Status on $PbWO_4$ Crystals

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and for the PANDA collaboration

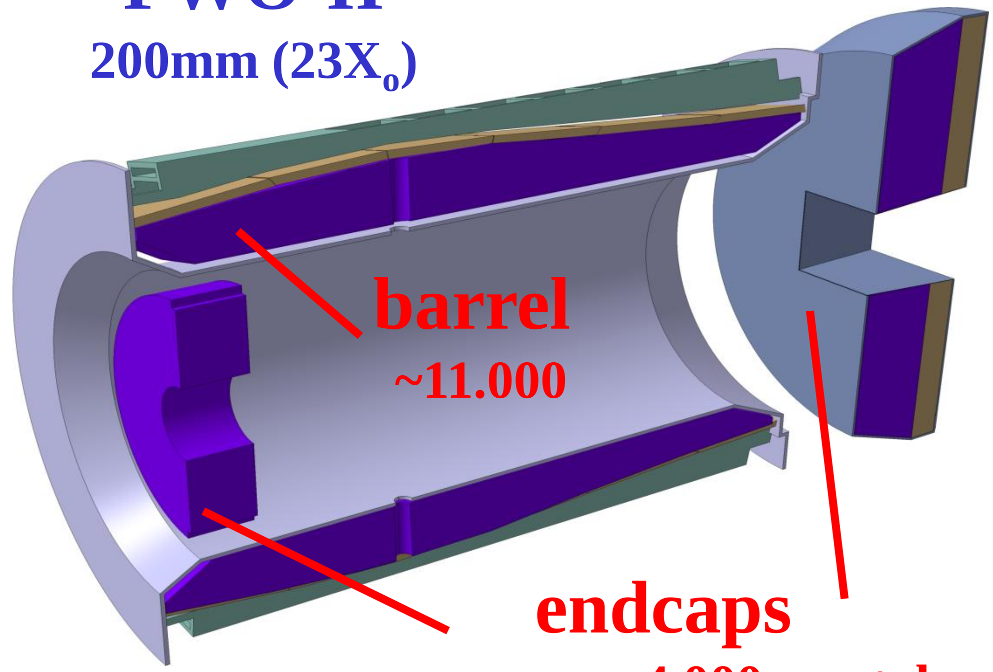
- The PANDA requirements
- The properties of PWO-II based on BTCP production
- Alternative Manufacturer
  - SICCAS
  - CRYTUR
- Alternative Scintillators

• the PANDA detector at FAIR

- photon detection with
  over
  10MeV < E
- high count-rate capa
- nearly 4π coverag
- sufficient radia
- timing information for

PWO-II

200mm ($23X_o$)



Target Spectrometer

4π detector for spectroscopy and reaction dynamics with antiprotons

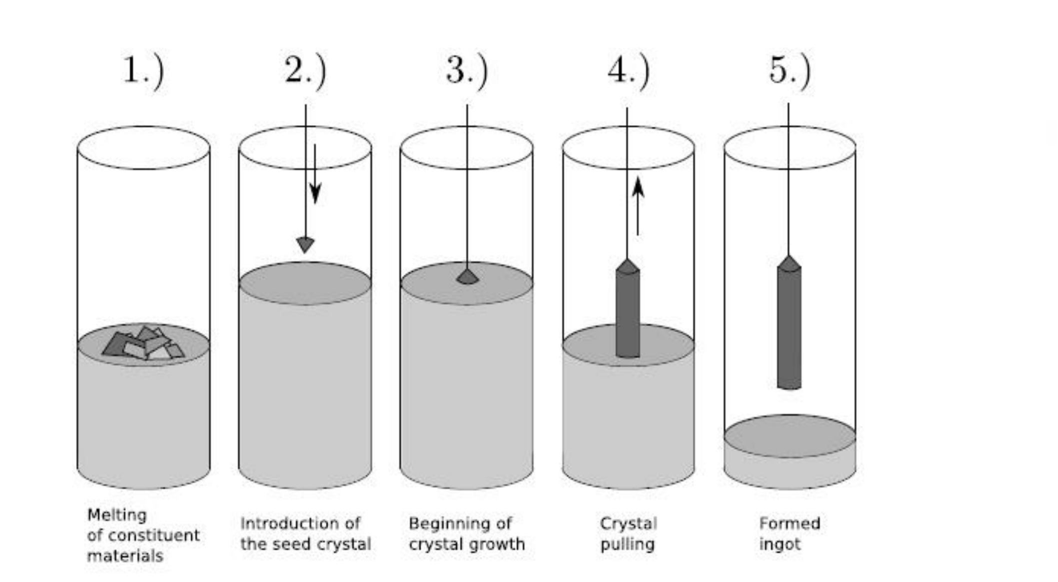
the Target Spectrometer:
based on high-quality PWO-II

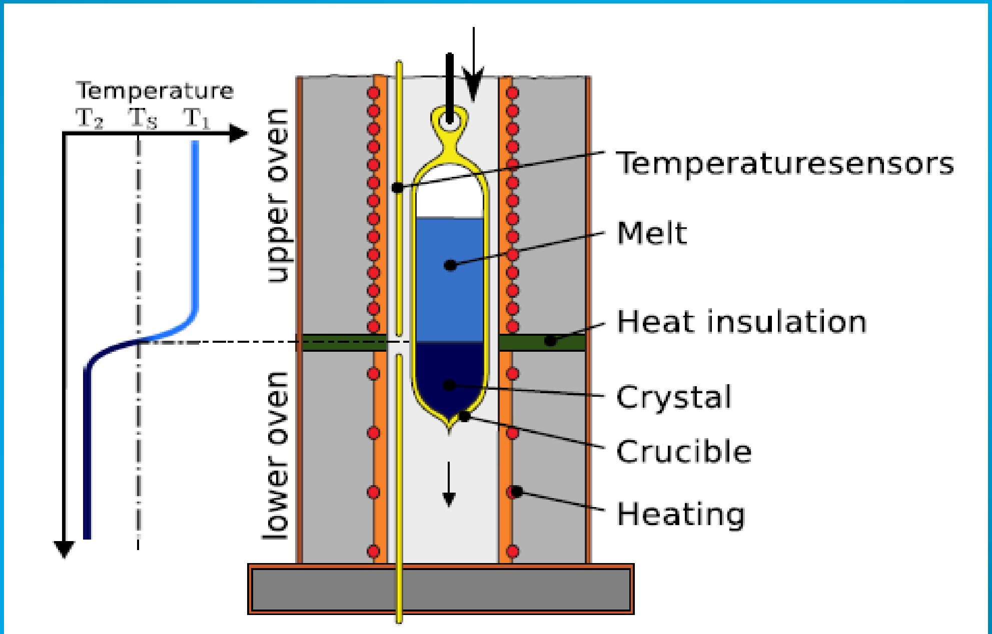
- physical goals of PANDA require further development

	PWO-I (CMS)	PWO-II (PANDA)
luminescence maximum, nm	420	420
La, Y concentration level, ppm	100	40
expected energy range of EMC	150MeV - 1TeV	10MeV - 10GeV
light yield, phe/MeV at room temperature	8-12	17-22
EMC operating temperature, °C	+18	-25
energy resolution of EMC at 1GeV, %	3,4	2,0

- **how to produce crystals**

Czochralsky-method

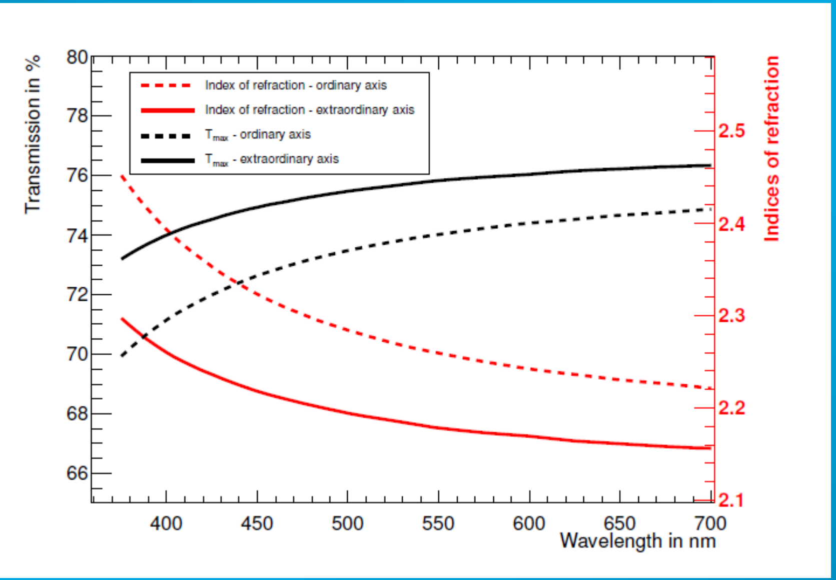




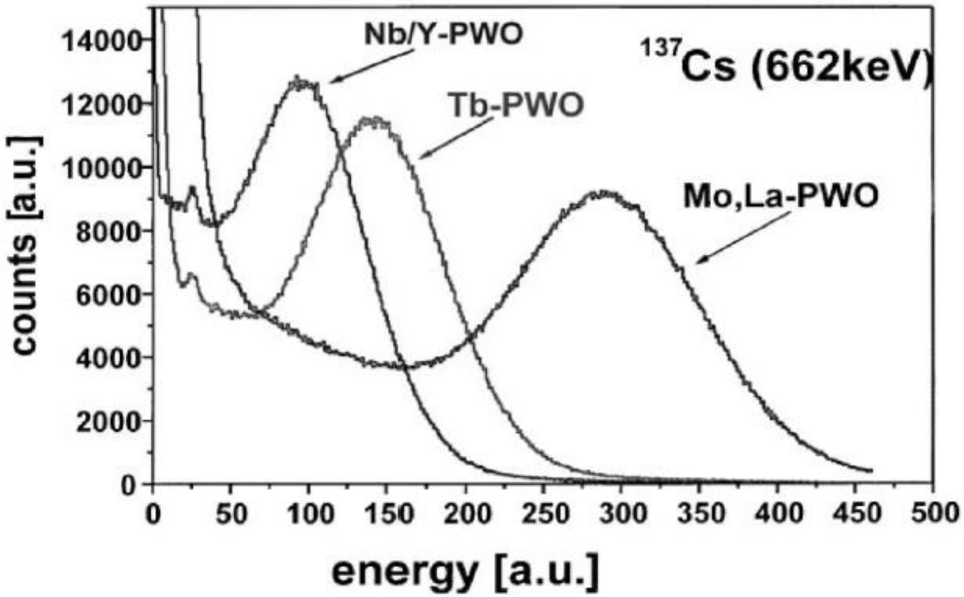
Bridgeman-technology

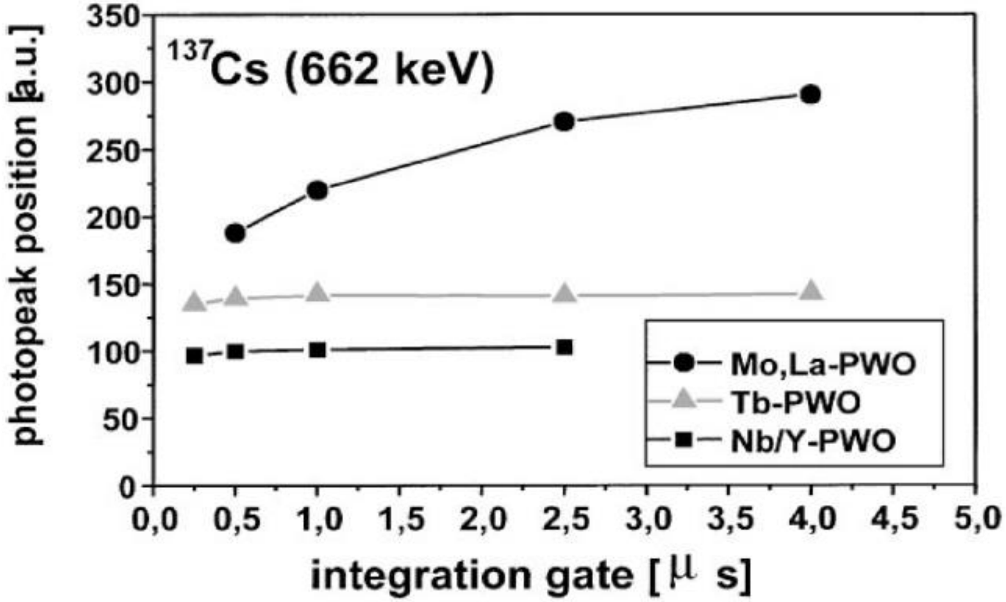
• some general remarks on PWO

index of refraction



increased light yield due to doping



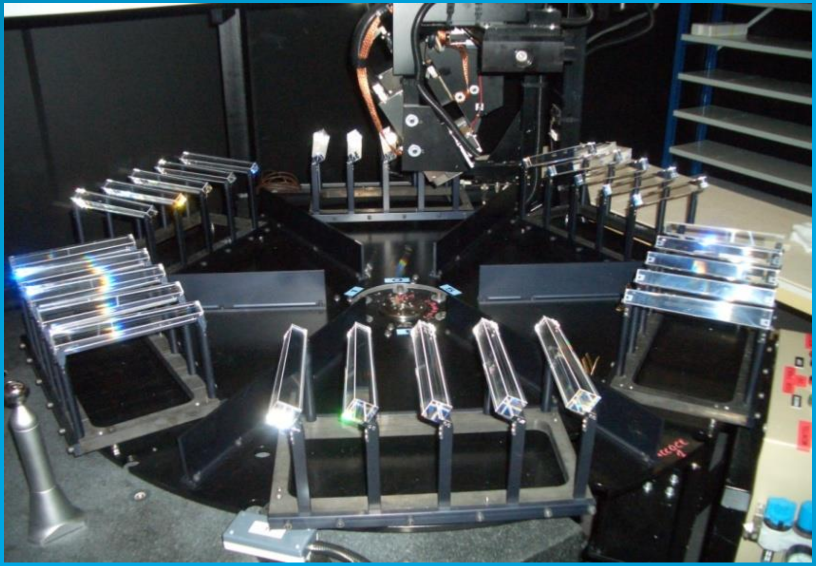


- **the quality requirements**

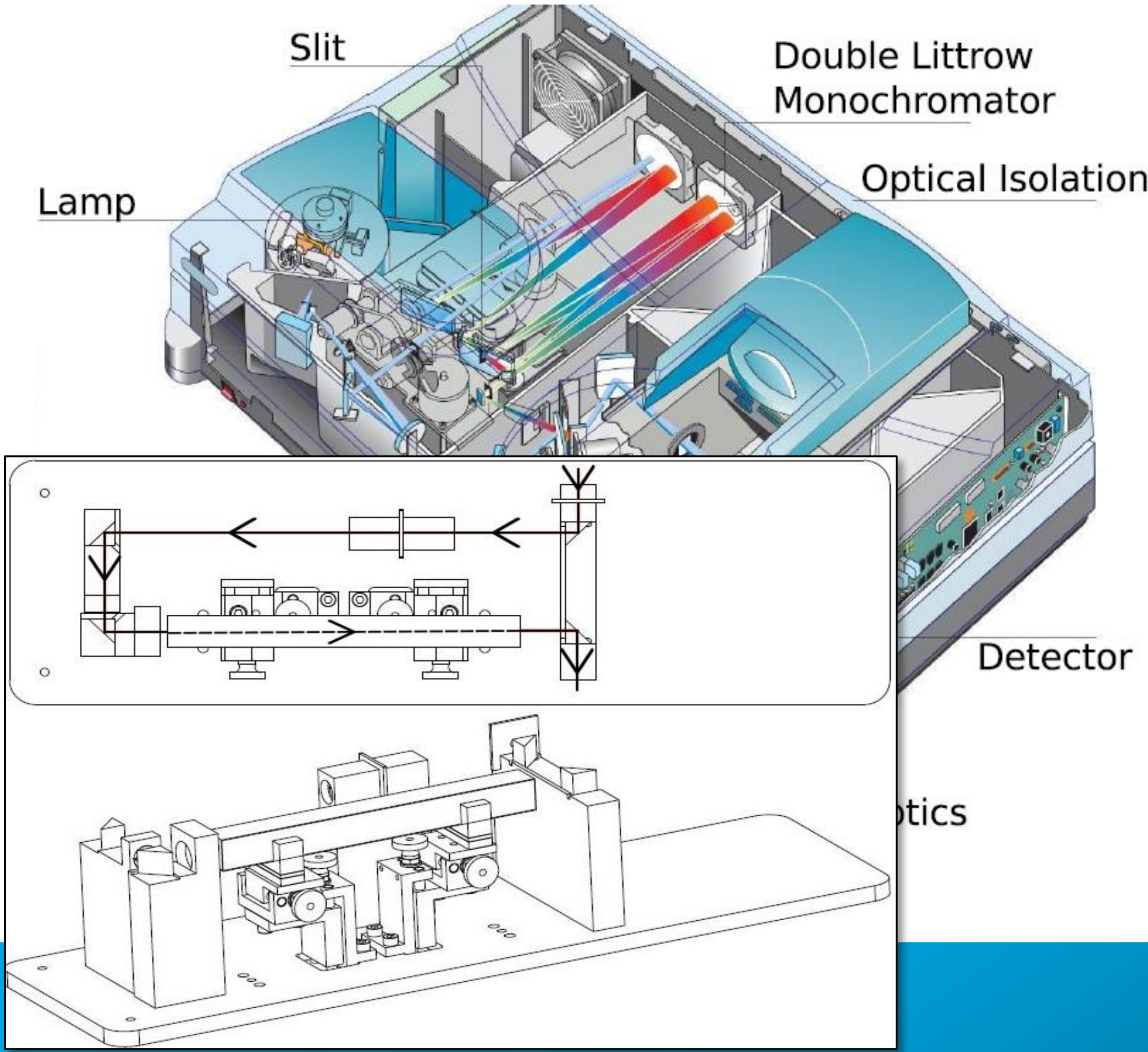
Property	Unit	Limit
longitudinal transmission at 360 nm	%	≥ 35
longitudinal transmission at 420 nm	%	≥ 60
longitudinal transmission at 620 nm	%	≥ 70
non-uniformity of transversal transmission at T= 50%	nm	≤ 3
LY at T= 18 °C	phe/MeV	≥ 16.0
LY(100 ns)/LY(1 μs)		≥ 0.9
induced absorption coefficient Δk at room temperature, integral dose 30 Gy	m^{-1}	≤ 1.1
mean value of Δk distribution for each lot of delivery	m^{-1}	≤ 0.75

