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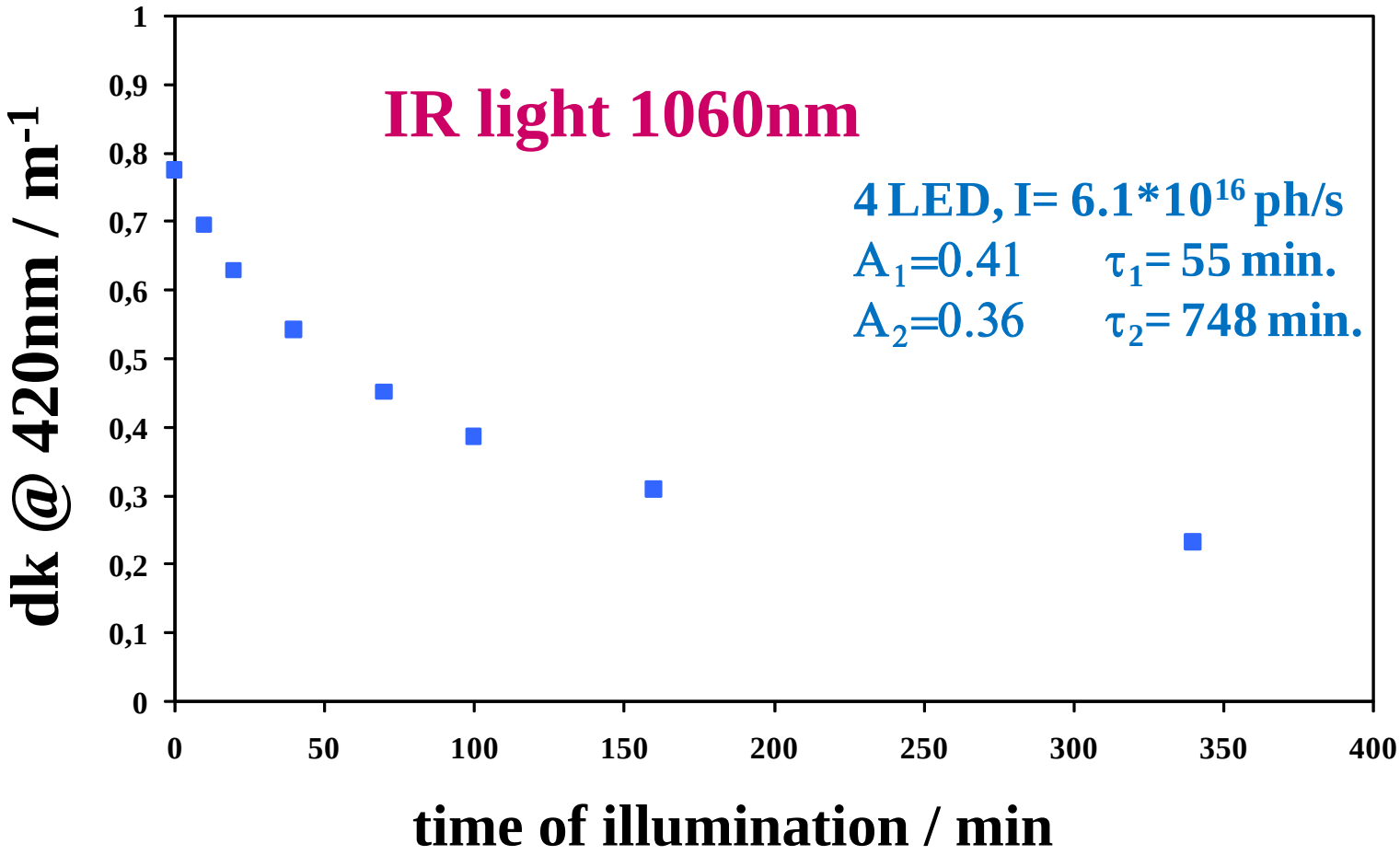
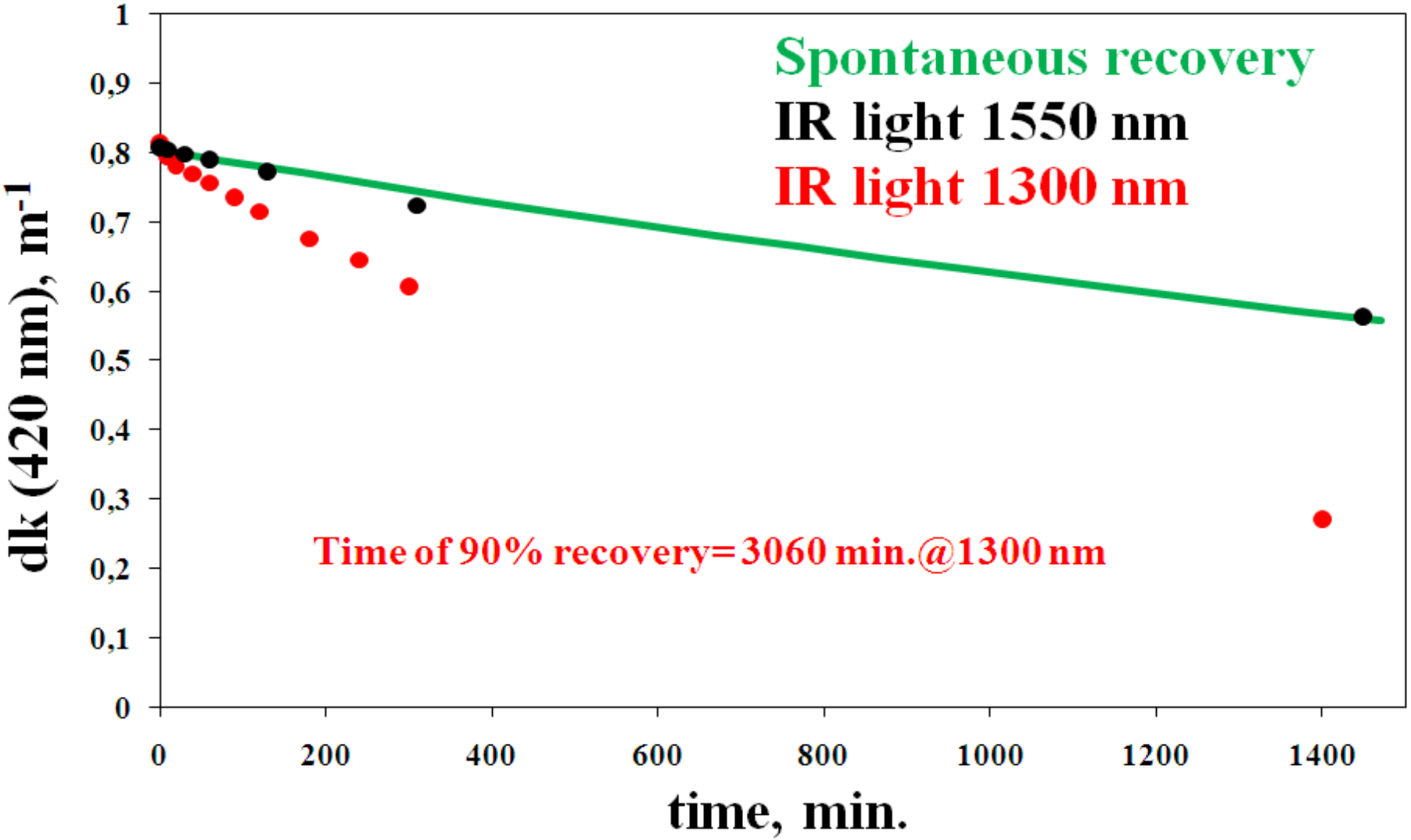
UNIVERSITÄT
GIESSEN

