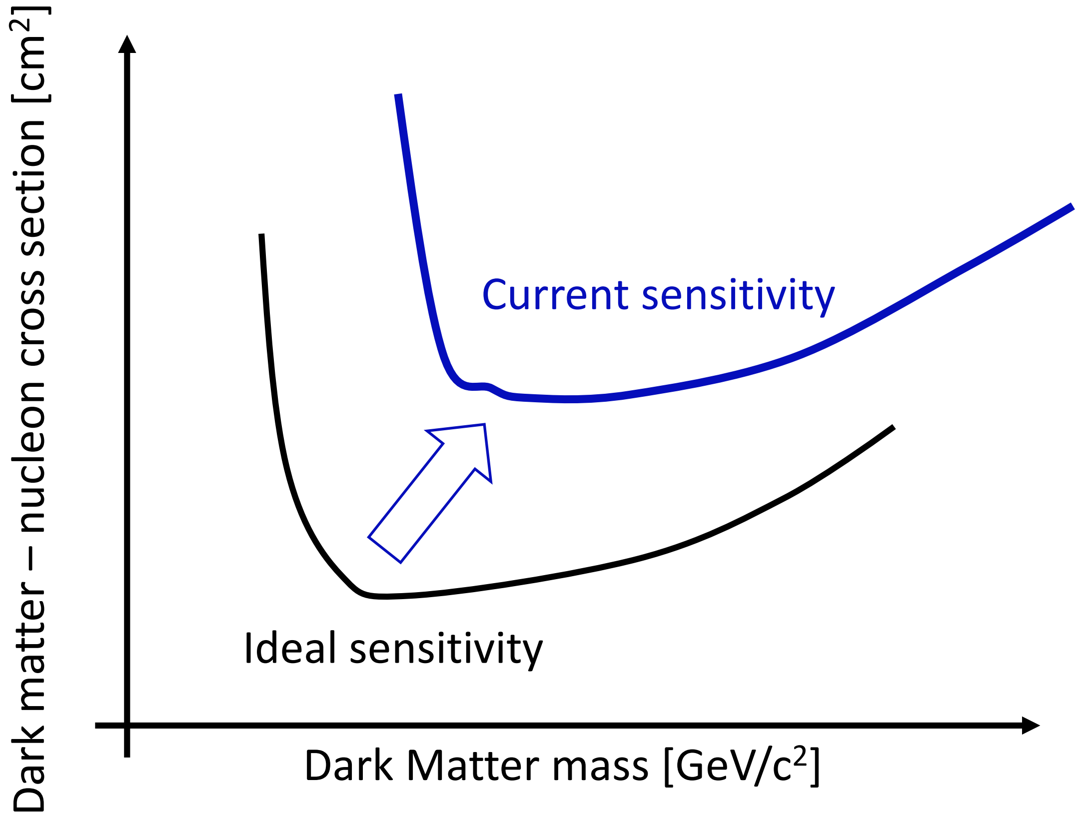
Plan and discussion for data analysis and calibration study

Tatsuhiro NAKA

Nagoya University

2018. 5. 28-29. NEWSdm collaboration system @ Capri, Italy

How do we analysis the dark matter sensitivity ?



- ☐ Background level
- ☐ Signal detection efficiency

Not enough !!!

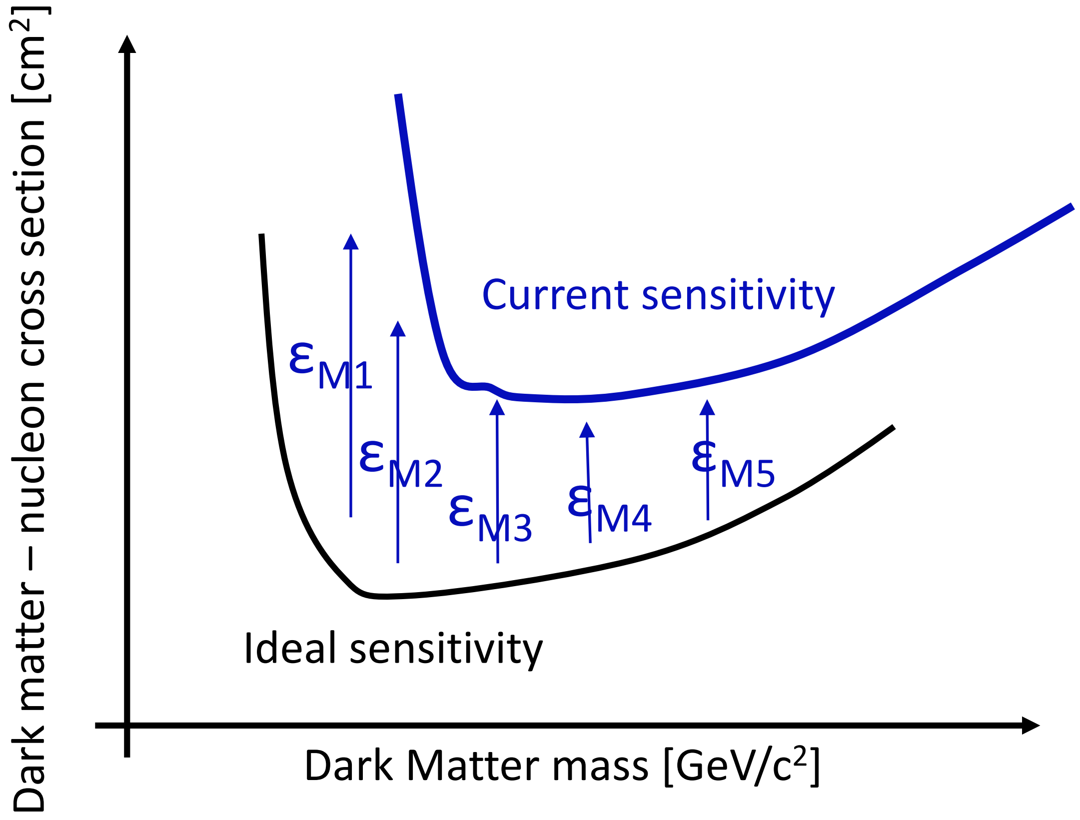
Methodology

1. Making of ideal distribution for output parameter
 (e.g., elliptical parameter)

2. Comparison between ideal and real distribution
 ⇒ Definition of efficiency

3. Apply the efficiency to expected dark matter spectrum (to each dark matter mass)

How do we analysis the dark matter sensitivity ?



Realistic sensitivity taken into account current detection performance to the standard dark matter scenario.

*** Surely, we can discuss about another dark matter model**

In conclusion, understanding of detection performance is essentially important.

Calibration

- ➢ Recoil nuclei signal
  - ion-implant system
  - neutron source
- ➢ electron signal
  - gamma-ray induced electrons
  - beta-ray source
- ➢ Underground calibration system

Same condition with dark matter run

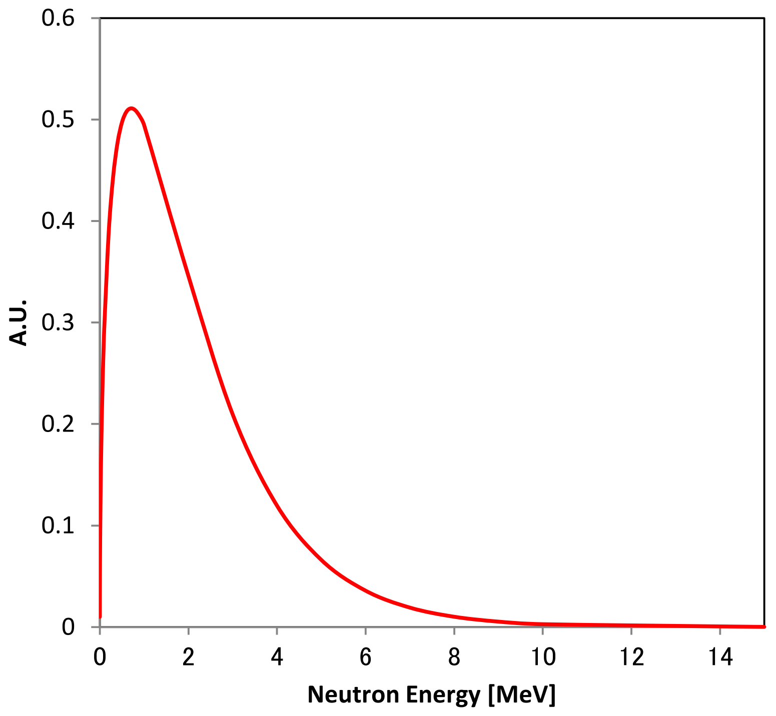
- ✓ temperature
- ✓ emulsion film structure and treatment
- ✓ scanning analysis

