Expected Background in the PandaX-III Neutrinoless Double Beta Decay Experiment

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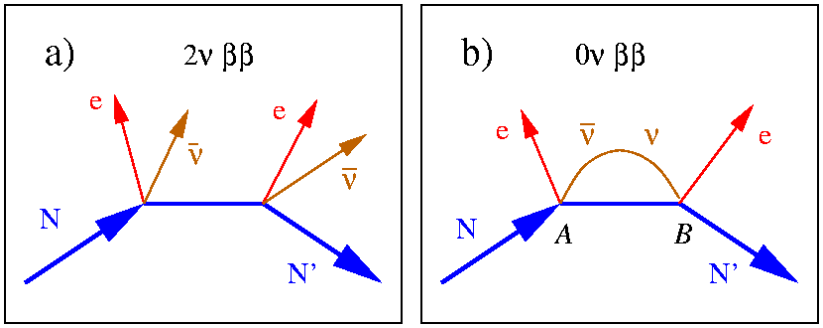
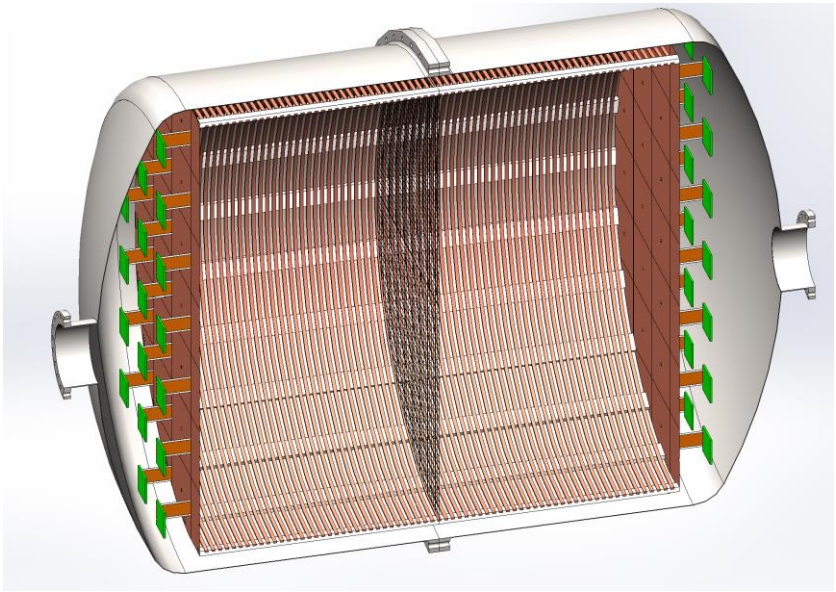
Outline

- Introduction
- Background Calculation
- Background Budget
- Trigger and readout window
- Conclusion

The PandaX-III Experiment

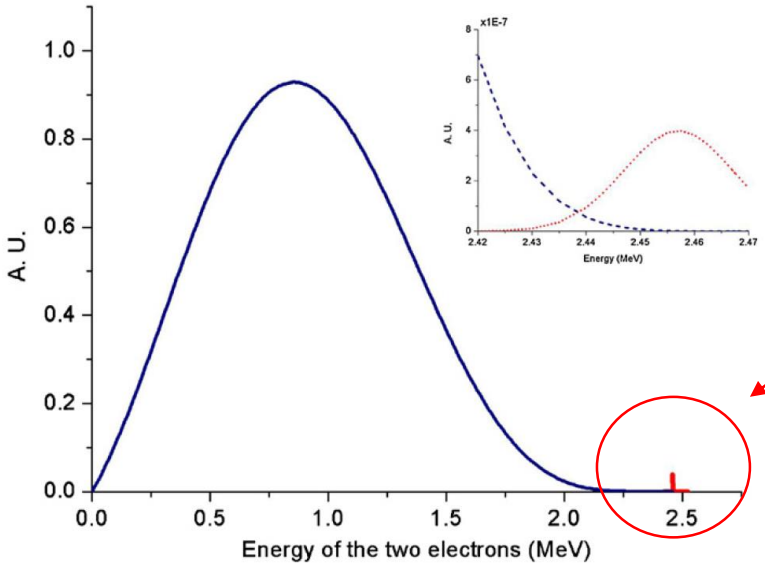




- Searching for 0νββ of 136Xe with high pressure gaseous xenon TPC.
- 200 kg enriched 136Xe gas (~90%) + 1% TMA
- Diameter 1.5m
- Length 2m