HIC for FAIR
Helmholtz International Center

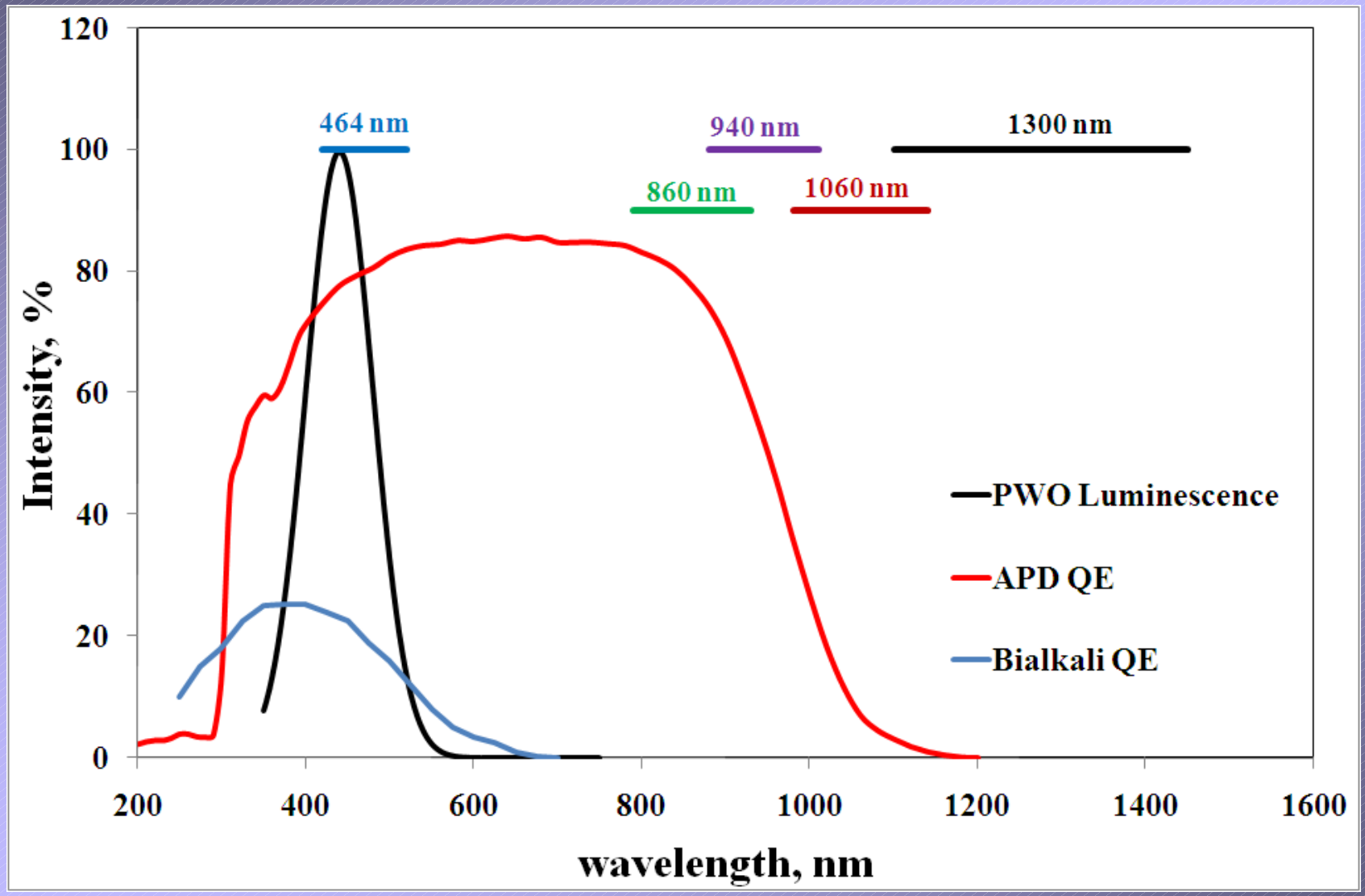
Radiation damage and recovery of PWO crystals

quantitative studies

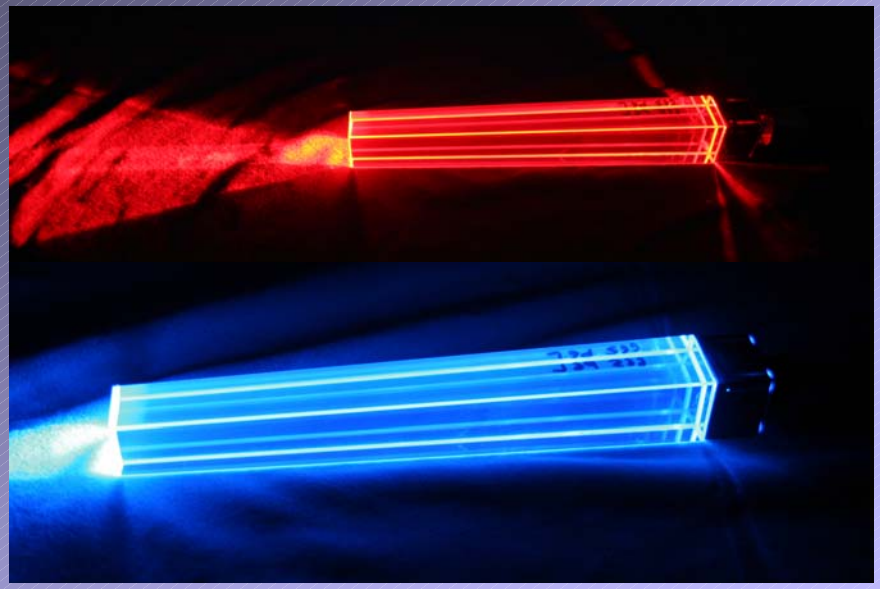


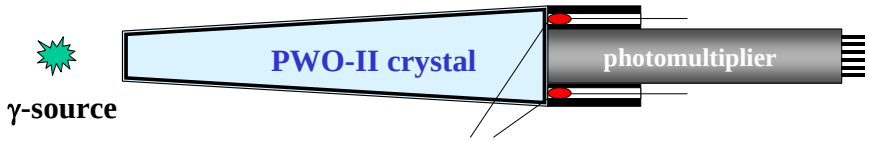

Spontaneous recovery
IR light 1550 nm
IR light 1300 nm
Time of 90% recovery=3060 min.@1300 nm
dk (420 nm), m-1
time, min.
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0
200
400
600
800
1000
1200
1400

