2016 Vertexing Status: Mostly L1L2 Analysis

Matt Graham (& Matt Solt)

HPS Collab Meeting

November 19, 2020

Outline (for me)

- Summary of where Matt Solt left off with L1L1 (link to Wednesday talk?)
- Somewhere, snapshot of presel and tight cuts
- Issues with L1L2
  - Show plot of L1L2 Vz vs mass
  - MC issues...vast underestimate of L1 inefficiency
  - Hit killing...old dumb way vs new, less dumb way (I don't think I have any good comparisons of this)
  - New hit killing trident rates
    - At least some differences due to MC/data differences in cut variables
- Investigating L1L2
  - Differences in L1PosL2Ele and L2PosL1Ele...WABs are important for one!
  - Where we miss hits in L1...very asymmetric
    - Plots of L1 extrapolation and truth for tritrig & data
    - Compare beam position between MC and data (and angles!)
    - Show A' L1 extrapolation distribution...note that acceptance is likely very dependent on beam parameters!

Recon & Preselection Cuts

Reconstruction-level selection

Cut Description	Requirement
Cluster Time Difference	$\|t_{e^+Cluster} - t_{e^-Cluster}\| < 2.5$ ns
e^+ Track-Cluster Time Difference	$\|t_{e^+Track} - t_{e^+Cluster} - 55\| < 10$ ns
e^- Track-Cluster Time Difference	$\|t_{e^-Track} - t_{e^-Cluster} - 55\| < 10$ ns
Ecal clusters in opposite volumes	$y_{e^+\text{ Cluster}} \times y_{e^-\text{ Cluster}} < 0$
Loose track-cluster match	$\chi^2 < 15$
Beam electron cut	$p(e^-) < 2.15$ GeV
Track Quality	$\chi^2/dof < 12$
Maximum Vertex Momentum	$V_{0p} < 2.8$ GeV

Preselection

Cut Description	Requirement
Trigger	Pair1
Track-cluster match	$\chi^2 < 10$
Cluster Time Difference	$\|t_{e^+Cluster} - t_{e^-Cluster}\| < 1.45$ ns
Track-Cluster Time Difference	$\|t_{e^+Track} - t_{e^+Cluster} - \text{offset}\| < 4$ ns
Track-Cluster Time Difference	$\|t_{e^-Track} - t_{e^-Cluster} - \text{offset}\| < 4$ ns
Beam electron cut	$p(e^-) < 1.75$ GeV
Track Quality	$\chi^2/dof < 6$
Vertex Quality	$\chi^2_{unc} < 10$
Minimum e^+ Momentum	$p(e^+) > 0.4$ GeV
Minimum e^- Momentum	$p(e^-) > 0.4$ GeV
Maximum Vertex Momentum	$V_{0p} < 2.4$ GeV

Tight Cuts

L1L1 Tight Cuts

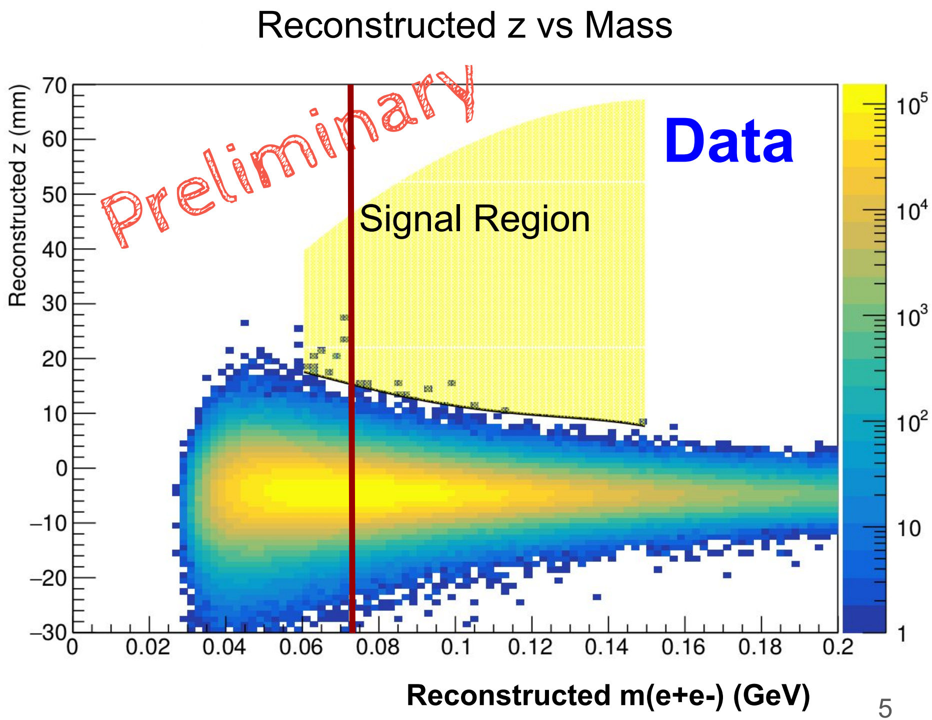
Cut Description	Requirement
Layer 1 Requirement	e^+ and e^- have L1 hit
Layer 2 Requirement	e^+ and e^- have L2 hit
Radiative Cut	$V_{0p} > 1.85$ GeV
V0 projection to target	Fitted 2σ cut
Isolation Cut	Eq. 7
Impact Parameters	Eq. 10

L1L2 Tight Cuts

Cut Description	Requirement
Layer 1 Requirement	e^+ xor e^- have L1 hit
Layer 2 Requirement	e^+ and e^- have L2 hit
Radiative Cut	$V_{0p} > 1.85$ GeV
V0 projection to target	Fitted 2σ cut
Isolation Cut	Eq. 7 or Eq. 12
Impact Parameters	Eq. 10

L1L1 Results Summary (MrSolt defense talk)

- Did we achieve the expected level of background necessary for a search?
  - **YES! A major accomplishment** (for mass greater than 70 MeV)
- What about mass less than 70 MeV?
  - **This excess is not observed in MC**
  - Statistically significant if one assumes 0.5 background events per mass slice, but not if one uses the mass sidebands to estimate background
- But first…
  - **How much signal do we actually expect?**
  - Can we set any exclusions in the canonical A′ parameter space?

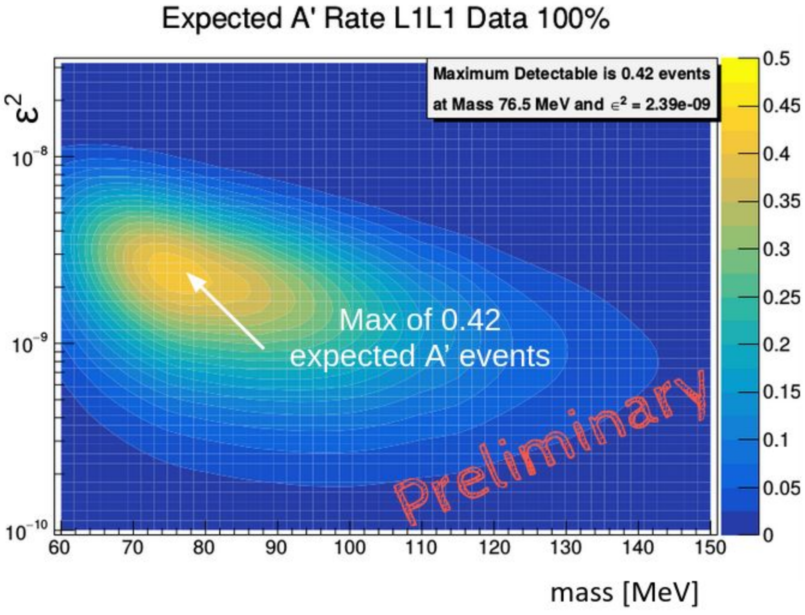


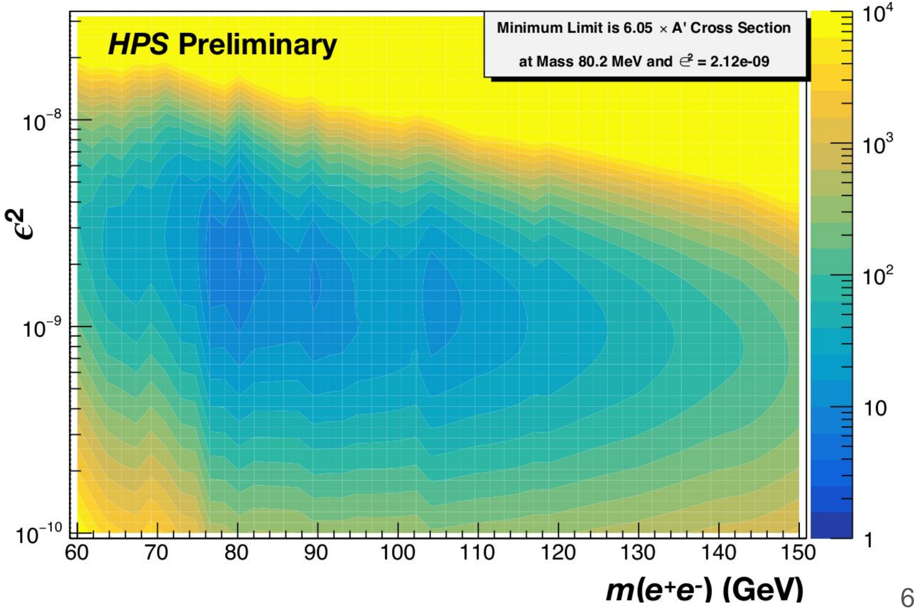
L1L1 Results Summary (MrSolt defense talk)

Plot the expected number of A′ events integrated past zcut.

$$N_{A'} = \int_{z_{cut}}^{z_{max}} \mathrm{sig}(m, \epsilon, z)\, \mathrm{accept}(m, z)\, \mathrm{eff}_{cut}(m, z)\, dz$$

Optimum Interval Method (OIM) was developed for DM direct detection and is used to set a limit.

