# Measurement of Transmittance, Emission and Light Output for PWO Crystals

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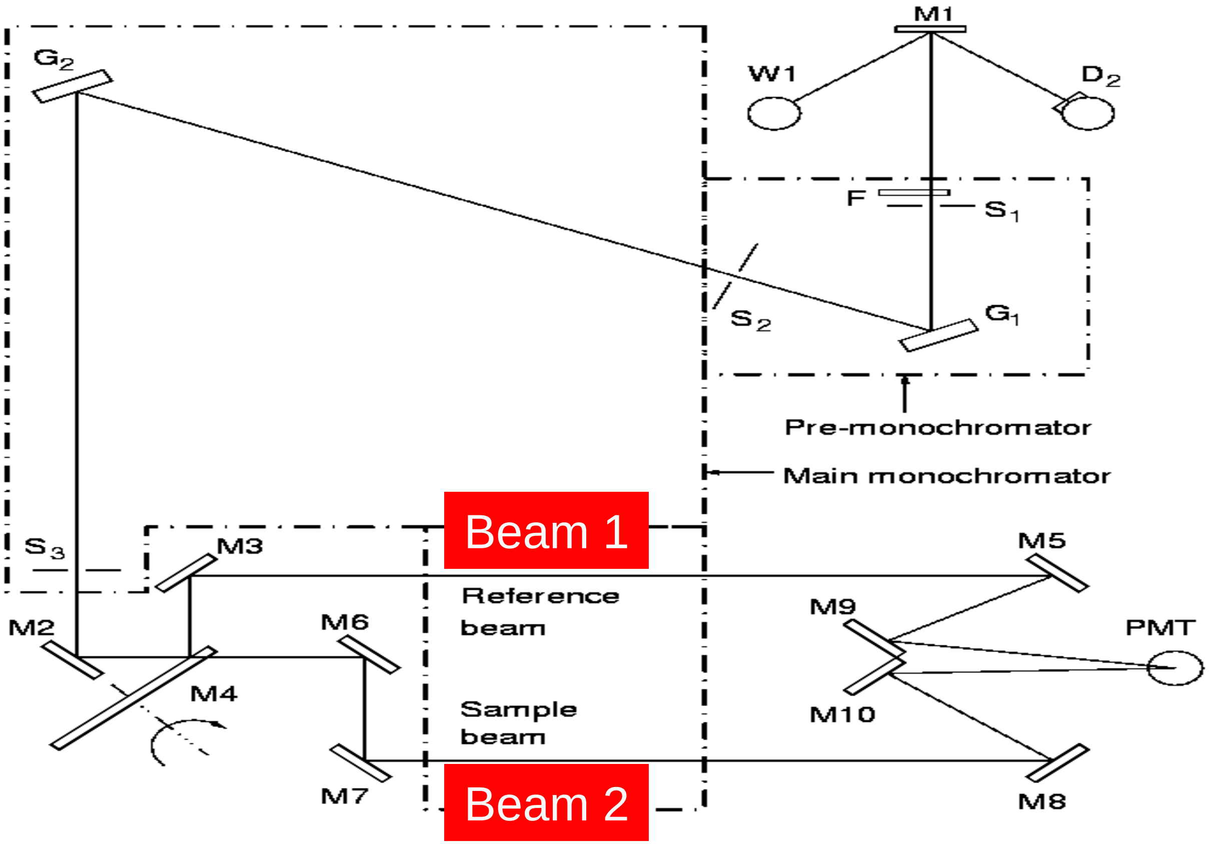
# Introduction

- Recent data shows following concerns on SIC PWO samples: 1) absorption; 2) red emission; 3) emission variation after irradiation; and 4) strange recovery in light output after irradiation.
- Although no new samples received, a series tests were made at Caltech with existing PWO samples to understand these concerns.
- With result presented in this report, we hope to clean up the confusion.
- Unless specified, all samples in this report are produced in 2001 and 2002 by BTCP and SIC respectively.

# Transmittance Measurement

## HITACHI U-3210 UV/VIS Spectrophotometer with a Large Sample Compartment




A simple way for looking absorption bands. No controversy.

Precision of 0.3% can be reached.

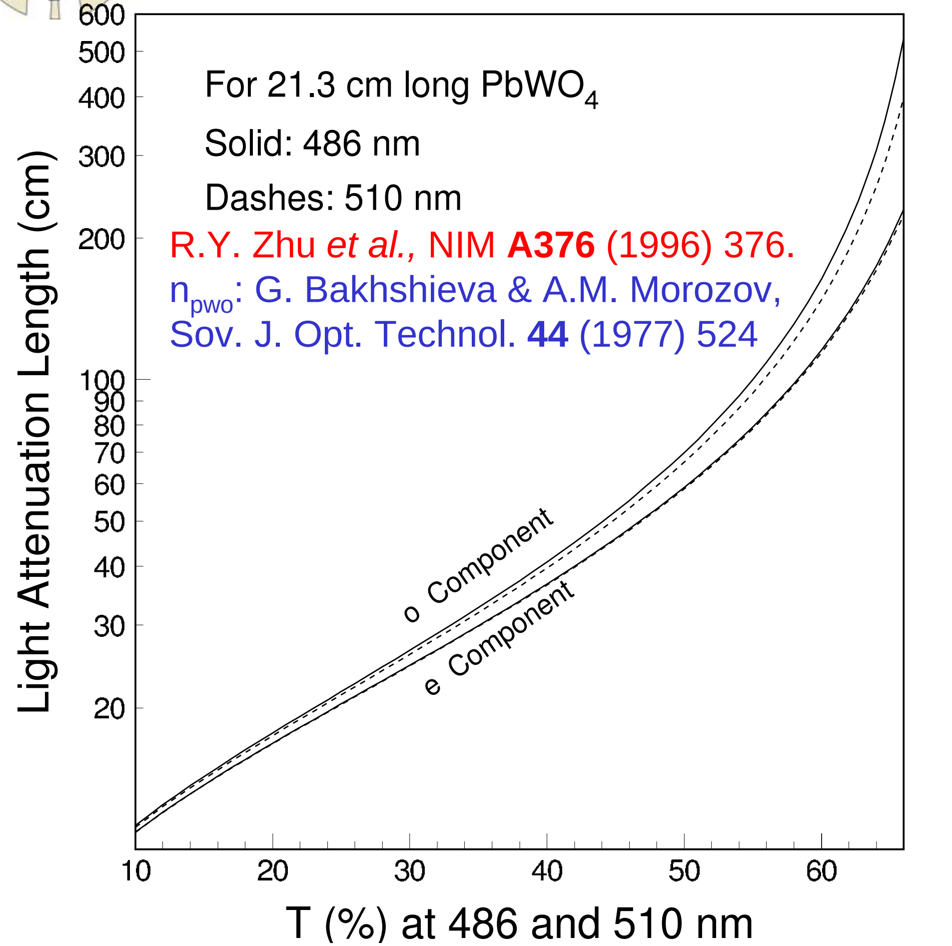
Issue for PWO: birefringence.

$T_s = (1-R)^2 + R^2(1-R)^2 + \ldots = (1-R)/(1+R)$, with

$R = \frac{(n_{crystal} - n_{air})^2}{(n_{crystal} + n_{air})^2}$.

Theoretical limit: D.A. Ma *et al.*, NIM **A333** (1993) 422

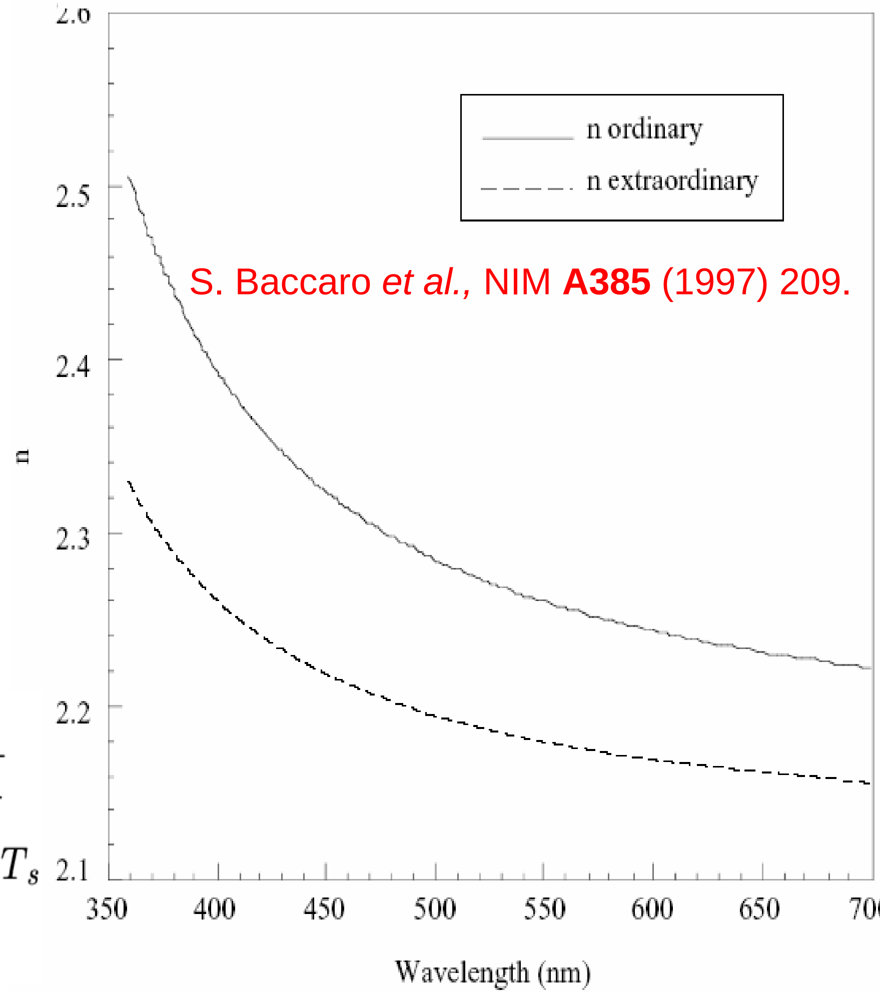
# PWO is Birefringent




$$LAL = \frac{\ell}{\ln\{[T(1-T_s)^2]/[\sqrt{4T_s^4 + T^2(1-T_s^2)^2} - 2T_s^2]\}}$$

