Status and background considerations of XMASS experiment

Yeongduk Kim
Sejong University

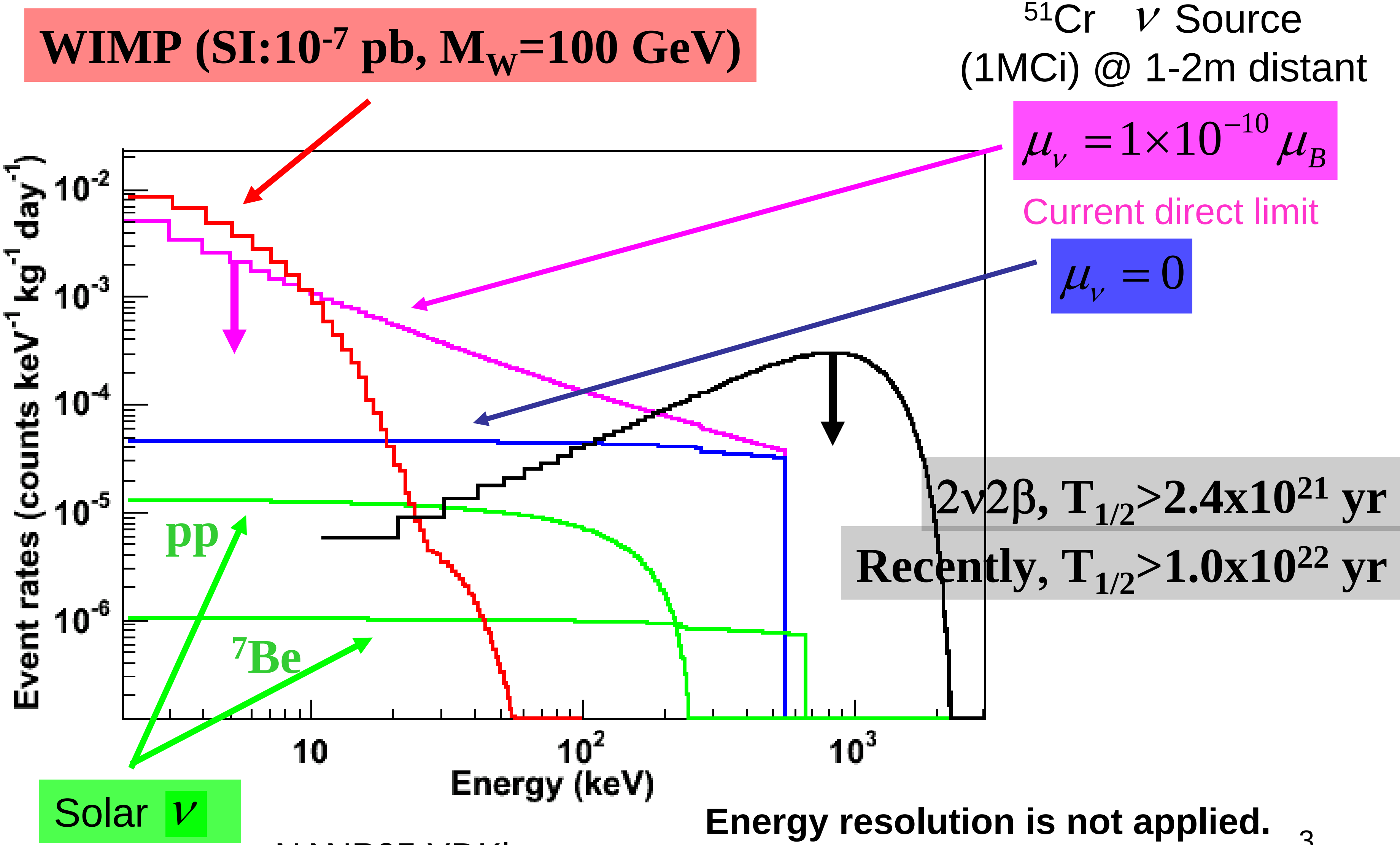
for the XMASS collaboration

LRT2006
Oct. 1-4, 2006
Aussois, France

Outline

1. Various signal rates in large LXe detector
2. 800kg detector design
3. Gamma backgrounds in 800 kg detector
4. Neutron backgrounds
5. Possible calibration sources

Signals expected with natural LXe

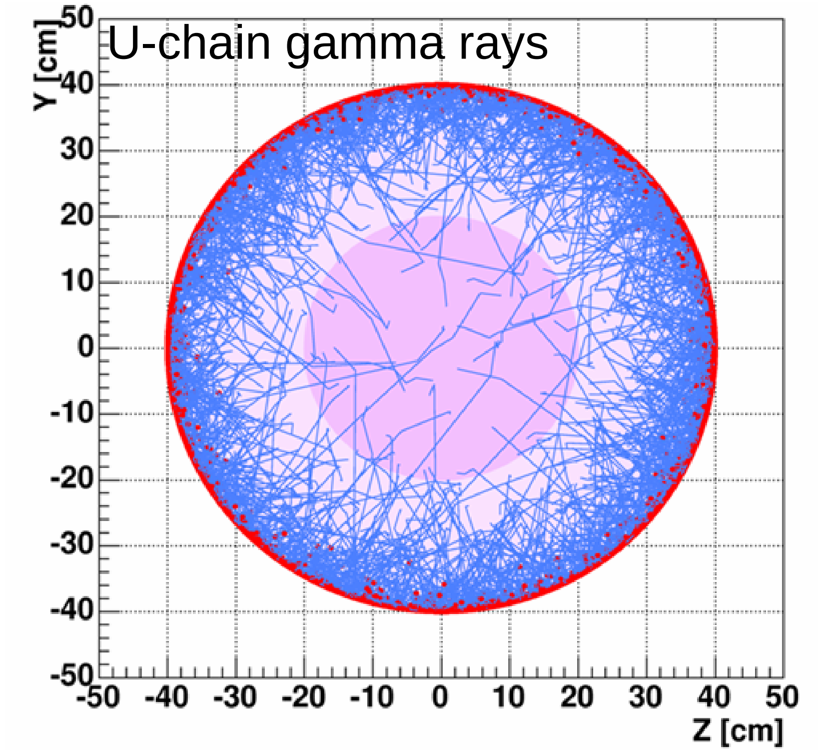


Energy resolution is not applied.

NANP05 YDKim

XMASS : homogeneous single phase LXe detector.
Confining FV→self shielding effect for low energy events

