Using ERTool to Investigate uBooNE Dirt Backgrounds

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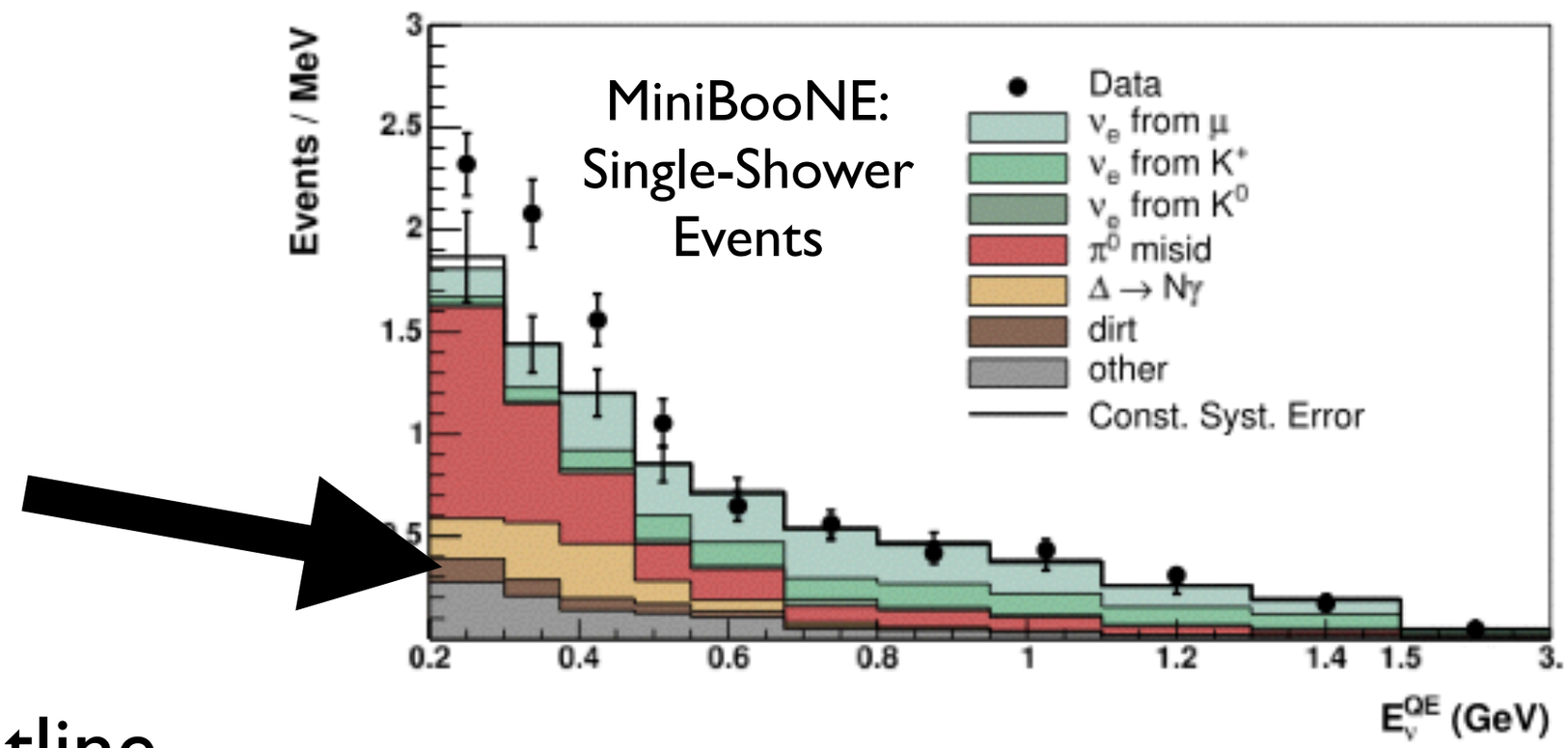
Eventual Goal of this Study

- Determine dirt contribution to SingleE analysis using real reconstruction tools



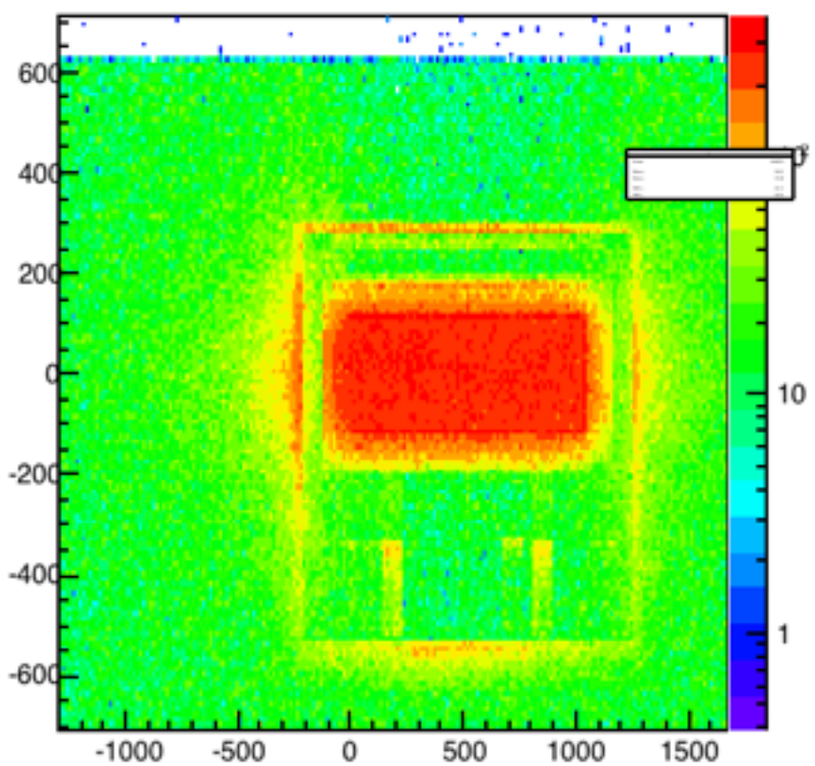
- Outline
  - Introduction
  - First look at dirt single-e candidates
  - Comparison to TPC-intrinsic single-e candidates
  - Same comparisons including mis-IDed gammas (will explain later)