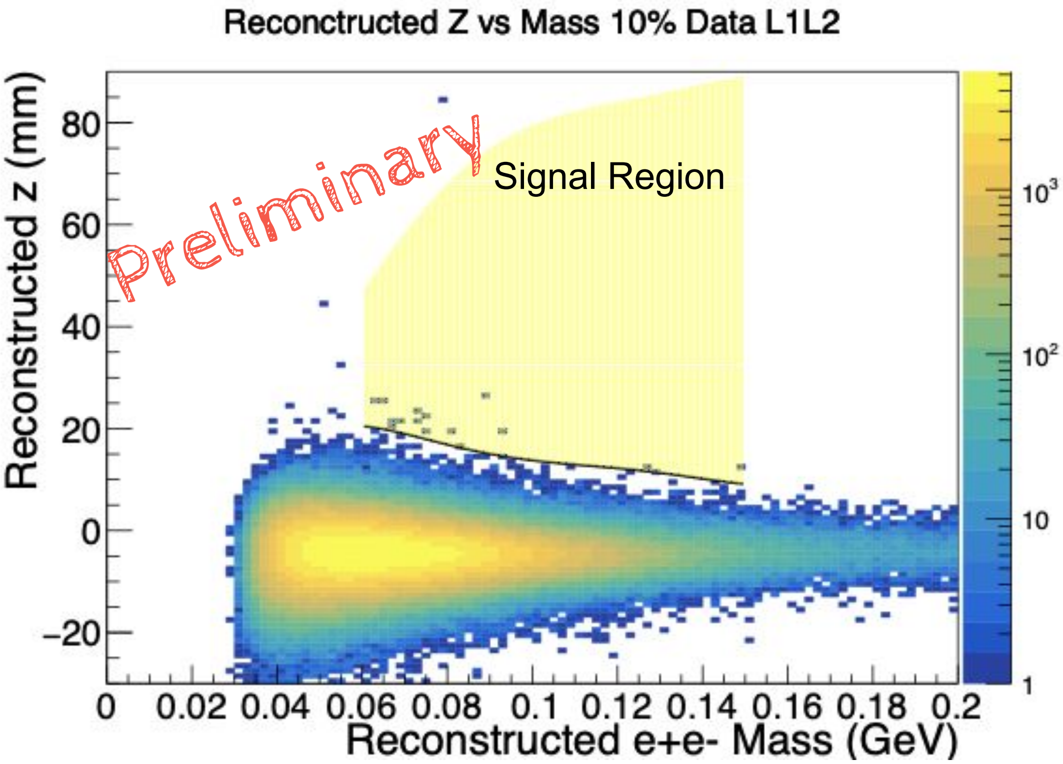




MrSolt's L1L2 Status (thesis defense)

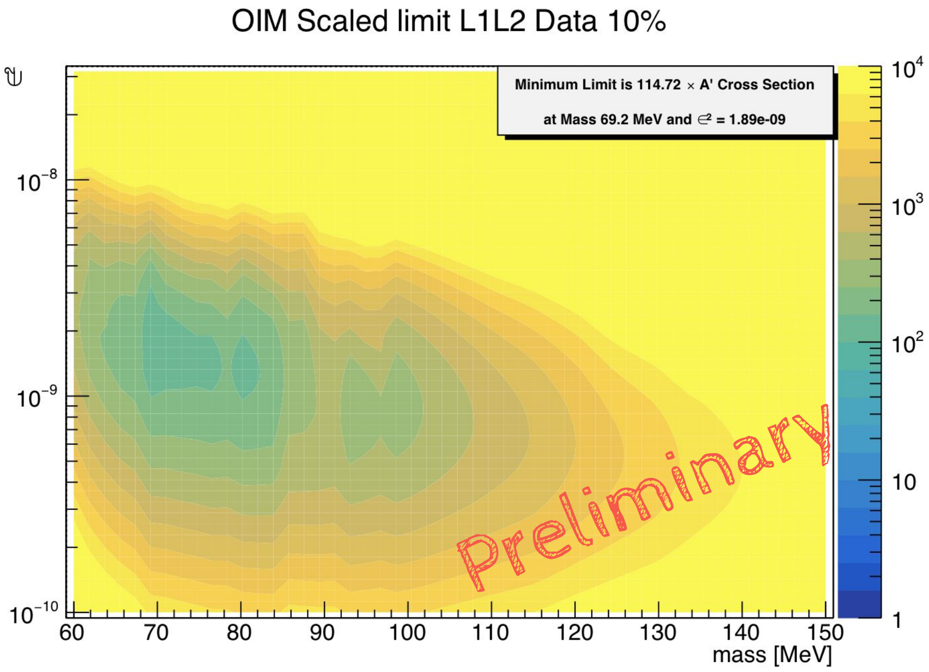
A peak of 0.21 A′ events is expected in the full L1L2 dataset, about 50% of the overall signal yield

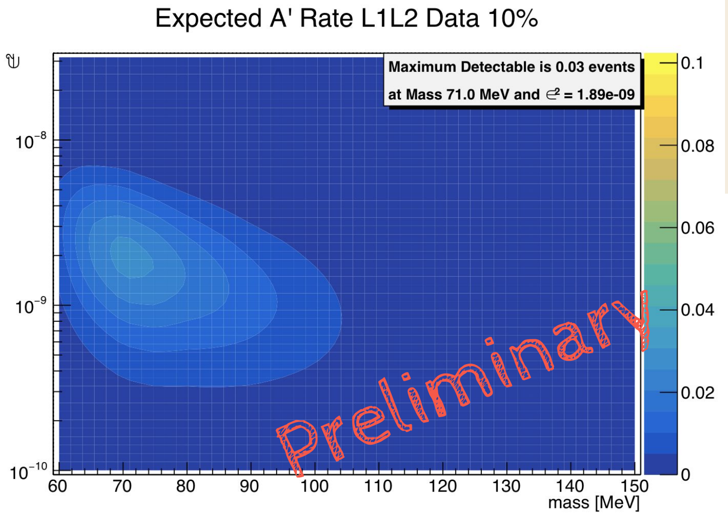
- L1L2 is currently blinded
- Data/MC discrepancies need to be resolved in order to unblind
- Many of these events don't appear "signal-like"
- What about the event at ~85 mm? See L2L2 (next slide)

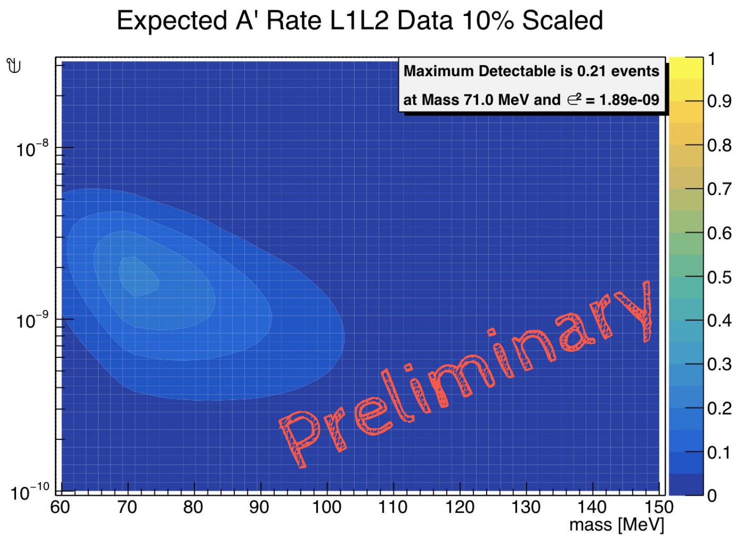


L1L2 "Results"

A peak of 0.21 A′ events is expected in the full L1L2 dataset, about 50% of the overall signal yield







