# $Pb(W_{1-x}$-$Mo_x)O_4$: La, Y SCINTILLATOR FOR ECAL End Caps UPGRADE AT SLHC .

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# MOTIVATION OF THE RESEARCH

An “unrecoverable damage” of scintillation detecting cells by neutral and charged hadrons in the End Caps region with high rapidity η becomes a factor which can make worse energy resolution of the detector.

“Unrecoverable damage” is the crystal matrix damage by products of the nuclear reactions of charged and neutral hadrons with nuclei of the crystal forming atoms.

**At the microscopic** level this damage is accompanied with creation of the Frenkel type defects by knocking out of the atoms from their sites in the regions of fragments tracks.

**At the macroscopic** level damaged areas like stars are produced by fragments giving rise of the Raleigh scattering.

# CRYSTAL OPTICAL TRANSMISSION UNRECOVERALBELE DAMAGE HAS BEEN RECOGNISED IN SEVERAL PUBLICATIONS


**M. Huhtinen, P. Lecomte, D. Luckey, F. Nessi-Tedaldi, F. Pauss, *"High-Energy Proton Induced Damage in PbWO4 Calorimeter Crystals"* , NIM A 545(2005)63**

**R. Chipaux, et.al., *,"Behaviour of PWO scintillators after high fluence neutron irradiation"* in Proc, SCINT 2005, eds. A. Getkin and B. Grinyiv, Institute for Single Crystals, Kharkov, Ukraine, (2006) 369**

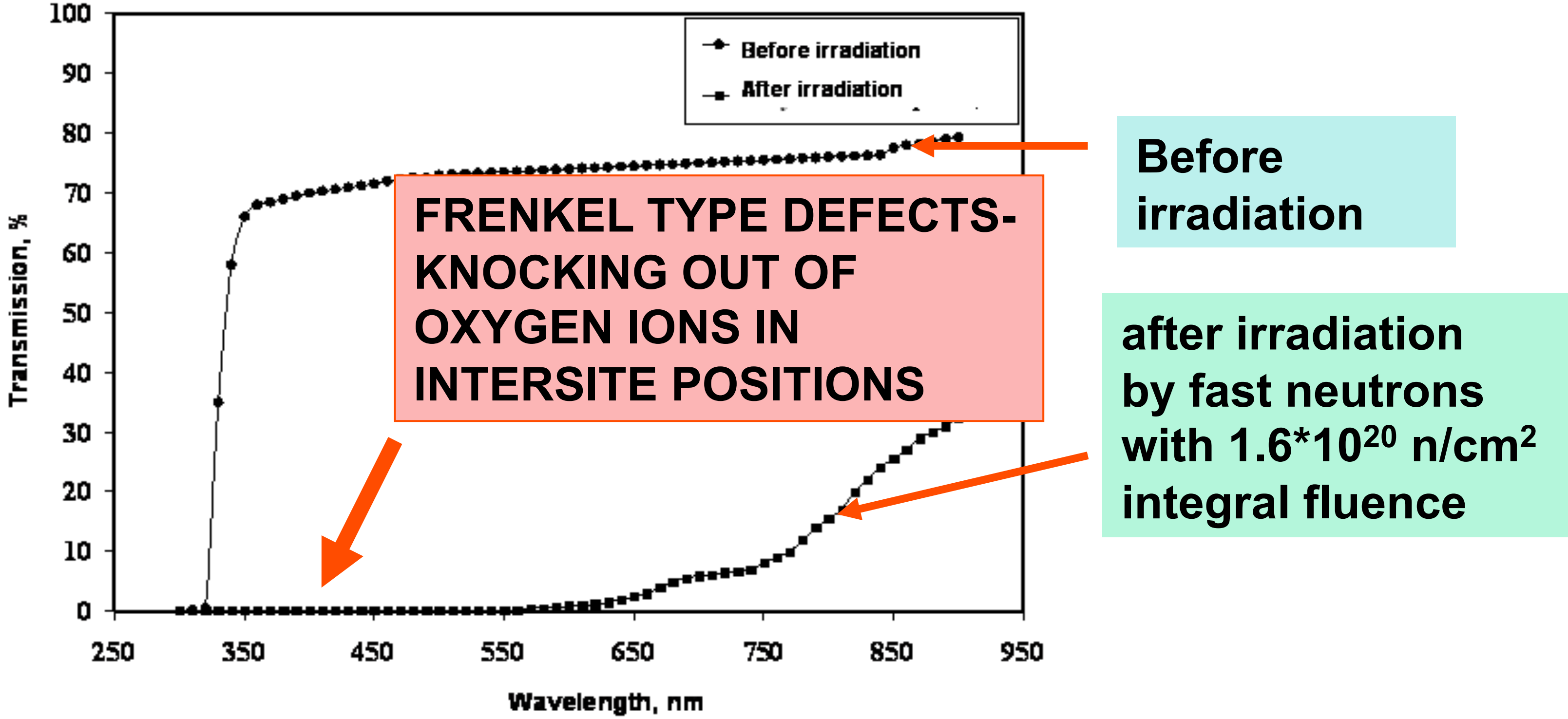
**P. Lecomte, D. Luckey, F. Nessi-Tedaldi, F. Pauss, *"High-Energy Proton Induced Damage Study of Scintillation Light Output from PbWO4 Calorimeter Crystals"* NIM A , 564(2006)164**

**P. Lecomte, D. Luckey, F. Nessi-Tedaldi, F. Pauss and D. Renker, *"Comparison between high-energy proton and charged pion induced damage in PbWO4 calorimeter crystals"* NIM A, 587(2008)266**