1. Recoil nuclei calibration

	Advantage	Disadvantage
Ion-implant system	➢ Monochromatic energy ➢ Directly detection of low-velocity ion [10 – 200 keV for Nagoya's machine] ➢ Uniform direction	✓ Not-realistic environment [high vacuum condition (~ 1E-6 torr) ✓ Thin film ✓ Signal on only surface
	Neutron source	
Cf neutron source	➢ Easy to use because of radioactive source ➢ Possible energy to make expected CNO recoil	✓ Broad energy spectrum ✓ Gamma-ray emission (sometime advantage for discussion of γ/n separation) ✓ Not so high intensity
Neutron emission due to nuclear fission reaction	➢ Mono-energy neutron ➢ Mostly point-like source ➢ High intensity	✓ Need to get the machine time (not flexible) ✓ Not so many experiment site

Cf-252 source

Calculated neutron energy spectrum

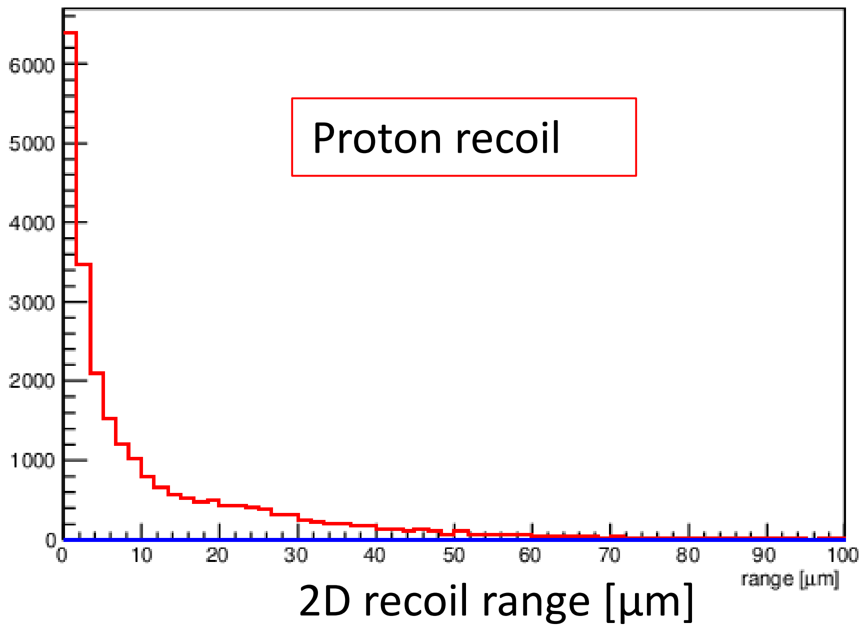


En = sqrt(E)xExp(-E/T)

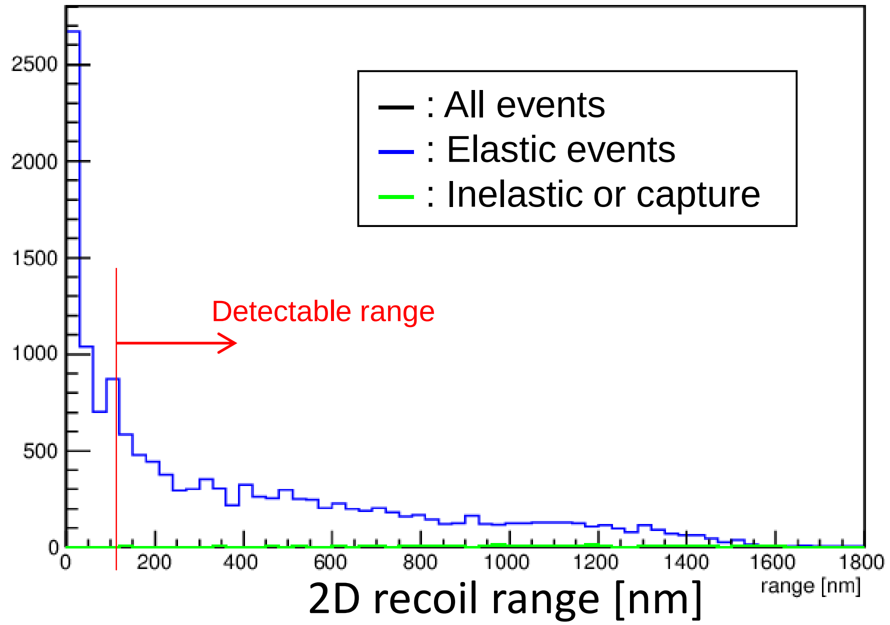
where T is 1.42 MeV

Paulo R.P. COELHO, Aucyone A. DA SILVA and Jose R. MAIORINO
Nucl. Inst. Meth. A 280 (1989) 270-272

