Uniformization of Light Collection in Lead Tungstate Crystals in View of a High Resolution Calorimeter

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Talk for CALOR 2000, 14/10/00

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Outline

- ***Why it is important the light collection uniformity ?***
- ***Wich are the parameters that define the uniformity curve ?***
- ***How to "uniformize" the crystals ?***
- ***Results of the uniformization task***

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Introduction

The energy resolution of the CMS ECAL can be expressed as follows:

$$\frac{\sigma}{E} = \left(\frac{a}{\sqrt{E}} \oplus \frac{b}{E} \right) \oplus c$$

where E is in GeV, ***a*** is the stochastic term, ***b*** is the noise term and ***c*** is the constant term.

• An homogeneous calorimeter allows an excellent ***a***. In order to take advantage of this, ***c*** must be limited to 0.5%.

• The most important contribution to ***c*** comes from the non-uniformity in the light collection along the crystal.

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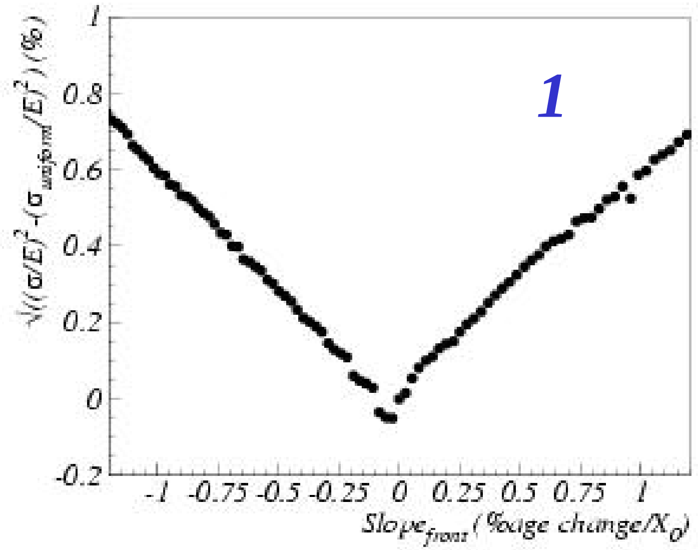
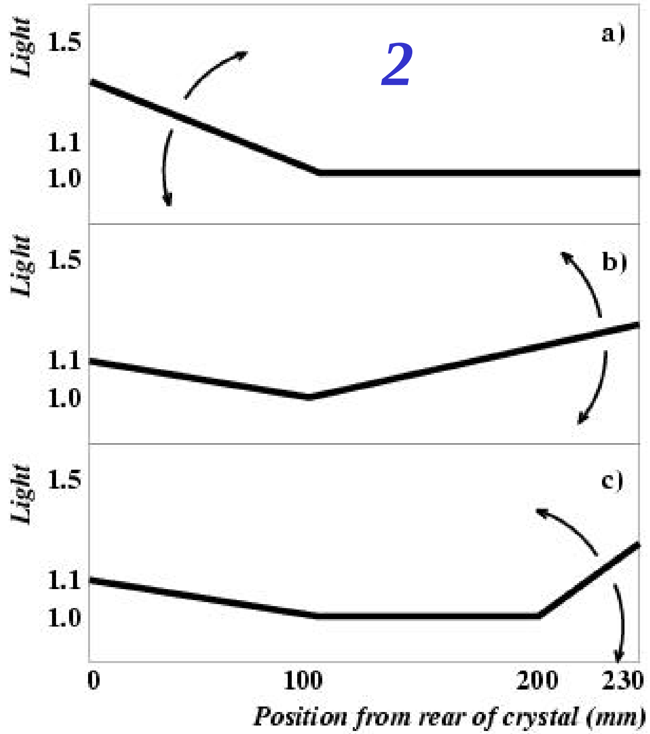
Influence of the Uniformity in E resolution

The slope in the Front region of the crystal (4-13 X_0) strongly affects the contribution to E resolution (see ***1***).





To limit that contribution to less than 0.3 % it is required: ***-0.35 %/X_0<Fnuf < +0.35 %/X_0***

Other possible configurations (see ***2***) have a much smaller influence.

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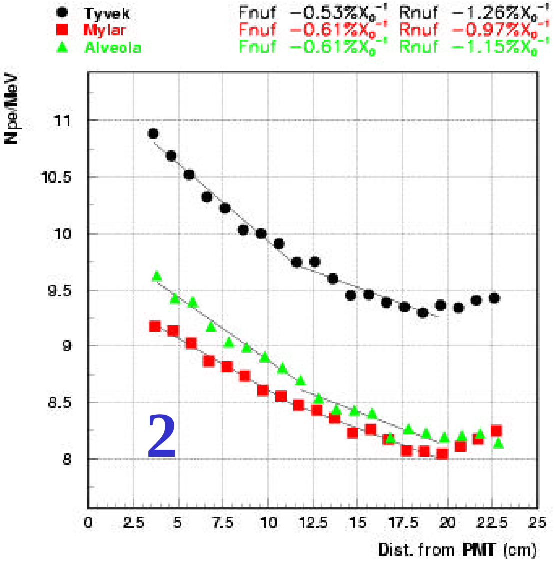
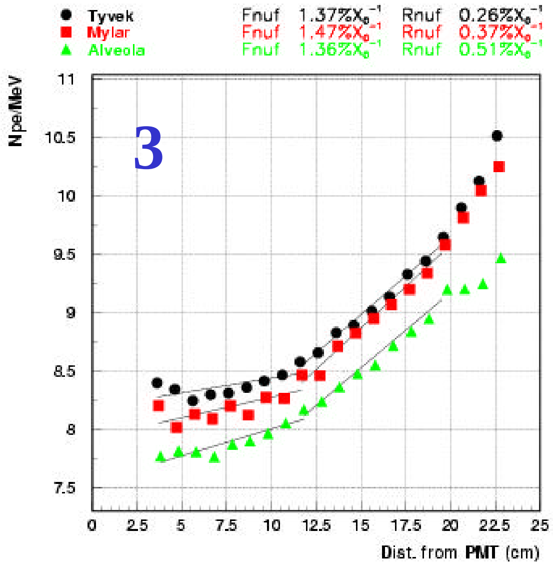
The Effects defining Uniformity