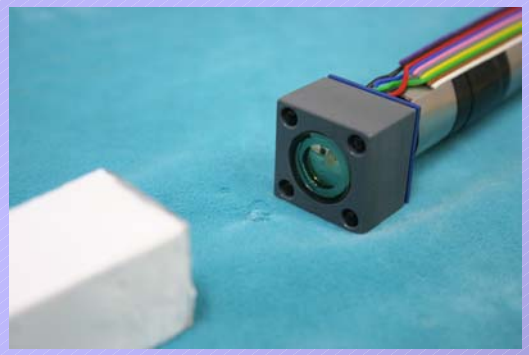
implications for final EMC operation



stimulated recovery of PWO @ T=-25°C

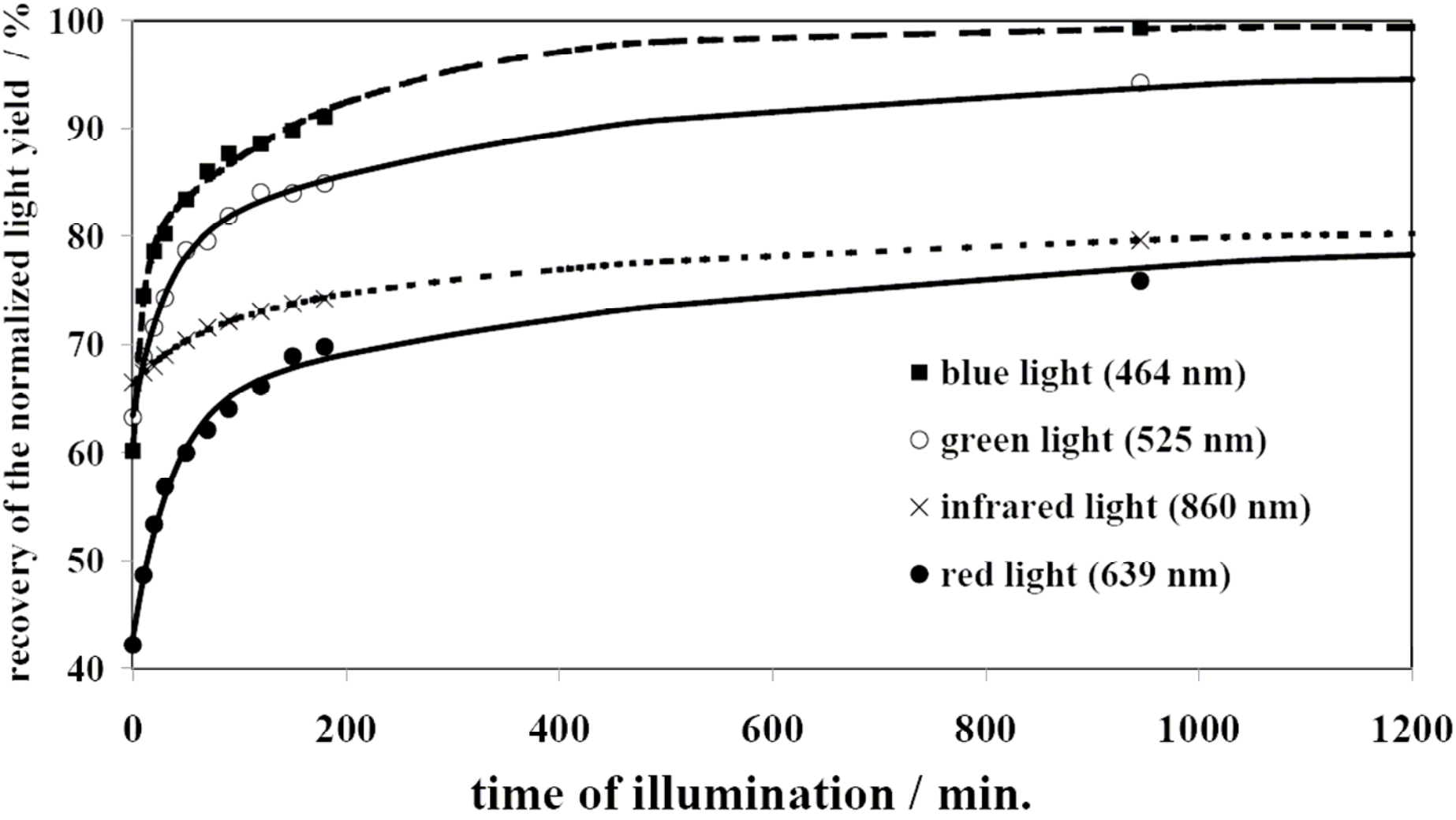






- measurement at T=-25°C
- irradiation with 30Gy (^{60}Co)
- damage and recovery characterized by light yield (^{60}Co)
- illumination with LEDs of different color
- crystals of different radiation hardness (dk)

stimulated recovery of PWO @ T=-25°C



understanding of the mechanism

recovery is a thermodynamical process

$$n_i = n_0 \exp(-w_T^i - \sum_j b_j I_j)t$$ with $$w_T^i = A_i \exp(-E_{TA}/kT)$$

