New Types of Lead Tungstate Crystals with High Light Yield

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for SIC, Caltech, BNL Collaboration

Calor00, Annecy
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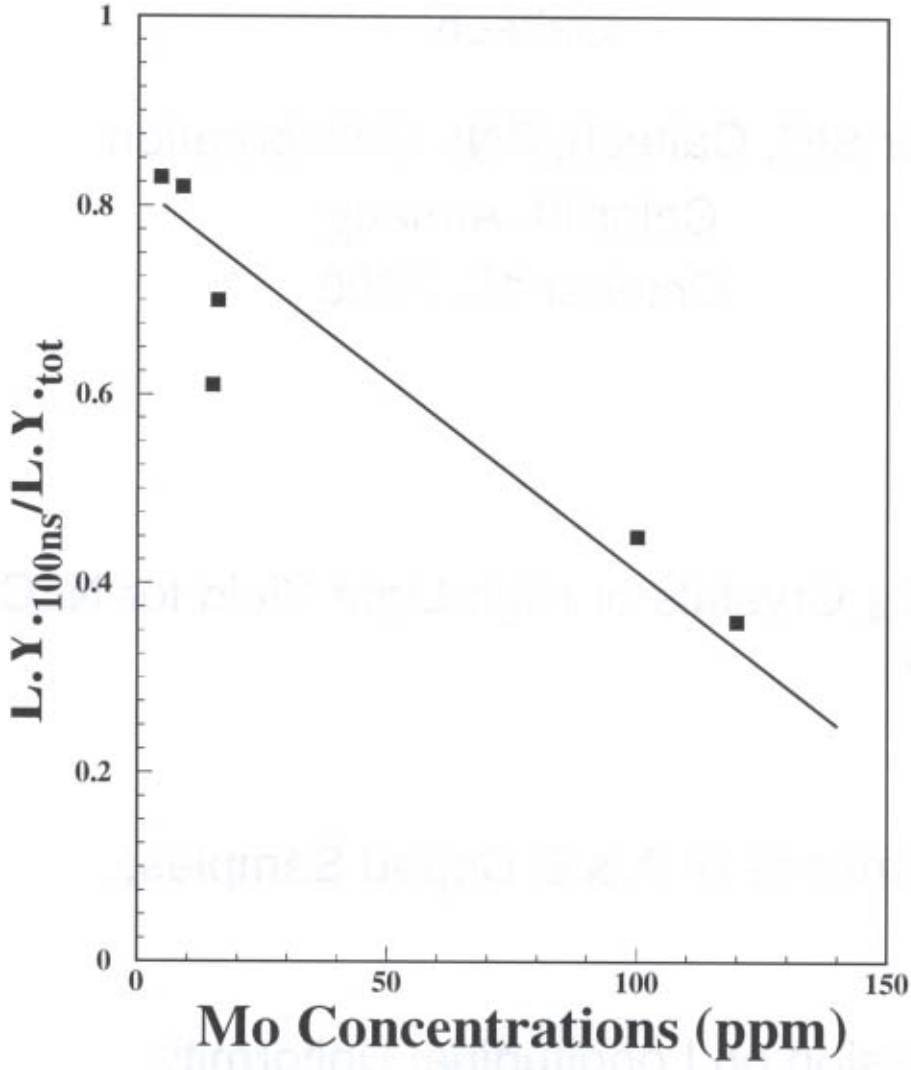
- $PbWO_4$ Crystals of High Light Yield for NLC and RHIC;
- Performance of A & B Doped Samples;
- Discussion on Longitudinal Uniformity.

Effect of Mo Contamination

For Six BTCP Samples

M. Kobayashi *et al.*, **NIMA 373** (1996) 333.R.Y. Zhu *et al.*, **NIMA 376** (1996) 319

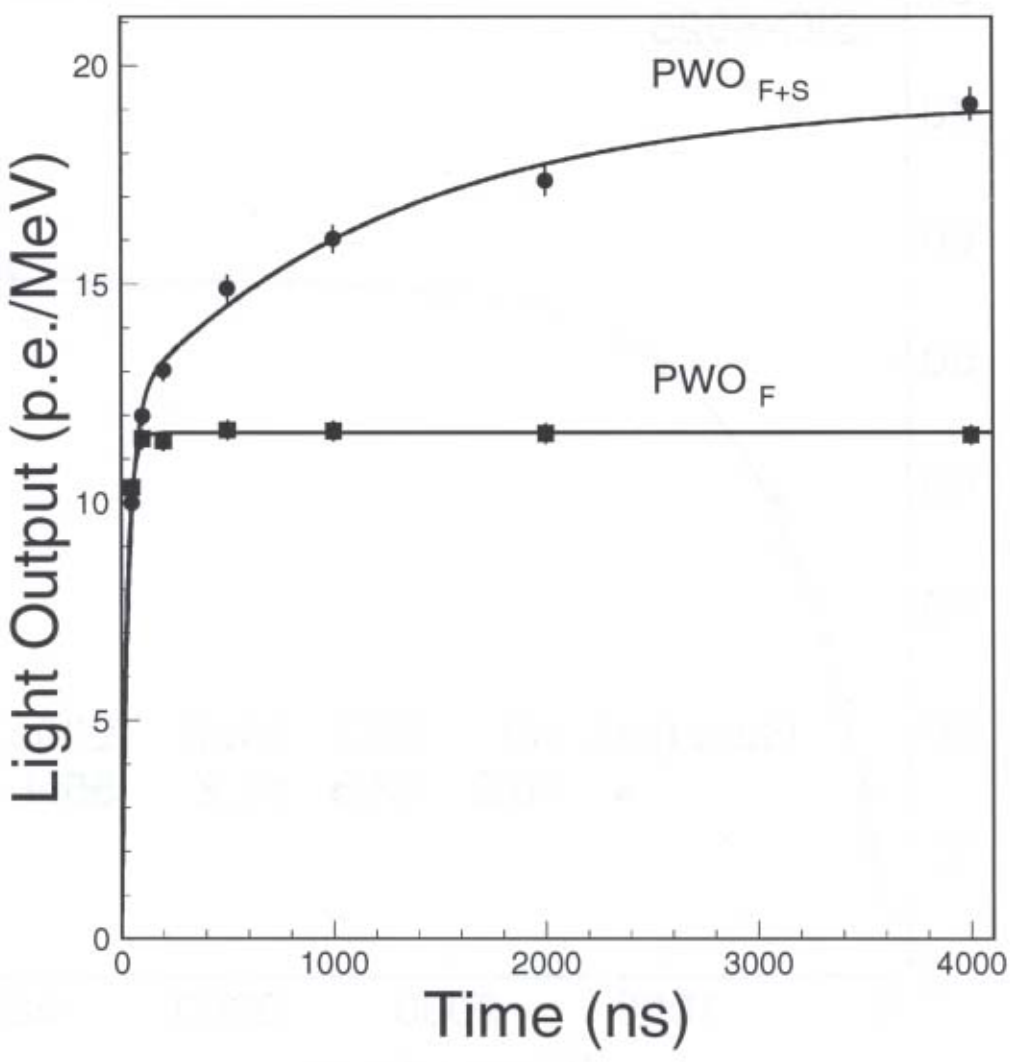


$PbWO_4$ Scintillation Light Output

Measured with R2059 PMT

23 cm $PbWO_4$: SIC-210 & BTCP-1971:La

NLC Detector Workshop, Keystone (1998)