# PWO CRYSTAL "UNRECOVERABLE" OPTICAL TRANSMISSION DAMAGE SOURCES AT DIFFERENT LUMINOSITIES

| Luminosity, $fb^{-1}$ | Expected irradiation environment at the $2 < \eta < 2.9$ | | Damage | | | |
|---|---|---|---|---|---|---|
| | n fluence, $n/cm^2$ | γ-quanta integrated dose, Mrad | Neutrons E<10MeV | Not recovering damage by γ-quanta | Not recovering damage by hadrons | Amorphisation of the material |
| 500 | $5 \cdot 10^{12}$ | 2 | - | - | +/- | - |
| 2500 | $5 \cdot 10^{13}$ | 17 | - | - | + | - |

# PWO OPTICAL TRANSMISSION DAMAGE WITH NEUTRONS

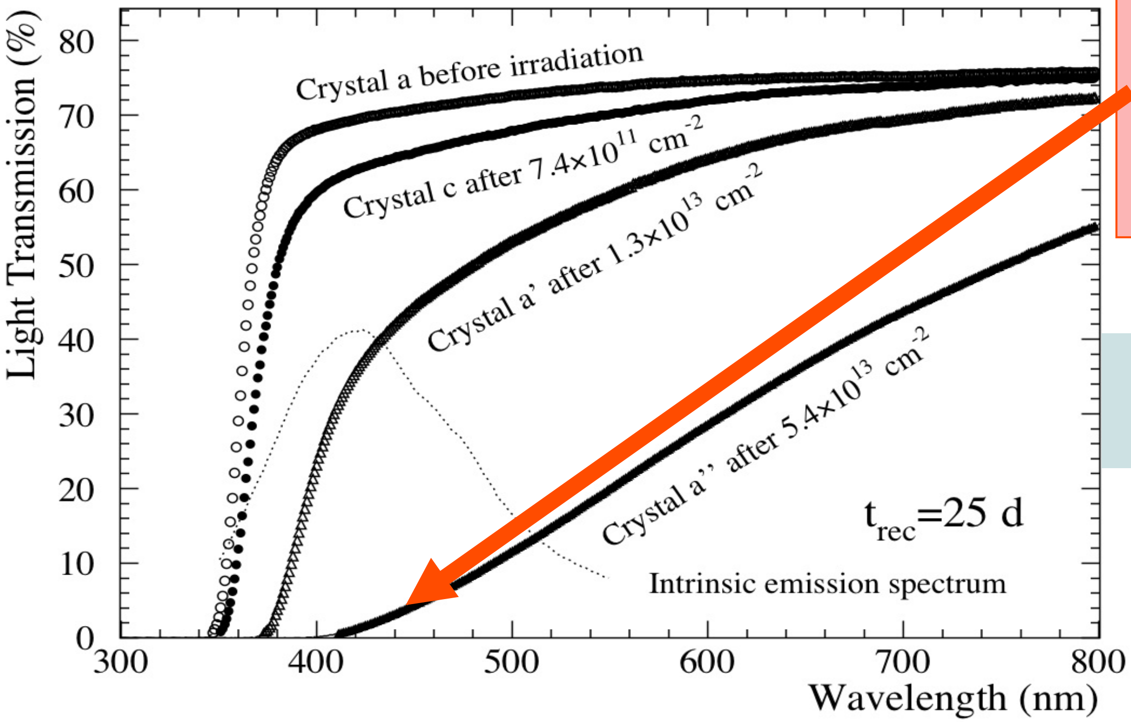



**Optical transmission spectra of 0,2 mm PWO crystal after $1.6 \cdot 10^{20}$ n/cm$^2$**

(**M.Korzhik, Physics of scintillation in oxide crystals, Minsk, 2003, 263 p.** (In Russian))

**No damage is expected with SLHC fluence ~ $5 \cdot 10^{13}$ n/cm$^2$, Δk is estimated to be less than 0.01m$^{-1}$ at the scintillation spectral maximum (420 nm).**

# DAMAGE BY CHARGED HADRONS.




**FRENKEL TYPE DEFECTS- KNOCKING OUT OF OXYGEN IONS IN INTERSITE POSITIONS**

**COURTESY OF Dr.F.Nessi-Tedaldi, CERN**

**Optical transmission spectra of PWO crystal change after irradiation with protons .**

(M. Huhtinen, P. Lecomte, D. Luckey, F. Nessi-Tedaldi, F. Pauss, NIM A 545(2005)63-87)

## HOW TO MINIMIZE CONSEQUENCES OF PWO CRYSTAL

## OPTICAL TRANSMISSION DAMAGE BY HADRONS ?

1. Replacement with a new material?
2. Modification of the PWO properties?

Shift of the scintillation spectrum to long wavelength range:

– PWO doping with $RE^{3+}$ or $RE^{2+}$ ?

$Yb^{3+}$, $Er^{3+}$, $Pr^{3+}$, $Eu^{2+}$

Disadvantage: slow scintillation

– PWO doping with Mo?

