Development in MOON

-- MOON-1 prototype detector status --

NOMACHI, Masaharu , Osaka University

MOON collaboration

MOON collaboration

P.J.Doe, R.G.H.Robertson, D.E.Vilches, J.F.Wilkerson、D. I. Will.
CENPA, Univ. Washington.
H.Ejiri, T.Itahashi, N.Kudomi, T.Shima
RCNP
R. Hazama, K.Ichihara, S.Umehara, K.Matsuoka, H.Nakamura,
M.Nomachi, T. Ogama, T. Sakiuchi, Y.Sugaya and V.H.Hai
Osaka Univ
S.Yoshida
Tohoku Univ
S.R.Elliott, LANL
J.Engel. Phys.Astronomy, Univ. North Carolina.
M.Finger, and K. Kuroda, Phys. Charles Univ. Prague

K.Fushimi, GAS, Tokushima Univ. Tokushima
M. Greenfield, ICU, Tokyo.
A.Gorin, I.Manouilov, A.Rjazantsev. High Energy Physics, Protvino.
A. Para FNAL
A. Sissakian, V. Kekelidze, V. Voronon, G. Shirkov A. Titov, JINR
V. Vatulin, V. Kutsalo, VNIIEF

MOON Project

(Molybdenum Observatory Of Neutrino)

- Object
  The effective Majorana mass 50meV with ~ton of ^{100}Mo.

- Characteristic
  - Source is separated from detector.
    It can be used ^{82}Se, ^{150}Nd, and others as well.
  - ^{100}Mo
    - The large Q value of ^{100}Mo is 3.034MeV.
      ^{100}Mo has large phase space factor proportional to $Q_{\beta\beta}^5$ for $0\nu\beta\beta$.
    - $0\nu\beta\beta$ energy signal well above most BG(<3 MeV).
    - The natural abundance is large.
  - Plastic scintillator(PL)
    - Purity of a PL is high.
    - Processing is easy to large scale.

Isotope	$Q_{\beta\beta}$ (MeV)	$G^{0\nu}$ ($10^{-14}y^{-1}$)	A (%)
^{48}Ca	4.276	4.46	0.187
^{76}Ge	2.039	0.44	7.8
^{82}Se	2.992	1.89	9.2
^{100}Mo	3.034	3.17	9.6
^{150}Nd	3.368	13.4	5.6

G^{0n}: phase space volume
A: isotope abundance ratio

MOON Detector

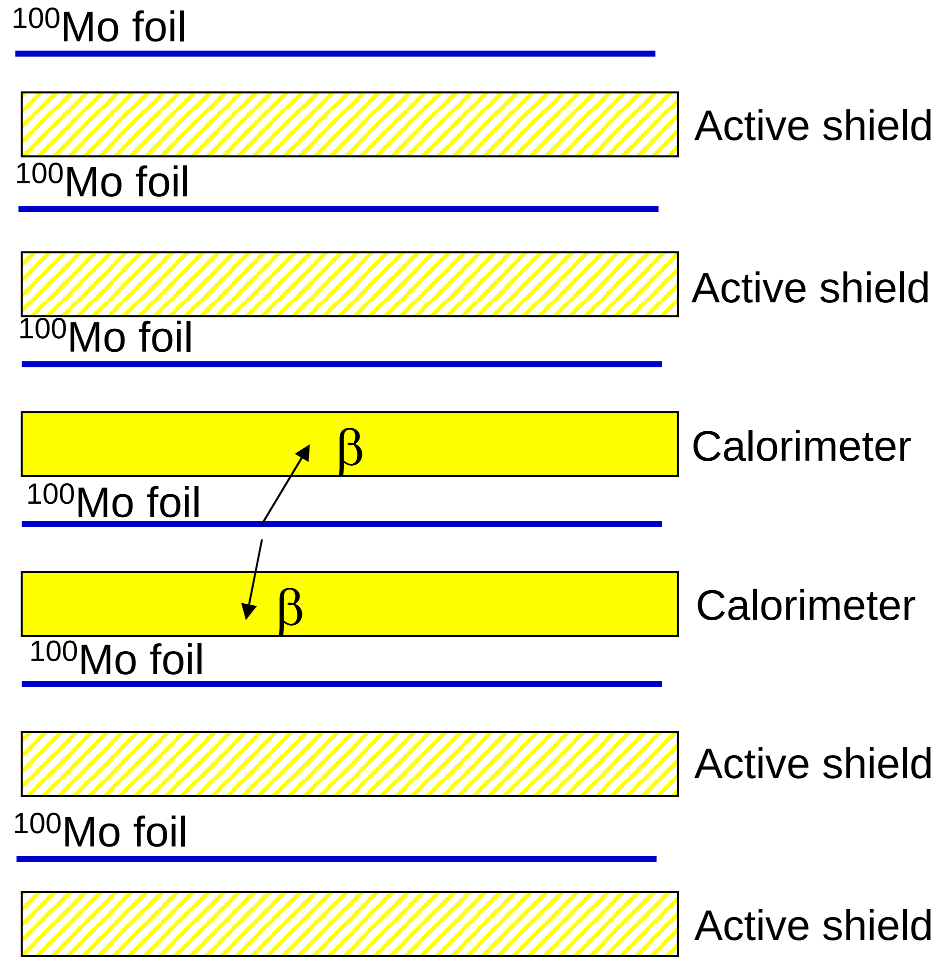
- **Multi layers module**
  - **^{100}Mo foil & Plastic scintillator**

    Mo foil is interleaved with PLs.
  - **Double layer hit**

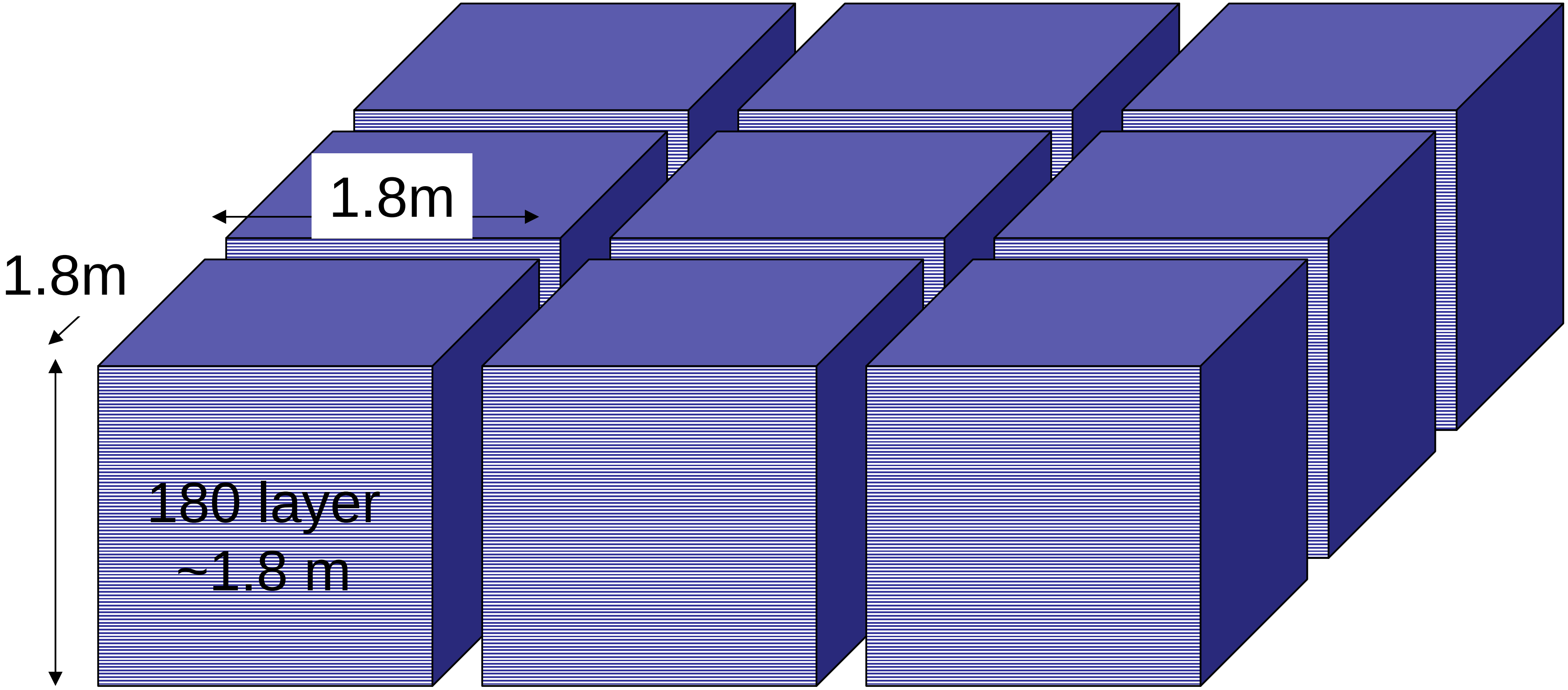
    To detect the double beta decay, two beta rays are detected by two PLs.
  - **Active shield**

    The other PL is used as active shield to reduce BGs.
  - **Compact module**

    PL works both as calorimeter and as active shield.



