Impact Parameter Style Cut – ‘Zalpha’

Abandoning the Zcut?

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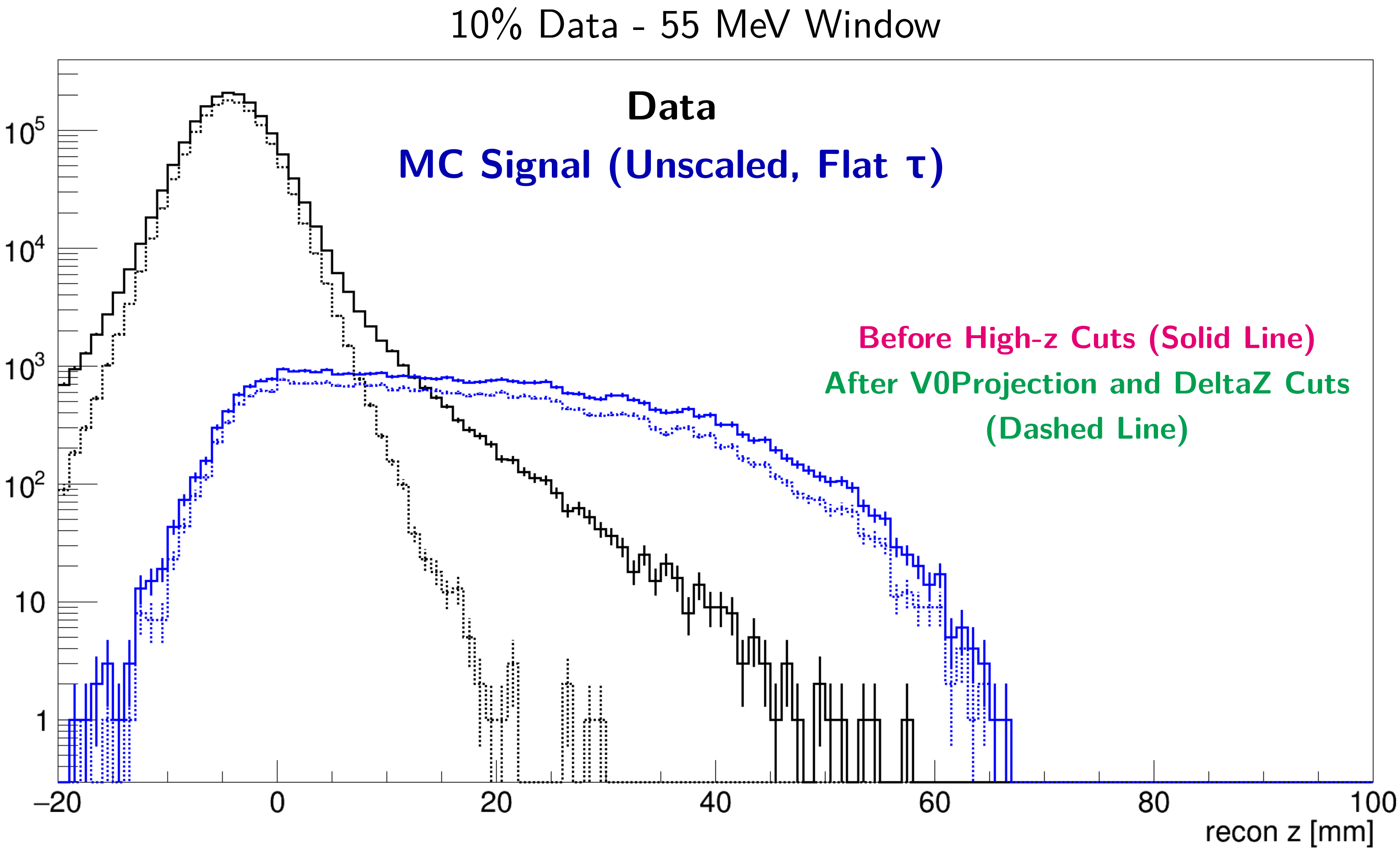
Introduction

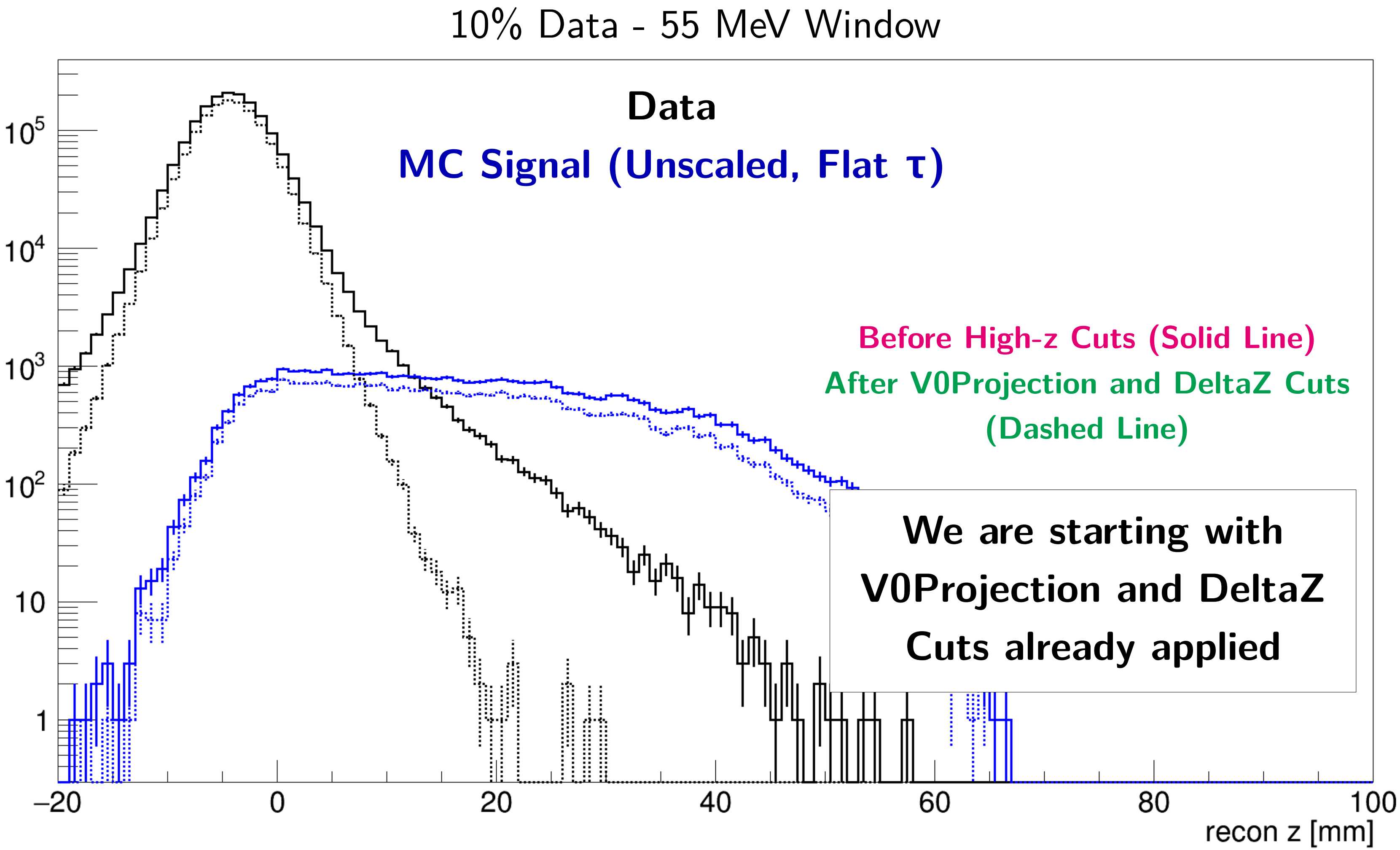
- Trying to get ready to run SIMP analysis on 100% of 2016 data **quickly**
  - (Cam's prepping sw and data for green light)
- **Working on finalizing high-z cuts**
- **Bkg z-tails largely reduced by V0ProjSig and DeltaZ cuts** (Shown previously using 10% Data)
- **Last high-z cut** (in my mind) **is Impact Parameter style cut 'Zalpha'**
- In last collaboration meeting, showed **Zalpha cut eliminated all bkg** (for single mass in 10% Data)
- Here I follow up on looking at all masses, scan Zalpha as f(slope, vertex, mass)
- Run a Reach Estimate
- Turns out **flat cut on track z0 (parameterized by mass) works just as well**...(sorry Matt G)
- **End up with 38 background events (in all of 10% Data), and peak expected signal of ~75**

