Study of backgrounds from detector materials in the XMASS experiment

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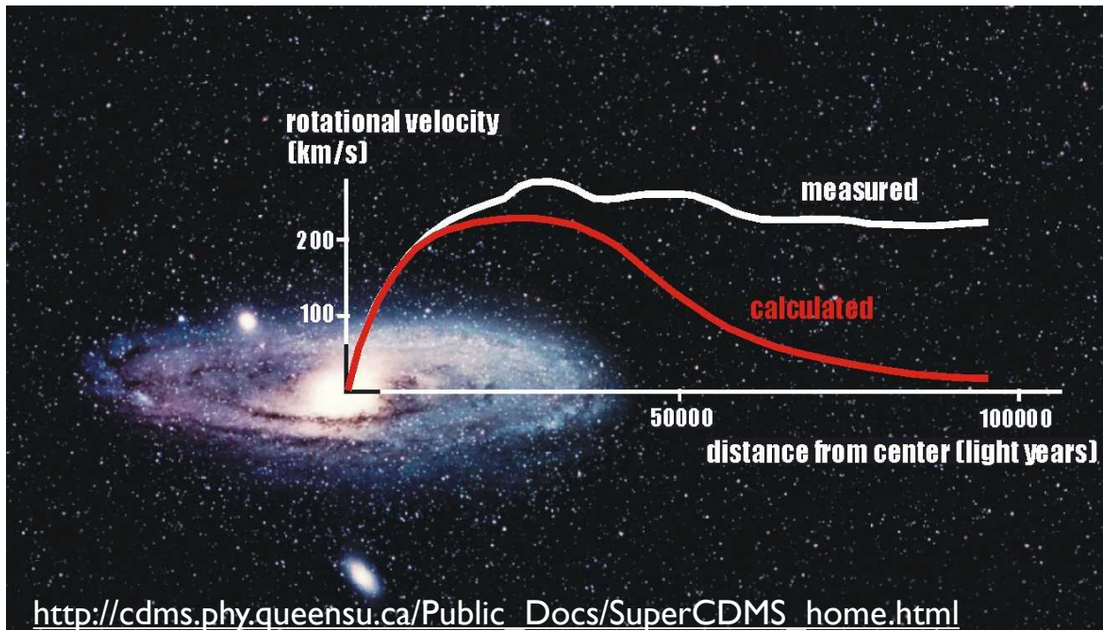
Dark Matter

- Evidence in various scale.



http://cdms.phy.queensu.ca/Public_Docs/SuperCDMS_home.html

Large

Scale

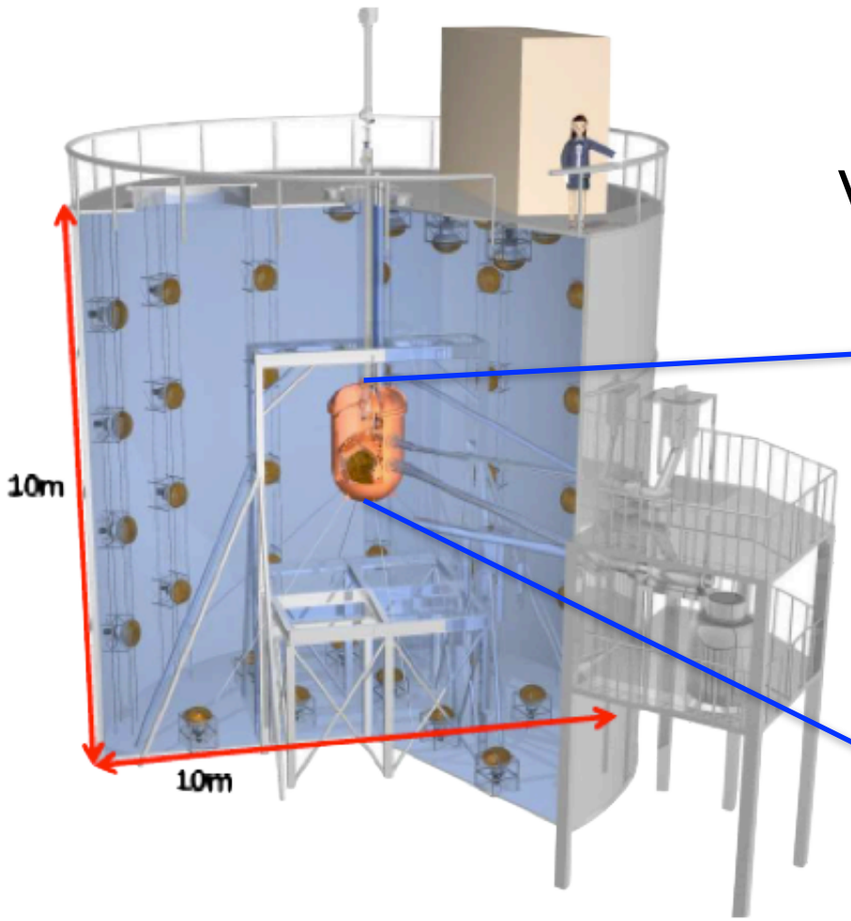
Small

- CMB, BBN
- Large-scale structure
- Collision of clusters of galaxies
- Velocity variance of galaxies in a cluster
- Rotation curves of spiral galaxies including our galaxy
  ↑ We can search directly

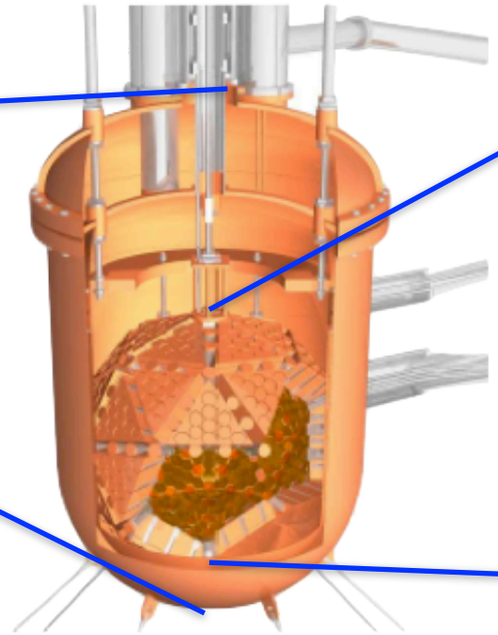
- WIMPs (Weekly Interacting Massive Particles) are the most likely candidate for particle DM is

