Study of PMT FEU-115M and FEU-115M-10

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Abstract

A photo detector for the LHCb calorimeters is an important component defining performance of the calorimeter Level 0 trigger. This note describes the main requirements for photo detector and the experimental results of the photo-multiplier FEU-115M and FEU-115M-10 study.

Document Status Sheet

Table 1 Document Status Sheet

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1. Introduction

The main requirements for the LHCb calorimeter photo detector have been formulated in TP [1]. The ECAL and HCAL detectors generate fast secondary light signals by the conversion in wavelength-shifting fibres of the primary scintillation of plastic plates. The signals from these detector elements are converted in the electrical signals by photo detectors. A photo-multiplier as a photo detector is a base option for calorimeters. The main difference between two systems is their light yield. The light yield in the ECAL cells will be in excess of 1000 photoelectrons per GeV. The estimated gains for three sections of ECAL are $5*10^3$, $4*10^4$ and $7*10^3$. For the HCAL the light yield will be of order of 50 photoelectrons per GeV and needed gain is about $2*10^5$. The analogue signal processing that has been chosen [1],[2] for the calorimeter front-end electronics requires to use a PMT with a high fastness (rise time less than 5 nsec), good linearity in the output current range up to 25 mA and reasonable long-term stability of gain.

The photo-multipliers FEU-115M [3] and FEU-115M-10 have been studied as the possible candidates of the calorimeter photo-detectors. The photo-multiplier FEU-115M has 12-stage AL-Mg alloy linear focused dynode system and a semitransparent Sb-K-Na-Cs photo-cathode. An average quantum efficiency of the photo-cathode is more than 12% for the wavelength range 400 – 500 nm. The FEU-115M-10 is a modification of the FEU-115M with a 10-stage dynode system. Figure 1 shows the photo-multiplier sizes and dimension of base. The set-up for measurement the PMT characteristics and the experimental results of these photo-multipliers study is presented in this note.

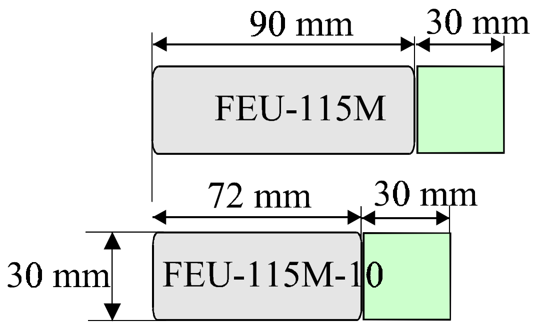

Figure 1 View on Photo-Multipliers with Base

2. Set-up for PMT Characteristics Measurement

The set-up for the photo-multiplier characteristic study is shown on Figure 2.

