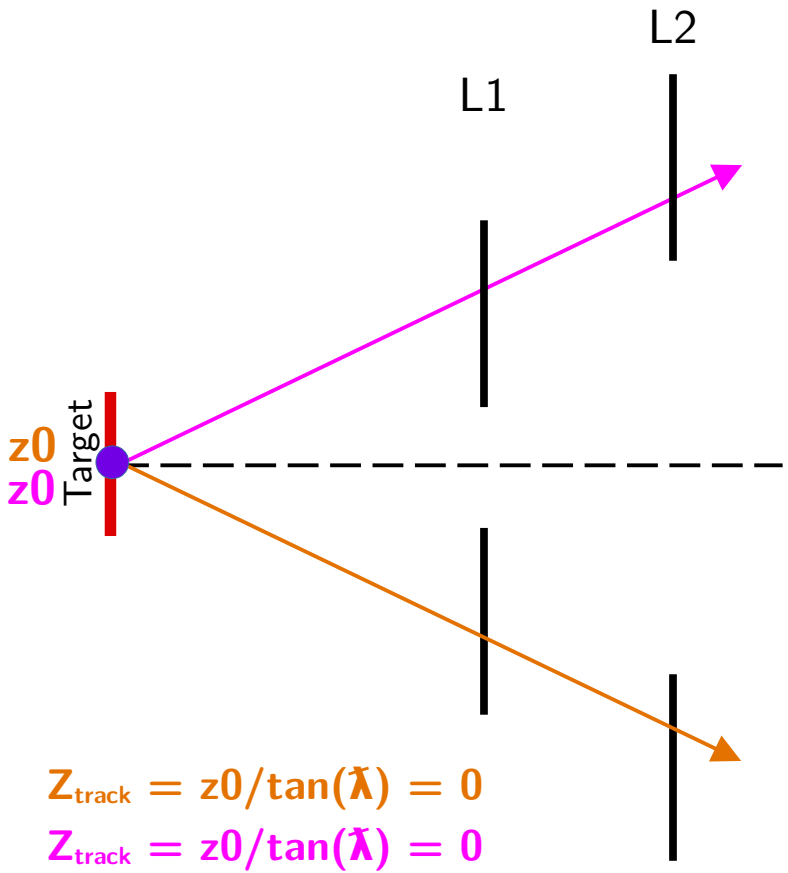


Displaced Signal - z0/tanƛ





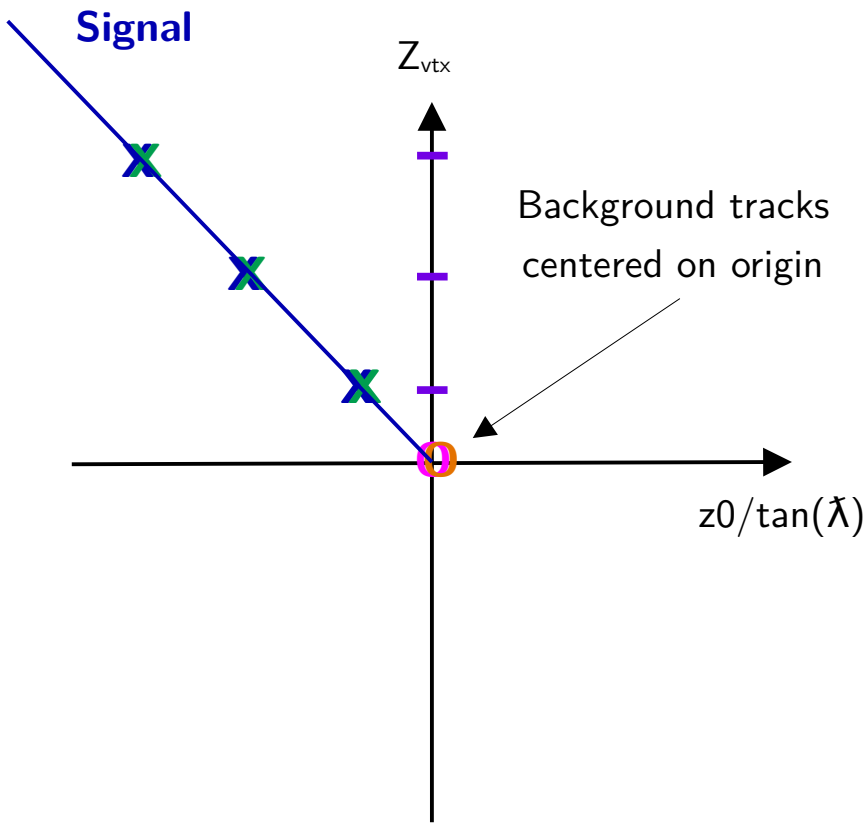
Background - z0/tanλ



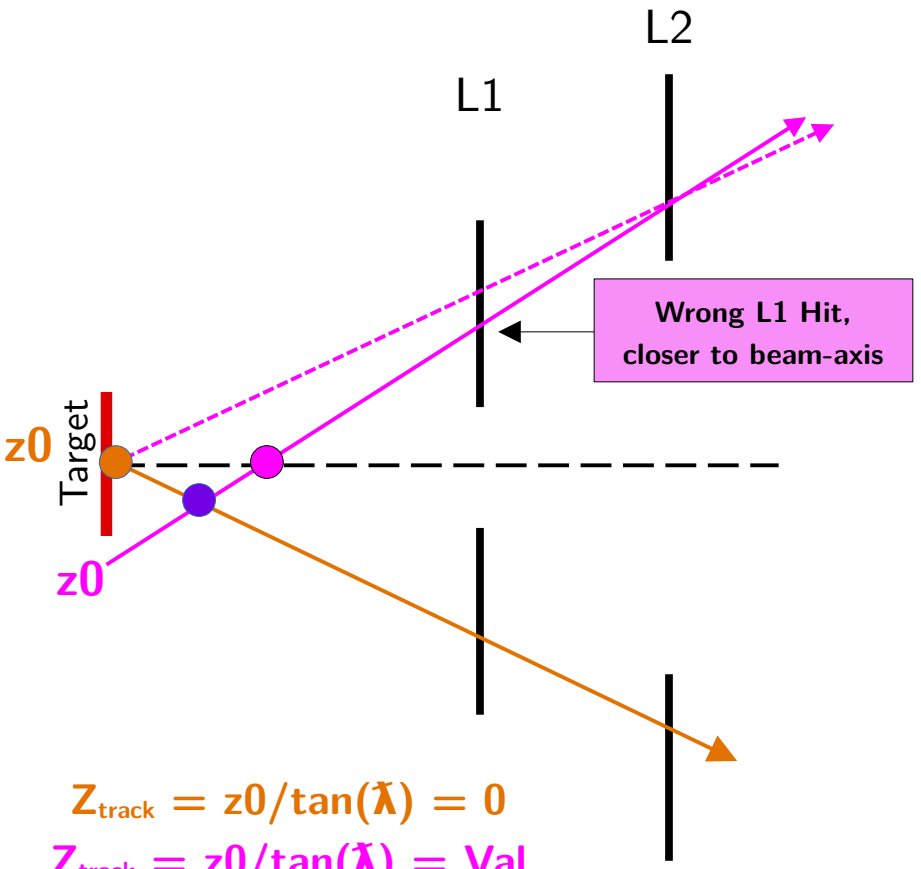
$Z_{track} = z0/\tan(\lambda) = 0$

$Z_{track} = z0/\tan(\lambda) = 0$

$Z_{vtx} \sim Avg(Z_{track}+Z_{track}) = 0$



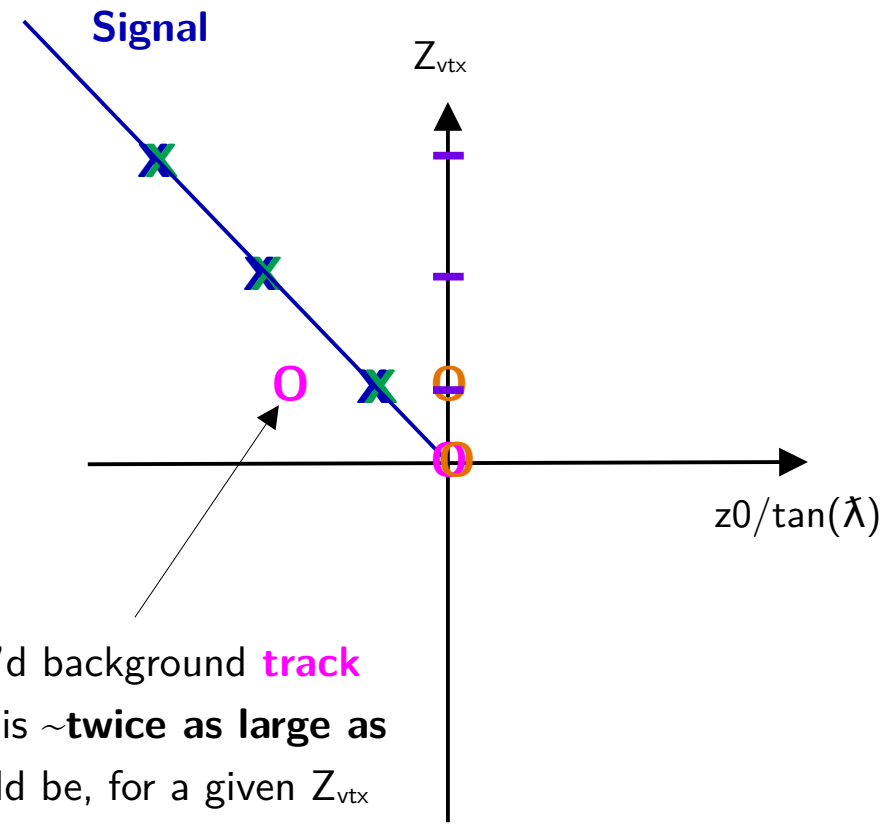
Background – z0/tanλ – Bad L1 Hit



$Z_{track} = z0/\tan(\lambda) = 0$

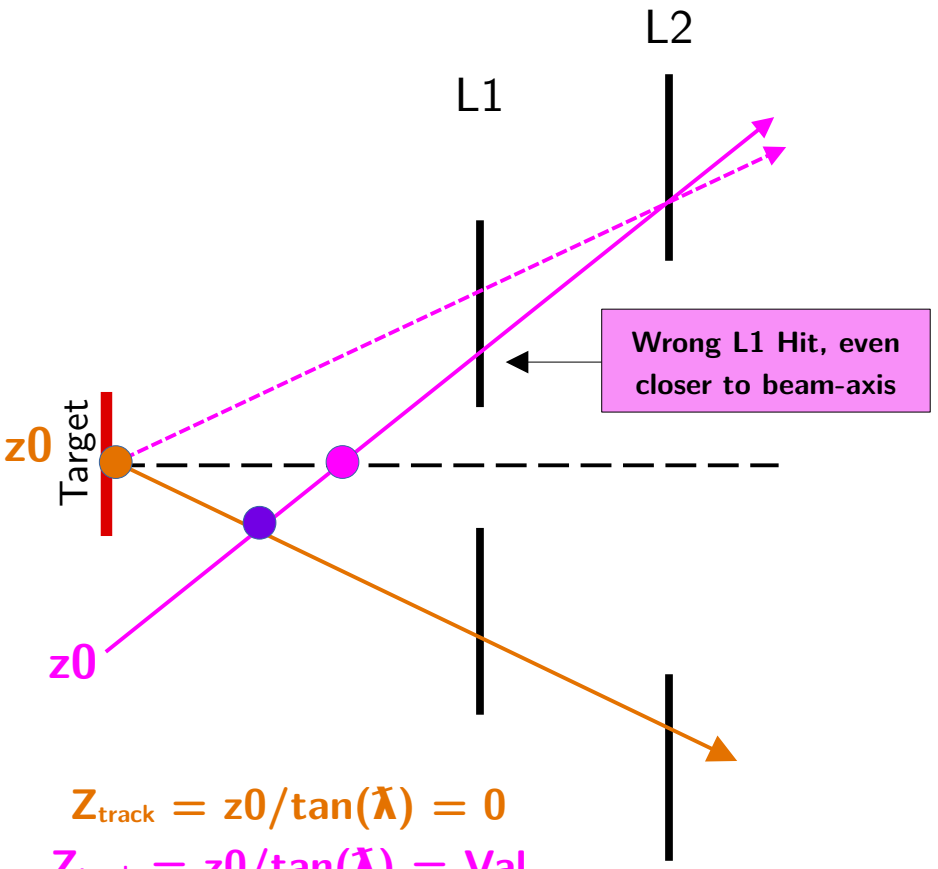
$Z_{track} = z0/\tan(\lambda) = Val$

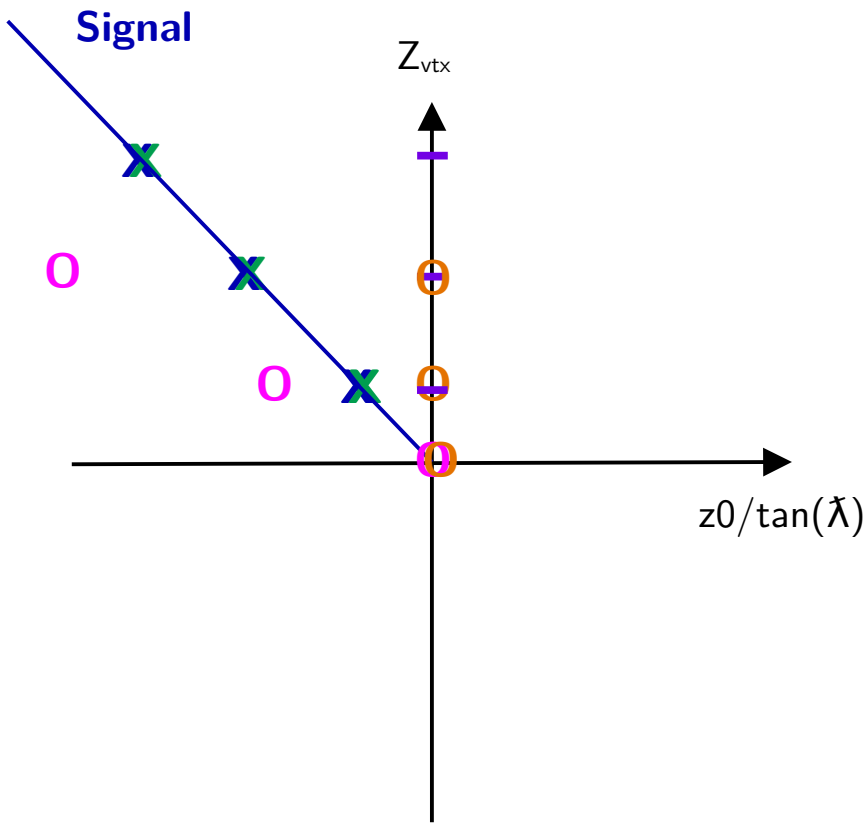
$Z_{vtx} \sim Avg(Z_{track}+Z_{track}) = Val/2$