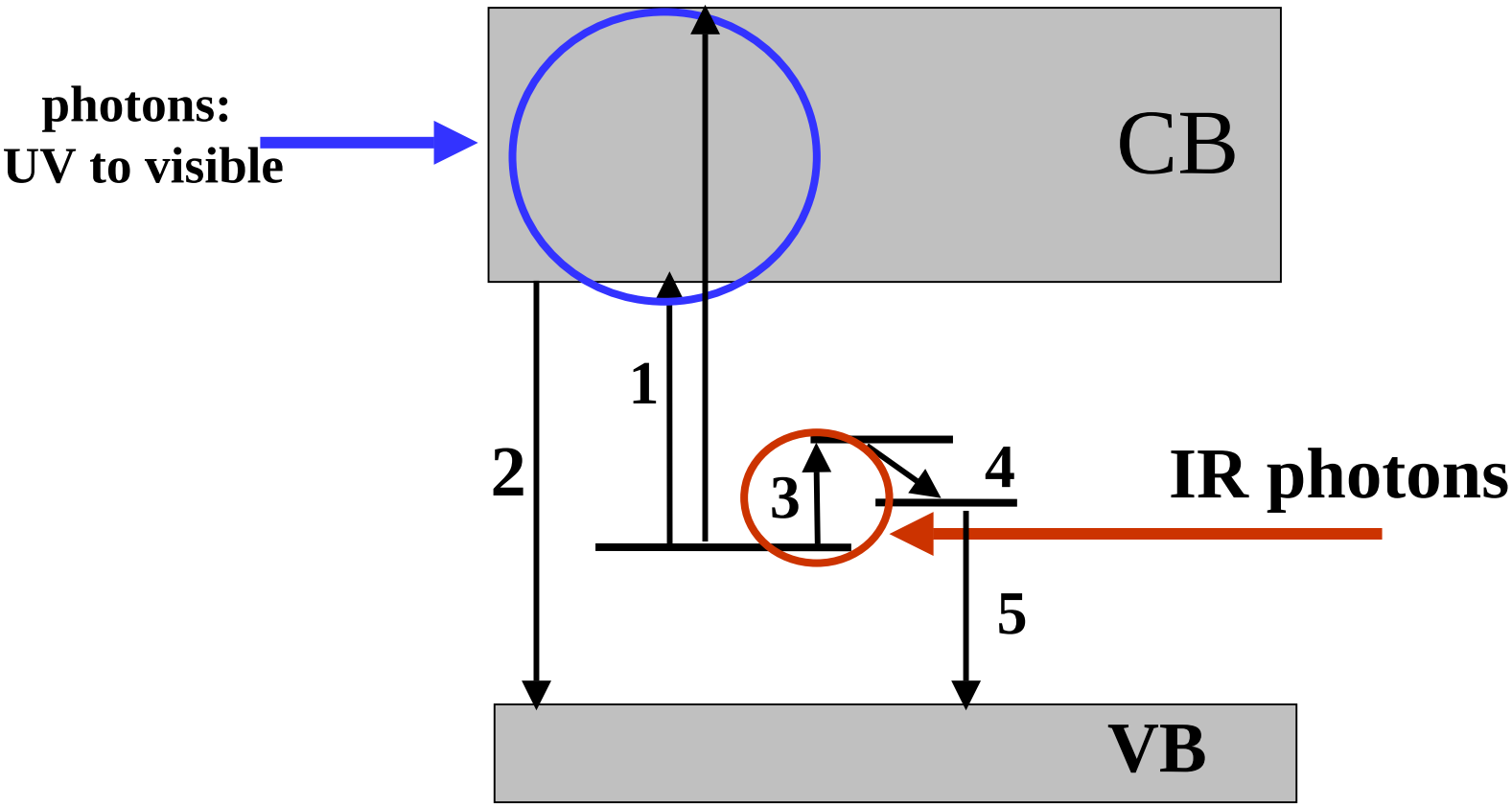
which can be accelerated by:

- significant heating
- photons: **optical bleaching** (ionization of color centers)
  stimulated recovery (intra-center resonant transition)
  initiated by minimum photon energy (IR)

necessary conditions:

- at least one energy level above the radiating state
- re-trapping should be strongly suppressed (small number of centers)

ionization and stimulation processes in PWO

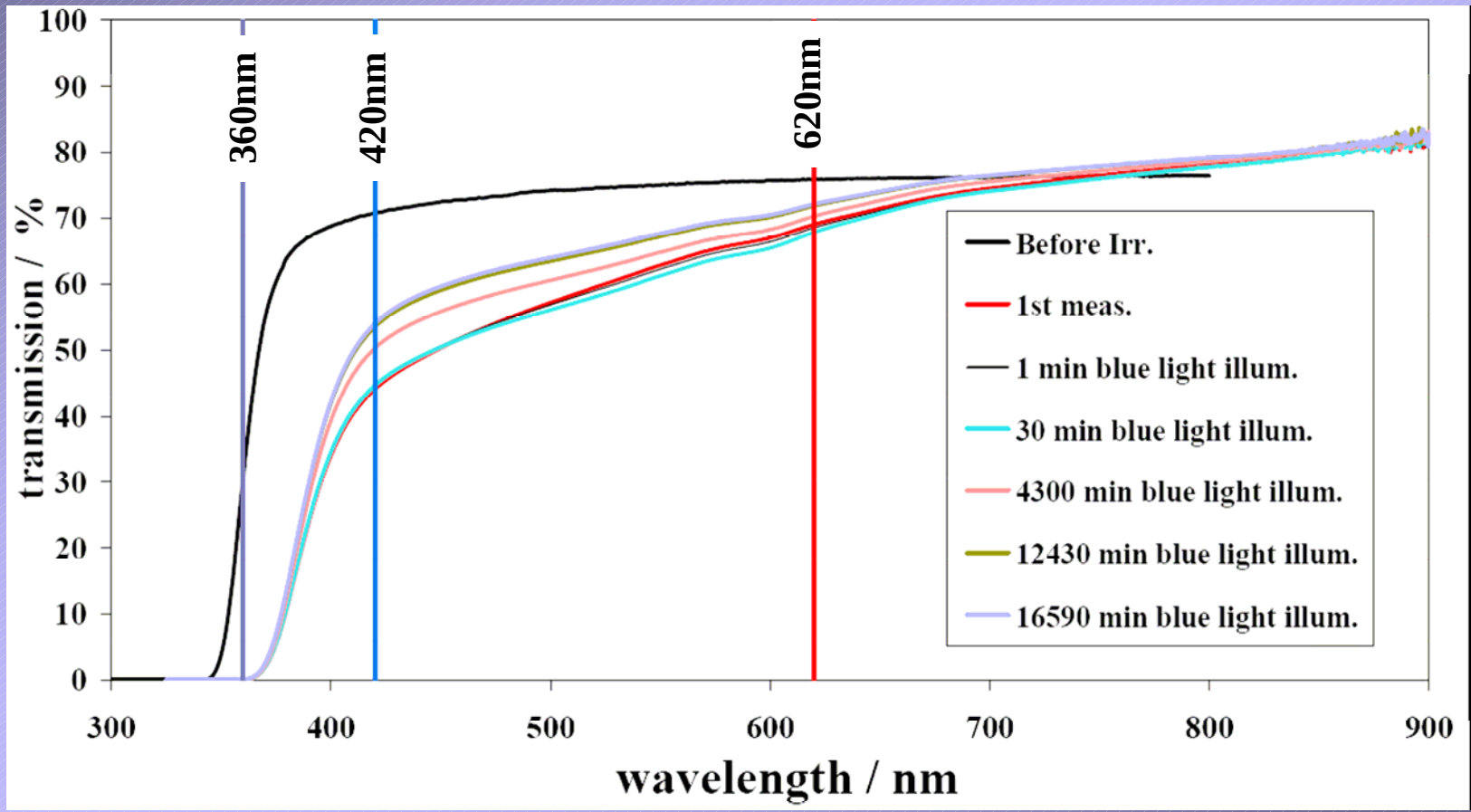


1 ionization of FTD_o, 2 radiative/non-radiative recombination,
3 intra-center absorption in FTD_o, 4 non-radiative relaxation,
5 radiative/non-radiative recombination of FTD_o.

