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МЕТОДИКА ФИЗИЧЕСКОГО ЭКСПЕРИМЕНТА

A PORTABLE X-RAY SOURCE FOR TESTING OF TRD/ALICE RADIATORS AND CHAMBERS

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Portable X-ray sources were designed and produced for experimental study of radiator absorption uniformity and mapping of large-scale drift chamber gain. The tests are performed on-line with creation of the Transition Radiation Detector (TRD) for the ALICE experiment at CERN. The source is a key element of automatic scanner, and it produces X-ray photons in the energy range up to 10 keV with required intensity. The design and characteristics of the source are described.

Портативные рентгеновские источники разработаны и изготовлены для экспериментального исследования однородности поглощения радиаторов и карты усиления дрейфовых камер большой площади. Эти испытания выполняются в линию с созданием детектора переходного излучения (TRD) для эксперимента ALICE в ЦЕРН. Источник является ключевым элементом автоматического сканера и производит рентгеновские фотоны в области энергий до 10 кэВ с требуемой интенсивностью. Описываются конструкция и характеристики источника.

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INTRODUCTION

The Transition Radiation Detector (TRD) of the ALICE experiment at CERN is a barrel detector with 18 units of 7-m supermodules, and it consists of six layers of large-scale drift wire chambers with total amount of 540 [1]. The main aim of the TRD is registration of GeV electrons on a large background of hadrons (mainly pions). The single chamber can be considered as a subdetector, and it includes both a radiator and an absorption volume filled with $Xe + CO_2$ mixture.

At the beginning of the TRD project, it was decided to design special test stands for automatic scanning of the radiators and chambers by soft X-ray photons with the aim of getting radiator absorption and chamber gain maps. The tests have to be done on-line with production because of hard requirement to the detector response uniformity. For realization of this task, we have recently designed, produced, and investigated a portable small-mass source of soft X-rays.

Now the X-ray sources are successfully applied for test measurements in laboratories involved in the TRD project: LHE (JINR) [2], Heidelberg University, Frankfurt University, GSI (Darmstadt), Muenster University, and NIPNE (Bucharest).

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1. X-RAY SOURCE

The X-ray source designed for the TRD scanners had to meet the following requirements: (1) the photon energies must be up to 10 keV, (2) the radiation must appear only if source high voltage is switched on, (3) the photon intensity should be changeable by user, (4) the radiation spot is $\sim 1{-}2$ cm, (5) the radiation characteristics must be stable during the measurements, (6) the source application should be simple for usage, (7) the source has to have small mass and low cost. View and scheme of the source are shown in Fig. 1.

The small-size X-ray tube BH2-Ag, produced by the «Svetlana-Rentgen» corporation, St. Petersburg, was chosen for generation of soft X-ray photons in the source because the tube characteristics are close to those that are required. The tube operates at negative high voltage up to -10 kV. The photon energy spectrum has a broad peak with maximum energy corresponding to high voltage magnitude on the tube. The photons are emitted by a silver anode through a beryllium thin window. In principle, the radiation intensity has to be proportional to the tube current which depends on cathode heating, or cathode voltage. Thus, one can vary the tube current and the X-ray intensity by means of increasing or decreasing the cathode voltage with a potentiometer.

A fluctuation of the cathode current leads to an instability of the source intensity. With the purpose to minimize this walk, a special stabilizer of the cathode current was designed and