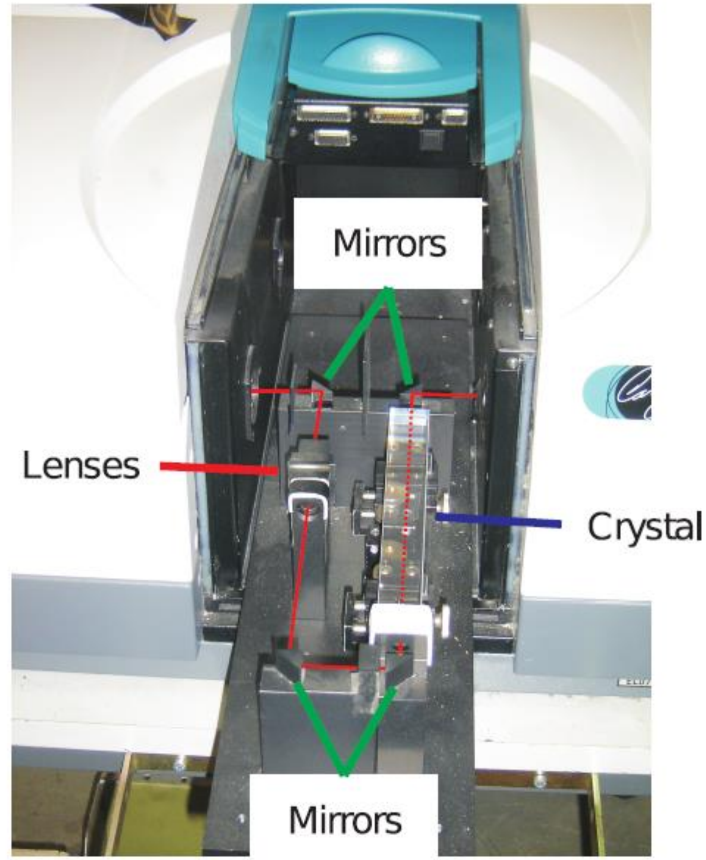
• production at BTCP

• quality control and performance



• the optical transmission

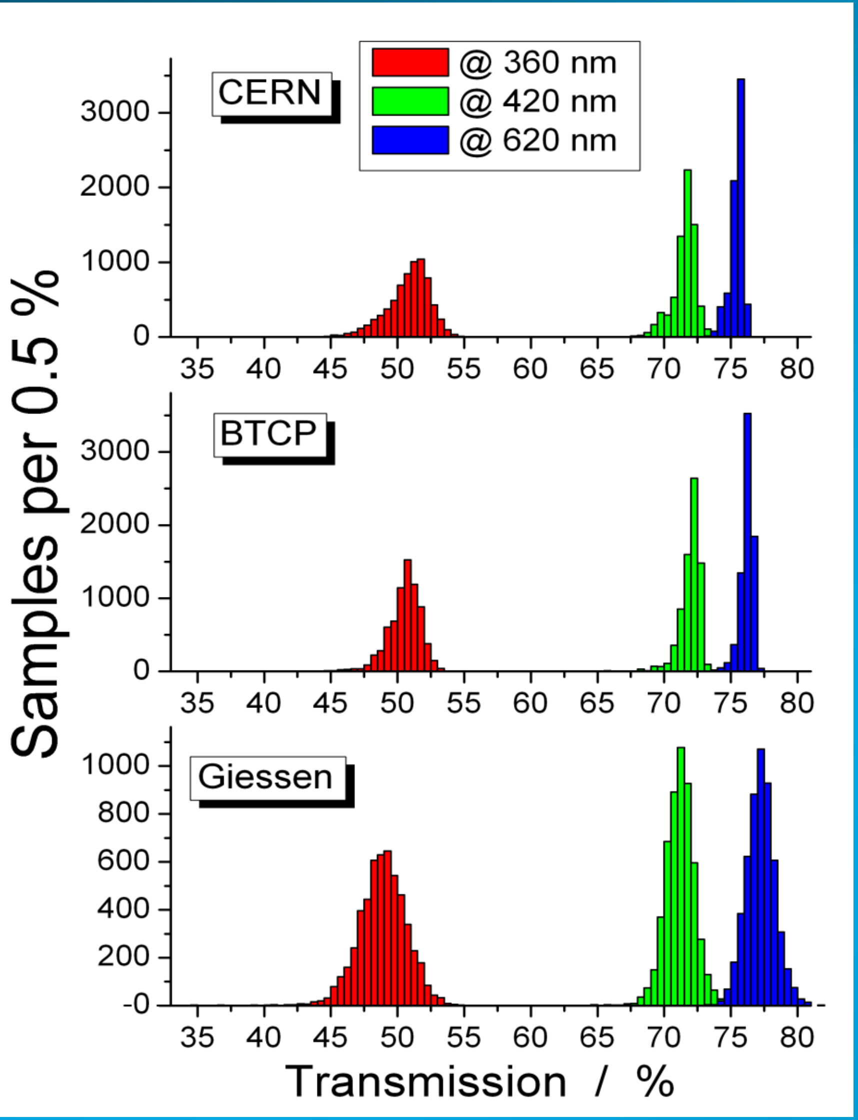




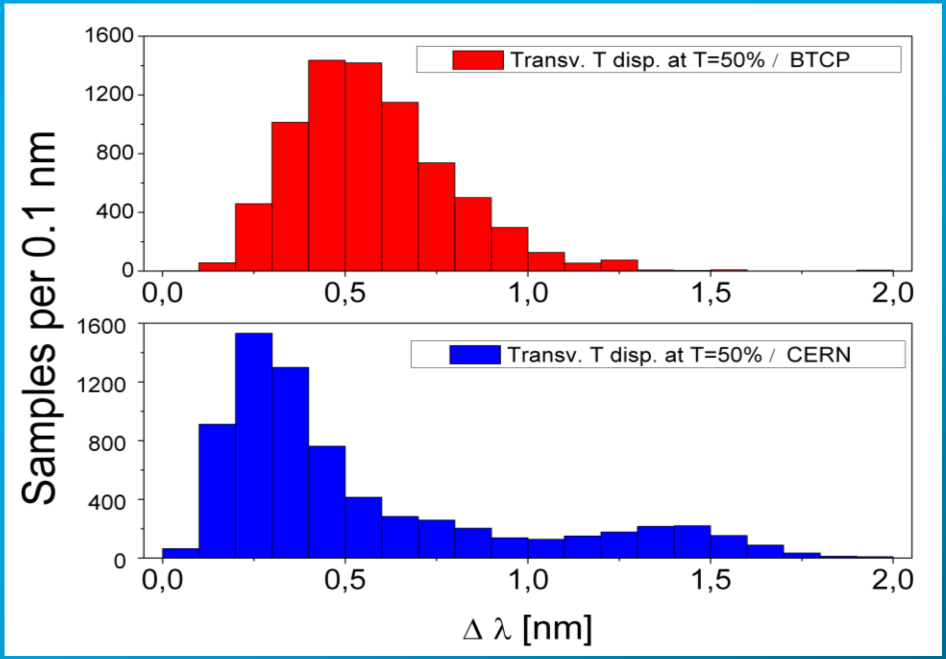
(b) Additional optics by [29].

- **the optical transmission**

property	condition	specification
longitudinal transmission	at 360nm	$\geq 35\%$
	at 420nm	$\geq 60\%$
	at 620nm	$\geq 70\%$
uniformity of transv. transmission	wavelength at $T = 50\%$	$\Delta\lambda \leq 3$nm

