Dark Matter Search Project PICO-LON

Ken-Ichi Fushimi, for PICO-LON Collaboration
The Univ. of Tokushima, JAPAN

Planar Inorganic Crystals Observatory for LOw-background Neutr(al)ino

Contents

- Introduction
- Merit of segmentation of NaI(Tl)
- Performance of thin NaI(Tl)
- Test measurement at Tokushima
- Summary & Prospects

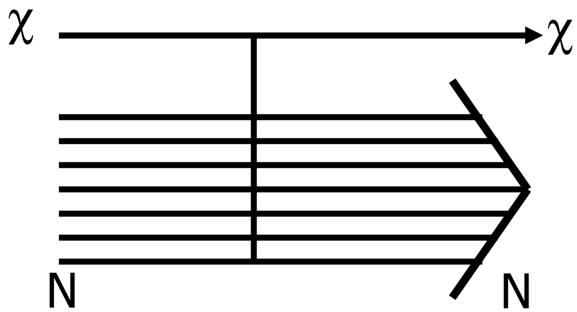
Collaboration (Welcome !!)

- The University of Tokushima
  - K.F, H.Kawasuso, K.Yasuda, E.Matsumoto, C.Shonaka, K.Yoshida, S.Nakayama, N.Koori
- Horiba Ltd.
  - K. Imagawa, H. Ito
- Osaka University
  - K.Ichihara, S.Umehara, M.Nomachi, H.Nakamura
- Hiroshima University
  - R.Hazama
- Tohoku University
  - S.Yoshida
- ICU, Spring-8
  - H.Ejiri

Interactions between WIMPs and nucleus

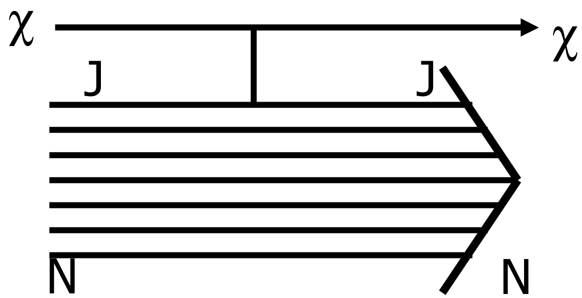
H.Ejiri K.Fushimi and H.Ohsumi,
Phys. Lett B317(1993)14

SI



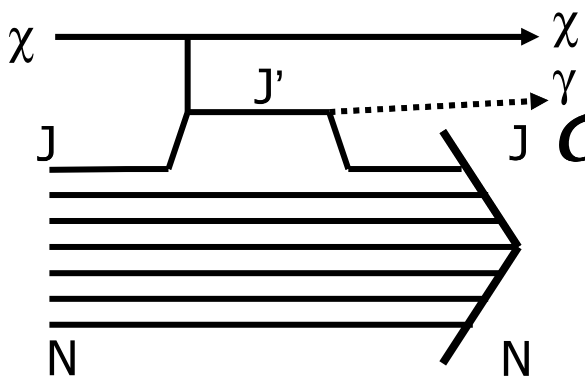
$$\sigma \propto A^2$$

SD



$$\sigma \propto C\lambda^2 J(J+1)$$

EX

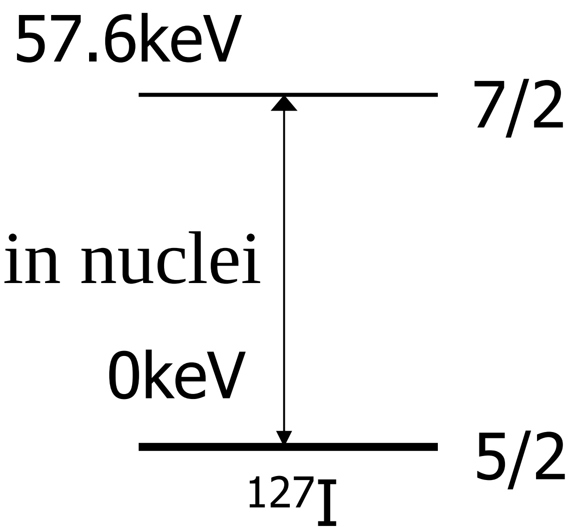


$$\sigma \propto \sqrt{\frac{2J'+1}{2J+1}}\frac{1}{g_M}\langle A|M1|A^*\rangle$$

We planned to study all the types of interaction!!

Why NaI(Tl) ?

- ^{23}Na & ^{127}I
  - Sensitive to SD and SI
  - 100% natural abundance of finite spin nuclei
- ^{127}I
  - Sensitive to EX
  - Low energy excited state



Experimentally obtained

$$|M_{M1}|^2 = 0.1$$

J.Ellis et al., PLB212(88)375

- Expect: 3.60×10^{-3}/day/kg (Higgsino)
- Limit: 4.98×10^{-2}/day/kg (ELE V NaI)

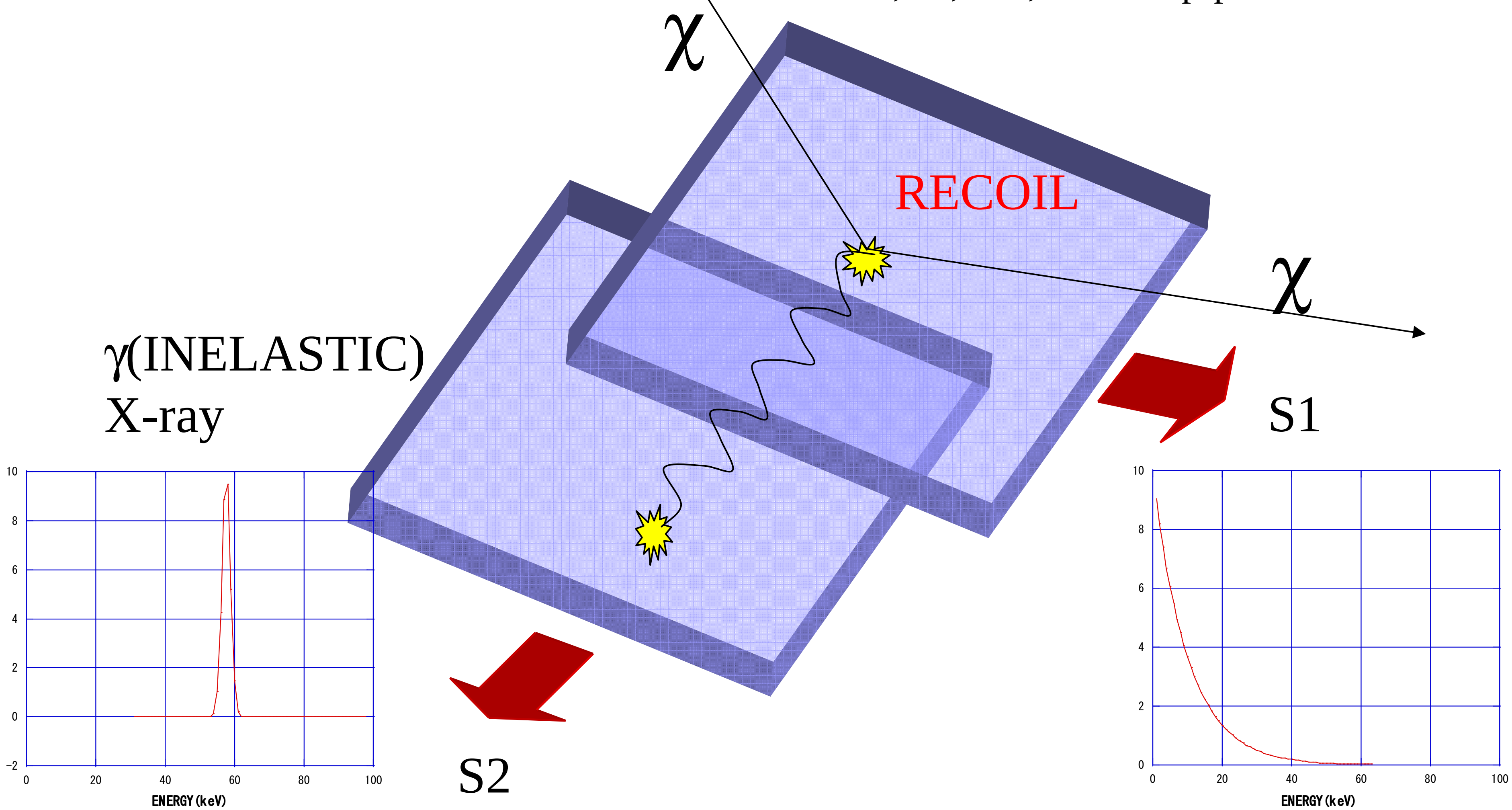
K.Fushimi et al., Nucl. Phys. B(Proc. Suppl.) 48 (1996) 70

Signal selection by Spatial and Timing Correlation (SSSTC)

- Signal Selection by Spatial Correlation
  - Signal → 57.6keV γ + Low energy recoil
  - Localized event in space and time
  - Background → U,Th chain, ^{40}K etc.
  - Diffused event in space and time
- Signal Selection by Timing Correlation
  - Signal → No following events
  - Background → Time-correlated events by decay chain (^{210}Pb)

Signal Identification by Segmentation

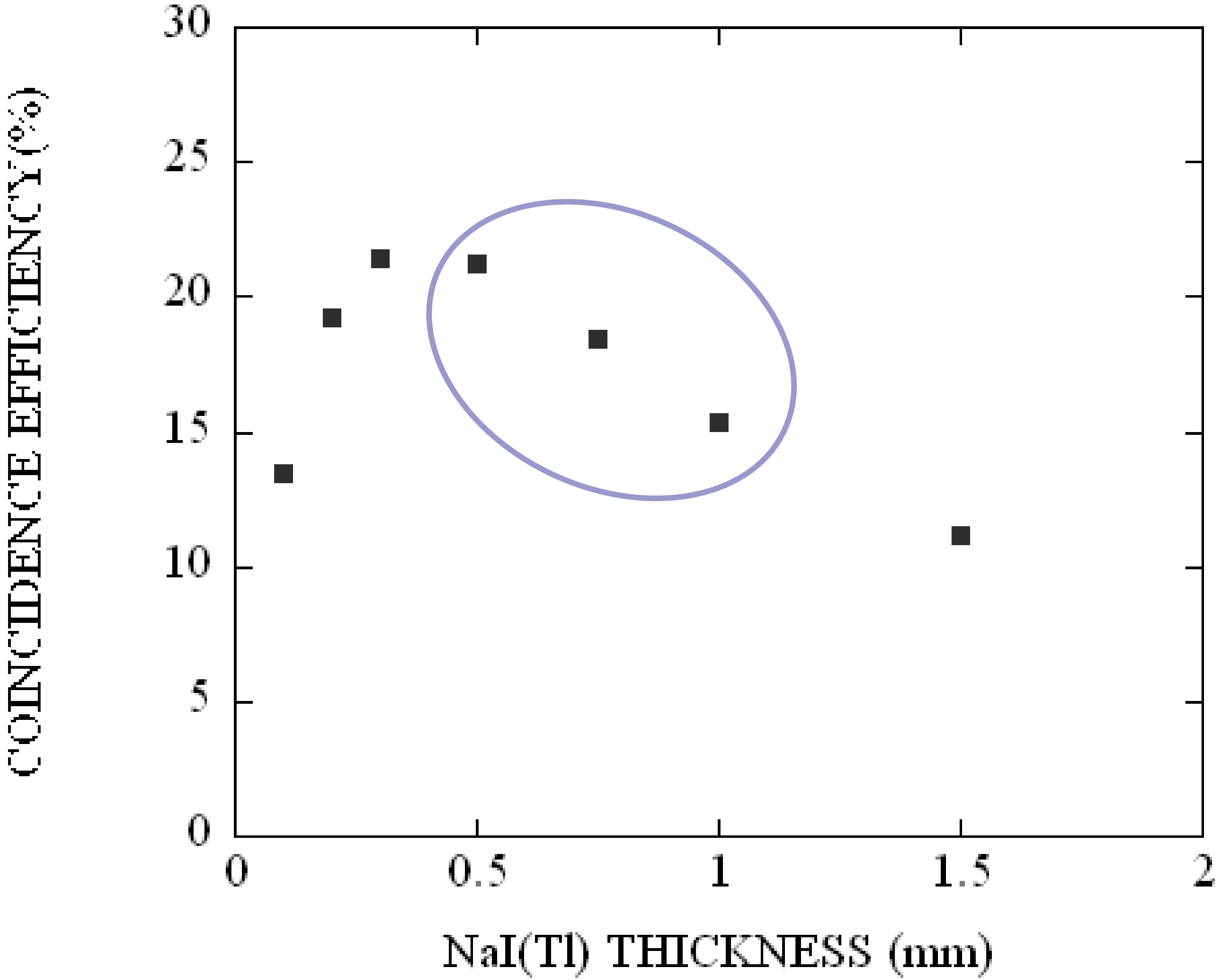
K.Fushimi et al., JPSJ74(2005)3117
astro-ph/0506329
H. Ejiri, Ch. C. Moustakidis, J.D. Vergados,
PL. B639, 06, 218, arXiv hep-ph/0510042 2005.



