XMASS experiment

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Kamioka Observatory, ICRR,
University of Tokyo
LRT2004 poster

- Ultra-low BG, multi-purpose detector
- 3kg fiducial volume (FV) prototype detector
- 800kg detector for DM Search

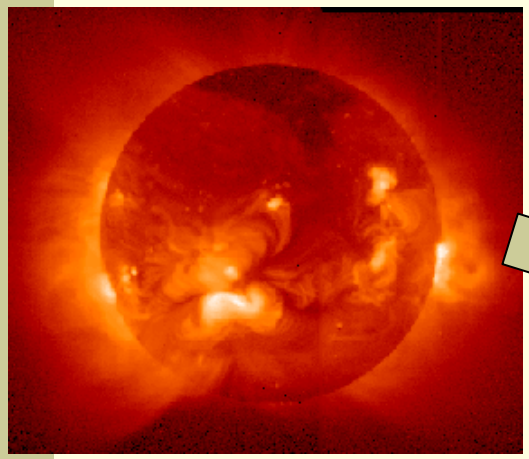
Ultra-low background multi-purpose detector

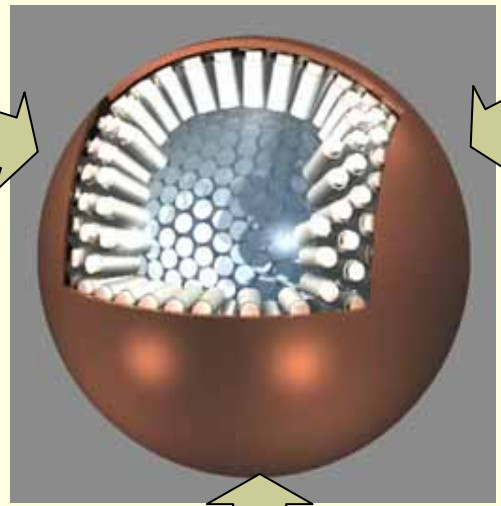
●XMASS

◎ **X**enon **MASS**ive detector for Solar neutrino (pp/^{7}Be)

◎ **X**enon neutrino **MASS** detector (double beta decay)

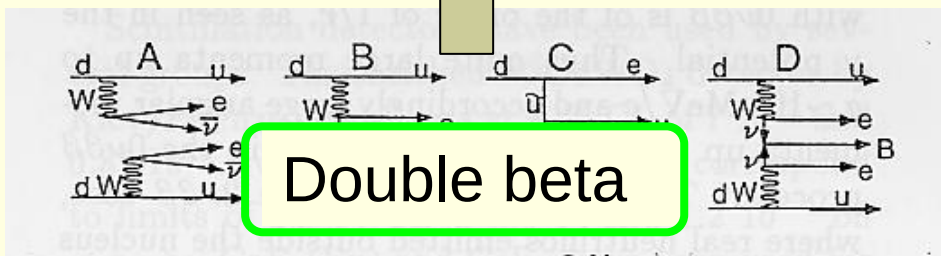
◎ **X**enon detector for Weakly Interacting **MASS**ive Particles (DM search)