Signal and Sensitivity

- 2 electrons with Q=2457.83 keV



Expected Signal of 0νββ

$$\left[T_{1/2}^{0\nu}\right] \propto \varepsilon ff \cdot I_{abundance} \cdot Source\ Mass \cdot Time$$

Background free

$$\left[T_{1/2}^{0\nu}\right] \propto \varepsilon ff \cdot I_{abundance} \cdot \sqrt{\frac{Source\ Mass \cdot Time}{Bkg \cdot \Delta E}}$$

Background limited

Note : Backgrounds do not always scale with active detector mass

Background calculation

- PandaX-III detector as a Calorimeter
  - assuming all energy depositions inside the TPC in one events are recorded
  - signal Q value = 2457.83 keV
- Mainly from the decay from ^{238}U, ^{232}Th and their decay products.
  - ^{214}Bi: 2447.7 keV
  - ^{208}Tl: 2614.5 keV
- Count the events within the energy window of Q±2σ.

$$N_{ROI}^{\sigma_i} = \sum_{E_n=E_i}^{E_f} \left\{ \int_{Q_{\beta\beta}-2\sigma_i}^{Q_{\beta\beta}+2\sigma_i} \frac{S(E_n)}{\sqrt{2\pi}\sigma_i} \exp\left(-\frac{1}{2}\frac{(E'-E_n)^2}{\sigma_i^2} \right) dE' \right\}$$

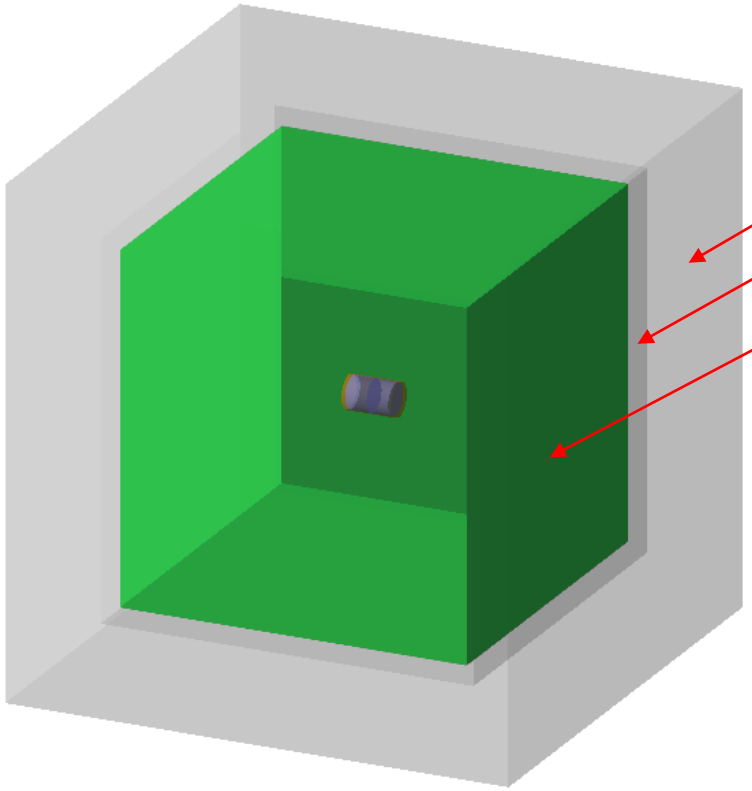
Reference Geometry

- The final design of the TPC is not released. Using a reference geometry in Geant4 based MC simulation.
- Core components:
  - Copper vessel
    - wall thickness: 3cm
    - endcap thickness: 15cm
    - inner radius: 75cm
    - height: 2m
  - Gas
    - enriched ^{136}Xe (90%, 200kg) + 1% TMA
    - 10 bar
  - TPC with traditional field cage design

