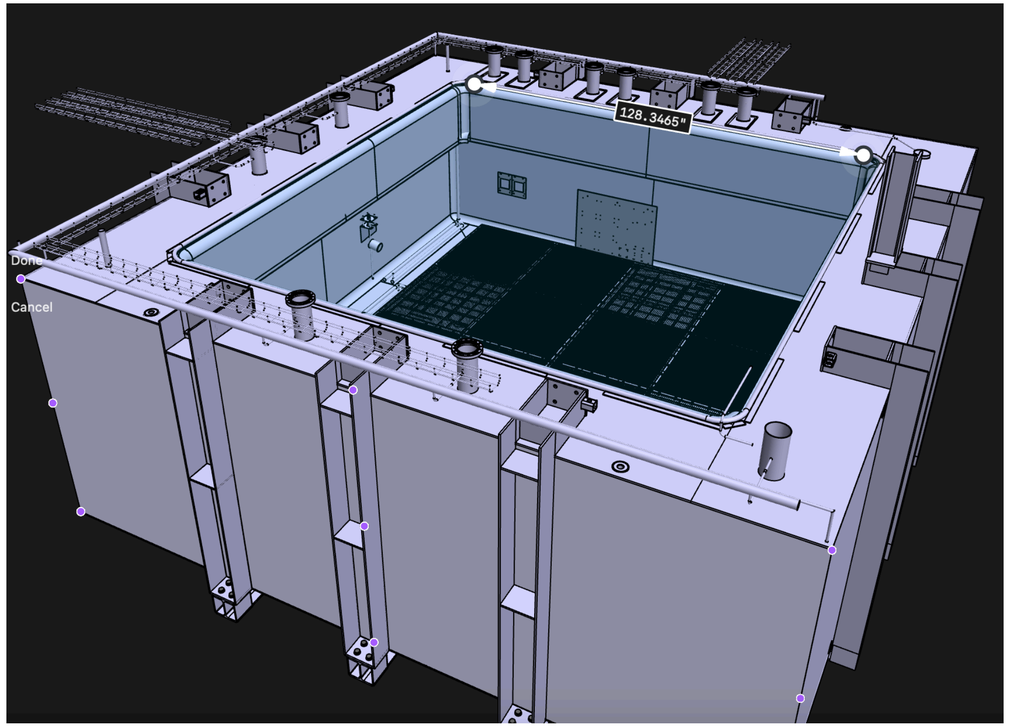
DUNE FD2 Photon Detection System Module-1 Run at ColdBox

