# Search for Scintillation in Doped Lead Fluoride Crystals

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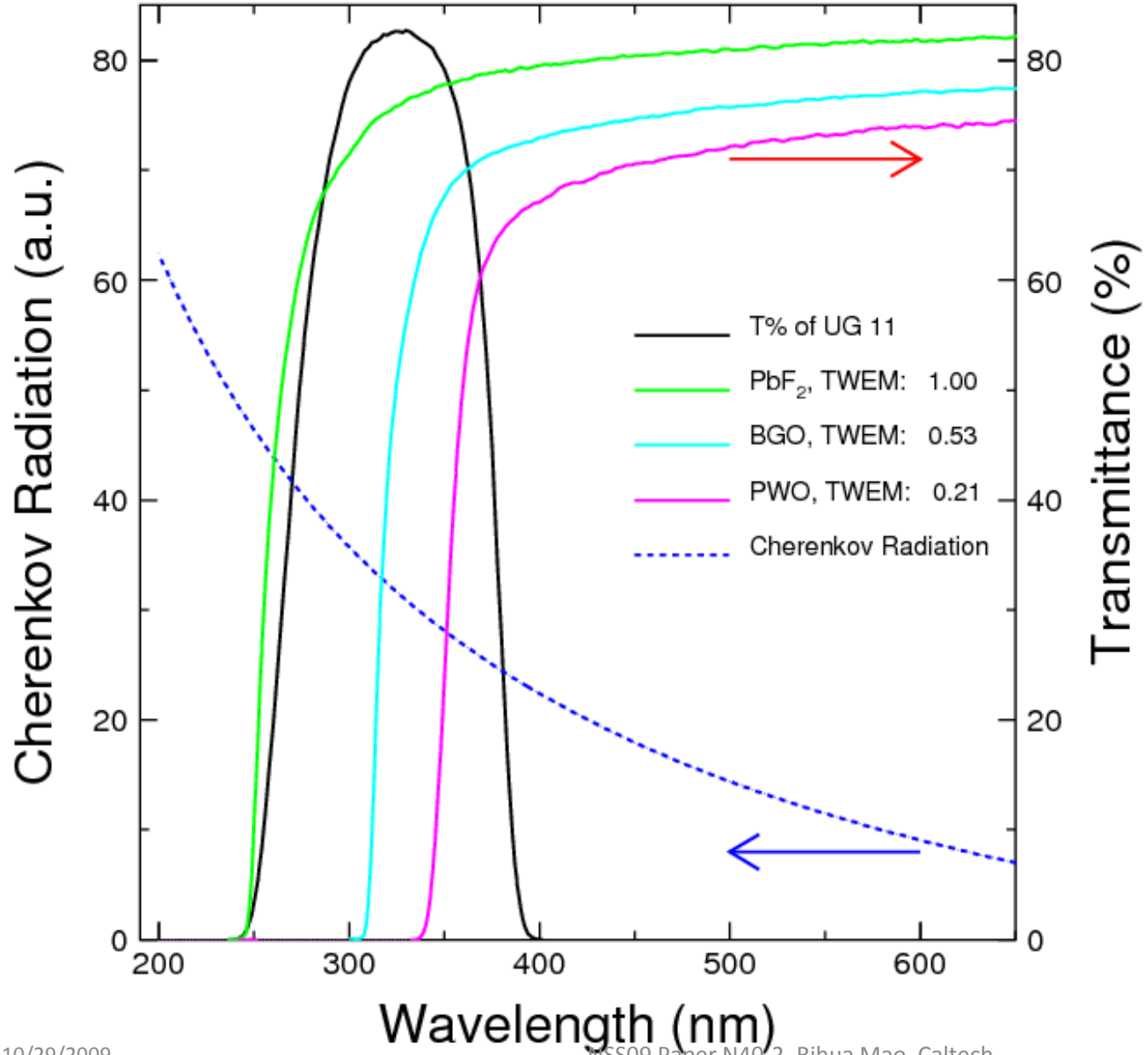
# Introduction

- This work focuses on a search for scintillation in doped lead fluoride ($PbF_2$) for the homogeneous hadronic calorimeter detector concept, where both Cherenkov and scintillation lights are measured for good hadronic energy resolution.

- Why $PbF_2$ ?
  - High density: 7.77 g/cc and short $\lambda_I$: 21 cm.
  - Good UV transparency down to 250 nm for Cherenkov.
  - Can be grown for large size of 20 cm.
  - Potentially low cost ($2/cc) : melting point at 824$^o$C and low material cost: 1/3 of BGO.

- Lead fluoride samples with rare earth doping were grown by Bridgman method. Photo- and X- luminescence, decay kinetics and ɣ-ray excited anode current and pulse height spectrum were measured.

# Cherenkov Needs UV Transparency

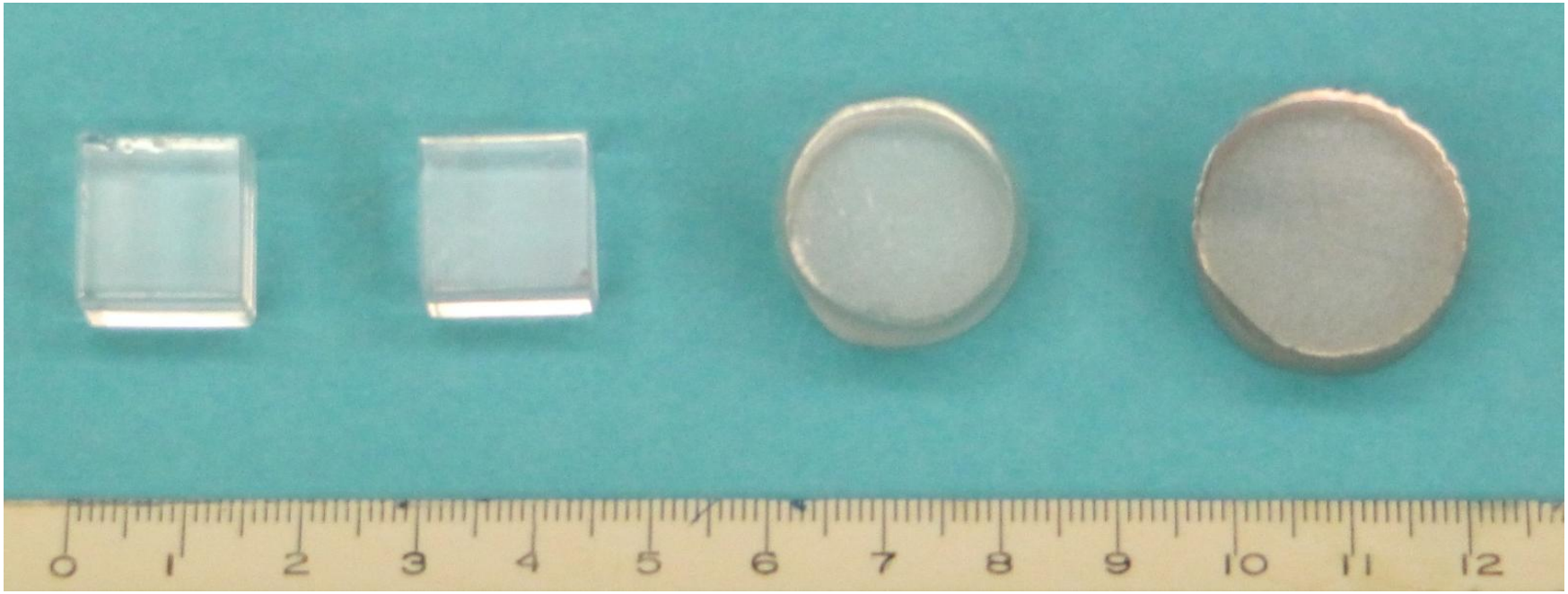



Cherenkov figure of merit

Using UG11 optical filter Cherenkov light can be effectively selected with negligible contamination from scintillation