γ tracking MC from external to Xenon



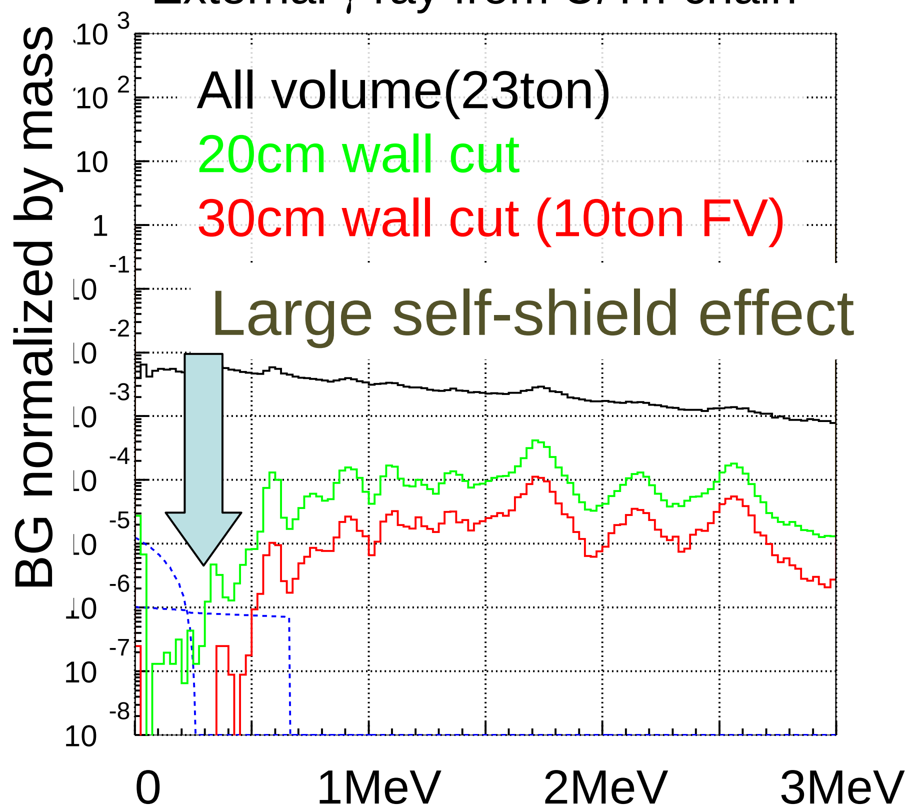
Blue : γ tracking

Pink : whole liquid xenon

Deep pink : fiducial volume

Total 800kg, 100kg FV

External γ ray from U/Th-chain



Background are widely reduced in < 500keV low energy region

Status of 800 kg detector

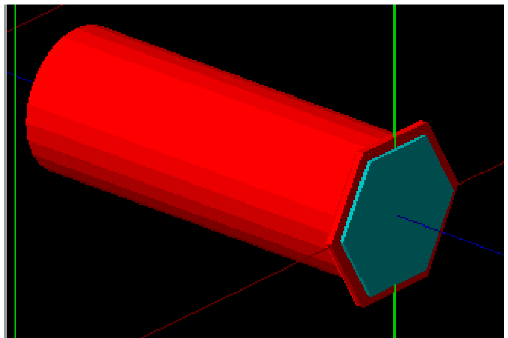
- **Basic performances have been confirmed by100 kg prototype detector.**
  - ✓ Vertex and energy reconstruction by likelihood fitting
  - ✓ Self shielding power.
  - ✓ BG level(~10^{-2} dru @ 100 keV, consistent with MC).

- **Detector design is under progress using MC**
  - ✓ Structure and PMT arrangement (812 PMTs)
  - ✓ Event reconstruction
  - ✓ BG estimation

- **New experimental hall will be prepared.**
  - ✓ Necessary size of shielding around the chamber

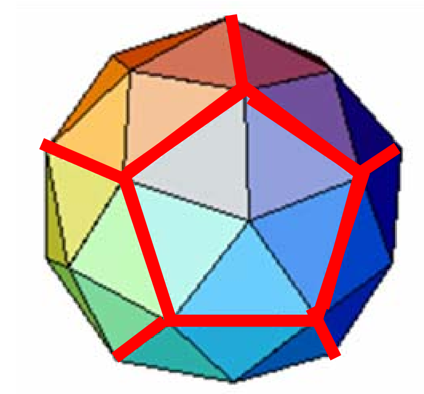
Structure of 800 kg detector

- tried to optimize the photocathode coverage.
- tried to minimize the wall effect.

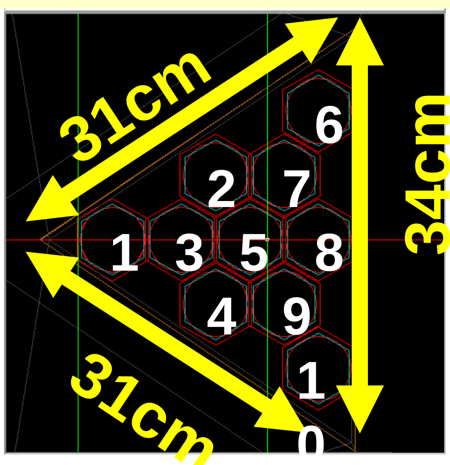


Hexagonal PMT

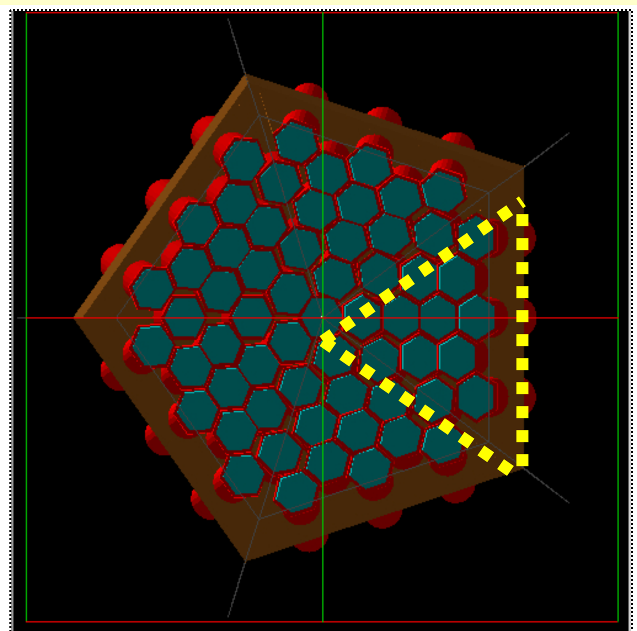
12 pentagons / 60 triangles
pentakisdodecahedron

