XMASS, Status of 800 kg detector design

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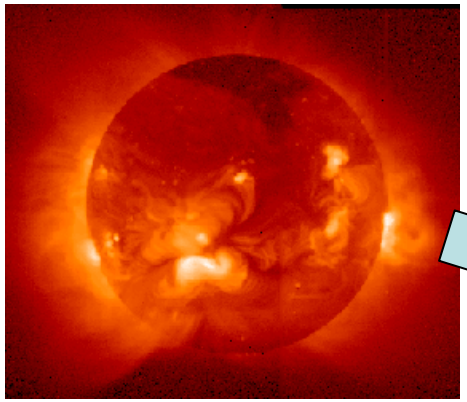
1. Introduction

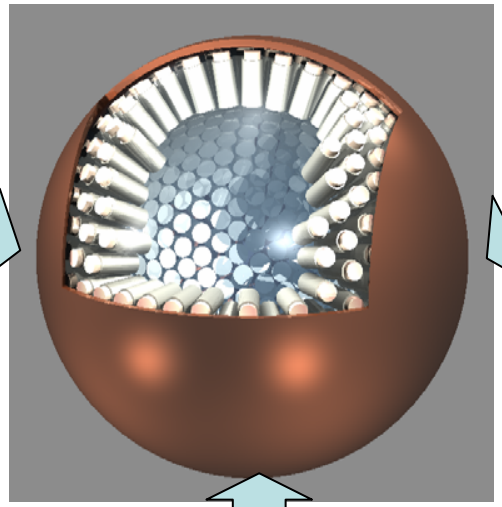
➢ What's XMASS

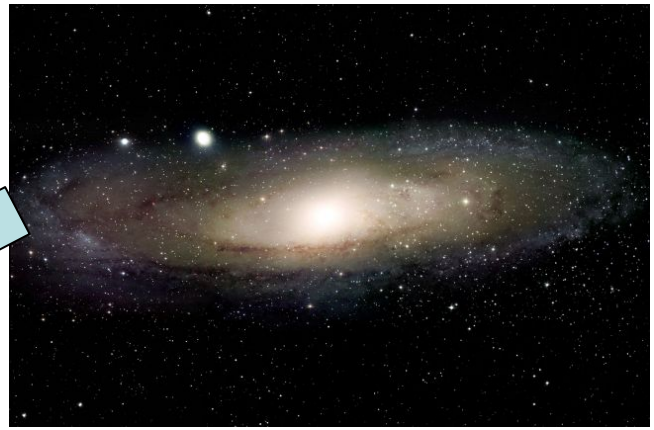
Multi purpose low-background experiment with liq. Xe

- **X**enon **MASS**ive detector for solar neutrino (**pp/^{7}Be**)
- **X**enon neutrino **MASS** detector (**bb decay**)
- **X**enon detector for Weakly Interacting **MASS**ive Particles (**DM search**)

