Neutron Updates – Hit Timing Thresholds

17 April 2025

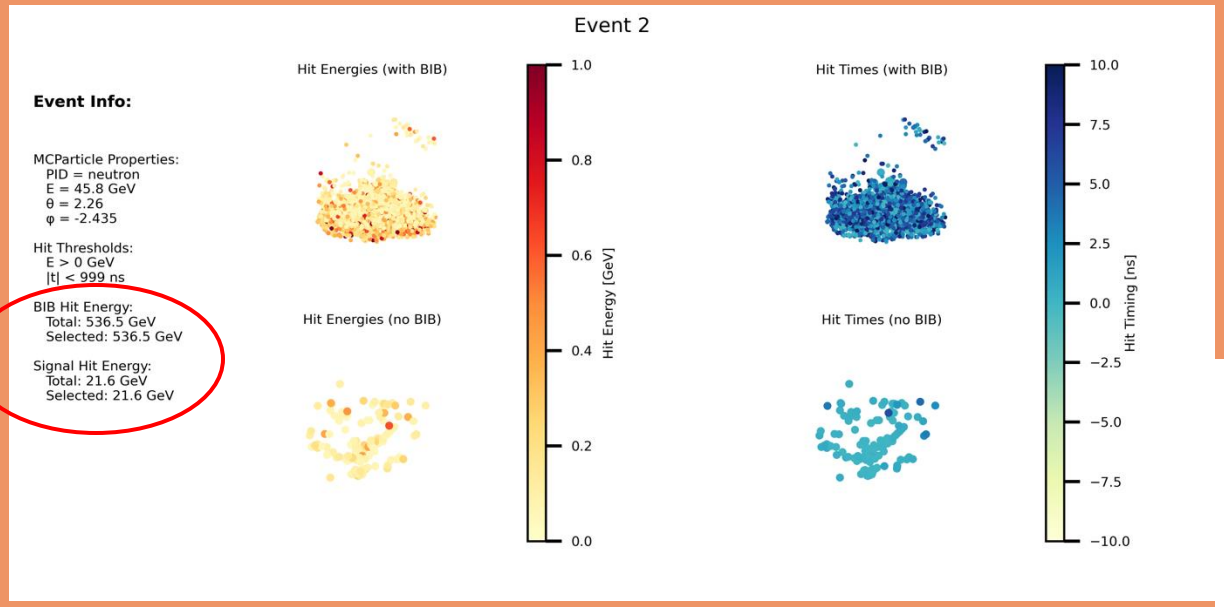
Recall: Neutron Resolution

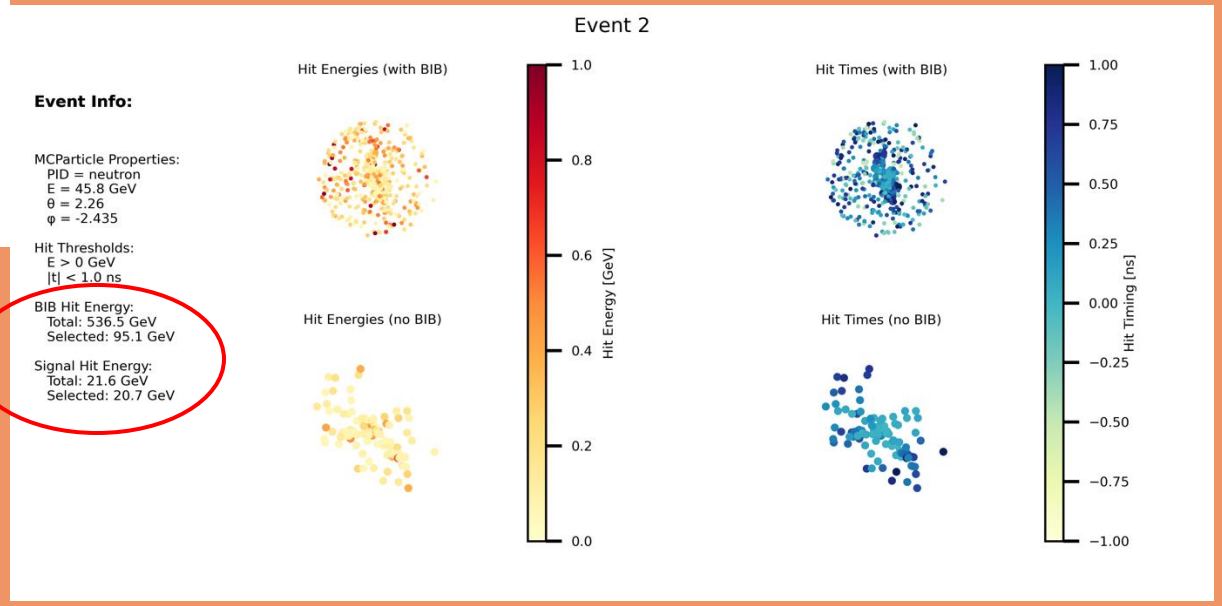
- *Our attempts at achieving reasonable energy resolution with v0.8 neutron samples was unsuccessful*
- *Struggled to match accurately, distinguish amongst fakes*
- *Wanted to visualize what was occurring in the calo*

Event Display

- *Thank you so much to Kiley for creating and helping adapt the event display for MAIA studies!*
- *Allows us to visualize hit energy, time, and spatial distributions*
- *Comparing BIB vs non-BIB for the same events*
- *Looked at the effects of "cleaning" hit collections by removing hits with relatively late/early times*
- *Motivated a closer inspection of hit timing – should we be cutting on hit timing? (Spoiler: yes!)*