Intro

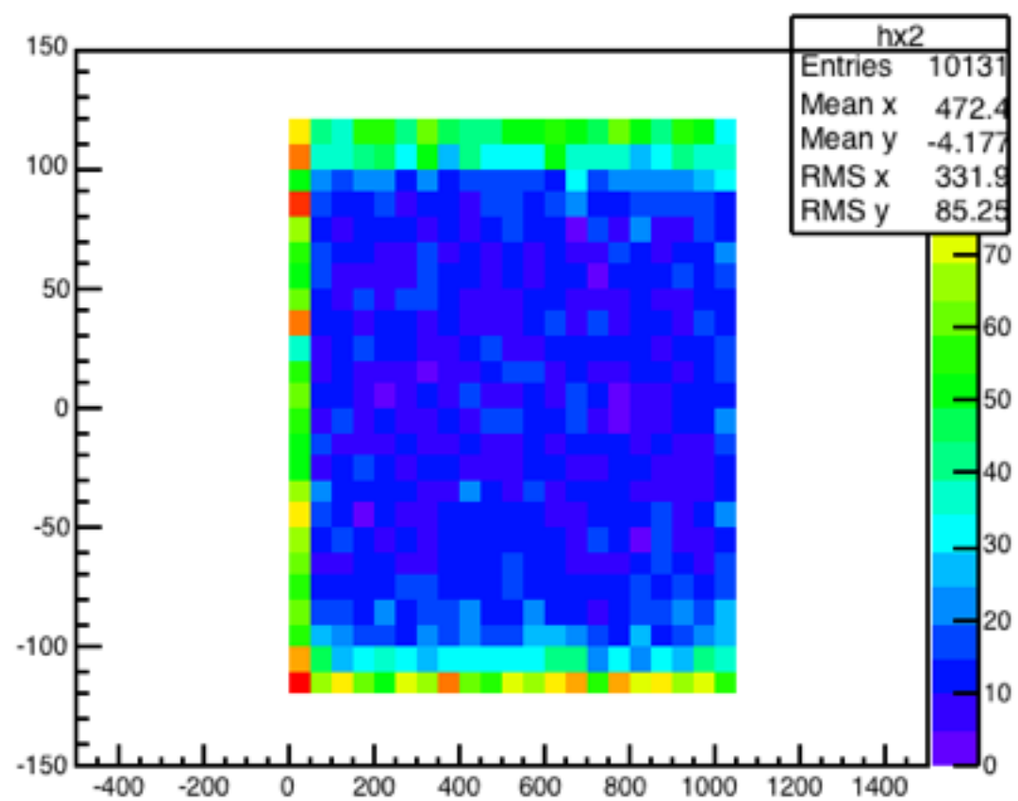
Before: Investigation using LArLite

- Using Joe's Dirt Sample for SBN Proposal:
  - /uboone/data/users/kterao/for_joseph
- Used LArLite to look at MCShower and MCTrack objects
  - MCTracks and MCShowers allow access to MC truth and 'perfectly reconstructed' quantities
  - Refer to Kazu's DocDB 3918 for more details
- Not worrying about normalization yet

True Start X-Z of All Produced MCShowers



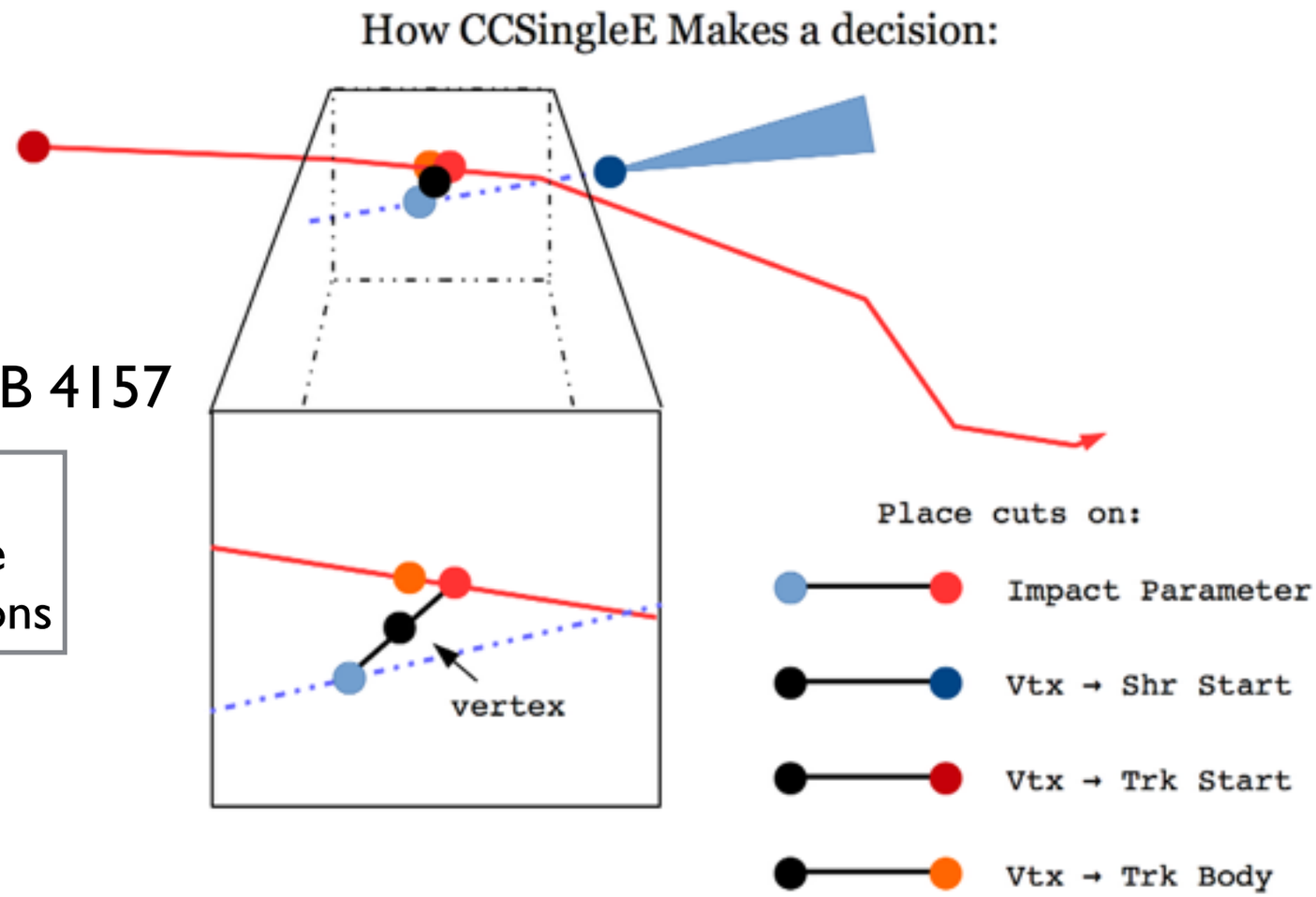
True Conversion X-Z for E>50 MCShowers produced outside TPC