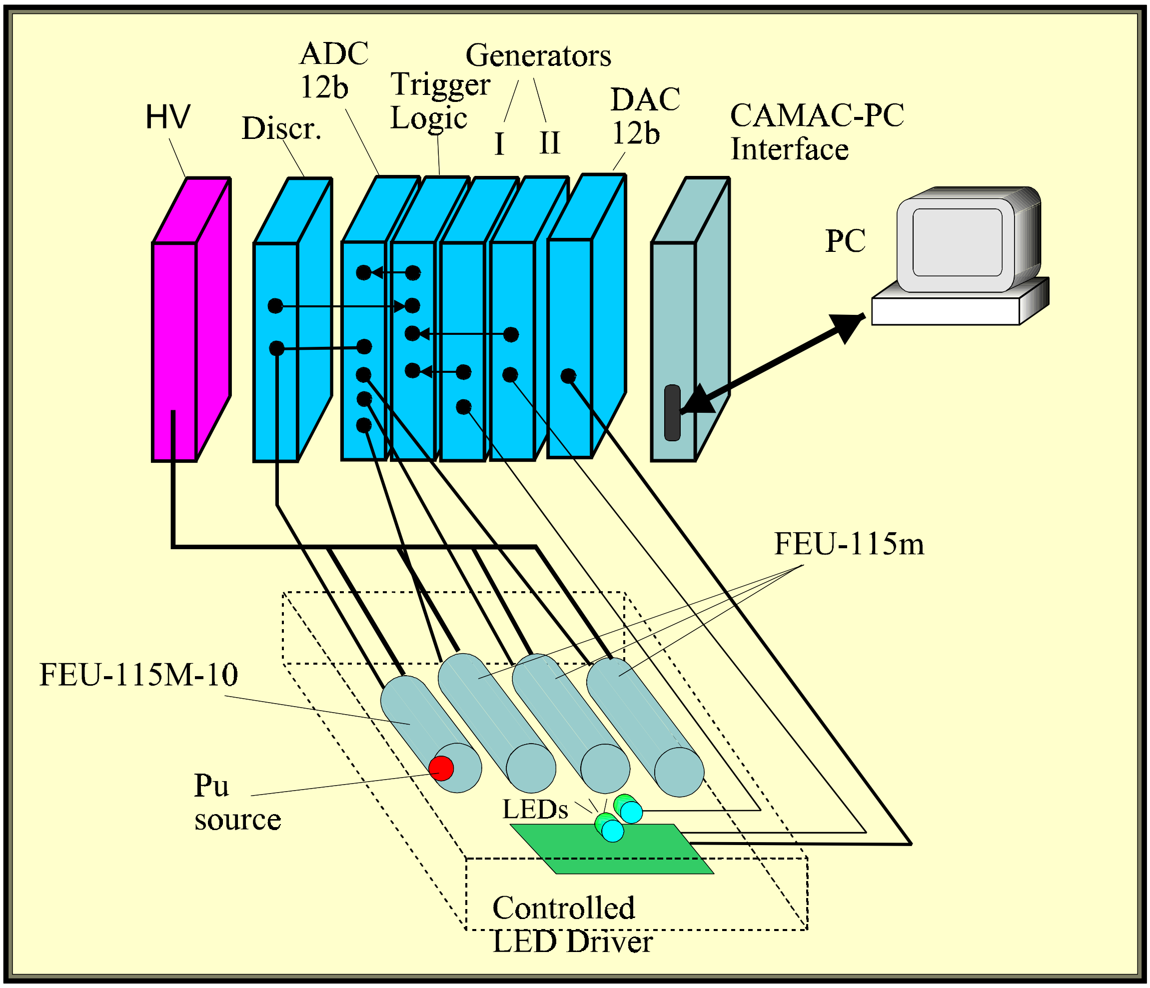

Figure 2 Set-up for PMT Characteristics Measurements

The tested photo-multipliers are placed into the light protected box. As the light sources two fast blue light emitting diodes (LED) and one Pu radioactive source implanted on a crystal of Y Al O_3 are used. The light emitting diodes are fed by a controlled from computer LED driver that allow to vary a light intensity in a large range. The radioactive source is glued on surface of a PMT photo-cathode. The pulse rate from this source is about 30 Hz and sigma of a pulse height distribution is 4 %. The data acquisition system is placed in one CAMAC crate. This system includes following electronic modules: discriminator, 12-bit ADC, trigger logic, two generators, 12-bit DAC and a CAMAC-PC interface controller. Dedicated software is written for automation the measurements of the PMT characteristics. Timing characteristics of the photo-multipliers were studied with an oscilloscope TDS-350.

3. Experimental Results

3.1. PMT Gain and Transit Time

The gain and transit time study of the photo-multipliers has been done in a large range of the HV power supply. The dependencies of the photo-multiplier gain and transit time versus the HV power supply are shown on Figure 3 and Figure 4.

