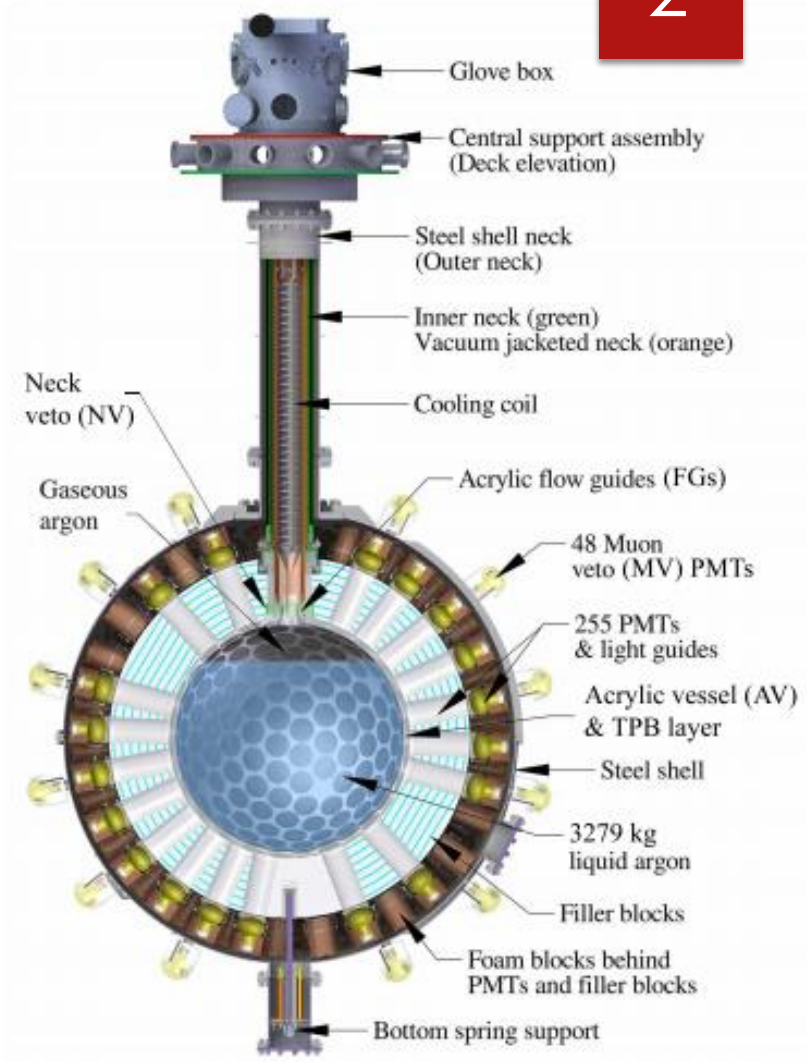
Dust Modeling With DEAP-3600

BY: MICHAEL SLOAN

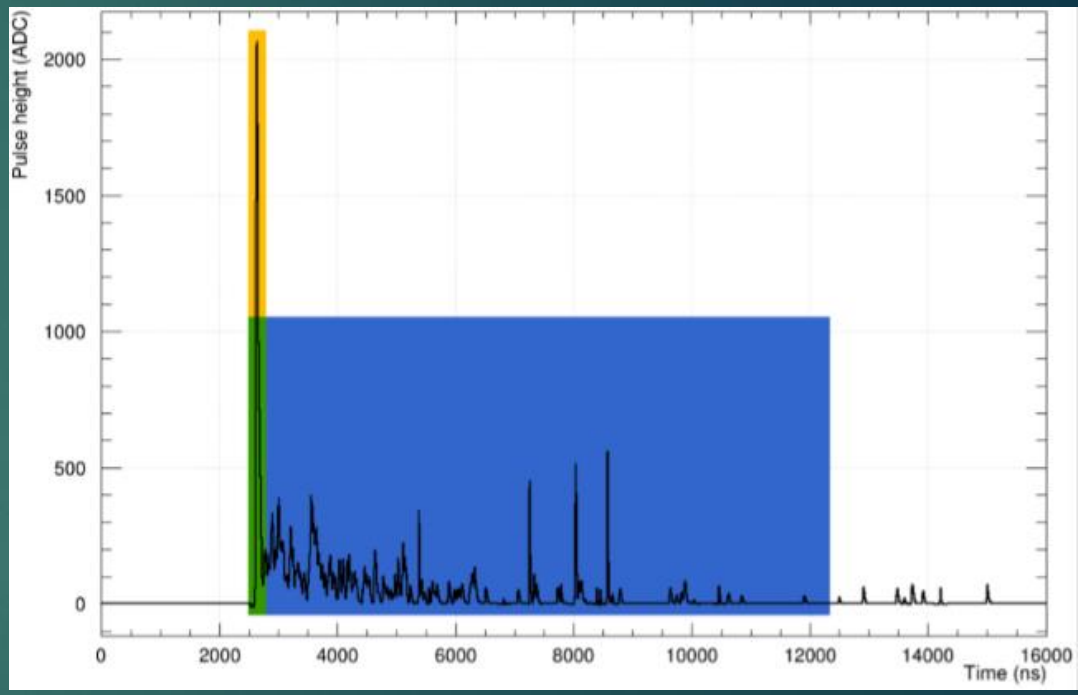
What is DEAP-3600?

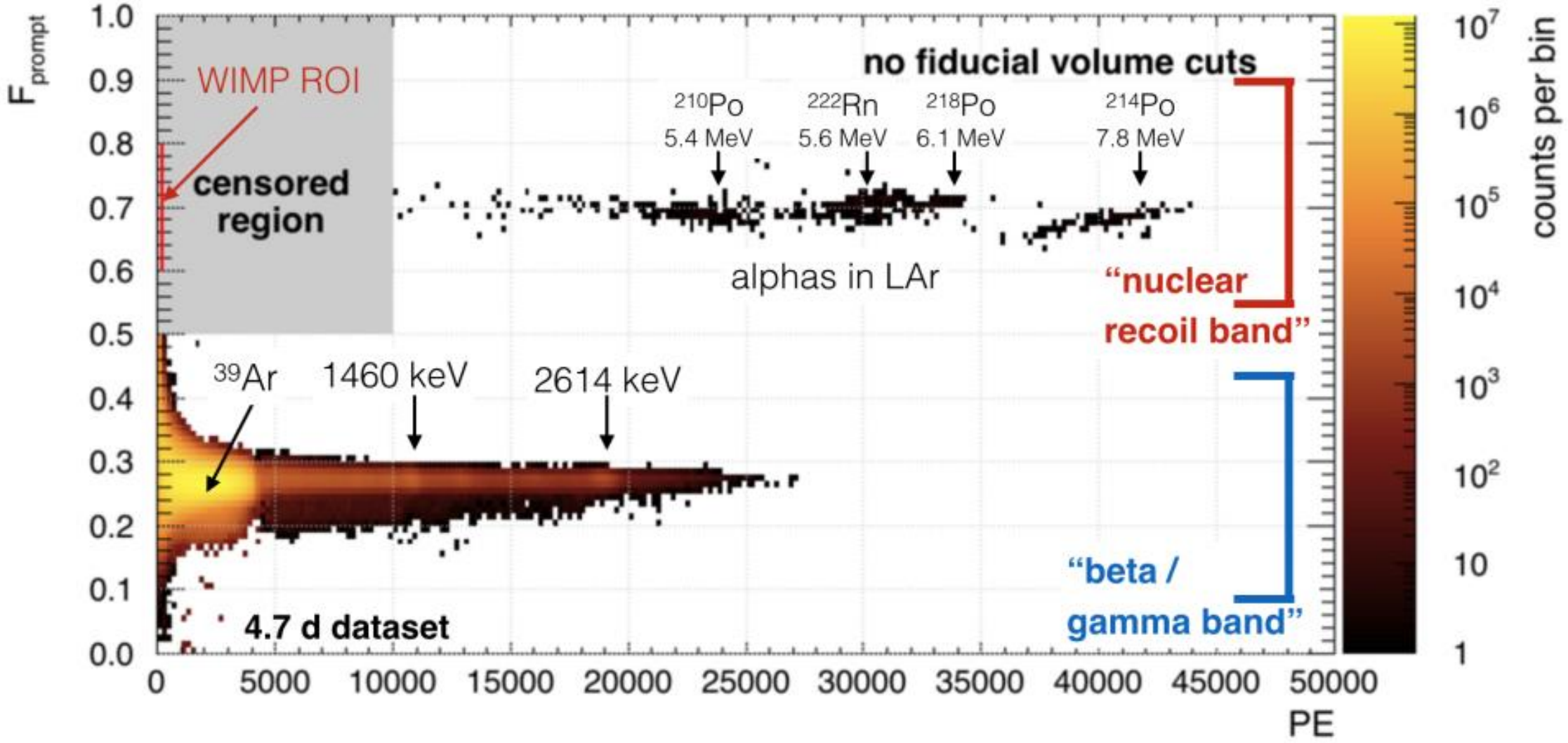
- DEAP-3600 is a single-phase liquid argon (LAr) direct detection dark matter experiment.
- Located 2km underground in SNOlab, Sudbury.
- 3279kg of liquid argon.
- Uses liquid argon scintillation light for event detection.

