インジウム錯体を用いた太陽ニュートリノ観測用液体シンチレータの開発

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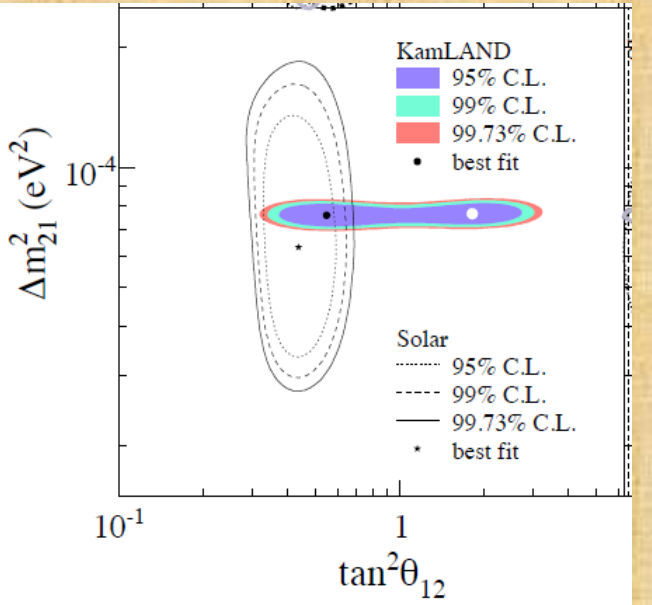
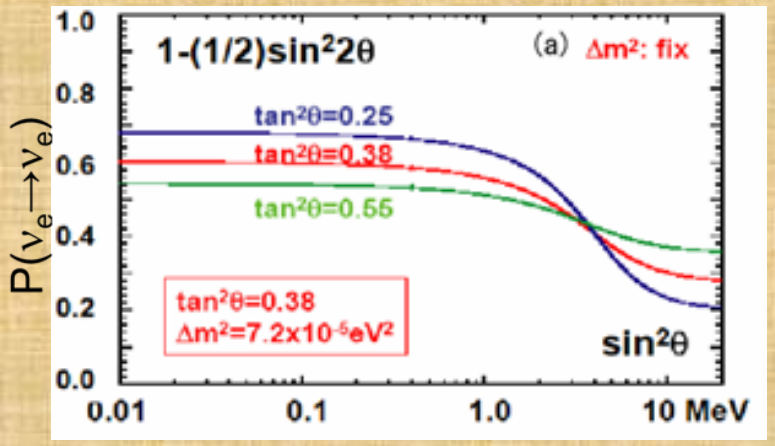
Motivation

Allowed region obtained by combined results and KamLAND



Survival probability for solar matter oscillation below 1MeV

Y.Suzuki@Neutrino2004



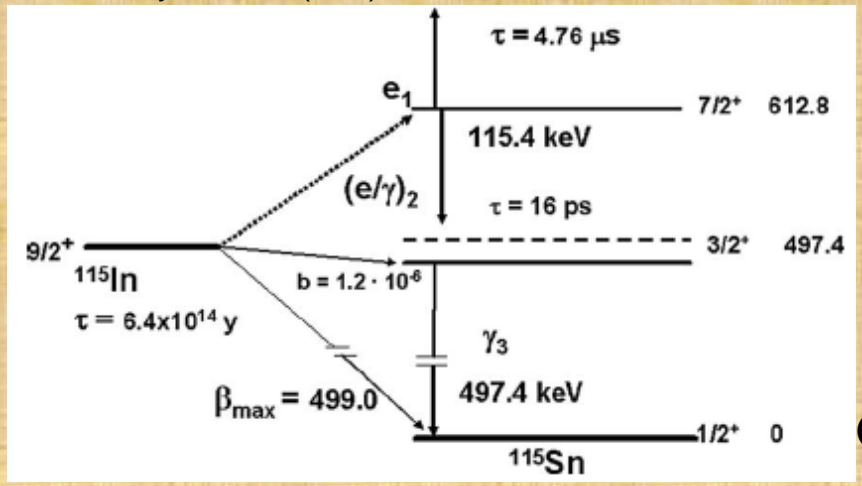
Neutrino energy

- mixing angle θ_{12} is not well determined compared with θ_{23} obtained by Atm. ν.
- Survival probability could increase at 5MeV or less in case of LMA solution, and the value of probability depends on θ_{12}.