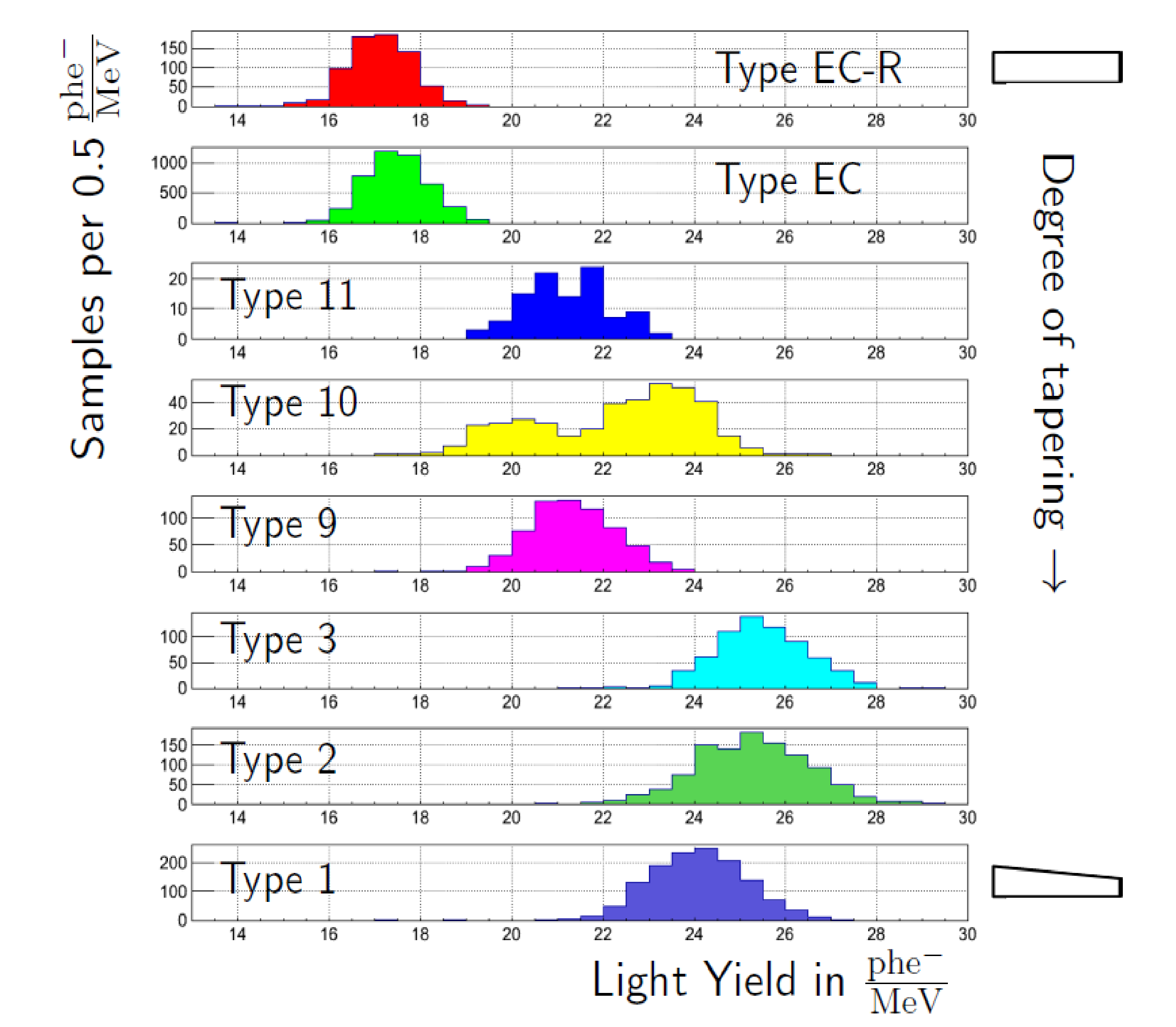


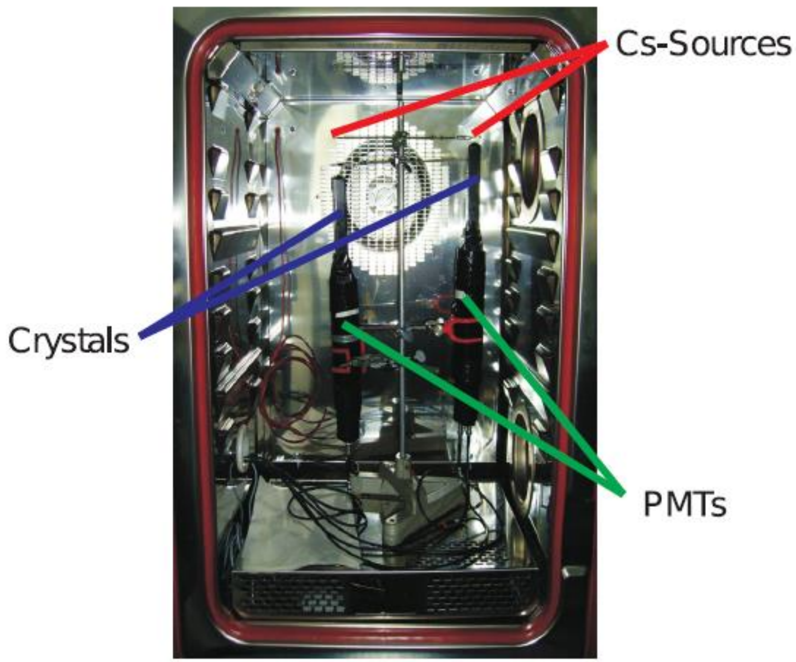
longitudinal transmission



homogeneity

- **light yield measurement**

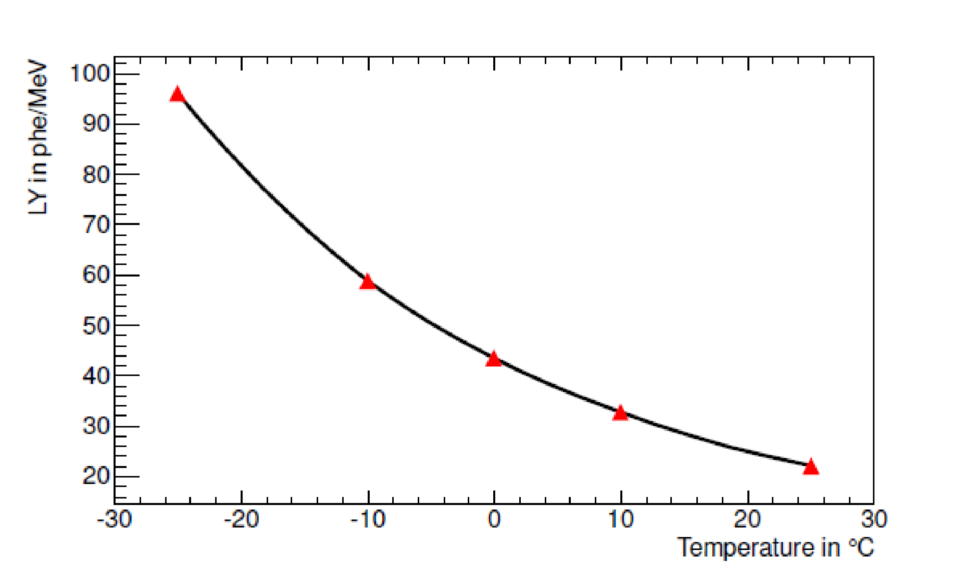


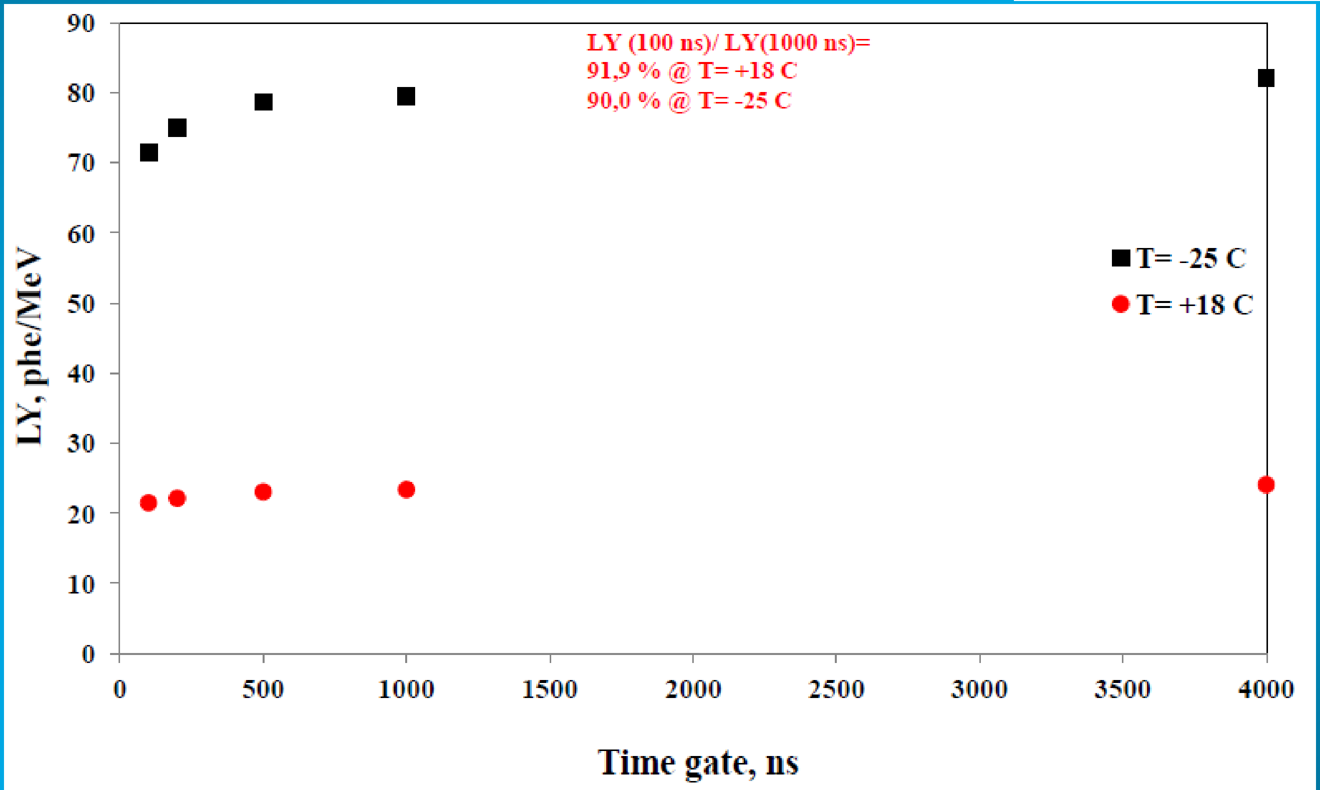


@ 18°C

- **light yield measurement**

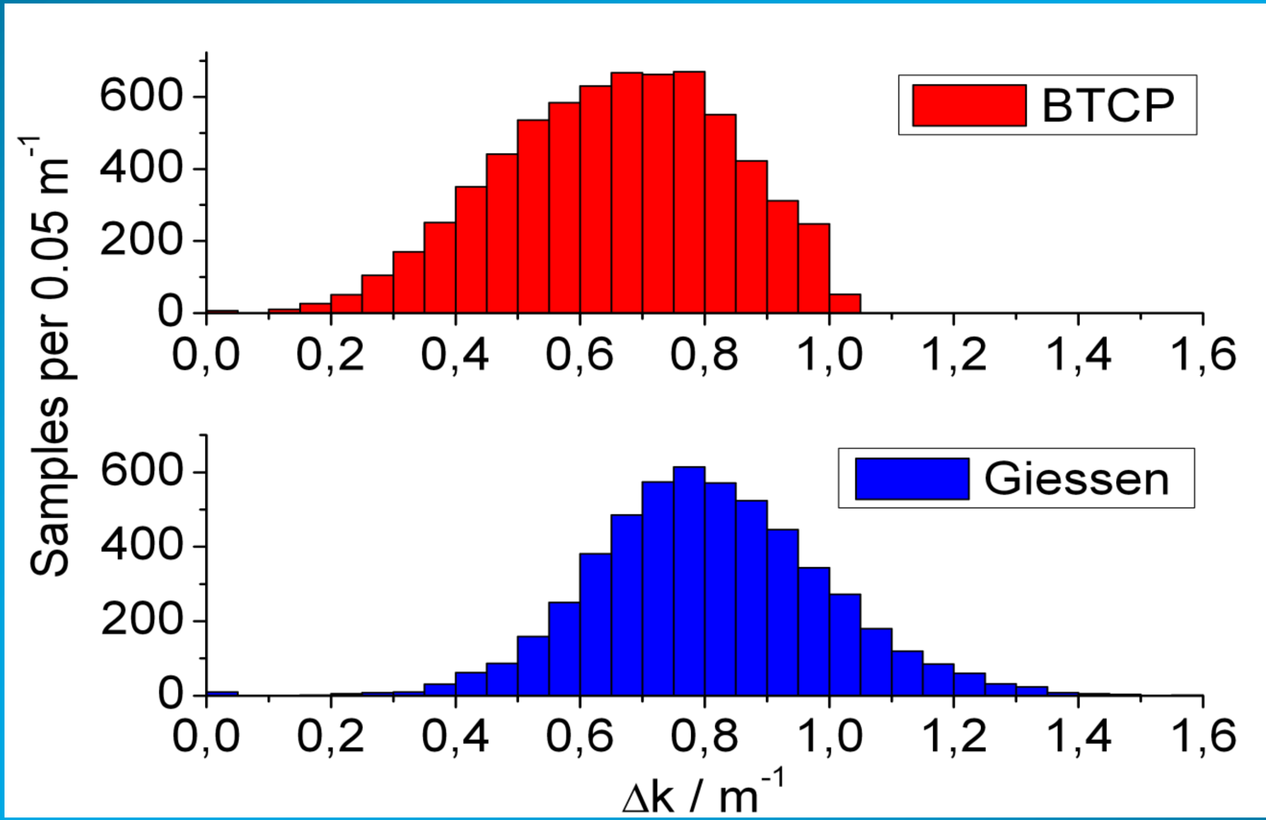
temperature dependence of luminescence





- **radiation hardness**

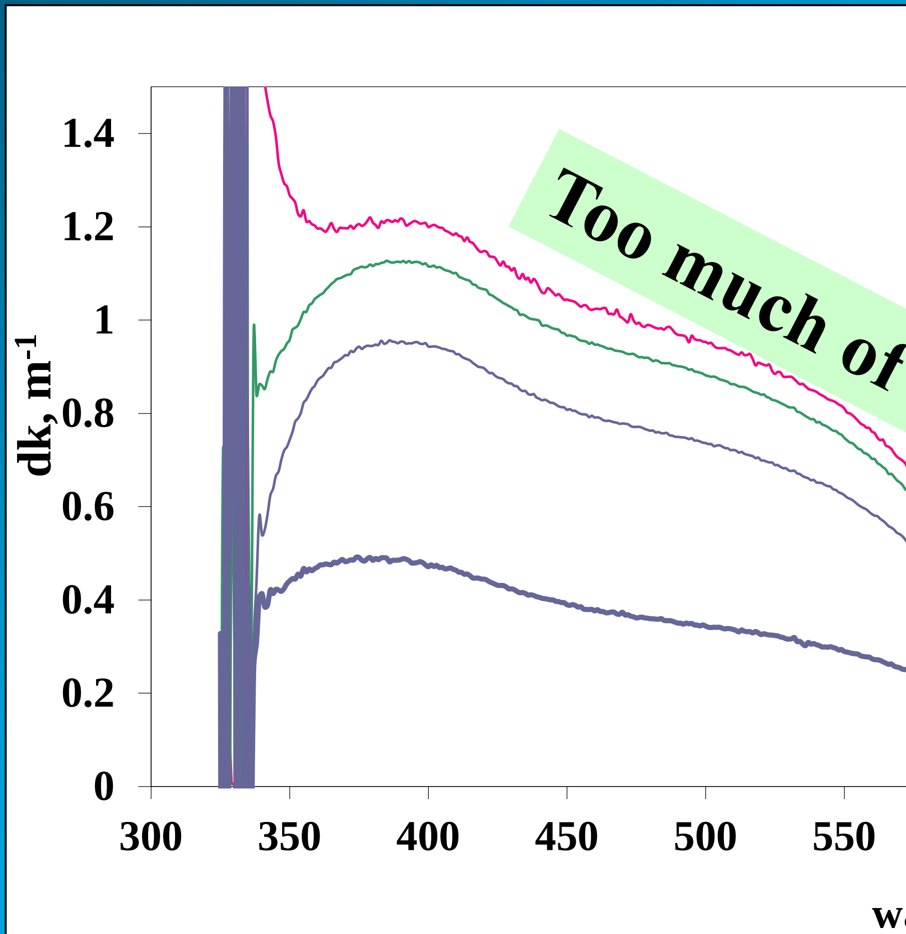
$$\Delta k = \ln\left(\frac{T_{bef}}{T_{after}}\right)\cdot\frac{1}{d}$$



tested using γ-rays: ~ 1.2 MeV ^{60}Co
integral dose: 30Gy

acceptance limit: $\Delta k < 1.1\ m^{-1}$

- **radiation hardness**



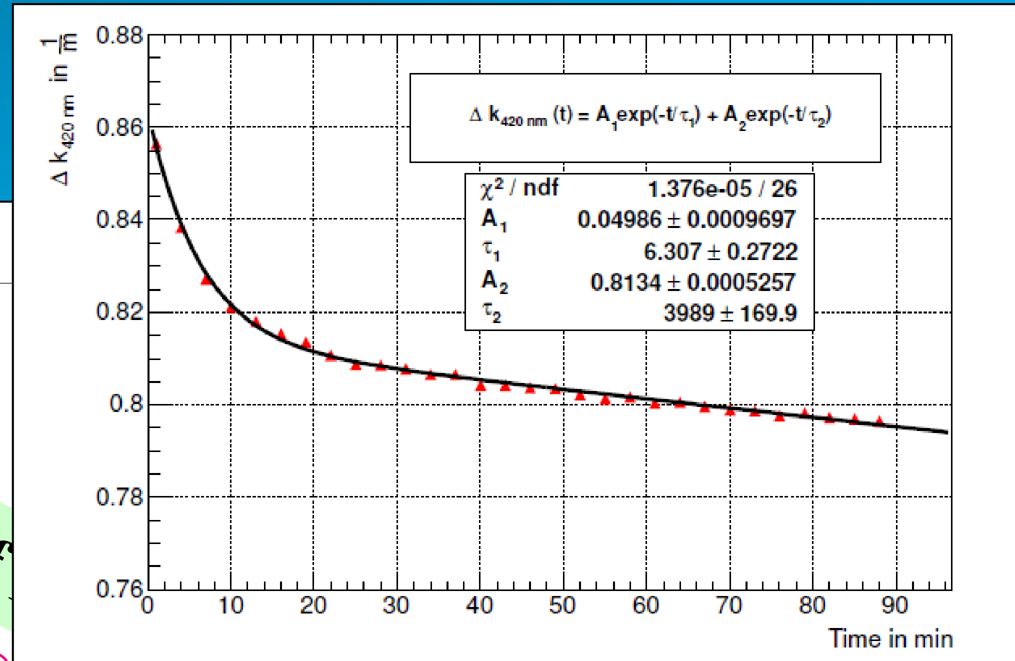
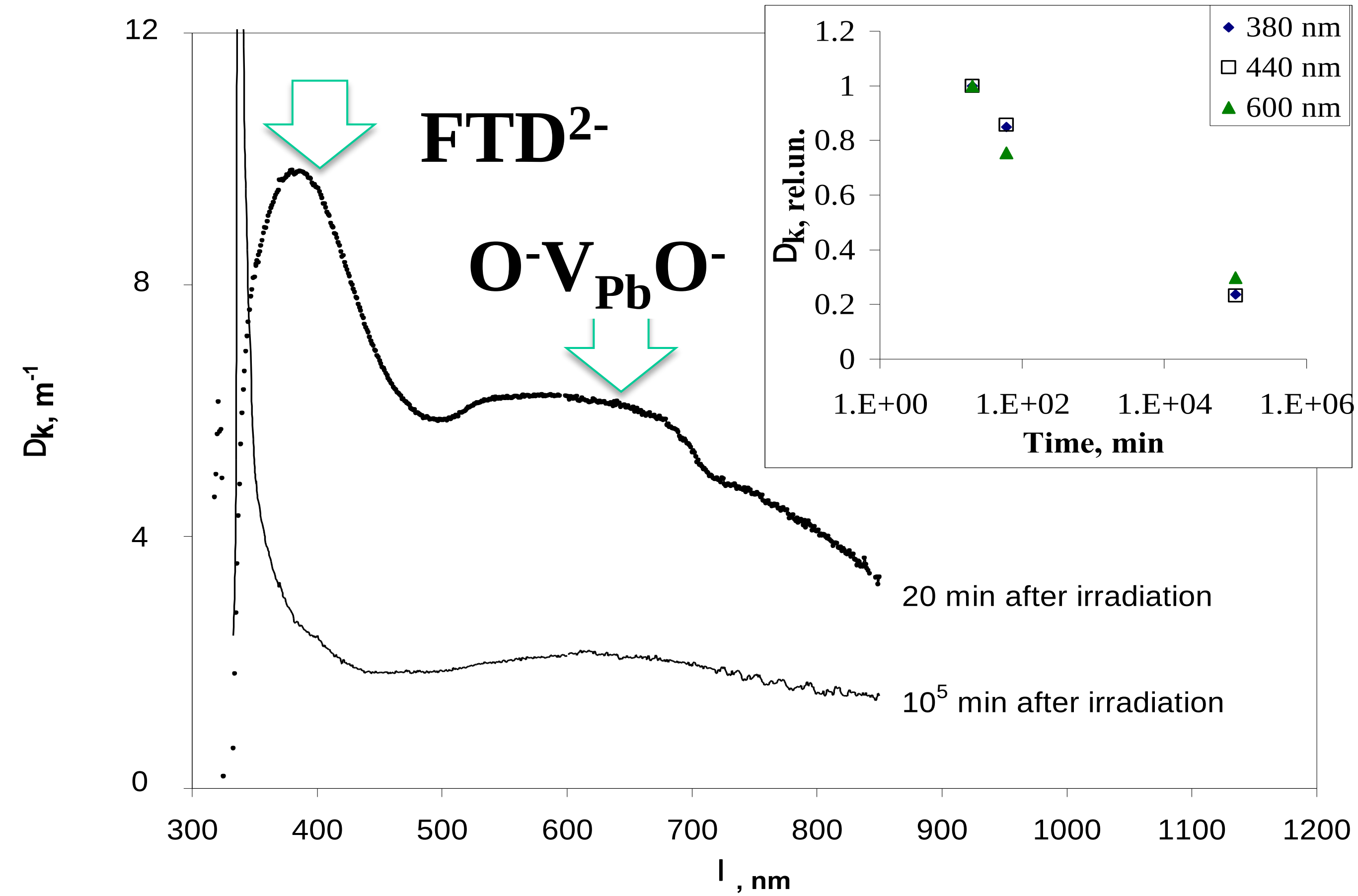


Figure 2.15: Spontaneous recovery for PWO at room temperature. A very fast recovery component gets visible with a constant of 6.3 min.