Estimation of signal selectivity

- Monte Carlo simulation (GEANT4)
- 57.6keV γ ray ($^{127}I^* \rightarrow {}^{127}I$) from one module
- γ is detected the another module
- Next module to the emitter module

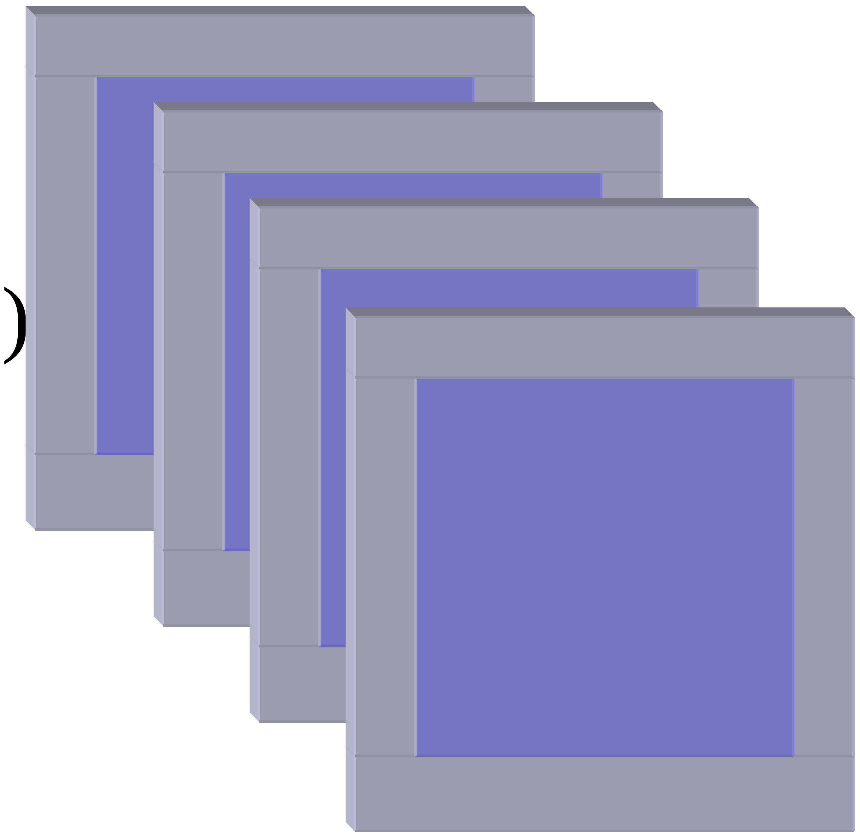
The fraction which is detected both sides of emitter



COINCIDENCE EFFICIENCY (%)
30
25
20
15
10
5
0
0
0.5
1
1.5
2
NaI(Tl) THICKNESS (mm)

Specification of thin NaI array

- 0.05cmX5cmX5cm NaI(Tl)
- 0.05cmX6cmX0.5cm Acrylic Light Guide
- ESR™ reflector
- 3plates (PICO-LON-II)
- 16plates (PICO-LON-III)
- 1024, 2176 (Future)

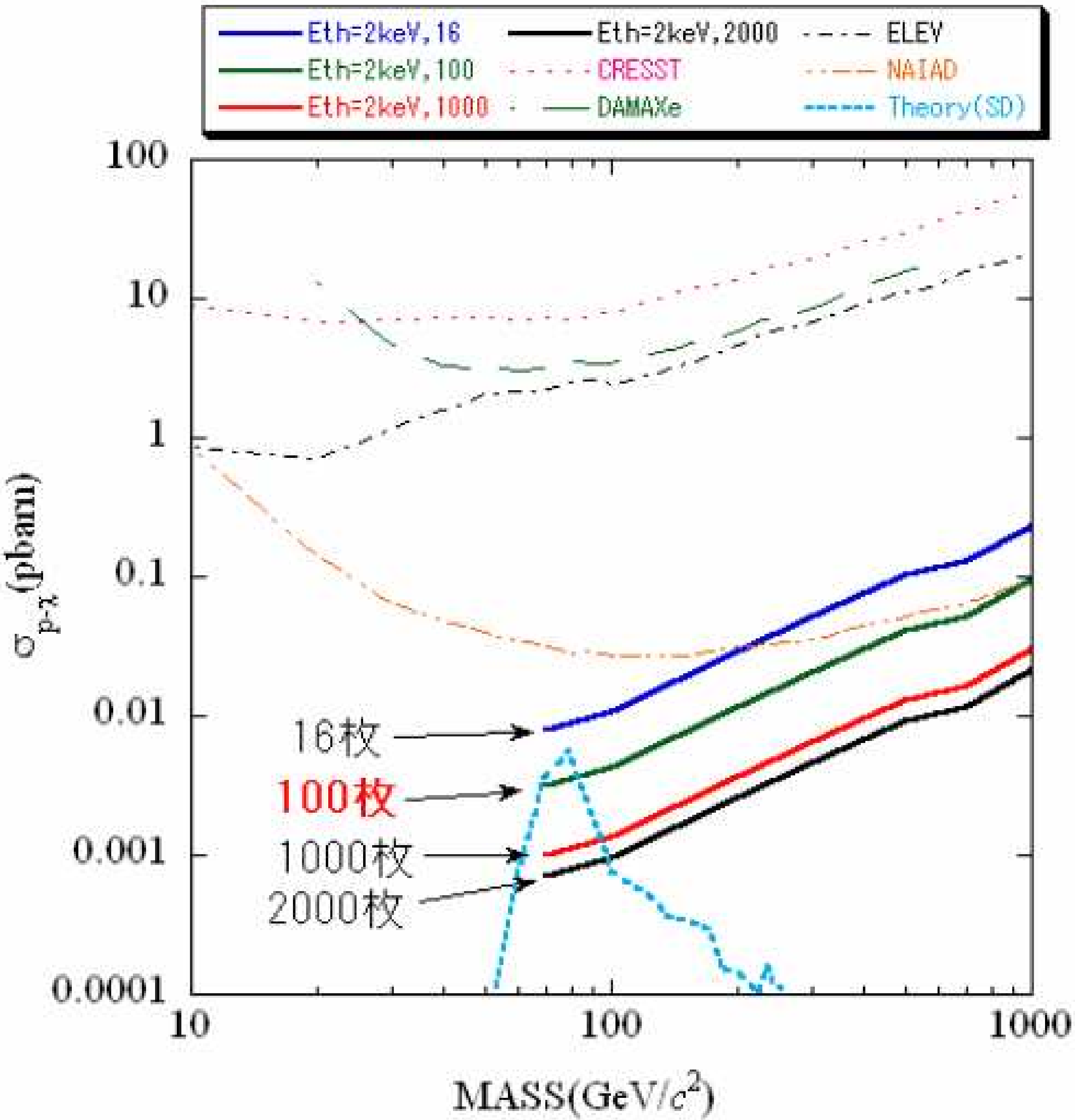


Estimation of sensitivity

- Radioactive contamination
  - Uniformly contaminated in NaI(Tl) crystal
  - ^{210}Pb 0.1mBq/kg (1/100 of present value)
  - ^{214}Pb, ^{214}Bi 10μBq/kg (present value)
- Monte Carlo Simulation
  - GEANT4

