

LYSO Gamma Ray Detector

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Inorganic Scintillation detectors for gamma ray

◆ Resolution	High!	1%?	×
◆ Response time			
– Dead time (decay time)	Short!	100ns?	○
– Time resolution	Good!	100ps	○
◆ Efficiency / Volume			
– Radiation Length	Short!	1cm	○
◆ Back ground	Low!	?	
◆ Cost	Low!	1kyen/cc	○
◆ Life			
– Radiation damage	Small!	?	○

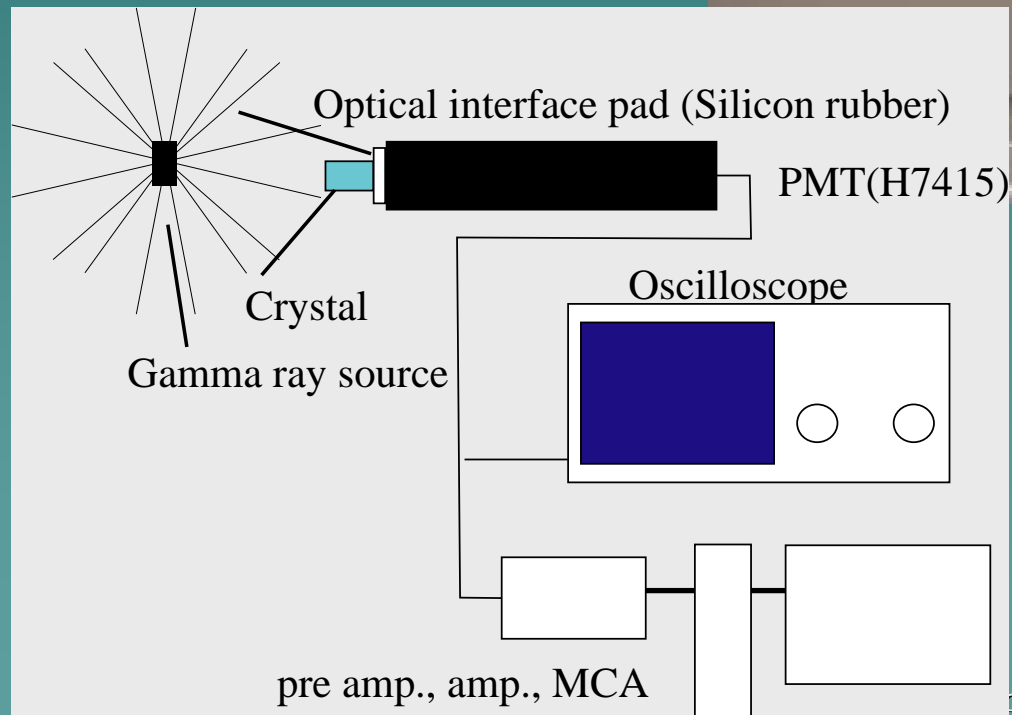
Test Samples

- ◆ LYSO:Ce 10mm x 10mm x 10mm
 - Lutetium-Yttrium Oxyorthosilicate,
 - Ce doped
 - (Lu:Y=98:2 (W))
- ◆ YSO:Ce 10mm x 10mm x 10mm
 - Yttrium Oxyorthosilicate
 - Ce doped
 - Y₂SiO₅
- ◆ Reference
 - BGO 10mm x 10mm x 10mm
 - NaI ϕ 13x20mm
- ◆ Response for gamma ray from ⁶⁰Co source