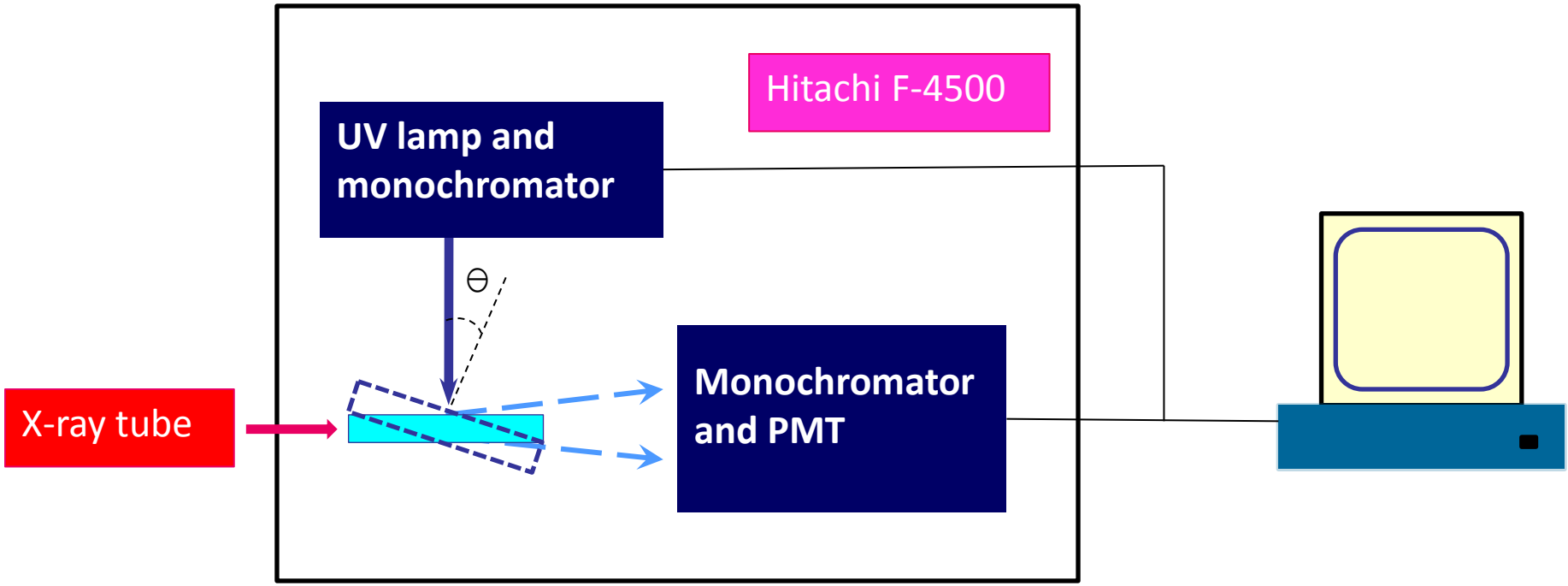
# $PbF_2$ Samples

- A total of 116 samples with various rare earth doping were grown by vertical Bridgman method at SIC and Scintibow.
- SIC samples are of 1.5 $X_0$ (14 mm) cube, while most of the Scintibow samples are of Φ 22 x 15 mm.



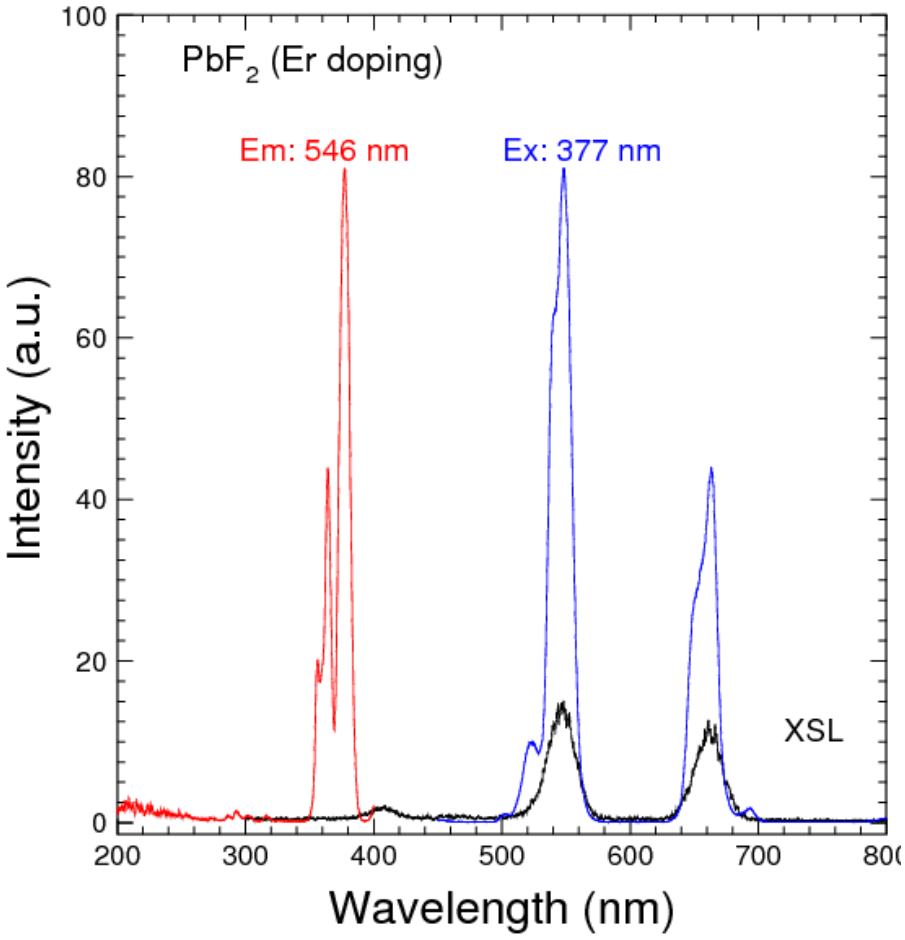
# Photo- and X-luminescence

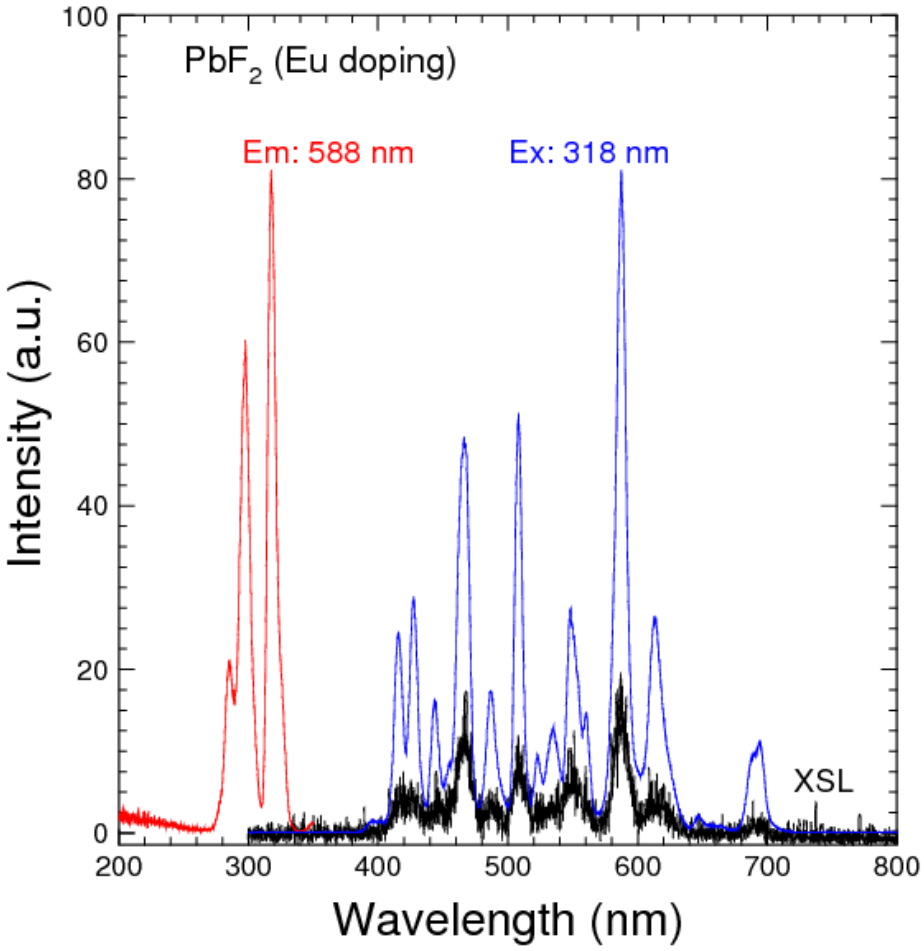
- Photo luminescence was measured by using Hitachi F-4500 fluorescence spectrophotometer.
- An AMTPEK portable X-ray tube was used for the X-luminescence measurement.



# Luminescence: Er & Eu Doped $PbF_2$

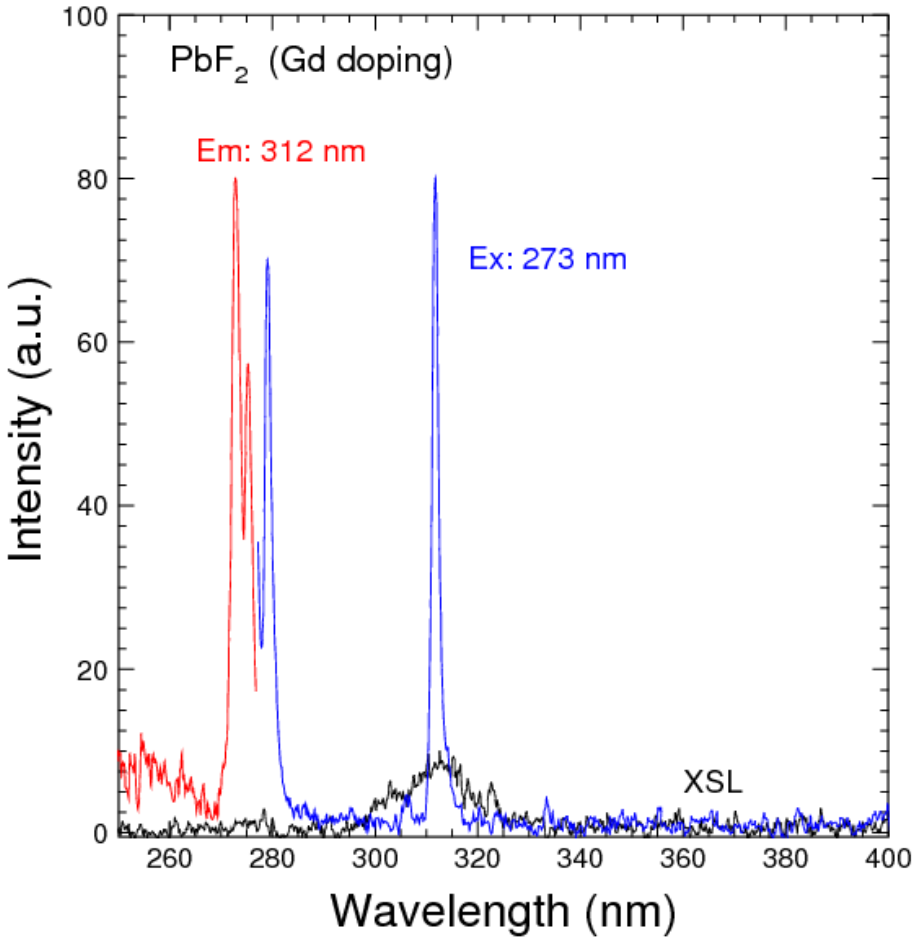
Consistent Photo- and X-luminescence observed