PNS PDS Meeting

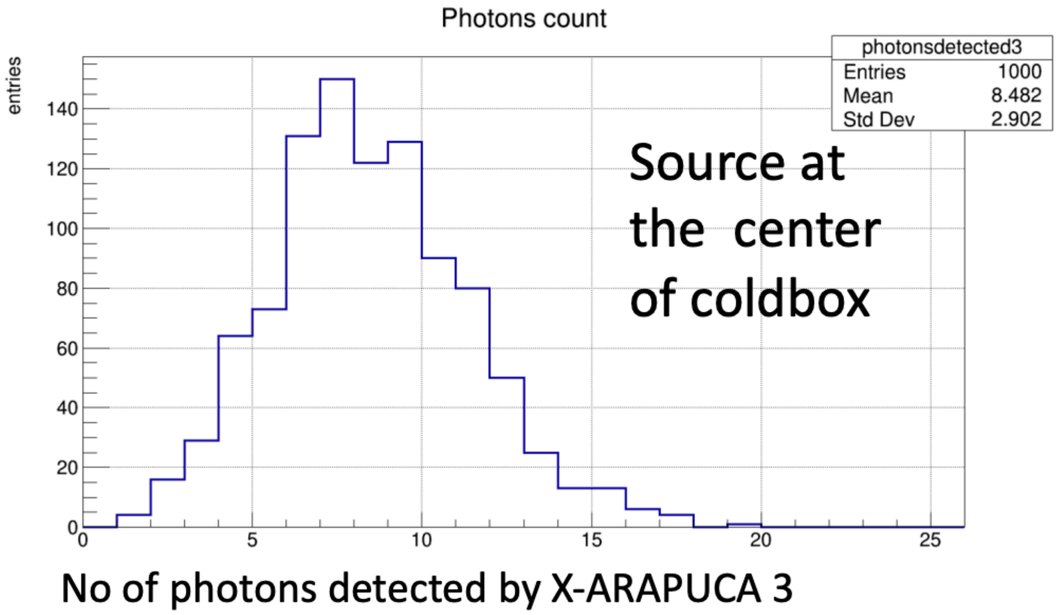
Wei

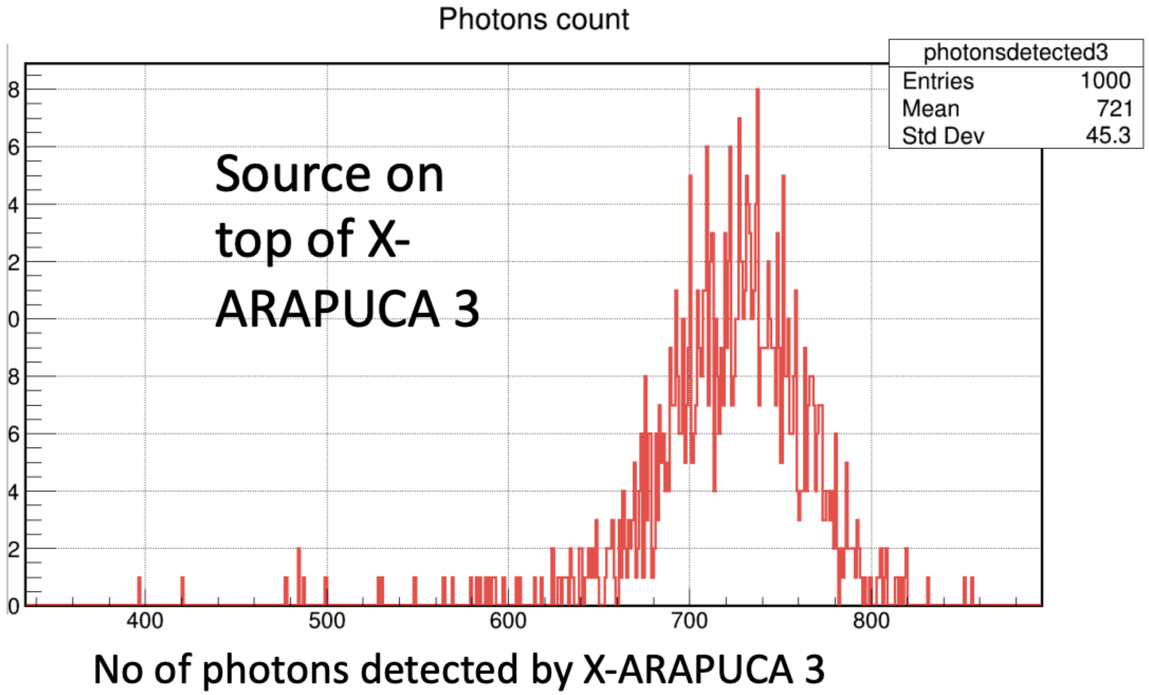


DEEP UNDERGROUND NEUTRINO EXPERIMENT

Stony Brook University

Simulated 4.7 MeV e^-





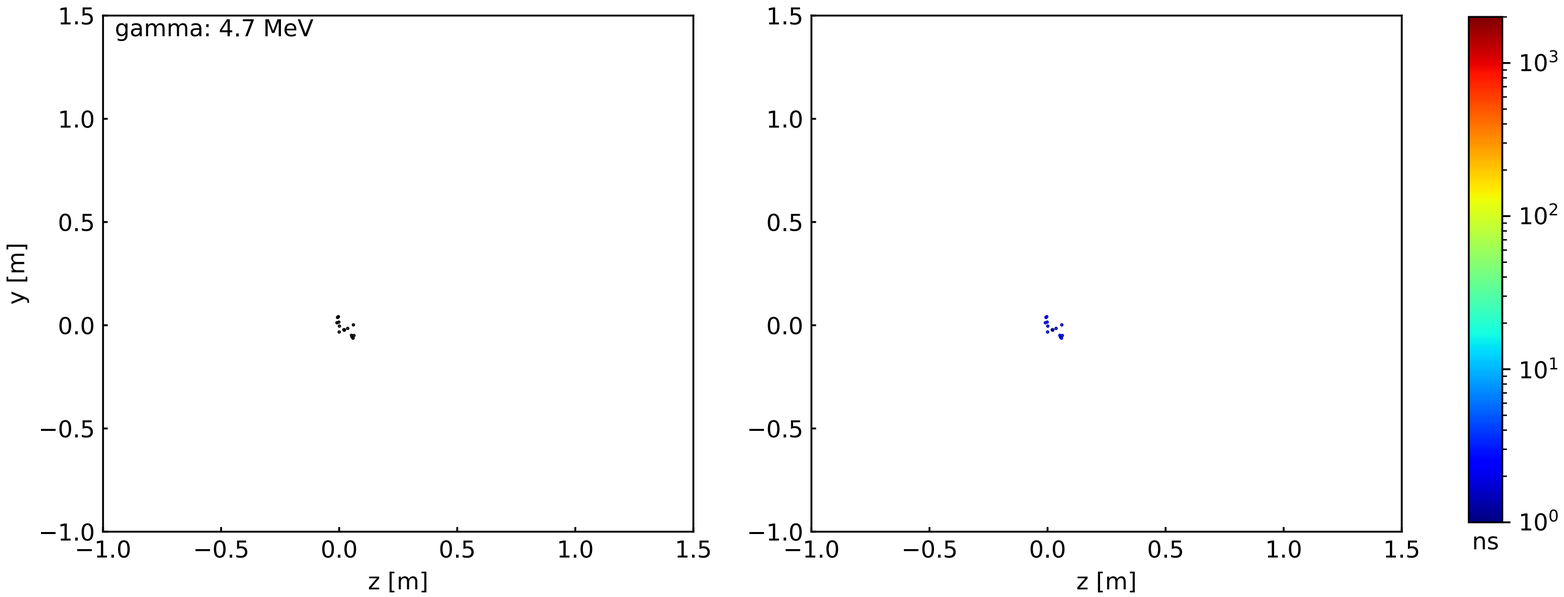
- ColdBox has small drift volume: a small change in source position makes huge difference in solid angle to the detector (and light yield)
- Focus on γ source (n-capture) right on top of any of the 4 XAs on cathode