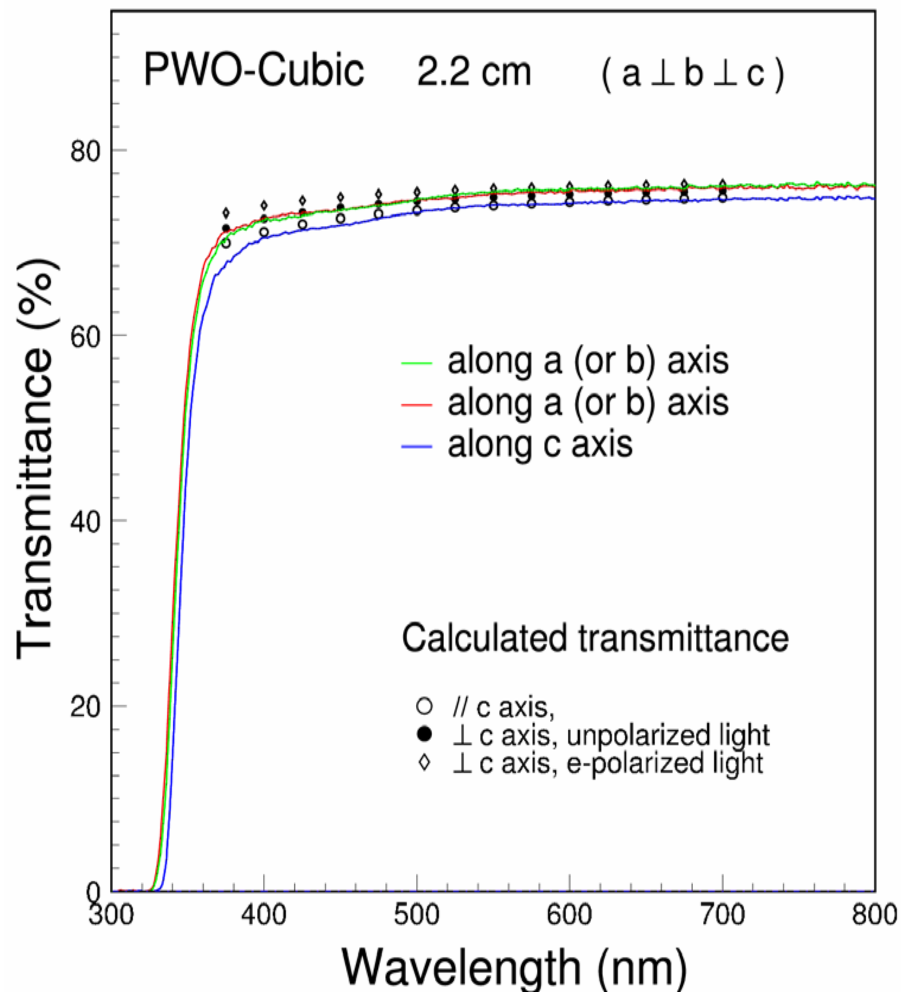
where $T$ is transmittance measured along crystal length $\ell$ and $T_s$ is the theoritical transmittance without internal absorption:
D.A. Ma *et al.*, NIM **A333** (1993) 422

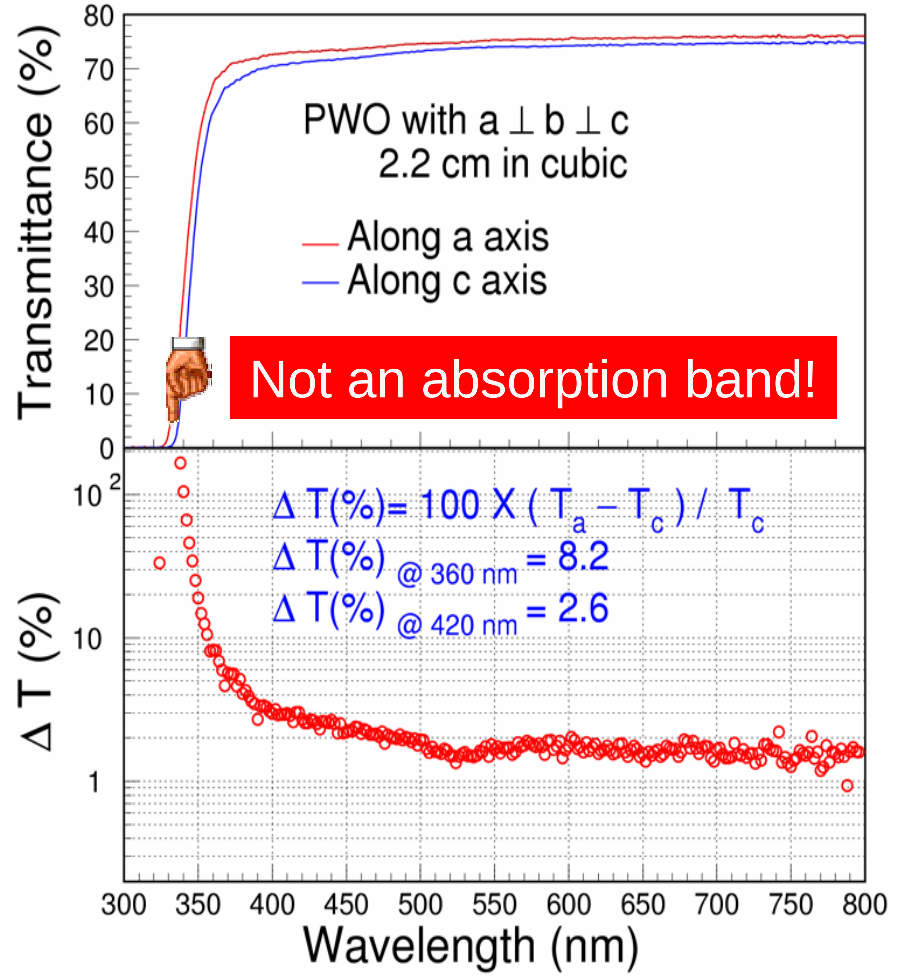
| λ (nm) | $n_o$ | $n_e$ |
|---|---|---|
| 375 | 2.452±0.009 | 2.297±0.025 |
| 400 | 2.393±0.009 | 2.260±0.019 |
| 425 | 2.353±0.009 | 2.236±0.015 |
| 450 | 2.323±0.009 | 2.218±0.013 |
| 475 | 2.301±0.009 | 2.205±0.011 |
| 500 | 2.284±0.009 | 2.194±0.010 |



