Vertexing 2016: Final Results

Matt Graham & Matt Solt

June 2021 Collab Meeting

June 25, 2021

Overview

- Quickly review the entire vertexing analysis from front to back
- We've unblinded both L1L1 and L1L2 with the full 100% dataset -- I'll go over those results
  - MattS already unblinded L1L1 for his thesis though when I took over I only looked at the 10% sample anyway
- I'm mostly done with systematic errors -- I'll go through them as well
- This analysis is documented in a physics analysis note at:
  - Vertexing Note Link

Data and MC events and recon

- Data: use the golden runs listed at Golden Runs List
  - Data were processed using pass4 version of hps-java, more details at reco pass page
- MC: many samples used with hps-java tag v4.5
  - Displace A’, rad-beam, tritrig-beam, wab-beam, large samples of tritrig-(wab)-beam
  - Change from MattS, I performed hit killing at the reconstruction level and then re-reconstructed tracks/V0s
    - This has a pretty small effect at the end of the day
  - There was an issue with Matt Solt’s WAB and tritrig samples where tighter MOUSE level cuts were used in reco...tighter than we used in analysis.
    - This gave a ~30% higher radiative fraction (rad events had correct cuts)
    - This is by far the biggest difference between the two analyses

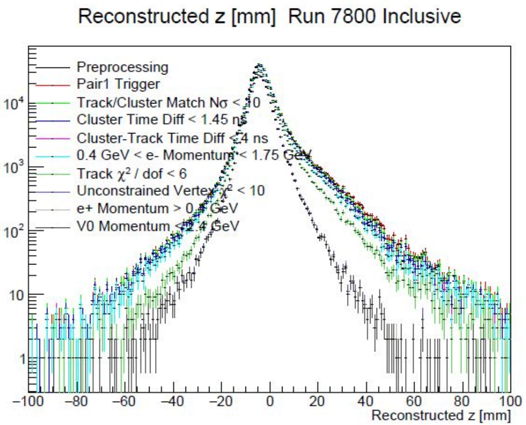
Preselection Cuts

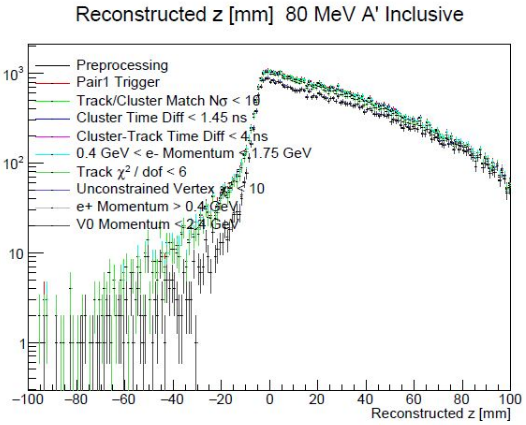
Cut Description	Requirement
Trigger	Pair1
Track-cluster match	$\chi^2 < 10$
Cluster Time Difference	$\lvert t_{e^+Cluster} - t_{e^-Cluster} \rvert < 1.45$ ns
Track-Cluster Time Difference	$\lvert t_{e^+Track} - t_{e^+Cluster} -$ offset$\rvert < 4$ ns
Track-Cluster Time Difference	$\lvert t_{e^-Track} - t_{e^-Cluster} -$ offset$\rvert < 4$ 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

Some of these cuts (track-cluster time, track quality) have some data/MC efficiency differences.

This is ok, since rates are normalized to radiative fraction ***after*** these preselection cuts

Preselection Cut Flow vs V0 Z-Vertex Position





These cuts reduce the data rate by ~x2 and (80 MeV) A' signal event by ~25%. Note that the high Z tails in data are reduced by a factor of ~x20 while the cuts are roughly independent of V0 z for signal.

Tight Cuts

The tight cuts are (mostly) focused on reducing the high z tails and getting rid of any outlier events. They also included the radiative PSum cut.

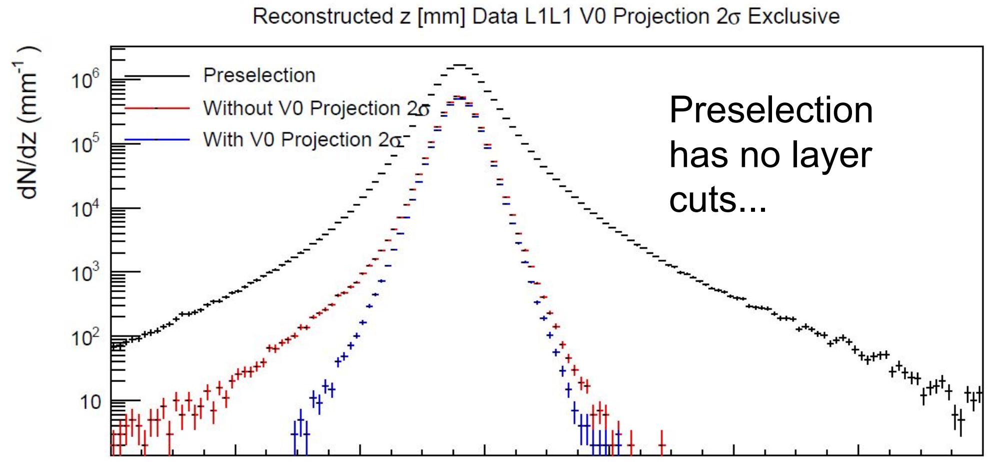
L1L1 Tight Efficiency (progressive)

	data ϵ_{tot}	tridents ϵ_{tot}	WAB ϵ_{tot}	AP ϵ_{tot}
Relative to preselection cuts with layer selection				
V_0 Projection to Target $< 2\sigma$	0.580	0.792	0.569	0.738
$V_{0p} > 1.85$GeV	0.304	0.274	0.413	0.578
Isolation Cut	0.287	0.268	0.401	0.520
Impact Parameter Cut	0.270	0.268	0.399	0.492

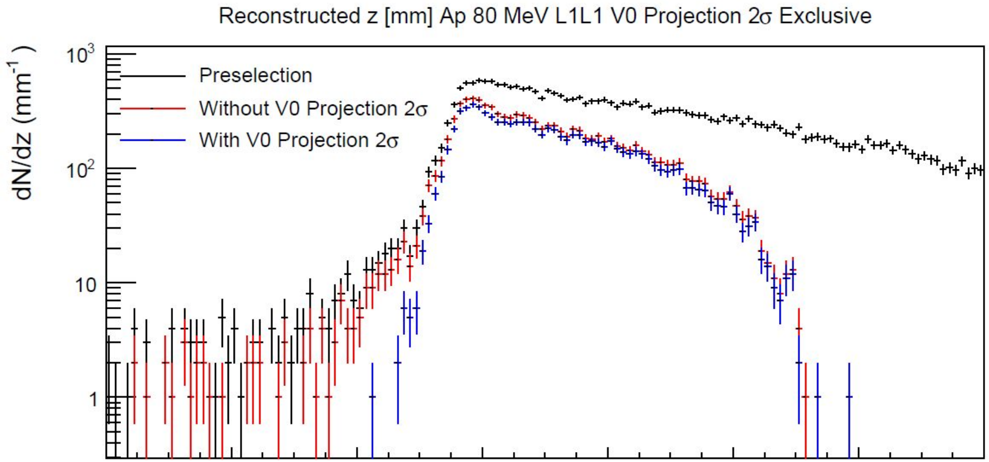
L1L2 Tight Efficiency (progressive)

	data ϵ_{tot}	tridents ϵ_{tot}	WAB ϵ_{tot}	AP ϵ_{tot}
Relative to preselection cuts with layer selection				
V_0 Projection to Target $< 2\sigma$	0.580	0.759	0.724	0.741
$V_{0p} > 1.85$GeV	0.304	0.340	0.521	0.631
Isolation Cut	0.287	0.334	0.489	0.551
Impact Parameter Cut	0.270	0.315	0.457	0.505