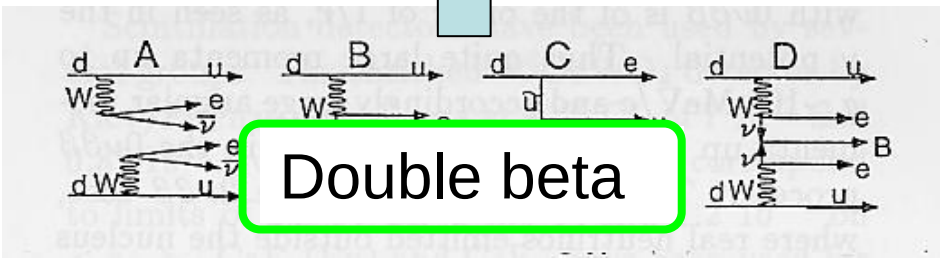


Solar neutrino





Dark matter

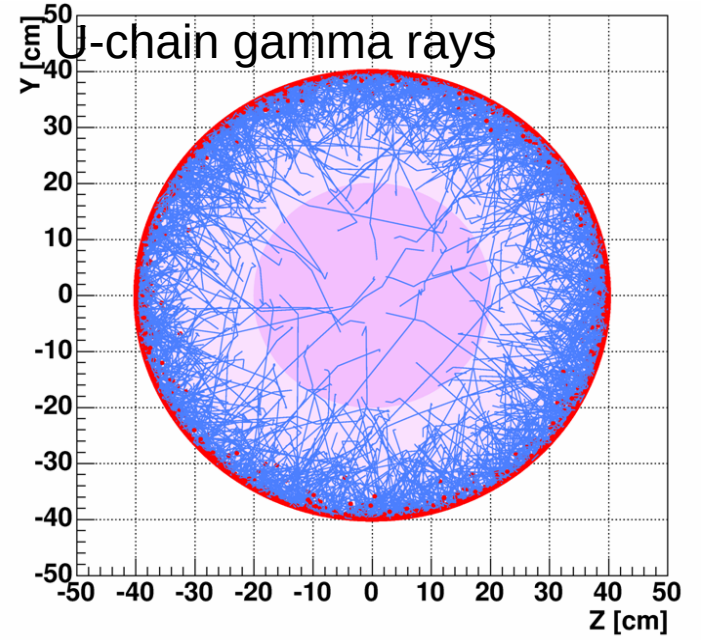


➢ Why liquid xenon

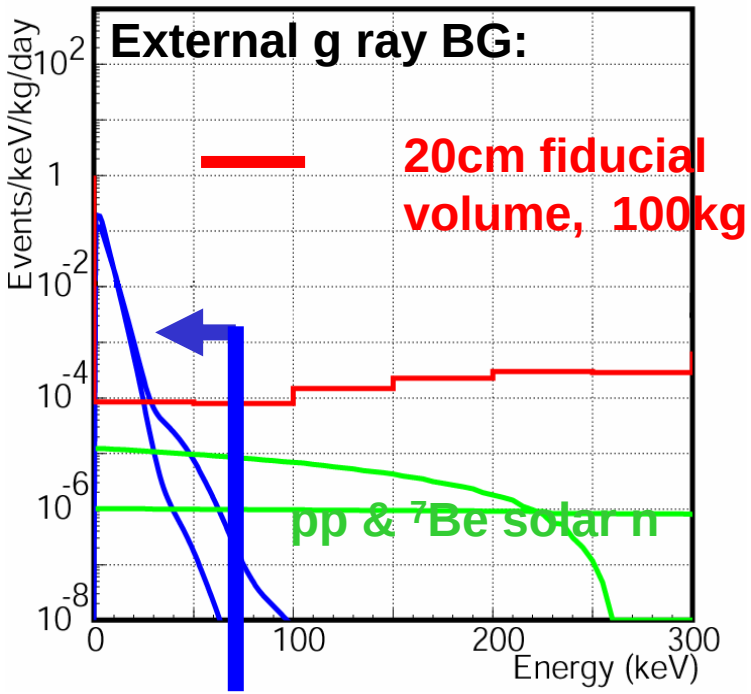
- **Large Z (=54)**
  Self-shielding effect
- **Large photon yield (~42 photons/keV ~ NaI(Tl))**
  Low threshold
- **High density (~3 g/cm^3)**
  Compact detector (10 ton: sphere with diameter of ~2m)
- **Purification** (**distillation**)
- No long life radioactive isotope
- Scintillation wavelength (175 nm, detected directly by PMT)

Target for 800kg : Dark Matter search

γ tracking MC from external to Xenon



Blue : γ tracking
Pink : whole liquid xenon
Deep pink : fiducial volume



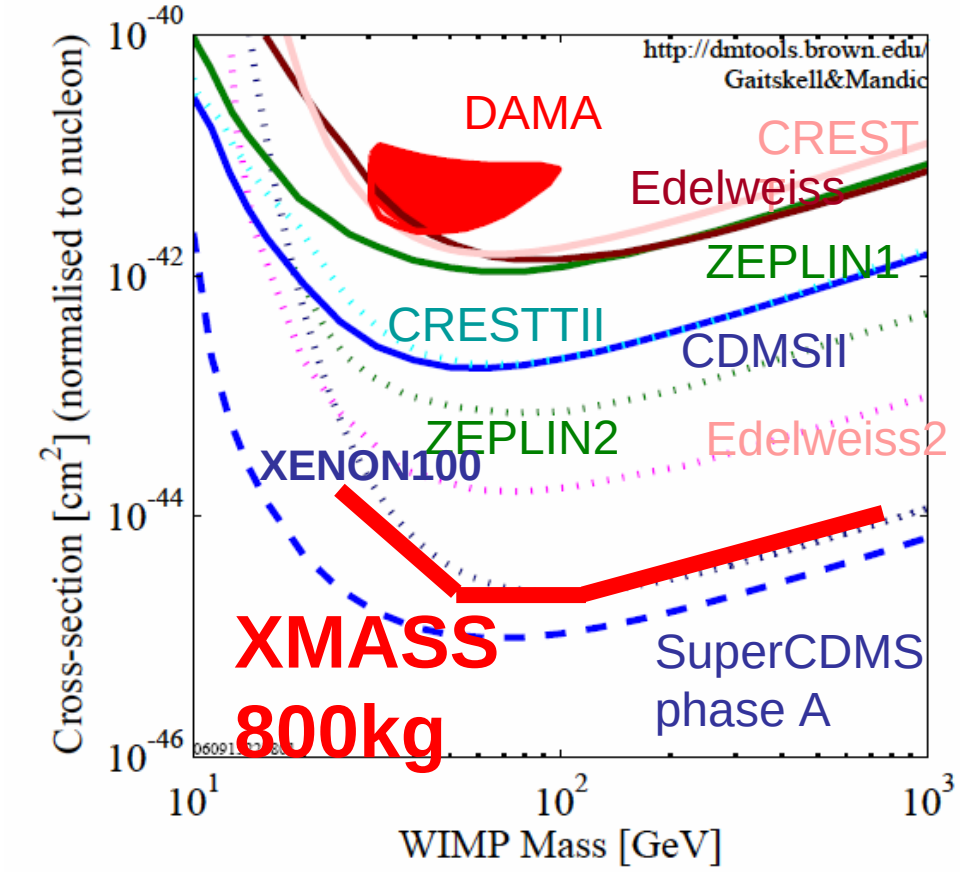
Expected dark matter signal (assuming 10^{-42} cm², Q.F.=0.2 50GeV / 100GeV,)

