SVT Hit and Track Efficiency for 2016 Run

Matt Graham
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U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

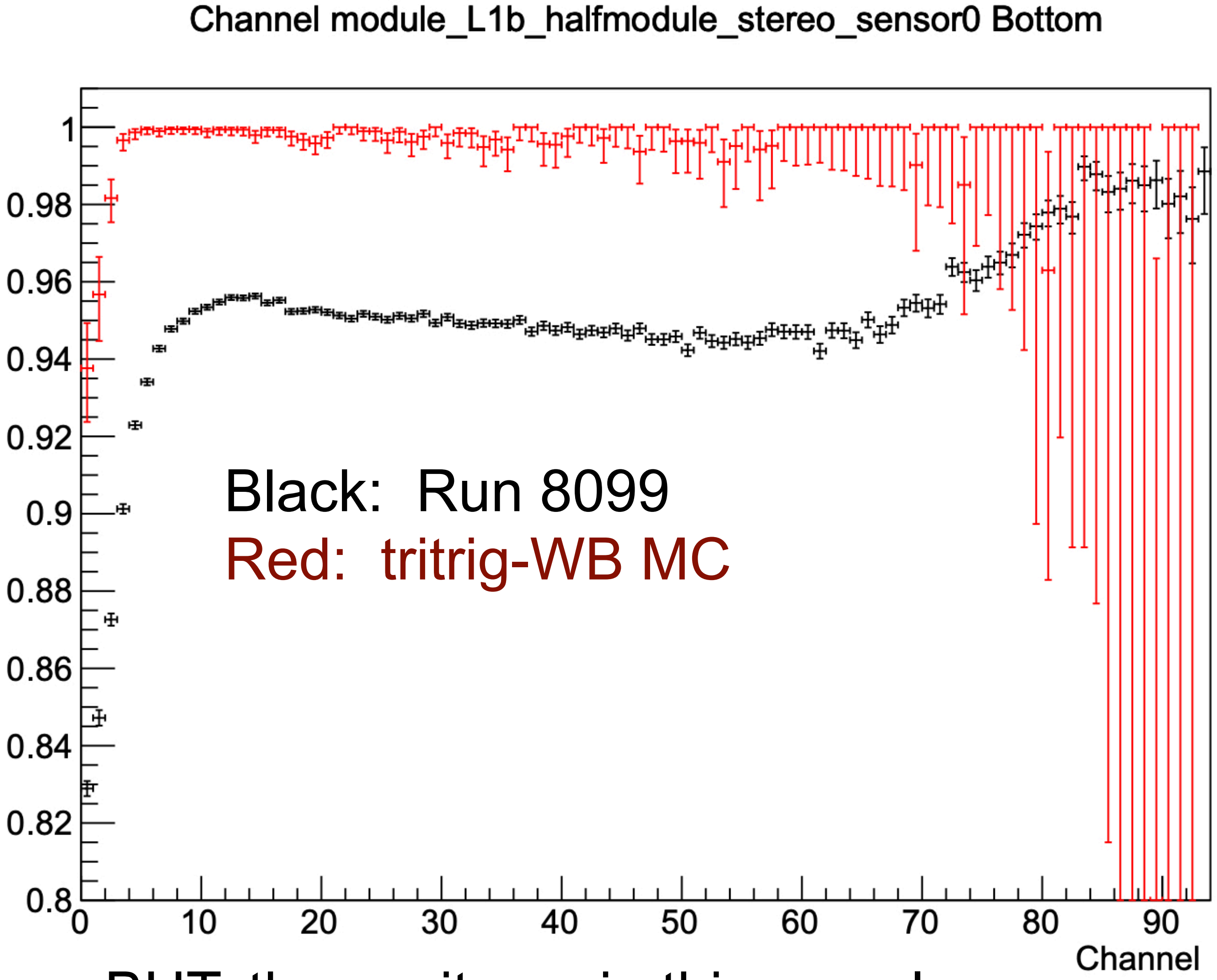
Procedure

- Using code Matt Solt wrote for calculating SVT hit efficiencies:
  - This code is really nice! It worked out of the box
- Basic event and track selection — just regular reconstruction
- Method:
  - Six 3d hit collections made, one with each module's hits removed
  - tracks are reconned (all combos) with 5-hits required
  - 5-hit tracks extrapolated to missing layer; check to see if hit is found within 5sigma
  - look at efficiency vs channel #, "y", momentum
  - this driver also plots residuals, pulls and other stuff
- Calculated this way, efficiency necessarily goes down at edges due to particles that miss sensor…Matt S made an attempt to correct for this (and I went through it and the logic seems ok to me) but it ends up overcorrecting
  - I'll just show uncorrected efficiencies here…my primary goal is to compare data and MC and determine if/what layers need tweaking in the MC

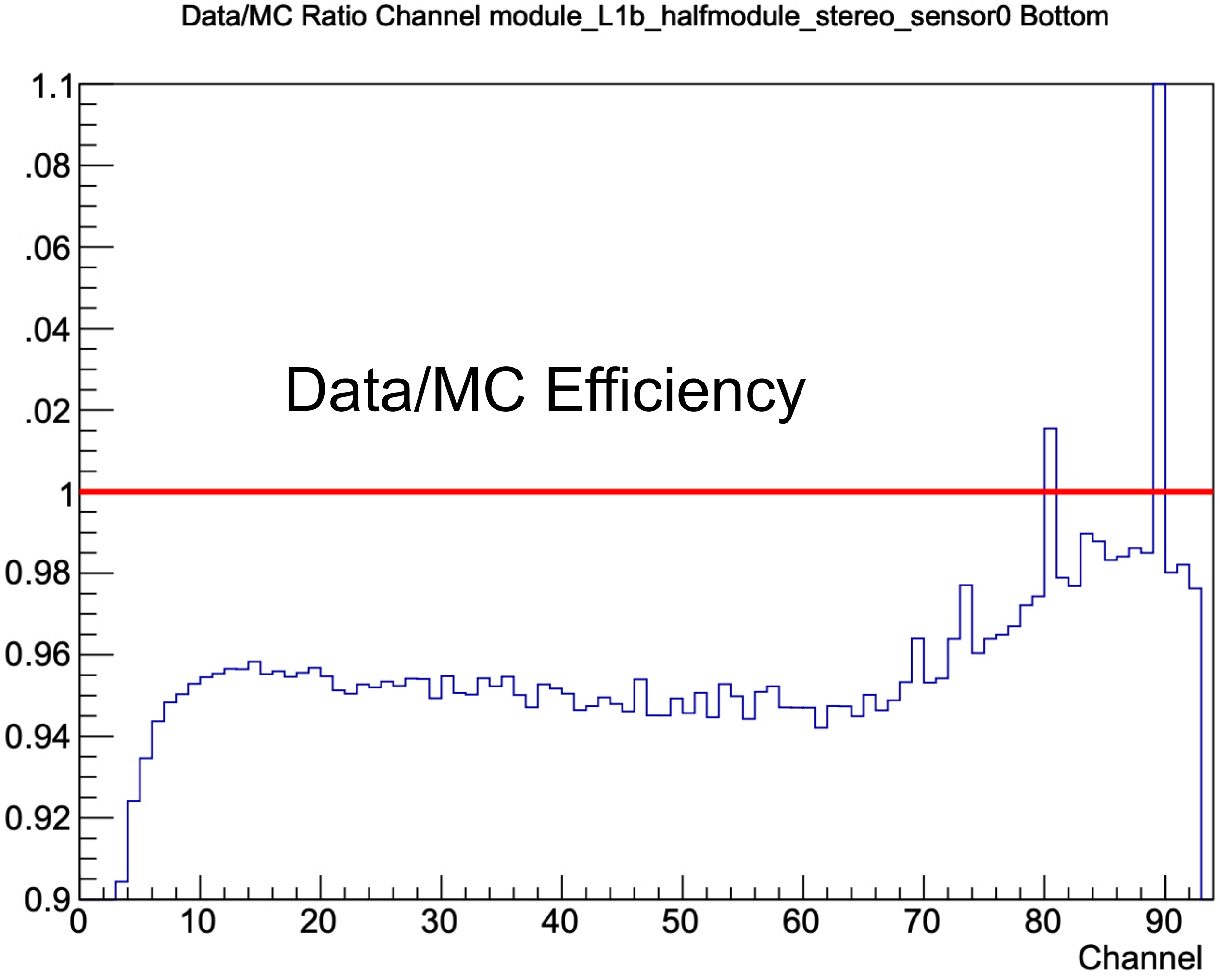
Data sets

- Used the V0 skim of run 8099
  - does the V0 skimming bias the efficiency?
  - for some reason, all of our tracking strategies require layer 3…so that one is definitely biased
  - checking different runs is on my to-do list…this run is the very last one we took
- Use pass-4 tritrig-WB for MC comparison
  - simulates the pileup, but not he WAB contamination (see later)
  - could use a lot more of this (which I think is coming)
- The plots I show are all indexed to readout channel on the sensor calculated from the projection of the 5-hit track

Layer 1 Bottom-Stereo Efficiency vs Channel



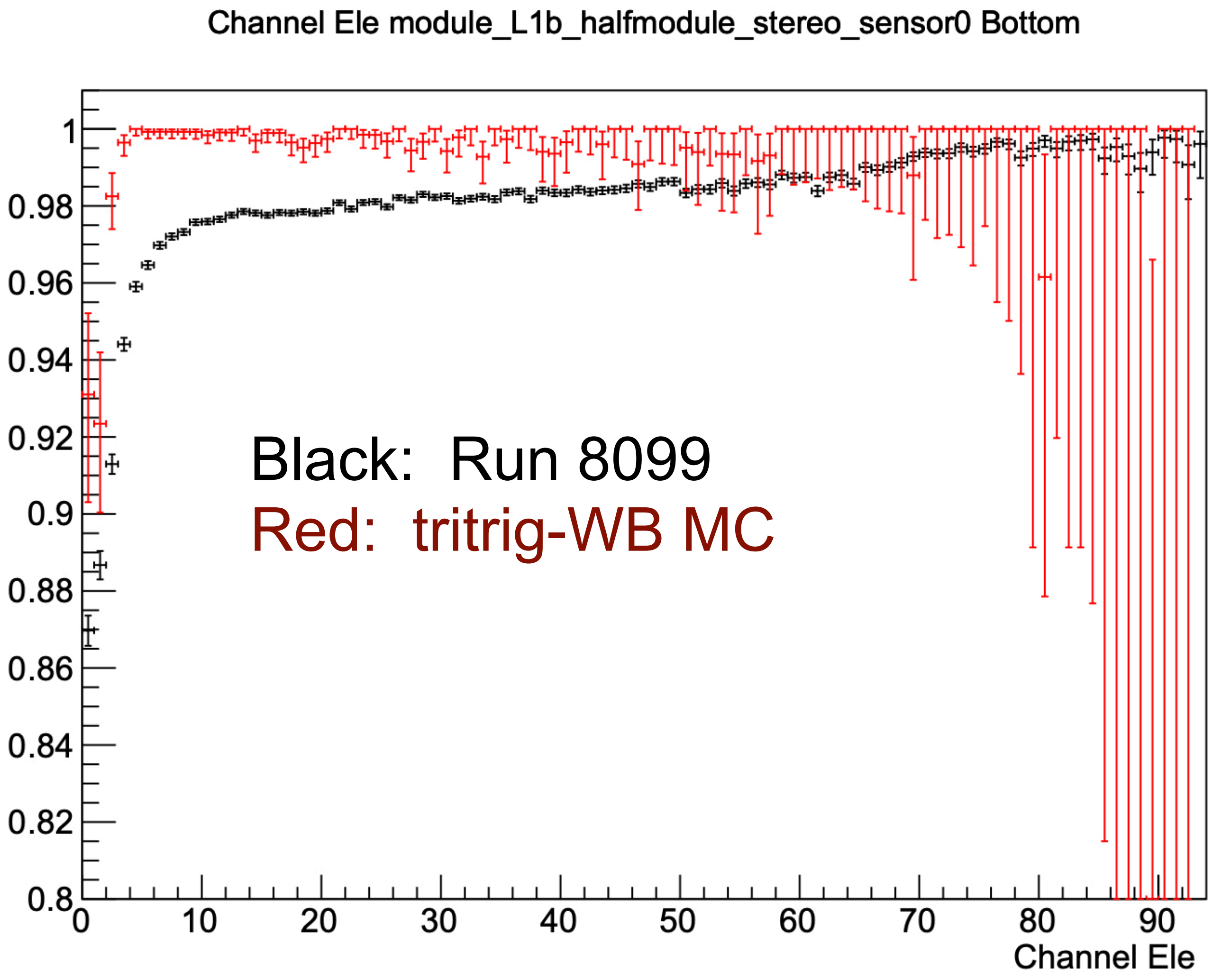
These are efficiency vs. channel for L1, all tracks (regardless of charge).



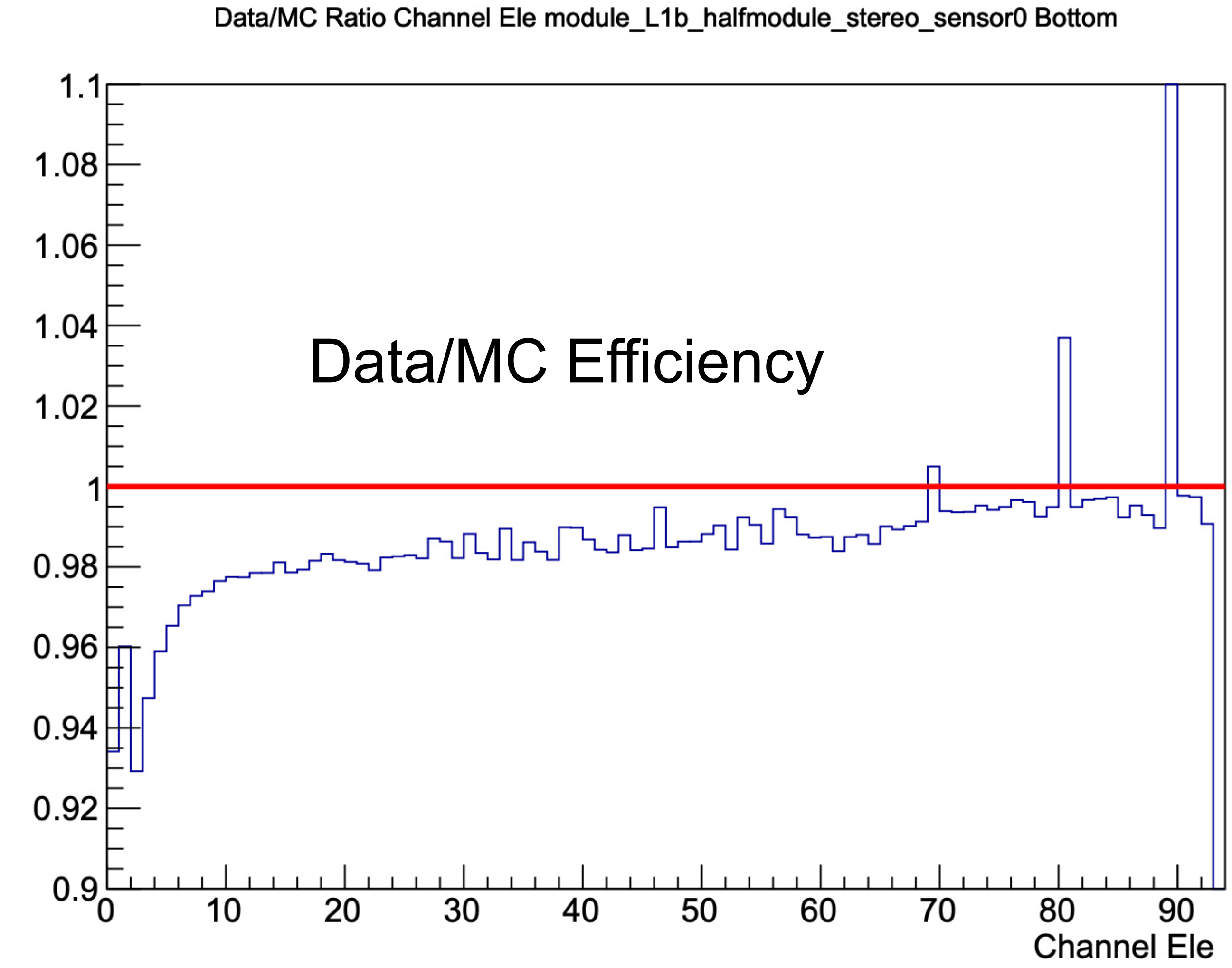
BUT, the positrons in this sample can come from WABs (in data, not MC) so must separate charges, just look at electrons.

For downstream layers (L2-L6) pos/ele combining is ok.

Electrons Only! Layer 1 Bottom-Stereo Efficiency vs Channel

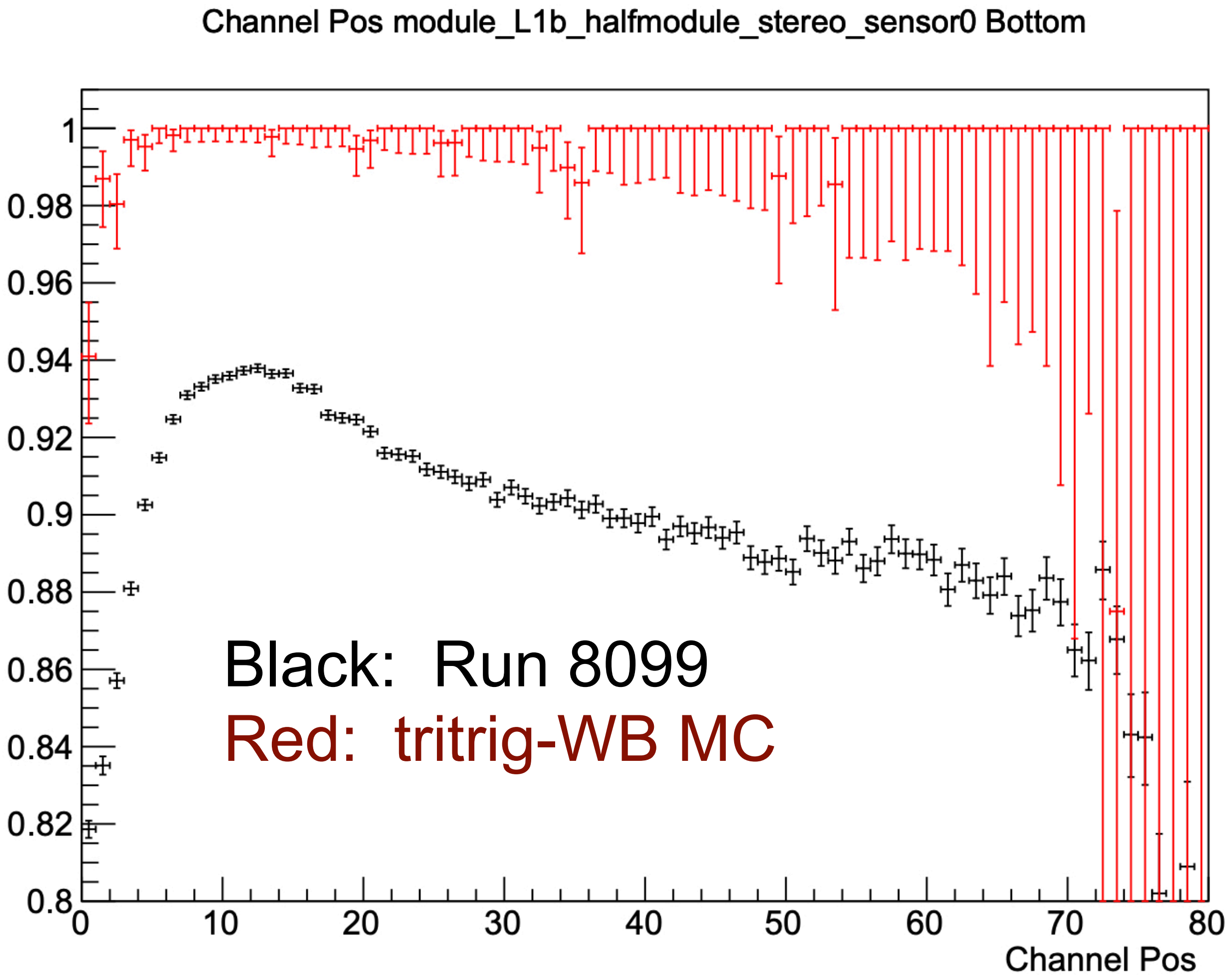


This data/MC efficiency difference is (mostly, probably) real.

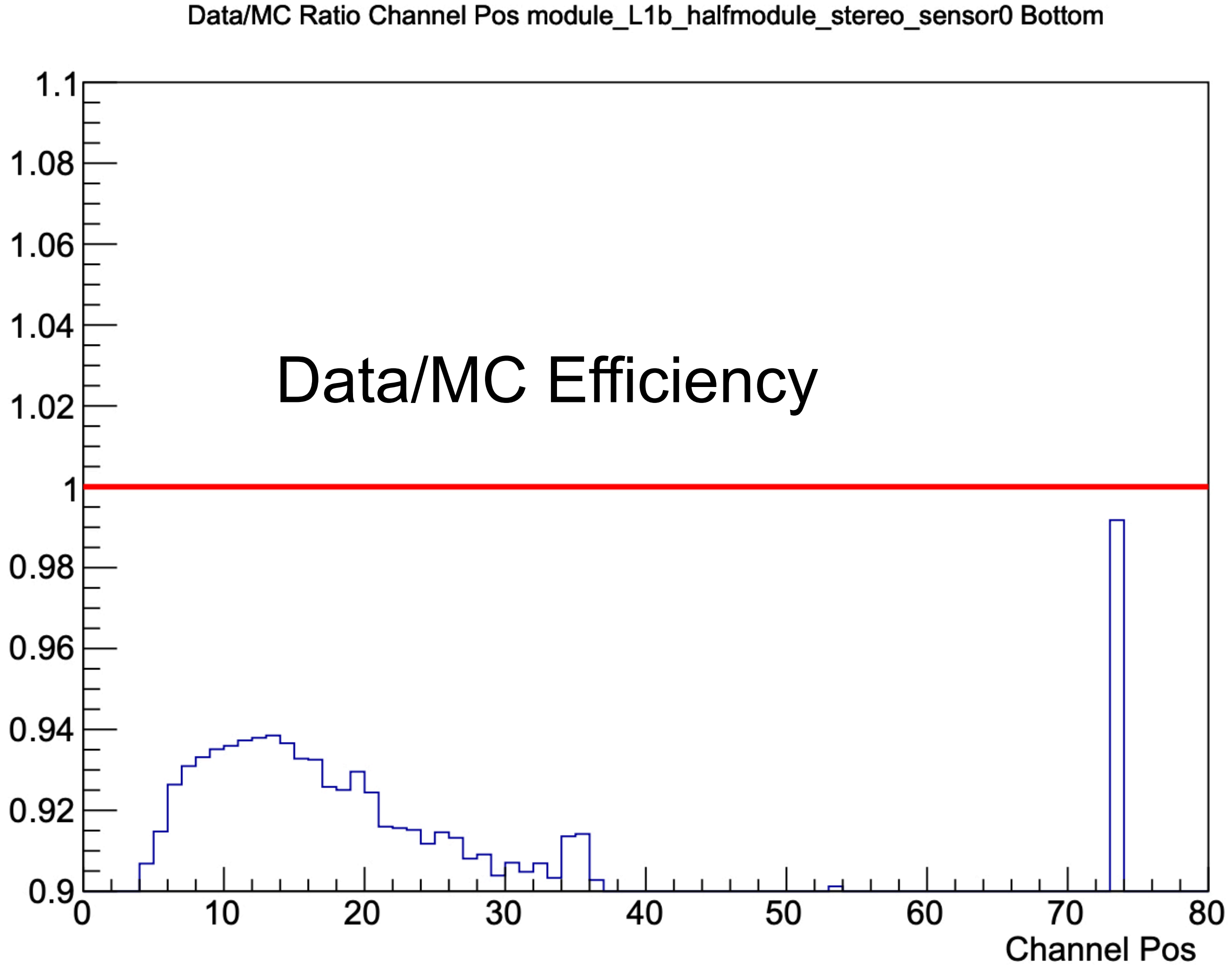


…misalignment in data is one thing that can though this efficiency off, particularly near the edge of the sensor.

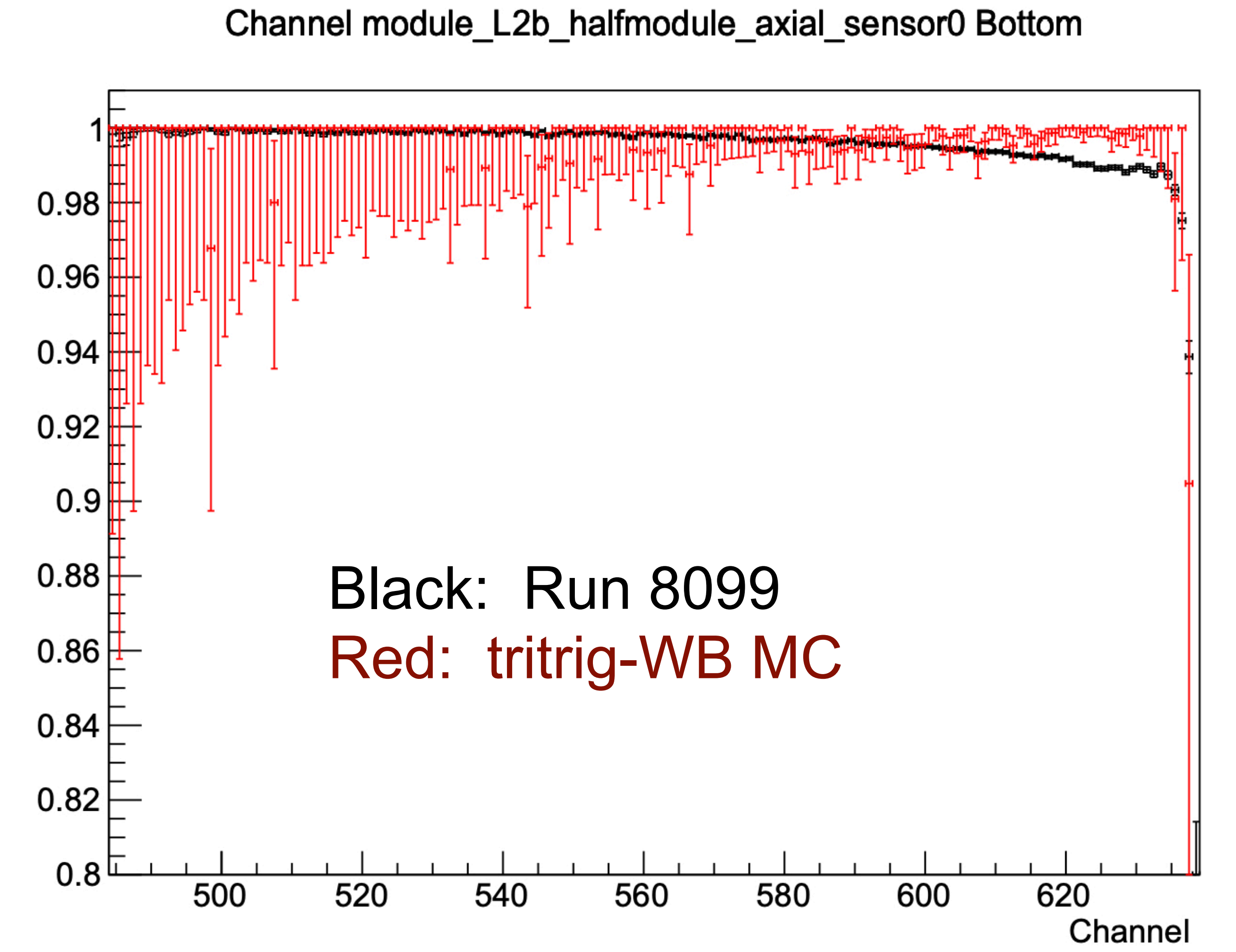
Positrons Only! Layer 1 Bottom-Stereo Efficiency vs Channel



As expected, positrons show large "inefficiency" due to WAB conversions in first layer.



