Tridents Rates & Shapes for 2021 pass0

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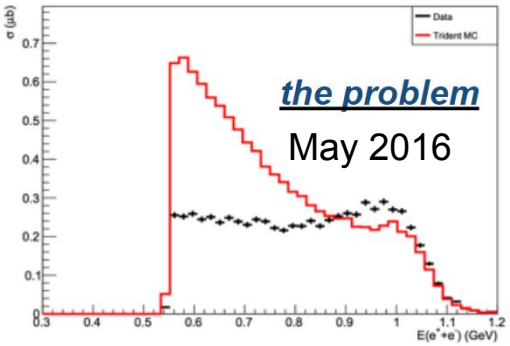
Summer 2023 HPS Analysis Workshop

Tuesday August 8, 2023

Back in the olden days….



When we started looking at 2015 & 2016 data in earnest, we had a big problem…the 2-prong trident data did not look like our expected MC at all***, not even close, particularly at low Psum.

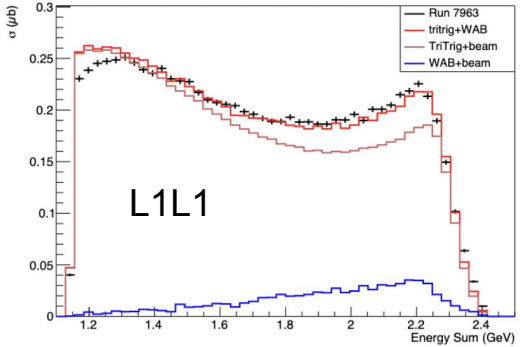
In July 2016 we had a Trident Summit where we looked at all of the ideas of where this could be coming from.

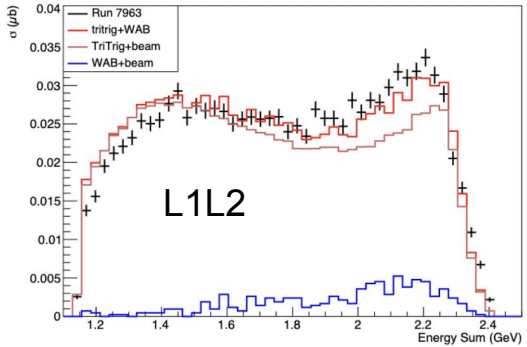
it ***was tantalizingly close at high Psum…

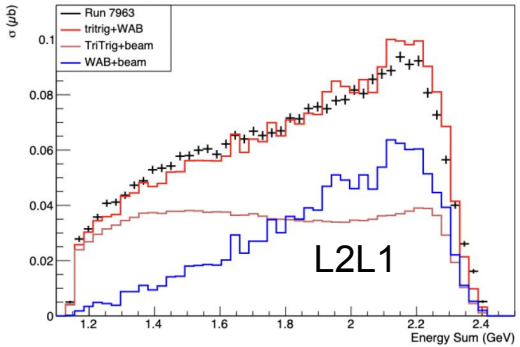
At the end of the day, this was not just one problem, but a whole bunch of them.

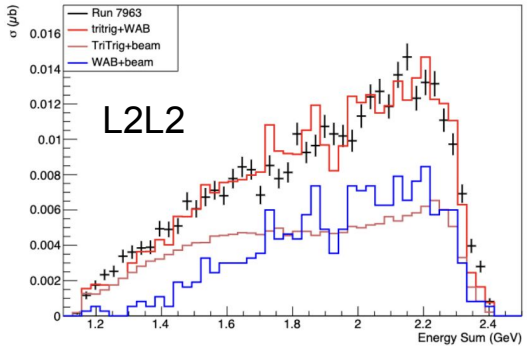
- We had neglected the photon conversions of wide-angle Bremsstrahlung
  - IIRC we thought we were doing things correctly in EGS BUT, as it turns out, EGS doesn't simulate the angle of the photon..just puts it dead forward.
  - By the time of the workshop we had discovered this and started using MG to simulate it correctly
- There was an issue with the form-factor used in MG
  - Matt Solt looked at FEEs rate vs angles from carbon & tungsten, compared to calculation, data and MC…MC was way off

And this is what we got after a bit of work…









NOTE: there is an overall 0.89 scaling to all MC here!

This also required L1 hit-killing in MC based on track slope (same killing was used in physics analysis).

…and it matched pretty great in track parameters, vertexing, etc

2015 Tridents & WABs Note
2016 Trk Eff + Tridents & WABs Note

What's the point?

- The point is/are:
  - Even though we weren't (at the time) interested in low PSum, we felt we needed to understand the entire range if we were going to claim we really understood our data and plausibly get physics from any of it
  - …and it forced us to really dig into some dirt, disinter, and interrogate some skeletons until they cracked. This was very fruitful and now we have more faith in our MC and data
- It is useful to look at the data & MC from a bunch of different angles…slice it up and see how well it does (or doesn't) match
  - Sometimes this shows a deficiency in or MC but can also show ways to improve the data
- We try to rely as little on MC as possible
  - for an analysis like the bump hunt, we only depend on the MC ratio of trident/WAB rates vs mass and the mass resolution (but that is tweaked by what we see in FEEs and cross-checked by Mollers)
  - …vertexing, a bit more as we need the relative efficiency versus decay z-position
  - SIMPs/iDM will be more dependent