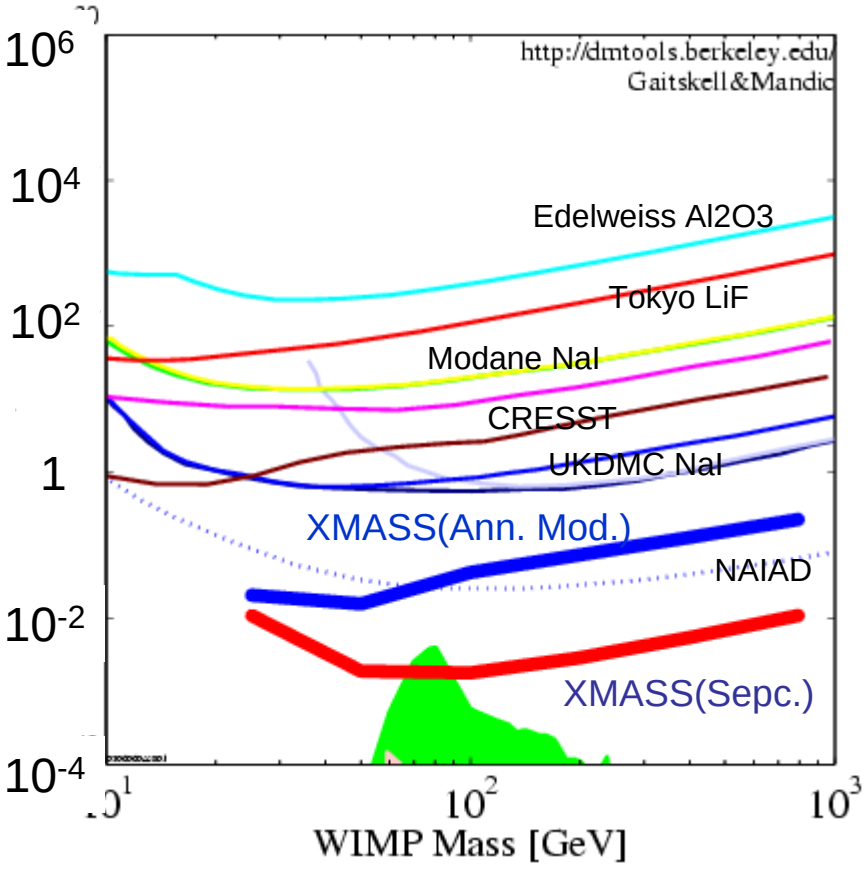
1. Dark matter search

1. With liquid xenon ~1ton, reduce BG below 100 keV to 10^{-4}/day/keV/kg by self shielding.
2. Search the signal from dark matter in low energy region.

Expected sensitivities

XMASS FV 0.5 ton year
Eth = 5 keVee~25 p.e., 3s discovery
w/o any pulse shape info.





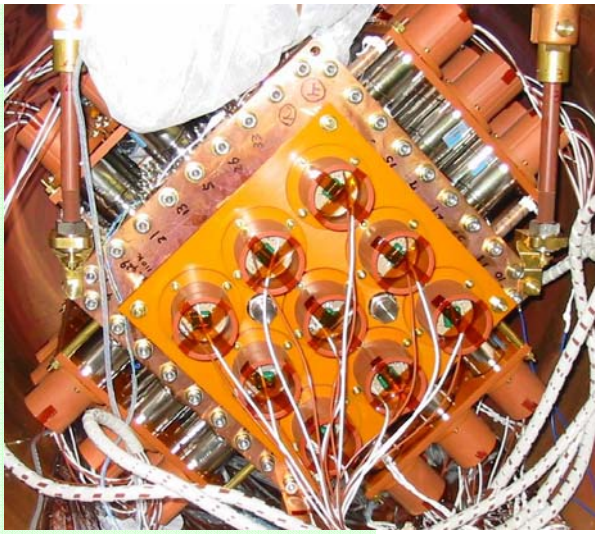
- Large improvements will be expected
  Two order higher than experimental results so far.

Plots except for XMASS:
http://dmtools.berkeley.edu
Gaitskell & Mandic

➢ Status of 800 kg detector

● **Basic performances have been already confirmed using prototype detector**

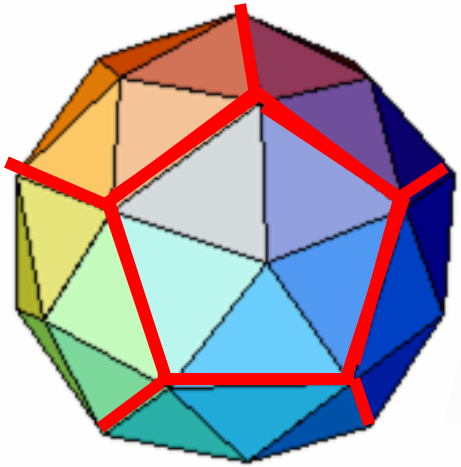
- ✓ Method to reconstruct the vertex and energy
- ✓ Self shielding power
- ✓ BG level