# Transmittance of a PWO Cube

## Transmittances measured along the *c* and *a* axis are **NOT** directly comparable



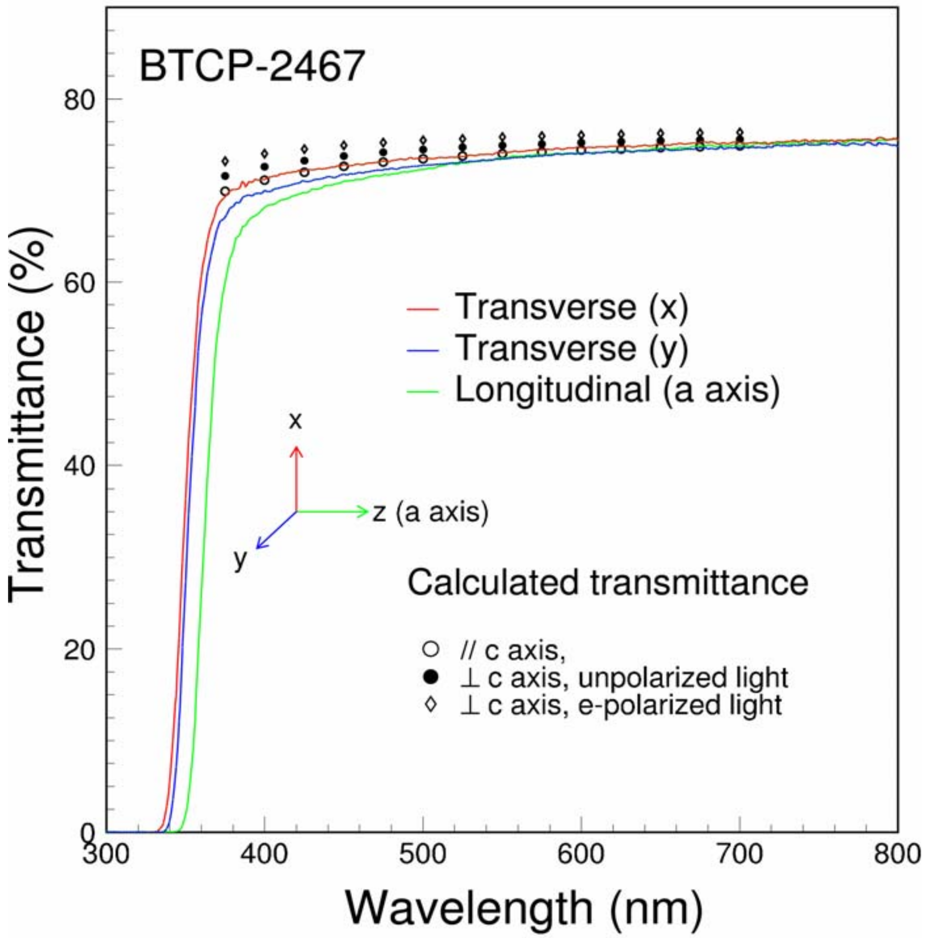



# Transmittance of CMS Samples

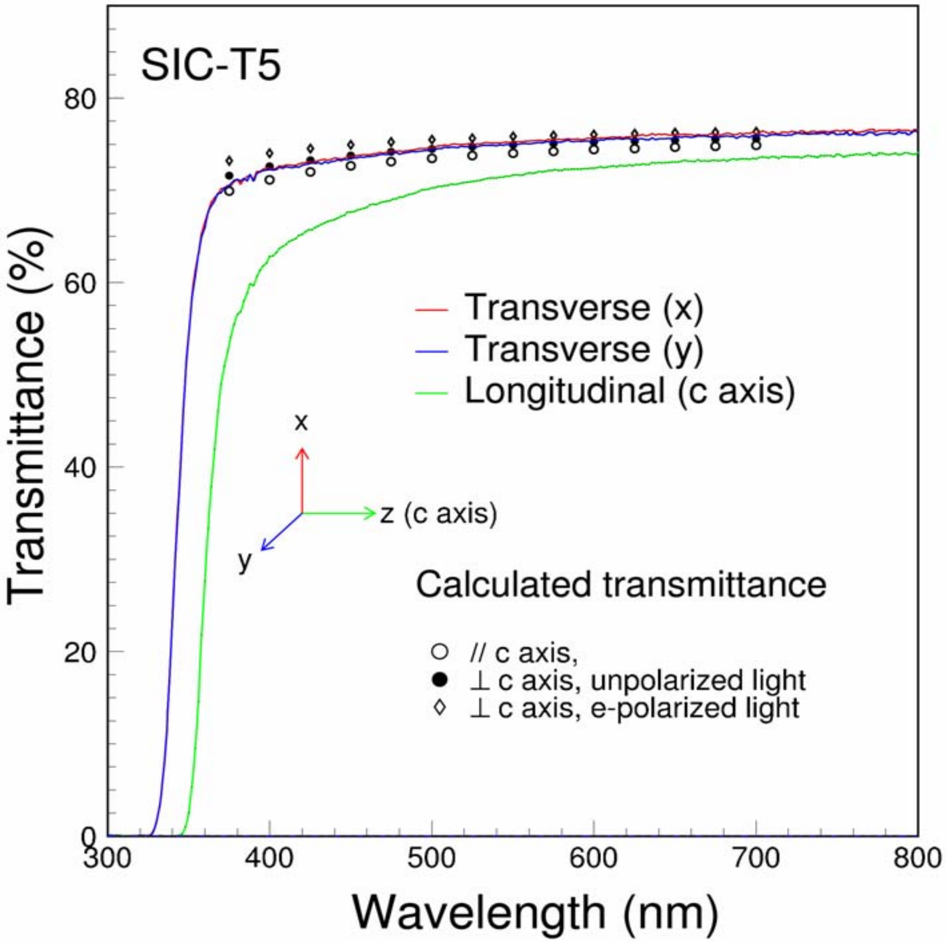
***a axis***: better L.T., but non-isotropic T. T.