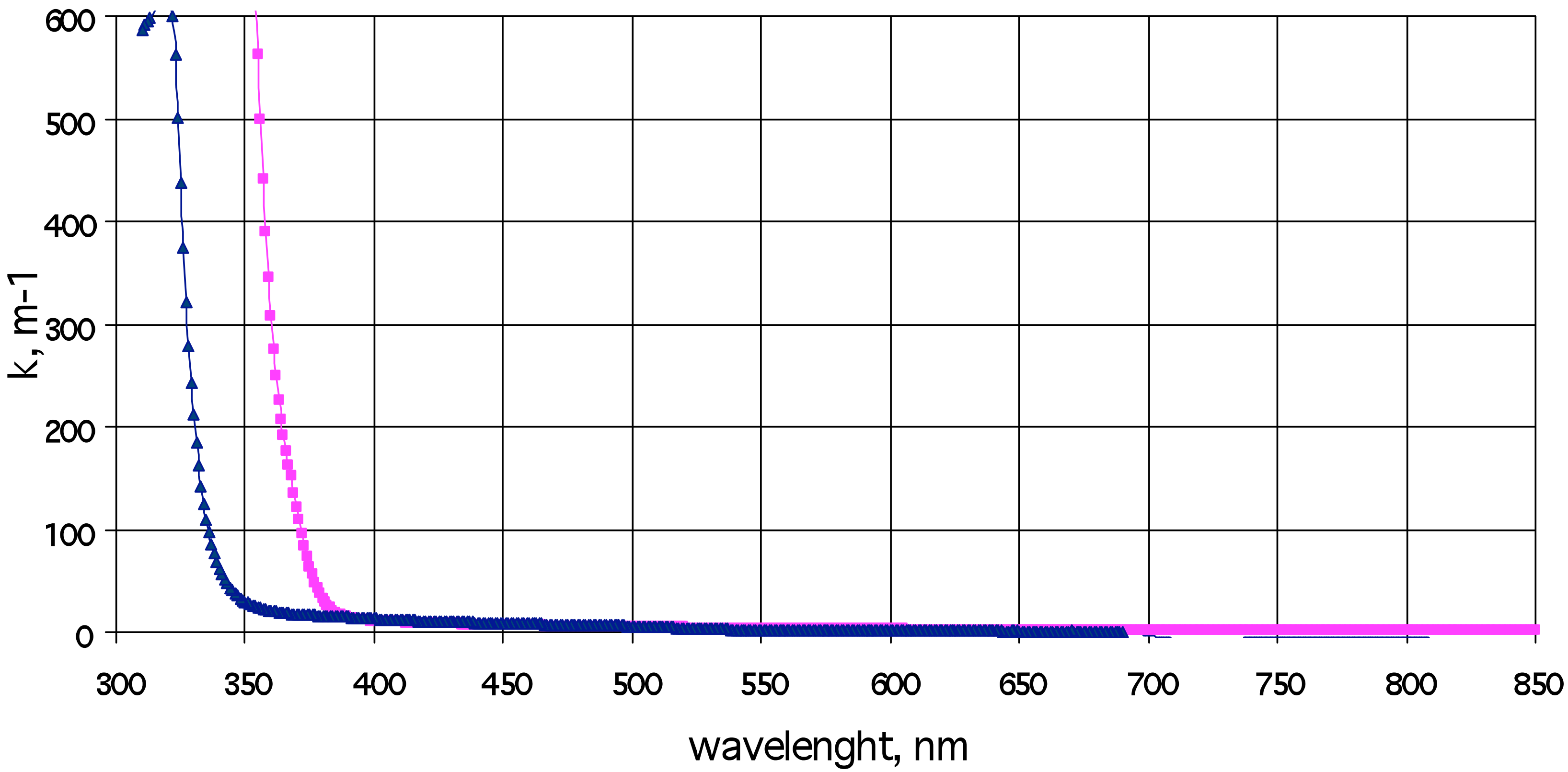
Disadvantage : high fraction of slow scintillation at low Mo concentration

# $Pb(W_{1-x}\text{-}Mo_x)O_4$:La,Y (PWMO) SCINTILLATOR

| Mo doping | Electron capturing center parameters | $E_{TA}$, eV | Scintillation kinetics & radiation hardness to γ |
|---|---|---|---|
| ~ 10ppm | *Axial $(MoO_4)^{3-}$ | 0.5 | scintillation + phosphorescence<br>bad radiation hardness to γ |
| ~ 1000ppm | *Cubic $(MoO_4)^{3-}$ | 0.33 | Scintillation with large fraction of slow component<br>acceptable radiation hardness to γ |
| ~ 10000ppm | Host matrix forming center | 0.30 | Scintillation with reduced fraction of slow component due to migration quenching |
| ~ 10000ppm + Y, La | Host matrix forming center | 0.30 | Scintillation with reduced fraction of slow component due to migration quenching<br>good radiation hardness to γ |