15cmX15cmX0.1cm
NaI(Tl) system

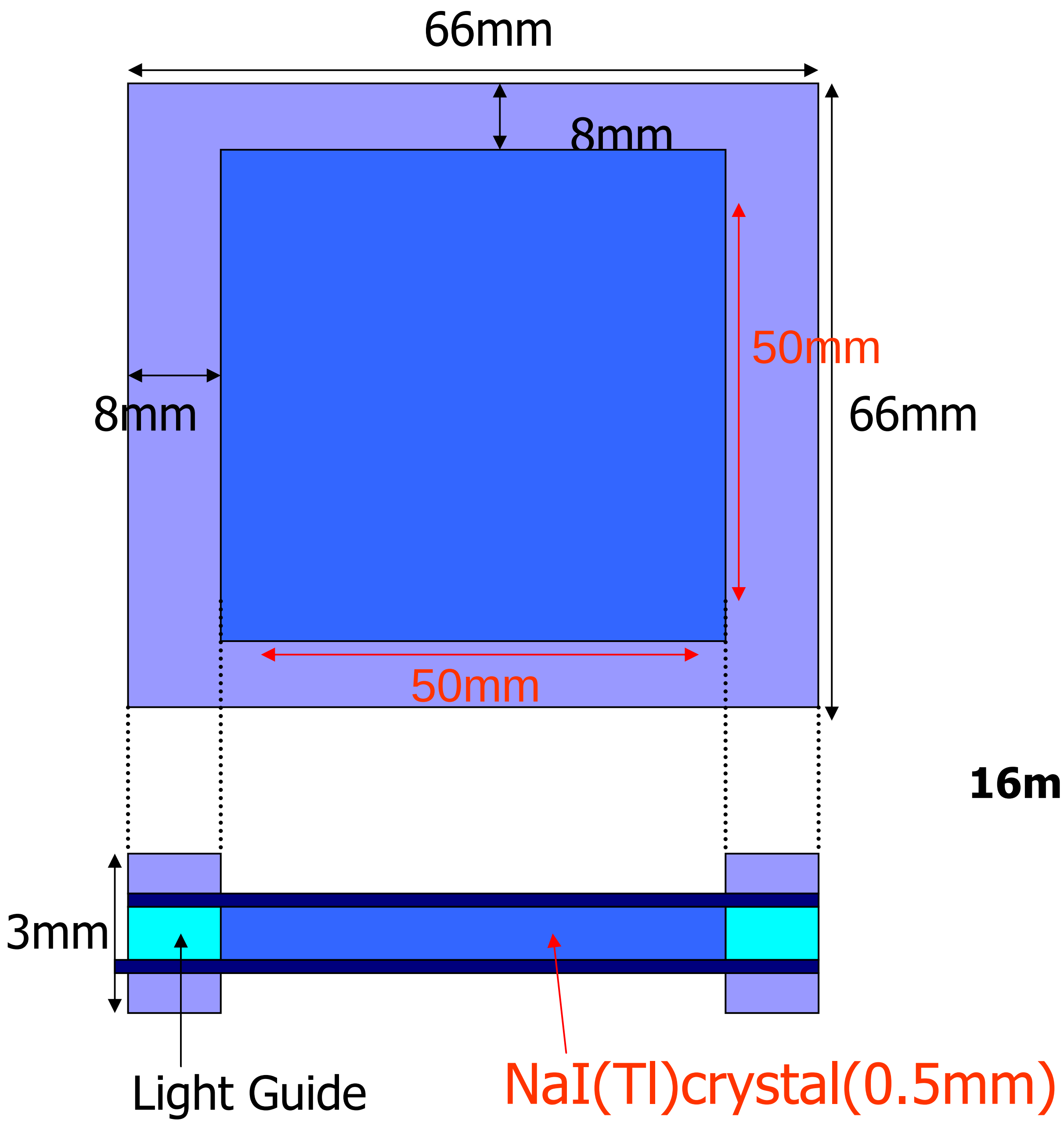
Applying
JSPS Wakate-S

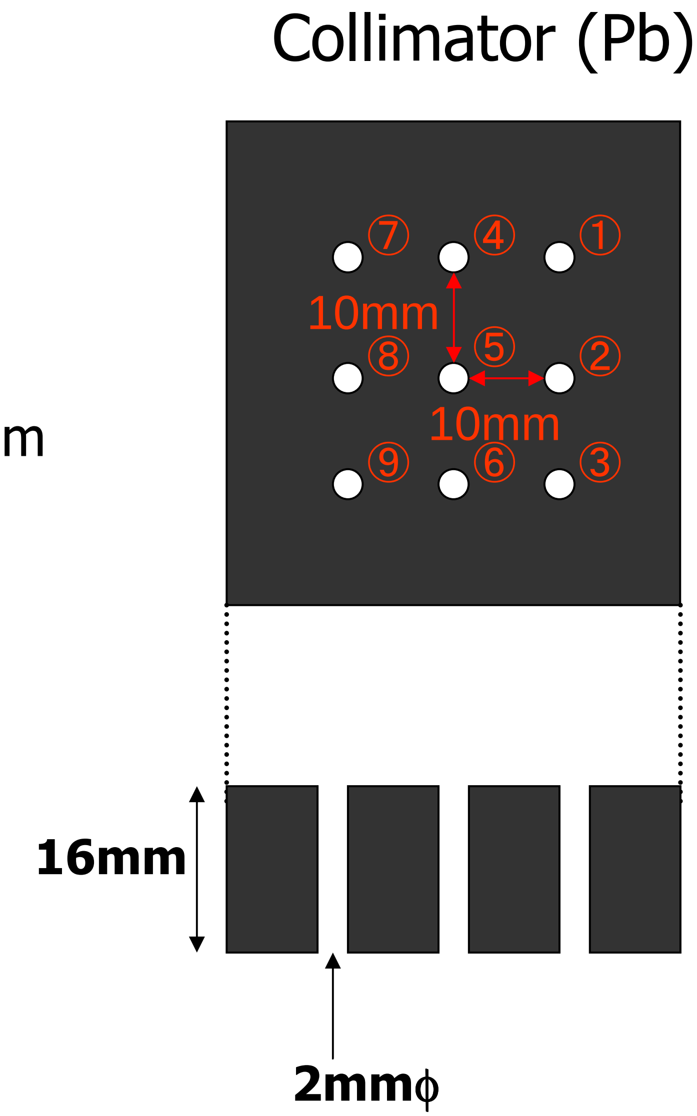


Development of thin NaI(Tl) PICO-LON-I

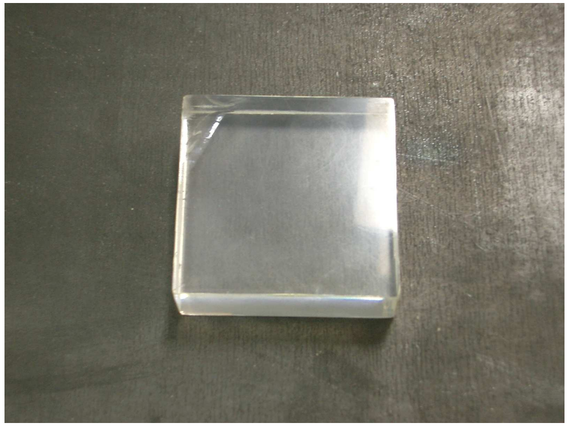
- Collaboration with Horiba Ltd.
  - Production of thin NaI plate
  - Selection of reflector ESR^{TM} by 3M
- ~2004/Feb.
  - Design and production method were discussed
- 2004/Apr.
  - First single plate was completed!!
- 2004/May~
  - Performance, stability test.
- 2005/June~
  - 16plates detector and 3plates detector was completed.

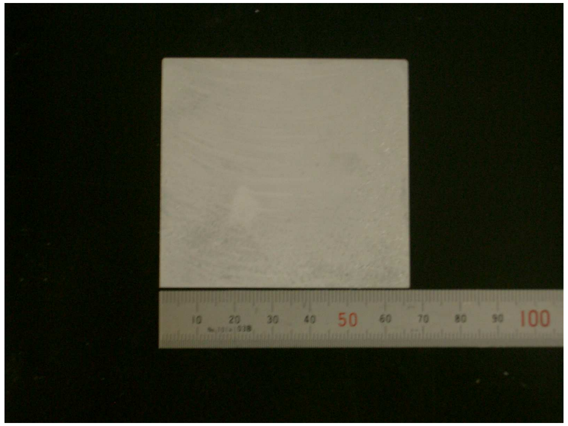
PICO-LON-I

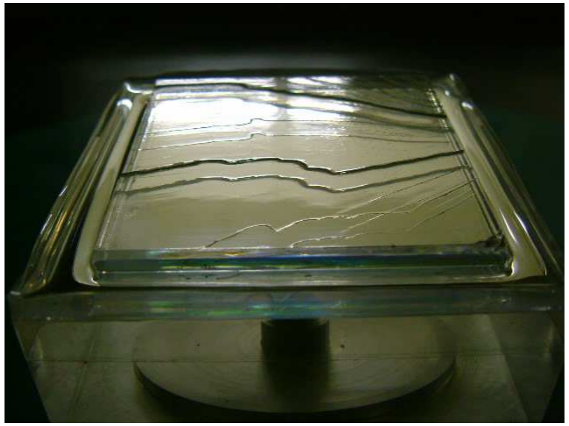

66mm
8mm
50mm
8mm
66mm
50mm
3mm
Light Guide
NaI(Tl)crystal(0.5mm)

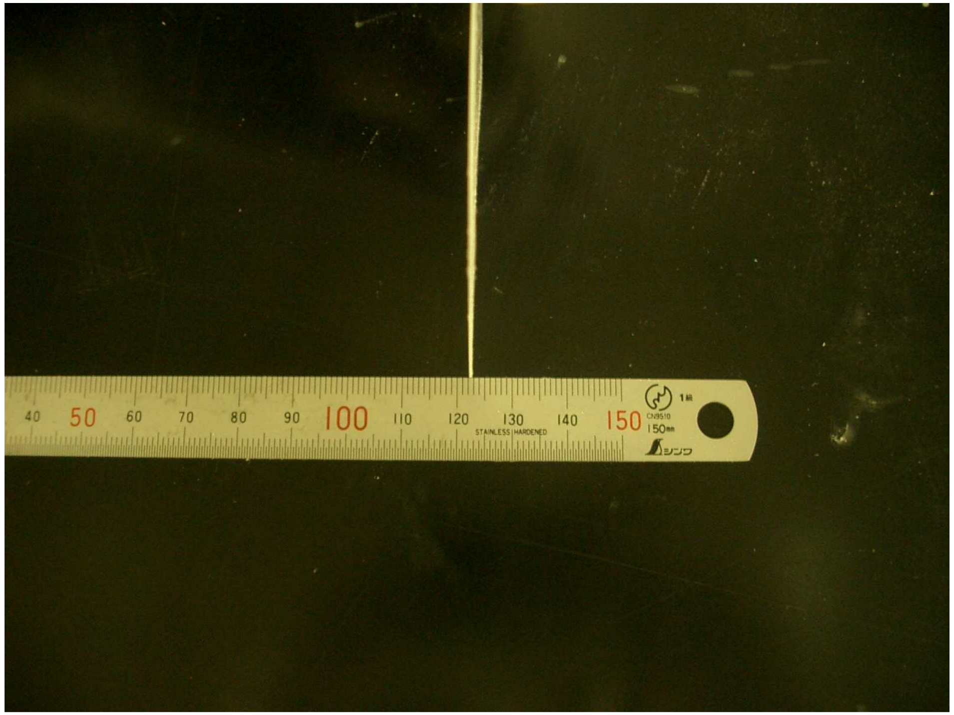

Collimator (Pb)
⑦
④
①
10mm
⑧
⑤
②
10mm
⑨
⑥
③
16mm
2mmϕ

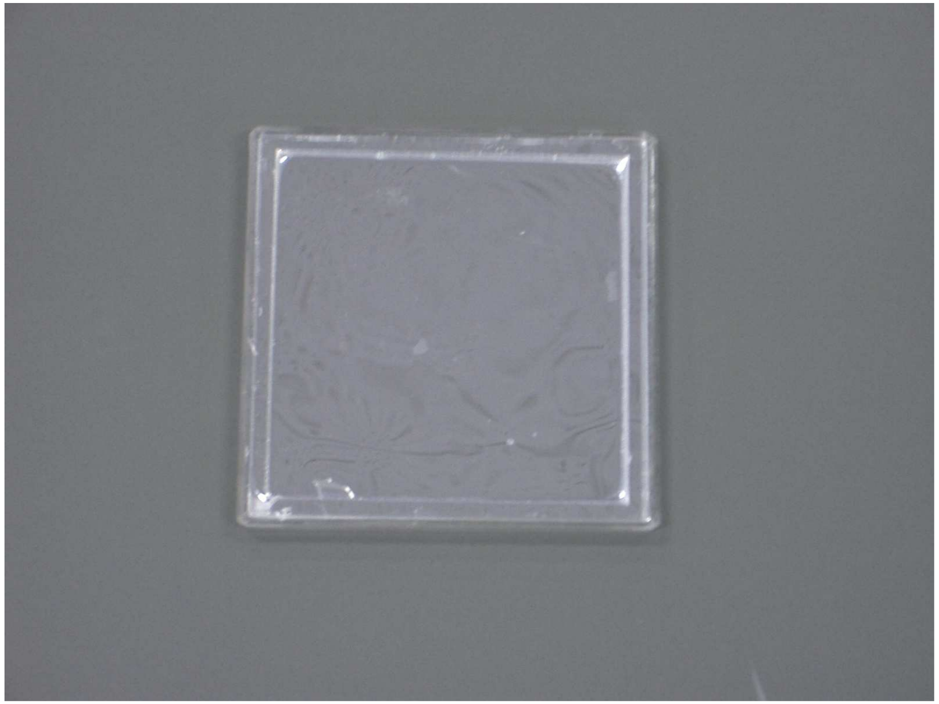
Production of thin NaI(Tl) by Horiba Ltd.









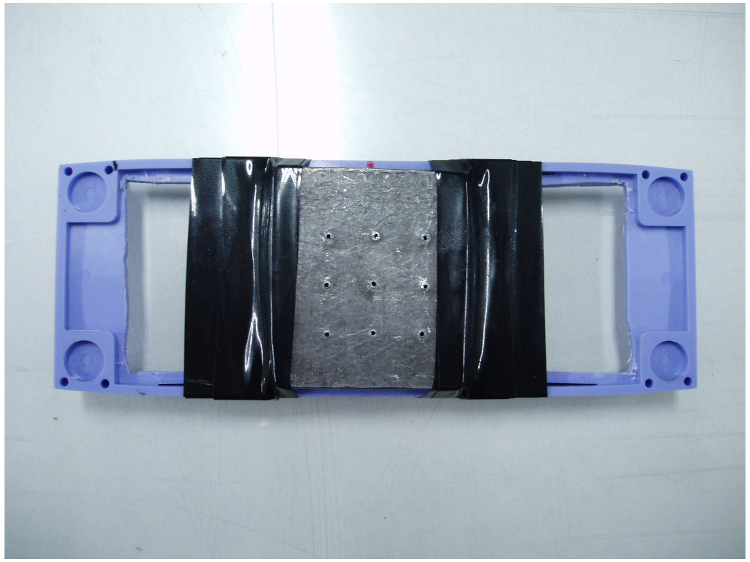


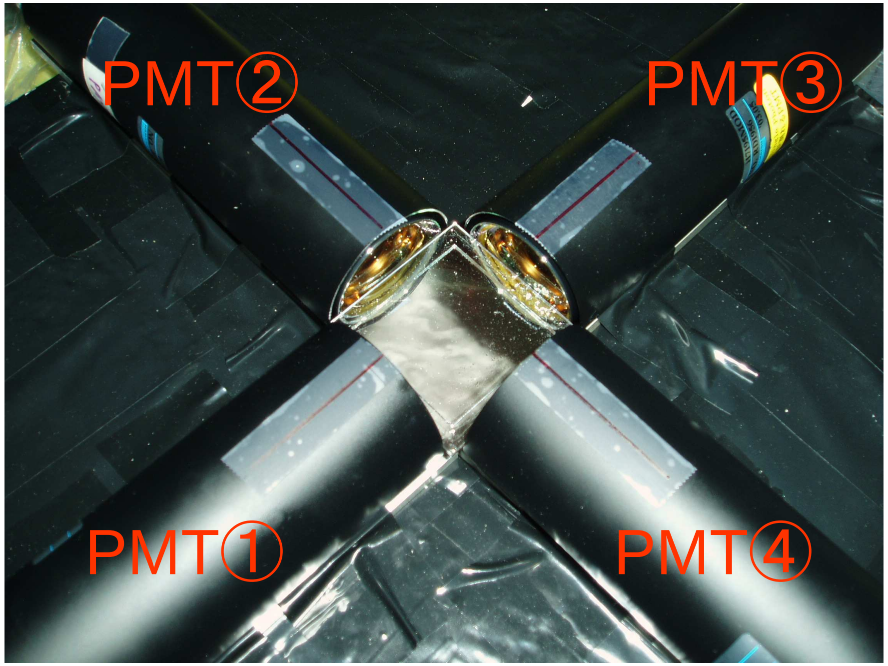
Performance of PICO-LON-I

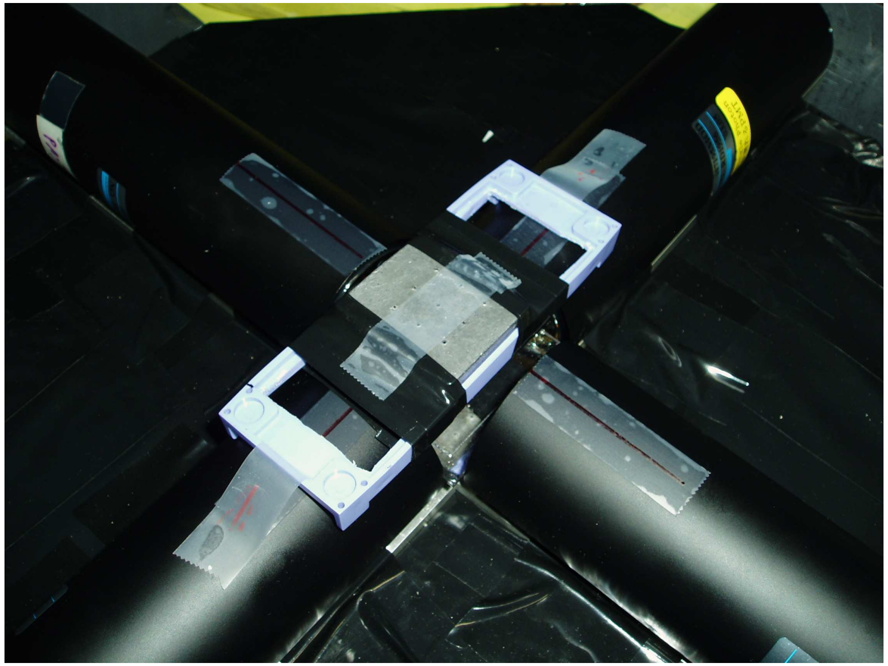
- Dimension of NaI(Tl)
  - 0.05cmX5cmX5cm
- Energy resolution
- Energy threshold
- Photon number/keV
- Position selectivity
- PMT : Hamamatsu R329P

