XMASS experiment
Current status

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What is XMASS ?

XMASS is a multi purpose low background experiment using Liq.Xe.

●XMASS

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

- **Low energy solar neutrinos** Plenty information for osc. parameters

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

- **Dark Matter** Non Baryonic Cold Dark Matter Candidate ⇒ Neutralino

Leading Candidate

Direct Detection of WIMPs(Neutralinos)

↳ Very important for Astrophysics and Particle physics .

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

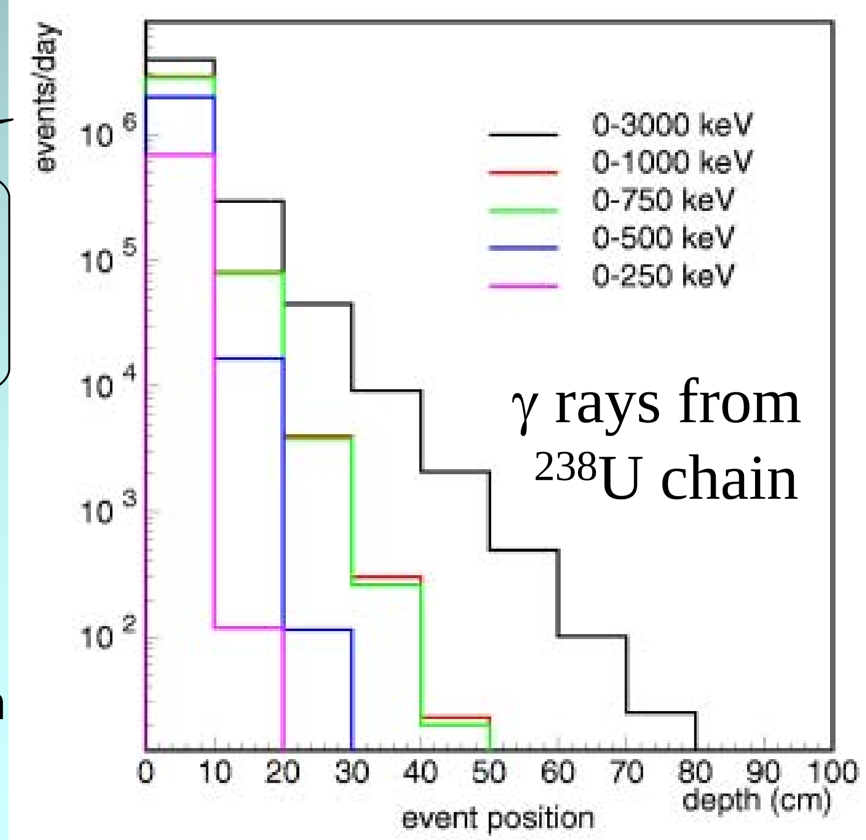
- $0\nu\beta\beta$, $2\nu\beta\beta$ decay

Why liq. Xe?

- Large photon yield (~42000photons/MeV)
- Compact detector size (~3g/cm^3 10ton=1.5m cubic)
- Purification (distillation)
- No long life isotope
- Scintillation wavelength (175nm, detect directly by PMT)
- Relative high temperature (~165K)

- Self-shield (large Z=54)

Several orders of magnitude reduction can be expected for energy less than 250keV at 20cm



- easy isotope separation

^{136}Xe : double beta decay
odd-Xe : WIMPs spin Dep. interaction
even-Xe : WIMPs spin InDep. interaction

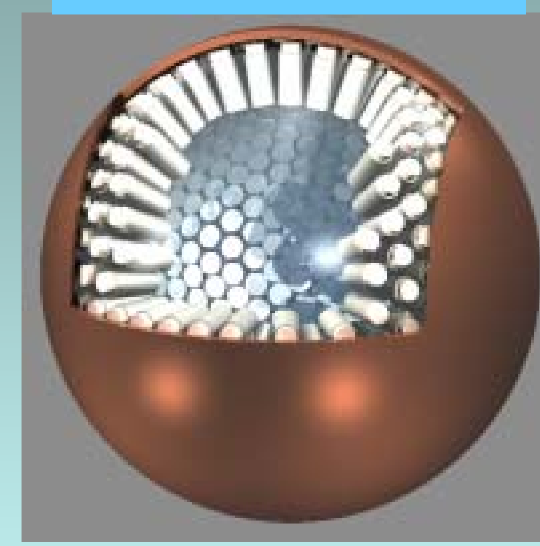
Experimental strategy

As a first step of XMASS, Dark matter search is main purpose.

100kg Detector
Mainly R&D

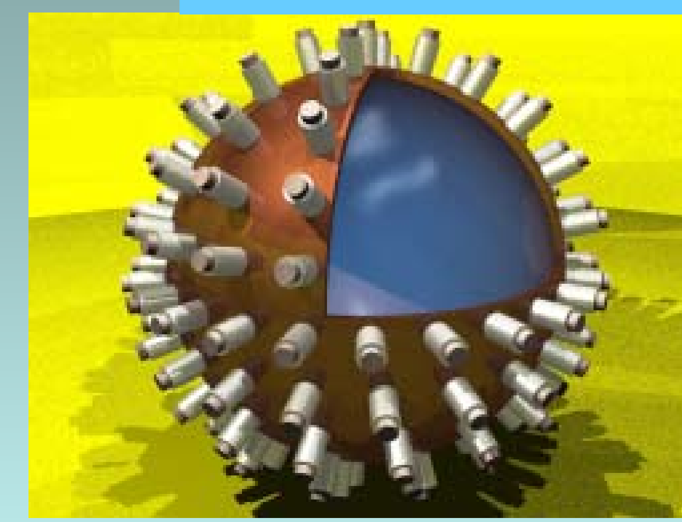
Now started!!

800kg Detector
Dark matter search



Next planning!

~10 ton Detector
Solar ν / Dark matter



Performance demo., R&D

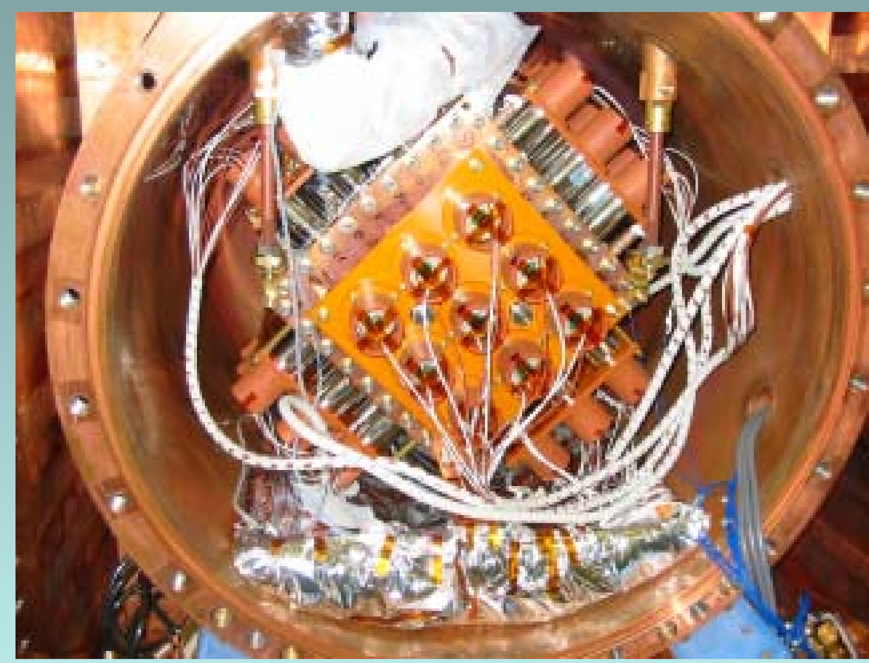
LowE solar neutrino detection

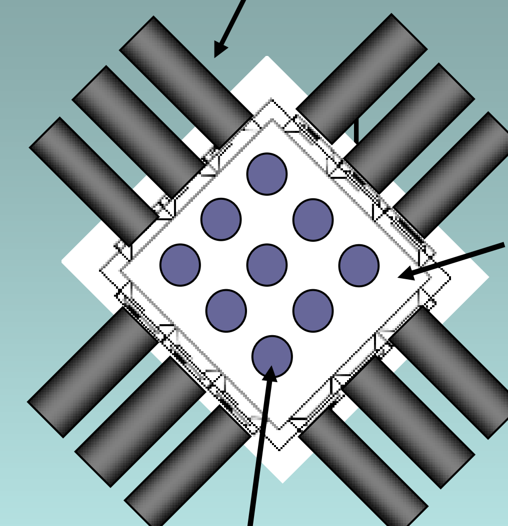
Dark matter search

R&D of the double beta dedicated detector

100kg Detector current status/analysis

1. Introduction of 100kg detector





Menu of R&D

- Low background setup
- Vertex / energy reconstruction
- Demonstration of self-shielding
- Purification system
- attenuation length
- neutron B.G. study etc.

