A surface reflector on the end of the WLS fiber BCF-92 for the VVS detector CKM.

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1 Introduction

The VVS sector module scintillator stack is readout with a plant of wavelength shifting (WLS) fibers. The fiber of choice is a fast 1mm diameter double clad fiber, Bicron BCF-92/99. The end of the fiber at the inner radius of the station module is mirrored with an aluminum vacuum evaporation process to increase the light yield [1].

In this note we describe the results of an investigation effect of reflection of surfaces of a mirrored fiber, in the mass production.

2 WLS fibers

The used WLS doubled clad fiber(Bicron BCF-92) have 1mm diameter and are 90 cm long. Before mirrored fiber, the fiber ends have been cut and polished by using a fine grain abrasive paper. We have taken particular care to prepare fiber end coupling to the PM windows to maximize the light transmission efficiency on the one hand, and on the other to get the best quality of reflection of surfaces the other end of the WLS fiber. 500 WLS fiber ends were mirrored by aluminum sputtering and coated with MgF_2 to protect the mirror end was production.

From 500 fibers chosen at random:

- 50 fibers for measurement the reflection coefficient R with disintegrating control;
- 50 fibers for measurement light yield with out disintegrating control

3 Reflection coefficient R measurement

3.1 Experimental setup

Experimental setup of measurement of the R and light yield is shown in Fig.1. Light is injected into the WLS fiber via LED. The LEDs used were generic ultra bright LEDs from RS

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Components [2] with a peak emission wavelength of 470 nm typical opening angle of 15^o. The LEDs were driven by a nominal 30 ns pulse with a voltage output 112.8V. A schematic of the relative timing of the signals with respect to the gate is shown in Fig.2 for the pulse generator. The photodetector we have used is a PMT FEU-84. The PM is operated at - 1500V. Data was taken using 14bit ADC.

3.2 Results

We measured reflection coefficient R in the following way:

1. The pulse height for the mirrored fiber was measured at 16 points with at 5cm intervals.

2. The next step was determine the light yield of one fiber with out mirror. We have placed the cut of end of fiber inside the mineral oil filled bar to obtain a good optical matching, what is the same ideal black end. To keep the fiber in place, a thin plastic slab has been put over the bar. The second end of fiber with coupled the PM window is free of stress.

Fig.3 shows a typical pulse height distribution for differents LED position.

The next step is to determine the light yield I_M - with mirror, I_{NM} - with out the mirror, from the pulse height distribution. The I_M is given by

$$I_M = \frac{(\mu_M - P)\times C}{(\mu_C - P)}, \quad where$$

μ_M and μ_C – peak is fitted with a Gaussian distribution for LED and control LED respectively;
C – average peak position control LED for all 1600 run's
P – is pedestal counts.

In Fig.4, we show the result both for an unmirrored and a mirrored fiber. Experimental data have been fitted with the following function:

$$I_{NM}(x) = e^{P_1+P_2x} + e^{P_3+P_4x}, \quad where$$

$\lambda_1 = \frac{1}{P_2}$ and $\lambda_2 = \frac{1}{P_4}$ are respectively, the attenuation lengths of the light trapped into the external cladding plus effect of spectral variation of fiber emission ("cladding light") and of the light guided by internal reflection into the fiber core ("core light") [3,4];
x – is the distance from the PM;
P_1 and P_3 is a common normalization factor.

The light yield $I_M(x)$ is correctly given by the following expression:

$$I_M(x, R_j) = I_{NM}(x) + e^{P_4(L-x)}\times R_j\times I_{NM}(L), \quad where$$

L – 90 cm is the fiber length, and R_j is the mirror reflectivity as parameter.

The reflection coefficient R has been defined as minimum of χ_j^2, that is given by the following expression:

$$\chi_j^2 = \frac{1}{n}\sum_{i=1}^{i=16}\frac{[I_M(x_i, Rj) - I_M(x_i)]^2}{I_M(x_i)}, \quad where$$

n=16,$I_M(x_i)$ – experimental data;
R_j=0.6÷1.0,$\triangle R_j$=0.01.

The date fitted results are in Fig.4(upper right).

