RESEARCH CORPORATION for SCIENCE ADVANCEMENT
U.S. DEPARTMENT OF ENERGY | Office of Science

v5 samples

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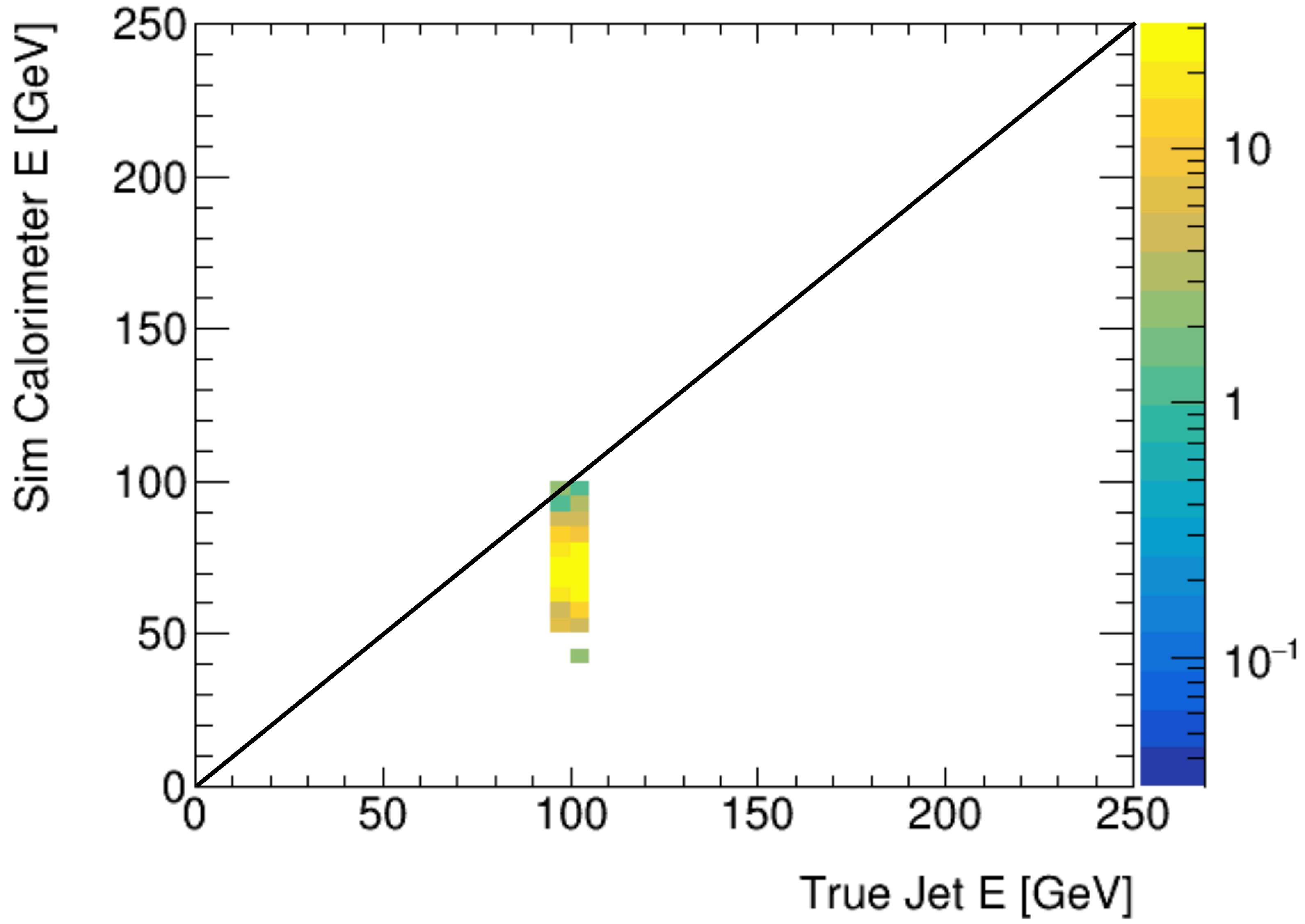
MAIA DETECTOR CONCEPT
18 JULY 2025

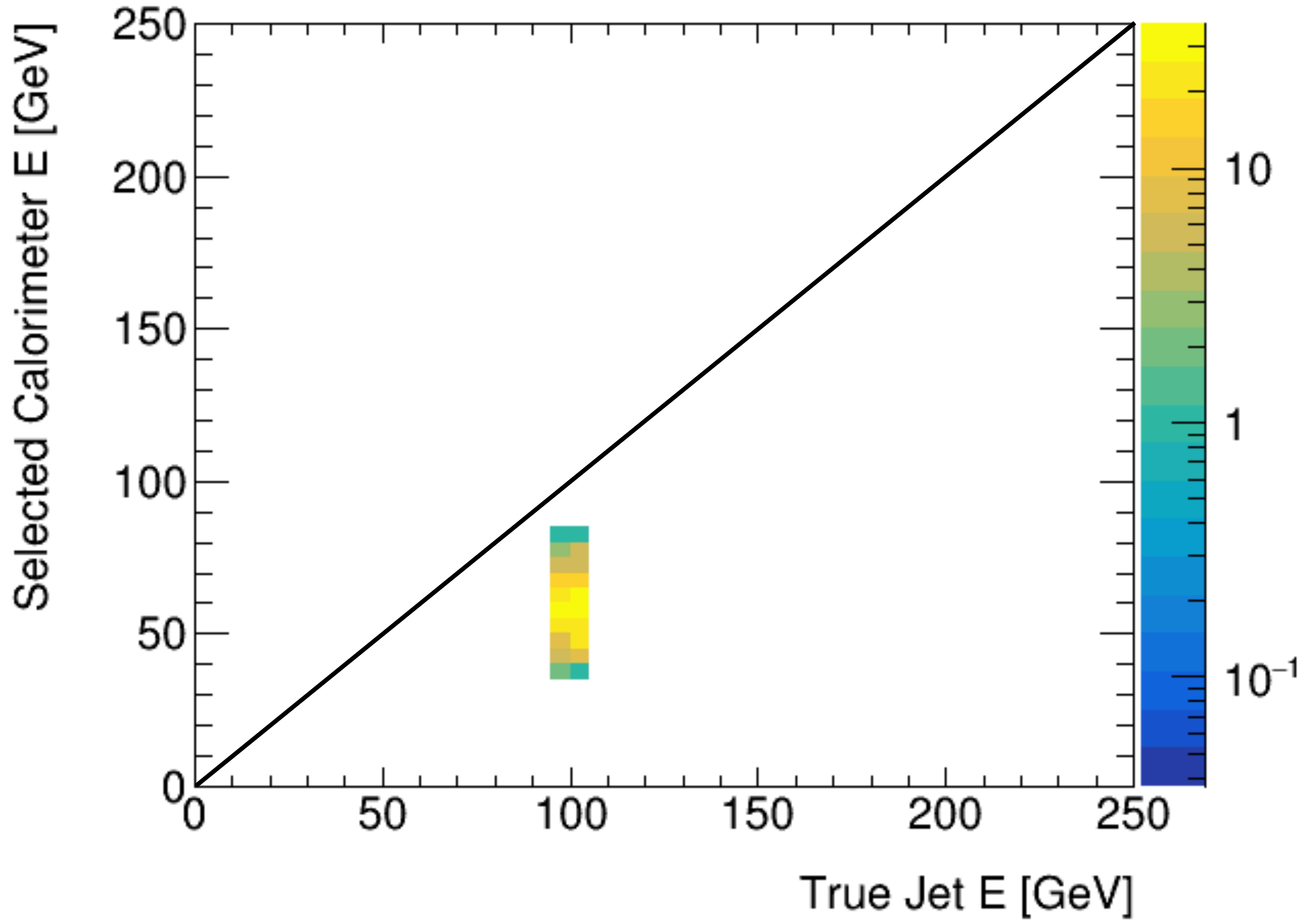
v5 di-jets

unfortunately I only have access to the 100 GeV invariant mass sample , so we're just looking at that

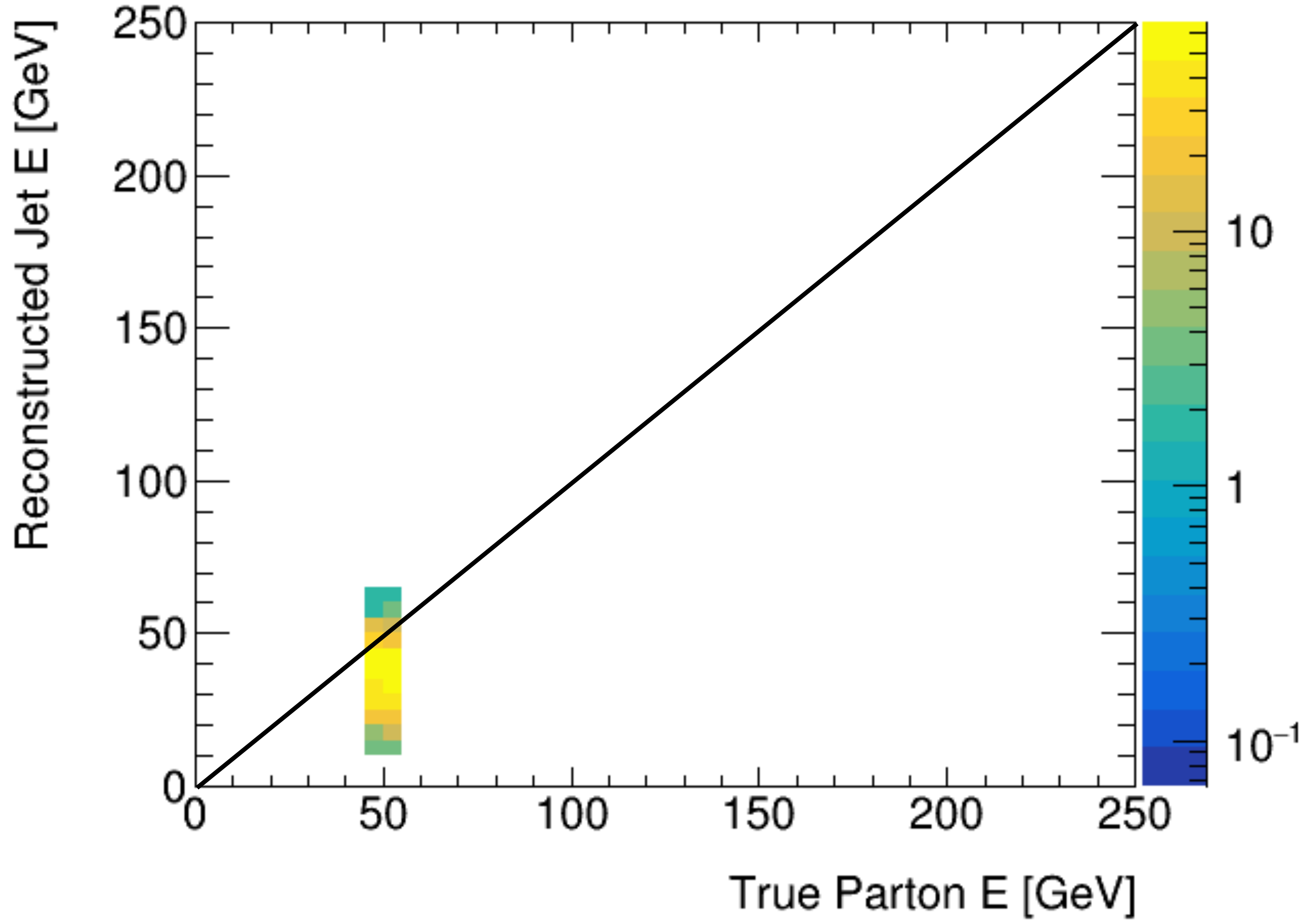
Cluster energy comparison (0-1.1 eta)

First look at jets — only using 100 GeV invariant mass.





Digitization + cone selection has a small loss. What is cone?



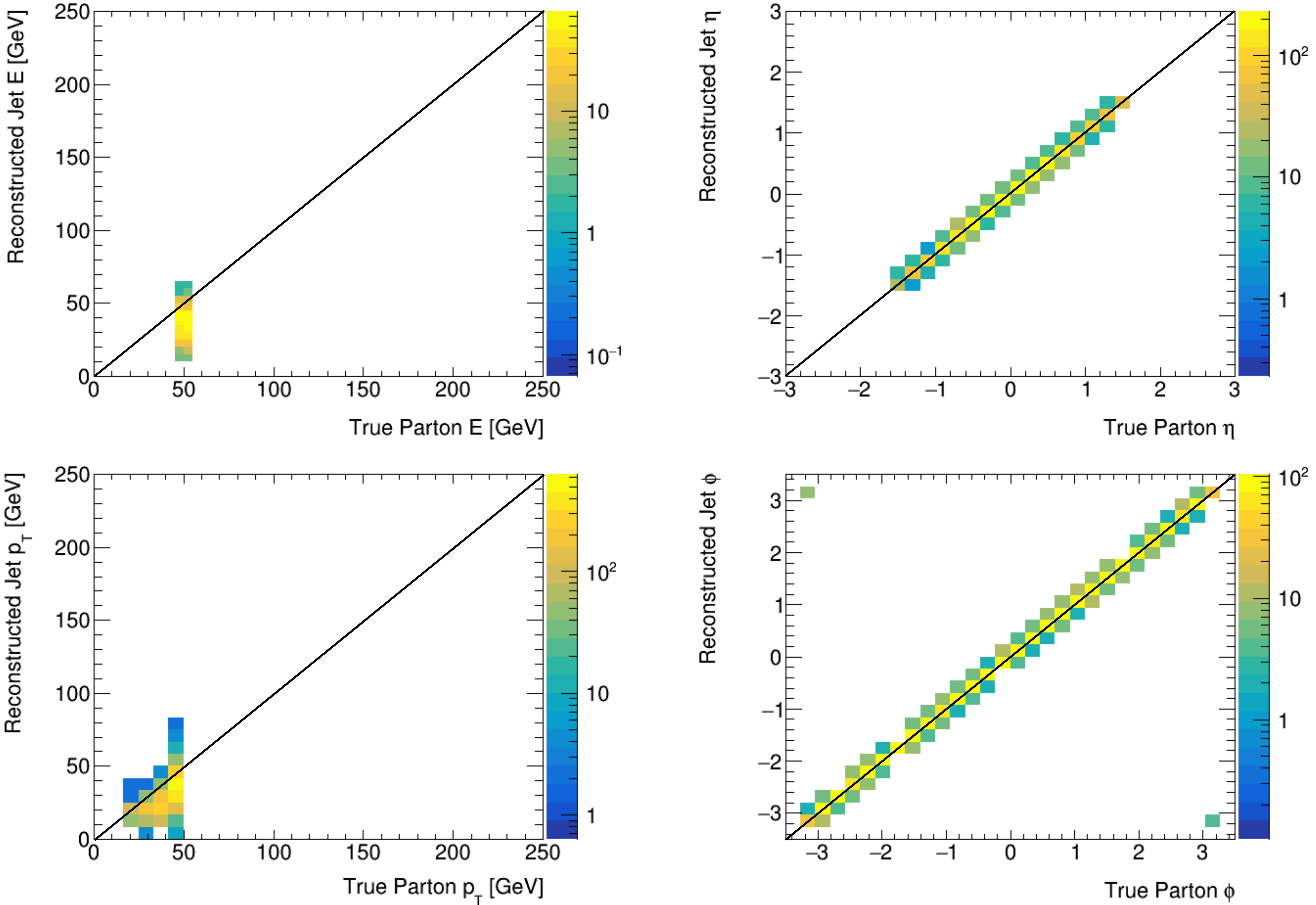
Did actual matching here to look at individual jets instead of the sum. Looks similar to the bias at the sim hit level

Matching requirements:

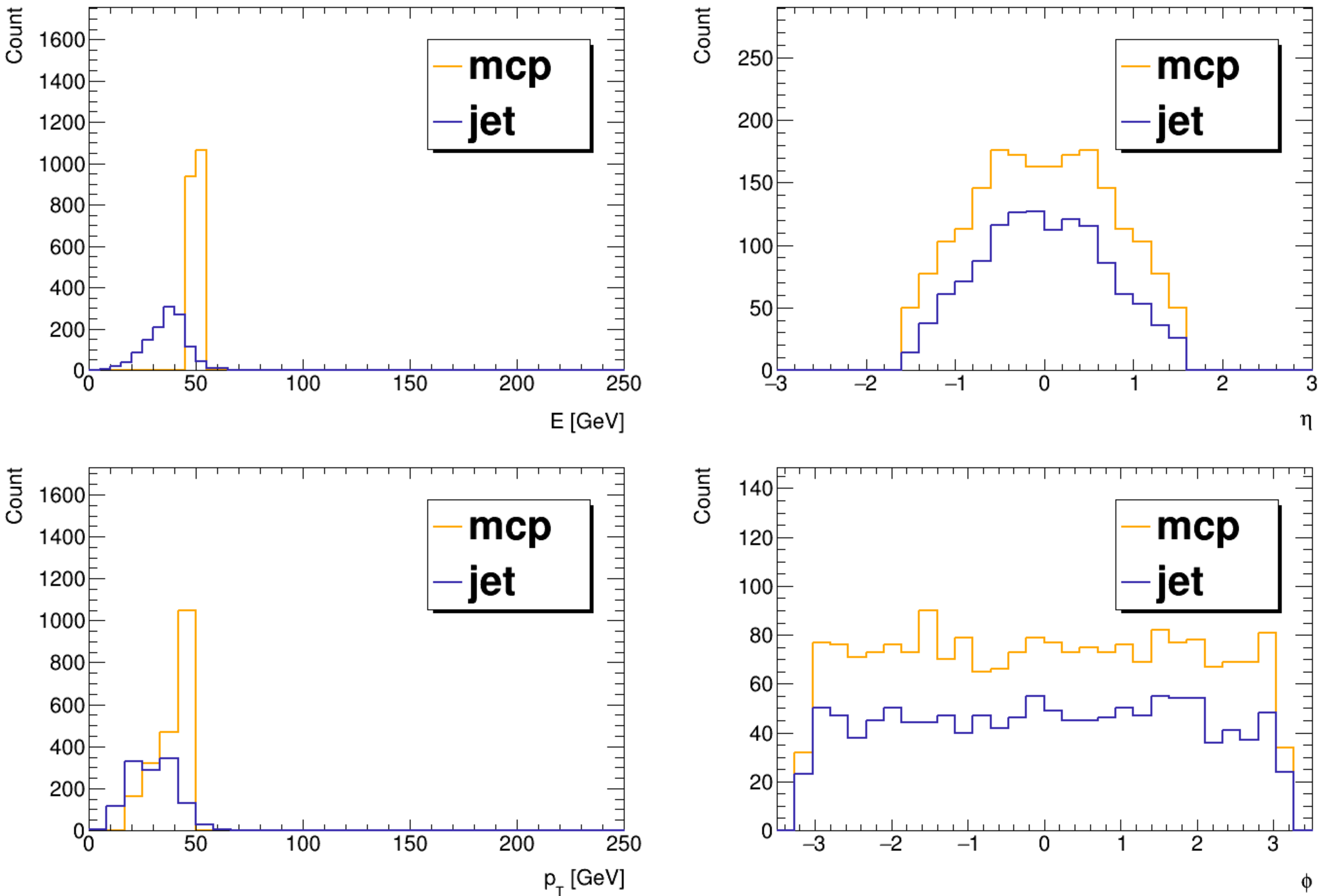
dR < 0.1

highest E match is kept

Looking at reconstructed jets



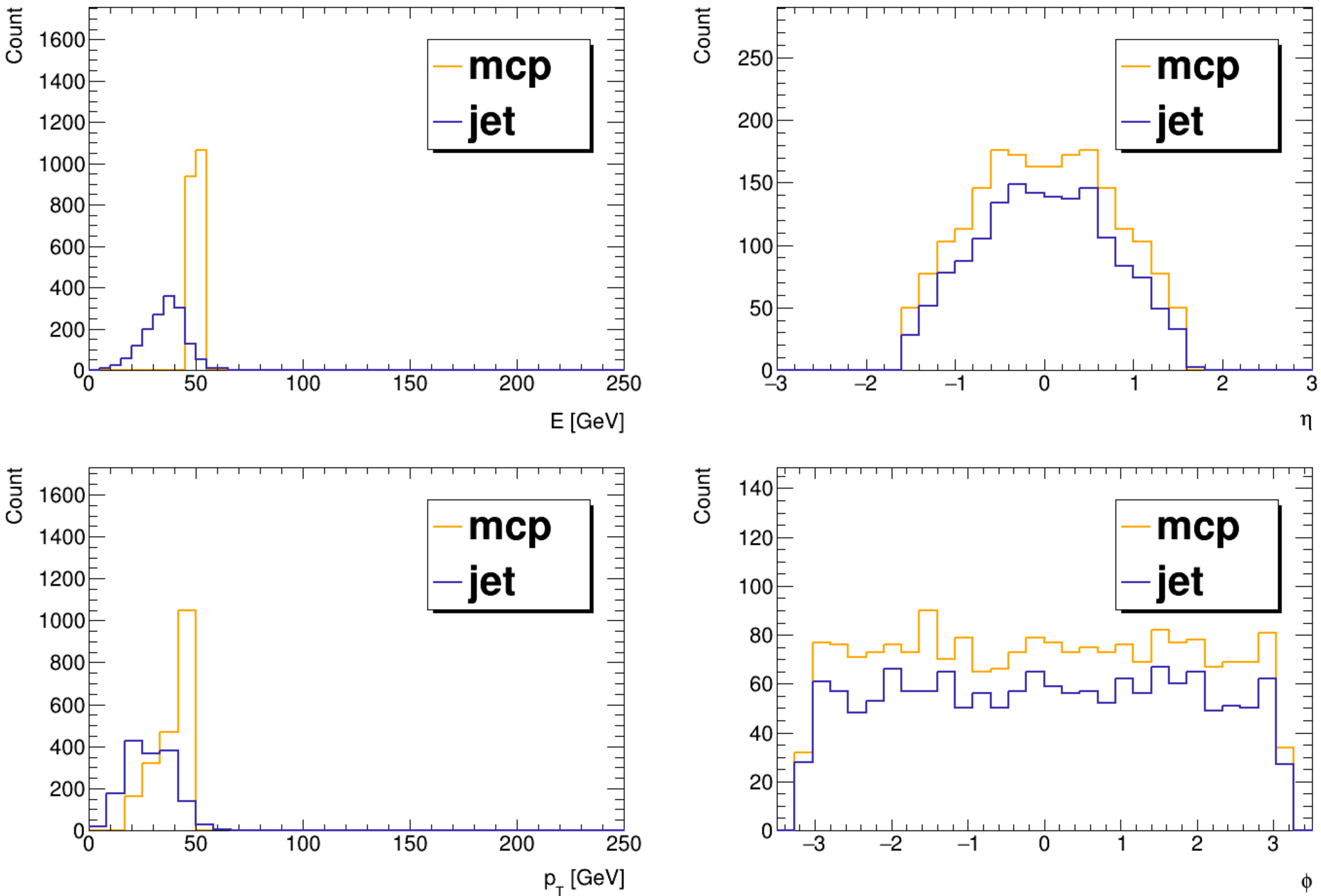
Reconstructed jet efficiencies



Efficiencies are pretty poor

testing a 0.2 matching requirement just to see if that matters

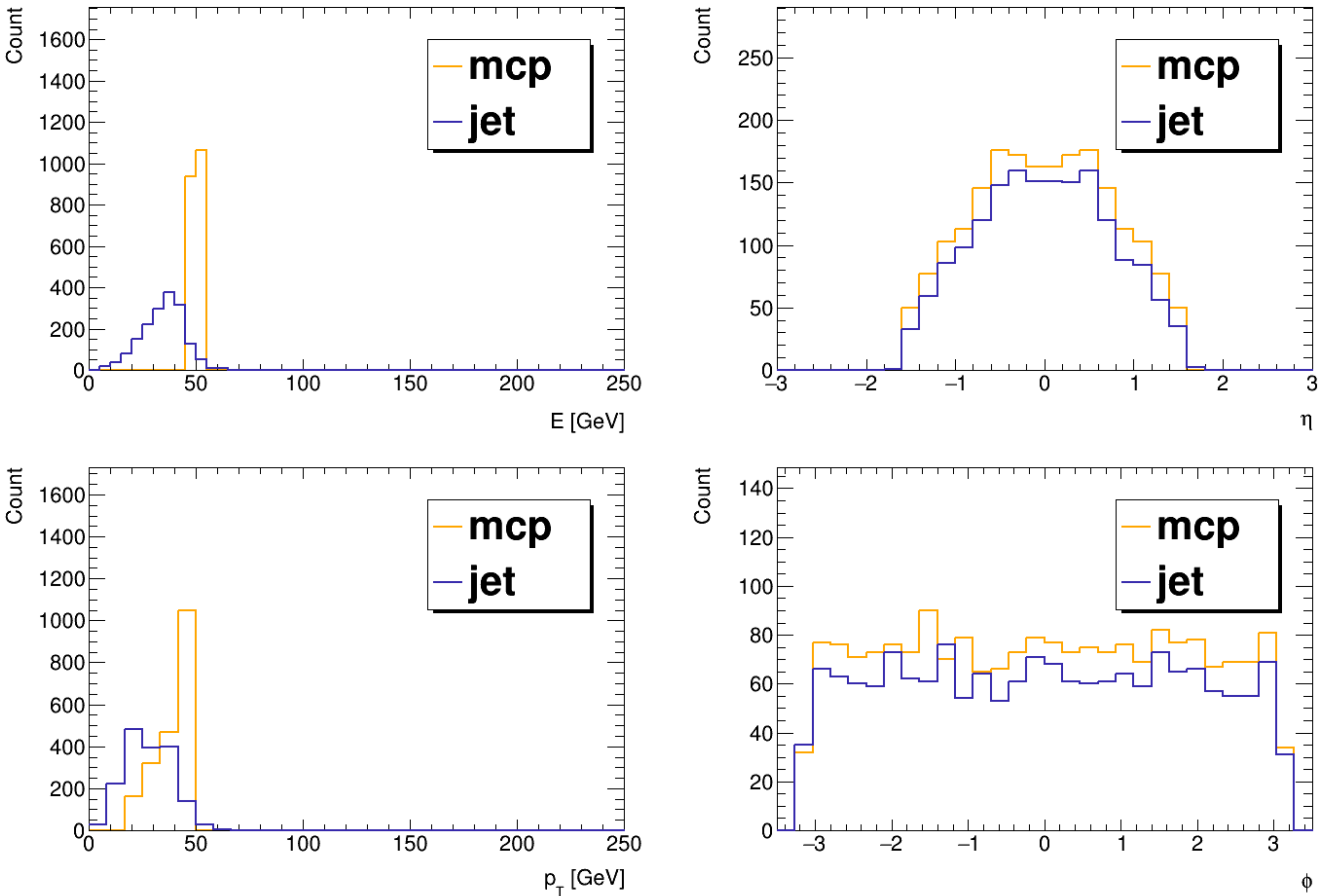
Reconstructed jet efficiencies



Efficiencies with 0.2 matching requirement

significant gain without any worrying low-E peaks. Will try 0.3

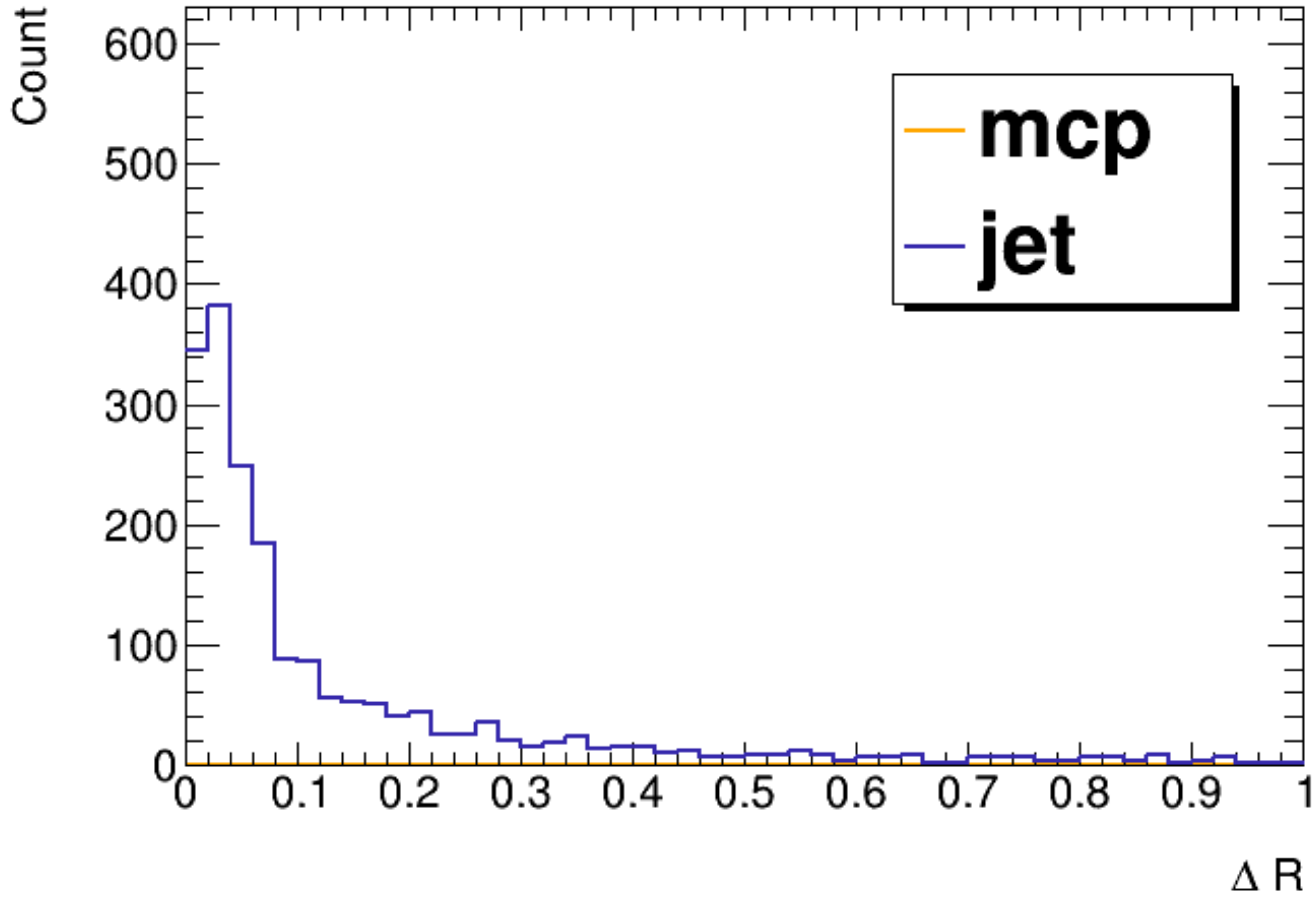
Reconstructed jet efficiencies



Efficiencies with 0.3 matching requirement

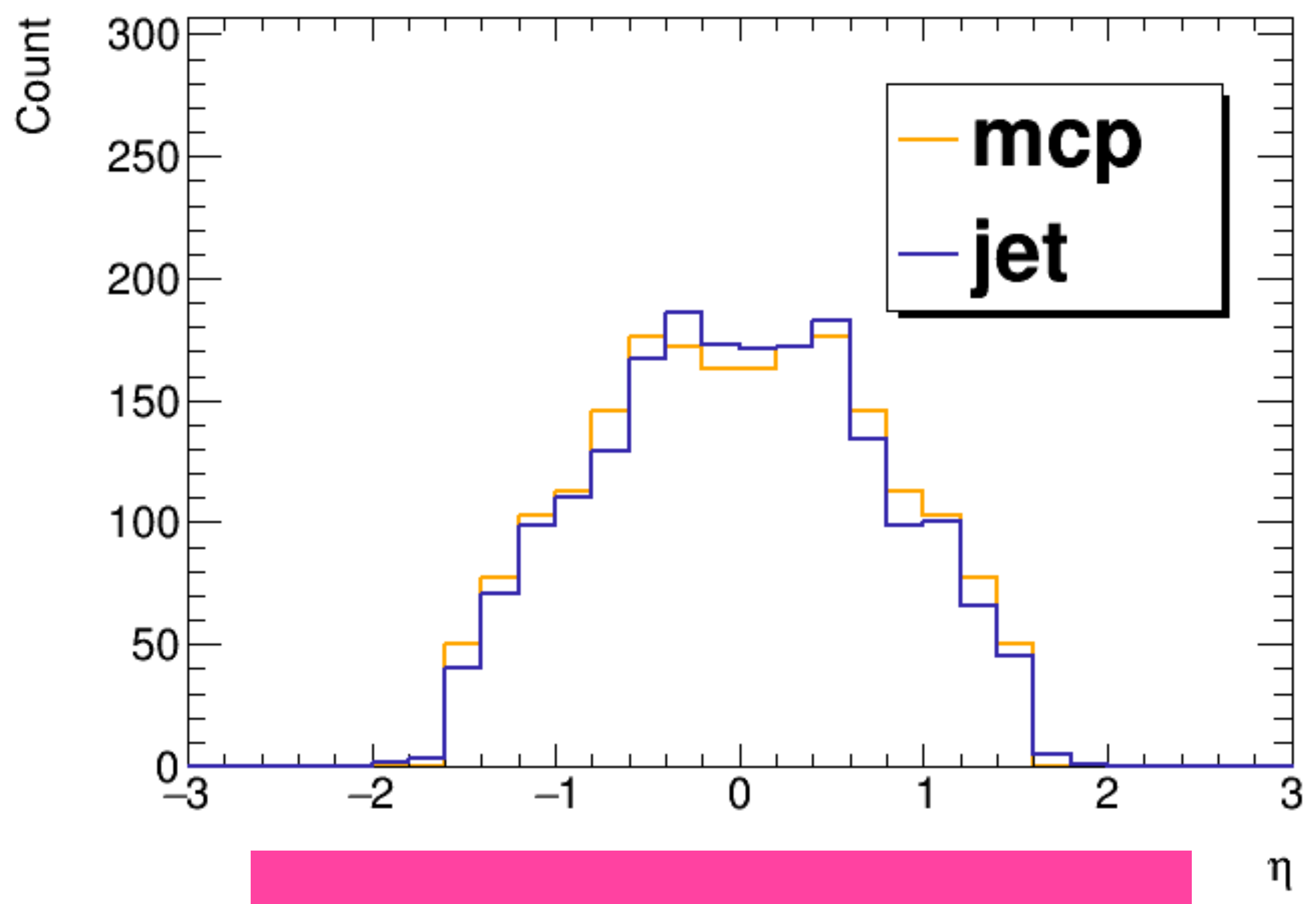
Higher efficiency but starting to see increase on low E side

Delta R investigation



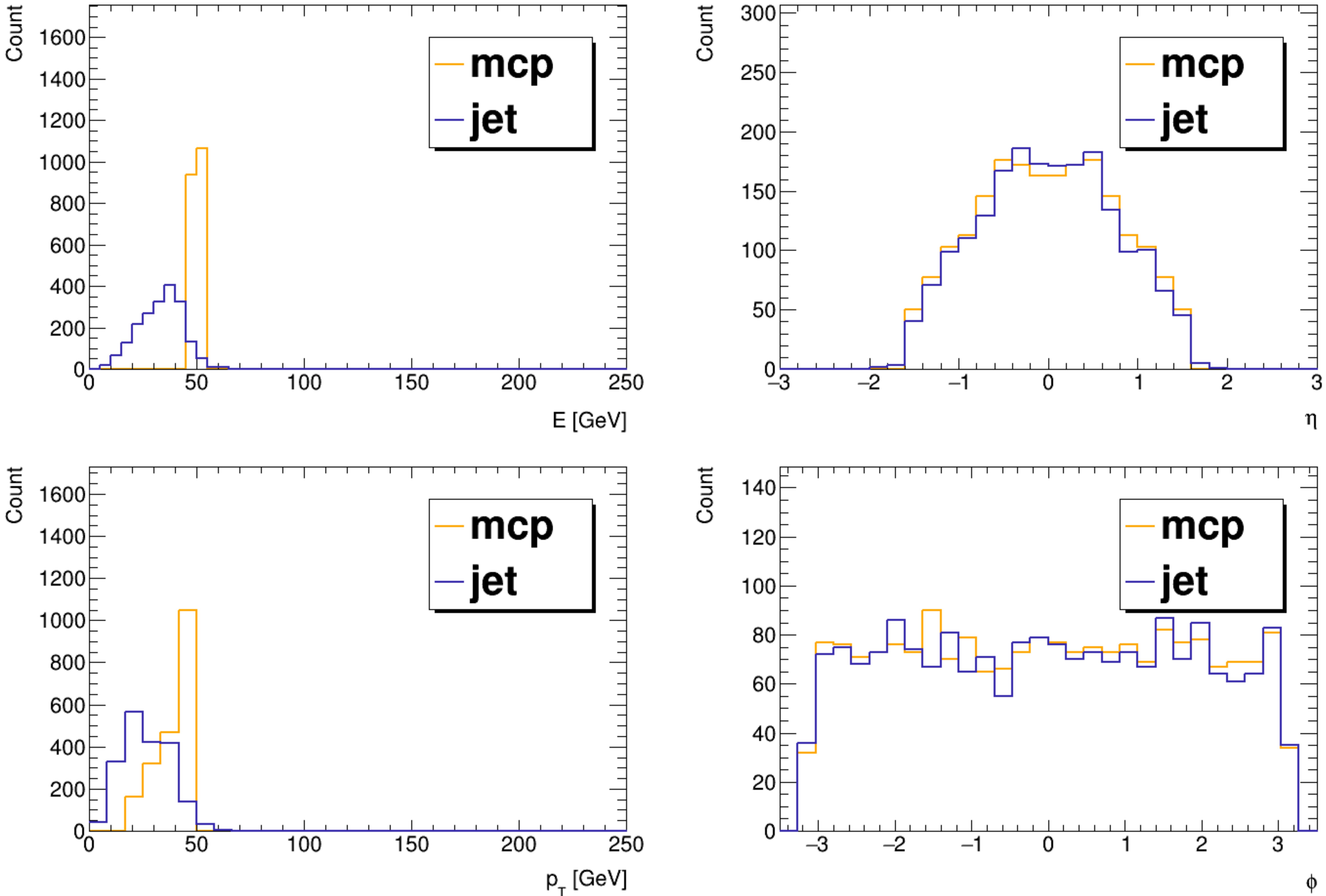
Making dR< 1 requirement then plotting distribution of matches

(ignore mcp line, just hacky plotting)



This results in very good efficiency, but how much is “fake”?

Delta R investigation



Efficiencies with 1 matching requirement

Can now see a substantial increase in low E matches

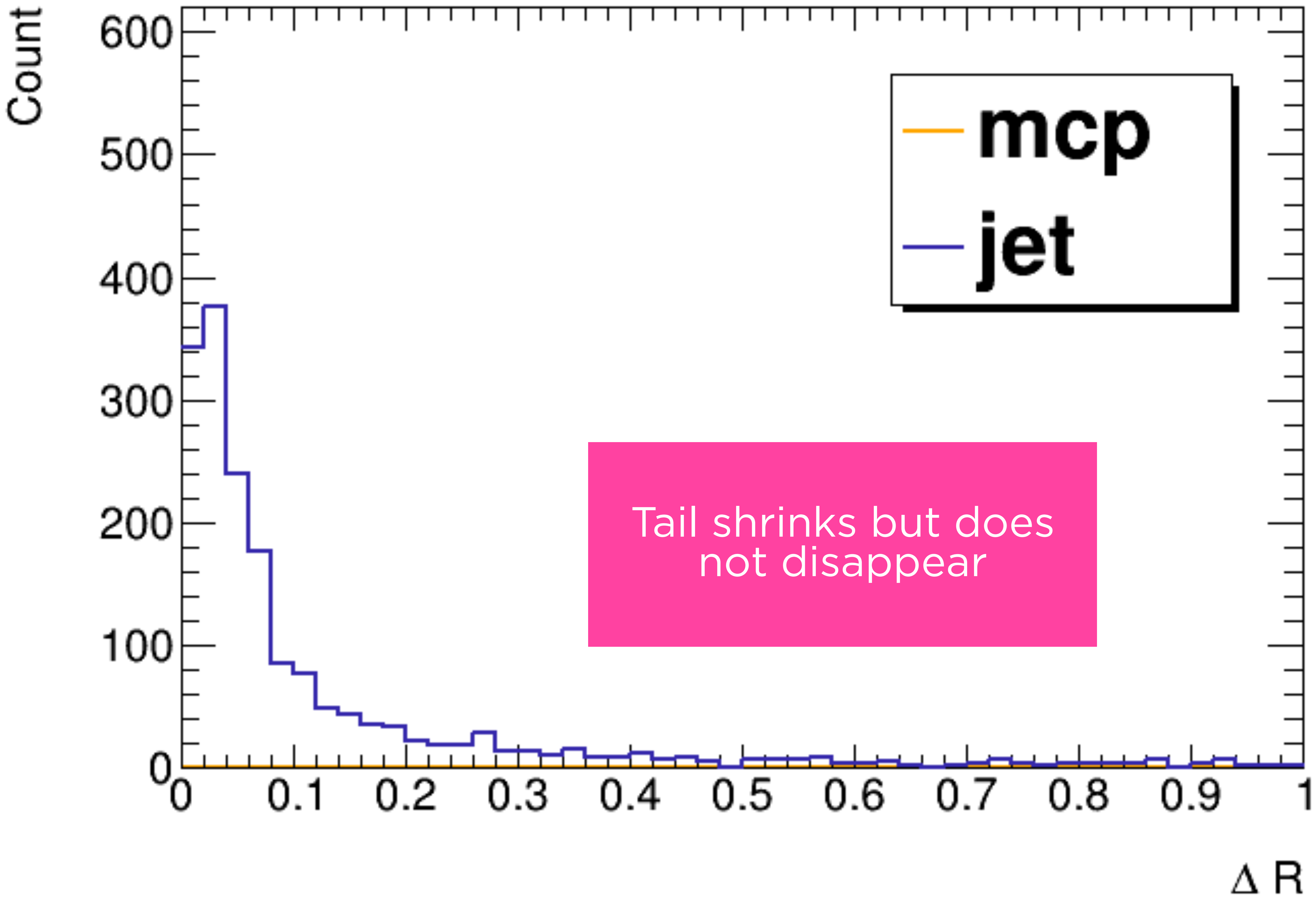
Likely explanation is some jet splitting, resulting in lower energy clusters with bad axis measurements

Next steps would be to start looking into the algorithm and event displays to understand this splitting (and confirm it exists)

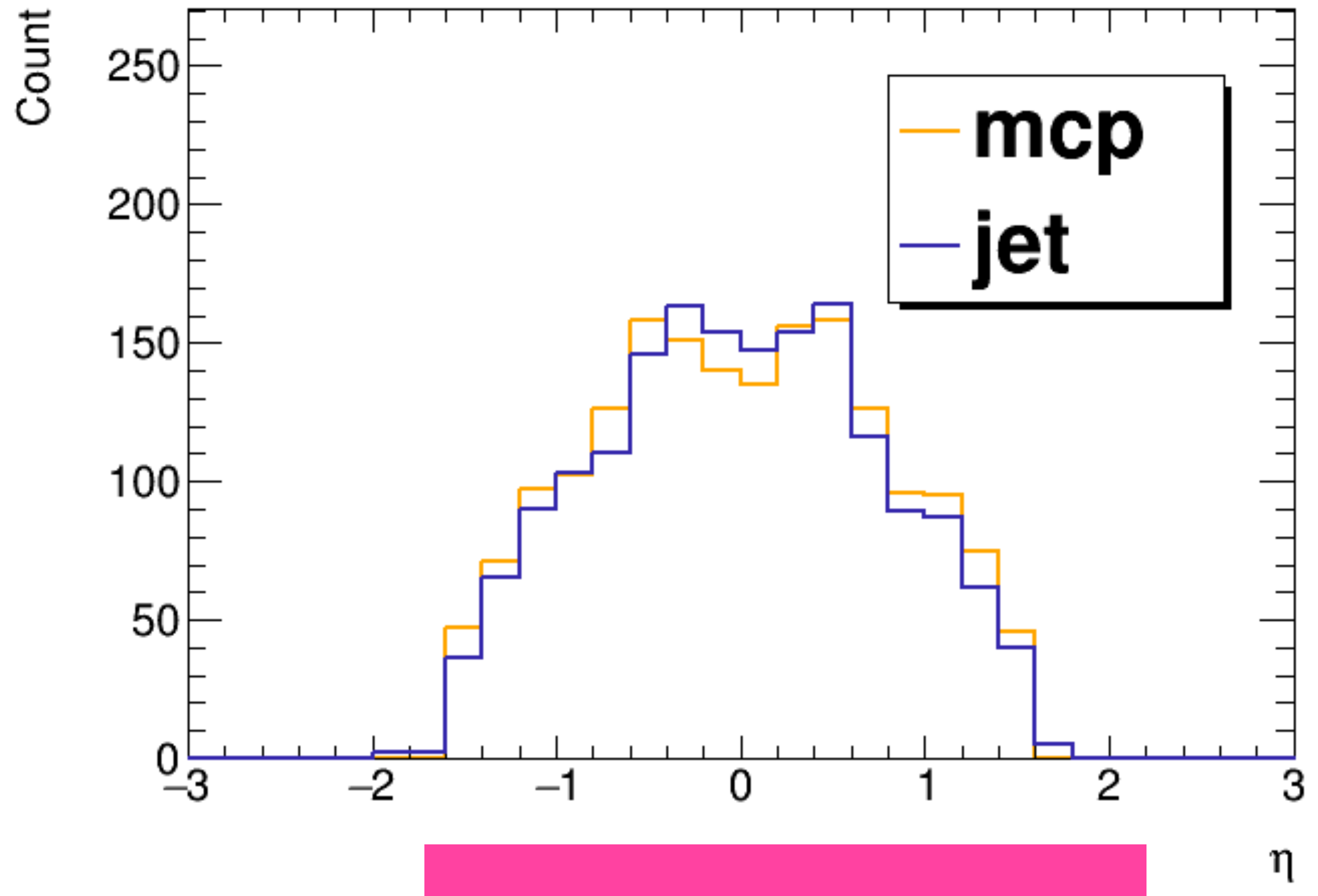
Cluster splitting?

Now only considering events with one matched jet w/i dR of 1 and throwing away others

note: all these jets are generated back-to-back so I don't think there's any risk of picking up the wrong one

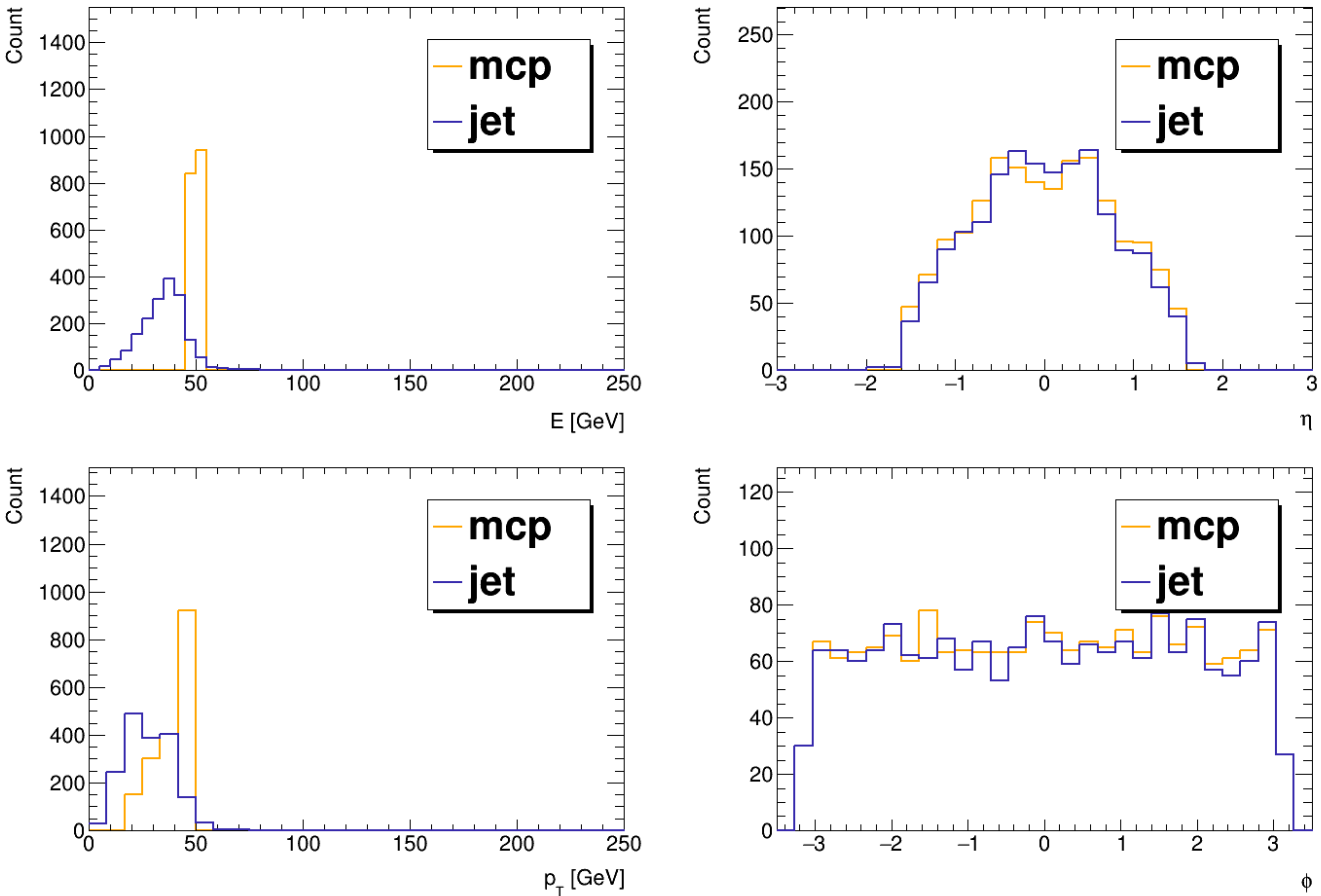


Tail shrinks but does not disappear



Overall efficiency looks similar

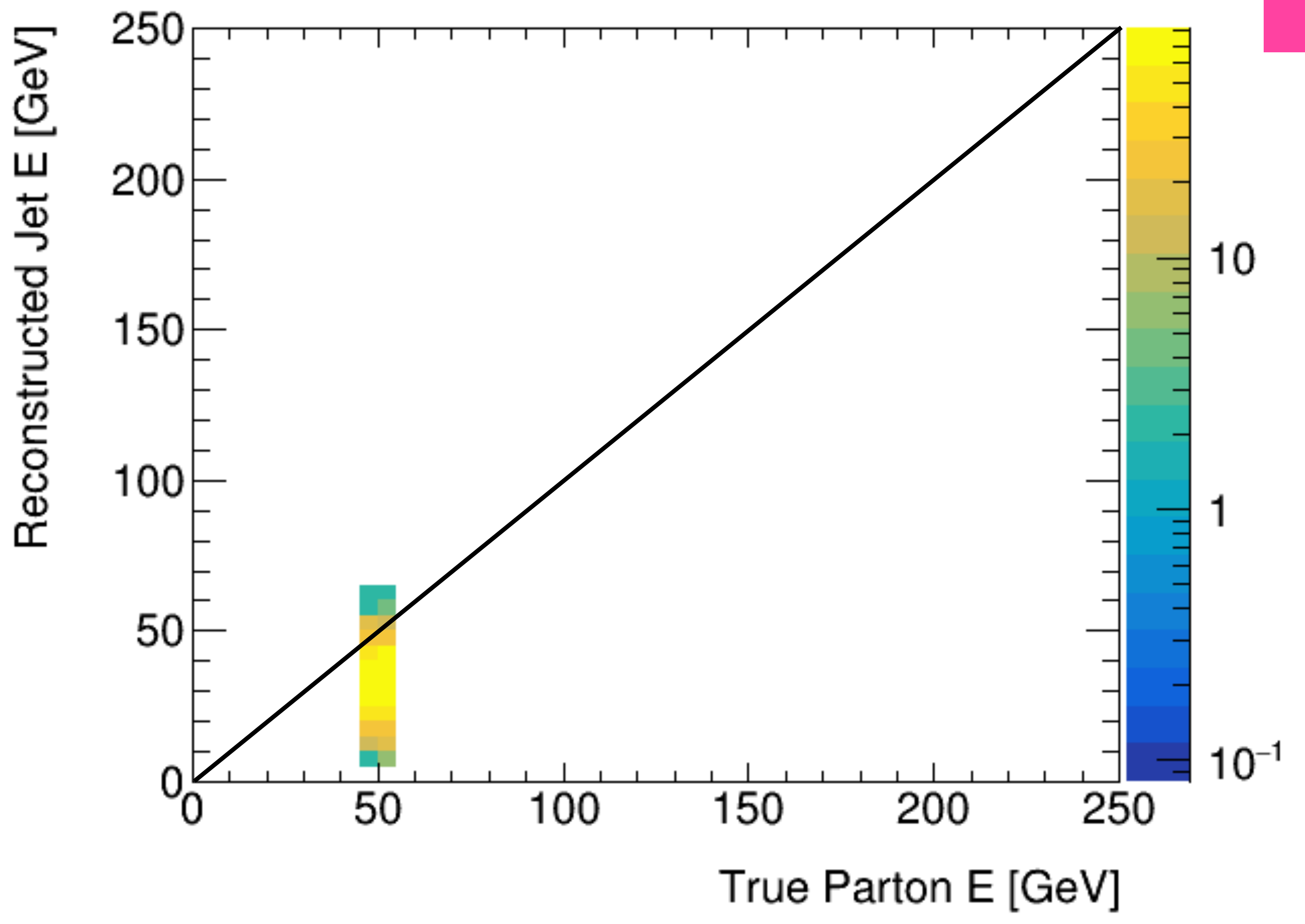
Cluster splitting?

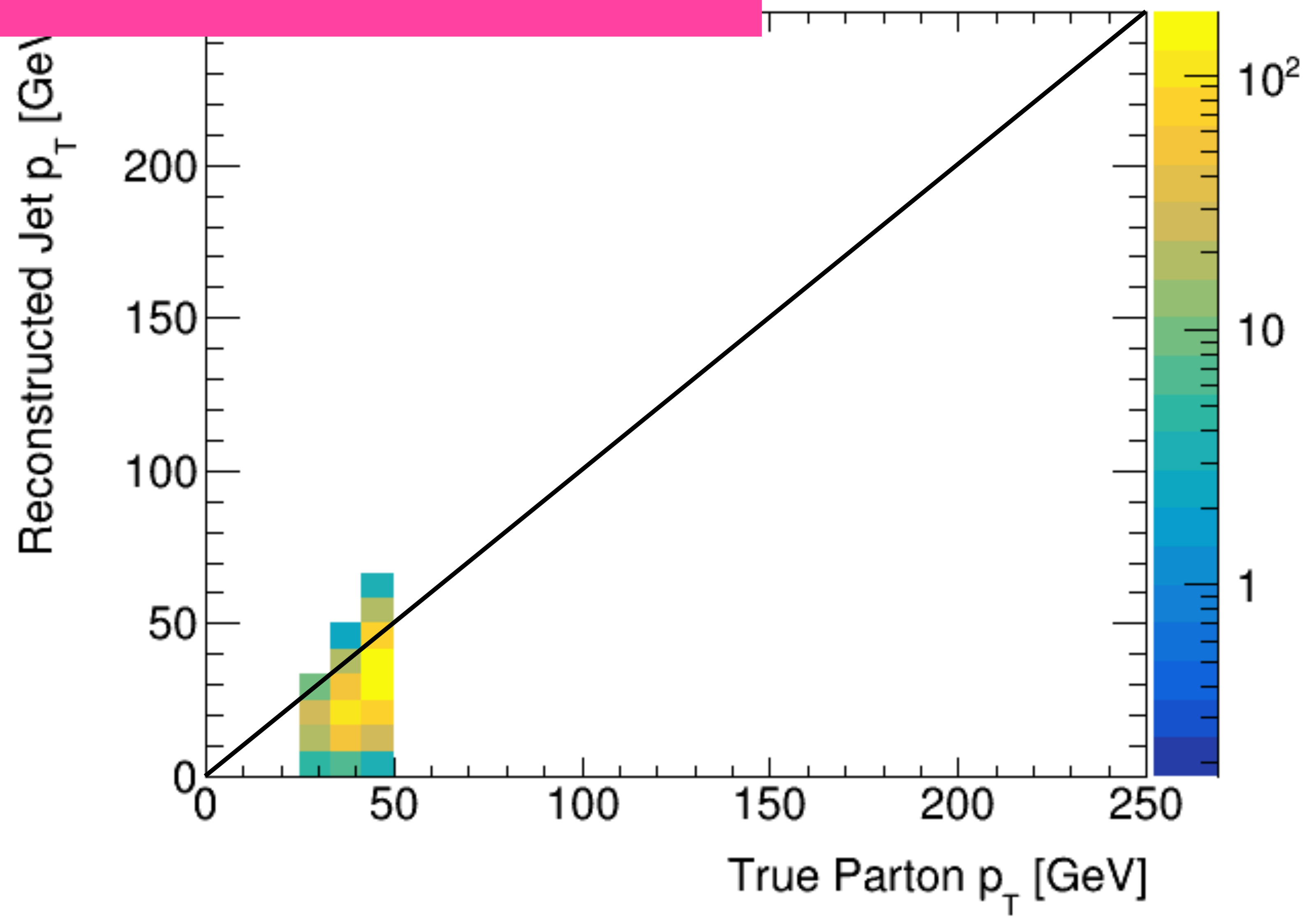


Does a good job removing some of the low E instances

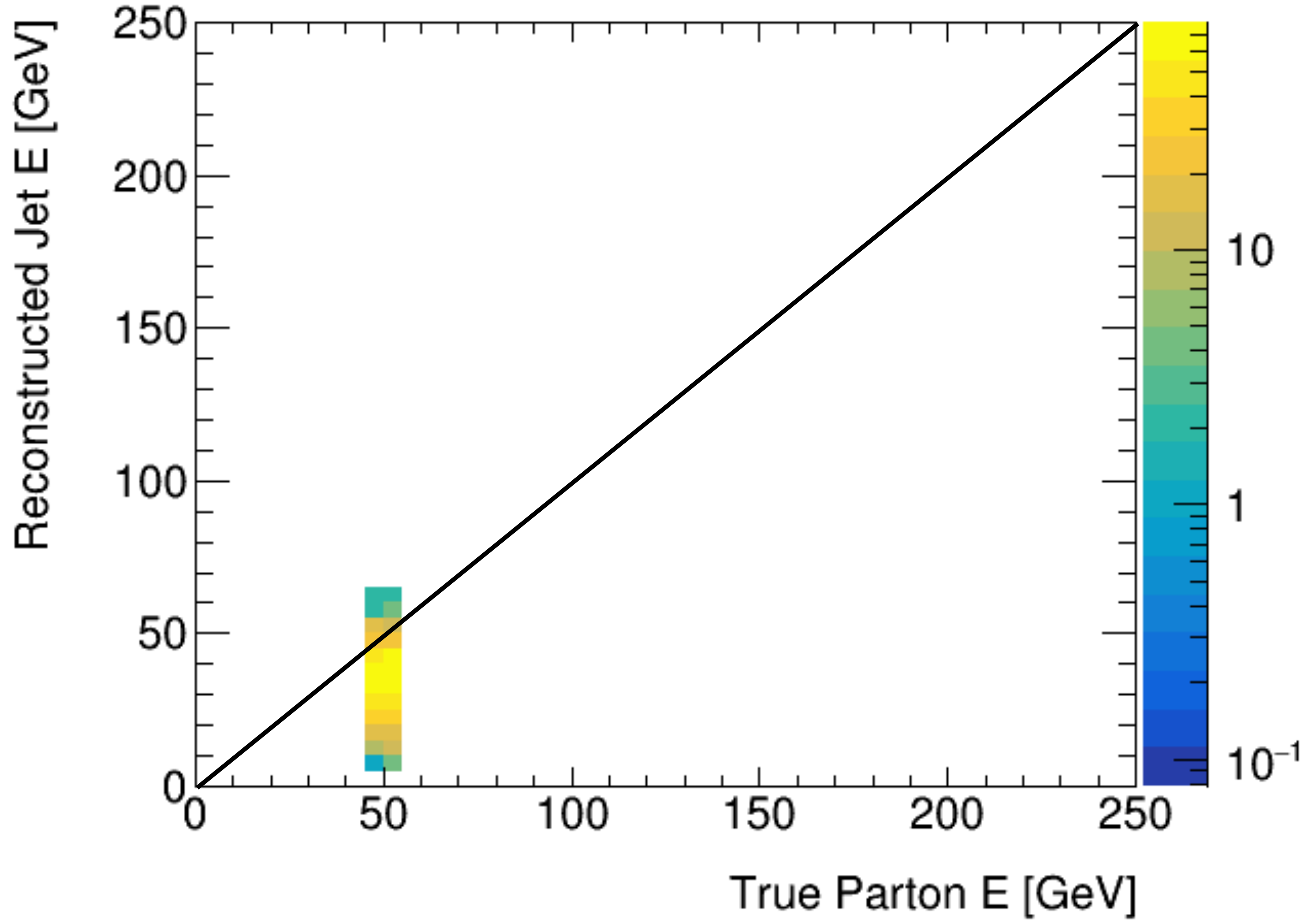
Comparison

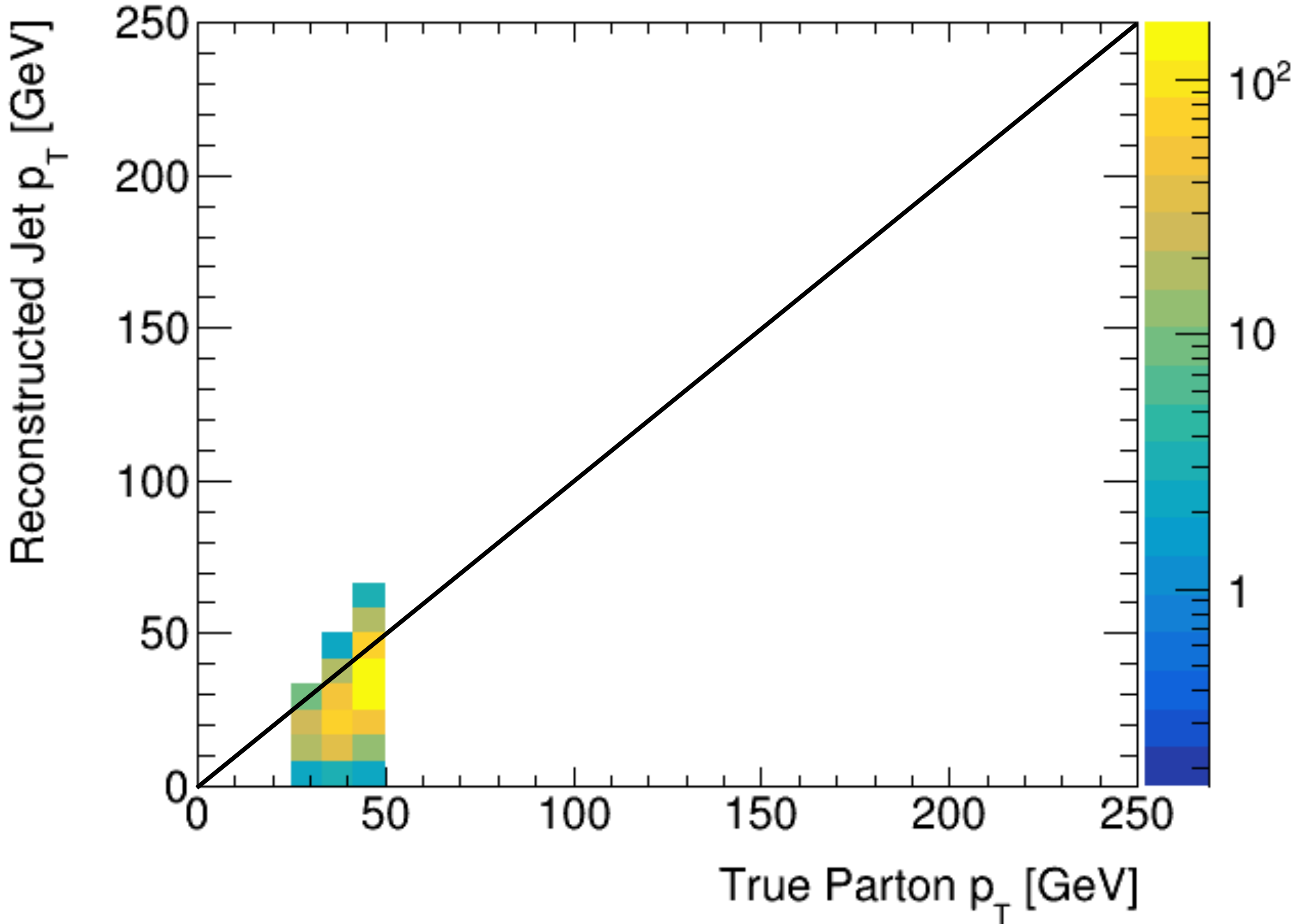
Conclusion — it'd be nice to run on more masses, but I don't have permissions on others





Best match w/i dR < 1



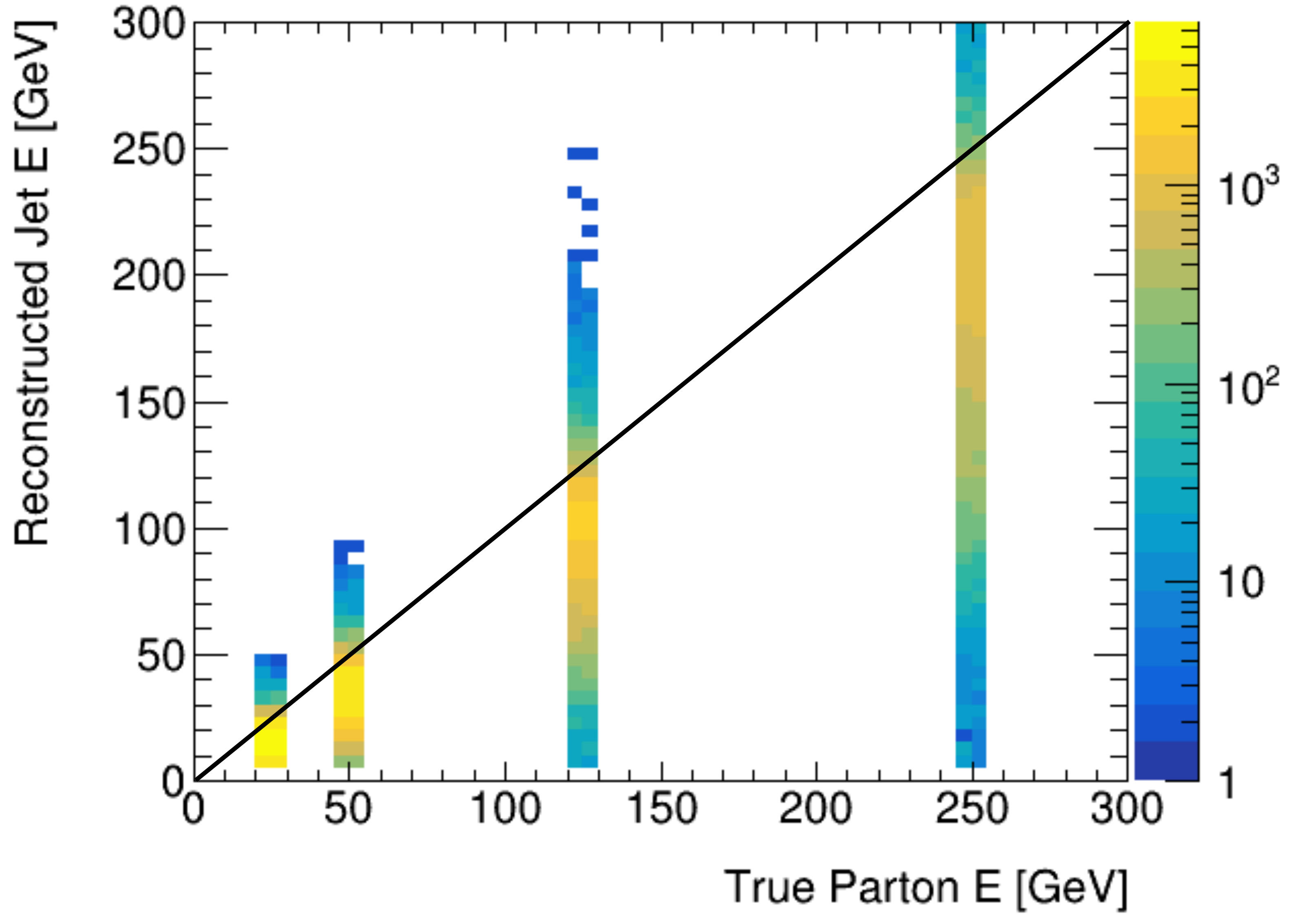


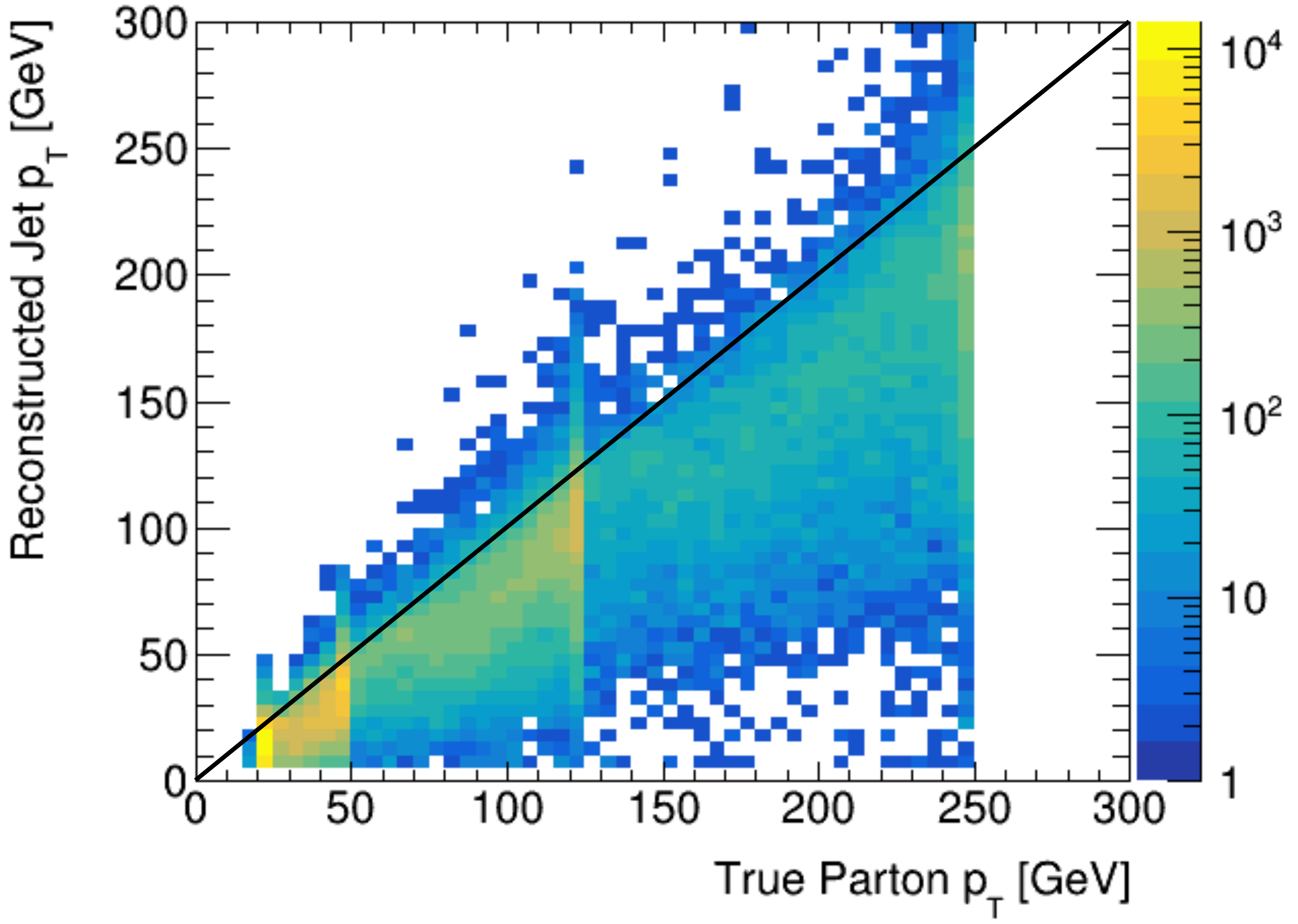
Match w/i dR < 1, remove events with more than one match

