Liquid Scintillator for CANDLES System

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CANDLES Collaboration:

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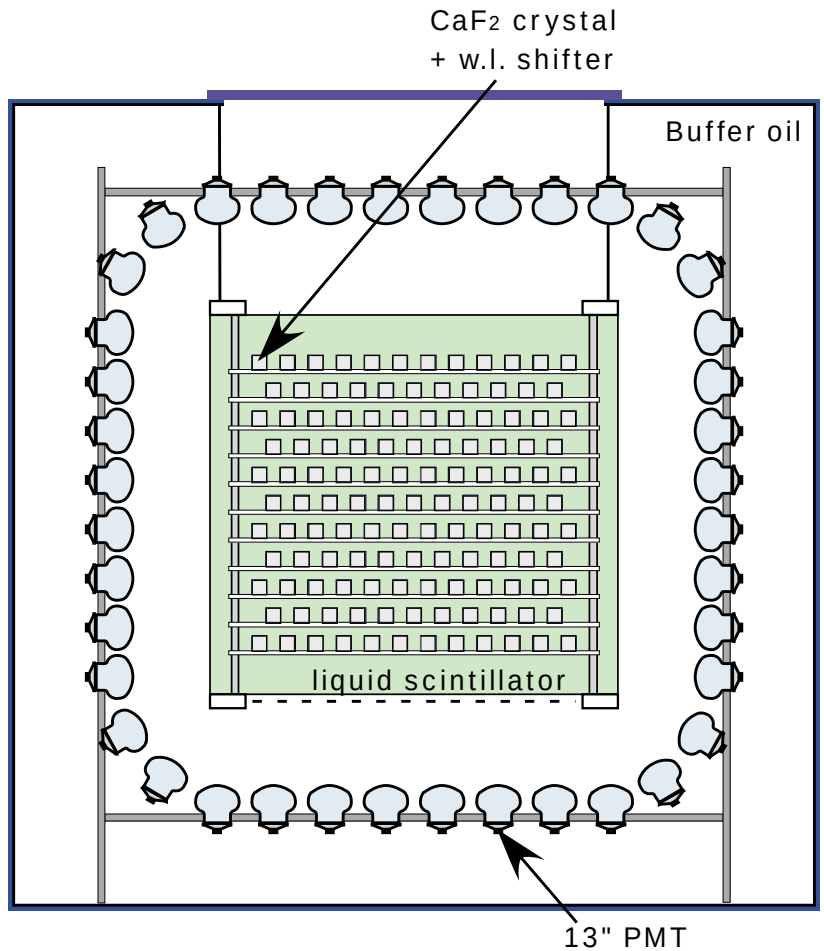
Outline

- Introduction – CANDLES –
- Requirements for liquid scintillator
- Two phase system
  - LS for conversion phase
  - LS for veto phase
  - Performance of two phase system
- Summary

Concepts of CANDLES system

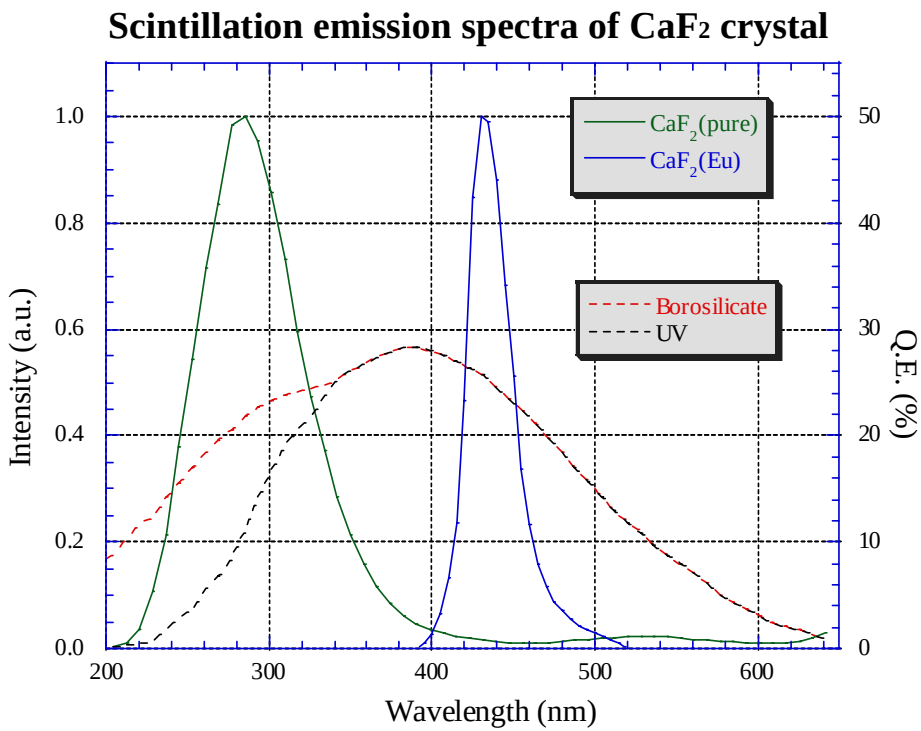
Undoped CaF_2 crystals immersed in a liquid scintillator

- CaF_2(pure) crystal
  - Long attenuation length
    - ⇒ large scale detector
- Liquid scintillator
  - 4π active shield
    - Difference in decay time of signal
      900 nsec : CaF_2(pure)
      a few×10 nsec : liquid scintillator
  - WLS
    - Convert UV light from CaF2(pure) to visible light



CaF_2(Eu) and CaF_2(pure)

- CaF_2(Eu)
  - Commonly used scintillator
  - 24 photons / keV
  - $\lambda_{emission}$ = 420 nm
  - Self absorption
- CaF_2(pure)
  - Commonly used as lens
  - Good transparency
  - Can be used as scintillator
  - ~10 photons / keV
  - $\lambda_{emission}$ = 285 nm



- CaF_2(Eu) : from BICRON catalogue
- CaF_2(pure) : measured value

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Requirements for liquid scintillator (1)

- Photon collection of CaF_2(pure)
  - WLS
    - UV light from CaF_2(pure)

      ⇒ sensitive region (visible light) of PMTs
    - Short fluorescent lifetime
      - not distort pulse shape of CaF_2(pure) ⇐ PSD for BG rejection
  - Base solvent
    - Transparent to UV light from CaF_2(pure)
    - Refractive index: closed to that of CaF_2(pure)
      - avoid optical loss at a boundary

Requirements for liquid scintillator (2)

- Passive shield
  - large quantity with reasonable costs
- Low background
  - purification
    - Simple mixture
- 4π active shield
  - large light output
  - highly transparent against its light
- Long term and safe operation
  - high flush point
  - chemical stability