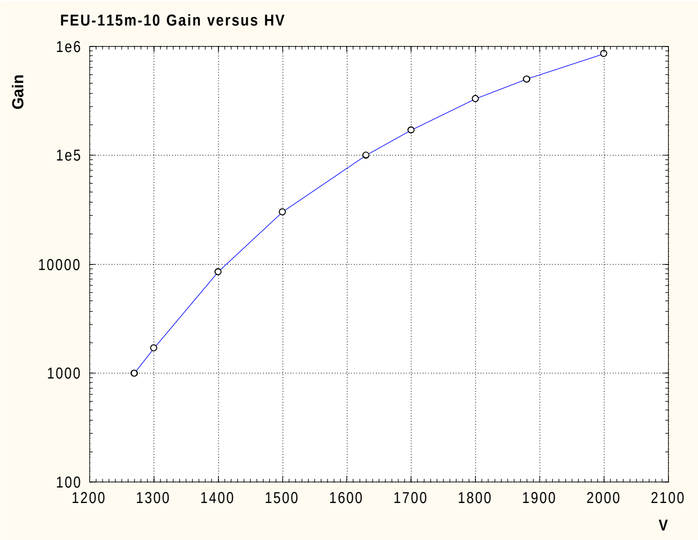

Figure 3 Photo-multiplier Gain versus HV Power Supply

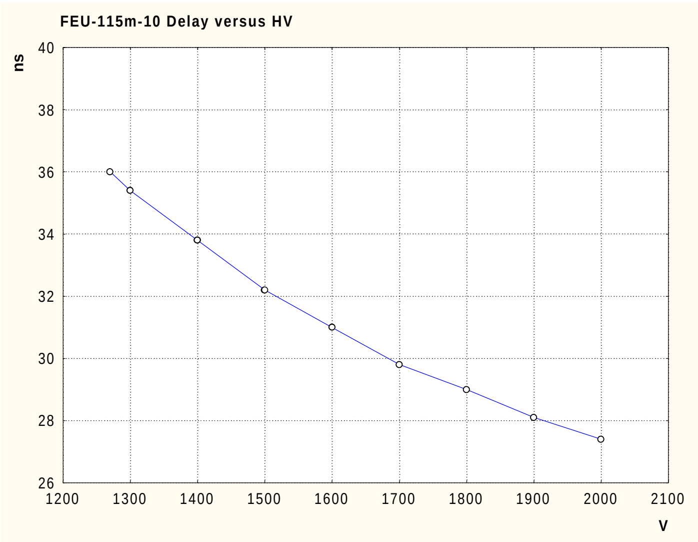

Figure 4 Photo-multiplier Transit Time versus HV Power Supply

For this measurement the four last dynodes of PMT were fed by the independent power supply. The gain is changed from 10^3 to 10^6 for HV variation from 1250 V to 2000 V. The PMT transit time is changed on about 9 nsec in the same HV range.

Oscillograms of the digitized FEU-115M-10 signals for different values of the HV supply are shown on Figure 5.