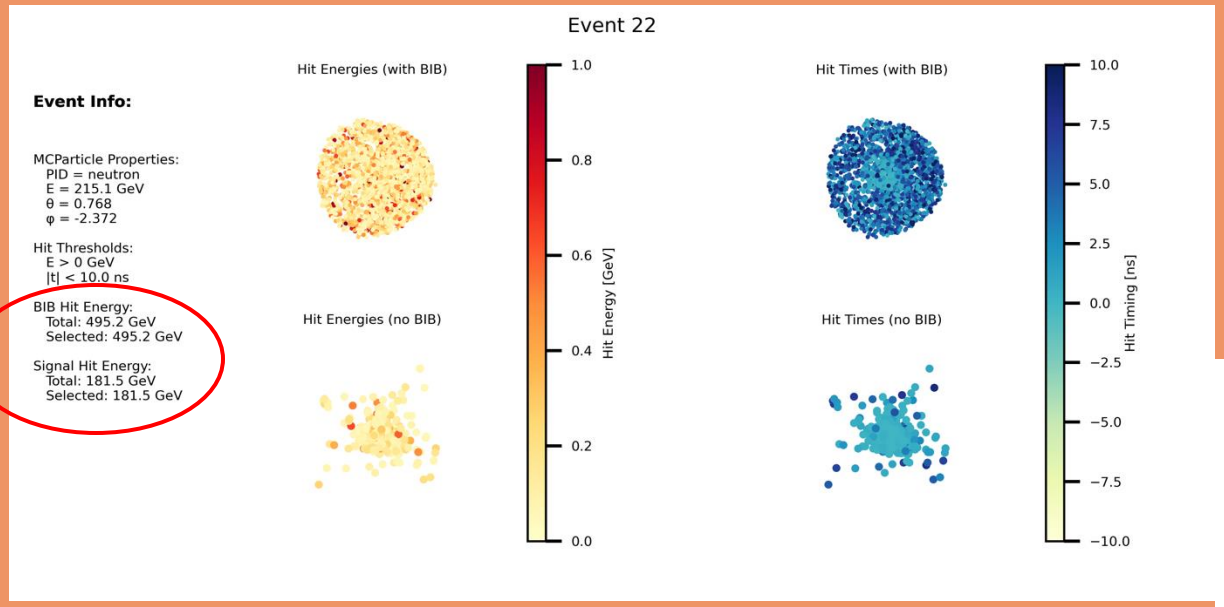
Examples of Time-Cleaning

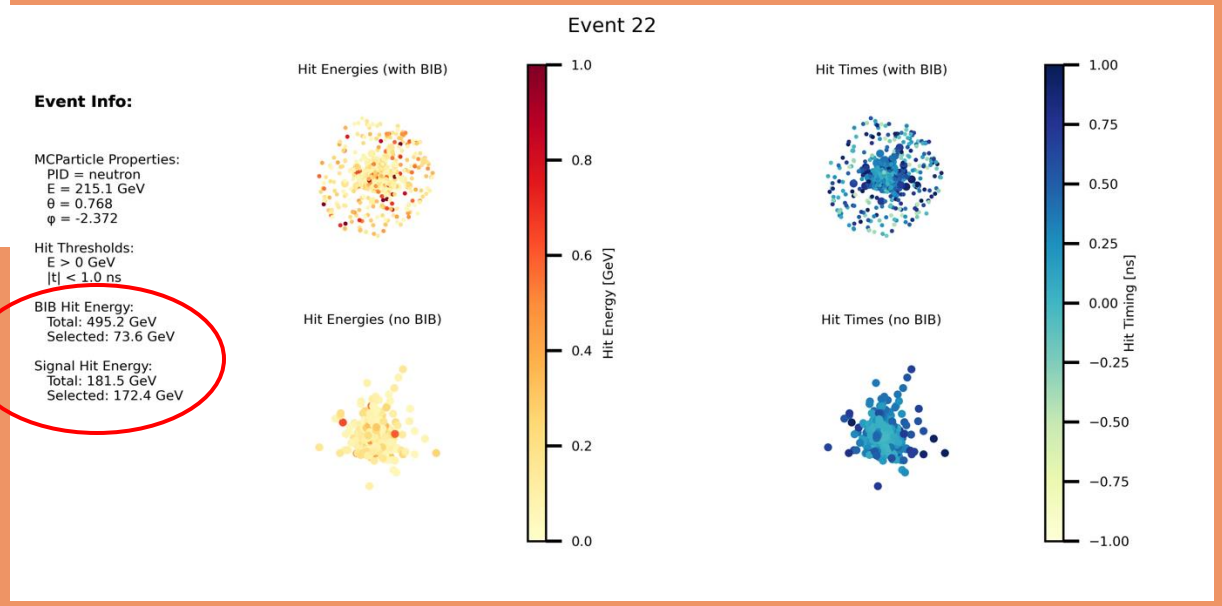




- *Signal loss: 4.2%*
- *Bkg loss: 82.3%*

Examples of Time-Cleaning





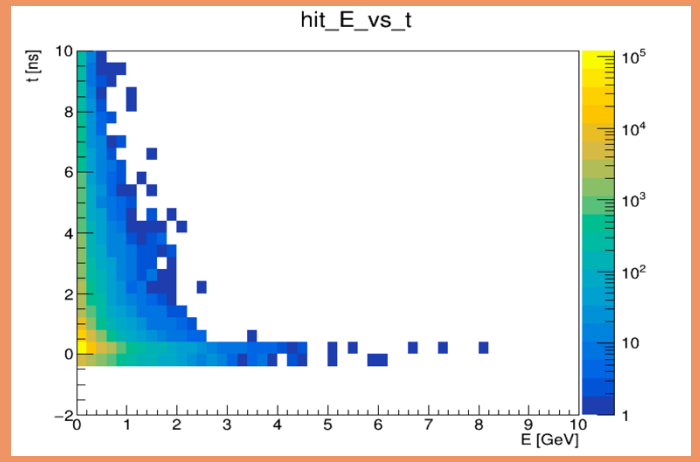
- *Signal loss: 5.0%*
- *Bkg loss: 85.1%*

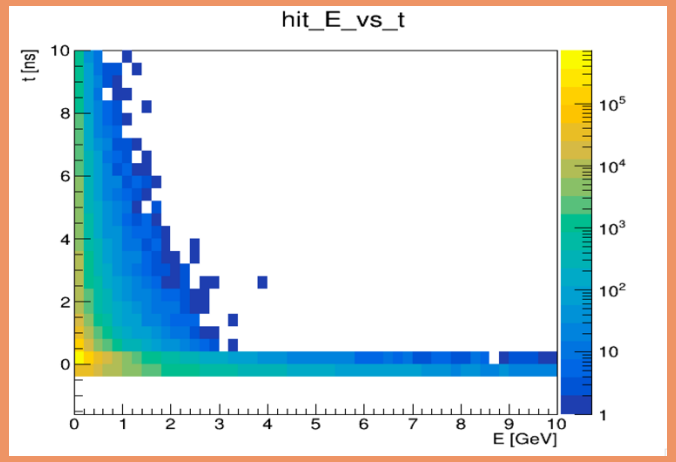
Energy vs Time

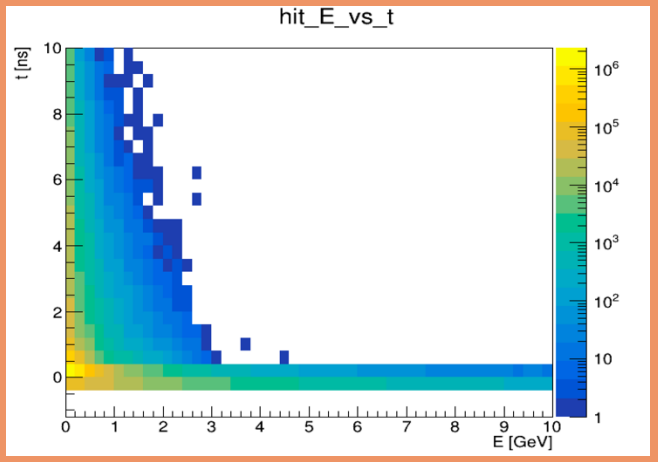
- *Looking at a few events, it appears that the more non-prompt HCal hits (no-BIB) are very soft; less so for BIB*
- *Signal energy loss should be minimal*
- *Confirmed across the sample with 2d hists of HCal hit timing*
  - *(See analogous plots for all hits in backup – addition of ECal does not change distro)*

Hit energy vs time (HCal only)