2. Low background setup

・selection of material

- Inner Vacuum Chamber
- Outer Vacuum Chamber

} made of OFC

- PMT

・PMT base : glass PCB ⇒ PTFE PCB

^{238}U ～1/100 (～ 10^{-3} Bq/PMT)

・Glass tube ⇒ metal tube

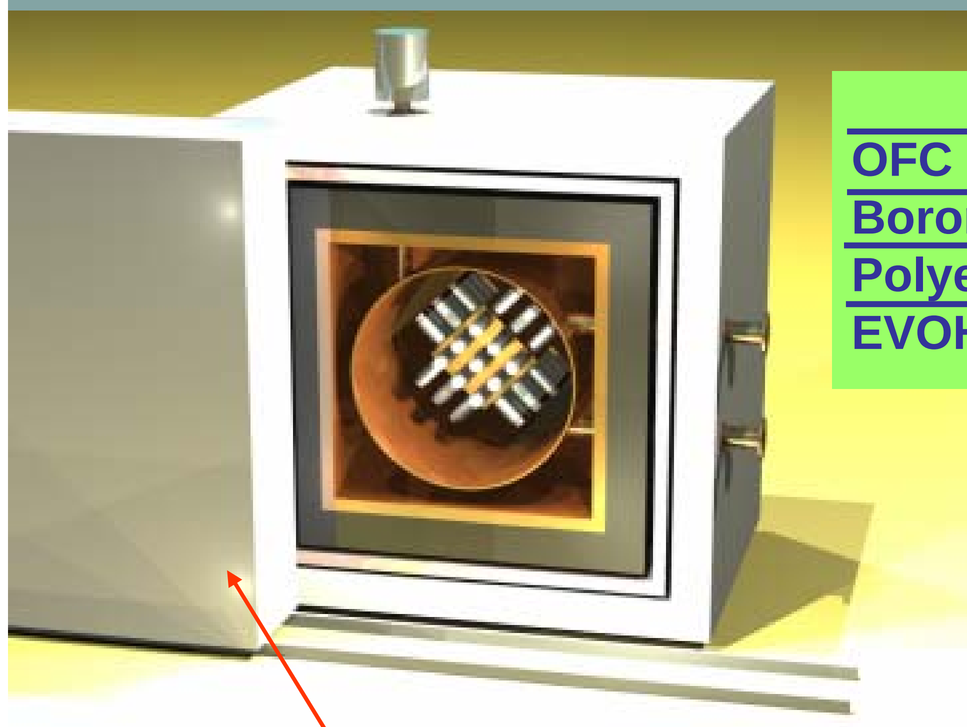
	U(Bq/PMT)	Th(Bq/PMT)	K(Bq/PMT)
R8778	2.0×10^{-2}	7.0×10^{-3}	1.4×10^{-1}
ZK0667	5.0×10^{-1}	1.2×10^{-2}	6.1×10^{-1}

Low background PMT !!

- Other materials are also low radioactivity.

2. Low background setup

・external BG shield



OFC (5cm), Lead (15cm)	γ、β
Boron (5cm)	neutron
Polyethylene(15cm)	neutron
EVOH sheet	radon

4π shield with door
⇒ Easy access to chamber

3. Vertex/Energy reconstruction

GEANT simulation → PMT hit-map

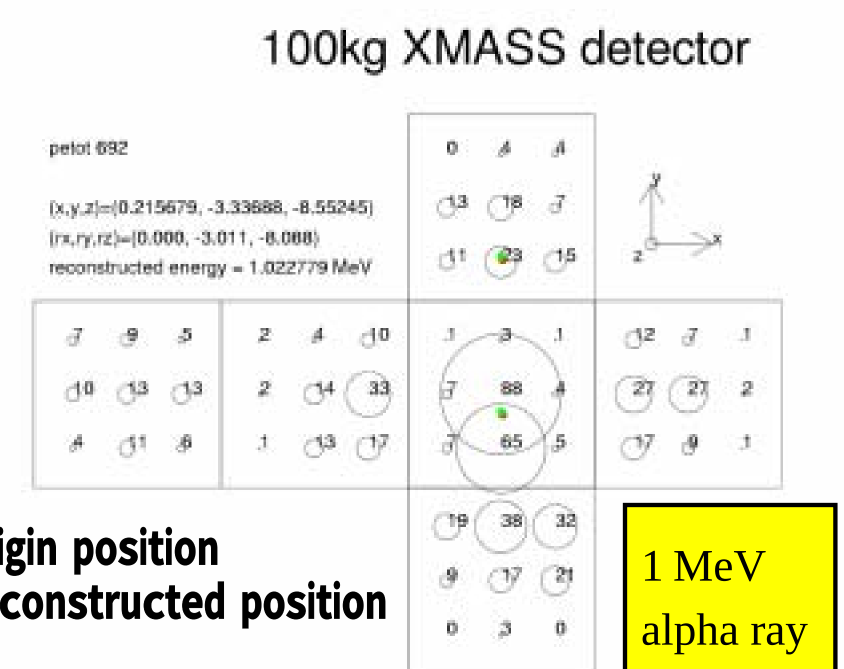
F(x,y,z,i) : acceptance of ith PMT view from position(x,y,z)

Interpolation with Event simulation @ 2.5[cm] lattice points of 100kg chamber

Find vertex and Energy which gives MAX Likelihood

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

L: likelihood
μ: F(x, y, z) x
(total p.e./total acceptance)
n: observed number of p.e.



4. PMT gain calibration

- **175[nm] wave length**
- **compact**

→ **VUV standard light source**

GAS-Xe chamber + ^{241}Am α-source

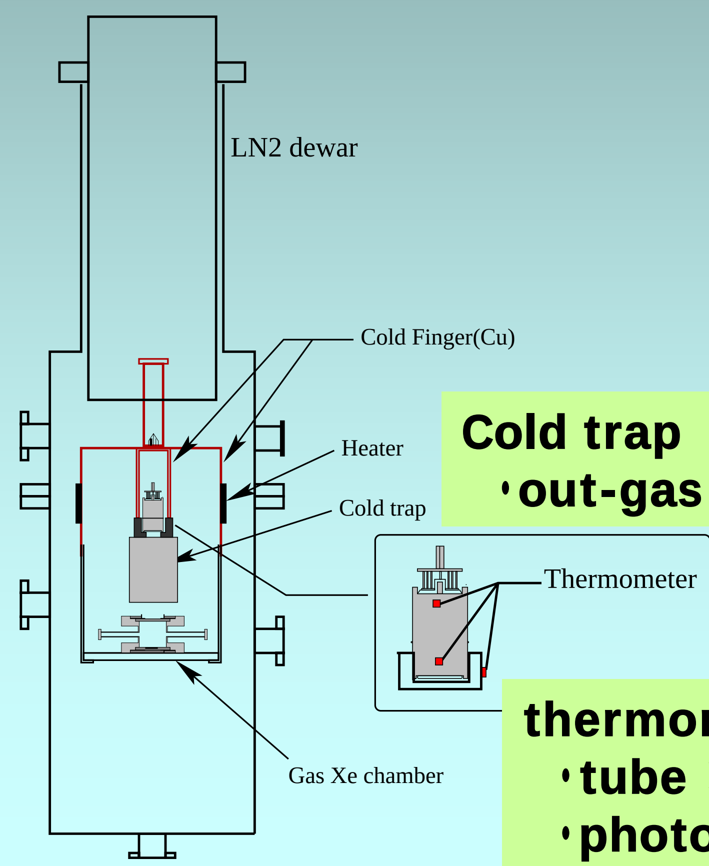
- ^{241}**Am α**(5.45MeV)
- GAS-Xe：2[atm]
- MgF_2 window：90**%** transmittance**@175**nm

