Quality status

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Outline

Simulation of light propagation in a $PbWO_4$ crystal

Aim? determination of systematic error of Δk due to multiple reflection

Formula which is used for Δk-calculation (integral dose 30Gy):

$$\Delta k = \frac{1}{20\text{cm}} \ln\left(\frac{T_{\text{before}}}{T_{\text{after}}}\right)$$

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 in principle wrong (in the order of a few percent):
Formula only takes photons into account which pass only once through the crystal!

$$\Rightarrow \Delta k_{\text{photons/one time}} \neq \Delta k_{\text{photons/all}}$$

Simulation of light propagation in a $PbWO_4$ crystal

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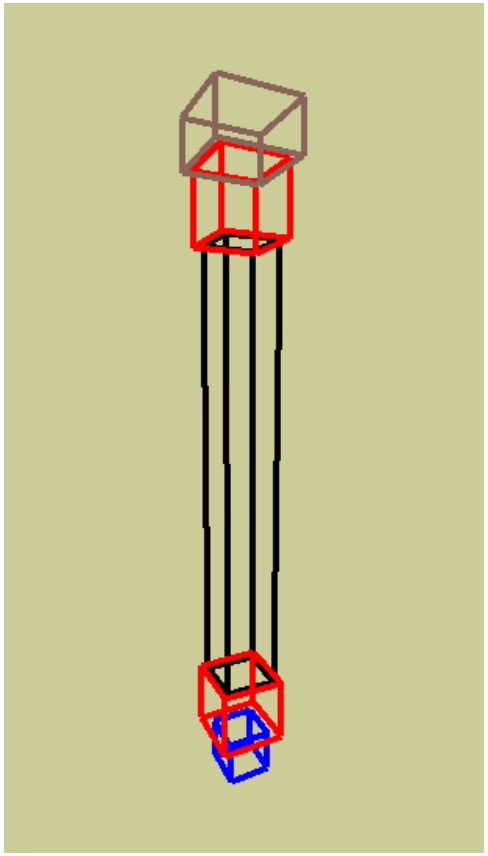
Simulation of light propagation in a $PbWO_4$ crystal

How?	"Litrani" = Monte-Carlo based program simulating light propagation in isotropic or anisoptropic media
Setup?	arrangement of crystal, beam shape ect. should be similar to the used one
Which input parameters?	index of refraction $n(\lambda)$ absorption length $l_{ABS}(\lambda)$

Inserted setup



Detector	(QE=1, sees everything!)
Air gap 1	
Crystal	available geometries: EC, 1L, 1R surrounded by air
Air gap 2	
Light source	elliptical beam shape deviation $\approx 0{,}3^\circ$

Input parameters

$PbWO_4$ in the simulation:

$\longrightarrow$ isotropic medium $\longrightarrow$ no optical axis

In Litrani: Index of refraction given by "Sellmaier law":

$$n(\lambda) = \sqrt{1 + A^2 + \frac{B^2\lambda^2}{\lambda^2 - C^2}}$$

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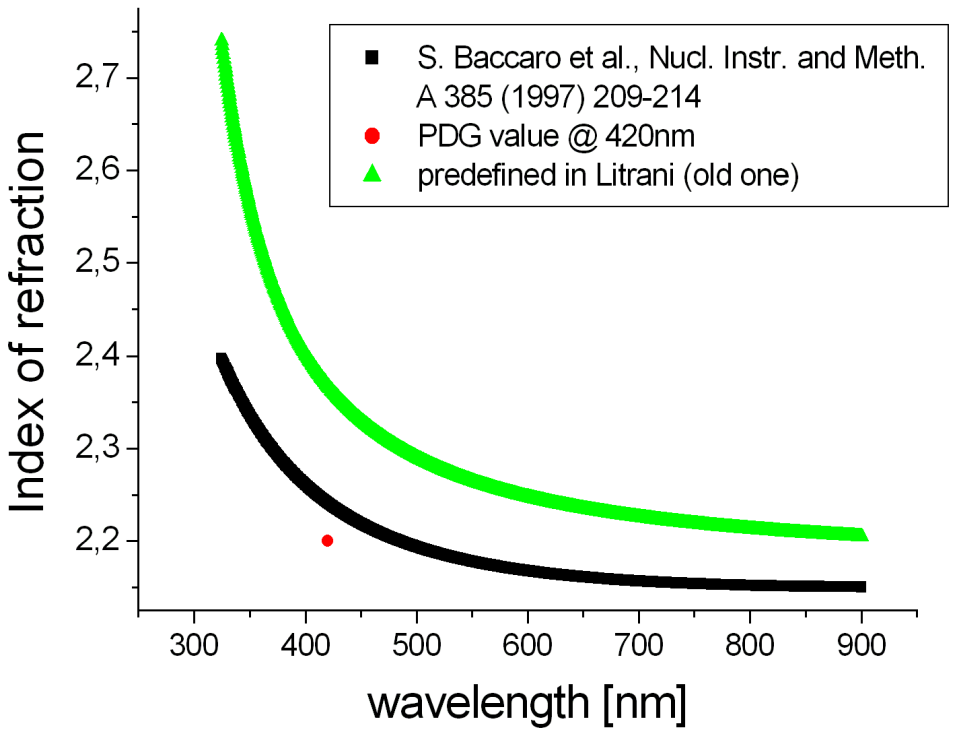
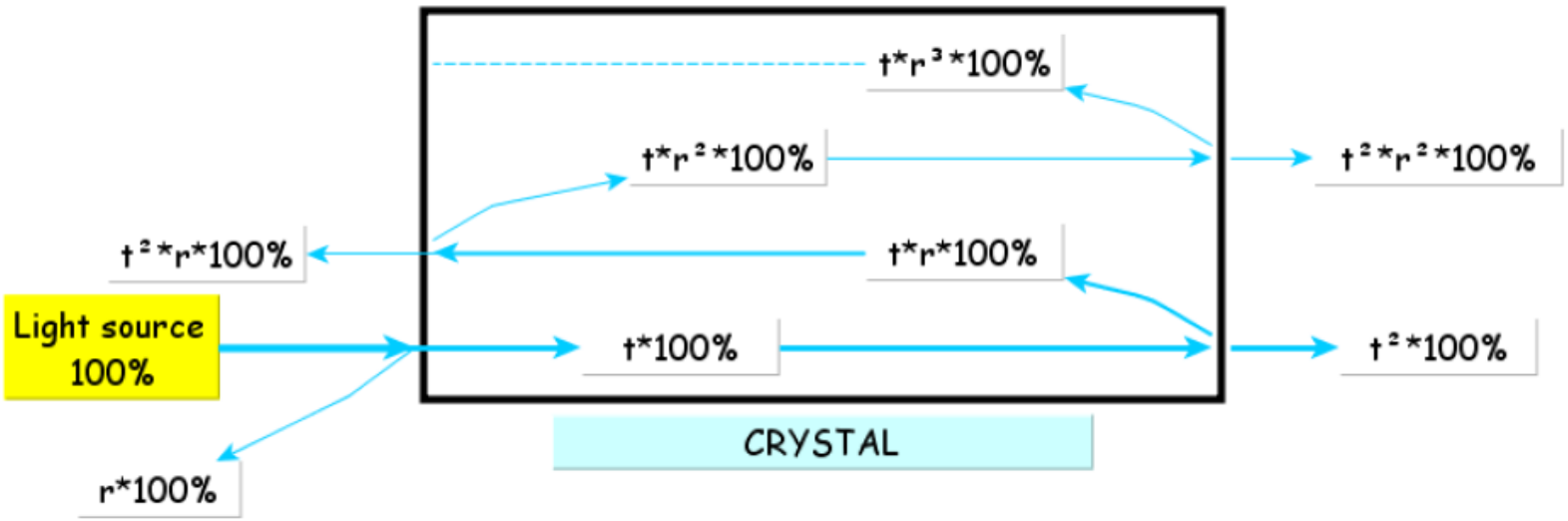