Finally, the distribution of reflection coefficient R for 50 WLS fibers is shown in Fig.5. The average reflection coefficient R and the RMS variation were measured to be 86.2% and 4.9%.

4 Fiber-to-fiber uniformity

For the light yield studies, 50 mirrored fibers have been used. We have studied the fiber-to-fiber uniformity of light collection as a part of quality control program during the mirror production.

Light is injected into the WLS fiber for LED position x=70 cm(as average point for simulation scintillator-fiber combination). Light yield test results after the mirror fabrication for 50 WLS fibers is shown in Fig.6. The average light yield and the rms variation were measured to be 203.0 and 9.0.

5 Conclusion

5.1

We performed the quality test for the WLS fiber mirrored production. The average reflection coefficient R is 86.2%. This result satisfied our requirements. But , rms = 4.9% is unsuitable for scintillator-fiber combination. There is a need checked quality of fiber mirror (R ≥80%) to select them satisfying our requirements. We have an understanding of construction set-up for quality control of mirroring.

5.2

It is of interest to estimate effect of mirrored end of fiber as compared with loop around the scintillator tile. The light yield $I_{loop}(x)$ for loop geometry was not measured, it can been calculated from the formula:

$$I_{loop}(x) = I_{NM}(x) + e^{P_4(L-x)} \times R \times I_{NM}(L), \qquad where$$

R=1.00

A comparison of there two techniques is illustrated in Fig.7., where

$$I_{loop} = \int_{x=50cm}^{x=90cm} I_{loop}(x)dx$$

$$I_M(R_j) = \int_{x=50cm}^{x=90cm} I_M(x, R_j)dx, \qquad where$$

R_j is real reflection coefficient for one fiber;

$50 \leq x \leq 90$ limit is estimated of effect when the fiber is loaded into scintillator tile.

It is evident that light yield to increased, as shown of Fig.7. But an increase of 7 percent is little more than mirrored end of fiber.

6 References

1. Proposal 'CKM'. The second edition. April 2,2001.
2. RS Components Stock Number: 235-9922.
3. Ph.Rebourgeard et. al.,Nucl. Instr. and Meth. A427(1999)543-567.
4. K.V. Alexandrov et.al., Nucl. Instr. and Meth. A457(2001)447-453.

