MOON Mo Observatory Of Neutrinos.

ν masses by ββ and low-energy solar ν's

Hiro Ejiri Osaka /JASRI /ICU
The MOON collaboration

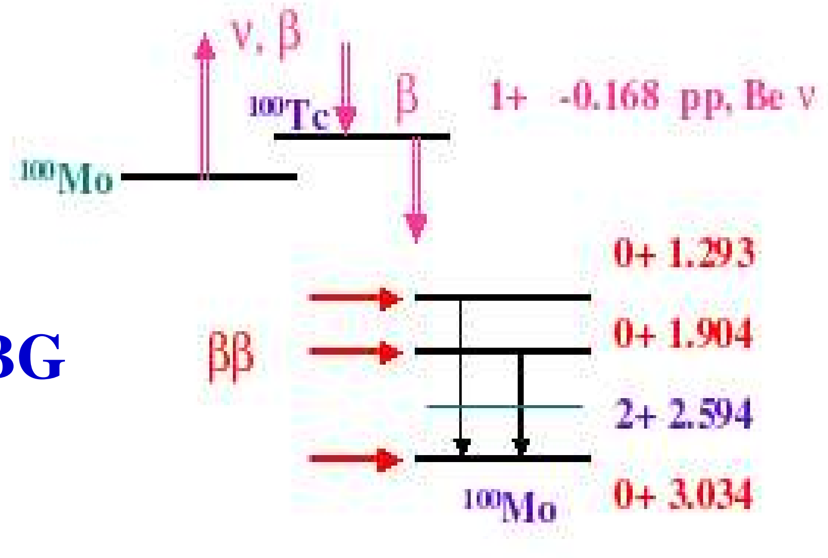
PANIC Sept. 005

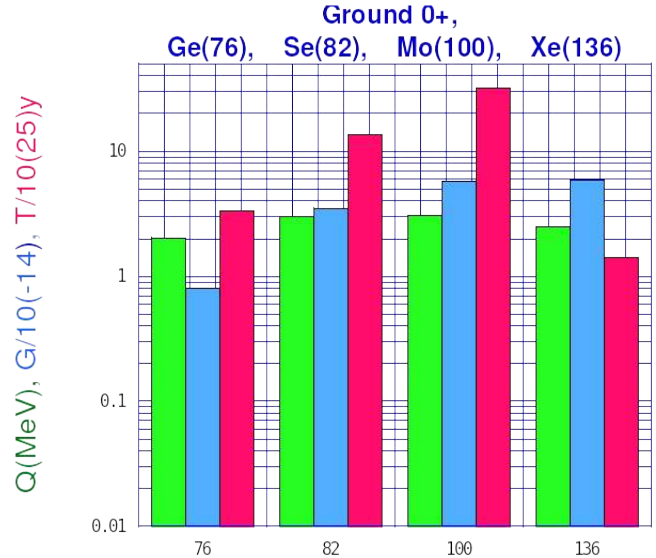
MOON objectives and Unique features for ββ

ββ spectroscopy m_ν~30 meV.

- 1. Large Q = 3.034 MeV,
- large phase space,
- large signals above most RI BG
.
- 2. Excited 0+ by γ–γ ,
- less BG's of 2νββ, RI.
- 3. ββ angular correlations
- to identify the m_n term .
- 4. Localization in space and time
- to get good S/N.
- 5. Multi-use for other ββ nuclei as

^{82}Se, ^{150}Nd etc and ^{7}Be solar-ν





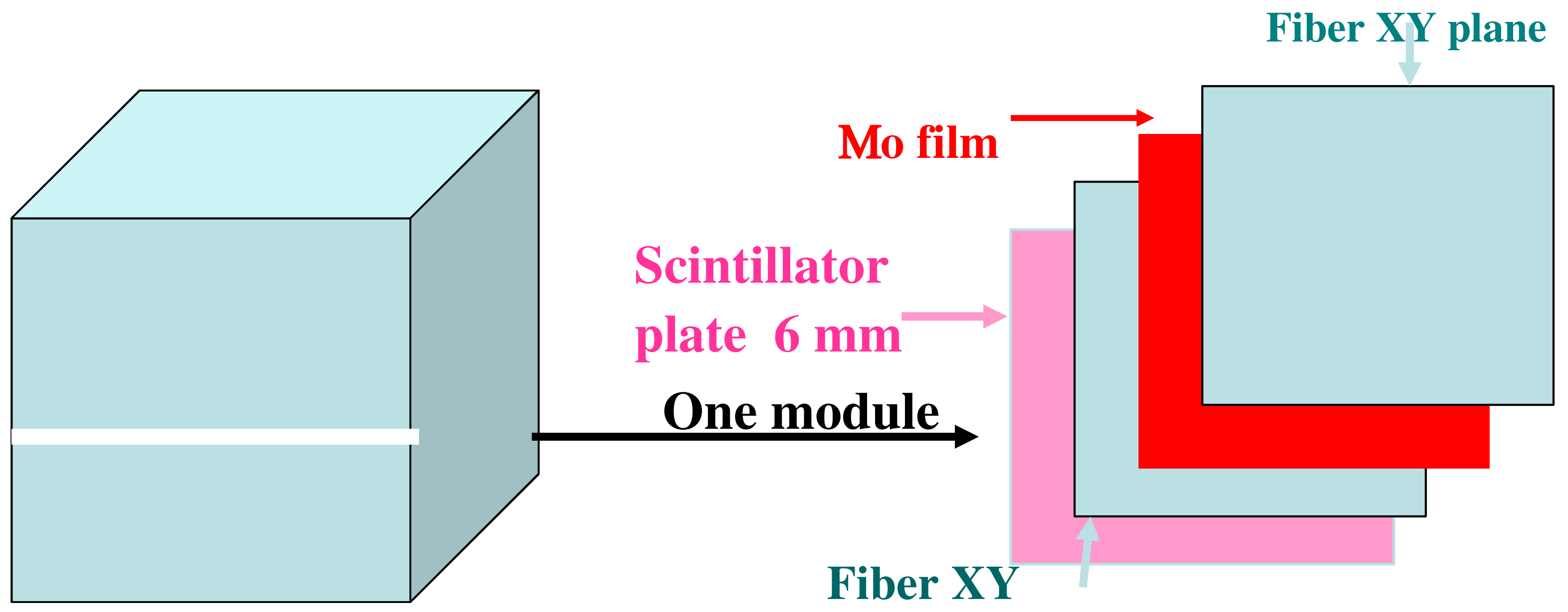
MOON detector concept

A Super-module of Mo films and fiber/plate scintillators*.

1. Position read-out by fibers with 4 mm - 0.4 mm

2. Energy read-out by plate scintillators with ΔE $\sigma \sim 2.5$ % .

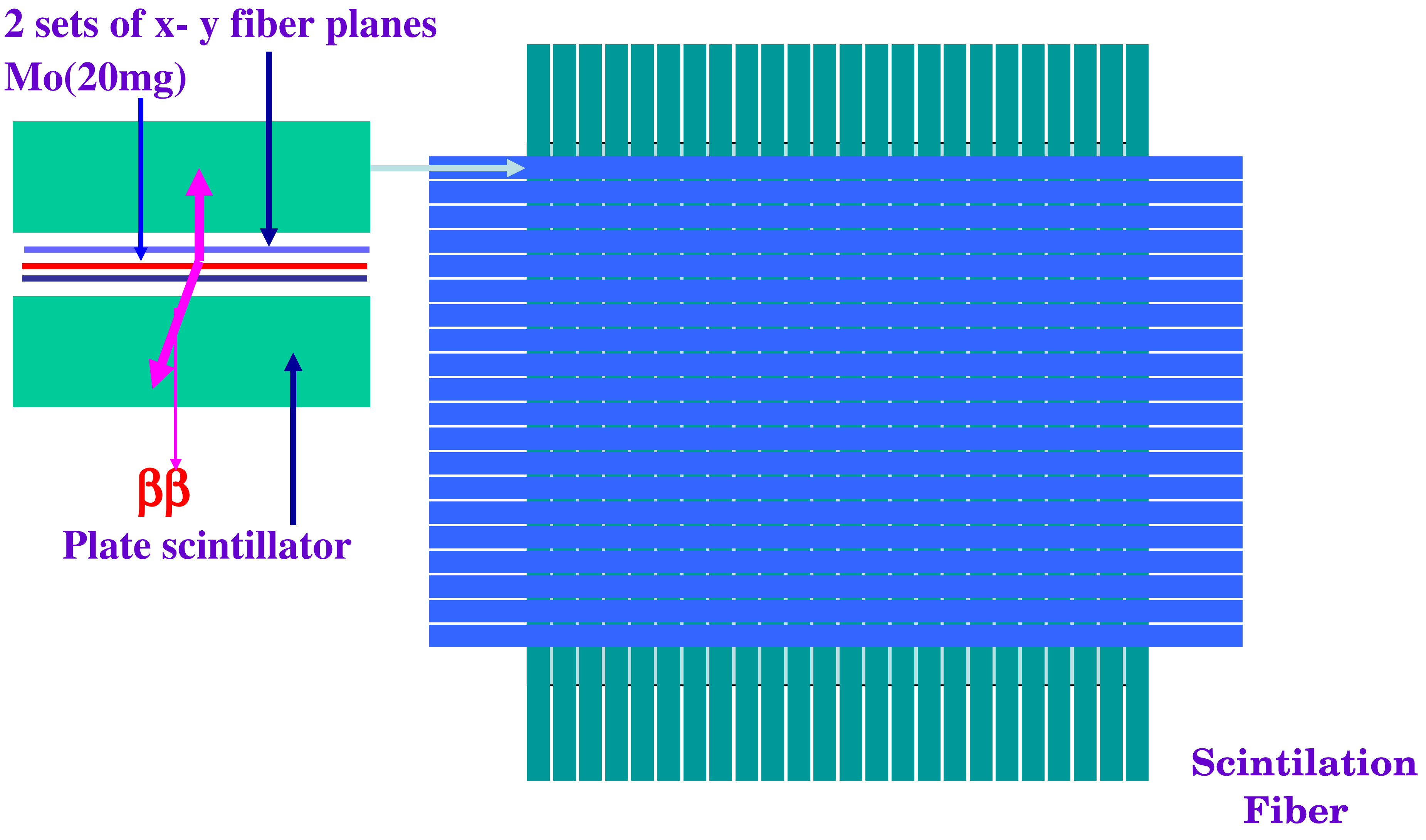
4. Enriched ^{100}Mo 0.5~ 1 ton by centrifugal separation of MoF_6 gas



