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Magnetic shielding studies for FEU115M phototube of the FAMUS pixel counters

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Abstract

Studies of photomultiplier FEU115M magnetic shielding are described. These photomultipliers will be used in the scintillation counters of the DØ Forward Angle MUon System (FAMUS).

Introduction

The upgrade of the D0 Muon system for Run II is reveiwed in [1]. The FAMUS system (Forward Angle MUon System) covers the $|\eta| \leq 2$ region. It consists of the following major parts: 3 layers of mini-drift tubes (MDT) for muon track reconstruction; 3 layers of scintillation counters for triggering on events with muons [2]; shielding around the beam pipe from calorimeter to the accelerator tunnel to reduce trigger rates, fake track reconstruction and ageing of detectors [3]. The detectors are arranged so that muons from the interaction point traverse three layers of MDT's (A,B,C) and three planes of scintillation counters on both sides of the detector, with layer A closest to the interaction and followed by layers B and C. Counters are arranged in $R - \phi$ geometry to match central fiber detector trigger segmentation and muon bending direction in the toroidal magnets. A and B layers will be placed before and after EF magnets. A layer, which is closest to the interaction point, will be in the region of fringing field of superconducting solenoid. The maximum field value in the A layer region is $\sim$550 Gs and maximum field in the phototube region can reach 340 Gs[4]. Magnetic field affects sensitivity of phototube. In order to decrease magnetic field two layers of magnetic shield surrounding photomultiplier are used. Inner layer is made from μ-metal and outer layer is from soft iron[5]. Cylindrical shielding is more "transparent" when magnetic flux is parallel to the tube axis (longitudinal field component). The goal of our studies was to design effective magnetic shielding for phototube FEU115M in the field with longitudinal component till 340 Gs.

FEU115 in longitudinal magnetic field.

We have tested five randomly selected phototubes in a solenoidal magnetic field. Same resistive phototube base was used for this test. Solenoid has the following geometrical sizes: inner diameter 22 cm, outer diameter 43 cm, and 50 cm length. For measurements each phototube has been fixed in the center of the solenoid along its axis. Non-uniformity of the magnetic field in the region of FEU115M was less than 5%. Using "current method" we measured signal from phototube irradiated by green light emitting diode (LED) versus magnetic field. The field in solenoid was increased from 0 Gs to 30 Gs and then decreased till 0 Gs. In Fig. 1 the dependence of phototube signal against value of the magnetic field is shown.

The experimental data shows that magnetic field of a few Gs considerably decreases phototube signal. The hysteresis has been observed: when field came back to 0 Gs output signal was $\sim 75\%$ from signal before the magnetic test. Low magnetic fields can be suppressed by μ-metal shielding and we have done studies aimed on the optimization of μ-metal shield.

μ-metal shielding.

Length optimization for μ-metal shileding was performed in the solenoid discribed above. Phototube with resistive base and LED was placed along the axis of solenoid. 127 mm long and 0.8 mm thick μ-metal tube surrounded base and phototube and was designed to slide along them. Length of FEU115M phototube is 90 mm. We have measured the phototube signal versus position of μ-metal