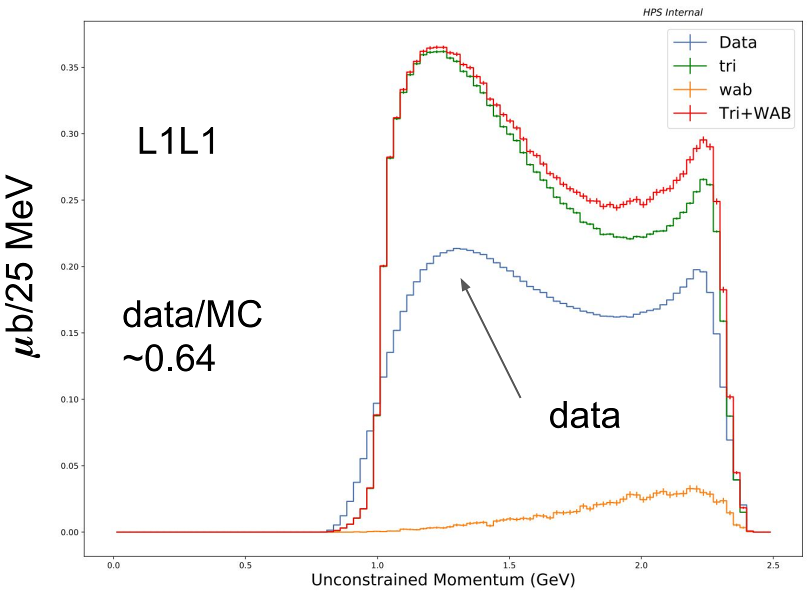
Data & MC Samples

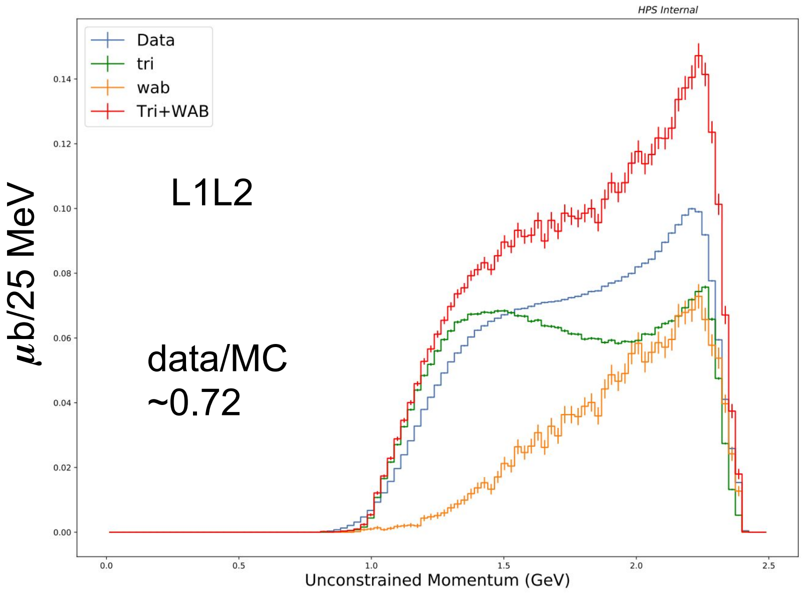
- Everything I use was reconstructed with 2016 pass-4
- For data, I’m looking at the 10% unblind samples
    - I also have a full run (8099) reconstructed with loose cluster deltaT to study accidentals
- I use a variety of MC Samples:
    - Tritrig-beam & WAB-beam use Tongtong’s centrally produced samples
    - Large (~3x data) tritrig (no beam) sample generated by Takashi/MattS
    - Large (~1x data) tritrig-wab-beam sample generated by Takashi/MattS

Hit-killing + re-recon

- To get ~ correct rate of L1L2 events in MC, need to do “L1 hit killing” and the right way to do this is to kill hits and then do track finding/fitting
  - The way we did it in BH analysis is really just a re-classification, no track refitting
  - Ideally we would do this based on sensor-position level hit inefficiency (done by “track tag-probe” i.e. tracking in L2-6, projecting to L1 sensors and checking whether hit is there or no)...but this doesn’t seem to give desired L1 mishit rates
  - Instead, use same track slope-based, WAB electron-based inefficiency used in BH to kill L1 hits and then re-find/fit tracks
  - When looking up inefficiency, I adjust the track slopes based on their V0-reconstructed Z position (larger +ive Z position→ larger slope)
- Short talk here on this hit killing
- Everything I show here uses this hit killing

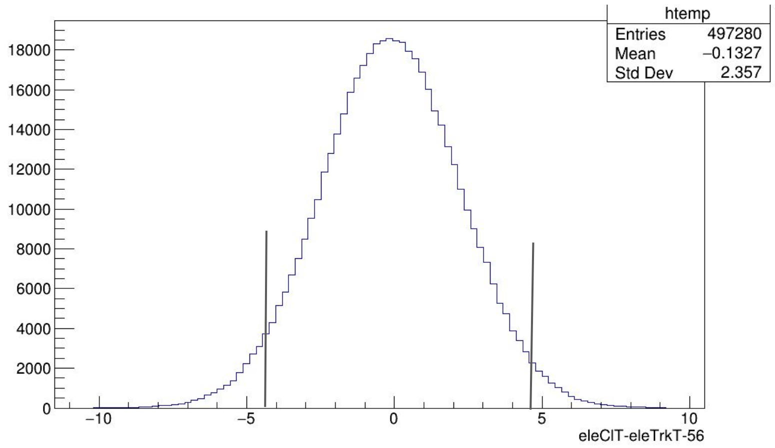
Data & MC Rates: Preselection

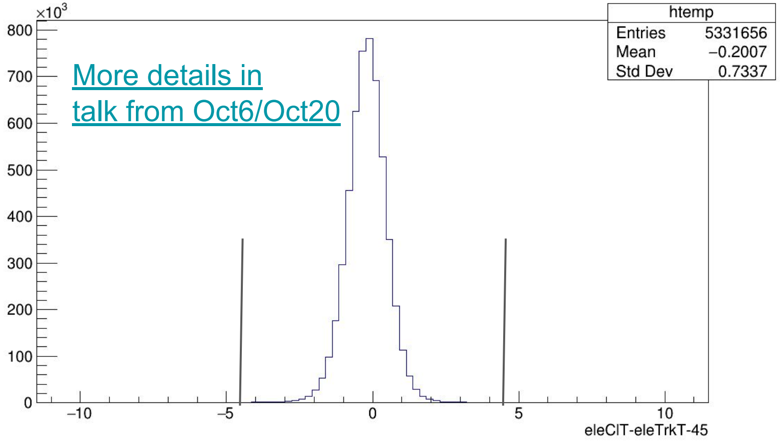




The MC are normalized to the expected rates given generated cross-sections
At preselection, data-MC rate agreement not good...

Looking closer at some data/MC comparisons...



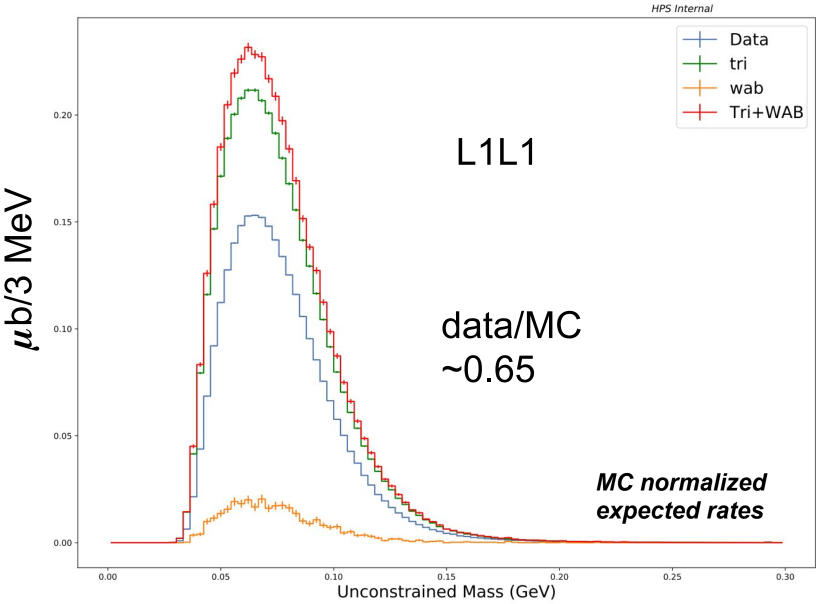


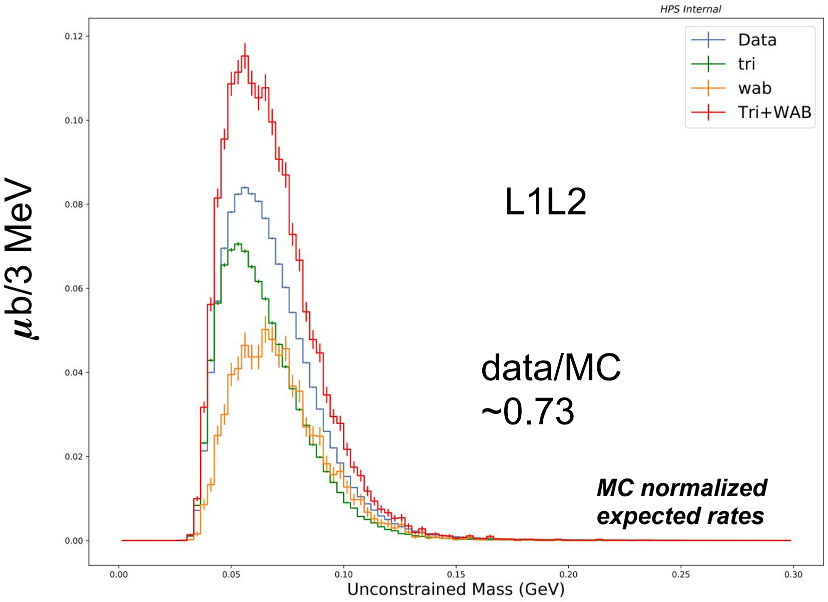
The preselection makes a cut at max(abs(eleT,posT))<4.5ns….this is pretty tight in data but plenty loose in MC. Relative efficiency of this cut (data/MC) ~ 0.85. So this is one source of data/MC rate disagreement.

