[redacted]tus of XMASS

GLA2011, Department of Physics, University of Jyväskylä, Finland

8th Jun. 2011

A.Takeda for the XMASS collaboration

Kamioka Observatory, ICRR,

University of Tokyo

The XMASS collaborations

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- **KRISS:** Y.H. Kim, M.K. Lee, K. B. Lee, J.S. Lee

41 collaborators,
10 institutes

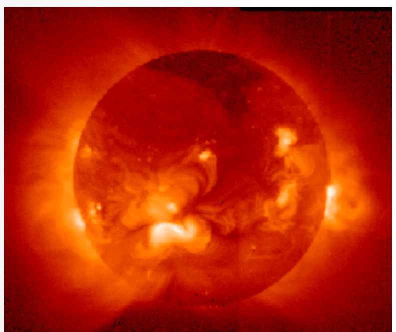
1. XMASS experiment

➢ What's XMASS

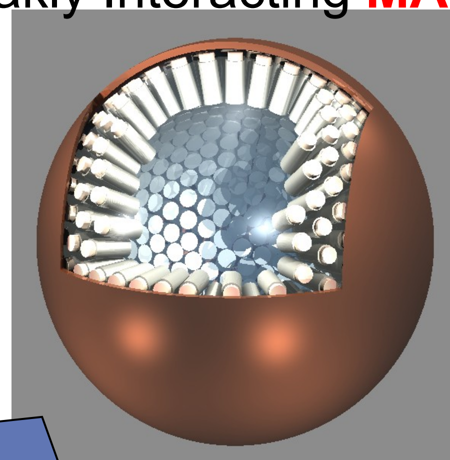
Multi purpose low-background experiment with liquid Xe.

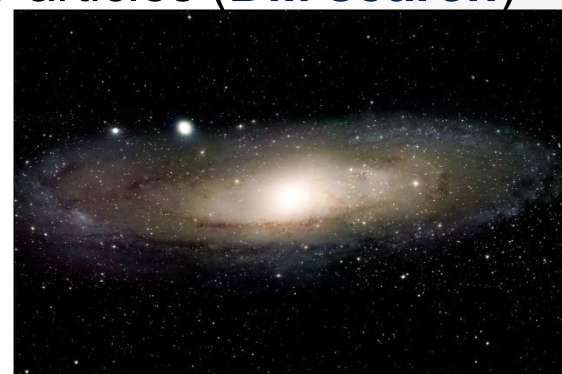
Y. Suzuki et al., hep-ph/0008296

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

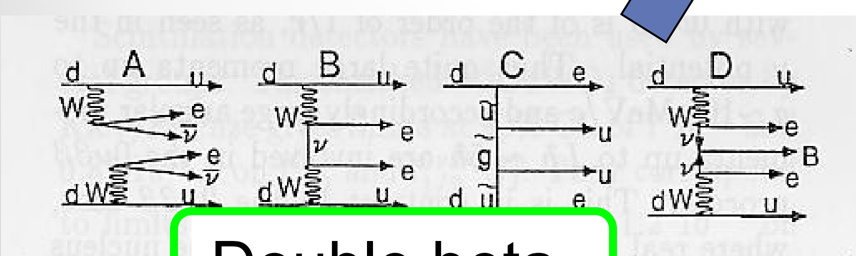


Solar neutrino





Dark matter



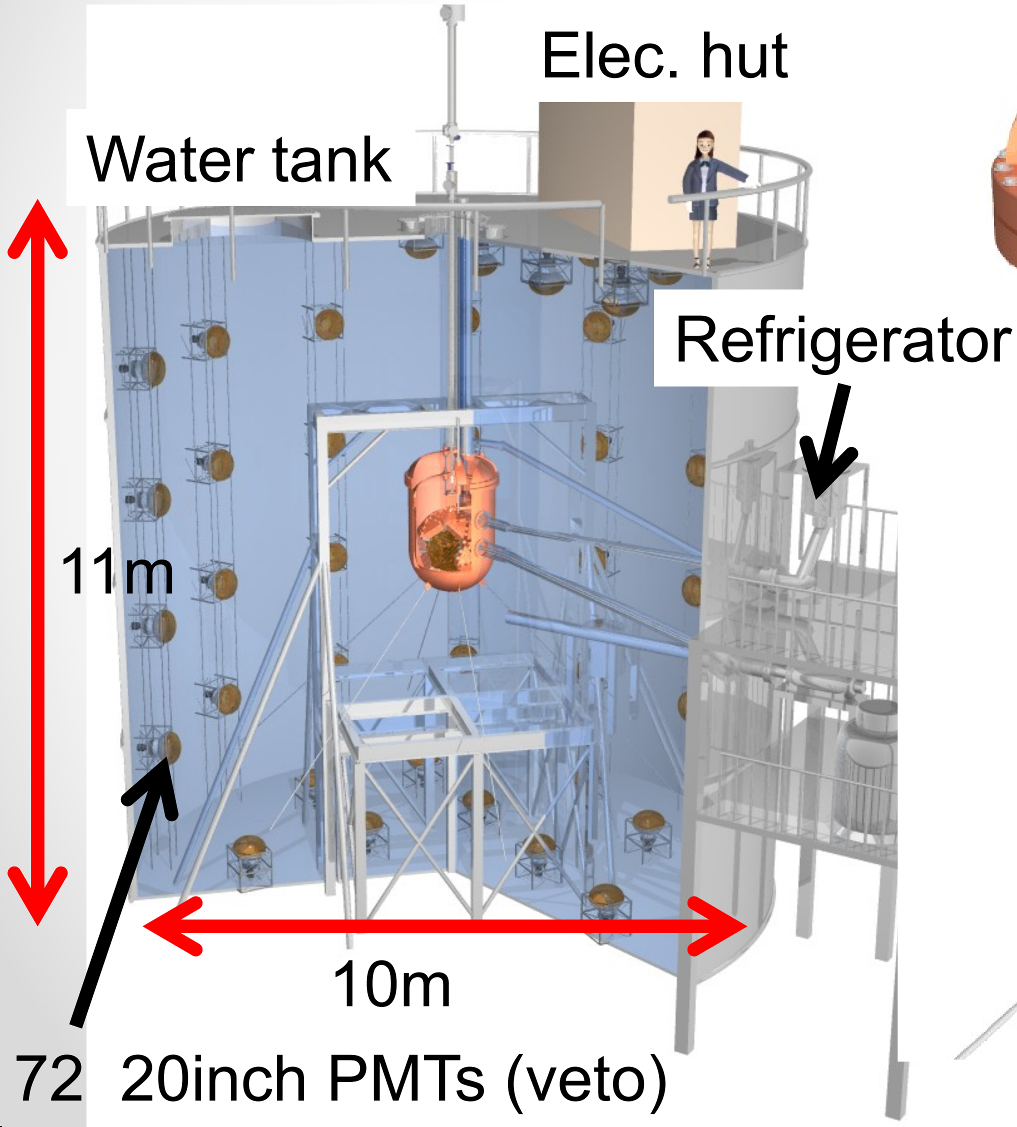
Double beta

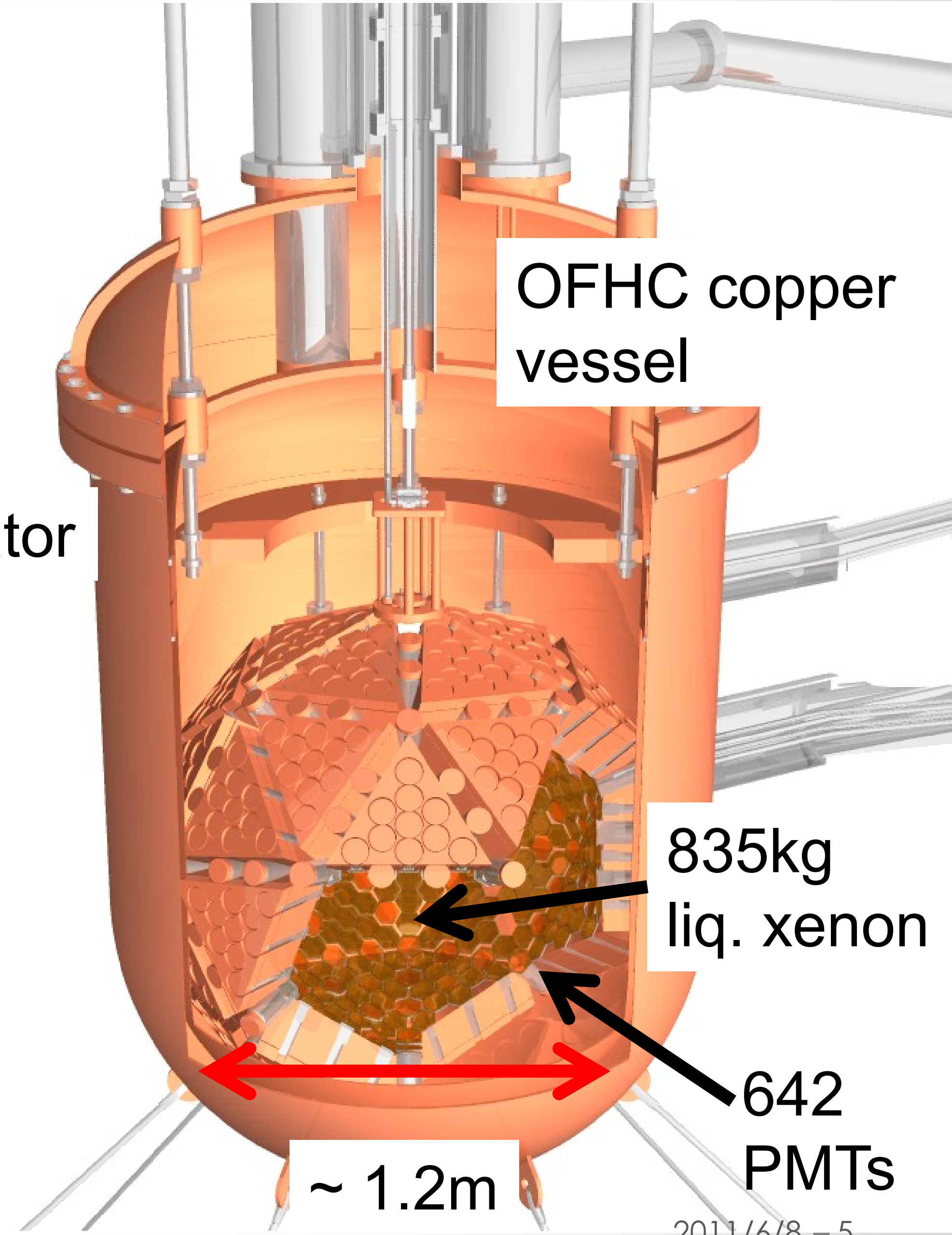
As a 1st phase, an **800kg detector** for dark matter search has been constructed.

