Self-shielding effect for liq. xenon

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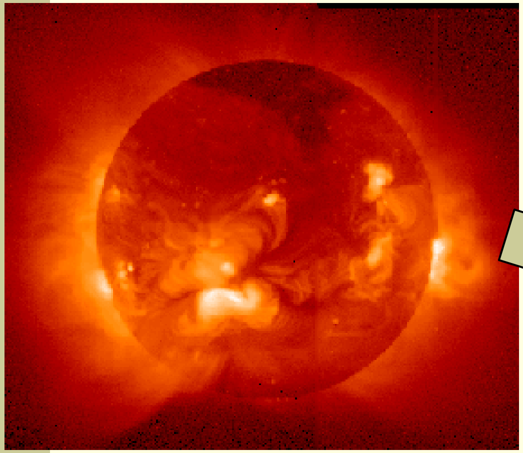
- XMASS experiment
- Self shielding effect for low energy ext. γ
- Demonstration: liquid xenon prototype det.

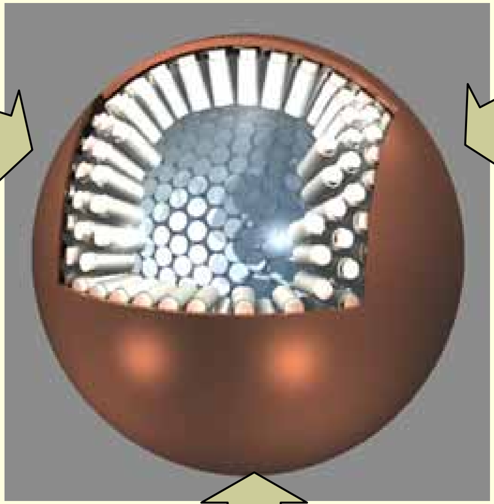
XMASS experiment

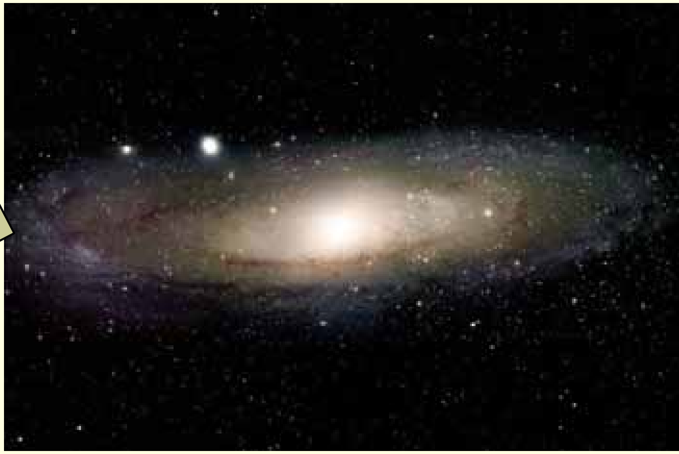
●XMASS

- ◎ Xenon MASSive detector for Solar neutrino (pp/^{7}Be)
- ◎ Xenon neutrino MASS detector (double beta decay)
- ◎ Xenon detector for Weakly Interacting MASSive Particles (DM search)