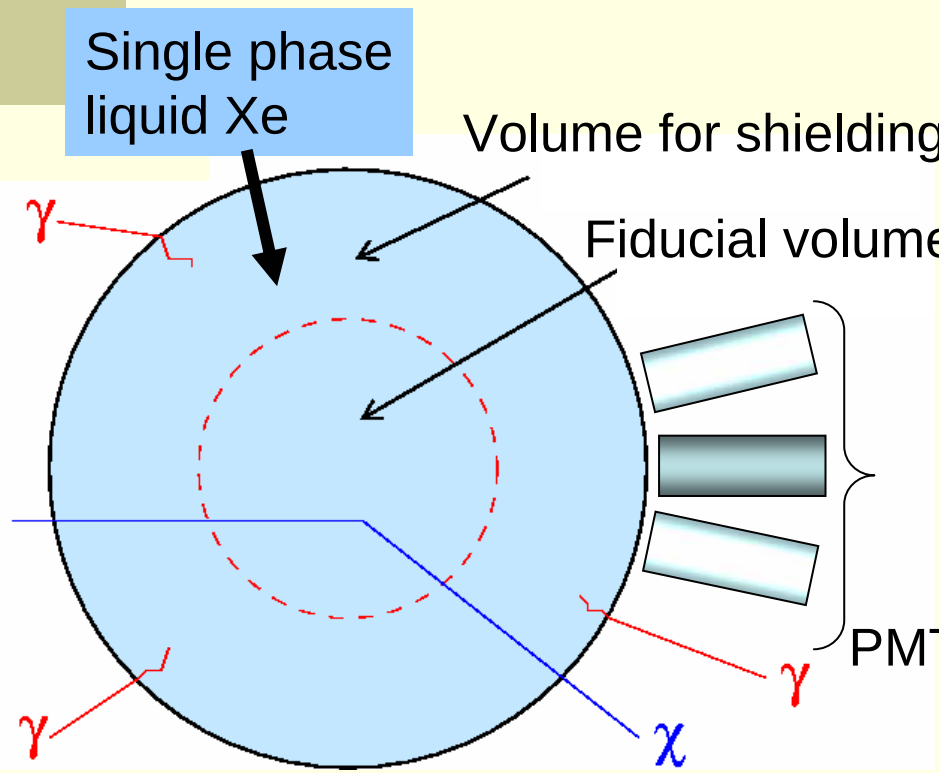
Solar neutrino

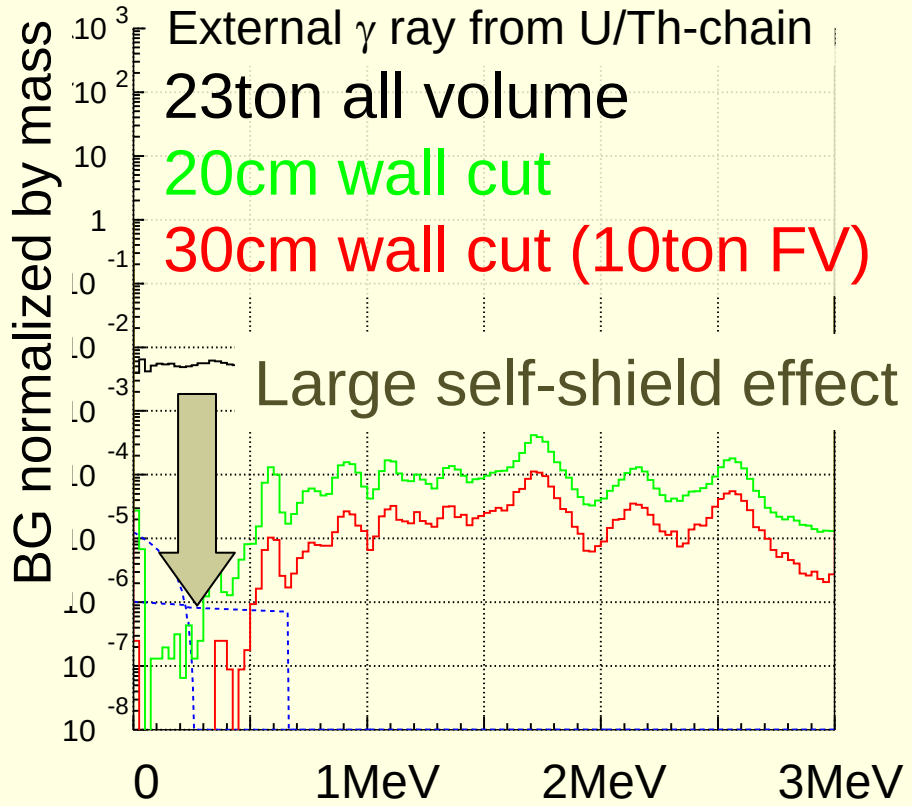
Dark matter



Double beta

Key idea: self shielding effect for low energy signals

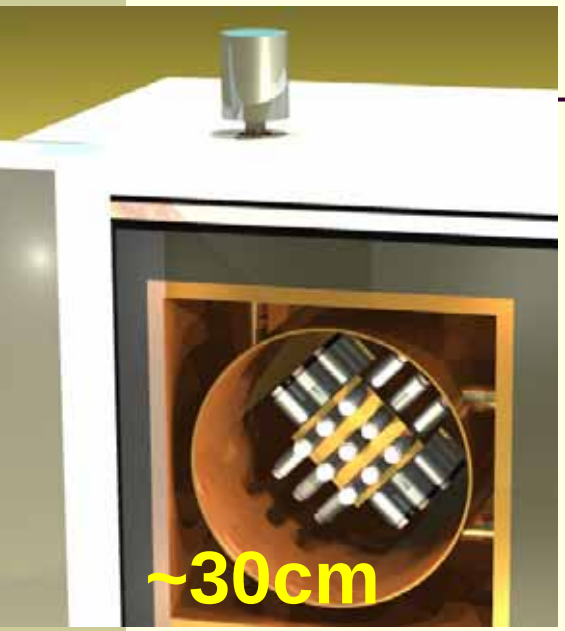




- Large Z makes detectors very compact
- Large photon yield (42 photon/keV ~ NaI(Tl))

Liquid Xe is the most promising material.

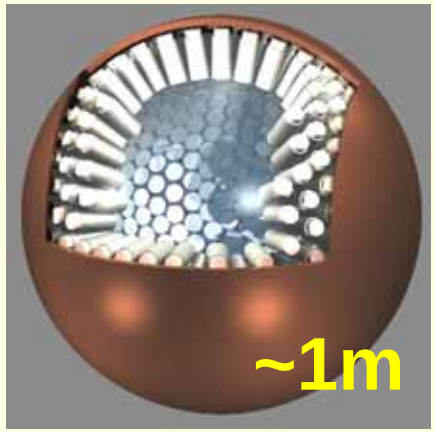
Strategy of the XMASS project



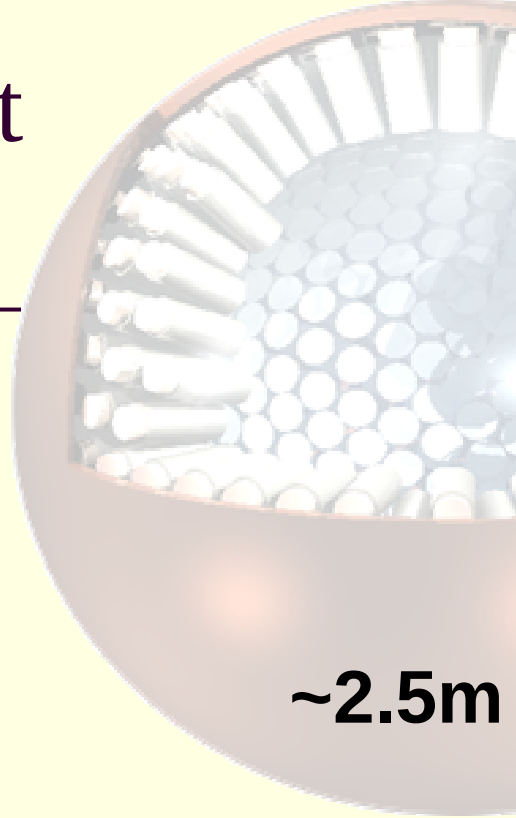
Prototype detector
(FV 3kg) R&D

Confirmation of feasibilities of the ~1ton detector

Good results



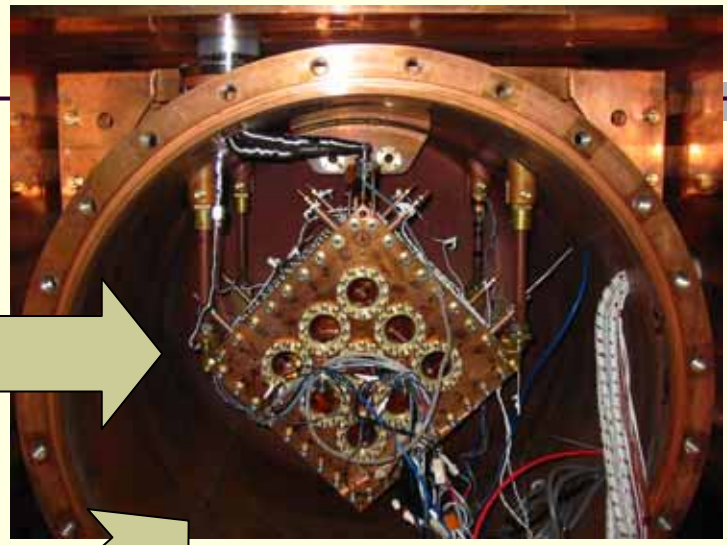
~1 ton detector
(FV 100kg)
Dark matter search