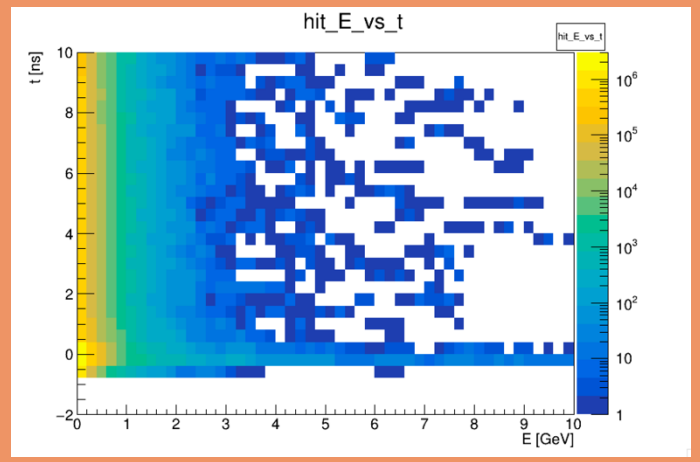
No BIB

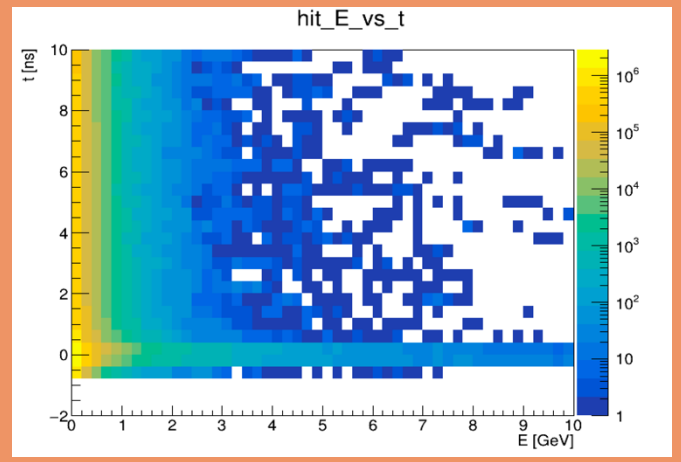


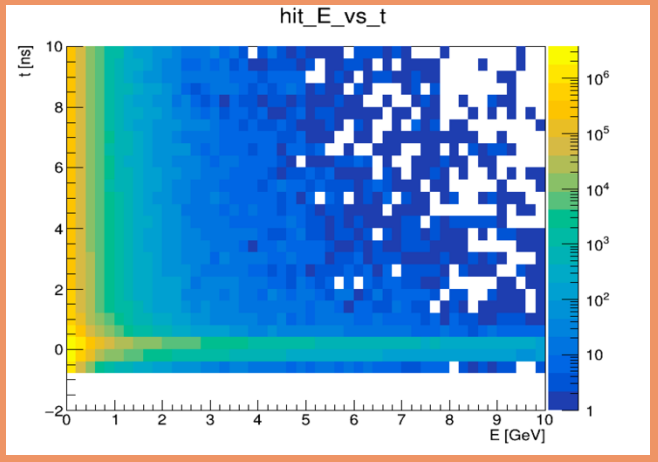




BIB







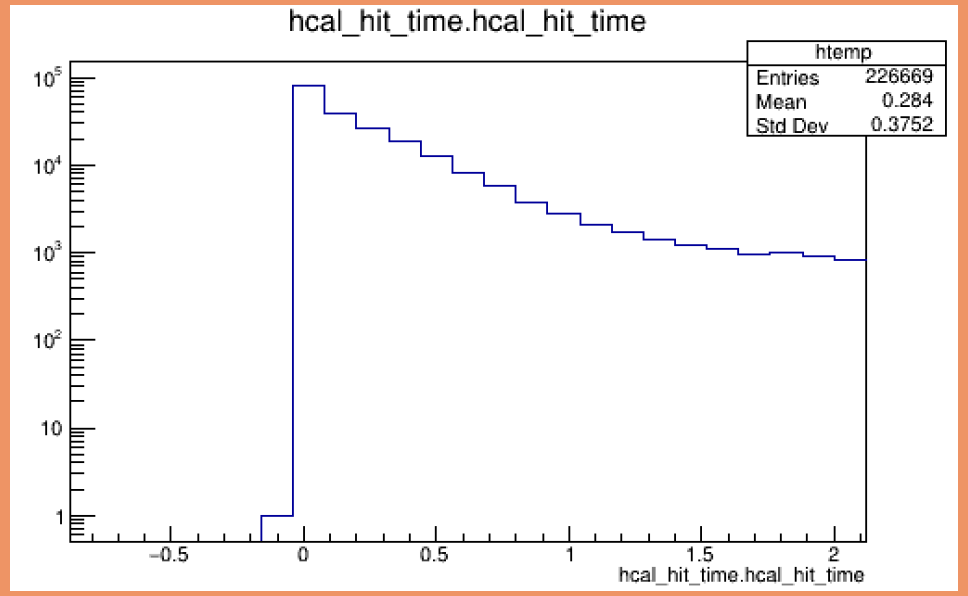
[0,50]GeV

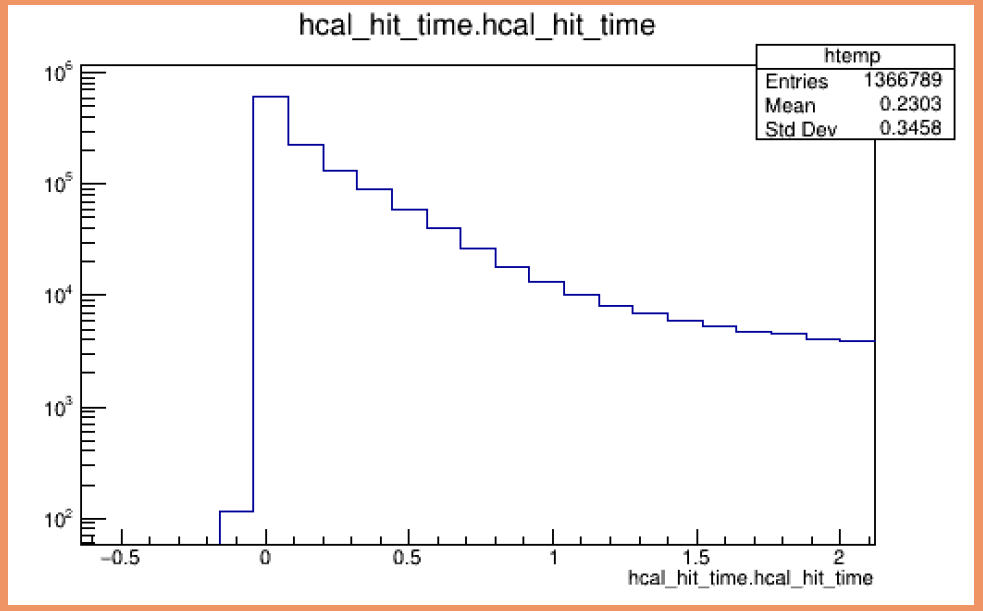
[50,250]GeV

[250,1000]GeV

Negative timing cut

- *Notice the no-BIB samples have **no** hits with t<-0.2 ns*
- *We should not allow any earlier HCal hits*
- *(Examples of hit timing for 0-50 and 50-250 GeV no-BIB slices)*



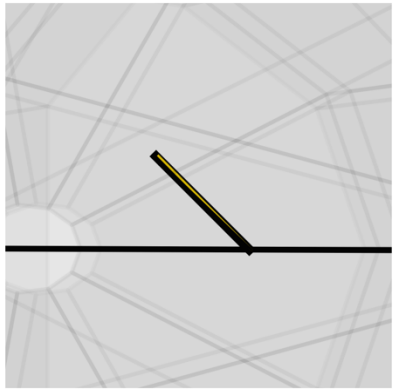


Another look at PFOs

- *To decide whether we should try to modify the existing PFOs or start from scratch with clustering, wanted to determine if there is any value to the current PFOs or if they are just total garbage*
- *Looked at them in the event display first*
- *Predictably, the PFOs in the BIB sample are disastrous*

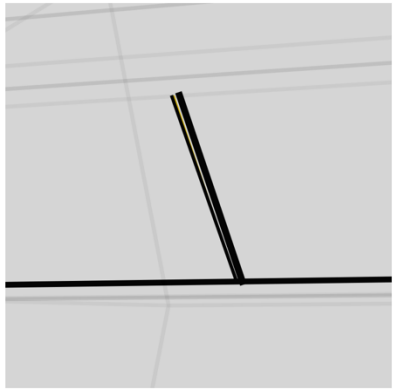
No-BIB: Photons, spurious fragmentation

Event 14



MC Particle, pt = 151.4 GeV
PFO, pt = 28.5 GeV
PFO, pt = 31.3 GeV

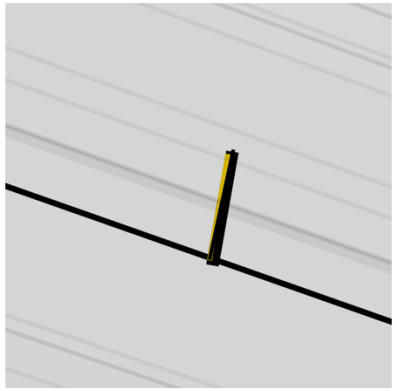
Event 21



MC Particle, pt = 105.2 GeV
PFO, pt = 15.0 GeV
PFO, pt = 44.9 GeV

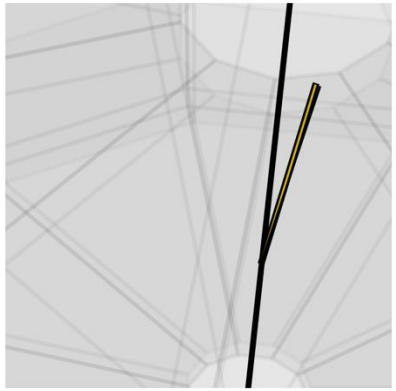
Here, gold tracks are photons, black tracks are neutrons