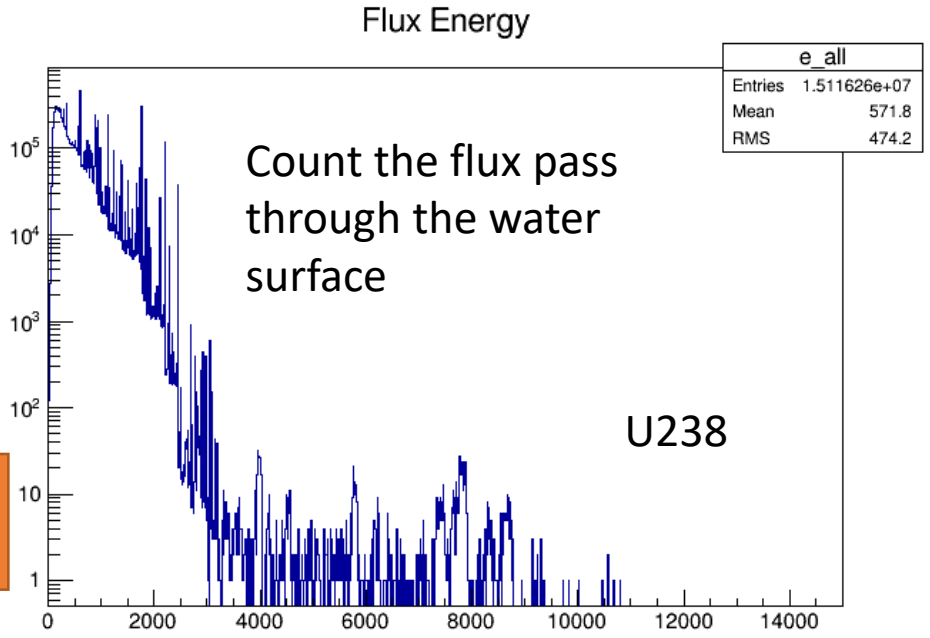
Background Contributor

- The laboratory wall (rock & concrete)
- The water shield
- The copper vessel and stainless bolts
- The steel supporter
- The Electronics
- The TPC
  - MicroMegas detector
  - Teflon supporter
  - Copper field cage
  - Rn in the gas