Example: 55 MeV Mass Window

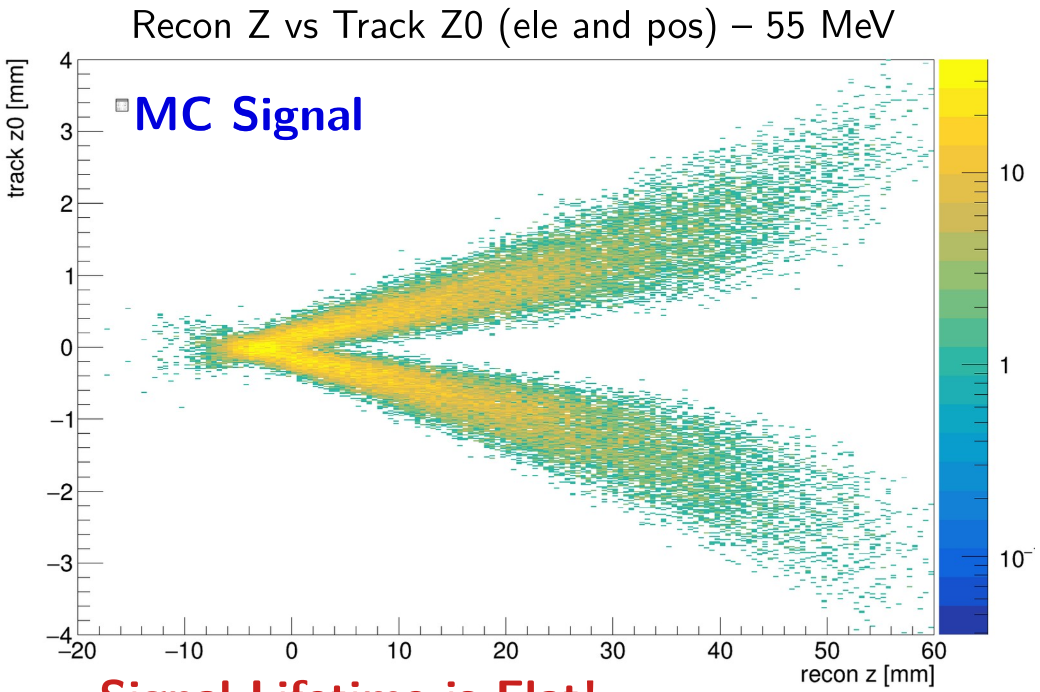
55 MeV Example – Recon Z

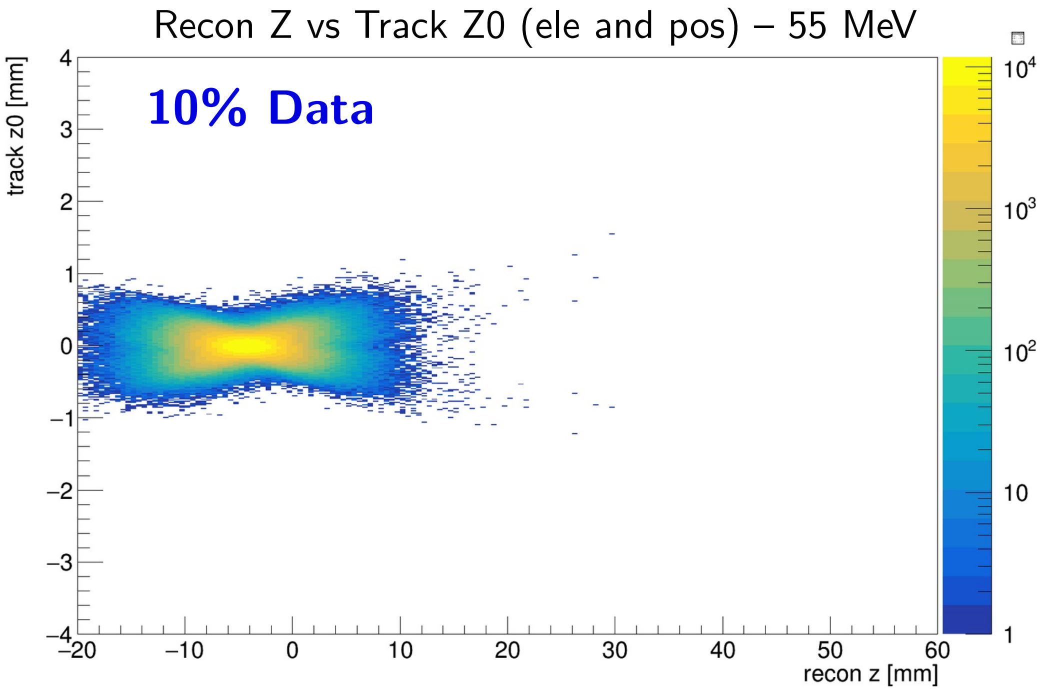


55 MeV Example – Recon Z



55 MeV Example – Impact Parameter vs Recon Z

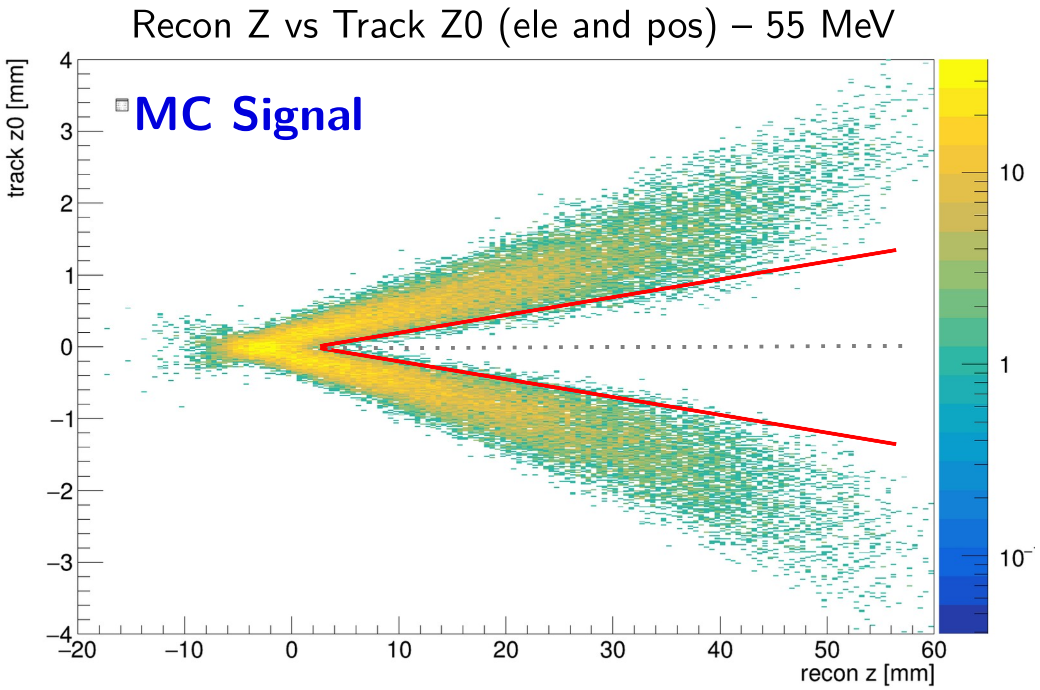


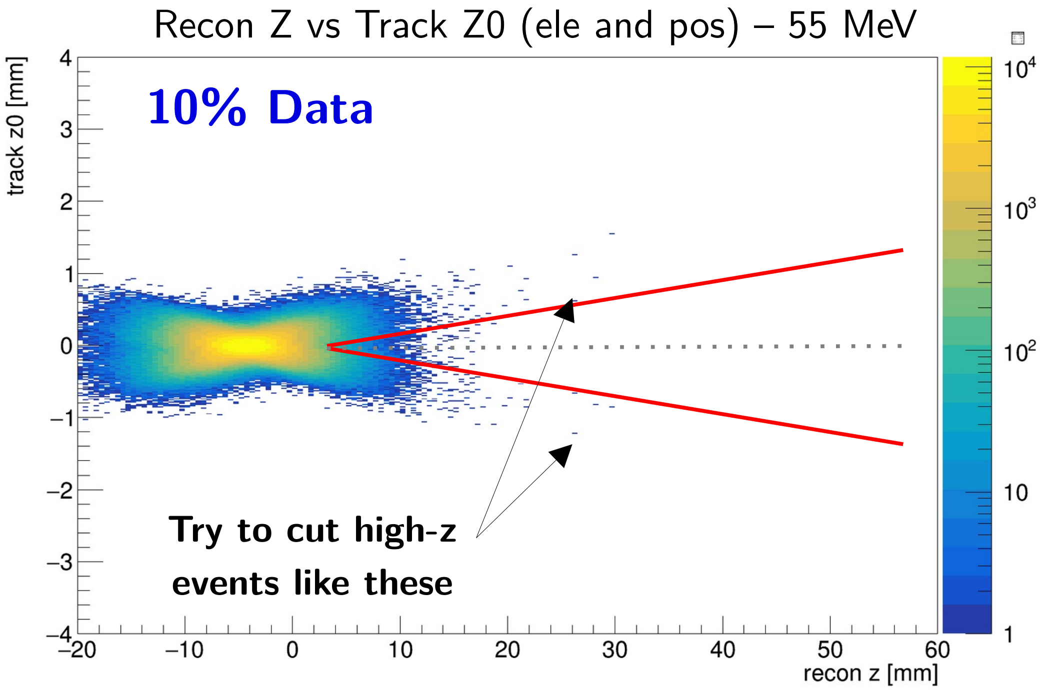


Signal Lifetime is Flat!

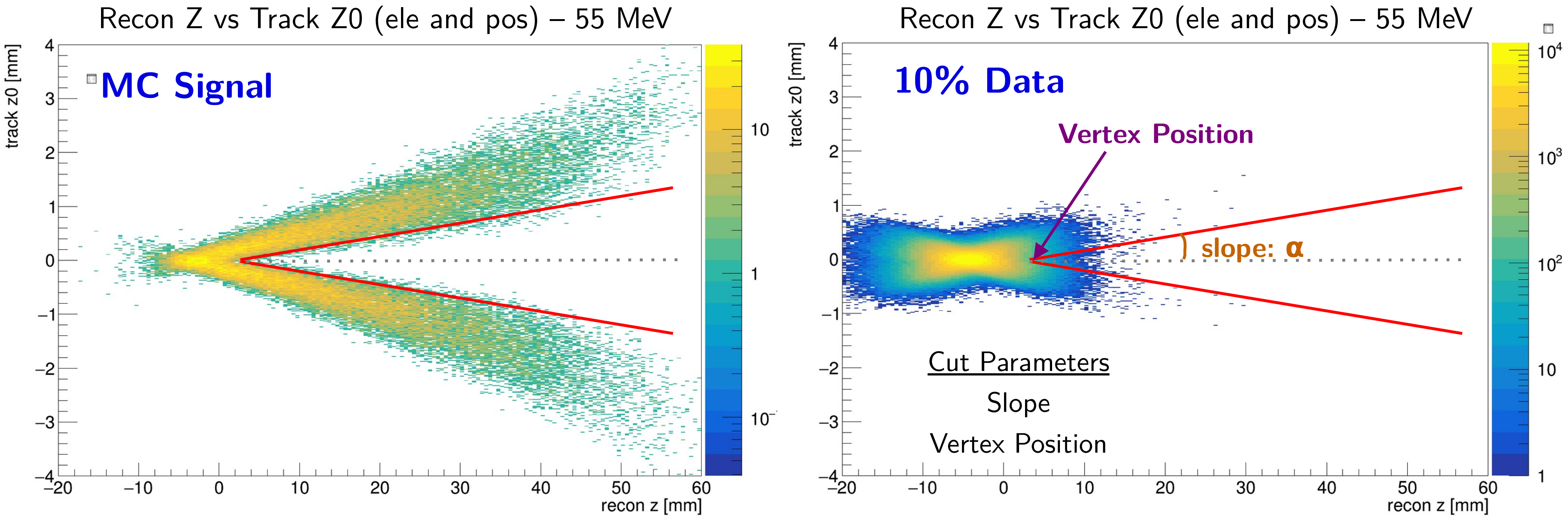
Re-weighted by exponential decay when calculating Expected Signal

55 MeV Example – Impact Parameter vs Recon Z

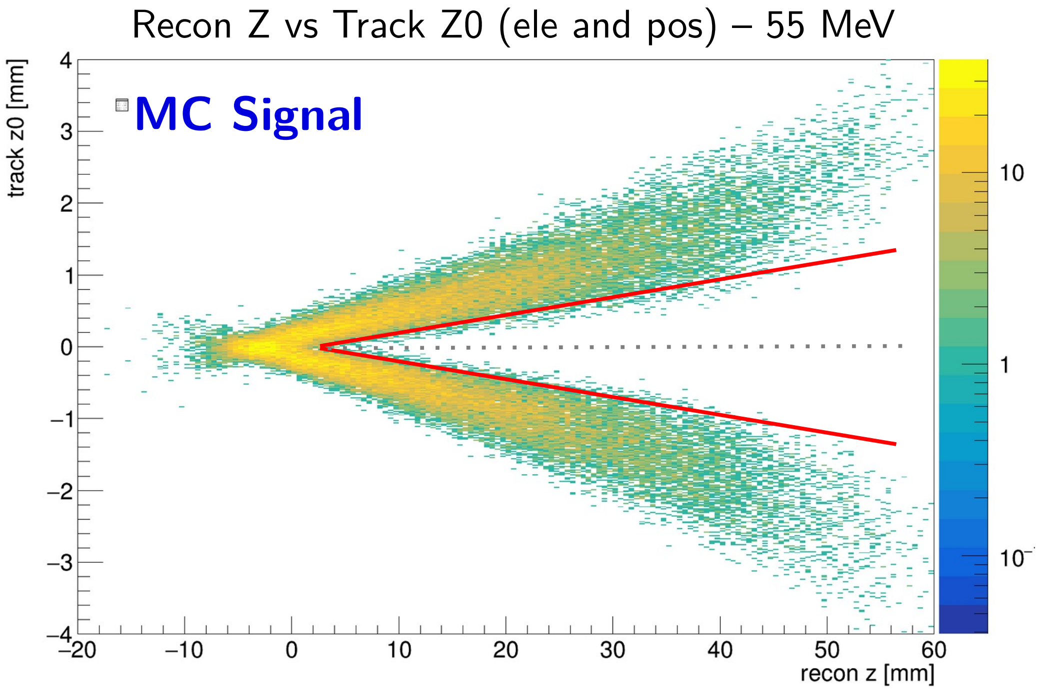


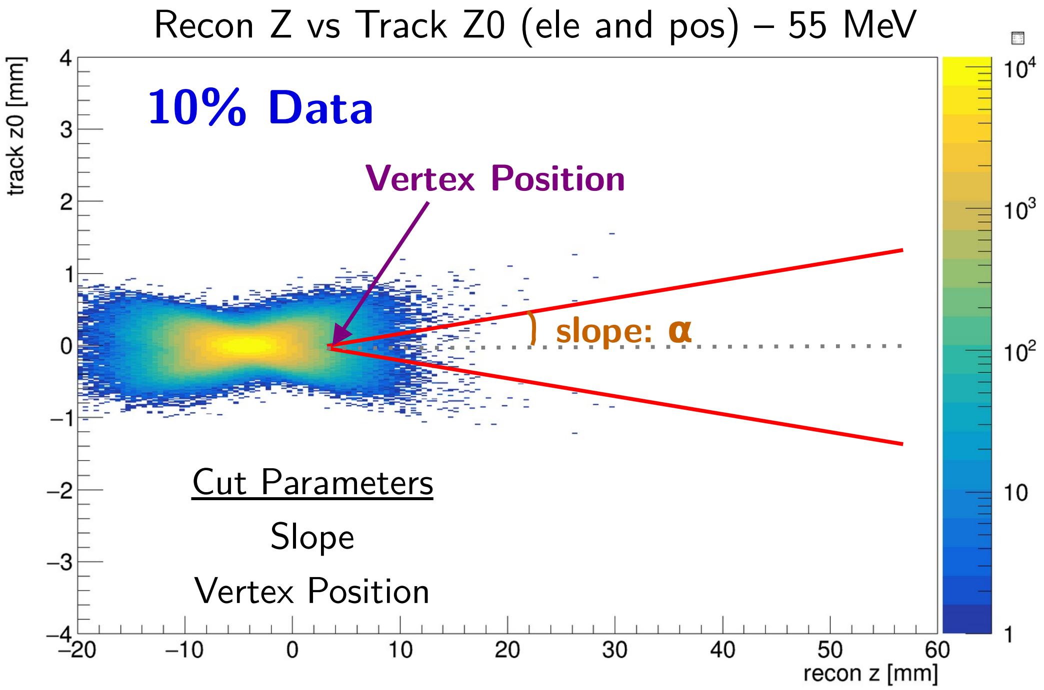


55 MeV Example – Impact Parameter vs Recon Z



55 MeV Example – Impact Parameter vs Recon Z



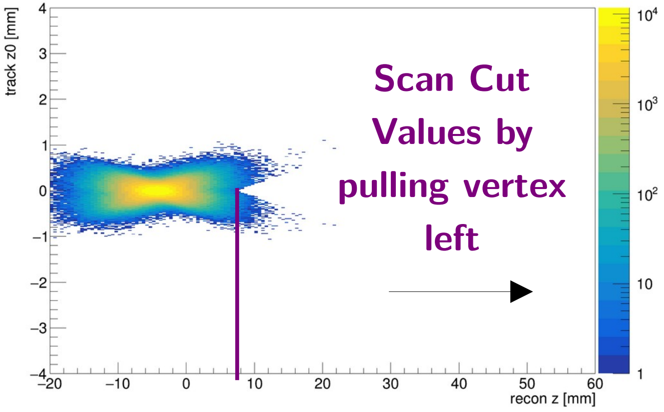


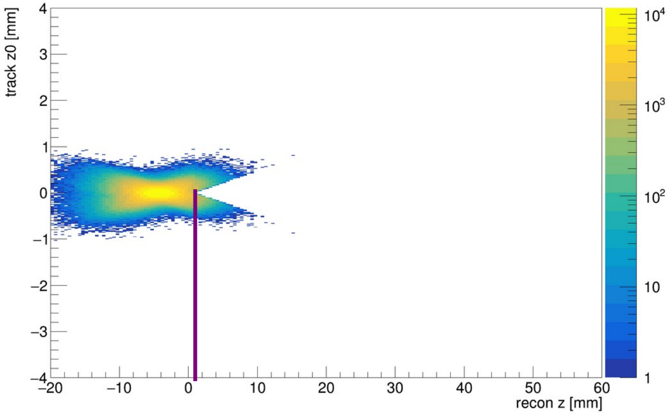
In a given mass window, what Slope and Vertex Position maximizes sensitivity (Zbi)?

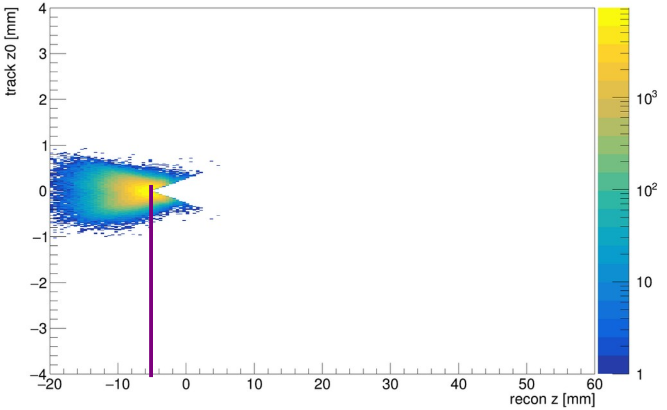
55 MeV Example – Large Zalpha Slope

Large Slope (α = 0.05)

