KOBE UNIVERSITY Graduate School of Science

DM direct searches in JAPAN

Keishi Hosokawa, Kentaro Miuchi

XMASS Dark Matter Search

THANKS
Japanese Experimental Dark matter Investigators

Direction-Sensitive WIMP-search NEWAGE

ANKOK GROUP

PICO-LON

Emulsion

Xenon Kamioka

Argon surface (Waseda)

NaI surface (Tokushima)

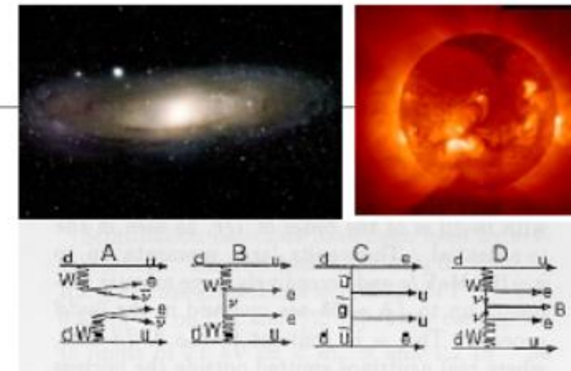
Emulsion surface (Nagoya)

Gas TPC Kamioka

XMASS

HIRAIDE @ IDM2014

The XMASS experiment

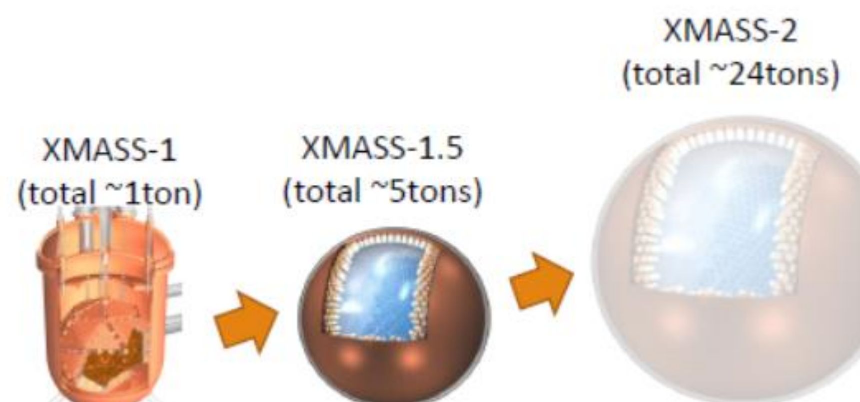


- **Proposed as a multi purpose experiment with liquid Xenon**
  - **X**enon detector for Weakly Interacting **MASS**ive Particles (**dark matter**)
  - **X**enon **MASS**ive detector for solar neutrino (**pp/^{7}Be solar neutrino**)
  - **X**enon neutrino **MASS** detector (**double beta decay**)

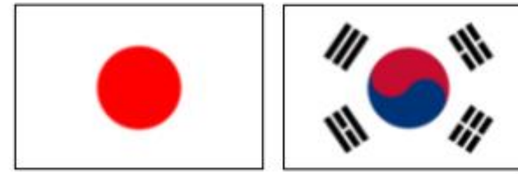
- **Low energy threshold**
- **Sensitive to *e*/γ events as well as nuclear recoil**

  WIMPs (by elastic and ^{129}Xe inelastic scattering),
  Solar axions, Bosonic super-WIMPs,
  Supernova neutrino burst, double electron capture, …

- **Large target mass and its scalability**



The XMASS collaboration



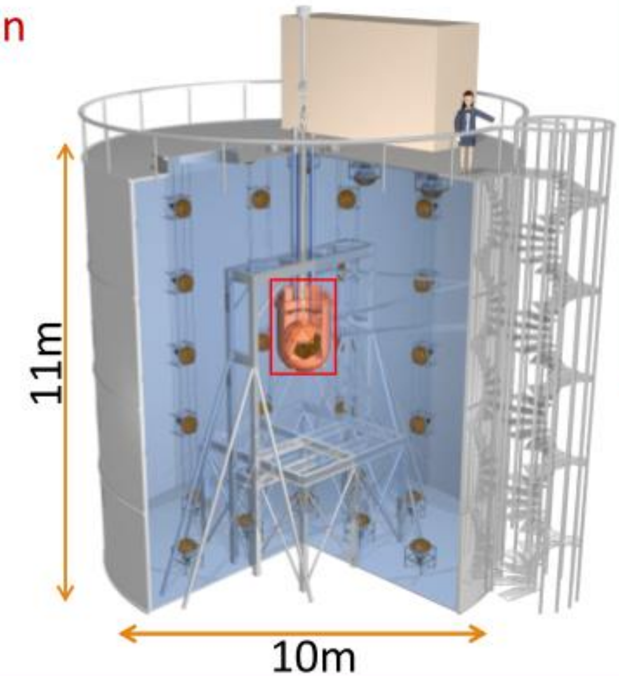
Kamioka Observatory, ICRR, the University of Tokyo: K. Abe, K. Hiraide, K. Ichimura, Y. Kishimoto, K. Kobayashi, M. Kobayashi, S. Moriyama, M. Nakahata, T. Norita, H. Ogawa, H. Sekiya, O. Takachio, A. Takeda, M. Yamashita, B. Yang
Kavli IPMU, the University of Tokyo: J.Liu, K.Martens, Y. Suzuki
Kobe University: R. Fujita, K. Hosokawa, K. Miuchi, Y. Ohnishi, N. Oka, Y. Takeuchi
Tokai University: K. Nishijima
Gifu University: S. Tasaka
Yokohama National University: S. Nakamura
Miyagi University of Education: Y. Fukuda
STEL, Nagoya University: Y. Itow, R. Kegasa, K. Kobayashi, K. Masuda, H. Takiya
Sejong University: N. Y. Kim, Y. D. Kim
KRISS: Y. H. Kim, M. K. Lee, K. B. Lee, J. S. Lee

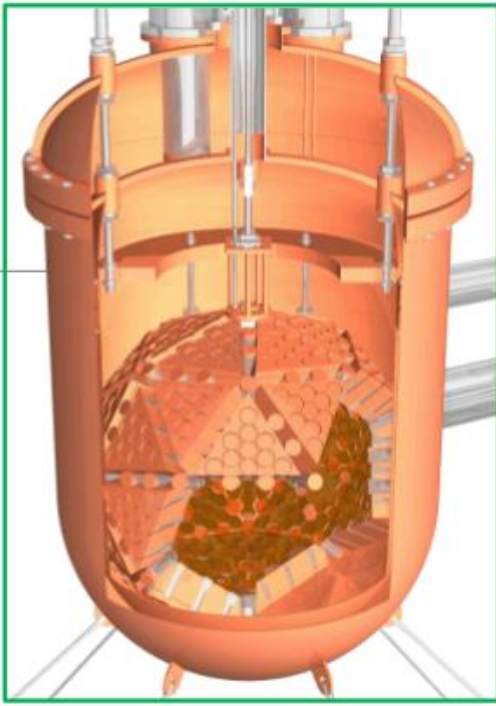
10 institutes
~40 physicists

June 2014

The XMASS-1 detector

- Located in the Kamioka mine in Japan (~2,700m water equivalent)
- A single-phase detector employing ~830kg of liquid xenon
- Equipped with 642 PMTs
- Active water shield





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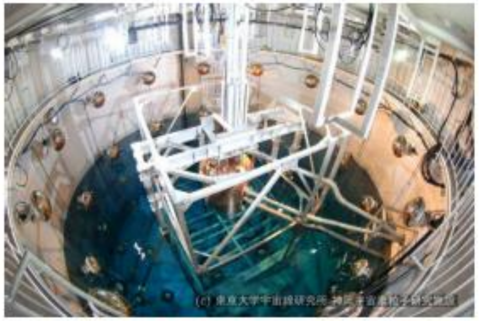
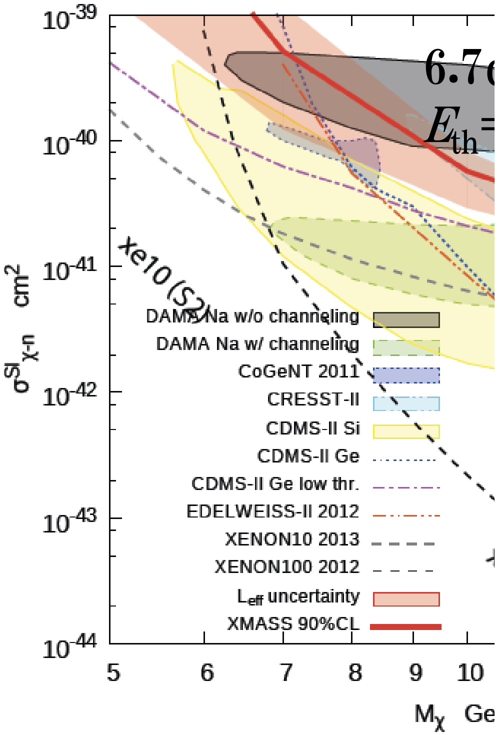
History of XMASS-1

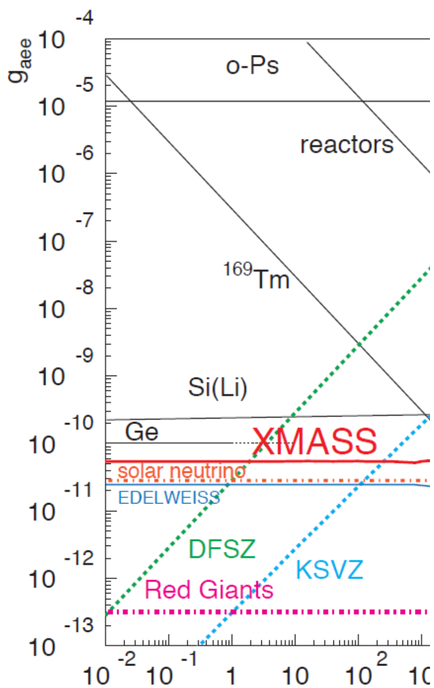
- Sep. 2010: Detector construction completed.
- Dec. 2010 – May. 2012: Commissioning data-taking
- Aug. 2012 – Oct. 2013: Detector refurbishment
- Nov. 2013 : data-taking resumed.

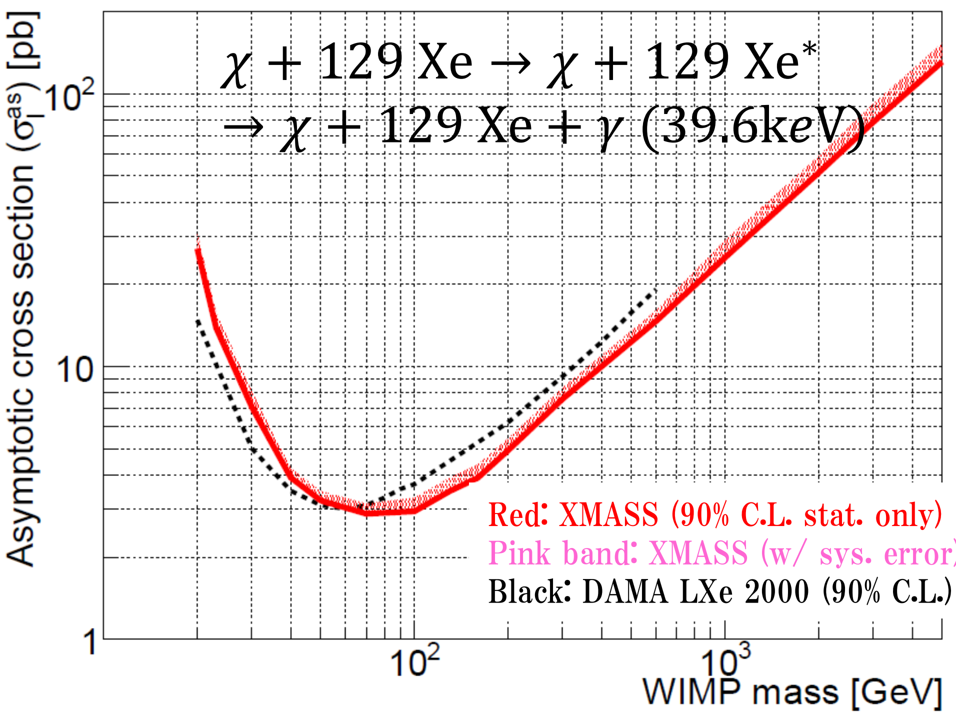


XMASS Commissioning Run

* Search for light WIPMs (Phys. Lett. B 719 78 (2013))
* Search for Solar Axion (Phys. Lett. B 724 46 (2013))
* Search for ^{129}Xe inelastic scattering (PTEP 063C01(2014)) editor's choice
* Search for bosonic super-WIMPs (Accepted by PRL on Aug. 20th)

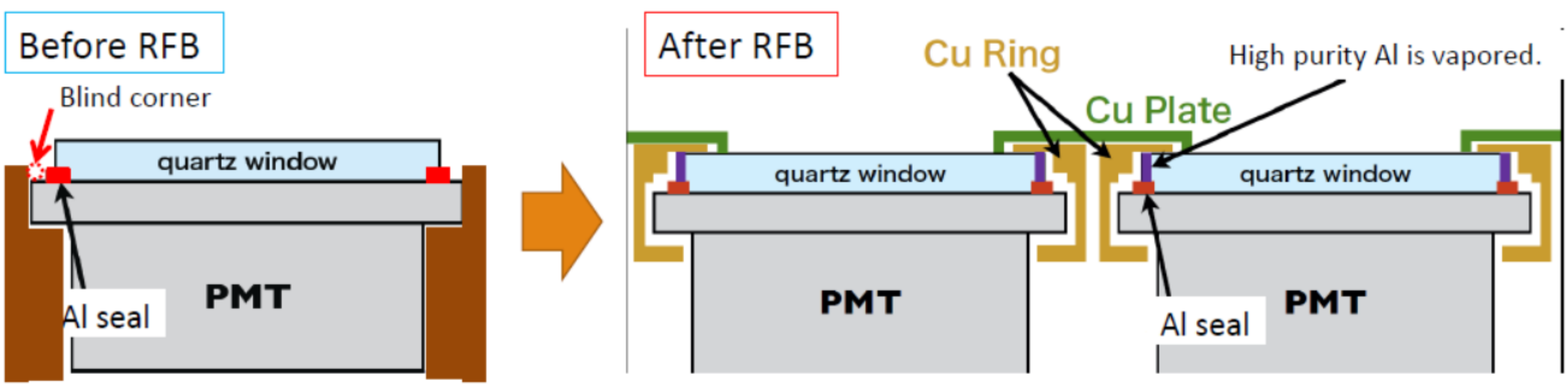






Detector refurbishment

- Found RIs (210Pb, 238U) in the Aluminum seal of PMT.
- BG events at the blind corner of PMT are often misidentified as events in the fiducial volume.
- To reduce this background, new structures to cover this Al seal were installed.