54 PMTs were calibrated within 2% (@room temp.)

5. PMT cooling test

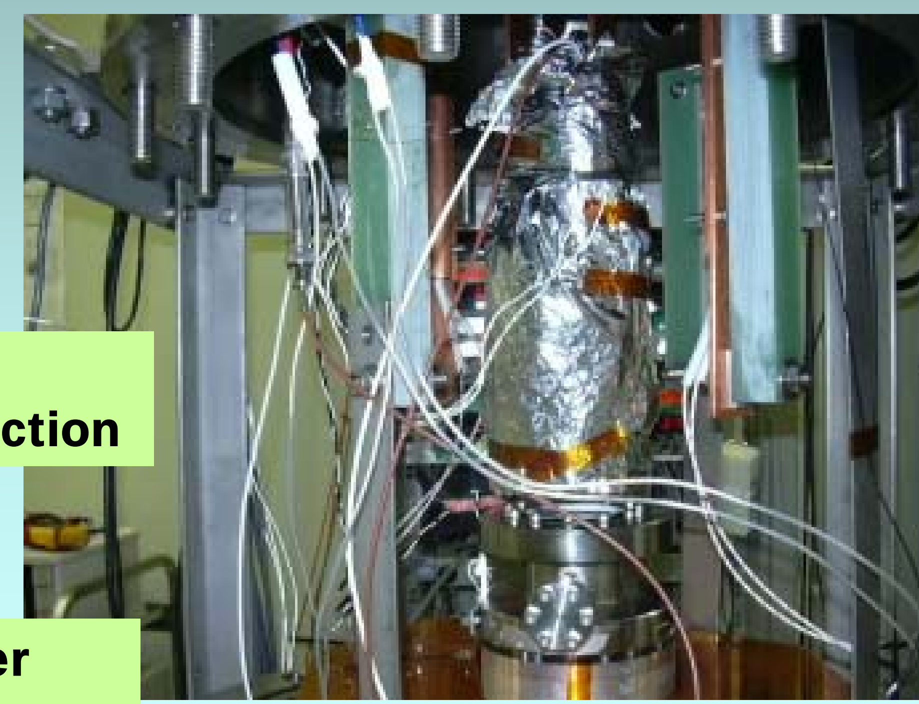
Actually, PMT temperature is about 200[K] during measurement.

- **multi photons measurement** with **gas Xe chamber** : Q.E×Gain
- **single photon measurement** with **LED** : Gain

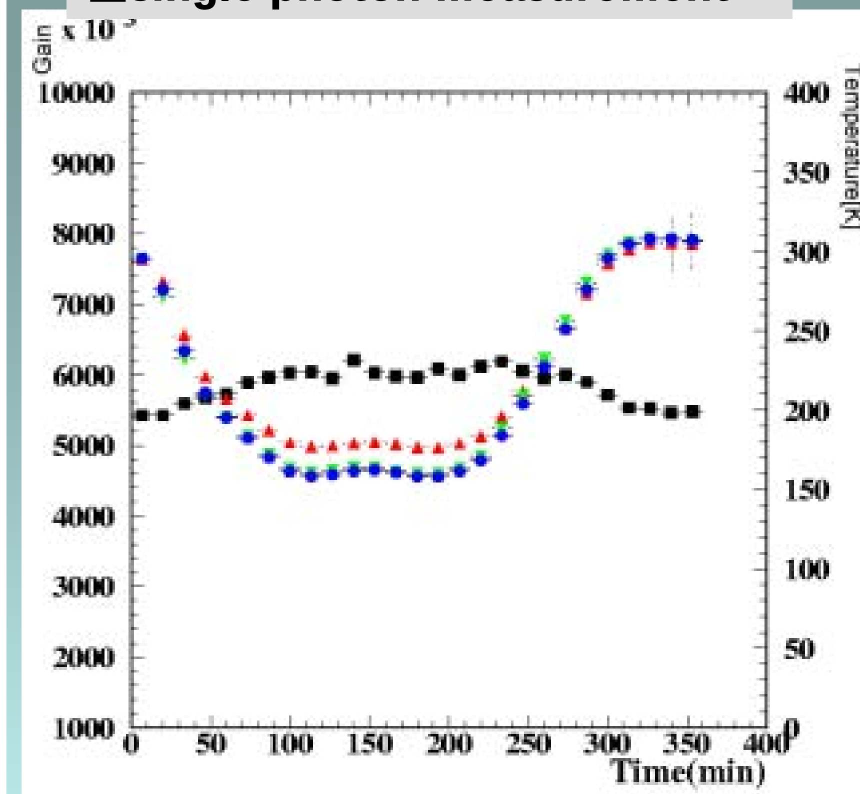


Cold trap
・**out-gas rejection**

thermometer
・**tube ×2**
・**photo-cathode**

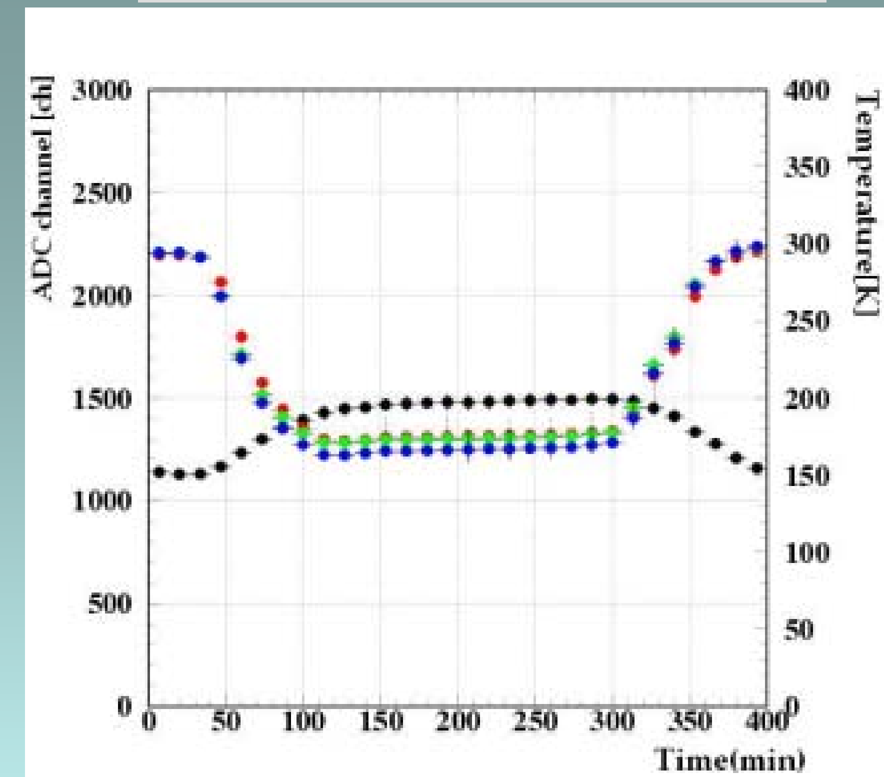


■single photon measurement



Gain increase
at low temperature

■multi photons measurement



Q.E ×gain also increase
at low temperature

Measured about 4 sample PMTs

Gain increase ratio	Q.E increase ratio
Average : 13.9% RMS: 5.4%	Average : 12.2% RMS : 4.7%

There is individual difference

assumption of gain calibration
from vertex/Energy reconstruction simulation

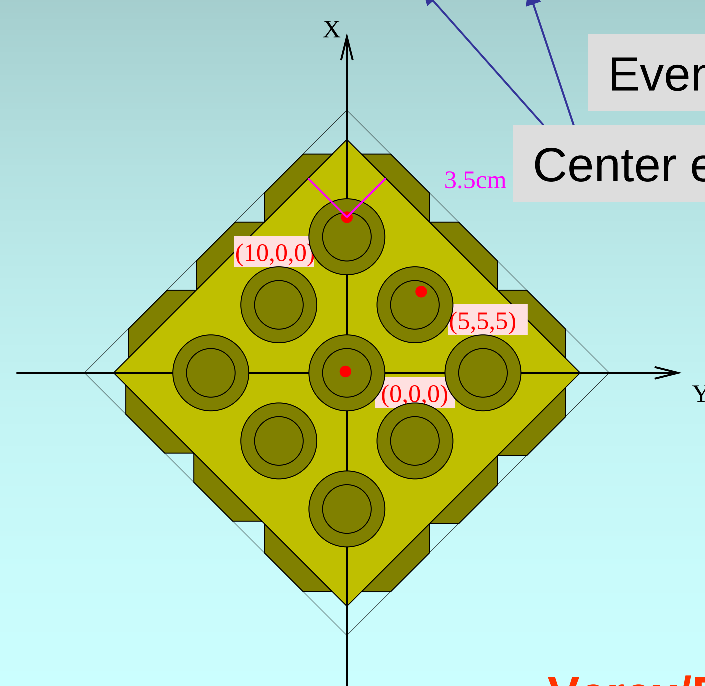
EVENT simulation by GEANT
⇒ get p.e. MAP about 54 PMTs