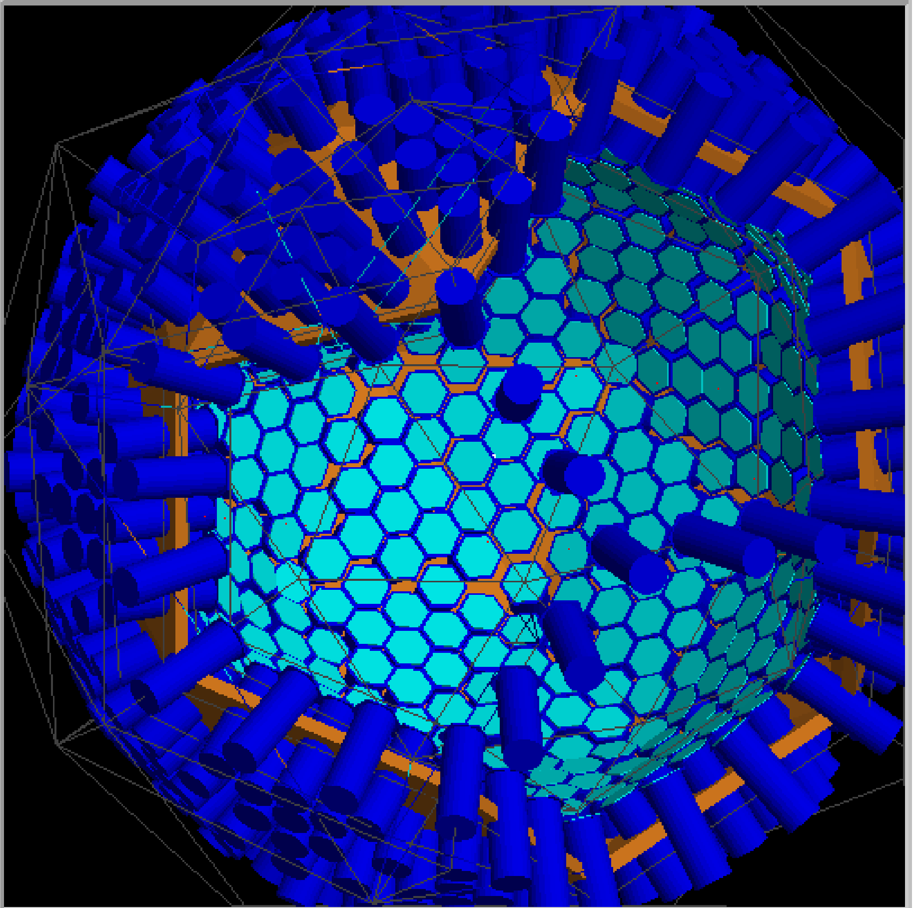


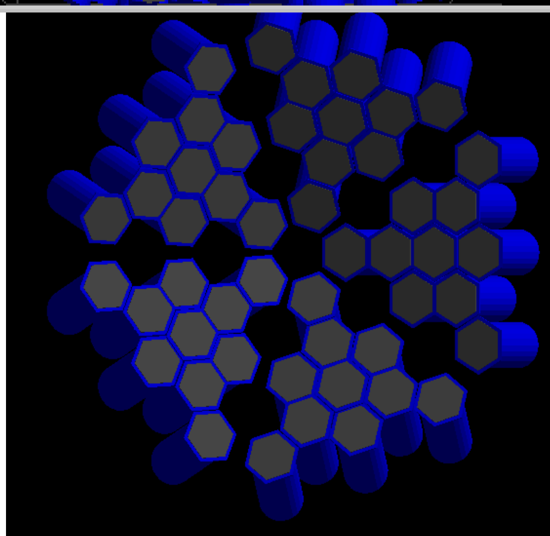
10 PMTs / triangle surface



5 triangles make pentagon





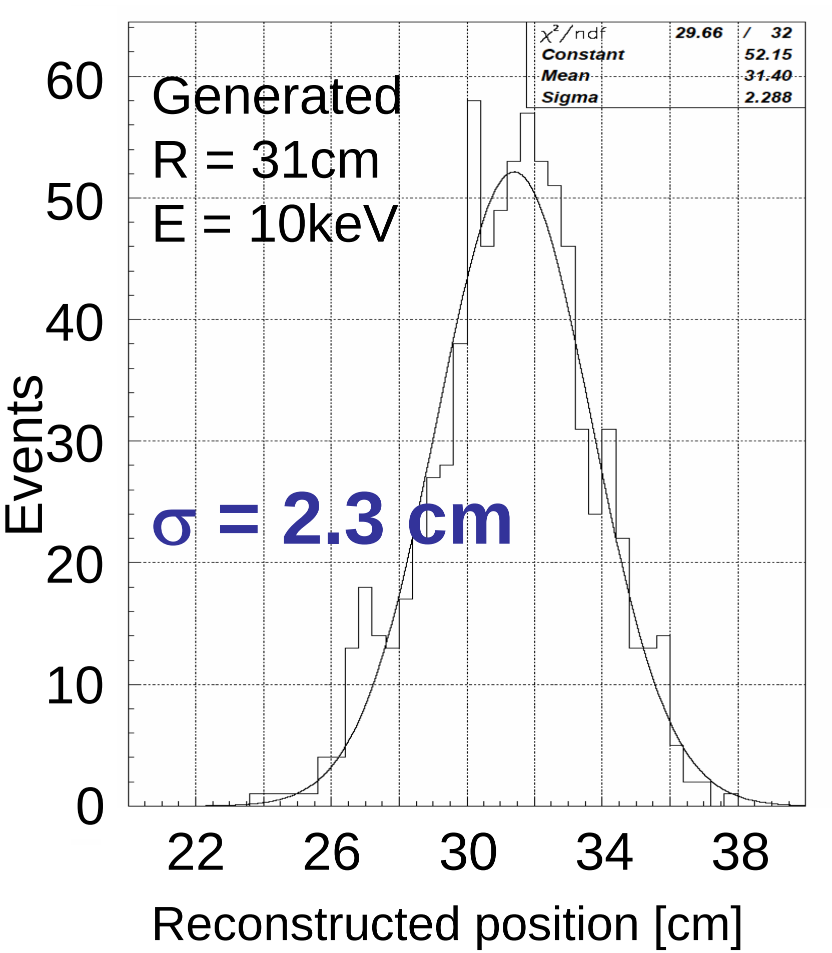


- Total **812** hexagonal **PMTs** immersed into liq. Xe
- **~70%** photo-coverage
- Radius to inner face **~44cm**

Each rim of a PMT overlaps to maximize coverage

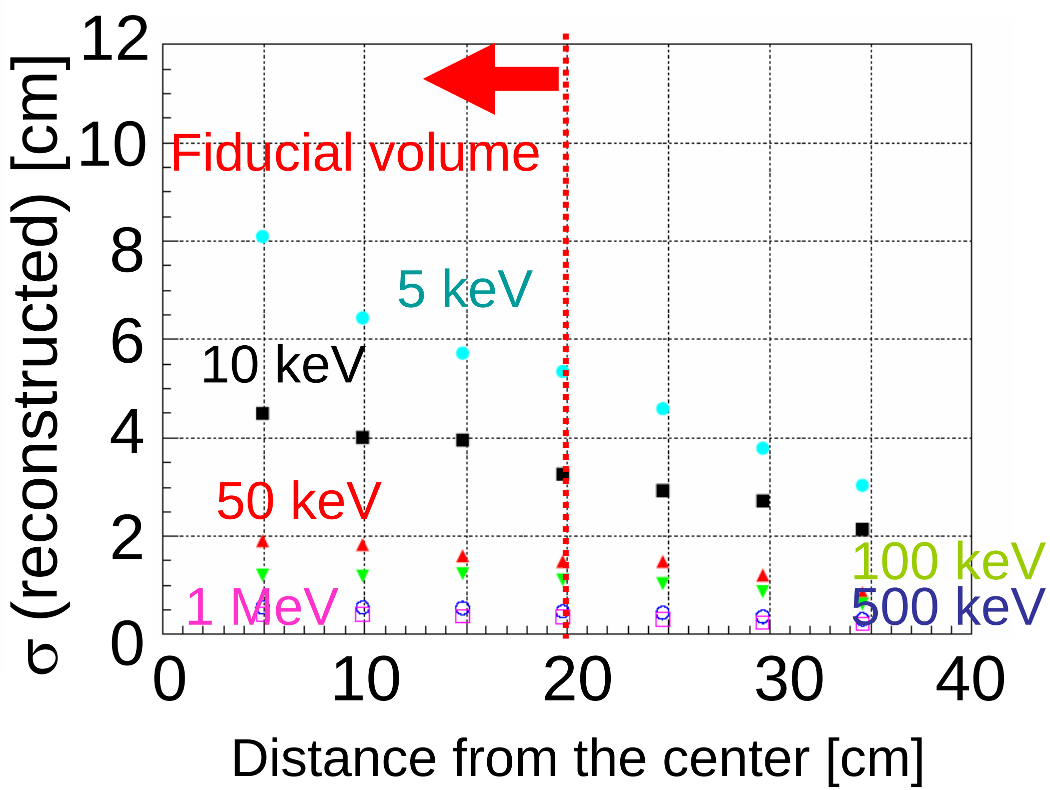
Event reconstruction(Simulation)