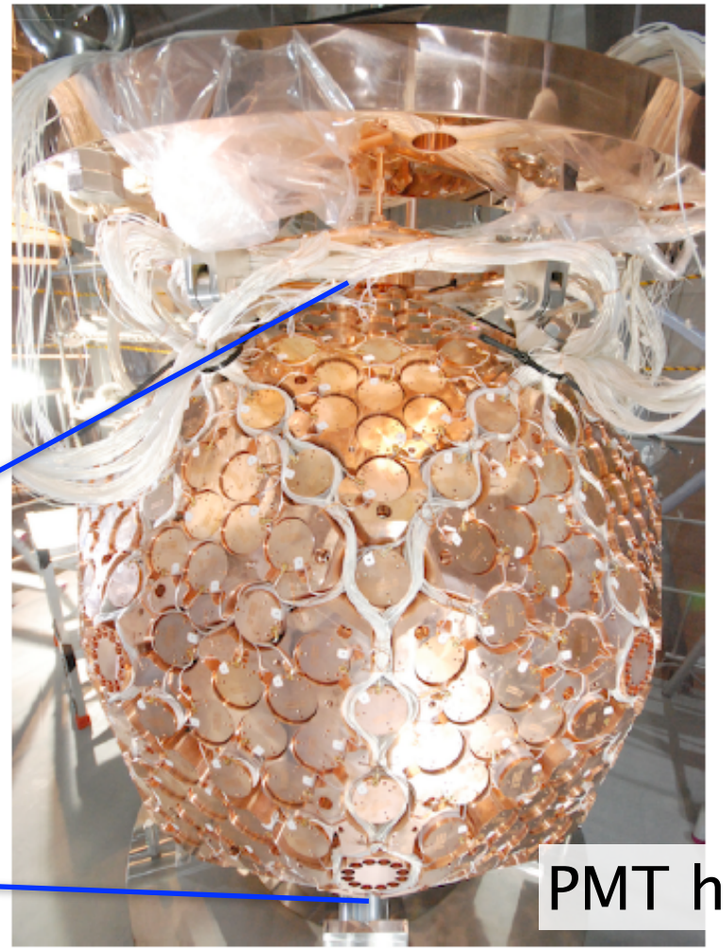
The XMASS experiment

Water tank



Outer/Inner
Vacuum Chamber

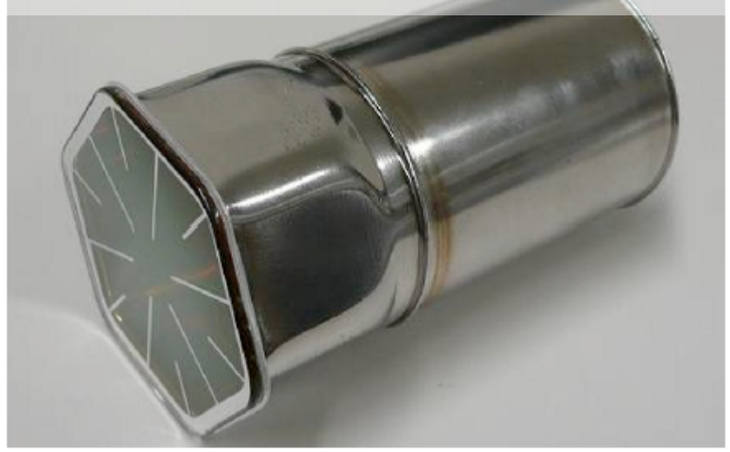




PMT holder

642 PMTs view 835 kg of liquid xenon inside.

PMT Hamamatsu10789-11

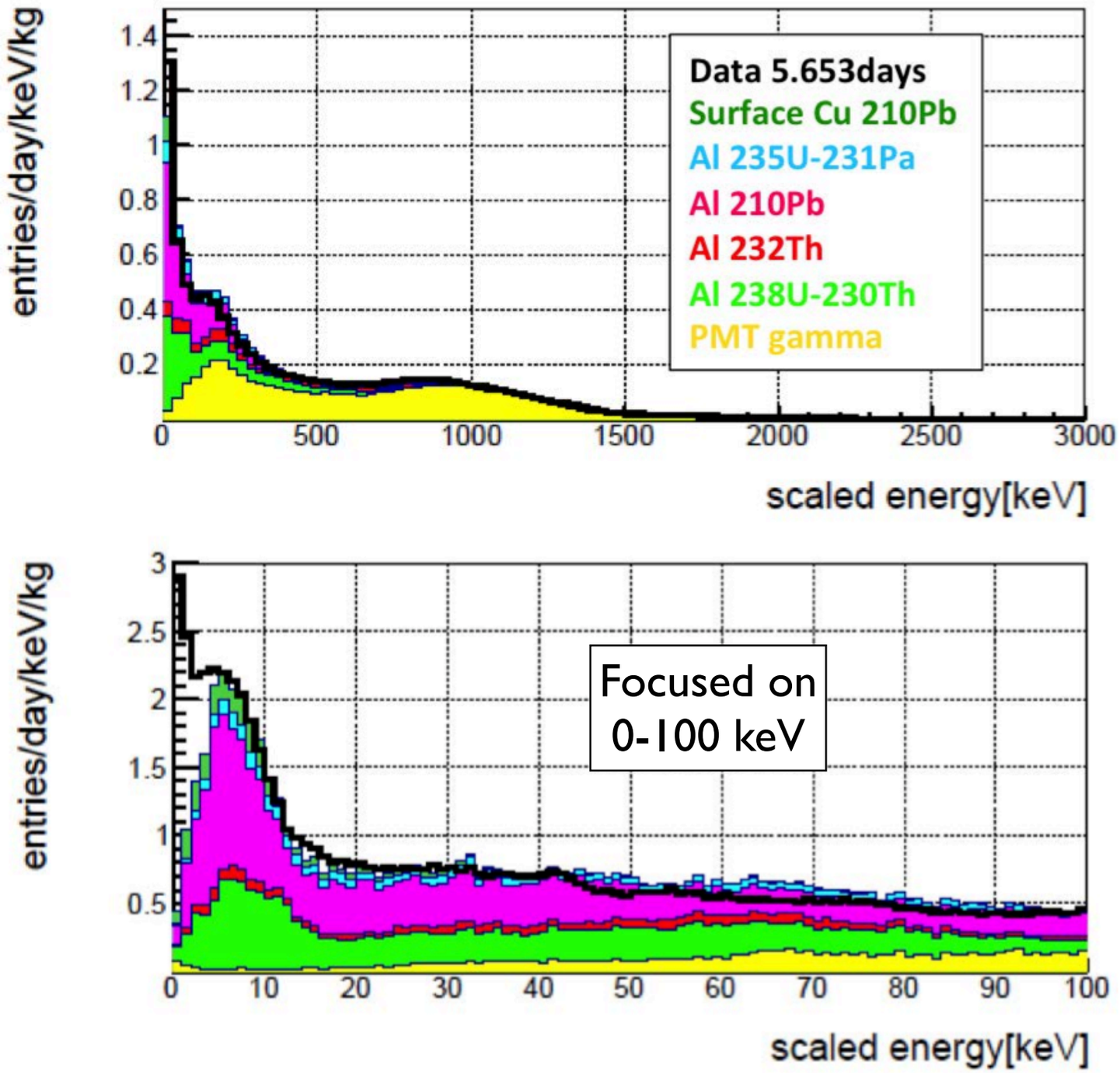


Backgrounds in XMASS (2010~2012)

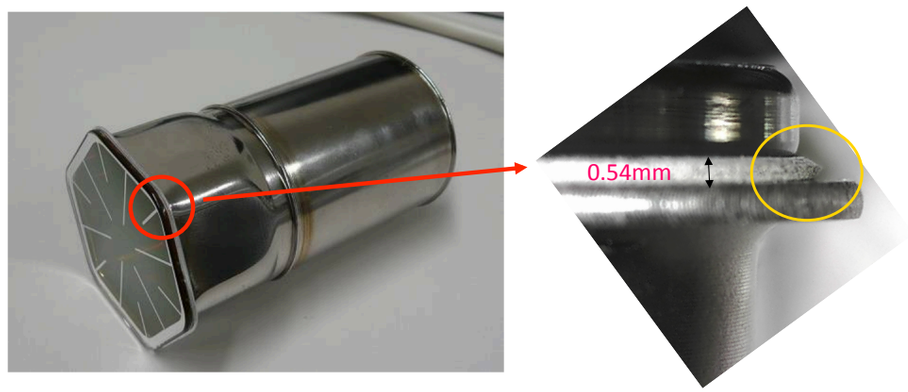
- From detector materials
- From RI(^{85}Kr, ^{222}Rn(U chain), ^{220}Rn(Th chain)) in liquid xenon
- From outside (neutron)

- Contribution from detector material is dominant in this experimental phase.

Backgrounds from detector materials (2010~2012)

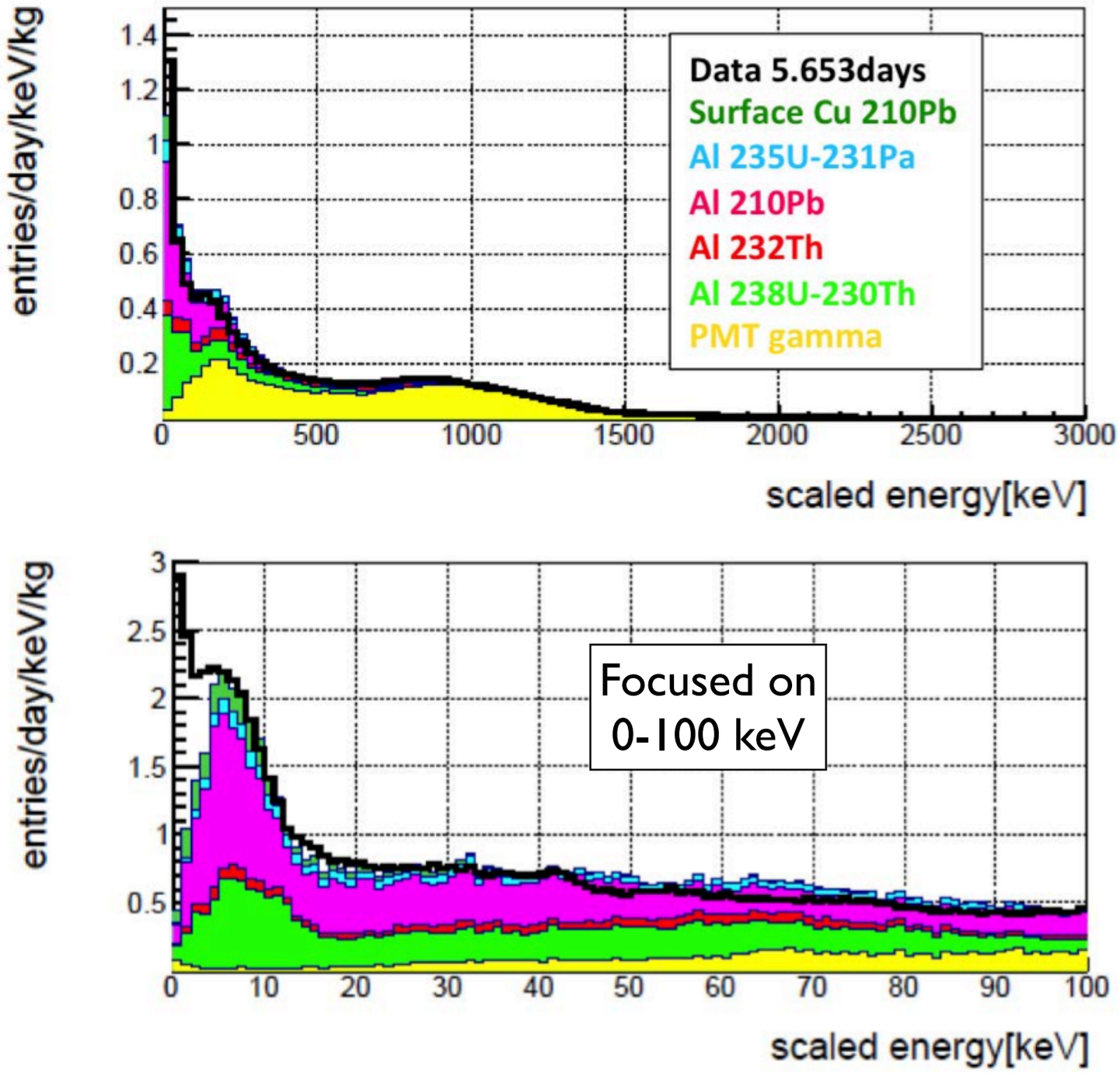


- Most of backgrounds were from PMTs.
- ← Energy spectrum in XMASS (~2012) before fiducial volume cut
- Black:Observed data
- Yellow: Simulation of gamma ray from PMT (Expected before construction)
- Other: Simulation of Surface BG (Unexpected)