Update: Use ERTools SingleE Selection

- Use ERTool CCSingleE selection algorithm on dirt events
  - Use only MCShower and MCTrack objects ('perfect reconstruction')
    - Includes perfect gamma rejection from dE/dx information
  - Committed a filter selecting events with neutrino interactions outside TPC:
    - https://github.com/larlight/larlite/blob/trunk/UserDev/LArLiteApp/CCSingleE/MC_Dirt_Filter.cxx
  - Use same selection algorithm developed by David, David, and Kazu that has already been applied to a set of in-TPC BNB events
    - https://github.com/larlight/larlite/blob/trunk/UserDev/SelectionTool/ERTool/Algo/AlgoSingleE.cxx
    - No changes to any of the applied cuts
  - Do analysis on outputted analysis variables
    - https://github.com/larlight/larlite/blob/trunk/UserDev/LArLiteApp/CCSingleE/ERAnaSingleE.cxx
    - No changes to any outputted variables

CCSingleE Selection Cuts Review



DocDB 4157

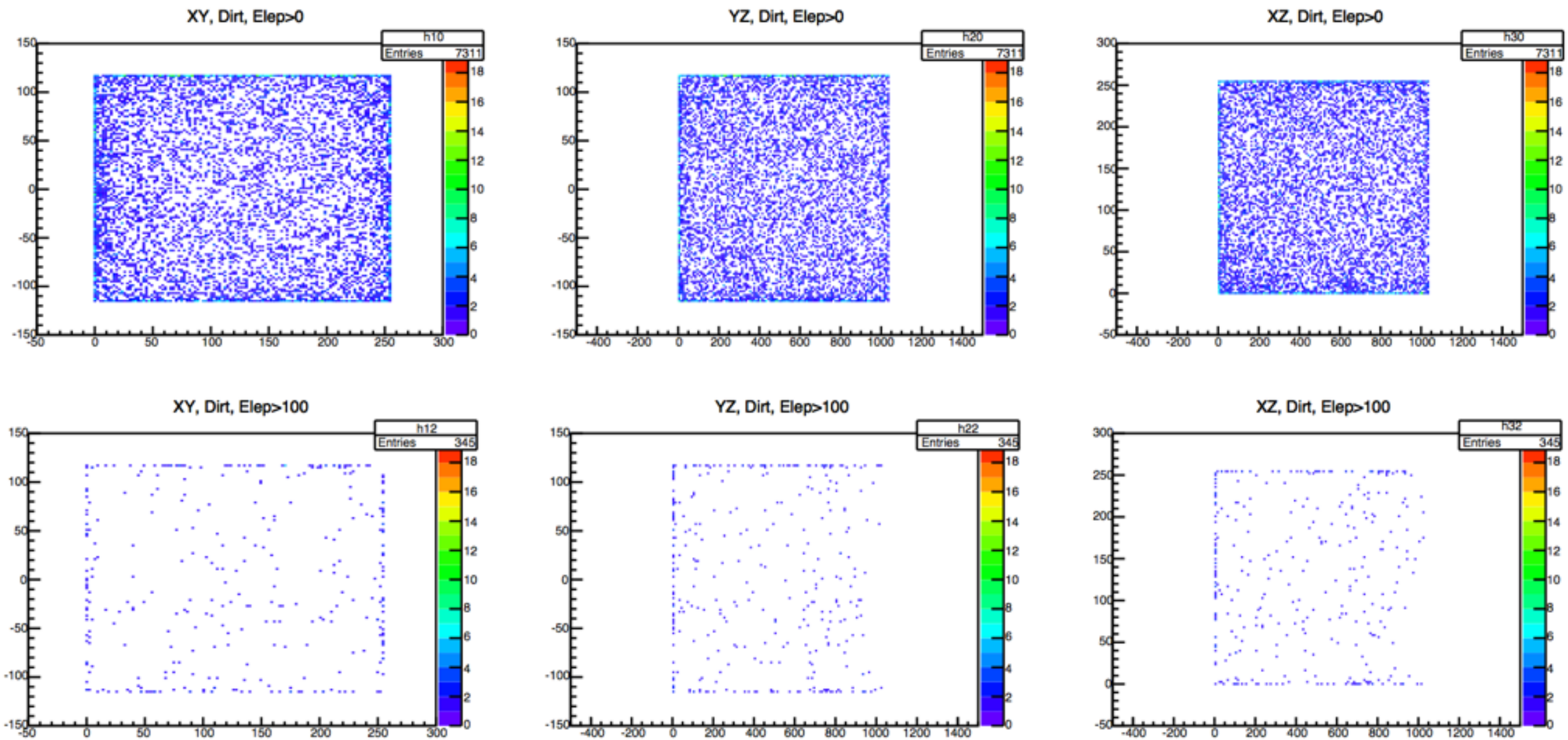
ID a vertex halfway along closest distance between object directions

- Reject if:
  - **Multi-e-like shower:** multiple e-like showers sharing a vertex with both **<50cm** from vertex
  - **Along track:** track+shower with small closest distance where muon-vertex distance **>1cm** and shower-vertex distance **>50cm**
  - **Gamma-like single shower:** Has dE/dx more like gamma than electron (currently **ALL gammas**)
  - **Gamma-like, with track:** shower and track sharing a vertex with shower looking like a gamma (has radiation length, dE/dx more like a gamma than like an electron; determined by LL function)
  - **Unrelated vertex:** A e-like shower **>5cm** from an unrelated track-track vertex

