

The impact of permanent magnetic fields on photomultiplier HAMAMATSU R7899-20 used in a hadron calorimeter of LHCb experiment

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Abstract. The influence of a permanent magnetic field strength up to 40 Gs (4 mT) to operation PMT HAMAMATSU R7899-20 with its standart magnetic screens and without them is investigated. This PMT is used in a hadron calorimeter of LHCb experiment at CERN. It is shown that the use of a protective housing made of steel in joint its use with permalloy screen significantly reduces screening efficiency. It proposed to use a protective housing made from non-magnetic material (duralumin) electrolytic coated with a multilayered film as magnetic shield. This solution can be used in a hadron calorimeter, the CERN installations SHiP.

1. Introduction

The main physical problem, the solution of which was created the Large Hadron Collider (LHC) [1], and set on it the experimental installations was successfully solved in 2015 - confirmed the existence of Higgs boson [2]. After that, there was a question about the new fundamental problems that could be solved at the LHC. Among them one of the most interesting problems is the search for the so-called massive Majorana neutrino [3]. New experiment SHiP (Search for Hidden Particles), is planning on the LHC will be devoted to the search for these particles. The scheme of the experimental setup detecting part SHiP shown in figure 1.

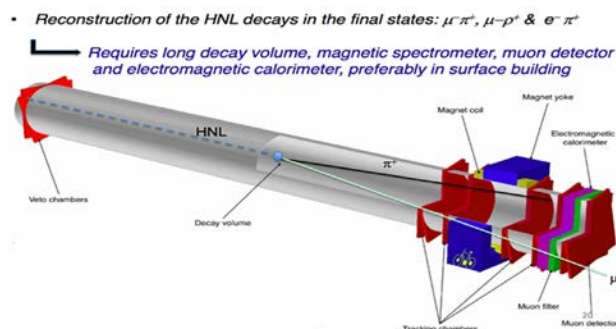


Figure 1. The scheme of the the experimental setup detecting part SHiP.

It is planned that the experimental setup SHiP will be created with the use of technical solutions and separate components applied on to existing installations at CERN ATLAS [4] ALICE [5] and the LHCb [6], which itself positively and firmly have proven. This will significantly reduce the cost of the experiment and accelerate its realization. Examples of such components can be hadron and electromagnetic calorimeters. These assemblies contain electronic photomultiplier tubes (PMT), which are usually located near sources of static magnetic field. Residual (scattered) field of these magnets can have a negative impact on PMT operation. For this reason, they have to be protected with special screens. During the years since the creation of experimental facilities of the LHC significant time have passed. The new technologies are developed for this time so that is advisable to use when creating of the experimental setup SHiP. This particularly concerns the screens to protect the PMT from magnetic fields. Currently appeared Multilayer Film Screens (MFS), manufactured by electrolytic deposition [7], which are more efficient and technologically advanced [8, 9] compared to traditional magnetic screens of permalloy foil. For this reason, it is advisable to study the shielding properties of the screens used in the current experimental facilities at CERN, in terms of the effectiveness of their protection, are used in these settings PMT. This information will allow to develop better magnetic screens for SHiP experiment. In this article presents the results of research of the effect of a constant magnetic field to work PMT HAMAMATSU R7899-20, which is used in the hadron calorimeter of LHCb experimental setup and to made recommendations for their upgrading.

2. Experiment description

The hadron calorimeter LHCb experiment uses a photomultiplier HAMAMATSU R7899-20, protected by Permalloy screen and placed in a steel housing. Electronics, including the power source and the high voltage power supply, integrated with PMT and is also located in a protective housing (figure 2).



Figure 2: PMT HAMAMATSU R7899-20 integrated with electronics, permalloy screen and steel protective housing.

During the test, the PMT was placed in a light-tight box. The longitudinal axis of the photomultiplier was oriented along the field lines of the magnetic field of the Earth, which has a declination in Moscow - 11° inclination - 70° . This reduced the effect of the magnetic field of the Earth because the magnetic field directed along its longitudinal axis is less impact on the work of the PMT than field directed perpendicular to its longitudinal axis (figure 3).



Figure 3. Experimental setup and location of its elements relative to Earth's magnetic field.

The magnetic field was created by the two permanent magnets symmetrically disposed with respect to the PMT. Their mutual displacement allowed to change the magnetic field strength. The maximum value of the magnetic field near the PMT was 40 gauss (4 mT). PMT was illuminated by light pulses LED located in front of the photocathode. The dependence of the output pulse amplitude of the magnetic field strength and orientation of the PMT relative to the magnetic field was measured.

3. Experimental results

Measuring the dependence of the output amplitude of PMT HAMAMATSU R7899-20 without protective screens showed that it is very sensitive to the magnetic field. Thus, when the magnetic field of about 0.25 mT directed perpendicular to the longitudinal axis of the PMT, the output signal amplitude is reduced in twice, and at a voltage of 0.5 mT PMT stops working (figure 4).

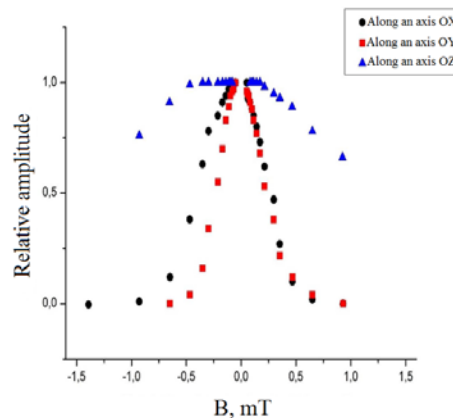


Figure 4. Dependence of the relative output pulse amplitude of the magnetic field induction for non-shielded photomultiplier HAMAMATSU R7899-20. (Errors within the experimental points).

In measurements using permalloy screen and steel housing it found that permalloy screen used alone exhibits good shielding properties. At the same time the steel housing also has protective properties, although much weaker. However, in a regular situation, when the PMT protected by permalloy screen located inside the steel housing, the resulting effect of screening considerably decreases (figure 5).

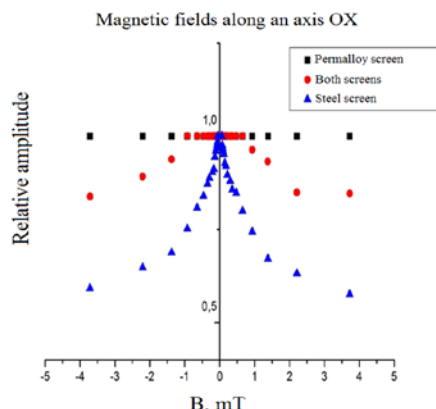


Figure 5. Dependence of the relative output pulse amplitude of the PMT HAMAMATSU R7899-20, protected by screens on the magnitude of the magnetic field is directed along the OX-axis. (Errors within the experimental points).

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This result is explained by the fact that the steel housing reduces the magnetic field applied to the permalloy screen. As a result, the magnetic permeability, and hence the shielding factor of permalloy screen decreases significantly so that summing permalloy screen shielding factor and the steel housing becomes smaller compared with when permalloy screen taken separately used.

3. Conclusion

The use of a steel housing with permalloy screen significantly reduces the resulting shielding effect. It is recommended to make housing of non-magnetic material (aluminum) and cover it with Multilayer Film Screens formed by electro deposition method [10].

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