Mineral oil base with **aromatic solvents**

Aromatic solvents

To increase light output of LS → aromatic solvents

solvent	Q.Y.	τ_F (nsec)	λ_{max} (nm)	
			absorption	emission
benzene (C_6H_6)	0.07	29	255	280
toluene (C_7H_8)	0.17	34	260	285
p-xylene (C_8H_{10})	0.40	30	270	285
m-xylene (C_8H_{10})	0.17	30.8	270	285
o-xylene (C_8H_{10})	0.19	32.2	265	285
ethyl-benzene (C_8H_{10})	0.18	31	260	285
mesithylene (C_9H_{12})	0.17	36.5	275	290
pseudocumene (C_9H_{12})	0.41	27.2	270	290
cumene (C_9H_{12})	0.12	22	260	280

absorption in UV region ↑

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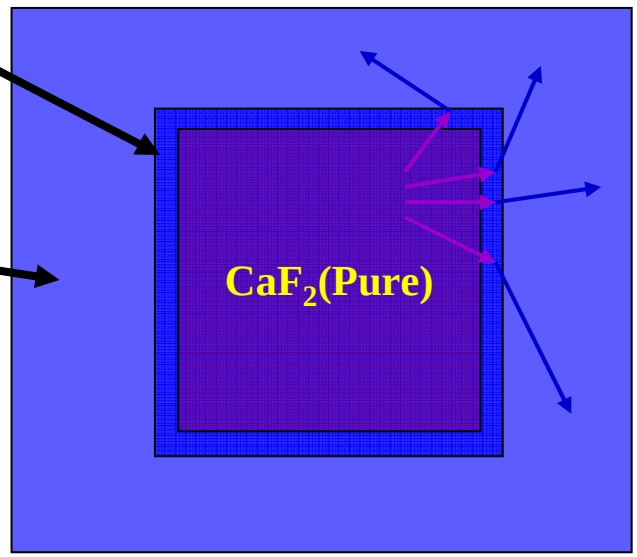
Two Phase System

Concept of Method

- Conversion Phase
  - Large conversion eff.
  - good transparency for UV
- Veto Phase
  - Large light output with aromatic solvent



CaF_2 Emission (~280nm)

⇩

Conversion by WLS(350~400nm)

⇩ propagate

PMT

Requirements for two phase system

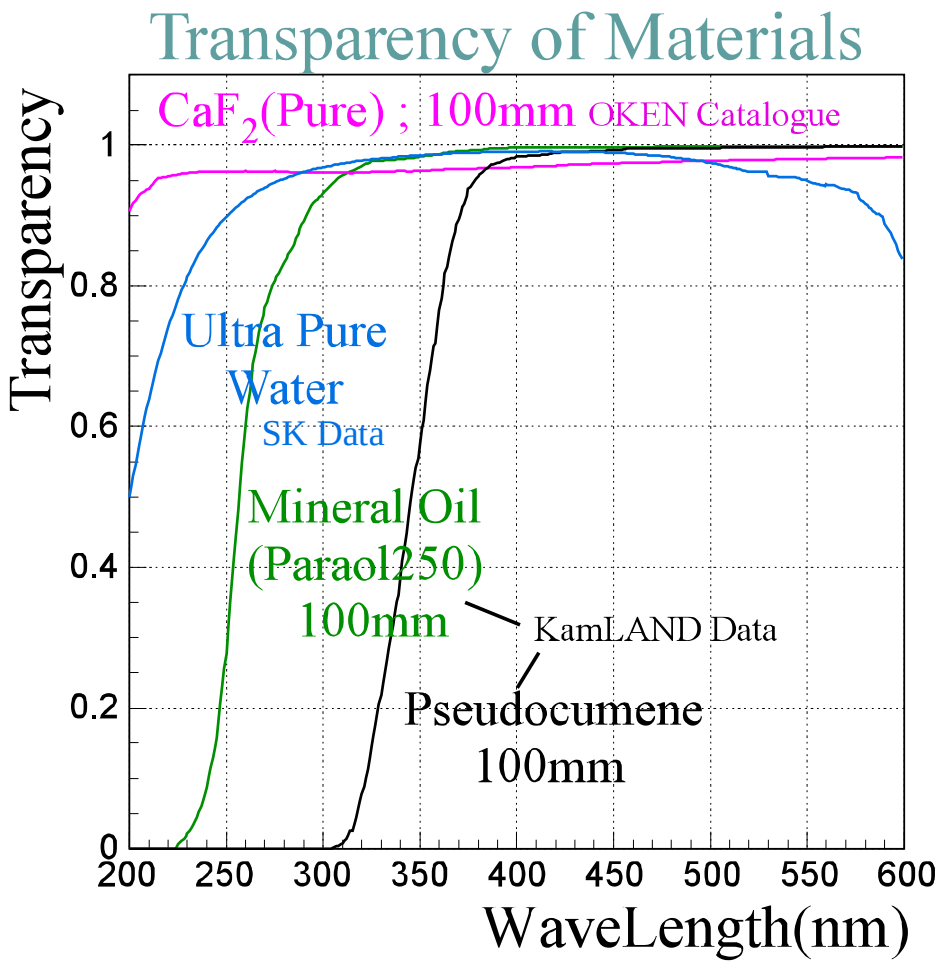
- Thickness of conversion phase
  - As thin as possible

  - BG rejection efficiency is worse in conversion phase because of its low light output

LS for conversion phase

- Solvents
  - Paraol250

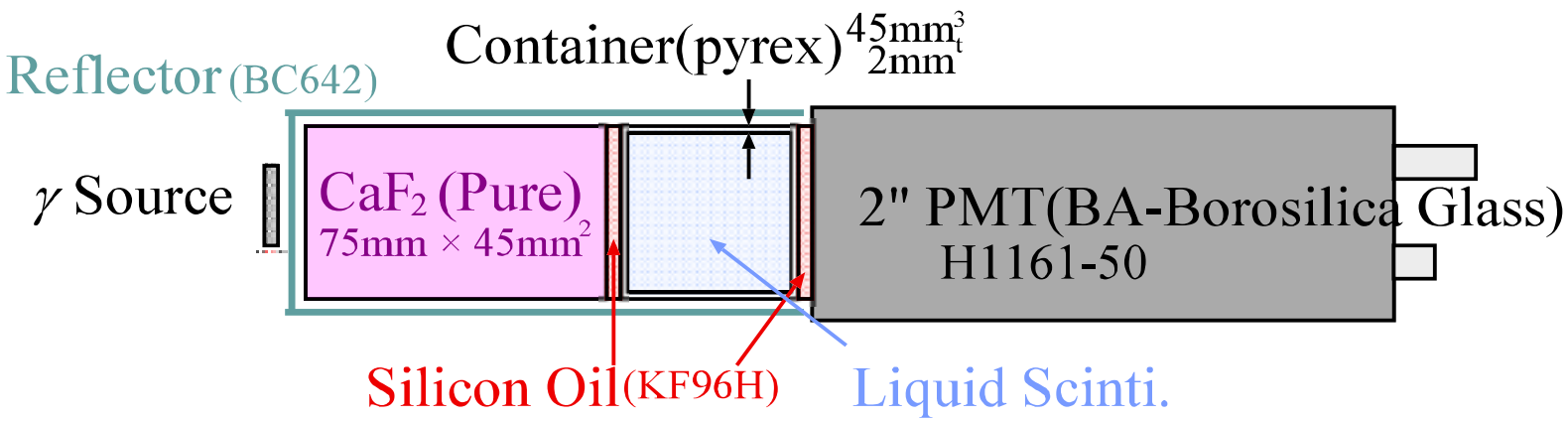
    good transparency in UV region



Optimization of WLS

Investigated Solute

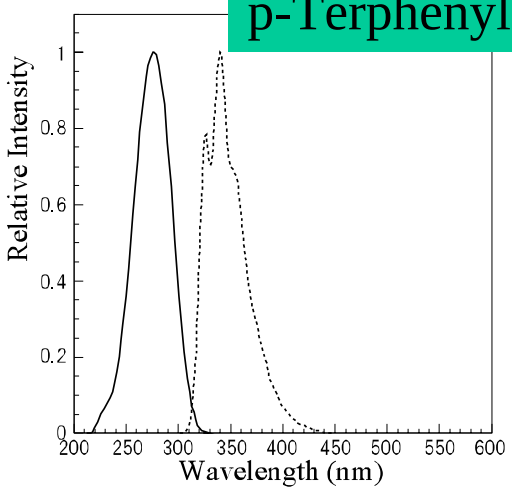
Solute	Q.Y.	τ_F (nsec)
p-Terphenyl	0.93	1.21
PPO	0.84	1.44
bis-MSB	0.94	1.24
α-NPO	0.94	2.06
Dimethyl-POPOP	0.93	1.50