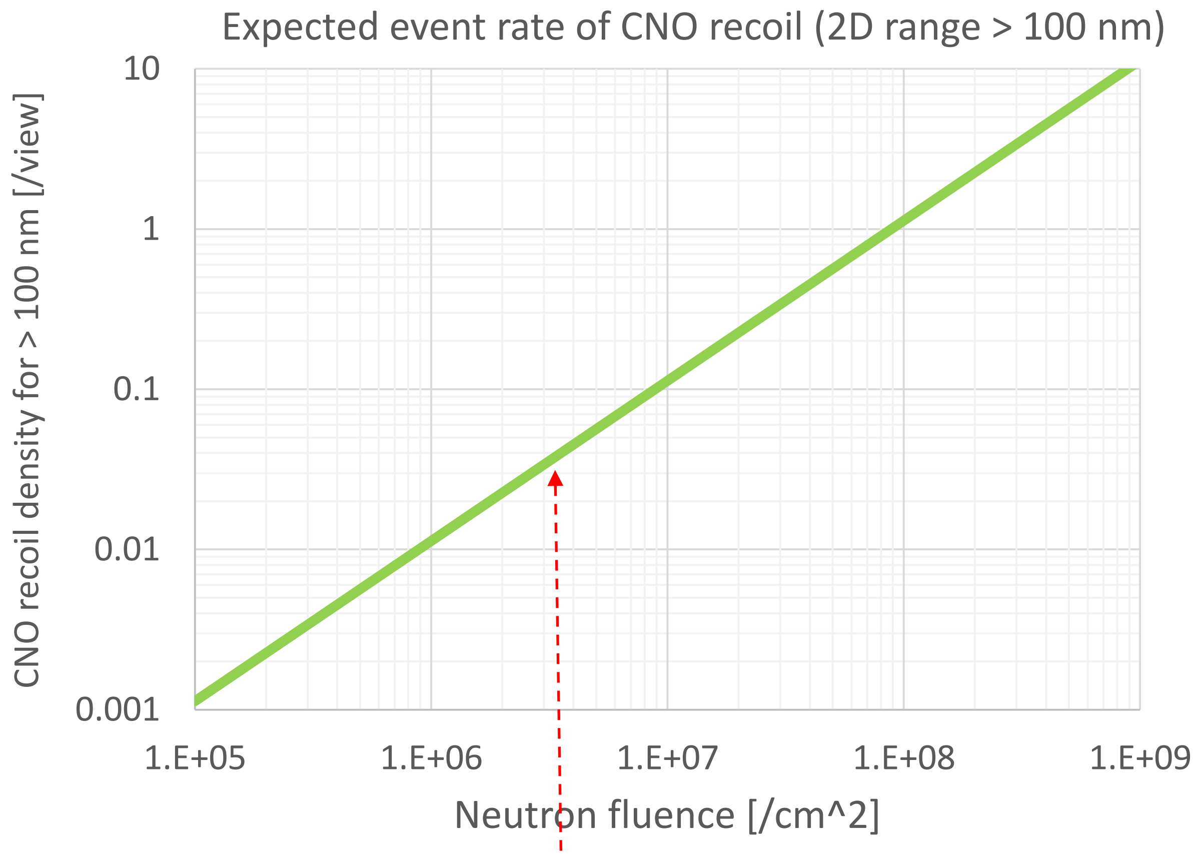
Elastic scattering Proton recoil range

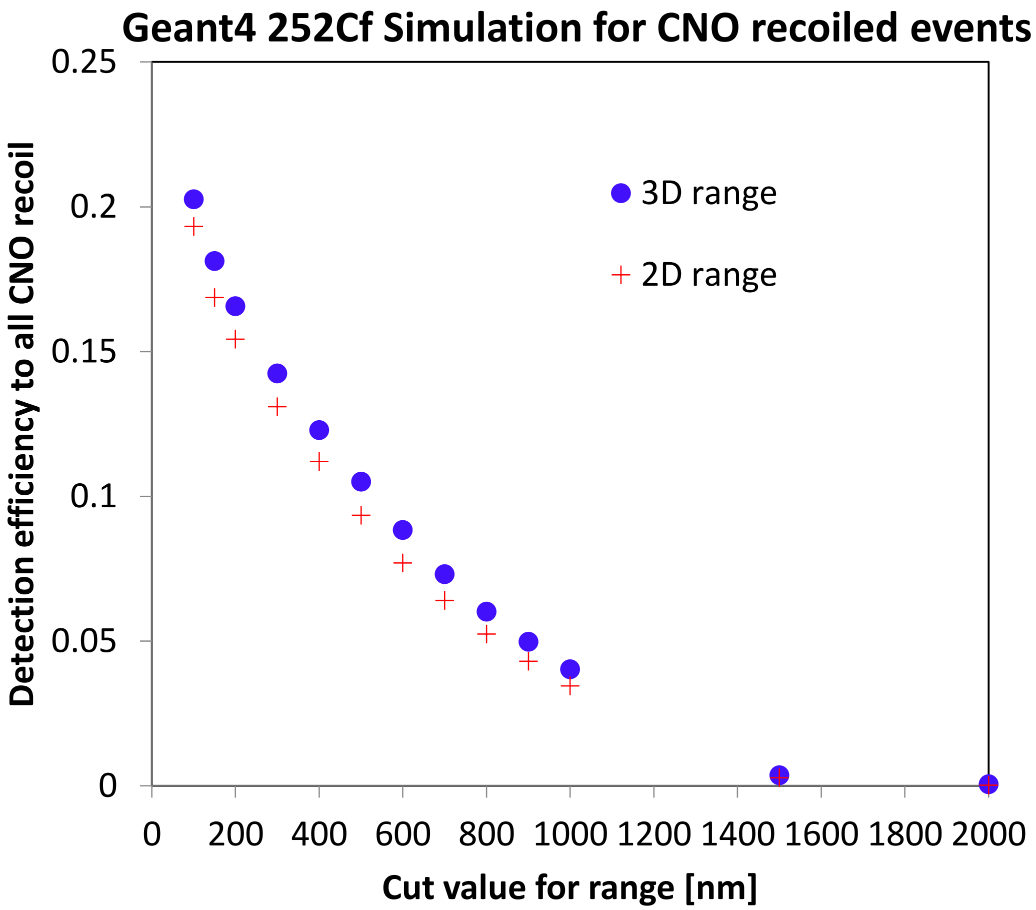


Elastic scattering CNO 2D recoil range



Expected event rate for case of Cf-252





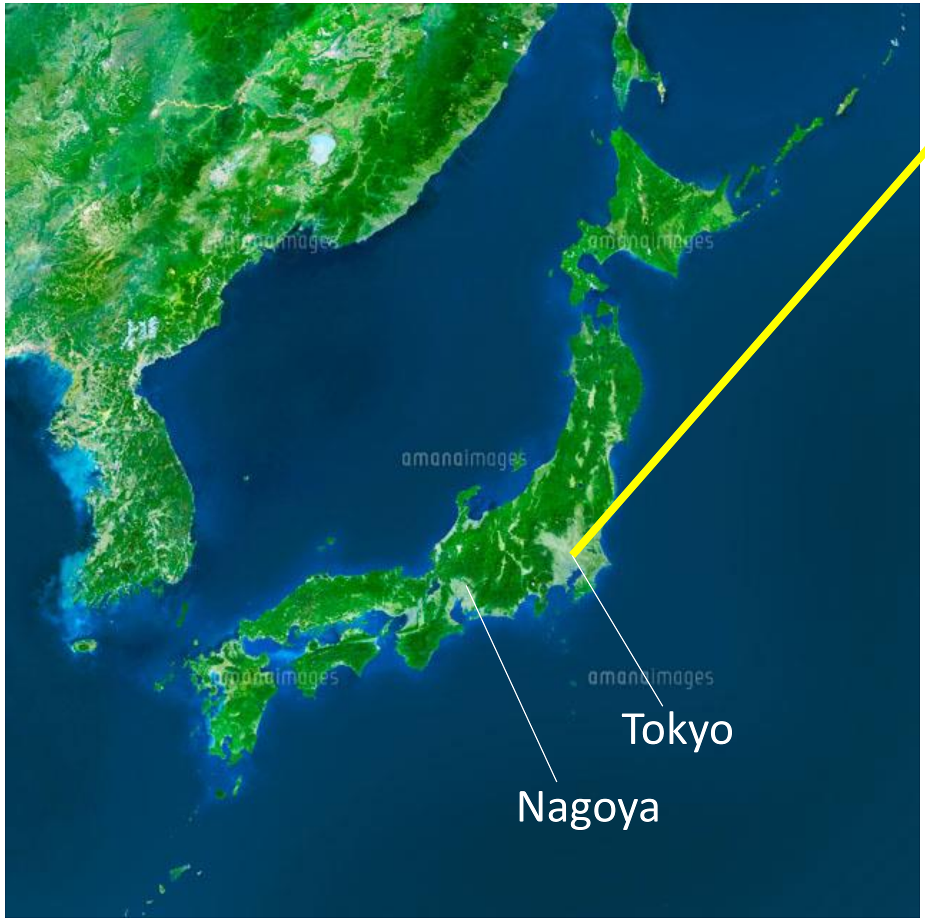
Ex) 1 x 10^3 /cm^2/sec and 1 hour exposure
⇒ neutron fluence : 3.6E+6 /cm2