For simulations:

Fitted $n(\lambda)$ of **black** curve

$\longrightarrow n(420\text{nm}) = 2,24$

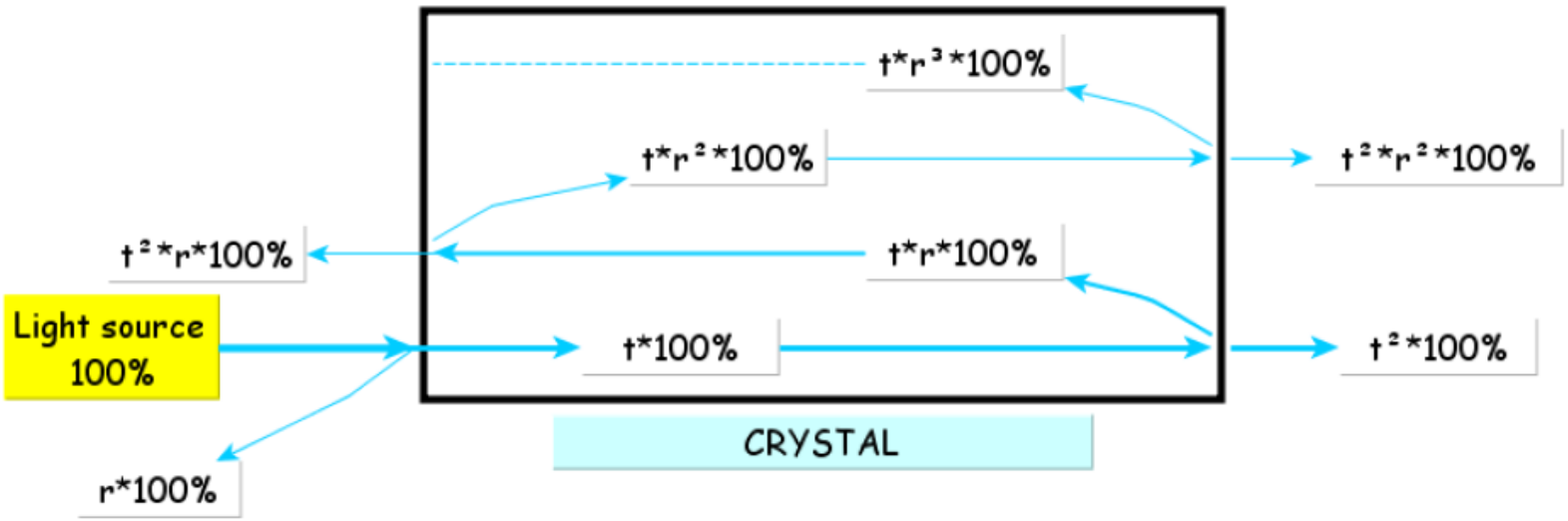
Input parameters



$$r = \left(\frac{n_{\text{Cry}} - n_{\text{air}}}{n_{\text{Cry}} + n_{\text{air}}} \right)^2 \qquad t = 1 - r$$

$$\text{T}_{\text{max}} = 100\% t^2 \cdot (1 + r^2 + r^4 + ..) = 100\% \cdot \frac{t^2}{1-r^2} = 100\% \cdot \frac{1-r}{1+r}$$

Input parameters



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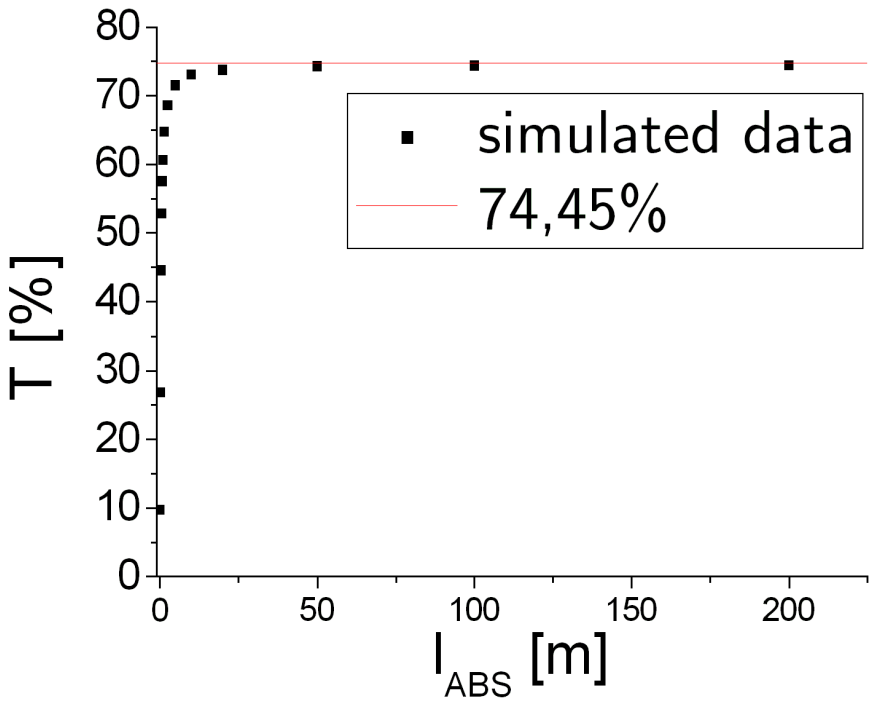
$$\Rightarrow T_{\text{max/@ 420nm}} = 74,45\%$$

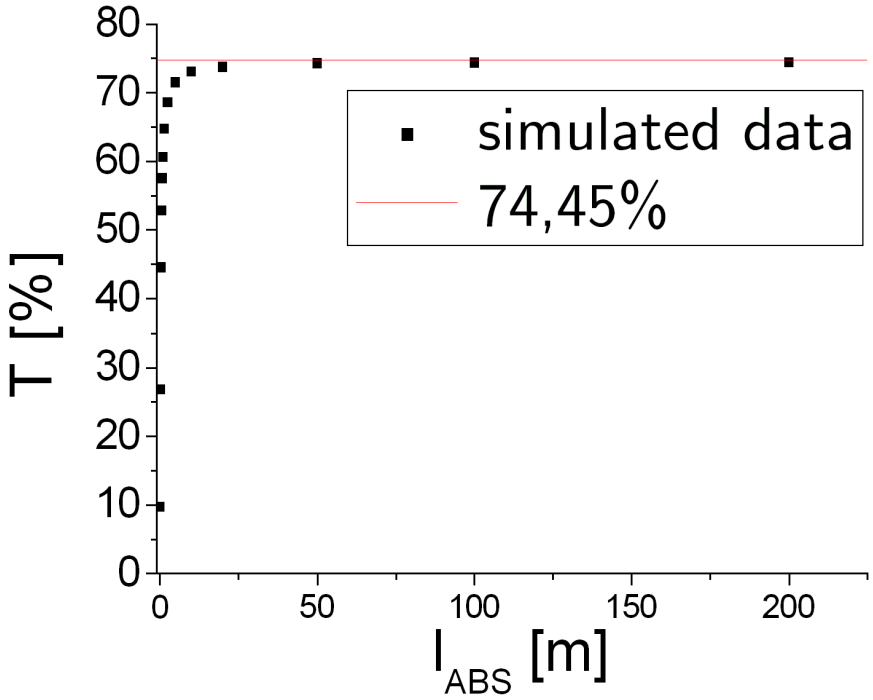
Input parameters

- Does Litrani use correct physics?