*A. Hofstaetter, et. al., Z.Phys. B30 (1978), 305

# COMPARISON OF THE PWO:La,Y and $Pb(W_{1-x}\text{-}Mo_x)O_4$:La,Y OPTICAL ABSORPTION AT 293K

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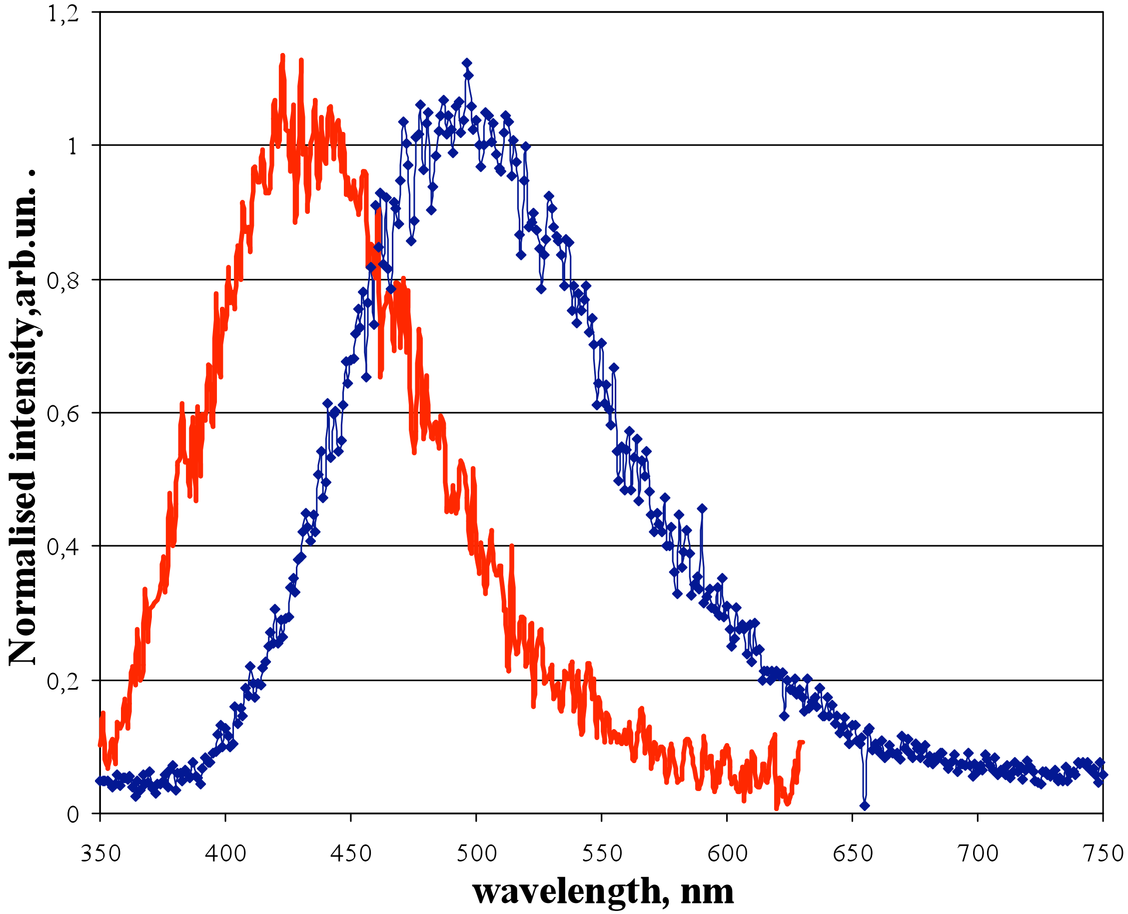
# COMPARISON OF THE PWO:La,Y and $Pb(W_{1-x}-Mo_x)O_4$:La,Y RADIOLUMINESCENCE AT 293K