Both approaching theoretical limit

BTCP: grown along the ***a axis***




SIC: grown along the ***c axis***

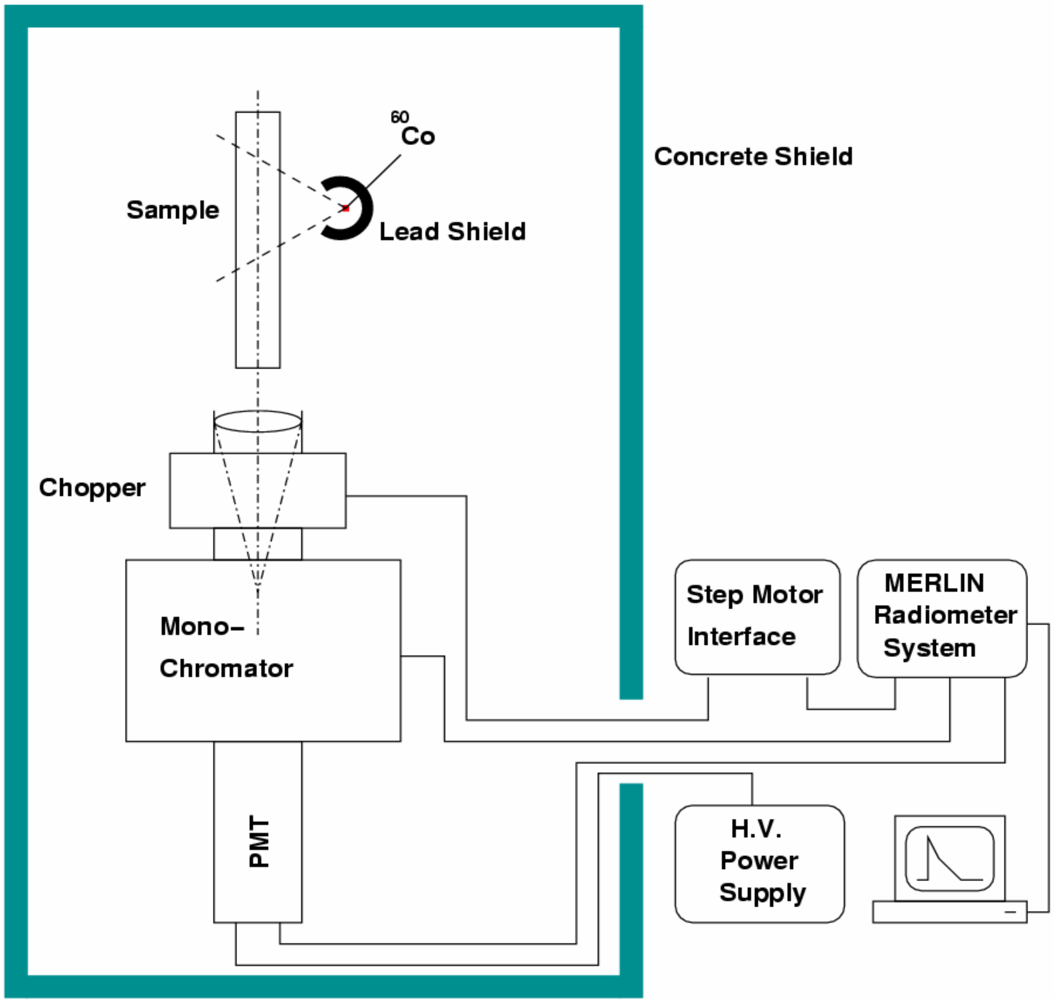


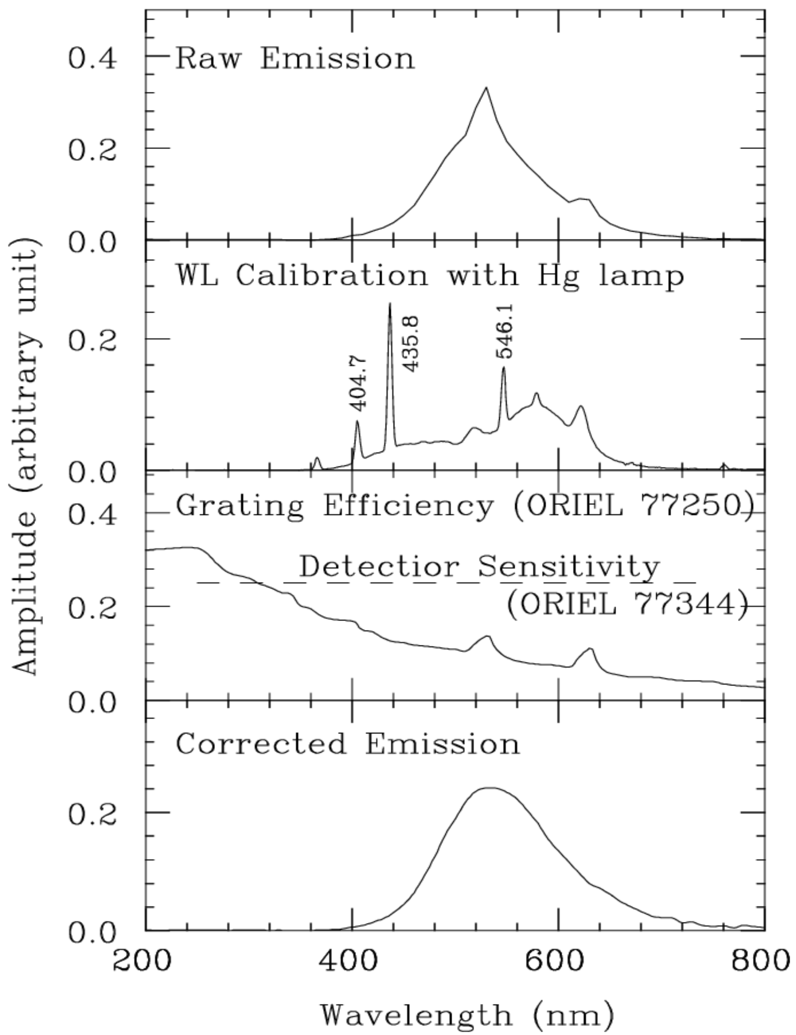
# Radio-Luminescence Measurement

## Issue: Absorption affects emission blue edge

### Corrections: Grating efficiency & PMT (Hamamatsu R758) QE

R.Y. Zhu *et al.*, NIM **A376** (1996) 376



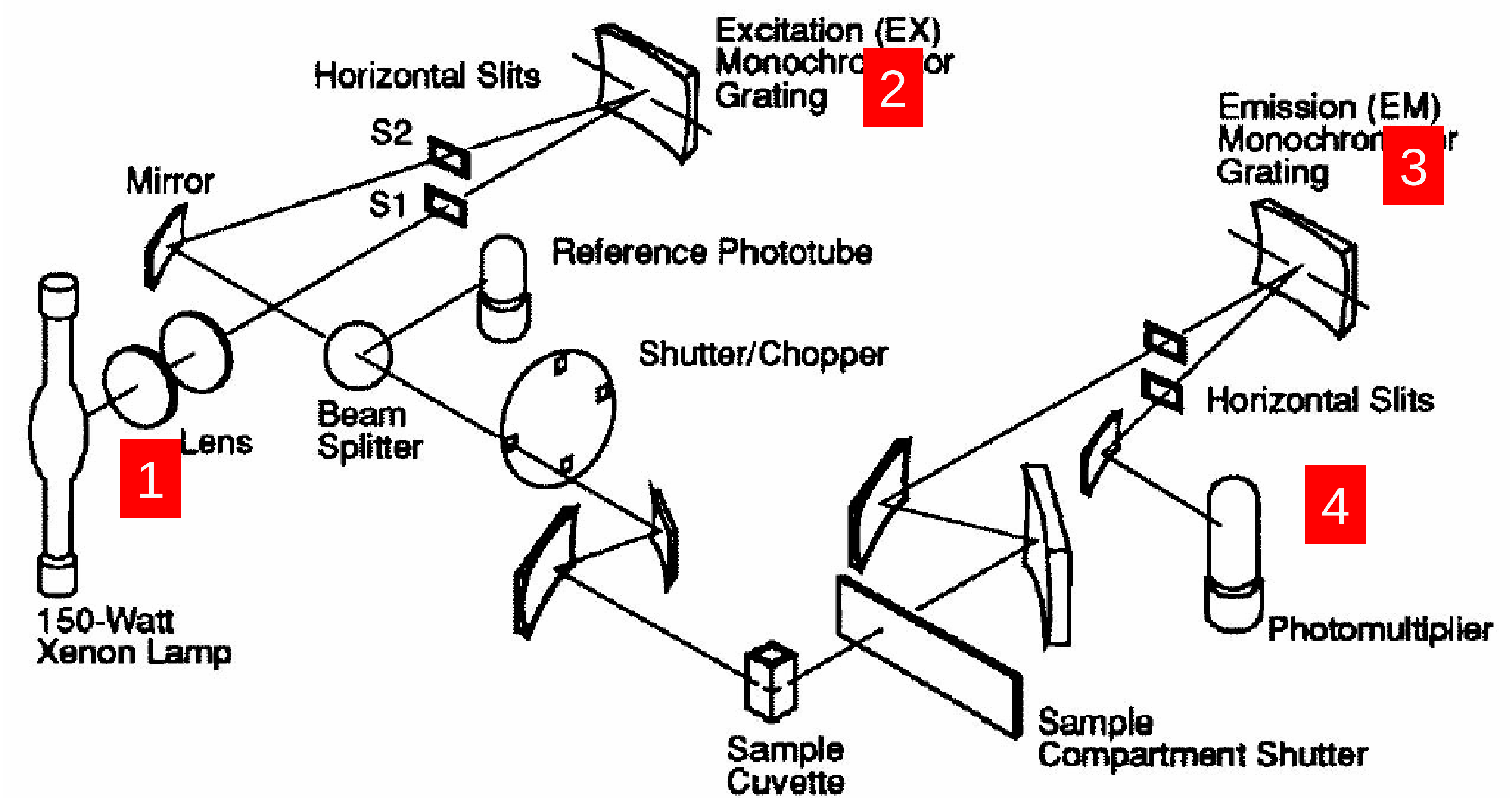



# Photo Luminescence Measurement

## HITACHI F4500 Fluorescence Spectrophotometer

## Light Source (1), Gratings Efficiencies (2 & 3) & PMT QE (4)

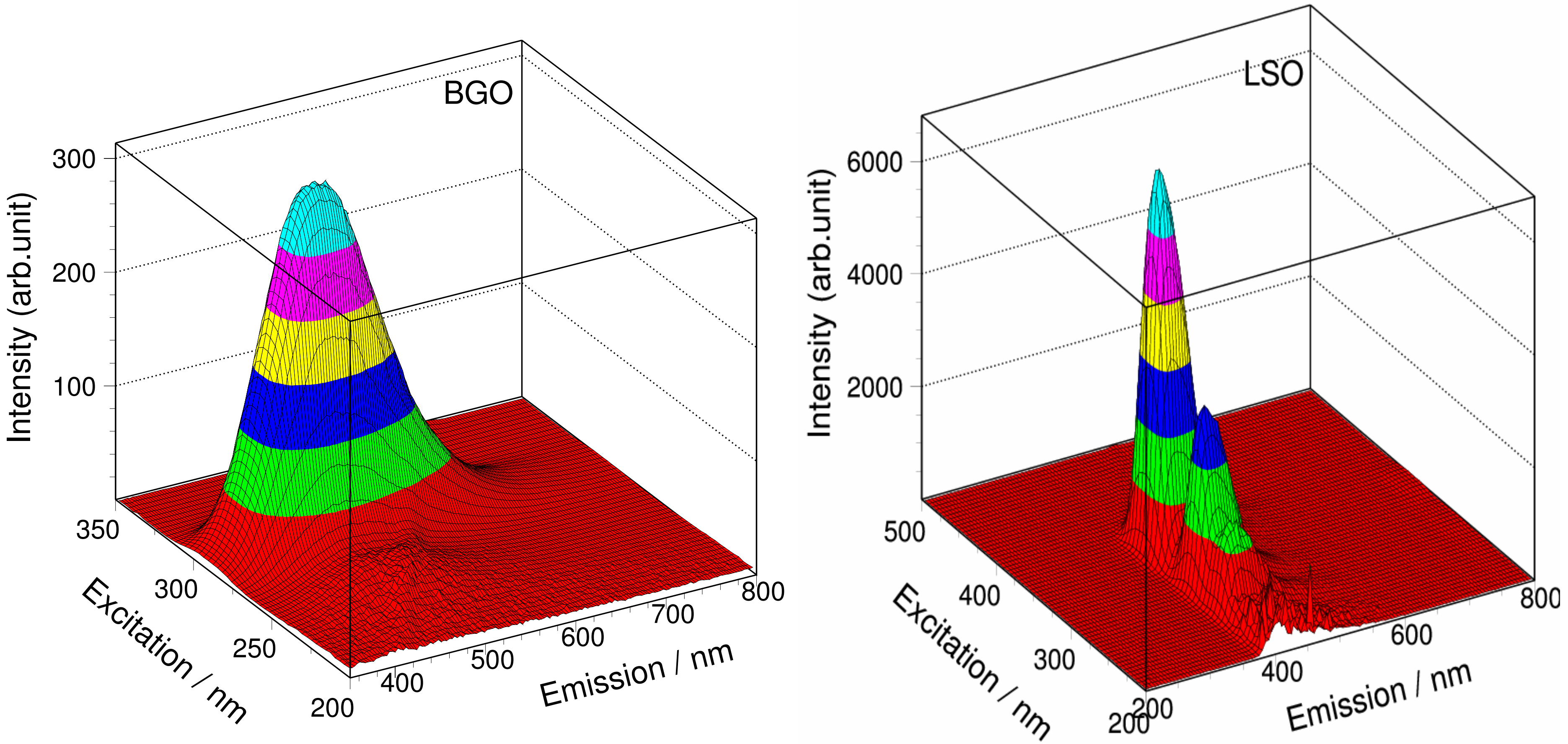
## Red-Extended Hamamatsu R928 PMT(4): 185 to 900 nm



# 3-Dimensional Contour for Emission & Excitation

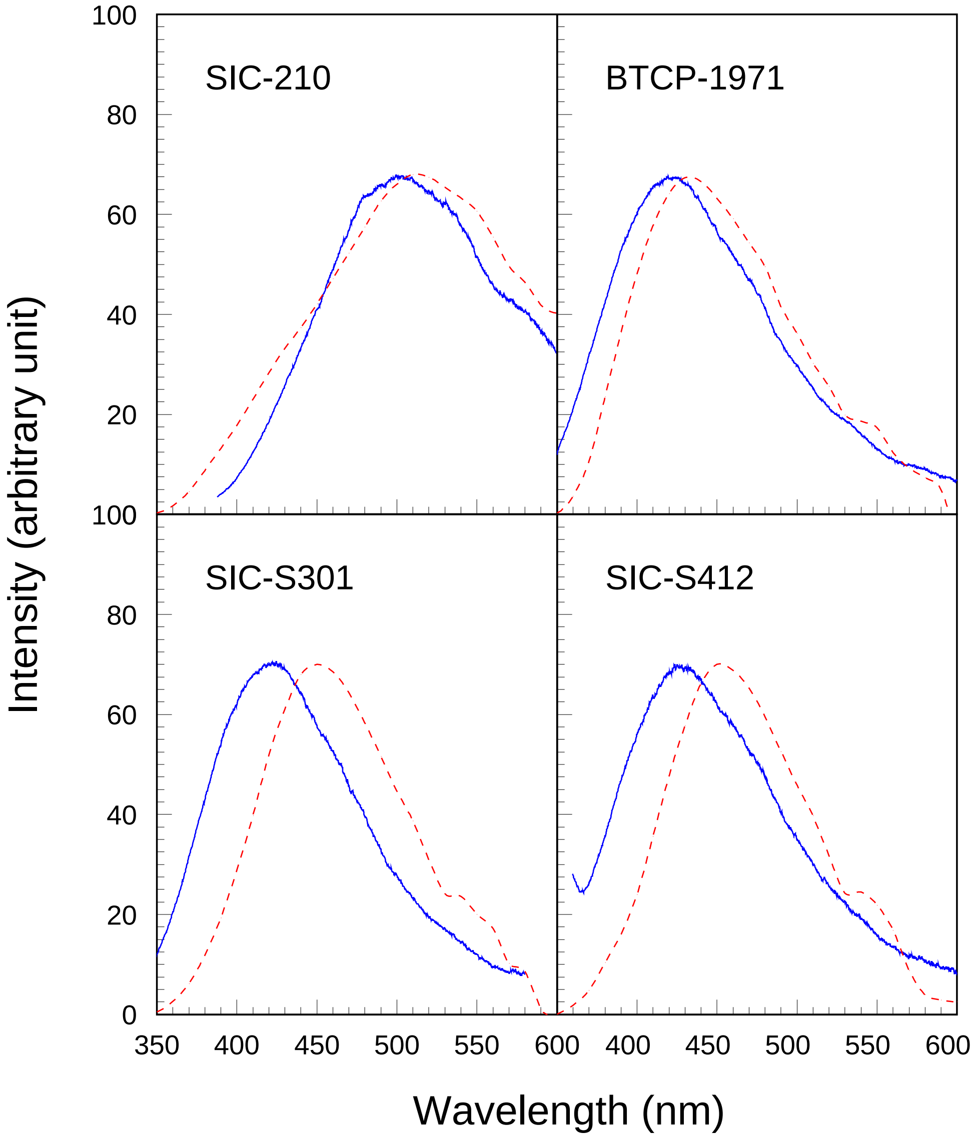
## Measured by using HITACHI F4500

## No controversy for bright scintillators



# Radio & Photo Luminescence

X.D. Qu *et al.*, IEEE Trans. Nucl. Sci. **NS-47** (2000) 1741

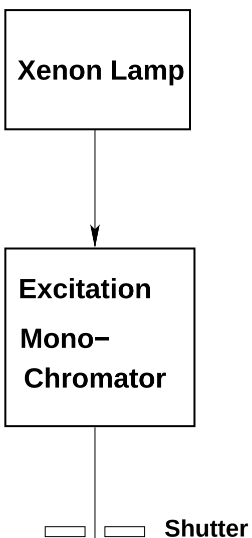



Radio luminescence has a red shift as compared to photo luminescence because of internal absorption.