MOON



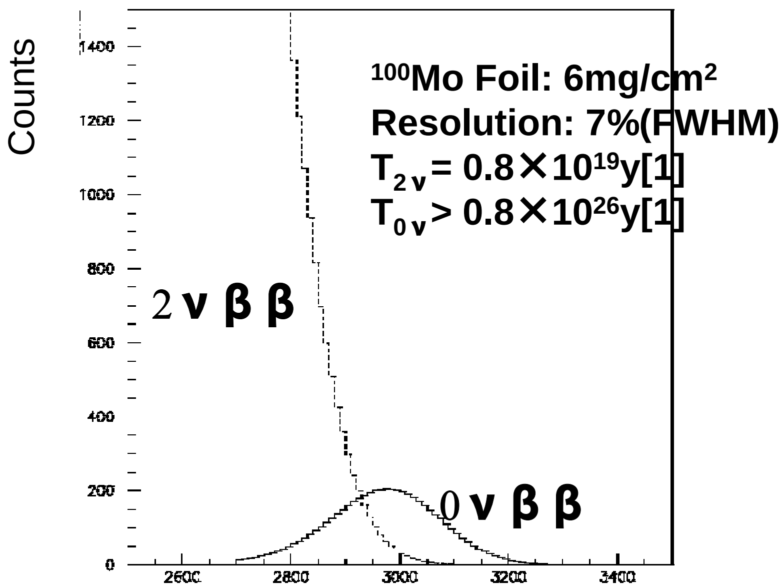
9 module x 1.8m x 1.8m x 180 layer= 5250m^2

^{100}Mo 40mg/cm^2 ~2t

Requirement on energy resolutuion

- **Good Energy resolution**

  including the energy loss in the foil and a detector resolution.



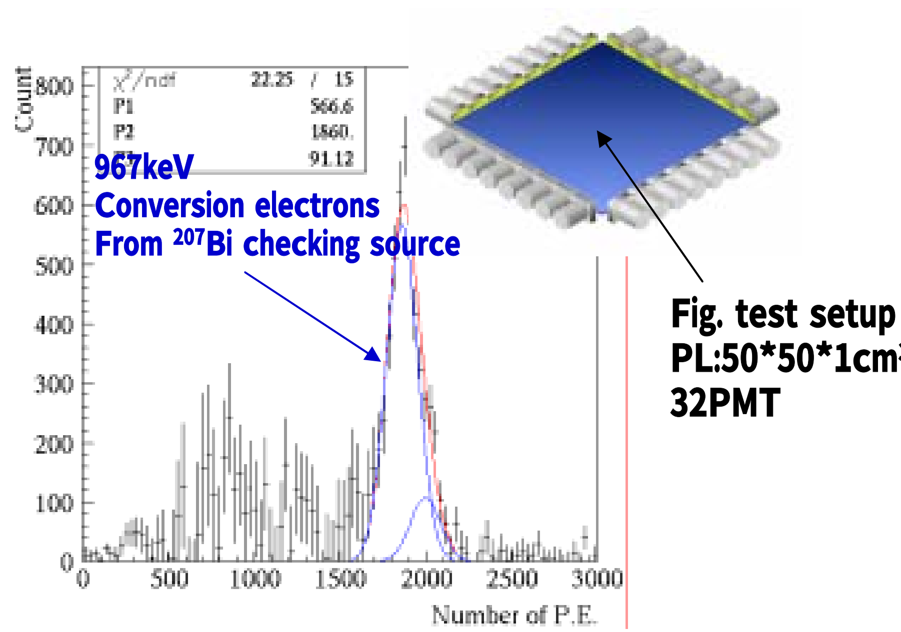
Good energy resolution is key to distinguish 0νββ from 2ν

[1] Nucl.Instrum.Meth.A536:79-122,2005

- **Photon Collection**

  To achieve the good energy resolution, photon collection efficiency should be high.

  MOON-1 detector is large coverage for sides of a scintillator with many PMTs (about 80 % surface of the four sides is covered.)



11.4%(FWHM) at 1MeV region.

MOON-1 Detector

MOON prototype detector (MOON-1) was developed
to study the energy resolution and BG rejection capability.

- **Plastic scintillator (PL), 6layers, 53x53x1cm^3**
  BC408. equivalent .
- **^{100}Mo(94.5% enrich), 142g 40mg/cm^2, 3layers**
  Mo foils are interleaved with two PLs.
  2νββ is expected to ~3decay/year
  in the energy window 2.7-3.2 MeV region.
  (7% energy resolution is assumed)
  - Aluminized Mylar films are used to support Mo foil. and also, to suppress the cross talk of photon between PL layers.
- **56 PMTs(^{40}K Free 0.7Bq) are attached to PLs.**
  HAMAMATSU, R6236-01 K-MOD
  - Silicon cookie is used for the optical contact.

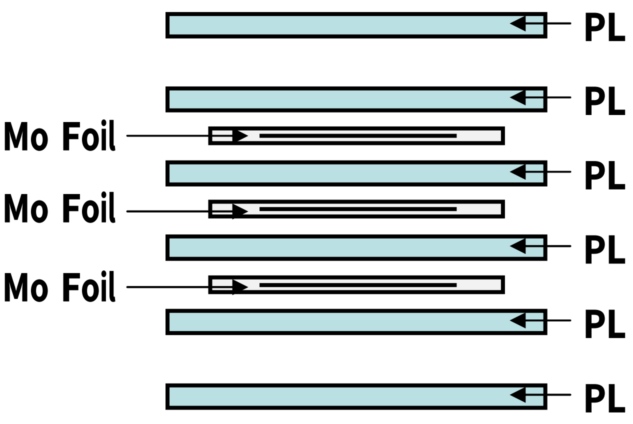
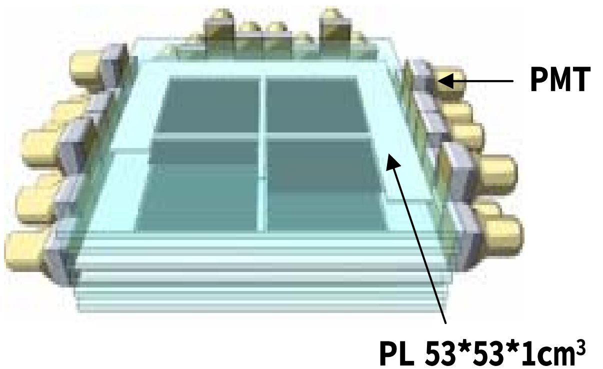
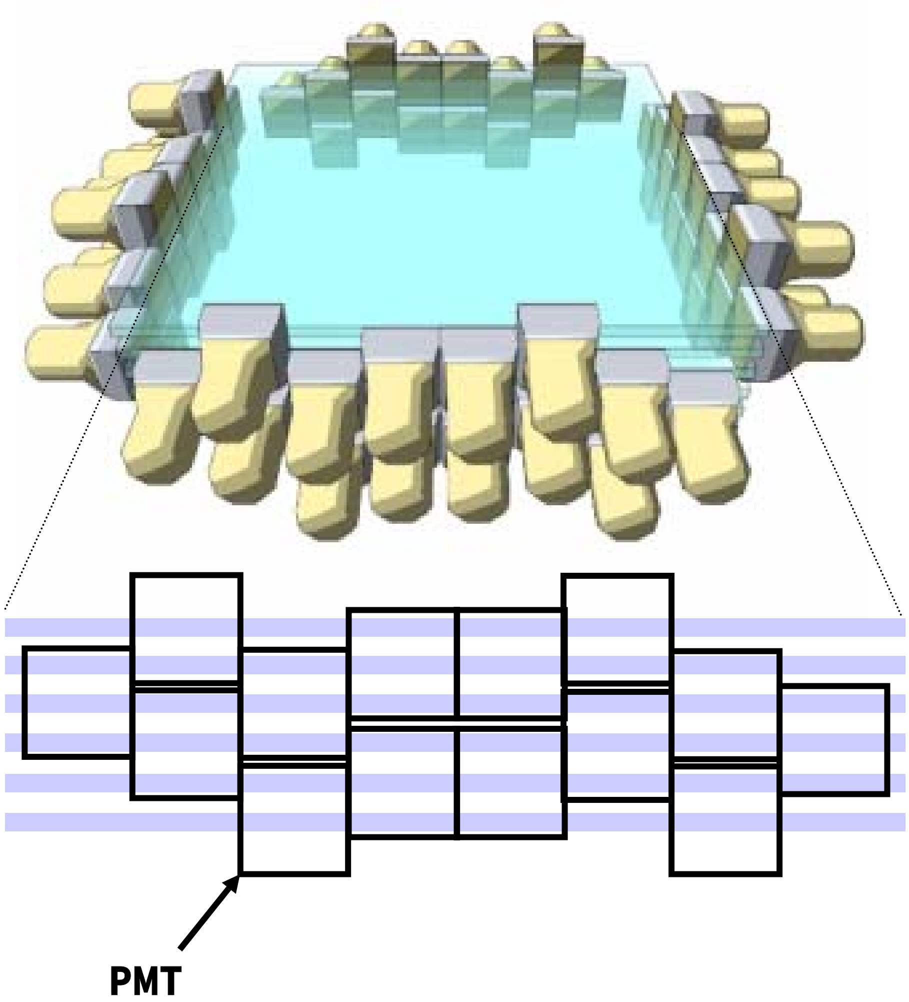