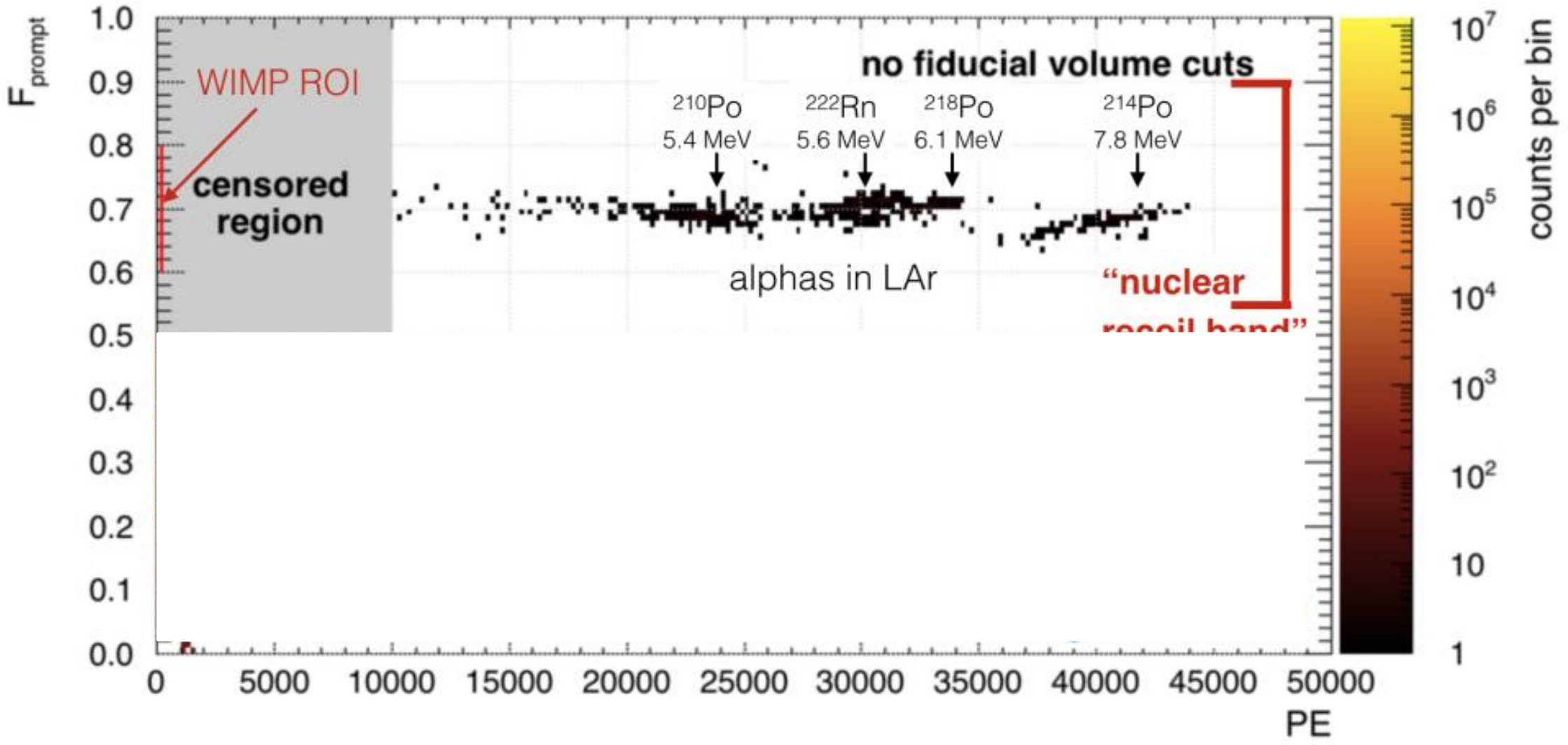


Some Important Variables

- qPE = Estimated number of photo-electrons per PMT (proportional to energy of the event)
- Fprompt = fraction of light arriving in a short window at the beginning of a pulse $= \frac{\sum_{-28ns}^{60ns} PE(t)}{\sum_{-28ns}^{10us} PE(t)}$
- MblikelihoodX, mblikelihoodY, mblikelihoodZ, mblikelihoodR = estimated position coordinates based on position reconstruction algorithm.




F_prompt
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
WIMP ROI
censored region
no fiducial volume cuts
210Po 5.4 MeV
222Rn 5.6 MeV
218Po 6.1 MeV
214Po 7.8 MeV
alphas in LAr
"nuclear recoil band"
39Ar
1460 keV
2614 keV
"beta / gamma band"
4.7 d dataset
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
PE
10^7
10^6
10^5
10^4
10^3
10^2
10
1
counts per bin


F prompt
1.0
0.9
0.8
0.7
0.6
0.5
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0.1
0.0
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alphas in LAr
"nuclear recoil band"
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
PE
counts per bin
10^7
10^6
10^5
10^4
10^3
10^2
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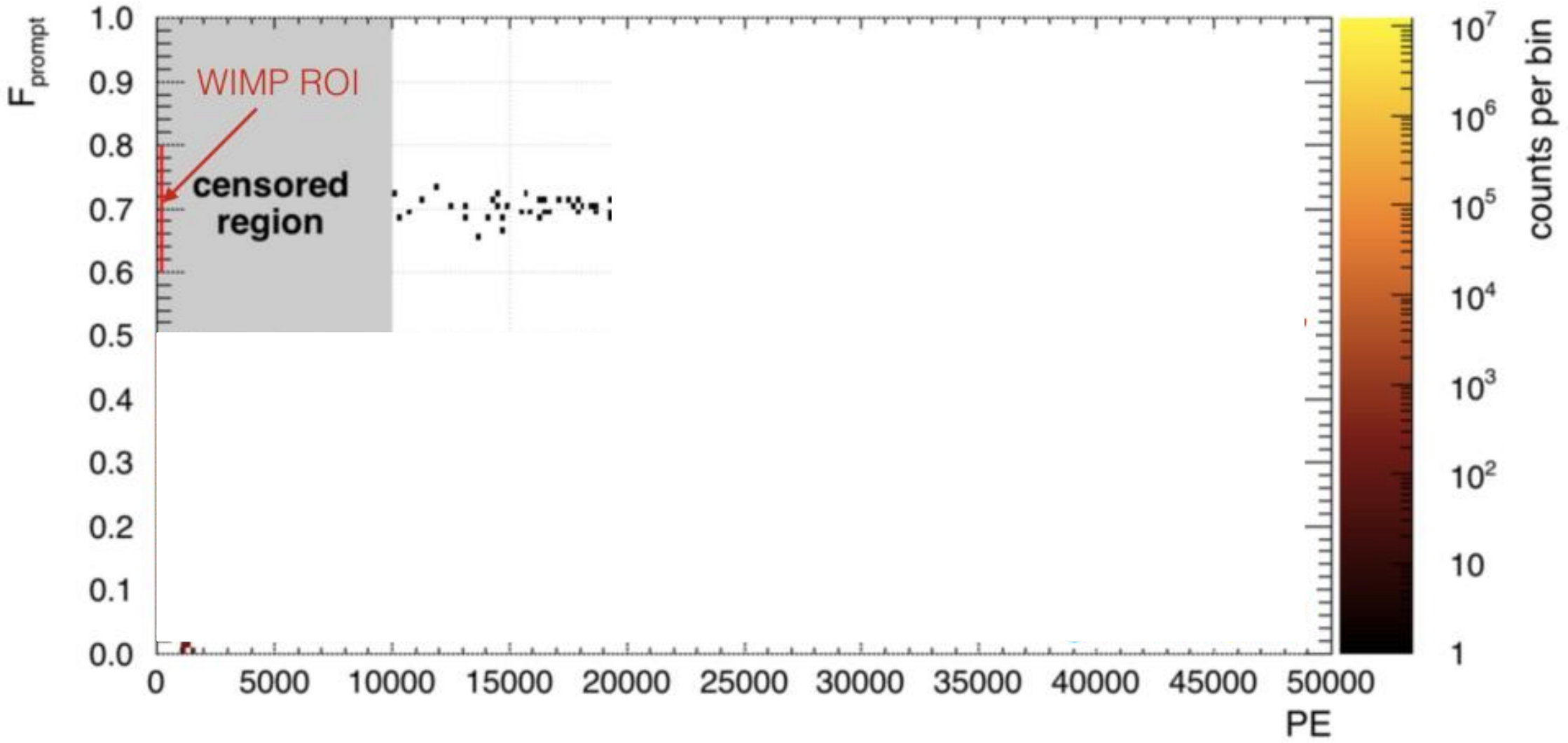
1


F_{prompt}
1.0
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0.4
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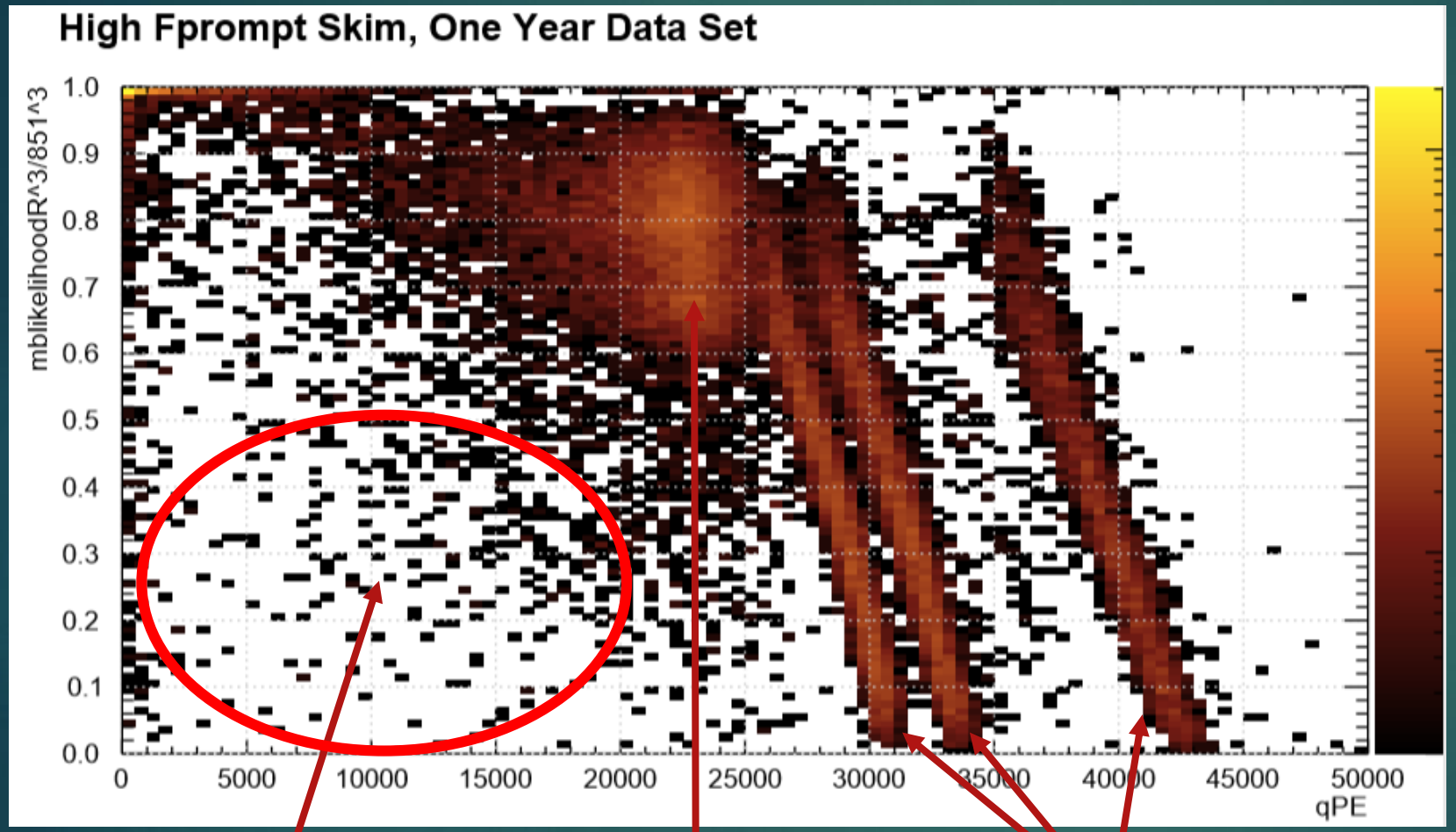
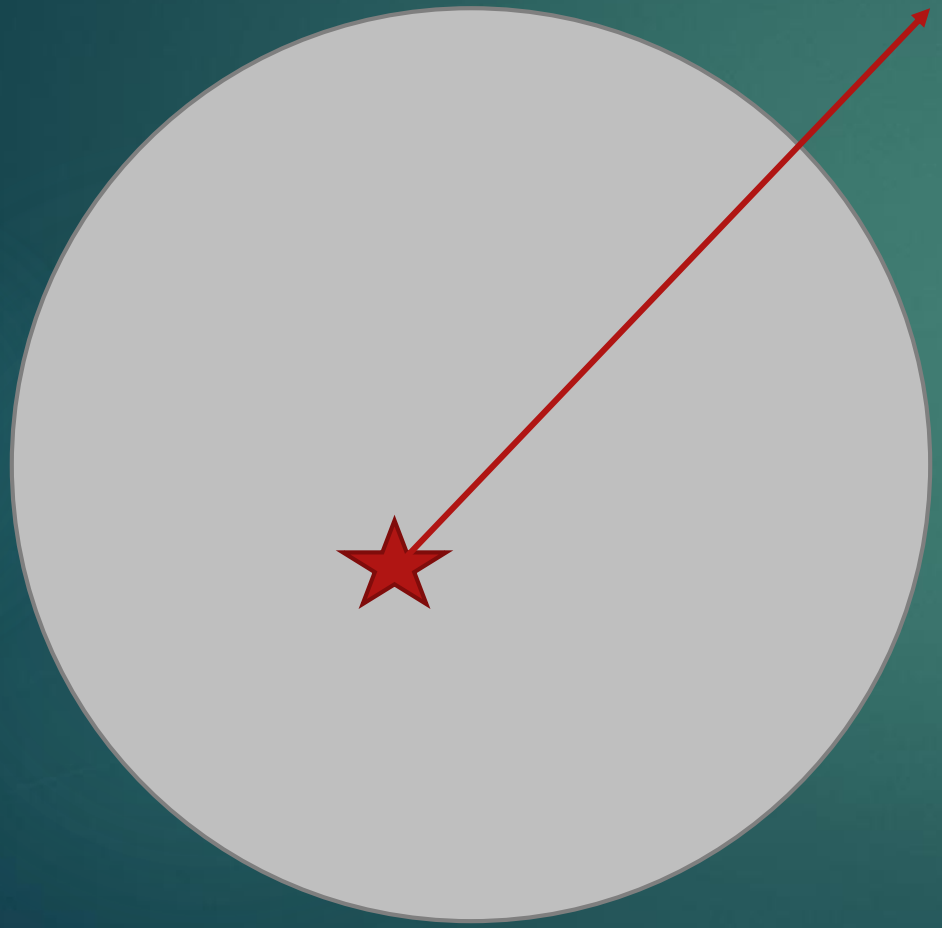
WIMP ROI
censored region
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
PE
10^7
10^6
10^5
10^4
10^3
10^2
10
1
counts per bin

