Development of a Radiation Monitoring System for the CBM Experiment

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This work is carried out as part of the preparations for the launch of the CBM (Compressed Baryonic Matter) experiment, which is designed to explore the Quantum Chromodynamics (QCD) phase diagram in regions of extreme baryon densities and low temperatures [1]. To achieve the required statistical precision for observing rare probes, the experiment will operate at a nuclear interaction rate of up to 10 MHz. Such high-intensity environments impose significant radiation loads on detector components, making real-time monitoring of beam stability and the radiation environment a task of paramount importance for the experiment's duration and data quality. To address this task, the Department of High Energy Physics (INR NAS of Ukraine) proposed creating a new radiation monitoring system (RMS-CBM) based on the proven technology of the RMS-R3 system currently operating at the LHCb experiment (CERN) [2]. The base configuration of the system uses metal foil detectors (MFD), which operate on the principle of secondary electron emission (SEE) [3].

To theoretically validate the concept, comprehensive modeling was conducted using FLUKA and LTspice packages [4]. FLUKA Monte Carlo simulations investigated the sensor's response to photon radiation and the transition from laboratory air conditions to the experiment's vacuum environment. The simulation results demonstrated the asymmetric nature of secondary electron emission in the air medium. Furthermore, reducing the gap between components compared to the RMS-R3 design led to a noticeable reduction in background noise.The electronic readout chain was modeled in LTspice to assess the baseline hardware noise level [4]. By modeling the registration of the induced signal and the noise spectral density, it was demonstrated that the system's equivalent noise charge (ENC) remains at approximately 1000 electrons. This result fully satisfies the strict standards for CBM-sensitive detector systems and ensures that the physical signal remains clearly distinguishable from the hardware noise.

Comprehensive laboratory tests of the manufactured physical prototype were also conducted. Analysis of the voltage-response (V-R) characteristic showed that the system reaches a saturation plateau at an operating voltage of 5 V. This rapid saturation is a direct consequence of the ultra-compact geometry, which prevents the accumulation of background electrons from ionized air. Long-term stability measurements conducted in an isolated, grounded environment showed that the standard deviation of the baseline frequency does not exceed 3.4 Hz. Current results demonstrate significant potential for the RMS-CBM prototype, providing a solid foundation for further improvements aimed at its eventual installation as a permanent monitoring complex in the CBM experiment.

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3. Pugatch, V., et al. (2004). Metal foil detectors and their applications. Nuclear Instruments and Methods in Physics Research Section A, 535(1-2), 566-570.
4. Kshyvanskyi, O. O., Pugach, V. M., & Teklishyn, M. A. (2025). Simulation of the radiation monitoring system prototype for the CBM experiment. Science and Technology Today, 13(54), 2744-2754.

<u>РЕЄСТРАЦІЙНА СТОРІНКА</u>

РОЗРОБКА СИСТЕМИ РАДІАЦІЙНОГО МОНІТОРИНГУ ДЛЯ ЕКСПЕРИМЕНТУ CBM

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