Input parameters

- Absorption length l_{ABS} for simulation from experimental transmittance data
- T_{EXP} given by *Nucl. Instr. and Meth. A 385 (1997) 209-214*



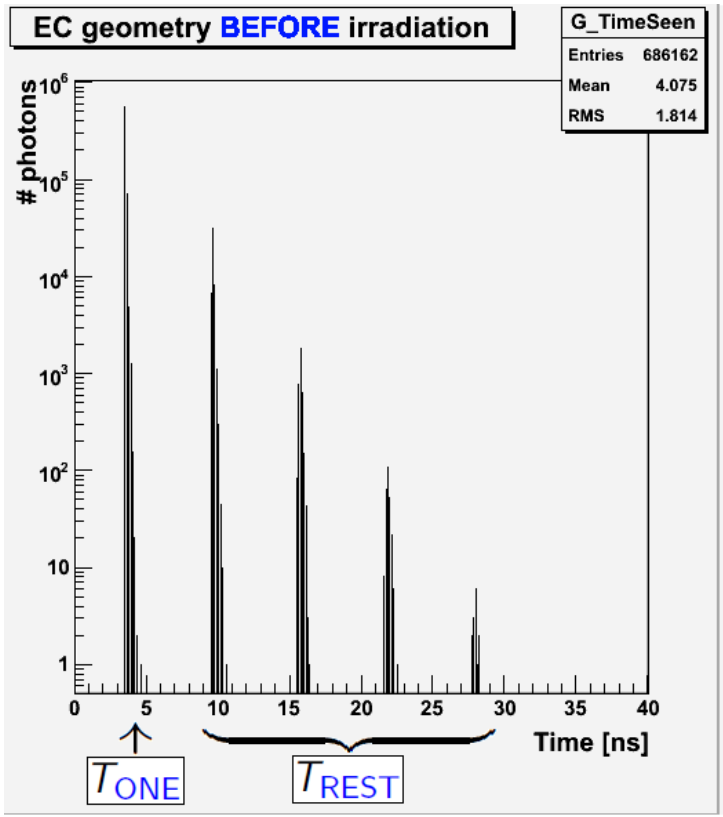
$$T_{EXP} = \underbrace{\frac{t^2 e^{-kd}}{1 - r^2 e^{-2kd}}}_{\text{includes multiple reflection}}$$

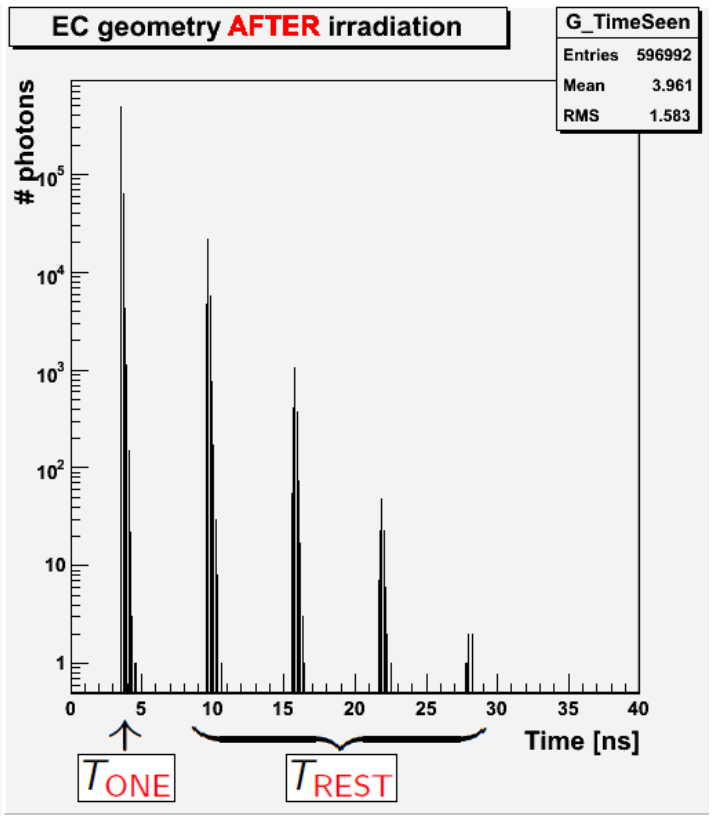
$\rightarrow k[m^{-1}]$

$\rightarrow l_{ABS}[m]$

$\Rightarrow$ reflections reproduce able

Simulation results

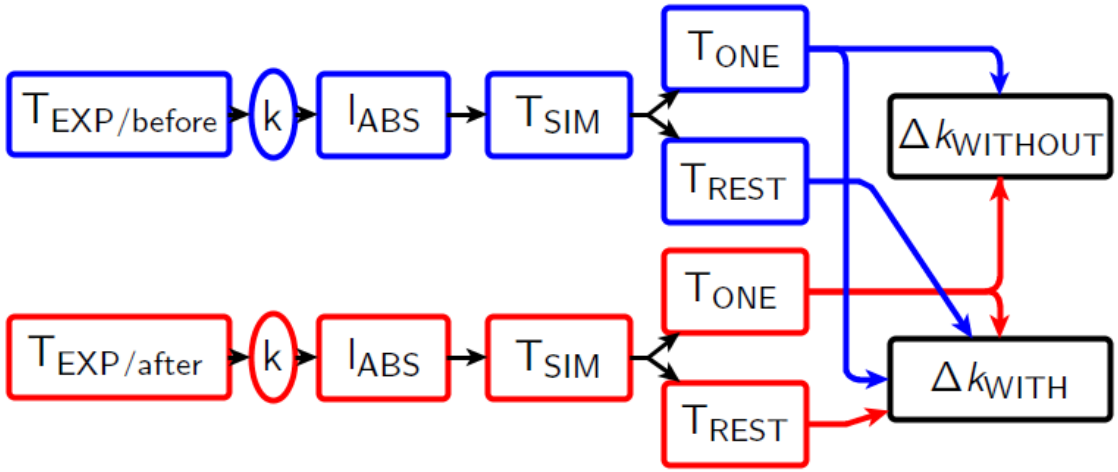




What is the difference between Δk_{WITH} and $\Delta k_{\mathrm{WITHOUT}}$?