Mis-recon'd background **track** **z0/tan(λ)** is ~**twice as large as** **signal** would be, for a given Z_{vtx}

Background – z0/tanλ – Bad L1 Hit



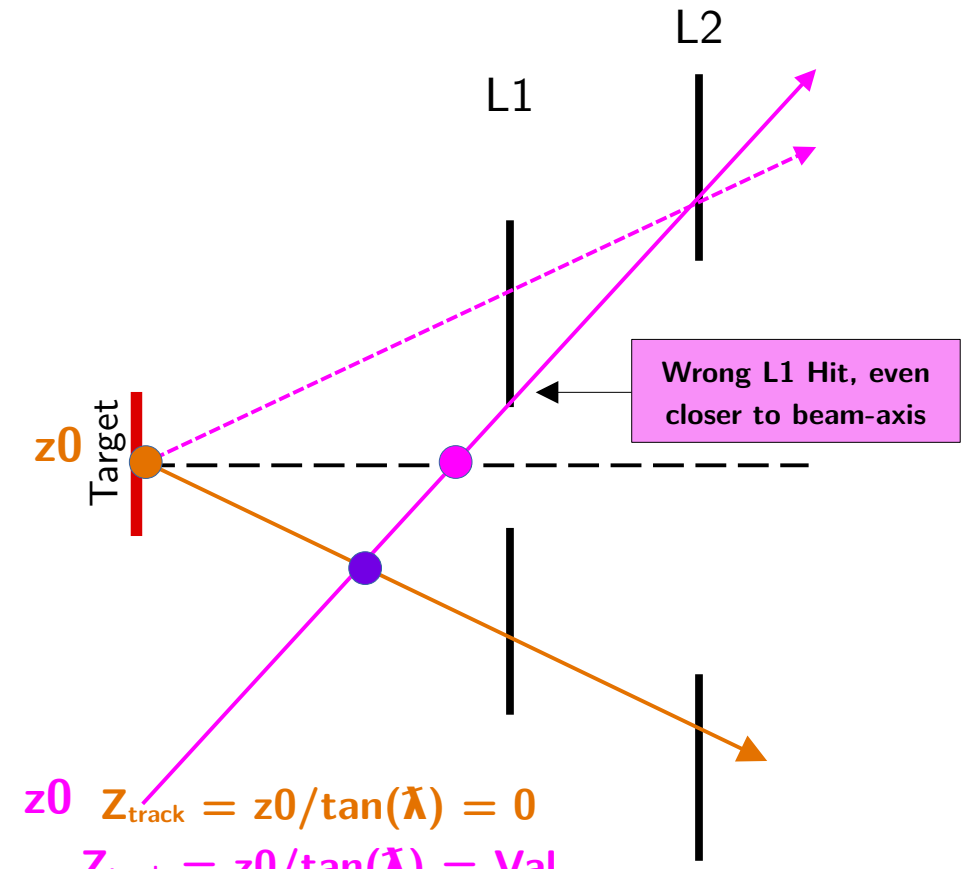


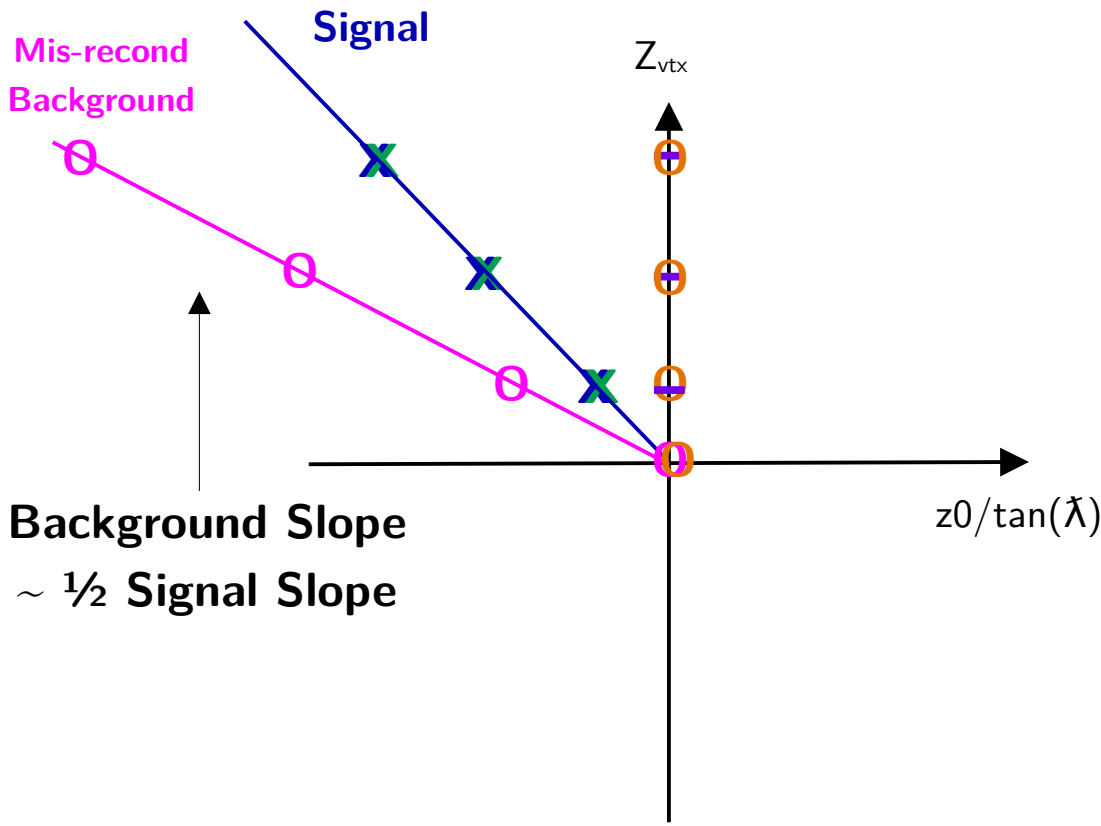
$Z_{track} = z0/\tan(\lambda) = 0$

$Z_{track} = z0/\tan(\lambda) = Val$

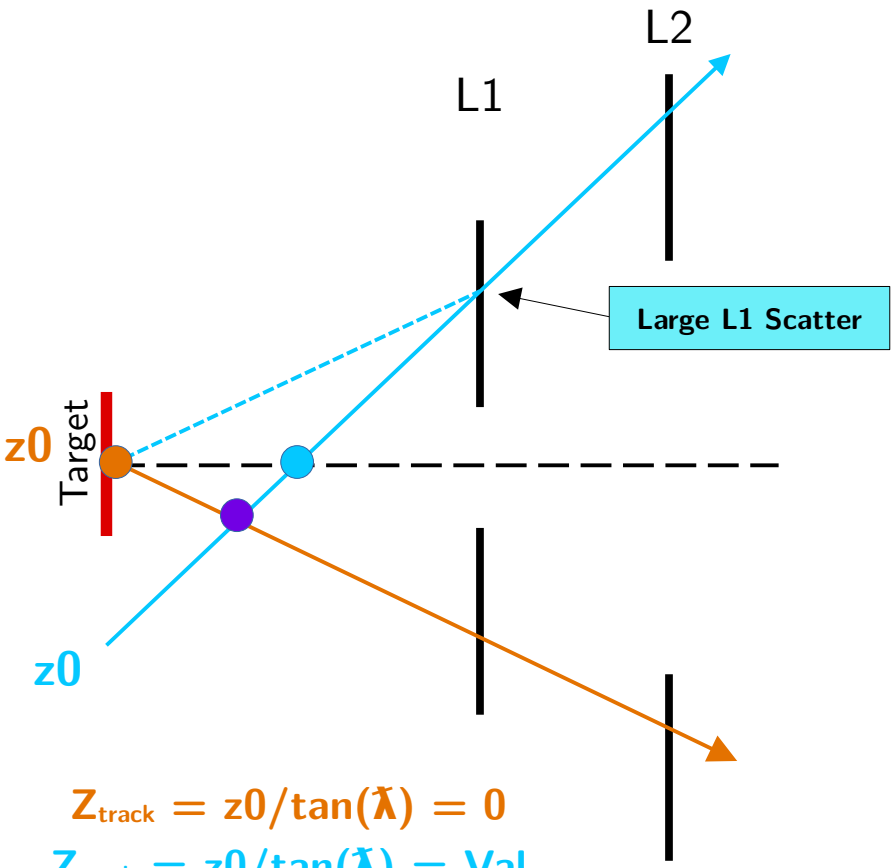
$Z_{vtx} \sim Avg(Z_{track}+Z_{track}) = Val/2$

Background – z0/tanλ – Bad L1 Hit





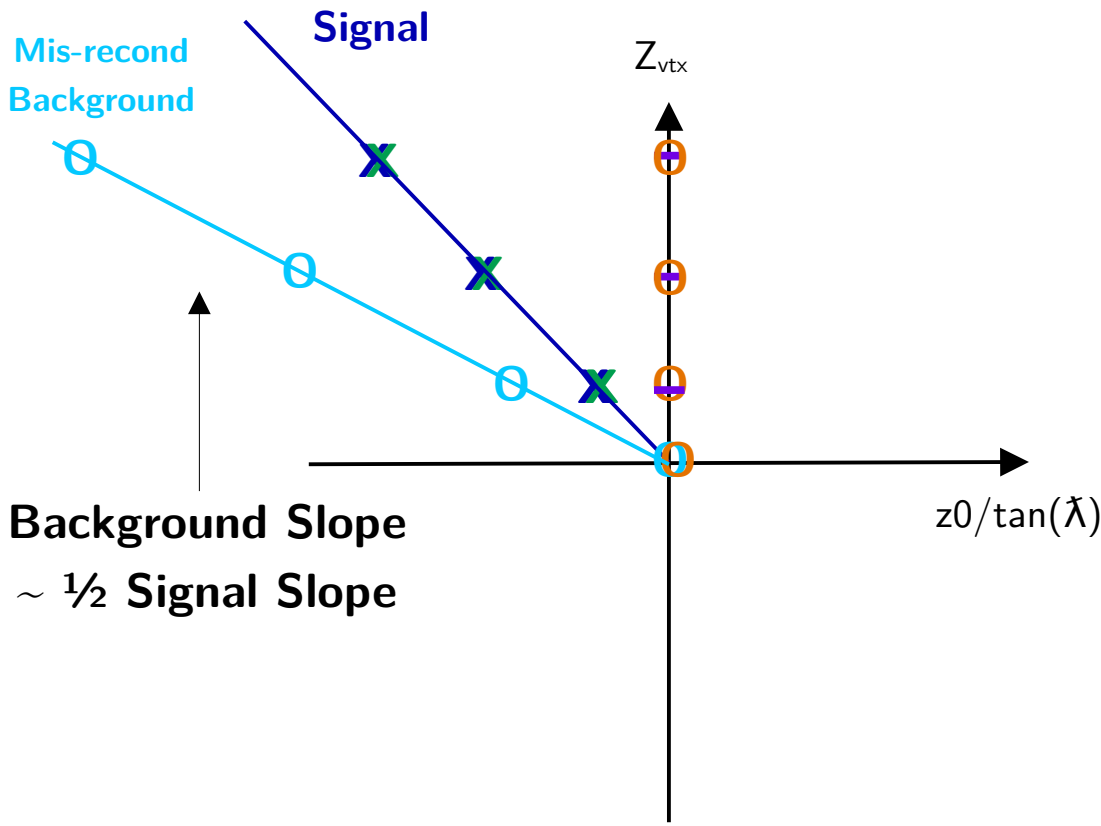
Background – Large L1 Scatter – z0/tanƛ



$Z_{track} = z0/\tan(ƛ) = 0$

$Z_{track} = z0/\tan(ƛ) = Val$

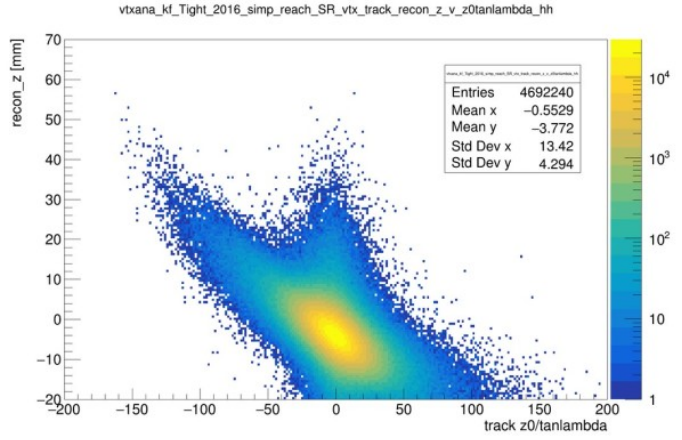
$Z_{vtx} \sim Avg(Z_{track}+Z_{track}) = Val/2$