4.7MeV γ in a LAr Bath (200m x 200m x 200m):
Pair production

e^+e^- total KE: 3.68MeV (fixed)

```
event 5
Marley events: assert info from file name
vertex @: (0.0, 0.0, 0.0) [mm]
    pdg    name trkId parId  acId        KE  selfDepo   allDepo
                                       [MeV]     [MeV]     [MeV]
-------------------------------------------------------------------
     22   gamma     0    -1     0      4.70      0.00      4.70
     11      e-     1     0     0      1.60      1.60      1.60
    -11      e+     2     0     0      2.08      2.08      3.10
     22   gamma     3     2     0      0.51      0.10      0.51
     22   gamma     4     2     0      0.51      0.08      0.51
     11      e-     5     4     0      0.01      0.01      0.01
     11      e-     6     4     0      0.26      0.26      0.26
     11      e-     7     4     0      0.09      0.09      0.09
     11      e-     8     4     0      0.05      0.05      0.05
     11      e-     9     4     0      0.03      0.03      0.03
```

Very localized deposits



If happens on a XA, it should see all 4.7 MeV energy deposit

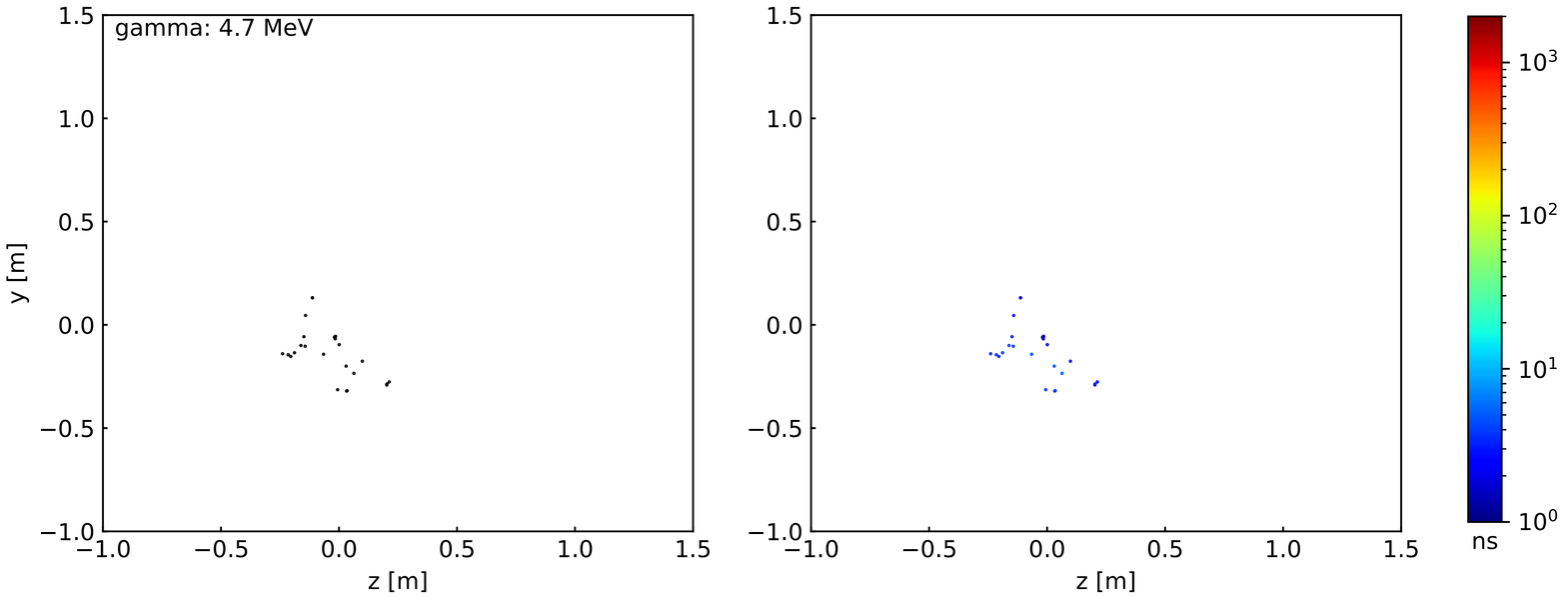
4.7MeV γ in a LAr Bath (200m x 200m x 200m):

