Evaluation of properties of YAG(Ce) poly-crystal scintillator

Scintillating Crystals and their Applications in Particle and Nuclear Physics

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Topics

1. **Introduction**
2. **Basic Properties**
   - **Emitting Spectrum**
   - **Transmission rate**
   - **γ-ray spectrum & light yield**
   - **Decay time**
   - **Uniformity & intrinsic BGD**
   - **Response for α-particles (α/γ ratio)**
   - **Evaluating with APD**
3. **Summary**

Inorganic Scintillators

Single crystals have played a major role, so far.

- **Difficulty in crystallizing** (Chochralsky method)
- **Weakness of a mechanical strength**
- **Late production and high cost**

→ **Few materials exist for useful scintillators.** (e.g. NaI,CsI,GSO,BGO)

If we use poly-crystals, we may overcome these problems.

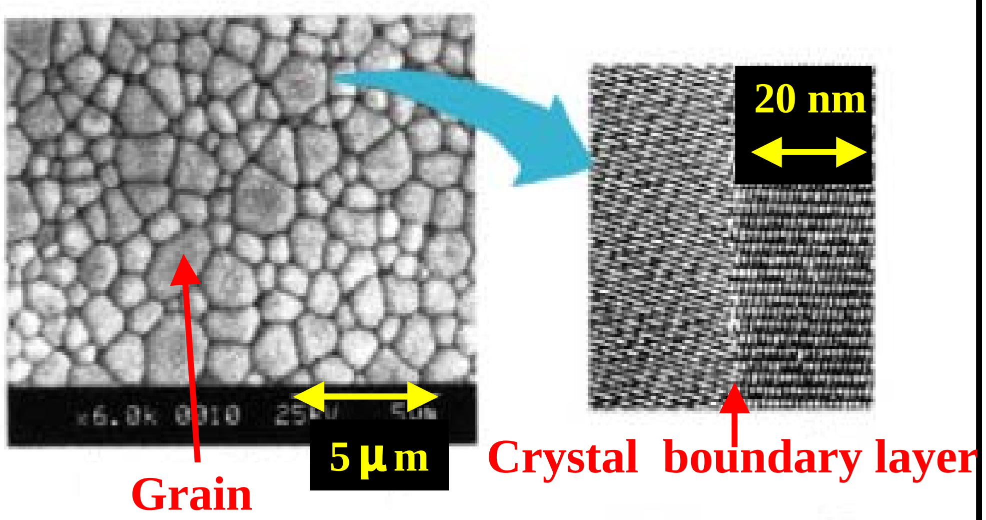
We demand large and strong scintillators for the space use.

Studies in last year

2003.3 *The Physical Society of Japan* **Annual Spring Meeting,** 2003.9 *The Physical Society of Japan* **Annual Autumn Meeting**
Kasama 2003, Master thesis (Cooperated by Konoshima Chemical and Baikowski Japan)

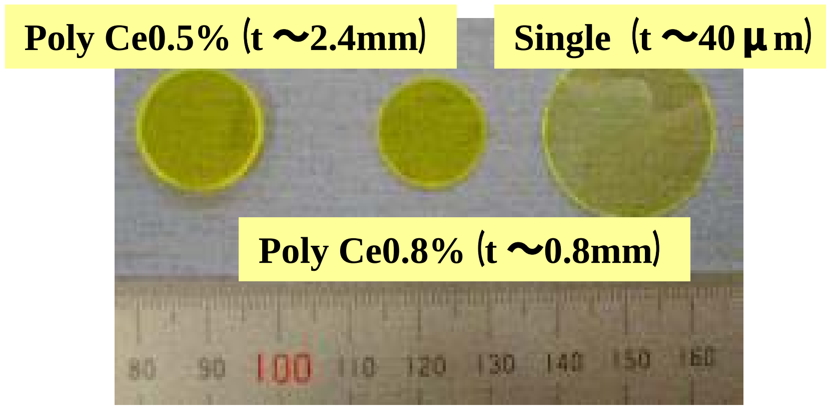
Microscope image of poly crystal

(presented by Konoshima Chemical Inc)



Ce:YAG ($Y_3Al_5O_{12}$, 4.57g/cm^3)

We evaluated basic properties.