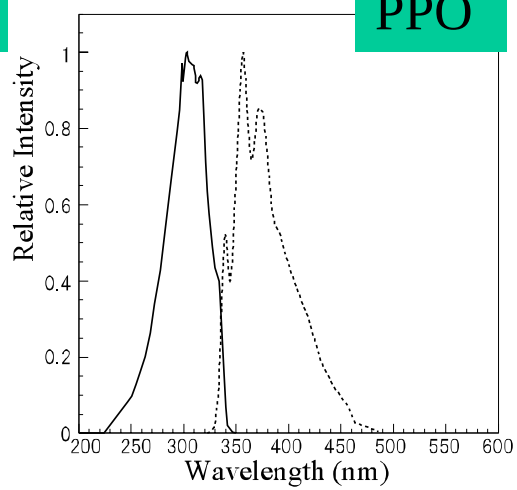
LS for conversion phase

- absorption/emission curve

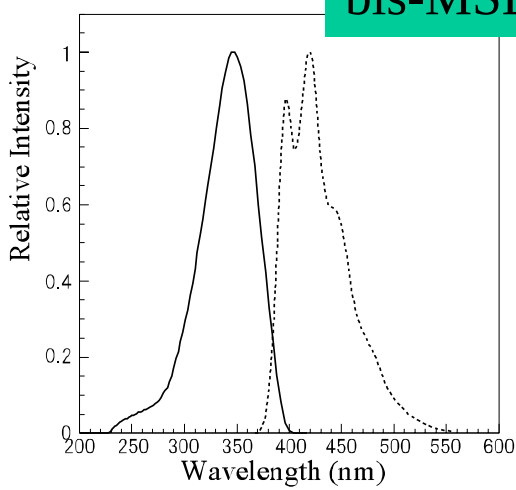
p-Terphenyl



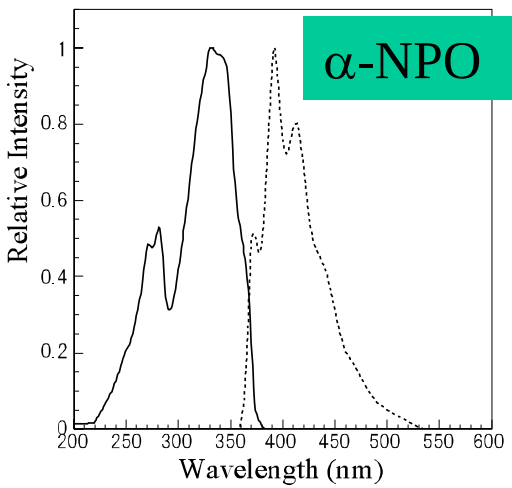
PPO



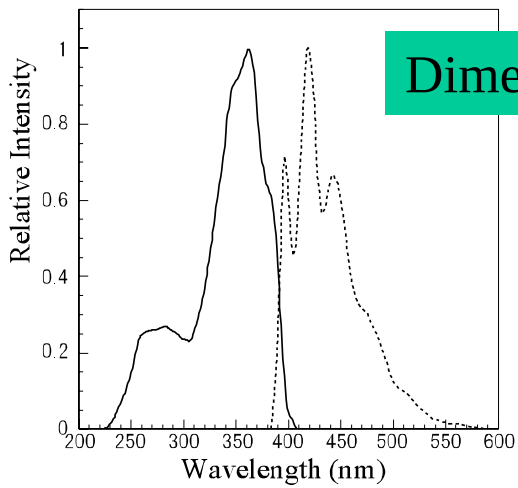
bis-MSB



α-NPO

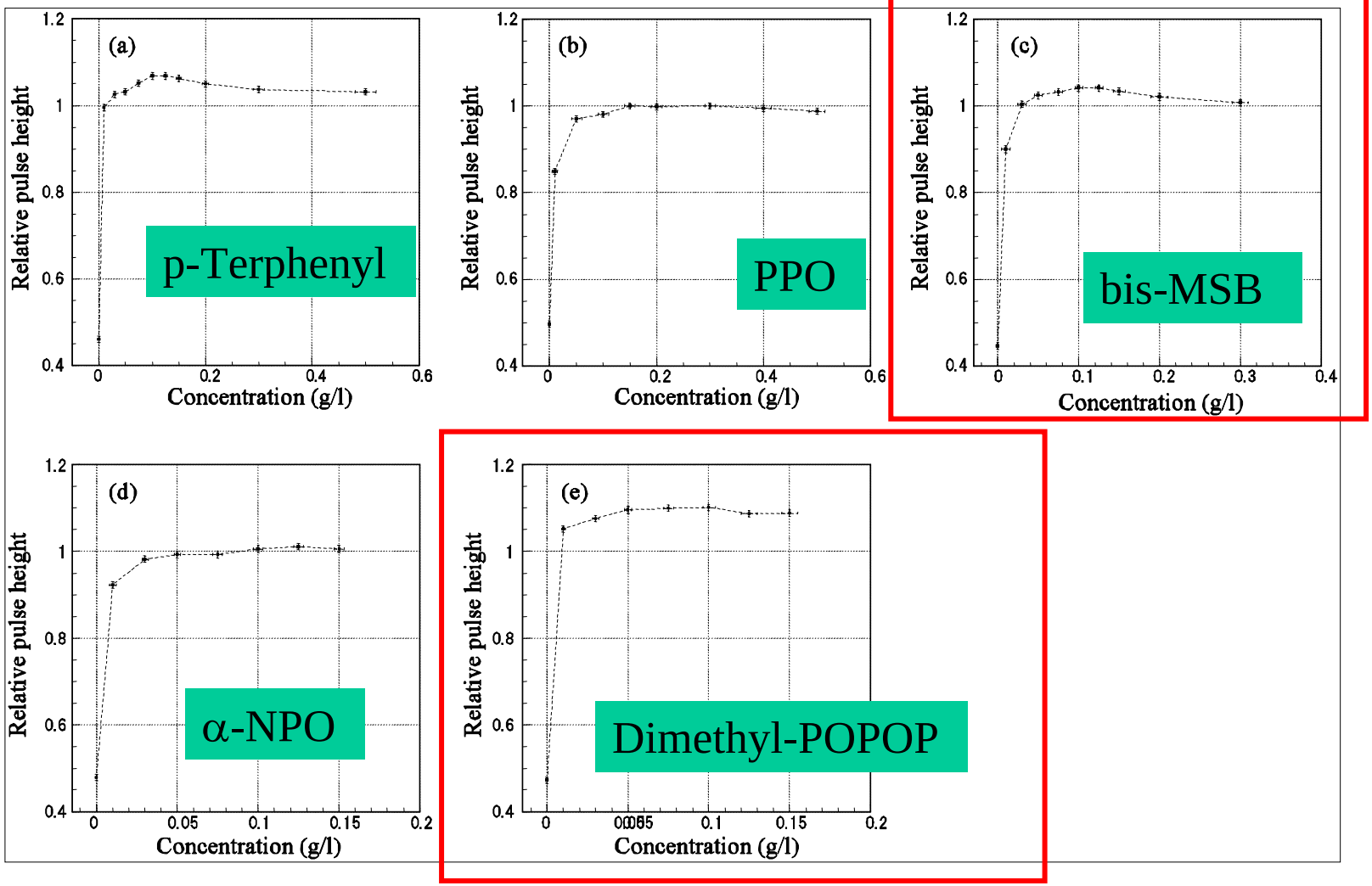


Dimethyl-POPOP



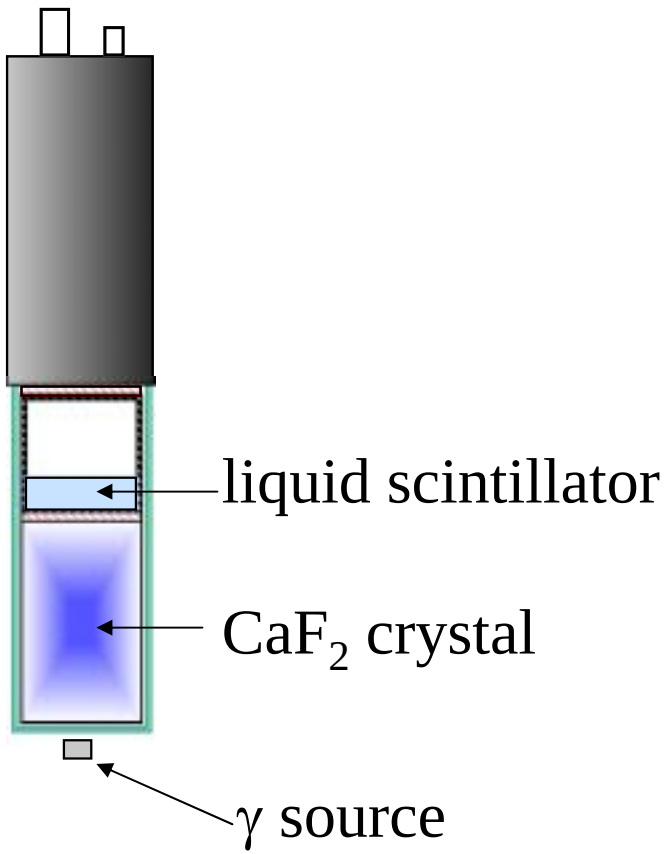
Results

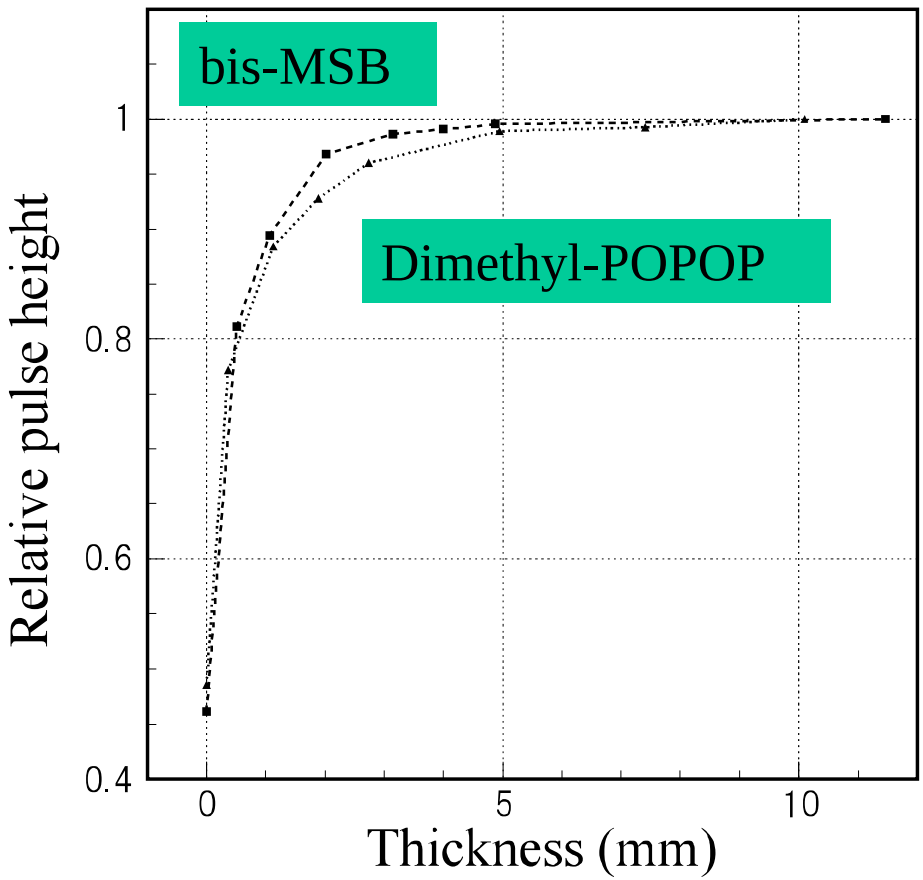