Pair production - another example

e^+e^- total KE: 3.68MeV (fixed)

```
event 3
Marley events: assert info from file name
vertex @: (0.0, 0.0, 0.0) [mm]
     pdg     name trkId parId  acId        KE  selfDepo   allDepo
                                        [MeV]     [MeV]     [MeV]
-------------------------------------------------------------------
      22    gamma     0    -1     0      4.70      0.00      4.70
      11       e-     1     0     0      0.61      0.61      0.61
     -11       e+     2     0     0      3.07      3.07      4.09
      22    gamma     3     2     0      0.51      0.09      0.51
      22    gamma     4     2     0      0.51      0.08      0.51
      11       e-     5     4     0      0.01      0.01      0.01
      11       e-     6     4     0      0.05      0.05      0.05
      11       e-     7     4     0      0.02      0.02      0.02
      11       e-     8     4     0      0.24      0.24      0.24
      11       e-     9     4     0      0.02      0.02      0.02
```

Spread over 50cm x 50cm,
511 keV γs Compton scatter

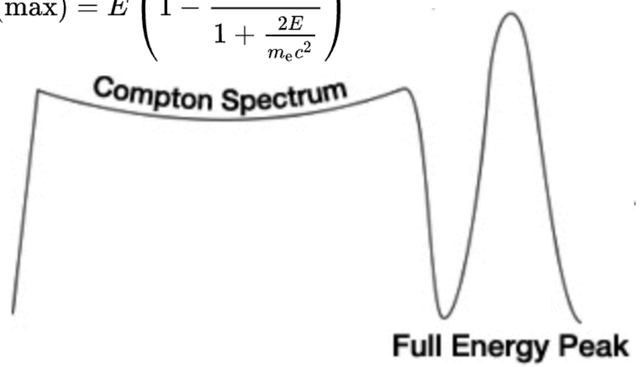


XA size is 60cm x 60cm
If happens on a XA, it should see energy deposit [3.68, 4.7] MeV
(+ In ColdBox, some energy deposits is lost due to smaller drift region)

4.7MeV γ in a LAr Bath (200m x 200m x 200m):
Compton scattering

$$E_{\mathrm{er}} = E_\gamma^2 \frac{1-\cos\theta}{m_\mathrm{e}c^2 + E_\gamma(1-\cos\theta)}$$

$$E_T(\max) = E\left(1 - \frac{1}{1+\frac{2E}{m_\mathrm{e}c^2}}\right)$$

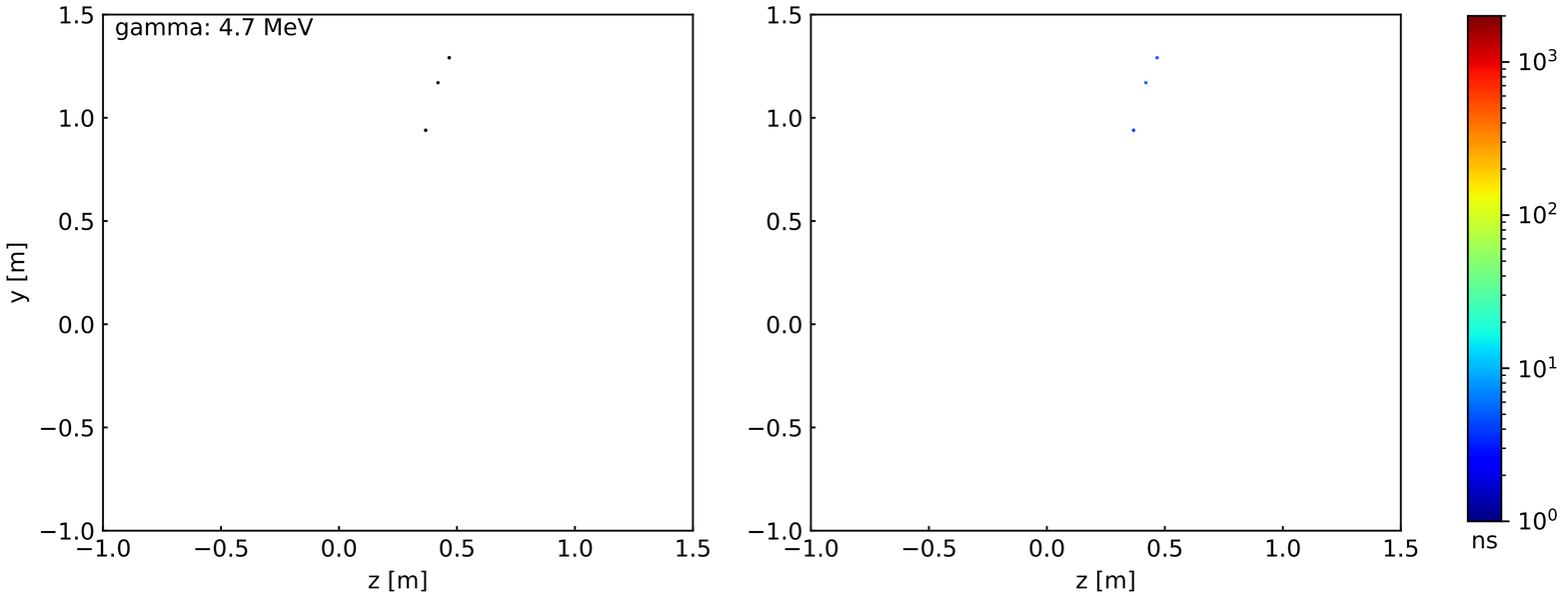


Contribute to Compton Continuum

event 2
Marley events: assert info from file name
vertex @: (0.0, 0.0, 0.0) [mm]

