28 Jan. 2015, Joint Winter Conference on Particle Physics, String and Cosmology

The Status of KIMS-NaI Experiment

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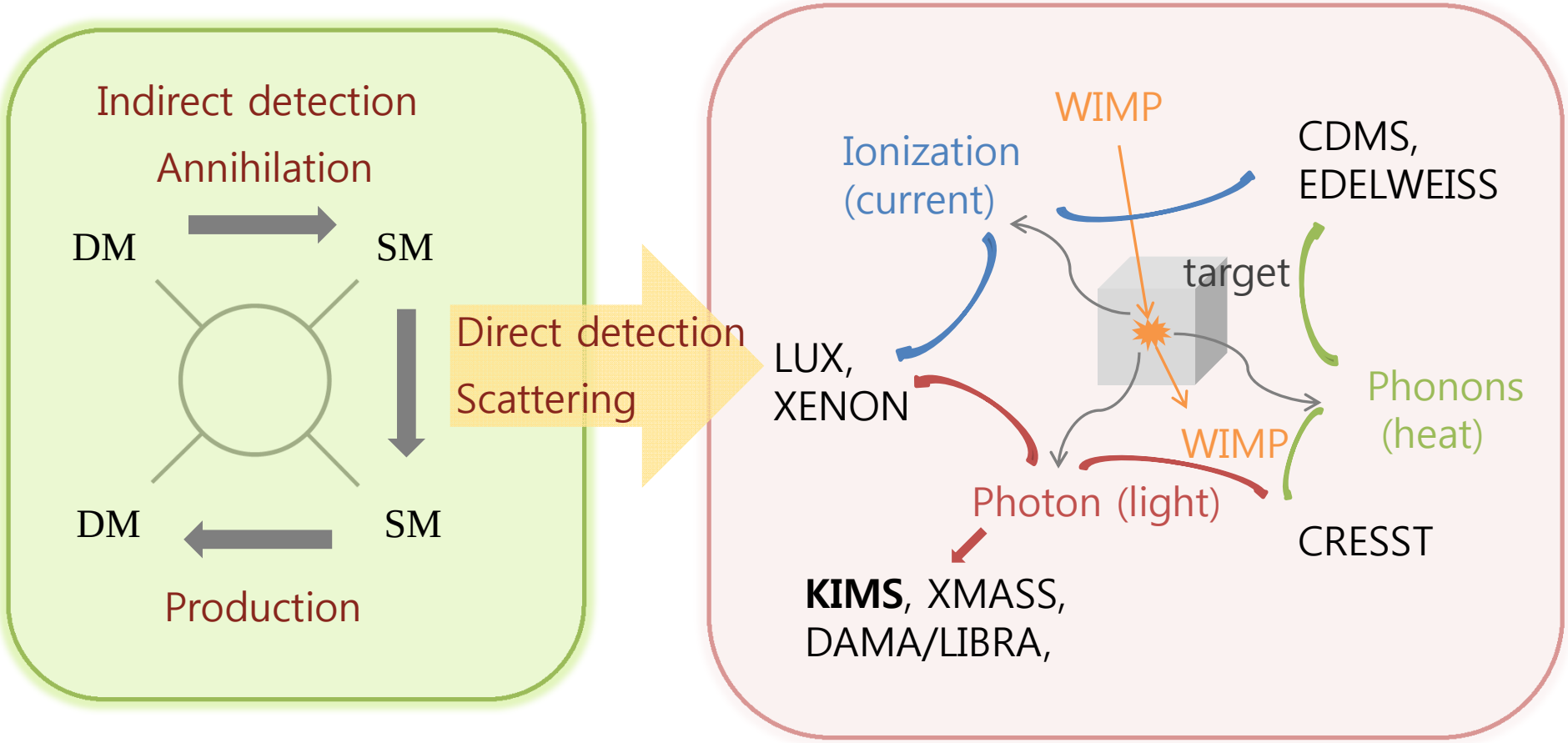
Center for Underground Physics (IBS),
Seoul National University

On behalf of the KIMS-NaI collaboration

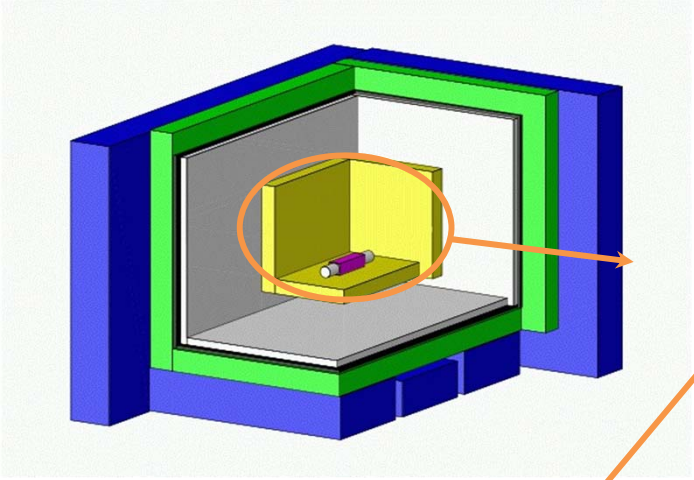
Searches for WIMP



KIMS experiment

@ Yangyang Underground Laboratory - Minimum depth: 700 m

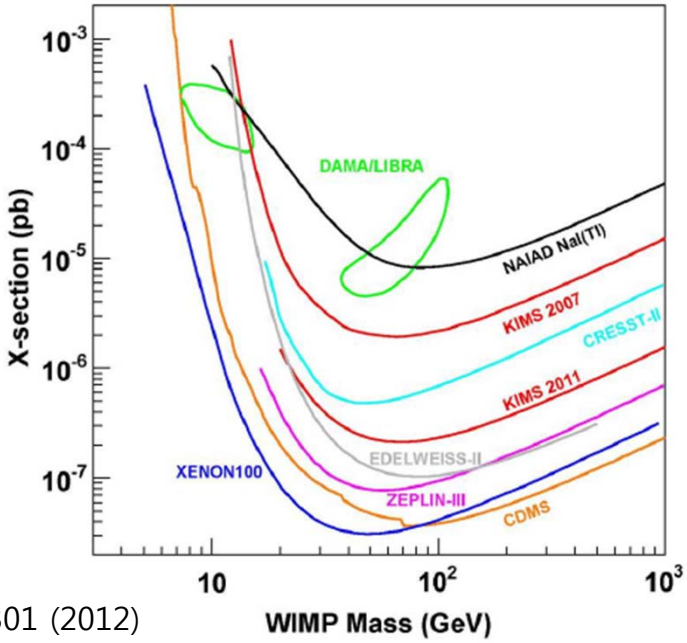
KIMS-CsI



4x3 CsI(Tl) crystals,
Total mass: 103 kg
Background level: 2 ~ 3 cpd/kg/keV
1 year of data (Sep.2009-Aug.2010)
published with PSD analysis

CsI(Tl) Crystal 8x8x30 cm3 (8.7 kg)

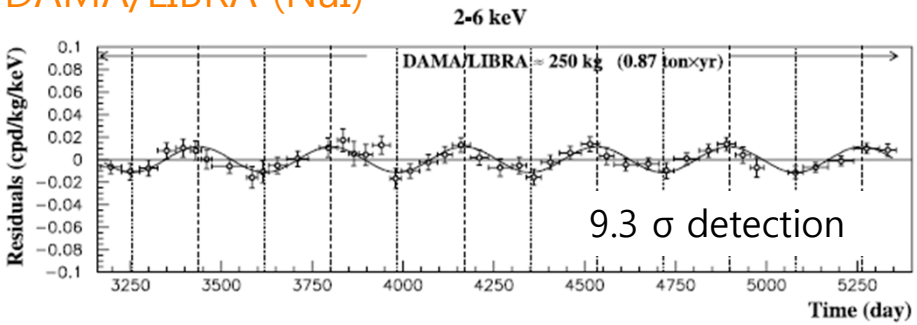
3” PMT (9269QA, Electron tube)



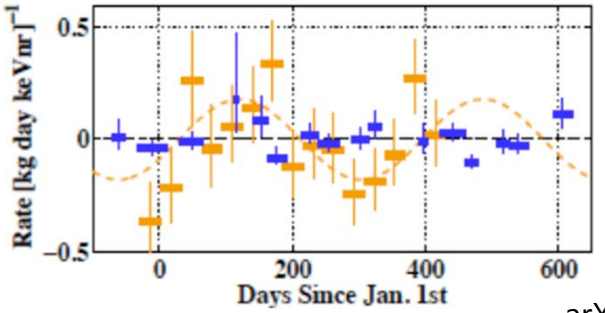
PRL. 108 181301 (2012)

Motivation of KIMS-NaI

DAMA/LIBRA (NaI)