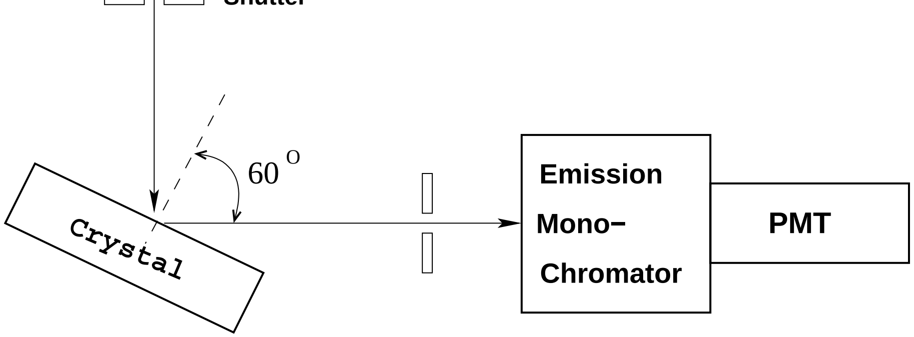
Photo luminescence has a red tail caused by scattering.

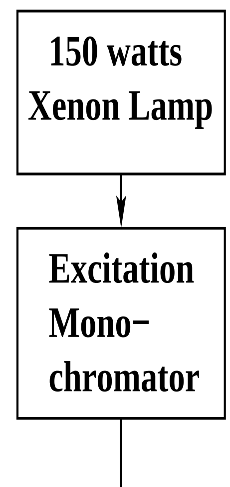
# Photo-luminescence Measurement

Issues: excitation light and its scattering light may pass emission grating at multiple wavelength, causing artificial peaks at red for PWO.

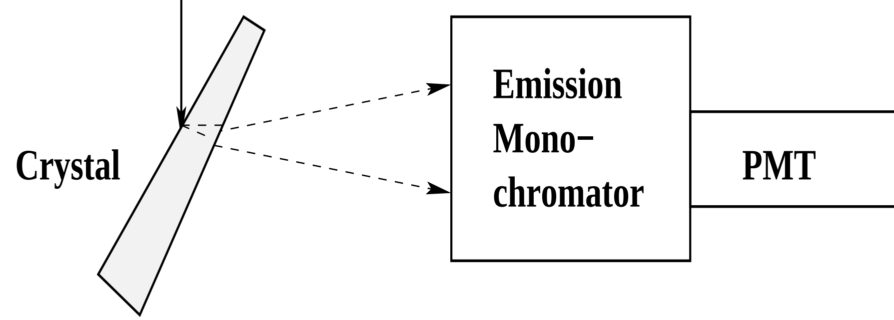



Forward surface excitation:
No absorption, but watch out scattering.
Not good for emission at red.



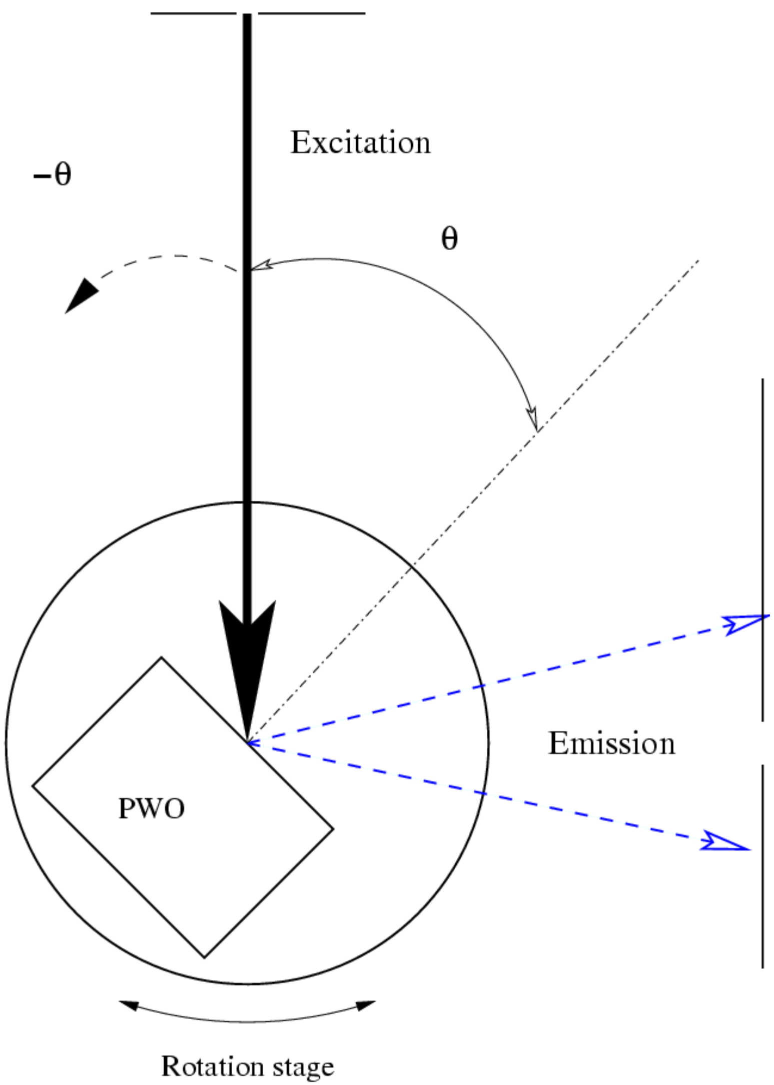



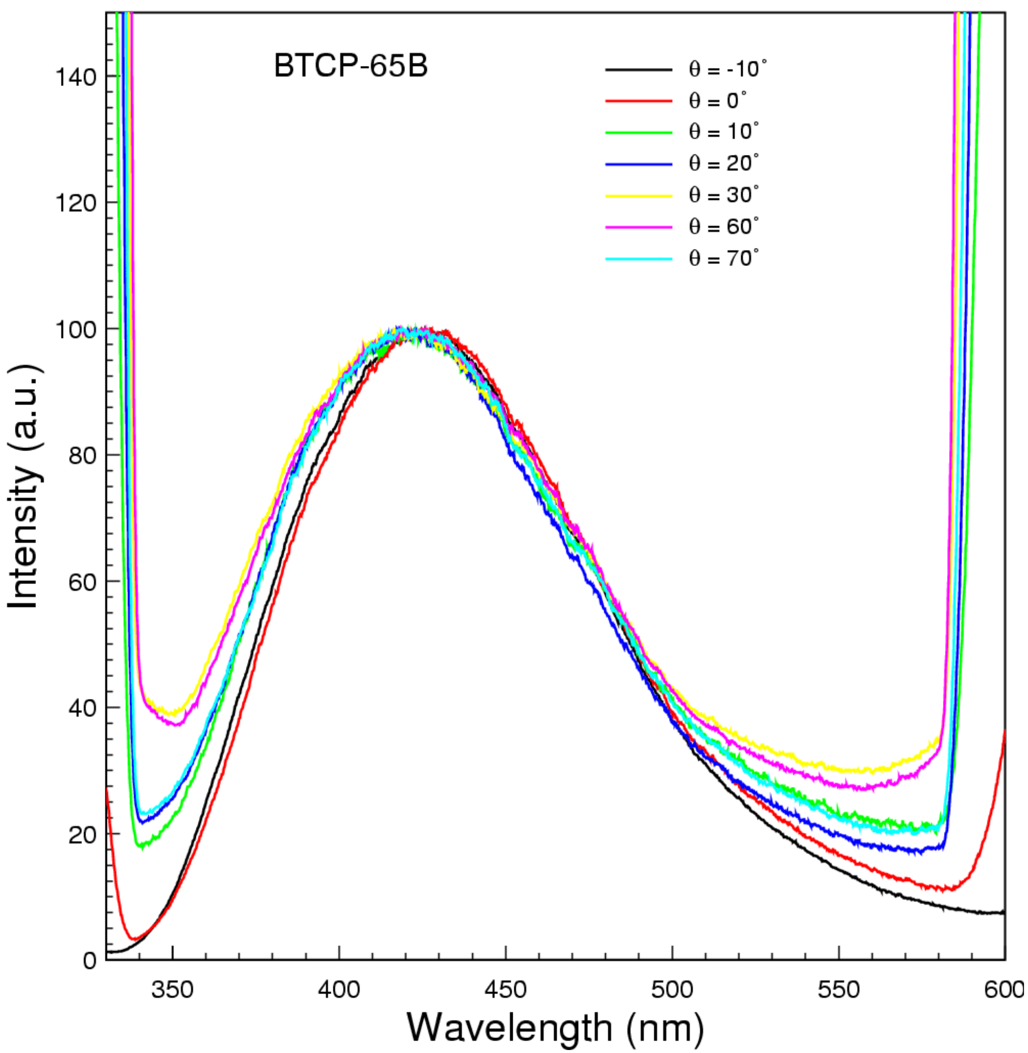

Backward surface excitation: No scattering, but with some absorption.
Not good for emission at blue.



