

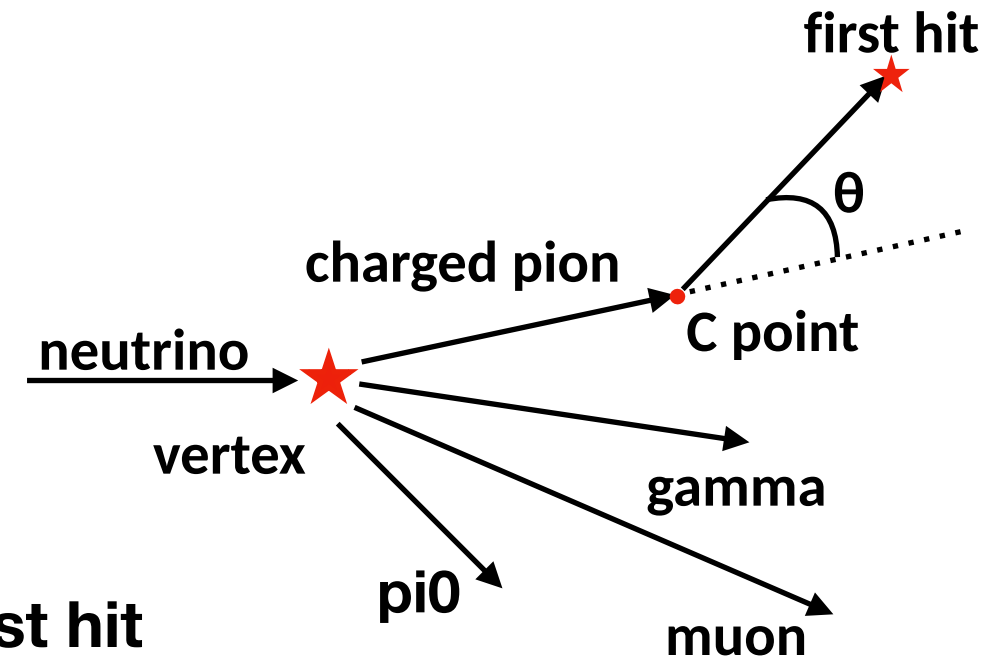
Secondary background in 3DST

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Reminder

- **Assumption:** we can select exclusive channels, $CC1P_{i\pm} 0P \times N 0P_{i0}$, $CC0p_{i\pm} 1P \times N 0p_{i0}$, $CC0p_{i\pm} 0P \times N 0p_{i0}$, x in integer.
- **4 categories:**
 - primary neutron: neutron from vertex
 - secondary neutron: other neutron
 - primary gamma: gamma from vertex
 - secondary gamma: other gamma
- **7 variables**
 - lever arm: distance between vertex and the first hit
 - time of flight: time difference between vertex and the first hit
 - CubeE: total energy inside the first cube
 - number of cube: number of fired cube cluster including the first cube
 - beta: relativistic beta, speed of particle/speed of light
 - angle: θ in the figure
 - distance between C point and hit
- **Training sample for BDT:**
 - signal (primary neutron)
 - background (secondary neutron+primary gamma+secondary gamma)
- **bugs fixed**



CDR discussion

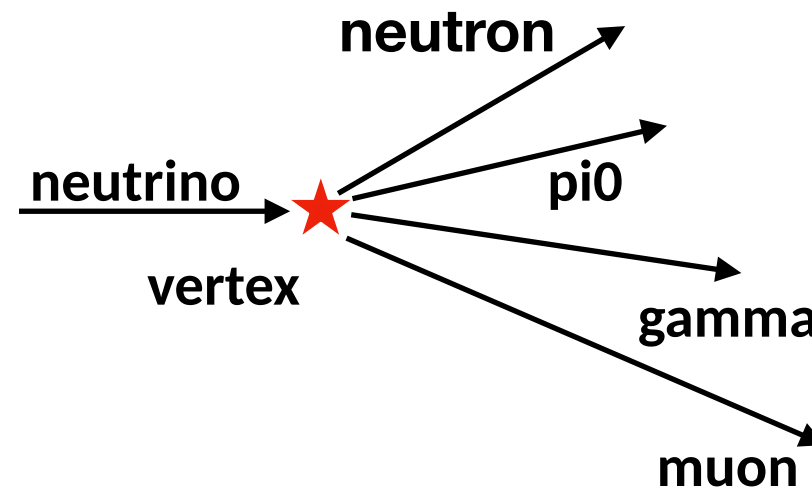
- Previous result:

<https://indico.fnal.gov/event/43906/contributions/189023/attachments/129986/157981/20200616.pdf>

- At the moment the above result needs to be improved to go into CDR
- The editor didn't agree with the exclusive channel selection.
 - He is okay with the selection for muons, charged pions and protons.
 - But he asked to include π^0 as a potential background source.
- Therefore we study channels with π^0 included.