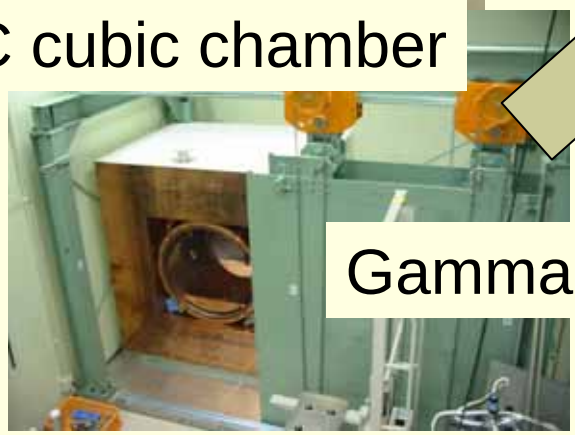
~20 ton detector
(FV 10ton)
Solar neutrinos
Dark matter search

3kg FV prototype detector

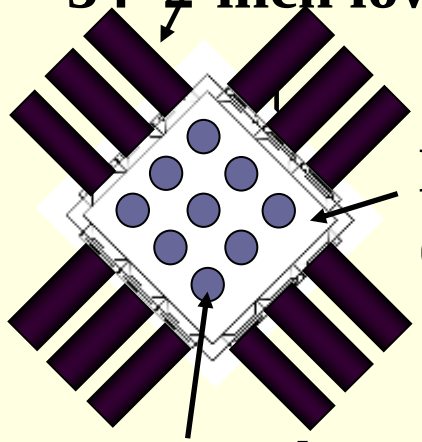
OFHC cubic chamber



In the Kamioka Mine (near the Super-K)



Gamma ray shield



- 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.

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

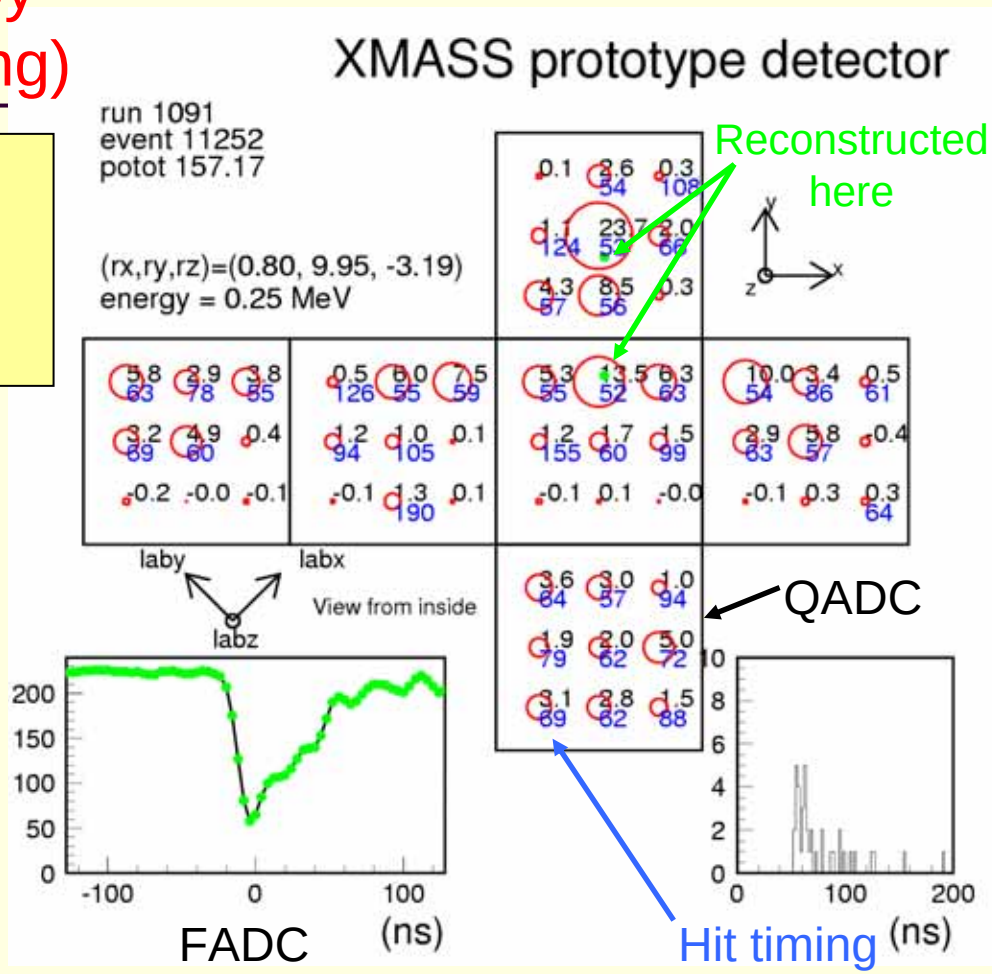
L: likelihood

μ : $\dfrac{F(x,y,z,i)}{\Sigma\, F(x,y,z,i)}$ x total p.e.

n: observed number of p.e.