pdg	name	trkId	parId	acId	KE [MeV]	selfDepo [MeV]	allDepo [MeV]
22	gamma	0	-1	0	4.70	0.08	4.69
11	e-	1	0	0	0.95	0.95	0.95
11	e-	2	0	0	0.54	0.54	0.54
11	e-	3	0	0	0.48	0.46	0.48
11	e-	4	0	0	2.20	2.19	2.19
11	e-	5	0	0	0.23	0.23	0.23
11	e-	6	0	0	0.13	0.13	0.13
11	e-	7	0	0	0.01	0.01	0.01
11	e-	8	0	0	0.01	0.01	0.01
11	e-	9	0	0	0.01	0.01	0.01

Energy deposits far from source vertex and wide spread

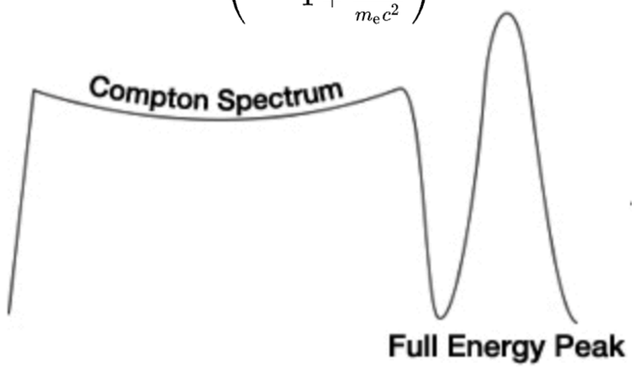


XA should see limited energy deposit

4.7MeV γ in a LAr Bath (200m x 200m x 200m):
Compton scattering - another example

$$E_{\mathrm{er}} = E_\gamma^2 \, \frac{1-\cos\theta}{m_e c^2 + E_\gamma(1-\cos\theta)}$$

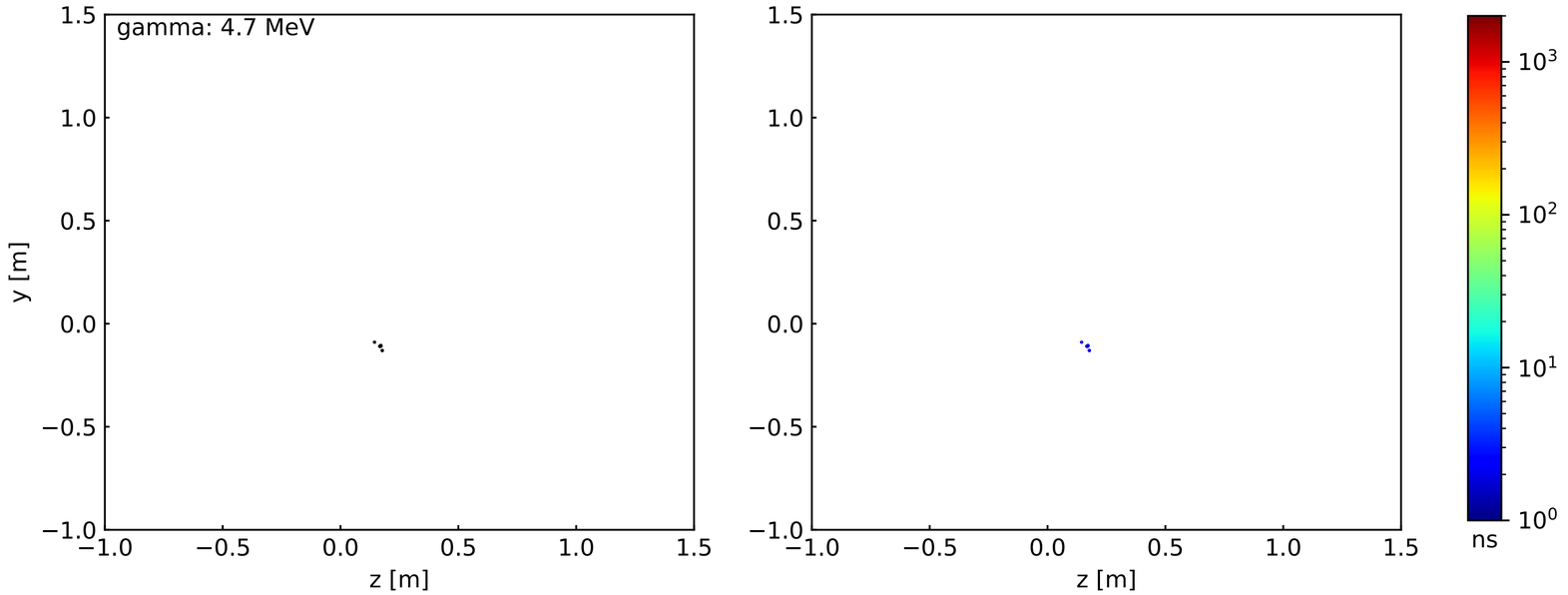
$$E_T(\mathrm{max}) = E\left(1 - \frac{1}{1+\frac{2E}{m_e c^2}}\right)$$