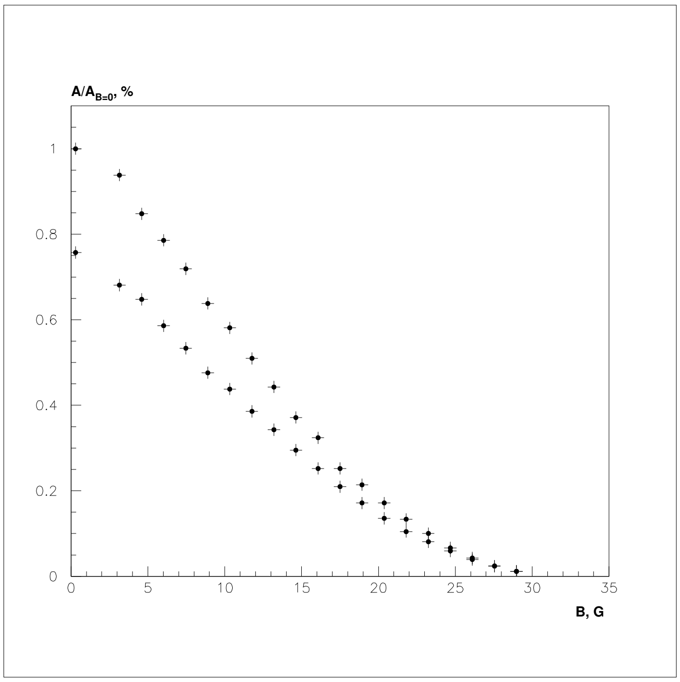

Figure 1: Relative phototube signal versus value of the magnetic field. Top curve is for increase in magnetic field, bottom is for decrease (see text for details).

screen for longitudinal magnetic fields of 20, 30 and 40 Gs. Position of phototube pins end was selected as zero. The distance from zero to the near edge of screen measured in mm defines the position of the screen. Direction to the photocathod was selected as negative. Dependance of output amplitude versus the position of μ-metal screen is shown in Fig. 2. The phototube signal is stable for longitudinal magnetic field till 30 Gs when position of μ-metal screen is in the range from +20 mm to -15 mm. In order to simplify design edge of the μ-metal screen can be fixed in the base at 3 mm according to Fig. 2. Magnetic shields should extend beyond the photocathode. The value of minimum overloop (17 mm) can be taken from experimantal data when screen is shifted to position +20 mm. Hence

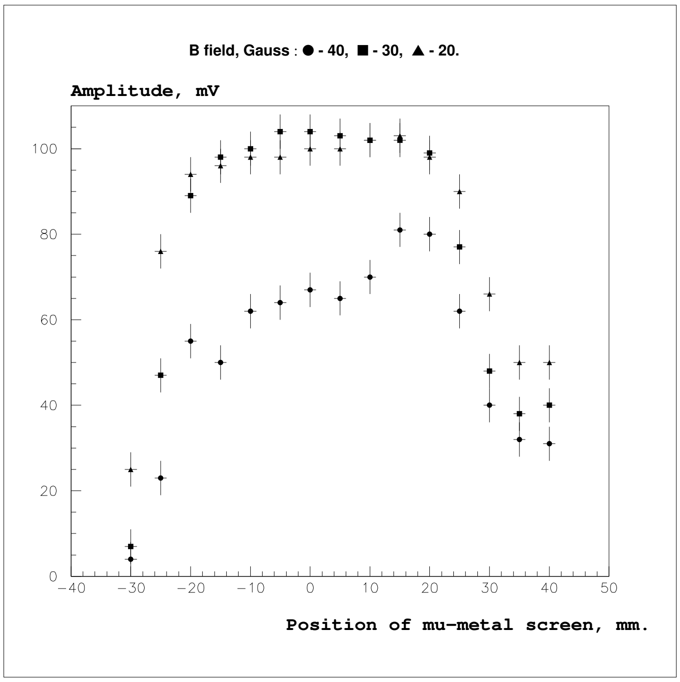

Figure 2: Measurements for optimization of μ-metal screen position and length.

the minimal μ-metal screen length should not be less than 110mm. The selected length of μ-metal shield for FAMUS scintillation counters is 116 mm and 1.2 mm thickness.

Using Hall probe and changing its position inside the 1.2 mm thick μ-metal screen we measured the value of magnetic field inside the shielding, when solenoidal magnetic field was 40, 30, 20 Gs. Results of measurements are shown in Fig. 3. The field in the middle of this shielding allows phototube to work, but field penetration from the edges of μ-metal cylinder should be reduced by a supplimentary shield from soft steel.