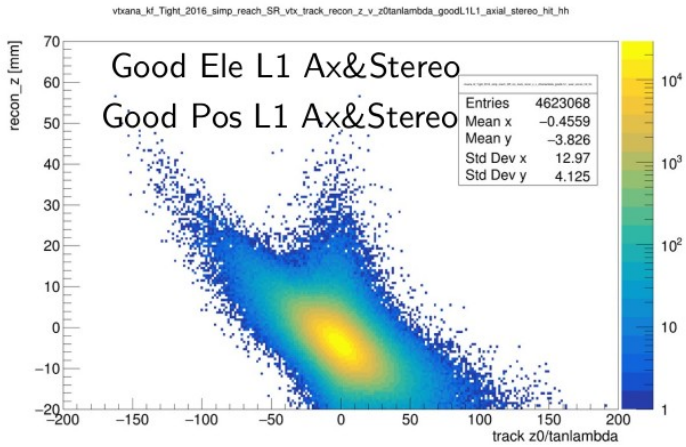


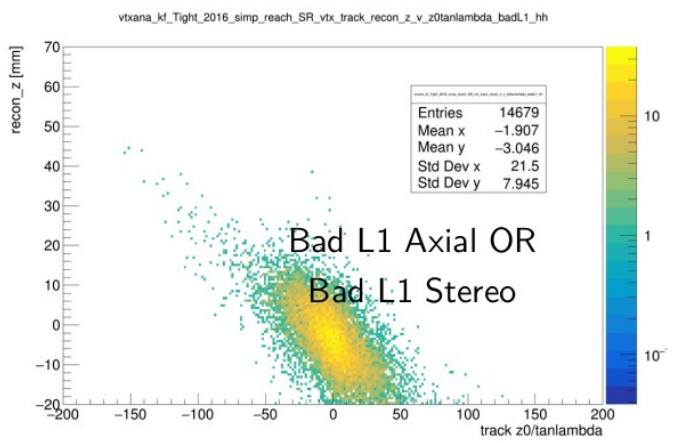
Exit Crude Diagrams

Enter MC Truth

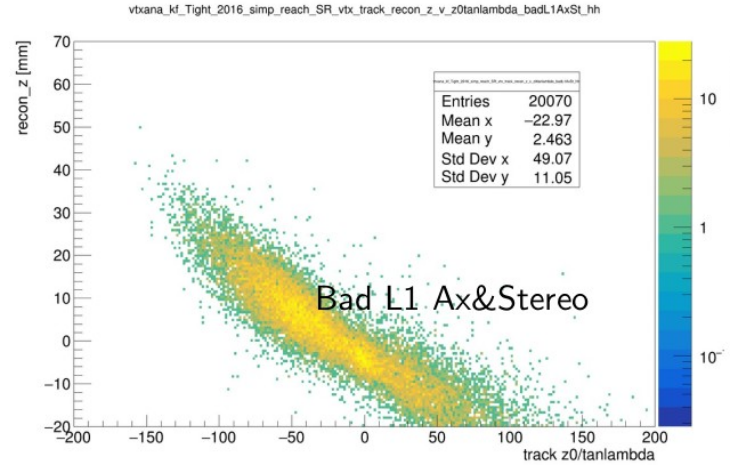
Tritrig+Beam MC Truth

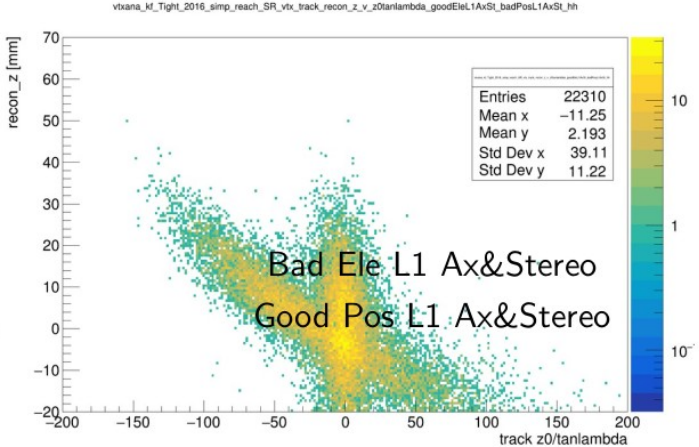


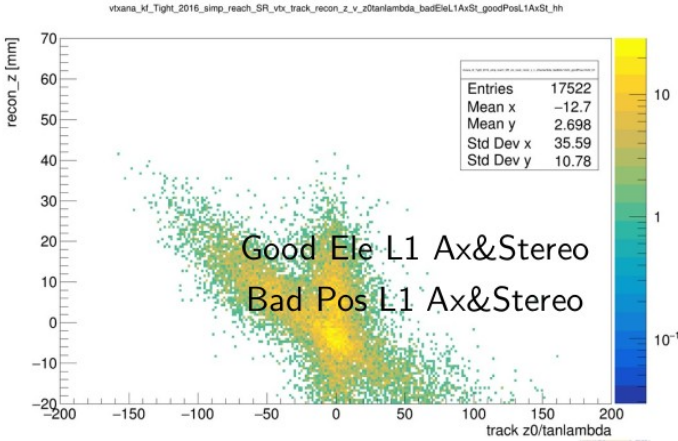




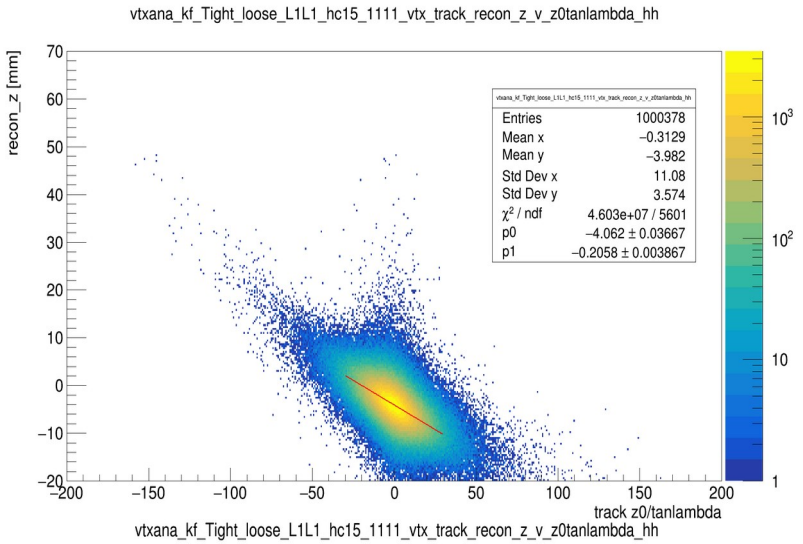
All masses

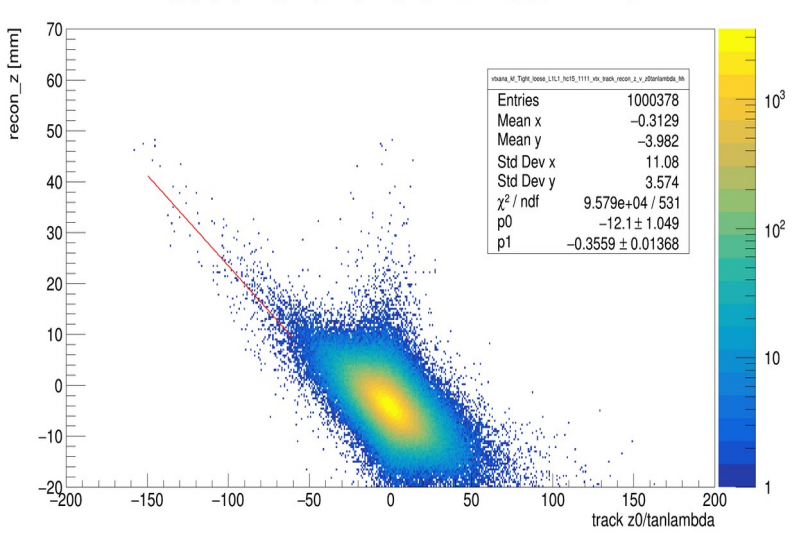






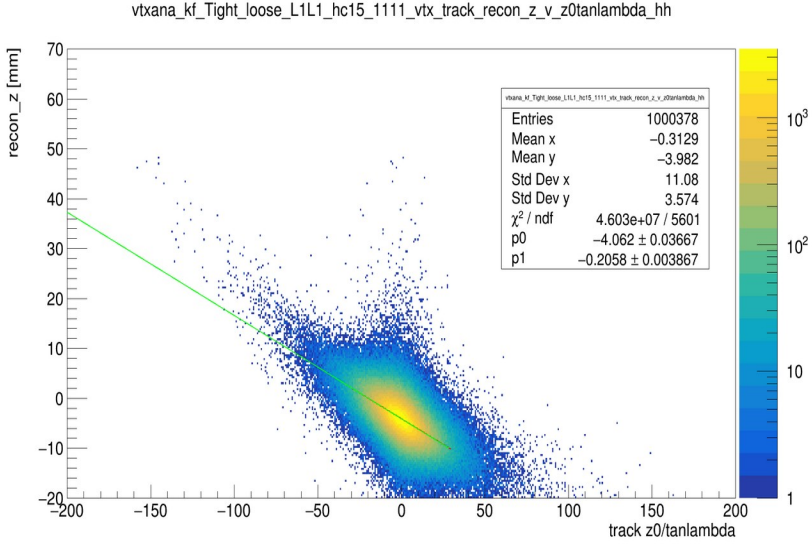
Tritrig+Beam MC Truth

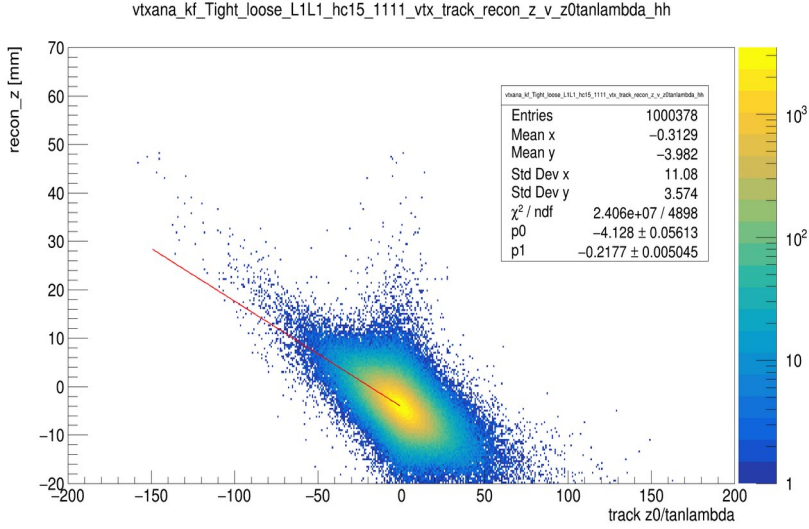




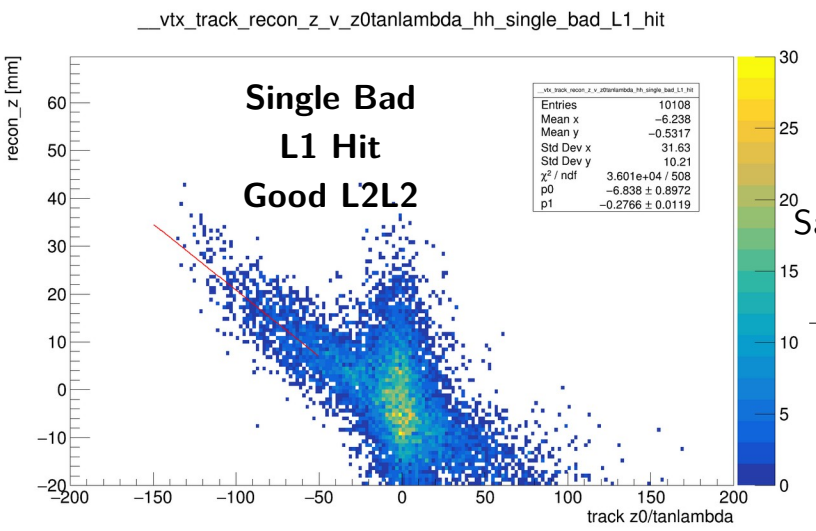
All masses

Good L1L1 and L2L2 hits

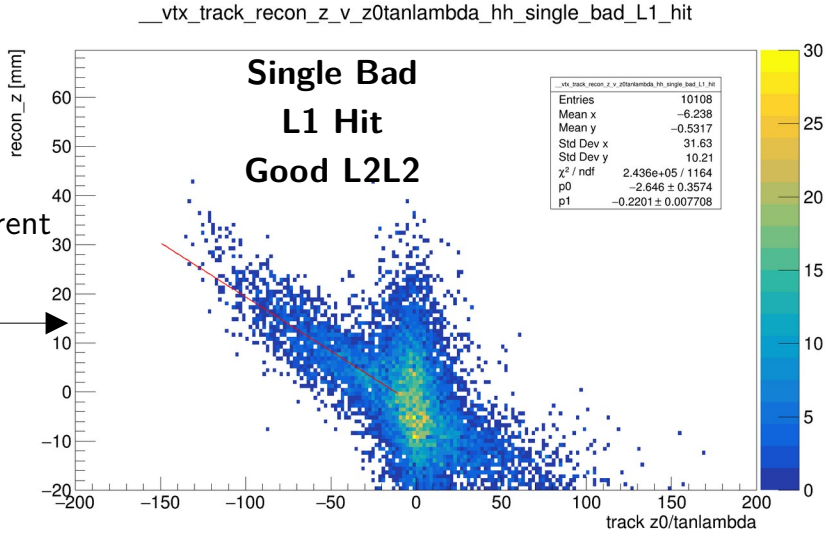