first attempt of recovery of damage due to protons

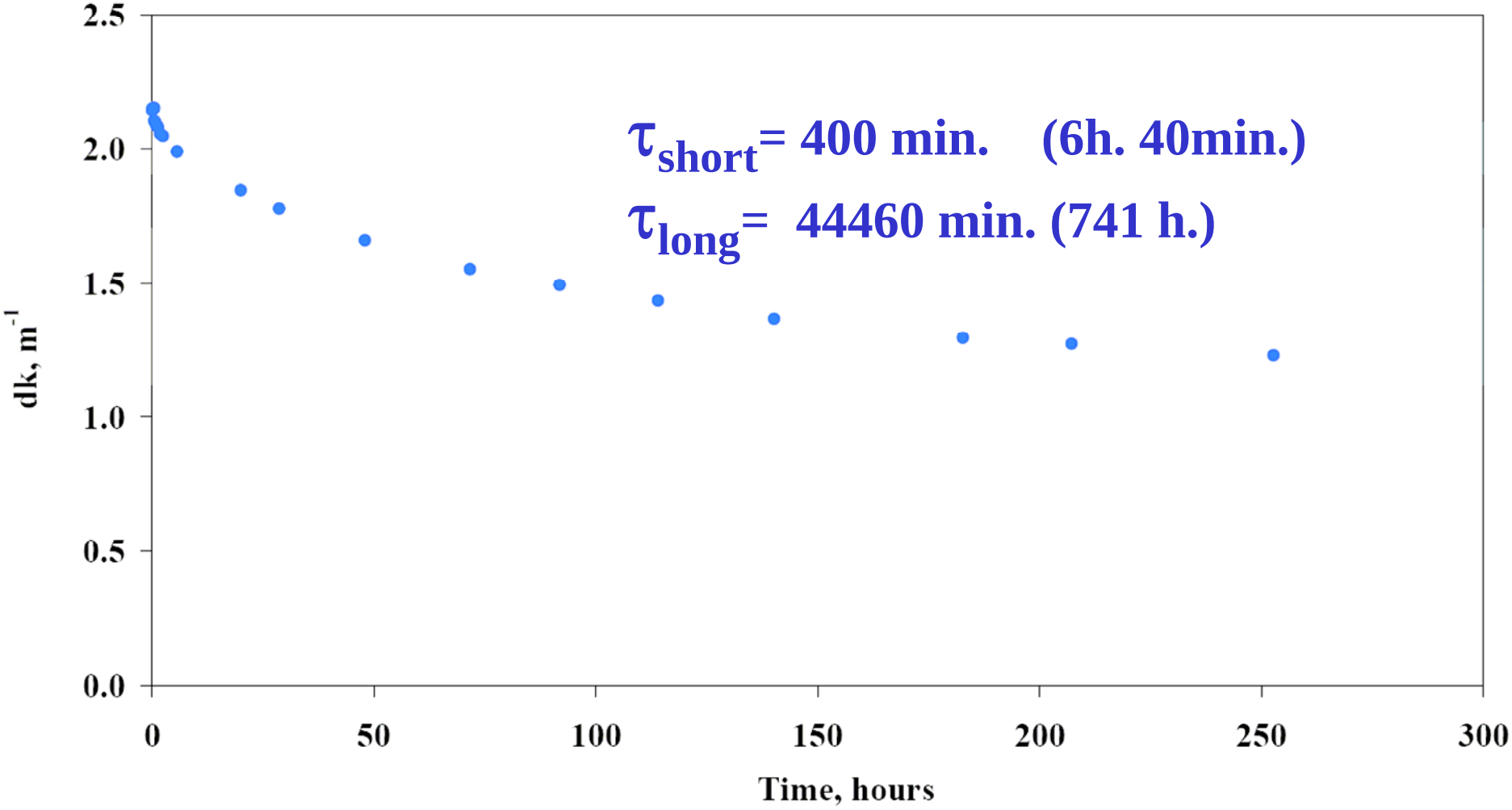
in collaboration with F. Nessi-Tedaldi et al.