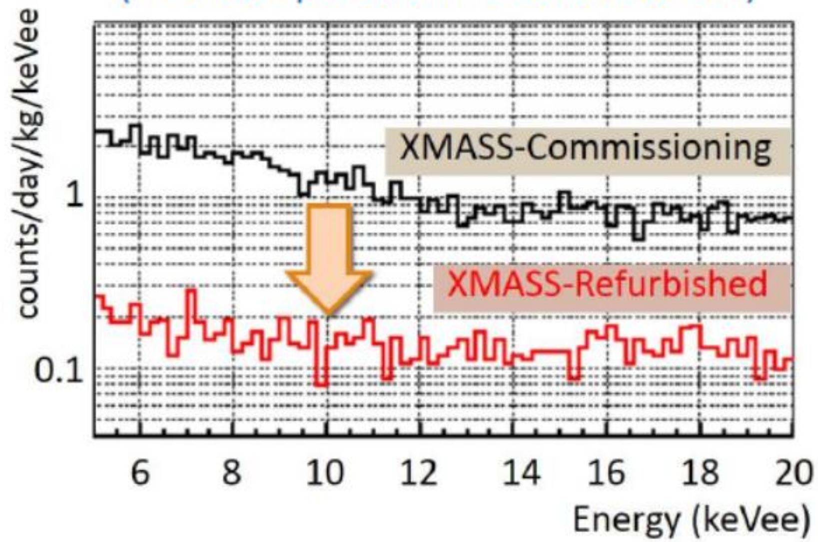


HIRAIDE @
IDM2014

Current status

- Understanding of detector response
- Understanding of reconstruction performance
- Understanding of BG
  - ➔ They are on-going
- Quick check of BG in entire volume
  - One order of magnitude reduction above 5 keVee for entire volume achieved.
- Results will come in near future

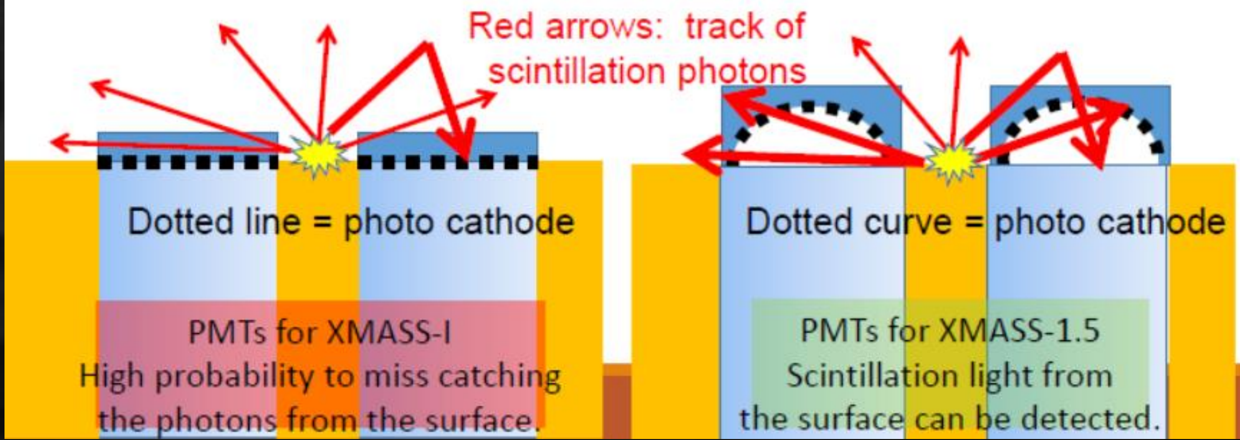
Energy spectra in entire volume
(without position reconstruction)

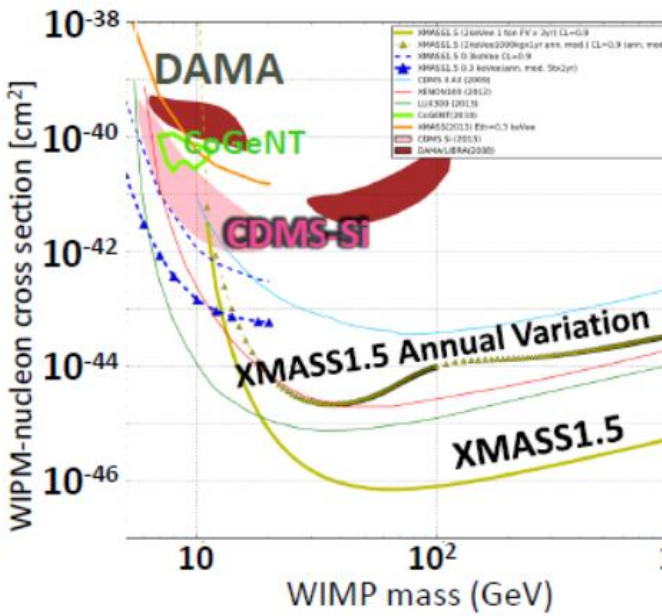


HIRAIDE @ IDM2014

Future: XMASS-1.5

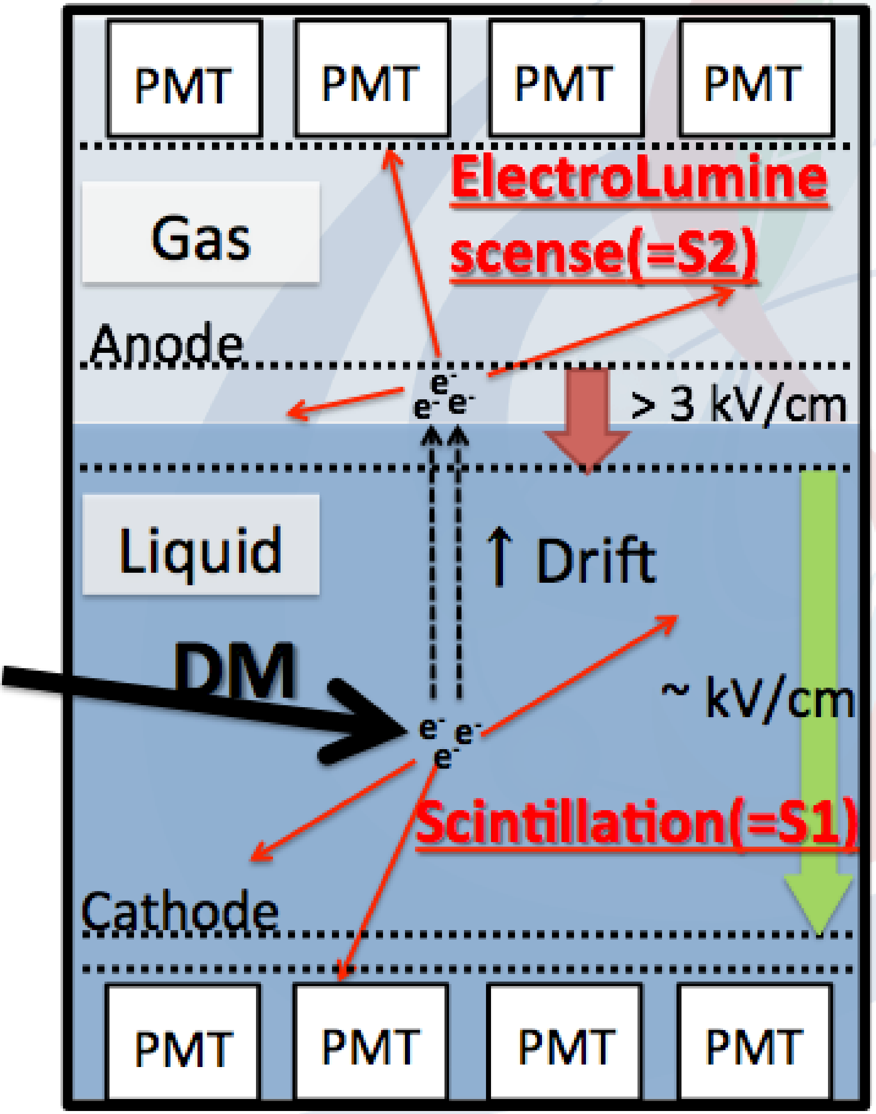
- Total 5 tons of liquid xenon (with fiducial mass of 1 ton)
- Target sensitivity for $\sigma_{SI} < 10^{-46}$ cm^2 for 100 GeV WIMPs
- Design of the detector is on-going





ANKOK

Double phase argon detector



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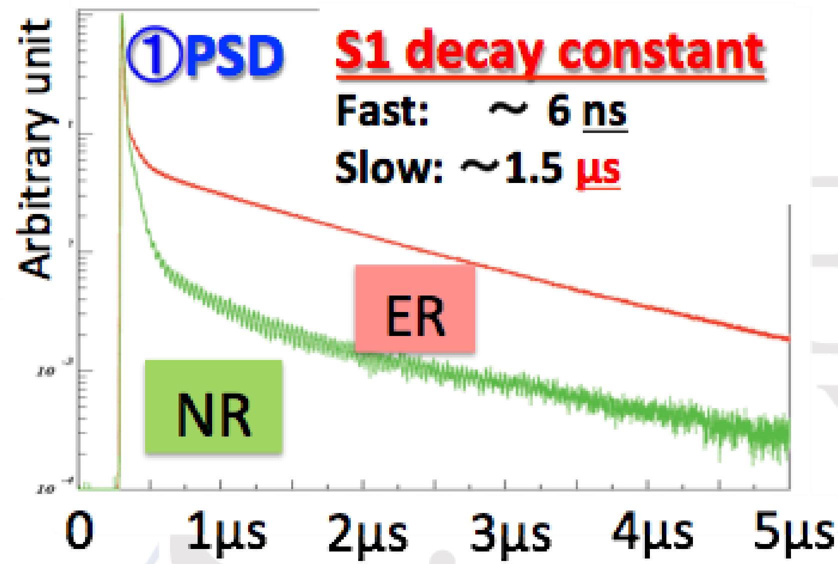
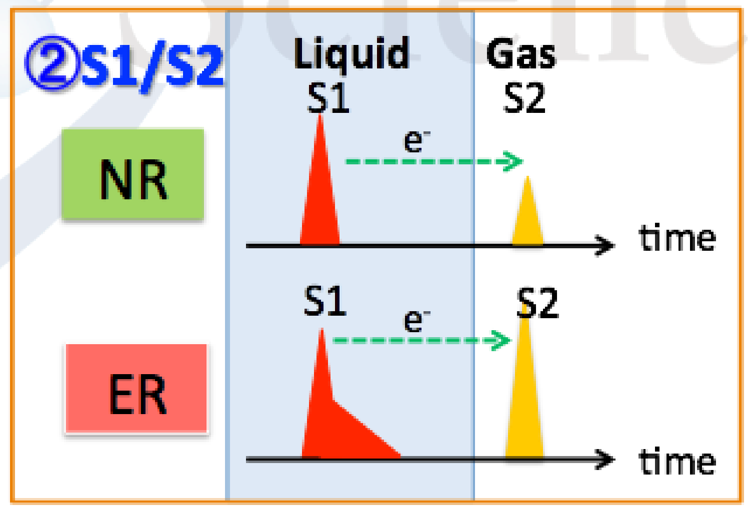
Ar basic properties

- Density: 1.39 g/cm^3
- Boiling point: −186℃
- Scintillation
  - ~128nm(VUV)
    - Will be converted to visible light by WLS
  - ~50 photons/keV (S1)
- Low-priced!! (same as water or cheap wine.)
- ^{39}Ar β-ray background

BG reduction techniques

- WIMP signal:
  ➡ Nuclear Recoil(NR)
- Gamma・β(include ^{39}Ar):
  ➡ Electron Recoil(ER)
  1. PSD(Pulse Shape Discrimination)
     Slow/total (Ar merit)
  2. S2/S1 ratio
- α : higher energy + vertex
- μ: veto (+ go underground)
- Neutron: (NR)
  ➡ Shield
  + multiple interaction
  (+ go underground)





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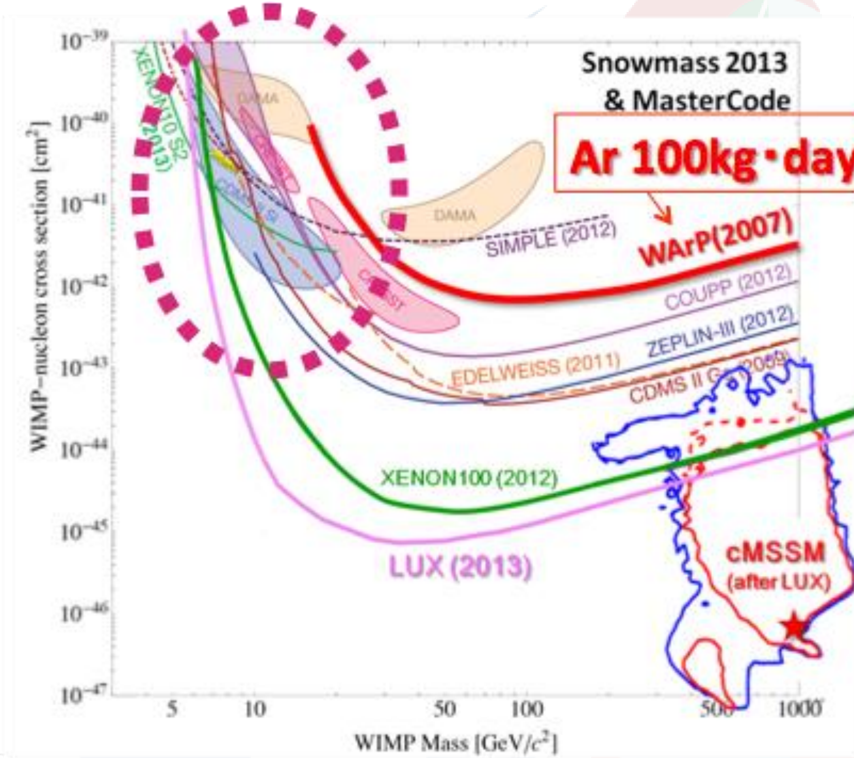
Target of ANKOK



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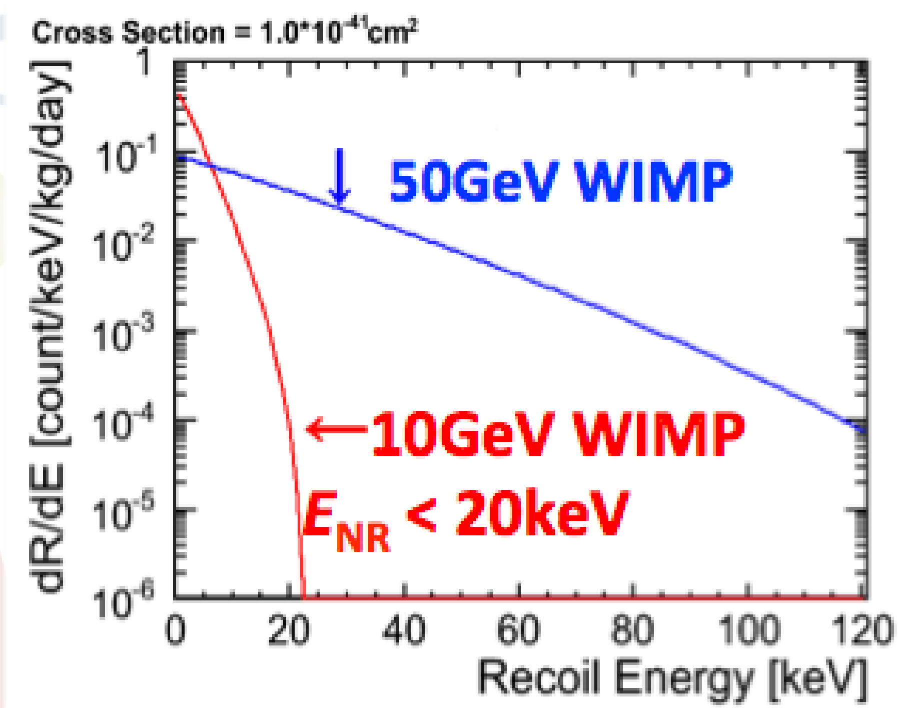
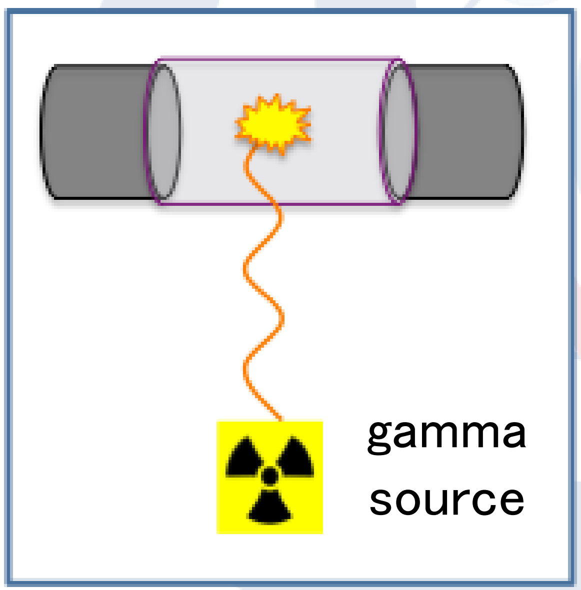