Tight Cuts: V0 Projection

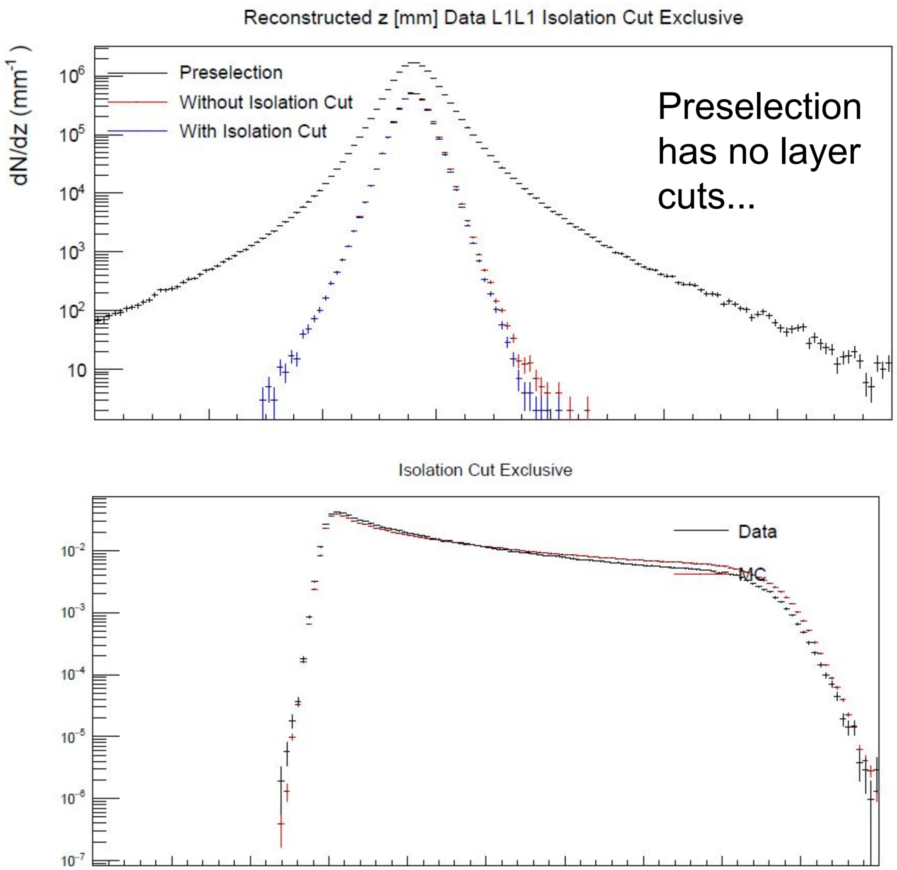


Preselection has no layer cuts...



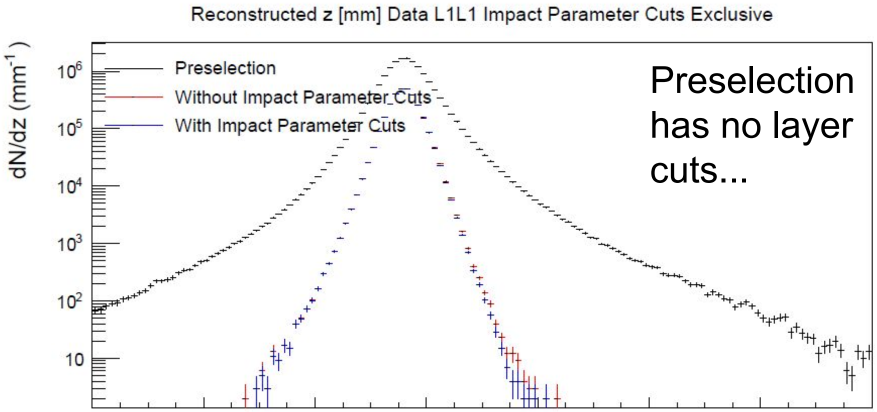
The "V0 projection" cut requires the V0 to project back to the target within a 2sigma window.

Tight Cuts: L1 Isolation

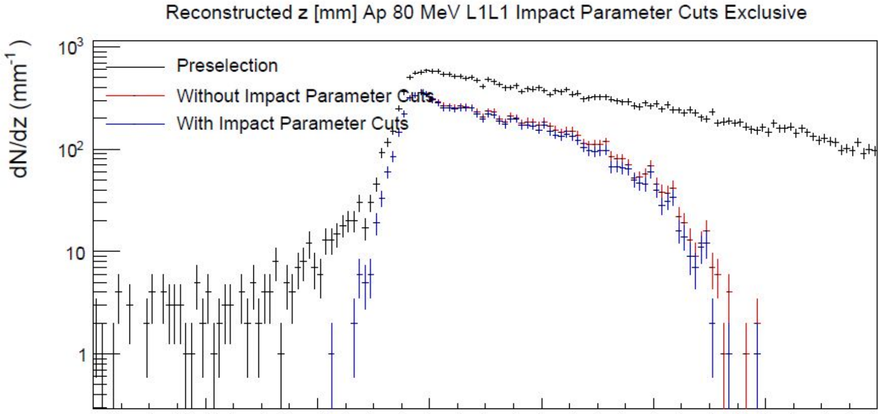


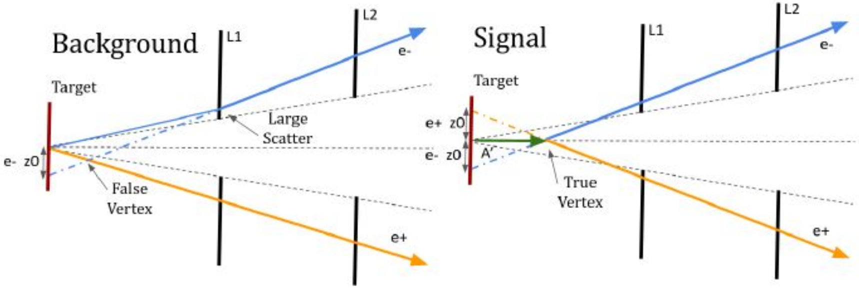
"Isolation" means there is not another hit on the L1* sensor that could be consistent with the hit-on-track. There is a ~complicated algorithm for this and it only includes hits closer to the beamline for the iso requirement. See note for more details.

Tight Cuts: Impact Parameter

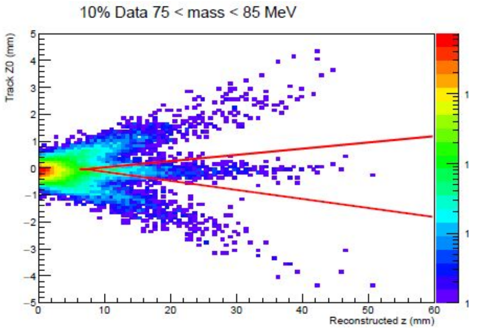


Preselection has no layer cuts...