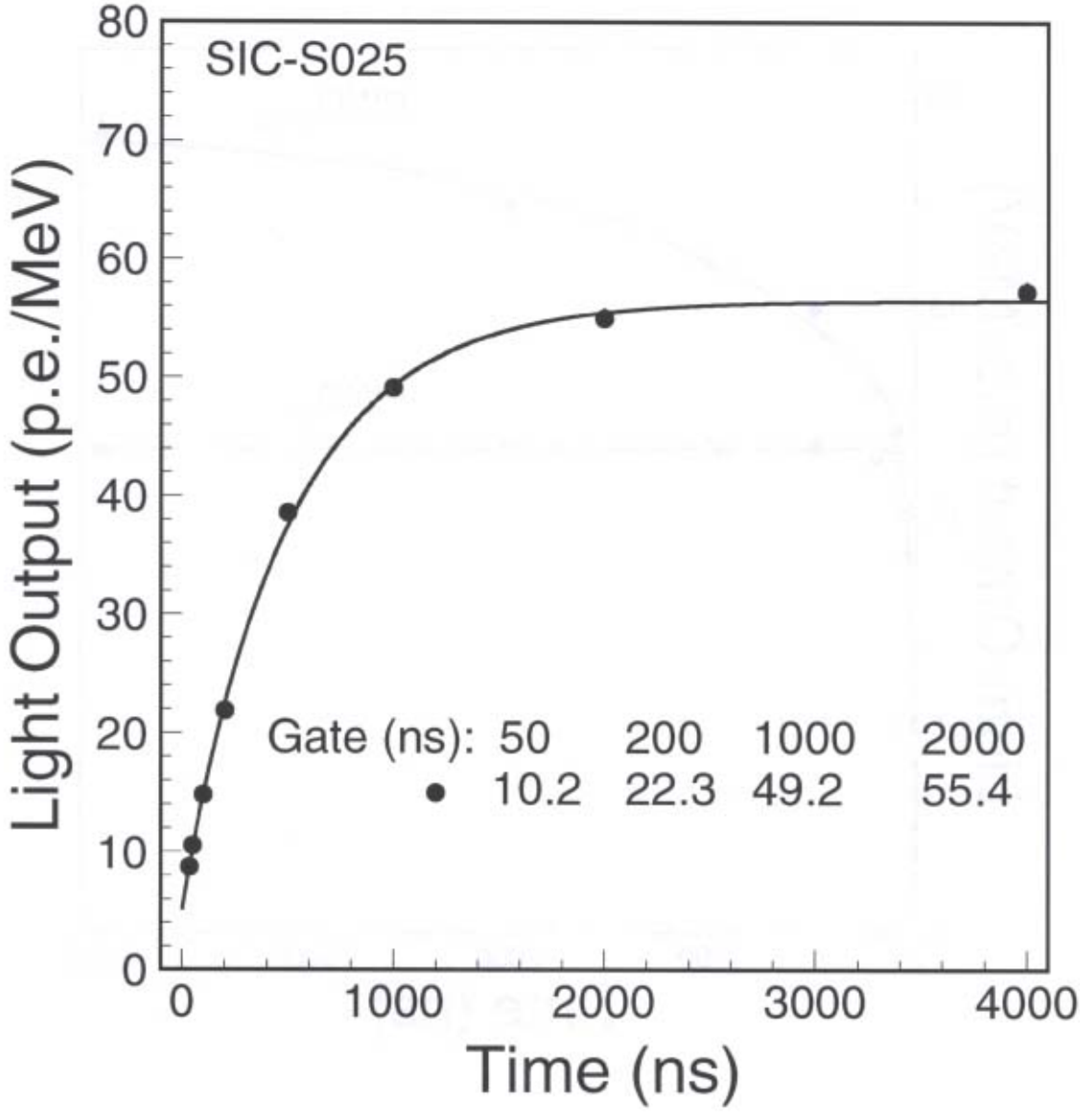


$PbWO_4$ Scintillation Light Output

Measured with with R2059 PMT

10 cm $PbWO_4$ S-025: 56 p.e./MeV in 2 μs

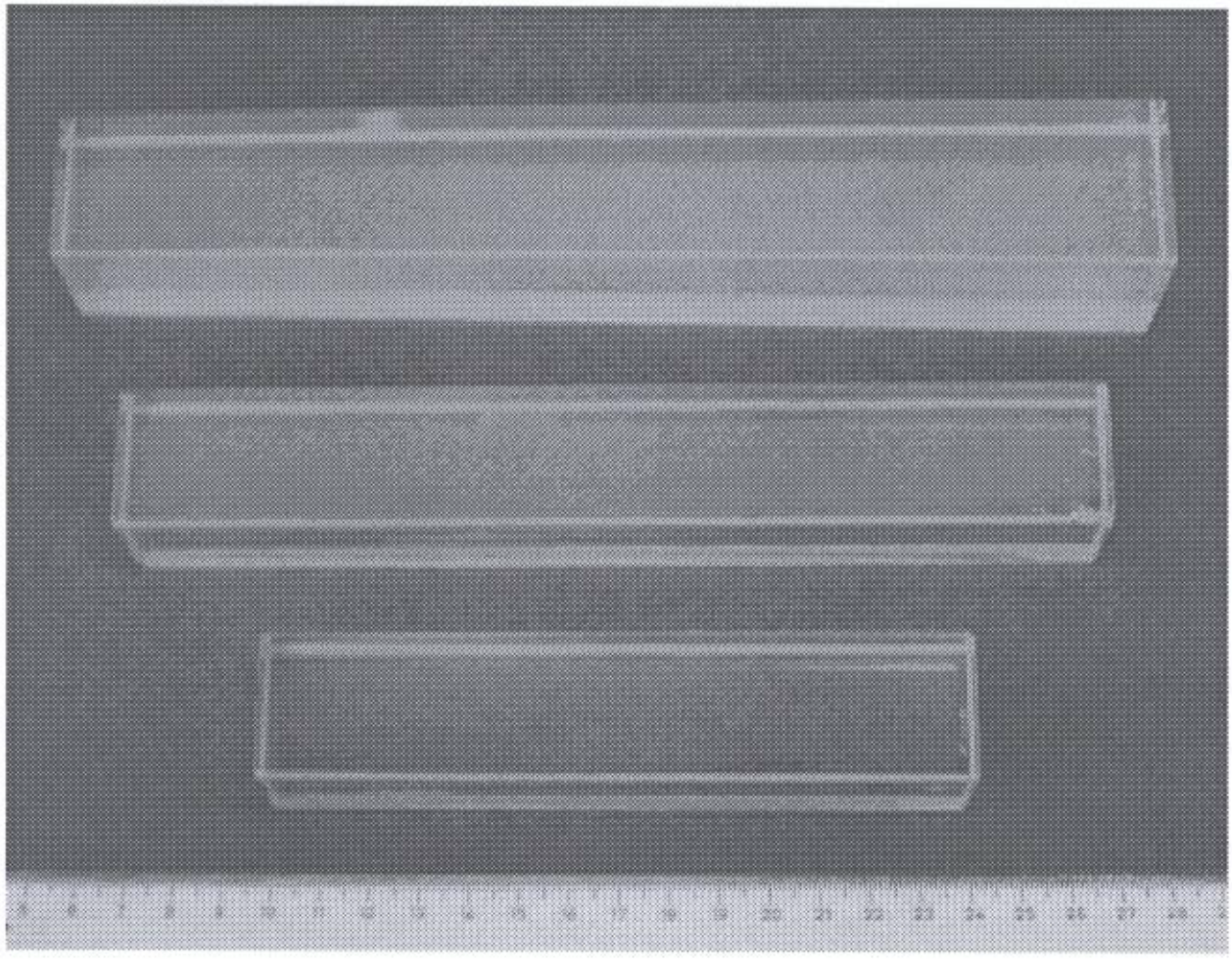
Calor99, Lisbon (1999) 226



List of $PbWO_4$ Samples

ID	Dimension(cm)	λ_{pho} (nm)	Date
	Samples Doped with Dopant A		
S25	2.9 × 9.5 × 2.9	550 – 600	4/23/1999
S27	2.0 × 12.0 × 2.0	550 – 600	4/26/2000
Z9	2.0 × 19.8 × 2.0	550 – 600	4/26/2000
Z14	2.0 × 17.9 × 2.0	550 – 600	7/21/2000
Z22	2.0 × 16.0 × 2.0	550 – 600	7/21/2000
Z23	2.0 × 9.7 × 2.0	550 – 600	7/21/2000
Z24	2.0 × 3.0 × 2.0	550 – 600	9/20/2000
Z25	2.0 × 12.0 × 2.0	550 – 600	9/20/2000
	Samples Doped with Dopant B		
Z20	2.0 × 14.0 × 2.0	550 – 600	7/21/2000
Z21	2.0 × 10.3 × 2.0	550 – 600	7/21/2000
	A Standard CMS Y Doped Sample		
S762	2.2 × 23.0 × 2.6	420	8/25/2000