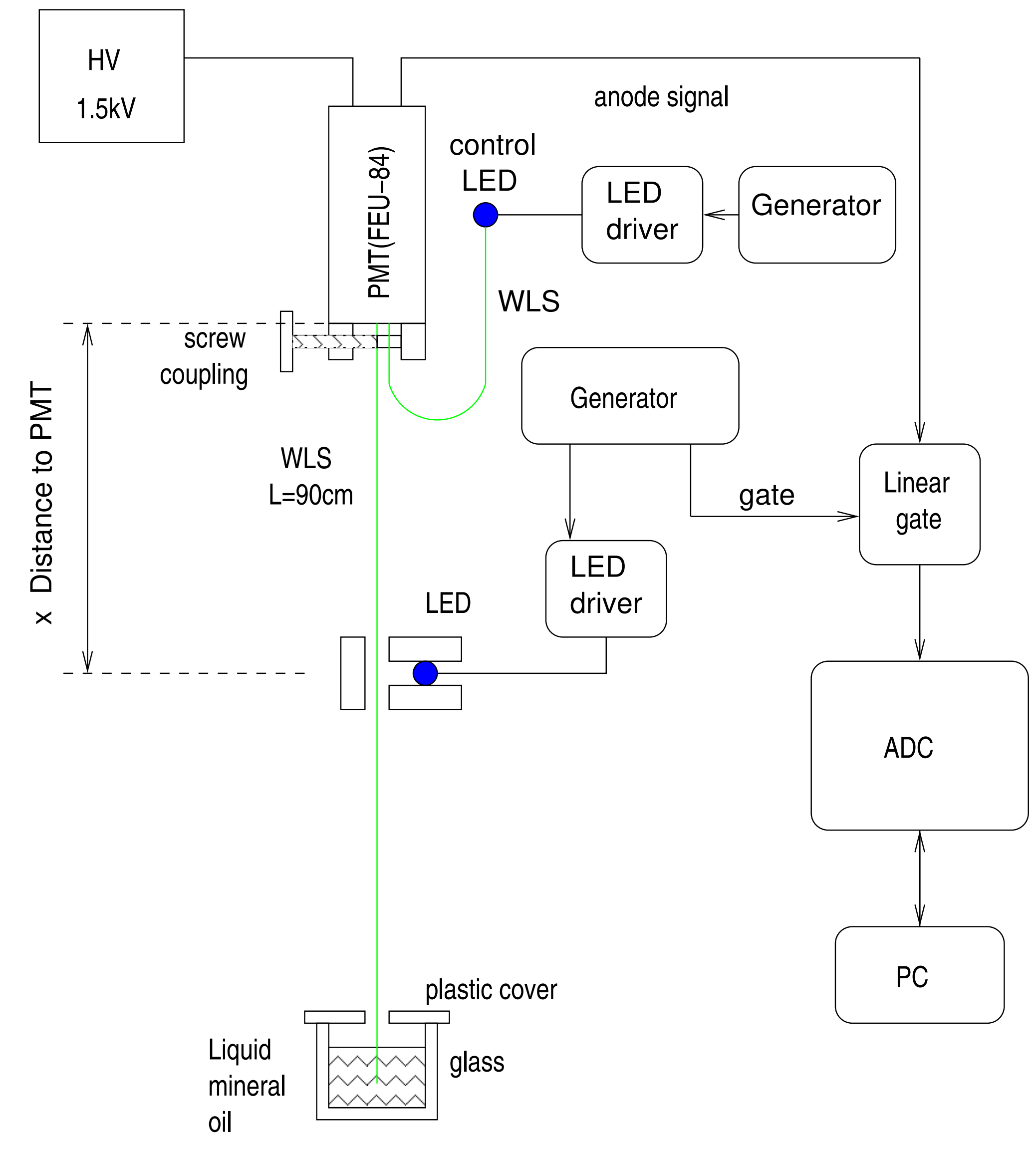

Figure 1: Sketch of the setup used for the light attenuation and mirror reflectivity measurements.

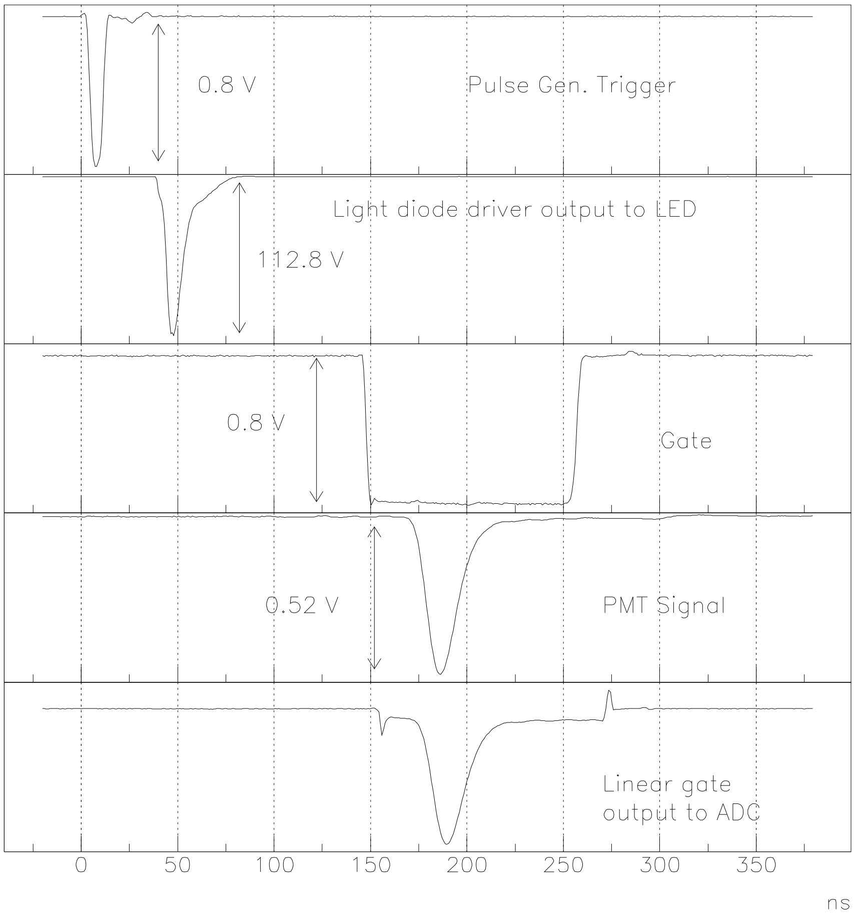

Figure 2: A schematic of the relative timing of the signals with respect to the gate.

