LOWE VALIDATION UPDATE

Sergio Manthey Corchado

Task list:

Needed for lowe production (updated validation fcls: dunesw, dunesim larsoft_v09_83_00)

- 1. HD (evaluated using https://github.com/DUNE/duneana/tree/solar_duneana/duneana/SolarNuAna/fcl):
  - Correct for external bkg attenuation ✅
  - Simulate central detector region (no ext. backgrounds in central APA) ✅

- 2. VD (evaluated using https://github.com/DUNE/duneana/tree/solar_duneana/duneana/SolarNuAna/fcl):
  - Correct for external bkg positioning (test for GammasInCaverwall) ✅
  - Understand increased rate ▢
  - Missing attenuation changes to all .root files ▢

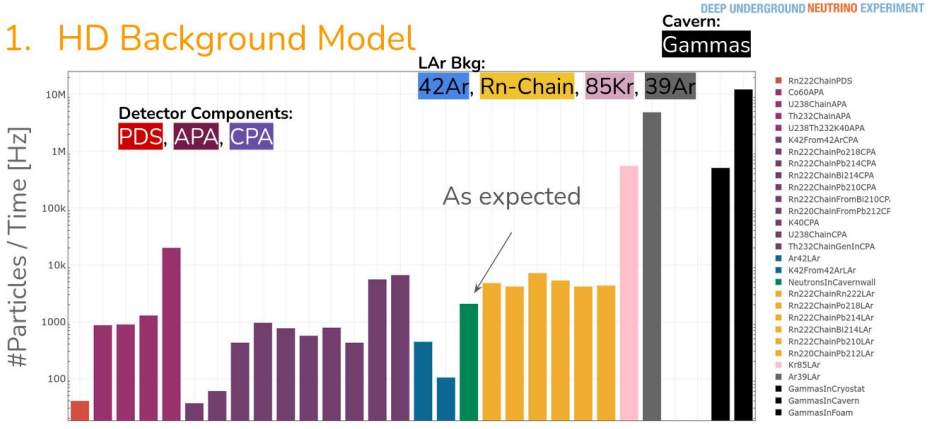
Needed for solar analysis:

- 3. Improve bkg rejection with additional features: e.g. track-like cluster vs blip-like cluster
- 4. Standard OpFlash → Estimated ~ **6% correct flash match probability** for solar neutrinos
  - Working on **new lowe flash algorithm** (solar_duneana/duneana/SolarNuAna)

Previously presented

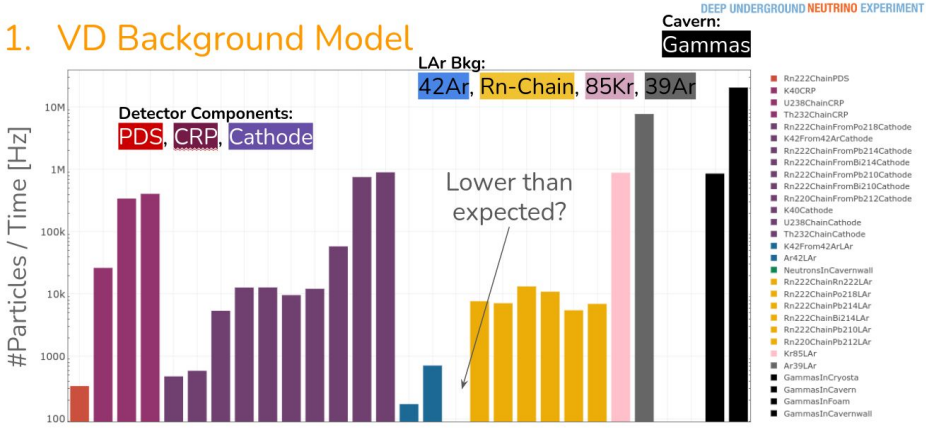
- Previously presented bkg. rates not updated to the latest simulation standards.
- HD: missing geometry update (v3.6) to include CPA thickness change and APA electronics.
- VD: wrong physics list (missing neutrons) & wrong ext. gamma end-cap placing.

1. HD Background Model



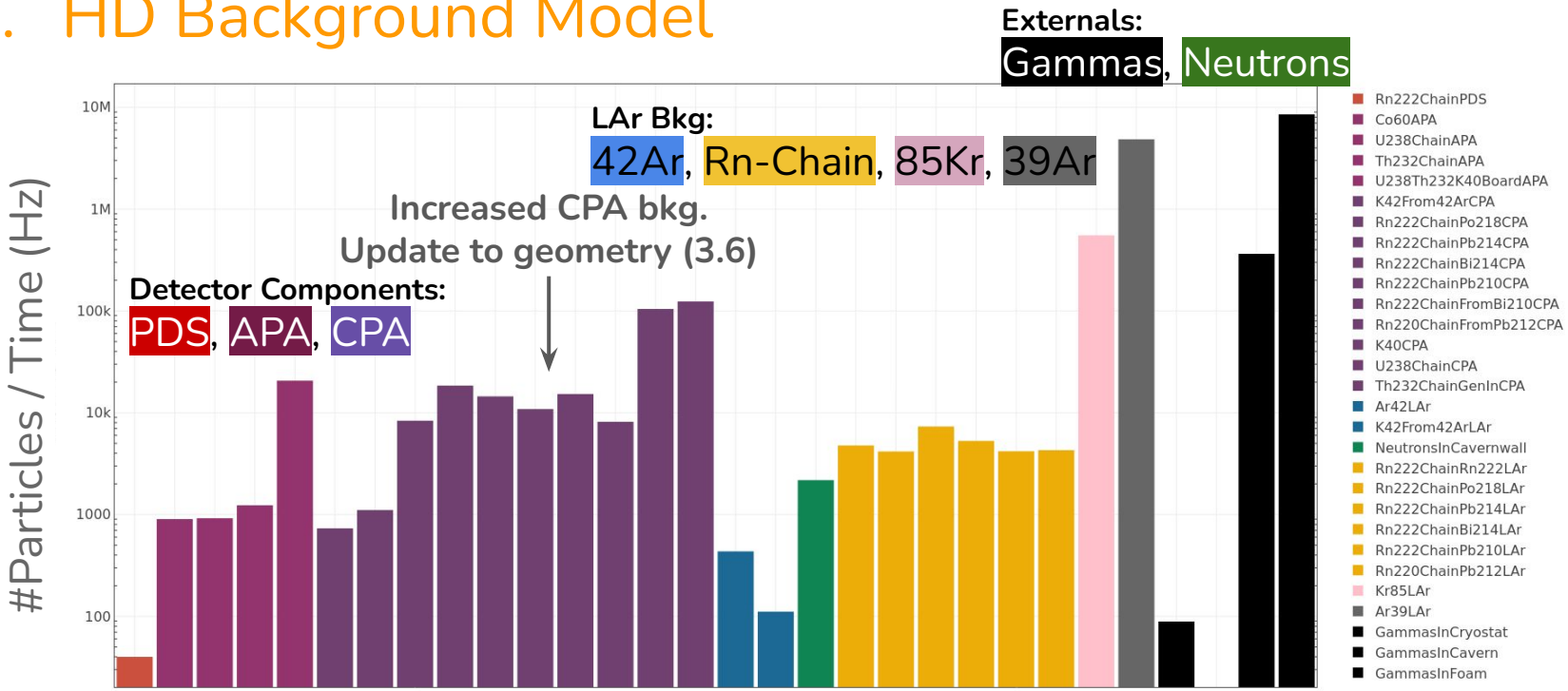
- Background frequency calculated from reduced sample simply by #Particles/Time.
- Multiply by ~8 for full detector rate.

1. VD Background Model



- Background frequency calculated from reduced sample simply by #Particles/Time.
- Multiply by ~6 for full detector rate.

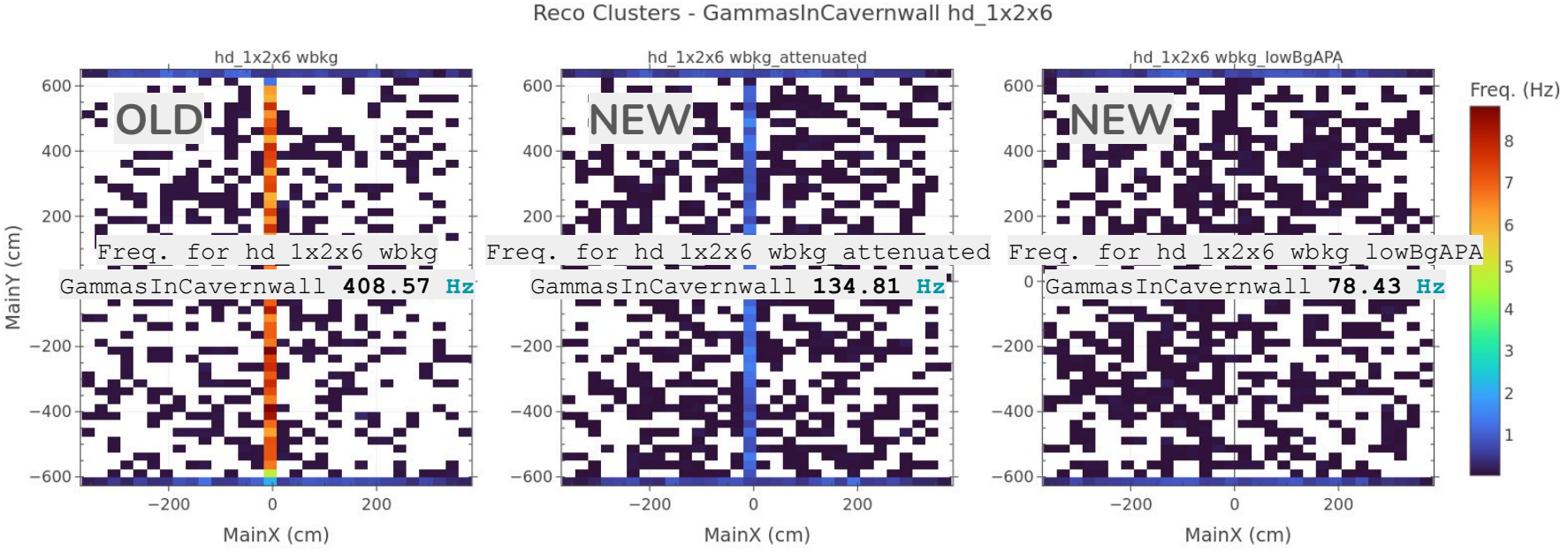
1. HD Background Model



- Background frequency calculated from reduced sample simply by #Particles/Time.
- Multiply by ~8 for full detector rate.

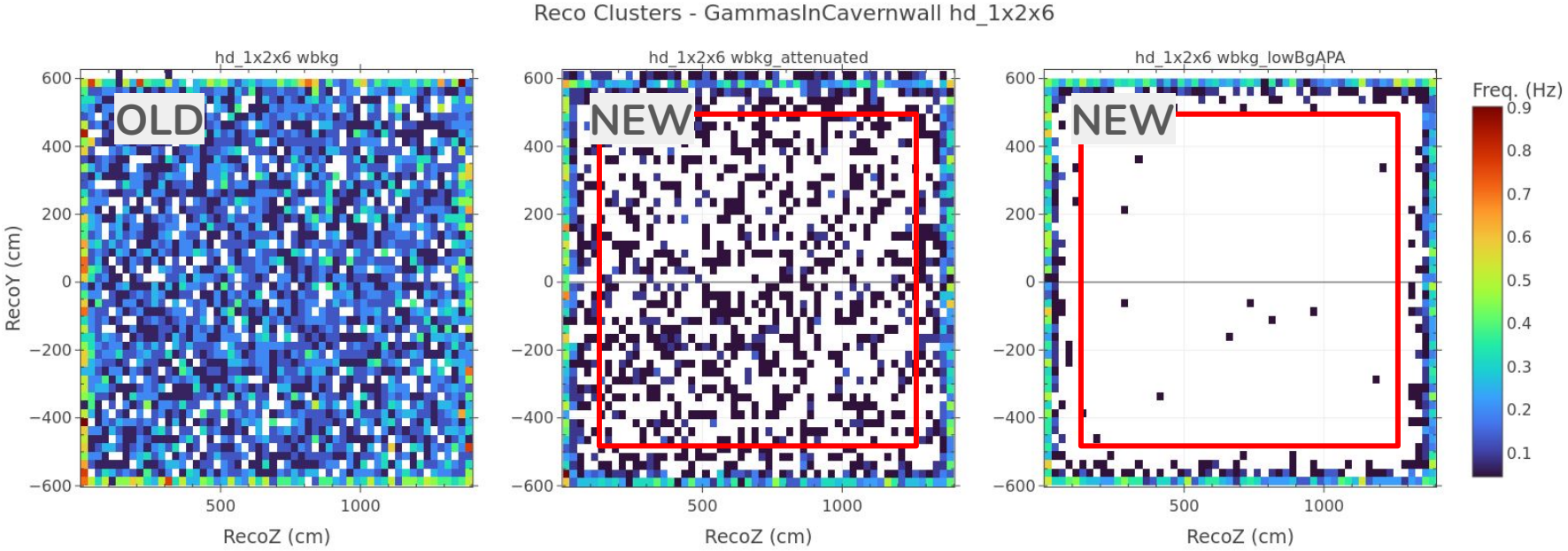
1. HD Bkg. Attenuation & lowBgAPA Generatrion