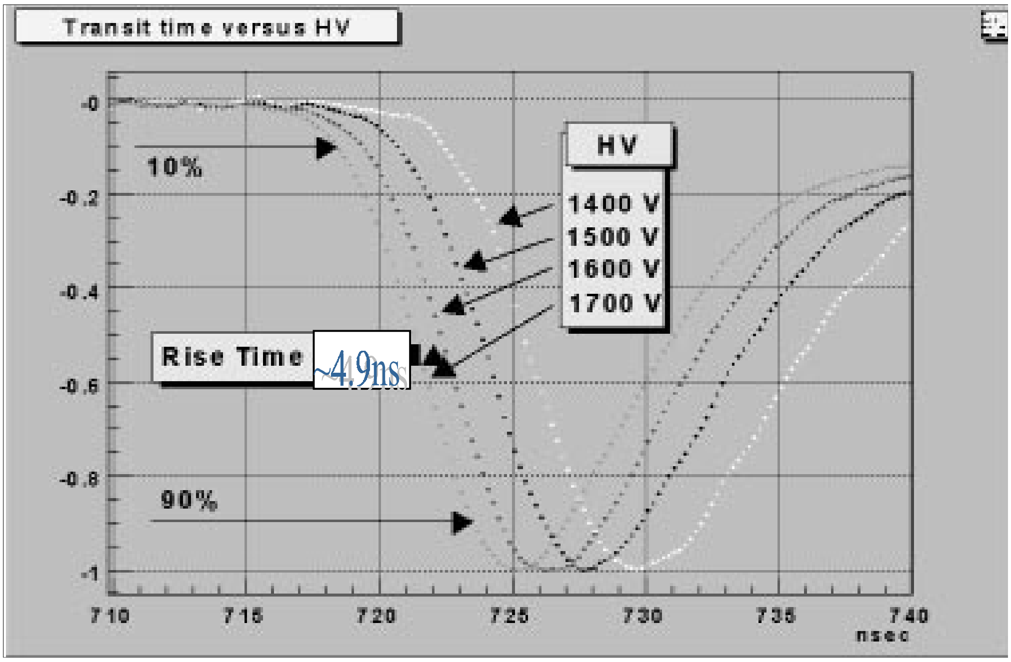

Figure 5 Oscillograms of the FEU115M-10 Signals for Different HV Voltages

The rise time of the signal is about 4.9 nsec and there is no visible degradation of the PMT rise time versus high voltage variation.

3.2. Linearity

For linearity measurement a little light increment method was used. Two independent LEDs lit the PMT as shown on Figure 2. A light intensity of one LED (base LED), controlled by PC varied step by step so that a PMT response was varied in range from 10 mV up to 5 V. Second LED (increment LED) had a constant light intensity and PMT response was about 100 mV. ADC digitized the PMT signals. Measurement sequence was as following: pedestal, base LED, increment LED, base LED plus increment LED measurements. Each measurement had 1000 events. Figure 6 illustrates this incremental method of the photo-multiplier linearity measurement.

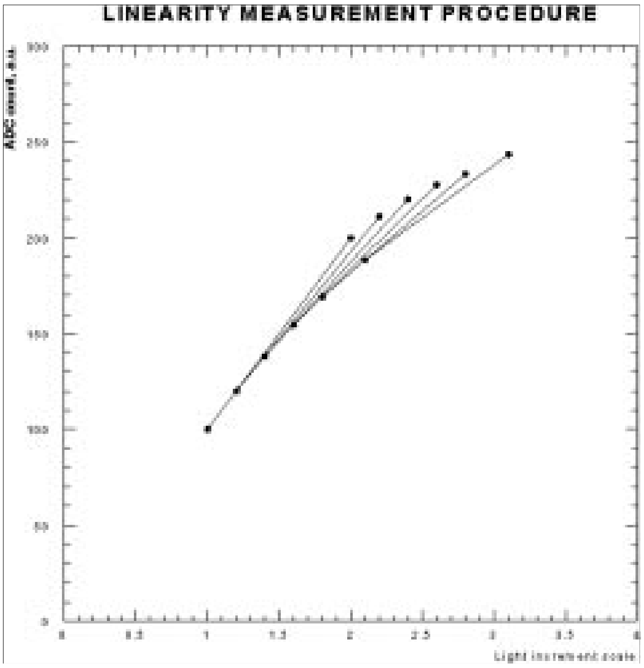

Figure 6 The Linearity Measurement Incremental Method

Four samples of the FEU-115M have been measured. The deviation from straight-line fit of the linearity dependence is less then 2 % up to 60 mA of the PMT anode current as shown on Figure 7.