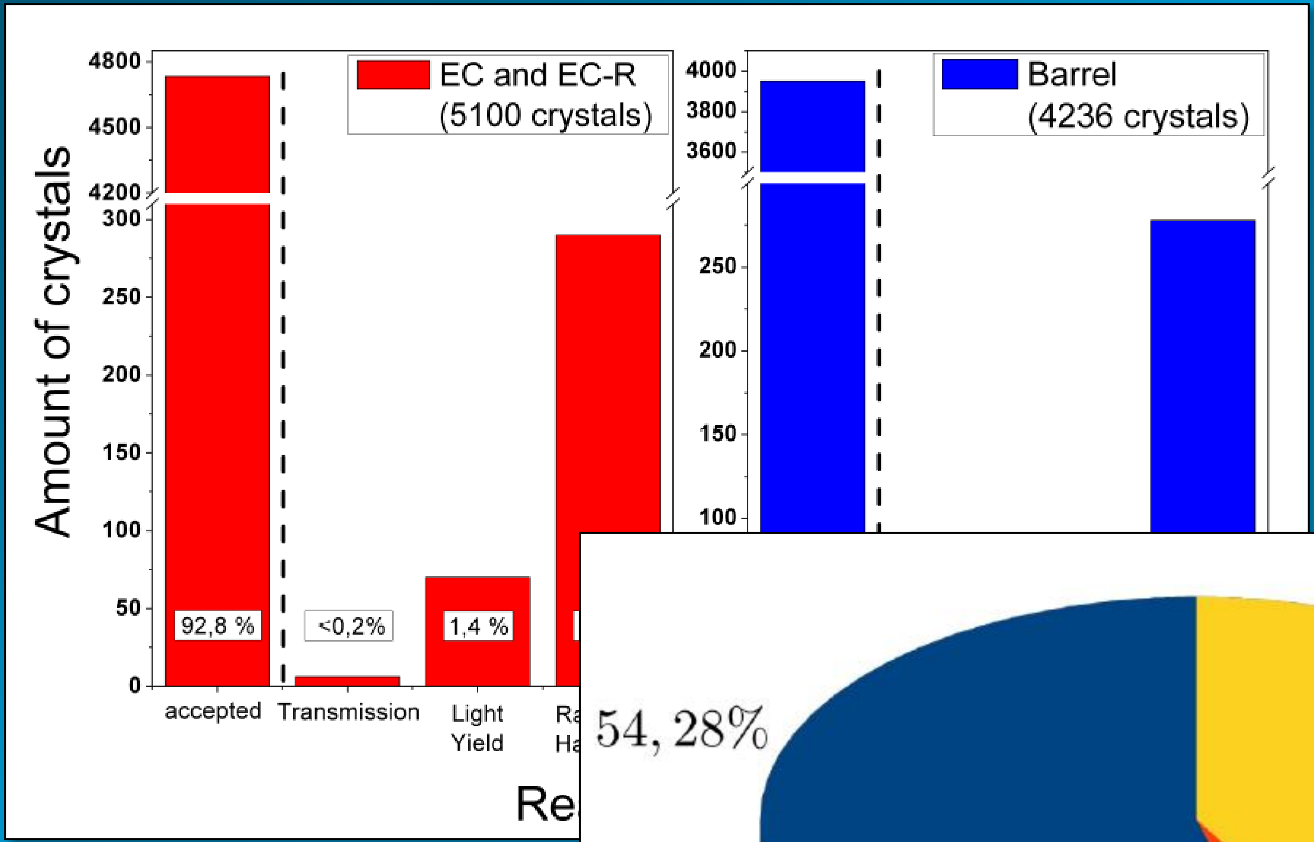
Induced absorption spectra of PWO crystal in early days of PWO-II

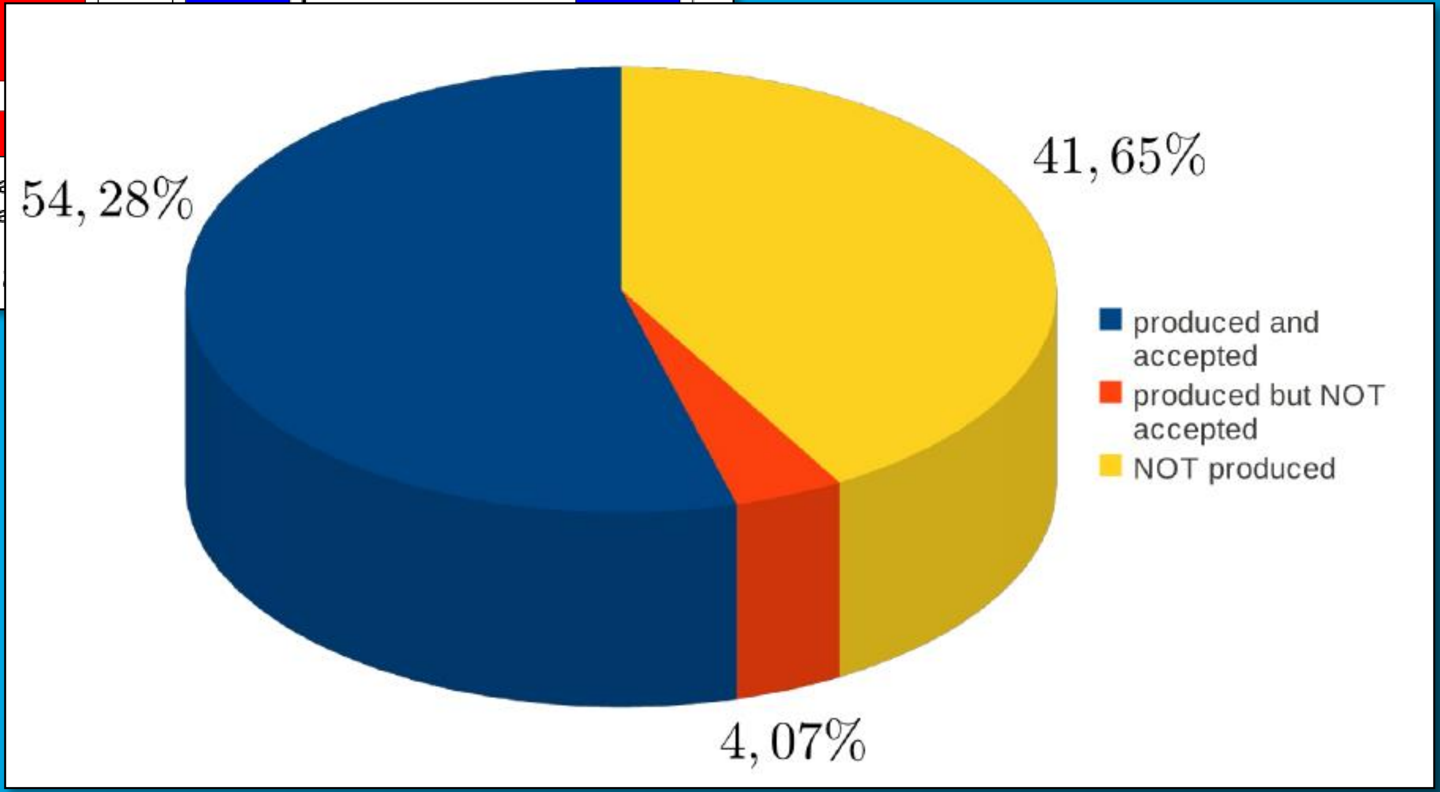
• radiation hardness



Typical induced absorption spectra of PWO undoped and uncompensated crystal grown in early days

- **overall quality**

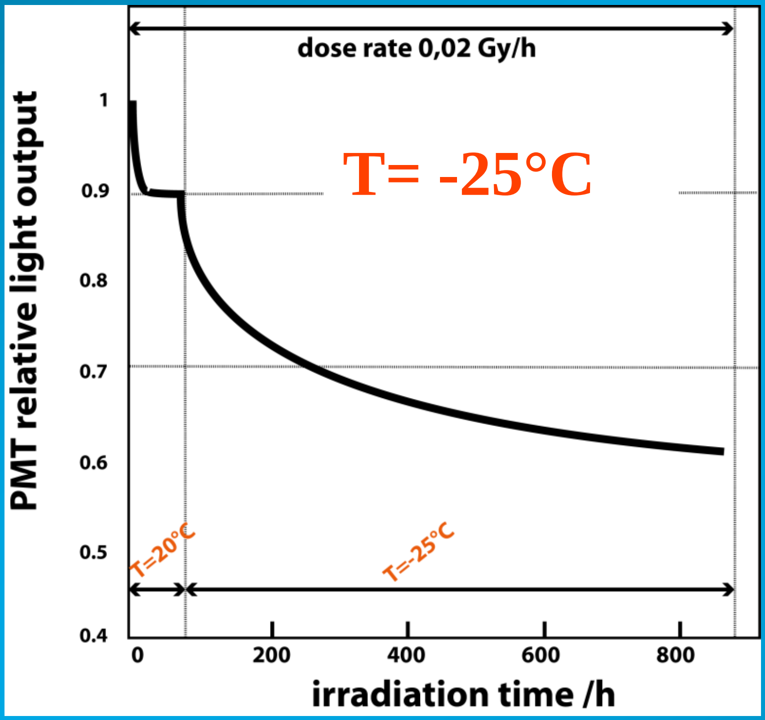


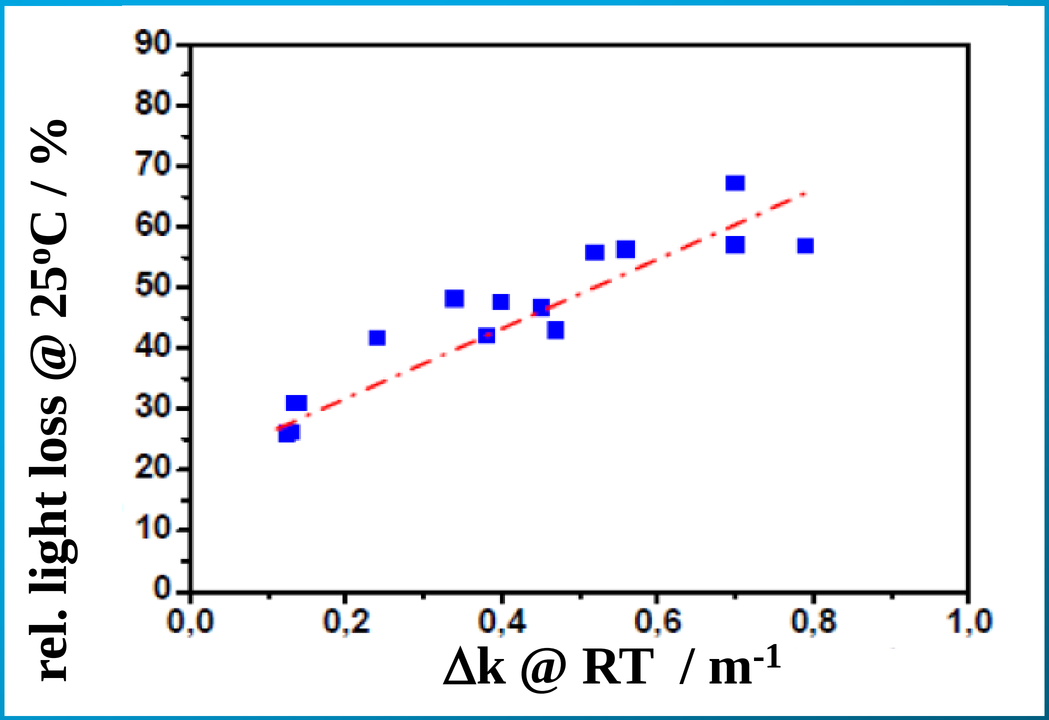


• consequences of cooling

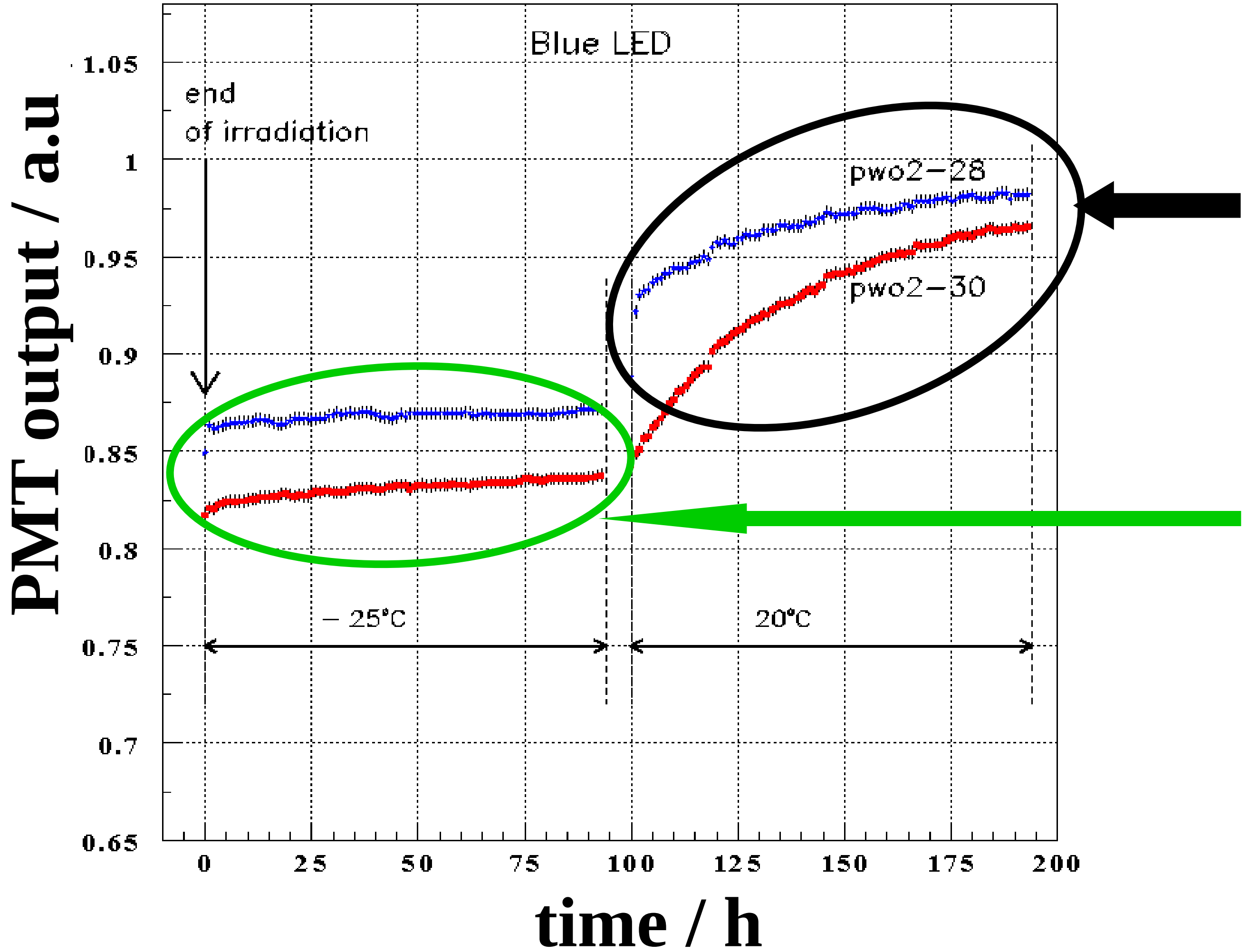
• fast decay kinetics even at T=-25°C: LY(100ns)/LY(1µs) > 0.9
• constant temperature gradient: LY(-25°C)/LY(+18°C) ~ 3.9

• „no“ statistical recovery of radiation damage at T=-25°C
asymptotic light loss correlated with Δk (@RT)





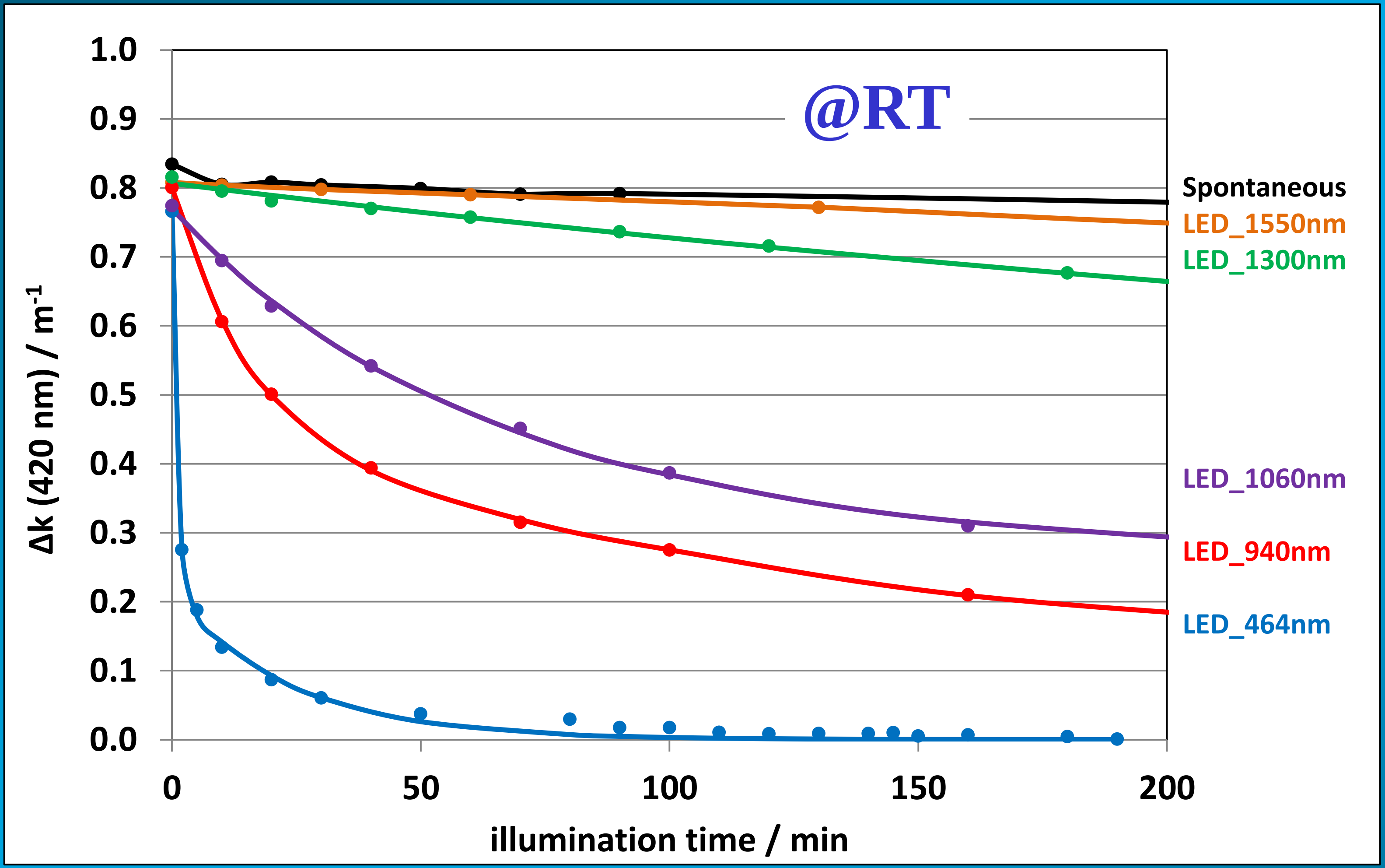
• radiation hardness: limitations at T=-25ºC