5. One unit: ^{100}Mo 0.1 ton, 4 ton PL (1.2 m 1.2 m 3m), 4.5K 6cm PM

B Liq Ar with Mo film UW Ionizations and lights give better

MOON Plastic fiber-Mo Ensemble

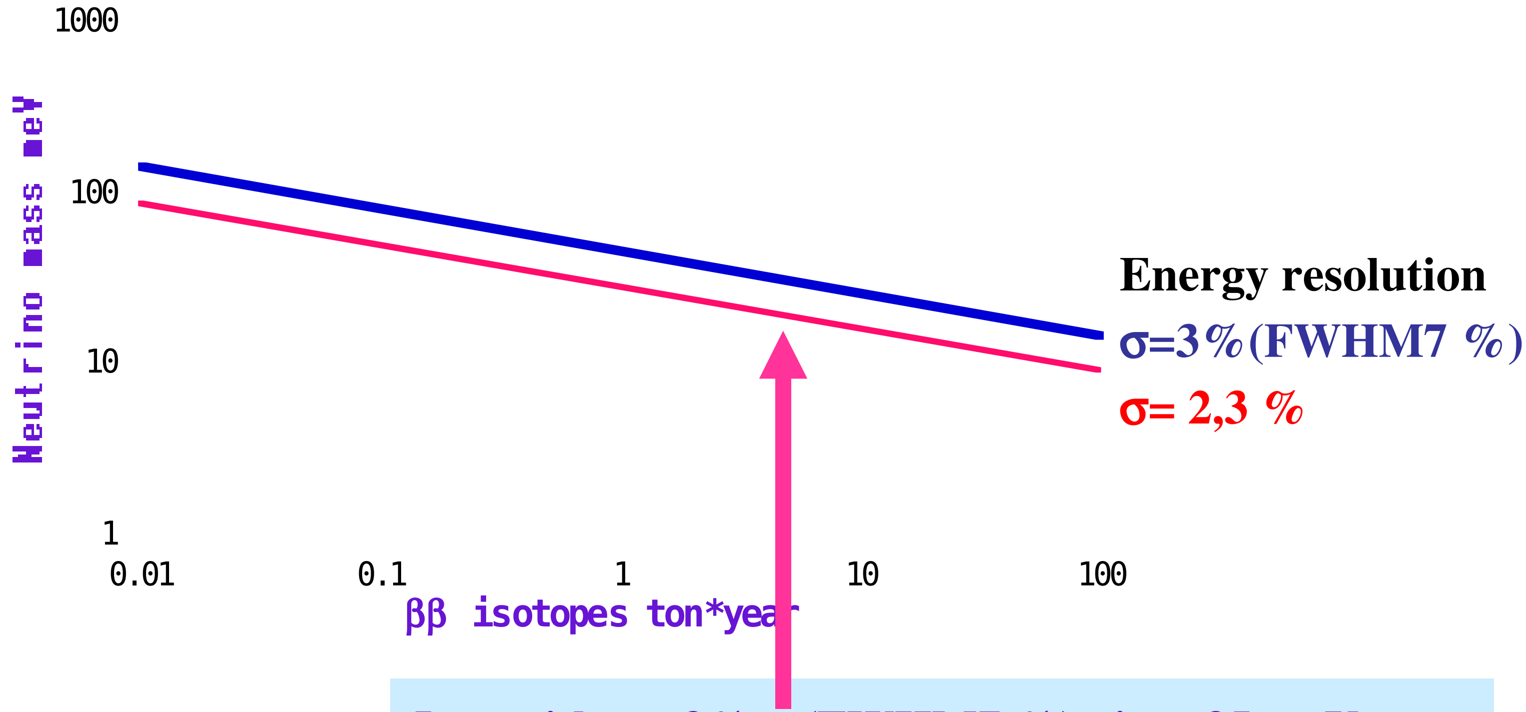


MOON sensitivity

Signal $T = S_N m_n^2$: $S_N \sim 1.3\ 10^{-24} / (eV)^2$ with $M^{0n} \sim 3$,

$Y^{0\nu}$ with signal efficiency of 0.3 is 6 per ton year for 50 m eV

2σ peak requires $Y^{0\nu} > 2\ (BG)^{1/2}$, $BG = Y^{2\nu} = 8\ t\ y\ (s / 3\%)^6$



5 t y with σ= 3% (FWHM7 %) gives 35 meV

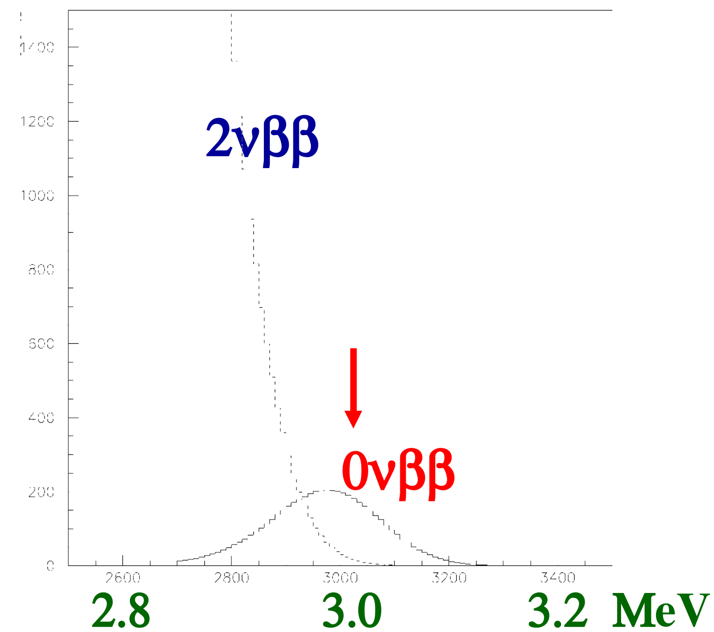
σ= 2,3 %(FWHM 5 %) 19 meV

III. MOON R&D Key elements for IH-L 25 meV

$$1/m_\nu = k\, M^{0\nu}\, (N_{\beta\beta}/BG)^{1/4}$$

C. $M^{0\nu}$? M = 3 QRPA

(4.6 ~ 1.2) Charge exchange reactions



B. Signal rate ^{100}Mo $N_{\beta\beta}$ ~ 0.5 -1 ton ?

0.1 t/ y by centrifugal separation of MoF_6

0.8 10^{26}y, 80 meV

ββ relative spectrum

6mg ^{100}Mo with s ~3%

C. BG per Mo ton ? A few / t y

1. BG in ββ = 2νββ / E-resolution ?

BG ~ 10 ~ 2 for σ = 3 ~ 2.3 %

2. RI-BG rates: RI-impurity ?

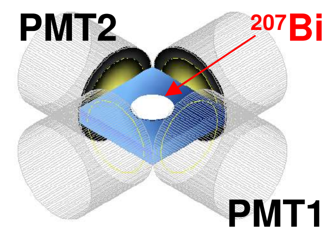
Mo 20 mg / cm2: FWHM? = $0.035/2^{1/2}$ = 0.025 MeV, σ = 11 keV = 0.4 %

N... Modest 10 m Bq/ton gives RI-BG << 1 /t y

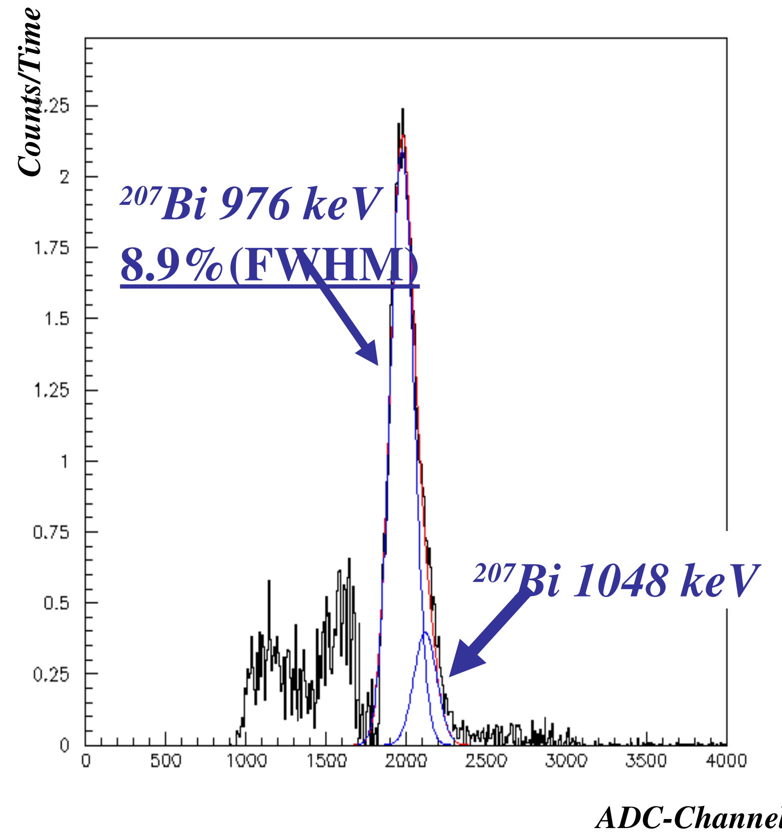
Test of a small PL with ^{207}Bi conversion electrons
PL (0.06 m 0.06 m 0.01 m)

Goal : Energy Resolution σ ~ 2-3 % (FWHM ~ 5-7 %)

Obtained @ 0.97 MeV
- Np=10K photons / MeV,
- Q_E =24% photo-electron efficiency,
- T = 78% photon collection.
- Ne= 1830 photo-electrons / MeV.
- E-resolution σ =3.8 %
  with sta. 2.3 % and non-sta. 3 %



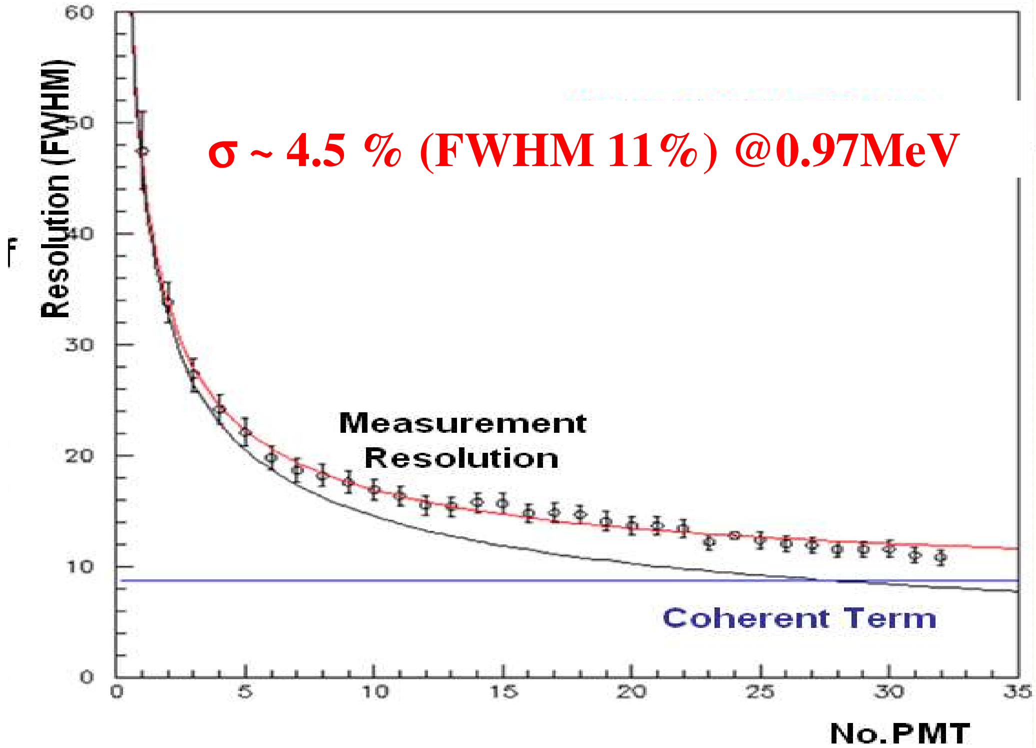
σ = 3.5 % @ β_1=1.5 MeV
if intrinsic σ remains same 3 %

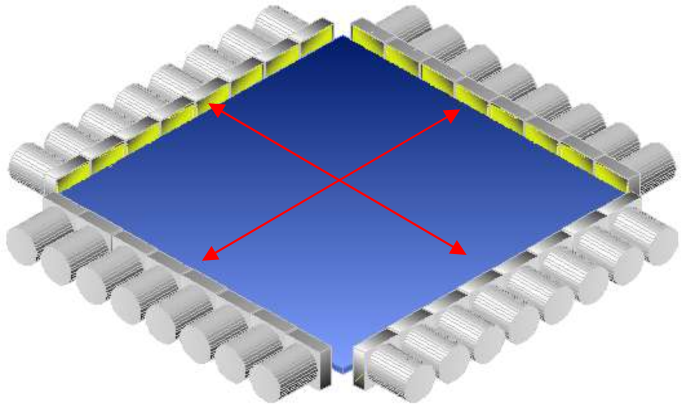


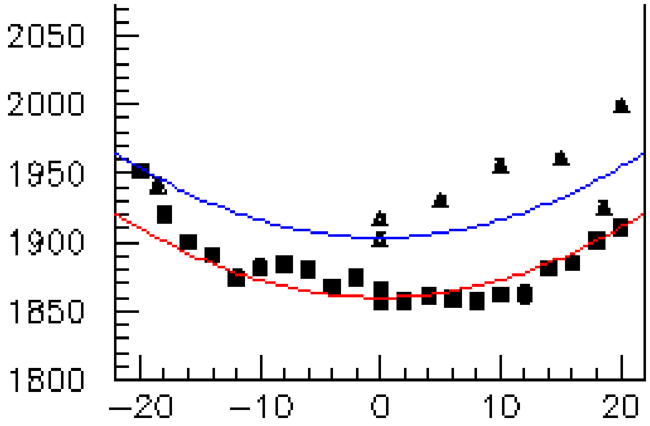
σ = 2.5 % (FWHM 6%) @ $Q_{\beta\beta}$

Medium size PL with 0.53 m 0.53m 0.01 m.