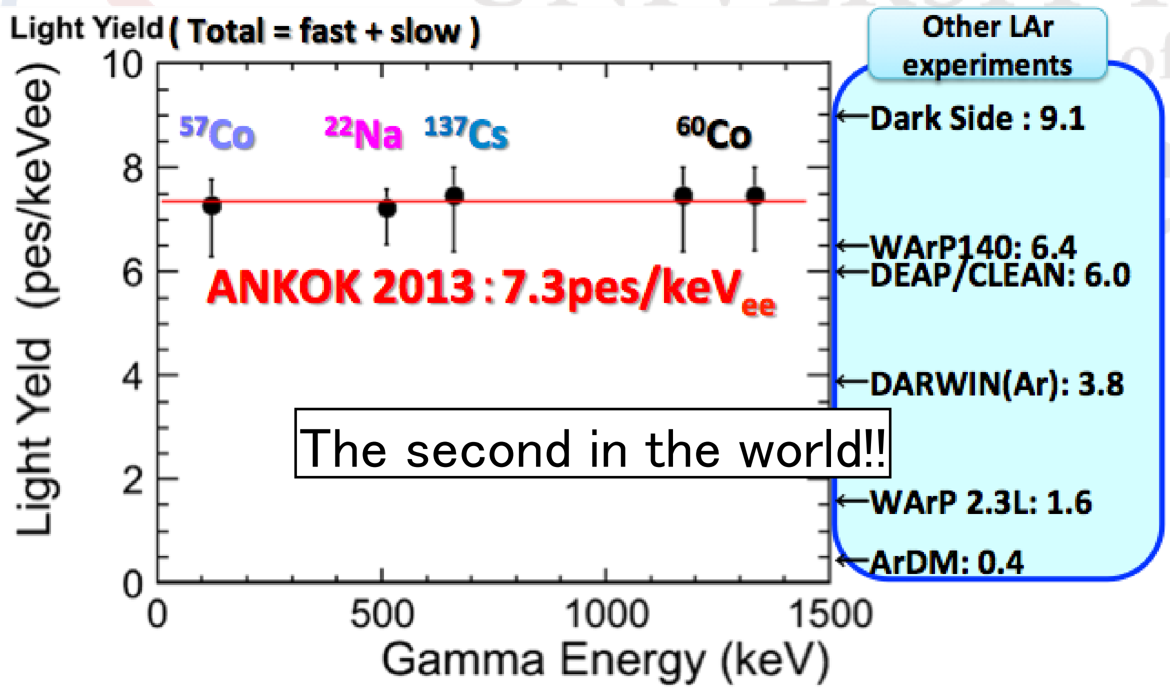
- Need to detect > ˜20 keVnr nuclear recoil signal.

➡ Aim 1. High sensitivity (Highest photo yield)
2. BG reduction power

- Light yield test with a 1-phase liquid argon detector.
  - Optimize method to soak WLS on PMT and reflector surface (evacuation) and amount of soaking WLS.
  - Reduce impurities in LAr.



Consists of LAr, 2 PMT, reflector and WLS



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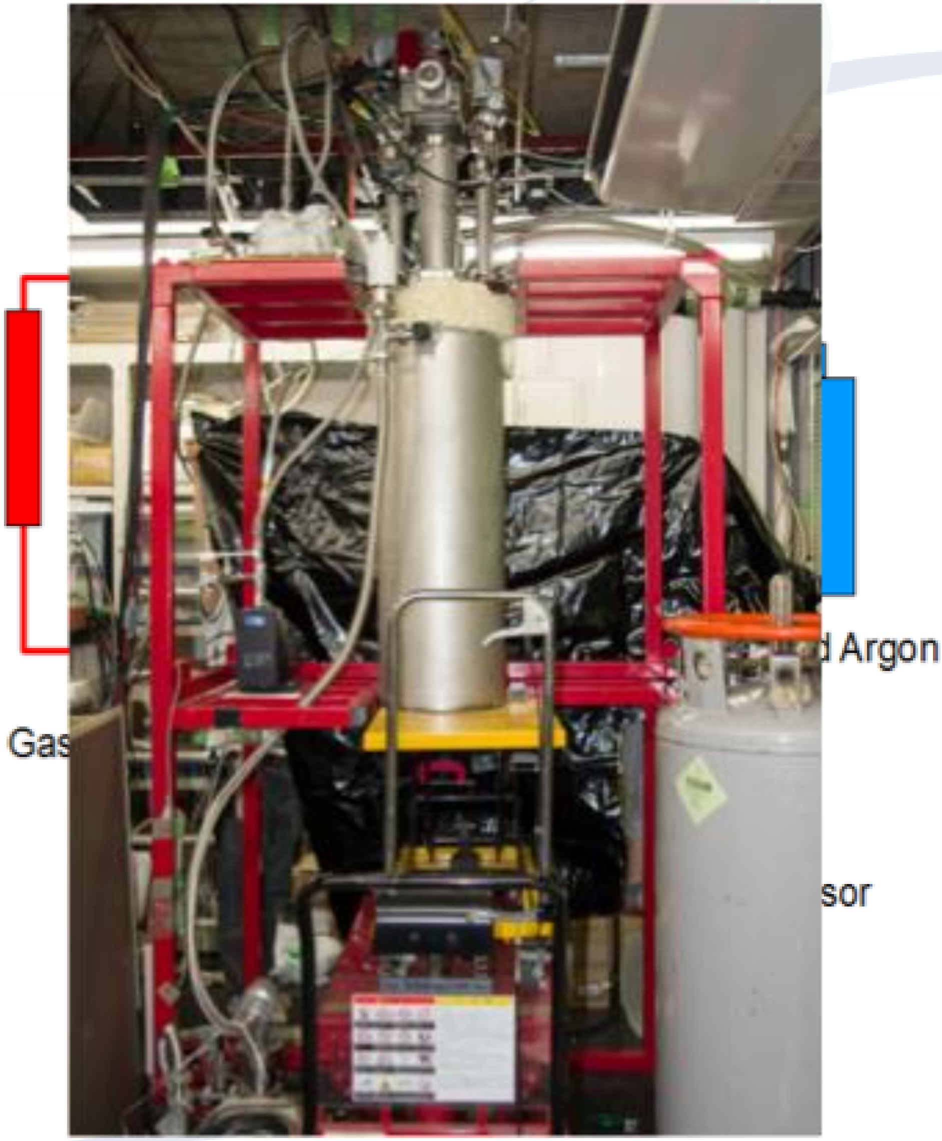
Surface run for test stand



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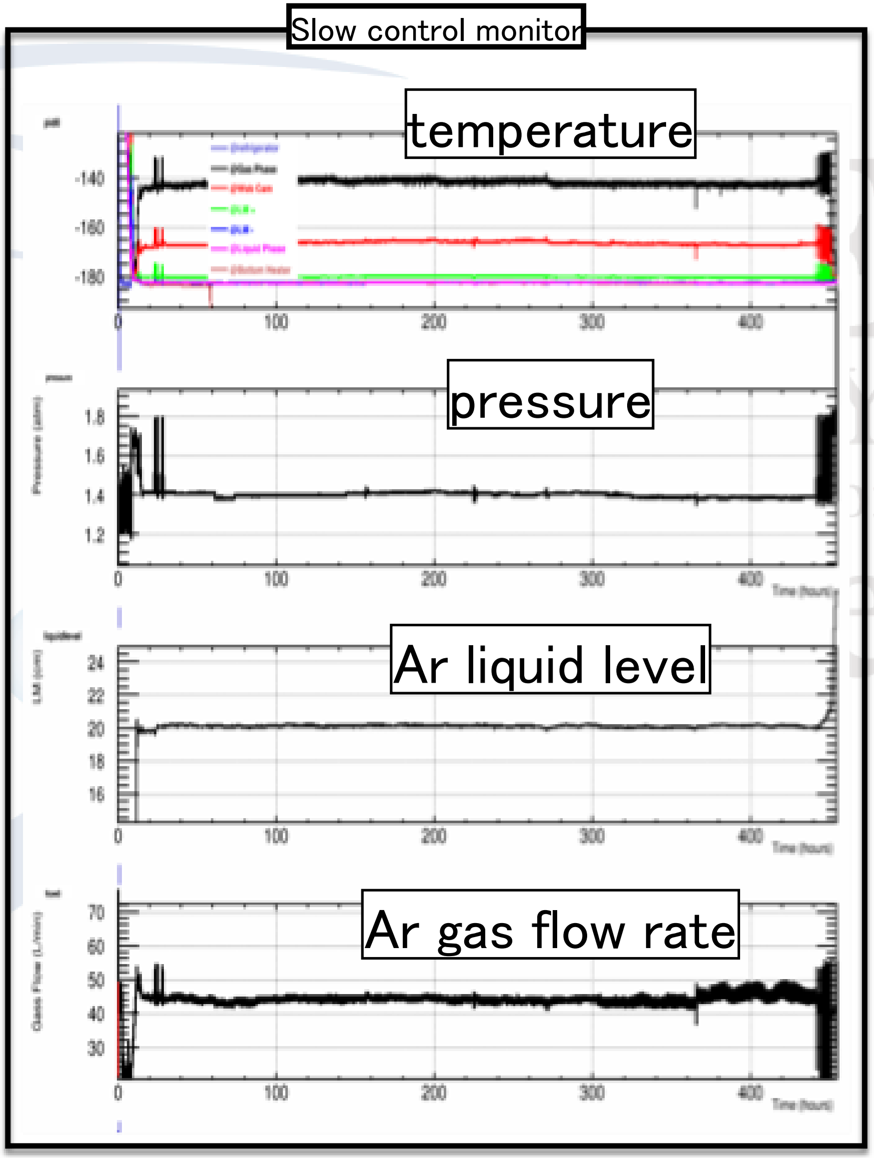
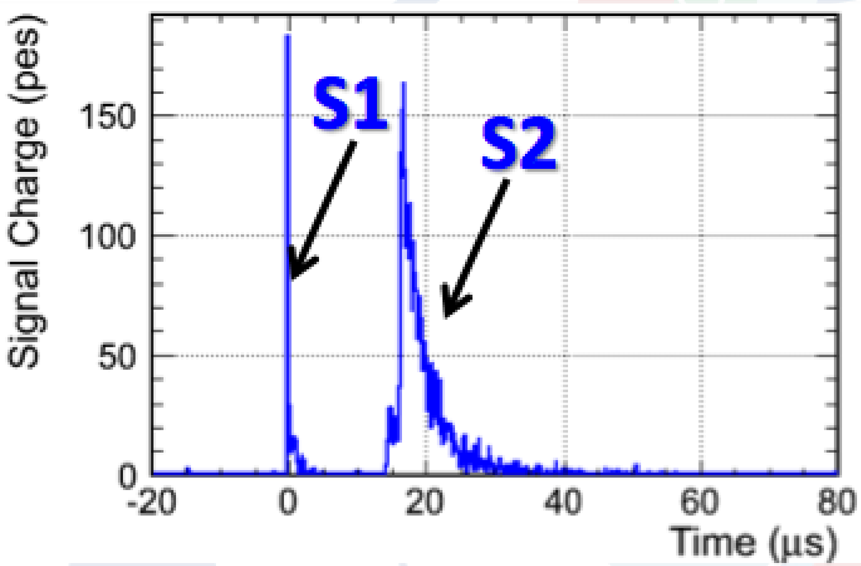
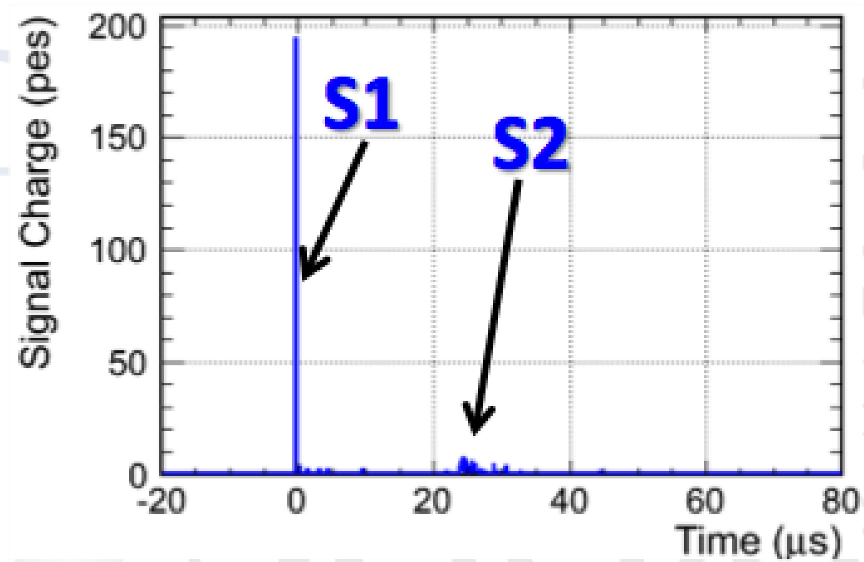


Typical events

☆^{60}Co ER event



☆^{252}Cf NR event



S1 fast : t=0〜100ns
S1 slow : t=100ns〜5 μ s
S2 : t=5 μ s〜80 μ s

Event Selection::
S2 exists （＞~1p.e.）
Multiple Event Veto
Drift time (= z−fiducual) cut
S1 light yield (100 〜500 p.e.)
etc.

