MOON Detector

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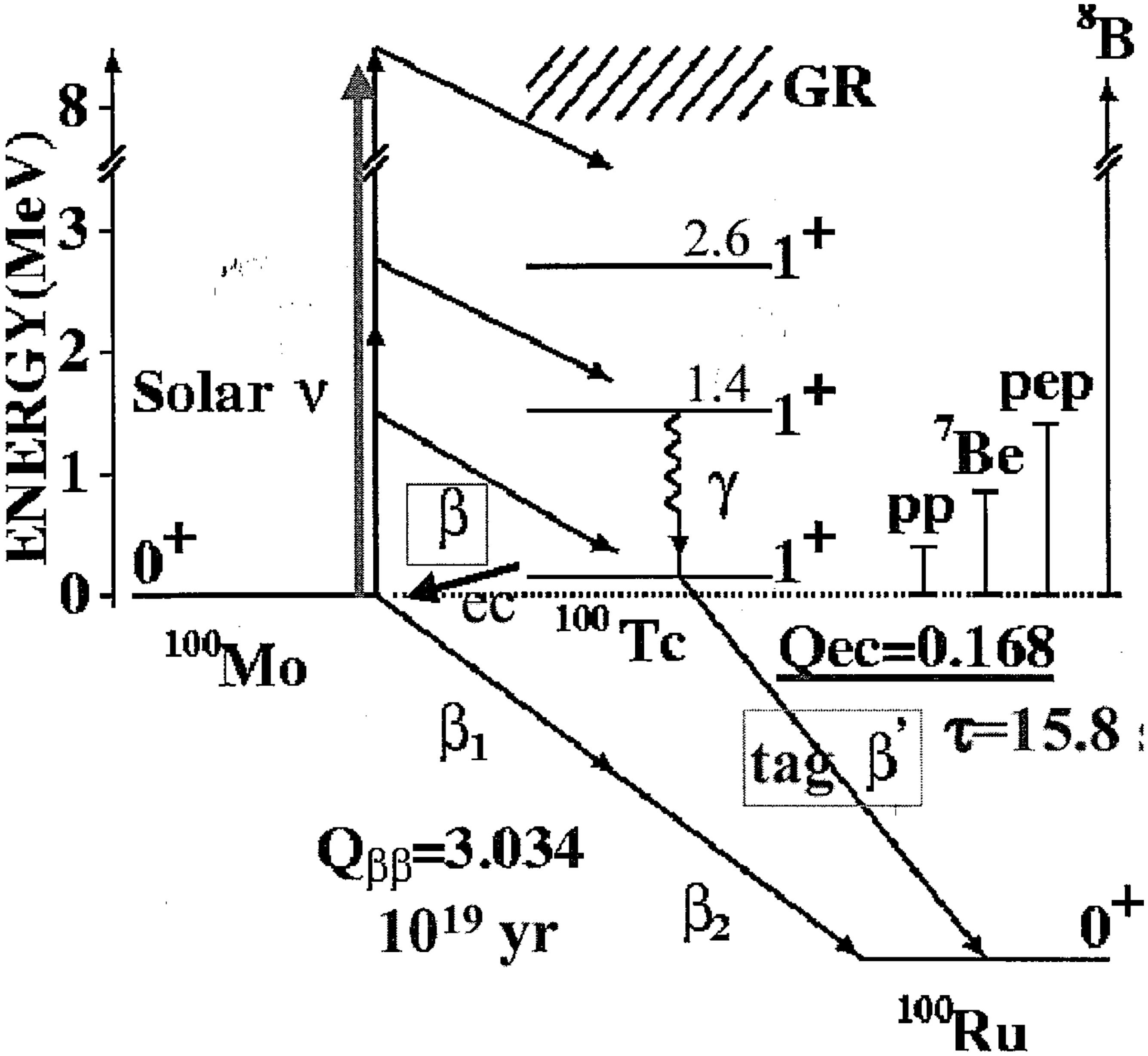
MOON Objectives

- **Double beta ($\beta\beta$) decays with m_ν~0.03 eV.**
- **Low energy pp&^{7}Be solar ν_e and supernova ν_e by inverse β followed by successive β**

240

Spectroscopy of two β rays from 1ton of ^{100}Mo

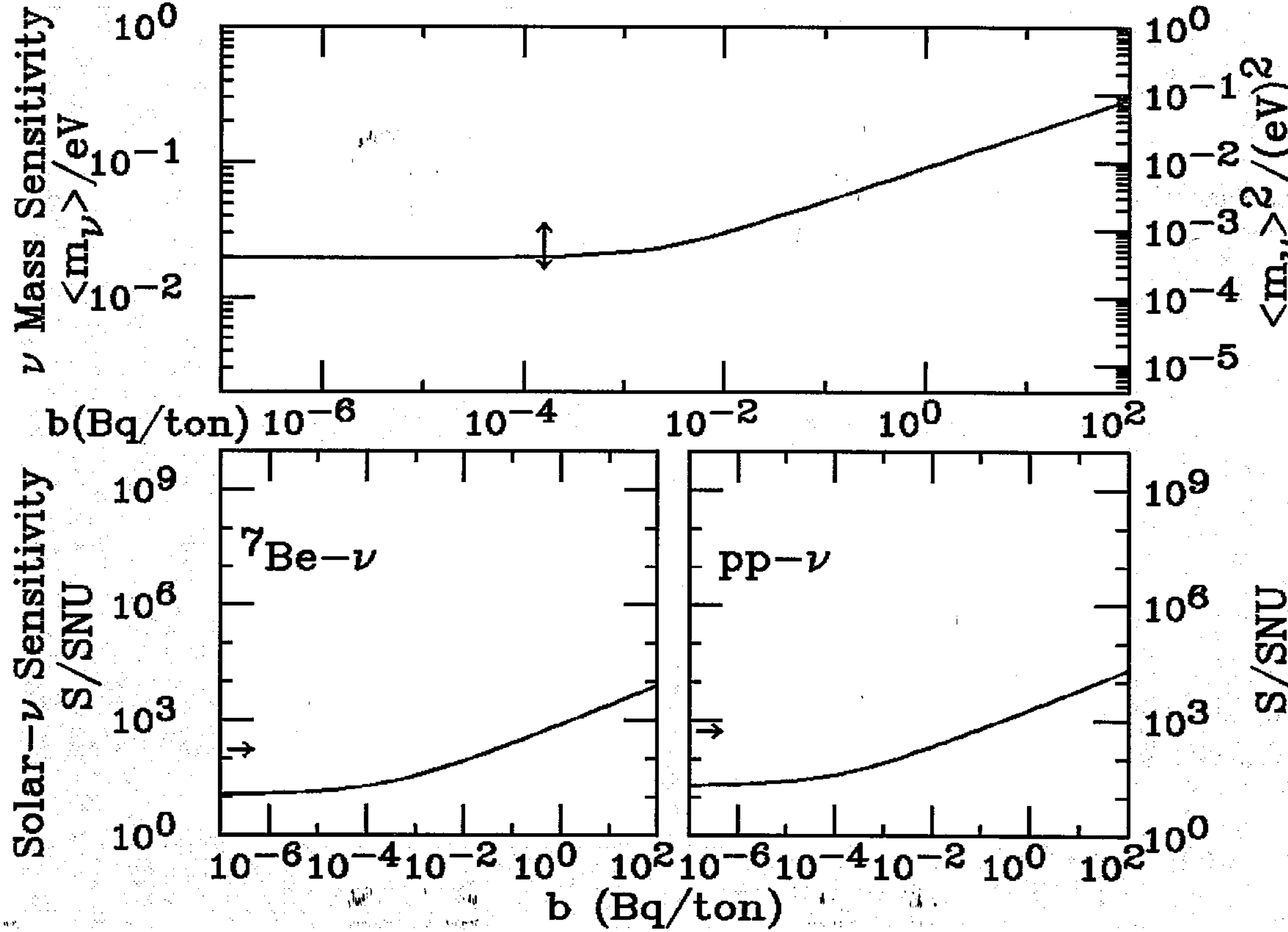
- **large responses for $\beta\beta$-ν and low energy solar/supernova ν_e**
- **low threshold (Q_β)**


ENERGY(MeV)
8
3
2
1
0
GR
2.6
1+
1.4
1+
1+
0+
Solar ν
β
ec
γ
pp
7Be
pep
8B
100Mo
100Tc
Qec=0.168
τ=15.8
β1
tag β'
Qββ=3.034
10^19 yr
β2
0+
100Ru

Major BG at the 0νββ window

- Radio Activities in Detector/Source
  - 0.1ppt of U-Th: 1.25-0.45 mBq/t .
- Cosmogenic Radio Activities
  - Negligible at underground lab.
- 2νββ
  - $T_{1/2} \sim 10^{19}$y