Comparison

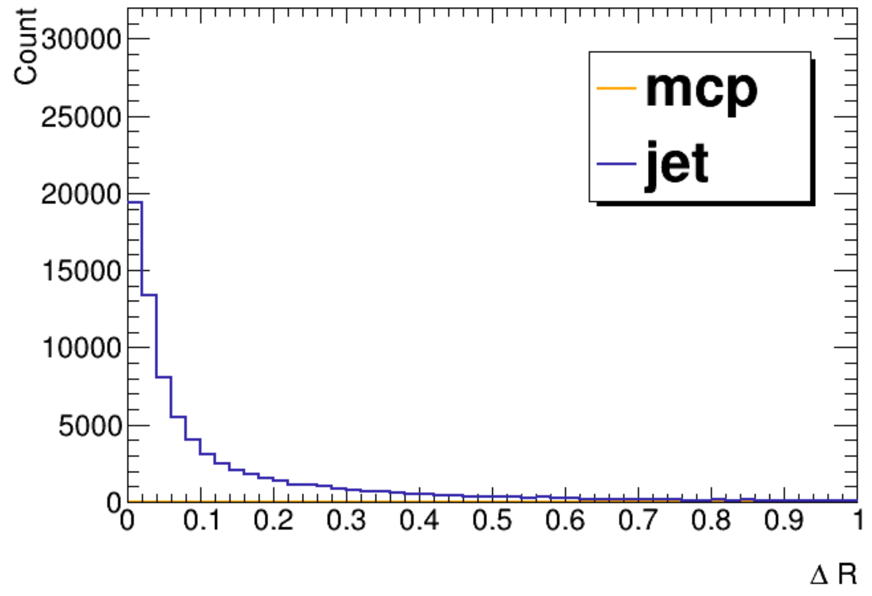
With all samples with mjj ≤ 500 GeV

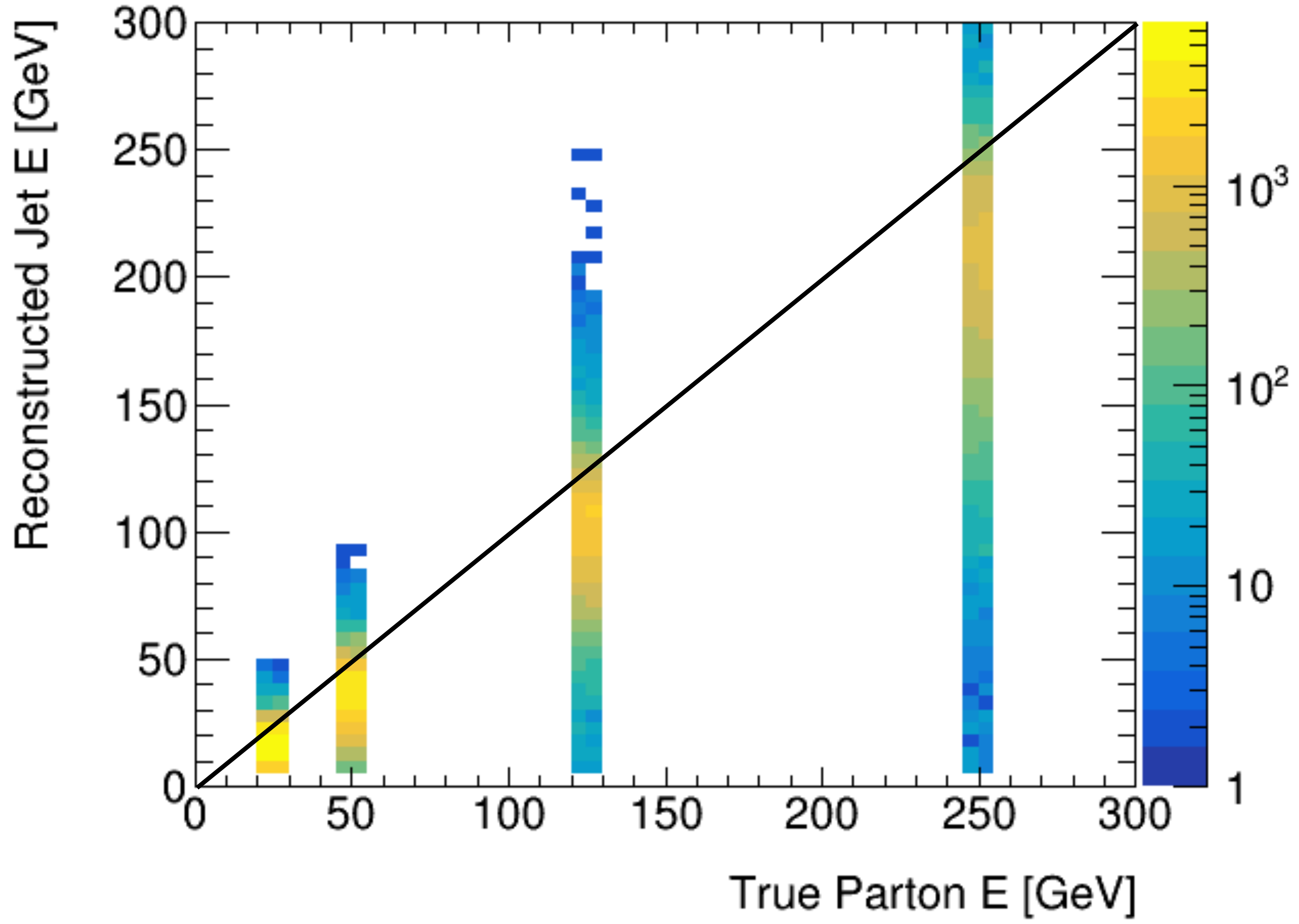
effect is pretty minor - but this isn't the best way to find splitting

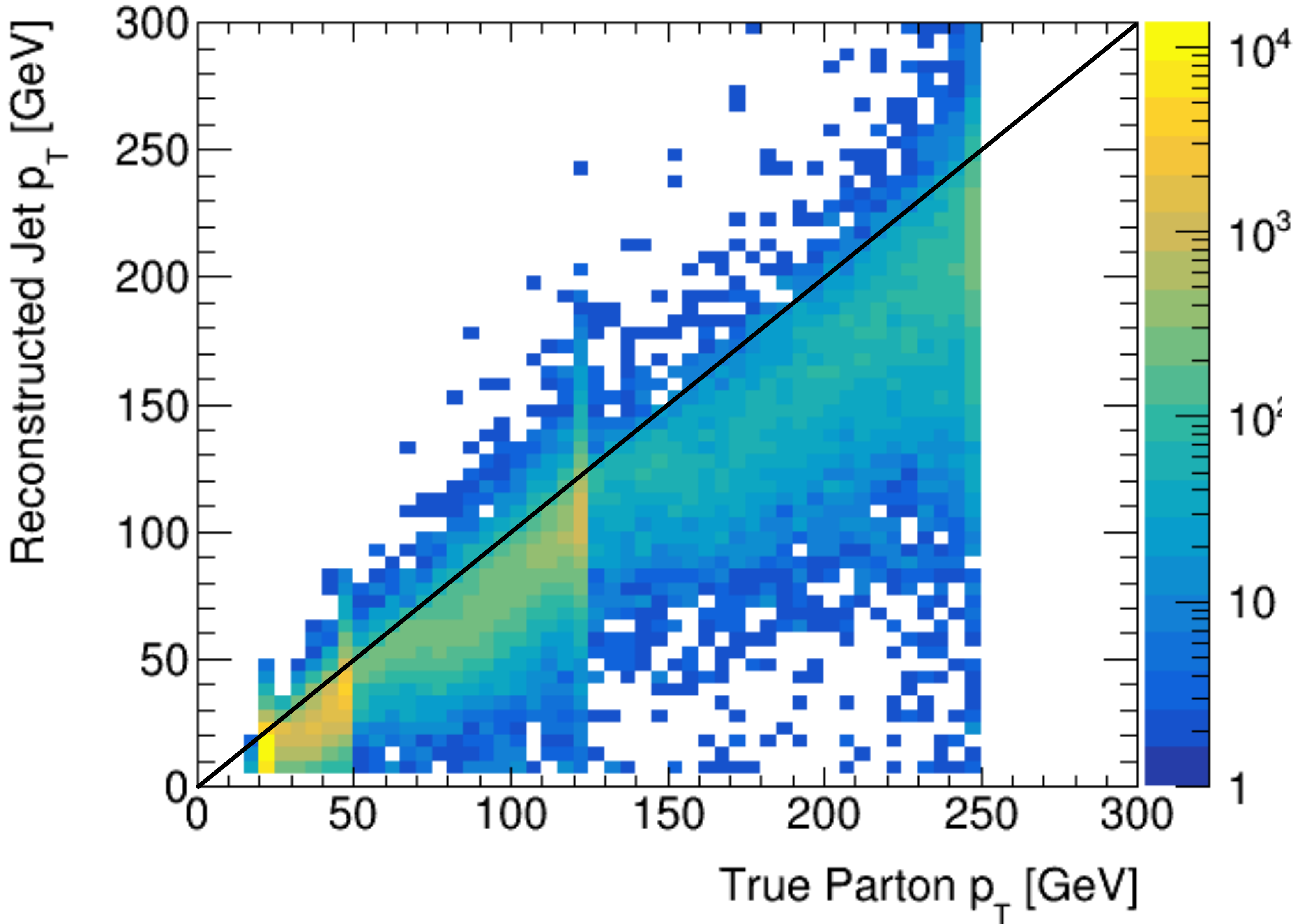




Best match w/i dR < 1







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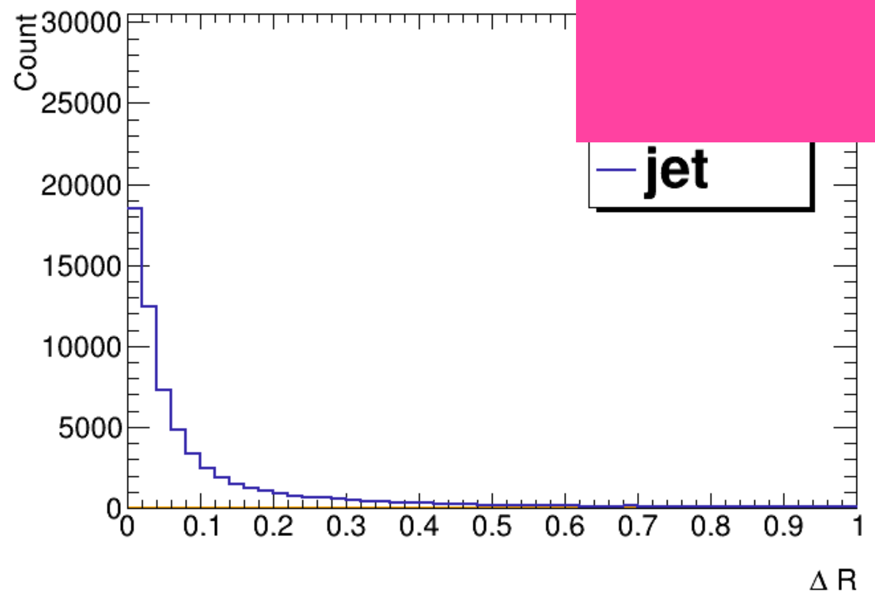
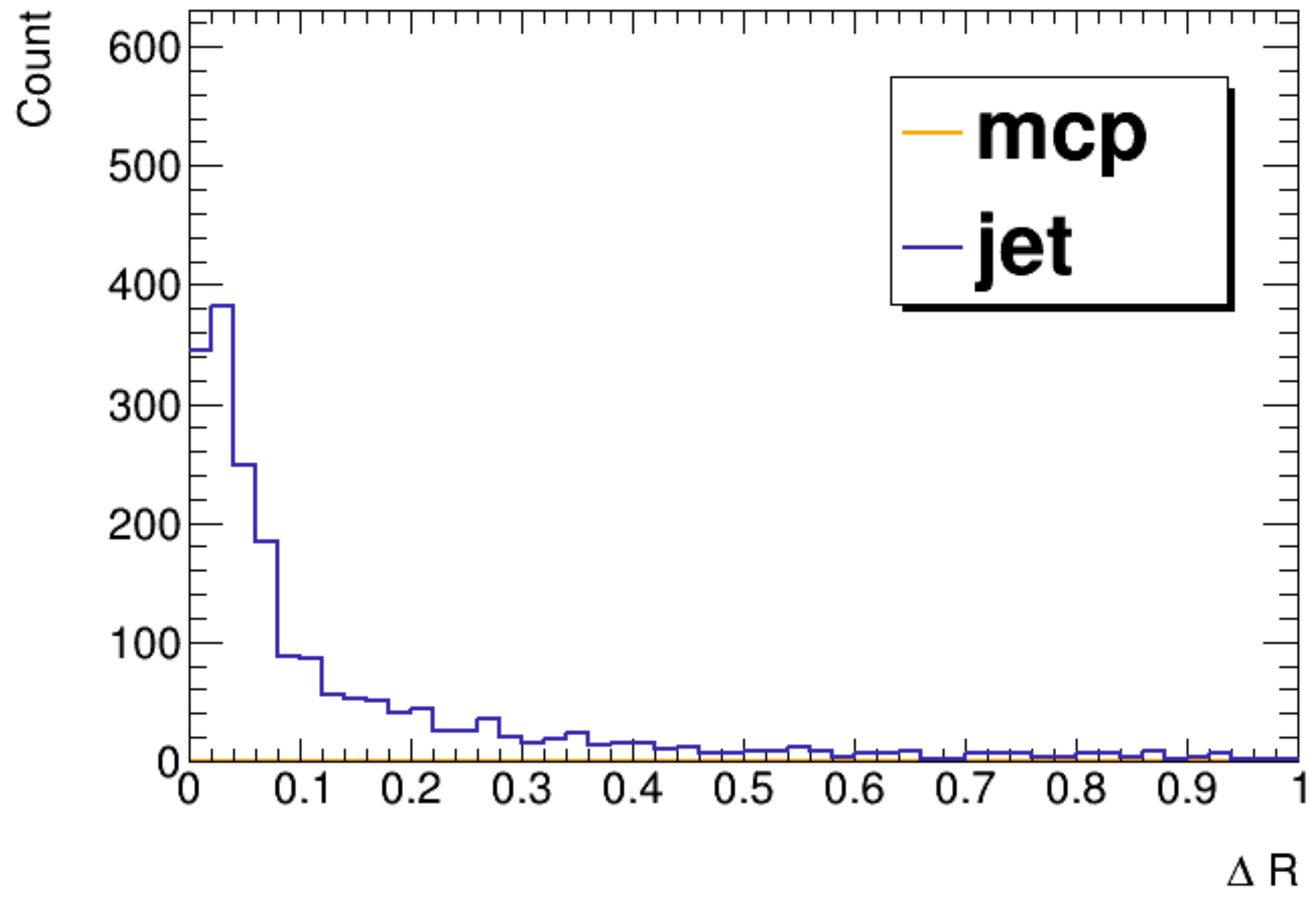


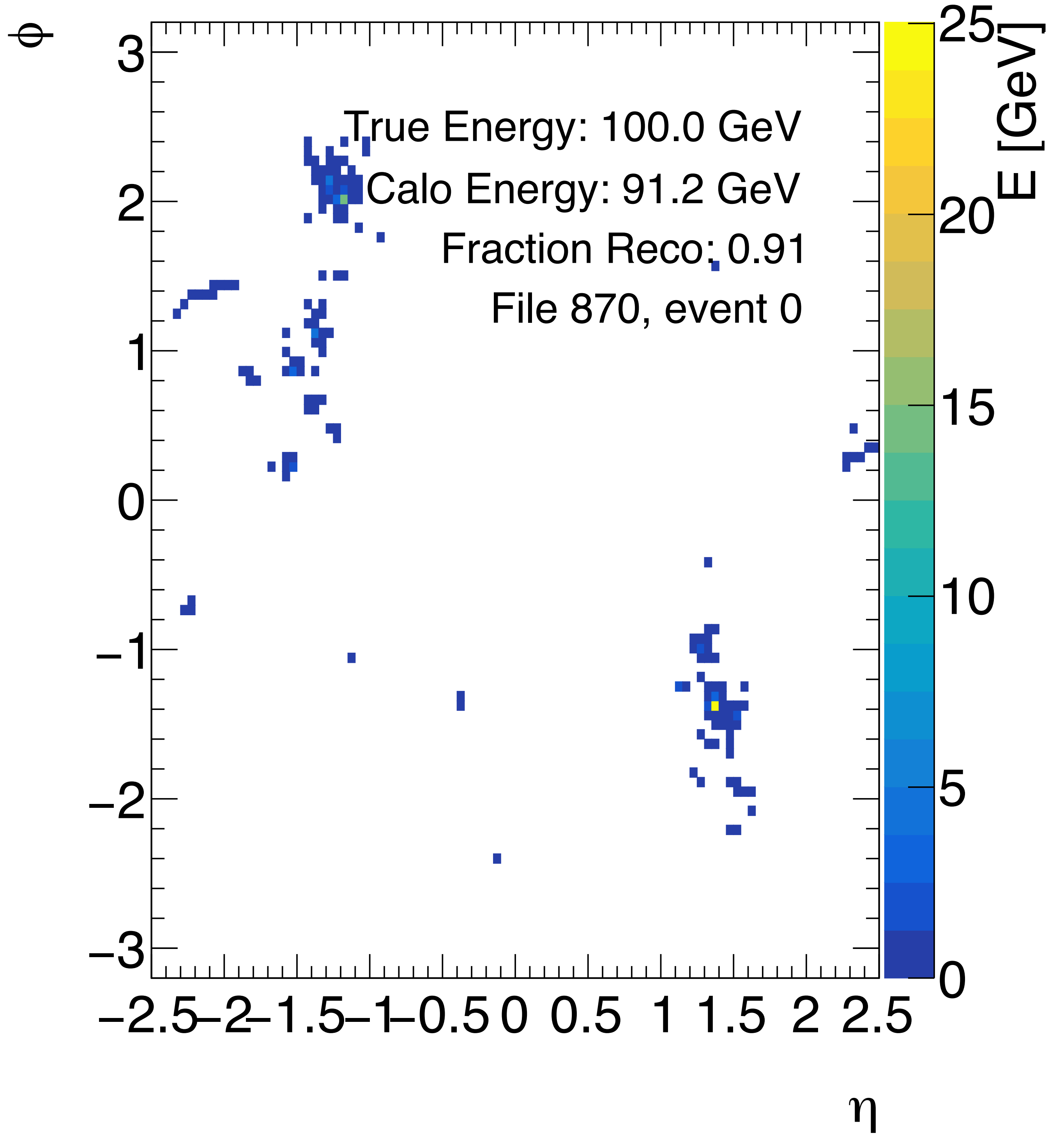
Conclusions

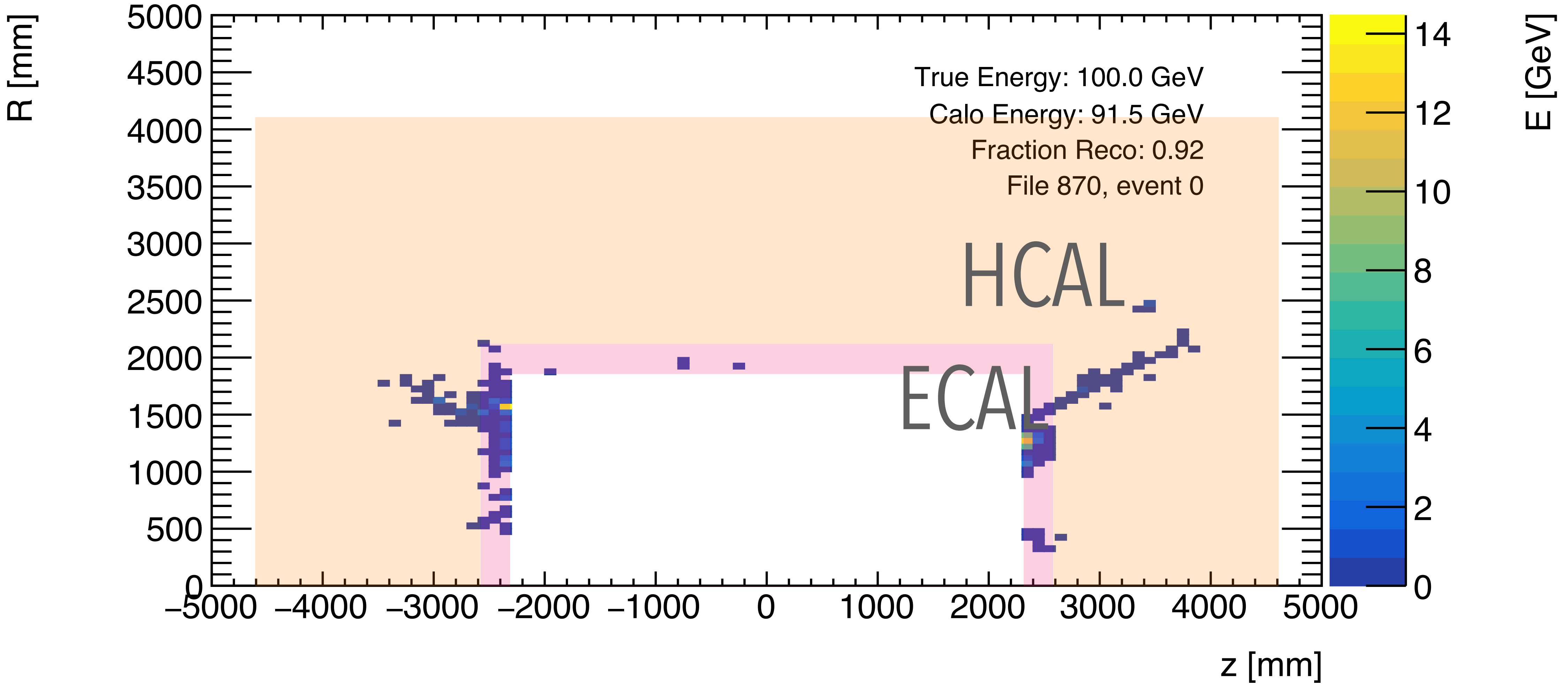


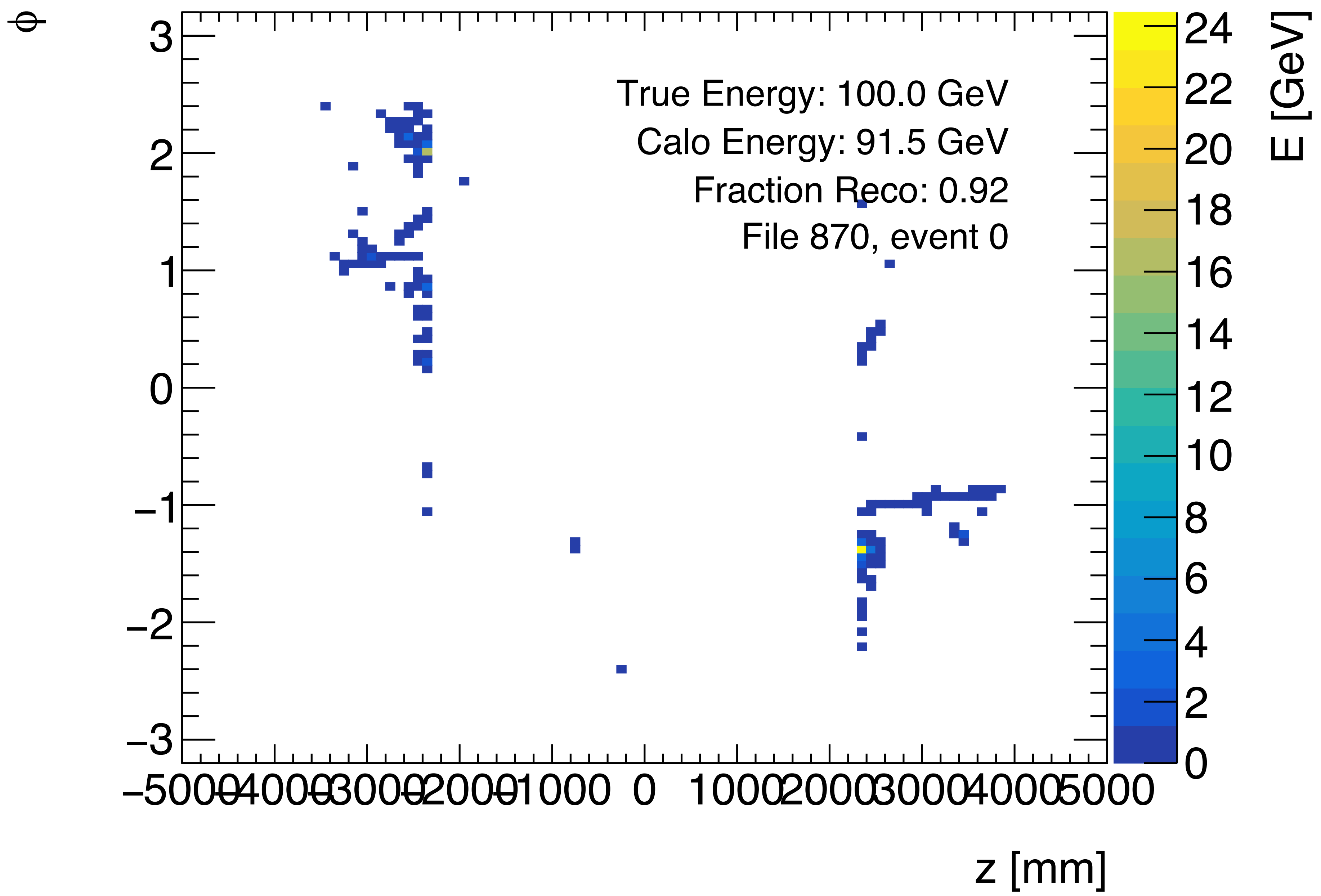
- We have jets out of the box that look 0th order sane
- The sim energy is low compared to the true energy by ~20%
  - Gets a little bit worse with digitization + coning
- The dR distribution is pretty large
  - 0.2 cut seems to be OK – improves efficiency without doing anything too weird to energy
  - larger dR have some correlation with low energies – suggests splitting
  - removing events with two matched jets helps but does not remove the tail
- Next steps:
  - start looking into the algorithm and event displays to understand potential splitting
  - check on digi coning to see if this is related to this effect - removing parts of the jet

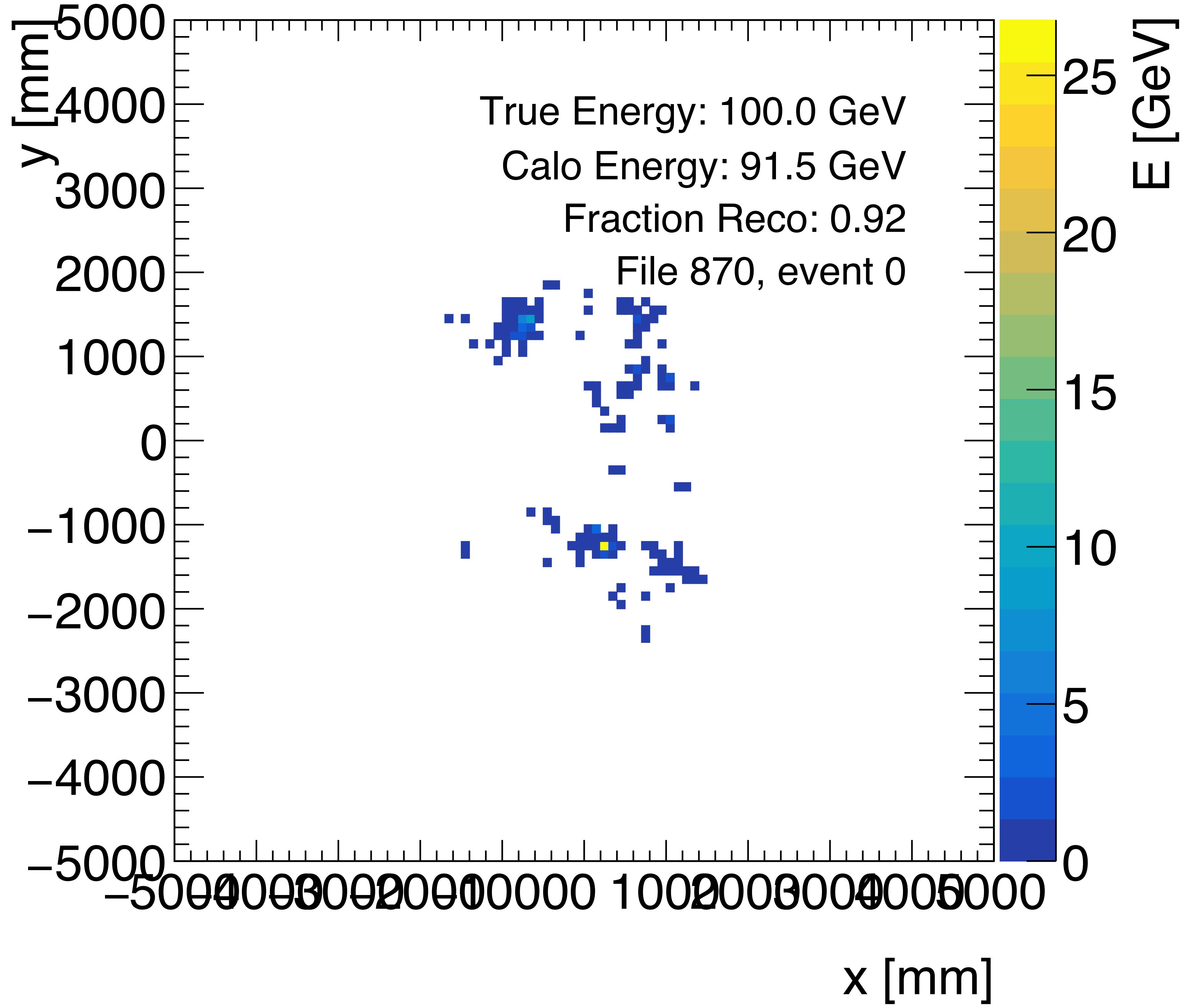
Visualizing jets

all digitized hits









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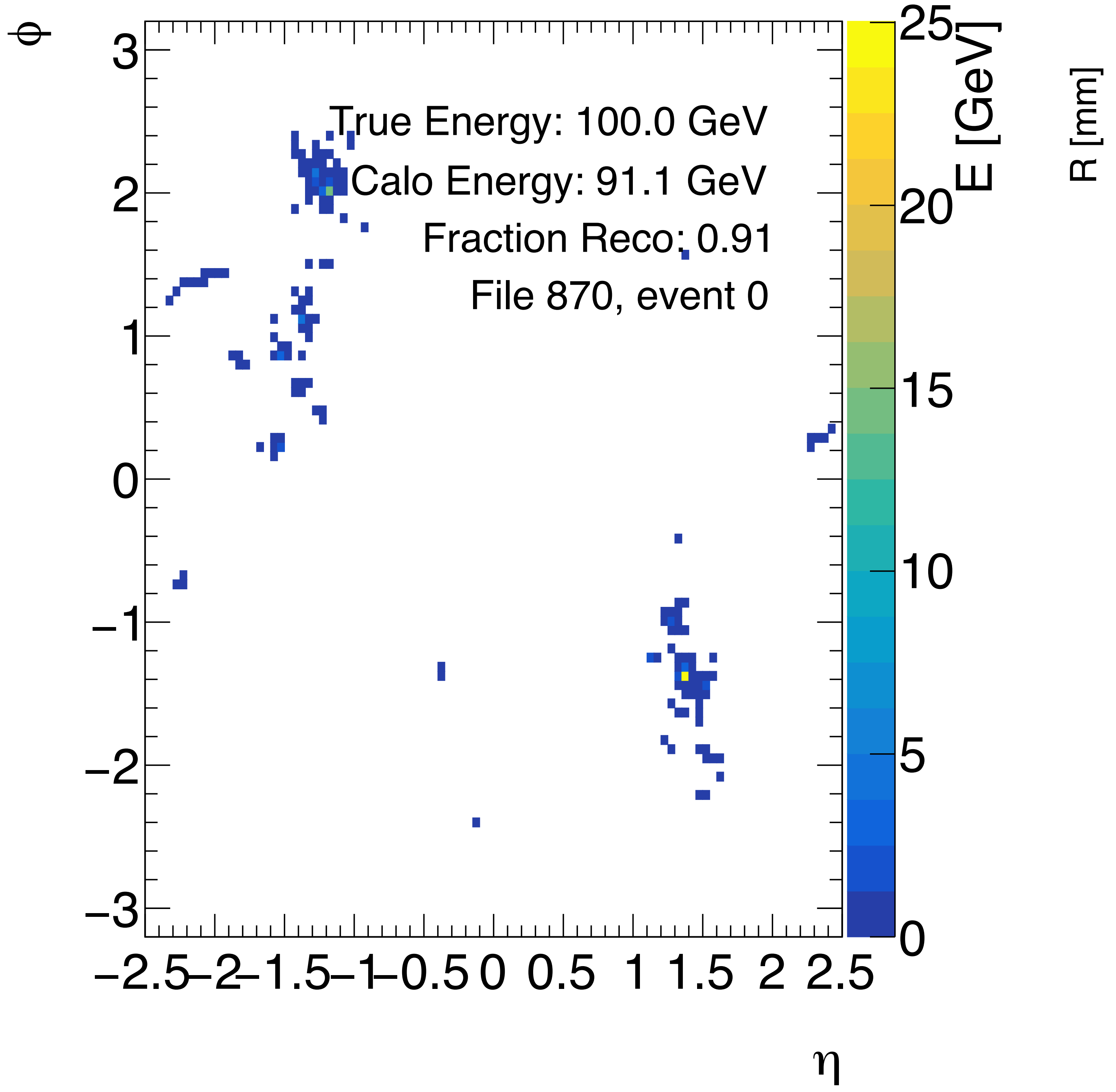
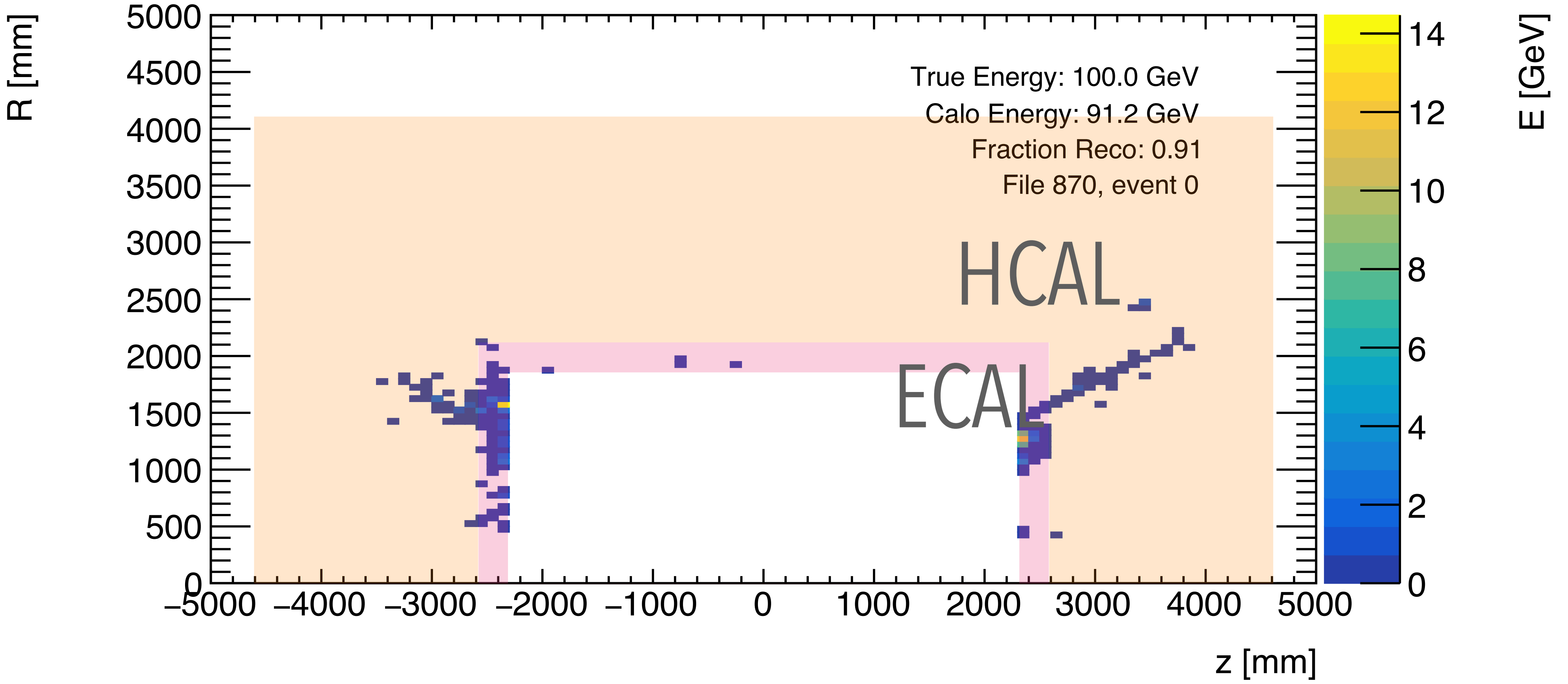
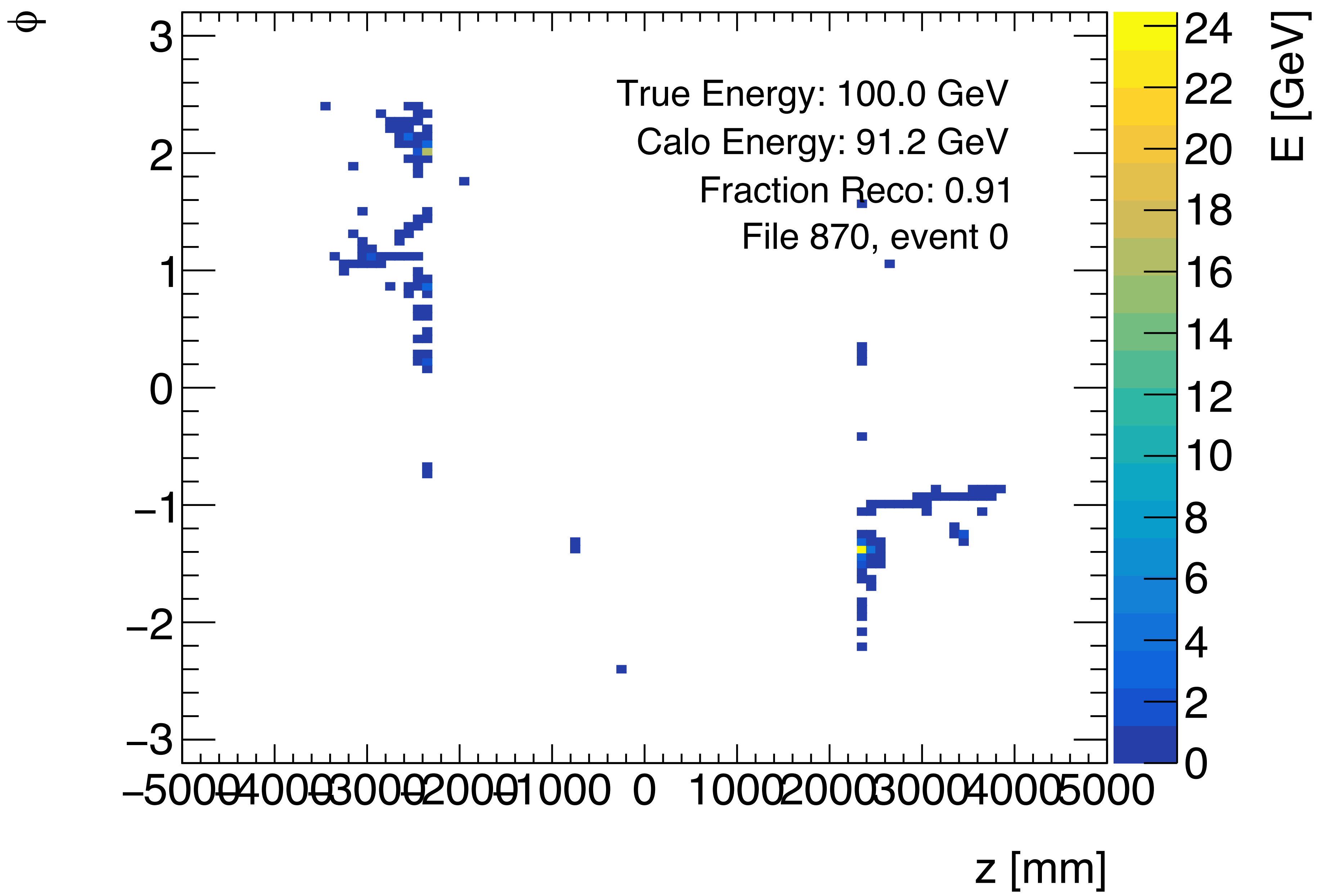
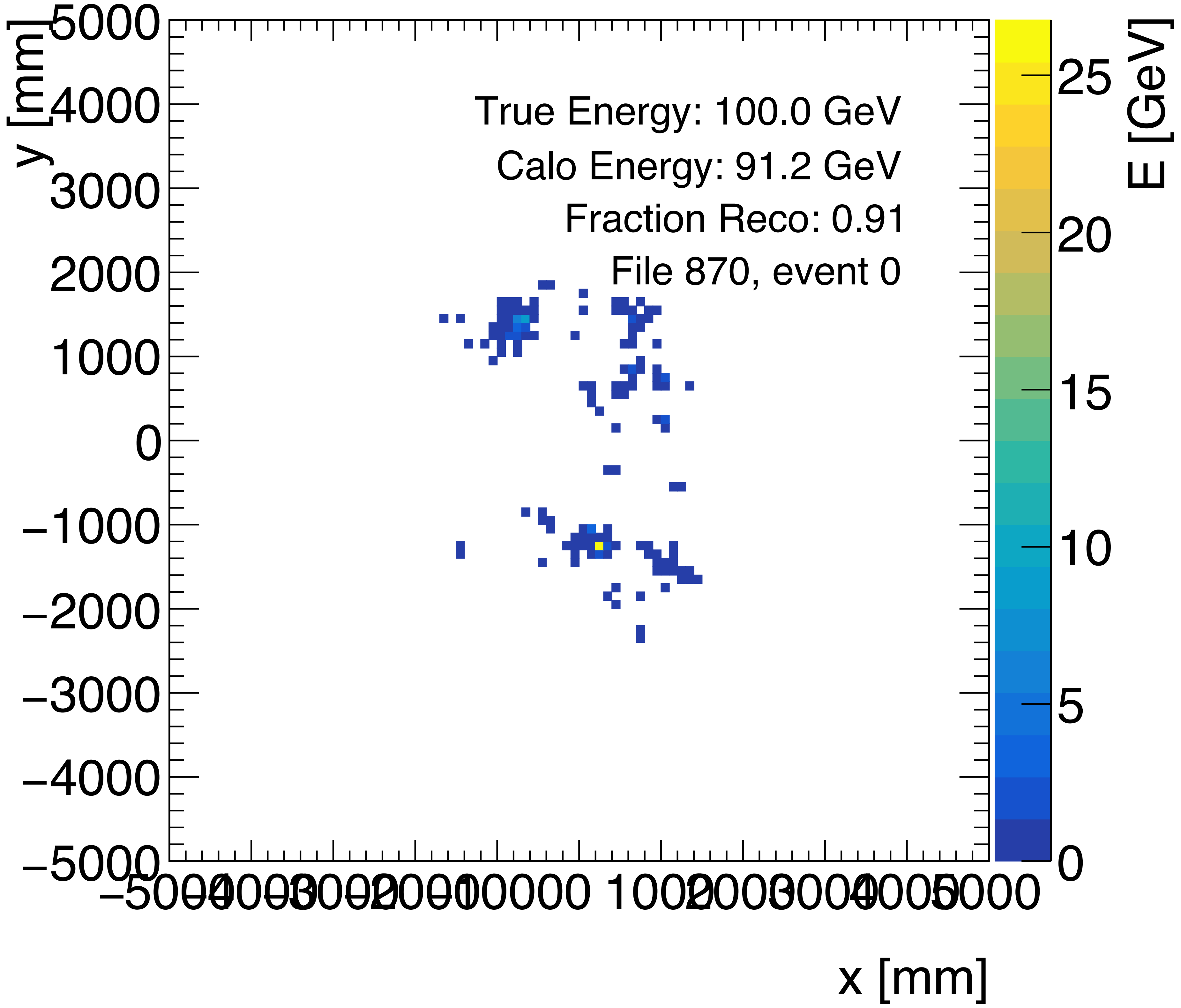




selected by threshold + coned

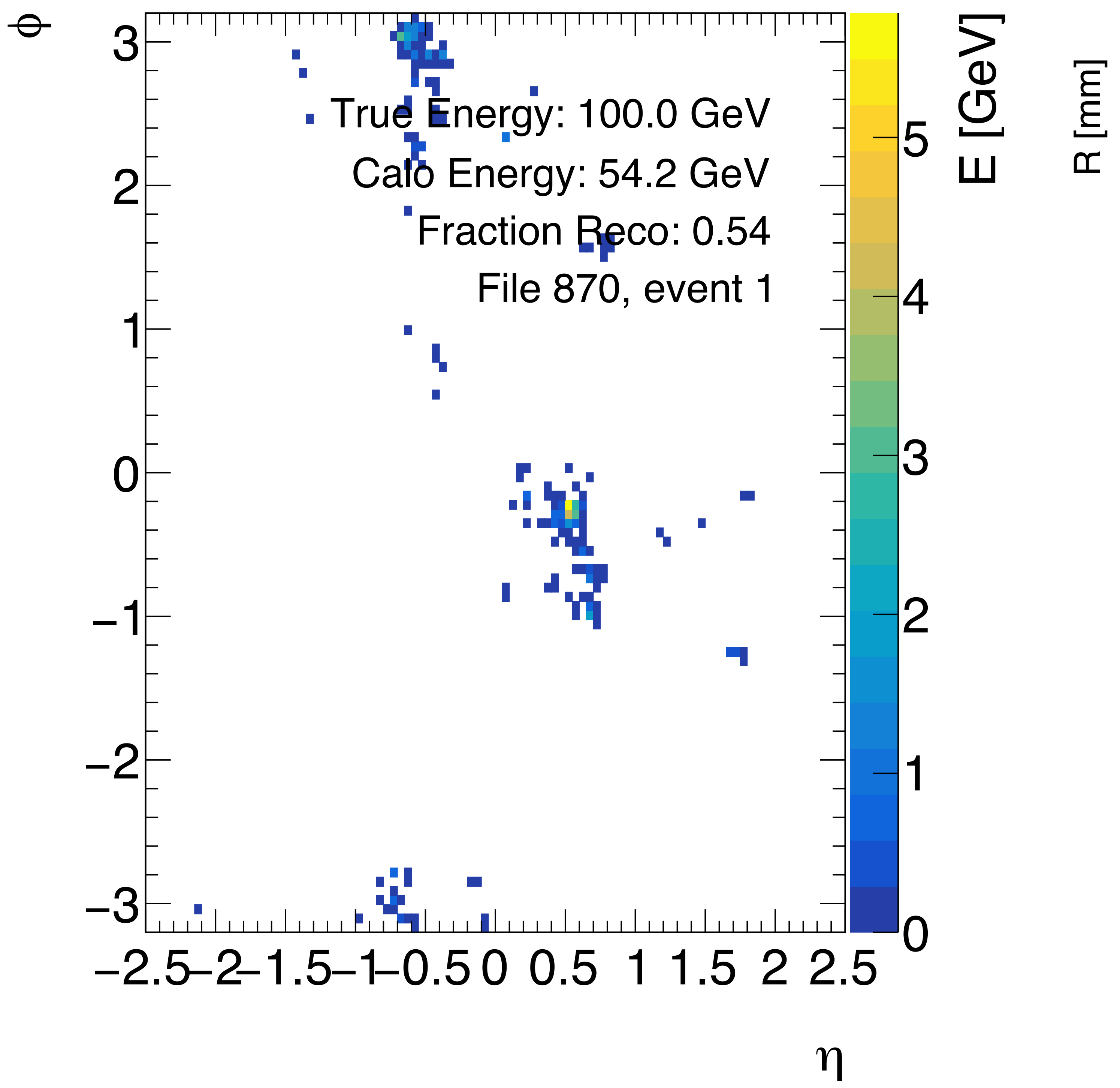
seems like impact from this selection is very minor, unlikely to cause the stuff we saw — but will check more cases

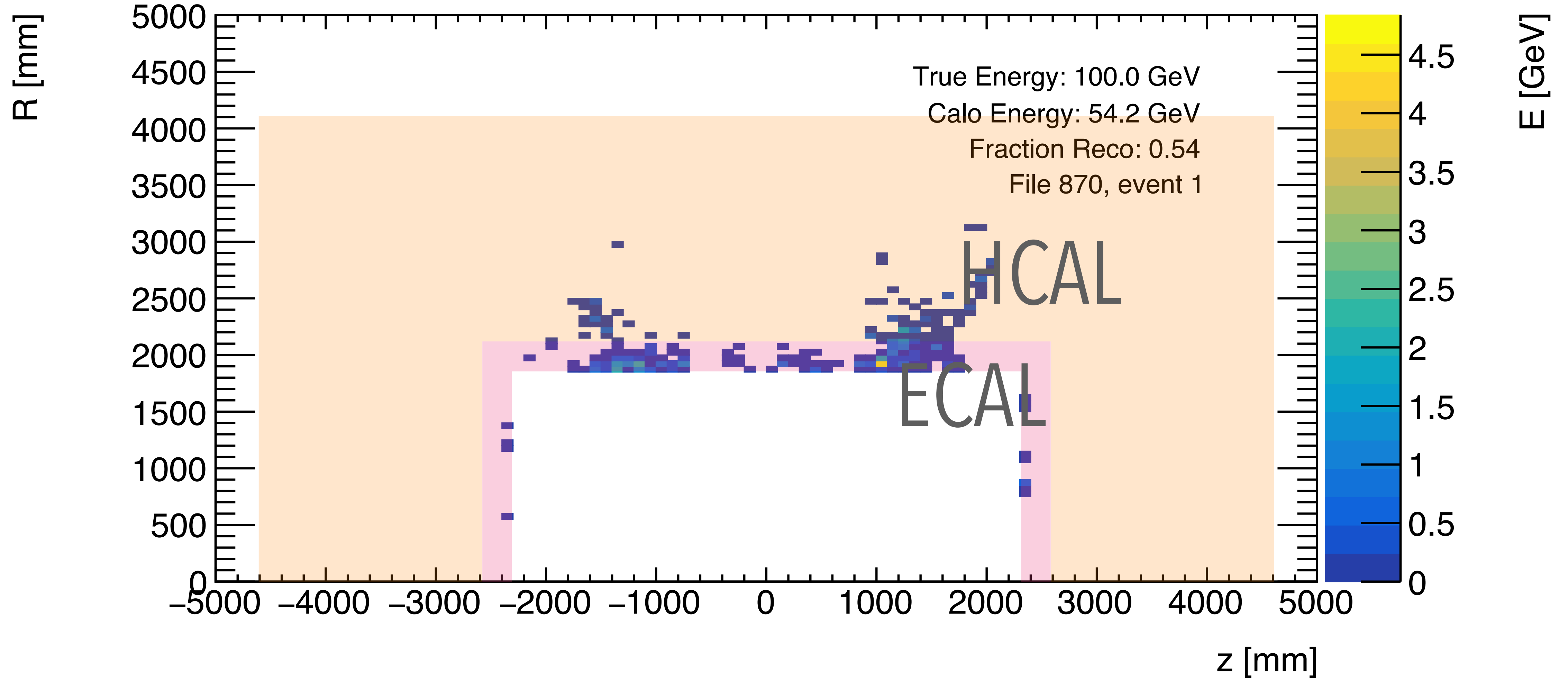


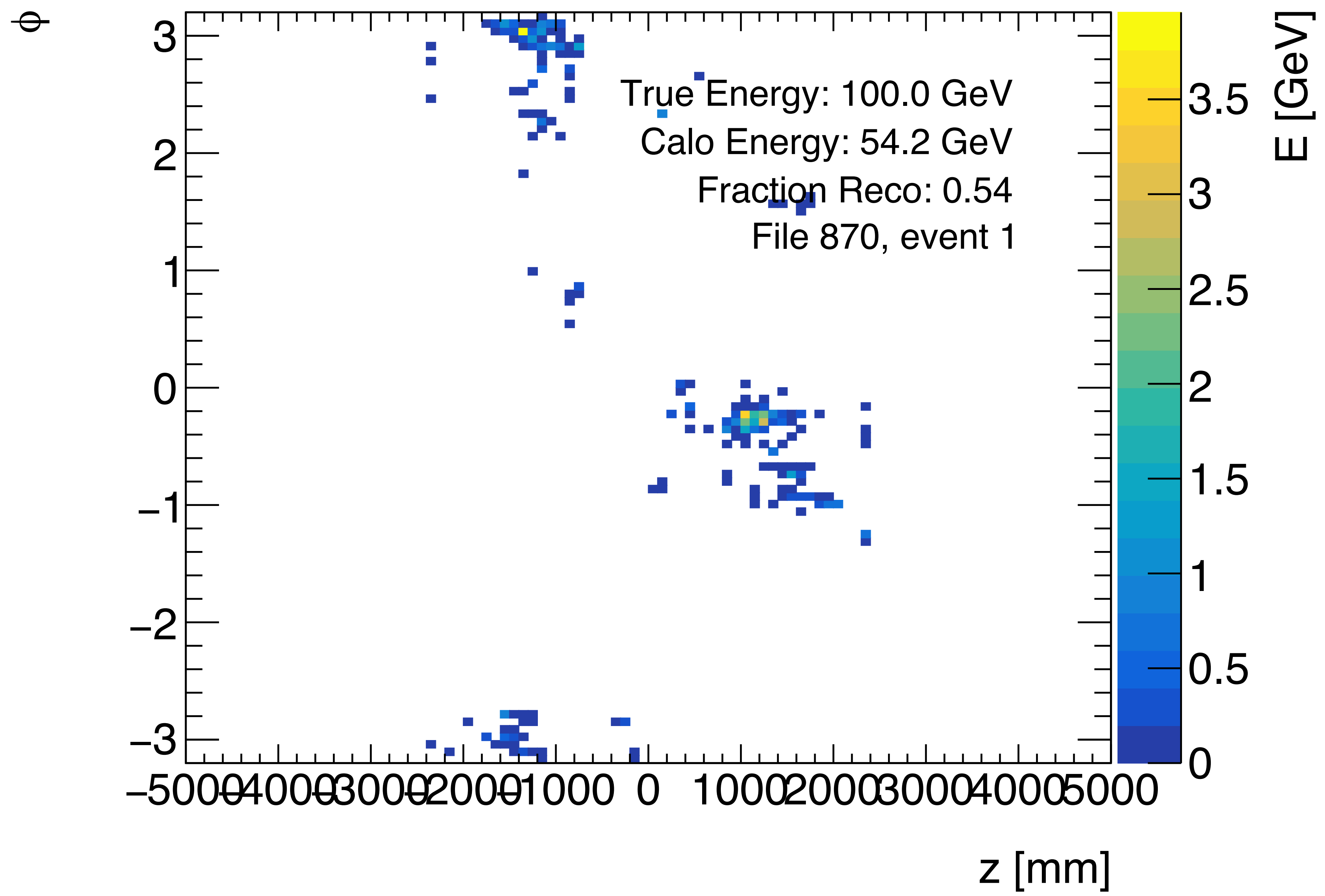


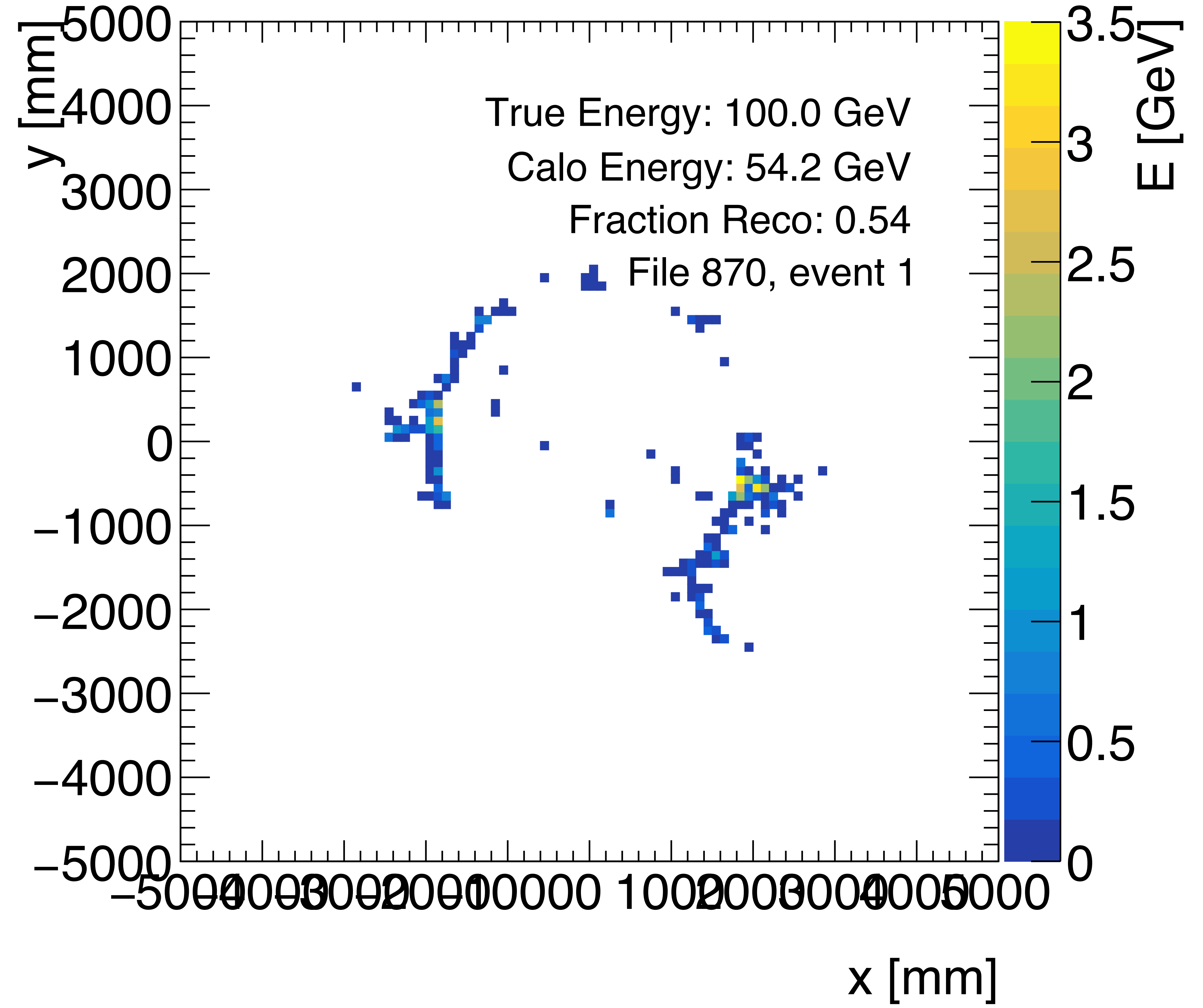
Visualizing jets

all digitized hits









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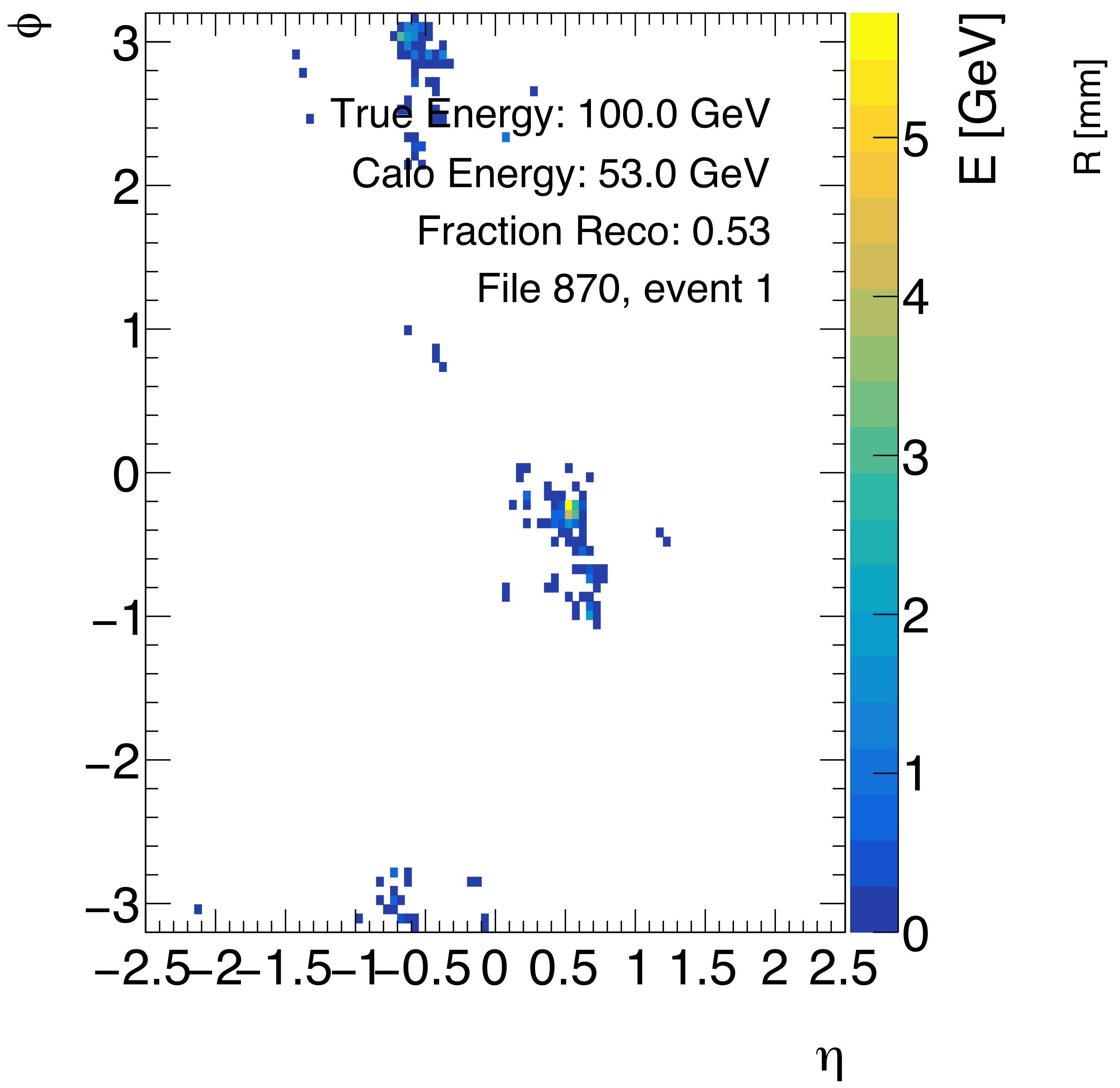

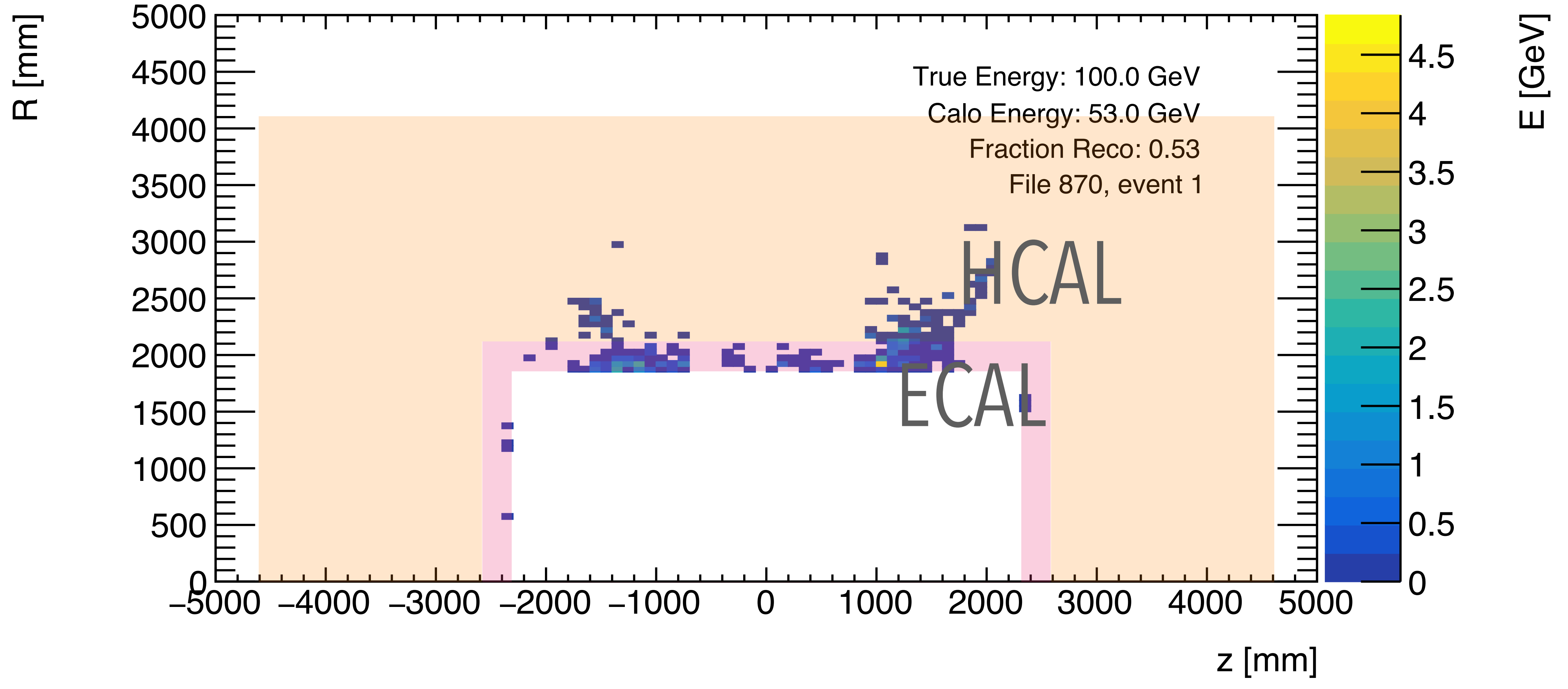

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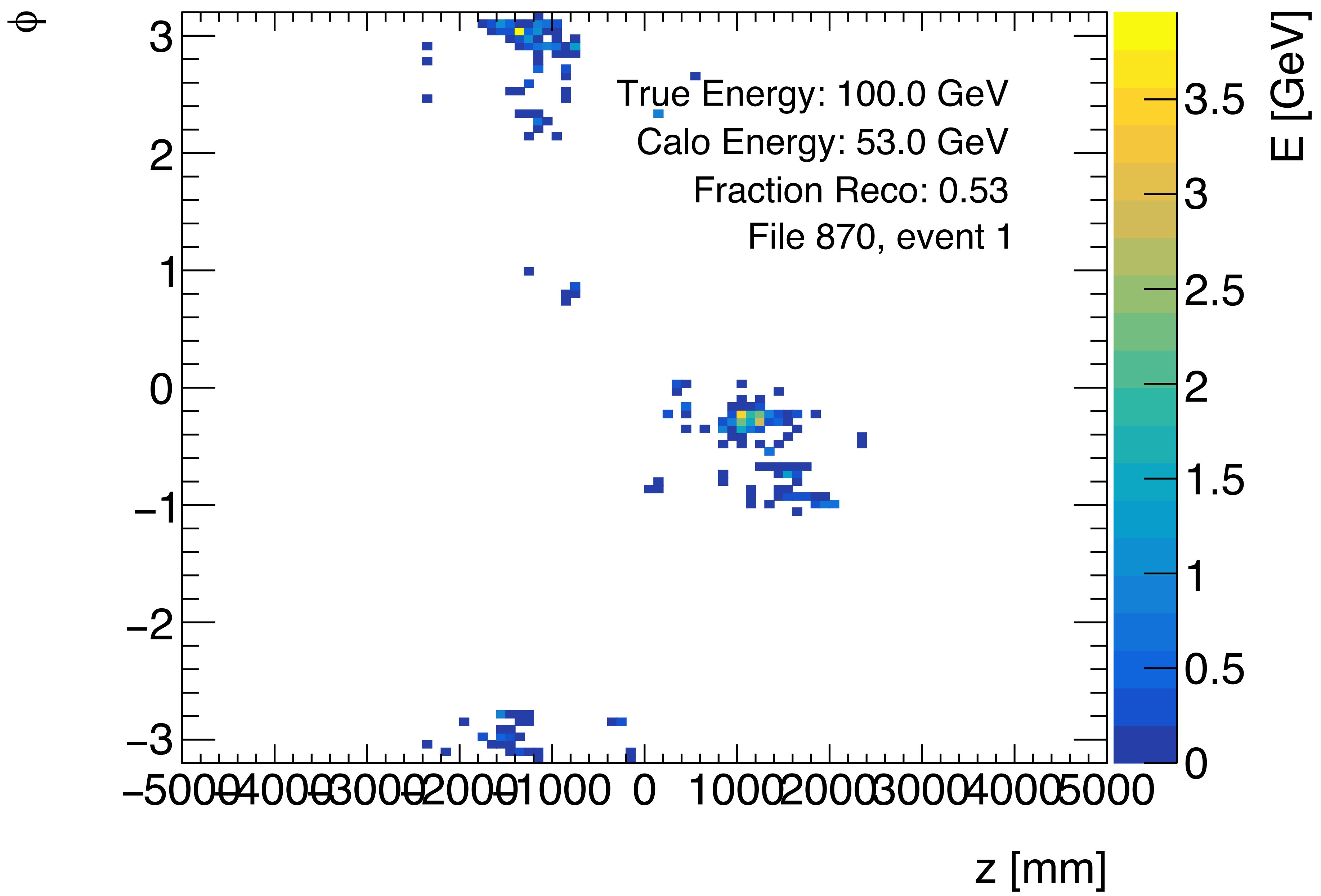

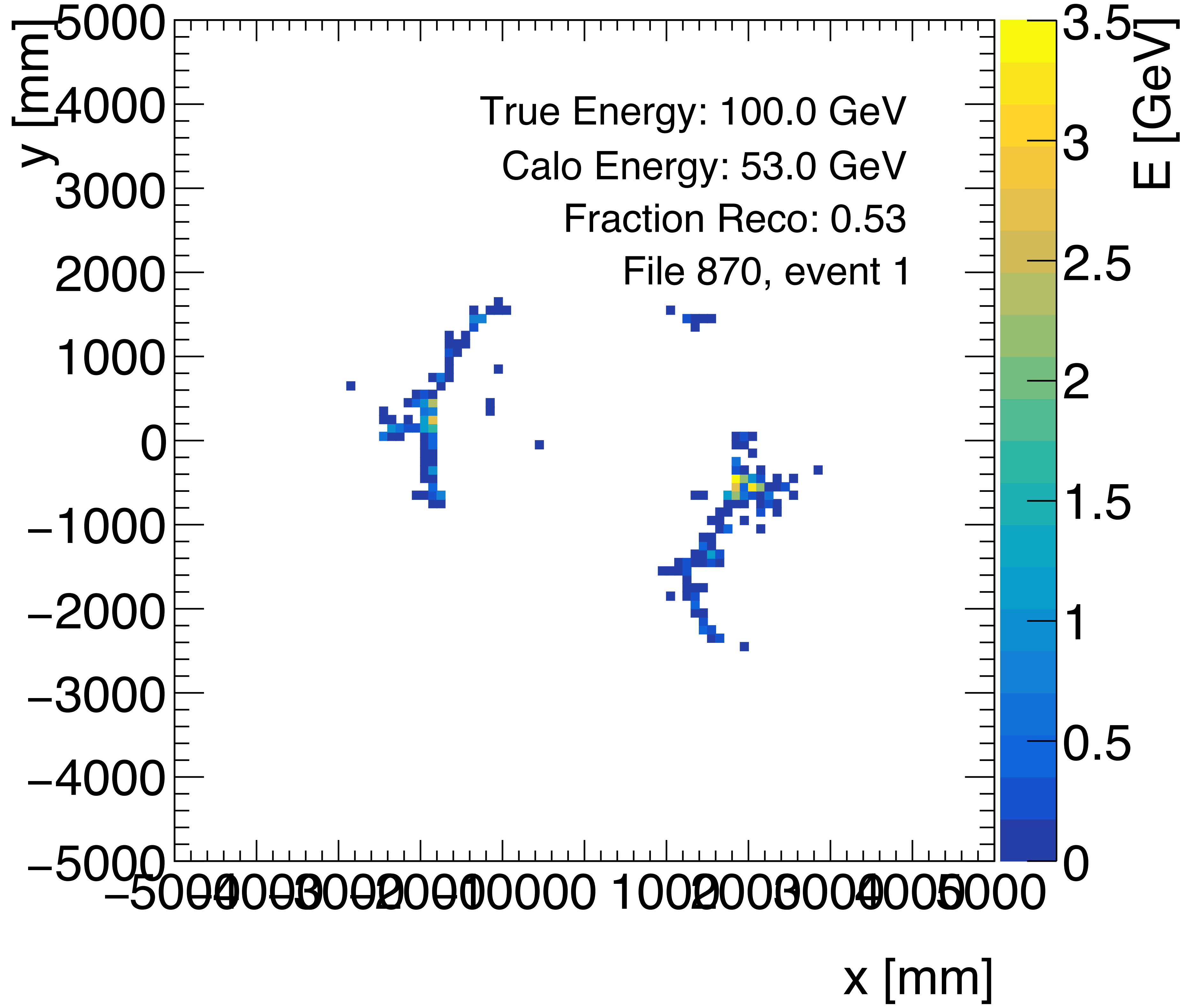

Visualizing jets

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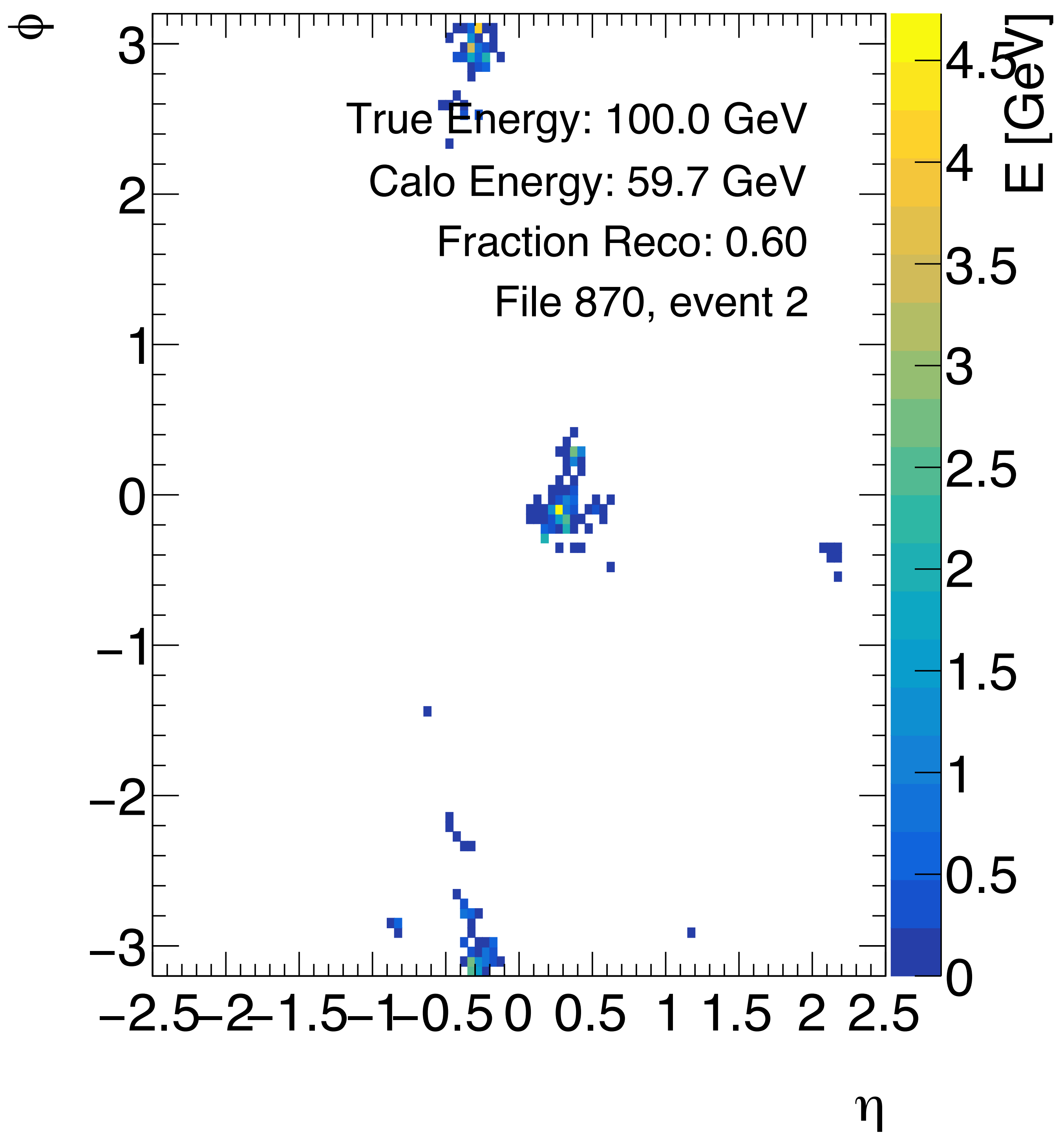