Medium PL (0.53 m 0.53 m 0.01 m) with
32 Hamamatsu 60 mm sq. R6236-01 PM







N=10 K / MeV, T = 65 %, QE=30 %.
σ ~ 3% (FWHM 7% @ 3MeV
with σ ~1.35 % stat., ~2.7% non-

Left/right photon yield ratio gives position. 2.5 % / 20 cm
can be corrected with of 2 cm

MOON-1 Detector

MOON prototype detector (MOON-1A).

- **PL 6 layers, 53x53x1cm^3** BC408. equivalent .
- **^{100}Mo(94.5%), 142g 40mg/cm^2, 3 layers**
- **(MOON 1B with ~1 Kg Mo 2006)**
- **56 PMTs** HAMAMATSU, R6236-01.

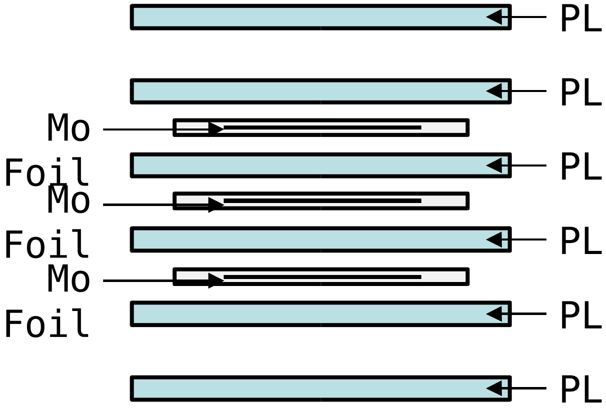
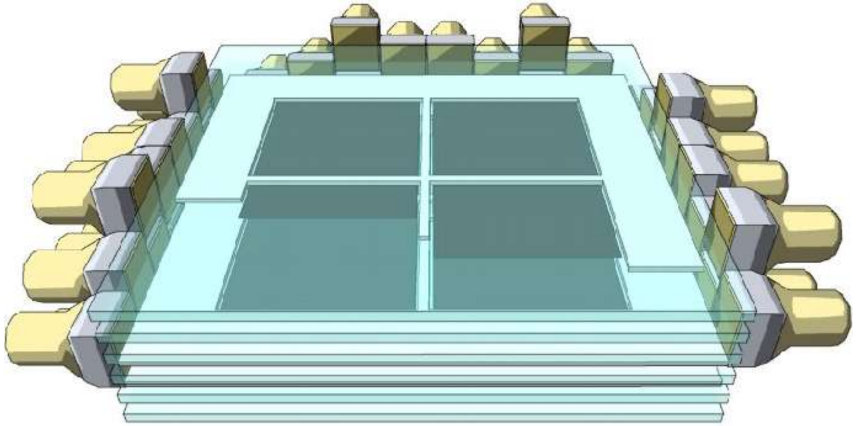


Fig. Cross section view of



PMT location

- In MOON-1 detector, a PMT see the 3 plastic scintillators.
- The plastic scintillator, which has energy deposit, is identified by PMT hit pattern.

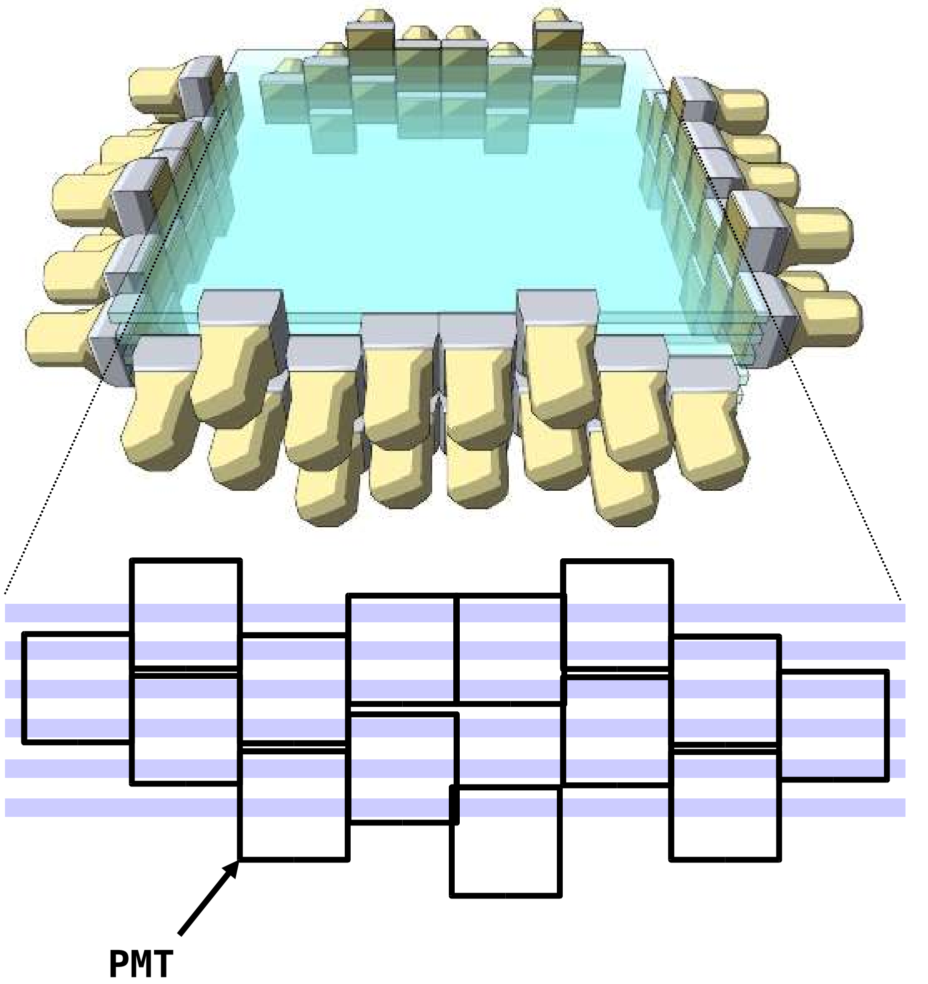
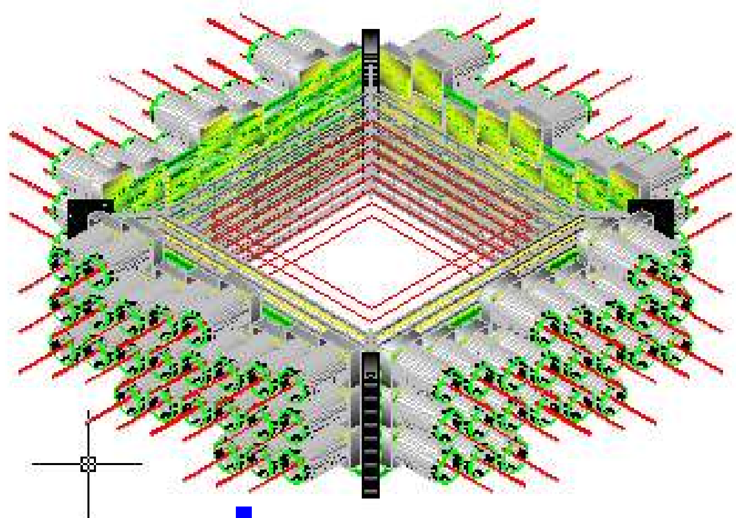
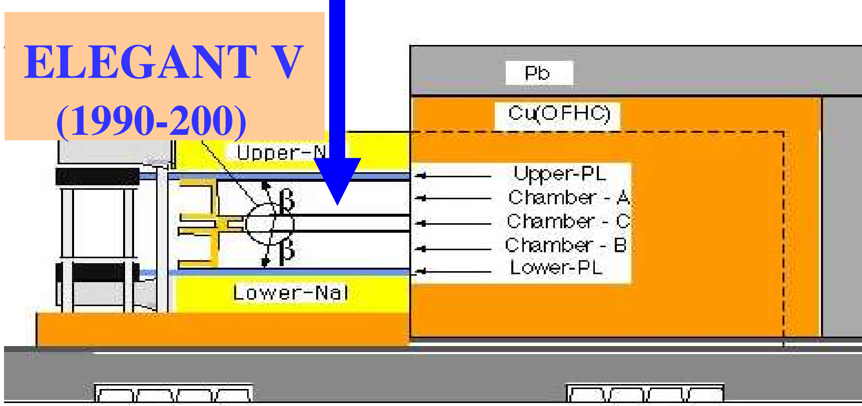