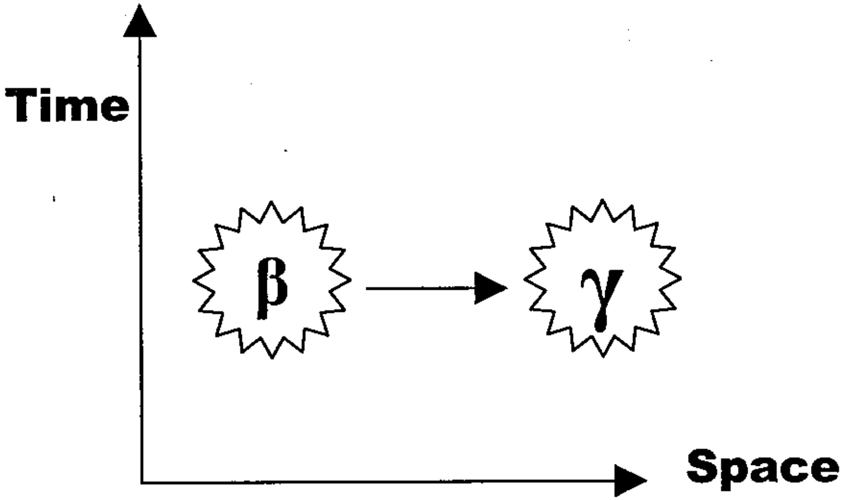
ν–mass and solar ν sensitivities and U-Th impurities,



243

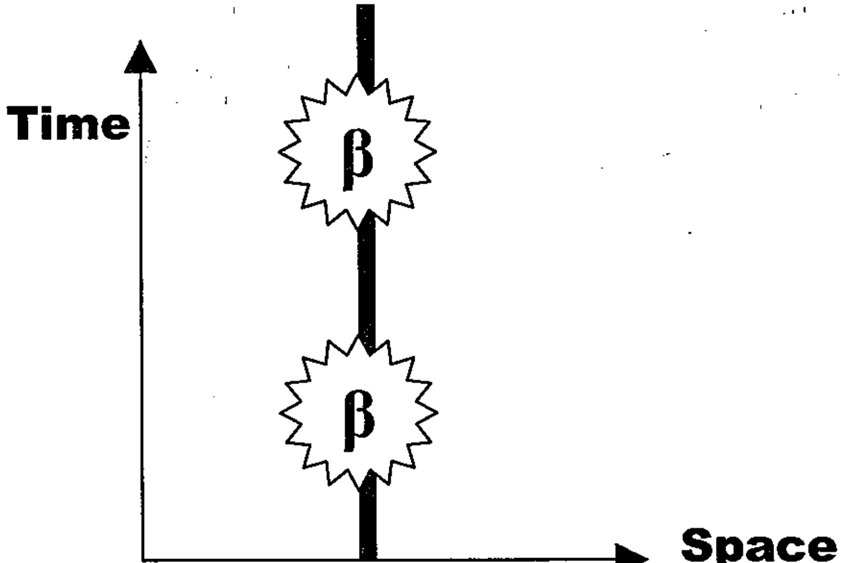
Background Identification

- Most of alpha/beta decays are followed by gamma decay, which may cause second energy deposit in the scintillator.



β γ Successive decay
Two energy deposit
Distance
Two energy
Coincidence

- Many of alpha activities causes another signal at the same position by a following decay.