pp/^{7}Be solar neutrino spectrum gives us precise θ_{12}

Capture of low energy solar neutrinos by ^{115}In

Nuclear Physics A 748 (2005) 333-347



R.S.Raghavan Phs.Rev.Lett37(1976)259

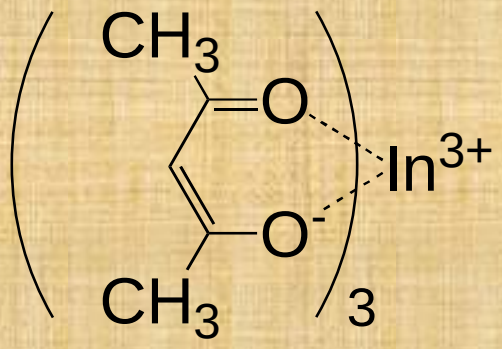
^{115}In + ν_e → ^{115}Sn* + e$^-$
^{115}Sn*(4.76μs) → ^{115}Sn + γ_1(115keV) + γ_2(497keV)

- Advantage
  - large cross section (~640SNU)
  - direct counting for solar neutrinos
  - sensitive to low energy region ($E_\nu \geqq 125$keV)
  - energy measurement ($E_e = E_\nu - 125$keV)
  - triple fold coincidence to extract neutrino signal from huge BG ($e_1 + \gamma_2 + \gamma_3$)
- Disadvantage
  - natural β-decay of ^{115}In ($\tau_{1/2} = 4.4 \times 10^{14}$ yr , Ee≧498keV)
  - possible BG due to correlated coincidence by radiative Bremsstrahlung

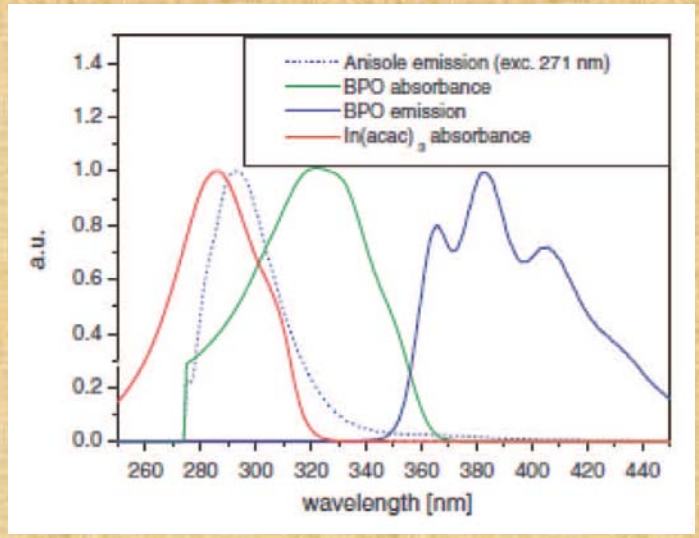
Requirement for the detector

1. Good energy resolution : 10%(FWHM) → high light yield (BC505: 60%)
2. Fine segmentation (10^4–10^5) or **fine vertex resolution**
3. **High efficiency γ detection**
4. Low Backgrounds → small detector (solubility : 5wt%)

Indium loaded Liquid scintillator



ジケトン錯体



- LENS
  1. カルボン酸インジウム（$In(RCOO)_3$）をシュードクメンに8wt%（BC505比 55%、透過長8m）
  2. ジケトン錯体をアニソールに10wt%以上を溶解

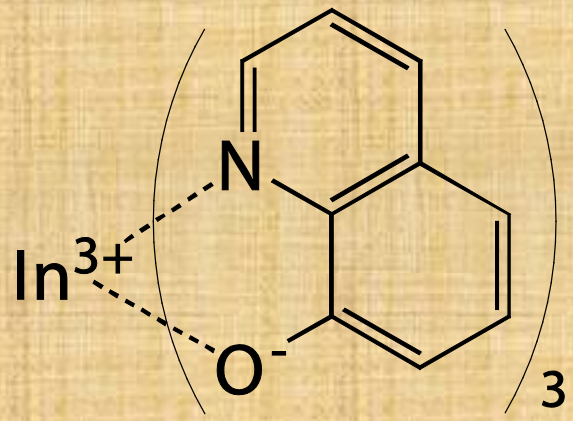
(Chem. Phys. Lett., 435(2007), 252)

錯体の吸収とアニソールの発光帯が重なり機能が低下

Liquid scintillator using Indium complex

- Indium complex

  tris(8-quinolinolate) indium (InQ_3)