Fig. Cross section view of MOON-1

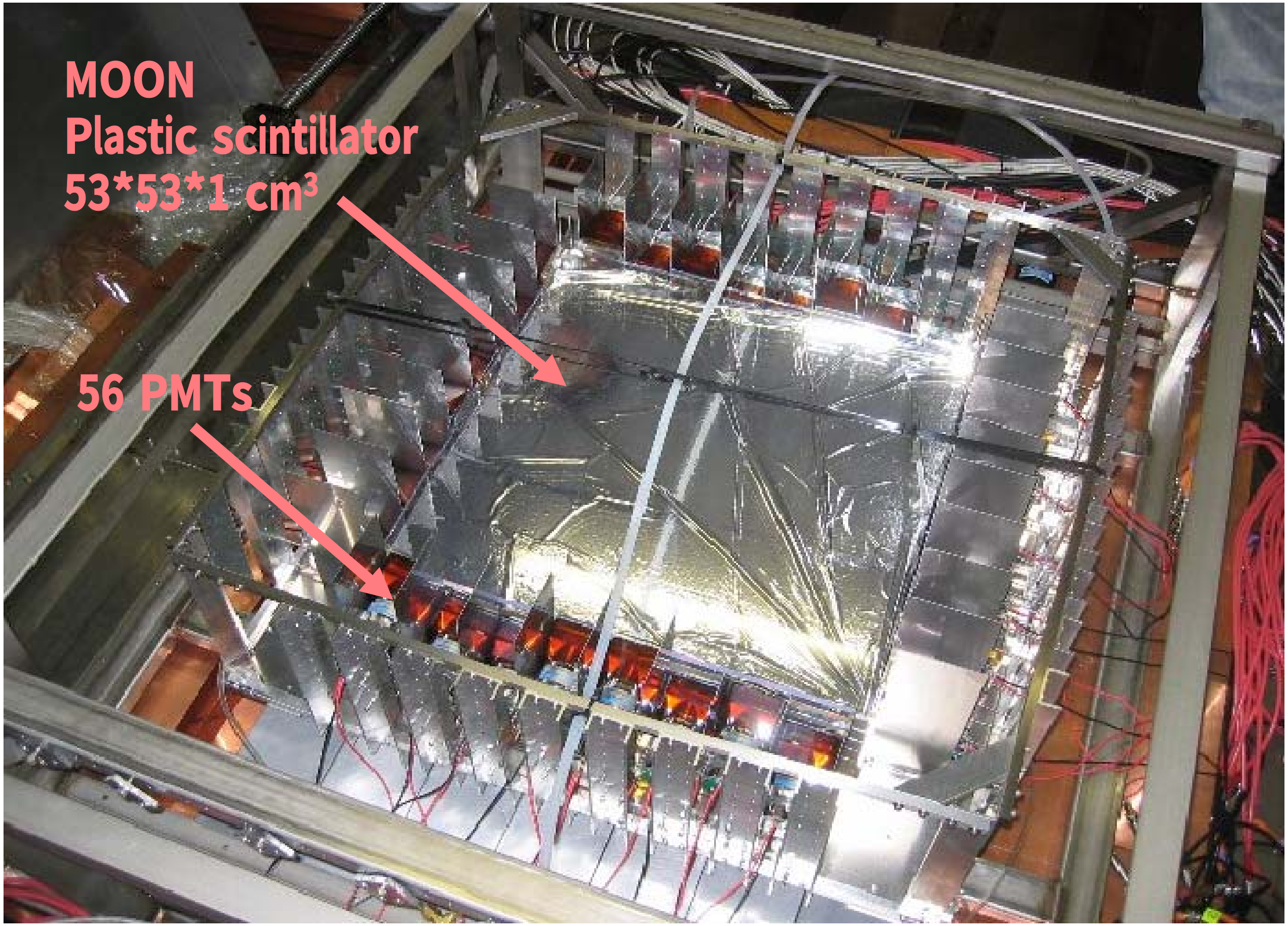


PMT location

- **A PMT is attached to the 3 plastic scintillators.**
- **The plastic scintillator, which has energy deposit, is identified by PMT hit pattern.**



MOON-1 detector



Oto underground Laboratory

MOON-1 detector has been working at Oto underground Laboratory since April/2005.

This lab was used at ELEGANT-V experiment.

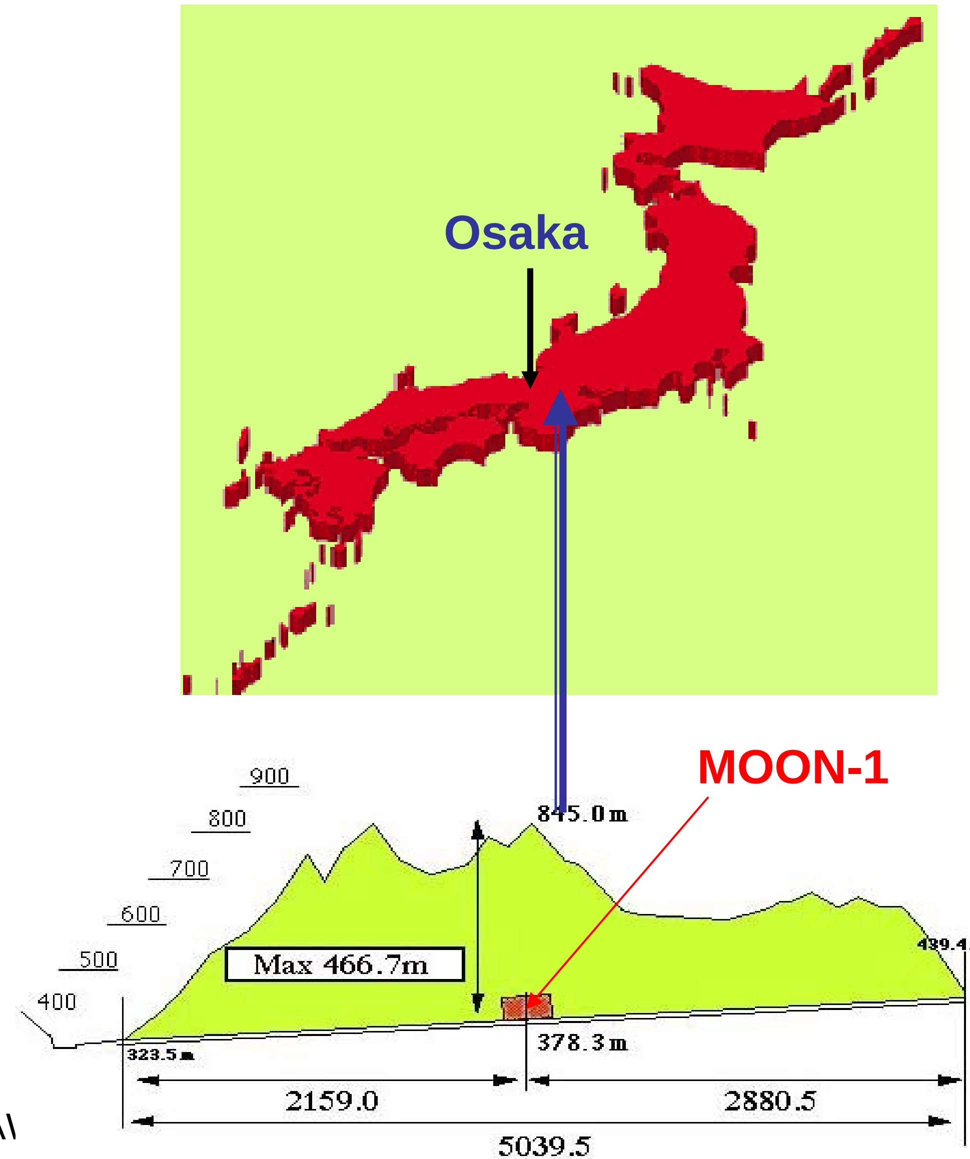
- **Depth**

  the lab is placed at 1,300m w.e.