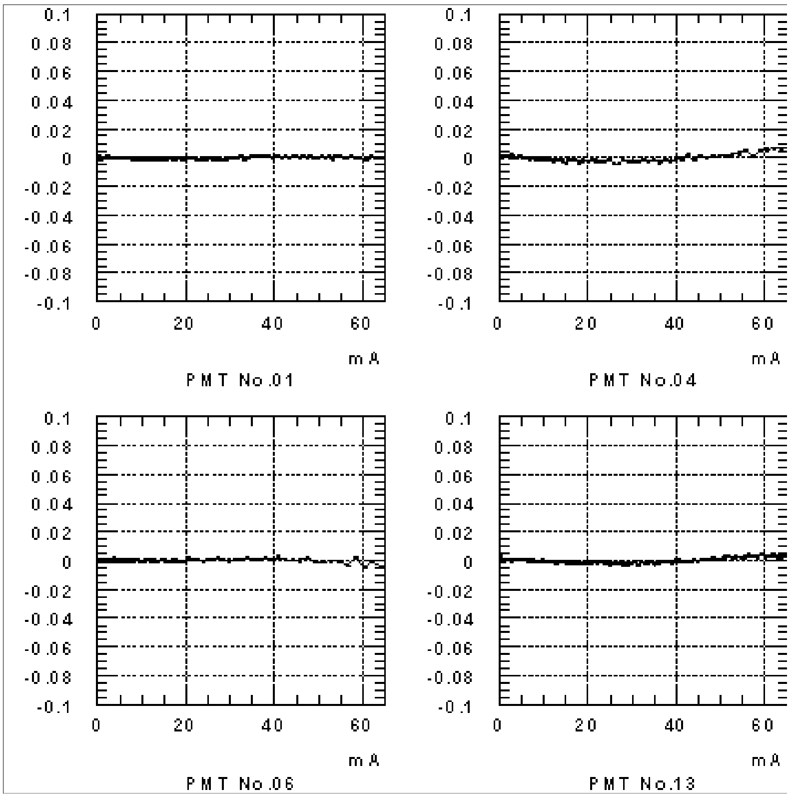

Figure 6 The Deviation from Straight-line Fit for four Samples of FEU-115M

3.3. Long-term Stability

The study of the long-term stability of the photo-multiplier FEU-115M-10 was done with using Pu radioactive source. During few weeks the set-up collected the data. Every ten minutes a histogram of the amplitude distribution of the PMT signals was stored on a hard disk. Figure 6 shows the two dependencies of a normalized gain versus the time. First plot illustrates the time interval 1.5-day from the beginning of the measurement. One can see on this plot a photo-multiplier stabilizing time that is about few hours. On the second plot the six day time interval is shown. For this interval the distribution of the gain stability has been calculated and it is shown on third plot. The sigma of the distribution is less than 0.5%.

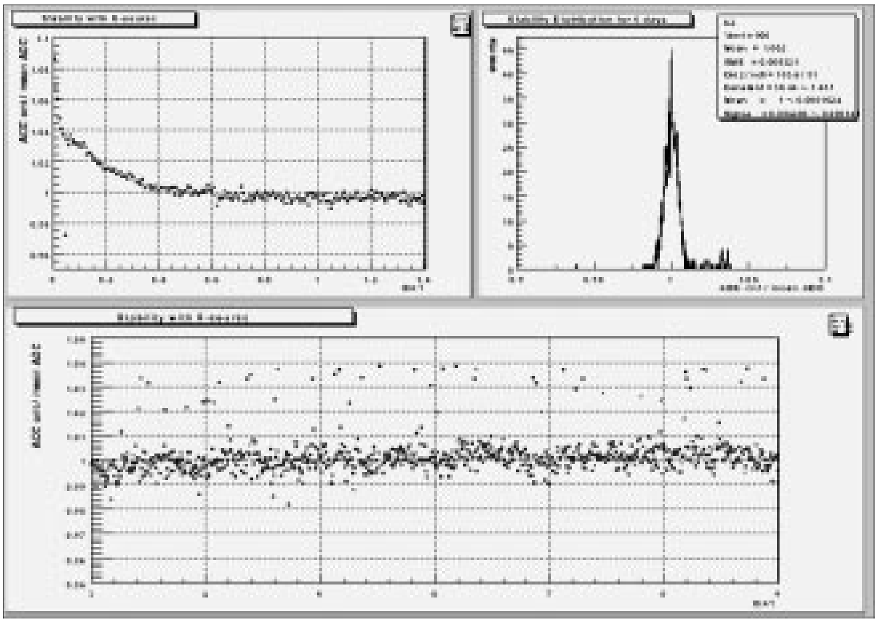

Figure 8 Long-term Stability of the FEU-115M-10

3.4. Operation in Magnetic Field

The study of the photo-multiplier FEU-115M operation in a uniform magnetic field has been done in IHEP. Simplified view of the magnet and a PMT position inside it is presented on Figure 7.