recovery at +20ºC

recovery at –25ºC

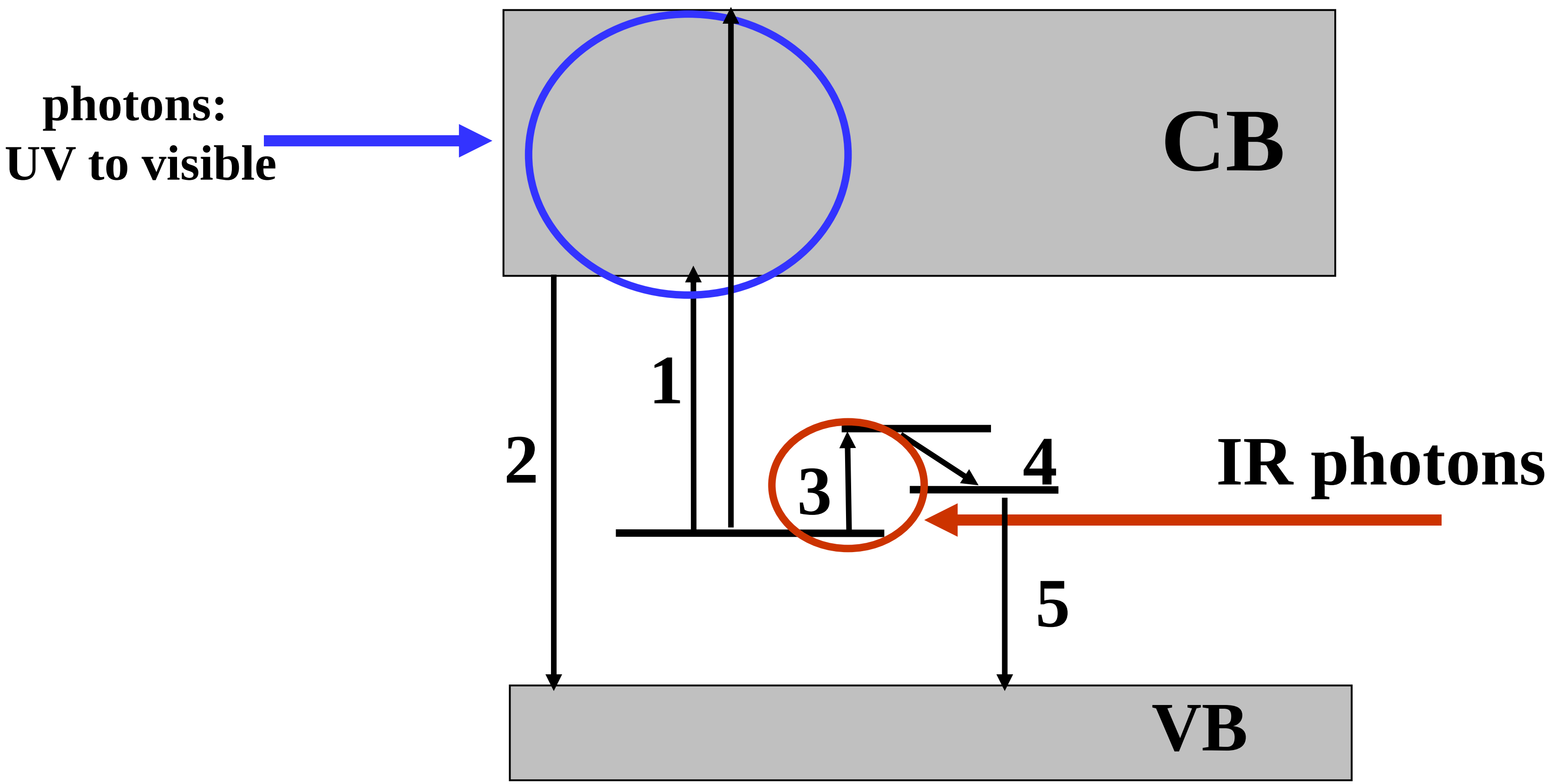
- ***stimulated recovery*** **of radiation damage**



applied integral dose of ^{60}Co: D = 30Gy

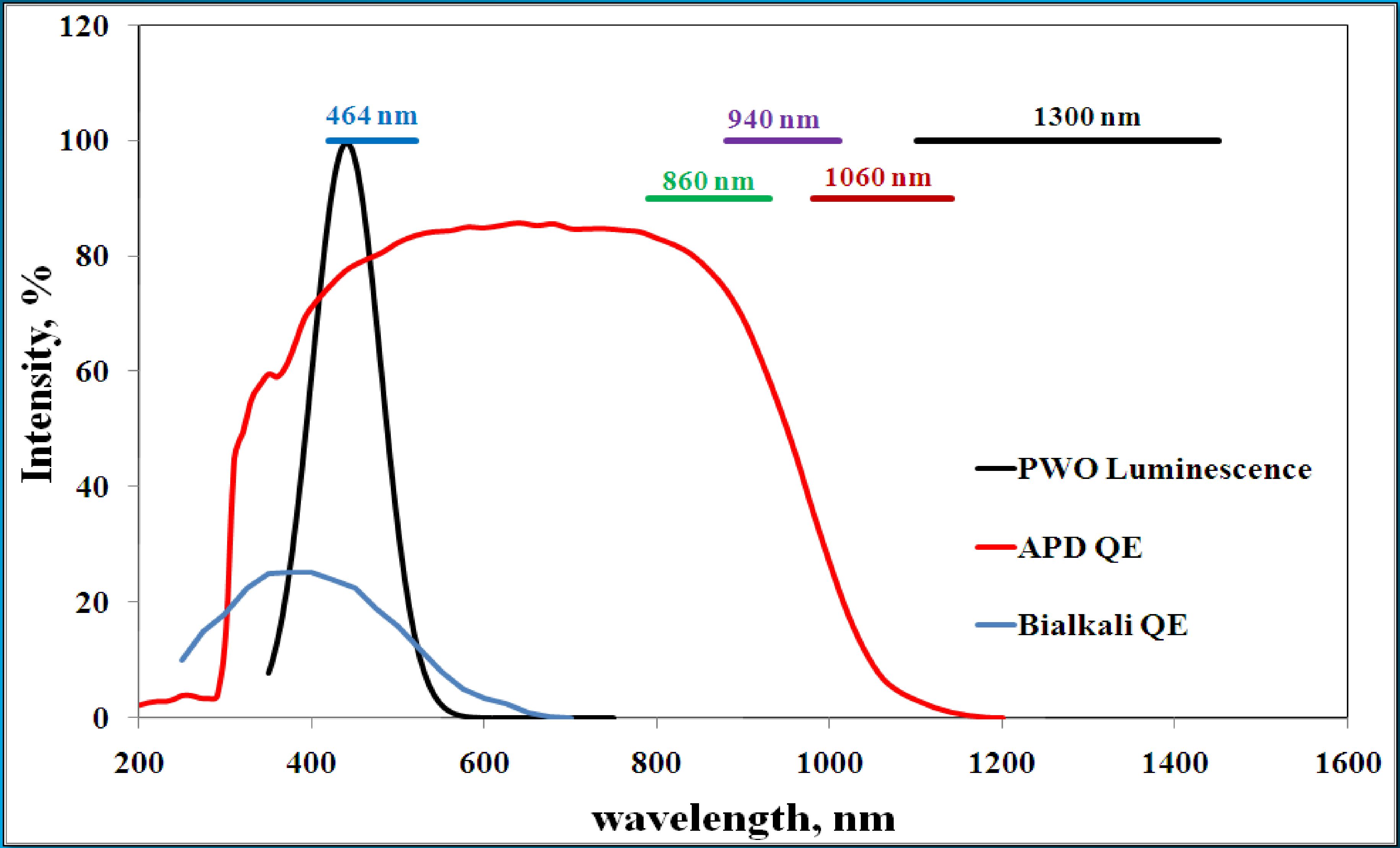
V. Dormenev et al., NIM A623 (2010) 1082 - patented

ionization and stimulation processes in PWO

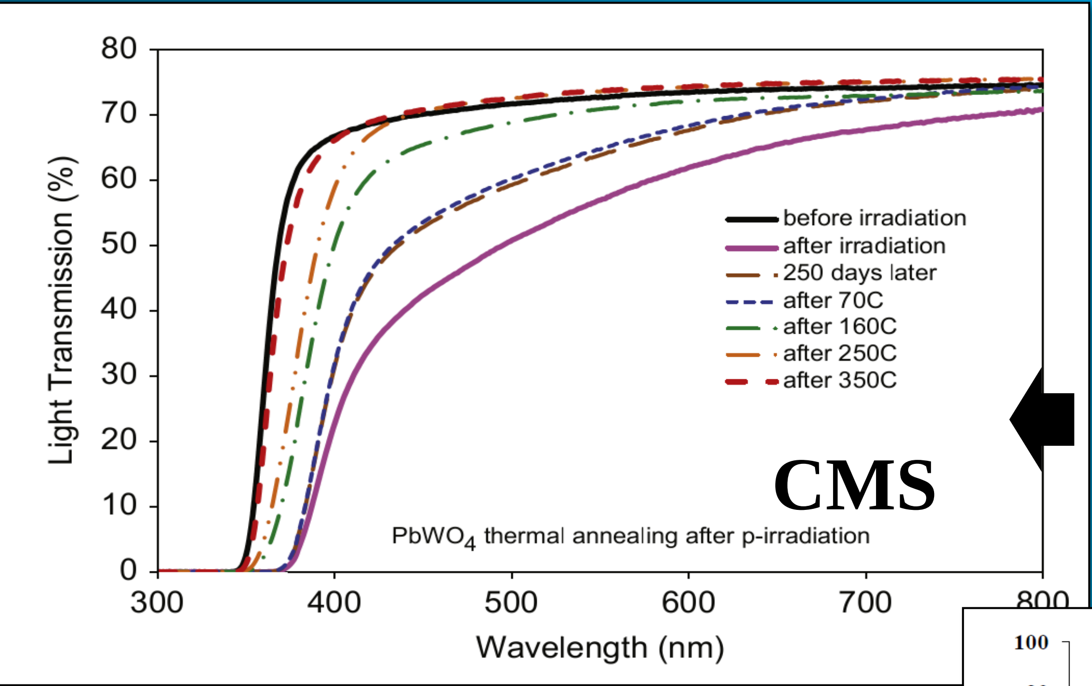


1 ionization of FTD_o, 2 radiative/non-radiative recombination,
3 intra-center absorption in FTD_o, 4 non-radiative relaxation,
5 radiative/non-radiative recombination of FTD_o.

- **implications for EMC operation**



• observation of severe radiation damage due to hadrons



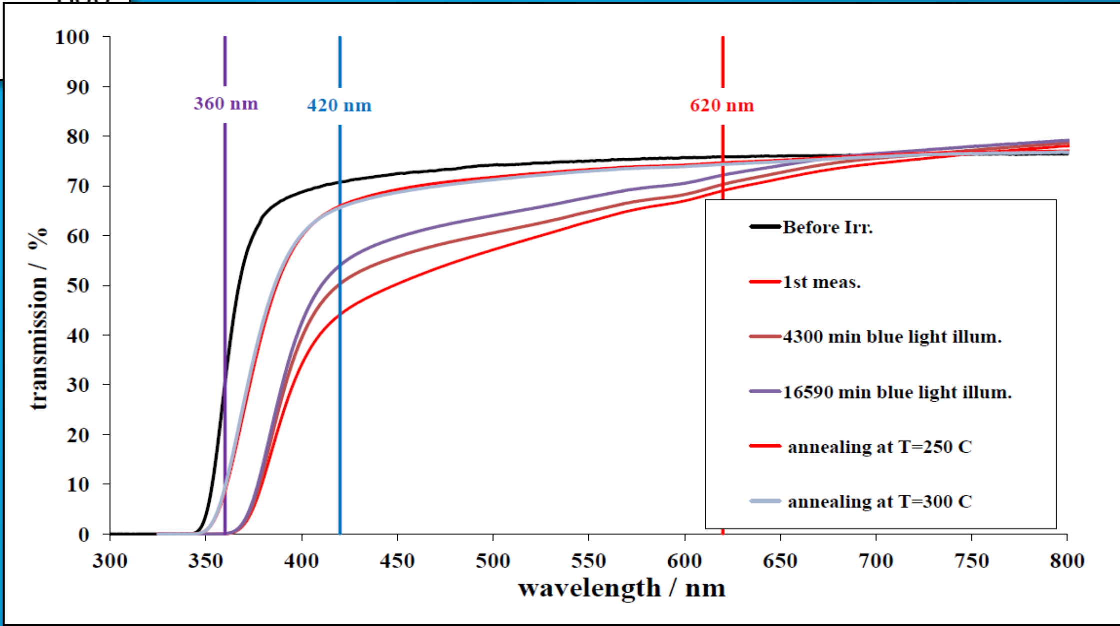
G. Dissertori et al., NIM A684 (2012)57

24 GeV/c protons

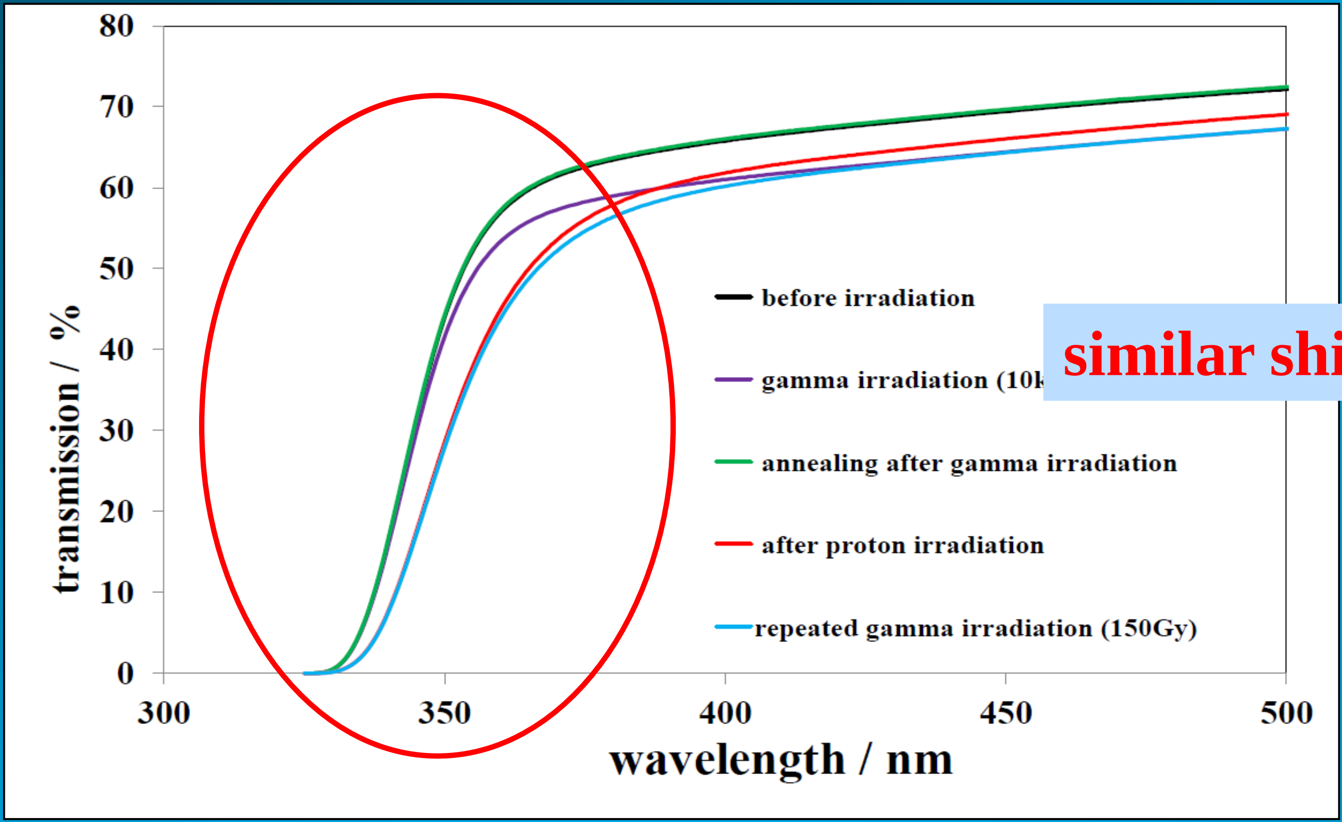
fluence: $(1.32 \pm 0.11)10^{13}cm^{-2}$

thermal treatment up to T=350°C

measurements and treatments @ GI
started several months after irradiation:
stimulated recovery + heating