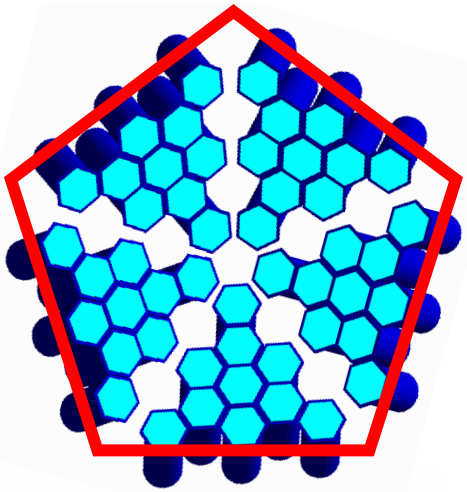


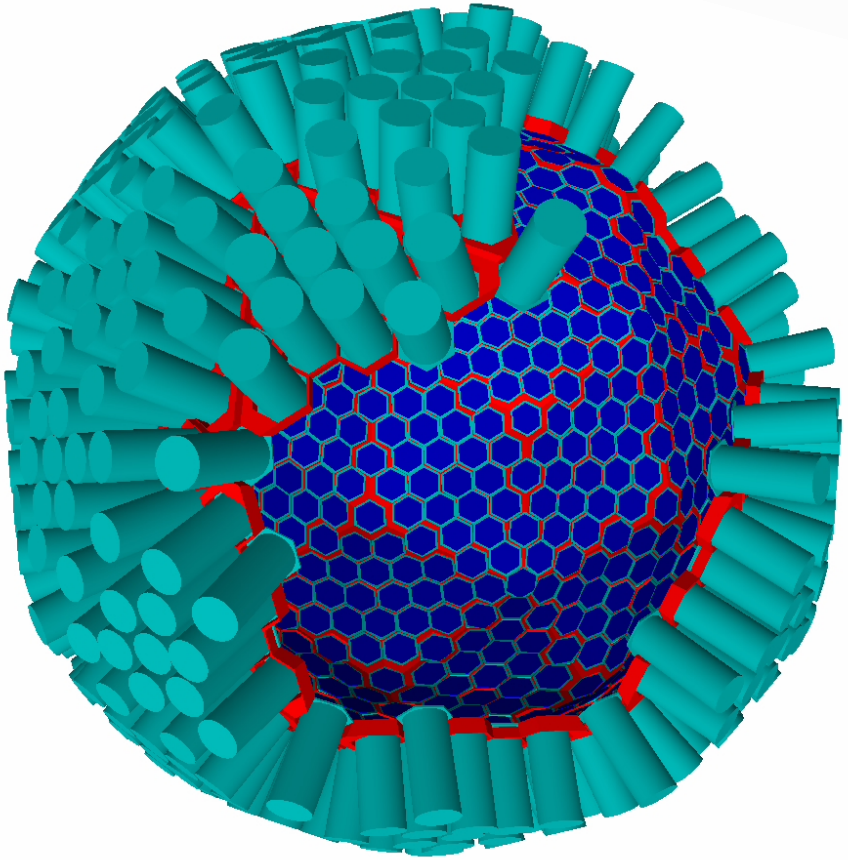
● **Detector design is going using MC**

- ✓ Structure and PMT arrangement (812 PMTs)
- ✓ Event reconstruction
- ✓ BG estimation