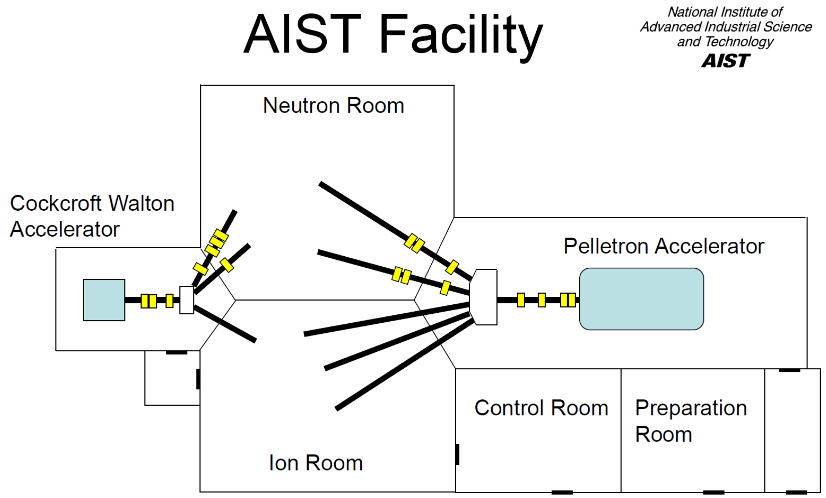
+ γ-ray emission

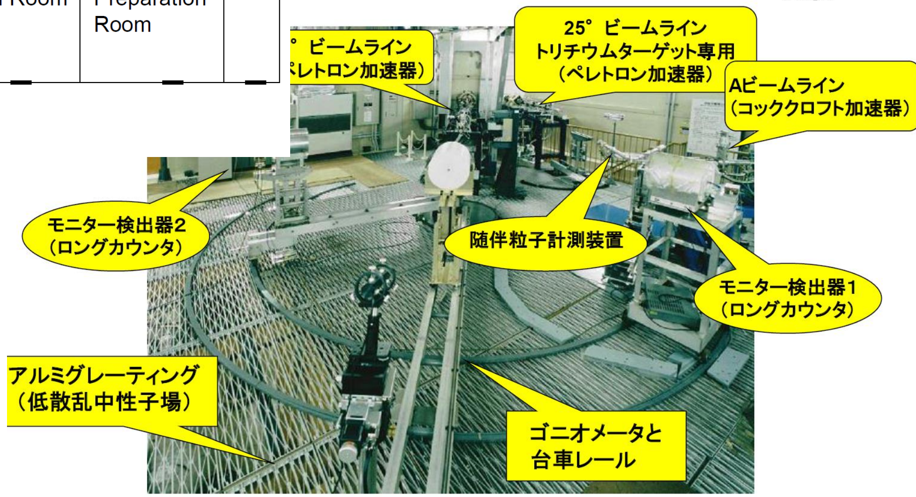
0.958 , 0.858, 0.0179 MeV

National Institute of Advanced Industrial Science and Technology

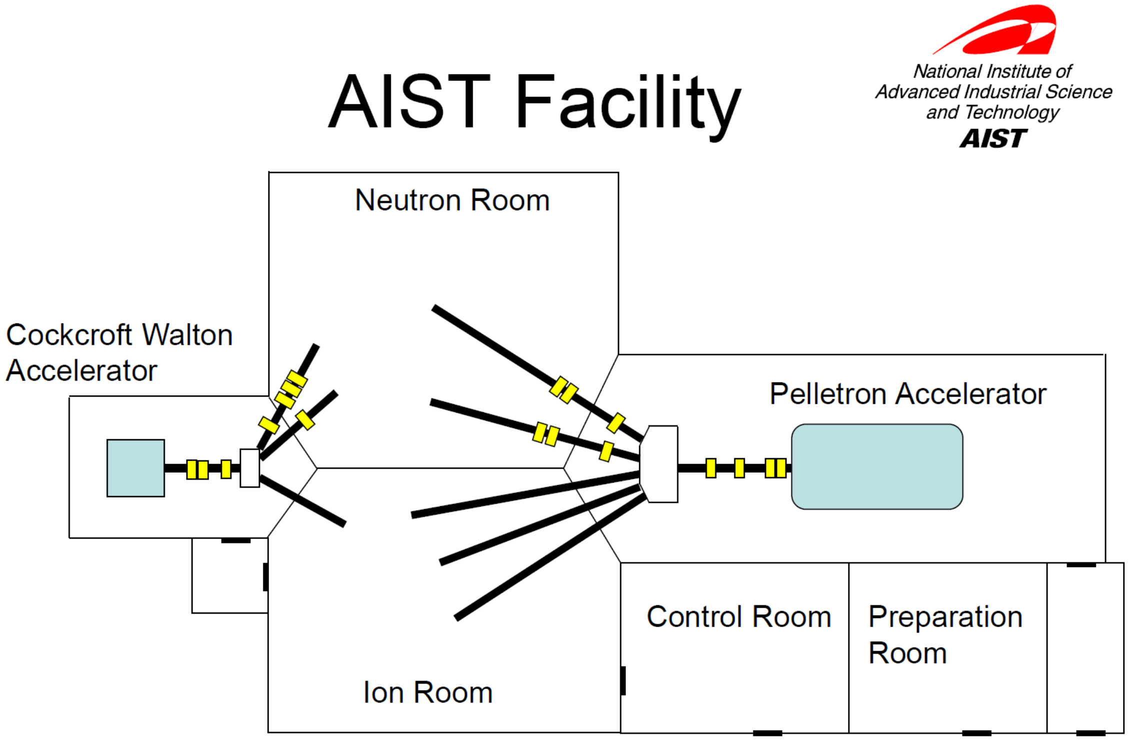
NATIONAL INSTITUTE OF ADVANCED INDUSTRIAL SCIENCE AND TECHNOLOGY (AIST)