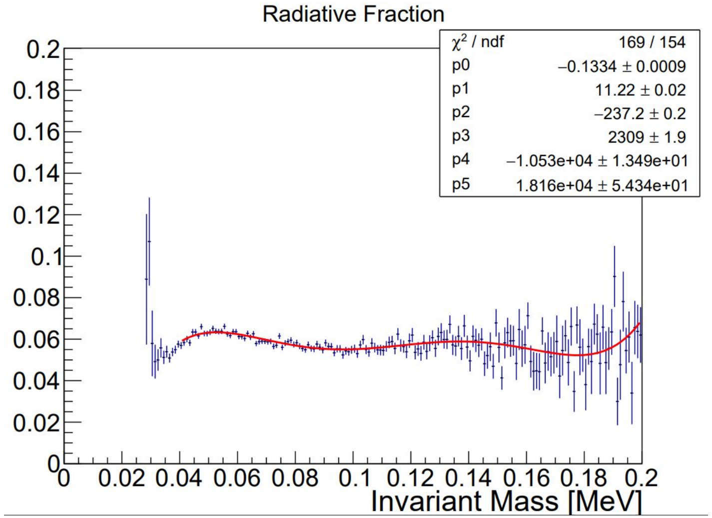


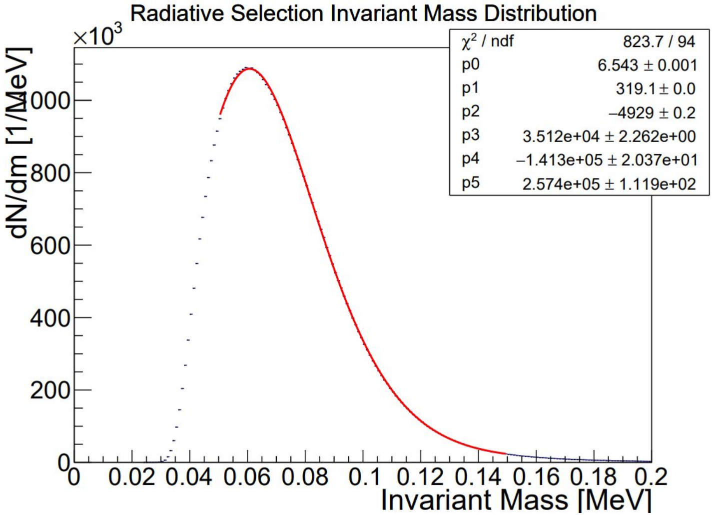


This cut removes V0s where one of the tracks really looks like it comes from the target. Uses a z-vertex-dependent cut on the Z0 of the track. Again, the form is pretty complicated, see note...



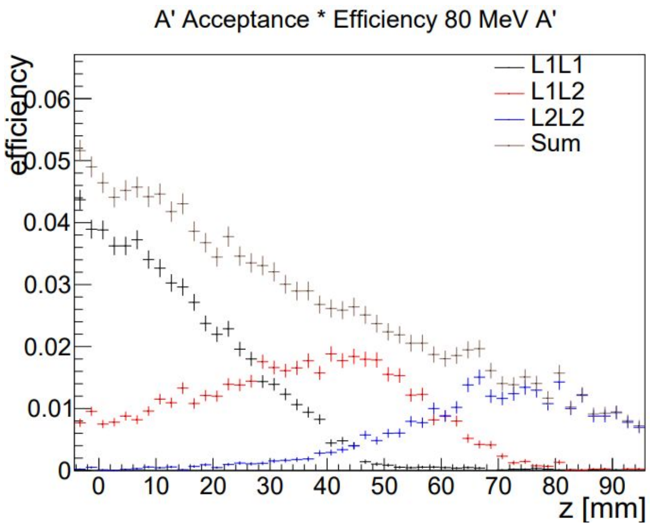
Radiative Fraction & Number of Pairs (after Preselection Cuts)



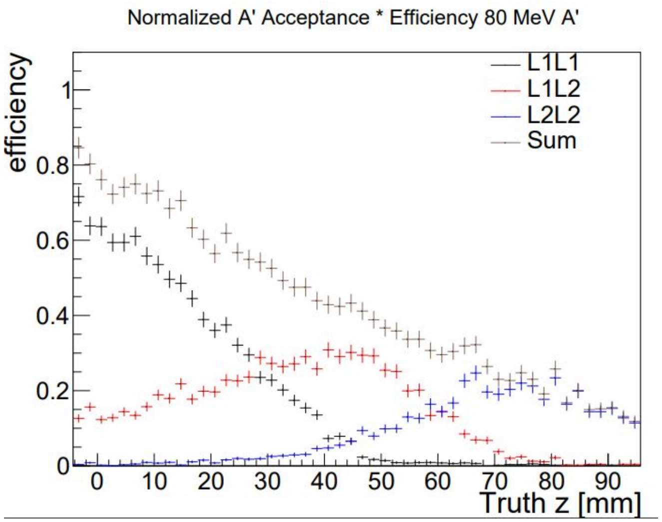


The radiative fraction (using tri-/wab-/rad-beam MC) and (number of V0s)/mass (using full unblinded data) are both obtained using preselection cuts + the radiative pSum cut. Above the the results obtained for this analysis. Note that the radFrac is ~15-30% lower than what MattSolt had in his thesis.