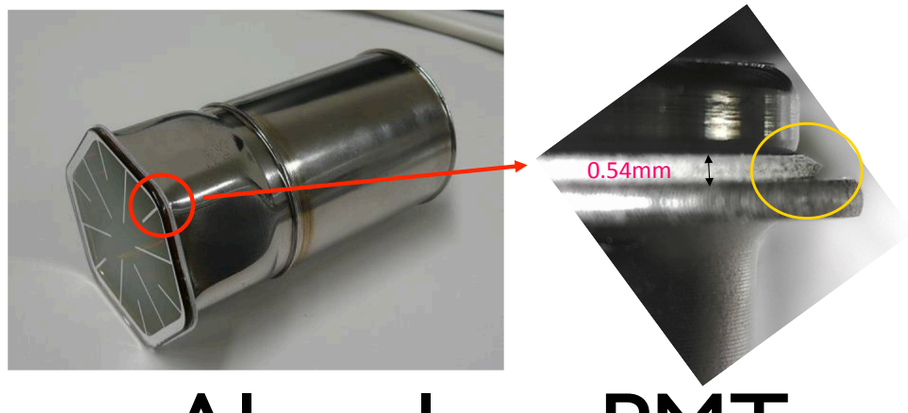
Al seal on PMT

Backgrounds from detector materials (2010~2012)



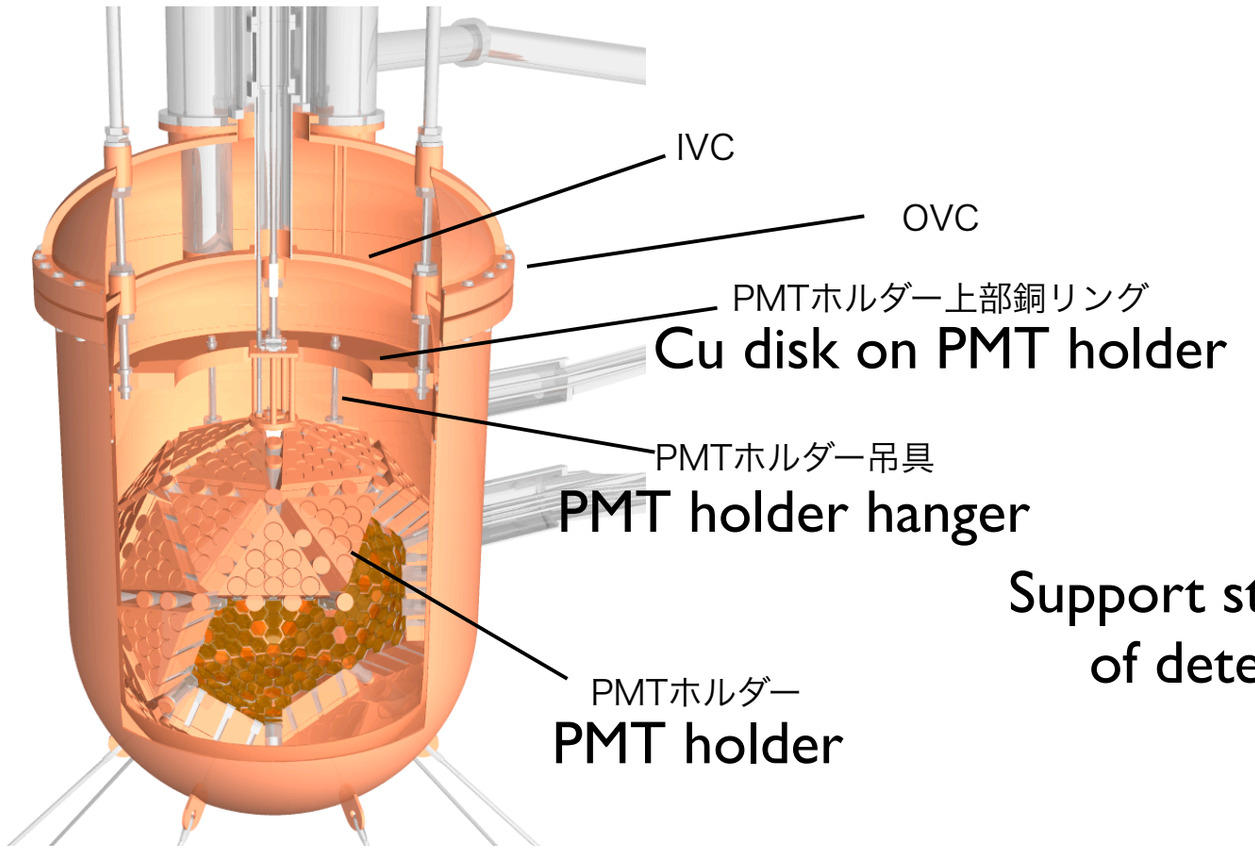
- After the refurbishment of XMASS conducted until 2013,
  - component other than yellow will be reduced.

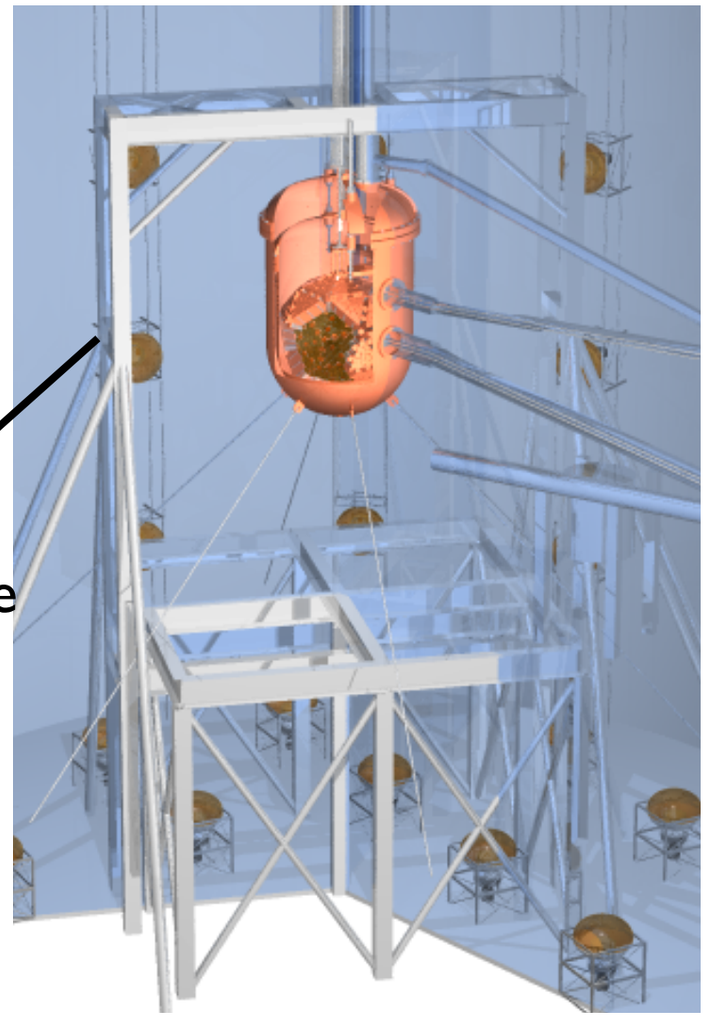
➡ Gamma ray from materials other than PMT needs to be studied.



Al seal on PMT

Materials other than PMT





- Gamma-ray contribution from these materials was studied in this thesis.

RI measurement by Ge detector

- Measured before detector construction in 2010.
  - Measured about 250 samples, about 90 were used in XMASS.
- I rearranged these materials into 13 parts by position and evaluated its effect by Monte Carlo simulation.