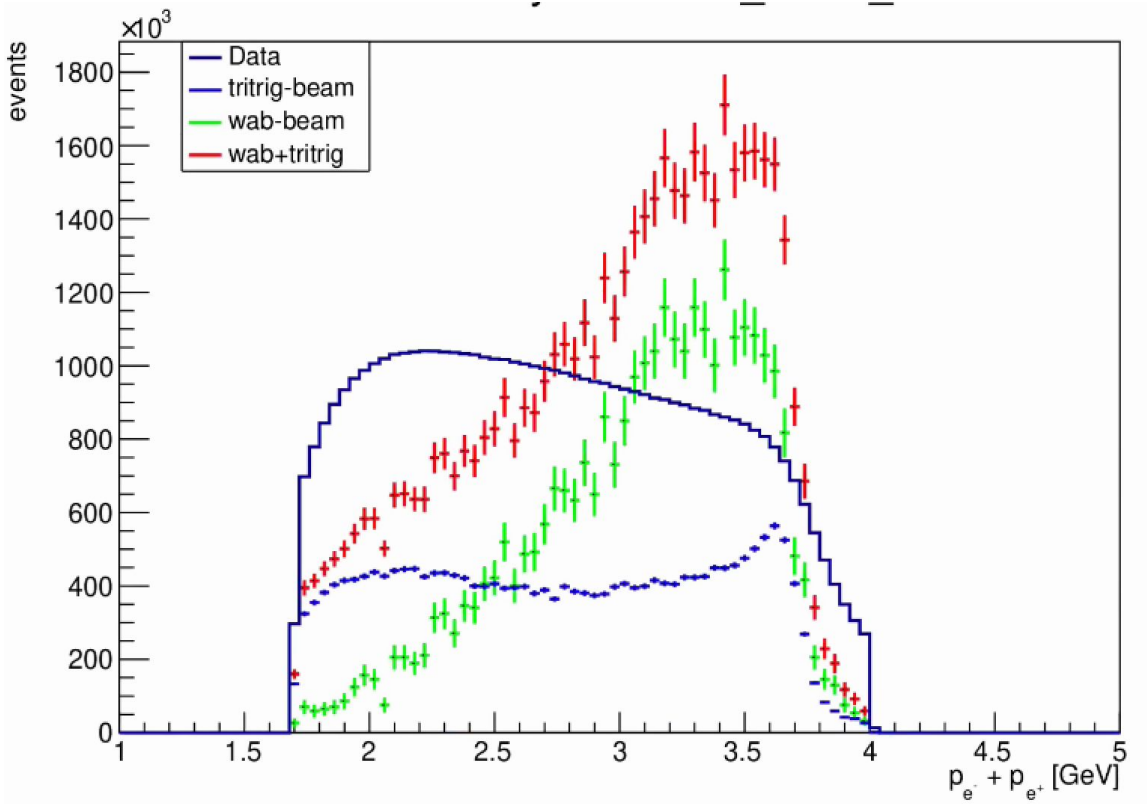
We gotta do this for 2019/21 data as well

- …so that's what I'm going to show today…data & MC overlays of 2-prongs, with MC rates normalized to data luminosity
- For this talk, just looked at 2021 data/energy
- For data: pass0 hpstr ntuples (<1% of data)
- For MC: tridents – see confluence for generation/recon info
  - Also this...for normalizations
  - These use a very old detector (HPS_Run2021Pass2FEE) but for this purpose it doesn't matter too much
- Selections:
  - ***For each track, NHits >= 9 and chi^2 < 250 (yes, 250)***
  - ***Both tracks P>750MeV and P(ele)<3.0 GeV***
  - ***Unconstrained vertex chi^2<5000 (yes 5000)***
  - ***1.75 GeV<P(e^++e^-)<4 GeV***
  - ***|track time| < 15ns***
  - ***|track -cluster|<10ns for tracks that have cluster match***
  - ***|cluster-time-diff|<5ns for events where both tracks have cluster match***
- I categorize by first layer hit in track and whether ele/pos has cluster match
- My talk from April workshop is similar to this with a bit tighter cuts (plus timing cuts)

Disclaimer

- We know the detector that we used for pass0 data recon ain't perfect and improvements have been made and will be made in the future
- We expect to get both better hit and track efficiency in future alignment iterations and with the online baselines
  - Cameron showed more tracks and better momentum scale/resolution at CM talk here
  - Rory has shown the increase in # of tracks (and, hopefully better track pars) a few times, most recently here
- So…this is not exactly state of the art…

Just everything…

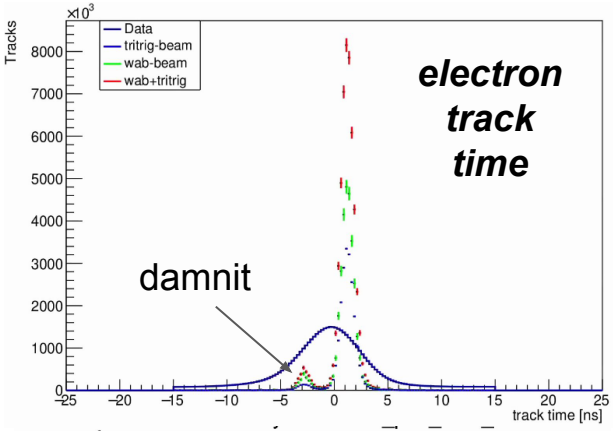


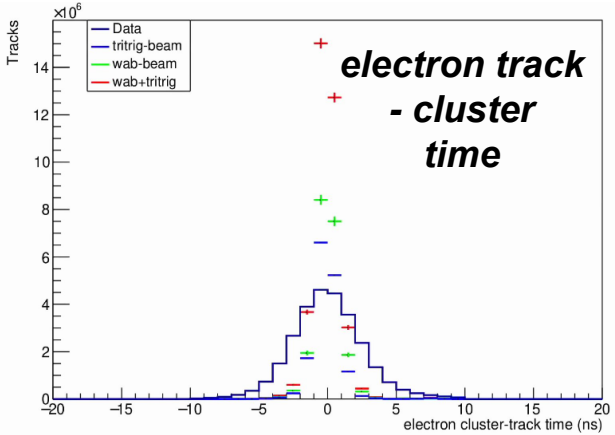
This is what you see making the cuts I described and just plotting the V0 pSum….not great.

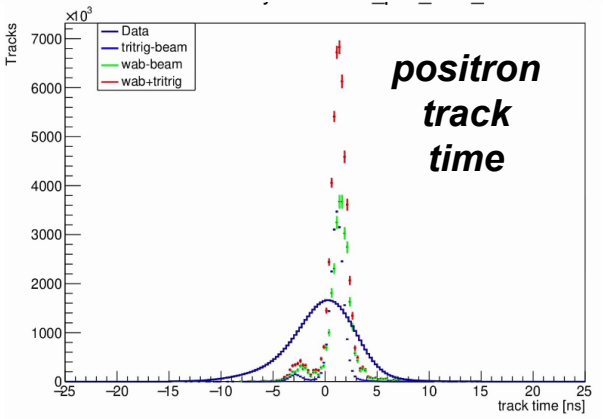
Why are there so many WABs?