➢ Why liquid Xe ?

- High Atomic mass Xe (A~131) good for SI case ($\sigma \propto A^2$).
- Odd isotope (^{129}Xe (26.4%), ^{131}Xe (21.3%)) with large SD enhancement factors.
- High atomic number (Z=54) and density (ρ=~3g/cc)
  -> Effective self-shielding.
  -> Compact for large mass detector.
- High photo yield (~46000 UV photons/MeV at zero field)
- Easy to purify for both electro-negative and radioactive impurities.
  -> By circulation of Xe with getter for electro-negative.
  -> Distillation for ^{85}Kr removal.

➢ 800kg detector





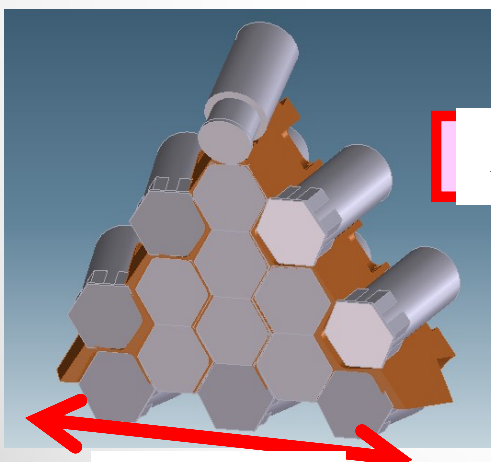
➢ Structure

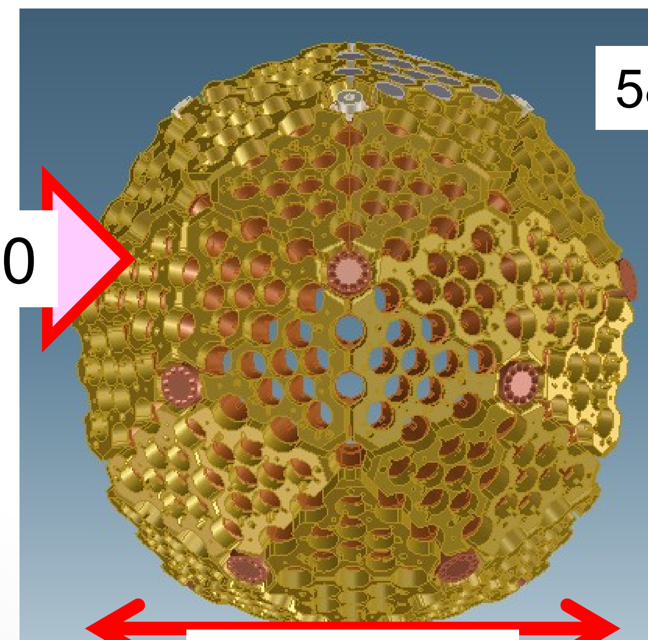
Single phase liquid Xenon detector

- 835 kg of liquid xenon, 97 kg in the fiducial volume
- 642 Photo Multiplier Tubes (PMTs): 630 hex +12 round
- Q.E. : 28-39%
- Photo coverage: 62.4%
- 3D event reconstruction
- 5keVee threshold

Hex: R10789-11

Round: R10789-11MOD





➢ Background (BG) reduction (1)

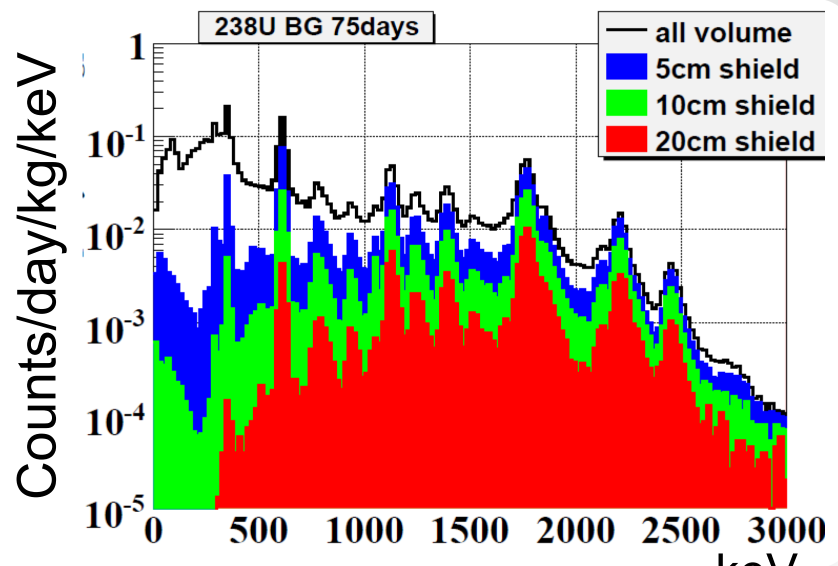
BG from detector materials

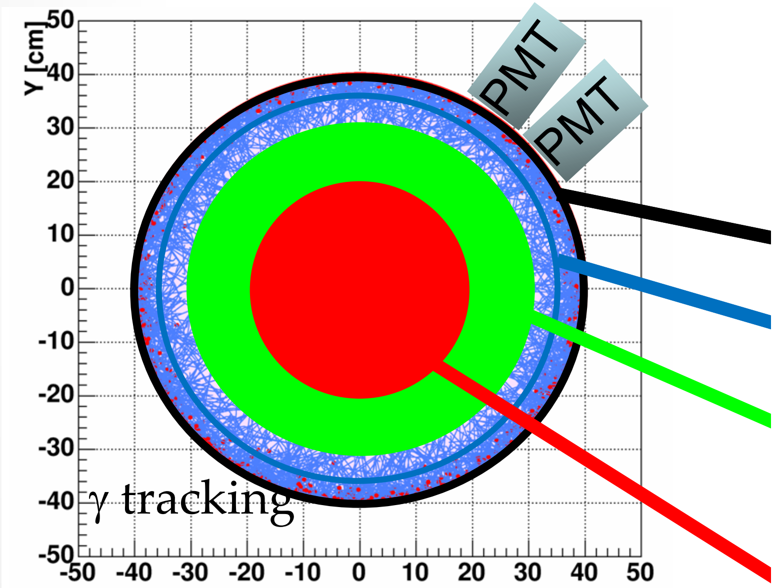
- 642 PMTs: Main BG source although radioactive isotope (RI) level is 1/100 of ordinary PMT.
- OFHC copper: Bring in the mine < 1month after electrorefining (Mitsubishi Material Co.)
- Other materials: All the components were selected with HPGe and ICP-MS. (>250 samples were measured) The total RI level is much lower than PMT BG.

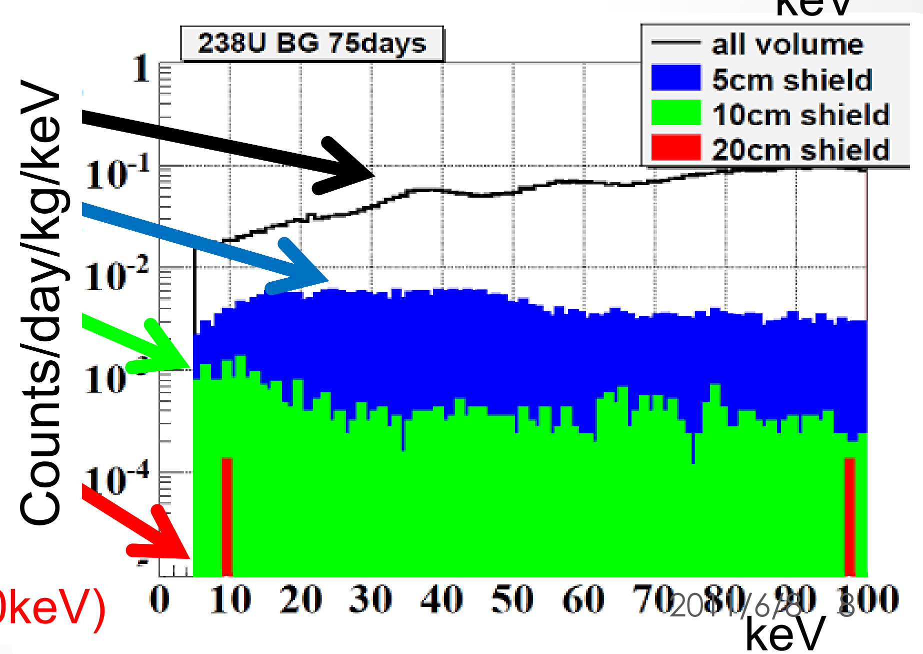
We developed new ultra low RI PMT (R10789) with Hamamatsu.
(1/100 of ordinary one).