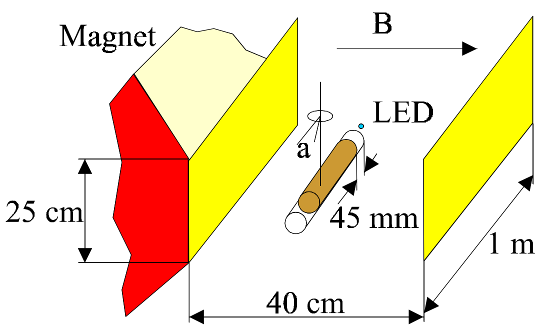

Figure 9 Set-up for PMT Operation in Magnetic Field Study

For PMT protection against a magnetic field a tube of three layers of 50-μkm soft iron has been covered the photo-multiplier. A size of this tube is about 45 mm large than photo-multiplier. The signal amplitude has been measured for different magnetic field values with the same LED pulse intensity. Figure 8 shows the PMT gain dependence versus a perpendicular magnetic field.

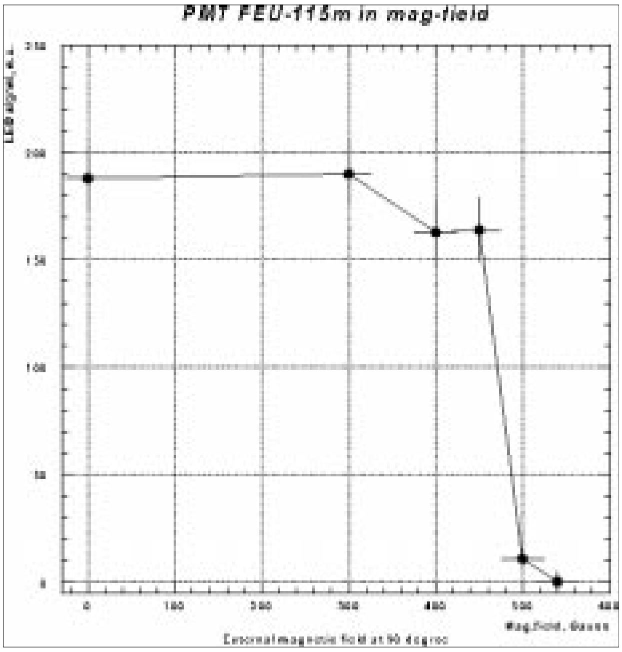

Figure 10 PMT Gain Dependence versus Perpendicular Magnetic Field

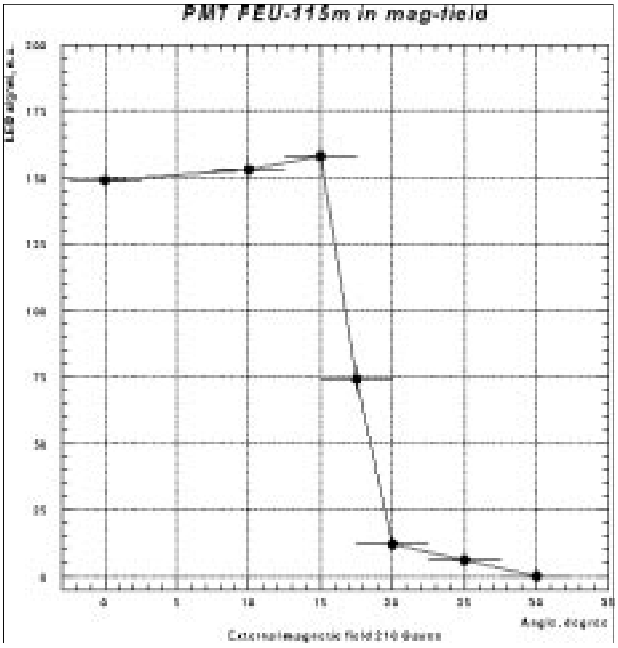

Figure 11 PMT gain Dependence versus PMT Rotation Angle

On Figure 9 the PMT gain dependence versus a rotation angle in external magnetic field of 210 Gauss is shown. From these plots one can conclude that with a simple protection the FEU-115M operates in perpendicular magnetic field up to 400 Gauss. Protection against axial magnetic field could be made with using others methods (for example with a compensating coil around PMT).