$$\Delta k_{\mathrm{WITH}} = \frac{1}{d} \ln\left(\frac{T_{ONE}+T_{REST}}{T_{ONE}+T_{REST}}\right) \qquad \Delta k_{\mathrm{WITHOUT}} = \frac{1}{d} \ln\left(\frac{T_{ONE}}{T_{ONE}}\right)$$

Simulation results



Crystal quality ($T_{EXP/before}$)	"good"	"average"	"bad"
$\Delta k_{WITHOUT}[m^{-1}]$	0,854	0,556	0,514
$\Delta k_{WITH}[m^{-1}]$	0,883	0,561	0,531
$\frac{\Delta k_{WITH} - \Delta k_{WITHOUT}}{\Delta k_{WITHOUT}}[\%]$	**3,4**	**1,5**	**3,7**

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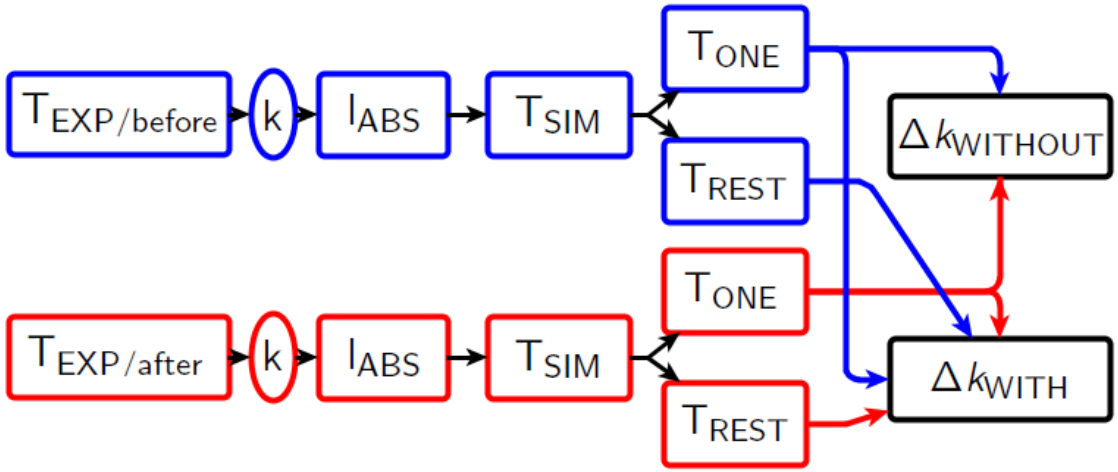

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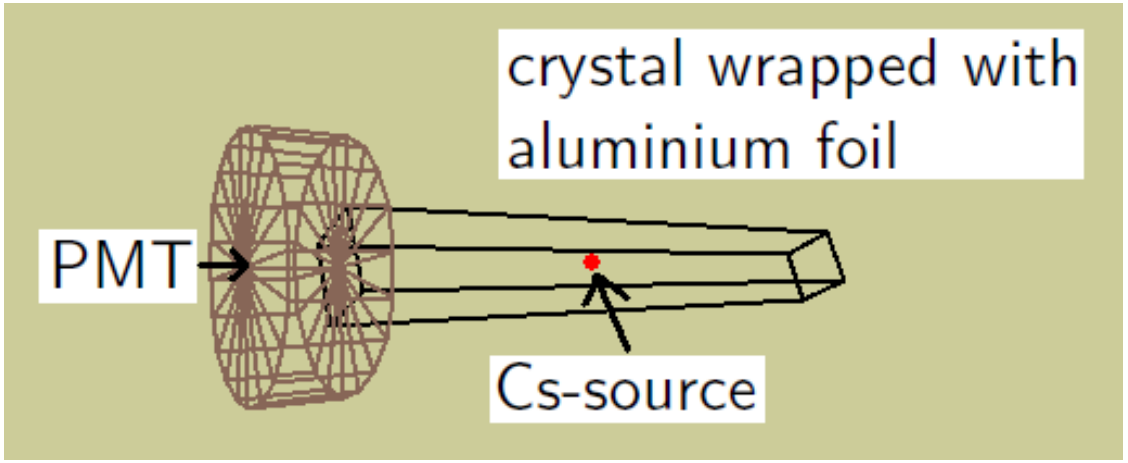
$\Rightarrow$ Systematic error due to multiple reflection is on the order of a few percent

Simulation outlook

Next step:

- Studies of light collection depending on the geometry



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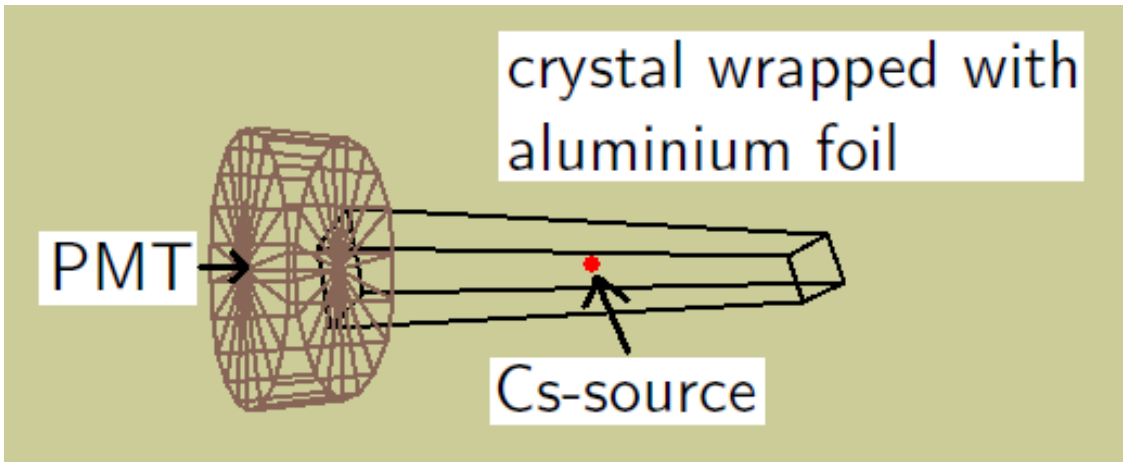


Innovations:

- $PbWO_4$ as uniaxial negative birefringent
- More input parameters: Cross section for Photo effect, QE of PMT, Fluorescence Components, ect.