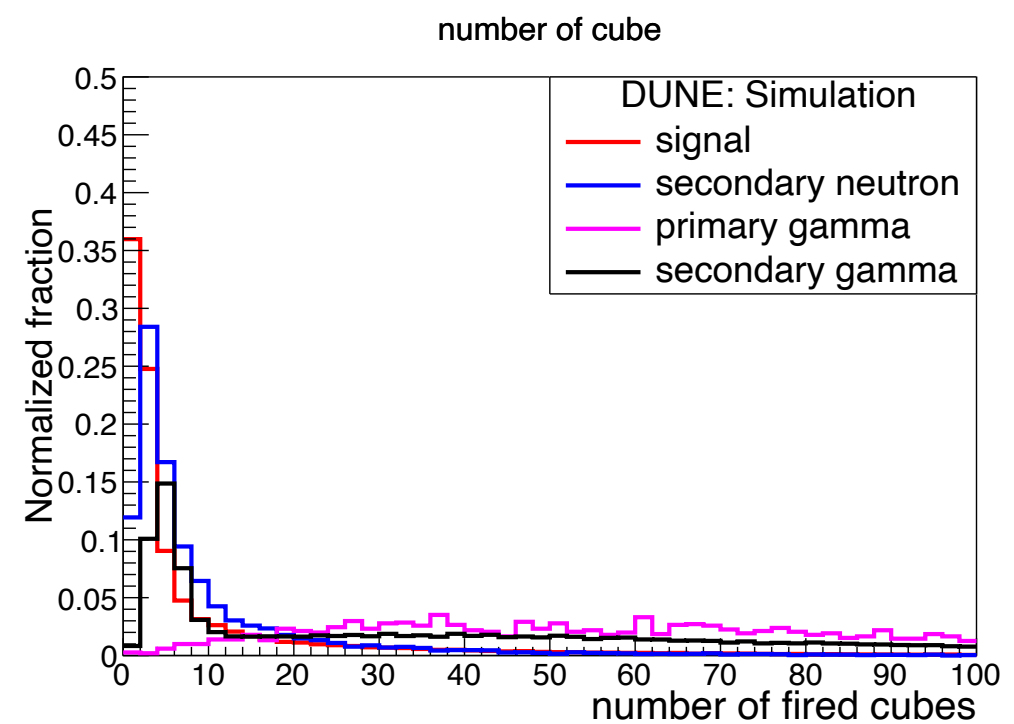
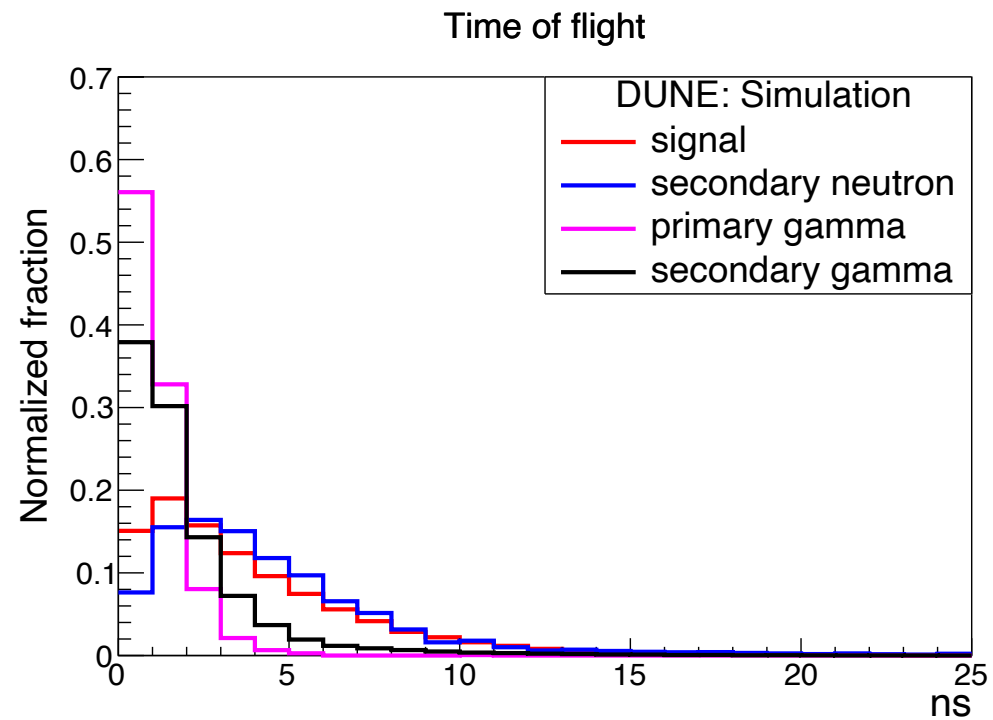
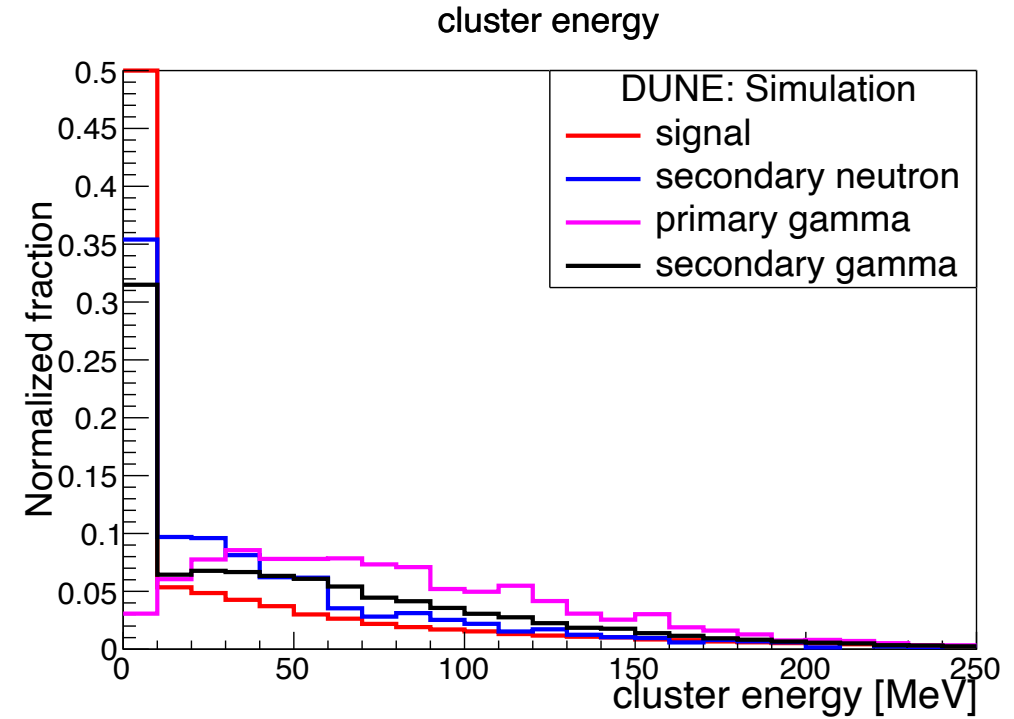
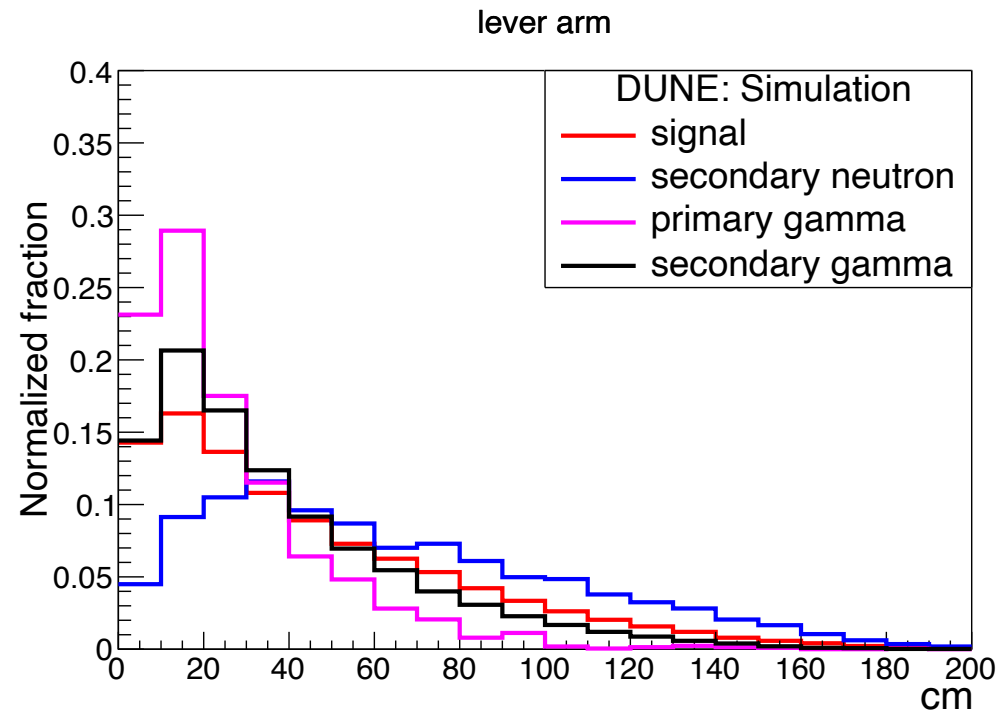
Channel with pi0 included