Fig.. Schematic view of MOON-1 det

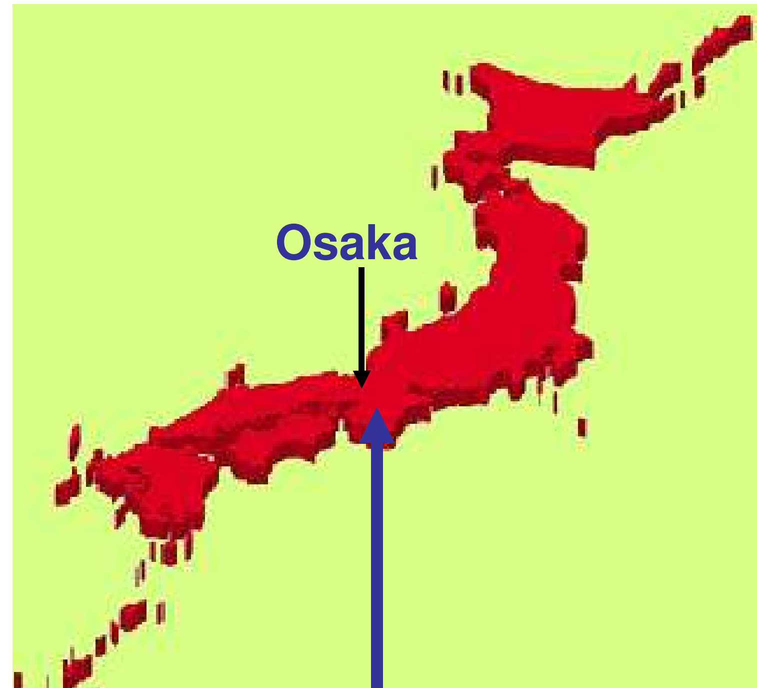
Oto underground Laboratory

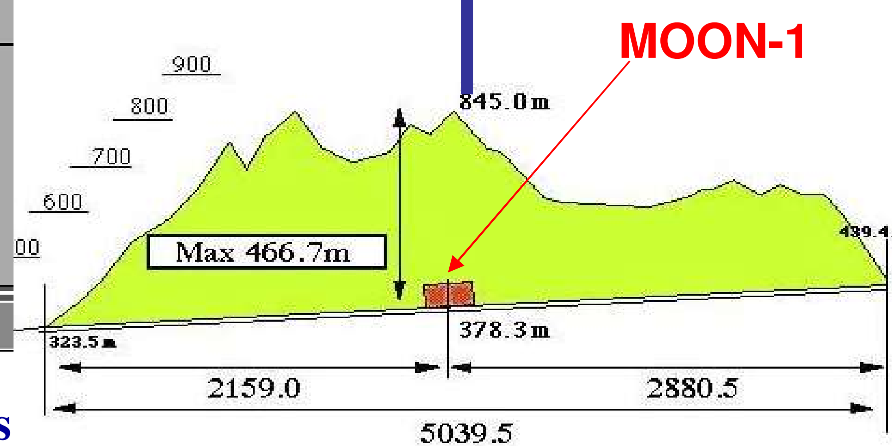
100 km south from Osaka , 1,300m w e

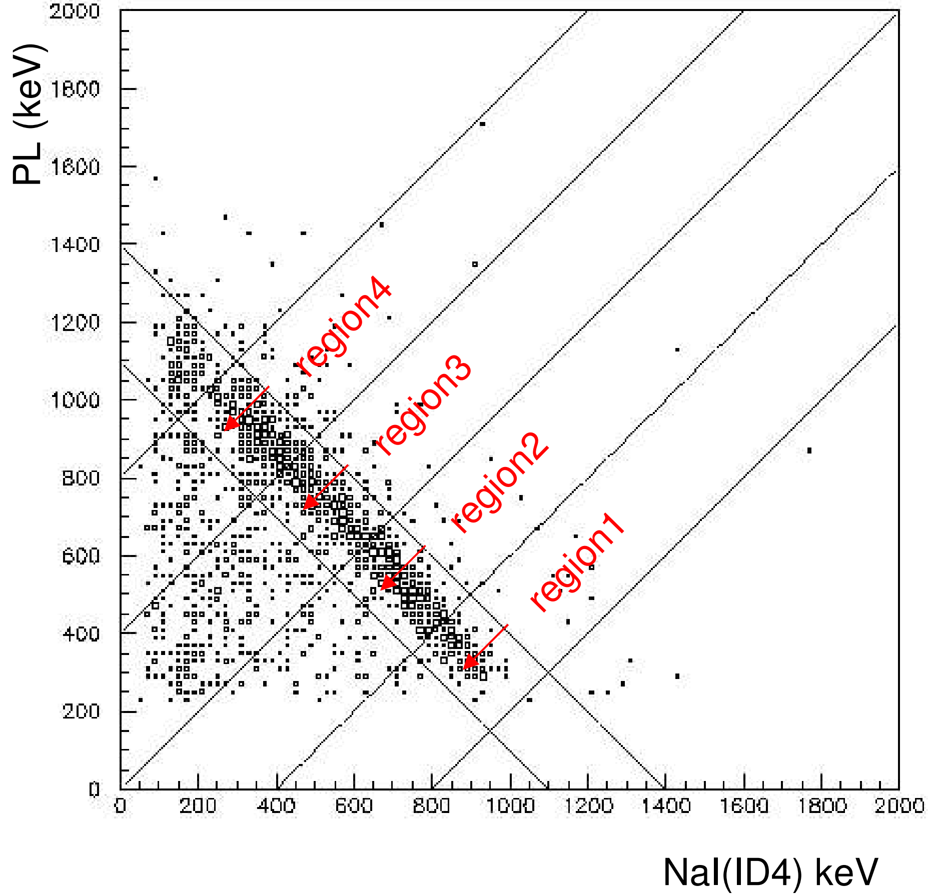


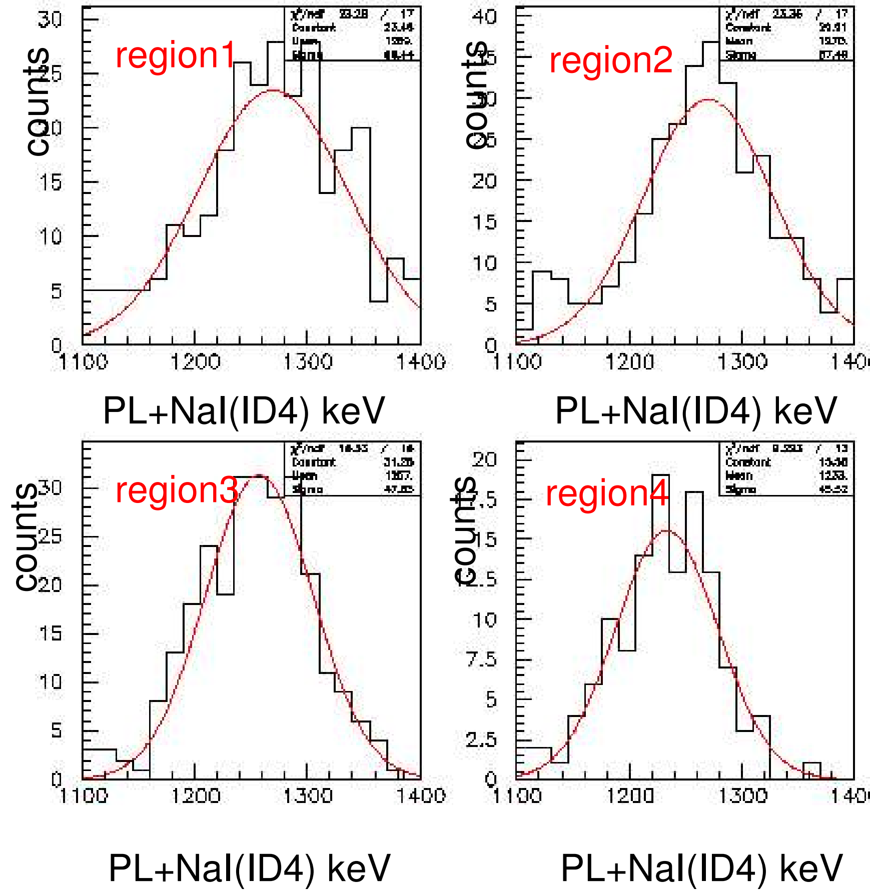


Passive Pb Cu and active 10 cm NaI shields

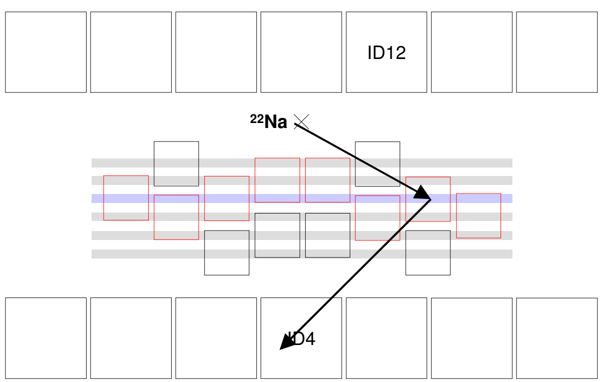








Na22 1.27 MeV γ Compton scattering



PL + NaI @ 1.27 MeV.

σ ~ 3.8 % (8.7±0.8%(FWHM)

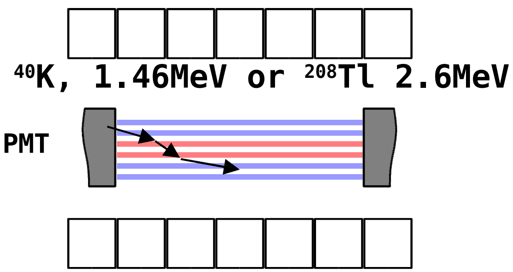
PL 0.7-0.9 MeV. σ ~ 4.2%,

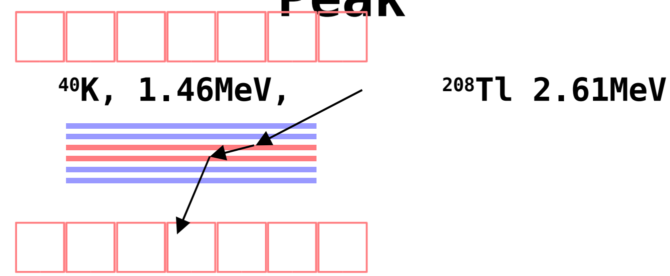
σ~ 2.7 % @ Q

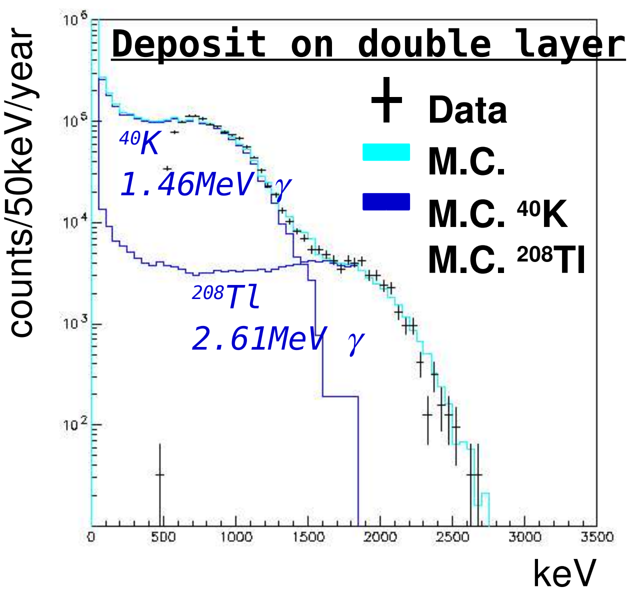
with 1.3 sta. 2.4 % non-sta.

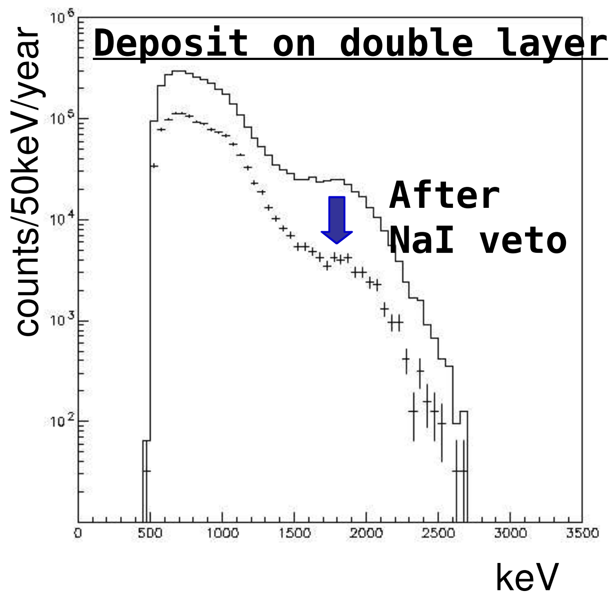
Remaining Events

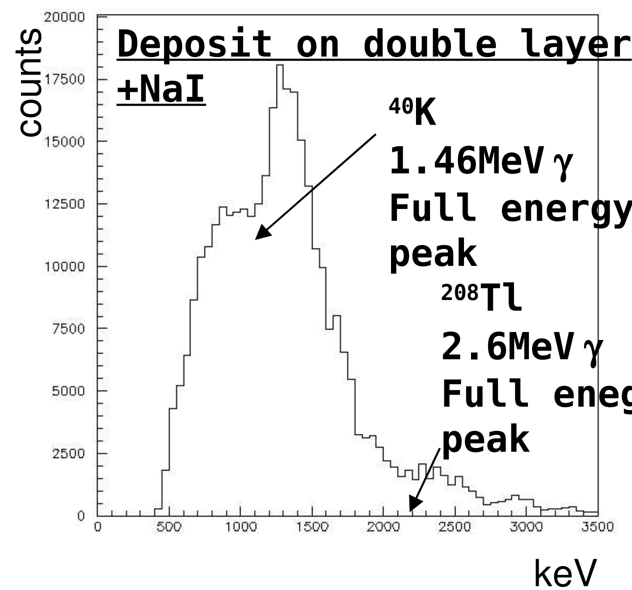
1. M.C. simulation
1. NaI active shield
1. Reconstruct Peak