- Showing **true** bkg position (**MainX/Y/Z**) & and frequency for reco clusters (+3Hit) on updated productions (e.g. GammasInCavernwall 10k prod.).
- **APA bkg. (-5 < MainX < 5) attenuated to ~80%** of the original value



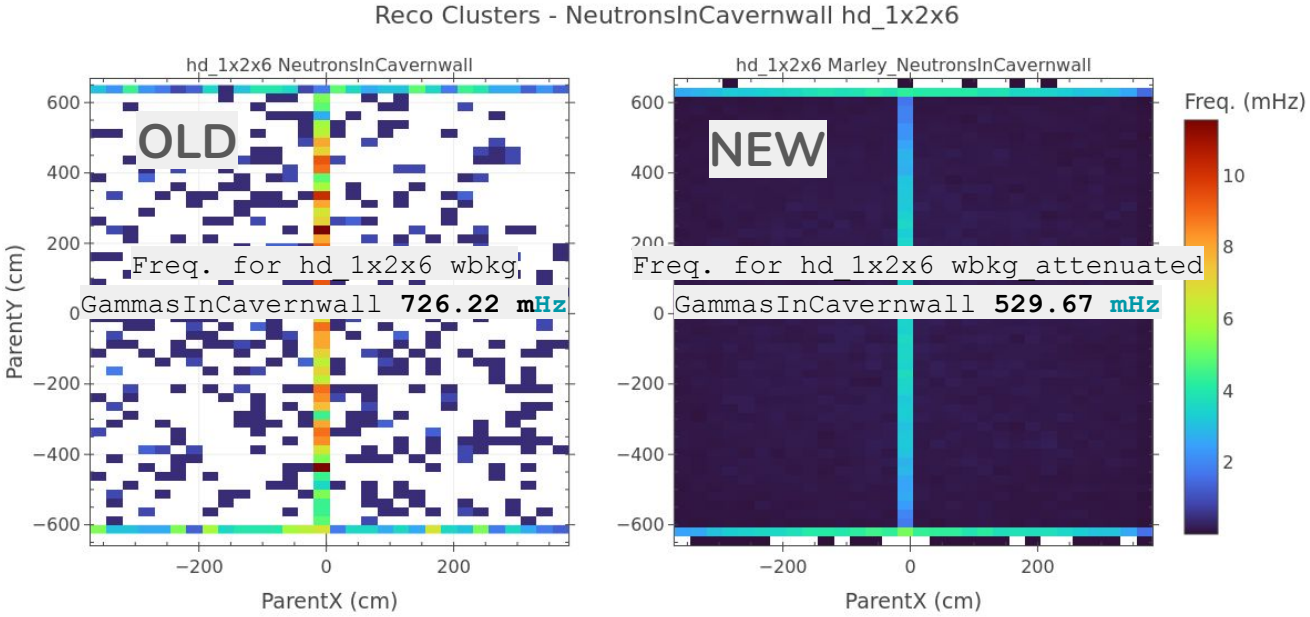
1. HD Bkg. Attenuation & lowBgAPA Generatrion

- Showing **reco** bkg position (**RecoY/Z**) for reco clusters (+3Hit) on updated productions (e.g. GammasInCavernwall 10k prod.).
- **TPC-Fiduzialization possible in HD!**



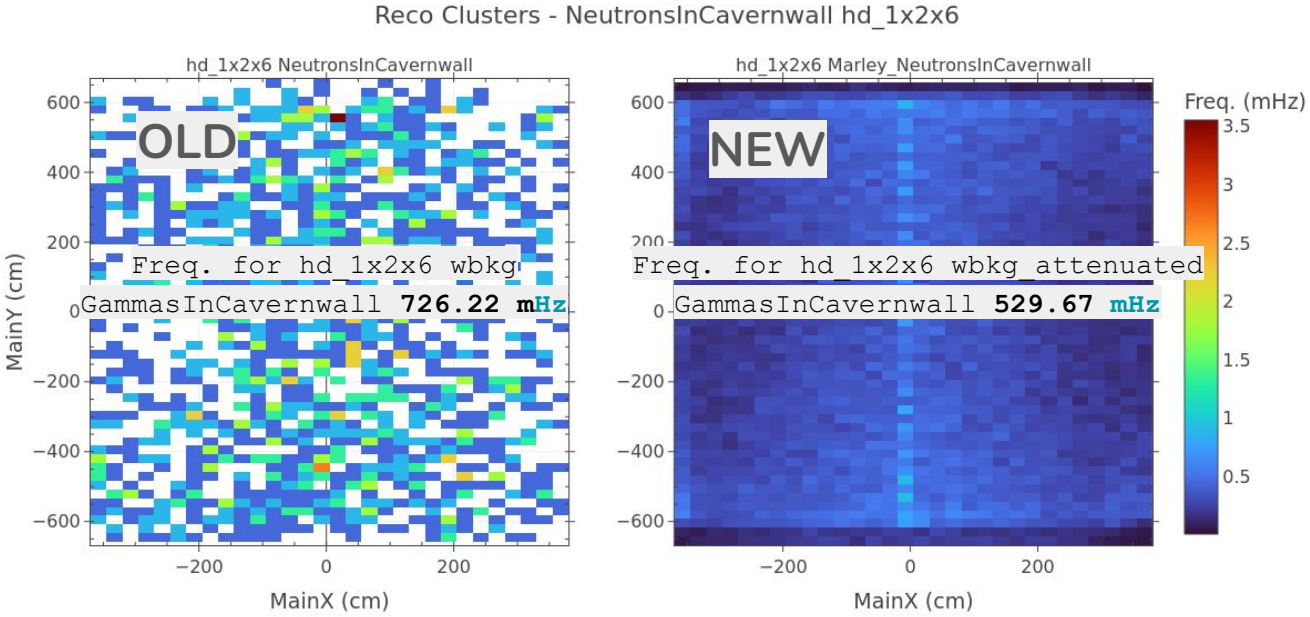
1. HD Bkg. Attenuation & lowBgAPA Generatrion

- Showing true bkg **start** position (**ParentX/Y**) & and frequency for reco clusters (+3Hit) on updated productions (e.g. 1k*NeutronsInCavernwall 10 - 100k prod.).



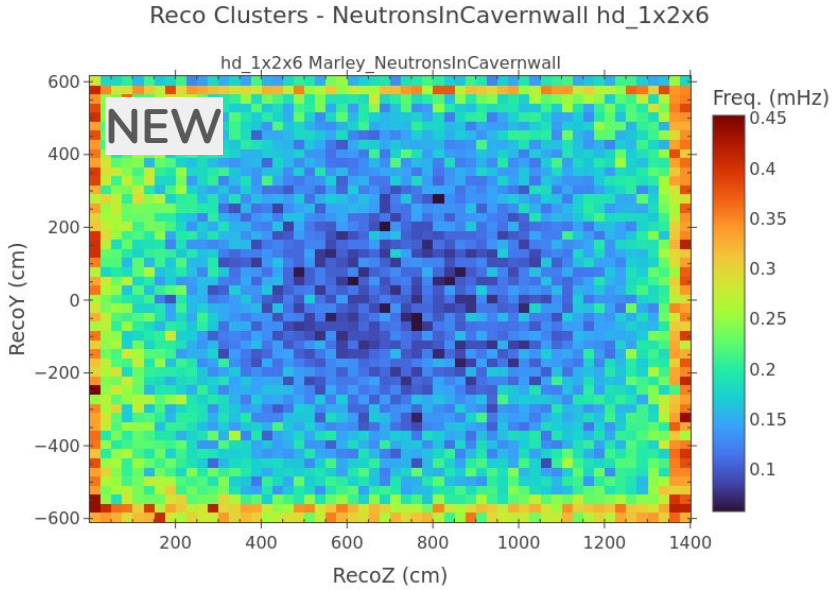
1. HD Bkg. Attenuation & lowBgAPA Generatrion

- Showing true bkg **end** position (**MainX/Y**) & and frequency for reco clusters (+3Hit) on updated productions (e.g. 1k*NeutronsInCavernwall 10 - 100k prod.).



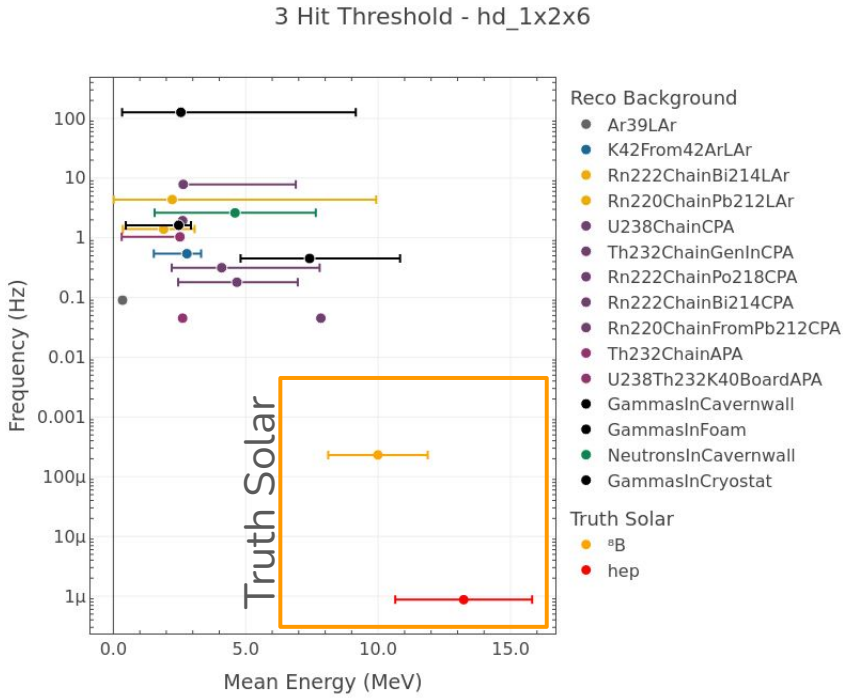
1. HD Bkg. Attenuation & lowBgAPA Generatrion

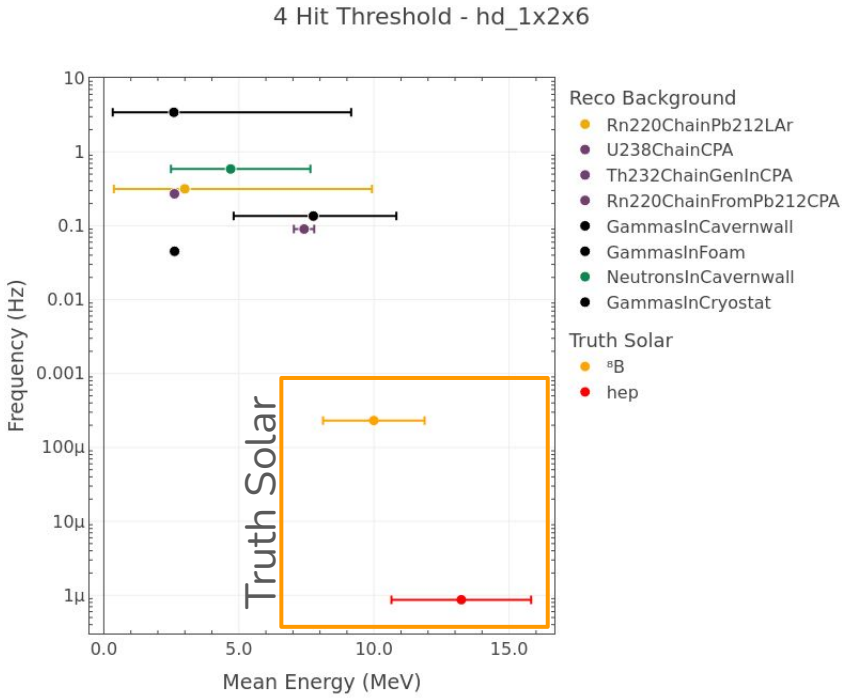
- Showing **reco** bkg position (**RecoY/Z**) & and frequency for reco clusters (+3Hit) on updated productions (e.g. 1k*NeutronsInCavernwall 100k prod.).