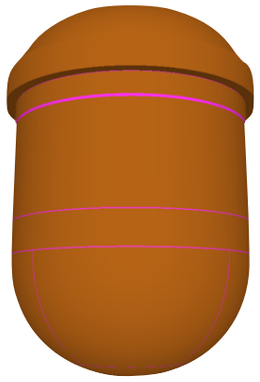
表 5.11　XMASS-1 検出器に使用された部材の場所ごとの RI 含有量

場所	部材数	^{238}U 系列 (mBq)	^{232}Th 系列 (mBq)	^{60}Co (mBq)	^{40}K (mBq)
PMT ホルダー内側表面	4	8.0 ± 3.3	2.7 ± 3.4	0.34 ± 1.3	-34 ± 41
PMT ホルダー内部その 1	7	-3.4 ± 4.2	-2.8 ± 23	-3.6 ± 1.7	-7.9 ± 51
PMT ホルダー内部その 2	22	28 ± 22	50 ± 22	231 ± 13	-306 ± 208
PMT ホルダー吊具	3	24 ± 11	103 ± 12	261.2 ± 9.3	-116 ± 78
PMT ホルダー上部の銅リング	17	4 ± 34	-5.6 ± 31.2	22 ± 13	-390 ± 290
フィラー内部	2	0.0 ± 1.2	-0.6 ± 1.3	-1.00 ± 0.50	-20 ± 15
IVC 外側表面	16	1181 ± 375	920 ± 354	246 ± 133	722 ± 3339
IVC 上フタ溶接	1	1310 ± 640	1070 ± 610	31 ± 230	-2000 ± 5800
IVC 下容器溶接	1	-250 ± 110	2240 ± 160	28 ± 33	-870 ± 980
OVC 上フタ溶接	1	510 ± 250	420 ± 240	12 ± 88	-790 ± 2300
OVC 下容器溶接	1	-300 ± 131	2620 ± 180	33 ± 39	-1020 ± 1140
OVC 外側表面から 1m 以内	8	5330 ± 760	4720 ± 810	2300 ± 430	-3900 ± 5500
検出器架台	3	-21100 ± 2600	5000 ± 2700	6700 ± 1400	-30000 ± 20000

Ge detector

Method

Develop a geometry of a material in XMASS MC, and simulate decays of RIs on that.



Ex. of geometry
Welding on
vacuum chamber

↓

Convert the result into real time energy spectrum by using Ge data.

Evaluate by using
upper limit (1σ)

↓

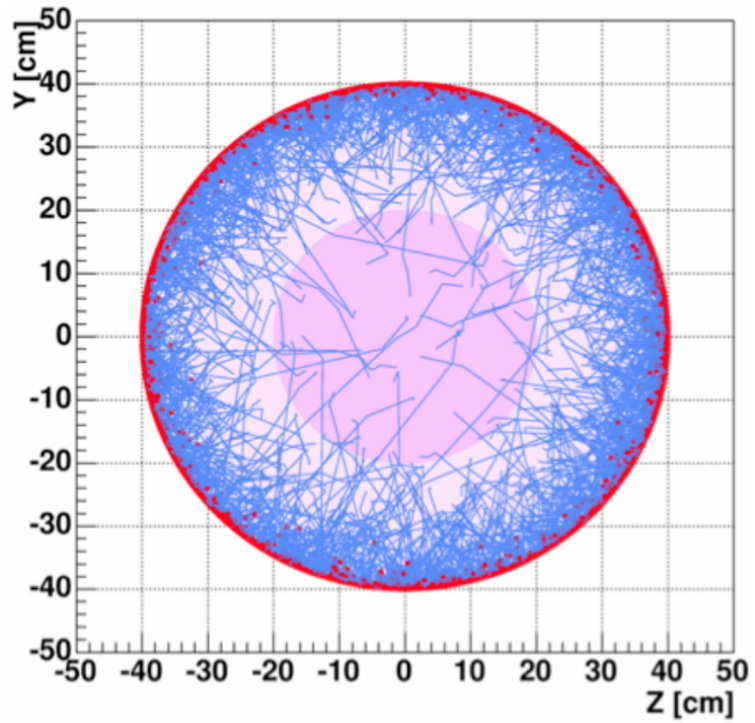
Apply cuts in same way as WIMP analysis and evaluate BG contribution.

- PMT hit time distribution
- Čerenkov cut
- Reconstruction and fiducial cut

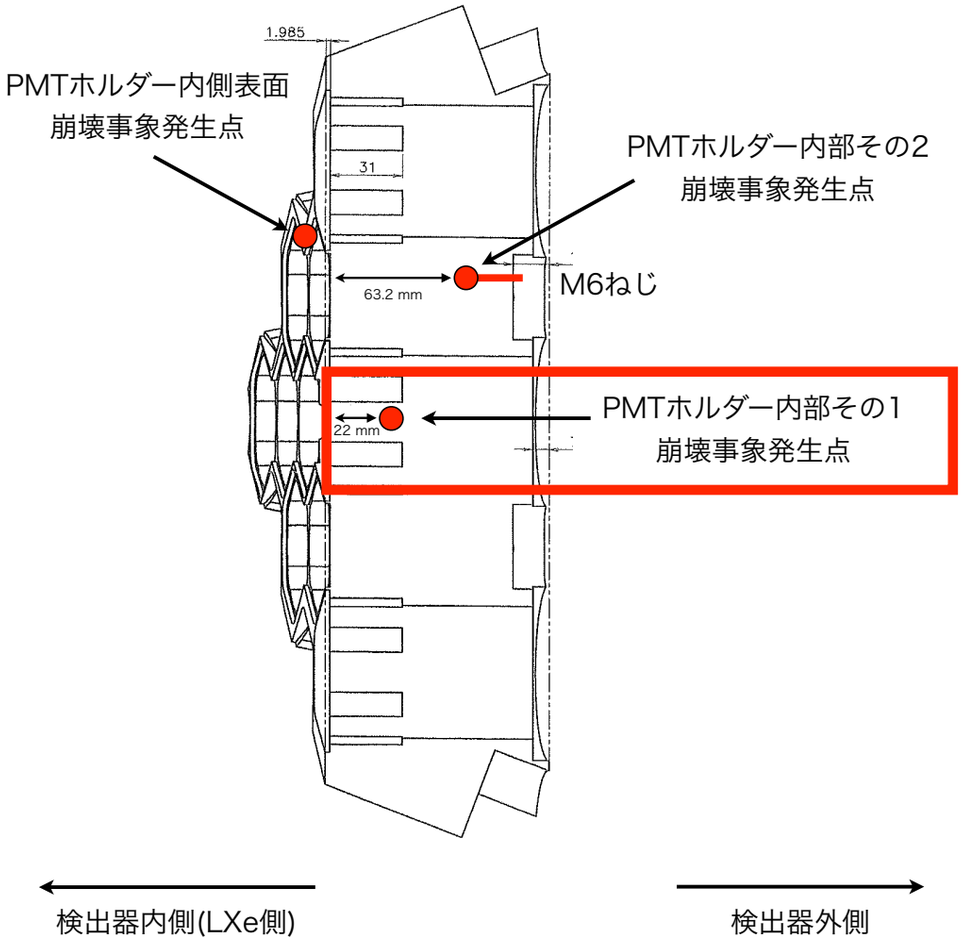
Self shielding,fiducial cut, and reconstruction

- As atomic number of Xe is large, cross section of gamma ray is large and center area of liquid xenon is gamma-ray less.
  - Gamma ray achieved center area will deposit all energy, and it will be larger than WIMP signal region (few 10 keV).
- By removing events R>20 cm with vertex reconstruction, low BG measurement is realized.
  - Mis-reconstruction of events will not be negligible.

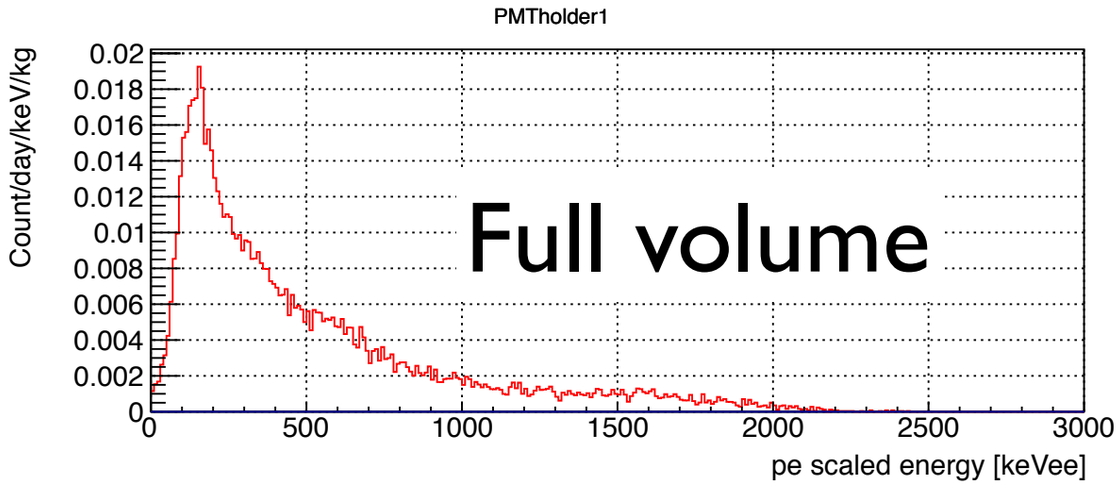
MC simulation of gamma rays from decay of U-chain on XMASS detector inner surface (R=40 cm).
Blue tracks show gamma rays.
Deep magenta shows fiducial volume (R<20cm)