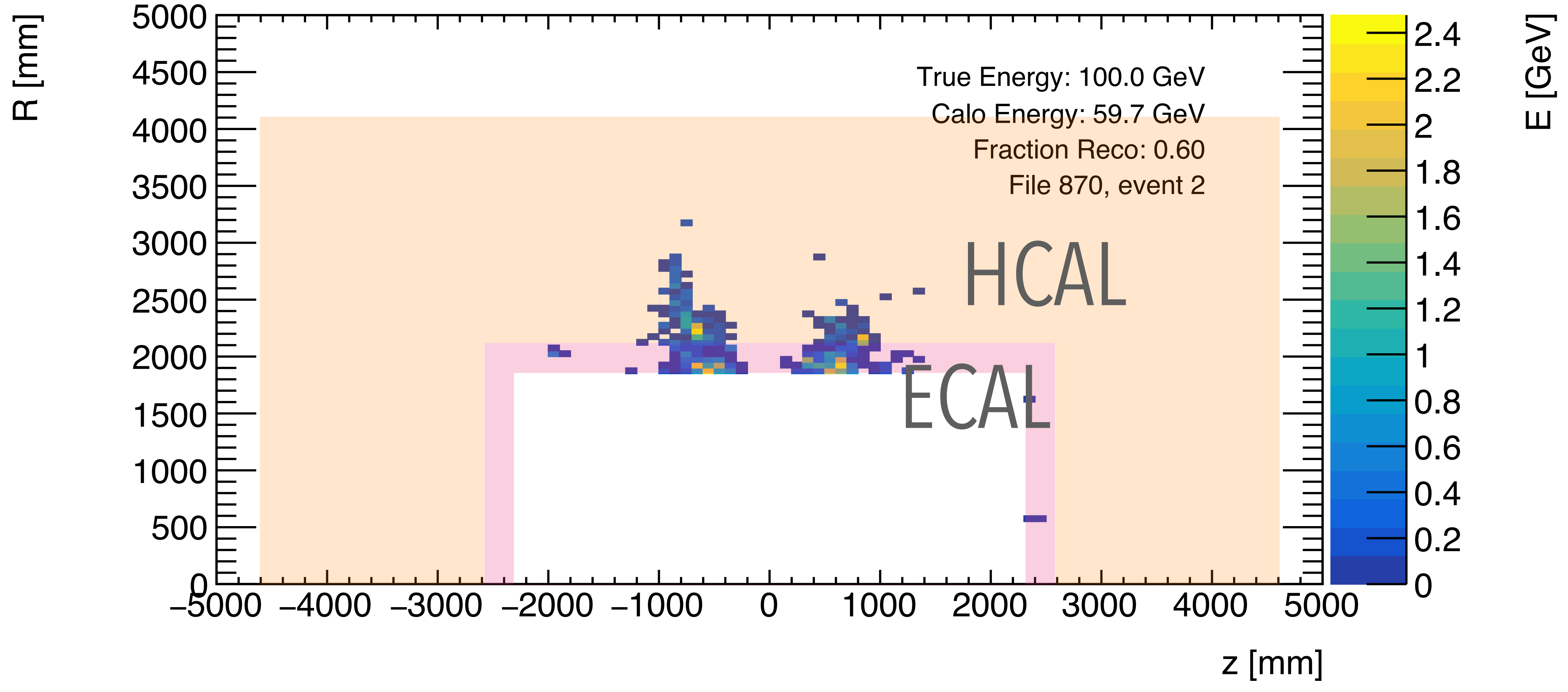

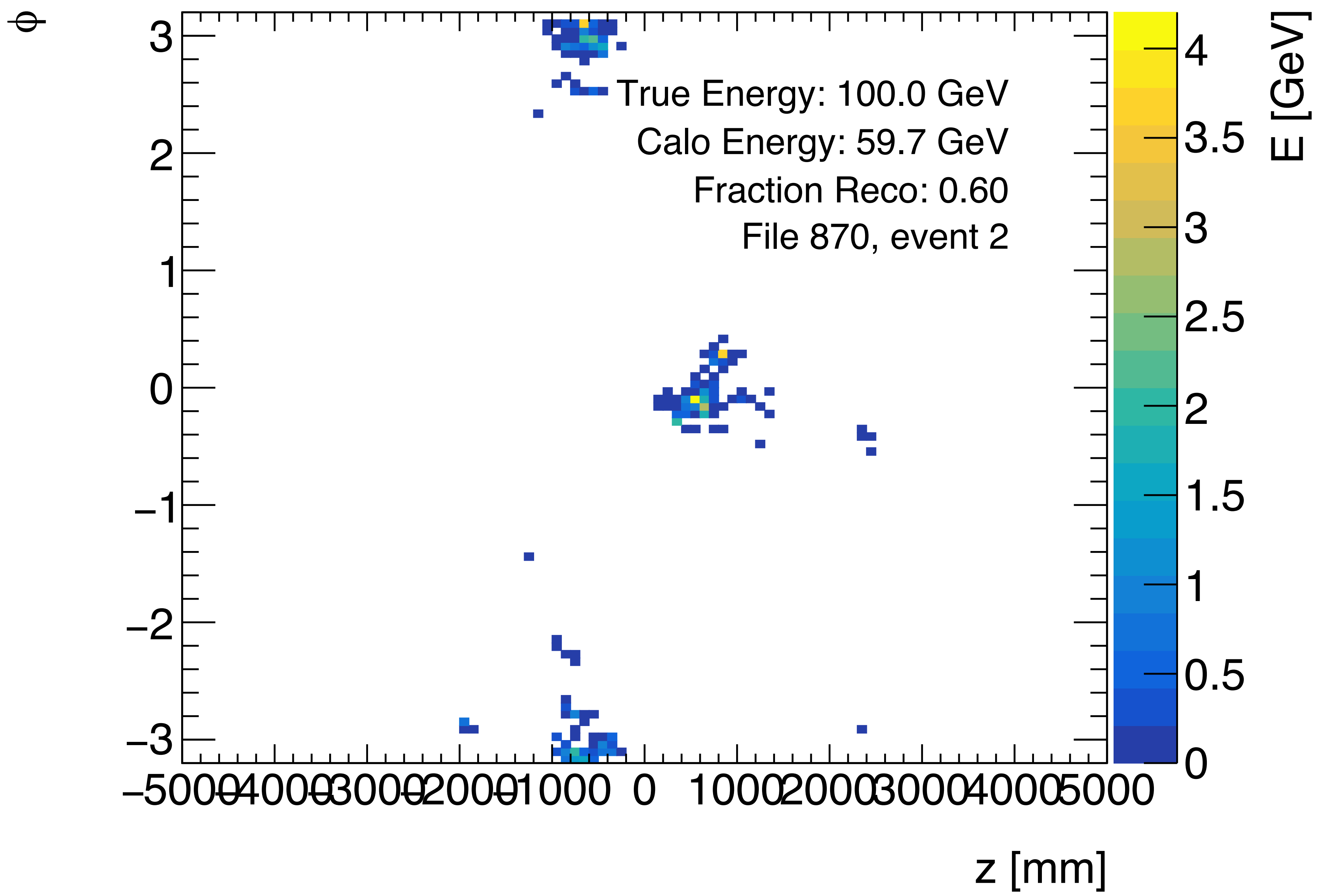

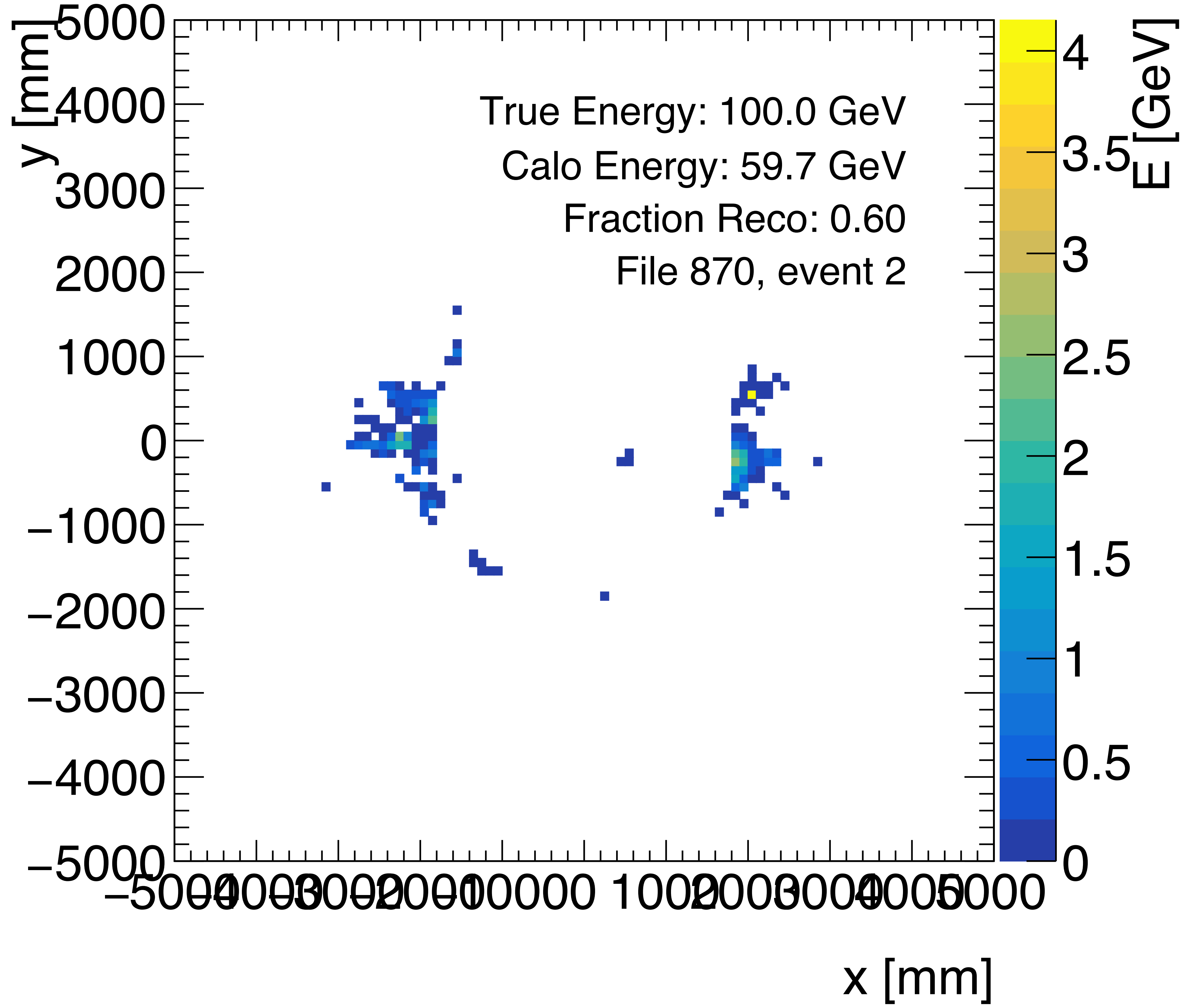

Visualizing jets

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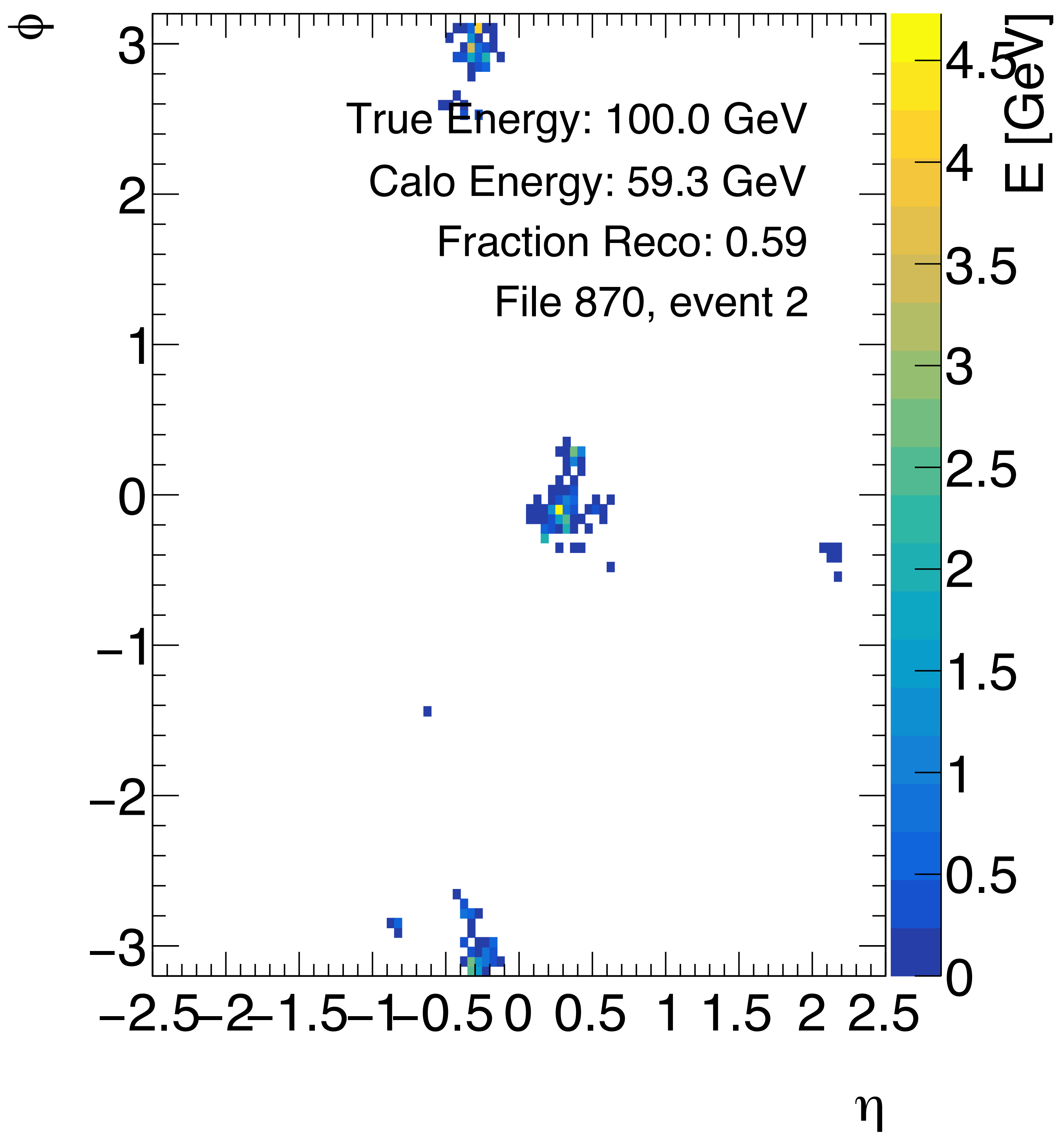
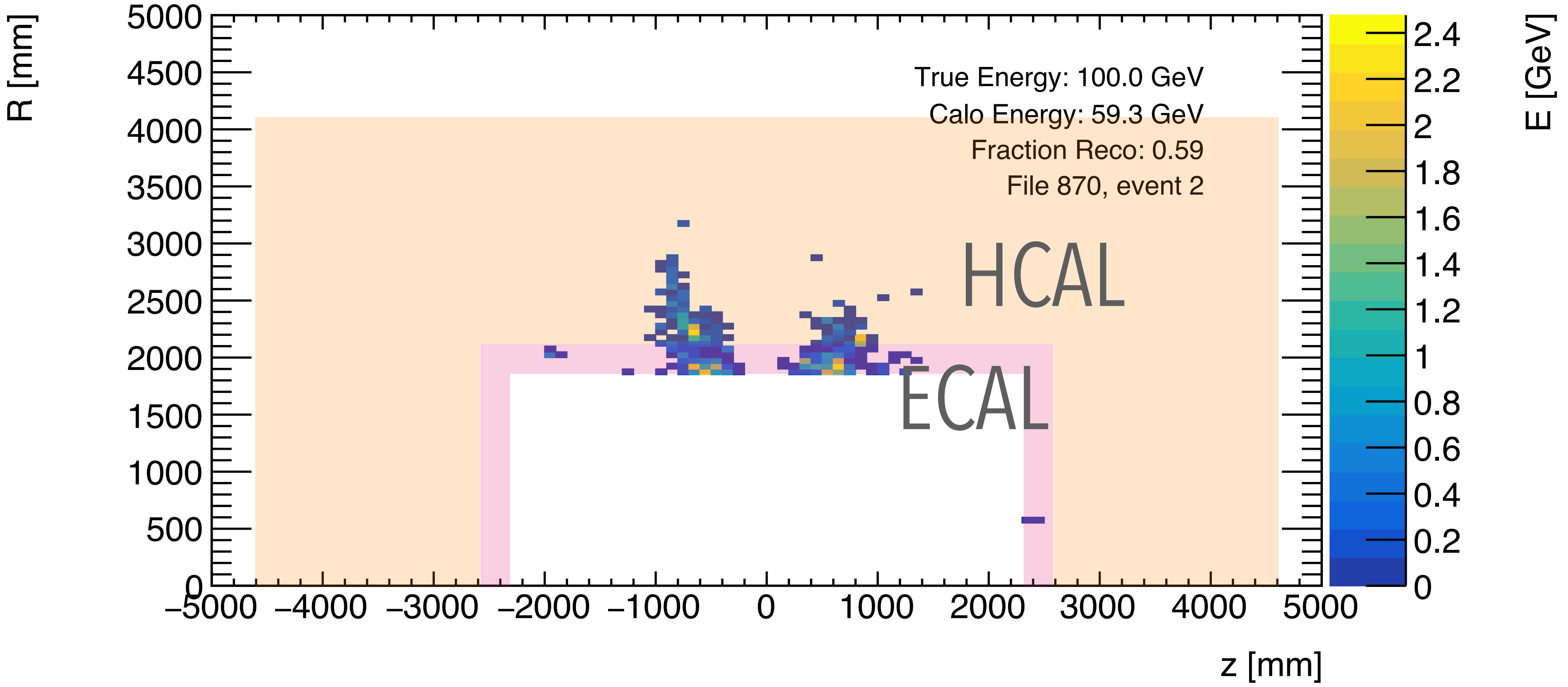
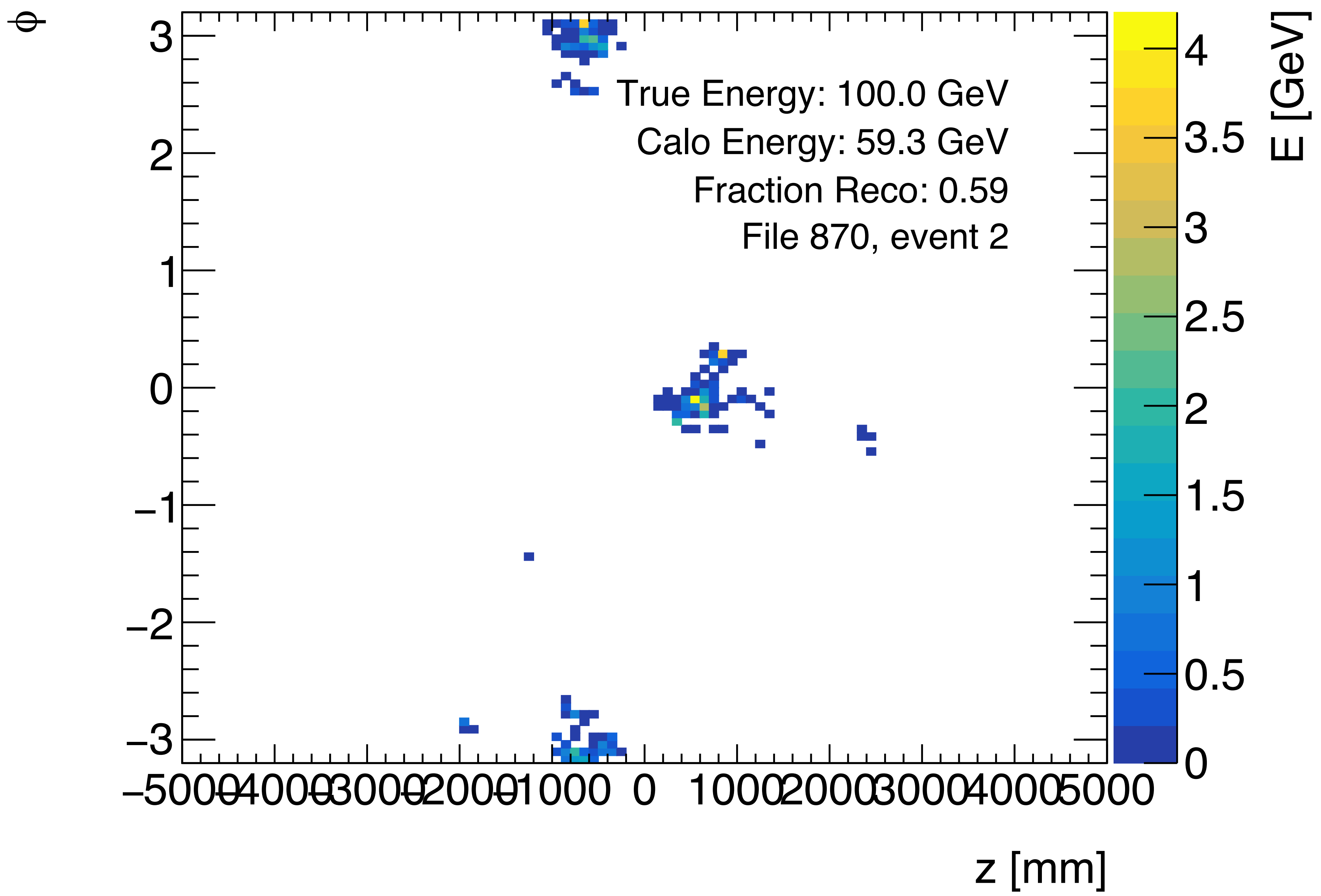
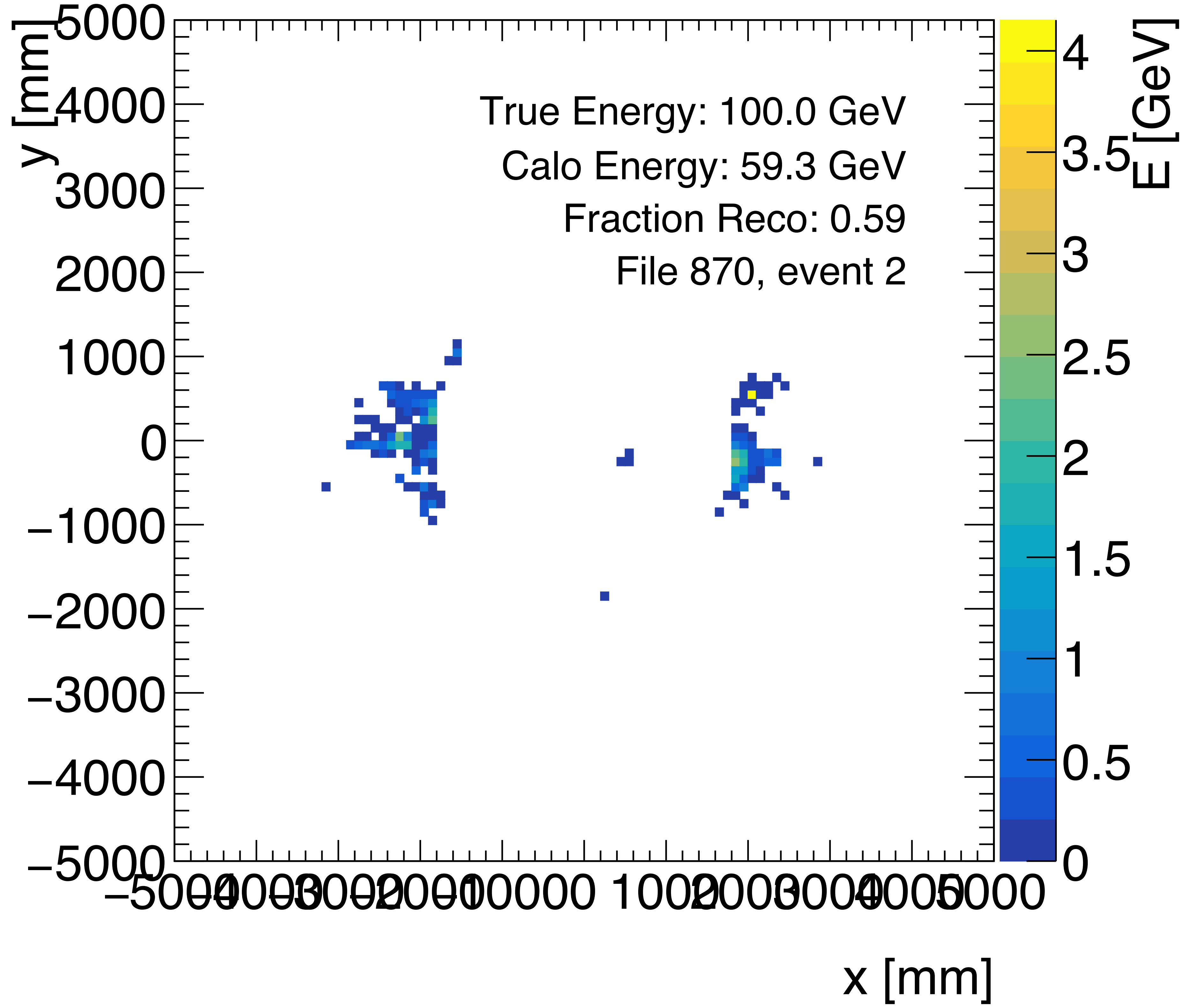


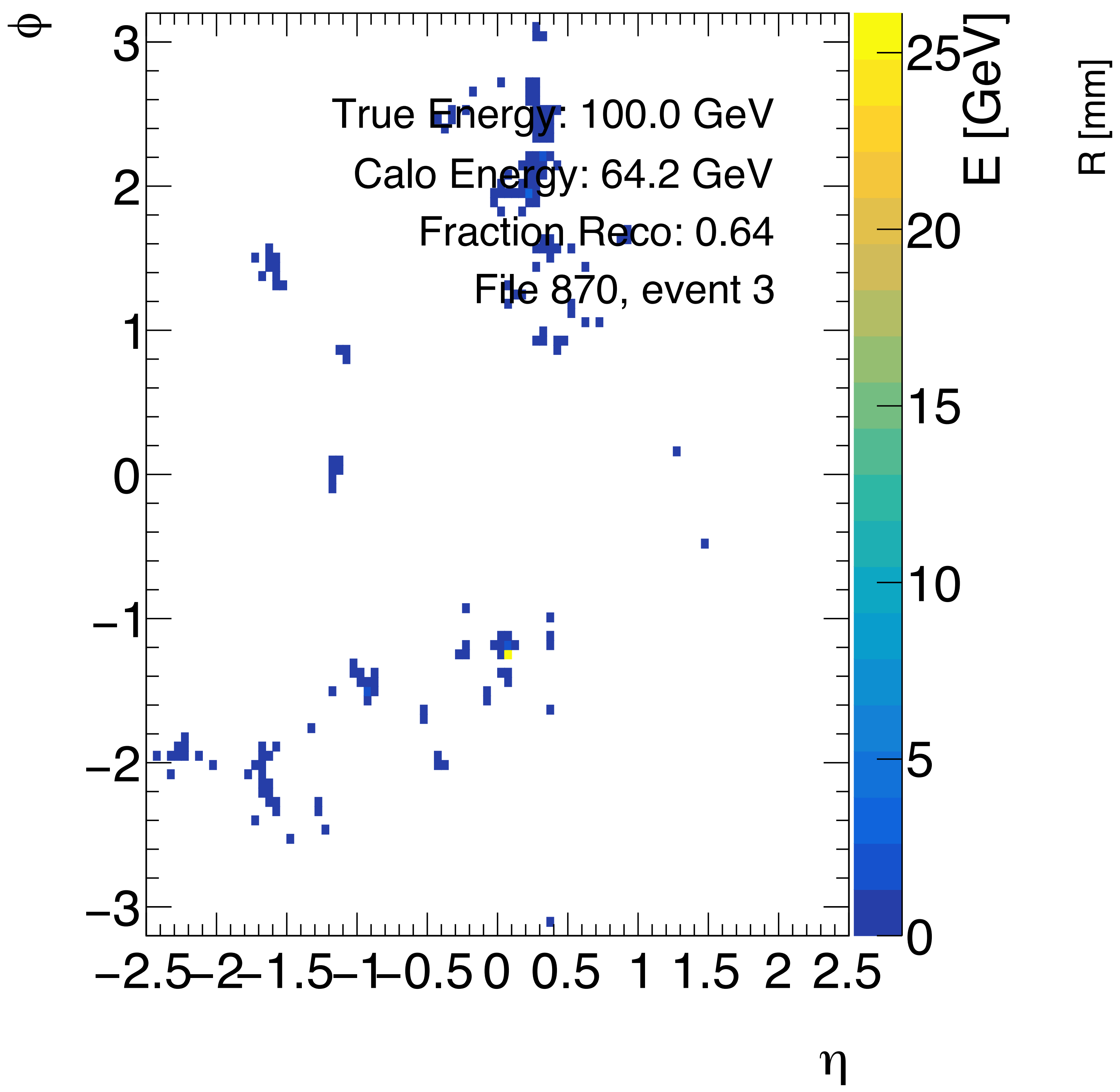


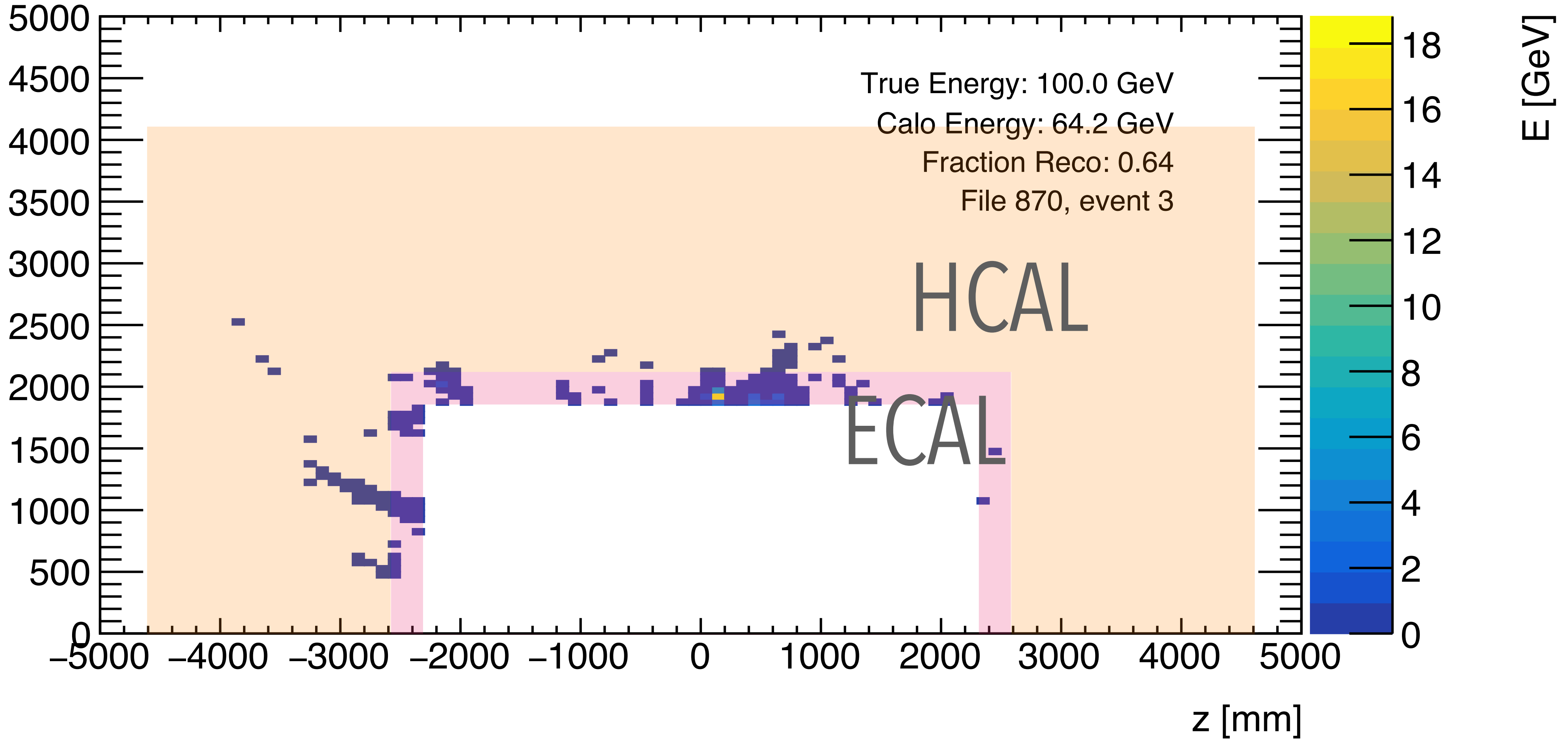


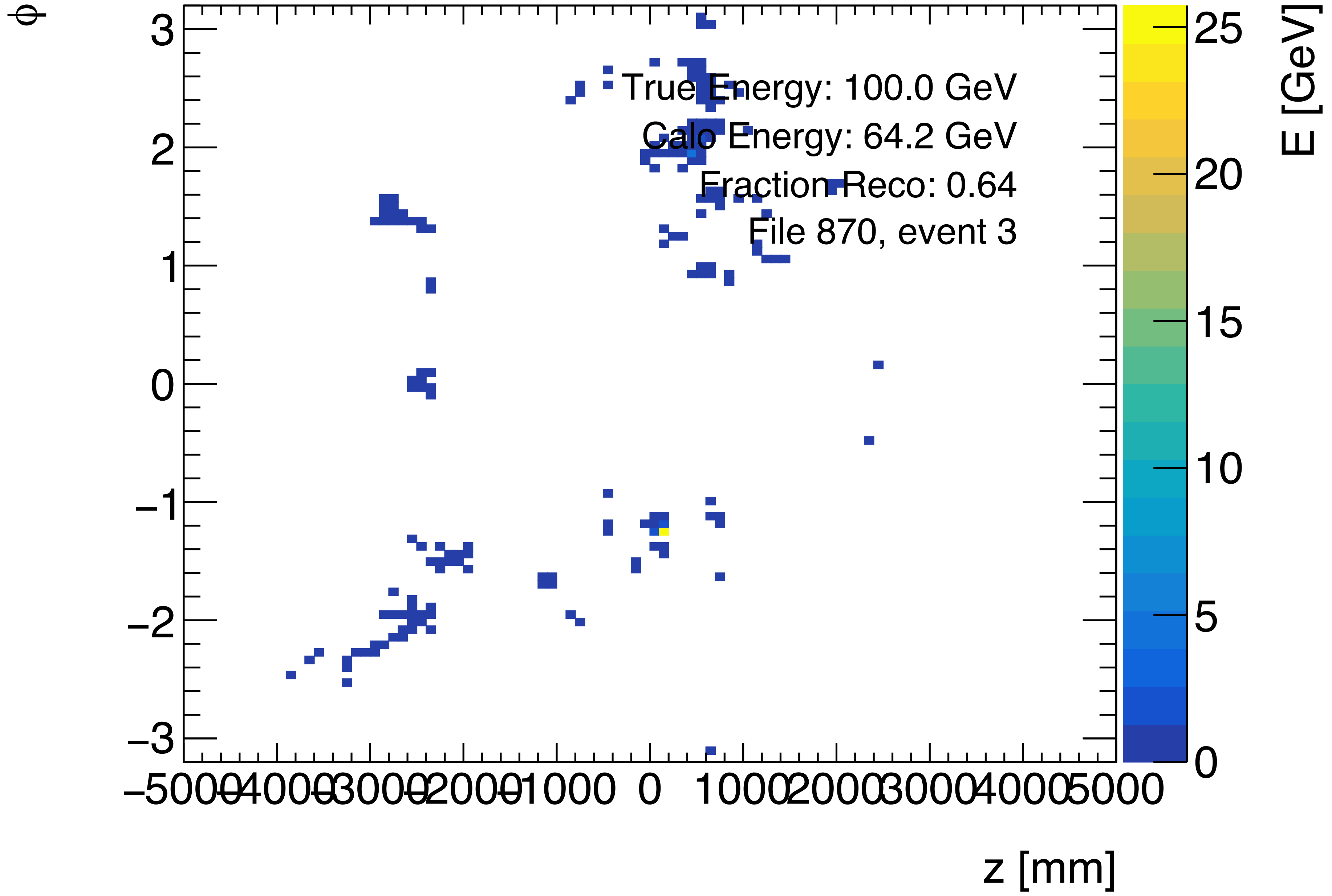


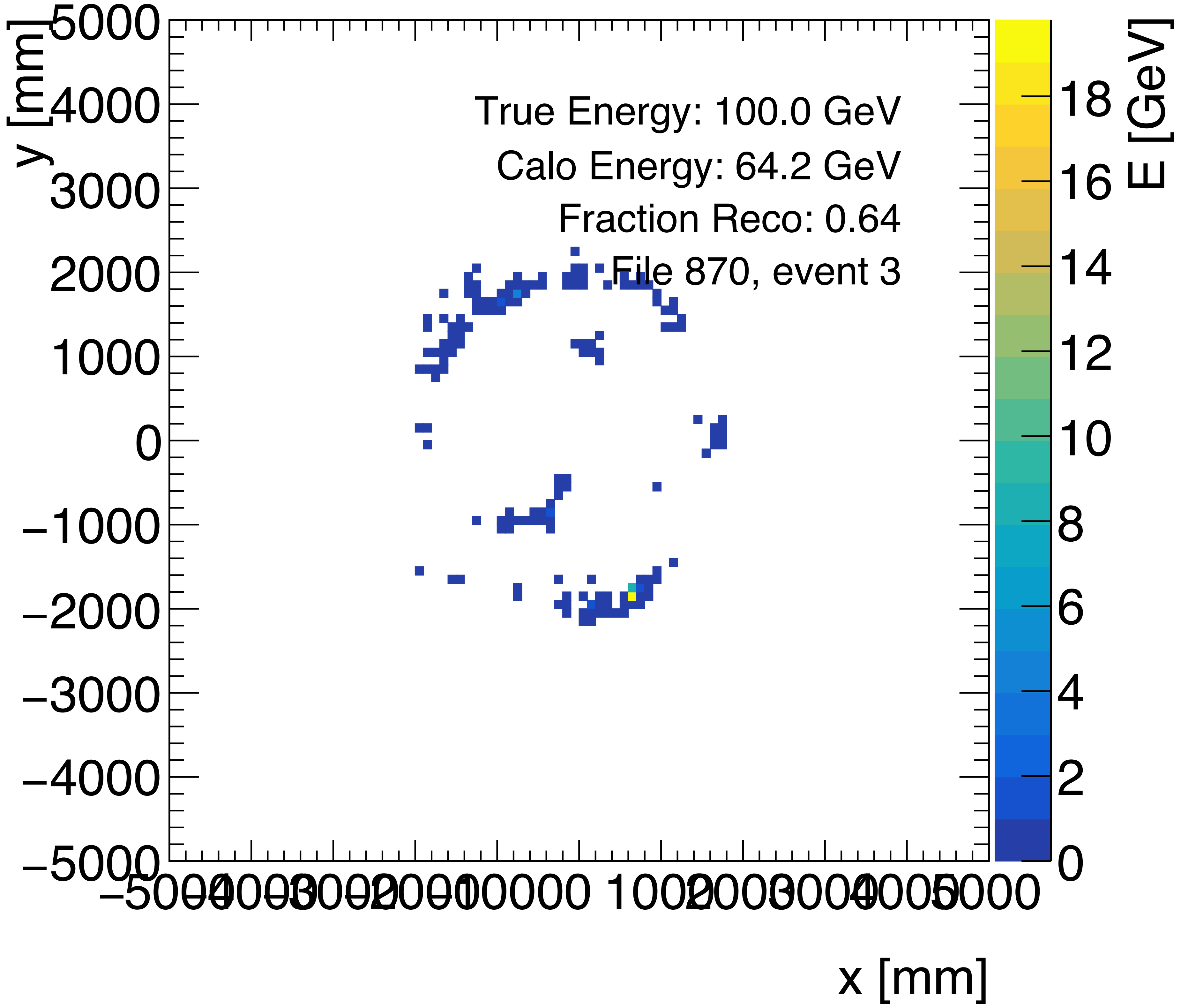
Visualizing jets

all digitized hits









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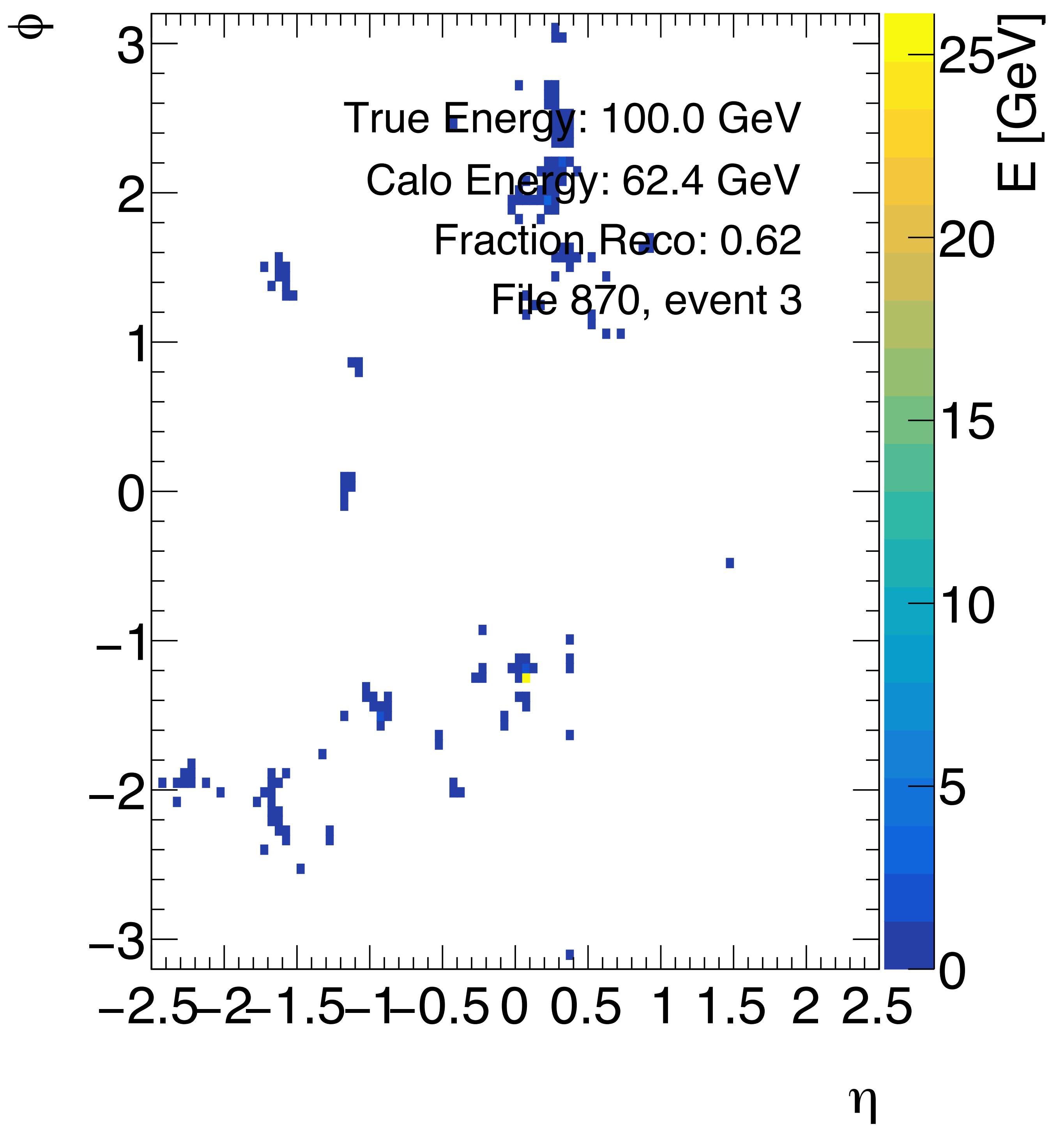
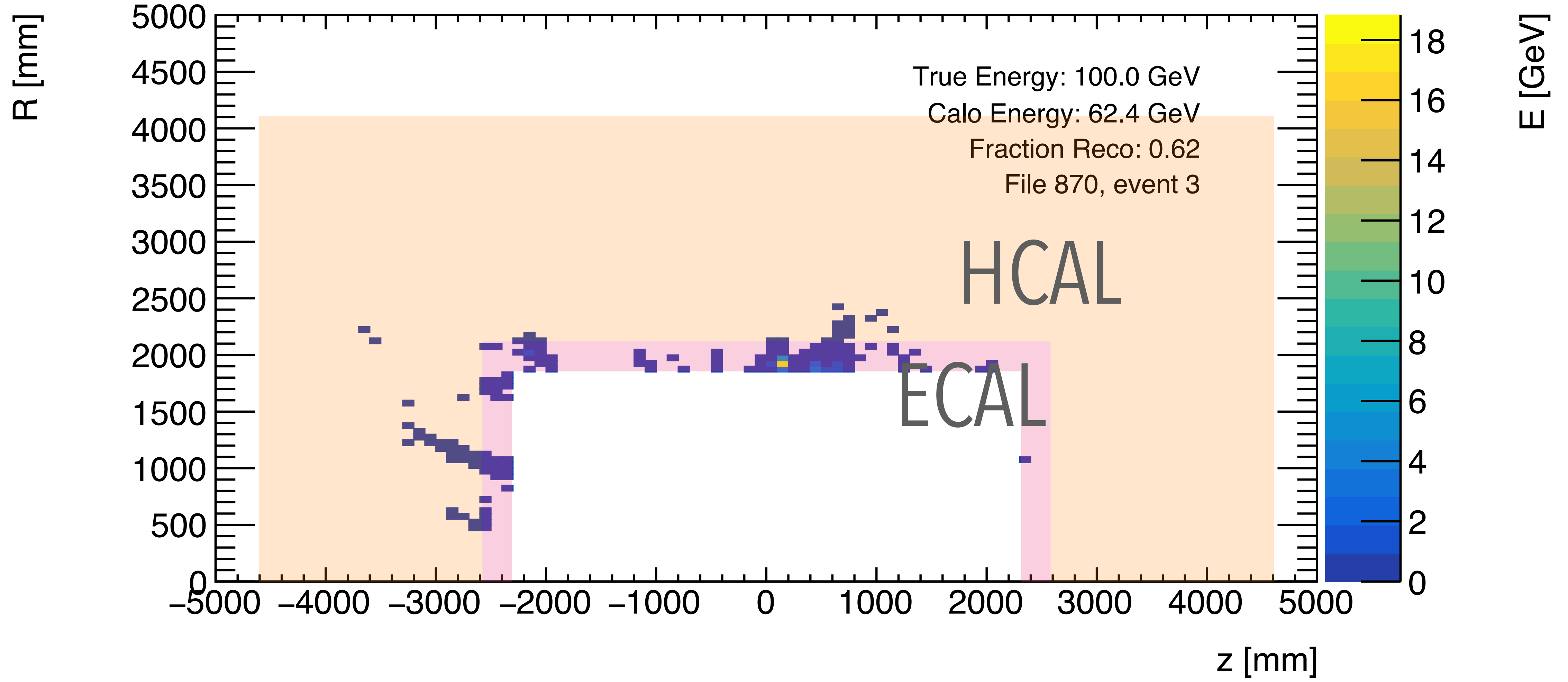
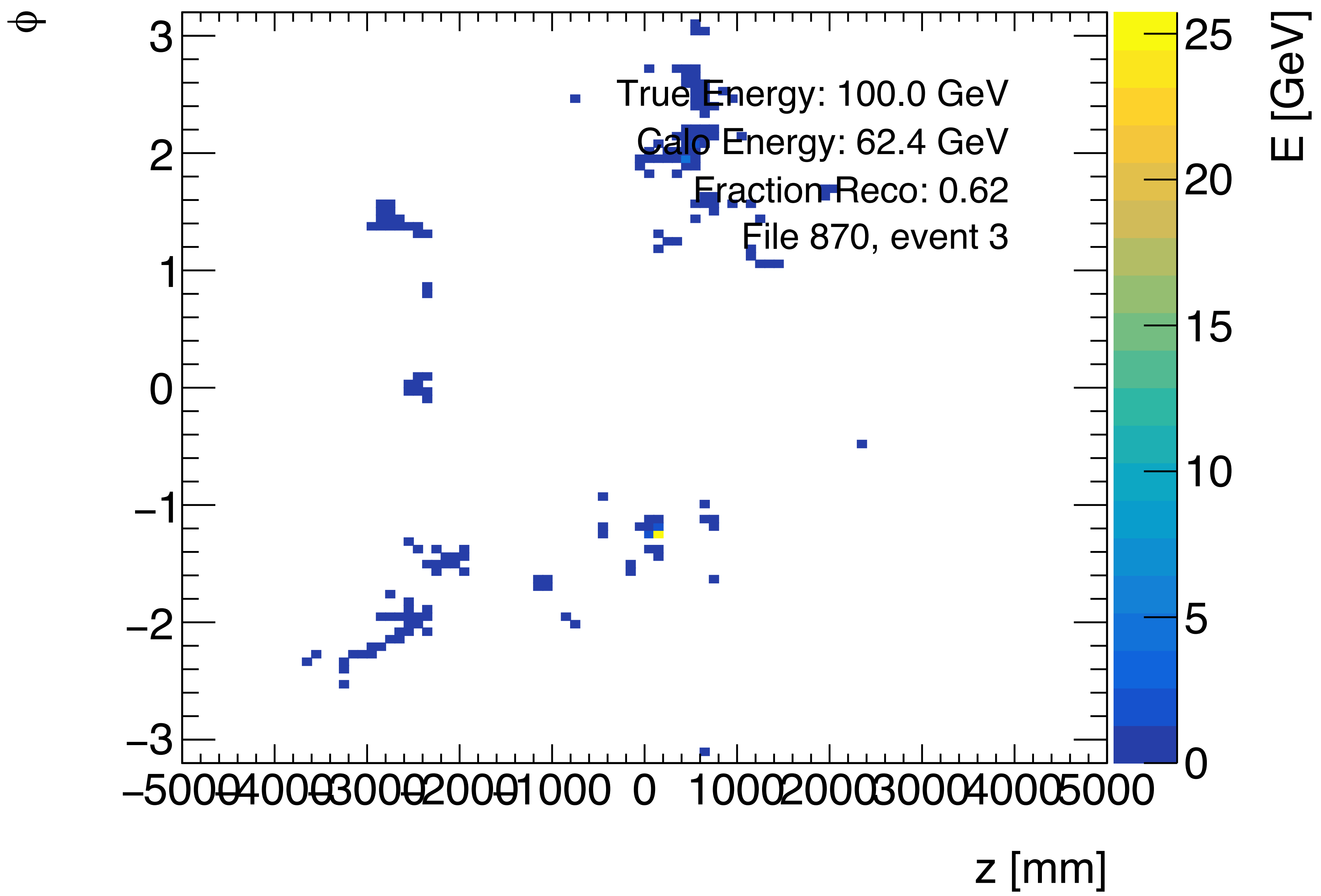
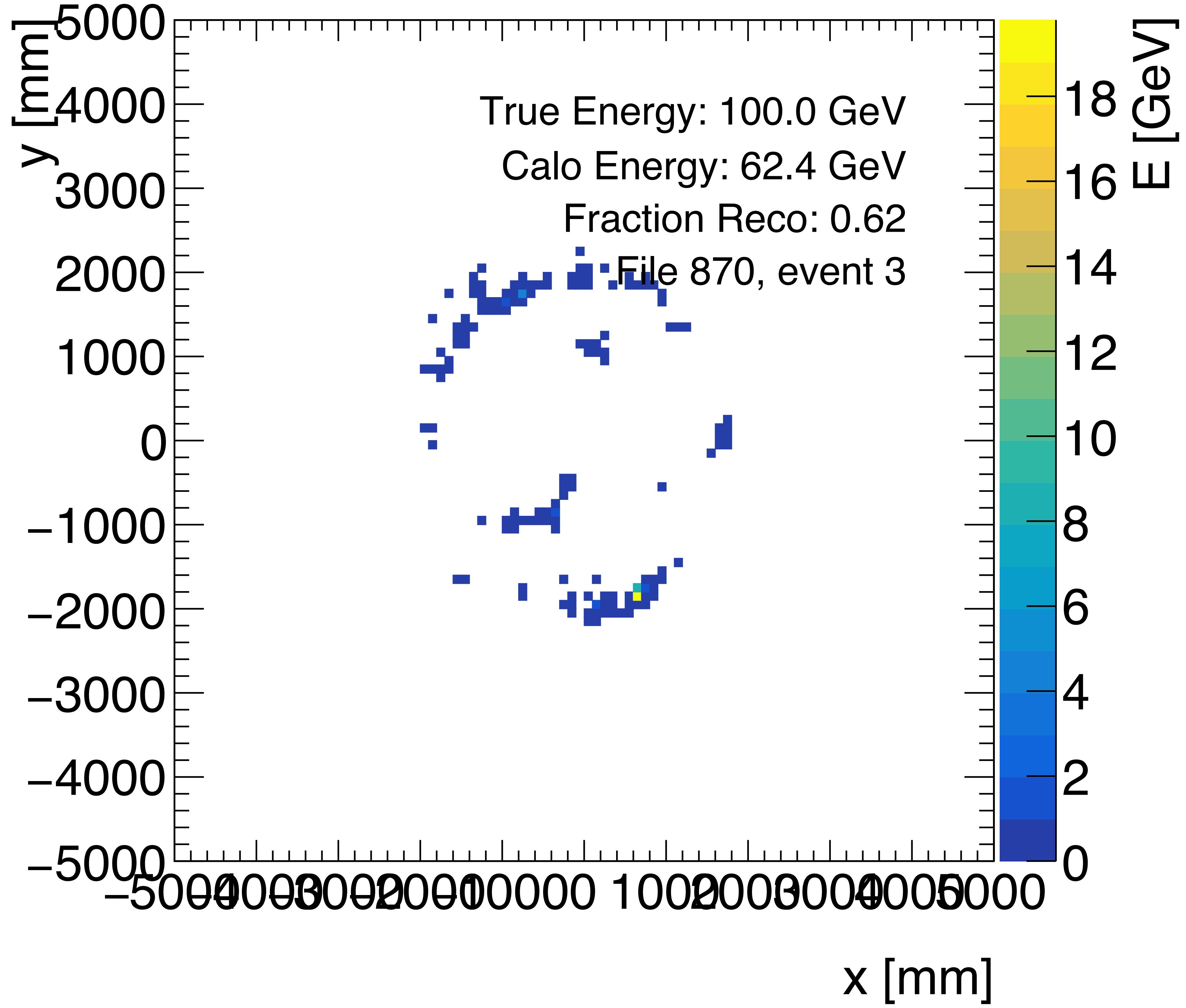


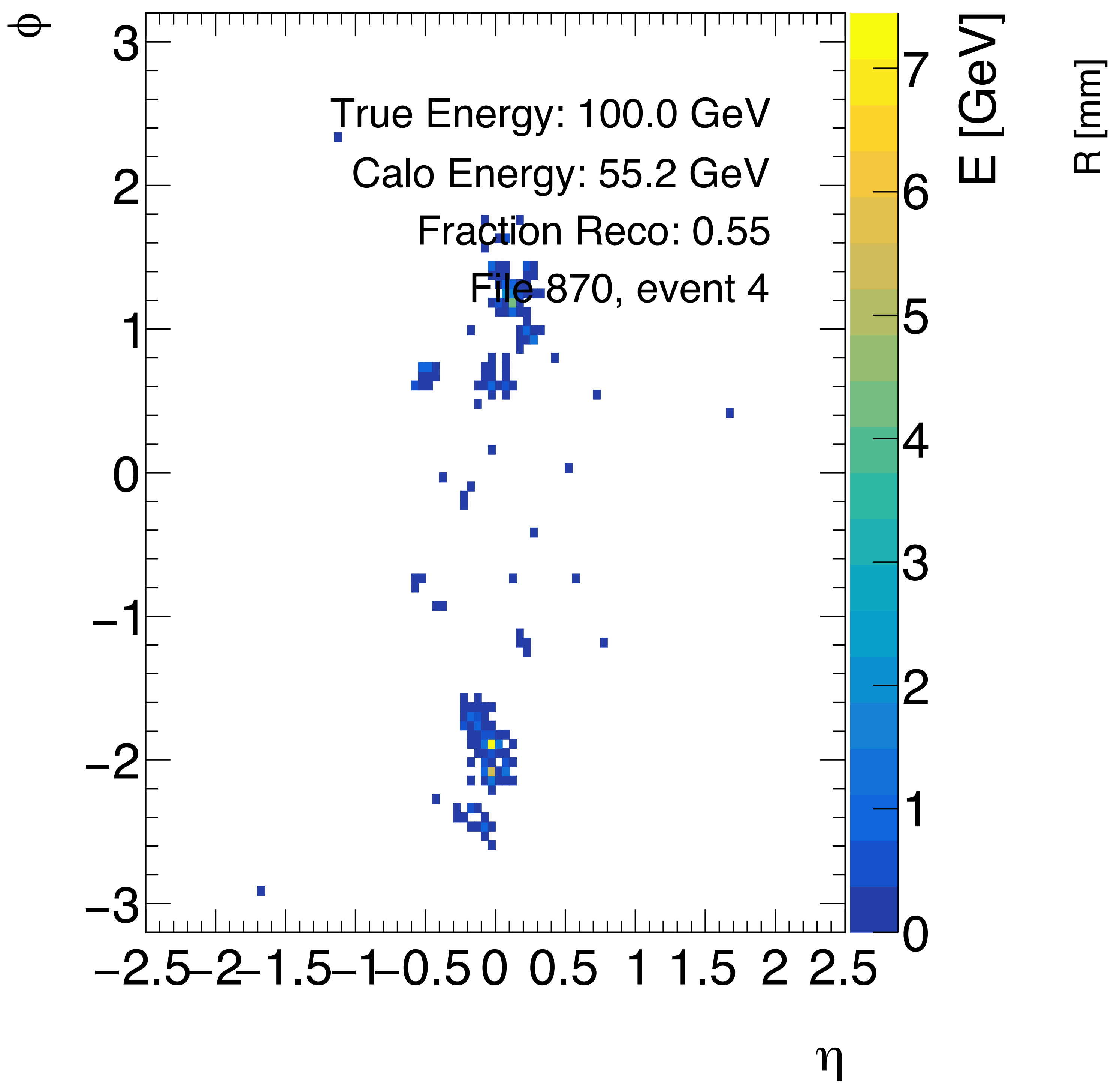


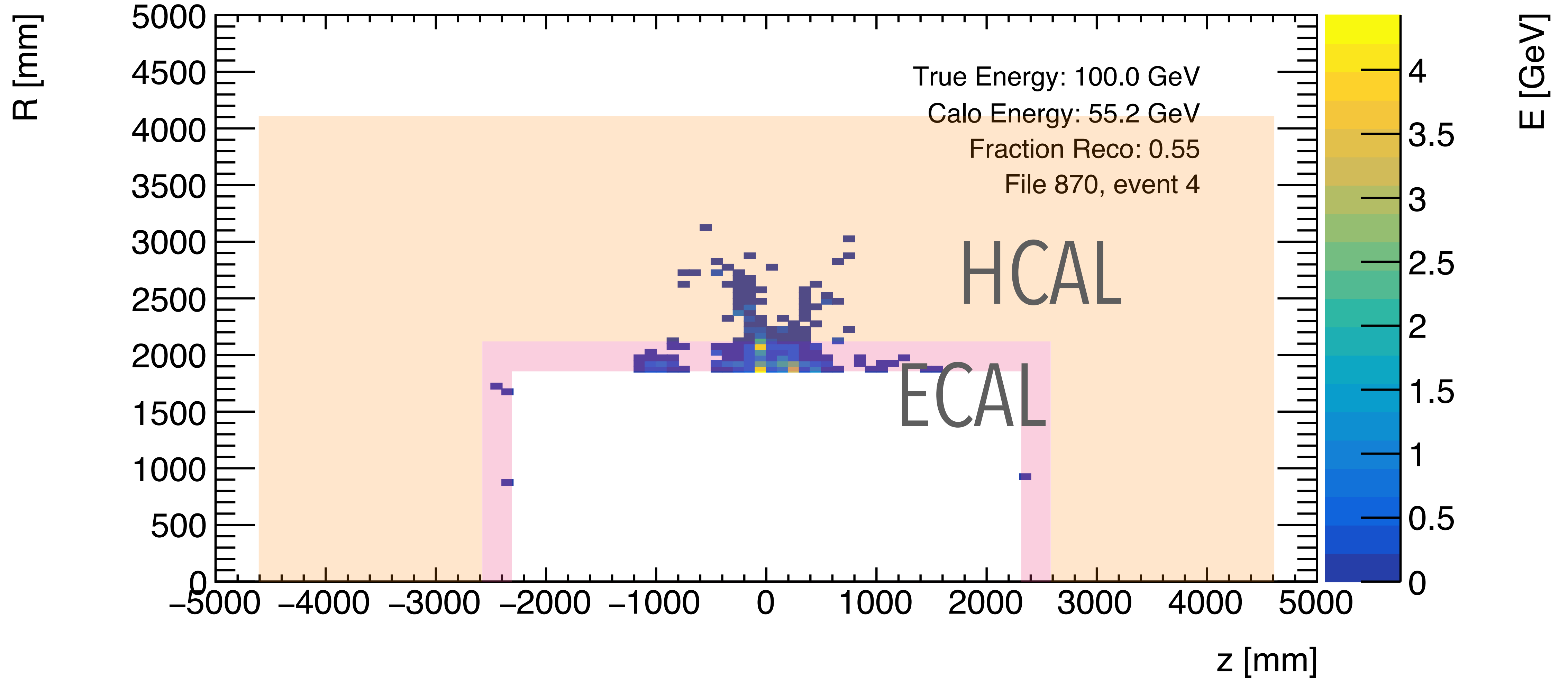


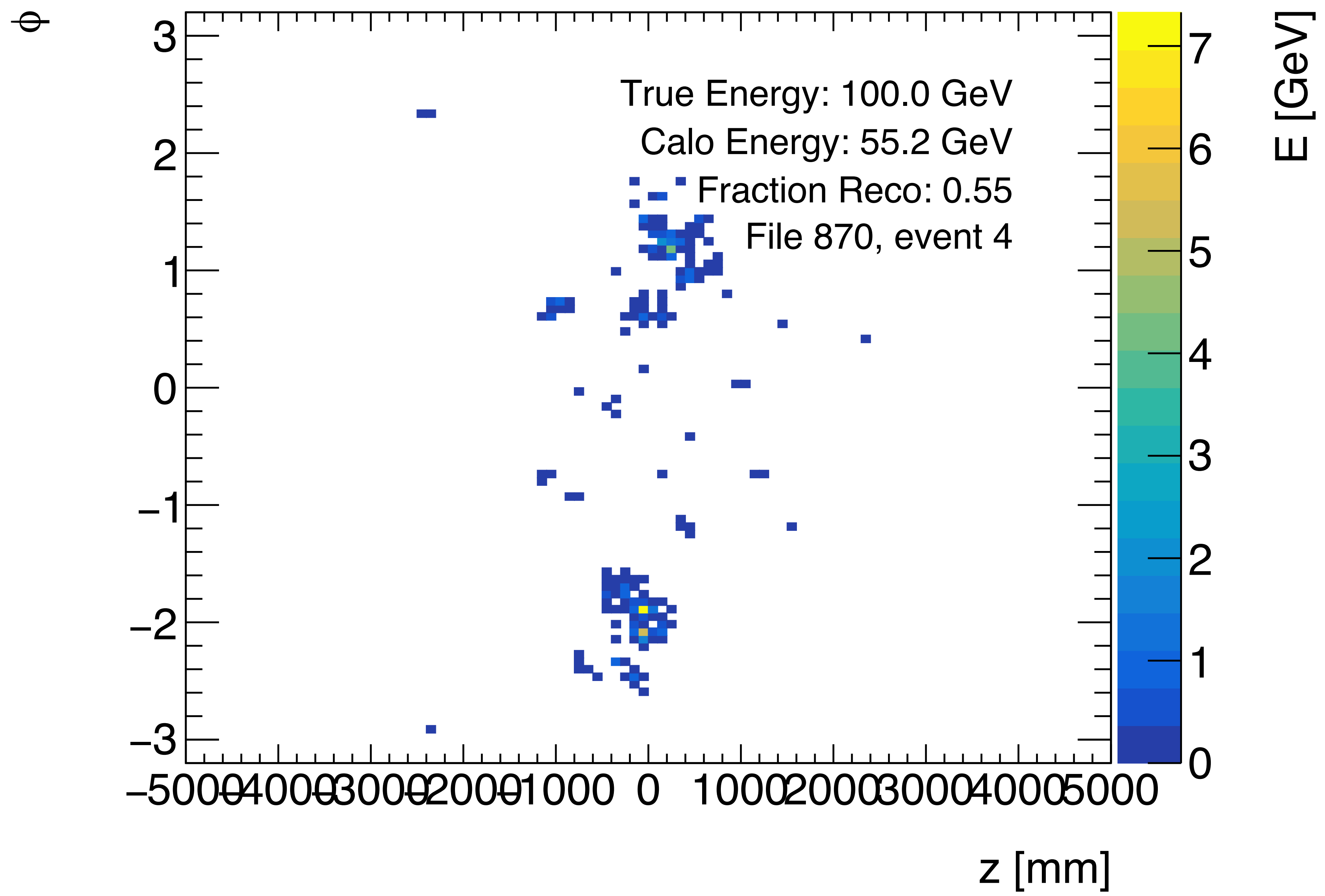


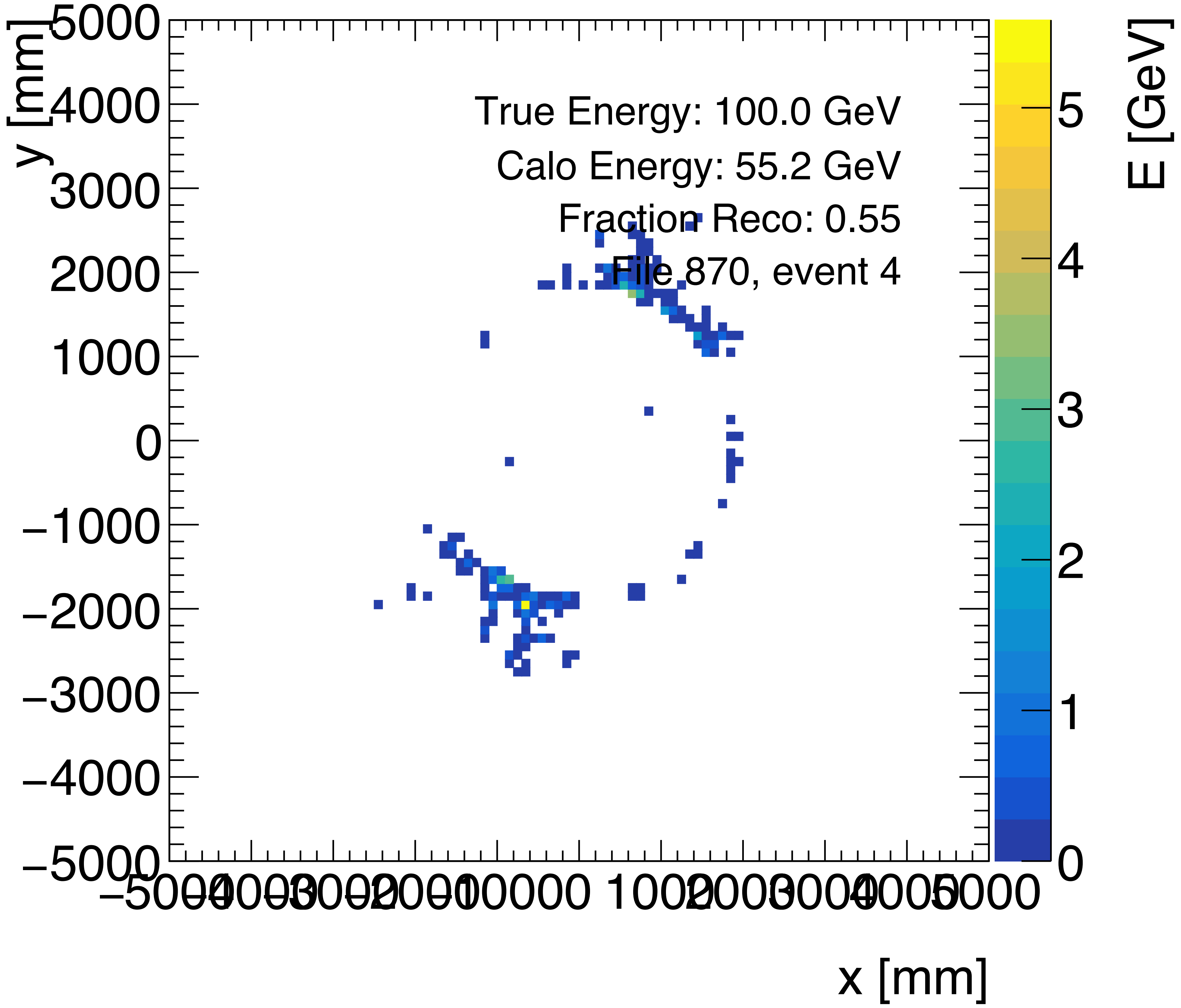
Visualizing jets

all digitized hits









Visualizing jets

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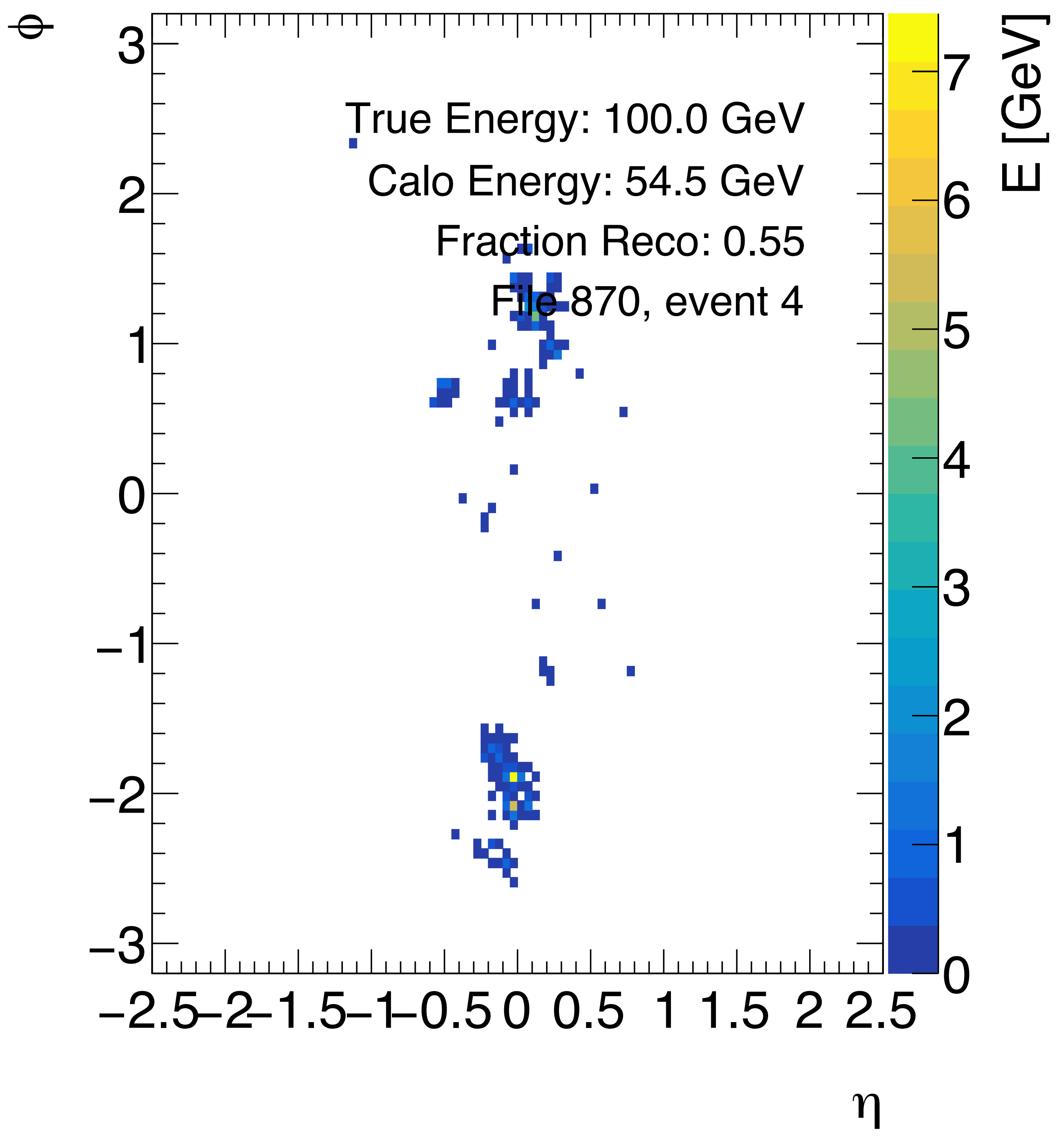
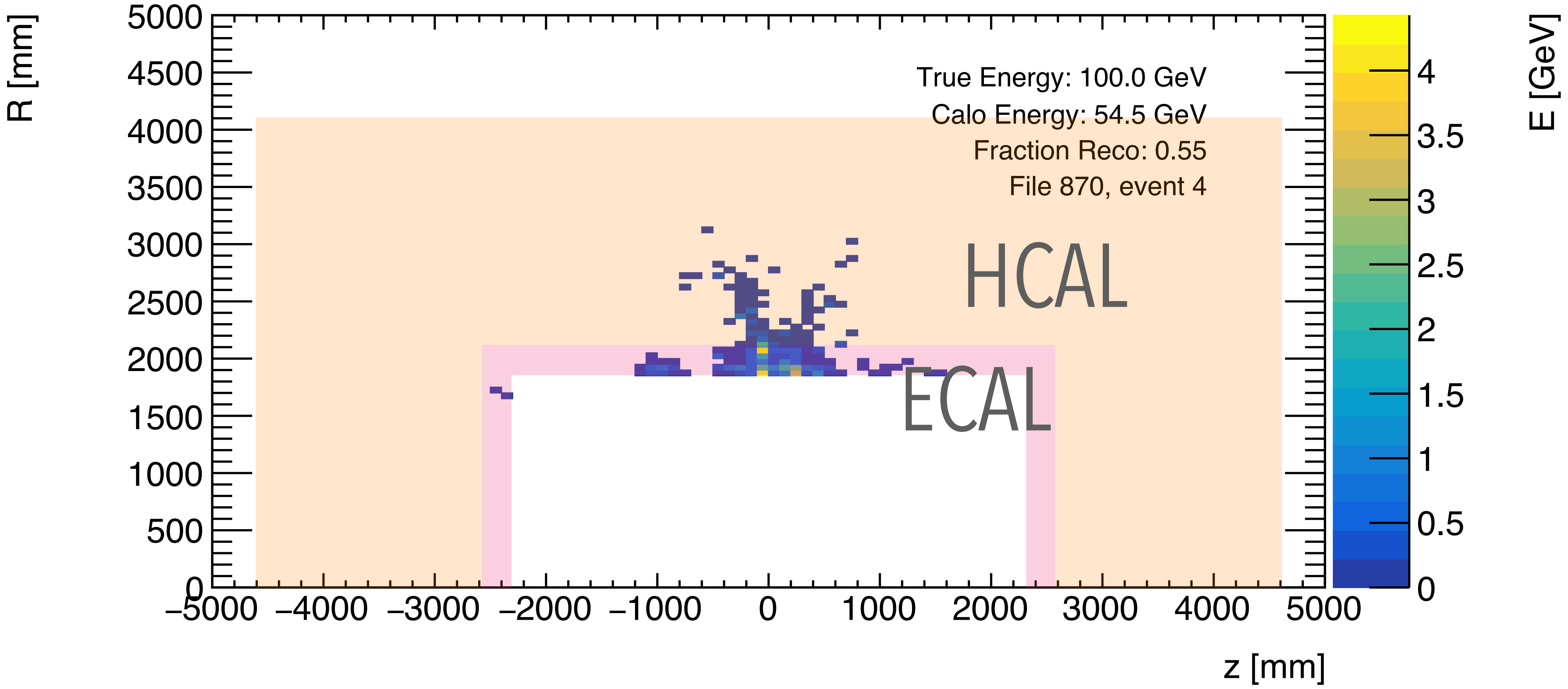
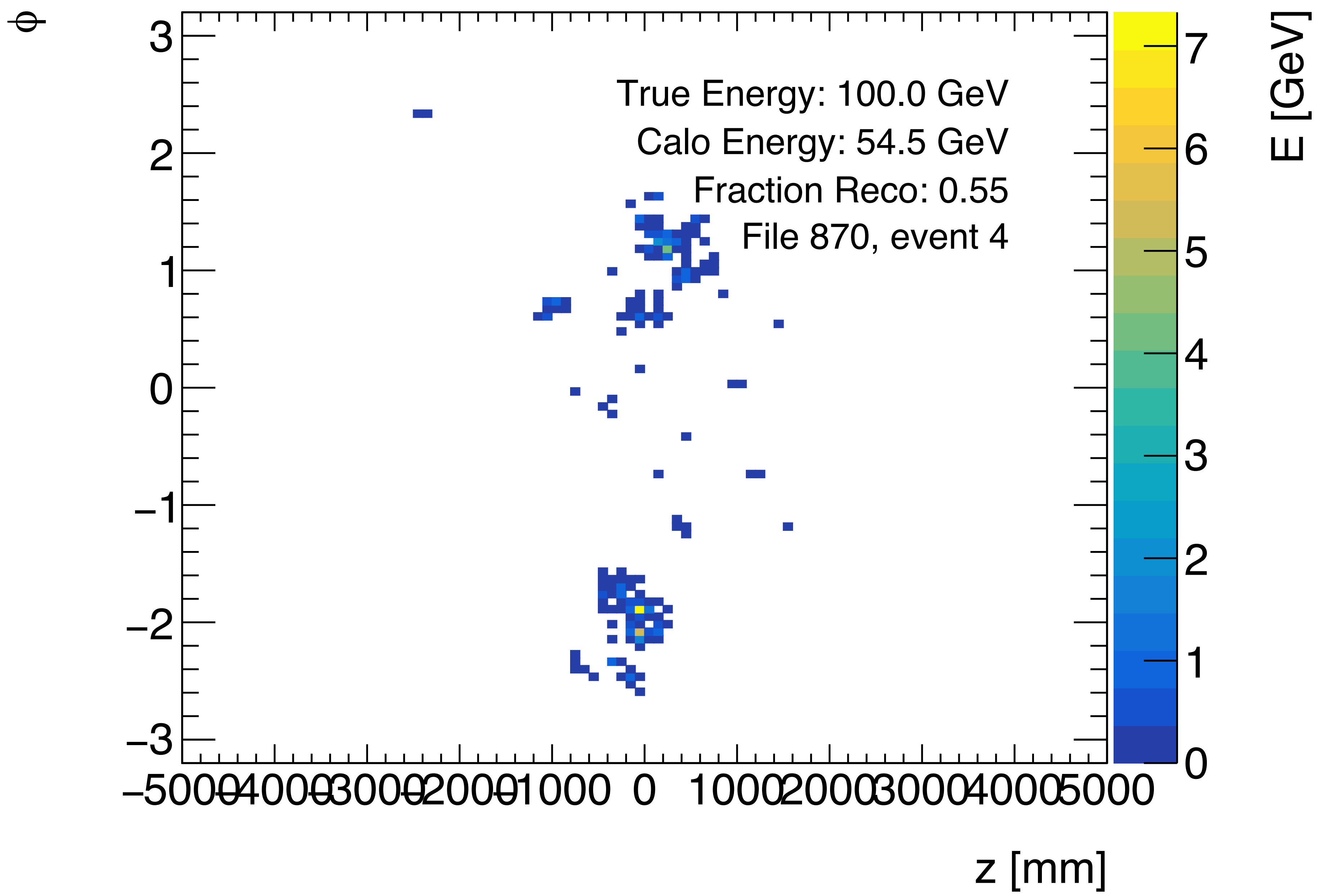
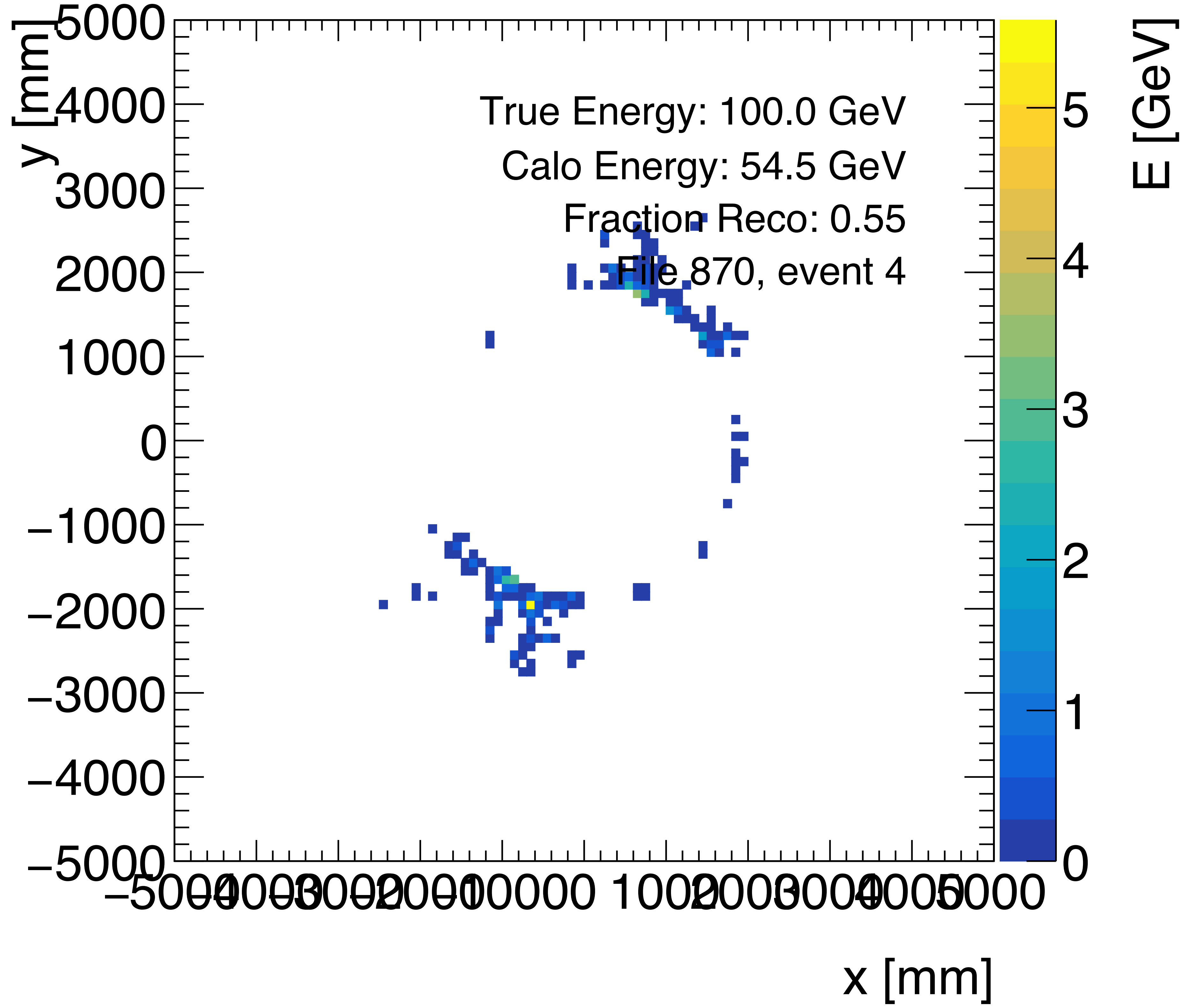