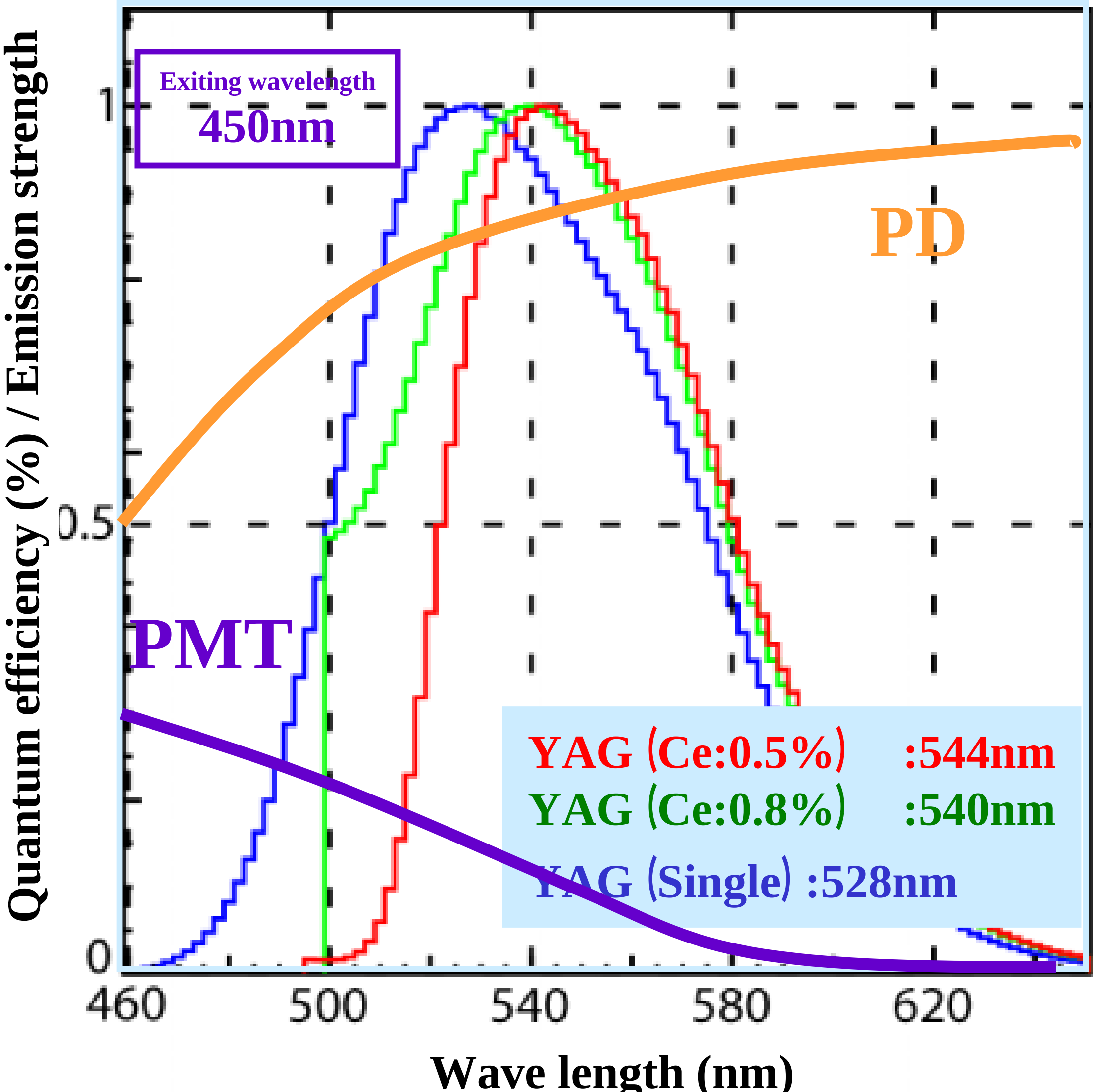
Emitting spectrum of YAG

We investigated the emitting spectrum to choose the suited detector.

Self-absorption : corrected

Sensitivity of the PMT : un-corrected

Peak emission wavelength is ~540nm.



NaI:415nm
GSO:440nm
BGO:480nm
CsI:540nm

↓

PD is more suited for poly-YAG than PMTs.

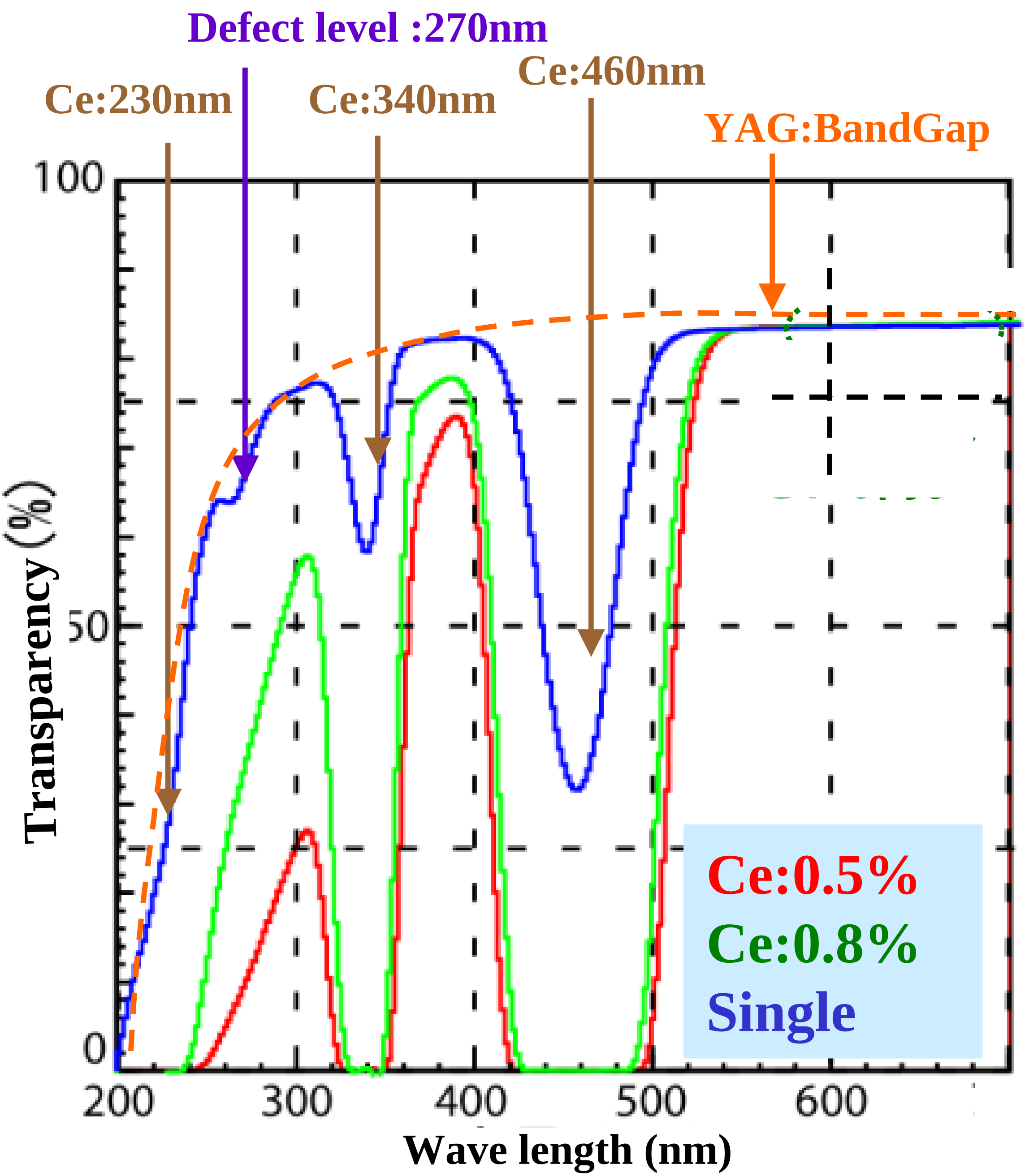
↓

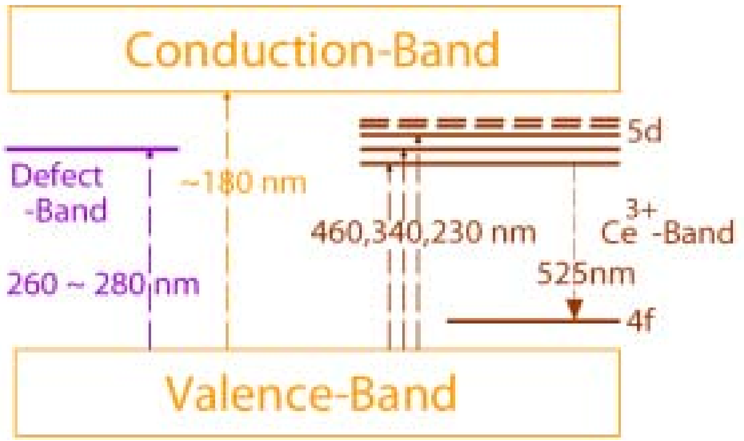
APD(Avalanche Photodiode)
Hamamatsu S8664-55
5✕5✕5 YAG(Ce:0.5%)
(see poster 16 yanagida et al.)

↓

Miniaturizing a measuring system.
Future space use.

Transparency

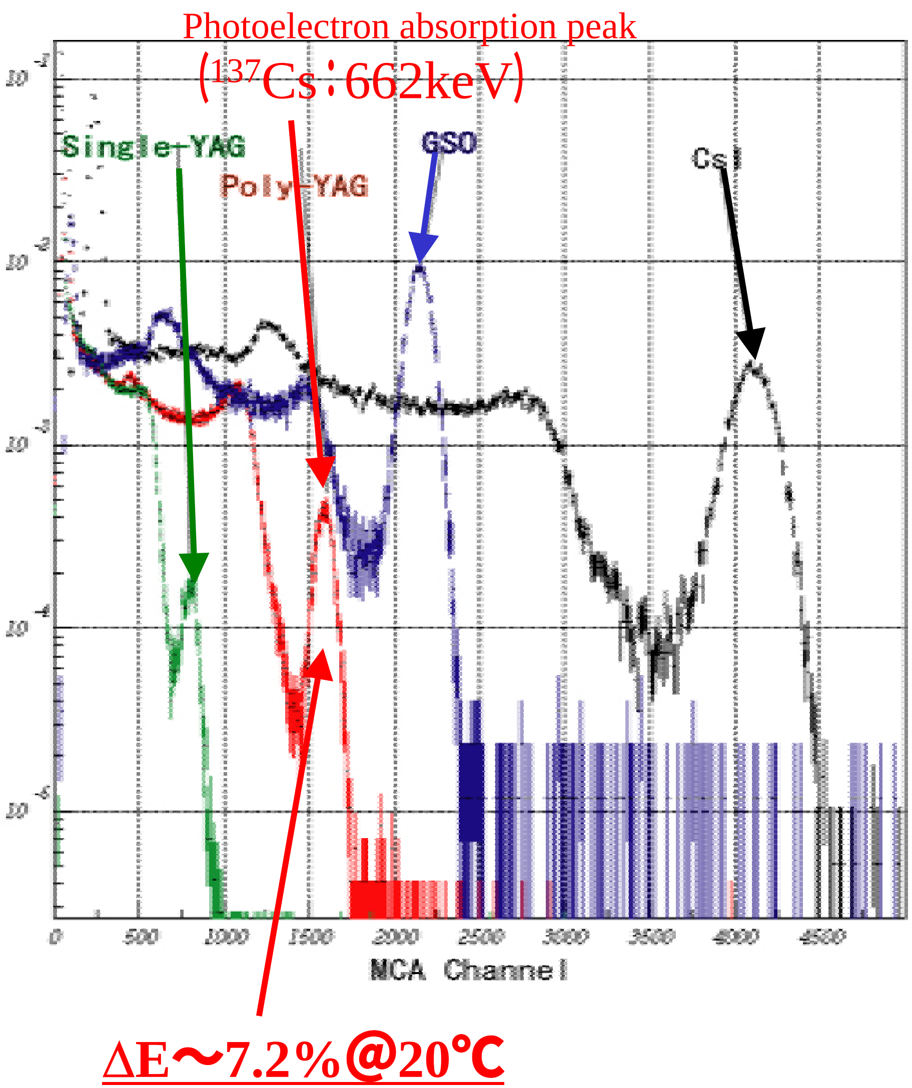




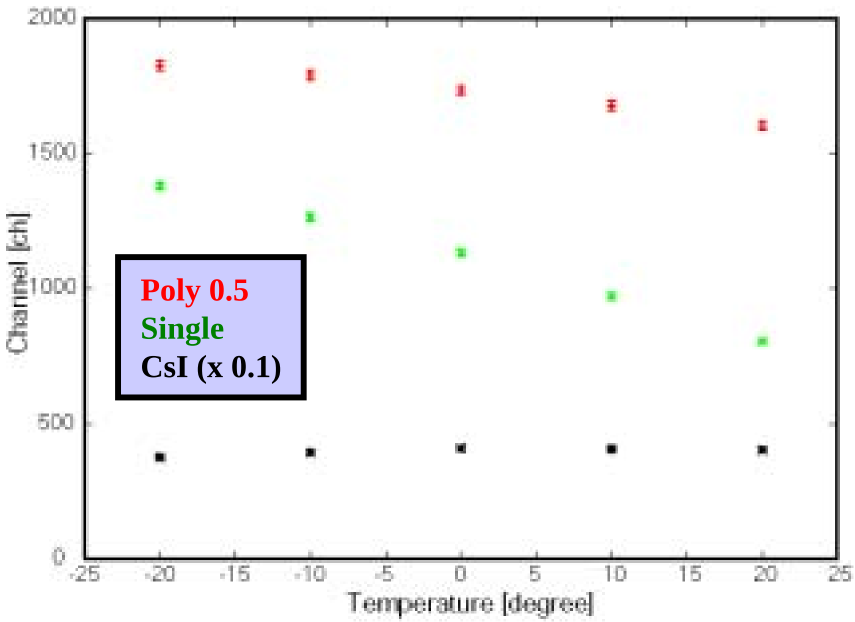
- No particular absorption exists for a poly-crystal.
- Absorption band properties are same as single one.
- Few lattice defects exists.
- Little influence by self-absorption.