Thin NaI(Tl) scintillator

Collimator

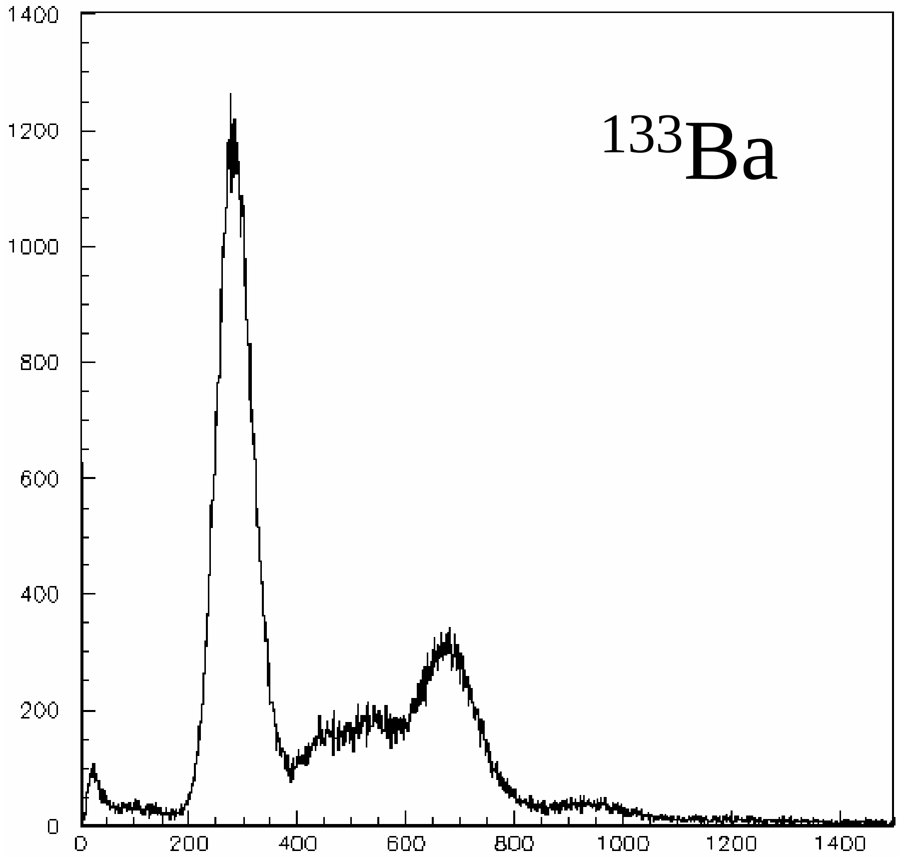


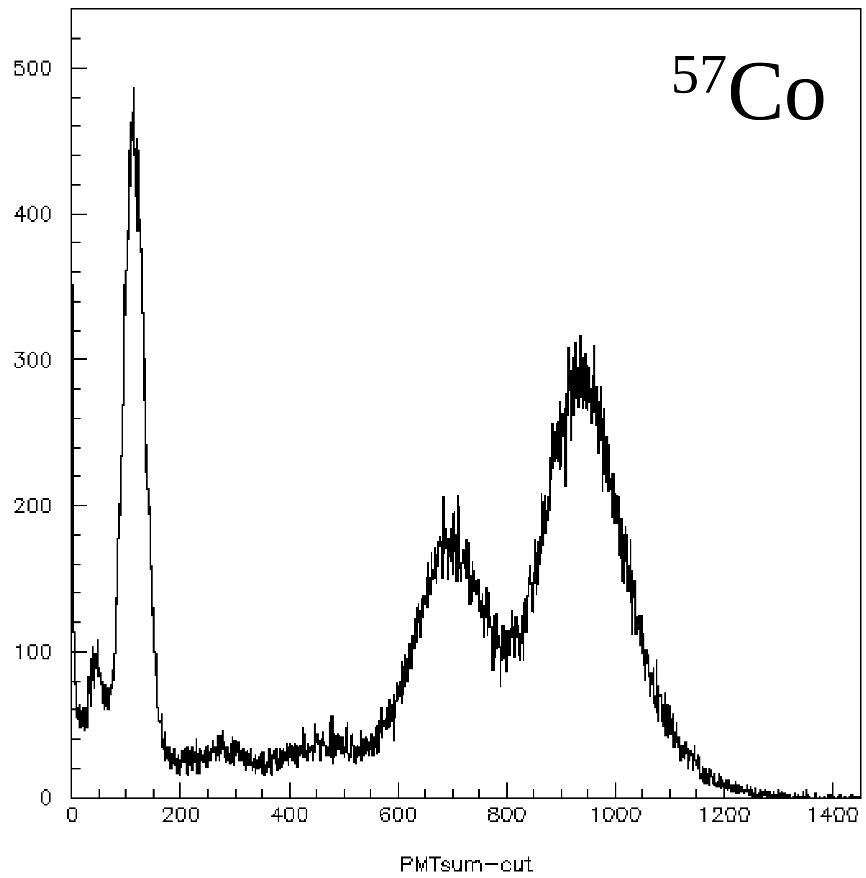




Result

K.Fushimi et al., JPSJ 75 (2006) 064201



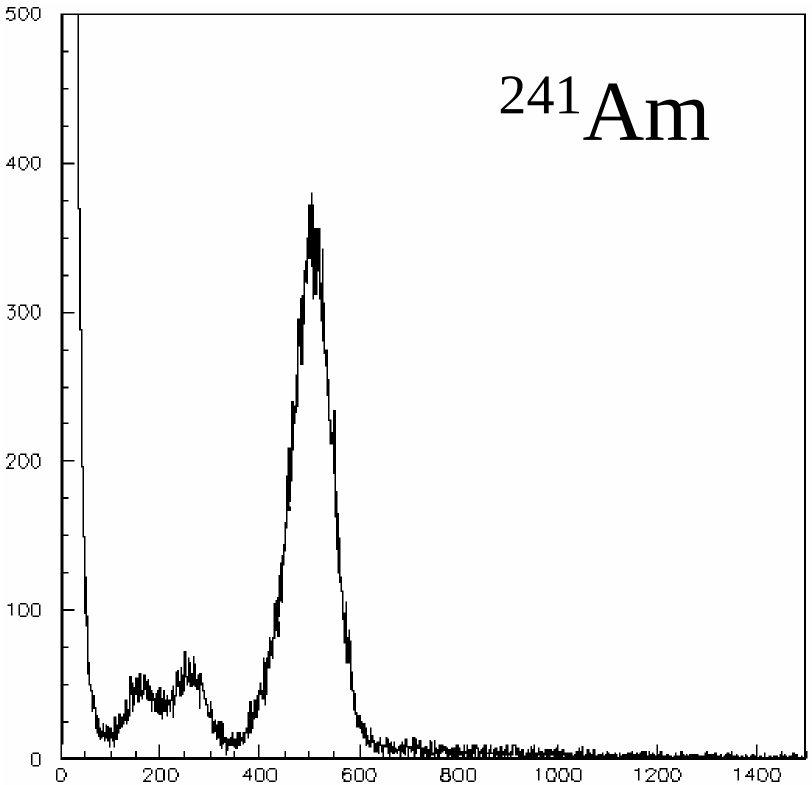


30keV R(FWHM)=0.25

122keV R(FWHM)=0.14

81keV R(FWHM)=0.13

Energy spectrum of low energy γ rays



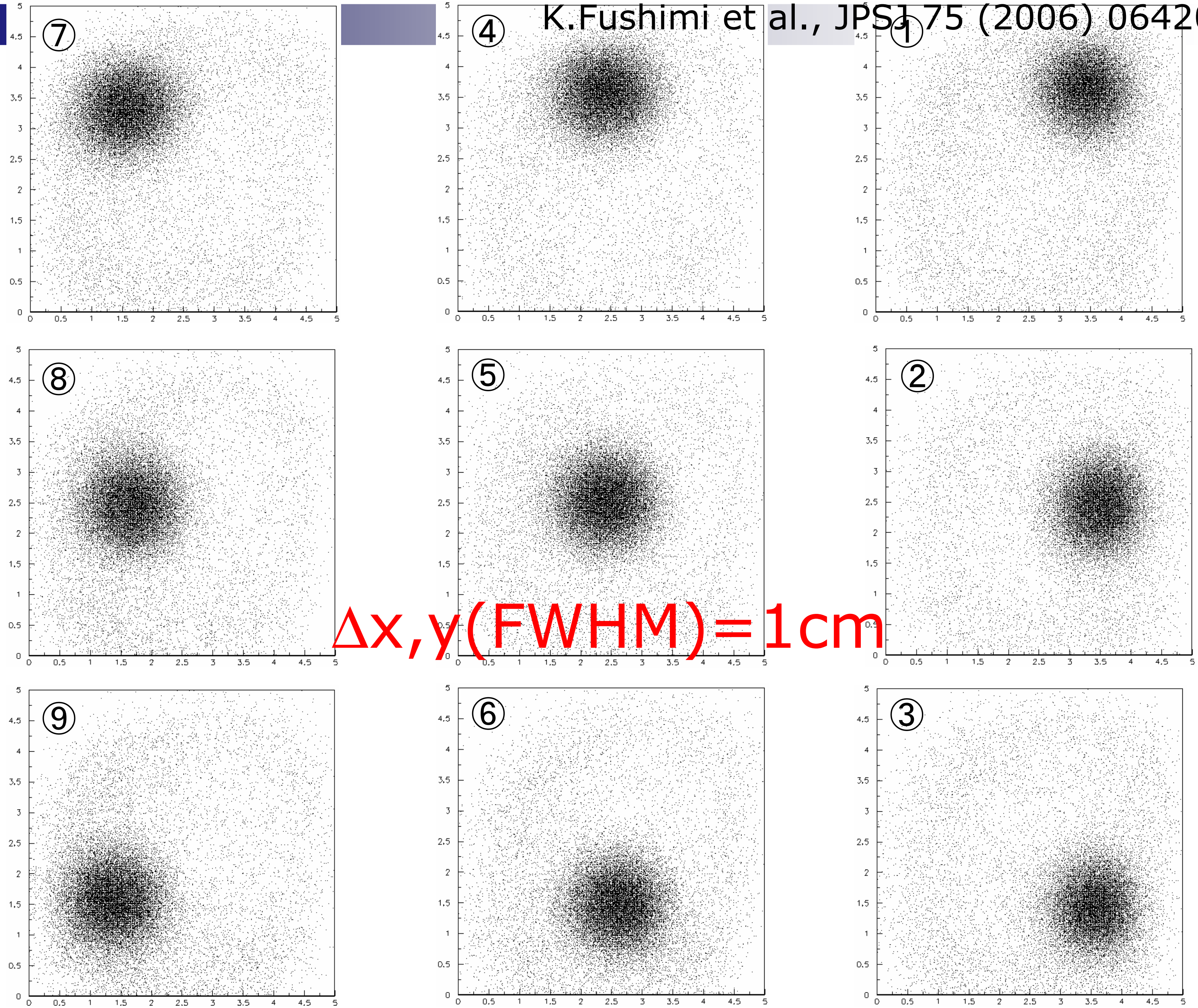
60keV ΔE/E(FWHM)=0.18

Source	Energy	FWHM
^{133}Ba	30keV	0.25
^{241}Am	60keV	0.18
^{133}Ba	81keV	0.13
^{57}Co	122keV	0.14