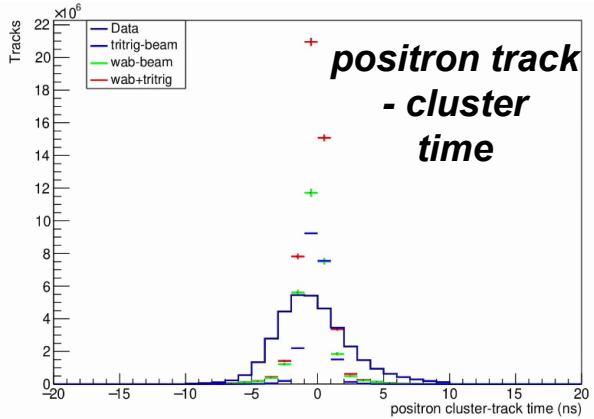
The overall integrated normalization is actually pretty close to 1 but shapes are not close.

Just everything…time distributions

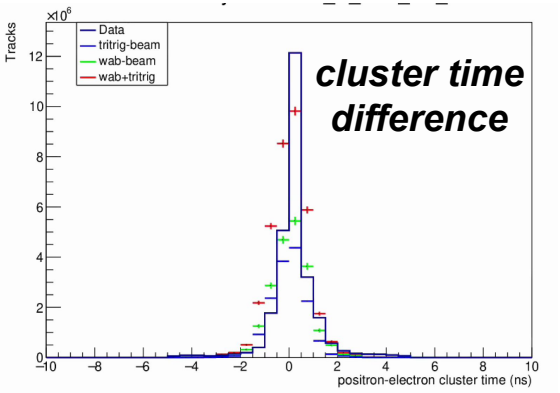






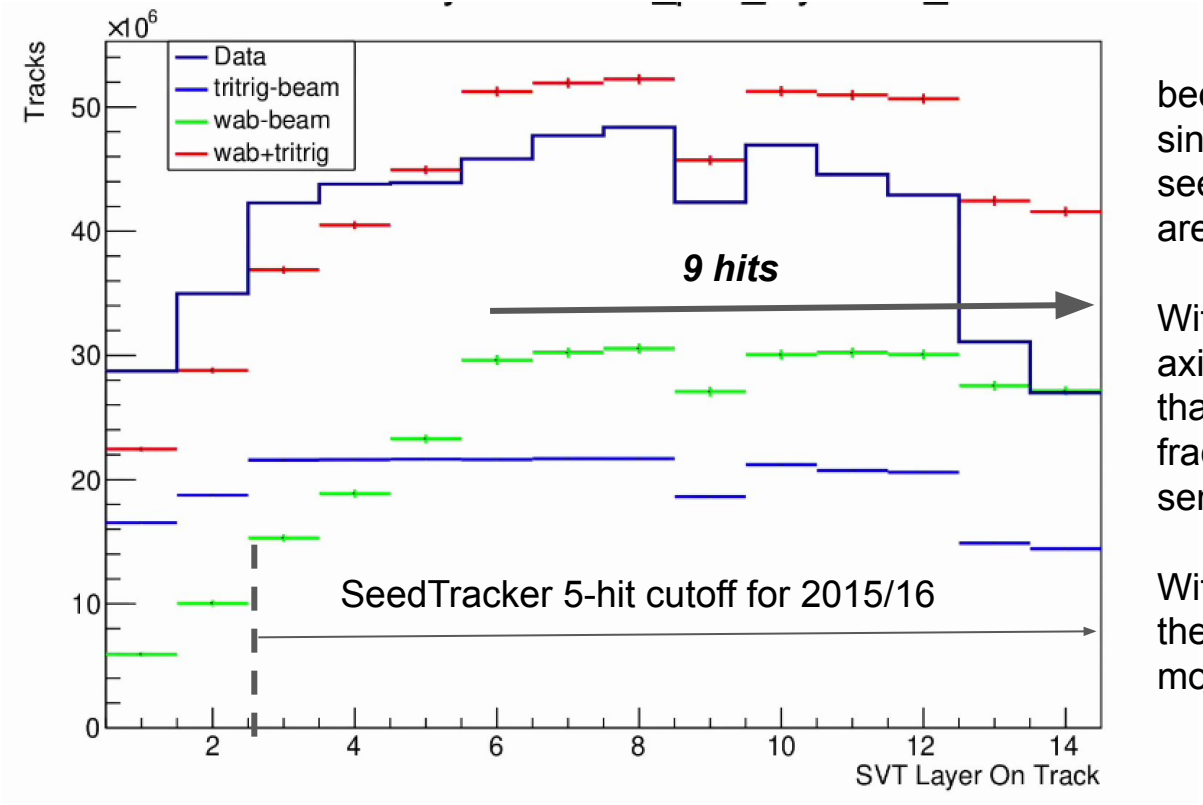


remember cluster times only for track-matched clusters not all events shown in track times



This does not have sensor/phase SVT time corrections in it…track times will look better in next pass

Why all the WABs?