Specification

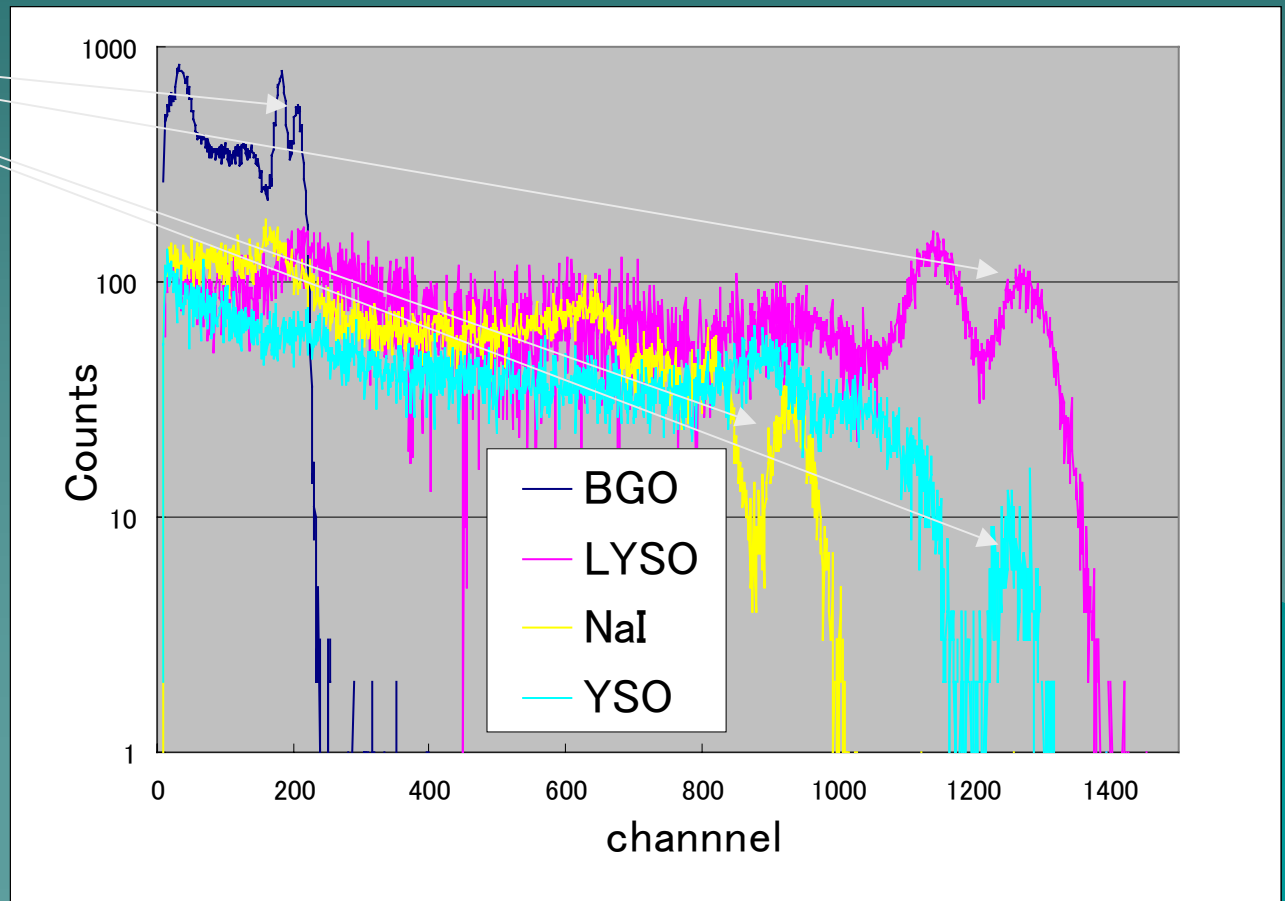
	NaI	YSO	LYSO	BGO
Density (g/cc)	3.67	4.45	7.4	7.13
Radiation length (cm)	2.59		1.16	1.12
Light output (NaI: 1.00)	1.00	0.8	0.75	0.12
Light wave length (nm)	410	420	428	480
	Hygrosco picity		Decay of ^{176}Lu	

Experiment



Light output, Energy resolution, Photo-peak efficiency

- ◆ Response for gamma ray
 - ^{60}Co 1.17 and 1.33 MeV



Light output, Energy resolution, Photo-peak efficiency

	NaI	YSO	LYSO	BGO
Resolution*	2.8%	2.4%	2.7%	3.9%
Light output	1	0.74	1.16	0.17
P.P. efficiency	1**	0.23	4.40	4.80