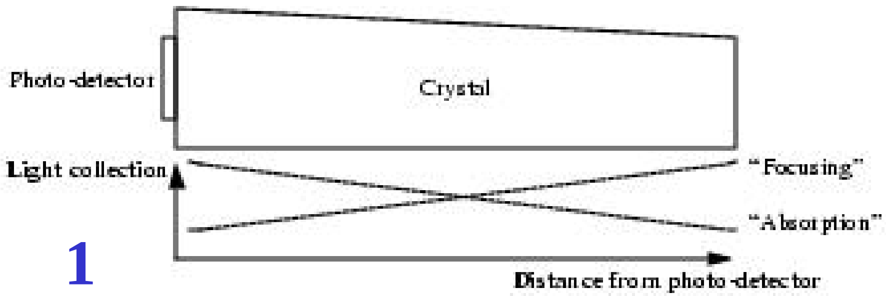
The light collection uniformity is given by two competing effects: the *absorption* and the *focusing effect* (see **1**). The focusing effect is due to the *tapering* of the barrel crystals:

- Absorption dominates in a crystal with a depolished face (R_a~0.5 μm) as the focusing effect is strongly reduced (see **2**).

- Focusing dominates in a fully polished crystal, (see **3**).







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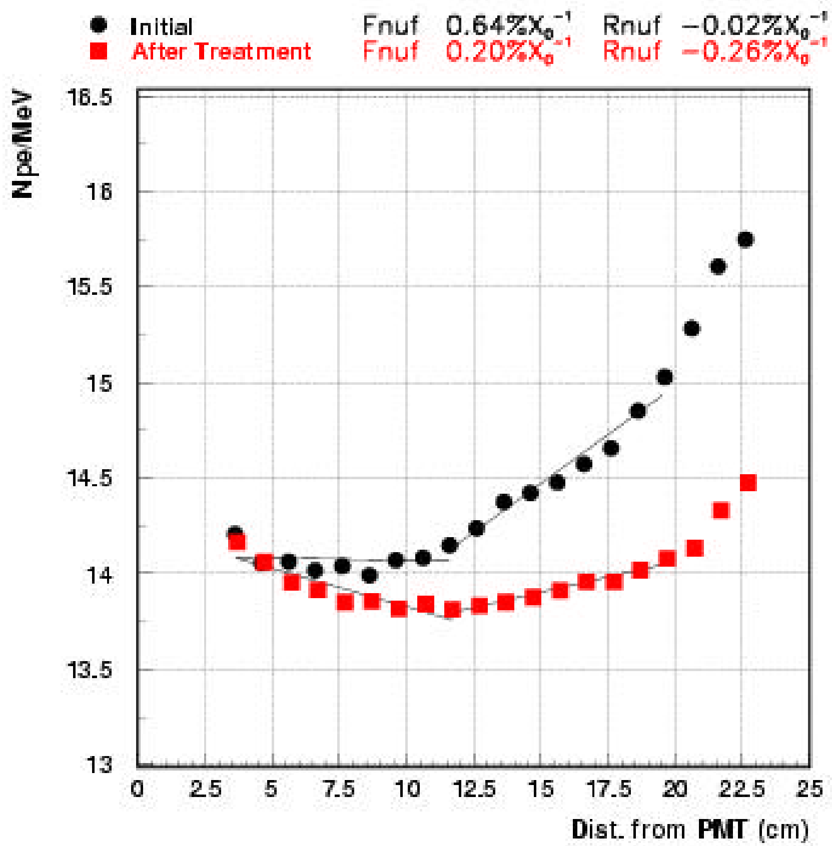
The Uniformization Procedure (I)

- It is necessary to find an intermediate state of roughness (R_a~0.3 μm) in order to get a Fnuf matching our limits (±0.35 %/X_0) as in the example.

- The exact R_a value and the procedure was defined with preproduction crystals 2 years ago. It can be described as follows:

- The treatment is applied to 3 crystals each time and can be divided in:



1) The ***lapping*** (30 Kg., 15 μm, resin wheel, 5 min).
2) The ***polishing*** (15 Kg., 15 μm, soft tissue on a polishing wheel).