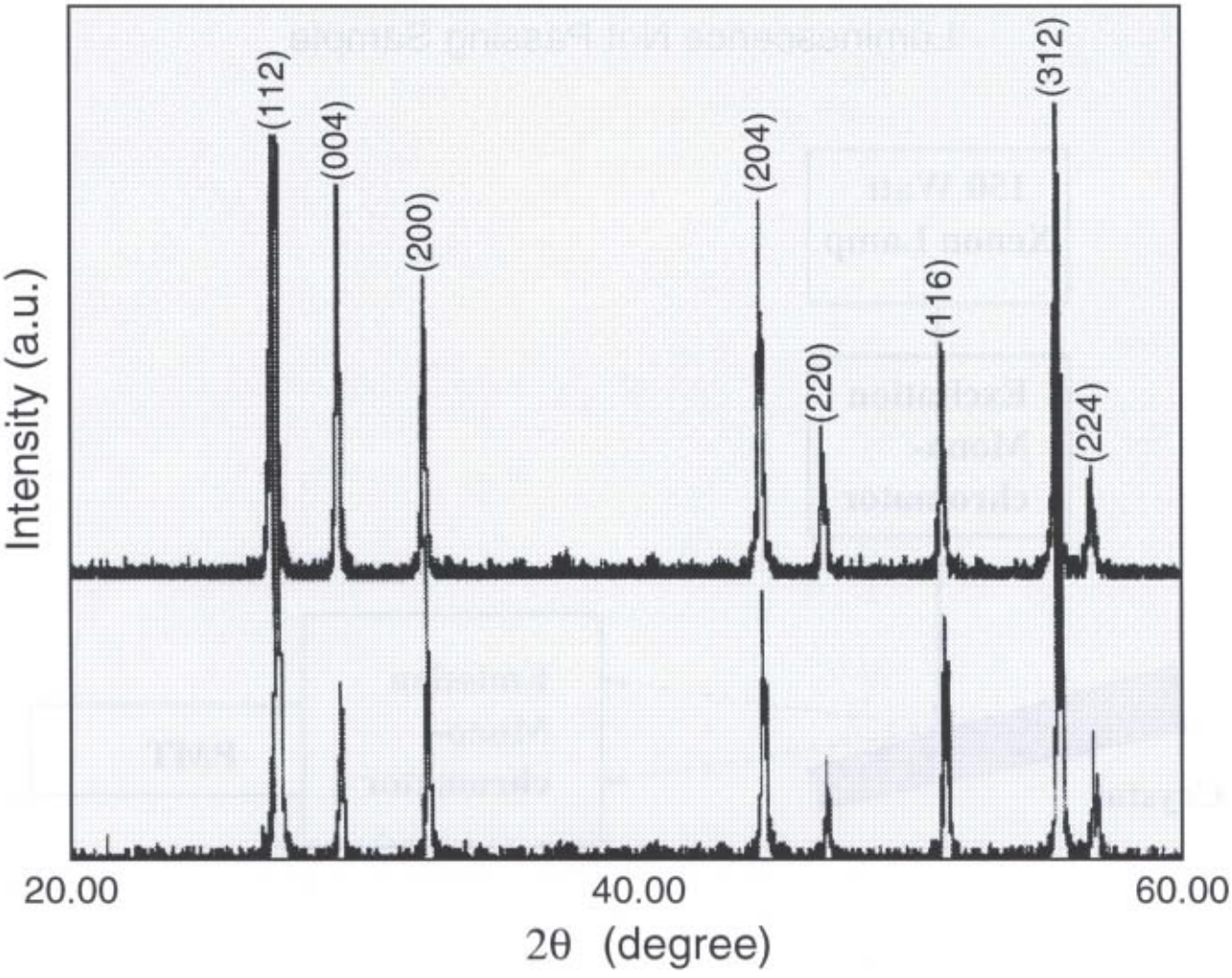
Photograph of $PbWO_4$ Samples: S762:Y, Z9:A, Z20:B