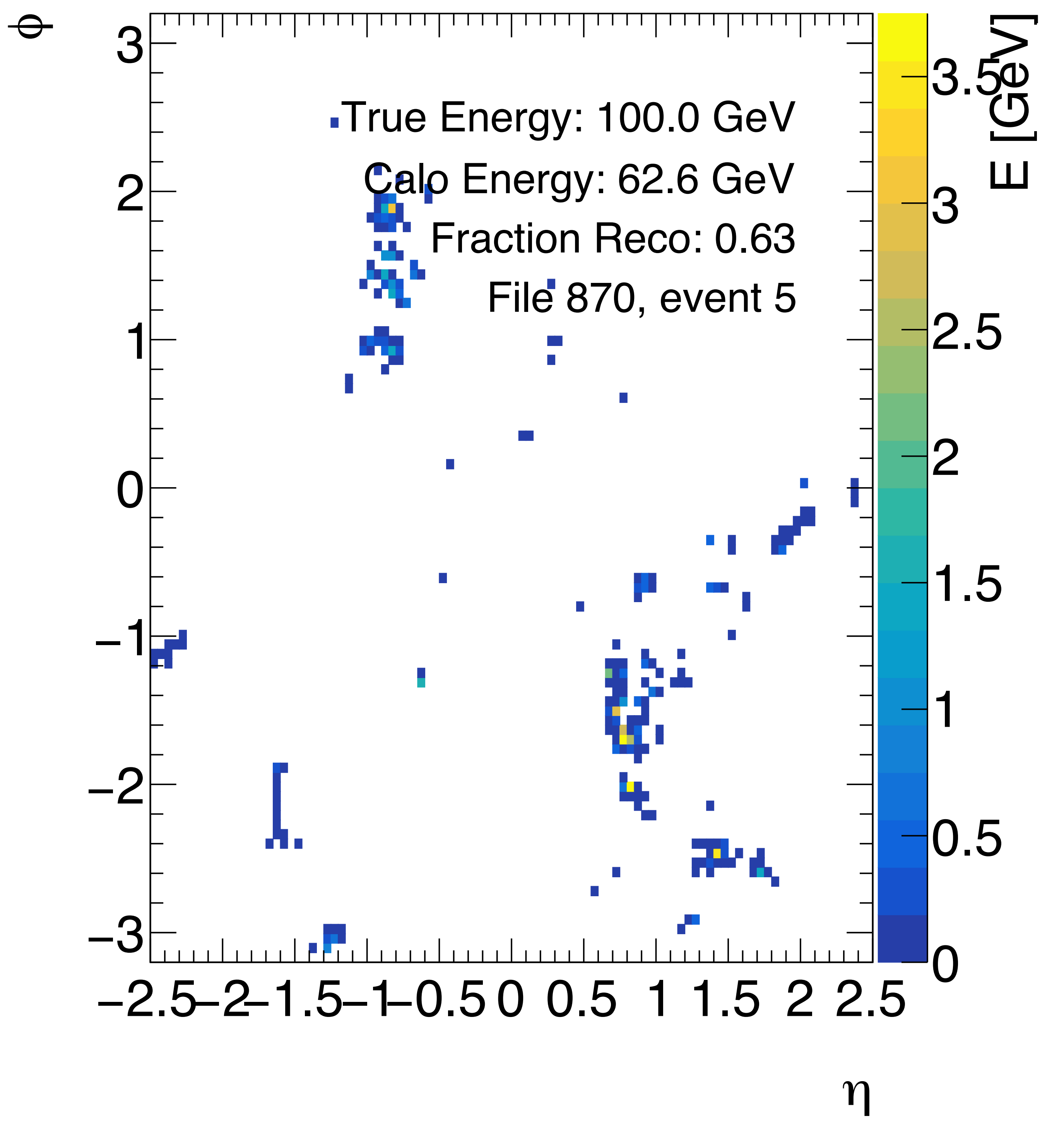


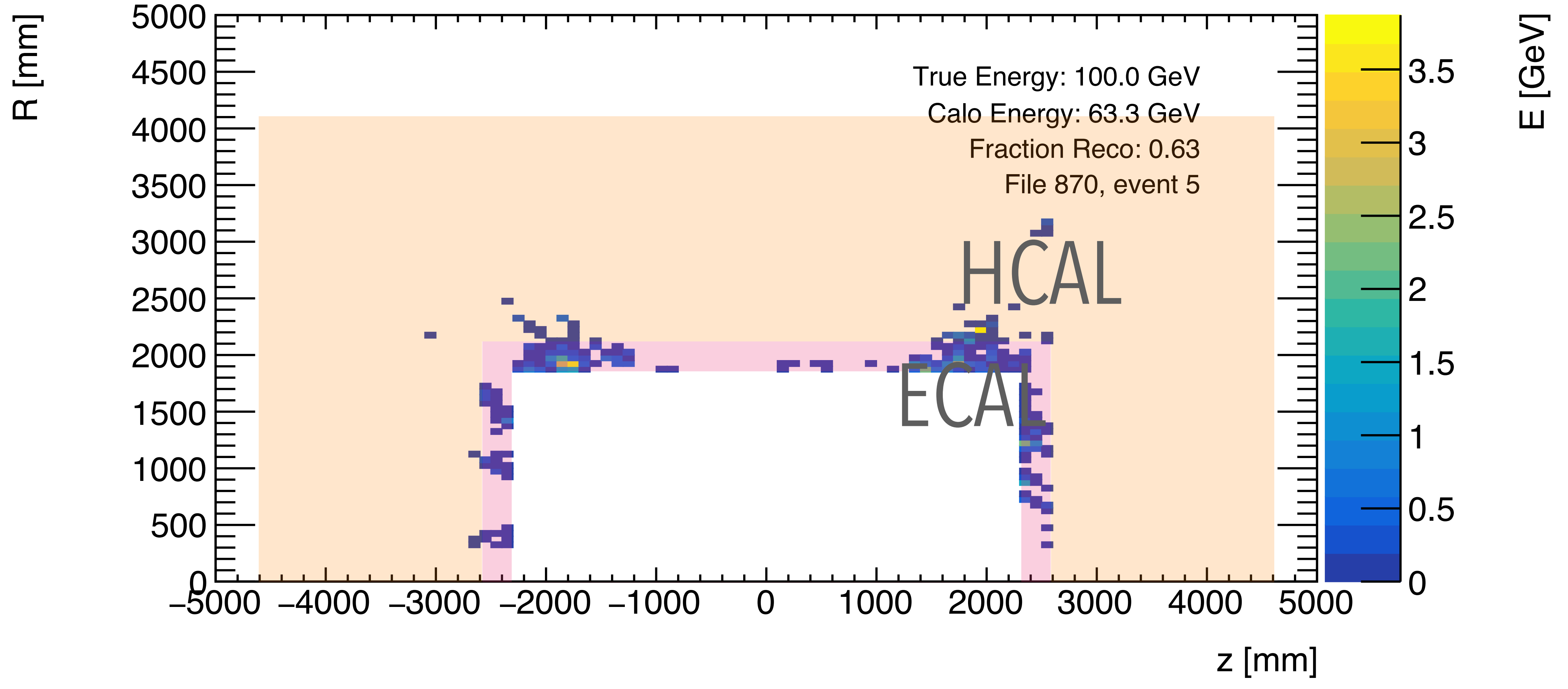


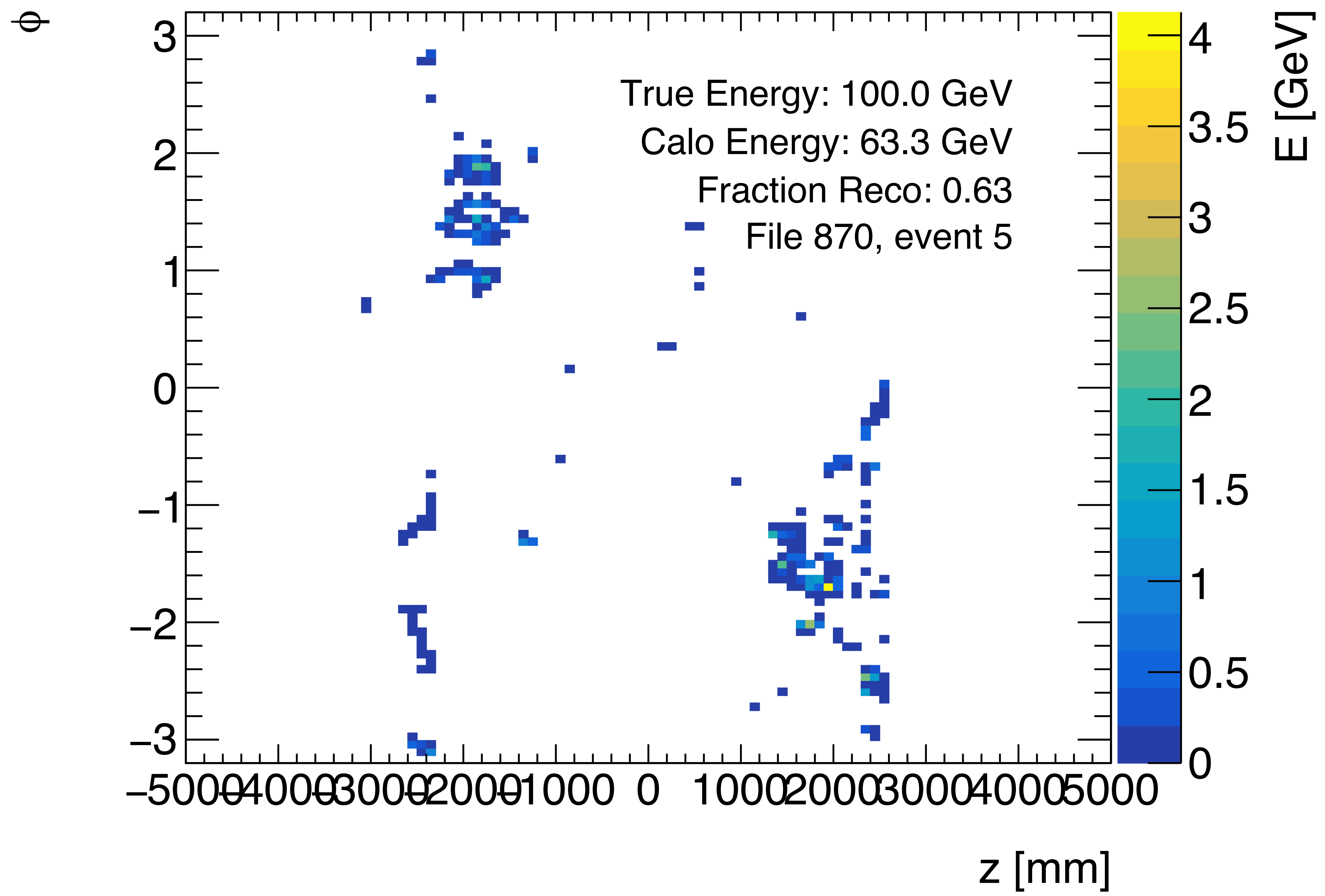


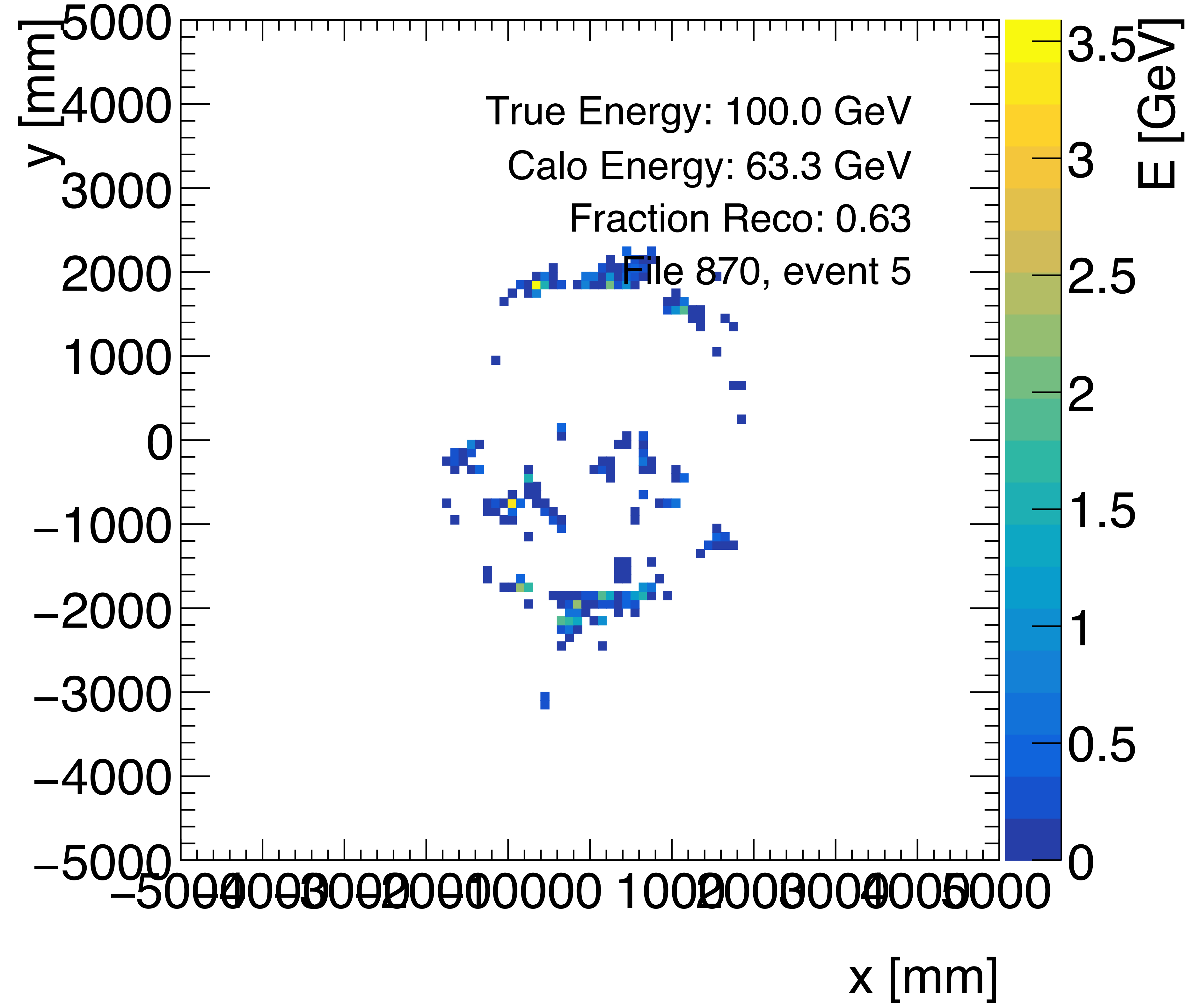
Visualizing jets

all digitized hits









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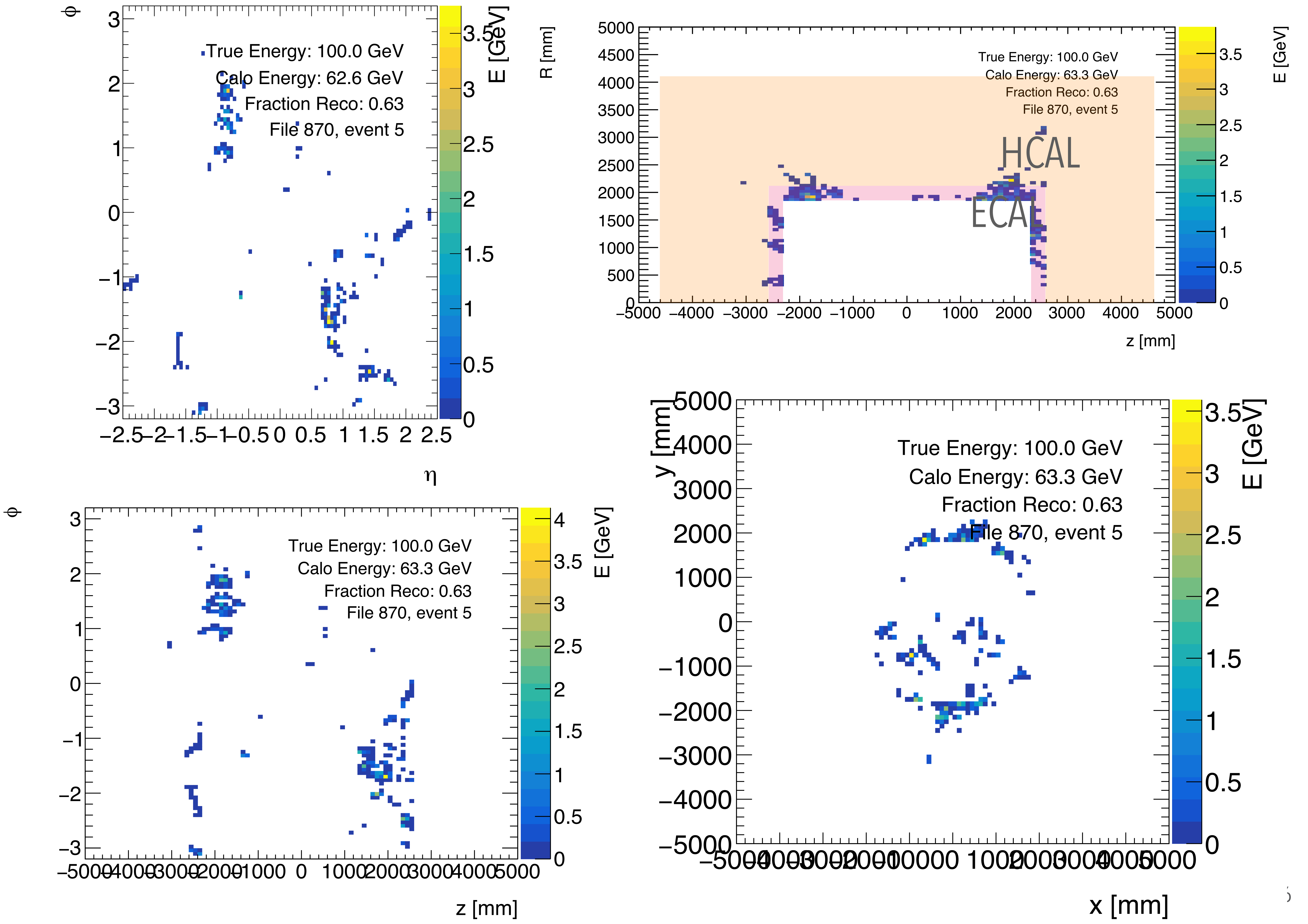
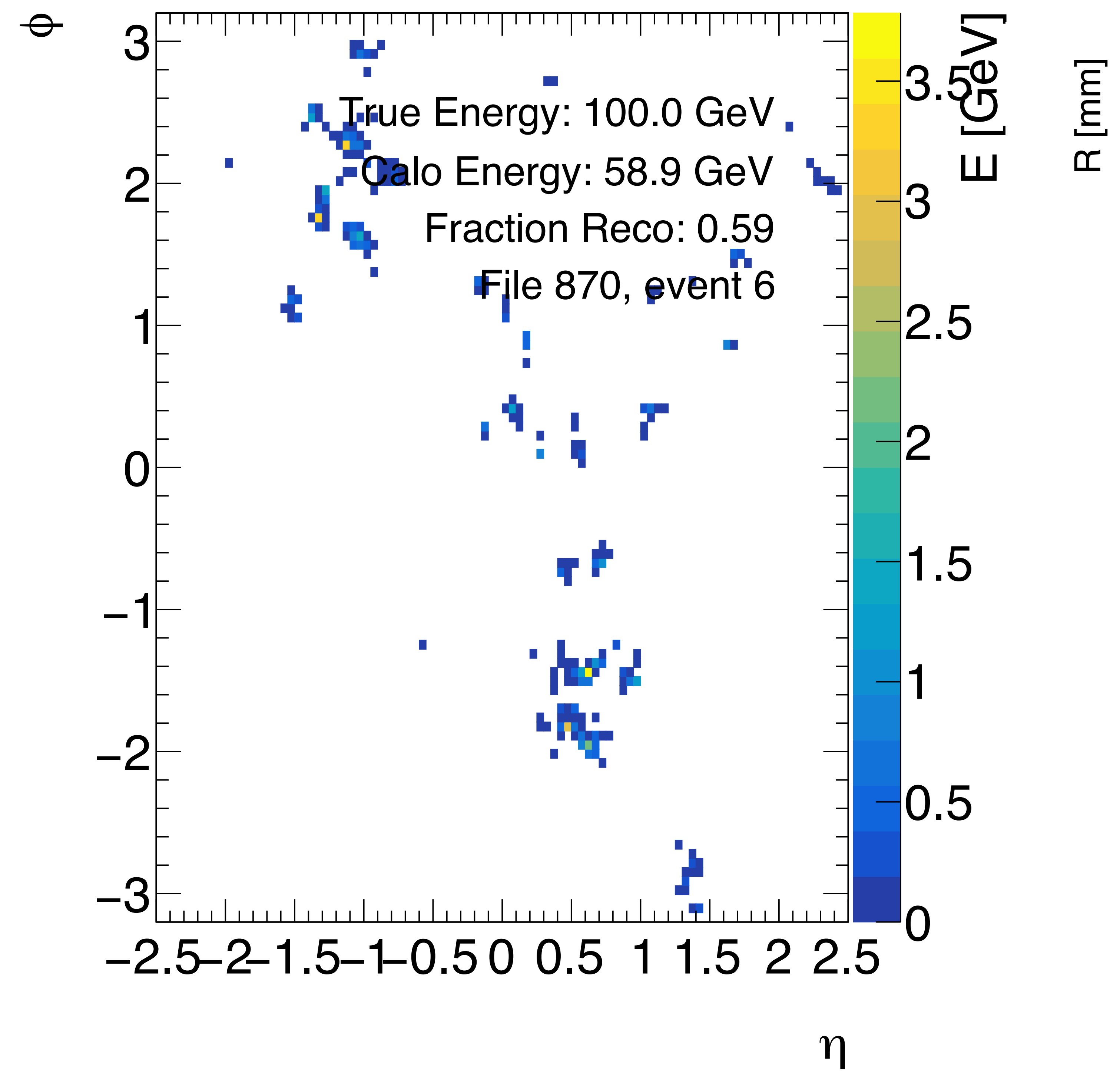
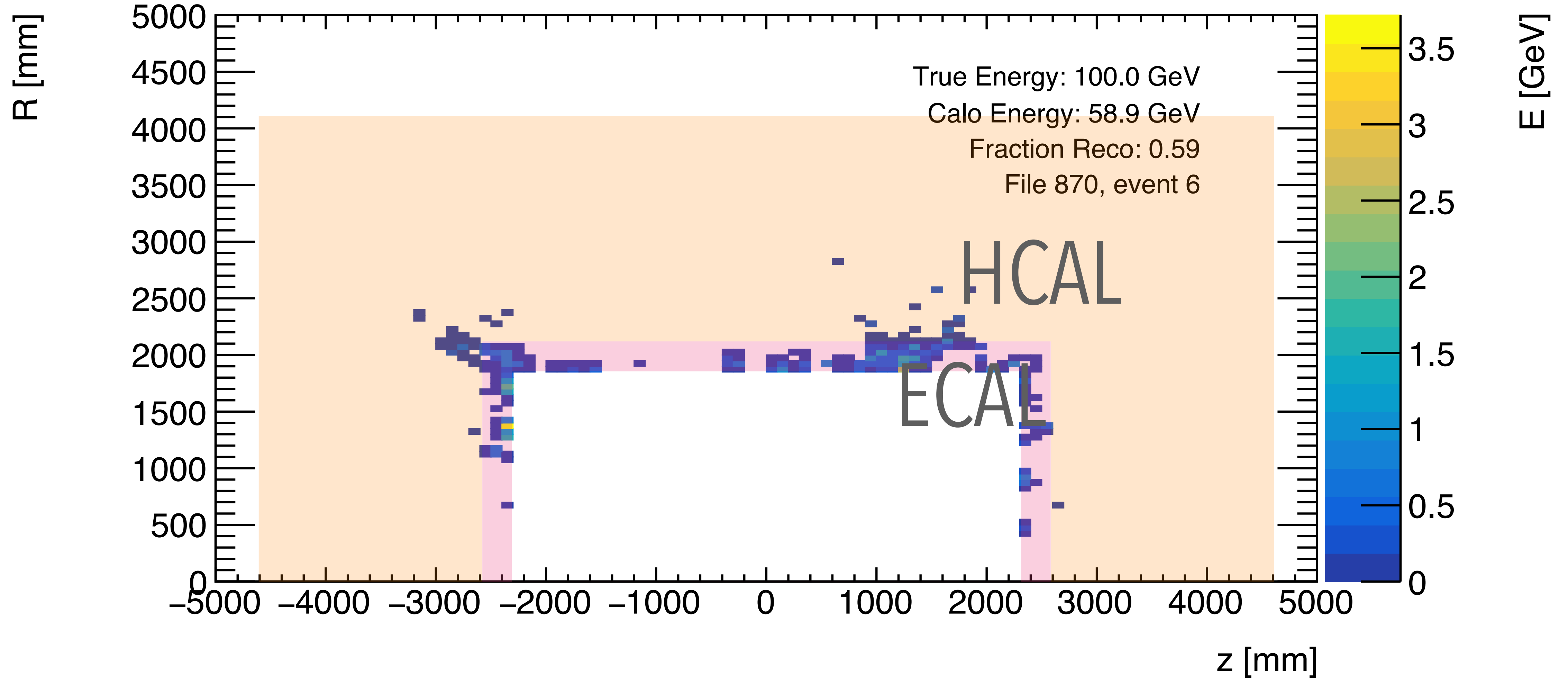
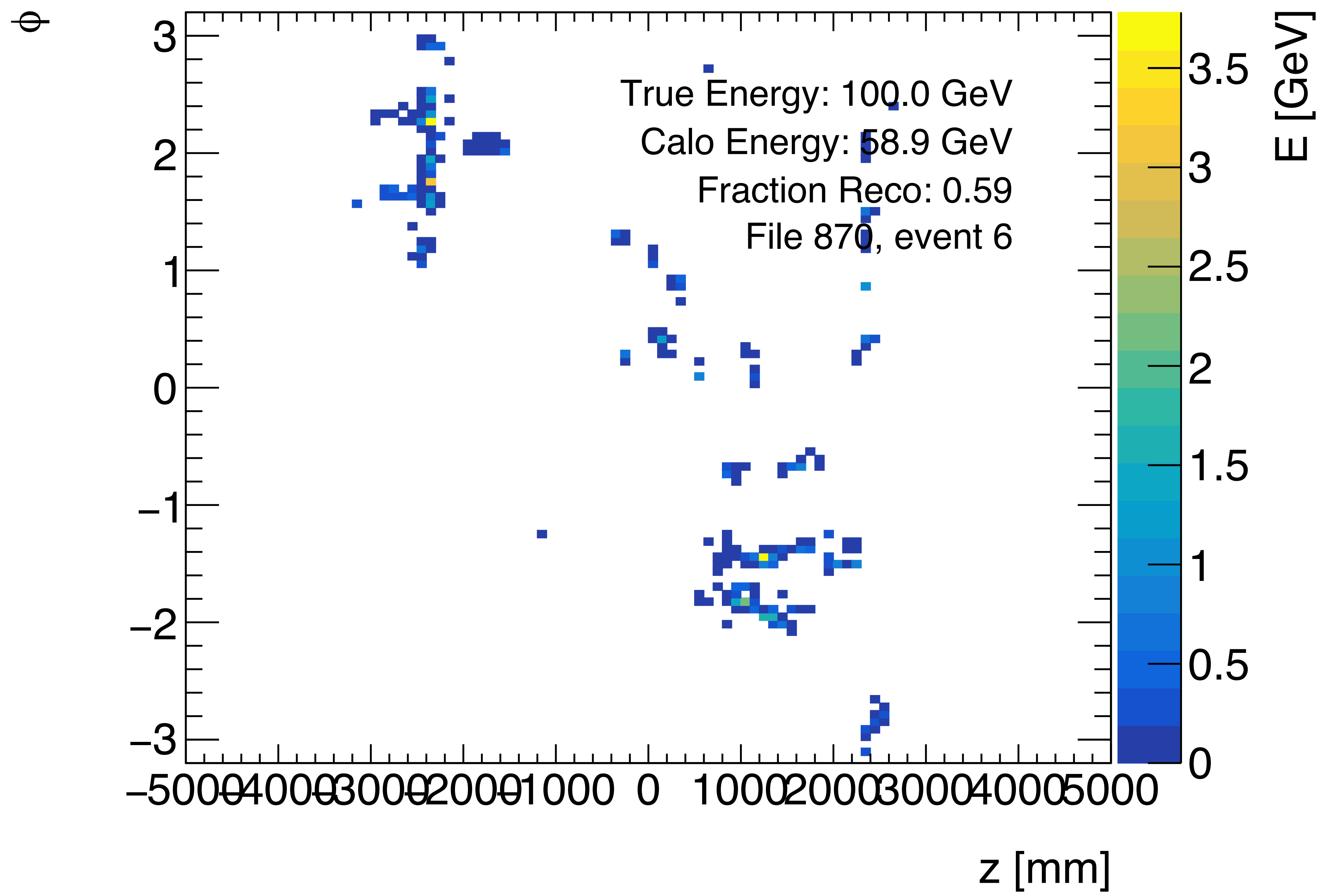