Event 15



MC Particle, pt = 216.5 GeV
PFO, pt = 72.0 GeV
PFO, pt = 52.5 GeV

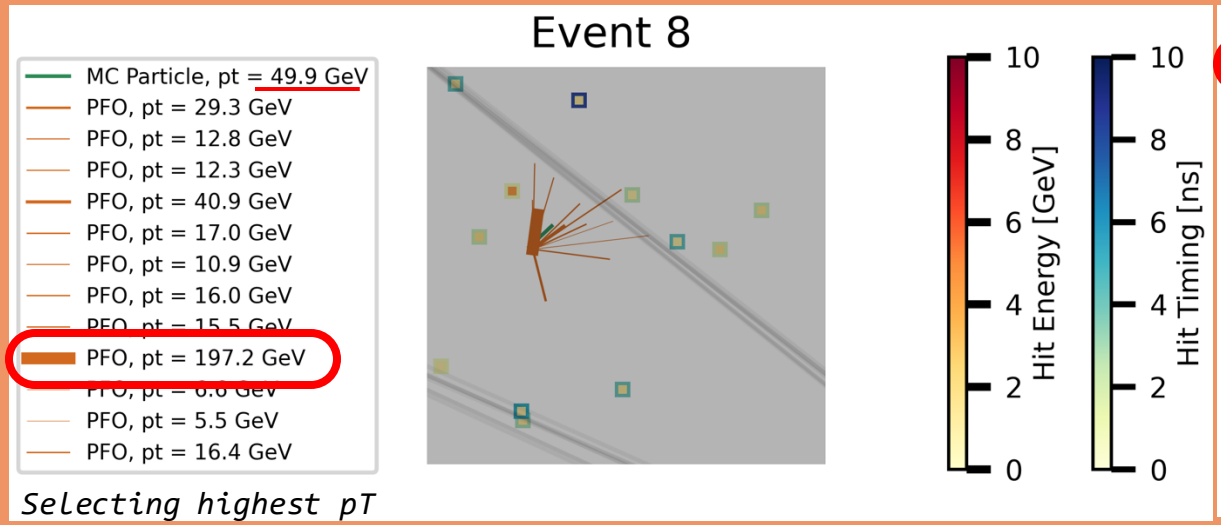
Event 18

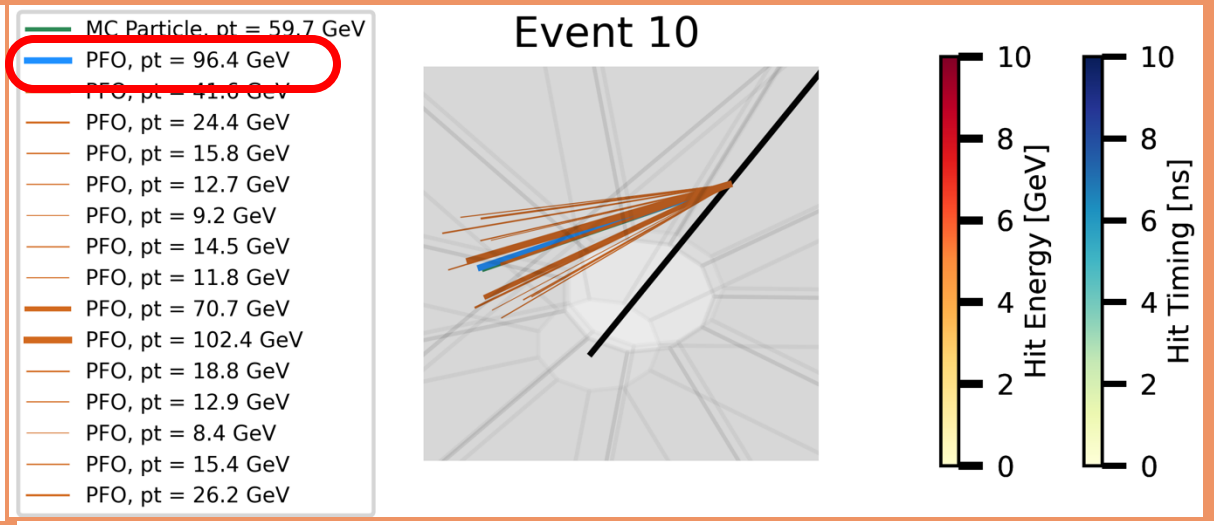


MC Particle, pt = 106.7 GeV
PFO, pt = 26.1 GeV
PFO, pt = 28.9 GeV

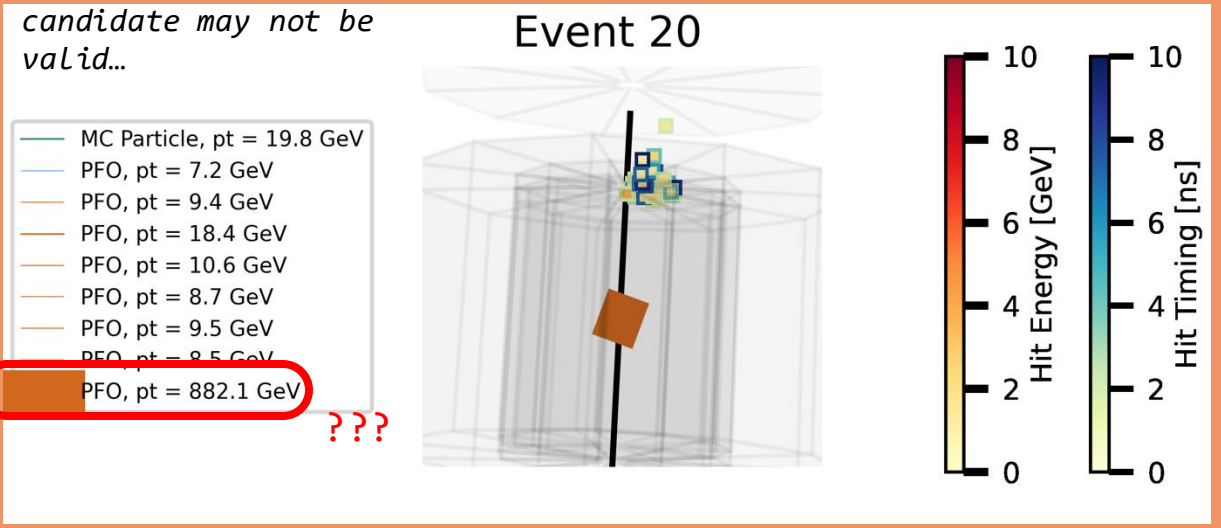
BIB: Cluster Fragmentation Disaster

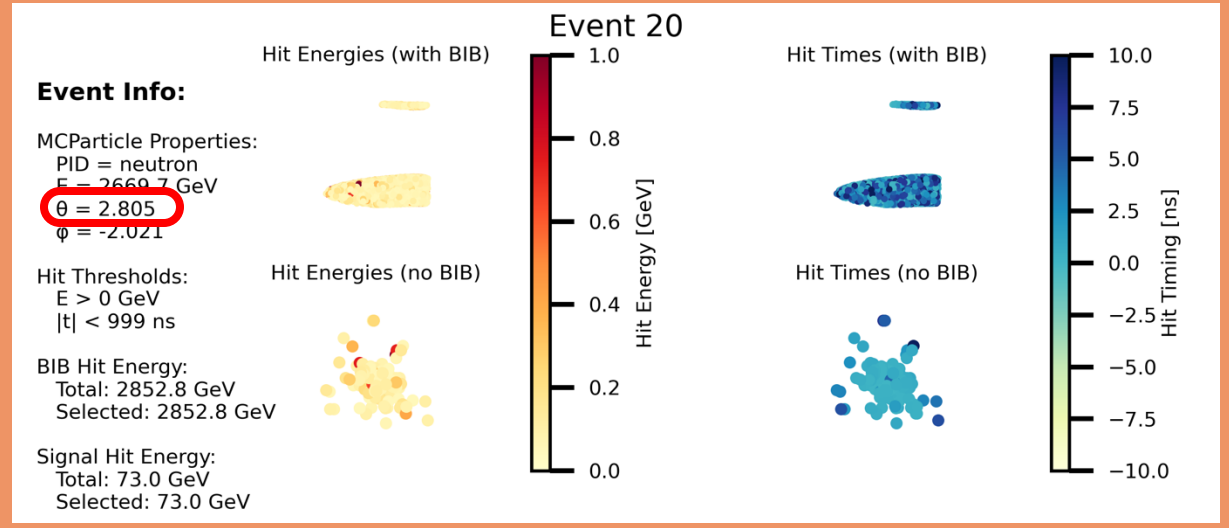
Here, brown tracks are neutrons, blue are photons, and green are MC gen neutron