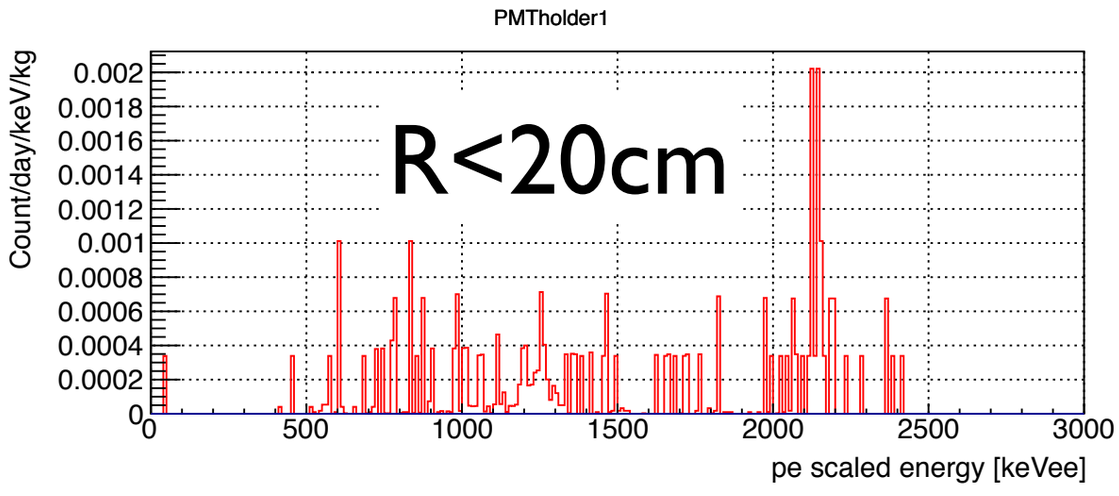


Ex1:PMT holder part 1



Decay event generated point

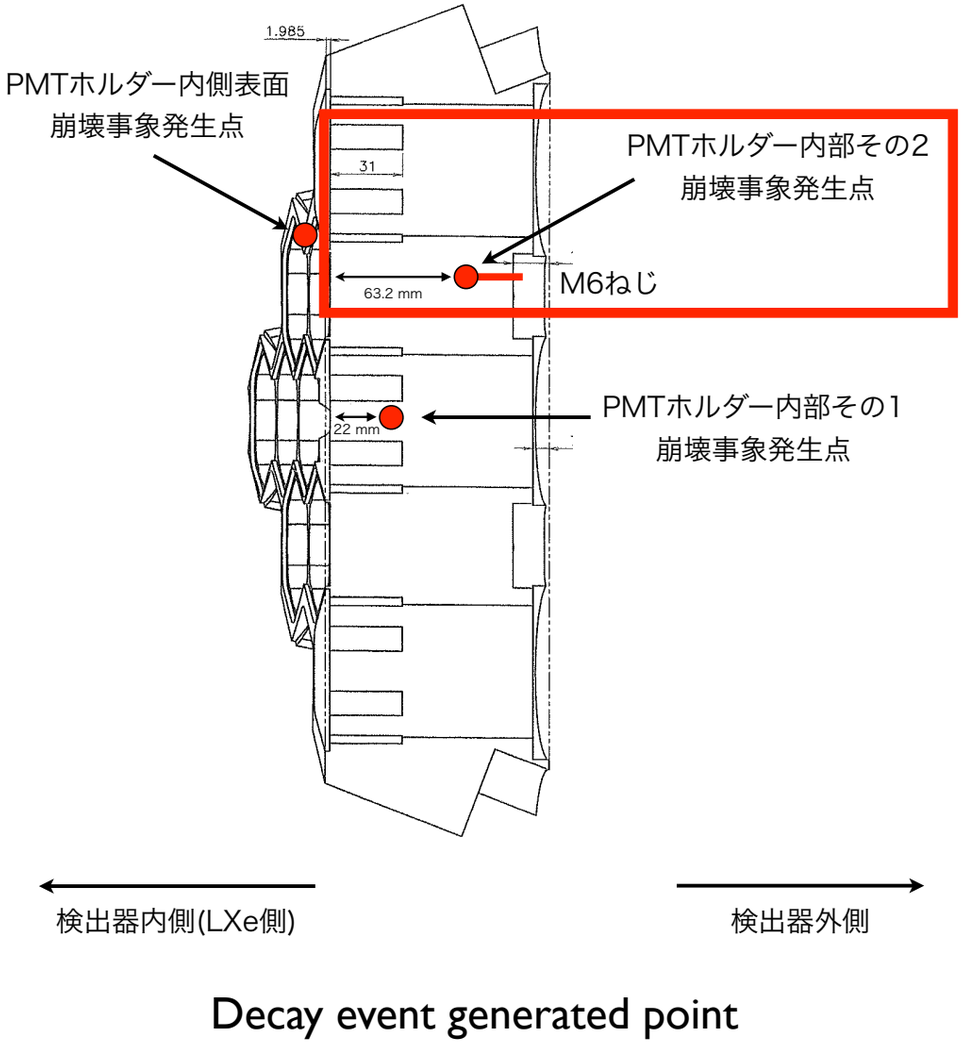




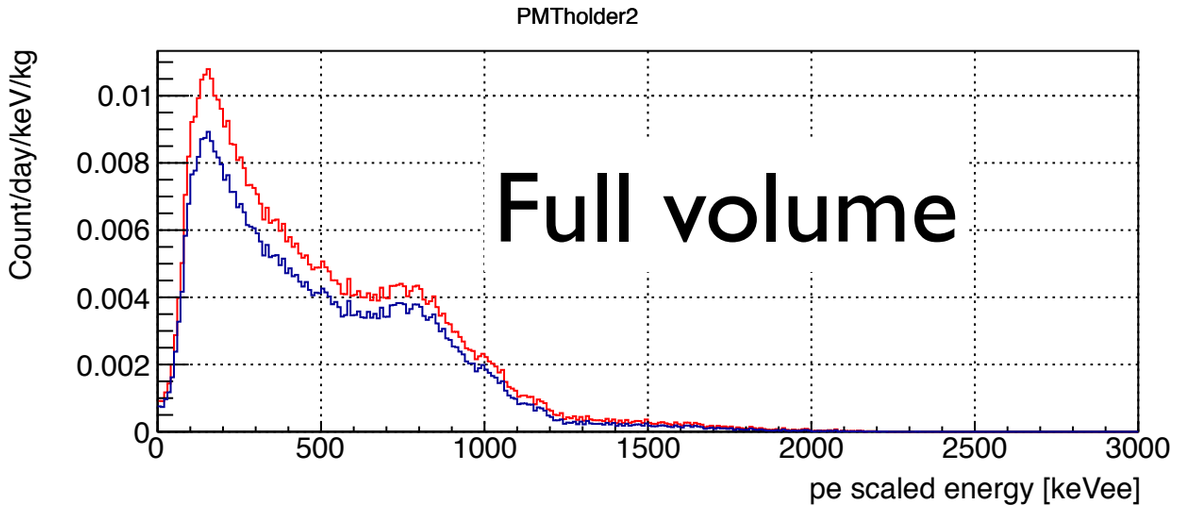
BG spectrum

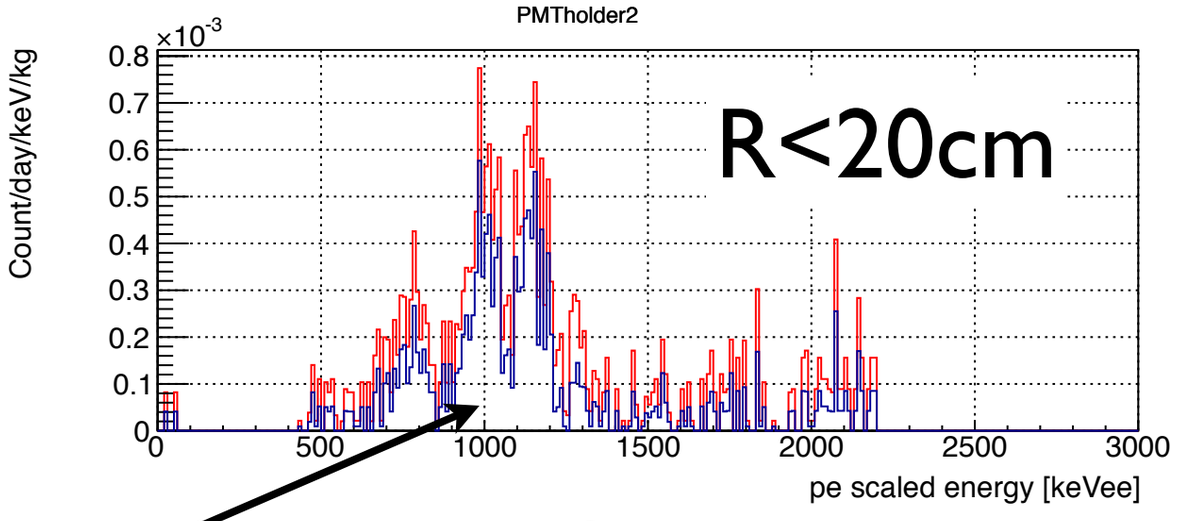
- Largest contribution in this study.
- Dominant origin is Th-chain on thermometers.