- Pulse height spectra



Thickness of Conversion phase

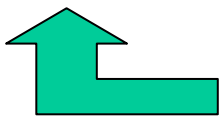
- 5 mm thickness is sufficient





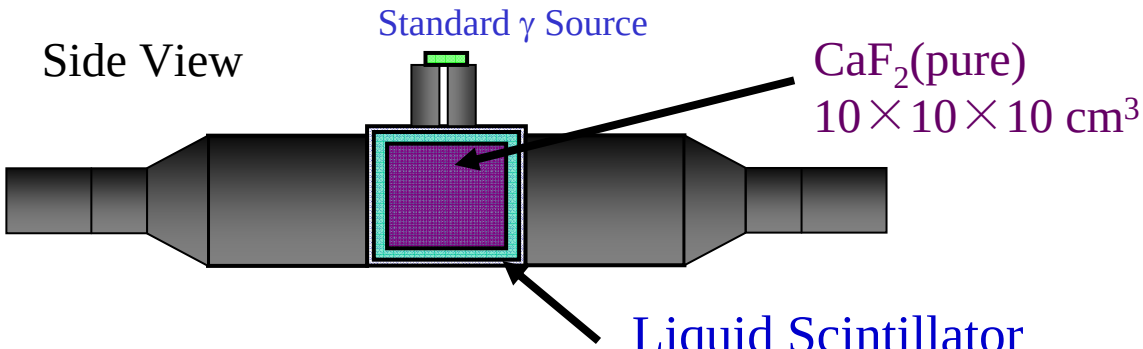
Mixture for conversion phase

- Solvent
  - Mineral Oil (Paraol250)
- WLS
  - bis-MSB 0.1 g/l



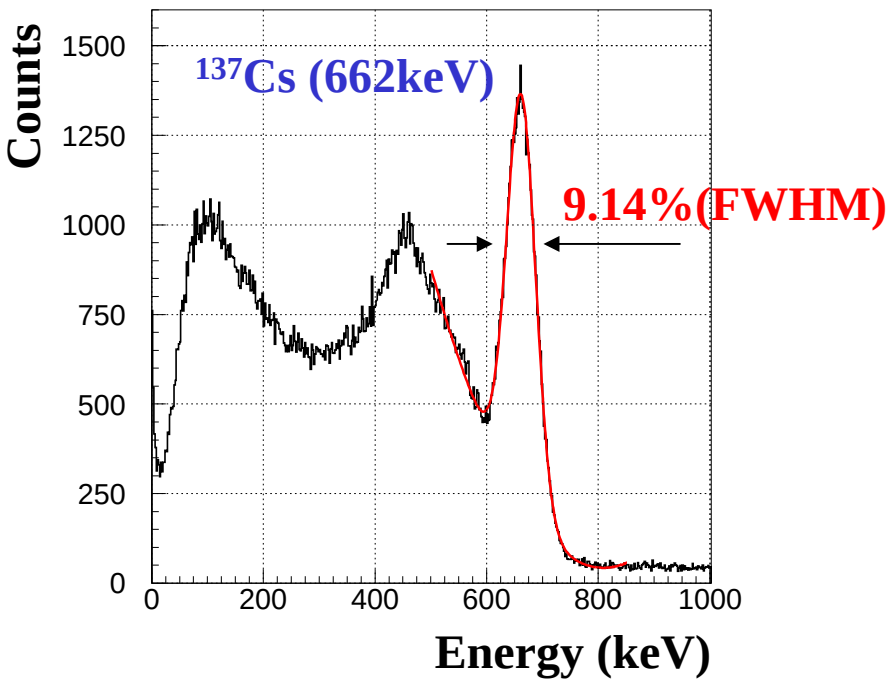
good solubility in Mineral Oil
- Thickness
  - 5 mm

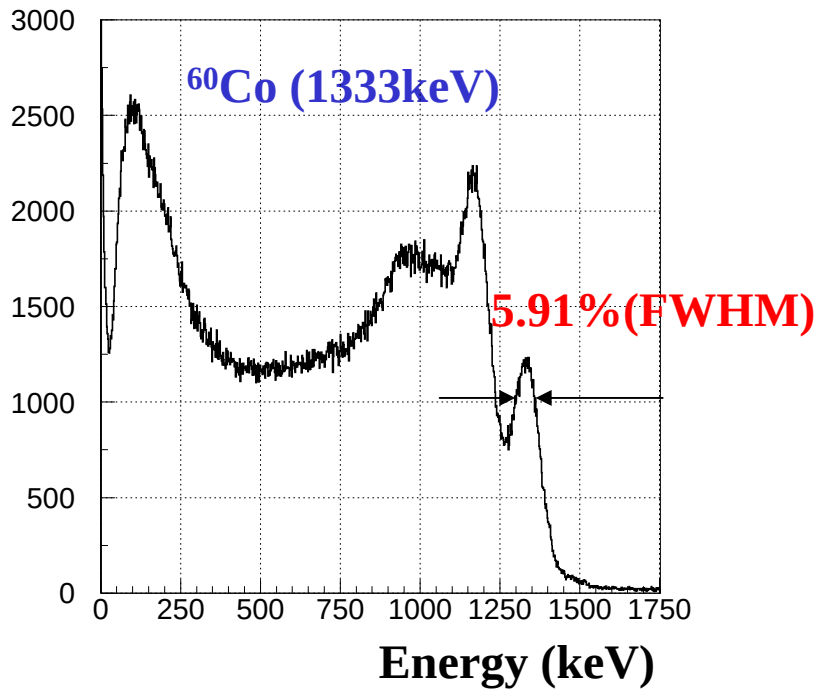