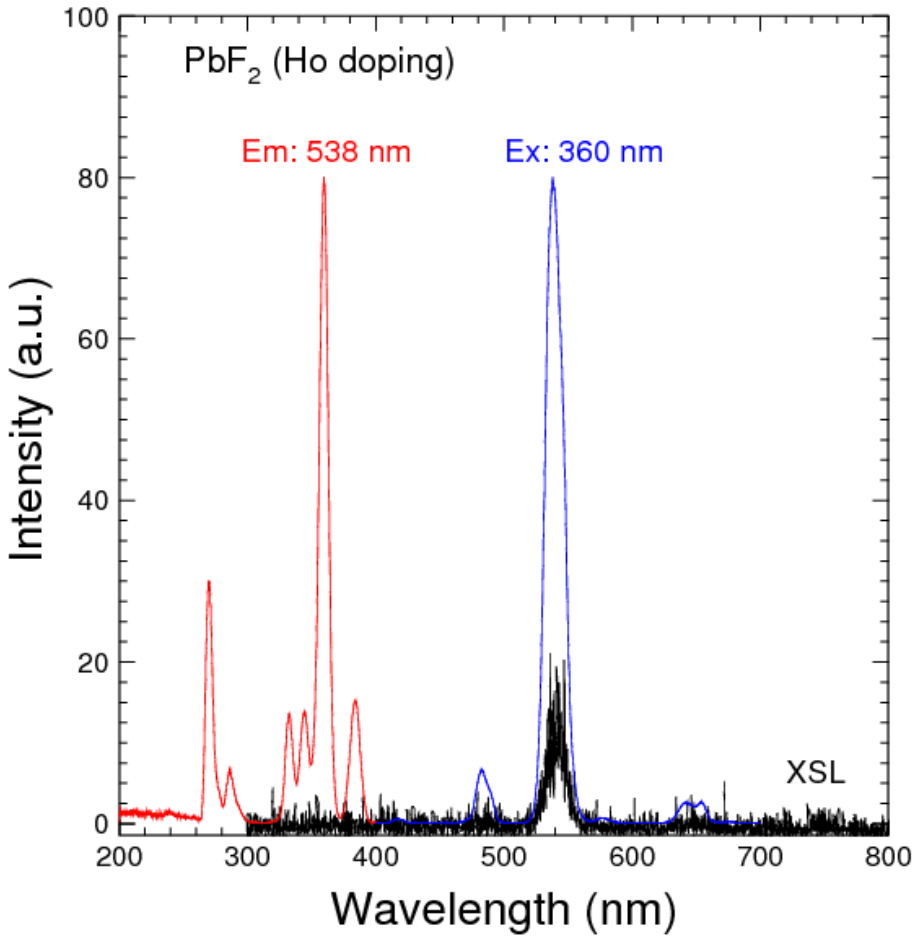


# Luminescence: Gd & Ho doped $PbF_2$

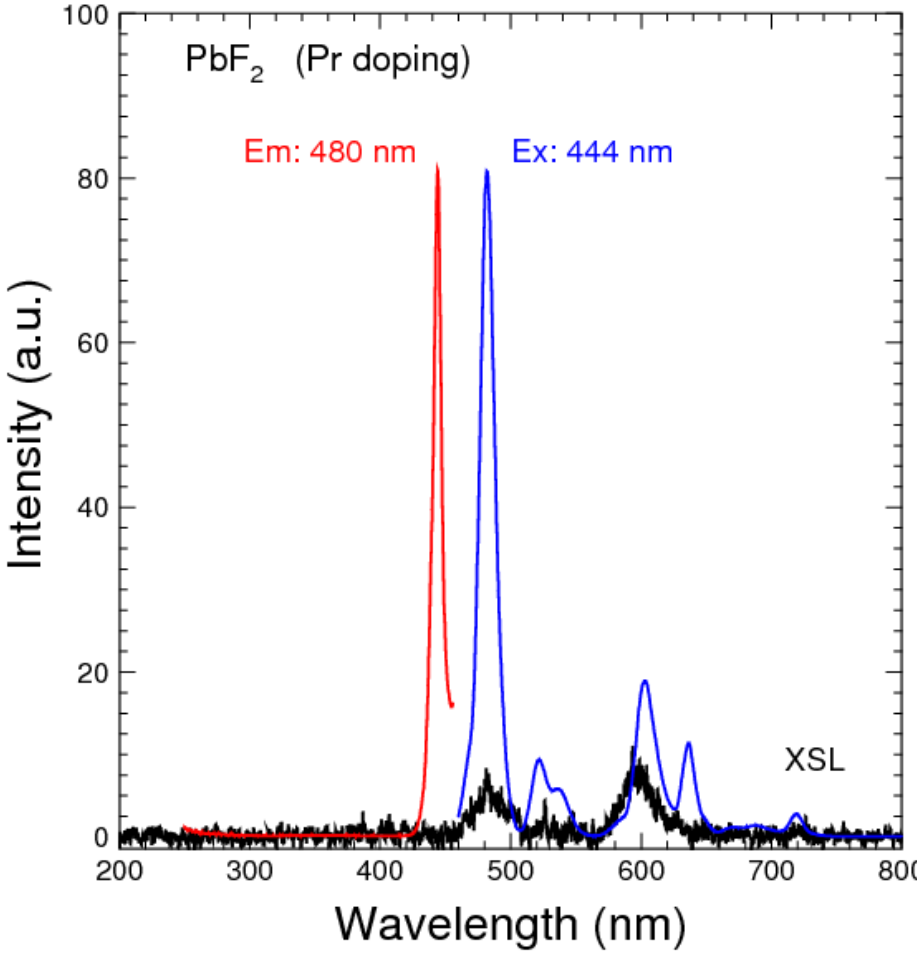
Consistent Photo- and X-luminescence observed