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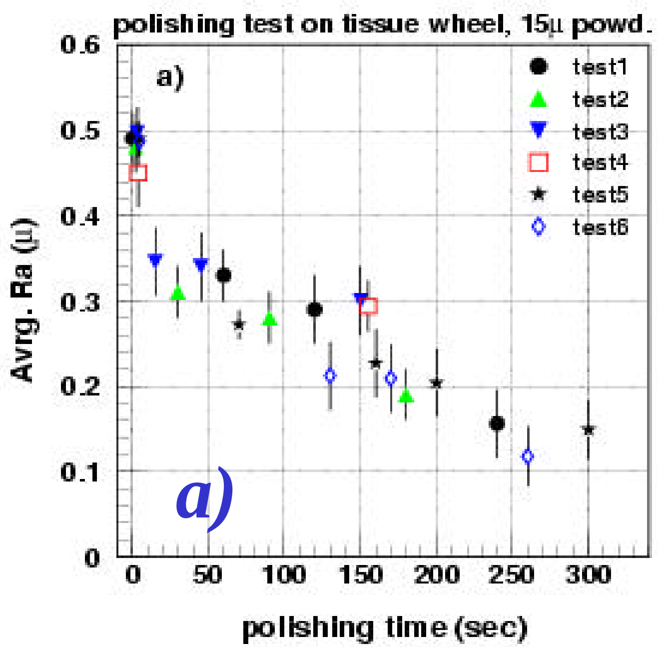
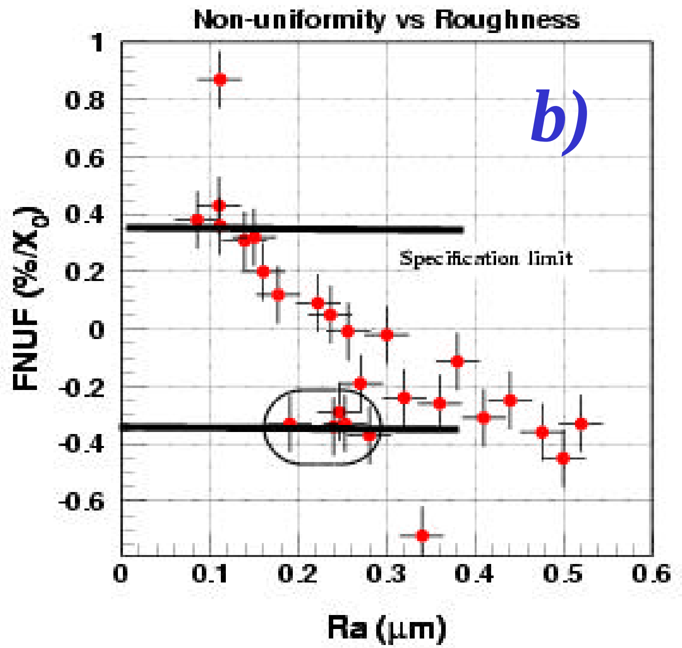
The Uniformization Procedure (II)

- The evolution of the R_a with time is shown in ***a)***, and its influence on the Fnuf in ***b).*** As can be deduced from ***b)*** the treatment was chosen to provide Ra~0.3µm.
- Recent improvement in the optical quality of crystals has reduced absorption , therefore a redefinition of the Ra required was needed (Ra ~0.45 µm).





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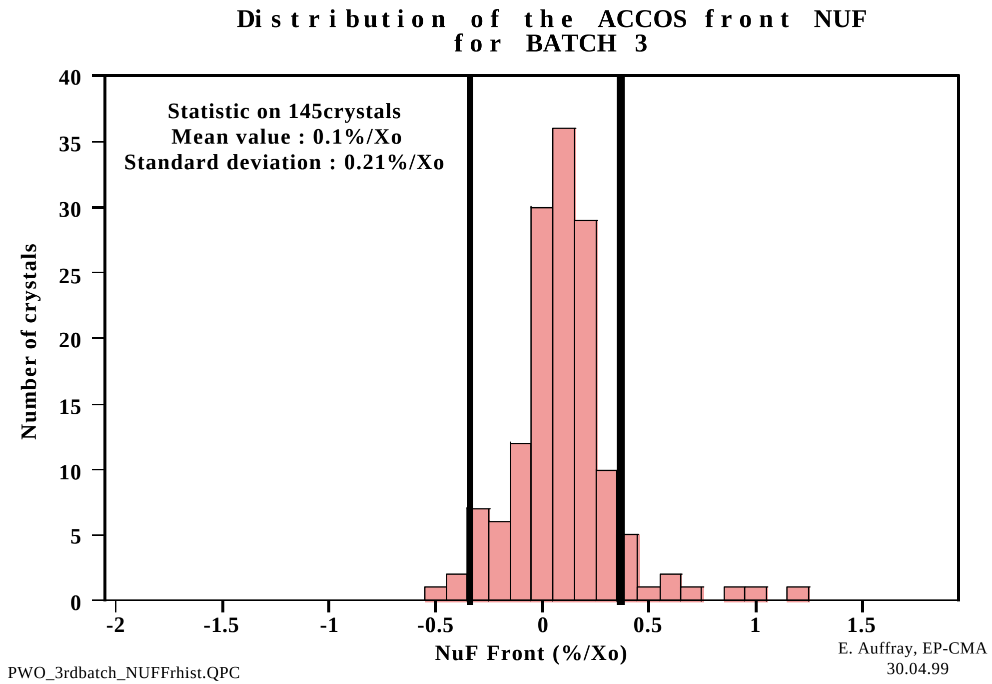
Report on the Uniformization Task (I)

Since end of 98 up to now we have received 5000 cx in CERN R.C. grouped in 12 batches. We can classify them according to their Fnuf distribution:

• ***Batches 1 - 4***: The treatment defined at CERN R.C. and transferred to producers worked properly. *Fnuf distribution was well centered* (see Batch 3).

• ***Batches 5 - 7***: Producers tuned their methods to improve the quality of the crystals. The reduction of the absorption *shifted the Fnuf distribution* (see Batch 6).