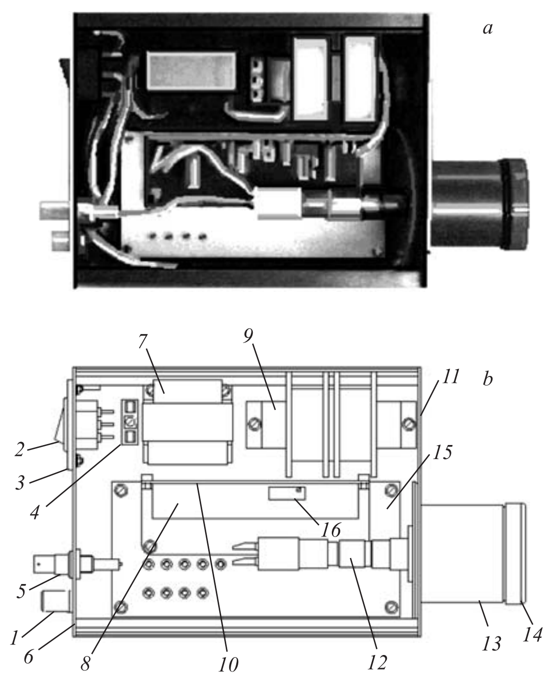

Fig. 1. View (a) and scheme (b) of the X-ray source: *1* — the ground contact; *2* — the power switch ($\sim$ 230 V); *3* — the power connector; *4* — the fuse; *5* — the HV connector; *6* — the back panel; *7* — the transformer (230/12 V AC); *8* — the stabilizer of heating current; *9* — the insulation transformer; *10* — the stabilizer's PCB; *11* — the front panel; *12* — the X-ray tube; *13* — the collimator; *14* — the collimator's nut; *15* — the assembling plate; *16* — the potentiometer for cathode current adjustment

applied. This current source includes a plate with electronics of the stabilizer and an isolated transformer with ~ 12 V on input. The transformer is needed because the cathode is under high voltage, and the stabilizer scheme has to be isolated from the ground and low-voltage parts of the X-ray generator module. The tube anode is grounded, and it mechanically sits in a brass socket of cooler. The cooler is applied for regime with large current in a range from 50 to 500 μA according to the tube producer requirement. The total mass of the source is 3 kg.

The X-ray radiation has a broad angular distribution with a maximum at $0°$. The tube provides 5-mm diameter radiation spot on the tube window. The 5-mm lead collimator defines the radiation acceptance (or irradiated area) and the photon intensity.

For the gain measurements, the source has to have high enough intensity of about 10^6 photons per second behind the radiator, in the chamber gas volume, because of large absorption of keV photons in the TRD radiator.

2. SOURCE CHARACTERISTICS

The X-ray source characteristics and operation were investigated in laboratory measurements with a radiator prototype. In these measurements we studied: (1) the correlation between the tube current and the photon intensity, (2) the time fluctuation of the intensity, (3) the photon absorption in the radiator, (4) the dependence of the intensity on high voltage and cathode voltage.

The photon maximum energy is set by adjustment of high voltage magnitude, and the photon intensity by choice of the cathode voltage value.

In our laboratory measurements the high voltage of -8 kV was provided by the high-voltage power supply CAEN model 126. The tube current dependence on the cathode voltage was carefully studied, and the results are shown in Fig. 2. This dependence is very strong, and a variation of the cathode voltage from 1.0 to 1.3 V leads to increasing of the tube current and the X-ray intensity by a factor of ~ 100. It proves necessity of a good stabilizer for the cathode power supply.