BG estimation from 642 PMTs

	BG/PMT [mBq]
U chain	0.70 +/- 0.28
Th chain	1.51 +/- 0.31
^{40}K	< 5.10
^{60}Co	2.92 +/- 0.16







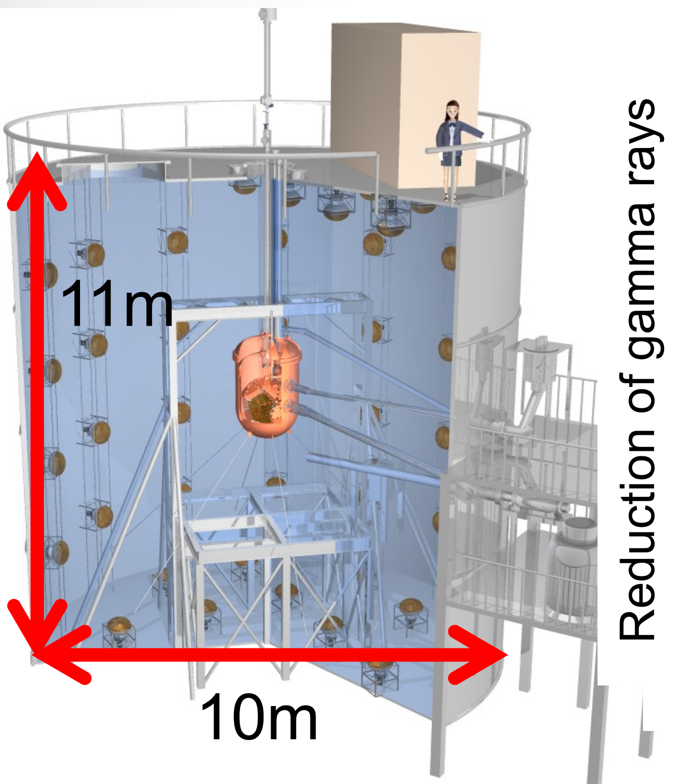
< 10^{-4} /keV/day/kg (100kg F.V.)

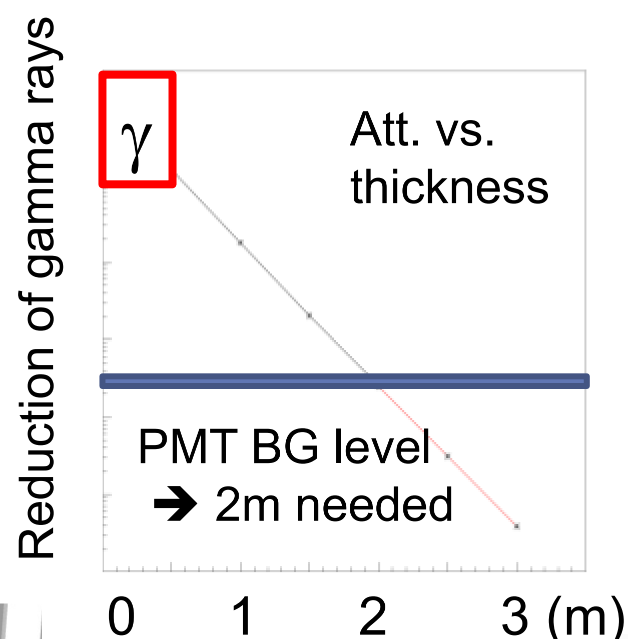
n contribution < 1.2×10^{-5}/keV/d/kg (5-10keV)

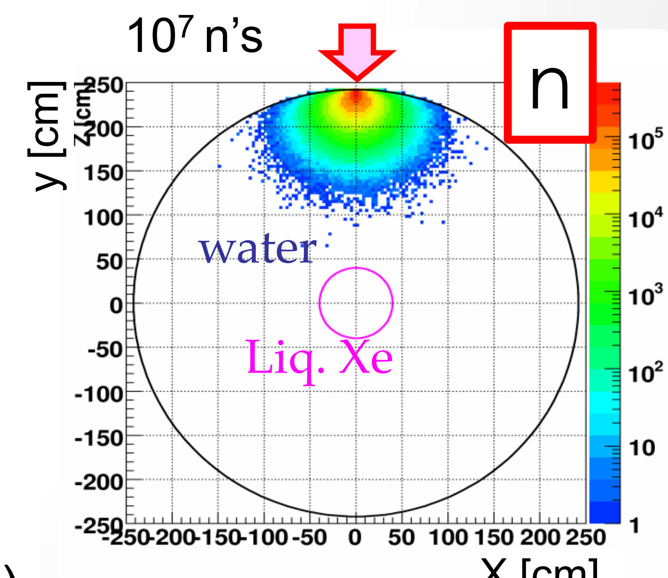
➢ BG reduction (2)

γ and n from rock

- γ and neutrons (n) from rock are sufficiently reduced by a 2m thickness pure water tank:
  γ < γ from PMT, n << 10^{-4} /day/kg
- 10m dia. and 11m height water tank for future extensions.
- 72 20” PMTs for active veto for cosmic-ray μ.







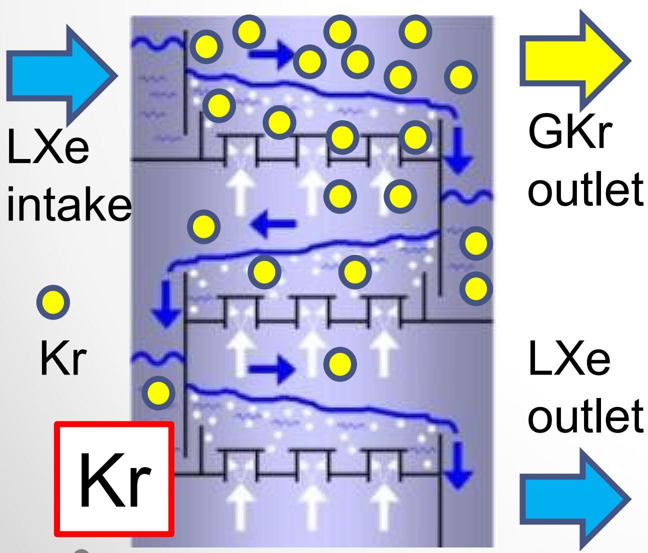
5m dia. = ~2m wall thickness

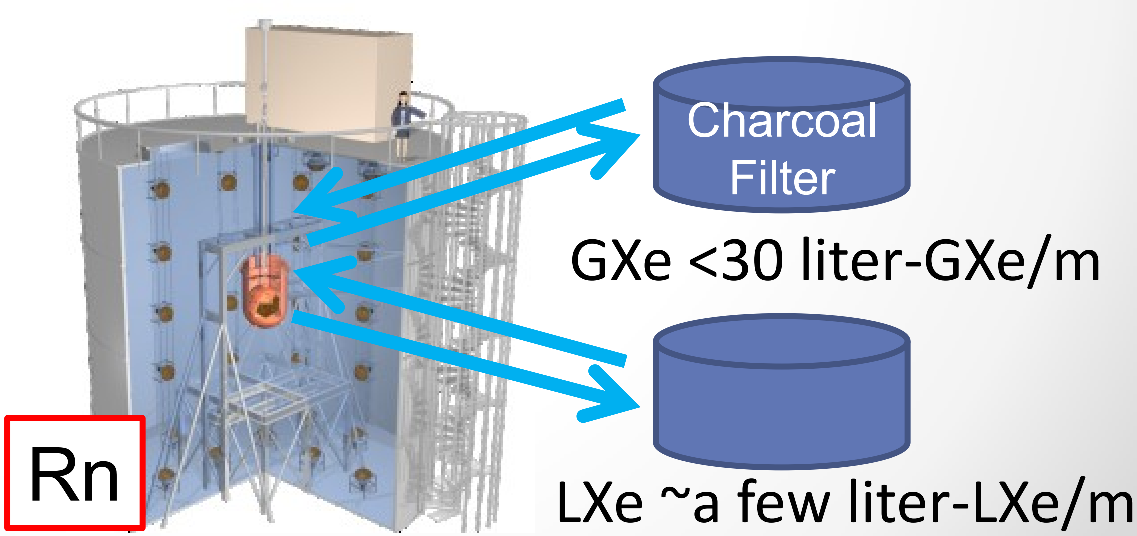
➢ BG reduction (3)

Internal Kr and Rn

- Kr (^{85}Kr: Q_β=687keV, τ=10.8y) and Rn can be reduced by:

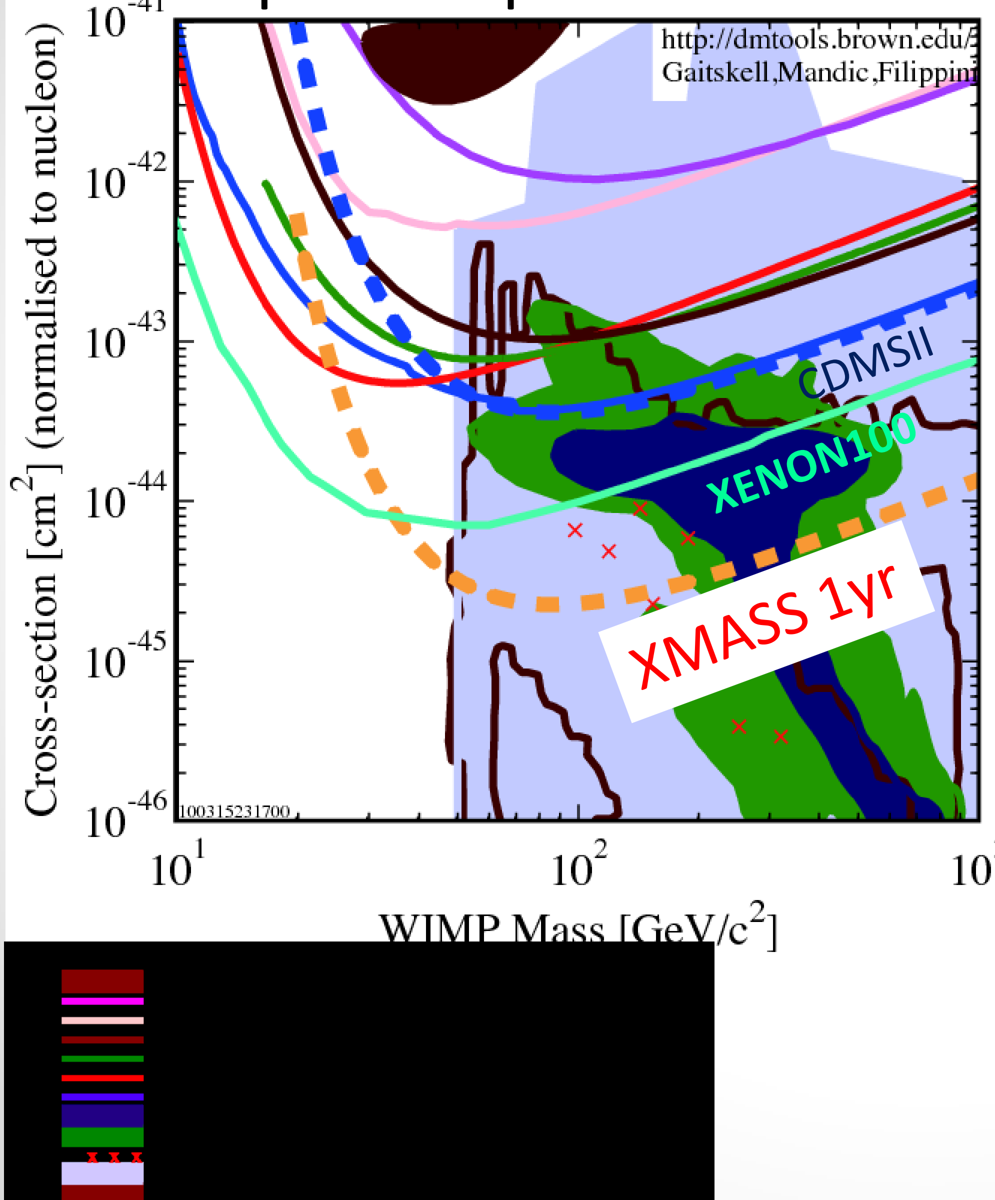
1. Distillation: Kr has lower (~150K) boiling point than Xe (~175K)
   5 orders of magnitude reduction with 4.7kg/hr was achieved for test sample. *K. Abe et al. for XMASS collab., Astropart. Phys. 31 (2009) 290*
   Distillation of 1ton Xe was finished before filling into the detector.
2. Filtering: by gas and liquid under study.





➢ Expected sensitivity

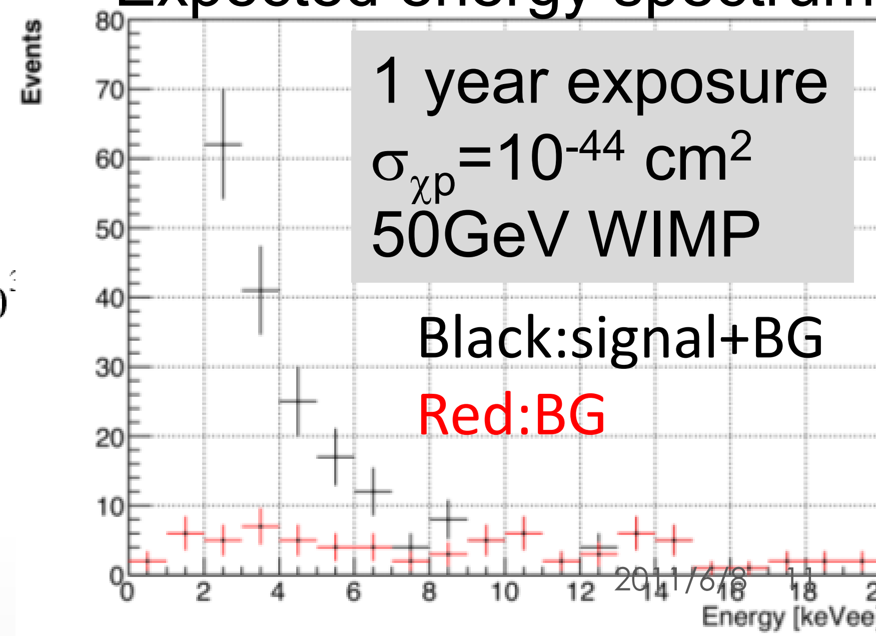
Spin Independent



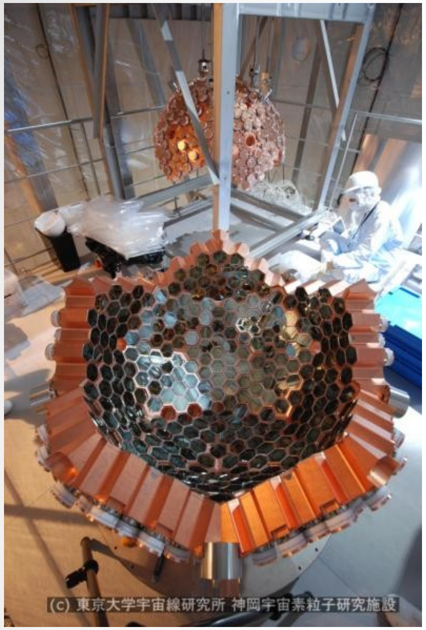
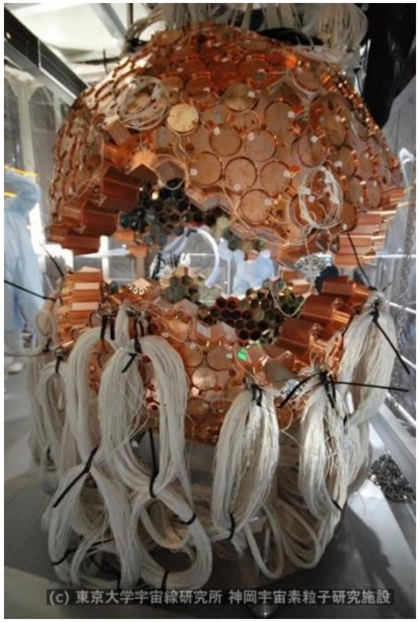
$\sigma_{cp} > 2 \times 10^{-45}$ cm^2
for 50-100 GeV WIMP
(90%C.L.)

1yr exposure, 100kg FV
BG: 1×10^{-4} /keV/day/kg
Q factor: 0.2

Expected energy spectrum



2. Current status of detector

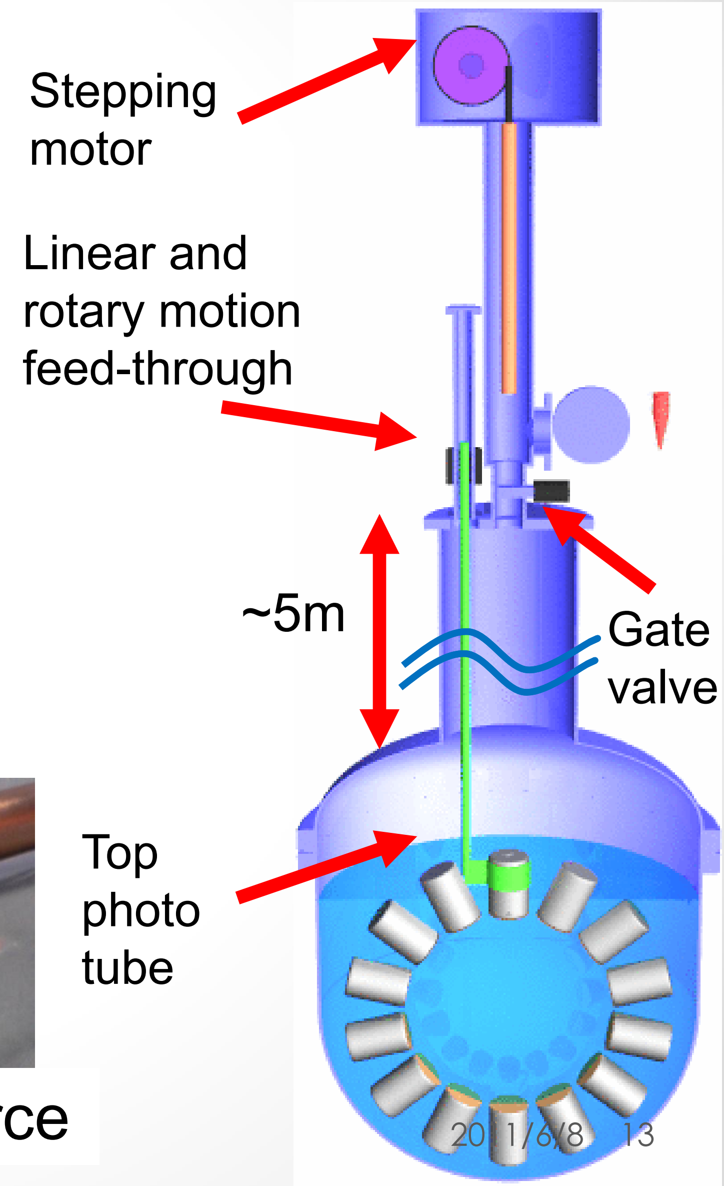



- 2010 Feb.: PMT installation was finished.
- 2010 Sep.: Detector assembly was finished.
- 2010 Sep.: Distillation and liq. xenon filling.
- 2010 Oct.-: Commissioning run has been started.
  Calibration and internal Rn evaluation.