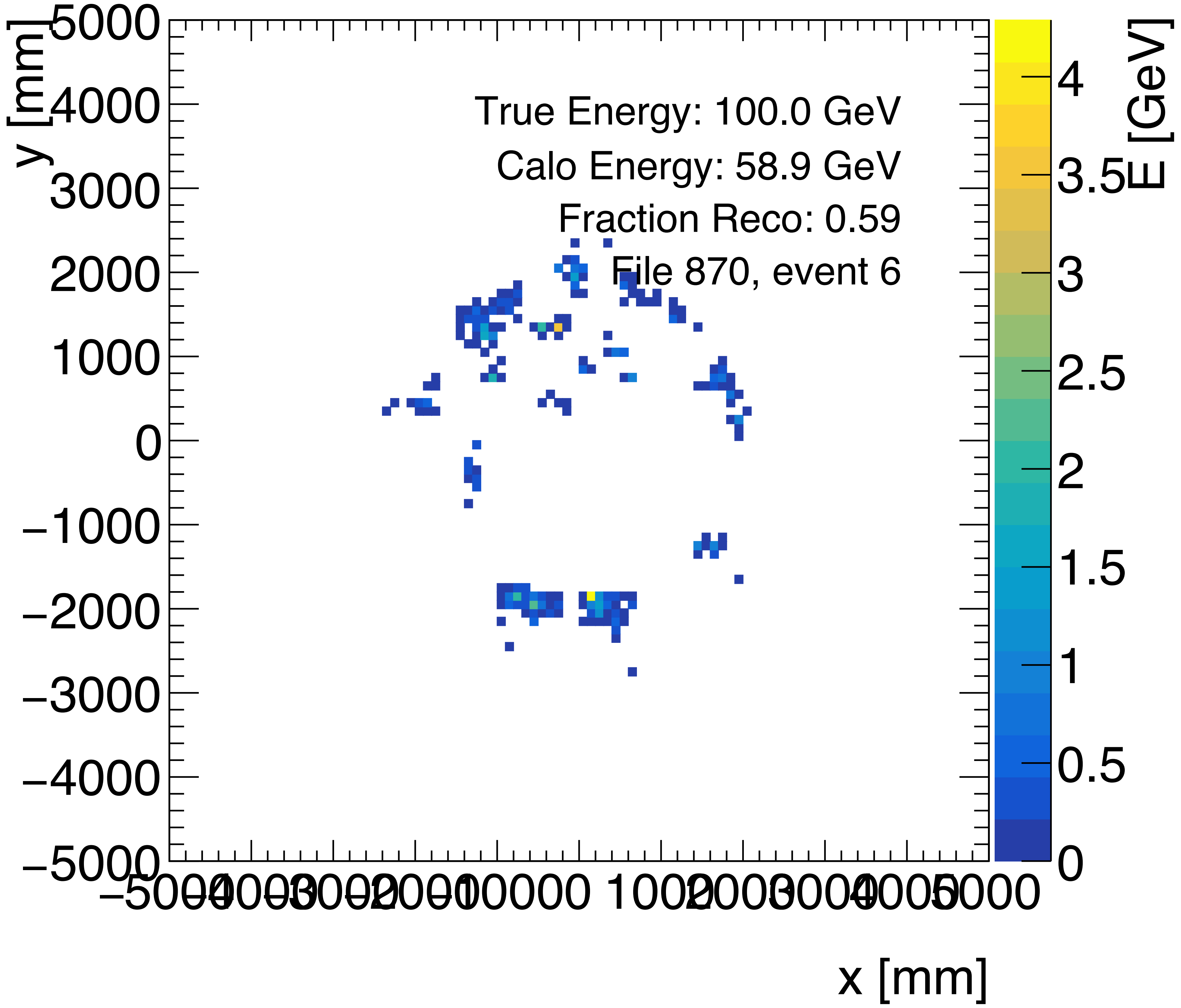
Visualizing jets

all digitized hits



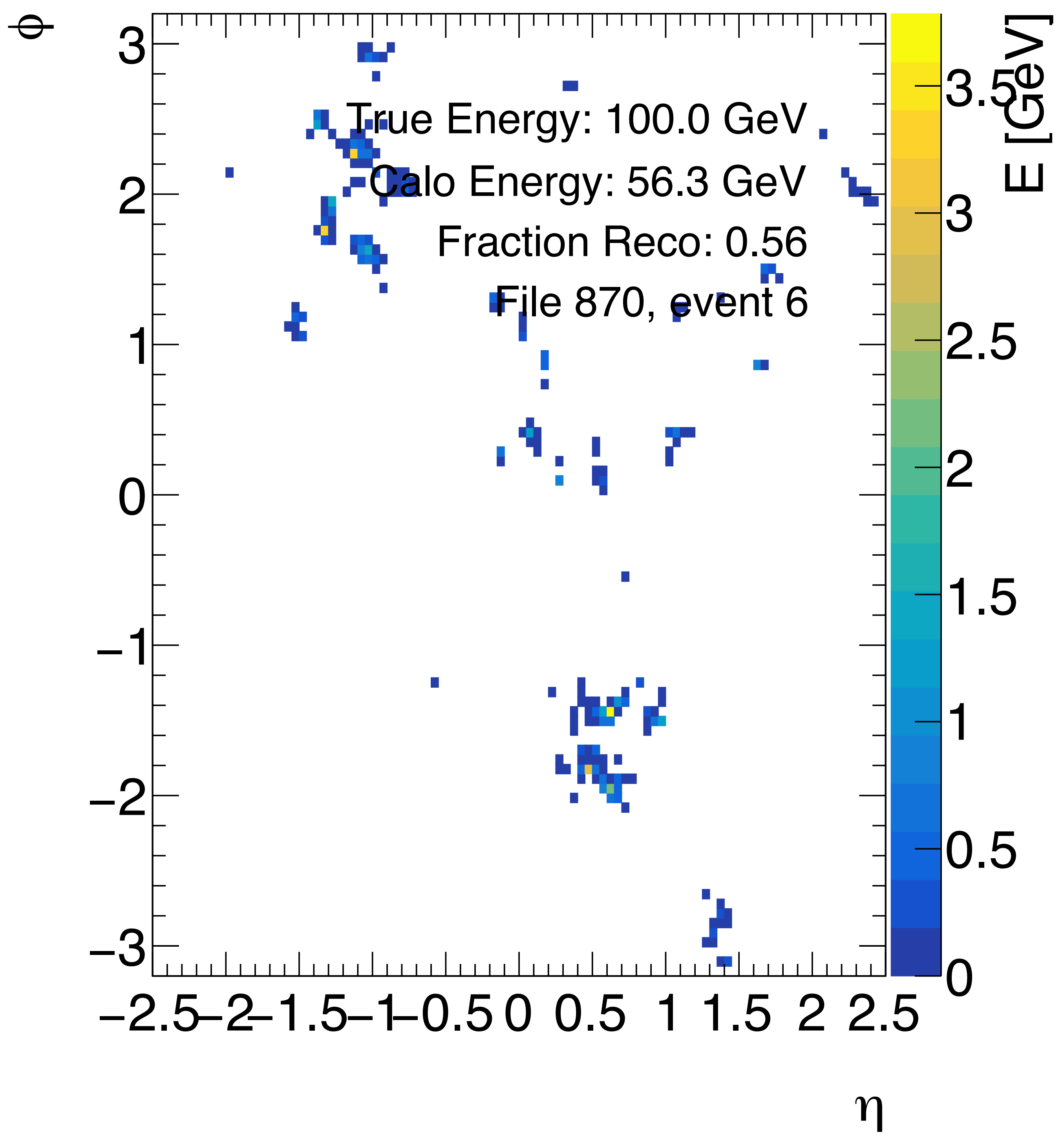


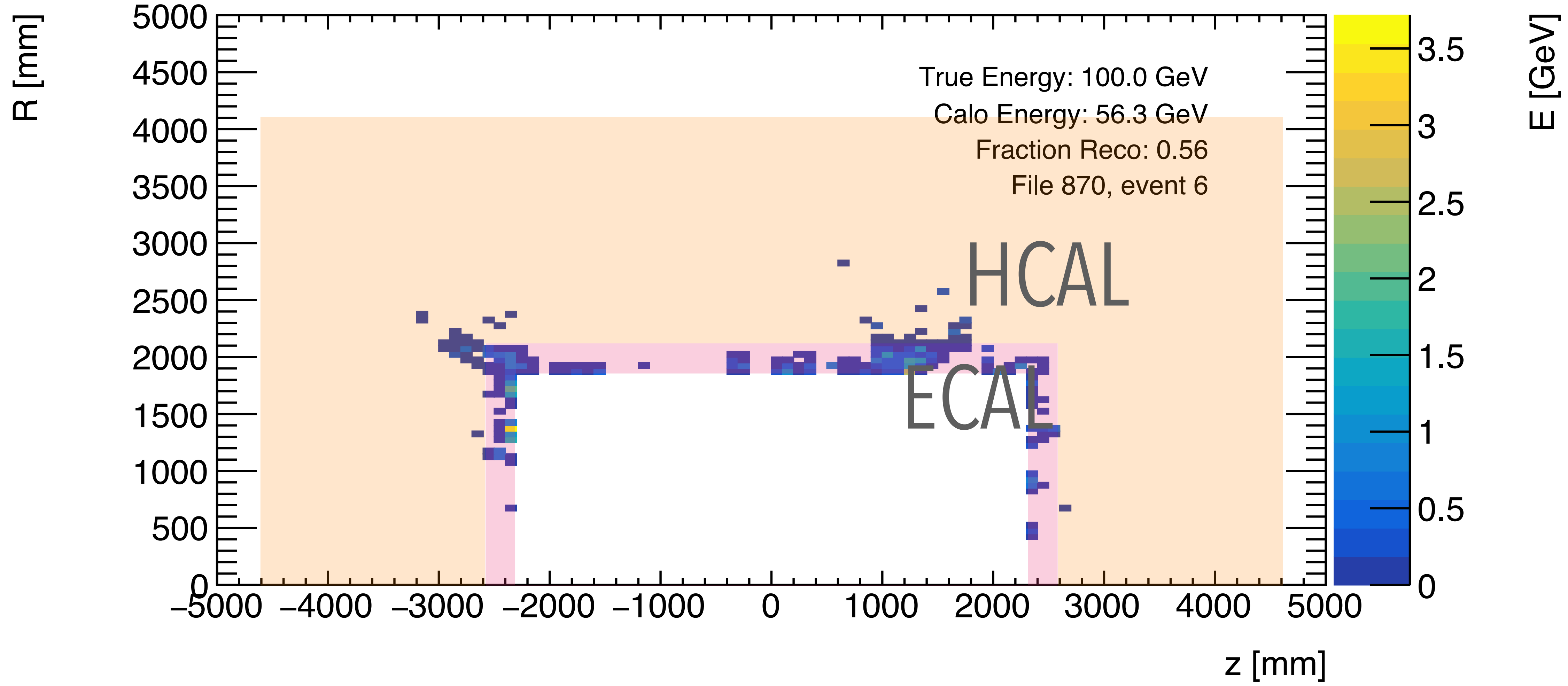


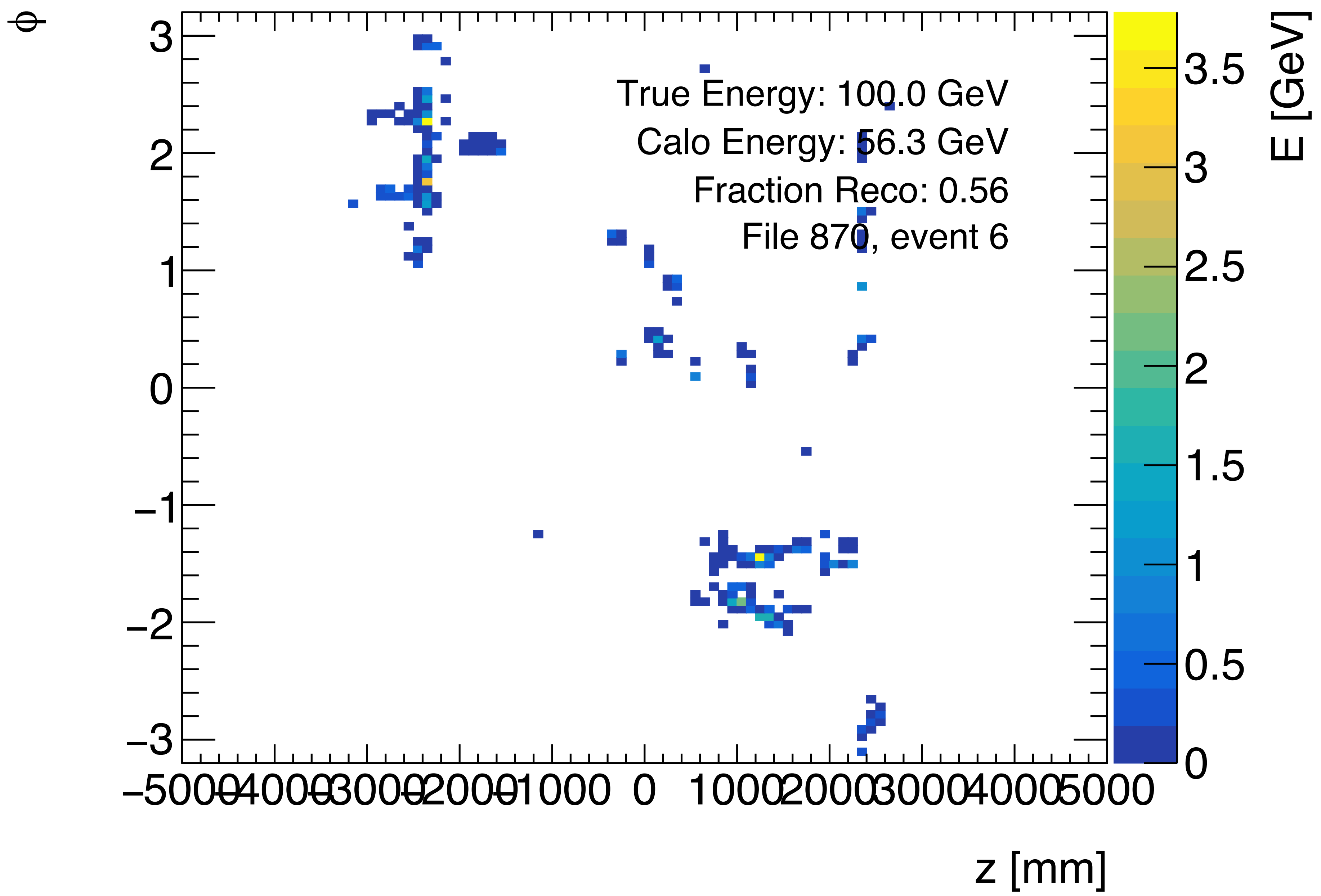


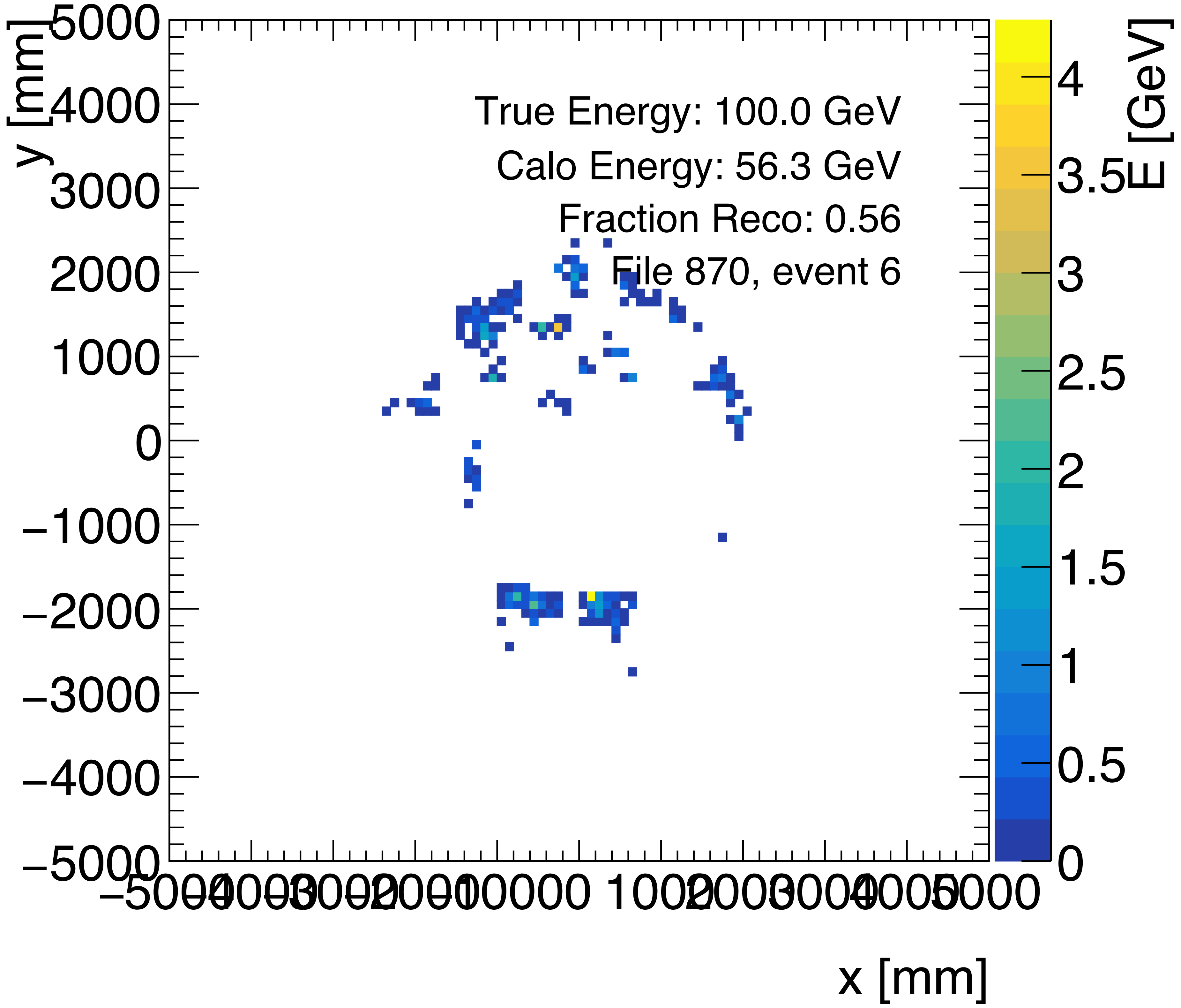
Visualizing jets

selected by threshold + coned



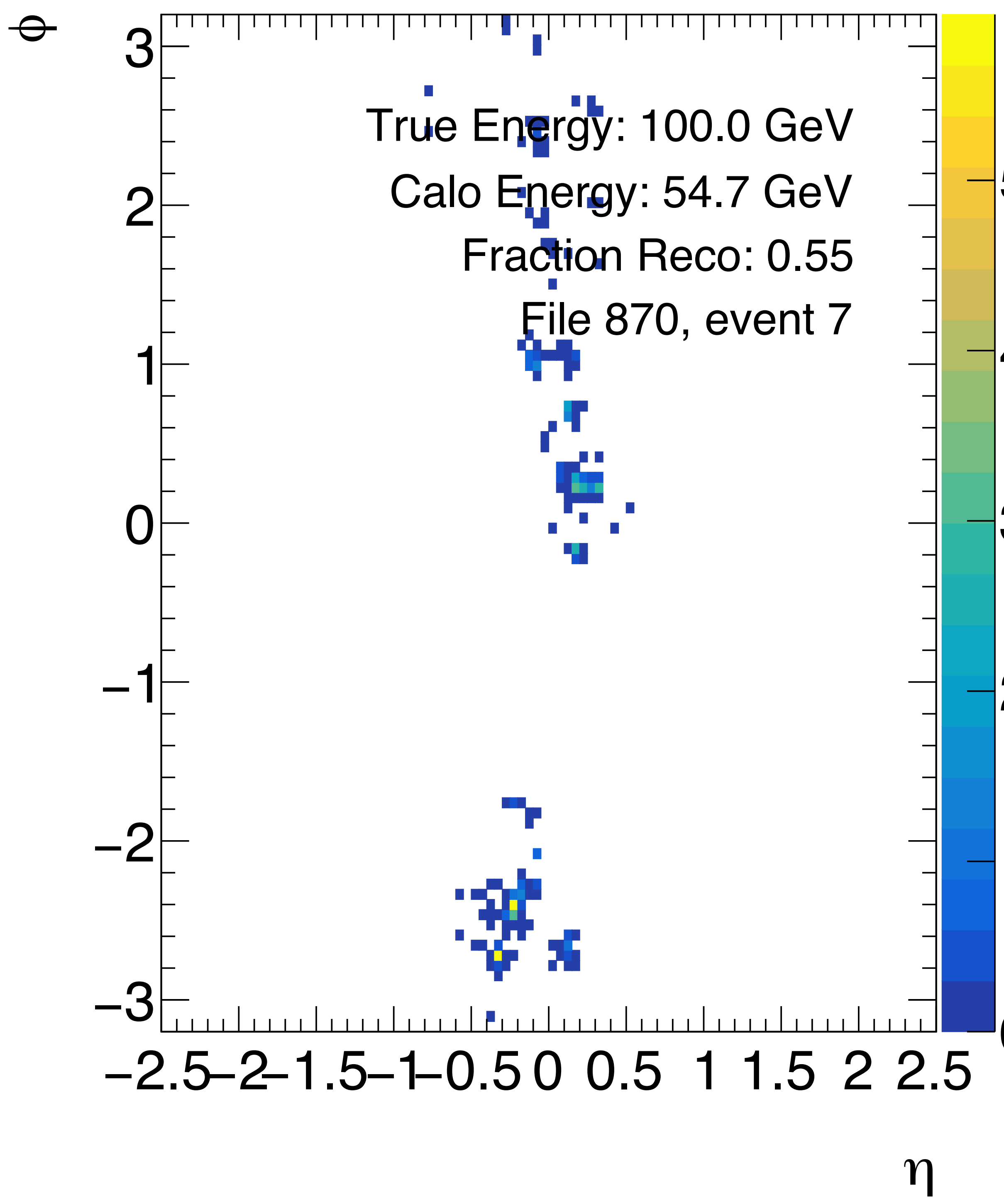


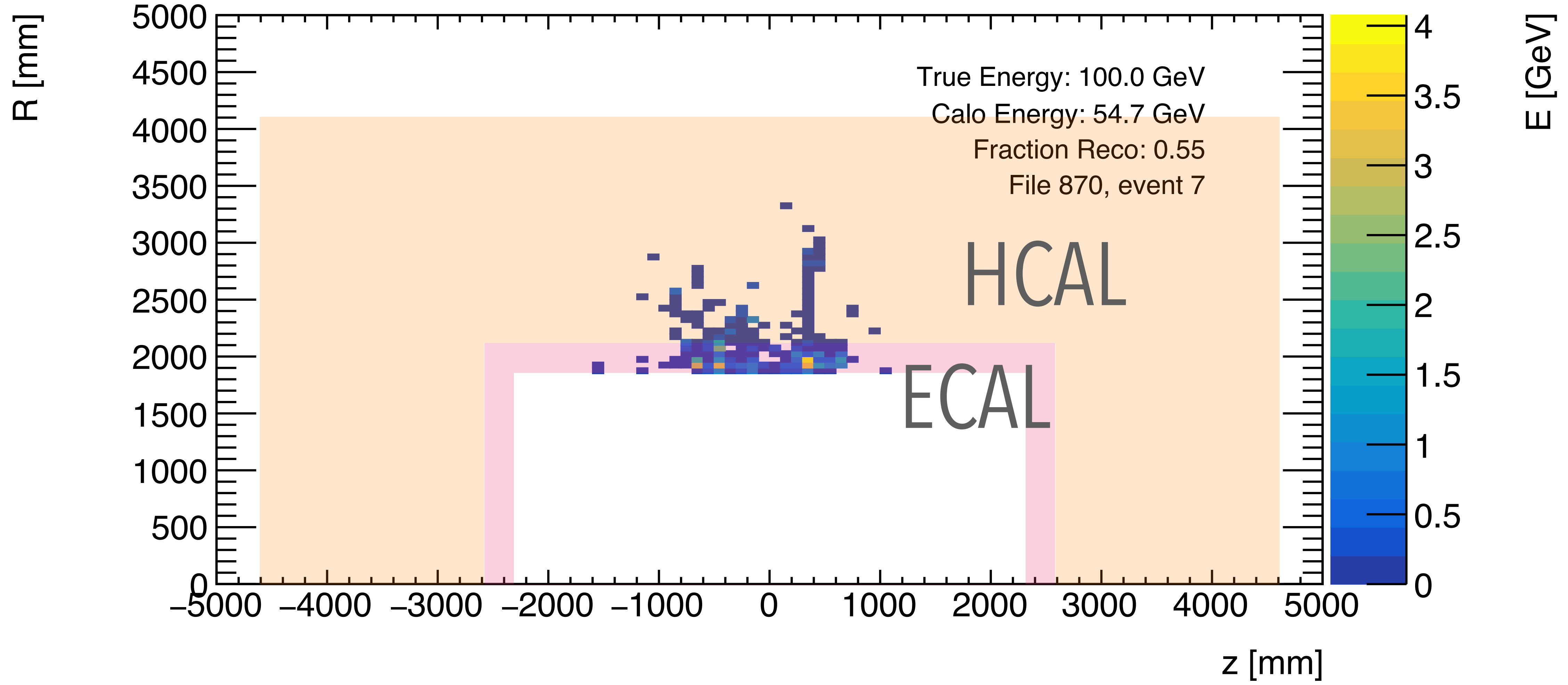


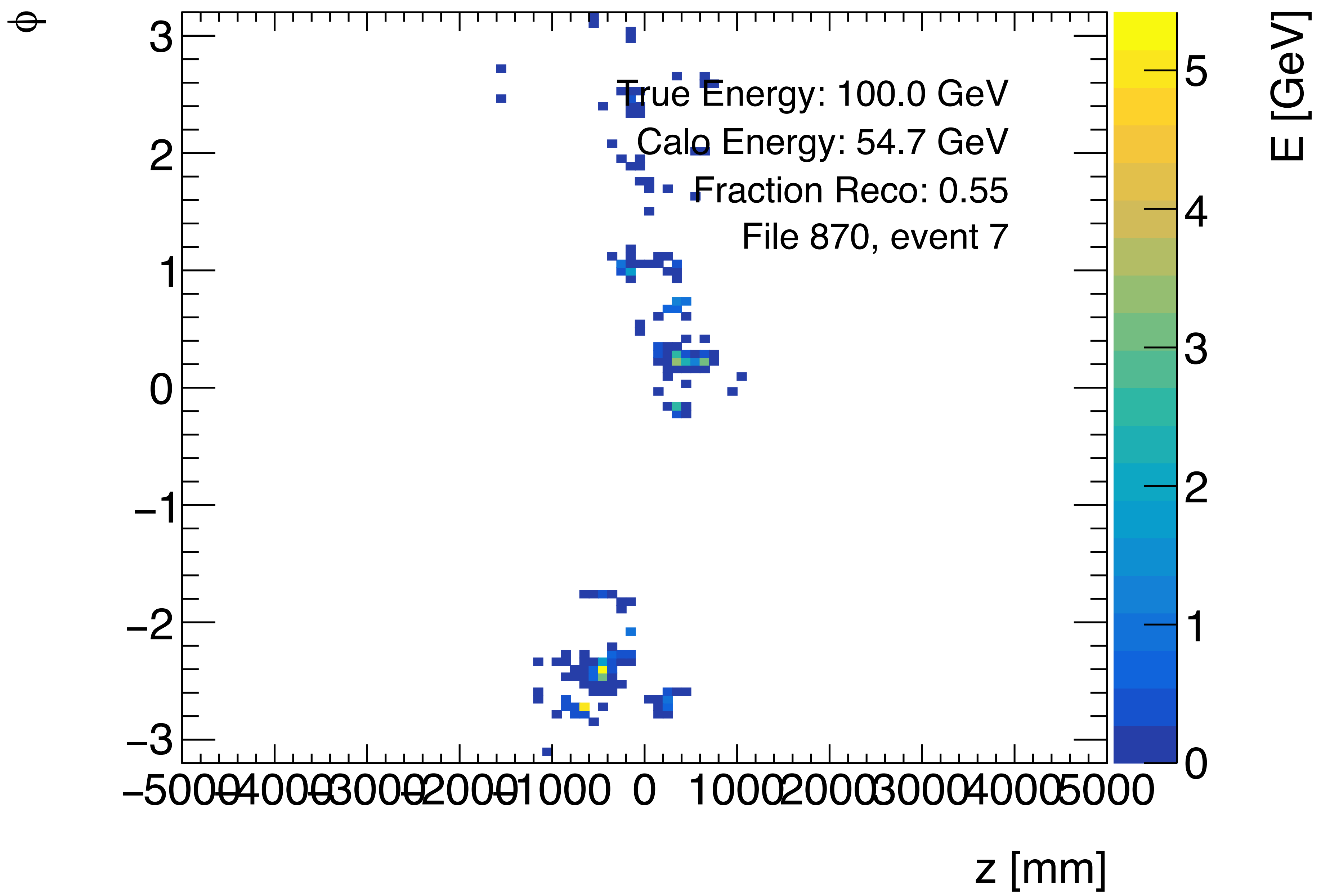


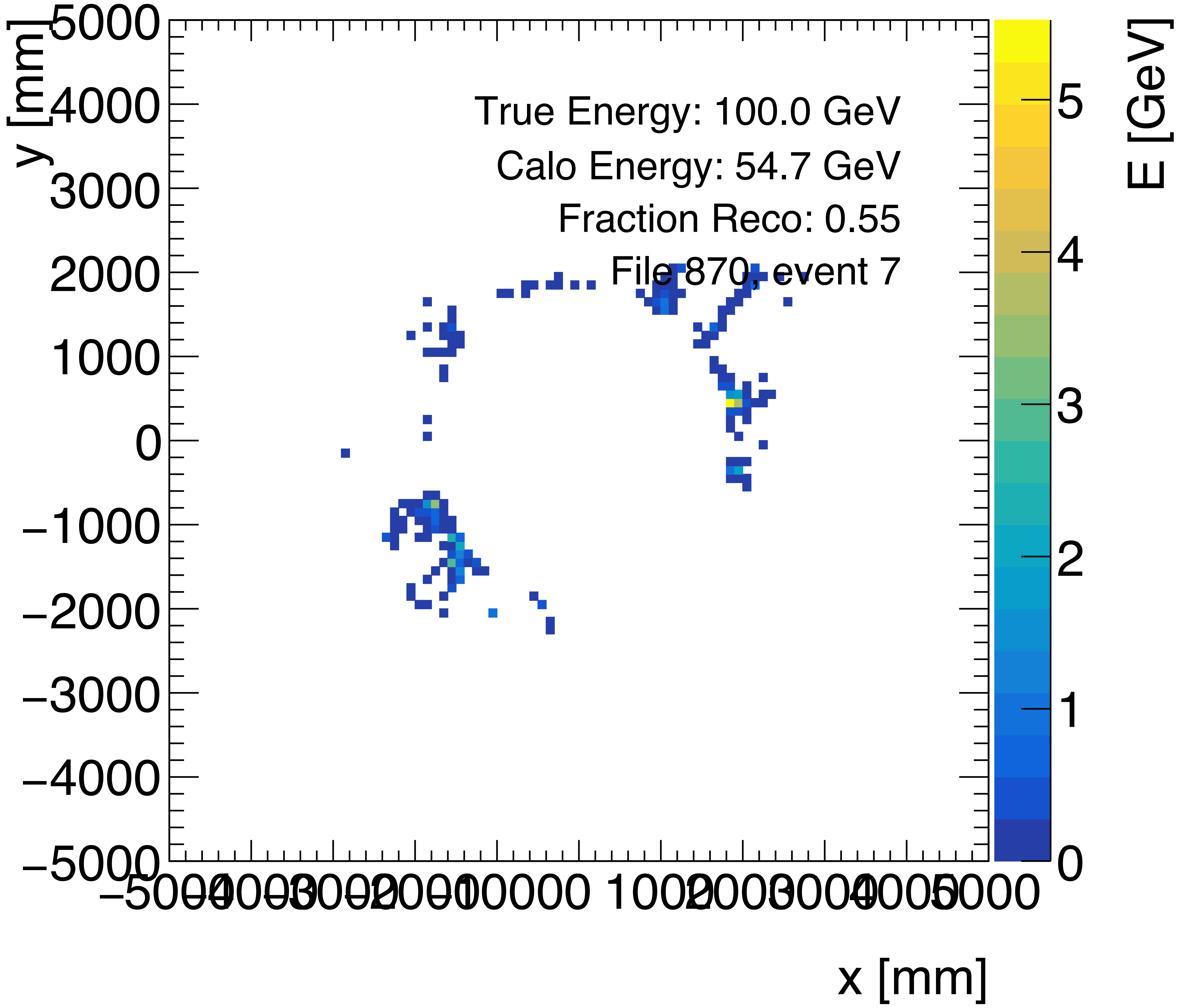
Visualizing jets

all digitized hits

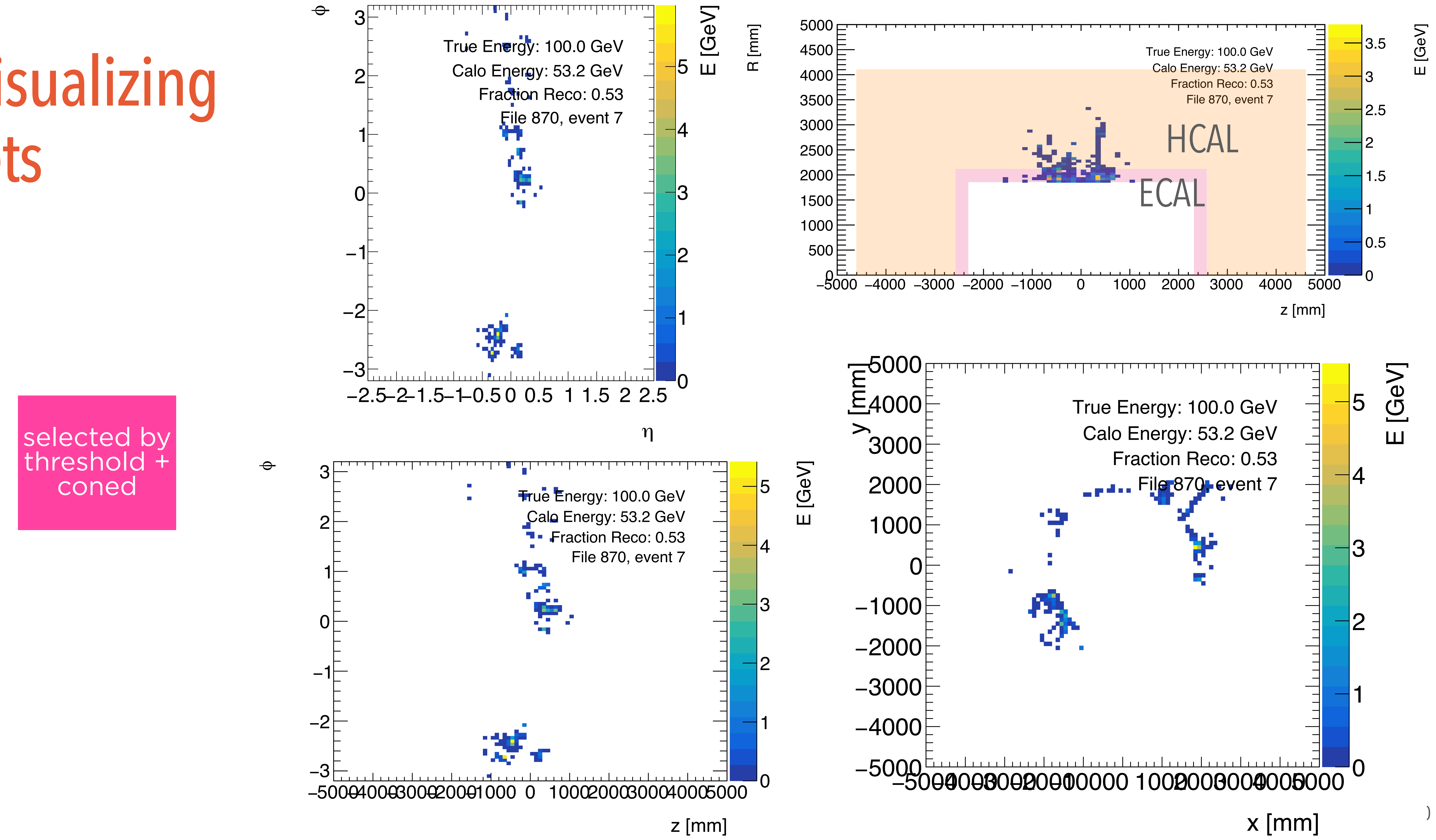




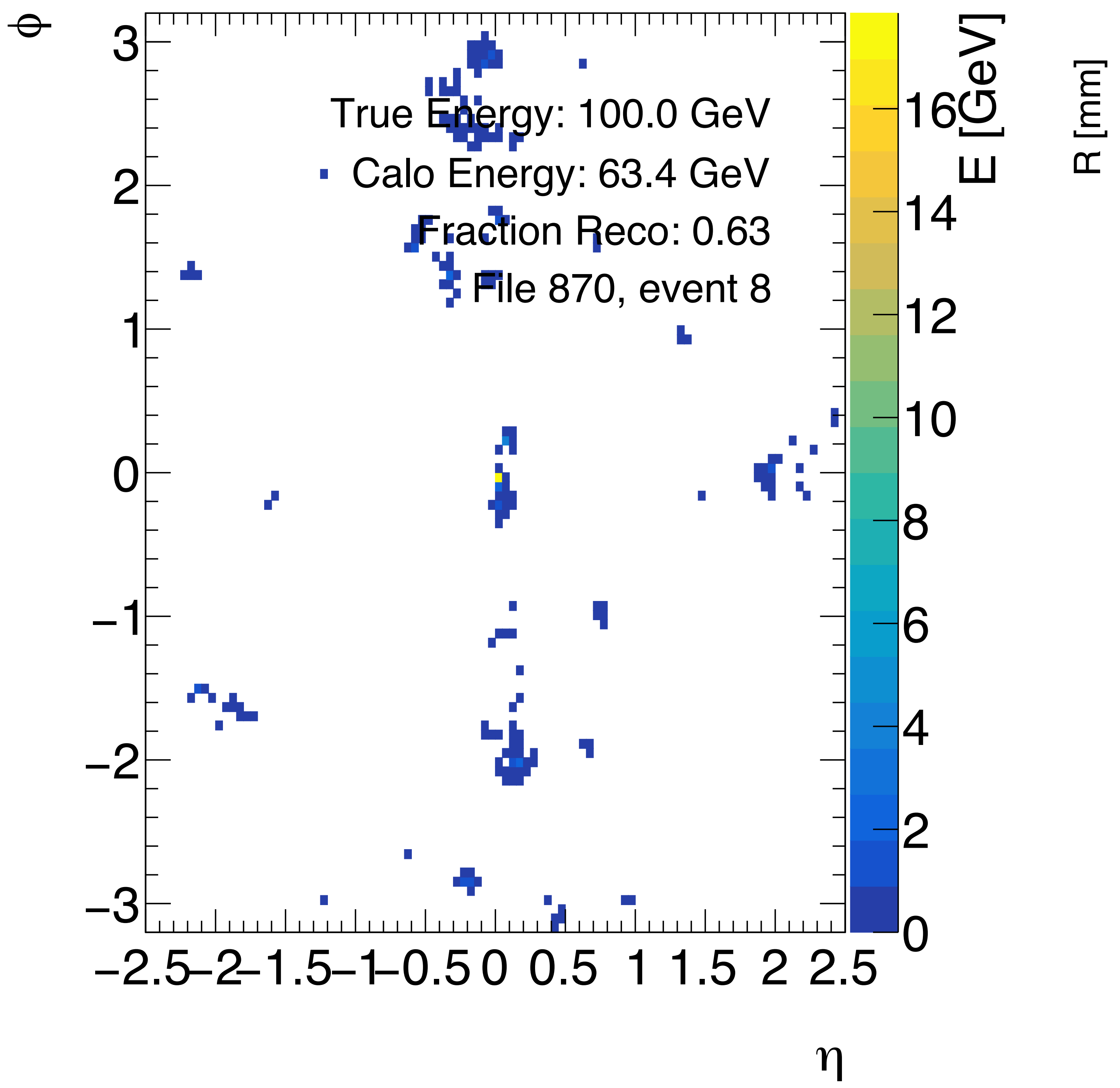


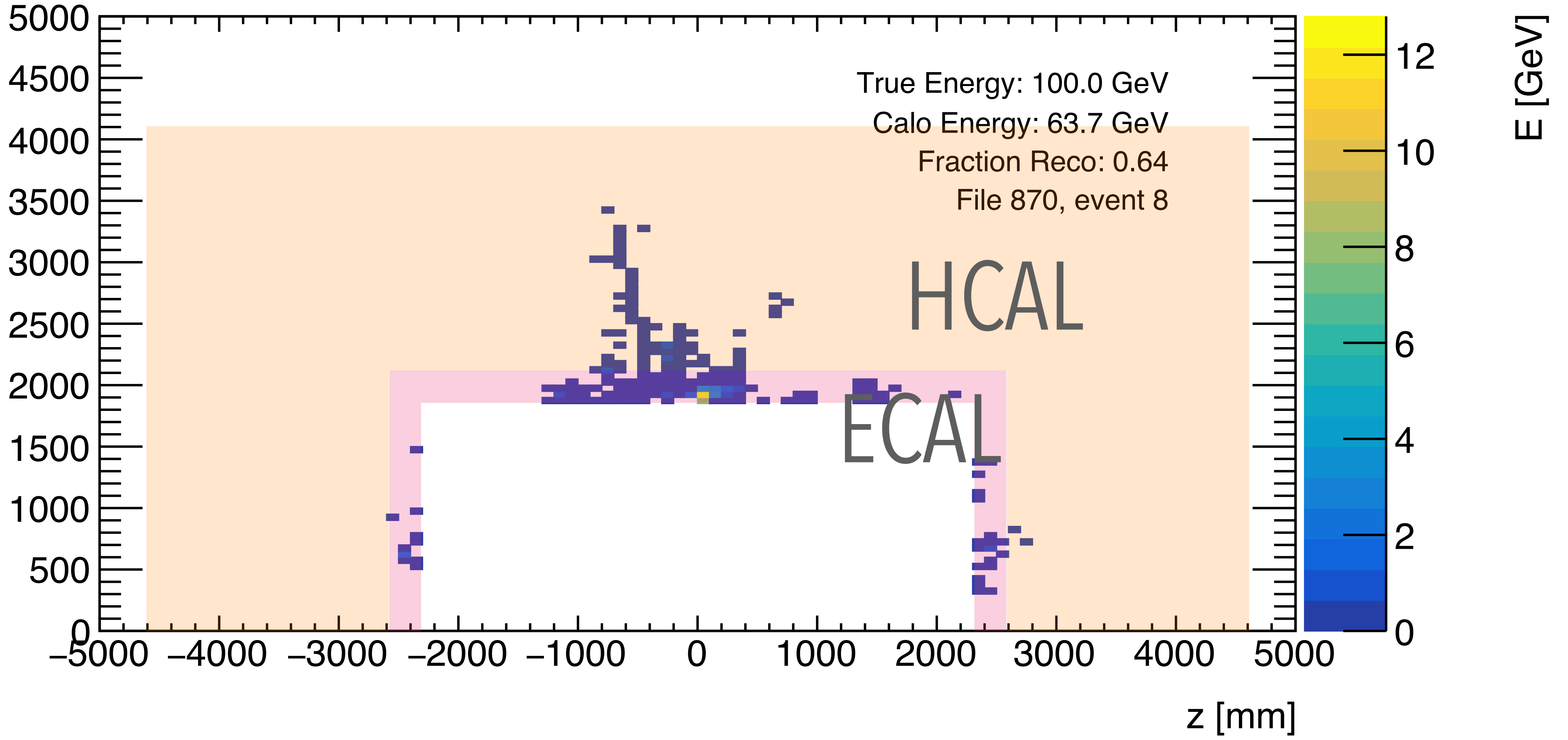


Visualizing jets

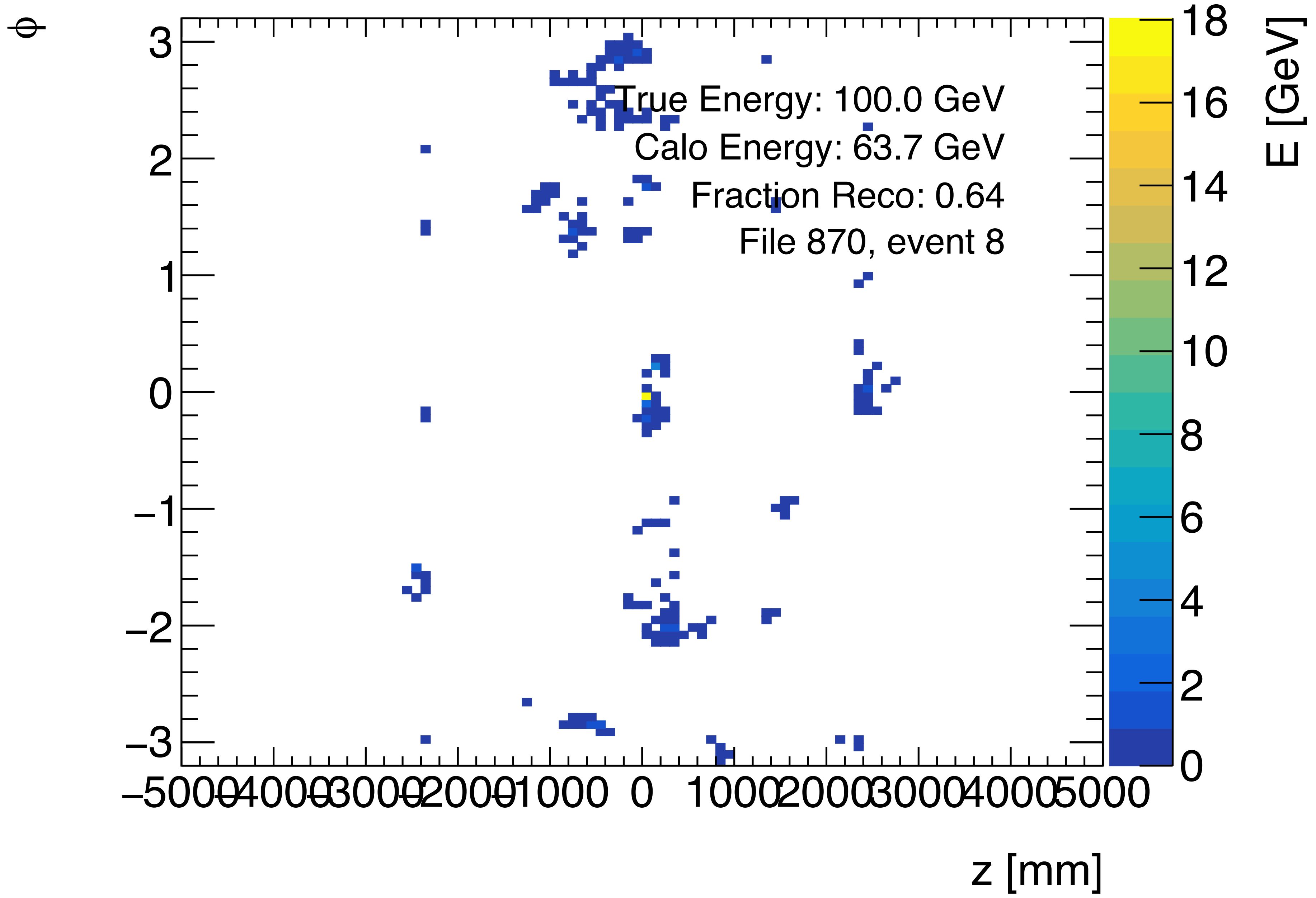


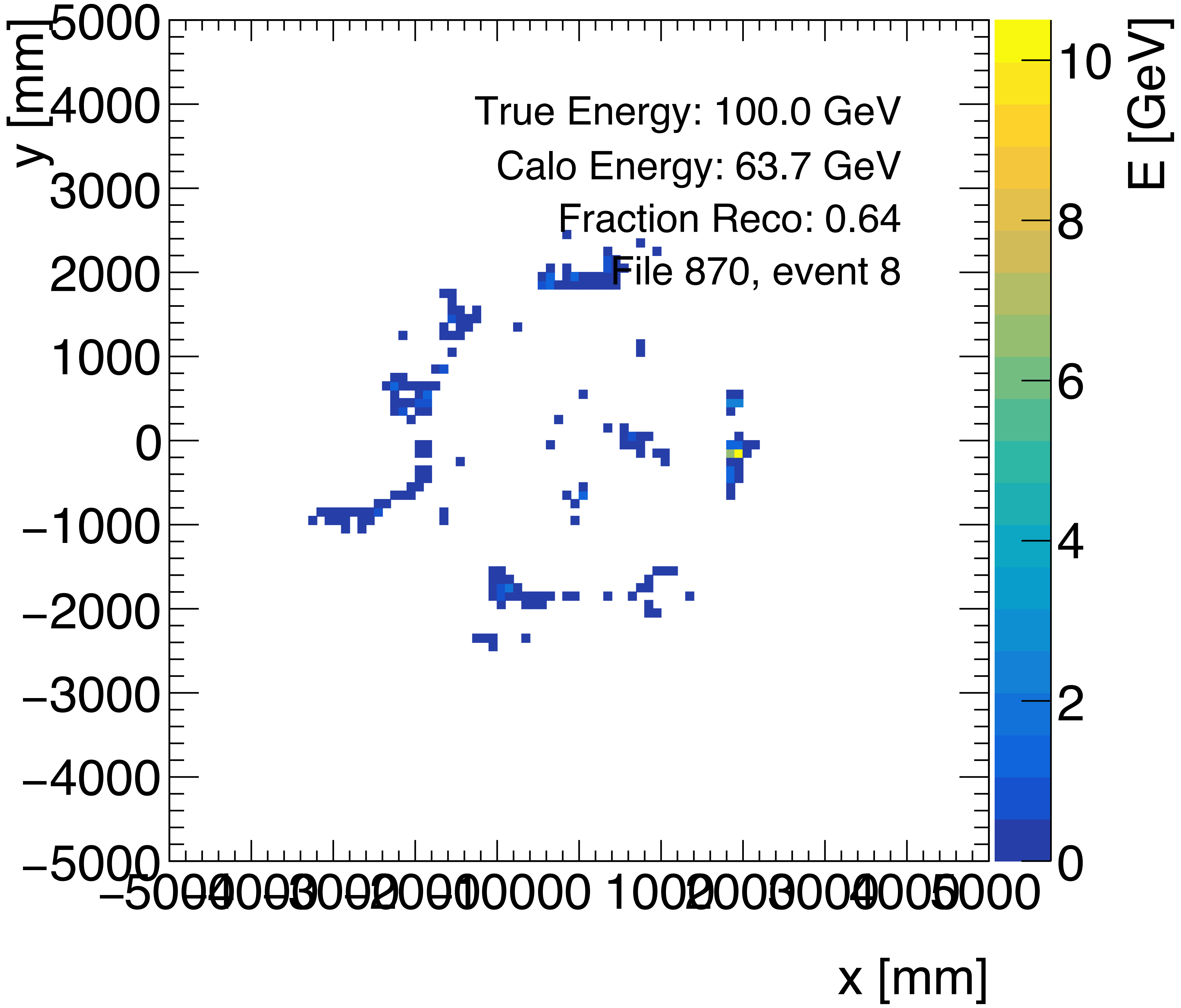
Visualizing jets





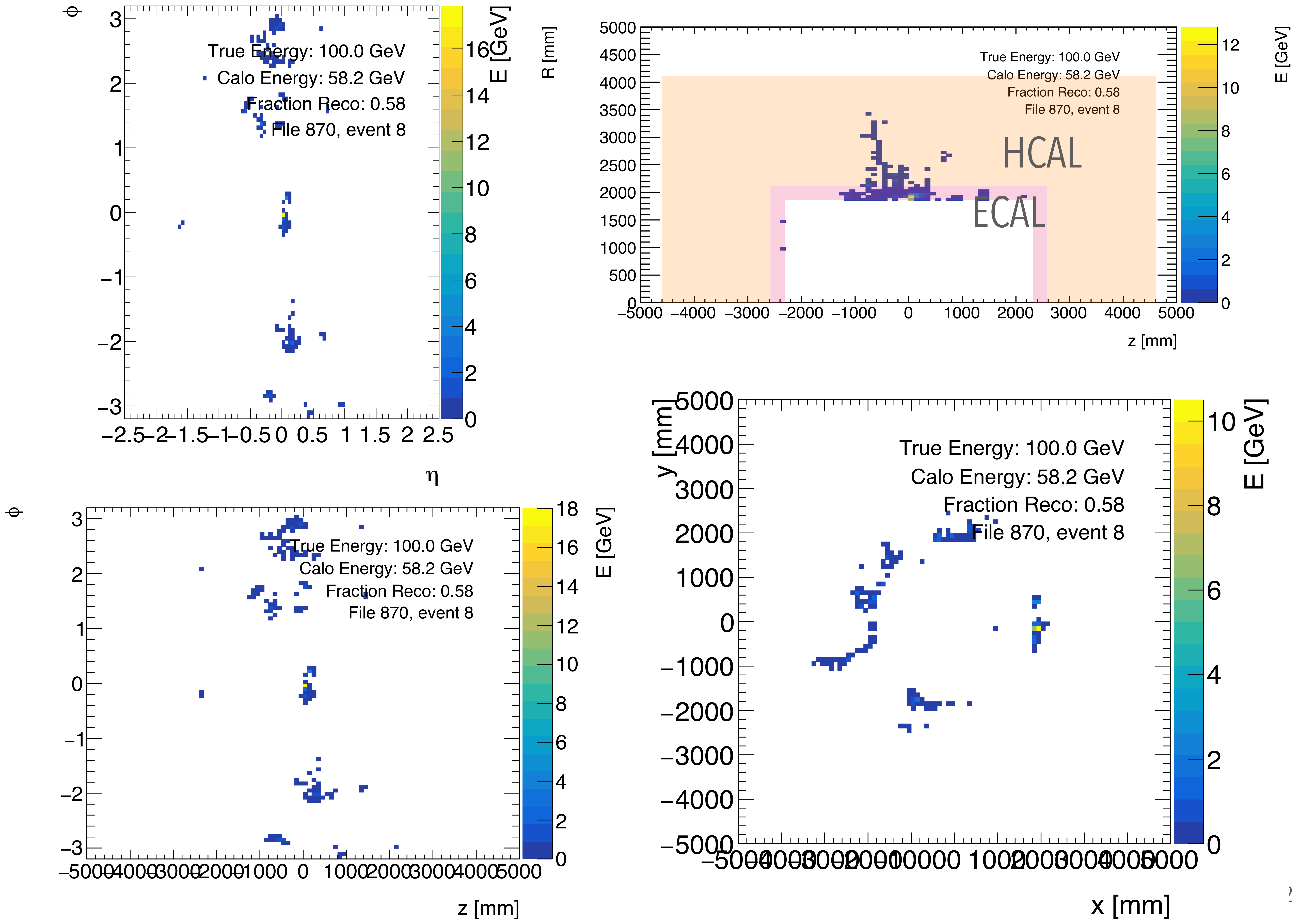
all digitized hits





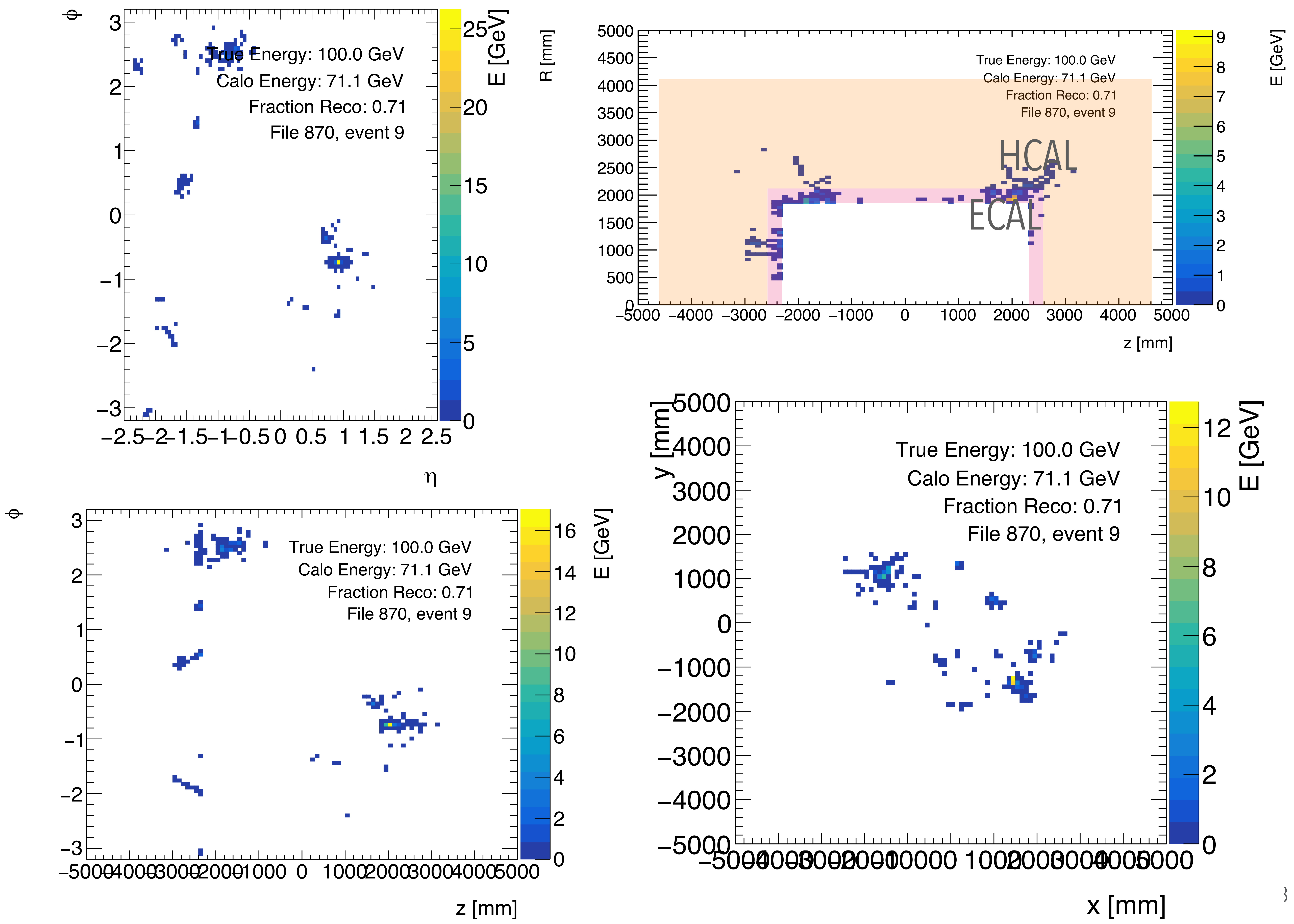
Visualizing jets

selected by threshold + coned



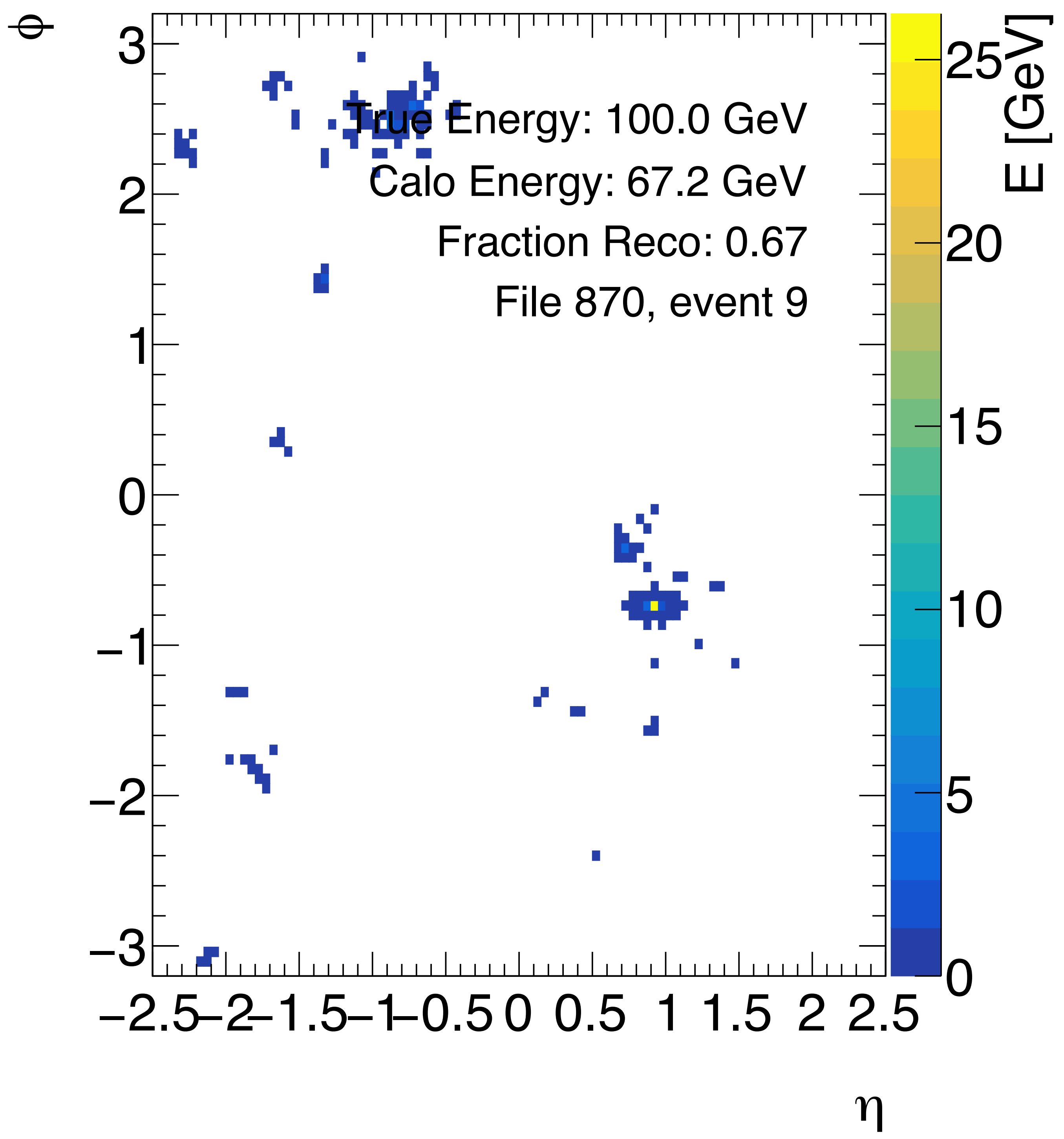
Visualizing jets

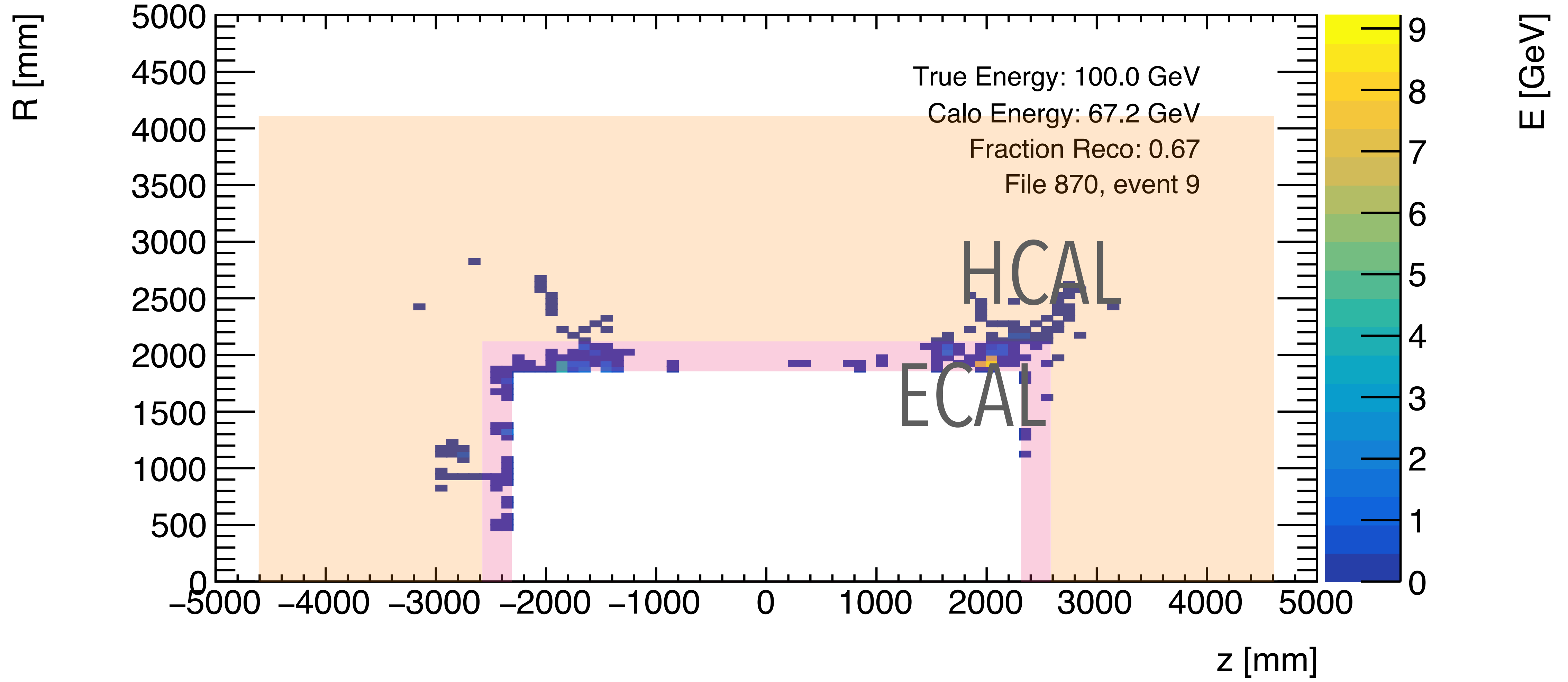
all digitized hits

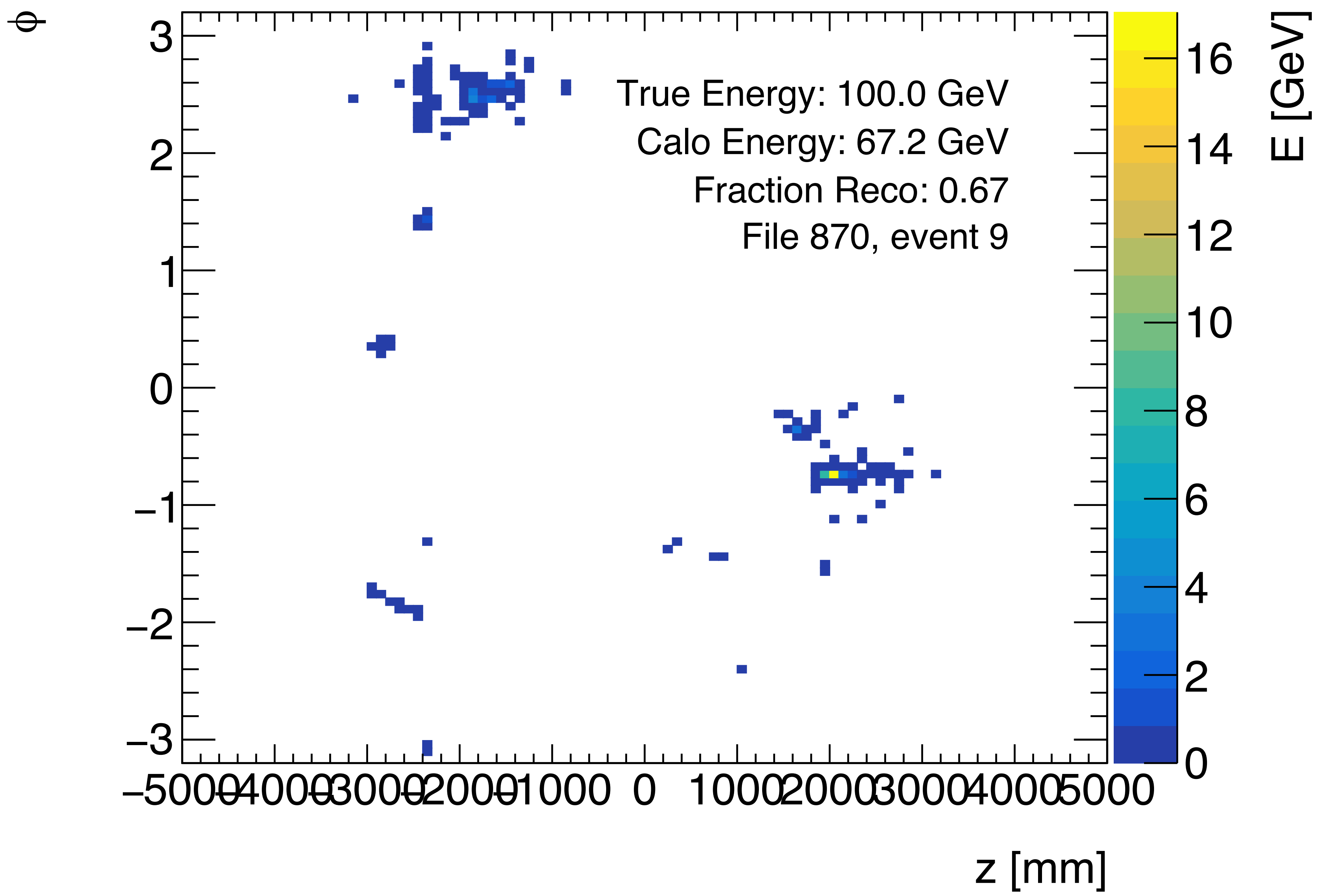


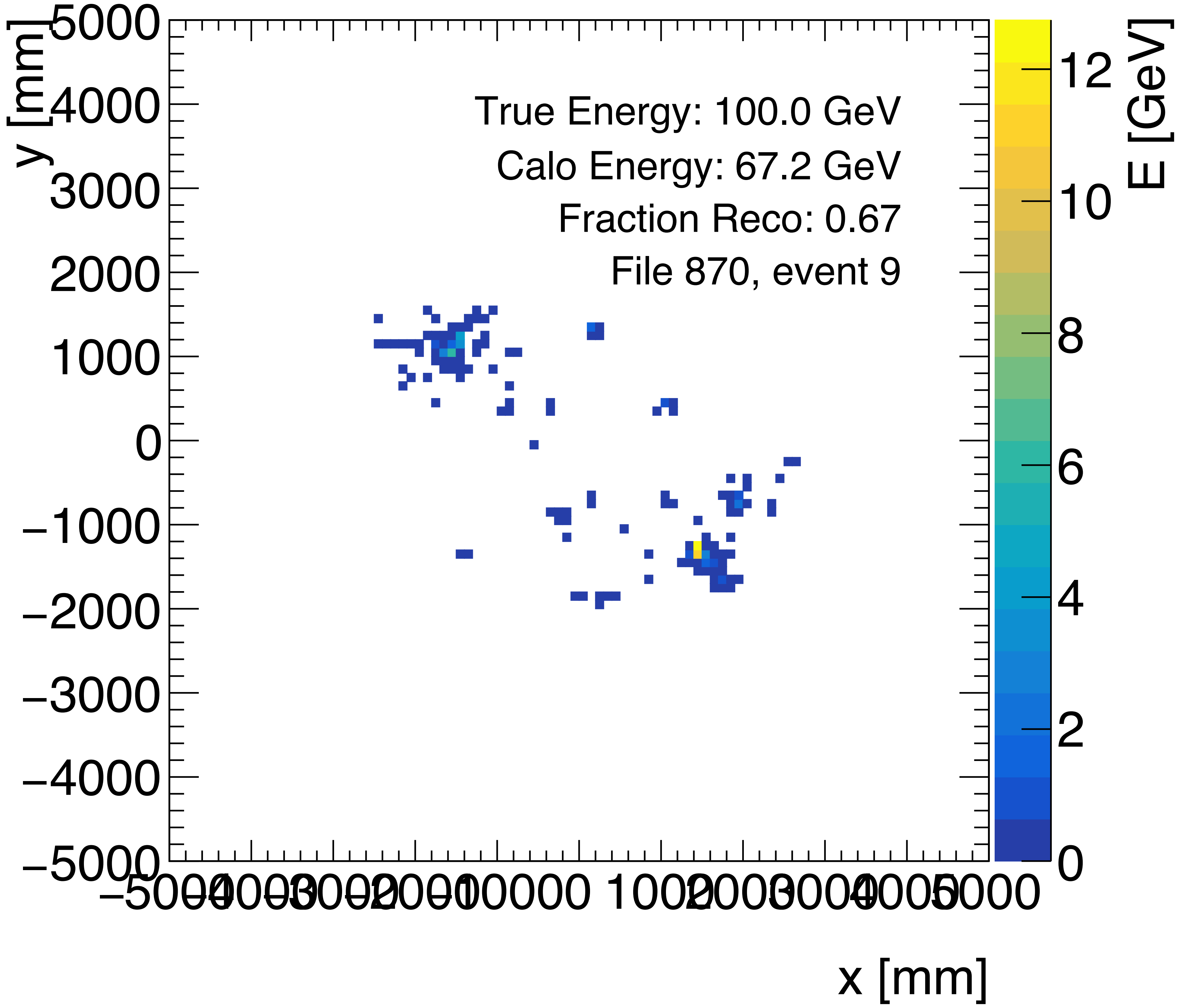
Visualizing jets

selected by threshold + coned









Conclusions

- It seems like we're coning around the generator stable particles, not just initiating partons
- In most events the effect of coning is very minor, but in some it can be at the 10% level. Nonetheless, the removed hits are far enough away in these cases that it's unlikely that it's recoverable in a jet
- In all cases, the HCAL fraction is tiny compared to ECAL
    - at most around 30% is in HCAL, usually much less – not what we're used to
    - we do see a lot of charged pion activity in ECAL though, so may be consistent – but we haven't really looked at low energy pions.

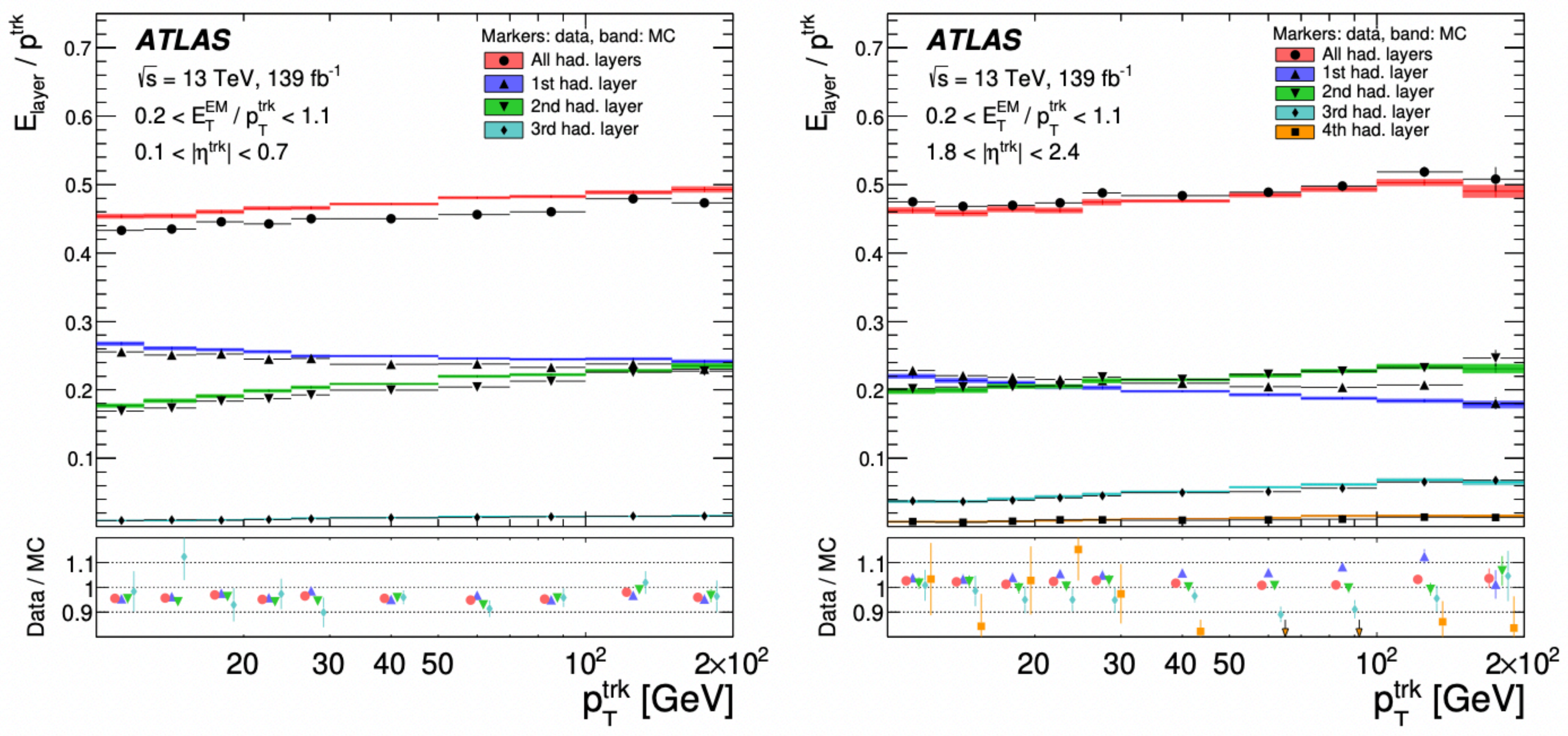


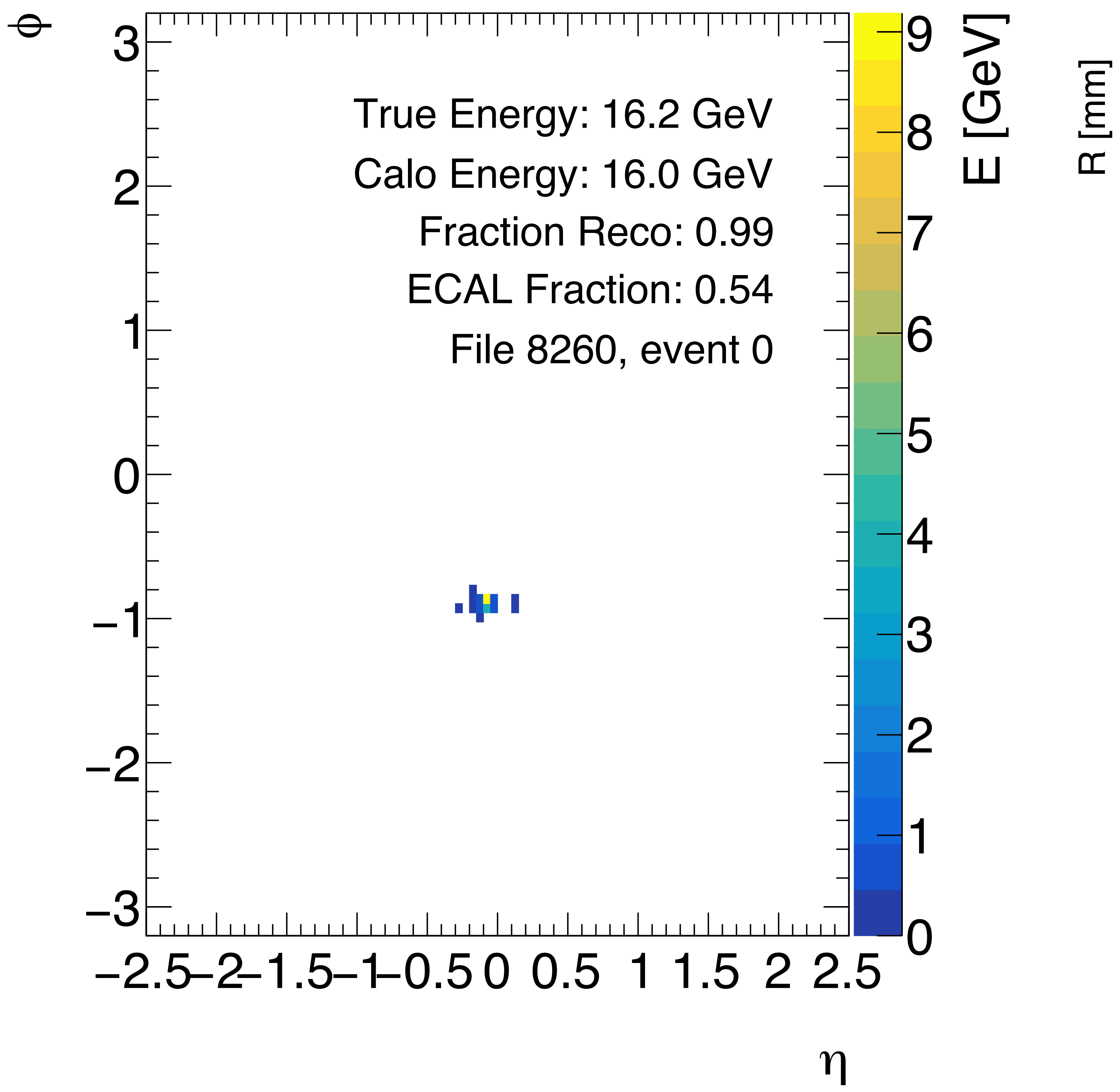
Figure 10: The average energy within each hadronic layer normalised to the track momentum as a function of track p_{T} in the barrel (left) and endcaps (right). Also shown are the ratios of the sum of energies in all layers of the hadronic calorimeter to the track momentum. Data are required to have $0.2 < E_{\mathrm{T}}^{\mathrm{EM}}/p_{\mathrm{T}}^{\mathrm{trk}} < 1.1$ to primarily select single-pion events. Shown in the lower panel is the ratio of data to simulation. The error bars and uncertainty band show the uncertainties from the limited number of events in the dataset and simulated samples.

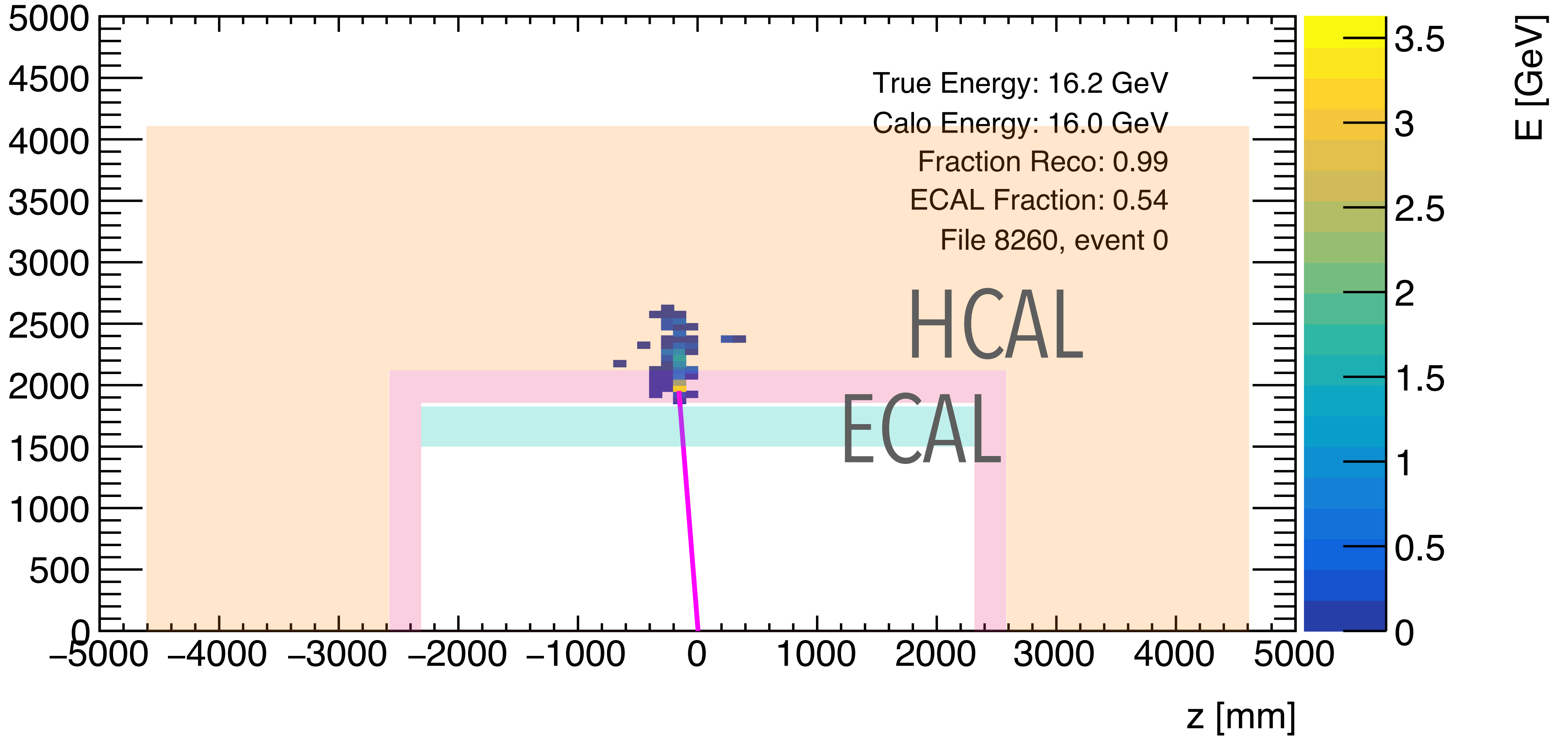
- Next steps:
    - Explicitly visualize cases where the dR is large
    - Check out low energy charged pions to understand the ECAL fraction (+ add that to these plots)
    - Study at higher jet energies: what is the relationship between jet E and pion E? fragmentation is weird!