A’ Efficiency vs V0 Vertex Z

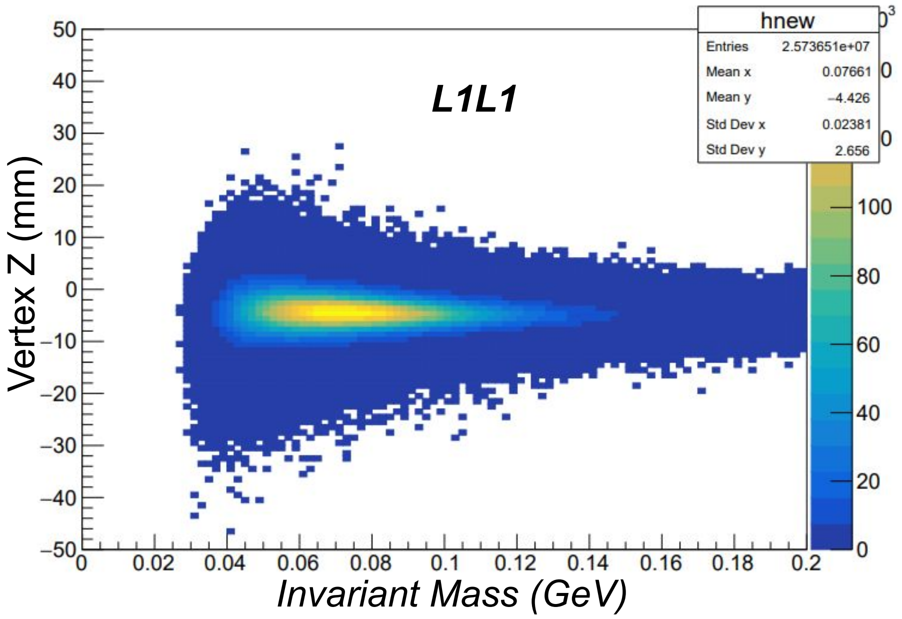


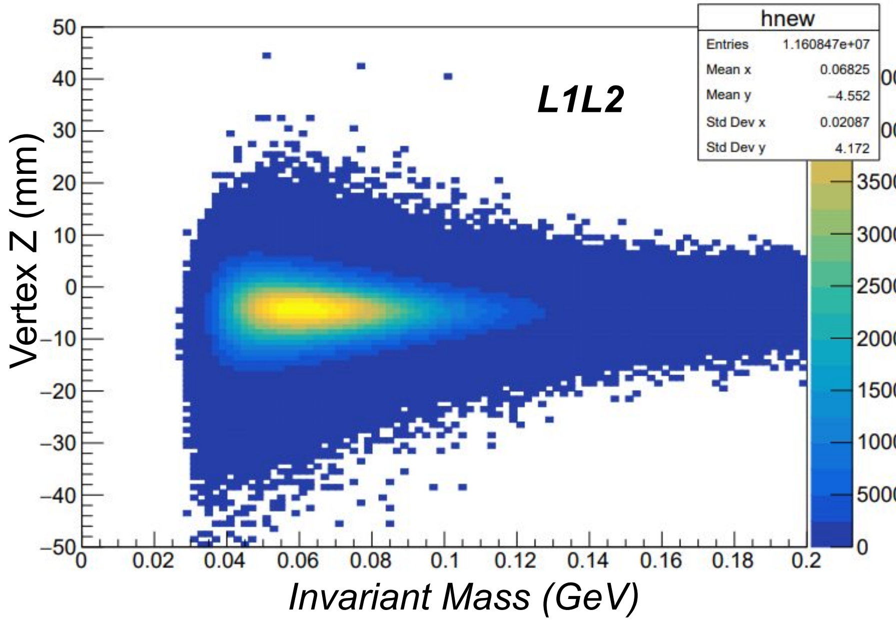
Normalized relative to preselection



The radFrac*(number of pairs) is used along with the A’ MC efficiency vs. V0 vertex Z to calculate the number of detectable A’ as a function of mass/epsilon. The efficiency vs. Z for each mass bin is scaled to be the tight selection efficiency relative to (preselection+rad psum cut) @ Z=target.

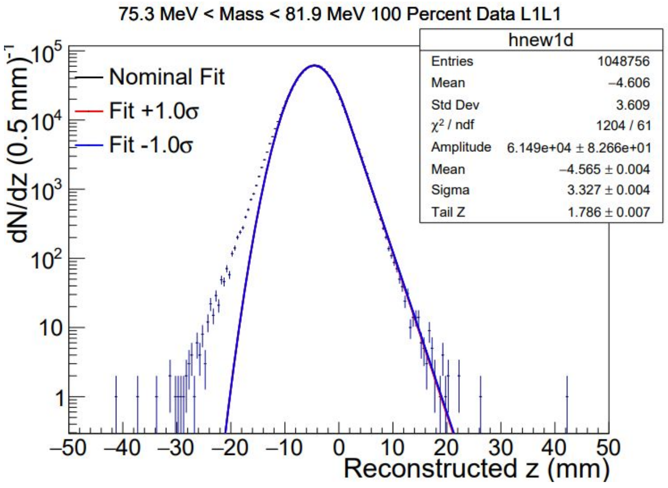
Mass vs V0 Z for final unblind sample with Tight cuts



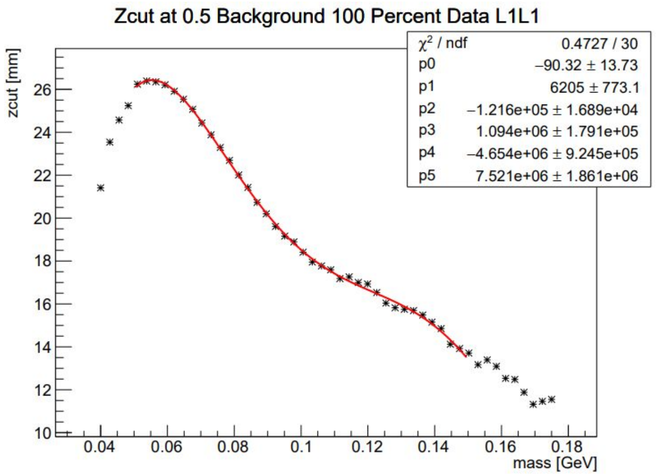


Here are the full unblind Vertex Z vs Mass plots...

V0 Vertex-Z Cut

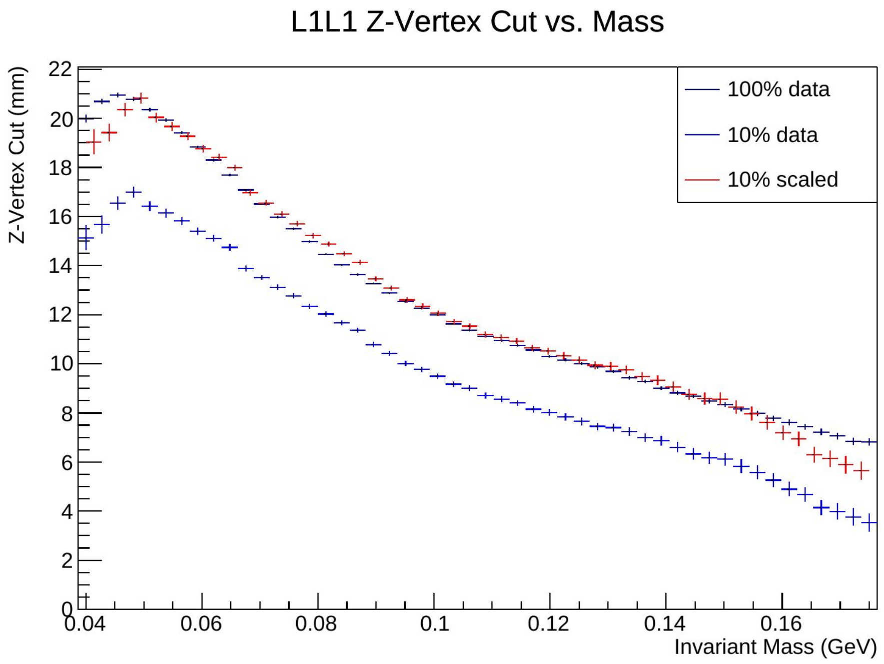


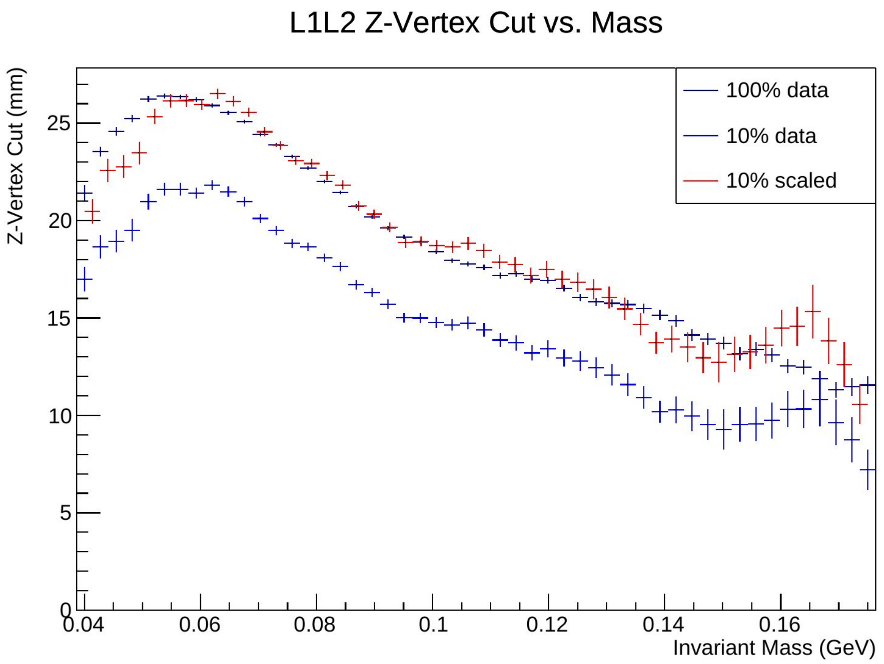
For each mass slice, get Nbkg<0.5



We make the Z-cut that defines the region where we calculate the limit. I have done some studies on the effect of z-cut on the OIM limit (it does matter some) but I decided to keep using the z-cut that gives <0.5 extrapolated background events.