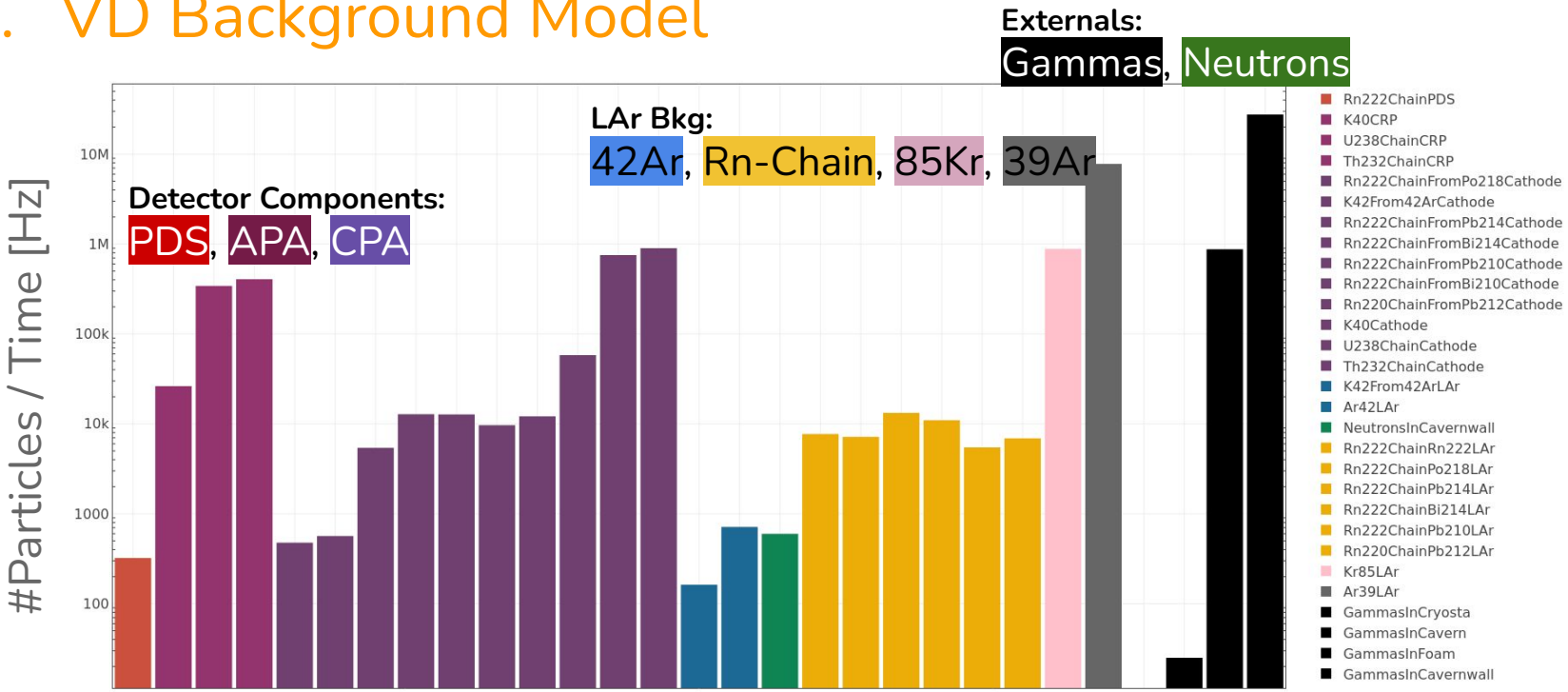
1. HD Bkg. Attenuation: Main Bkg #Hits per Cluster

- Showing **new** predominant reco (**NHit per cluster**) bkg rates vs true energy.





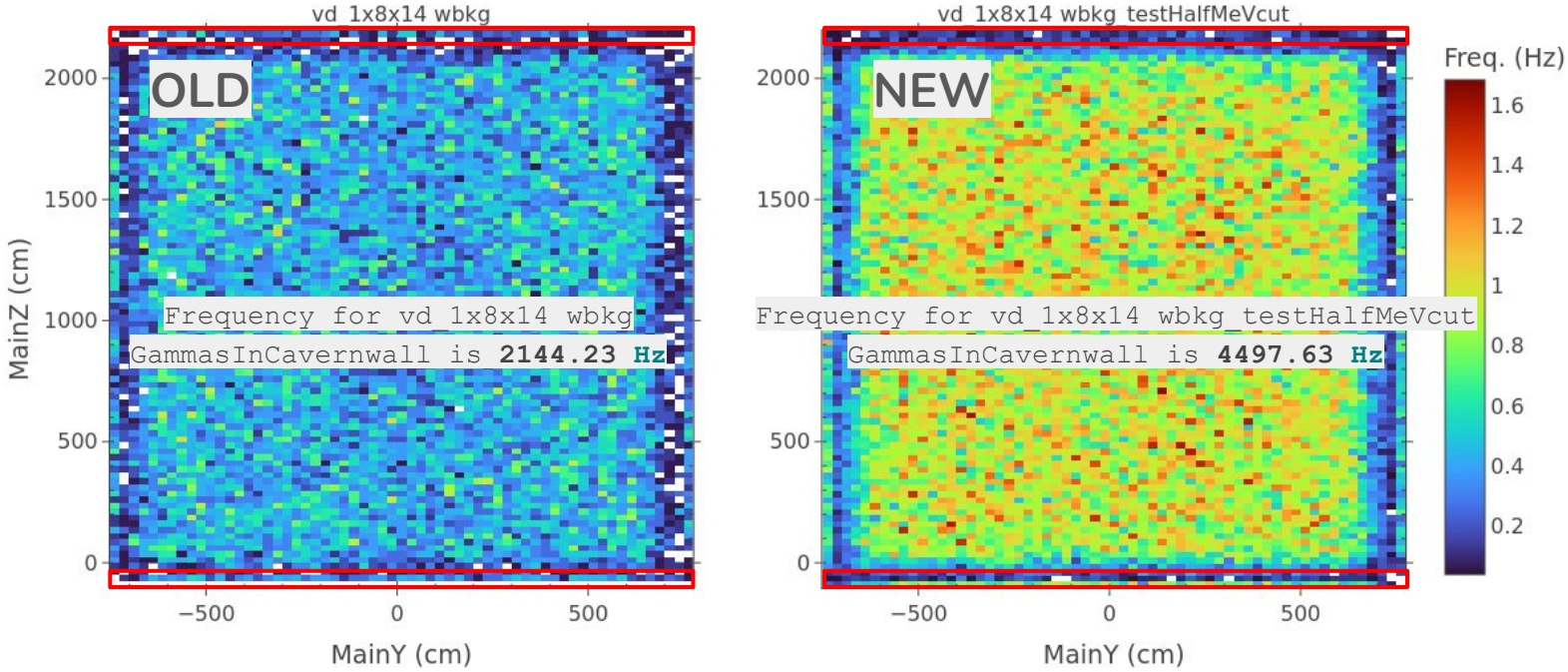
2. VD Background Model



- **Only GammasInCavernwall adjusted for this config. Missing root files for other ext. backgrounds.**
- Multiply by ~6 for full detector rate.

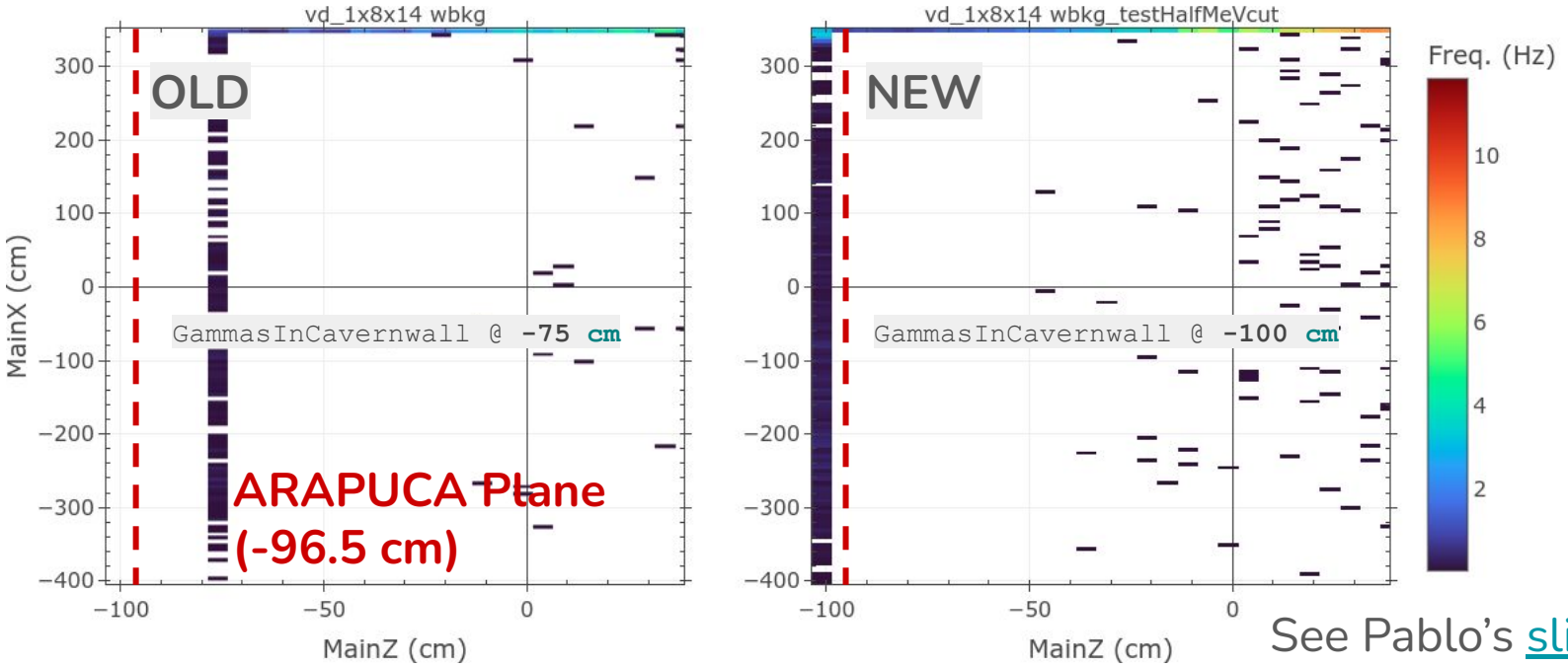
2. VD Bkg. Attenuation

- Showing true bkg position & and frequency for reco clusters (+3Hit) on updated production.



2. VD Bkg. Attenuation

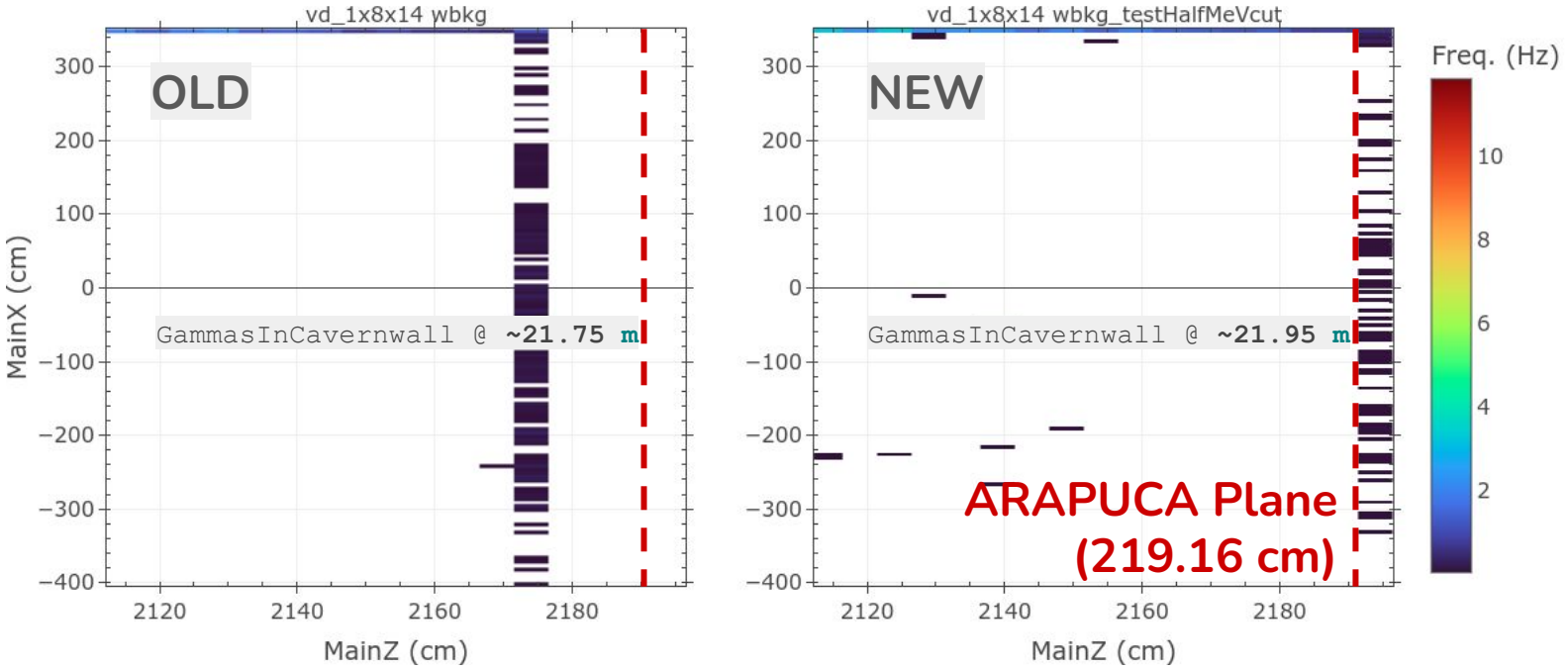
- Showing zoom to end-cap regions to determine correct placement of bkg. planes.