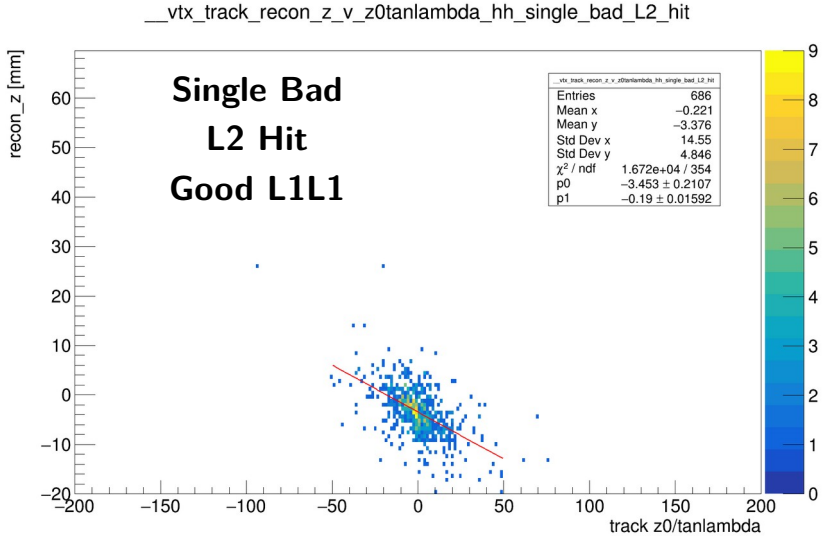


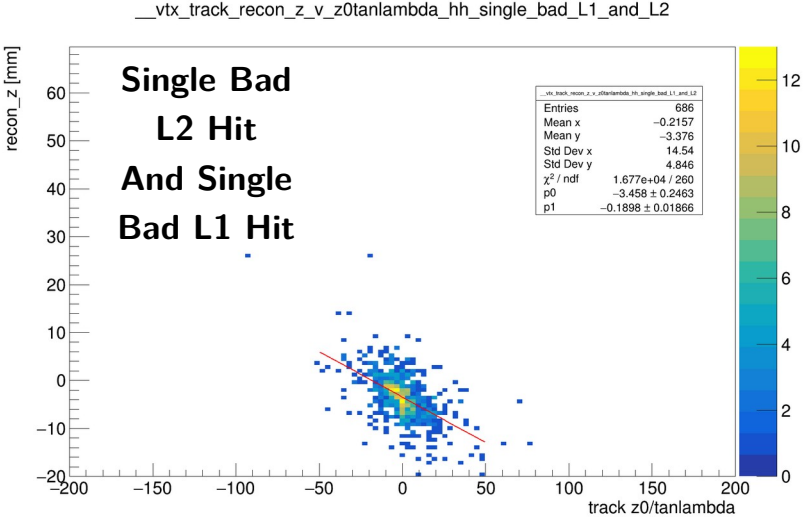
Tritrig+Beam MC Truth



Same plot, different fit range



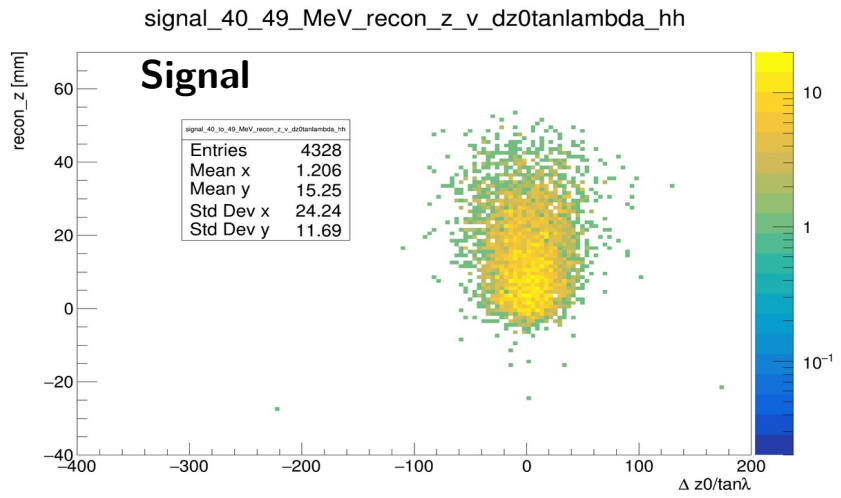


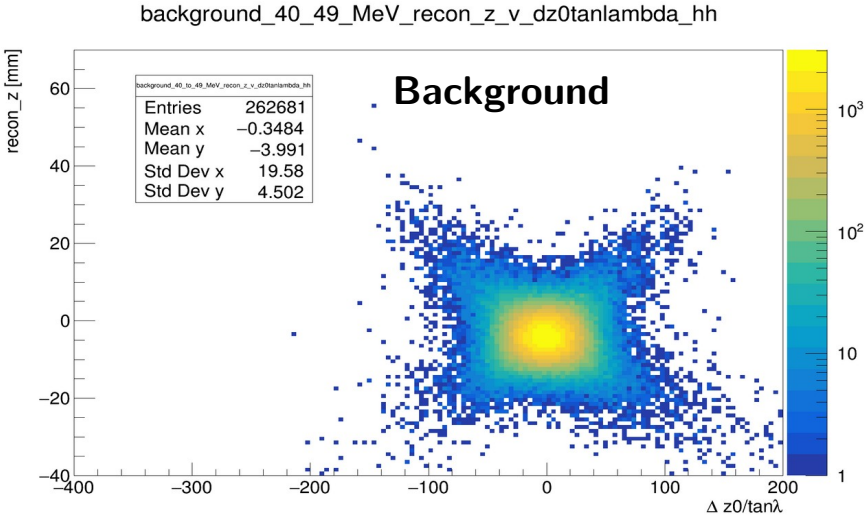


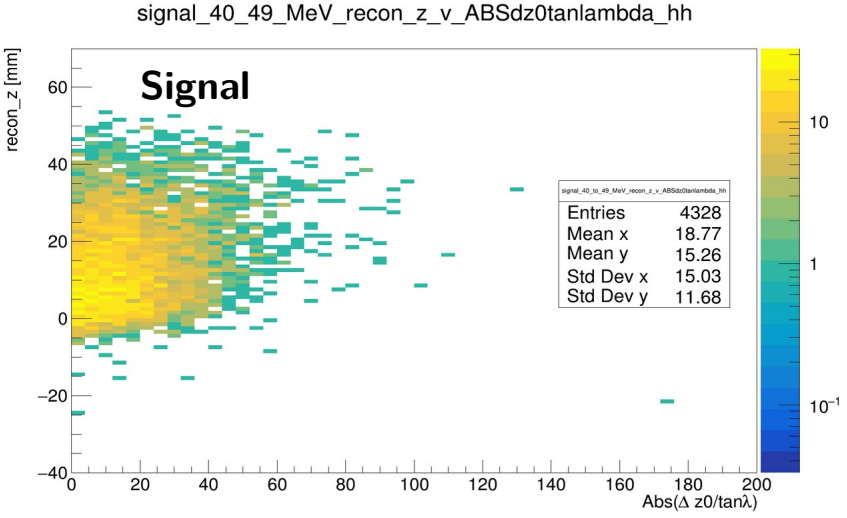
Delta z0/tan(ƛ)

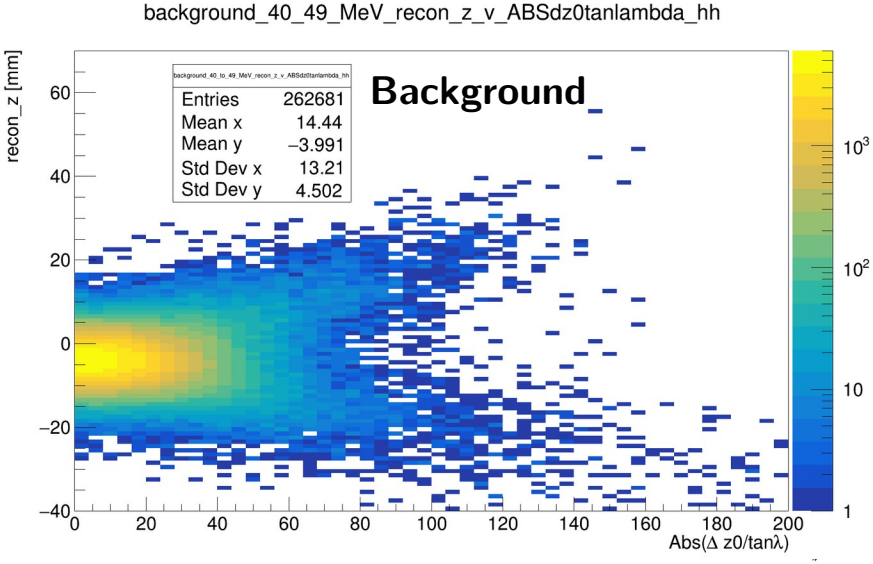
*pos - ele

Pos-Ele z0/tan(λ)

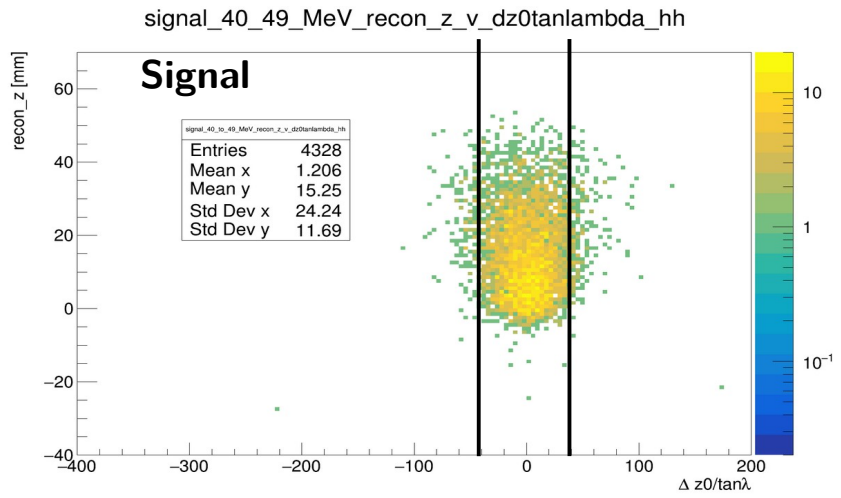


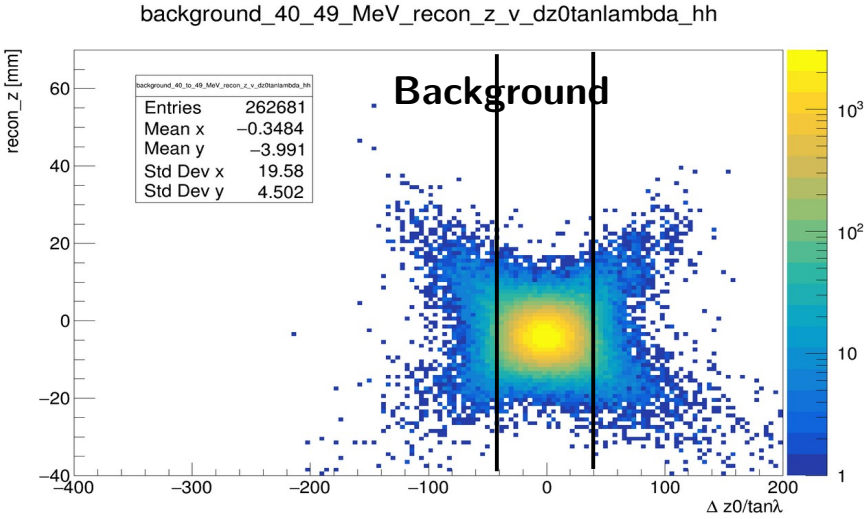


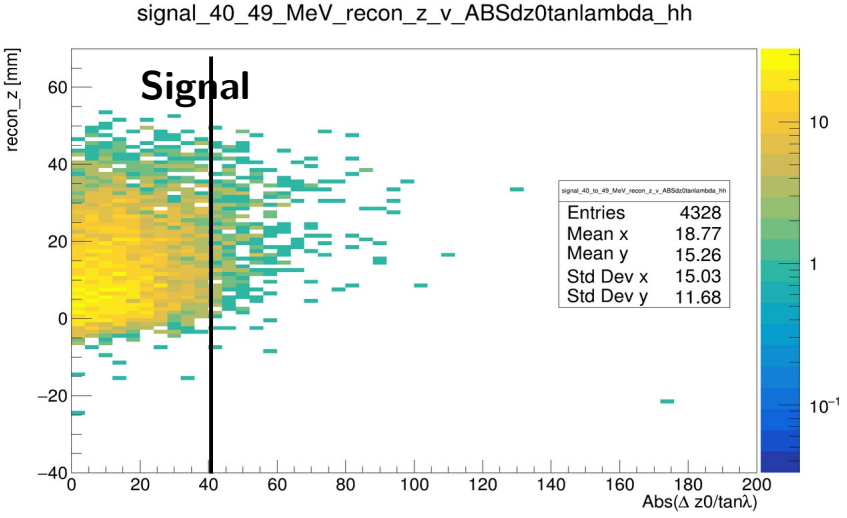


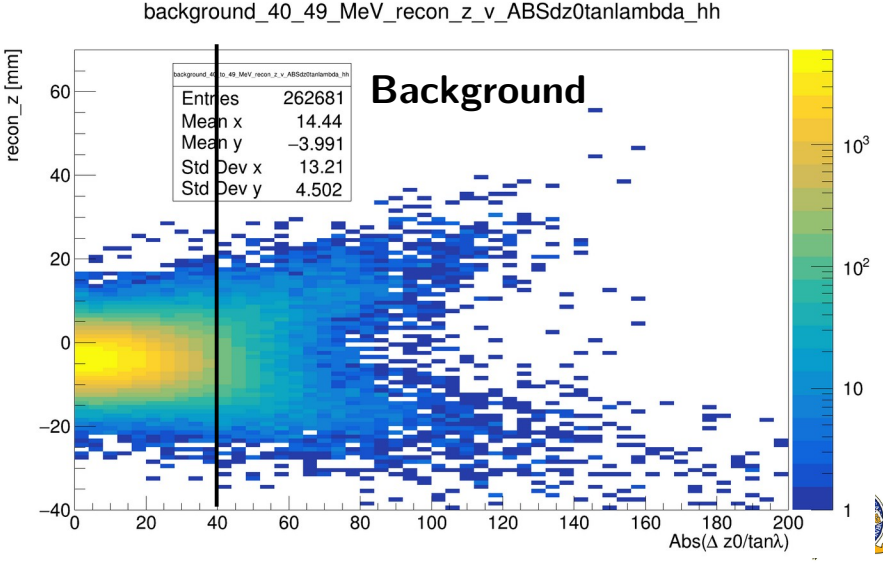


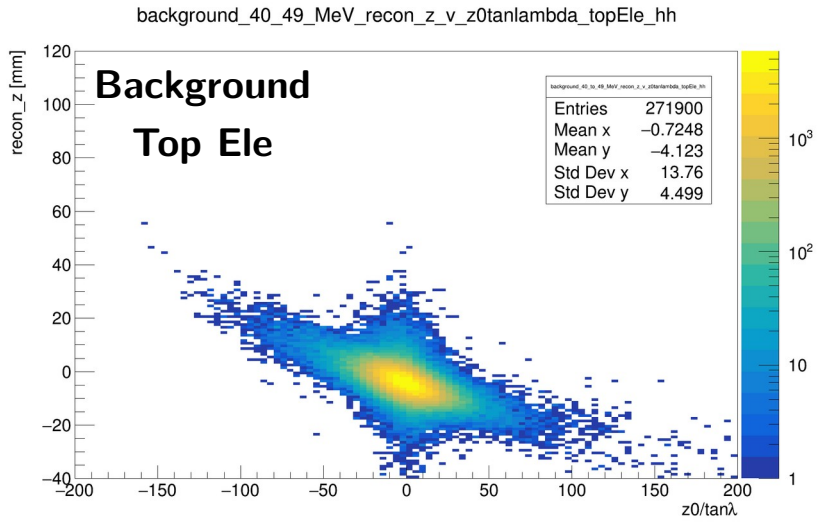
Pos-Ele z0/tan(λ)