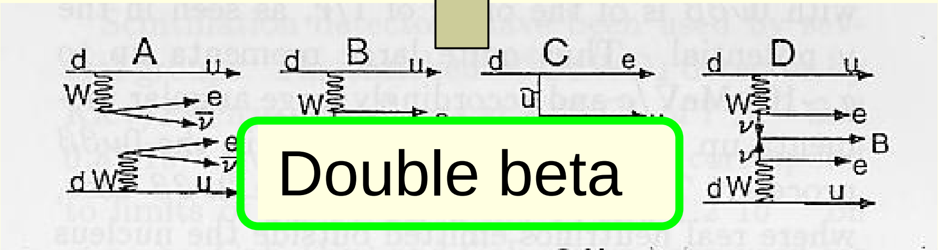


Solar neutrino



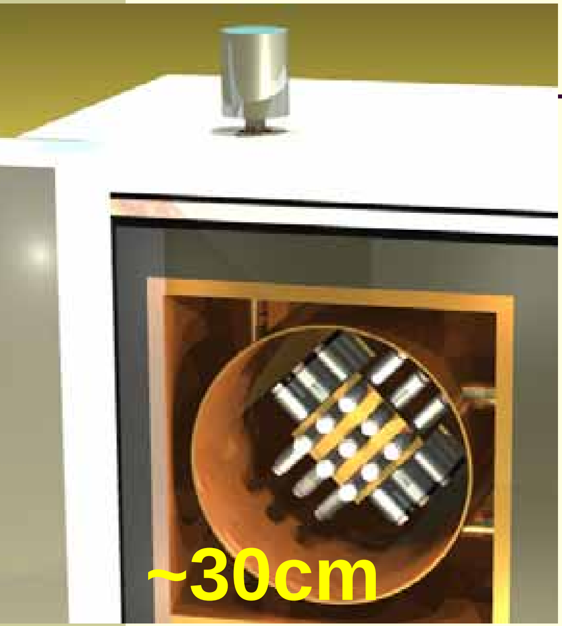


Dark matter



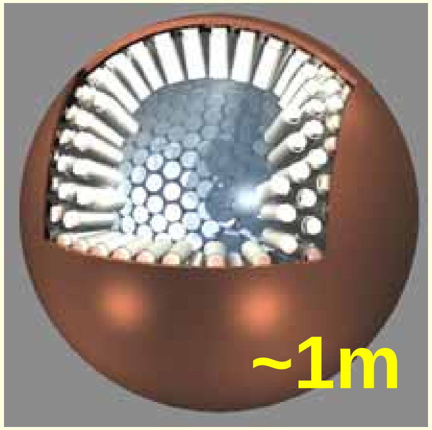
Double beta

Strategy of the XMASS project

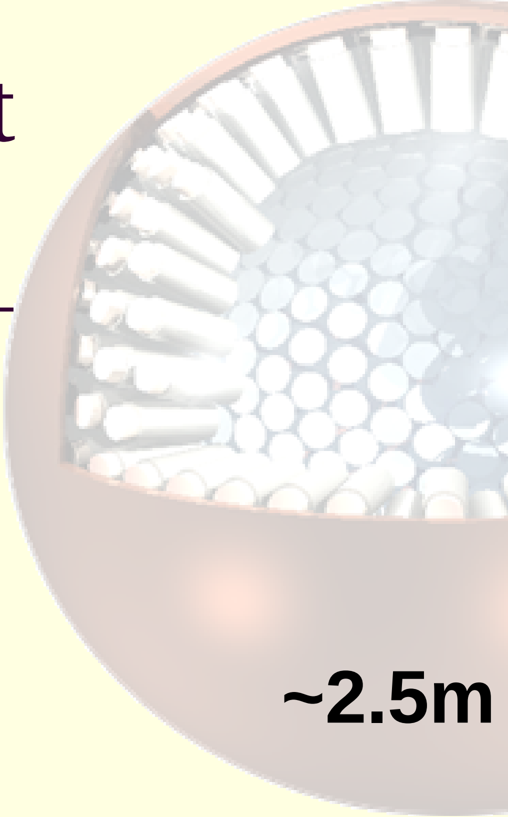


Prototype detector
(FV 3kg) R&D

Confirmation of feasibilities
of the 800kg detector



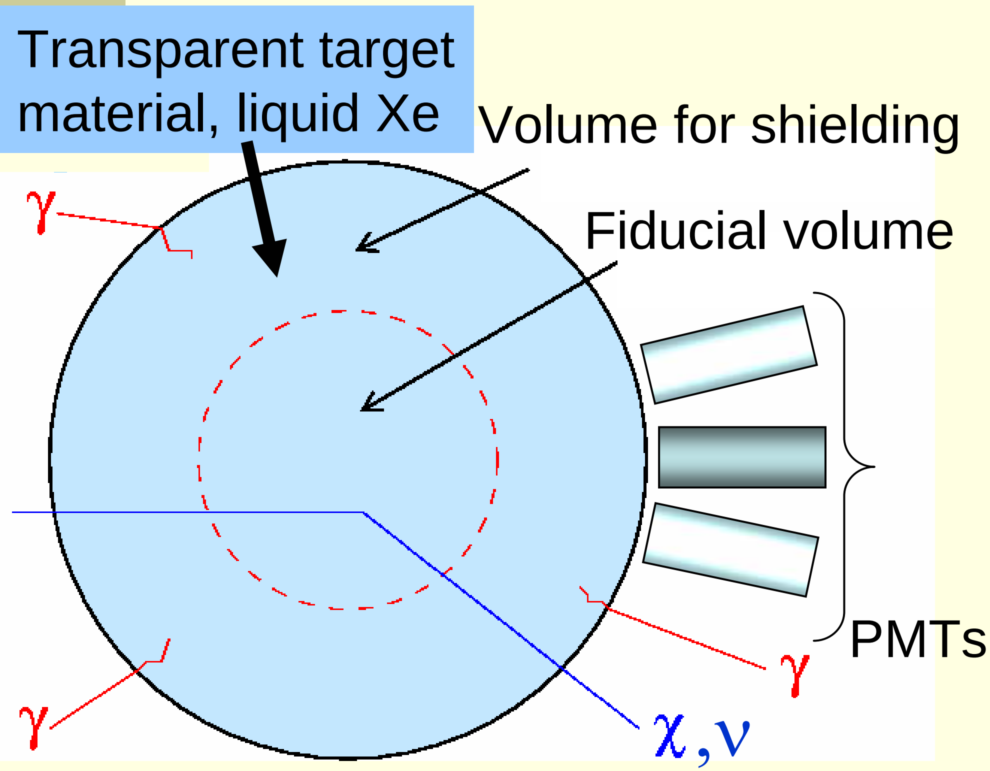
800kg detector
(FV 100kg)
Dark matter search

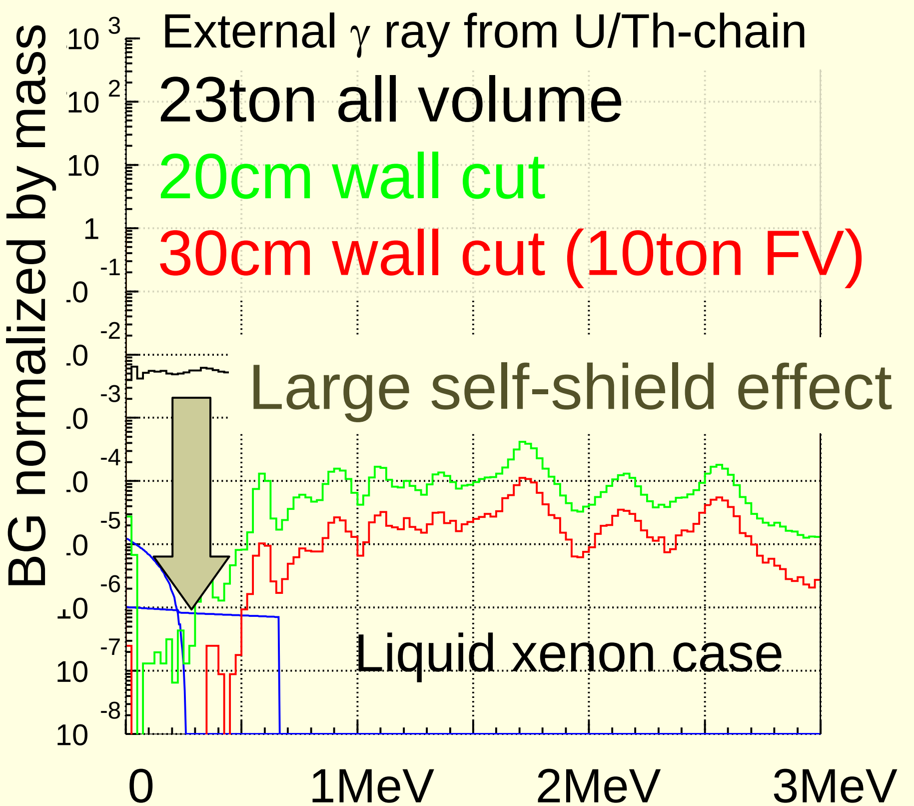


~20 ton detector
(FV 10ton)
Solar neutrinos
Dark matter search

Demonstration of
self shielding

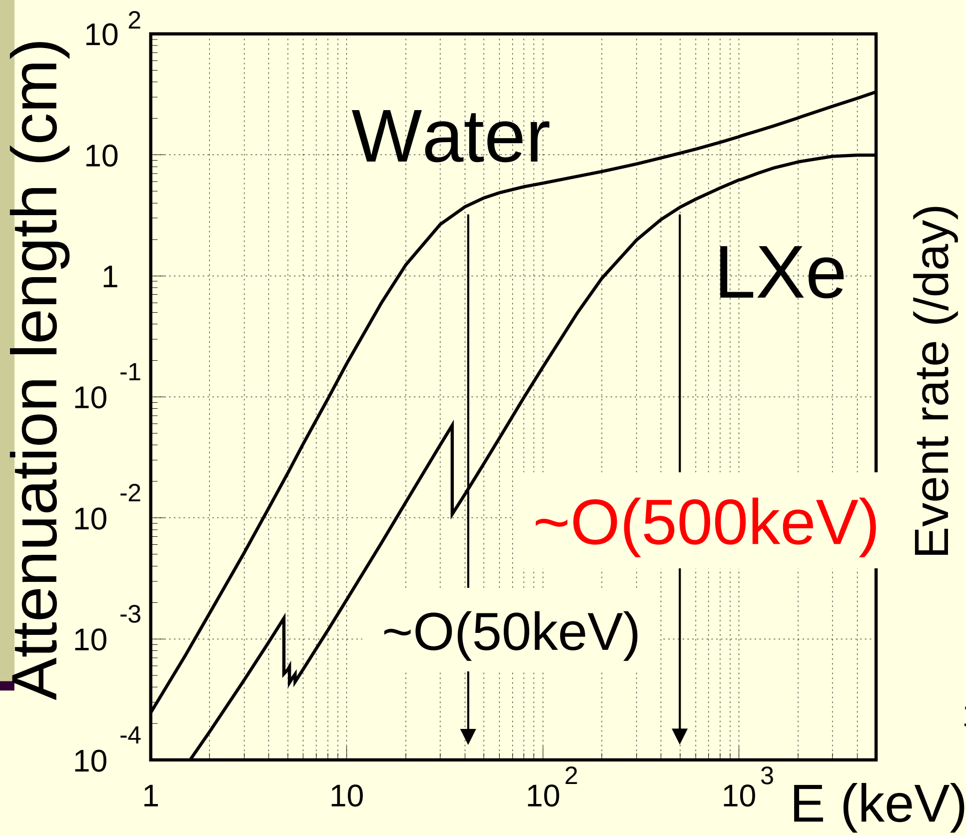
Self shielding effect for low energy external gamma rays



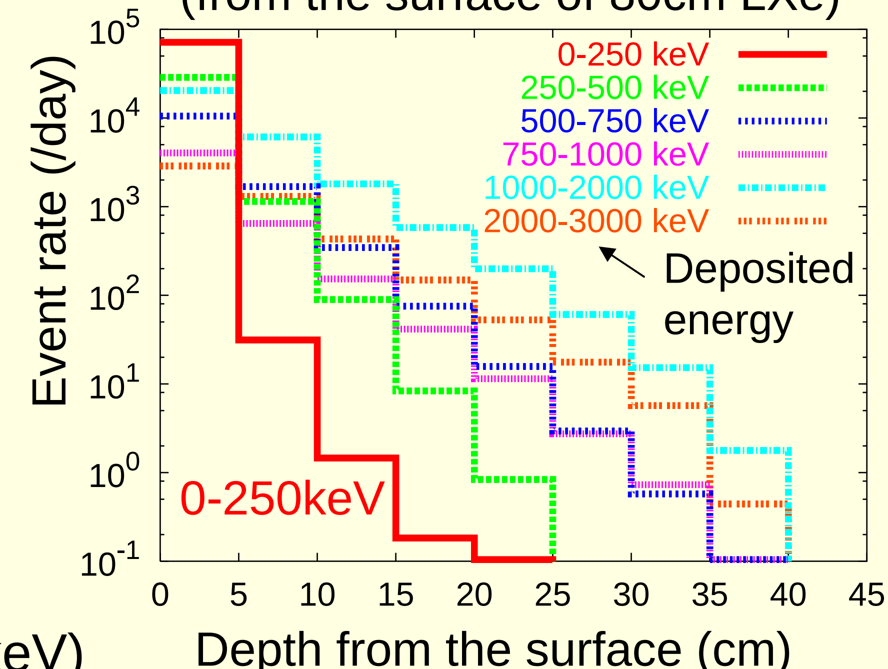


- Super-K, SNO, and KamLAND are good examples.
- Photoelectric effect with large atomic number make the effect much stronger especially for low energy region.