β β Successive decay
Same position
Two energy
Interval

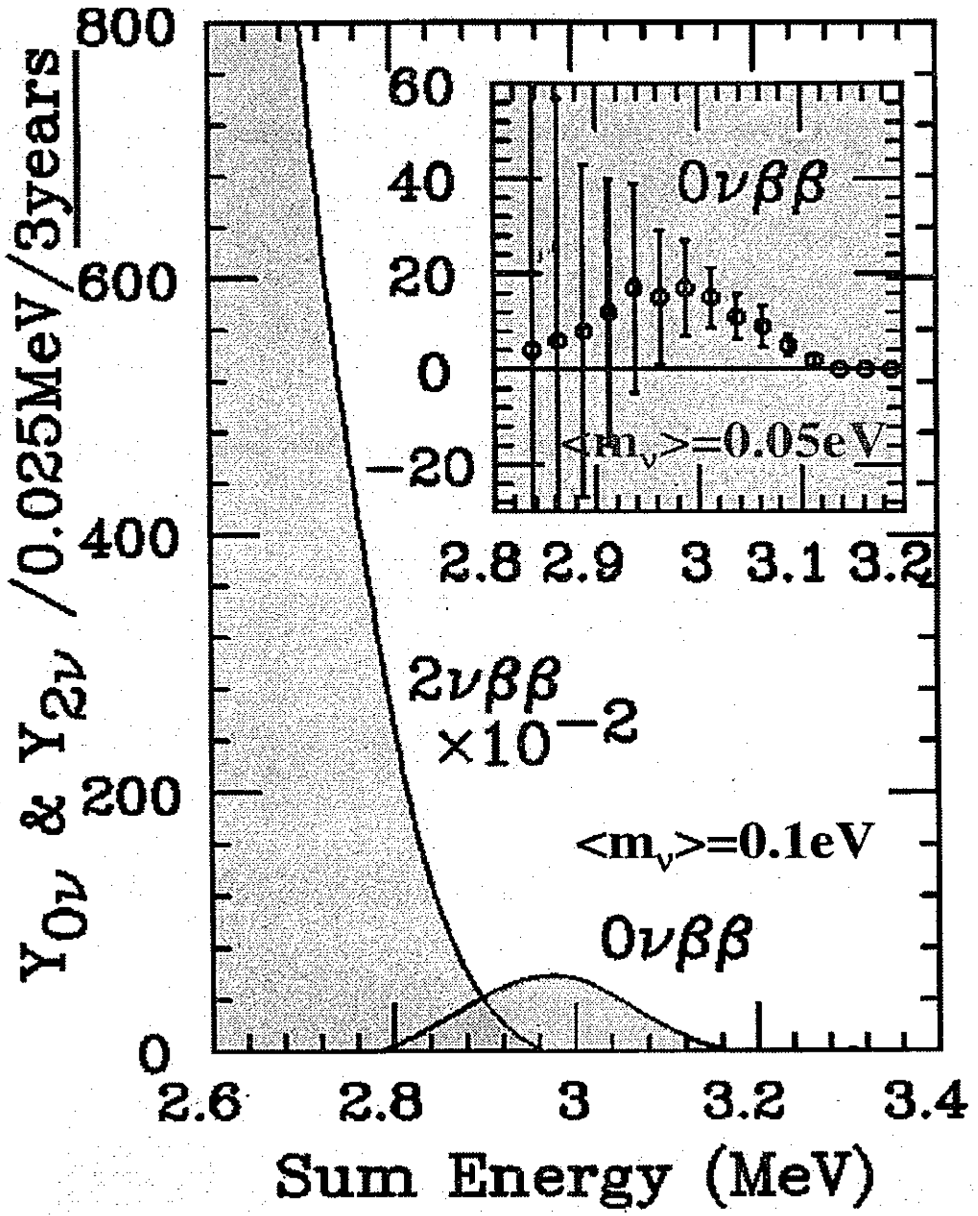
Space-Time topology

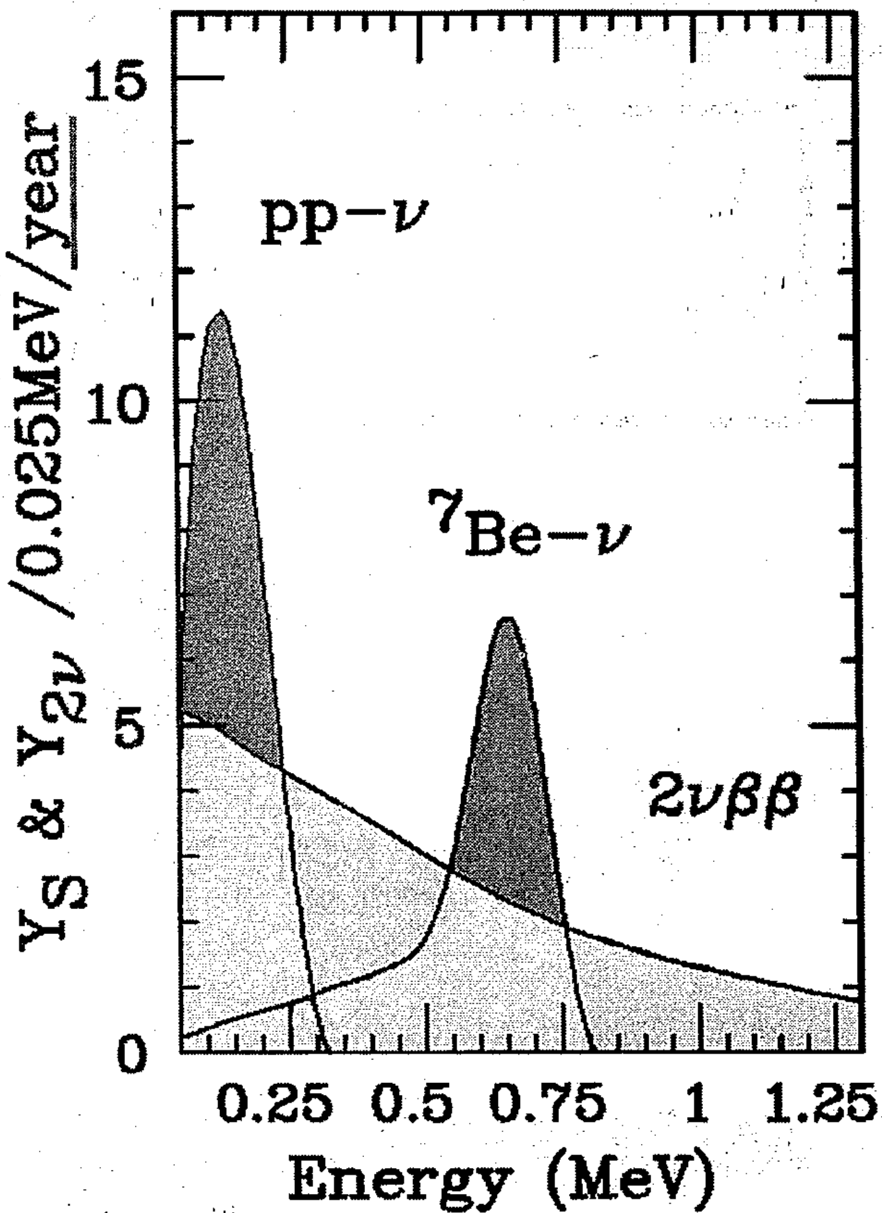
Major BG at the $0\nu\beta\beta$ window

- **Radio Activities in Detector/Source**
  - **0.1ppt of U-Th: 1.25-0.45 mBq/t .**
- **Cosmogenic Radio Activities**
  - **Negligible at underground lab.**
- **$2\nu\beta\beta$**
  - **$T_{1/2} \sim 10^{19}$y**

245

^{100}Mo ββ and solar ν



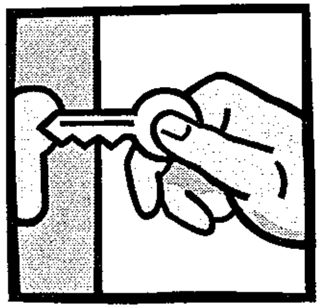


246

Ultra-low background

- Extremely good event selection is necessary
  - Energy deposit
  - Event topology (Space-time)

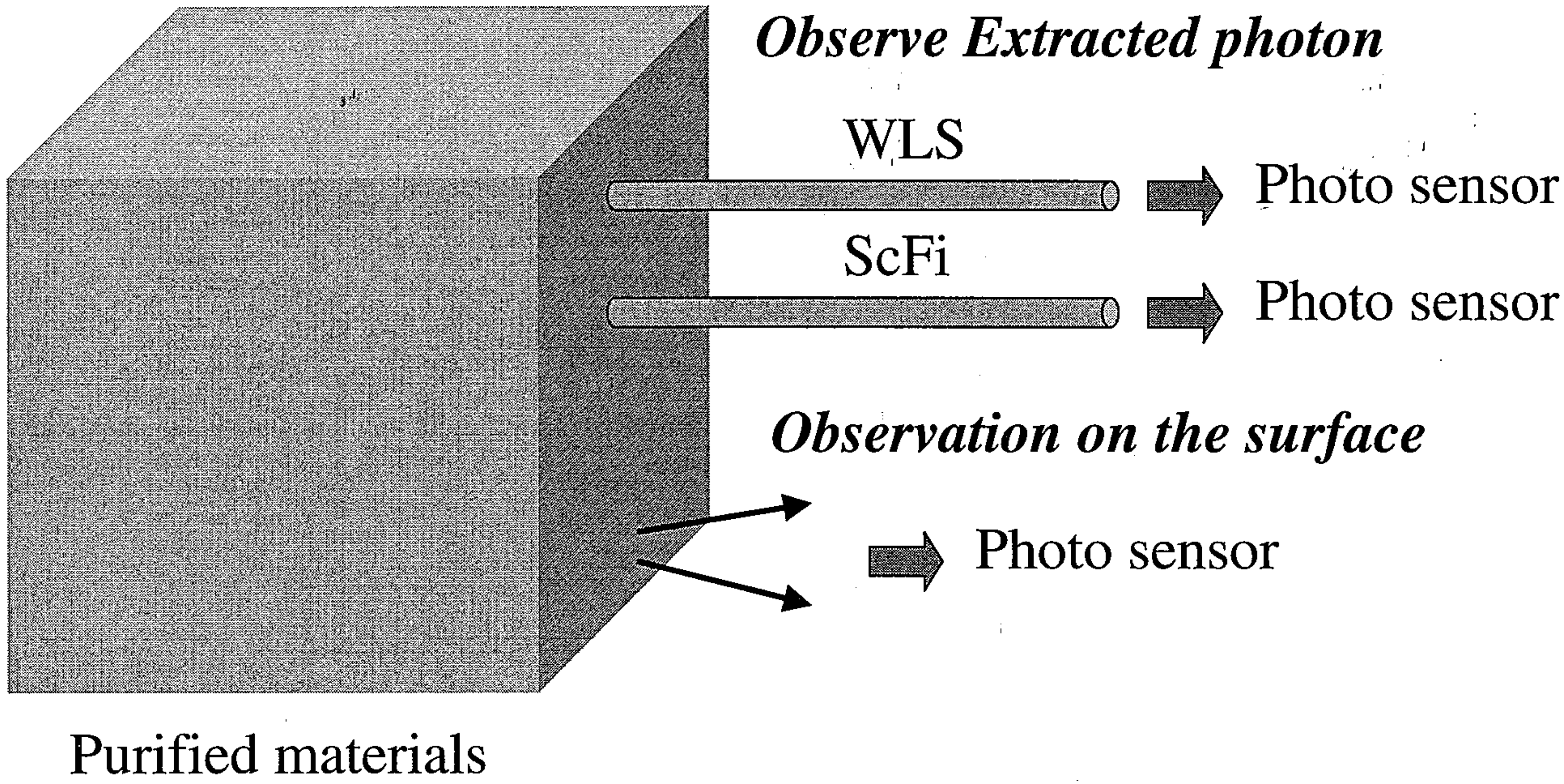
- Efficient photon collection
- High granularity



- Extremely good purification is necessary
  - Purified material (less kind of material)

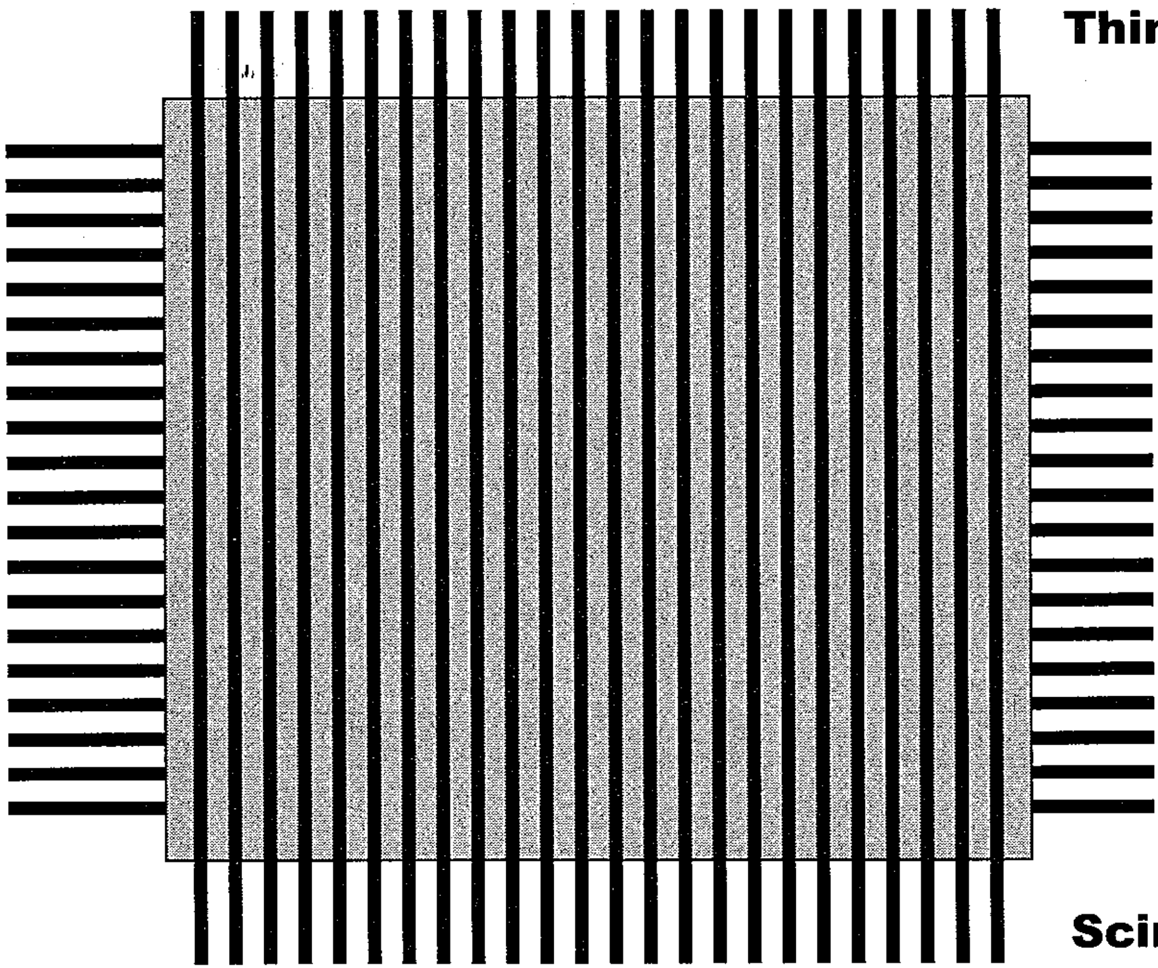
Requirements for MOON

• Large mass of ^{100}Mo	~1 ton
• Two β coin.	Δt ~ns for ββ,
	Δt~1-30s solar-ν.
• Dynamic range	E_{β} ~0.1-40 MeV
• Energy resolution	7% for 3MeV 0νββ
• Granularity	~ 10^9
• Purity	0.1 ppt 10^{-3} Bq/ton
	for U, Th isotopes.