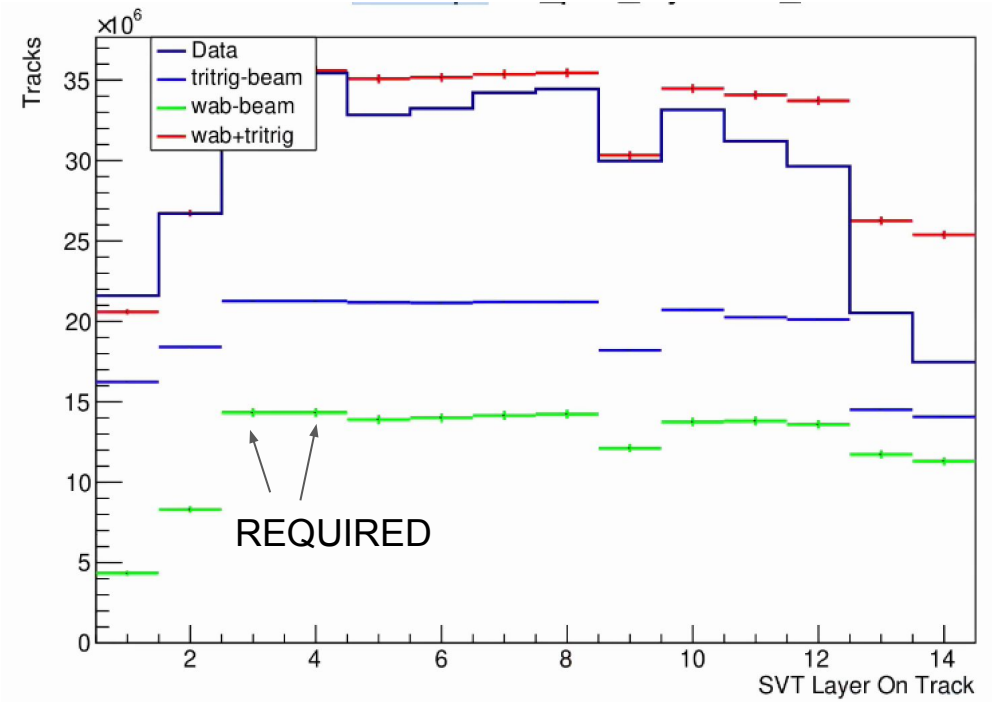


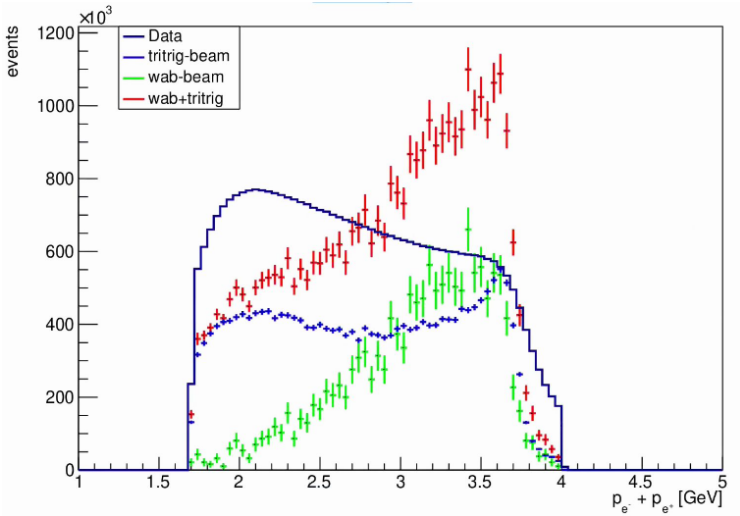
because I'm only requiring 9 hits + the single-sensor tracking from KF we will see more converted WABs than we are used to.

With SeedTracker requiring 5 axial+stereo pairs, we could see WABs that converted in module 1 and a fraction of them that converted in first sensor of module 2.

With my requirements & KF we see them all the way up to (first sensor) of module 4

Ok, require hits in module 2…

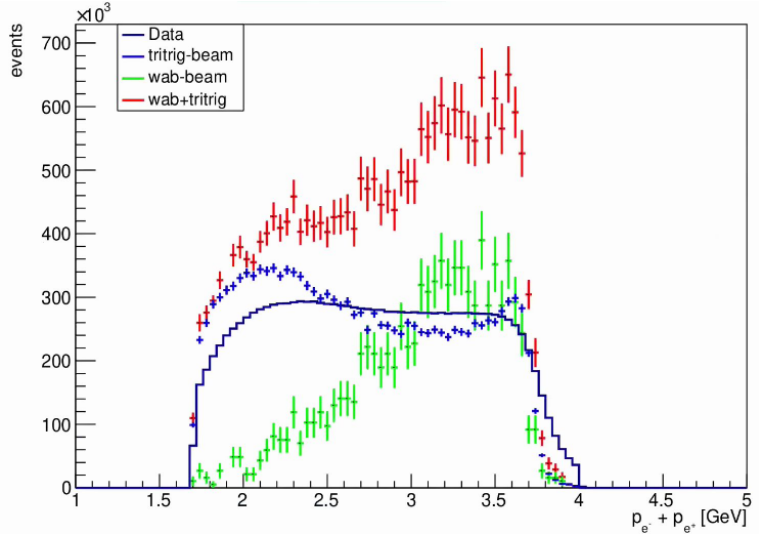


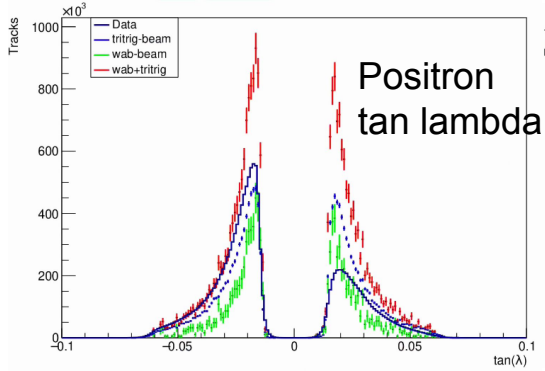


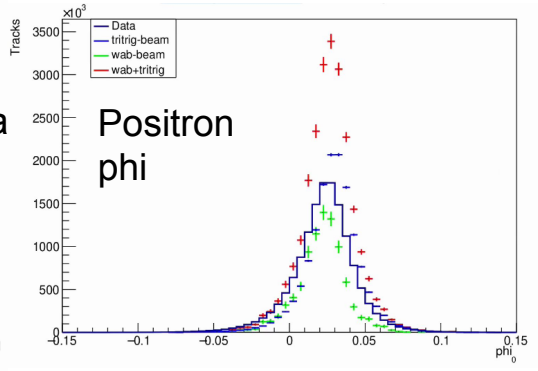
Ok…better, but still more cWABs than we are used to seeing. Did I get normalization wrong?

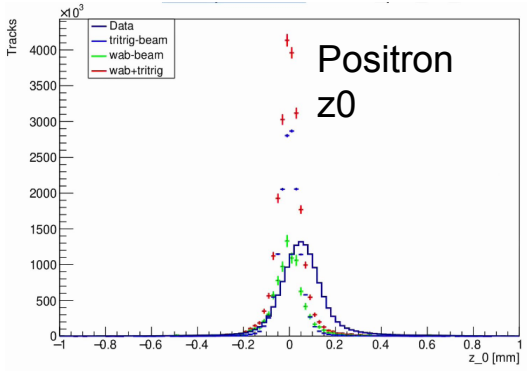
Anyway, let's start requiring some cluster matches …start with BOTH tracks matching