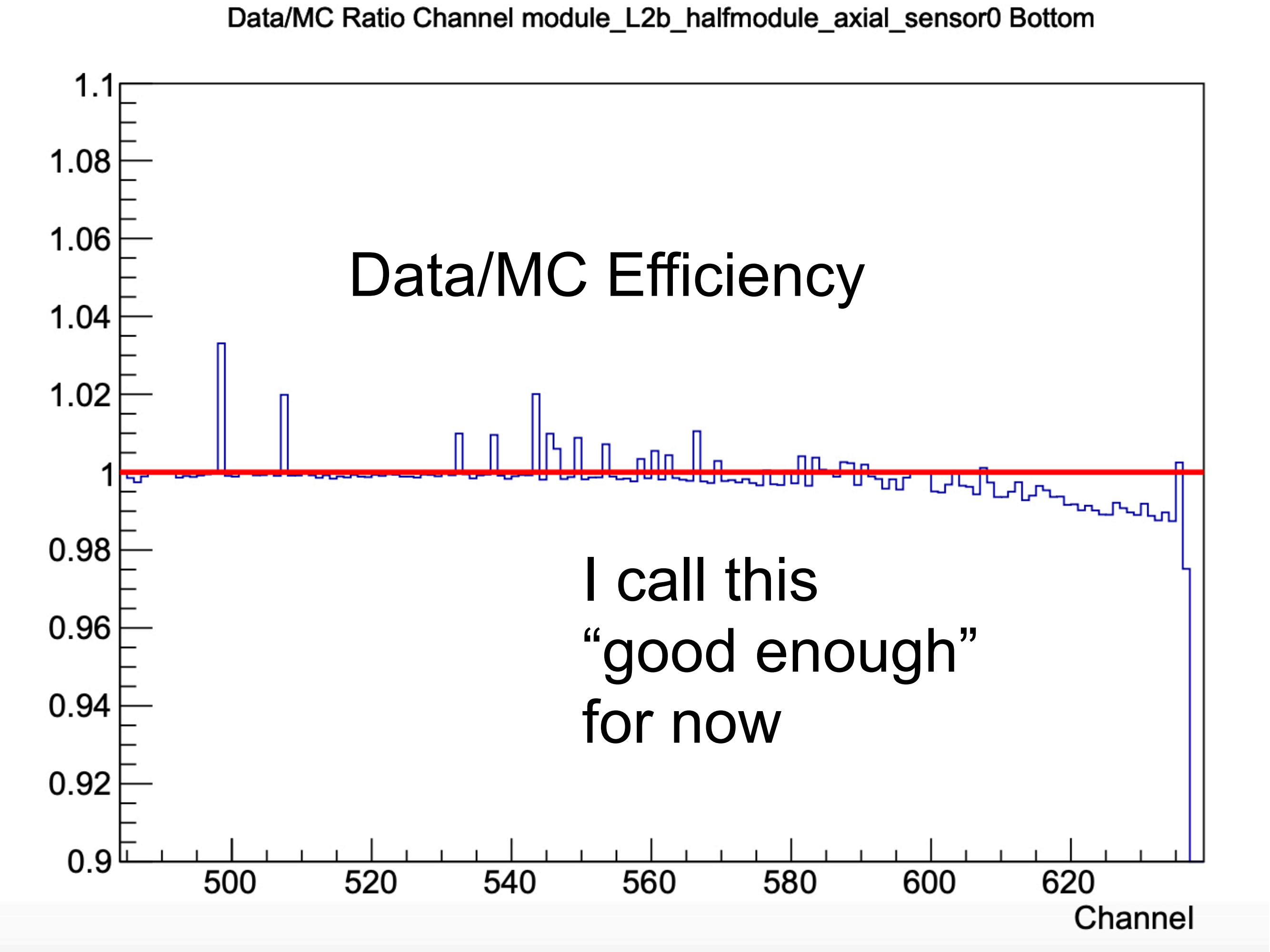
Layer 2 Bottom-Axial Efficiency vs Channel



Black: Run 8099

Red: tritrig-WB MC

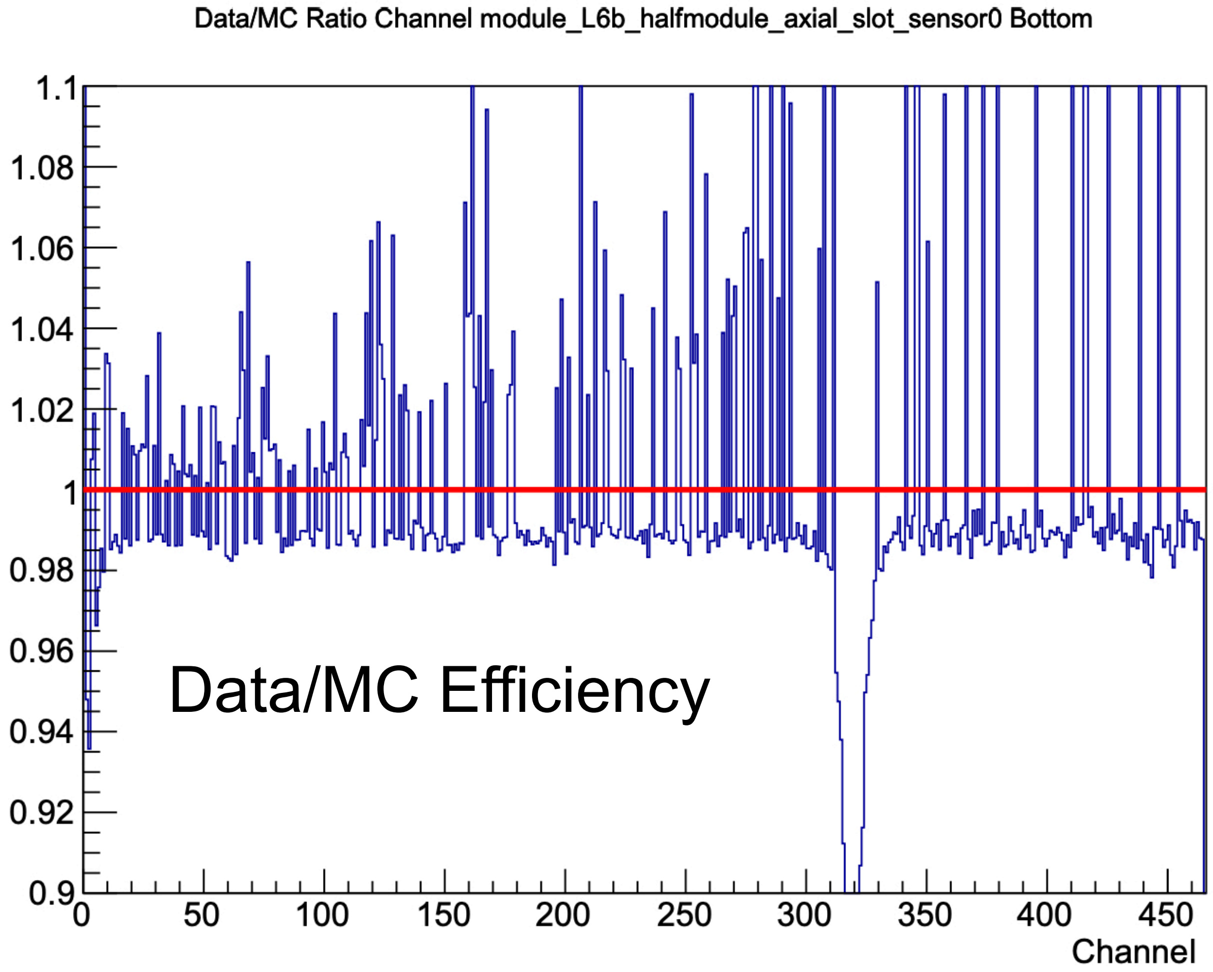
Downstream layers generally have very good Data/MC efficiency agreement and high efficiency in general.



Data/MC Efficiency

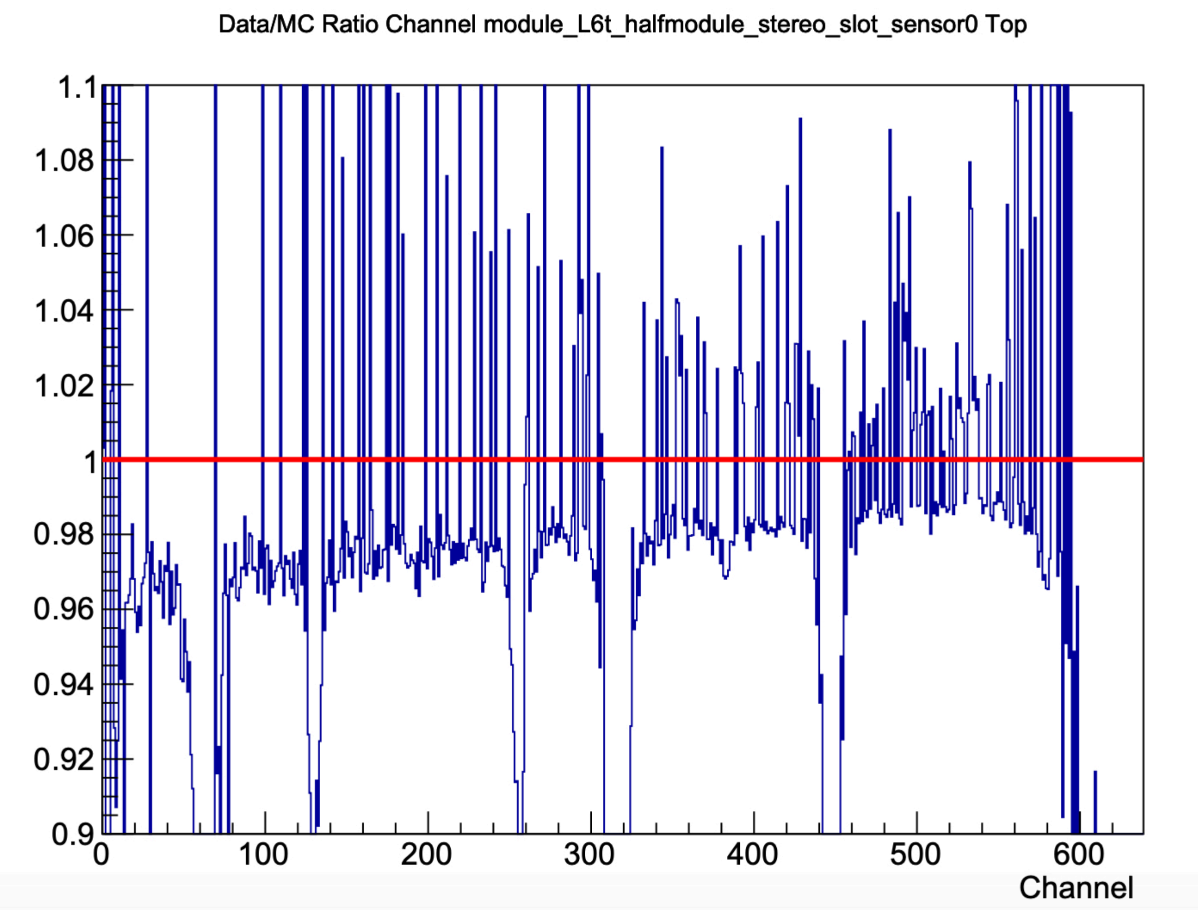
I call this
“good enough”
for now

Bad Channels in Layer 6

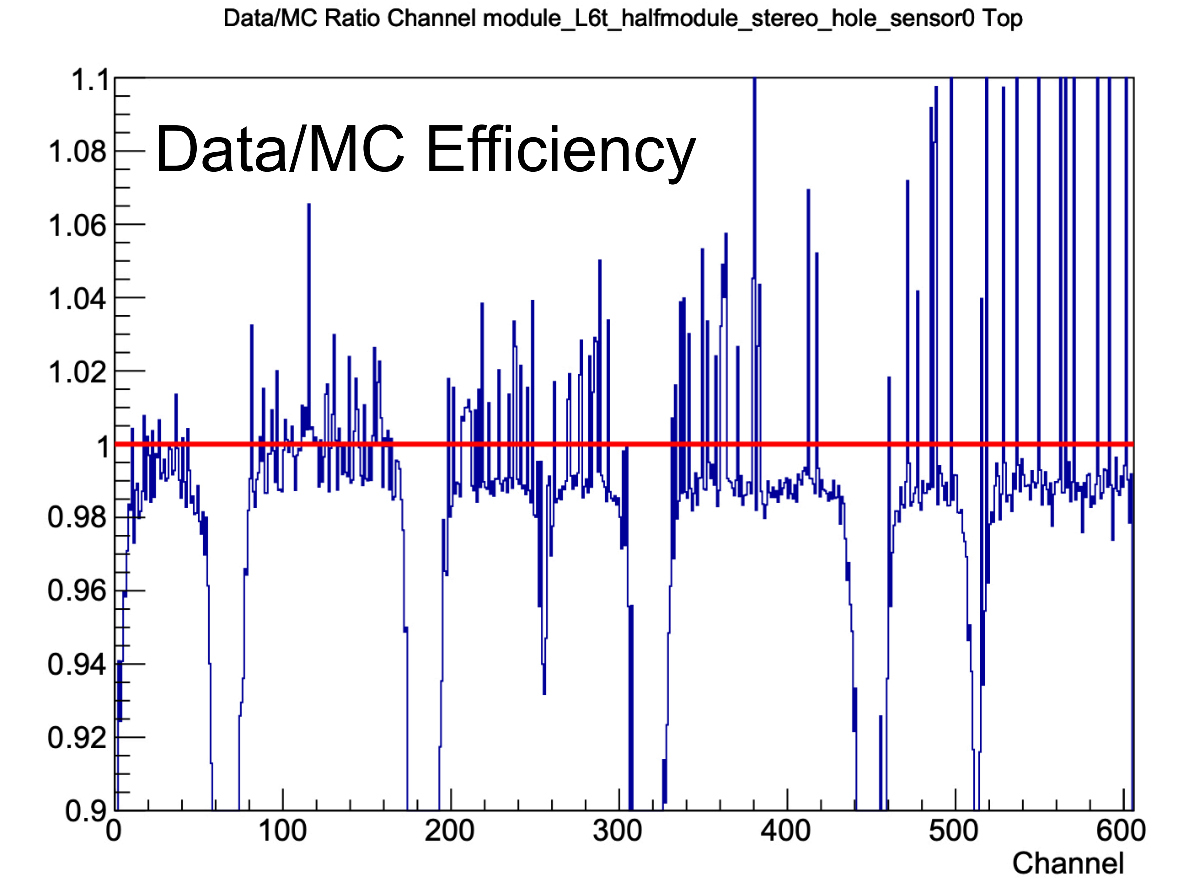


Data/MC Ratio Channel module_L6b_halfmodule_axial_slot_sensor0 Bottom

Data/MC Efficiency



Data/MC Ratio Channel module_L6t_halfmodule_stereo_slot_sensor0 Top



Data/MC Ratio Channel module_L6t_halfmodule_stereo_hole_sensor0 Top

Data/MC Efficiency

Generally, layer 6 sensors are ~1% less efficient in data vs MC (not including bad channels)

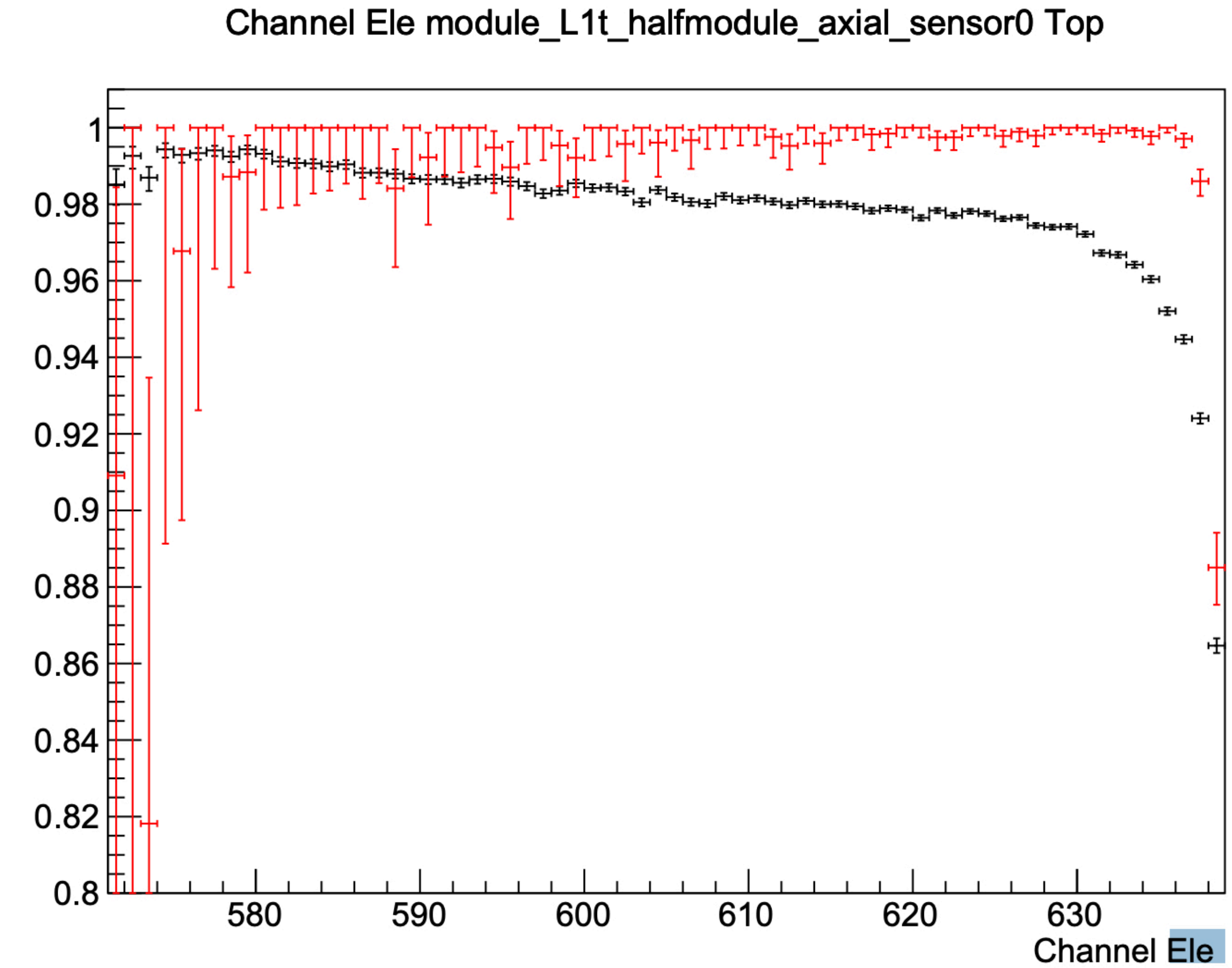
So…what?

- I want to use these data/mc efficiency ratios to kill SVT hits in the MC.
  - based on plots I’ve looked at, only L1 and L6 sensors need this…the other layers look great
  - for L1, need to use electrons only…for L6 can (and should) use both
- how to implement this….need to be careful
  - even though the plots I show are vs “channel number” the is/is not decision is looking for a 1d cluster; the channel numbers just come from the projection of the track
  - probably the right thing is kill hits on the 1d cluster level, transforming the cluster position to a channel number (or use seed channel); alternatively just use ratio vs. u position directly.
  - I DON’T want to use 5-hit track projections because that requires us to already have a track (i.e. it wouldn’t kill any tracks)
- Need more Monte Carlo to bring down the MC-efficiency error bars

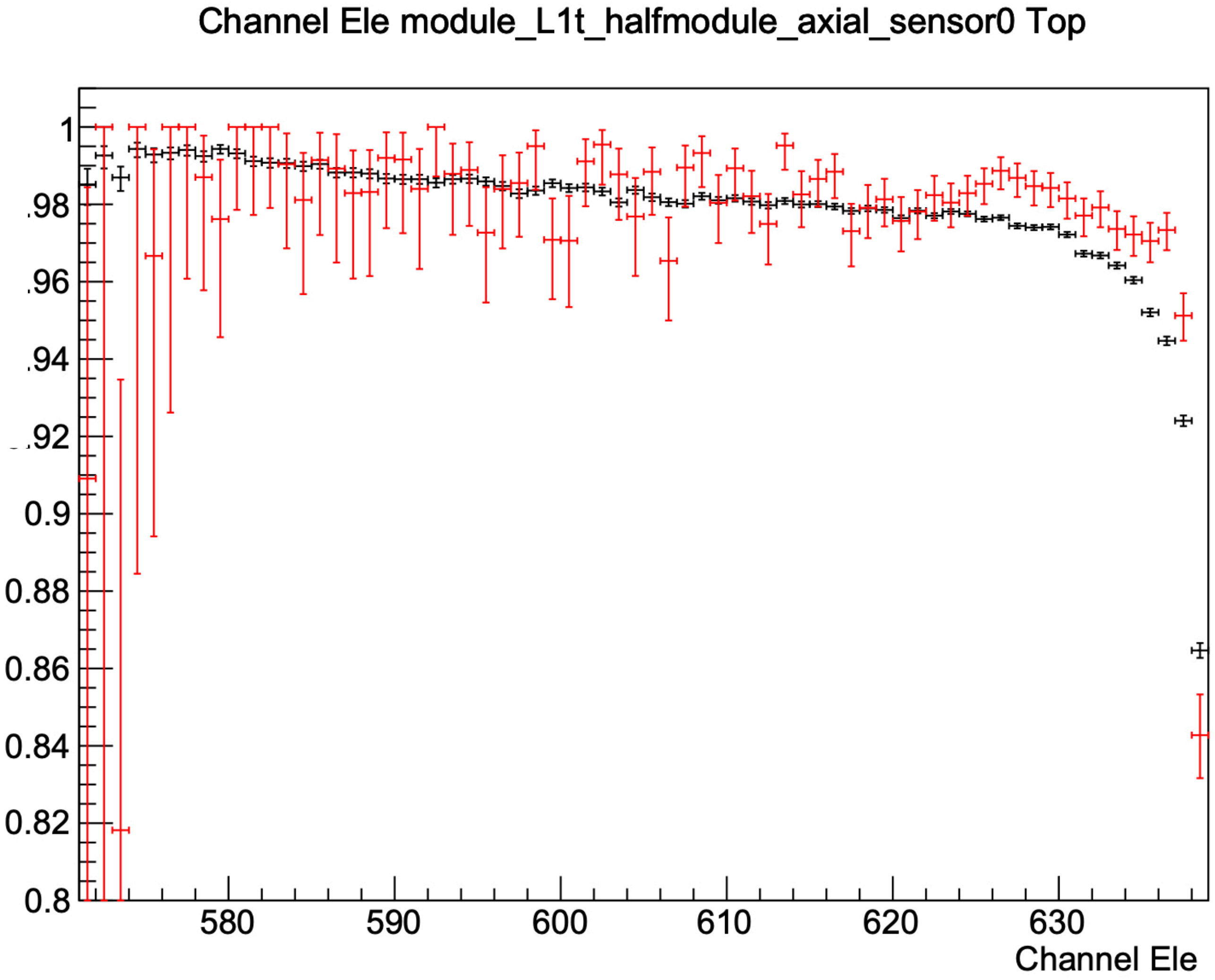
What's the right way to kill hits based on these layer-based hit efficiencies?

- The SVT hit efficiency analysis uses 1D clusters, so I use them
- In the steering file, run StripHitKiller.java after DataTrackerHitDriver.java (MC only!)
- Only kill clusters in L1 and L6
- Well, I don't really know, but I've tried a few things:
  - kill cluster based MC/Data ratio in the bin it is in
    - very simple BUT this isn't really what that efficiency calculation does…it looks for a hit within 5-sigma of the 5-hit track projection (**σ**~0.1mm)
      - this corrects MC ~half way for layer-1, doesn't get the structure in L6
  - kill ALL clusters within "5-sigma" (0.5mm) of a cluster to be killed (still using the MC/Data ratio of the bin that cluster is in)
    - this does better, but is not "right" and tends to overcorrect
  - kill clusters based on "gaussian-weighted ratio"
    - given the SICluster position as the mean, calculate & sum the ratio*integral over channels around it and use that ratio to do accept/reject.
    - width of gaussian is ~projection error (**σ**~0.1mm); can be a tunable parameter
    - this is more smart! and more in line with how efficiencies are obtained

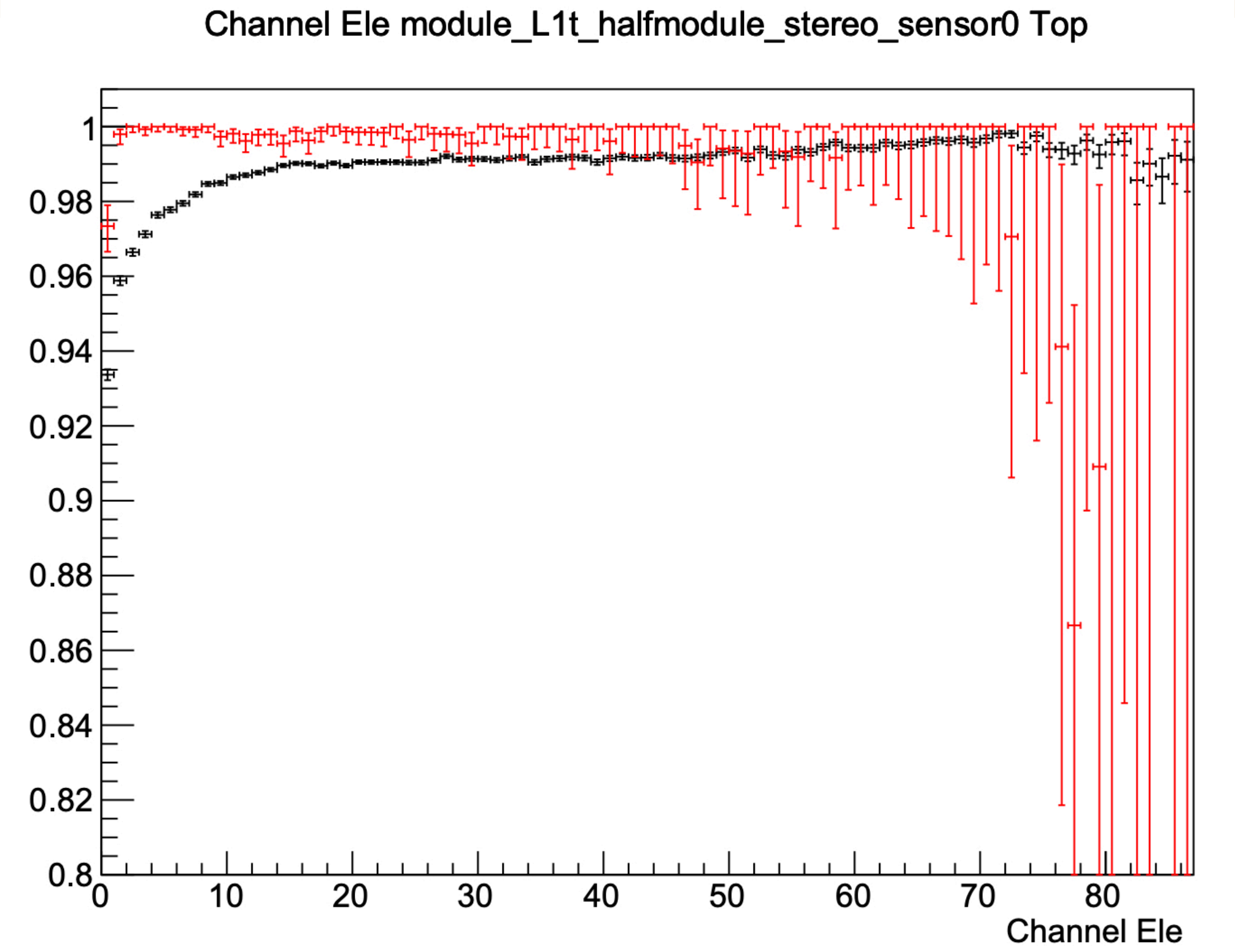
L1-top-axial SVT hit efficiency before and after MC cluster killing



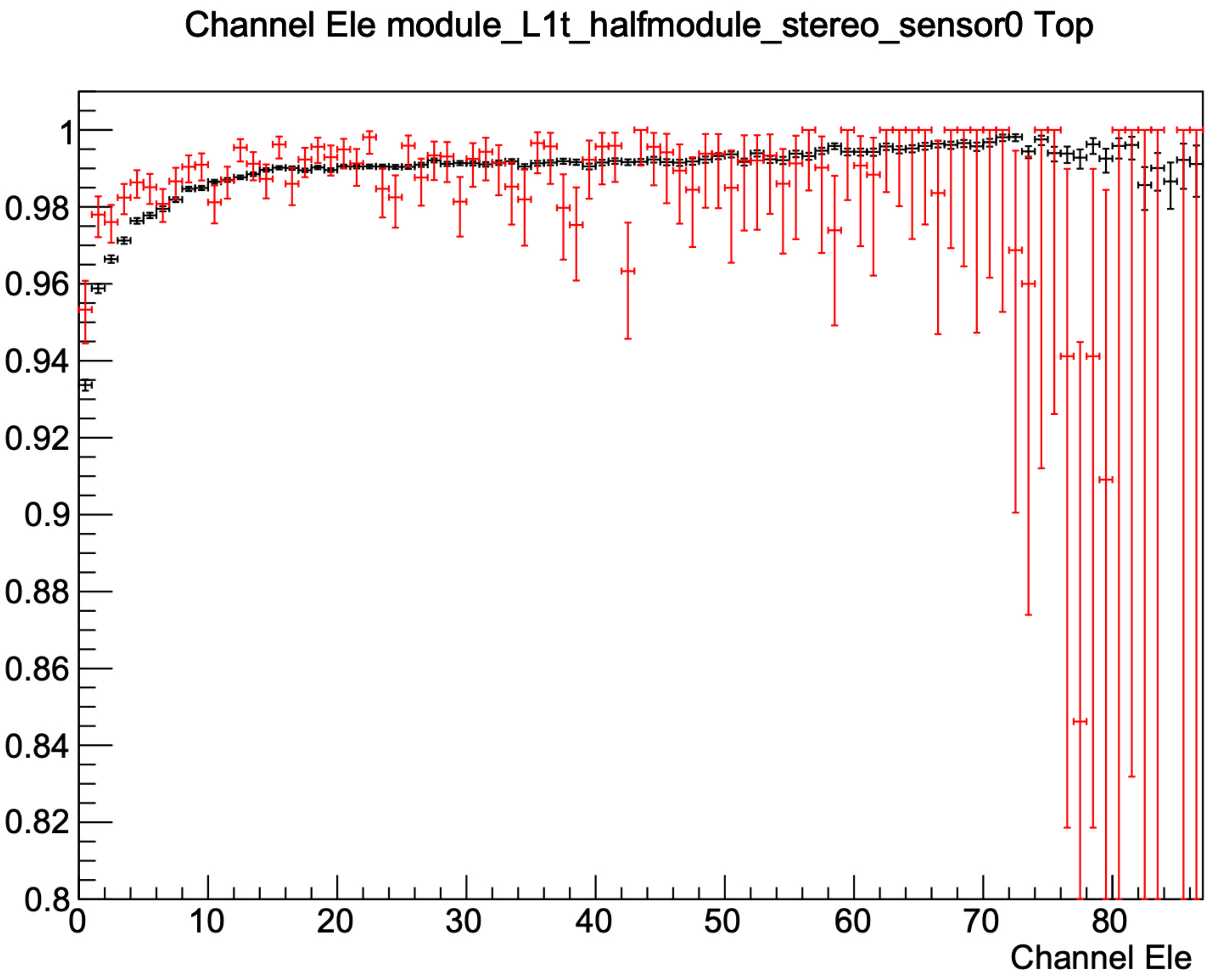
The “killed” L1 efficiencies look pretty good!