Self shielding effect with liq. xenon



Light barycenter distribution of ^{238}U external gamma ray (from the surface of 80cm LXe)



Large photoelectric coeff. for low energy γ

Vertex (~light barycenter) reconstruction

➔ low BG deep inside the detector

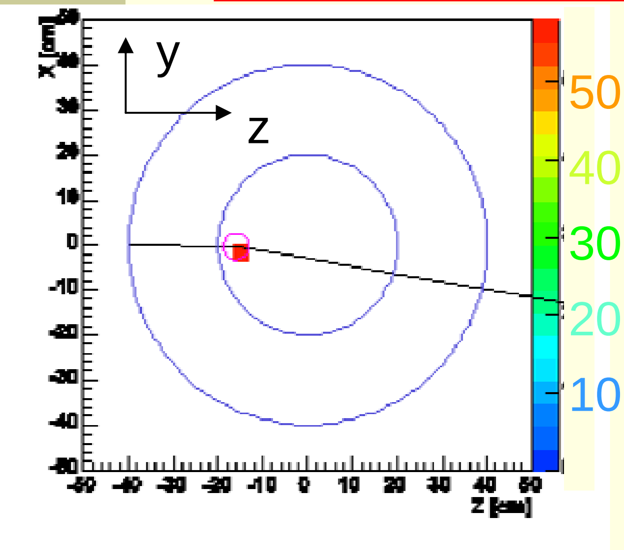
Why there are very small number of BG events at the low energy region?

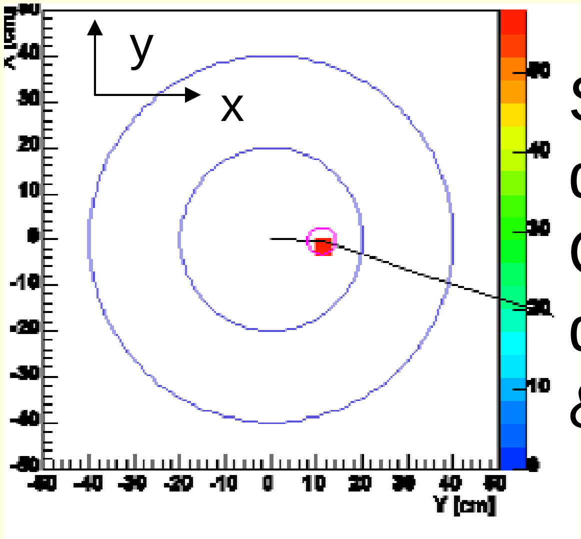
- Answer: To leave ~100keV in the FV, high energy gamma ray need to penetrate long path.

Toy MC: 80cm diameter liquid xenon with U gamma rays

Initial 1760keV, 57keV deposited

○ Light barycenter





Simulated 4.3×10^6 U decays on the sphere. Only 7 events recorded dep. energy <300keV & the light center in FV

Deep event with low energy deposit (Edep.) Very rare!

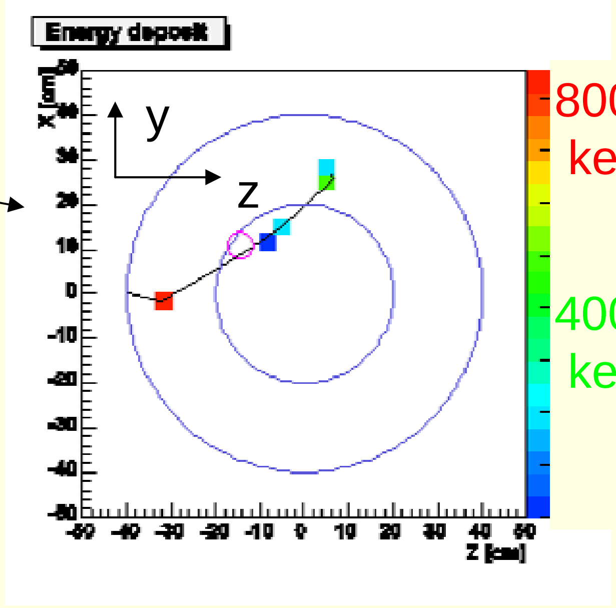
- Fate of the events which give finite energy deposit in the FV.

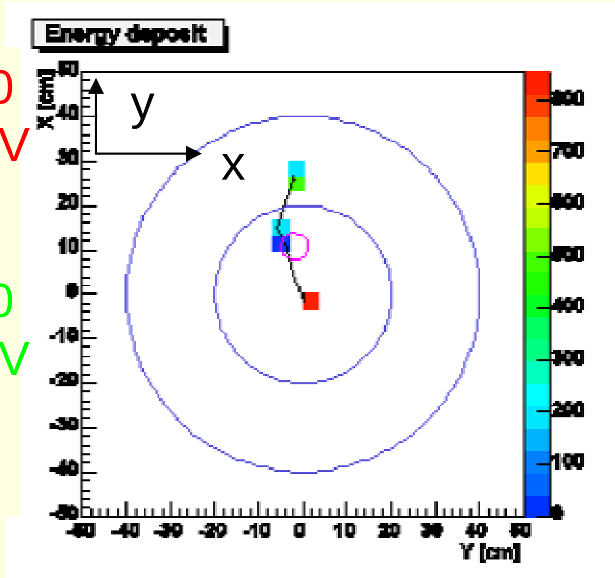
Finite energy deposition in FV

	Edep in all vol. <300keV	Edep in FV <300keV
Light center FV	7 (last page)	272
Light center out FV	2	2276

4.3×10^6 ^{238}U decay

Original energy 1760keV, Edep in FV 221keV
Edep in OV 1539keV



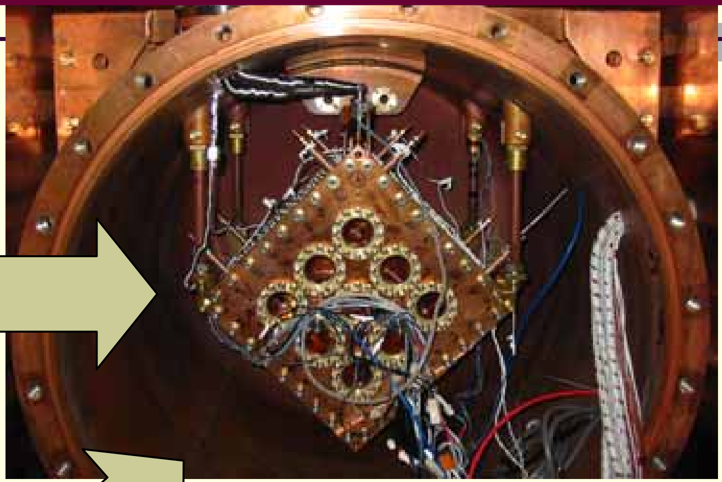


○ Light barycenter

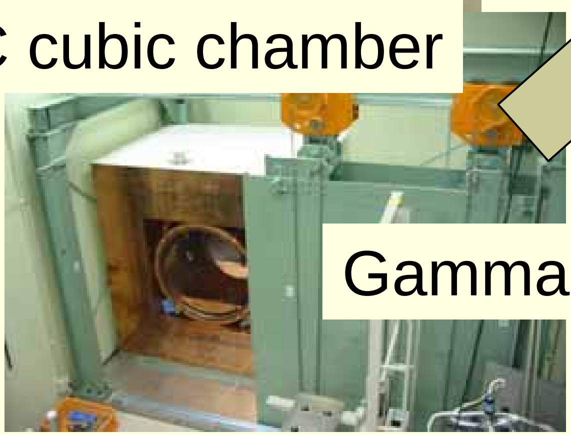
Even if Edep. in FV, additional Edep.
change its energy deposit higher.