Similarly, the track chisq cut has relative (data/MC) ~ 0.93...there may be some other cuts that have some relative efficiency but these two variables we know to be "too good" in MC vs data.

Unfortunately, I think this means we have to scale our expected signal rates down...

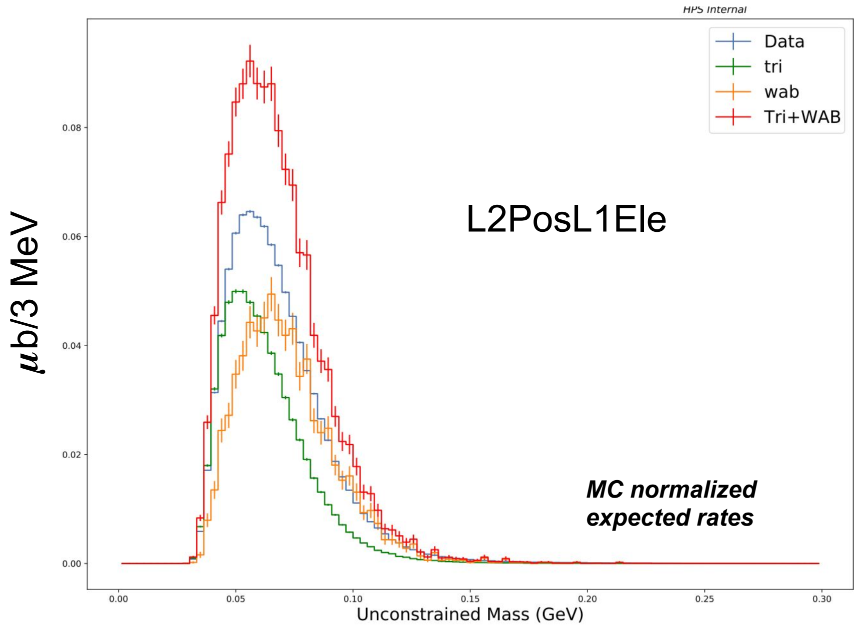
Data & MC Rates: Tight Cuts

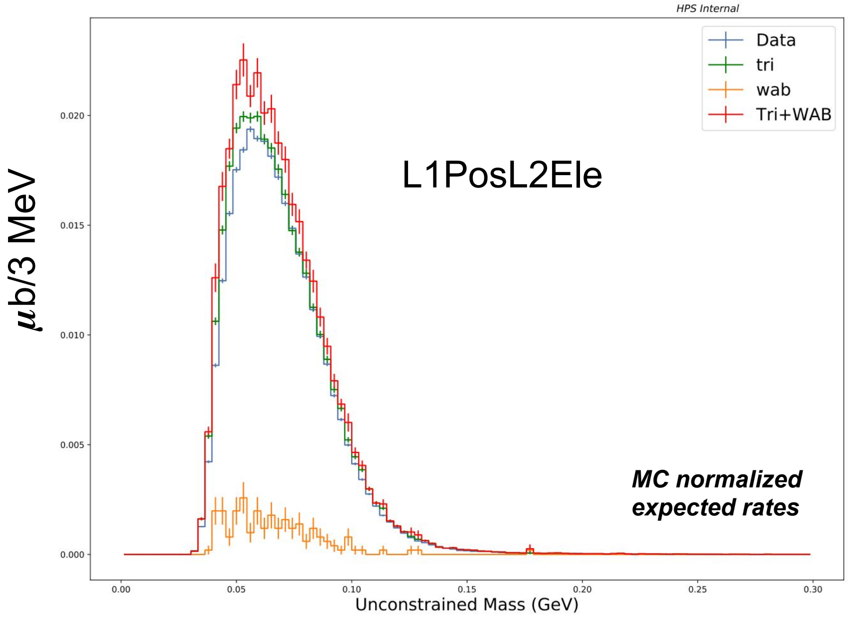




Tight selection basicly show the same data-MC rate dis-agreement … I show the mass spectrum here since we have PSum>0.8*EBeam in the tight cuts.

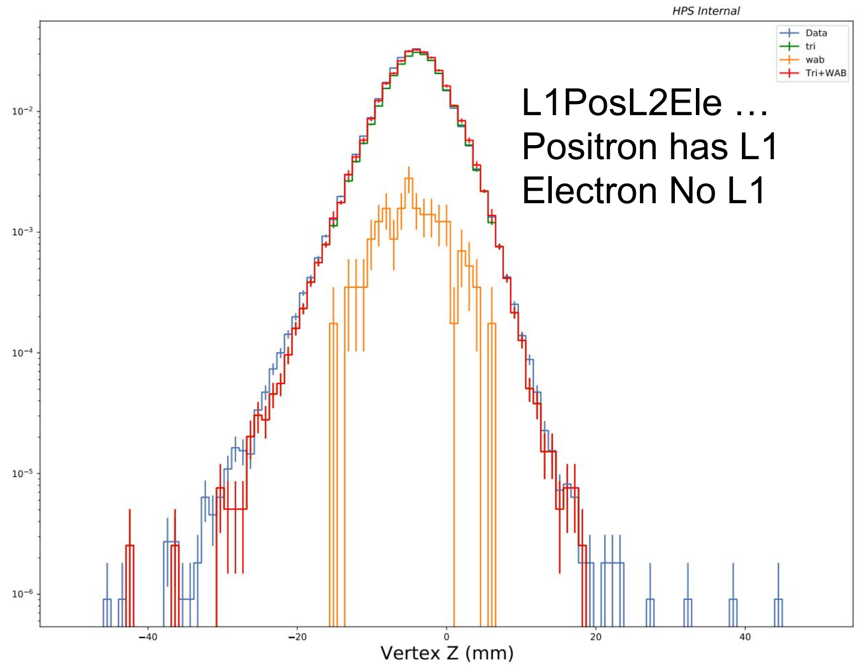
L1L2 == L1PosL2Ele & L2PosL1Ele (Tight Cuts)

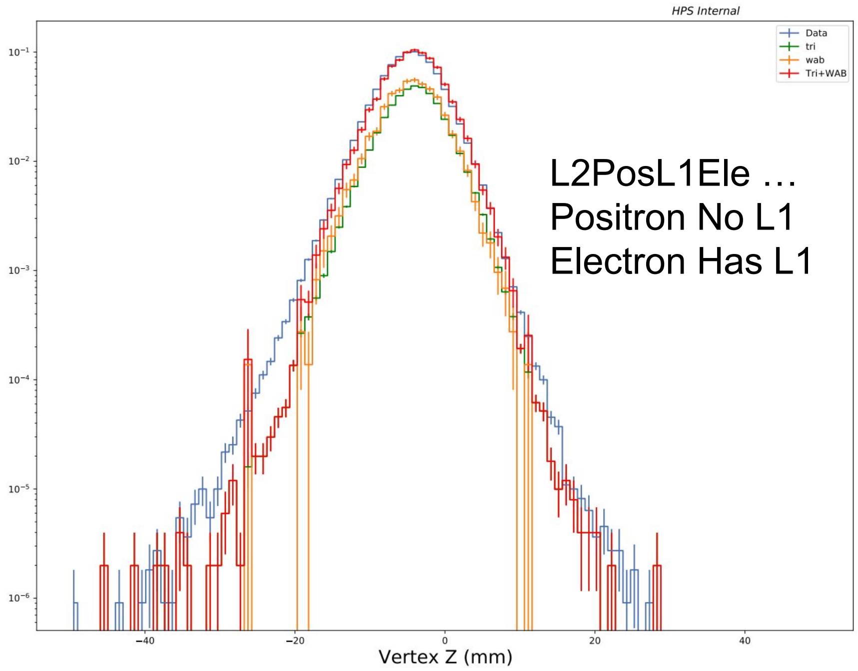




- Many more L2PosL1Ele than L1PosL2Ele … some of this is WABs, some I will get to in next few slides
- Also, we see the data/MC rates differences are different between the two...much less discrepancy in L1PosL2Ele