What Am I Doing?



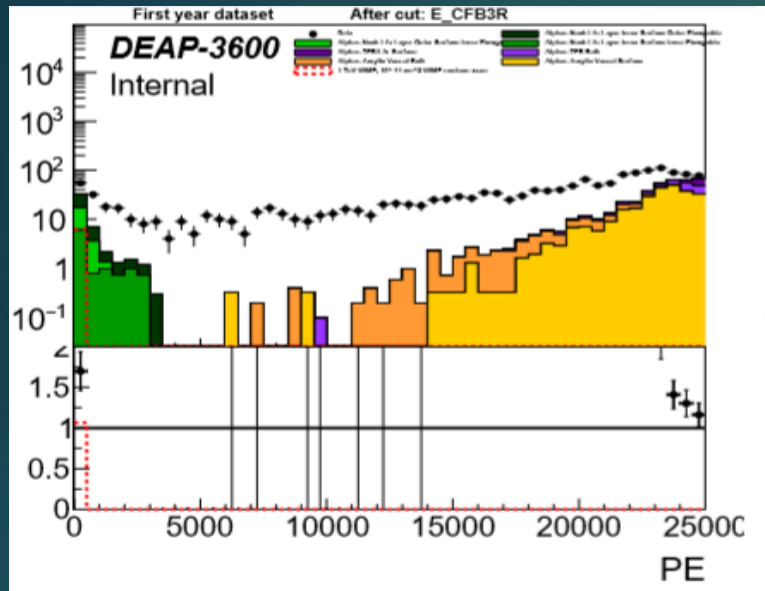
- Cuts applied to select "alpha like" events.
- Have a population that looks like alphas but are shifted down to lower energy. What are these???
- Could be alphas in dust???

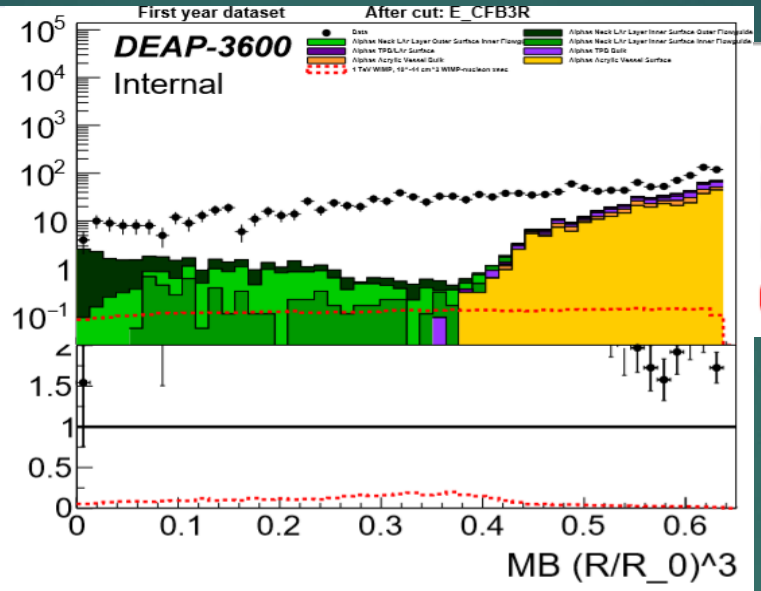
Why Dust?

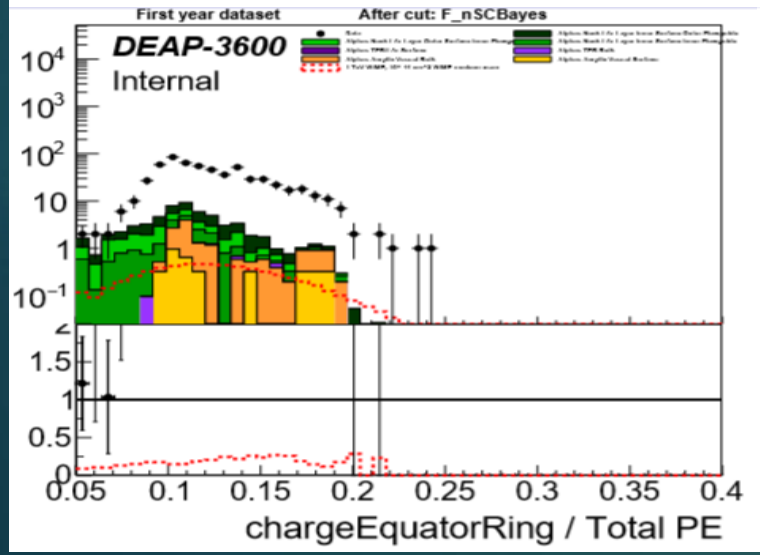


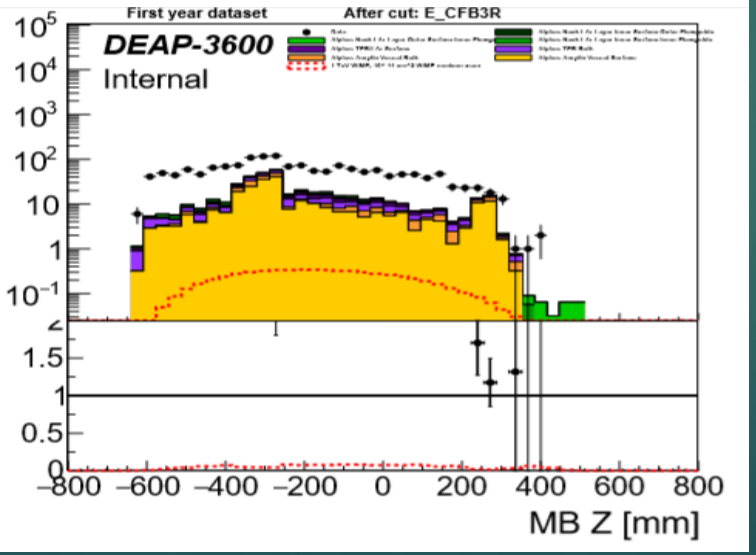
- Alpha needs to "break out" of the dust particle.
- Can cause a shift to lower qPE
- Could be distributed all throughout the detector