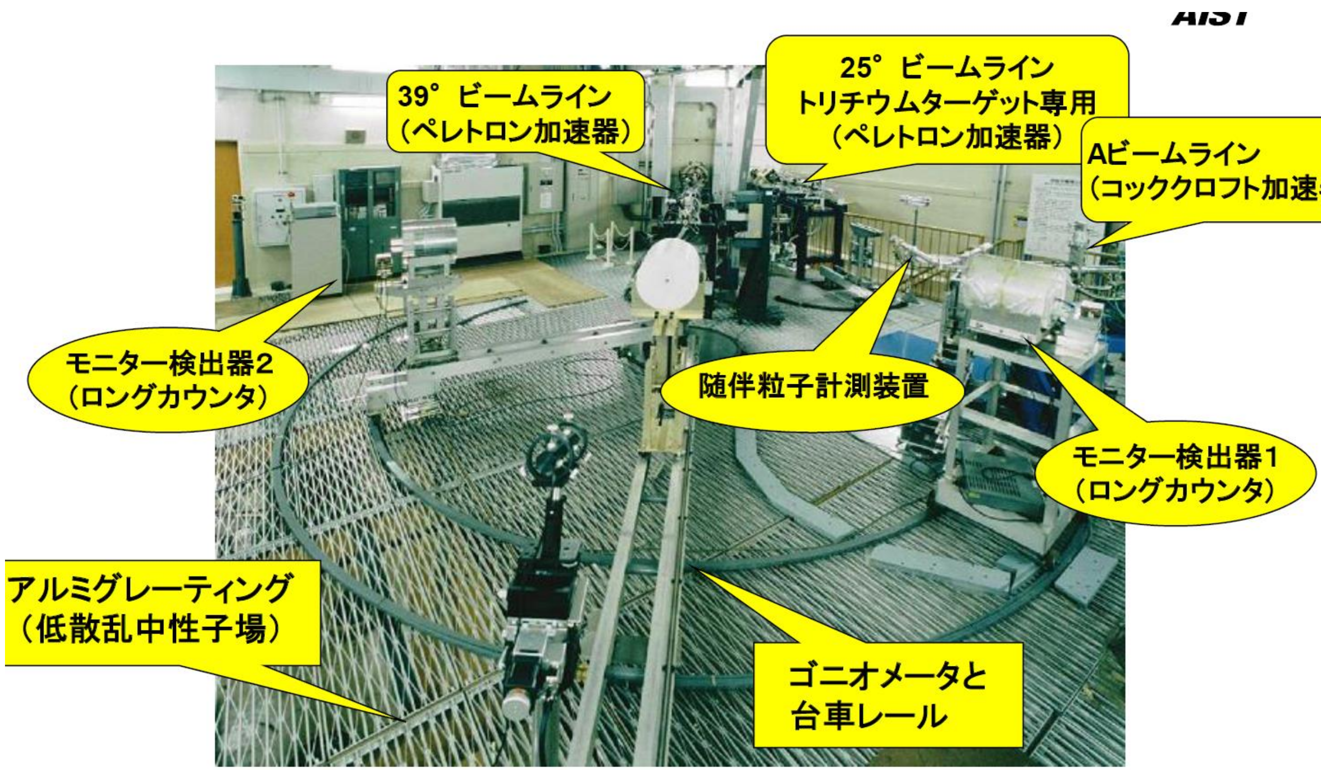






Neutron source due to nuclear fission





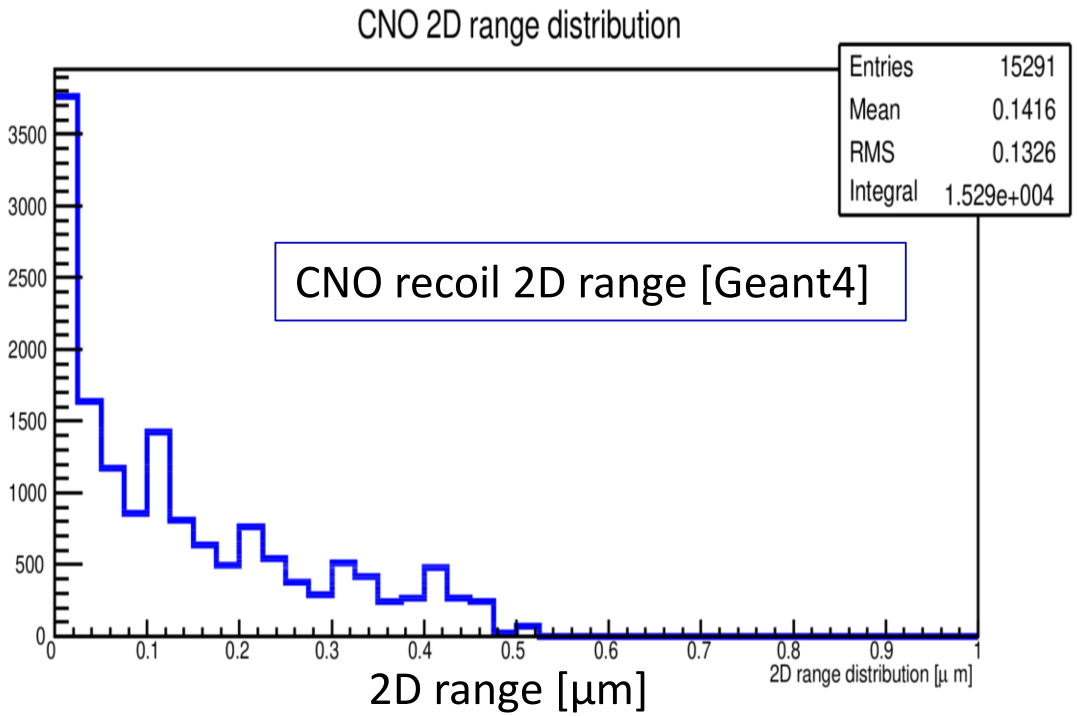
D-D : ~ 2.5 MeV
D-T : ~ 14 MeV
Li-p : ~ 565 keV

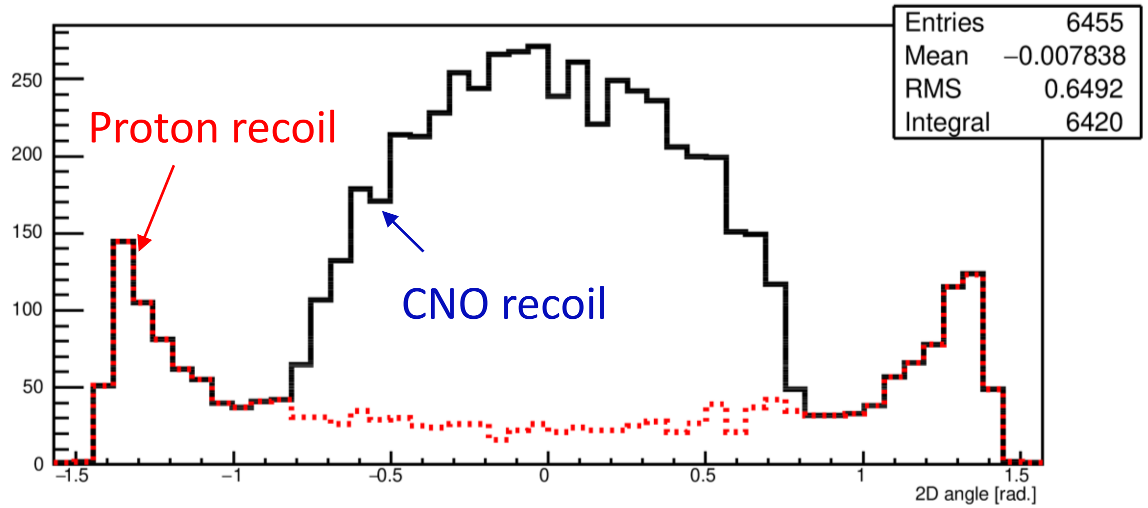
$^{7}Li\ (p, n)^{7}Be \Rightarrow$ 565 keV neutron

Simulation result for very simple setup [w/o detail geometry]

2D range	Proton	CNO
No cut	30033	15291
0.2 – 0.5 μm	2034	4421
> 1μm	22953	-

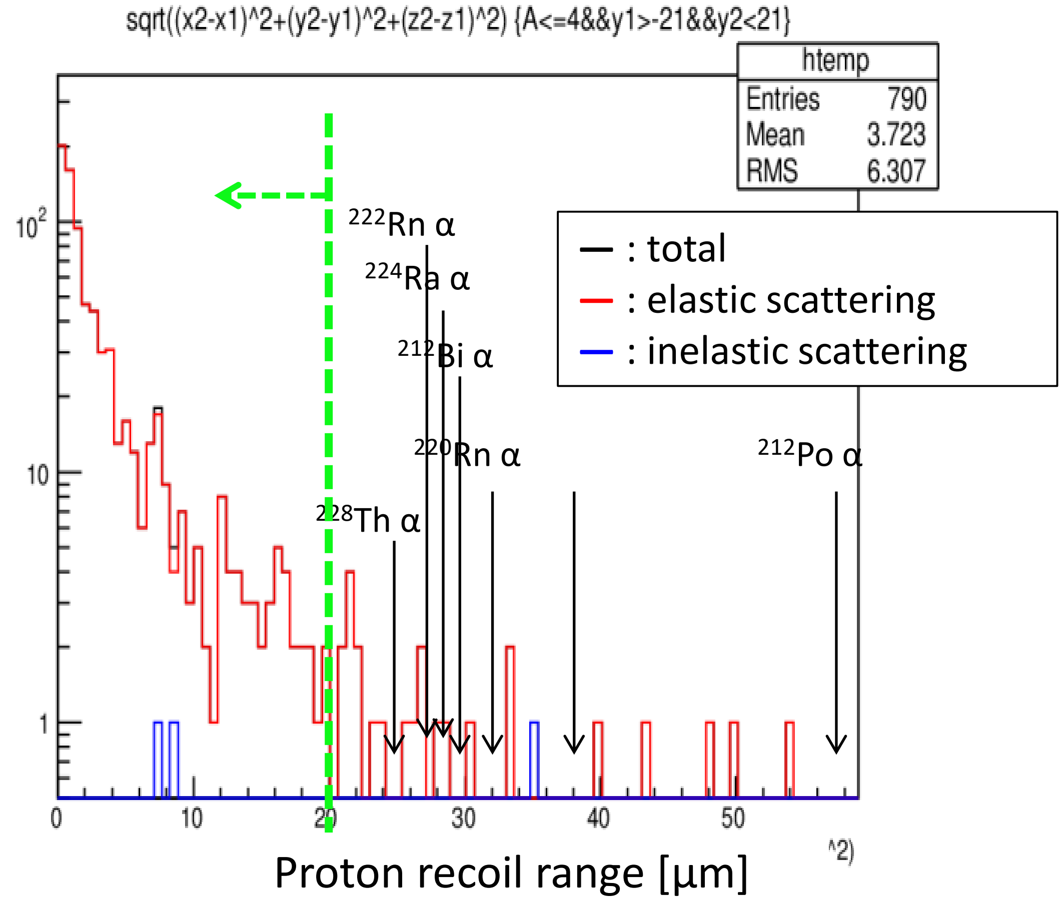
# of neutron : 100000
# of interaction of NIT layer : 62516