- **Channel for BDT training: $CC0P_{i\pm}0P_xN_yPi0$, $x > 0$, x and y are integer:**
 - there must be primary neutron
 - no charged pion and no proton
 - there may or may not be pi0 present

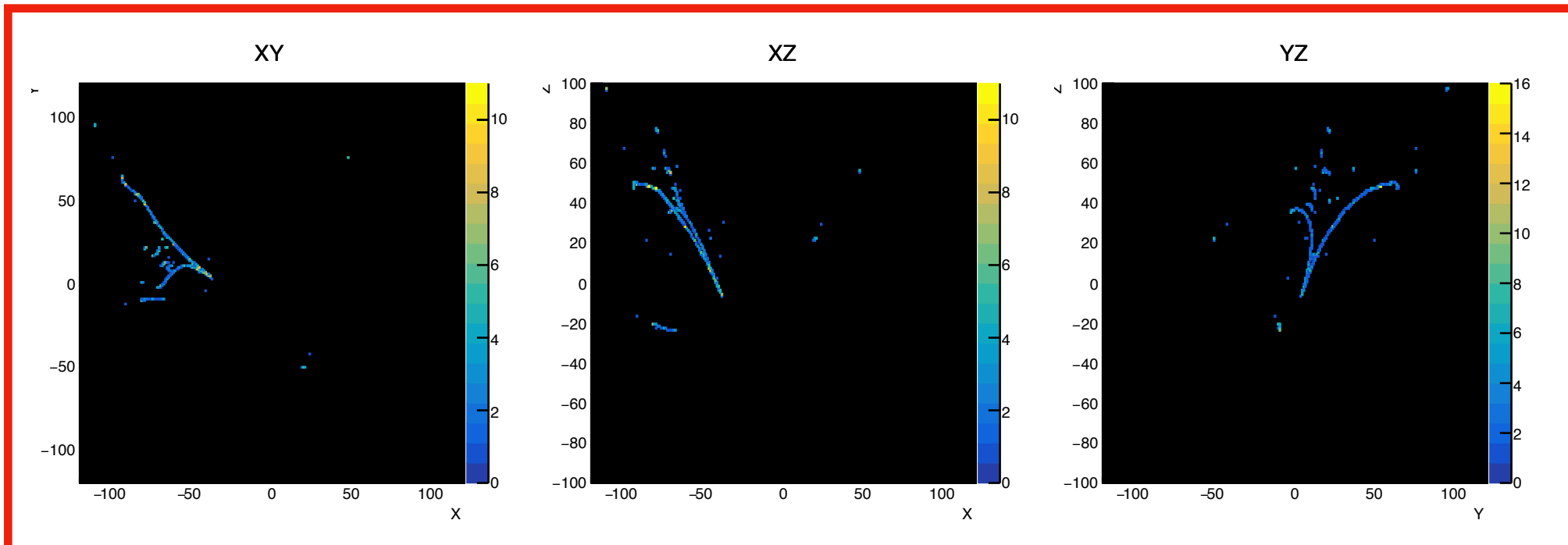


- **4 variables as an input of BDT training**
 - lever arm: distance between the first hit and the vertex
 - time of flight (TOF): time difference between the first hit and the vertex
 - number of cubes: number of fired cube cluster including the first cube
 - cluster energy: sum of energy deposit in the cube cluster