Performance Test (conversion phase)



(conversion phase; 7mm)

R = 3.5 %
@ Q-value





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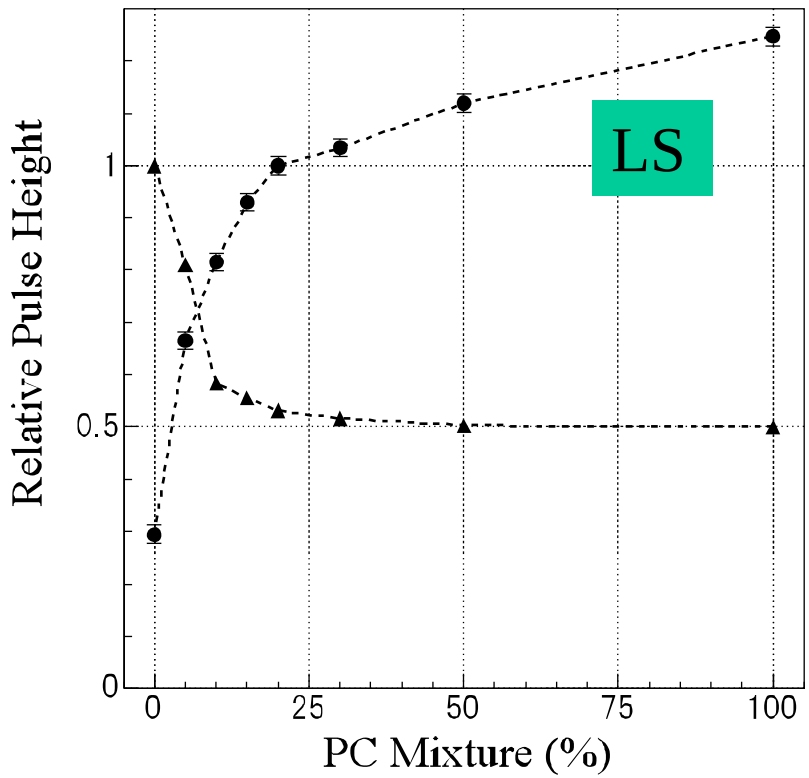
LS for veto phase(1)

Solvent

- Pseudocmene in Mineral Oil
  - long attenuation length
  - high chemical stability
  - refractive index close to that of CaF_2(pure)
  - acrylic vessel dissolved in PC