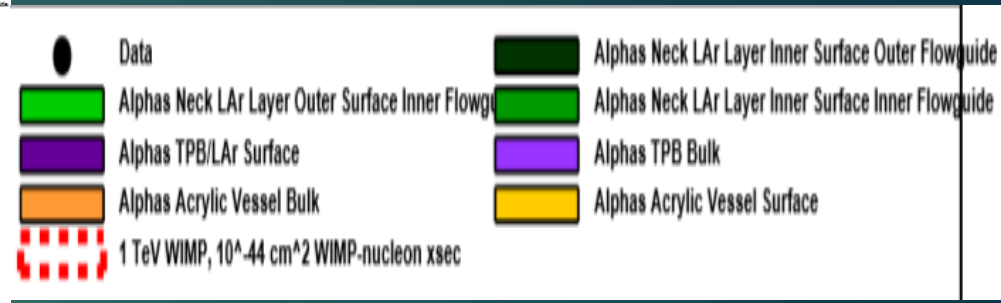
Without Dust







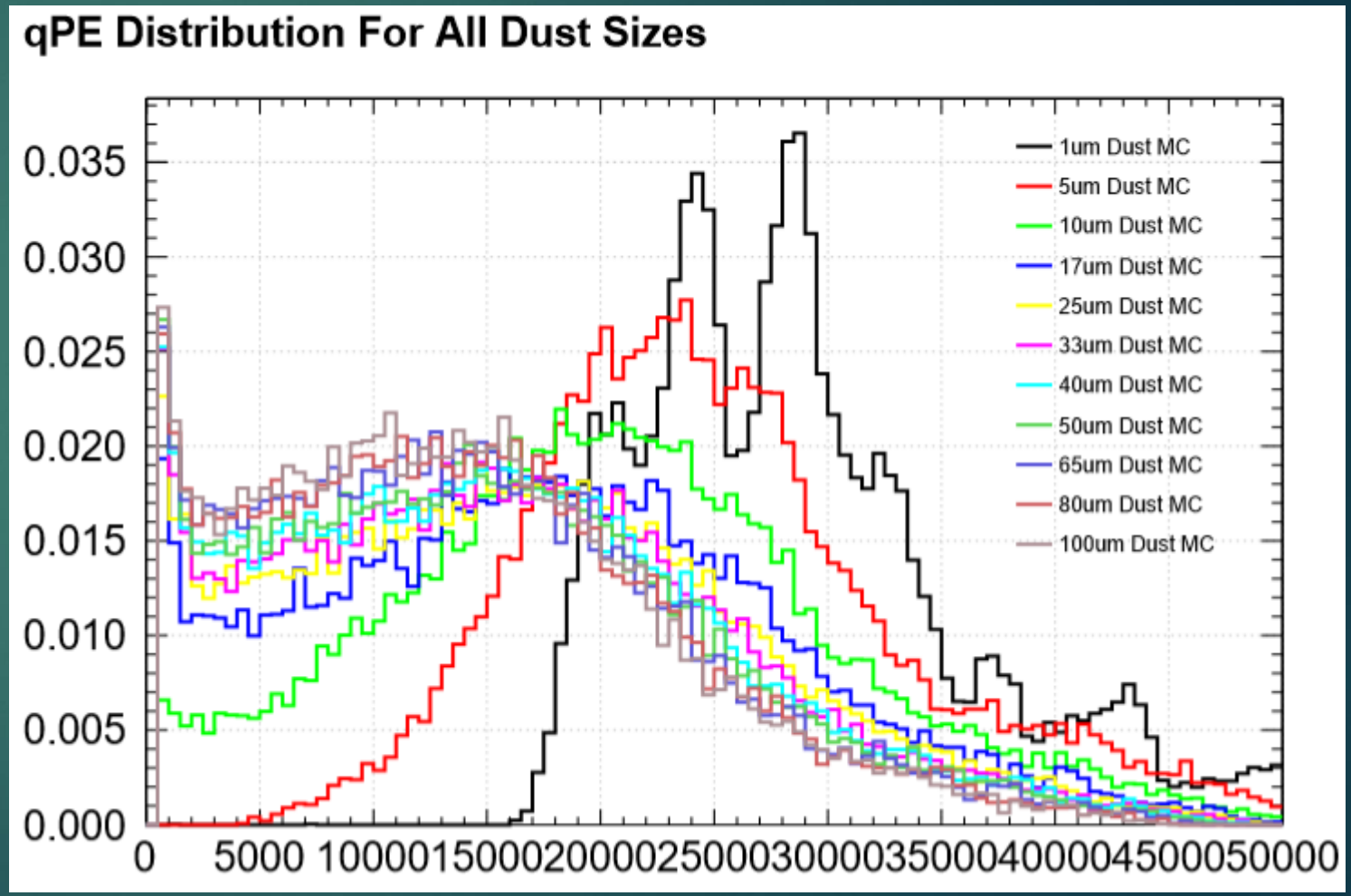




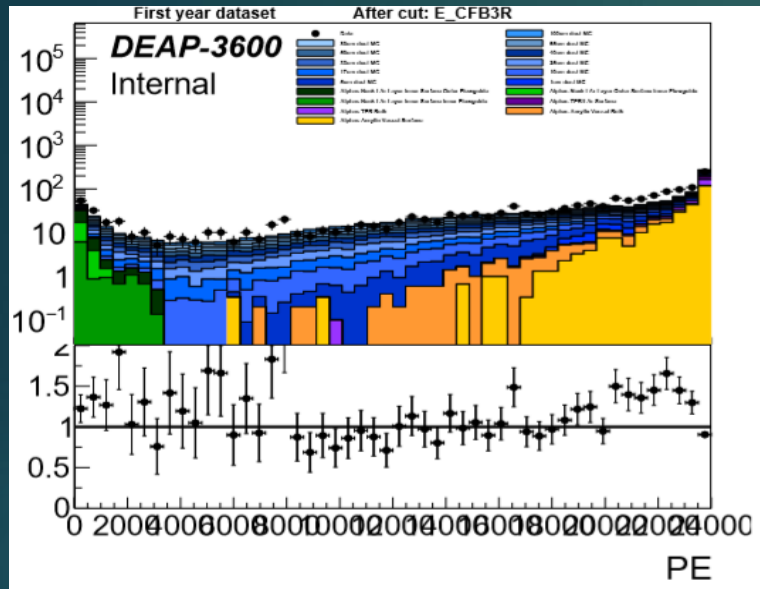
- Selecting alpha like events
- Large discrepancies between data and simulated known backgrounds

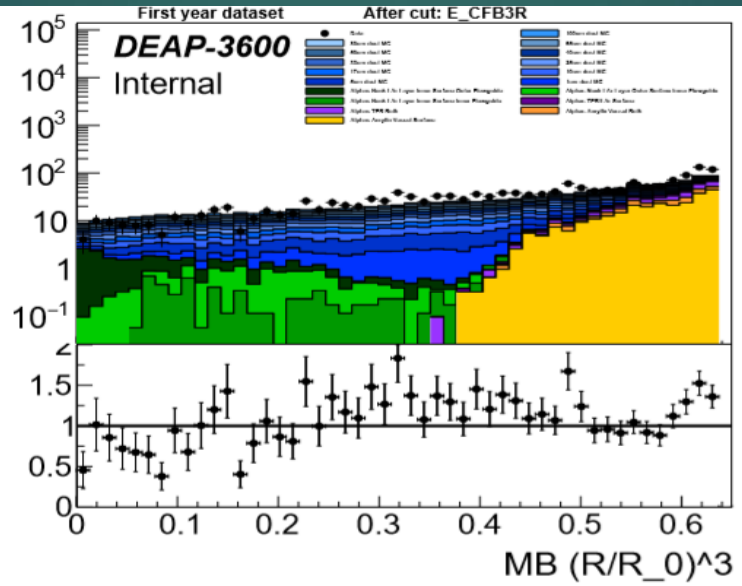
What's Been Done

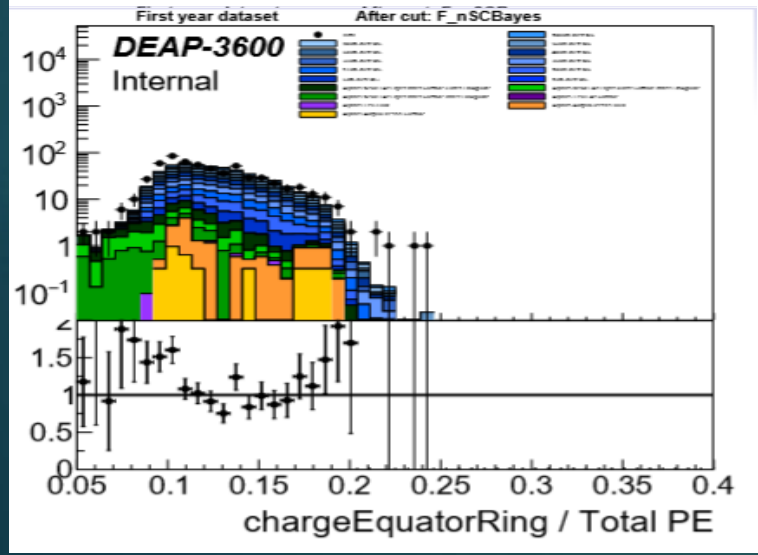
- Simulations of alpha decays inside particles of norite dust were generated.
- Dust particle Radii: 1um, 5um, 10um, 17um, 25um, 33um, 40um, 50um, 65um, 80um and 100um.
- Dust distributed uniformly throughout the detector.