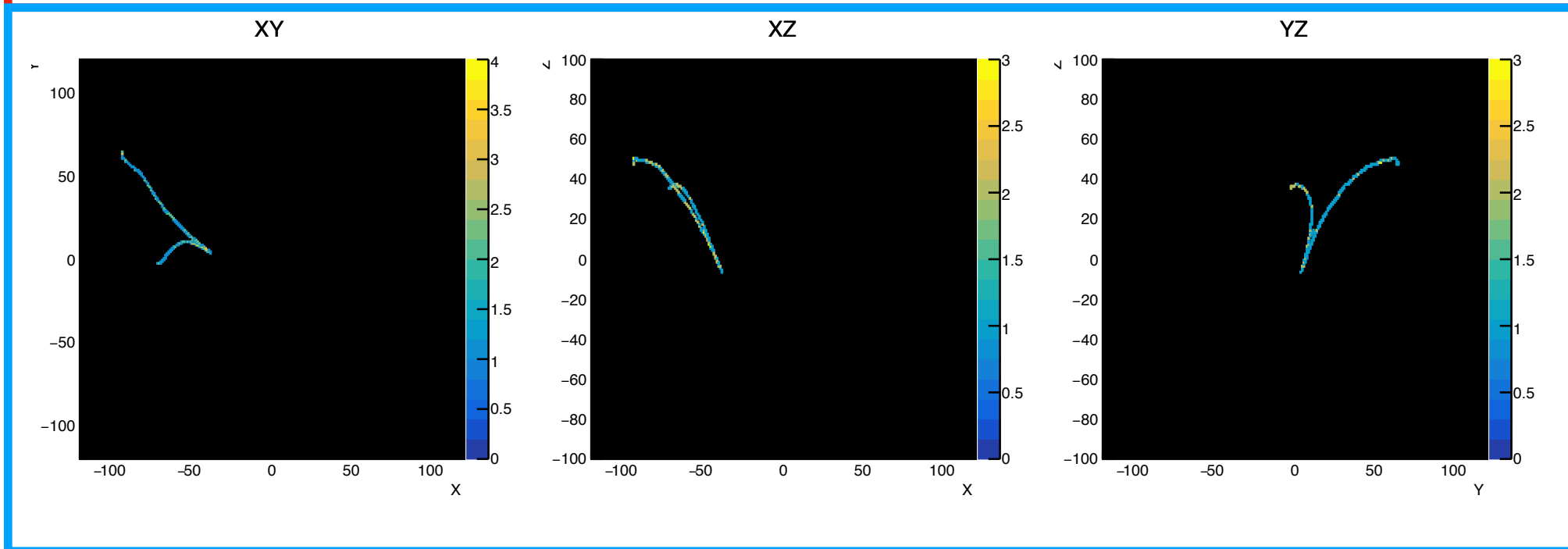
Updated variable distributions



gamma event #1



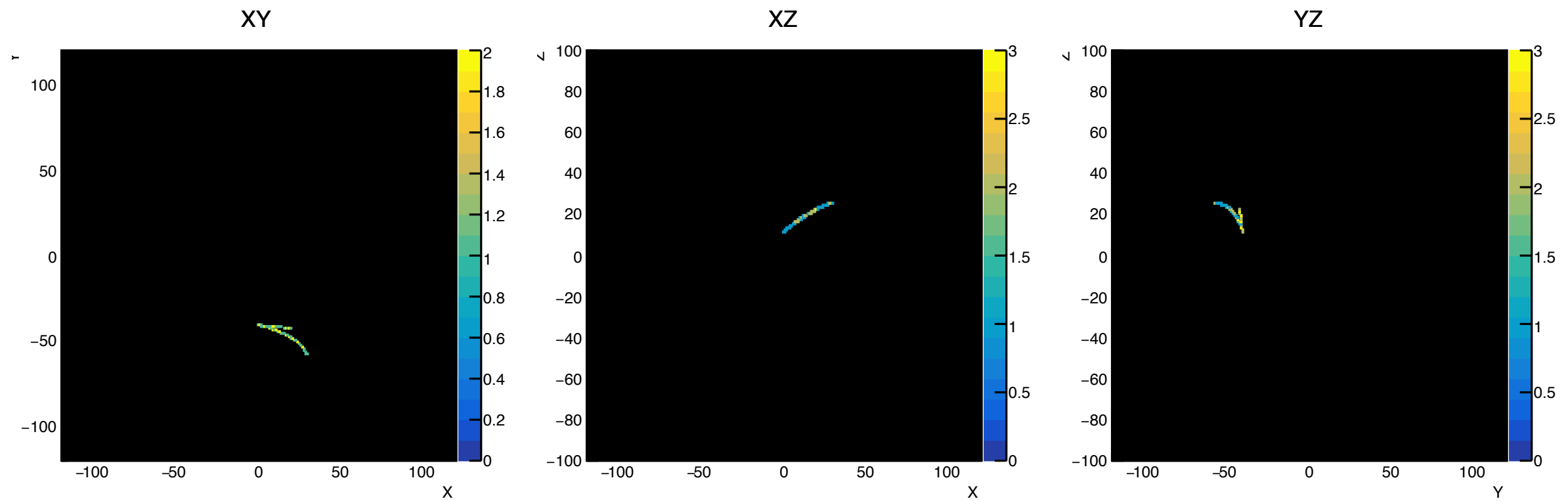
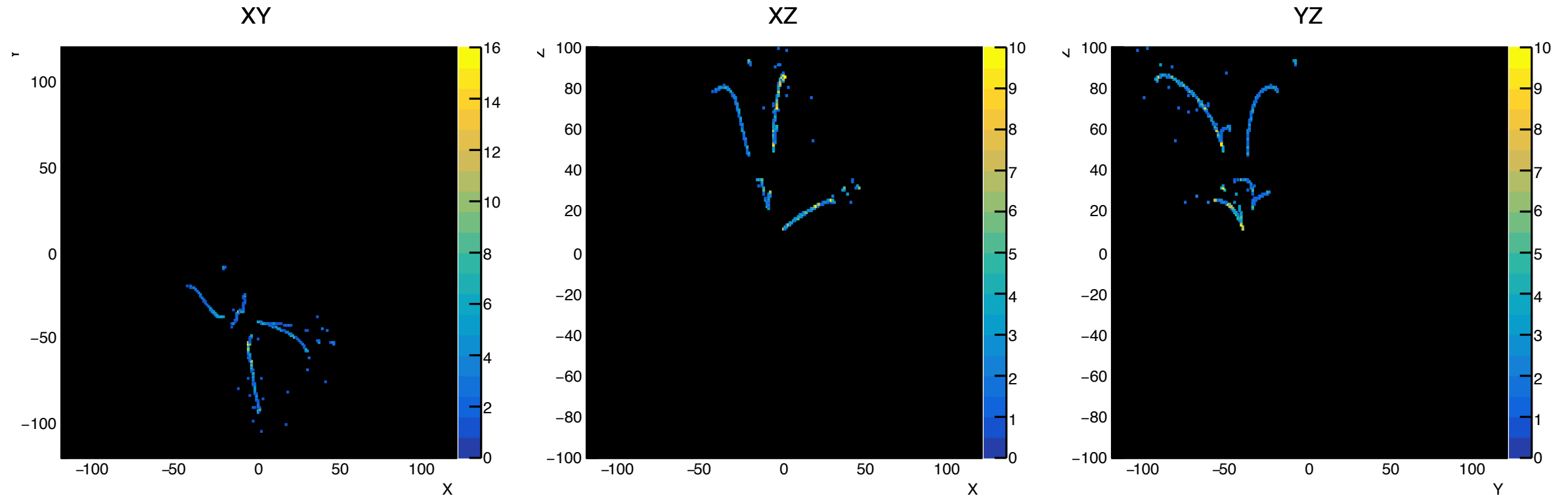
before clustering



