Development of Liquid Scintillators Using New Fluorescent Compounds

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Outline

- *Introduction*
  - *Motivation of development of liquid scintillator using new fluorescent compounds,*
  - *fluorescent compounds used in organic light emission device (OLED)*
- *Measurements*
  - *new fluorescent compounds(OLED compounds)*
    - *solubility,*
    - *emission and absorption spectra*
  - *liquid scintillators using the OLED compounds*
    - *Light yields,*
    - *decay constants*
- *Summary and outlook*

Motivation

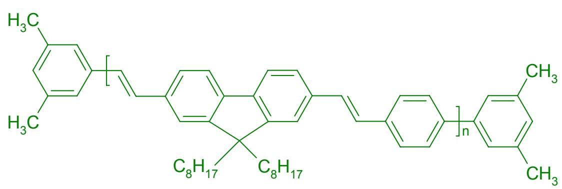
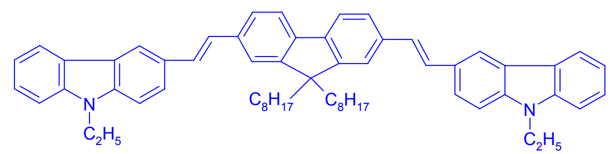
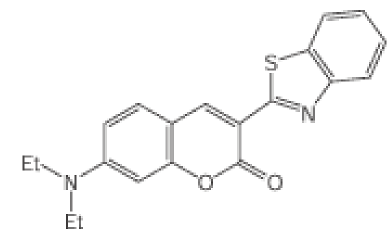
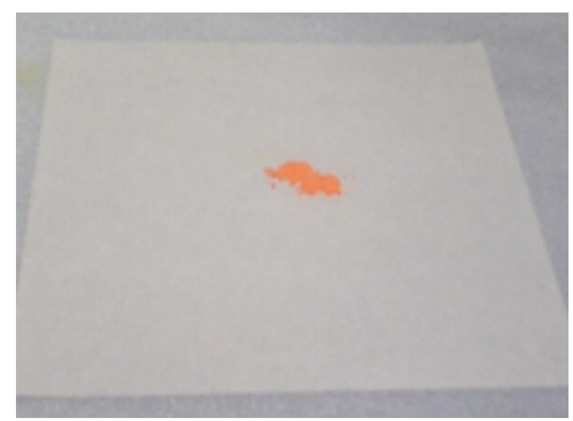
- *Recently, many new organic fluorescent compounds have been developed for organic light emitting devices (OLED), which are commercially used for flat-panel displays.*
- *Some of the fluorescent compounds have good properties to scintillators for HEP application, such as*
  - *high luminous efficiency,*
  - *blue or green light emitter, and*
  - *a short decay time constant (~nsec).*

www.nanonet.go.jp/japanese/ mailmag/2004/073a.html

... In This Study,

- *We investigate the properties of liquid scintillator cocktails using some of the compounds to study their potential for radiation detectors.*

Fluorescent compounds used in this study

ADS128GE	ADS086BE	Coumarin6
American Dye Source, Inc.	American Dye Source, Inc.	OHJEC Co.
		
Poly[(9,9-dioctylfluorenyl-2,7-diyl)-co-(1,4-divinylene-phenylene)]	*1,4-Bis(9-ethyl-3-carbazovinylene)-9,9-dihexyl] fluorene*	*3-(2-Benzothiazolyl)-7-(diethylamino)coumarin*
		

Measurements

For each of OLED compounds,

- *solubility,*
- *emission and absorption spectra,*

For each of liquid scintillator cocktails using OLED compounds (OLED-LS),

- *light yields, and*
- *decay time constants*

were measured.

All the measurements were performed at a room temperature.

Solubility in Psuedocumene

Note; Pseudocumene (1,2,4-trimethylbenzene) is a typical solvent of liquid scintillator.

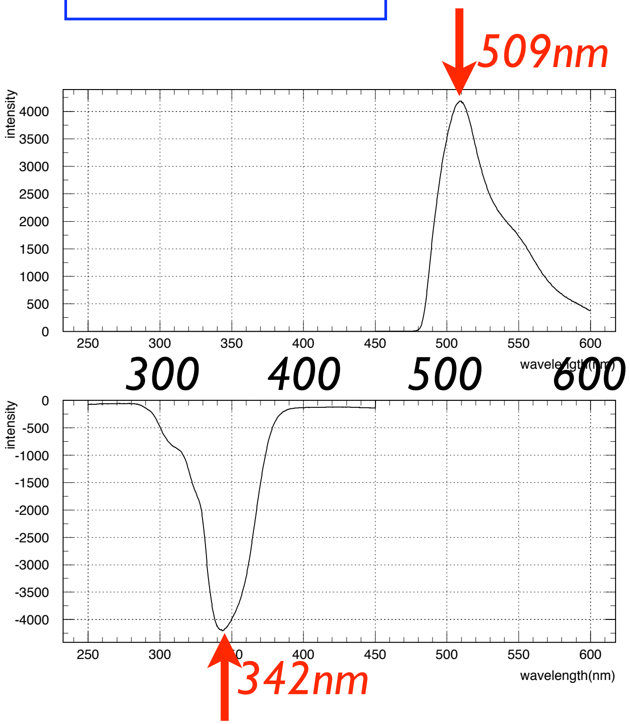
Compounds	**solubility[g/l]@room temperature**	
PPO	6.0	conventional fluorescent compounds for liquid scintillator
POPOP	0.07	
bis-MSB	0.75	
ADS086BE	3.8	OLED compounds
ADS128GE	<1.0	
Coumarin-6	<0.8	

These compounds have reasonably solubility, although it is smaller than PPO, which is typical primary solute.