See Pablo's slides

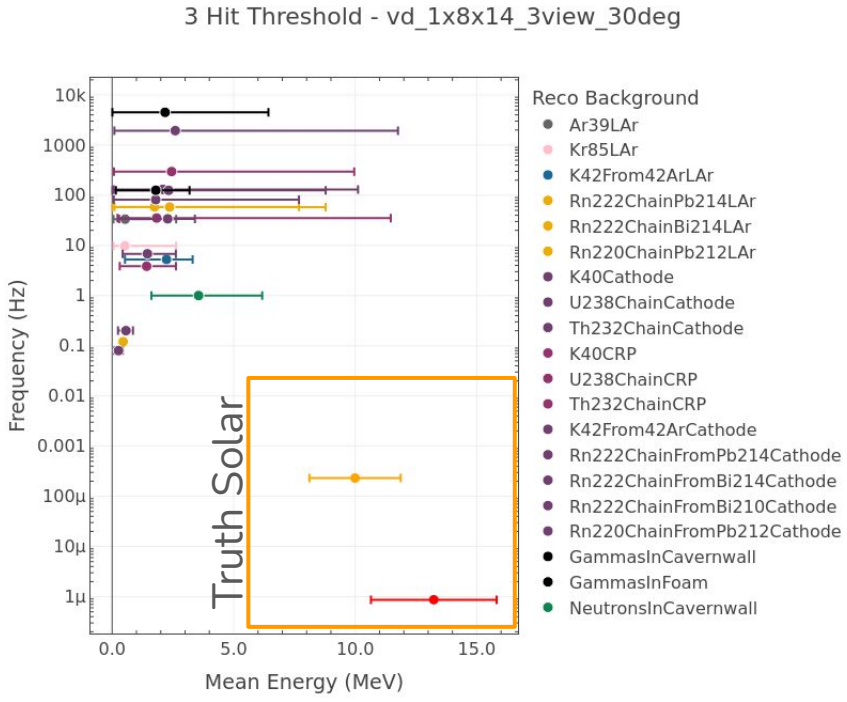
2. VD Bkg. Attenuation

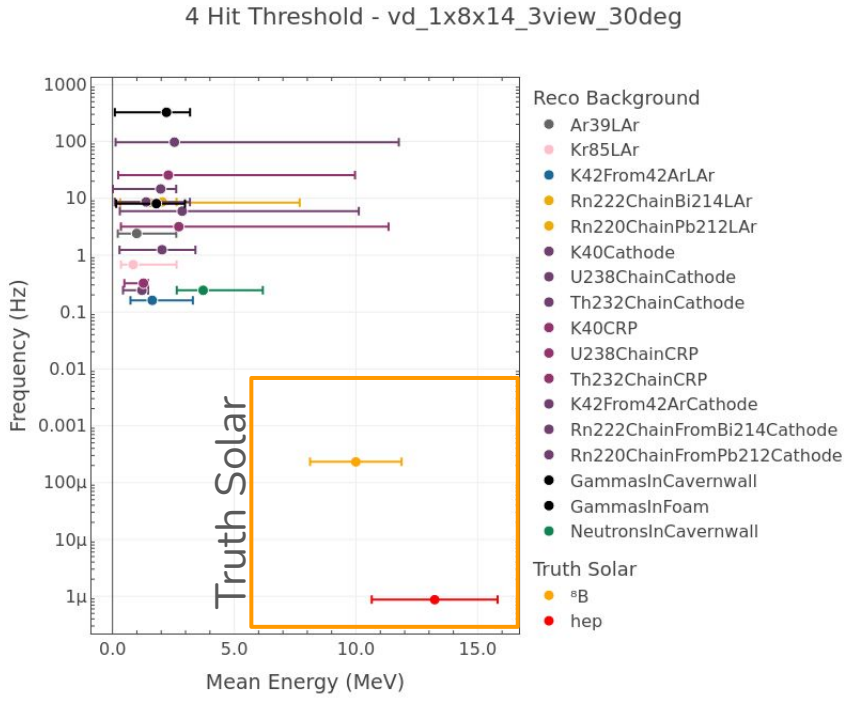
- Showing zoom to end-cap regions to determine correct placement of bkg. planes.



2. VD Bkg. Attenuation: Main Bkg #Hits per Cluster

- Showing **new** predominant reco (**NHit per cluster**) bkg rates vs true energy.

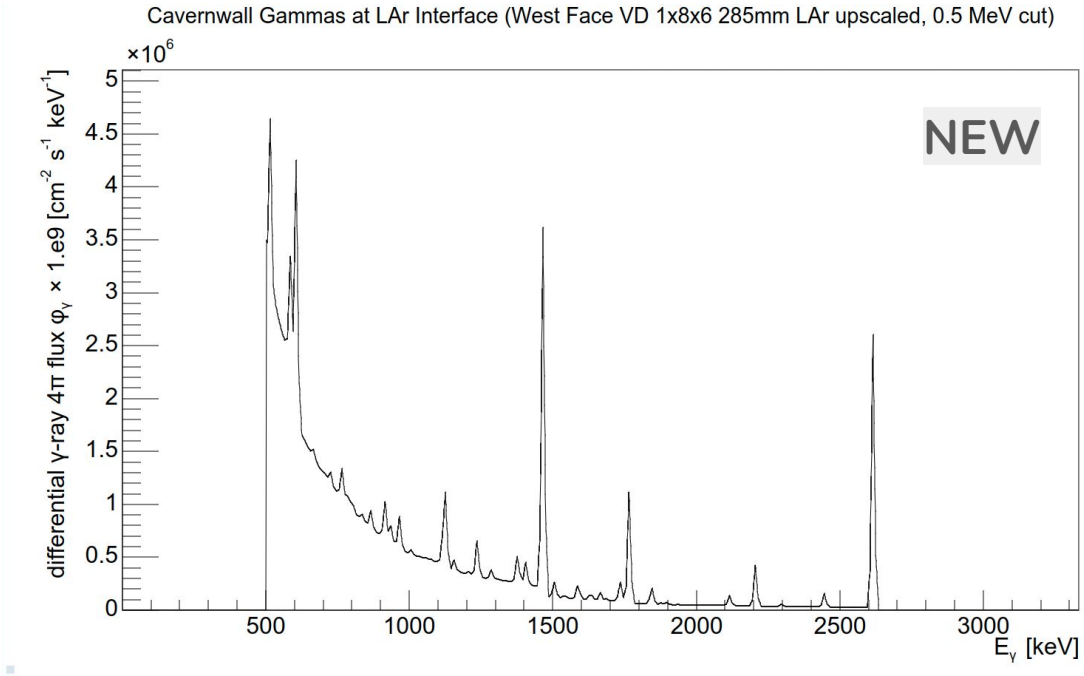




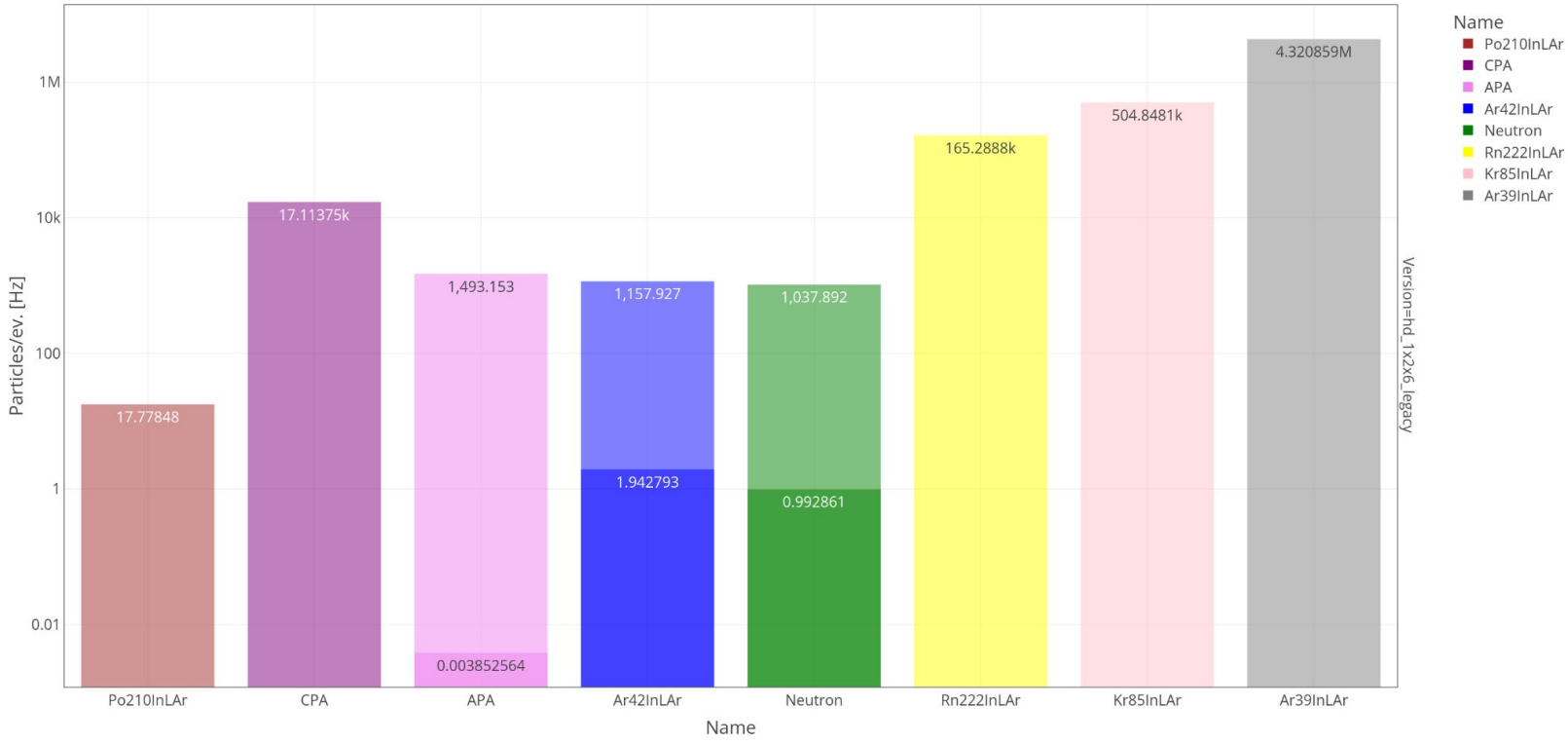
Backup

2. VD Bkg. Attenuation

- Showing input GammasInCavernwall energy spectrum.



1. HD Legacy Background Model



1. HD Background Model

For HD increased rates (~1 kHz) of Neutrons generated.

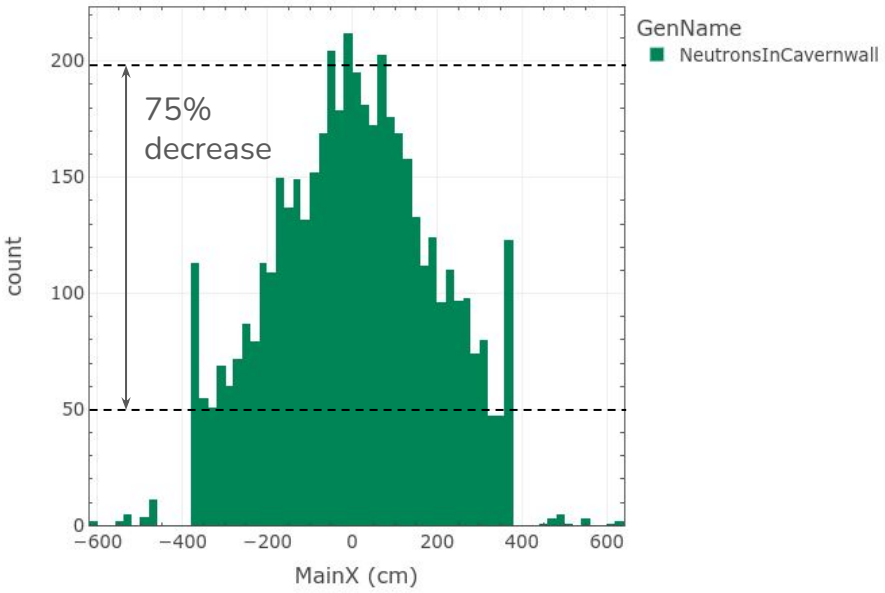
Select Neutron sample from **central APA** (see prev. slide).

- abs(X) < 20
- abs(Y) < 600
- 0 > Z < 1400

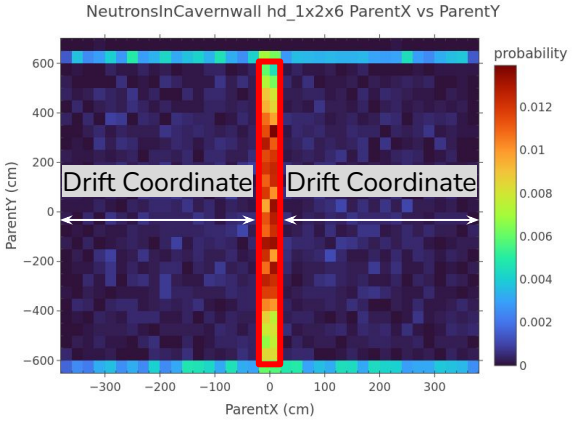
Simulation results in **75% attenuation over 360 cm** of travelled distance.

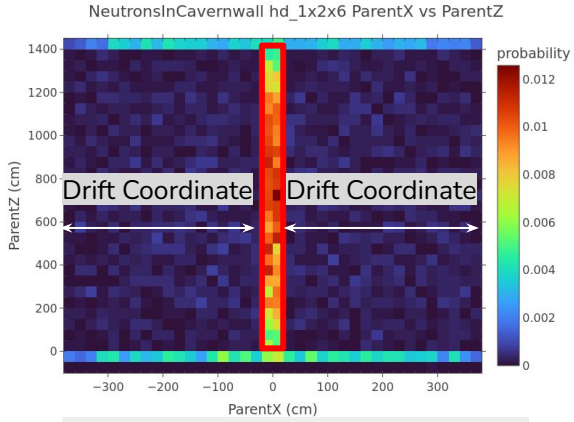
Should be included when simulating neutrons directly at APA interface to account for missing buffer region?