Observe Extracted photon
WLS
Photo sensor
ScFi
Photo sensor
Observation on the surface
Photo sensor
Purified materials

MOON

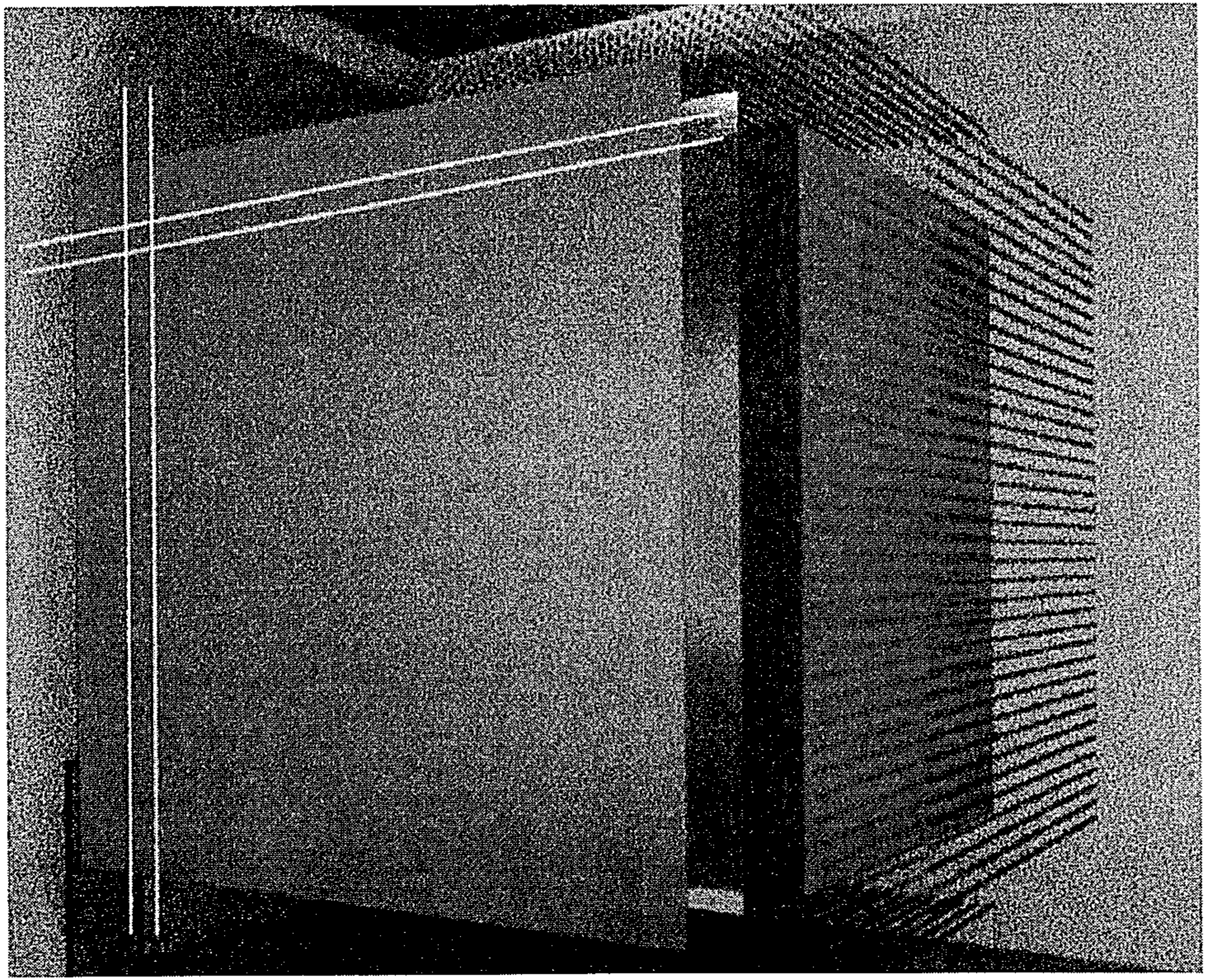
Plastic fiber-Mo Ensemble



250

MOON

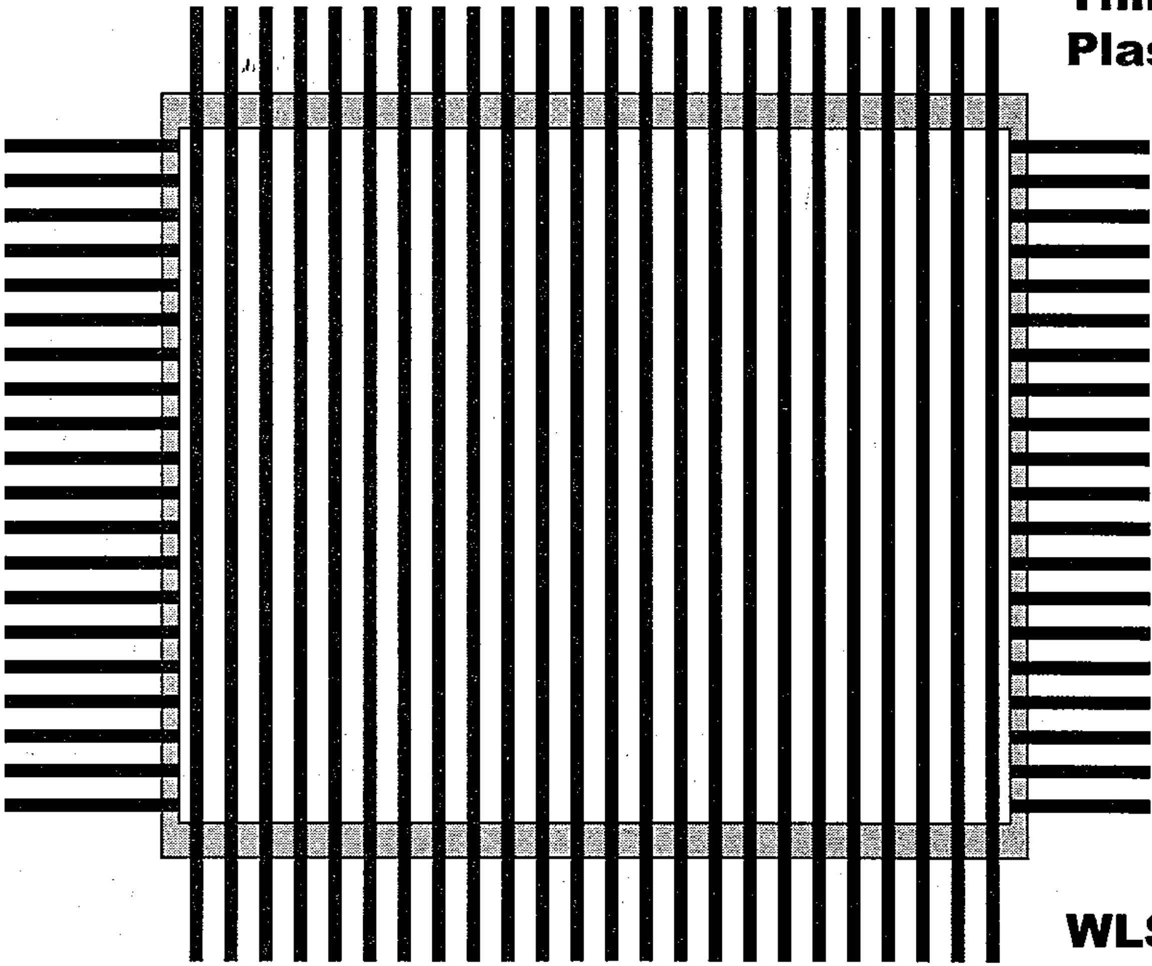
Plastic fiber-Mo Ensemble



A.Plastic Scintillation Fiber Detector

- Scintillator λ~430 nm
  - Transmission (both end) $t \sim 0.144$
  - One unit =250 modules, 2.5m-2.5m-0.5m
  - One module 2.5m-2.5m-2mm
  - Number of fibers /unit with $n_f \sim 250K$
- PMT Hamamatsu M6A 16 anodes
  - With one anode: 4 fibers. N_{pm}~10 K
- Mo 30 mg/cm^2 ^{100}Mo (9.6%) ^{100}Mo 0.045 ton
  - 85% enriched ^{100}Mo 0.4 ton
- MOON with 1 ton ^{100}Mo uses 2 units, 20K PMT

MOON
WLS fiber - Mo Ensemble



B. WLS (WaveLengthShifter) Read Out for Energy and Position

- Scintillator BS 414 $\lambda = 392$ nm

  One unit ≐200 modules, 2m-2m-0.5m.