$PbWO_4$ X-Ray Diffraction Spectra

D/MAX-C Diffractometer, Cu target, 40 kV, 30 A and 2°/min

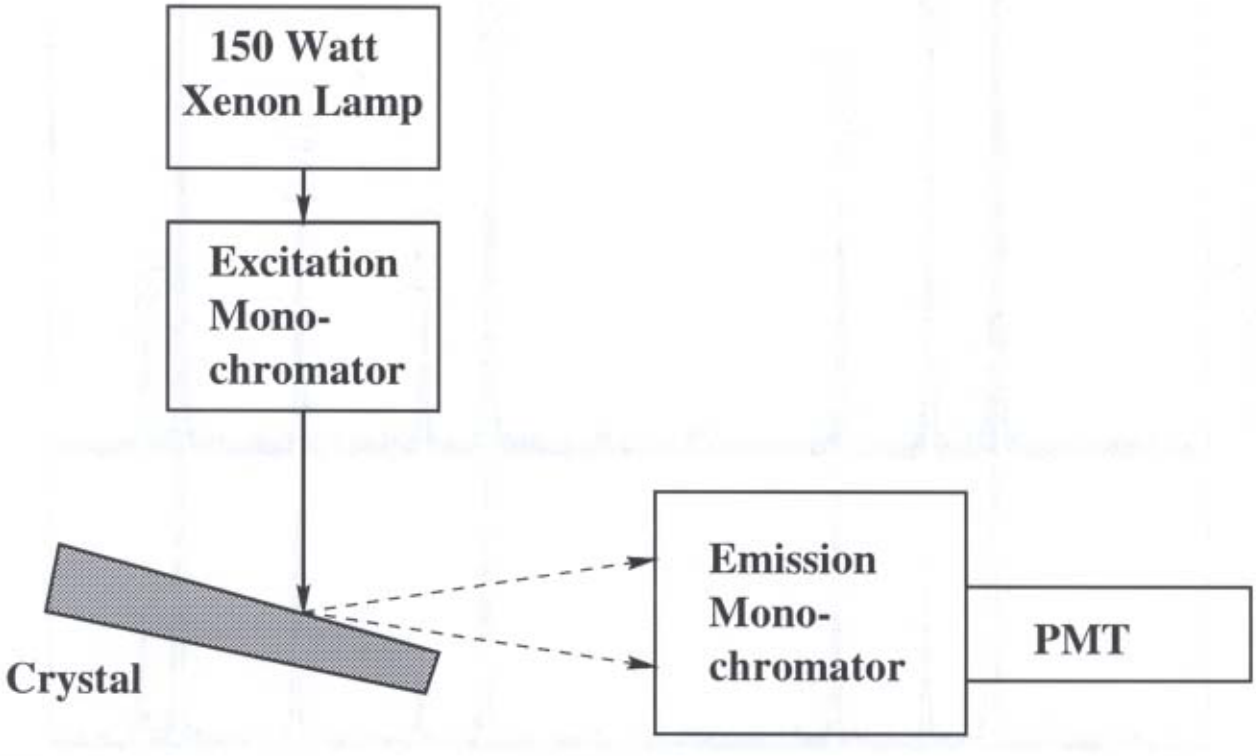
Samples Z24:A and Z25:A ⇒ Pure Sheelite



Setup for Photo Luminescence Measurement

HITACHI F-4500 Fluorescence Spectrophotometer

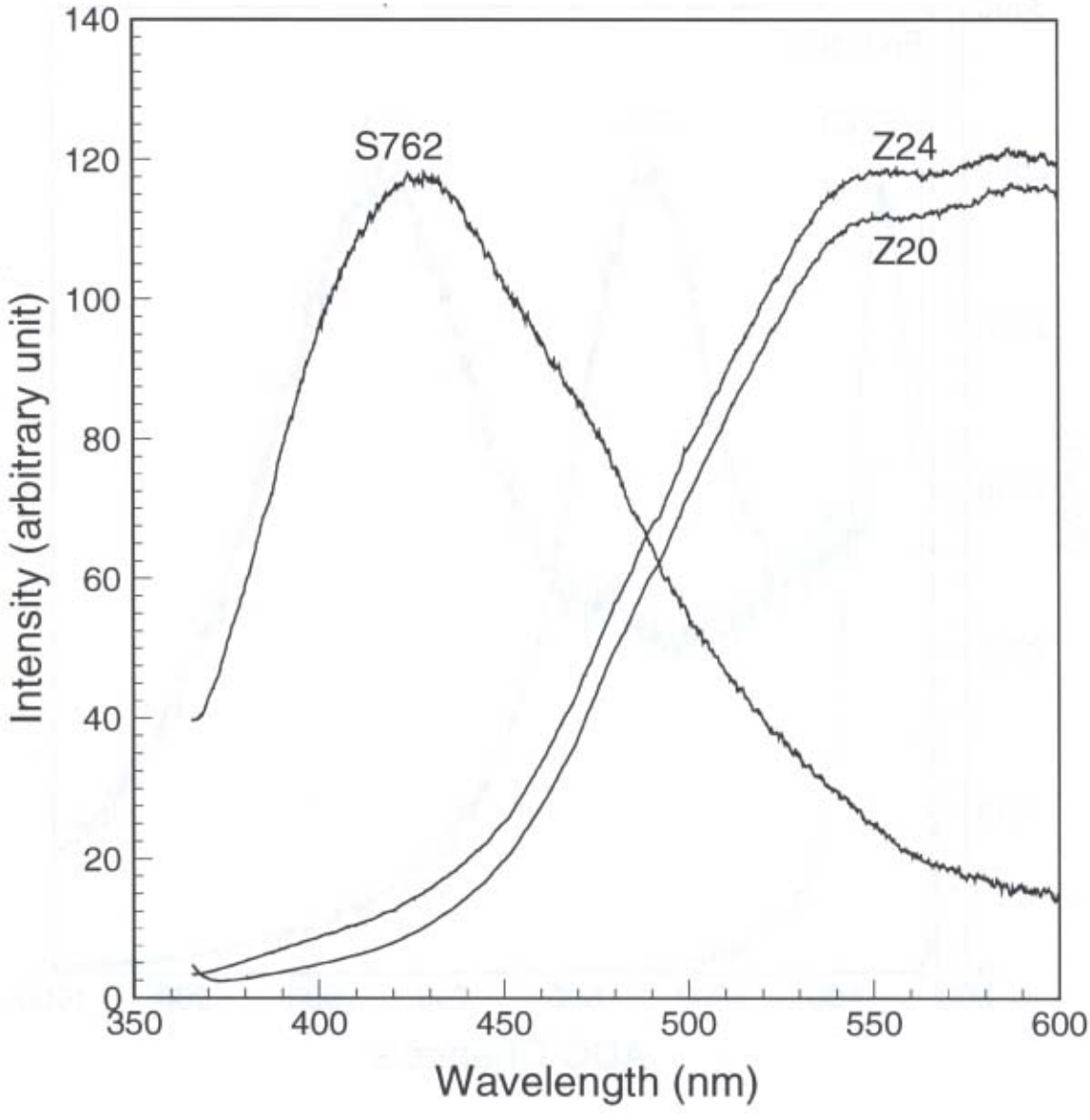
Luminescence Not Passing Sample



$PbWO_4$ Photo Luminescence Spectra

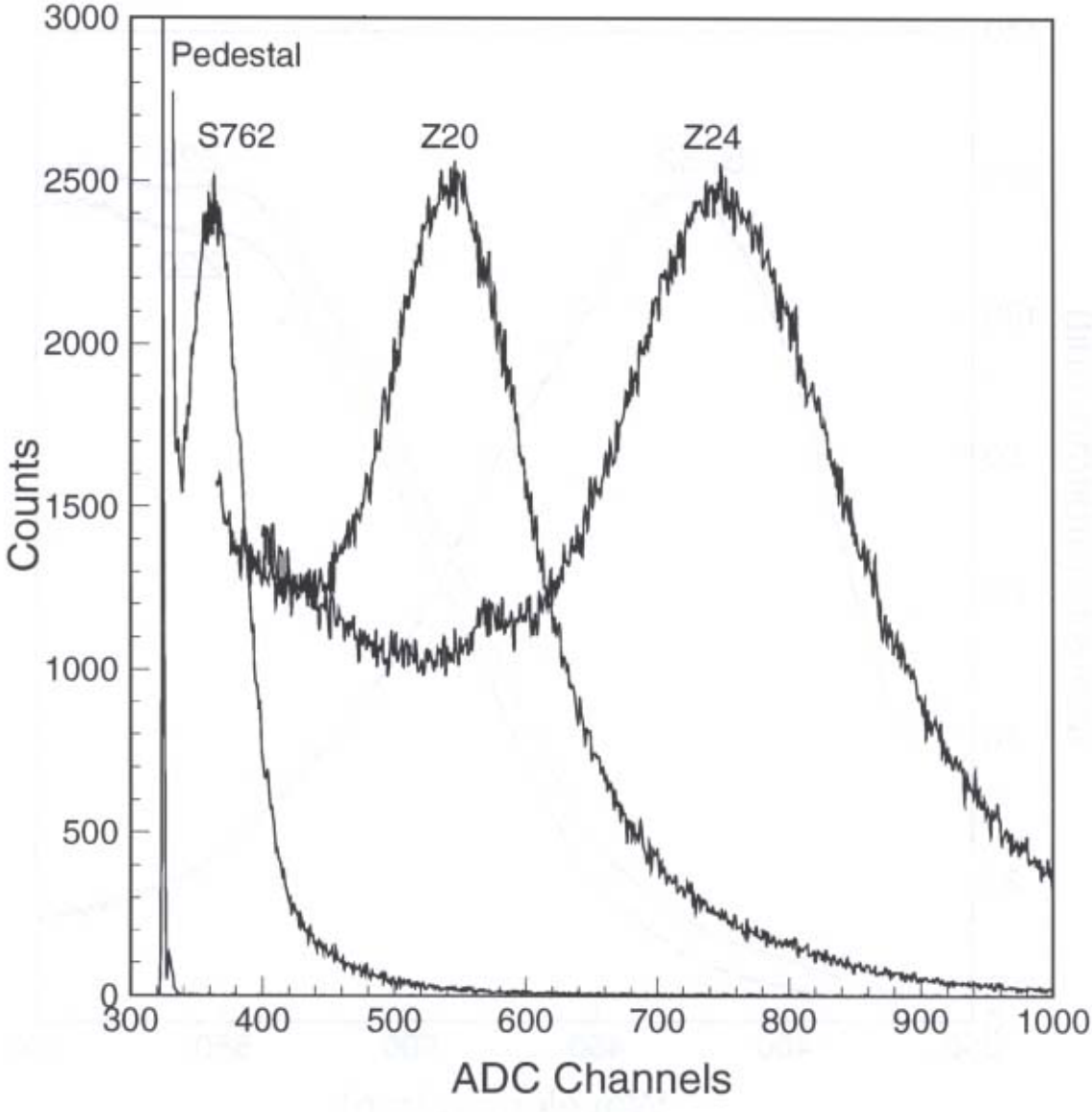
Measured with HITACHI F-4500 Fluorescence Spectrophotometer

Samples: S762:Y, Z24:A and Z20:B



$PbWO_4$ ^{137}Cs Peak Spectra, Integrated in 2 μs

Samples: S762:Y, Z24:A and Z20:B



Result of $PbWO_4$ Light Output (p.e./MeV)