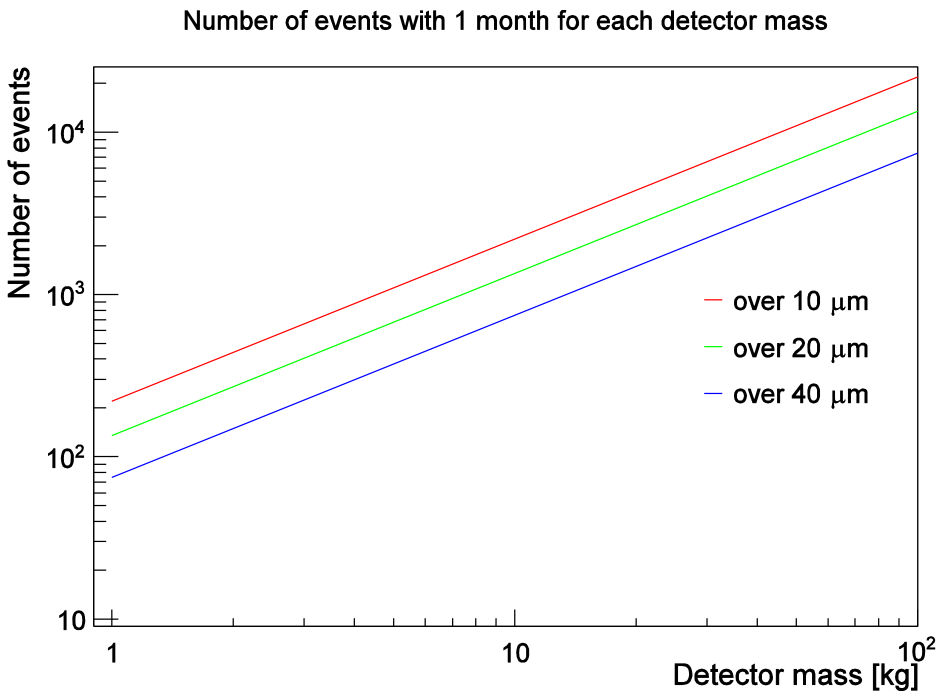
2D angular distribution [rad.]

Underground neutron measurement



Proton recoil detection for underground neutron measurement

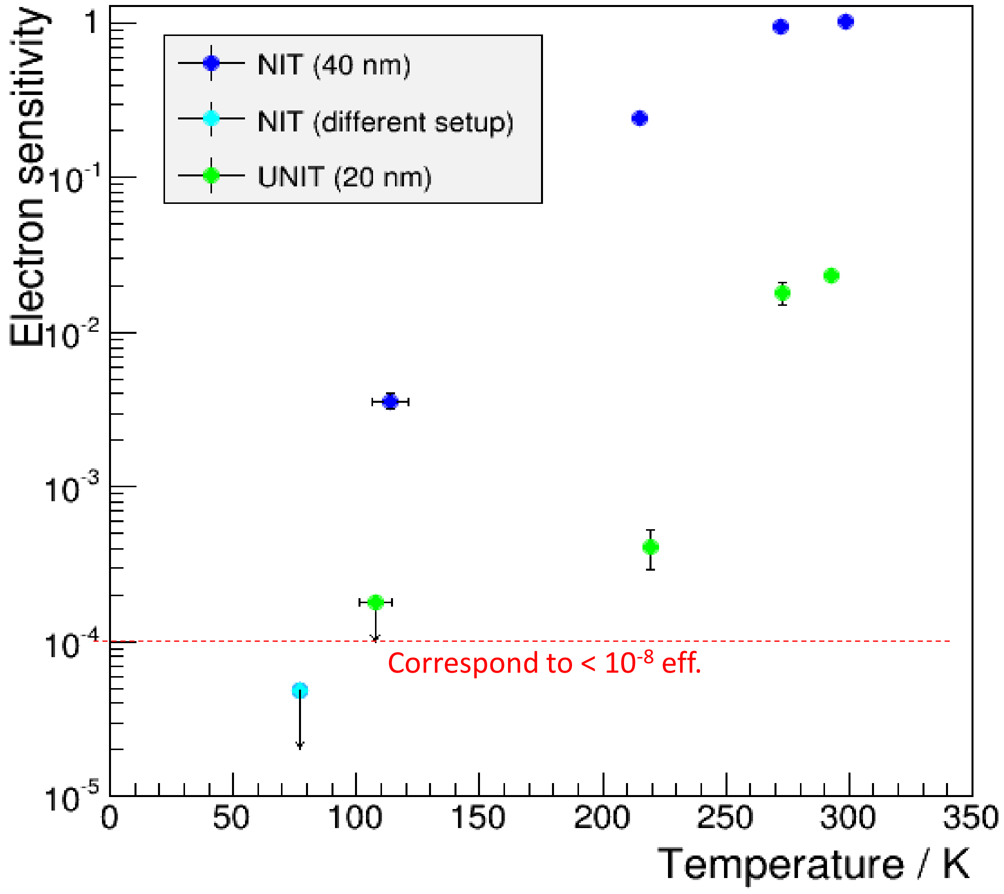
⇒ < 10 μm proton detection is important to discriminate from α-ray background



100 g･month detector (w/o shield)
⇒ several 10 events can be detected

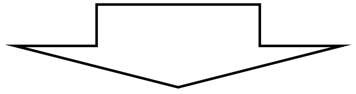
2. Electron background calibration

Just manual check and device condition is not difference for current one



M. Kimura et al., NIM A 845 (2017) 373 -377
https://doi.org/10.1016/j.nima.2016.06.052

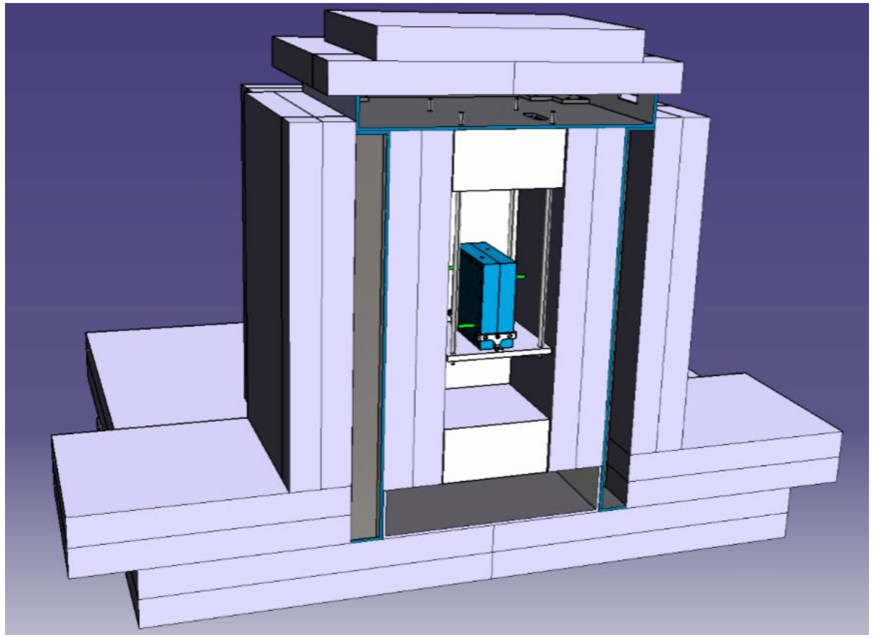
We can expect strongly dependence of temperature for electron signal.