Selecting highest pT candidate may not be valid…



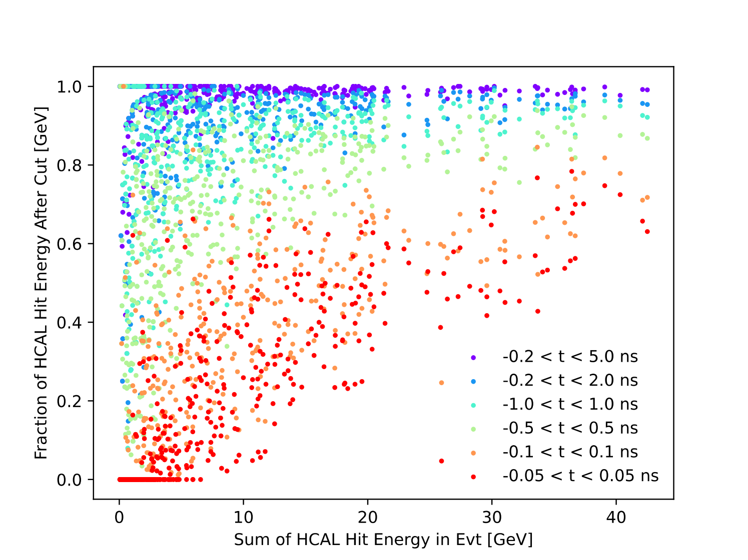


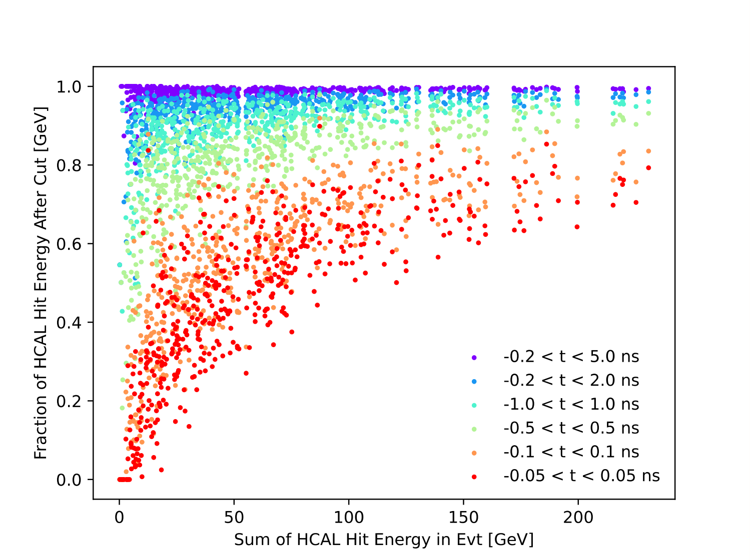
Reclustering, Time Cuts

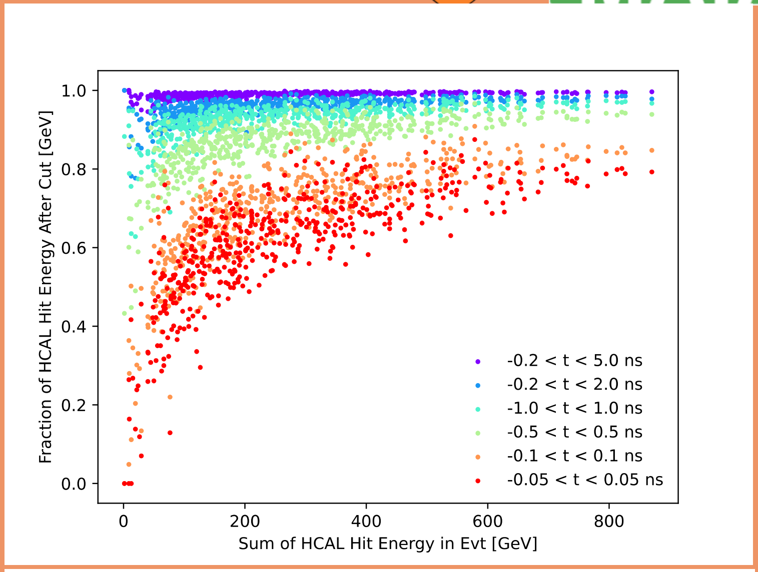
- *Clearly we need to reevaluate our matching criteria and our clustering strategy*
- *Start by getting a better sense of how timing cuts impact overall energy loss*
- *Reproduced Kiley's ECAL plots, but for HCAL hits*
  - *Also implementing negative energy cut*

Running over 500 events in each slice

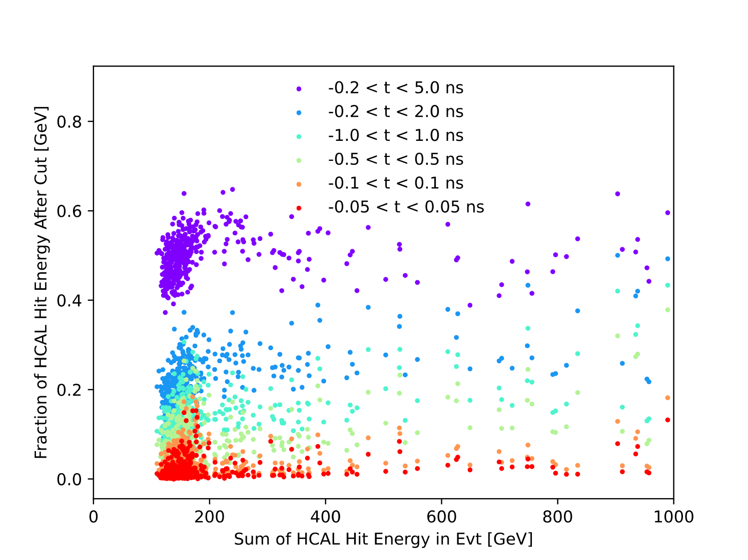
No BIB

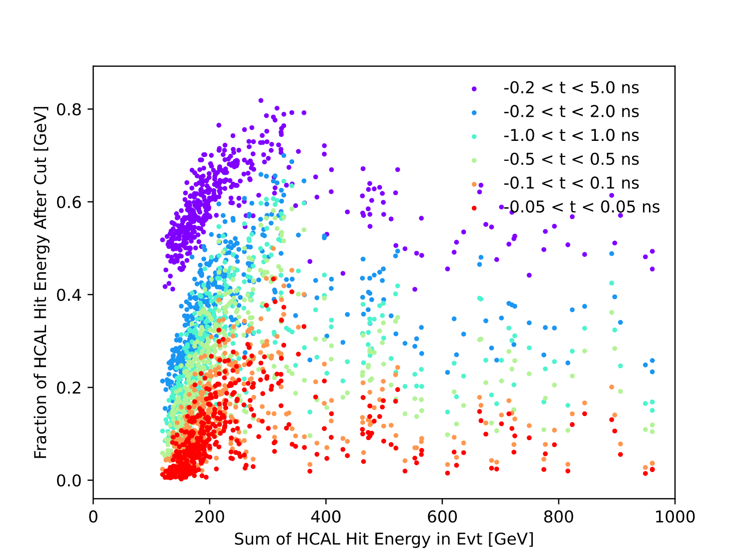


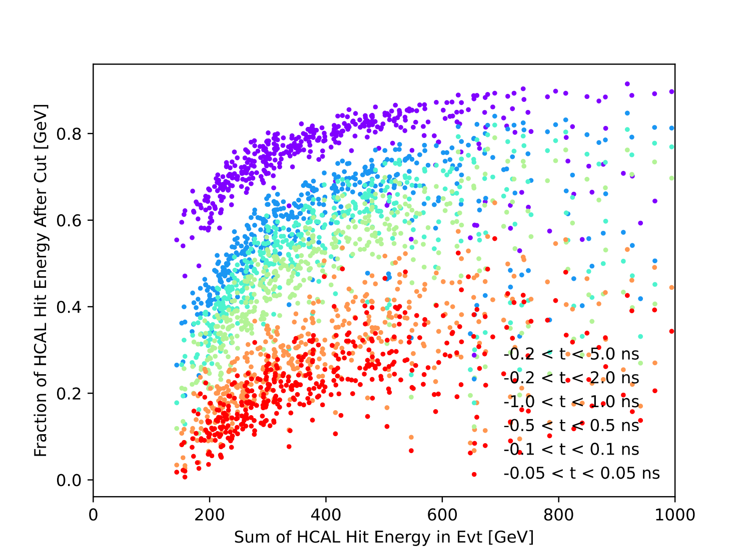




BIB







[0,50]GeV [50,250]GeV [250,1000]GeV

Takeaways from previous slide

- *A cut of 1.0 ns leaves between 80 and 100% of signal hit energy intact while reducing BIB hit energy by between ~40 and 60% (up to 80% in lowest energy slice)*
- *A more aggressive cut of 0.5 ns might be appropriate for the highest energy slice, where it leaves ~80% of signal hit energy intact*
- *See similar patterns as in Kiley's studies of ECAL timing cuts; cuts must be loosened slightly for hadronic energy contributions*