Measured by an R2059 PMT

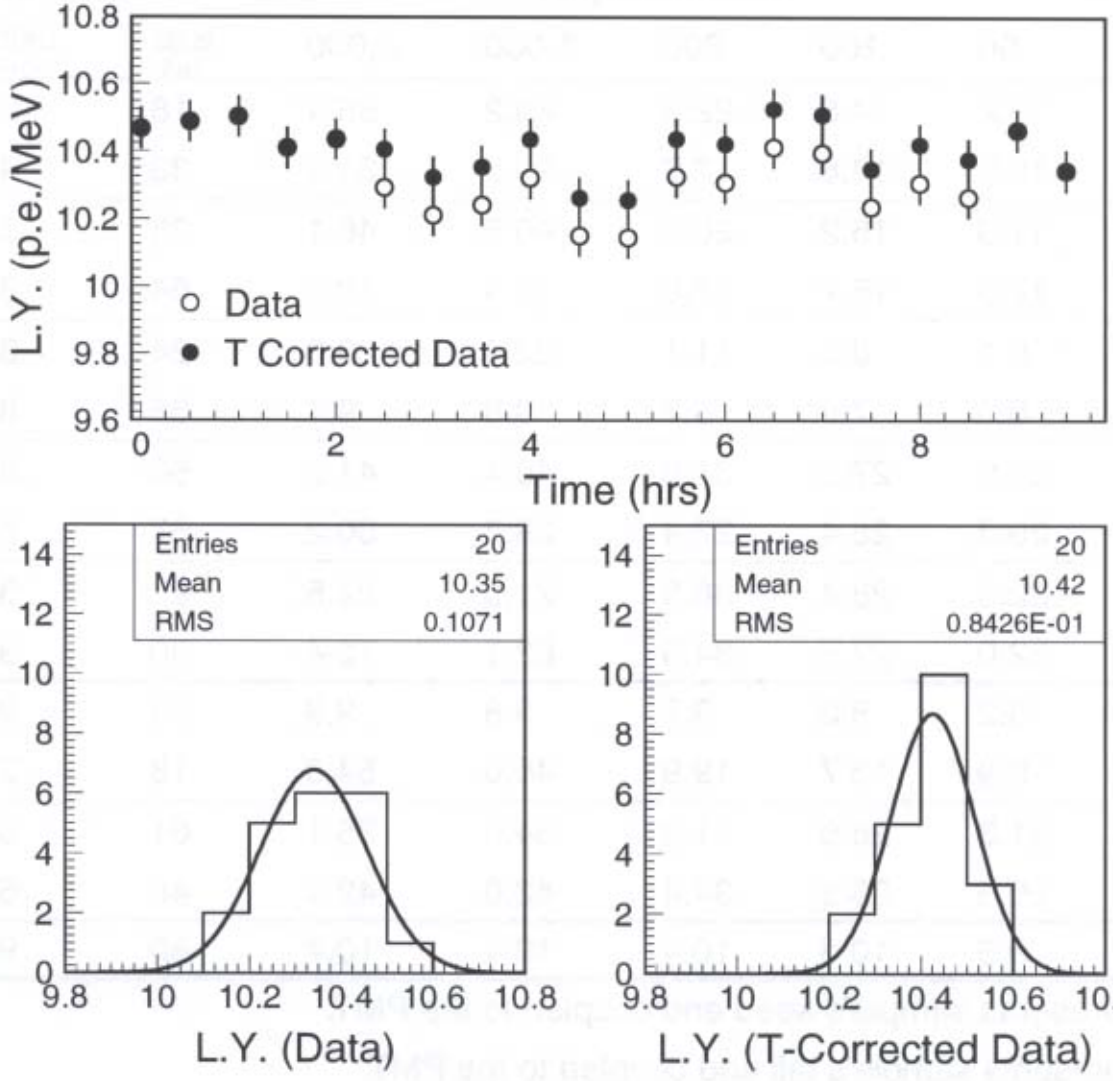
Sample	Gate width (ns)					Fraction(%)	
ID	50	100	200	1,000	2,000	$\frac{50ns}{2\mu s}$	$\frac{100ns}{2\mu s}$
S25^s	10.2	14.8	22.3	49.2	55.4	18	27
S25^t	10.5	13.8	17.7	29.8	31.8	33	43
S27^s	11.3	15.2	20.4	40.5	46.1	25	33
S27^t	12.5	15.7	17.0	18.9	19.4	64	81
Z9^s	6.1	8.3	11.1	22.4	26.0	24	32
Z9^t	6.0	7.9	8.7	9.0	9.1	66	87
Z23^s	21.0	27.3	31.5	40.4	41.8	50	65
Z23^t	20.3	25.4	27.4	29.7	30.2	67	84
Z24^s	22.3	28.4	36.5	71.0	82.5	27	34
Z24^t	22.0	27.5	34.5	63.1	72.4	30	38
Z20^s	8.2	9.5	9.7	9.8	9.9	83	96
Z20^t	9.9	13.7	19.9	46.0	54.3	18	25
Z21^s	21.3	28.0	31.3	34.5	35.1	61	80
Z21^t	20.5	28.5	34.4	42.0	42.4	48	67
S762	9.3	10.3	10.4	10.4	10.4	89	99

^{s} represents sample's seed end coupled to the PMT.

^{t} represents sample's tail end coupled to the PMT.

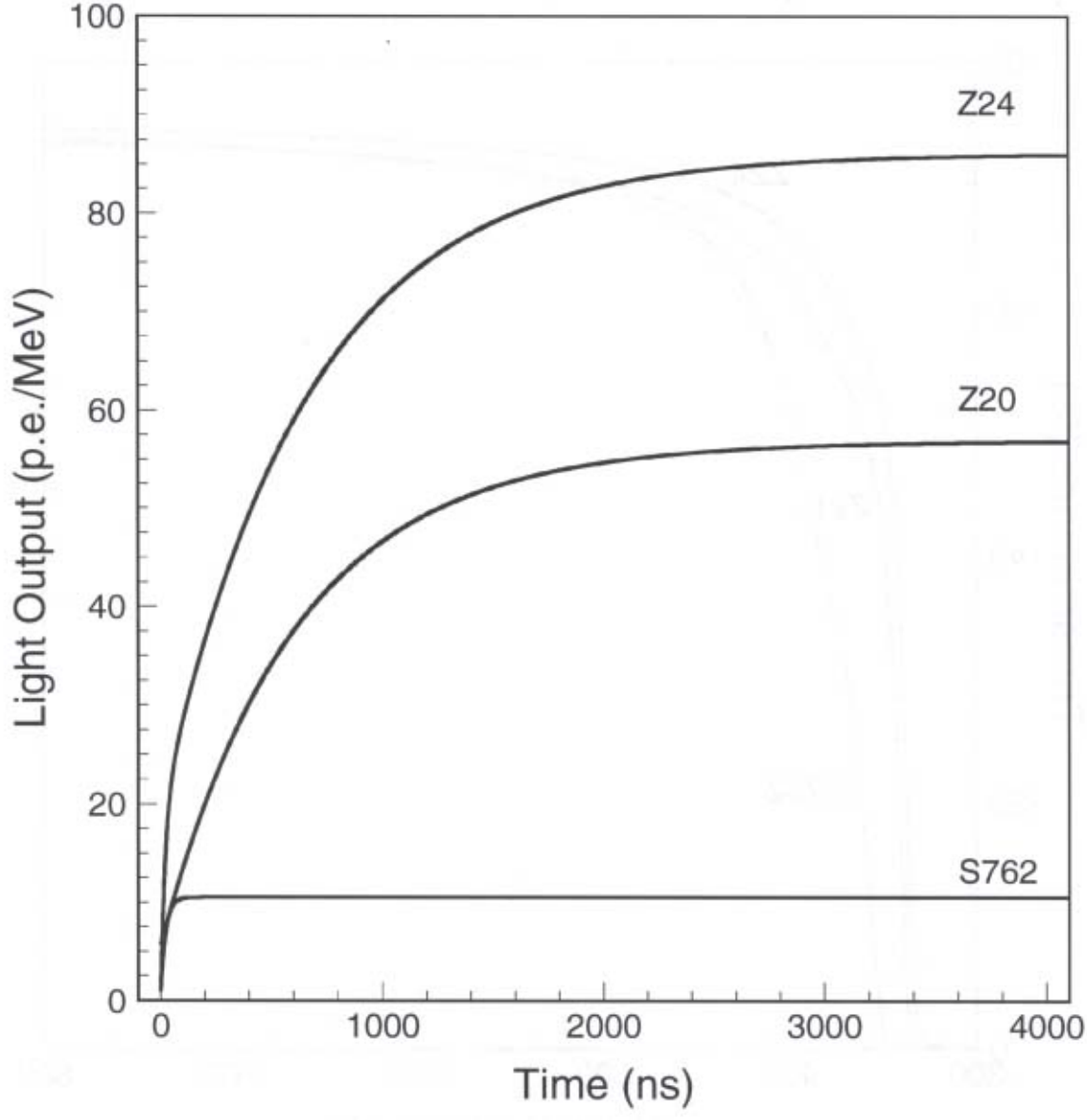
Stability of $PbWO_4$ Light Output Measurement