  One module 2m-2m-2.5mm.

- WLS BCS 99-35A $\lambda - \lambda_1 = 380$nm-435nm

  2.7 cm interval x - y directions on PL

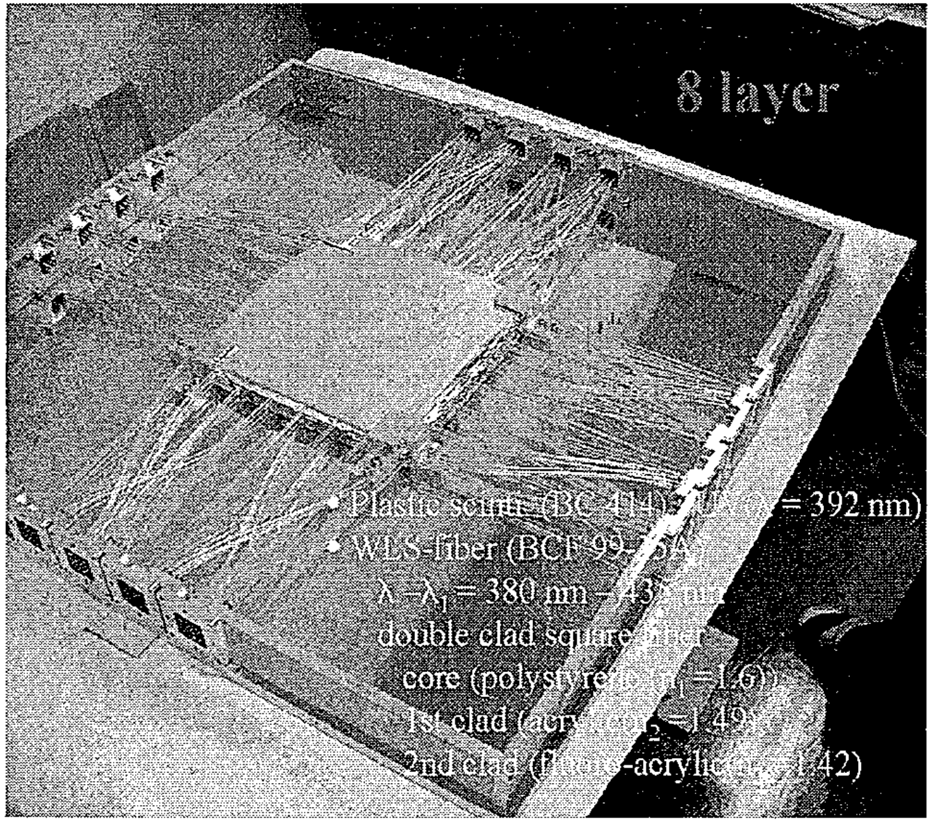
  Double clad with polystyrene(n_1=1.6), acrylic(n_2=1.49), fluoro-acrylic(n_3=1.42) t = 14.6 %

  Number of fibers /unit with ~30K.

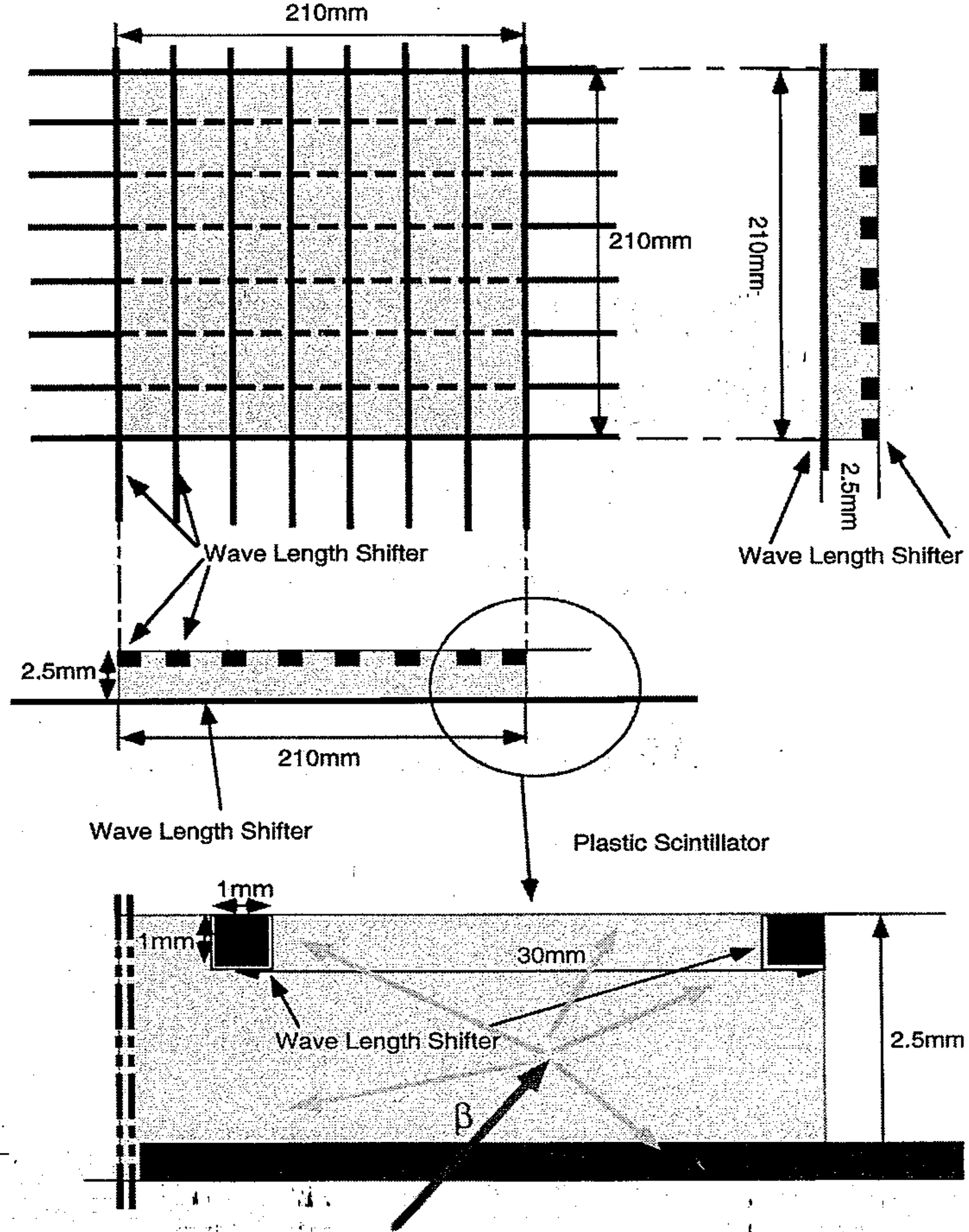
- PMT Hamamatsu M6A 16 anodes

  Number of PMT ~620.