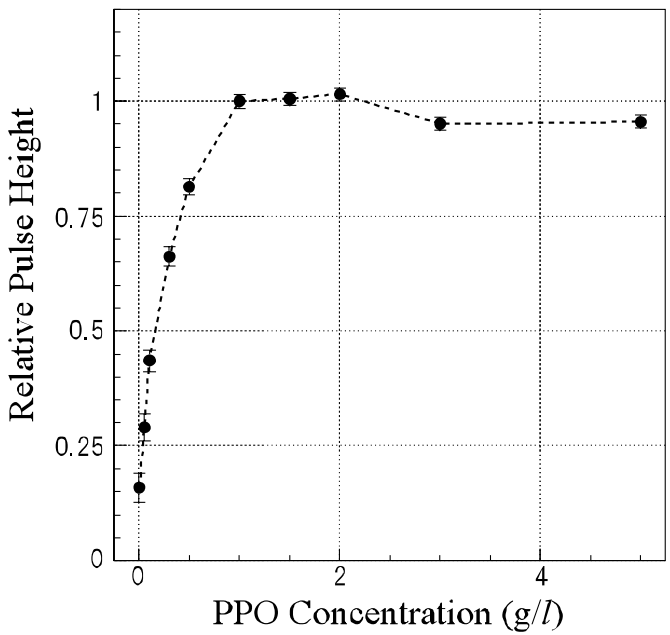
20 vol% of PC in P250

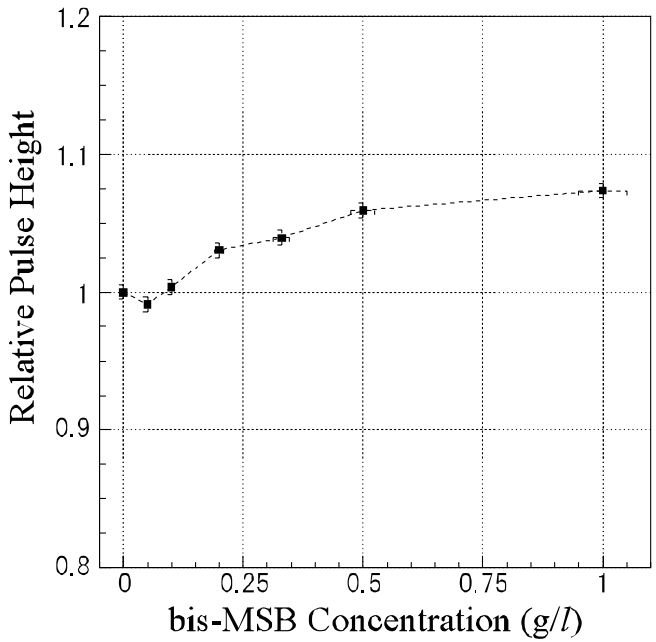


LS for veto phase(2)

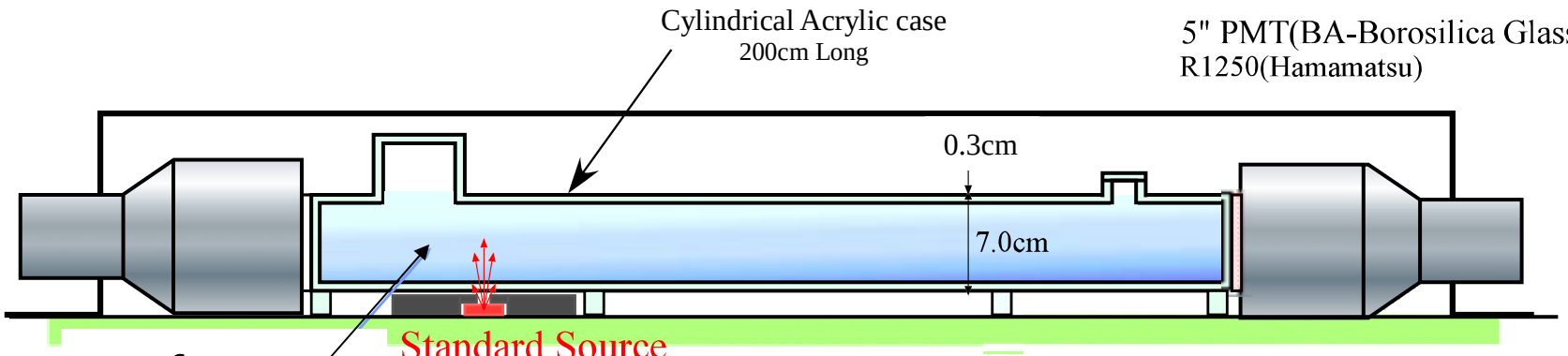
Solute

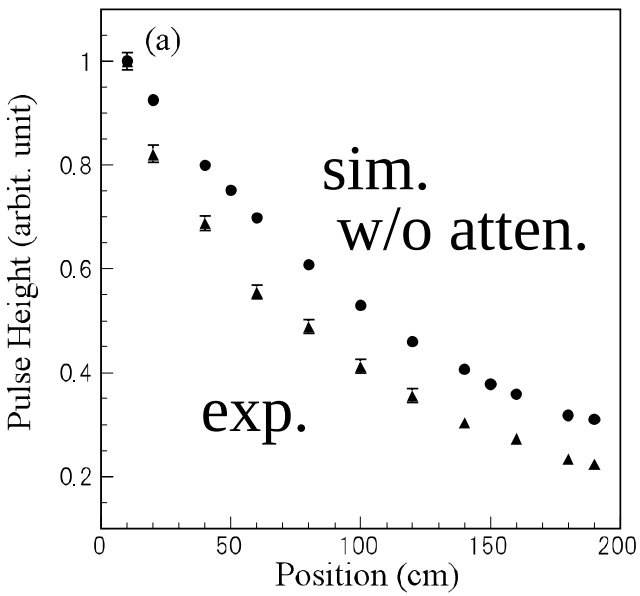
- PPO (P250(0.8)+PC(0.2))
  - 1.0 g/l
- bis-MSB (P250(0.8)+PC(0.2)+PPO(1.0 g/l))
  - 0.1 g/l ⇐ Same WLS in conversion phase

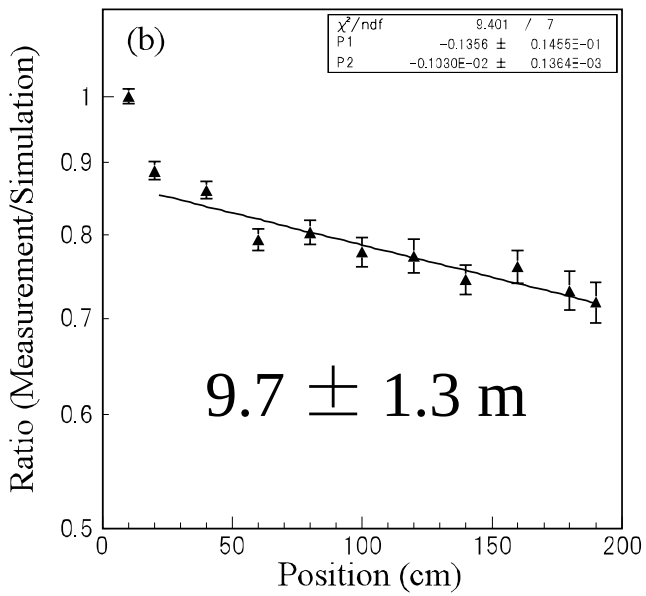




Attenuation length







Mixture for Veto phase

- Solvent
  - Mineral Oil (Paraol250) 80 vol%
  - Pseudocumene 20 vol%
- WLS
  - PPO 1.0 g/l
  - bis-MSB 0.1 g/l
- Attenuation length
  - 9.7 m w/o purification