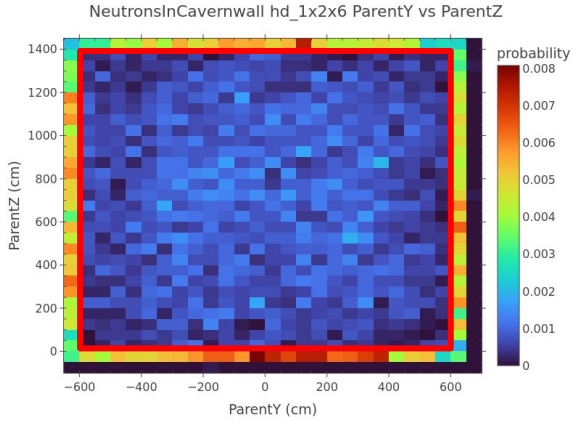
Still does not explain differences between HD & VD.



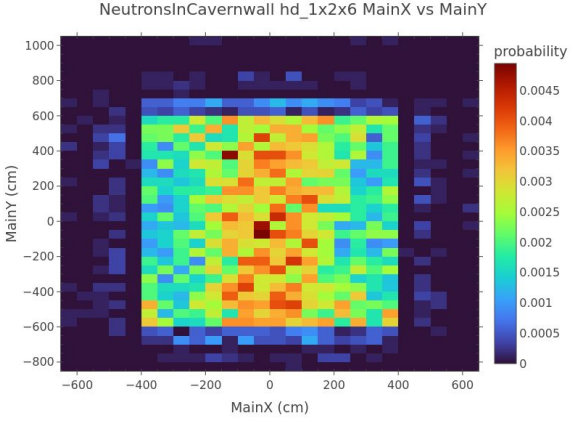
HD Neutron Production

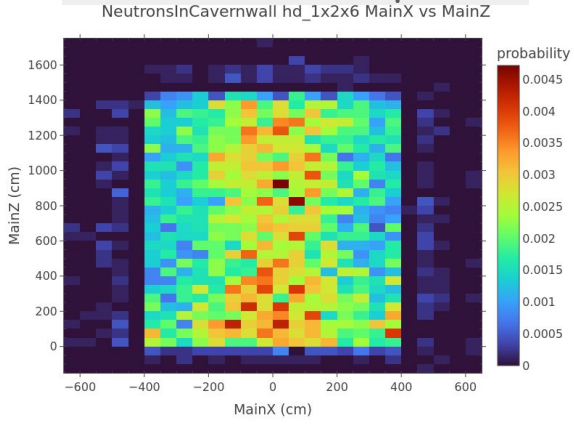


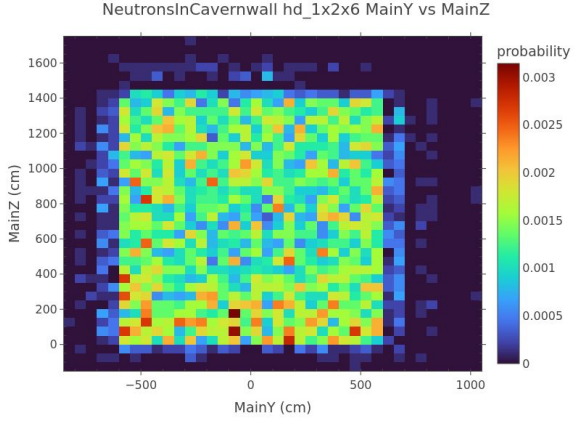




HD Neutron Captures

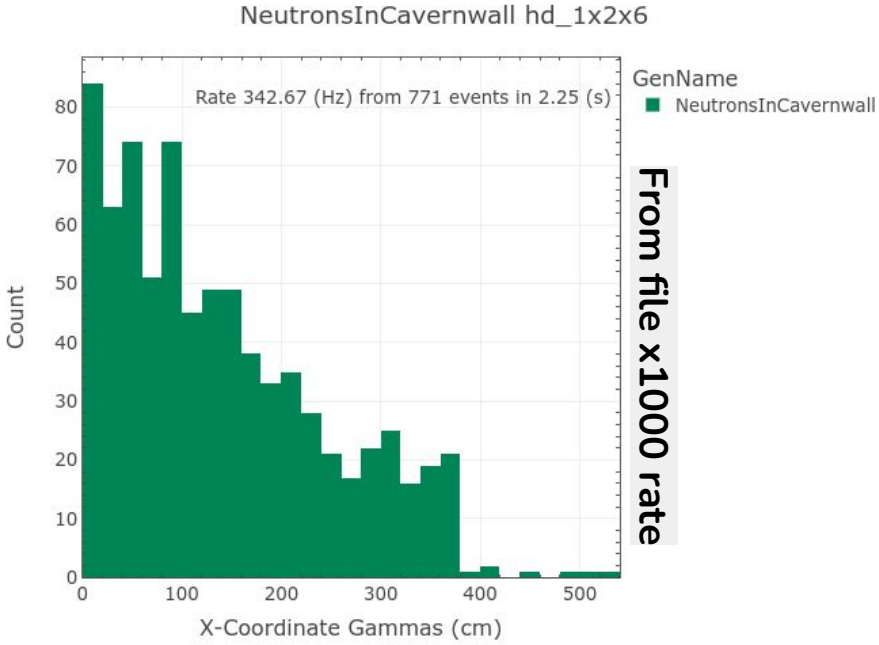


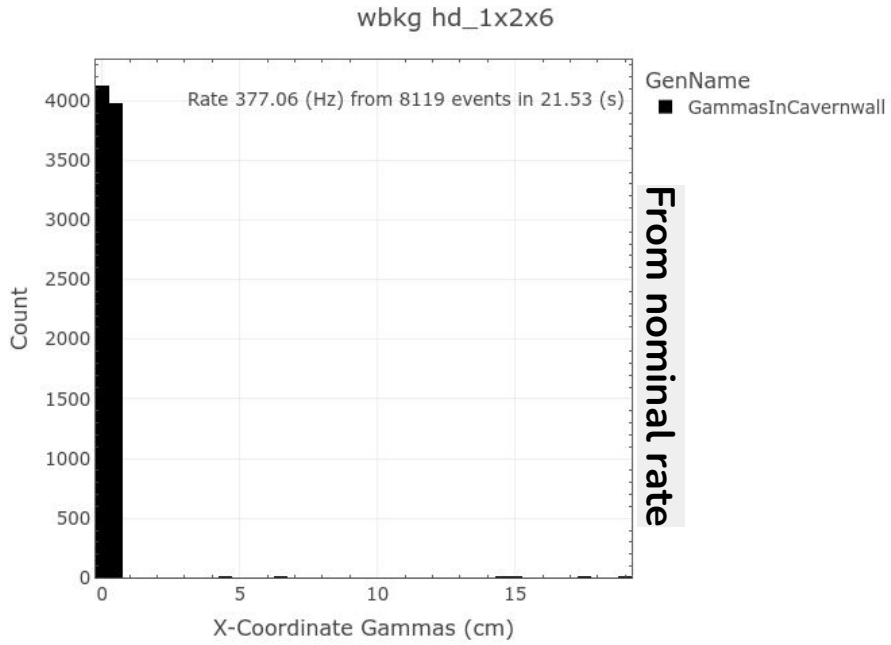




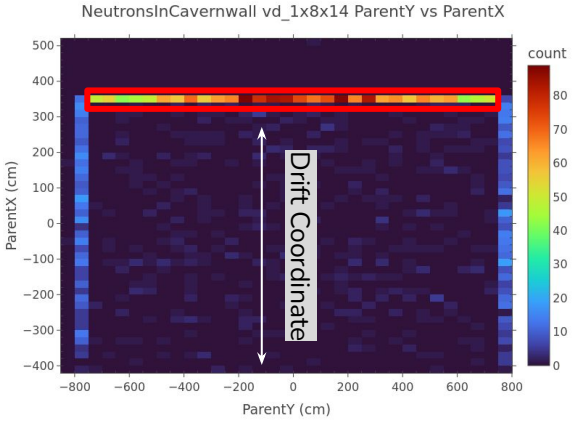
HD External Background Signal Rate

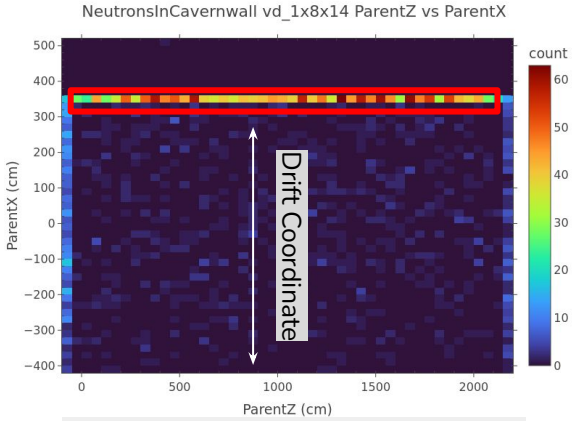
- Using **selected bkg sample** from central APA plane (abs(x) < 20; abs(y) < 600; 0 < z < 1400 cm).
- Evaluated Neutron capture (**0.34 Hz**) and Gamma (+3Hits **377.06 Hz**) Signal Rates.