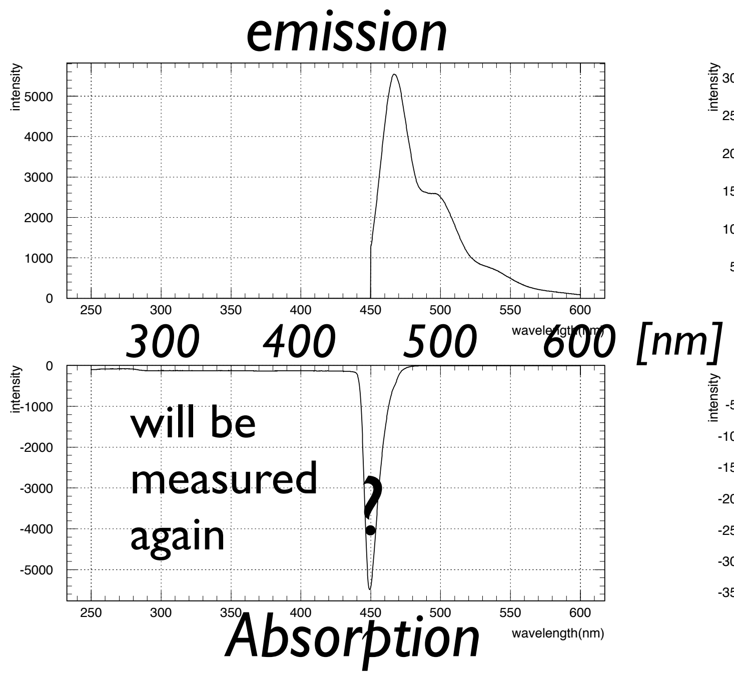
Emission and Absorption Spectra

in PseudoCumene

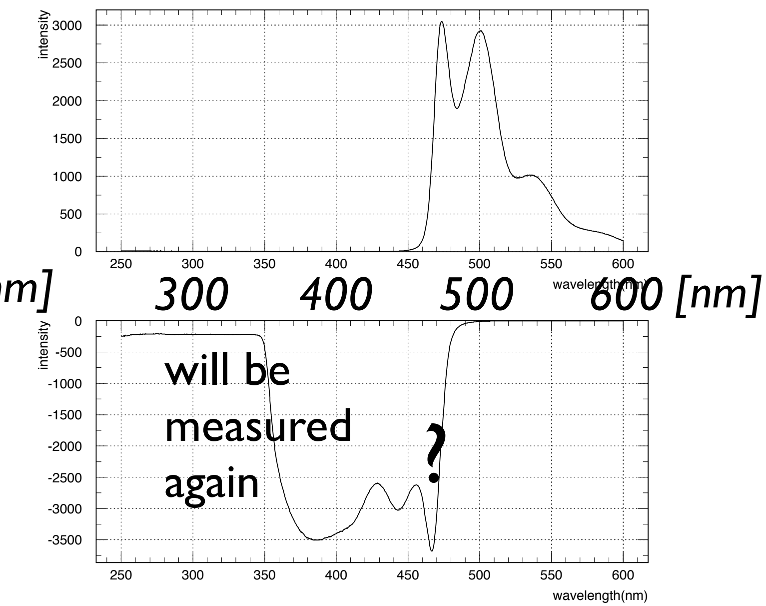
Coumarin-6



ADS086BE



ADS128GE



Upper Fig.: Emission spectra with the highest absorption wavelength
Lower Fig.:Absorption spectra with the highest emission wavelength

The absorption spectra of ADS086BE and ADS128GE will be measured again because of measurement mistakes (Raman scattering into a detector).

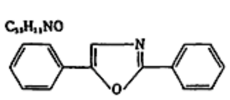
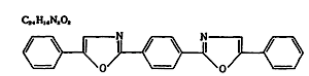
Wavelengths of Maximum Emission and Absorption

compounds	max.absorption	max.emission
PPO	352nm	375nm
POPOP	397nm	429nm
ADS086BE	(449nm)	467nm
ADS128GE	(383nm)	474nm
Coumarin6	342nm	509nm

- These OLED compounds are seem to have absorption around the emission wavelength of PPO.
- It suggests that they can be excited by the emission of PPO, as a wavelength shifter.

Primary and Secondary Solutes

- *Basic process of energy transfer in organic scintillators*
  - *Charged particles interact with the solvent molecules*
  - *Energy transfer process occurs between the solvent and the primary solute molecules.[non-radiative]*
  - *Radiative transfer process between the primary and the secondary solutes occurs. Finally, the secondary solutes [wavelength shifter] emit photons with a longer wavelength than that of the primary solutes.*

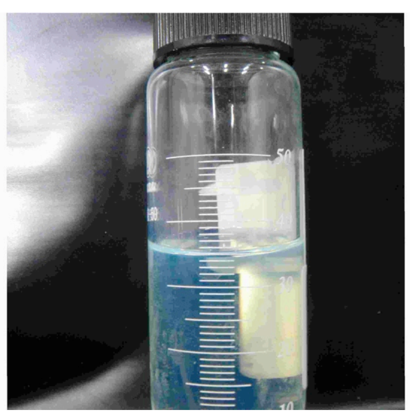
		Absorption/emission			absorption/emission
PPO		303nm/364nm	POPOP		385nm/418nm

Generally, the concentration of the secondary solutes are often only 1% of that of the primary solute.In case of large-volume applications of liquid scintillators it is necessary to use a secondary solute.