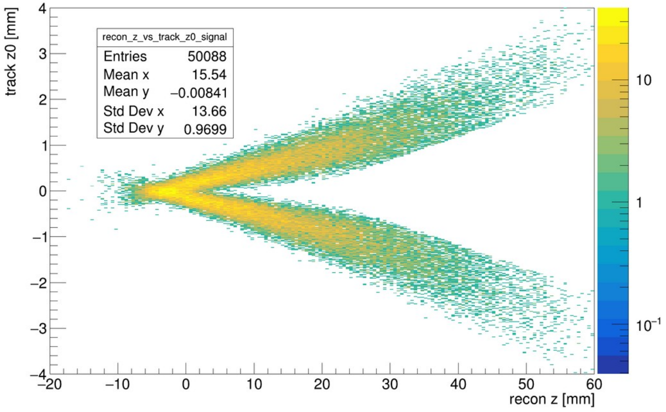
10% Data – 55 MeV

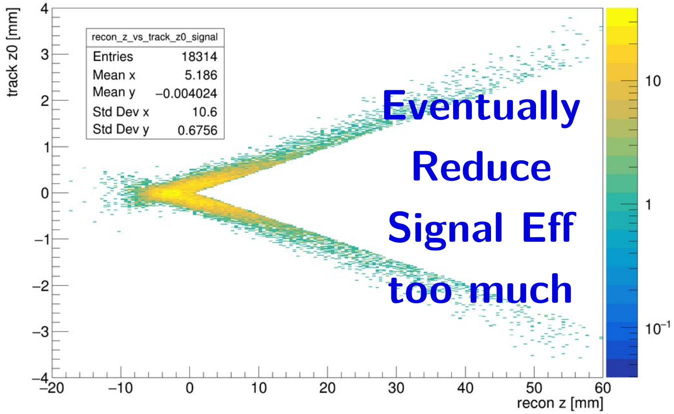


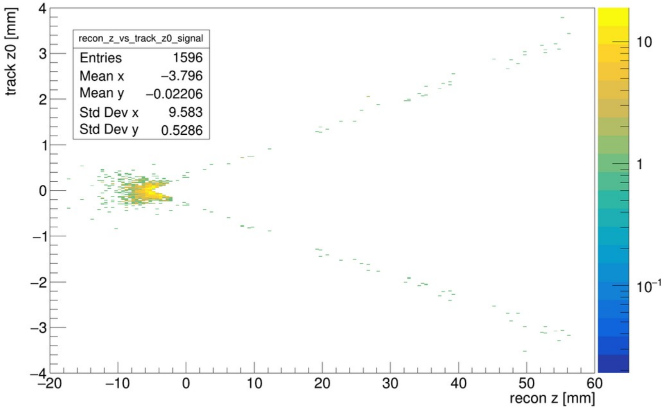




MC Signal – 55 MeV



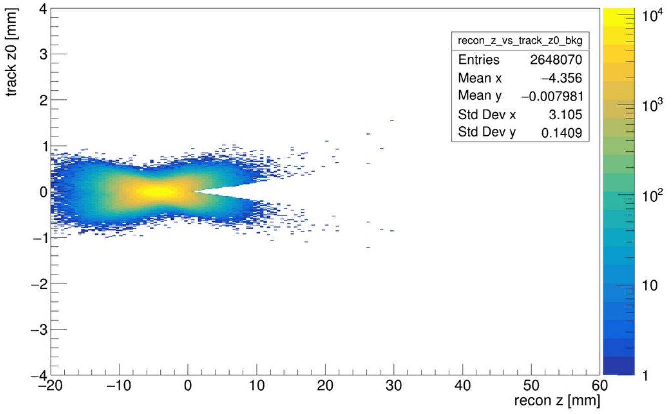


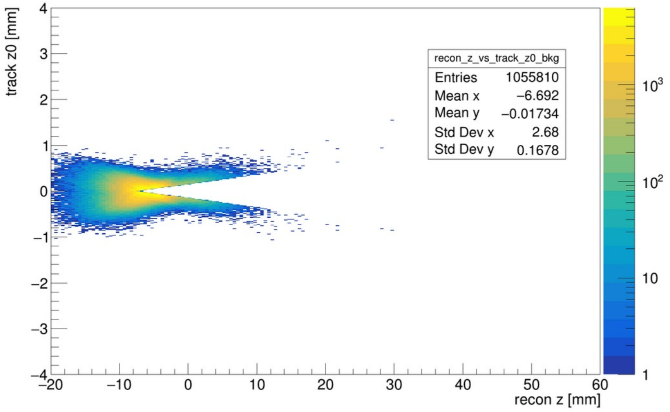


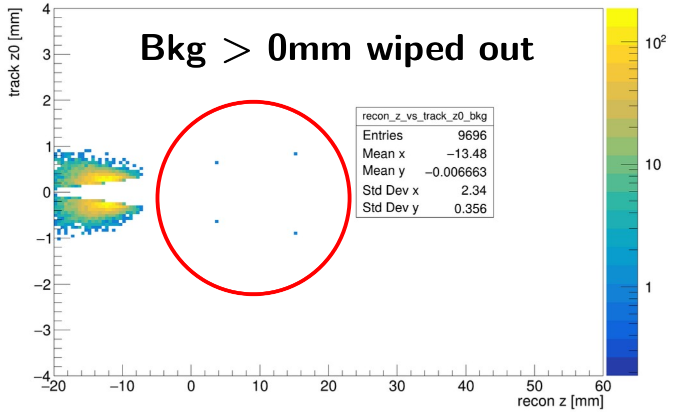
55 MeV Example – Medium Zalpha Slope

Medium Slope (α = 0.02)

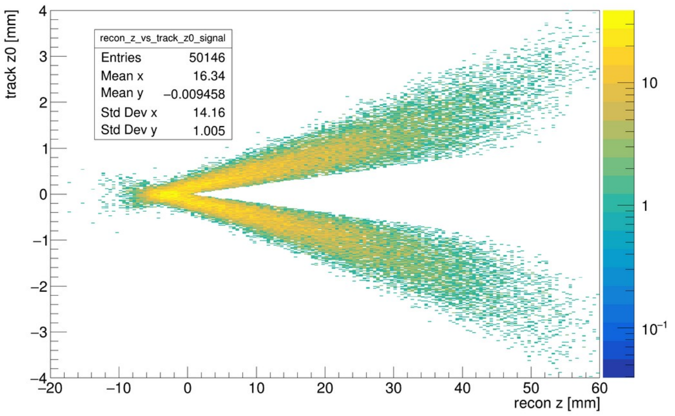
10% Data – 55 MeV

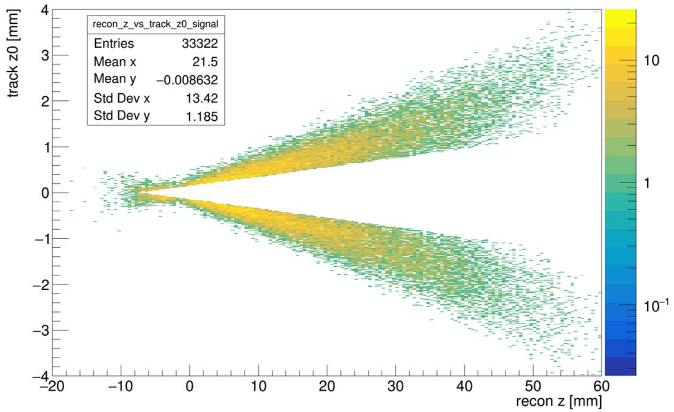


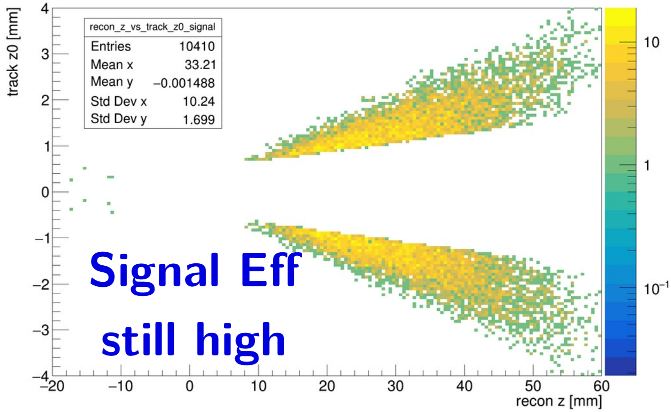




MC Signal – 55 MeV



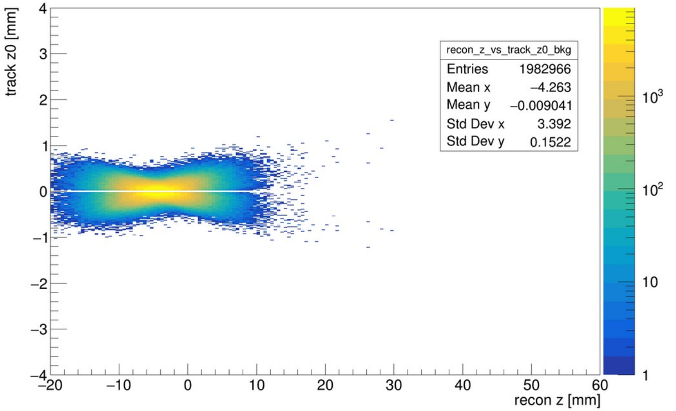


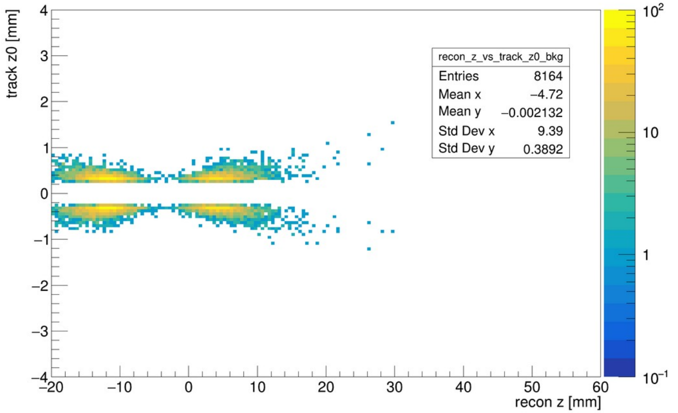


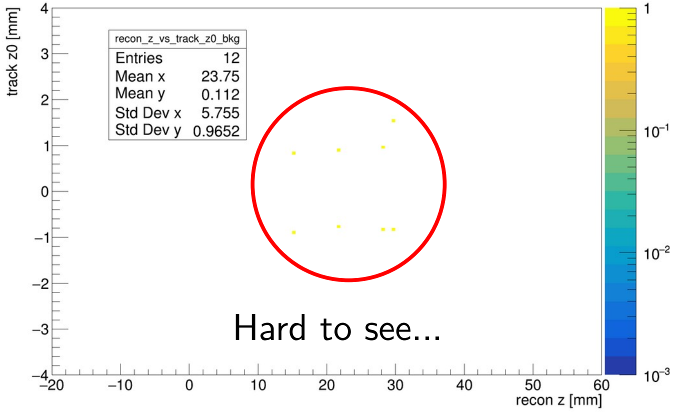
55 MeV Example – Small Zalpha Slope

Flat Z0 (α = 0.00)

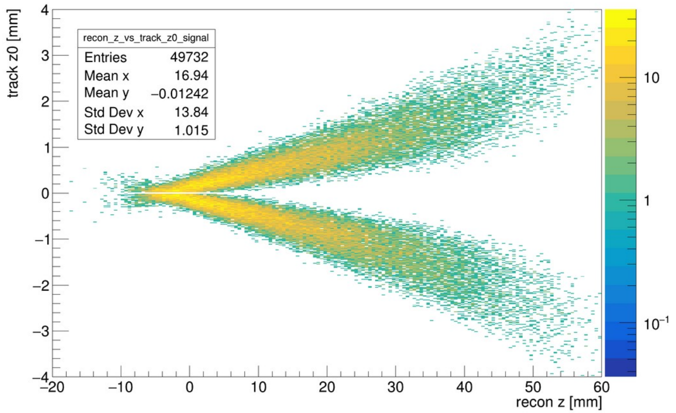
10% Data – 55 MeV

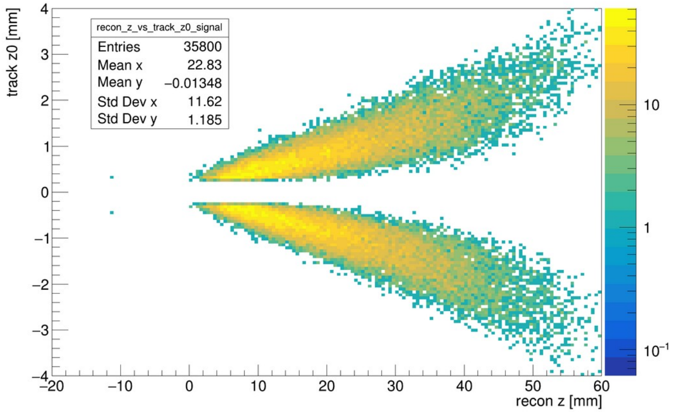


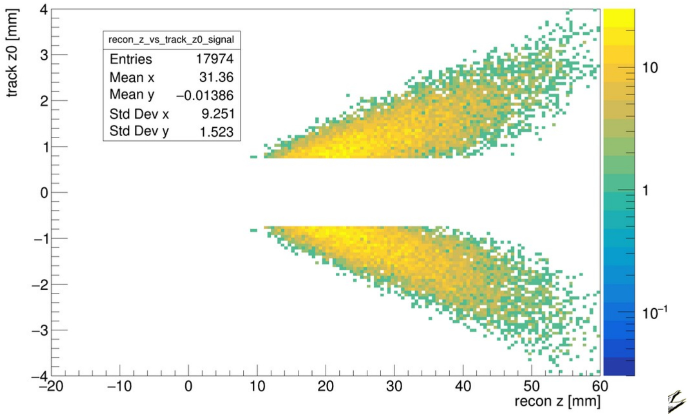




MC Signal – 55 MeV

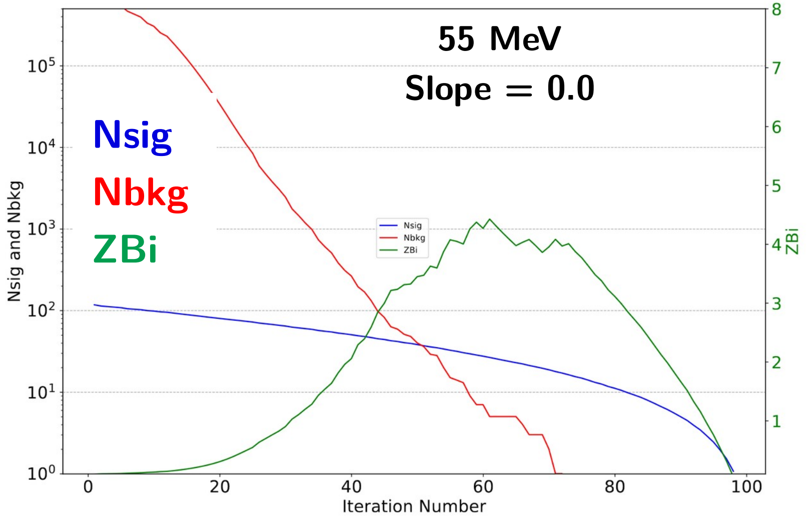


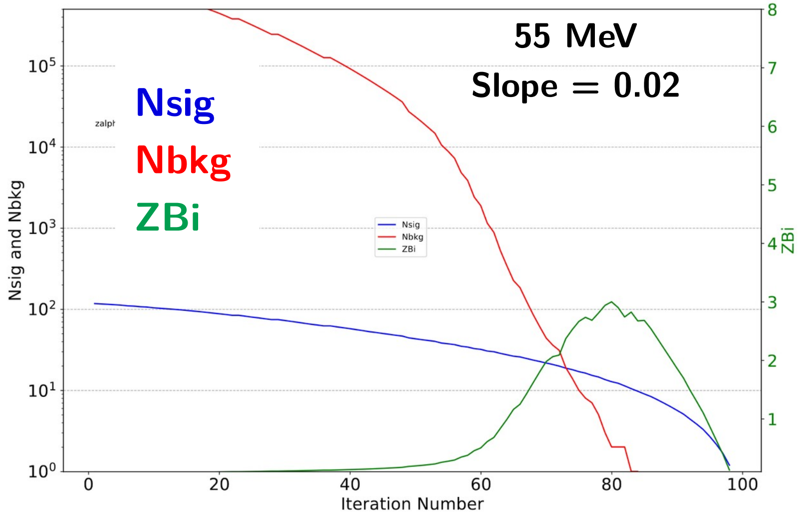


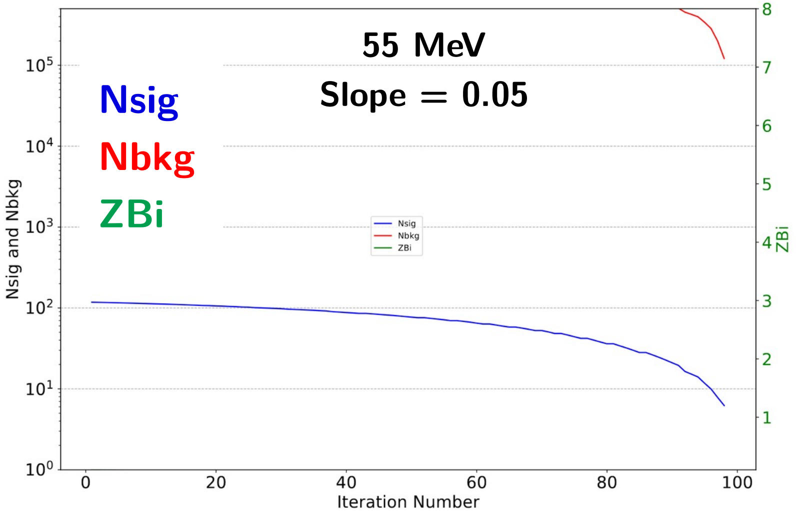


55 MeV Example – Results

- **Calculate Expected Signal Nsig, Nbkg, and significance Zbi**
- Single value of ε: $\log(\varepsilon^2) = -5.5$
- **No Zcut!** (Or rather, just the Target Position)
- Cut Value (Zalpha Vertex Position) tightens as 'Iteration Number'
- Nbkg in 10% Data (add 0.5 events if Nbkg=0, for Zbi calc)
- **Nsig** in 10% Data, AND **scaled up by factor of 5**