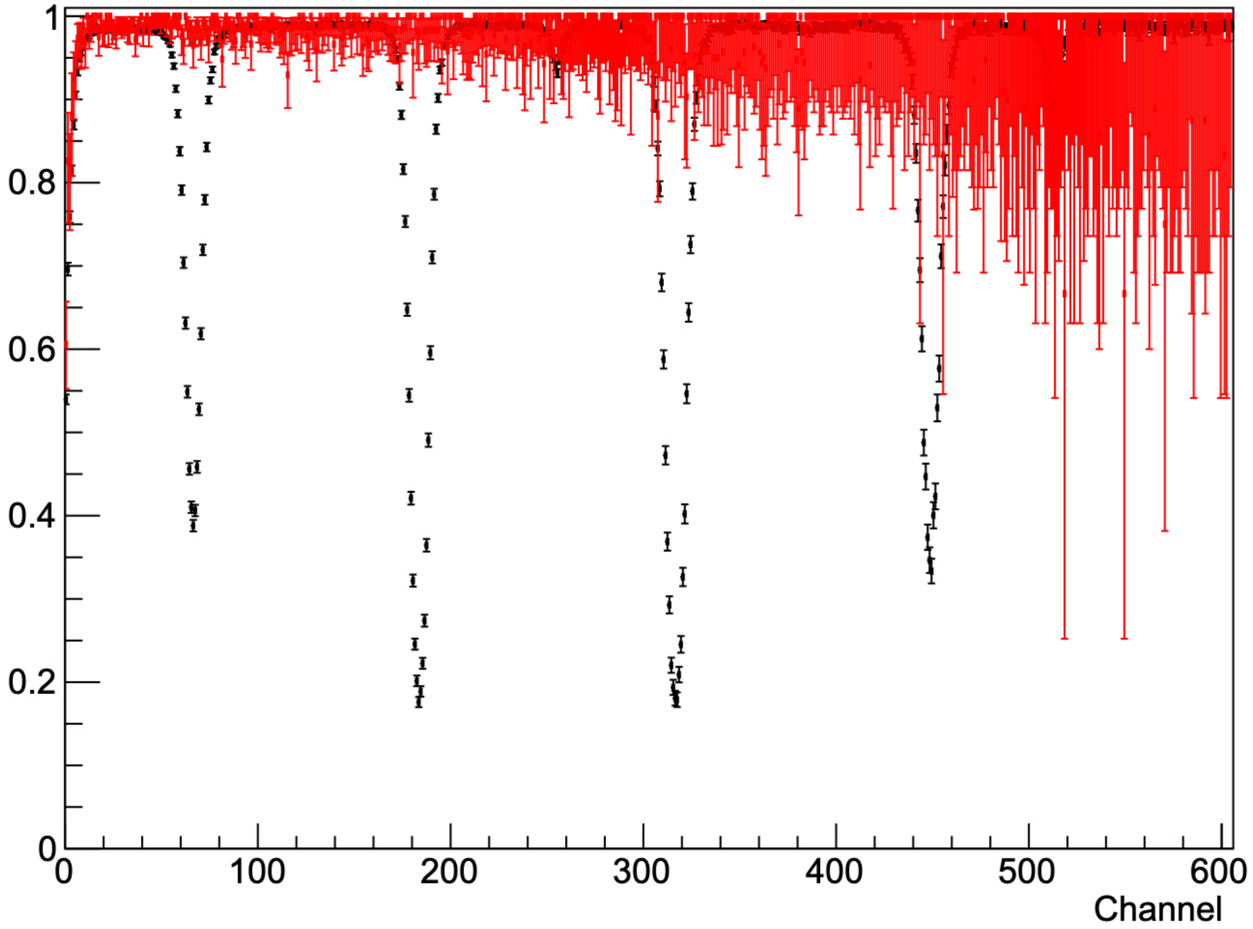
L1-top-stereo SVT hit efficiency before and after MC cluster killing



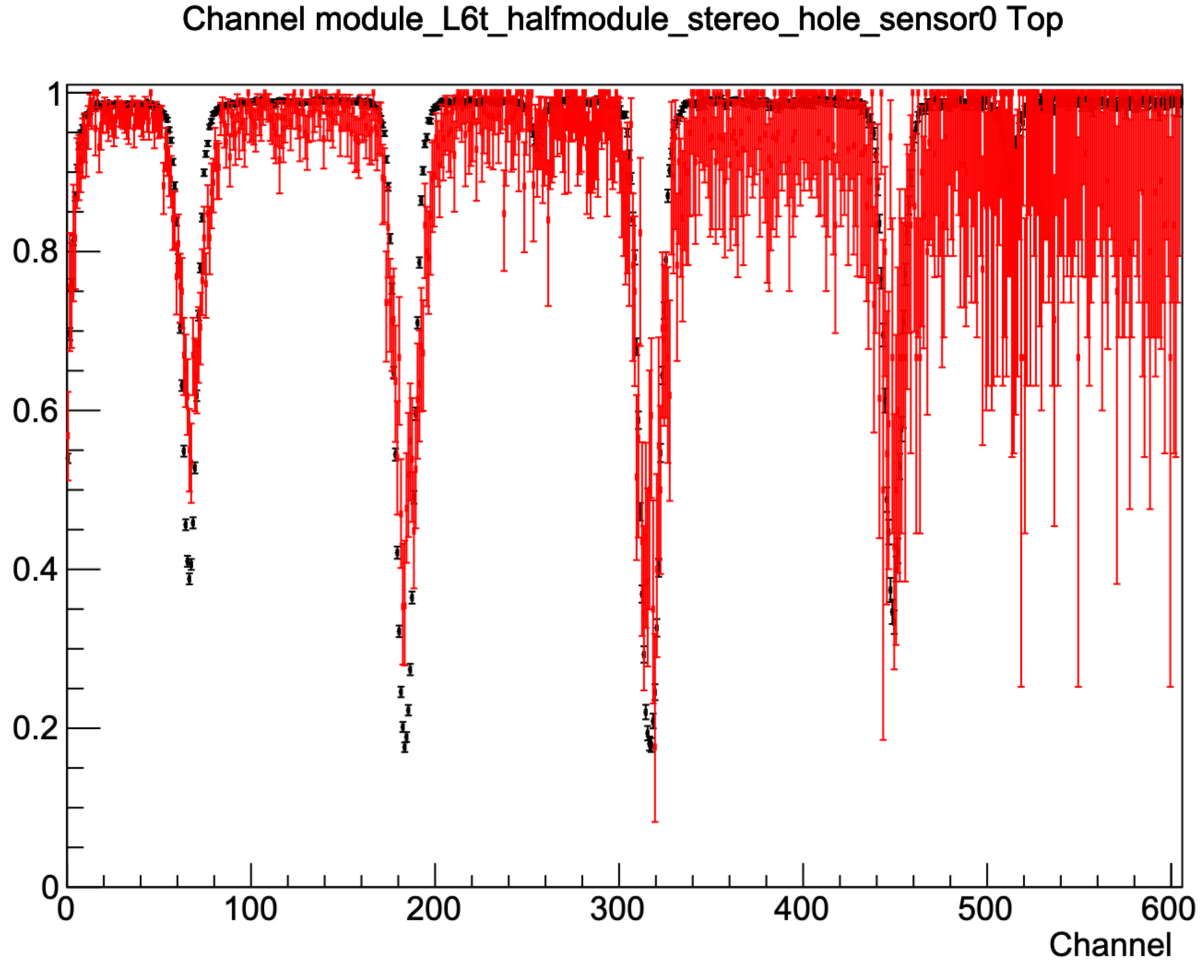
The “killed” L1 efficiencies look pretty good!



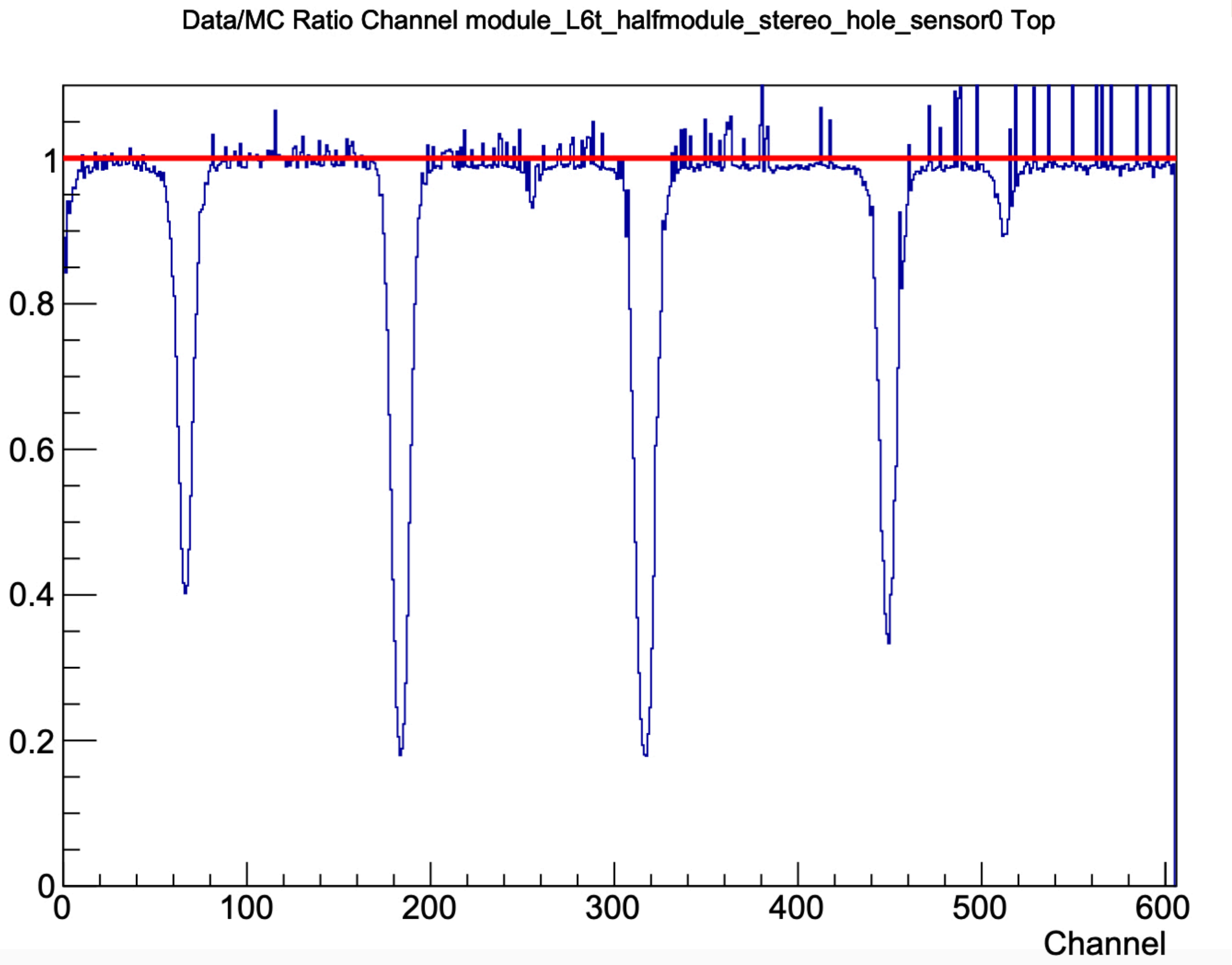
L6-top-stereo-hole SVT hit efficiency before and after MC cluster killing

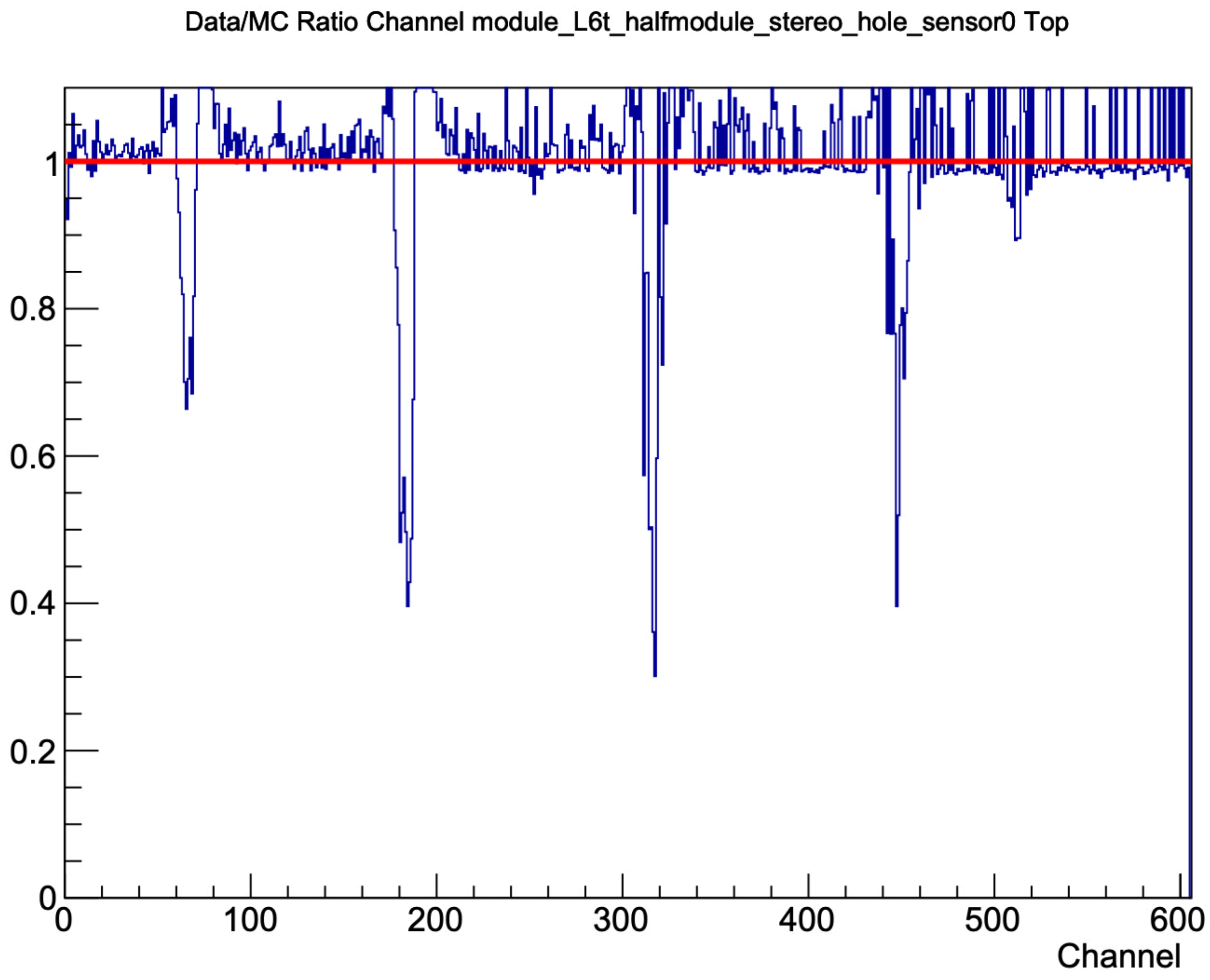


The “killed” L6 efficiencies look … better…



L6-top-stereo-hole SVT hit efficiency *ratio* before and after MC cluster killing





The “killed” L6 efficiencies look …but not perfect — doesn’t get the full dip and overshoots on the tails

Track Efficiency for 2016 Data & MC

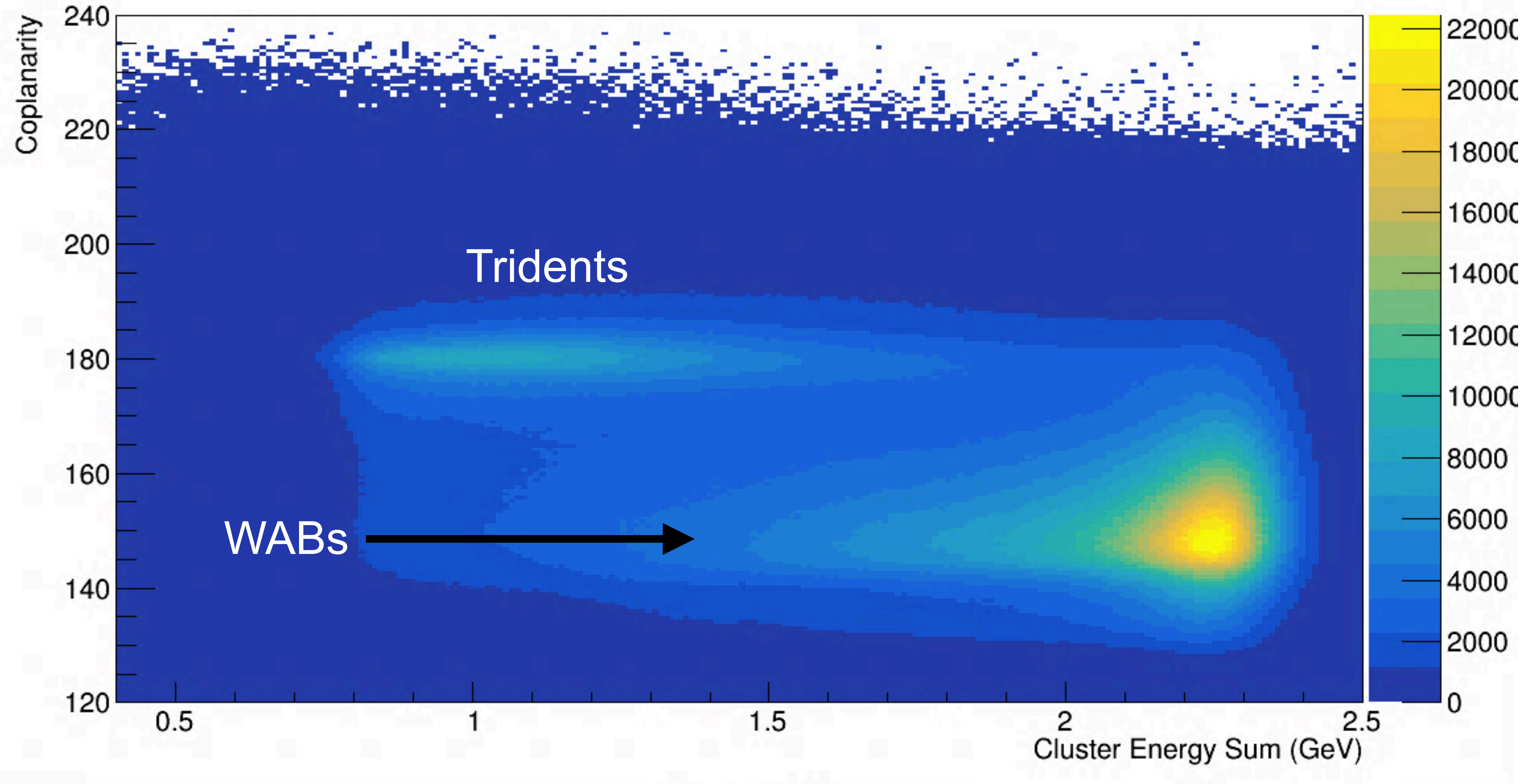
- Use the same method as 2015 — Tag with a positron, probe with electron:
  - positrons ~ only come from tridents or WAB conversions, in both cases there is a real electron there on the other side
- Keep event selection very minimal, for good or ill…good: differences in MC distributions have small impact; ill: junk clusters/tracks may get in and be simulated incorrectly in MC
  - 2 clusters, in time ~ 2ns apart, opposite quadrants (top/bottom & left/right)
  - positron-side cluster has a +ive charged track pointing to it
  - "coplanarity" of the two clusters is
- The electron track efficiency is just the fraction of time we see a negatively charged track associated to the electron-side cluster (give above tag-requirements)

Data Sets Used

- For 2016 data:
  - Run 8099 (the last run!) DSTs…complete run (almost)
- For 2016 MC:
  - Most recently produced tritrig-WB & wab-BT DSTs
    - pass4_4.3.1
  - Also, re-ran the reco tritri-WB slcio with weighted-ratio Si cluster killing

Two Clusters: Coplanarity vs Energy Sum

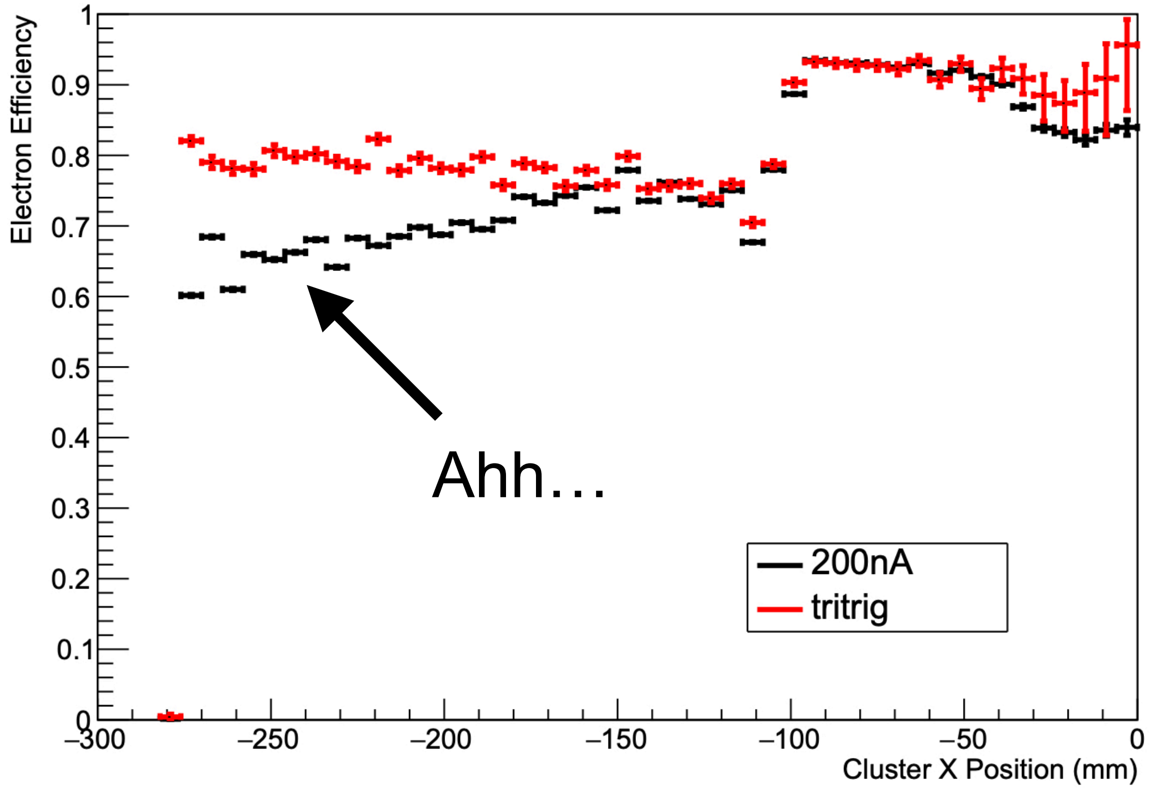
No cuts except 2-cluster timing



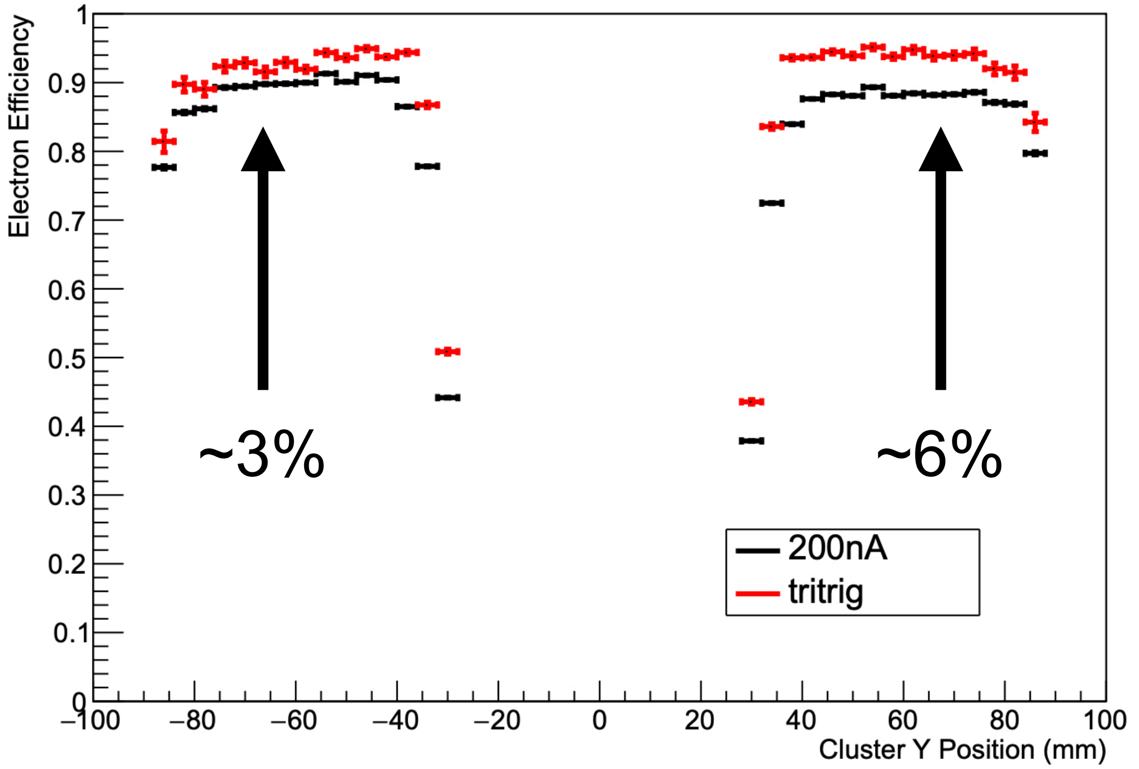
…we trigger on a lot of unconverted WABs…this will be better in 2019!