Radiation from the Laboratory Wall



Rock Wall: 3m
Concrete Wall: 0.5m
Water

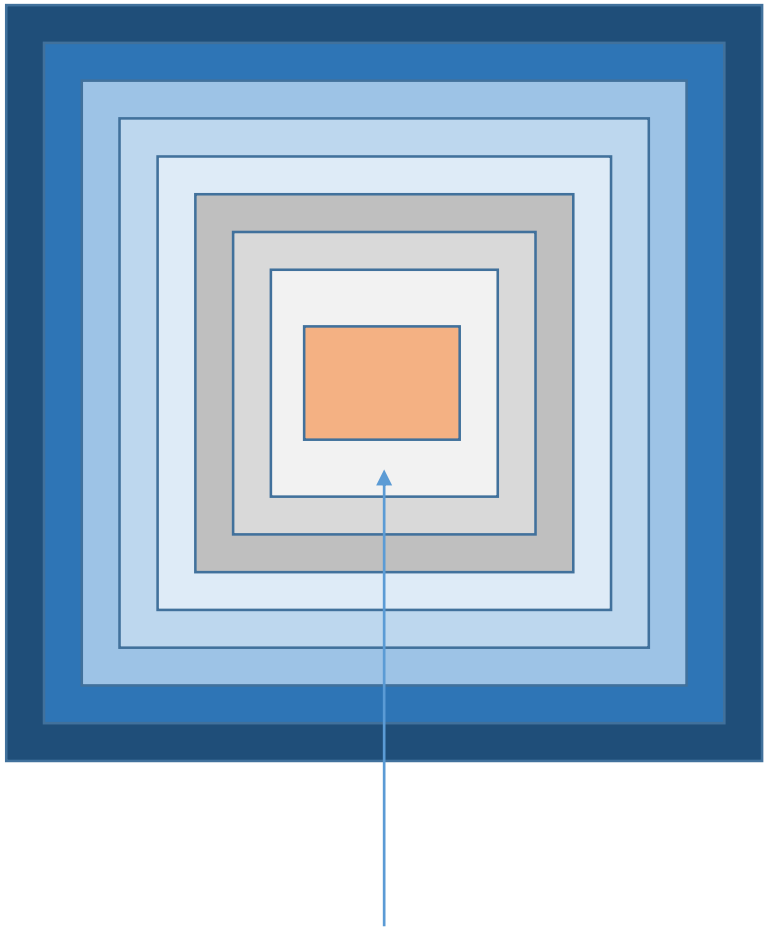


The flux from the rock is at the order of $(2\sim3)\times10^{-4}$ of that from the concrete wall.

^{238}U flux rate with E>2.4 MeV: 6.82 $m^{-2}s^{-1}$
^{232}Th flux rate with E> 2.4 MeV: 63.19 $m^{-2}s^{-1}$

Water Shielding Effect

- Water will block most of the radiation
- Biasing technique applied:
  - Multiple layers
  - Output flux from outer layer as input of inner layer
- 12m width water pool can suppress the background events contribution from lab wall to the level of below 1 count per year.

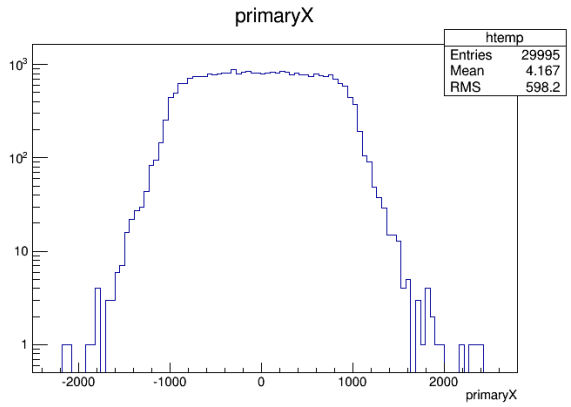


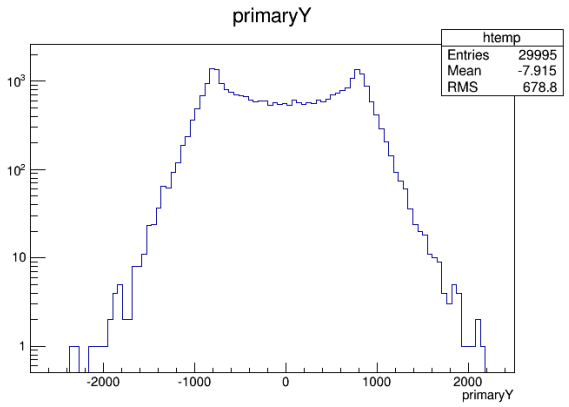
Background from Water

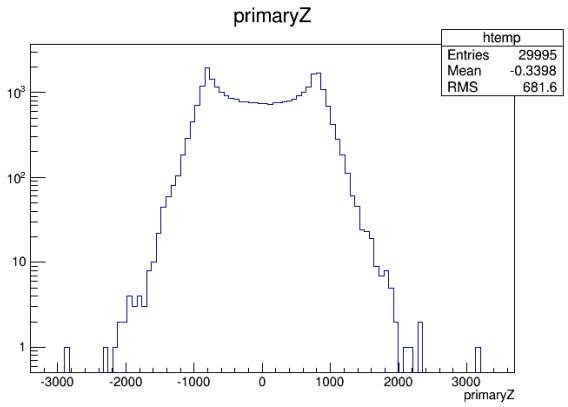
- Nearly all background in water comes from a region within 3 meters to the detector center and the background from outer region can be ignored.
- Input Activity 1 μBq/kg
  - ^{238}U(0.08ppt)
  - ^{232}Th(0.25ppt)

Source	Count per year
^{238}U	0.60
^{232}Th	1.71

at %1 FWHM







Background from Vessel

- Pressure-retain version: 15cm in endcap, 3cm in wall.
- Mass: 7721.74 kg.