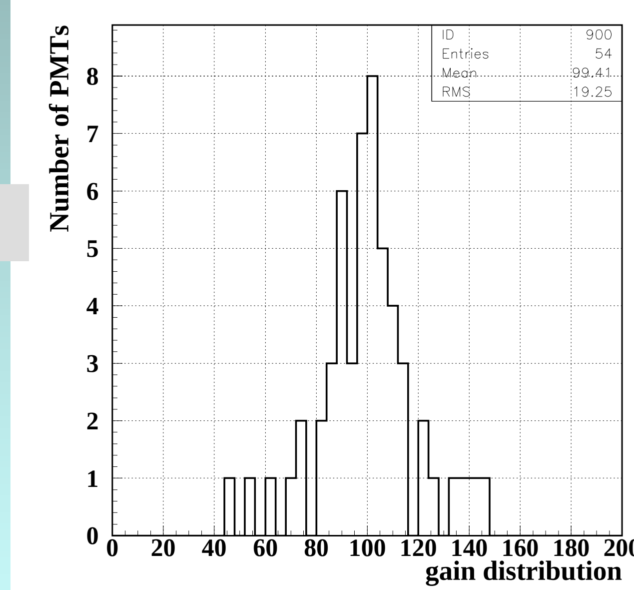
Input
10% and 20% Gain Dispersion
At random

Energy : 100keV ,500keV, 1MeV
Position : (0,0,0) (5,5,5) (10,0,0)

Event near window

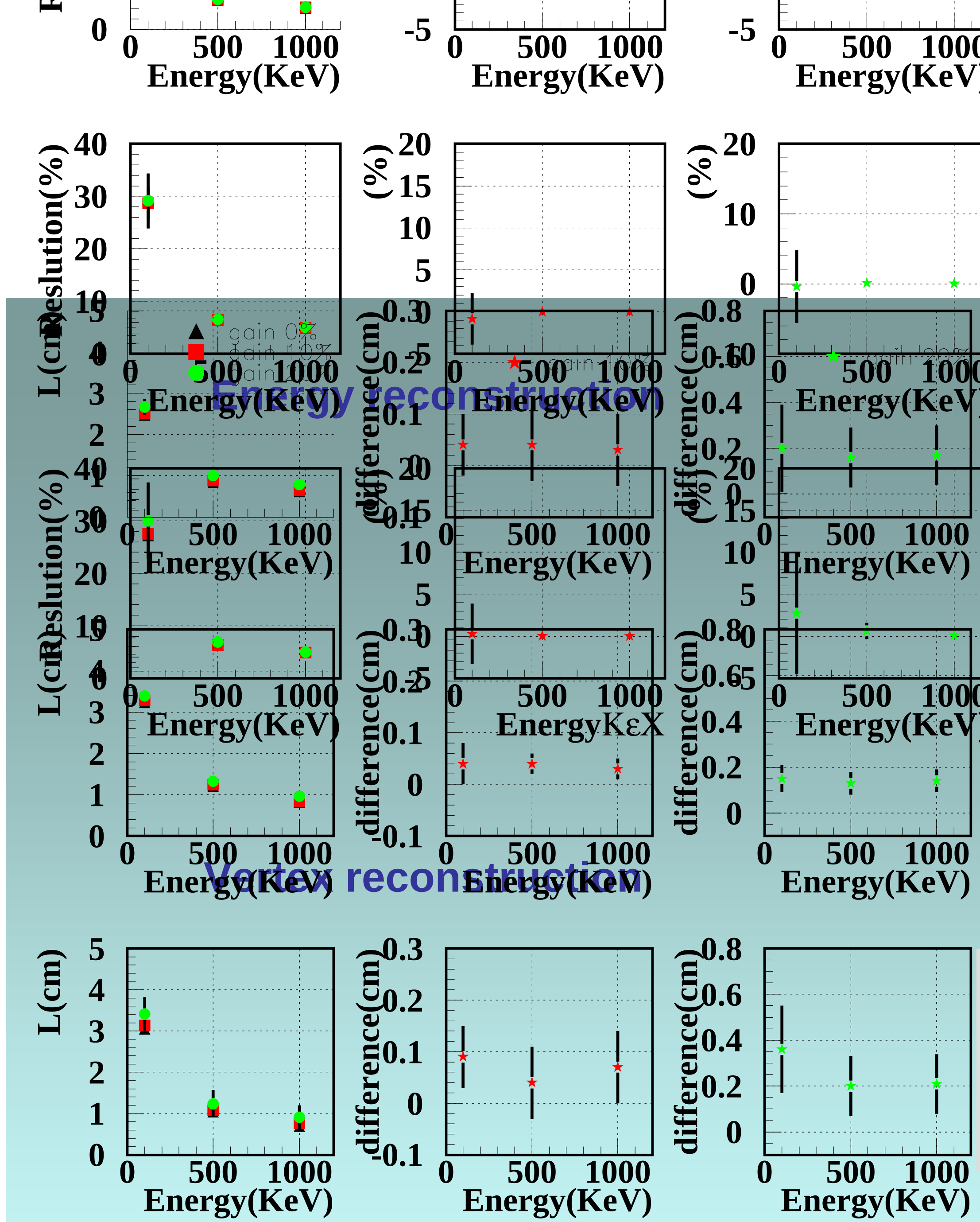
Center event sample





20% gain dispersion

Verex/Energy resolution ??



Gain : 20％
Energy resolution ＜ 10％

No problem

Gain : 20％
position resolution＞0.5cm
Gain : 10％
position resolution ＜ 0.15cm

Event reconstruction request for gain within less than 10% accuracy

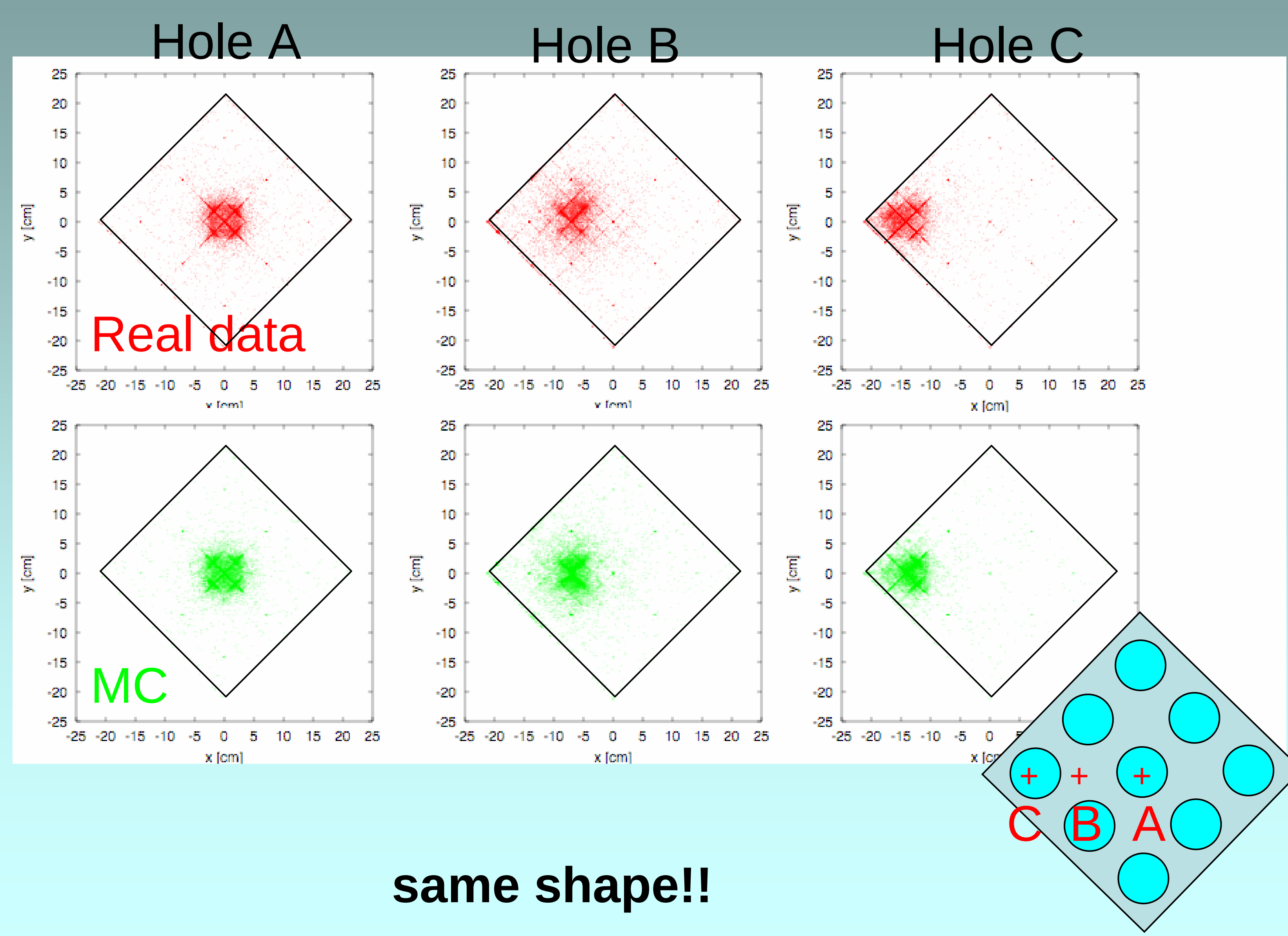
Dispersion of PMT gain at low temperature is no problem