L1L2 z-vertex (more illuminating)

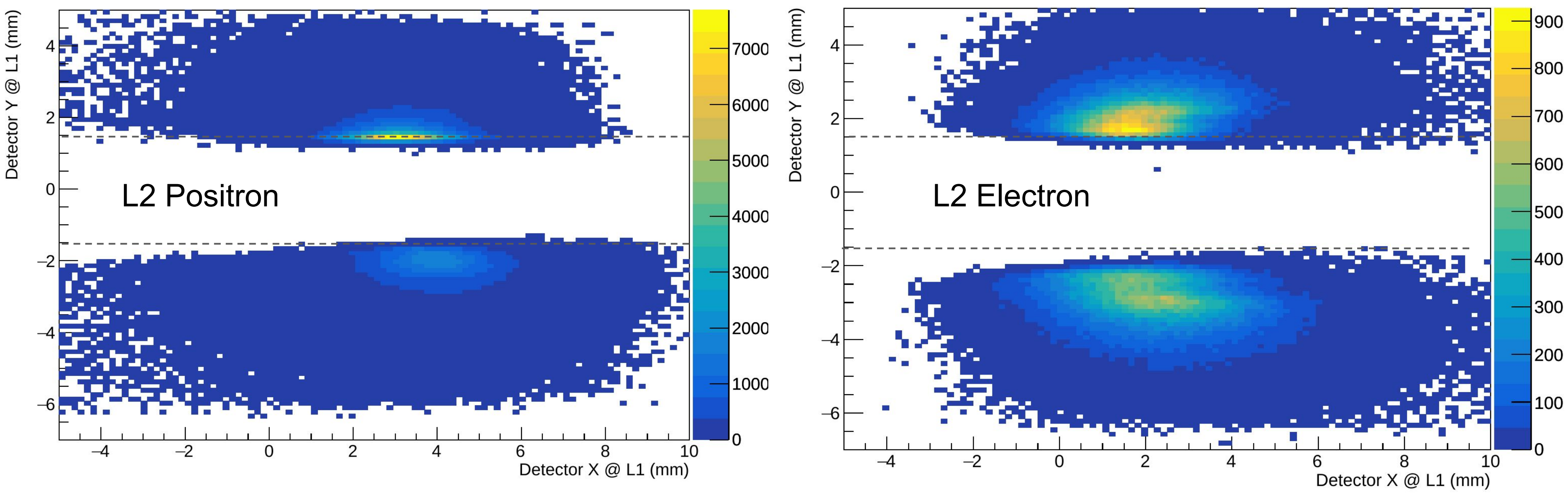




These plots are both have MC scaled to data rates for this selection (so integral of blue==red)

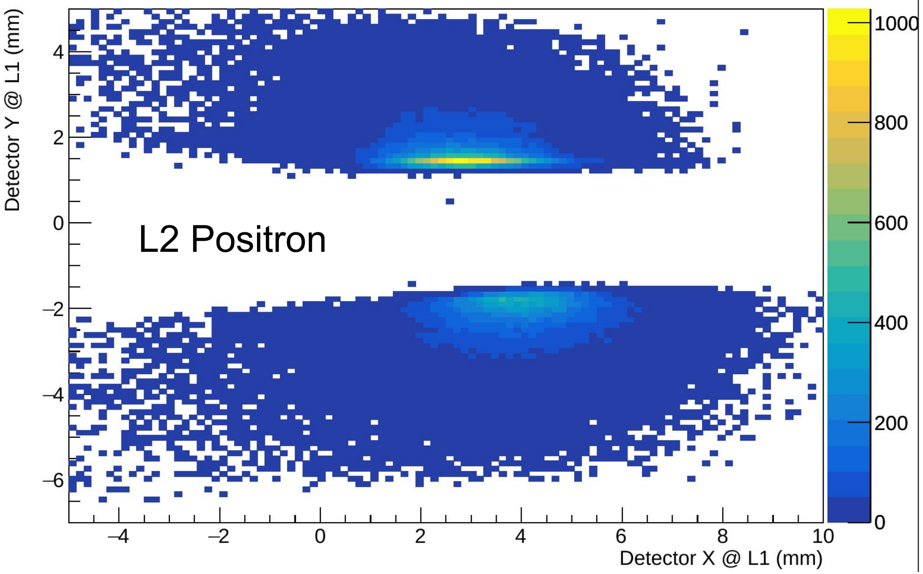
- For L2PosL1Ele, definitely see the cut off of WAB statistics in the vertexZ tail
- Since L1PosL2Ele has so few WABs relatively, don't really see cutoff..
    - Definitely see data events at z>20mm, not seen in MC...this is the small tritrig MC sample

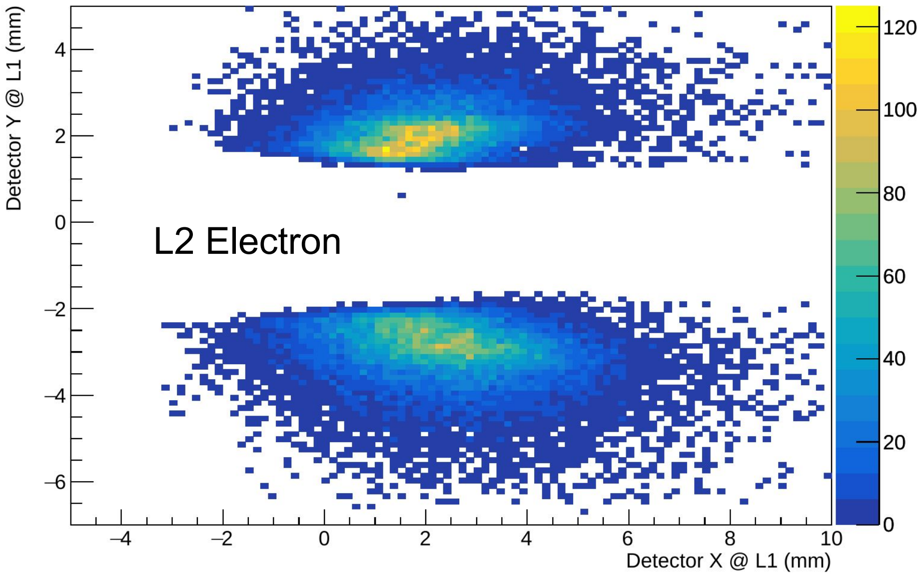
Where the lepton points in L1 (tritrig MC)



Almost all of the events point to ~ within SVT sensitive area … except maybe on top L2 Positron...big spike right at the edge of sensor.

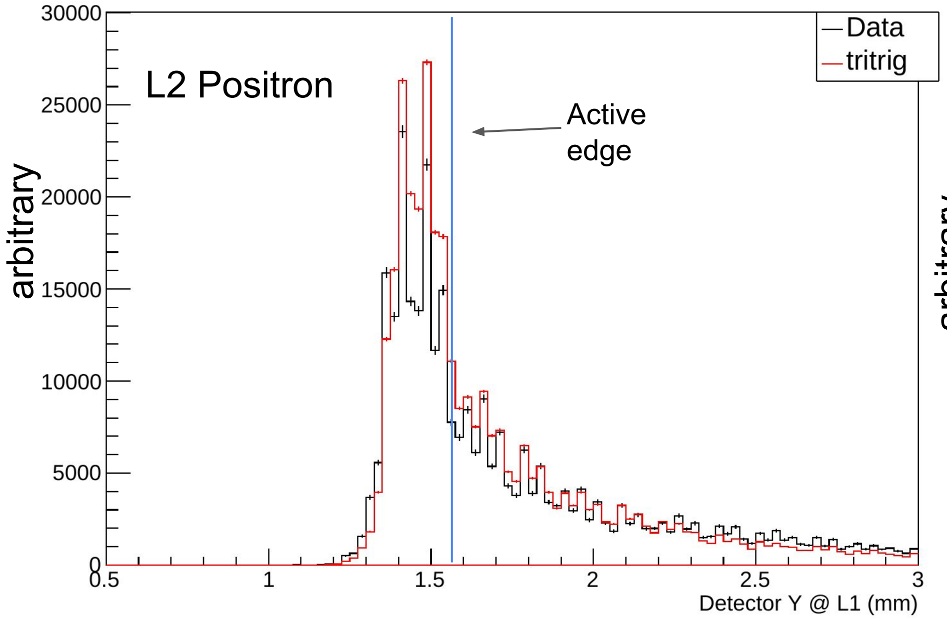
Where the lepton points in L1 (10% data)