Low-temperature exposure is required.

- **Radiation source possible to use in low-tem. environment**
- **Exposure system with cooling and sample mount system**

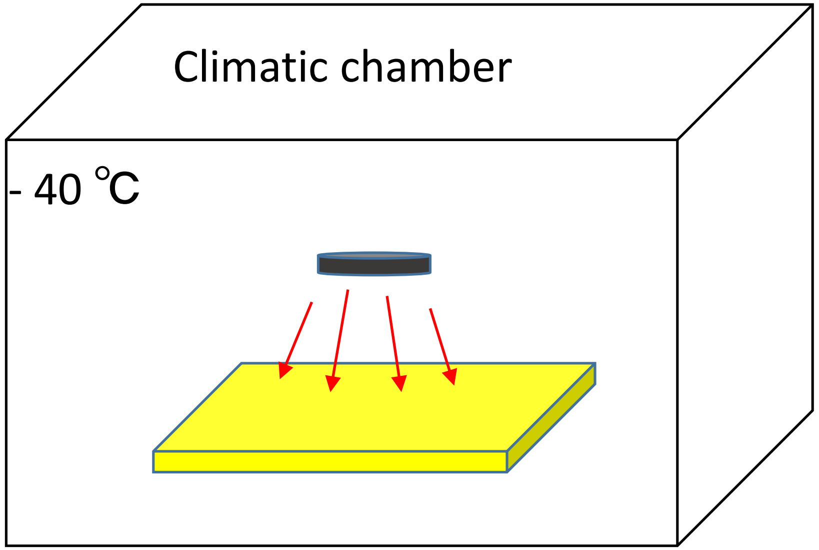
Discussion :
How to expose the radiation in cooling condition



1. Exposure of γ-ray from outside of cooling system
   ⇒ It should be used higher energy gamma-ray (e.g., Co, Cs)

2. Insertion of radiation source stick

3. Exposure in the climatic chamber
   - automation system to move the source in the chamber



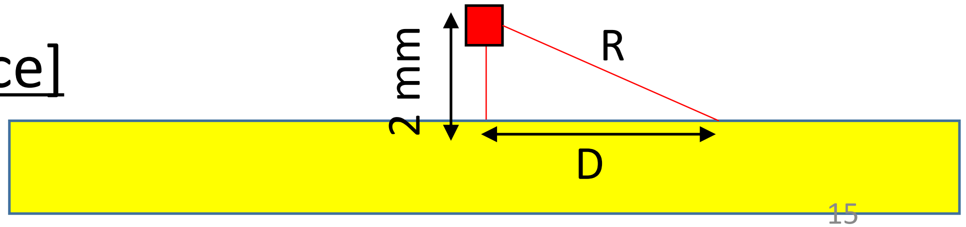
Normalization to R distance of 1mm [exposure 2 min]

Normal temp.	D [µm]	Event density For the scan area	R [µm]	Average event density [/(10µm)^3] for R of 1mm
PN1	**2248 – 2291**	1.09 +- 0.1	3008-3041	10.0+- 0.9
PN2	**952-2181**	1.19 +- 0.1	2215-2959	7.9 +- 0.6

Average : 8.9 +- 1.1 [/(10µm)^3 for 1mm R correspondence]

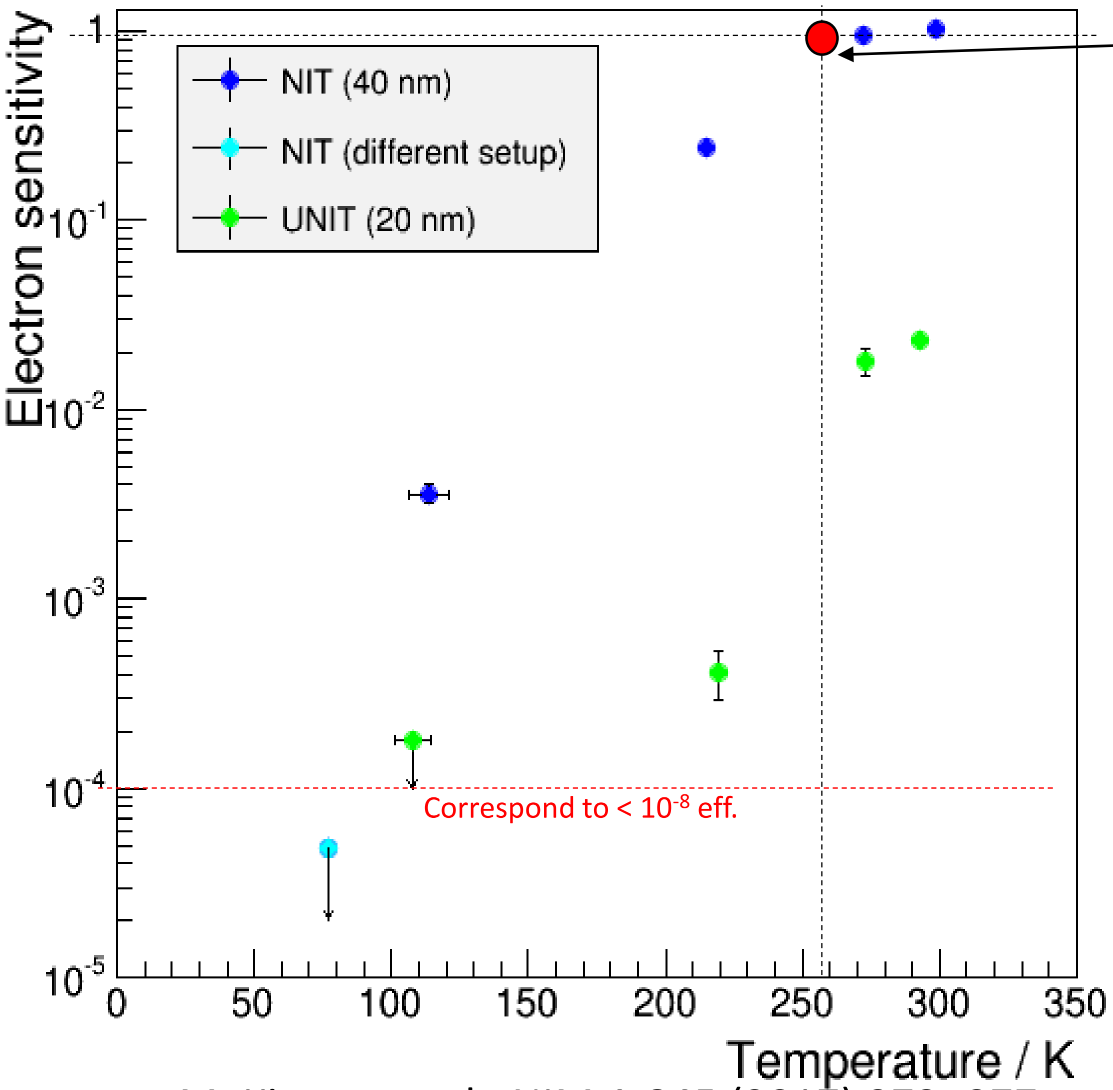
-15 - -10 ℃ temp.	D [µm]	Event density For the scan area	R [µm]	Event density [/(10µm)^3] for R of 1mm
PL1	**1055 - 1223**	1.72 +- 0.1	2261-2344	9.1+- 0.5
PL2	**900-1318**	1.64 +- 0.1	2193-2395	8.7 +- 0.5

Average : 8.9 +- 0.7 [/(10µm)^3 for 1mm R correspondence]