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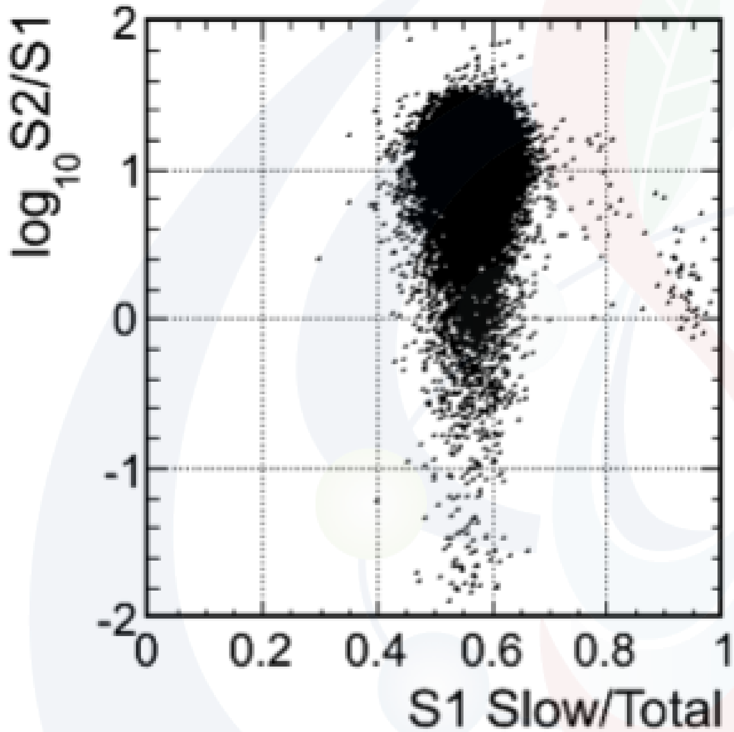
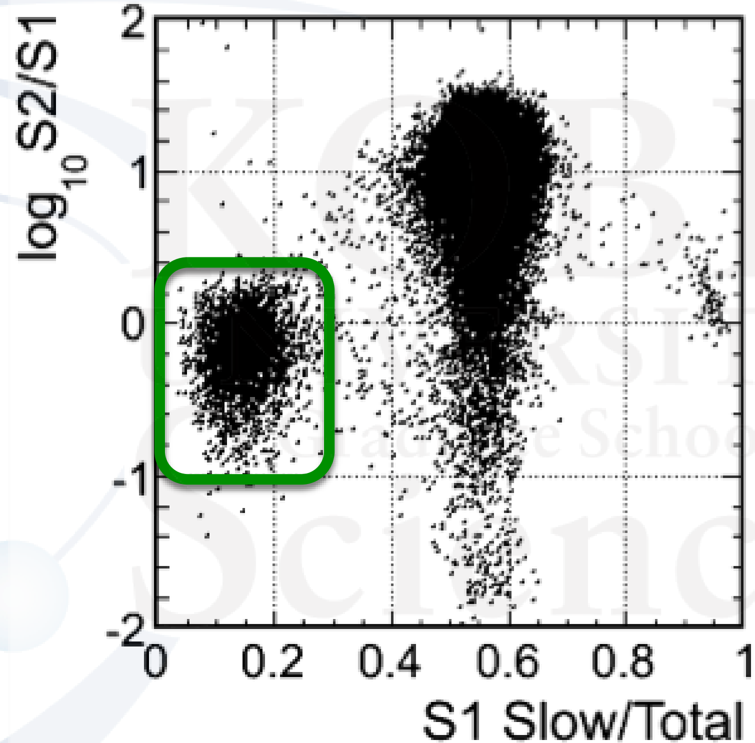
Gamma rejection by "S2/S1" & "PSD"

☆^{60}Co source



☆^{252}Cf source



- Whole gamma events was rejected in this ^{60}Co data.
- Detail analysis is ongoing.
  - Energy dependance study, quantitative study on rejection power and so on.

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Summary

- ANKOK experiment is a direct WIMP search experiment using a 2-phase Ar detector.
- They constructed a stable detector system.
  A surface run is ongoing.
- Whole gamma events was separated from neutron event region by "S2/S1" & "PSD" analysis in ^{60}Co data.
  - Detail analysis is ongoing.


POCO-LON

KamLAND-PICO
Dark Matter Search Project

Ken-Ichi Fushimi
for
KamLAND-PICO

PICO-LON for WIMPs search

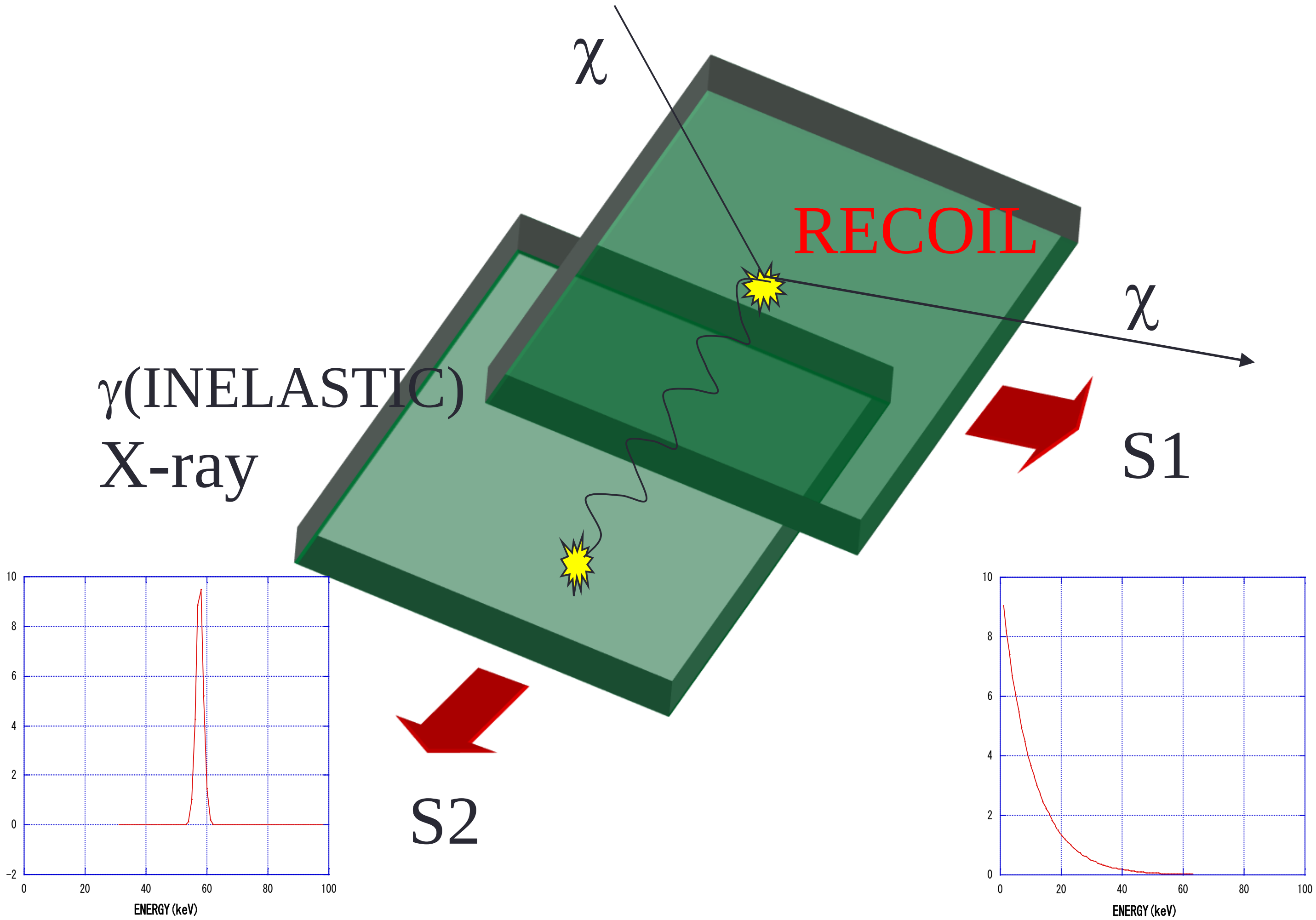
- **P**lanar
- **I**norganic
- **C**rystal
- **O**bservatory for
- **LO**w-background
- **N**eutr(al)ino

- High selectivity
- Background reduction

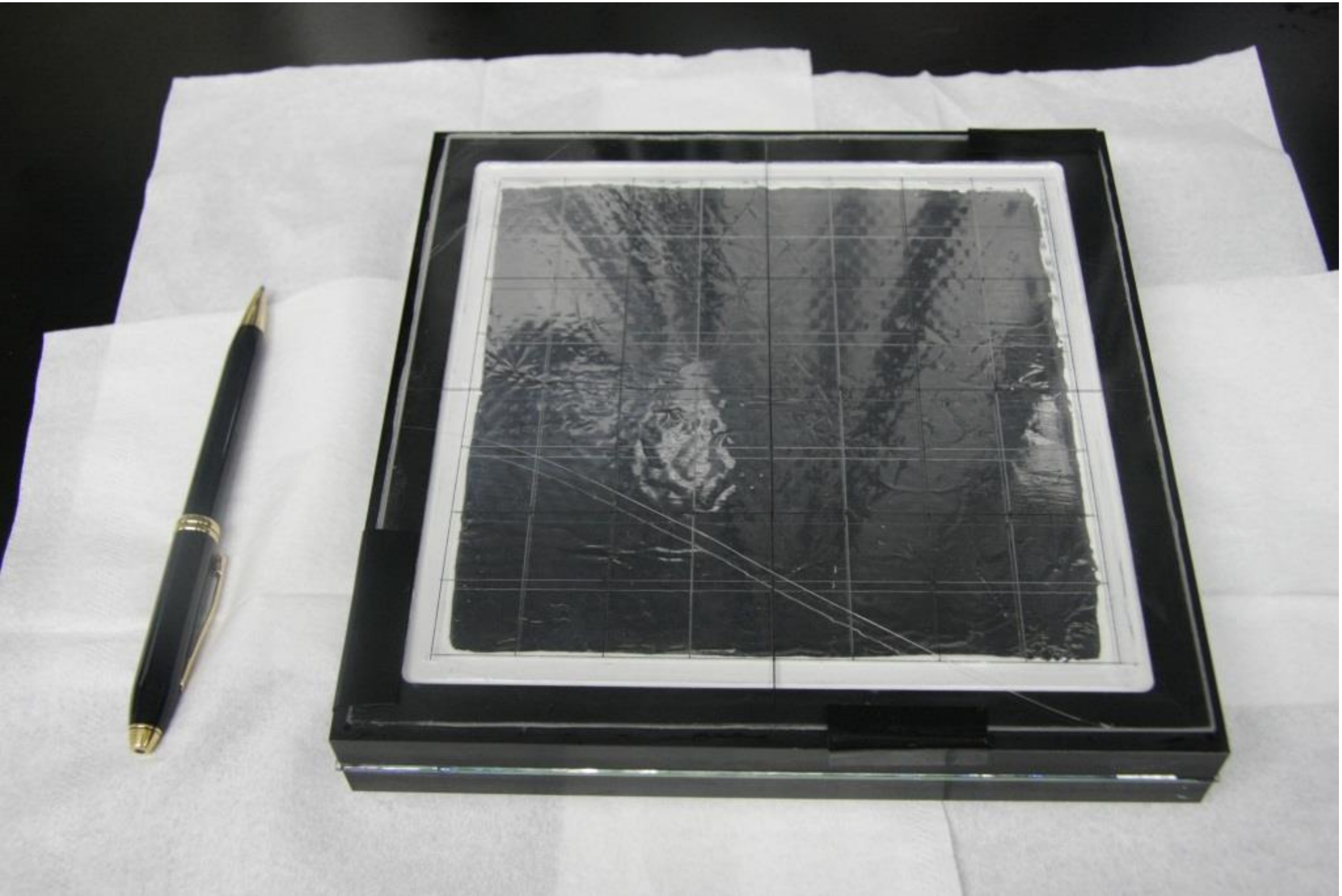
- Sensitive to
- Elastic scattering (SI+SD)
- Inelastic scattering (SD)

- Study the interaction type of WIMPs

Concept of PICO-LON detector



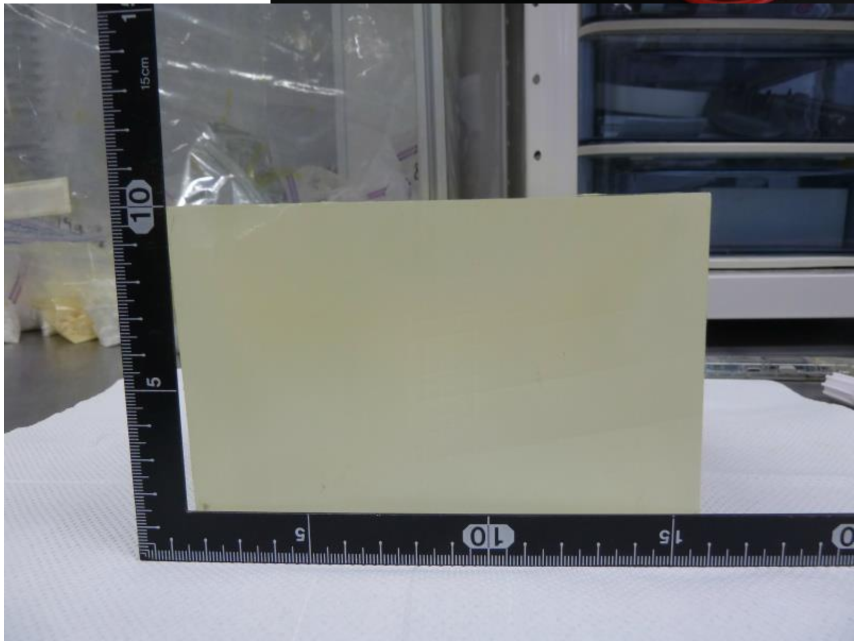
PICO-LON single layer module



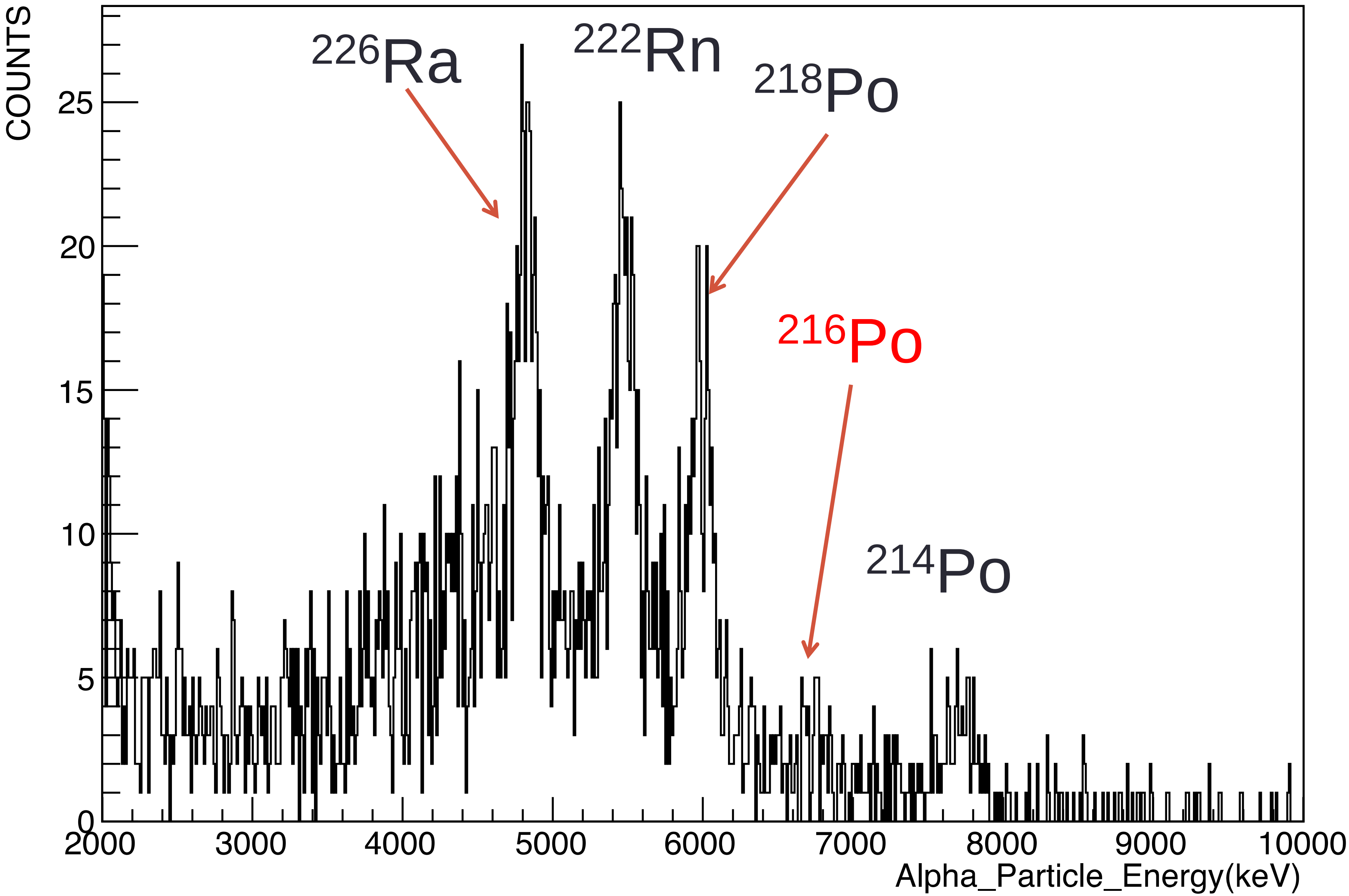
R&D for pure NaI(Tl) production

- developed by I.S.C. Lab.
- pod selection
- NaI(Tl)powder selection
- lab status