- **BG level**

  The BG level were measured by ELEGANT group[2].

  - **Cosmic Ray: $4 \times 10^{-7}/cm^2/sec$**
  - **Neutron Flux: $4 \times 10^{-5}/cm^2/sec$**
  - **Rn: $10 Bq/m^3$**



[2] Nucl. Instr. and Meth. A459(2001)177-181

Experimental setup of MOON-1

MOON-1 is placed in active and passive shield.

- NaI(Tl) detector

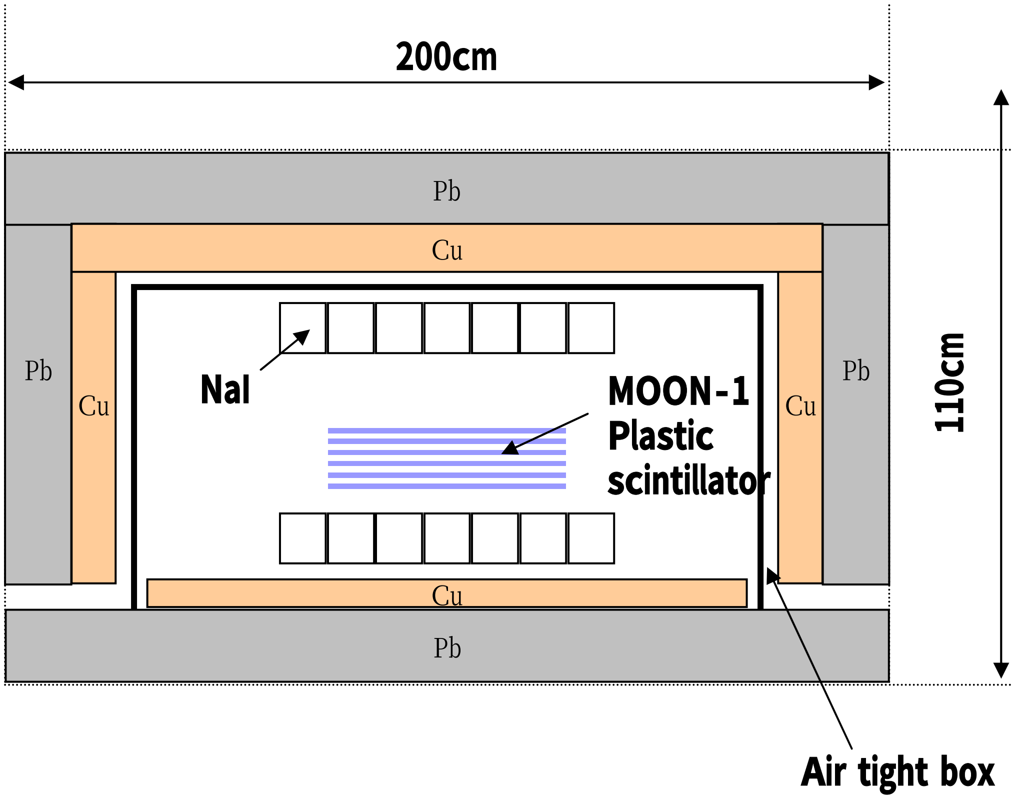
  14 of NaI(Tl) detectors are put above and below MOON-1 detector. Those are used as gamma ray active shield

- Air tight box

  To keep Rn concentration low, N_2 gas was flushing. Rn concentration was 125mBq/m^3.

- Lead & Copper passive shield

  The outside of the air tight box is covered with 10cm Cu, 15cm Pb as passive shield.



Analysis outline

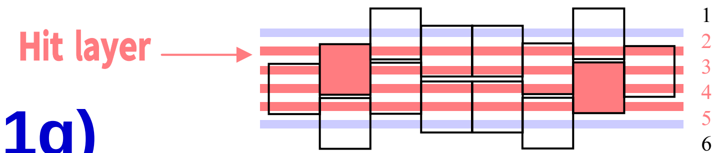
- **Measurement**

  The first data of 11 days (live time 276 hours).
- **Trigger**

  Any hit at 2,3,4,5 layer is required for trigger.

  Trigger signal is made by summed signal of 8 PMT on four sides.

  The trigger threshold is 180 keV.



- **Analysis for one layer of Mo foil (51g)**

  1) Energy calibration

  2) The double layer hit event selection

  3) The sum energy spectrum for
     double layer hit events.

  4) The remaining events

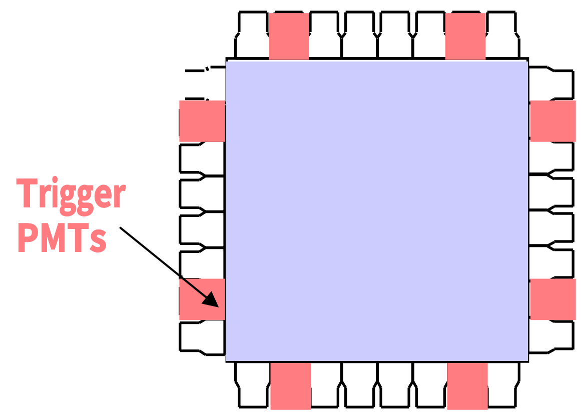
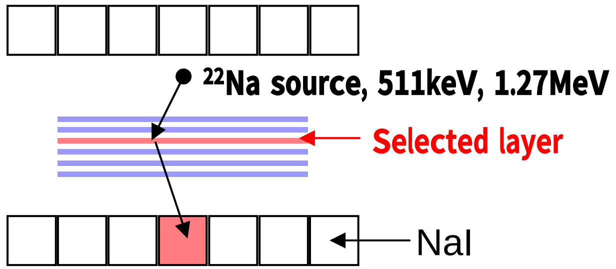
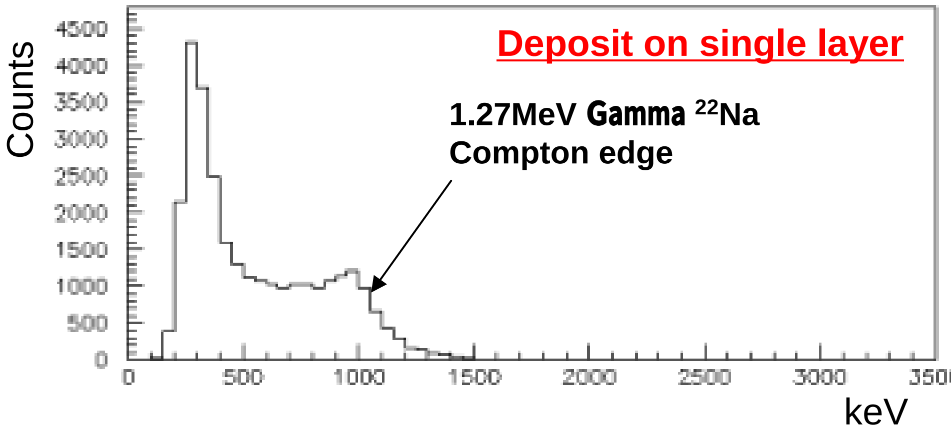


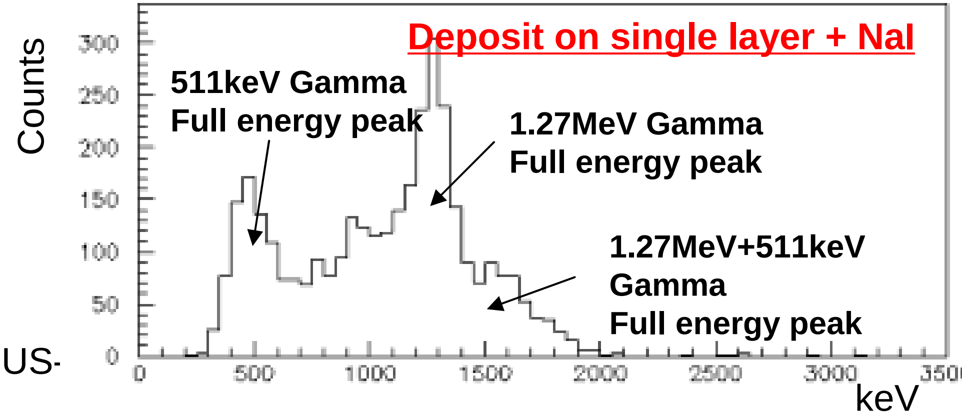
Fig. the schematic view of MOON-1

Energy calibration

- **Energy calibration**
  Compton edge of 1.27MeV gamma-ray from ^{22}Na source
  single layer events are selected.
- **Full energy peak**
  The sum of the energy deposits on plastic and NaI(Tl) may cause full energy peak.
- **MOON-1 energy resolution**
  The energy resolution is 15%(FWHM) for 1.27MeV full energy peak.
  The energy resolution of NaI(Tl) is 9%(FWHM) at 1.27MeV.