6. Data analysis

- ○ vertex / Energy reconstruction
- ○ Demonstration of self-shielding
- ○ Low Background

■Self shielding performance

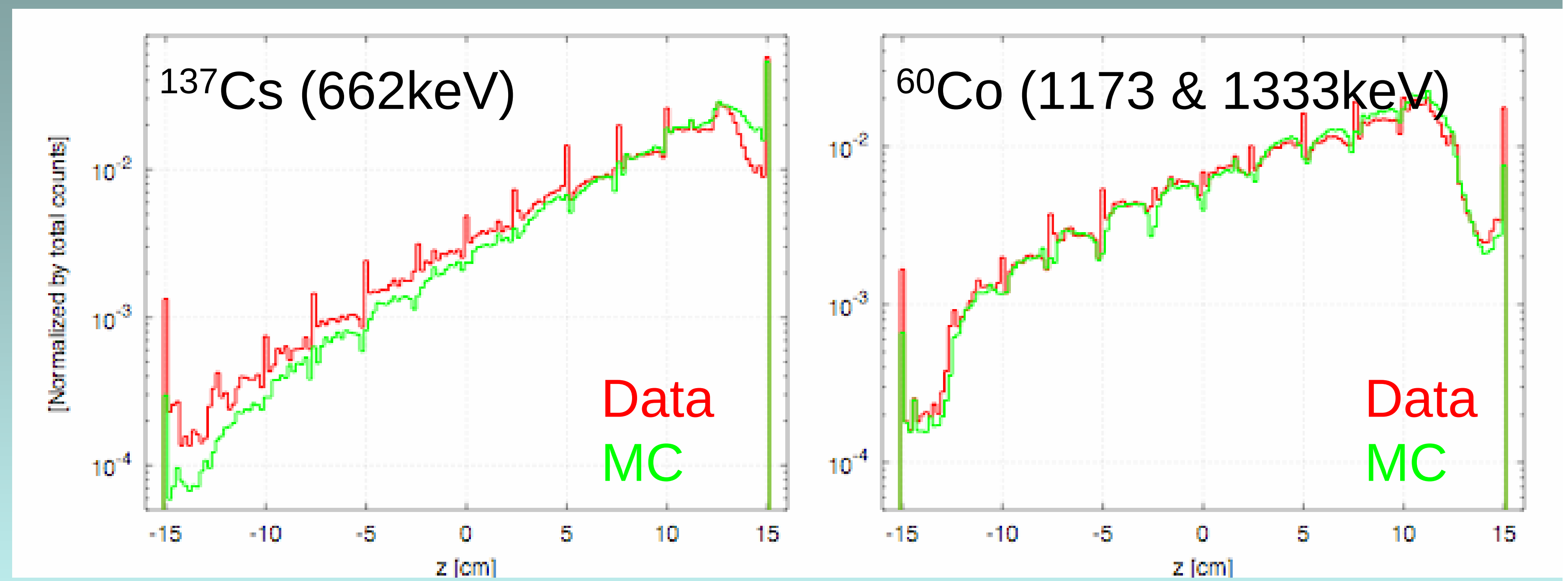
Scatter plot of 3 collimators' run

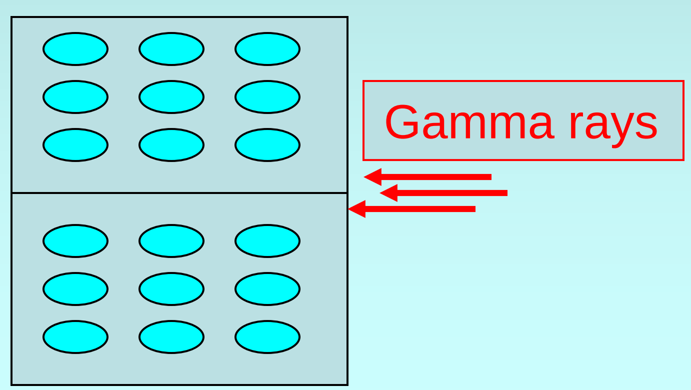


same shape!!

■Self shielding performance

Z position distribution of photoelectric peaks

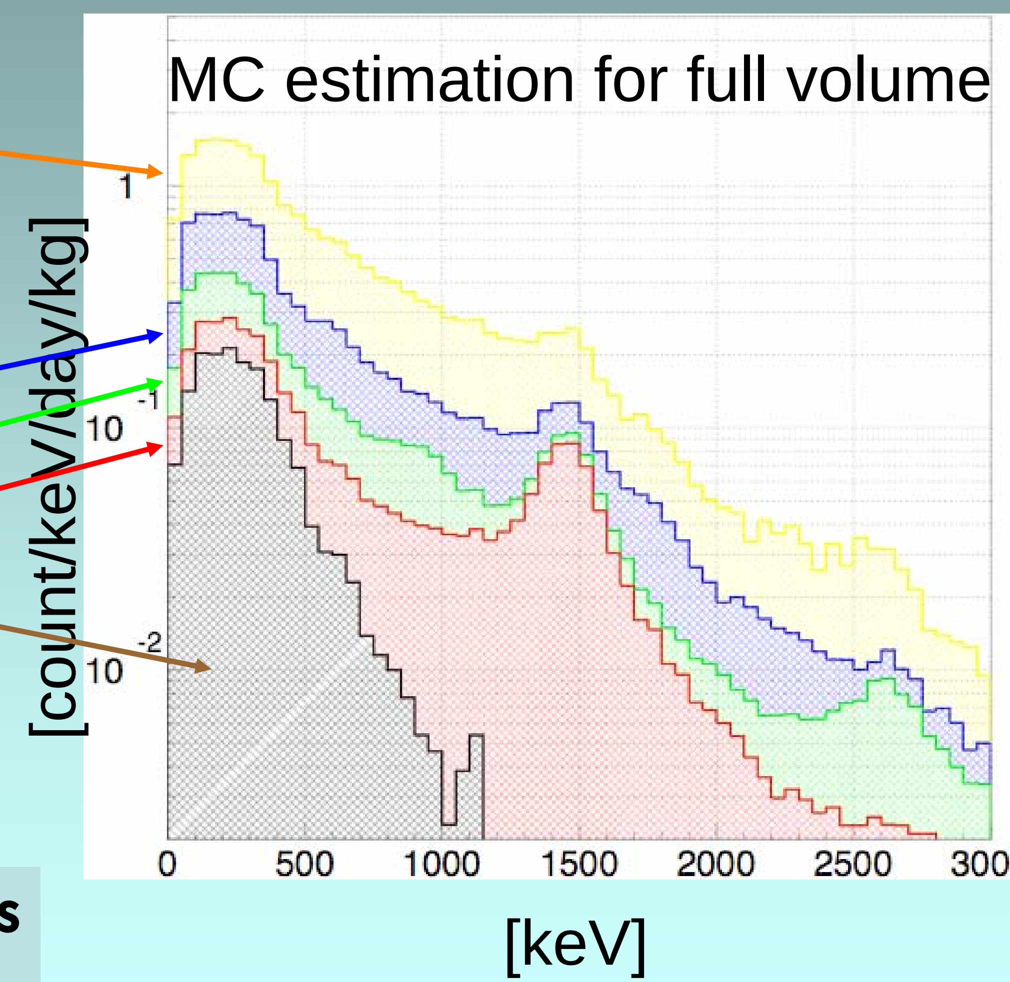




- **Good agreement with MC**
- **Self shielding power works well as expected**
- **(Need to improve fitter)**