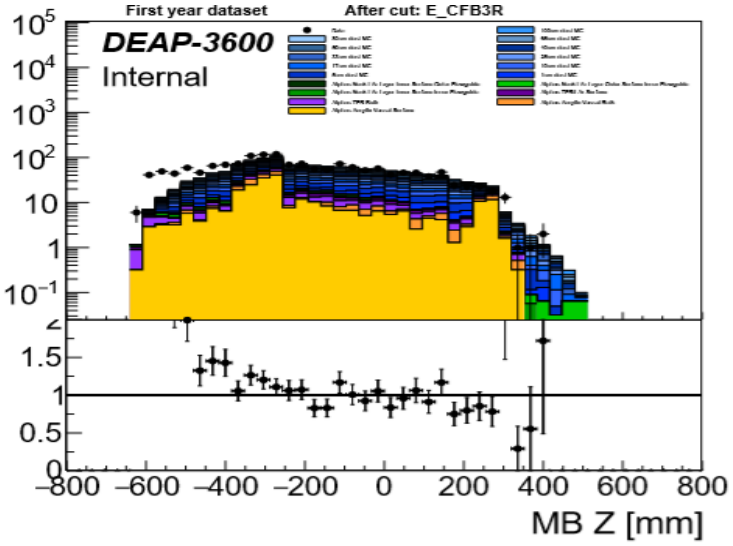


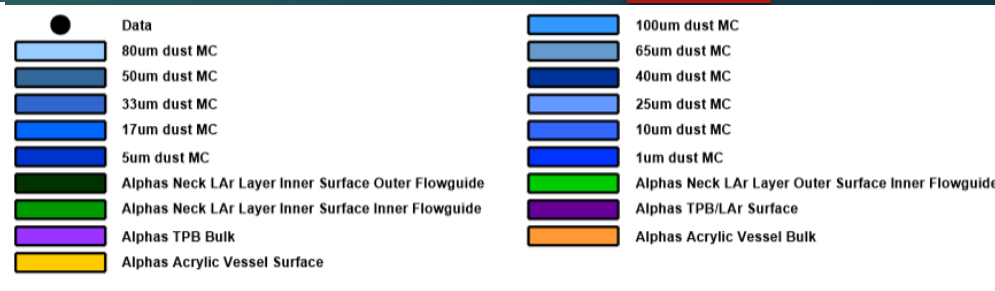
Now With Dust





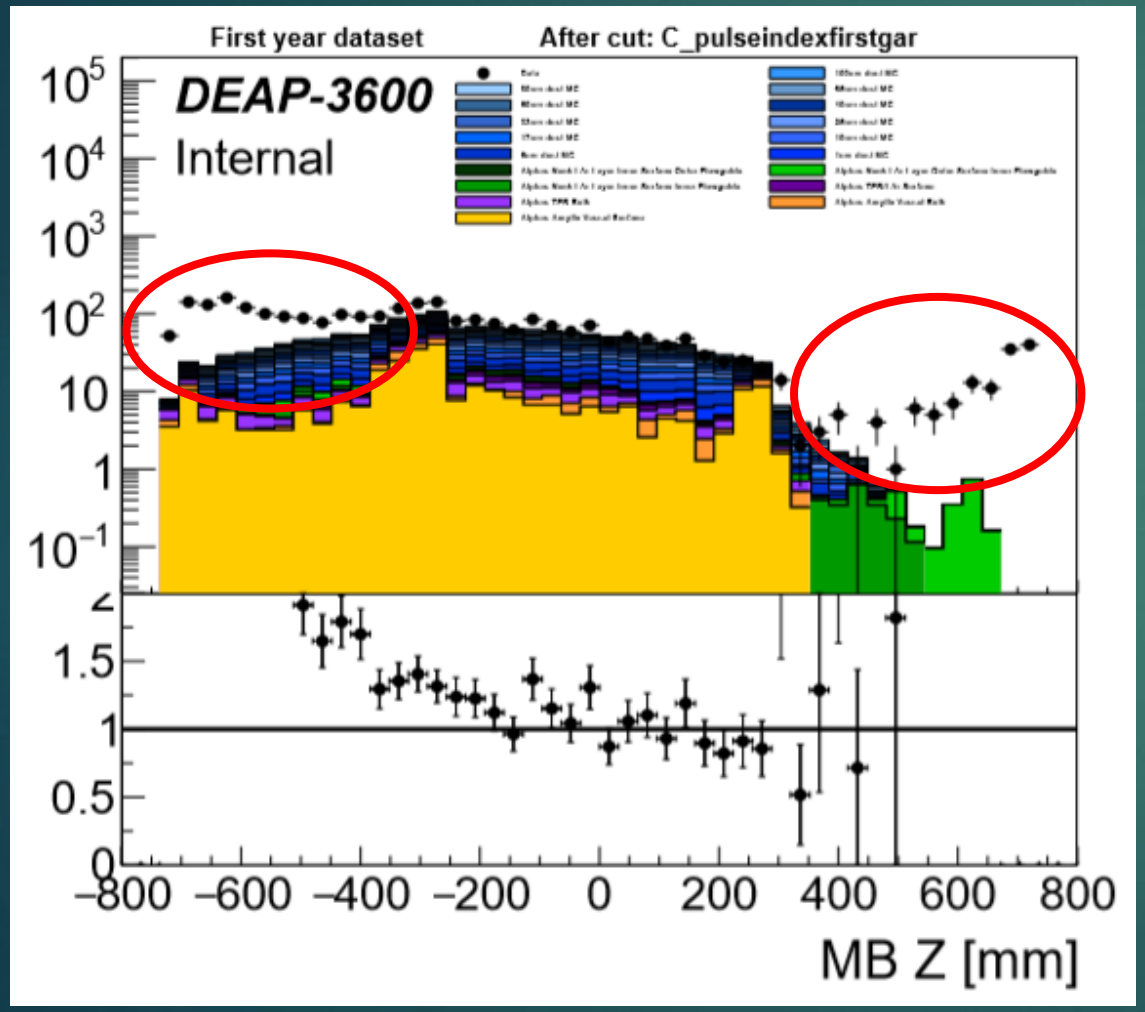


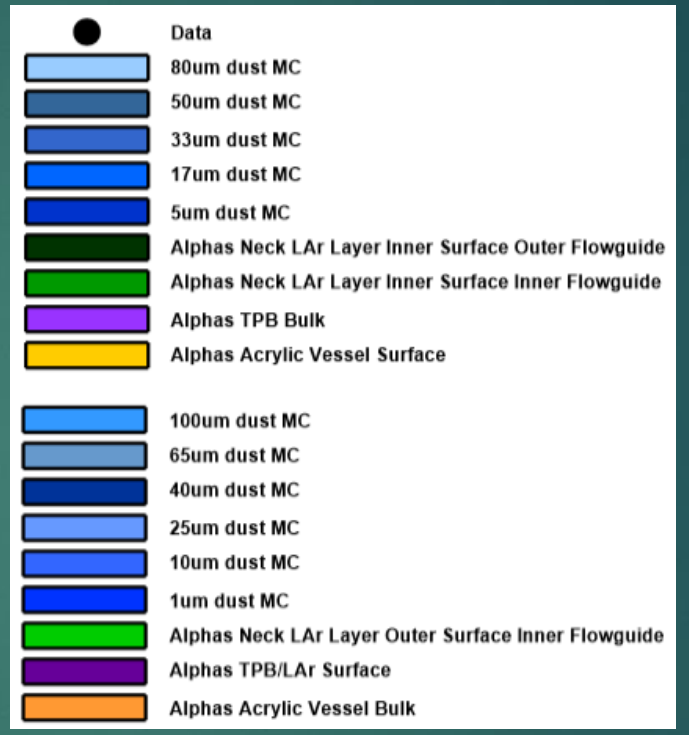




- Same plots as before with dust sims added.
- Remarkable fit between simulation and data

Looking at mblikelihoodZ



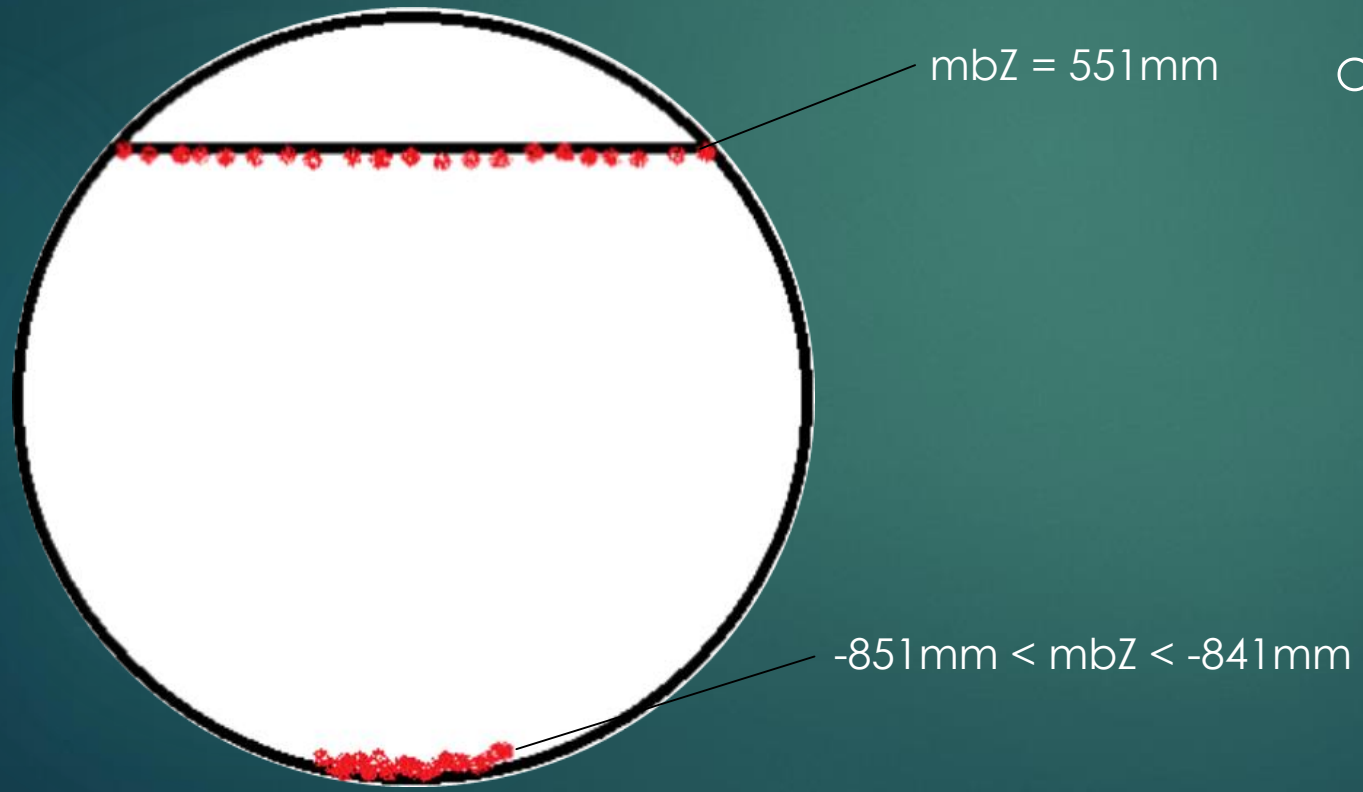


- Looser cuts than previous plots
- Allows more events near the top and bottom of the detector.

What are these events? Can they be dust? If yes, where is this dust?

Hypothesis

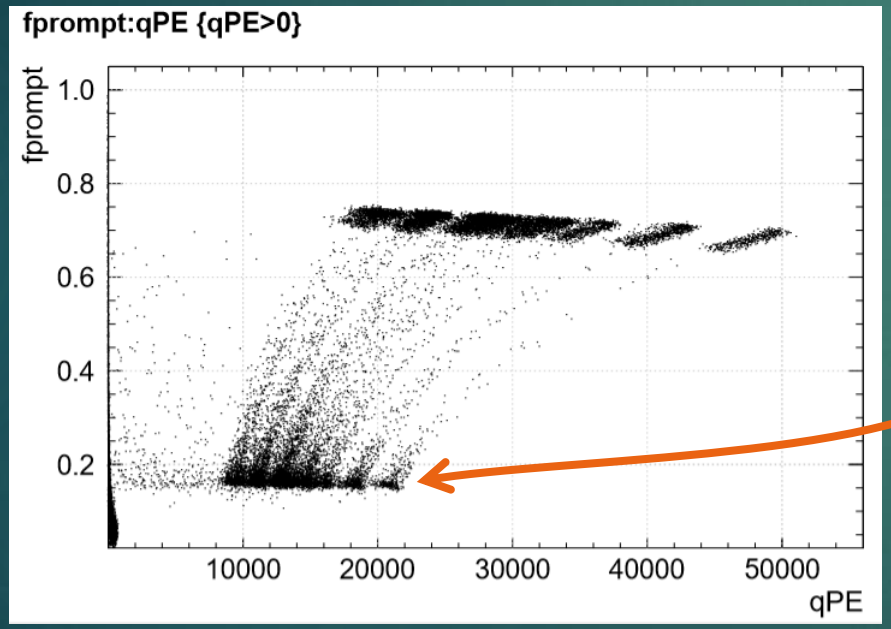
- These events could be from dust particles that have sunken to the to the bottom of the detector, or dust that is floating at the fill level.