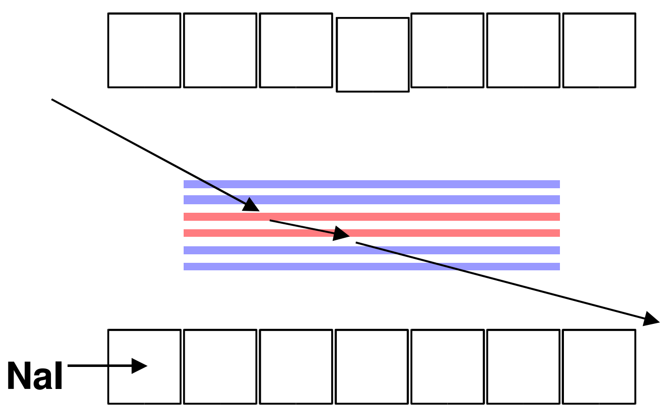


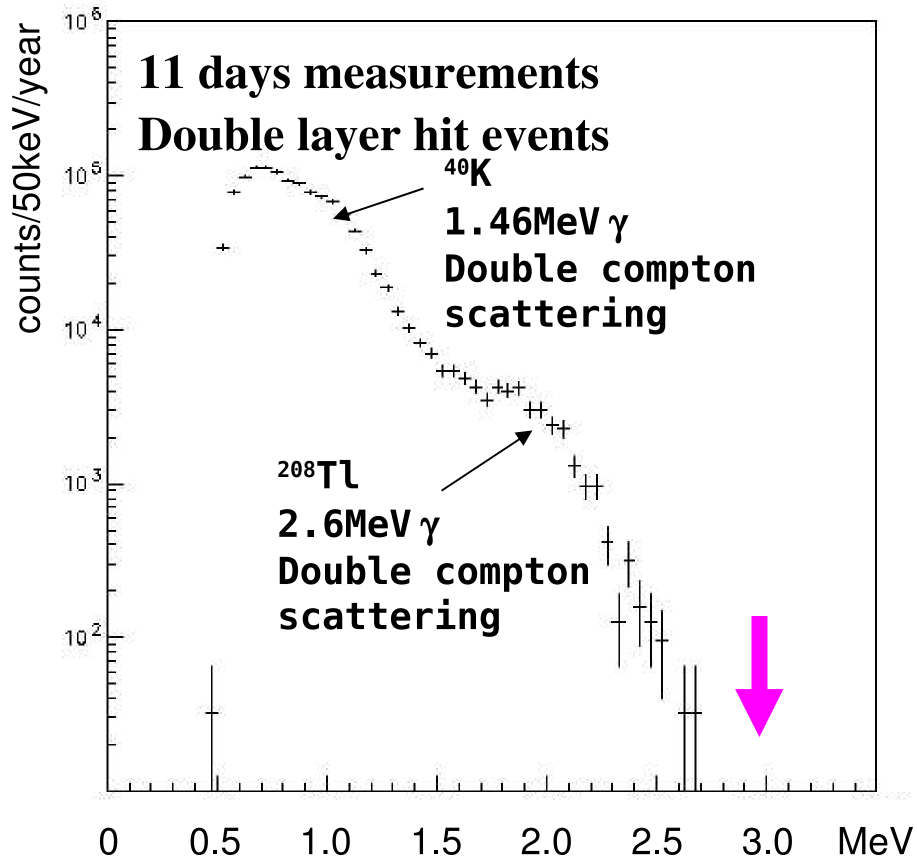


component of remaining events is double Compton sc

Double layer hit event selection and spectrum

0. Sum energy spectrum
   double layer hit events with
   all other PL and NaI :
   active shields





< 0.8 / kg kev y with 68% CL(1.6 counts)

- No event is at Q-value (3MeV)
- BG events : double Compton scattering of γ ^{40}K and ^{208}Tl.

Concluding Remarks

MOON for m_ν ~ 25 meV and ^{7}Be ν's with different isotope and different method (spectroscopic) is of great interest.

Keys of MOON R&D to achieve the IH-L 25 meV

. 1. Nuclear sensitivity , i.e. $M^{0\nu}$ ~ 3 within 20~30 % ?
- 1+, 2-, etc strenghts by (^{3}He,t) and (d,^{2}He), (γ,IAS) RCNP, KVI, HIGS.

- 2. Signal rate 2/ t y requires ^{100}Mo ~ 0.5 -1 ton ? Centrifugal Separation.

- **3. BG 2νββ rates / E resolution ?**
- Photo electrons of 2 K/ MeV, by collection efficiency of 65 %, and
- the resolution of σ ~ 2.5 < 3 % have been achieved, as required.
- It may be 1.5 ~2 % by reducing non-statistical contribution.
- MOON 1 proves overall properties as a system in 2005. Liq. Ar in UW.

- 4. RI rates/cut efficiency and RI impurity RI-BG << 1 /t y ?
- Simulation and NEMO data, to be checked by MOON 1 in 2005-6.

- 5. MOON with external ββ source can be used for Se, Nd, and others as well.

MOON collaboration

- P.J.Doe, R.G.H.Robertson*, D.E.Vilches, J.F.Wilkerson D. I. Will.

  CENPA, Univ. Washington.

- H.Ejiri*, R. Hazama, K.Ichihara, Y.Ikegami, H. Ishii, T.Itahashi N.Kudomi, K.Matsuoka, H. Nakamura, M.Nomachi+, T. Ogama, T. Shima, Y.Sugaya,
- RCNP, and Physics OULNS, Osaka Univ.

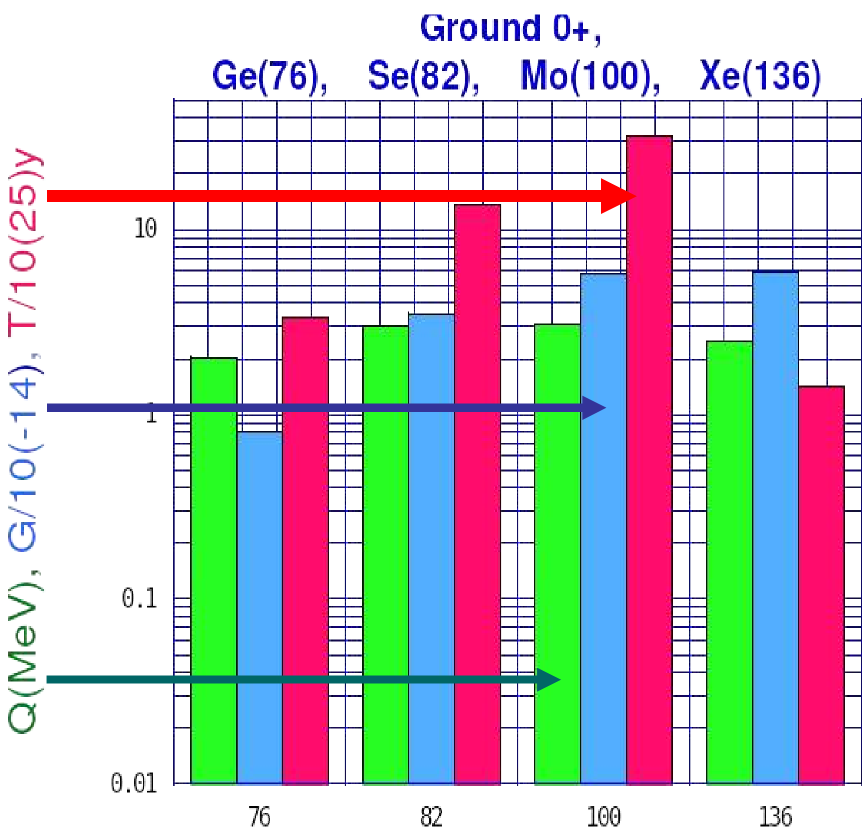
- S.R.Elliott, LANL
- J.Engel. Phys.Astronomy, Univ. North Carolina.
- M.Finger, and K. Kuroda, Phys. Charles Univ. Prague
- K.Fushimi, K. Ichihara, GAS, Tokushima Univ. Tokushima
- M. Greenfield, ICU, Tokyo.
- A.Gorin, I.Manouilov, A.Rjazantsev. High Energy Physics, Protvino.
- A. Para FNAL
- A. Sissakian, V. Kekelidze, V. Voronon, G. Shirkov A. Titov, JINR
- V. Vatulin, V. Kutsalo, VNIIEF

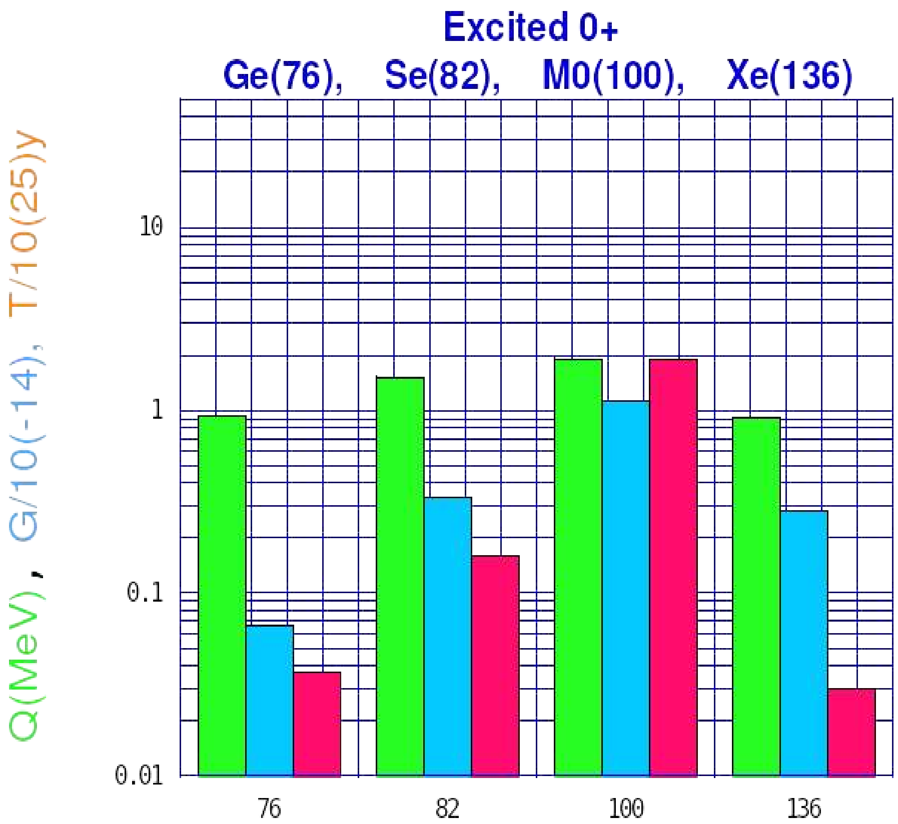

Thank you for attention
Welcome to
MOON collaboration

^{100}Mo: Large Q value, large phase volume G, and large transition rate T.