WABs make it very difficult to get positron efficiency…lots of 2-cluster events with electron but no positron

Electron Efficiency: Cluster Top/Bottom Left/Right Coplanarity ~ 180º

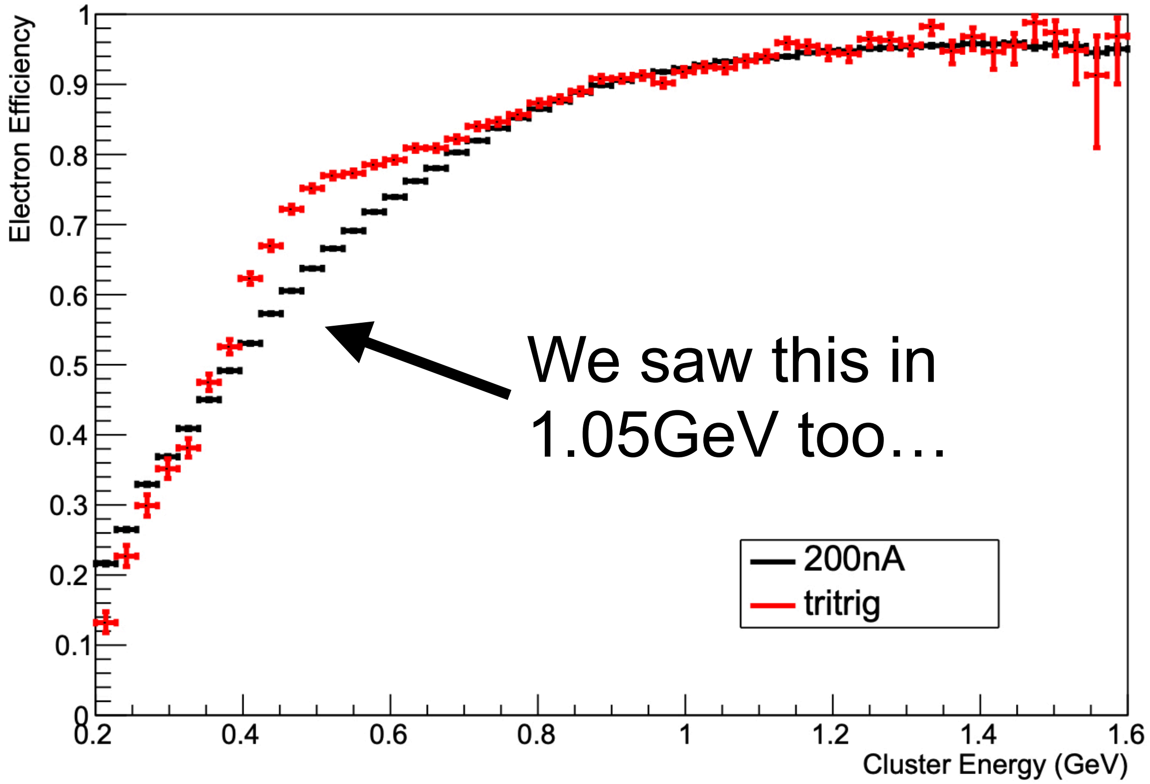


Ahh…



~3%

~6%

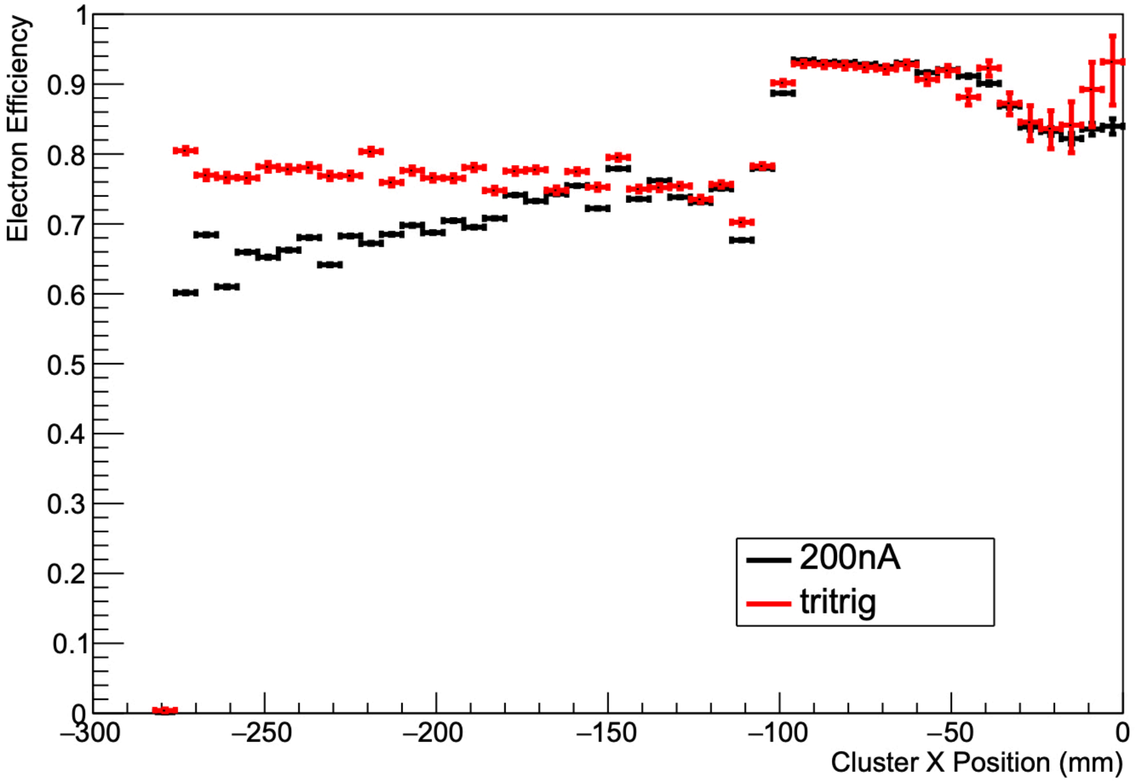


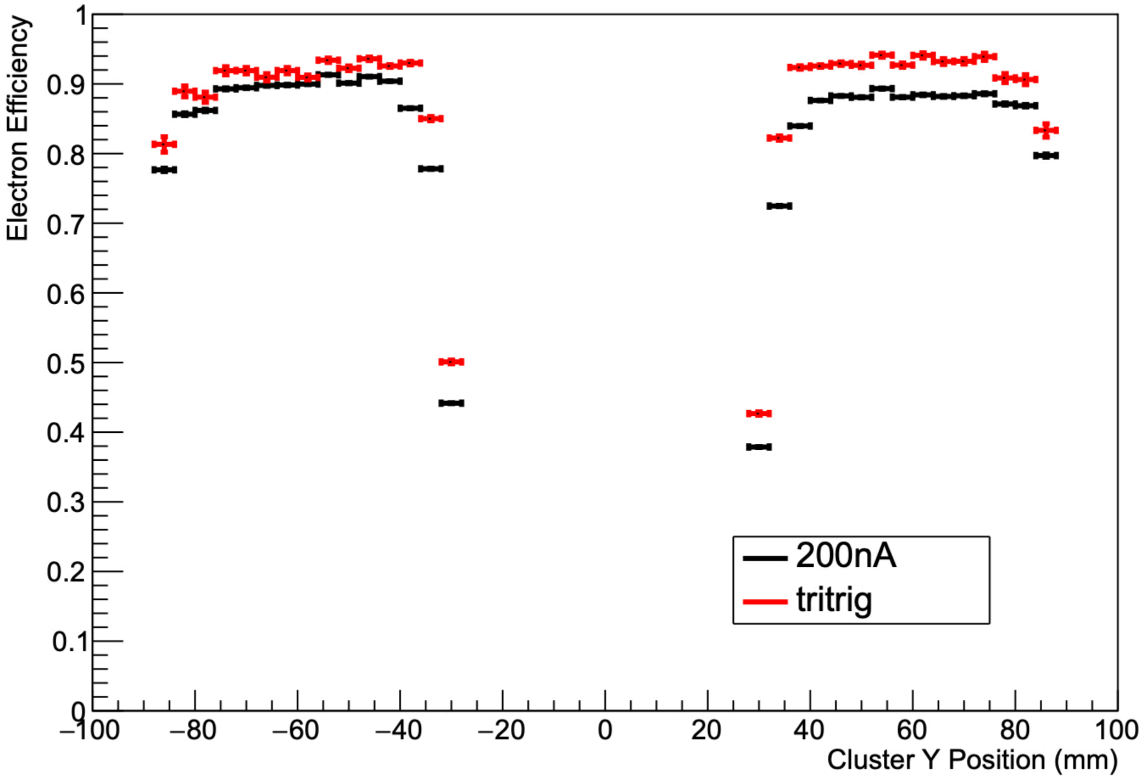
We saw this in 1.05GeV too…

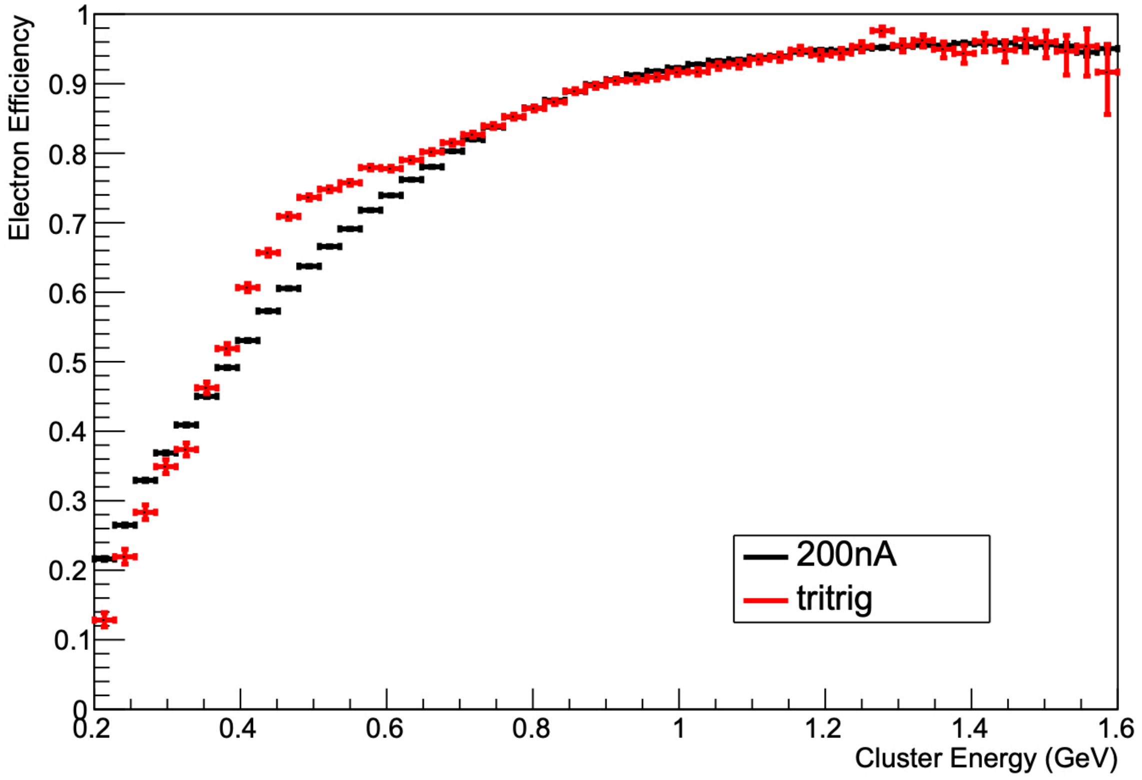
This before cluster killing… will that fix everything?

Red: tritrig-WB MC
Black: run8099

Electron Efficiency: Cluster Top/Bottom Left/Right Coplanarity ~ 180^o with cluster killing



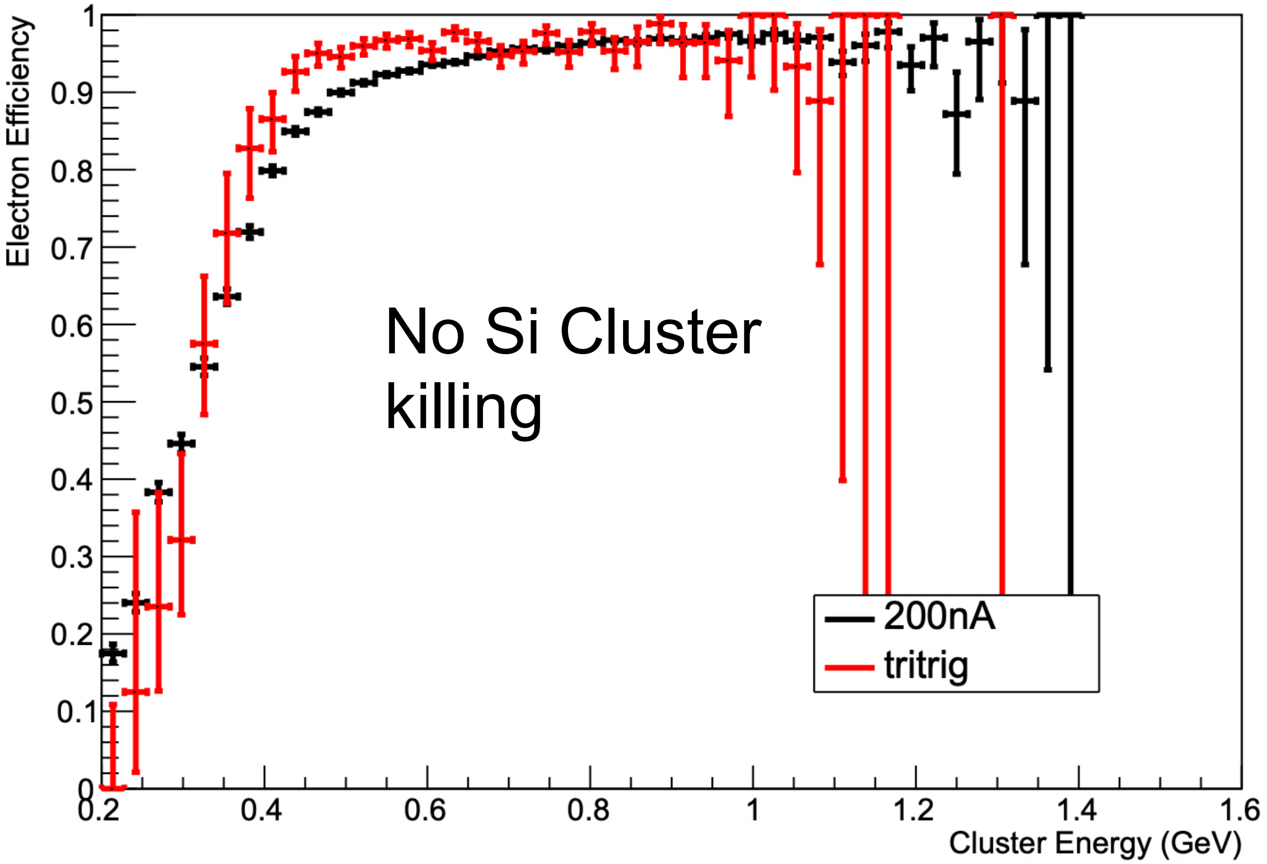




NO!

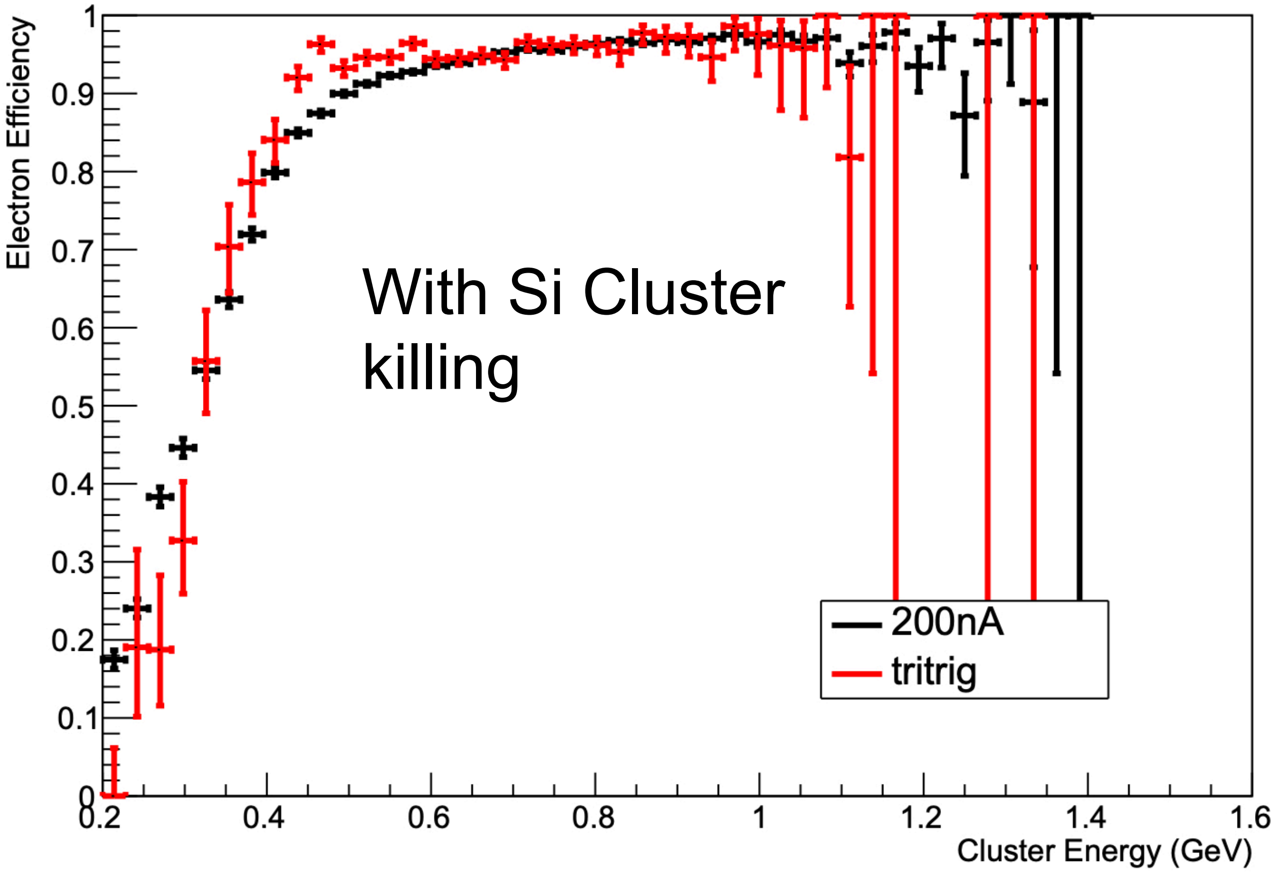
Use a magnifying to see the differences

Electron Efficiency: Cluster Top/Bottom Left/Right Coplanarity ~ 180^o in SuperFiducial region



No Si Cluster killing

SuperFiducial: cluster seed not allowed in edge or hole crystal

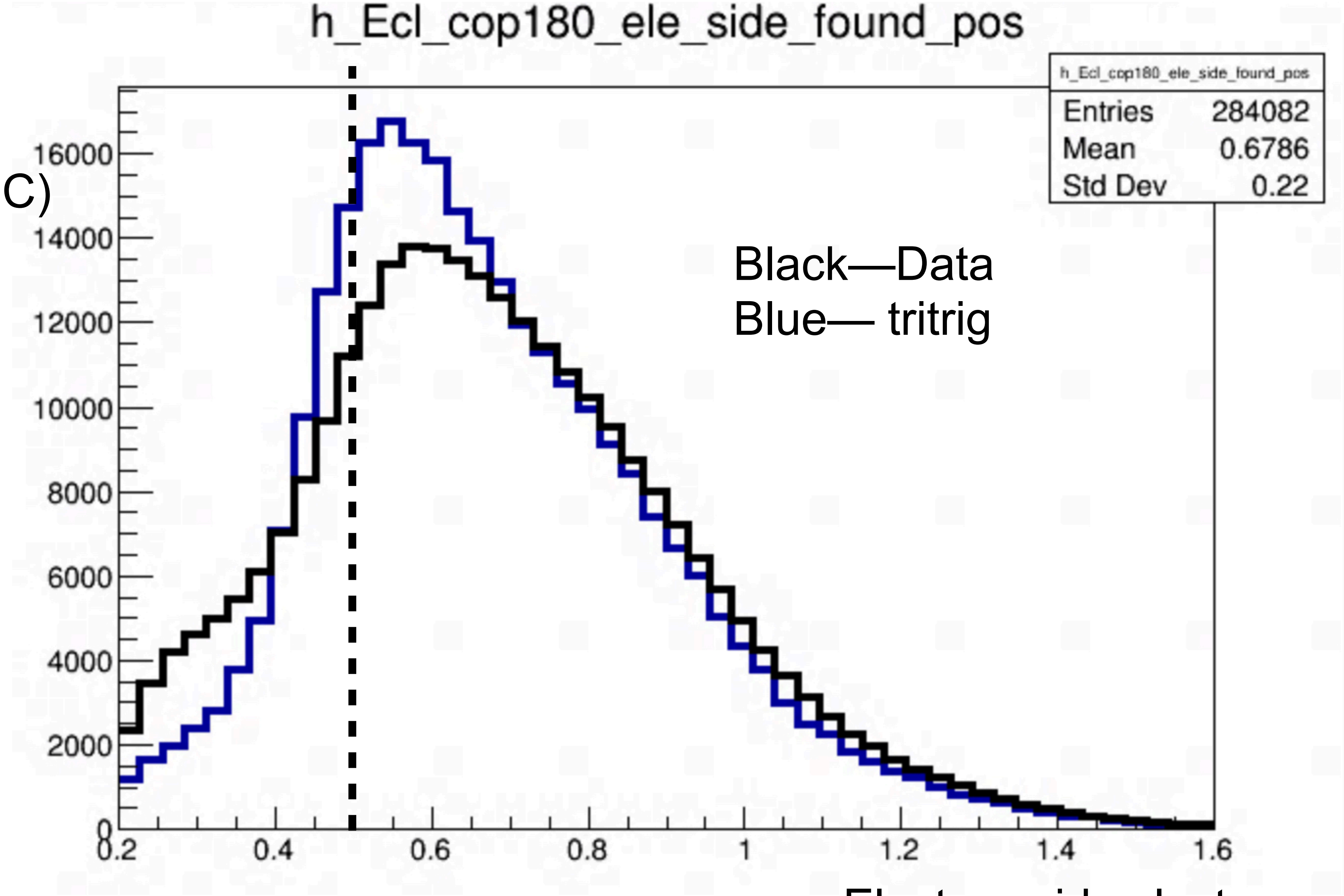


With Si Cluster killing

The weird bump ~ 500MeV in MC is (mostly) gone when cutting on ECal fiducial…I suspect issue with ECal MC resolution near edges

Look at the efficiency bump ~500MeV

N Events
(scaled to MC)

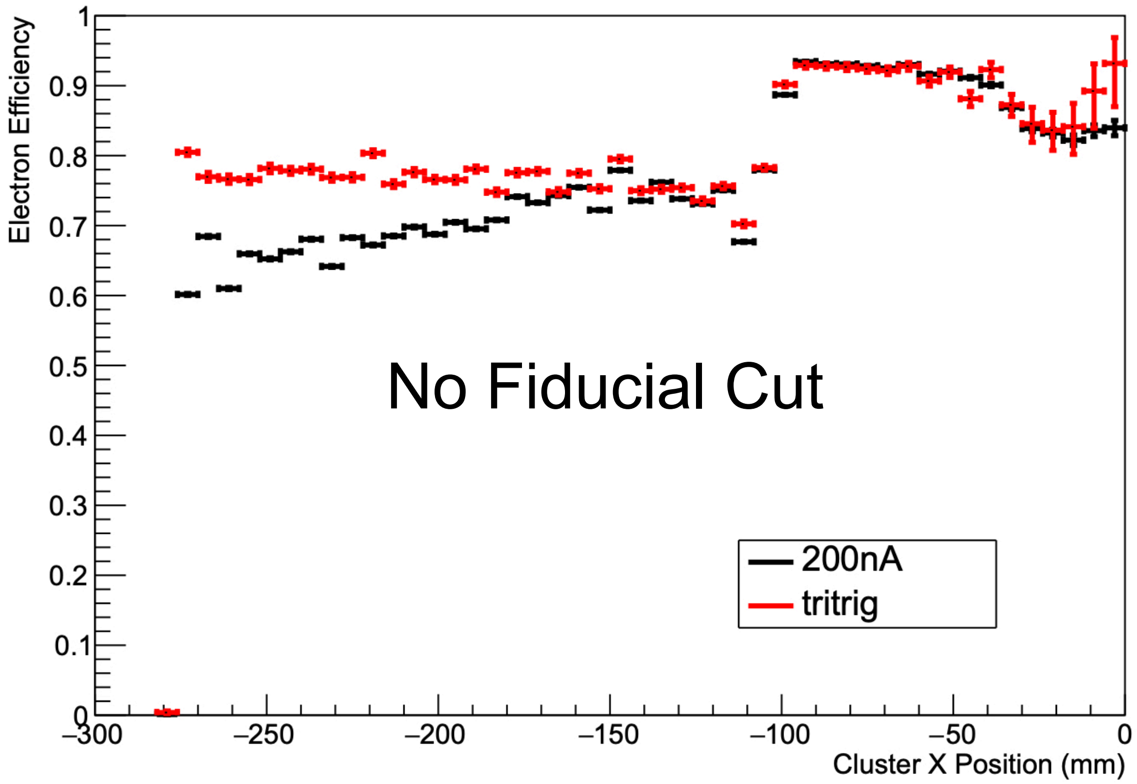


Black—Data
Blue— tritrig

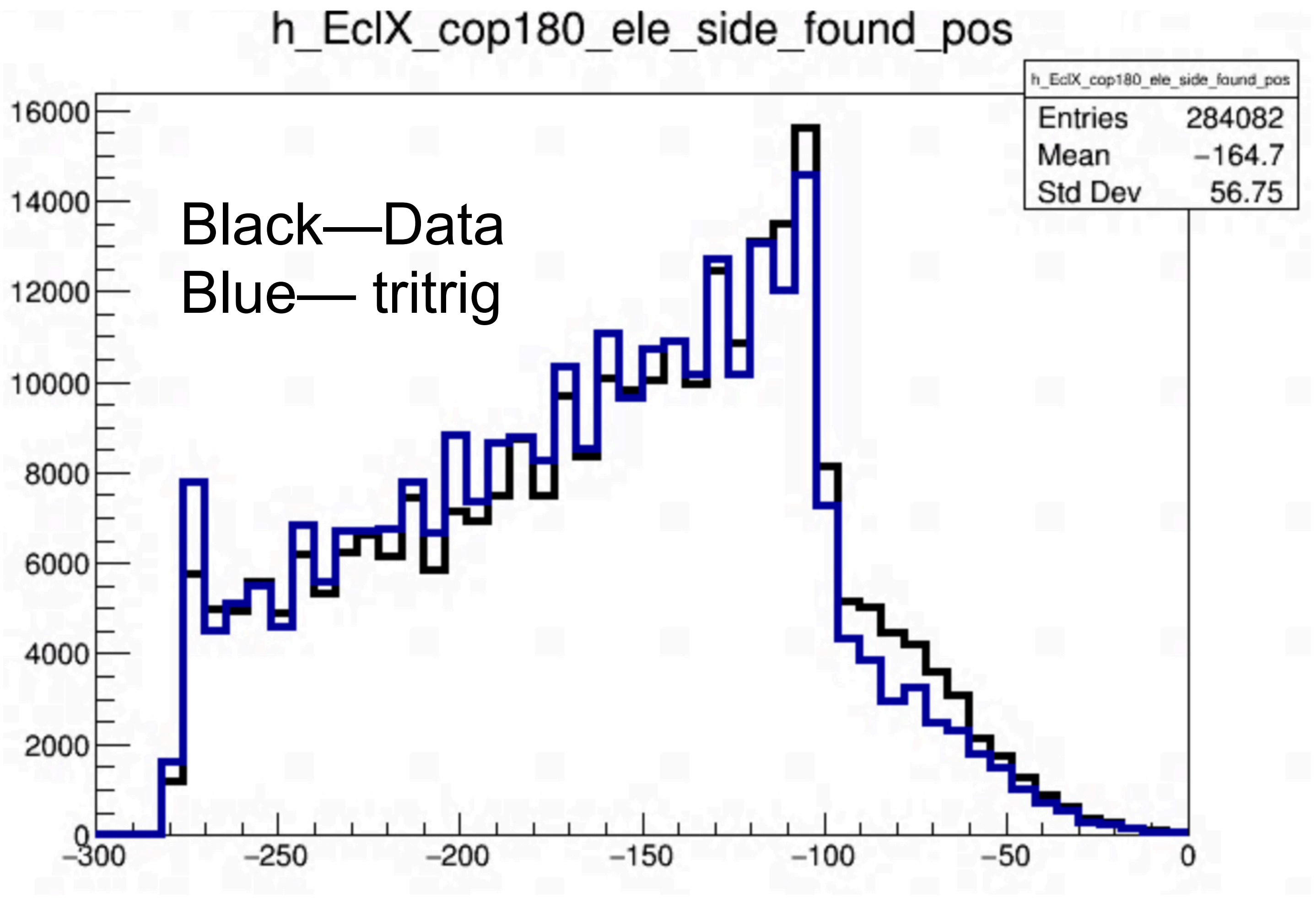
Electron-side cluster energy (positron tagged, no electron track requirement)

Is the low tail mismatch due to MC ECal resolution? Un-simulated background?

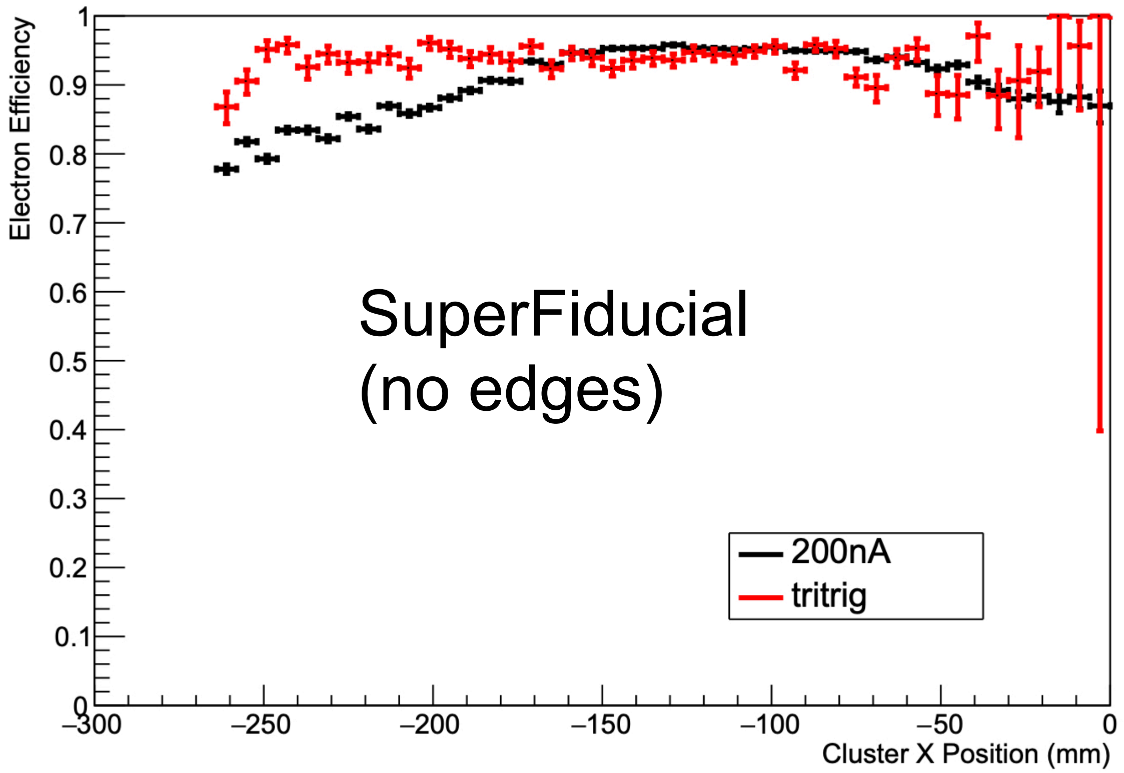
Why does efficiency drop at X<-200mm?