Without/with T Correction: **1/0.8%**



$PbWO_4$ Decay Kinetics, Measured by R2059 PMT

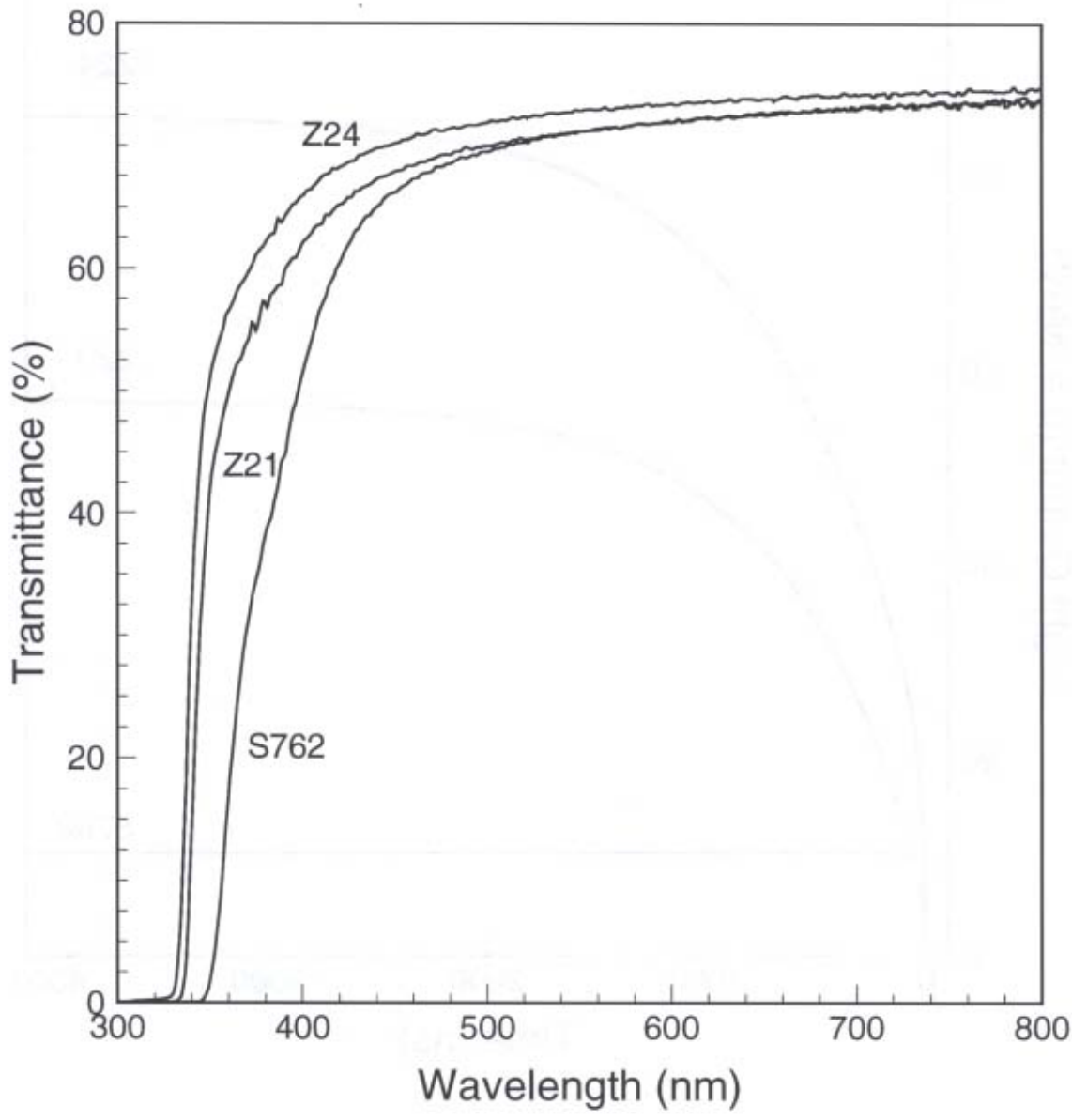
Samples: S762:Y, Z24:A and Z20:B



$PbWO_4$ Longitudinal Transmission

Measured with Hitachi U-3210 Photospectrometer

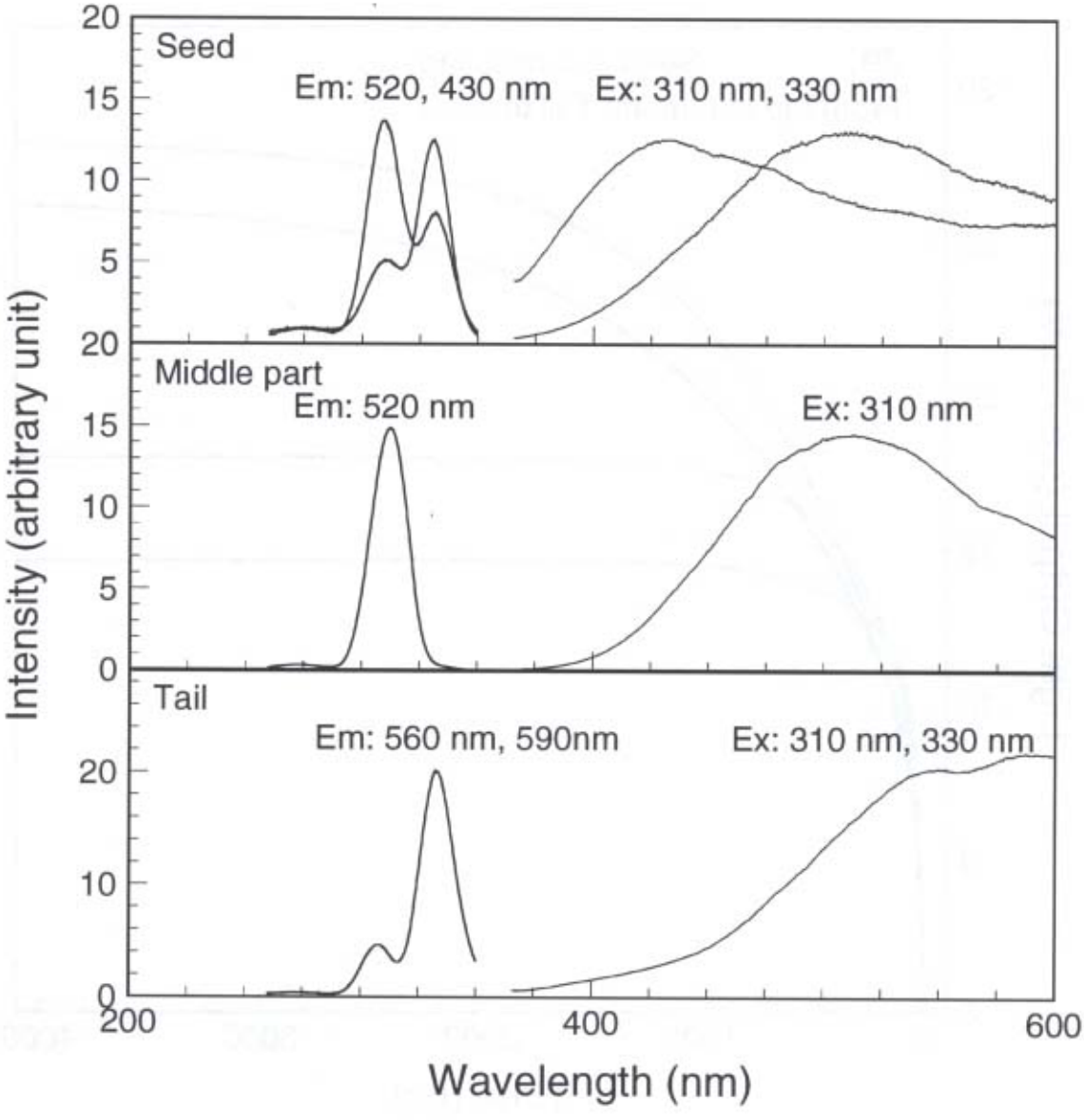
Samples: S762:Y, Z24:A and Z20:B



Longitudinal Uniformity: Photo Luminescence

Measured with HITACHI F-4500 Fluorescence Spectrophotometer

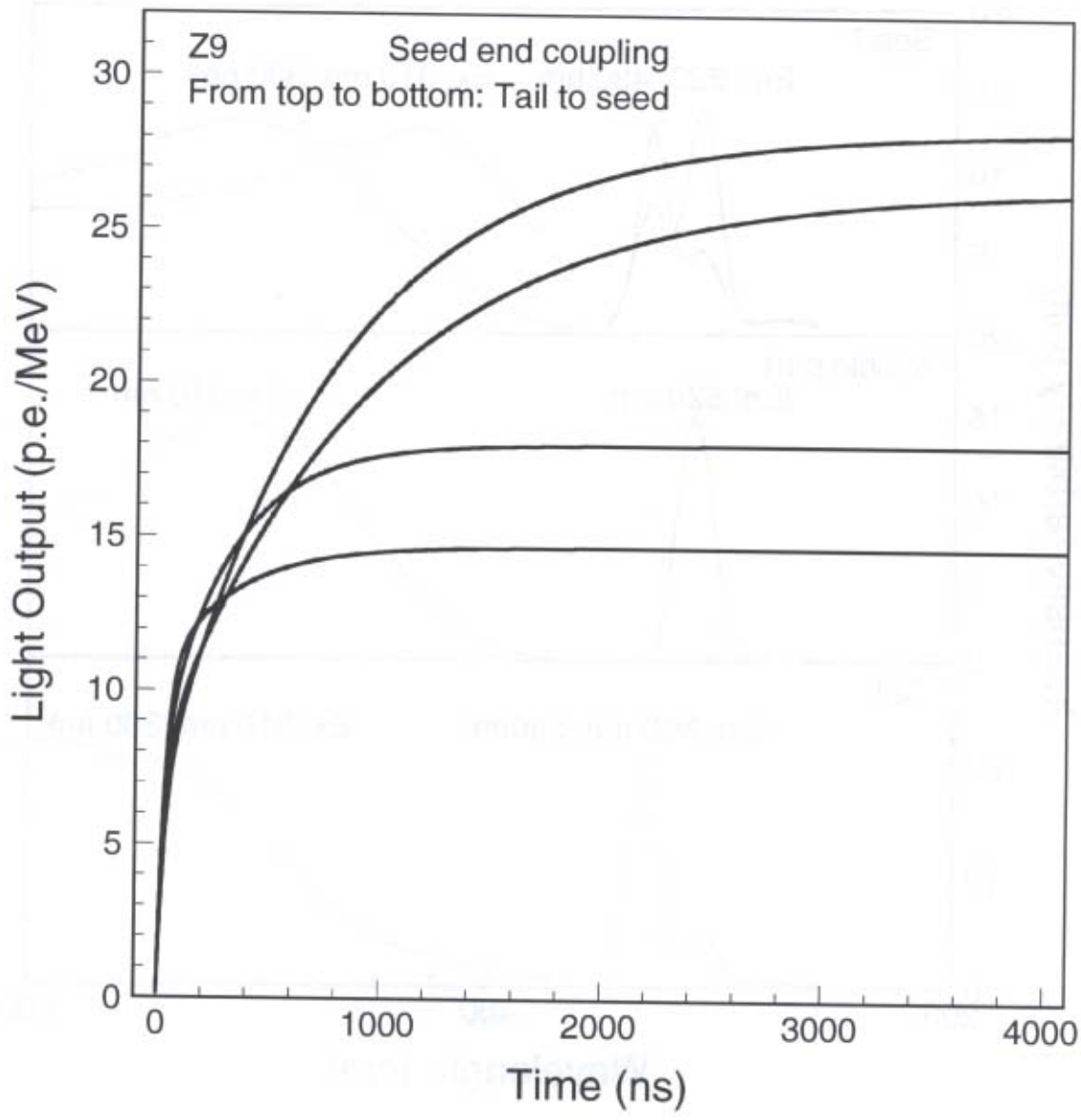
A 20 cm $PbWO_4$ Sample Z9:A



Longitudinal Uniformity: Decay Kinetics

Measured with R2059 PMT

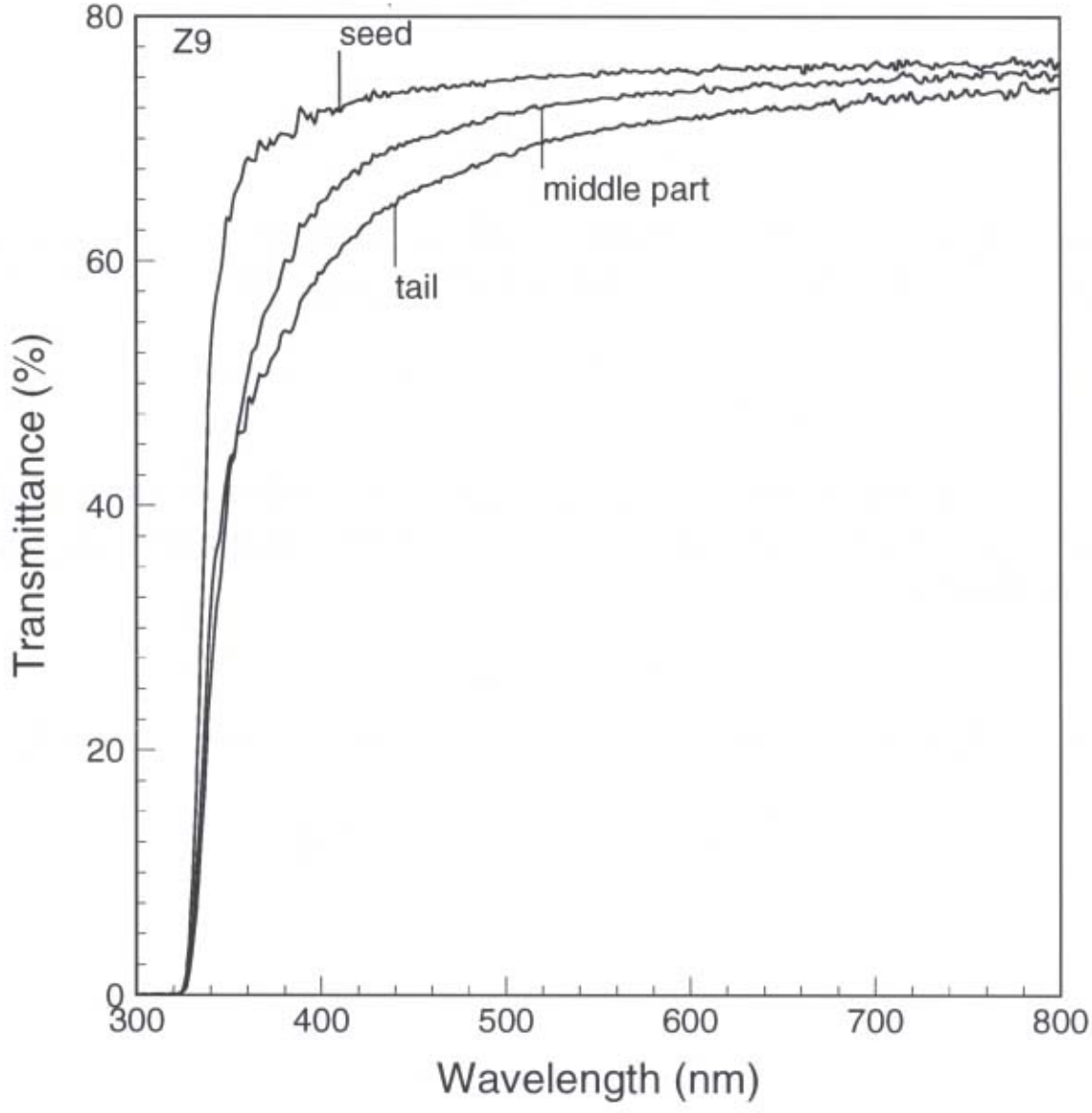
A 20 cm $PbWO_4$ Sample Z9:A



Longitudinal Uniformity: Transverse Trasmittance

Measured with a Hitachi U-3210 Photospectrometer

A 20 cm $PbWO_4$ Sample Z9:A



Segregation Coefficient

$$k_e = \frac{C_{crystal}}{C_{melt}}. \tag{1}$$

Assuming a slow, steady state growth process, the distribution of dopant concentration in crystal can be expressed as

$$C_{crystal}(g) = k_e \frac{C_0 - \int_0^g C_{crystal}(t)dt}{1-g}, \tag{2}$$

where C_0 is the initial dopant concentration in the melt, g is the ratio of the solidification volume to whole melt volume. The solution of Equation 2 is