Ground and excited 0+ states in ^{76}Ge, ^{82}Se, ^{100}Mo, and ^{136}Xe

QRPA matrix elements by Simkovic et al '04





Energy and angular correlations of 0nbb rays

H. Ejiri, Phys. Rep. 338 2000 265

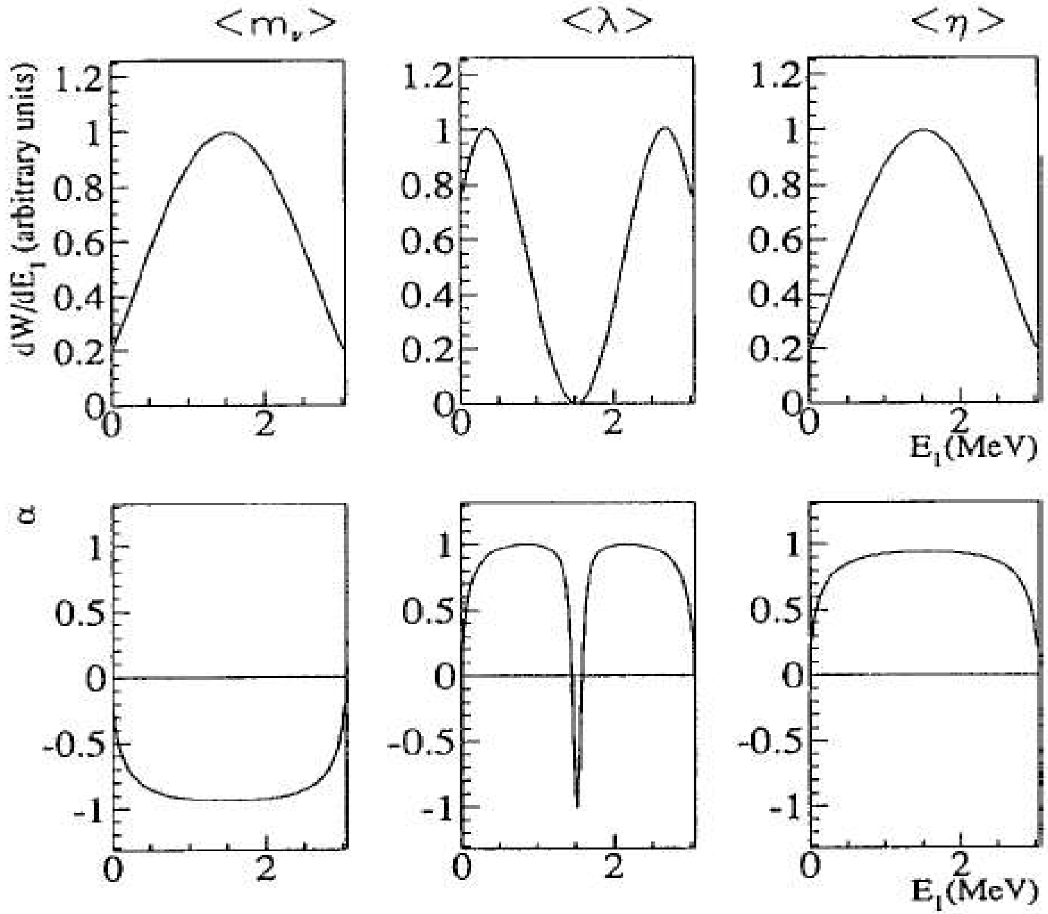
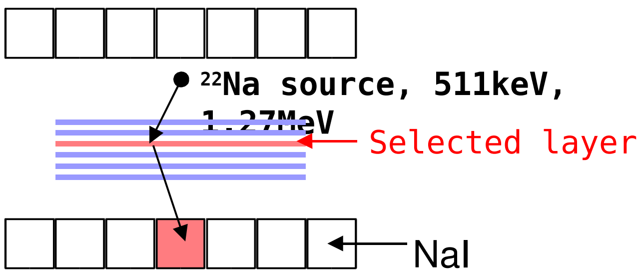
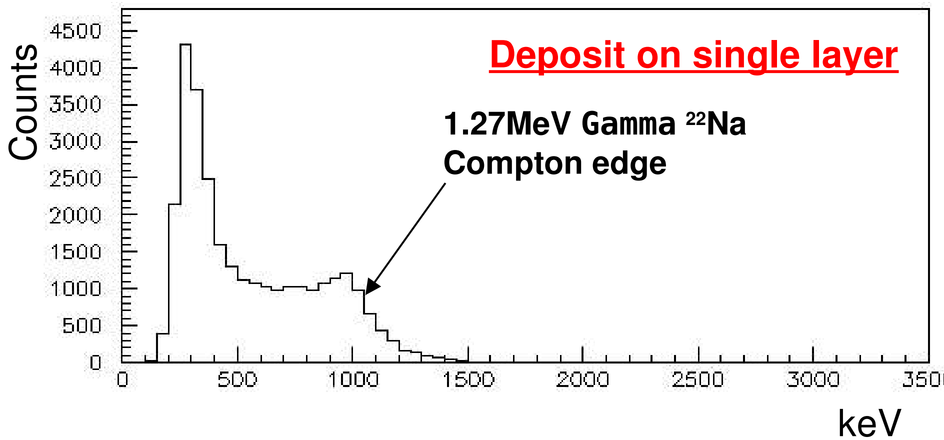


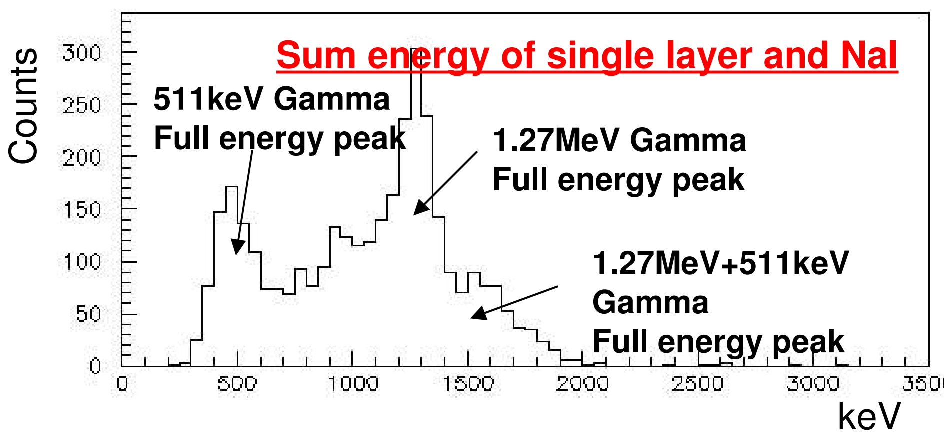
Fig. 4. Energy and angular correlations for the ^{100}Mo $0\nu\beta\beta$ process caused by the mass and right-handed current terms of $\langle m \rangle$, $\langle \lambda \rangle$ and $\langle \eta \rangle$. Top: Calculated single-β spectra. Bottom: $\beta_1 - \beta_2$ angular correlation coefficients α defined by $W(\theta_{12}) = 1 + \alpha \cos\theta_{12}$.[4)]

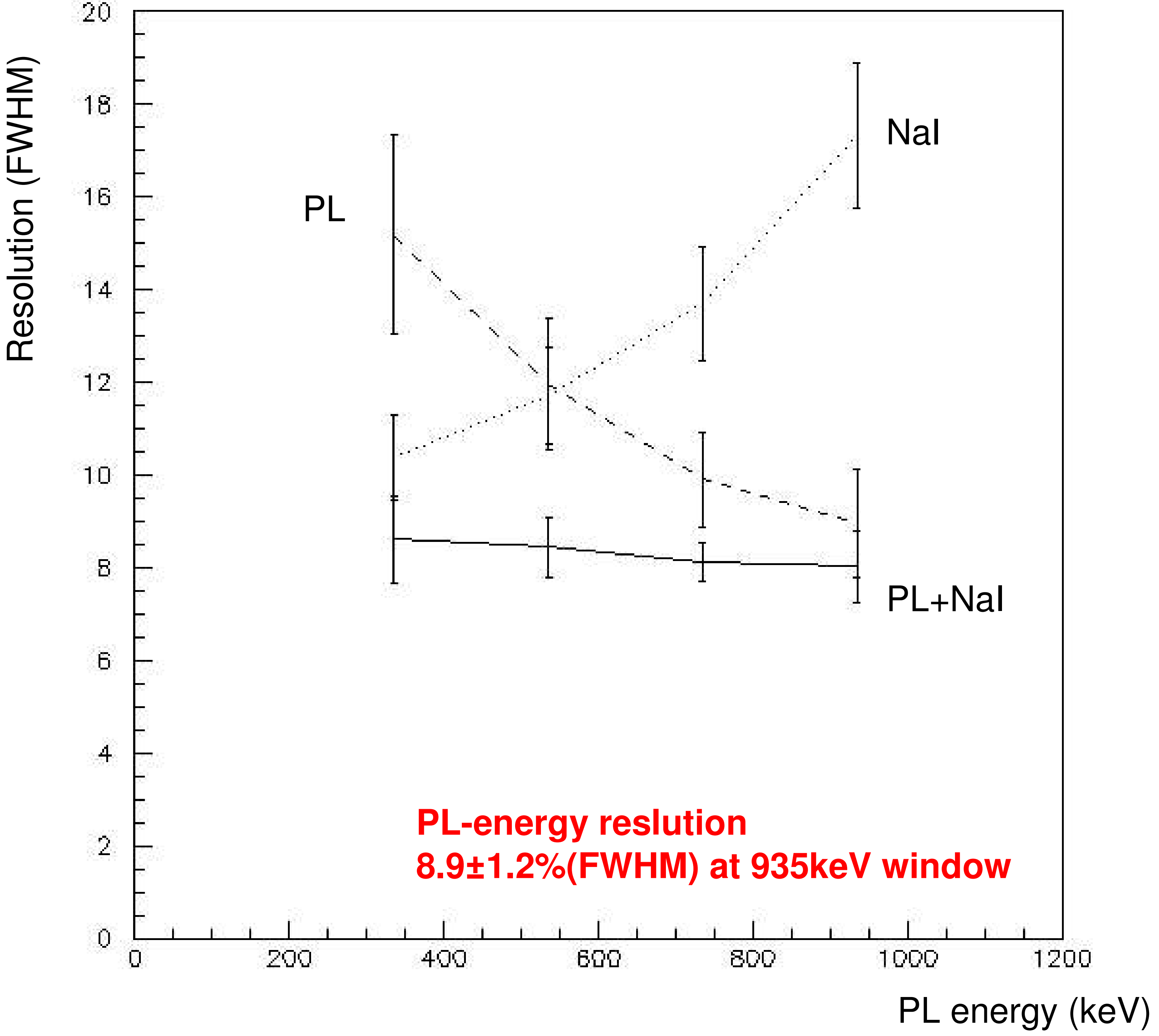
Energy calibration

- **^{22}Na checking source**
  1.27MeV, 511keV gamma rays are emitting.
- **Energy calibration**
  To calibrate the energy, 1.27MeV Gamma Compton edge from ^{22}Na source is used.
- **Single layer Hit**
  To calibrate the energy scale for each layer, the single layer events are selected.
- **Full energy peak**
  The sum of the energy deposits on plastic and NaI causes full energy peak.
- **MOON-1 energy resolution**
  Preliminary result of the energy resolution shows 15% (FWHM) for 1.27MeV full energy peak. The energy resolution of NaI is 9%(FWHM)





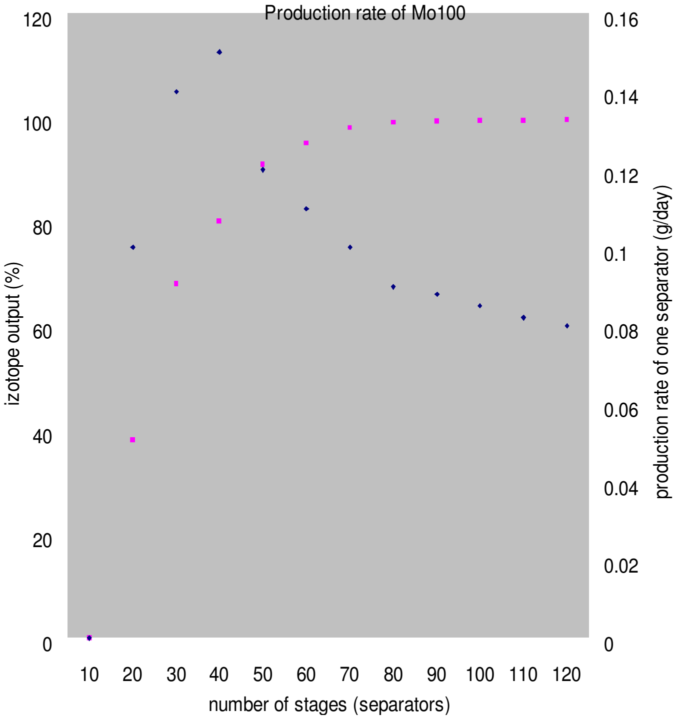




Resolution (FWHM)
PL energy (keV)
PL
NaI
PL+NaI
PL-energy reslution
8.9±1.2%(FWHM) at 935keV window
0
2
4
6
8
10
12
14
16
18
20
0
200
400
600
800
1000
1200

R&D B. Enriched ^{100}Mo isotopes

- VNIIEF is ready to produce 1 Kg immediately, and 0.1 t / y soon.
- Rate 0.5 t ^{100}Mo(90 %) / 5 y with 6 K centrifuges and 40 processes.