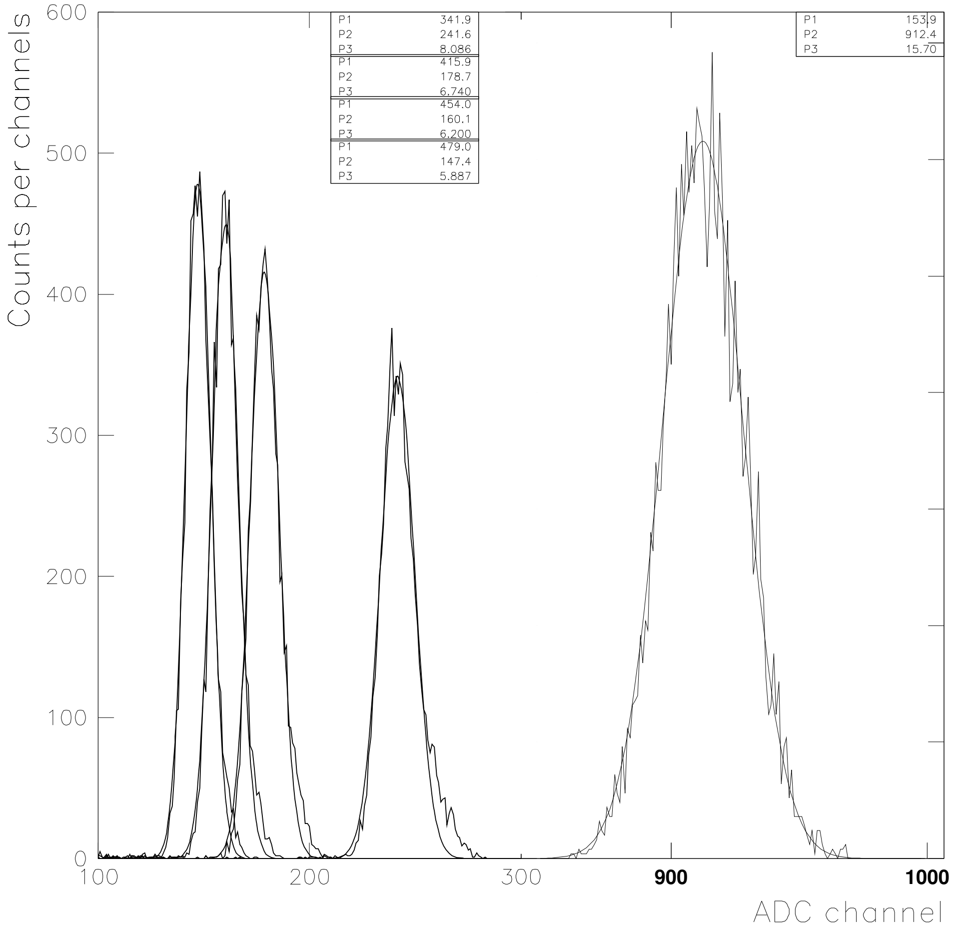

Figure 3: Typical the ADC pulse-height spectra of PM pulses with different distances x of the light source (LED) from the readout edge(PM), together with control LED peak. x=10,30,50 and 70 cm.