Demonstration of self shielding effect with 3kg FV prototype detector

OFHC cubic chamber



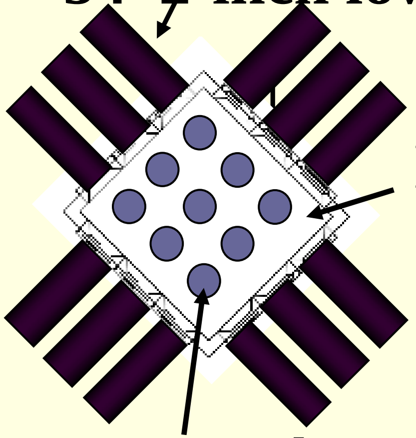
In the Kamioka Mine (near the Super-K)



Gamma ray shield

54 2-inch low BG PMTs

Hamamatsu R8778



Liq. Xe $(31\text{cm})^3$

16% photo-coverage

MgF_2 window

- Demonstration of reconstruction, self shielding effect, and low background properties.

Vertex and energy reconstruction

Reconstruction is performed by PMT charge pattern (not timing)

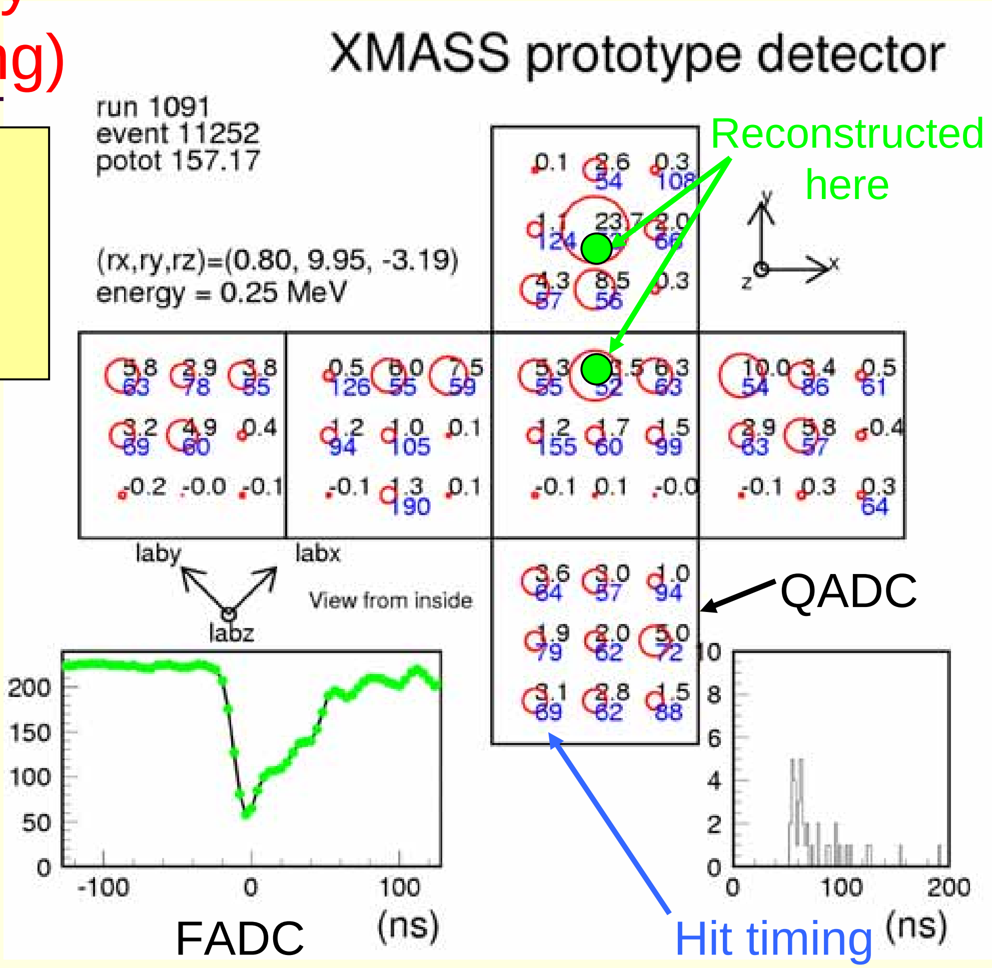
Calculate PMT acceptances from various vertices by Monte Carlo.
Vtx.: compare acceptance map F(x,y,z,i)
Ene.: calc. from obs. p.e. & total accept.

$$\mathrm{Log}(L) = \sum_{PMT} \mathrm{Log}\left(\frac{\exp(-\mu)\mu^n}{n!}\right)$$

L: likelihood

$$\mu : \quad \frac{F(x,y,z,i)}{\Sigma F(x,y,z,i)} \text{ x total p.e.}$$

n: observed number of p.e.

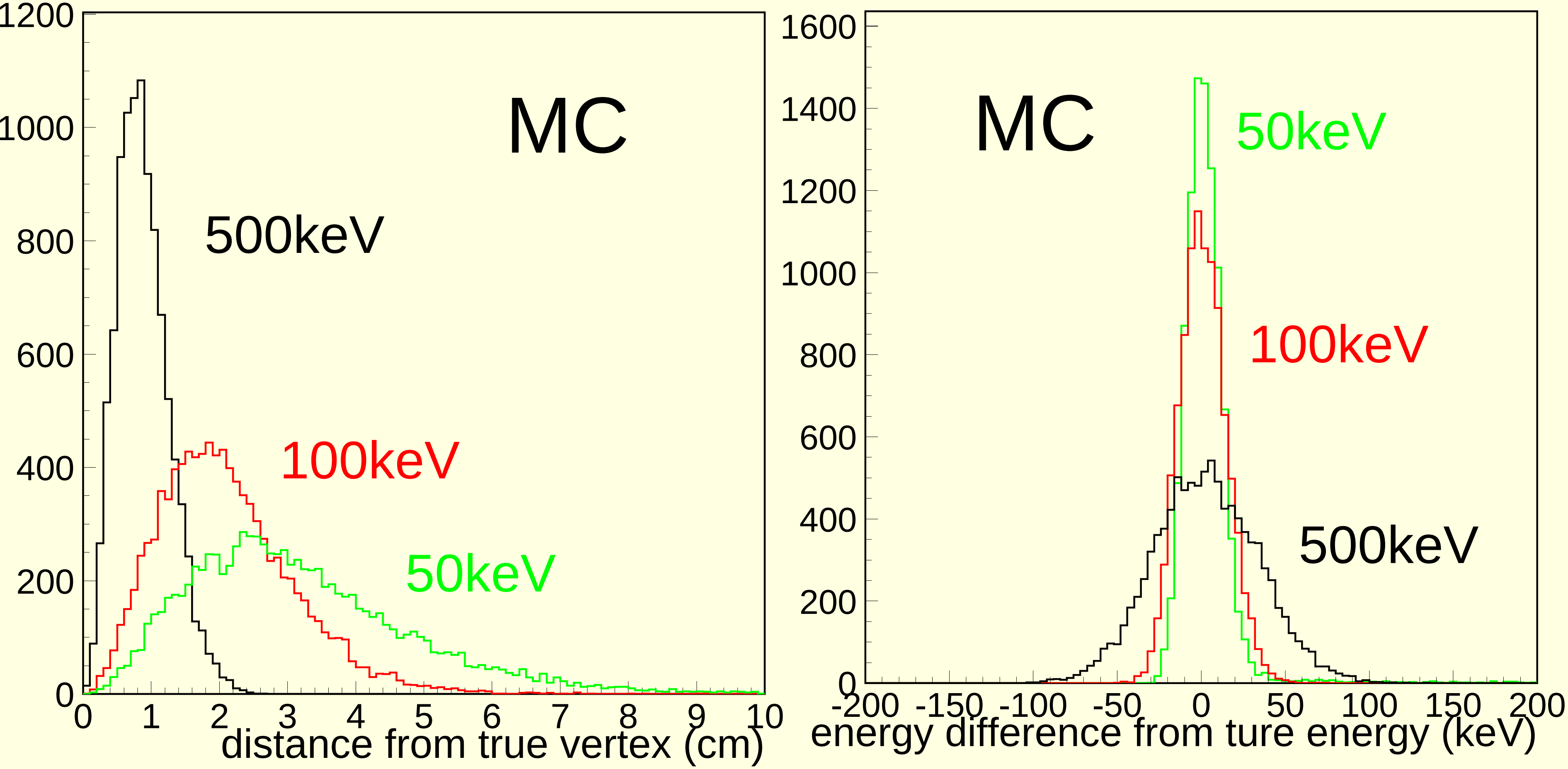


F(x,y,z,i): acceptance for i-th PMT (MC)
VUV photon characteristics:

L_{emit}=42ph/keV
τ_{abs}=100cm
τ_{scat}=30cm

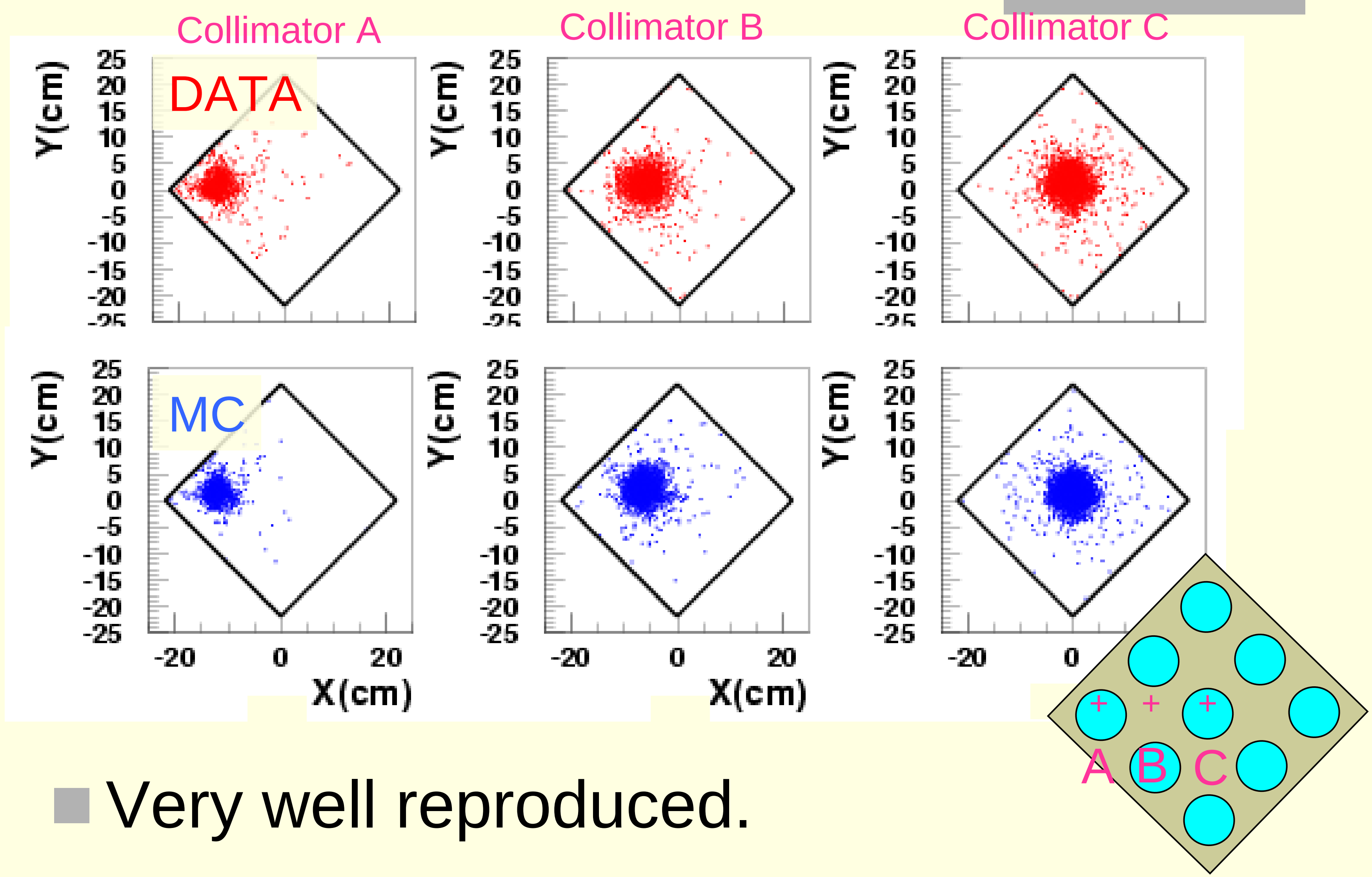
=== Background event sample ===
QADC, FADC, and hit timing information are available for analysis

Expected reconstruction performance in 10cm cubic fiducial volume



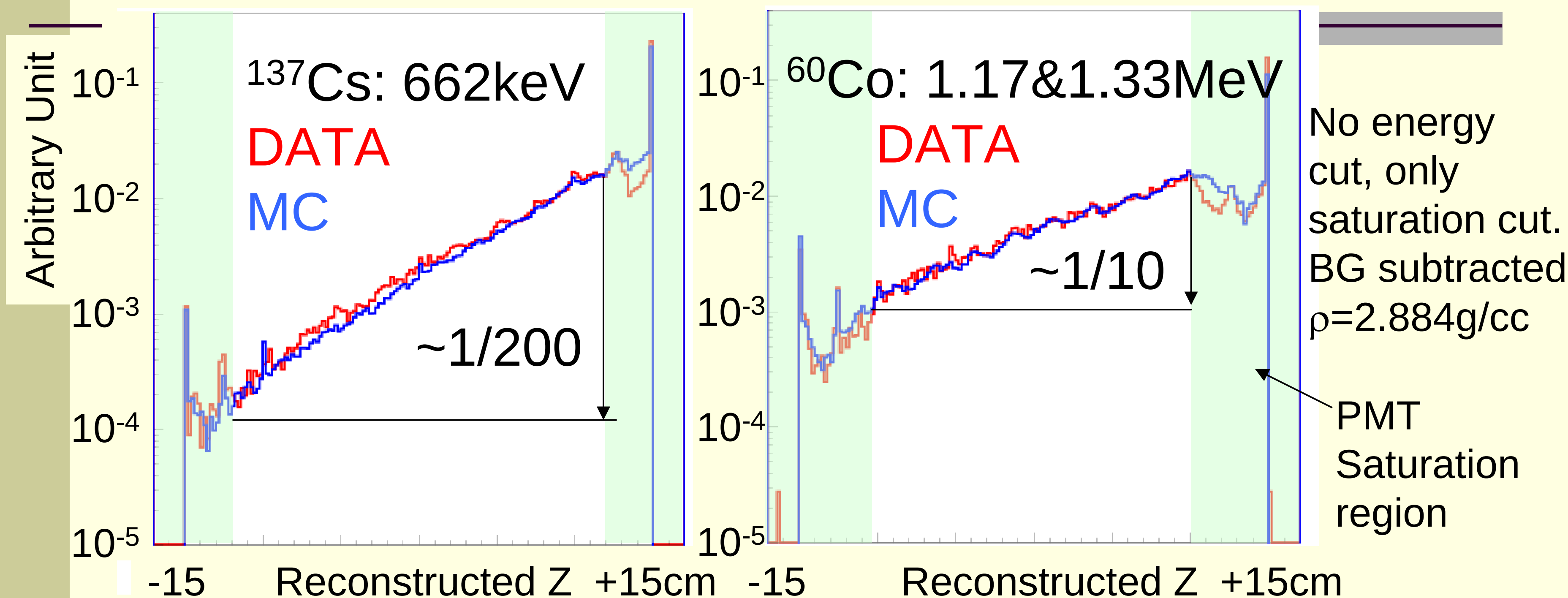
- 10cm cubic FV events reconstructed well.

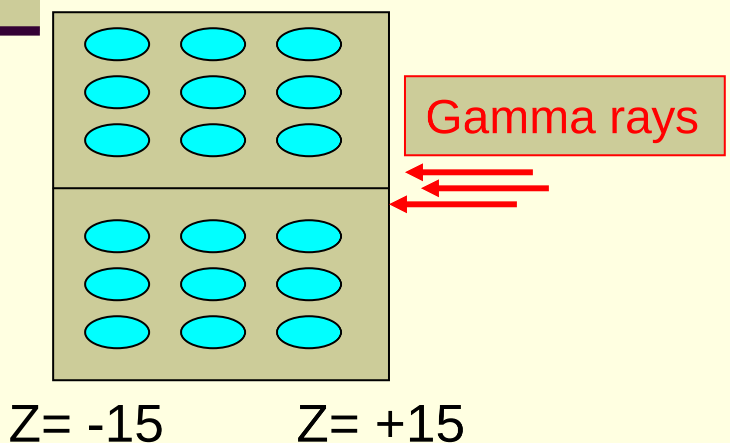
Source run
(γ ray injection from collimators) I



- Very well reproduced.