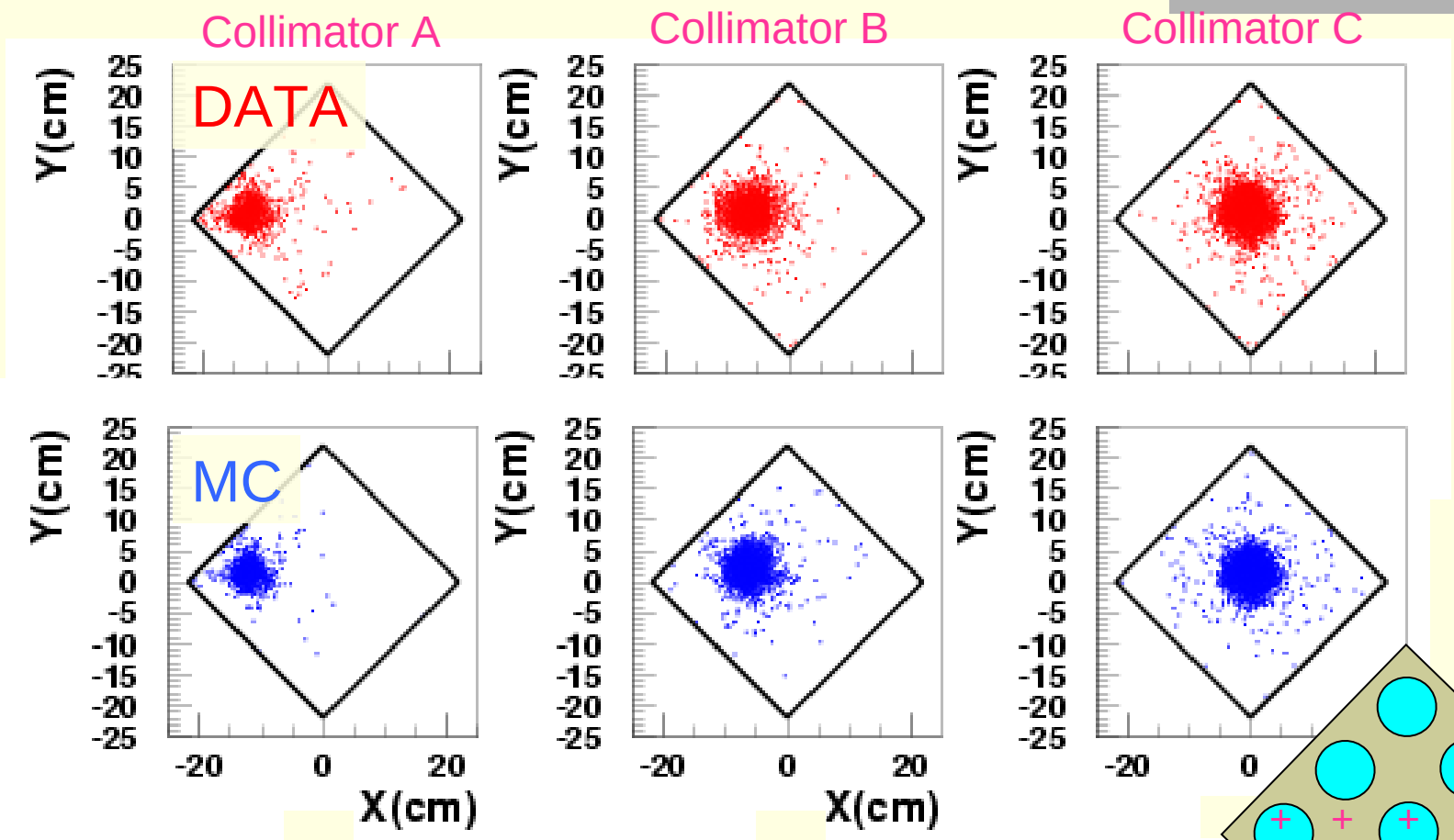
F(x,y,z,i): acceptance for i-th PMT (MC)
VUV photon characteristics:

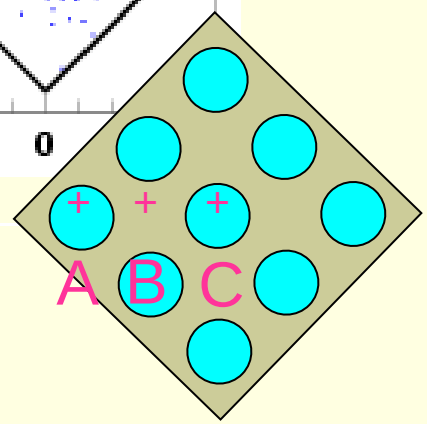
L_{emit}=42ph/keV
τ_{abs}=100cm
τ_{scat}=30cm



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

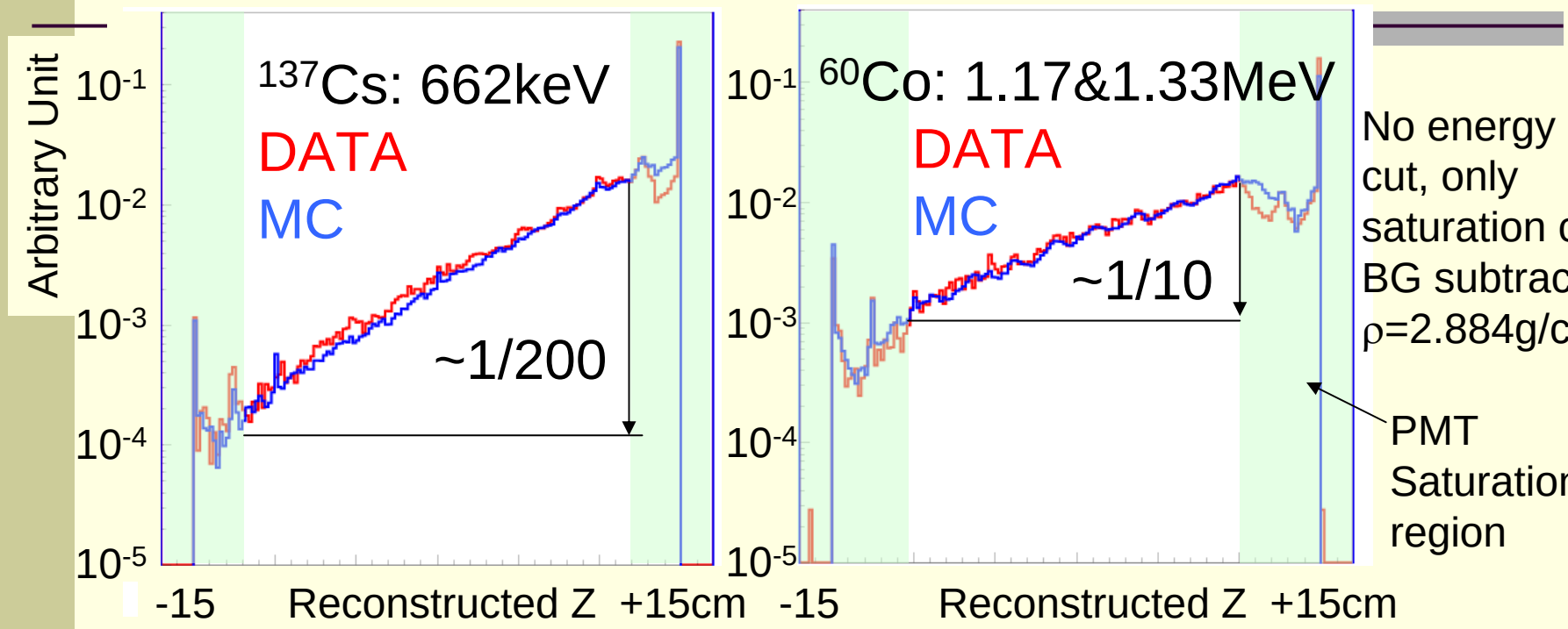
Source run
(γ ray injection from collimators) I