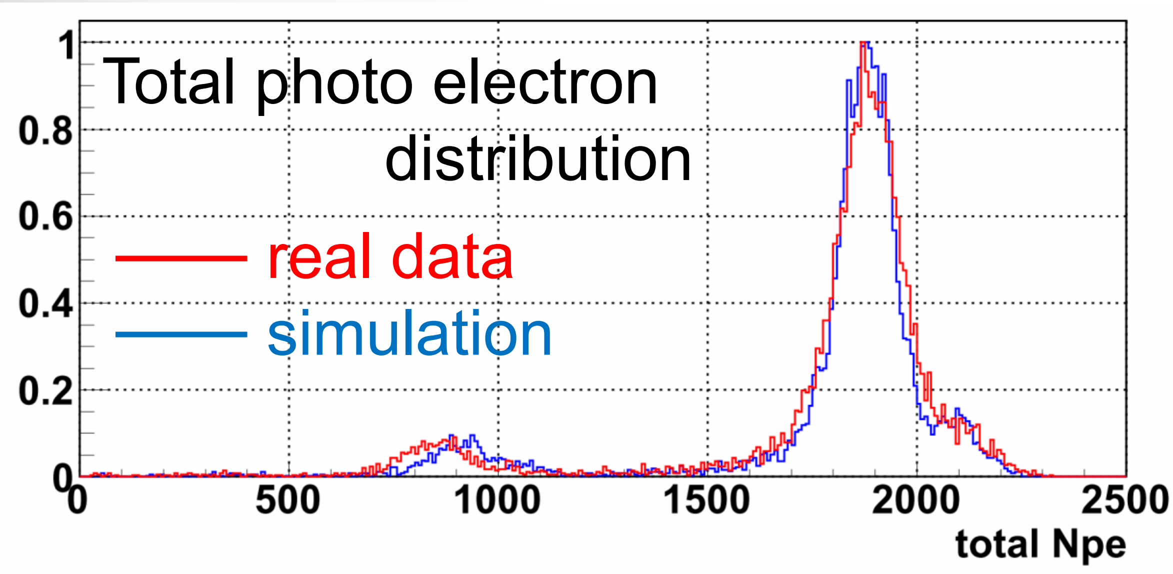
➢ Calibration

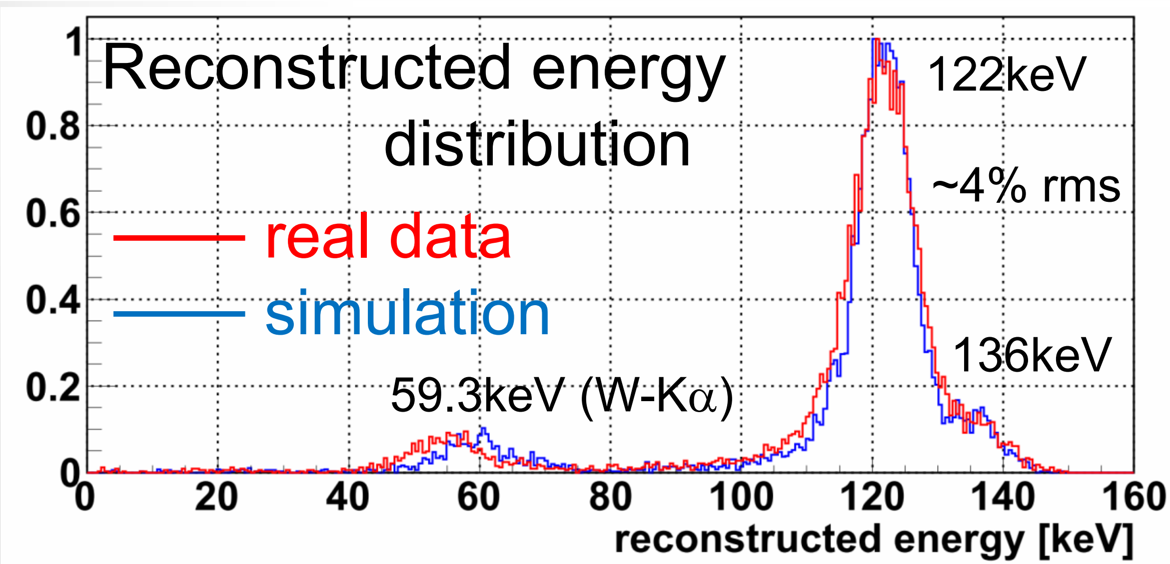
- XMASS Calibration system
  - Introduction of radioactive sources into the detector.
  - <1mm accuracy along the z axis.
  - Thin wire source for some low energy sources to avoid shadowing effect.
  - ^{57}Co, ^{241}Am, ^{109}Cd, ^{55}Fe, ^{137}Cs…

Source rod with a dummy source



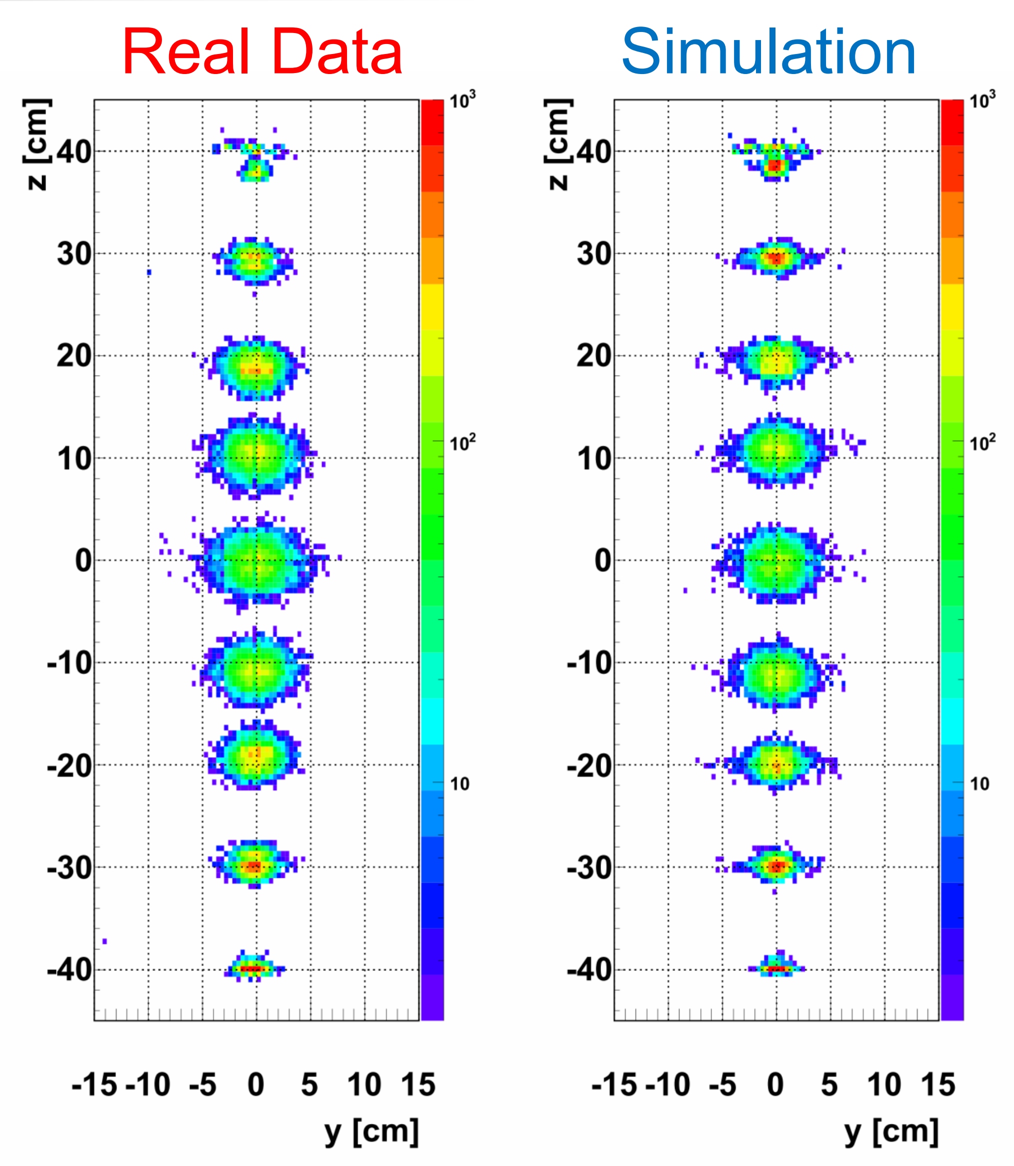
➢ Detector response at center





- ^{57}Co source at the center of detector.
- The photo electron distribution was reproduced by a simulation well.
- High p.e. yield 15.1+/-1.2p.e./keV was obtained.
- Energy resolution for 122 keV γ was ~4%(rms)