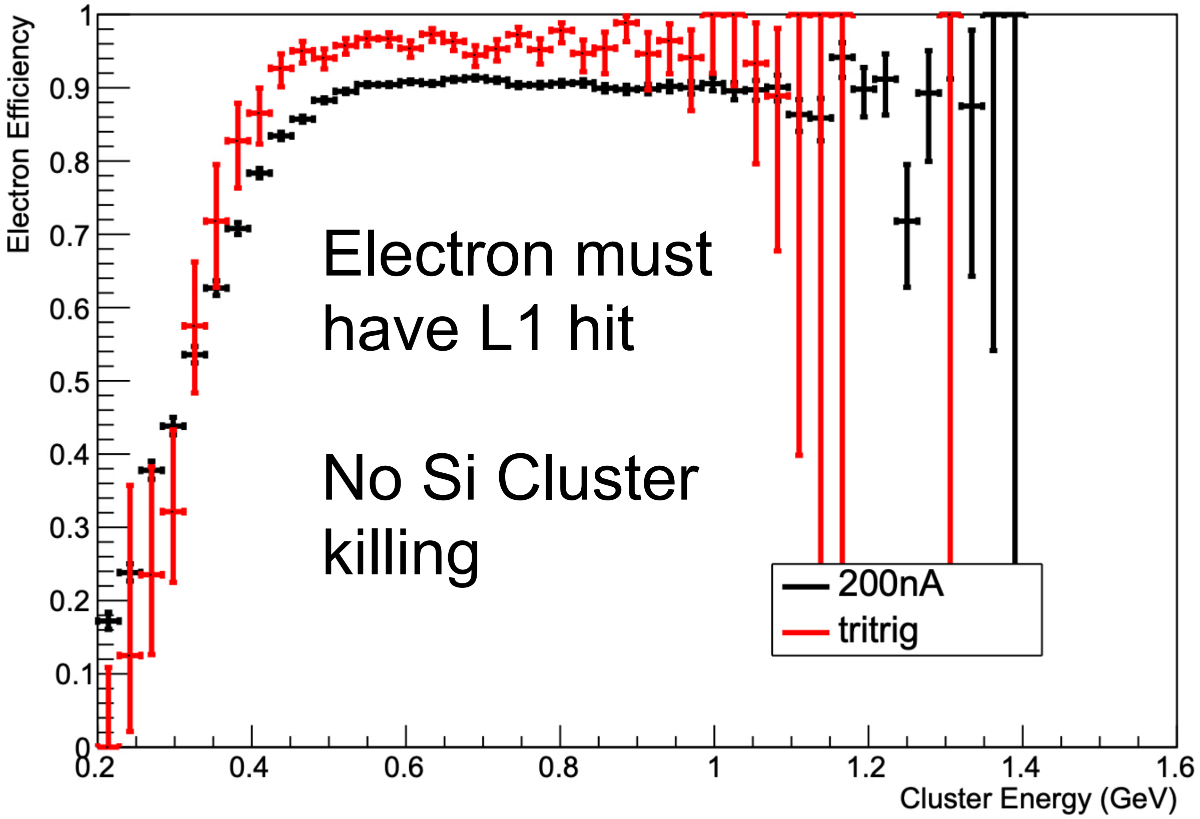
So…why the drop here? Not sure yet…



Electron-side cluster energy (positron tagged, no electron track requirement)



Electron Efficiency vs Probe Cluster Energy: Requiring an L1 Hit (and superFiducial)



Electron must have L1 hit

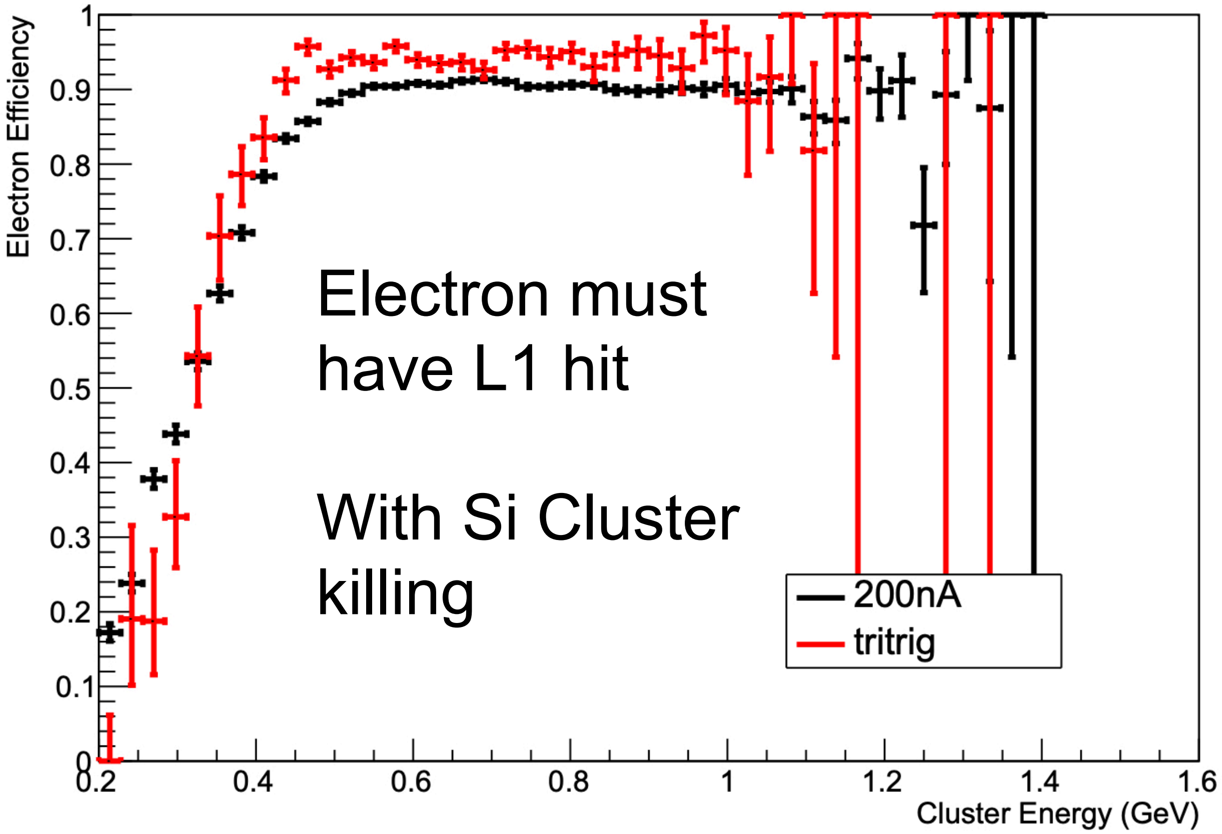
No Si Cluster killing

One big issue we've had is the MC overestimating the fraction of tracks with an L1 hit…I'm hoping this is fixed with the Si cluster killing.

BUT, while killing improves things a bit, doesn't take it all the way down to data.

Data peaks out at ~91% efficiency;
No killing MC ~96%
With killing MC ~94%

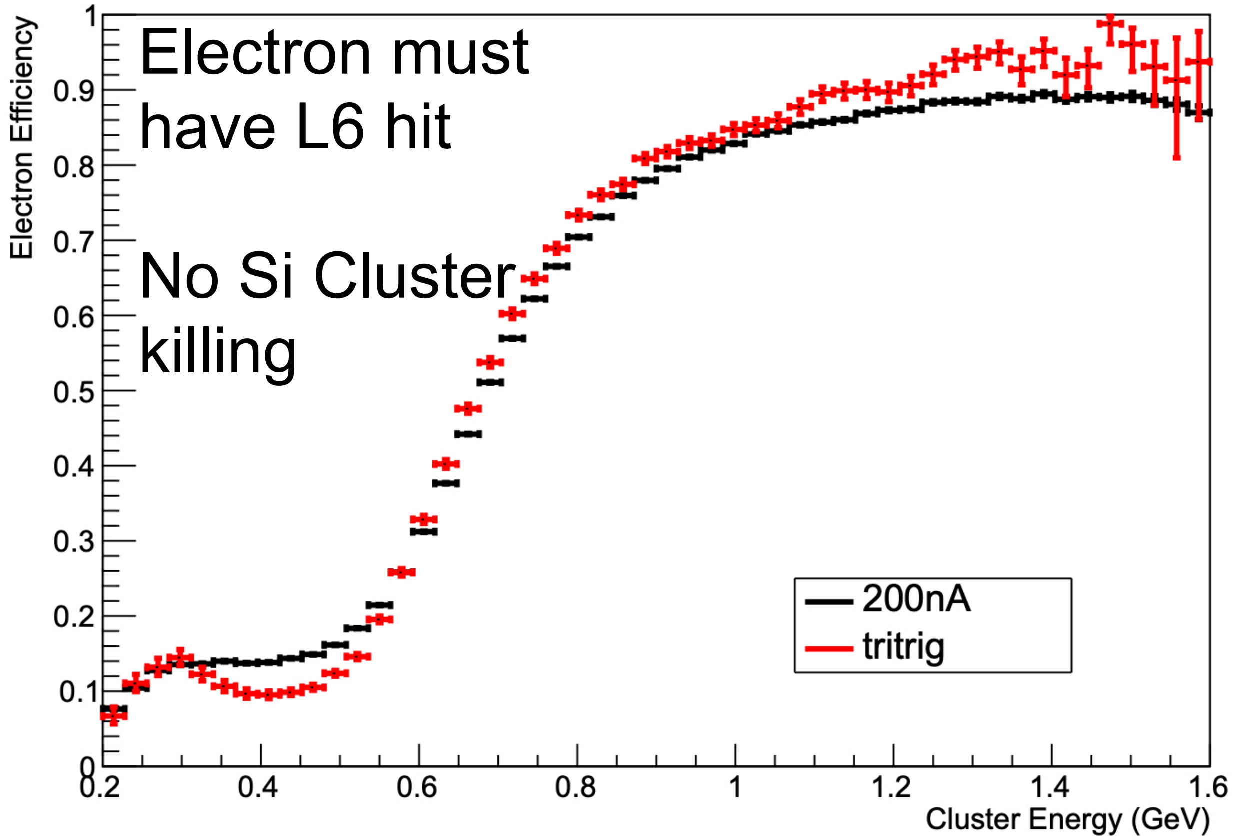
Why doesn't this work???



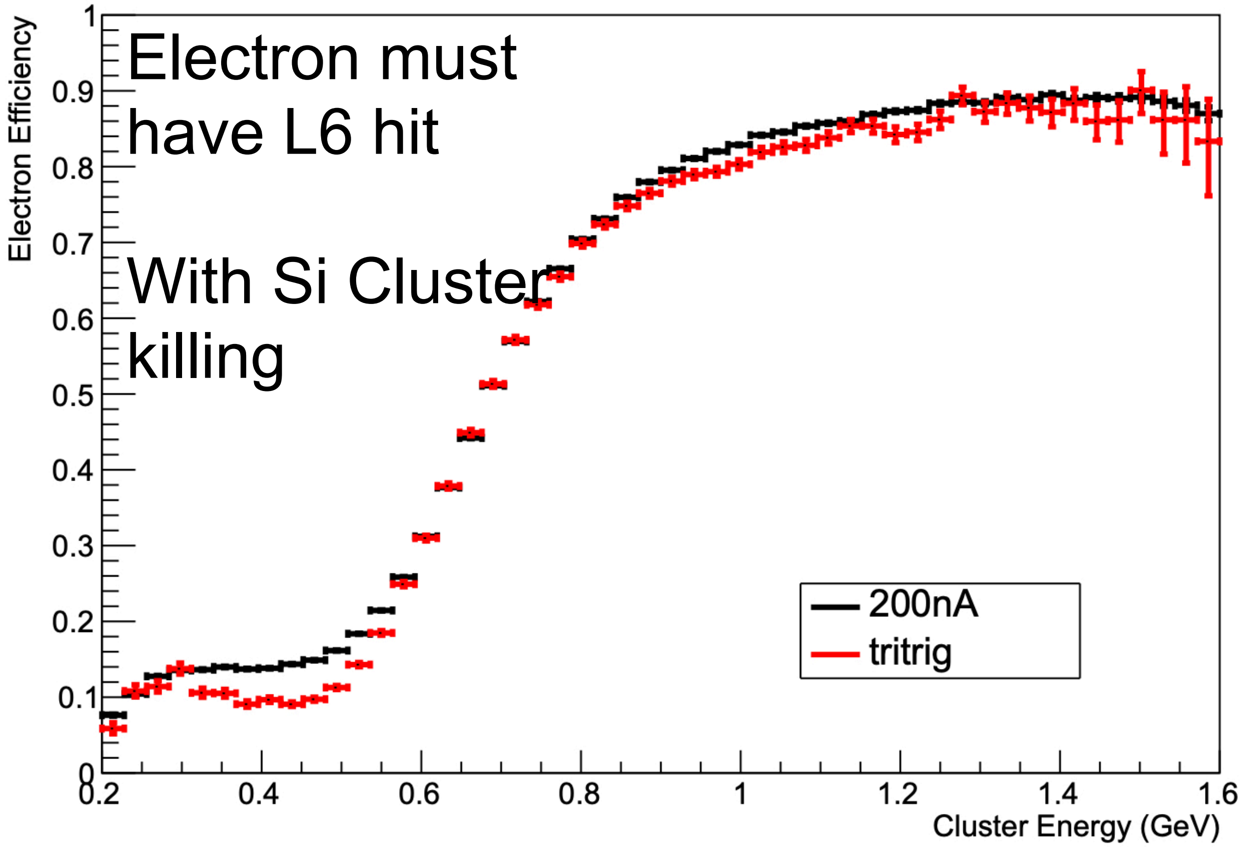
Electron must have L1 hit

With Si Cluster killing

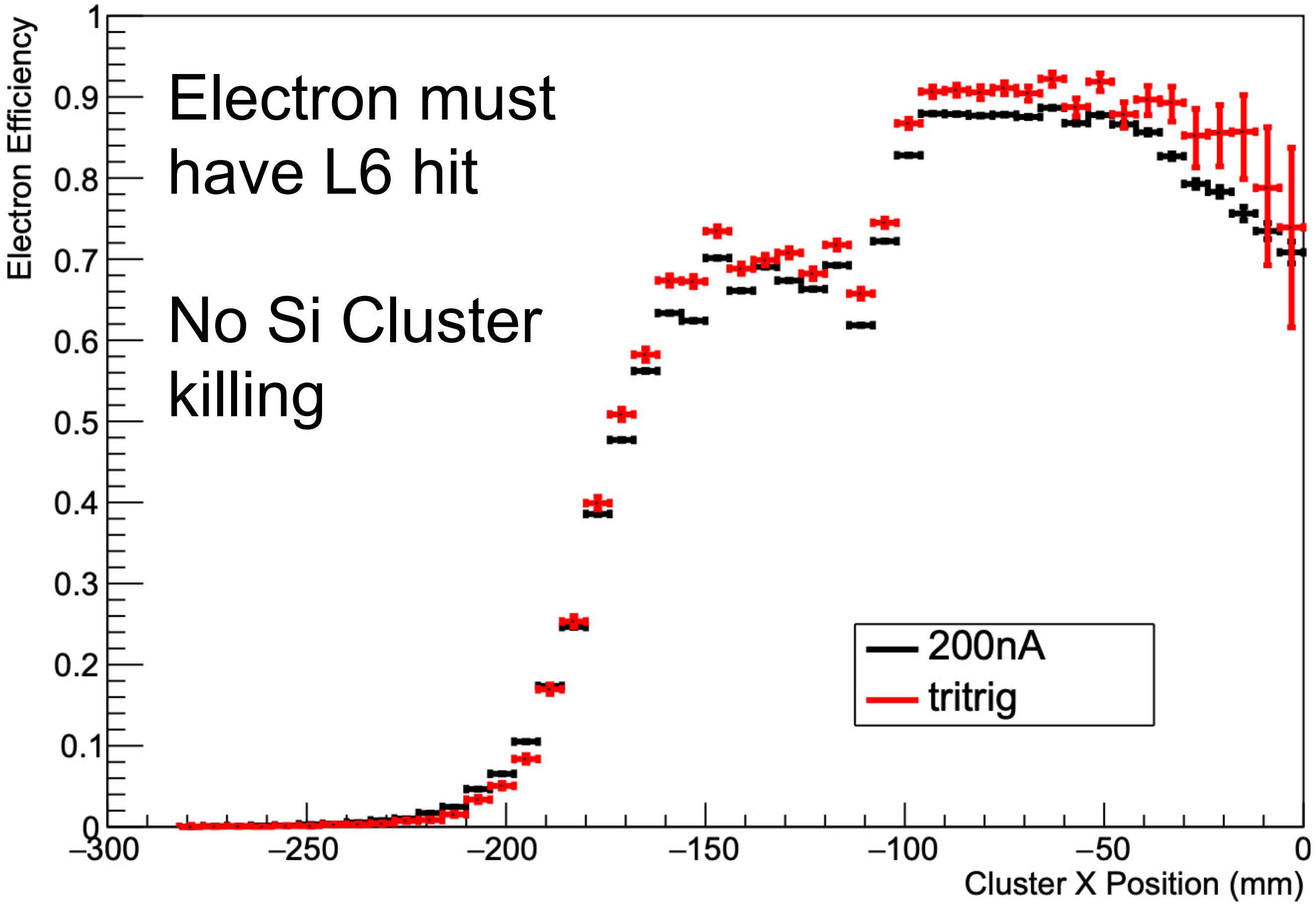
Electron Efficiency vs Probe Cluster Energy: Requiring an L6 Hit



We do see the (over) correction from SVT cluster killing when looking at efficiencies requiring an L6 hit …these events are skewed to higher energies since low p tracks are bent out of L6 acceptance



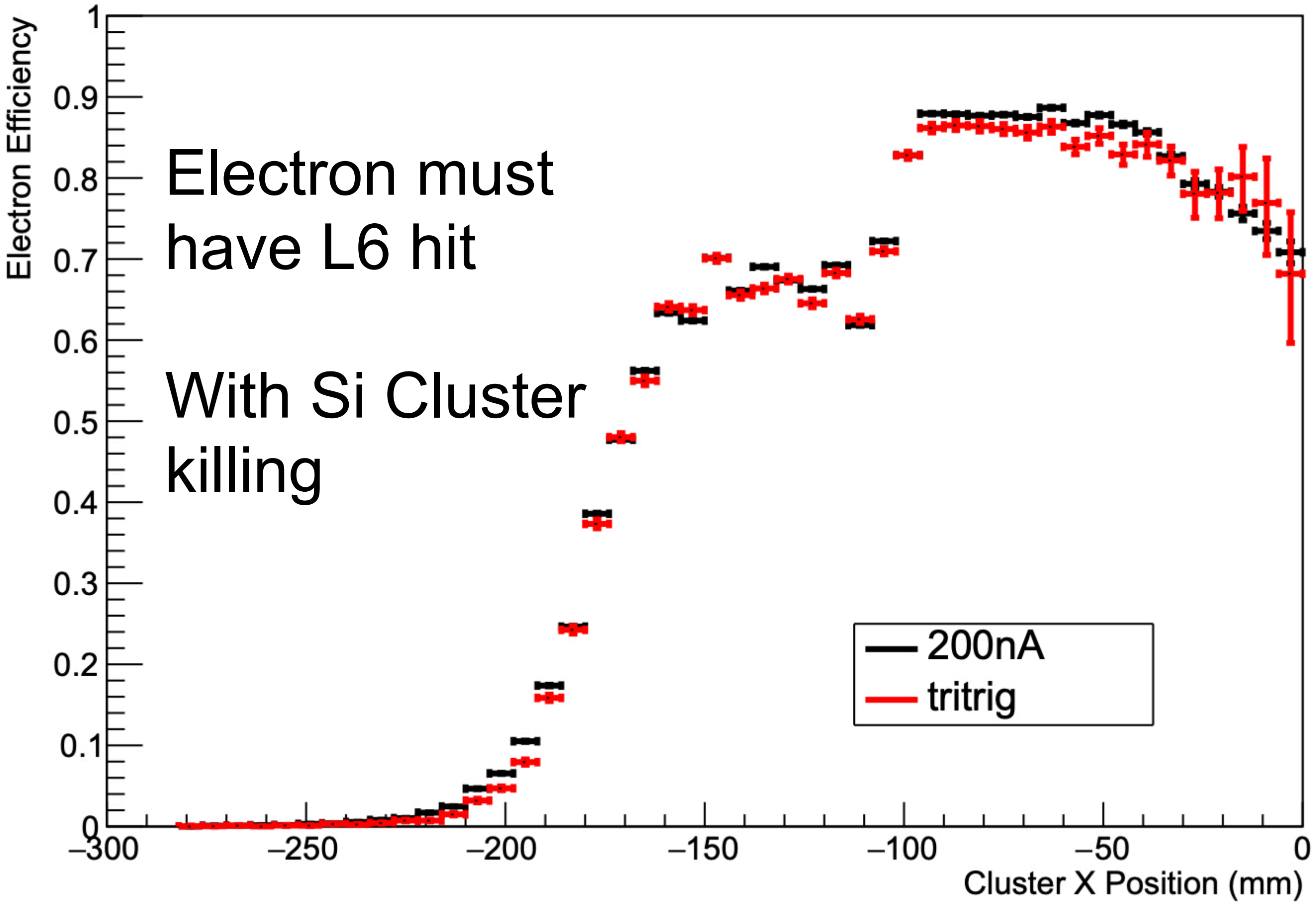
Electron Efficiency vs Probe Cluster X: Requiring an L6 Hit



Electron must have L6 hit

No Si Cluster killing

Similarly looking at the X position of the cluster…basically a wholesale shift to lower efficiency



Electron must have L6 hit

With Si Cluster killing

Halftime Summary: SVT Cluster & Track Efficiency

- SVT hit in-efficiency is not simulated very well
  - for L6, we know there were bad channels in the readout…these should be put in the DB ***and*** used in simulation (which can lead to tricky bookkeeping)
    - hopefully, if these bad channels are included in simulation, the SVT cluster efficiency (as calculated) will just agree between data/MC
  - for L1, I think the loss of efficiency has too due with occupancy/pileup/radiation damage/???
    - I haven’t shown occupancy plots here (I should have)…does our tritrig-WB occupancy match data?
    - if there is damage to the sensor leading to inefficiency, how do we simulate it?
  - apart for the dips in L6, we are talking about ~few percent differences between data/MC
- Even though I’ve made a big deal about a few weird things, the track efficiency data/MC looks pretty good and in line with 2015
  - since we allow 5-hit tracks and we still have pretty good single hit efficiency, the small corrections to the SVT in L1 and L6 don’t effect the overall efficiency much
  - what I wanted to accomplish was to get the L1/L2 ratios for trident & WABs correct…which brings me to second talk

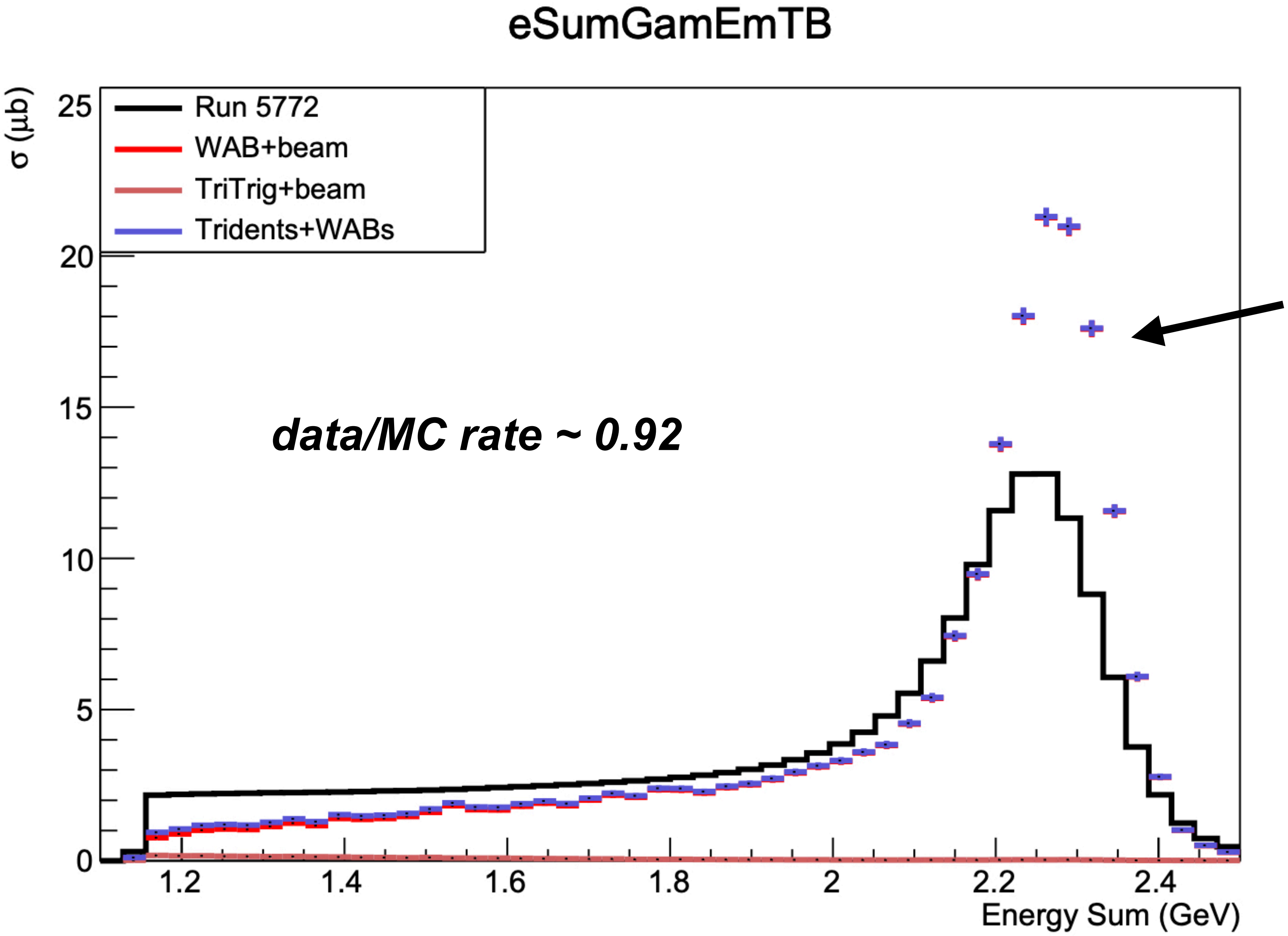
Cuts:

- For all pairs:
  - pairs1 trigger
  - two clusters, top/bottom $\Delta t<2$ns
- For ɣe⁻:
  - one matched electron; second cluster unmatched with track (standard recon matching)
  - electron track $\chi^2<40$
  - track time-cluster time < 5.8ns
- For e^+e^-:
  - one each positron and electron matched with cluster
  - both track $\chi^2<40$
  - unconstrained vertex $\chi^2<75$
  - track time-cluster time < 5.8ns

Data Sets:

- run 8099: pass4
- tritrig-WB, wabtrig-BT MC samples: pass4
  - post-recon MC tweaks: SVT weighted-ratio hit killing (unless specified

Energy Sum (cluster E + track p) for γe⁻

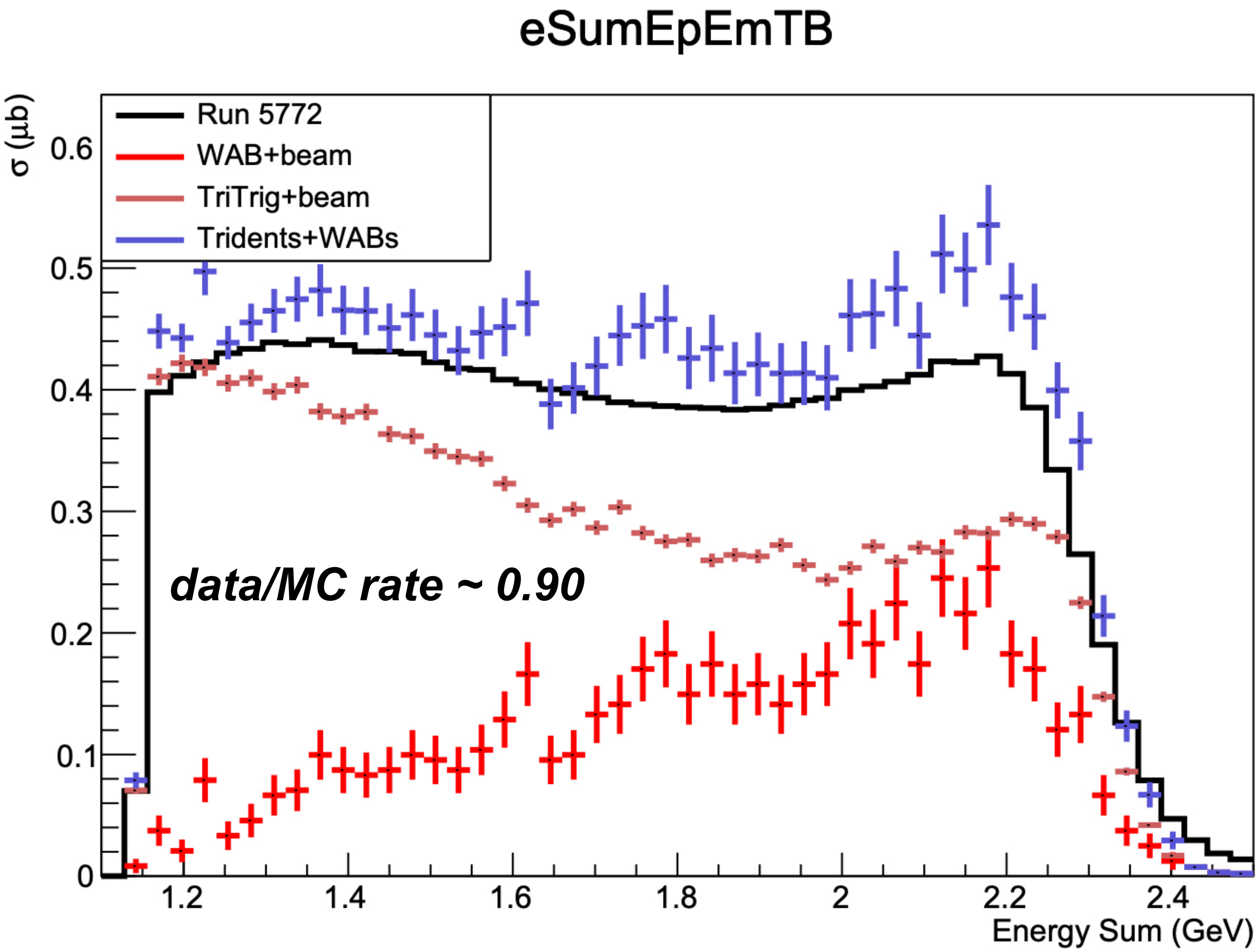


data/MC rate ~ 0.92

MC cluster resolution too good?