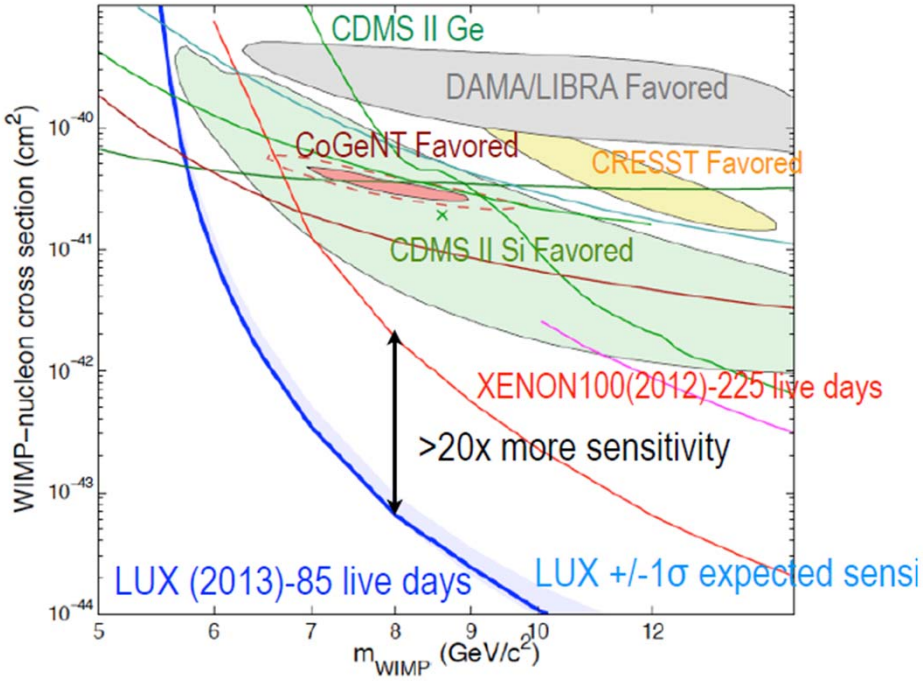


Eur. Phys. J. C 73:2648 (2013)

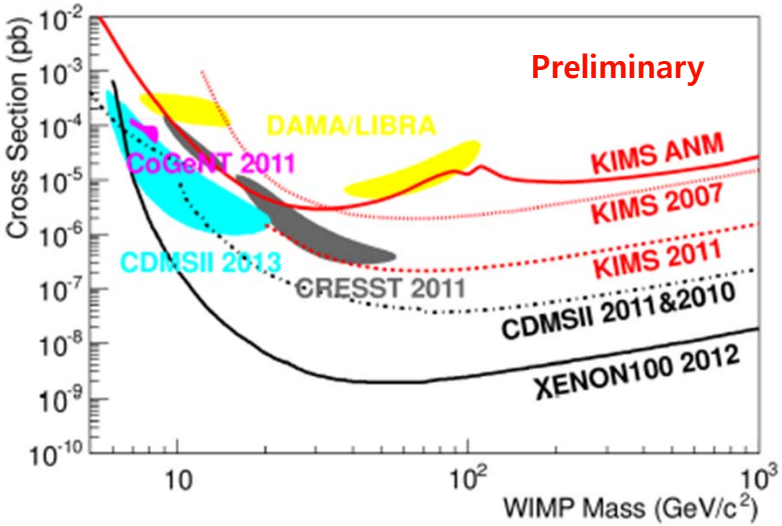


arXiv:1203.1309

LUX



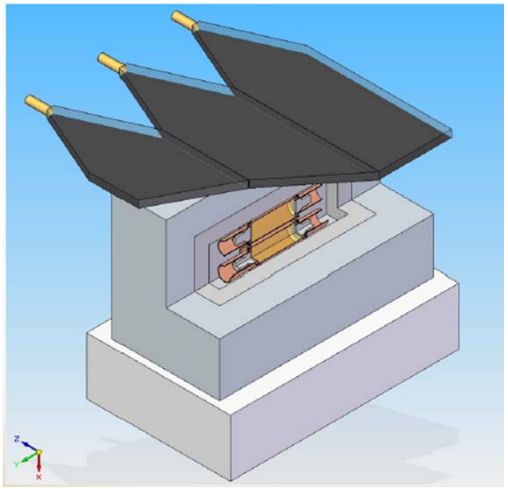
KIMS-CsI



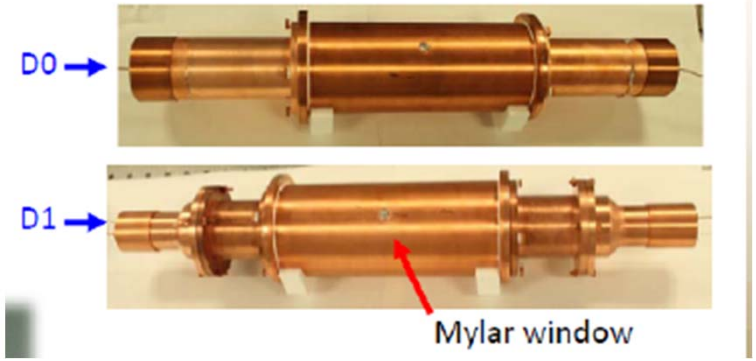
We want to confirm Na signal model independently.

Motivation of KIMS-NaI

ANAIS @ Canfranc (2000~)

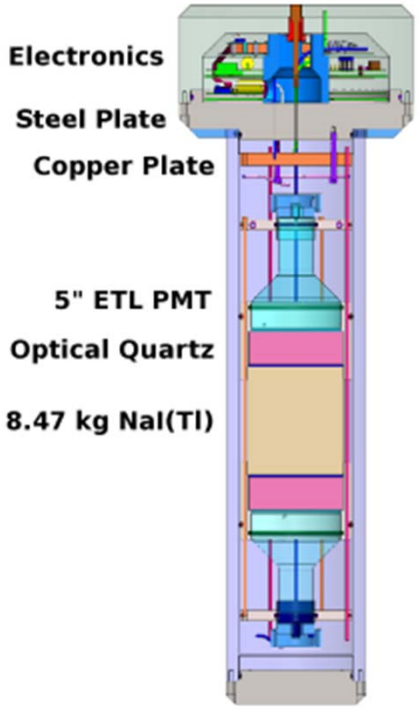


(2x) 8.5-kg NaI(Tl) modules



arxiv: 1308.3478

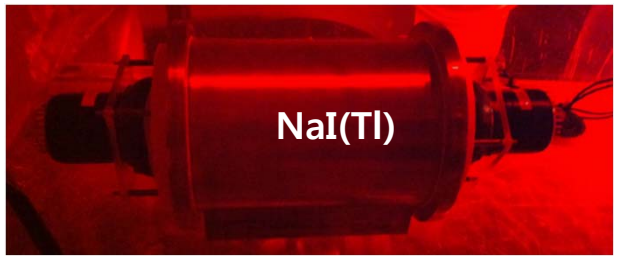
DM-ICE @ South pole (2011~)



arXiv:1401.4804

KIMS-NaI Detector

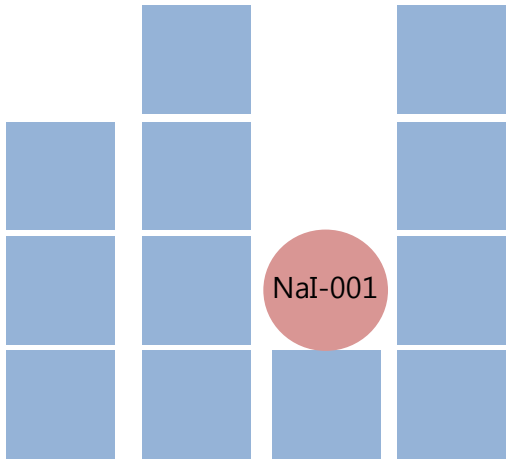
- Two NaI(Tl) crystals by Alpha Spectra company in US



NaI-001 (Aug. 2013)
5”(D) X 7”(L), 8.26 kg

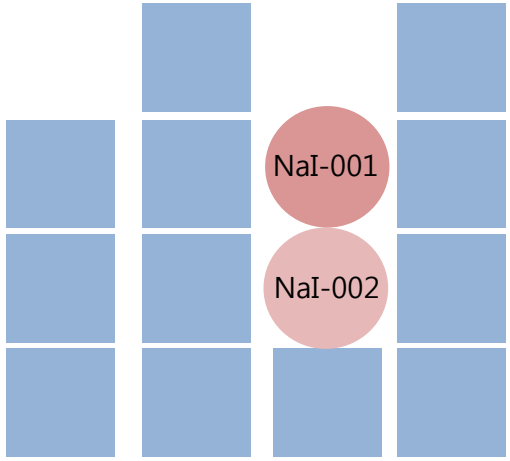
NaI-002 (Dec. 2013)
4.2”(D) X 11”(L), 9.2 kg