➢ Performance of the reconstruction

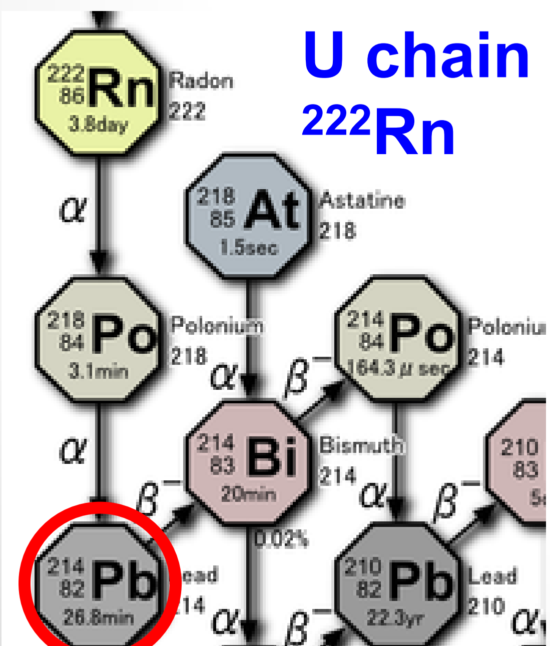


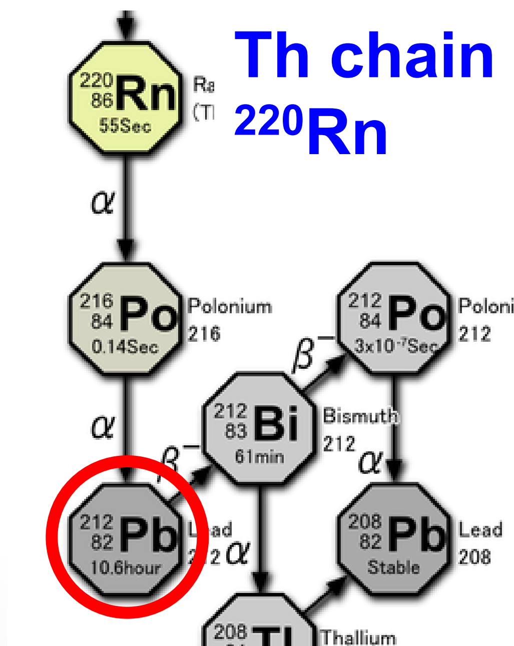
- Reconstructed vertices for various positioning of the ^{57}Co source.
- Position resolution was as expected by a simulation.

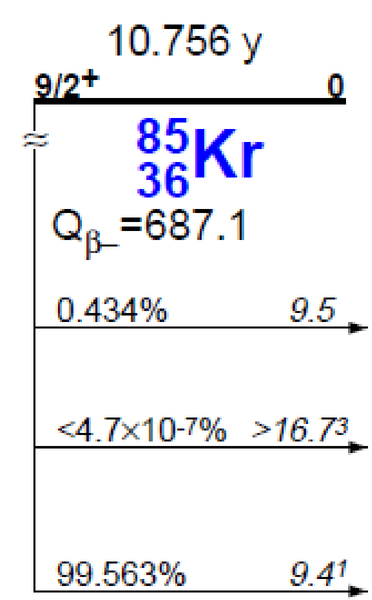
z=0cm: 1.4cm RMS
z=±20cm: 1cm RMS
(@122keV, γ)

➢ Evaluation of internal BG

- External BG (γ and n) can be effectively reduced by the water tank and outer part of liq. Xe. On the other hand, Internal BG (radioactive contaminations) need to be reduced by other means.
- Possible internal BG sources are ^{222}Rn, ^{220}Rn and ^{85}Kr.

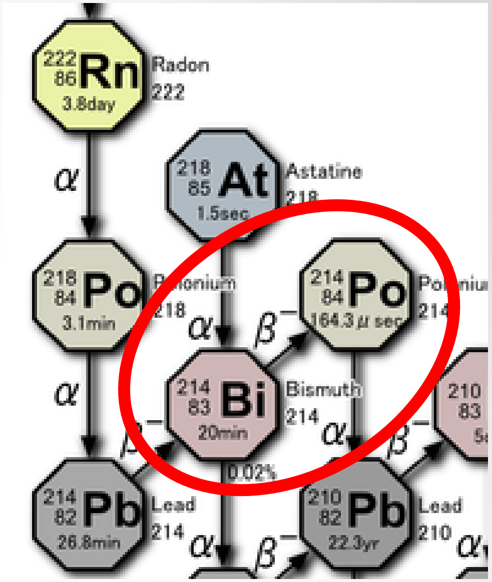




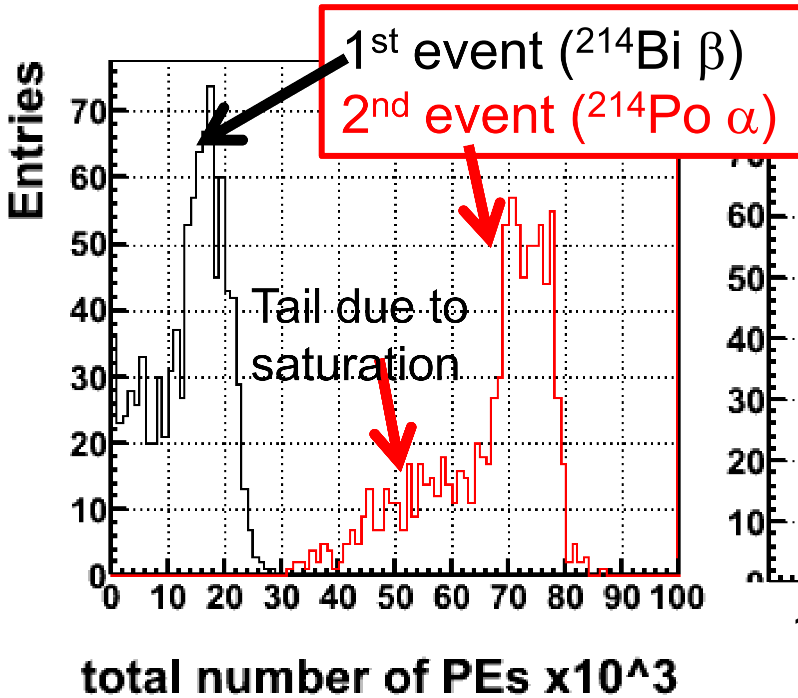


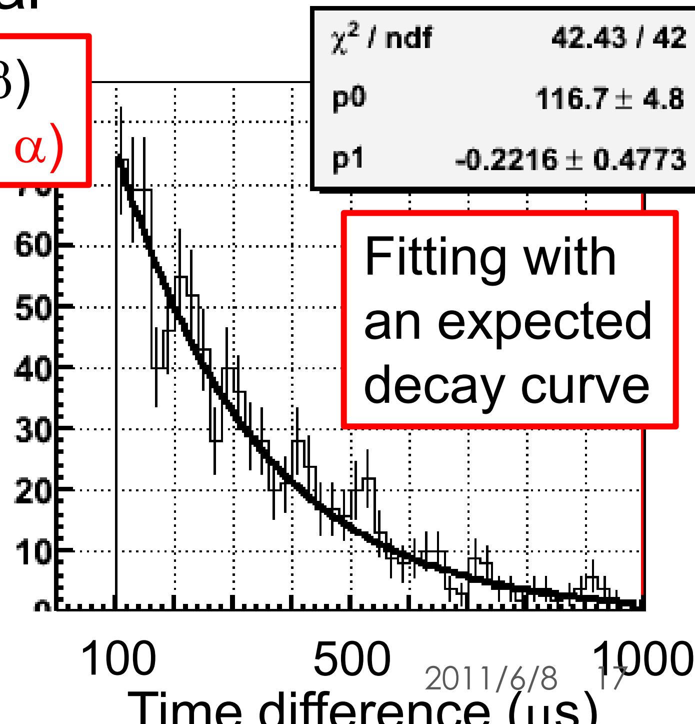
➢ ^{222}Rn in liq. Xe

- Tagged by a short time coincidence between ^{214}Bi and ^{214}Po ($t_{1/2}$=164μs).
- Gain of 321 PMTs (1/2 of all) are reduced to have larger dynamic range.
- Result: 8.2+/-0.5mBq. (<-> goal: 1.0mBq)



-> would be reduced by a cooled charcoal column in gas phase. (under study)