Single P.E. energy = 0.35keV

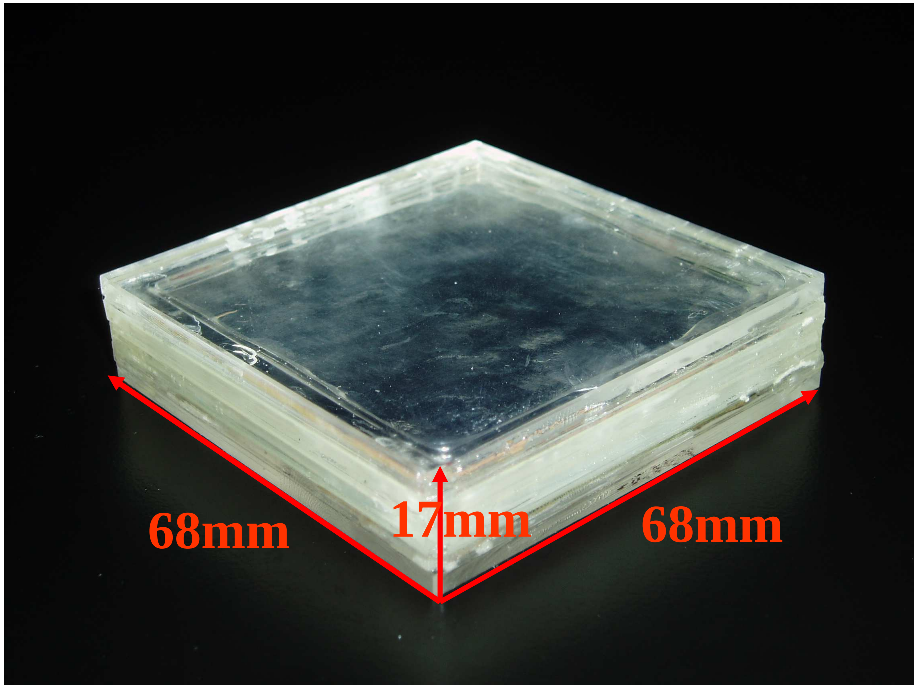
K.Fushimi et al., JPSJ 75 (2006) 064201

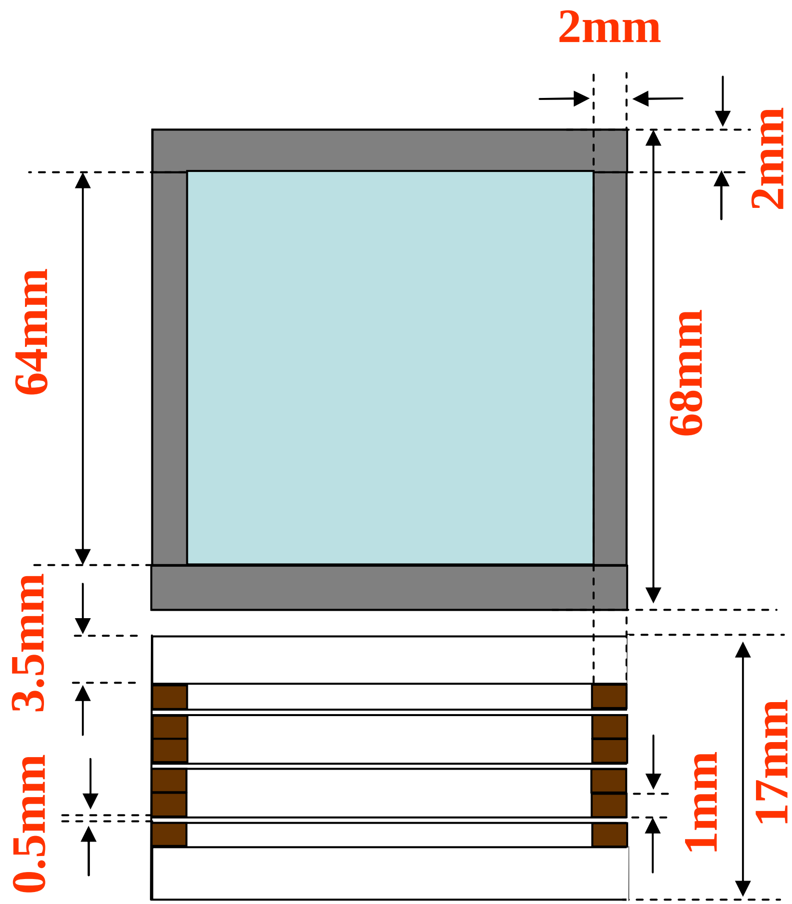
NaI(Tl) Real Position



PICO-LON-II (3-layer NaI(Tl))

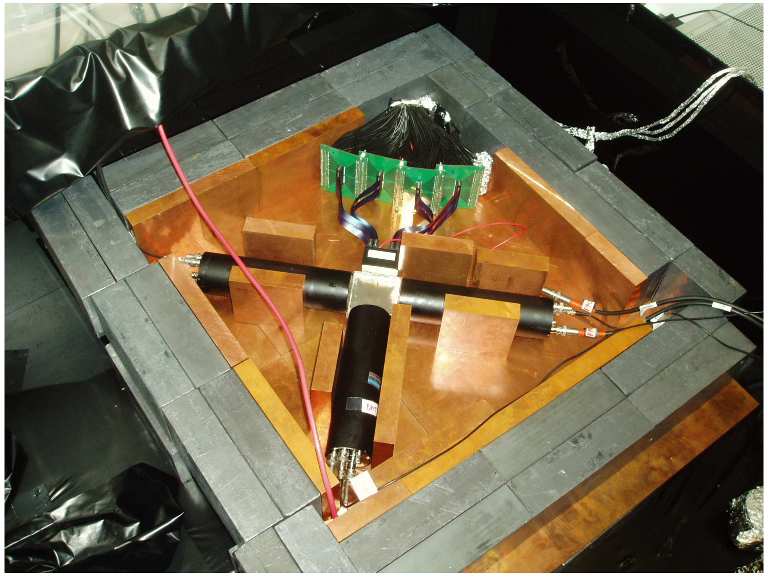
PICO-LON : Planar Inorganic Crystals Observatory
for LOw background Neutr(al)ino

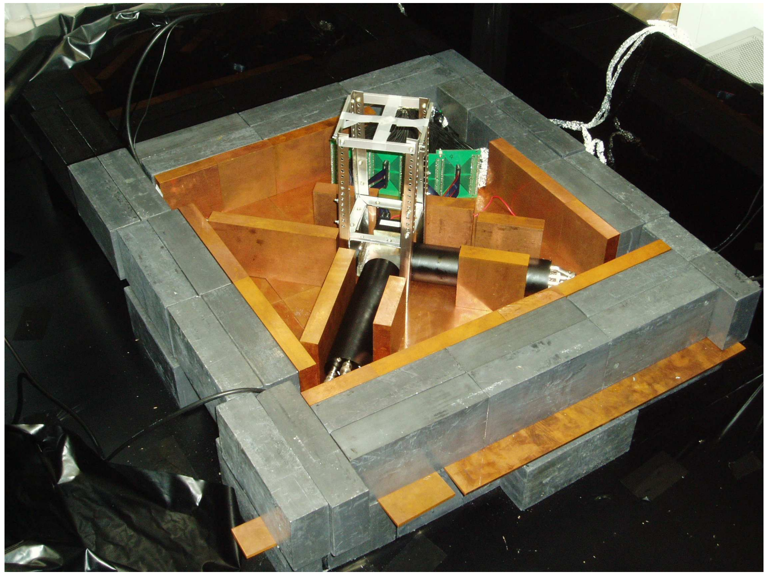


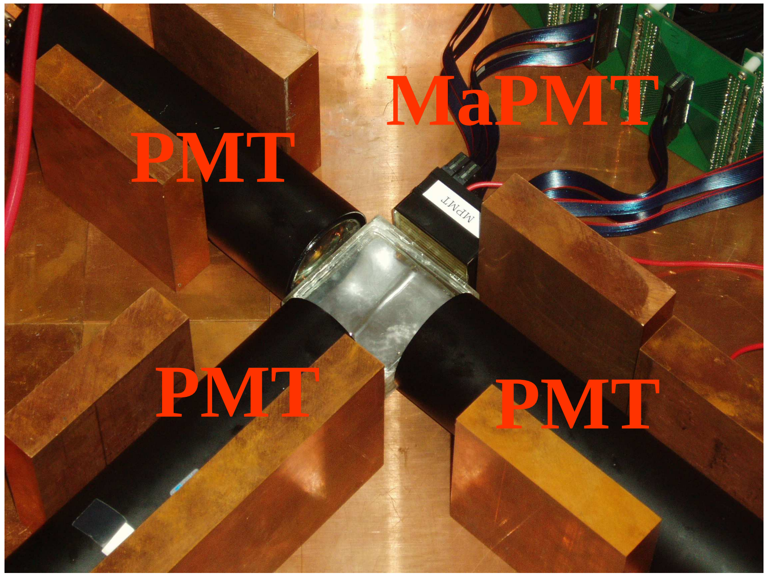


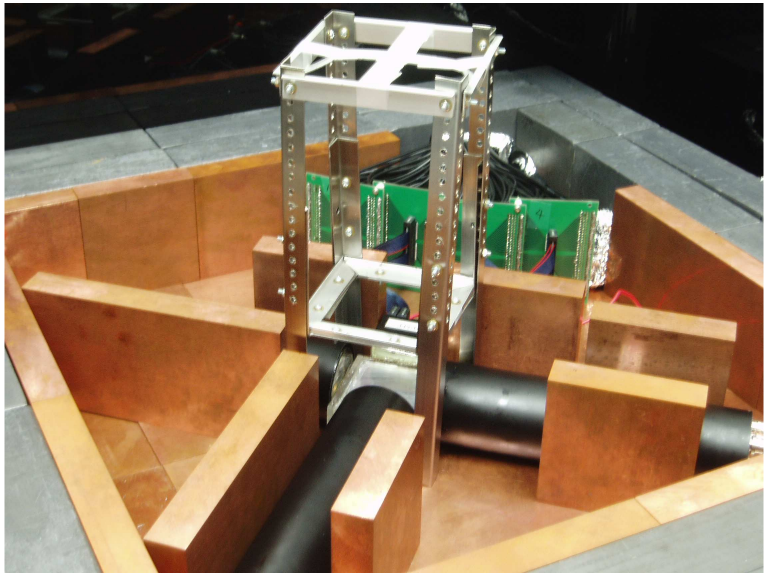
- Energy resolution (^{241}Am , ^{133}Ba)
Background reduction
WIMPs search