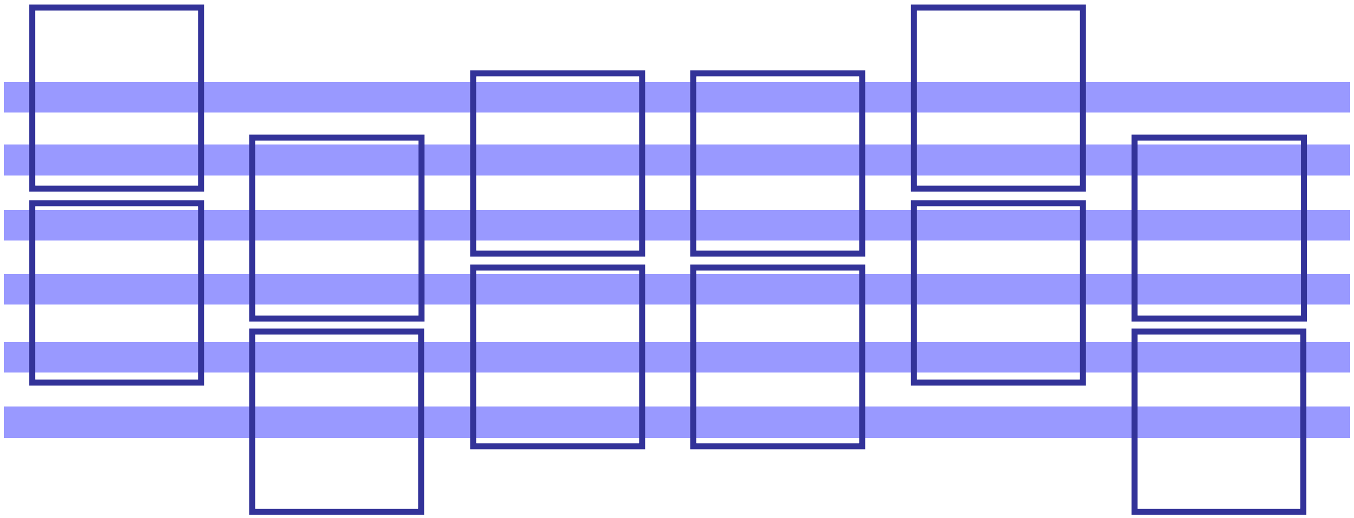






Event selection by PMT hit pattern

- **PMTs are attached to plastic scintillators.**

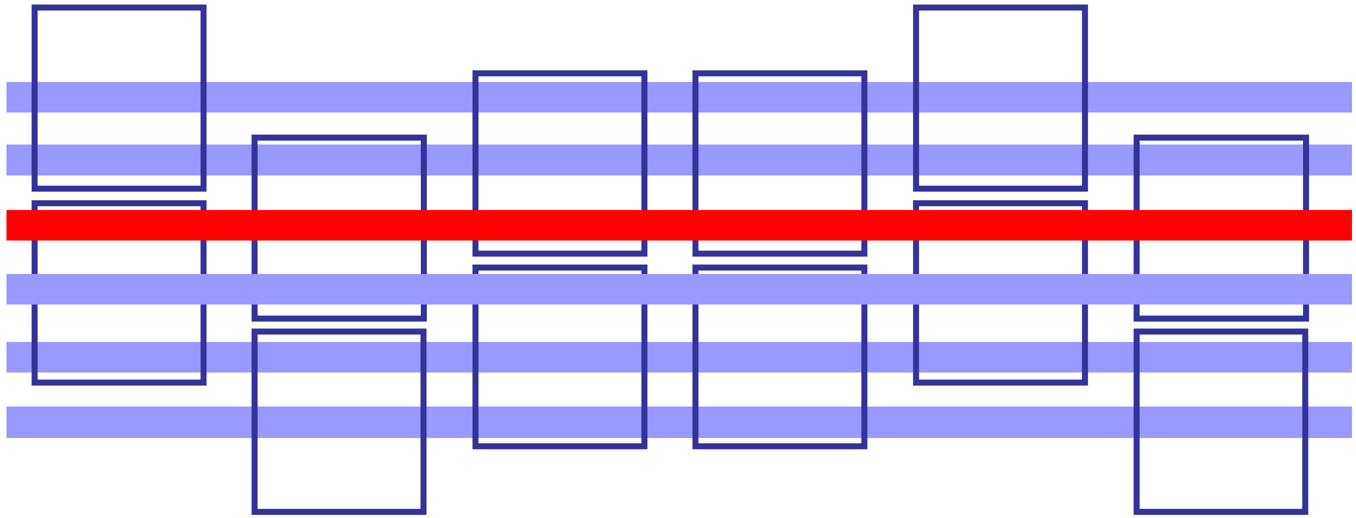


Each PMT is attaced to 3 plastic scintillators.

Hit pattern of 12 PMTs are used for event selection

Event selection by PMT hit pattern

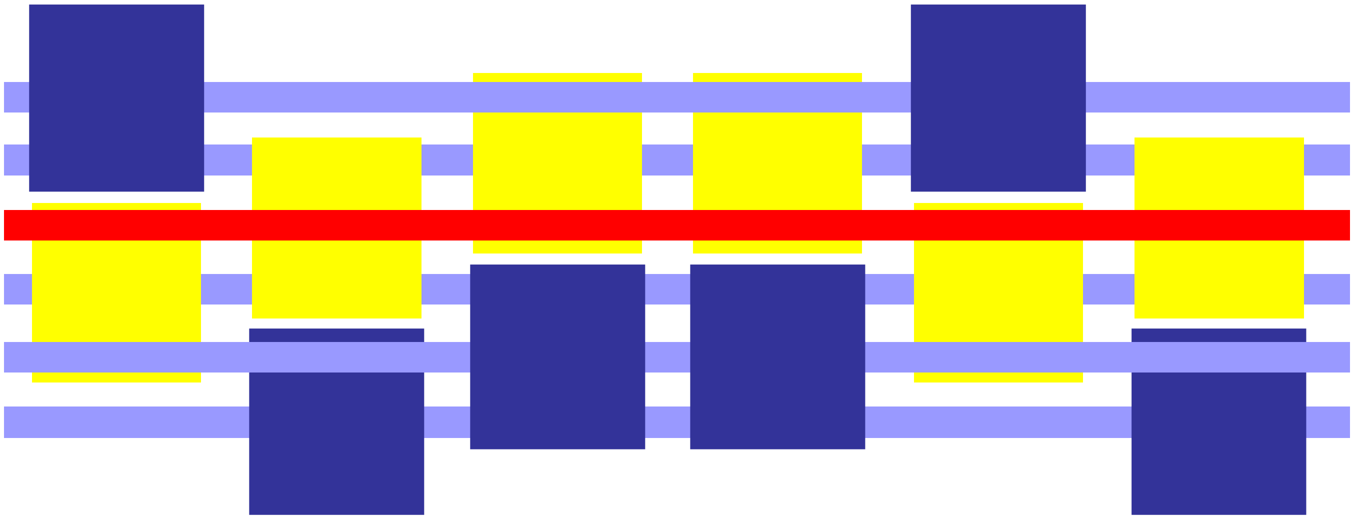
- **Single layer Hit events**



For the energy calibration, single layer hit events are selected.

Event selection by PMT hit pattern

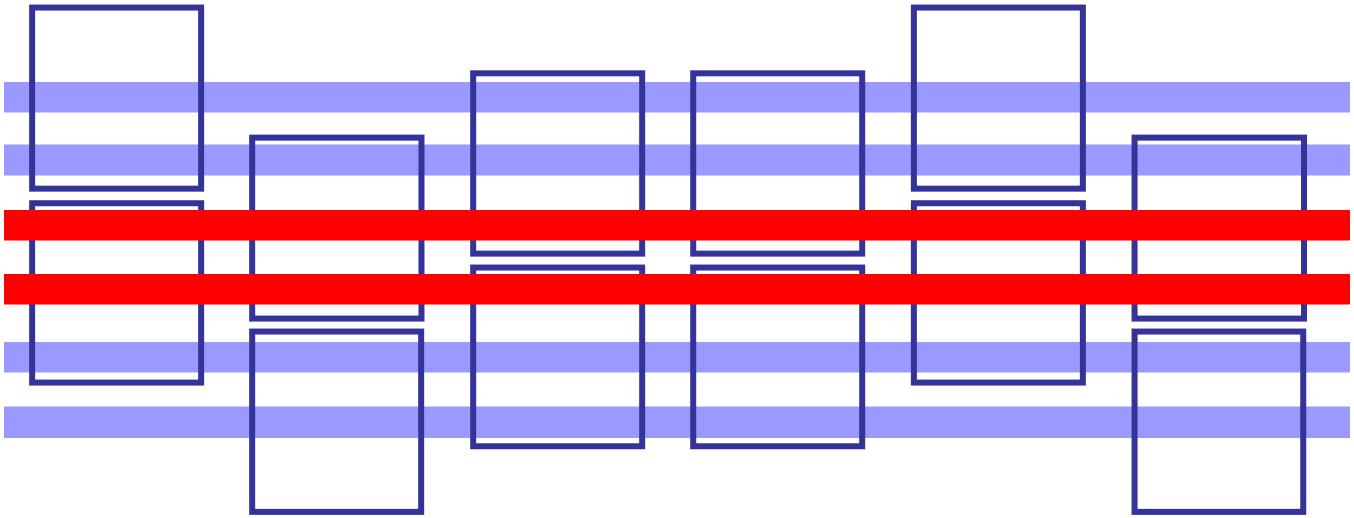
- **Single layer Hit events**



- Threshold Level -
Yellow PMT: 200keV
Blue PMT: 200keV

Event selection by PMT hit pattern

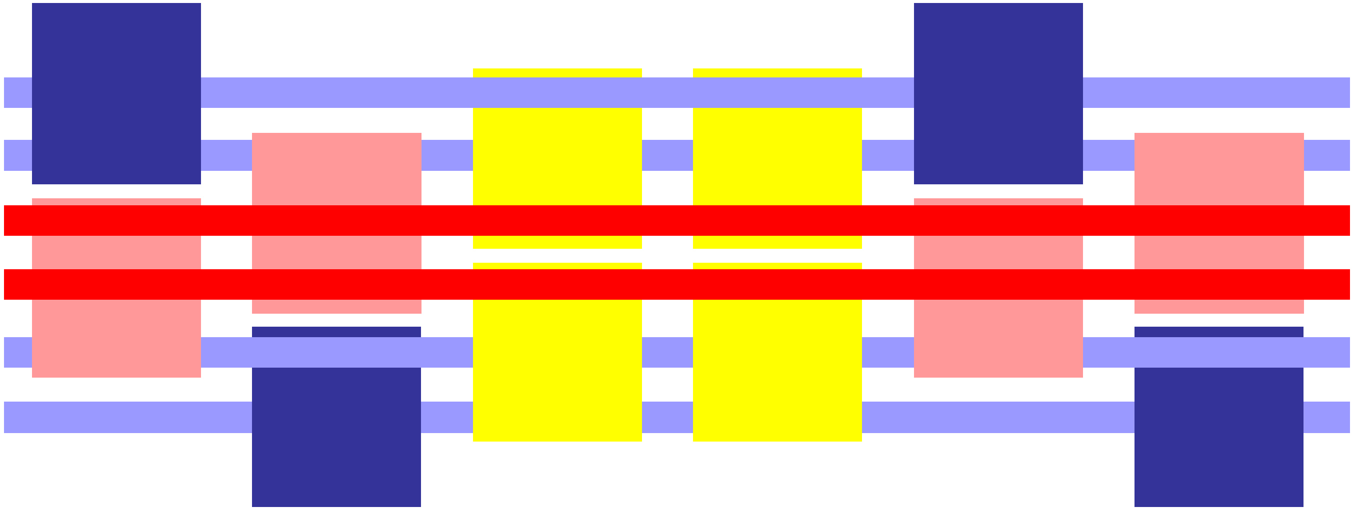
- **Double layer Hit events**



Double beta decay events are the double layer hit.

Event selection by PMT hit pattern

- **Double layer Hit events**



- Threshold Level -

Yellow PMT: 200keV

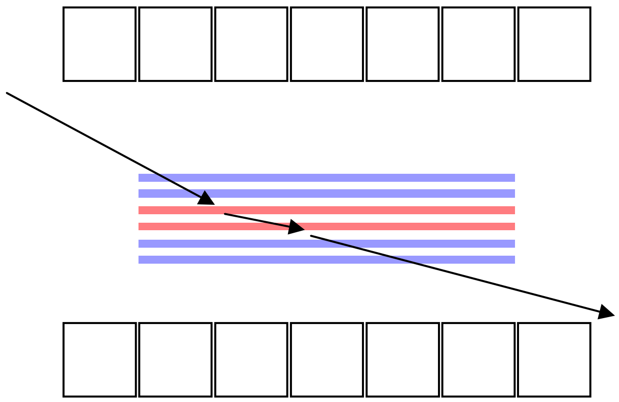
Red PMT: 500keV

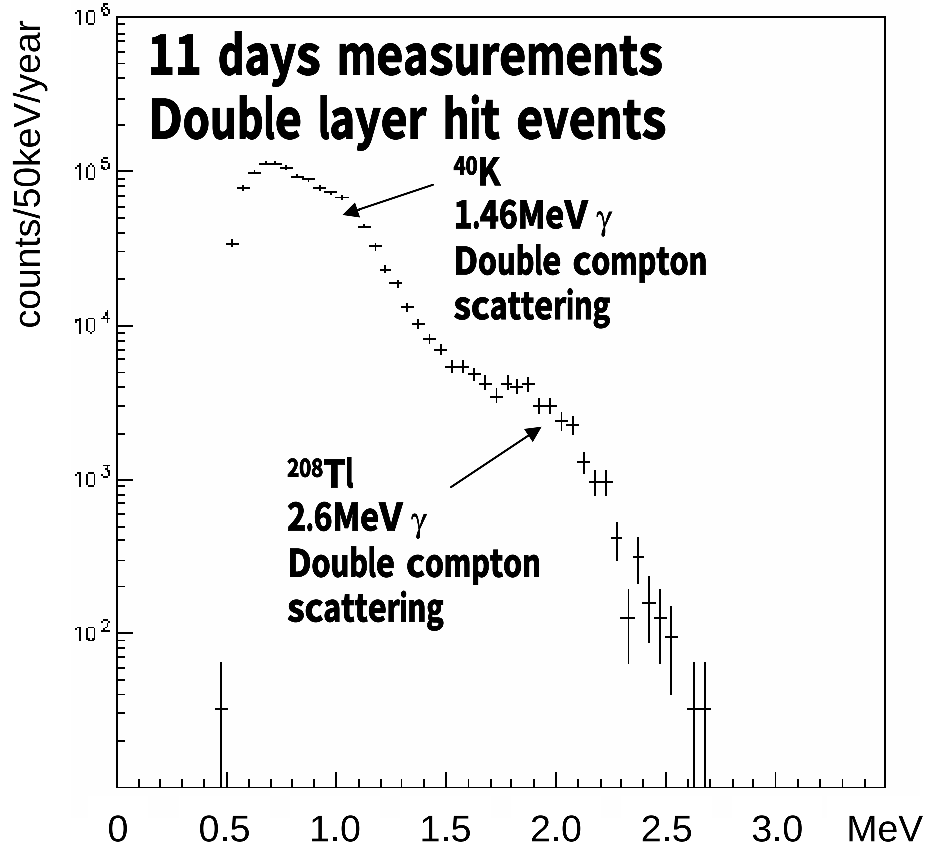
Blue PMT: 200keV

Double layer hit events

Sum energy spectrum

- the double layer hit events after 11 days of data collection
- 51g ^{100}Mo
- NaI detectors are used for gamma-ray veto.