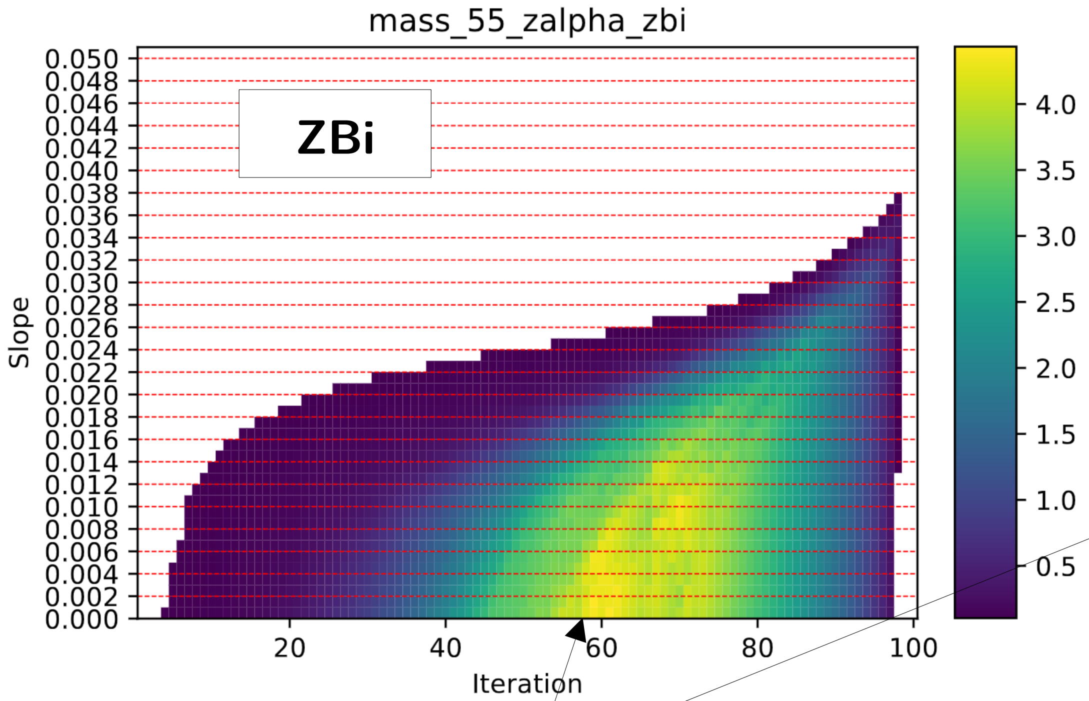


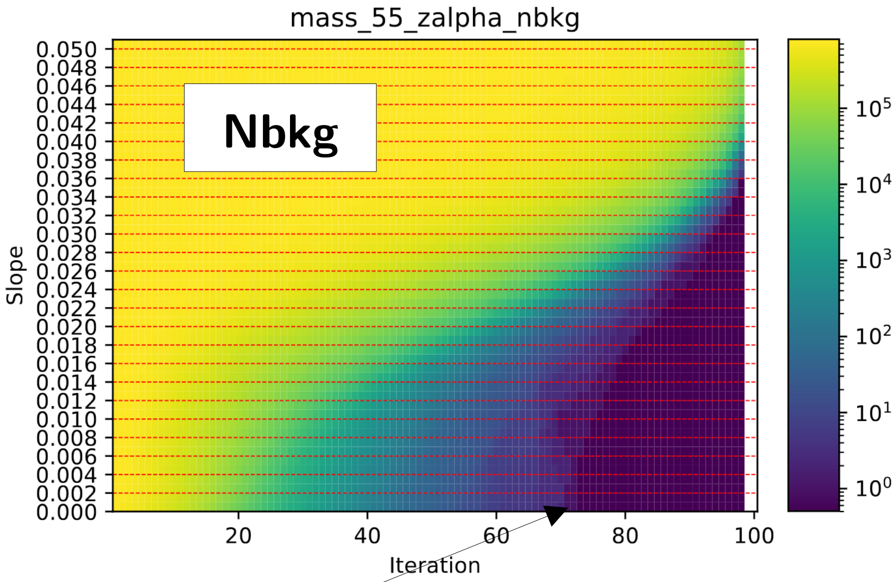


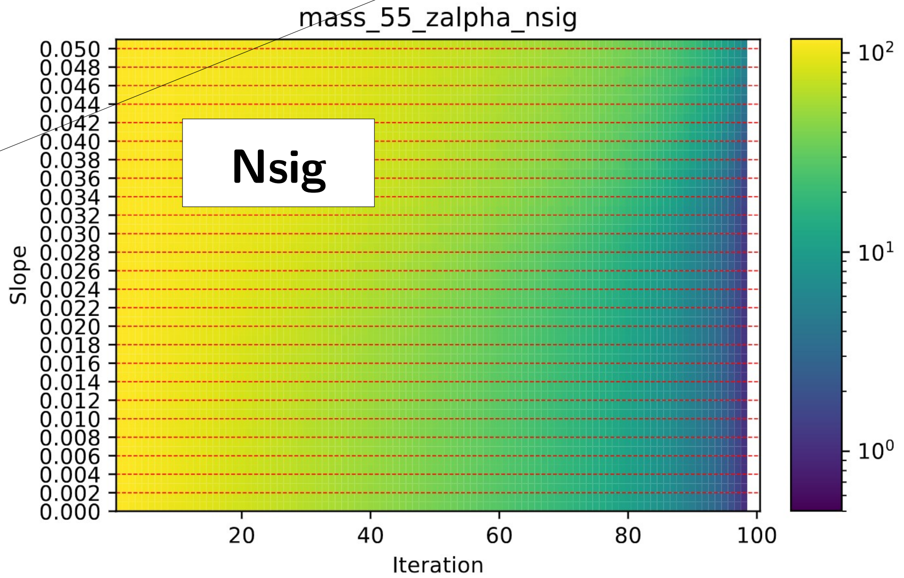


55 MeV Example – Full Results

Cut value (Zalpha Vertex Position) tightens with iteration







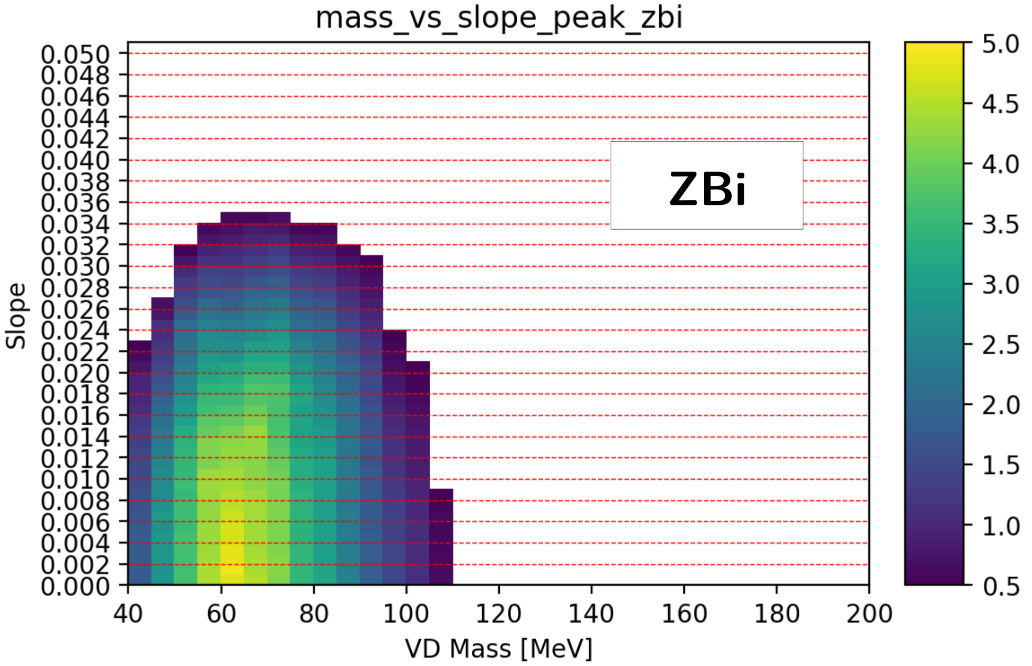
Maximum Zbi occurs before Nbkg = 0

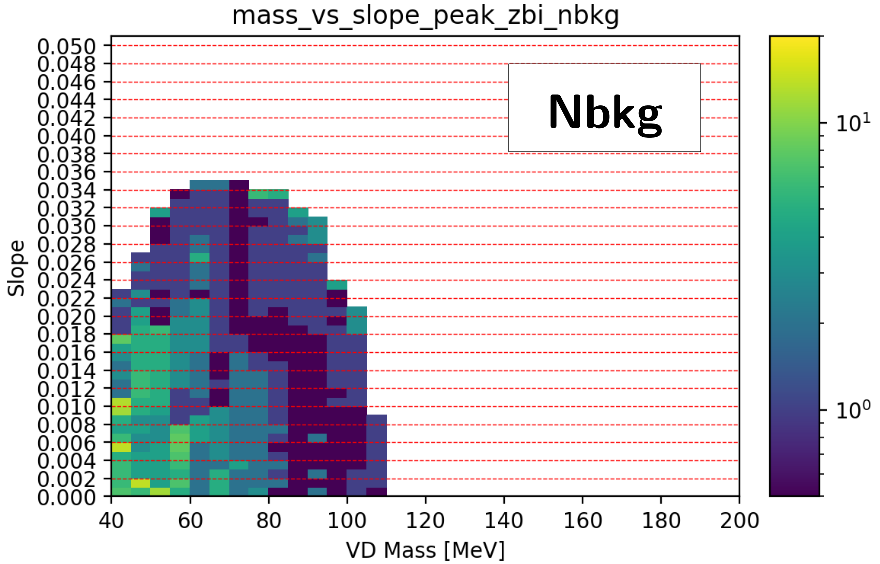
All Mass Results

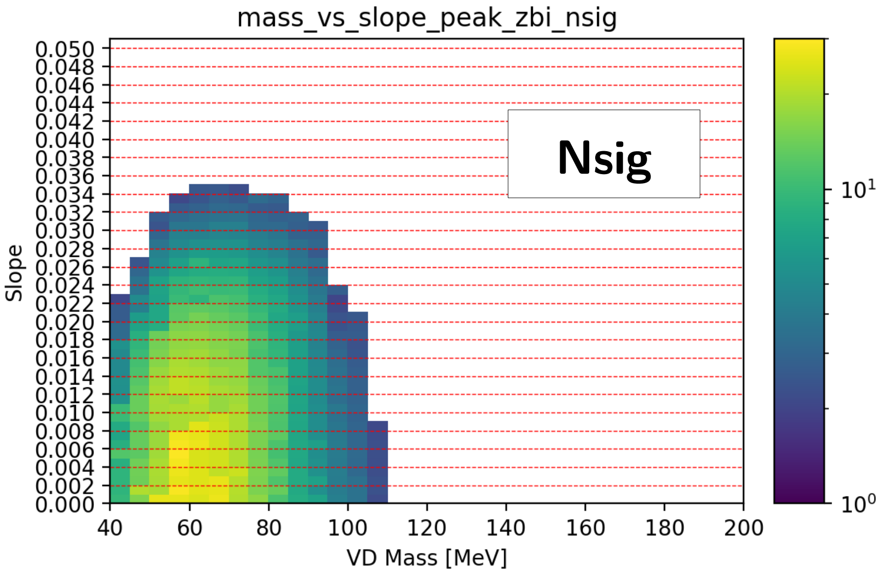
Maximum ZBi

Zalpha – Results for Max ZBi

Only plot results where Zbi $>$ 0.5



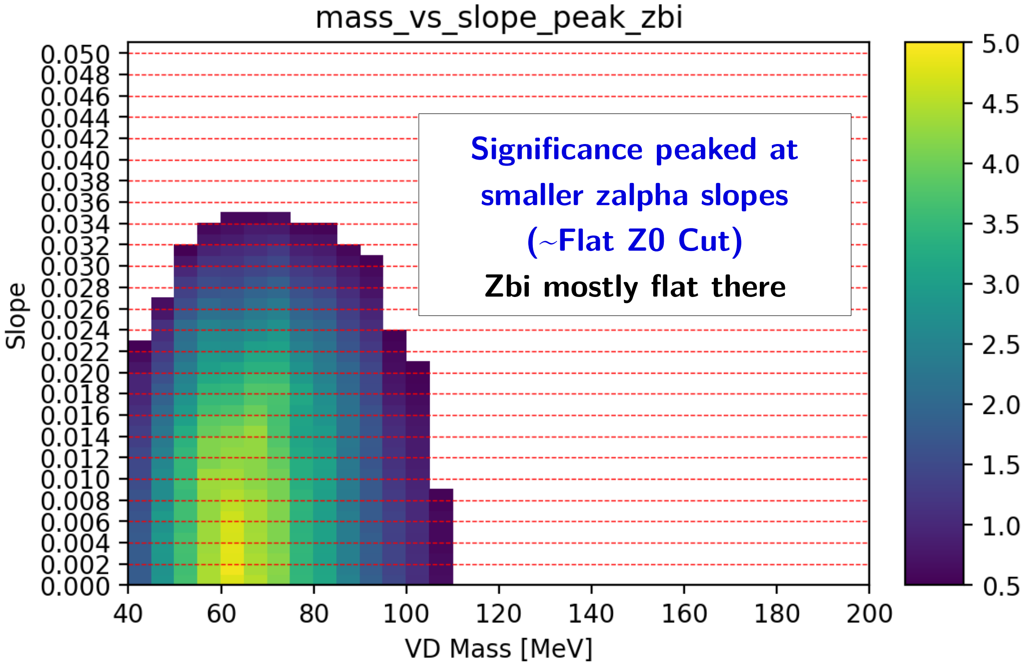


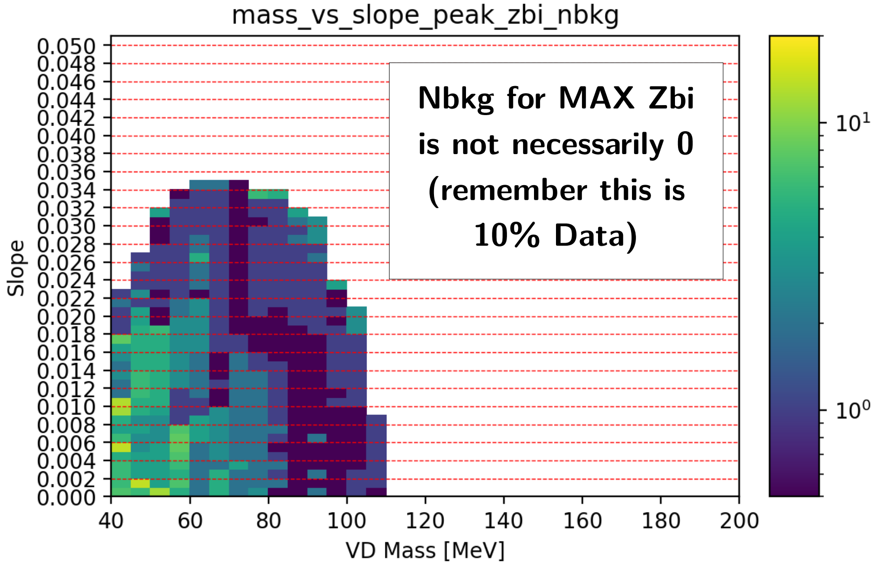


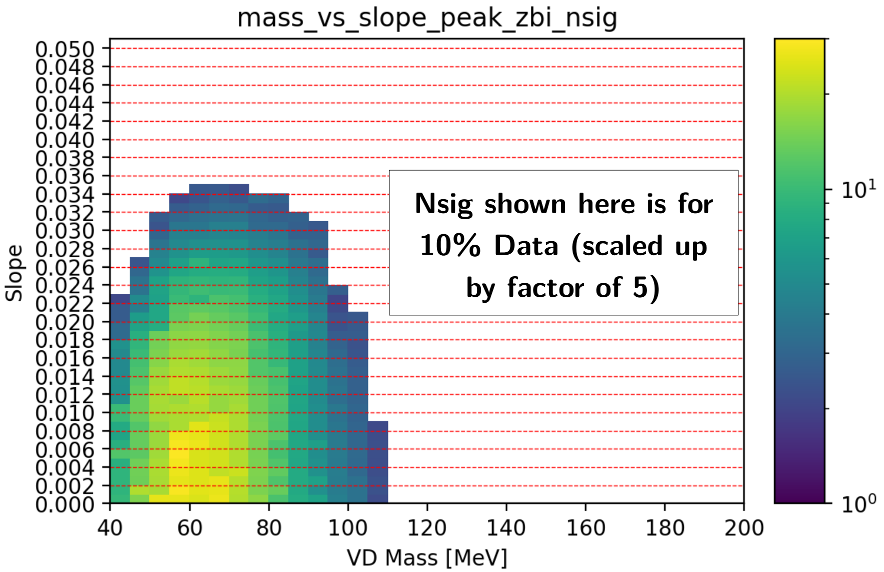
Each Bin corresponds to whatever Cut Value results in the MAXIMUM ZBi for that Zalpha Slope

Zalpha – Results for Max ZBi

Only plot results where
Zbi > 0.5

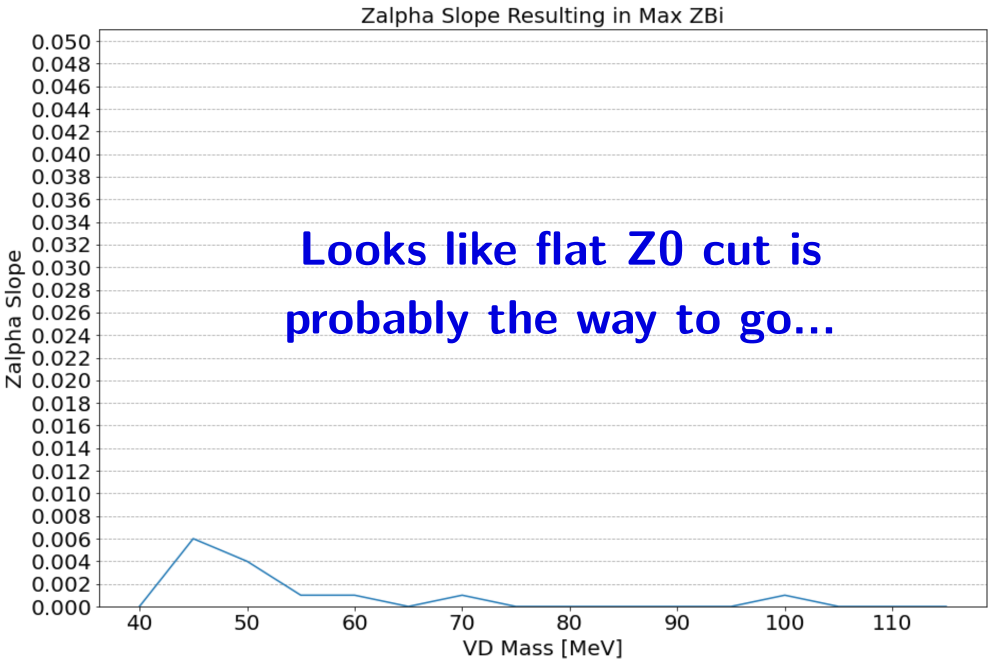






Each Bin corresponds to whatever Cut
