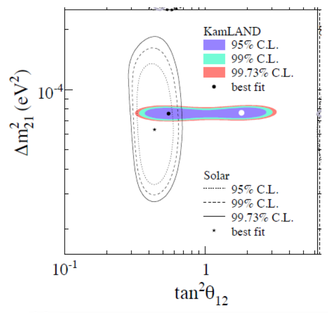
Development of InP solid state detector and liquid scintillator containing indium complexes for a measurement of pp/7Be solar neutrinos

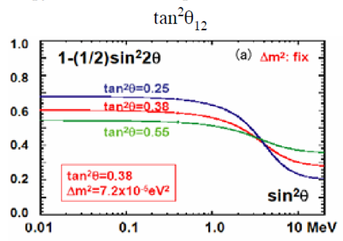
Y.Fukuda[a] T.Beni[a] T.Izawa[d] K.Kasai[a] S.Moriyama[b] T.Namba[c] A.Obata[a] H.Sekiya[b] K.Watanabe[a]

[a] Miyagi University of Education [b] ICRR, University of Tokyo [c] ICEPP, University of Tokyo [d] Solid state division, Hamamatsu Photonics K.K.

1. Introduction

◆ Purpose : Measurement of precise mixing angle θ_{12}





- 96%C.L. allowed region obtained by global fit
  LMA solution (blue) : Cl + Ga + SK (D/N spectrum)
  KamLAND (green) → **confirm Δm^2_{12}**

$27^\circ < \theta_{12} < 37^\circ$

- mixing angle θ_{12} is not fixed compared with θ_{23} (obtained by Atm. ν)
- survival probability would increase at 5MeV or less in case of LMA solution, and the shape depends on the value of θ_{12}.

pp/^{7}Be solar neutrino spectrum could obtain precise θ_{12}

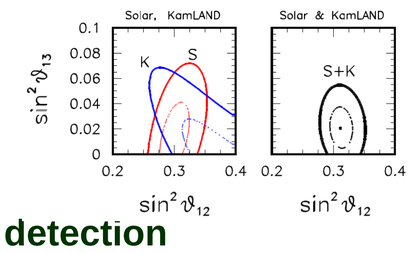
● **on-going solar 7Be experiment**
- KamLAND (Liquid scintillator, electron elastic scattering [ES])
- Borexino (Liquid scintillator, ES)

● **future solar pp/^{7}Be experiment**
- XMASS (LXe, ES, DARK MATTER)
- LENS (Liquid scintillator loaded In/Ye, charged current [CC])
- others

Y.Suzuki@Neutrino2004

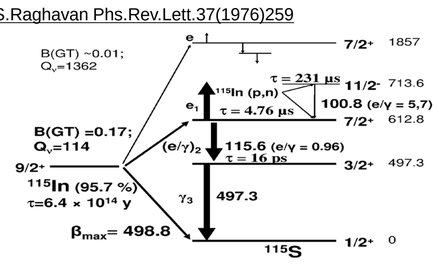
◆ Contribution to determination of θ_{13}

- Precise θ_{12} from solar neutrino experiment and KamLAND experiment will contribute to determination of θ_{13}
  (Phys.Rev.Lett. 110(2008)141801)



◆ Technique of low energy solar neutrino detection

R.S.Raghavan Phs.Rev.Lett.37(1976)259

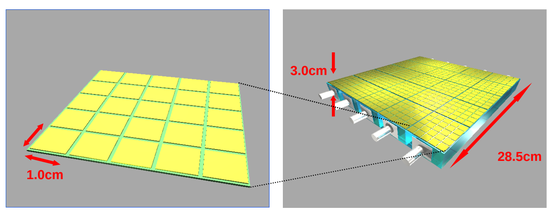


^{115}In + ν_e → ^{115}Sn* + e_1^-
^{115}Sn*(4.76μs) → ^{115}Sn + γ_2(115keV) + γ_3(497keV)

● **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 accidental coincidence by radiative Bremsstrahlung

◆Indium Project on Neutrino Observation for Solar interior (IPNOS) experiment



●**Hybrid structure of InP and external scintillator**
- InP multi-pixel detector (10mmX10mmX0.2mm cell)
- external scintillator to detect γ_1 and γ_2

●**4tons of ^{115}In detector for solar ν experiment**
- InP : 5.1tons (2.0X10^6 modules with **ΔE/E~10%**)
- high Z material for external scintillator
- total size ~5m X ~5m X ~5m (depends on structure)