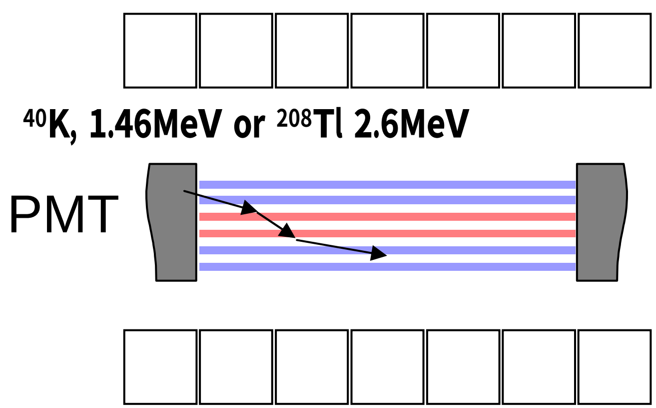


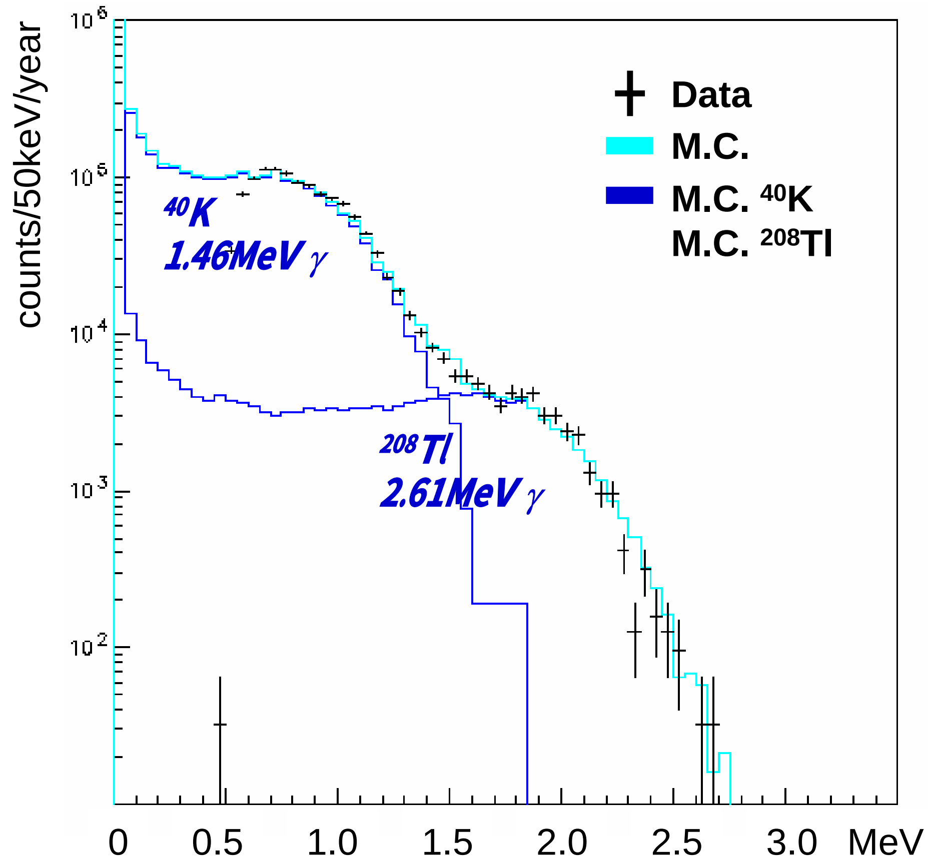
- **No event is observed at Q-value (3MeV) region.**

Remaining Events

1. M.C simulation

- M.C. simulation for double Compton scattering
- The gamma rays were generated at PMT.
- The Normalizations are selected to be fit experimental data.



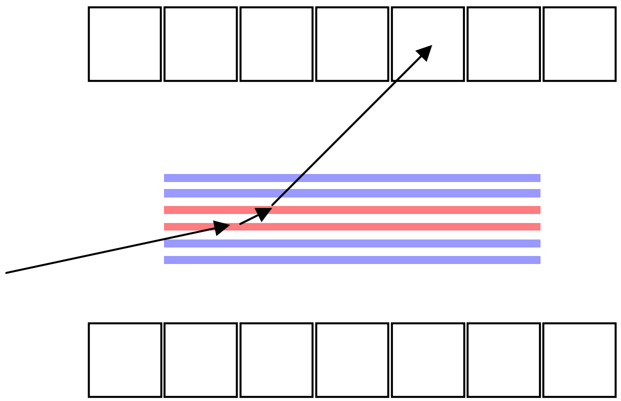


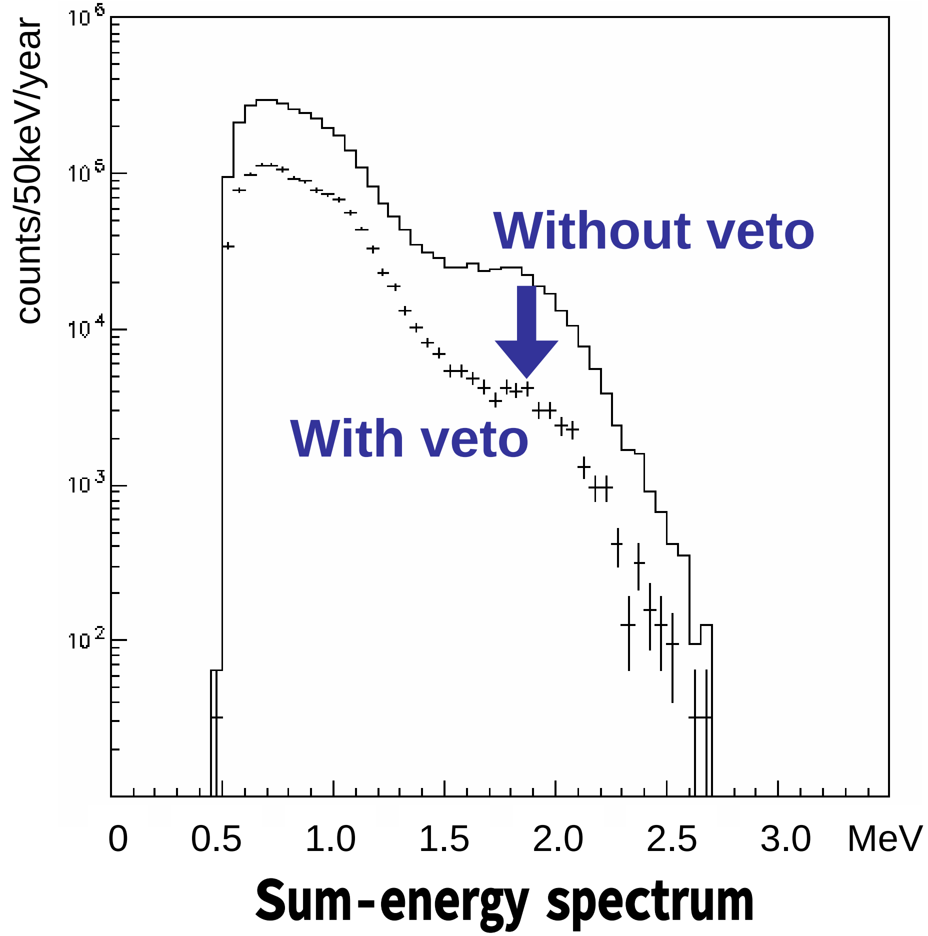
Sum-energy spectrum

- **The shape of the spectrum shows good agreement.**

Remaining Events

2. NaI active shield

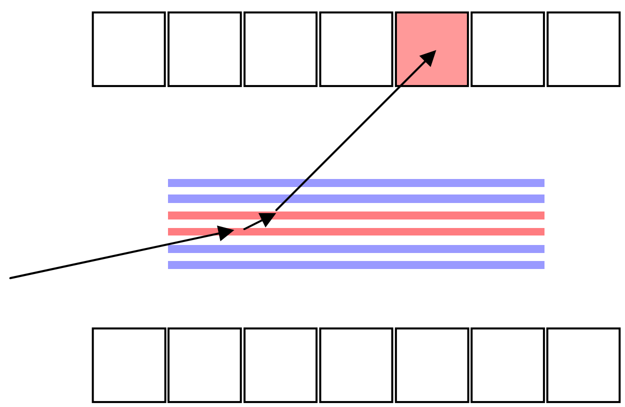




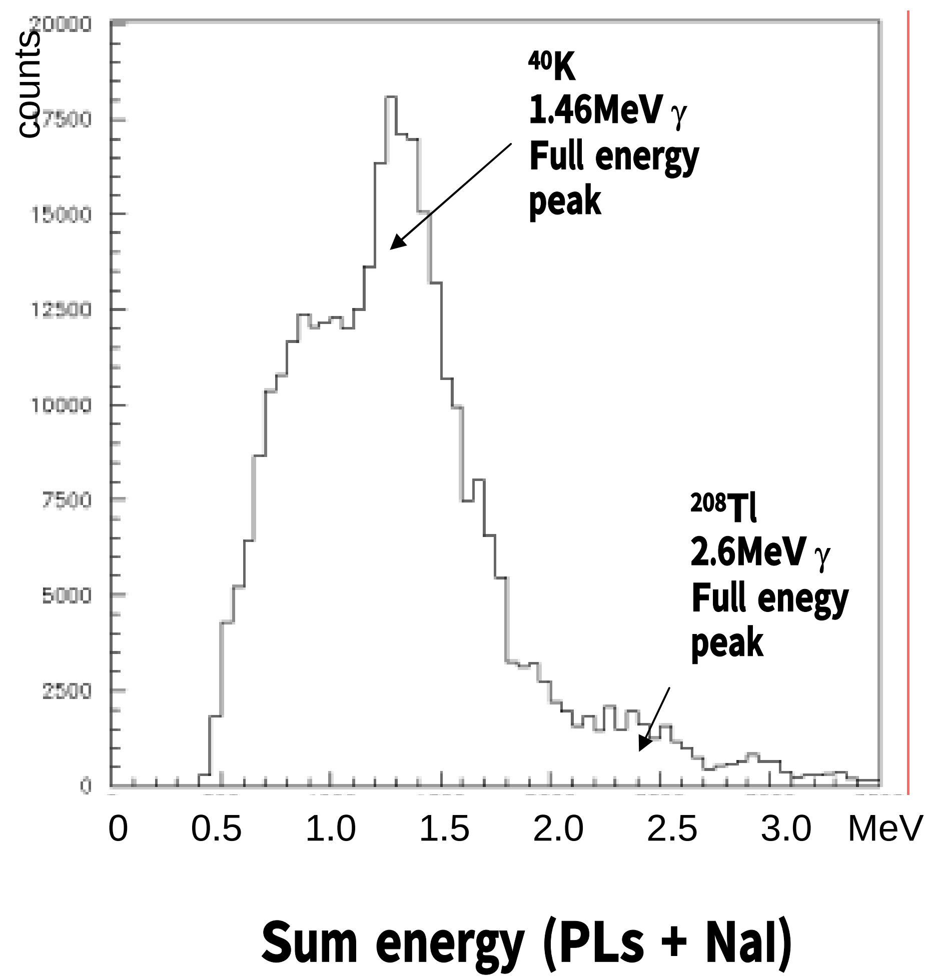
- **The events are reduced to about 50% by the gamma-ray veto.**
- **The amount of the reduction is consistent with the solid angle of NaI detectors looking from the MOON-1 detector.**