WLS Test at OSAKA



Good Energy and Position Resolution



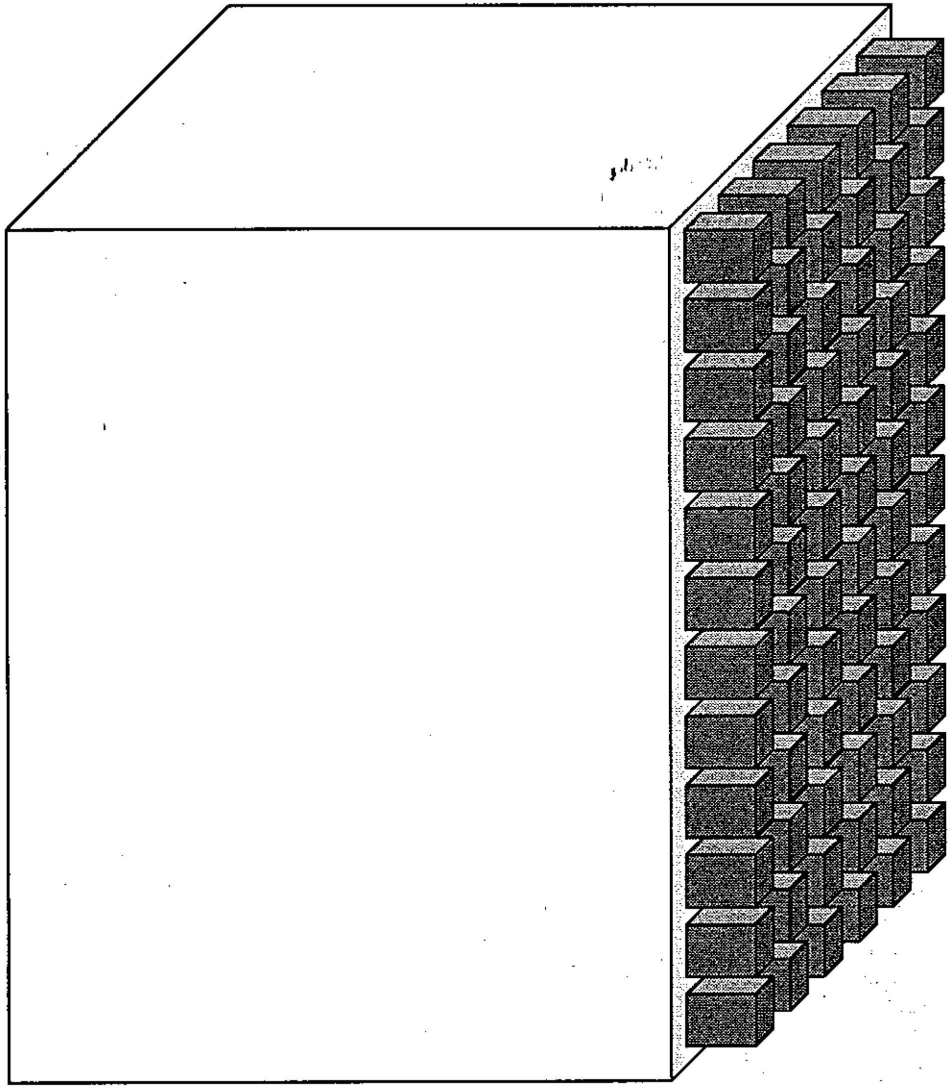
Efficiency for light collection of WLS

$\varepsilon_w \sim 0.14$ (Expected to be 1.0)

Need increase to get a required energy resolution

MOON

^{100}Mo loaded Liquid Scintillator

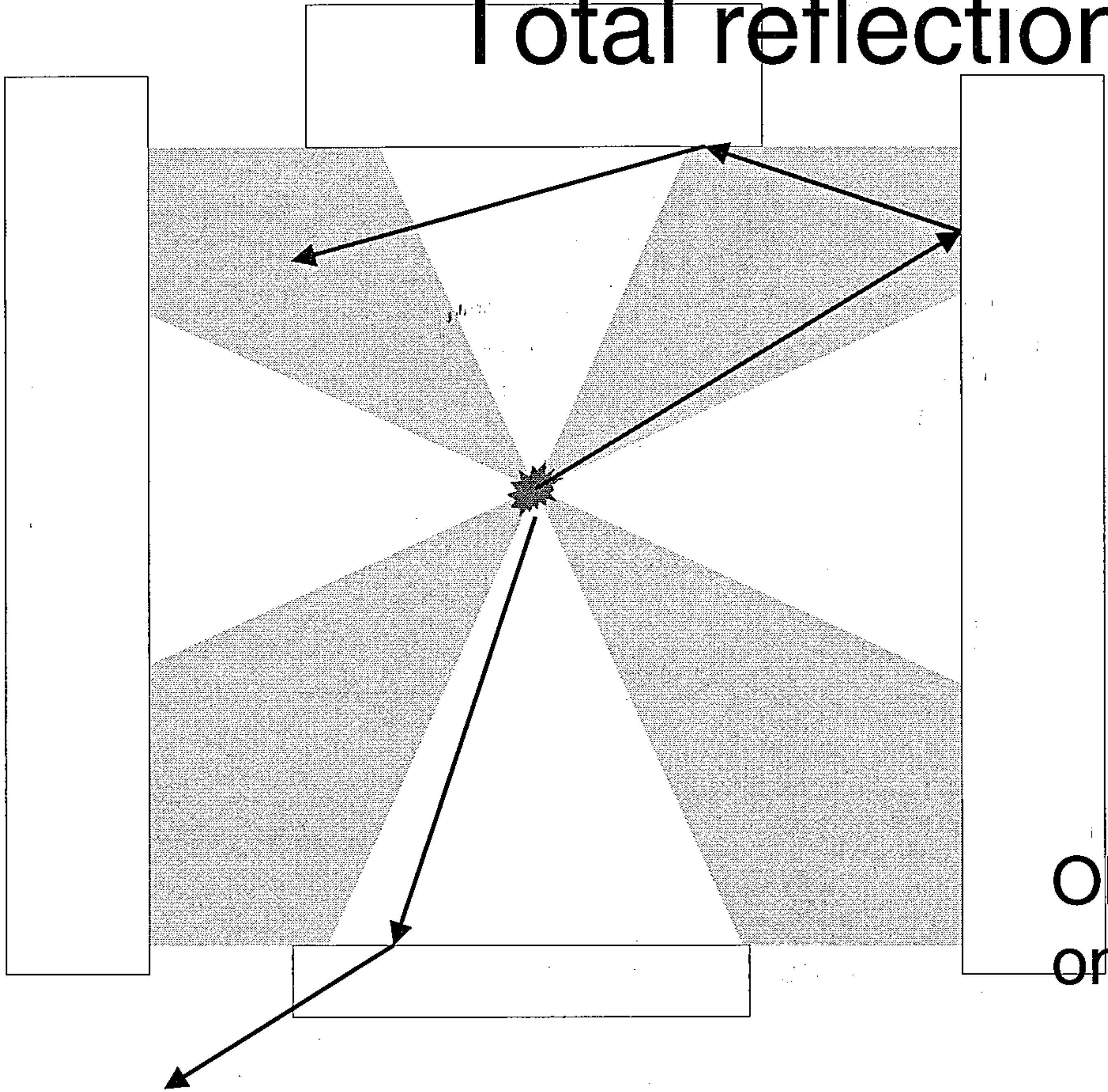


Photon detector array on all surfaces

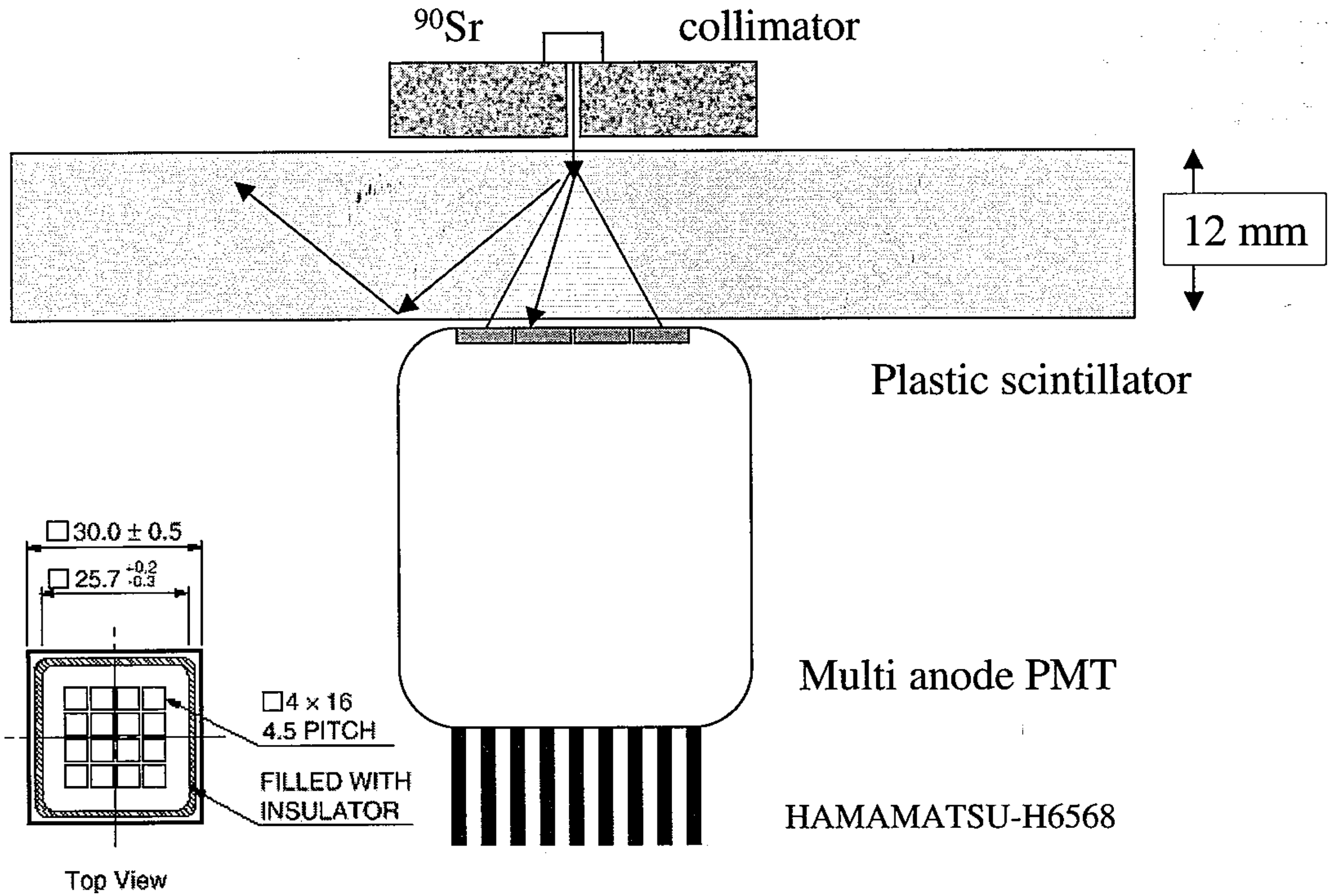
1. Photon sensor is far from source.
2. No structure near source.
3. Less kind of material