after clustering

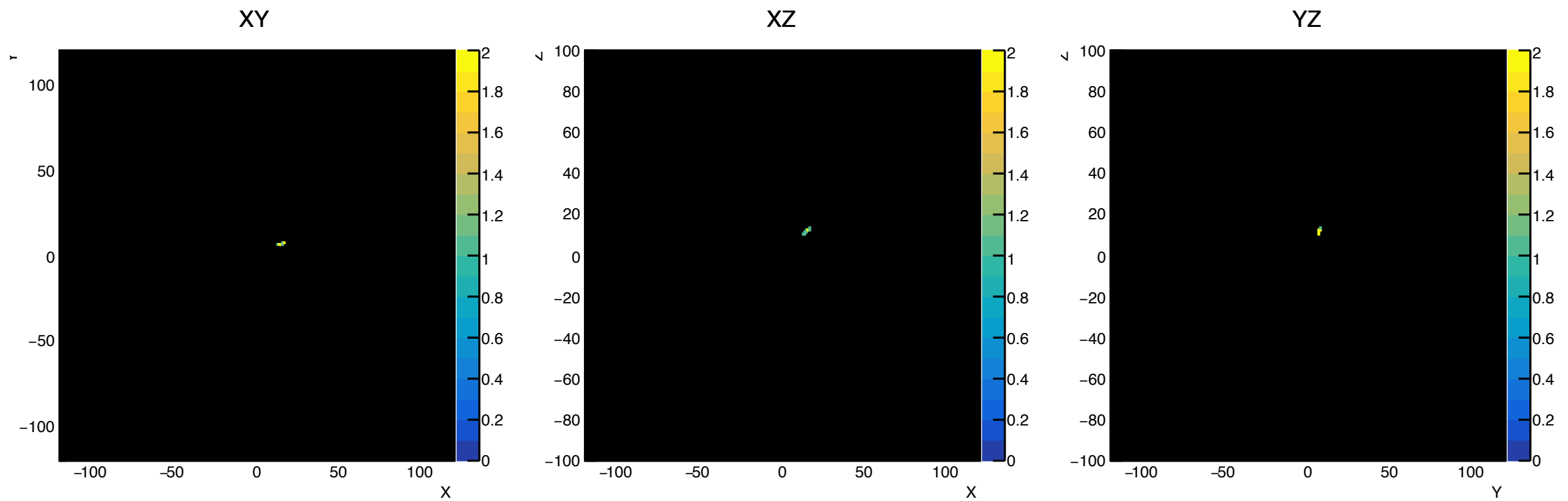
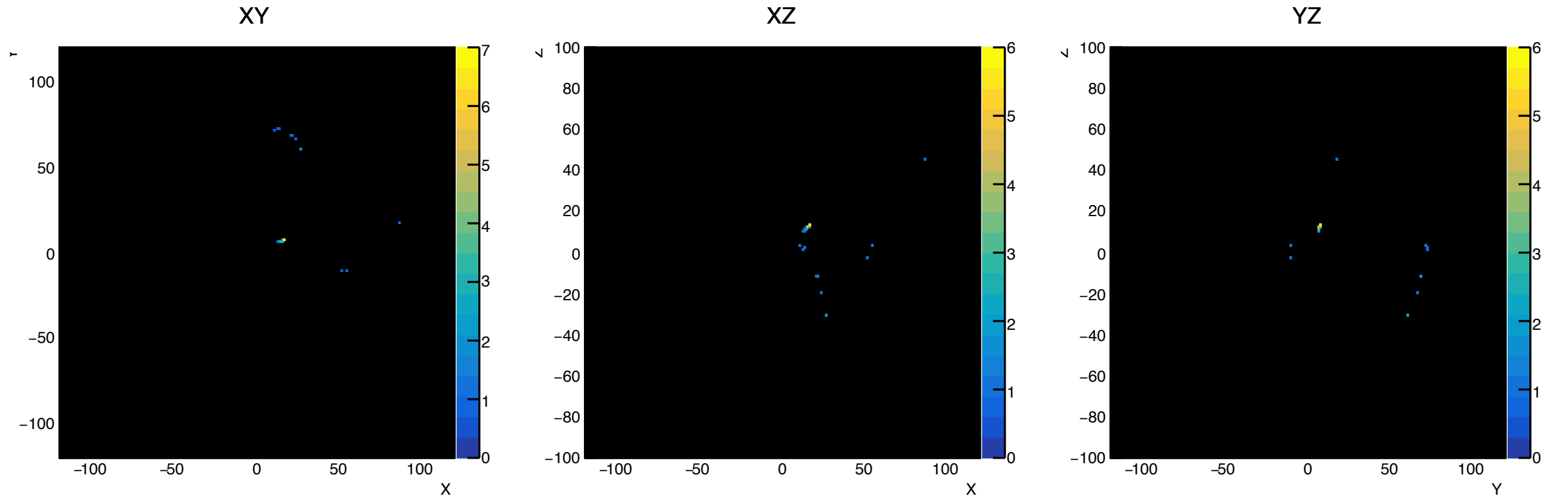
long track