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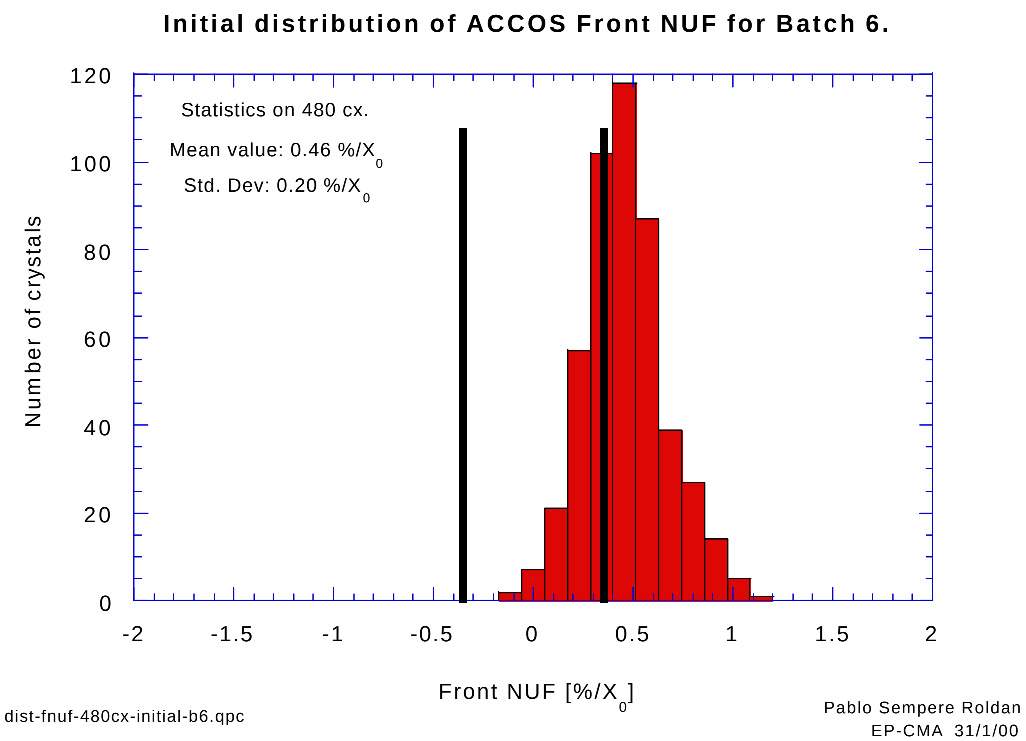
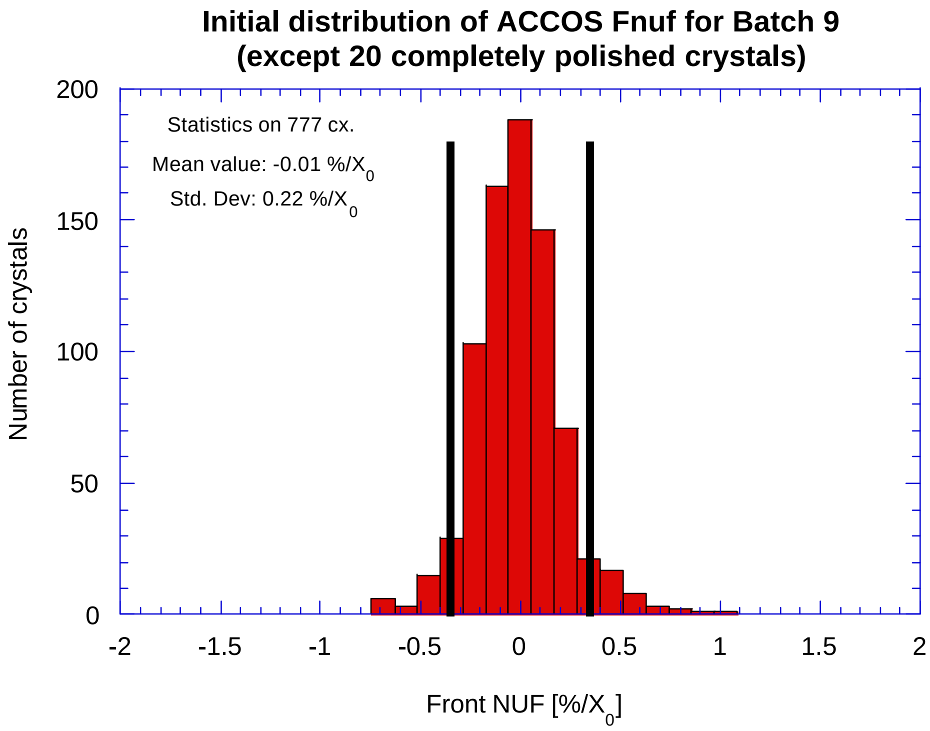
Report on the Uniformization Task (II)

- ***Batches 8 - 12***: After several studies, we proposed a higher R_a to producers (R_a~0.45µm). *Fnuf dist. are again well centered* (see Batch 9).





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Report on the Uniformization Task (III)

- The uniformity of light collection in crystals belonging to batches with Fnuf distributions “well centered” (1 to 4 and 8 to 12) is easily achieved as typically less than 10% need to be retreated. For these crystals, the treatment applied in one face by producers is corrected at CERN R.C. depending on the sign of the slope (i.e: if Fnuf>0.35%/X_0 we increase R_a by lapping but, if Fnuf<-0.35 %/X_0 we reduce R_a by a soft polishing).

- The situation for Batches 5 to 7 (Fnuf distribution shifted) has been analyzed and corrected. In spite of the initial amount of crystals non-uniform, the uniformization task produced excellent results:

Batch	# Cx.	# Cx. Non-uniform	# Cx Treated	# Cx uniformized	Yield (%)
5	400	177	168	157	93.5
6	500	348	345	340	98.6
7	550	199	199	194	97.5