• similar observation for 150MeV protons



fluence: 1.8 x 10^{13}p/cm^2

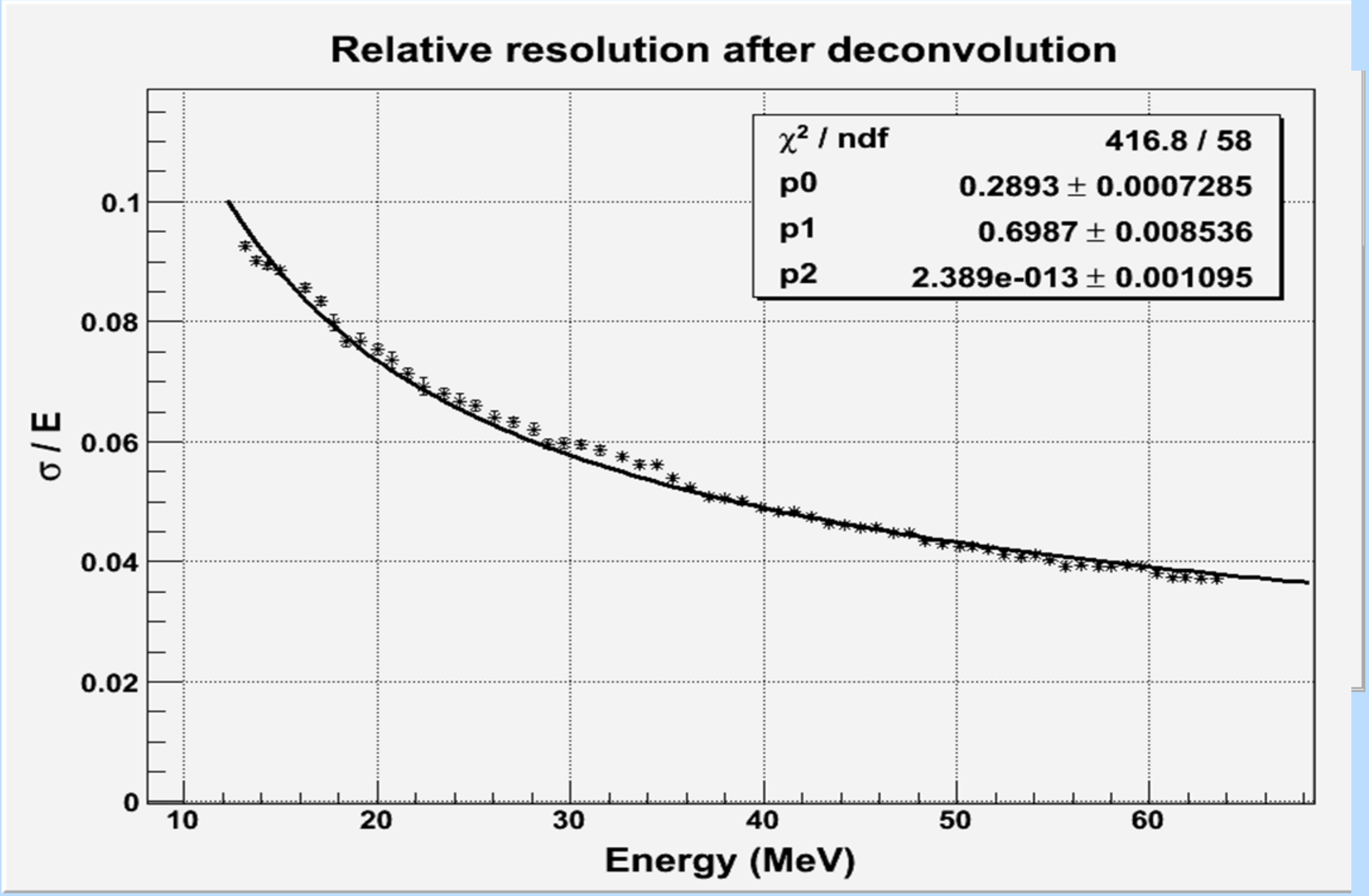
similar shift like at 24GeV/c

- **strong radiation damage due to protons at high fluence**
  severe damage due to highly ionizing secondaries
  clusters of color centers due to ion displacements
- **damage due to γ-rays: stimulated recovery**
  proton damage: annealing by heating

prototype performance

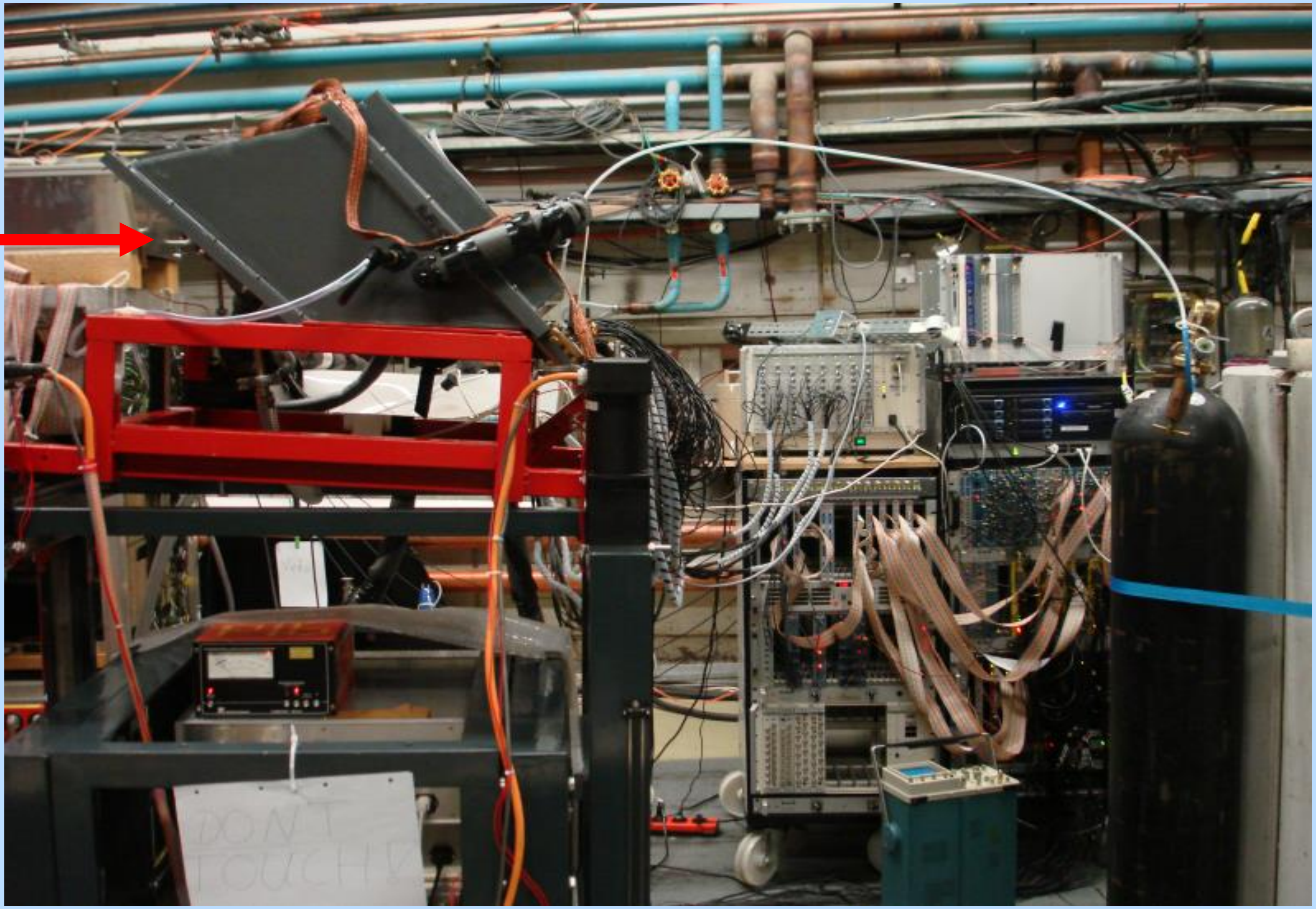
- optimized light output: PWO-II
- cooling: operation at T=-25ºC