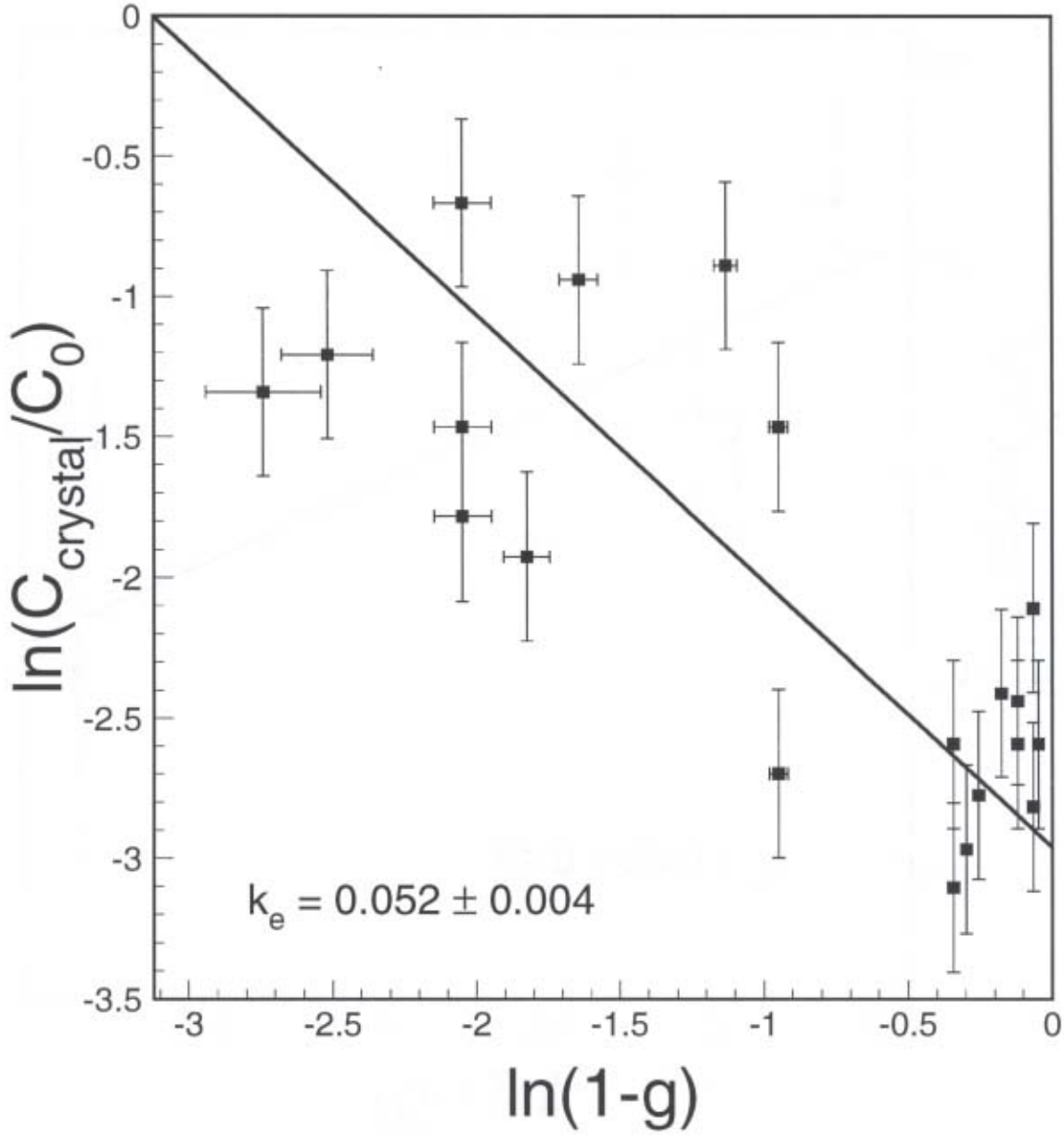
$$C_{crystal} = k_e C_0 (1-g)^{k_e - 1}. \tag{3}$$

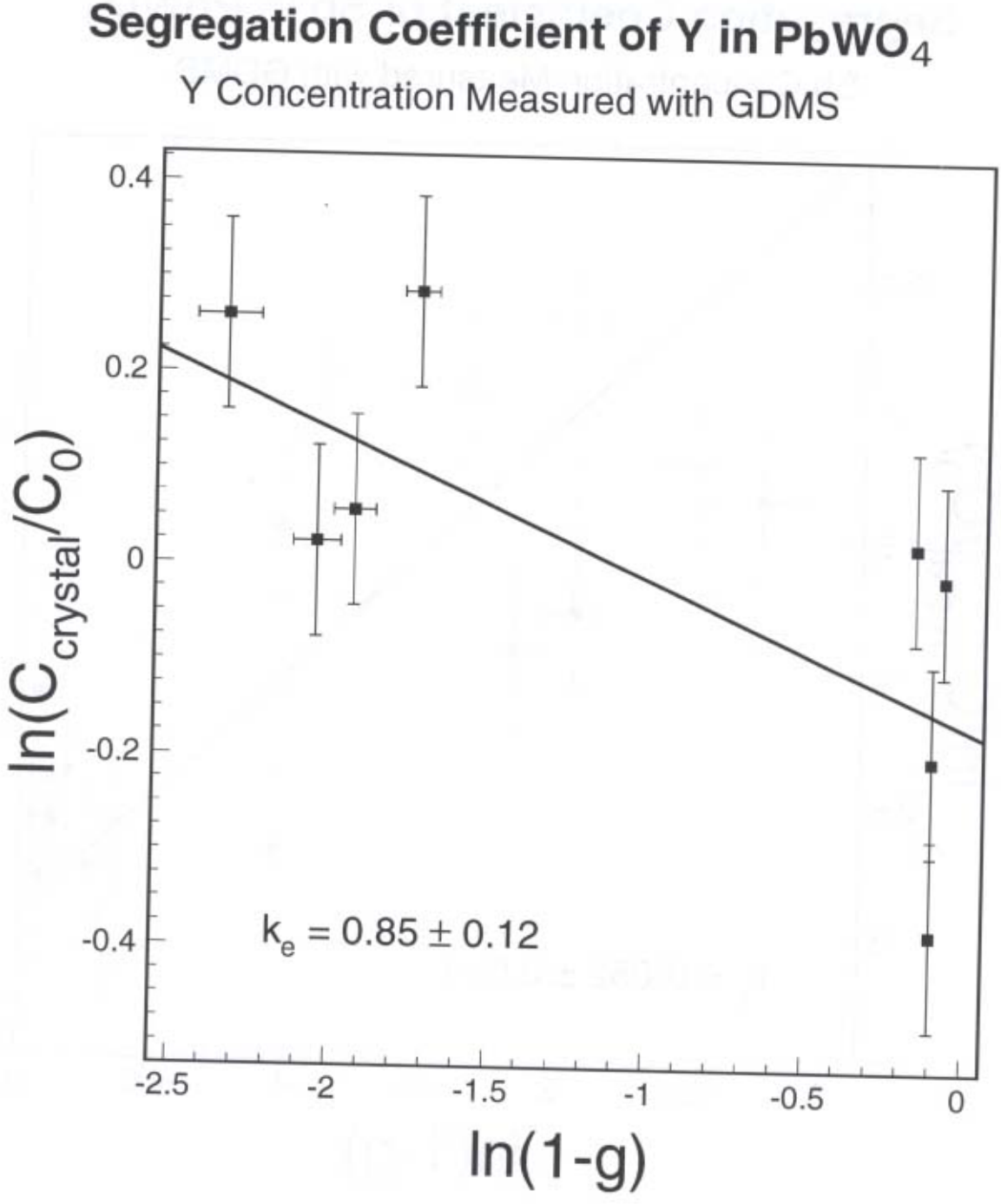
Taking logarithm, Equation 3 can be written as a linear equation:

$$\ln \frac{C_{crystal}}{C_0} = \ln k_e + (k_e - 1)\ln(1-g). \tag{4}$$

Segregation Coefficient of Sb in $PbWO_4$

Sb Concentration Measured with GDMS




Segregation Coefficient of Y in PbWO4
Y Concentration Measured with GDMS
0.4
0.2
0
-0.2
-0.4
ln(Ccrystal/C0)
ke = 0.85 ± 0.12
-2.5
-2
-1.5
-1
-0.5
0
ln(1-g)

Summary

- Two dopants A and B are found to be effective in increasing $PbWO_4$ light output up to 6 folds, mainly in μs decay component, as compared to the standard Y doped CMS sample.

- Both A or B dopping has poor longitudinal uniformity. An approach to double dope A and B might lead to longitudinally uniform crystals since A and B have compensating segregation coefficients.

- These new types of $PbWO_4$ crystals are expected to find applications in high energy and nuclear physics field, but may still fall short for medical applications.