Ex2:PMT holder part 2



Decay event generated point

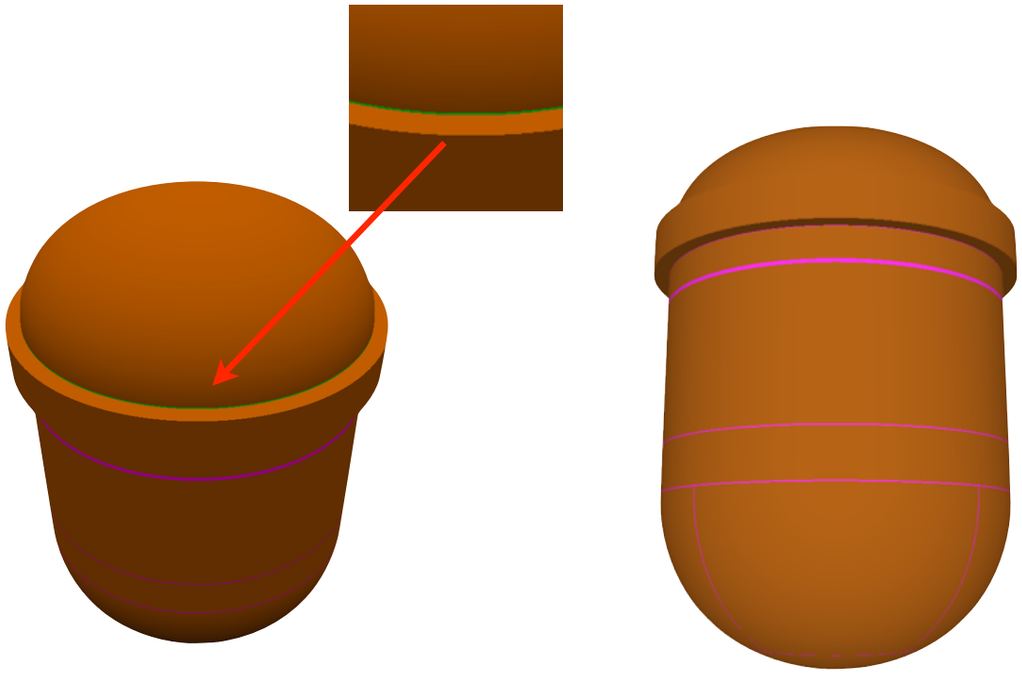




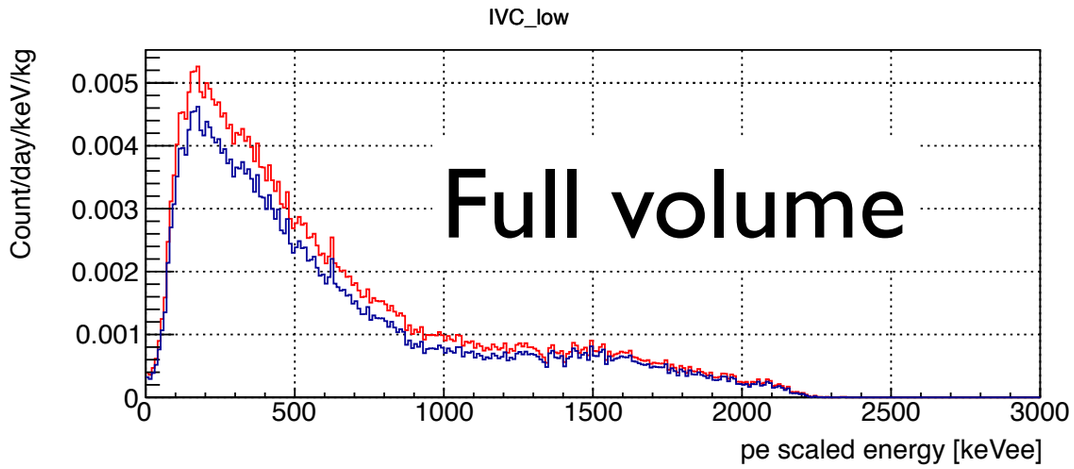
BG spctrum

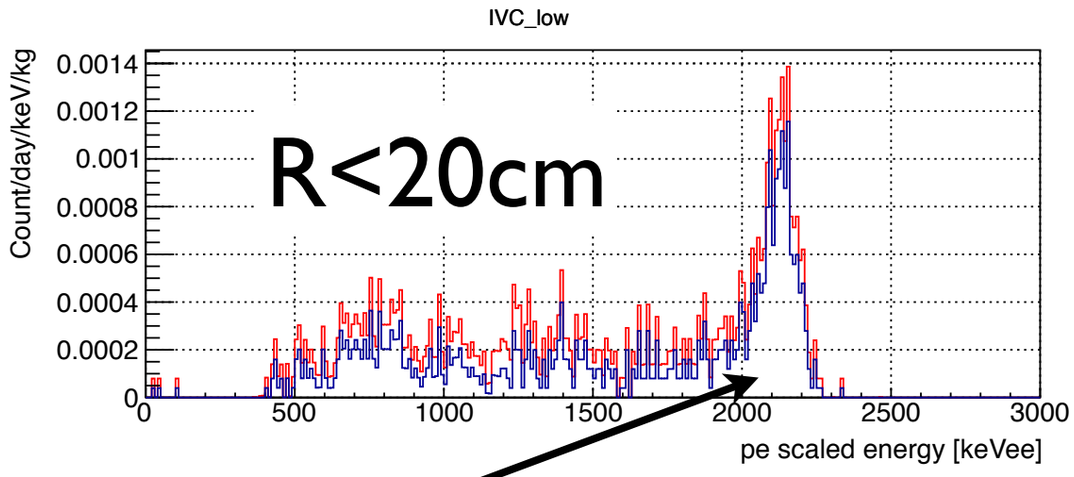
- Contribution of ^{60}Co on stainless bolts was large.

Ex3: Welding on IVC and OVC



Decay event generated point (for IVC)