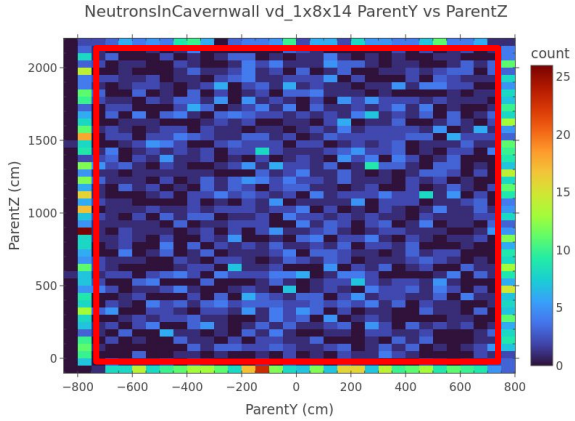




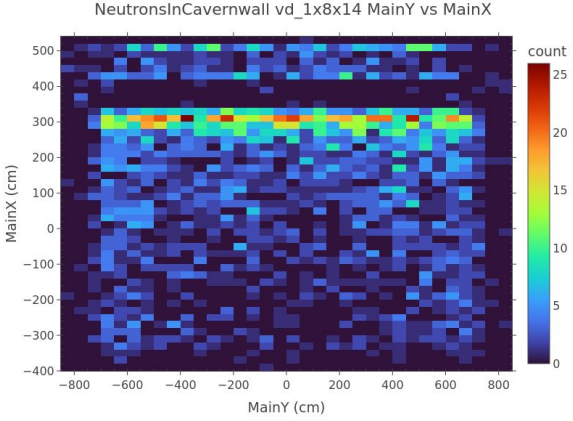
VD Neutron Production

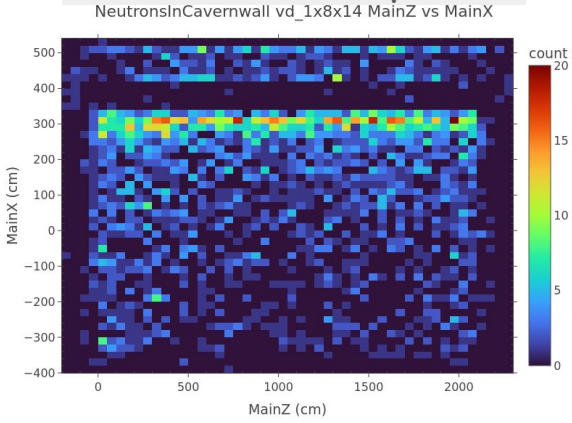


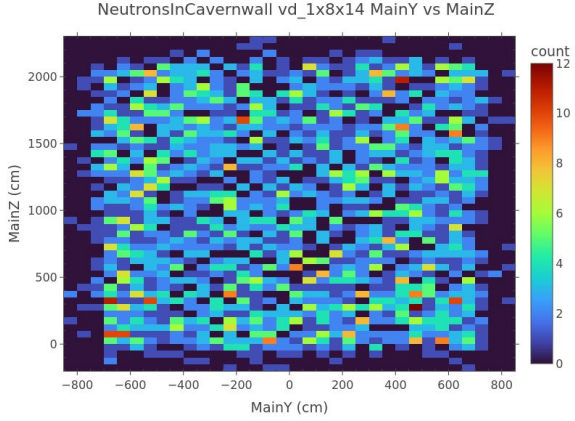




VD Neutron Captures

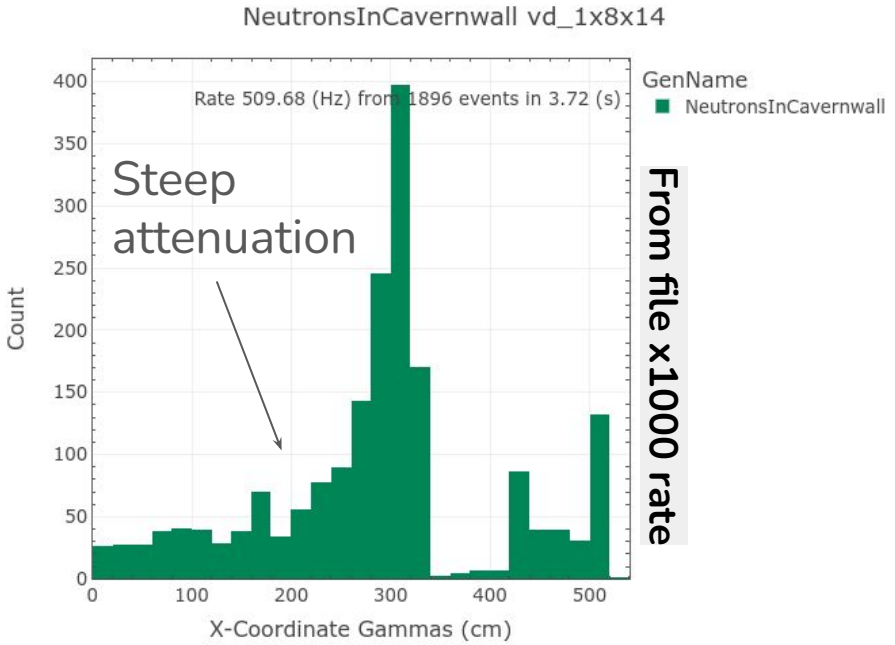


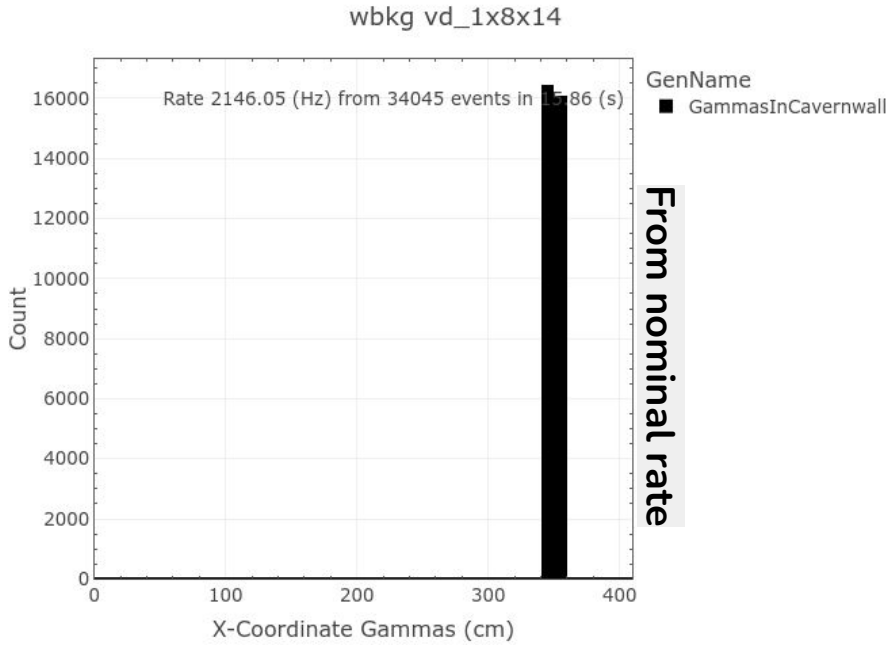




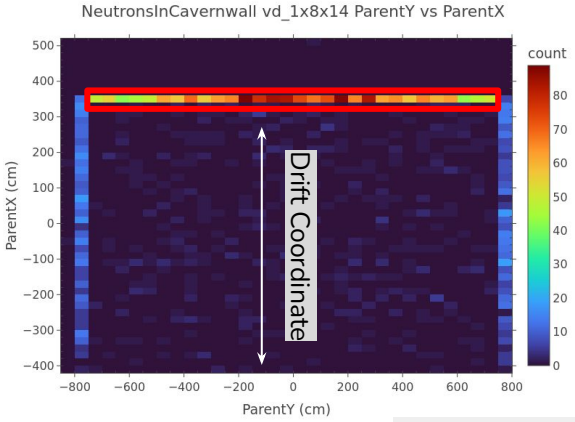
VD External Background Signal Rate

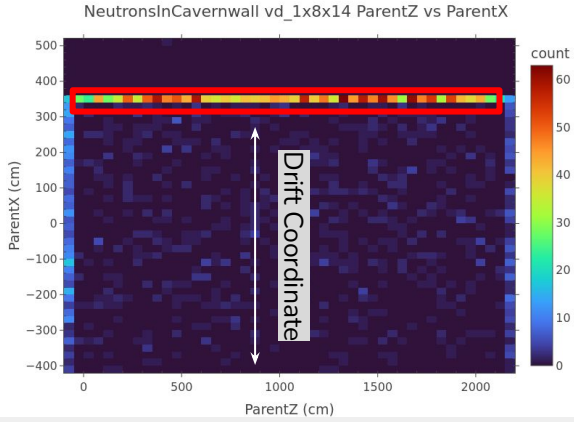
- Using **selected bkg sample** from central APA plane (340 < x < 360; abs(y) < 750; -50 < z < 2200 cm).
- Evaluated Neutron capture (**0.51 Hz**) and Gamma (+3Hits **2146.05 Hz**) Signal Rates.

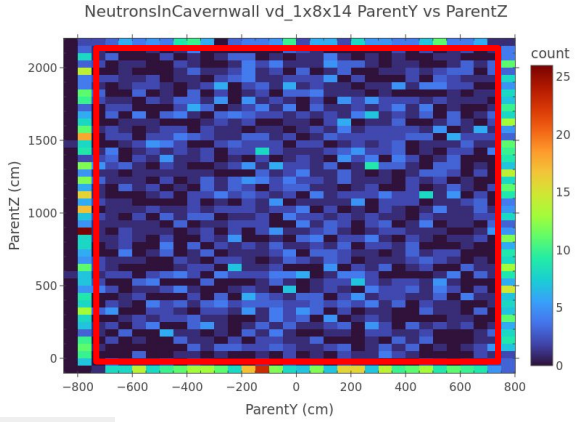




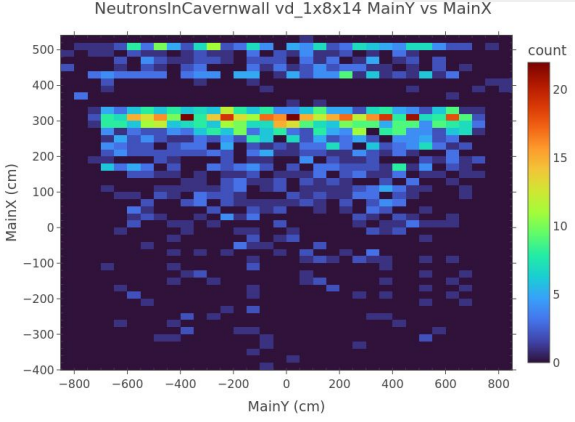
VD Neutron Production

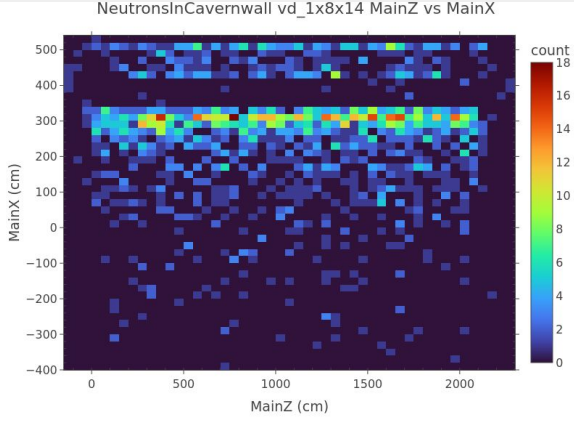


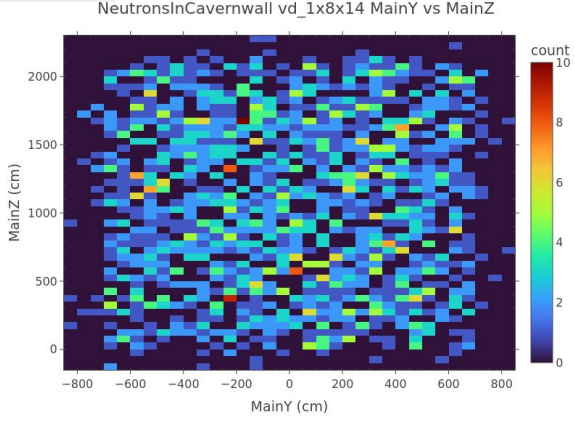




VD Neutron Captures from Selected Region







SolarNuAna_module

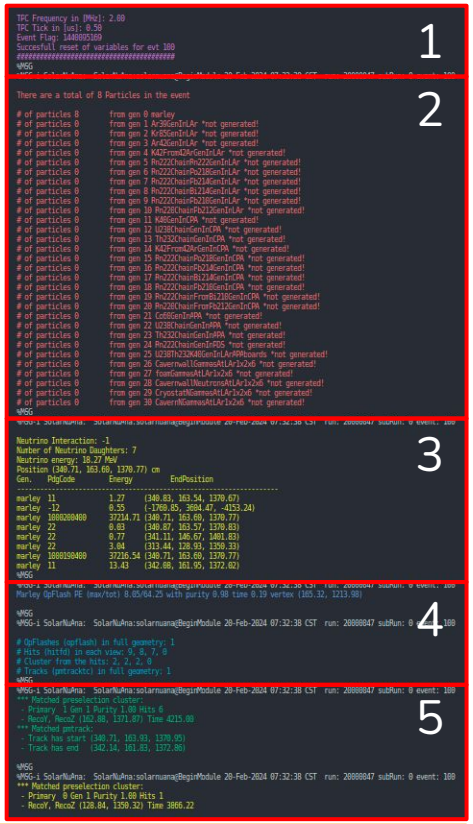
Marley analyzer for lowe vertex & energy reconstruction

Module focuses on generating & finding **tpc clusters** according to preselection criteria:

- Min #Hits
- Ind. plane matching (with optional charge, #hit cuts)

New features added to the module:

- OpHit collection from selected flashes.
- PMTrack matching to preselection clusters.
- Optional collection of true energy deposits for marley event.



SolarNuAna_module

Event Information

1

```
TPC Frequency in [MHz]: 2.00
TPC Tick in [us]: 0.50
Event Flag: 1440095169
Succesfull reset of variables for evt 100
########################################
```

Marley Interaction

3

```
Neutrino Interaction: 1
Number of Neutrino Daughters: 7
Neutrino energy: 18.27 MeV
Position (340.71, 163.60, 1370.77) cm
Gen.    PdgCode         Energy          EndPosition
------------------------------------------------------------------
marley  11              1.27      (340.83, 163.54, 1370.67)
marley  -12             0.55      (-1760.85, 3604.47, -4153.24)
marley  1000200400      37214.71  (340.71, 163.60, 1370.77)
marley  22              0.03      (340.87, 163.57, 1370.83)
marley  22              0.77      (341.11, 146.67, 1401.83)
marley  22              3.04      (313.44, 128.93, 1350.33)
marley  1000190400      37216.54  (340.71, 163.60, 1370.77)
marley  11              13.43     (342.08, 161.95, 1372.02)
```

Generator production

2

```
There are a total of 8 Particles in the event

# of particles 8        from gen 0 marley
# of particles 0        from gen 1 Ar39GenInLAr *not generated!
# of particles 0        from gen 2 Kr85GenInLAr *not generated!
# of particles 0        from gen 3 Ar42GenInLAr *not generated!
# of particles 0        from gen 4 K42From42ArGenInLAr *not generated!
# of particles 0        from gen 5 Rn222ChainRn222GenInLAr *not generated!
# of particles 0        from gen 6 Rn222ChainPo218GenInLAr *not generated!
# of particles 0        from gen 7 Rn222ChainPb214GenInLAr *not generated!
# of particles 0        from gen 8 Rn222ChainBi214GenInLAr *not generated!
# of particles 0        from gen 9 Rn222ChainPb210GenInLAr *not generated!
# of particles 0        from gen 10 Rn220ChainPb212GenInLAr *not generated!
# of particles 0        from gen 11 K40GenInCPA *not generated!
# of particles 0        from gen 12 U238ChainGenInCPA *not generated!
# of particles 0        from gen 13 Th232ChainGenInCPA *not generated!
# of particles 0        from gen 14 K42From42ArGenInCPA *not generated!
# of particles 0        from gen 15 Rn222ChainPo218GenInCPA *not generated!
# of particles 0        from gen 16 Rn222ChainPb214GenInCPA *not generated!
# of particles 0        from gen 17 Rn222ChainBi214GenInCPA *not generated!
# of particles 0        from gen 18 Rn222ChainPb210GenInCPA *not generated!
# of particles 0        from gen 19 Rn222ChainFromBi210GenInCPA *not generated!
# of particles 0        from gen 20 Rn220ChainFromPb212GenInCPA *not generated!
# of particles 0        from gen 21 Co60GenInAPA *not generated!
# of particles 0        from gen 22 U238ChainGenInAPA *not generated!
# of particles 0        from gen 23 Th232ChainGenInAPA *not generated!
# of particles 0        from gen 24 Rn222ChainGenInPDS *not generated!
# of particles 0        from gen 25 U238Th232K40GenInLArAPAboards *not generated!
# of particles 0        from gen 26 CavernwallGammasAtLAr1x2x6 *not generated!
# of particles 0        from gen 27 foamGammasAtLAr1x2x6 *not generated!
# of particles 0        from gen 28 CavernwallNeutronsAtLAr1x2x6 *not generated!
# of particles 0        from gen 29 CryostatNGammasAtLAr1x2x6 *not generated!
# of particles 0        from gen 30 CavernNGammasAtLAr1x2x6 *not generated!
```