* 1.33 MeV gamma ray

**YSO, LYSO BGO: 10 x 10 x 10 mm cube

NaI: ϕ 13 x 20 mm cylinder

Fluorescence Decay Time

- ◆ Decay constant τ

$$V(t) = V_0 \exp\left(-\frac{t}{\tau}\right)$$

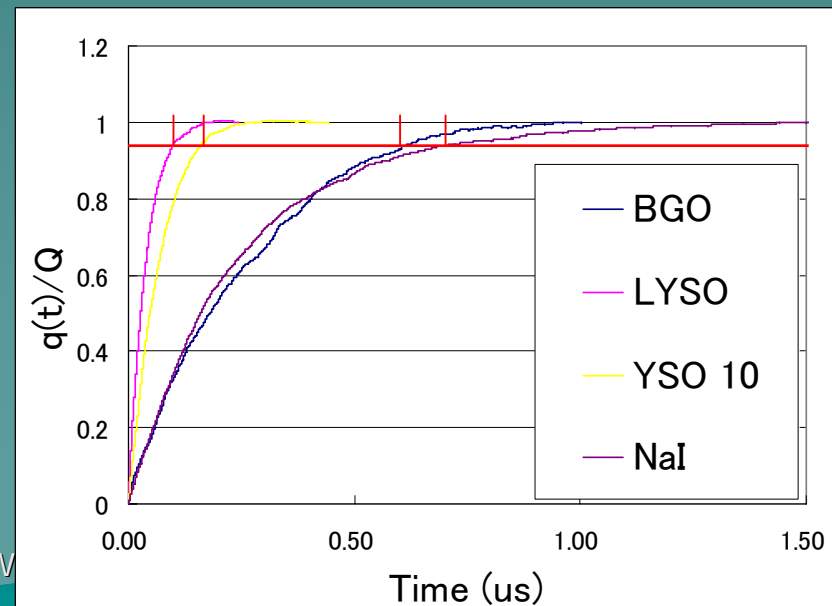
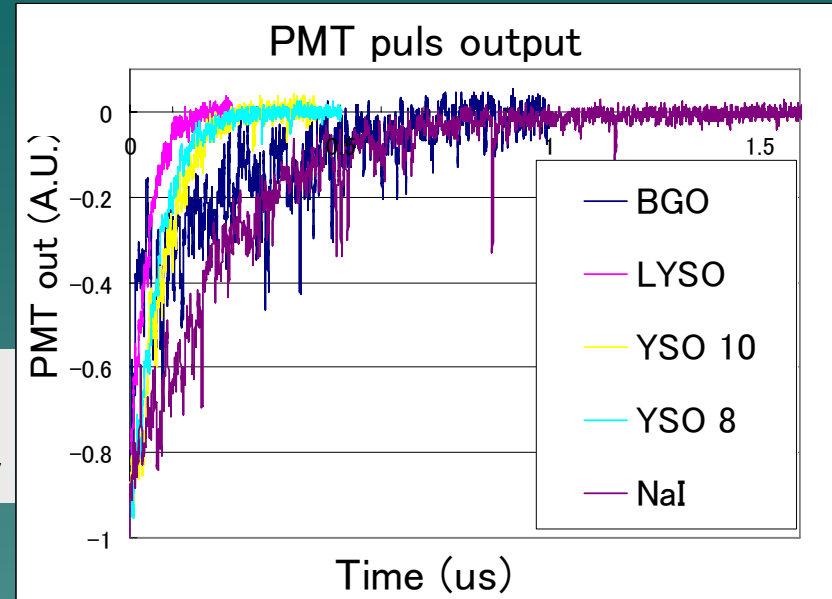
- ◆ Time integration of charge $q(t)$