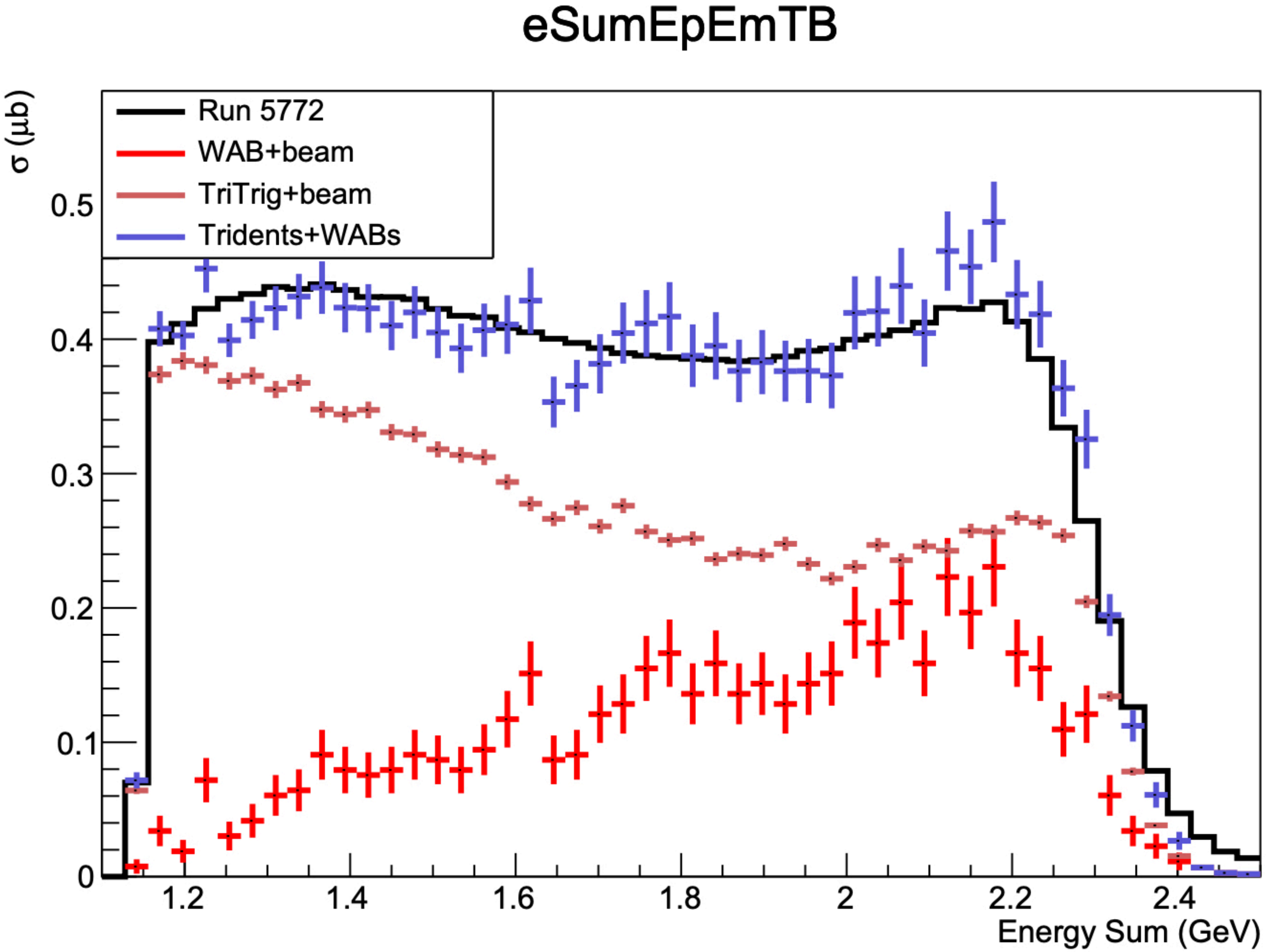
data cross-section = 191.0 ub
wabtrig-BT MC cross-section = 204.4 ub
tritrig-WB MC cross-section = 3.2 ub

Energy Sum for e⁺e⁻



data cross-section = 17.1 ub
wabtrig-BT MC cross-section = 5.6 ub
tritrig-WB MC cross-section = 13.3 ub

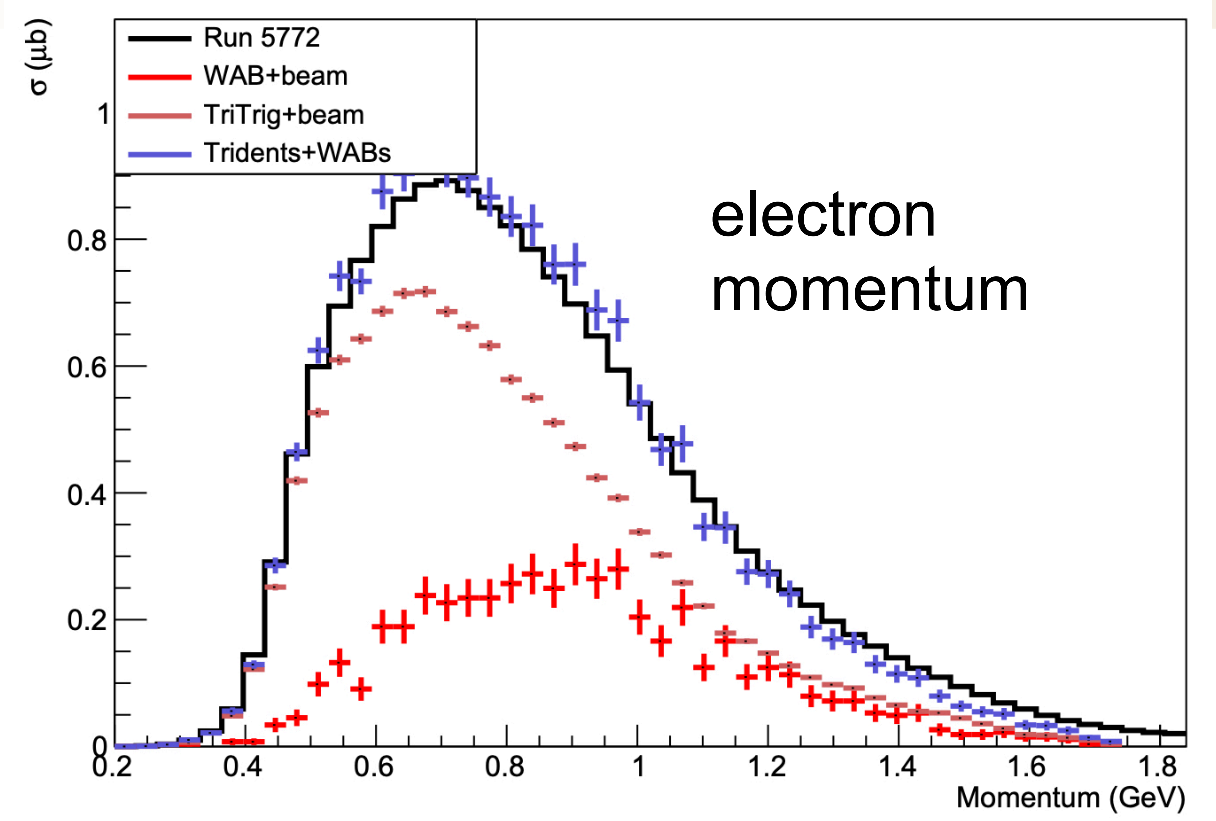
Ok, scale both tritrig & wabtrig by 0.91

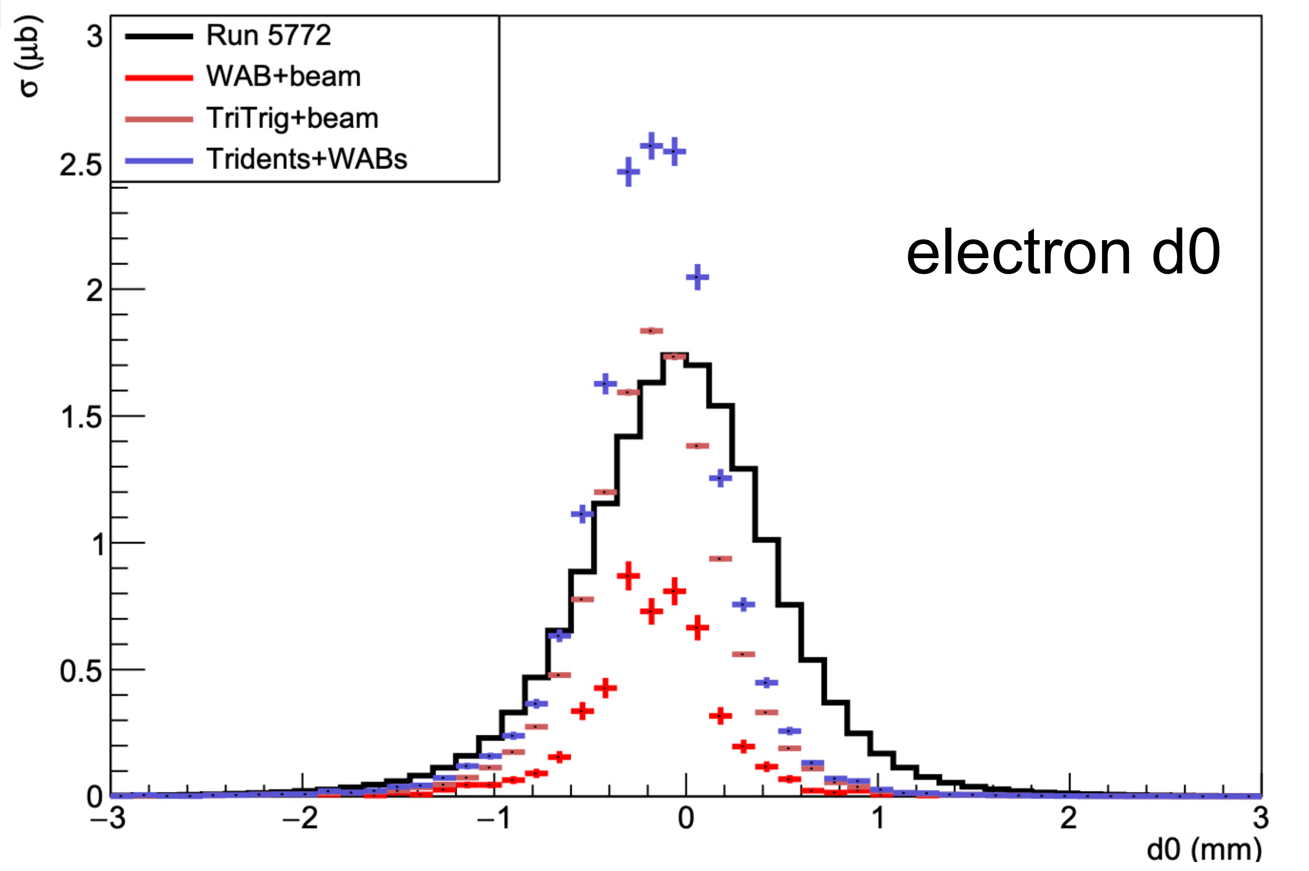


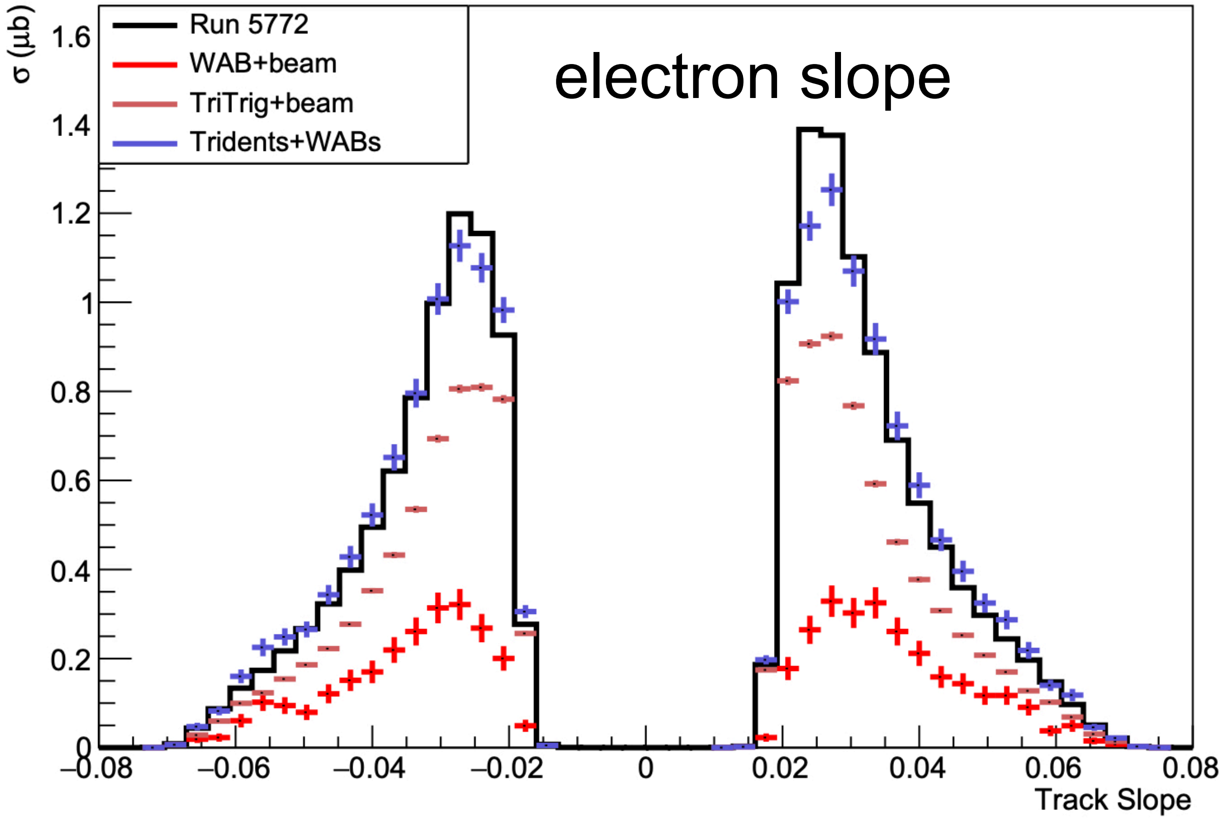
…we had a fudge factor 0.87 in 2015 data…so, ok, fine.

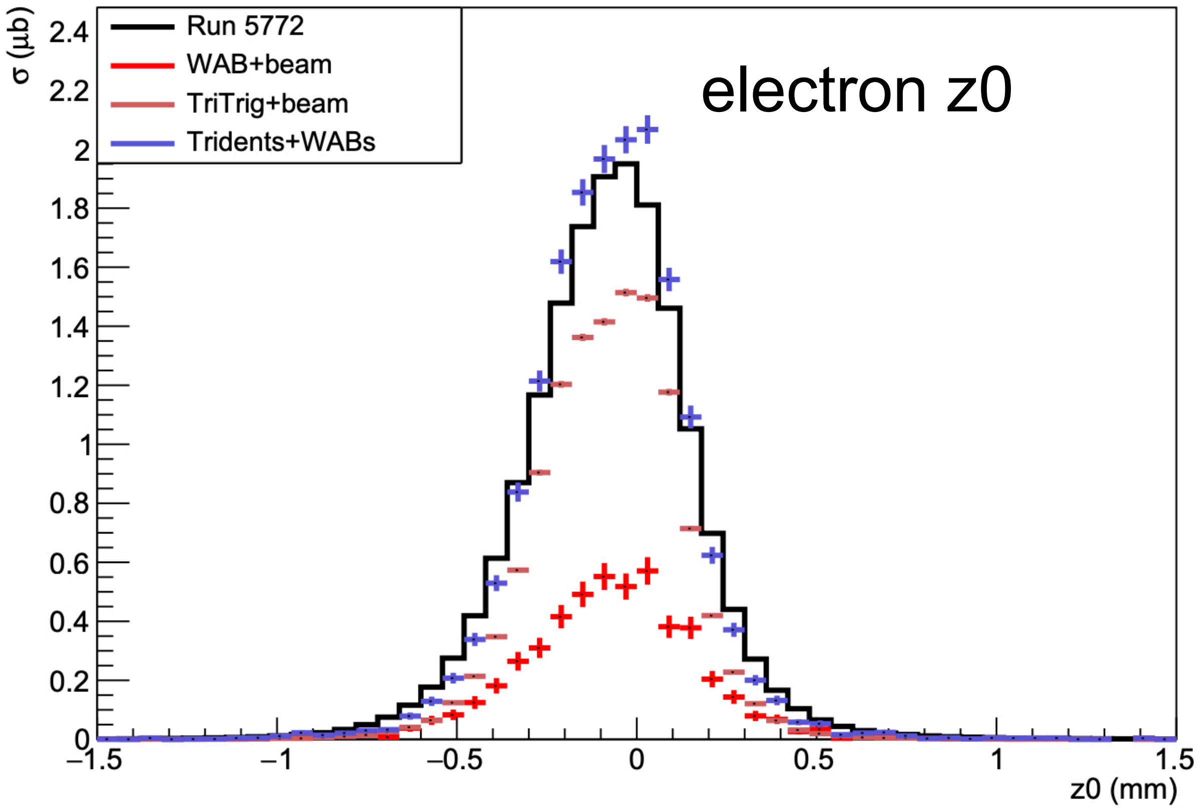
The shape agreement is great!!!!! Stop looking!