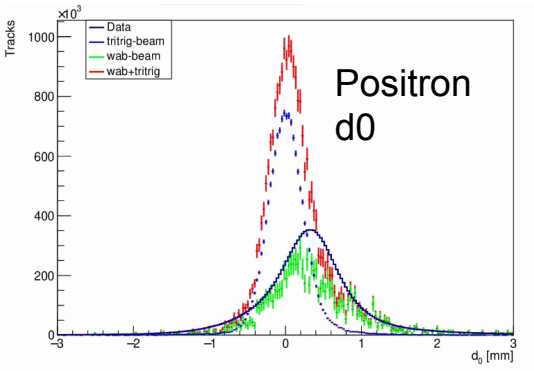
These require both hits in module 2







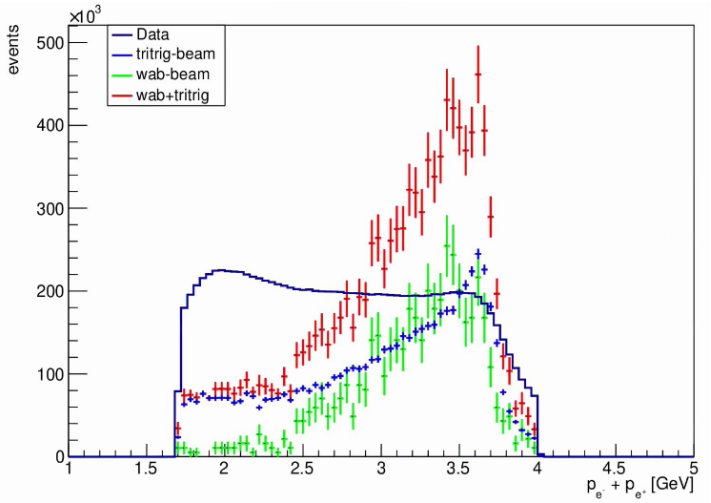


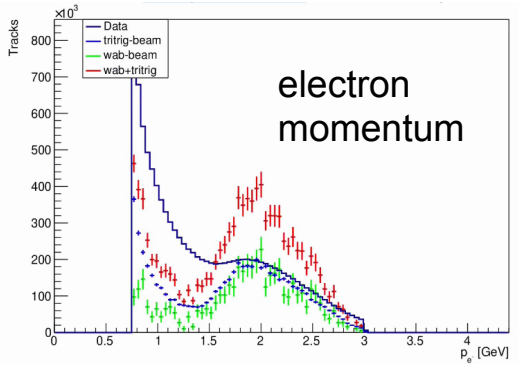


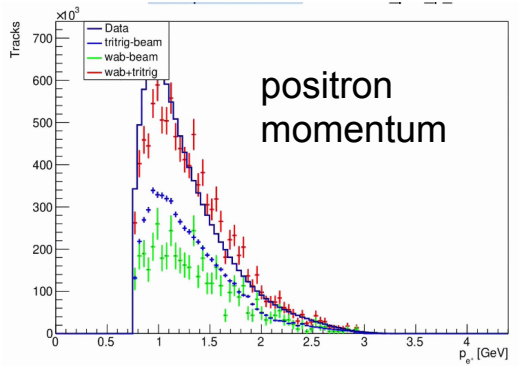
Overall rate isn't good, but we know we have track-finding inefficiencies. pSum flattens out for data…still a lot of WABs

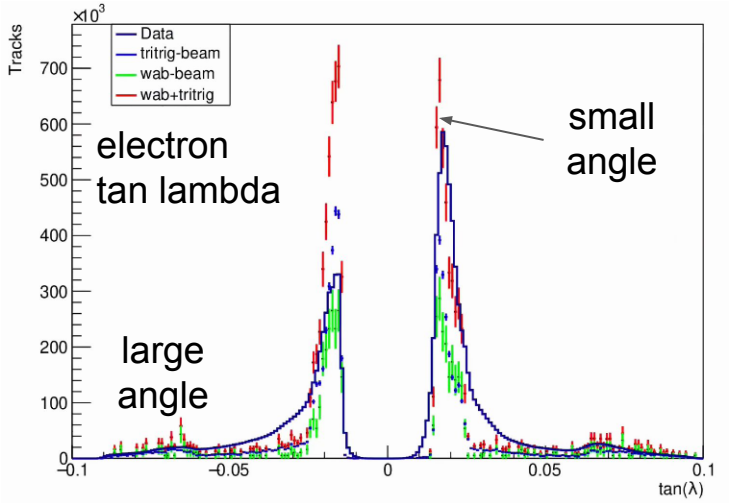
These require both hits in module 2

Positron cluster match…no electron match



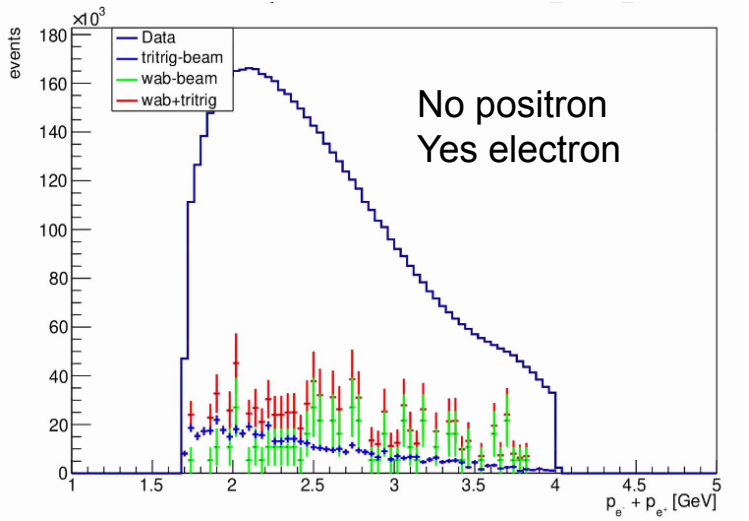


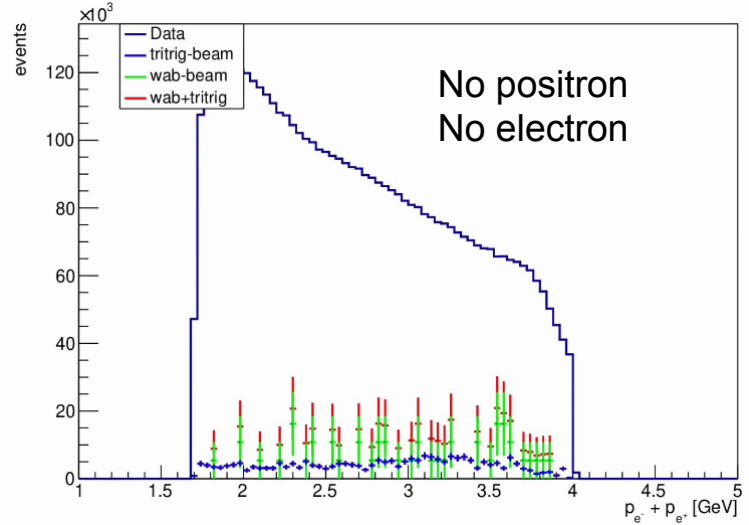




Data still looks pretty flat while trident MC peaks at high pSum (GOOD). Trident & WAB MC populates tan(lambda)<0.2 and >0.5, which makes sense I think. Data shows some of that, but also some "regular" angle stuff…cluster-matching inefficiency?