$$f(t) = \frac{q(t)}{Q} = \frac{\int_0^t V(t) dt}{\int_0^\infty V(t) dt}$$

$$T : f(T) = 0.95$$

$$T = -\tau \ln 0.05 \cong 3\tau$$

	τ (ns)	T(ns)
NaI	240	750
YSO	80	240
LYSO	40	120
BGO	230	680



Background form Decay of ^{176}Lu

◆ Lu

– ^{175}Lu 97.41%, ^{176}Lu 2.59%

– ^{176}Lu

◆ beta decay

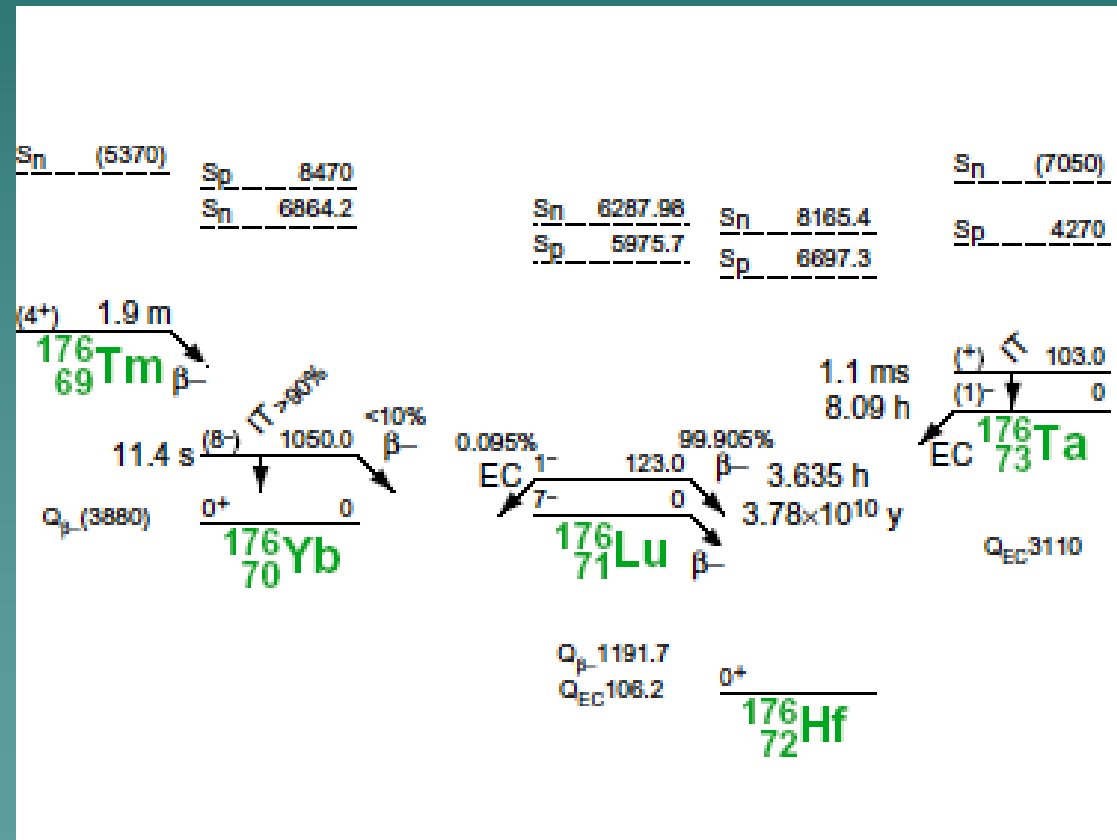
◆ $\tau = 3.78 \times 10^{10} \text{y}$

◆ Natural Lu

– 75 decay/g/s

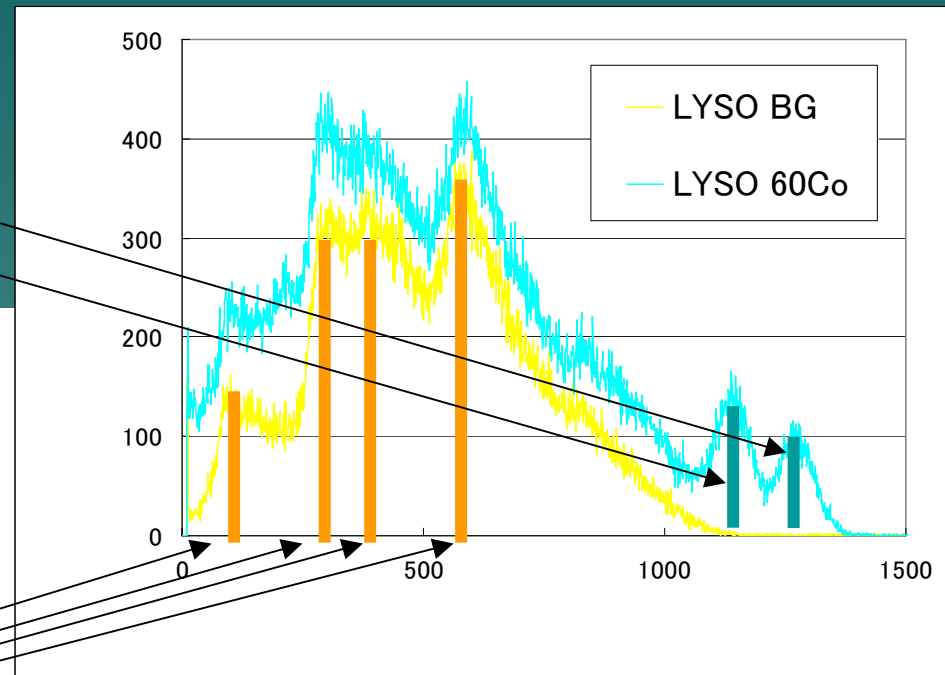
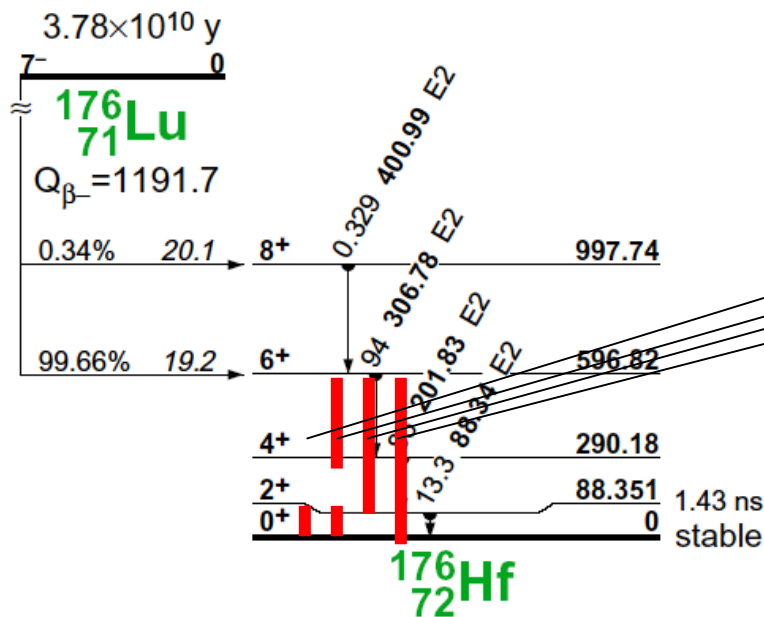
◆ LYSO

– 300 decay/cc/s



Beta decay of ^{176}Lu

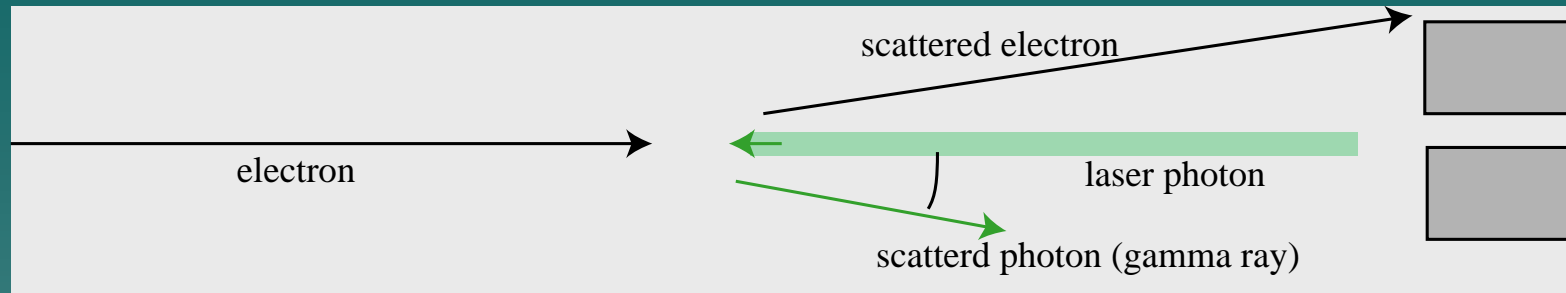
- ◆ ^{60}Co 1.17, 1.33 MeV
- ◆ Gamma + β spectrum