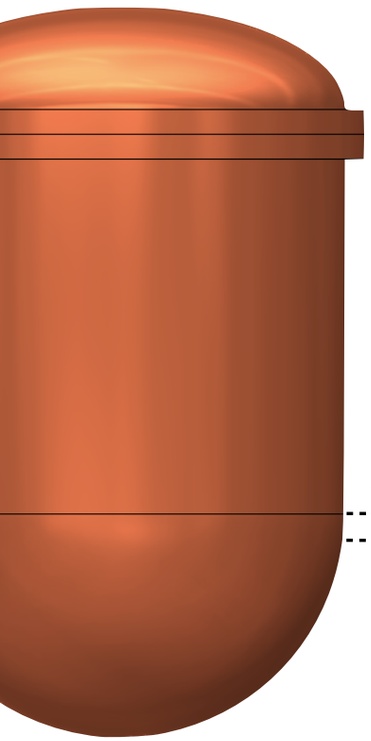


^{208}Tl

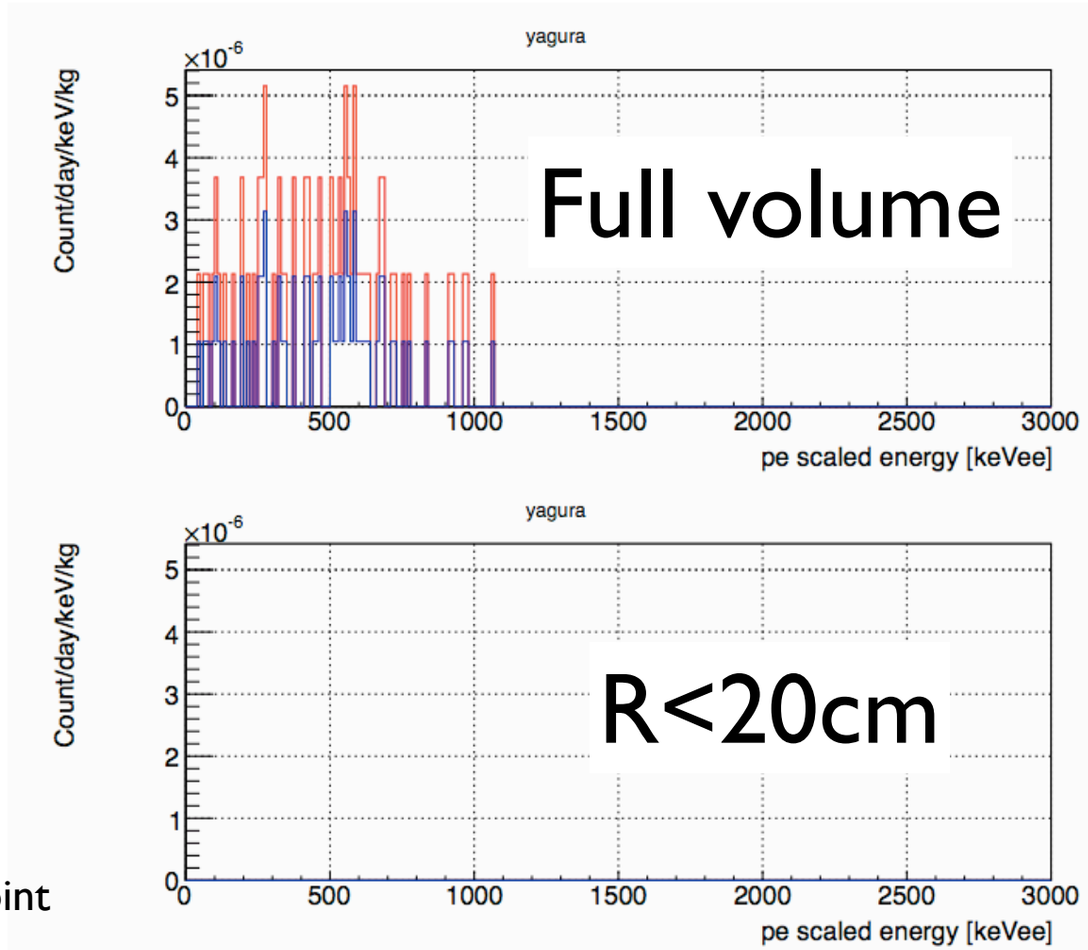
BG spectrum (for IVC lower welding)

- Contribution of Th-chain and U-chain was large.

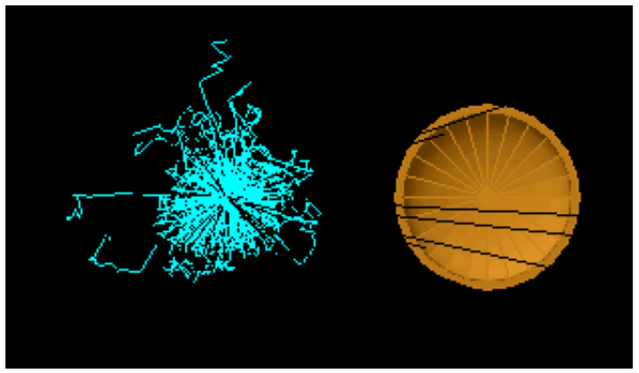
Ex4: Support structure

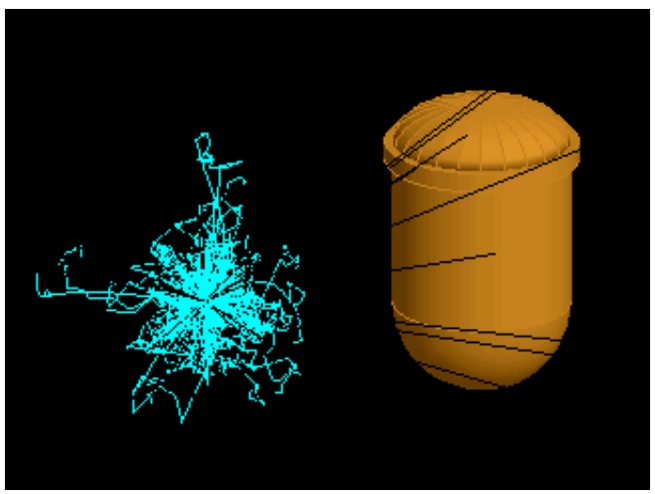


Decay event generated point



BG spectrum

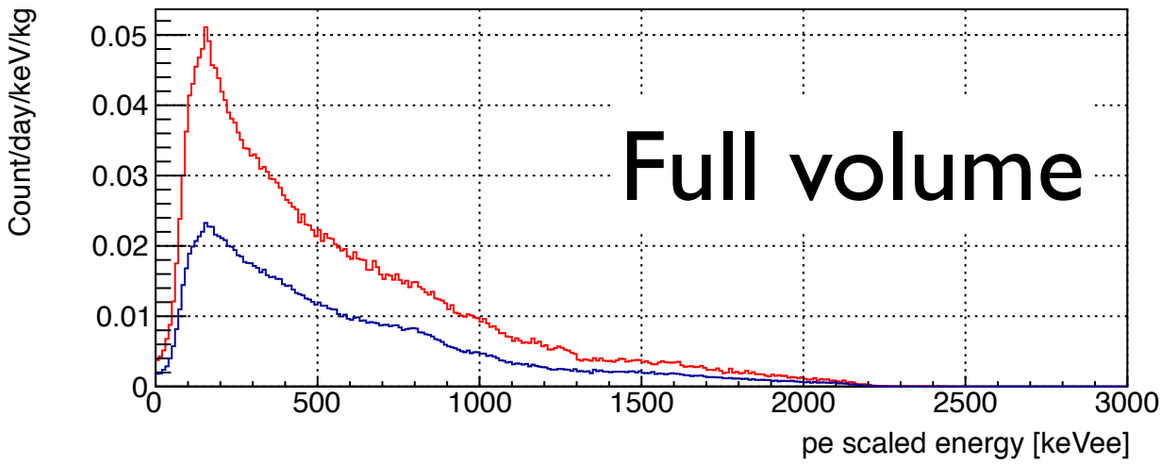


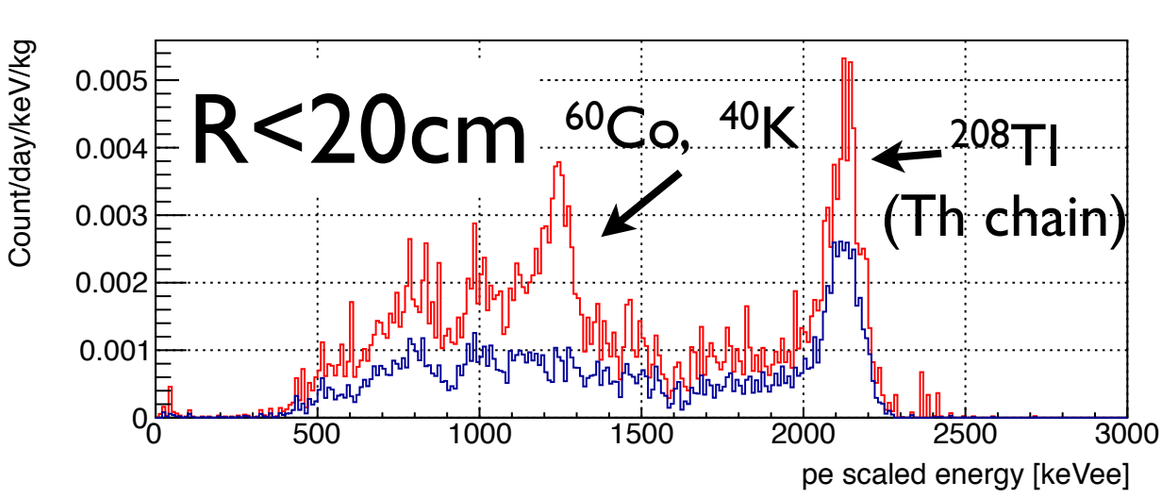


MC simulation of 100 times decay of ^{60}Co at support structure position. (Light blue shows gamma ray, black shows neutrino.)

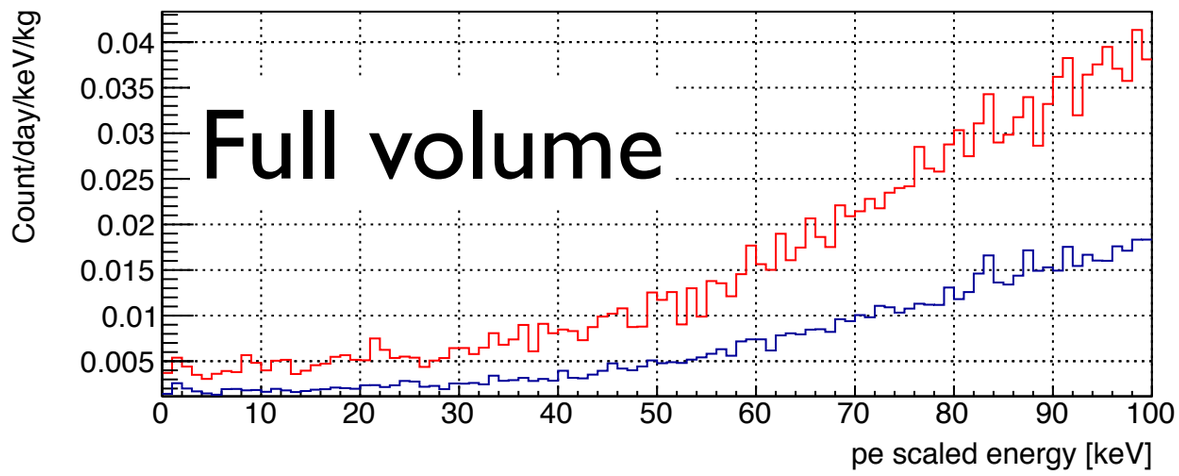
- Contain much RI, but distant from detector and shielding by water was effective.