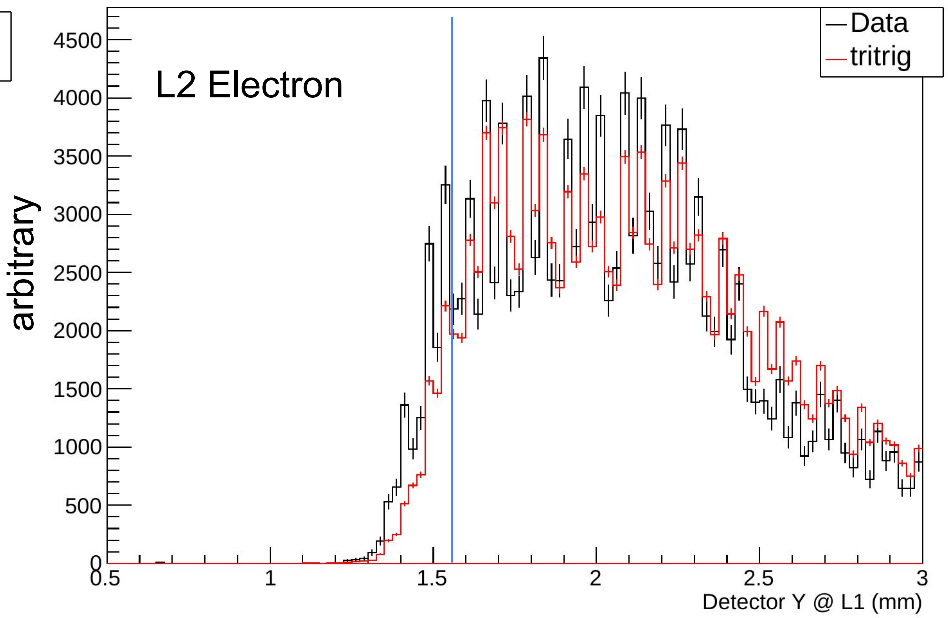




We see very similar distributions in data, which is a relief…but why the bright spot in L2-positron? ...recall that data has WABS which contribution ~half of the entries in L2-positron (but very little in L2-electron).

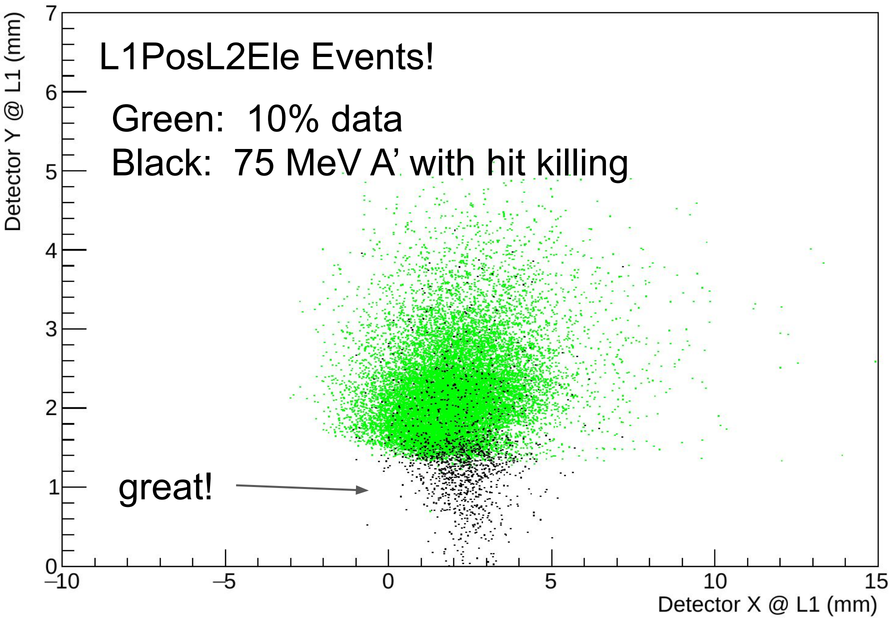
Zoom on top detector Y; compare data/tritrig

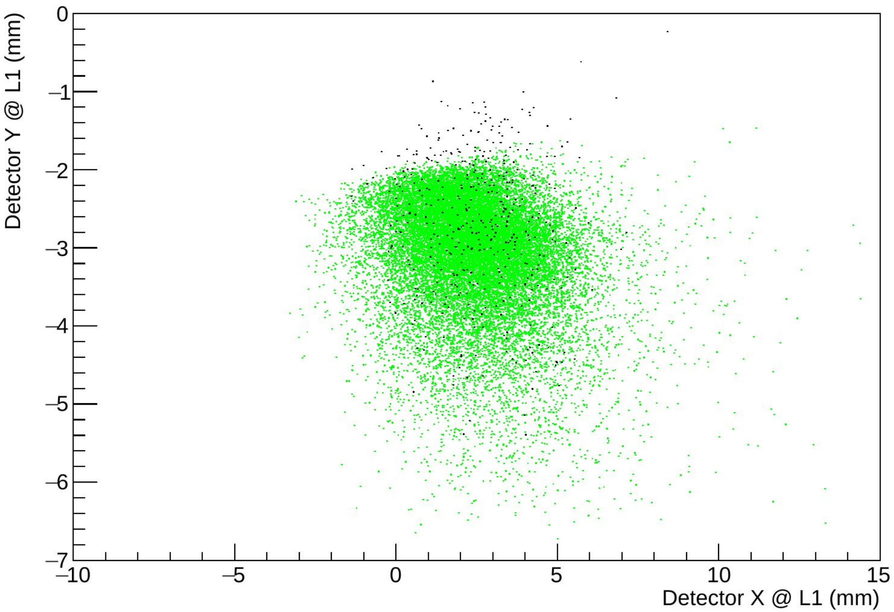




It looks like positrons part of phase space where they hit layers L2-6 but miss layer 1….at least that's the explanation I'm going with... Makes sense since stereo sensors dip into positron side.
Why not on bottom though? Because beam is low?
Beam is at ~ (-90um, -80um, -4.3mm) in MC and been tuned to data...

L1 Electron Track Extrapolation: data & A'(75) tight



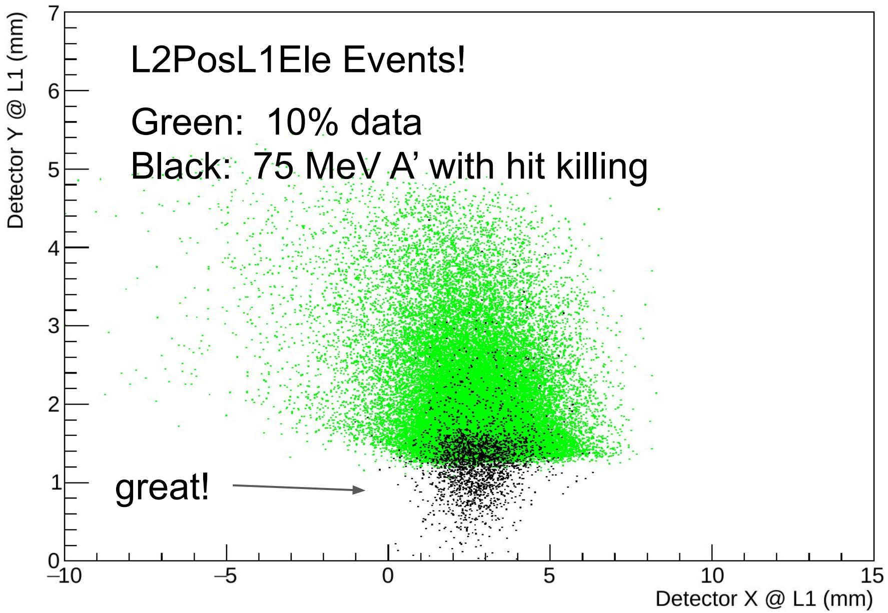


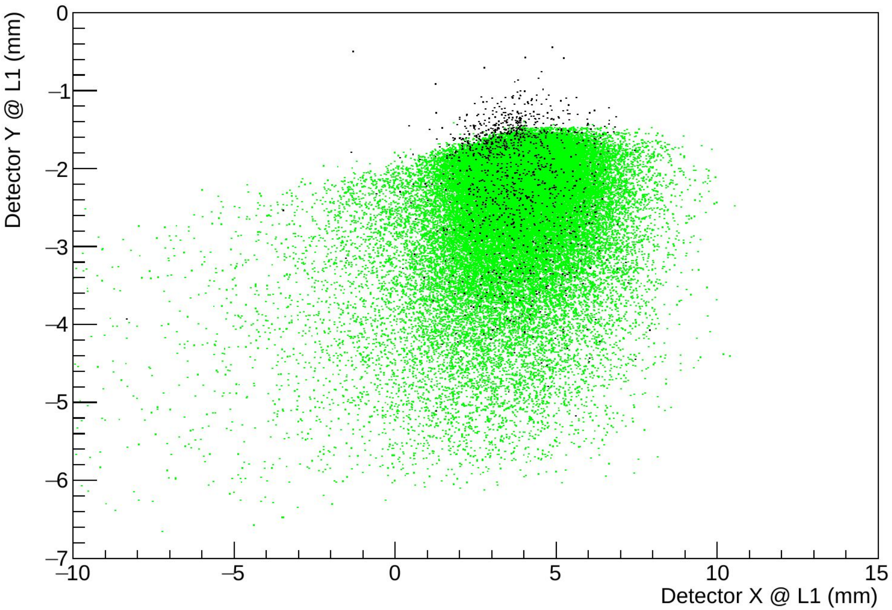
These plots are "tight" selection...