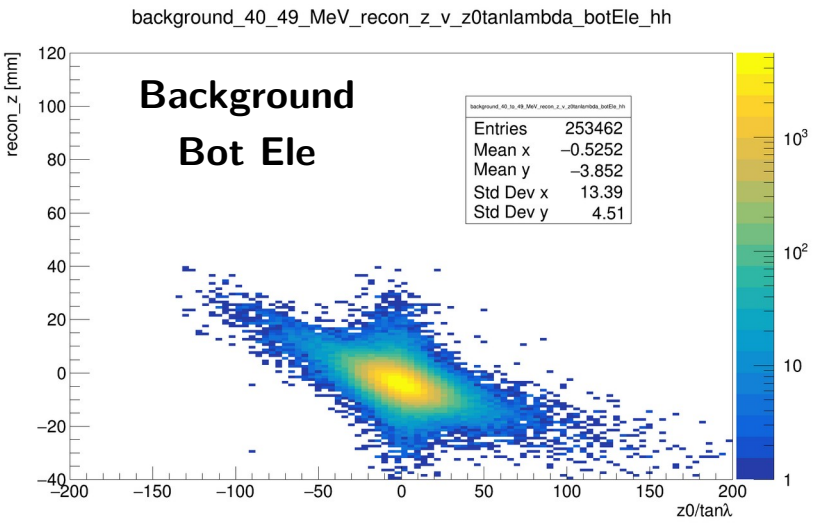


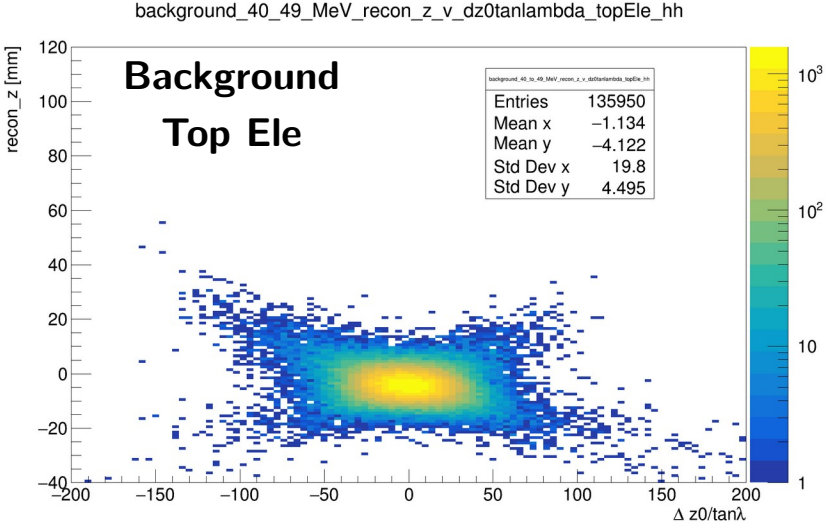


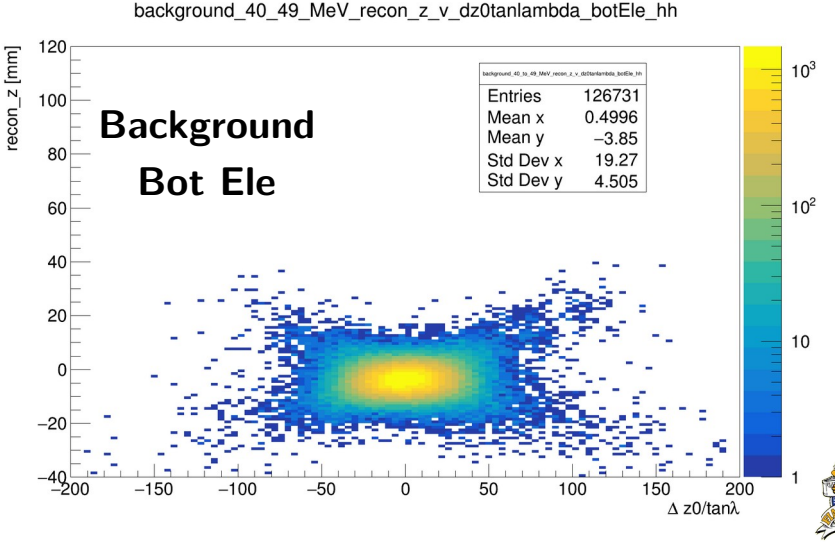





background_40_49_MeV_recon_z_v_z0tanlambda_topEle_hh
Background
Top Ele
Entries 271900
Mean x −0.7248
Mean y −4.123
Std Dev x 13.76
Std Dev y 4.499
recon_z [mm]
z0/tanλ


background_40_49_MeV_recon_z_v_z0tanlambda_botEle_hh
Background
Bot Ele
Entries 253462
Mean x −0.5252
Mean y −3.852
Std Dev x 13.39
Std Dev y 4.51
recon_z [mm]
z0/tanλ


background_40_49_MeV_recon_z_v_dz0tanlambda_topEle_hh
Background
Top Ele
Entries 135950
Mean x −1.134
Mean y −4.122
Std Dev x 19.8
Std Dev y 4.495
recon_z [mm]
Δ z0/tanλ


background_40_49_MeV_recon_z_v_dz0tanlambda_botEle_hh
Background
Bot Ele
Entries 126731
Mean x 0.4996
Mean y −3.85
Std Dev x 19.27
Std Dev y 4.505
recon_z [mm]
Δ z0/tanλ

Summary and Conclusions

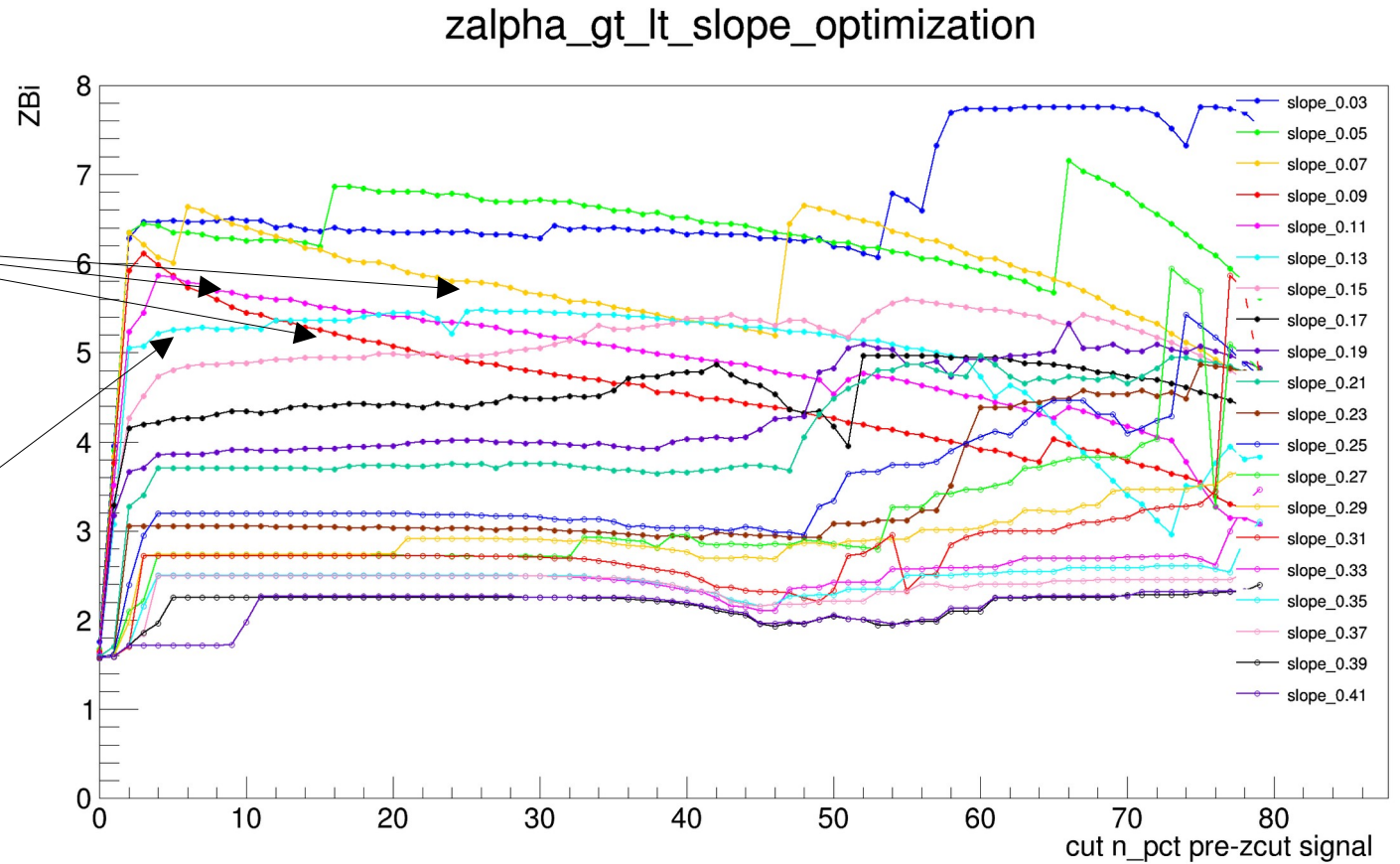
- True displaced vertex z0/tan(lambda) vs recon_z expected to be linearly correlated
  - Why is the slope found to be 0.5, instead of 1.0? Bug in vertexing code??
- Variable appears to be good handle on mis-reconstructed background (bad L1/L2 hits)
  - Expect large scatters and mis-selected hit events as combination of vertical spike in z0/tanlambda (~0) vs recon_z, and left-wing with slope ~1/2 of true displaced vertices
  - Bad hits claim validated using MC truth info
- Variable shows obvious power in removing high-z background while maintaining high signal efficiency
  - Showed at workshop that this variable results in much larger signal significance than using Isolation Cut (though Iso cut will be re-investigated for *very high-z events)
  - Showed similar performance to Impact Parameter Cut...
    - Impact parameter cut requires tedious slope optimization
- **Delta z0/tanlambda avoids slope optimization, looks like a great variable to use, and it's SIMPLE!**
- Will run performance test of this variable on 10% data sample asap!

Backup/Junk

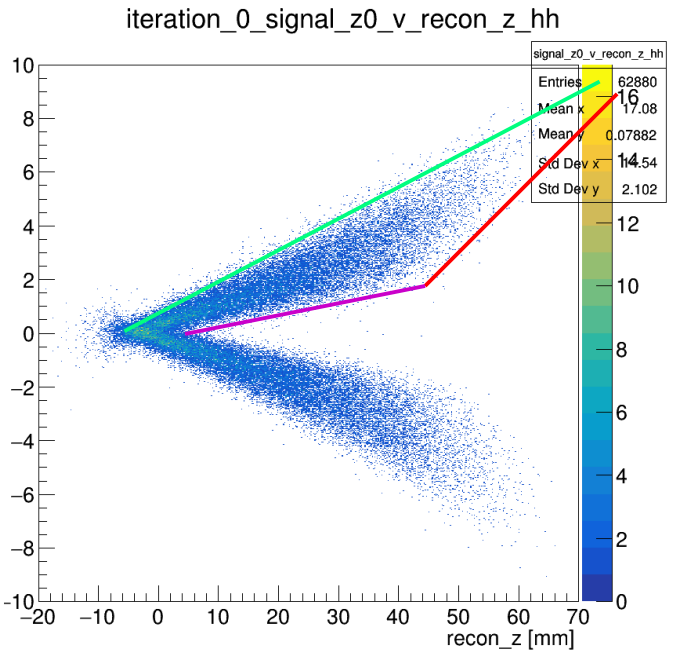
Zalpha Slope Optimization Funniness

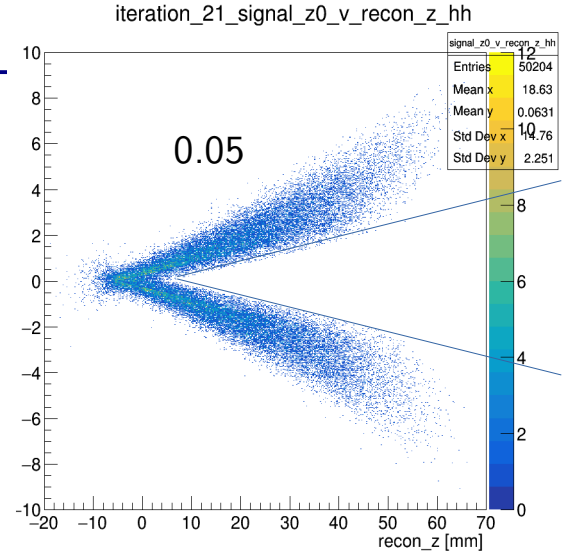
Slopes 0.07, 0.09, 0.11 ZBi all decreasing