● **New excavation will be done soon**







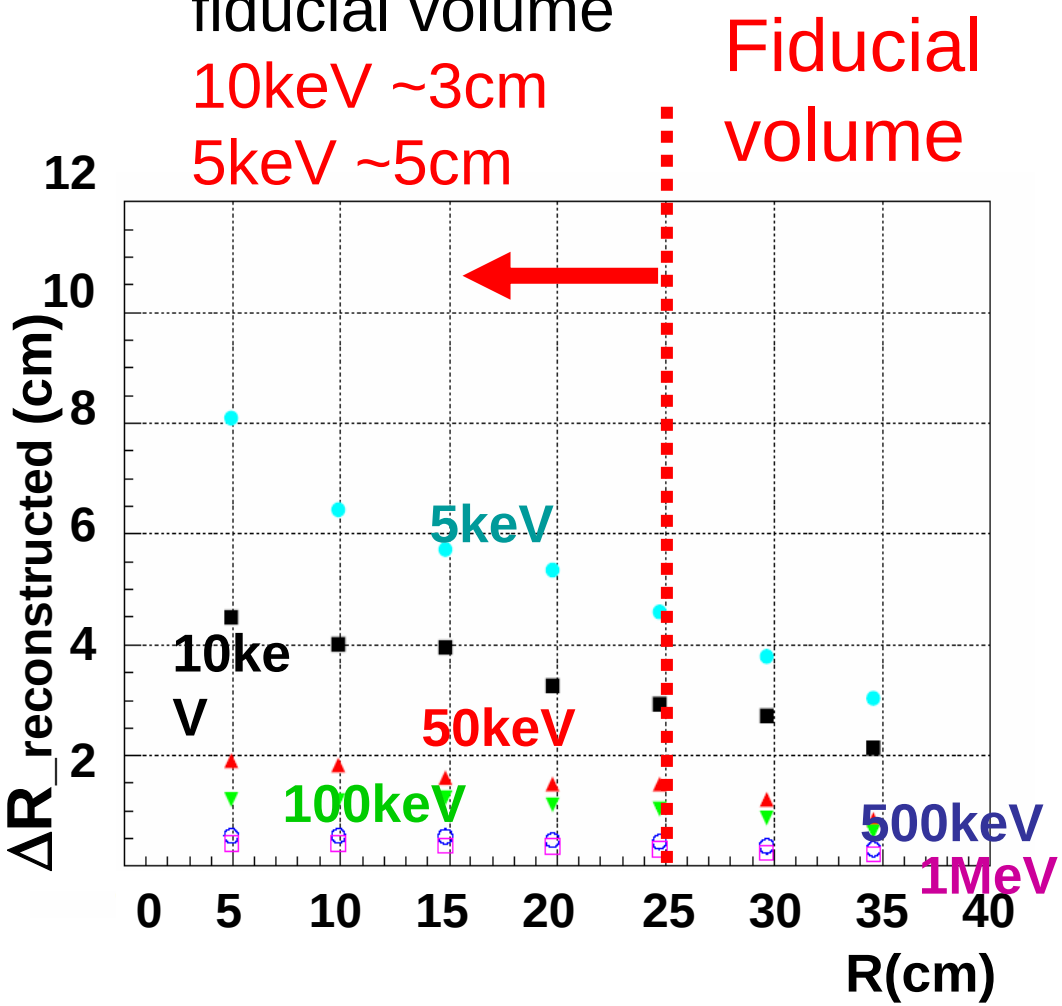
Design of 800kg ①detector

- 60 triangles
- 10 PMT/triangle x 60 = 600 PMTs
- + 212 PMTs in triangle boundary region
- Total 812 PMTs
- Photo coverage 67.0%
- Center to photocathode ~45cm
- Fiducial vloume is 25cm from center.
- PMTs are inside liquid xenon.

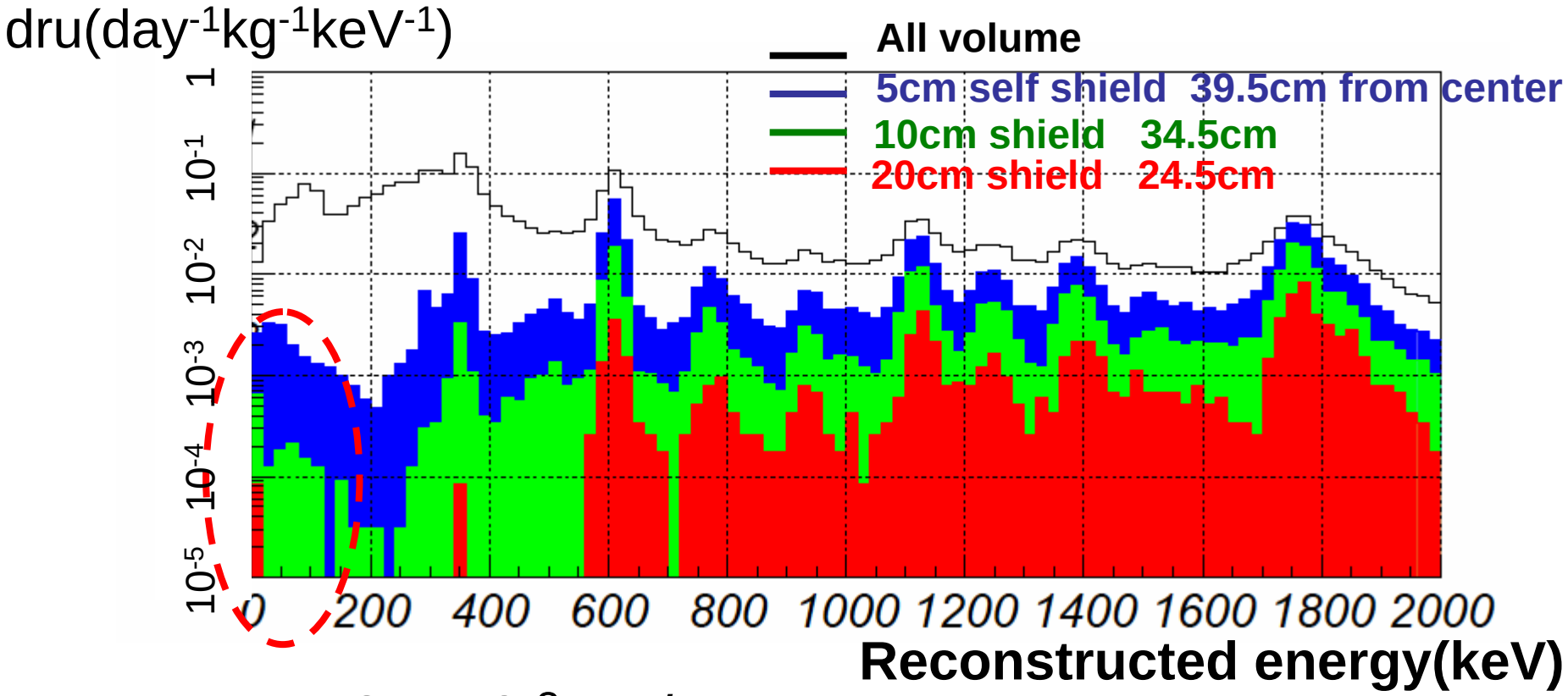
Resolution of event reconstruction and BG estimation from MC