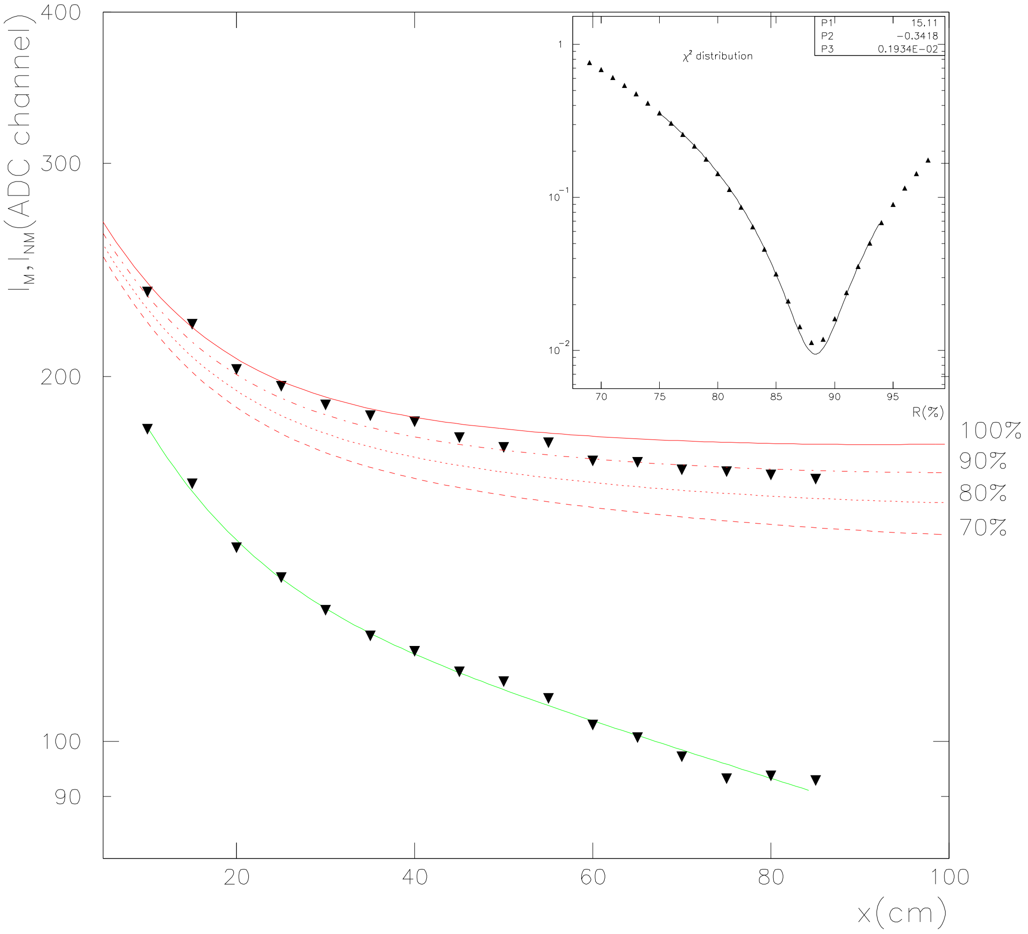

Figure 4: Light yield as a function of x the distance between the light production point and the PM.
Experimental data for mirrored WLS fiber have been fitted with the following function
$I_{NM}(x) = e^{P_1+P_2x} + e^{P_3+P_4x}$
Experimental data for no mirrored WLS fiber have been fitted with the following function
$I_M(x, R_i) = I_{NM}(x) + e^{P_4(L-x)} \times R_i \times I_{NM}(90)$
where R_i=70,80,90,100% ; $L = x_{max}$=90cm.
Also present χ^2 distributed for estimated coefficient of reflection R.