Dirt SingleE Candidates

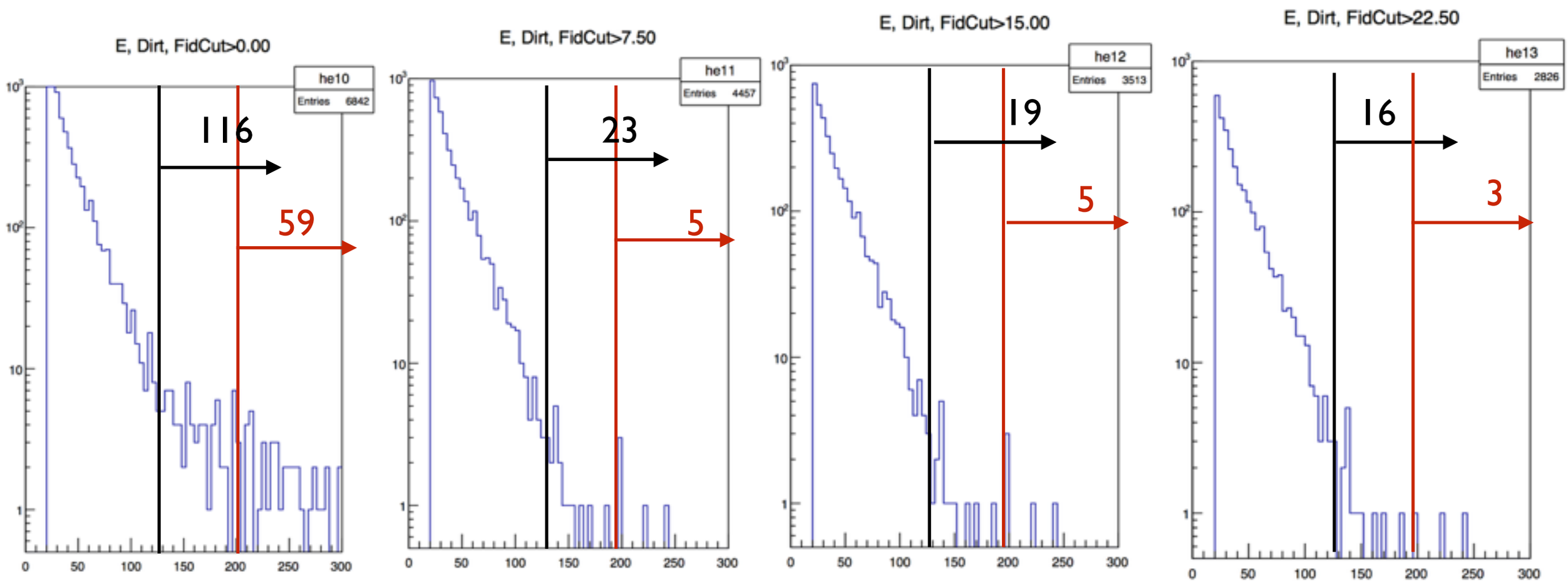
Dirt CCSingleE Candidates

- $[X,Y,Z]_{lep,reco}$ of dirt e-like candidates:
  - Tons of events present if we include lepton energies > 20 MeV
  - Tend to cluster around TPC edge when we require $E_{lep,reco}$ >100 MeV



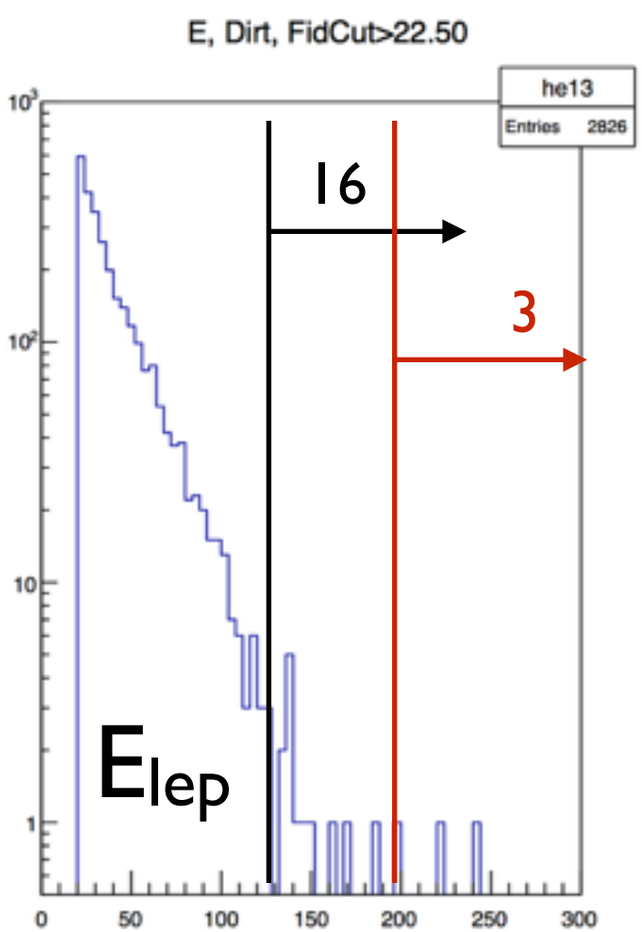
Dirt CCSingleE Candidates

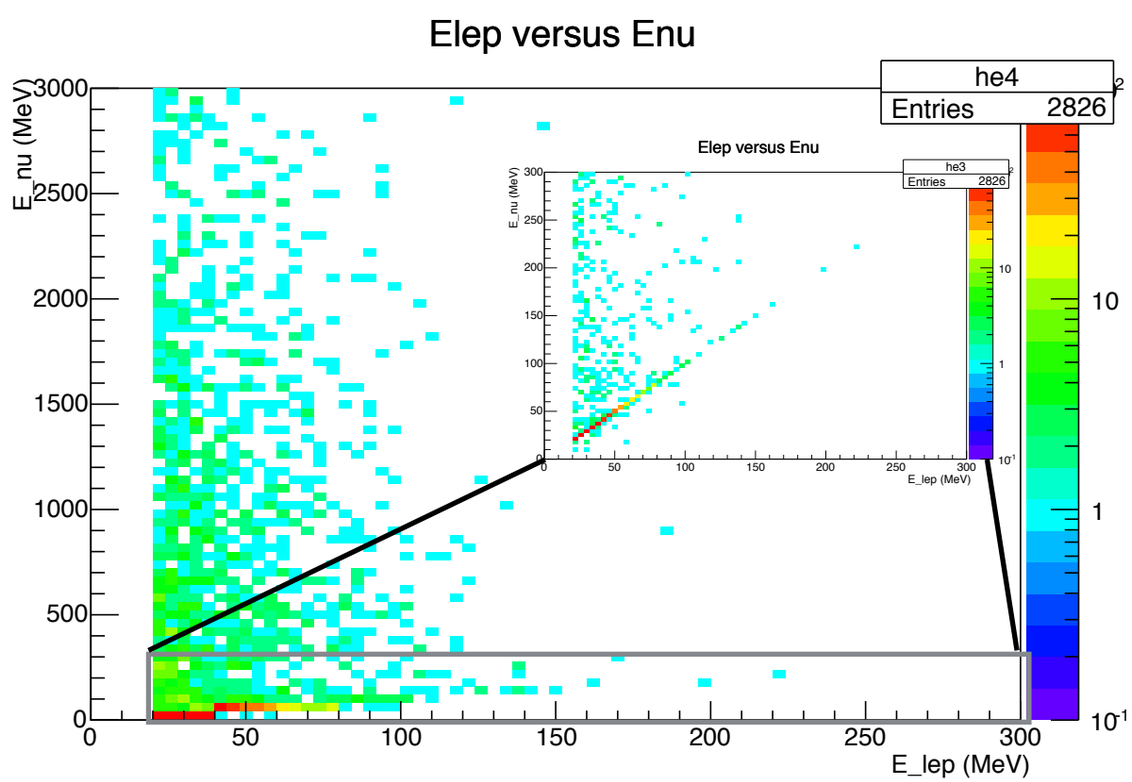
- $E_{lep,reco}$ of dirt e-like candidates:
  - Highest-energy events can be greatly reduced using fiducial volume cuts
  - Remember: no mis-IDed gammas present in this sample
  - Also remember: not properly normalized yet