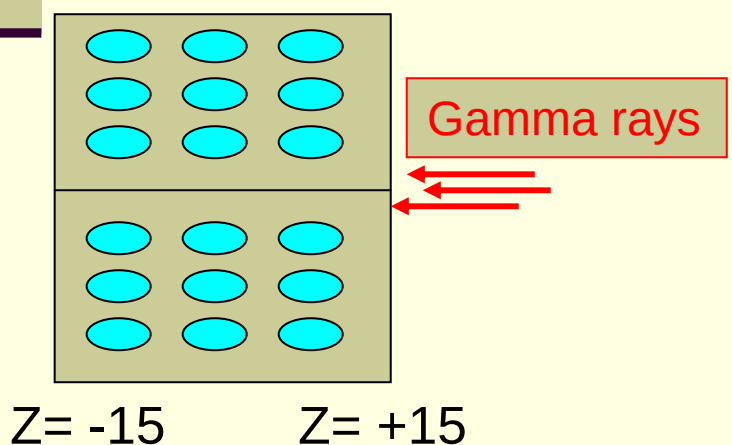




- Well reproduced.

Source run
(γ ray injection from collimators) II



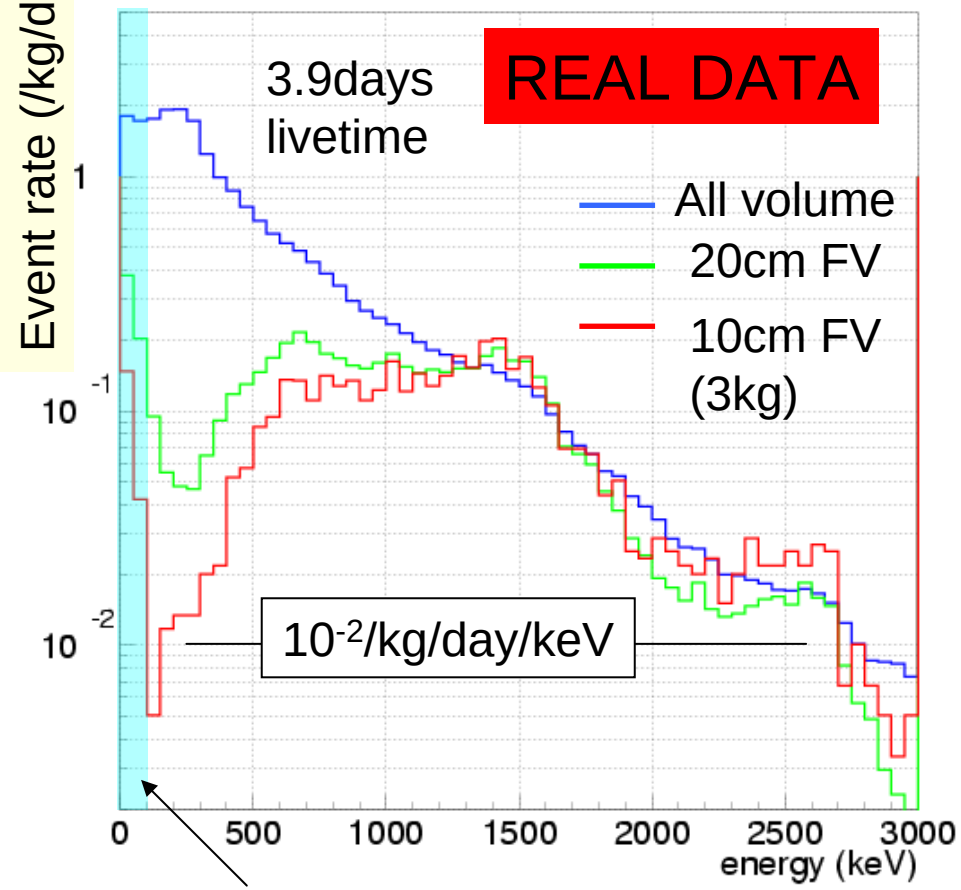


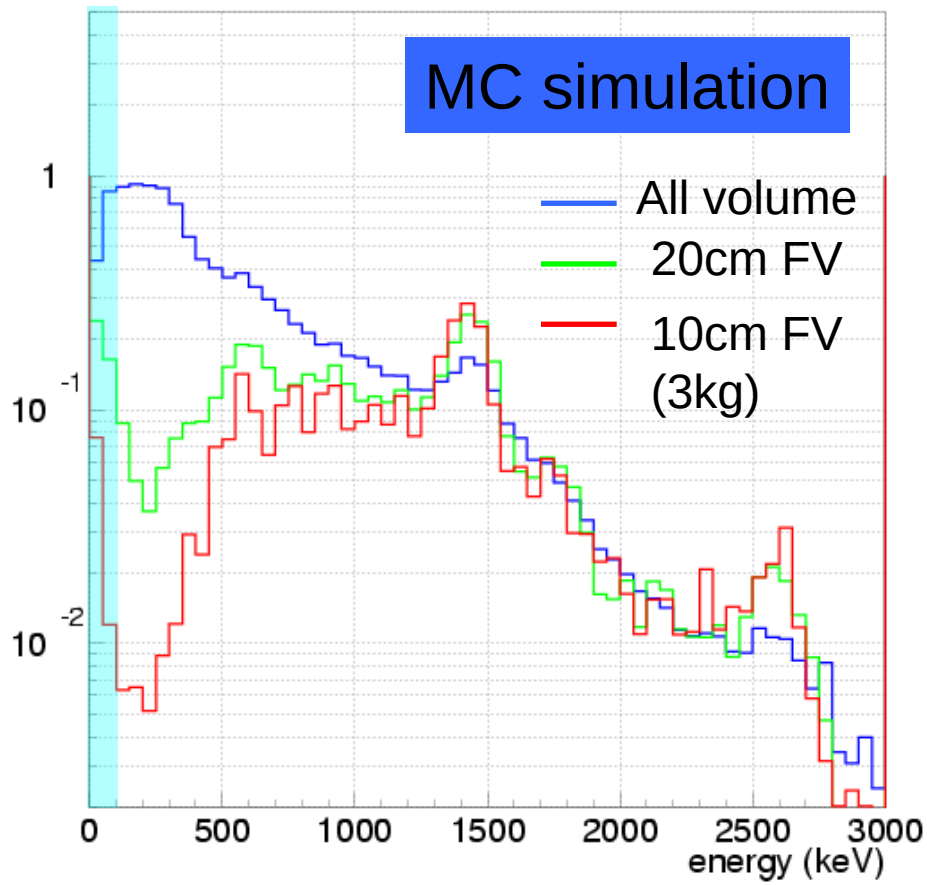
- Good agreements.
- Self shield works as expected.