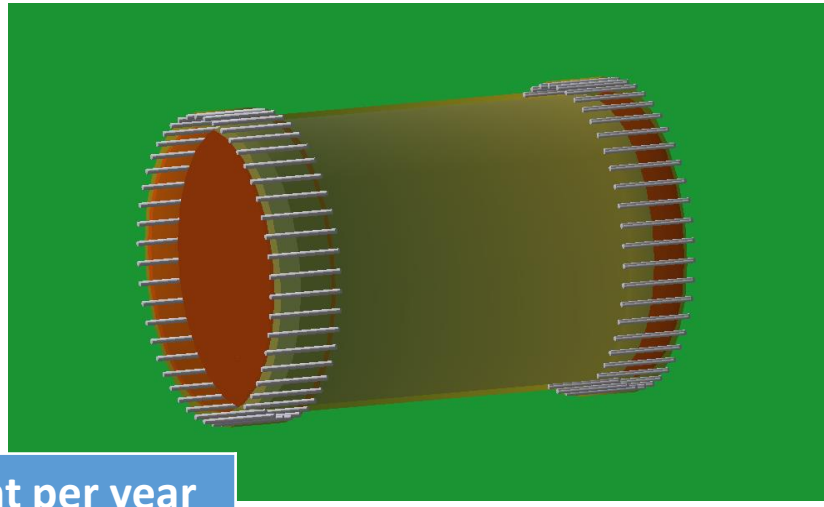
Source	Activity (μBq/kg)	Count Per Year
^{238}U	1	4.44
^{232}Th	1	14.78
^{60}Co	100	57.6

at %1 FWHM

It's very hard to obtain copper with such a high purity. If the activity of ^{238}U and ^{232}Th is 20 μBq/kg, then we may expect more than 400 counts per year from vessel!

Background from Bolts

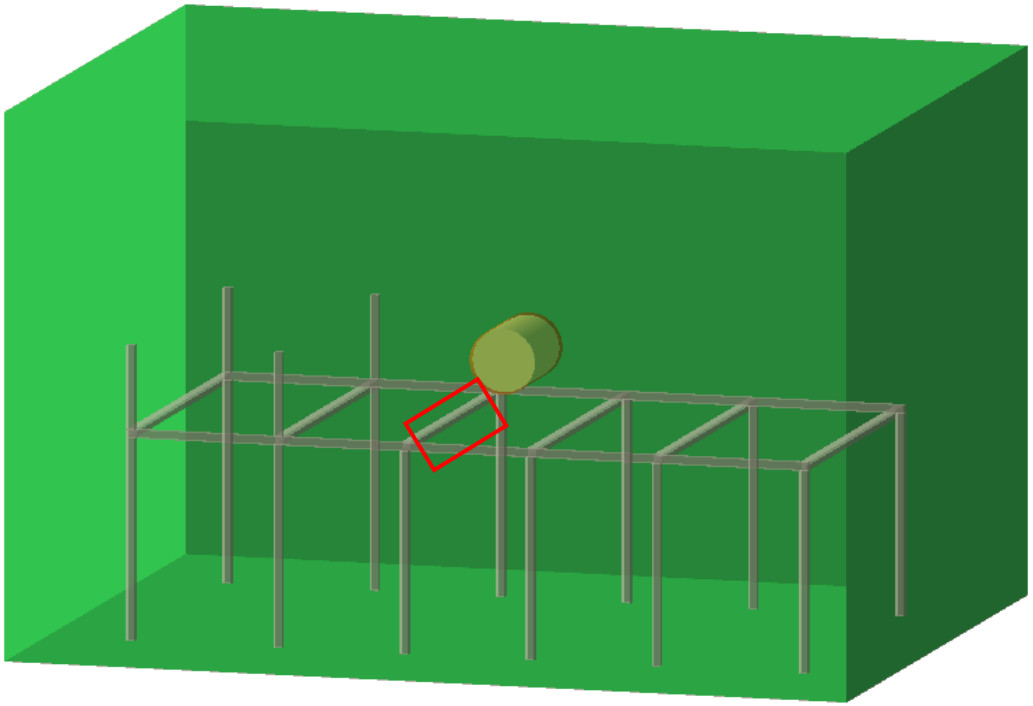
- 48x2 stainless steel bolts
- 189.3 kg



Source	Activity (mBq/kg)	Count per year
U238	10	95.04
Th232	10	381.28

Another main source of backgrounds!