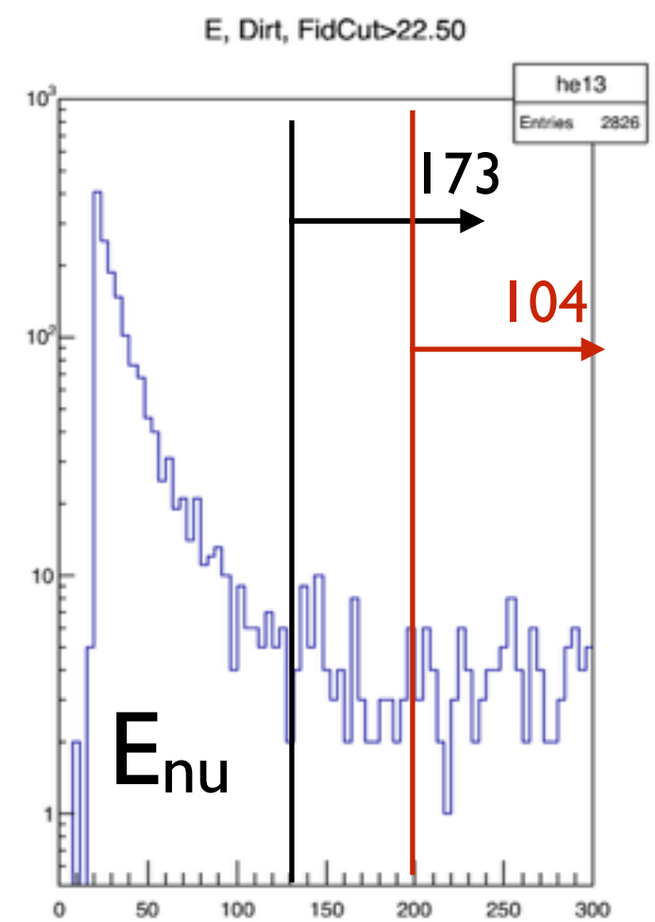


Dirt CCSingleE Candidates

- $E_{nu,reco}$ of dirt e-like candidates: add vertex energy, if any
  - Low-energy leptons can be associated with tracks of much higher energy
  - Means our over Enu,reco is often much larger than Elep for dirt events
  - Lots of high Enu,reco dirt background still remaining after fiducial volume cut







Dirt-TPC Comparison

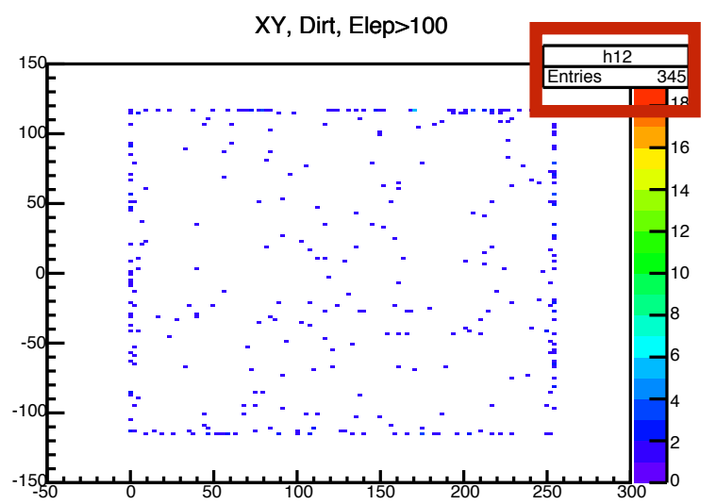
Dirt-TPC Comparison

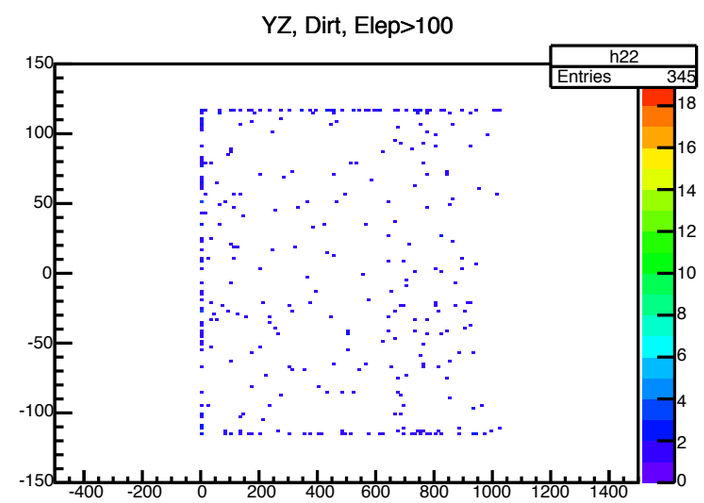
- Dirt events: neutrino interaction happening outside TPC
- In-TPC events: neutrino interaction happening inside TPC
  - Basically like MCC BNB event set, but with different normalization
- Concept:
  - Maybe we don't have normalization or exactly perfect cuts hammered out
  - BUT, if we know dirt contribution is lower than in-TPC backgrounds, then we there there's likely not any new scary surprises from dirt
  - Know relative contribution of dirt WRT other beam-intrinsics

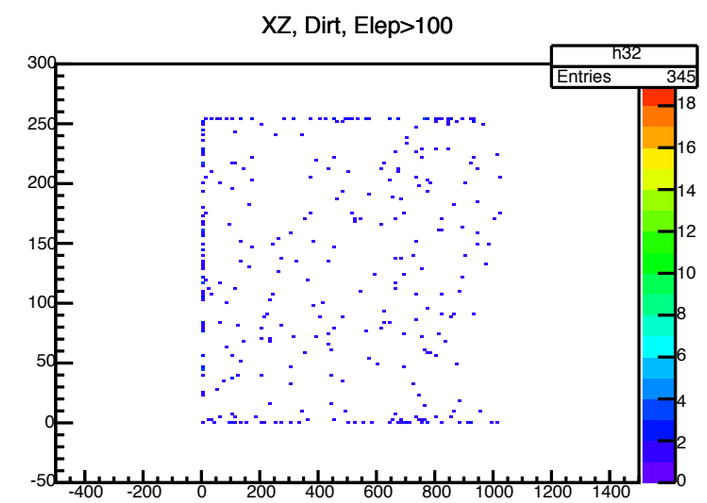
Single E: Dirt Versus In-TPC

- Flip my dirt filter to get in-TPC events
- Look at position distributions to start
  - In-TPC shower starts uniformly distributed over TPC, as expected
- Less >100MeV dirt e-like events, even w/o fiducial volume cut