NaI-001 crystal only

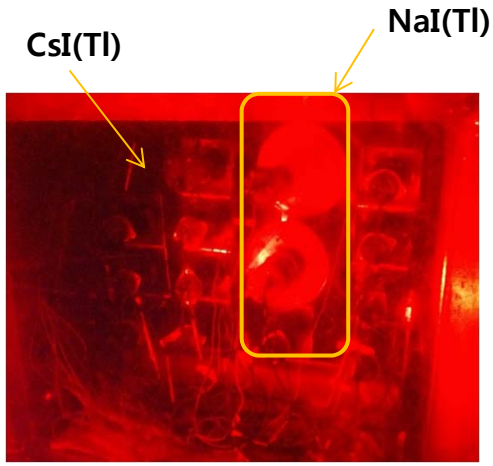


2013. 11. ~ 2014. 1.
~ 78 days data

NaI-001, NaI-002 installed



2014. 2. ~ 2014. 8.
~ 133 days data

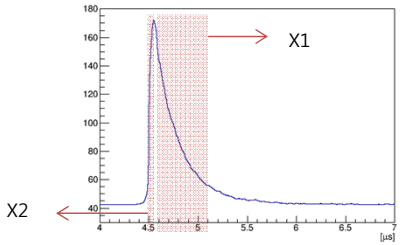


High Light yield ~ 15 p.e./keV

Background reduction

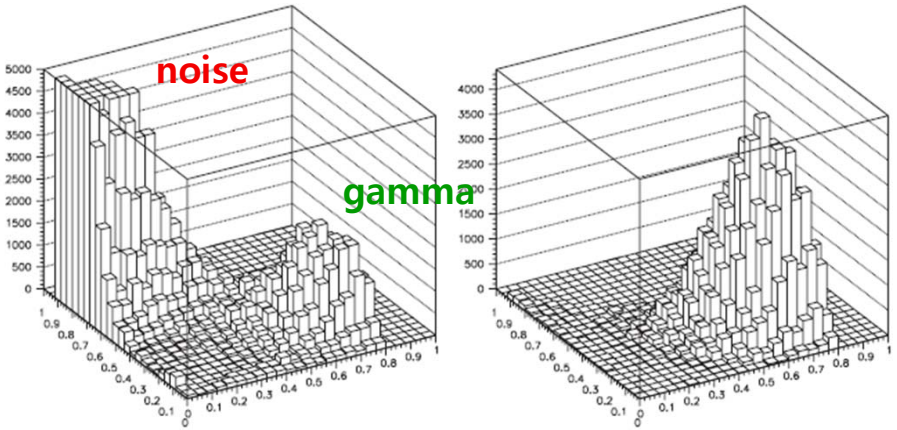
- Accidental fast events, small cluster events rejected.
- Reduction using same parameter as used in DAMA

x1: slow component
x2: fast component

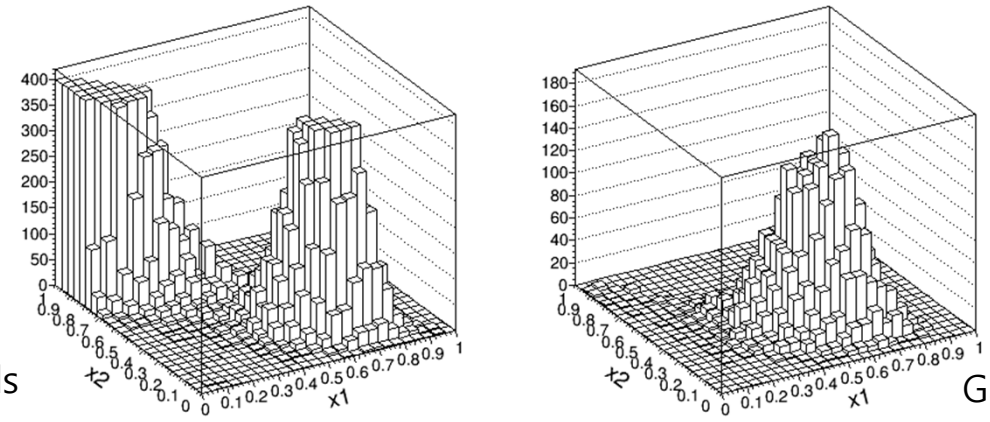


2 ≤ E < 4

DAMA



KIMS-NaI



Backgrounds

Gamma source

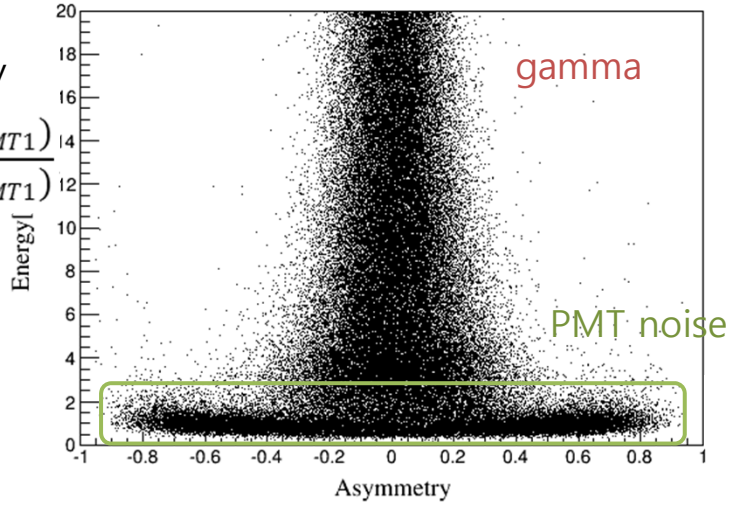
Same results with DAMA's PMT noise reduction