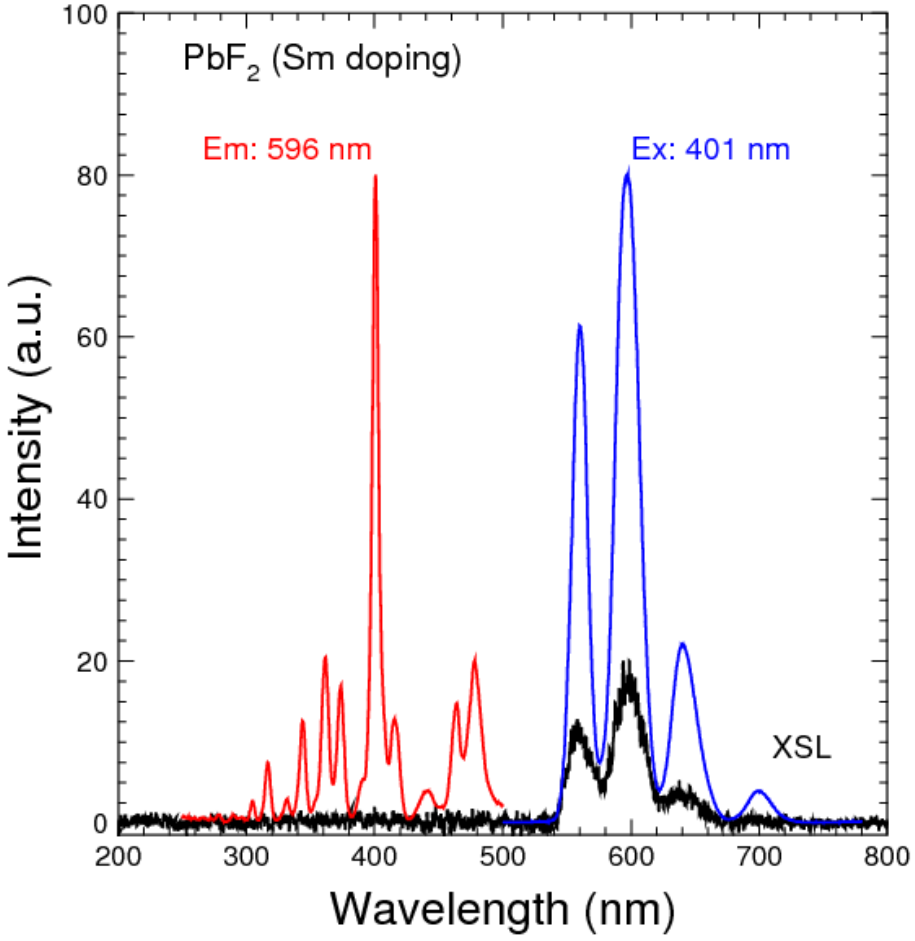


# Luminescence: Pr & Sm Doped $PbF_2$

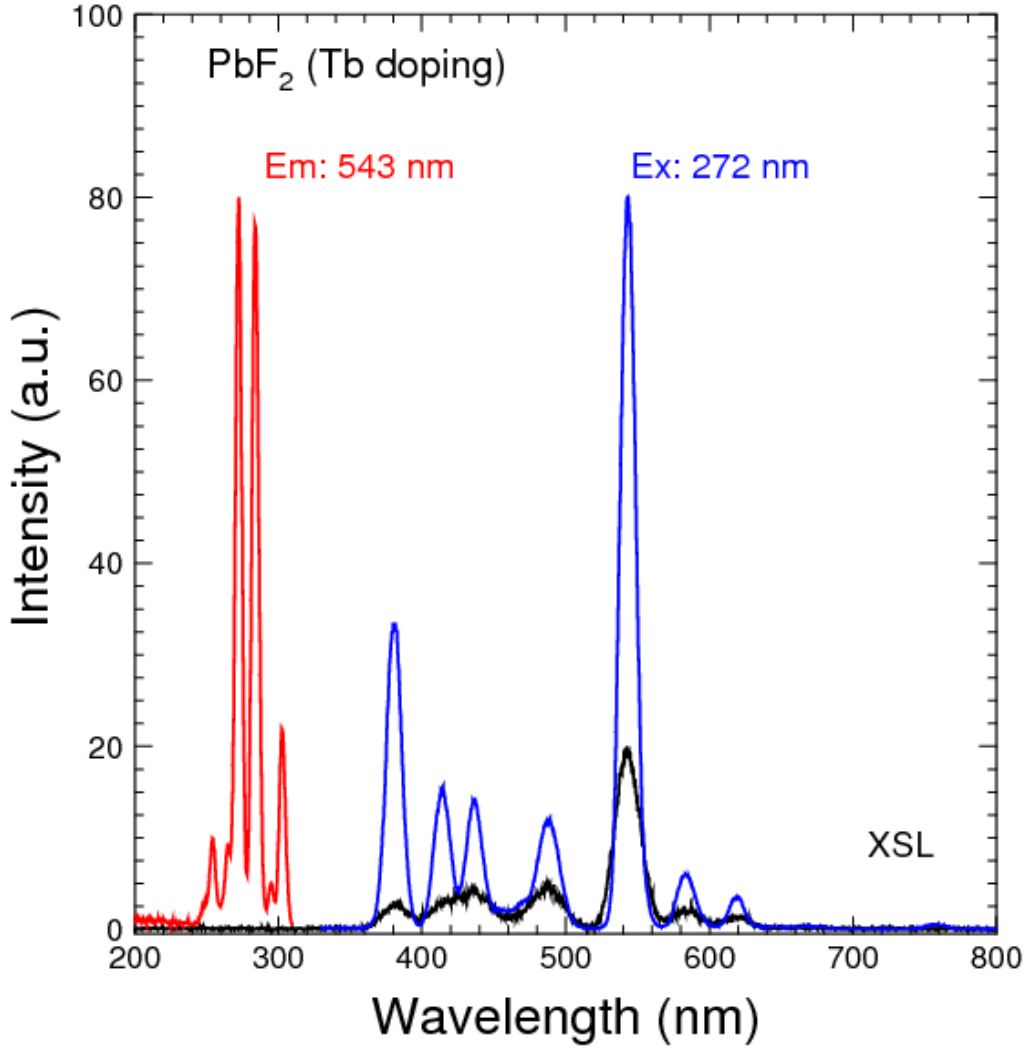
Consistent Photo- and X-luminescence observed