Finally,

- ◆ Is LYSO available for gamma ray detection?
 - Energy resolution ○
 - Response time ○
 - Stopping power ○
 - Radiation damage Unknown
- ◆ Decay of ^{176}Lu
 - Counting rate of back ground limits maximum volume
 - ◆ 300cc -> 100ns x 100kcps: dead time 1%
- ◆ Coincidence measurement?
 - 100 keV – 1 MeV
 - Small ball?
- ◆ Gamma calorimeter
 - ...

LCS (Laser Compton Scattering) gamma ray



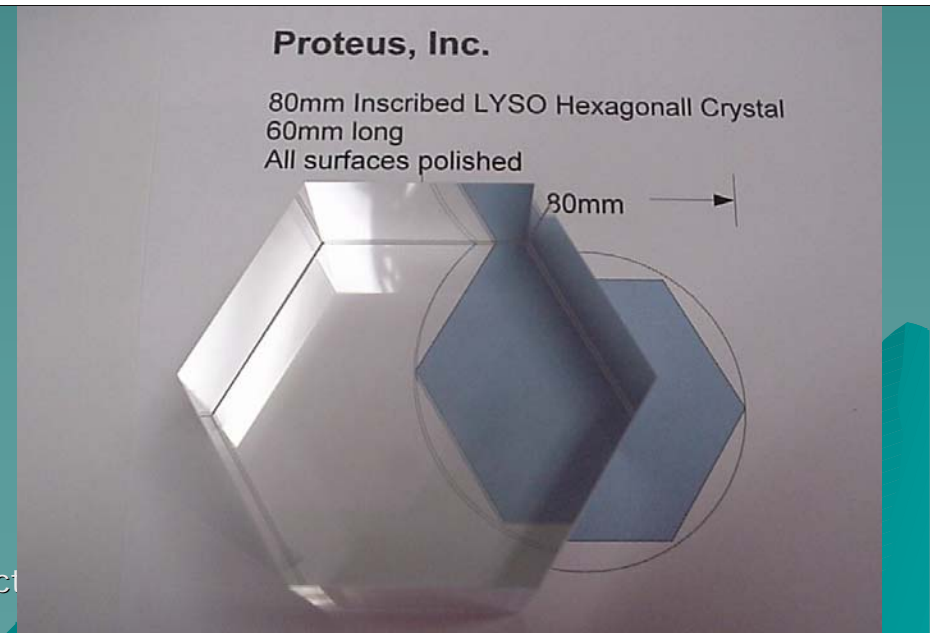
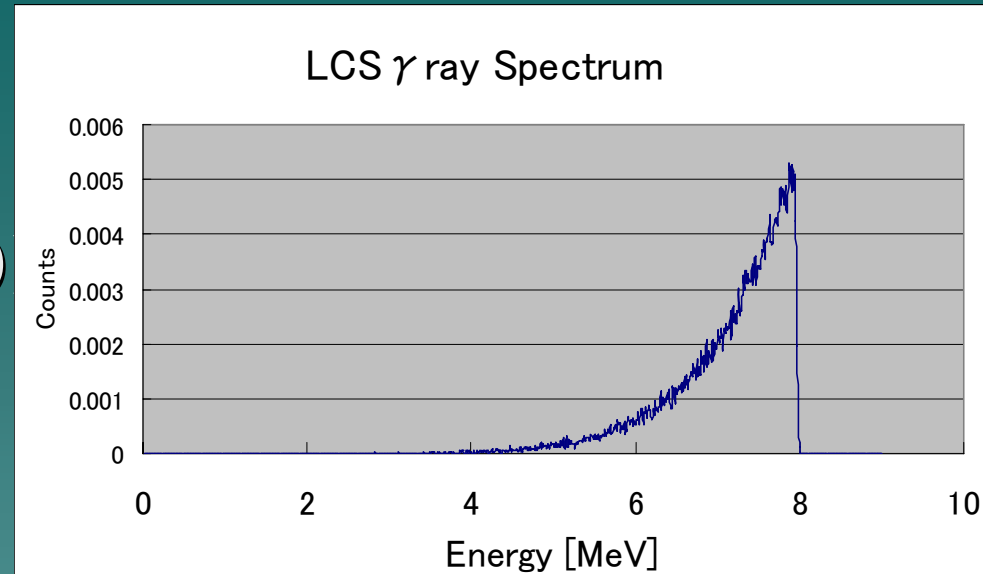
- ◆ TERAS (AIST, Tsukuba)
 - $E_e = 400-800$ MeV
 - $E_\gamma = 2-20$ MeV
- ◆ NewSUBARU (Nishi Harima)
 - $E_e = 1.0-1.5$ GeV
 - $E_\gamma = 4-40$ MeV
- ◆ SPring-8 (Nishi Harima)
 - $E_e = 8$ GeV
 - $E_\gamma = 2-3$ GeV