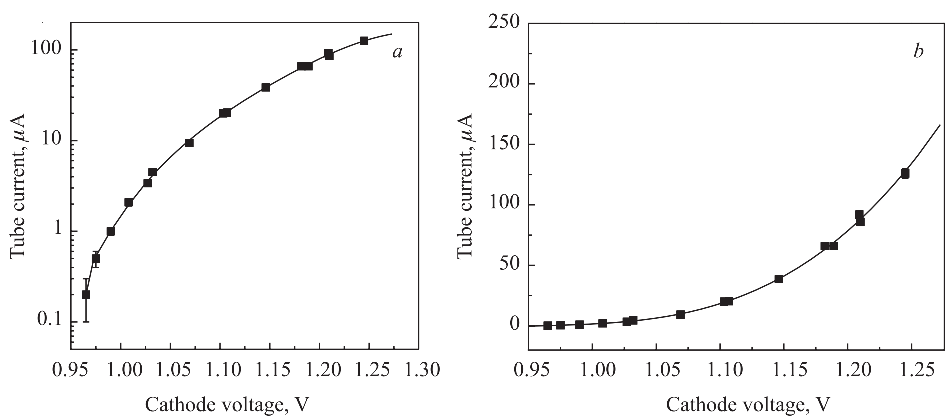

Fig. 2. Dependence of the tube current on the cathode voltage

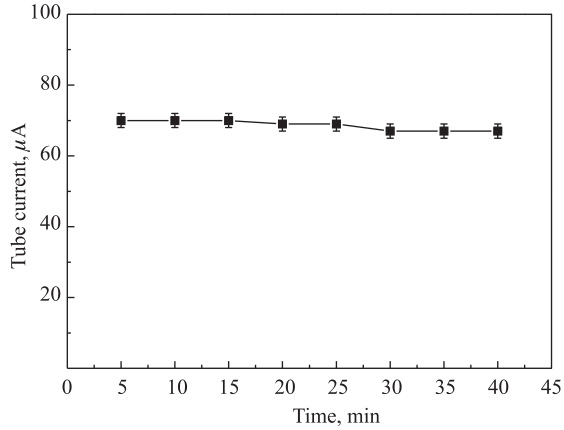

Fig. 3. A typical time variation of the X-ray tube current

A typical time variation of the tube current is shown in Fig. 3. In real tests this effect is corrected by simultaneous measurement of both the chamber and tube currents.

In the laboratory experiment the X-ray photons were registered by a detector with 5-cm plastic scintillator coupled with low-noise photomultiplier FEU-183. The PMT current is proportional to absorbed energy of the X-ray radiation. The measurement showed very good correlation between the currents of the PMT and X-ray tube, and it proved good proportionality between the tube current and the radiation intensity, as expected.

Also, two different measurements without and with radiator were made with a goal to investigate the photon absorption in the radiator. The obtained data are shown in Fig. 4. In the first experiment without radiator the PMT current monotonically increased with high voltage of the X-ray tube. The second one showed total absorption of the photons in the radiator in energy range below $\sim$ 6 keV. At higher energies some fraction of emitted photons passed through the radiator. This effect explains increasing of the PMT response with the X-ray tube high voltage. So, one can see that only the photons with energies above $\sim$ 6 keV have a chance to reach the TRD chamber gas volume and to be detected.

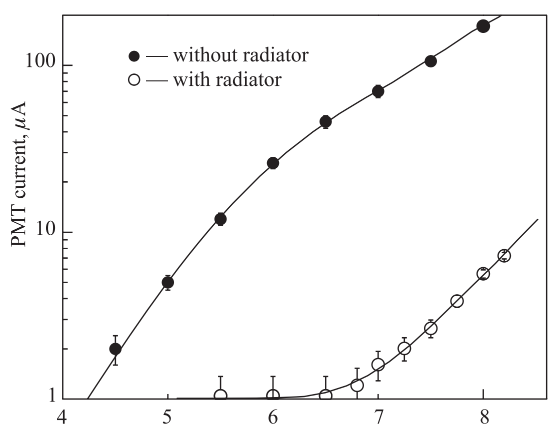

Fig. 4. Results of the test measurements with and without the TRD radiator

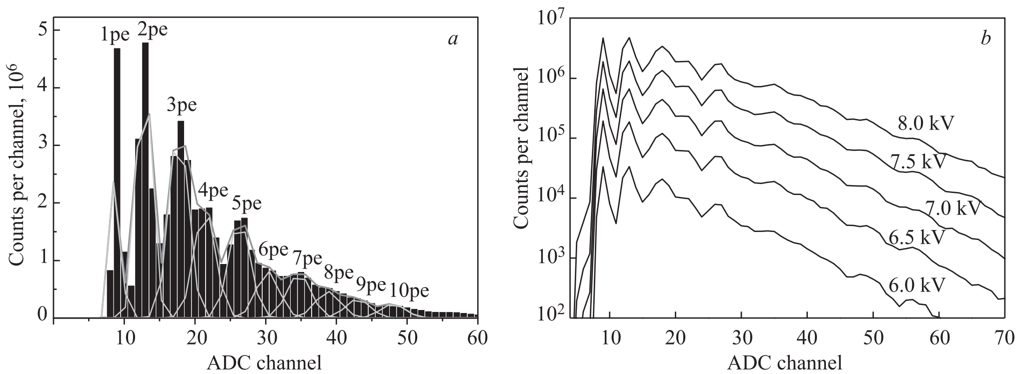

Fig. 5. Pulse height distributions measured with the scintillation detector. *a*) The tube HV $= -8$ kV, the curves — the Gaussian multiple-peak fit. *b*) The amplitude spectra obtained with different magnitudes of the tube high voltage

Thus, we are coming to the important conclusion that the photons of low-energy part of TR spectrum with energies below about 10 keV are effectively absorbed in the TRD radiator. The radiator transparency improves with the photon energy, and registration of the energetic TR photons will give main contribution to formation of specific TRD response for GeV electrons.