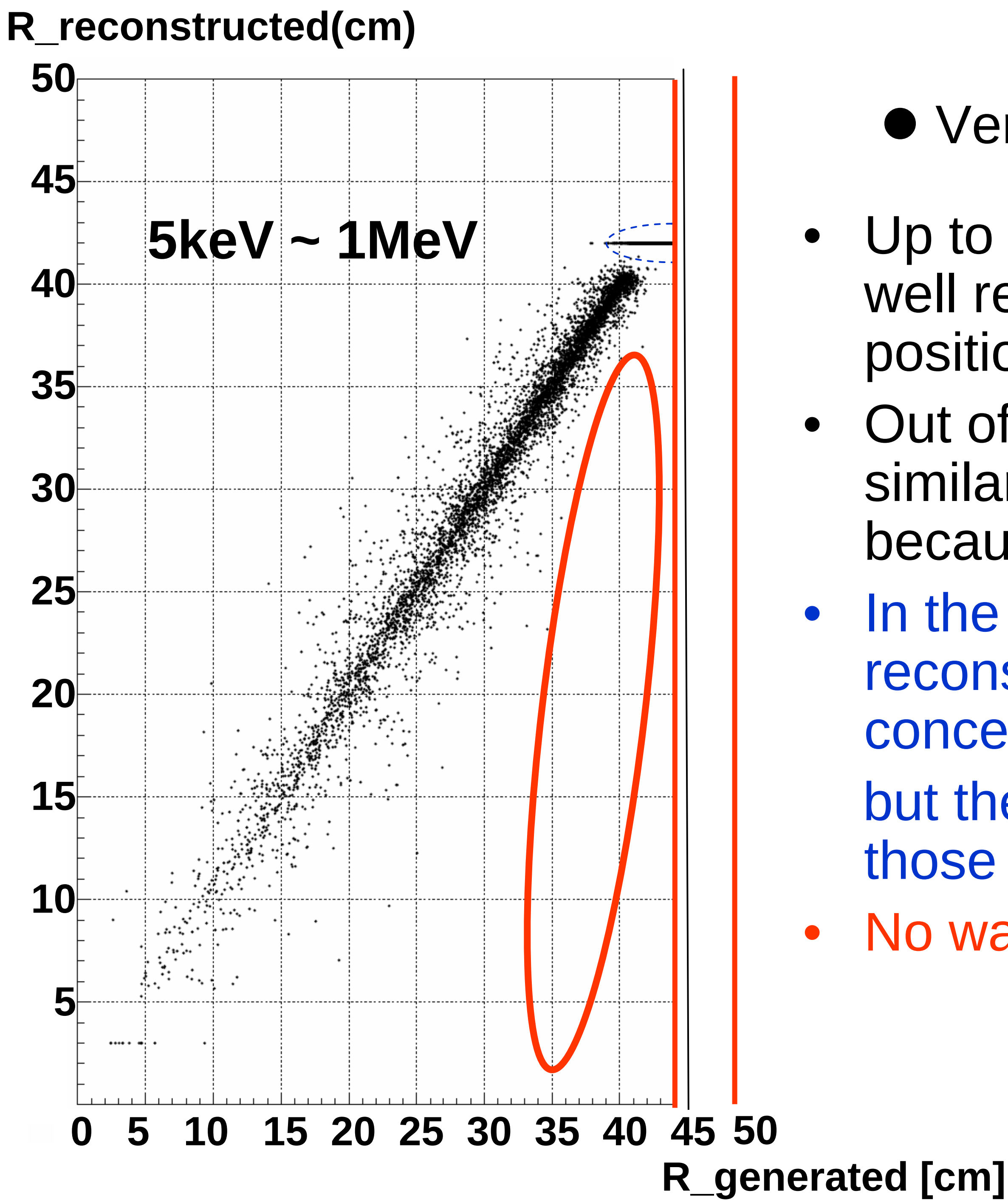
- Position resolution



Boundary of fiducial volume

10 keV ~ 3.2 cm
5 keV ~ 5.3 cm





- Vertex reconstructed

- Up to <~40cm, events are well reconstructed with position resolution of ~2~3cm
- Out of 42cm, grid whose most similar distribution is selected because of no grid data
- In the 40cm~44cm region, reconstructed events are concentrated around 42cm, but they are not mistaken for those occurred in the center
- No wall effect

800kg BG study

Achieved (prototype detector)		Goal (800kg detector)
γ ray from PMTs ~ 10^{-2} cpd/kg/keV	1/100 →	10^{-4} cpd/kg/keV
^{238}U = $(33 \pm 7) \times 10^{-14}$ g/g	1/33 →	1×10^{-14} g/g
^{232}Th < 23×10^{-14} g/g (90% C.L.)	1/12 →	2×10^{-14} g/g
Kr = 3.3 ± 1.1 ppt	1/3 →	1 ppt

- γ ray from PMTs ~ 10^{-2} cpd/kg/keV
  → Increase volume for self shielding
  → Decrease radioactive impurities in PMTs (~1/10)

- Liquid Xenon

  ^{238}U = $(33 \pm 7) \times 10^{-14}$ g/g
  → Remove by filter

  ^{232}Th < 23×10^{-14} g/g (90% C.L.)
  → Remove by filter (Only upper limit)

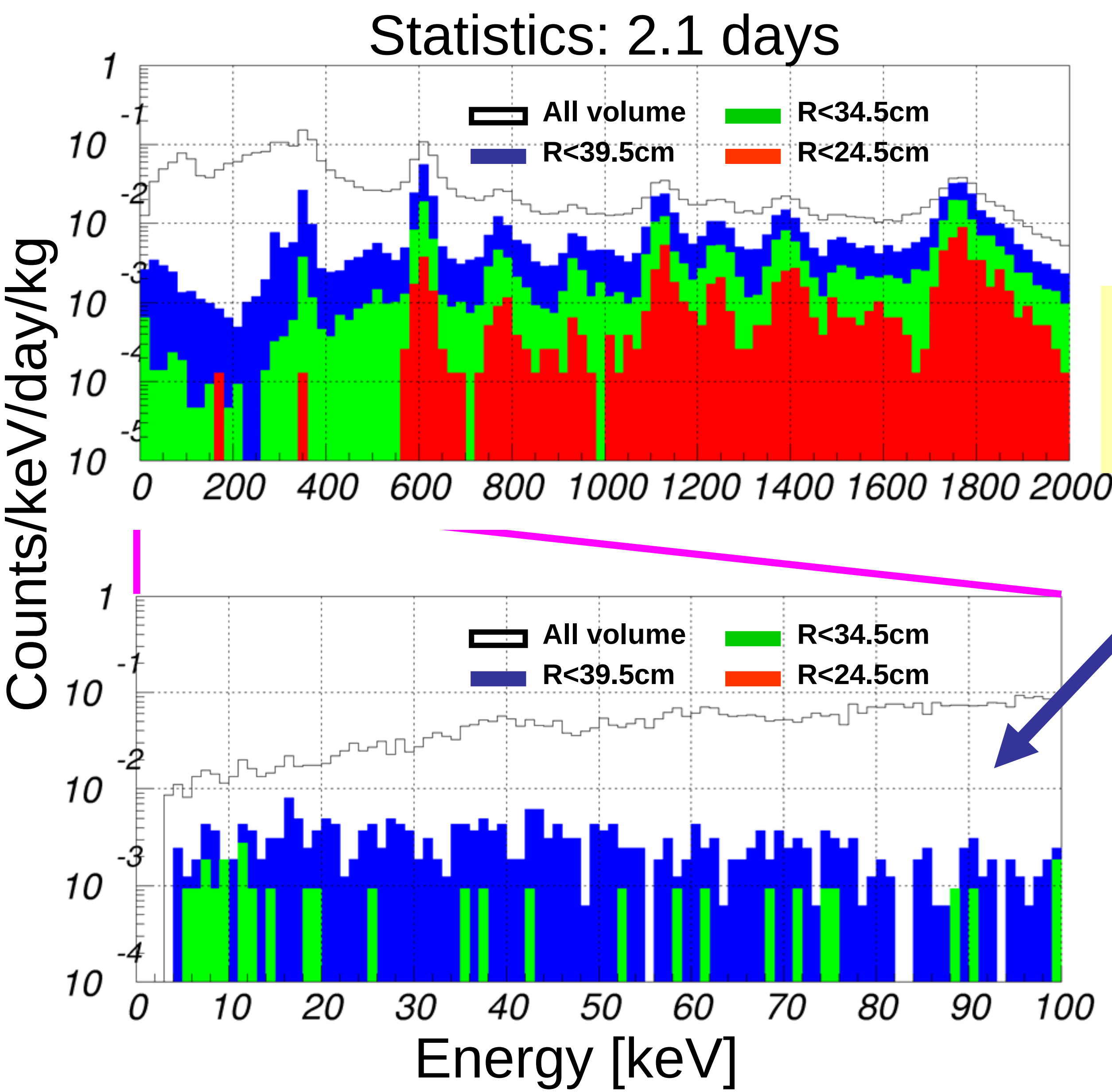
  Kr = 3.3 ± 1.1 ppt
  → Achieve by 2 purification pass