H.Kawasuso, K.Yasuda



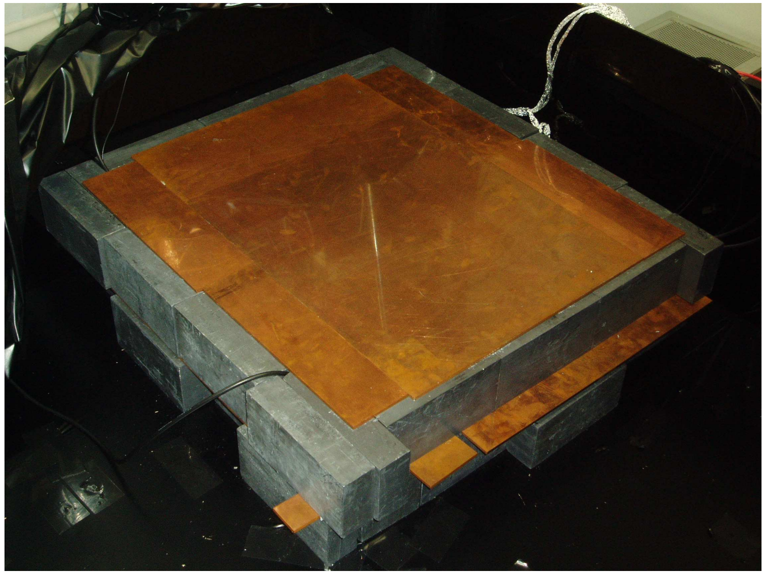


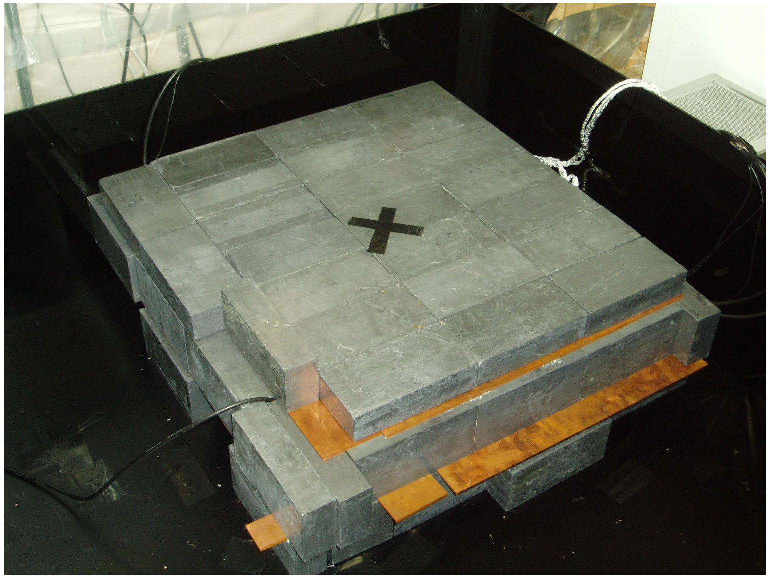


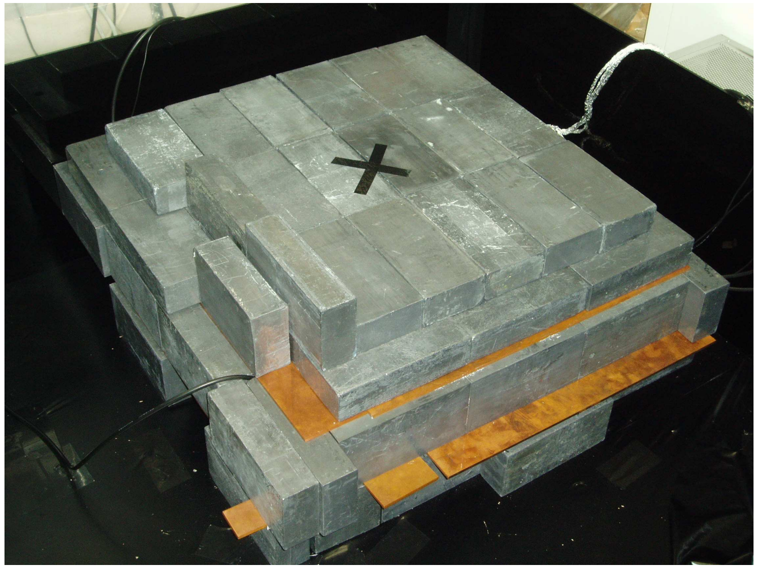


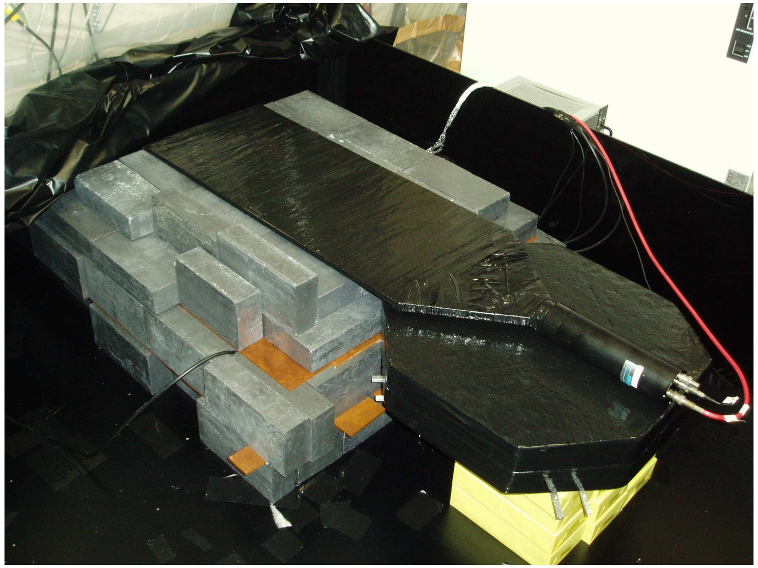
H.Kawasuso, K.Yasuda

Background reduction







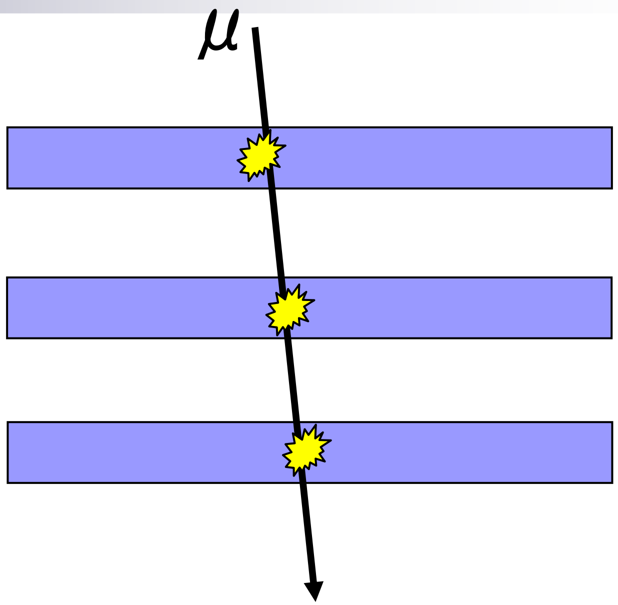


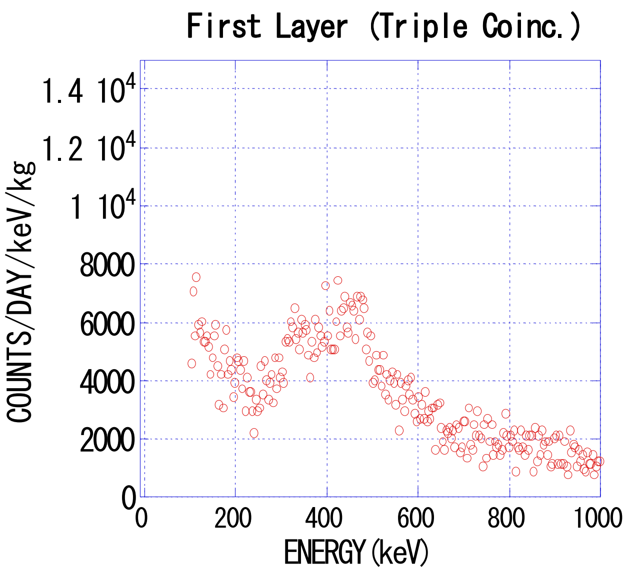
H.Kawasuso

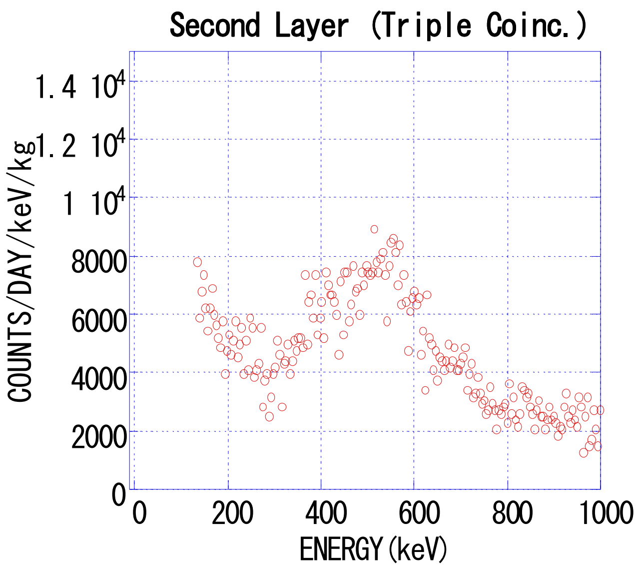
Performance check

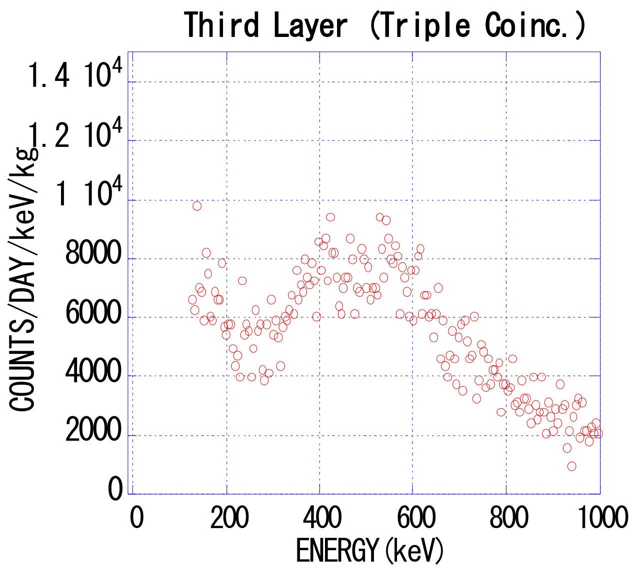
Cosmic ray