- 3.0”ϕX3.0” NaI(Tl)
- Improvement step by step



Ingot 23 results (26 days live time)



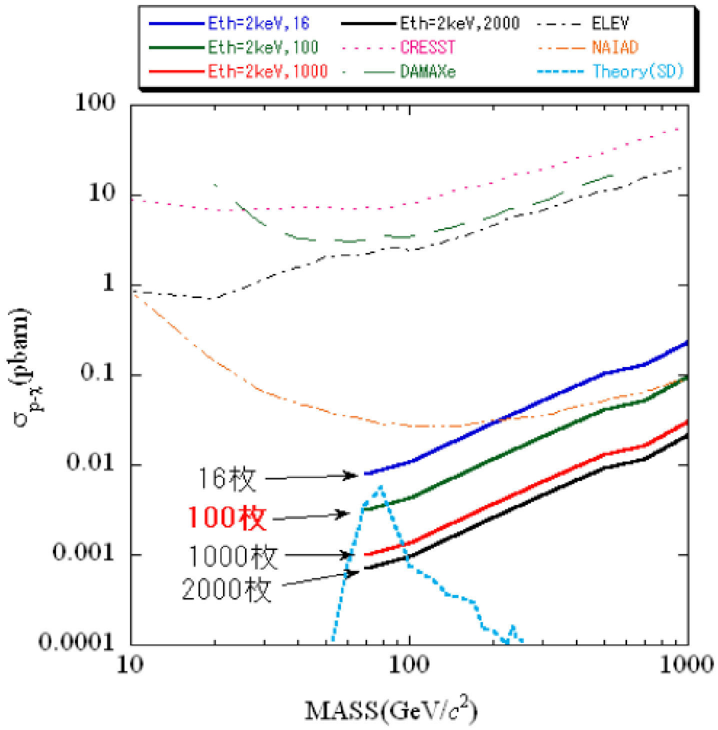
Present result

	DAMA	DM-Ice	Ingot 23	Goal of PICO-LON
^{nat}K (ppb)	<20	660	Not yet	<20
^{232}Th(ppt)	0.5-0.7	2.5	3.3±2.0	<1
^{238}U(ppt)	0.7-10	1.4	5.4±0.9	<1
^{210}Pb (μBq/kg)	5-30	1470	58±26	<100

- U-chain: 1ppt= 12.3μBq/kg
- Th-chain: 1ppt= 4.0μBq/kg
- ^{210}Pb: 1ppt=2.5kBq/kg

Summary

- PICO-LON for WIMPs search
- High sensitivity to all the types of interaction.
  - Elastic scattering for SD+SI
  - Inelastic scattering for SD
- Good performance for WIMPs search
- KamLAND-PICO
  - Low background study for NaI(Tl) with 4π active shield.
- Detector performance OK
- Impurity of NaI(Tl) OK



EMULSION

Nuclear Emulsion Technology and Directional Dark Matter Study

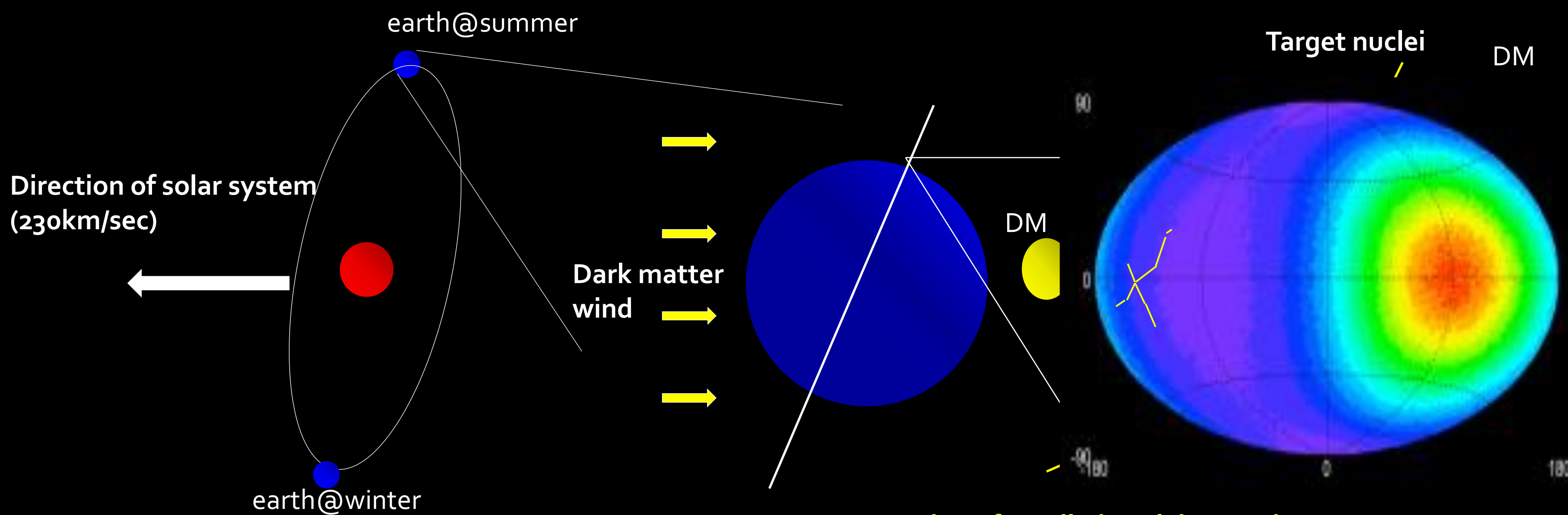
Fundamental Particle Physics Laboratory
Graduate School of Science of Nagoya University
Division of Particle and Astrophysical Sciences

Tatsuhiro NAKA

KMI / IAR, Nagoya University

KMI2013 @ Nagoya University, Dec. 12th (11-13), 2013

Directional Dark Matter Search



Detection of recoiled nuclei as tracks

Direction sensitive detector → **Emulsion detector**

Current Collaboration

Nagoya University

T. Naka, T. Asada, T. Katsuragwa, M. Yoshimoto, K. Hakamata, M. Ishikawa, A. Umemoto, S. Furuya, S. Machii, Y. Tawara, M. Nakamura, O. Sato, T. Nakano

Chiba University

K. Kuge

University of Napoli

G. de Lellis , A. Di Crescenzo, A. Sheshukov , A. Aleksandrov, V. Tioukov

University of Padova

C. Sirignano

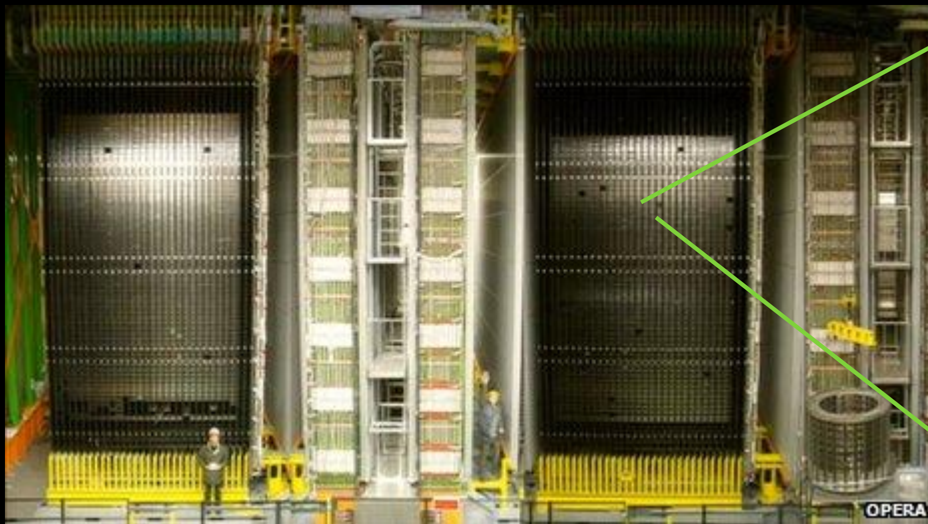
Laboratori Nasionale de Grann Sasso (LNGS)

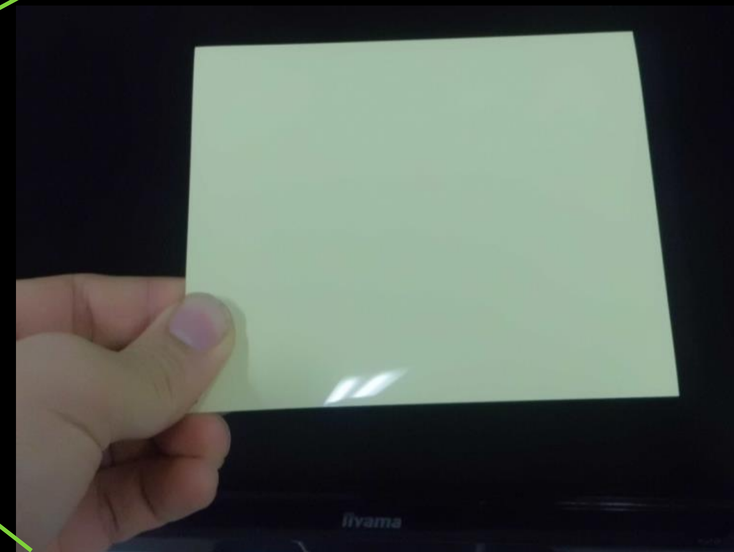
N. D'Ambrossio, N. Di Marco, F. Pupilli

Technical Support

- SPring-8
- DarkSIDE group at LNGS
- retired FUJI FILM engineer etc.

OPERA detector





Emulsion mass ~ 30 ton

Why is it capable of detection of tau neutrino ?

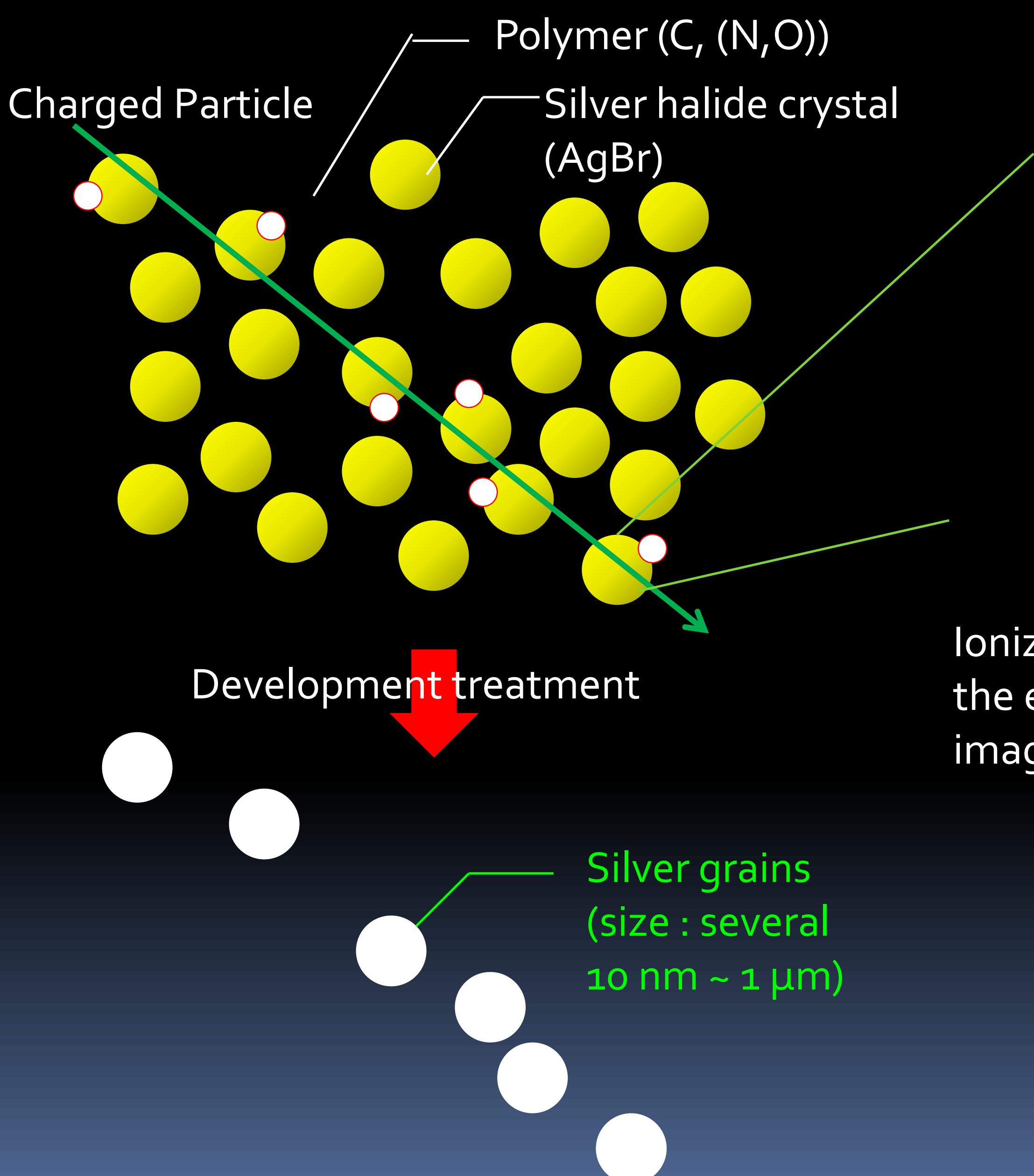
↓

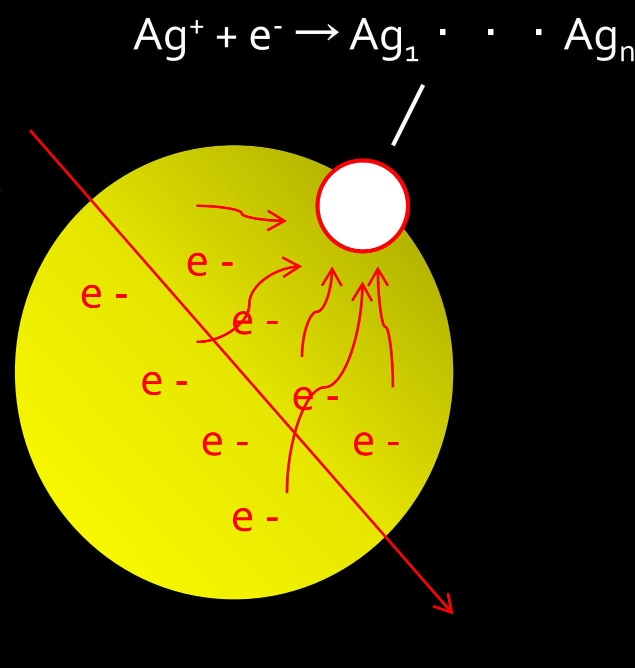
It has extremely high spatial resolution .
(tau decay length ~ 100 μm)

↓

Why does it have such high spatial resolution?