■Background estimated from known sources

- From outside of the shield:
  0.71 g/cm2 (>500keV)
- RI sources inside of the shield
  - PMTs (Bq/PMT)
    - 238U : 1.8 $\times 10^{-2}$
    - 232Th:6.9 $\times 10^{-3}$
    - 40K :1.4 $\times 10^{-1}$
- Pb-214 in the lead shield:
  250 Bq/kg

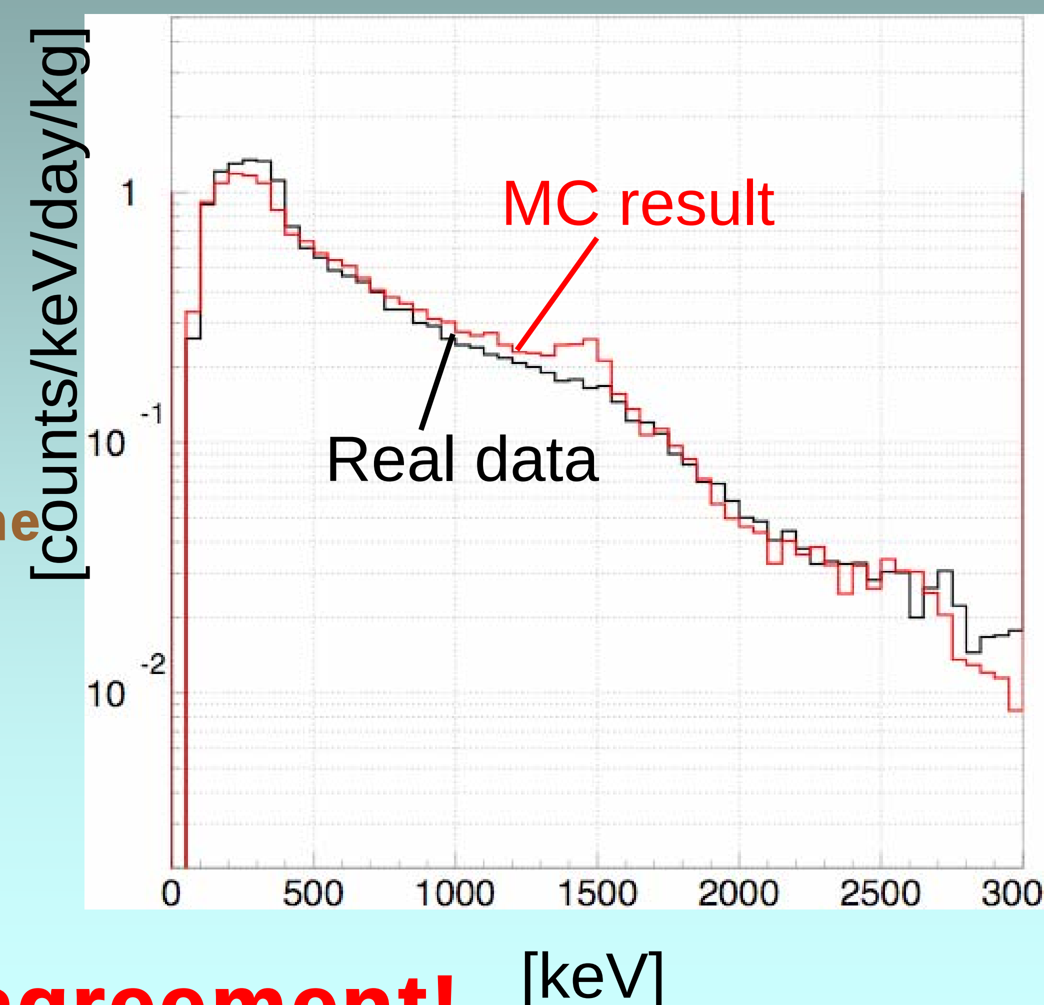


◆ **Xenon internal radioactivities**
- ^{238}U, ^{232}Th contamination
- ^{85}Kr contamination

■BG comparison with MC estimation

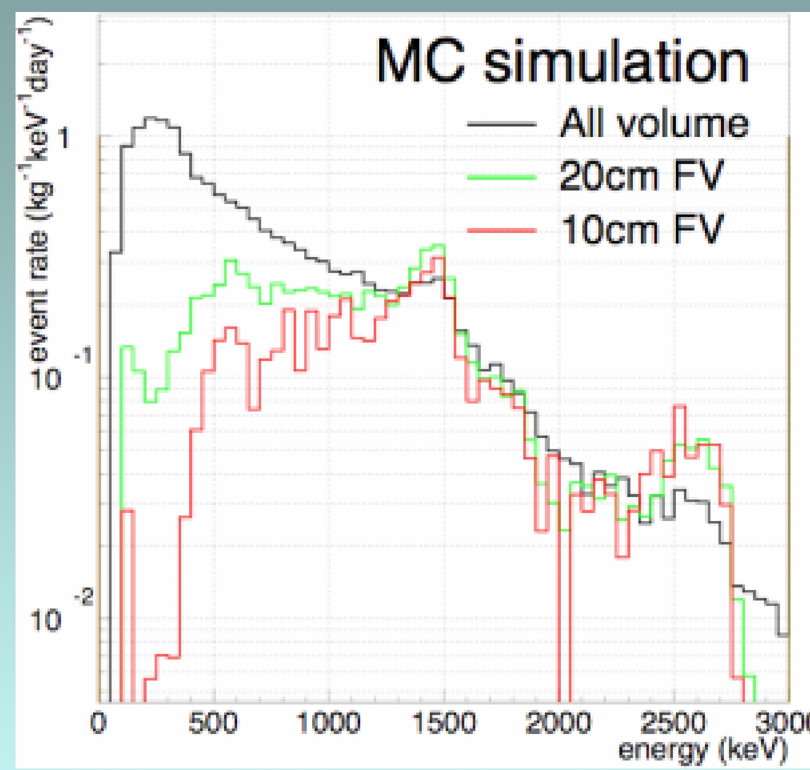
- **MC**
  Gamma from outside
  RI in PMTs(U,Th,K)
  ^{210}Pb in the lead shield

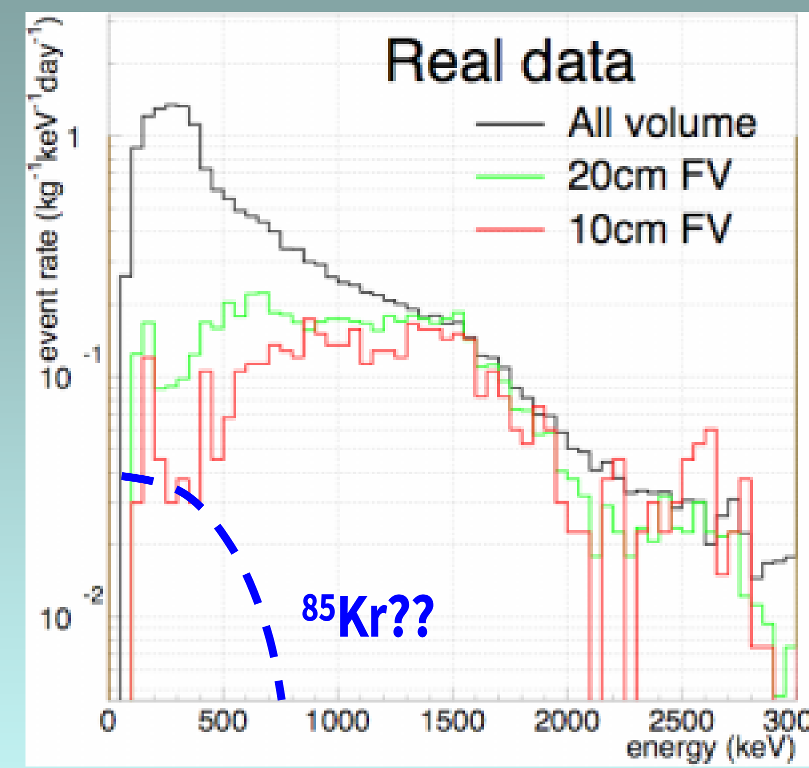
- **Real data for full volume**
  (livetime: 0.9days)



Good agreement!