3.5. Photo-cathode Uniformity

The results of the photo-cathode uniformity for about 2000 FEU-115M are presented in preprint [4]. For inner region 10 by 10 mm the photo-cathode non-uniformity is less than 10%. The same study one of the first prototypes of FEU-115M-10 has been done in Orsay [5]. Figure 10 shows a plot of the photo-cathode scan for this phototube.

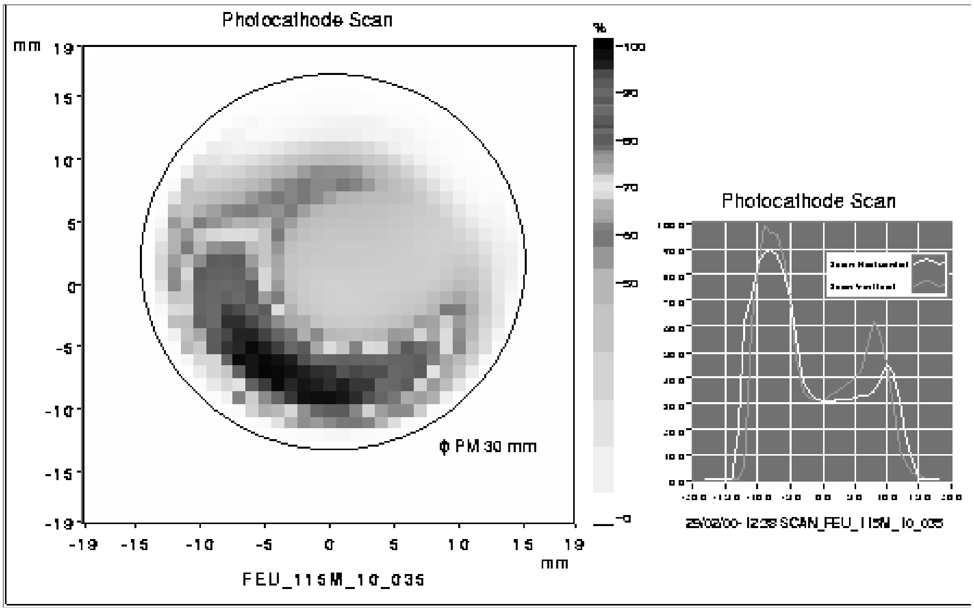

Figure 12 Photo-cathode Non-uniformity of FEU-115M-10

The photo-cathode uniformity for this sample is worse than for FEU-115M, but in the future the manufacture guarantees the photo-cathode non-uniformity less then 10 %.

4. Conclusion

As was mentioned above, the choice of the photo detector and an optimization its characteristics for the LHCb calorimetric detectors is important for achieving maximal performance of the calorimeter Level 0 trigger. The dedicated set-ups for PMT characteristic measurement have been build in IHEP (Protvino) and LAL (Orsay) laboratories. The study of the photo-multipliers FEU-115M and FEU-115M-10 has been done. It lets make a conclusion that the studied characteristics of these phototubes satisfy the requirements for the LHCb calorimeter photo-detector.

5. References

[1] LHCb Collaboration, LHCb Technical Proposal, CERN/LHCC 98-4, 20 February 1998

[2] A. Konopliannikov, “ Zero dead-time charge sensitive shaper for calorimeter signal processing ”, LHCb Technical Note, LHCb 2000-041, CALO

[3] V.Rykalin et al., “ Photo-multiplier with Improved Linearity on the Base of FEU-115”, Preprint IHEP 95-12, Protvino, 1995

[4] S.Belikov et al., “Characteristics of the Photo-multipliers FEU-115M for EMCal PHENIX”, Preprint IHEP 96-42, Protvino, 1996

[5] B. Jean-Marie, “Comparative Studies of 5 photo-tubes”, presentation on October 12-th, 1999 meeting.