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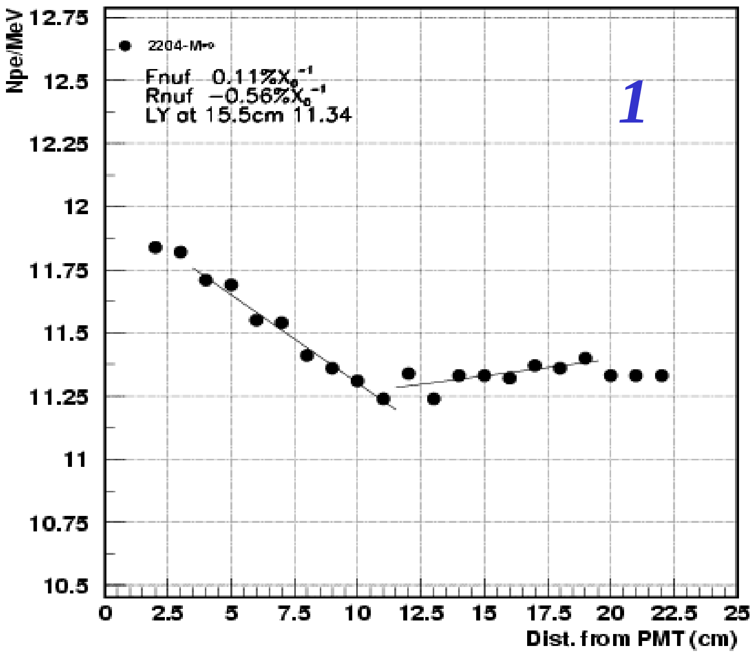
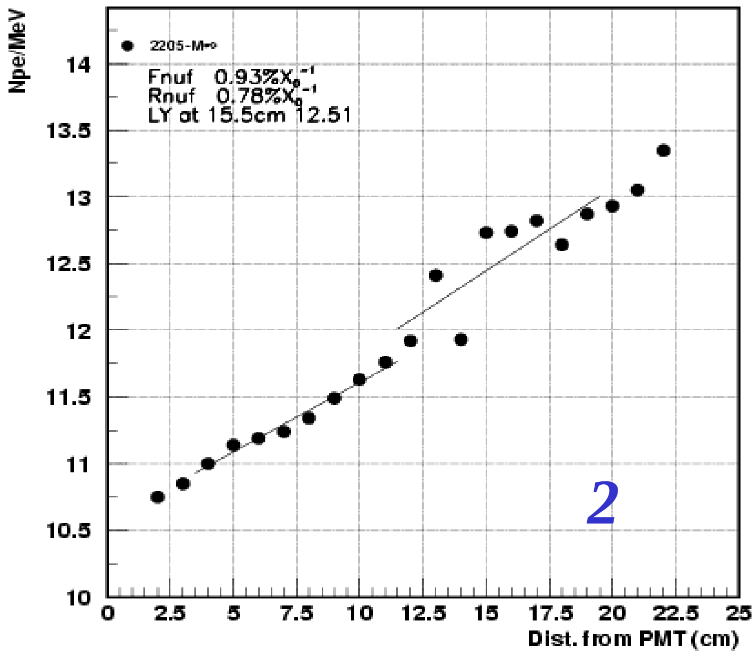
Other parameter affecting non-uniformity

- The endcaps are supposed to be naturally uniform due to smaller tapering.
- Studying small batches of 10 endcaps crystals we found some of them (4 cx) following the behavior predicted by the simulations (see ***1***) and some other (6 cx) behaving completely different, (see ***2***).





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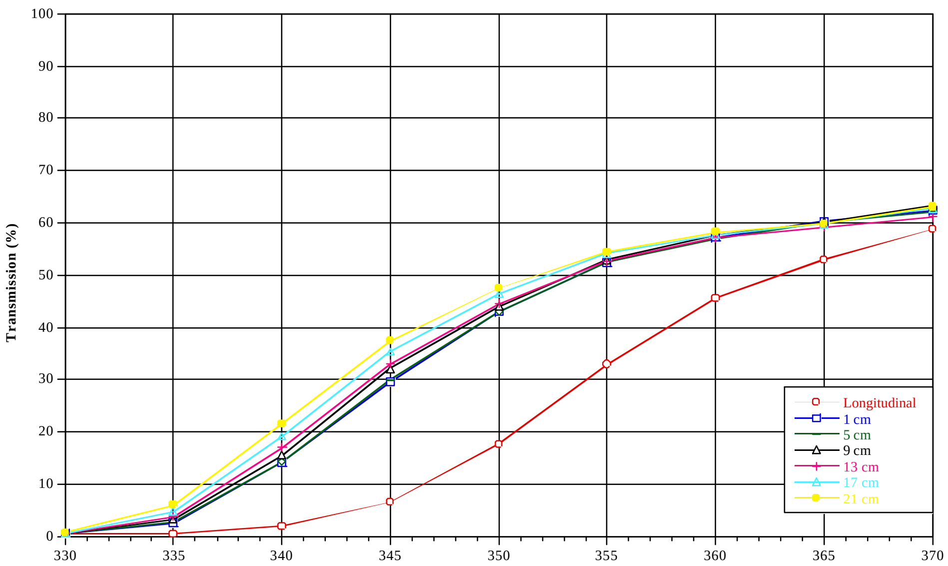
Other parameter affecting non-uniformity (II)

- The 10 endcaps were fully polished, had the same geometry and a very similar longitudinal light transmission so, *no significant difference in uniformity should be expected*.
- The only difference was a "gradient" in the transversal light transmission at the band edge (● ~345nm).

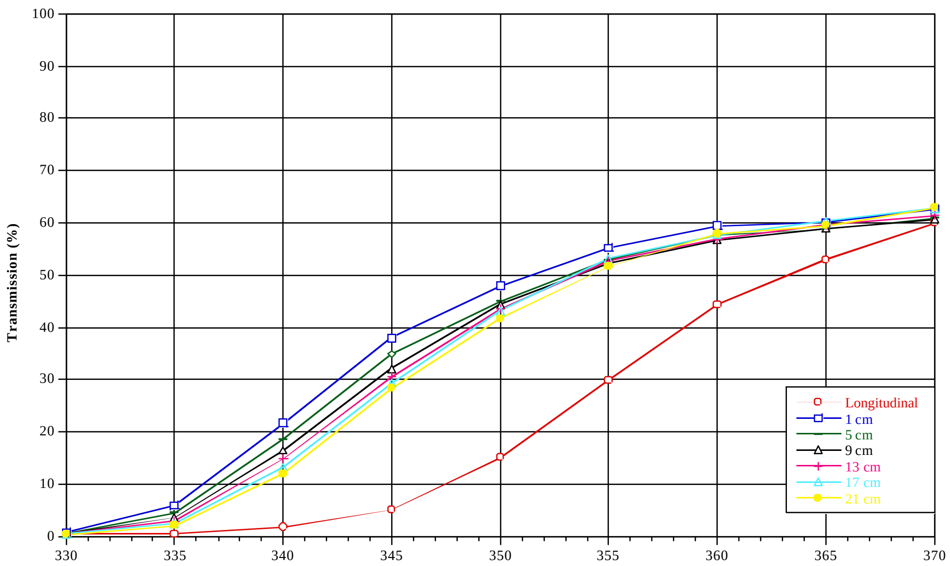
Longitudinal and transversal transmission of PWO2204 crystal.



PWO2204_allcm.plt

E.Auffray,F.Antoniella,R. Marcos/EP-CMA,Labo27 13/07/99

Longitudinal and transversal transmission of PWO2205 crystal.

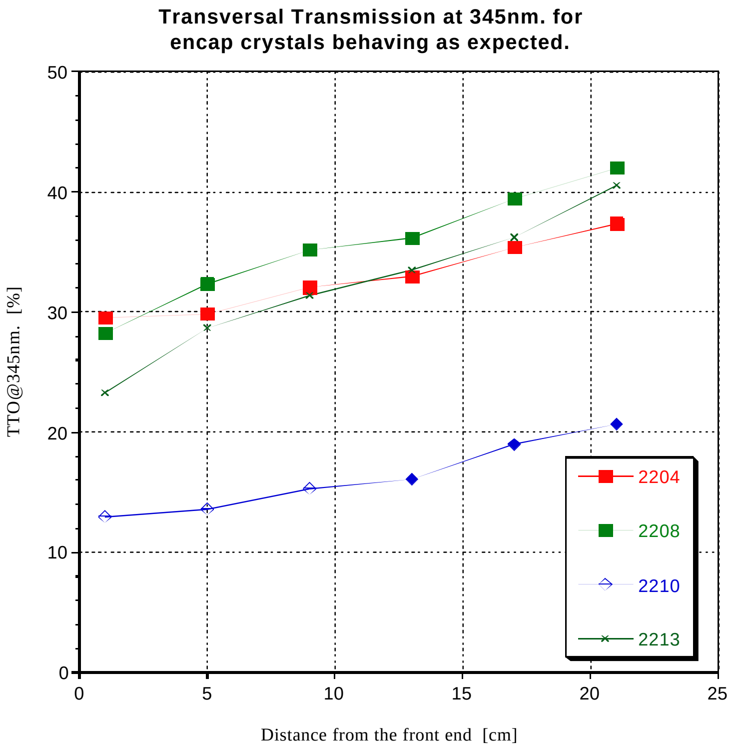


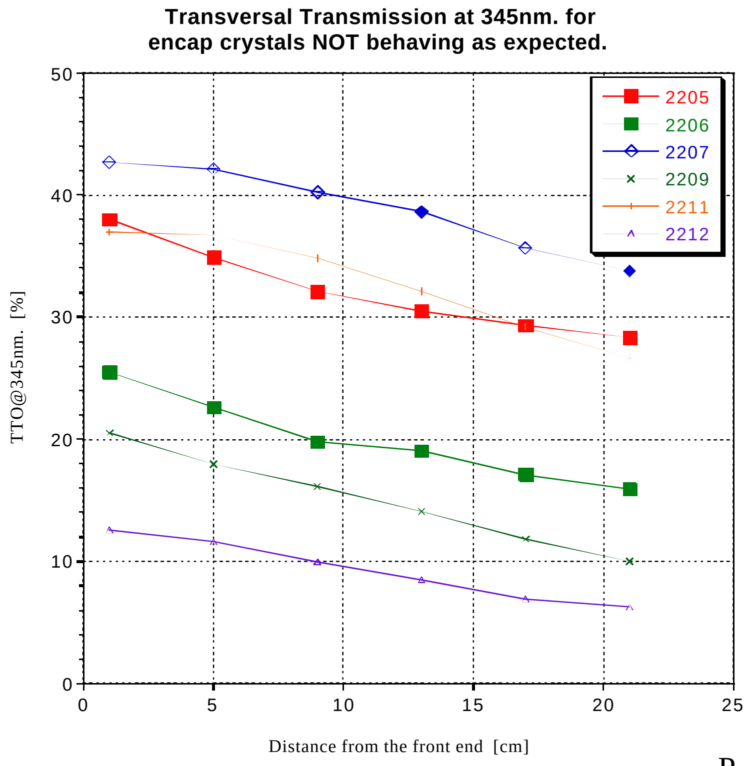
PWO2205_allcm.plt

E.Auffray,F.Antoniella,R. Marcos/EP-CMA,Labo27 13/07/99

Other parameter affecting non-uniformity (III)

- The variation of TT@345 nm. along the crystals is plotted below. Two groups are made according to Fnuf behavior.
- Clearly, the slope sign of this variation characterizes each family.





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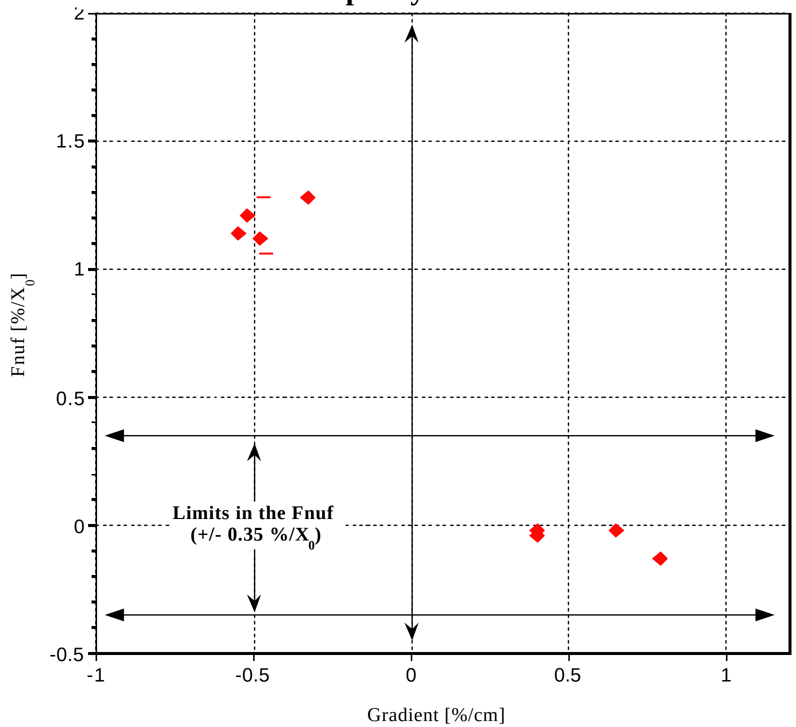
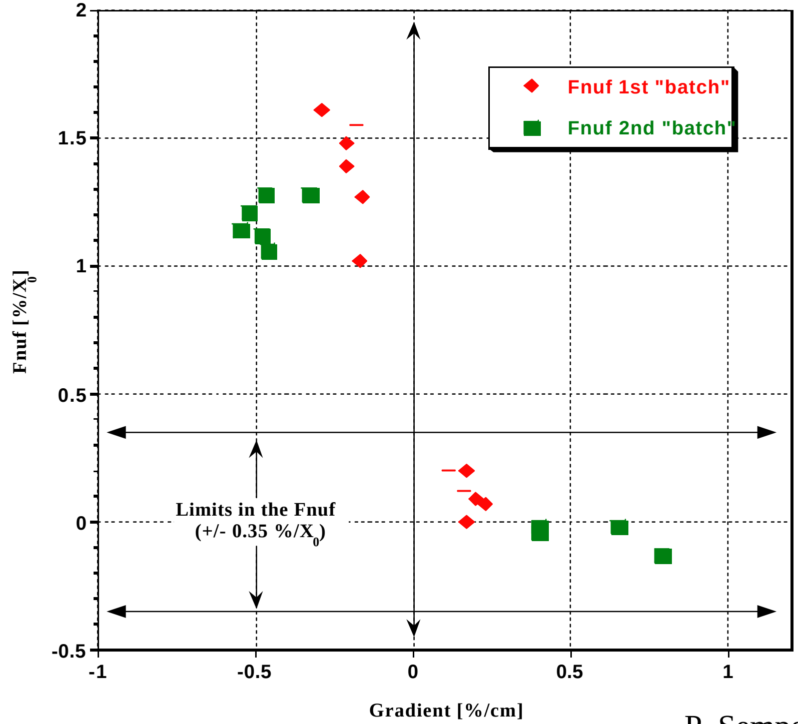
The influence of the gradient in Fnuf

The correlation between the slope of the fit (*gradient**) in the previous plot and the Fnuf of the crystals explains the 2 behaviours in the Fnuf. This is also good for old batches of endcaps crystals.

Comparison of the Fnuf vs. the "gradient" for last 10 encaps crystals received.



Comparison of the Fnuf vs. the "gradient" for 22 encaps crystals.



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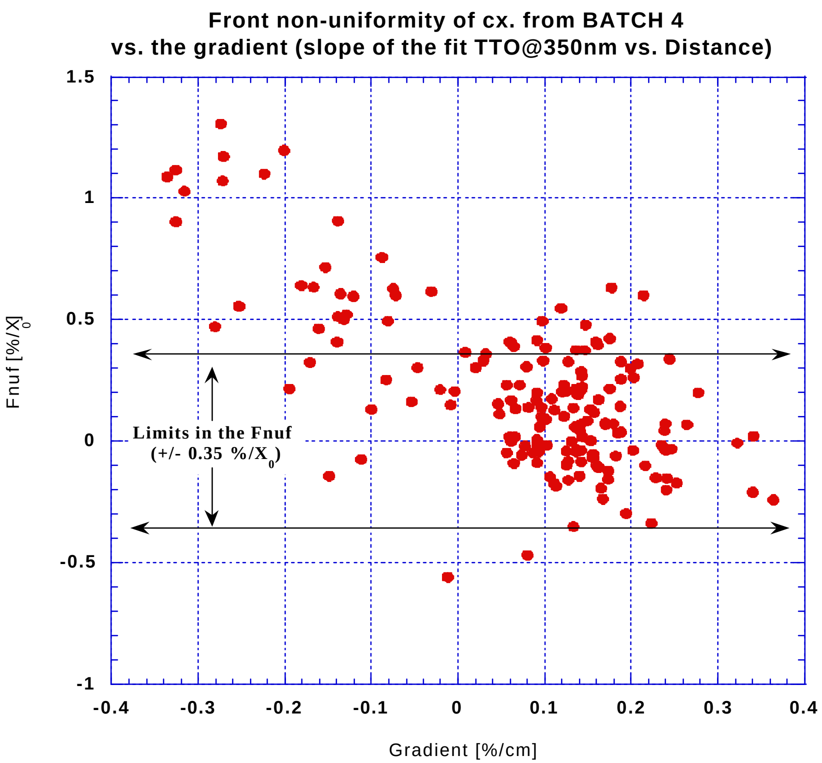
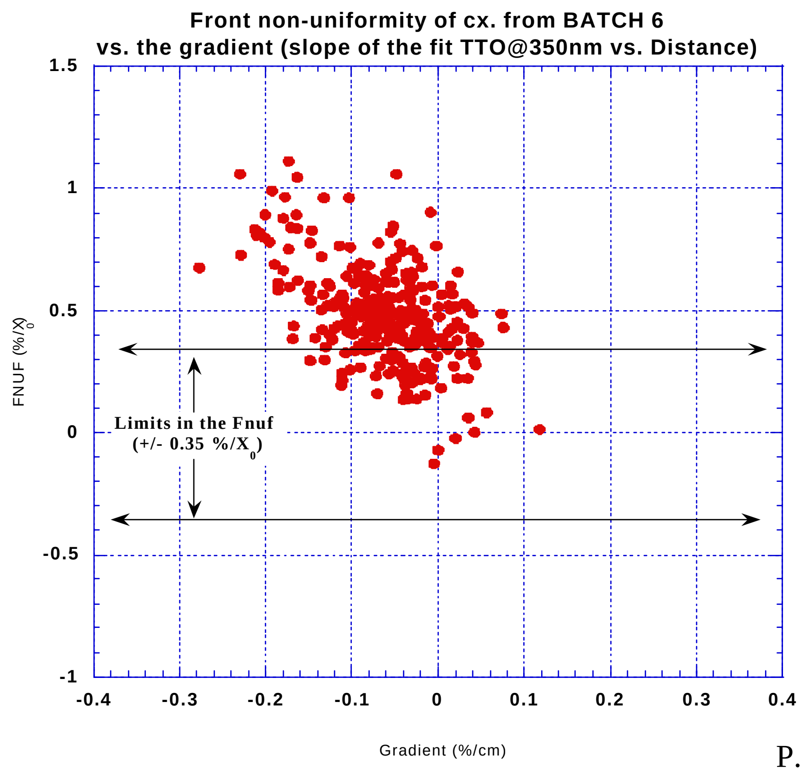
The gradient in the barrel crystals

