INTRODUCTION

The Compressed Baryonic Matter (CBM) Collaboration [1, 2] conducts dedicated heavy-ion experiments to investigate the properties of highly compressed baryonic matter as is produced in nucleus–nucleus collisions at the Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany.

The experimental setup has to fulfill the following requirements:

(i) reliable electron identification (which requires a pion suppression factor on the order of $10^5$);
(ii) the identification of hadrons in a large acceptance;
(iii) the determination of the primary and secondary vertices with an accuracy of ~30 μm,
(iv) the fast response of the detector apparatus and read-out system;
(v) minimal detector dead time;
(vi) maximum data speed of acquisition and processing;
(vii) detectors and other electronics equipment must be radiation-resistant;
(viii) the system must be tolerant to delta-electrons.

Figure 1 depicts a general layout of the CBM experimental setup. A silicon tracking system (STS) consisting of four planes of Micro-Vertex Detector (MVD) microstrip detectors and three silicon coordinate planes is located right behind the target between the poles of the superconducting dipole magnet. The STS must restore the charged particle trajectory and reconstruct secondary vertices with high accuracy under conditions of high-density tracks. The STS information will also be used for determining the momenta of the charged particles with 1% accuracy. The Ring Imaging Cherenkov (RICH) detector identifies electrons produced as a result of low-mass vector-meson and charmonium decays and it suppresses the intensive pion’s background. The transition radiation detector (TRD) has two main functions: (1) reconstructing the trajectory of charged particles and (2) identifying high-energy electrons and positrons under the conditions of a dominating back-

METHODS OF PHYSICAL EXPERIMENT

Peculiarities of Applying the $\omega_n^k$ Criterion for the Electron Identification Problem Based on the Transition Radiation Detector in the Compressed Baryonic Matter Experiment

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Abstract—The problem of electron identification under conditions of a dominating pion background with the help of a multilayered transition radiation detector (TRD) in the Compressed Baryonic Matter (CBM) experiment is considered. With this aim, various mathematical methods, including methods based on the nonparametric goodness-of-fit $\omega_n^k$ criterion, have been elaborated and investigated. The characteristic properties of distributions of energy losses by electrons and pions in the TRD radiators are considered, and specific features of applying traditional statistical methods, methods based on the $\omega_n^k$ criterion, and artificial neural networks to the analyzed problem are discussed. The results of a comparative analysis of the power of these methods are presented, and recommendations for their usage are given.

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PECULIARITIES OF APPLYING THE $\omega_n^k$ CRITERION

Ground from pions. TRD must allow a pion suppression coefficient of 150–200 to be reached at an effective registration of electrons no less than 90%. Hadron identification will be performed with the time-of-flight (TOF) system, which is based on the resistive plate chamber (RPS) planes. The accuracy of registration should be significantly less than 100 ps, and the expected particle flow in the central part of the TOF detector will be about 25 kHz/cm². An electromagnetic calorimeter (ECAL) will be used for identifying electrons and photons.

Dilepton pairs from the decays of short-living vector mesons and charmonium will be registered and used for investigating the peculiarities of hot and dense fireballs in the CBM experiment. Measurements of the spectra of $\rho$, $\omega$, and $\phi$ mesons in their dilepton decays will be used for researching the effects of the restoration of chiral symmetry. Because charmonium (in this context mostly $J/\psi$ meson) decays in the quark–gluon phase of the nuclear matter much more often than in a hadron one [3], one will be able to investigate the phase transitions occurring in the fireball at the early stage of collision. Moreover, when the charmonium decays into a pair of leptons (electron or muon), which do not enter strong interactions with the nuclear substance, the distribution of invariant weights of the dilepton pairs allows one to obtain information about the effect of the restoration of the chiral symmetry [4].

Within the CBM experiment, both dielectron (a corresponding scheme of the installation is presented on Fig. 1) and dimuon modes of the above-considered particle decays will be investigated. In this work we investigate the problems of registering dielectron pairs from the decays of short-living vector mesons and charmonium. For this purpose, two problems should be solved: (1) suppress the intensive background from secondary pions and (2) reliably identify electrons.

For the electrons with a momentum of $p > 1.5$ GeV/c ($\gamma > 2000$), a TRD is best-placed to address these problems. It consists of a multi-layered radiator, which produces X-ray transition radiation (TR) from high-energy electrons–positrons and a TRD. In our case the TRD is a multiwire proportional chamber (MPC). The MPC coordinate planes within the TRD structure will be used to reconstruct the charged particle trajectories with a coordinate restoration accuracy of 200–300 $\mu$m.

This work specifically focuses on the methods based on the nonparametric goodness-of-fit criterion $\omega_n^k$ [5] intended for a reliable identification of electrons–positrons under the conditions of an intensive background from pions. Some observed peculiarities of the distributions of the energy losses of electrons and pions in the TRD layers [6] have allowed us to modify the procedure of applying the $\omega_n^k$ criterion to the analyzed data and to increase its power essentially. In this work we discuss some peculiarities of applying methods based on the $\omega_n^k$ goodness-of-fit criterion, traditional statistical methods, and artificial neural networks (ANN) to this problem; the results of a comparative analysis of their power is also presented.

1. DESIGN OF THE TRANSITION RADIATION DETECTOR

Figure 2 presents a schematic layout of the CBM experiment. The scheme gives a standard version of the TRD detector which comprises three stations (TRD1, TRD2 and TRD3) located 5, 7.25, and 9.5 m from the target along the direction of the beam, accordingly.

Each station consists of four identical modules. Figure 3 gives a scheme of the TRD module prototype developed jointly by specialists from GSI (Darmstadt) and IFIN–HH (Bucharest).

The module includes (see Fig. 3):

(i) a layered radiator consisting of N alternating layers of a polypropylene film of thickness $D_f$ and air intervals of thickness $D_g$ for producing X-ray transition radiation from high-energy electrons–positrons;