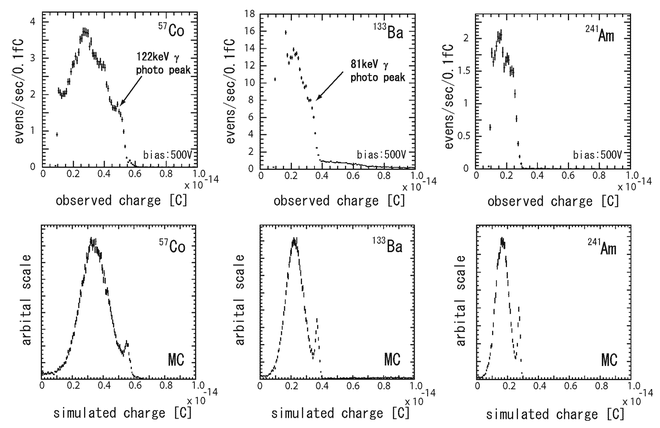
- Number of expected events assuming no ν oscillation → 1885
- Number of expected event assuming LMA solution with Ee≧100keV → 720

Statistical and theoretical error in total → **~3.5 %** ⇨ **$\theta_{12} = 30^\circ - 34^\circ$**

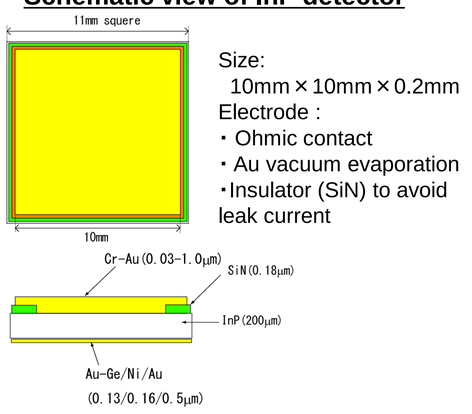
2. SI InP cell detector

◆InP detector in vacuum dewar

◆Response for γ–ray from radioactive source



Schematic view of InP detector



Size:
10mm × 10mm × 0.2mm
Electrode :
- Ohmic contact
- Au vacuum evaporation
- Insulator (SiN) to avoid leak current

Setup Clearpulse 5102 preamplifier
Clearpulse 4417 shaping amplifier
CAEN V419 peak sensing VME ADC

- Measured clear photo- peak , but two peak structure
- Lower peak: induced charge
  (L_{ed}~200μm L_{he} ~ 30μm)
  Higher peak: e^- full collection
- Energy of electron-hole pair production :3.5eV
- Energy resolution : 25%@122keV

3. InP photon detector

◆ InP detector inside Liquid Xenon

- Liquid Xenon has large cross section to detect γ-ray
- InP detector should keep cool to reduce dark current

If InP detector would work as photon detector , LXe should be good scintillator to detect γ_2 and γ_3

◆ Development of InP photon detector

- thin electrode to pass the lights
  (Au :100Å / Cr : 100Å)
- detector size 6mm × 6mm × 0.2mm

◆ Measurement of CsI scintillation lights

- CsI light source pulsed by ^{241}Am α (3MBq : average 6α's)
- solid angle : 0.2
- transparency of Au/Cr electrode : 0.57 X 0.37 = 0.21
- observed signal : 0.5 ~ 2.0 fC

External and internal conversion efficiency : 0.3

Success to detect both scintillation lights and γ's

4. IPNOS phase-I experiment

◆ Detector

- 30cm cubic chamber (like XMASS 100kg prototype detector)
- InP multi-pixel detector inside of Liquid Xenon
- Chamber includes ~10kg InP detector

◆ Purpose

- demonstrate LowBG environment
- long stable operation (1 ppν event will be expected for half year)

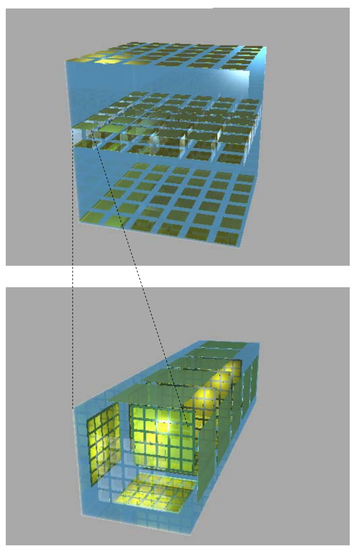
◆ Requirements to detect γ_3

- transparency of Au/Cr electrode : 0.43 X 0.39 = 0.17
- assuming same conversion efficiency : 0.3
- assuming surface coverage : 0.8

Expected scinti. light yield ~ 3keV ⇨ not enough…

- modify shape of electrode such as mesh structure
- assuming 50% for naked area then transparency recovers 0.58

Expected scinti. light yield ~10keV ⇨ maybe ok!