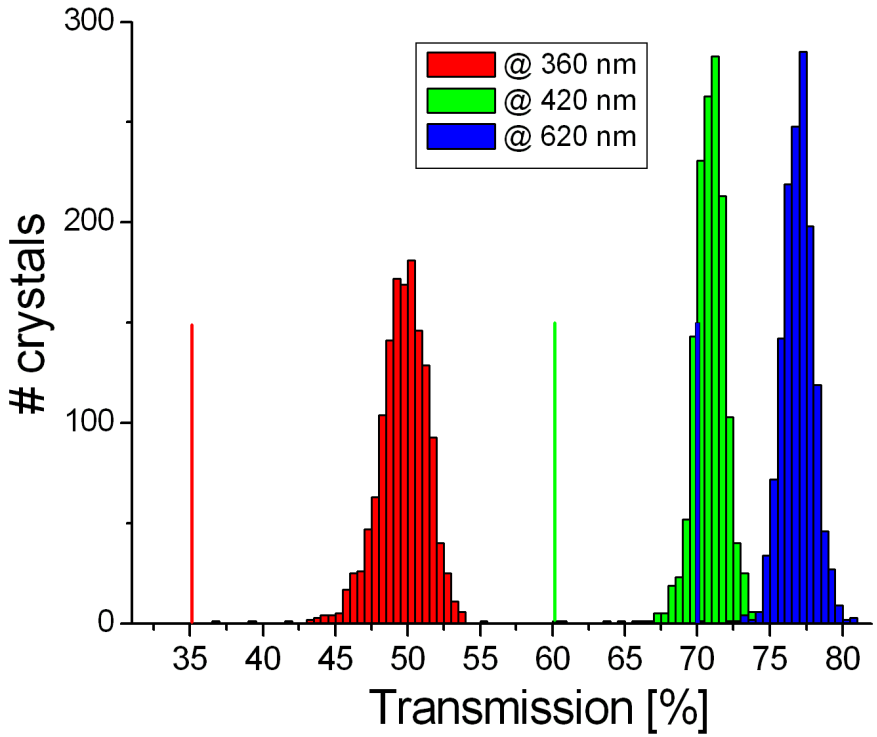
Delivery status

Type		Lot B1 - B4	Lot B5	Lot B6	Lot B7	Lot B8	Lot B9
End Cap		4400					
Backward EC						70	630
Barrel	Type 1	375		270	695		
	Type 2					140	
	Type 9			330	325		
	Type 10					120	
Total		**4775**		**600**	**1020**	**330**	**630**
Delivered?		✓		✓	✓	✓	✓
Present station		Giessen	CERN		Uppsala	Giessen	

- EC complete
- all together 7355 crystals were produced

Quality status / Transmission

- Transmission at 360, 420 and 620 nm / Giessen
- Lot B-1 and 70% of Lot B-2 $\hat{=}$ 1420 crystals



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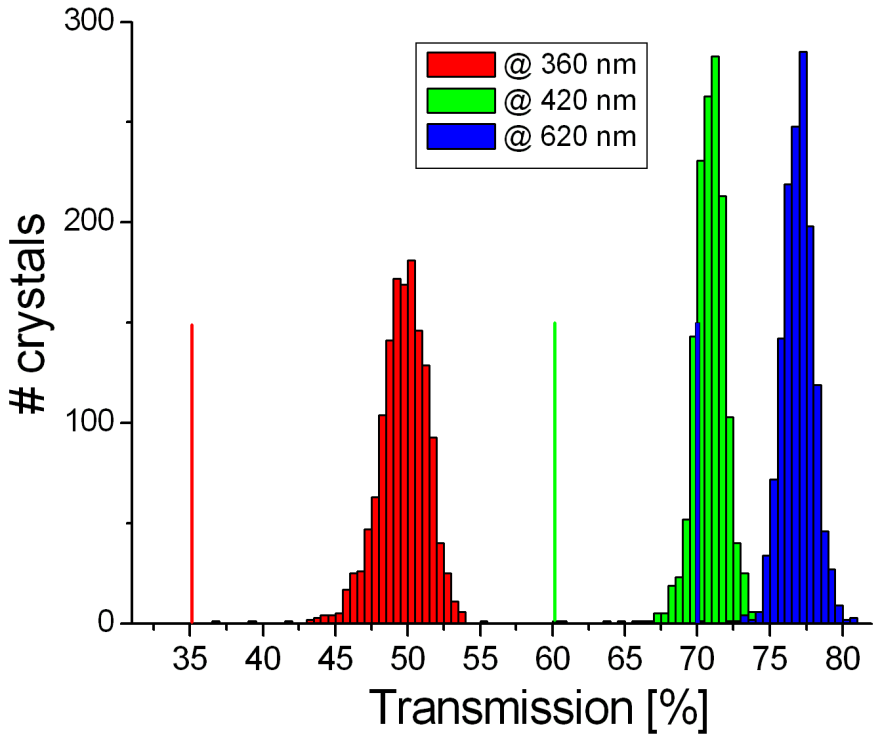
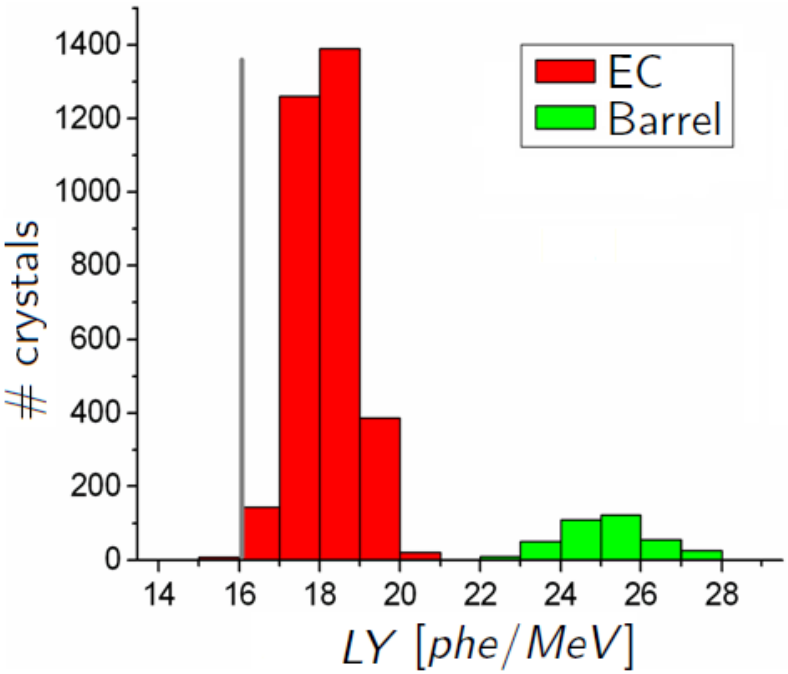
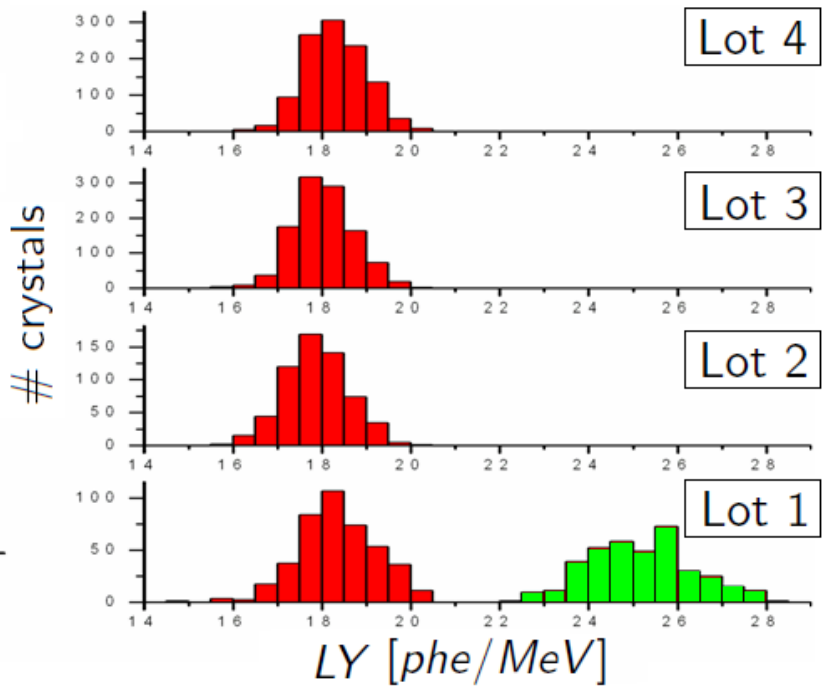