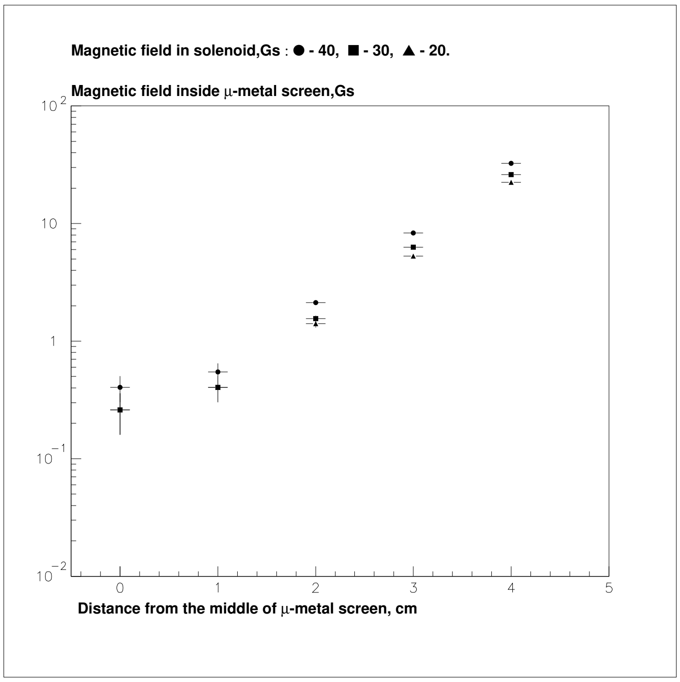

Figure 3: Magnetic field along the axis of μ-metal shielding.

Soft steel as a shielding.

Simulation of the soft steel shield demonstrates that there is an optimal length for steel tube, when magnetic field inside the tube has minimal value. For the external field of 360 Gs for steel tube with 1.82 and 2.4 cm internal and external radiuses this length is about 10-12 cm[4]. The residiual value of magnetic field in the center of such tube is approximately 10 Gs and can be suppressed by μ-metal shielding. We have measured the value of magnetic field on the axis of assembly consisting of internal μ-metal tube (116 mm length, 16.7 mm radius and 1.2 mm thick) placed inside soft steel tube (118 mm length, 24 mm radius and 6 mm thick) in solenoid having 300 Gs field. The data obtained are shown in Fig. 4 as solid circles. Empty circles present measurements with the same screen with soft

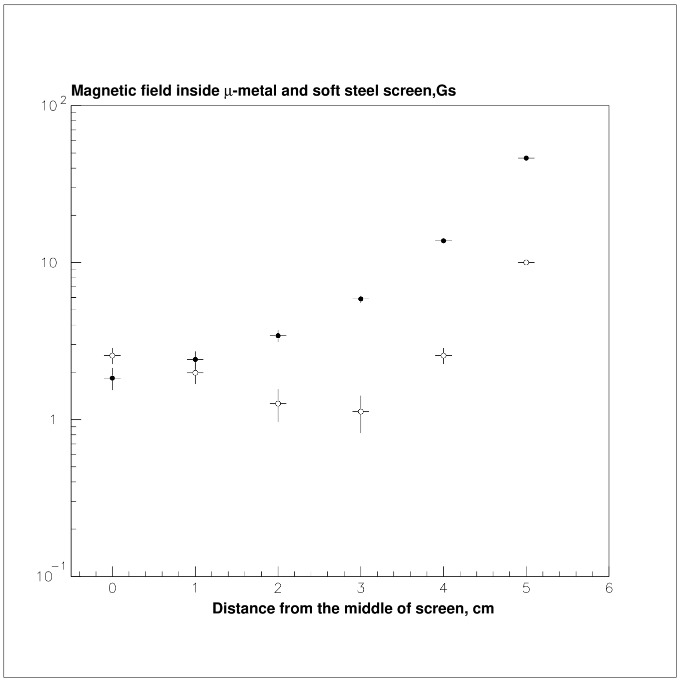

Figure 4: Magnetic field along the axis of soft steel and μ-metal assembly.

steel cap added. This cap is fixed on the scintillation counter in order to attach phototube with shielding to the counter. This cap has 1.4 cm square window in order to pass WLS to the photocathode. Cap provides an additional attenuation of incoming magnetic flux to less than 3 Gs in the region of the photocathod. This variant was selected as baseline design.