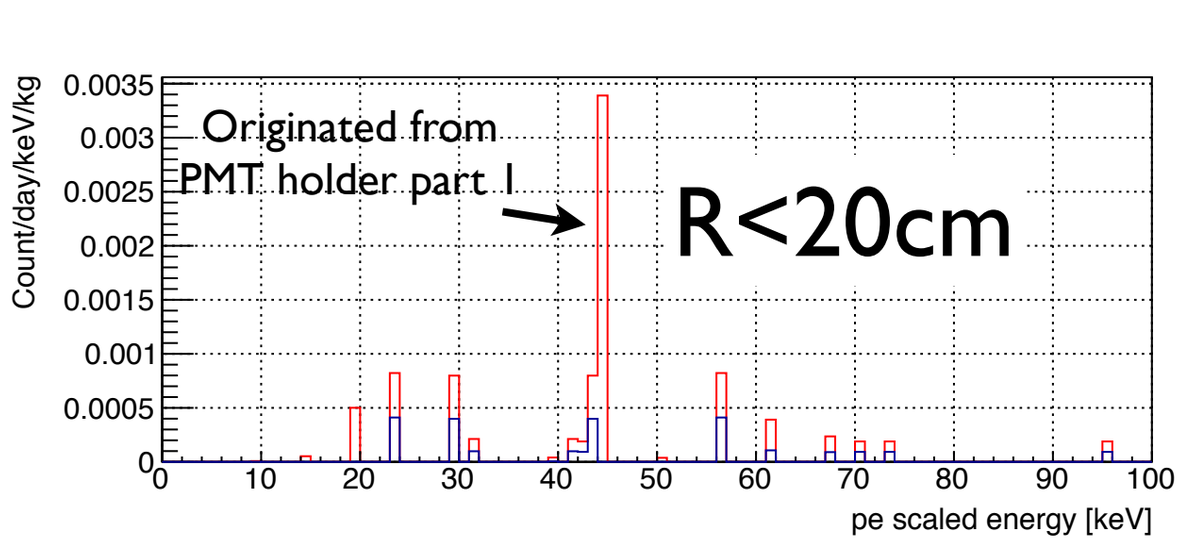
Result





Summed spectrum of simulated result

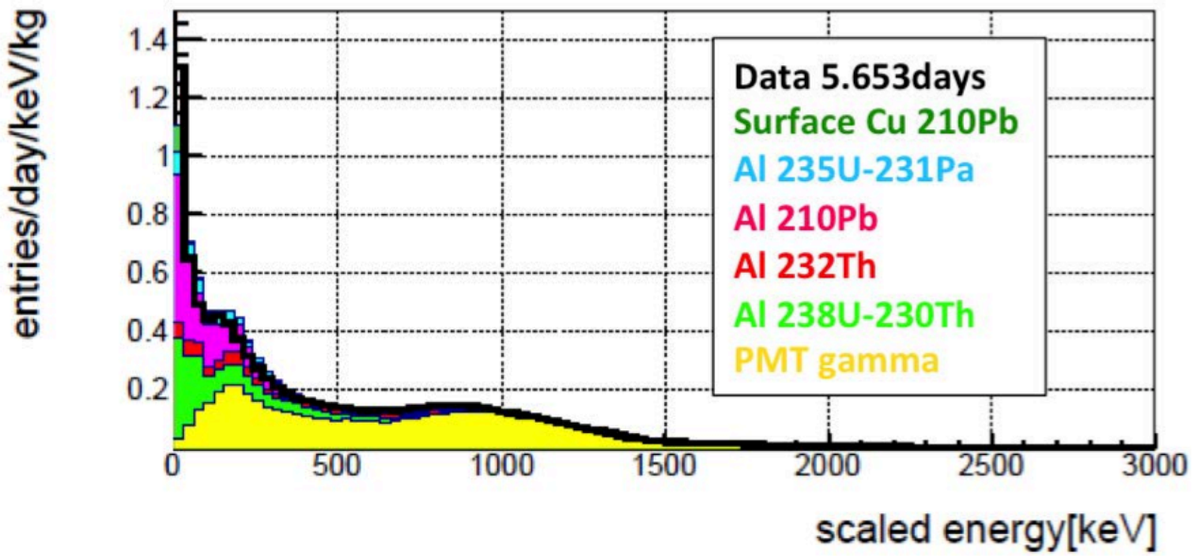


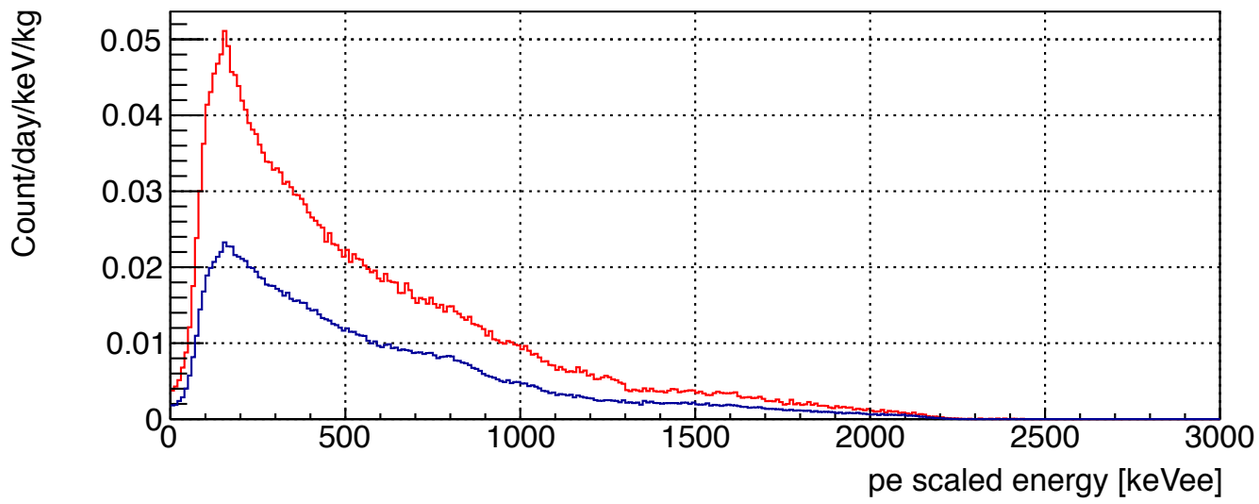


0-100 keV

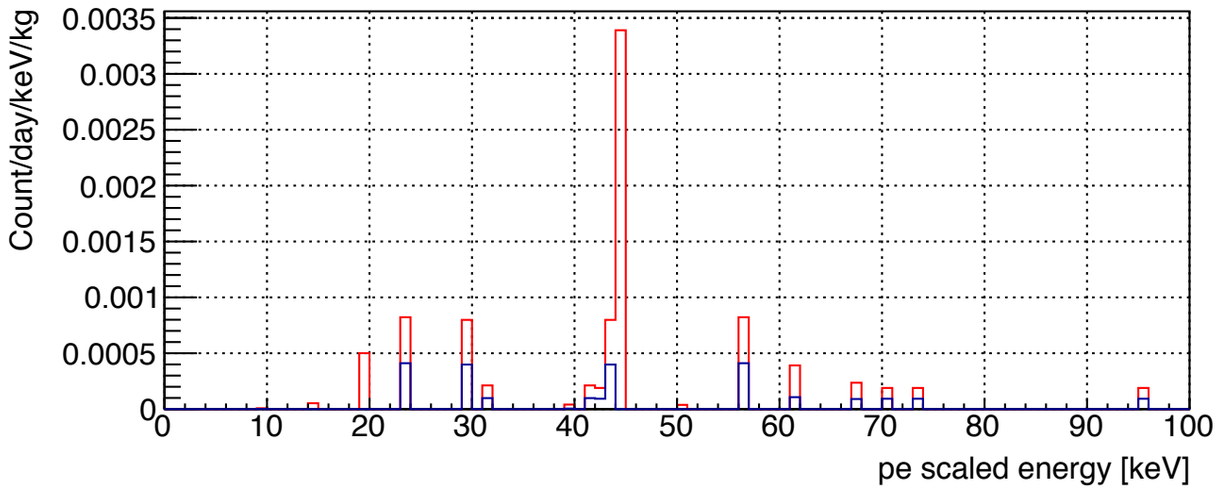
- Right lower figure shows expected BG spectrum in WIMP signal region after fiducial cut.

Conclusion





- By comparison of full volume spectrum, gamma ray contribution from materials other than PMT (red in right figure) was at most 25% of gamma rays from PMT(yellow in left figure).
- This effect is smaller than uncertainty of gamma ray from PMTs.



- After fiducial cut, mis-reconstructed events were left in below 100 keV.
- Improvement reconstruction is necessary to reduce them.