LY(100 ns)($20x20x10mm^3$)
22 phe/MeV at T= +20º C

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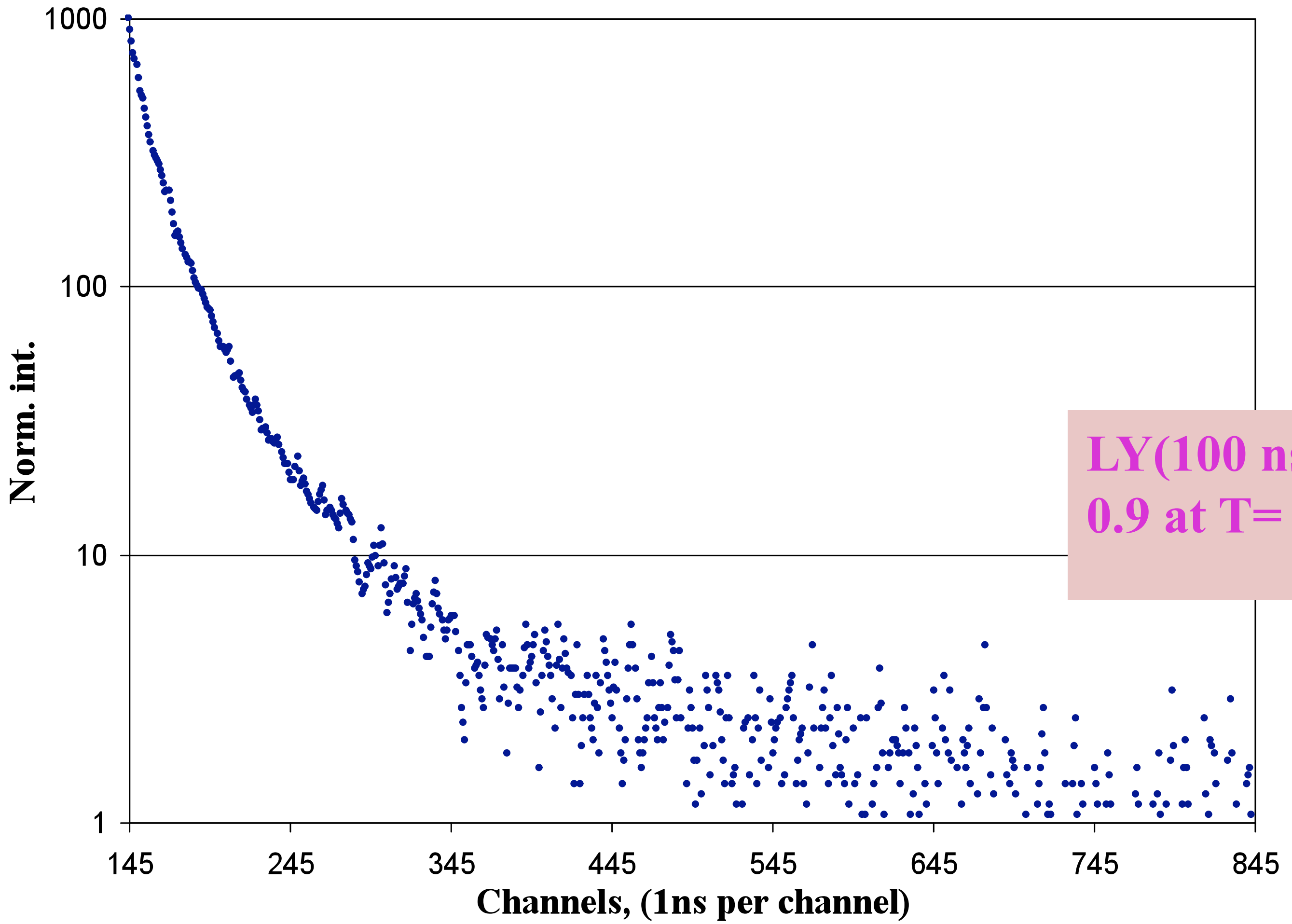
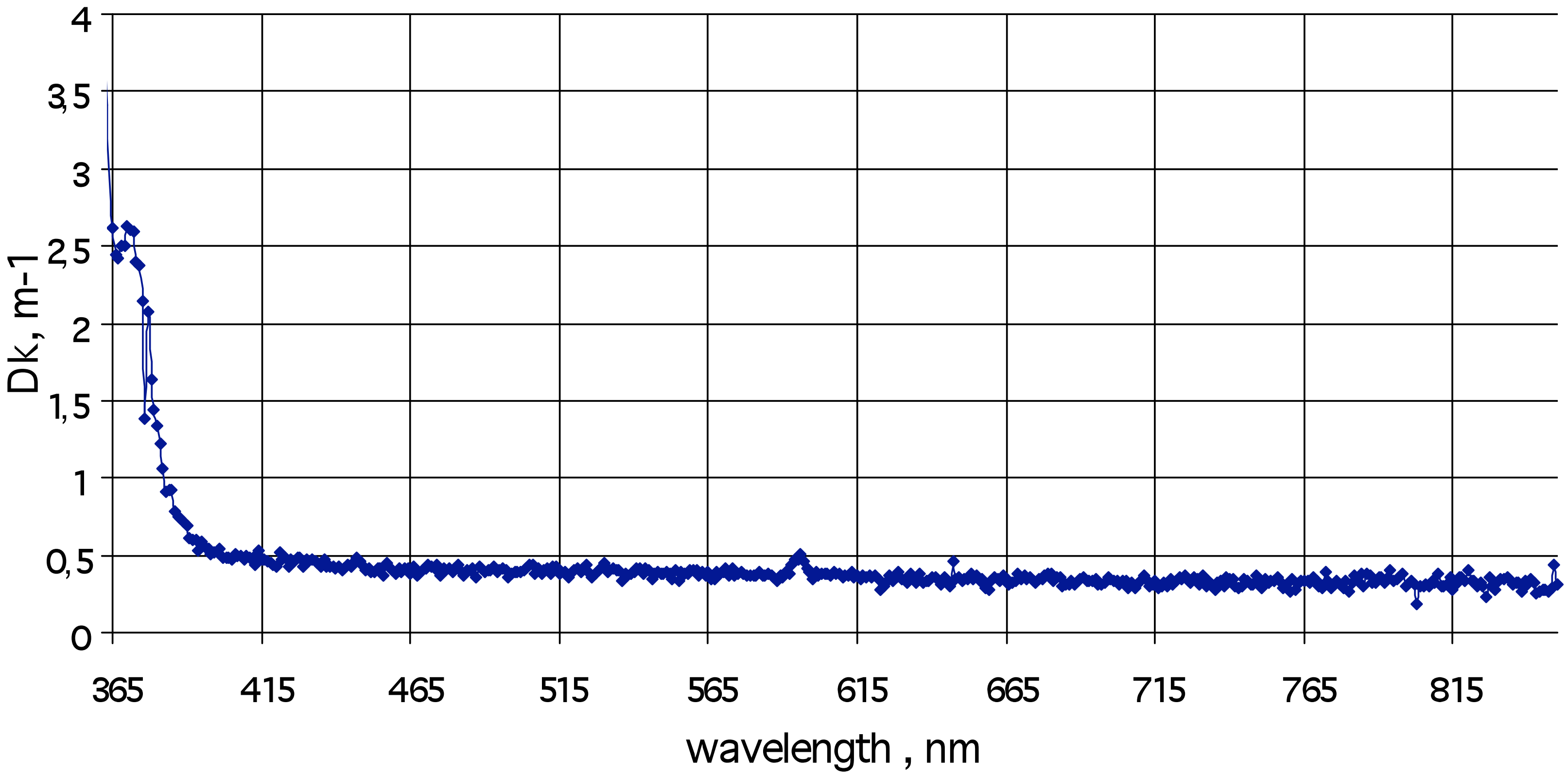
# SCINTILLATION KINETICS OF $Pb(W_{1-0.05}\text{-}Mo_{0.05})O_4$:La,Y AT 293K