# Scattering & Incident Angle

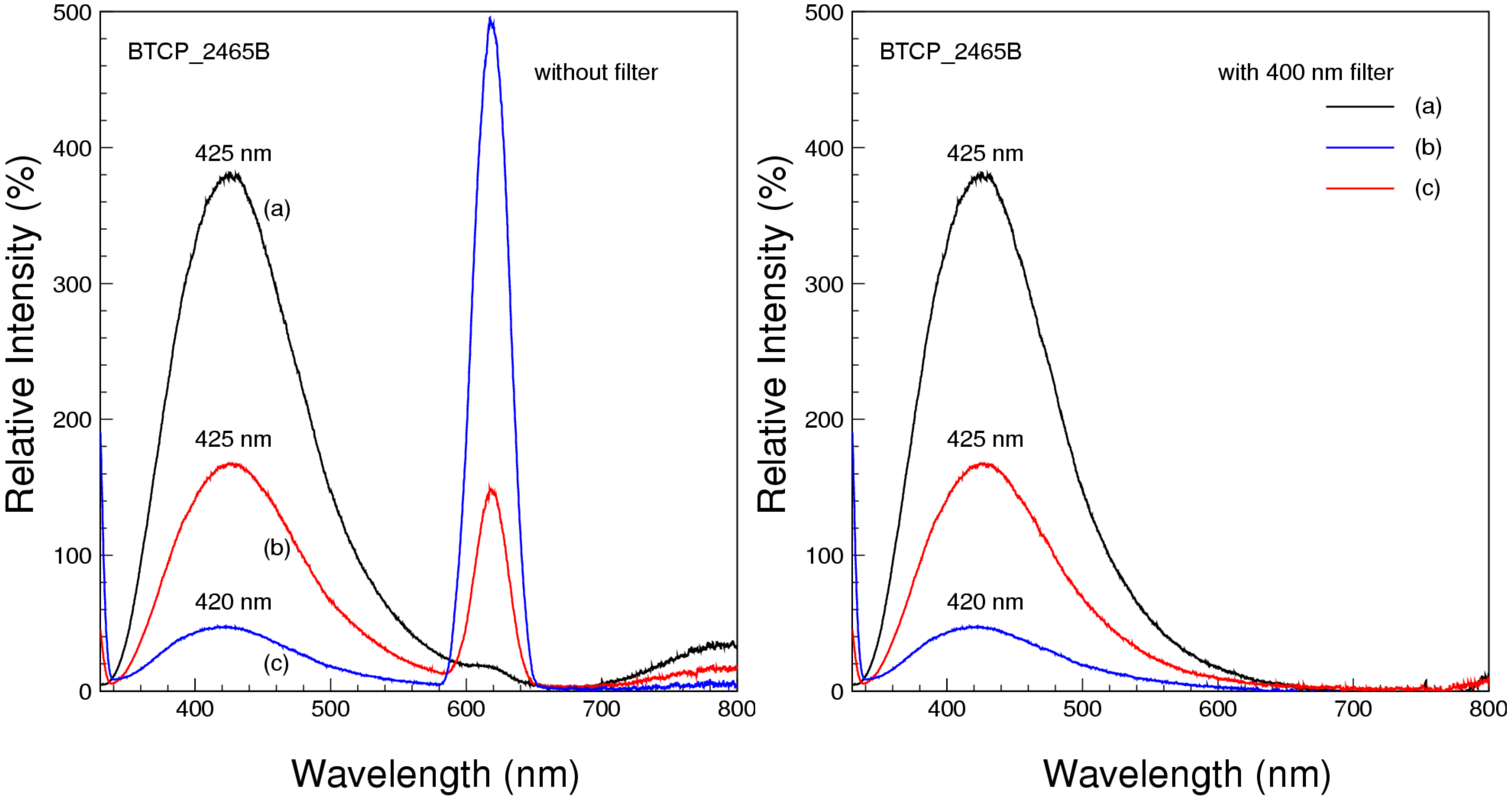
## Backward surface excitation reduces scattering