extension to energies < 50MeV @ MaxLab

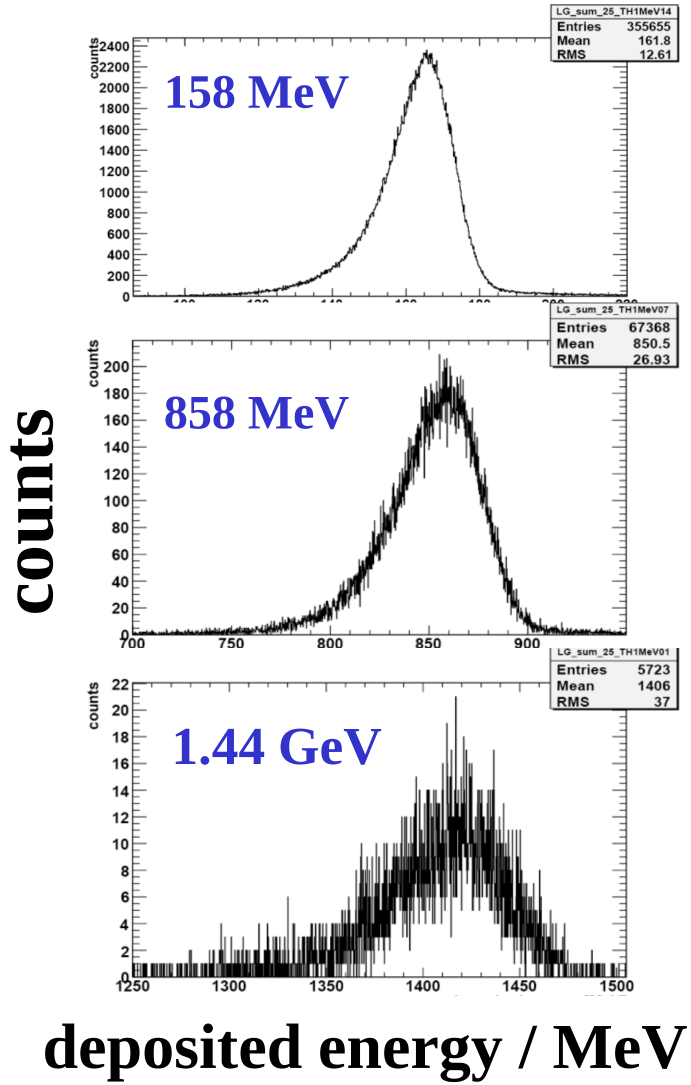


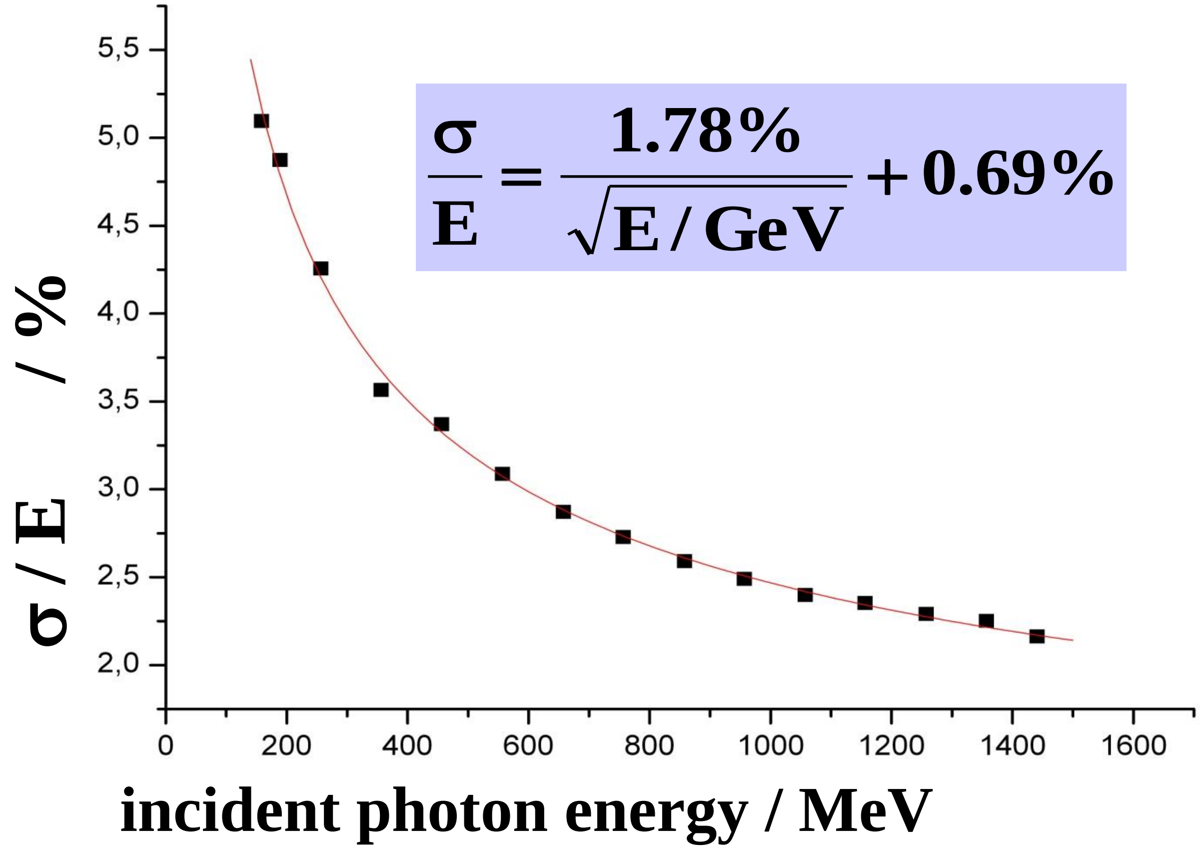
prototype performance PROTO 60

photon beam



prototype performance PROTO 60



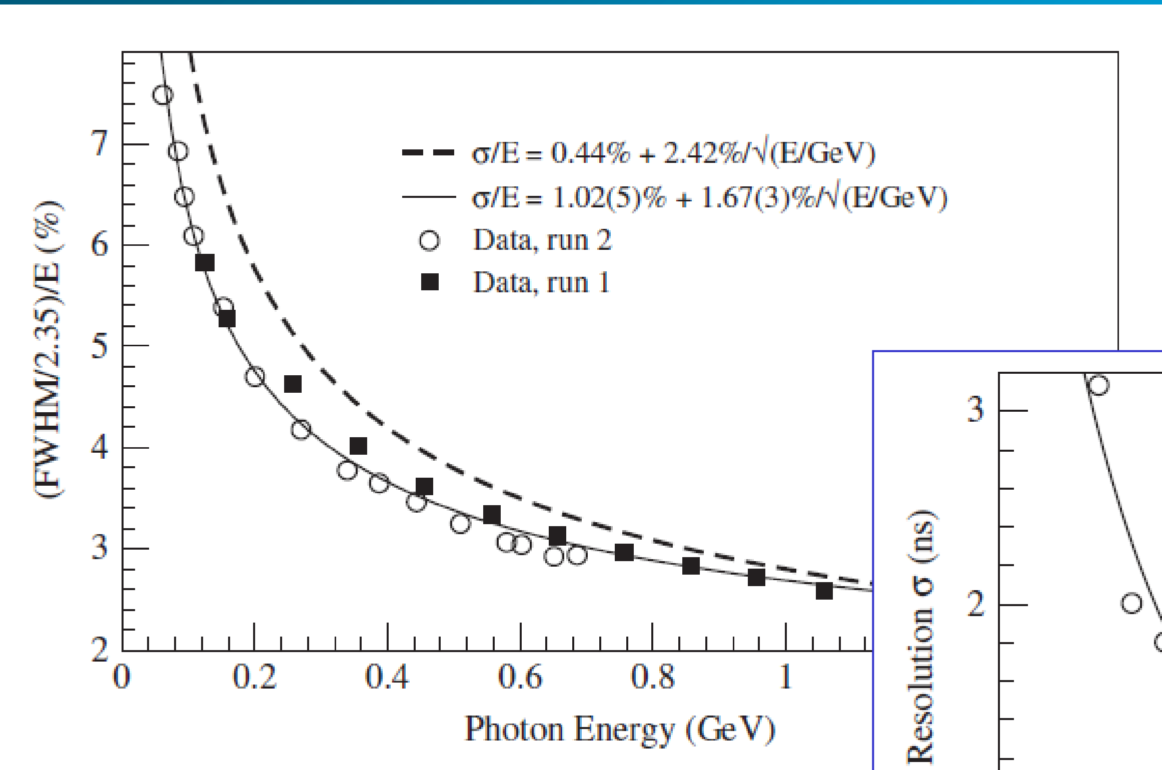


$$\frac{\sigma}{E} = \frac{1.78\%}{\sqrt{E/GeV}} + 0.69\%$$

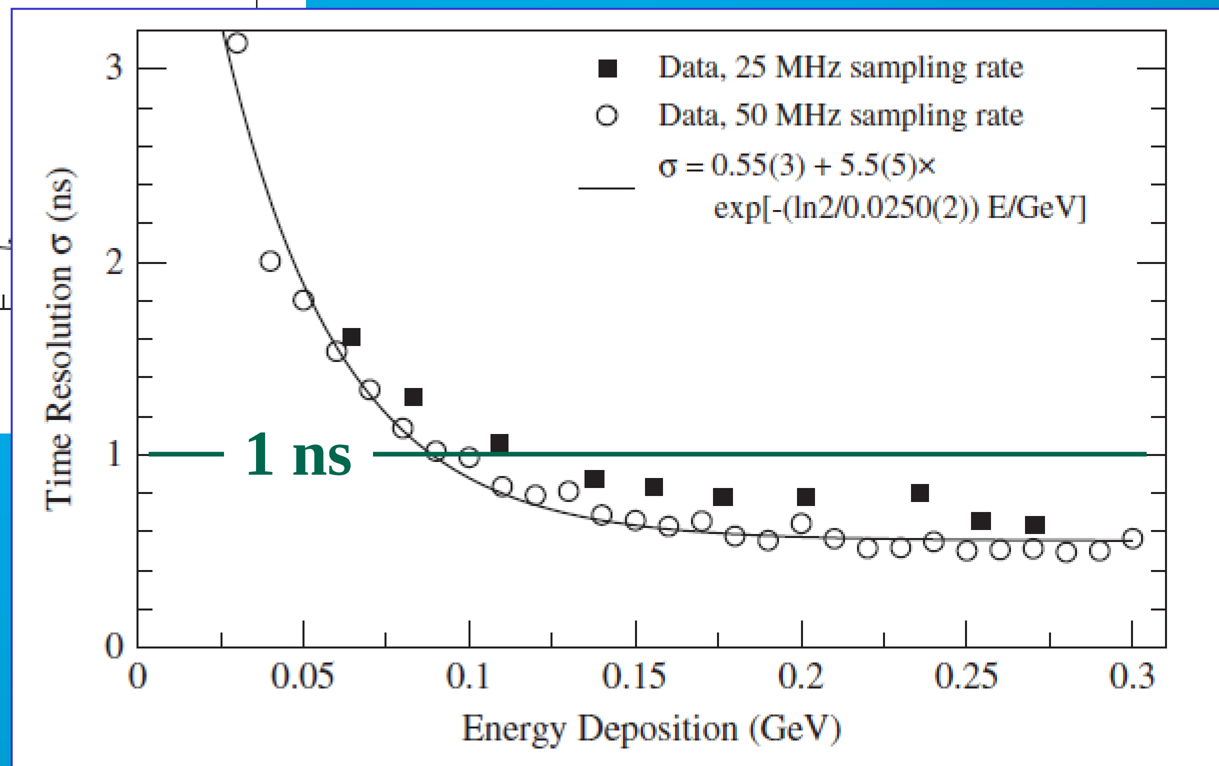
- digitization:
  shaping /peak-sensing ADC

readout via SADC: ⟹ further improvement

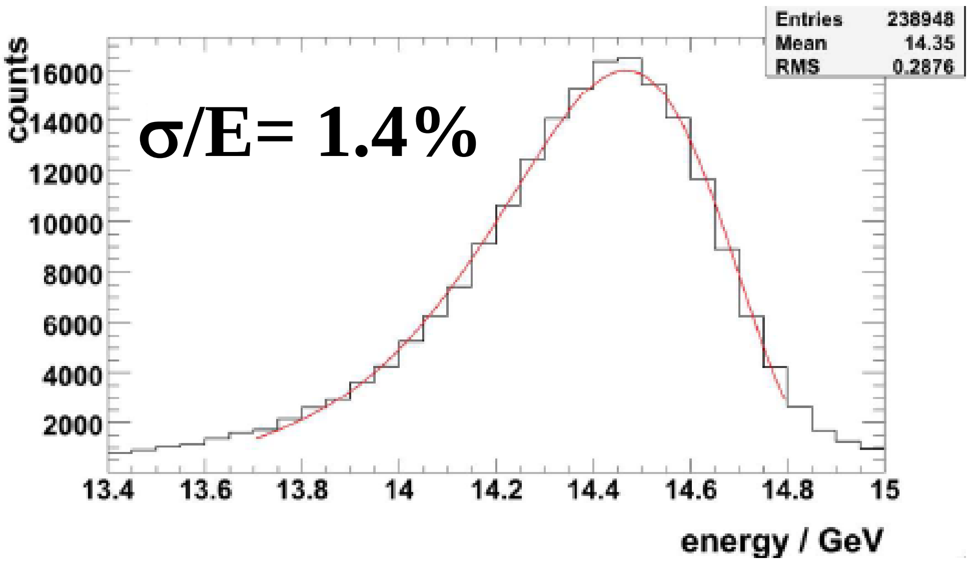
energy-resolution (3x3 matrix)