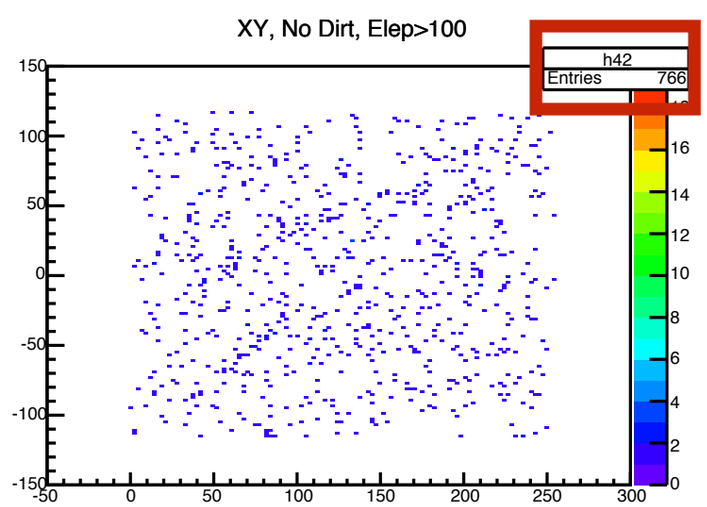
Dirt

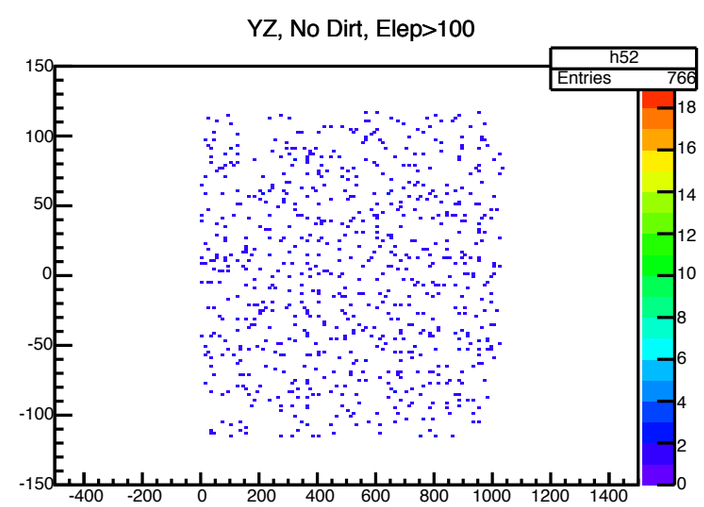


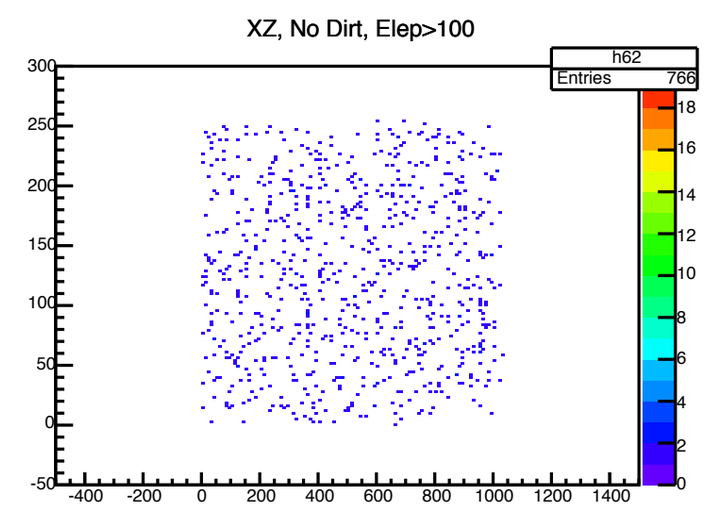




Non-Dirt

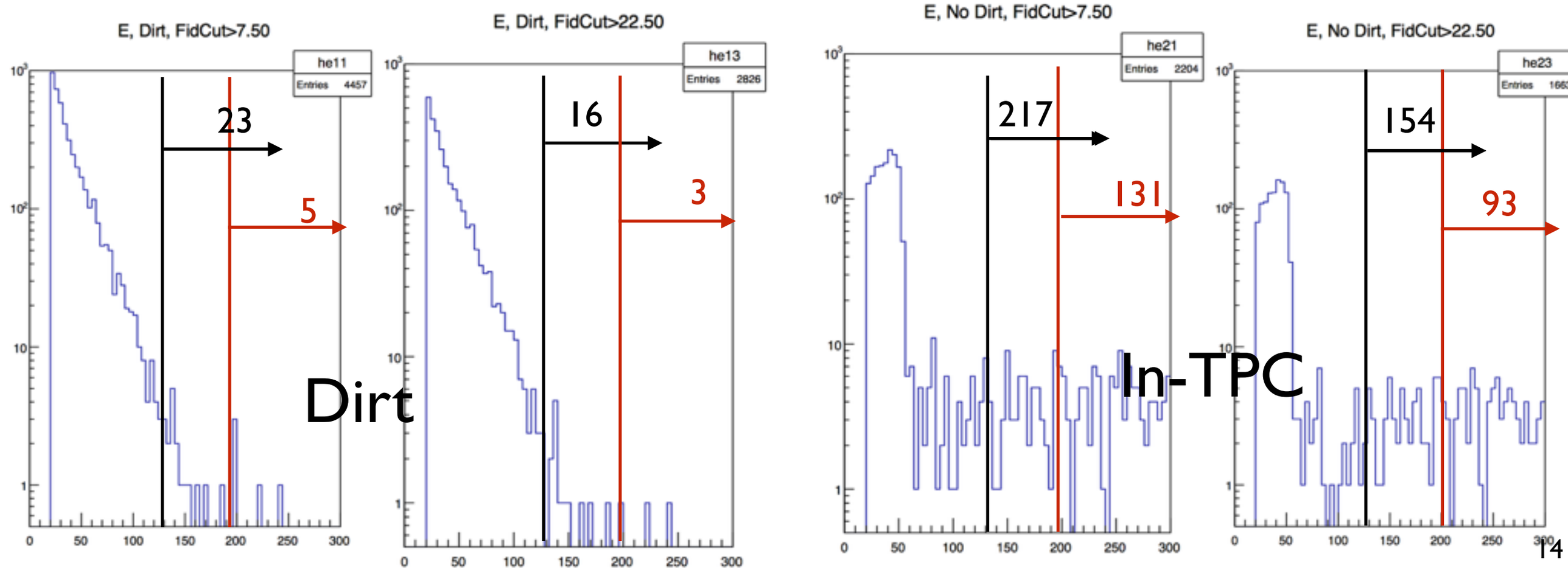






Single E: Dirt Versus In-TPC

- Dirt-TPC comparison with fiducial volume cuts
  - Above about 130 MeV, dirt is not the dominant background
    - This may change when single-gammas with mis-IDed dE/dx are included
  - Dirt then begins to dominate increasingly with lower and lower energy