- Photo electron yield ~ 0.8p.e./keV for all volume

Background data

Aug. 04 run
preliminary

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

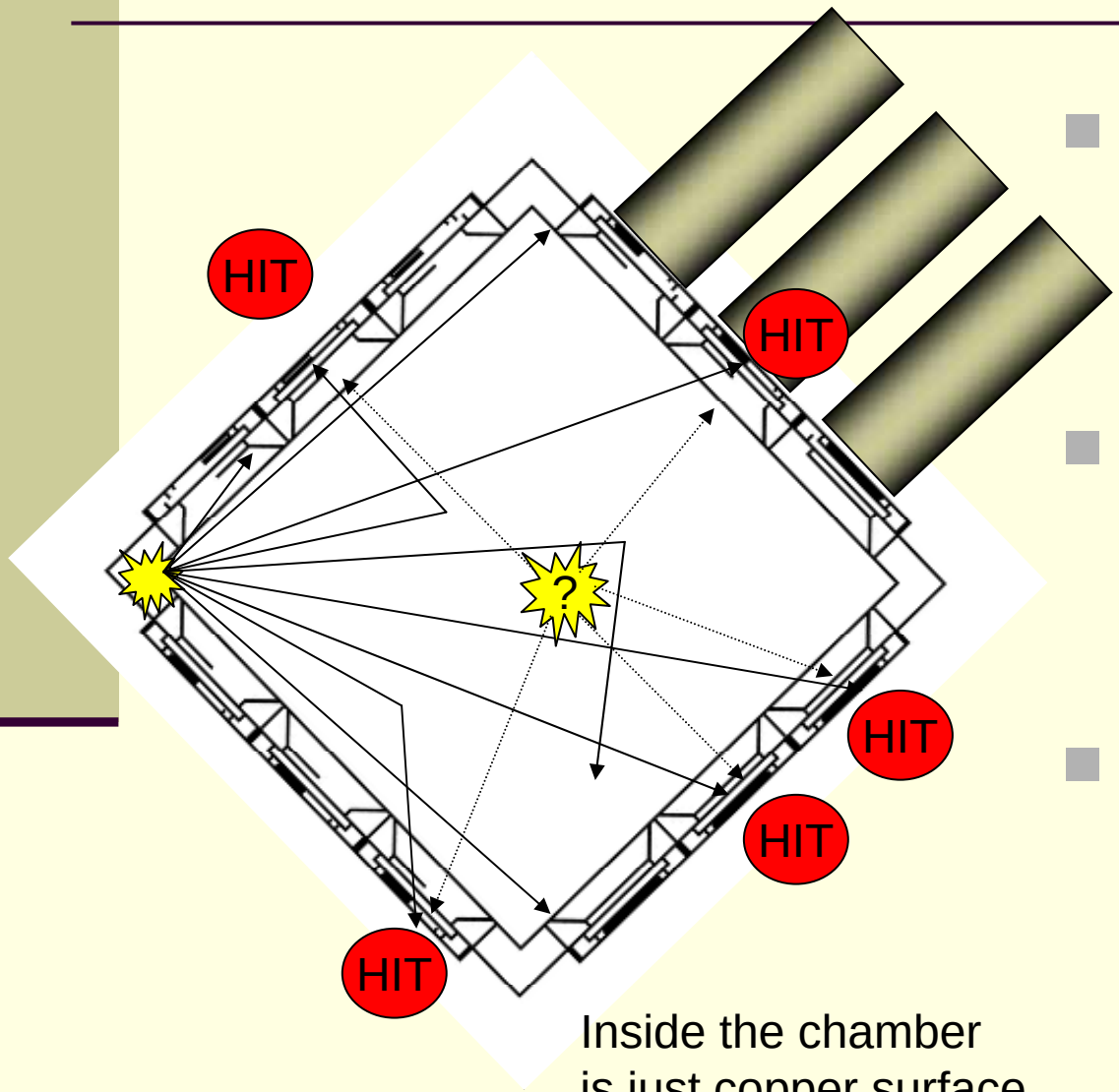




Mis-reconstruction due to dead-angle region from PMTs.