Reco Objects

4

```
Marley OpFlash PE (max/tot) 8.05/64.25 with purity 0.98 time 0.19 vertex (165.32, 1213.98)

%MSG
%MSG-i SolarNuAna:  SolarNuAna:s                Feb-2024 07:32:38 CST  run: 200000

# OpFlashes (opflash) in full geometry: 1
# Hits (hitfd) in each view: 9, 8, 7, 0
# Cluster from the hits: 2, 2, 2, 0
# Tracks (pmtracktc) in full geometry: 1
```

Clusters

5

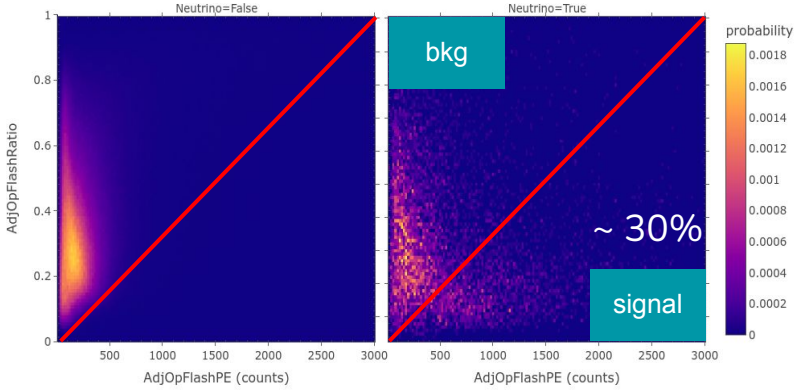
```
*** Matched preselection cluster:
 - Primary  1 Gen 1 Purity 1.00 Hits 6
 - RecoY, RecoZ (162.88, 1371.87) Time 4215.00
*** Matched pmtrack:
 - Track has start (340.71, 163.93, 1370.95)
 - Track has end   (342.14, 161.83, 1372.86)

%MSG
%MSG-i SolarNuAna:  SolarNuAna:solarnuana@BeginModule 2
*** Matched preselection cluster:
 - Primary  0 Gen 1 Purity 1.00 Hits 1
 - RecoY, RecoZ (128.84, 1350.32) Time 3866.22
```

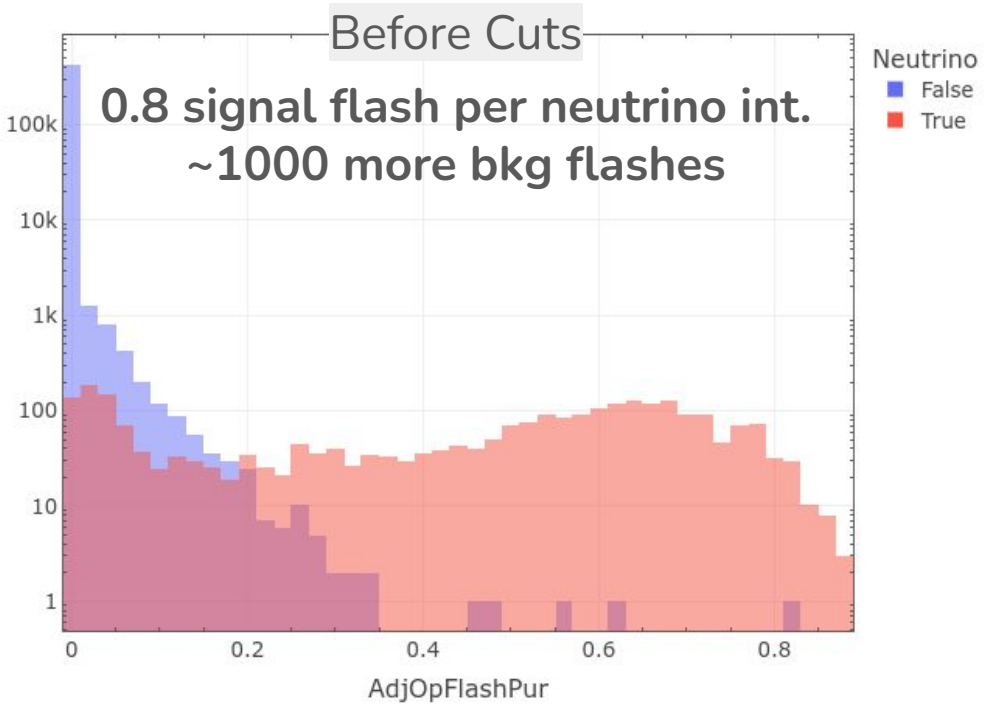
4. HD OpFlash Matching

For HD:

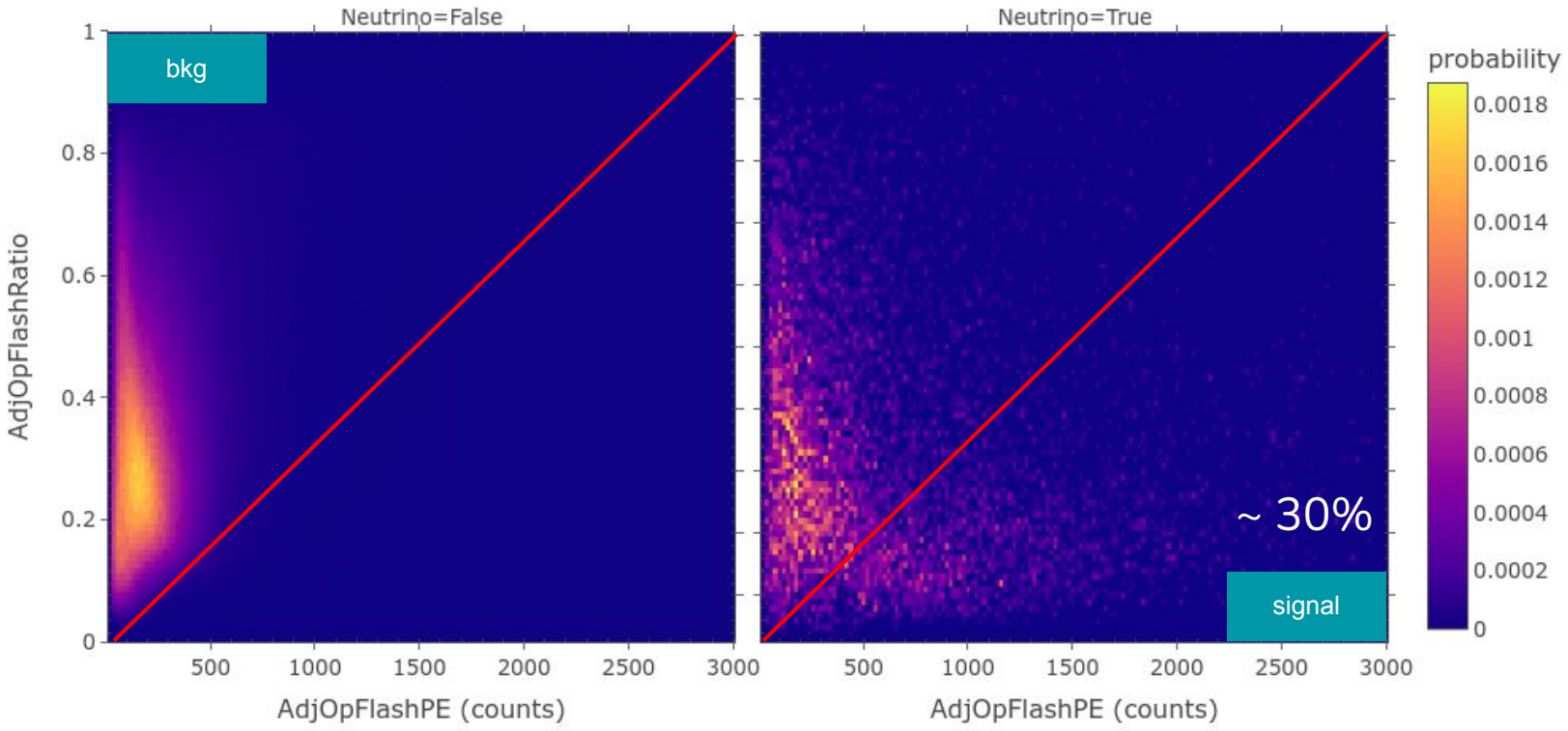
Select **Neutrino flashes** abs(t) < 5 tick

- Huge #flashes per event ~2 k.
- OpFlashRatio cuts 70% signal & > 99% bkg.
- Selected cuts: 0.25 signal & 4 bkg flashes per event.