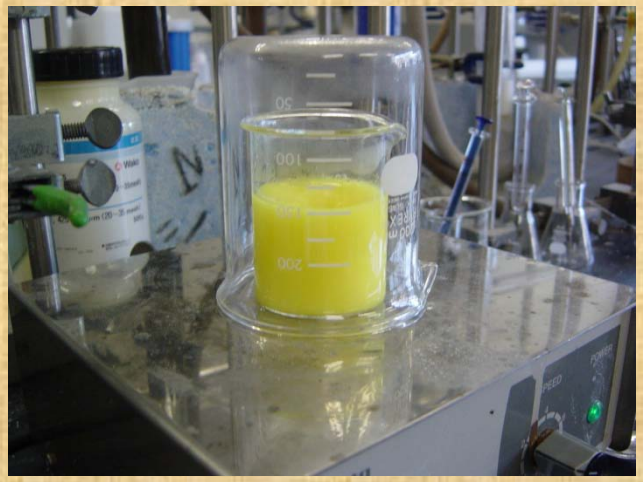


molecular mass : 542.78

- AlQ_3 has been established as Organic Electro Luminescence material (@~530nm)
- InQ_3 should also have a property of luminescence with same range WS

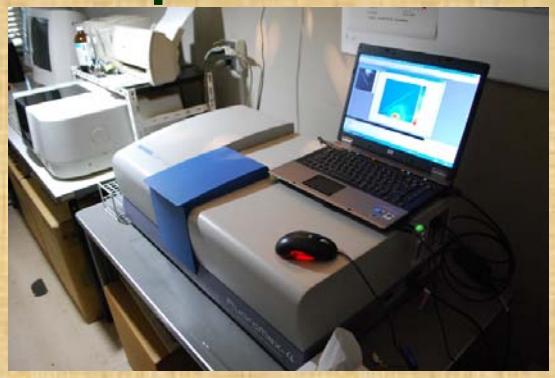
It will be used for fluorescent object and help for light yield

Synthesis of InQ_3

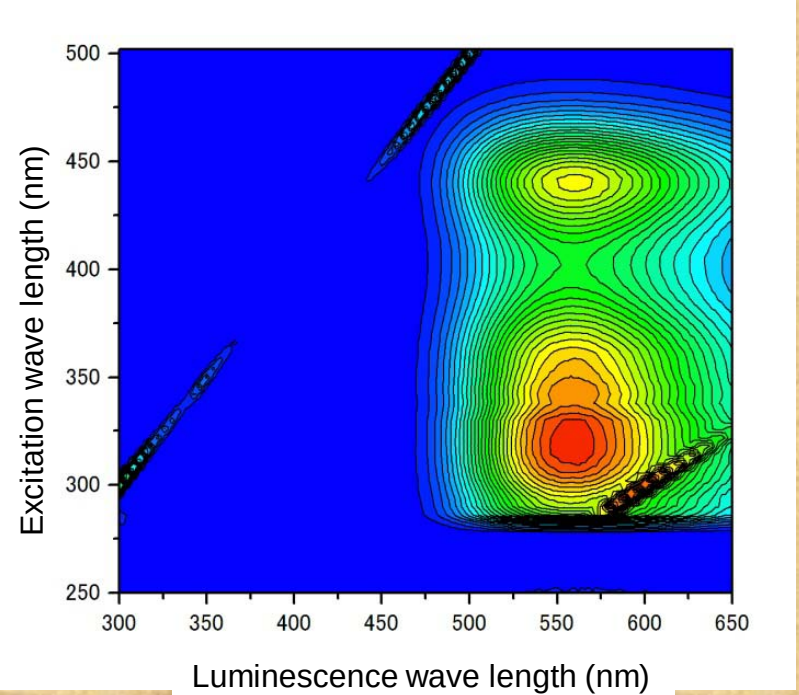


Luminescence of InQ_3 complex

- Measurement of photo luminescence
  - Device : HORIBA FluoroMax-4
  - Solvent : Toluene
  - Concentration : 10^{-4}
  - Max. excitation wavelength : 320nm
  - Max. luminescence wavelength : 560nm



HORIBA FluoroMax-4 (宮城教育大学　村松研究室所有)