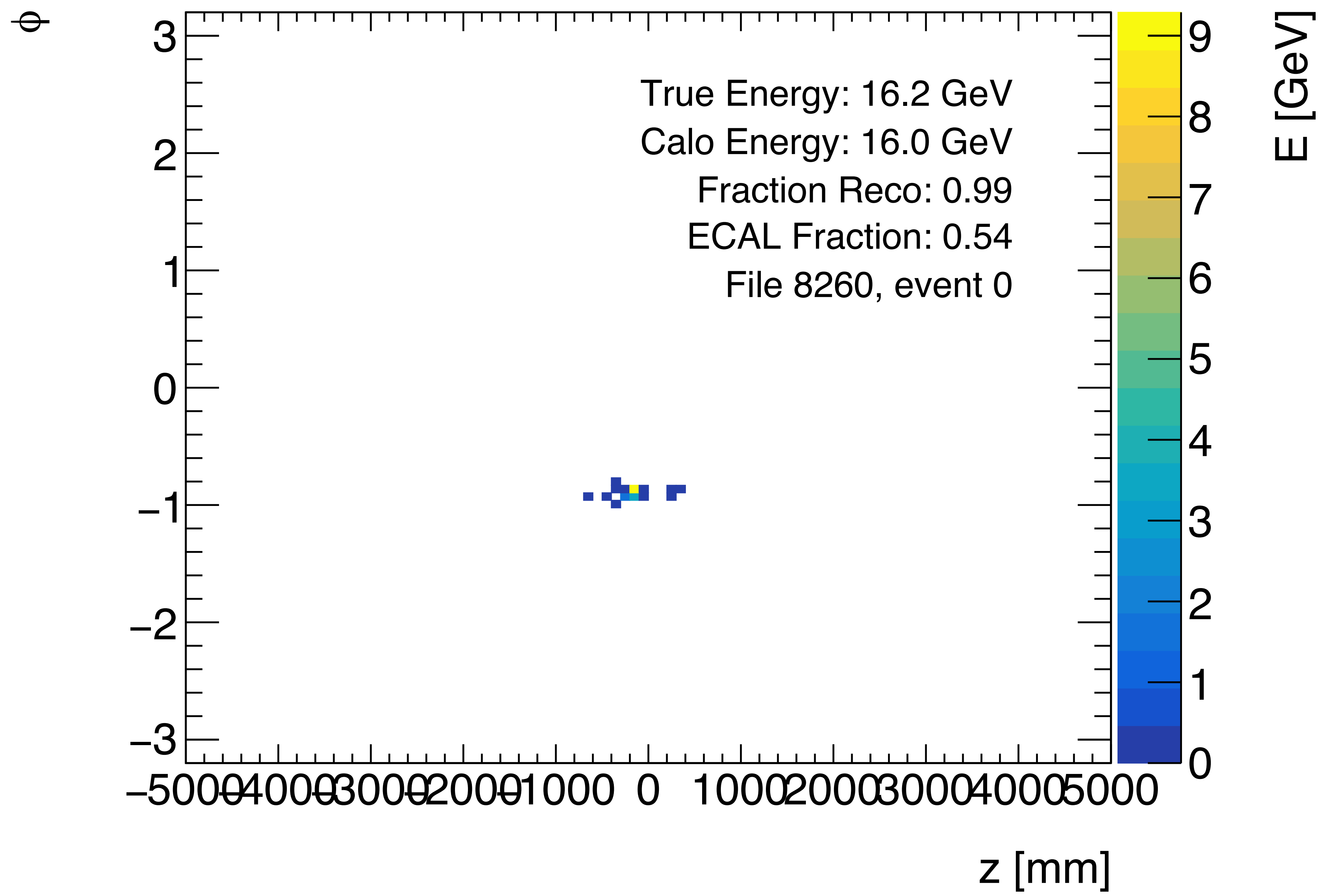
Visualizing pions

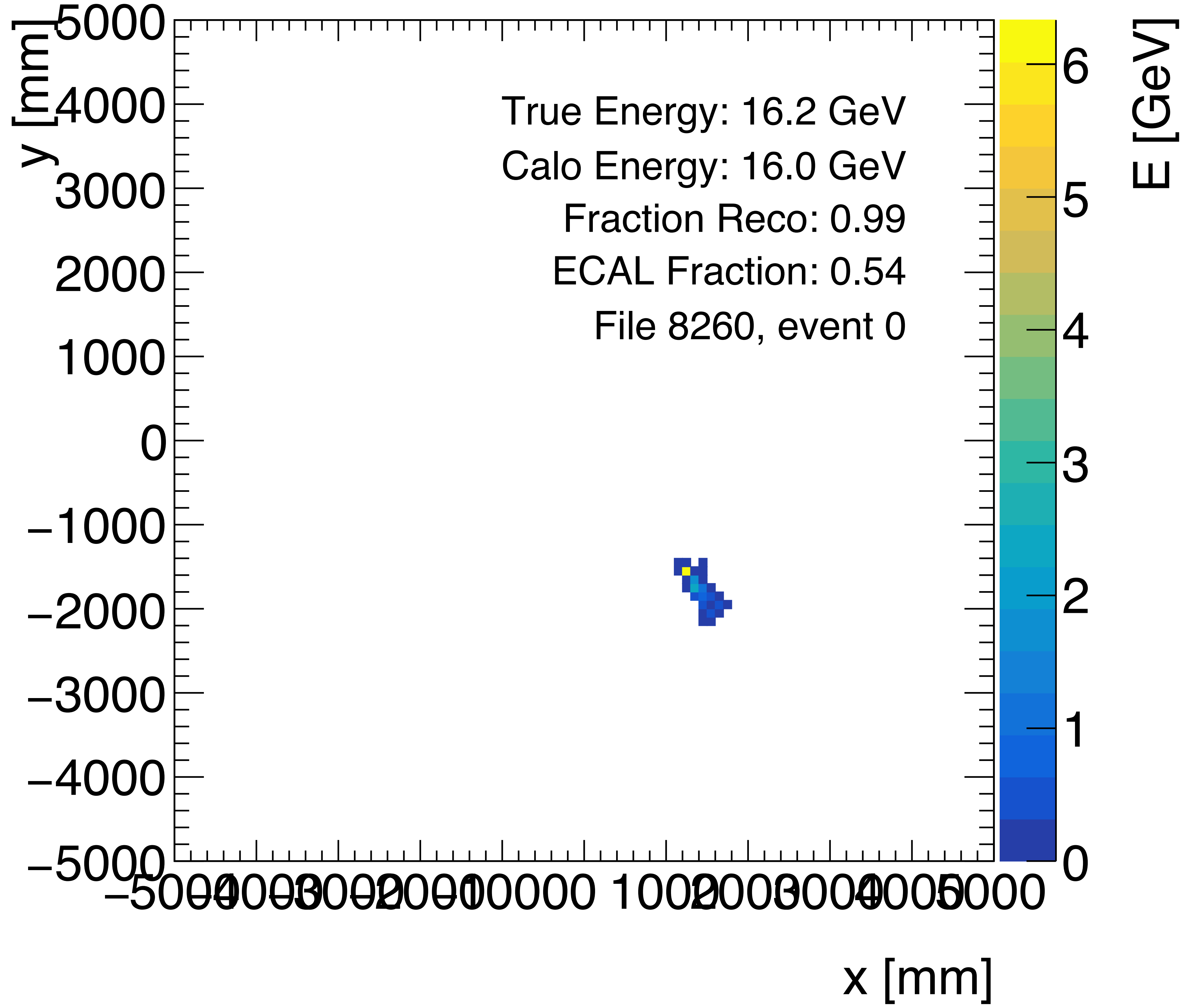
this section will have all rec hits

it's also going back to v4, but I don't htink makes much difference

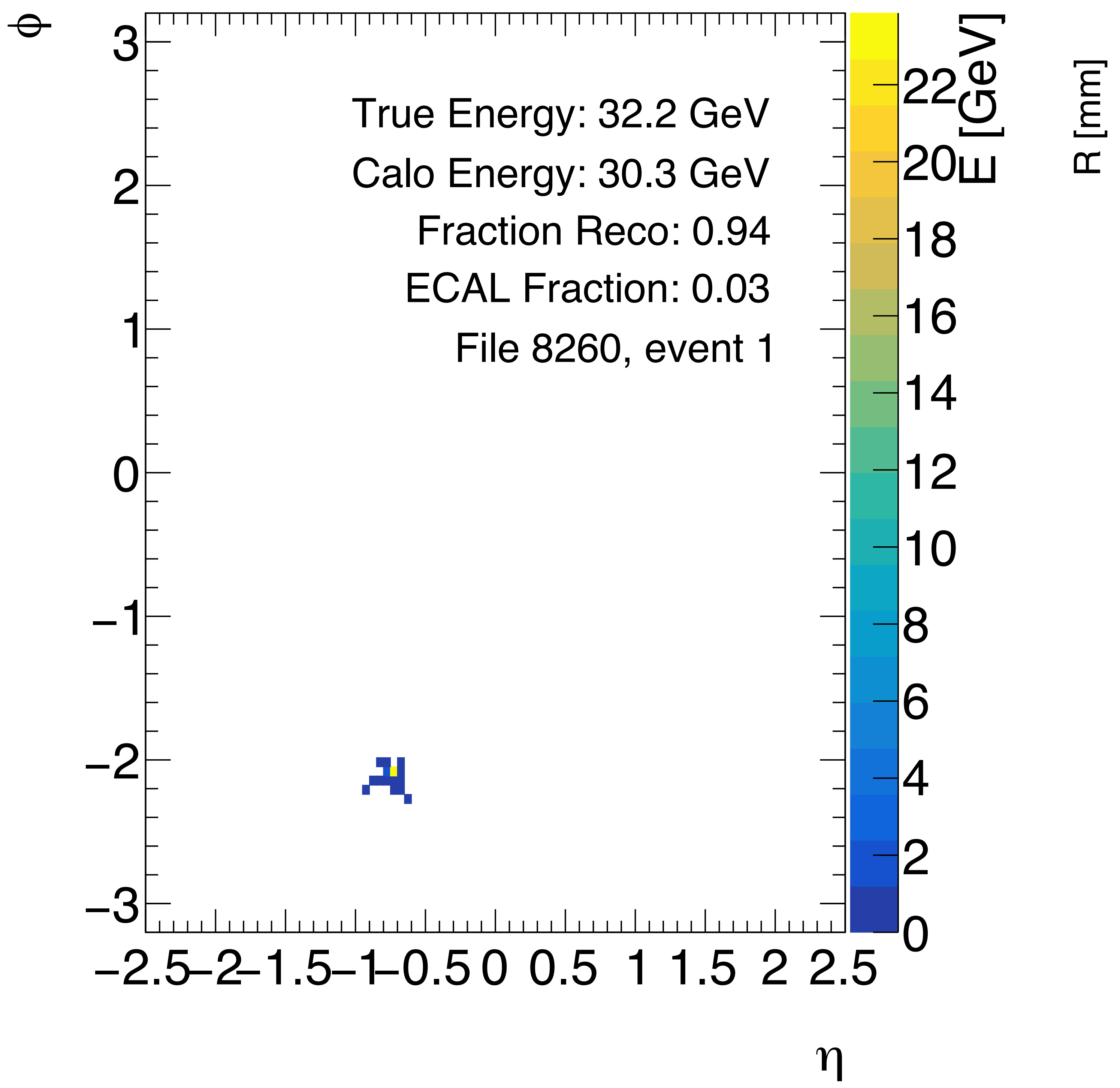


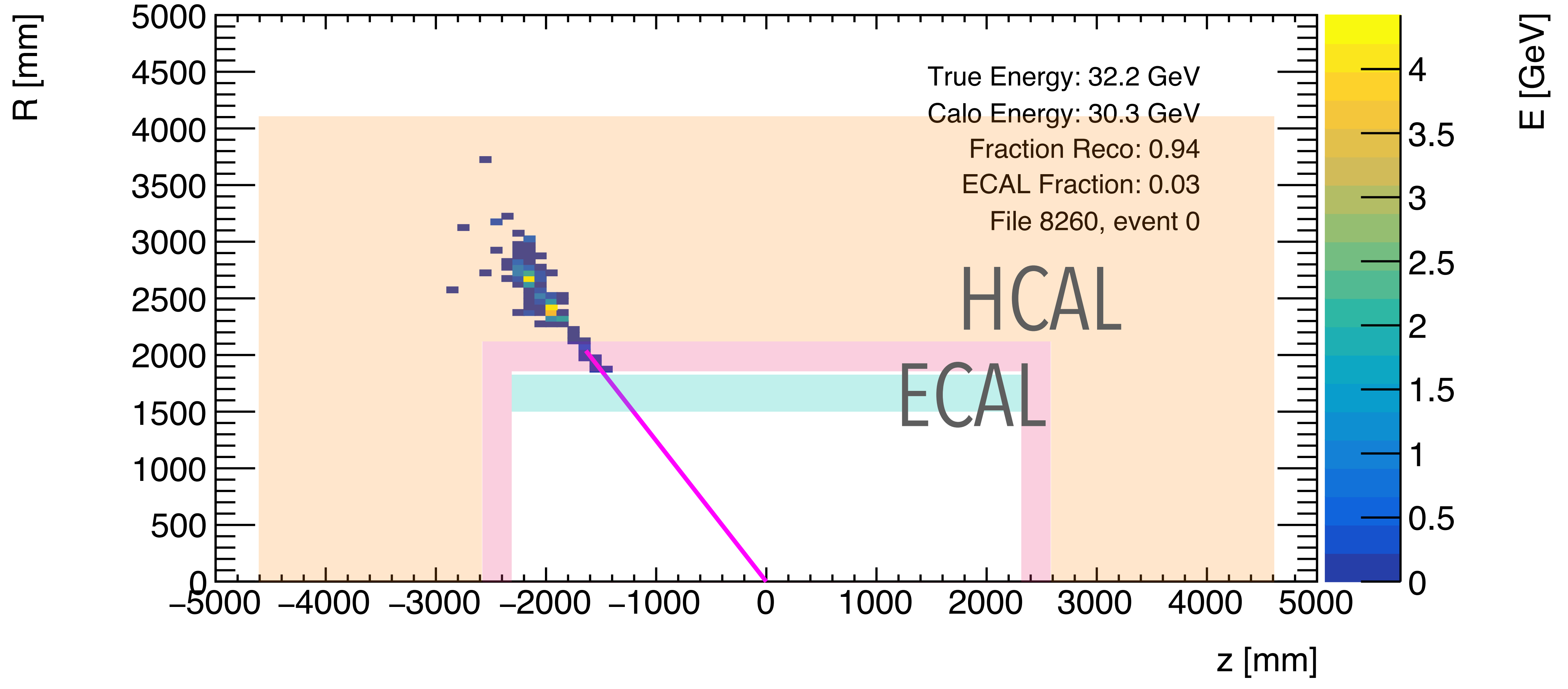


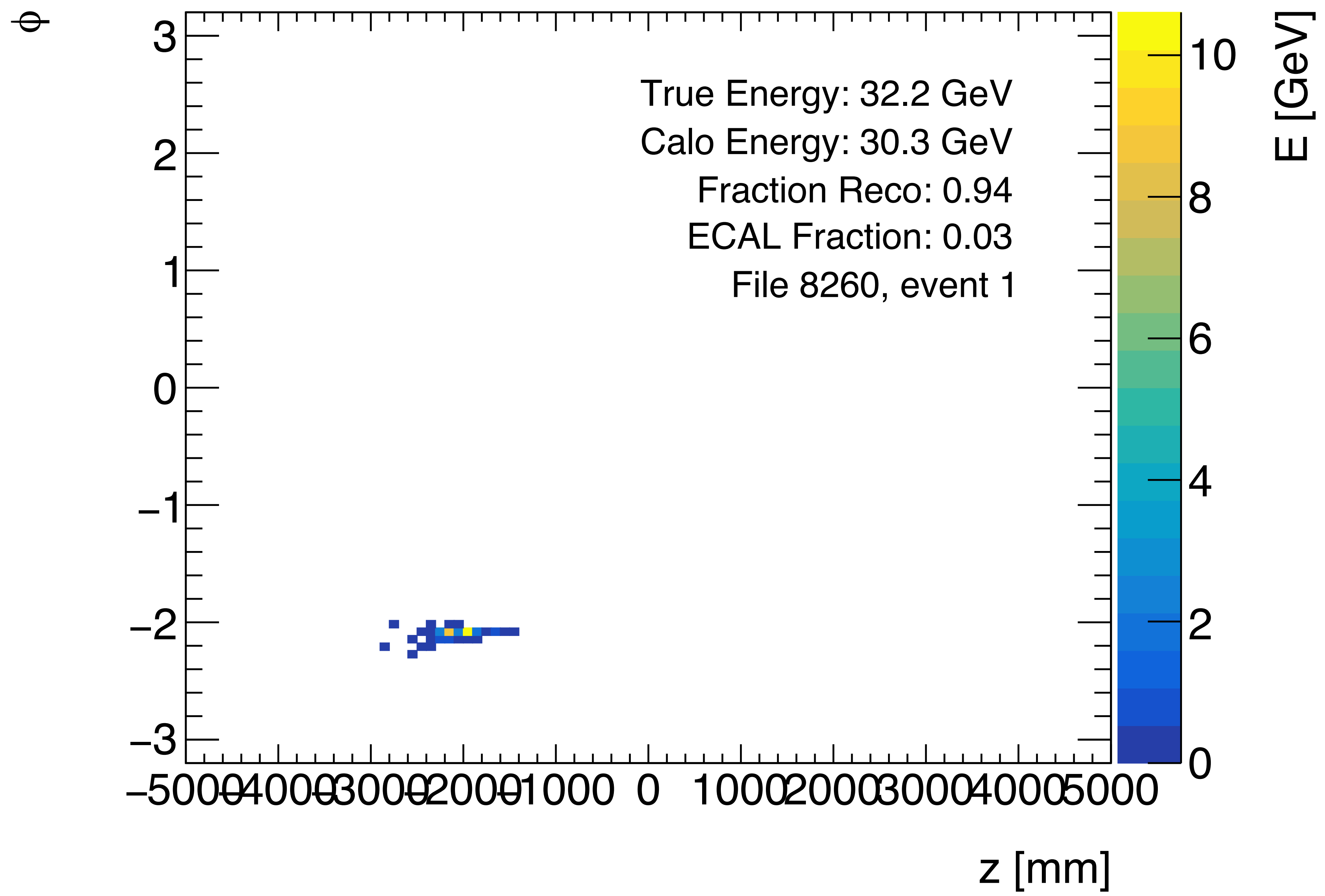


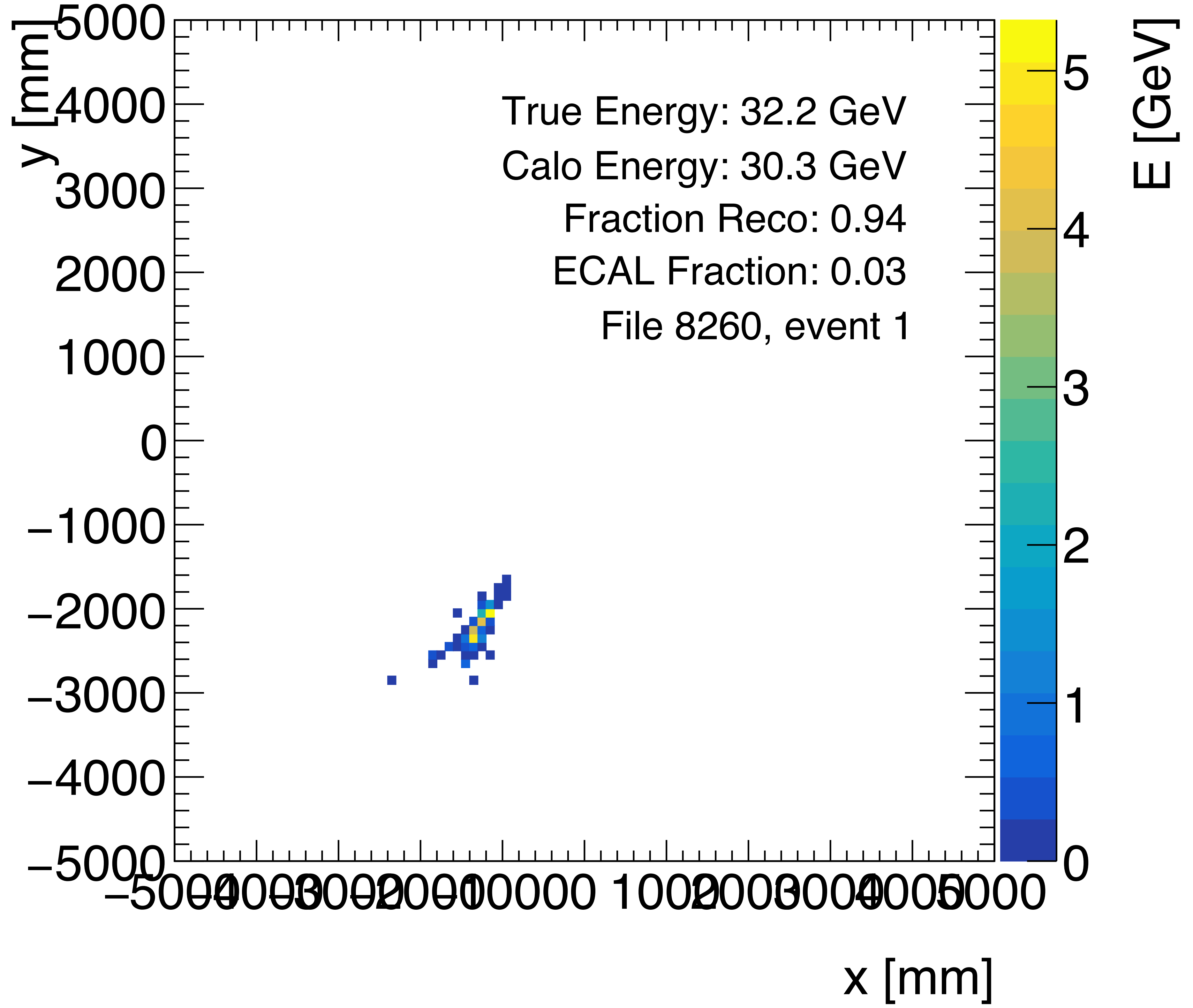


Visualizing pions

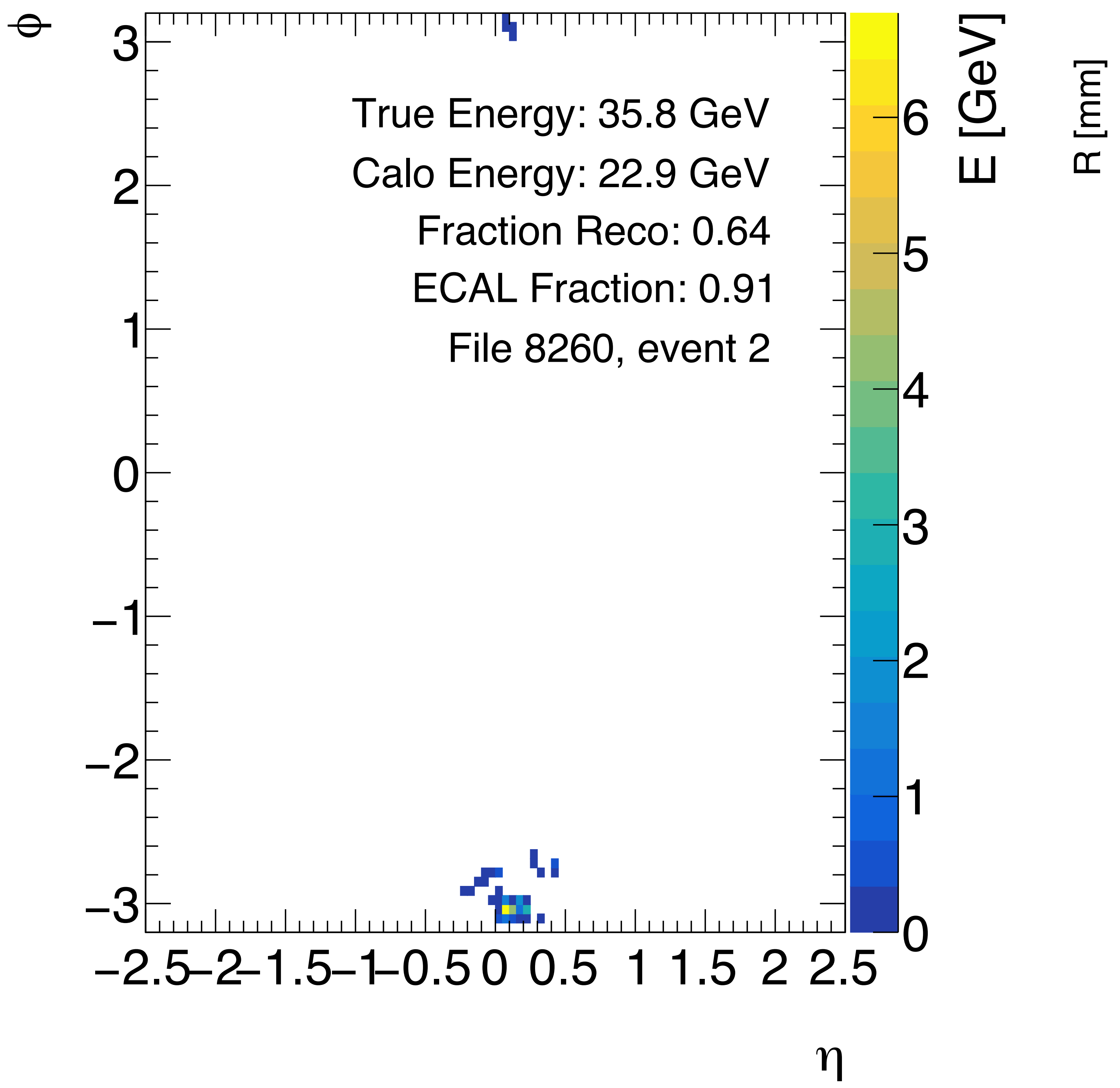


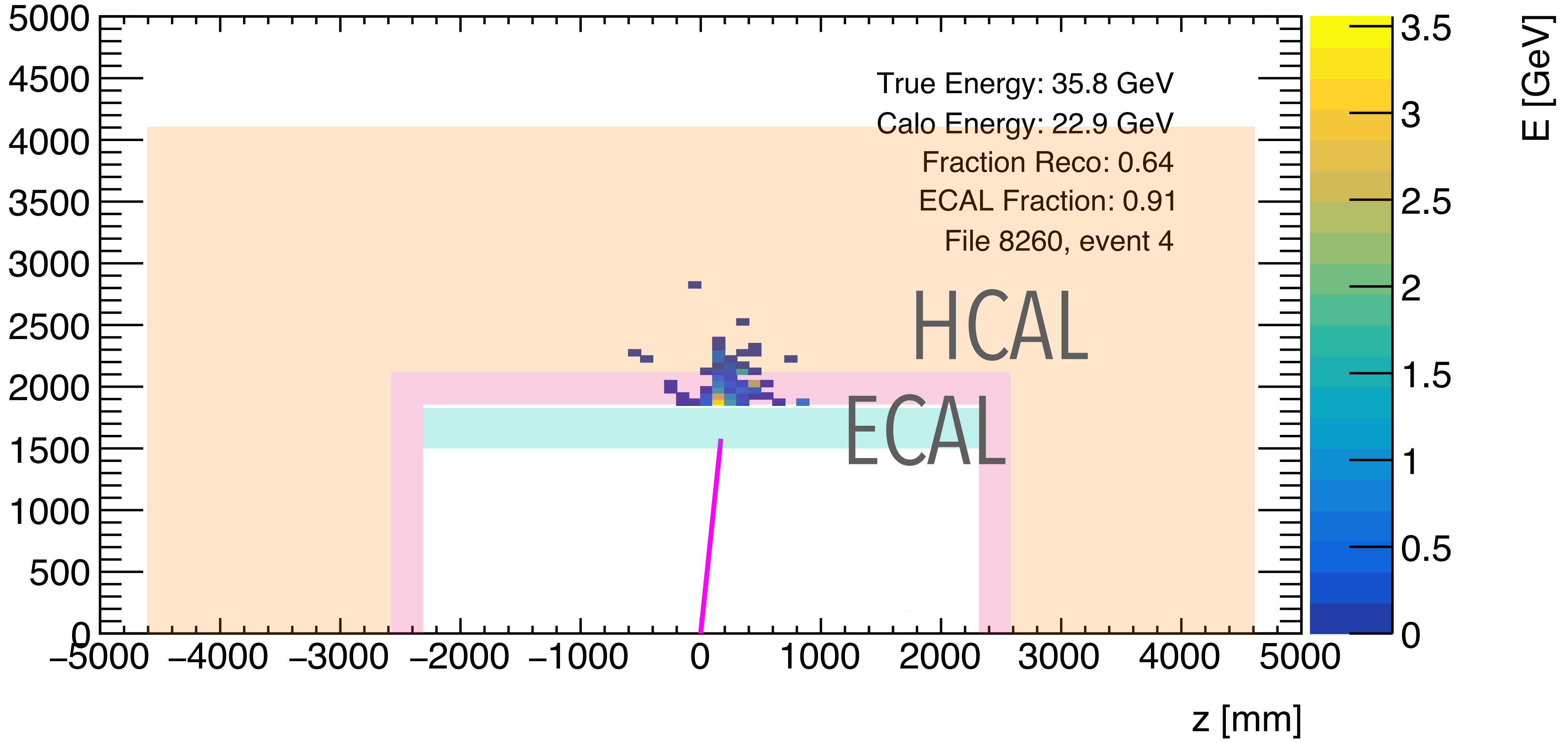


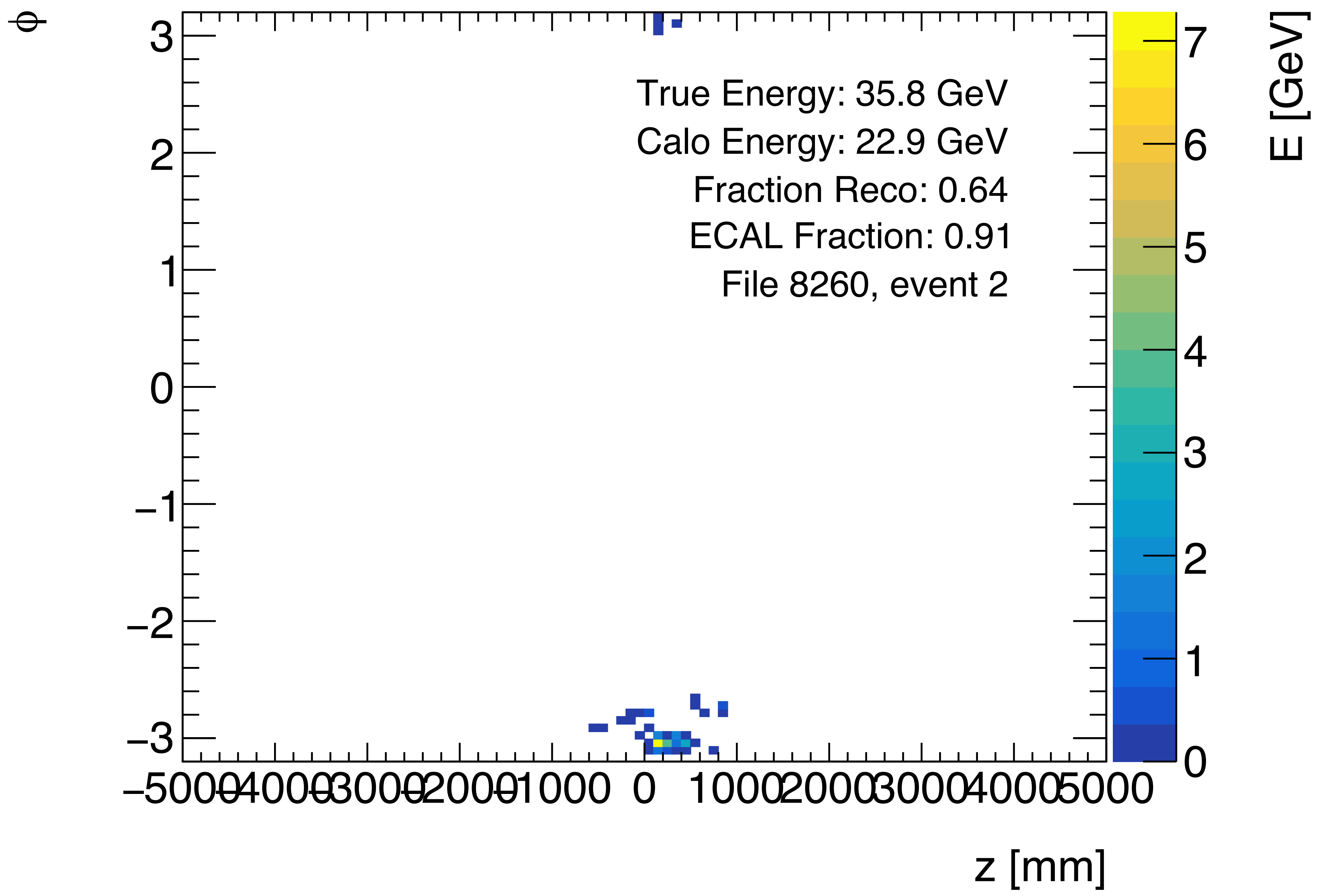


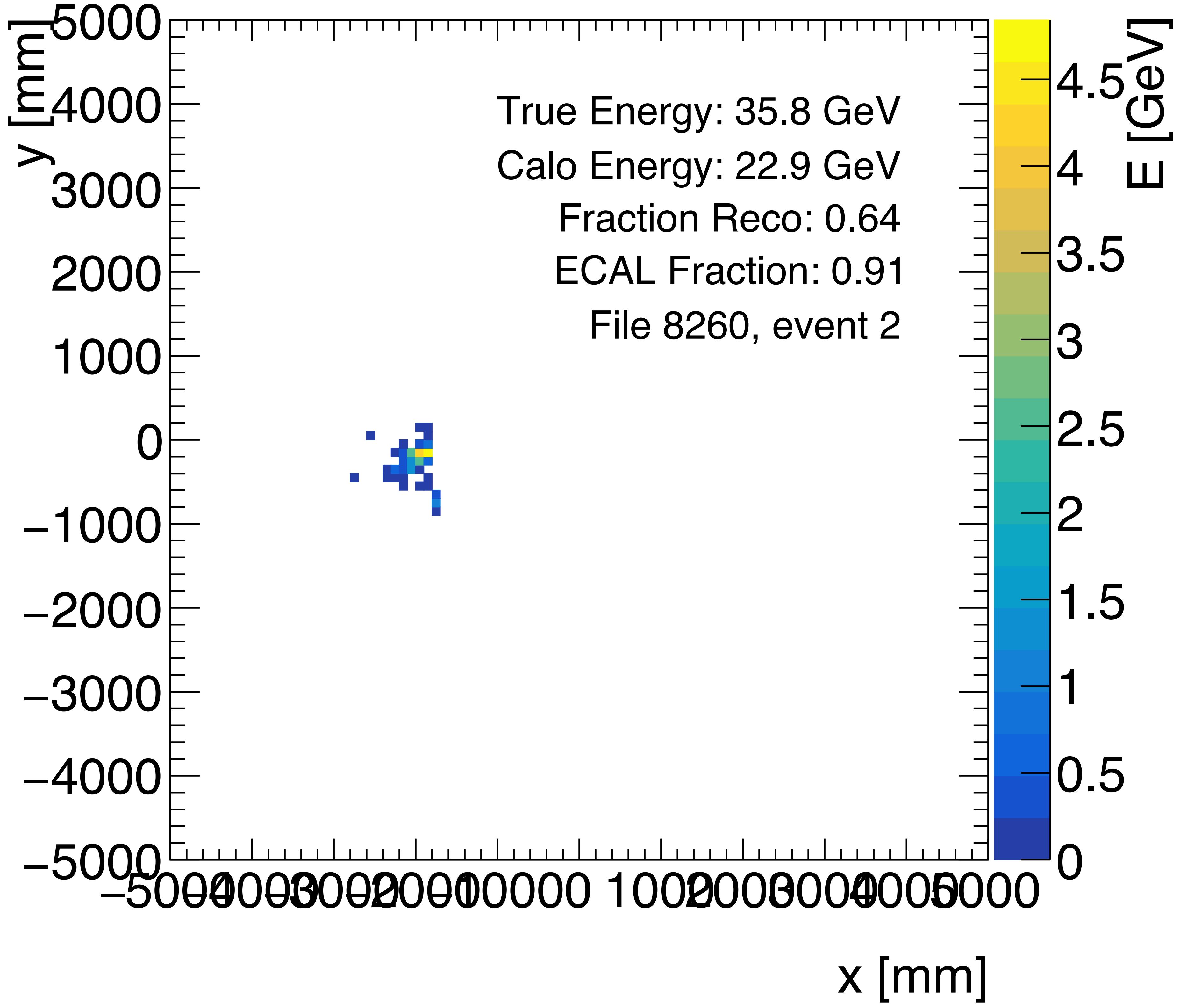


Visualizing pions

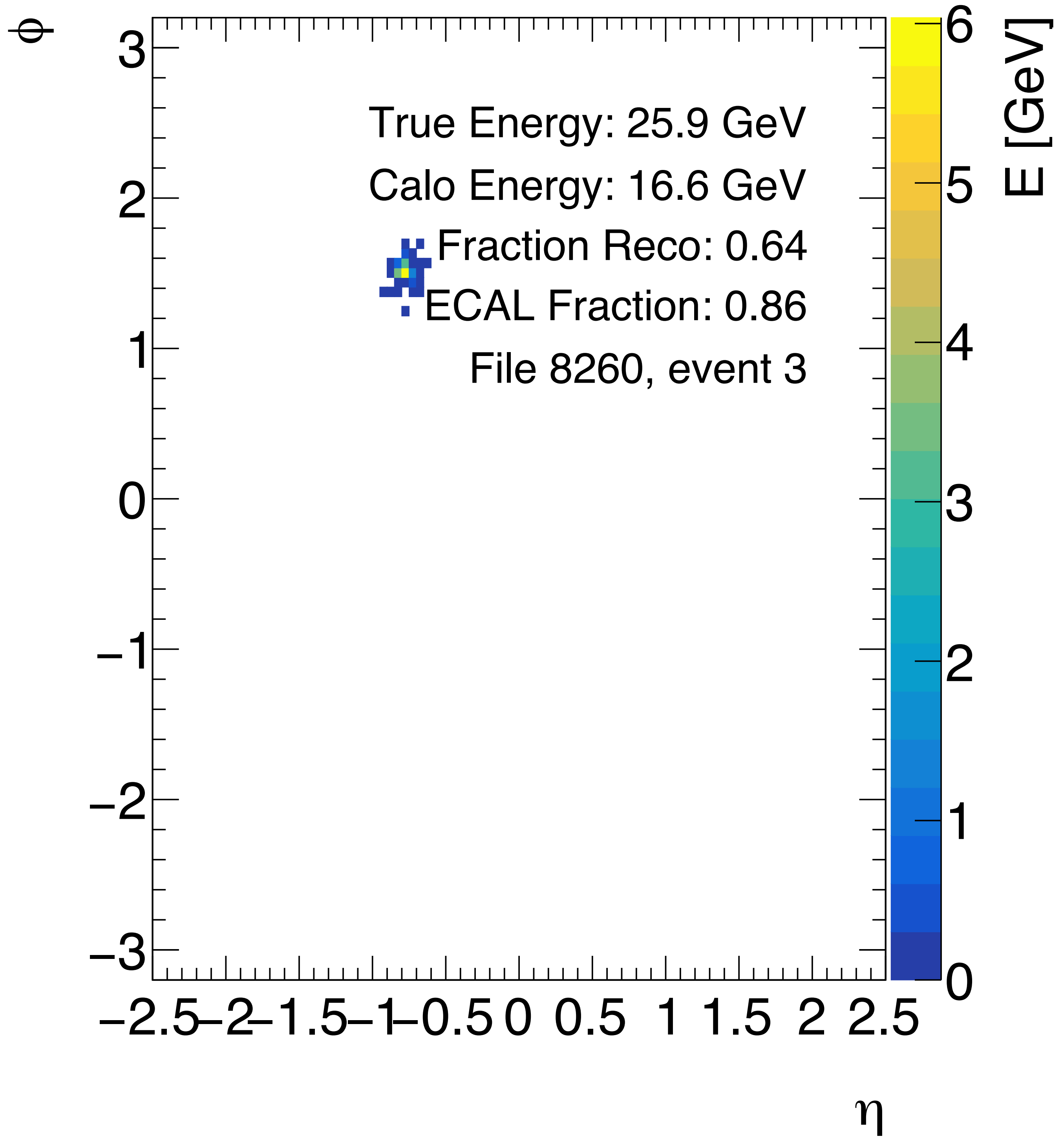


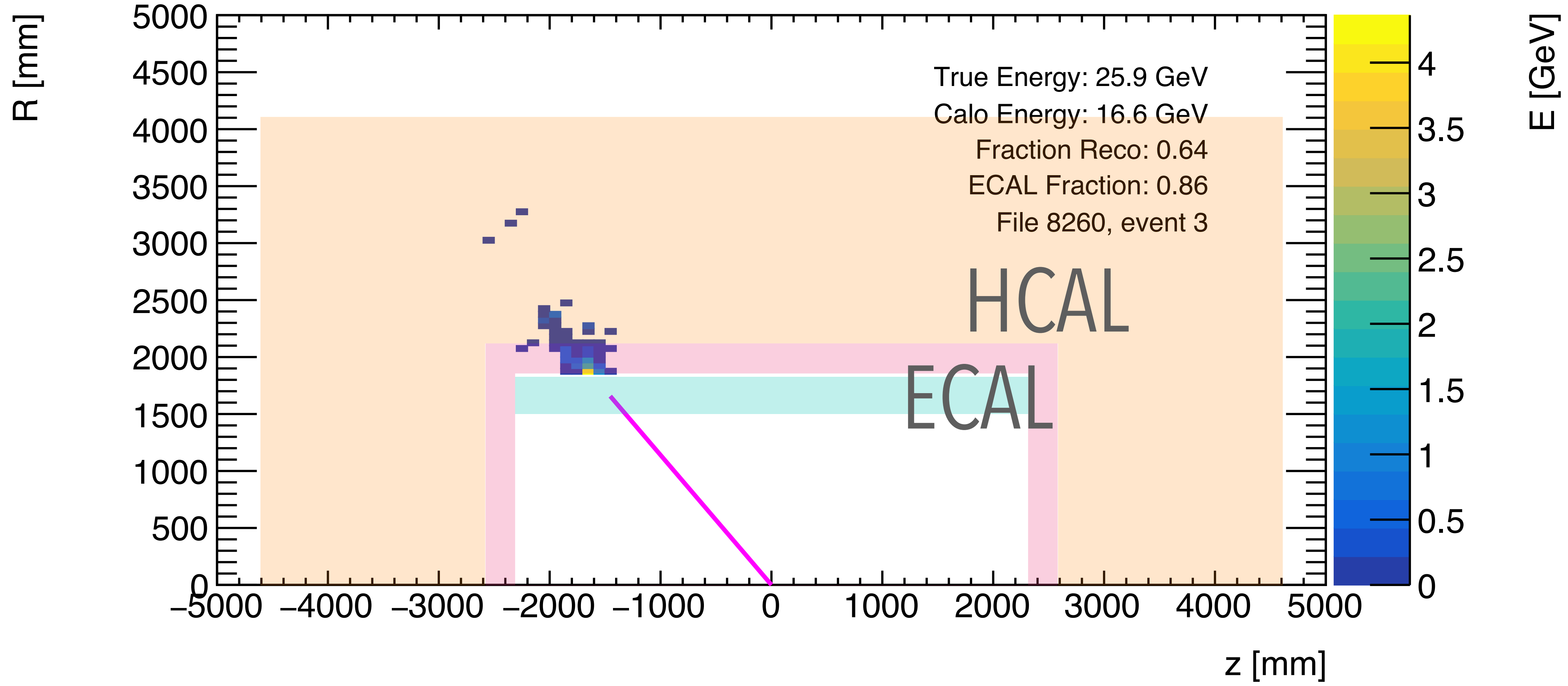


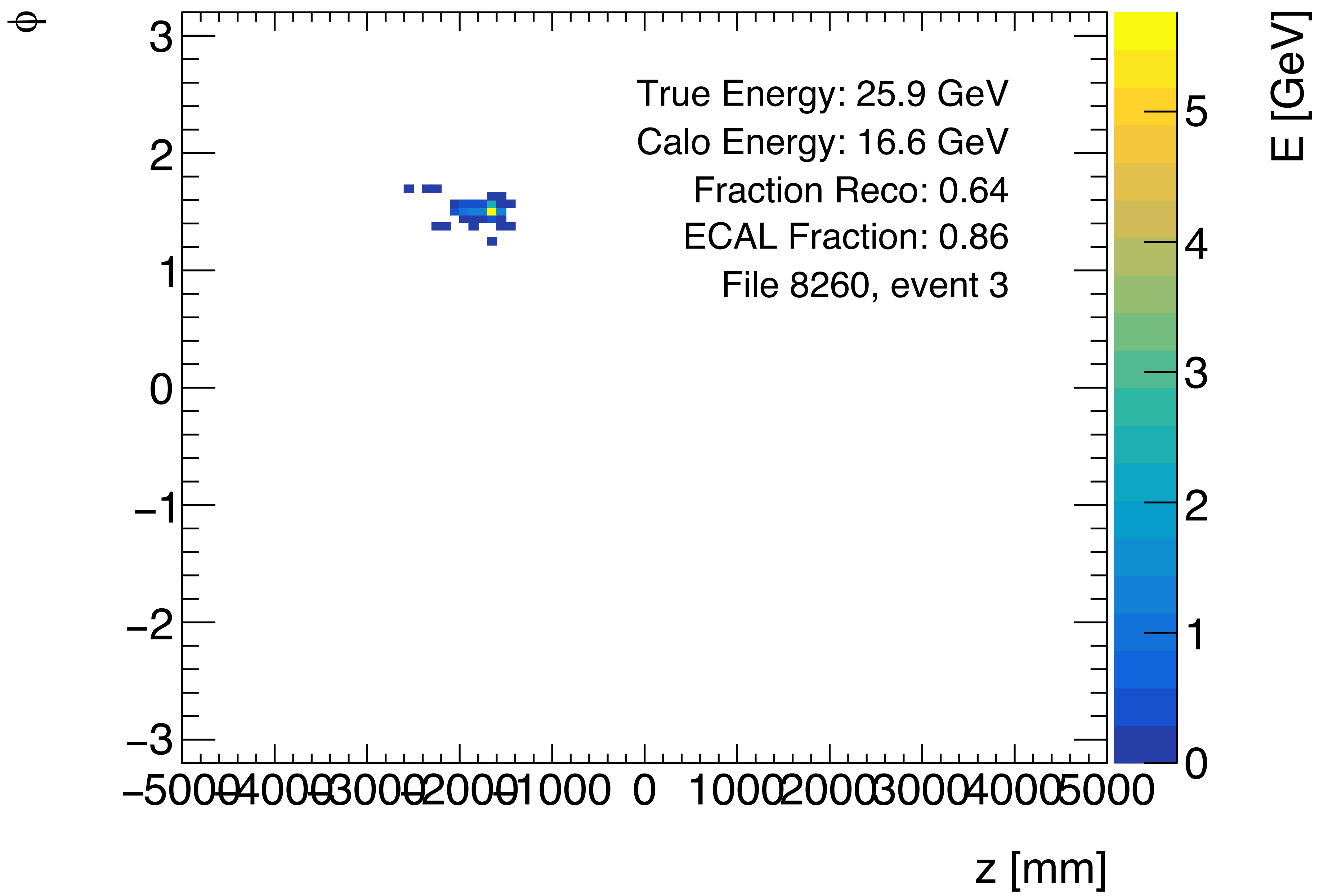


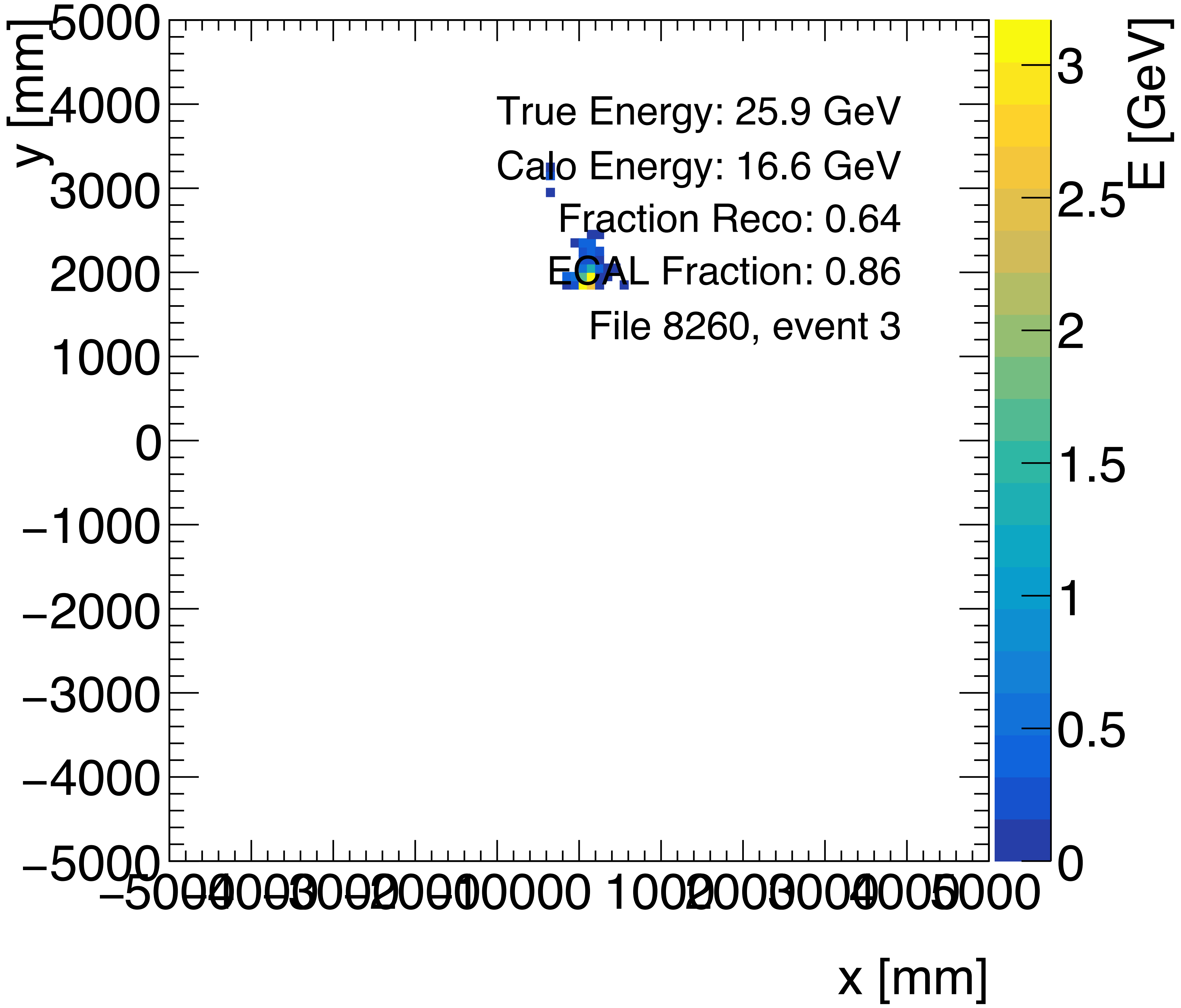


Visualizing pions

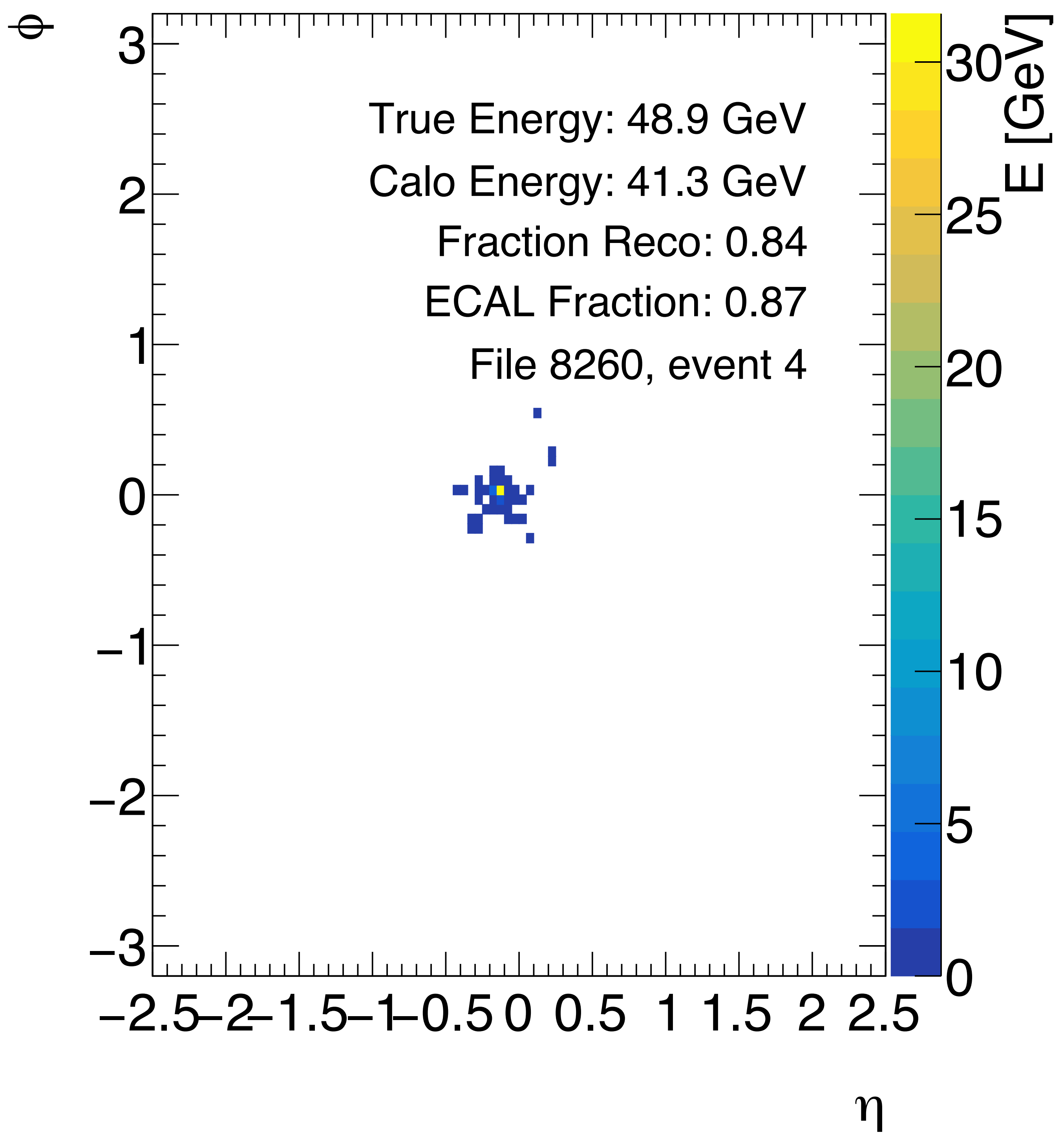


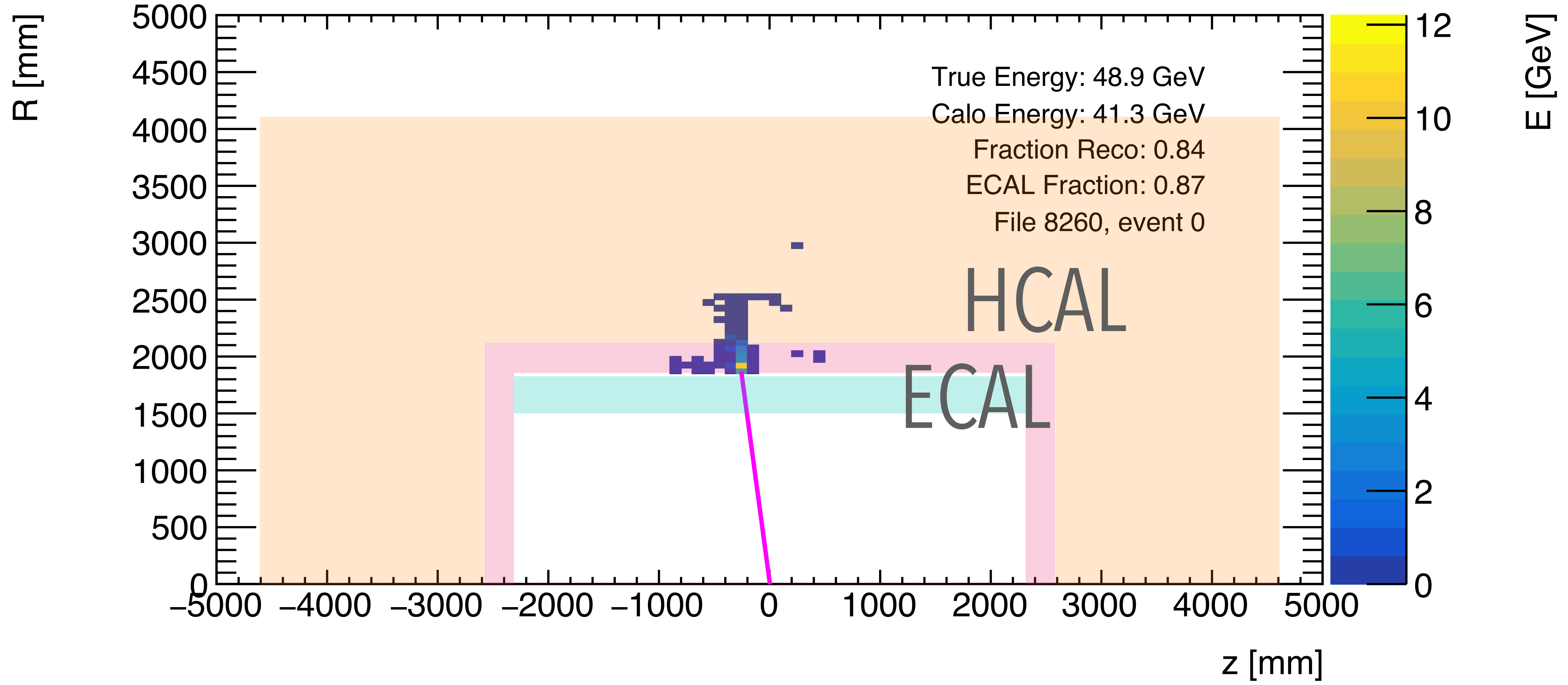


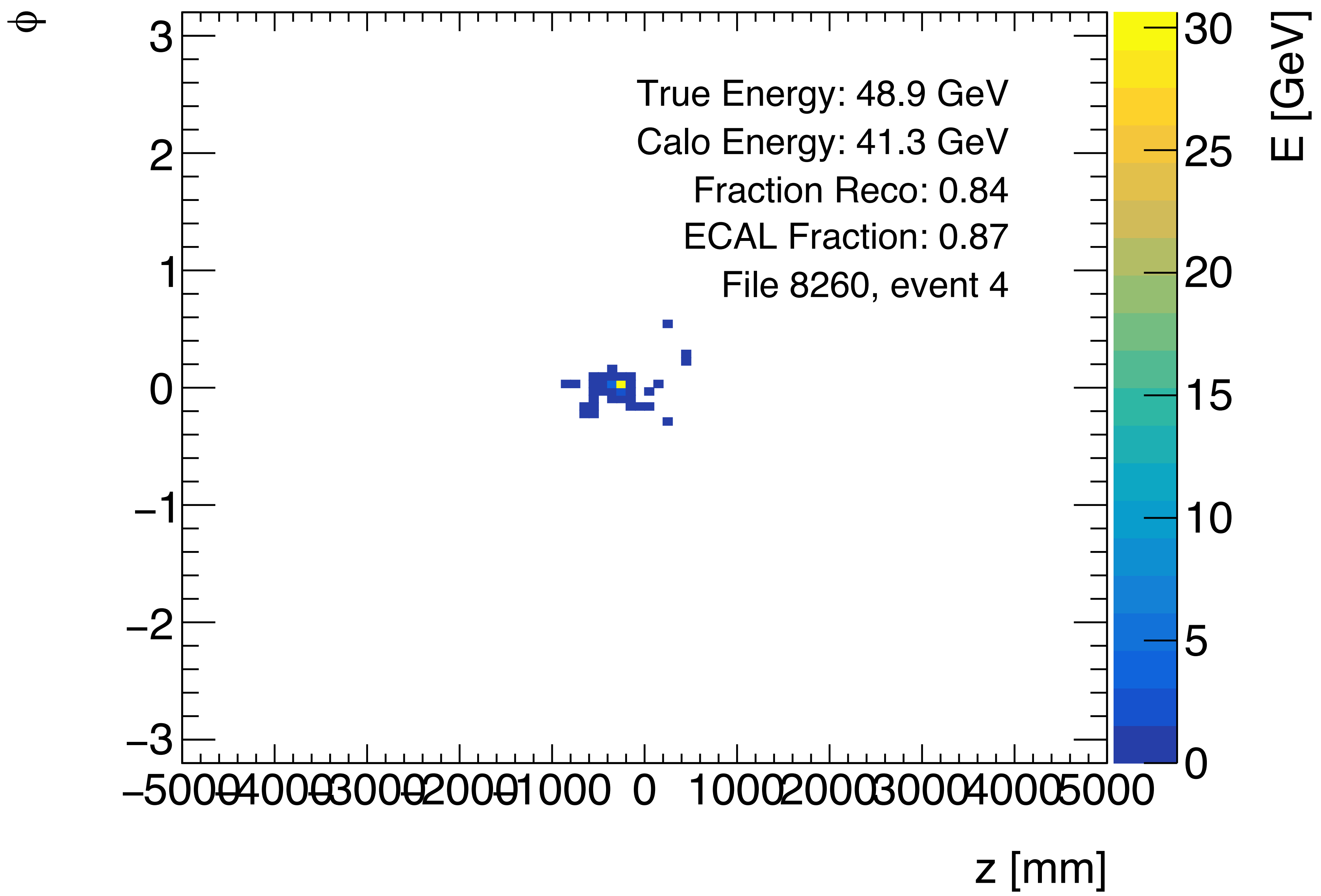


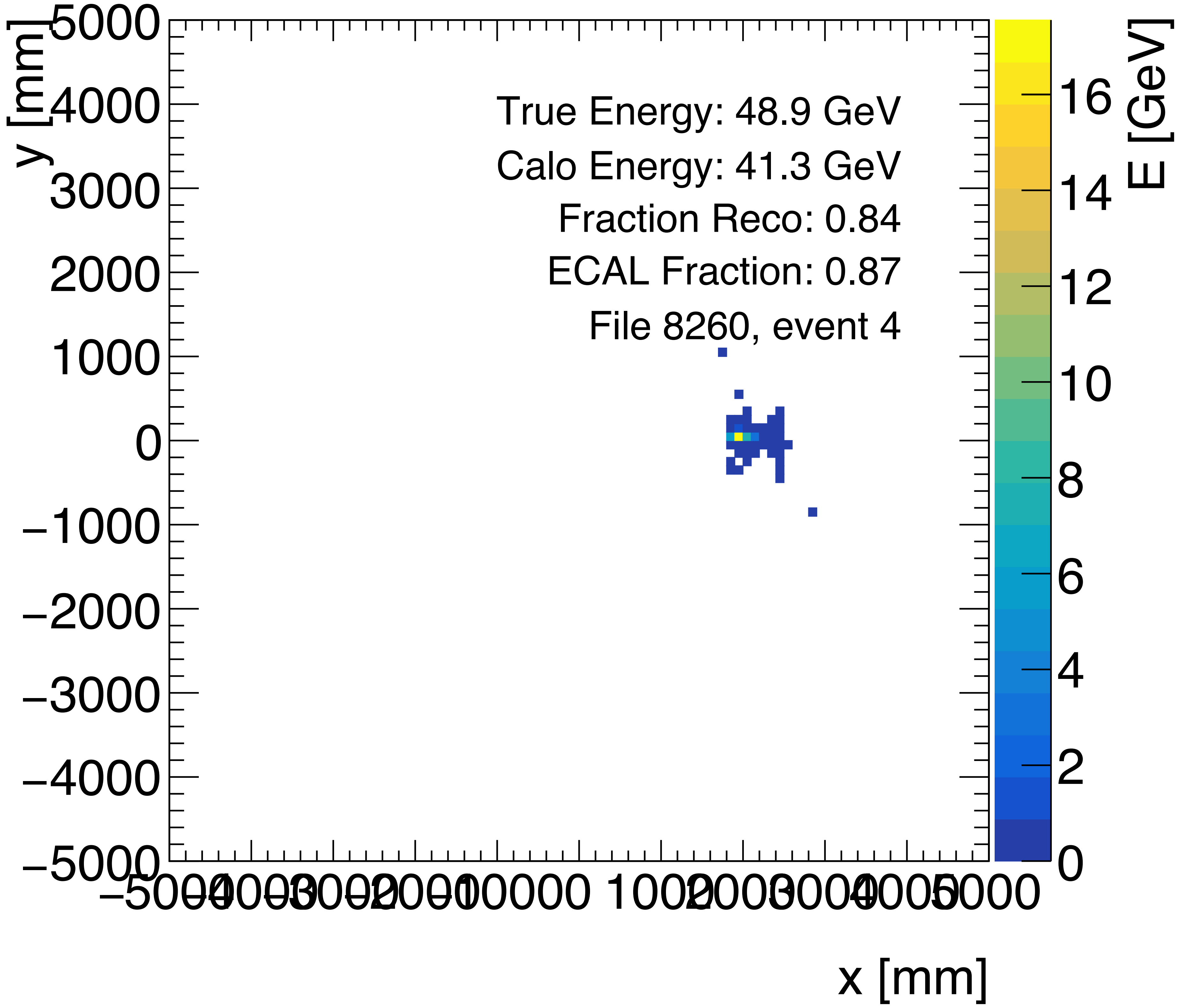


Visualizing pions

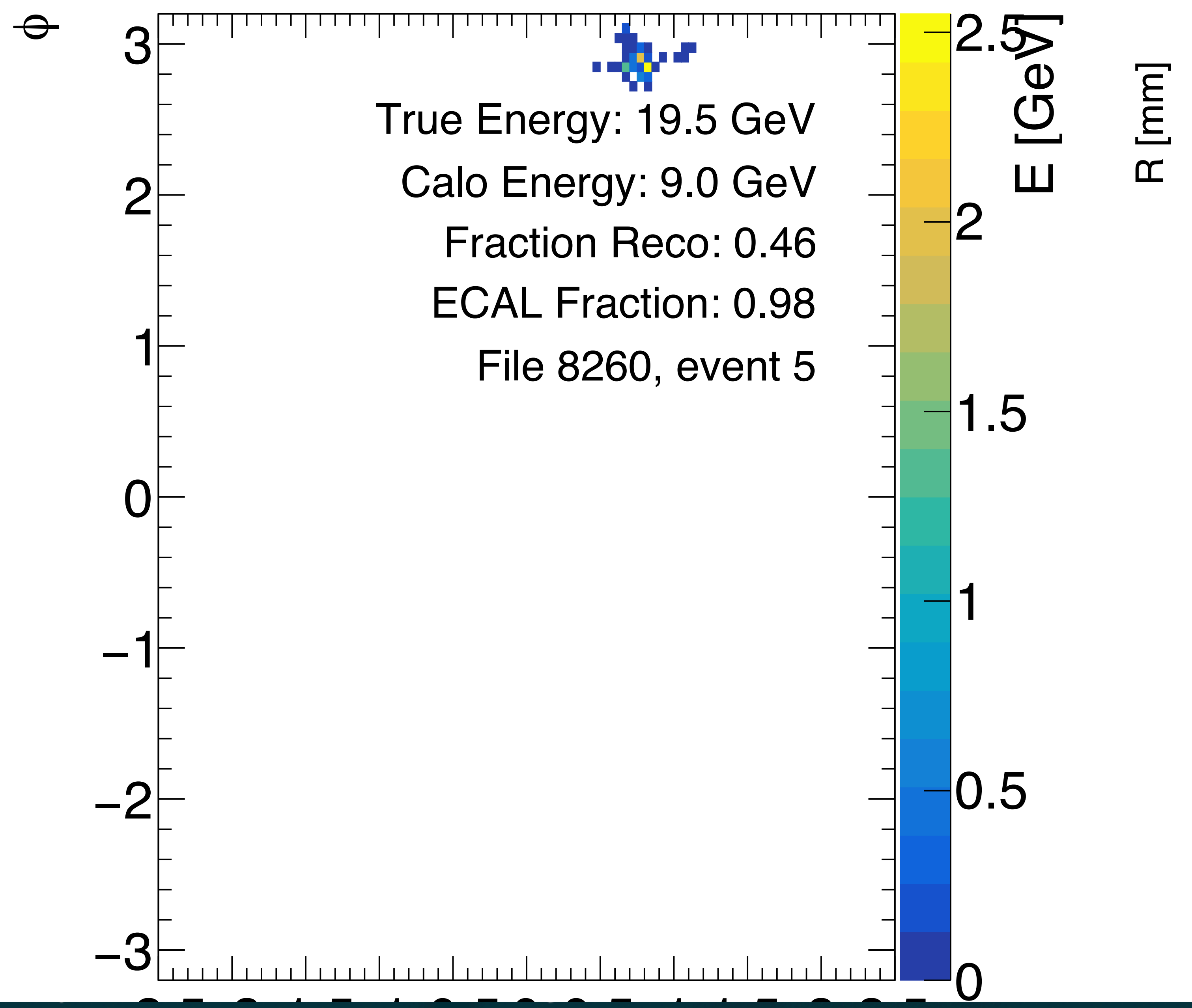


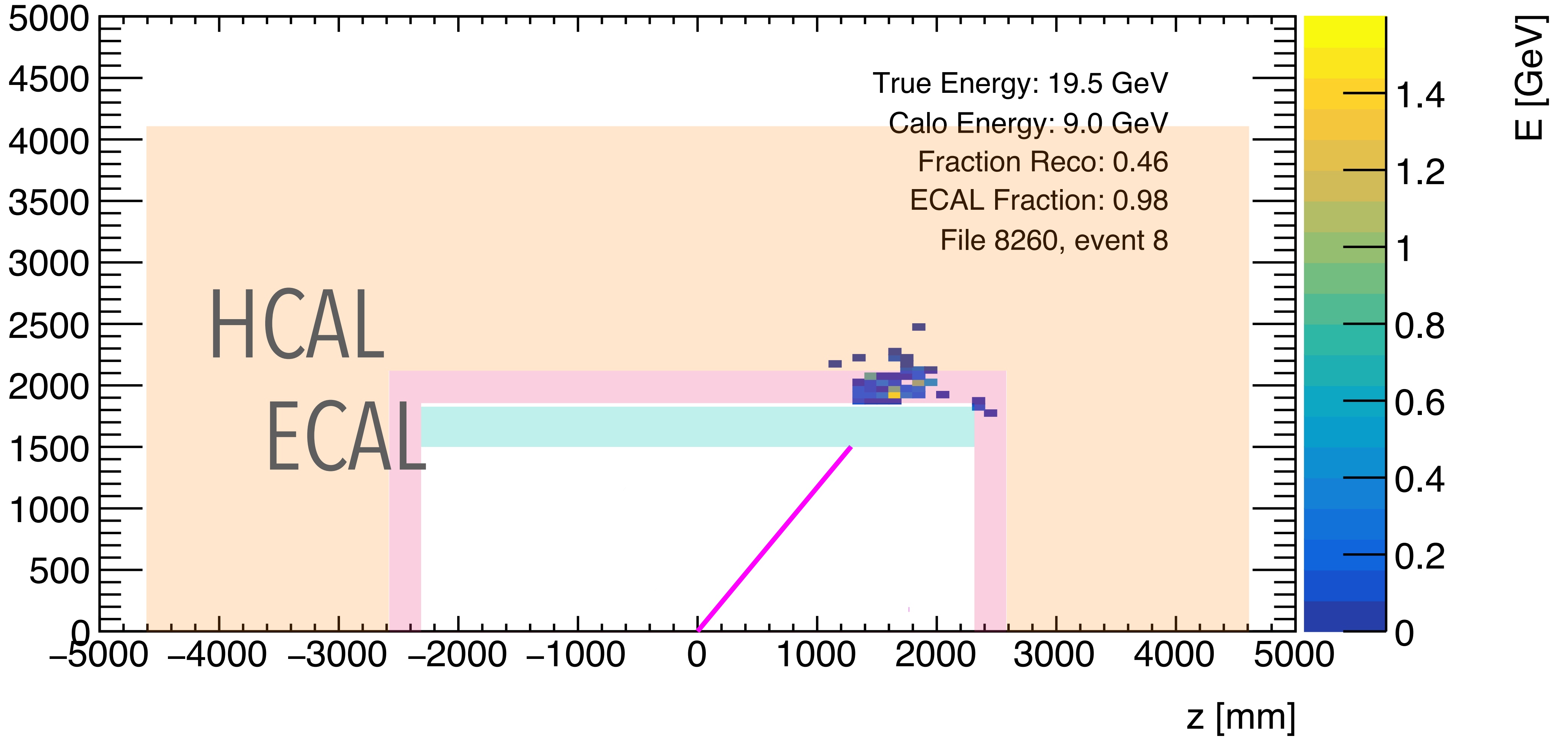






Visualizing pions



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                MCP end xyz: 140.90, -1148.69, -611.97, E: 0.00
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                parent: pdgid:211 E: 19.46 GeV prodR: 0.00 status: 0 xyz: 0.00, 0.00, -0.66
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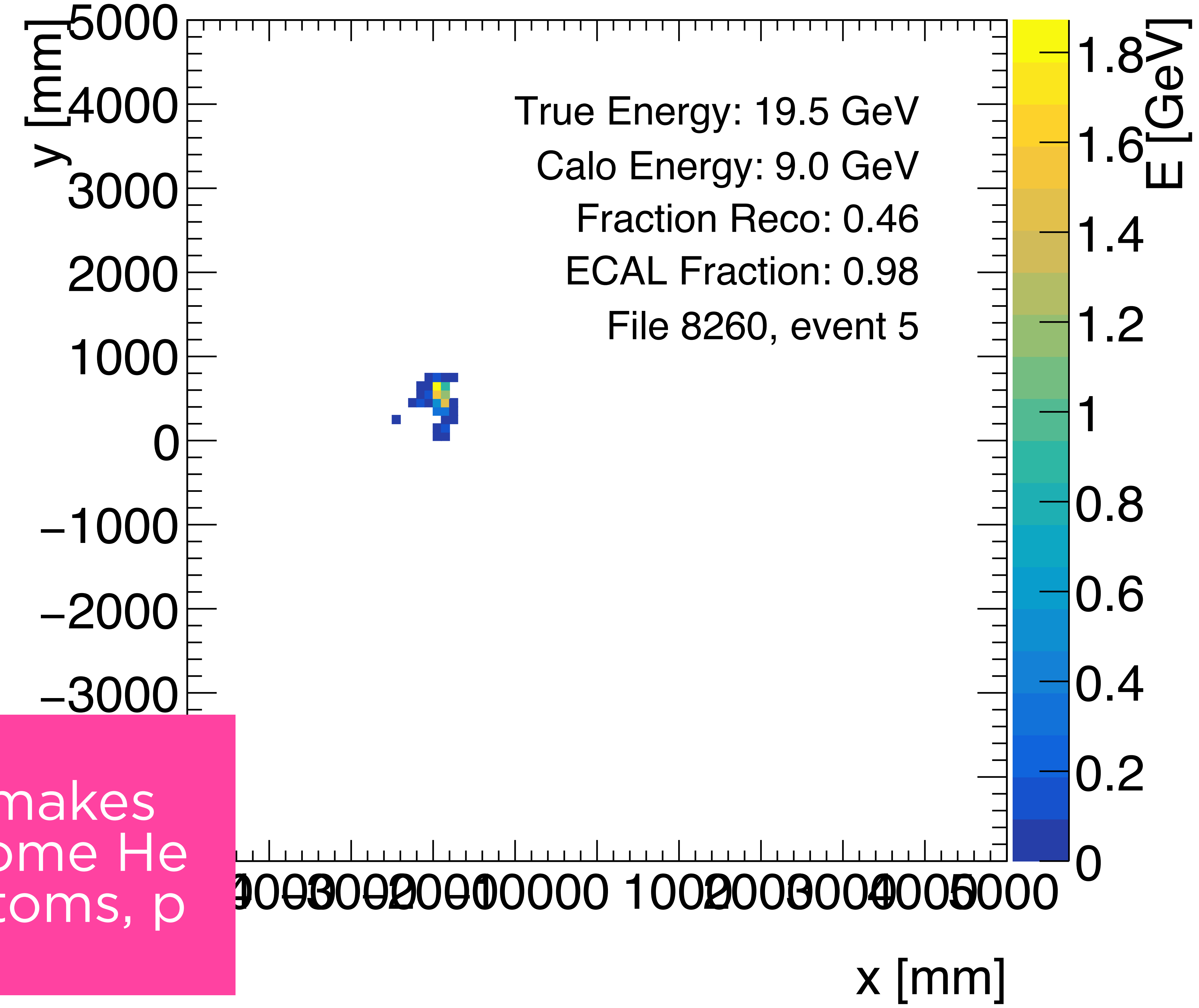
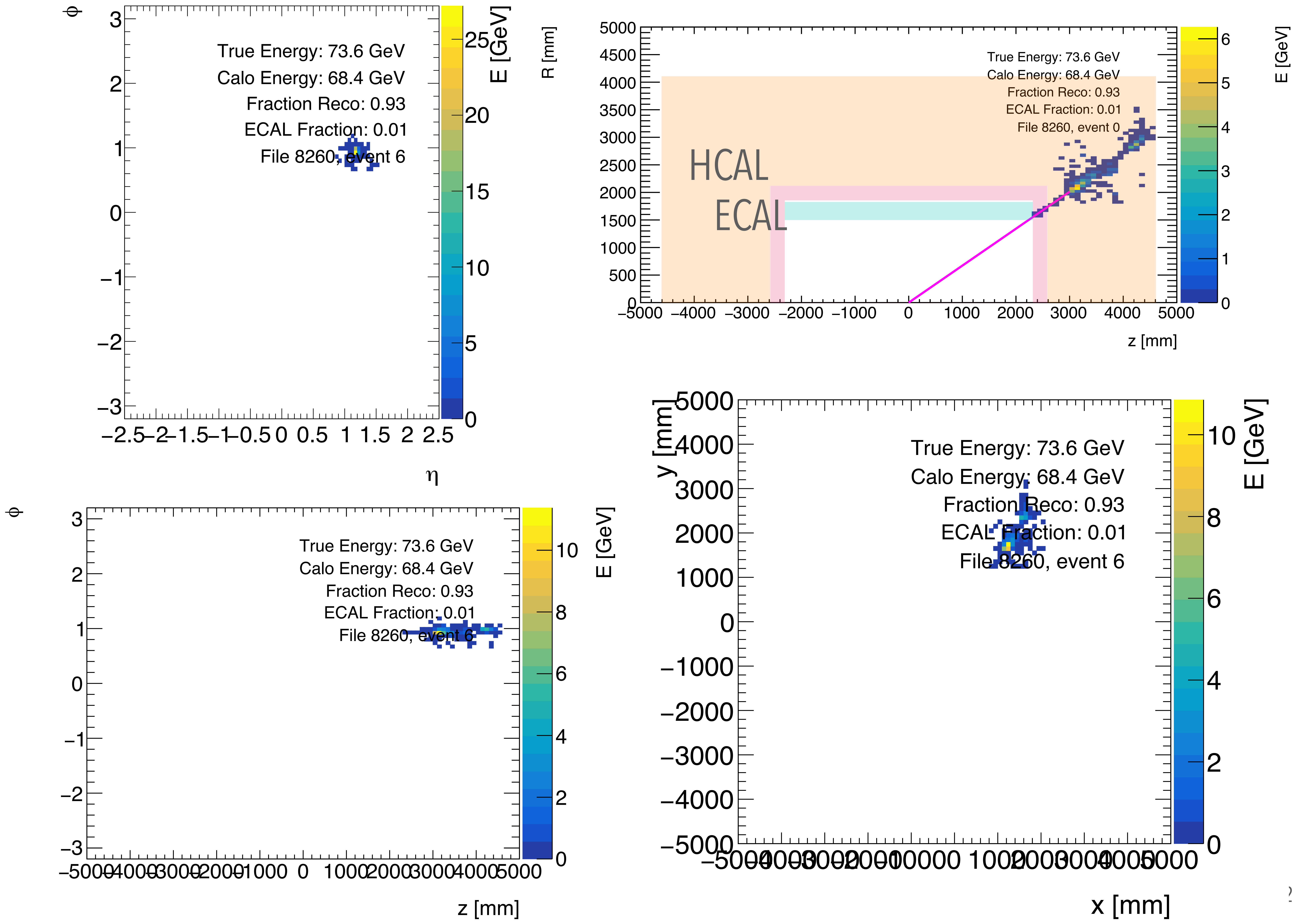
total ECAL: 8.84, total HCAL: 0.21
Calo E / True E: 0.46
```

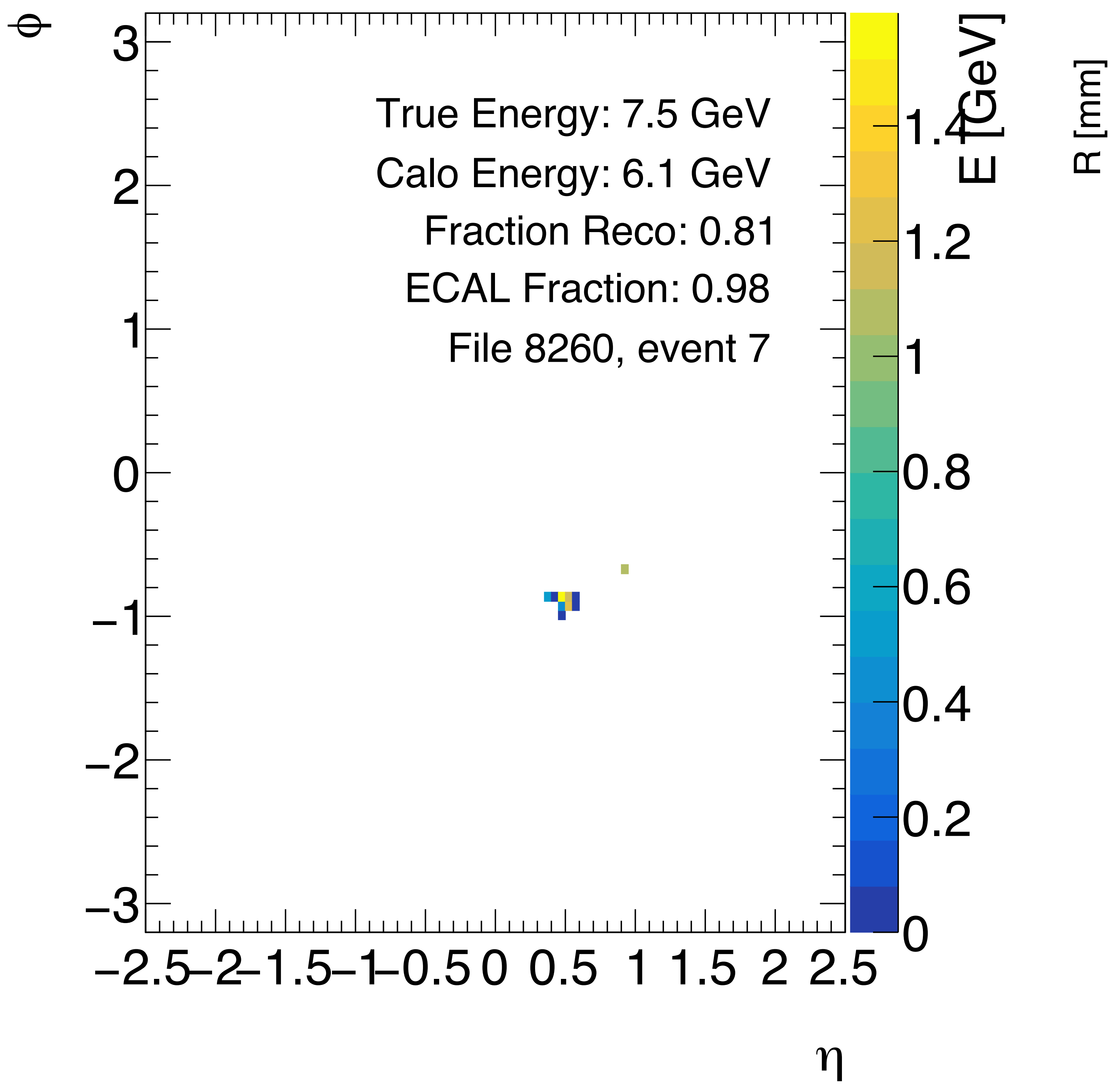
makes some He atoms, p

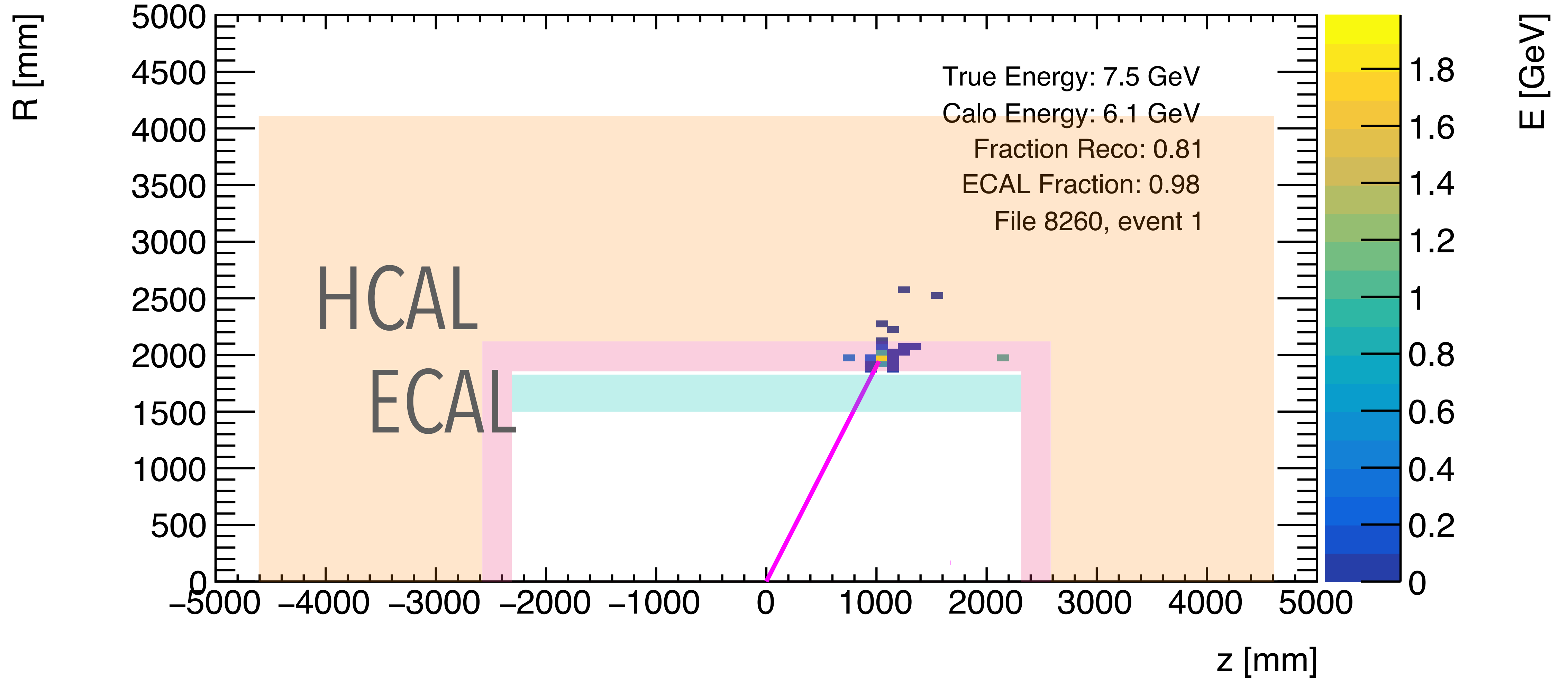


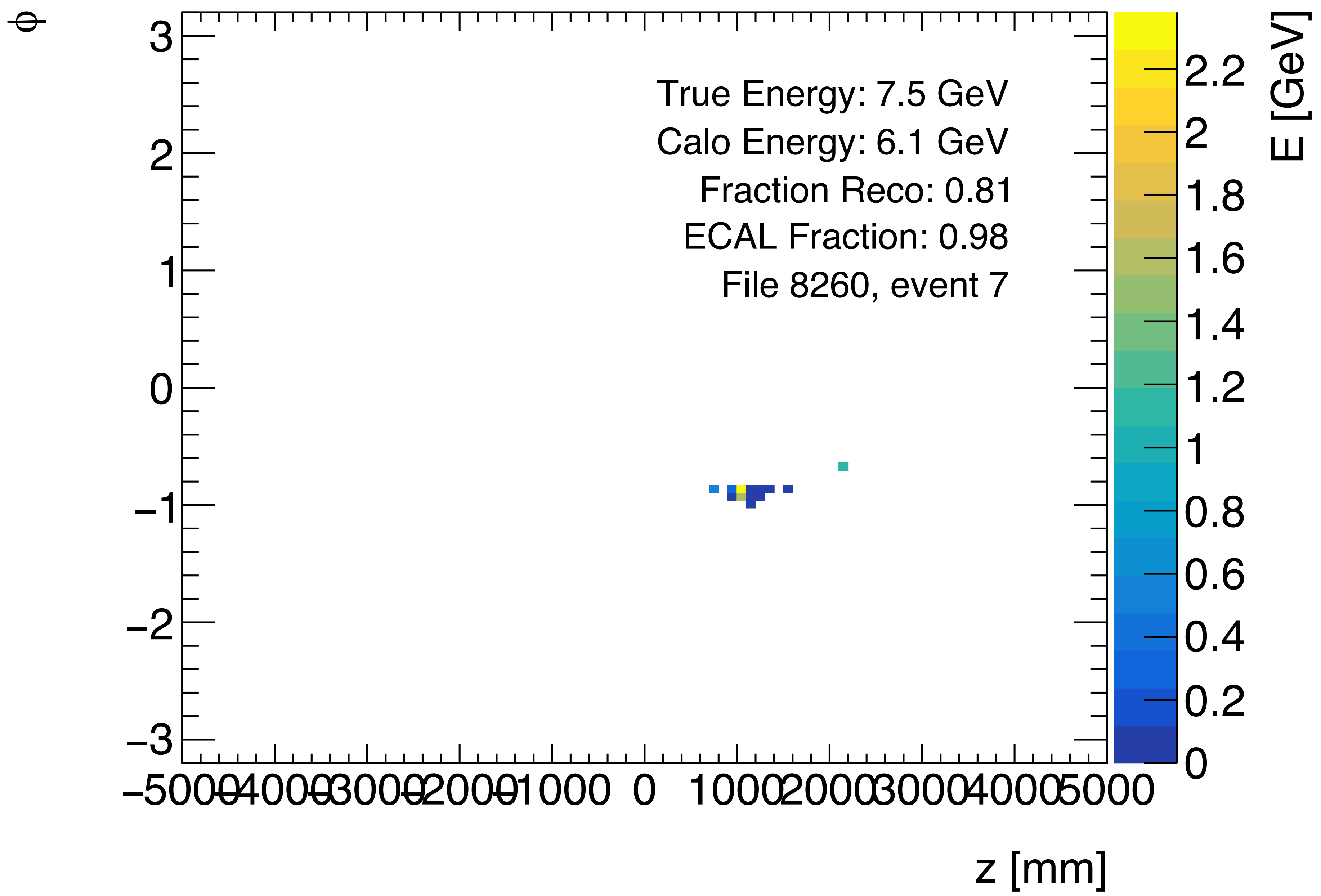
Visualizing pions