Test of FAMUS pixel counters in magnetic field.

As a result of described above studies magnetic shielding for FAMUS scintillation counters was designed. 48 mm external diameter shields will be used for

A-layer counters and 42 mm external diameter will be used for B - and C - layers counters, were the fringe field is below 200 Gs. Both screens were tested at IHEP in SP-41G wide apperture magnet, which produces uniform field in a large volume. The procedure of measurements was the same as for tests in solenoid. Signals from phototubes in both screens were not affected till at least 700 Gs when photoube was installed transverse to the magnetic field. Results of shielding studies with tube axis parallel to the magnetic field are presented in Fig. 5 as solid markers: circles are 42 mm external diameter screen, boxes are 48 mm external diameter screen. Tests of magnetic shield show that the effect of magnetic field on the phototube signal is less than 10% up to 350 Gs for a 48 mm A-layer shield and less than 10% up to 240 Gs for a 42 mm B - and C-layers shields. Results of shields test after delivery of produced at IHEP shields to Fermilab are presented in Fig. 5 as well. They are in a good agreement with results obtained during design studies at IHEP.

Summary and conclusions

As a result of calculations and experimental studies magnetic shielding for FEU115M phototube of the FAMUS scintillation counters is designed. It consists of two cylindrical layers of metal (μ-metal and soft steel) surrounding phototube. Experimental tests at IHEP and FNAL show that the effect of fringe magnetic field of the DØ superconducting solenoid and toroidal magnets on the phototube signal is less than 10%.

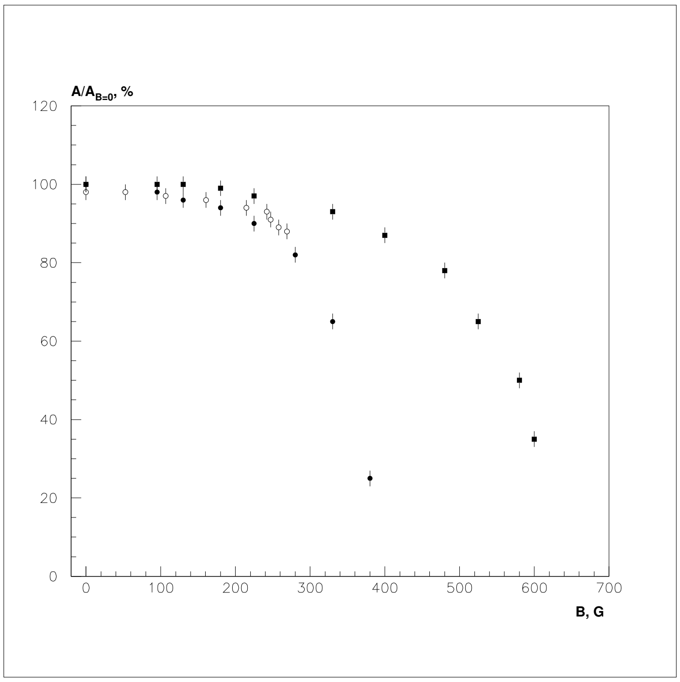

Figure 5: Relative gain change of 115M phtomultiplier in a magnetic field parallel to the tube axis. Solid markers: circles - 42 mm external diameter screen, boxes - 48 mm external diameter screen. Open circles are results of scintillation counters with 42 mm shield tests in a solenoidal field at FNAL.

References

[1] R.Jayanti et al.,"The DØ Muon System Upgrade", DØ Note 2780, January 30, 1996.

[2] V.Abramov,"Forward muon system for the DØ detector upgrade", Nucl. Instr. and Meth. A 419 (1998) 660.

[3] J.M. Butler *et al.*, "Reduction of Tevatron and Main Ring induced backgrounds in the DØ detector", FNAL TN-629, Fermilab, 1995.

[4] V.Korablev, "Forces on photomultiplier shields in magnetic field of the DØ Detector", DØ Note 3500, Fermilab, September, 1998

[5] "Photomultilier tubes. Principles and applications" Philips Photonics, 1994