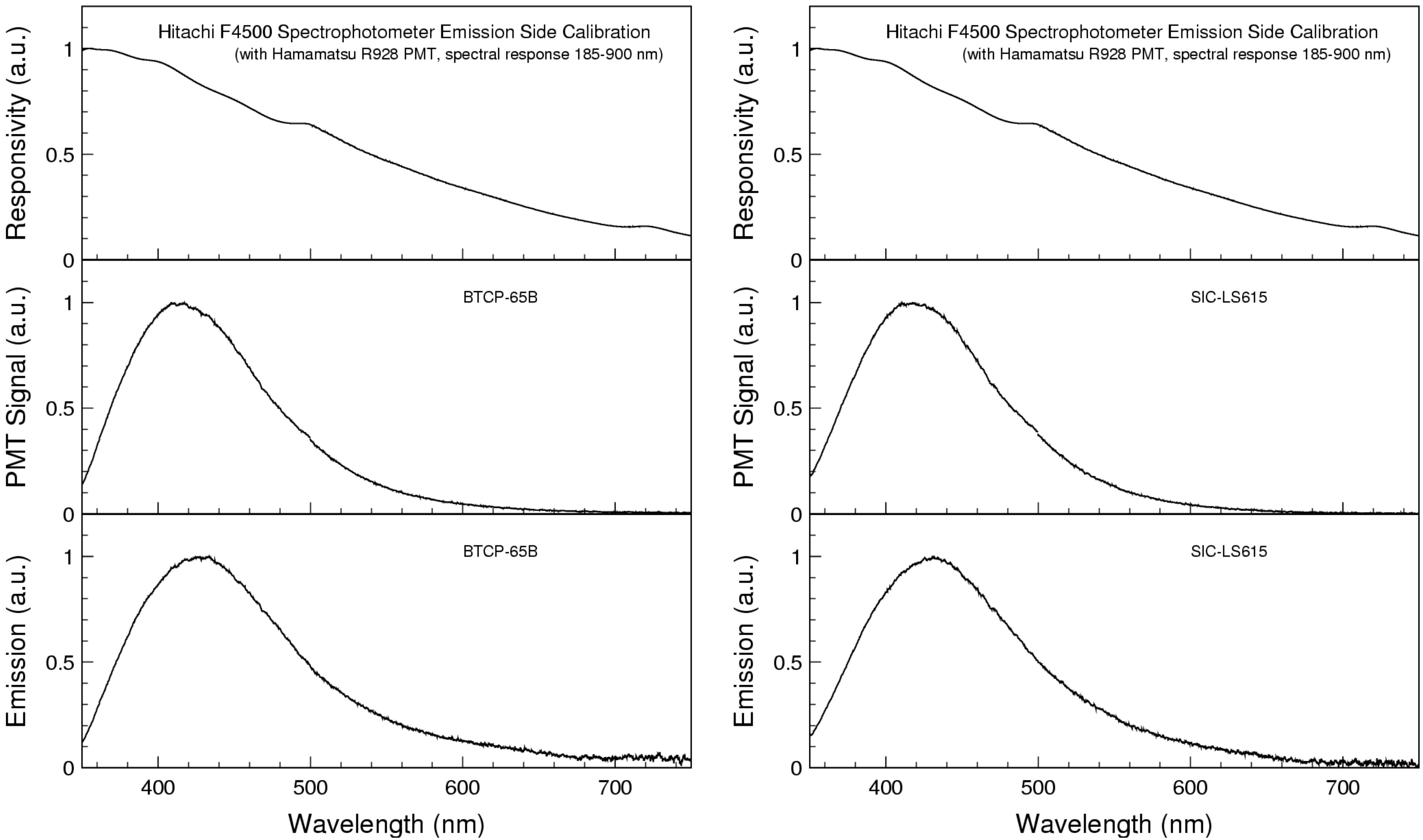
# Red Peak May Caused by Scattering

## A low pass filter may eliminate scattering



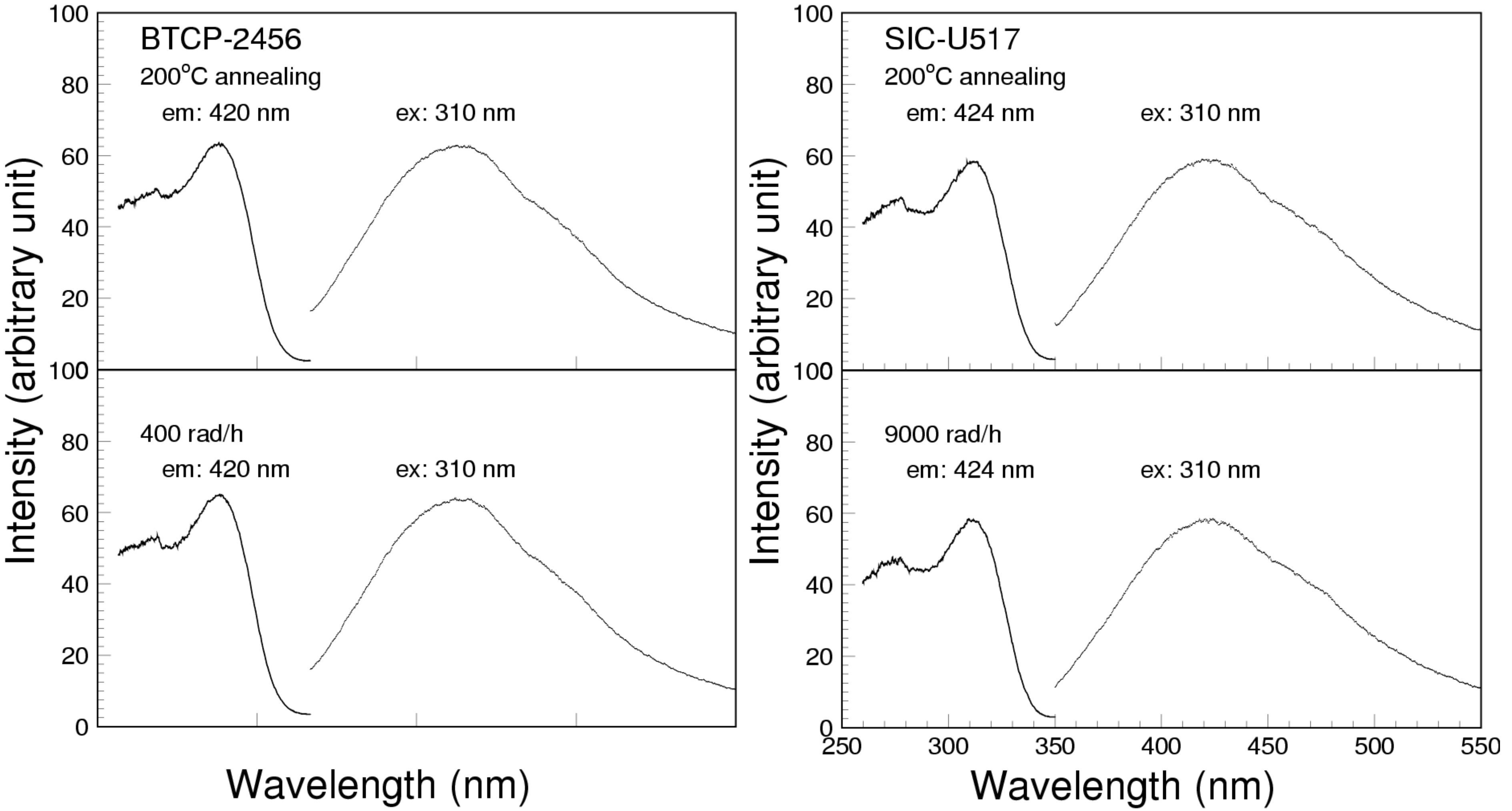
# Full Wavelength: 350 to 800 nm

## No red emission observed in BTCP & SIC samples



# Photo Luminescence (350-550 nm)

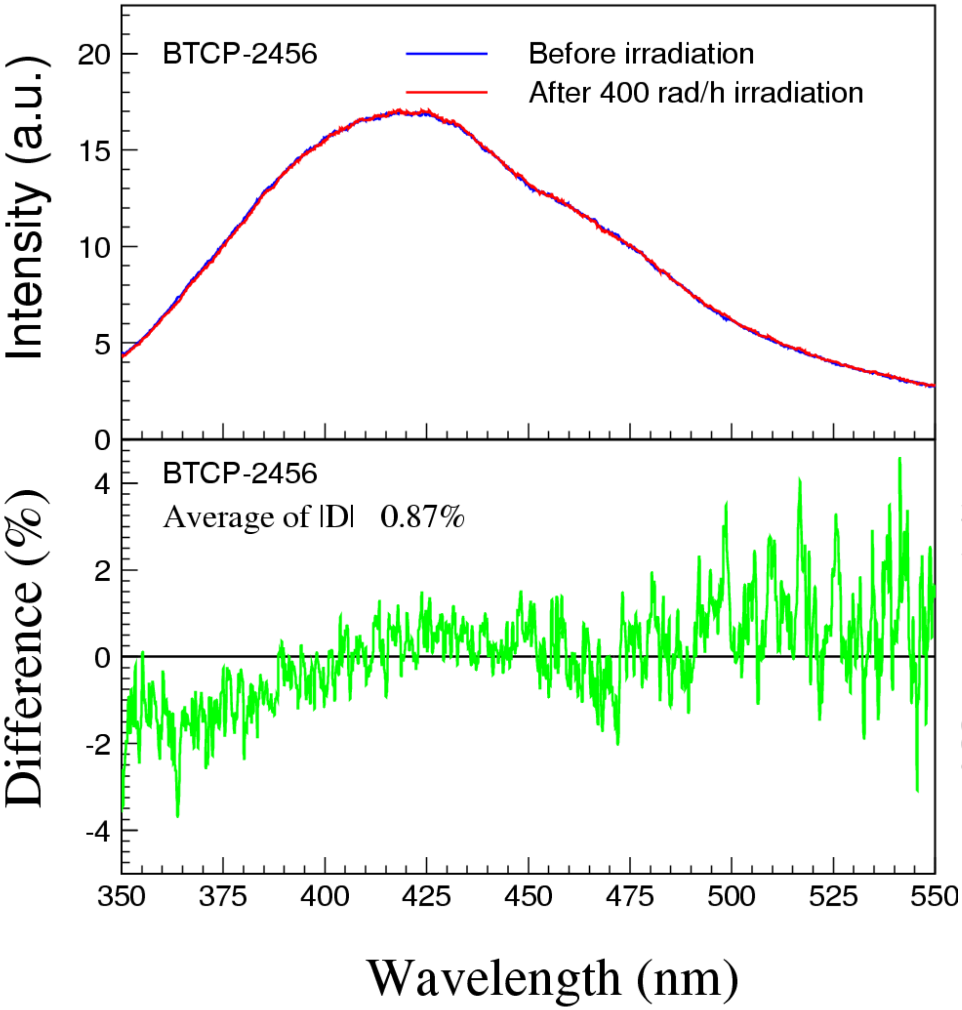
No variation in either excitation or emission spectrum
No damage in scintillation mechanism