- MC uses U/Th/K activity from PMTs, etc (meas. by HPGe).
- 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 the prototype detector)



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 miss 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

Internal background activities

Preliminary

Goal to look for DM by 1ton detector

- Current results

NEW

- ^{238}U(Bi/Po): = (33+-7)x10^{-14} g/g ← 1x10^{-14} g/g

x33

Factor ~30, but may decay out further

- ^{232}Th(Bi/Po): < 63x10^{-14} g/g ← 2x10^{-14} g/g

x32

Factor <~30 (under further study)

NEW

- Kr: =3.3+/-1.1ppt ← 1 ppt

x3

Achieved by distillation

Very near to the target level of U, Th Radon and Kr contamination.

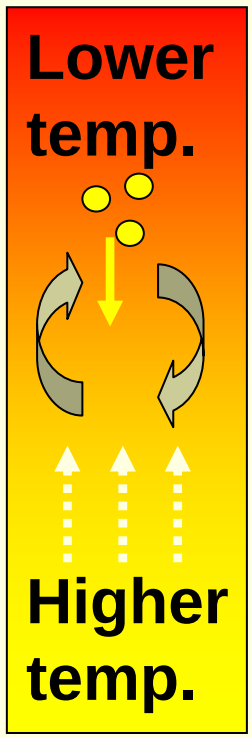
Distillation to reduce Kr (1/1000 by 1 pass)

- Very effective to reduce internal impurities (^{85}Kr, etc.)
- We have processed our Xe before the measurement.

	Boiling point (@1 atm)
Xe	165K
Kr	120K

Original Xe:
~3 ppb Kr

13 stage of



~1%

Off gas Xe:
330±100 ppb Kr
(measured)

Operation: 2 atm
Processing speed: 0.6 kg / hour
Design factor: 1/1000 Kr / 1 pass

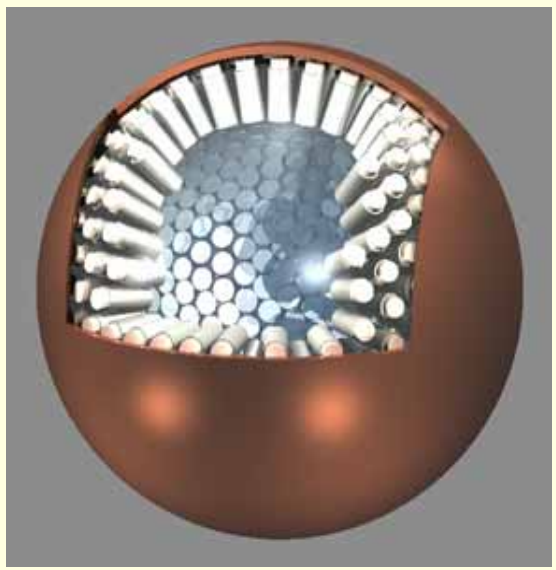
~99%

Purified Xe:
= 3.3 ppt Kr
(measured after Kr-enrichment)

1 ton (100kg FV) detector for DM Search

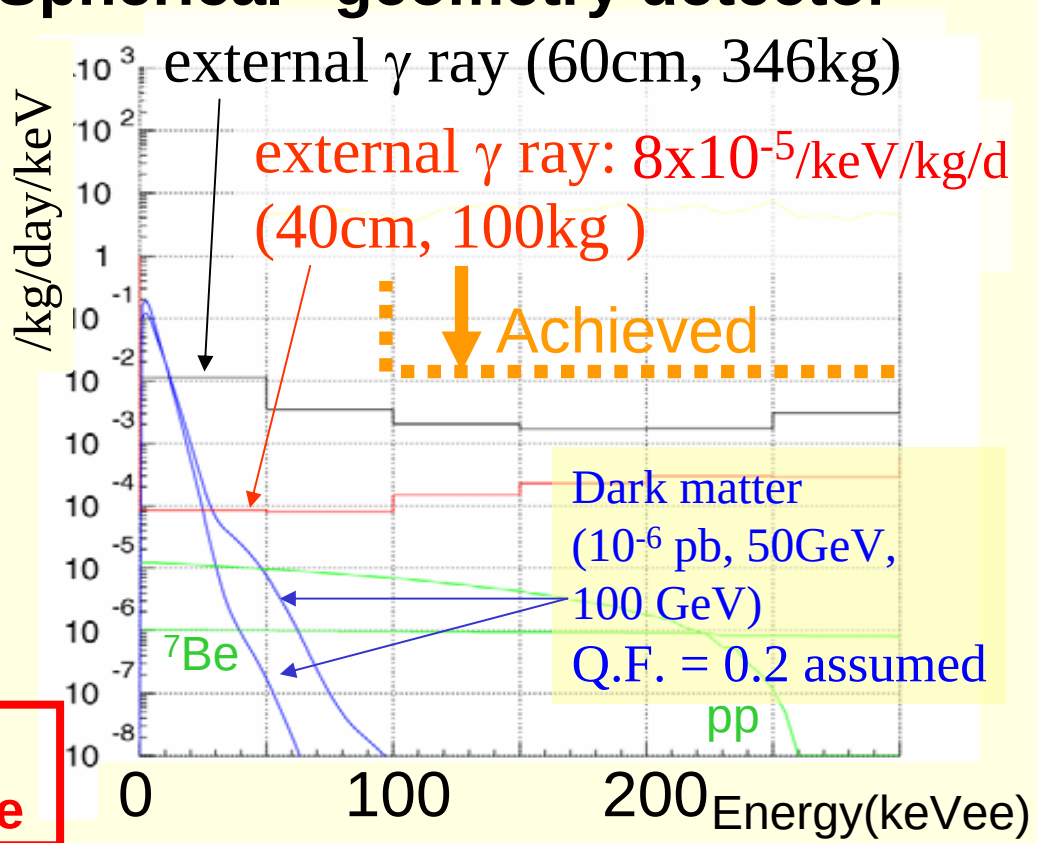
- Solve the miss reconst. prob. ➔ immerse PMTs into LXe
- Ext. γ BG: from PMT's ➔ Self-shield effect demonstrated
- Int. BG: Kr (distillation), Radon ➔ Almost achieved
- Neutron: water or LS active shield (1/10⁴) ➔ To be studied