| τ, ns | P, % |
|---|---|
| 10 | 62 |
| 36 | 33 |
| 216 | 5 |

**LY(100 ns)/LY(4000 ns) = 0.9 at T= +25° C**

## RADIATION INDUCED ABSORPTION OF $Pb(W_{1-0.05}-Mo_{0.05})O_4$:La,Y AT ABSORBED DOSE 1000Gy ($^{60}$Co) 293K

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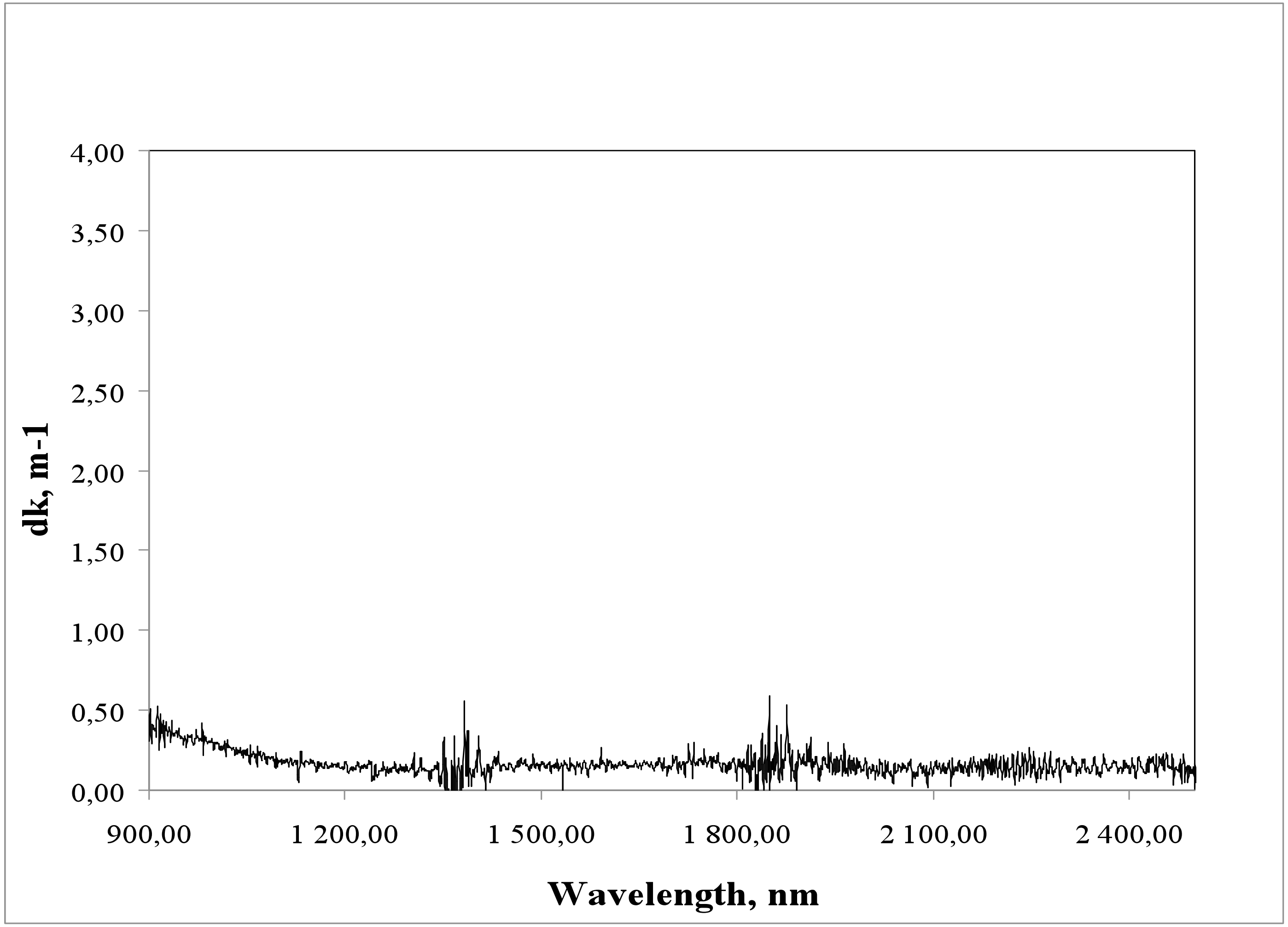
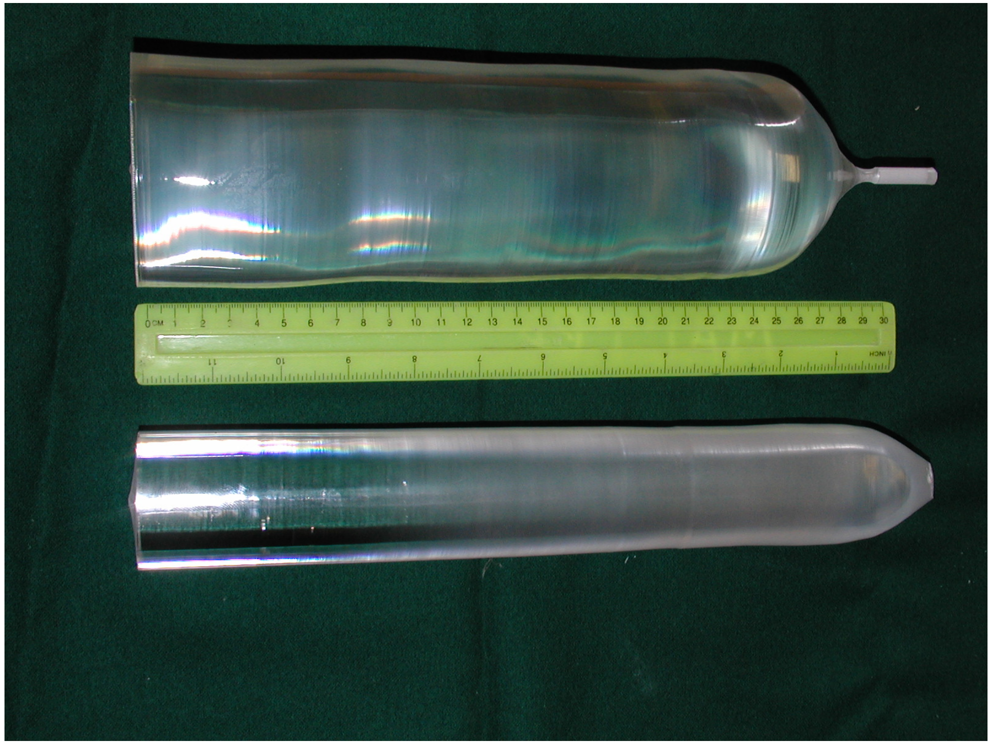
# IR RADIATION INDUCED ABSORPTION OF $Pb(W_{1-0.05}-Mo_{0.05})O_4$:La,Y AT ABSORBED DOSE 100Gy ($^{60}Co$) 293K