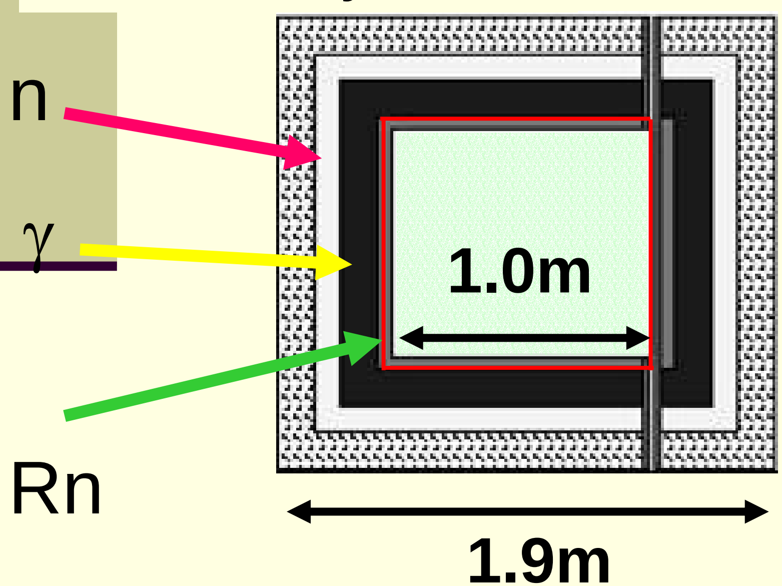
Source run
(γ ray injection from collimators) II





- Good agreements.
- Self shield works as expected.
- Photo electron yield ~ 0.8p.e./keV for all volume

Gamma ray shield



- Polyethylene (15cm)
- Boric acid (5cm)
- Lead (15cm)
- EVOH sheets (30 μm)
- OFHC (5cm)
- Rn free air (~3mBq/m^3)

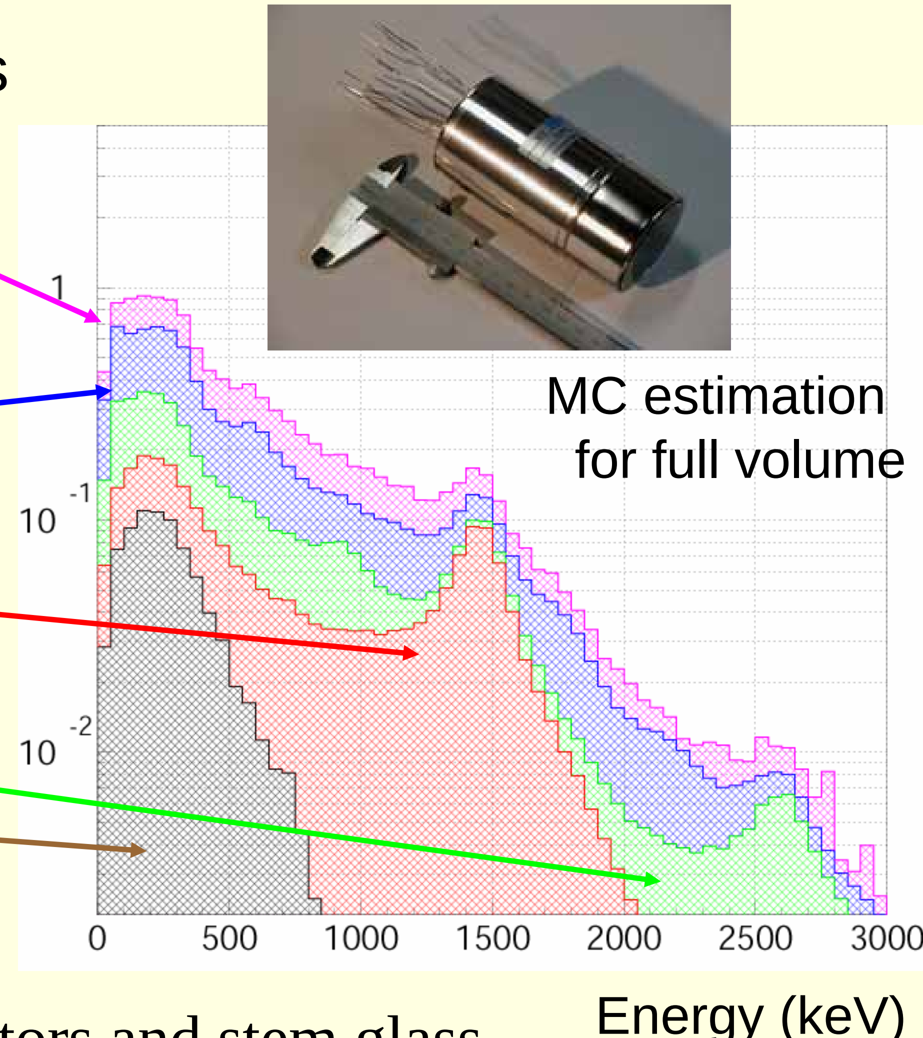
Rn concentration in the clean room ~10Bq/m3

External background source

- Background level was estimated from known sources

Dominant contribution: PMTs

- γ rays from outside shield
  ~0.7γ/cm^2/s (>500keV)
- **Low background PMTs**
  - ^{238}U series
    18+/-2mBq/PMT
  - ^{40}K (incl. beta branch)
    140+/-20mBq/PMT
  - ^{232}Th series
    6.9+/-1.3mBq/PMT
- ^{210}Pb in the lead shield
  250Bq/kg

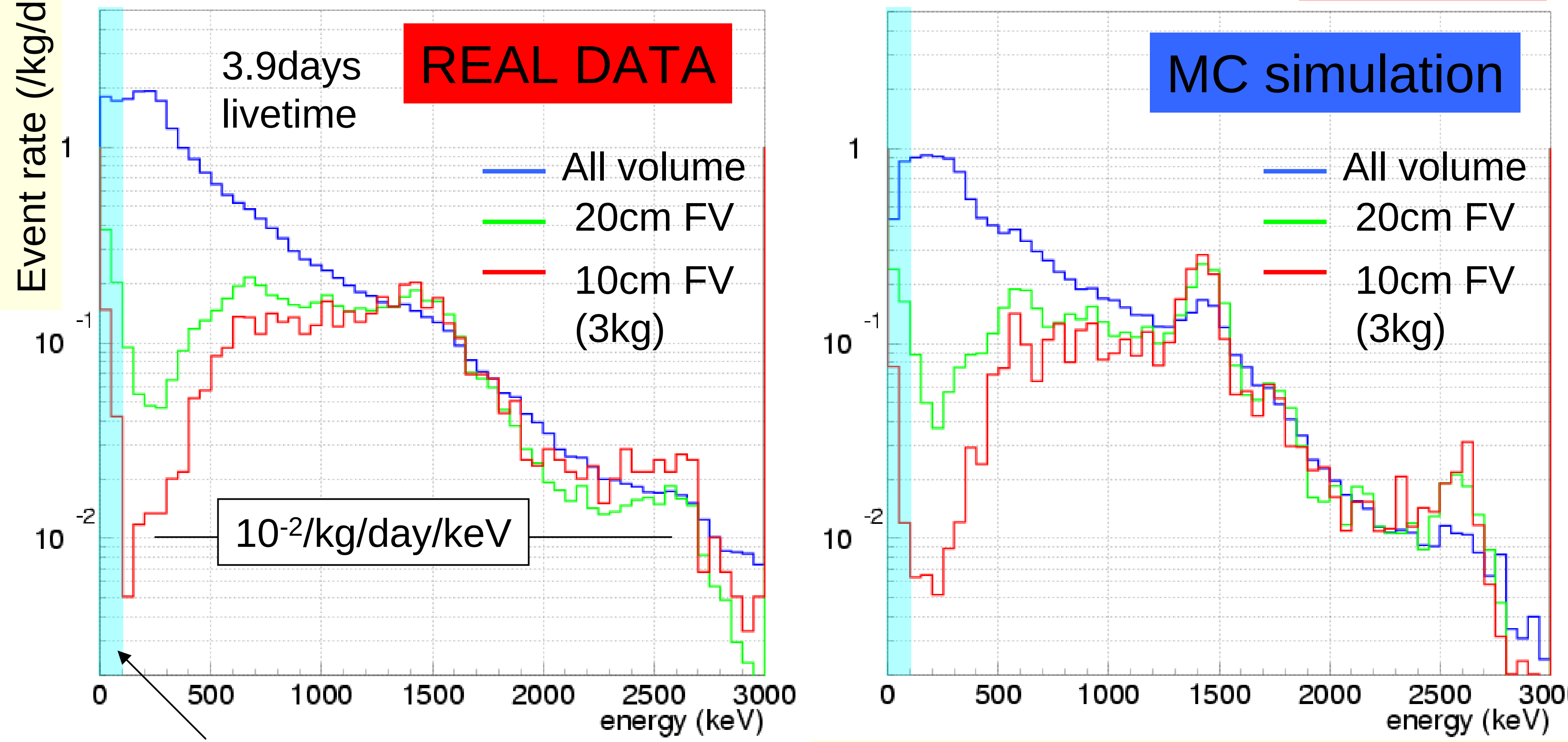


Measured by HPGe
Main contribution from inner insulators and stem glass.