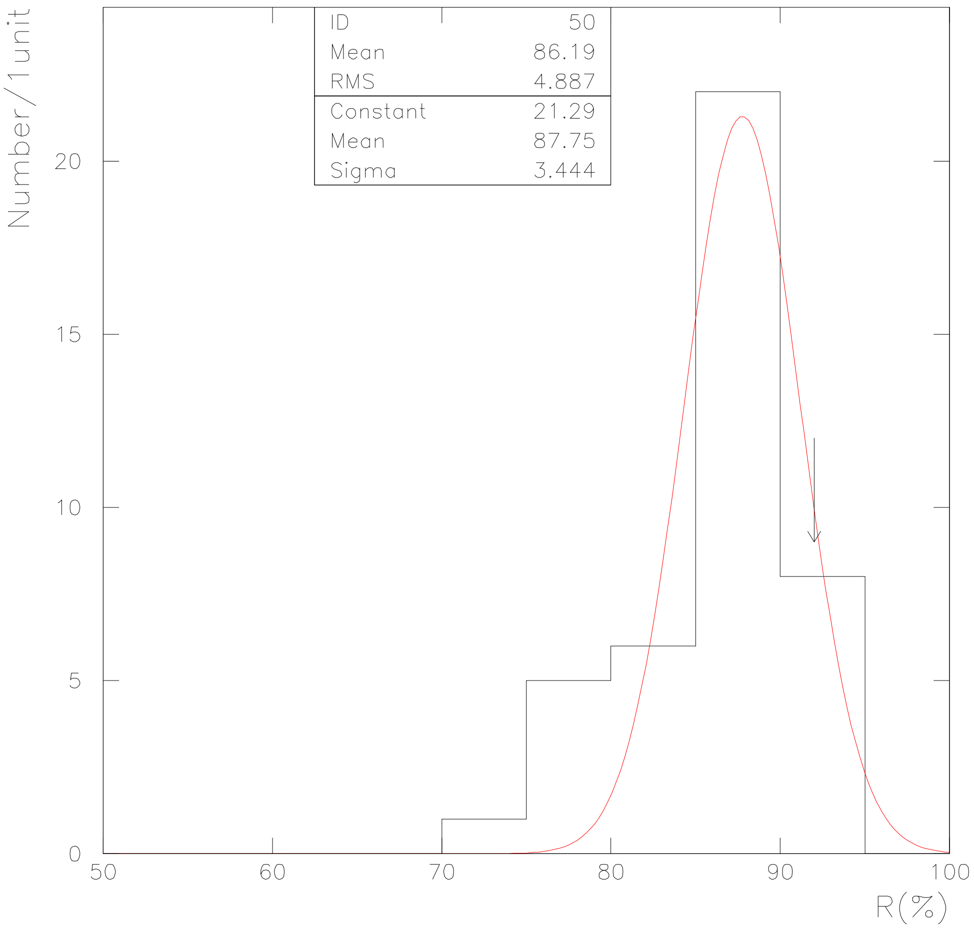

Figure 5: A distribution of the reflection coefficient **R** of WLS fibers. WLS fiber end were mirrored by aluminum sputtering, and coated with MgF_2 to protect the mirror end. Arrow is what would be expected of ideal aluminum with **R**=92%