Background from Supporting Structure



- Supporting structure with stainless steel.
- Consider the background from nearest steel frame (8.2x0.2x0.2m3, 2624kg).

Source	Activity (mBq/kg)	Count per year
U238	4	0.611
Th232	4	1.477

at %1 FWHM

The contribution is from only one bar. The final results should be doubled.

Background from Electronics

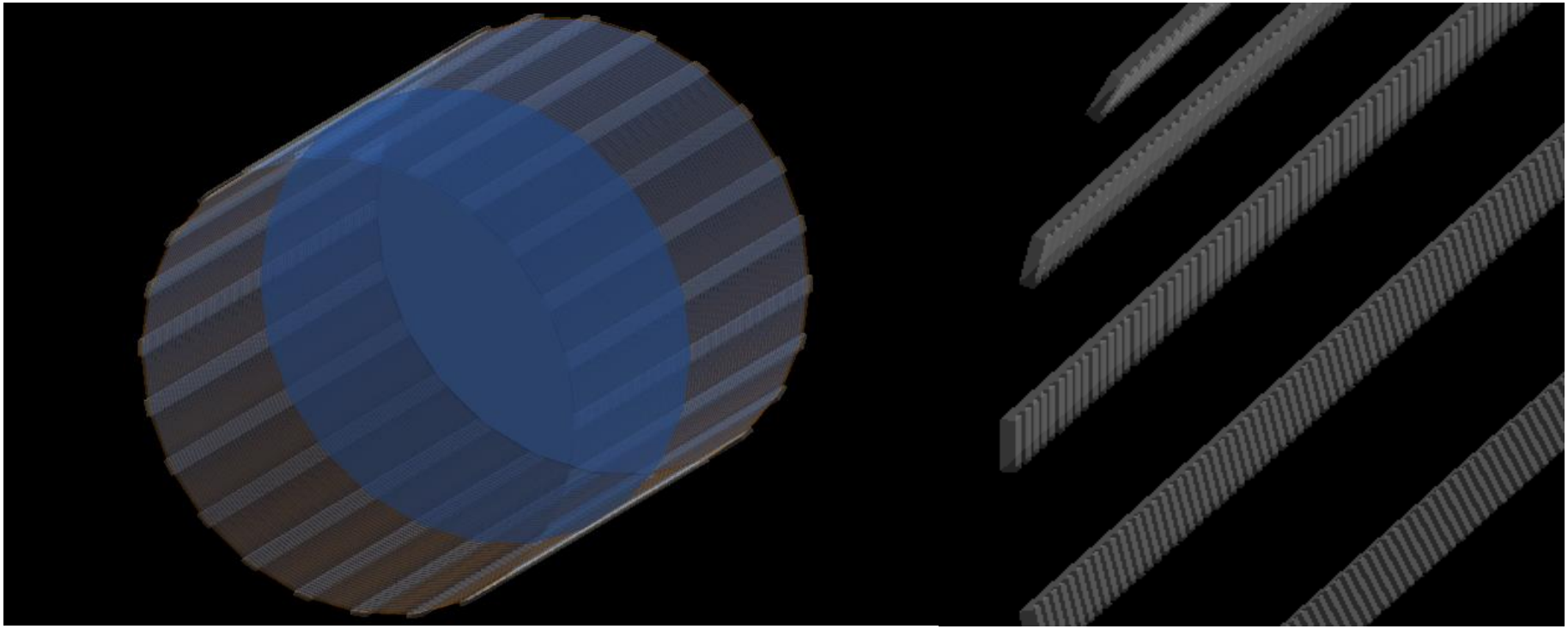
PANDA X

- The detailed geometry of electronics is not determined now. Just assuming the total activity of 1Bq for each type of unstable source.
- Placed out side the copper vessel

Source	Activity (Bq)	Count Per Year
^{238}U	1	6.24
^{232}Th	1	14.94

at %1 FWHM

The TPC



Field cage with copper shaping rings and Teflon supporting bars.