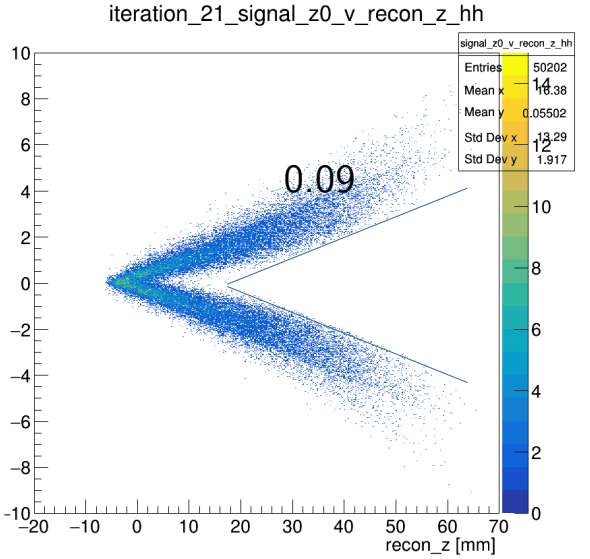
Slope 0.13 ZBi flattens back out

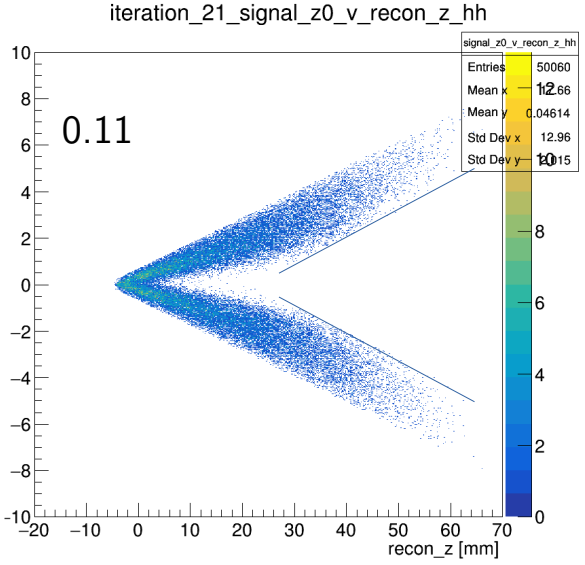


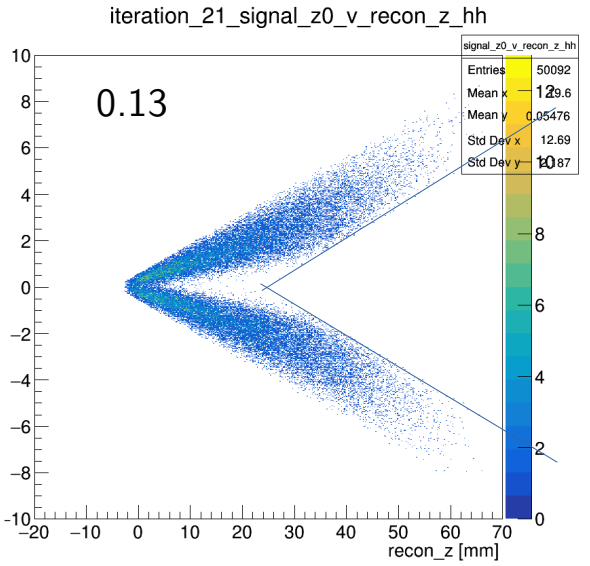
3 different Impact Parameter cuts to optimize



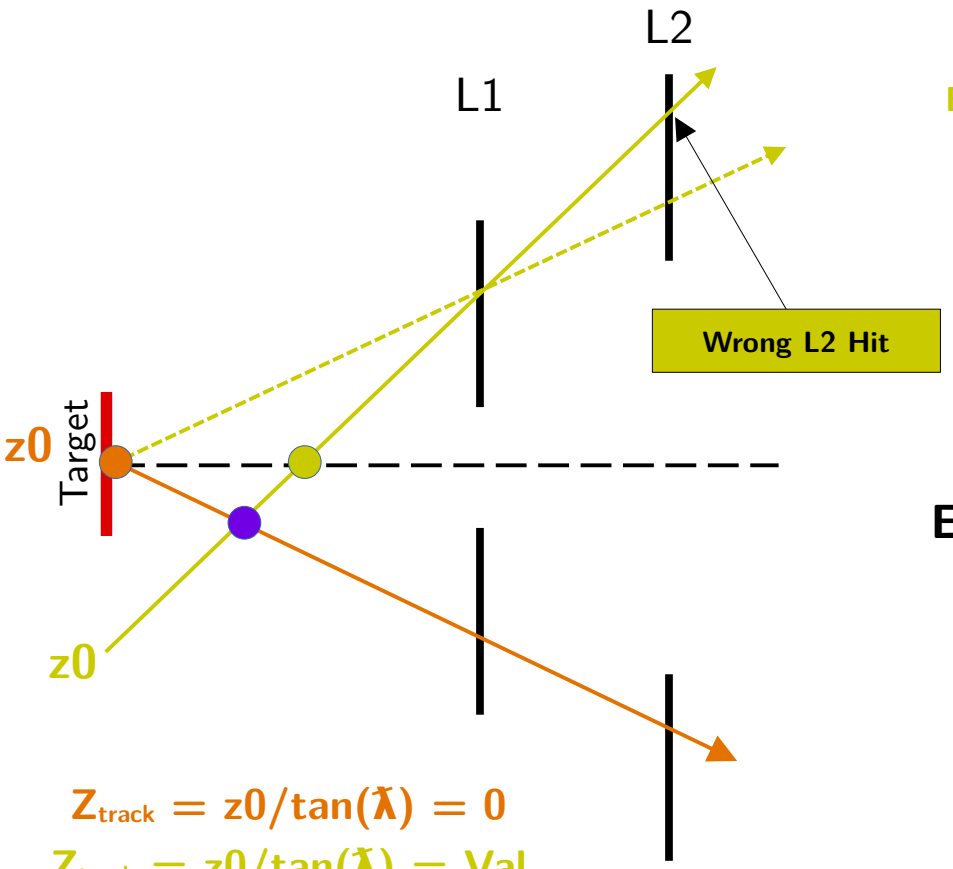








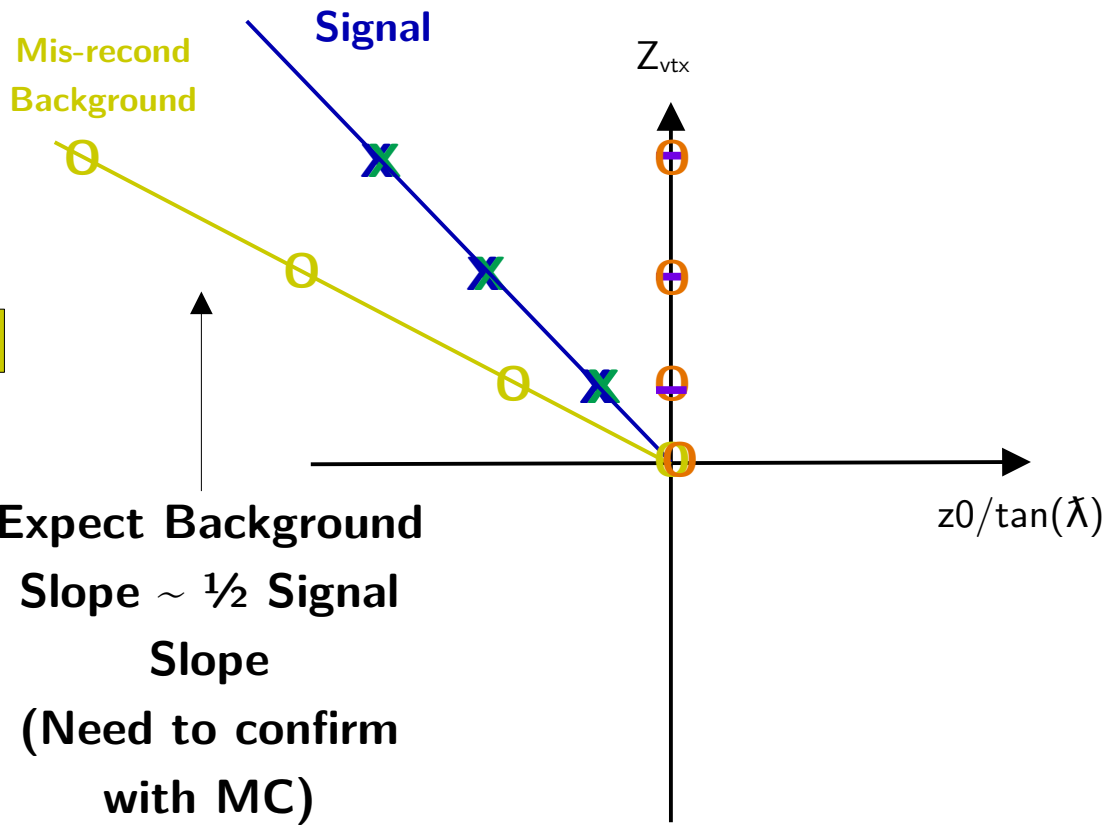
Background – z0/tanλ – Bad L2 Hit



$Z_{track} = z0/\tan(\lambda) = 0$

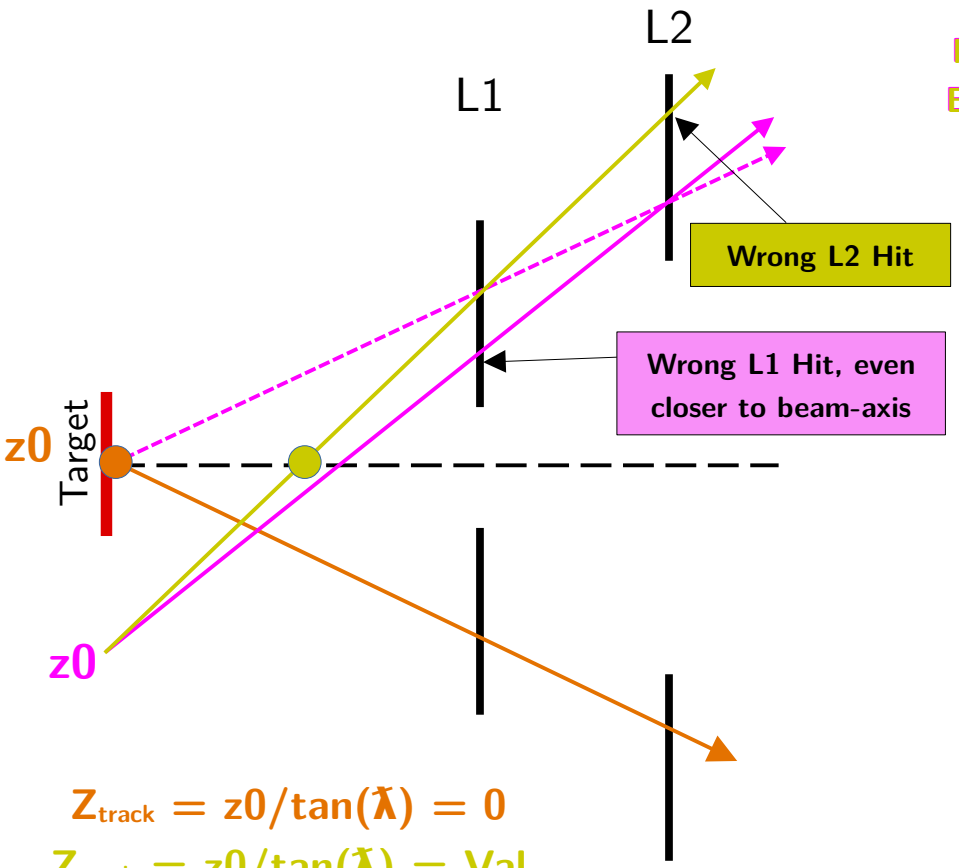
$Z_{track} = z0/\tan(\lambda) = Val$

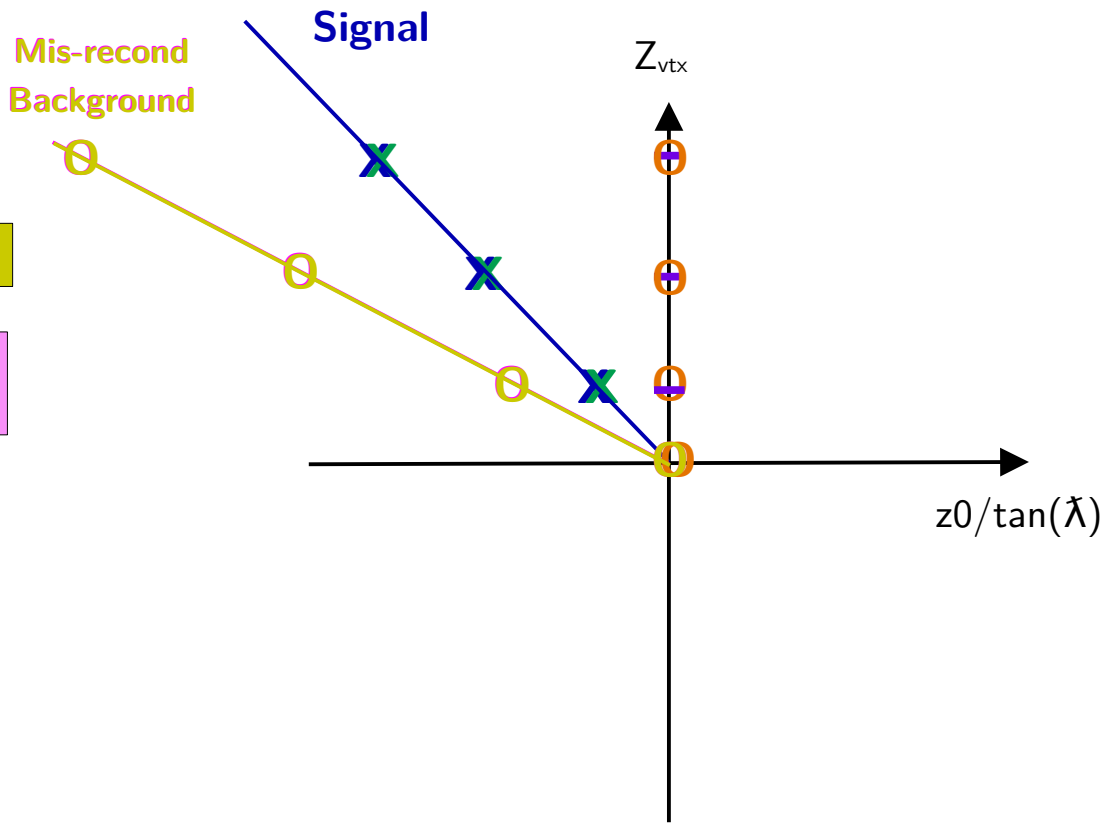
$Z_{vtx} \sim Avg(Z_{track}+Z_{track}) = Val/2$