# POSSIBLE SOLUTIONS FOR End Caps

1. REPLASEMENT OF THE PWO SCINTILLATION CELLS BY PWMO IN THE AREA WITH HIGH η. NO CHANGE OF THE CRYSTAL DIMENSIONS IS.
2. USE OF THE LONGER PWMO CRYSTALS ($35X_0$ or 1, 5 NUCLEAR ITERACTOION LENGTH) TO TAKE A POSSIBLE BENEFIT OF DUAL READOUT.



**PWMO scintillator**

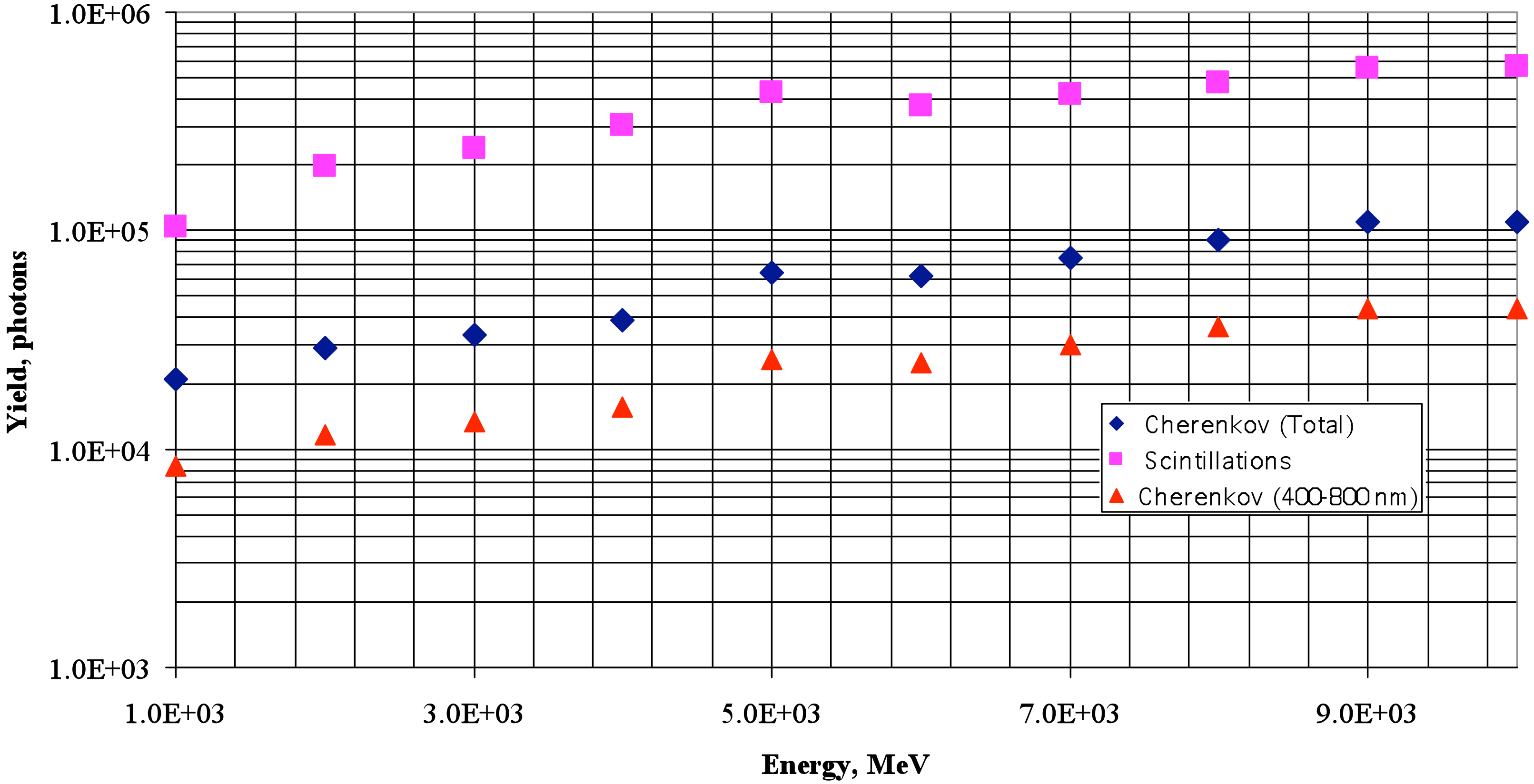
**electromagnetic calorimetry**

**PWMO Cherenkov radiator**

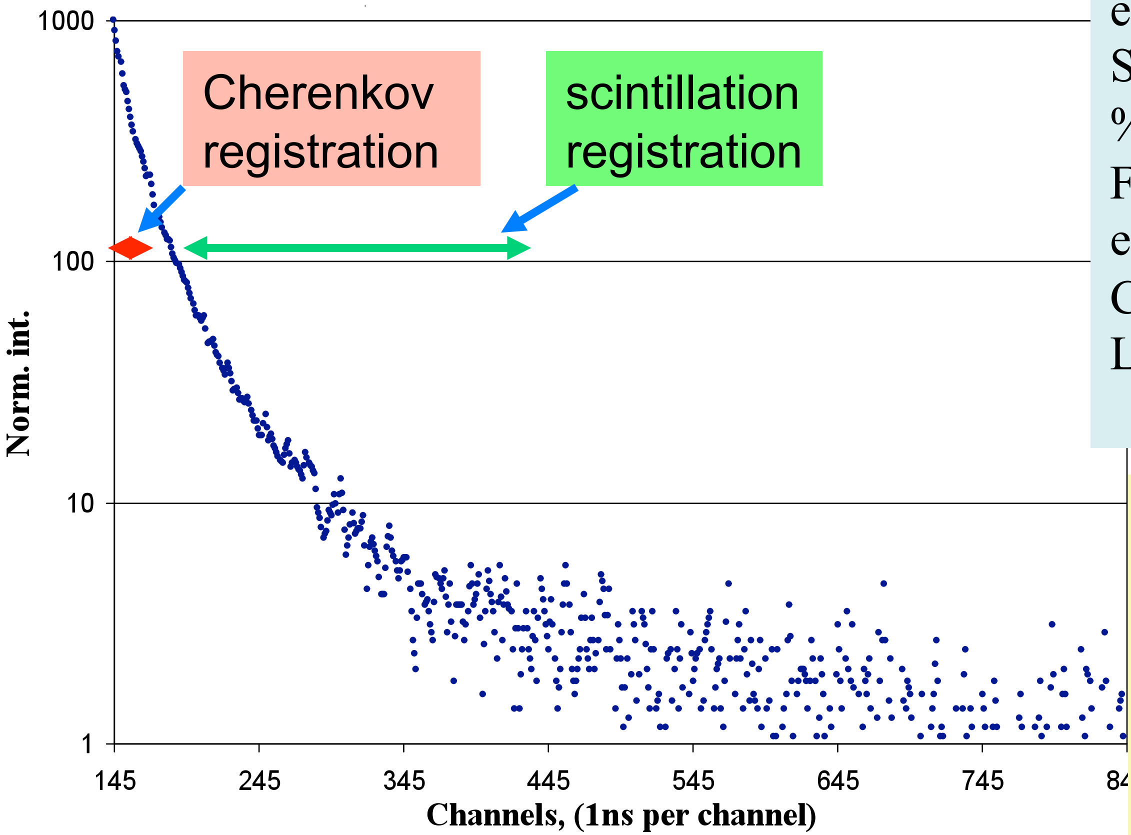
**preshower of charged hadrons**

**Laboratory production technology of crystals with length 30-32($33$-$36X_0$) cm is developed!**

# GEANT simulated yield of scintillation and Cherenkov light in 23 cm PWO crystal under pions



# **PWMO** ALLOWS DETECTION WITH TIME DISCRIMINATION OF SCINTILLATION AND CHERENKOV LIGHT




| Gate | 5 ns | 5-200 ns |
|---|---|---|
| Fraction of emitted Scintillation, % | 14 | 84 |
| Fraction of emitted Cherenkov Light, % | 100 | 0 |