9m³ Liquid Scintillater

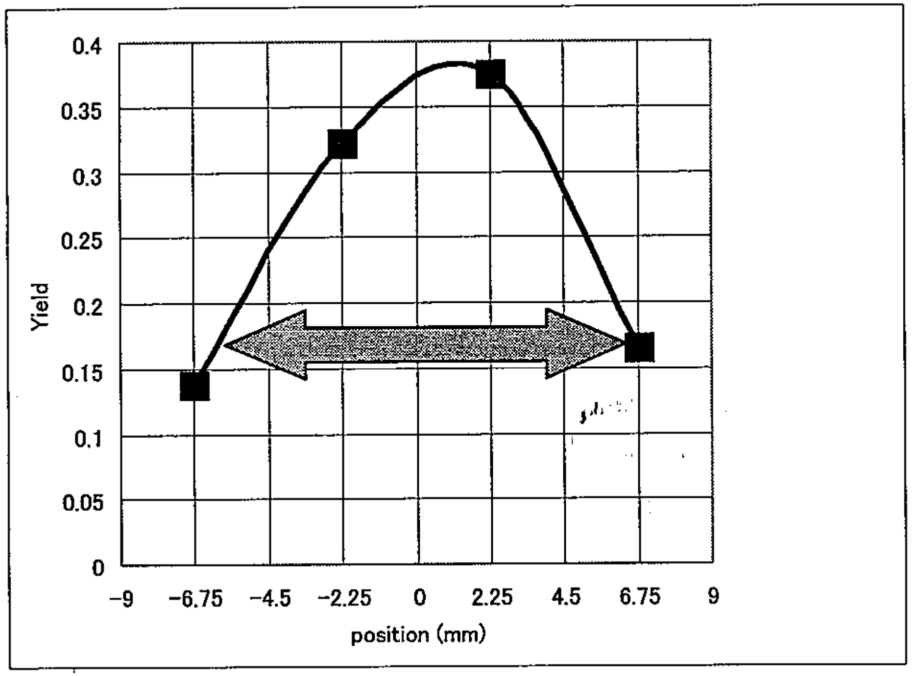
Total reflection

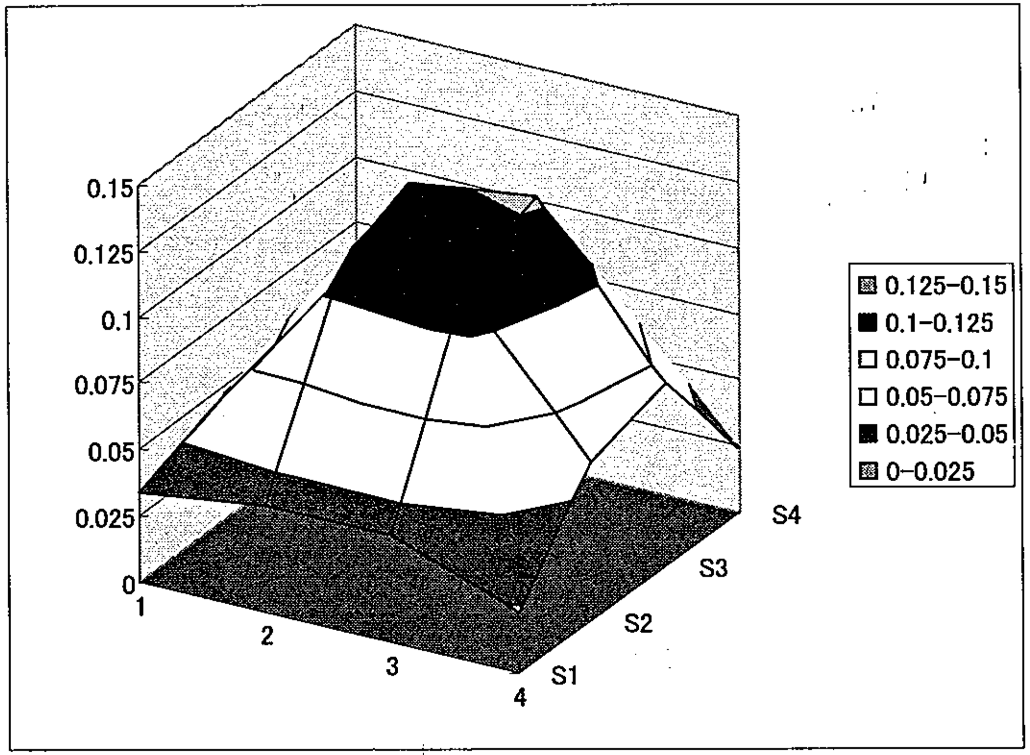


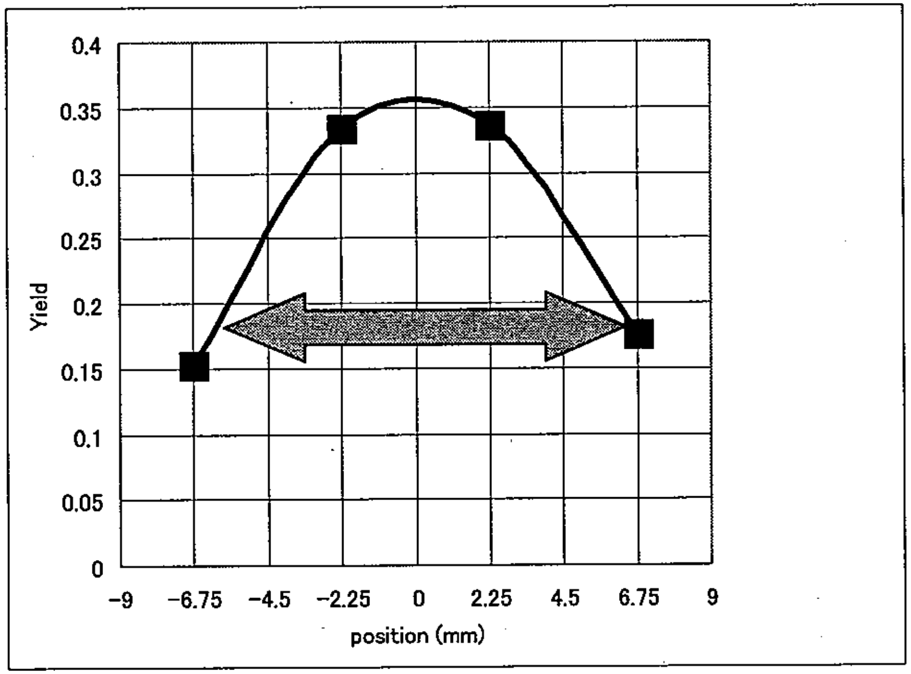
Observation
on the surface



^{90}Sr
collimator
12 mm
Plastic scintillator
Multi anode PMT
HAMAMATSU-H6568
□30.0 ± 0.5
□25.7 +0.2 -0.3
□4 × 16
4.5 PITCH
FILLED WITH
INSULATOR
Top View