Primary and Secondary Solutes

- *From the results of the solubility and the spectra measured, these OLED compounds can be used as a "wavelength shifter" in the scintillator solutions.*
- *Therefore, we prepared some liquid scintillators with*
  - *PPO as a primary solute, and*
  - *OLED compound as a secondary solute.*

Liquid Scintillator Cocktails with the OLED Compounds (OLED-LS)

Solvent	Pseudocumene 40 ml	Pseudocumene 40 ml	Pseudocumene 40 ml
Primary solute	PPO 240 mg	PPO 240 mg	PPO 240 mg
Secondary solute	ADS086BE 150 mg	ADS128GE <30 mg	Coumarin6 <30 mg
Picture			

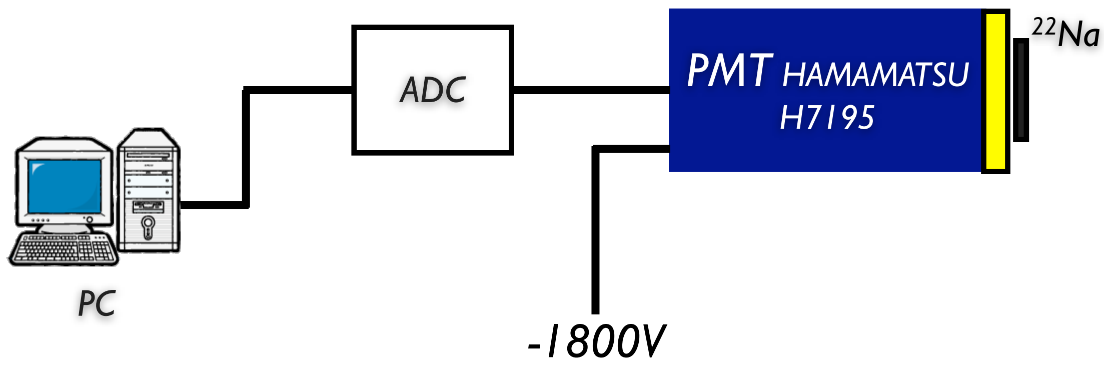
BC-505 Liquid Scintillator as a Reference

The BC-505 liquid scintillator from SAINT-GOBAIN CRYSTALS was used as a reference.

Solvent	*Pseudocumene* (>90% of chemical composition)
Solutes	*not known*
Light output	*80% of Anthracene*
Wavelength of max. emission	*425 nm*
Decay constant	*2.5 nsec*