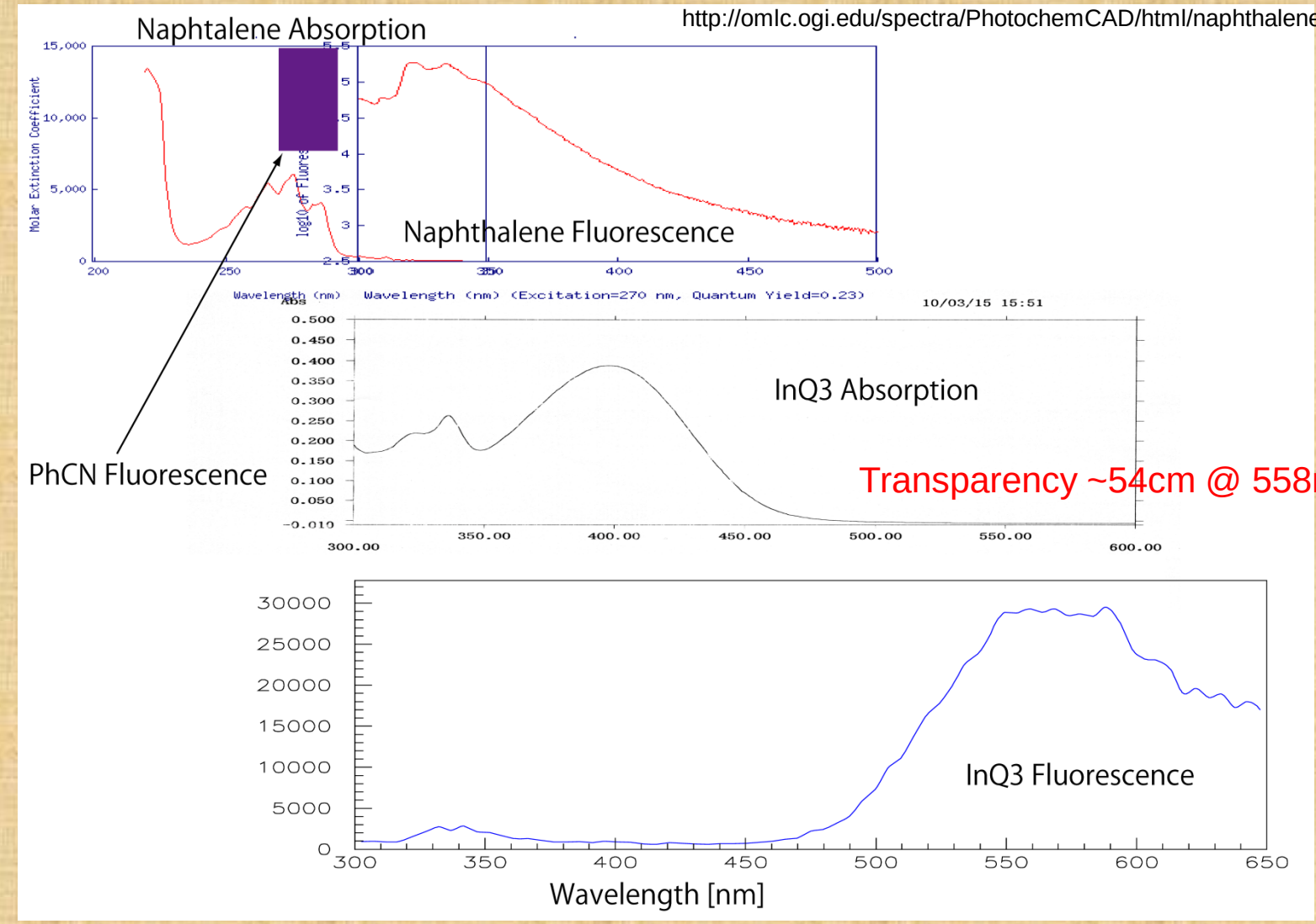
Solution on InQ_3 in organic solvent

- InQ_3 dissolved in some organic solvents with ~1%
  - Benzonitrile (PhCN: C_6H_5CN)