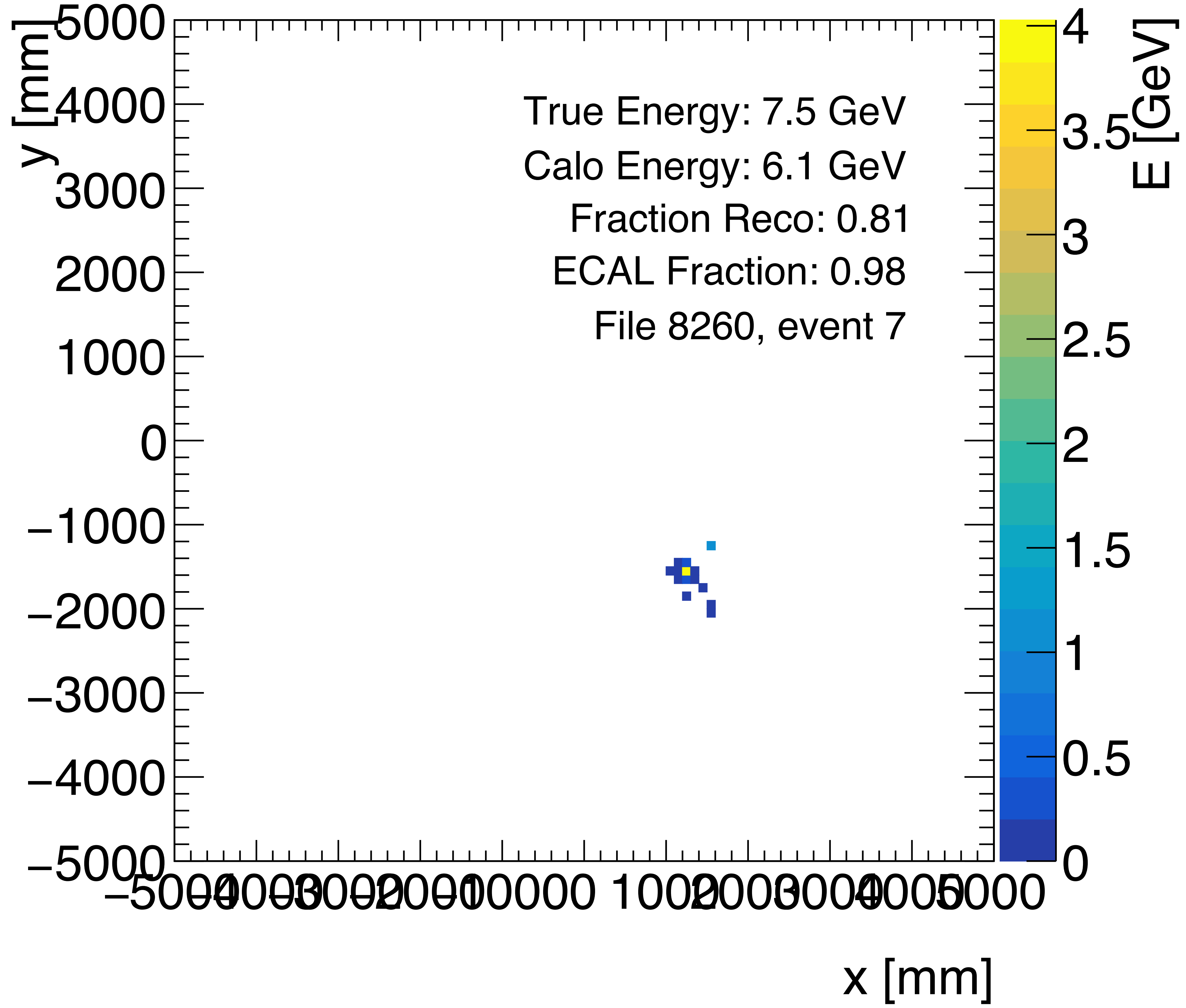


Visualizing pions





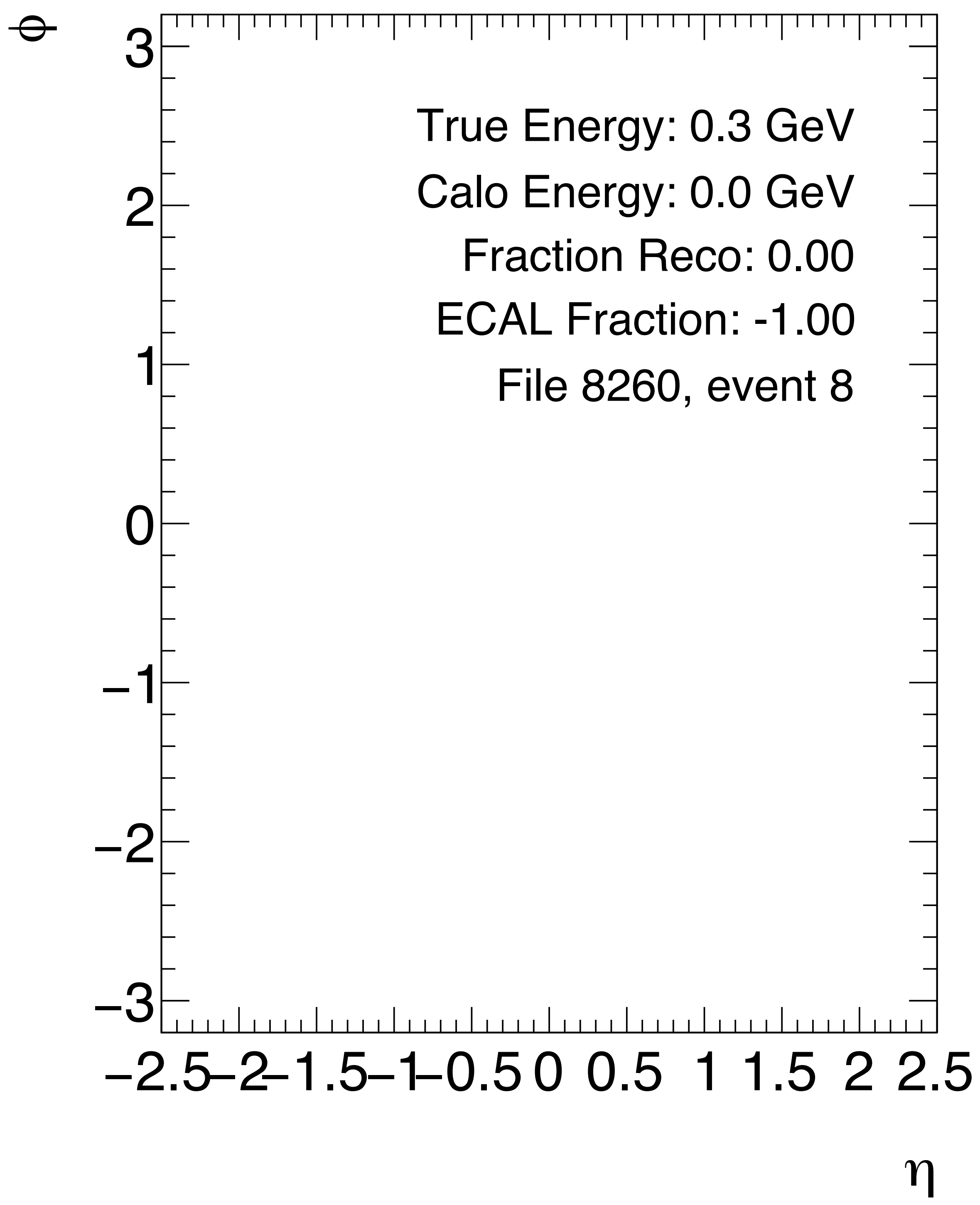


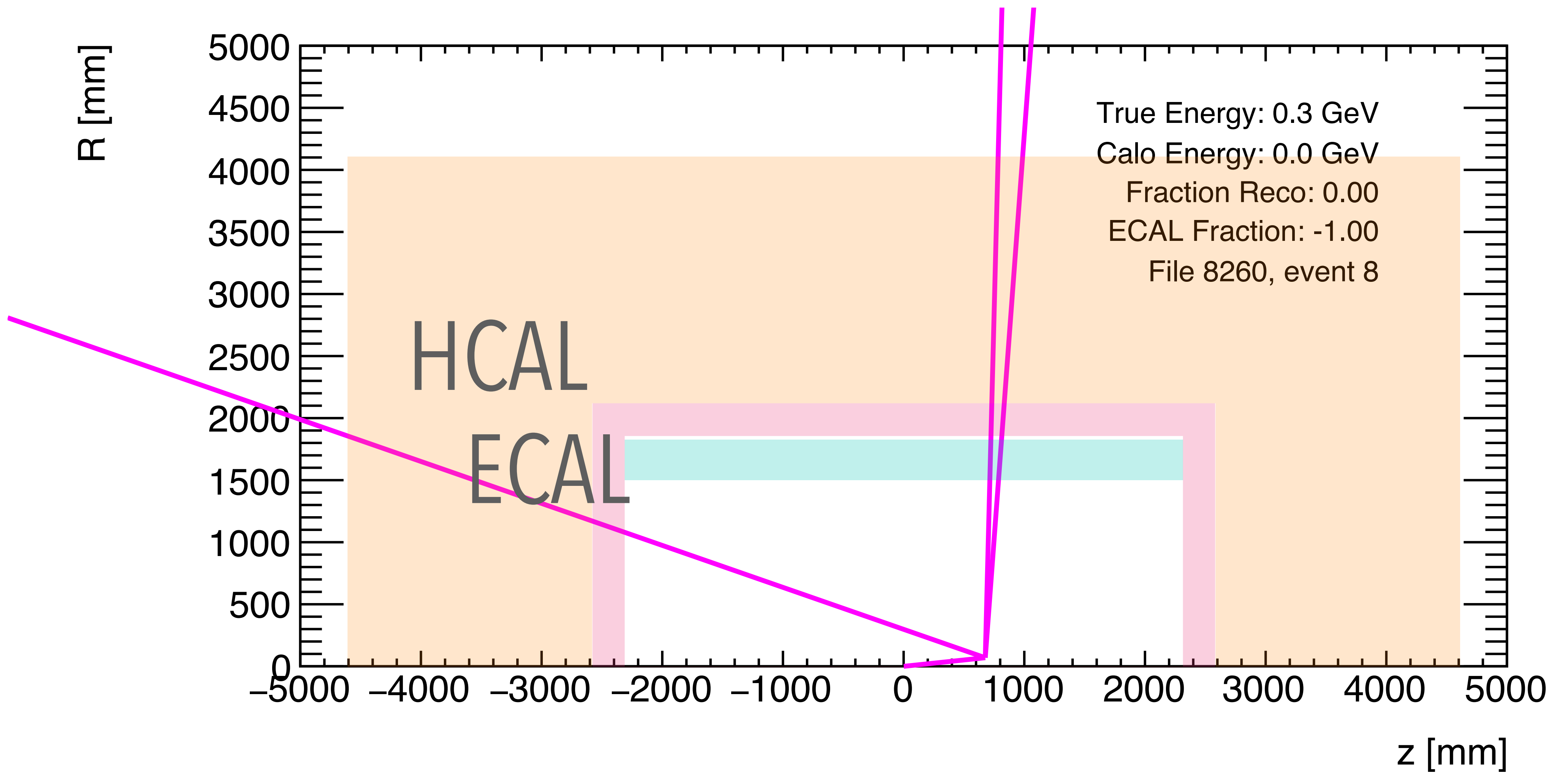


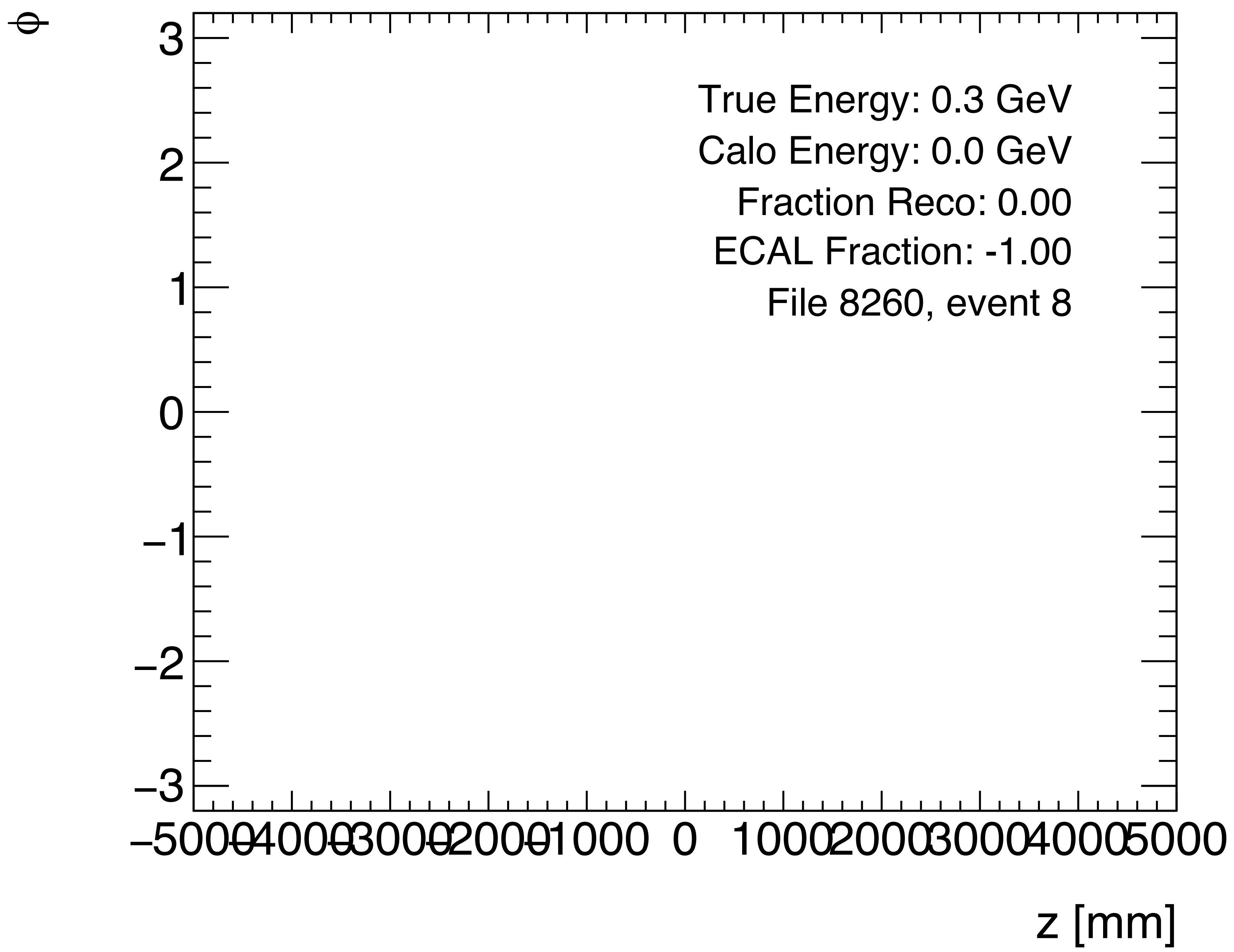
Visualizing pions

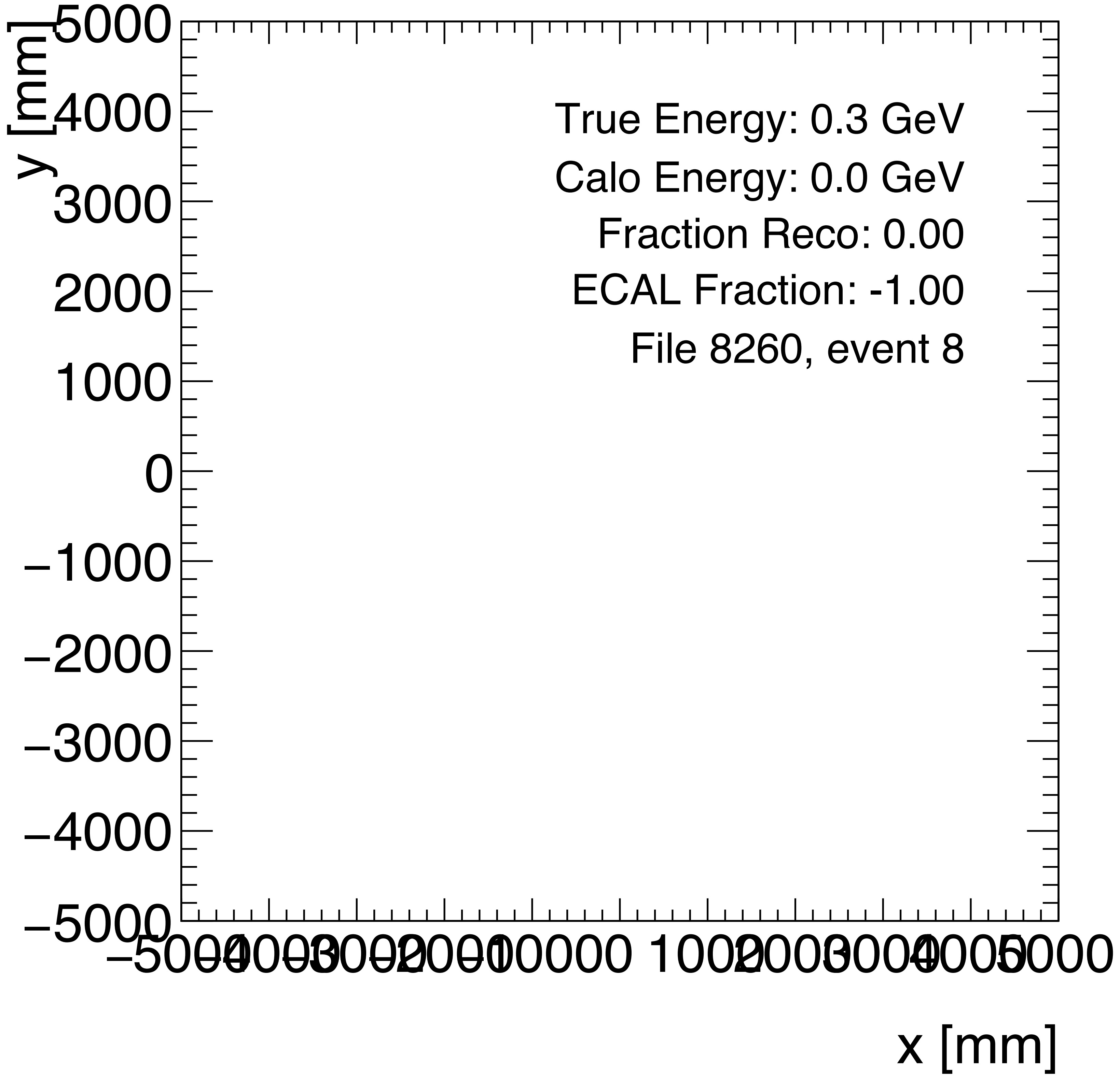
note: 2.25 GeV required for charged particle to make it through the tracker

makes sense this is 0

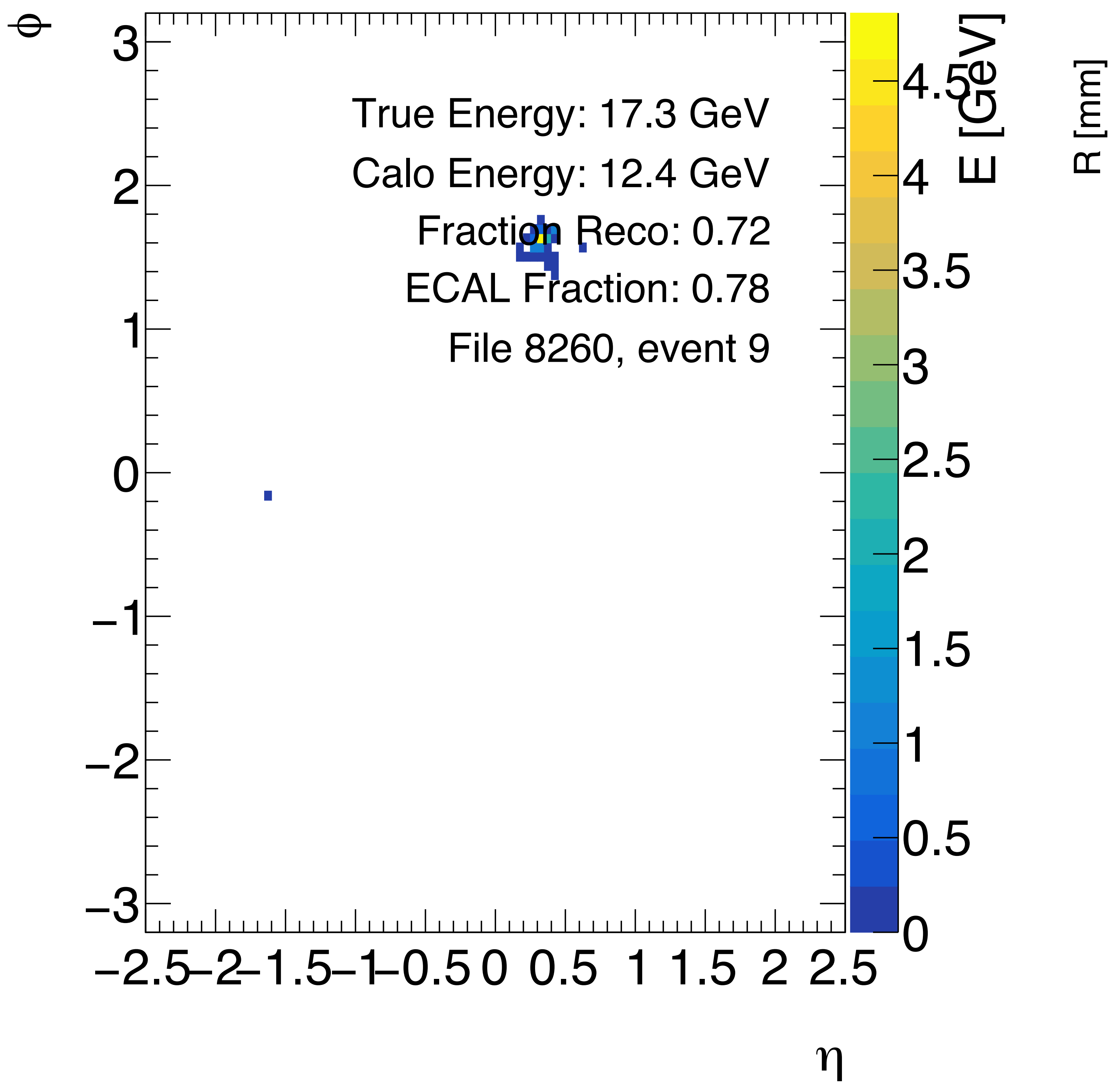


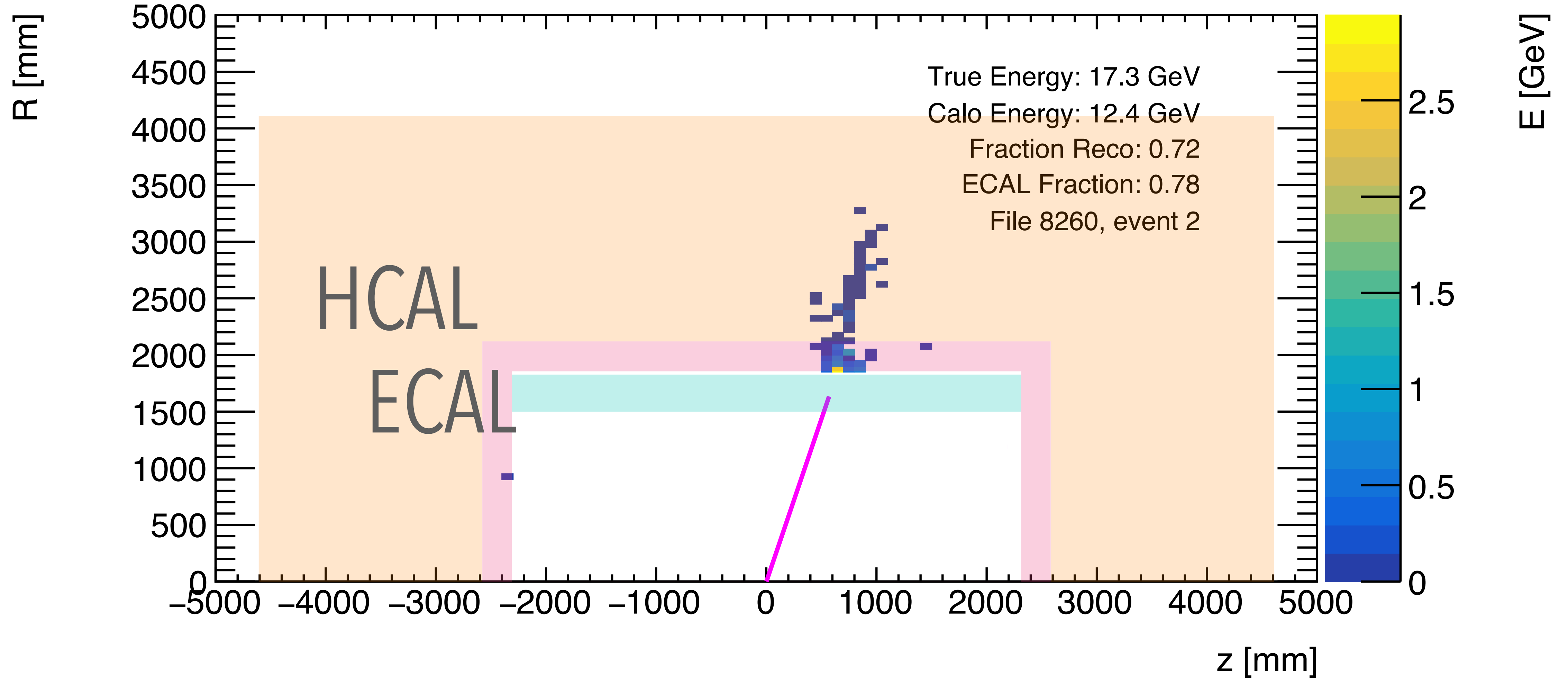


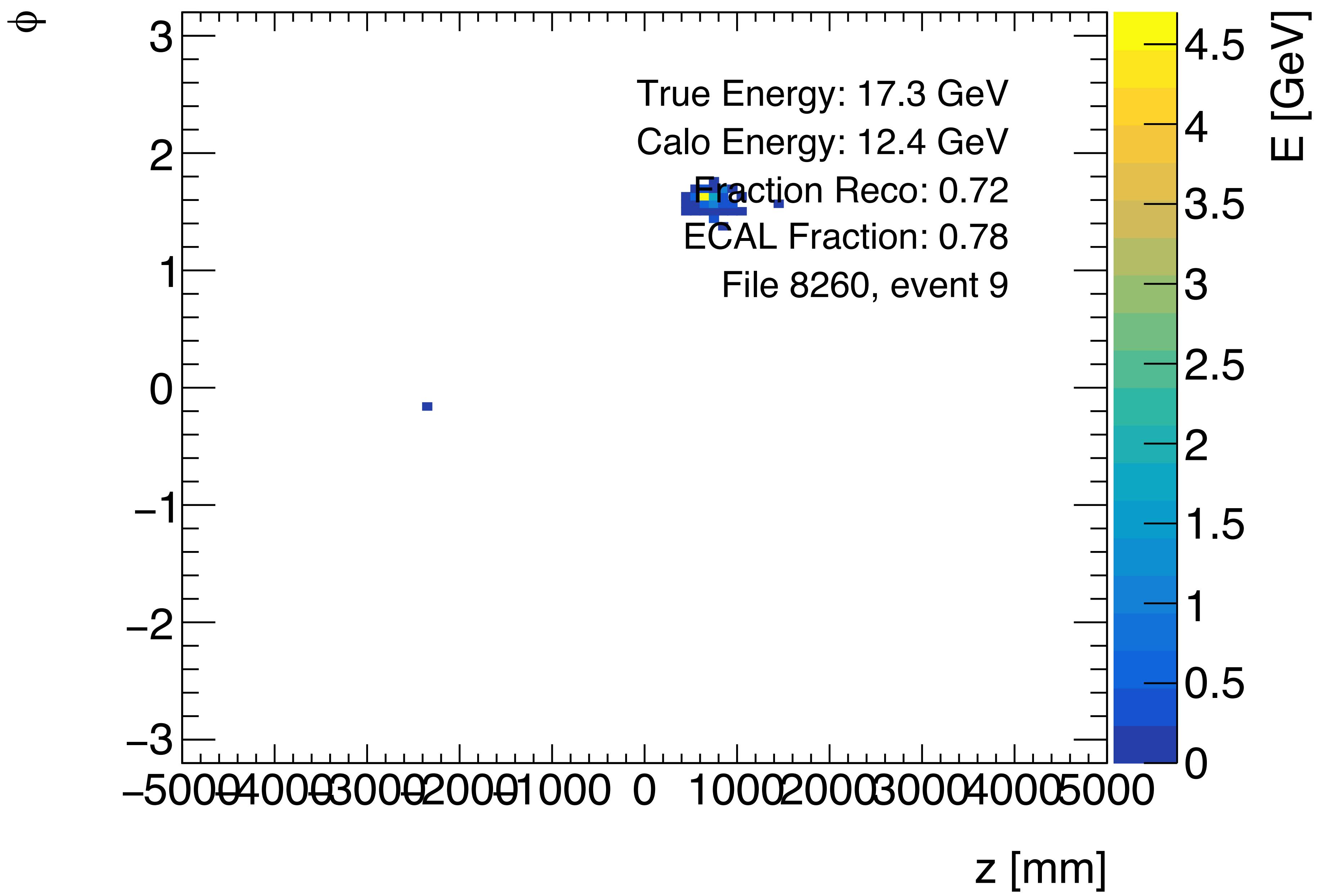


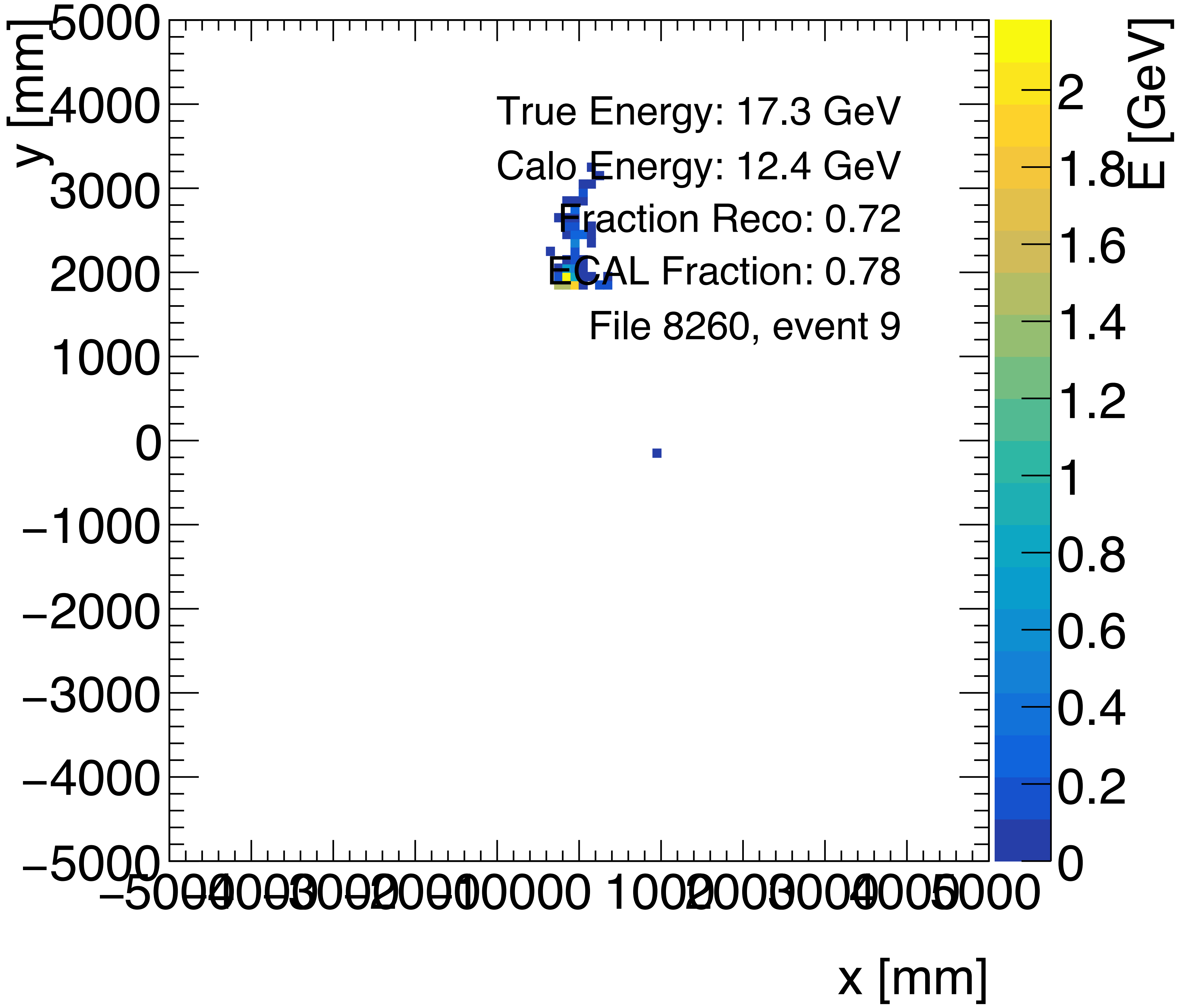


Visualizing pions







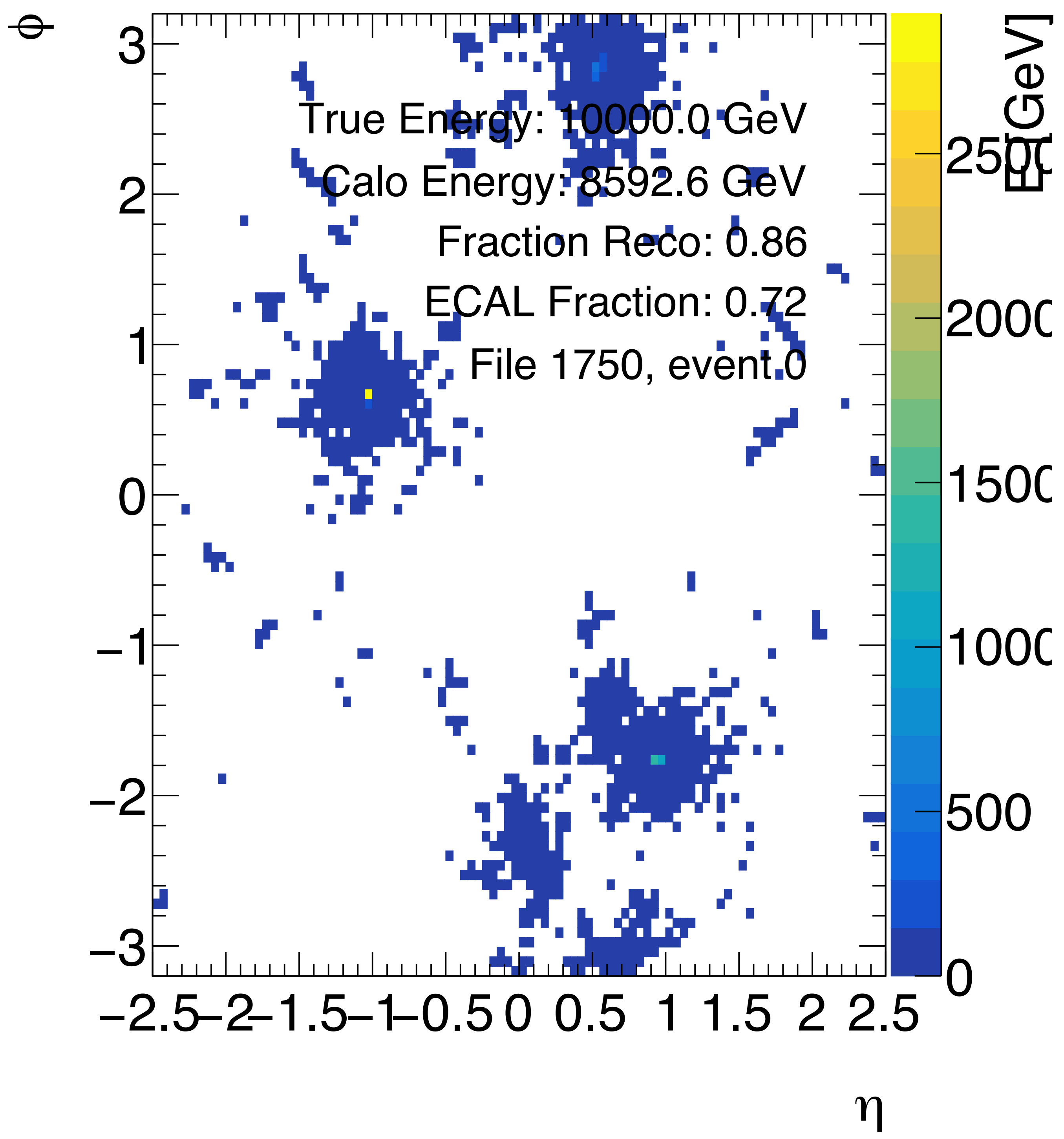


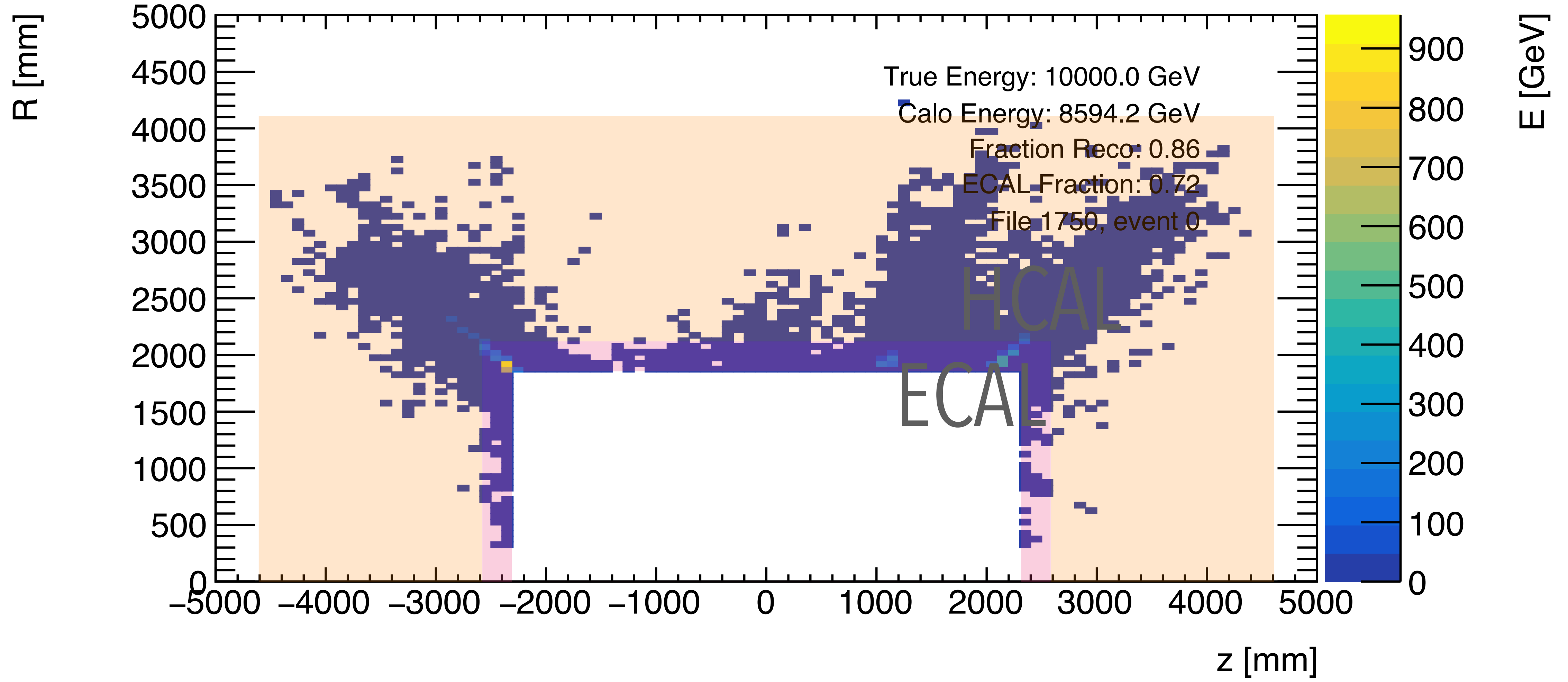
Conclusions

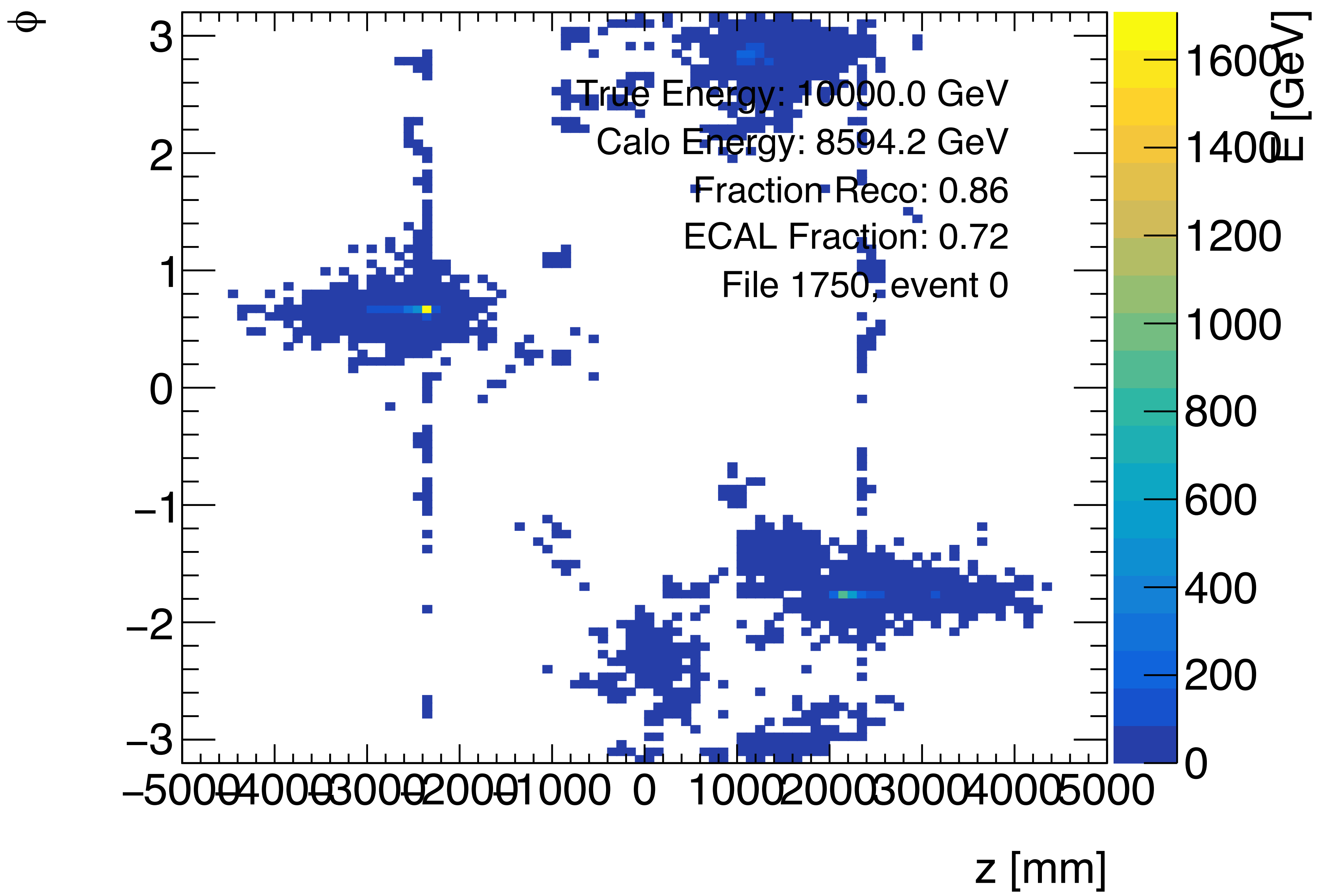
- ECAL fraction is bimodal but still very high on average for the single charged pions (i.e. consistent with jets)
  - Often see showering begin inside the solenoid (in teal) – this could account for an increase in this fraction, though it would be interesting to compare total interaction lengths between MAIA and ATLAS
- Still not totally convinced the physics makes sense in these cases where we don't get most of the energy and it looks like some kind of recoil
  - Looked at physics models:
    - https://geant4.web.cern.ch/documentation/dev/plg_html/PhysicsListGuide/reference_PL/QGSP_BERT.html
    - Seems like the inelastic is well handled (or at least specifically handled) at these energies
    - Elastic is just parametrized. Does it go to 0?

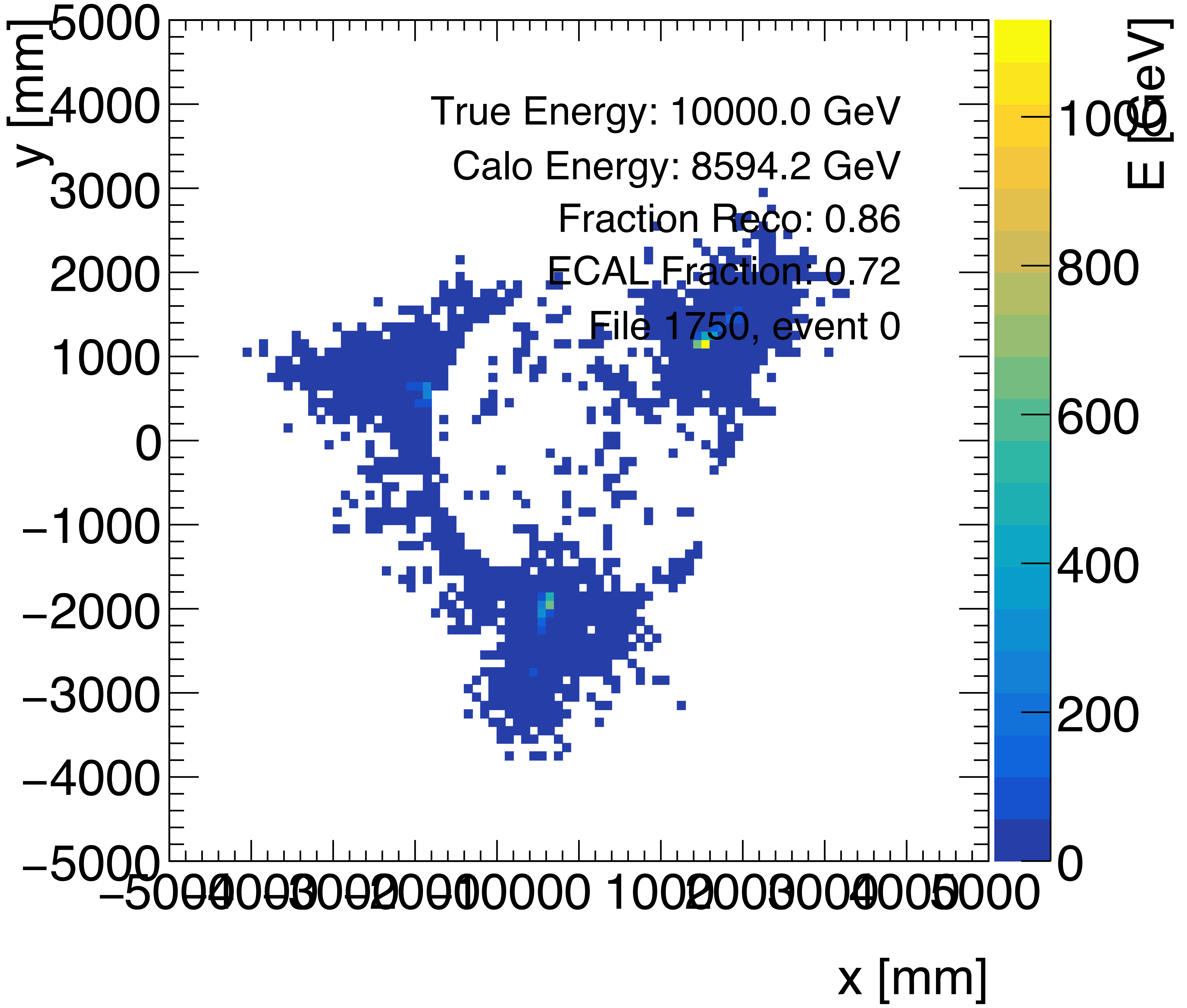
Visualizing high energy jets

“di-jets” at m_{jj} = 10 TeV

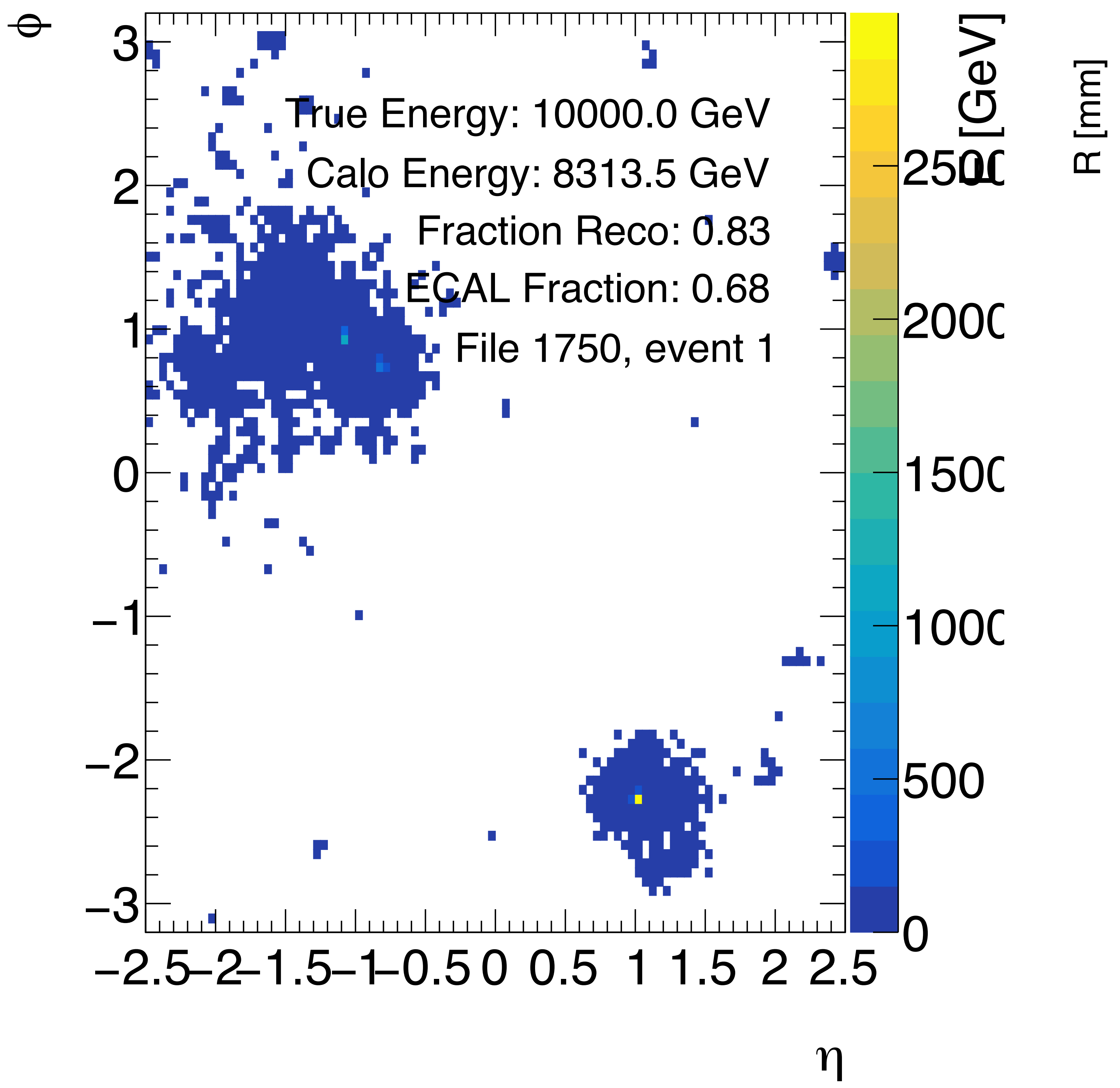


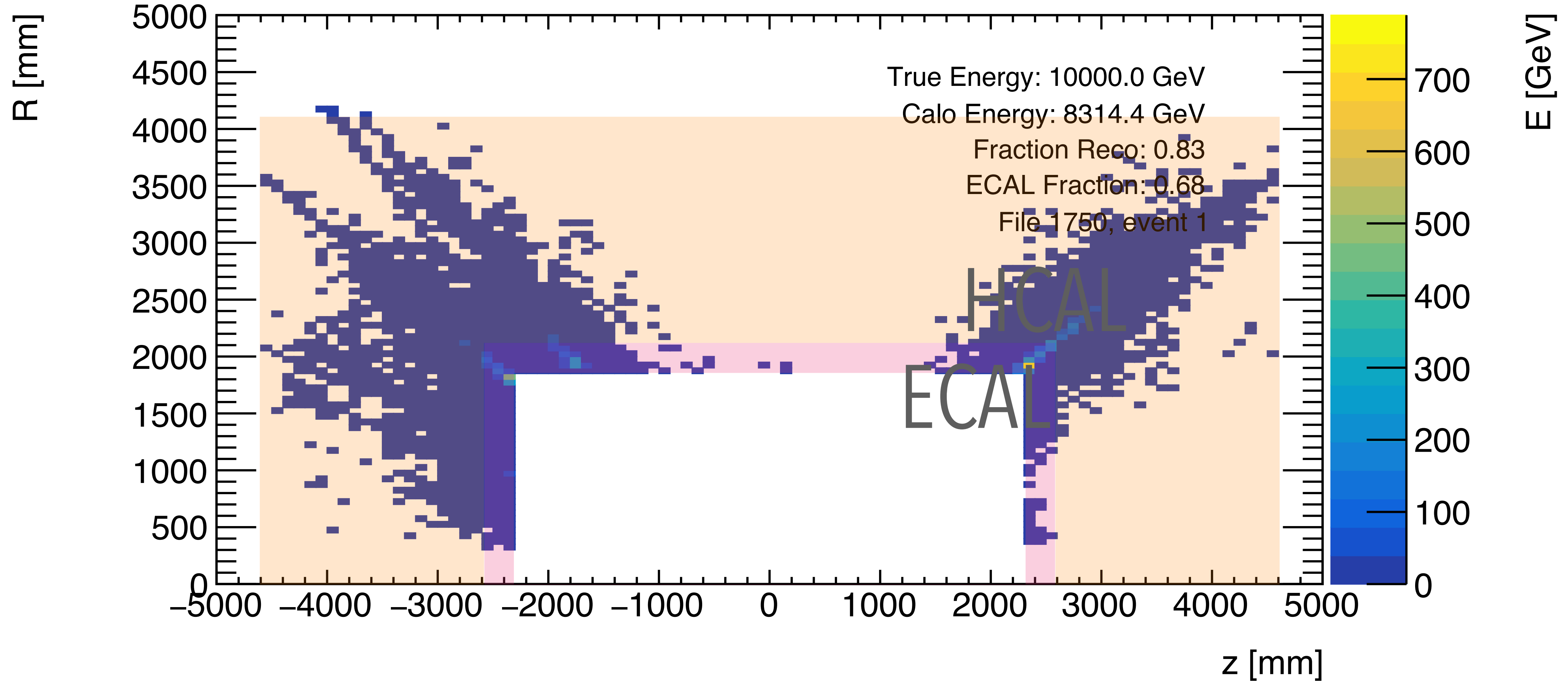


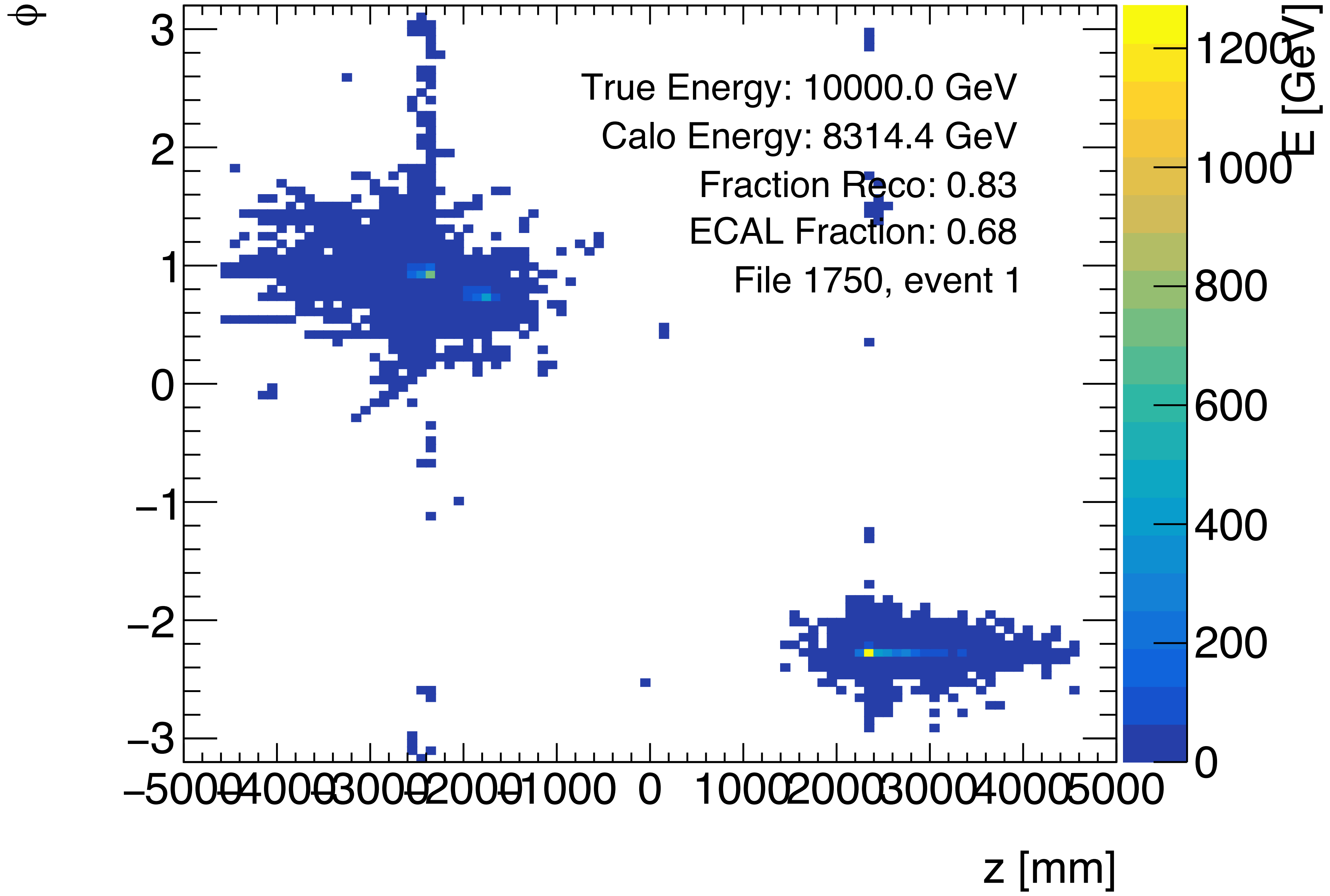


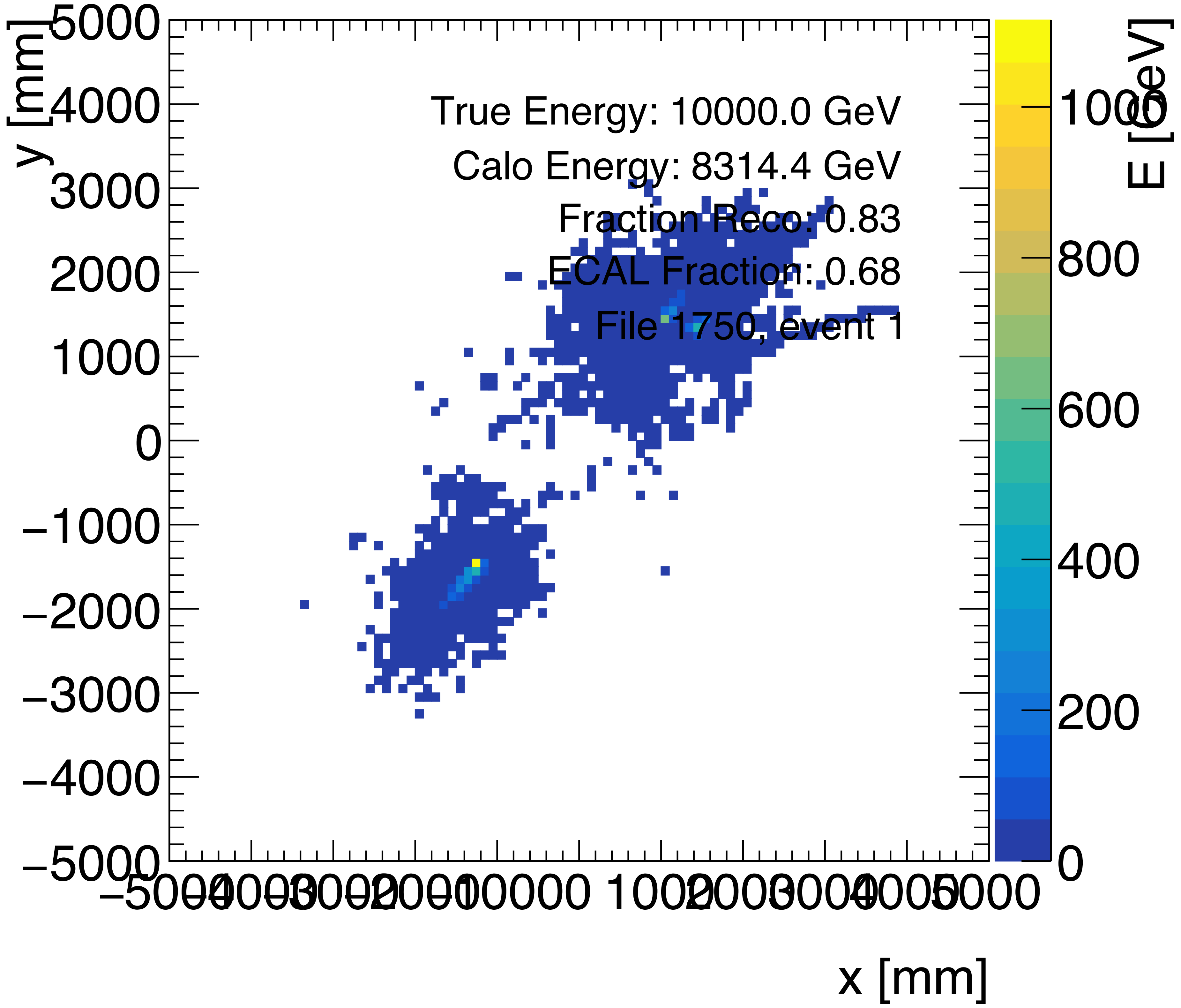