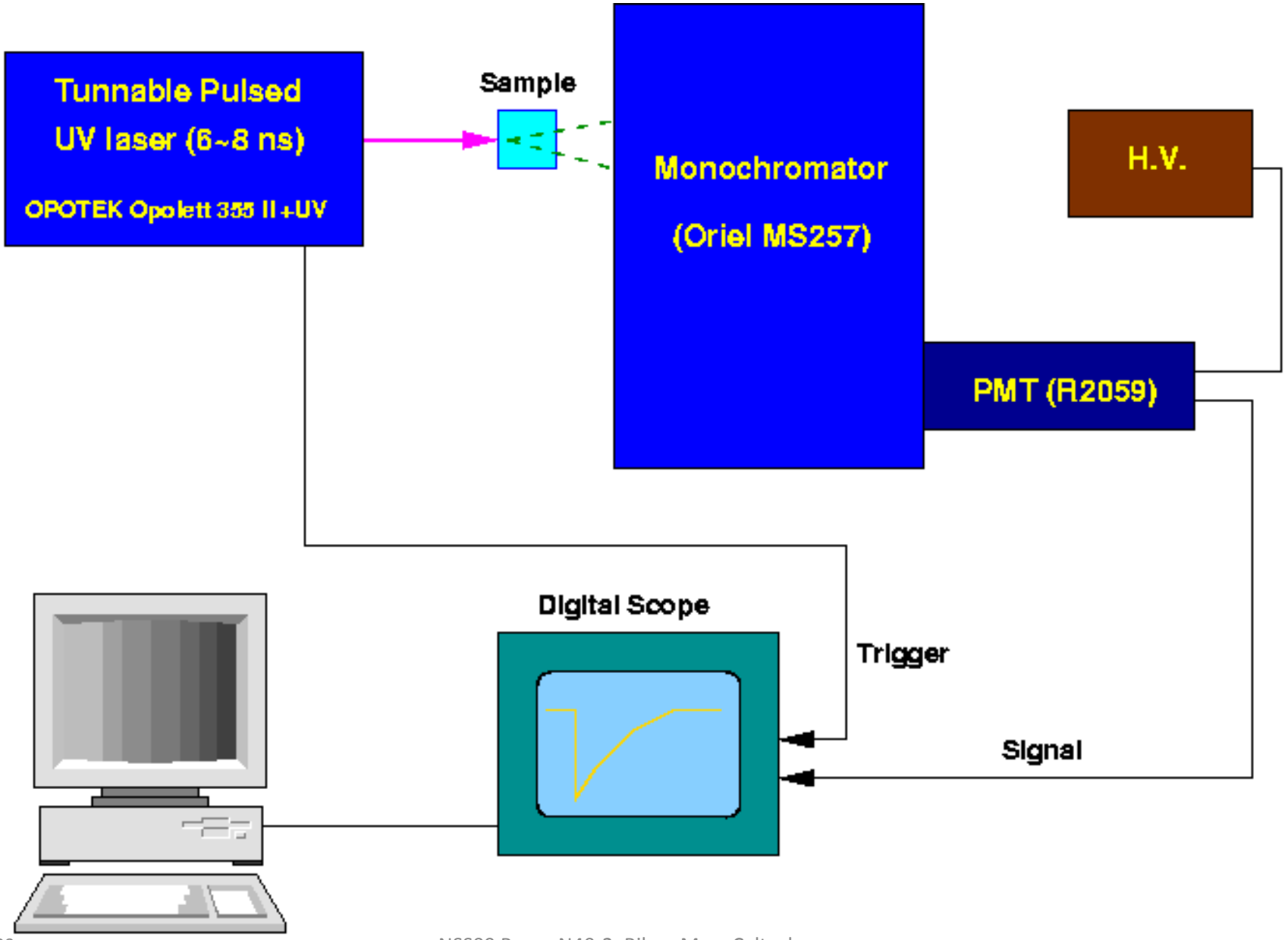



# Luminescence: Tb doped $PbF_2$

Consistent Photo- and X-luminescence observed

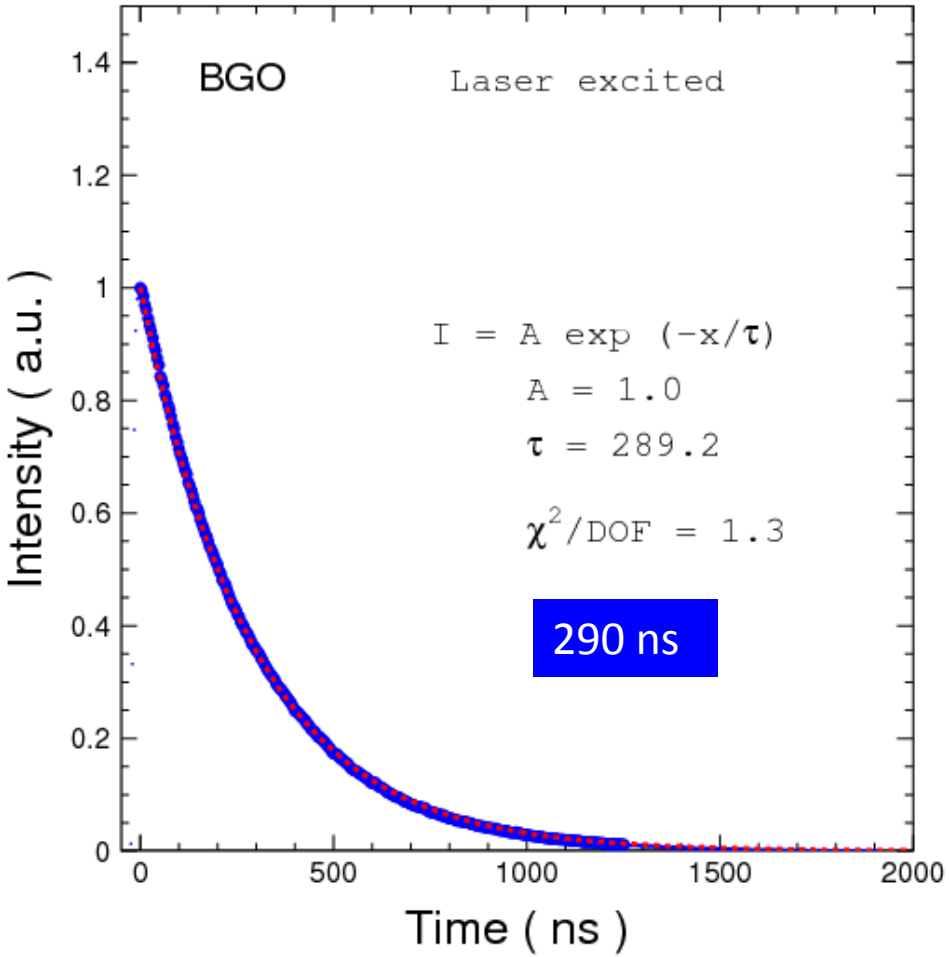


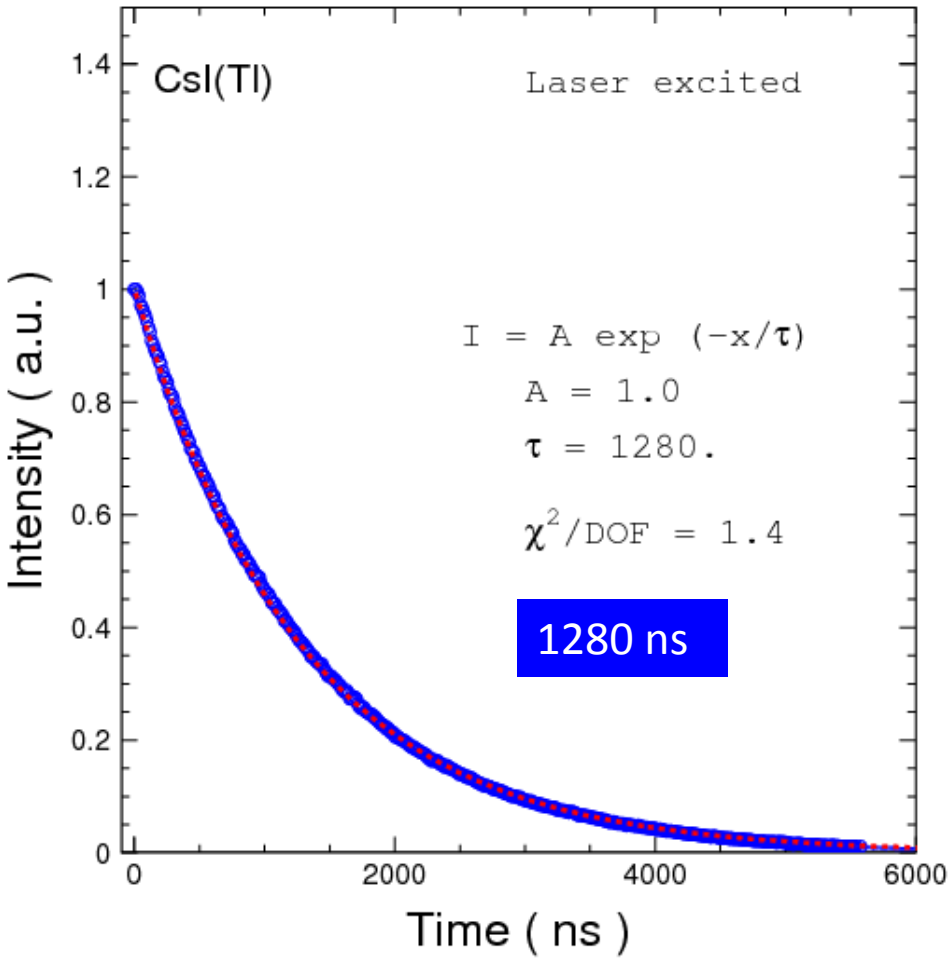
# Decay Time Measurement



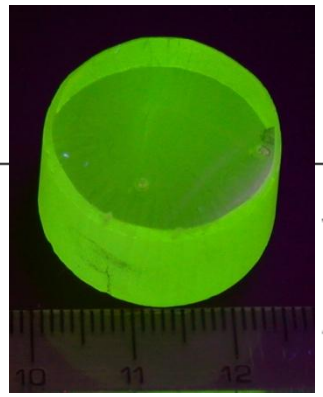
# Verified with BGO & CsI(Tl)