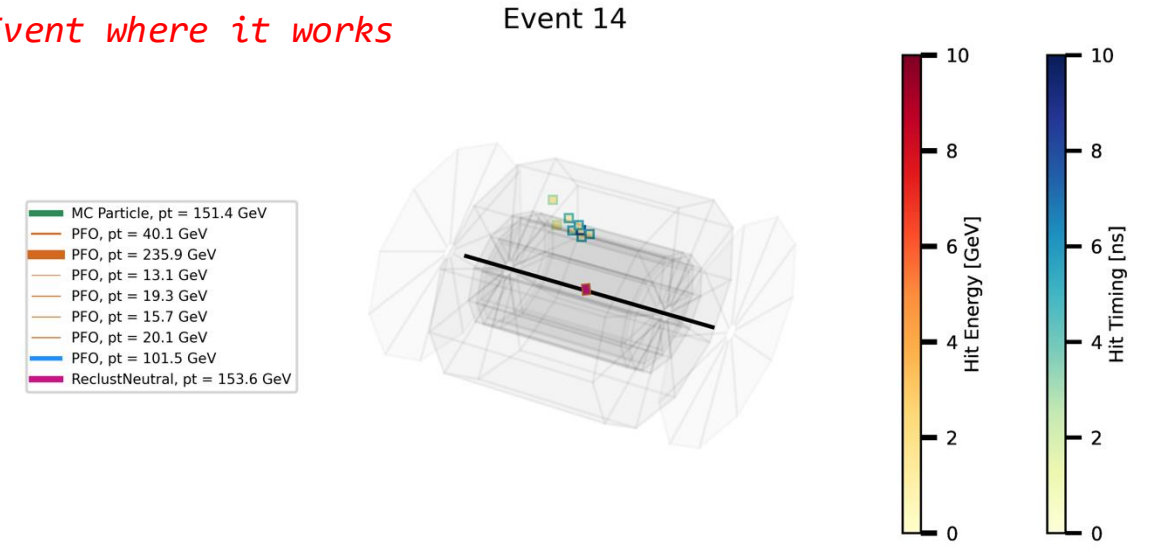
Simple Reclustering Attempt

- *A first attempt at time-aware clustering, sketched out an algorithm takes an HCAL hit collection and proceeds in 4 main steps:*
  - *Remove all hits outside loose/reasonable thresholds in energy, time, and theta (set by study of no-BIB sample and geo. acceptance)*
  - *Find the "core seed," removing all but the most prompt hits (very tight time cut) and setting aside the rejected hits for further sweeping*
  - *Find the mean and std of hit time and hit dR in the "core seed"*
  - *Sweep through "rejected" hits and add them back in based on their time and dR in relation to the stats found above*
    - *For dR, include hit if dR(hit, core) is within a threshold set by hit-hit dR distributions of no-BIB sample*

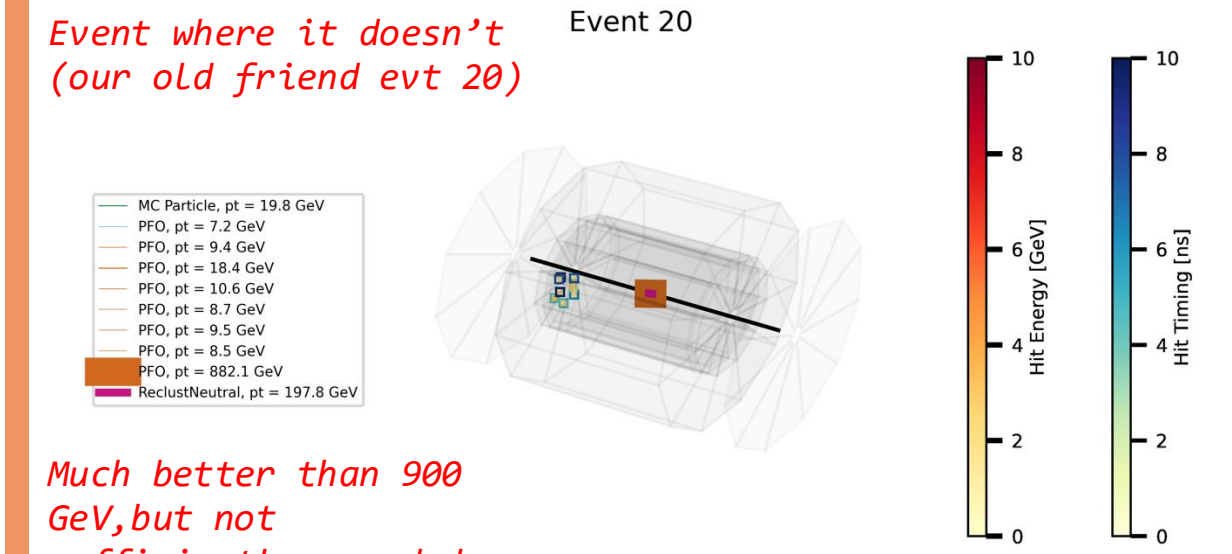
New Simple Reclustering Scheme

- *Roughly as (un)successful at reconstructing noBIB as Pandora. We lose energy across the board but do eliminate spurious photons (see backup)*
- *For BIB sample, trims down the energy of the very high-pT PFOs – to a sufficient level in some events, but not in others*

Event where it works



Event where it doesn't (our old friend evt 20)



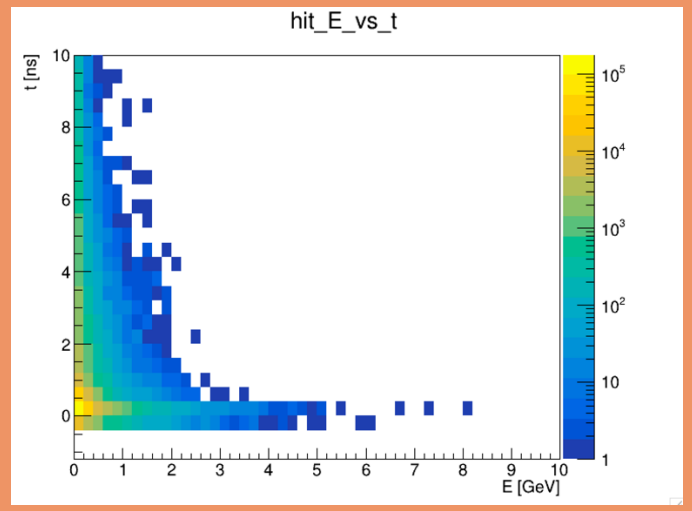
Much better than 900 GeV,but not sufficiently pared down

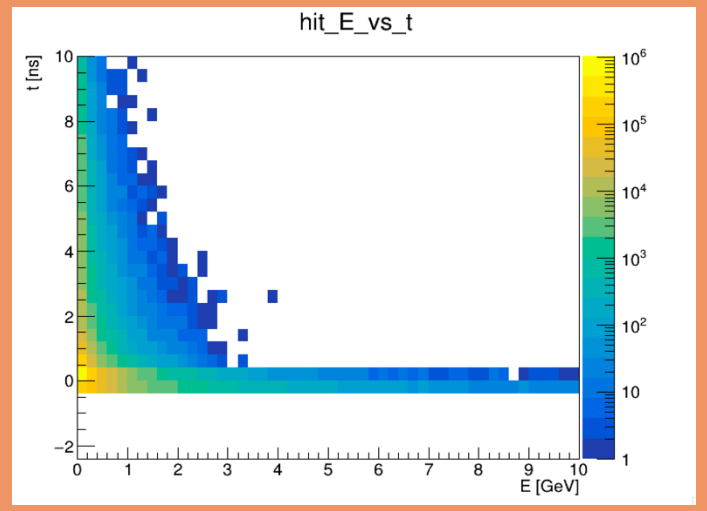
Next Steps

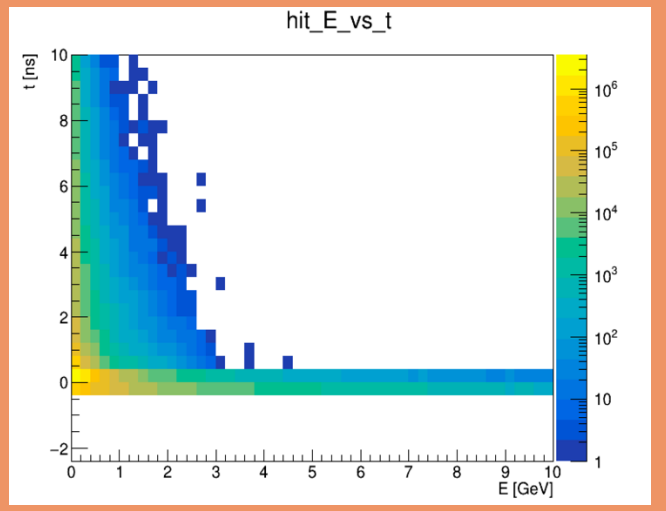
- *I want to continue investigating events like Event 20 with high BIB occupancy near the nozzle*
- *Want to better understand why these failures happen and if there are other quantities we can cut on to distinguish signal from BIB in high-occupancy events*
- *I will also look more closely at the Pandora algorithms and see if there is a convenient place to implement time-awareness*