Value results in the MAXIMUM ZBi
for that Zalpha Slope

Zalpha – Results for Max ZBi

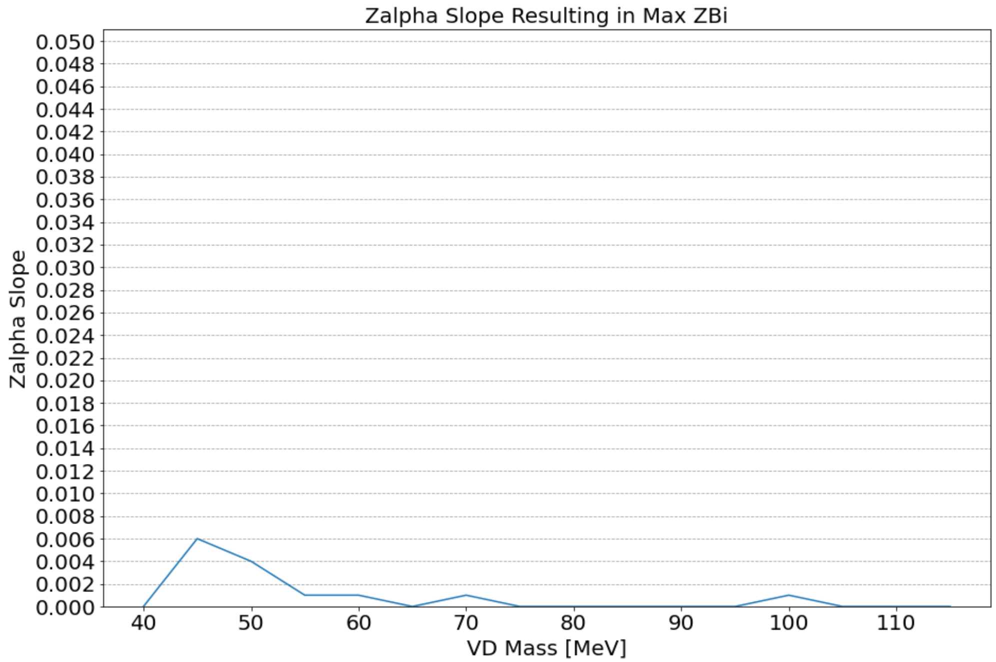


Looks like flat Z0 cut is probably the way to go...

For each Mass, plot whatever Zalpha Slope and Cut Value gives Maximum ZBi

Zalpha Slope that gives Maximum ZBi

Zalpha – Results for Max ZBi



What if we demand Nbkg to be 0 (or minimized for a given slope)

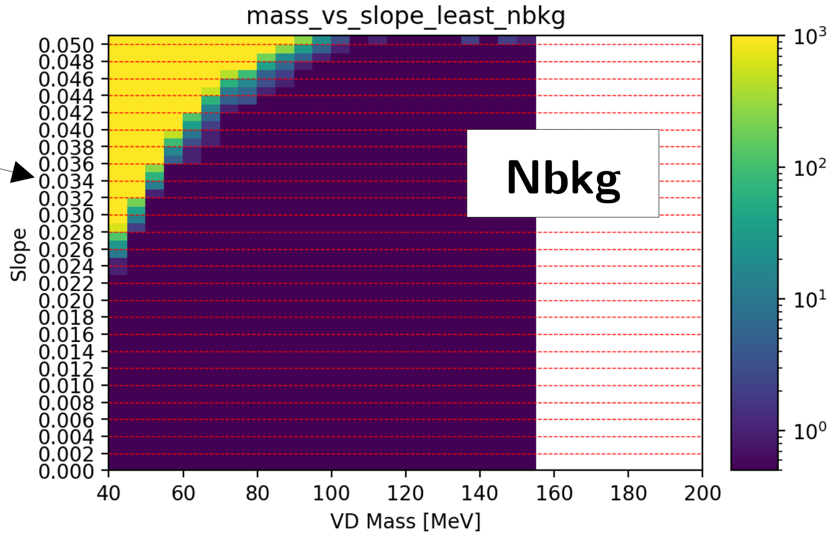
Instead of using Max Zbi?

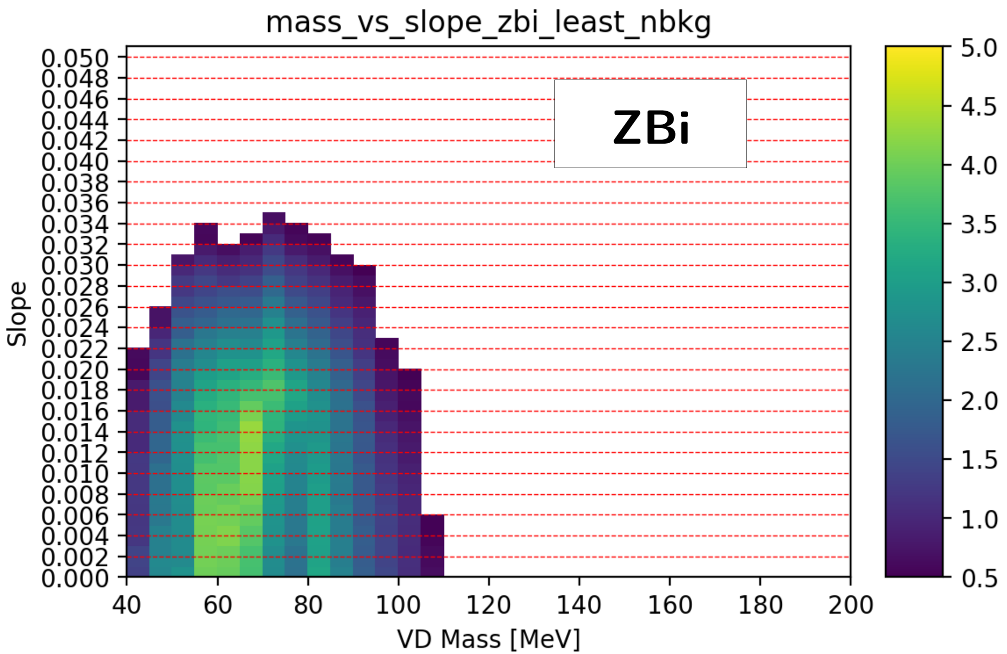
All Mass Results

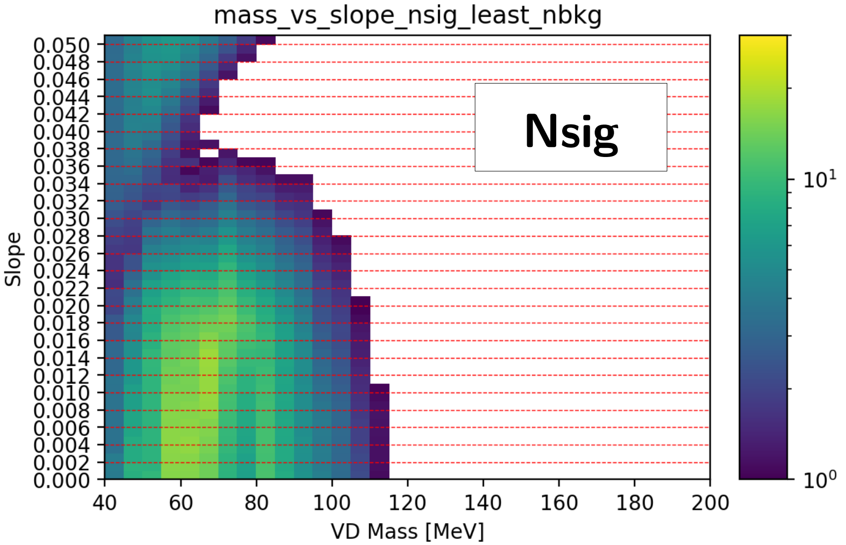
$$\text{Nbkg} = 0$$

Zalpha – Results for Min Nbkg

Always possible to eliminate ALL background in 10% Data

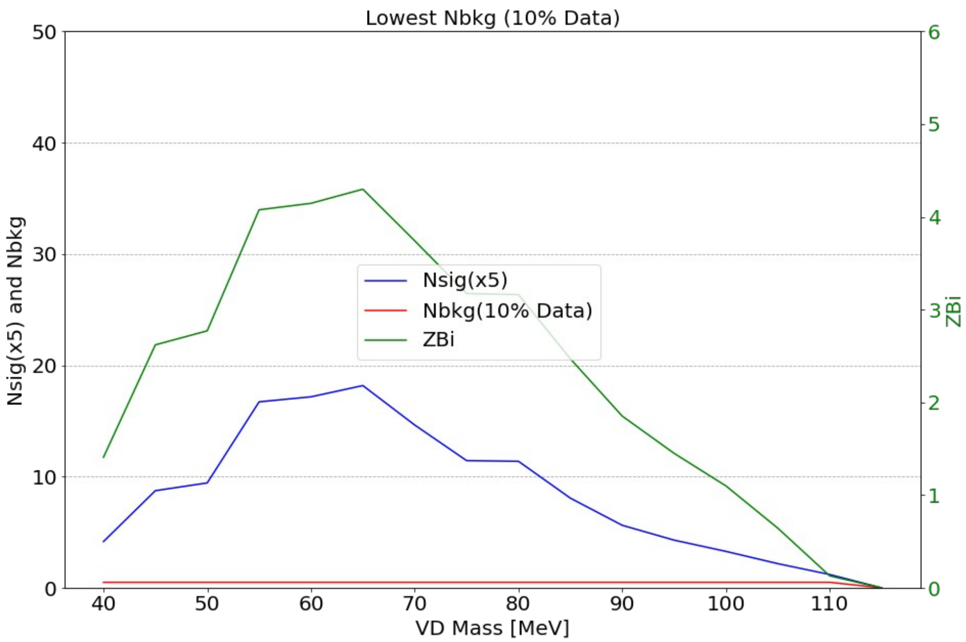


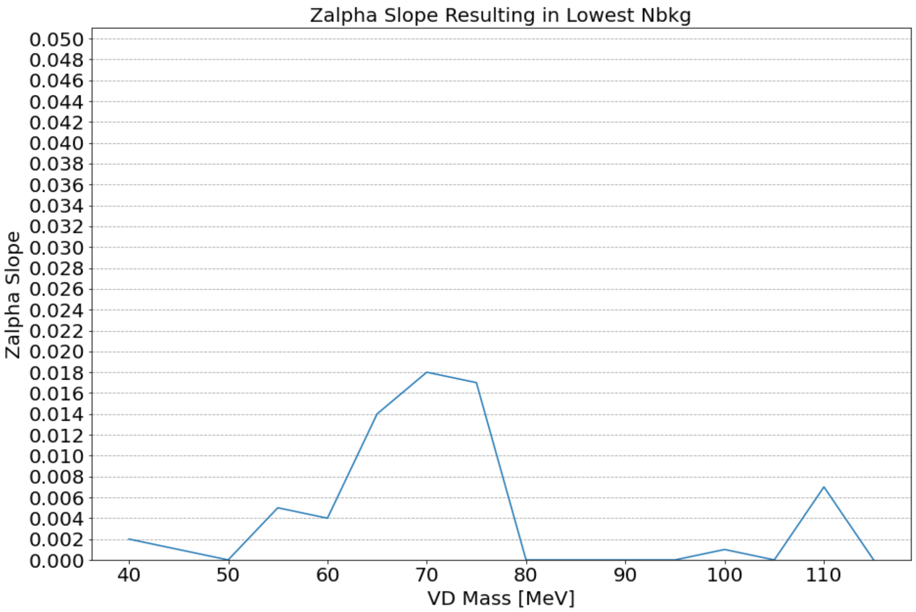




Each Bin corresponds to whatever Cut Value results in minimum background (or first time Nbkg=0)