gamma event #2



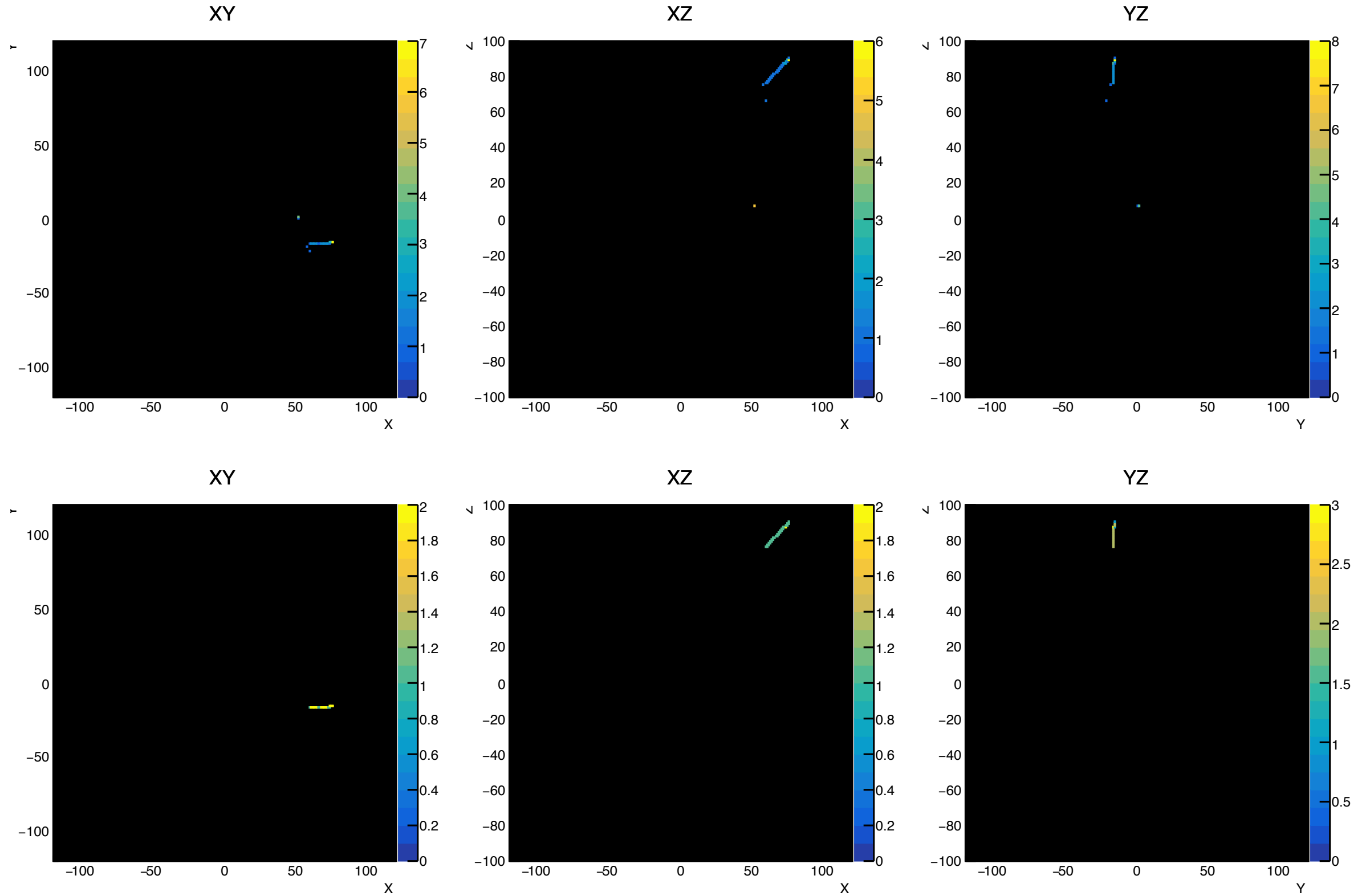
long track

neutron event #1



short track

neutron event #2

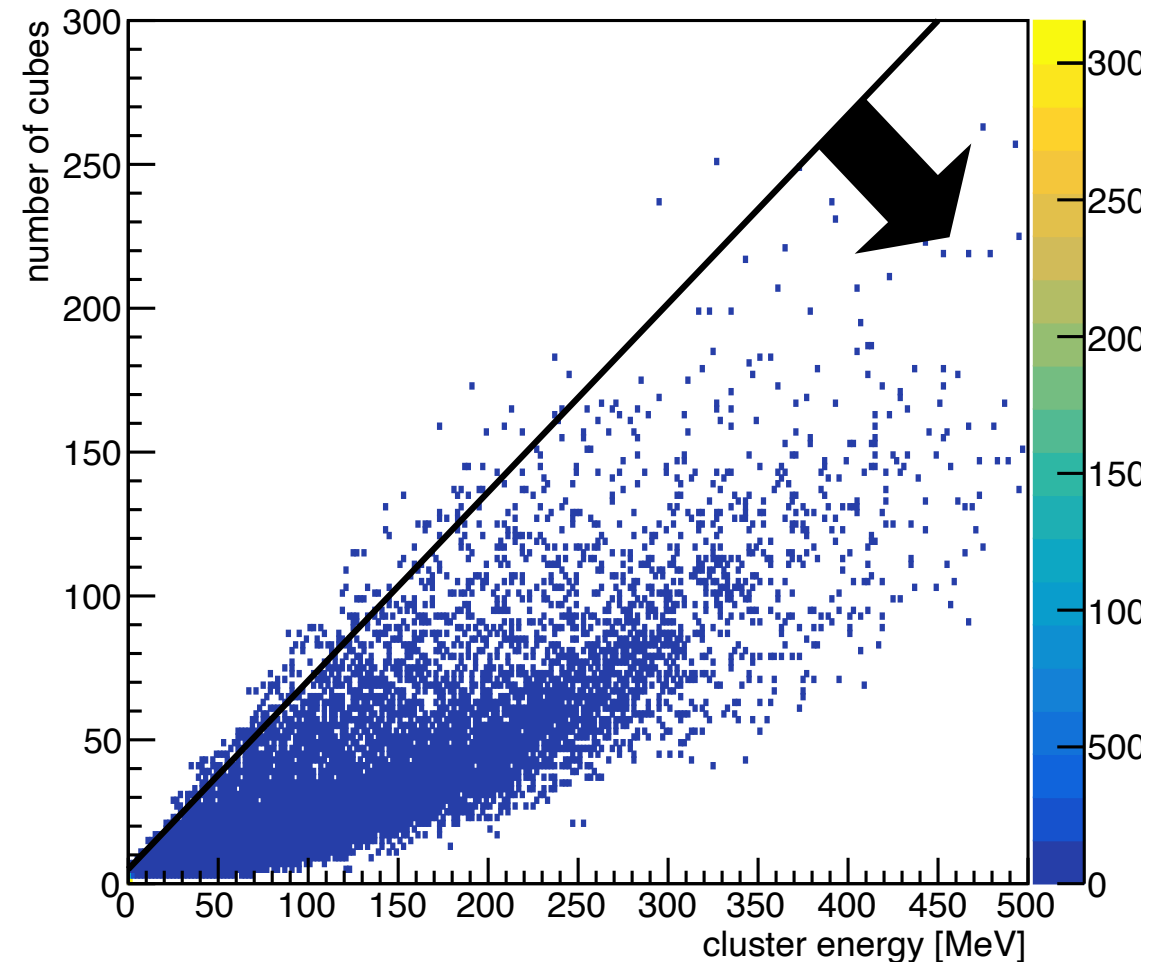
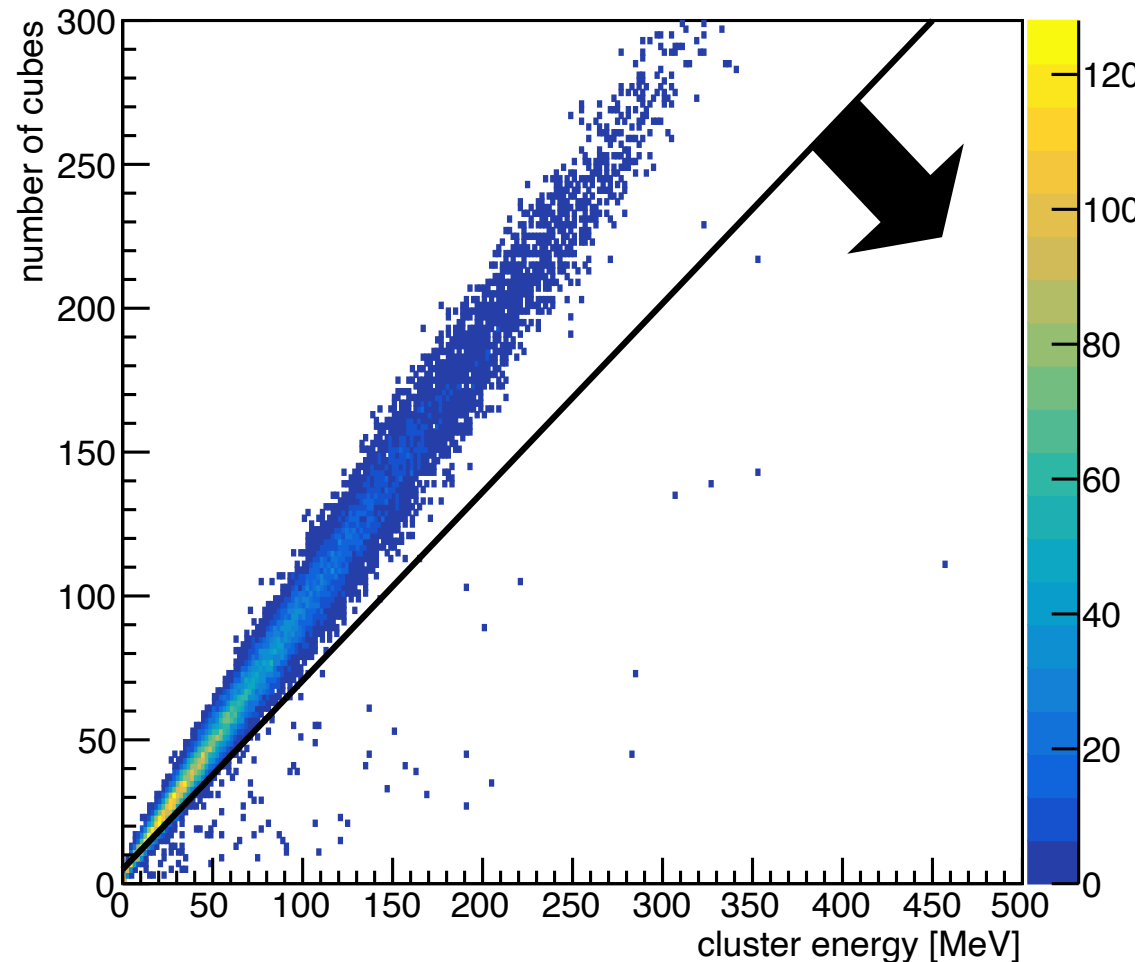