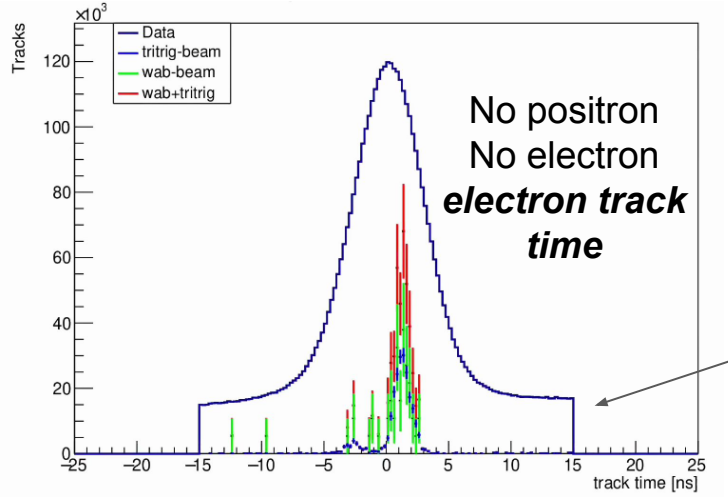
Electron cluster but no positron cluster match??? No cluster matches?



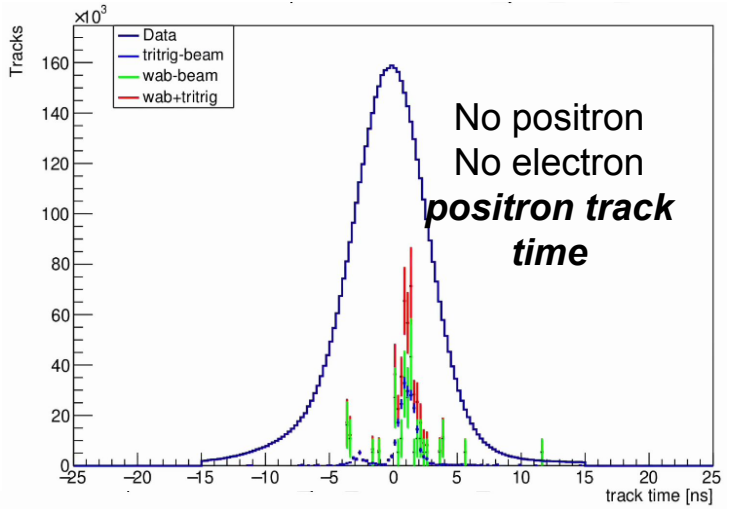


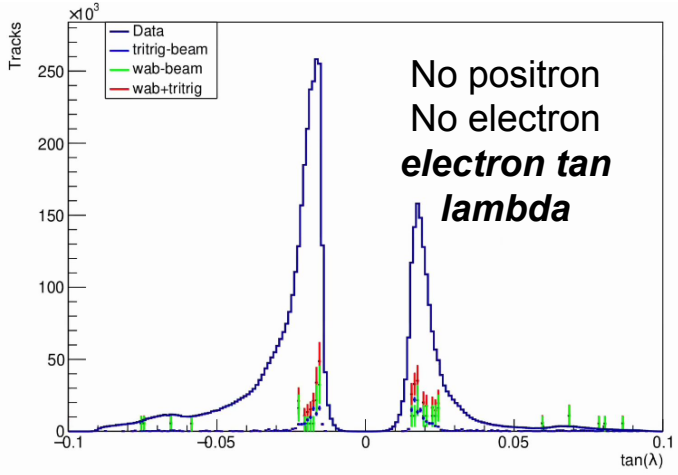
MC really wants to have the positron matched to a cluster…

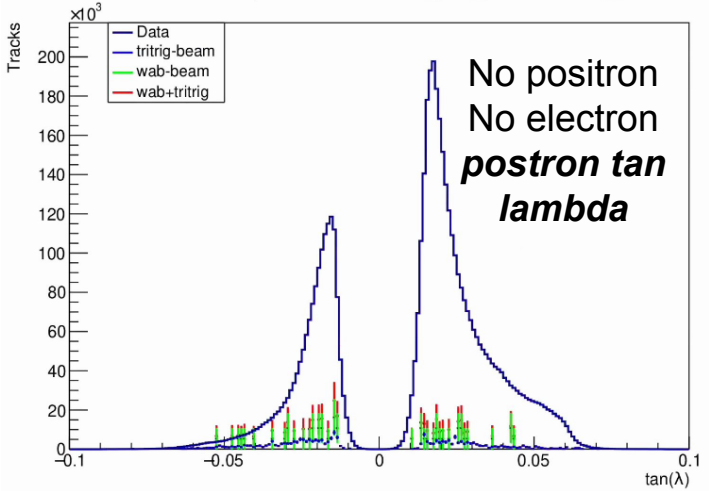
Let's look at these "no cluster match" events