Background reduction

After DAMA cut applied

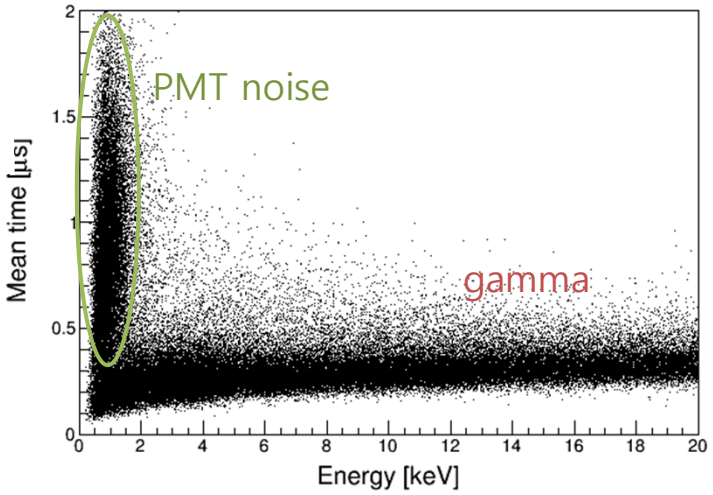
- Charge Asymmetry

$$Asymmetry = \frac{(Q_{PMT0} - Q_{PMT1})}{(Q_{PMT0} + Q_{PMT1})}$$

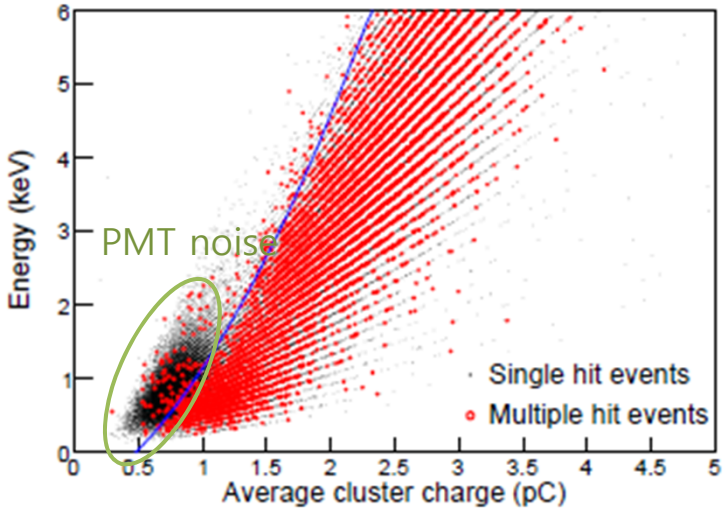


- Mean time

$$Mean\ time = \frac{\sum A_i \times t_i}{\sum t_i}$$



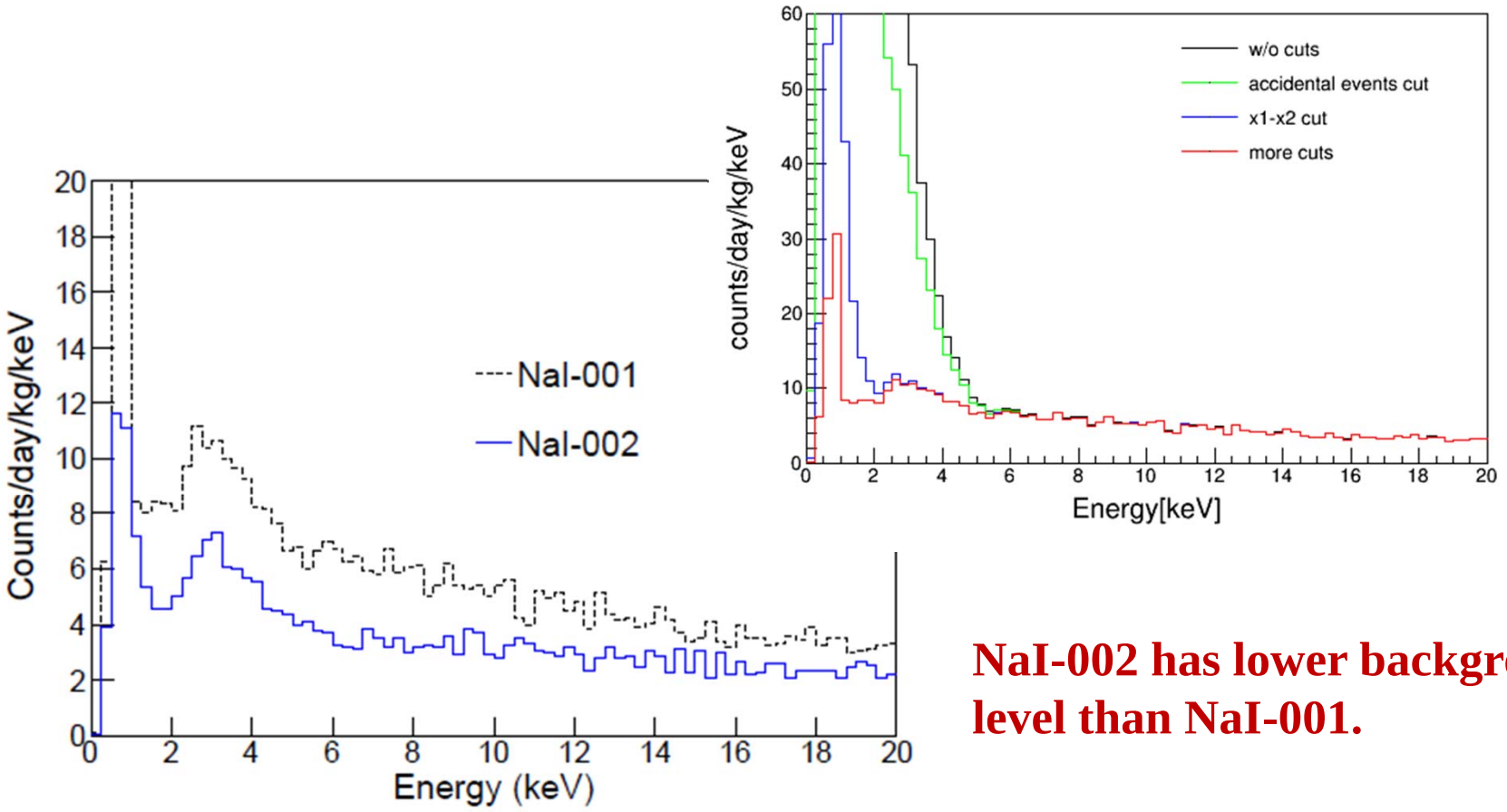
- Average cluster charge



Even after DAMA cut, we still have PMT noise.

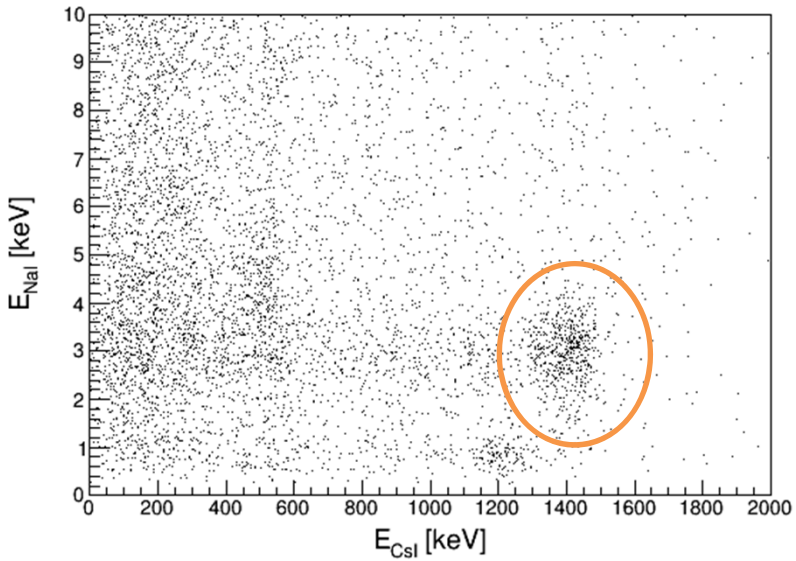
Low Energy Spectrum

We can reject remained PMT noise after several cuts are applied.

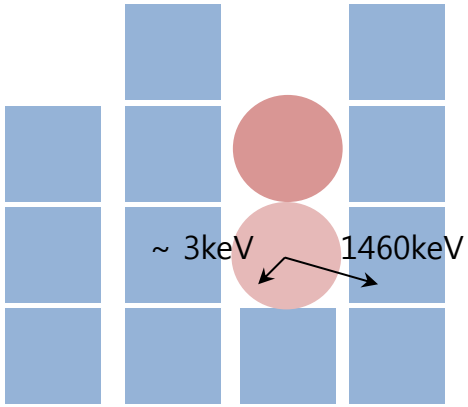


NaI-002 has lower background level than NaI-001.