Including Gamma Mis-IDs

Add in dE/dx Mis-IDed Gammas

- As I said previously, no gammas included in these plots
  - Cut out by giving MCShowers tight dE/dx values based on PDG ID
- Loosened dE/dx resolutions to 21% of central value
  - ~/larlite/UserDev/LArLiteApp/ERToolBackend/ERToolHelper.cxx
  - By running singleE selection on an all-single-gamma training sample, my first-go at widths gives 7 +/- 0.3% gamma mis-ID based on only dE/dx

```
void ERToolHelper::FillShowers ( const event_mcshower& mcs_v,
                                 ::ertool::EventData& res ) const
{
  for(auto const& mcs : mcs_v) {

    if(mcs.DetProfile().Momentum().E()<_minEDep) continue;
    //if(isnan(mcs.DetProfile().Momentum().E())) continue;
    //if(isnan(mcs.DetProfile().Momentum().Px())) continue;
    //if(mcs.DetProfile().Momentum().Mag2() == 0) continue;
    ::ertool::Shower s( mcs.DetProfile().Position(),
                        mcs.DetProfile().Momentum(),
                        _shrProfiler.Length( mcs.DetProfile().Momentum().E()),
                        _shrProfiler.ShowerRadius() );
    s._energy     = mcs.DetProfile().Momentum().E();
    //s._energy = mcs.Start().Momentum().E();
    s._dedx       = (mcs.PdgCode() == 22 ? gRandom->Gaus(4,4*0.214) : gRandom->Gaus(2,2*0.214));
    s._cosmogenic = (double)(mcs.Origin() == simb::kCosmicRay);
    res.Add(s);
  }

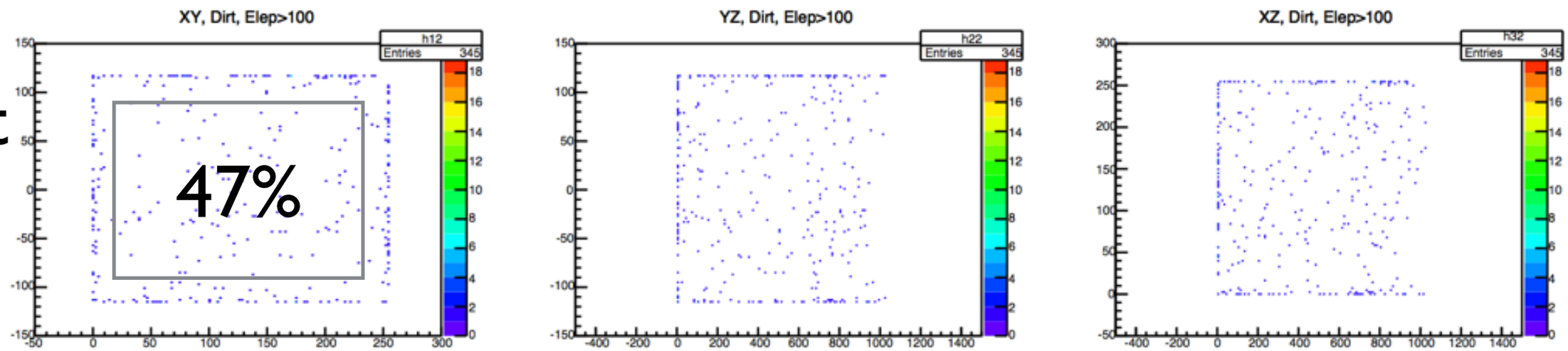
  return;
}
```

```
RESULTS:
Tot Events     : 18000
SingleE Events: 1255
Eff            : 6.97222 %
```

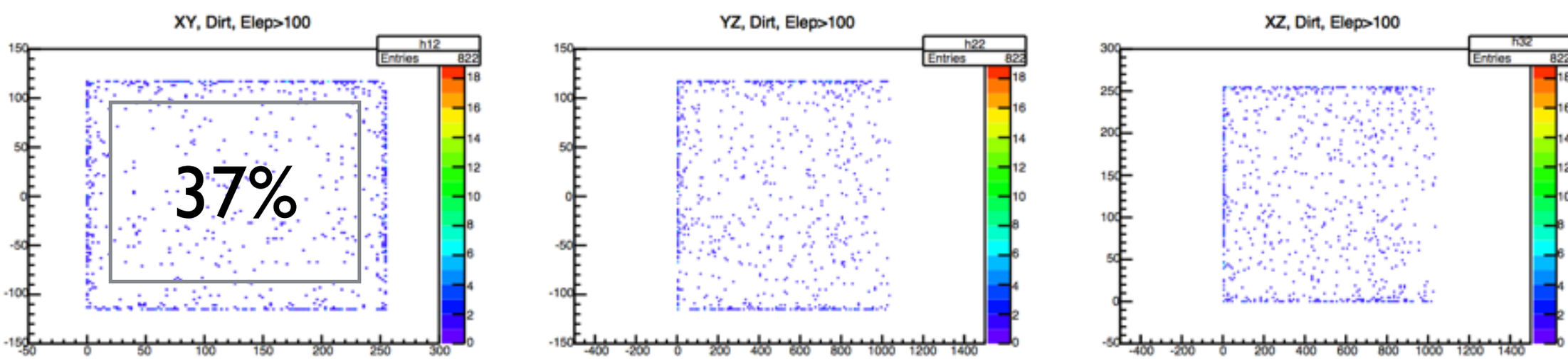
Dirt CCSingleE Candidates: With Gammas

- $[X,Y,Z]_{lep,reco}$ of dirt e-like candidates:
  - Dirt background sample has definitely grown: more than a factor of 2 higher
  - New gammas are preferentially near edge of detector
    - This should not be too surprising…