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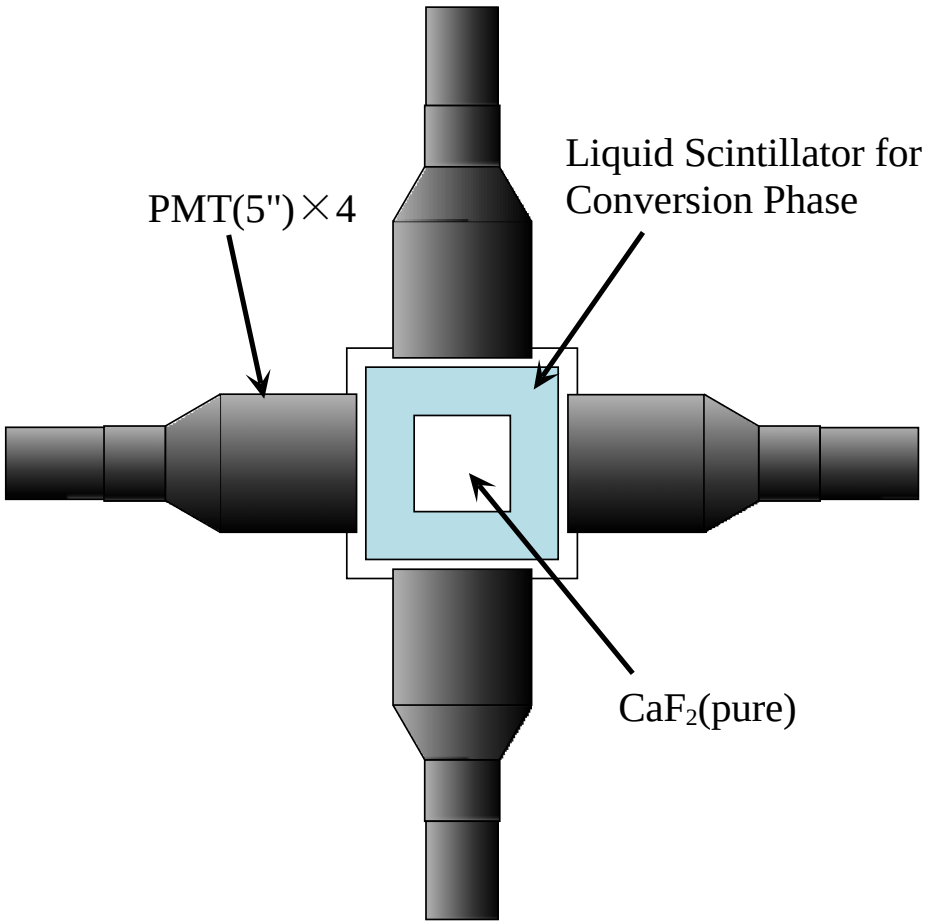
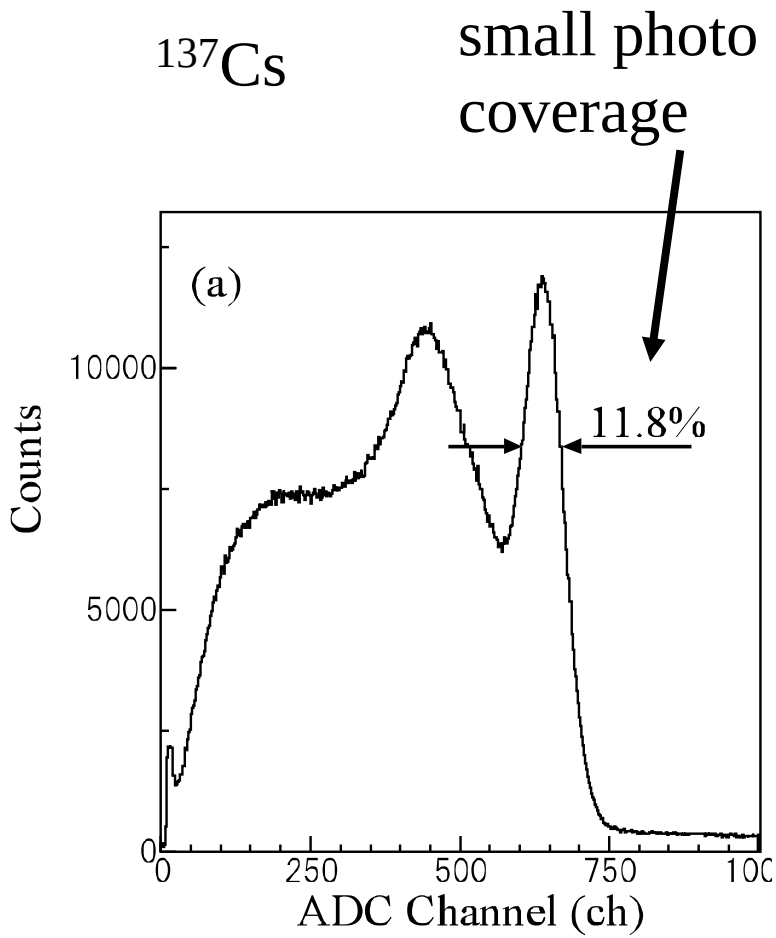
Performance of two phase system