Zalpha – Results for Min Nbkg

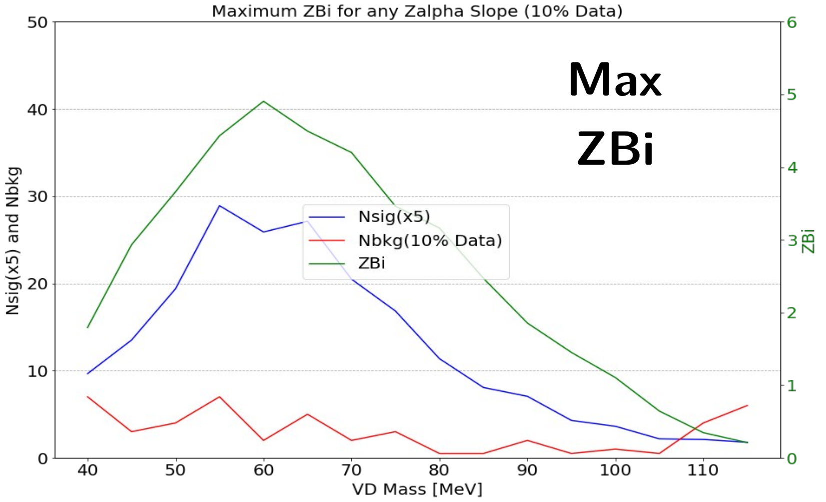


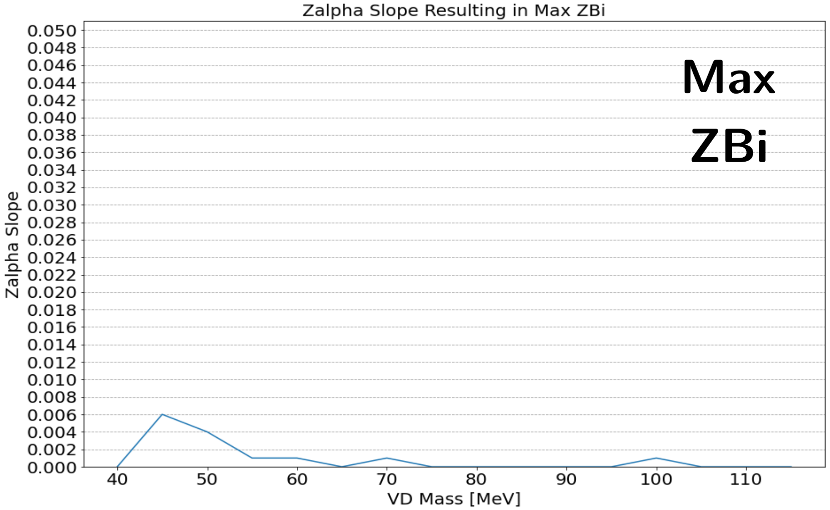


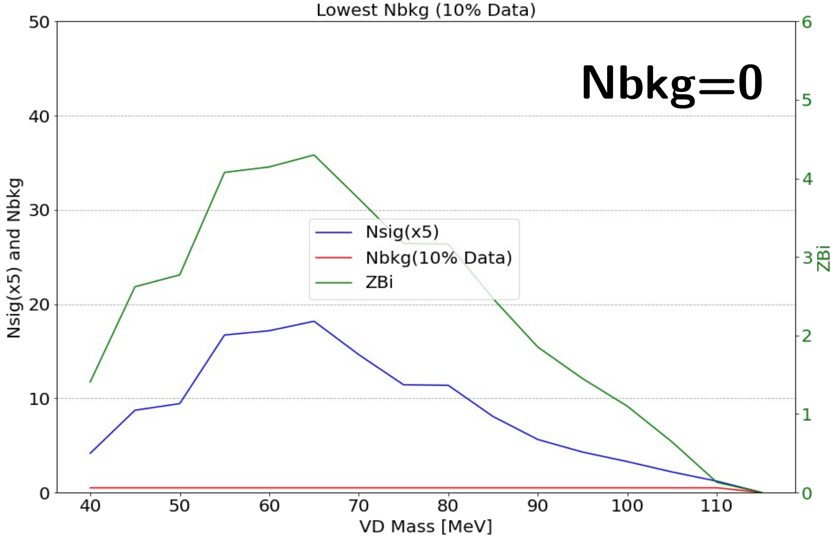
For each Mass, plot whatever Zalpha Slope and Cut Value gives max Zbi (where Nbkg = 0)

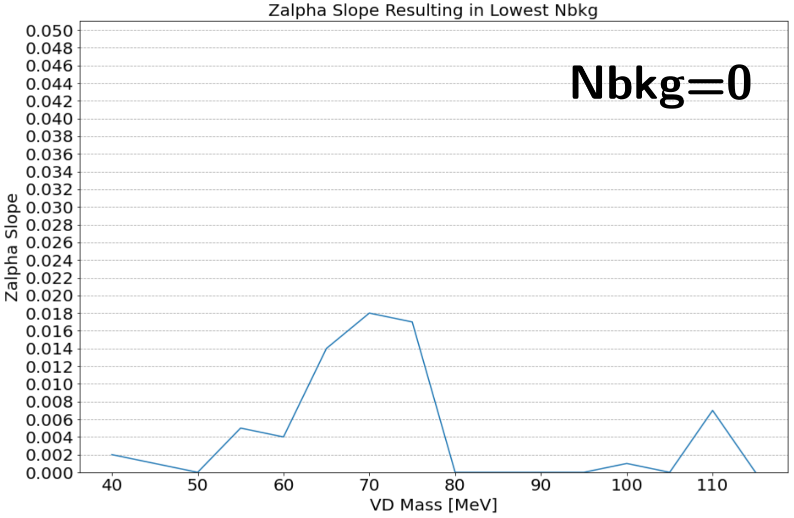
Zalpha Slope that gives maximum Zbi (where Nbkg = 0)