Nuclear Emulsion Detector

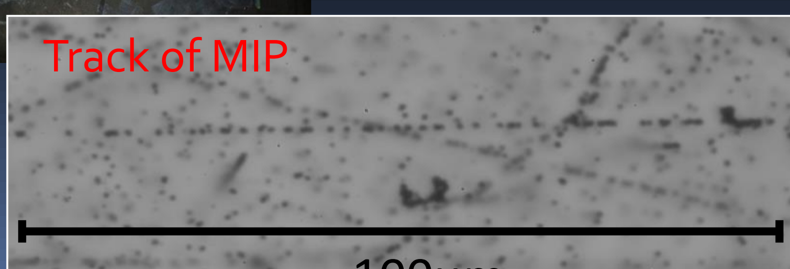




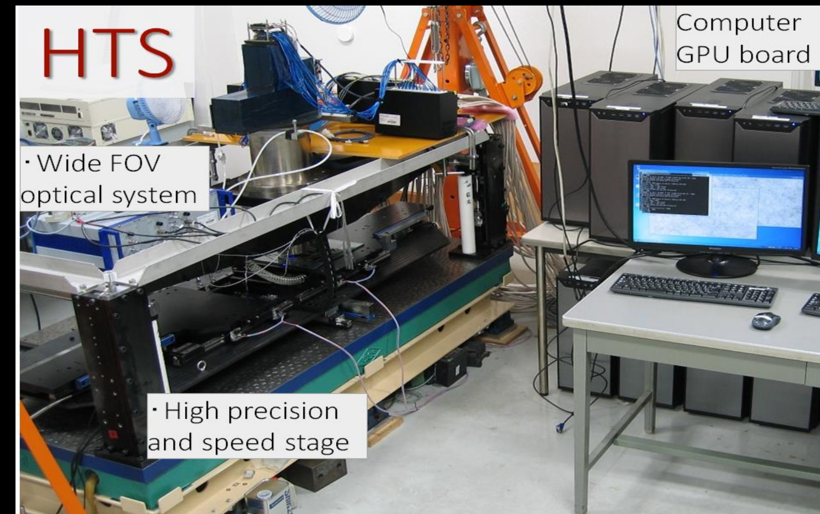
Ionized electrons concentrated on the electron trap to form the latent image specks in a crystal

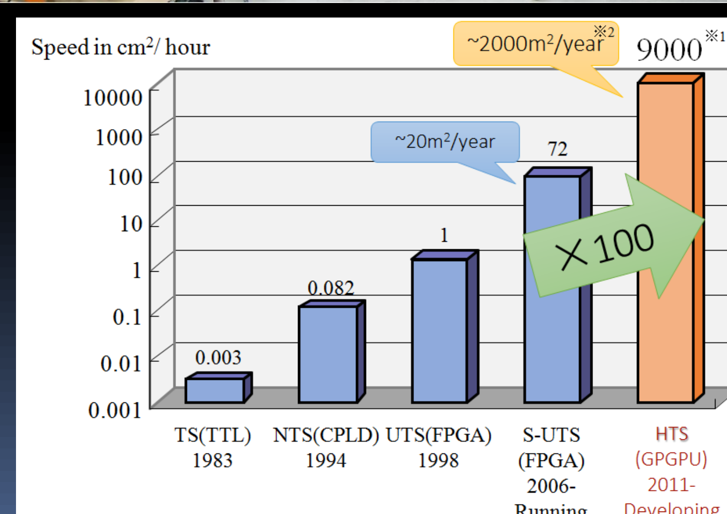
Key technology

Devise self-production



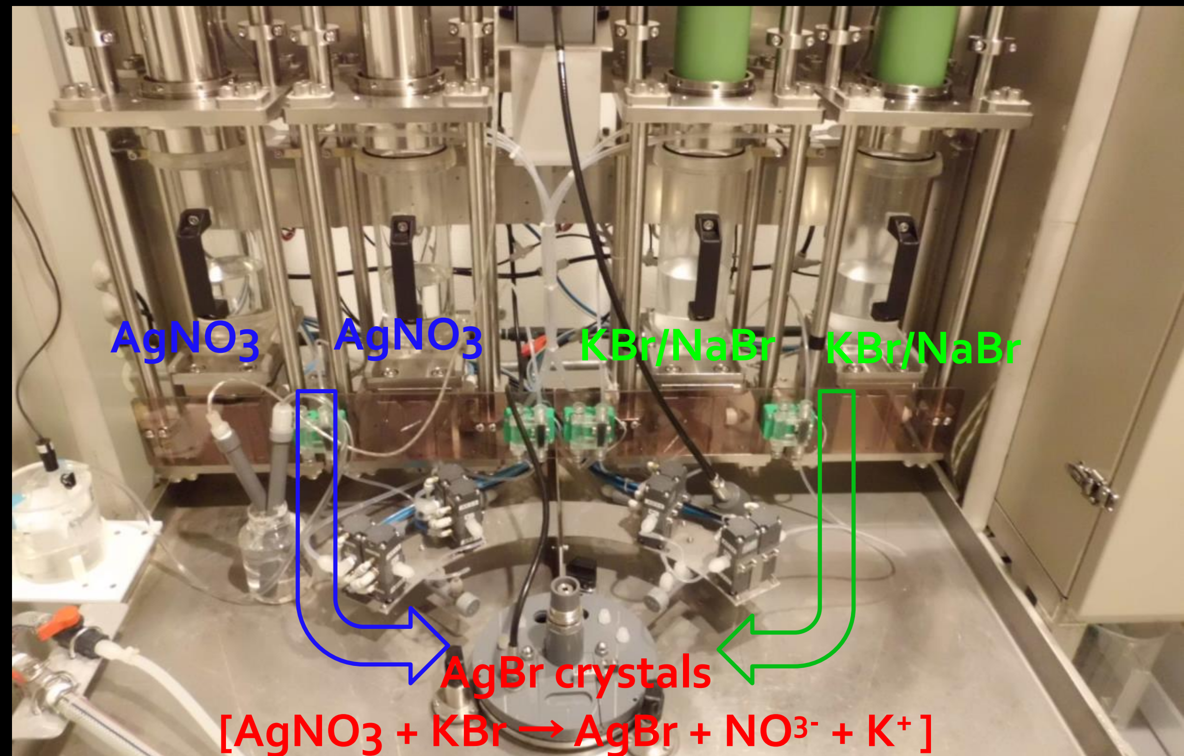
Readout system



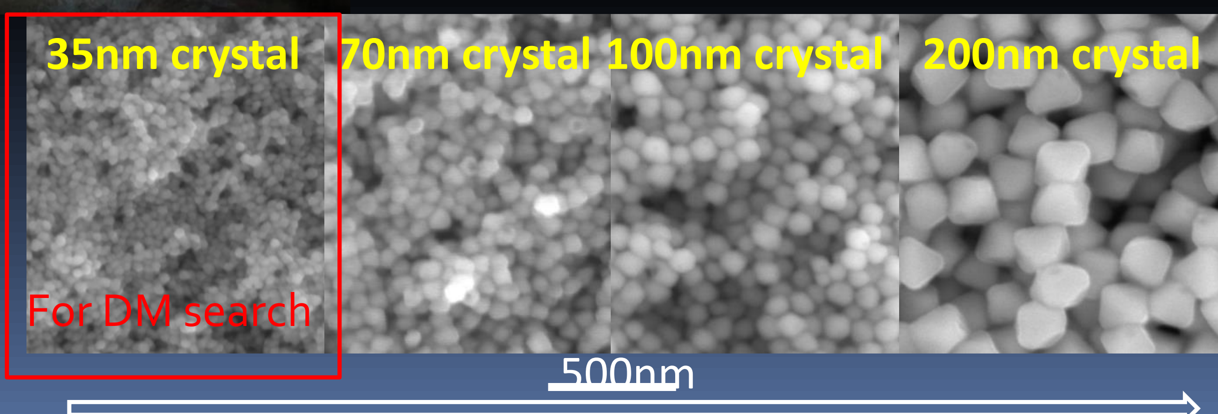


~ 100 kg order /year

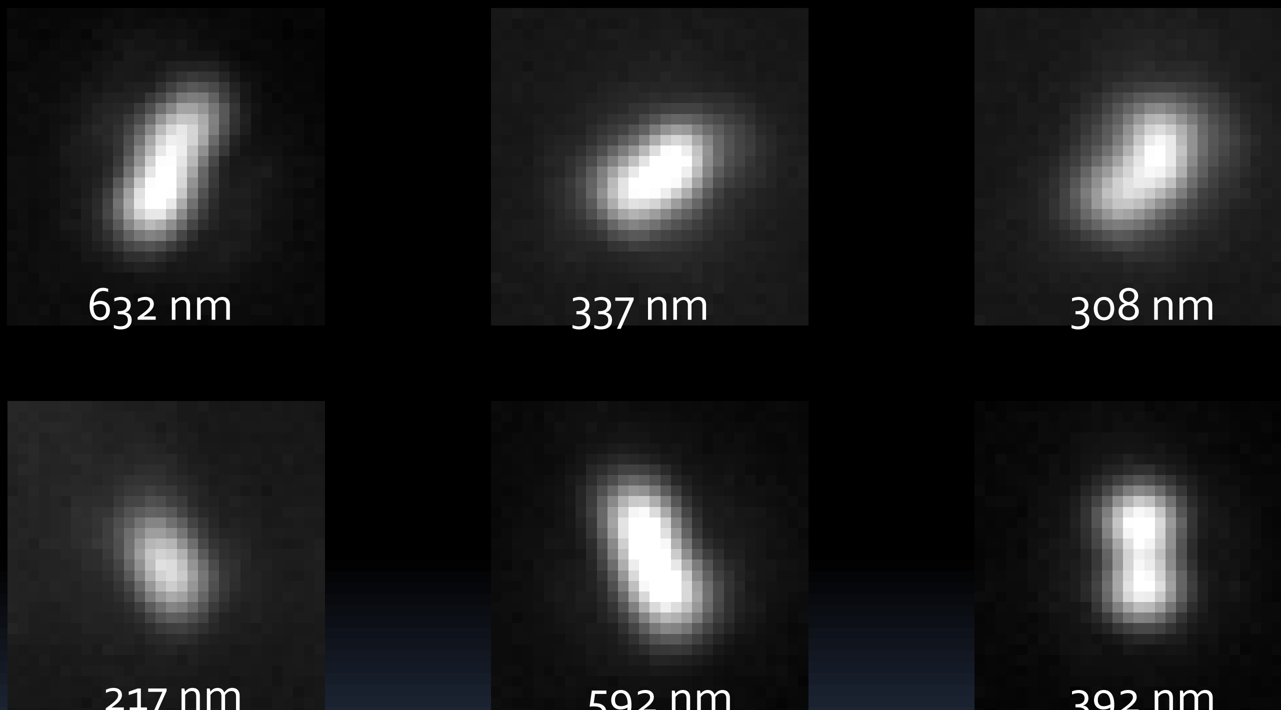
Emulsion Self-Production at Nagoya University



Production scale ~ 1 kg detector/week



Neutron (14 MeV) recoil track under optical microscopy



Almost Br recoil (170 - 600keV) because of low sensitivity tuning.

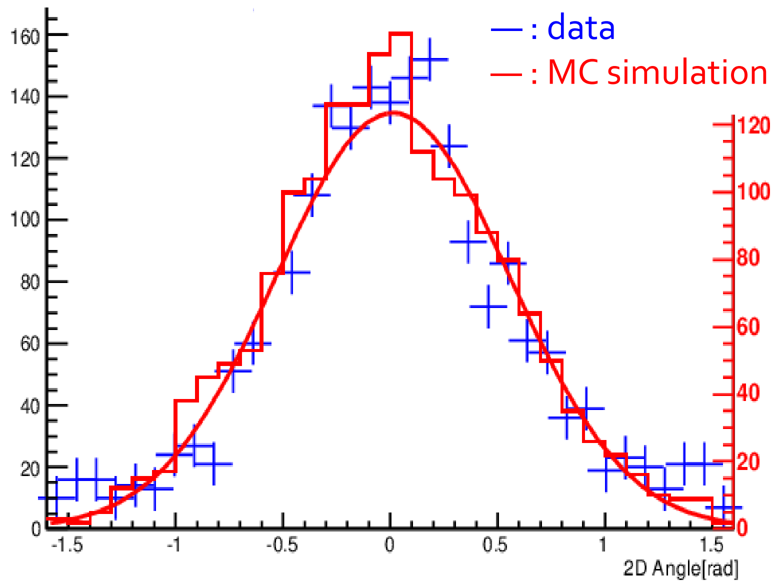
Direction Sensitivity

<u>Ion implant system</u>

⇒ 80, 100, 125, 150, 200 keV C ion
(realistic C ion demonstration)

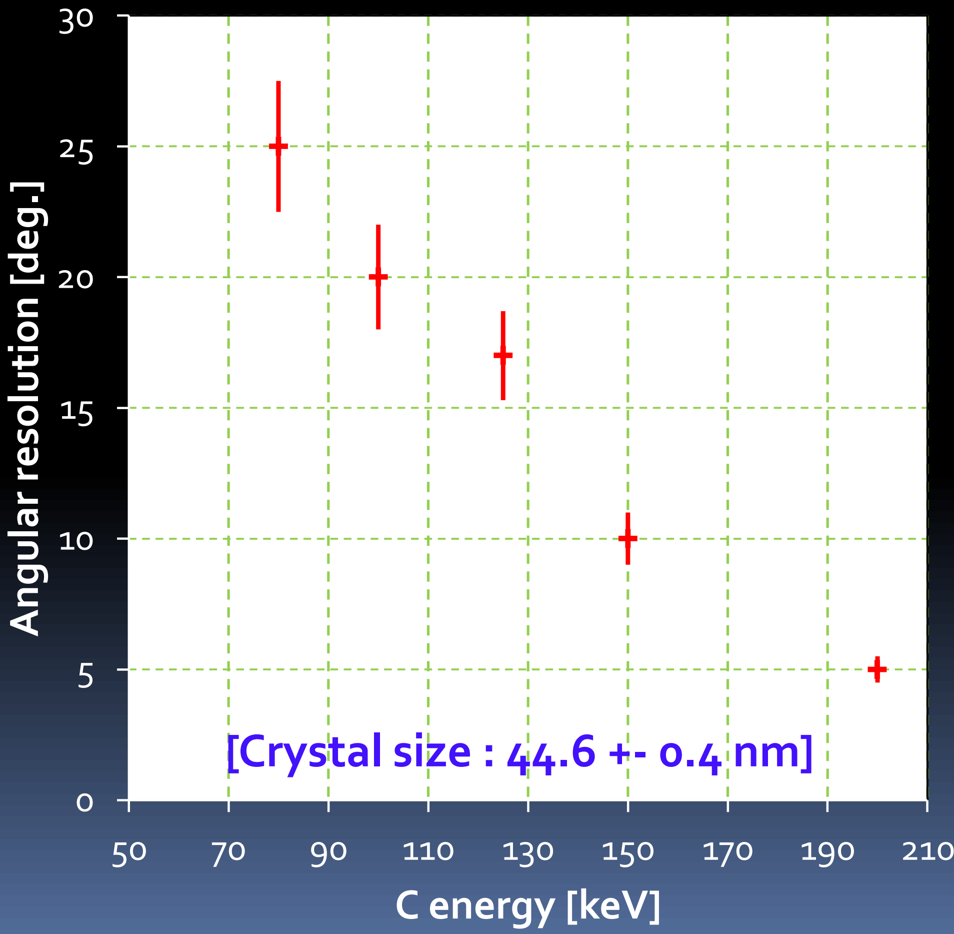
※ ⊿E/E < ~ 1 %

Angular distribution of 100 keV C ion



2D angle [rad.]