Decay time consists with well known values

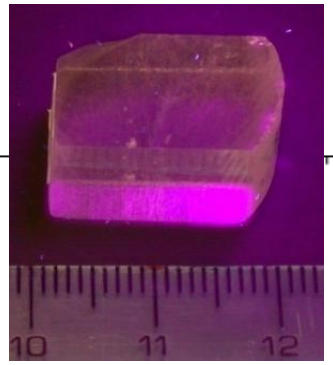


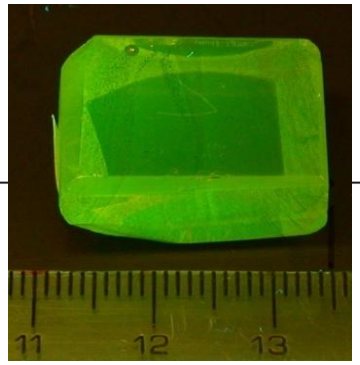
# Decay Time: Er & Eu Doped $PbF_2$



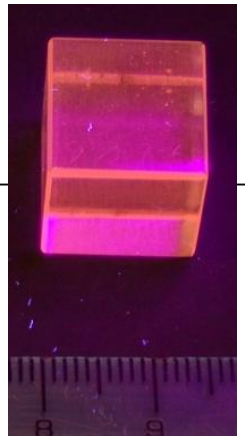


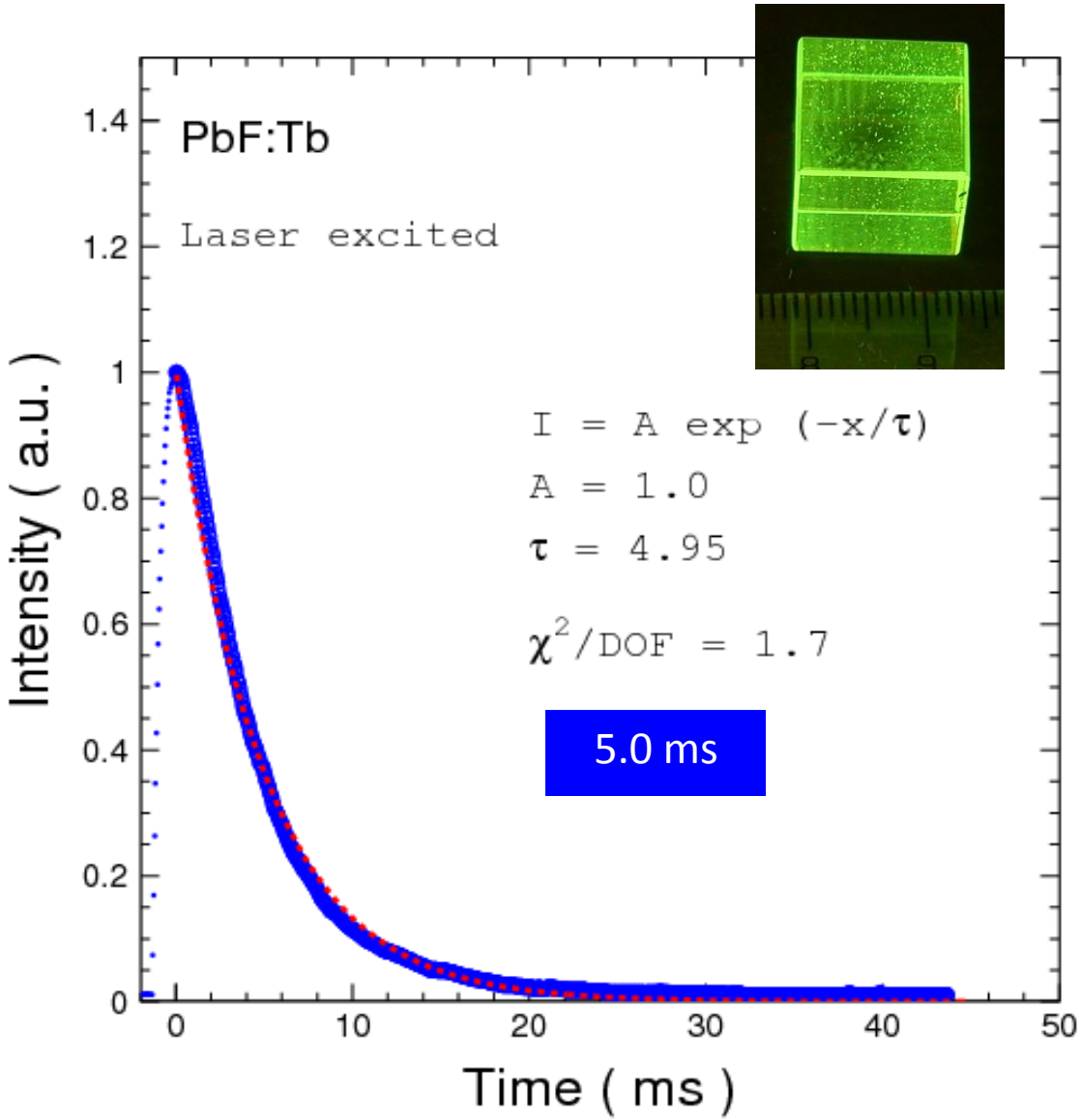
# Decay Time: Ho and Sm Doped $PbF_2$





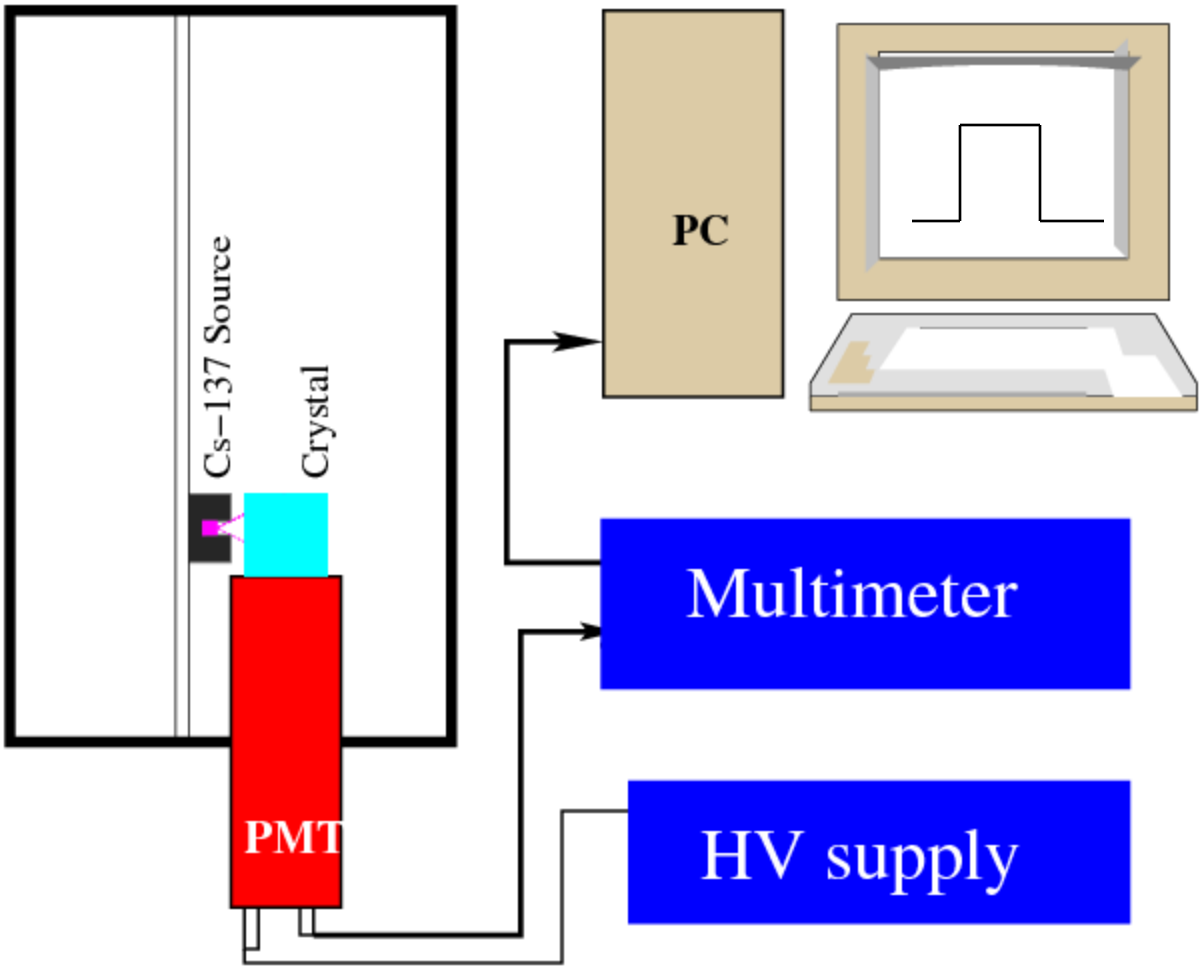



# Decay Time: Tb Doped $PbF_2$



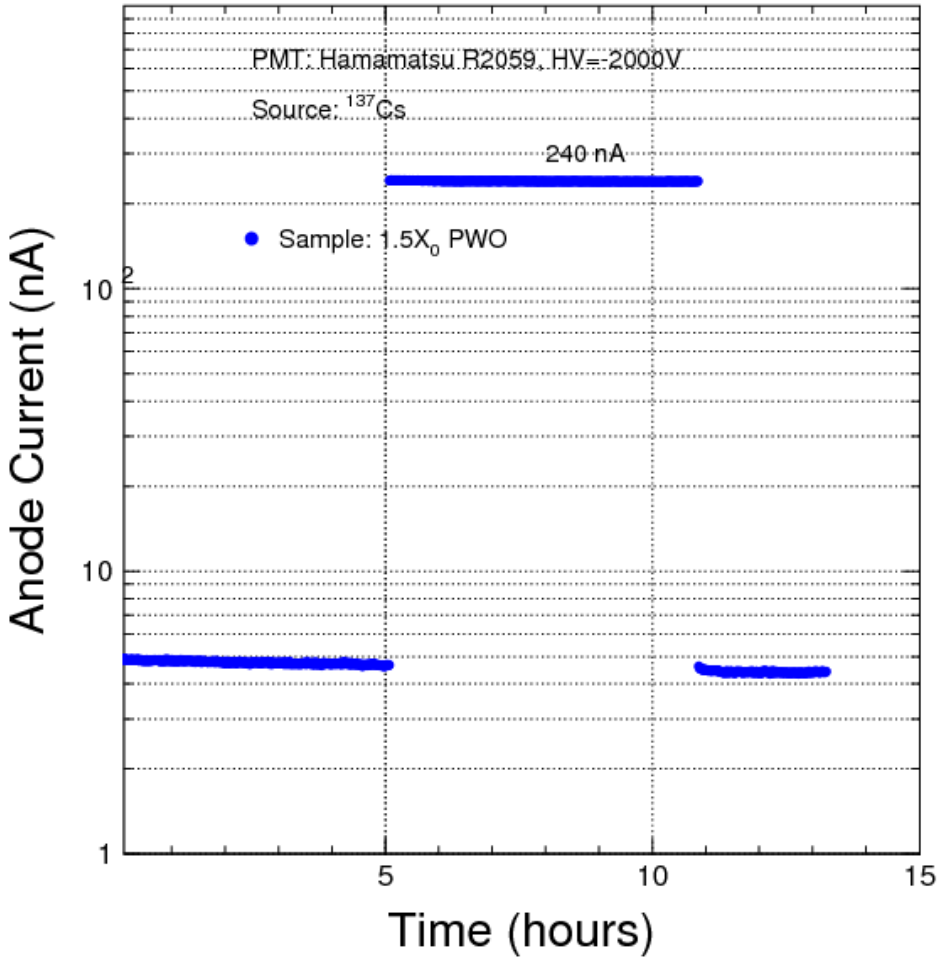
# Anode Current Measurement

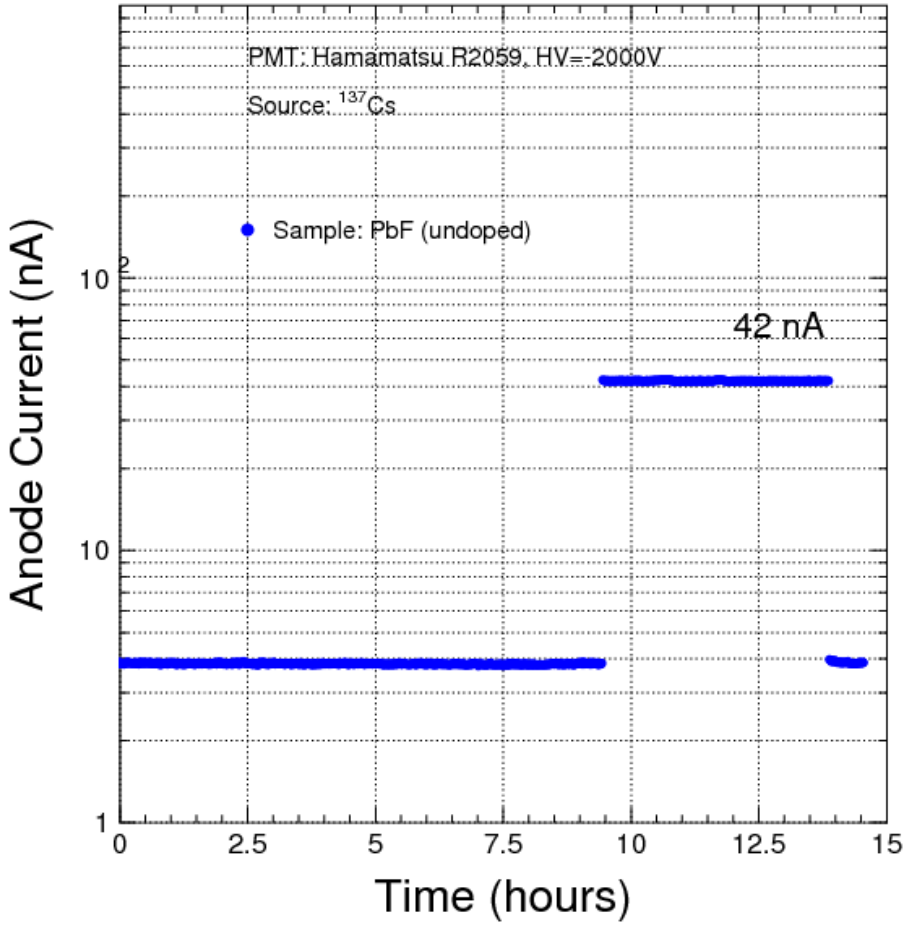
Distance between source and sample: 2 cm