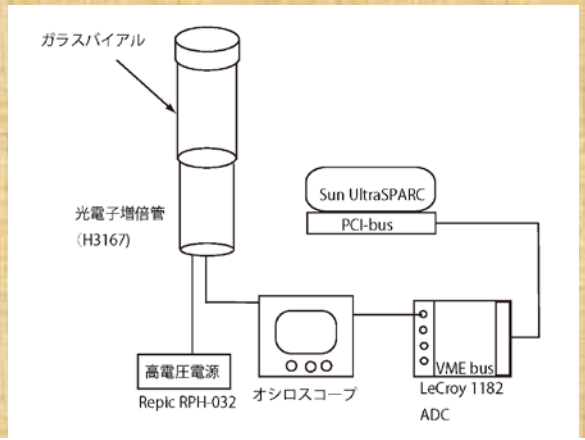
    density 1.0g/mL

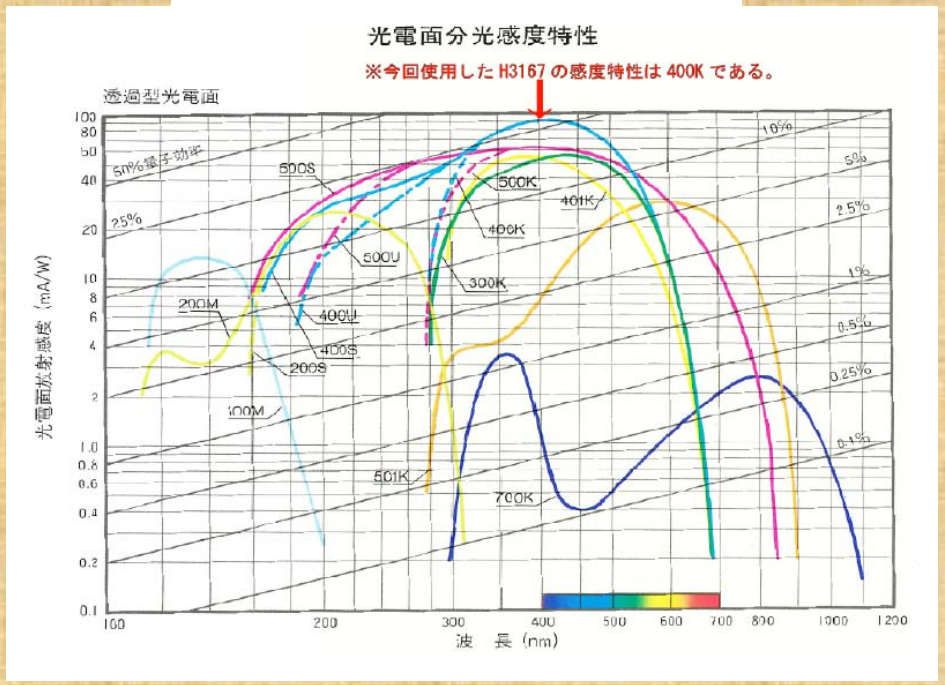
    flash point 75℃
  - Acetophenone ($PhCOCH_3$)
  - benzyl alcohol ($PhCH_2OH$)

Light absorption and fluorescence



DAQ setup





- Photomultiplier : H3167 (400K)
- VME ADC: Lecroy 1182
- High voltage : Repic RPH-032
- Photocathode radiant sensitivity :

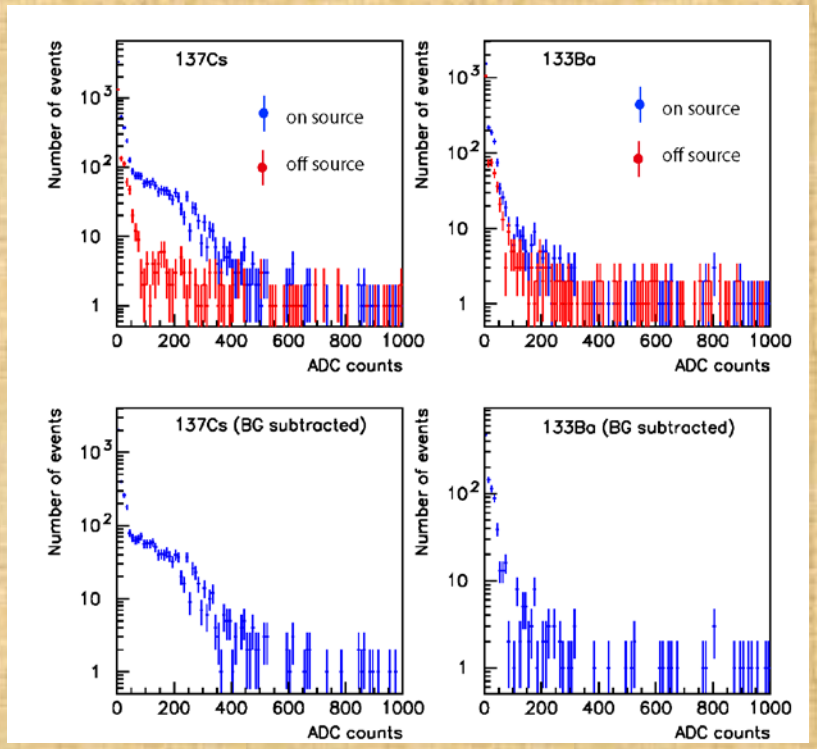
  30mA/W @ 291nm

  60mA/W @ 330nm

  40mA/W @ 560nm

Spectrum of γ's for several solutions

InQ3 (20mg) + Naphthalen(0.3g) in PhCN



Fuji-film SC-48 (λ > 520nm)

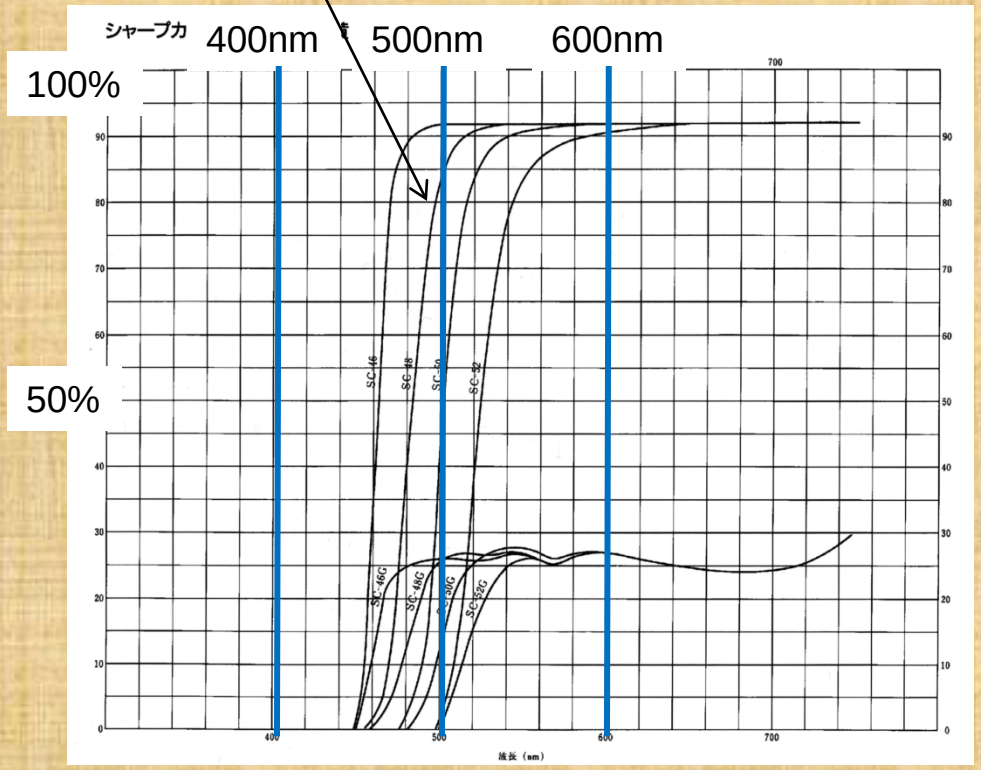
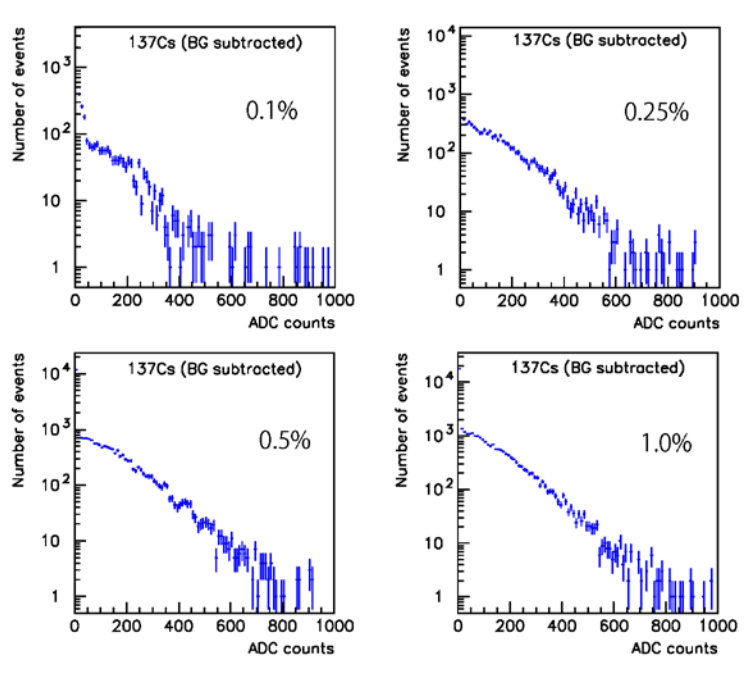
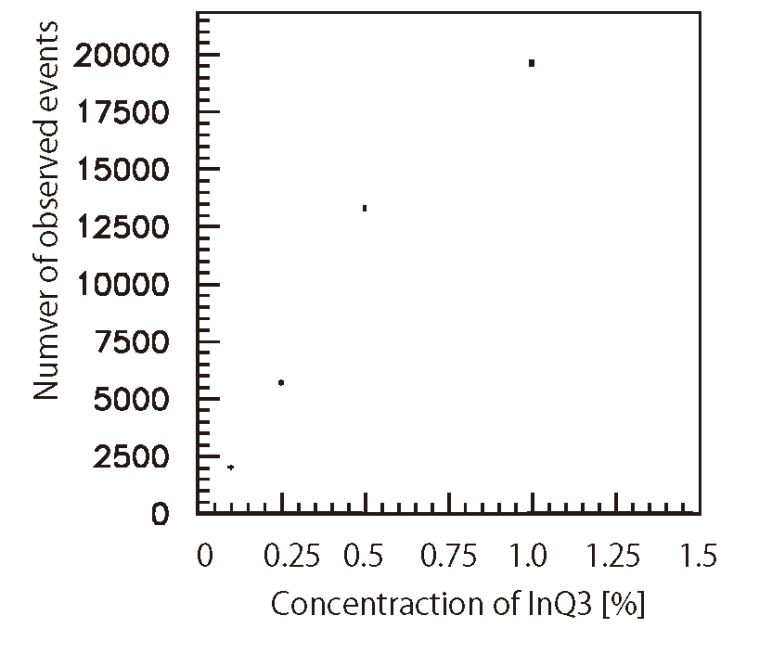


Photo luminescence due to γ radiation was confirmed

Concentration dependence





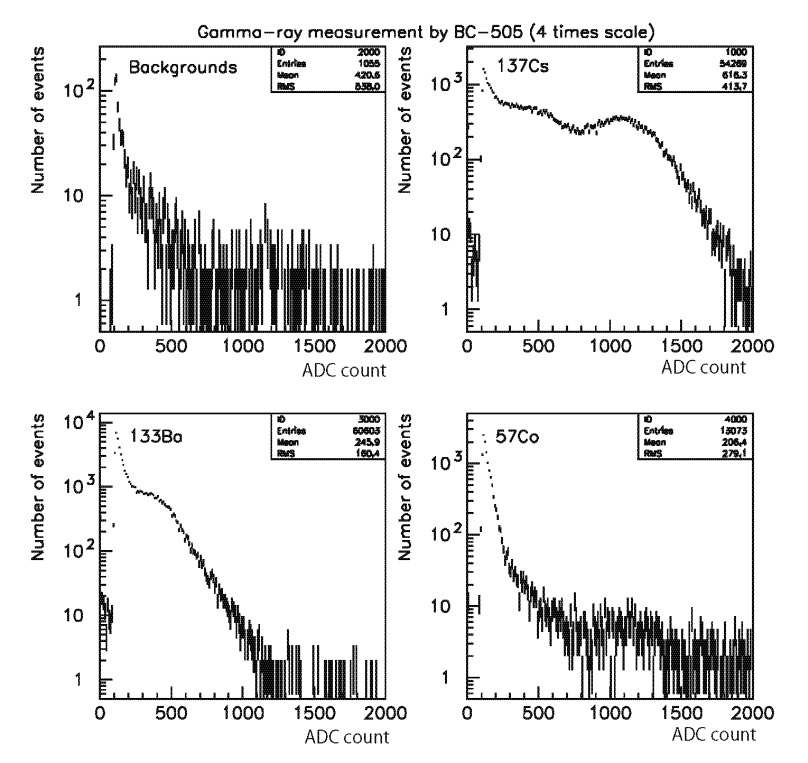
- $n = f \times \rho \times \sigma$

  n : number of events f : photon flux ρ : number of InQ_3 molecular in 20mL σ : cross section of photon absorption