yuck



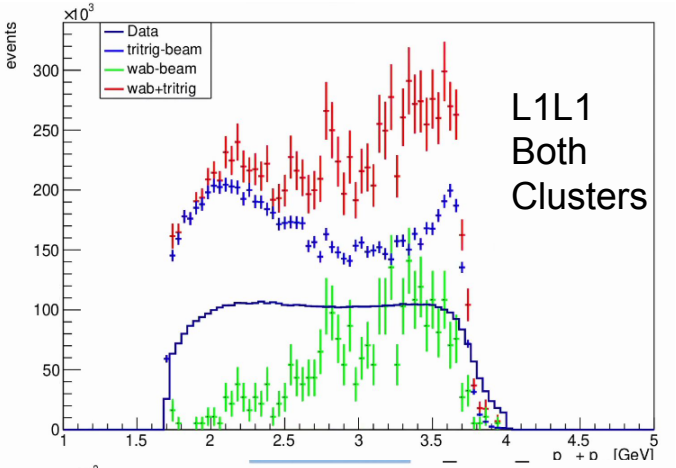


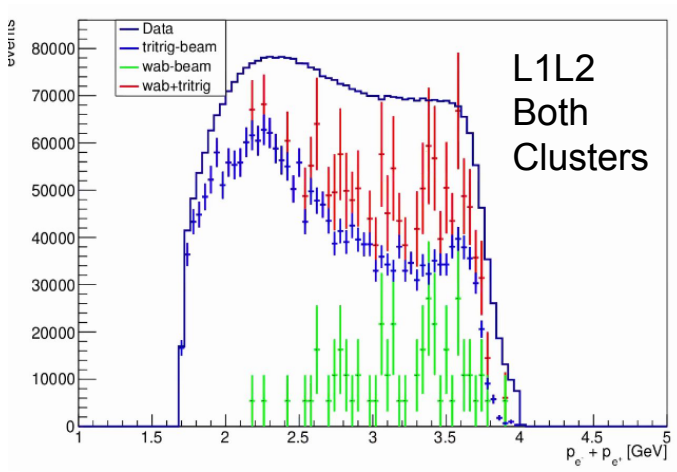


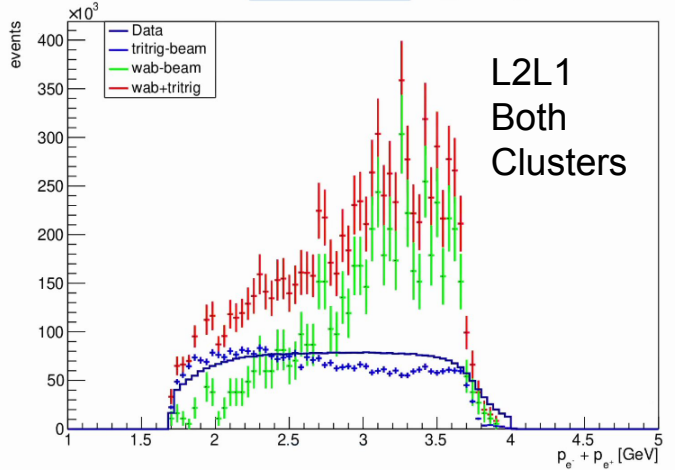
More no matches…

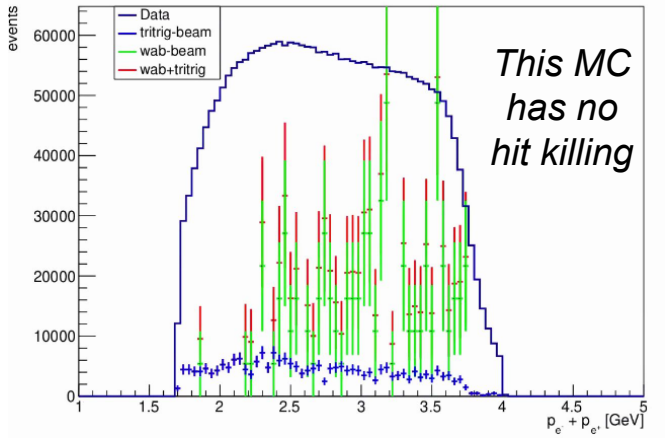
- The ratios of events for “both”, “pos-noele”, “nopos-ele”, “no-no” in data is:
  - 1:0.744: 0.424: 0.351
  - so number of events with no positron match is smaller but still way too many to make any sense
  - this is with the L2 requirement for both tracks
- Both track times show some contamination (esp. electrons) but have definite peaks
- The momentum spectrum is somewhat softer for positrons that have no match but not crazy
- Nothing too weird in phi distros
- Overall it looks like most tracks just look like normal tracks that should have a cluster match
- I’ll look further into this, in particular for the positrons:
  - Is there a positron-side cluster at all? Must be or no trigger
  - Is there a second positron track that is stealing this cluster?
  - Extrapolated positions at ECal