■Self shielding power



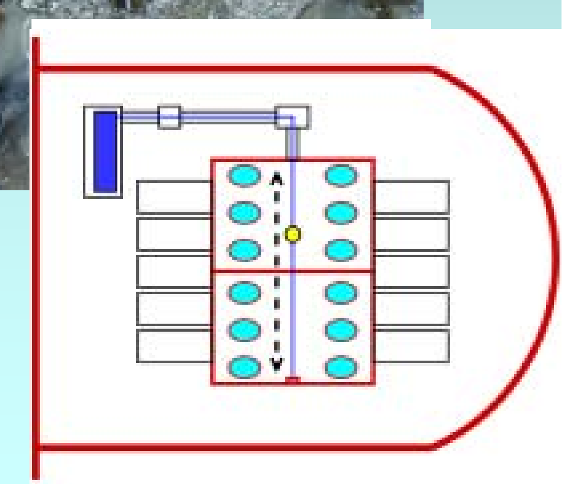


- Background decreases with the fiducial volume cut
  ⇨ Ultra-low BG at the inner volume
- Something exists at low energy region
  ⇨ ^{85}Kr??

Will be compared after processed by the distiller

Future plan with 100kg detector

- 1st run: DONE!
  - Confirmed the basic properties
  - Evaluated the event reconstruction performance
  - Background measurements and breakdown of its origin
- Further study:
  - Detailed study of event reconstruction
    Source run with inner sources
  - Detailed study of the background
    With a distiller and various purification systems
    With a neutron source



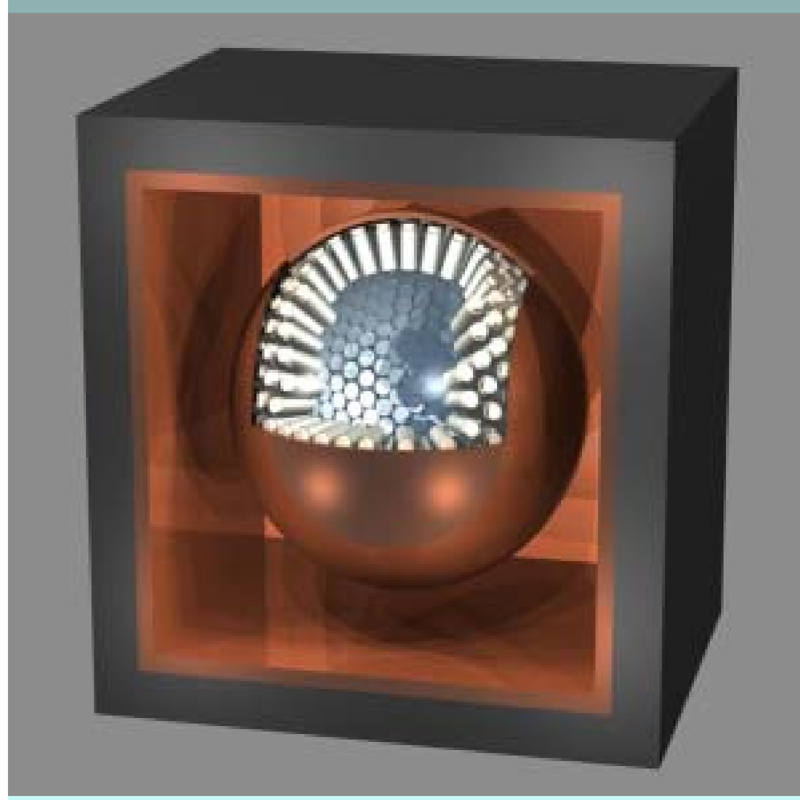
→ Development of the large size detector