$\Rightarrow$ all crystals above specification limit $\Rightarrow$ no rejection

Quality status / Light Yield

- Light Yield / CERN / Lot B-1 to Lot B-4 $\hat{=}$ 3950 crystals





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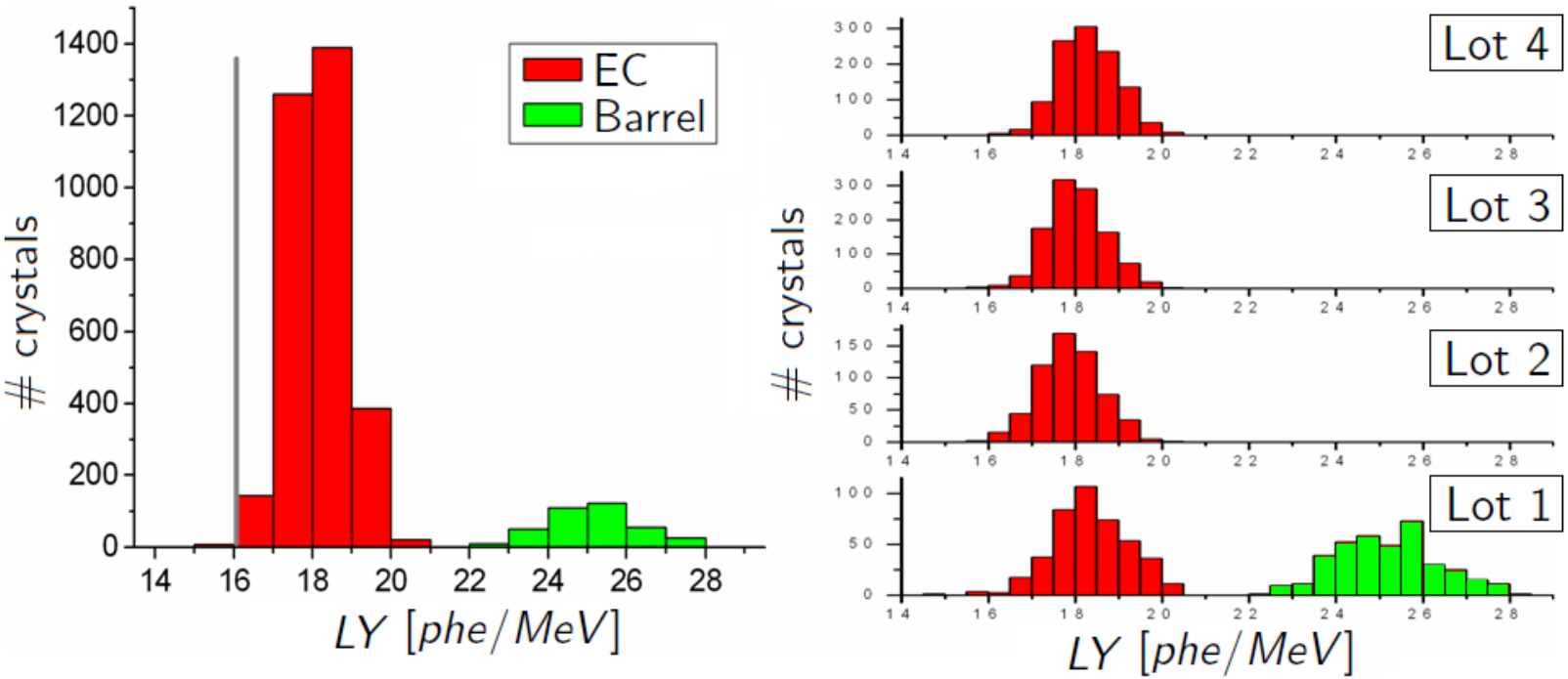
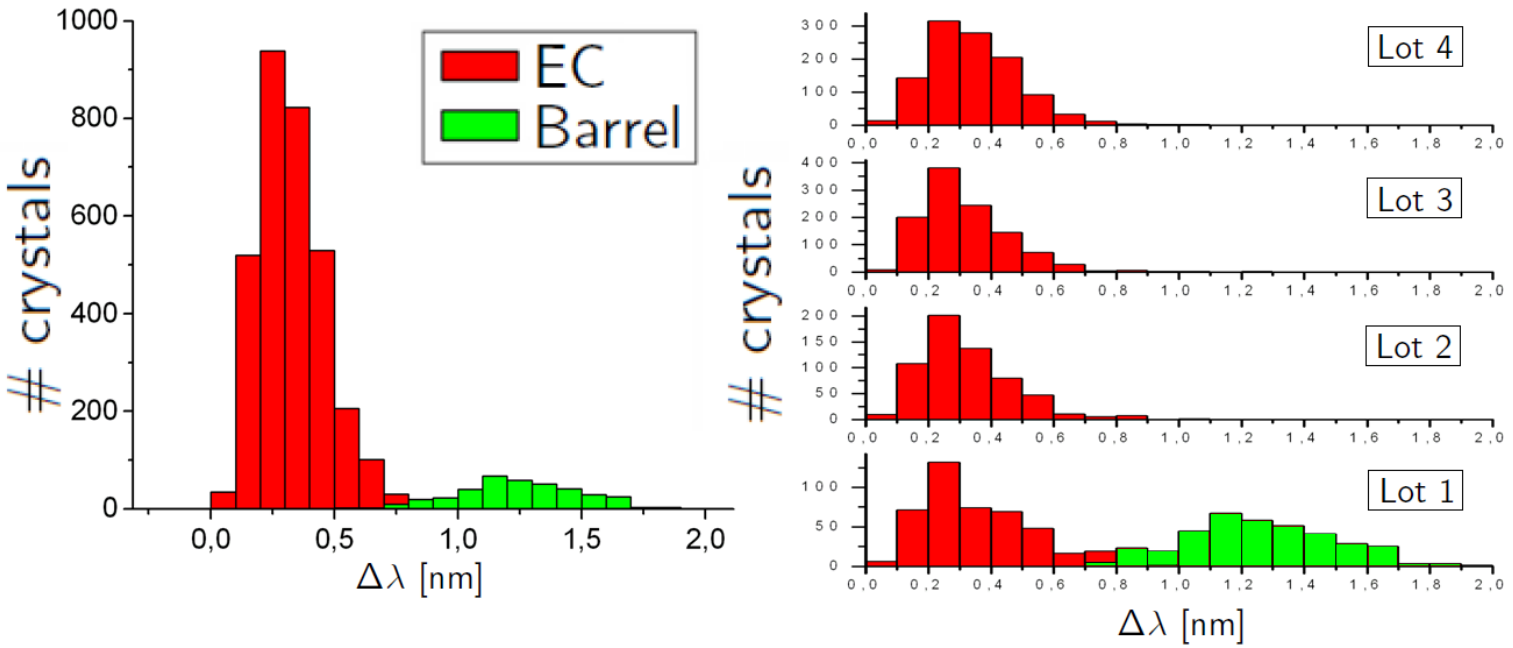