Estimation of γ BG from PMTs

- **Inside PMT, put vacuum space, and ceramic board.**
- **Decays of ^{238}U at ceramic board is simulated.**
- **assumed 10 times lower background than present R8778 pmt. → 1.26 x 10^5 decays/day**
- **Used Geant4 for all sequential decays.**

R8778 PMT	**^{238}U : 1.8×10^{-2} Bq/PMT**
	^{232}Th : 6.9×10^{-3} Bq/PMT
	^{40}K : 1.4×10^{-1} Bq/PMT

Result of ^{238}U background



No event is found below 100keV after fiducial cut (R<24.5cm)

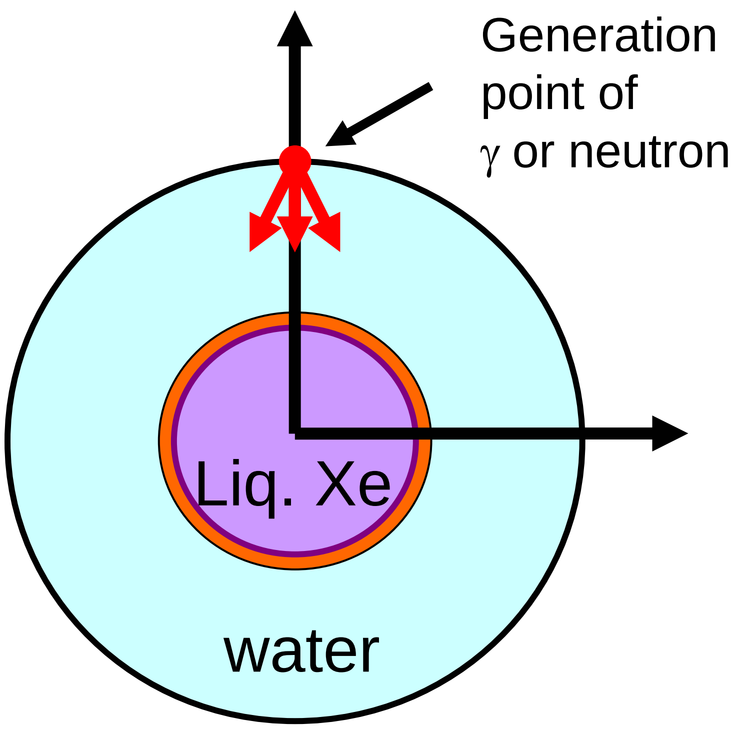
$< 1\times10^{-4}$ cpd/kg/keV can be achieved

(Now, more statistics is accumulating)

Shielding size should be estimated to fix the size of the new hall.

A proposal of shielding for 800kg detector

- Water shield for both ambient gammas and fast neutrons.
- Simple, not expensive, good for neutrons



MC geometry

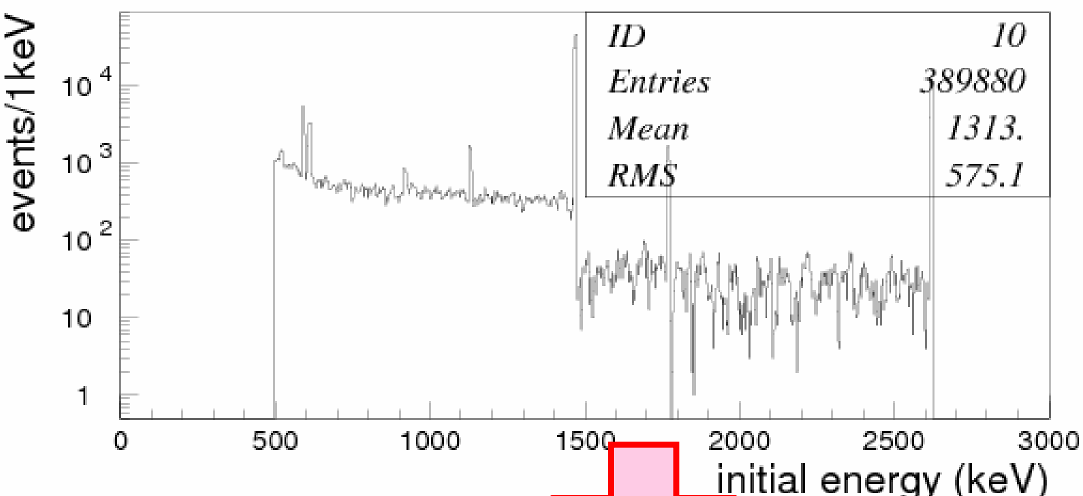
Configuration for simple estimation

- Put 80cm diameter liquid Xe ball
- Assume several size of water shield of 50 – 300cm thickness.
- Assume copper vessel (2cm thickness) for liquid Xe.
- Actual shape may be cylinder, but assumed as sphere for simplicity of MC.

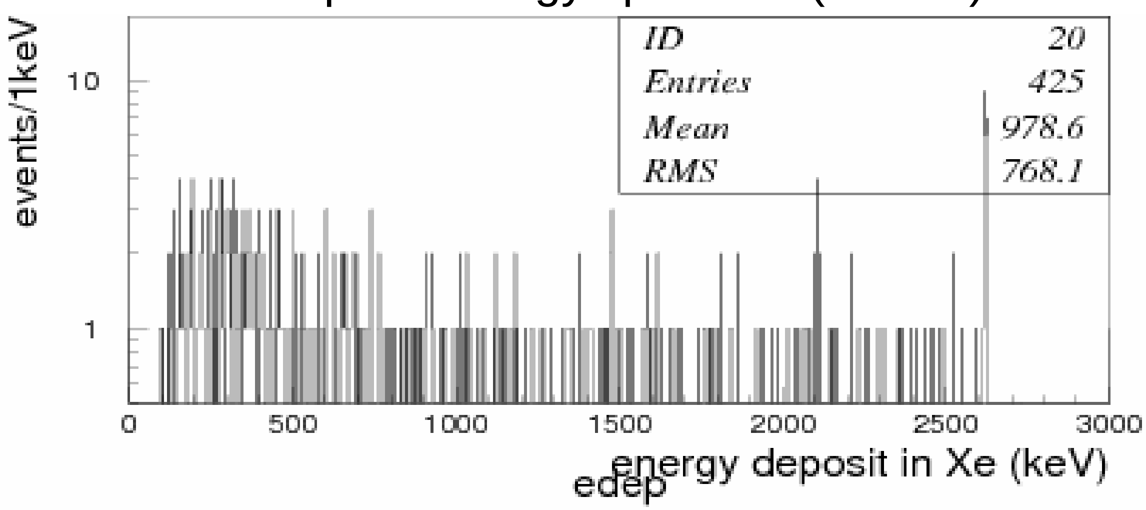
There are technical issues to be solved.