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



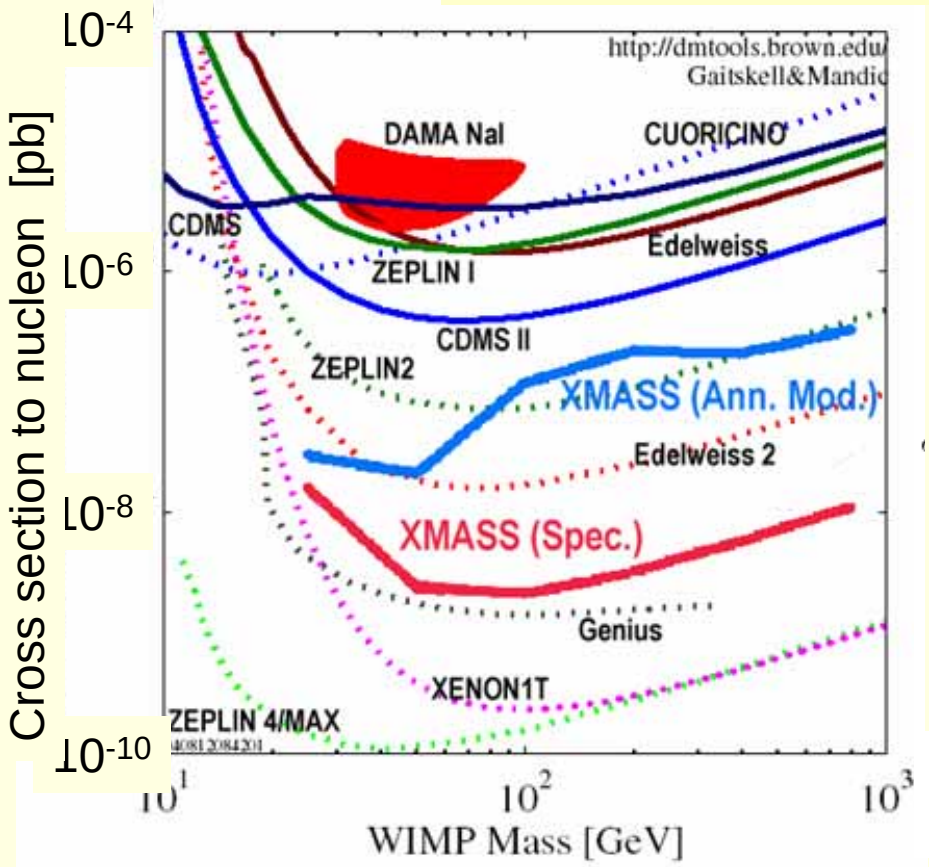
80cm dia.

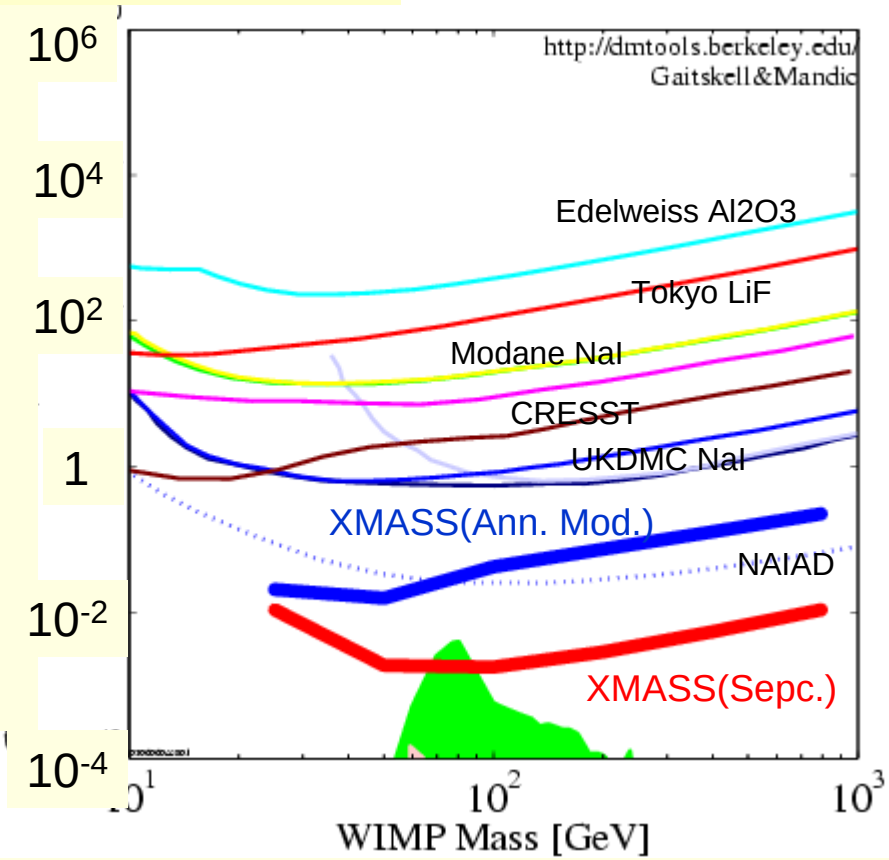
~800-2" PMTs (1/10 Low BG)
70% photo-coverage ~5p.e./keVee



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

Summary

- XMASS project: DM search with 100kg FV LXe.
- R&D by 3kg FV prototype is well going
  Demonstration of
  reconstruction, self shield, and low BG properties.
- Ext γ rays: 10^{-2} /kg/day/keV ➔ further self shield
  Kr: =3.3+/-1.1ppt ➔ requirement almost achieved.
  Radon (U) (33+-7)10^{-14}g/g (Th) < 63 10^{-14}g/g
  ➔ O(1/30) reduction is enough for 1ton det.
- Further study for neutron is needed.

Within a few years, we are planning to build
the 100kg FV detector and start to search for DM!