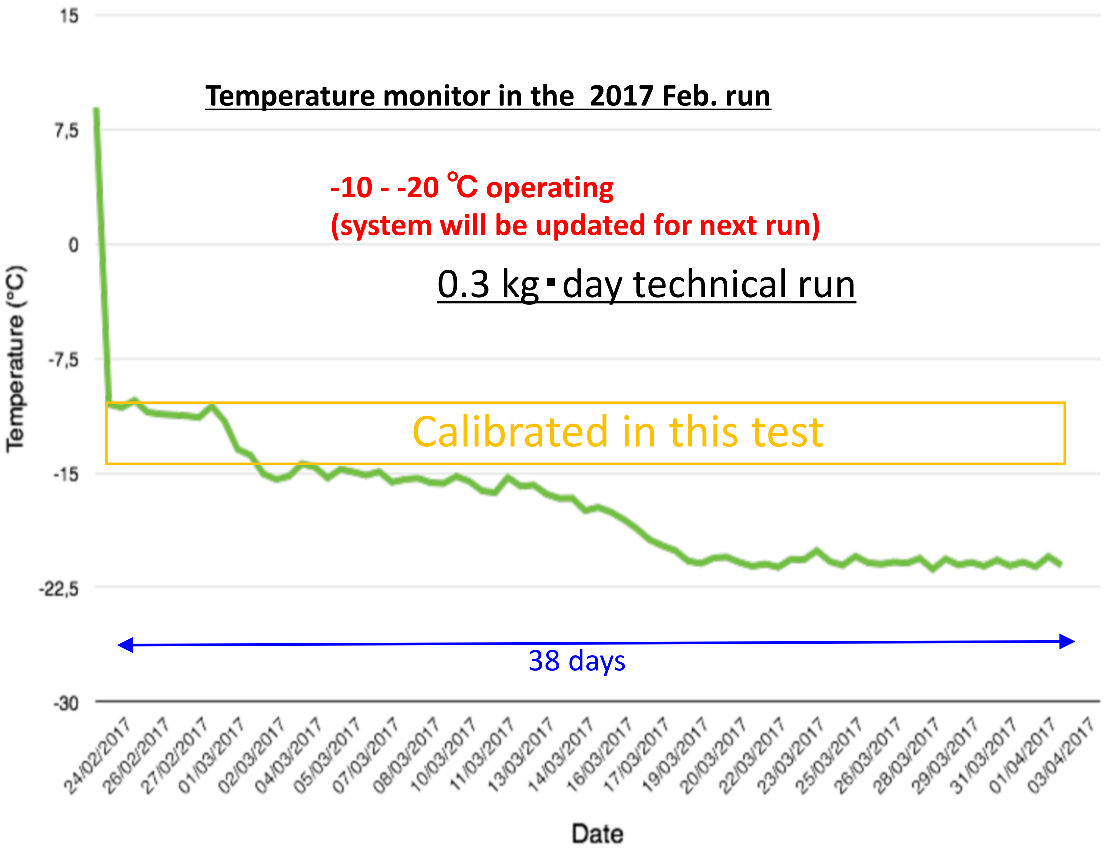


No effect for the sensitivity in this temperature !!

Temperature dependence result



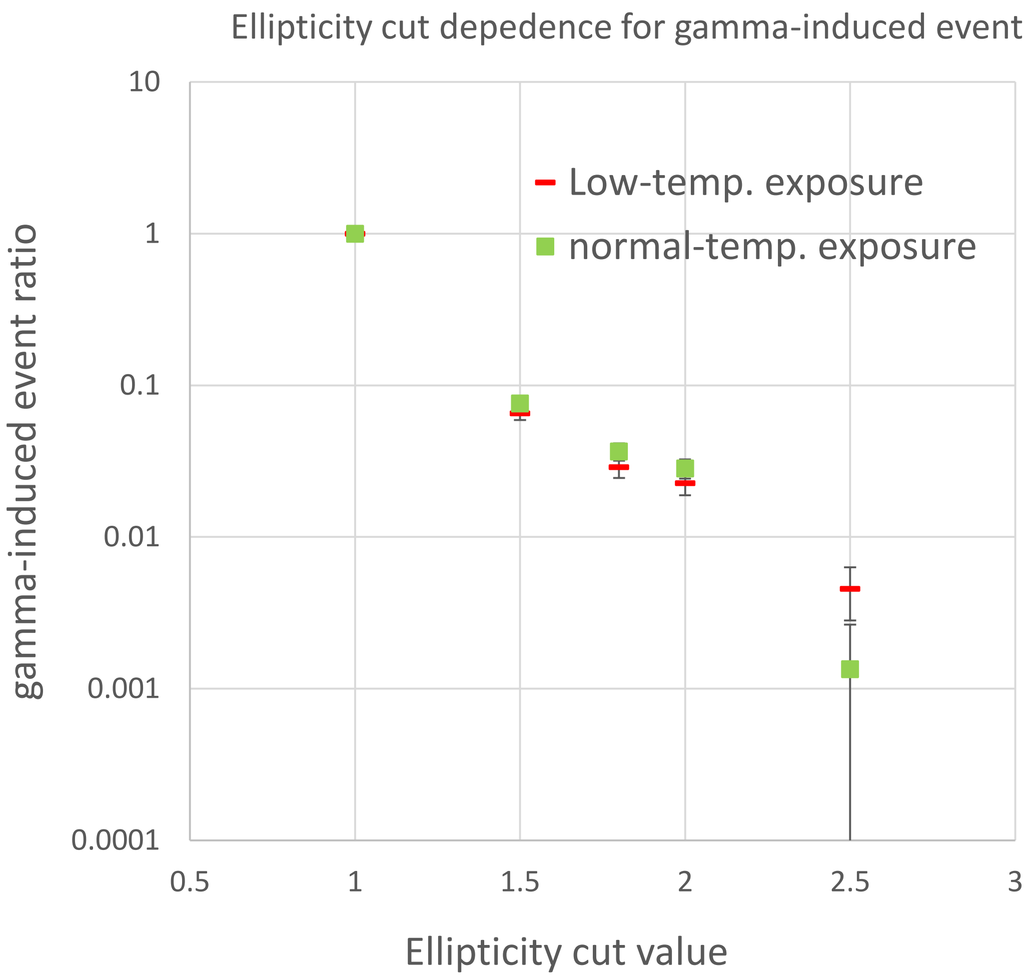
This work



M. Kimura et al., NIM A 845 (2017) 373 -377

https://doi.org/10.1016/j.nima.2016.06.052

Expected background ratio due to C-14



C-14 decay rate : 24 Bq/kg ➡ ~ 79000 /38days/g

Ellipticity > 1.5 : ~ 5200 events/38days/g

> 2.0 : ~ 1800 events/38days/g

<u>Father rejection using another parameters</u>

- ☐ Topological selection
- ☐ Brightness and spectrum
- ☐ Polarization effect due to the Plasmon

Comparison of background level

- 0.035 g data analysis

Expected value to see the excess with 95 %C.L. : 228

Expected C-14 background signal : < 63

$2\sqrt{\lambda} = 63$

$\lambda = 992$

⇨ **992/13000 = 1/13**

If current dust like event rejection will be 1/13, C-14 background excess may be observed.

⇒ this is very important to check our understanding of background

How do we make calibration system ?

✓ We should understand the detector performance using various method (e.g., radiation source, beam test)

- neutron source (e.g., Cf-252, nuclear fission facility)
- γ/β radiation source (Am-241, Co-60, Cs-133)
- Heavy ion beam

⇒ not only underground site
(e.g., Japan, LNGS surface and other Italian experimental site)

We will start to make the emulsion gel in underground

- It's required to evaluate the gel. produced in underground or surface lab.
- standard calibration system and method must be confirmed.

Summary of discussion points

- ☐ Making the exposure system
  - ✓ low-temperature condition
  - ✓ some kind of radiation (e.g., neutron, gamma-ray)
  - ✓ Good repeatability

- ☐ Do we need to have additional experiment site to evaluate the emulsion gel. produced in underground lab on the surface lab ?

  ⇒small handling, development room and microscope system should be set for quickly evaluation .