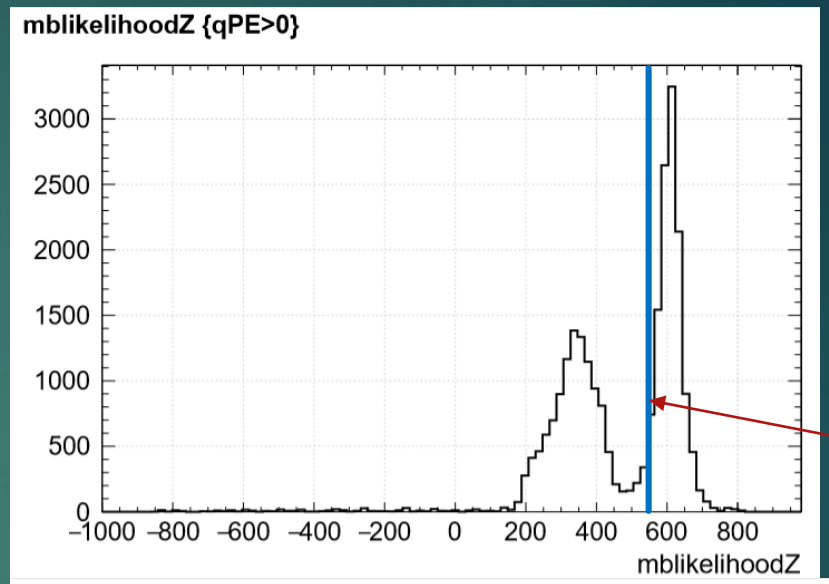


- New Samples were generated at the fill level and in the bottom 1cm of the detector for each size of dust particle; 1um, 5um, 10um, 17um, 25um, 33um, 40um, 50um, 65um, 80um, 100um

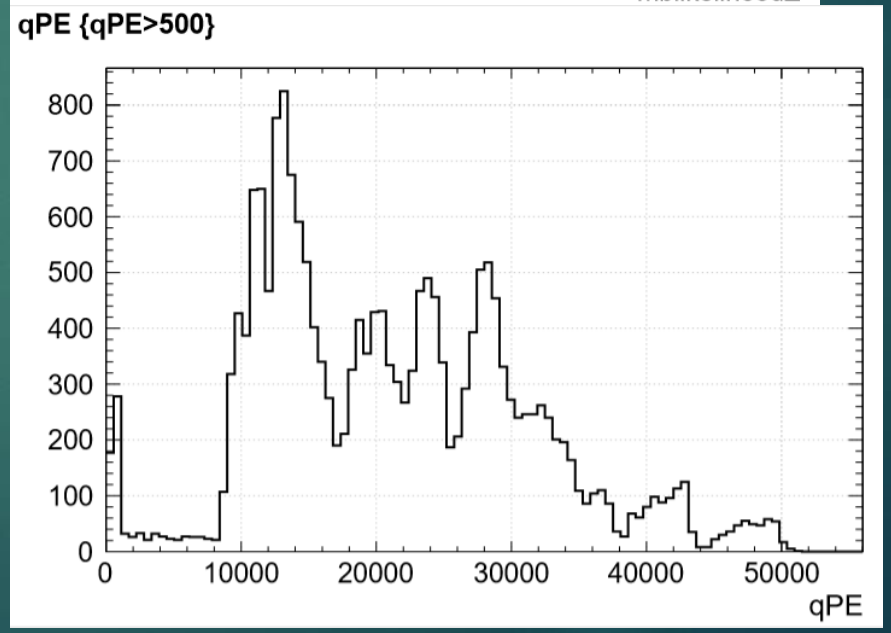
Looking at the floating dust MCs

- Showing 1um Radius dust simulation
- Don't like this…



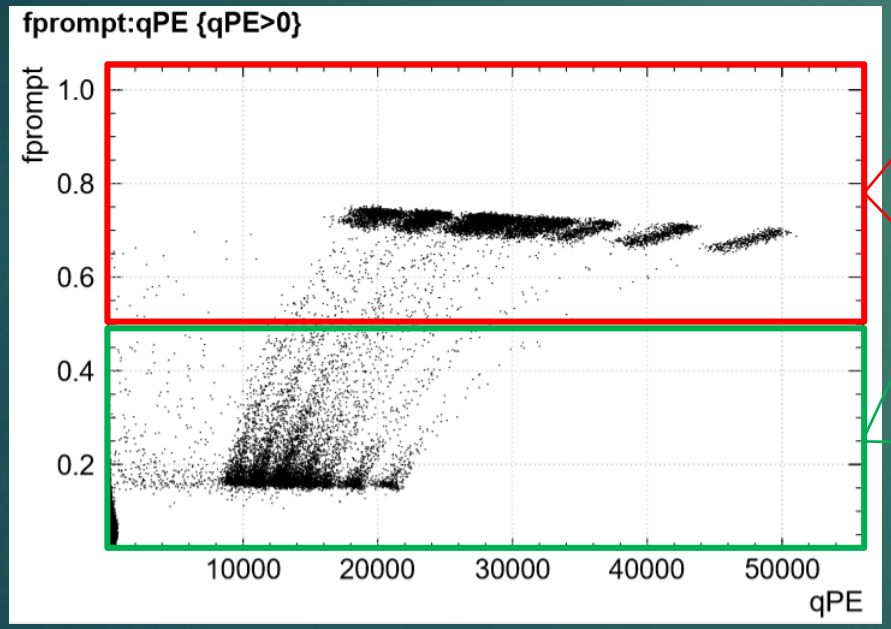


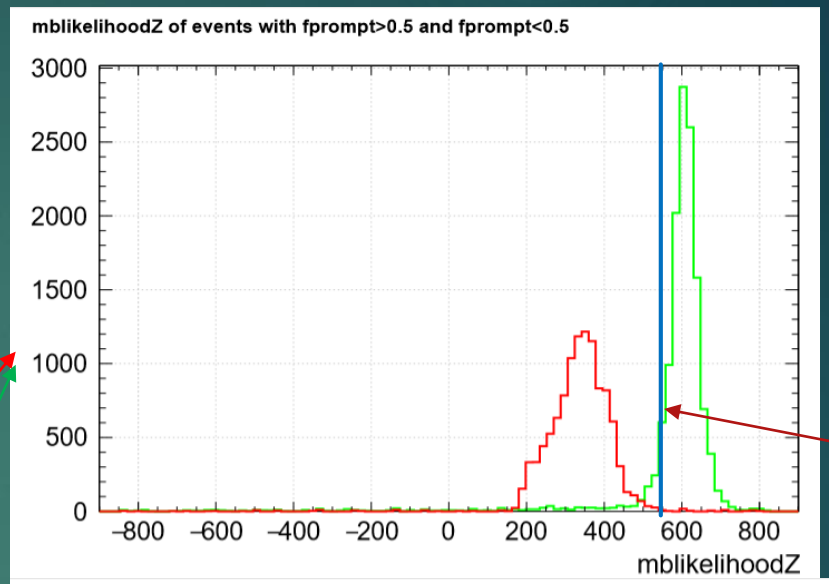
Fill level



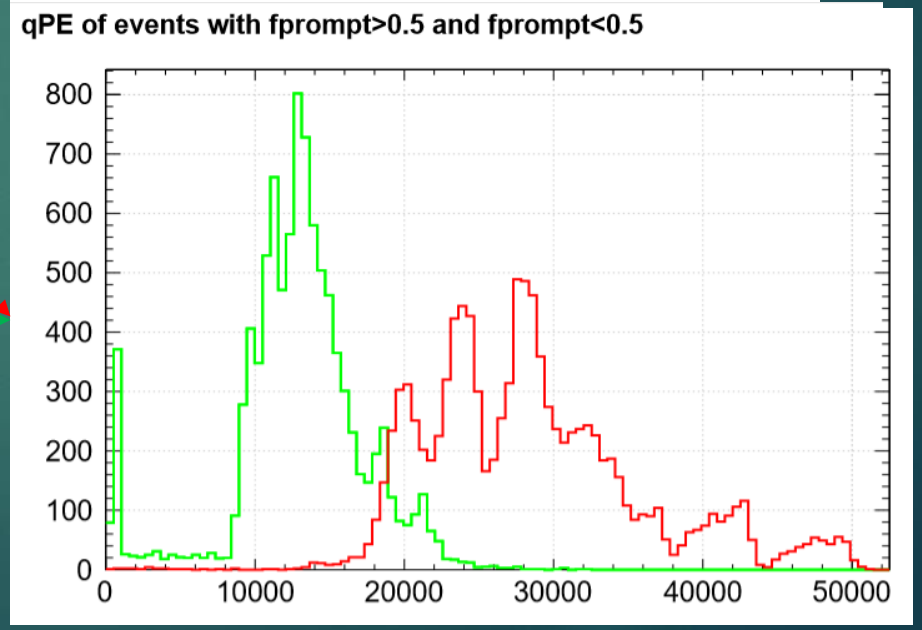
Looking at the floating dust MCs

- Splitting data into high fprompt (>0.5) and low fprompt (<0.5)
- High mblikelihoodZ events have low fprompt