Close to max energy transfer: 4.45MeV

```
event 0
Marley events: assert info from file name
vertex @: (0.0, 0.0, 0.0) [mm]
     pdg     name trkId parId  acId         KE  selfDepo   allDepo
                                          [MeV]     [MeV]     [MeV]
-----------------------------------------------------------------
      22    gamma     0    -1     0       4.70      0.11      4.70
      11       e-     1     0     0       4.40      4.40      4.40
      11       e-     2     0     0       0.16      0.16      0.16
      11       e-     3     0     0       0.03      0.03      0.03
      11       e-     4     0     0       0.10      0.00      0.00
-----------------------------------------------------------------
```

Very localized deposits
Many events like this one is in fact more localized than pair production



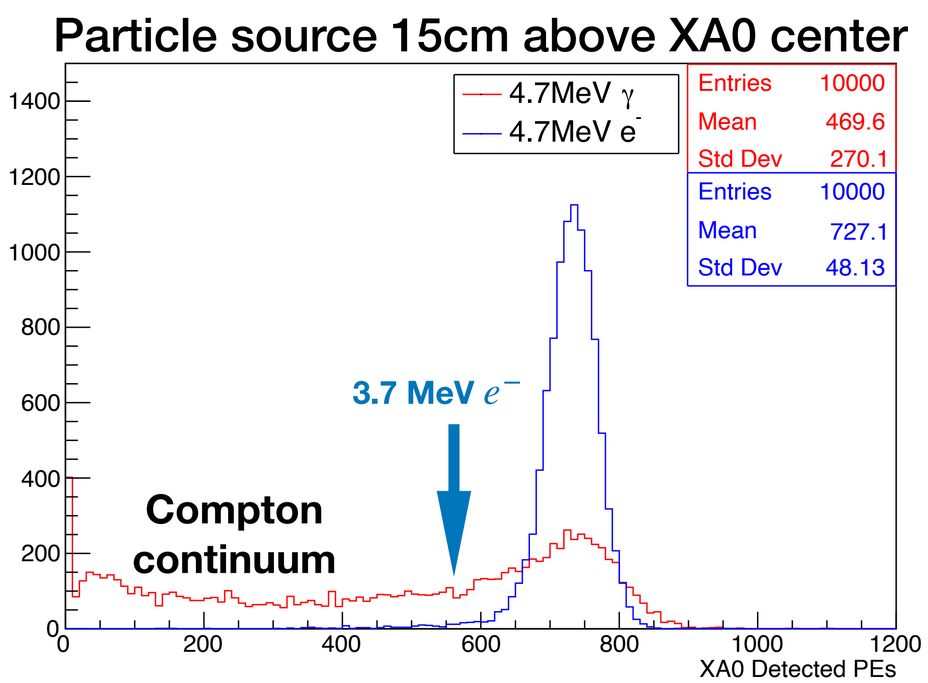
XA should see all 4.7 MeV energy deposit if such max energy transfer happens

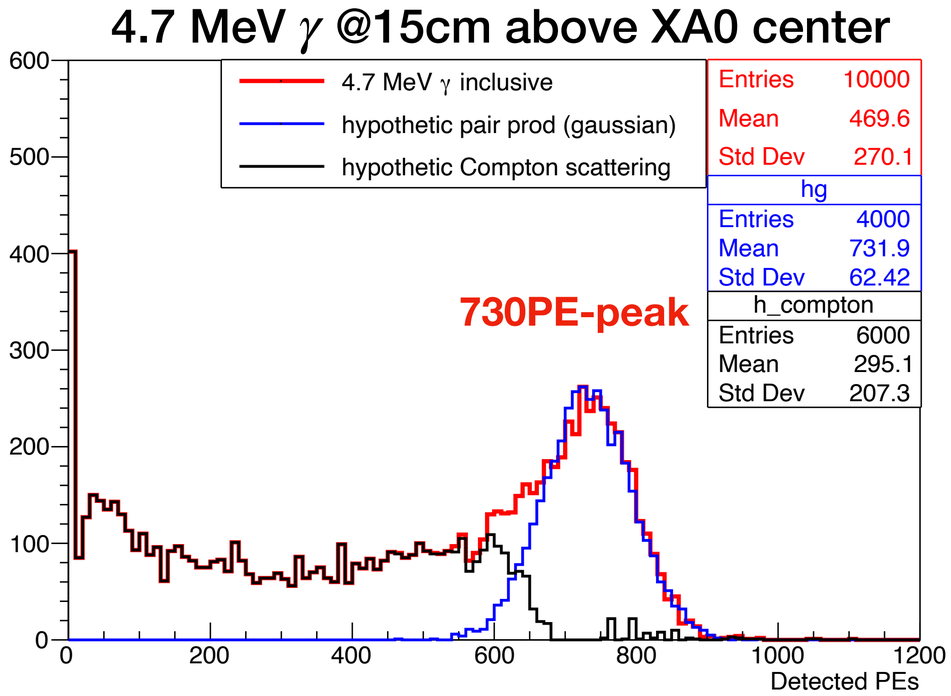
4.7MeV γ in a LAr Bath (200m x 200m x 200m)