Energy deposit of cosmic ray
$\approx 400\,\text{keV}$



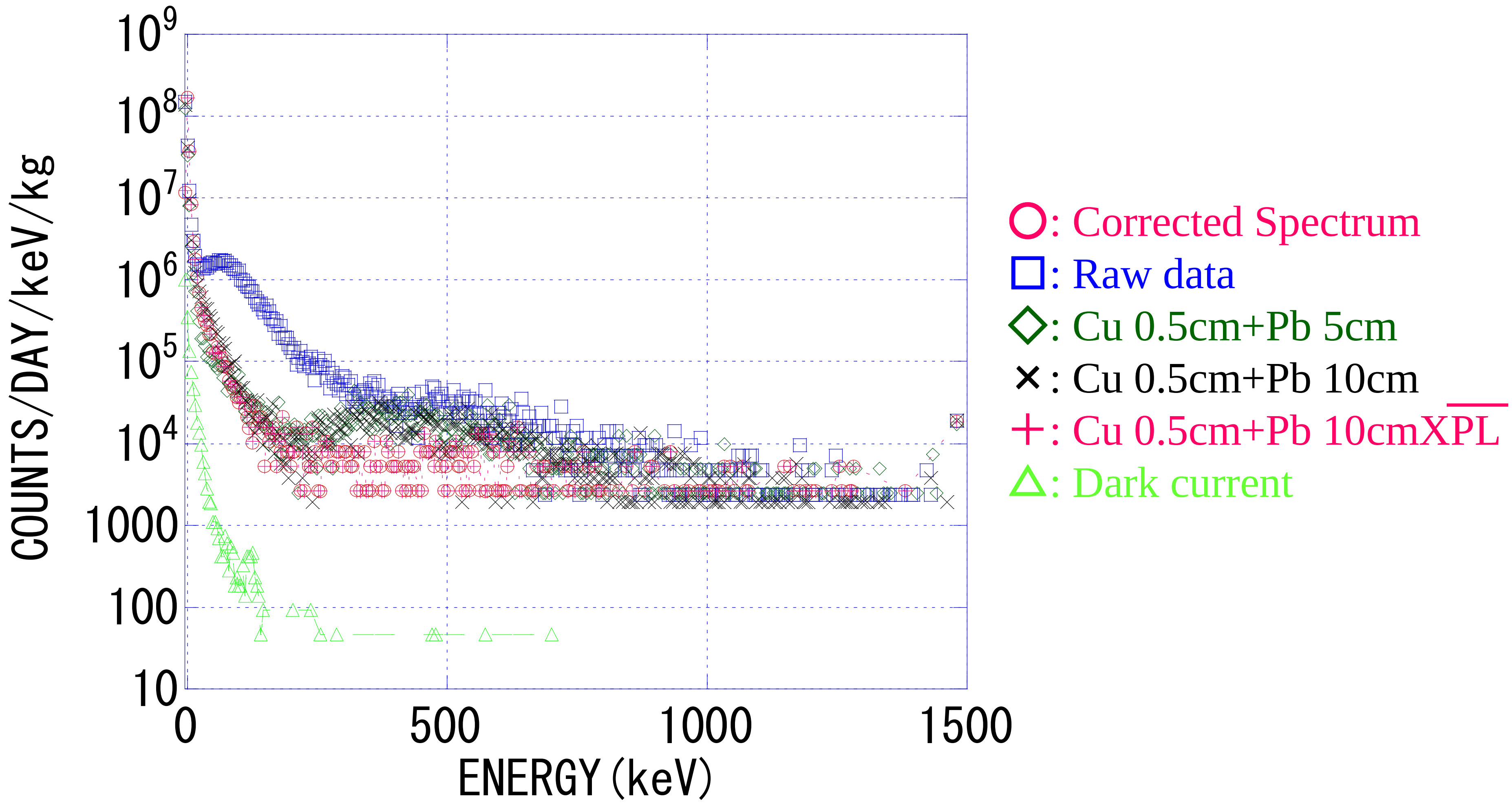






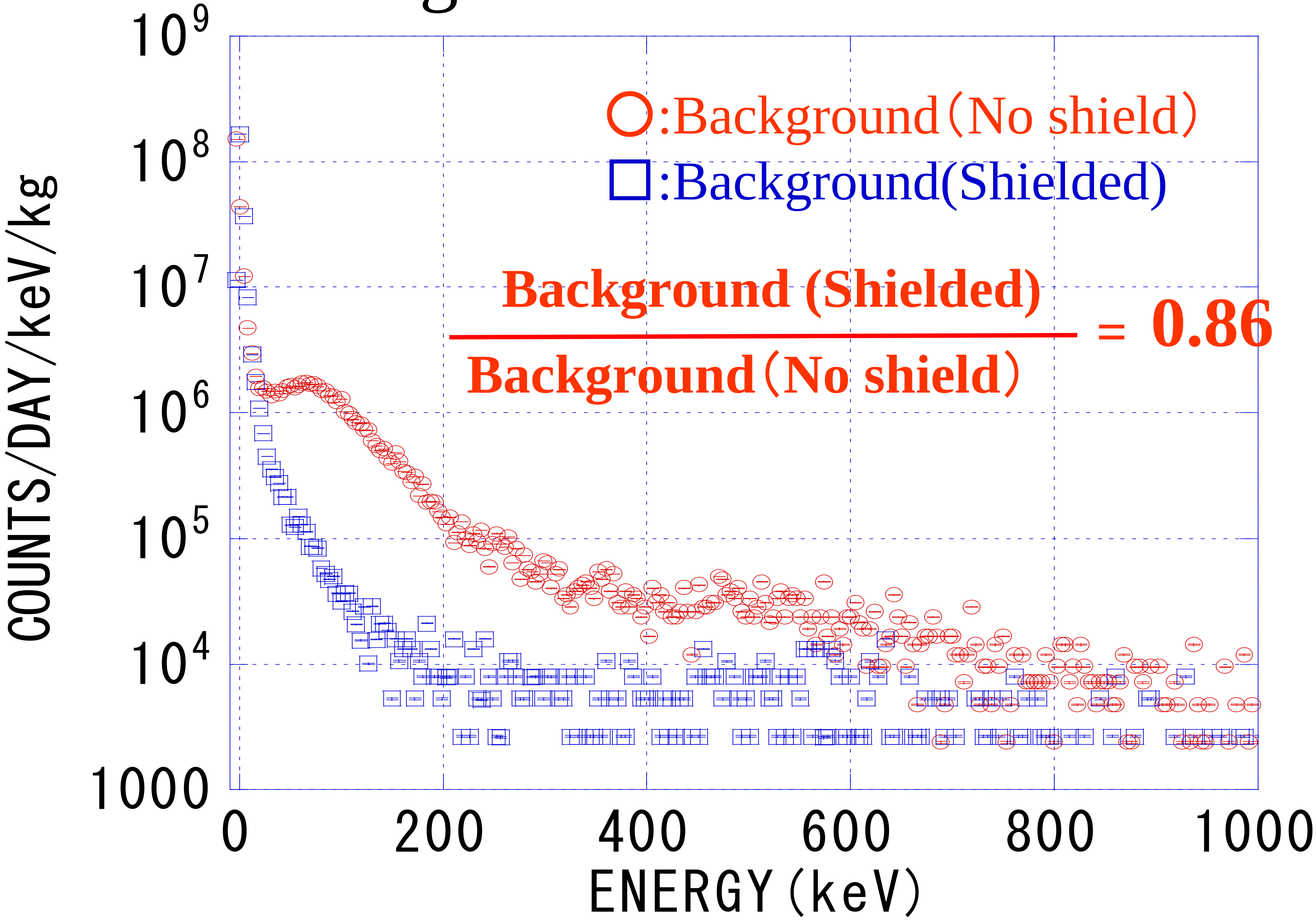
Experiment in Tokushima Univ.

Preliminary!

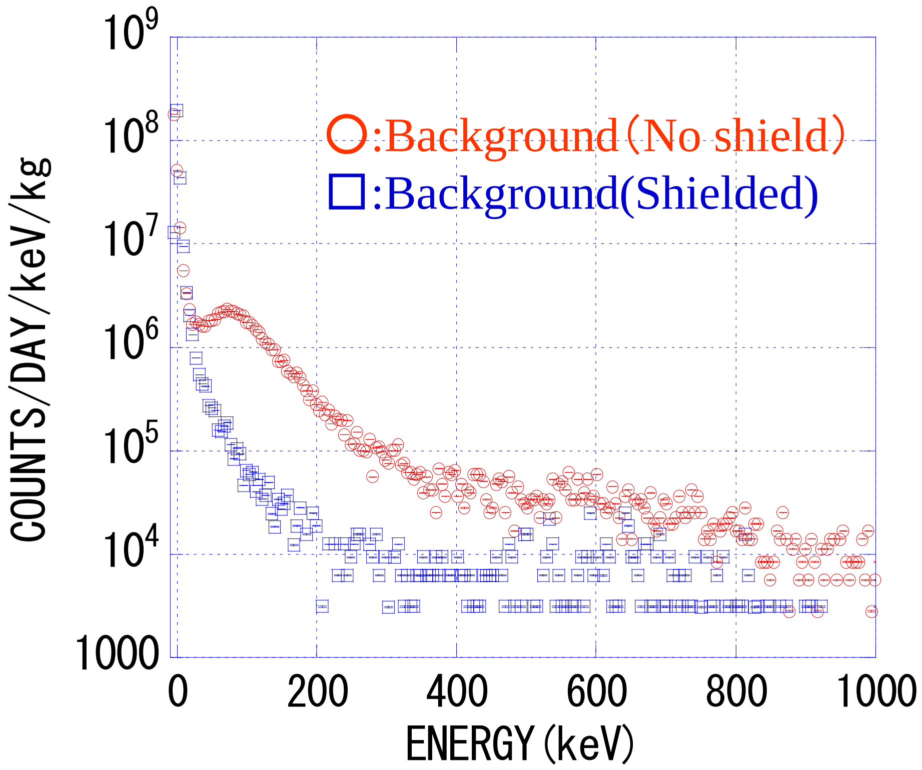


H.Kawasuso

Background reduction

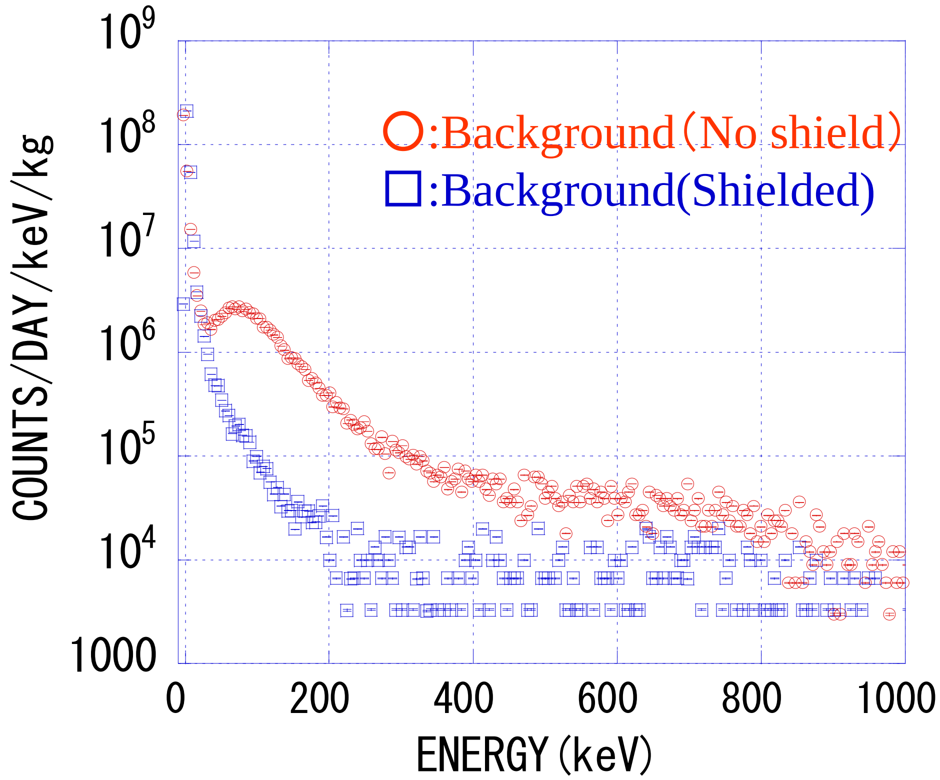


Second layer



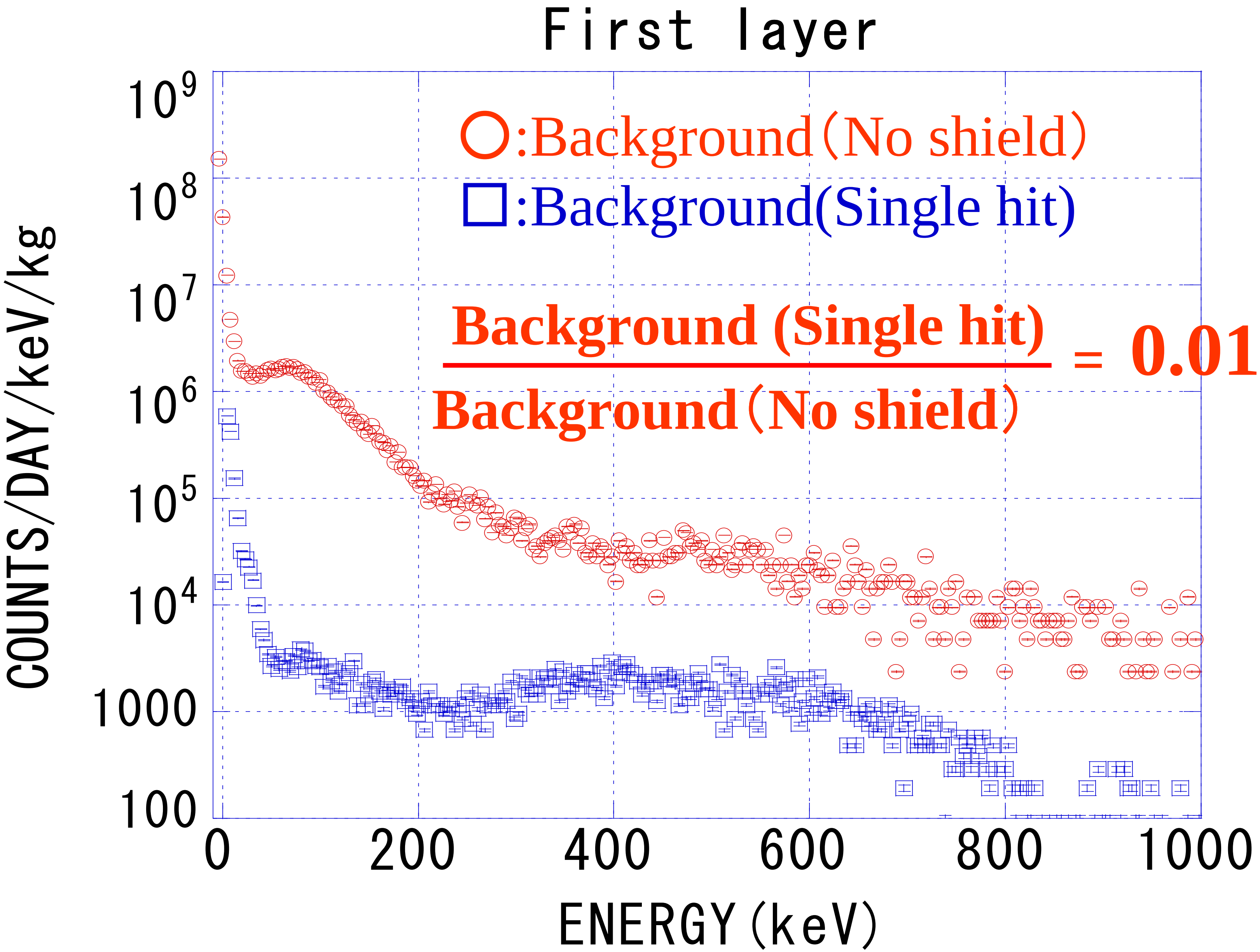
$$\frac{\text{Background (Shielded)}}{\text{Background (No shield)}} = 0.86$$