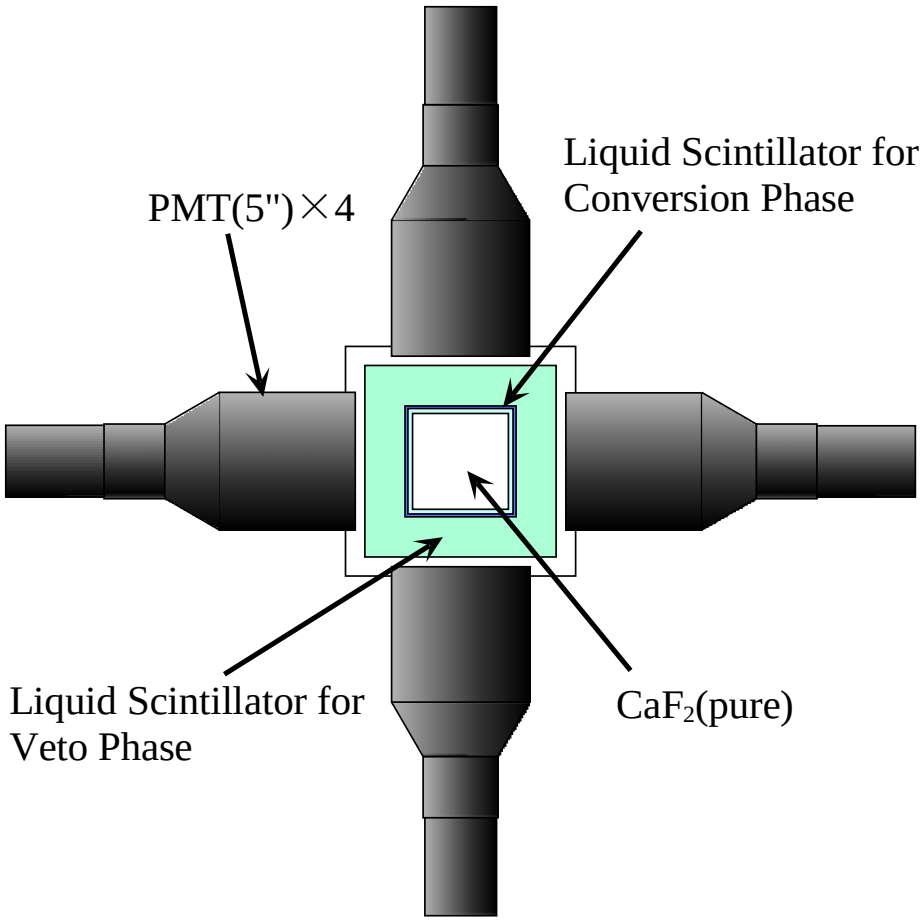
- Thick (5 cm) conversion phase only

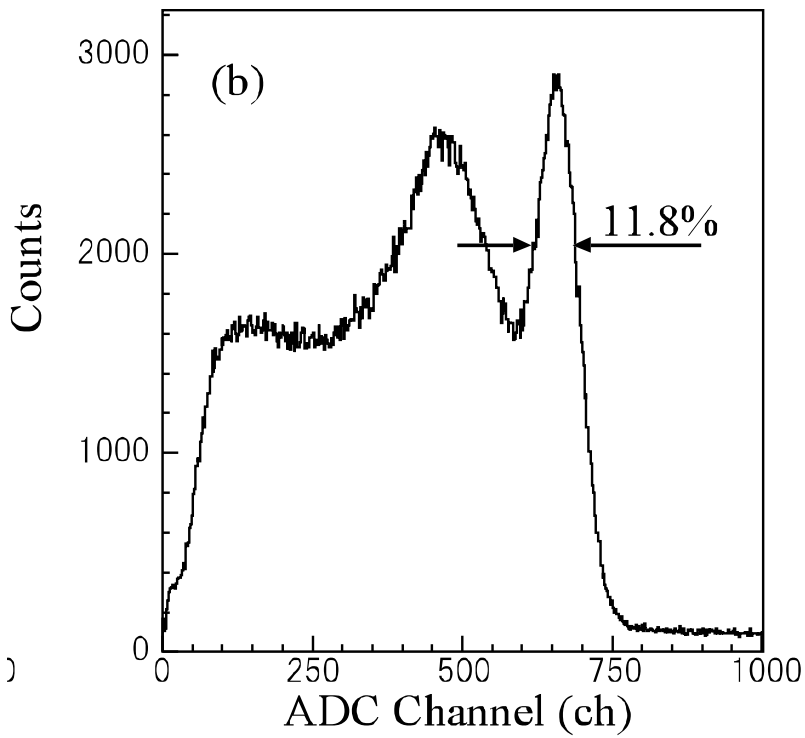




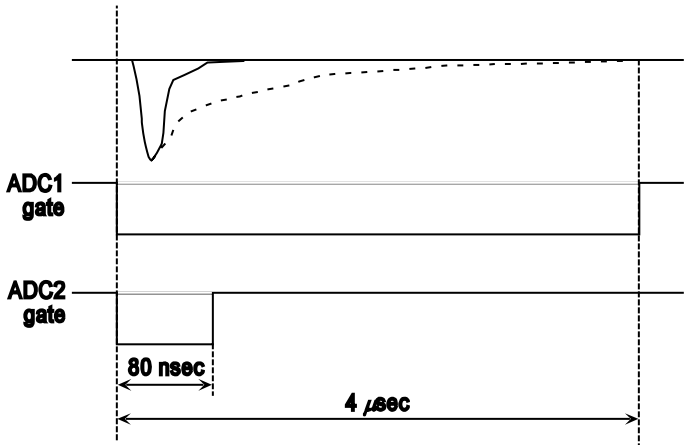
Performance of two phase system

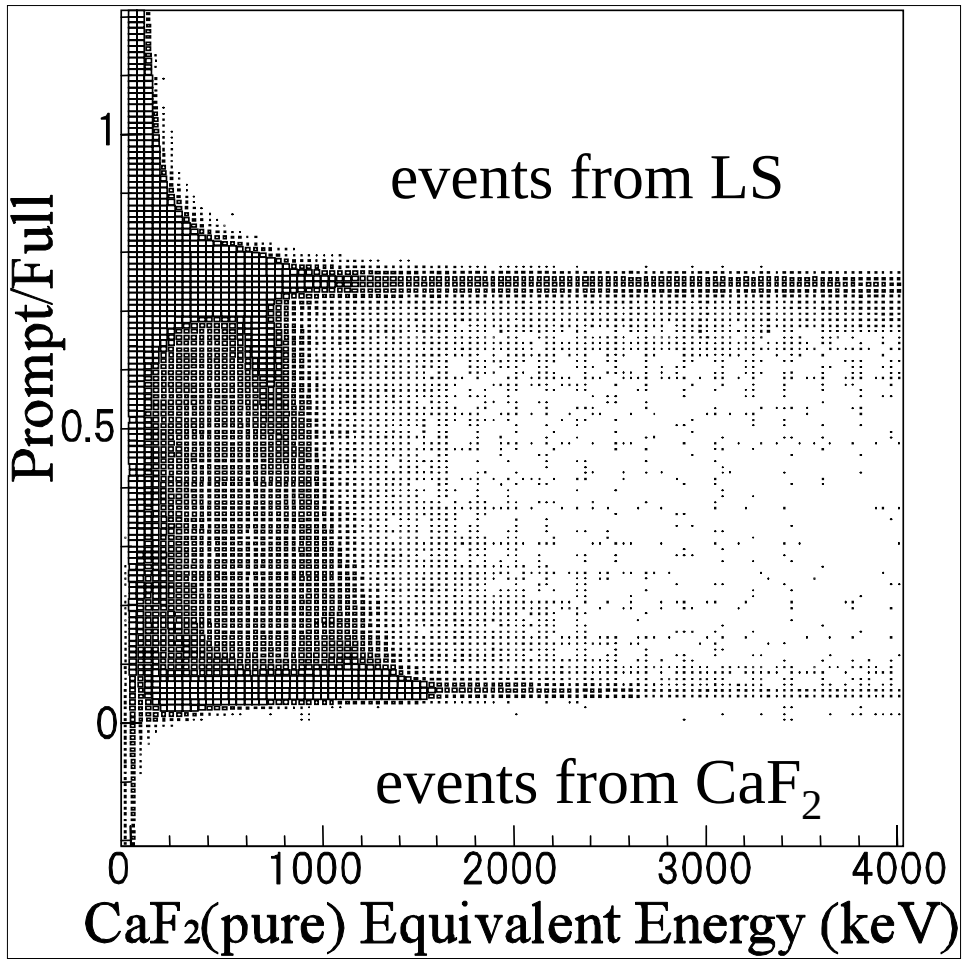
- Two Phase system (5 mm conversion phase)





Performance Test (Veto)





Summary

- LS in CANDLES System
  - complete 4π active shield
  - WLS for emission from CaF_2(pure)
- Two Phase System
  - conversion phase
    - Paraffin oil (Paraol250) + bis-MSB (0.1 g/l)
    - 5 mm in thickness
  - veto phase
    - P250(80 vol%) + PC(20 vol%) + PPO(1.0 g/l) + bis-MSB(0.1 g/l)
    - long attenuation length; 9.7 m (without purification)
    - large light output response; ~7✕10^3 photons/MeV
- In CANDLES System
  - Energy resolution of CaF_2(pure); ~4 % @ Q-value
  - light output in Veto phase; ~500 photoelectrons/MeV