Zalpha – Max Zbi vs Nbkg=0

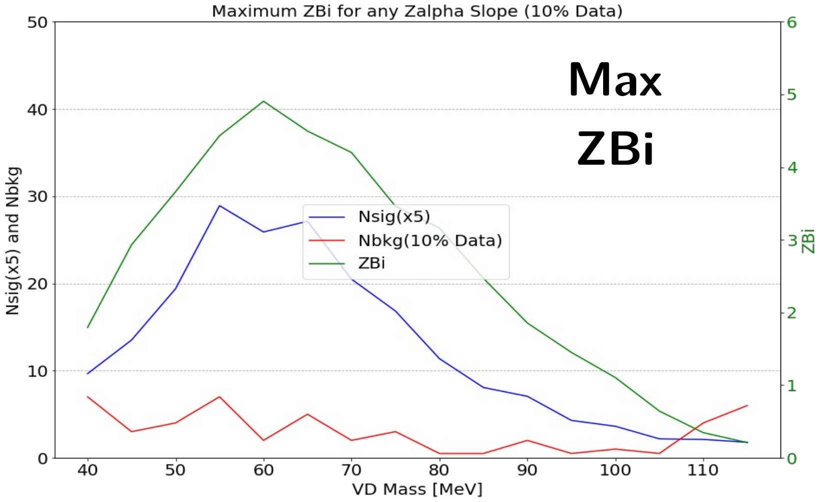


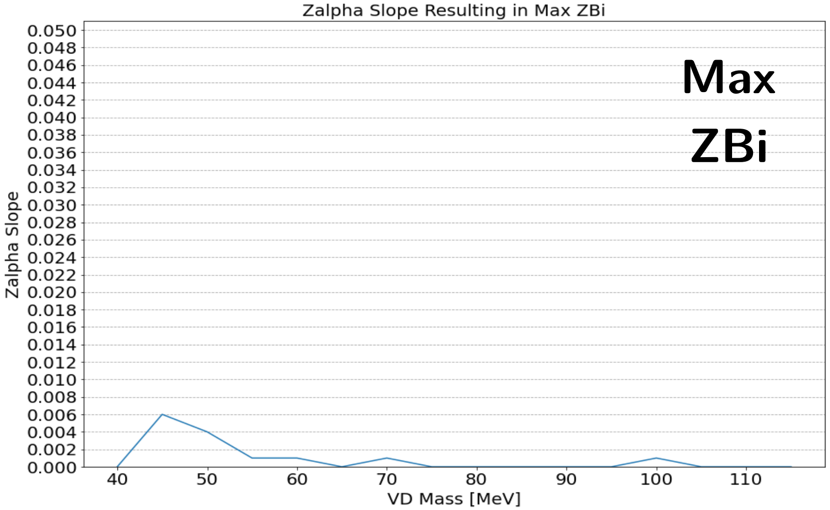


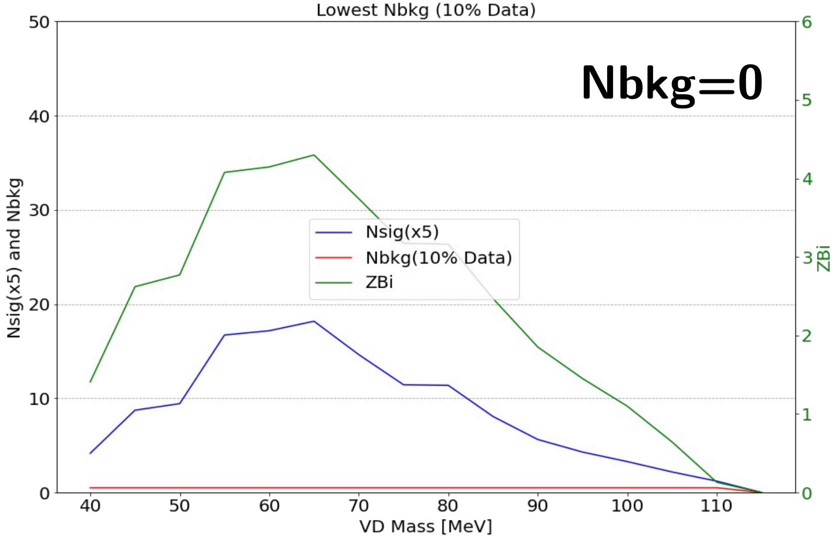


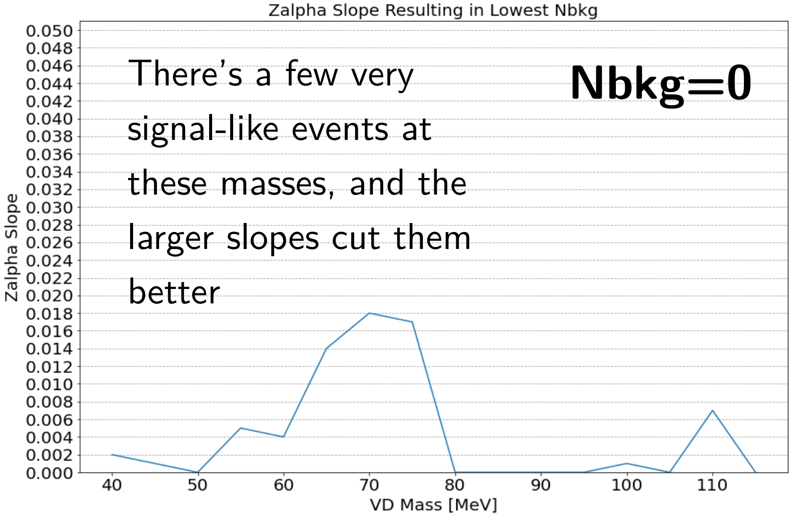


Zalpha – Max Zbi vs Nbkg=0





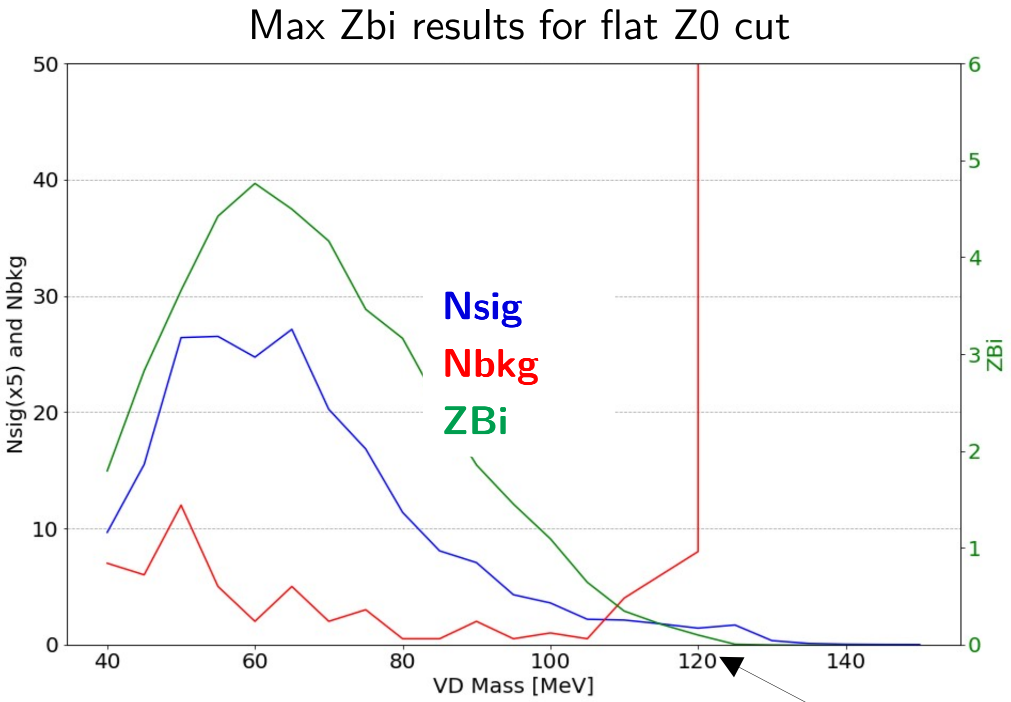


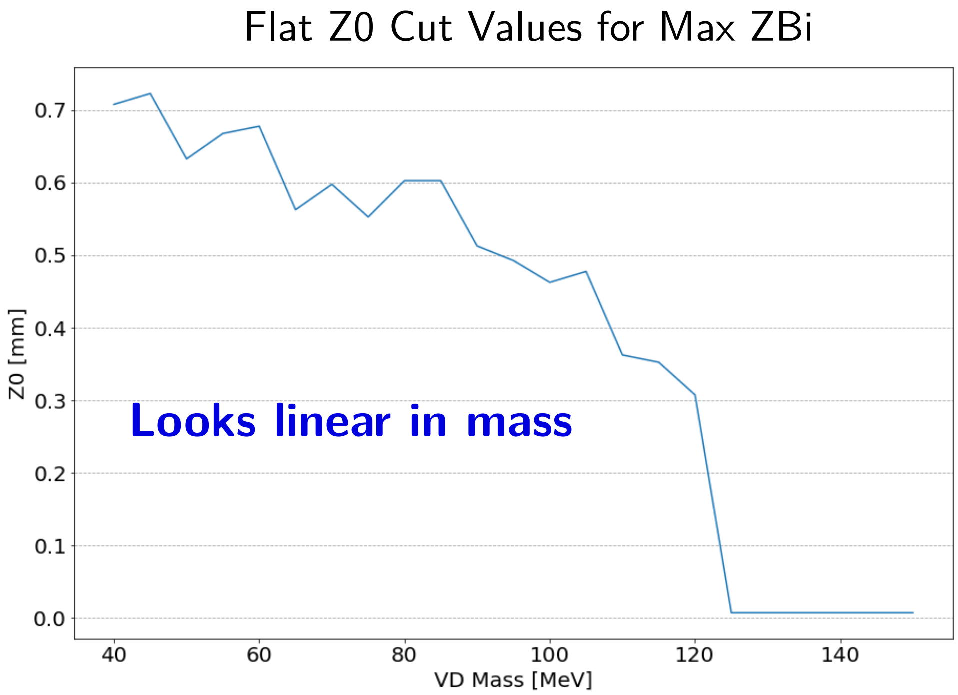


Flat Z0 Cut

Max ZBi

Flat Z0 Cut

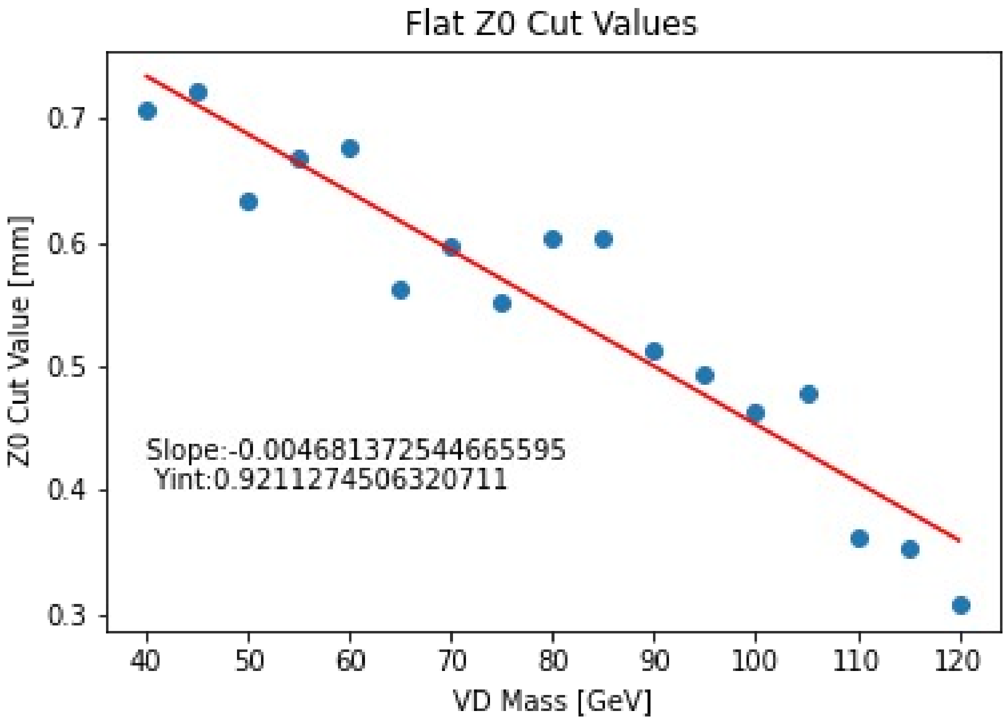




No sensitivity beyond 120 MeV VD (for this scaling)

M_{VD} must be < 126 MeV for this model anyways

Flat Z0 Cut



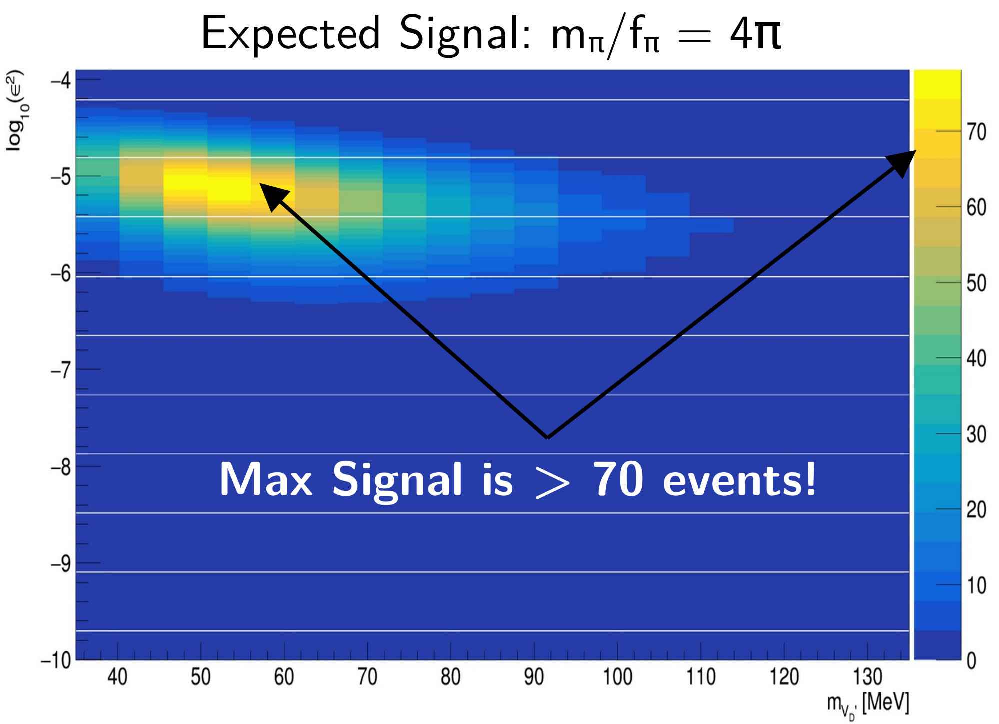
- Fit masses 40-120 MeV with a line
- Parameterize Flat Z0 cut as function of invariant mass using this fit

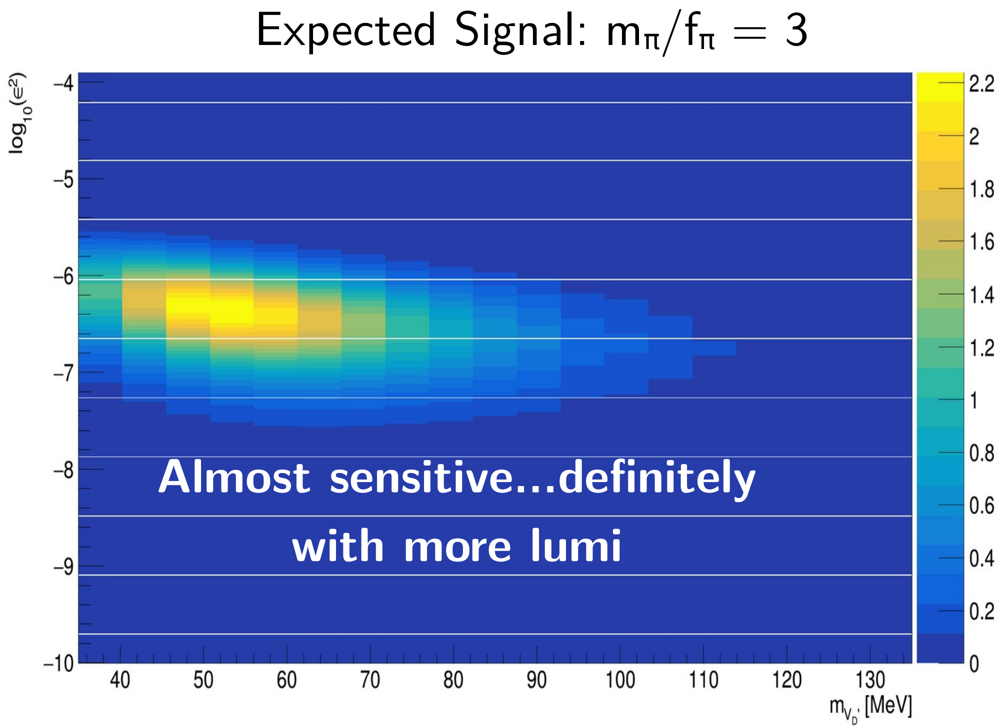
Reach Estimate

Reach Estimate

- Preselection and Tight Selection as found in backup
- 10% Data in CR (Psum $>$ 1.9 GeV) used to scale Nsig via radFrac, radAcc, dNdm
- Apply high-z cuts to MC Signal
  - Signal ele(pos) z0 corrected with offset -0.058(-0.098)
  - V0Projection Significance $<$ 2.0
  - DeltaZ(mass): 18.5972 + 0.159555*mass_mev
  - Z0(mass): 0.921 -0.00468*mass_mev
- **Run Reach Estimate**
  - Scaled by factor of 10 to ~Full Lumi
  - Yes, background is not going to be zero, and only represents 10% of the total data...
  - ‘Zcut’ set to target position (should include vtx resolution really)