total fluence of 24 GeV/c protons: $(9.87 \pm 0.69) \cdot 10^{12}$ p/cm^2

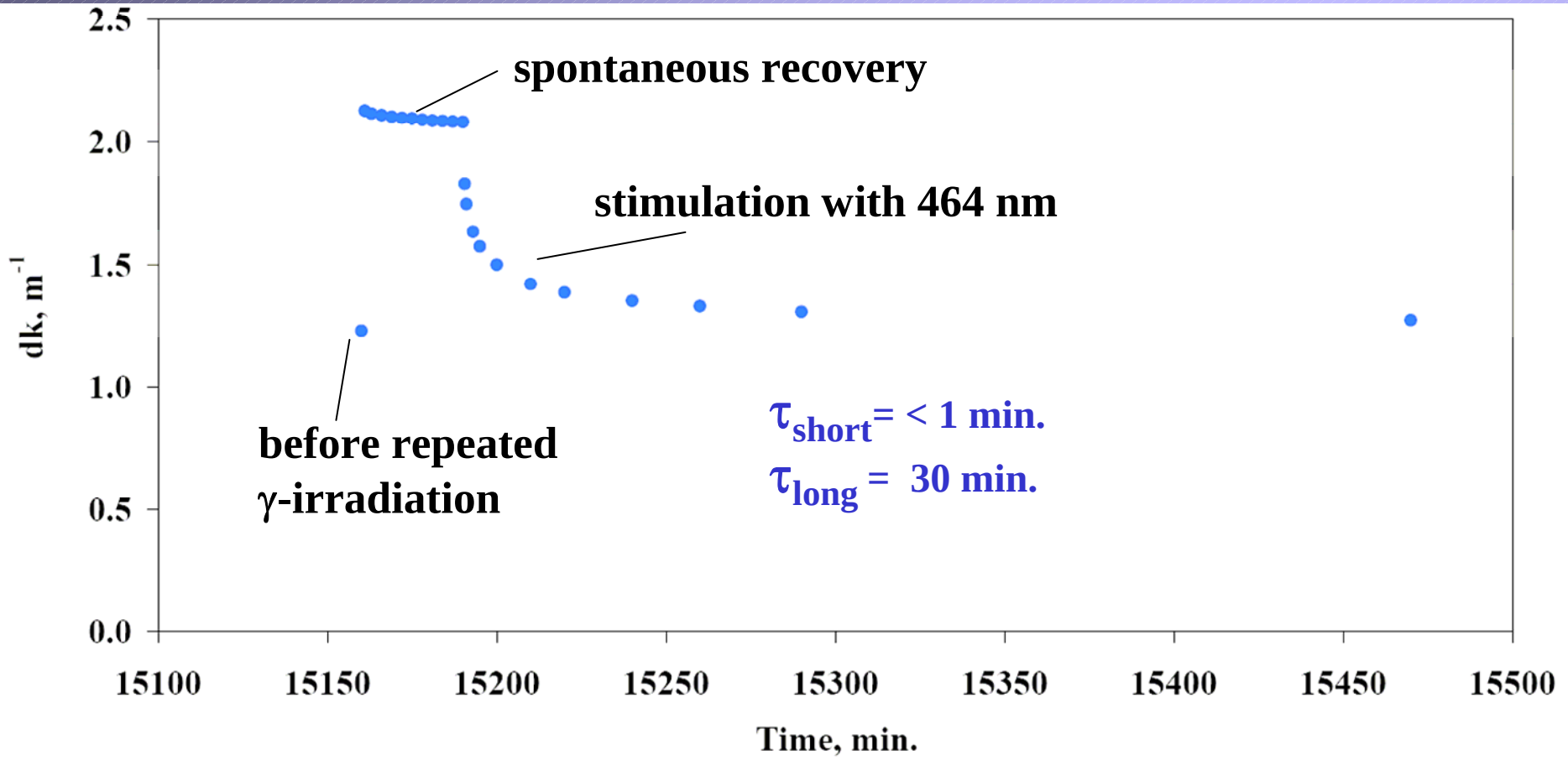


stimulation with blue light (464nm)

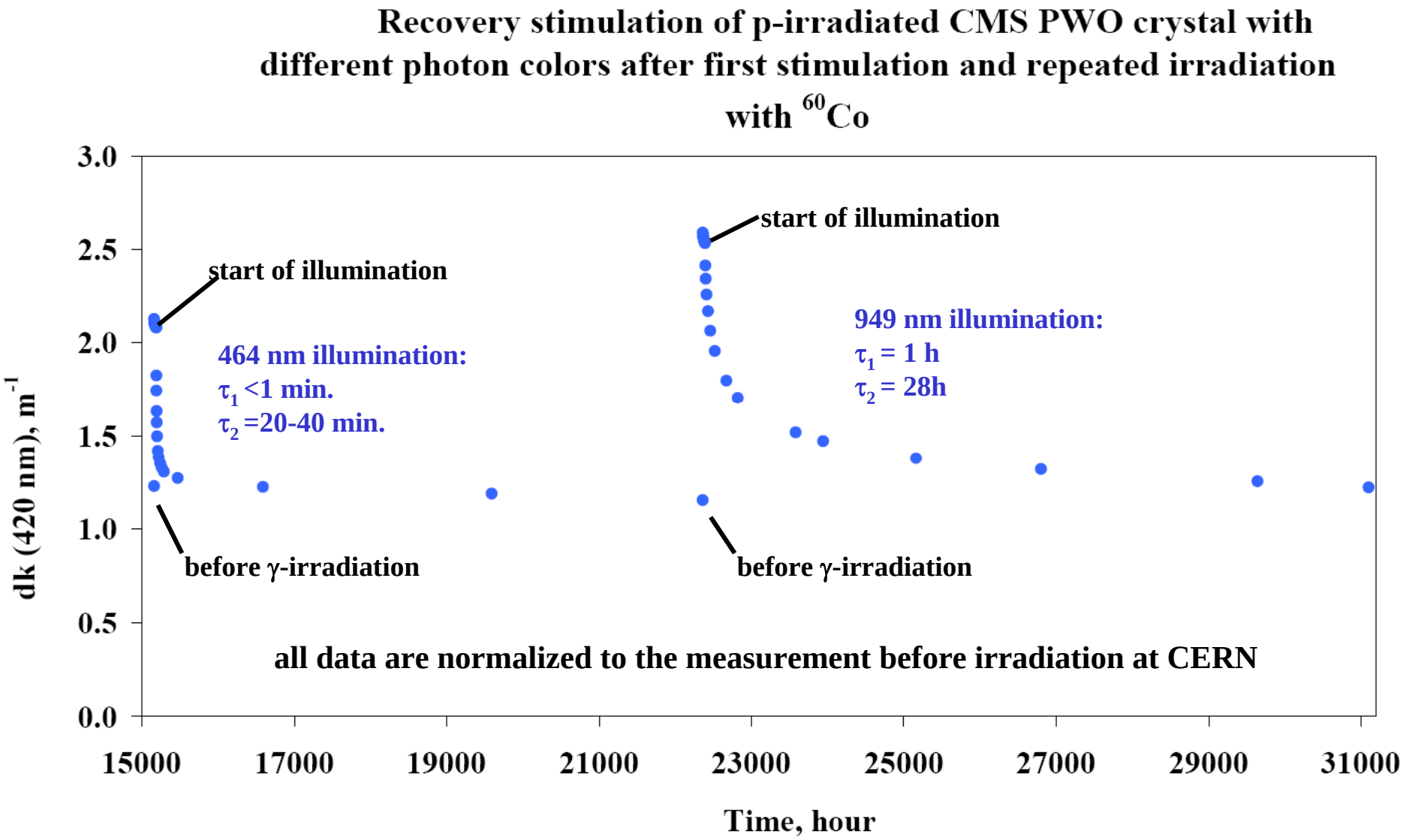
Fig.3 Stimulated recovery of the radiation induced absorption at 420nm of CMS EE PWO crystal, position of measurements #3