Light Yield Measurements for OLED-LS

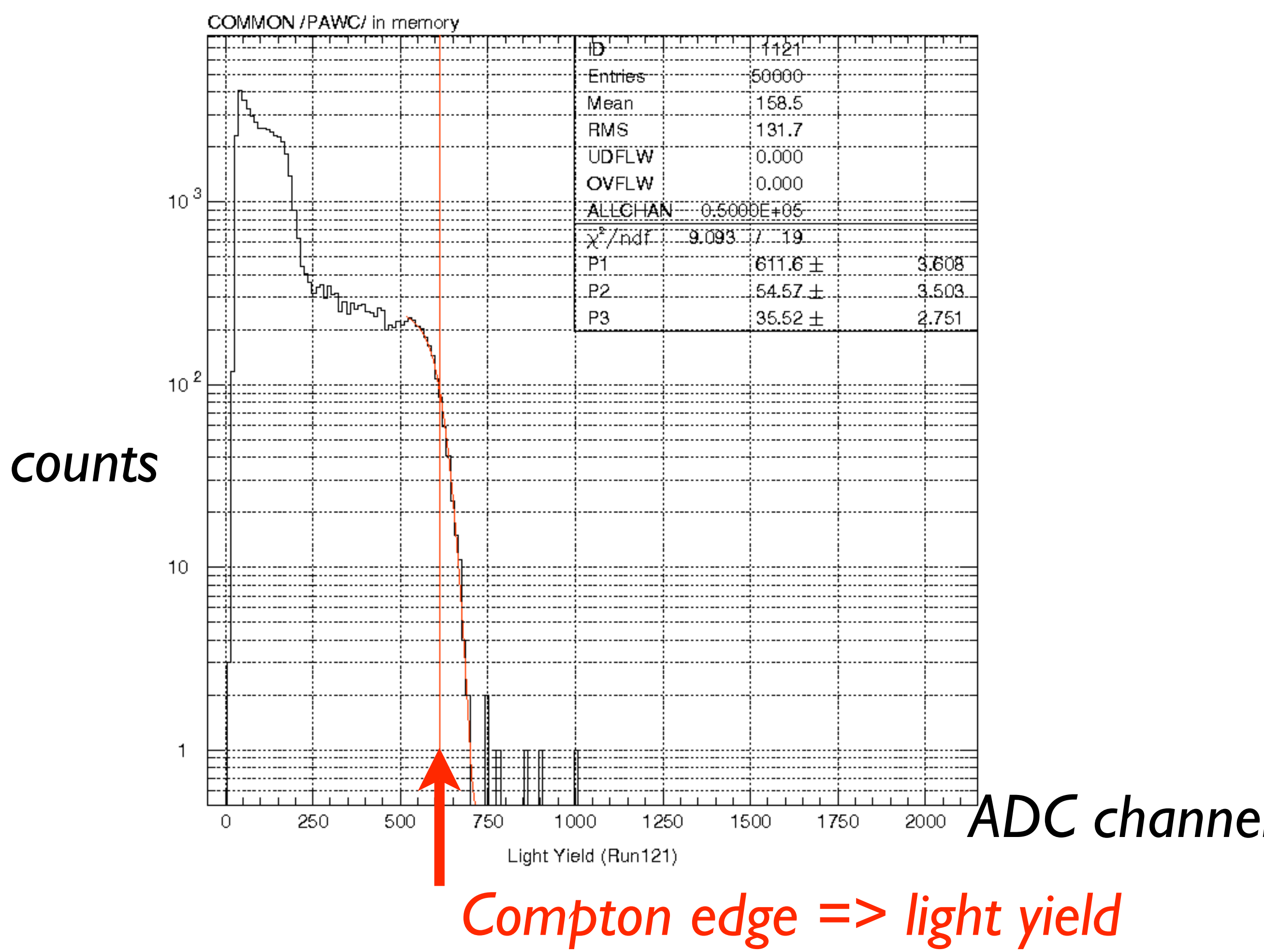
Experimental setup



quartz cell
10mm×10mm×50mm

The LS with the OLED compounds (OLED-LS) were excited by gamma-rays from a ^{22}Na source. A Hamamatsu H7195 PMT was used as a photon-detector. The LSs were filled in a quartz cell, and the PMT was placed directly on the cell.
Pulse hight spectra were recorded with CAMAC ADCs.

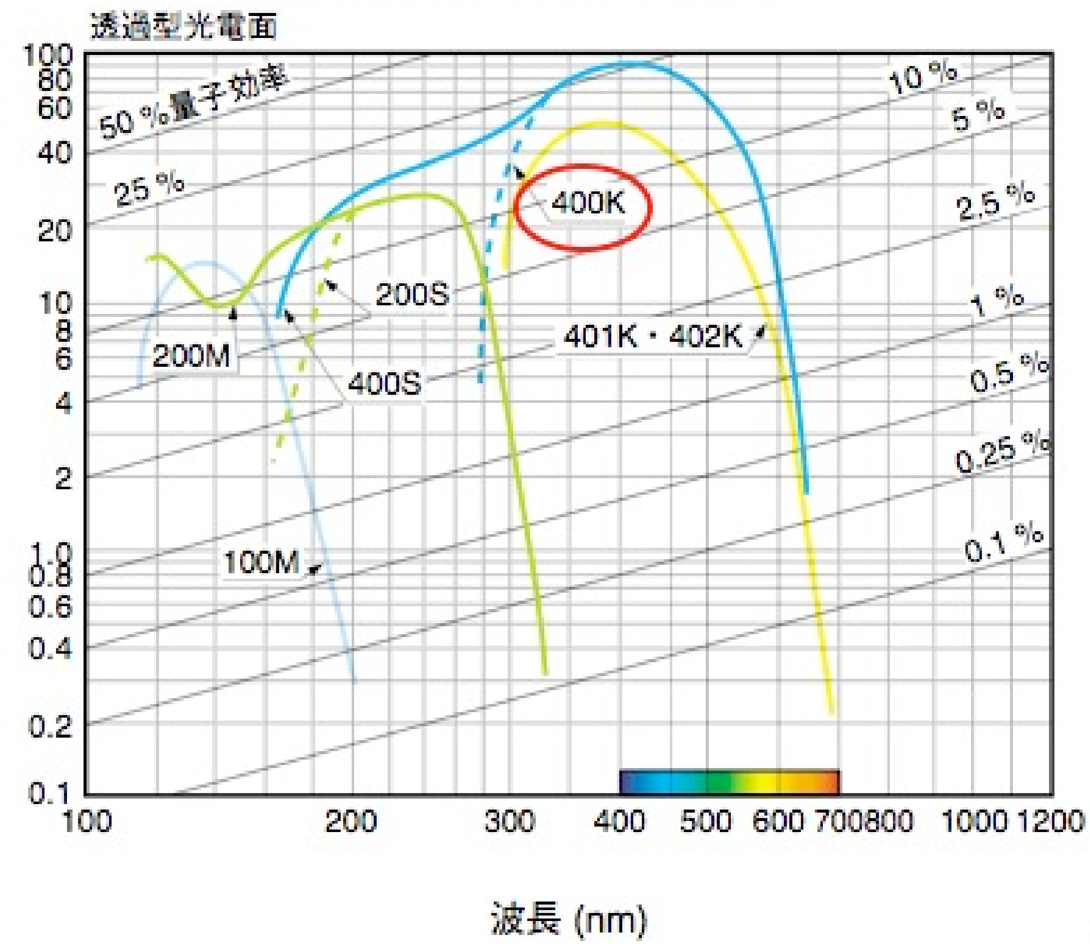
Typical ADC Spectra for ADS086BE



The ADC channels for the Compton edge were used as a measure of the light yield of the OLED-LS.