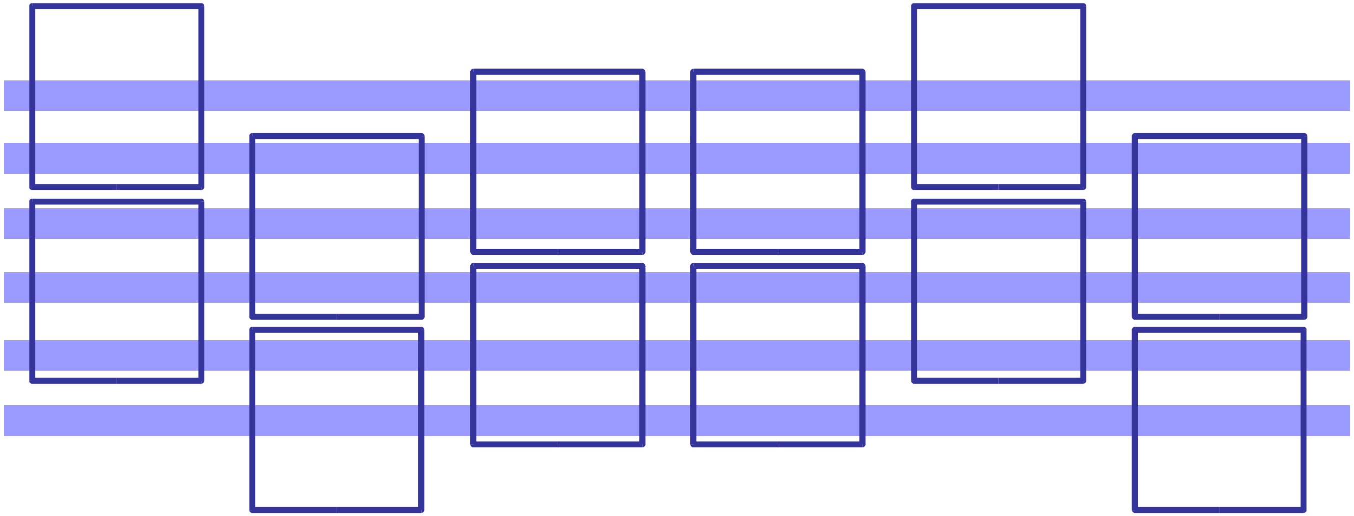


Event selection by PMT hit pattern

- **In MOON-1 detector, 6 plastic scinllators are used.**

Event selection by PMT hit pattern

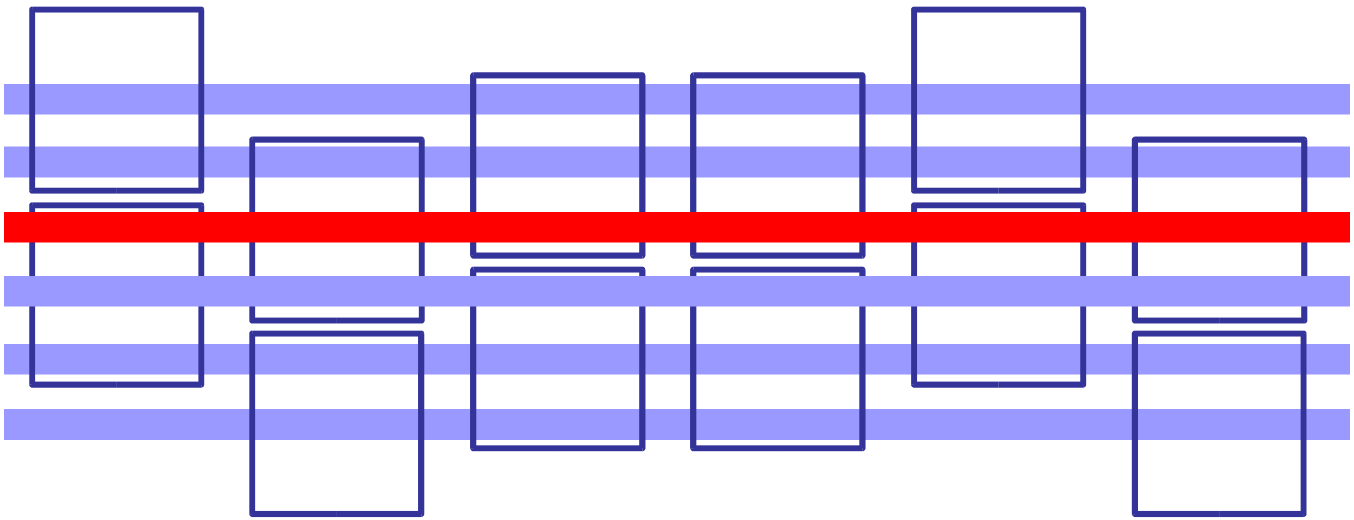
- **PMTs is attached to 3 plastic scintillators.**



To perform the event selection, these 12PMTs are used.

Event selection by PMT hit pattern

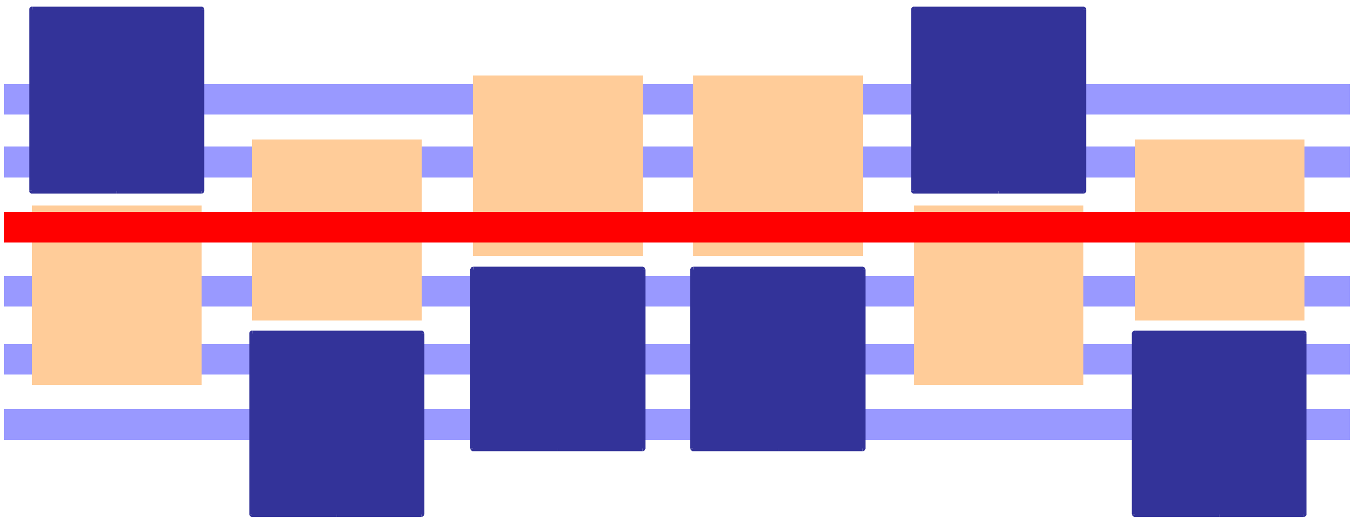
- **Single layer Hit events**



Event selection by PMT hit pattern

- **Single layer Hit events**

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

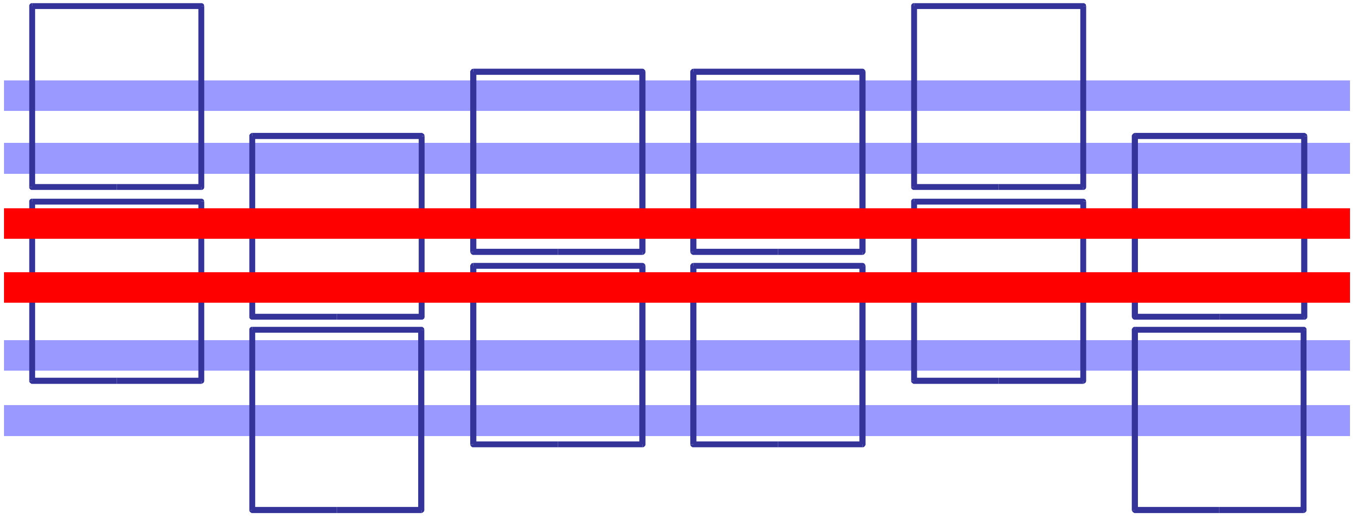


The single layer hit events requires the yellow PMTs singal, which see the layer, at 200keV

The blue PMT signals, which don’t see the layer, vetoes the other events at 200keV.

Event selection by PMT hit pattern

- **Double layer Hit events**



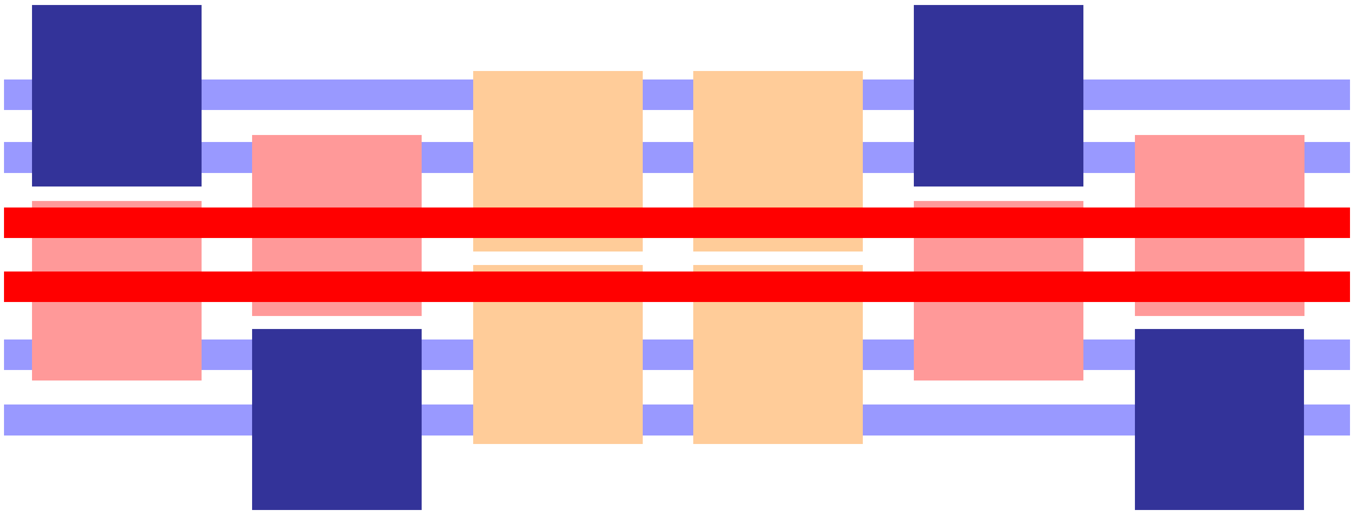
To identify the double beta decay, the double layer hit event should be select.