Expect Background Slope ~ ½ Signal Slope (Need to confirm with MC)

Background – z0/tanƛ – Bad L2 Hit



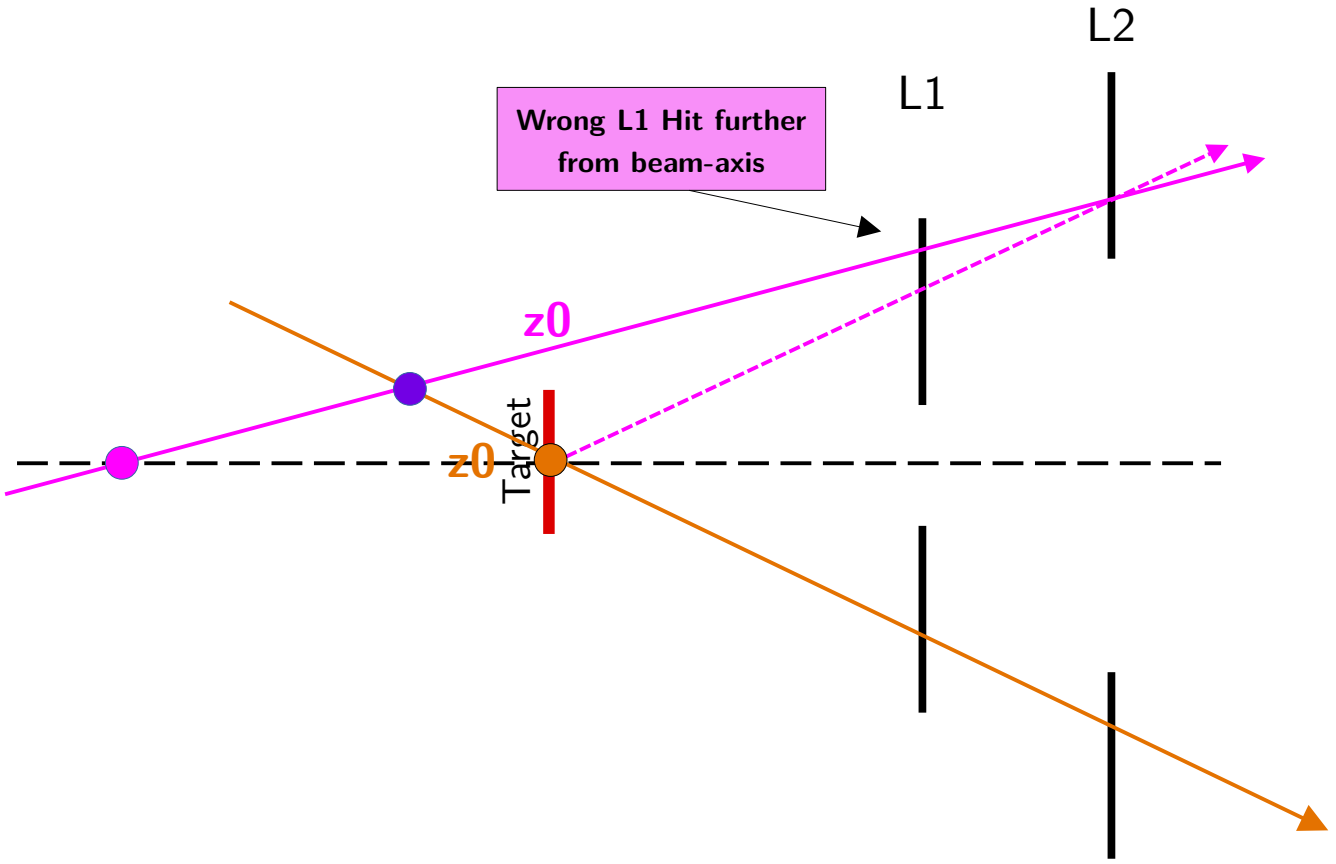


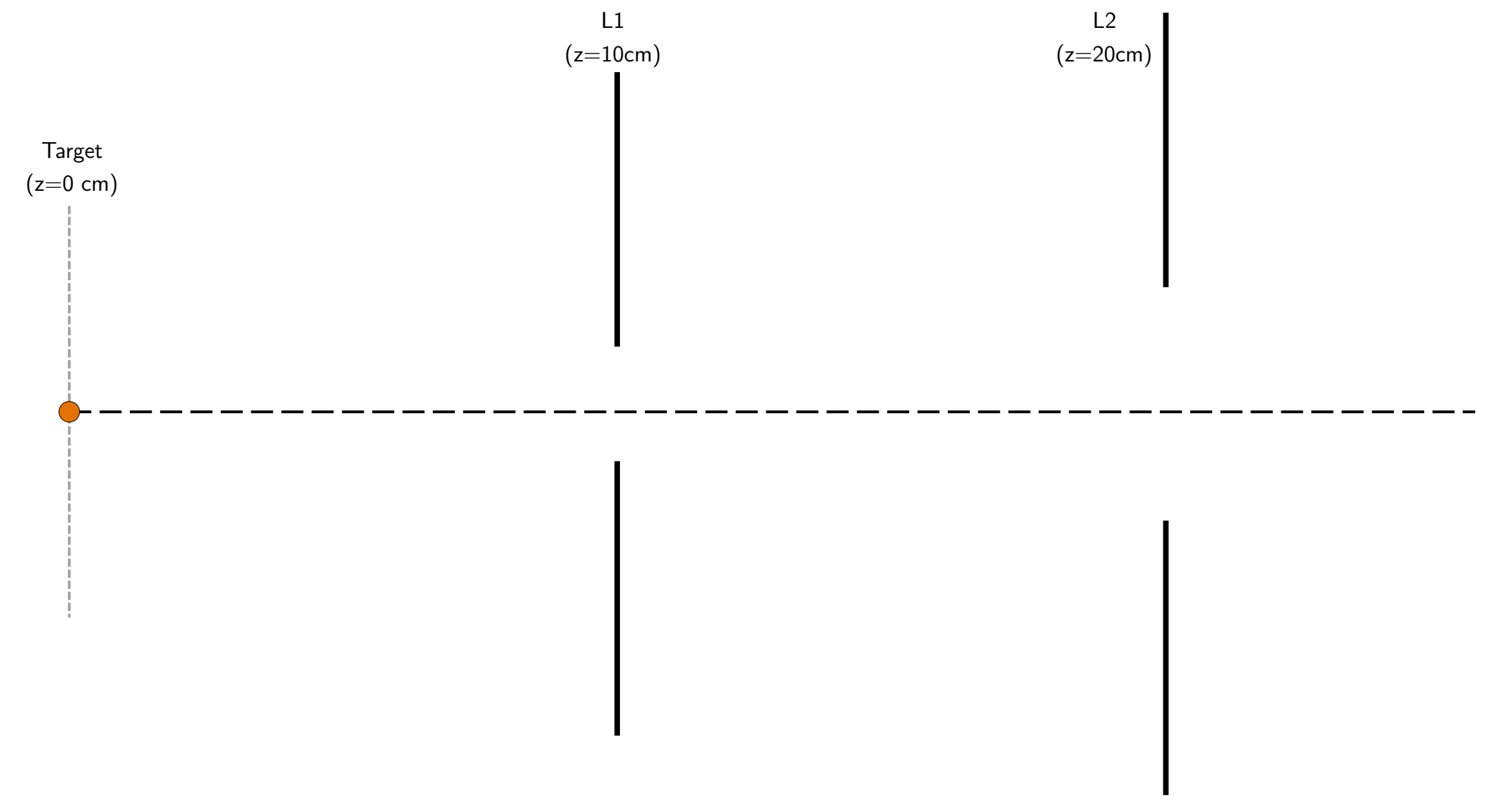
$Z_{track} = z0/\tan(ƛ) = 0$

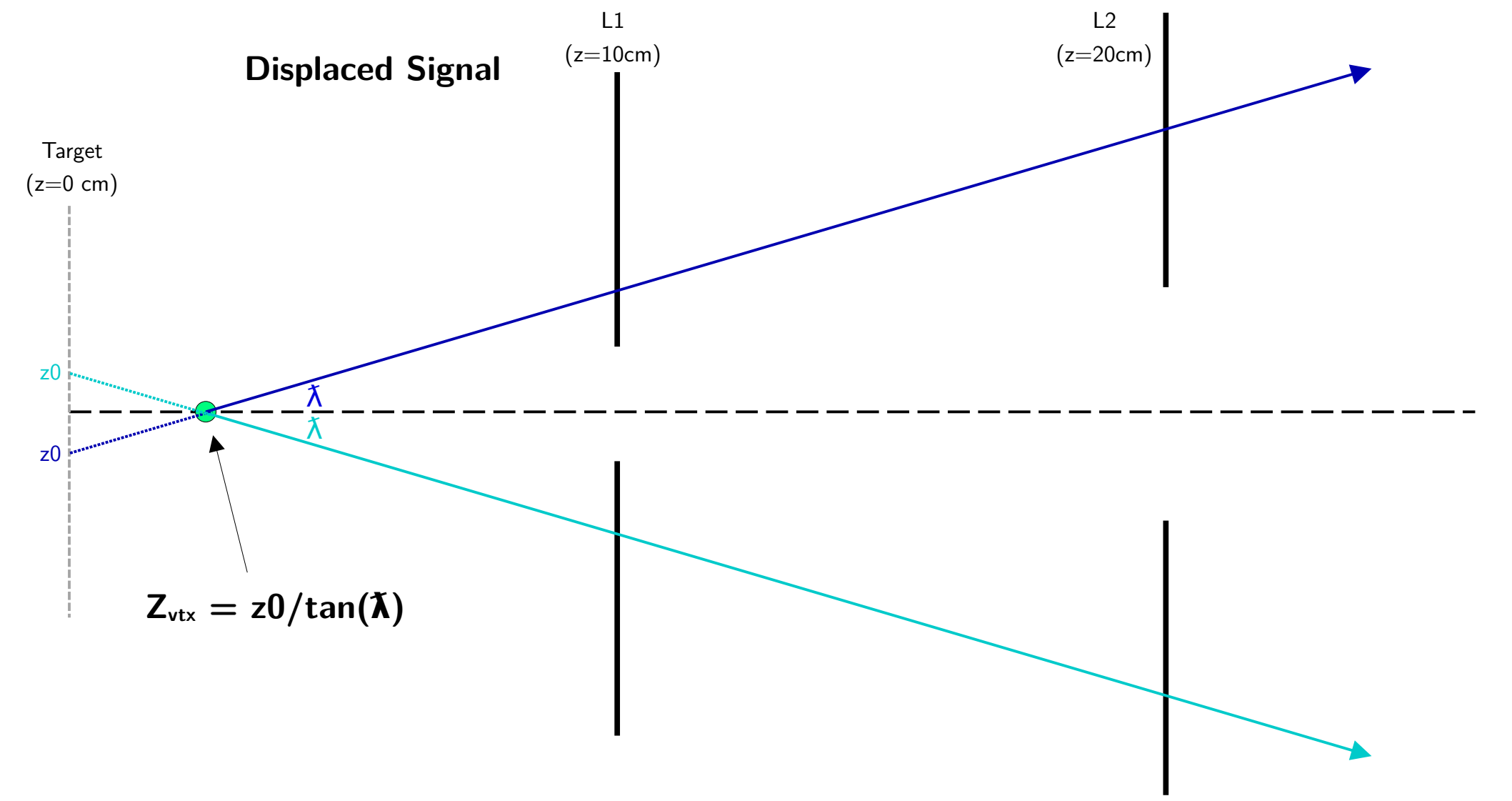
$Z_{track} = z0/\tan(ƛ) = Val$

$Z_{vtx} \sim Avg(Z_{track}+Z_{track}) = Val/2$

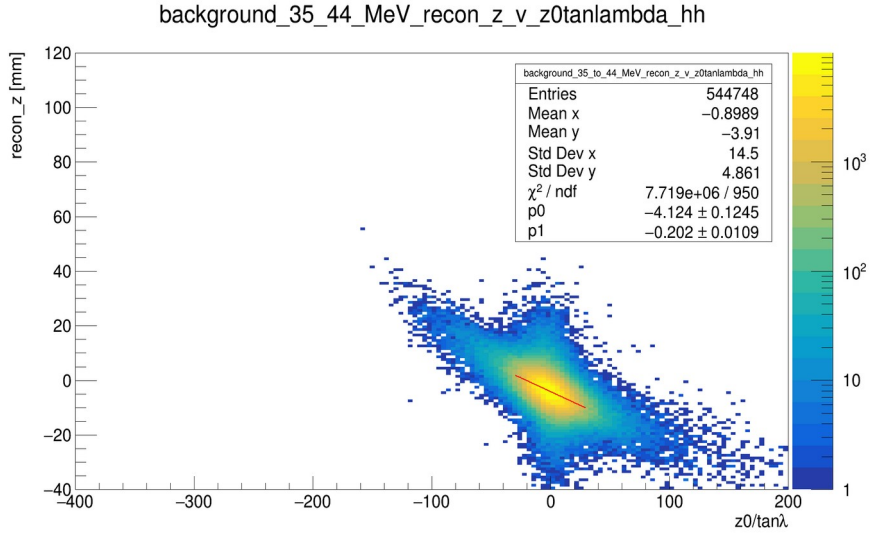
Background – Bad L1 Hit – z0/tanλ

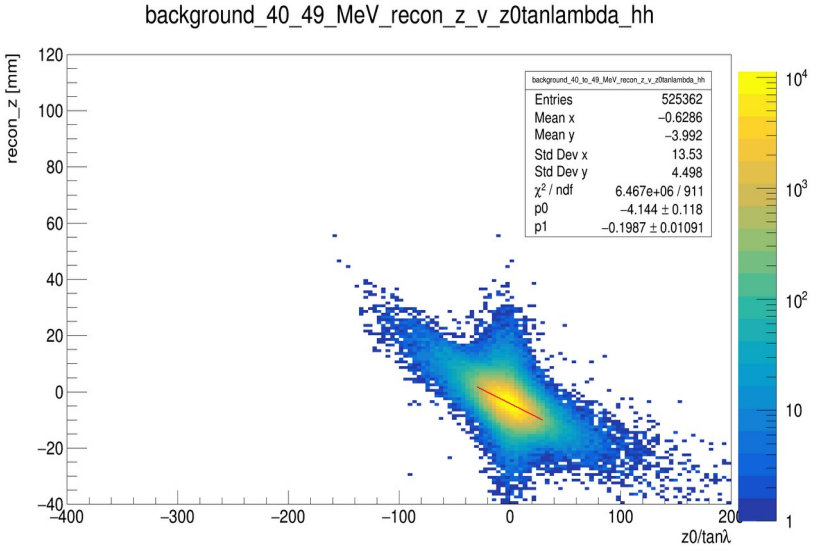


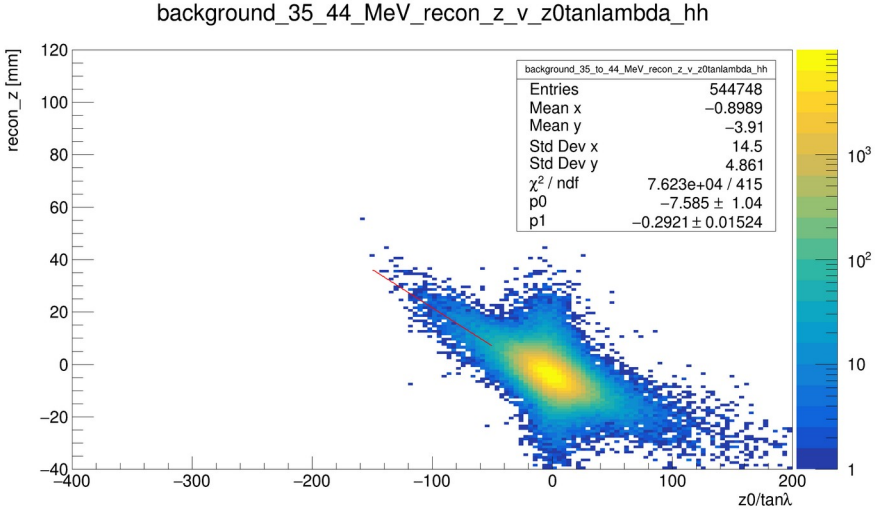

L1
(z=10cm)
L2
(z=20cm)
Target
(z=0 cm)

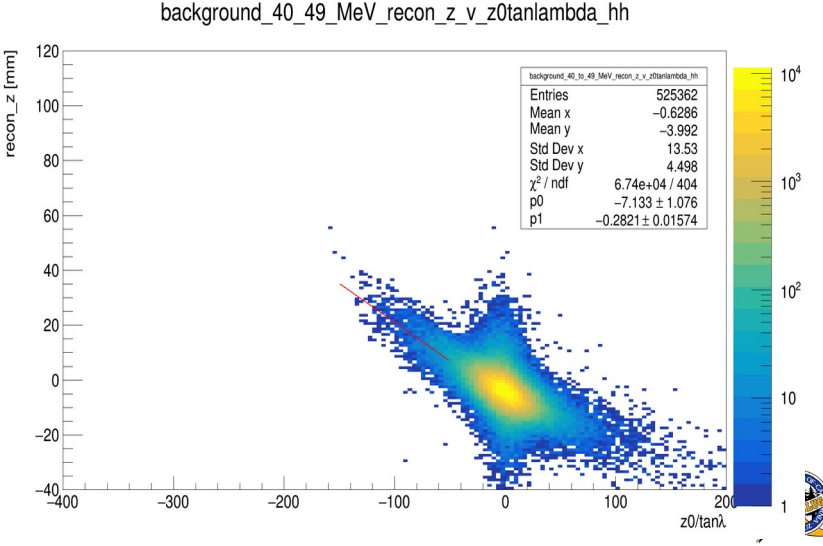

Displaced Signal
L1
(z=10cm)
L2
(z=20cm)
Target
(z=0 cm)
z0
z0
λ
λ
$Z_{vtx} = z0/\tan(\lambda)$

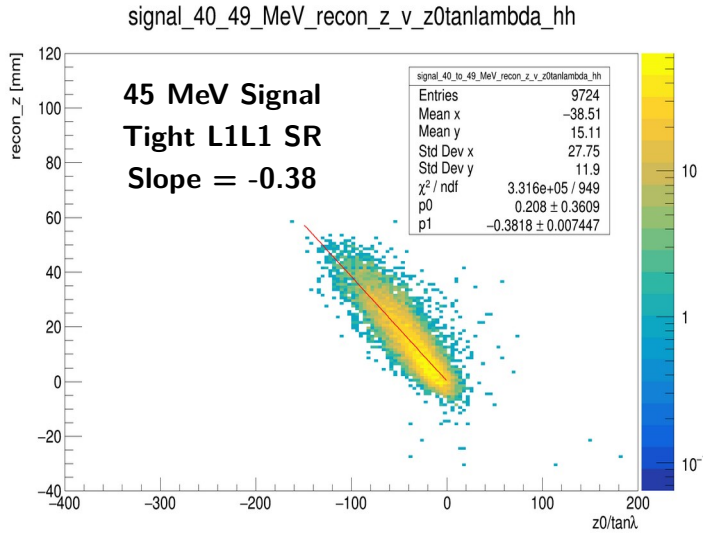
Tritrig+Beam MC Truth

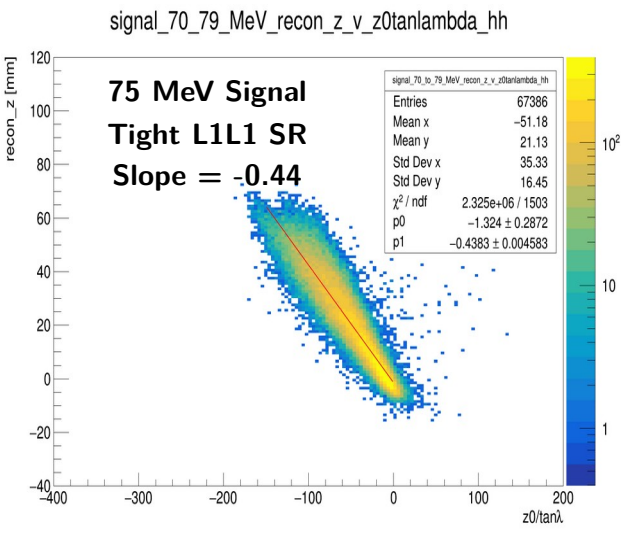


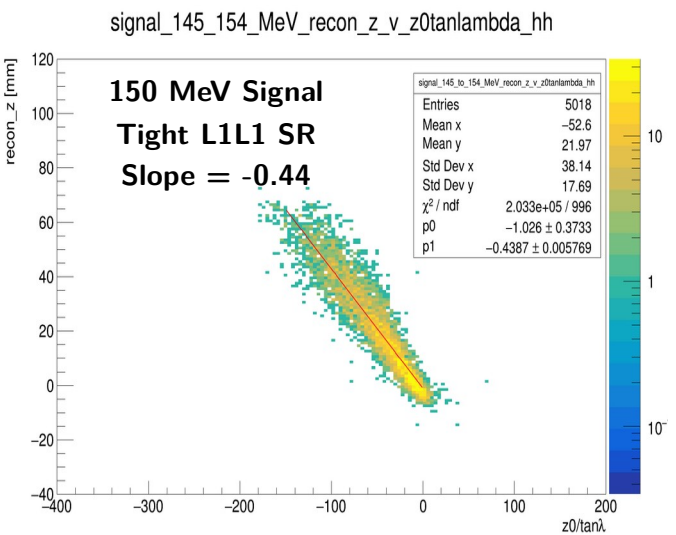


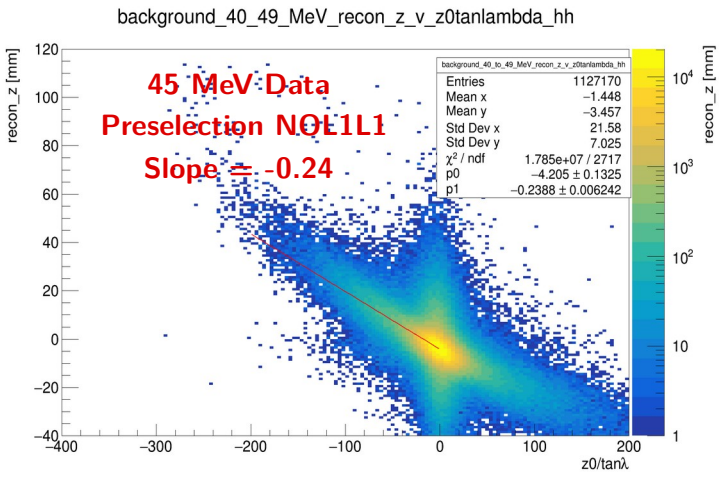


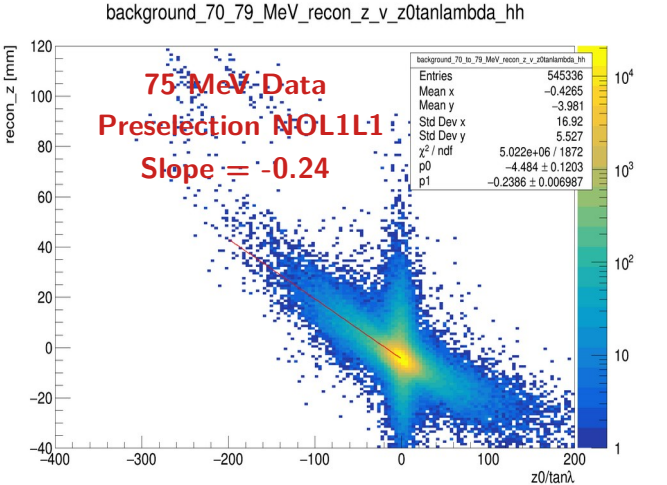


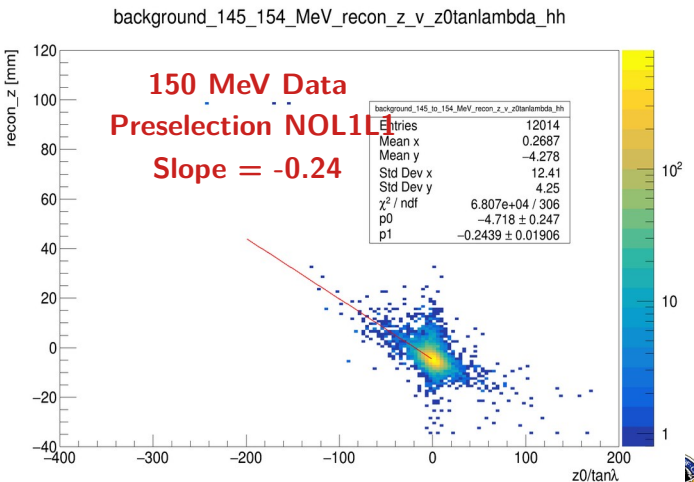

signal_40_49_MeV_recon_z_v_z0tanlambda_hh
45 MeV Signal
Tight L1L1 SR
Slope = -0.38
Entries 9724
Mean x −38.51
Mean y 15.11
Std Dev x 27.75
Std Dev y 11.9
χ² / ndf 3.316e+05 / 949
p0 0.208 ± 0.3609
p1 −0.3818 ± 0.007447
recon_z [mm]
z0/tanλ


signal_70_79_MeV_recon_z_v_z0tanlambda_hh