Backup – hit E vs t, ECal included

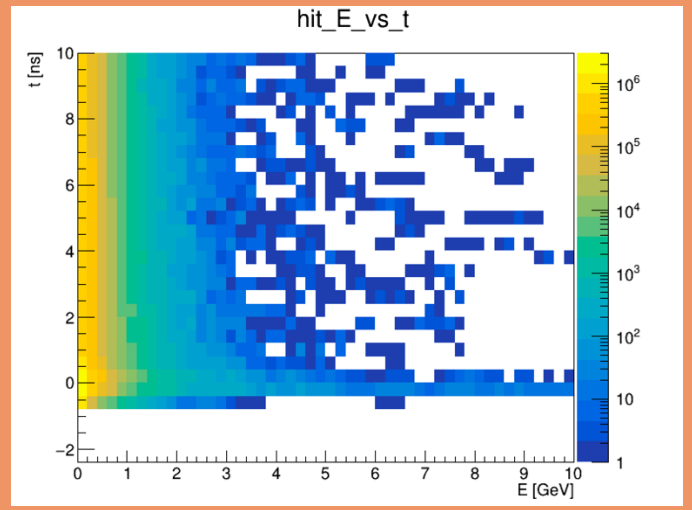
No BIB

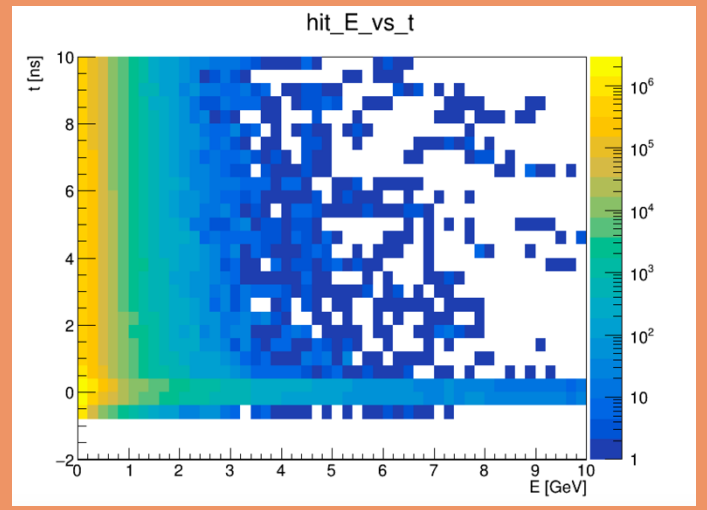


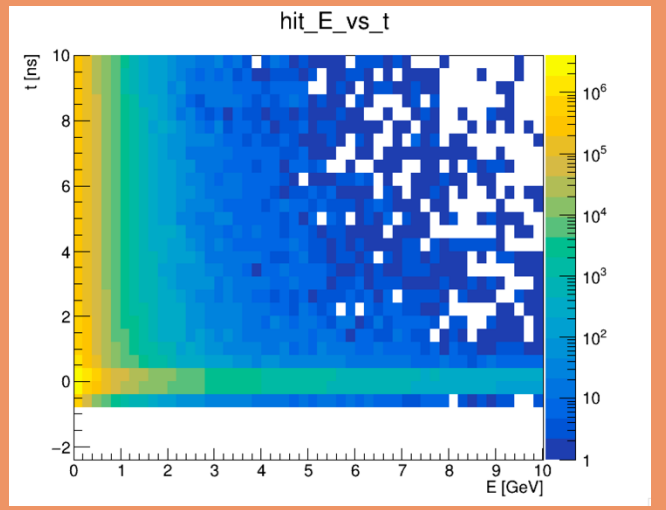




BIB





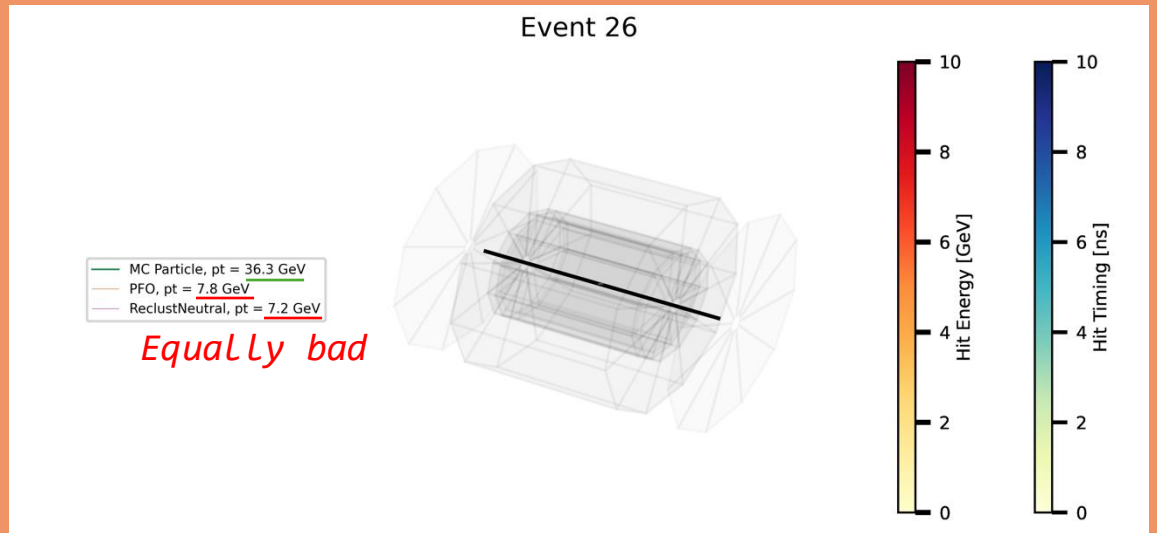


[0,50]GeV

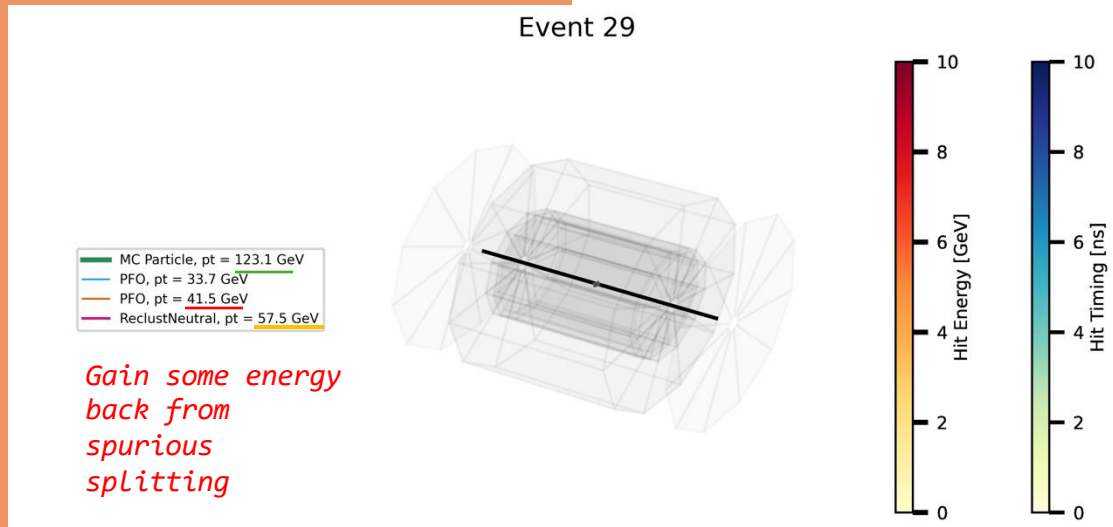
[50,250]GeV

[250,1000]GeV

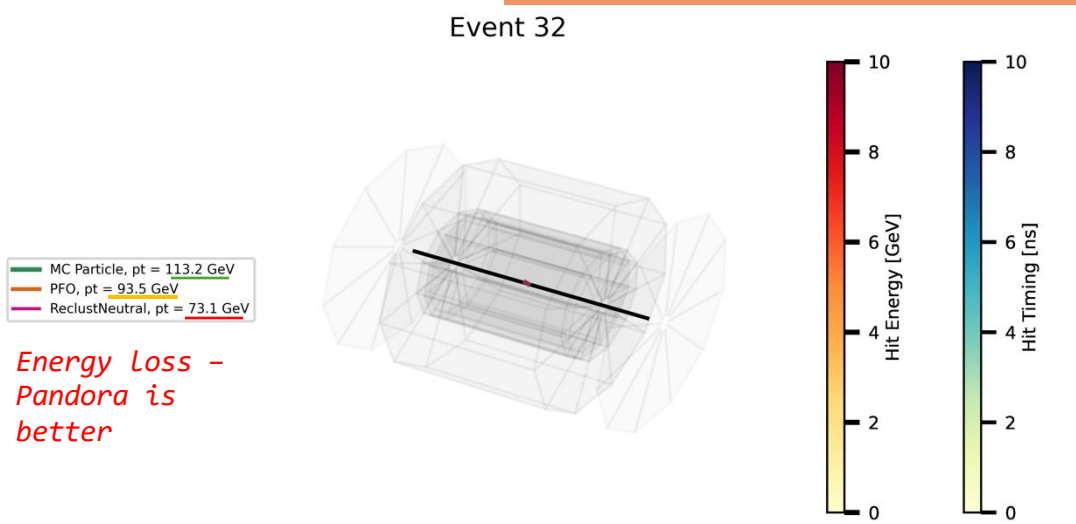