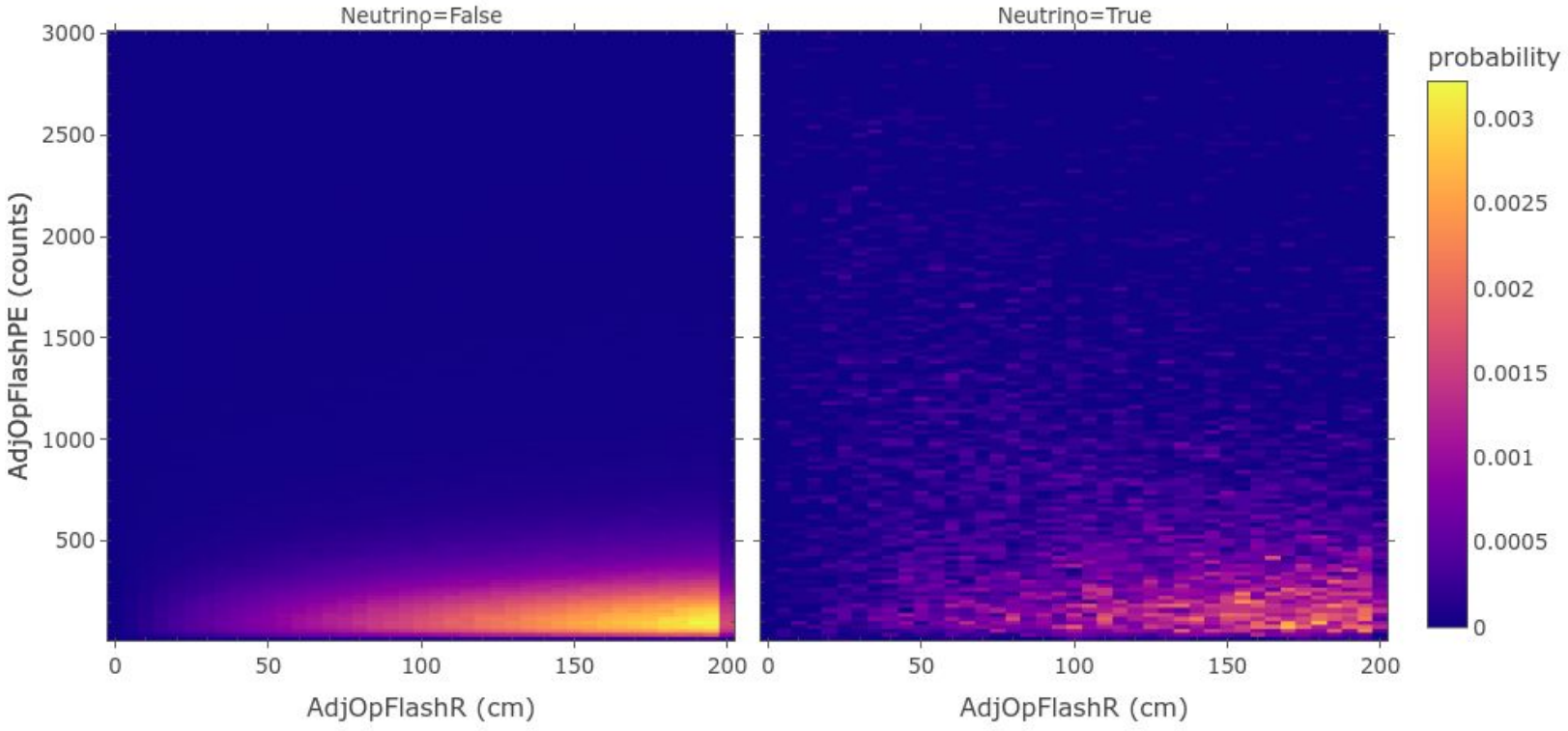




Reconstructed Flashes: Bkg + Signal

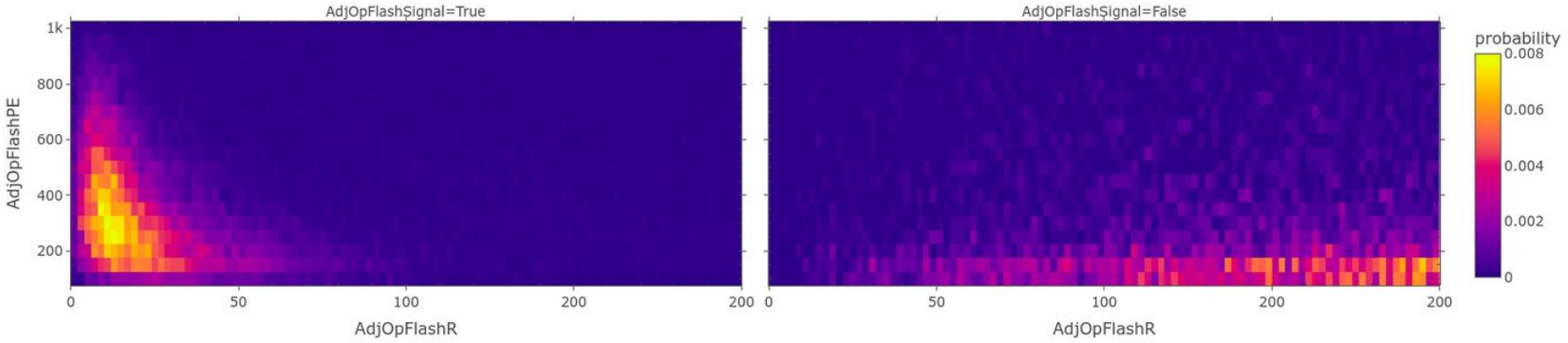


Reconstructed Flashes: Bkg + Signal



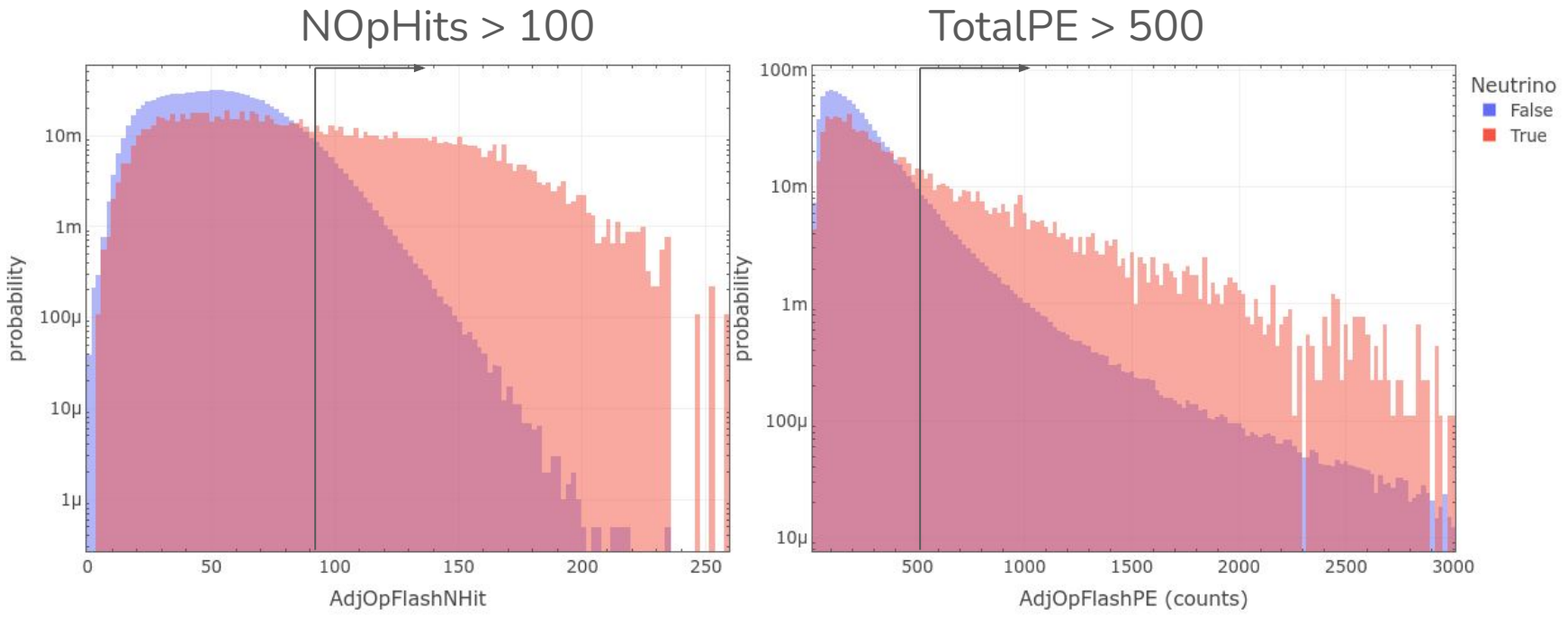
4. HD OpFlash Matching: Legacy

- OpFlash purity is not well reconstructed by the backtracker
  -> **Instead use OpFlash time = (-10,10) [ticks]*.**
- **Flat cut of OpPE > 100** & cut MaxHitPE / OpPE < 0.4 (to be optimised for each geo).
- TPC - PDS coincidence, requires y-z vertex distance < 100cm.
  - Matching **30% of solar** neutrino clusters
  - Matching **<< 10% of bkg** clusters (estimation limited by statistics)



*Marley events always happen at t=0.

4. HD OpFlash Matching

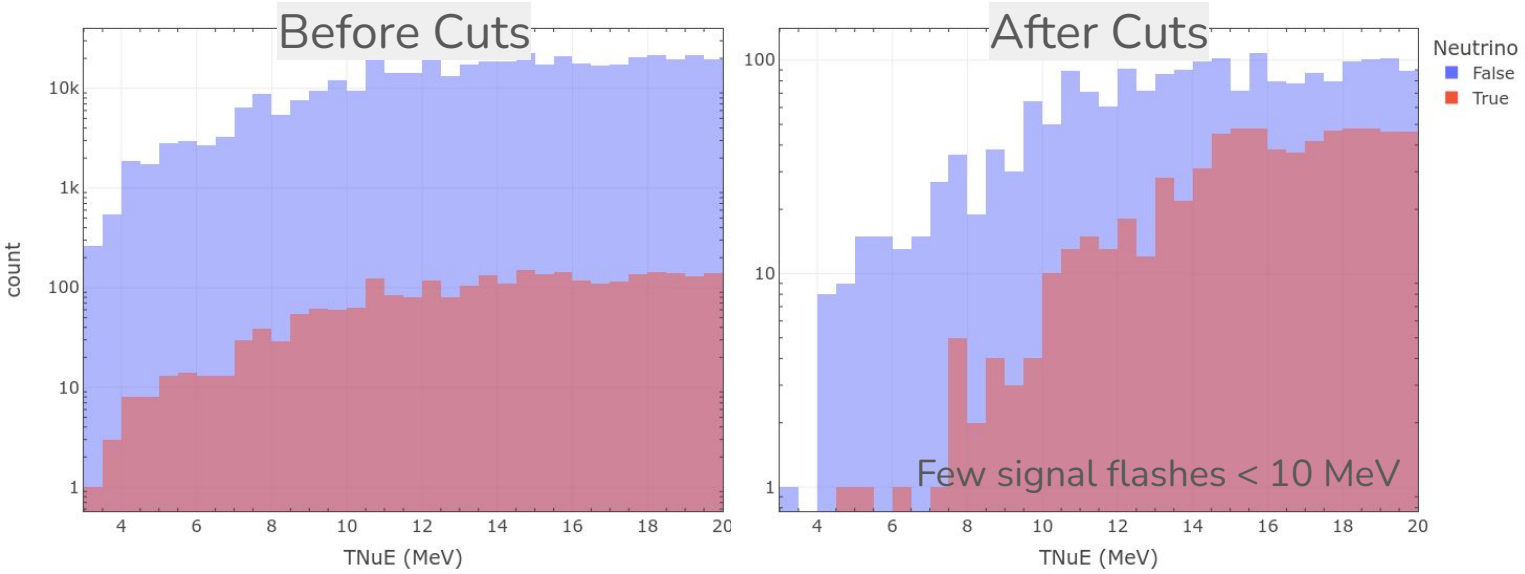


4. #OpFlash Distributions

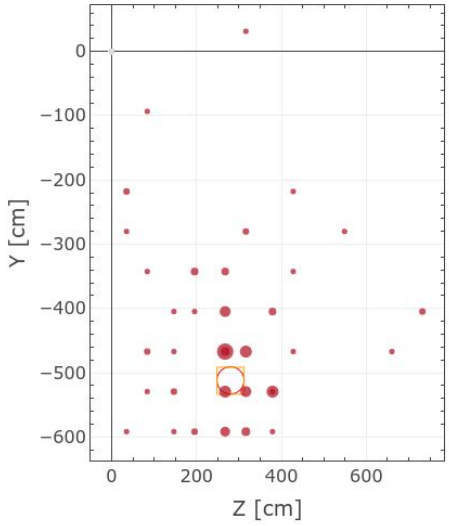
Selected cuts: OpFlashRatio > 3000*OpFlashPE, OpFlashPE > 500, OpFlashNHit > 100

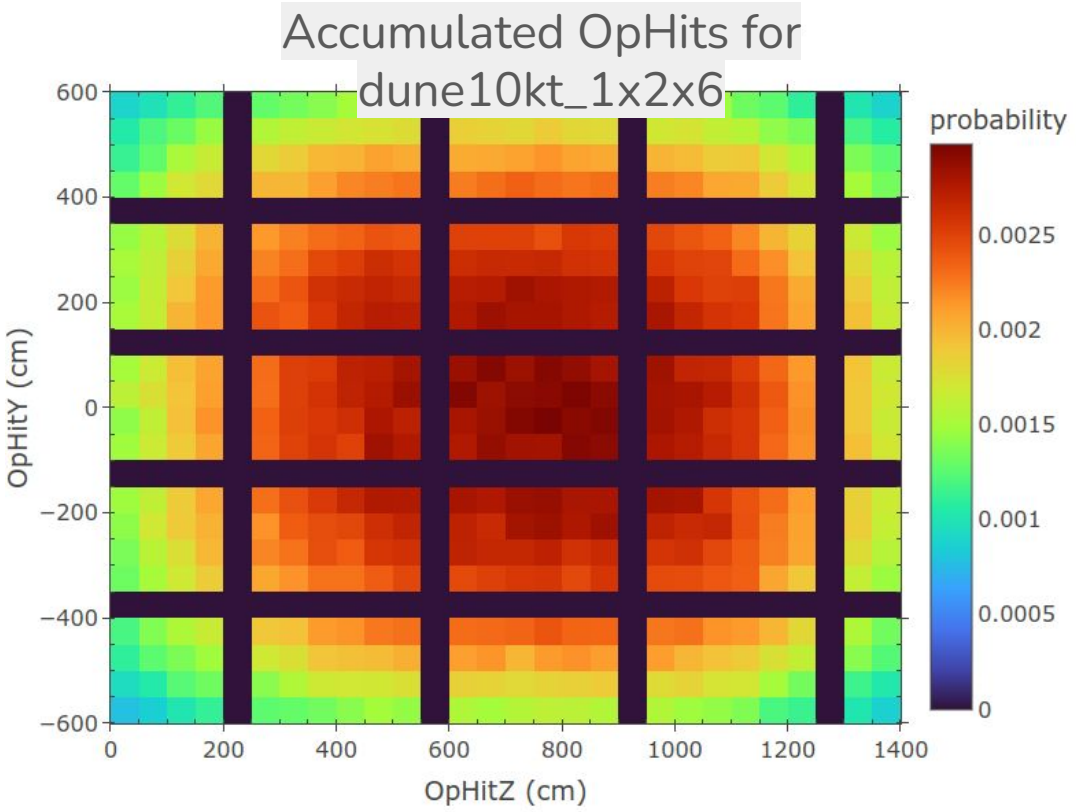
Resulting in only 25% of events potentially being flashmatched with 25% chance of selecting the right flash.

Only 6.25% correctly flashmatched.



PDS Event Display

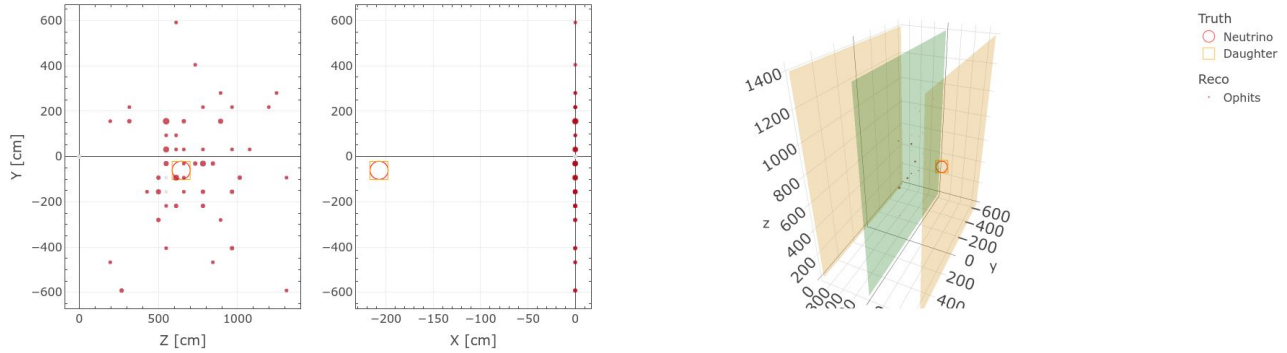




PDS Event Display

HD 1x2x6

TNuE: **9.67MeV** Cluster: 2562



HD 1x2x6

TNuE: **21.57MeV** Cluster: 87