- In current design, performance of detector was estimated using Geant4 MC.
  - Resolution of position.
  - BG from PMTs
- Resolution
  - Using signals from the PMTs, vertex position is calculated so as to maximize likelyhood.

- At boundary of fiducial volume
  10keV ~3cm
  5keV ~5cm

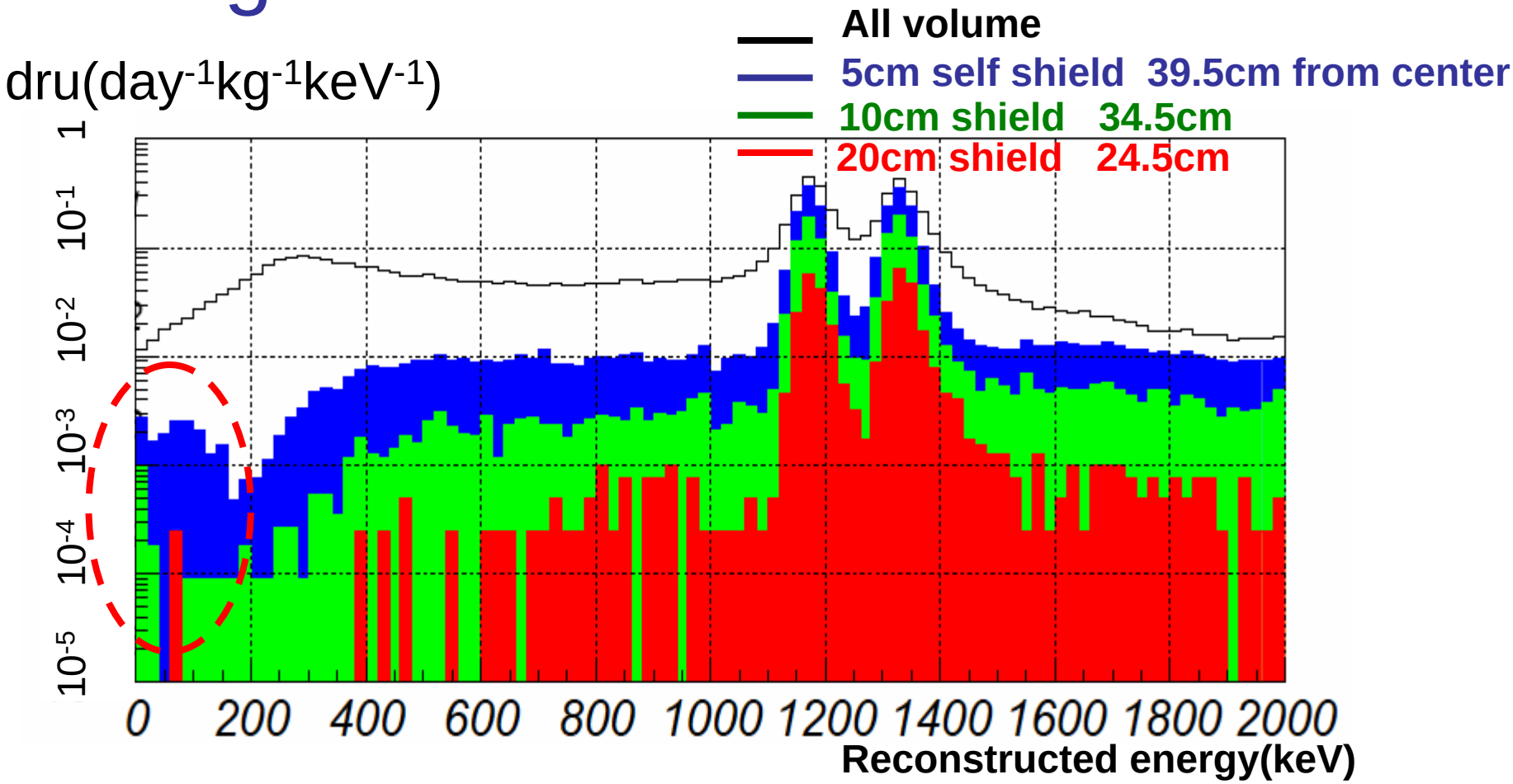


Background from PMT ^{238}U



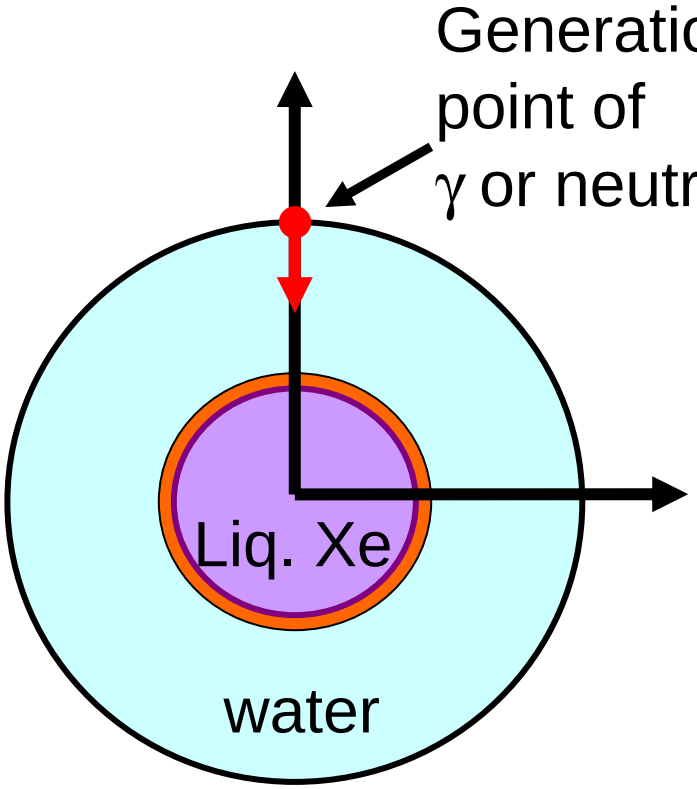
- 1.8 x 10^{-3} Bq/PMT
- <100keV
  - 5cm shield ~10^{-3} dru
  - 10cm shield ~10^{-4} dru