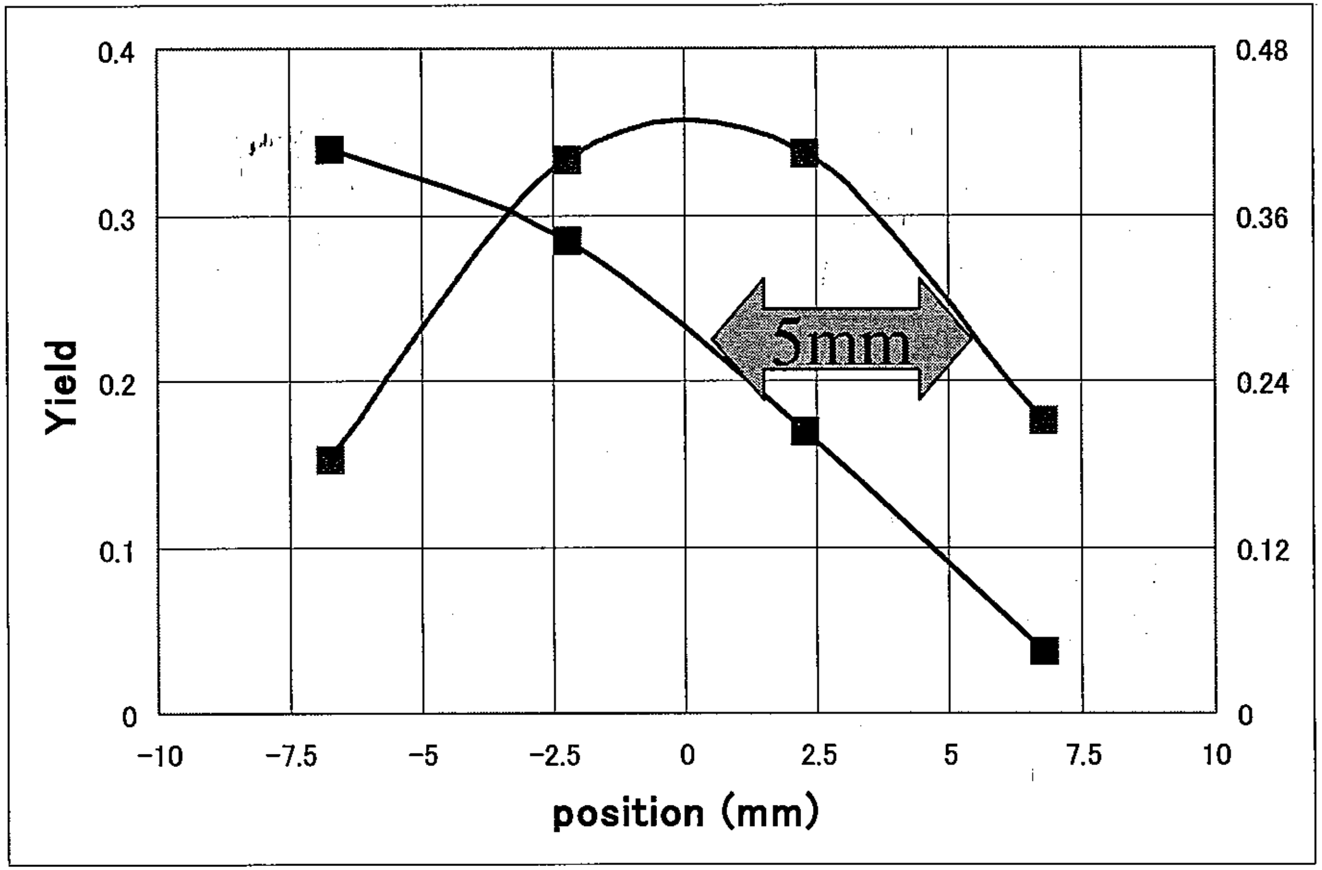






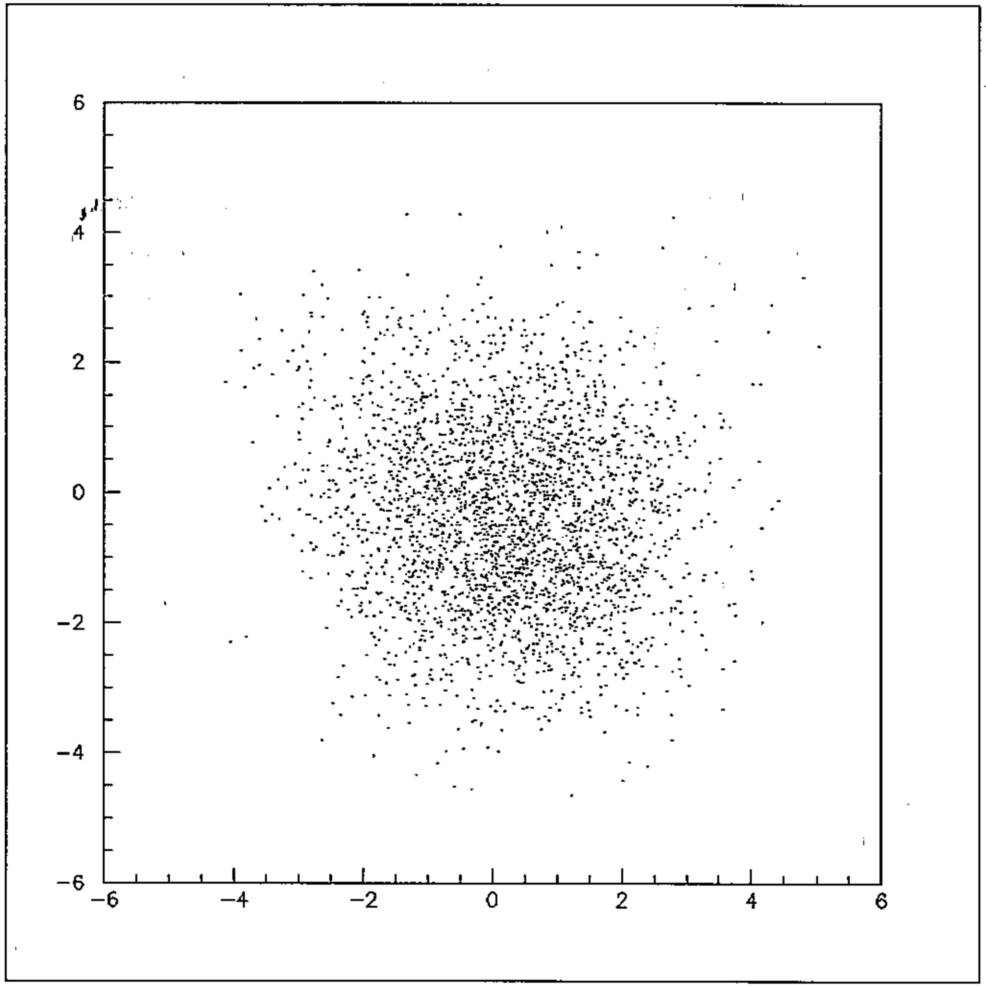
Photon distribution

~ 12mm (diameter)

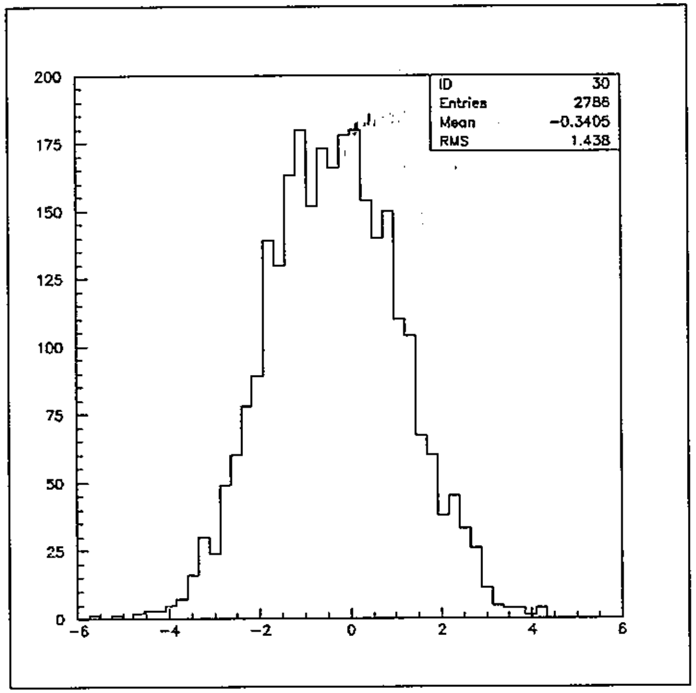


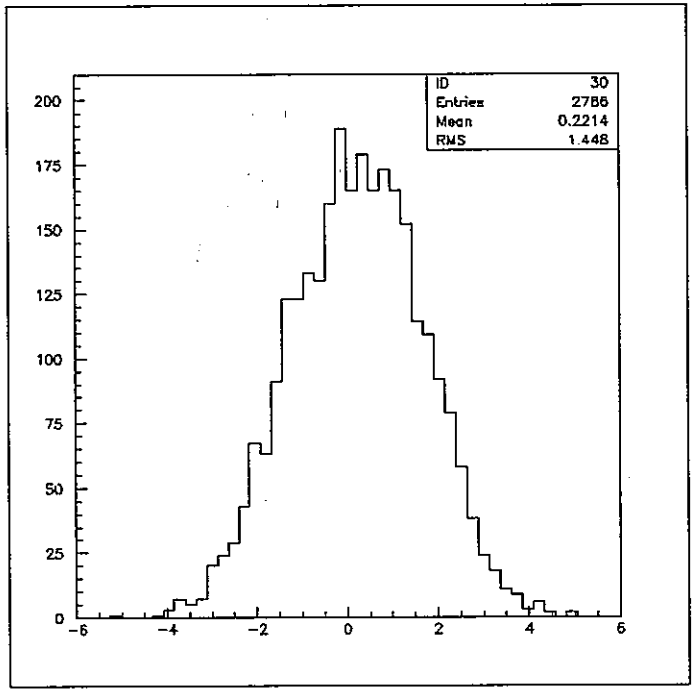
0.4
0.3
0.2
0.1
0
Yield
0.48
0.36
0.24
0.12
0
−10
−7.5
−5
−2.5
0
2.5
5
7.5
10
position (mm)
5mm

Distribution of calculated X-Y position



X-Y position is calculated by weighted mean.





Position resolution (RMS) : 1.4 mm

Successive α-decay

- Two successive alpha decay in GSO crystal

  $^{220}Rn \rightarrow {}^{216}Po$ 6.29 MeV

  $^{216}Po \rightarrow {}^{212}Pb$ 6.78 MeV

- Time Interval Half life 145 ms
- Position At the same position

96.0±8.6 mBq/kg is clearly identified

Energy spectrum

GSO
3.8cmx3.8cmx18cm
1.744kg

Time Interval

265