Background from the Shaping Ring and supporting bar

- Inner radius 720 mm
- 95 rings – 193.2 kg

Shaping rings contribute 1/10 backgrounds as those from the vessel.

Source	Activity (μBq/kg)	Count Per Year
^{238}U	1	0.73
^{232}Th	1	2.13

- Teflon bar – 36.14 kg

Source	Activity (μBq/kg)	Count Per Year
^{238}U	9.6	0.42
^{232}Th	1.1	4.63

at %1 FWHM

Background from ^{222}Rn

- Total volume is 3.496 m^3

Source	Activity (μBq/m^3)	Count Per Year
^{222}Rn	10*	1.417

at %1 FWHM

*Just an estimation.

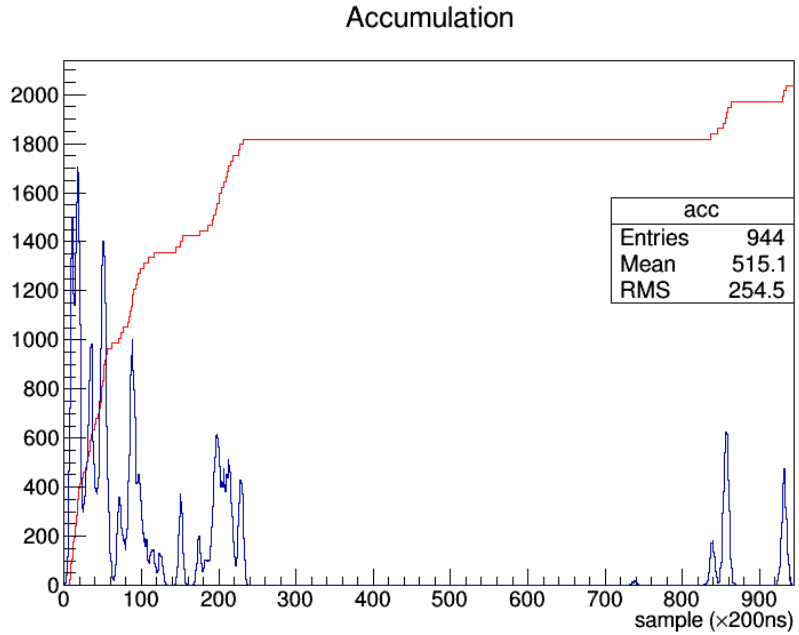
Background from MicroMegas

- The unit activity is low, but the area is too large ~ 3.3 m^2.
- The values are even higher than those from vessel.

Source	Activity (μBq/cm^2)	Count Per Year
^{238}U	0.1	43.69
^{232}Th	0.1	47.44

Considering Trigger

- Convert energy deposition to electrons
- Collect electrons in limited readout window (102.4μs, 5MHz sample rate, 512 samples).
- Considering trigger and readout window would help to suppress the background.



Blue: electrons collected over time

Red: accumulated electrons collected over time

Results with Trigger

Components	Source	Activity	Count per year
Water	^{238}U	1 μBq/kg	0
	^{232}Th	1 μBq/kg	0.84
Vessel	^{238}U	20 μBq/kg	8.8
	^{232}Th	20 μBq/kg	123.2
	^{60}Co	100 μBq/kg	4.87
Bolts	^{238}U	10 mBq/kg	4.09
	^{232}Th	10 mBq/kg	164.92
MicroMegas	^{238}U	0.1 μBq/cm^2	25.74
	^{232}Th	0.1 μBq/cm^2	17.83
Rings	^{238}U	1 μBq/kg	0.32
	^{232}Th	1 μBq/kg	0.73
Supporting Bar	^{238}U	9.6 μBq/kg	0.18
	^{232}Th	1.1 μBq/kg	1.65
Gas	^{222}Rn	10μBq/m^3	1.13

Total: 354.3 count/year

Summary and Outlook

- We studied the background of PandaX-III with Geant4 based MC, using a reference geometry and expected input activity.
- The background count is too high even considering the limited readout window.
- Main background comes from the vessel and bolts.
- The ability of tracking of the detector is not considered in current study, but it is expected to help to suppress the background greatly.