γ-ray spectrum

➤ **We used a PMT (Hamamatsu R6231) to investigate the γ-ray spectrum.**



Temperature dependence of light yield (^{137}Cs 662 keV)

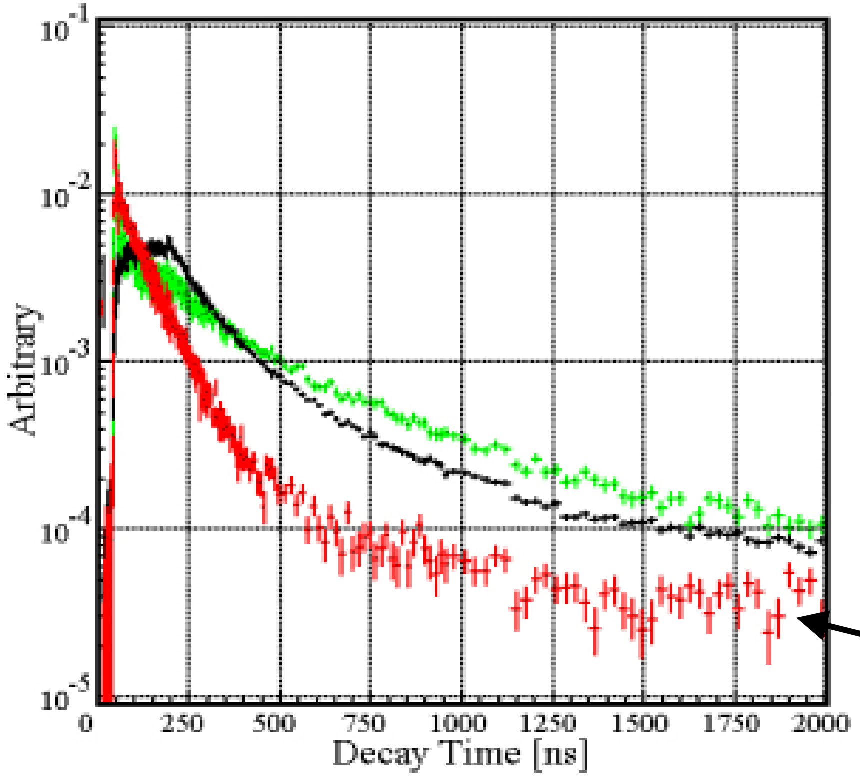


- Resolution is ~ 7.2% @ 662keV.
- Light yield : poly-YAG/GSO〜70%
- For poly-crystal, it has low dependence of the temperature.
- Light yield to energy ratio is constant up to 1275 keV.

Decay time

Decay time measurement ← •Pulse shape discrimination application •Influencing to dead time

- **Method : delayed coincidence method**



Red : 0.5% Poly
Green : Single
Black : CsI

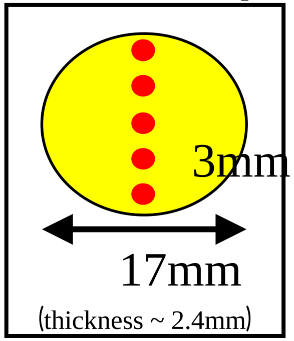
Poly : 86 & ~1000 (ns)