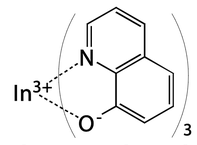


5. Liquid scintillator containing metal complexes

◆ Development of liquid scintillator using Indium complexes

● **goal : solublity : 5 wt%, light yield : 60% of BC505, attenuation length : 2~3m**

● **tris(8-quinolinolate) indium complex (InQ_3)**
- AlQ_3 has been established as **organic Electro Luminescence** material (maximum luminescence @ 530nm)
- InQ_3 should have same property of luminescence

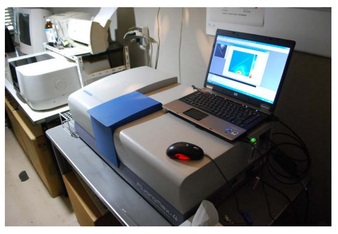


● **Synthesis of InQ_3 complex**

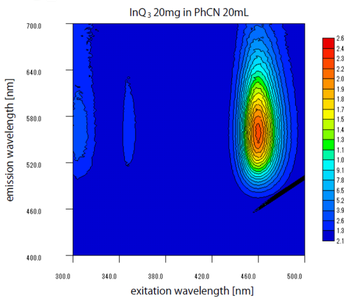
● **Solution of InQ_3 in organic solvent**

Solvent : **Benzonitrile** (PhCN: C_6H_5CN)
density : 1.0g/mL flash point : 75℃
Photon emission : 291nm@maximum
Solubility of InQ_3 complex: **2wt%**
Attenuation length : 66cm (@0.5wt%)

◆ Luminescence of InQ_3 complex

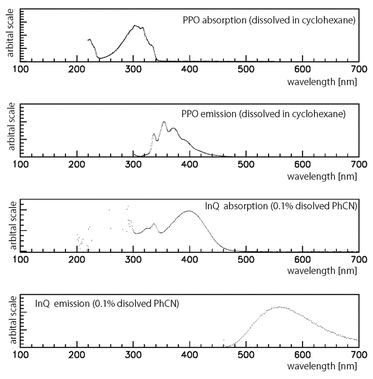


Courtesy of Prof. T.Muramatsu (Miyagi University of Education)



● **Measurement of photo luminescence**
- Device : HORIBA FluoroMax-4 (2-dim scanning)
- Solvent : PhCN Concentration : 0.1wt%
- Maximum excitation wavelength : 460nm
- Maximum emission wavelength : 560nm

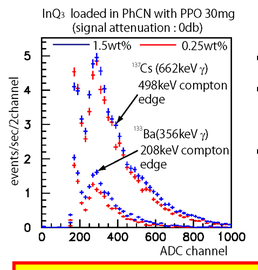
● **Light (energy) transfer to InQ_3**
- PPO dissolved as a wavelength shifter (0.15wt%)



◆ Performance of liquid scintillator

● **Setup**
- Hamamatsu H6410 2inch photomultiplier
- Fisherbrand 20mL Borosilicate Glass Scintilation Vials
- Acrylic light guide
- LeCroy 1182 charge sensitive VME ADC
- coincidence method was used for eliminating BG

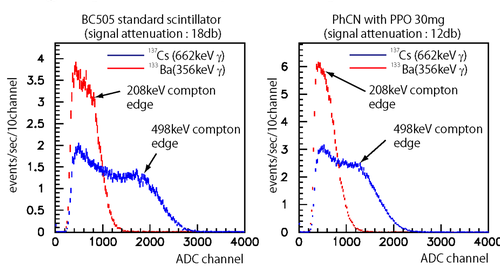
● **Response for γ–ray from radioactive source**



- γ-ray spectrum was observed
- No significant difference for concentration of InQ_3
- all scintillation lights have λ > 520 nm

Photo luminescence caused by γ-ray was confirmed

● **Light yield and quantum yield**

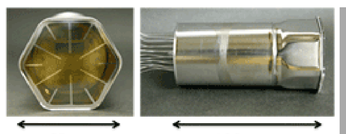


- quantum yield : 6% (3.9% ref. Inorg.Chem.46 (2007)5700)
- relative light yield to BC505 : 2% (36% for PhCN+PPO)

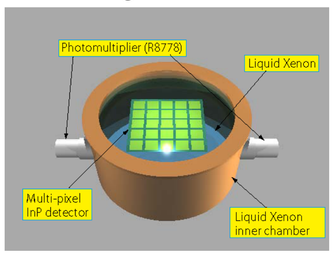
6. Next step

◆ For IPNOS phase-I

● Measurement of scintillation light from LXe



R8778 photomultiplier Producted by Hamamatsu Photonics (used for XMASS)



- direct measurement of LXe scintillation light
- construct small LXe chamber (volume : 0.15L)
- coincidence method using for R8778 PMT
- **finalize shape of electrode for InP detector**

supported by **Grant-in-Aid for Scientific Research on Priority Areas 22011001**

◆ For Metal complex loaded liquid scintillator

● In complex
- modify 8-quinolinolate ligand to add substituent groups (Cr, No_2, …)
- use another ligand which should be OEL (emission wavelength ~400nm)
- modify b-diketonate complex to shift absorption wavelength (J. Radioanal. Nucl. Chem., 258(2003)255)

● Zr , Mo, Cd, Nd complex
- Other metal Zr, Mo, Cd, Nd complex will be good detector for 0νββ experiment
- **goal :5wt% solubility and 2%@3MeV energy resolution**

supported by **Grant-in-Aid for Scientific Research (C) 22540303**