$$E_\gamma = \frac{4\gamma^2 \varepsilon_L}{1 + (\theta_\gamma)^2 + \frac{4\gamma\varepsilon_L}{mc^2}}$$

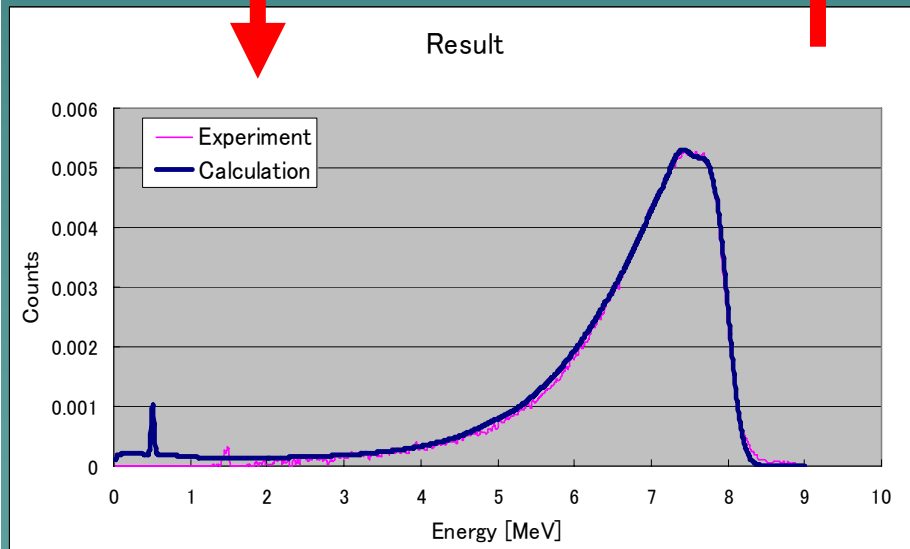
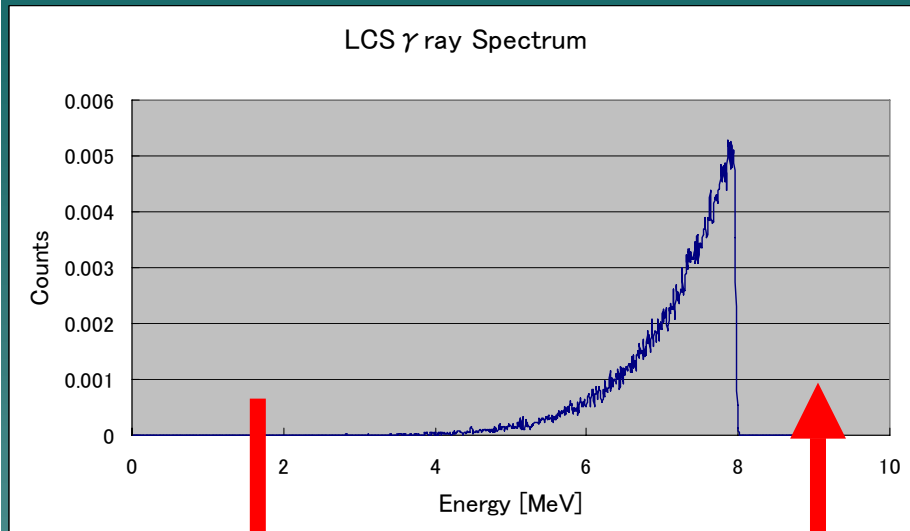
- E_γ : Energy of gamma LCS ray
- ε_L : Energy of incident laser photon
- m : electron mass
- γ : Energy of electron
- θ : Scattering angle of photon