Background data

Aug. 04 run
preliminary

~1.6Hz, 4 fold, triggered by ~0.4p.e.

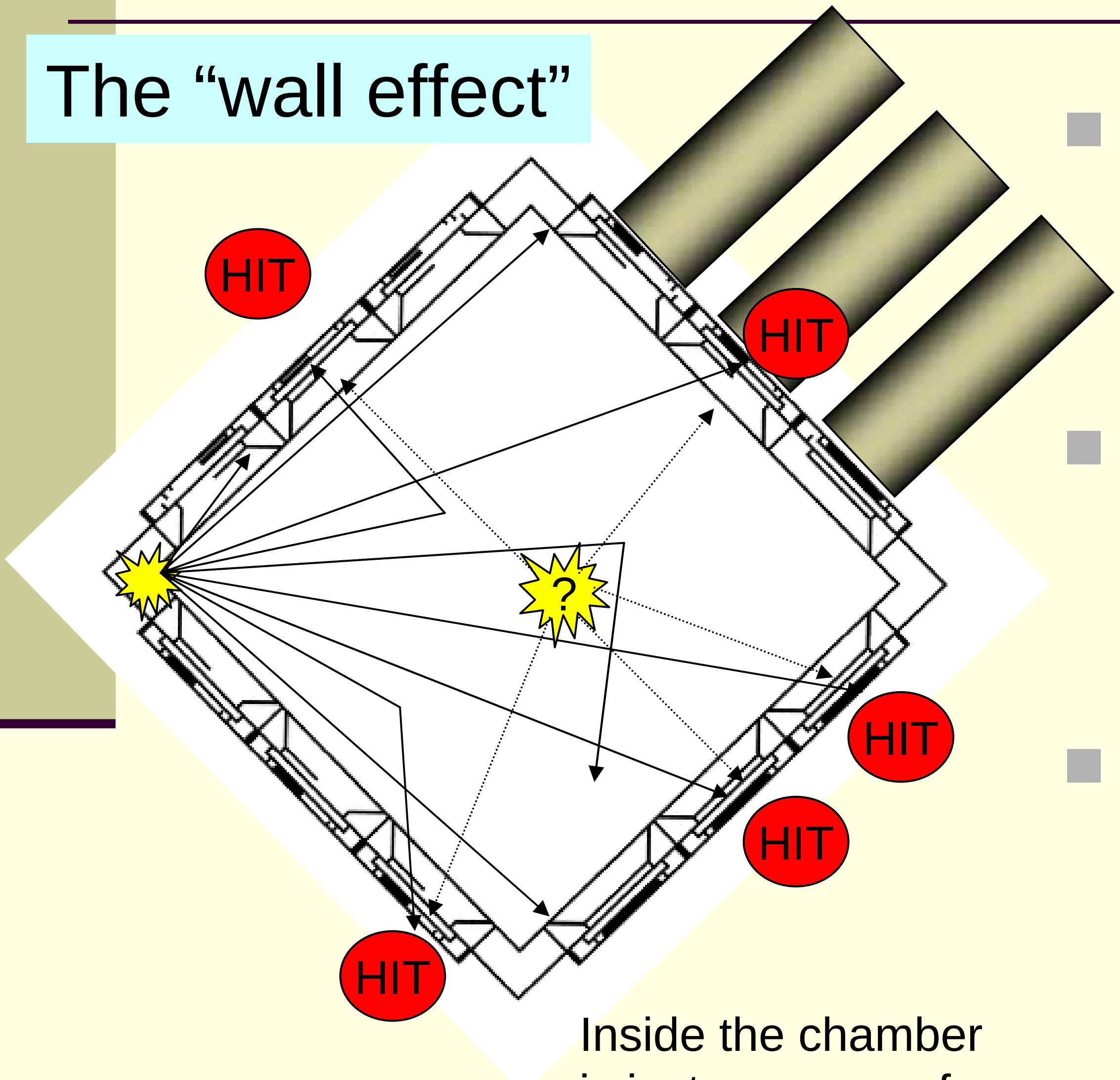


Mis-reconstruction due to dead-angle region from PMTs.

- Internal origins of background is negligible after FV cuts.
- Good agreement (< factor 2)
- Self shield effect can be seen clearly.
- Very low background (10^{-2} /kg/day/keV@100-300 keV)

Mis reconstruction: dead angle from the PMTs (only for this prototype detector)

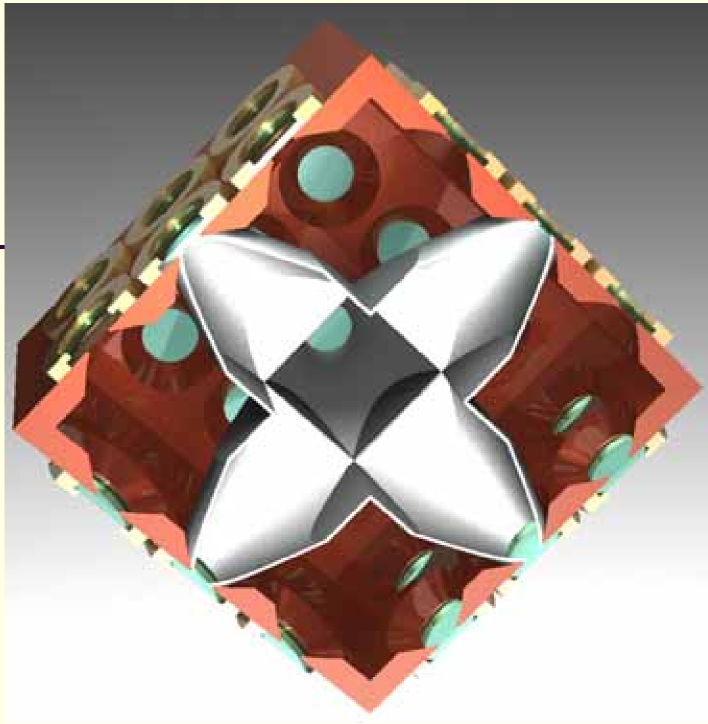
The "wall effect"



Inside the chamber
is just copper surface

- Scintillation light at the dead angle from PMTs give quite uniform 1p.e. level signal for PMTs.
- This cause mis reconstruction as if the vertex is around the center of the detector.
- Immersing PMTs into LXe and using spherical design solve this problem. ➔ It will give low BG in the ROI for DM search

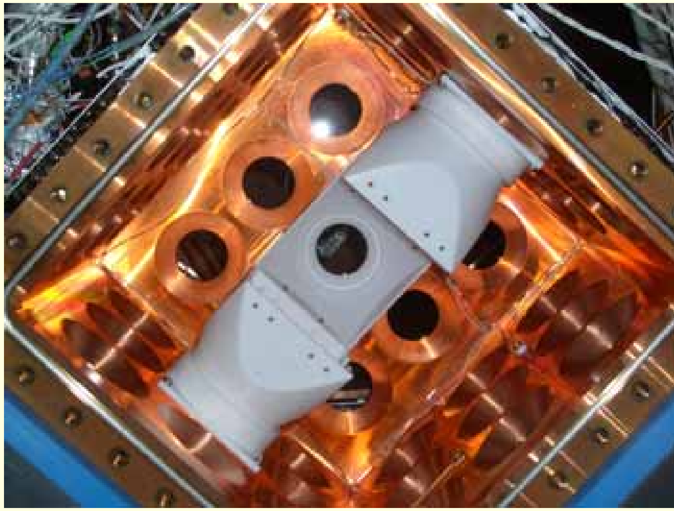
Further investigation of BG at low energy region



- By putting "PTFE light guide,"
  we can minimize the wall effect.