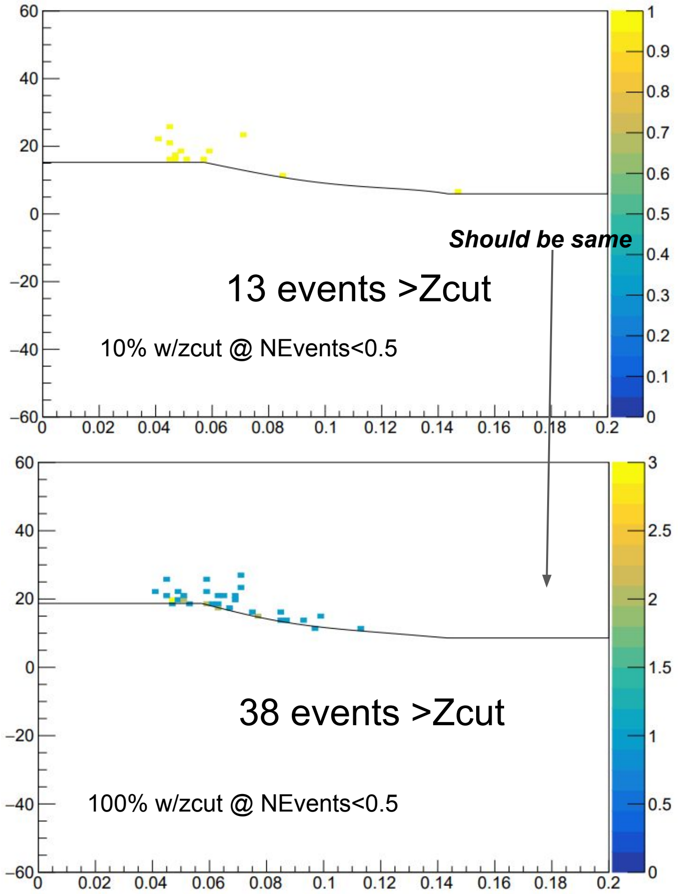
Vertex Cut for 100% unblind data



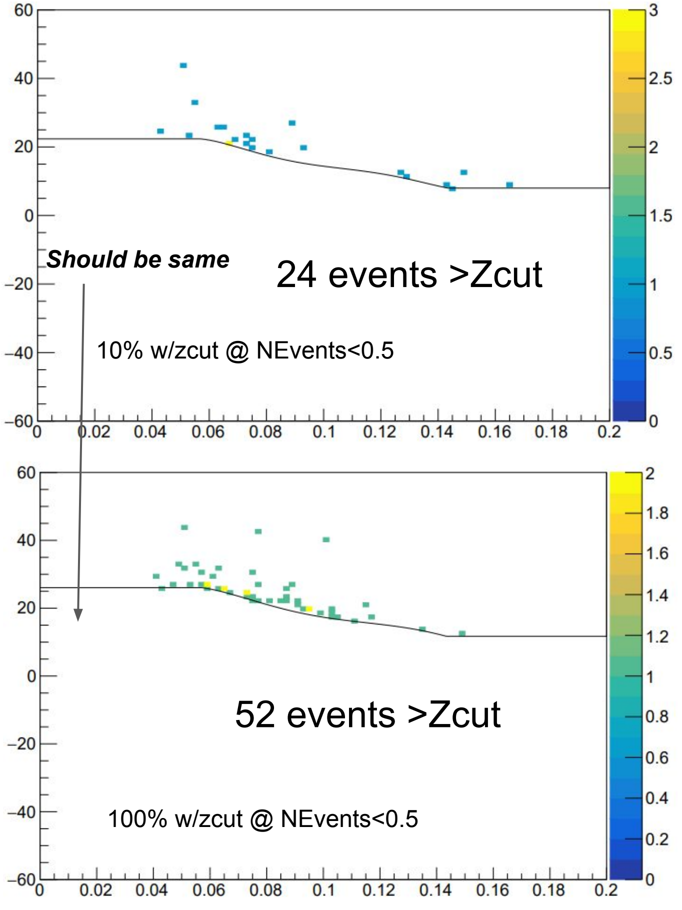


...fitting the Z-vertex distributions for 100% unblind data, cuts match up well with the scaled 10% values

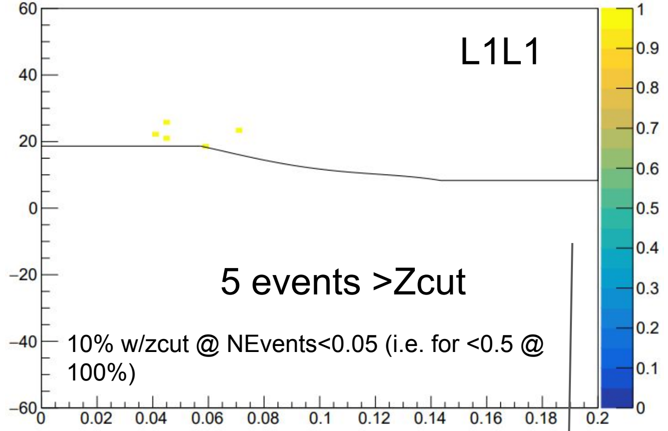
10% & 100% with their own zCut @ NBkg<0.5

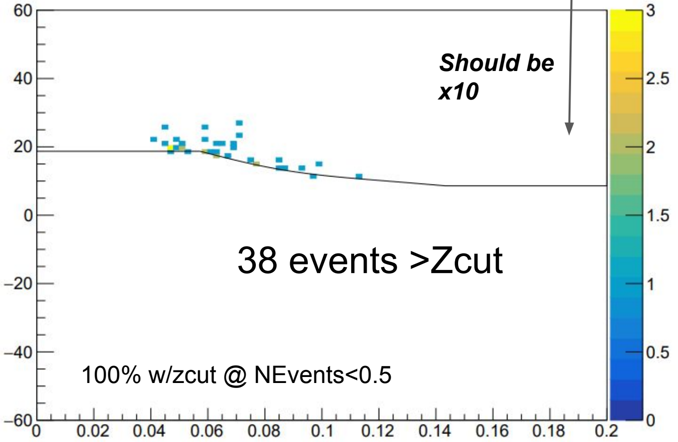


Ideally, N>ZCut would be ~ the same when cutting at projected NBkg<0.5 events… some background component not accounted for by cut