LCS γ beam monitor

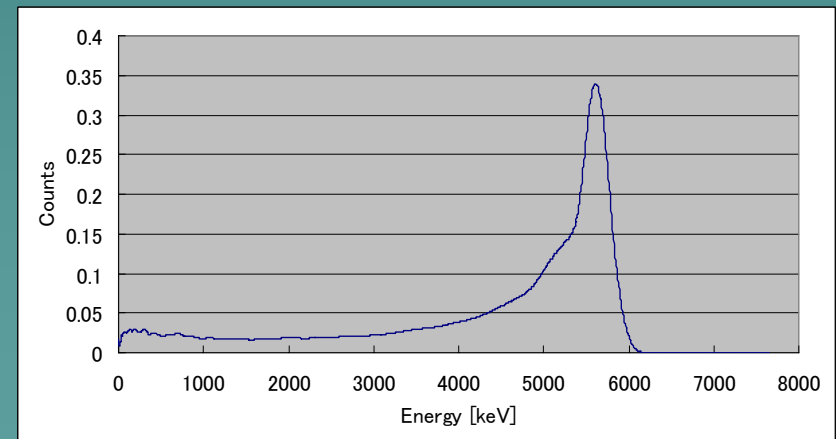
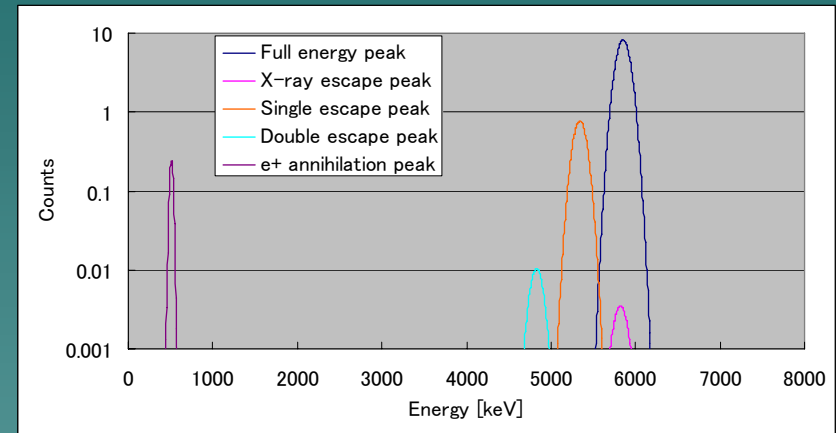
- ◆ Quasi monochromatic
 - $\Delta E/E = 2-10\%$
 - 2-40 MeV ($>E_{\gamma}$ (^{176}Lu))
- ◆ TERAS
 - NaI $\phi 8 \times 12$ inch
- ◆ NewSubaru
 - LYSO
 - ◆ Hex 80 mm \times 90 mm



Unfolding Experimental Spectrum with EGS5 Simulation



Response for monochromatic photon



Summary

- ◆ LYSO を NaI, BGO, YSOと比較した。
 - 発光量 NaI 並み
 - 阻止能 BGO並み
 - 発光時間 NaI, BGOの1/6
 - ◆ ところまではよいが、
- ◆ ^{167}Lu の崩壊によるbackgroundが
 - 300 cps/cc程度ある。
- ◆ これにより用途がかなり限定される。