Angular resolution of C ion due to Ion implant



Near Future plan

2013 | 2014 | 2015 | 2016 | 2017

2013–2015:

Detector R&D for low backgrounds

Evaluation of background rejection power and detection efficiency

Intrinsic background estimation @ LNGS

R&D phase

2015–2016:

1~10 g scale commissioning

⇩

background study

~ g scale commissioning

2017:

100g scale Run

➡ aim to DAMA 100 GeV/c^2 region

Physics run

↑ Proposal to LNGS

Underground neutron measurement

underground neutron flux > 1 MeV

NEWAGE

NEWAGE

Direction-sensitive dark matter search

Kiseki Nakamura (Kyoto univ.)

K.Miuchi[2], T.Tanimori[1], K.Kubo[1], A.Takada[1], H.Nishimura[1], J.D.Parker[1], T.Mizumoto[1], Y.Mizumura[1], T.Sawano[1], Y.Matsuoka[1], S.Komura[1], Y.Yamaguchi[2] , T.Hashimoto[2], A.Takeda[3], H.Sekiya[3]

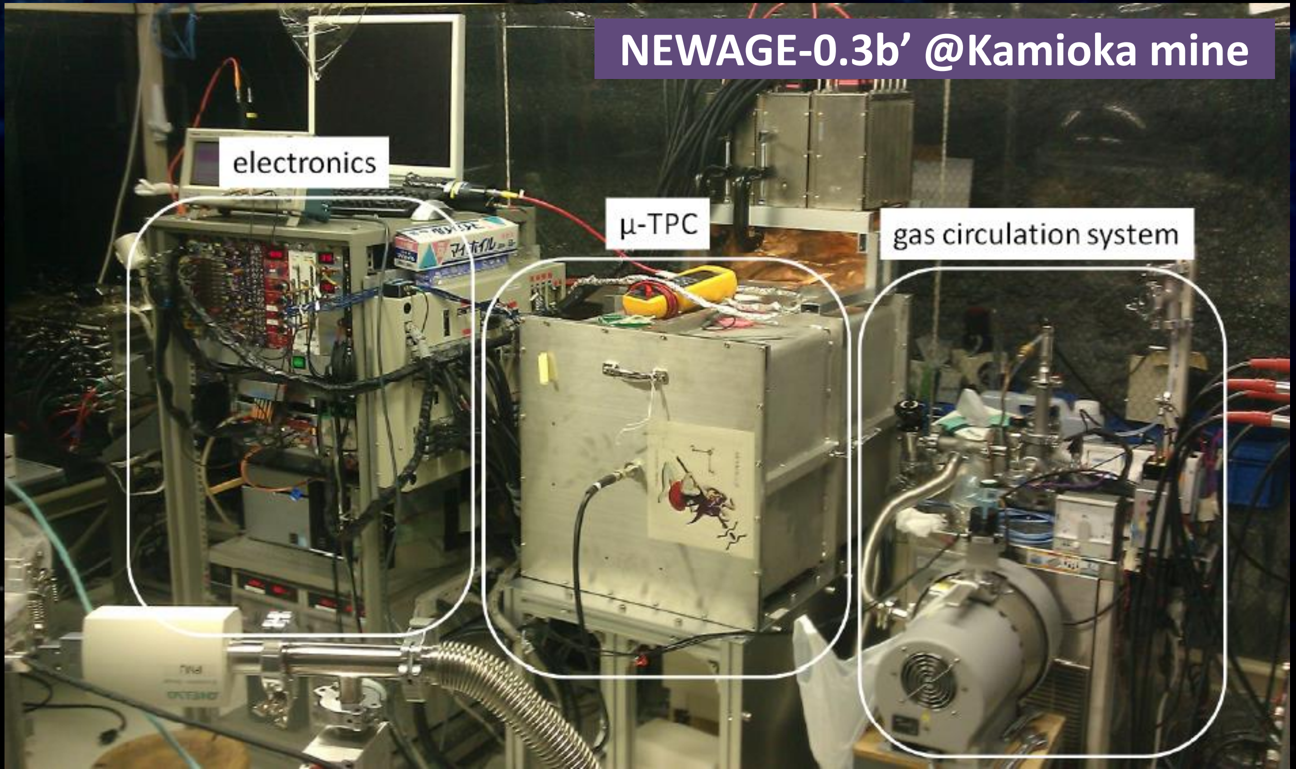
(1) Kyoto university department of physics
(2) Kobe university department of physics
(3) ICRR

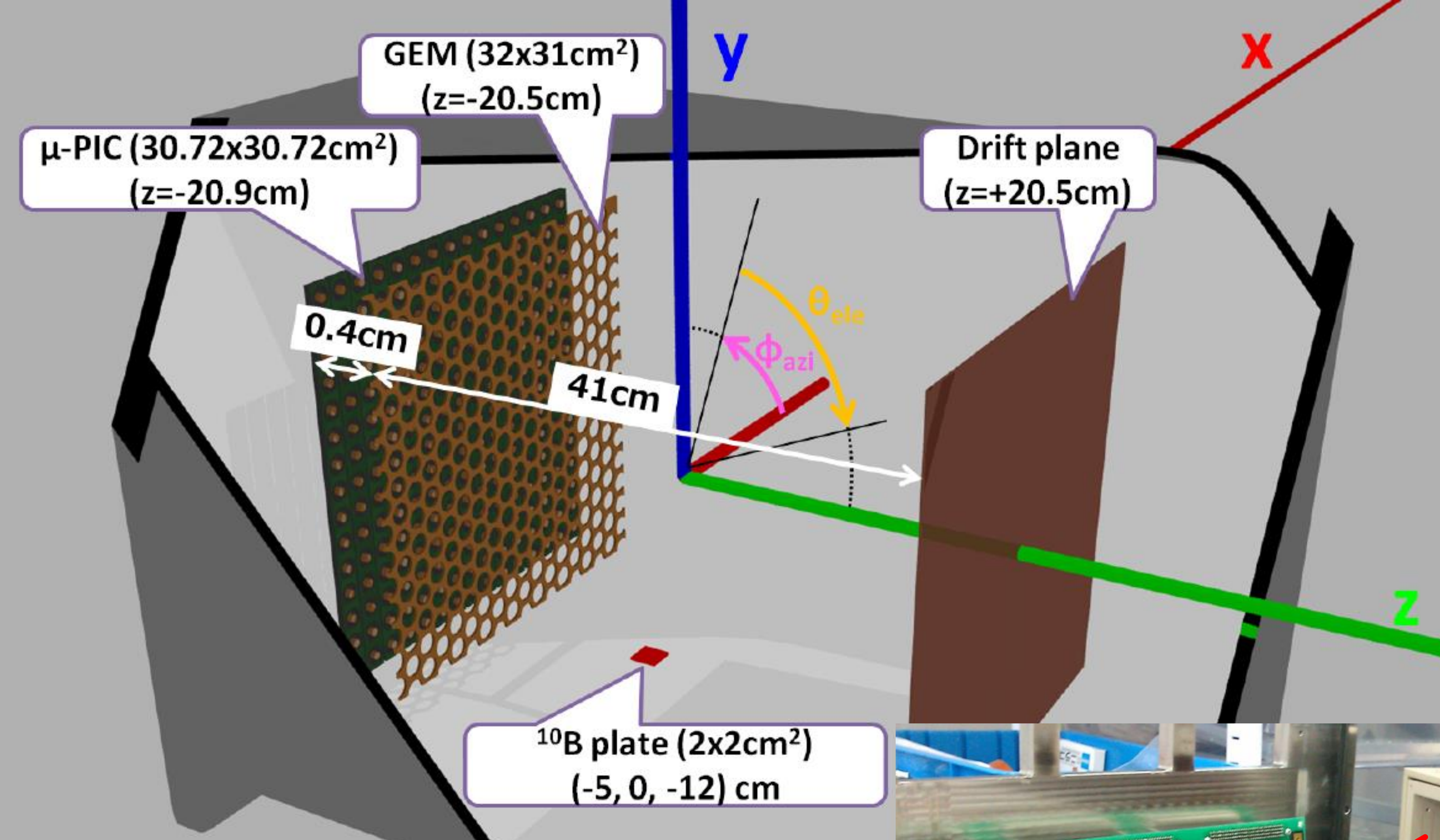
- NEWAGE detector
- Result of underground measurement
- Background study
- Summary

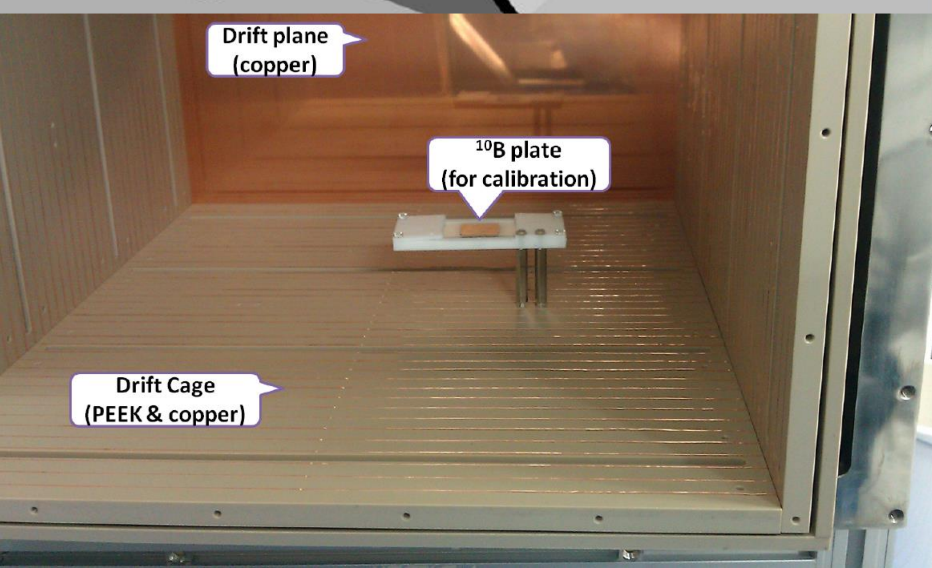
IDM2014@ Amsterdam 27 June 2014

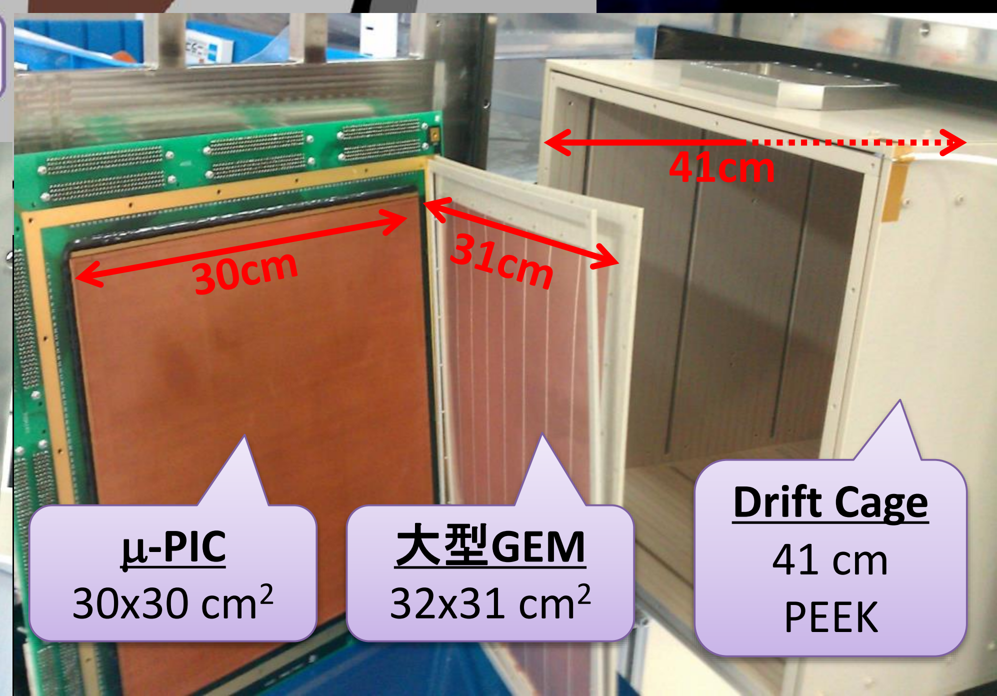
NEWAGE-0.3b' detector

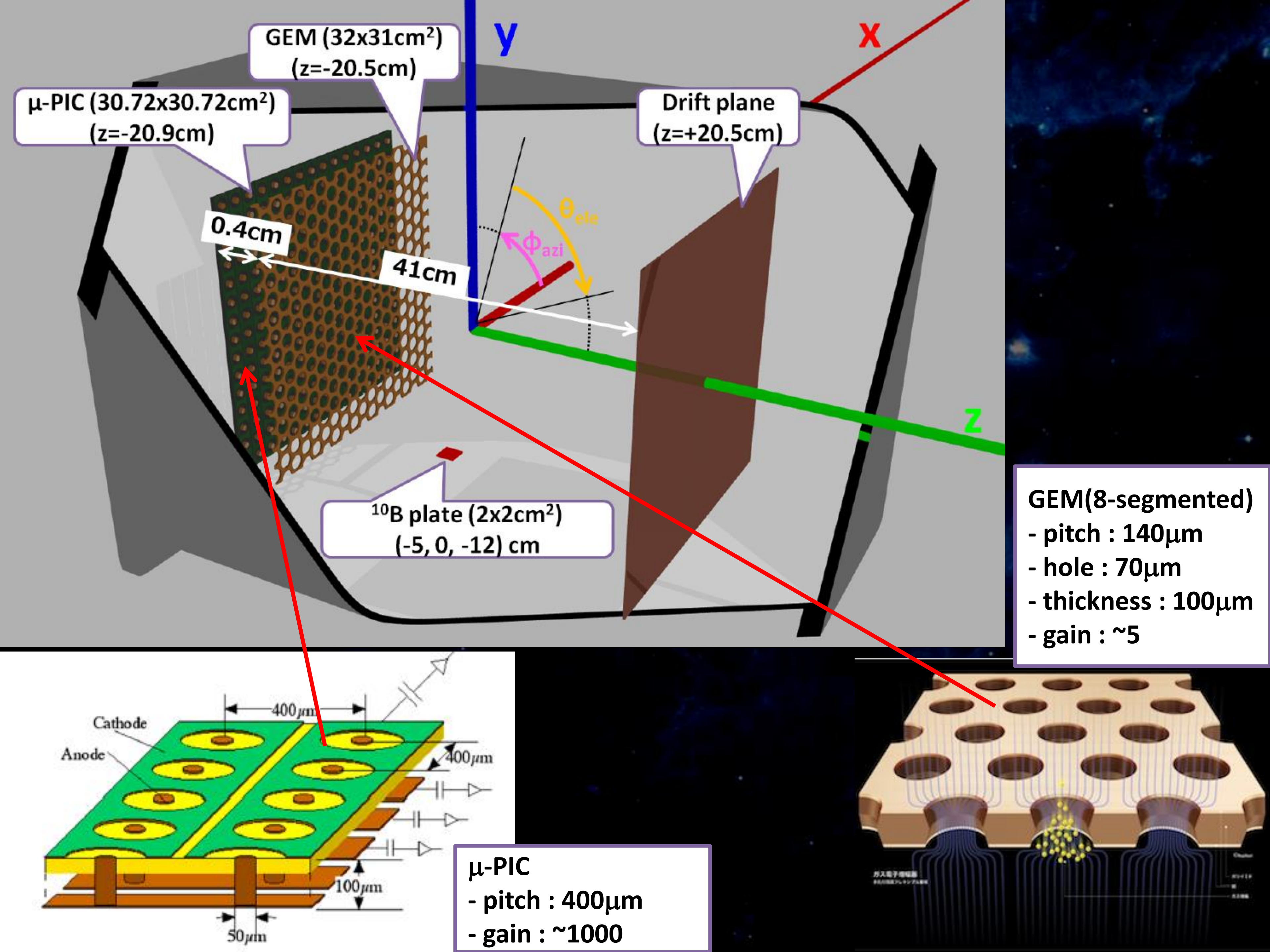
- Aim >x10 improvement from previous measurement (PLB2010)
  - Large size : ~x2 ($23 \times 27 \times 31 cm^3$ => $30 \times 30 \times 41 cm^3$)
  - Low pressure (low threshold) : 0.2 => 0.1atm (100 => 50keV)
  - Upgrade tracking algorithm (DAQ upgrade)
  - Gas circulation system with cooled charcoal