**TIME DISCRIMINATION ALLOWS:**

**TO KEEP GOOD ENERGY RESOLUTION FOR γ, e**

**TO IMPROVE DISCRIMINATION OF CHERENKOV LIGHT FROM SCINTILLATION**

# COMPARISON OF THE WIDELY USED OXIDE SCINTILLATION MATERIALS AND PWMO

| Material | Application | $X_0$, cm | Band gap, eV | Cut off of the absorption spectrum, nm | Emission maximum , mn | Scintillation decay time constant , ns |
|---|---|---|---|---|---|---|
| LYSO:Ce | PET SCANNERS | 1.15 | 6 | 370 | 420 | 40 |
| BGO | PET SCANNERS, HEP | 1.12 | 5 | 280 | 505 | 300 |
| PWO | HEP | 0.89 | 4.33 | 325 | 420 | 6-10 |
| PWMO | HEP | 0.91 | 4.33 | 360 | 520 | 20-25 |

# FURTHER SHORT TERM PLANS

- **To determine an optimal substitution of W by Mo in PWMO crystal.**
- **To study point structure defects in the PWMO crystals.**
- **To study electronic excitations energy transfer mechanism in the crystals.**
- **To make samples for the measurements of optical transmission of PWMO crystals with hadrons.**

# CONCLUSIONS

- **$Pb(W_{1-X}-Mo_X)O_4$:La,Y or PWMO scintillation material has been developed. It is fast and radiation hard material with scintillation spectrum maximum at 520 nm.**

- **PWMO is a good candidate to be used at upgrade of End Cap parts of CMS ECAL.**