Electron from e^+e^- distributions

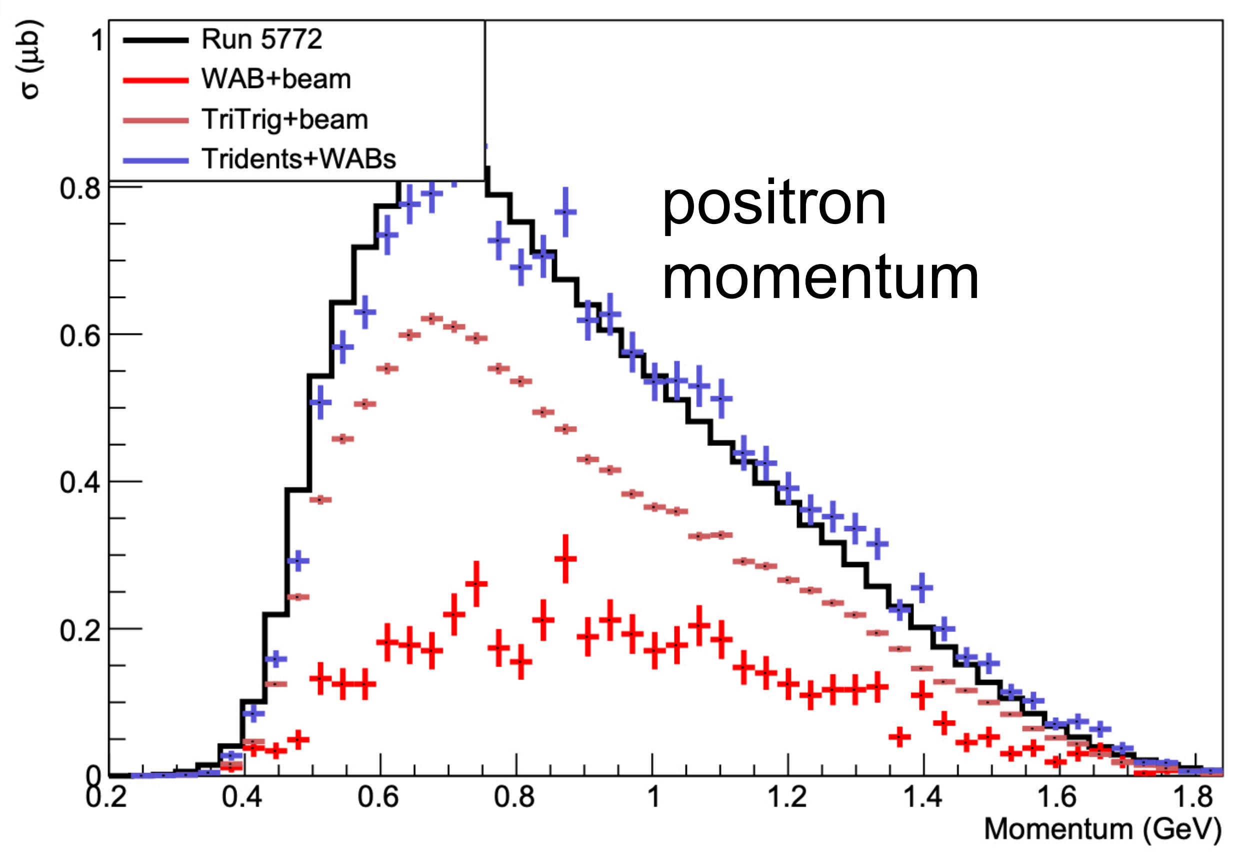


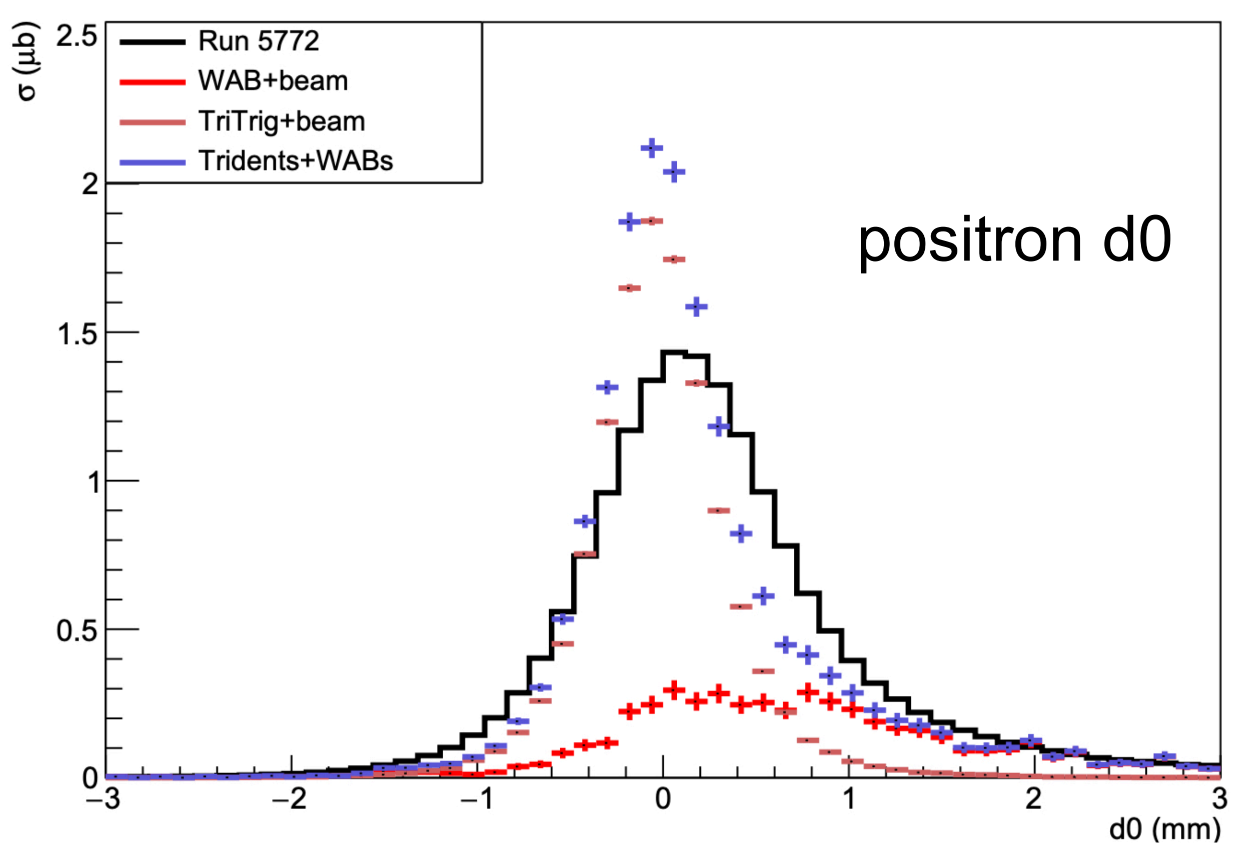


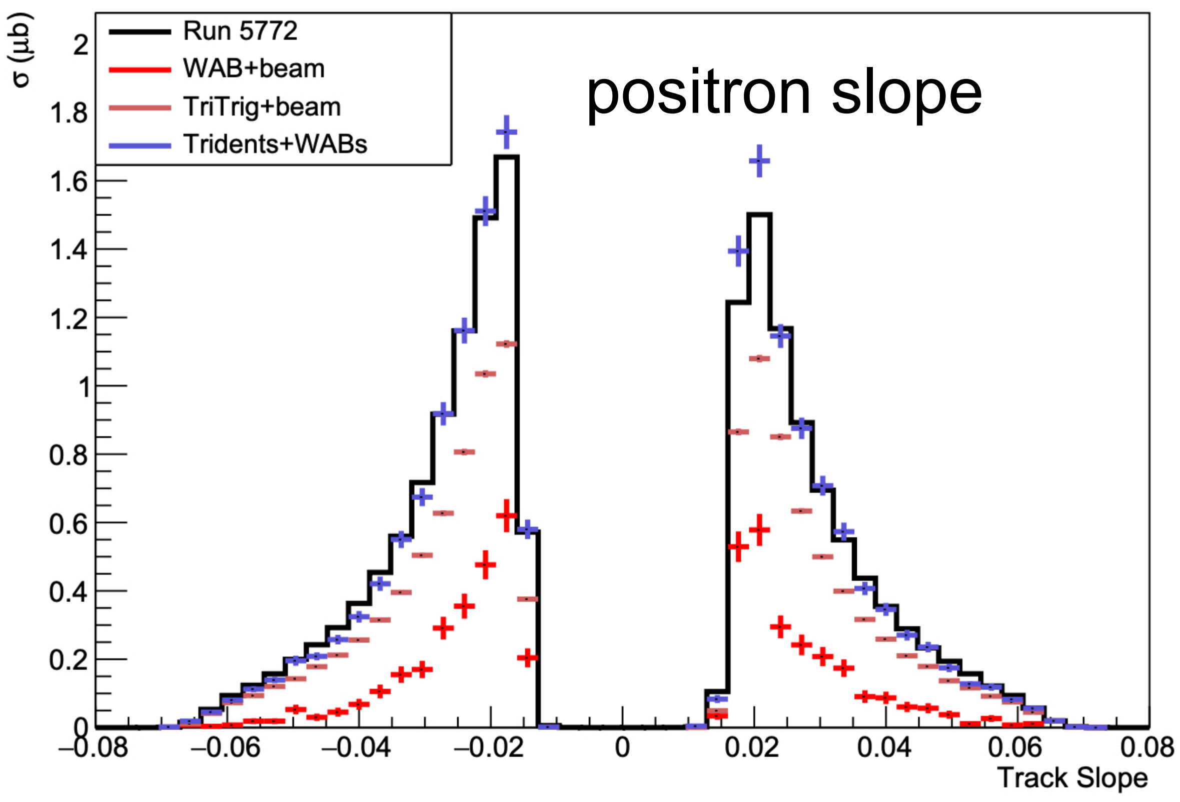


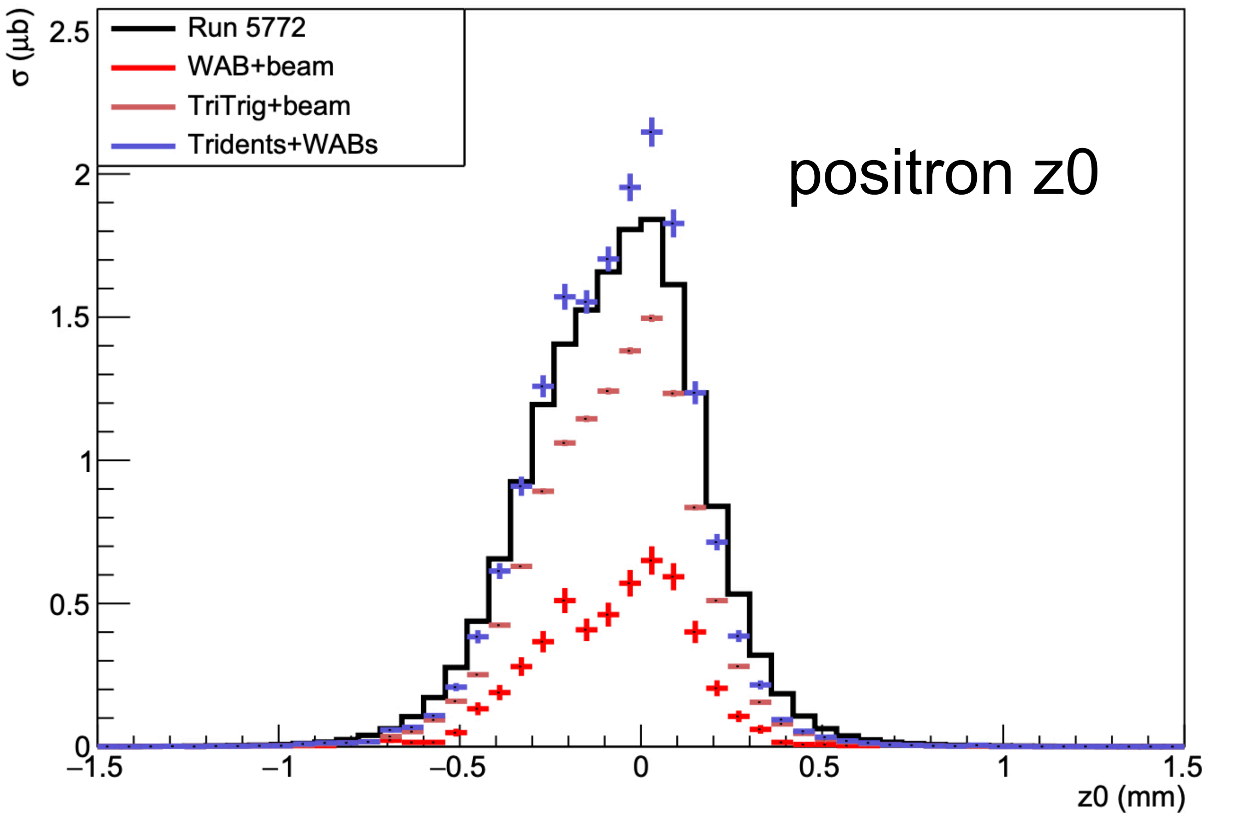


Positron from e⁺e⁻ distributions

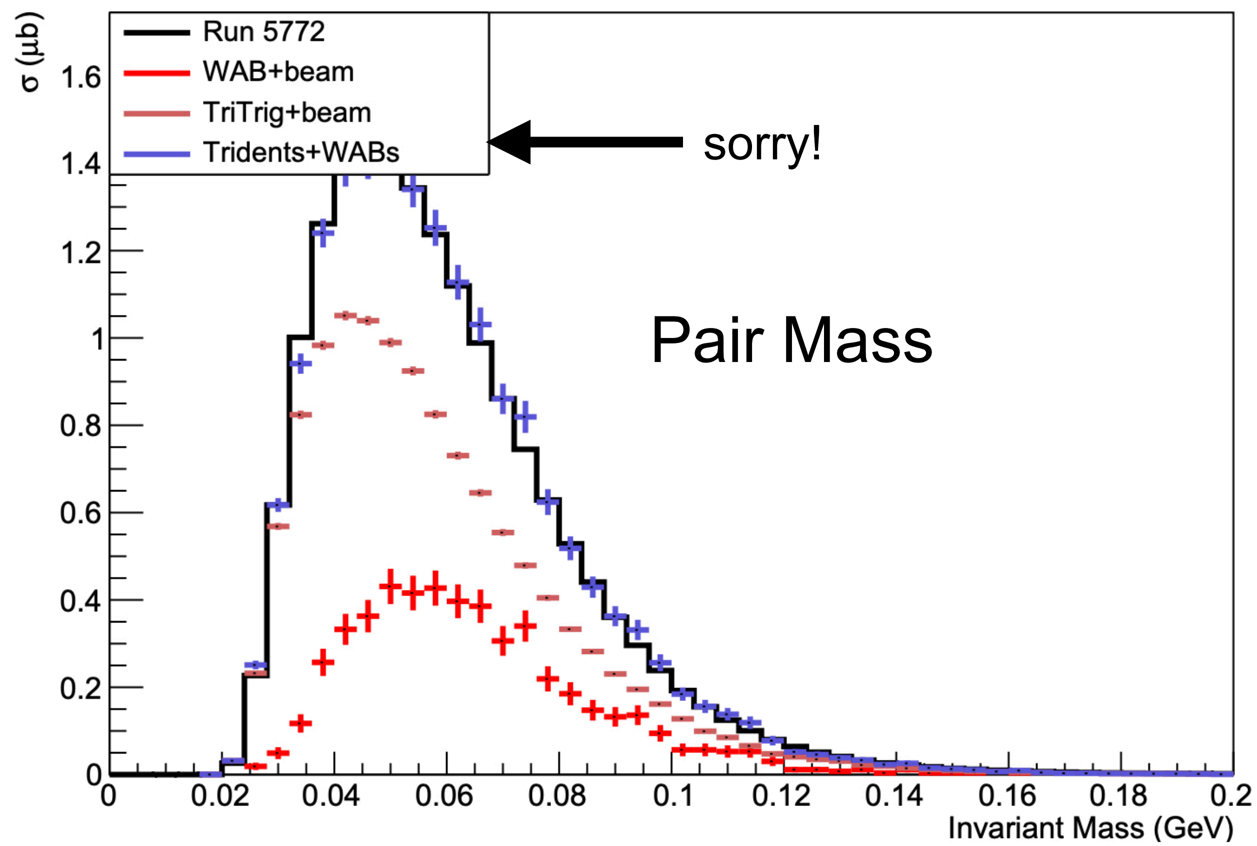

positron momentum


positron d0

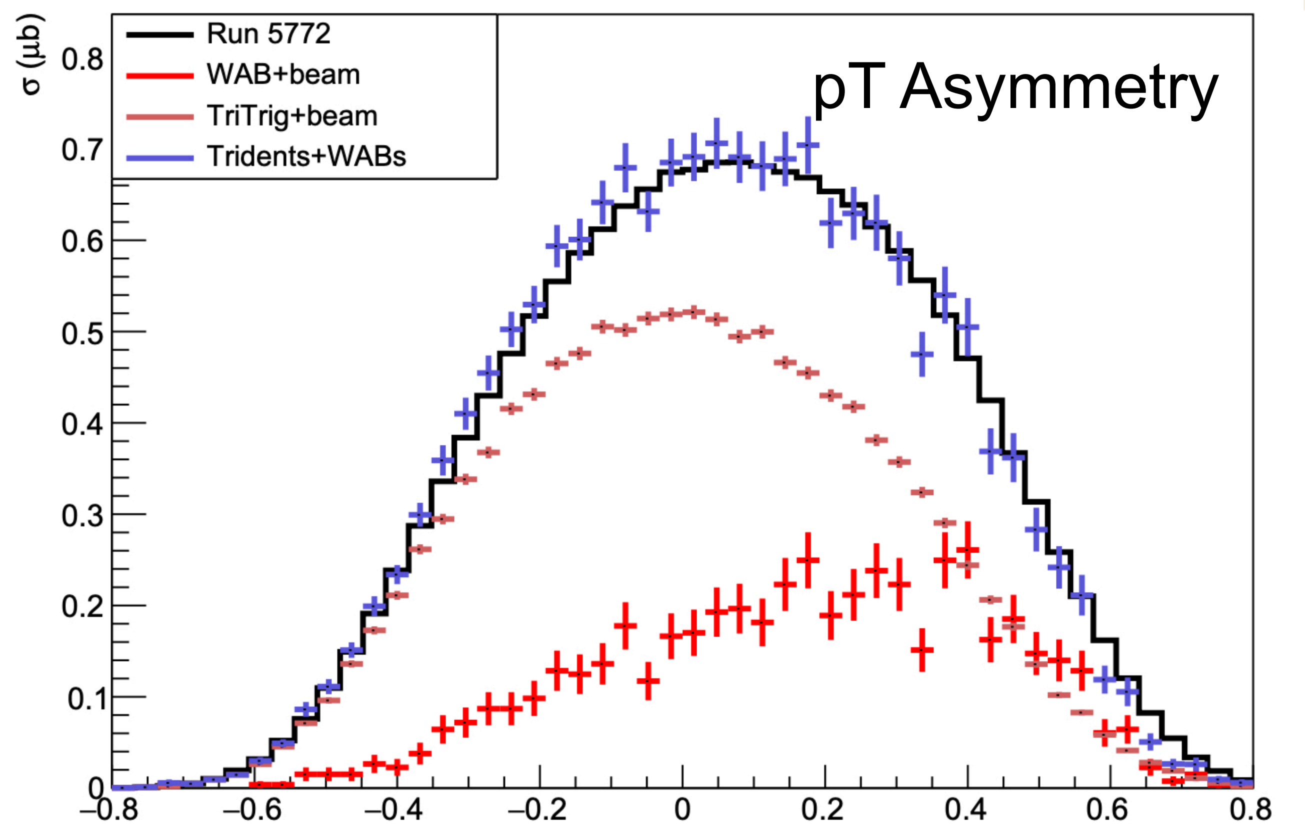

positron slope

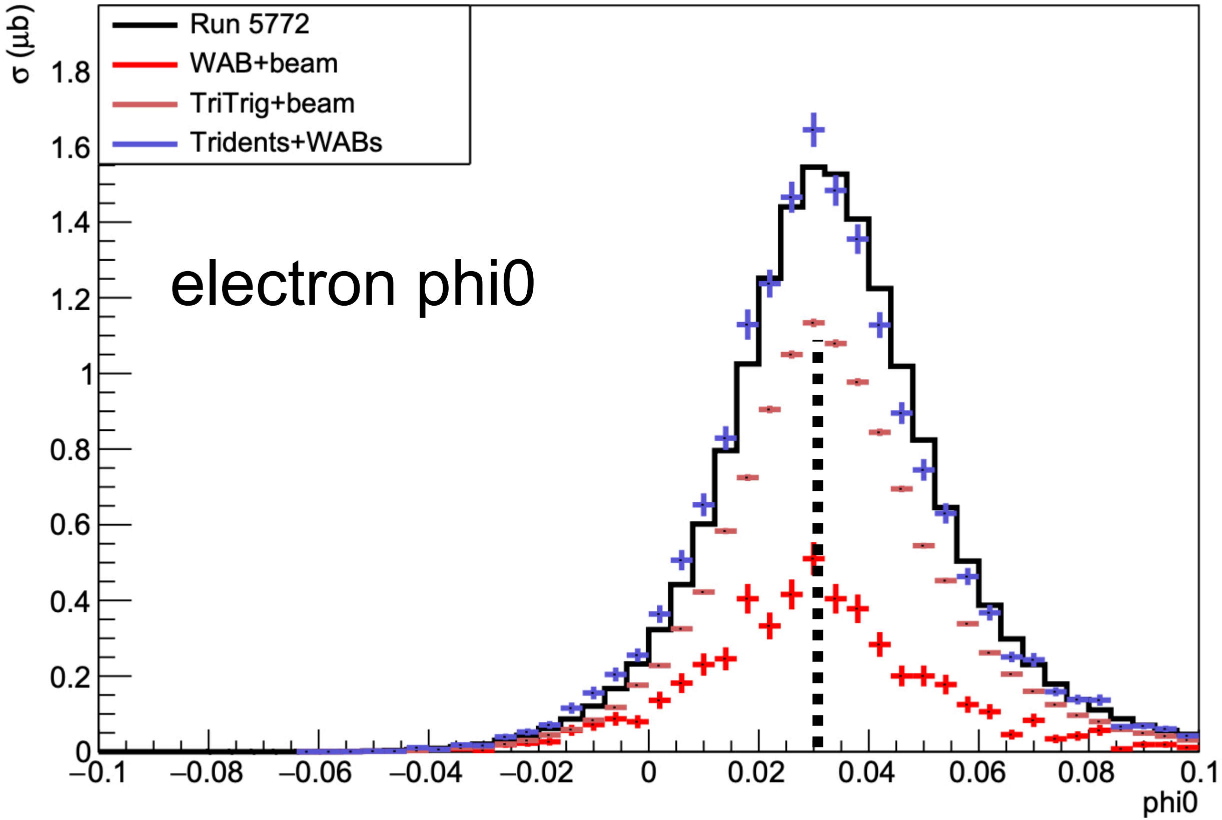

positron z0

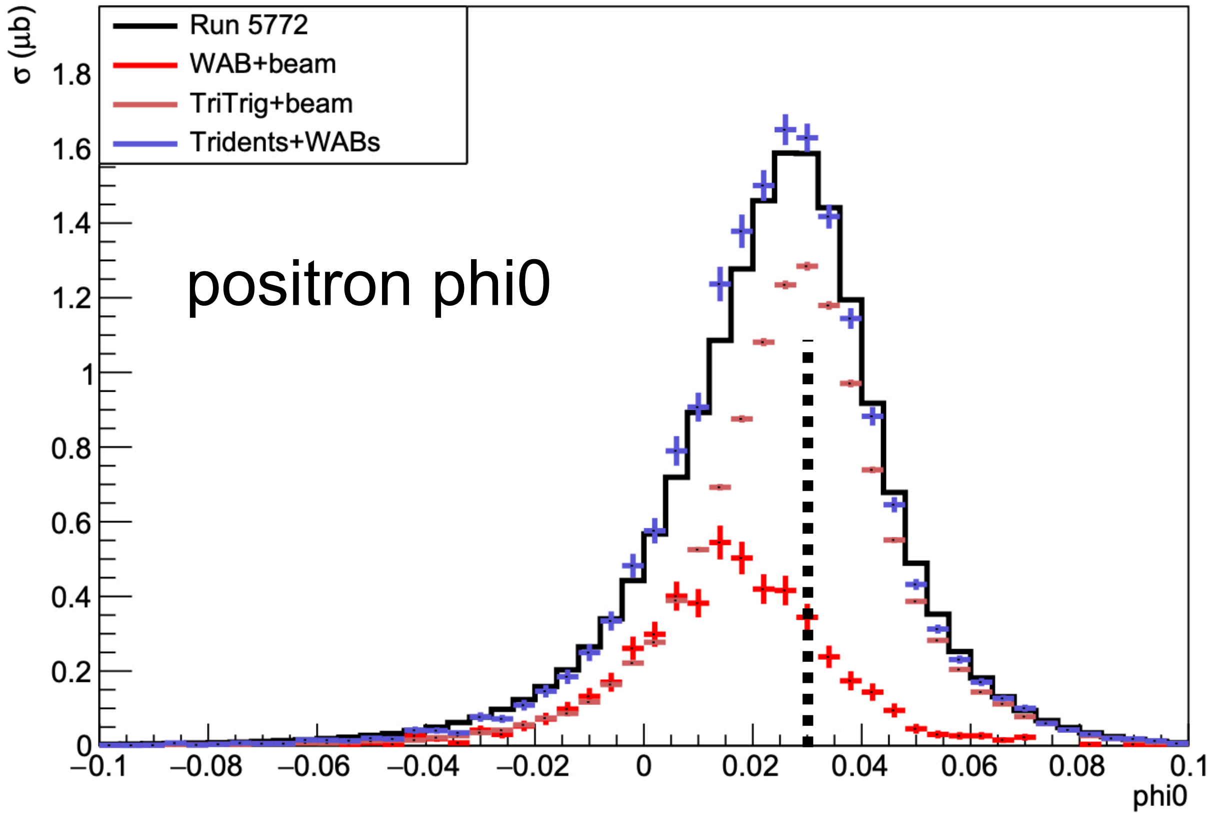
Pair stuff and track phi0



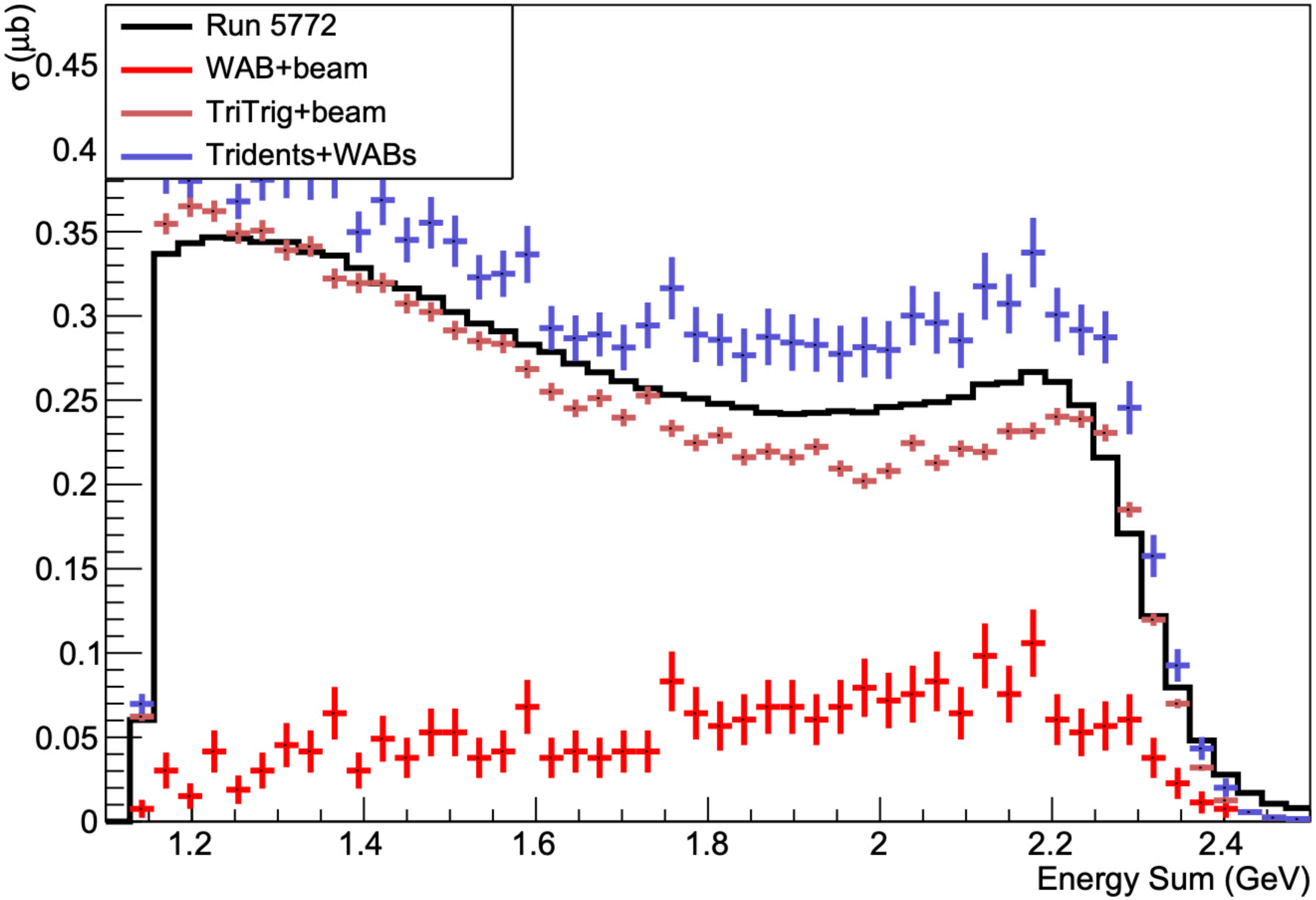
sorry!





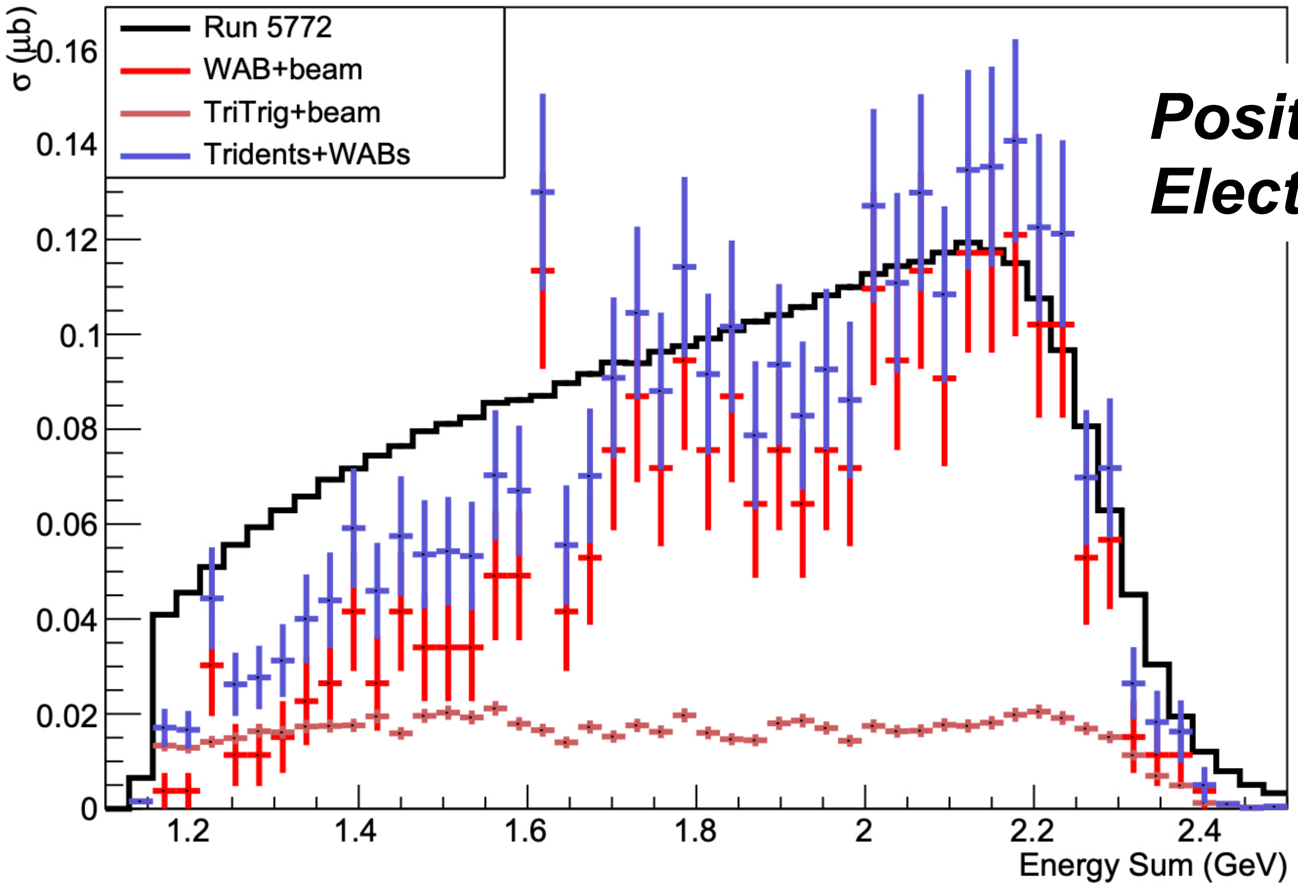


What if we require L1 hits for both e⁺ and e⁻



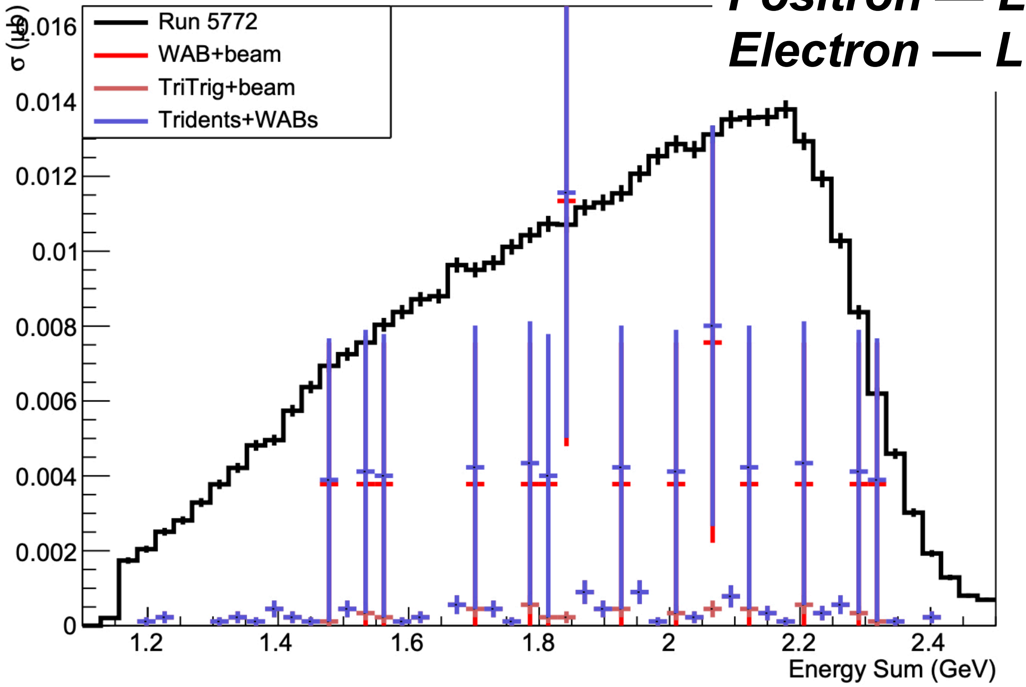
data/MC goes from ~1 (after 0.91×MC scaling) to 0.87…could be due to cWABs/tridents wrong or underestimating L1 SVT inefficiency or differences in geometry/acceptance or ???