Remaining Events

3. Reconstructed peak



- This is the energy spectrum obtained by summing energy deposits on two layers of plastic scintillator and on sodium iodide detector.
- The full energy peaks for ^{40}K and ^{208}Tl are reconstructed



Summary and perspective

- MOON prototype (MOON-1) detector.
  - Under the low BG environment, the measurement has been started since April/2005-

- Analysis
  - Energy calibration has been performed Compton scattering events.
  - Preliminary result of the energy spectrum of plastic and NaI shows 15%(FWHM) for 1.27MeV ^{22}Na gamma ray.

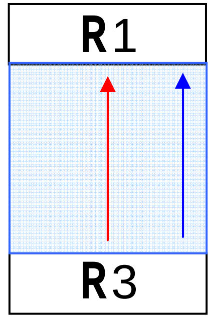
  - Double layer hit events are selected.
  - Main component of remaining events in the sum energy spectrum is double Compton scattering events.
  - At $0\nu\beta\beta$ decay (3MeV) region for 11 days measurement, ^{100}Mo 51g, no event is observed.

- Perspective

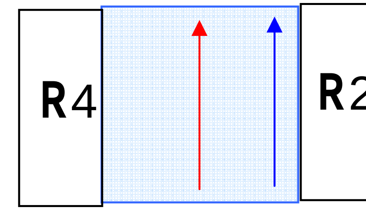
  We will continue the analysis,
  - Improve the energy resolution
  - Study the position resolution
  - Study the acceptance for double beta decay

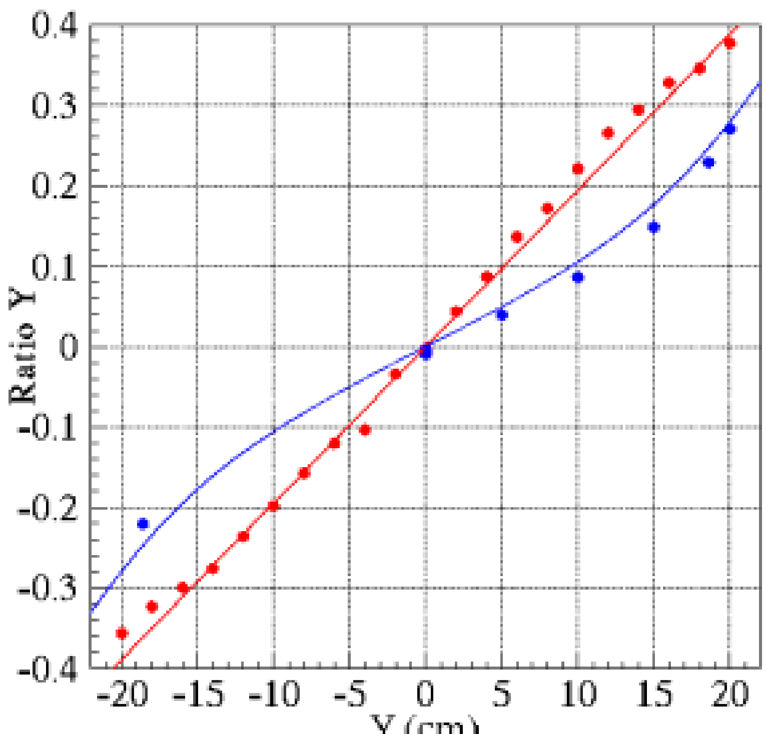
Position measurement

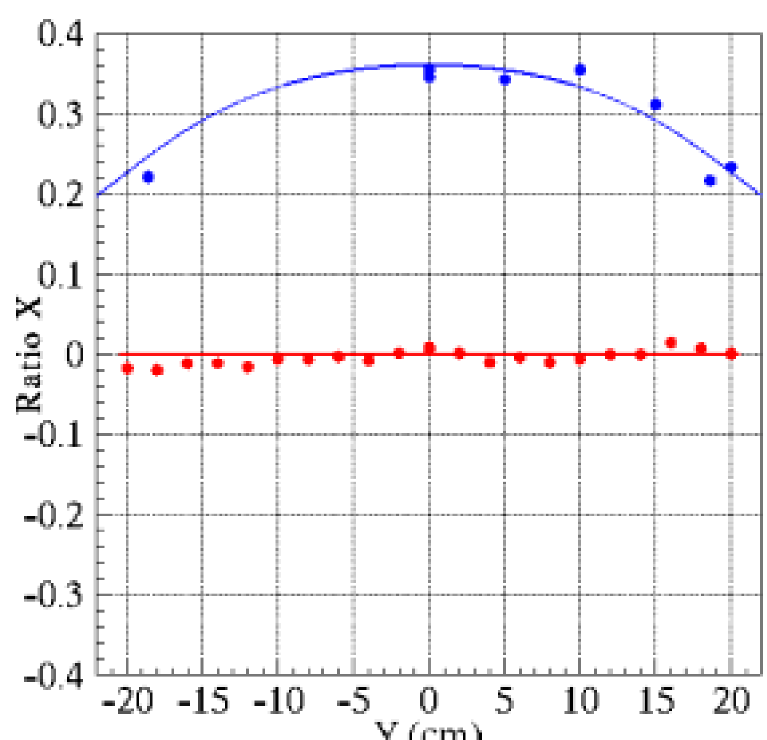
$$RatioY = \frac{R1 - R3}{R1 + R3}$$



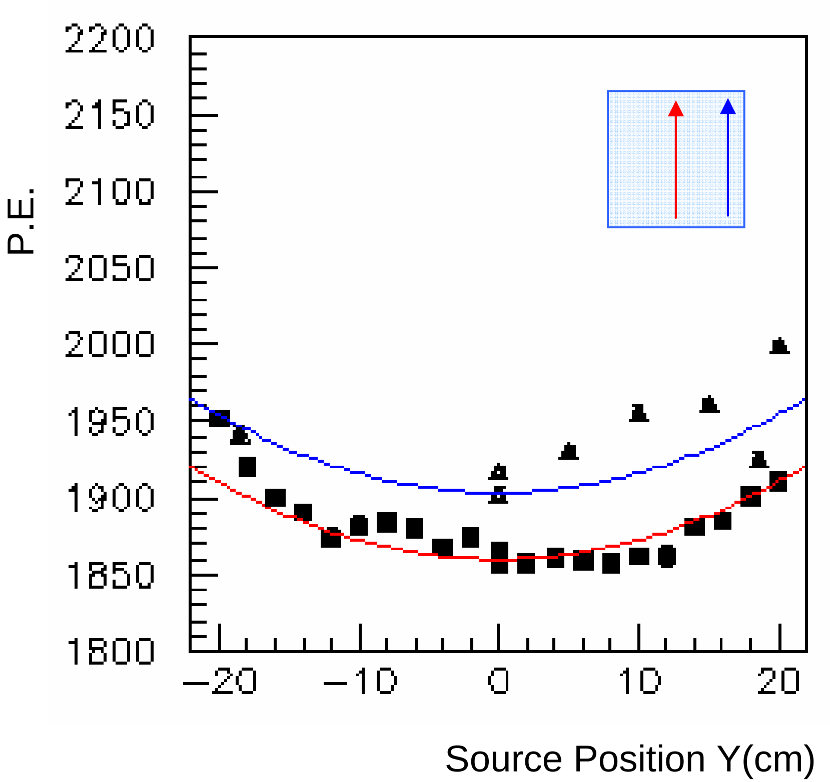
$$RatioX = \frac{R2 - R4}{R2 + R4}$$







Position dependence



of p.e.

$$= B \times \left(1 - a\left(\frac{X}{L}\right)^2 - a\left(\frac{Y}{L}\right)^2 - b\left(\frac{X}{L}\right)^2\left(\frac{Y}{L}\right)^2\right)$$

B :1860P.E.
a : -0.0474
b : -0.001

Red: X=0
Blue: X=18.6