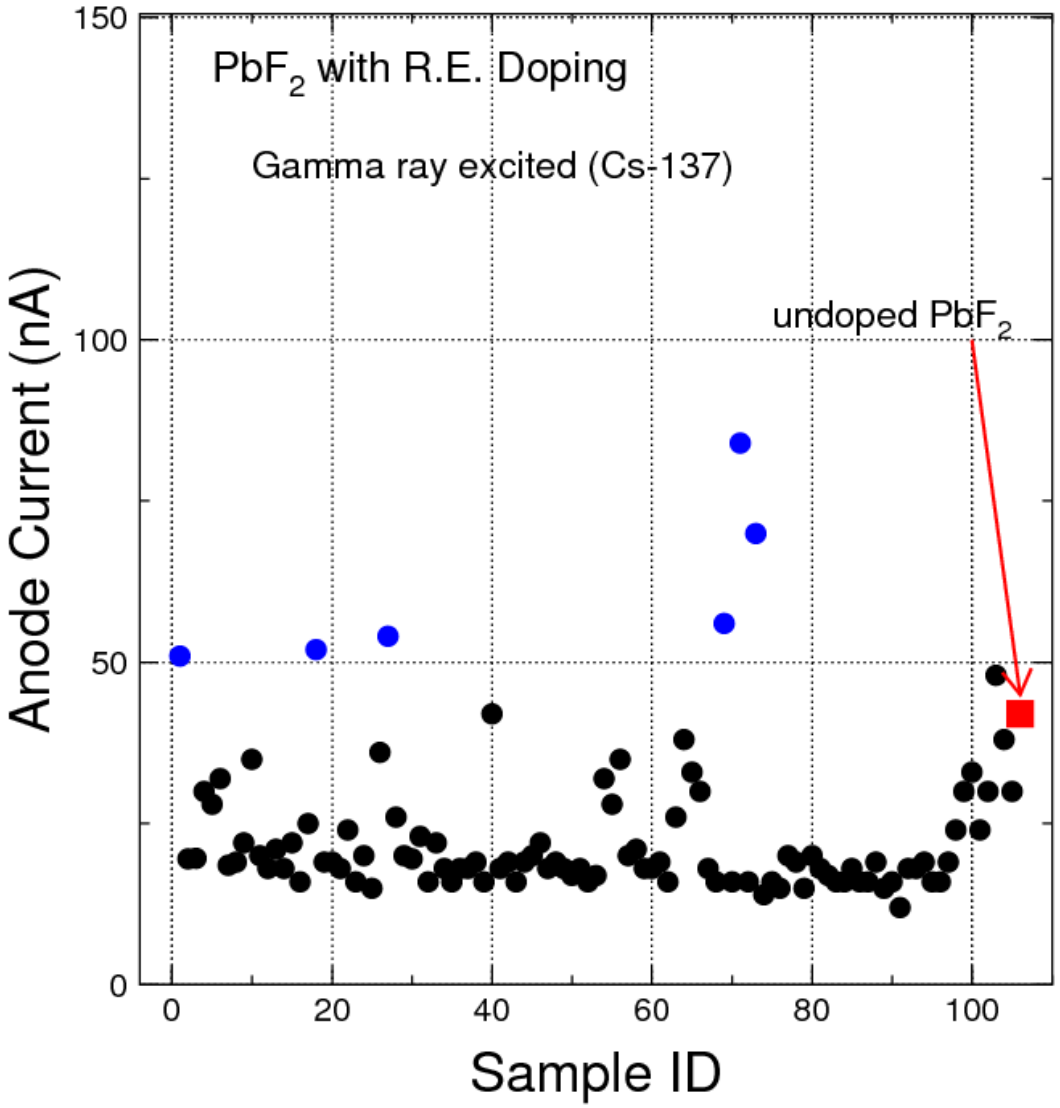
# Anode Current: PWO & Un-doped $PbF_2$

PWO: L.O. = 20 p.e./MeV, anode current = 240 nA



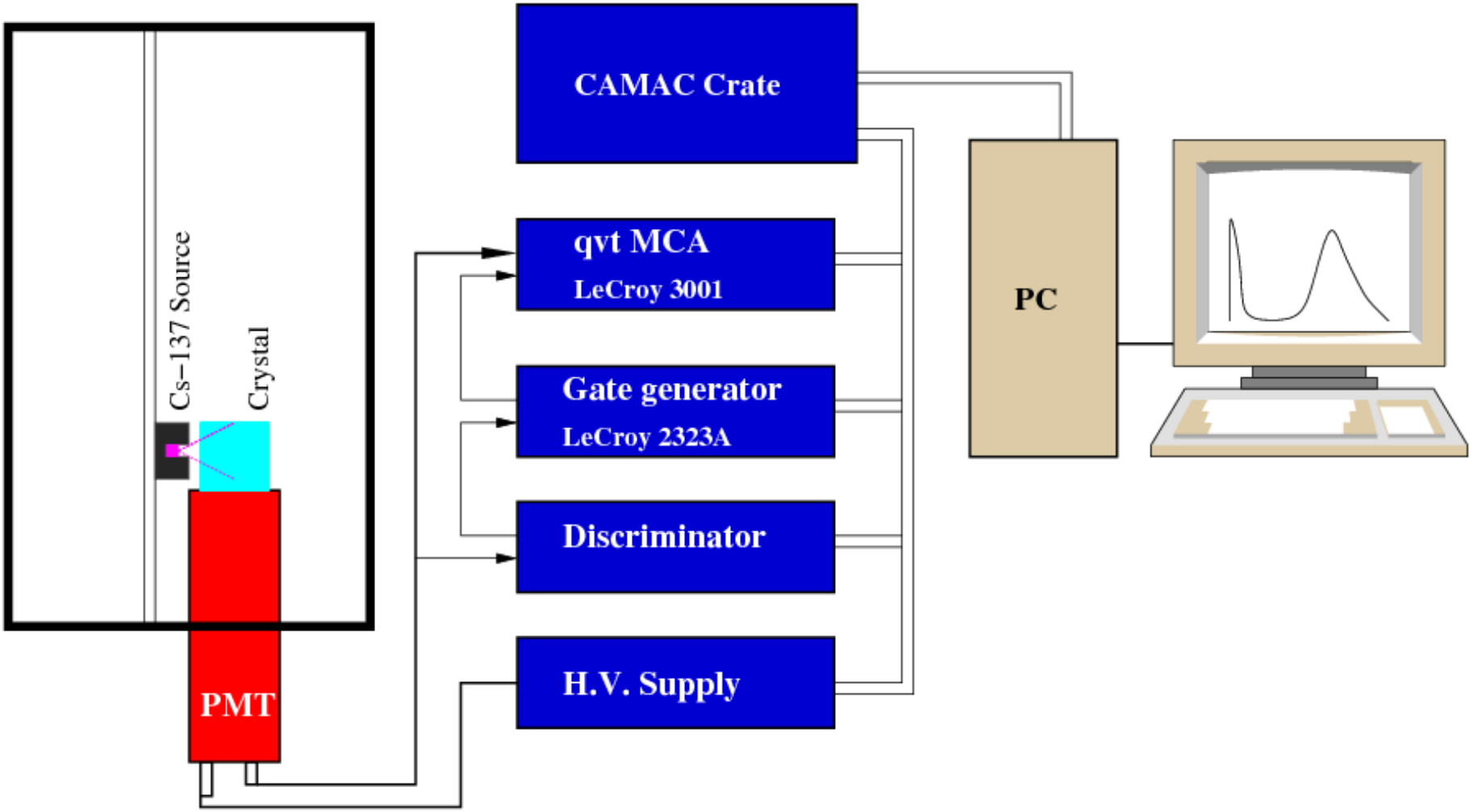
# Anode Current: All Samples



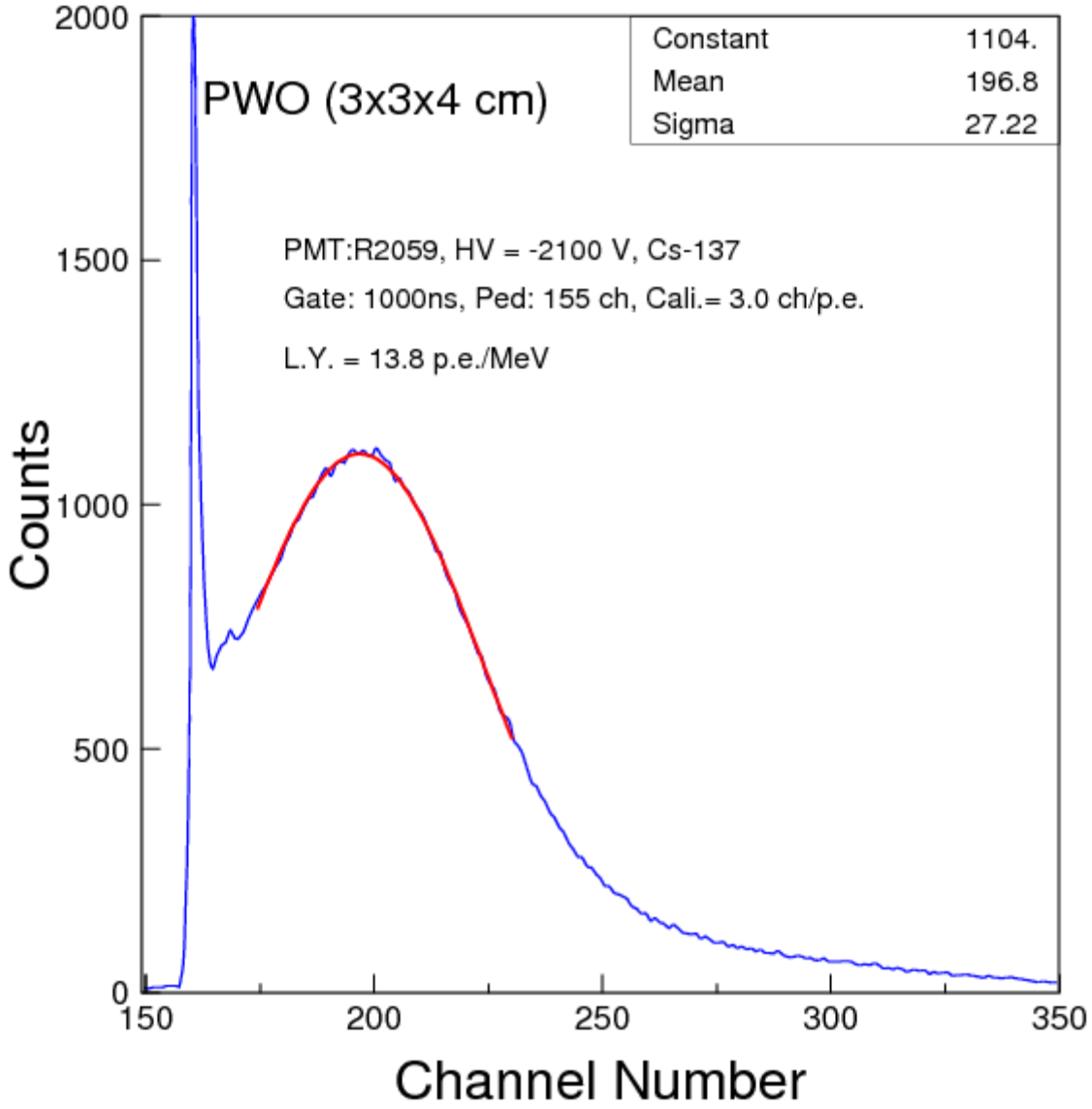
# Summary of Anode Current

| ID | Anode current (nA) | Size (mm) | Doping |
|---|---|---|---|
| Scintibow-1 | 51 | 18 x12 x10 | Eu |
| Scintibow-18 | 52 | Φ22X15 | Eu/Gd |
| Scintibow-27 | 53 | Φ20X15 | Eu/Tb |
| Scintibow-B19 | 56 | Φ20X15 | Eu/Tb/Na |
| Scintibow-B21 | 83 | Φ22X15 | Eu/Bi/Na |
| Scintibow-B23 | 73 | Φ20X15 | Eu/Bi/Na |
| Undoped | 42 | 14 x 14 x14 | -- |

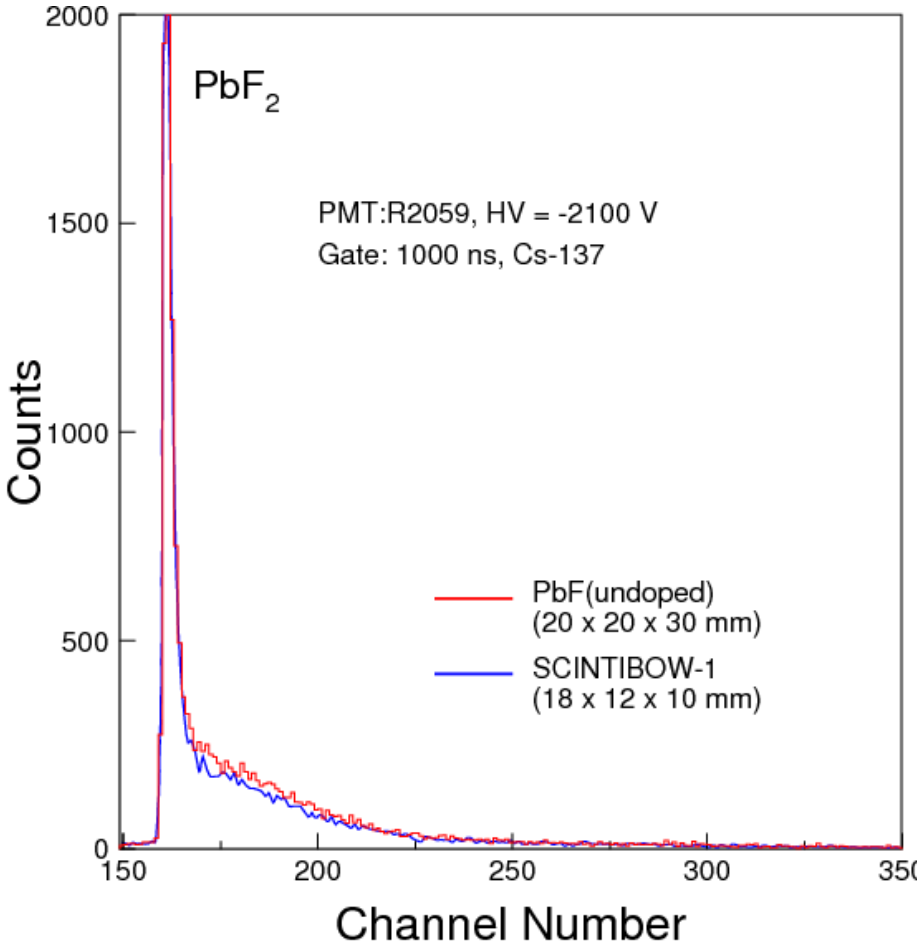
# γ-ray Excited Pulse Height Spectrum

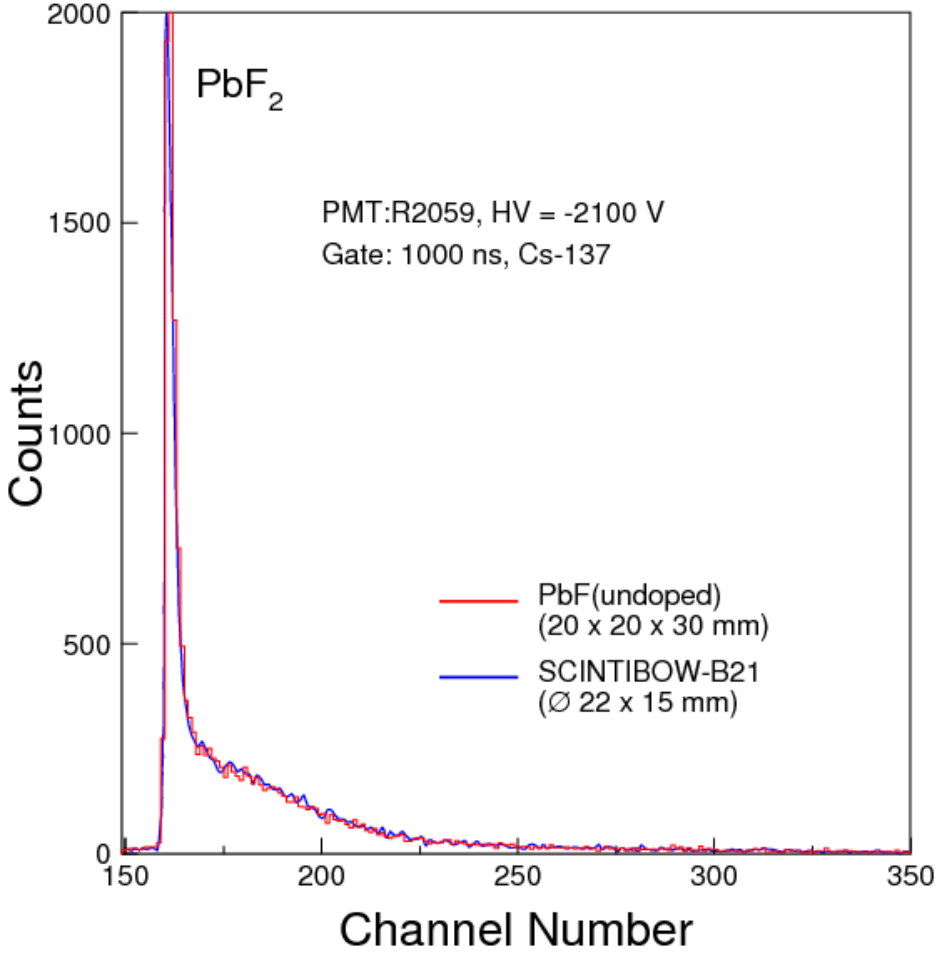


# γ-ray Excited PHS: PWO



# γ-ray Excited PHS: Doped $PbF_2$



# Summary

- Lead fluoride crystal samples doped with various rare earth dopant were grown by Bridgman method.
- Consistent photo and x-ray luminescence found in samples with Er, Eu, Gd, Ho, Pr, Sm and Tb doping.
- The decay time of doped samples was found to be very long at ms scale as expected from the f-f transition of the rare earth elements.
- While some doped samples show anode current larger then the un-doped samples, their γ-ray excited pulse height spectra were found identical to un-doped sample, indicating no scintillation light.
- Investigation will continue to search for scintillation in doped lead fluoride and other host materials.