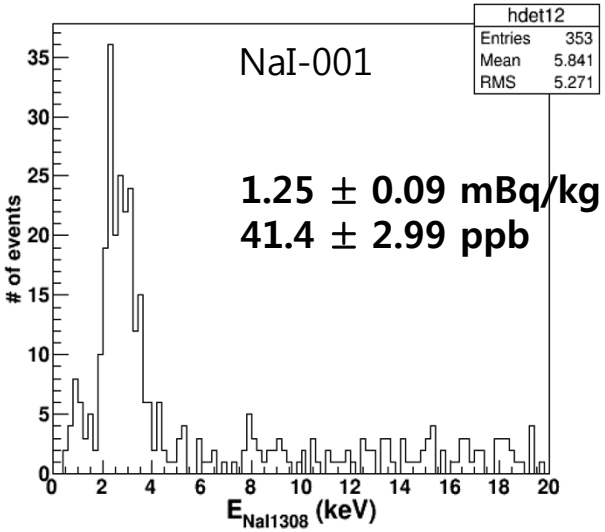
Internal background – ^{40}K

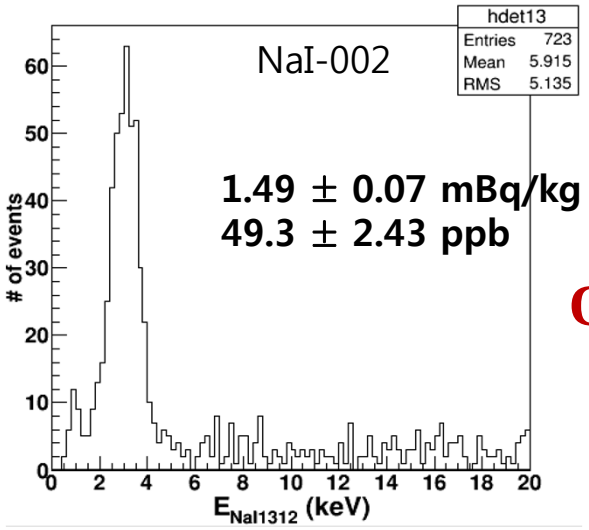


Measured by coincidence with CsI detectors



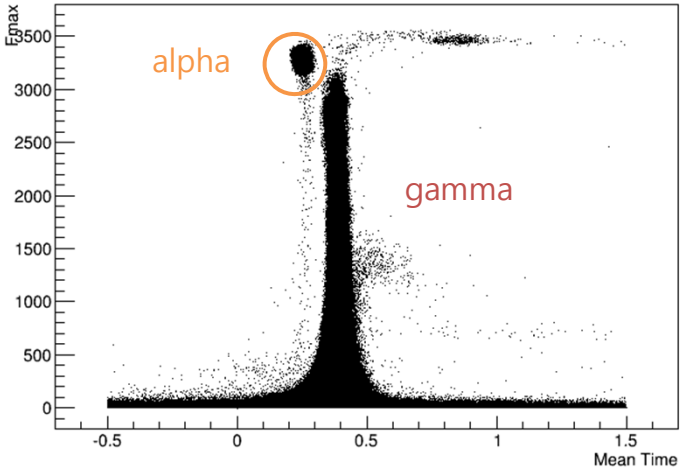
Based on GEANT-4 simulation



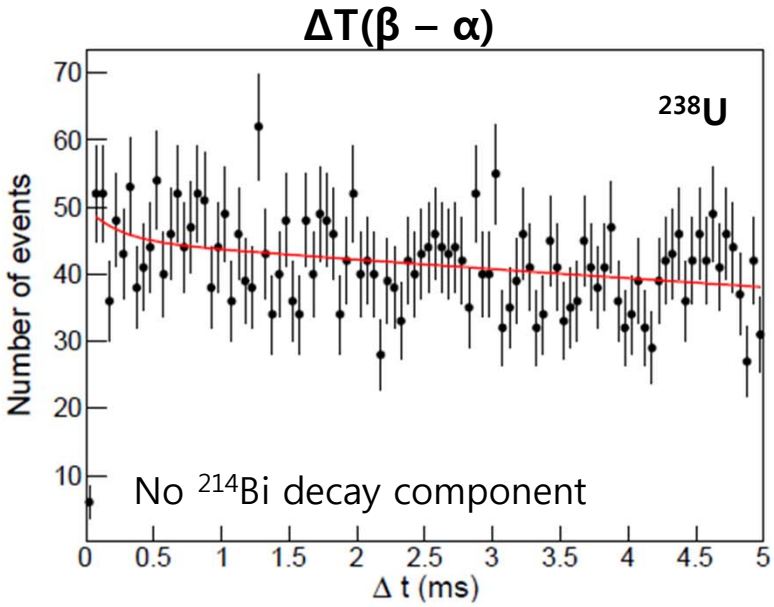


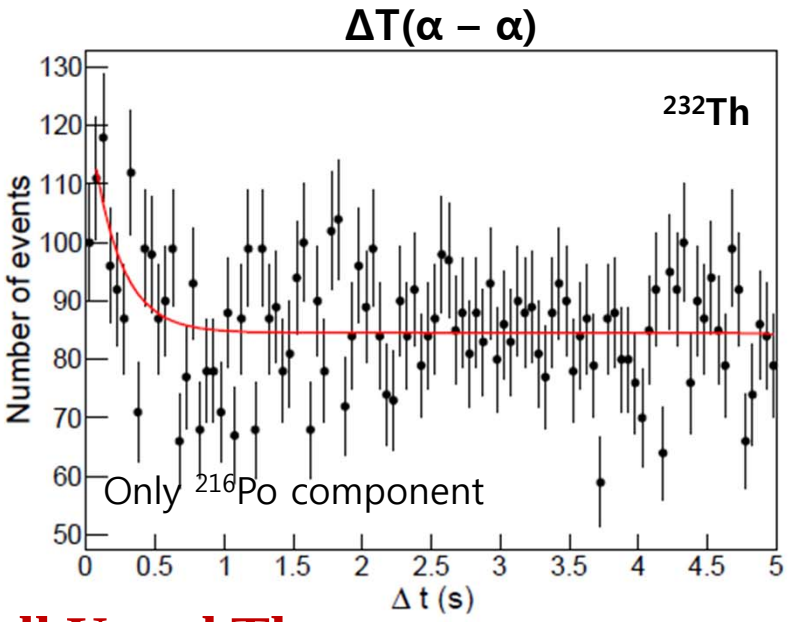
Our goal; < 10ppb.

Internal background – ^{238}U, ^{232}Th, ^{210}Pb



Radionuclei	NaI-001 [mBq/kg]	NaI-002 [mBq/kg]
^{238}U (^{214}Bi)	<0.0003	<0.0015
^{228}Th (^{216}Po)	<0.013	0.002±0.001
^{40}K	1.25±0.09	1.49±0.07
^{210}Pb	3.28±0.01	1.76±0.01
Total alphas	3.29±0.01	1.77±0.01

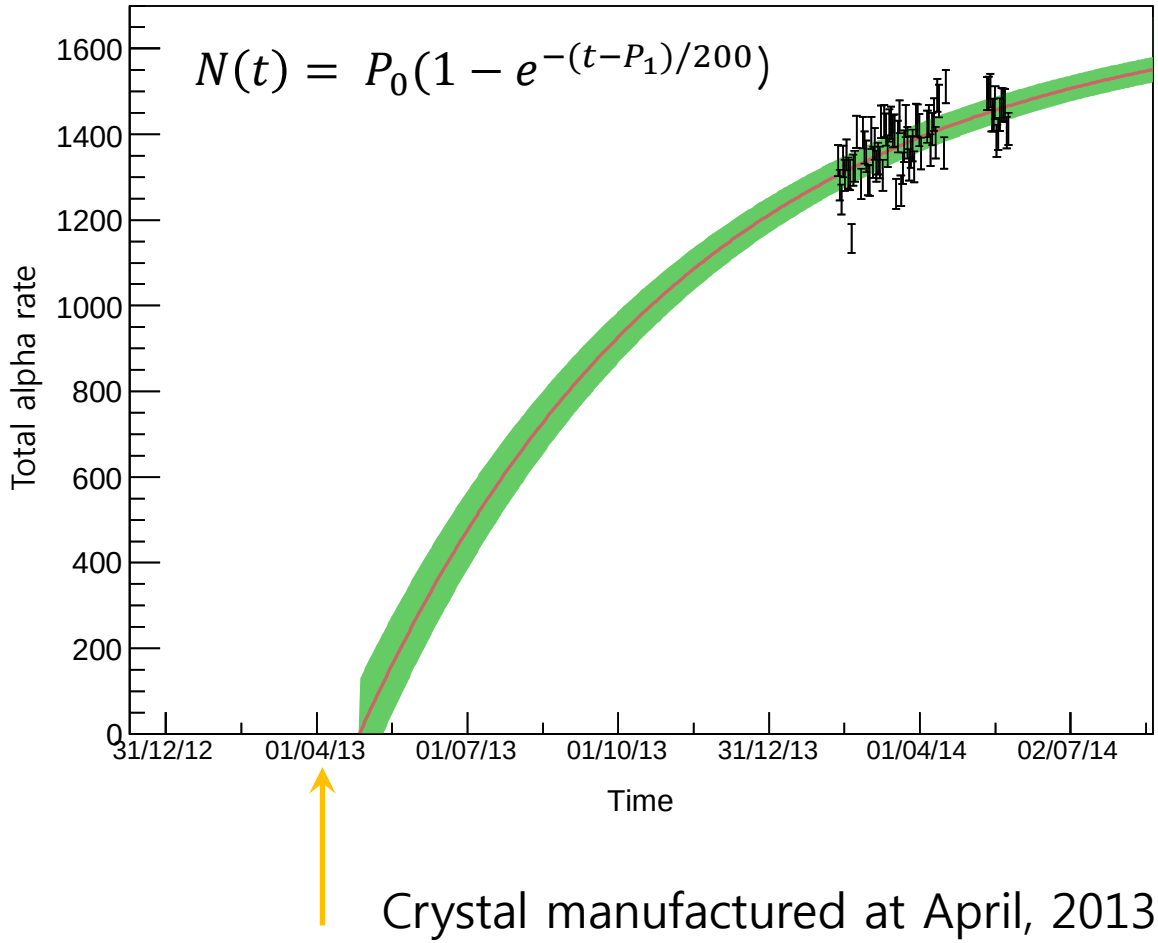




We have small U and Th.