800kg Detector simulation/future plan

1. Introduction
2. BG simulation
3. Expected Sensitivity for DM

1. Introduction of 800kg detector

DARK MATTER search



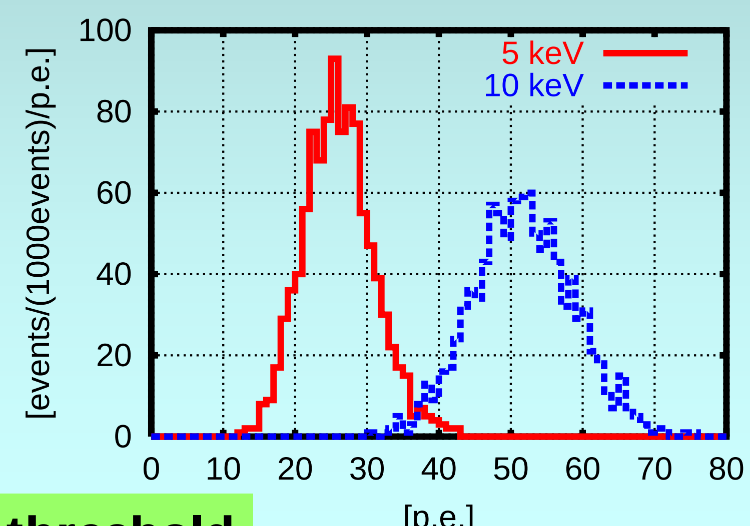
100kg liquid Xe

~80cm diameter sphere

About 640 2-in PMTs

75% photo-coverage

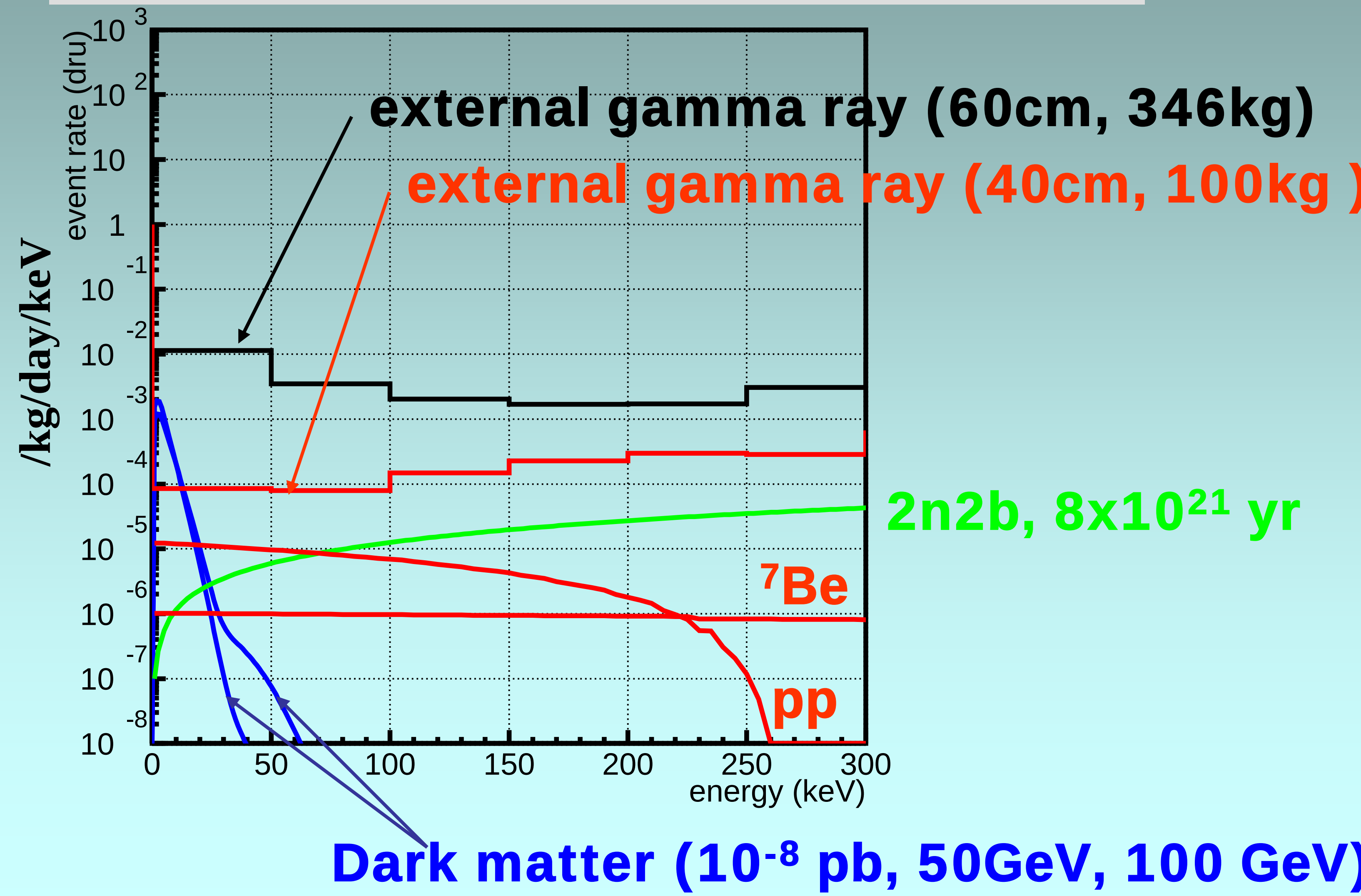
5 p.e./keV



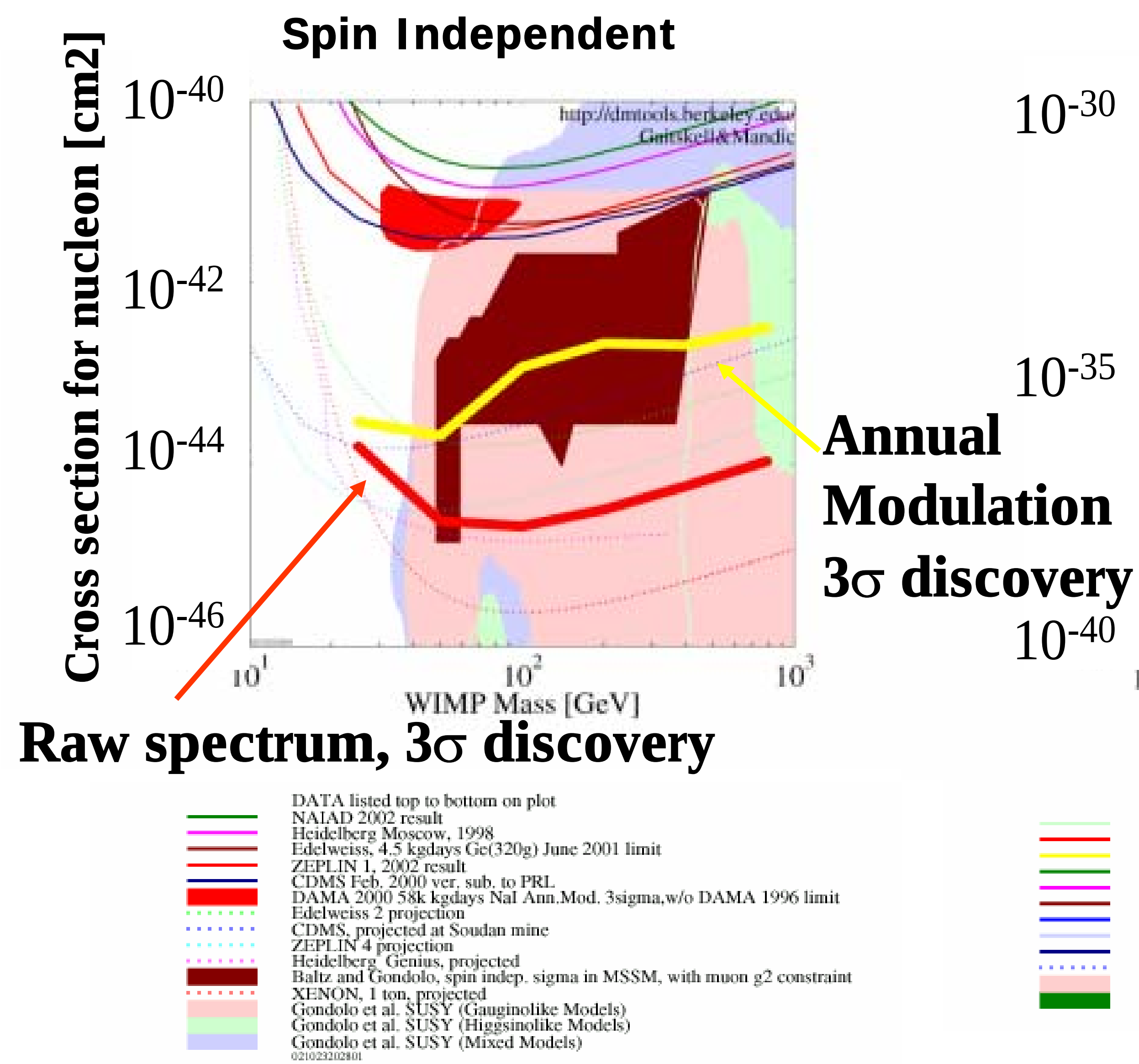
Very low Energy threshold

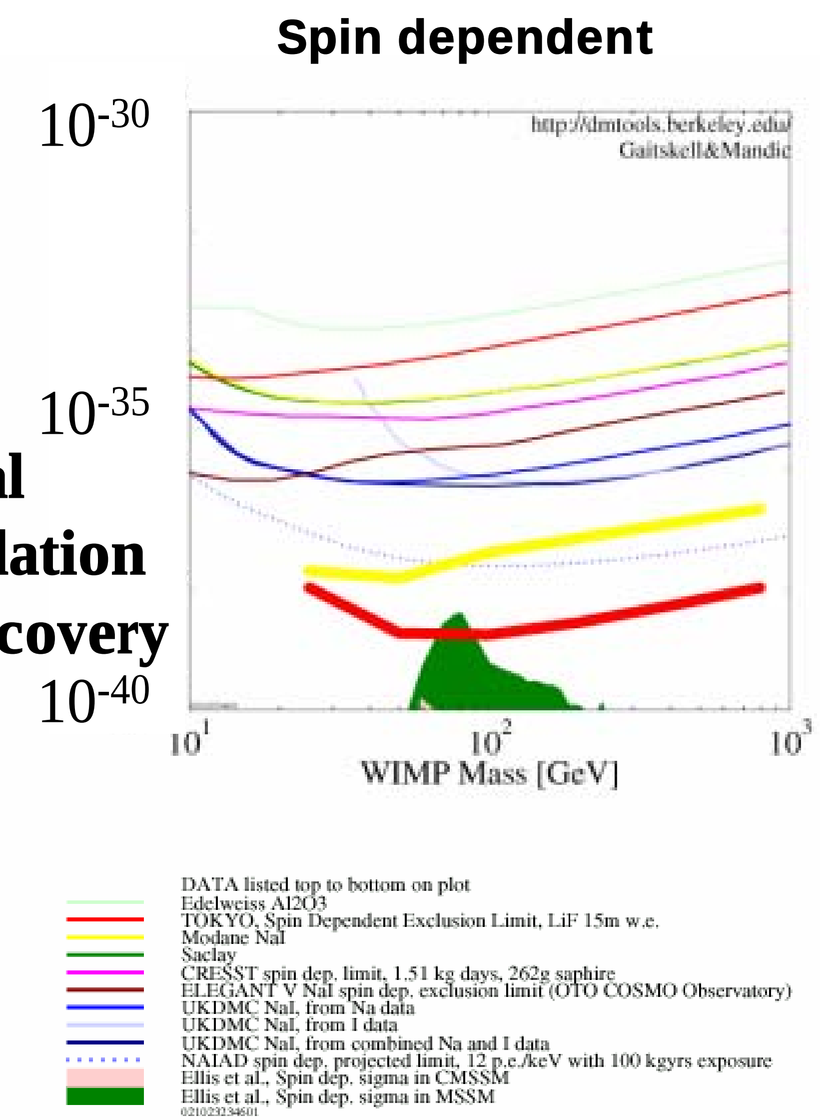
2. External background in 800kg detector

- **Dominant contribution is from PMT**
- **Assuming further 1/10 reduction of PMTs BG**



3. Expected sensitivity for DM





Summary

XMASS experiment:

Ultra low background experiment with liquid Xenon
And there are some physical purposes.

★1st run of 100kg detector was done:

Event reconstruction worked well
Background level was low as expected
Self-shielding power was confirmed

★Next 800kg detector:

Designed for dark matter search
Will has a extremely high sensitivity for DM detection