  - 20cm shield ~10^{-5} dru

Background from PMT ^{60}Co



- 5.5 x 10^{-3} Bq/PMT
- <100keV same level as ^{238}U
- We can achieve 10^{-5} dru level

➢ Design of 800 kg Detector
②Water shield for ambient γ and fast neutron



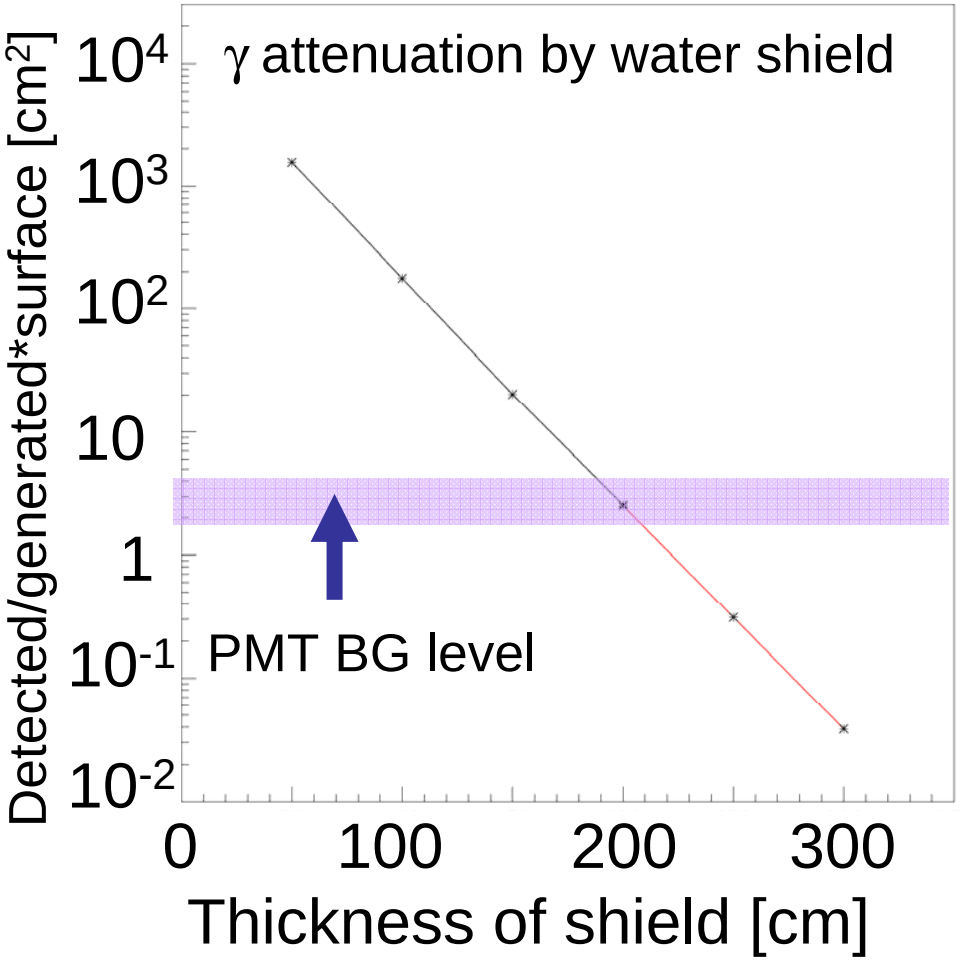
MC geometry

- Ambient background γ and neutron is another large background source.
- To reduce these background, use thick water shield.
- Estimated how thick shield is needed with simple simulation.