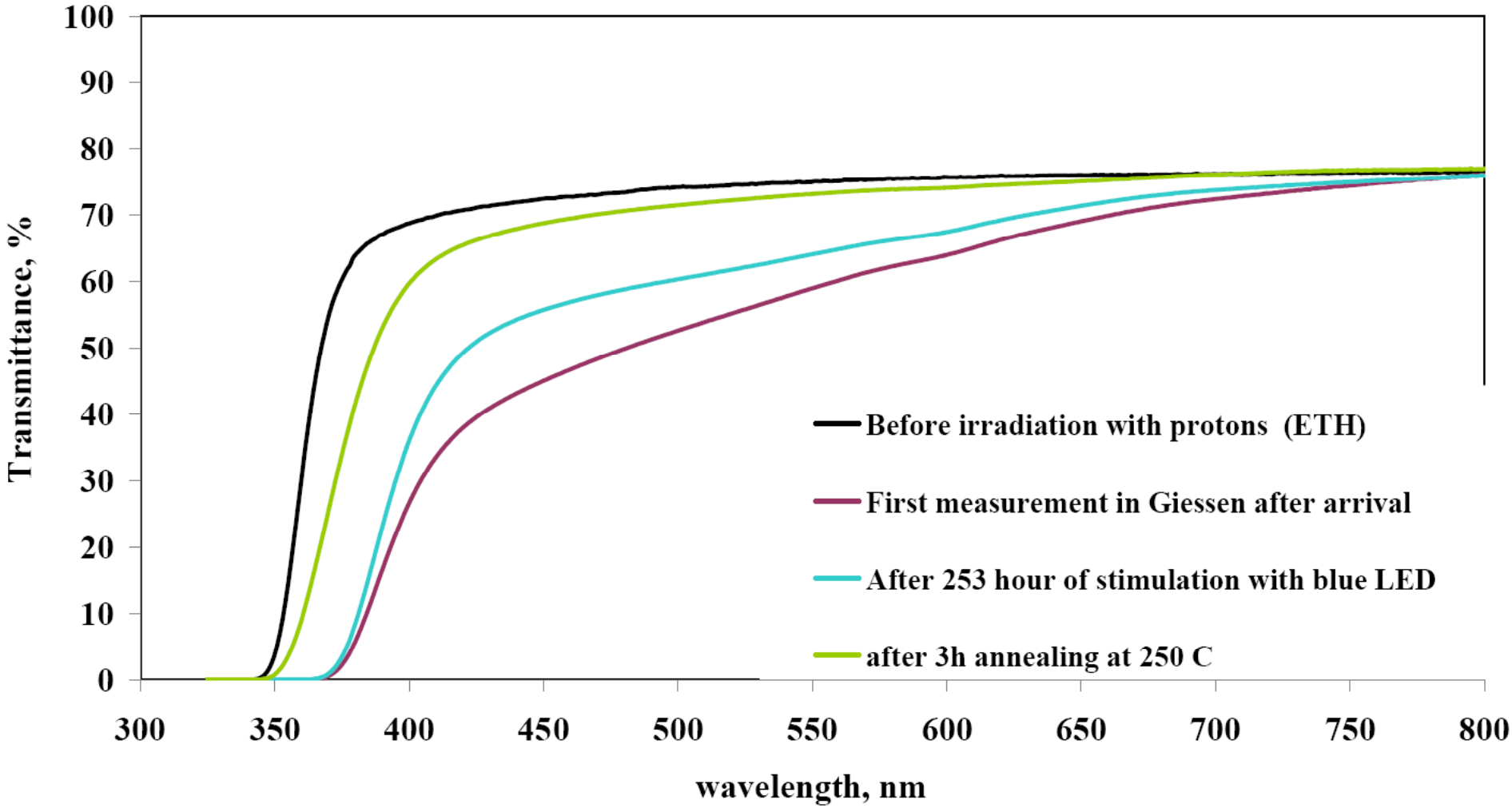
irradiation with 30Gy (^{60}Co) and subsequent recovery with blue light

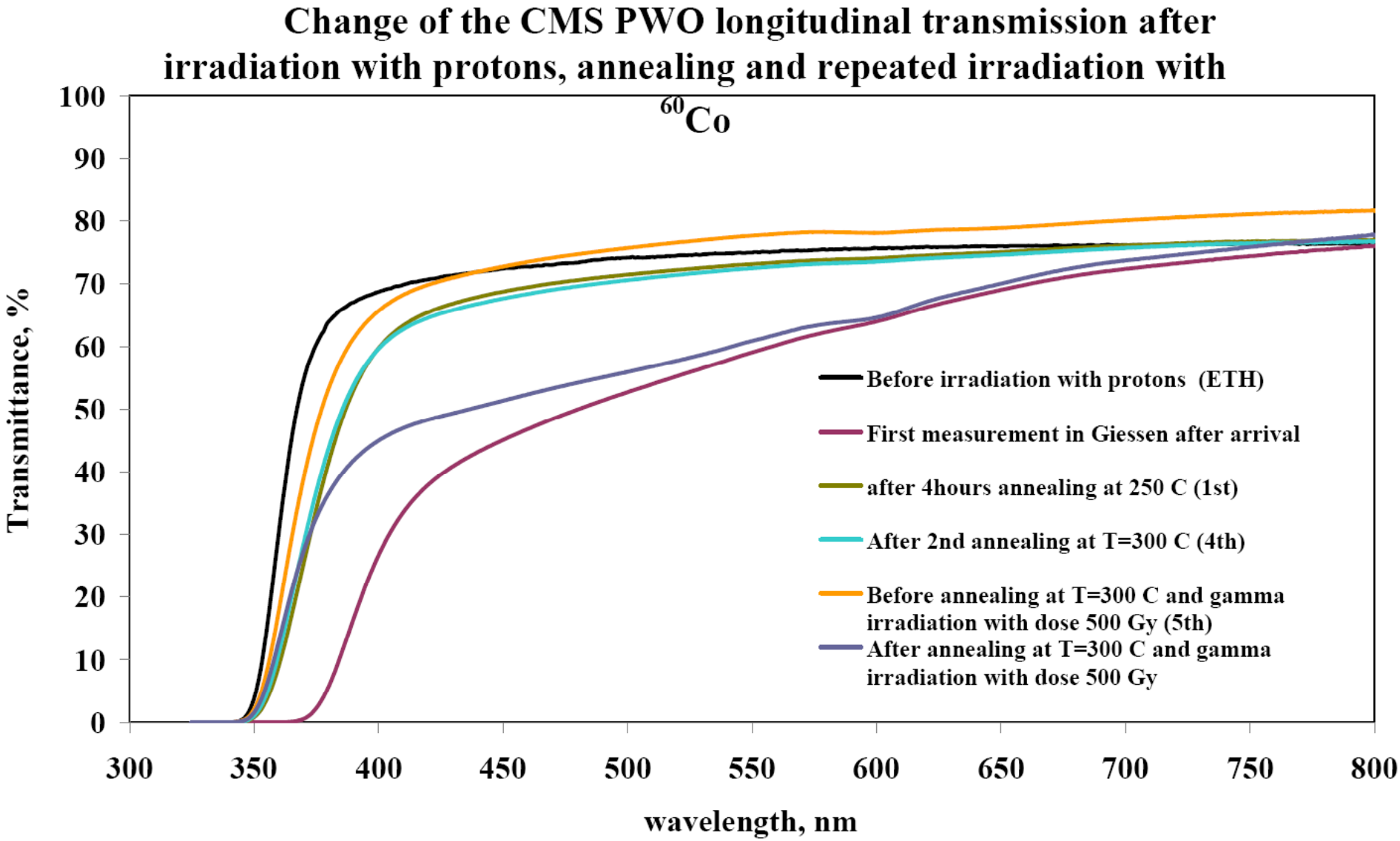


irradiation with 30Gy (^{60}Co) and subsequent recovery



Longitudinal transmission spectra of the CMS PWO crystal before and after p-irradiation, stimulation and annealing at 250 C