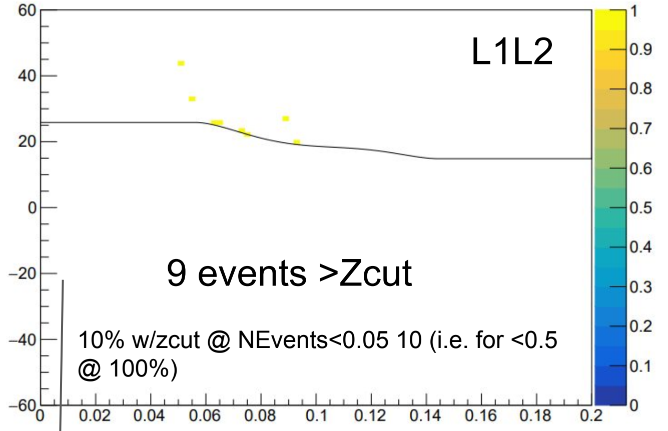


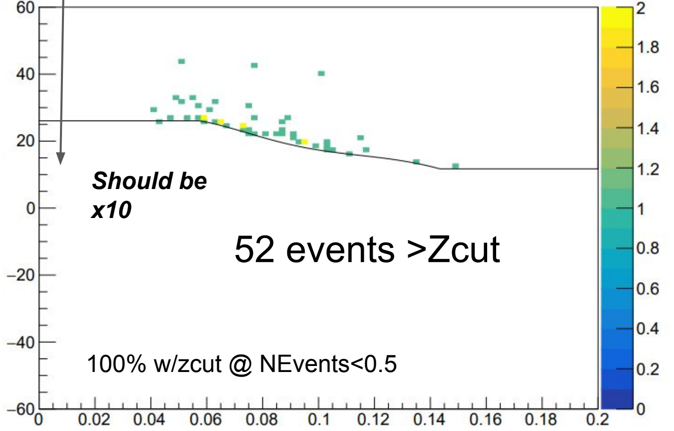
10% with zCut scaled to 100%



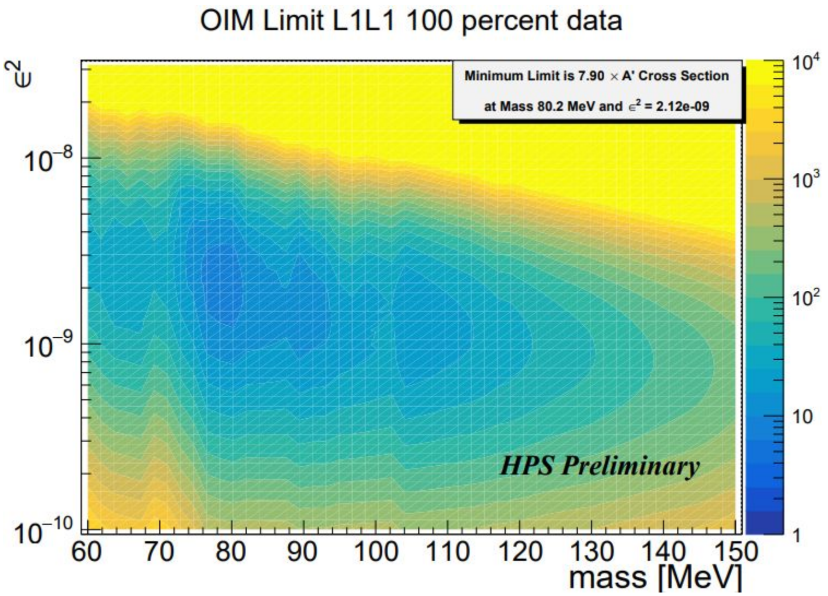


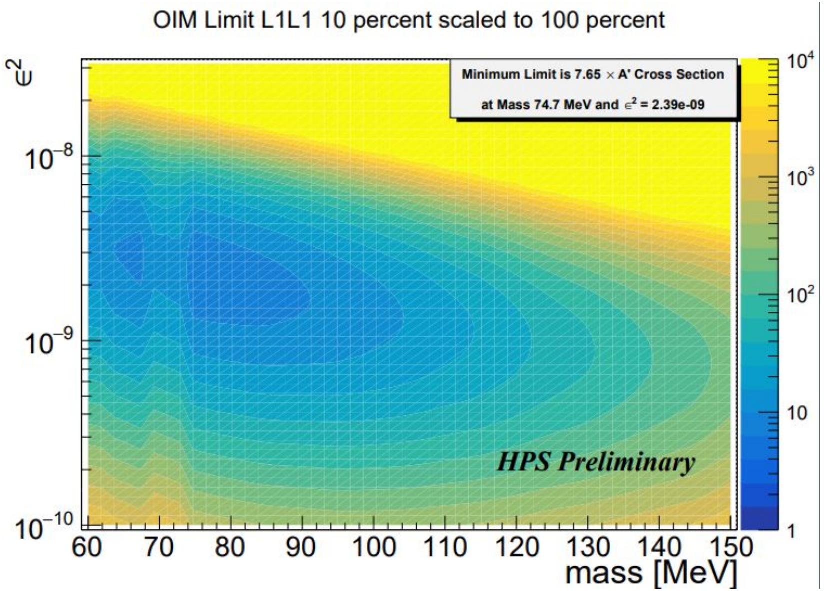
Using basically same z-cut here (see slide 2)…this background doesn't quite seem to scale with lumi, though 10% stats are low and likely just statistical.





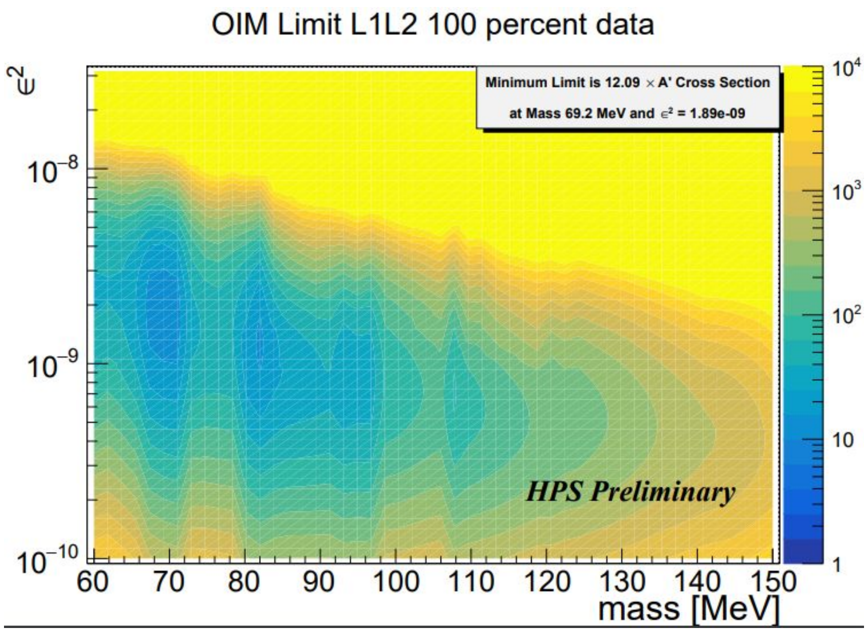
L1L1 Limits

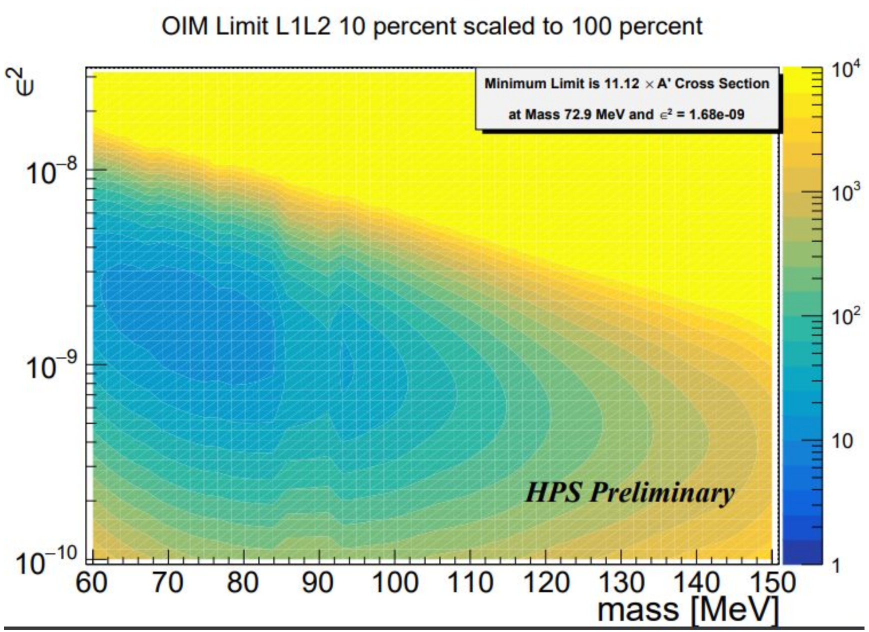




Decent agreement between unblind and scaled from 10% limits...unblind limits have more lower-limit “strips” in mass where events are