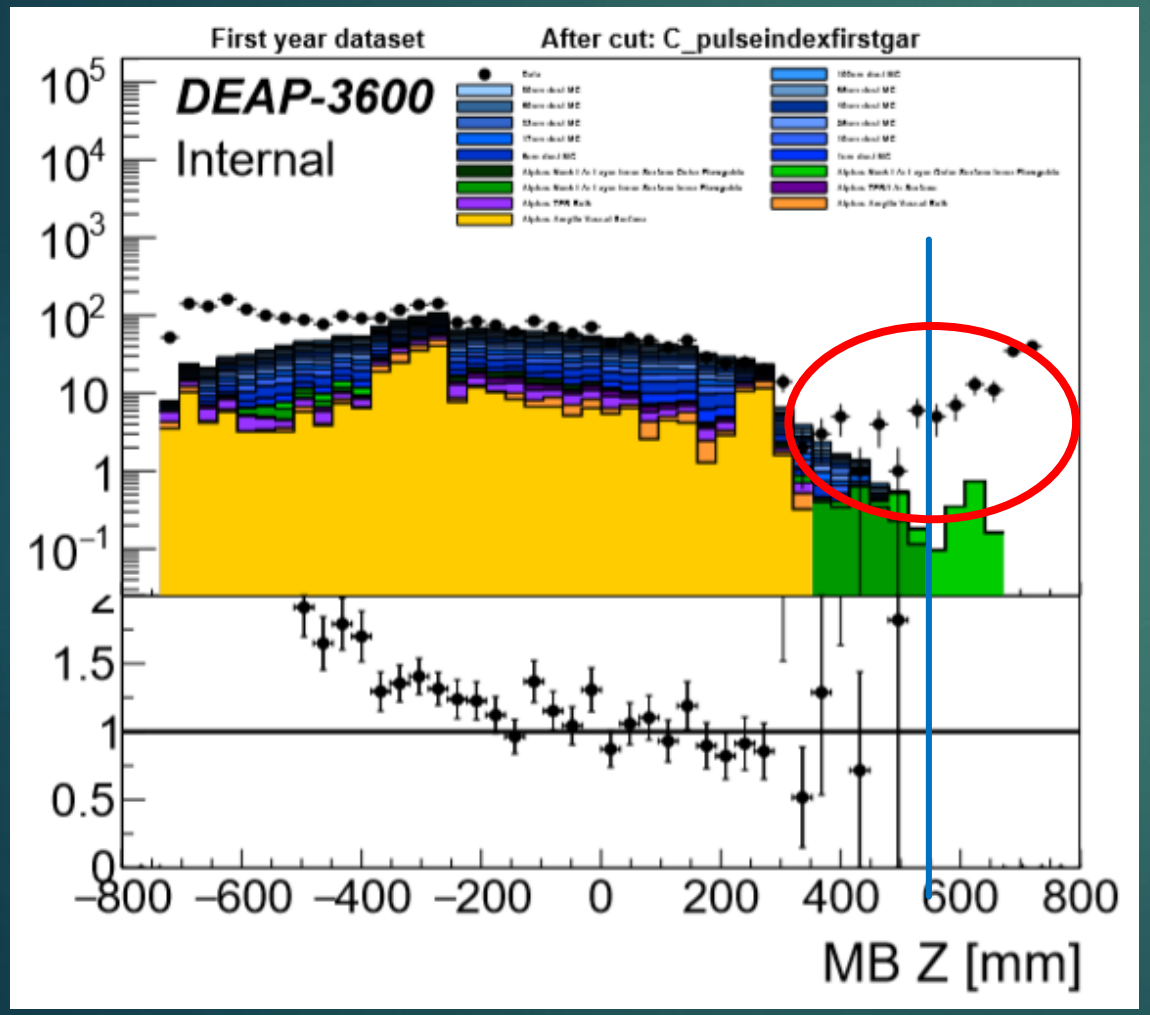




Fill level



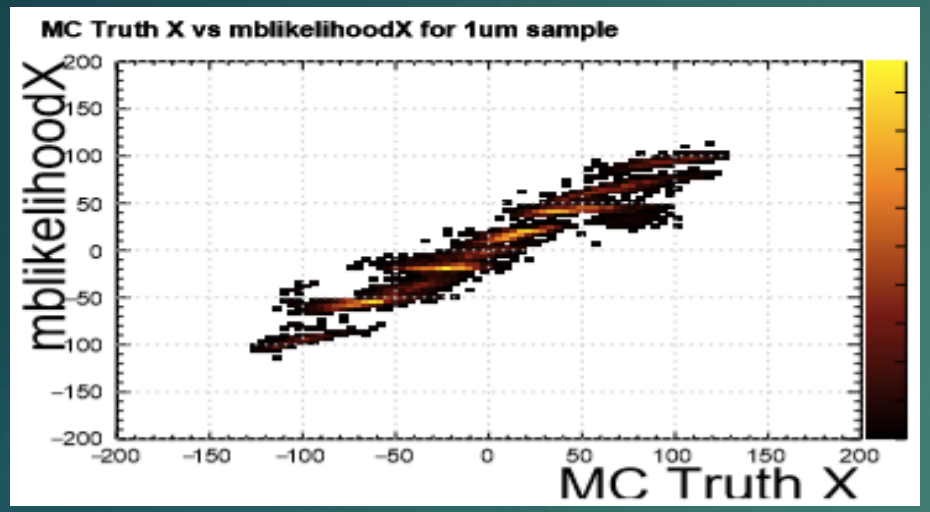
Conclusions For Floating Dust

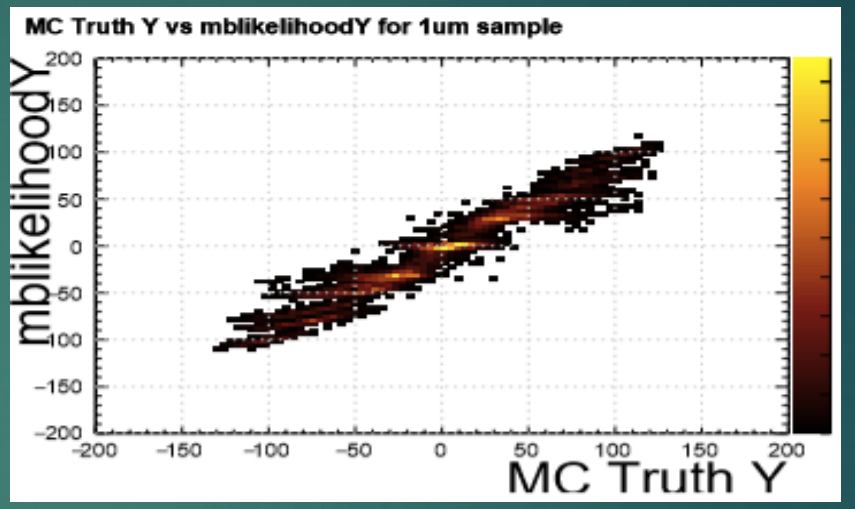


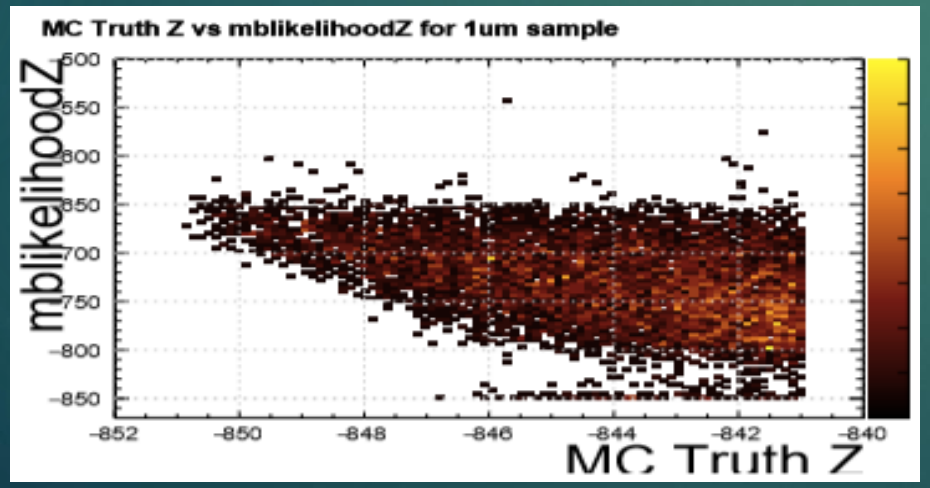
- Majority of mystery high mblikelihoodZ events reconstruct above the fill level
- All dust events that reconstruct above the fill level have low fprompt
- Floating dust cannot explain the bulk of these unknown events.

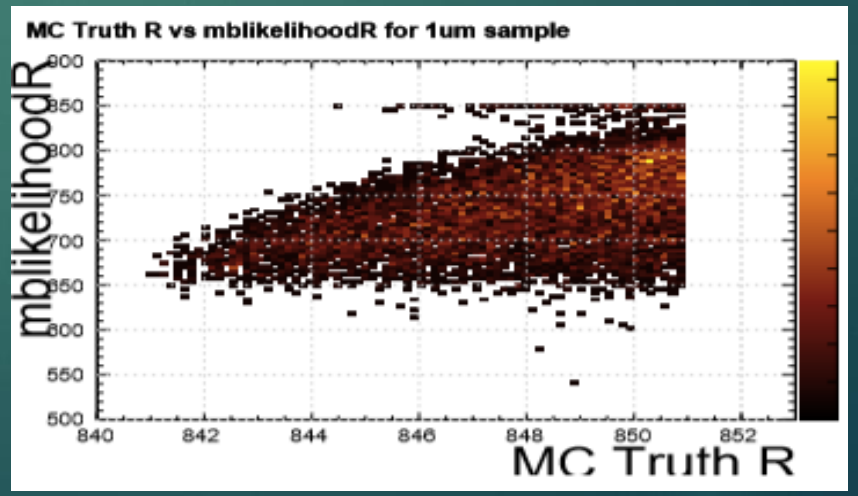
Now for sunken dust events

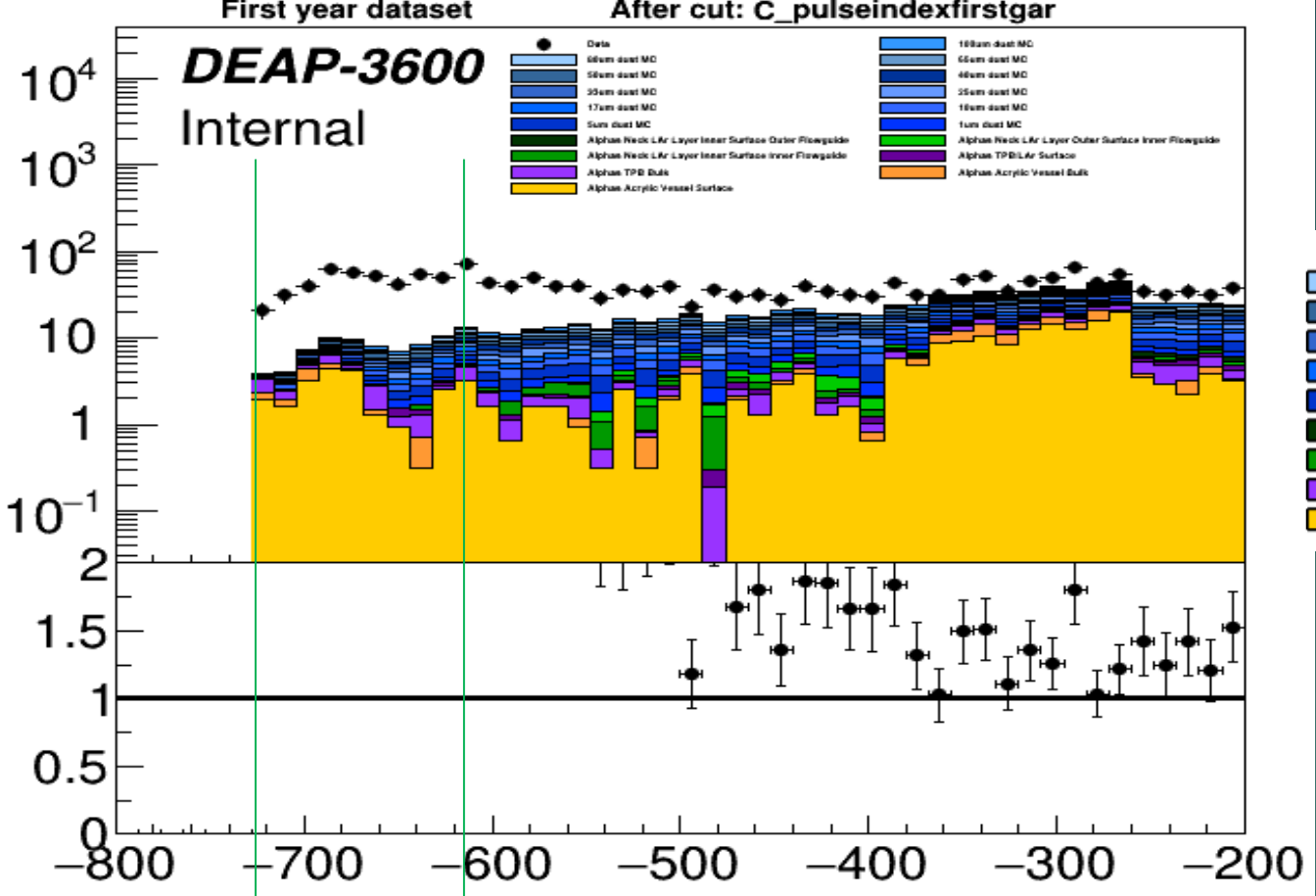
- Dust particles are generated in the bottom 1cm of the detector