Without Gamma

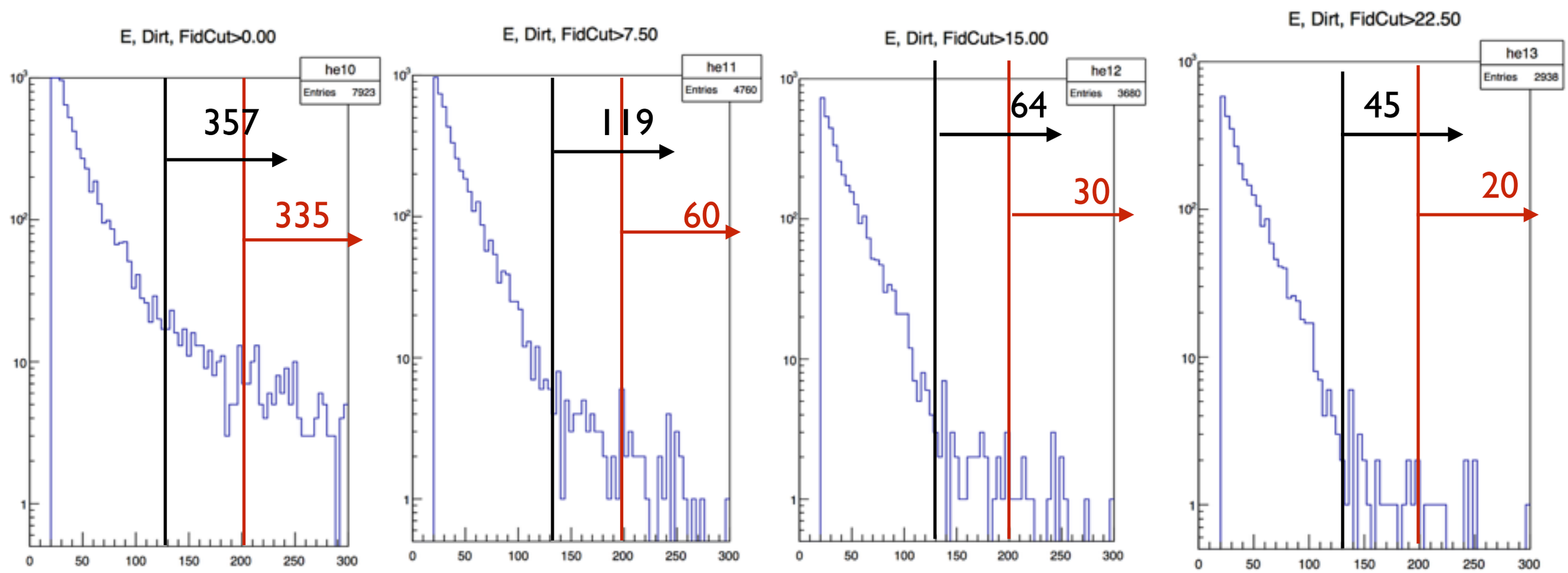


With Gamma



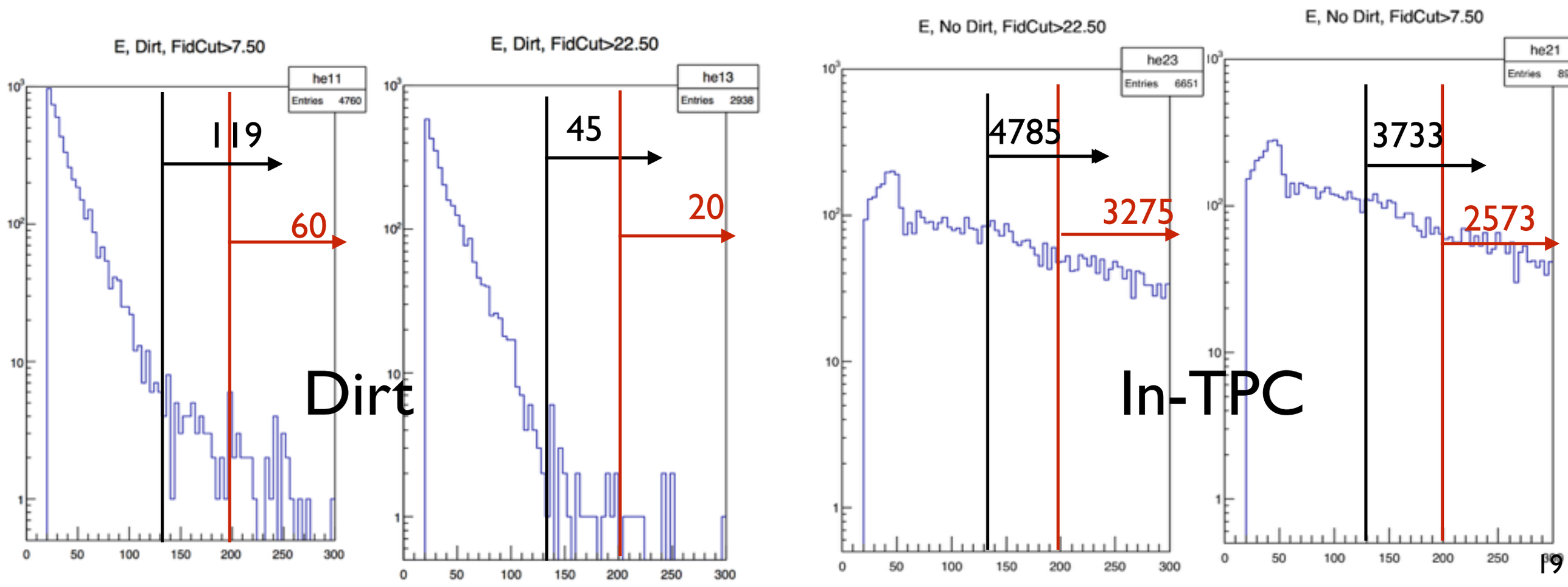
Dirt CCSingleE Candidates: With Gammas

- $E_{lep,reco}$ of dirt e-like candidates including mid-gammas:
  - As expected, fiducial volume cut is still very effective
  - Dirt showers with higher E inside fiducial up by factor of ~6-7
  - Background still appears to ramp up at around the same energy



Dirt Versus In-TPC: With Gammas

- Dirt-TPC comparison with fiducial volume cuts
  - Dirt: increase by a factor of ~7
  - In-TPC: increase by a factor of ~25
    - Much bigger increase - does this make sense?
  - This makes dirt look like even less of a problem than before
    - Doesn't really start to dominate until around 70 MeV



dE/dx Caveat

- MCShower dE/dx assigned according to PDG ID
- Joe has pointed out that both compton and pair production MCShowers are assigned a PDG ID of 22
  - Means that we are assigning 93% dE/dx rejection to comptons: WRONG!
  - However, similarly wrong for both dirt and in-TPC backgrounds
  - **Shouldn't change the sub-dominance of dirt above 70MeV, and may actually lower this value.**
- Will this feature be addressed in MCC6?

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    //if(isnan(mcs.DetProfile().Momentum().E())) continue;
    //if(isnan(mcs.DetProfile().Momentum().Px())) continue;
    //if(mcs.DetProfile().Momentum().Mag2() == 0) continue;
    ::ertool::Shower s( mcs.DetProfile().Position(),
                        mcs.DetProfile().Momentum(),
                        _shrProfiler.Length( mcs.DetProfile().Momentum().E()),
                        _shrProfiler.ShowerRadius() );
    s._energy     = mcs.DetProfile().Momentum().E();
    //s._energy = mcs.Start().Momentum().E();
    s._dedx       = (mcs.PdgCode() == 22 ? gRandom->Gaus(4,4*0.214) : gRandom->Gaus(2,2*0.214));
    s._cosmogenic = (double)(mcs.Origin() == simb::kCosmicRay);
    res.Add(s);
```

Summary and Next Steps

- Have Identified e-like dirt backgrounds using ERTool with 'perfect reconstruction'
- Preliminary take-aways:
  - Contribution of dirt backgrounds is sub-dominant to intrinsic beam-related background above E_{lep} of 70 MeV, perhaps even lower
  - Fiducial volume need not be too extreme to achieve sub-dominant dirt background (7.5 cm?)
- Improvements:
  - Need to obtain a proper normalization
    - Can be done by pegging to numu_cc in this sample (determined using MC filters)
  - Need to properly include Compton electrons to get totally correct event rates and background energy spectra
  - After these additions, I can begin to compare my numbers to MCTruth-based numbers from the SBN proposal for MicroBooNE