LXLY ESum distributions after SVT Cluster Killing

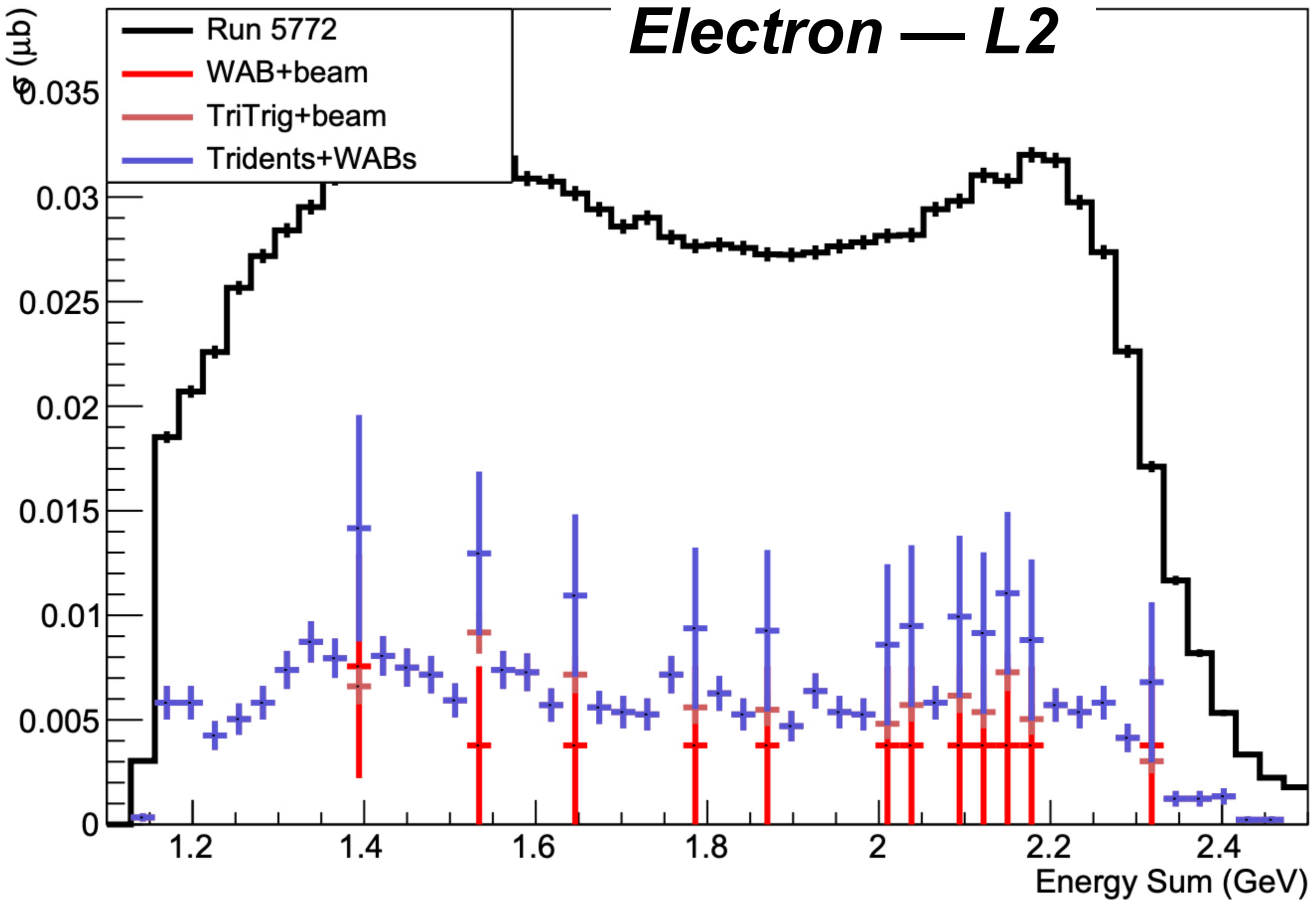


Positron — L2
Electron — L1

So…these still don't look great

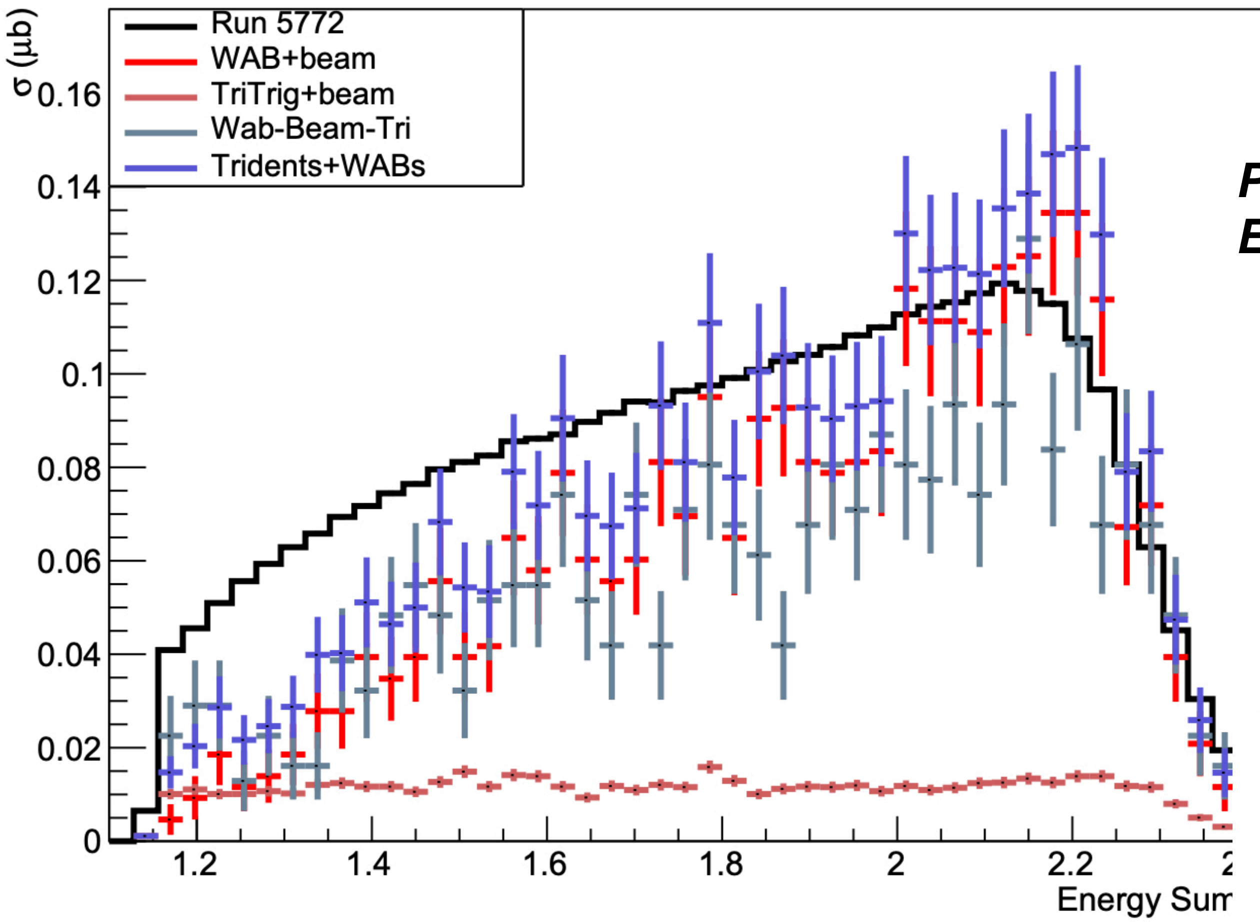


Positron — L2
Electron — L2



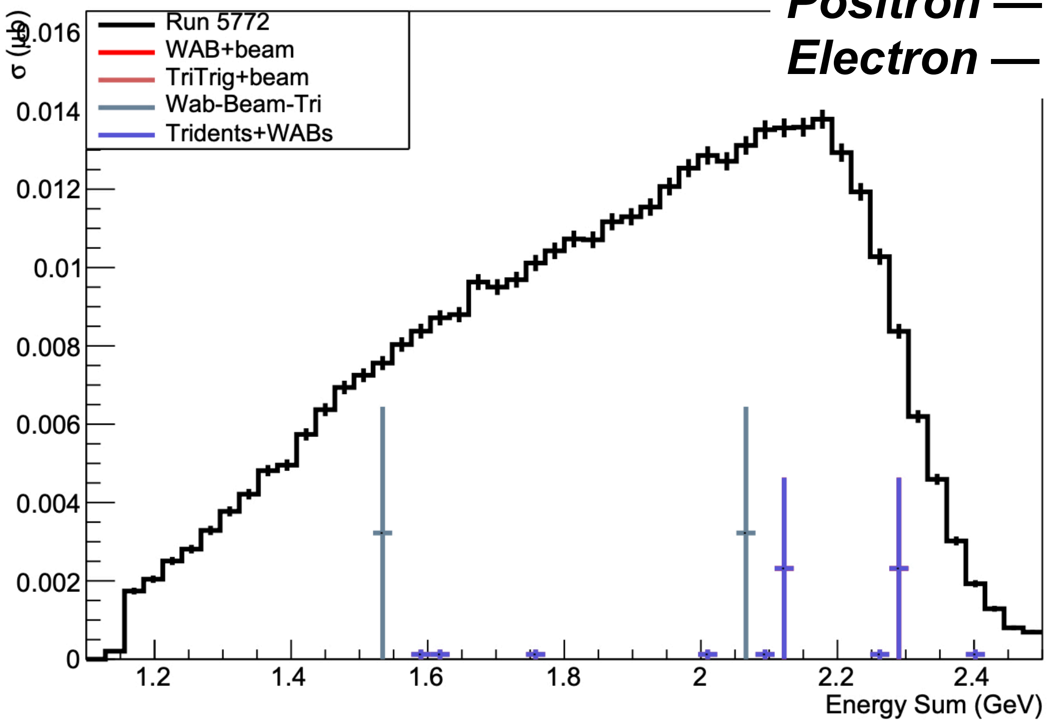
Positron — L1
Electron — L2

LXLY distributions before SVT Cluster Killing

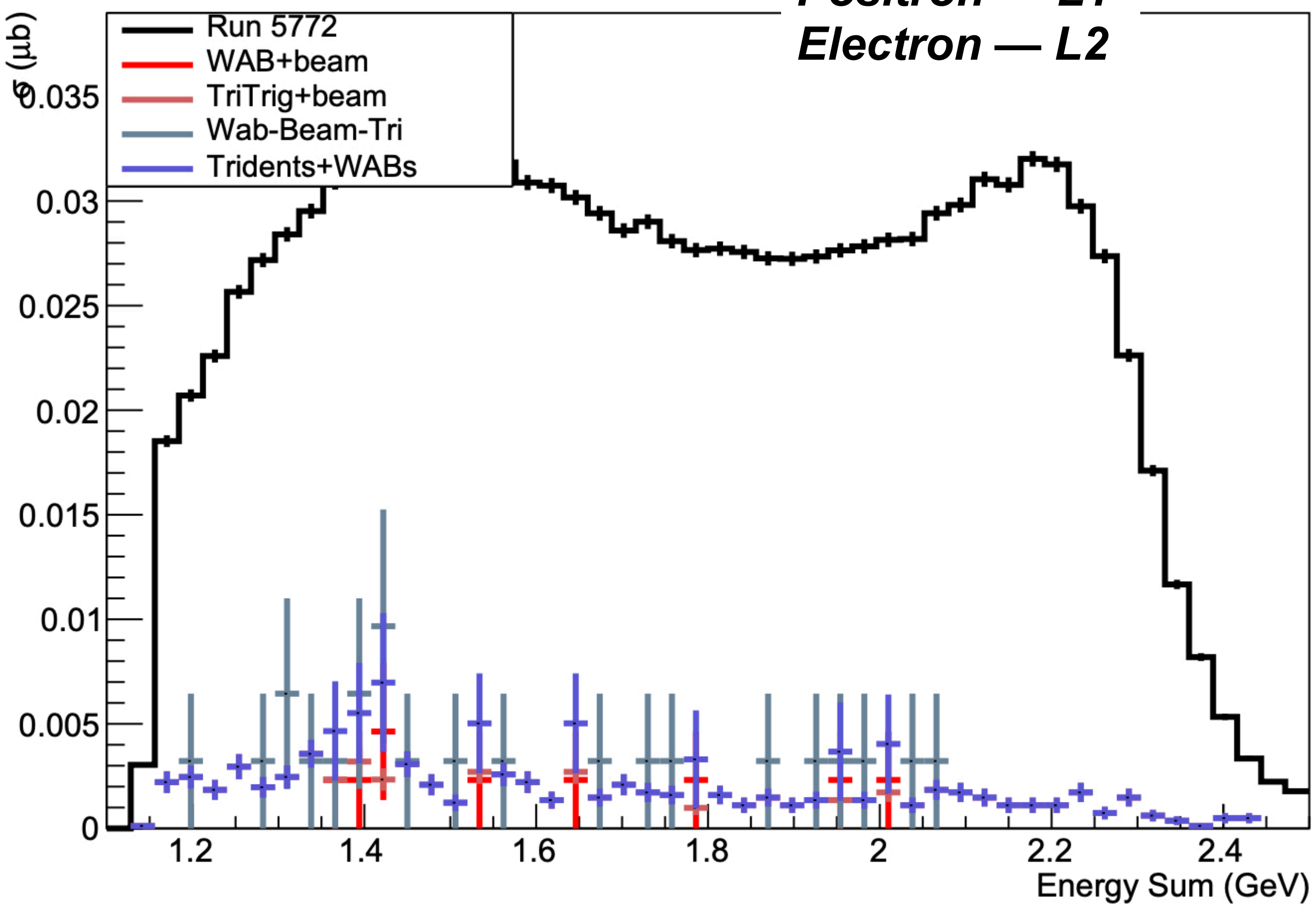


Positron — L2
Electron — L1

But, marginally better than they were before killing….

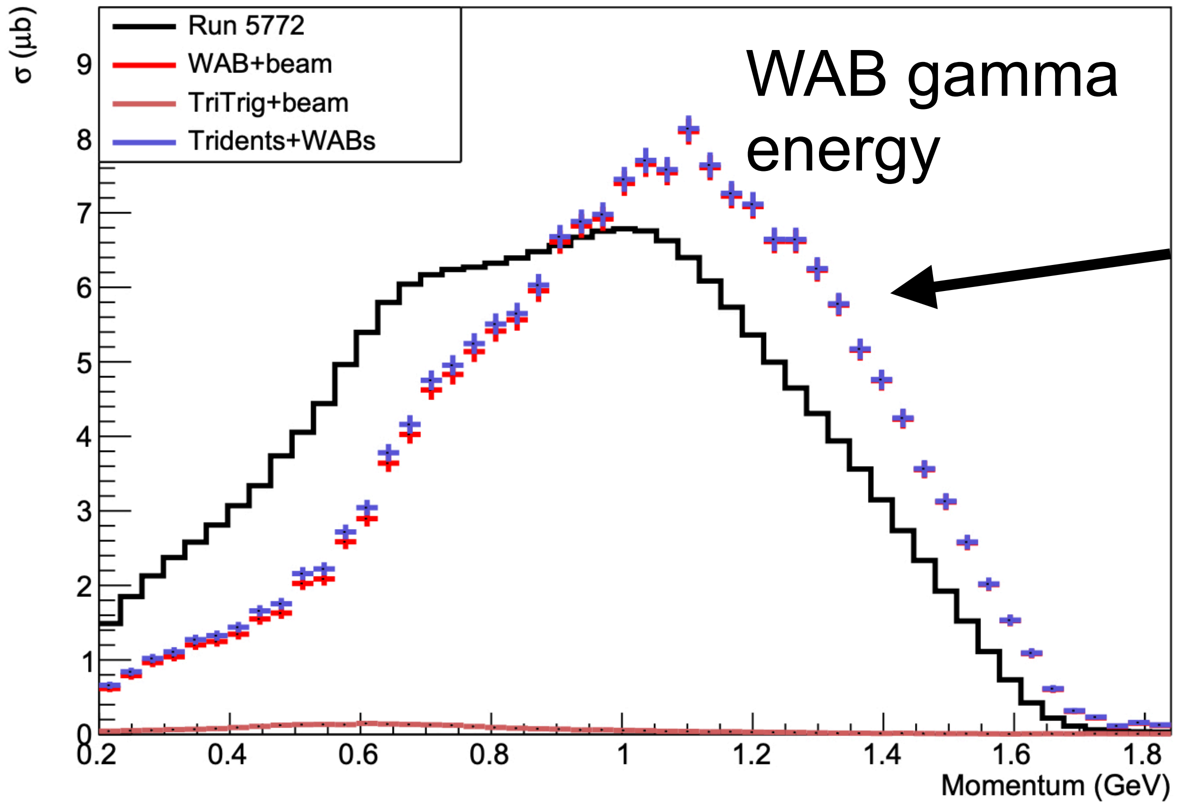


Positron — L2
Electron — L2

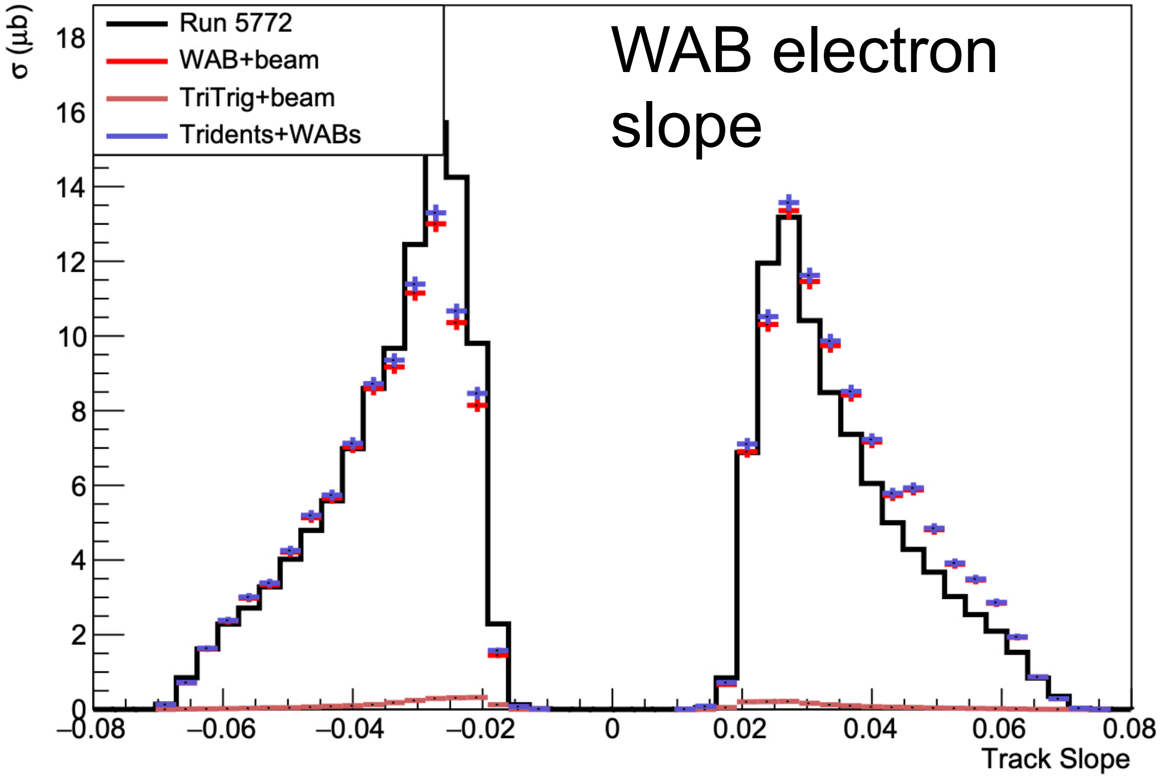


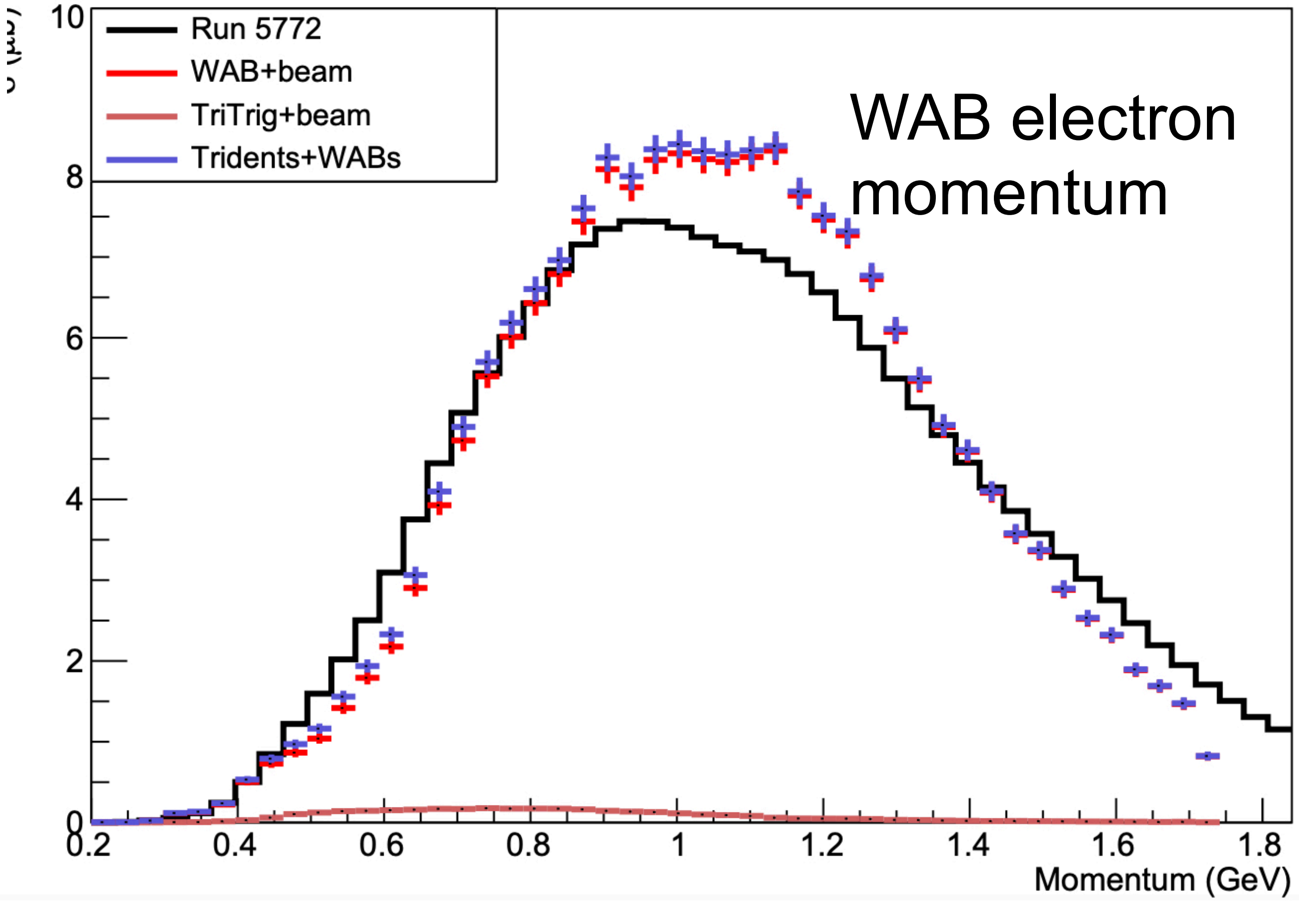
Positron — L1
Electron — L2

More γe⁻ distributions

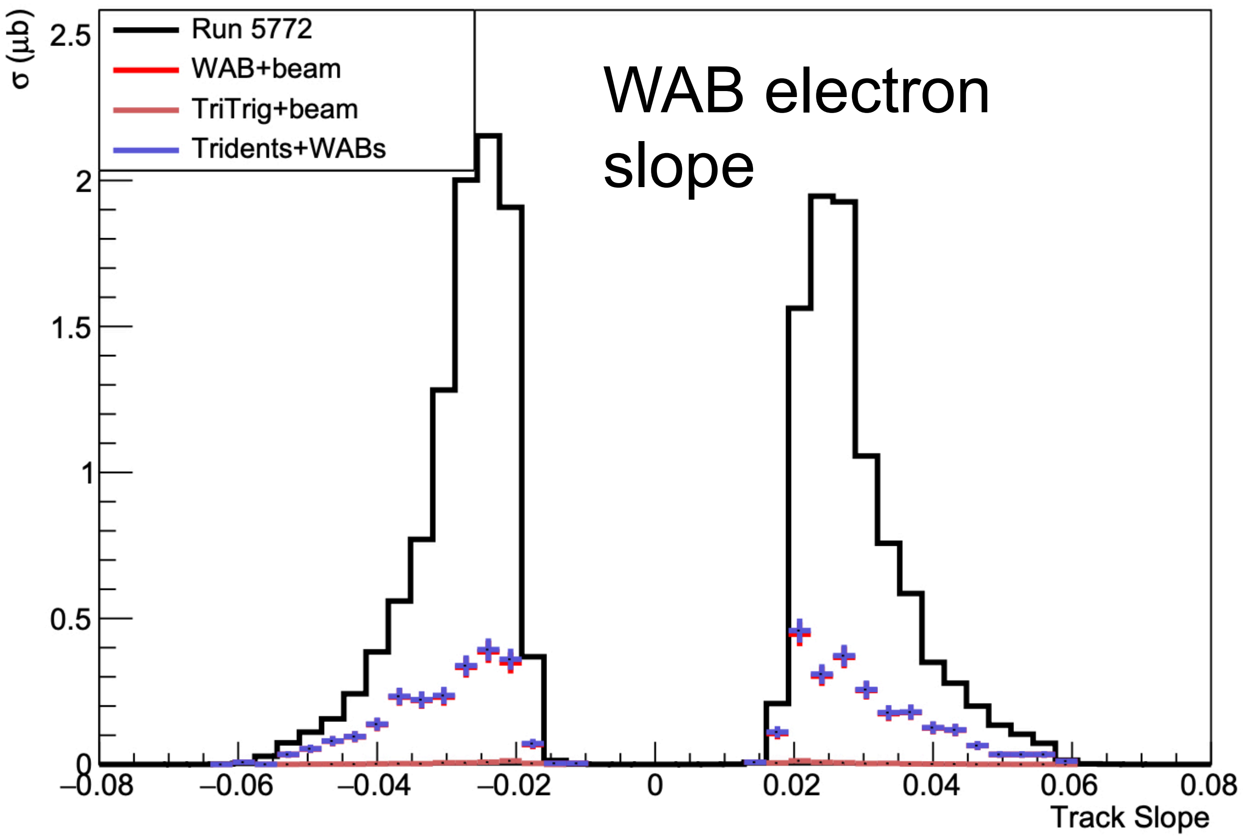

WAB gamma energy

Why is this so weird?


WAB electron slope

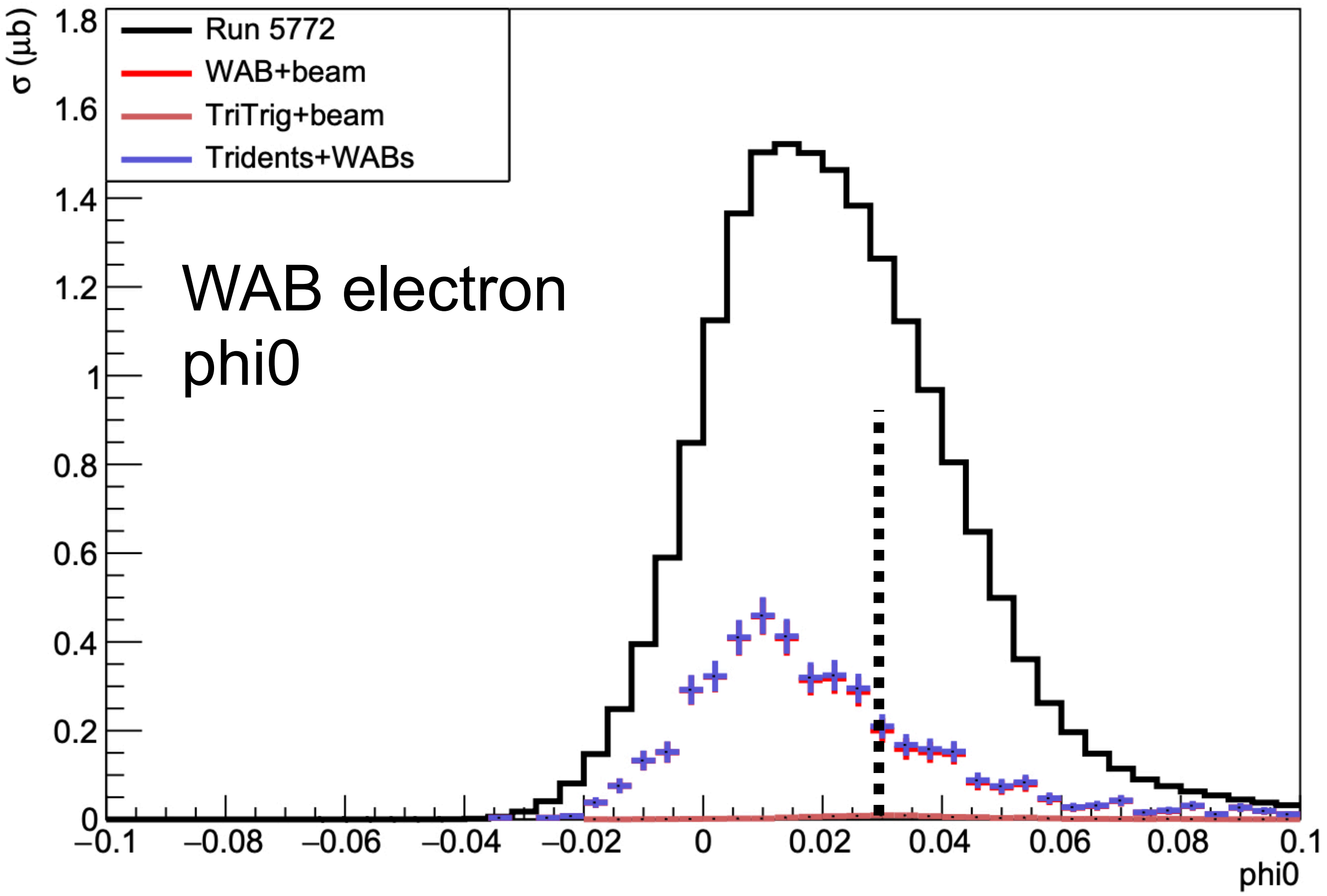

WAB electron momentum

Directional variables for ɣe⁻ with missing L1

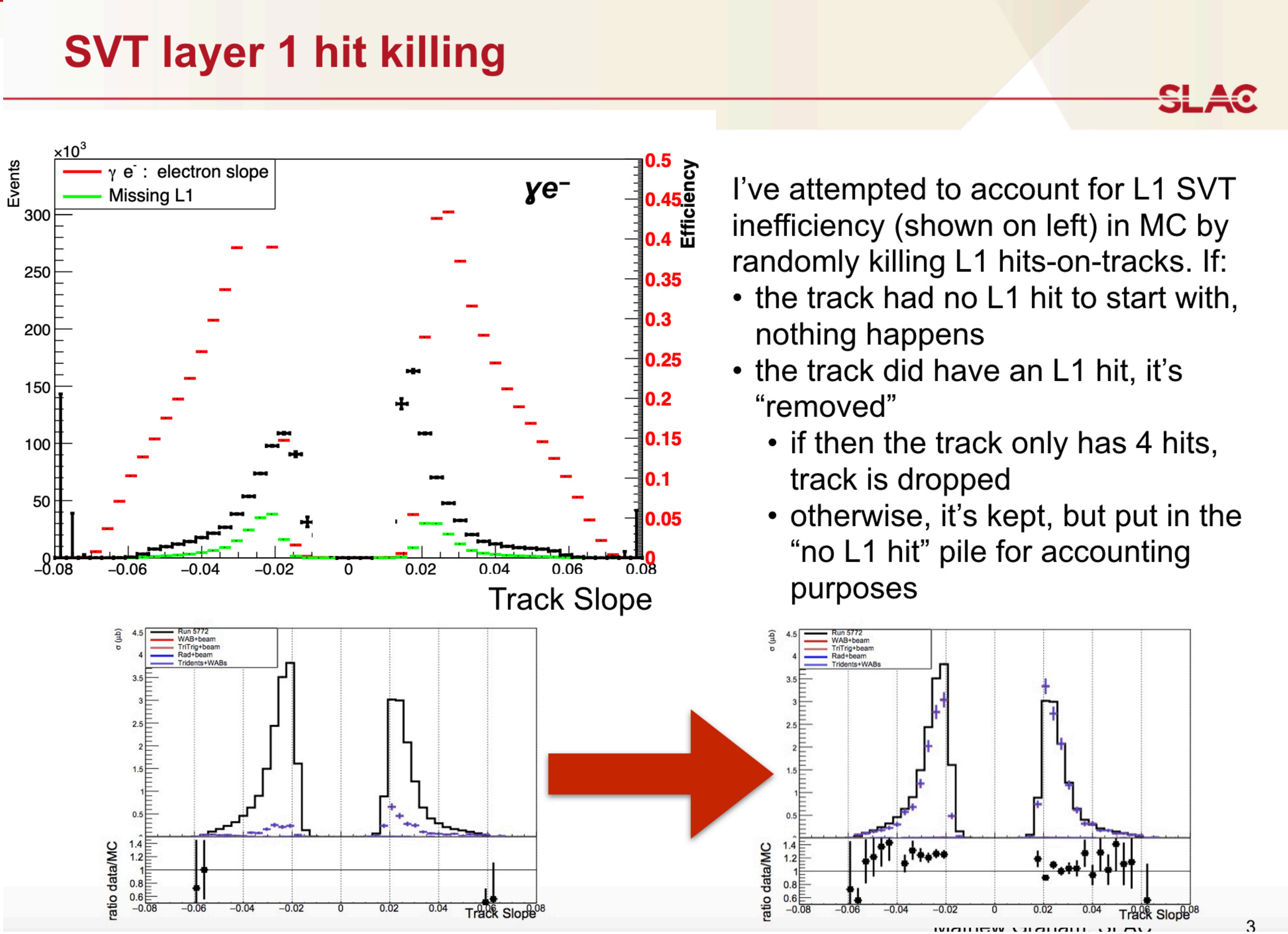


The electron slope & phi0 look fairly normal for both ɣe⁻ (shown) and e⁺e⁻ events for electrons without L1 hit

…I should really look at projections to the L1 sensors, but I think this suggests the high number of tracks with missing L1 hits is not due to geometry mis-matches…



So the SVT cluster killing isn't doing what I want… meanwhile, back in 2017 (using 2015 data)…



SVT layer 1 hit killing

I've attempted to account for L1 SVT inefficiency (shown on left) in MC by randomly killing L1 hits-on-tracks. If:

- the track had no L1 hit to start with, nothing happens
- the track did have an L1 hit, it's "removed"
  - if then the track only has 4 hits, track is dropped
  - otherwise, it's kept, but put in the "no L1 hit" pile for accounting purposes

What was done before, don’t want to do now

- For some reason, we are not making tracks with L1 hits for reasons not picked up by the SVT hit efficiency code
  - Overall, it’s not a HUGE effect…~5-10% … but very annoying to me
- We saw this in the 2015 analysis as well
  - implemented a post-recon, track-slope based hit killing (previous slide) using the electron from the γe^- sample as the reference
  - that method worked great for getting the L1L1, L1L2, L2L1, L2L2 rates for data and Monte Carlo to a agree
- I’d prefer to understand what’s going on this time
  - easier said than done as I obviously didn’t figure it out for 2015 data
  - I’ll spend a little more time digging down into this (until I give up and implement the 2015 kludge)

Summary

- The 2016 data and simulation is 100% awesome
  - Ok, mostly things look quite good and there aren't really any surprises compared to 2015 analysis
- I've implemented a SVT cluster killing driver to run on MC based on Matt Solt's SVT hit efficiency analysis
  - I'm disappointed and confused that this didn't make the L1L2, L2L1, L2L2 data and MC rates match up better
- Despite this issue, the overall data/MC agreement for trident events is very good
  - we should try to get the gamma cluster energy shape improved in MC → γe^- ESum shape looks terrible