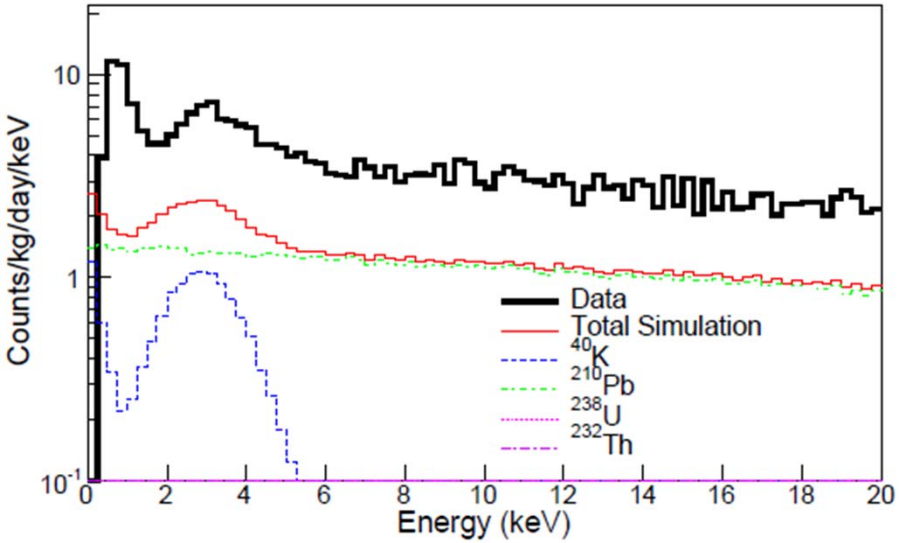
Confirmation of Rn contamination

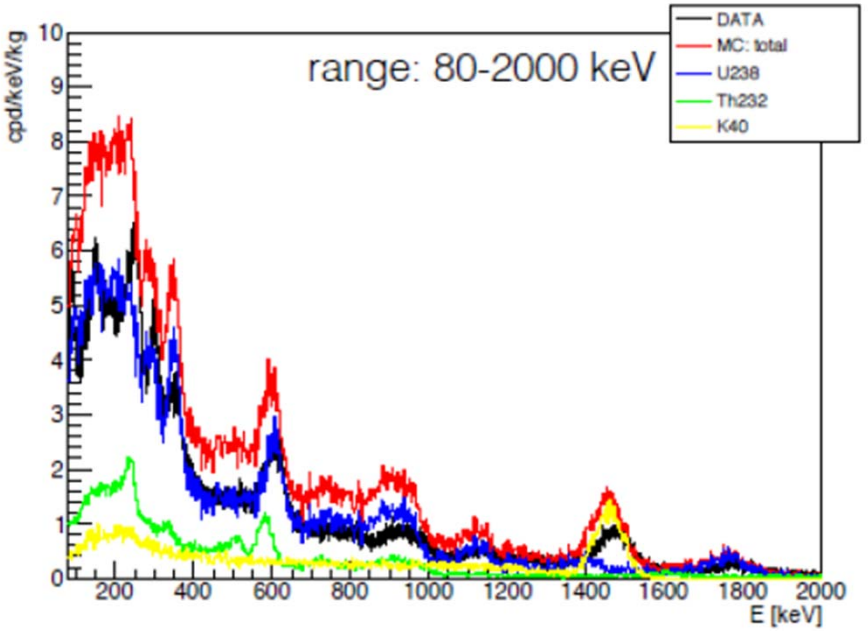
^{210}Pb is due to Rn contamination when crystal was grown.
We can estimate crystal manufactured date using alpha rate change.



Internal background – simulation

Background simulations of ^{40}K, ^{210}Pb, ^{238}U and ^{232}Th (full chain)

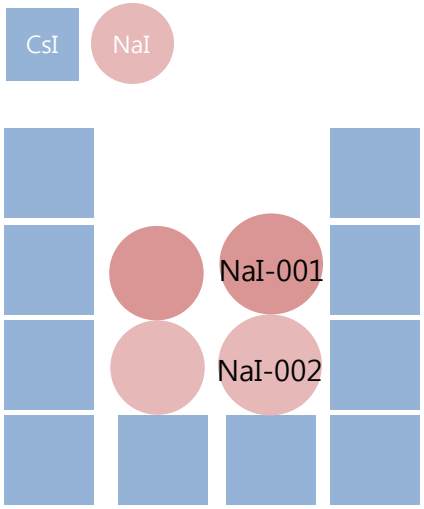




Significant internal backgrounds at low energy are ^{40}K, ^{210}Pb.
Other backgrounds (including PMT) are under study.

New crystals test

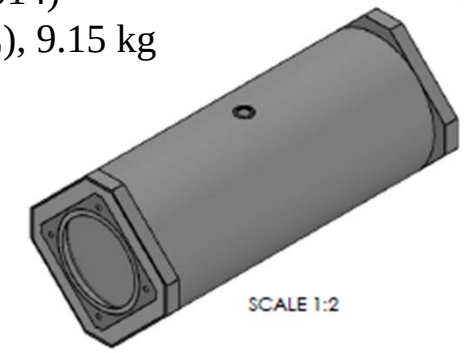
More crystals were tested to get low background crystal.

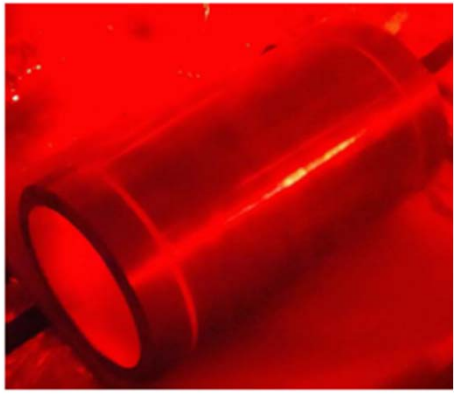


NaI003 (Aug. 2014)
4.5”(D) X 3.5”(L), 3.3 kg
Astro Grade powder

NaI004 (Aug. 2014)
4.5”(D) X 3.5”(L), 3.3 kg
Crystal Grade powder

NaI005 (Nov. 2014)
4.5”(D) X 11”(L), 9.15 kg
WIMP Scint Ⅱ



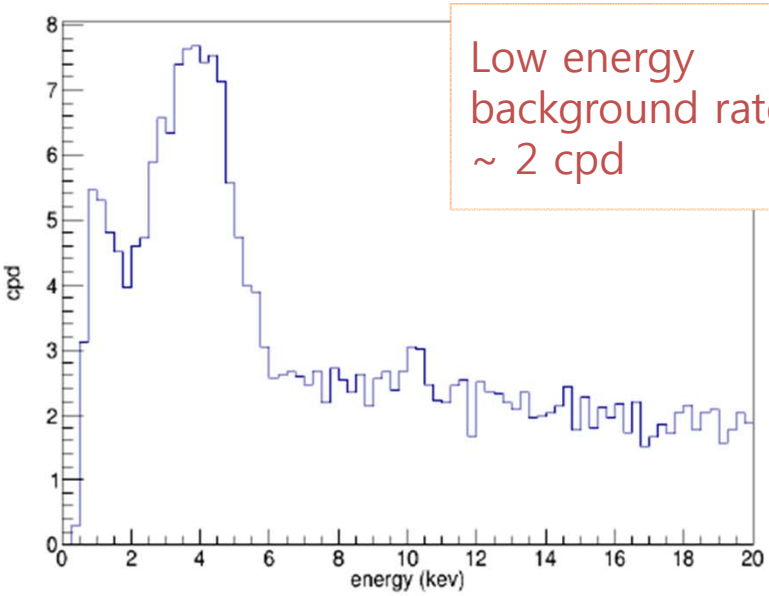


NaI006 (Jan. 2015)
110mm(D)X200mm(L),
~10kg, Crystal Grade

New crystals test

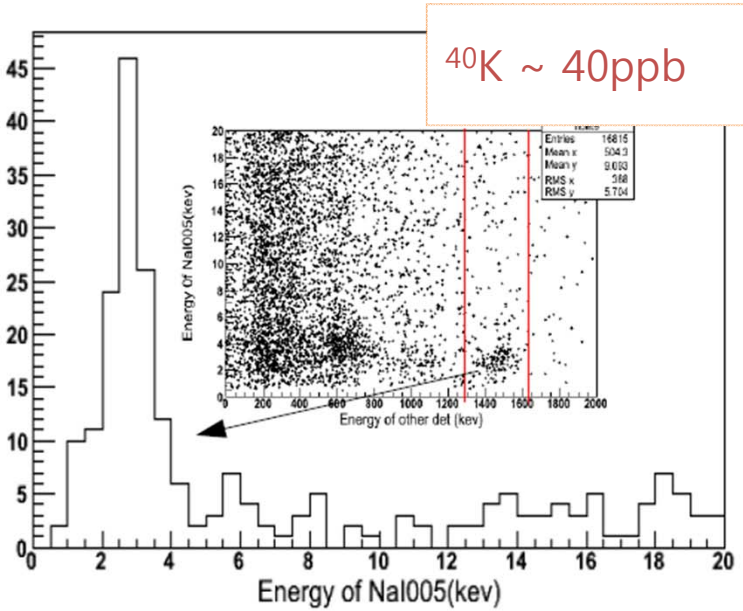
Name	Mass (kg)	Powder	Crystal	^{210}Pb (mBq/kg)	^{40}K (ppb)
NaI001	8.26	AS	Alpha spectra	3.29	41.4
NaI002	9.15	AS	Alpha spectra	1.77	49.3
NaI003	3.3	AS Astro grade	Alpha spectra	~2	25.12
NaI004	3.3	AS Crystal grade	Alpha spectra		115.25
NaI005	9.15	AS WIMP Scint II	Alpha spectra	0.44	40.13
NaI006	~ 10	SA Crystal grade	Beijing Hamamatsu		

New crystals test – NaI005

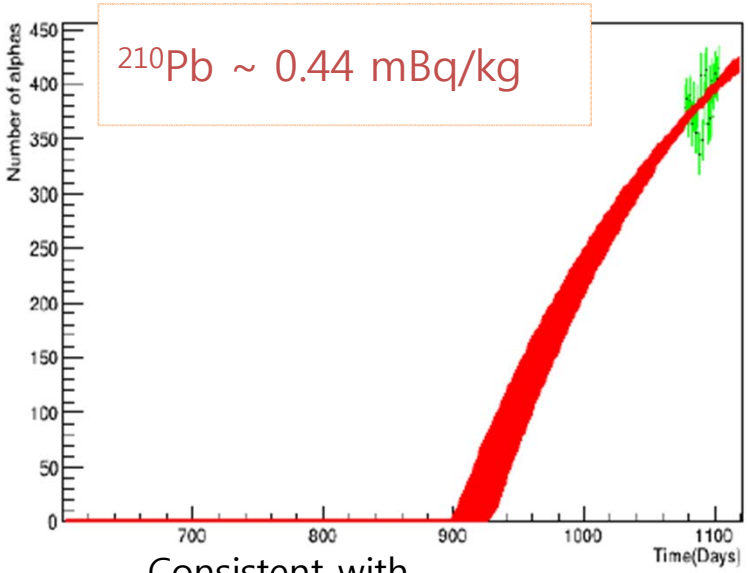


Low energy background rate ~ 2 cpd

NaI005 has low background and ^{210}Pb level.