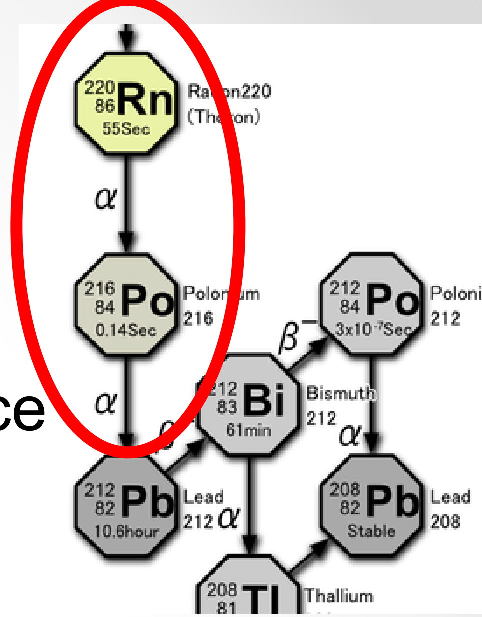


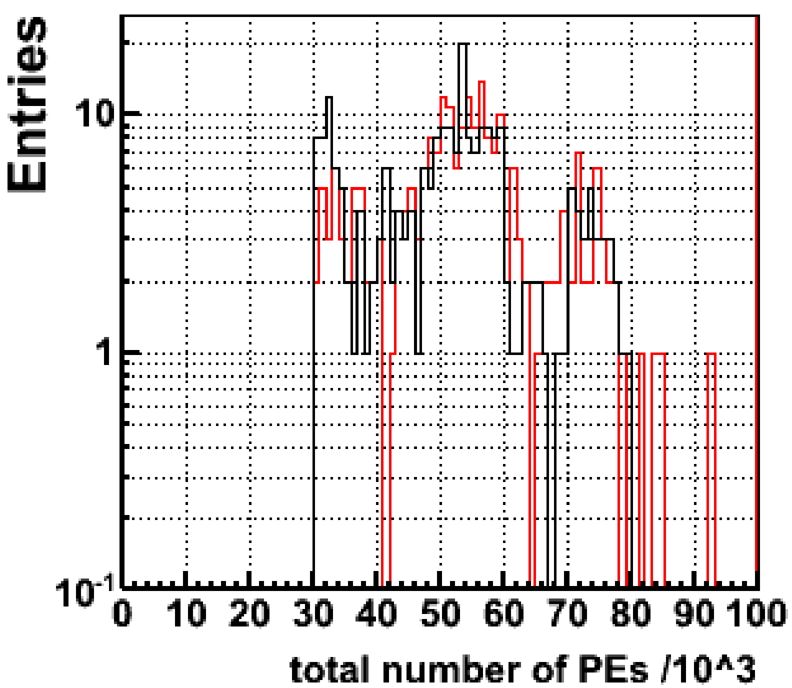


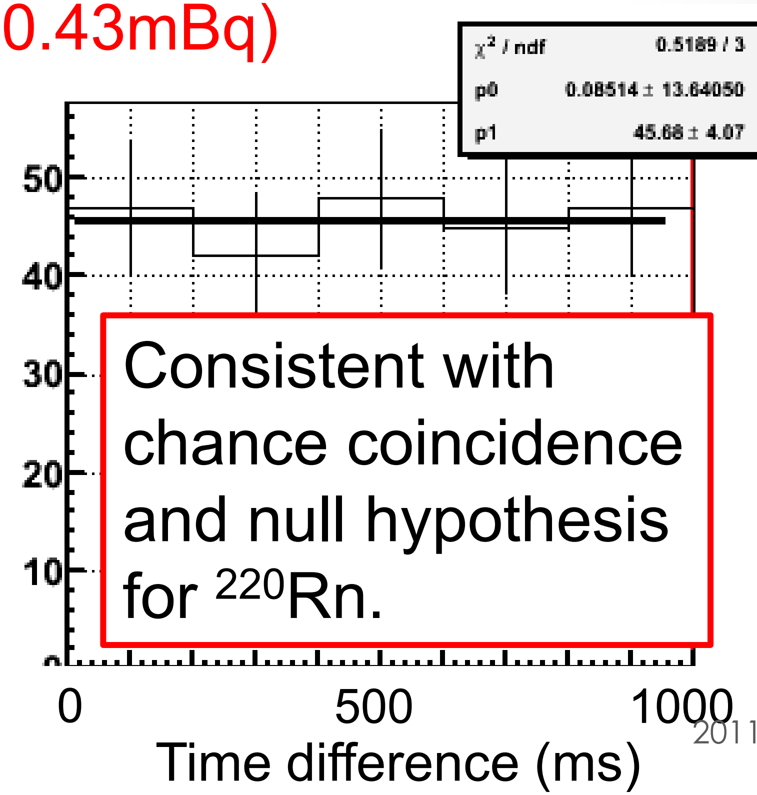
➢ ^{220}Rn in liq. Xe

- Tagged by a short time coincidence between two α's (^{220}Rn, ^{216}Po ($t_{1/2}$=0.14s)).
- Result was consistent with chance coincidence of α of ^{222}Rn.
- Upper limit < 0.28mBq (90C.L.)

(<-> goal: 0.43mBq)

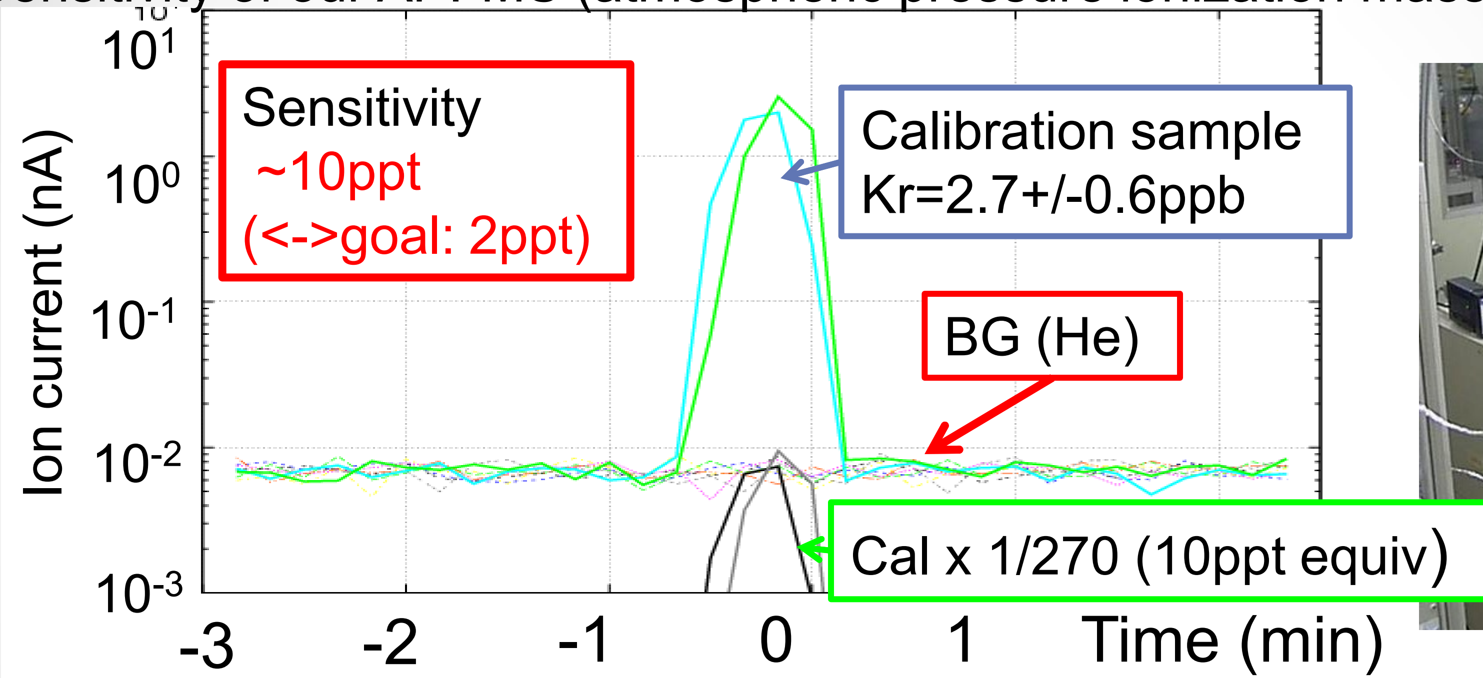




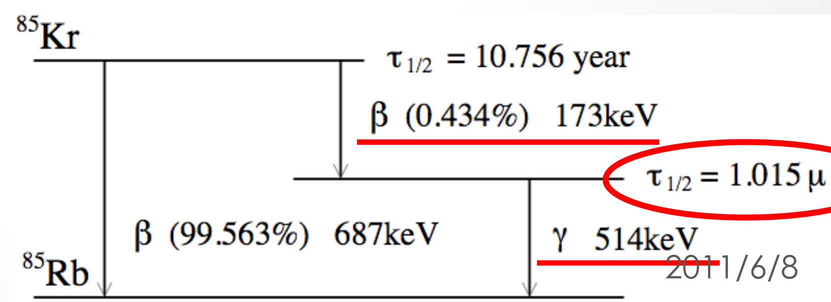


➢ ^{85}Kr in liq. Xe

Sensitivity of our API-MS (atmospheric pressure ionization mass spectroscopy)



- Gas chromatography and API-MS started to work (~10ppt sensitivity). More sensitive measurement (<1ppt) using a cold trap is under preparation.
- Data analysis to look for a delayed coincidence event is under study.



3. Summary

- The XMASS 800kg detector with a single phase liq. Xe target aims to detect dark matter with the sensitivity $2x10^{-45}cm^2$ (spin independent case).
- Construction of the detector finished last winter.
- Commissioning runs are on going to confirm the detector performance and low BG properties.
  - ✓ High p.e. yield was obtained: 15.1+/-1.2 p.e./keV
  - ✓ Energy and vertex resolution were as expected: ~1cm (position) and ~4% (energy) for 122keV γ.
  - ✓ Rn BG are close to the target values and Kr contamination will be evaluated soon.
- Physics run will start after commissioning.