$\Rightarrow$ For Lot B-1 and B-2: **4** crystals have to be rejected due their insufficient Light Yield

Quality status / Transversal Transmittance nonuniformity

- $\Delta\lambda$ / CERN / Lot B-1 to Lot B-4 $\hat{=}$ 3950 crystals



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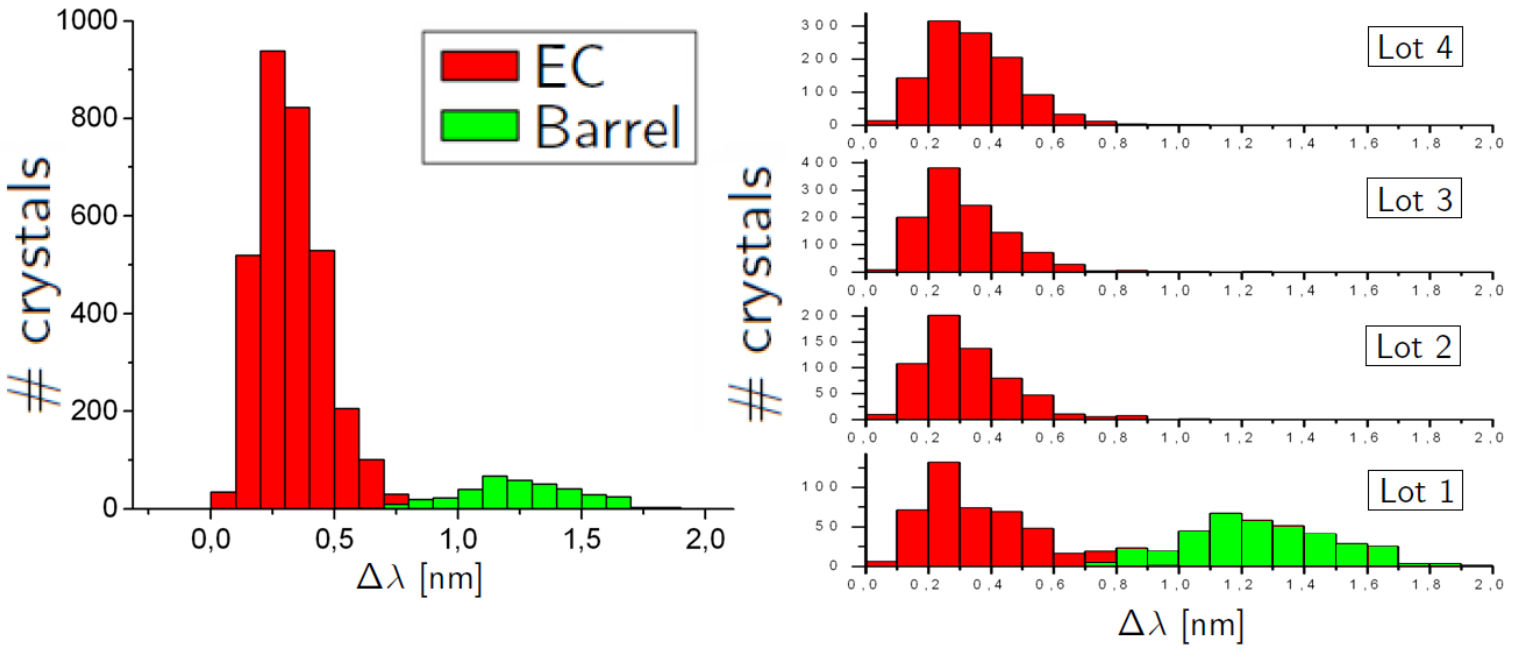
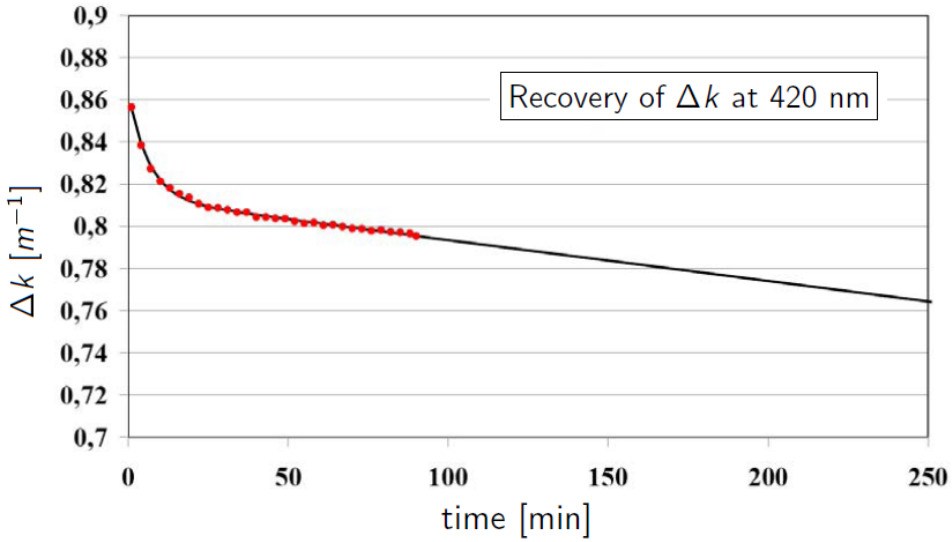


$\Rightarrow$ all crystals within specification range ($\leq$ 3 nm)