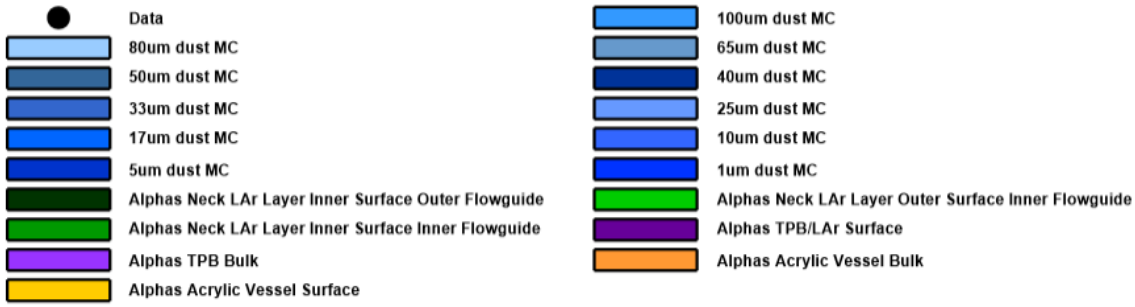


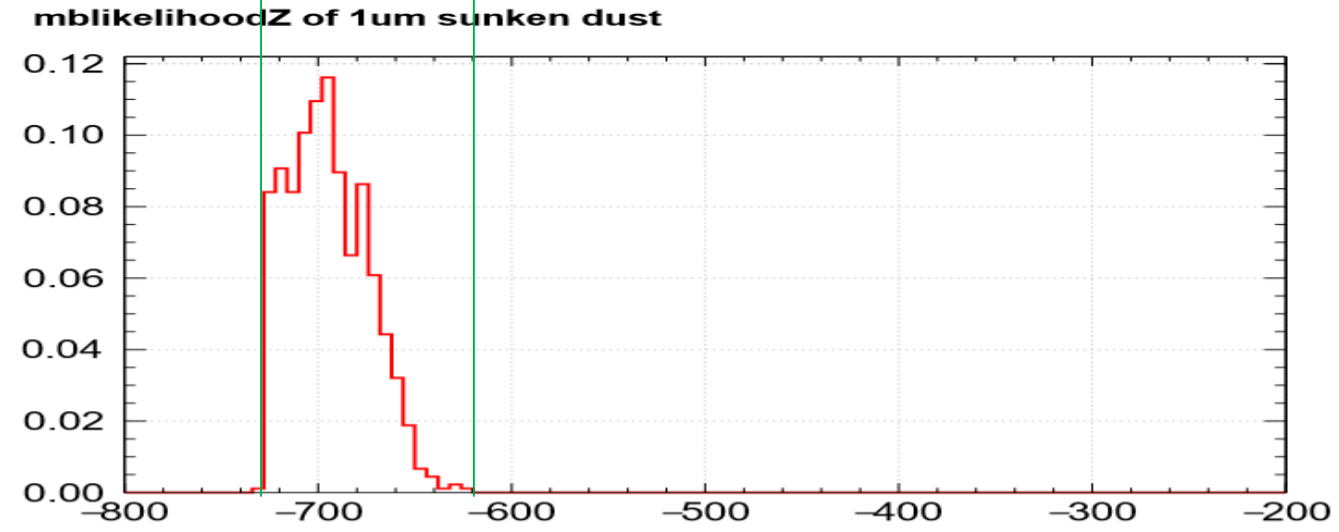




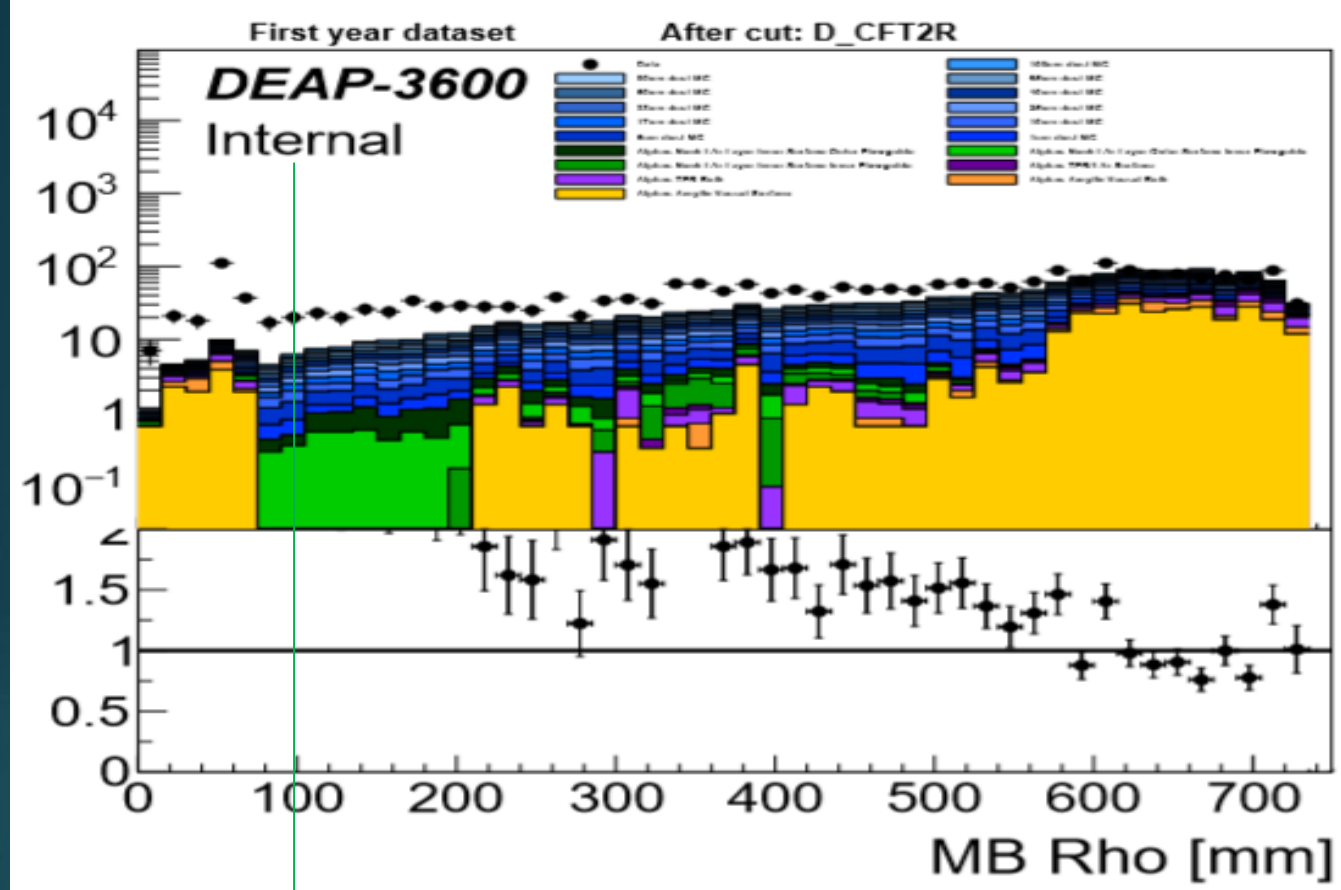


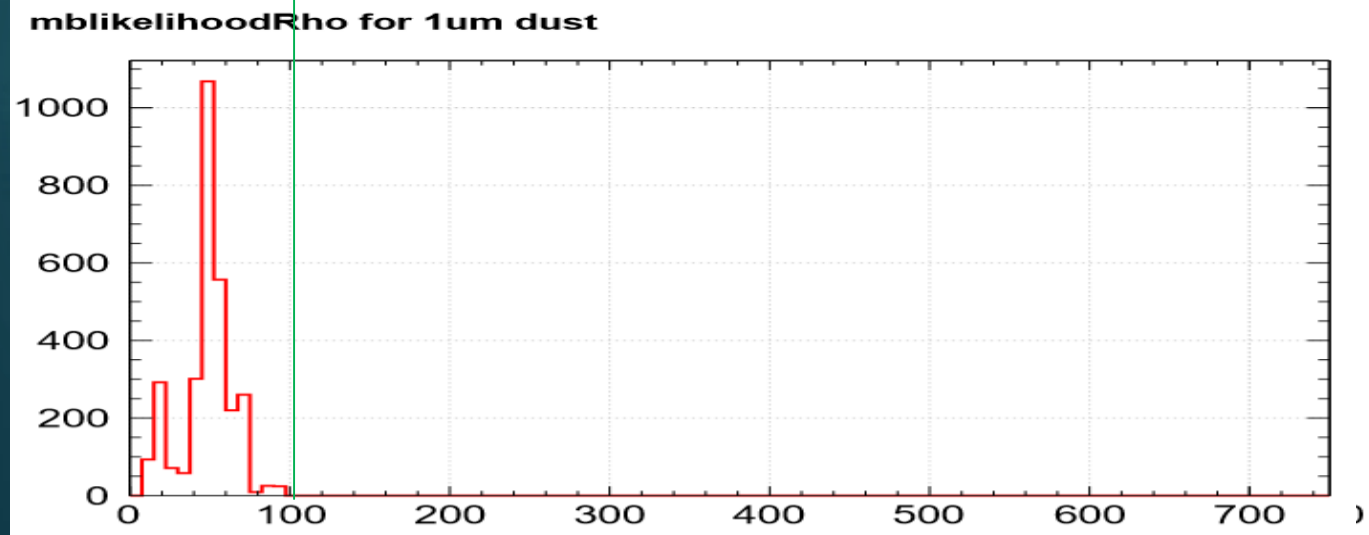


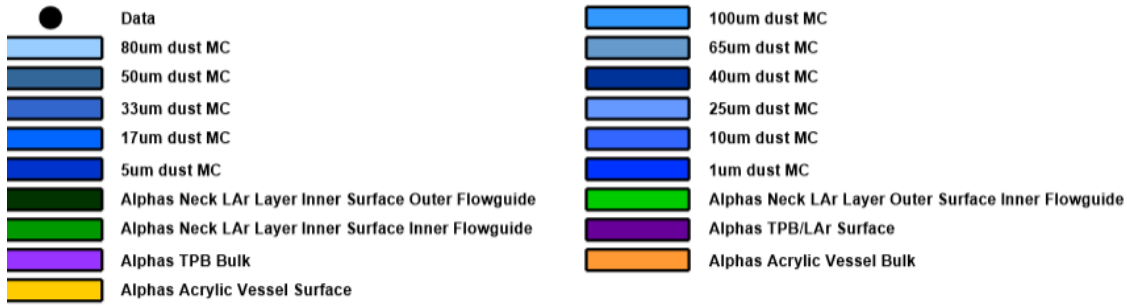




- The sunken dust samples only cover a small region of the mystery low mbZ events.
- Fits are being performed to see if sunken dust can explain some of the events in this region.







- Shape of mblikelihoodRho distribution fits well with data but only for lower section

Conclusions

- There seems to be degraded alpha like events present in the detector.
- Alpha decays in dust particles were hypothesized to explain these events
- Uniformly distributed dust cannot explain some of the dust like events
- High mblikelihoodZ events above the fill level are most likely not dusty (could be from neck Cherenkov)
- Sunken dust distribution may need to be modified to more accurately represent reality.
  - Bottom Semi Shell (in progress)