All 4.7 MeV energy is deposited eventually, in different ways

Both Compton scattering or pair production can have localized and wide spread energy deposits

A super simplified picture

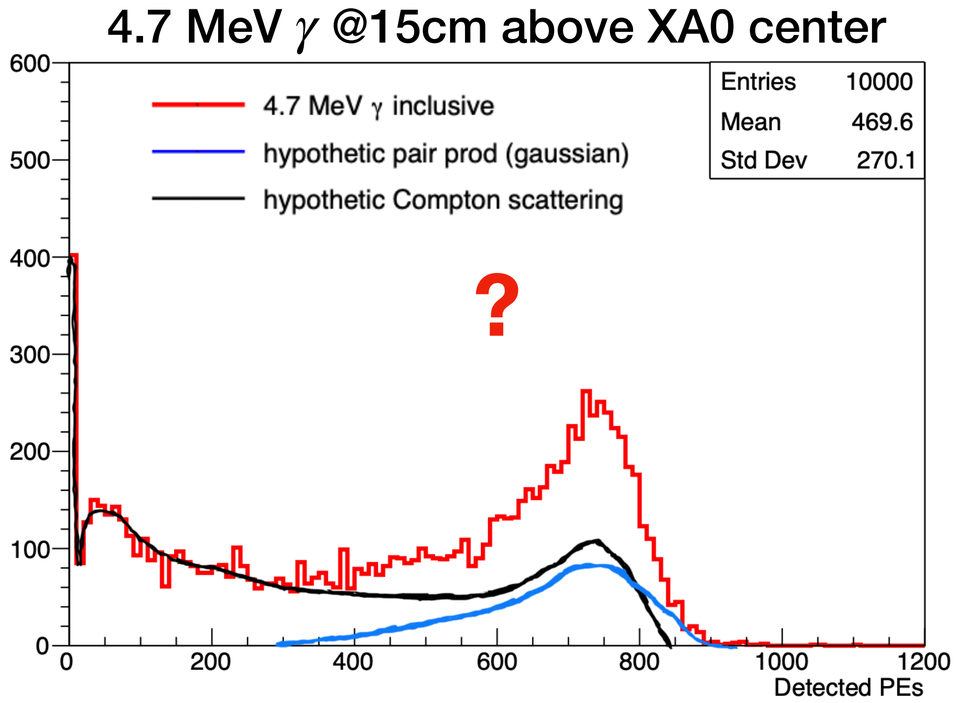


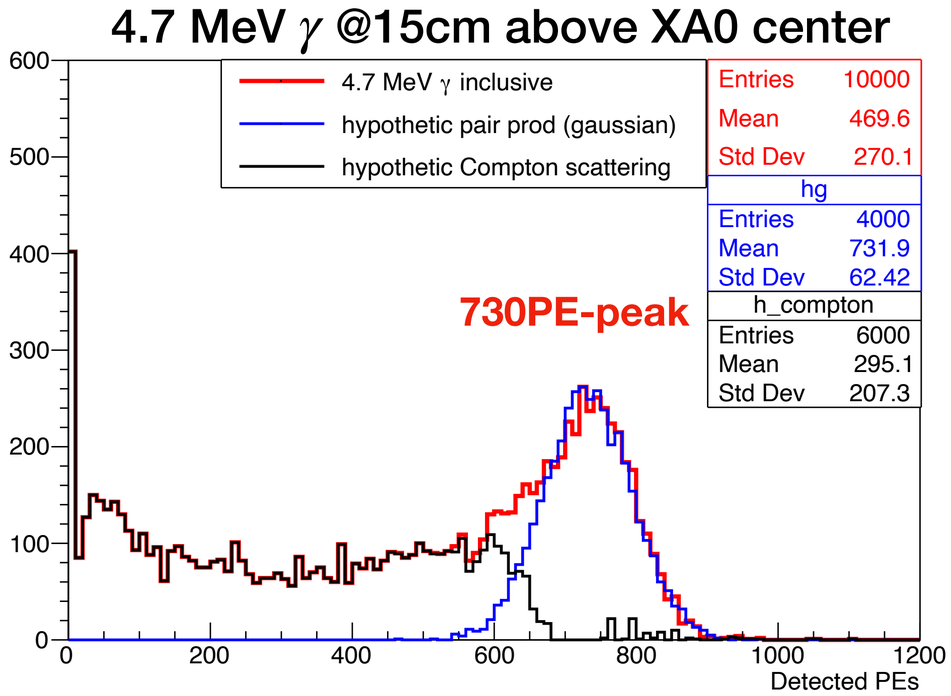


- The 730PE-peak comes from a total of 4.7MeV energy deposit for sure
  - Agrees with simulated electron with KE 4.7 MeV

- Is the right super simplified hypothetic breakdown correct? Probably not!
  - Hypothetic pair production is 40%, higher than expected (~20%, where is this expected number from?)
  - Pair production should have a longer tail to the left side of the distribution
  - Most likely Compton scattering with max E transfer also contribute to the 730PE-peak region

Another more educated picture?