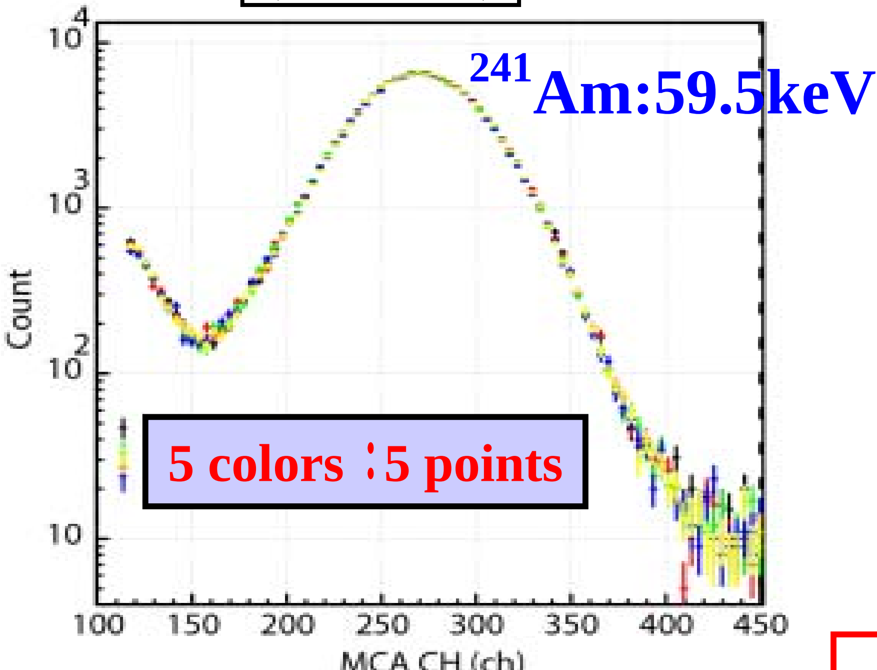
- Two components exist for poly-YAG.
- Faster than CsI scintillator.

Details are in poster 15 Takahashi et al.

Uniformity for poly crystal

- We used Pb collimator (ϕ=2mm).



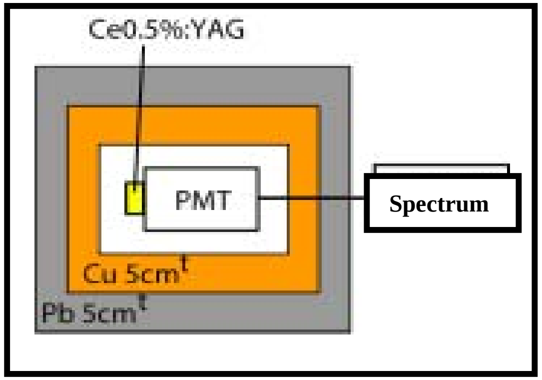


- •Peak CH: <0.5% consistent
- •Stopping power: <5% consistent

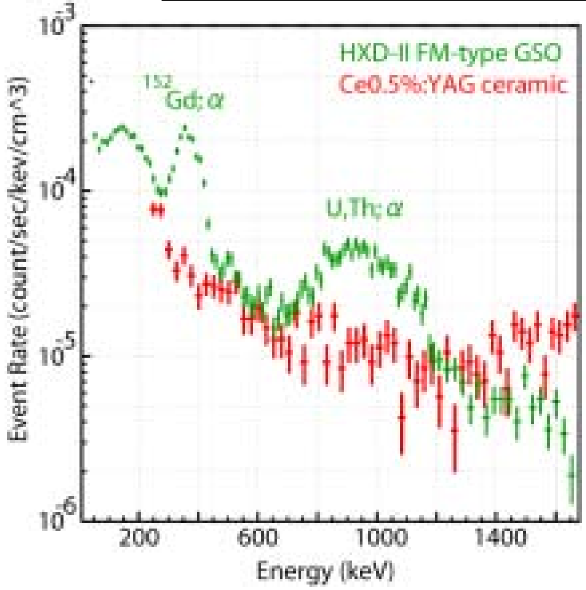
Uniformity has been confirmed.

Intrinsic Backgrounds

- Set up



- Data



- $\sim 1 \times 10^{-5}$ count/sec/keV/cm^3.
- No particular natural RI contamination exists.