^{40}K ~ 40ppb



^{210}Pb ~ 0.44 mBq/kg

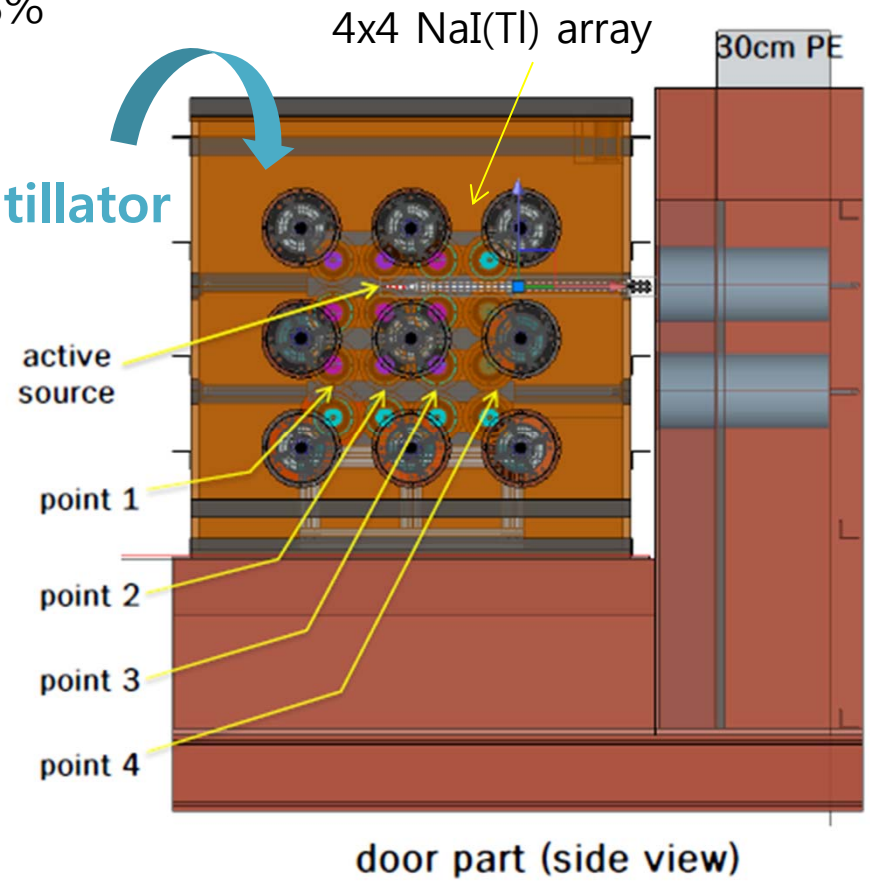
Consistent with crystal growing time

Liquid Scintillator veto system

- Veto efficiency in the low energy region of (0, 10 keV)
  (Based on Geant-4 simulation)

  ^{40}K: ~ 27%
  ^{232}Th: ~75%
  ^{238}U: ~78%

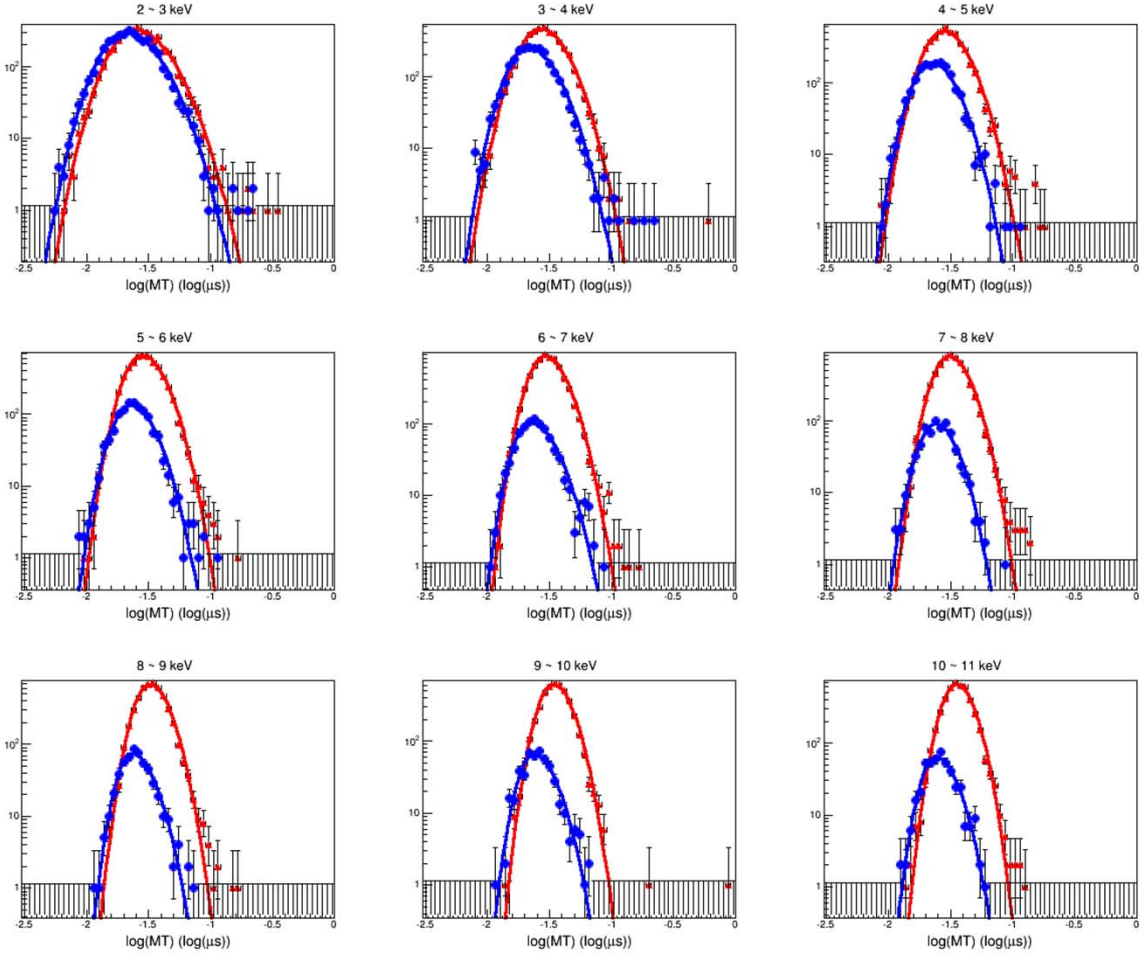
Liquid Scintillator



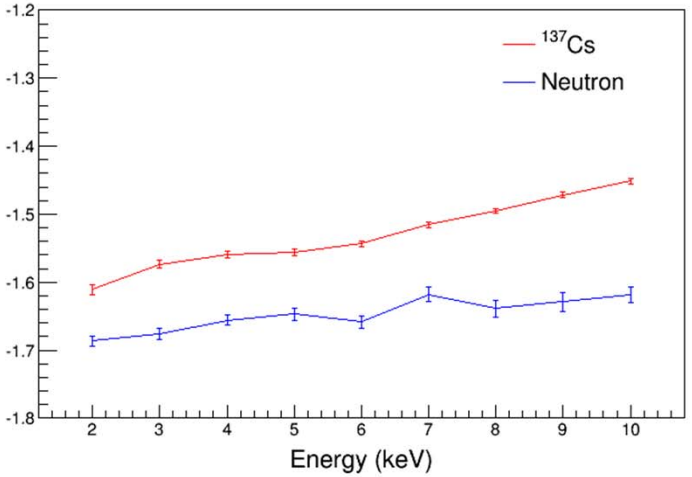
Various backgrounds can be reduced by liquid scintillator veto system.