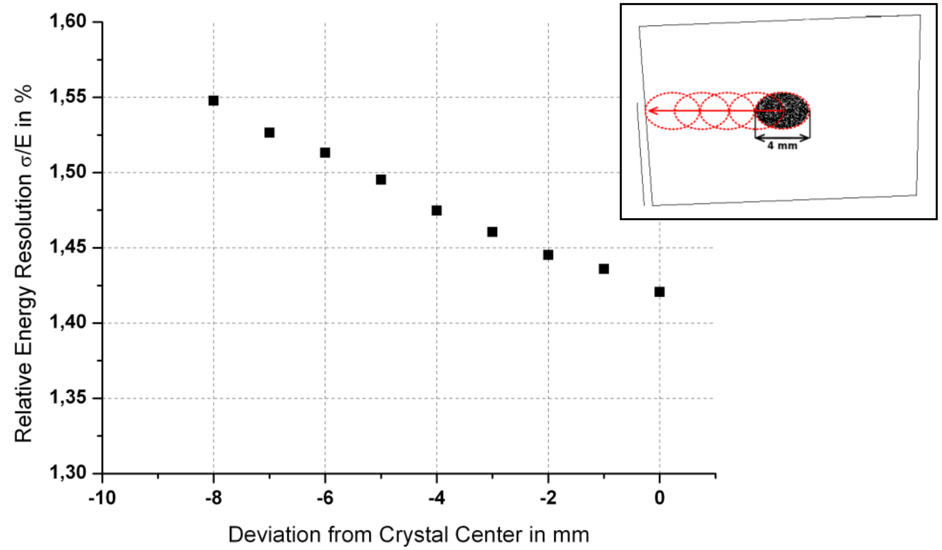


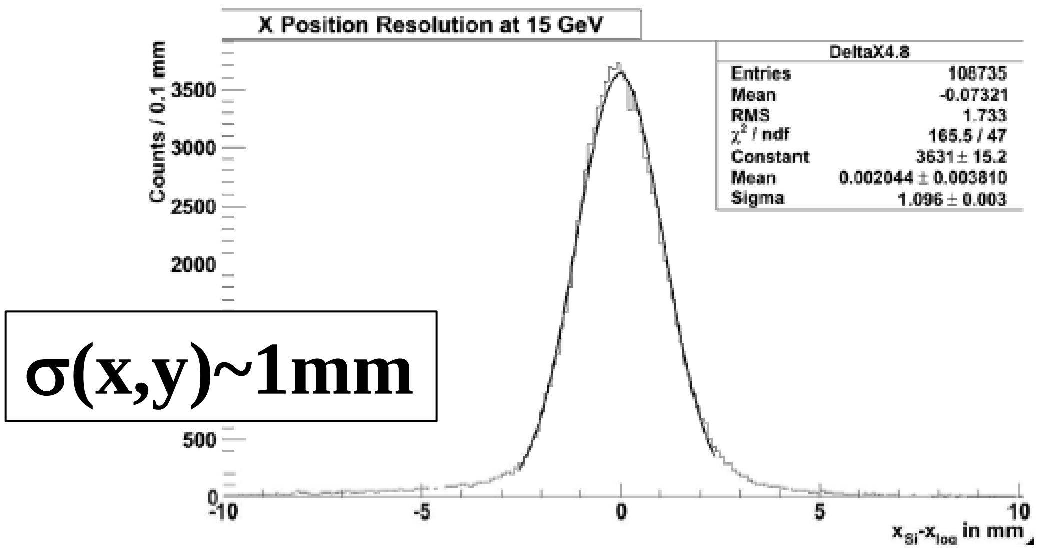
time resolution

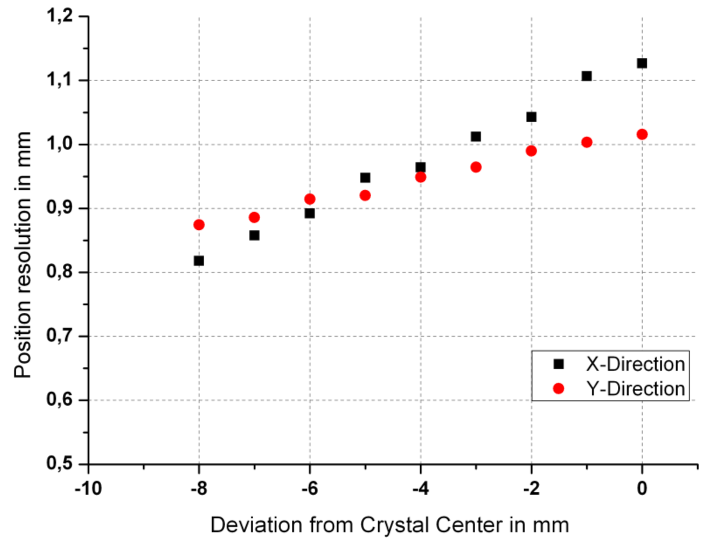


prototype performance PROTO 60 15 GeV positrons

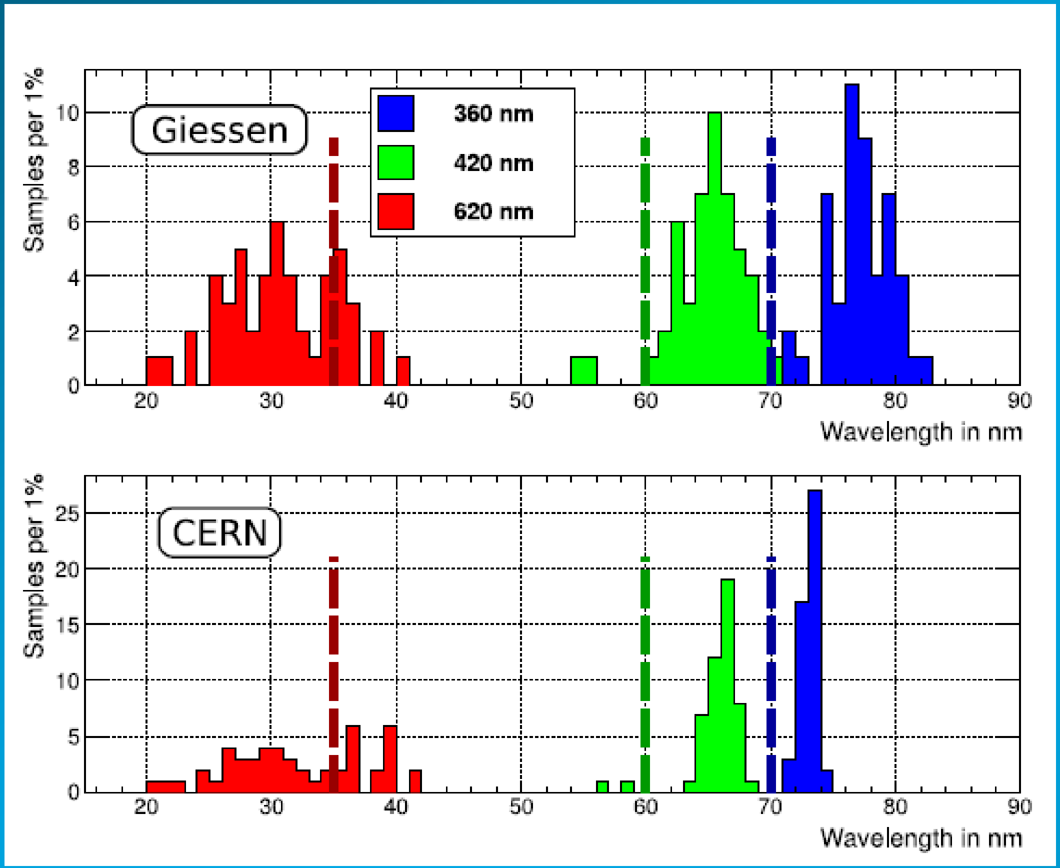


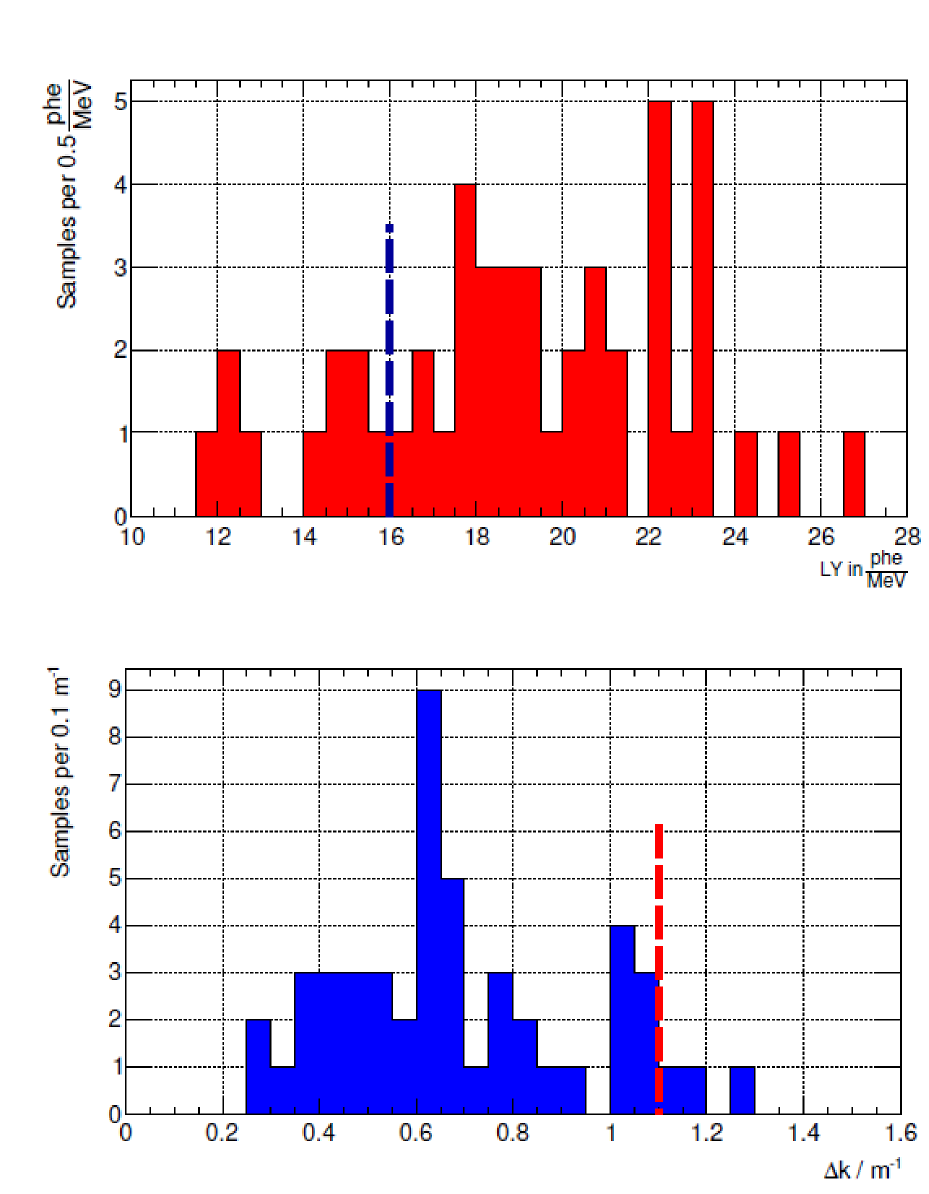






• former production @ SICCAS

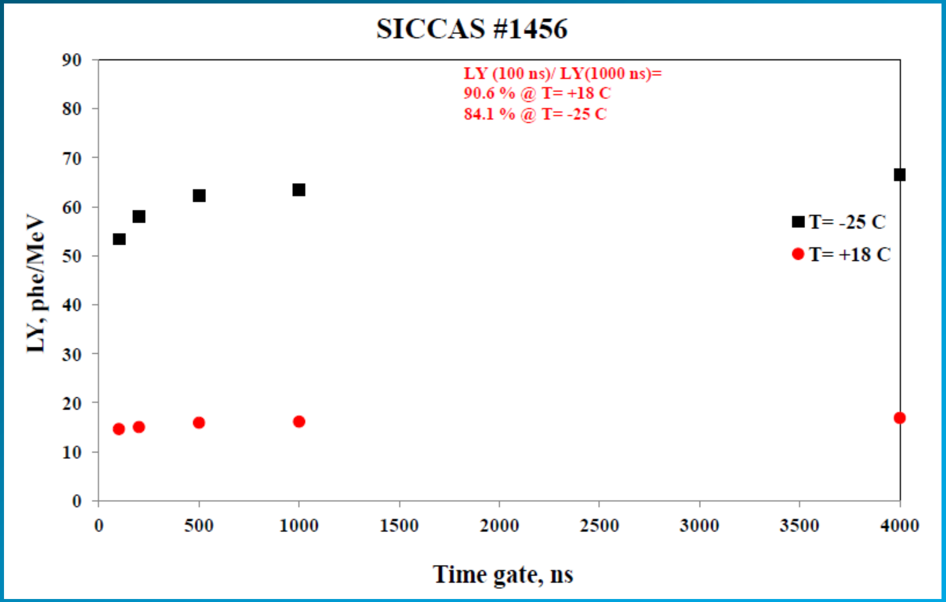


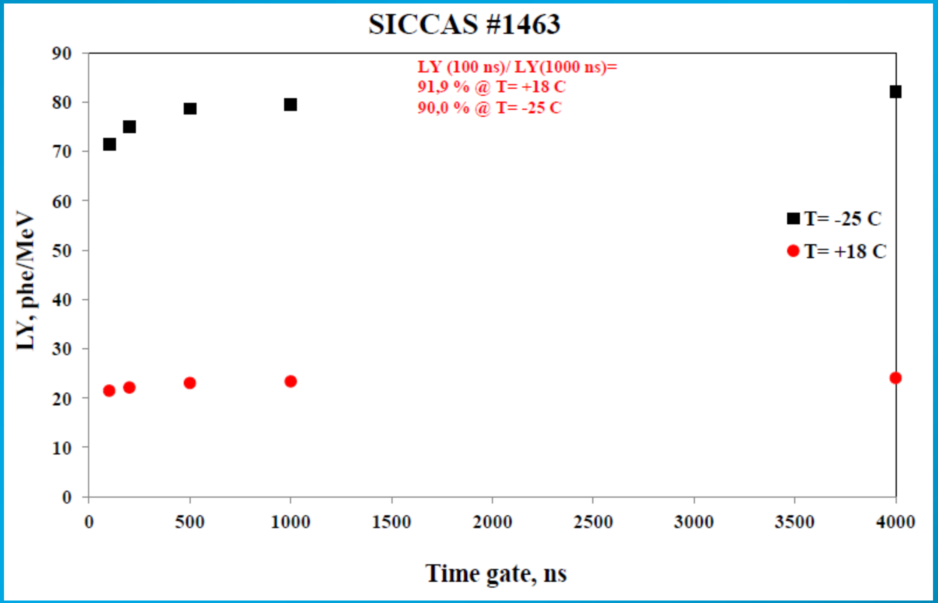


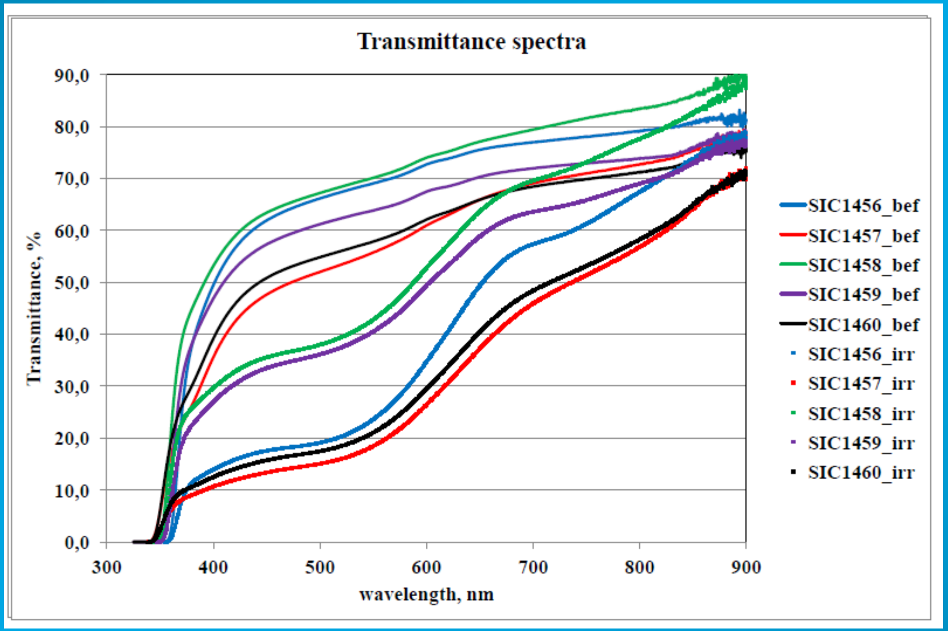
• recent delivery from SICCAS (1)

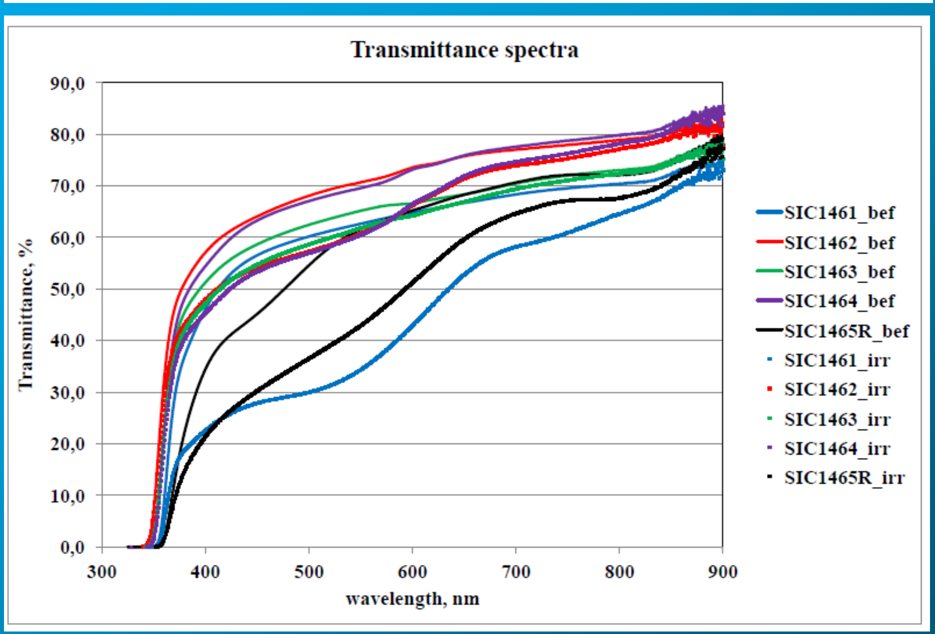
SICCAS ID	T(360	T(420	T(620	LY(T= +18 C, t=100	LY(100	dk(420 nm)	comment SICCAS	LY
	%	%	%	phe/MeV	at T=18C, %	m^{-1}		SICCAS
limits	≥ 35	≥ 60	≥ 70	≥ 16	> 90	< 1.1		
1451	19,0	58,8	73,8	22,3	94,1	1,92		
1452	25,2	62,9	74,2	22,3	94,1	0,72		
1453	23,2	57,8	75,3	11,1	90,4	3,94		
1454	35,0	67,2	77,8	26,9	93,7	0,69		
1455 rus	10,1	52,5	73,5	15,4	93,9	2,68		
1456	2,0	56,5	73,8	15,6	90,6	6,36	doping	17,1
1457	16,4	42,3	62,9	13,1 at -25 C	87,8	6,32	doping	13,4
1458	20,4	58,8	75,2	17,8	91,3	2,93	doping	22,0
1459	11,3	52,6	68,5	19,2	92,1	2,74	doping	21,1
1460	19,1	45,7	63,6	?	?	5,89	doping and raw materia	15,4
1461	8,8	52,0	65,6	19,7	91,7	3,59	doping and raw materia	20,5
1462	32,5	60,7	74,3	21,9	91,5	0,85	doping and raw materia	17,7
1463	22,9	55,1	67,3	21,5	91,9	0,38	doping and raw materia	19,7
1464	22,7	59,0	74,1	20,5	91,6	0,89	doping and raw materia	23,9
1465 rus	1,8	40,3	66,5	12,9	90,8	2,26		9,3

• recent delivery from SICCAS (1)

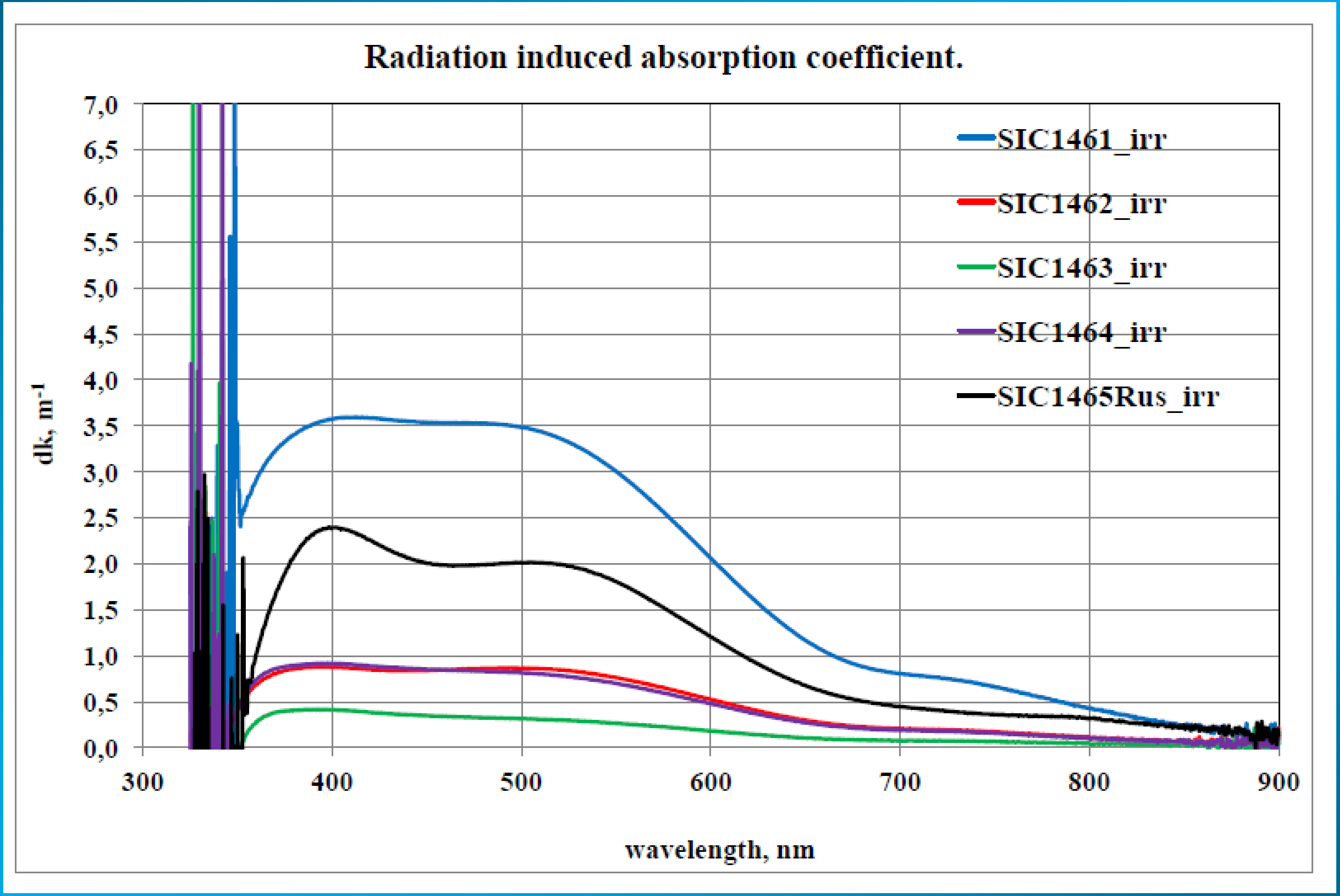




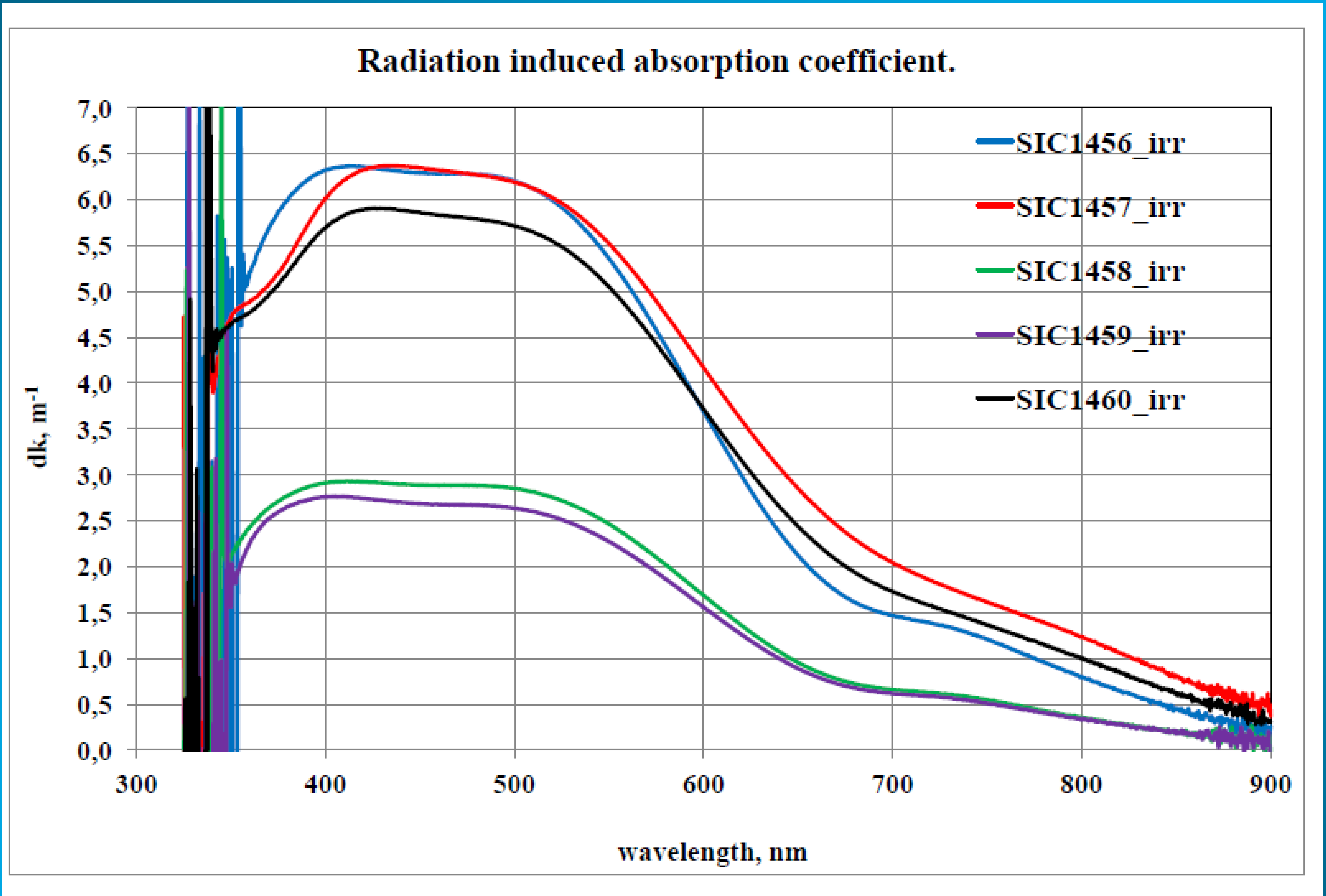




- **recent delivery from SICCAS (1)**



- **recent delivery from SICCAS (1)**



• additional new PWO manufacturer

CRYTUR – Turnov, Czech Republic

- R&D phase just started (June 2014)
- Czochralsky technology (identical to BTCP)
- know-how and raw material still available

- **alternatives ?**