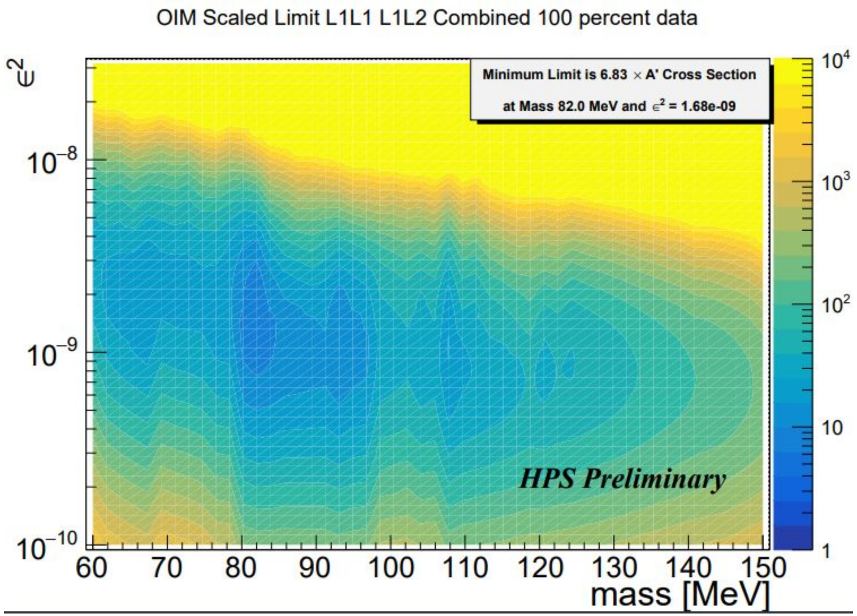
L1L2 Limits

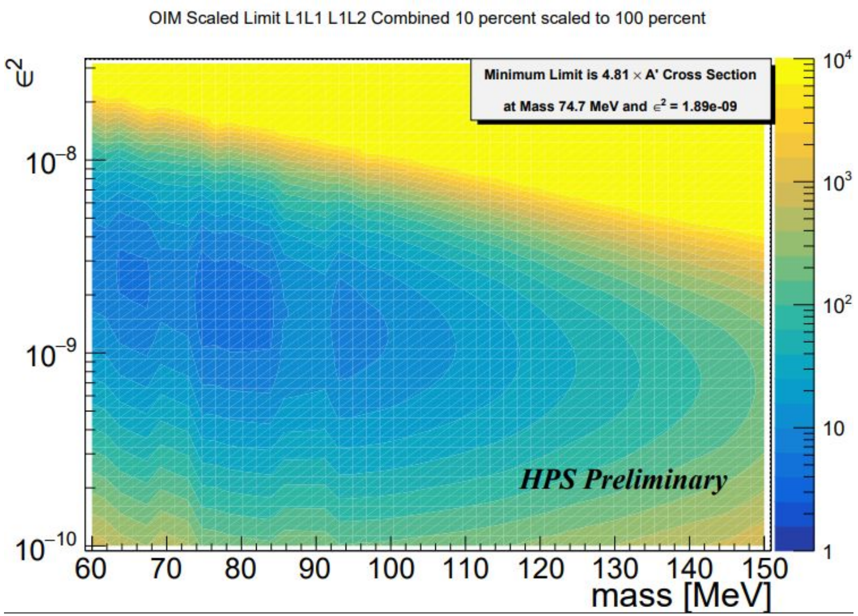




Decent agreement between unblind and scaled from 10% limits...unblind limits have more lower-limit “strips” in mass where events are

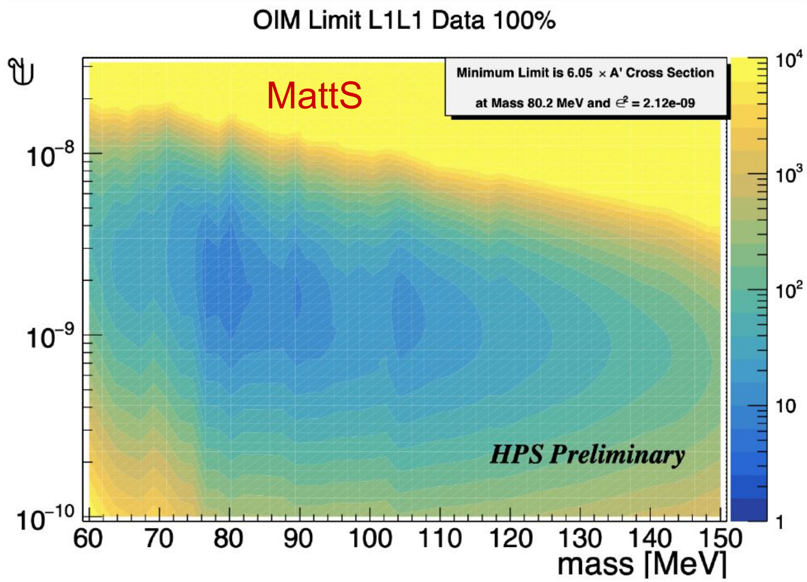
L1L1+L1L2 Combined Limits

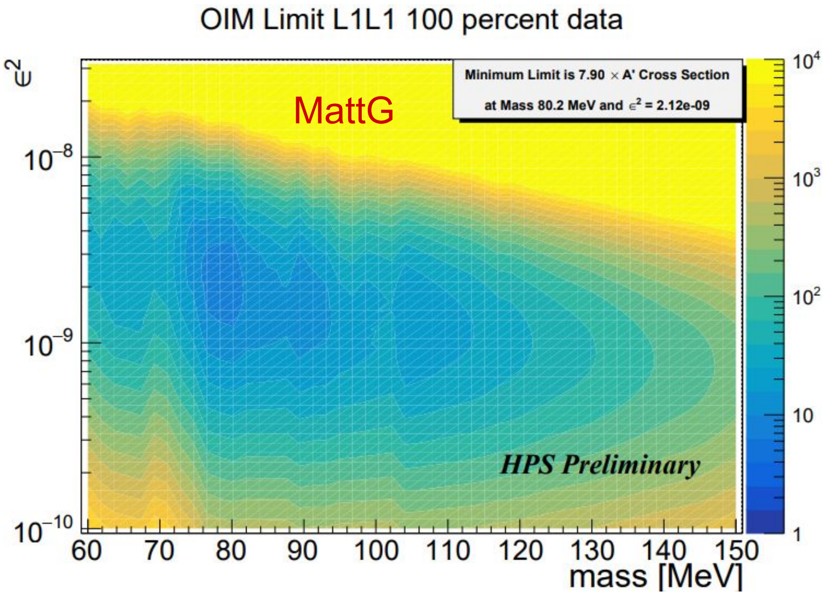




Decent agreement between unblind and scaled from 10% limits...unblind limits have more lower-limit “strips” in mass where events are … here it really shows up and we don’t get the minimum limit <x5 like projected.