Configuration of the estimation

- Put 80cm diameter liquid Xe ball
- Assume copper vessel (2cm thickness)
- Assume several size of water shield
  50, 100, 150, and 200cm thickness
  for liquid Xe

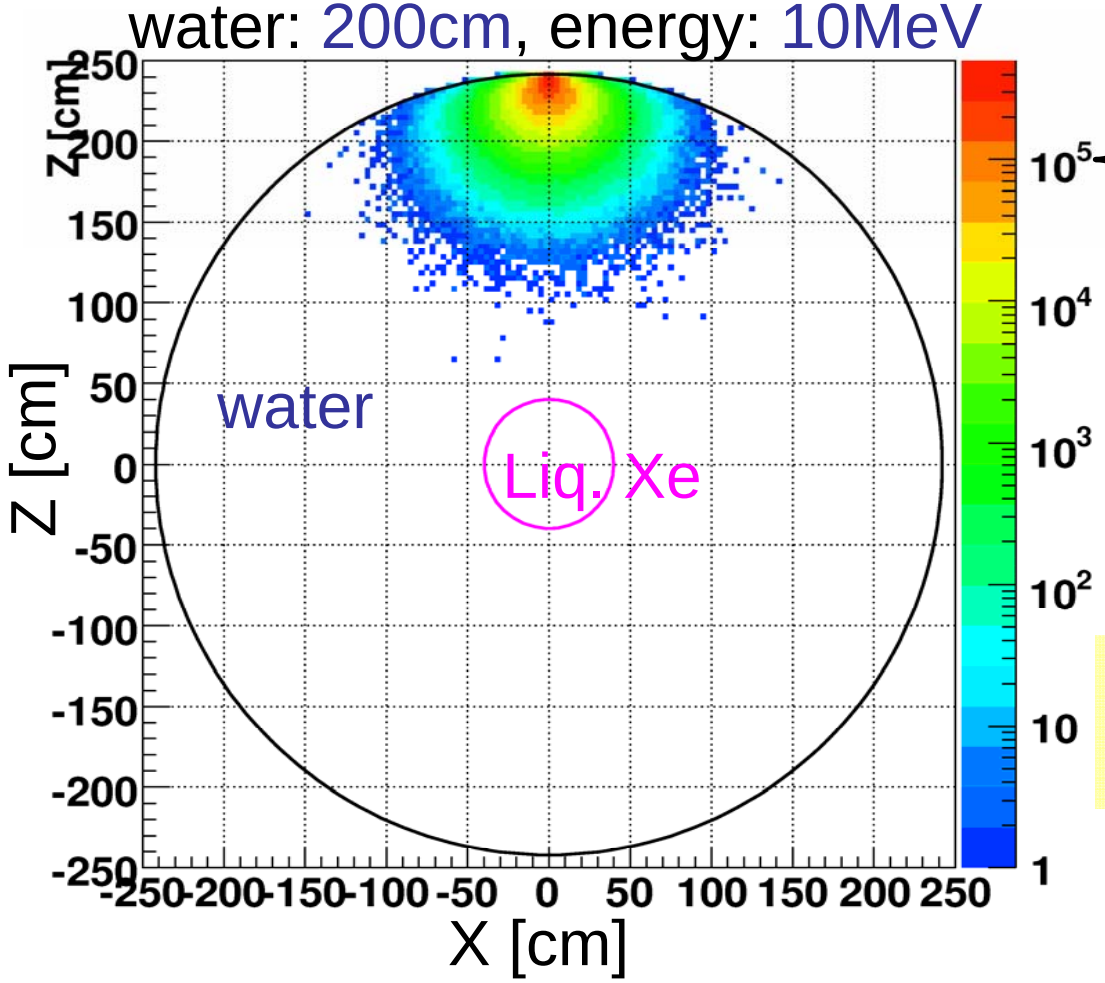
➢ γ attenuation



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

➢ Reach points of fast neutron

Reach points before thermalized
water: 200cm, energy: 10MeV



Generation:10^7

- Fast n flux @Kamioka mine:
  $(1.15 \pm 0.12) \times 10^{-5}$ /cm^2/sec
- Assuming all neutron's energies are 10 MeV very conservatively

$< 2 \times 10^{-4}$ counts/day/kg

200cm of water is enough to reduce the fast neutron

Summary

- XMASS 800kg detector
  - 1 ton liquid xenon, 90cm diameter, 60 triangles, 812 PMTs
  - BG level 10^{-4} dru($day^{-1}kg^{-1}kev^{-1}$)
  - Dark matter search 10^{-45} cm^2
- Detector design by simulation
  - Resolution of event reconstruction
    - 10keV ~3cm 5keV ~5cm at boundary of fiducial volume
  - Background from PMT
    - ^{238}U, ^{60}Co ~10^{-5} dru inside fiducial volume
  - Water shield for ambient γ and fast neutron
    - 200cm shield is enough