Event selection by PMT hit pattern

- **Double layer Hit events**

- Threshold Level -

Yellow PMT: 200keV
Red PMT: 500keV
Blue PMT: 200keV



The double layer hit event requires the yellow and red PMT signals with 200,500keV respectively.

Because, the red PMT see the sum energy of the two layer.

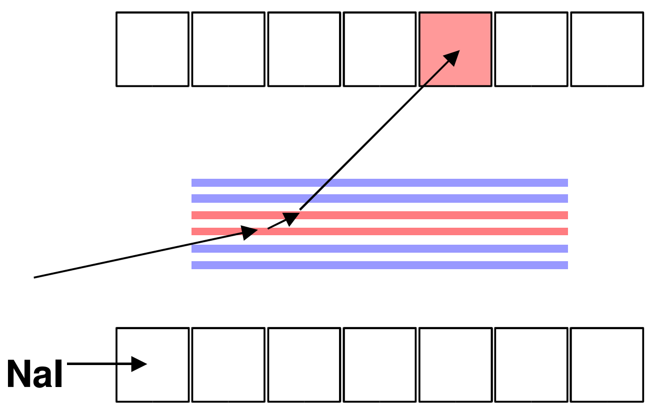
So, the threshold is higher than the yellow PMT, which sees the only one layer.

The blue PMT signals vetoes the other events with 200keV

Remaining Events

1. Reconstructed peak

- If the Gamma rays,which detected at NaI detectors, comes from double Compton scattering, adding energy deposit on NaI detector, the full energy peak may be reconstructed.



- The full energy peaks for ^{40}K and ^{208}Tl are reconstructed

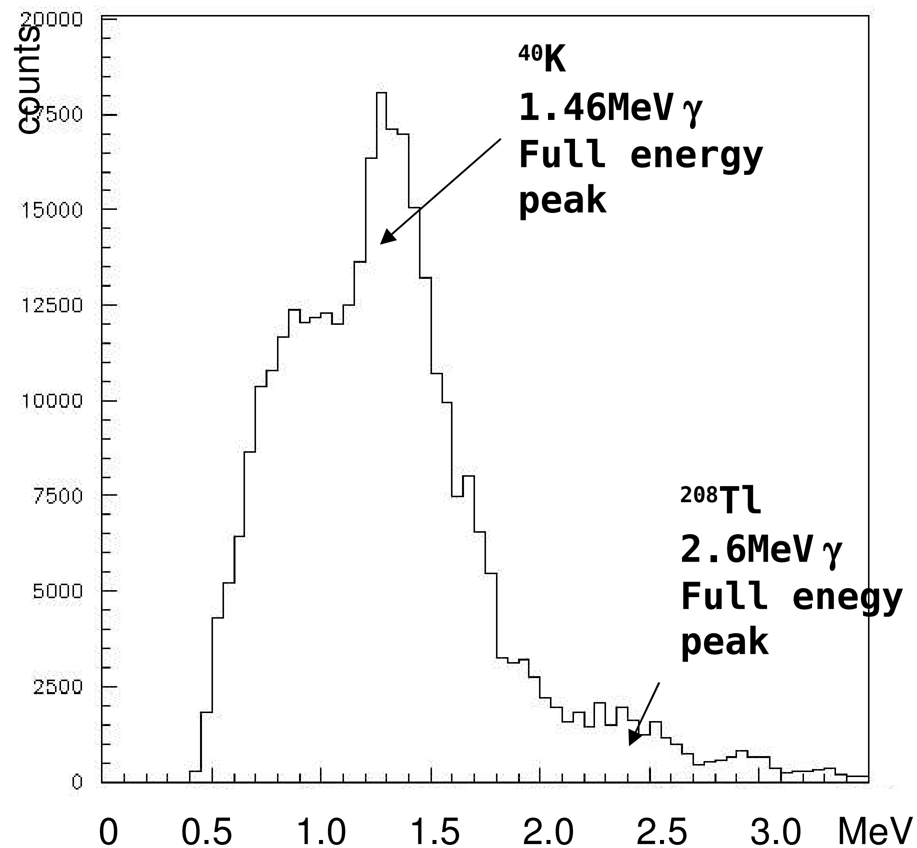


Fig. the sum energy spectrum obtained by summing energy deposit

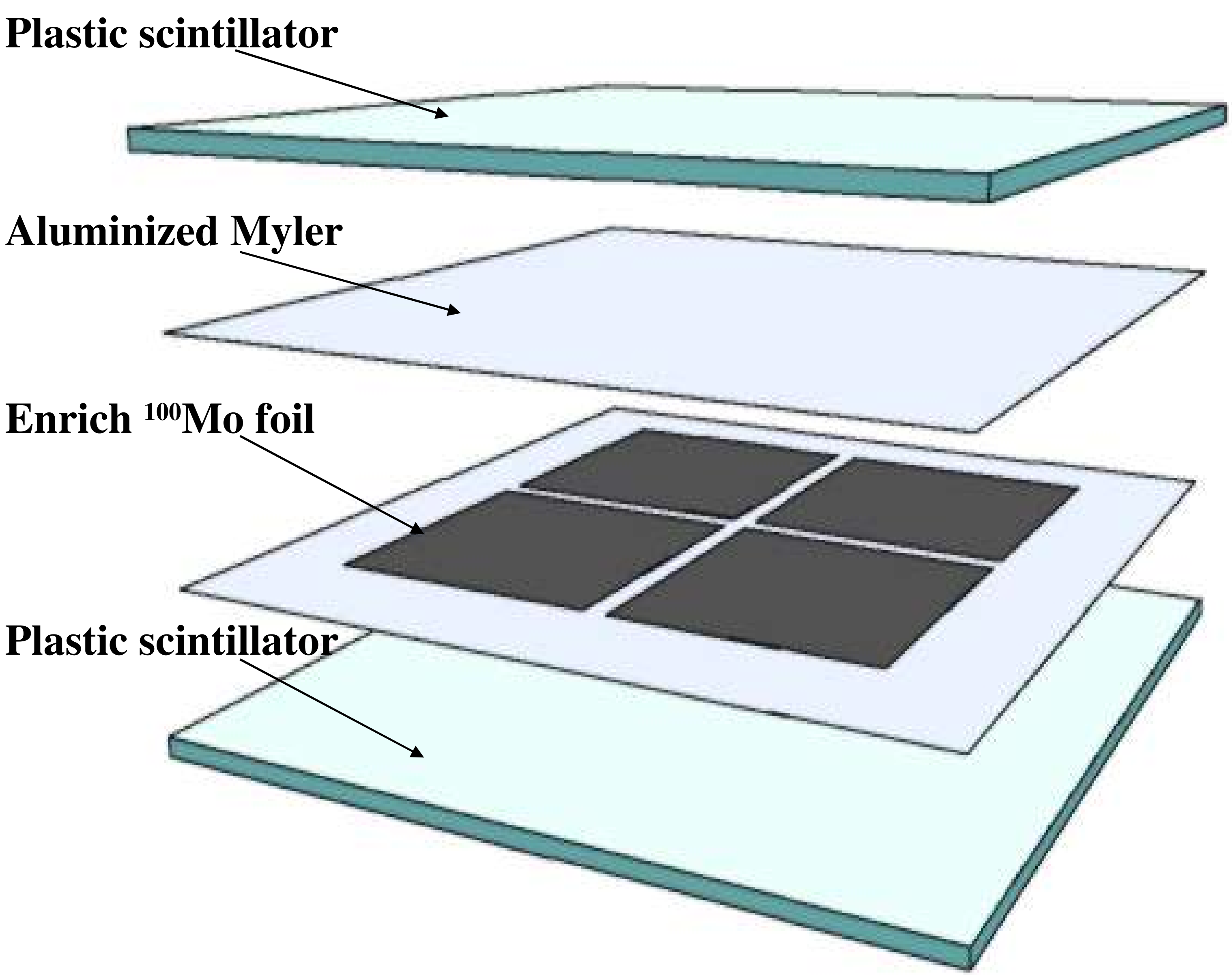


Figure 1. Schematic view of MOON-1 detector. The enriched ^{100}Mo, 142 g is used.

NNR05 Workshop
Neutrino Nuclear Responses in
ββ and Low-energy Astro-ν's

II. Date and place
Dec. 2-4, 2005.

CAST (Center for Advanced Science and Technology) and
JASRI (Japan Synchrotron Radiation Research Institute) SPring-8

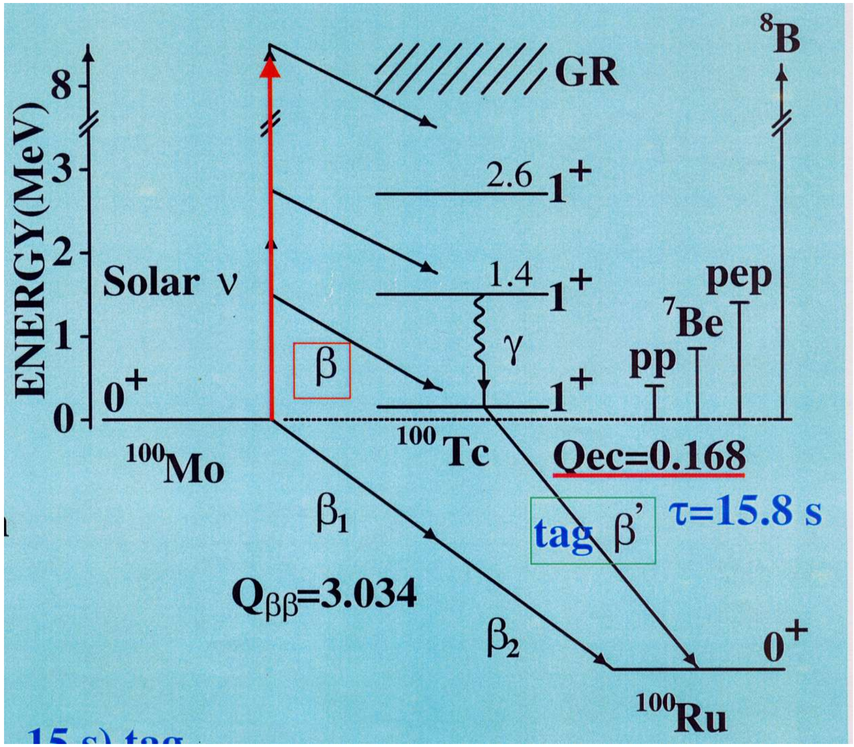
120 km west of Osaka Univ. and 120 km west of Kansai air-port.

1. Nuclear responses for ββ–ν
2. Charge exchange reactions for ββ–ν's
3. Astro ν nuclear interactions
4. Nuclear EM and weak probes for ν nuclear responses.
5. DM and Related subjects.

http://www.spring8.or.jp/e/conference/appeal/nnr05/ ,

Unique features for solar ν

- 1. Large CC rates with low E_{th}
- 2. GS: pp-ν and ^{7}Be-ν,
- B(GT) from EC.



- 3. Real time studies of CC
- 4. The two β (charged particles)
- coincidence to localize signa
- in s BG.
-

Nucleus	-Q(MeV)	pp	7Be	13N	pep	15O	8B	Tota
^{2}H[a]	1.442	0	0	0	0	-	6	6
^{37}Cl[a]	0.814	0	1.1	0.1	0.2	0.3	6.1	7.9
^{40}Ar[b]	>1.505	0	0	0	0	0	7.2	7.2
^{71}Ge[c]	0.236	70.8	35	3.7	2.9	5.8	12.9	132
^{100}Mo[d]	0.168	639	206	22	13	32	27	965