PSD analysis of first crystal

neutron – nuclear recoil
gamma – electron recoil

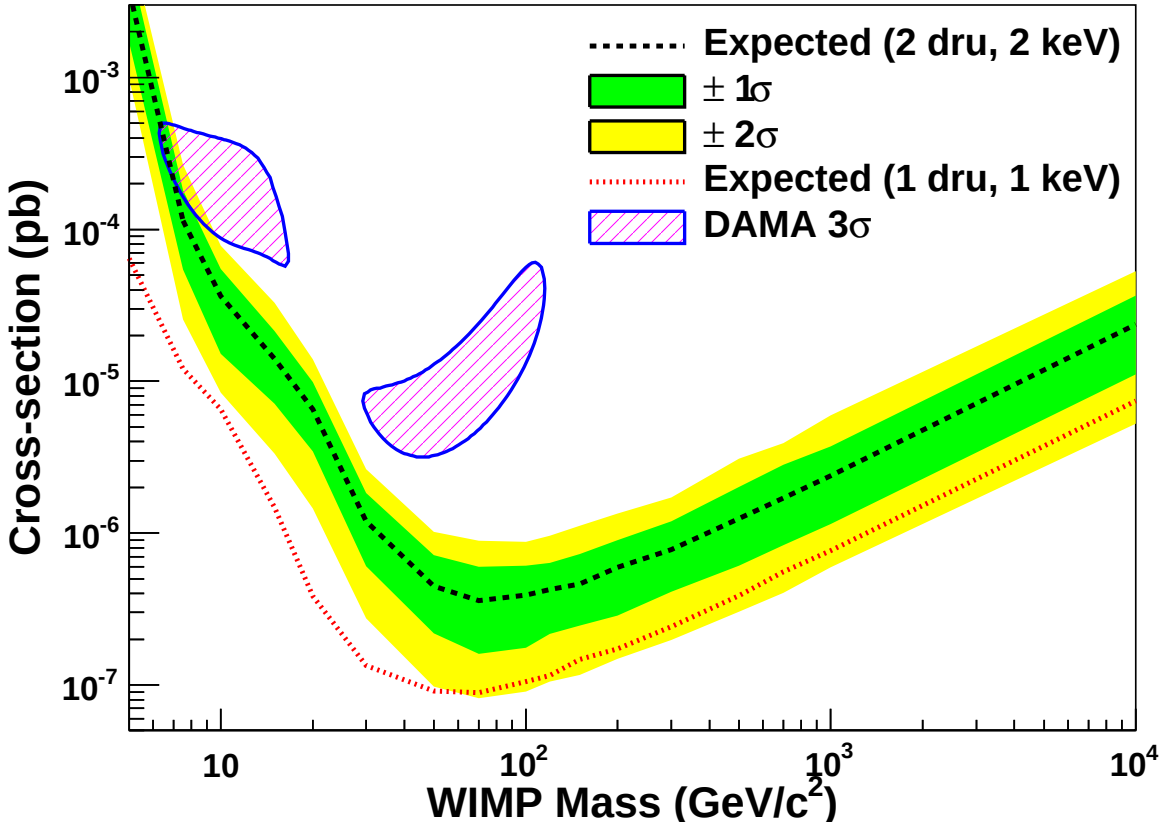


- A 300mCi Am/Be neutron source
- Small test crystal (same ingot with NaI001)



PSD analysis of first crystal

Expected limit using PSD – 100 kg, 1 year of data taking



Summary

- KIMS-NaI has been taking data with two NaI(Tl) crystals.
  - High light yield: ~ 15 photoelectrons/keV

- We have confirmed PMT noise reduction by “DAMA cut”
  - Observed additional PMT noise which was not removed by "DAMA cut”.

- Internal backgrounds from U, Th, Pb, K are studied.

- More NaI(Tl) crystals are installed and test is ongoing.

- NaI005 which is processed with new method has low background level. (2 cpd @ 6 keV, ^{210}Pb ~ 0.5mBq/kg)

- PSD analysis of first crystal is under study.

Prospects

Goal:

- Background level < 0.5 counts/day/kg/keV
- Threshold ~ 1 keV.

- Ultra-Pure crystals (internal backgrounds)
  – Mass production will be started within a year.

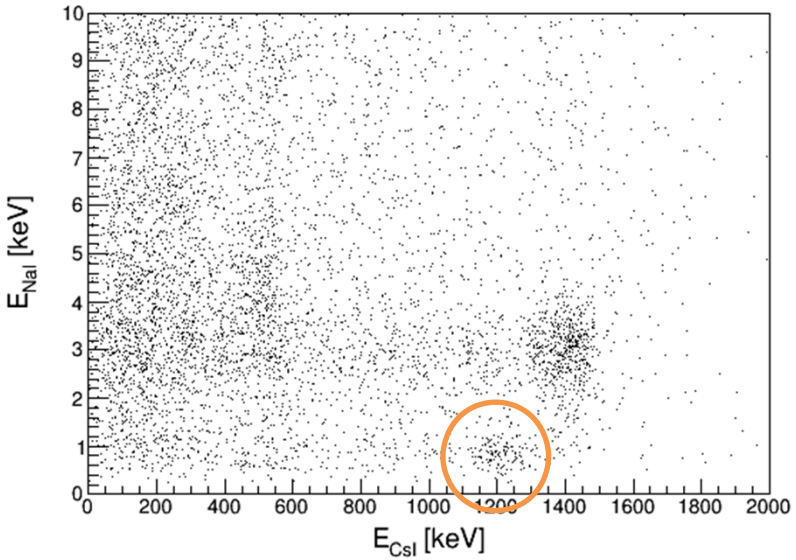
- Low background PMTs (external backgrounds)
  – Low background PMT from Hamamatsu
  – Decision of PMTs will be done within a year.

- Shielding design (external backgrounds)
  – LS veto system (prototype) will be setup soon.

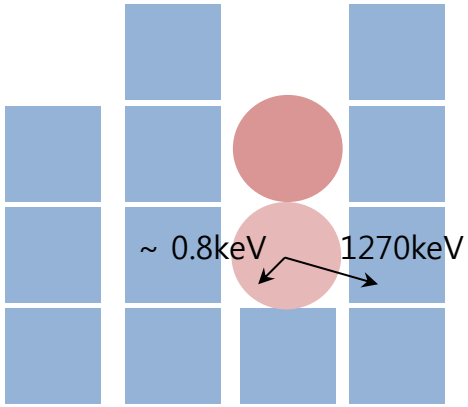
- We plan to run 100 kg from early of next year.

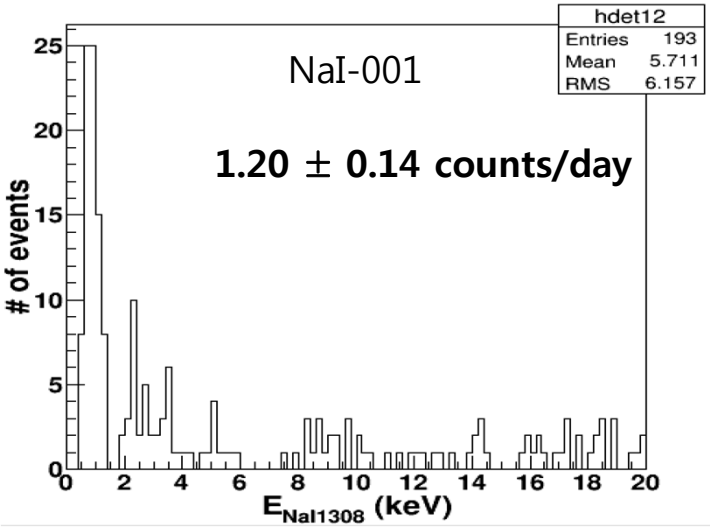
Backup Slides

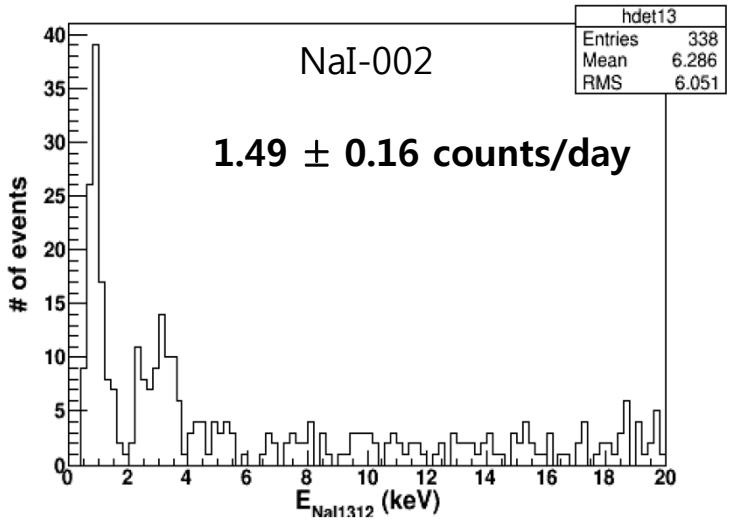
Background – Cosmic excitation: ^{22}Na



Measured by coincidence with CsI detectors







This can be used to study 1 keV energy signal.