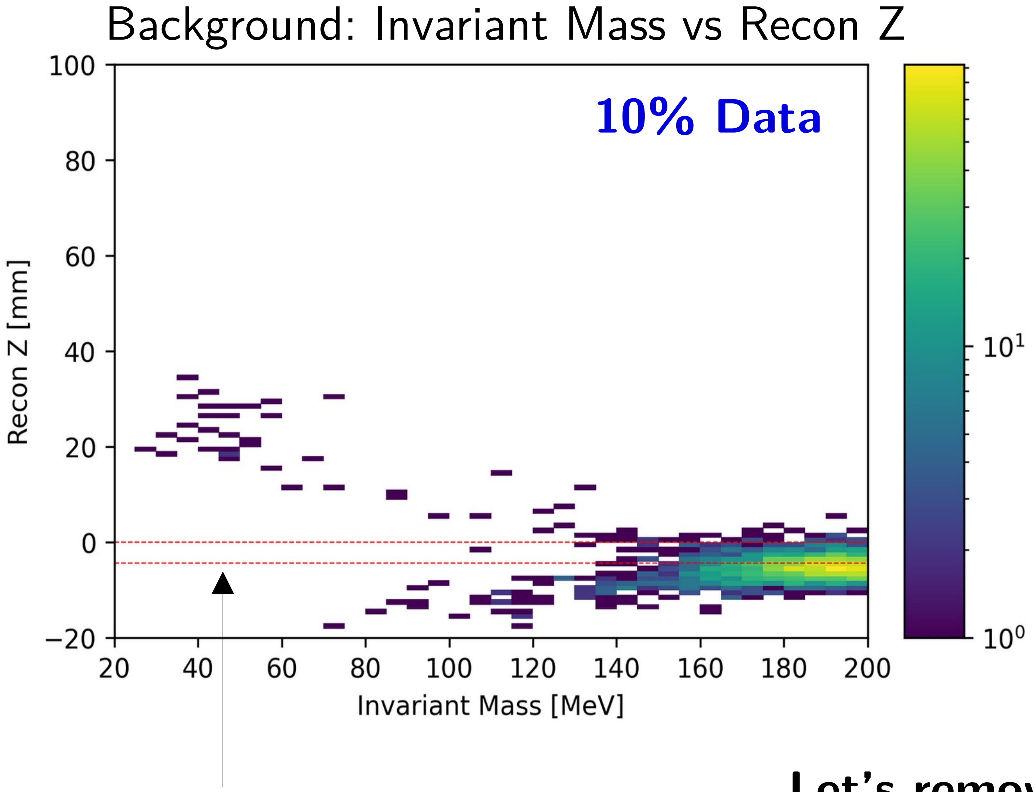
Reach Estimate - Expected Signal

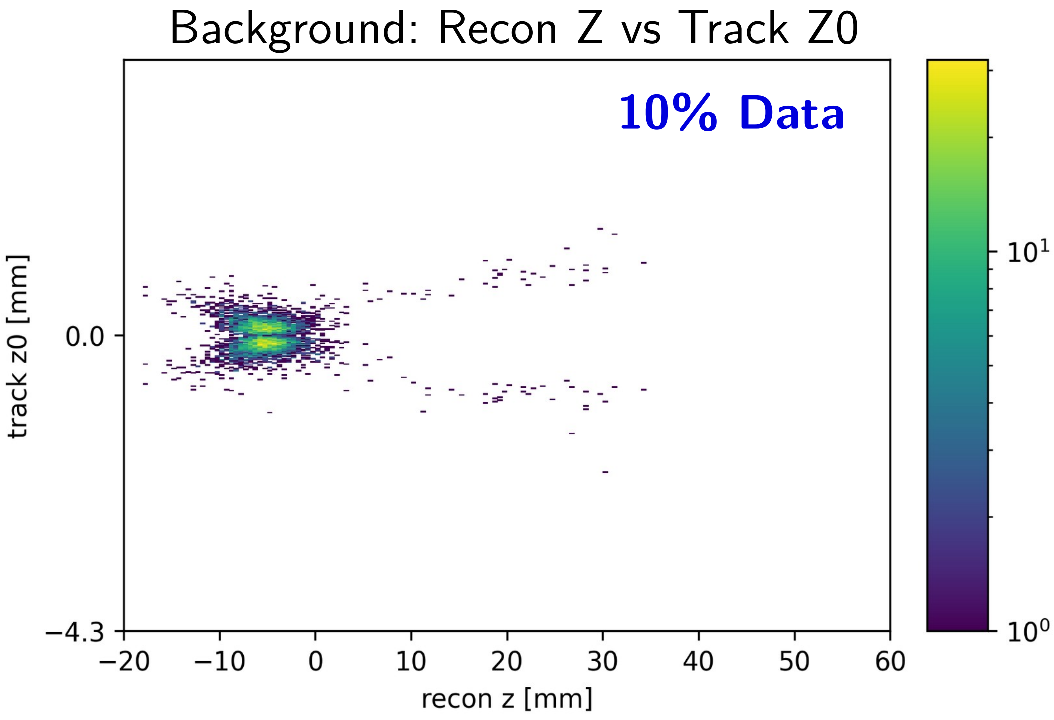




Full Lumi Reach Estimate

Reach Estimate – Remaining Background in 10% Data

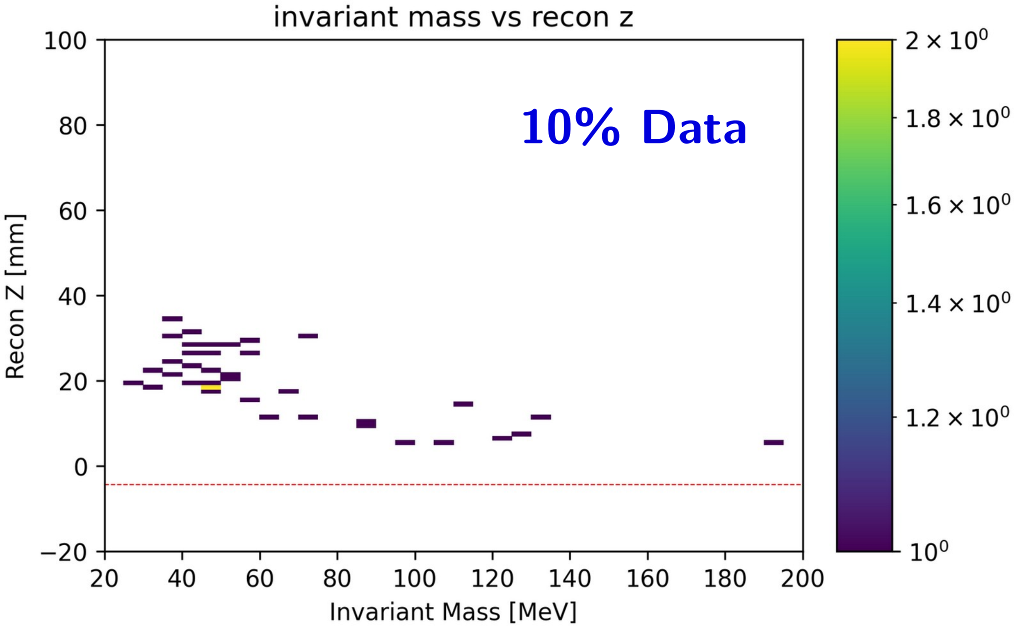


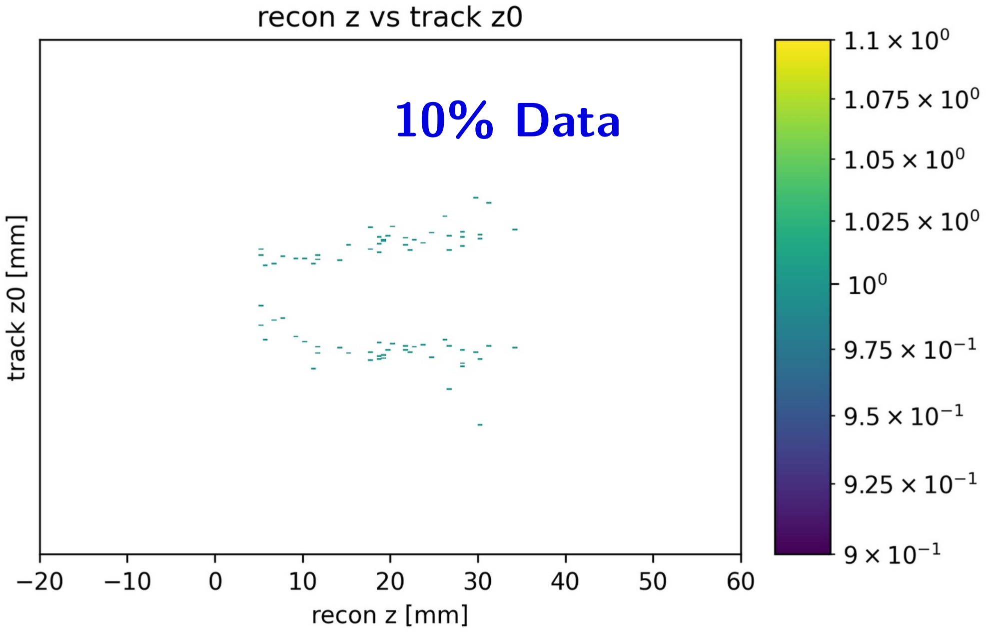


Target position at -4.3mm

Let's remove all the events at/behind the target

Reach Estimate – Remaining Background in 10% Data



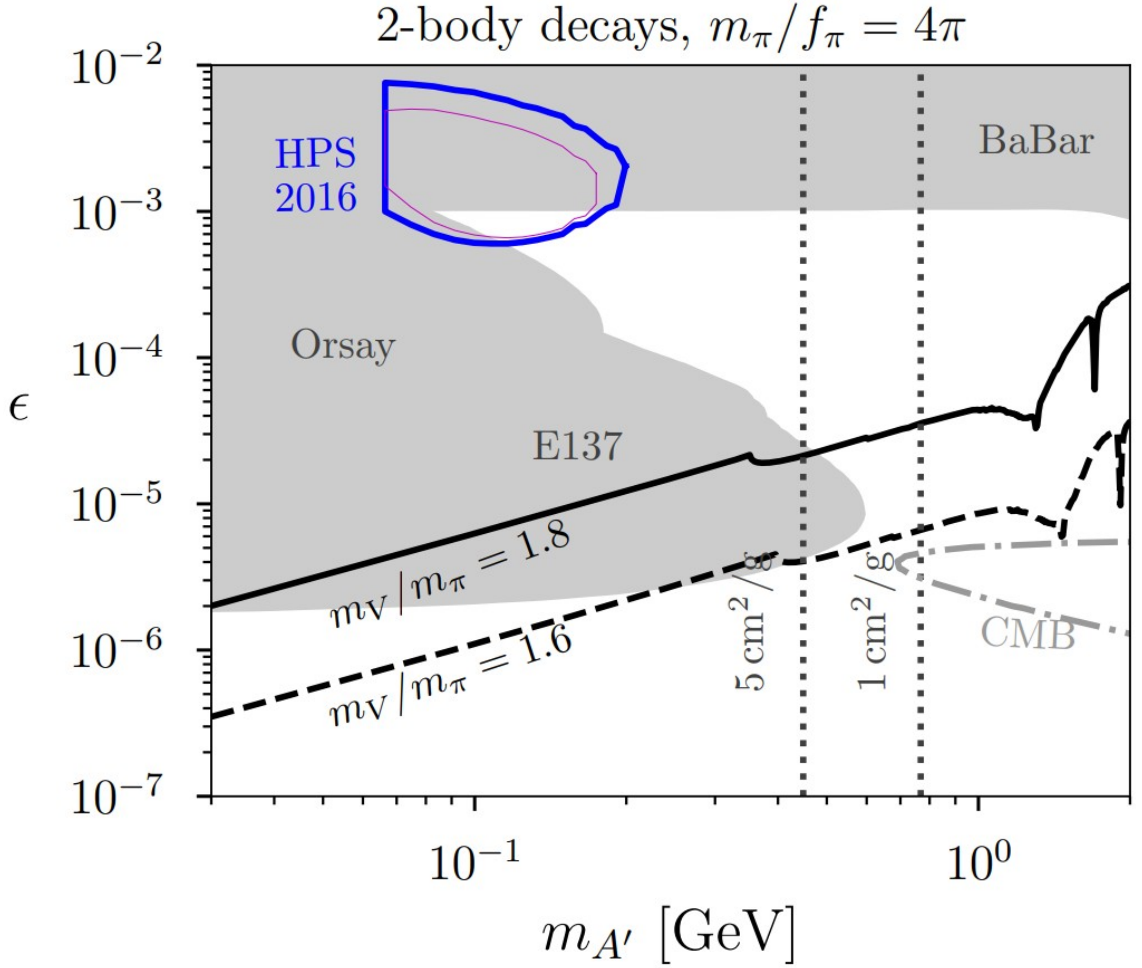


Cut all events < -4.3 mm

38 background events left in 10% Data

Reach Estimate – Exclusion Contour

- Previous Exc Contour (using standard z-cut styled analysis shown in magenta)
- New contour shown in blue
- Tiny gains in new territory
- Any thoughts on how to push this contour down in coupling?

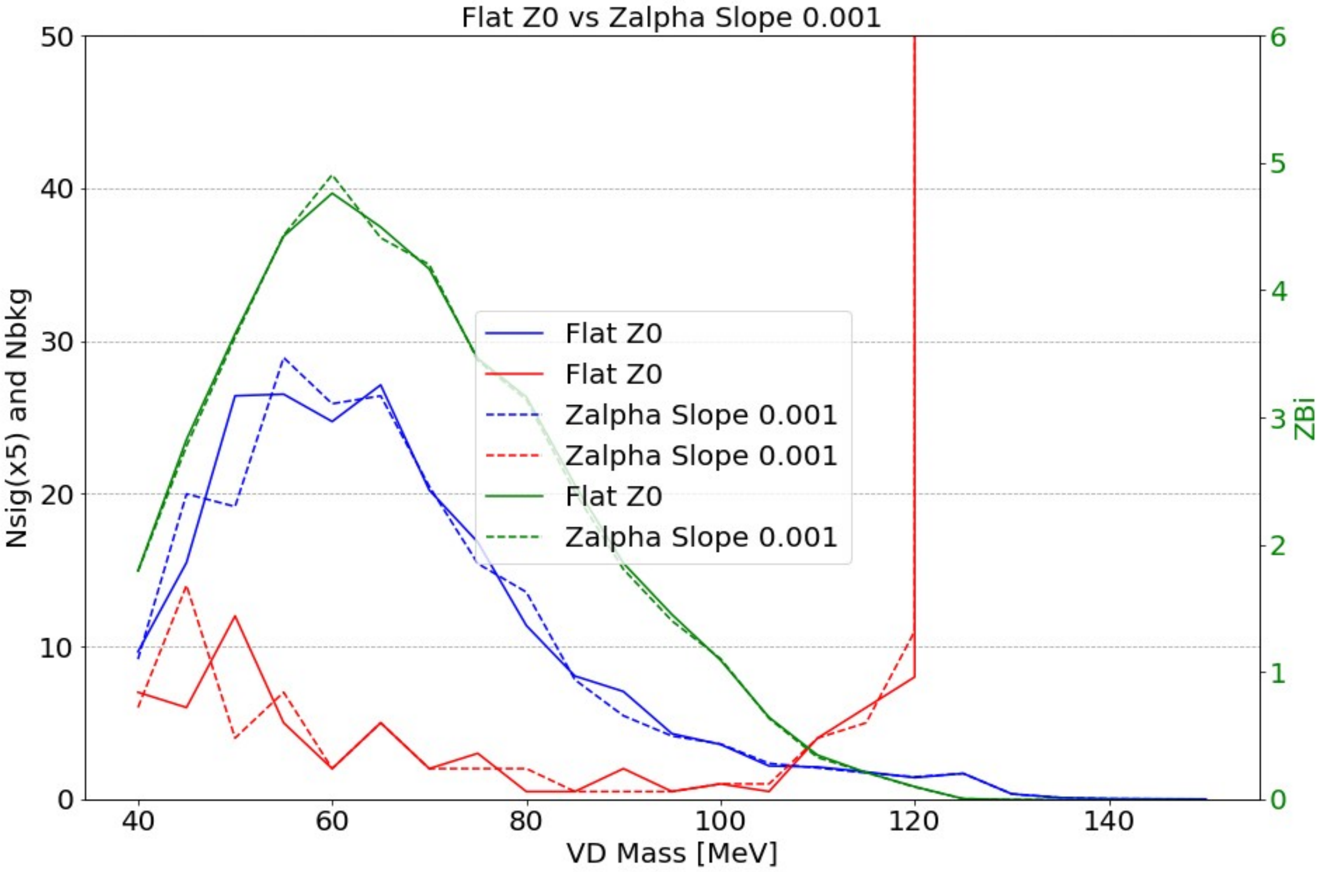


Summary and Conclusion

- Current set of high-z cuts can eliminate almost all background, and expect large signal
- Instead of using flat z0 cut, which leaves some background, will look at the zero-background case too (Zalpha with very small slopes)
- *Flat z0 is nice and simple...how much squeezing do we want to do really?
- Do we want to go for optimizing sensitivity, or zero-background?
- What systematics studies need to be done on this z0 cut before we feel cool with it?
- Cam and I want to look at 100% Data above 120 MeV, and use 100% of Control Region Data, to test these cuts further
- PF has momentum smearing mostly done
- Matt G finishing up hit killing
- Tongtong working on MC/Data low psum discrepancy
- Cam working on hpstr sw release and tuplizing data

Backup

- Is Flat Z0 the way to go?
- Maybe a *tiny slope is better?
- Plot compares Flat (Solid) and **Almost** flat Zalpha slope
- Don't see much difference



Introduction - Setup

Preselection and Tight Selection used for this work...

Cut Description	Requirement
ECal clusters in opposite volumes	$e^{-}Cluster_y \times e^{+}Cluster_y < 0$
Track-Cluster Time Difference (Data)	$\lvert Track_t - Cluster_t - 56ns \rvert < 10$ ns
Track-Cluster Time Difference (MC)	$\lvert Track_t - Cluster_t - 43ns \rvert < 10$ ns
Track-Cluster X Position Difference	$\lvert x_{TrackatEcal} - x_{Cluster} \rvert < 20.0$ mm
Track-Cluster Y Position Difference	$\lvert TrackAtEcal_y - Cluster_y \rvert < 20.0$ mm
Cluster Time Difference	$\Delta_t(Cluster_{e^-}, Cluster_{e^+}) < 2.5$ ns
Beam electron cut	$p_{e^-} < 2.15$ GeV
Vertex Momentum	$p_{Vtx} < 2.8$ GeV

Table 3: Reconstruction level requirements. Track-Cluster time difference in MC and data is corrected using offsets calibrated in [7]. The track positions are found by extrapolating the track from the last layer hit to the face of the ECal.

Cut Description	Requirement
Trigger	Pair1
Track Time	$\lvert Track_t \rvert < 6$ ns
Cluster Time Difference	$\Delta_t(Cluster_{e^-}, Cluster_{e^+} < 1.45$ ns
Track-Cluster Time Difference	$\Delta_t(Track, Cluster) < 4.0$ ns
Track Quality	$Track\chi^2/n.d.f. < 20.0$
Beam electron cut	$p_{e^-} < 1.75$ GeV
Minimum Hits on Track	$N_{2dhits}Track > 7.0$
Unconstrained Vertex Quality	$Vtx_{\chi^2} < 20.0$
Vertex Momentum	$p_{e^-+e^+} < 2.4$ GeV

Table 4: V_0 selection. The time offset for data is 56 ns and the time offset for MC is 43 ns.

Cut Description	Requirement
Layer 1 Requirement	e^- and e^+ have L1 hit
Layer 2 Requirement	e^- and e^+ have L2 hit
Control Region Momentum	$P_{e^-} + P_{e^+} > 1.9GeV$
Signal Region Momentum	$1.0 < P_{e^-} + P_{e^+} < 1.9GeV$
Single Vertex Event	1 Candidate Vertex Per Event

Table 7: V_0 Tight L1L1 selection as of 07/18/2023.