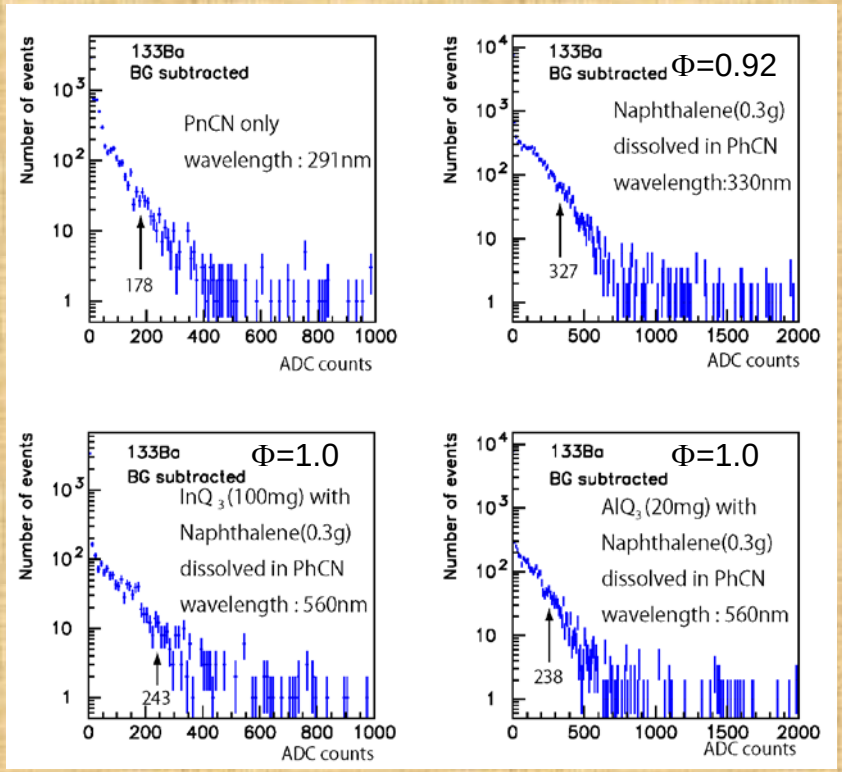
  - Linearity could be continued until ~0.75%, but saturation might occur above a few %

Light yield and Quantum yield

BC-505 (4 times scale)



Quantum yield for InQ_3



Relative yield : 10%

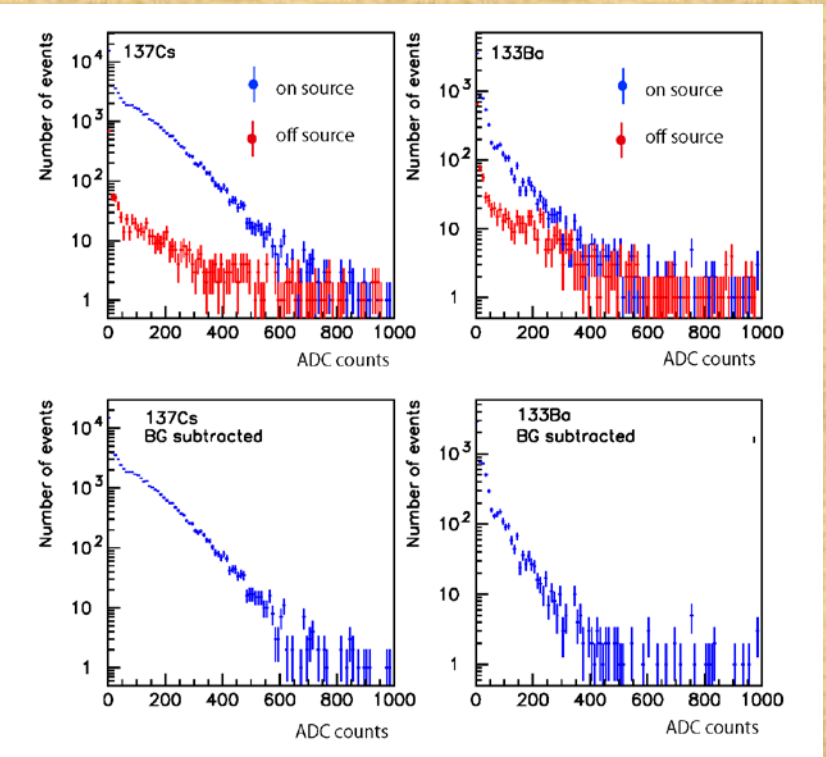
Quantum yield : ~1.0

Results

- tris(8-quinolinolate) indium complex (InQ_3) loaded liquid scintillator was made by PhCN as solvent and Naphthalen as fluorescent object.
- InQ3 has photo luminescence for the γ radiation.
- Transparency : ~54cm @ 558nm (1~2% dissolution)
- Light yield relative to BC505 : 10%
- Quantum yield : ~1.0
- First step for development of indium complex loaded liquid scintillator was successful.
- Next step : more light yield, solubility and transparency to modify complex

Spectrum of γ's for several solutions

PhCN only



Naphthalen (0.3g) in PhCN