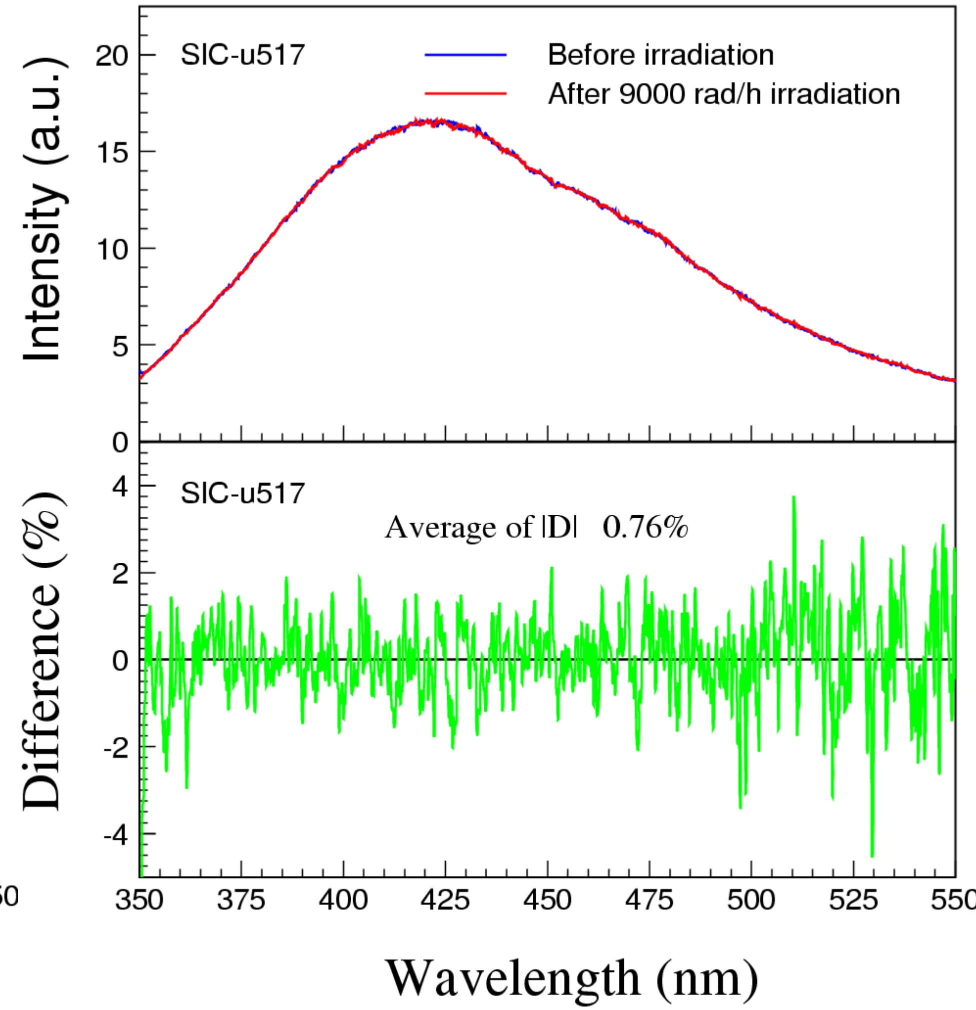


# Photo Luminescence (350-550 nm)

## Difference bin by bin in % with area normarization

## Systematic Uncertainties: 1%

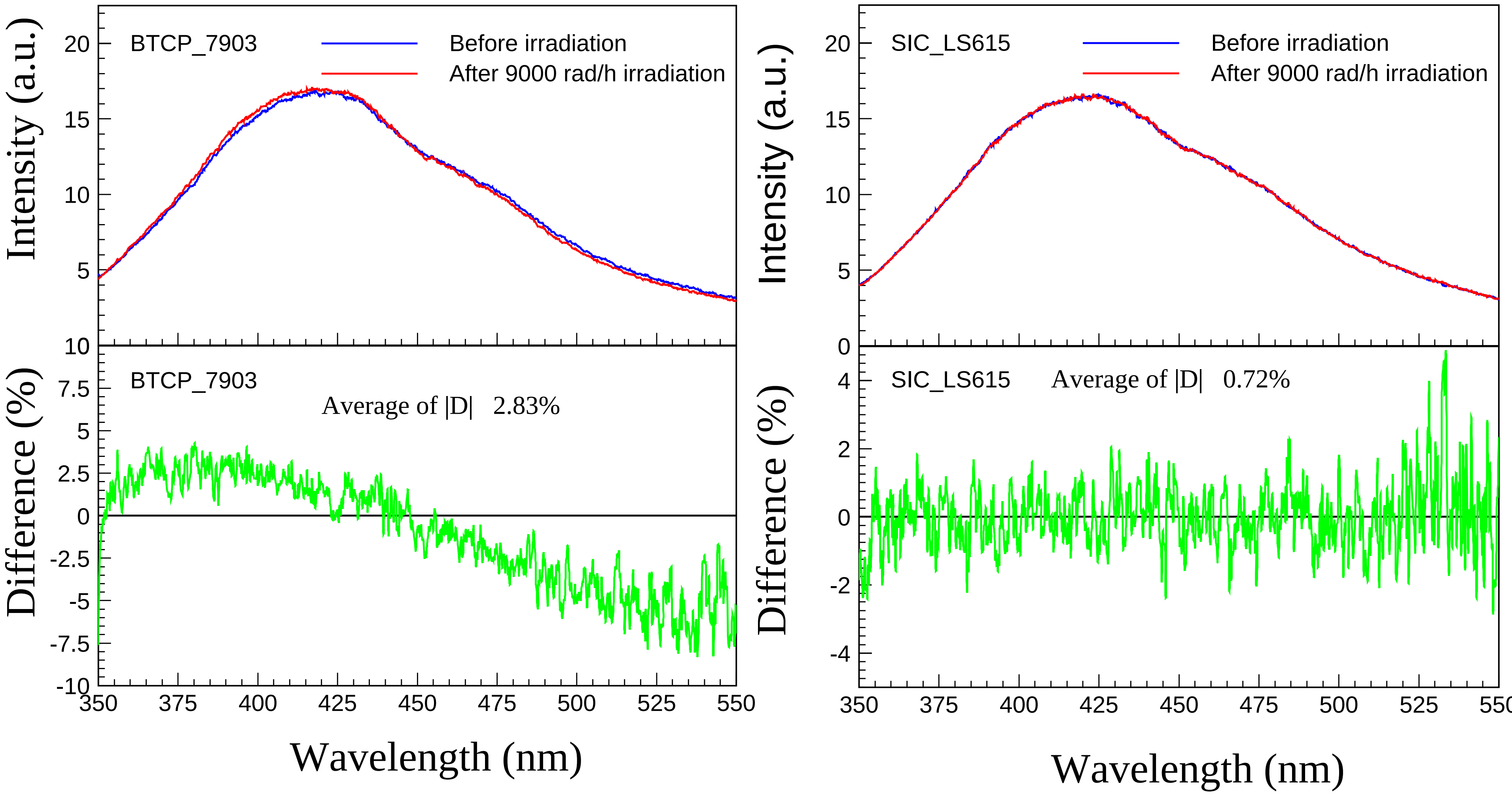


# Photo Luminescence

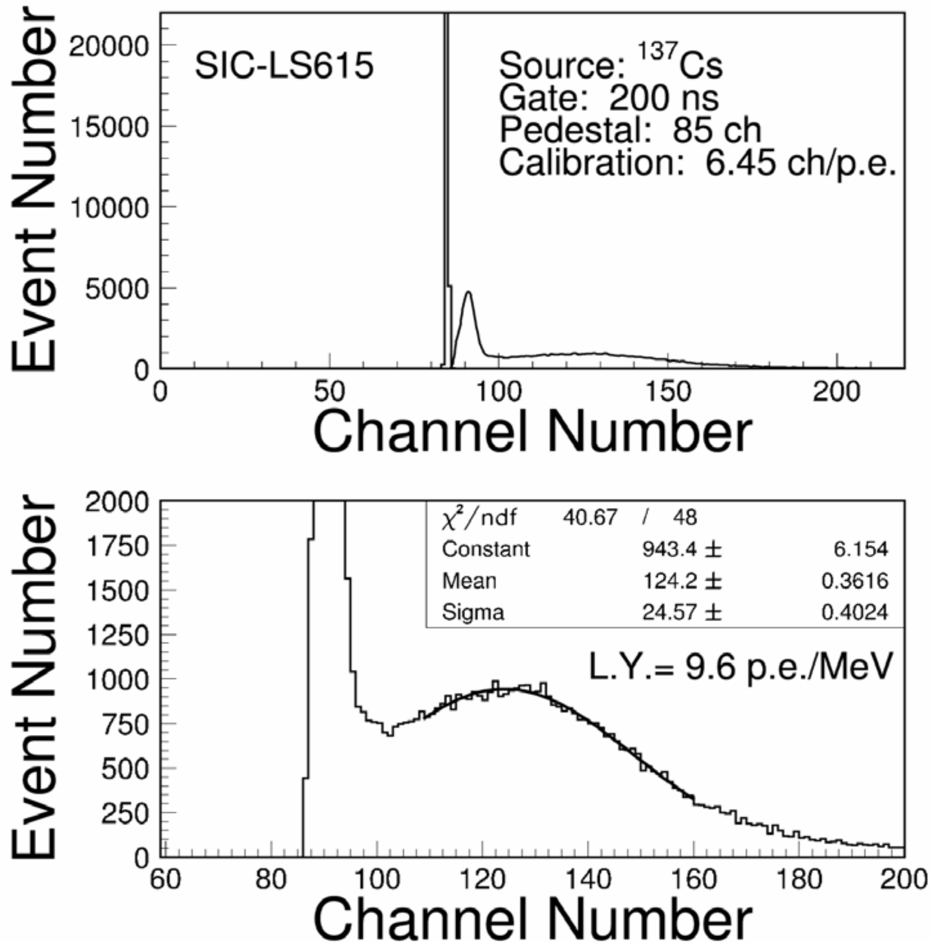
## Difference bin by bin in % with area normarization

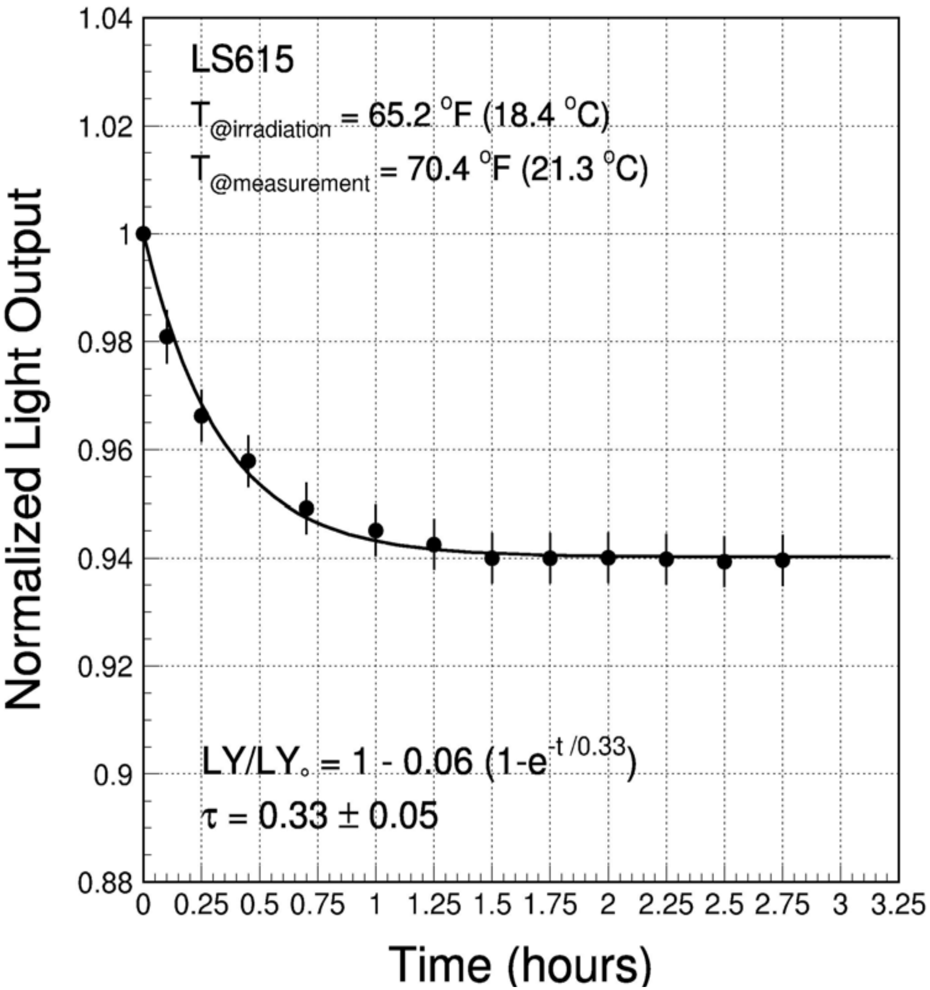
## Systematic Uncertainties: 2%



# Light Output Measurement

Corrections must be implemented for time of less than one hour after irradiation if there is temperature change.

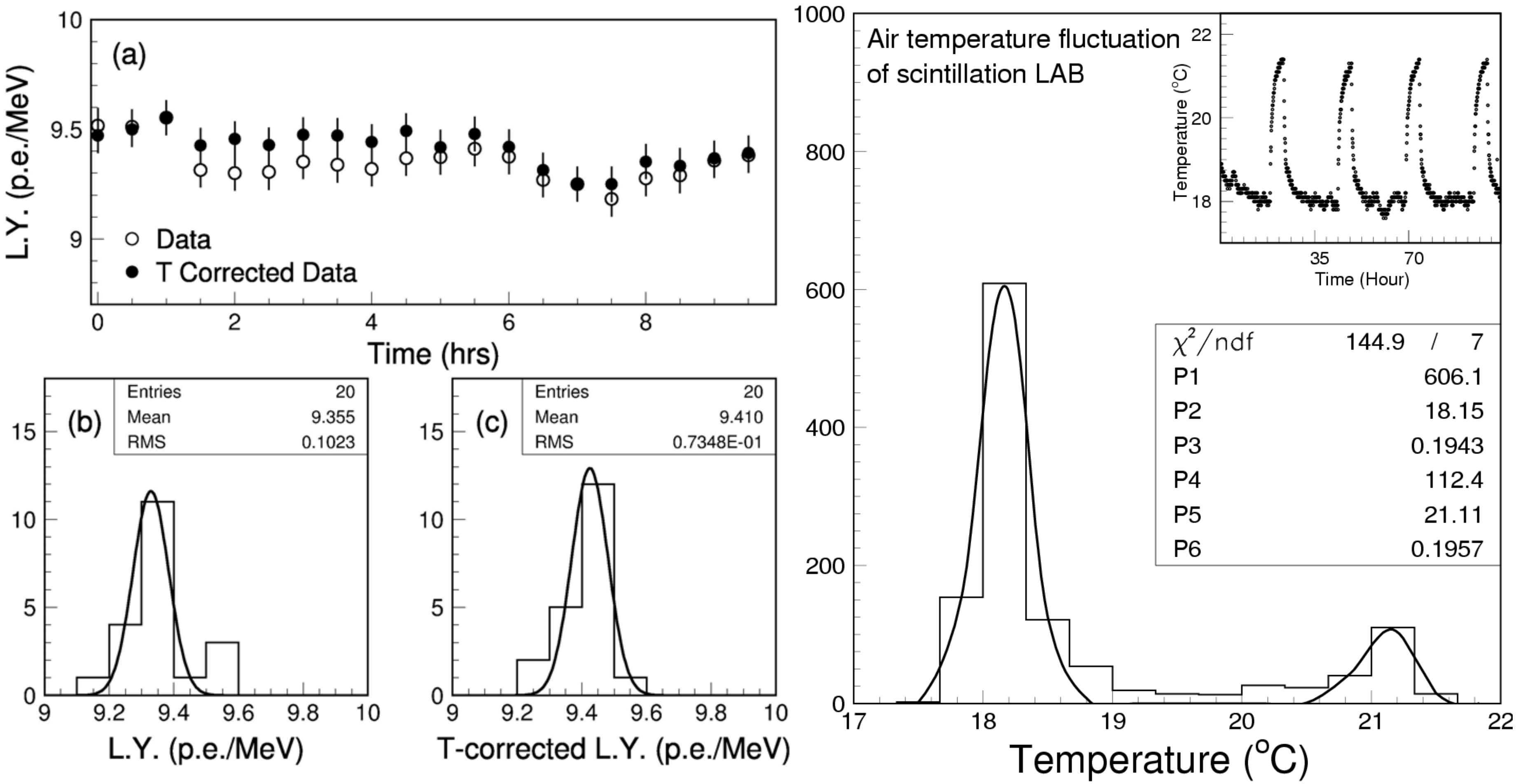


# Systematic Uncertainty: 1%

## With stringent control and temperature corrections

L.Y. Zhang *et al.,* IEEE Trans. Nucl. Sci. **NS-48** (2001) 372



# Summary

- 3 issues may cause confusion in laboratory characterization for PWO crystals:
  - Birefringence affects transmittance, photo luminescence and light output;
  - Dim scintillation light affects photo luminescence and light output;
  - Temperature dependent scintillation affects light output.

- With stringent and careful control systematic uncertainties can be reduced to 0.3%, 1% and 1%  for transmittance, emission and light output measurement respectively.