(1) γ attenuation

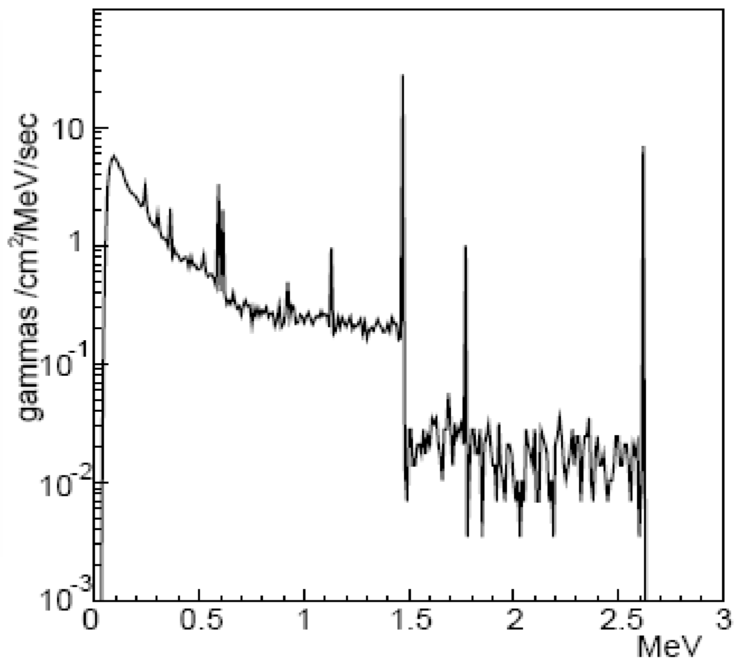
Initial energy spectrum from the rock



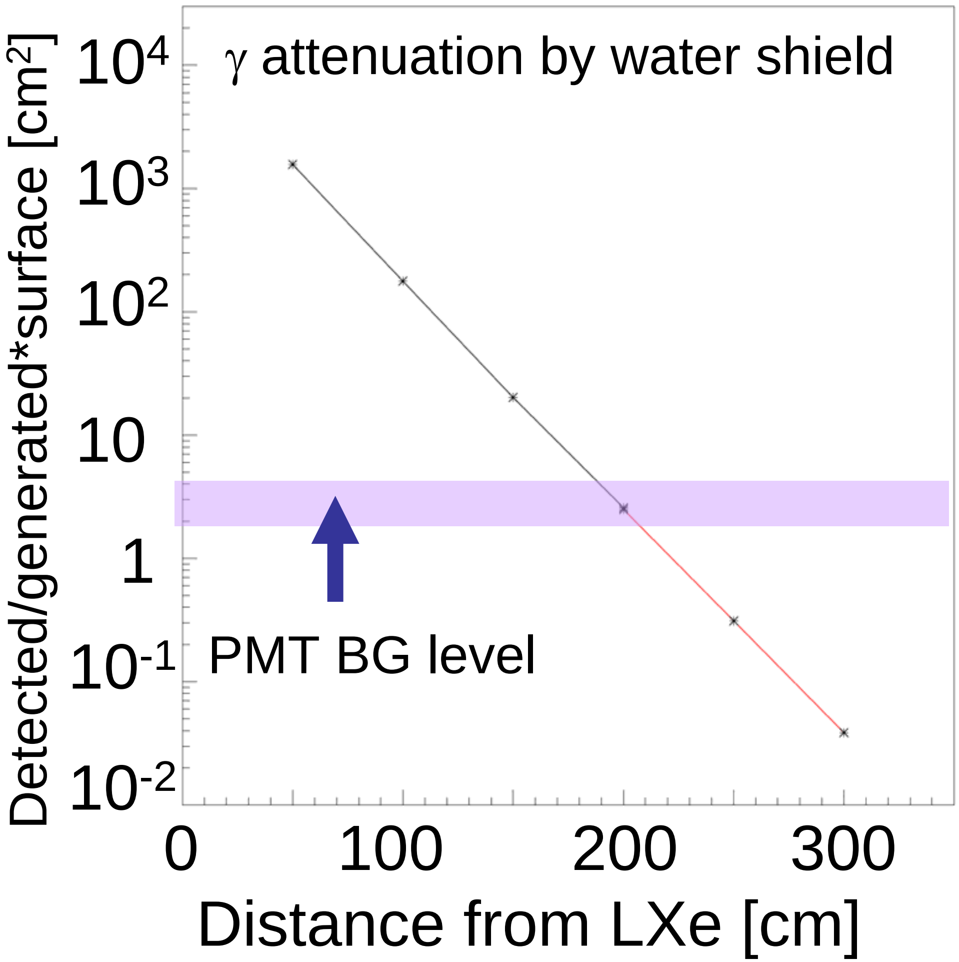
Deposit energy spectrum (200cm)