Ideally, all of the A' tracks would extrapolate out of active region and all background would be in it….not quite.

Unconstrained Vz>0mm

L1 Positron Track Extrapolation: data & A'(75) tight



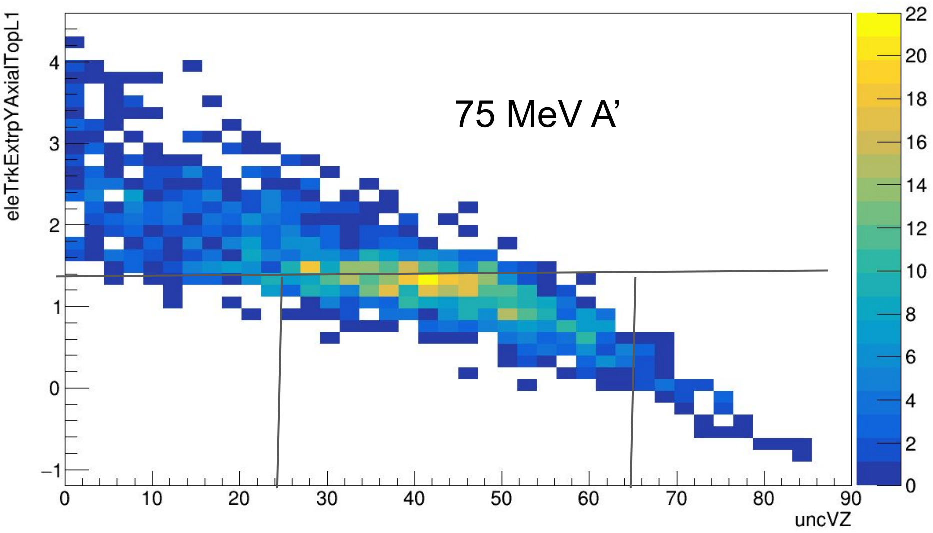


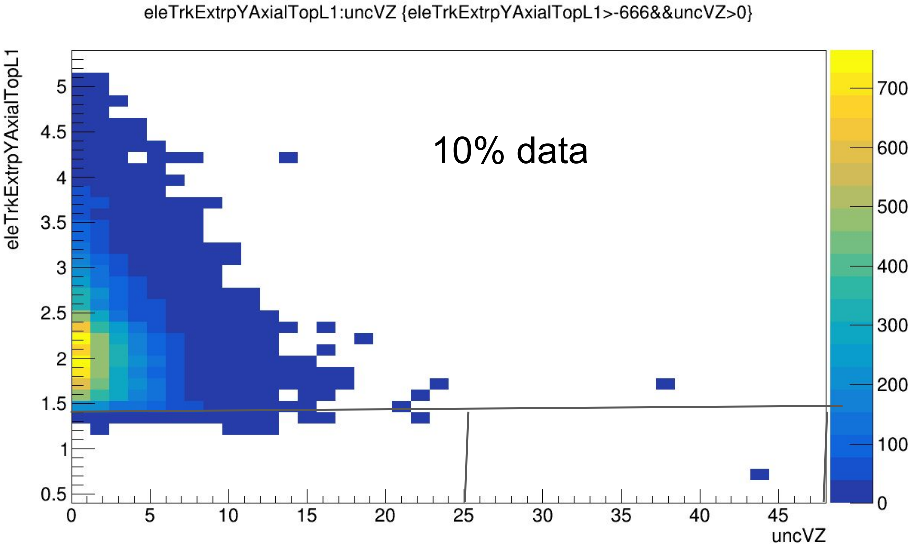
These plots are "tight" selection...

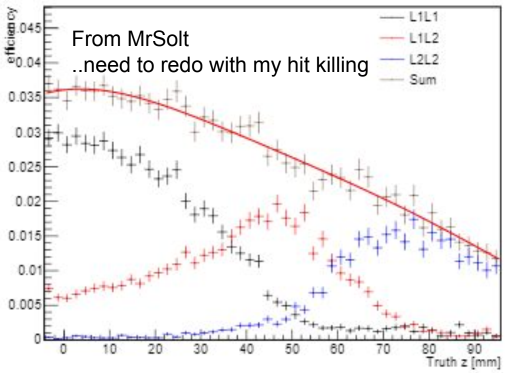
Ideally, all of the A' tracks would extrapolate out of active region and all background would be in it….not quite.

Unconstrained Vz>0mm

L1 ExtrpY vs Vz: L1PosL2Ele for A'(75) and data

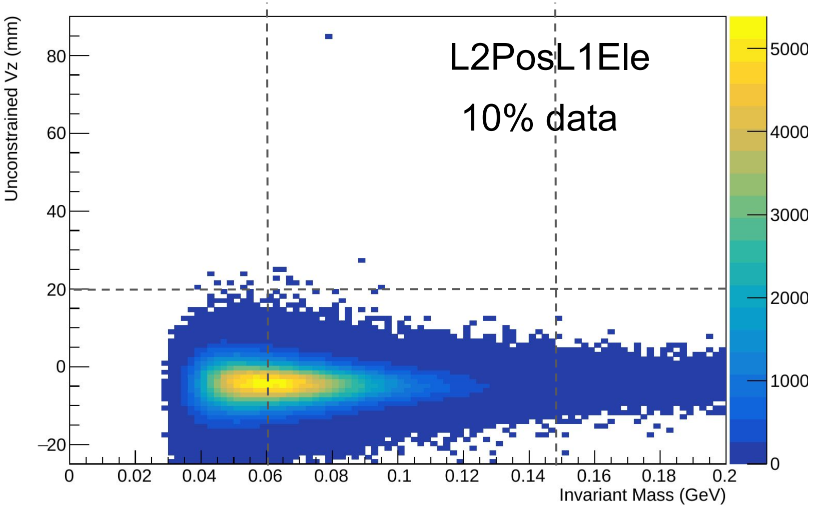


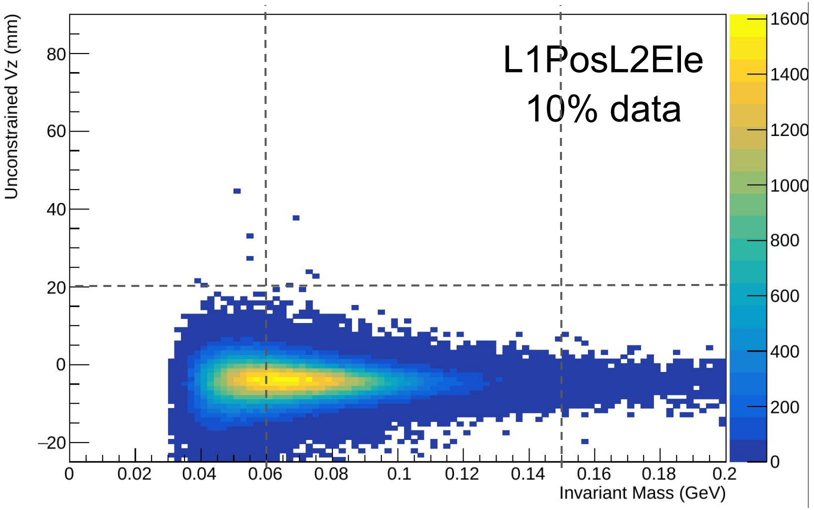




- Obviously there is strong correlation between L1-extrapolated position and z-vertex position for signal...in data, less clear (but probably still there)
- I still need to do what Jaros requested, quantify the effective Vz where we are most sensitive...