Backup – some no-BIB event displays with simple reclustering



Equally bad

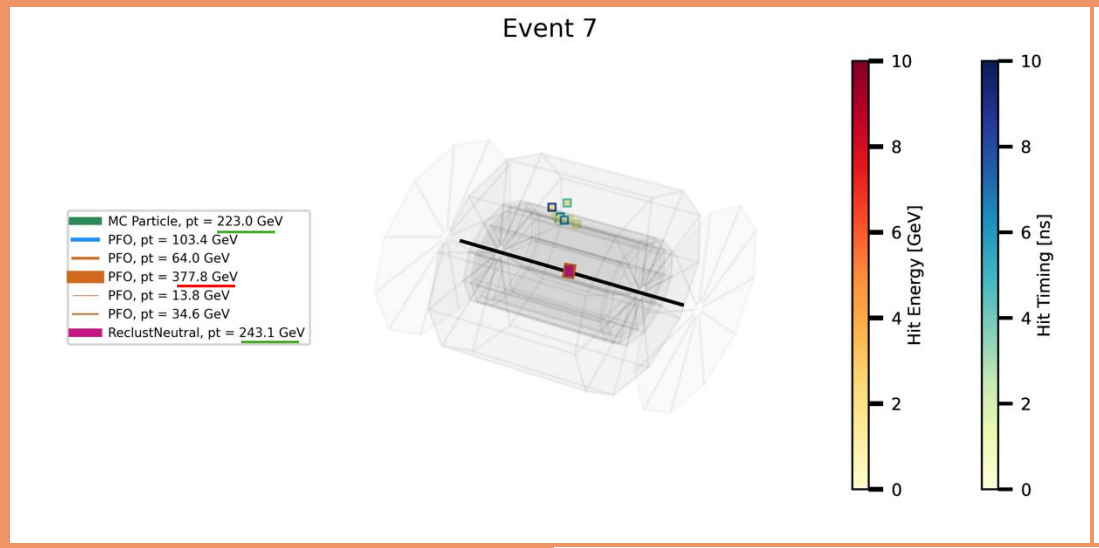


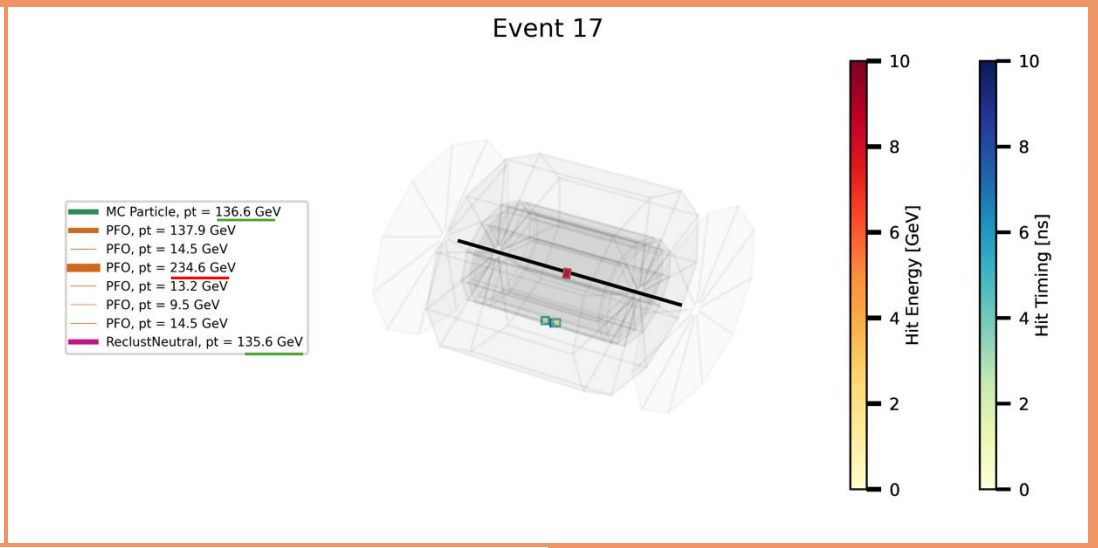
Gain some energy back from spurious splitting

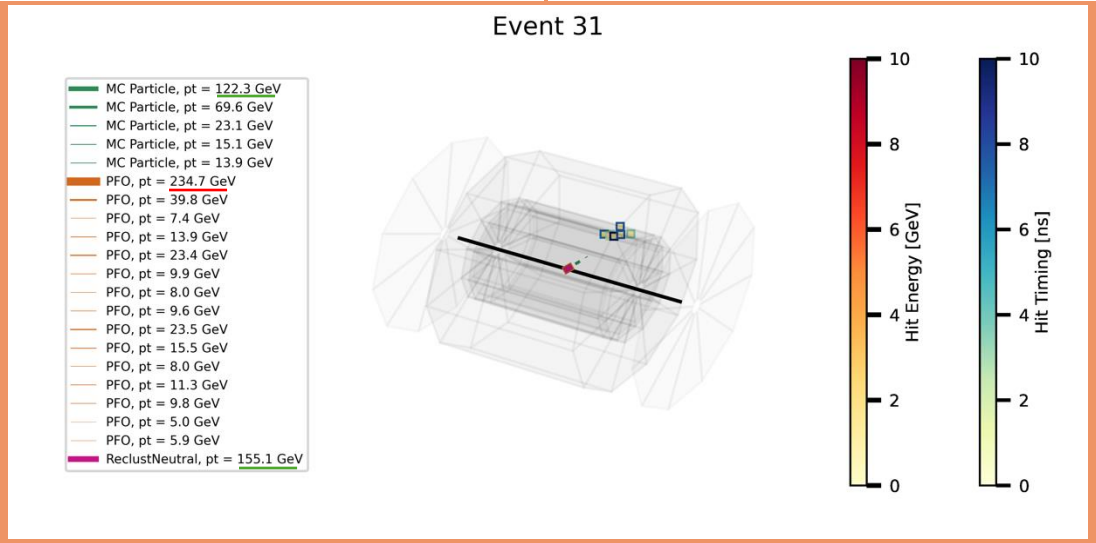


Energy loss – Pandora is better

Backup – more examples of reclustering working







Backup – more examples of reclustering **not** working