Gamma ray spectrum in the mine

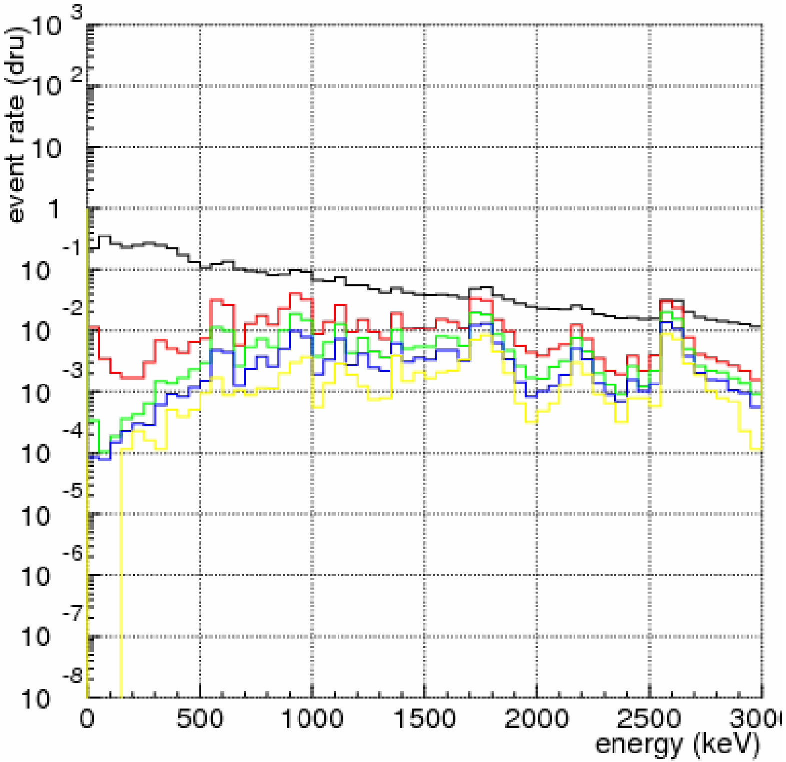


Total # of gammas
E>500keV
~ $0.7/cm^2/sec$



More than 200cm water is Needed to reduce the BG to the PMT BG level

Pmt backgrounds

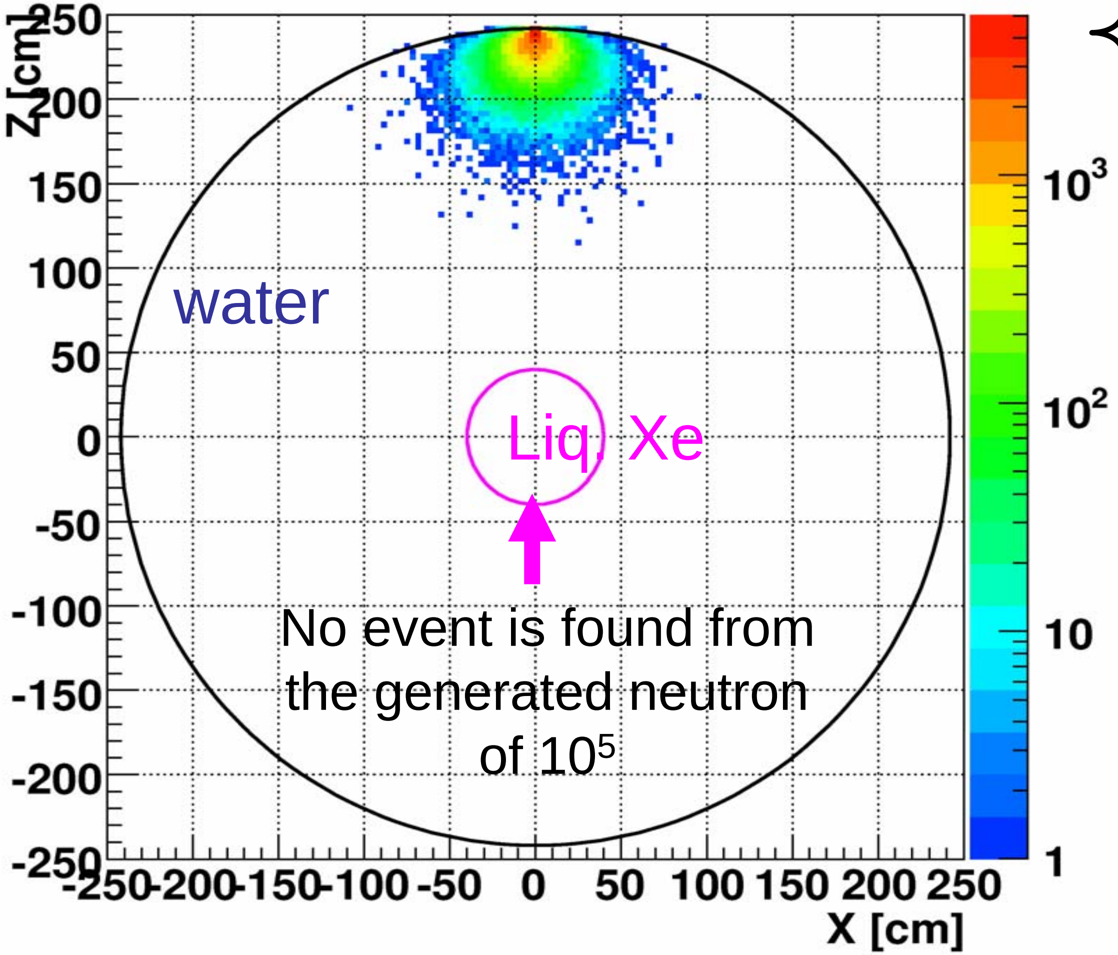


- Sum up the total histogram = 4.65
- 4.65*50(keV/bin)*804(kg)/86400(sec/day) →2.2Hz

(2) Fast neutron attenuation

10^5 neutrons(=0.14days) generated.

water: 200cm, n: 10MeV



- Fast n flux @Kamioka mine: $(1.15\pm0.12)\times10^{-5}$ /cm2/sec
- Assuming all the energies are 10 MeV conservatively

$< 2\times10^{-2}$ counts/day/kg

~200cm water is enough to reduce the BG to the PMT BG level

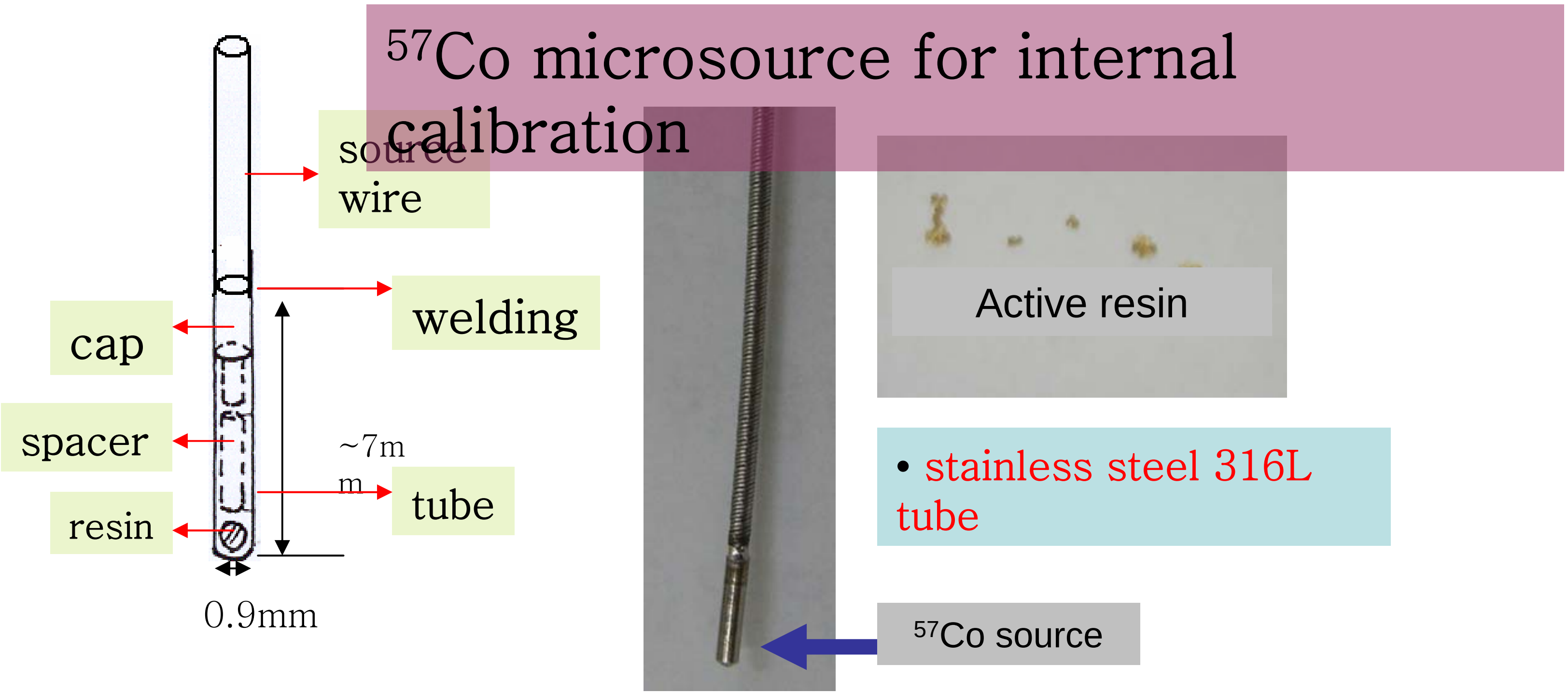
(BG caused by thermal neutron Is now under estimation)

Calibration Issues for homogeneous detector.

• to define fiducial volume for low energy events, we need to confirm the position resolution with definite source.

• Attenuation length of 20 keV gammas in LXe ~ 50 micrometer.

→ source size should be small.



• For lower energy and position calibration, need X-ray source.
• Electro deposition of I-125 on 20 micrometer metal wire is planned.
• Locate the wire source in many positions in LXe.

^{220}Rn(Thoron) source for position calibration

Beta-alpha coincidence events can be used to check the position resolution of low energy beta events since we know the position of alpha events acurately.

$$\boxed{{}^{228}_{90}Th \quad (1.9y)} \xrightarrow{\alpha} {}^{224}_{88}Ra \ (3.7d) \xrightarrow{\alpha} \boxed{{}^{220}_{86}Rn \quad (56s)} \xrightarrow{\alpha} {}^{216}_{84}Po \ (0.15s) \xrightarrow{\alpha} {}^{212}_{82}Pb \ (10h) \xrightarrow{\beta}$$

Longest $T_{1/2}$

$$\underset{(61m)}{{}^{212}_{83}Bi} \xrightarrow{\alpha} \underset{(3m)}{{}^{208}_{81}Tl} \xrightarrow{\beta} \underset{(stable)}{{}^{208}_{82}Pb} \ (36\%)$$

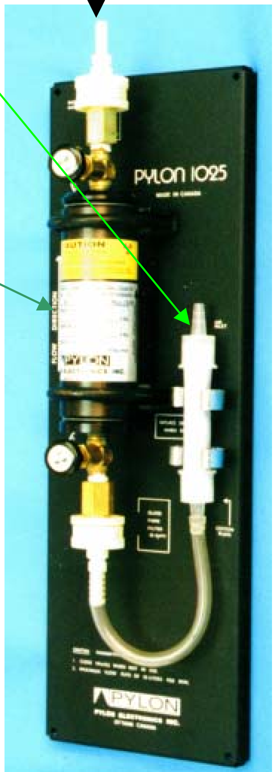
$$\boxed{\xrightarrow{\beta} \underset{(0.3\mu s)}{{}^{212}_{84}Po} \xrightarrow{\alpha} \underset{(stable)}{{}^{208}_{82}Pb} \ (64\%)}$$

Q=2.25MeV

$$\left|\vec{V}(\beta) - \vec{V}(\alpha)\right|$$

→ will give the position resolution of beta events.