short track

simple discrimination between gamma and neutron

gamma from pi0

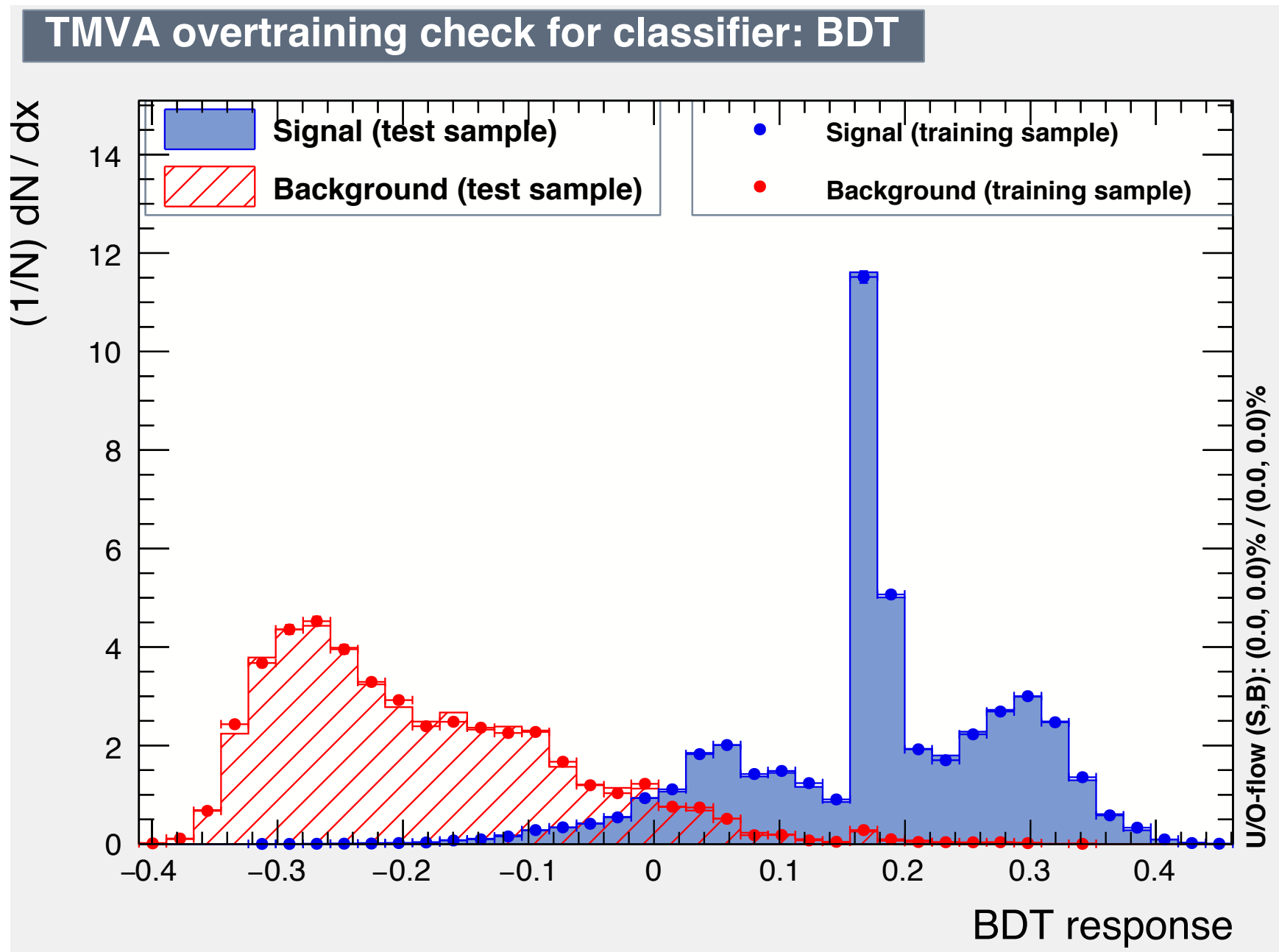
primary neutron



2D plots for gamma, neutron

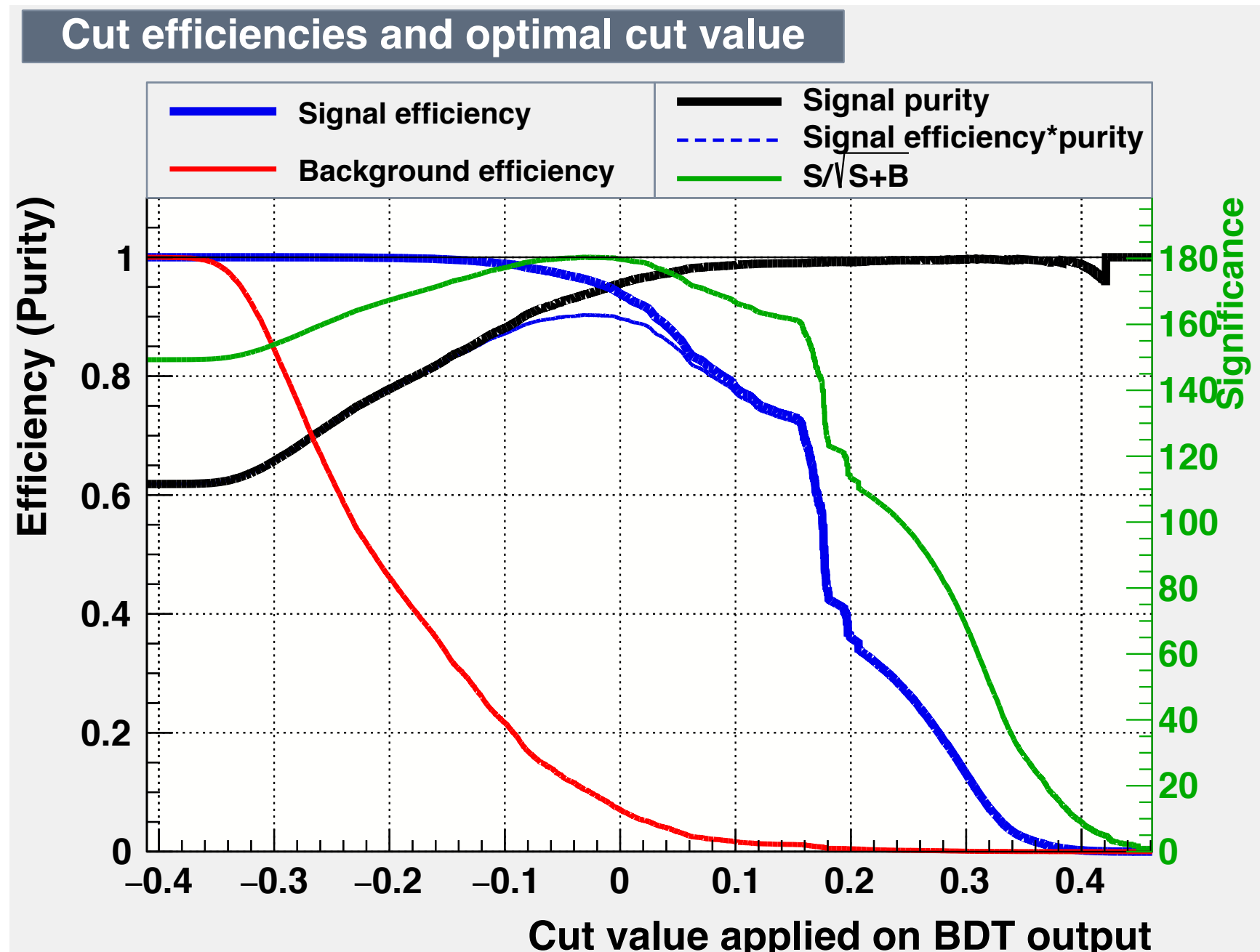
- gamma: CC1Pi0, neutron: CC1N
- We applied a 2D cut (the black line) and we got 99.7% for neutron and 7.8% for gamma with the cut.