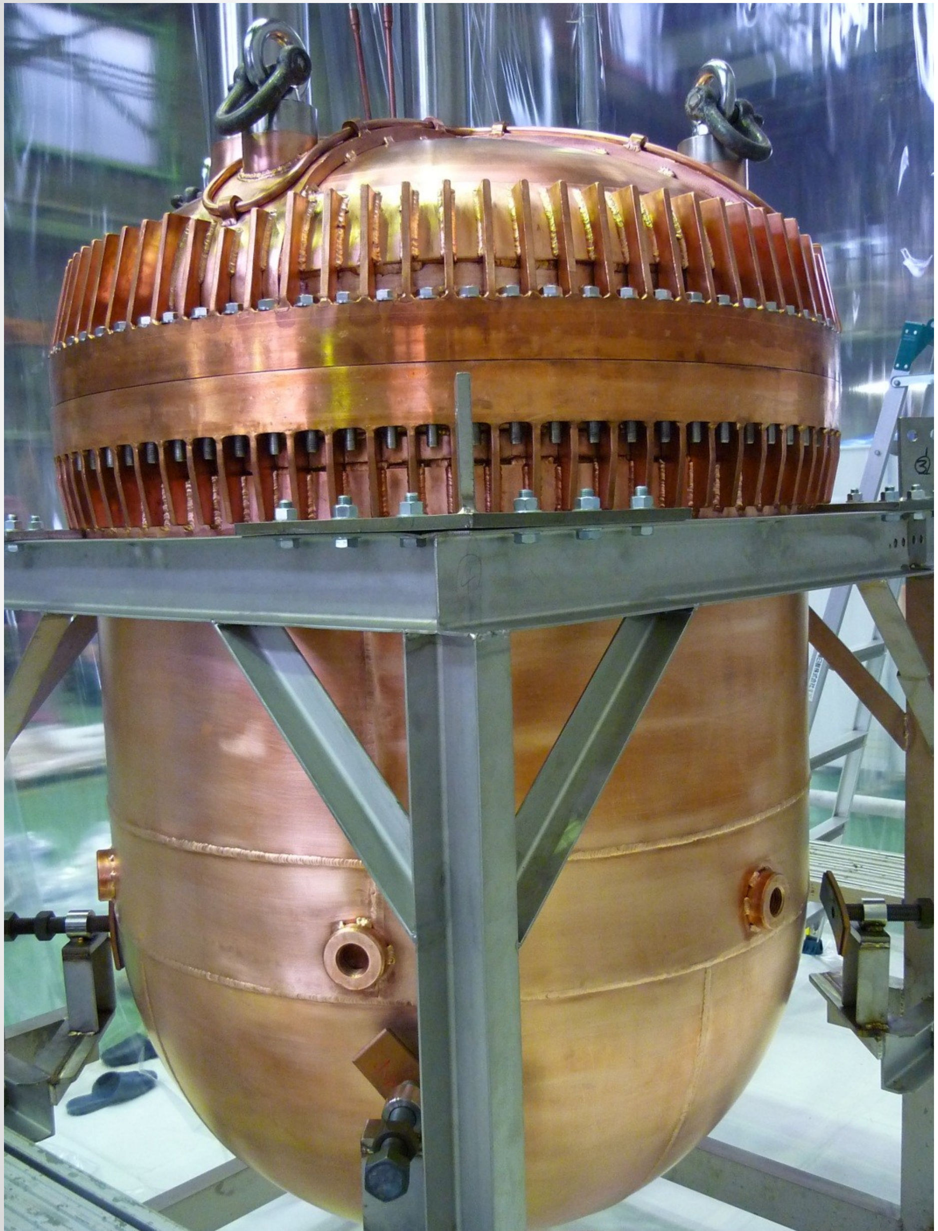
Backup

➢ FAQ

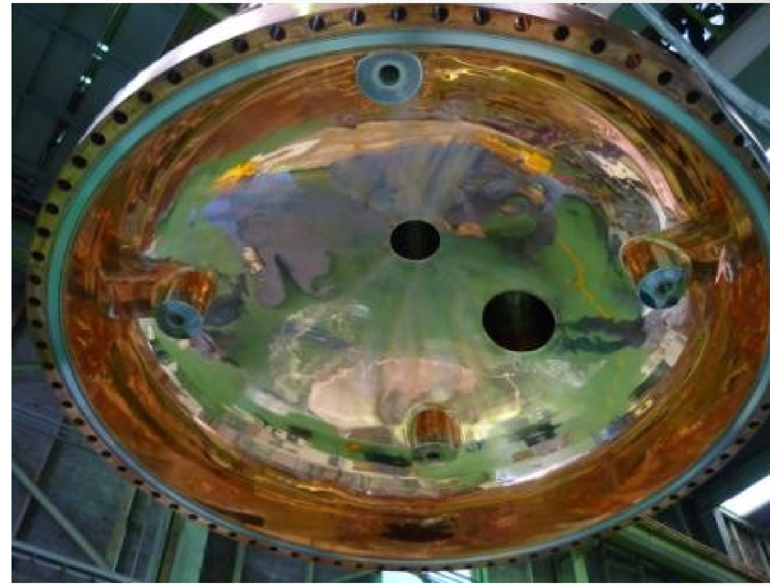
(1) How about detector stability in 7 month ?
(2) Rn removal. -> explain the current status of Rn removal test using backup slide.
(3) How about low energy BG level ? -> Now under analysis.
(4) Other BG sources ?
-> ^{3}H. Amount of H is under measurement with gas chro.
(5) When will the physics run start ?
-> as soon as possible after commissioning.
(6) What is remaining issues for commissioning run ?
-> Parameter tuning for reconstruction.
-> Kr evaluation from coincidence analysis.
-> preparation for FADC.


As of Sep. 2010

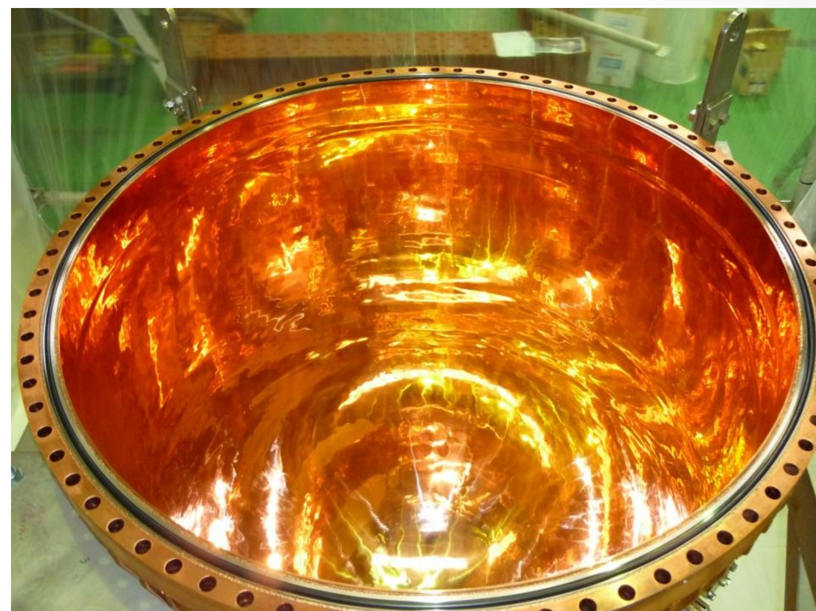
Inner Vacuum Chamber (IVC)



Upper part of IVC

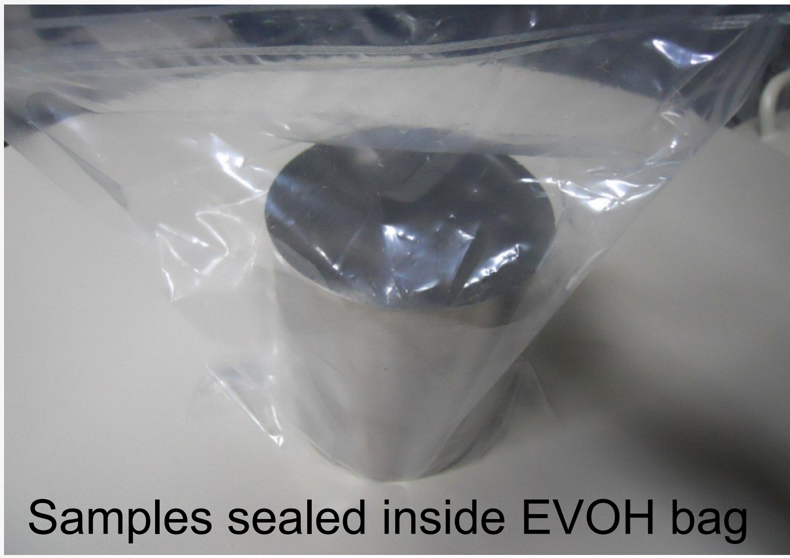


Lower part of IVC



➤ RI measurement with HPGe

- 3 HPGe in the Kamioka mine are used.



Samples sealed inside EVOH bag

- Almost all the components were measured used for XMASS detector.
- Number of samples measured is more than 250
- Sample is sealed inside the EVOH bag during measurement avoid lose Rn from sample.

➢ Removal impurities from liq. Xe

impurities	Allowed abundance	Method in liquid	Method in gas	Measurement for evaluation
Particle	< mg/all order	particle filter	evaporation unit, particle filter	particle counter
H_2O	< 0.1 ppb	molecular sieves (MS)	getter	dew-point meter
N_2, O_2, CO_2, CO	< 0.1 ppb	MS, charcoal activated Cu	getter	API-MS, GC
H_2	< 0.16 ppbw	MS, charcoal	getter	
Kr	< 0.1 ppt	-	distillation	API-MS
Rn	1.0 mBq/1ton xenon	ionization method	charcoal	Rn monitor
Organic?	?	charcoal	charcoal	FTIR?

➢ Removal impurities from liq. Xe

- Commercial MS contain ^{238}U which emanates ^{222}Rn
- Low-U MS was developed by ourselves.

Standard MS	This one
445 ppb	10 ppb

- 100g of this MS absorbs 13g of H_2O.

➢ Rn removal test in gas circulation

Charcoal housing

- Charcoal whose suitable hole size (~10Å) was selected.
- Tested in -105°C, with 10Bq Rn in xenon.

- More than 85% Rn removal was achieved.
  (charcoal weight: 25g, trap length: 60cm, flow rate: 0.5L/min).
  Rn removal efficiency is now being improved with more suitable trap length and flow rate.
- In the case of Rn removal emanated from only gas phase, our goal (<0.6mBq) can be achieved with 1.0 L/mim flow rate.

- Rn removal emanated from liquid phase is now under study.