Quality status / Radiation hardness

- strong dependence on a fast recovery components



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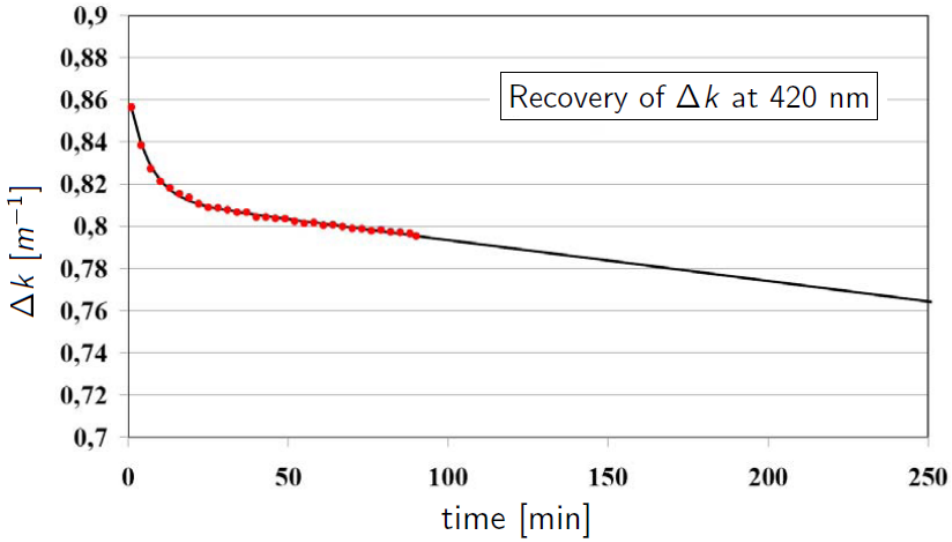
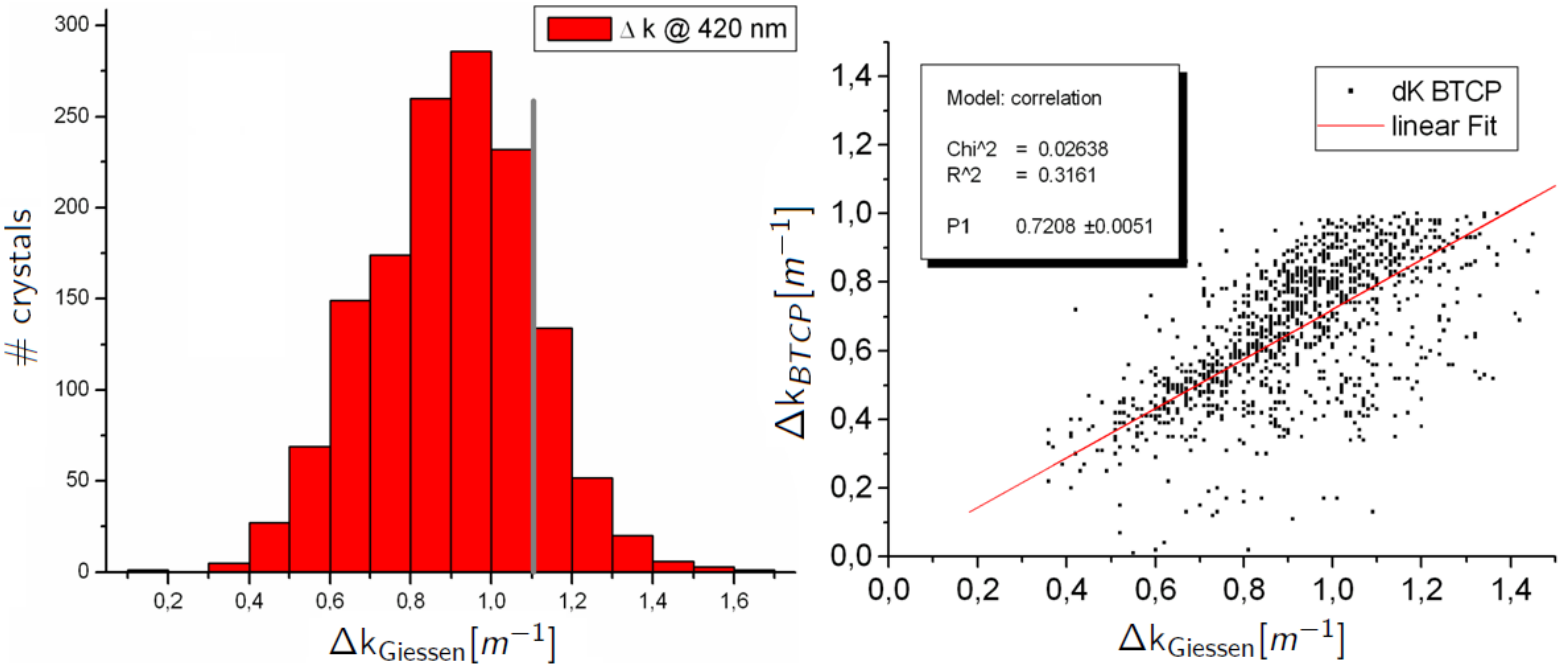


- crystals were/are measured within 30 minutes after irradiation
- modified specification limit:

$$\Delta k \overset{!}{\leq} 1,1 \text{ m}^{-1}$$

Quality status / Radiation hardness

- Δk / Giessen / Lot B-1 and 70% Lot B-2 $\hat{=}$ 1420 crystals



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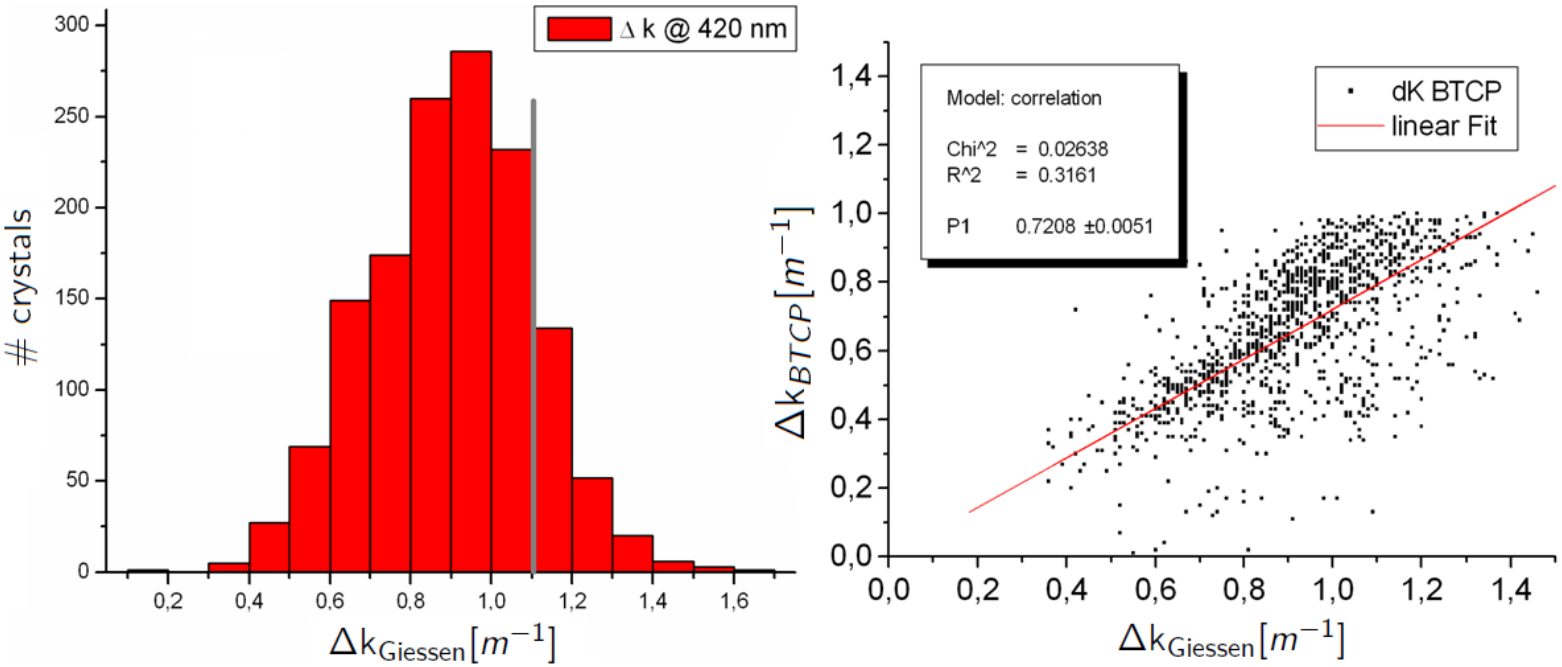

$\Rightarrow$ For Lot B-1 and B-2: **11** % rejected

Conclusion

- systematic error due to multiple reflection is on the order of a few percent
- simulations to study light collection depending on the geometry is in progress
- ca. 2000 crystals were tested
- for Lot B-1 and B-2: 11% are out of specification

Thank you for attention!