75 MeV Signal
Tight L1L1 SR
Slope = -0.44
Entries 67386
Mean x −51.18
Mean y 21.13
Std Dev x 35.33
Std Dev y 16.45
χ² / ndf 2.325e+06 / 1503
p0 −1.324 ± 0.2872
p1 −0.4383 ± 0.004583
recon_z [mm]
z0/tanλ


signal_145_154_MeV_recon_z_v_z0tanlambda_hh
150 MeV Signal
Tight L1L1 SR
Slope = -0.44
Entries 5018
Mean x −52.6
Mean y 21.97
Std Dev x 38.14
Std Dev y 17.69
χ² / ndf 2.033e+05 / 996
p0 −1.026 ± 0.3733
p1 −0.4387 ± 0.005769
recon_z [mm]
z0/tanλ


background_40_49_MeV_recon_z_v_z0tanlambda_hh
45 MeV Data
Preselection NOL1L1
Slope = -0.24
Entries 1127170
Mean x −1.448
Mean y −3.457
Std Dev x 21.58
Std Dev y 7.025
χ² / ndf 1.785e+07 / 2717
p0 −4.205 ± 0.1325
p1 −0.2388 ± 0.006242
recon_z [mm]
z0/tanλ


background_70_79_MeV_recon_z_v_z0tanlambda_hh
75 MeV Data
Preselection NOL1L1
Slope = -0.24
Entries 545336
Mean x −0.4265
Mean y −3.981
Std Dev x 16.92
Std Dev y 5.527
χ² / ndf 5.022e+06 / 1872
p0 −4.484 ± 0.1203
p1 −0.2386 ± 0.006987
recon_z [mm]
z0/tanλ


background_145_154_MeV_recon_z_v_z0tanlambda_hh
150 MeV Data
Preselection NOL1L1
Slope = -0.24
Entries 12014
Mean x 0.2687
Mean y −4.278
Std Dev x 12.41
Std Dev y 4.25
χ² / ndf 6.807e+04 / 306
p0 −4.718 ± 0.247
p1 −0.2439 ± 0.01906
recon_z [mm]
z0/tanλ