The absolute value of photon intensity was estimated in these measurements as well. Because of low intensity of light photons, induced by X-ray photon absorption in the scintillator, and small efficiency of the PMT photocathode ($\sim 20\%$), one could expect to see some peaks in a range of small amplitudes corresponding to 1 p.e., 2 p.e., 3 p.e., etc. The result obtained with a tube voltage of -8 kV is shown in Fig. 5, *a*. The pulse height distributions, measured at five high voltage magnitudes, have similar shape, but the intensity increases with the voltage, as shown in Fig. 5, *b*. The experimental yield of photoelectrons was compared

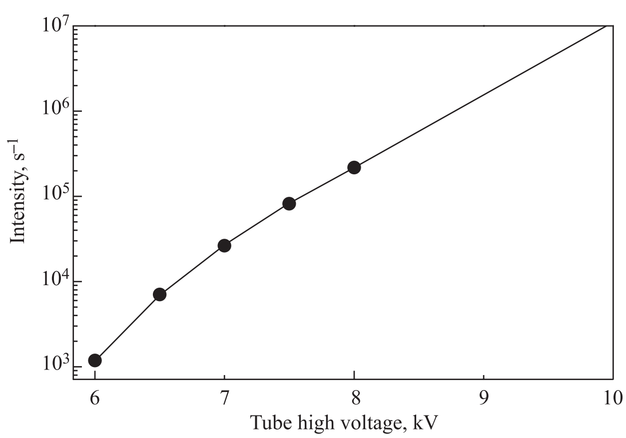

Fig. 6. The intensity of X-ray photons behind the radiator as a function of the tube high voltage, the tube current — 100 μA

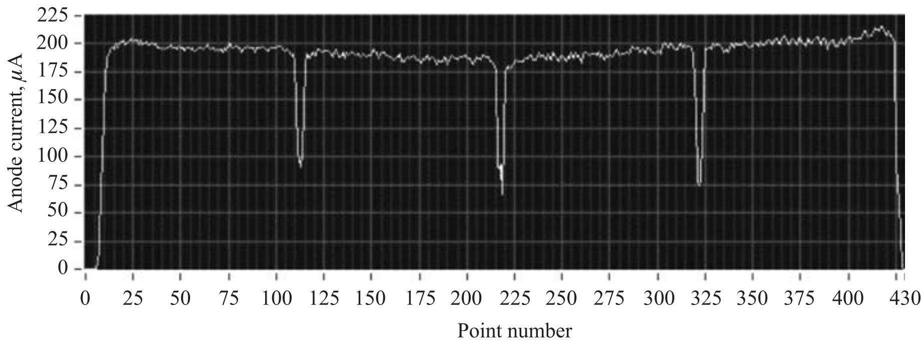

Fig. 7. Example of the current scan along tested TRD chamber with the X-ray source

with the Poisson distribution. It was found that the best fit was given by the distribution with parameter $\mu = 3$. This fact was used in calculation of X-ray photon registration efficiency for the scintillation detector, $\varepsilon_\gamma = 0.95$. The next step was determination of the absolute intensity of X-ray photons behind the radiator. The final results for five high voltage magnitudes and the extrapolating curve are shown in Fig. 6. The extrapolation to -9 kV gives an intensity of $\sim 10^6$ s^{-1}, and it is in accordance with the requirement. Another way of increasing the intensity is to rise the tube current.

Nowadays, the X-ray sources are extensively used by several groups for the TRD chamber gain mapping. An example of the anode current scan along the chamber is presented in Fig. 7. The observed narrow peaks correspond to large absorption of the photons between radiator cells. Some information about the TRD chamber tests can be found in [2]. The experience showed that single X-ray tube BH2-Ag provides required regime for the tests during a long period of about one year. Then the user has to change the tube.

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