Xe Gas In

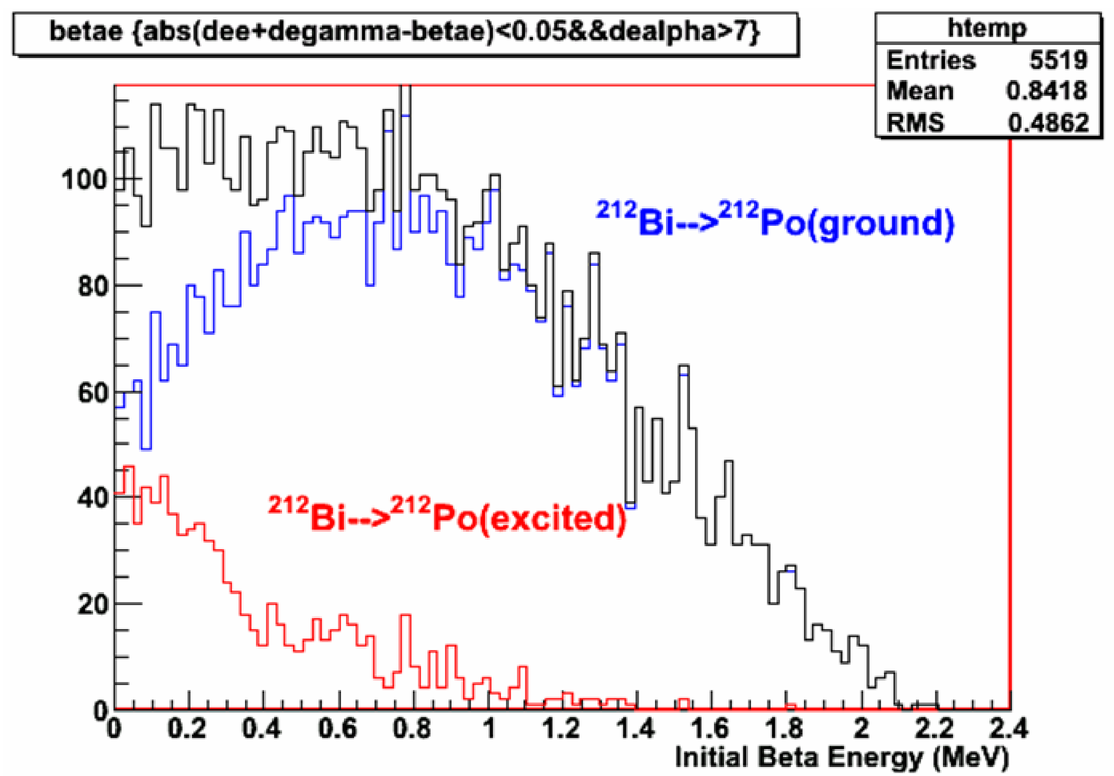


Since the chamber volume is small, most of the Rn gas will enter to Lxe chamber before decay.

If we flow 220Rn+ Xe gas for an hour, then within 10 minutes, most will be ^{212}Pb.

- For 10^5 beta-alpha coincidence events below E(beta)<100 keV with 10 hours data taking, the activity of ^{228}Th should be ~ 20 kBq.
- Whole volume of LXe can be studied.
- Is there any background left over ? → should be checked.

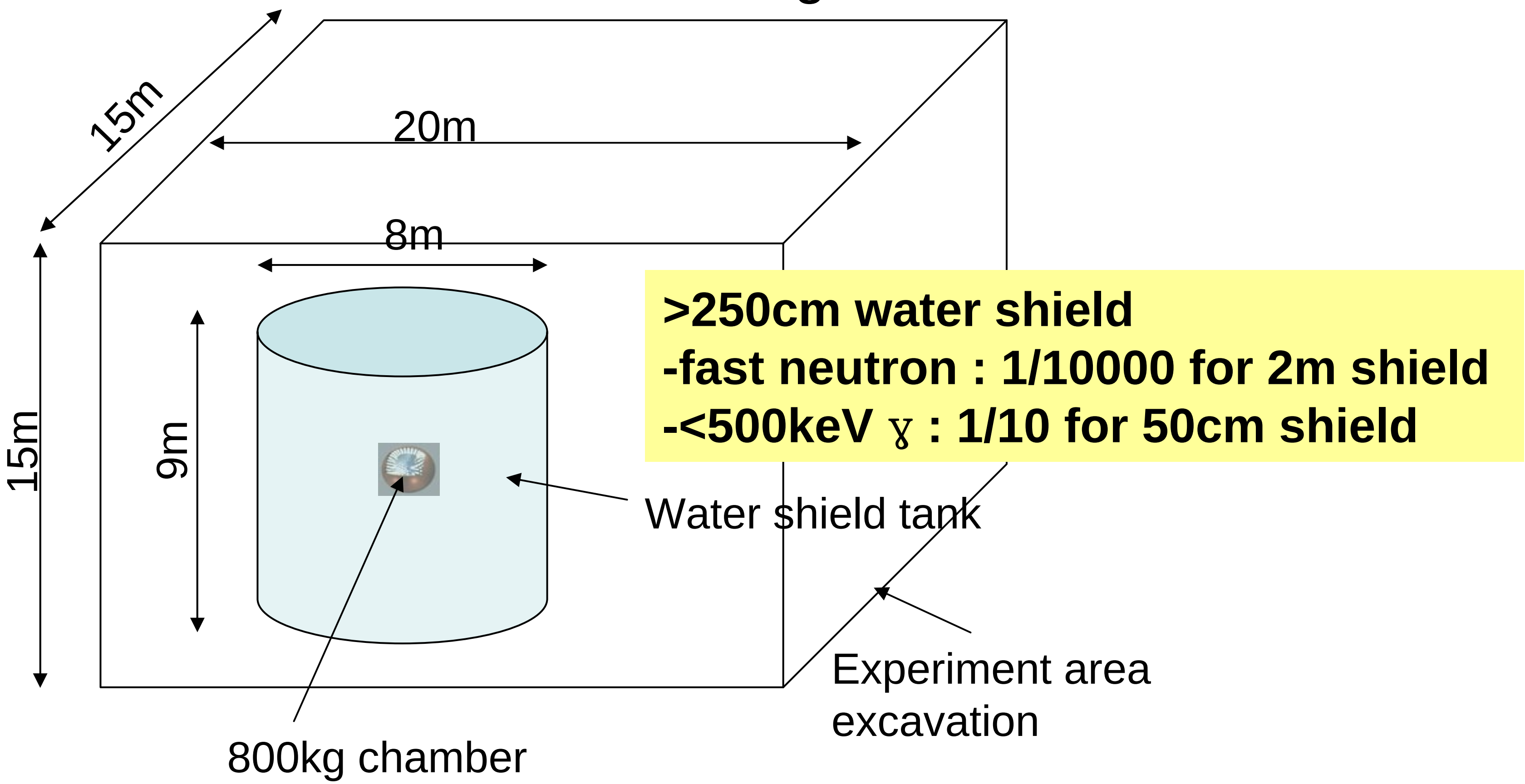
G4 simulation



Beta energy spectrum

New experimental hall will be made in kamioka mine for XMASS and other similar scale experiments.

※Tentative design



Other similar scale experiments such as CANDLES(DBD) can be housed.

Summary

- Multi-purpose ultra low background experiment with large mass liquid Xe.(ton scale)

- 800 kg detector:
  mainly for dark matter search.
  10^2 improvement of sensitivity
  above existing experiments is expected.

- Designing 800 kg detector is under progress.
  - ✓ BG estimation is done.
  - ✓ schematic shielding is studied.
  - ✓ New excavation is planned.
  - ✓ Hamamatsu PMT will be fixed, detail design is going on.