Vz vs Mass for L1L2 combos in 10% data





These are just L1L2 Vz vs Mass but separated by which particle has no L1 hit. I think this is the way to do L1L2 since the two categories have such different rates & backgrounds:

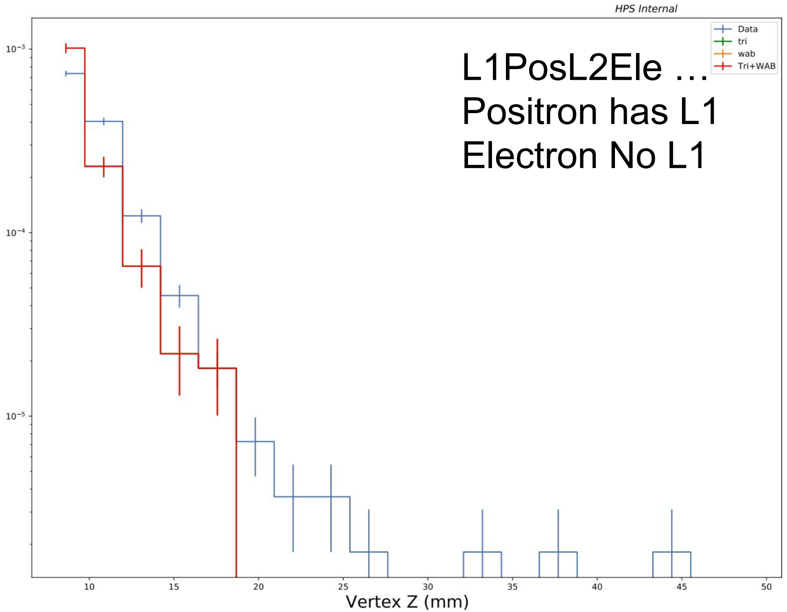
- L2PosL1Ele--cWABs+positron “hole” in top+L1 inefficiency
- L1PosL2Ele--almost entirely L1 inefficiency

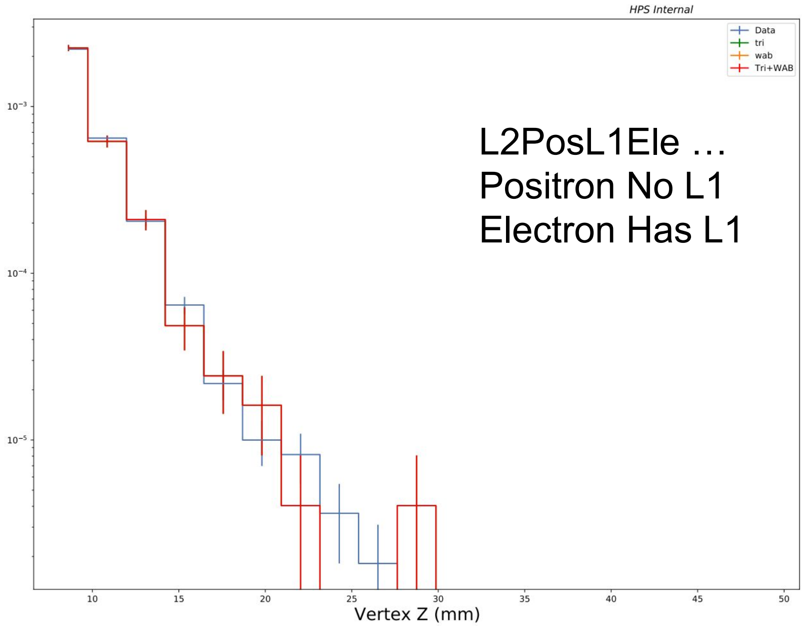
Dashed lines mark out the very, very rough sensitivity regions (didn’t do the Z-cut vs mass for these yet). It’s not clear if we could gain (i.e. lower Z-cut from this) if we removed tracks pointing to L1 active area...I’m thinking not based on Slide 21.

Words of wisdom...

- Matt Solt did a nice job with L1L1 and (almost completing) L1L2
- I think we need to adjust the signal rates down for the data/MC cut inefficiencies...
    - Other option is to open up track time, chi2 cuts and redo everything but...rather not
- Converted WABs are important for L2PosL1Ele...roughly same contribution as tridents.
    - We need more cWAB monte carlo … like 100x more.
- SVT inefficiency is a big deal, would like to reduce this (of course) but we may be able to do something smarter like looking at the raw SVT hits around the projected L1 position for likely activity
    - I’m not going to do this in earnest; ideally we’d have unfiltered SVT data
    - Using single-sensor tracking should be a big improvement for L1 efficiency (though maybe it just adds categories...
- I think separating L1L2 into 2 components is probably the way to go
- All of this is very dependent on geometry! Much more so than L1L1...this is not good but it does look like we did ok in 2016

L1L2 z-vertex -- high +ive Z-tails





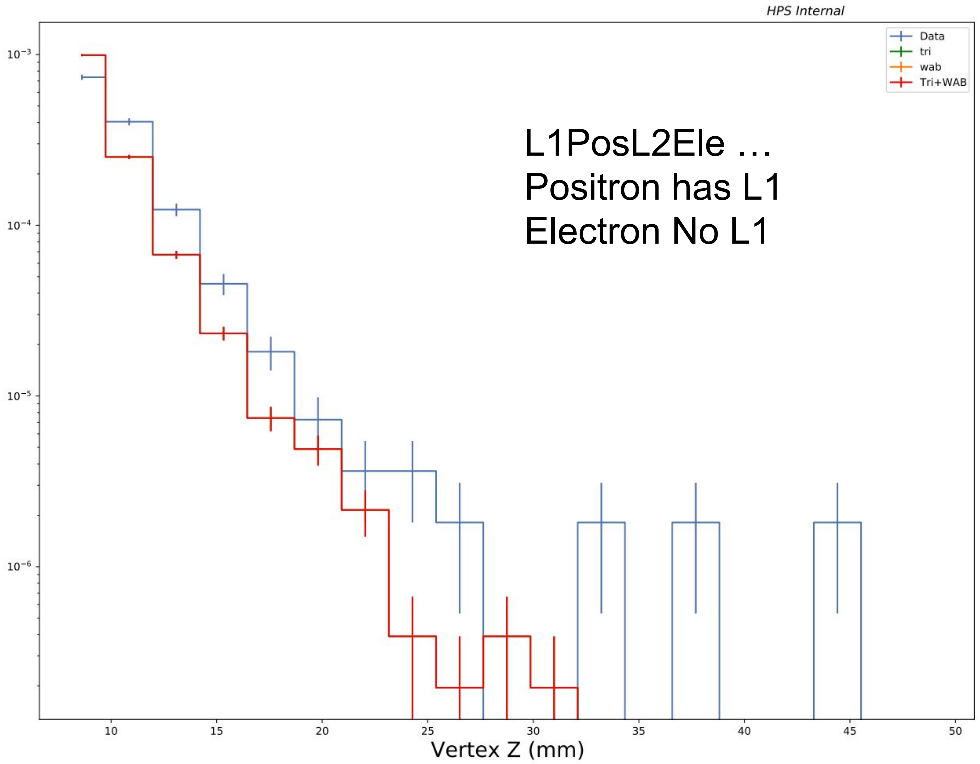
These plots are both have MC scaled to data rates for events>7.5mm

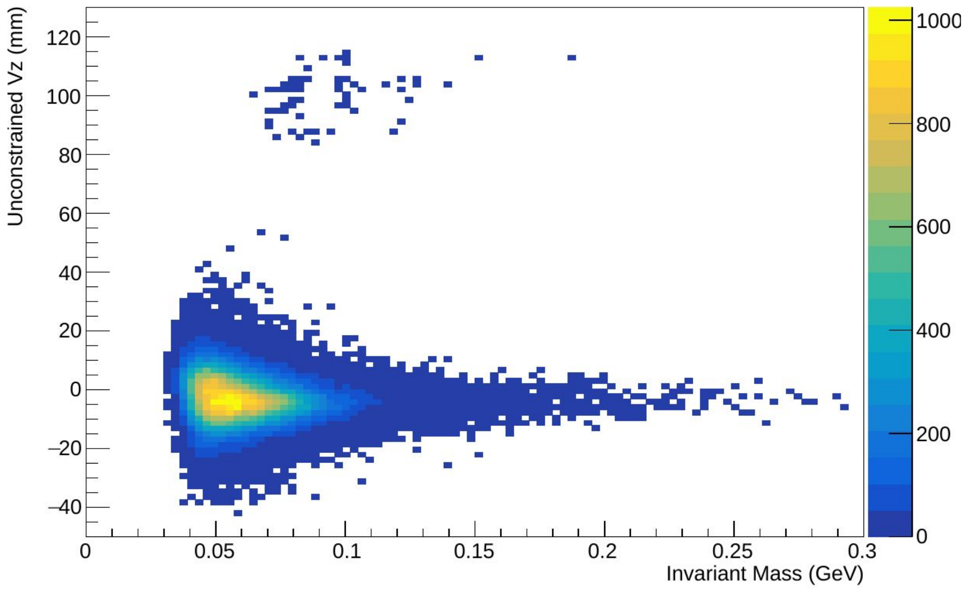
- For L2PosL1Ele, actually looks ok, but MC probably would be higher with more generated WABs
- L1PosL2Ele...ough...not good. MC falls off much faster than MC and doesn't get high Z tail at all.

L1PosL2Ele with large tritrig (no beam) sample

Using the large tritrig sample ~x3 data tridents (which does not have beam overlay) fills in from ~20-30mm but still not at the rate we see in data..

...I'm planning on looking at these events in more detail and check for pathologies. I'm not super hopeful.




Unconstrained Vz (mm)
120
100
80
60
40
20
0
−20
−40
0
0.05
0.1
0.15
0.2
0.25
0.3
Invariant Mass (GeV)
1000
800
600
400
200
0