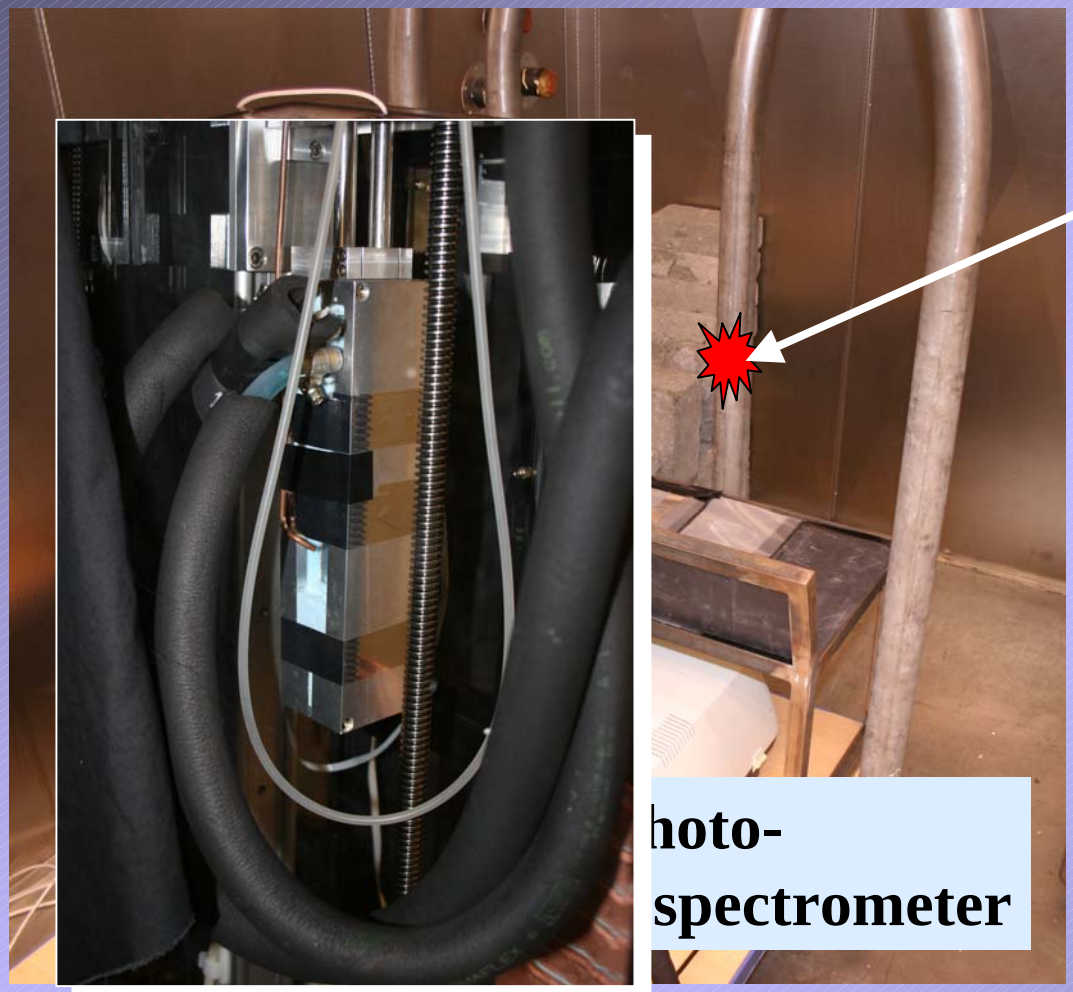



Change of the CMS PWO longitudinal transmission after irradiation with protons, annealing and repeated irradiation with ^{60}Co
Transmittance, %
100
90
80
70
60
50
40
30
20
10
0
300
350
400
450
500
550
600
650
700
750
800
wavelength, nm
Before irradiation with protons (ETH)
First measurement in Giessen after arrival
after 4hours annealing at 250 C (1st)
After 2nd annealing at T=300 C (4th)
Before annealing at T=300 C and gamma irradiation with dose 500 Gy (5th)
After annealing at T=300 C and gamma irradiation with dose 500 Gy

ongoing studies

1. **EPR studies of**
   1. PWO-II and PWO-I crystals before irradiation
   2. Studies of irradiation with photons or protons
   3. Impact of stimulated recovery
2. **Direct measurement of optical transmission of cooled crystals**
   1. Before/after irradiation
   2. Measurement of recovery times
   3. Impact of stimulated recovery
3. **Determination of optimum wavelength and photon flux**

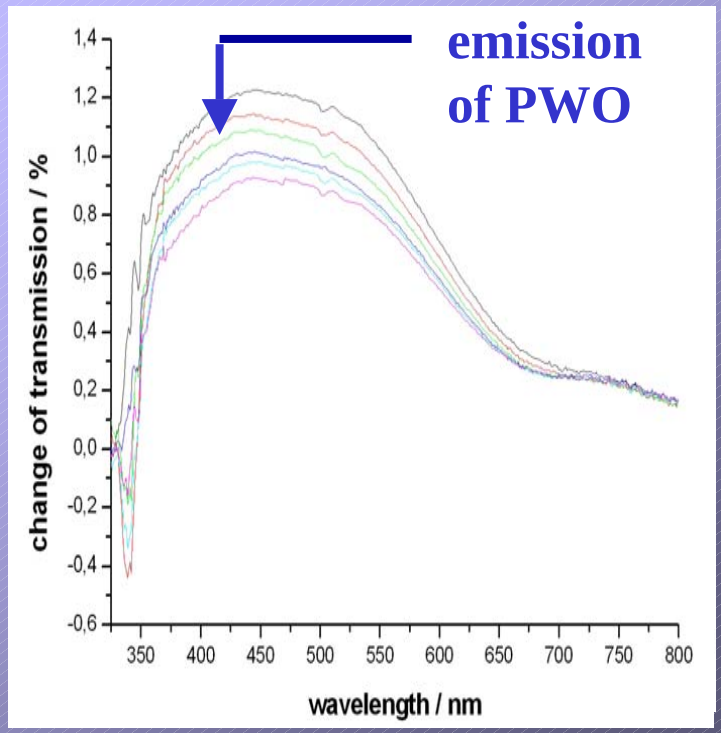
radiation center @ Giessen



hoto-
spectrometer

up to 5 γ-sources
^{60}Co (~1.25MeV)

$$\frac{dN}{dt} = 2.7 \cdot 10^{13}\,Bq$$



irradiation and recovery
of cooled crystals

radiation induced absorption Δk