Revisiting Page 3







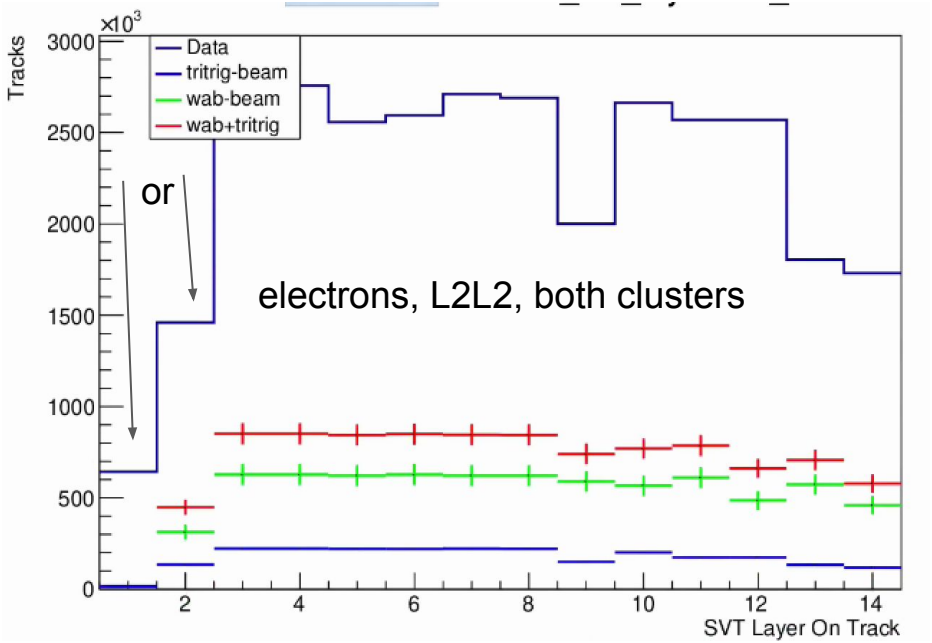


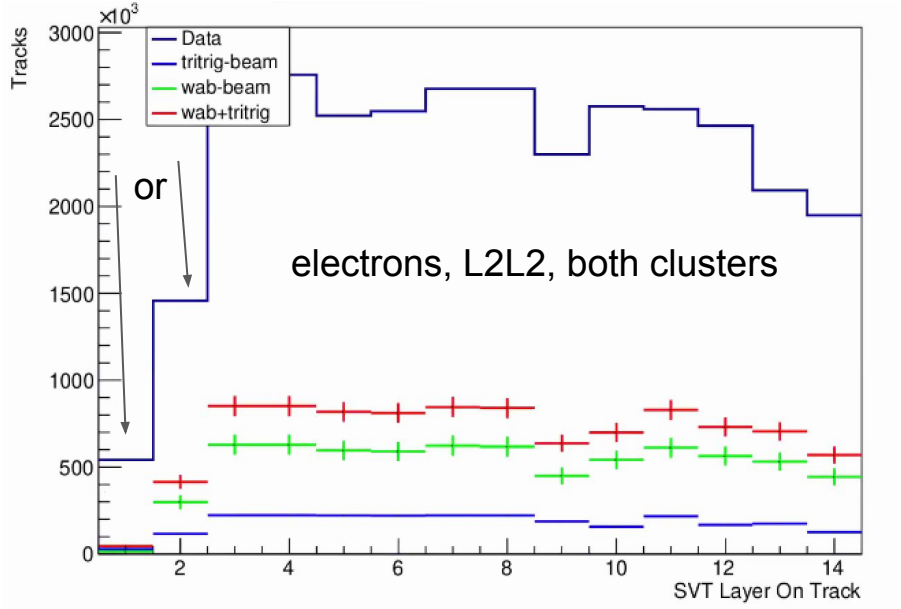
Recall: first LX is positron, second electron.

Also: this is a requirement on the ***first module*** to have a hit on the track…so "L2" means there wasn't a HOT in either of the L1 sensors. Tracks with e.g. an electron with only 1 hit from module 1 will be in L1L2 or L2L2 (depending on positron)

I need to start requiring things per sensor and not per module…

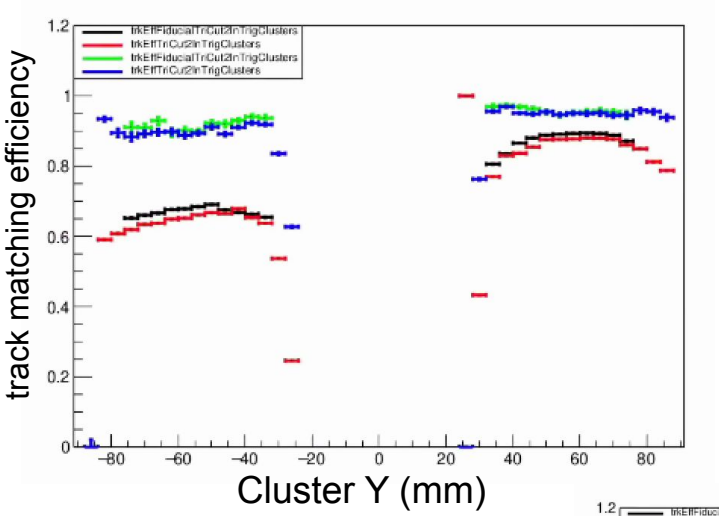
In fact…

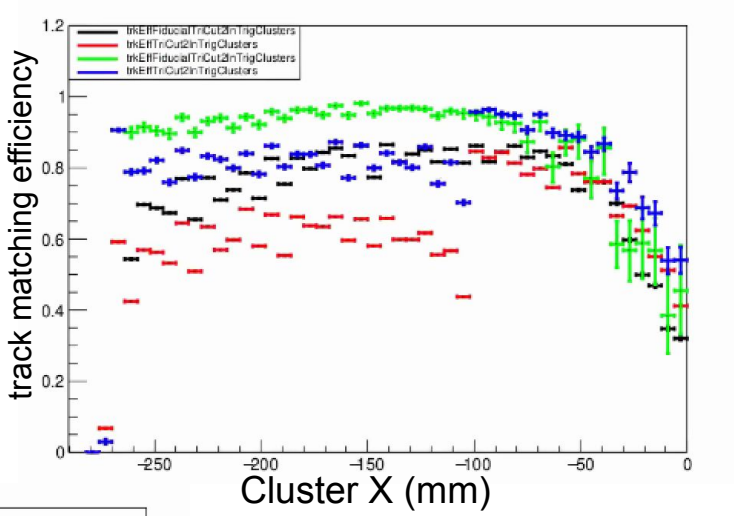




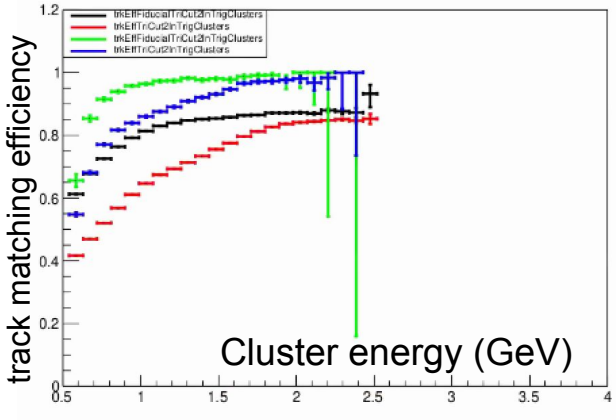
Over half of the tracks have one of the sensors hit in module 1…

One slide on 2021 track efficiency data/trident MC





green/blue: tritrig MC
black/red: 2021 data



[talk from June before MC efficiencies added]

Takeaways

- Well…we have some work to do, but we already knew that
- Track efficiency should get better with alignment and online baselines
  - both track finding efficiency and hit-on-track efficiency should be improved by these
  - I'm sure some hit-killing will need to be done to MC to make the layer combos match data
- I'm bugged by the number of un-cluster-matched-for-no-good-reason-I-can-see tracks we seem to have
  - We know the extrapolation to ECal isn't great but the matching criteria is "min-distance" with no cuts AFAIK … I'll look into it
- Need to start looking at things sensor-level instead of module level
  - how to track and vertex resolutions look if only one sensor in module has hit
    - right now they look terrible, but that will be helped by alignment

First layer hit ratios

I just wanted to compare the hit pattern we see now to what we got in 2016

LXLY/L1L1	L1L1	L1L2	L2L1	L2L2
current 2021	1	0.69	0.72	0.52
2016 (from note)	1	0.12	0.31	0.04

…we are currently to very close to 1 for my liking. But, I'm not sure this is a 1-to-1 comparison.

There is a large rate of L1L2/L2L1 tritrig we see on slide 16 that we didn't see (before hit killing) in 2016.

a lot of these are WABs that converted in L1