- The gradient is useful to define the crystals with the “worst” non-uniformity (Fnuf~ 0.7 to 1.0 %/X_0) in older batches (see Batch 4).
- For Batch 6 crystals were optimized, reducing the influence of the TTG, but also shifting the Fnuf distribution, as explained before.





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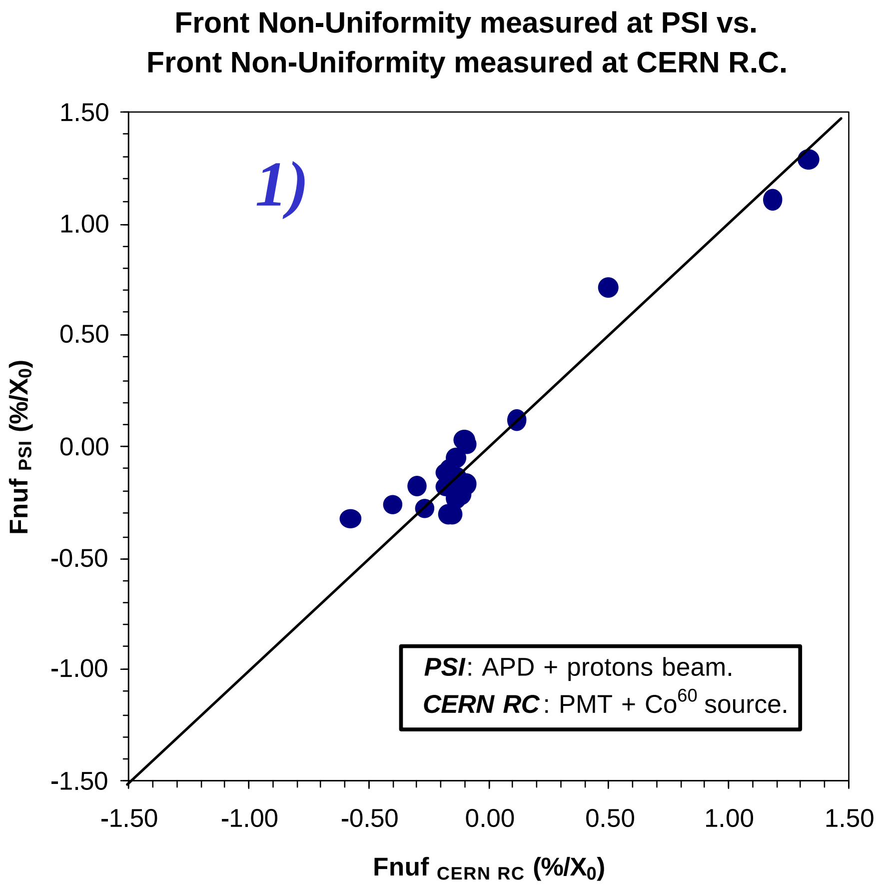
Verification of Fnuf in the Beam

- The Front and Rear non-uniformity are measured at CERN R.C. in classical benches (using PMT's and a Co^{60} or Na^{22} source). These measurements are used to calibrate the uniformity's measured with the ACCOS (Automatic Crystal Control System) devices.

- Excellent correlation is found between measurements at CERN R.C. (in classical benches) and in the "final conditions" (with 2 APD's glued and in beam conditions) see ***1)***.



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Conclusions

- Uniformities measured at CERN R.C. agree with values measured in *final* conditions.

- 5000 cx for the ECAL have been received at CERN R.C. and nowadays, just very few of them need a re-treatment.

- Batches 5 - 7 were initially problematic but situation is now under control.

- Thanks to this control on the light collection uniformity, we have got in the Proto 99 test beam ***a ~ 2.8 %*** and ***c ~ 0.4 %.***

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