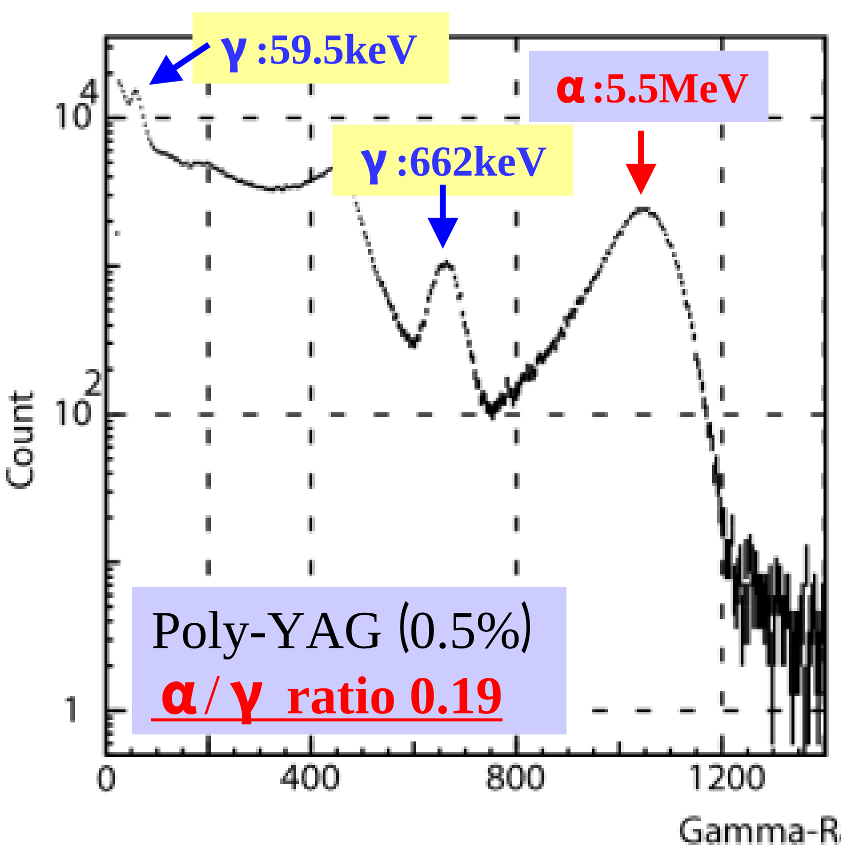
It is applicable for low BGD measurement.

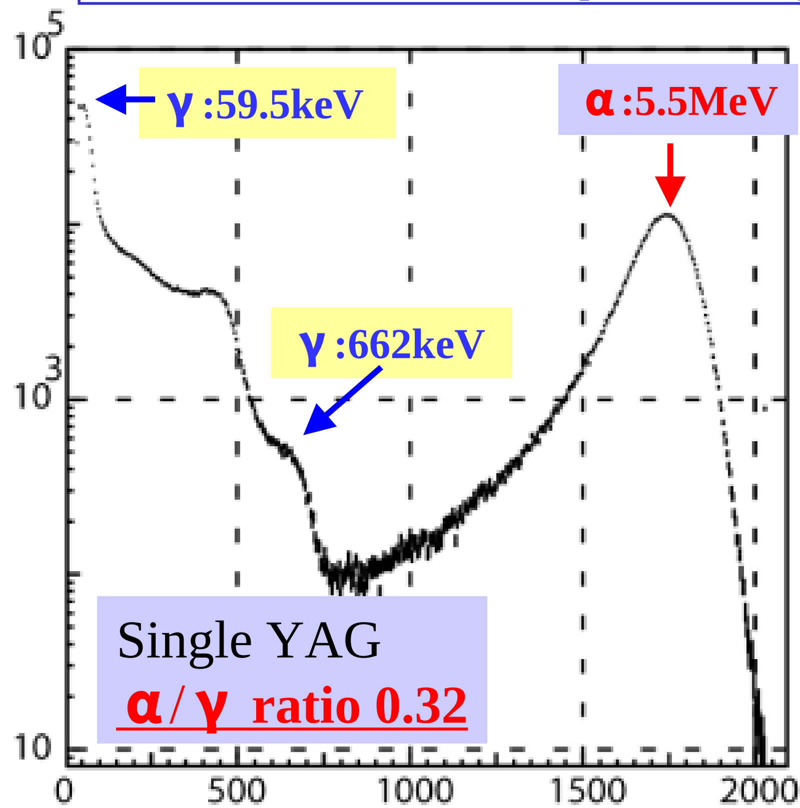
Response for α particles ～α/γ ratio～

The response for α particles (α/γ ratio) ← •Assuming a space environment •The possibility of a low BGD.