Comparison to MattS' L1L1 thesis result





Differences MattS→ MattG: Fixed a radfrac bug (~15-30%), Nbkg<0.5 calculation, hit killing for A' MC

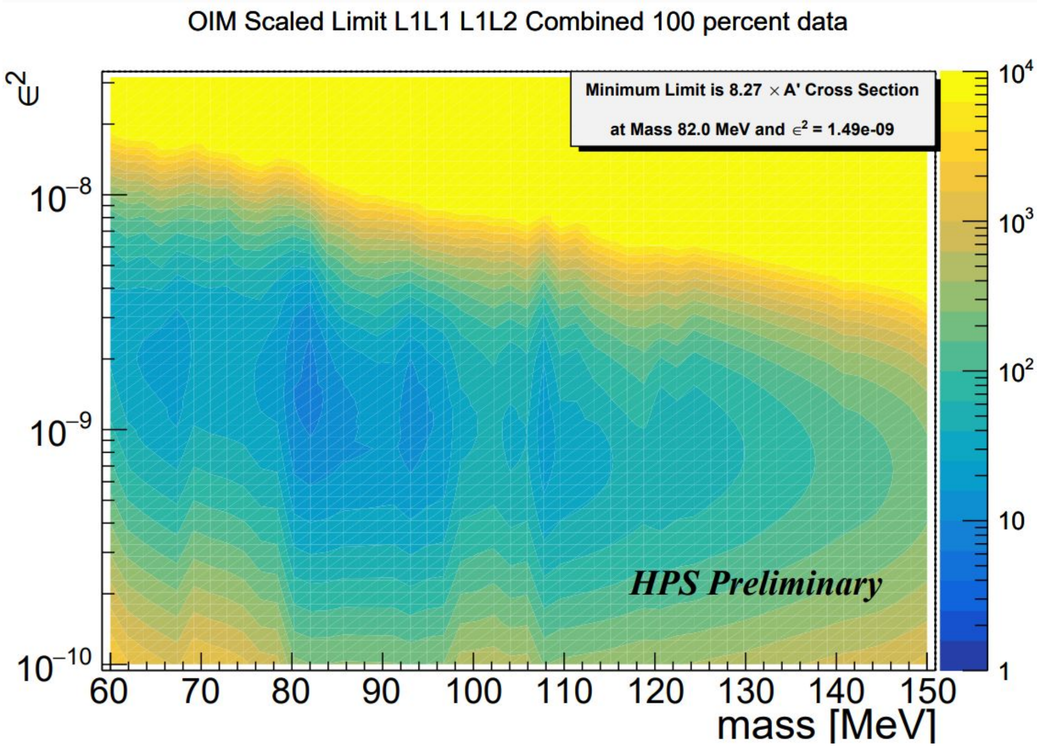
Systematic Errors

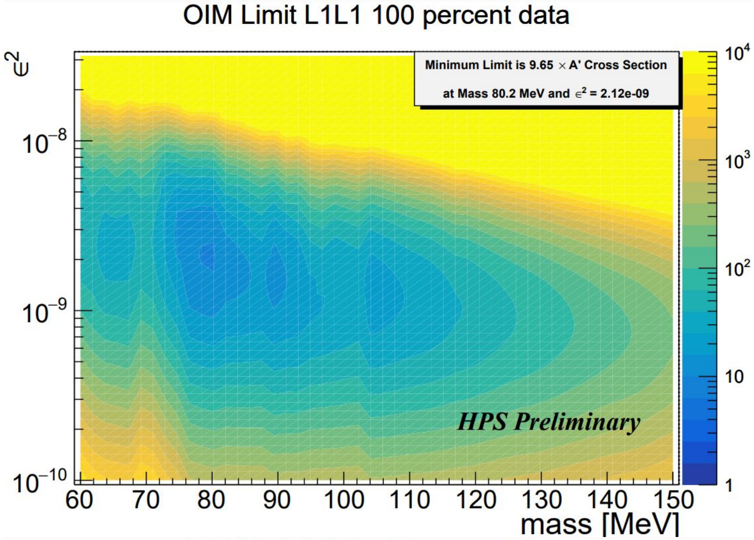
- trident/wab/rad composition
  - I studied this in detail for bump hunt, biggest effect is WAB cross-section uncertainty
- Mass resolution
  - Took difference between data/mc for moller events
- Analysis cuts
  - Tight cut efficiency is estimated from MC...goes directly into scaling from events to XS. I took ratio of data/tritrig-beam MC efficiency to estimate
- A' efficiency
  - This refers to uncertainty in A' efficiency scale after preselection @ target
- Target position
  - +/-0.5mm -- recalculate limit as if A' came from up/down stream

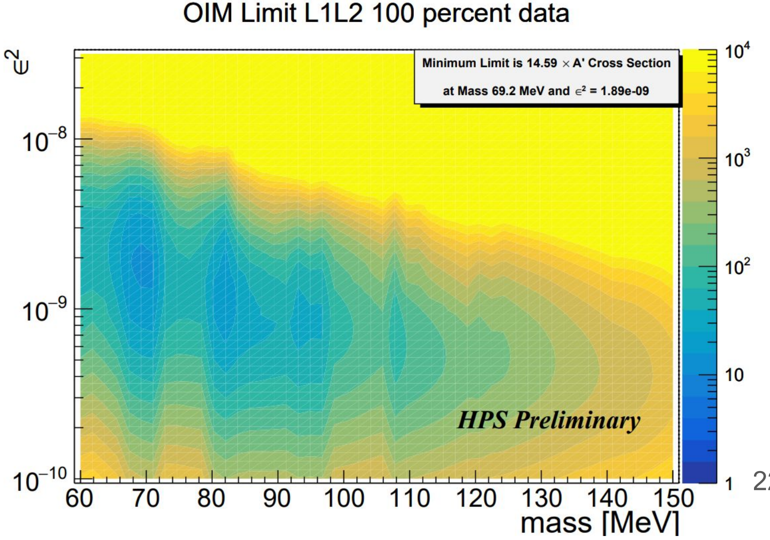
Systematic Description	**L1L1 Value**	**L1L2 Value**
e^+e^- Composition	$\sim$7%	
Mass Resolution	$\sim$3%	
Analysis Cuts	$\sim$8%	$\sim$13%
A' Efficiency	$\sim$5%	
Total in Quad	12%	16%
Target position	$\sim$5-10% (m/ϵ dep)	

Tight Cut	**L1L1 Data/MC Efficiency**	**L1L2 Data/MC Efficiency**
V0 Pointing	0.987	0.999
Electron Isolation	0.992	0.993
Positron Isolation	0.992	0.978
Impact Parameter	0.984	0.926
Shared Hits	0.964	0.976
Total	0.922	0.877

Final results with systematics







Conclusions

- I think we are almost done…
  - Need to update note (close.) and get RC final sign off.
  - Update vertexing section of paper
  - Shepherd paper through EC/collab
- The final result gives us some things to think about
  - We see quite a few events past our "Nbkg<0.5 events" cut
    - Obviously we could just fix the fit so that these events are included but that really doesn't do anything to help the result…although characterizing this tail is important. We should do our best to get rid of these events while keeping signal efficiency.
      - Stepan's idea of mixing tracks from different data events in order to get a very large sample of background V0's is worth following up on
      - MC event weighting for cWABs, double scatters, trident-in-silicon events would be very useful
      - Pulser overlay MC (hopefully coming soon) should also help MC look like data
      - An MVA which is *focused* on differentiating high Z background and signal may help a lot...
    - The concern is that we aren't in the background-free regime so instead of limits scaling linearly they scale as sqrt(lumi)
- Up to now we've been content to just set limits...that will change with the 2019 analysis. We should do real searches for signal. This will require some exploration & development.
  - MattSolt (and Sho) implemented a sort of side-band subtracted cut-and-count method that is reasonable but probably should be expanded on...a full ML fit would be even better depending on implementation...

Target Position Systematic