Quantum Efficiency Correction

Since different LSs have light emission of different wavelength, the light yields obtained from the measurements were corrected for quantum efficiency of the PMT over the range of fluorescence wavelength of the OLED-LS.



The comparison was made at wavelength of maximum emission for each.

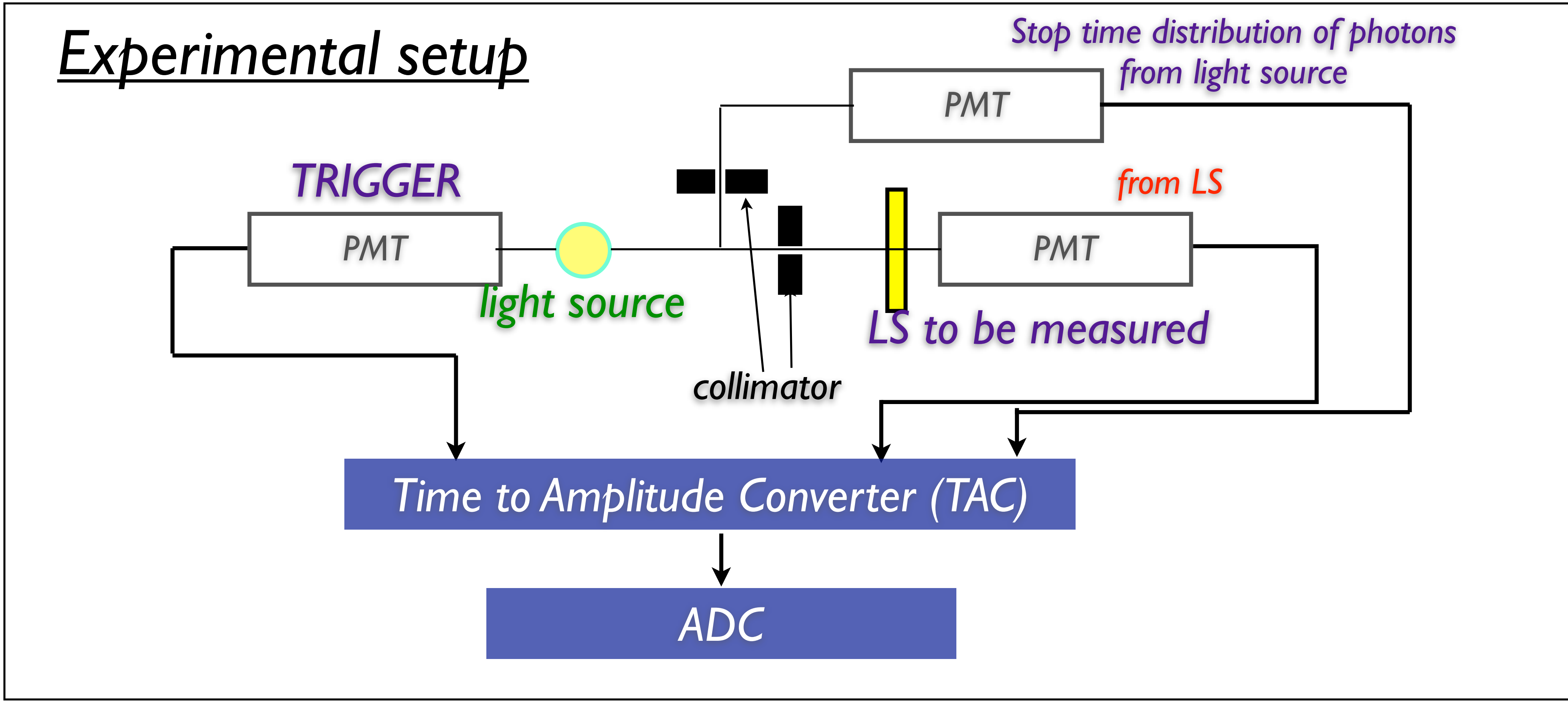
Result of Light Yield Measurements

LS	Compton edge [ch]	Relative QE correction	Relative Light yield [a.u.]
ADS086BE	284.7 ±8.5±1.6	1.3	110.7±3.0±0.6 (at 467nm)
BC505	332.8 ±8.9±1.6	1.0	100±2.7±0.5 (at 429nm)

The relative light yields were obtained by multiplying the QE correction factor to the ADC channels of the compton edge.