Third layer

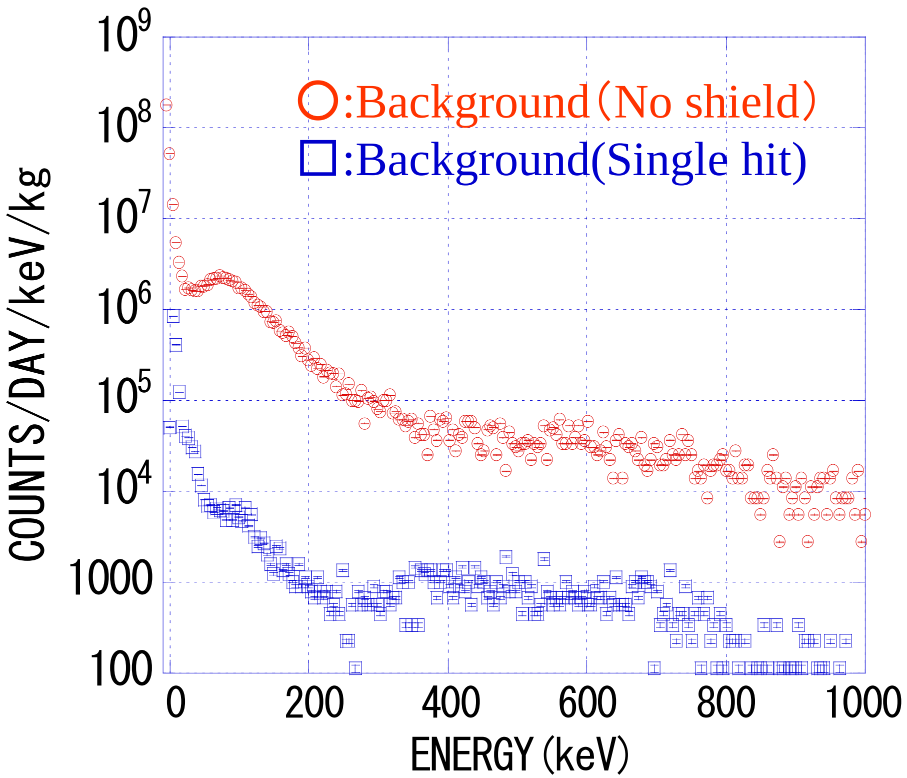


$$\frac{\text{Background (Shielded)}}{\text{Background (No shield)}} = 0.86$$

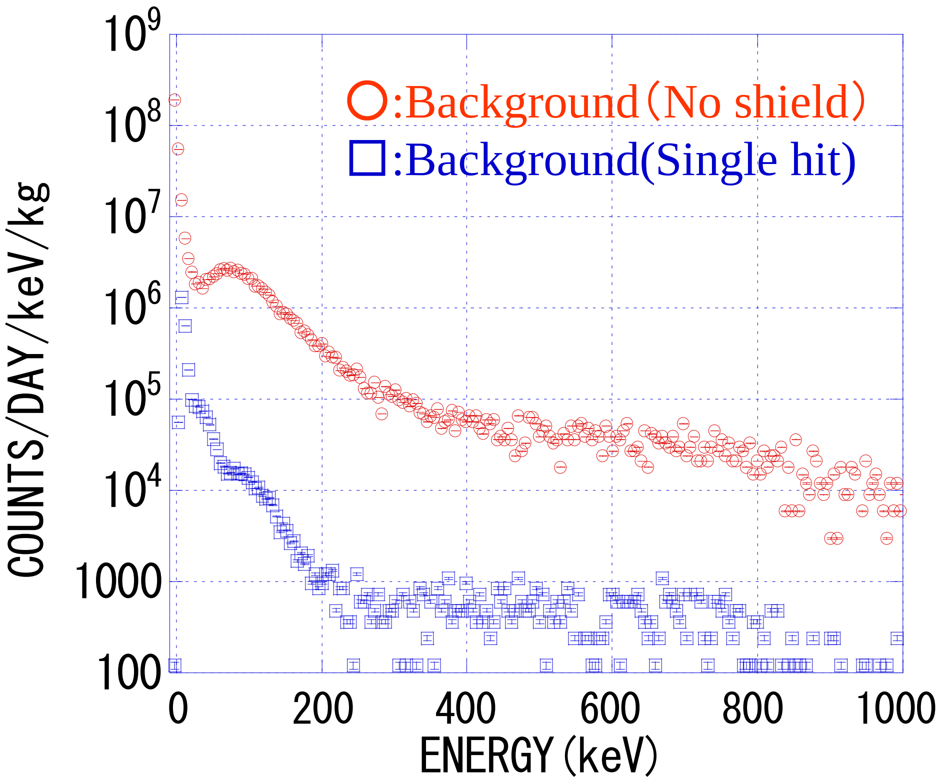
Single Layer Hit



Second Layer



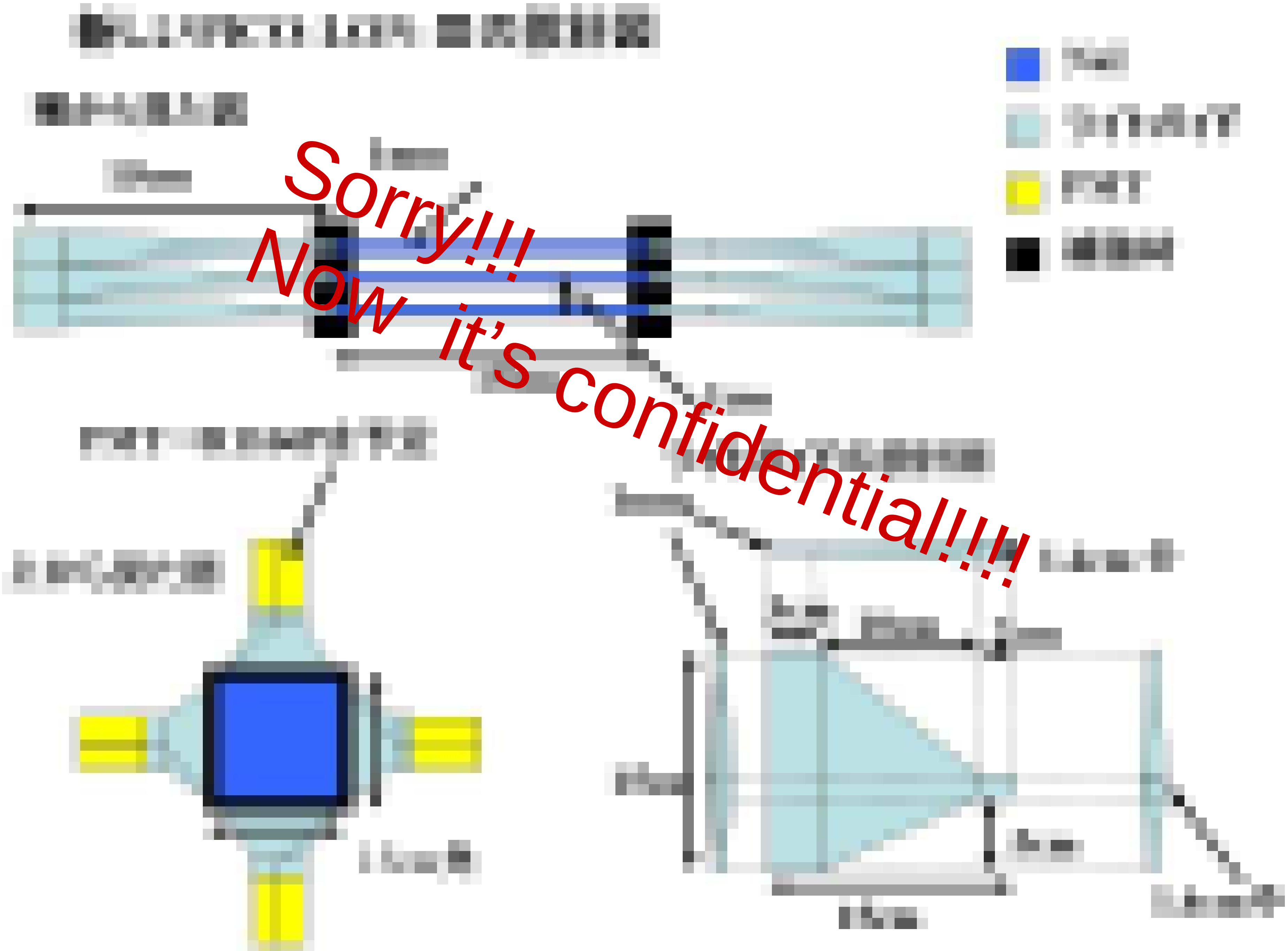
Third Layer



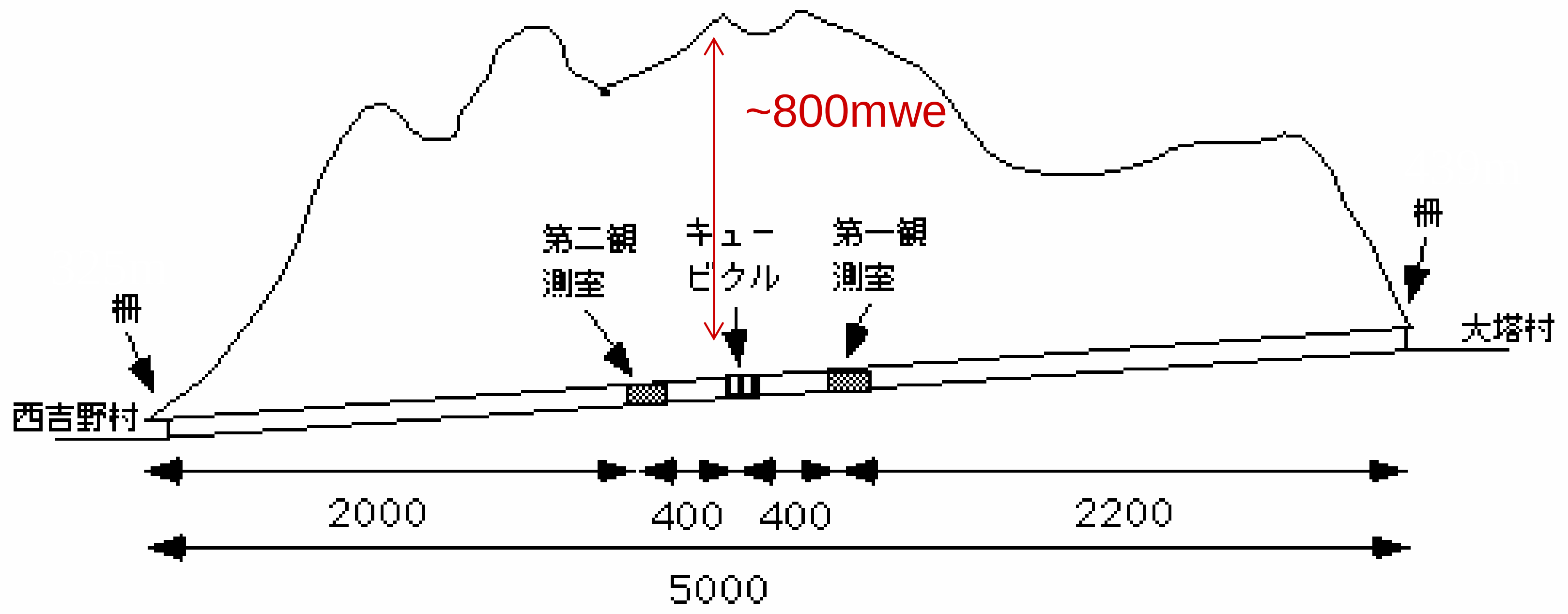
$$\frac{\text{Background (No shield)}}{\text{Background (Single hit)}} = 0.01 \qquad \frac{\text{Background (No shield)}}{\text{Background (Single hit)}} = 0.01$$

Future Plan of PICO-LON

- Larger area 15cmX15cm
- No MAPMT


Sorry!!!
Now it's confidential!!!!

OTO Cosmo Observatory



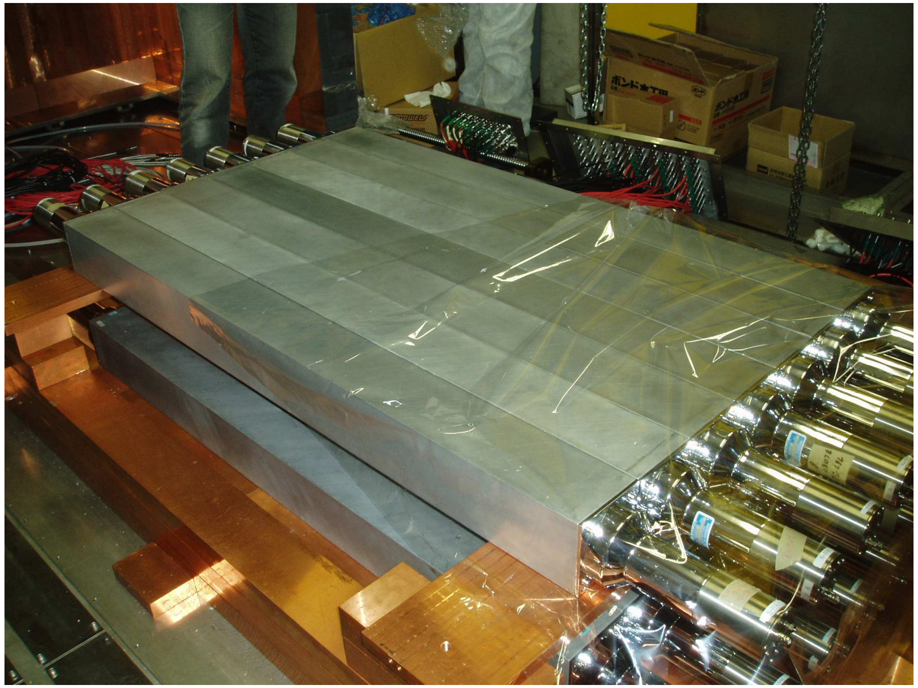
OTO

Cosmic ray : 4×10^{-7}/cm²/sec
Neutron : 4×10^{-5}/cm²/sec
Rn : ～10Bq/m³

Surface

Cosmic ray : 1.6×10^{-2}/cm²/sec
Neutron : 8×10^{-3}/cm²/sec
Rn : ～20Bq/m³

2nd Laboratory in OTO



- Segmentation of NaI(Tl) enhances the sensitivity
  - High selectivity of signal and BG by segmentation
  - 0.05cmX5cmX5cm NaI(Tl) plates was successfully made.
- Good performance was obtained
  - 20% FWHM at 60keV
  - E_{th}~2-3keV(S.P.E~0.35keV)
  - 3 layers detector (PICO-LON-II) and larger area detector (PICO-LON-III)
- Prospect
  - PICO-LON-II will be installed into OTO in July.
  - PICO-LON-III will be installed into OTO in this winter.