Visualizing high energy jets

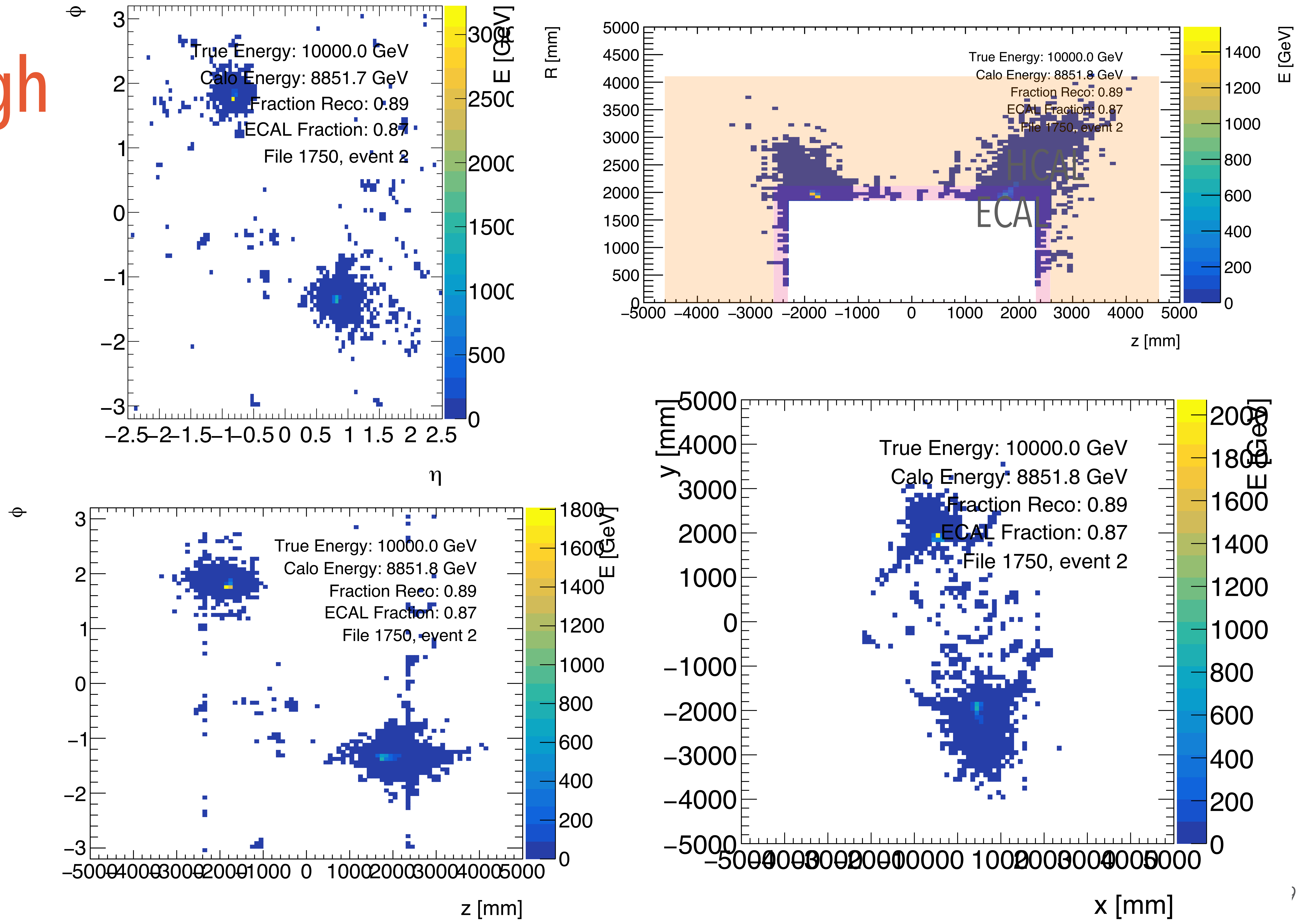




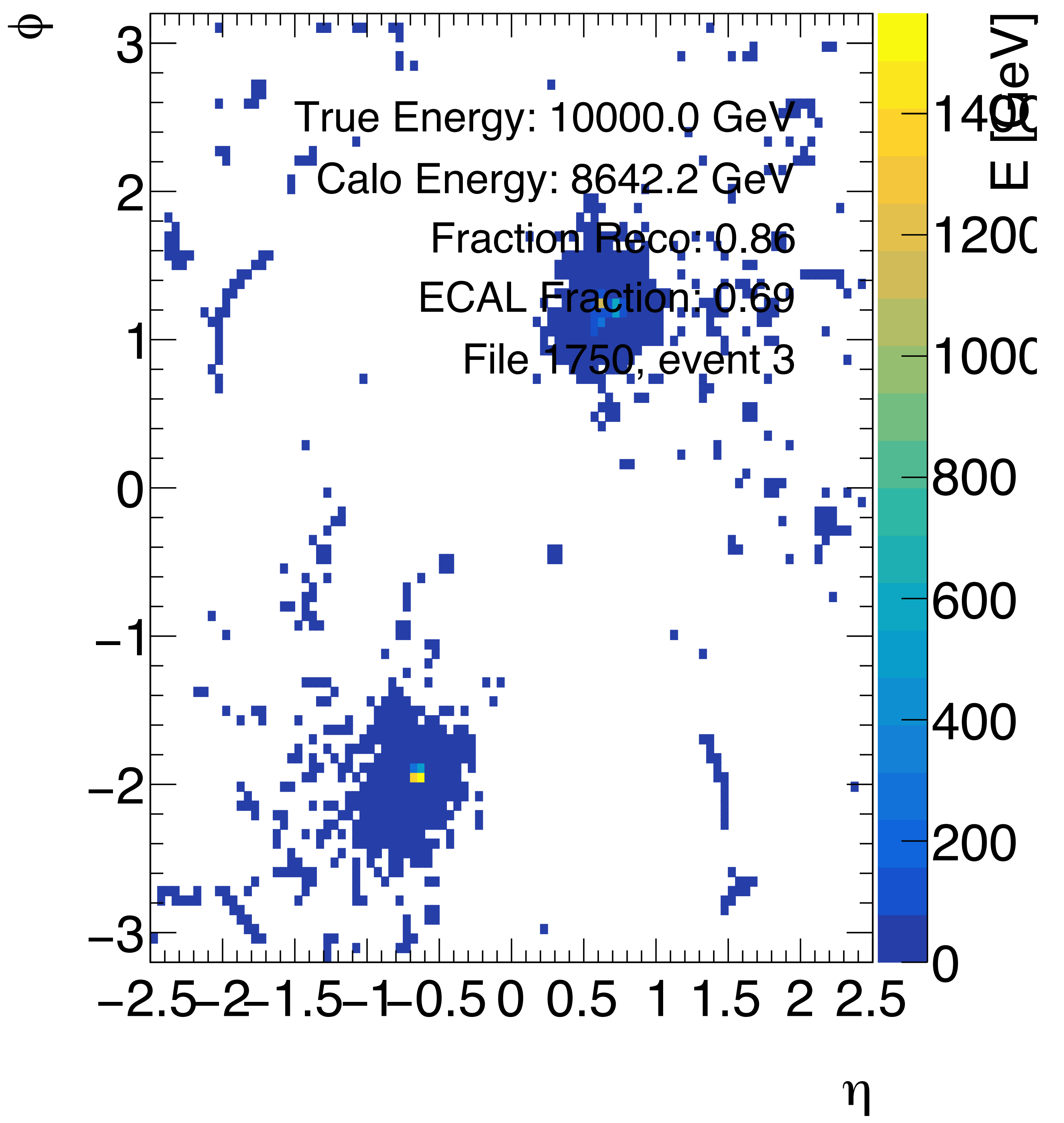


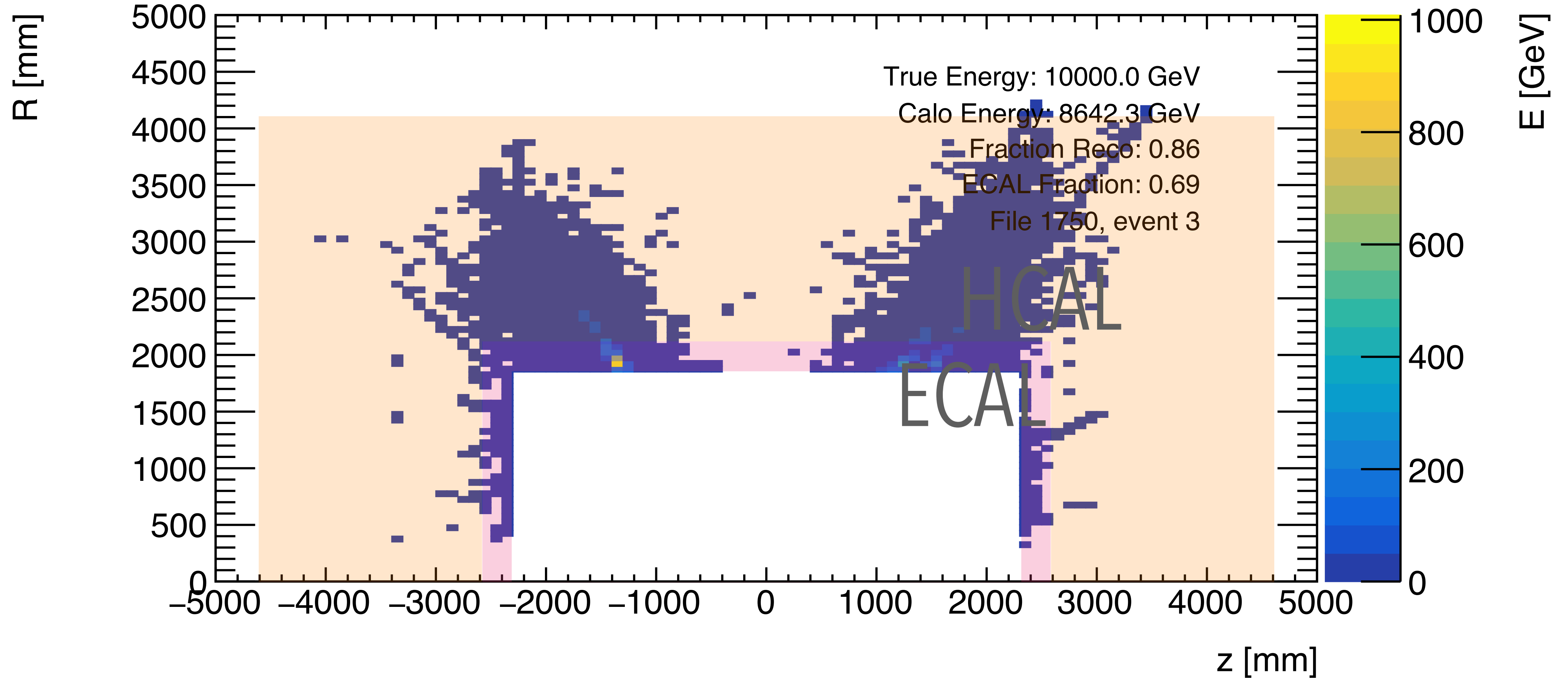


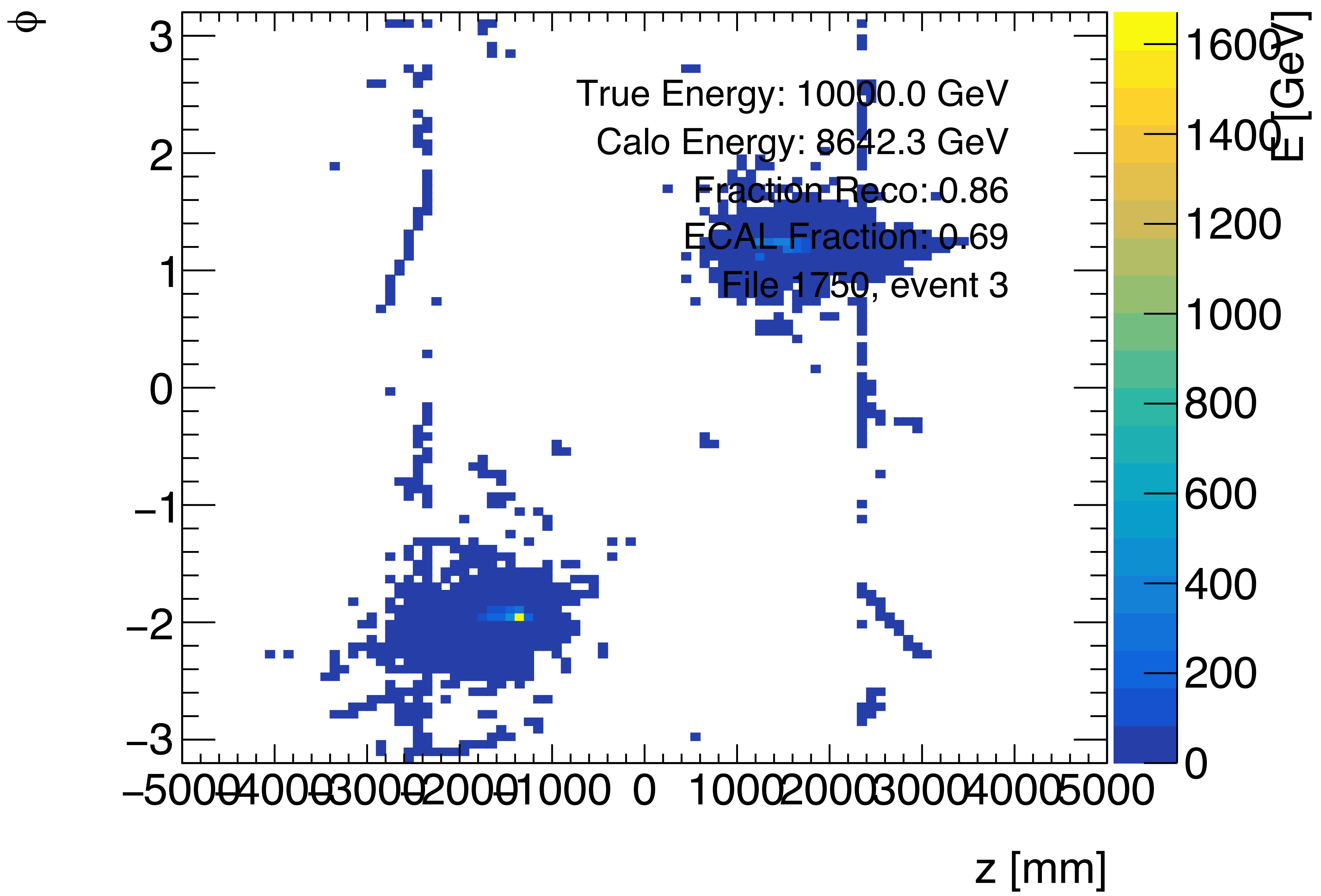
Visualizing high energy jets

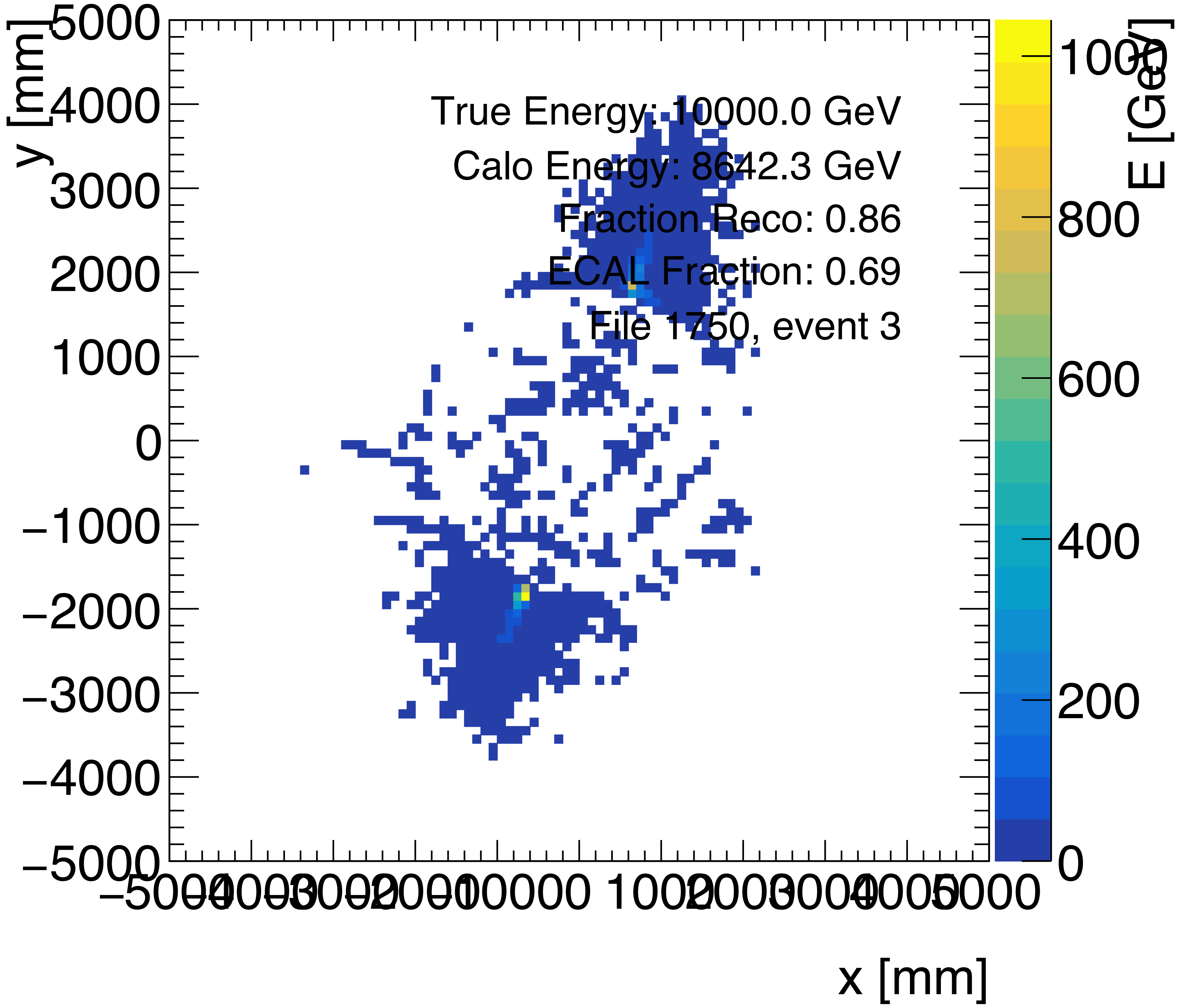


Visualizing high energy jets

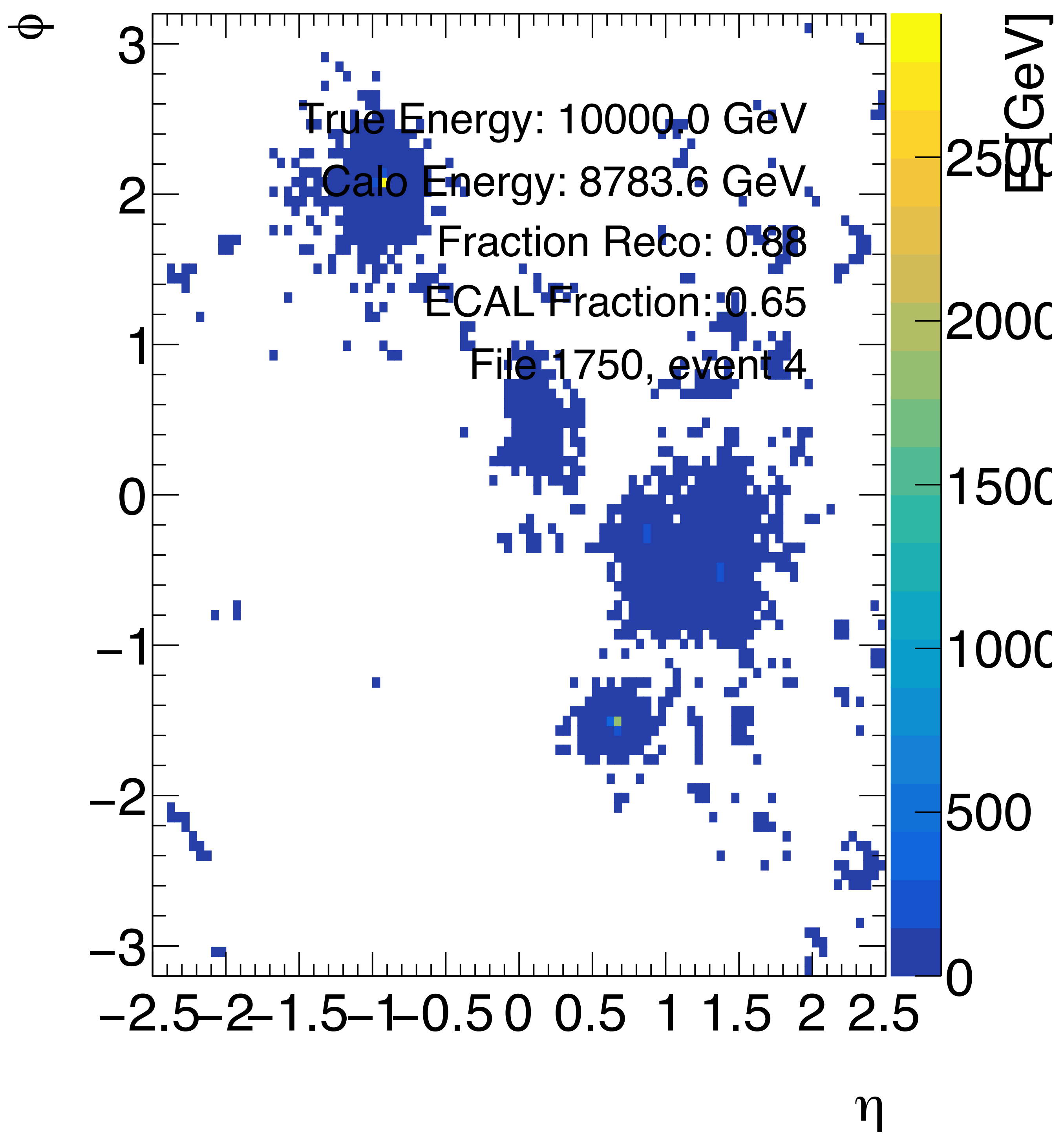


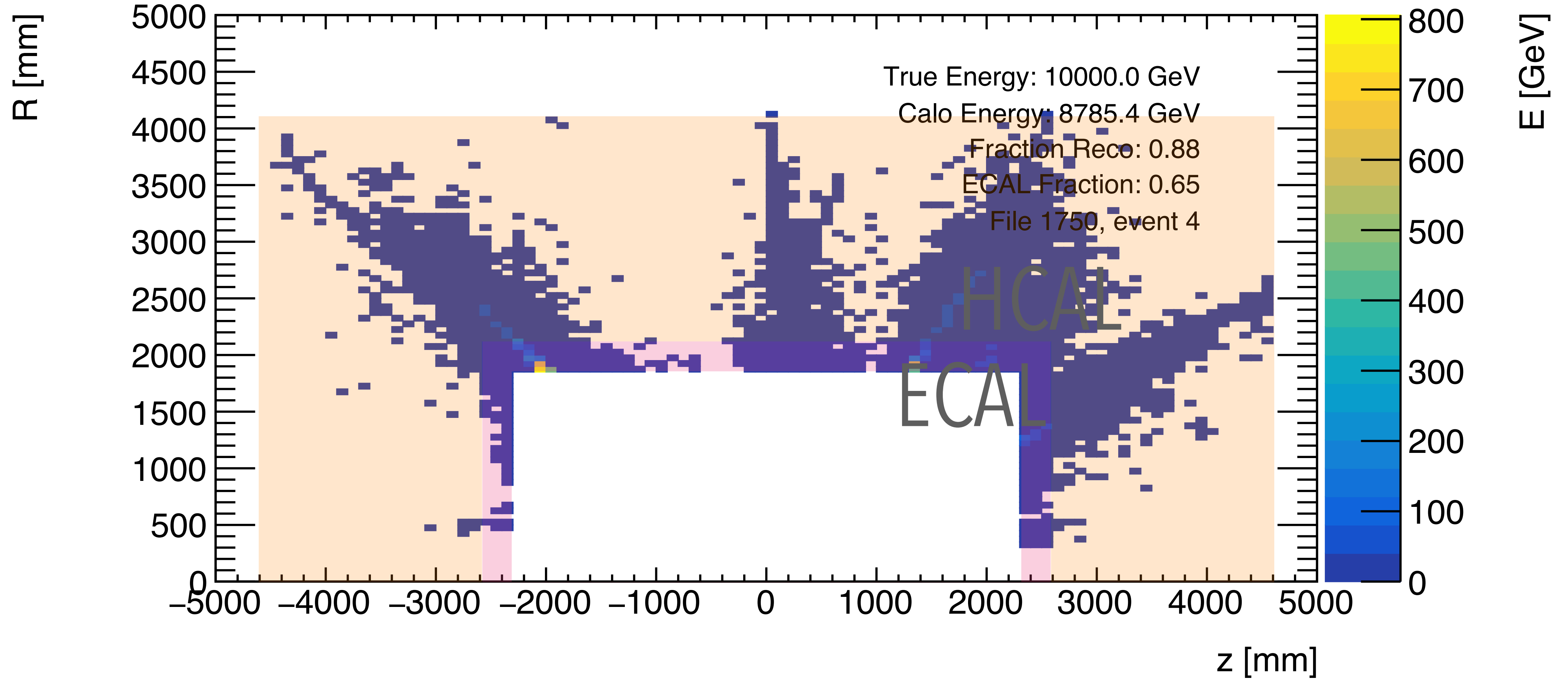


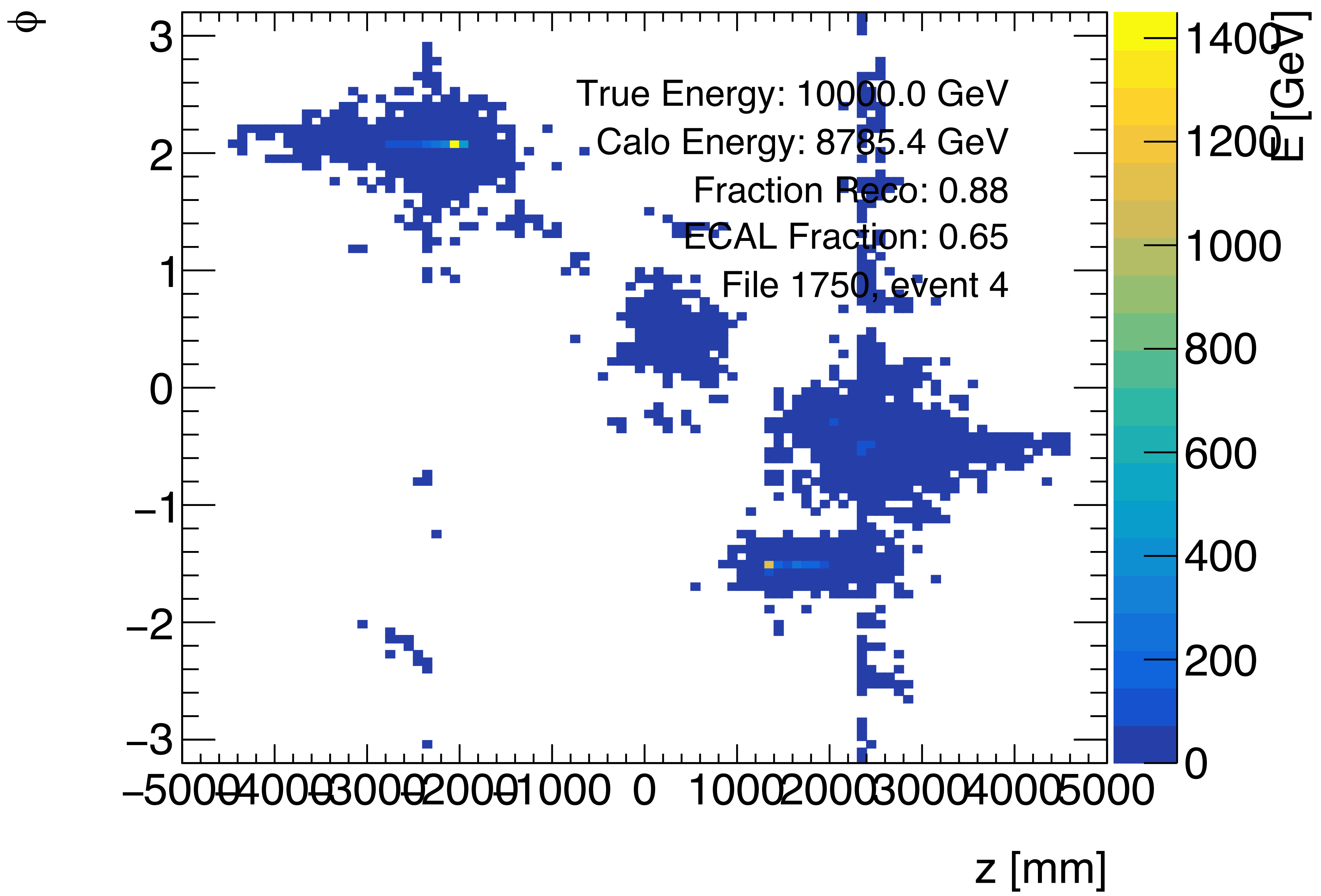


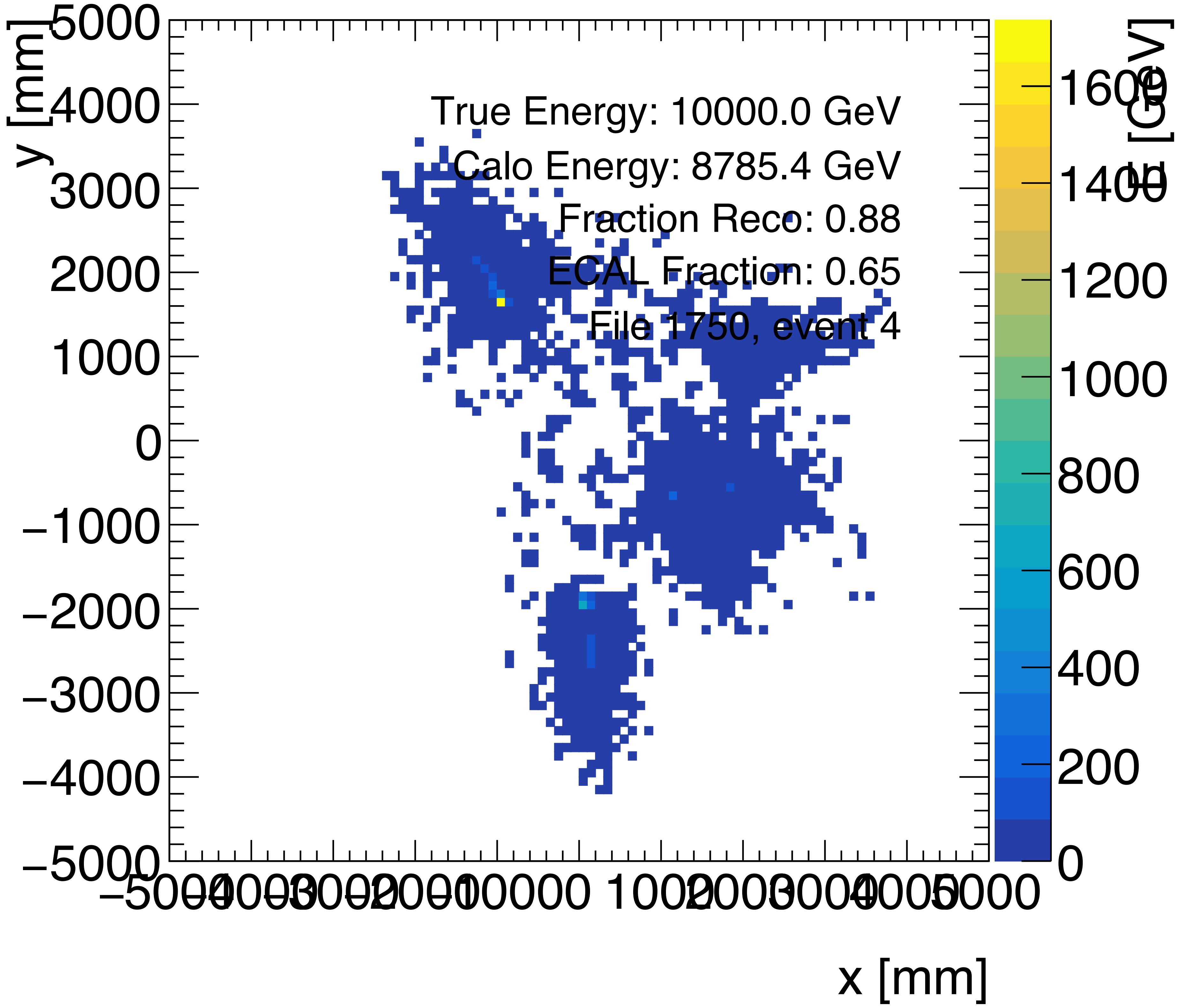


Visualizing high energy jets

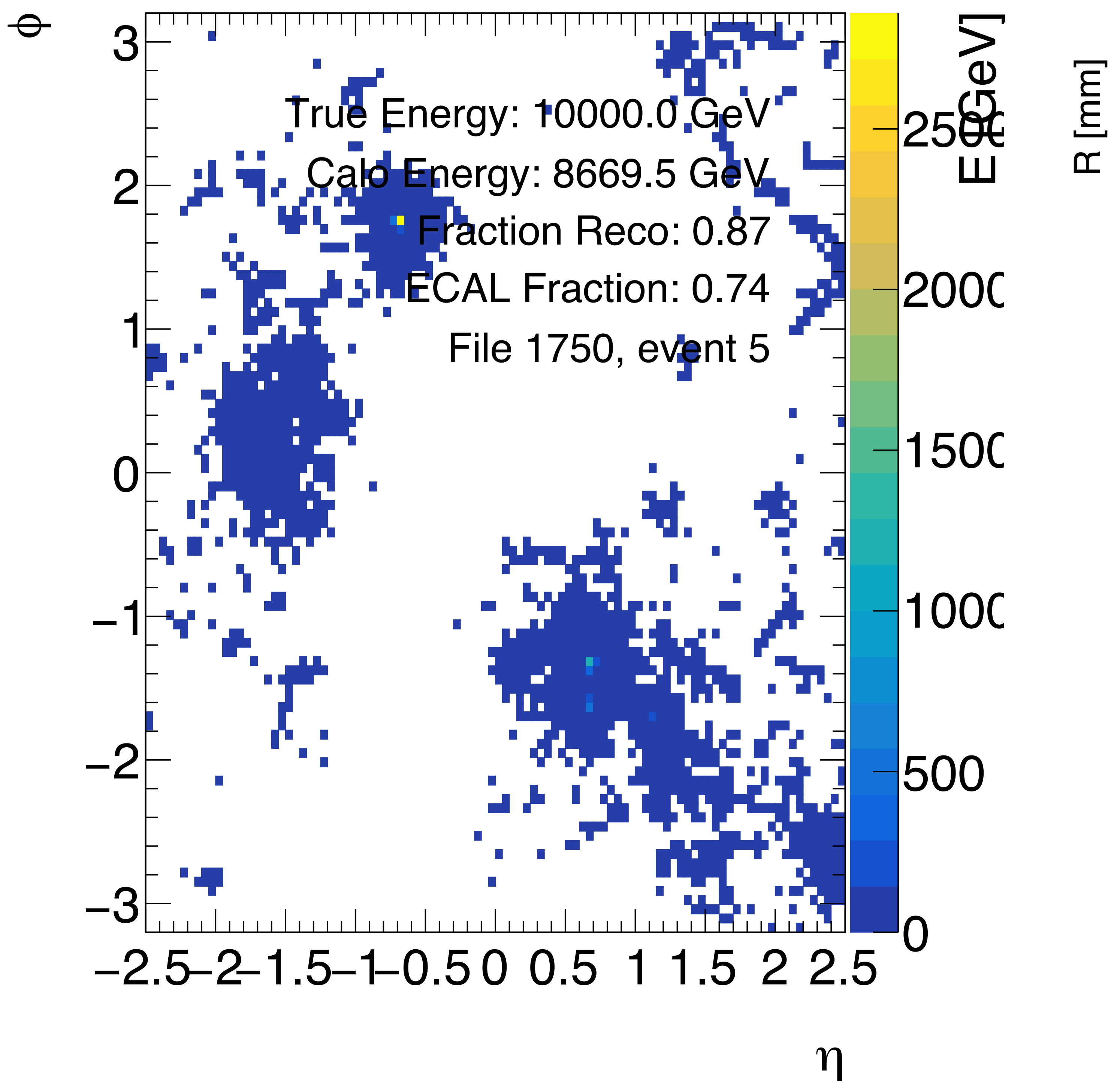


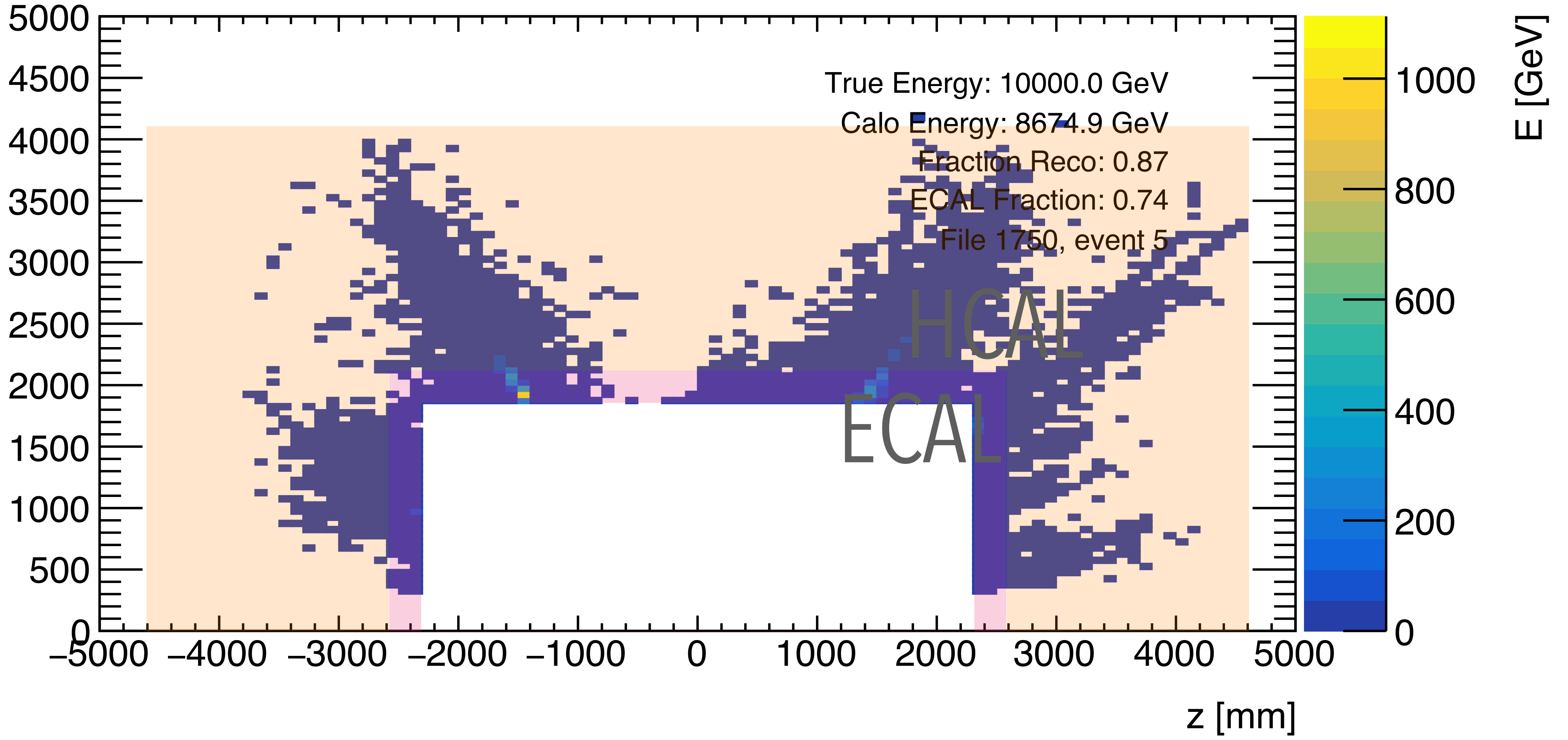


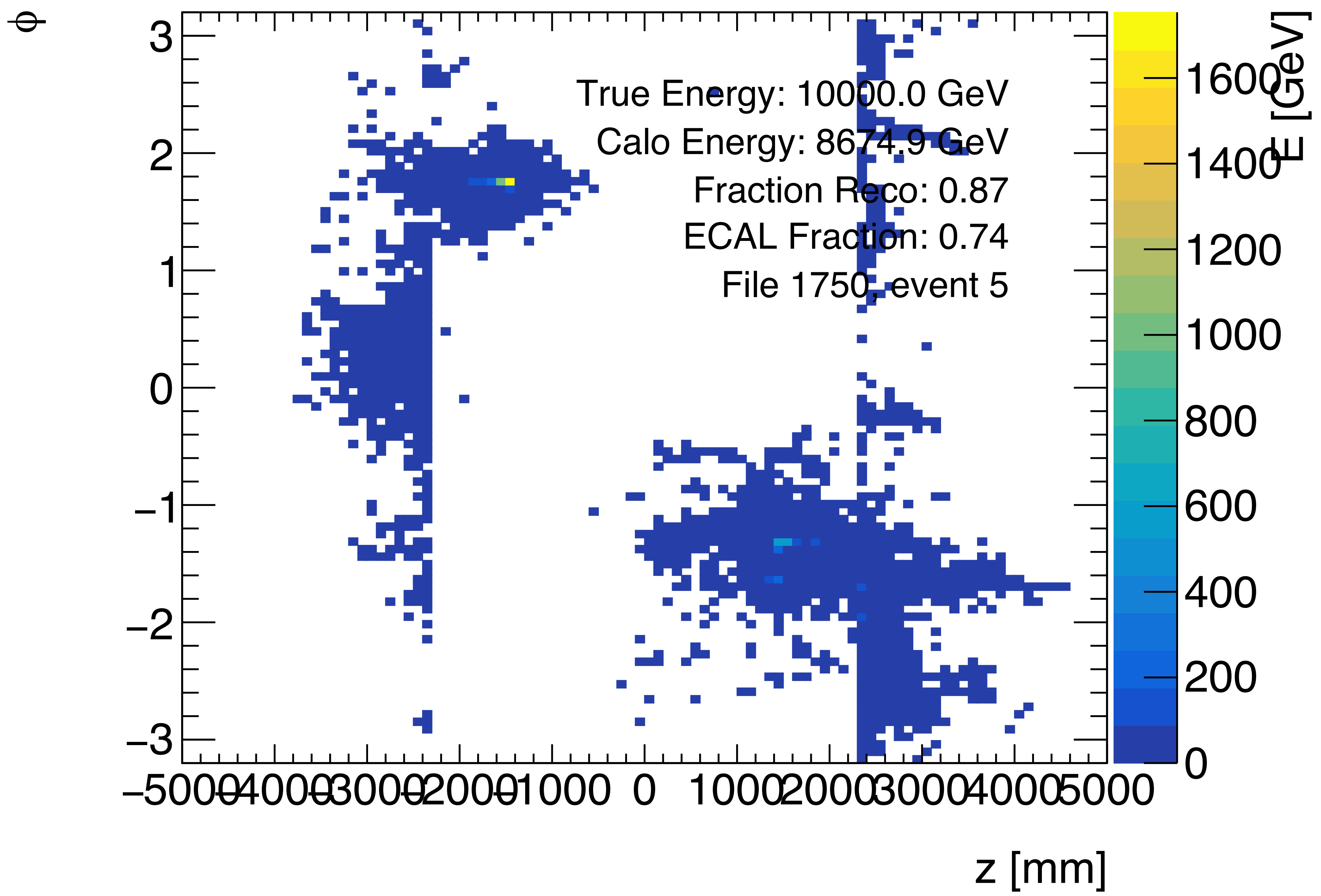


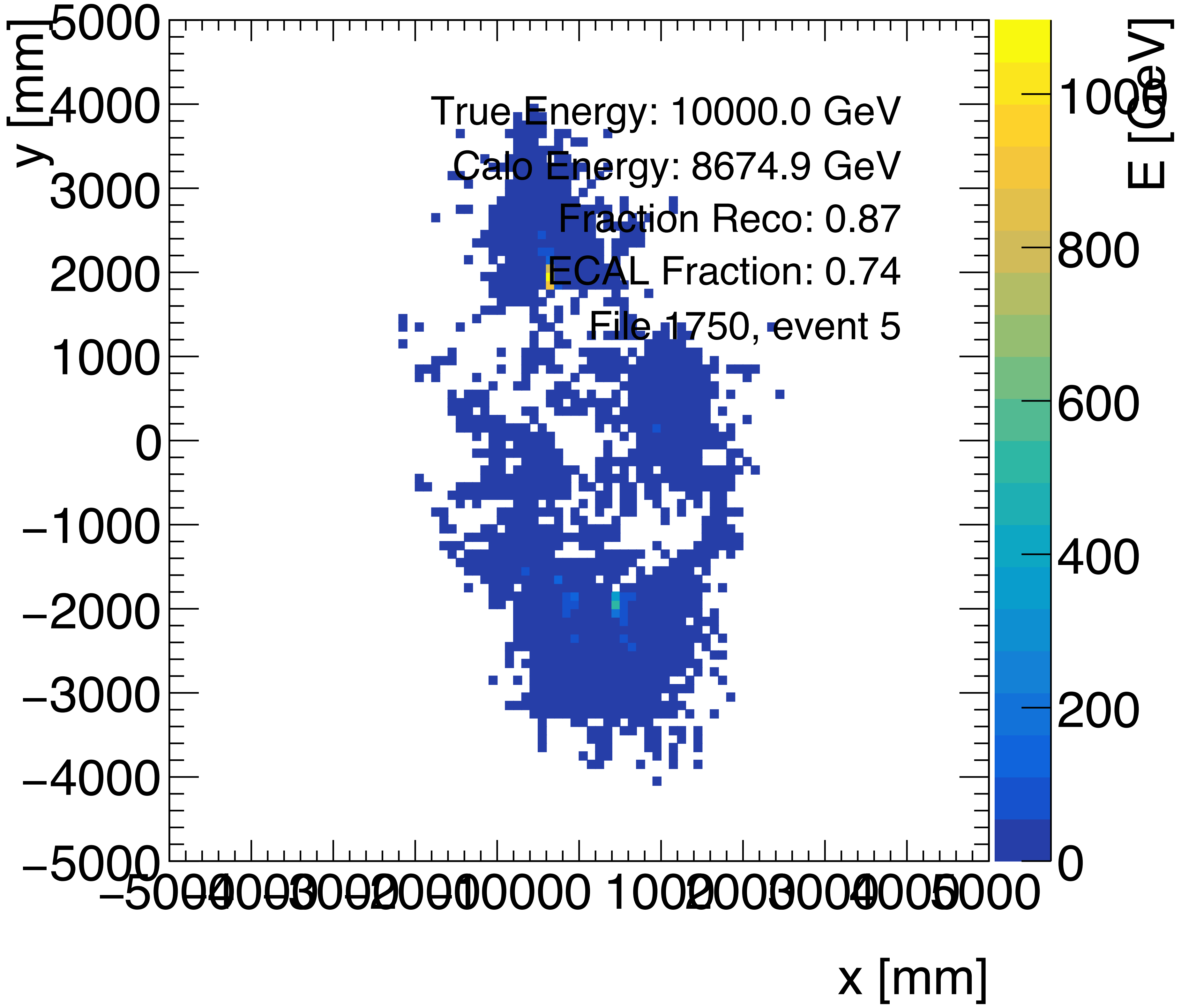


Visualizing high energy jets

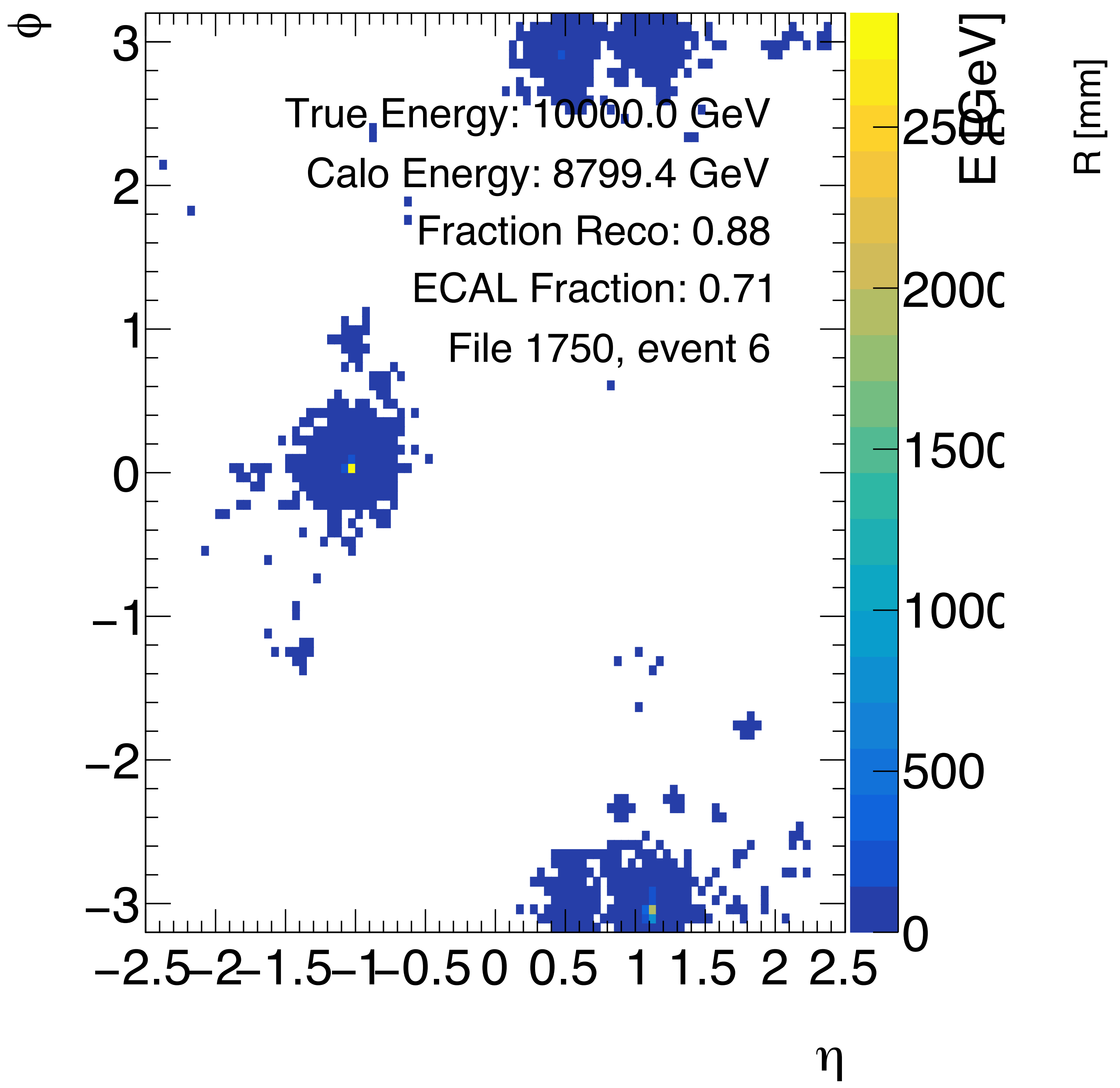


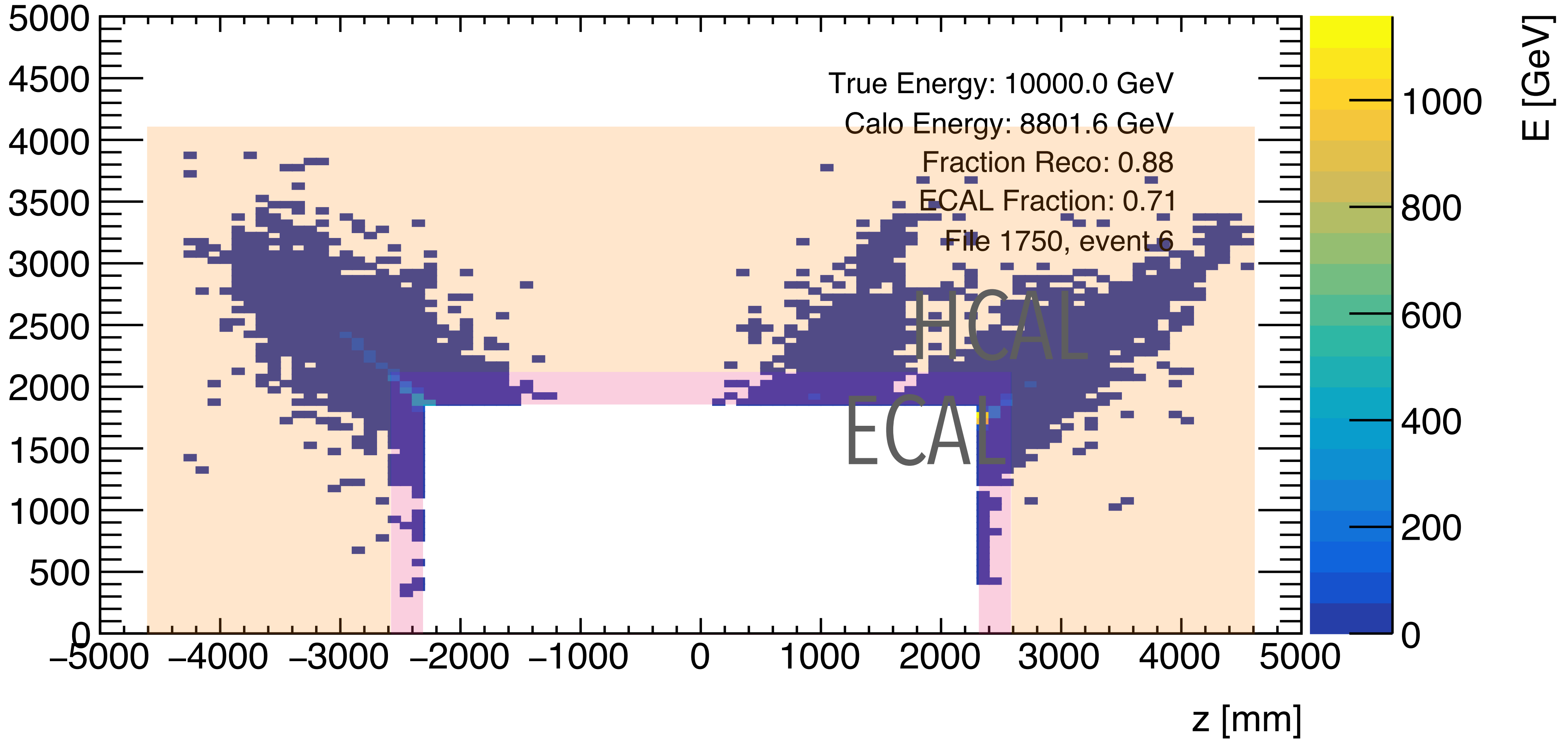


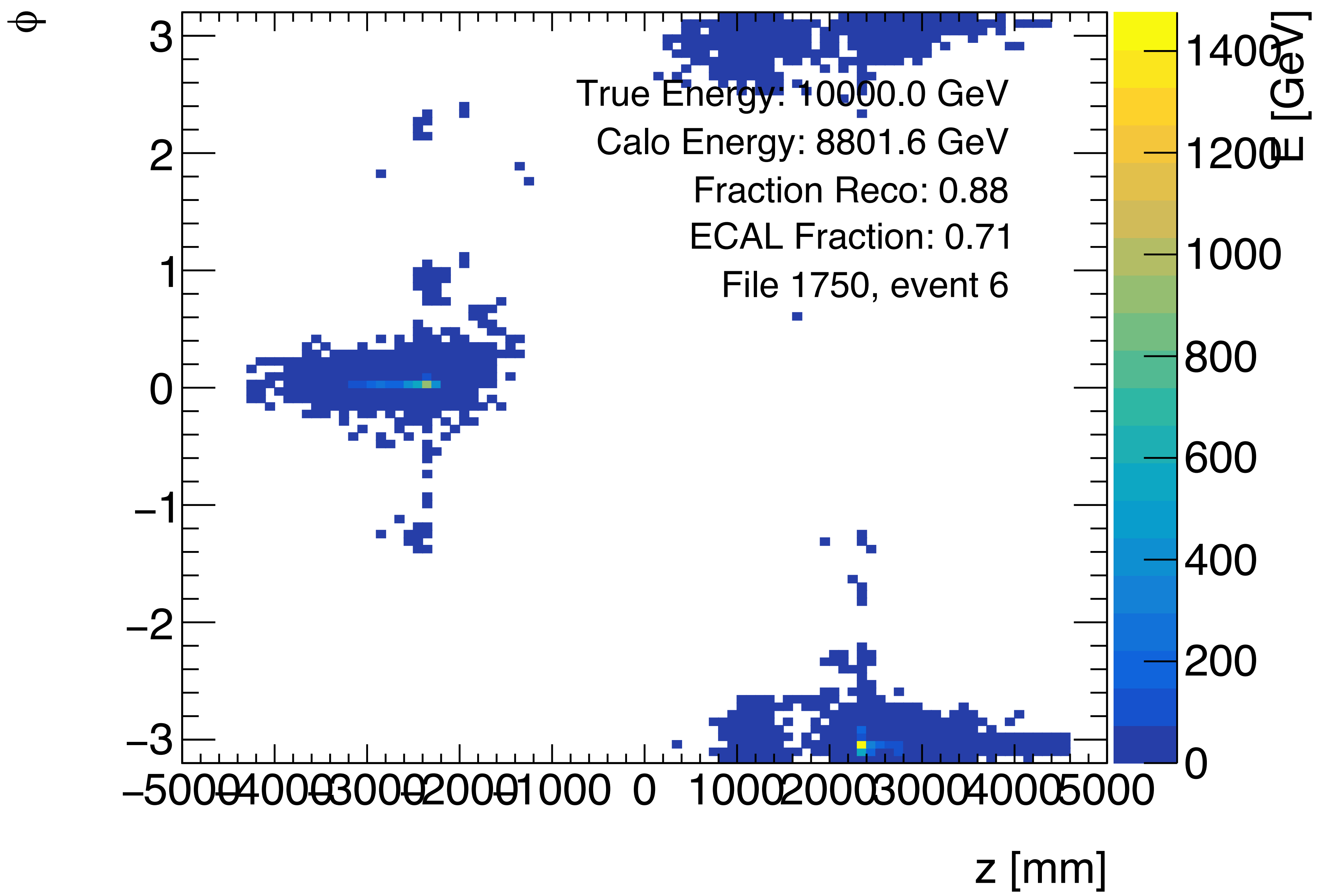


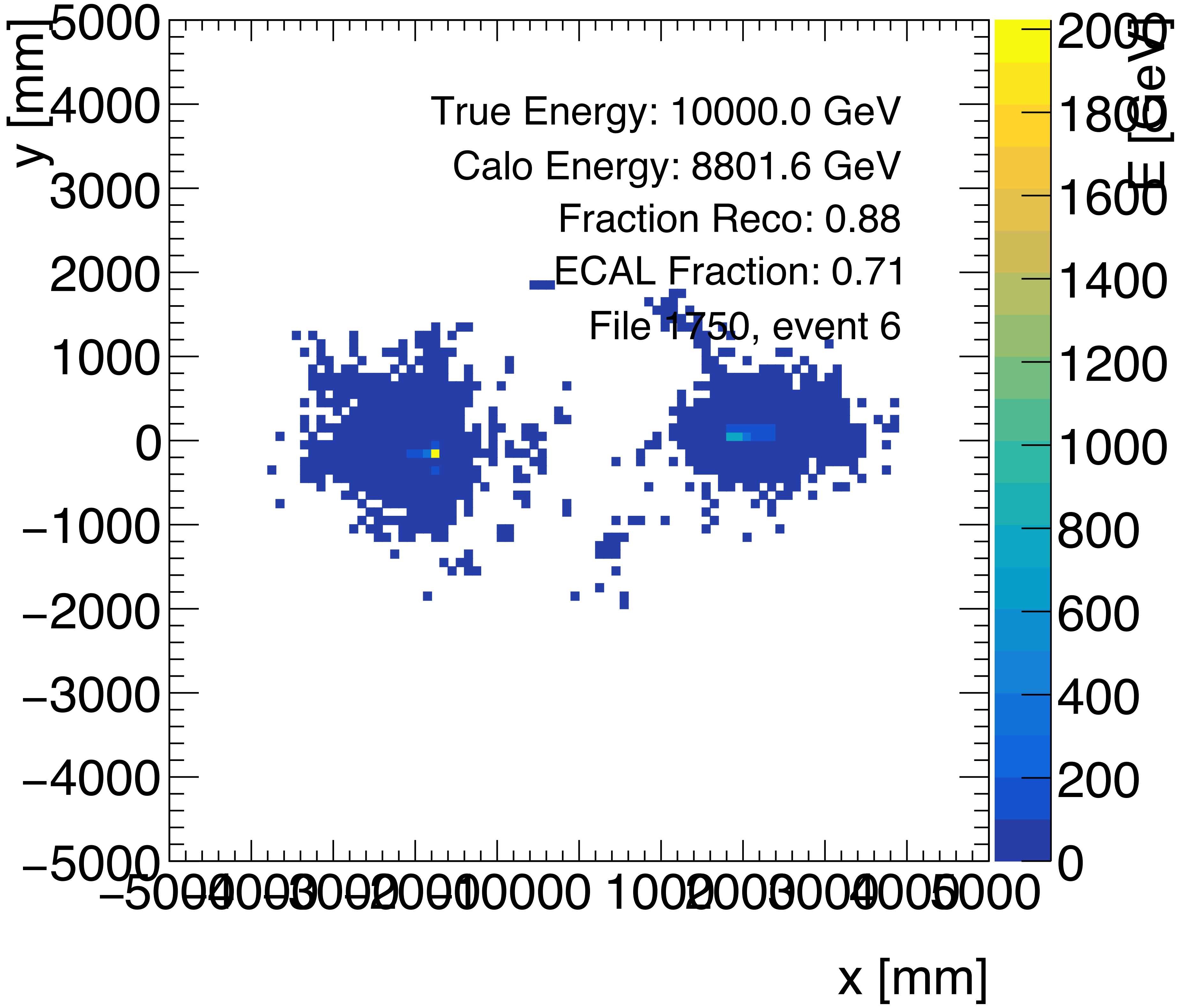


Visualizing high energy jets

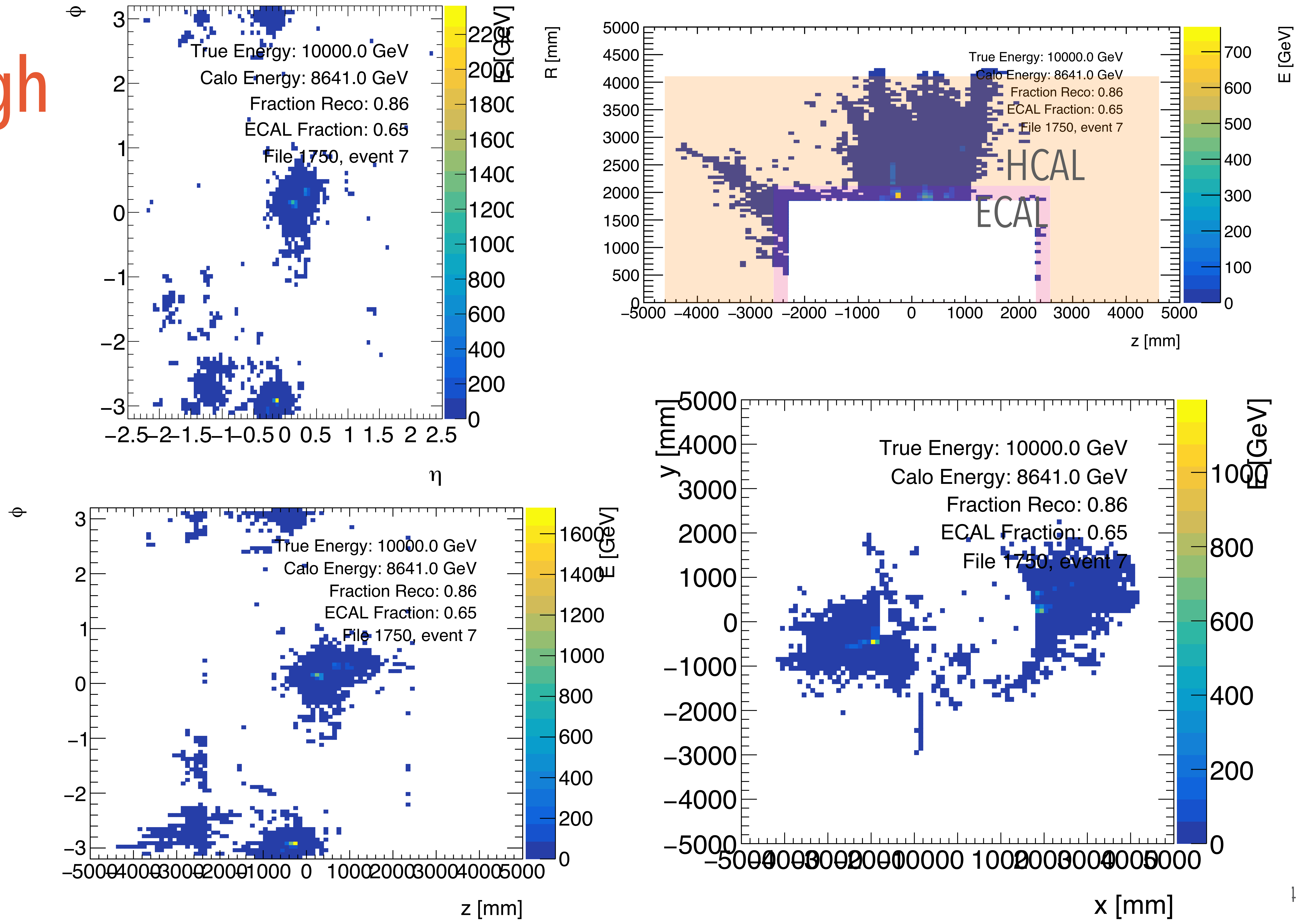




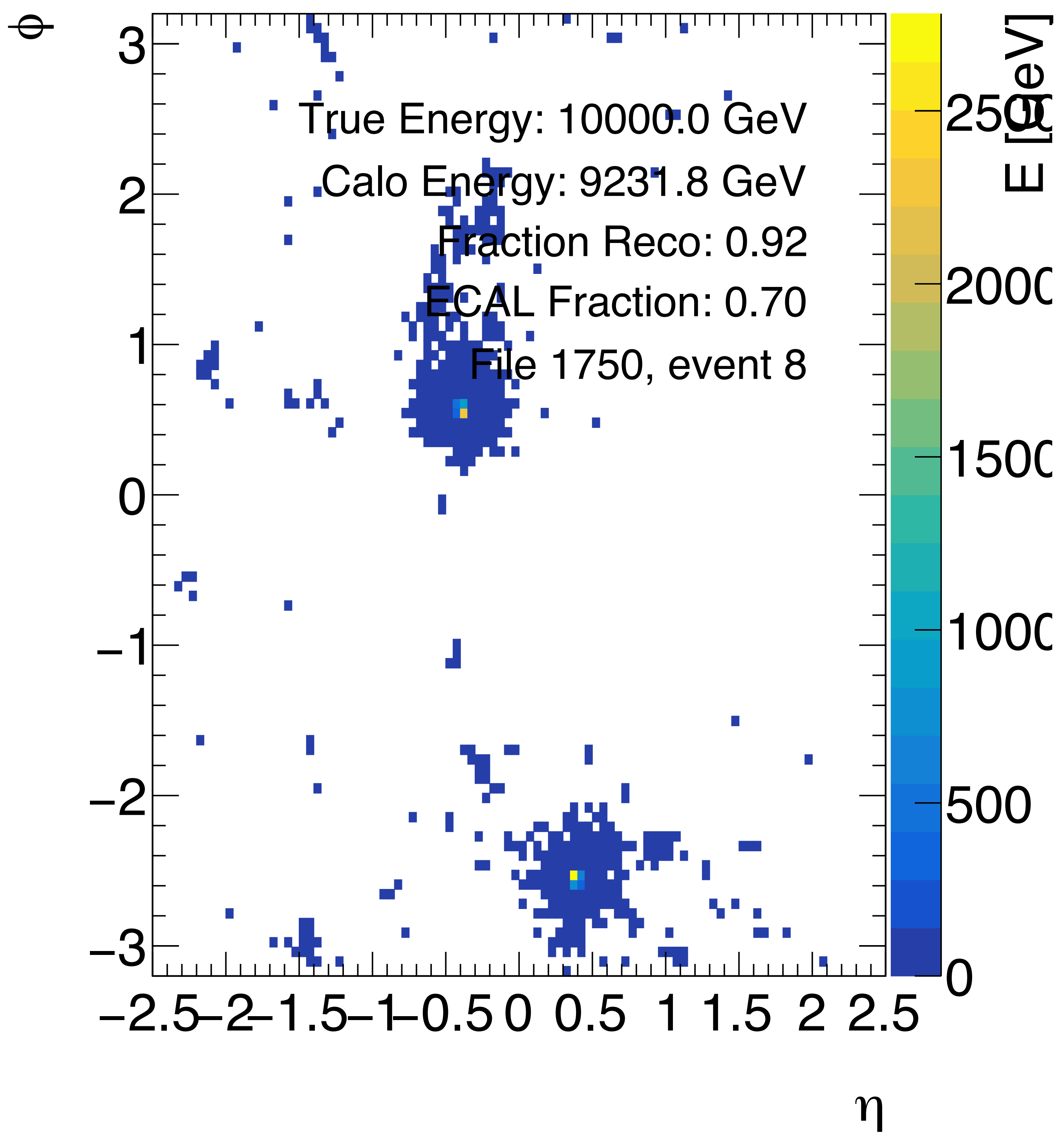


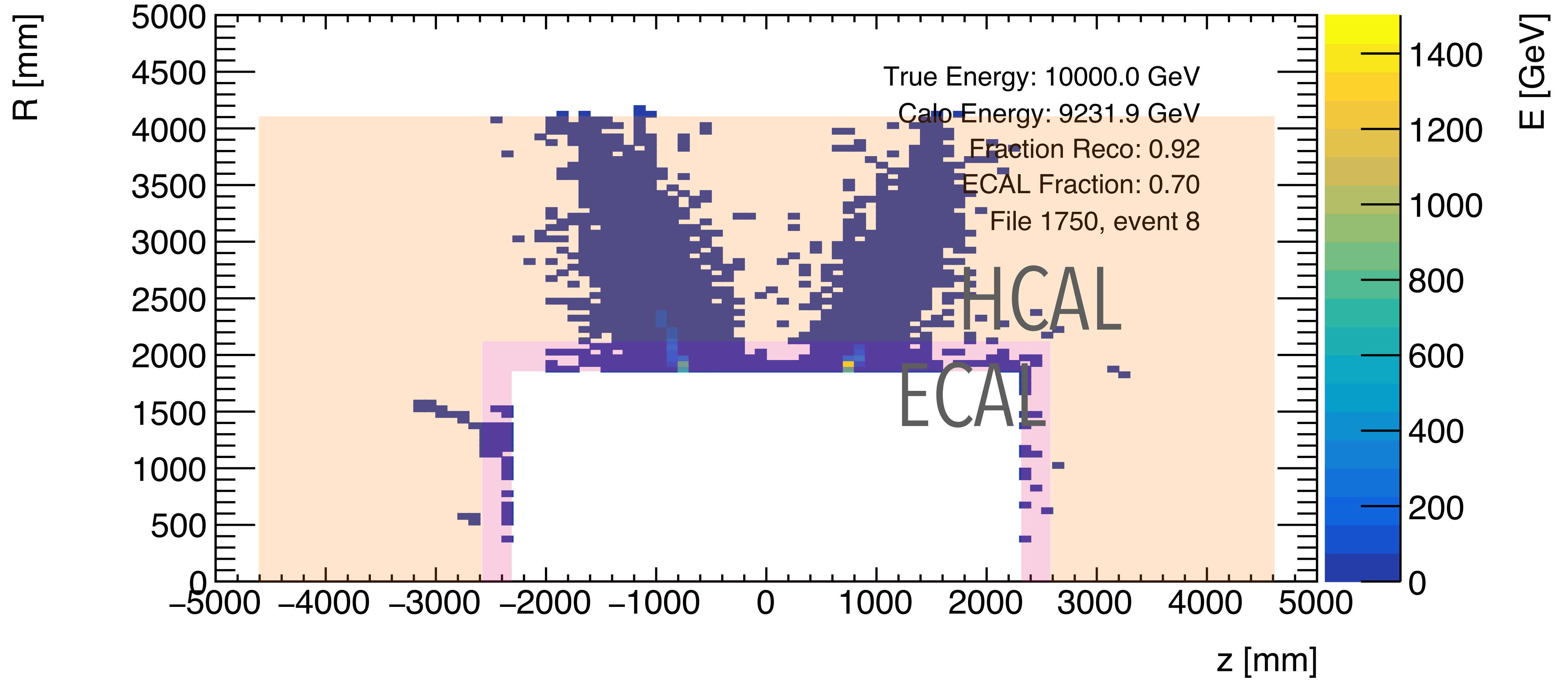


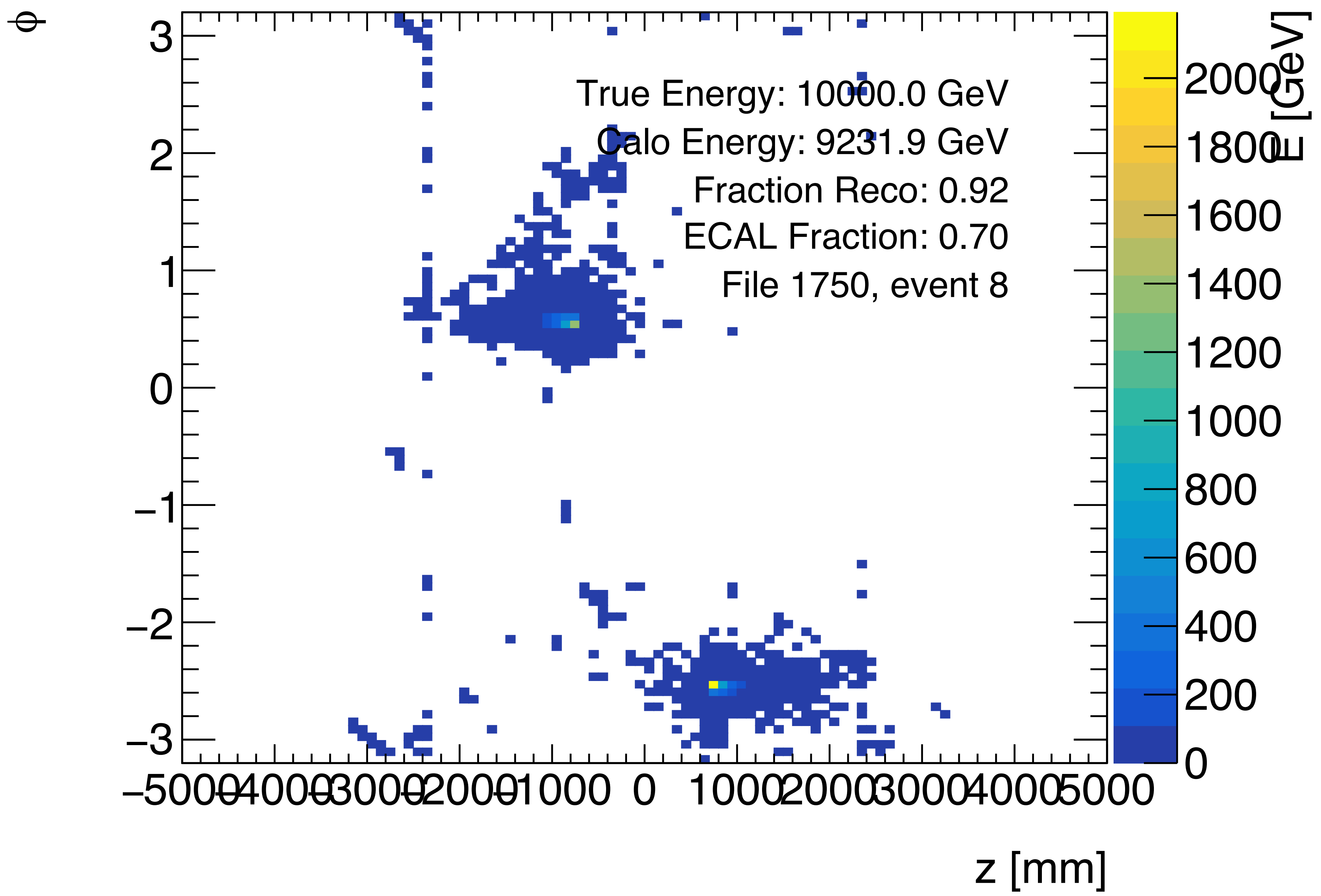
Visualizing high energy jets

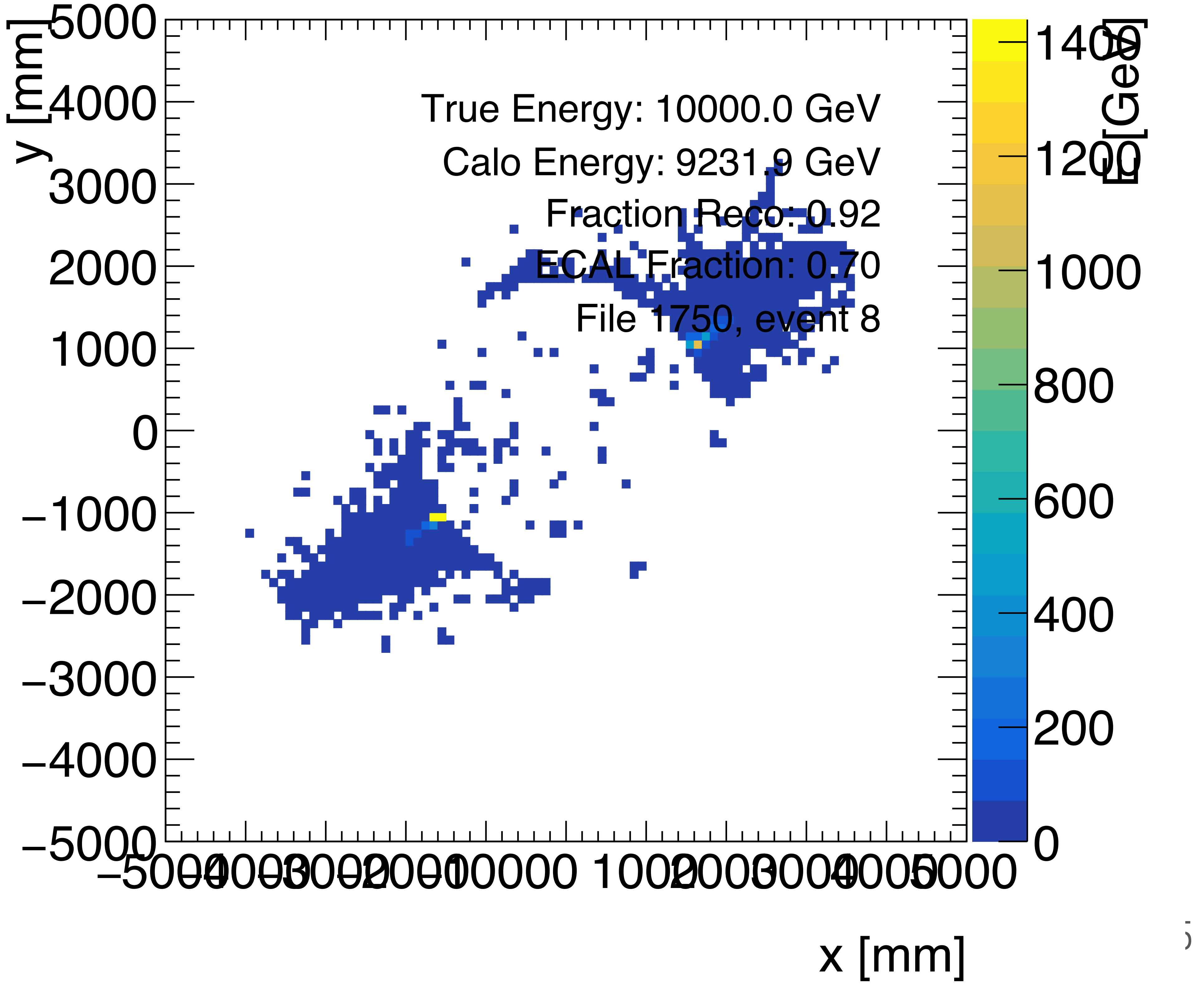


Visualizing high energy jets

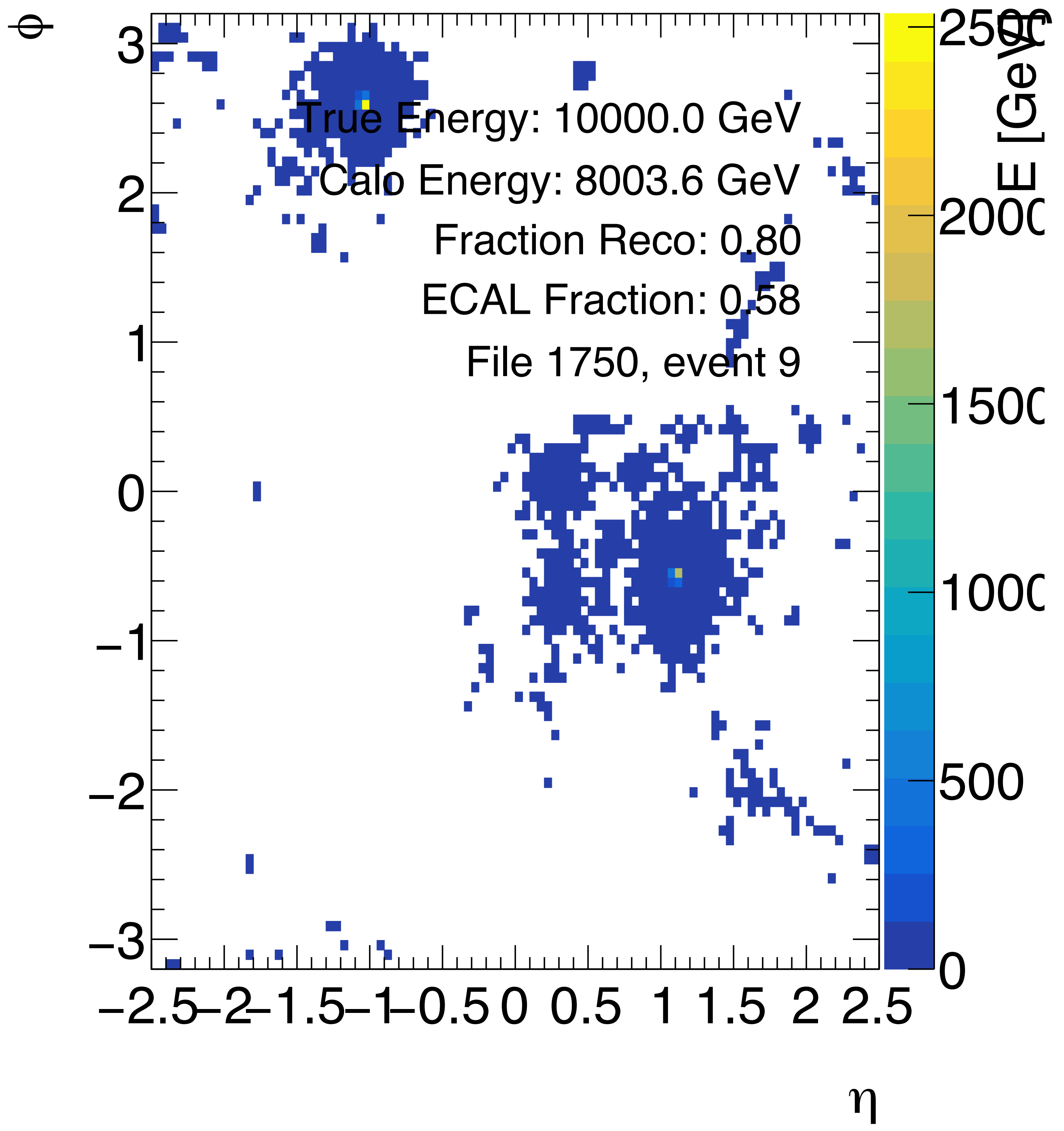


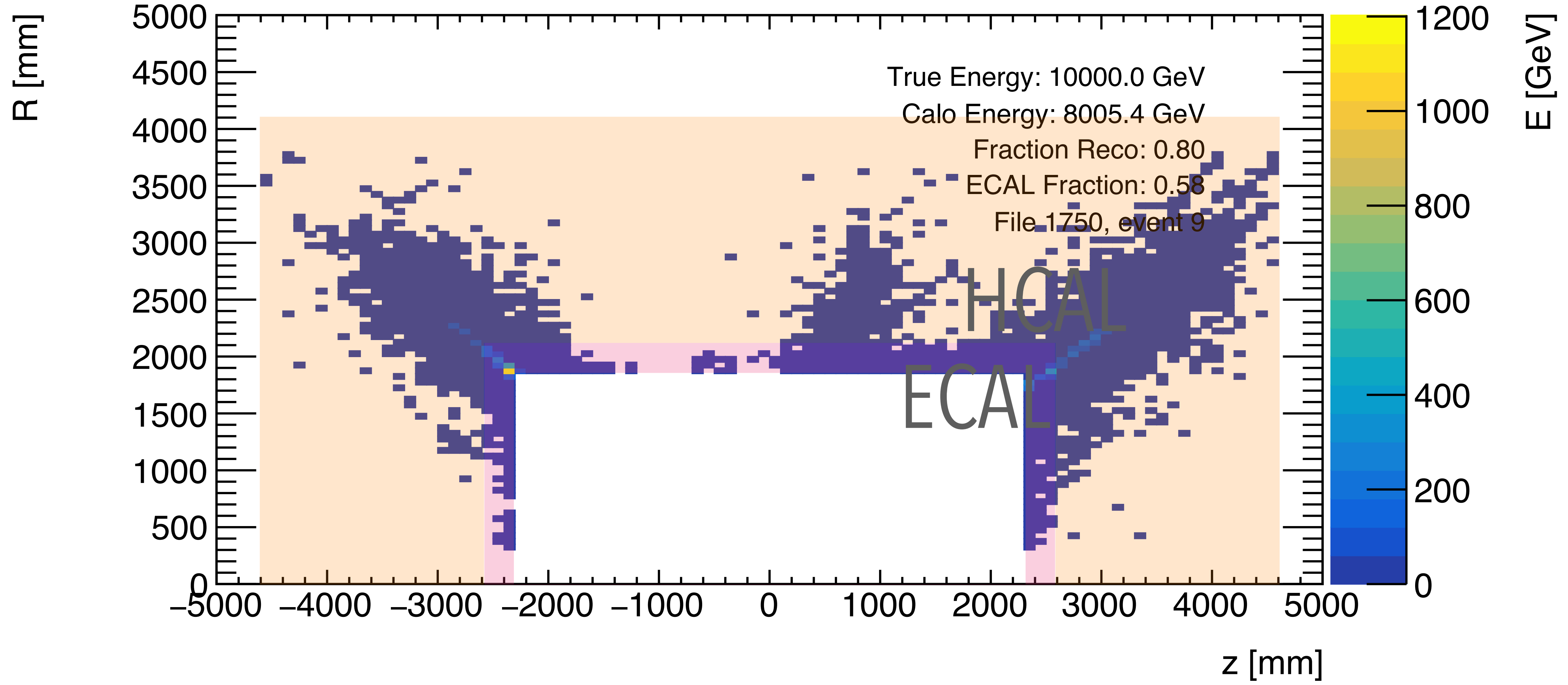


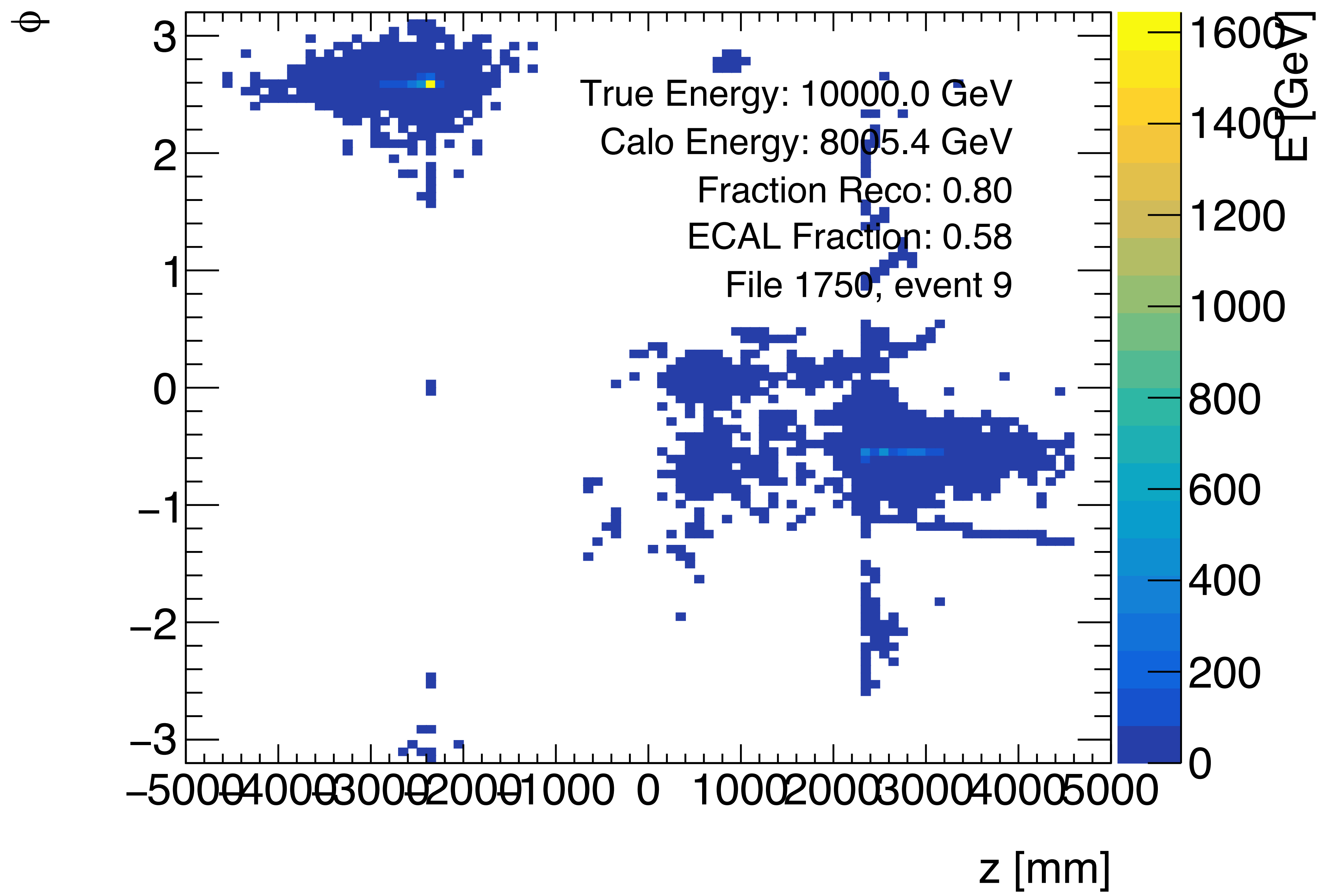


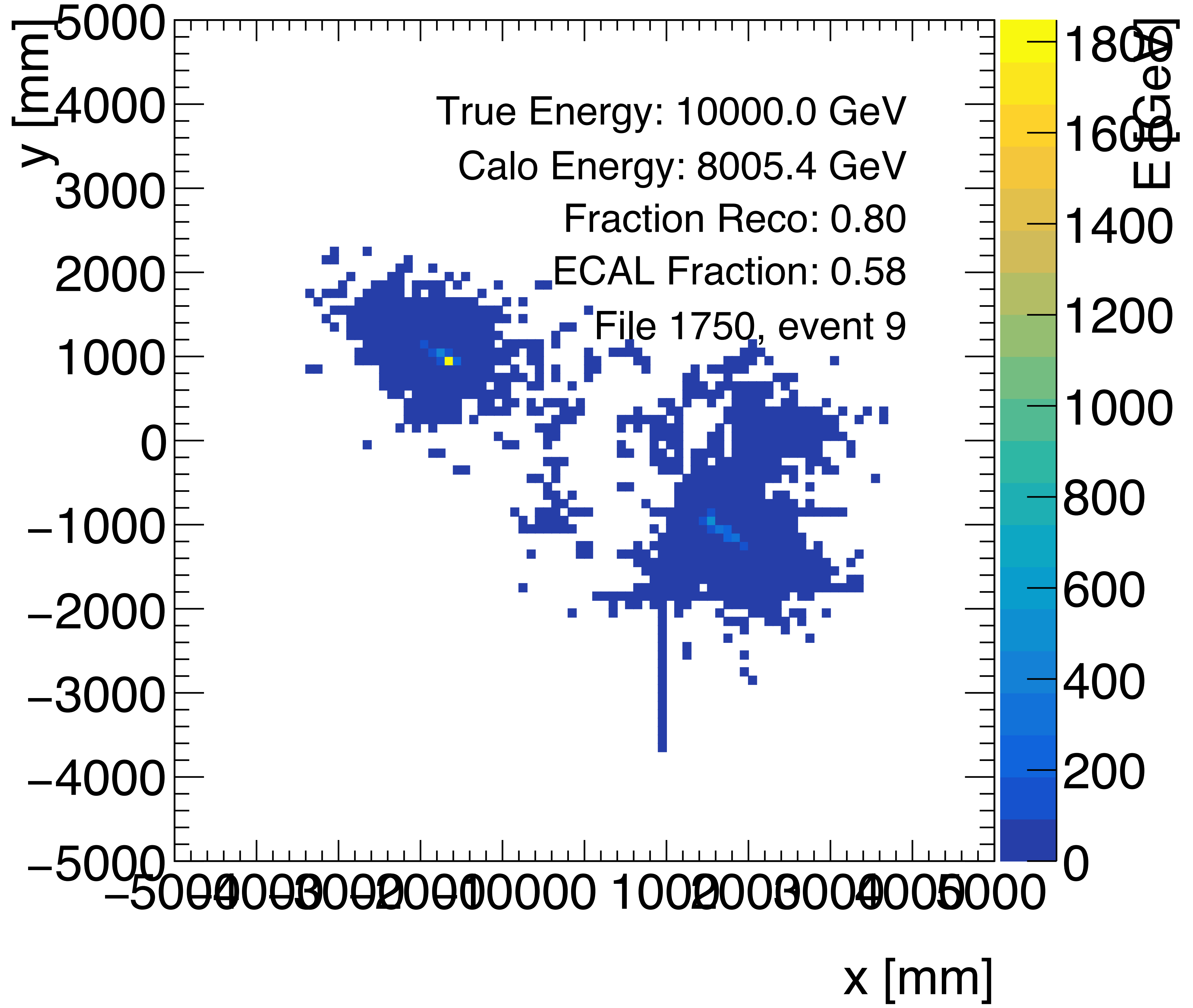


Visualizing high energy jets









Conclusions

- Sometimes see small amounts of punch through, but showers are mostly contained even at these maximum energies
- ECAL fraction is ~60-80%
  - Studies of individual pions showed that we often see showering begin in the solenoid, and thus see a high EM fraction, so this is potentially consistent