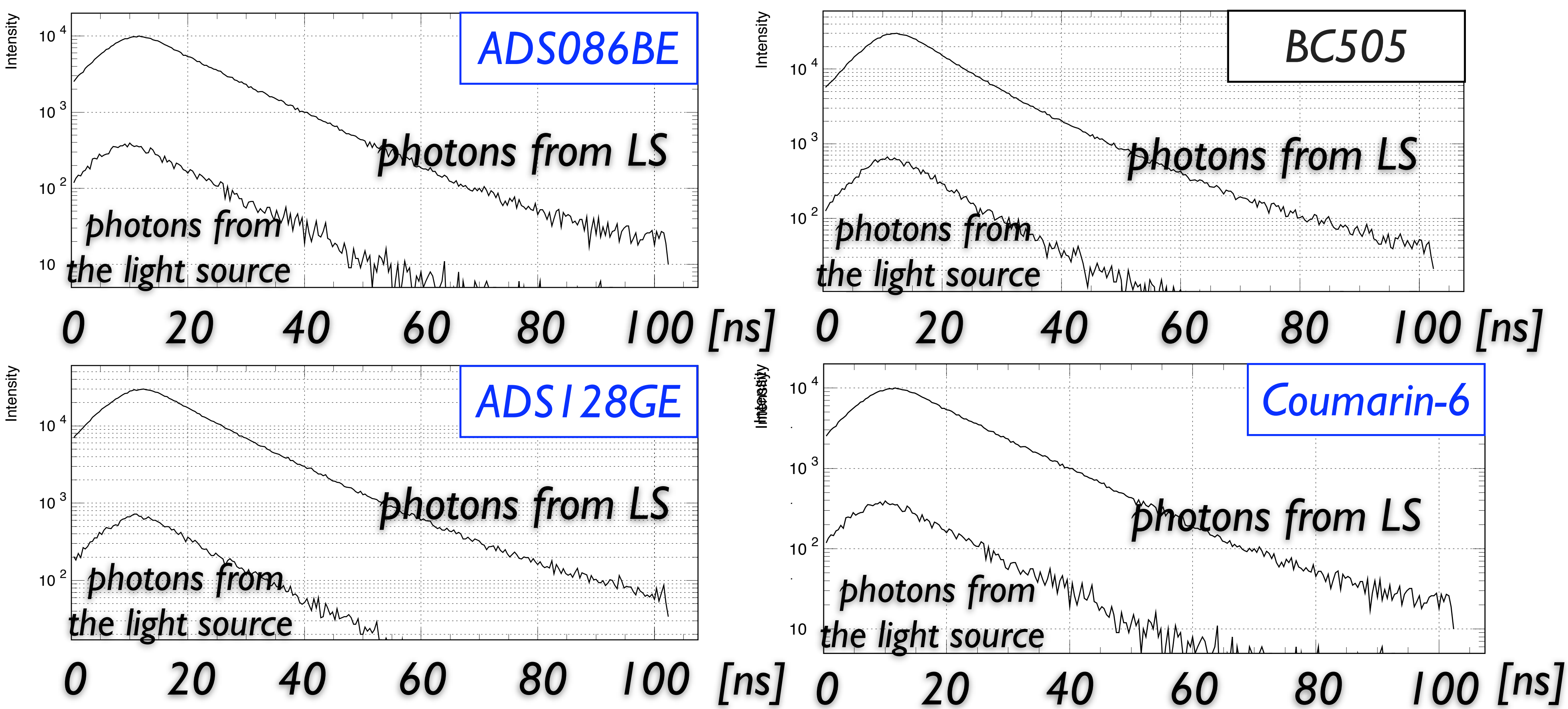
The OLED-LS using ADS086BE has a 10% larger light yield than BC505!

Decay Constant Measurement



The emission time distributions were measured by the single photon counting technique, by using a Horiba NAES-550 setup for each OLED-LS cocktail.

Emission Time Distributions



Determination of the decay constants

To determine the decay constants, the emission time distributions were fitted to a multi-exponential function, and the light-source decay time was de-convoluted.

$$I(t) = A \int_0^t G(t')exp(-\frac{t-t'}{\tau_1}) + B \int_0^t G(t')exp(-\frac{t-t'}{\tau_2})$$

Amplitude

Intensity of emission from LSs

Intensity of emission from light source

Decay constants

Result of Decay Constants Measurements

LS	BC505	ADS086BE	ADS128GE	Coumarin-6
Decay constant, main component [ns]	2.8±0.1	1.7±0.1*	2.8±0.2*	1.8±0.1*

* without Argon gas purge

The decay constant of some of the OLED-LS compounds (such as ADS086BE and Coumarin-6) have a faster decay contant than BC-505!

Summary of the LS measurements

LS	*Wavelength of max. emission [nm]*	*Relative light yield with H7195 [a.u.]*	*Relavtive light yield after QE correction [a.u.]*	*Decay constant [ns]*
BC-505	*429*	*100 ±2.7±0.5*	*100 ±2.7±0.5 (80%Anthracene)* *100 ±2.7±0.5 (80% Anthracene)*	*2.8±0.1*
ADS086BE	*467*	*83.6 ±2.5±0.4*	*108.3 ±3.2±0.6 (86%Anthracene)* *110.7 ±3.0±0.6 (88% Anthracene)*	*1.7±0.1*
ADS128GE	*474*	*72.5 ±2.1±0.3*	*105.4 ±3.1±0.5 (84% Anthracene)*	*2.8±0.2*
Coumarin-6	*509*	*41.3 ±1.2±0.2*	*67.6 ±2.0±0.3 (54% Anthracene)*	*1.8±0.1*

with Ar purge

Future Plan and Outlook

- *The decay constants of OLED-LSs will be measured with Argon gas purge. They are expected to be better (longer) when Argon gas is not purged.*

- *Water-base scintillator using OLED fluorescent compounds will be investigated for large and stable detector application.*