BDT result



signal: 36030
background: 22223

BDT result



Signal: primary neutron + secondary neutron
Background: primary gamma + secondary gamma

Summary

- **We studied a channel with π^0 included according to CDR editor's suggestion**
- **gamma from π^0 and neutron are clearly separated.**
- **BDT also confirms the separation.**
- **We want to send back the new result to the editor.**

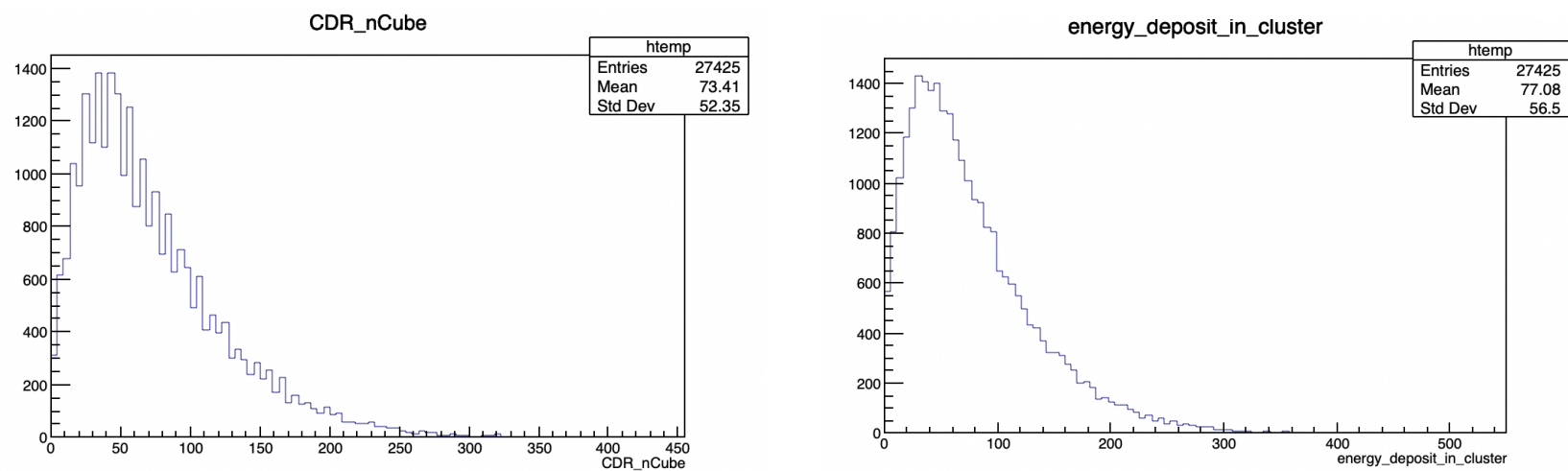
back up

We tested two channel to compare primary neutron and gamma from pi0.

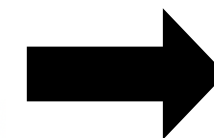
- 1. CC nothing: there are muon and neutron in final state**
- 2. CC1pi0: there are muon and 1 pi0 in final state**

We focused on two variables.

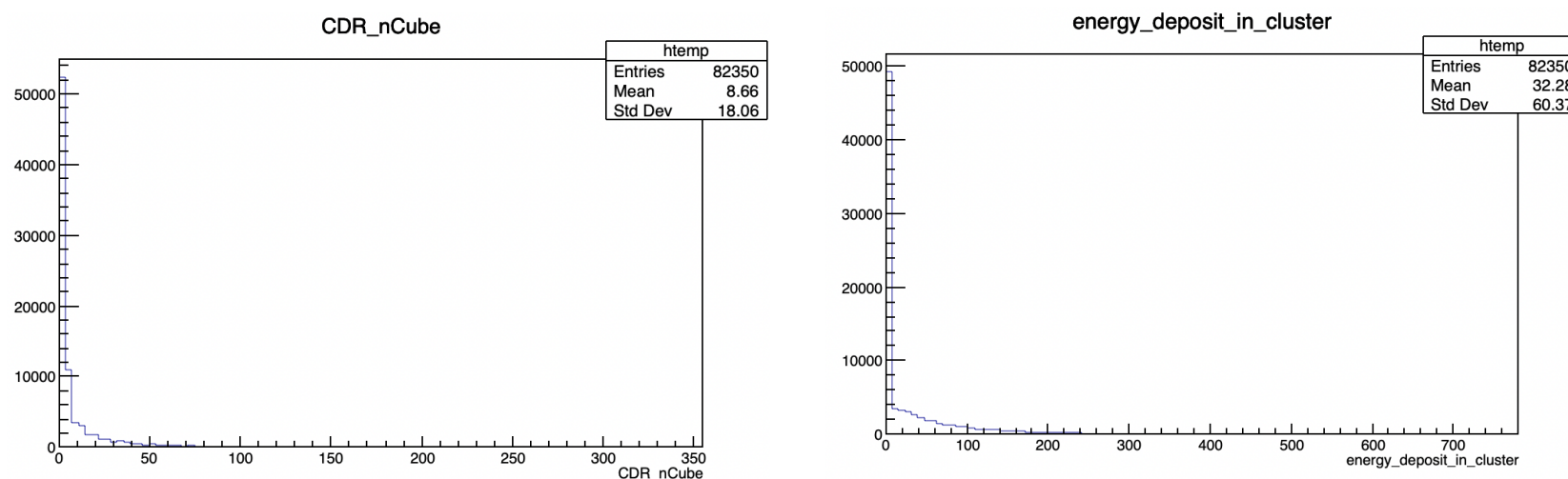
- 1. number of cubes in cluster**
- 2. cluster energy : sum of energy deposit in the cluster**



gamma from pi0



We can see the difference clearly.



primary neutron