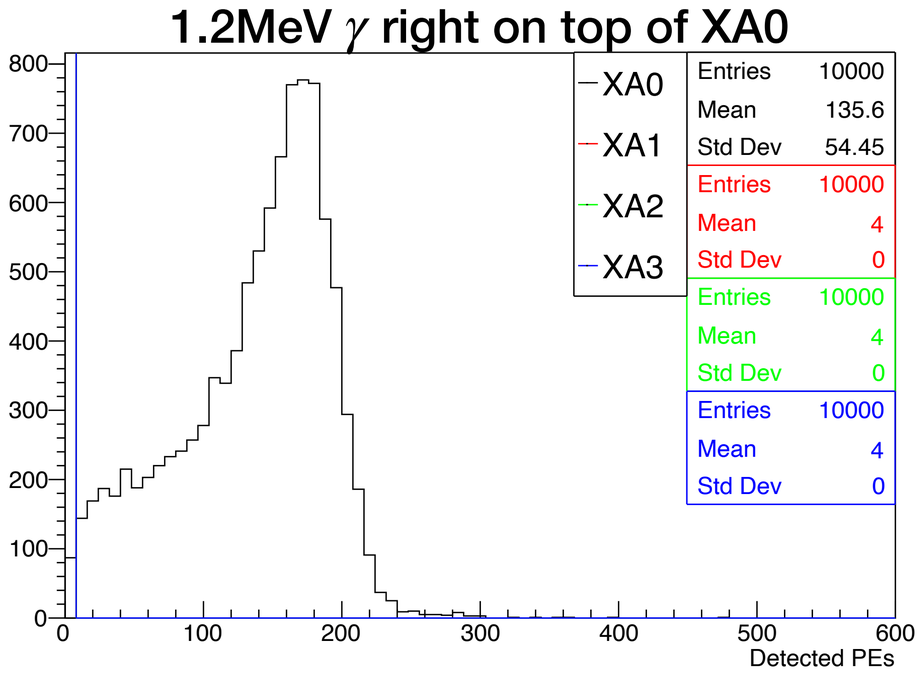


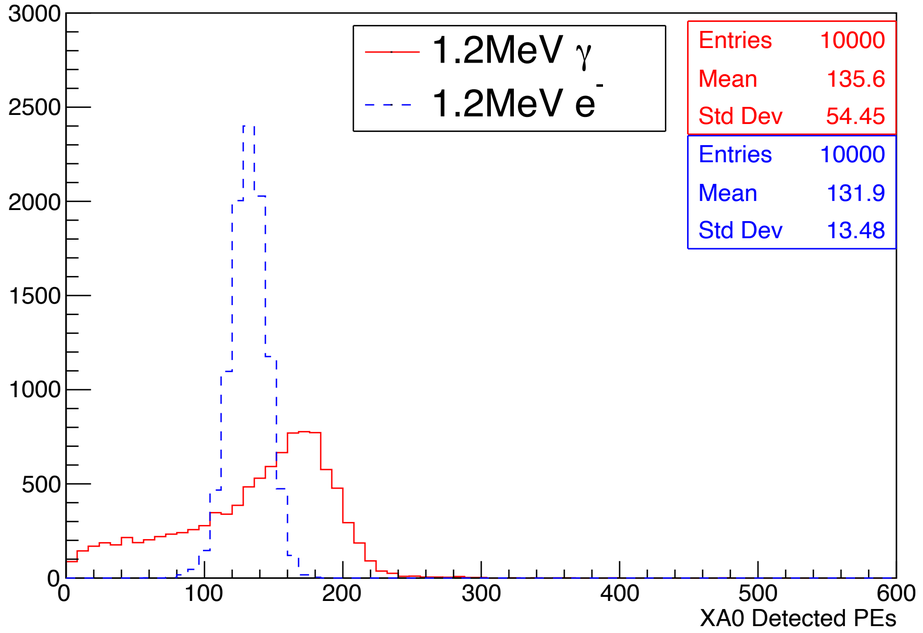


- **Would be interesting to look for this spectrum in data**
  - Trigger/offline data selection: a large XA0 signal (hundreds PE) + small signal on other XA_i (<10 PE)
  - If joint run with CRP, can also use CRP position information

- Further understand this spectrum from simulation
  - How does each process contribute to observed spectrum (next step study)

1.2MeV γ and e-: ~15cm above XA0 center





- At this energy, dominated by Compton scattering (no pair production)
  - Max energy transfer through Compton scattering is ~0.948MeV
  - How to understand the red signal shape from 1.2MeV γ? Need more study

Back Up

167keV γ: ~15cm above XA0 center

Generated at x=0, y=-38, z=257.9 (cm)