➔ 10^{-2}/keV/kg/d, E_{th}~10keV,
  and ~3kg FV will be achieved.

- We can select events at the center of the detector by requiring balanced hits for 6 PMTs.
- Data will be taken in early next year.



Summary

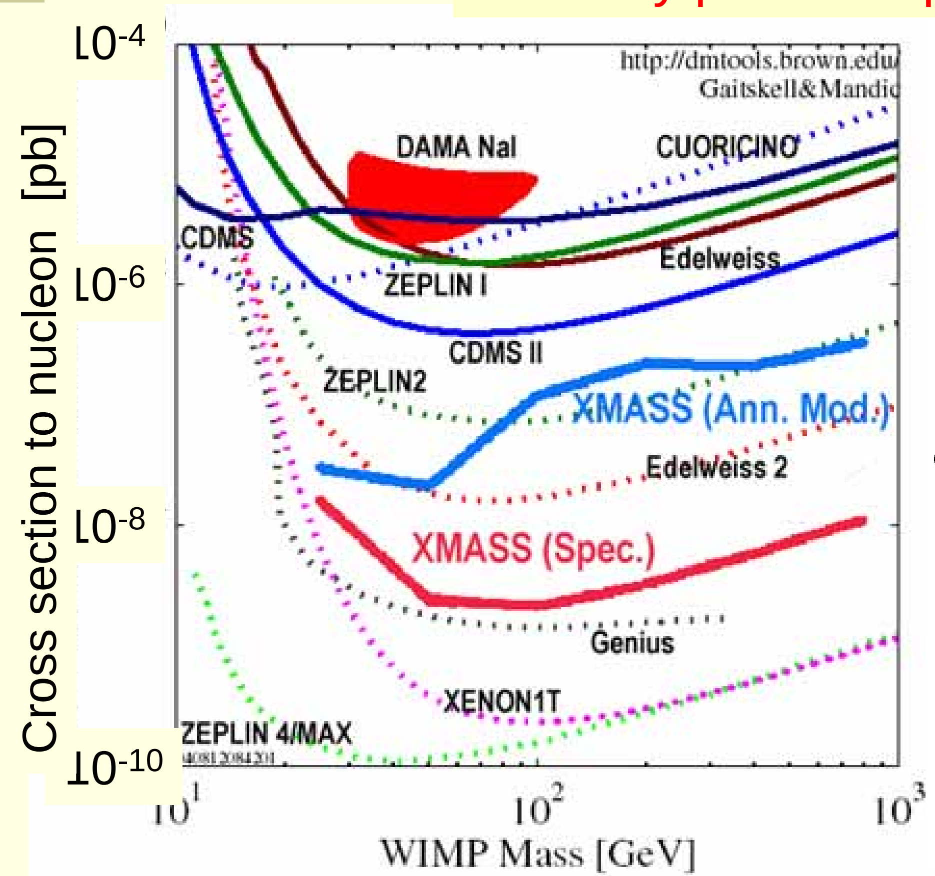
- XMASS utilizes self shield to achieve low BG.
- R&D by 3kg FV prototype is well going:

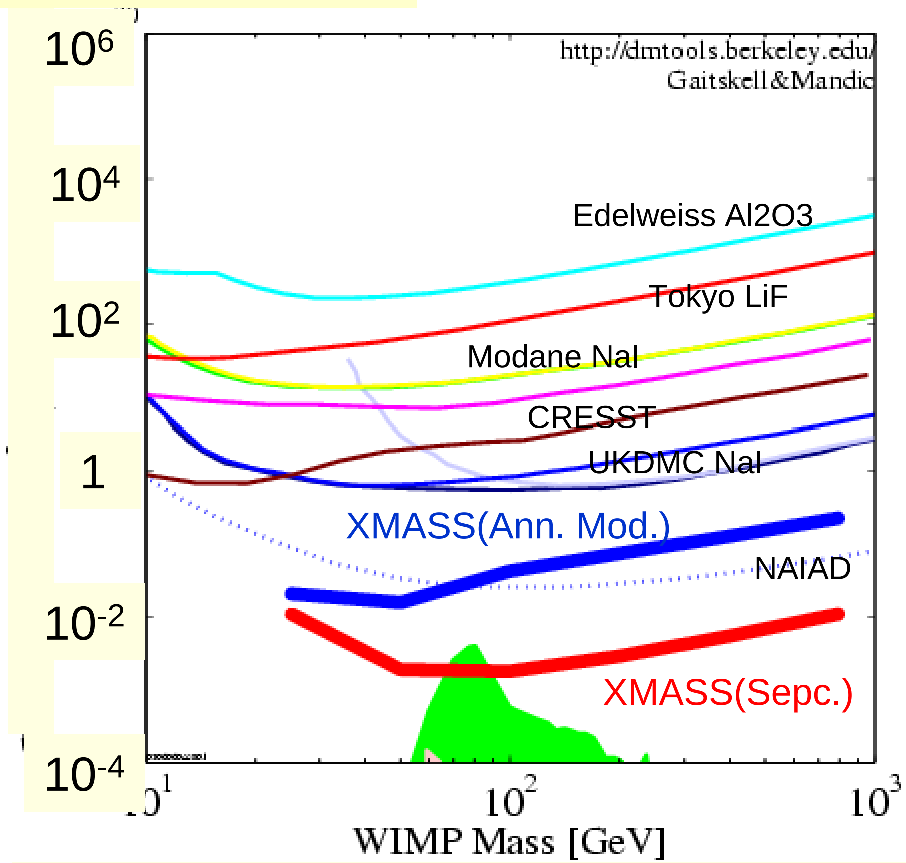
  Demonstration of

  reconstruction, self shield, and low BG properties.
- 1/200 exponential dumping over 24cm for 662keV gamma ray demonstrated.
- 10^{-2} /kg/keV/day@100keV in 10cm cubic FV was achieved by self shielding effect. Origins of background is well understood.
- By utilizing this self shield effect, we are planning to build a ton scale LXe detector (dark matter search, see poster) and investigate for a future low energy solar neutrino detector.

Expected sensitivity

XMASS FV 0.5ton year
E_{th}=5keVee~25p.e., 3σ discovery
W/O any pulse shape info.





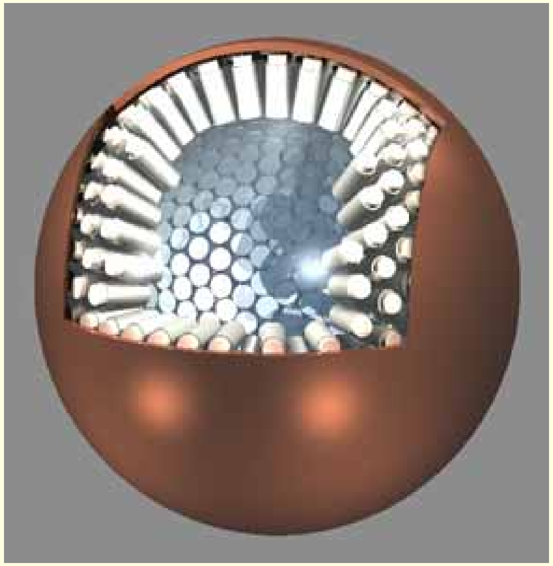
- Large improvements will be expected.
  SI ~ 10-45cm2 = 10-9pb
  SD~ 10-39cm2= 10-3pb

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

800kg (100kg FV) detector for DM Search

- Solve the miss reconst. prob. ➔ immerse PMTs into LXe
- Ext. γ BG: from PMT's ➔ Self-shield effect demonstrated
- Int. BG: Kr (distillation), Radon ➔ Almost achieved
- Neutron: water or LS active shield ($1/10^4$) ➔ To be studied

"Full" photo-sensitive, "Spherical" geometry detector



80cm dia.

~800-2" PMTs (1/10 Low BG)
70% photo-coverage ~5p.e./keVee