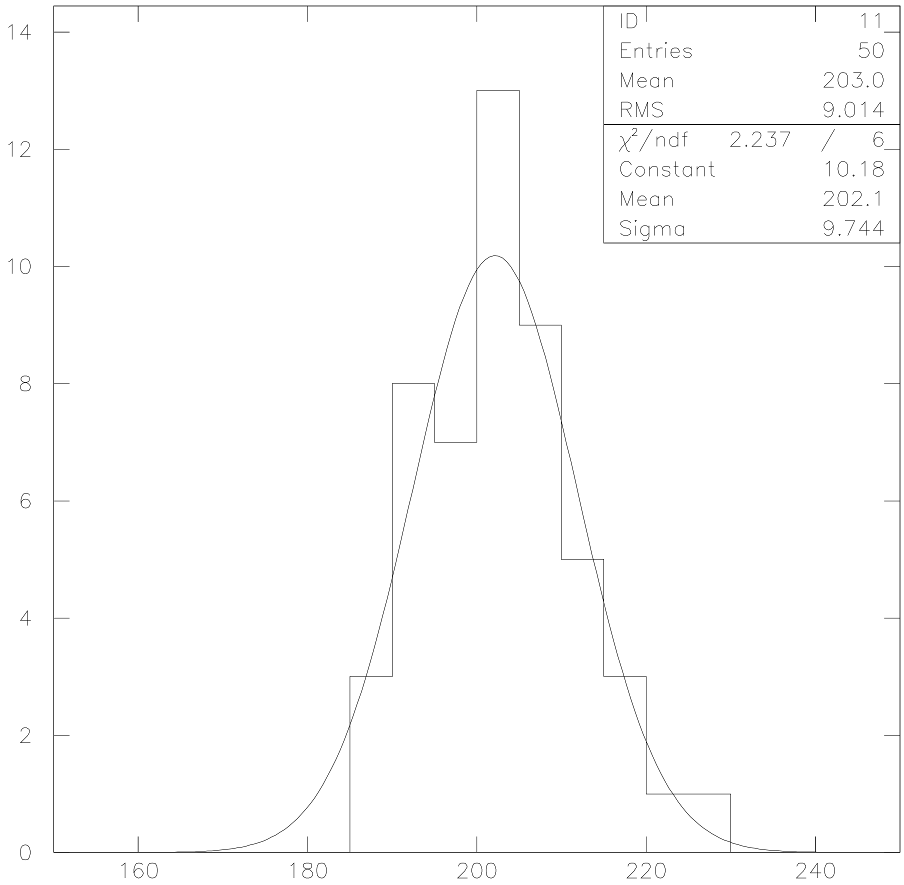

Figure 6: Light output $I_M(x = 70cm)$ uniformity measured with LED in position $x = 70cm$

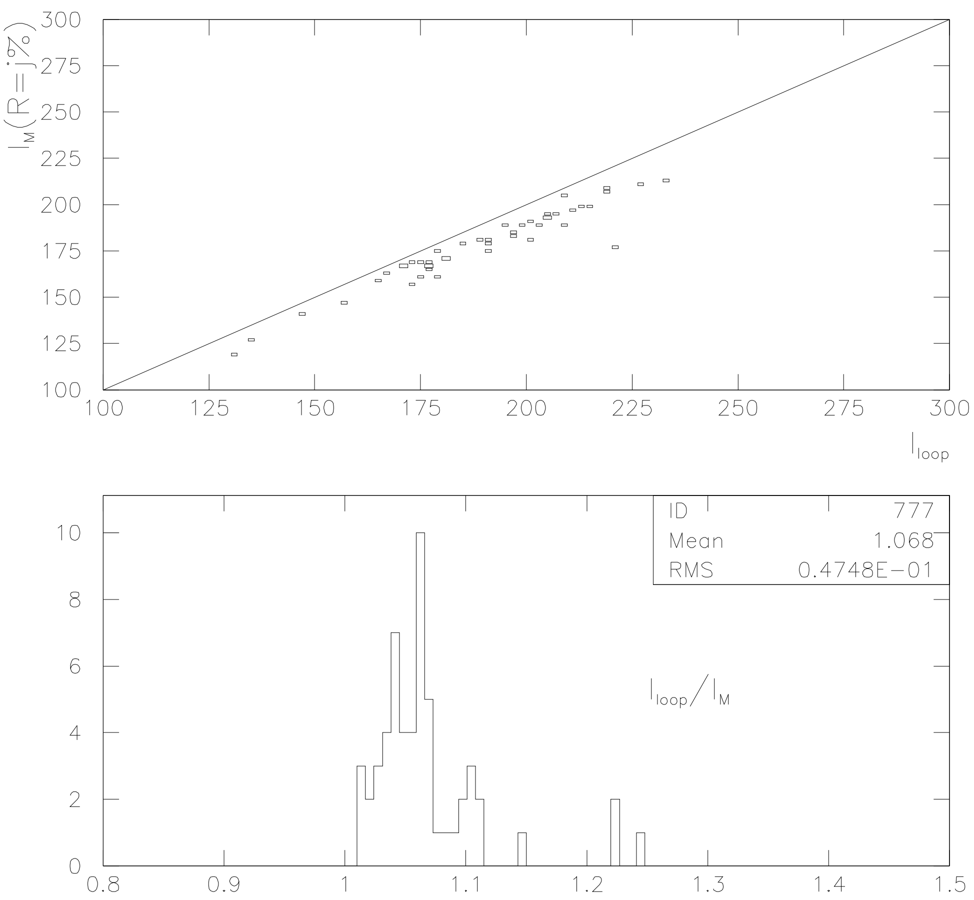

Figure 7: Different distribution than the light yield of tile/fiber assemblege have been with mirrored end fiber(I_M) or loop geaometry (I_{loop}).