- Method: Using ^{241}Am, we irradiated **α** particle (5.5 MeV) and **γ-ray** (^{137}Cs) .
- Energy spectrum

$$\alpha/\gamma \text{ ratio} = \frac{\gamma\text{-ray energy on the spectrum}}{\alpha \text{ particle energy}}$$

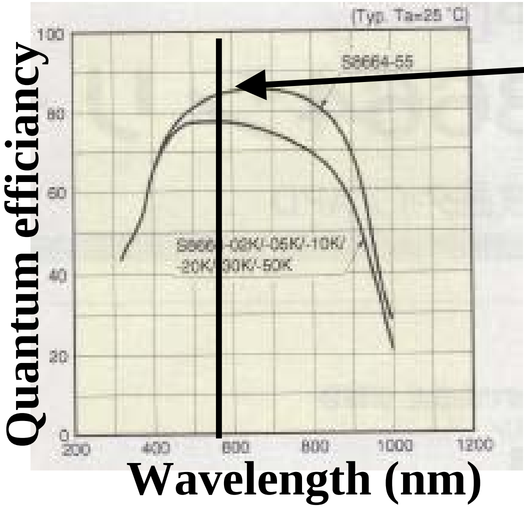




cf.
α/γ ratio
GSO:0.20
BGO:0.21

Poly crystal has a low efficiency to translate α particle into a scintillation light.

Evaluating poly-YAG with an APD

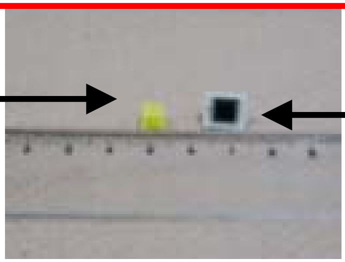


Quantum efficiency ~ 80% @ 540 nm (the peak emission wavelength of YAG)

APD : Internal gain is ~ 50 times.

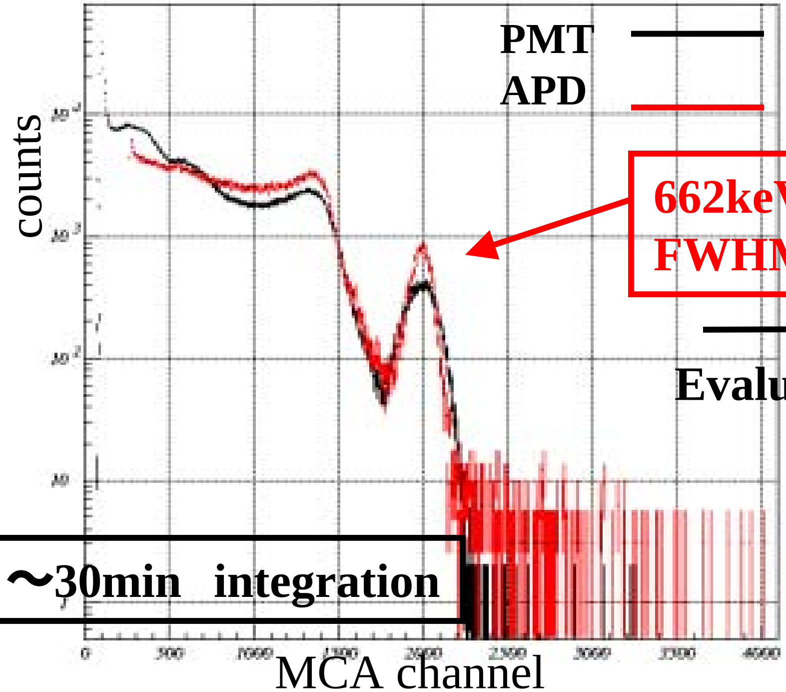
Energy resolution is expected to be improved.

Poly YAG : 0.5%



APD

^{137}Cs (662keV) YAG 5×5×5 spectrum @−20℃



662keV peak
FWHM=6.3% (APD)

～30min integration

Evaluation of results

We compared YAG with other famous scintillators

- CsI (3mm×3×3)
- GSO (5×5×5)
- BGO (6×6×4)
- Poly-YAG：(5×5×5)

Cf. APD：(5×5)

See p16 yanagida et al.

YAG showed a good performance compared with CsI.

Summary (Properties of poly-Ce:YAG)

properties	results	Comparing with single	remarks
Light yield	YAG/GSO～70%	Little temperature dependence	
Energy resolution	～7%@662keV		Comparative with HXD-GSO
Linearity	residuals＜1%		
Transparency	No particular absorption	Few lattice defects	Grain size?
Emitting spectrum	peak～540 nm	Shifting to longer	Good for PD or APD **(Yanagida et al.)**
Decay time	～90 nsec&～1000 nsec		**Takahashi et al.**
Response for the charged particles	**α / γ ratio**: 0.19	smaller	GSO:0.20 / BGO:0.21
	Decay time : same with **γ**	different	No longer component in single crystal.
Uniformity	**Δ**light yield＜0.5**%** **Δ**stopping power＜5%		
Stopping power	Consistent with the theorem value.		
Intrinsic BGDs	$\sim 1 \times 10^{-5}$ count/sec/keV/cm^3		No particular RI component