GEM (32x31cm^2)
(z=-20.5cm)
μ-PIC (30.72x30.72cm^2)
(z=-20.9cm)
y
x
Drift plane
(z=+20.5cm)
θ_{ele}
ϕ_{azi}
0.4cm
41cm
z
^{10}B plate (2x2cm^2)
(-5, 0, -12) cm


Drift plane
(copper)
^{10}B plate
(for calibration)
Drift Cage
(PEEK & copper)


41cm
30cm
31cm
μ-PIC
30x30 cm^2
大型GEM
32x31 cm^2
Drift Cage
41 cm
PEEK



GEM (32x31cm^2)
(z=-20.5cm)
μ-PIC (30.72x30.72cm^2)
(z=-20.9cm)
y
x
Drift plane
(z=+20.5cm)
0.4cm
41cm
θ_{ele}
ϕ_{azi}
z
^{10}B plate (2x2cm^2)
(-5, 0, -12) cm
GEM(8-segmented)
- pitch : 140μm
- hole : 70μm
- thickness : 100μm
- gain : ~5
400μm
Cathode
Anode
400μm
100μm
50μm
μ-PIC
- pitch : 400μm
- gain : ~1000

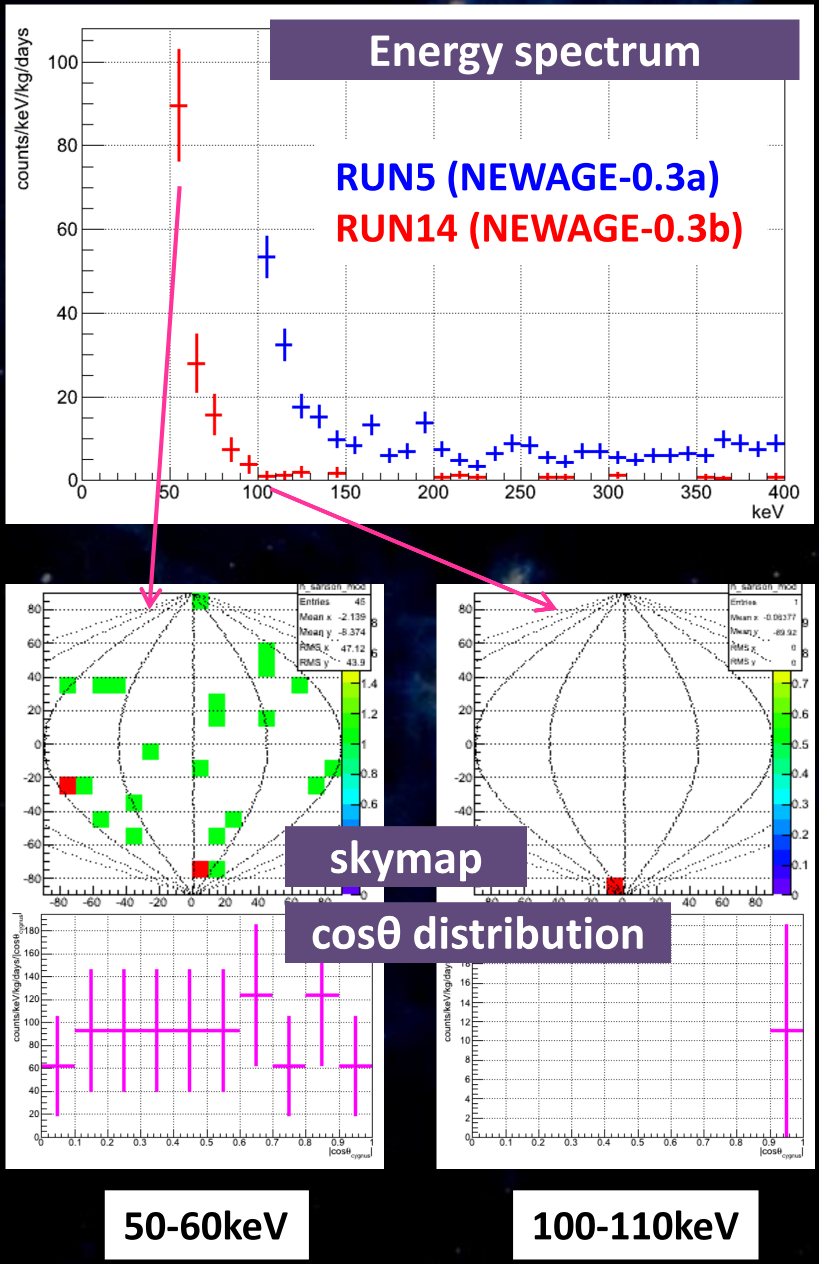
Underground measurement

<u>RUN14</u>

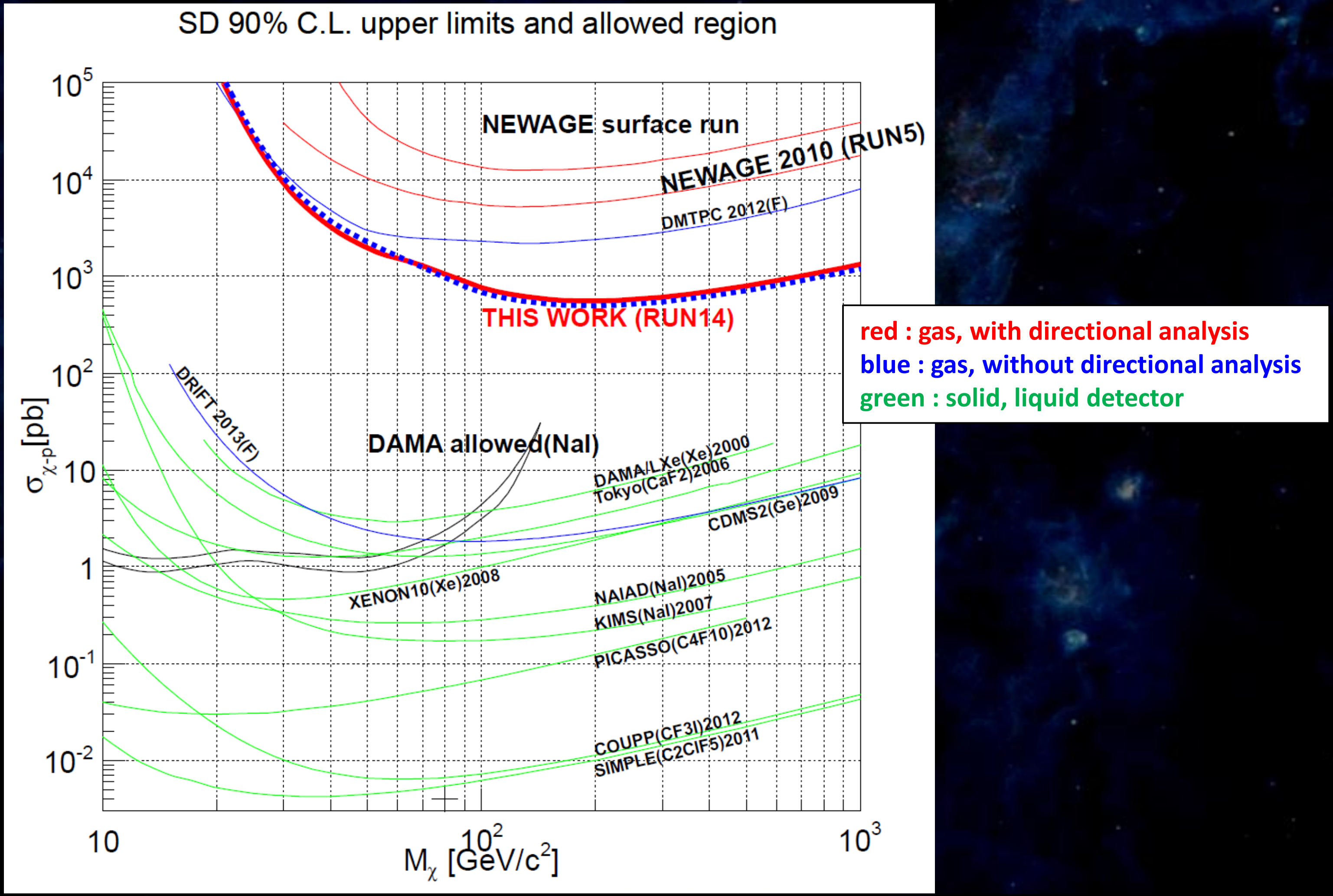
- period : 2013/7/20-8/11, 10/19-11/12
- live time : 31.6 days
- fiducial volume : $28x24x41cm^3$
- mass : 10.36g
- exposure : 0.327 kg･days

- *<u>Energy spectrum</u>*
  - Threshold : 100 => **50keV**
  - BG rate : **1/10**@100keV

- *<u>Skymap, cosθ distribution</u>*
  - Set limit by significant difference in 2-binned measured cosθ and DM-wind simulated cosθ



Direction-sensitive limit

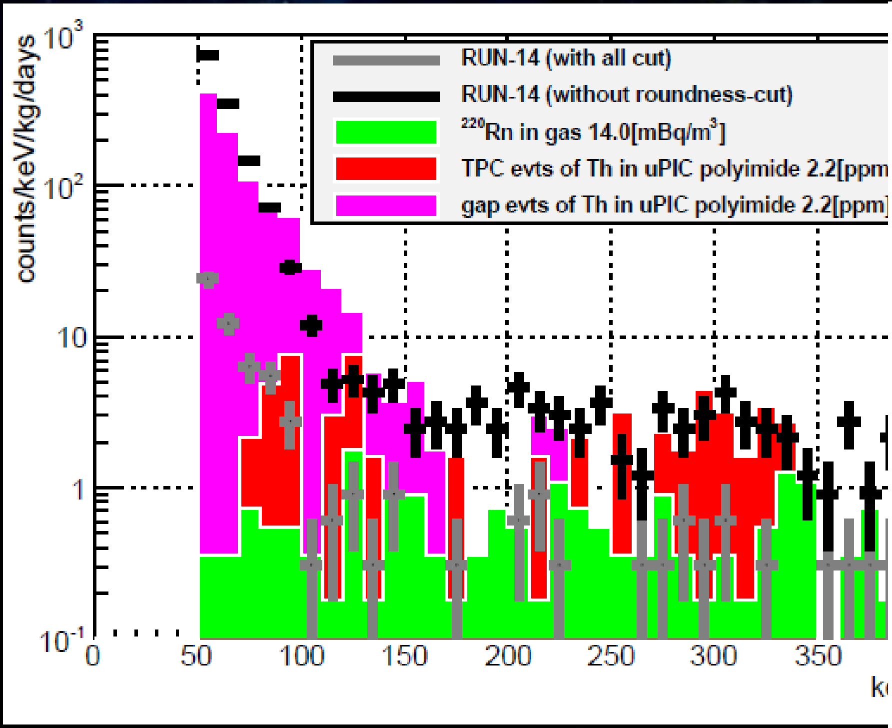


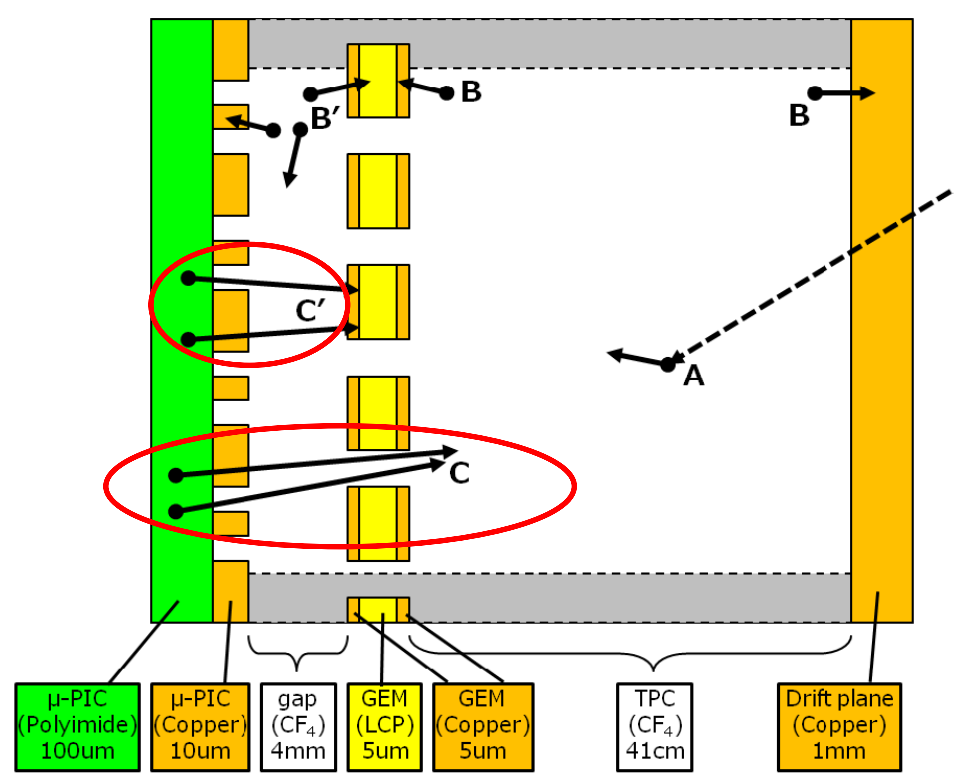
- Obtained limit : 557pb @200GeV
  (Best direction-sensitive limit)
- Improved one order of magnitude from previous RUN5

Background understanding

1. Estimate from high energy spectrum.
2. Estimate from gamma assay by Ge spectrometer.

Both indicate
Dominant BG is found to be alphas from μ-PIC





Xenon Kamioka

Argon surface (Waseda)

NaI surface (Tokushima)

Emulsion surface (Nagoya)

Gas TPC Kamioka