- *Solid film or bulk scintillator using the fluorescent compounds would also be developed.*

Summary

- *Many kinds of new organic fluorescent compounds have been developed for commercial flat-panel displays, and they can be used for radiation detectors.*
- *To investigate their potential for making scintillators used in HEP application, their emission and absorption spectra and its solubility in pseudocumene have been measured. The compounds used in this study have shown they can be used as a secondary solute in a liquid scintillator.*
- *For the liquid scintillator cocktails using the compounds (OLED-LS), the light yields and the decay constants have been determined.*
- *The light yield after the QE correction were 54-88 % Anthracene. And, ADS086BE has shown a 10% larger light yield than BC-505.*
- *The decay constants of all of the OLED-LSs were as fast as BC-505.*
- *The OLED fluorescent compounds would have high potential for new scintillator for the HEP use.*

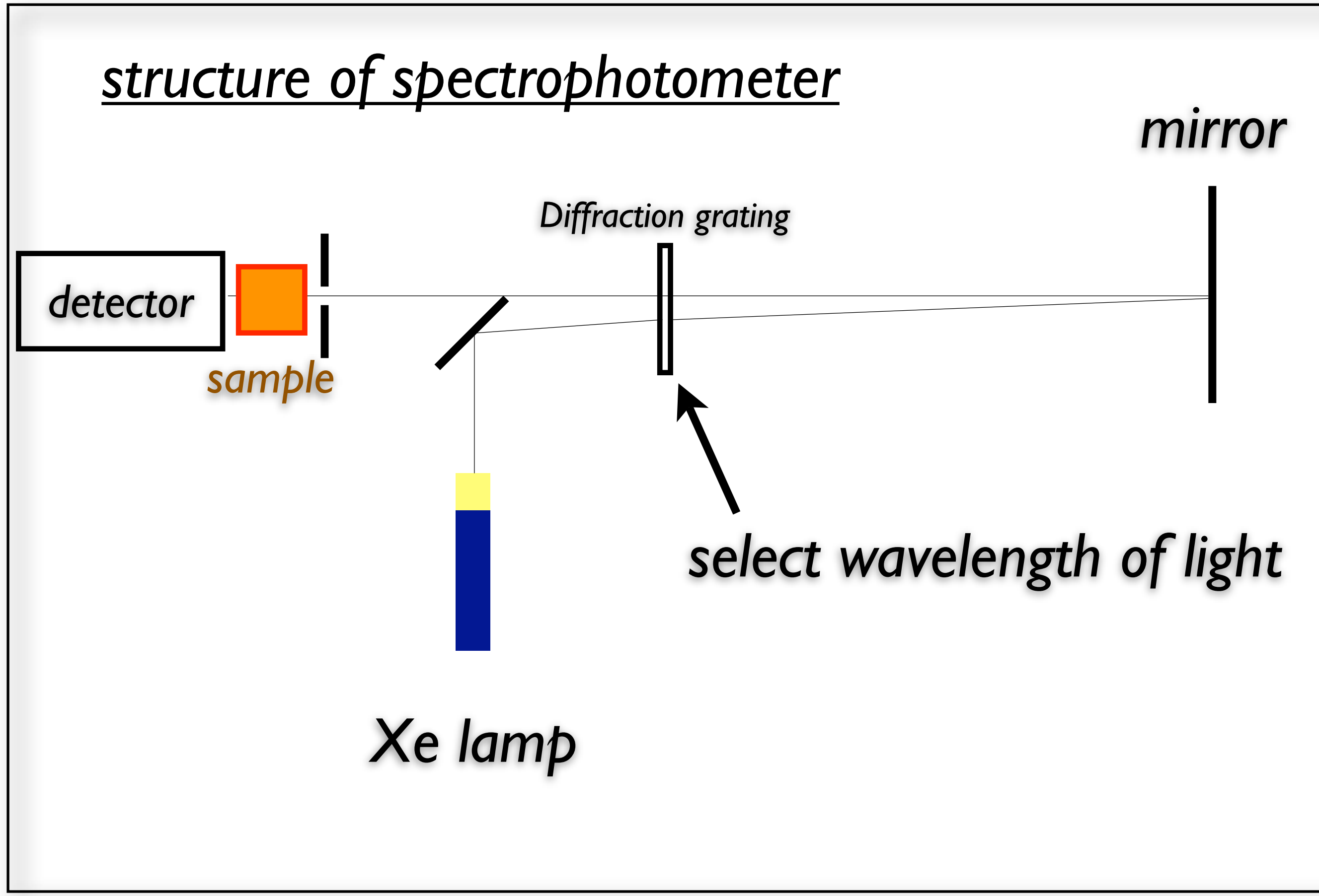
Back up sildes

spectrophotometer for spectra mesurement

HITACHI
spectrophotometer F-4500

wavelength of light for absorption:
250nm~600nm

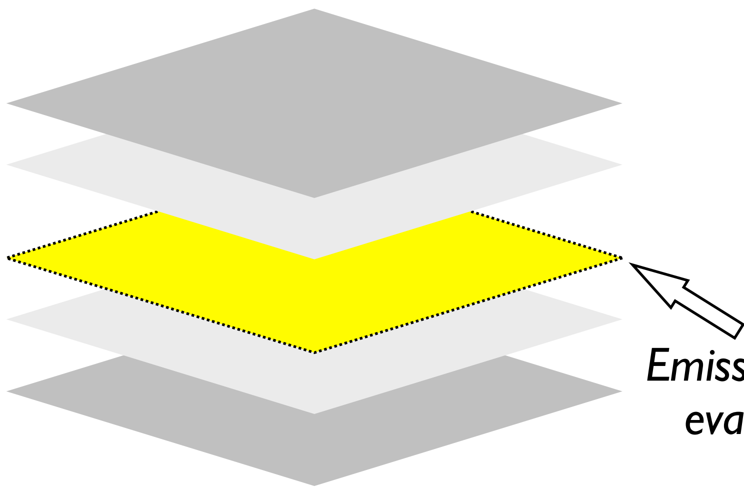
resolution:~1nm



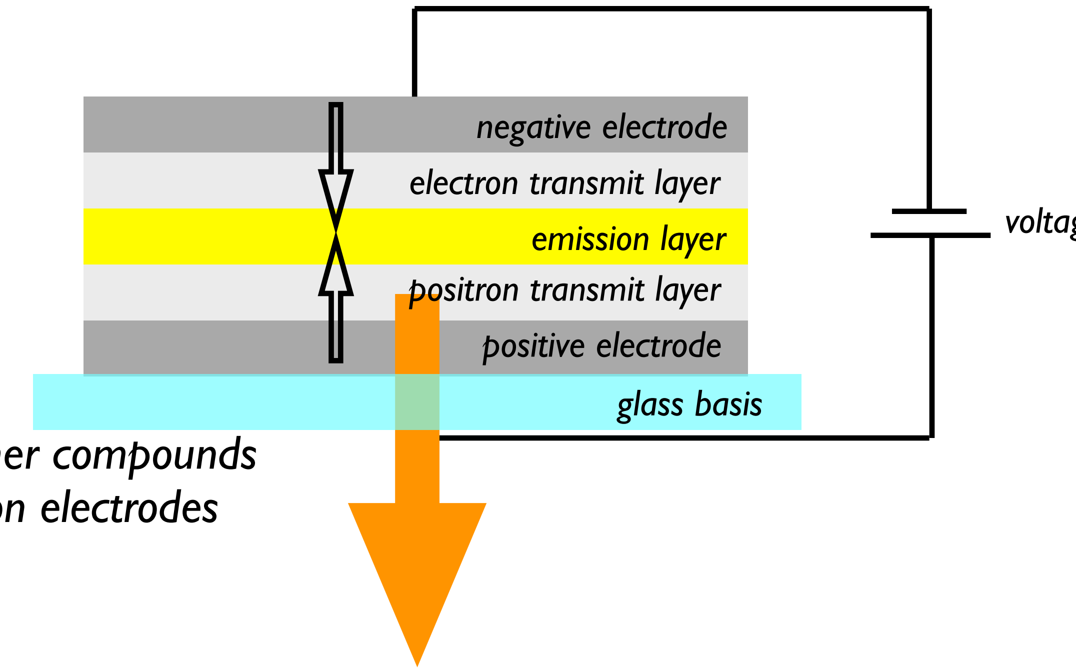
HITACHI spectrophotometer F-4500 was used,which excites samples by light with wavelength of from 250nm to 600nm selected at a diffraction grating.

Element device of flat-panel display

element device

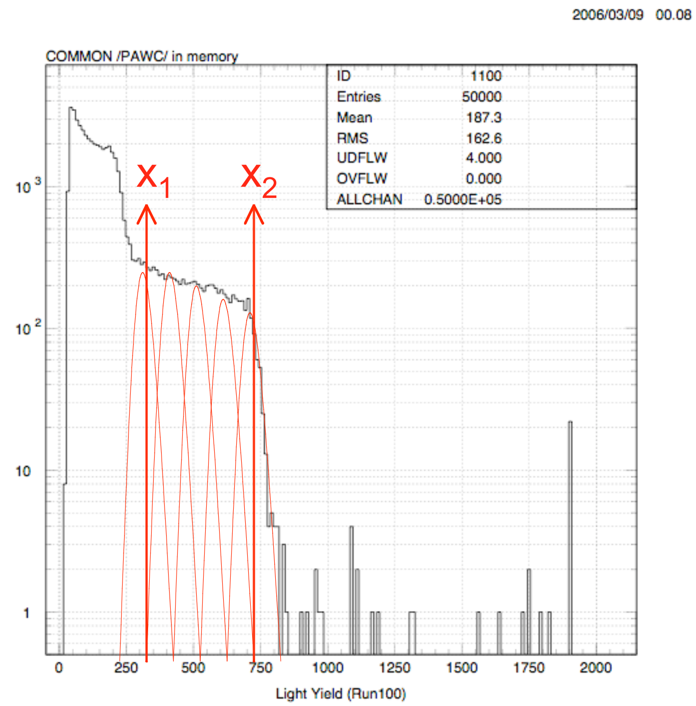


Emissive polymer compounds
evaporated on electrodes



They are advertized as display which are operated with low voltage supplied,and which has luminosity and rapid response.

Determination of the compton edge



$$Fittingfunc = Ae^{-\frac{x}{b}} e^{(-\frac{1}{2}[(x-x_i)/\sigma])^2}$$

$x_1 \sim x_2$: