E1-2020-37

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THE COSMIC RAY DETECTOR FOR THE **NICA** COLLIDER

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Белевич М. и др. E1-2020-37

Детектор космических лучей для коллайдера NICA

Многофункциональный детектор (MPD) является главной частью нового ионного ускорительного комплекса (NICA), расположенного в Дубне. Для повышения производительности MPD было предложено добавить дополнительную триггерную систему мюонов для калибровки вне пучка субдетекторов MPD и подавления фона космических лучей во время эксперимента. Также система может быть очень полезна для астрофизических наблюдений за космическими ливнями, инициированными первичными частицами высоких энергий. В статье описываются основные цели работы детектора MCORD и ранняя стадия разработки MCORD на основе пластиковых сцинтилляторов с кремниевыми фотоумножителями (SiPM) для сцинтилляционного считывания и электронной системы на основе стандарта MicroTCA.

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The Cosmic Ray Detector for the NICA Collider

Multi-Purpose Detector (MPD) is the main part of a new Nuclotron-based Ion Collider fAcility (NICA) located in Dubna. To increase MPD functionality, it was proposed to install an additional muon trigger system for off-beam calibration of the MPD sub-detectors and for rejection of cosmic ray background during experiments. The system could also be very useful for astrophysical observations of cosmic showers initiated by high-energy primary particles. This article describes the main goals of MCORD detector and the early stage of MCORD design, based on plastic scintillators with silicon photomultiplier photodetectors (SiPM) for scintillation readout and electronic system based on MicroTCA standard.

The investigation has been performed at the Veksler and Baldin Laboratory of High Energy Physics, JINR.

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INTRODUCTION

The new collider complex NICA (Nuclotron-based Ion Collider fAcility) with two circle accelerators (Booster and Nuclotron) is currently under construction at the Joint Institute for Nuclear Research (JINR) in Dubna, Russia [1]. At the first stage of operation the main detection system at NICA will be the Multi-Purpose Detector (MPD) [2] (Fig. 1).

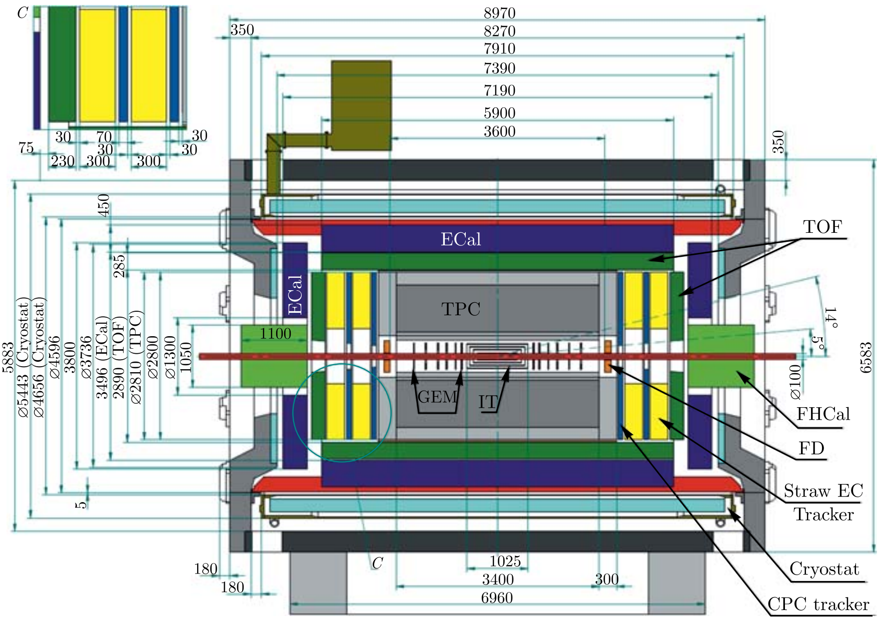

Fig. 1. Cross section of the MPD — the main NICA detection system [2]

1. MOTIVATION

The MPD was designed to identify particles emitted during ion–ion collisions. Recently, it was proposed to increase MPD functionality by installing an additional detection system surrounding the MPD, namely, Muon Cosmic Ray Detector (MCORD), see Fig. 2. The motivation for designing and constructing the MCORD detector is:

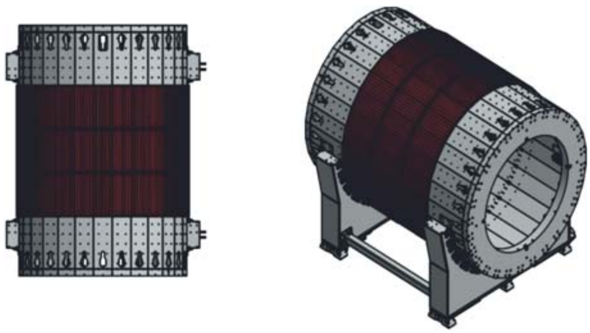

Fig. 2. The MCORD modules on the surface of the MPD magnet yoke

1. Providing trigger for testing and calibration of other sub-detector systems before completion of MPD, e.g., Time-of-Flight (TOF), Electromagnetic Calorimeter (ECAL) and Time Projection Chamber (TPC).

2. Identification of muons produced as a result of ion–ion collisions inside the MPD.

3. Providing data for astrophysical observations (similarly to ACORDE detector in ALICE experiment at LHC [3]), e.g., deducing directionality of muon showers [4].

4. Vetoing for rare events research to reduce cosmic ray background.

2. MCORD SYSTEM DESCRIPTION

MCORD will provide information on the time and amplitude of the signal induced by charged particles passing through scintillators. And additionally, after analyzing the signal, it will provide information about the direction from which the particle came and the path that will pass through the MPD detector. Since the MPD is a large-scale device (about 8 m in length and 6 m in diameter), the MCORD needs to be designed with relatively cheap materials and cost-efficient assembly. It was decided to use plastic scintillator bars equipped with wavelength shifting fibers. The MPD detector comprises a large magnet around which the MCORD detector should be installed, light readout will be done by means of silicon photomultipliers (SiPMs) [5], as they are insensitive to magnetic field. Each MCORD module (Fig. 3), will consist of three sections (Fig. 4), and each section will comprise eight

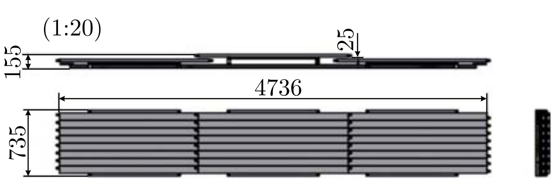

Fig. 3. The MCORD modules consist of three sections, eight scintillators each

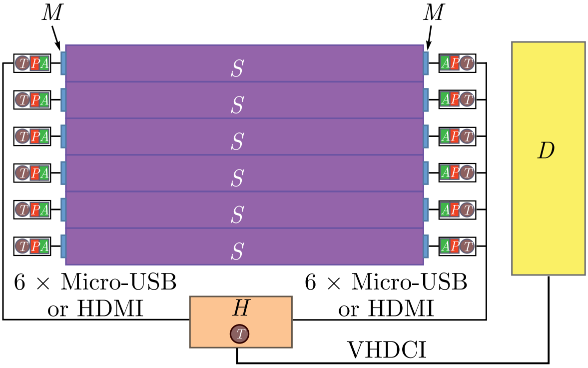

Fig. 4. Conceptual design of the MCORD detector readout section: S (purple) — plastic scintillator; M (blue — both ends of scintillators) — SiPMs; P (red) — power supply with temperature compensation circuit; T (brown) — temperature sensor; A (green) — amplifier; H (orange) — passive HUB; D (yellow) — MicroTCA digital system; A–P–T–H — analog front-end module

plastic scintillators with aluminum cover. At each end of a scintillator there will be a SiPM photodetector with a dedicated power supply, a temperature compensation circuit and an amplifier. As a result, one MCORD module will comprise 48 measurement channels. The SiPMs and related electronics (Fig. 5) will be embedded into scintillators aluminum cover with end-cups that will shield the scintillators from light and protect them from dust and water. The output signal from a SiPM will be amplified and shaped in an analog front-end module (Fig. 5) and subsequently will be sent to a MicroTCA System (MicroTCAB® is a modular, open standard for building high-performance

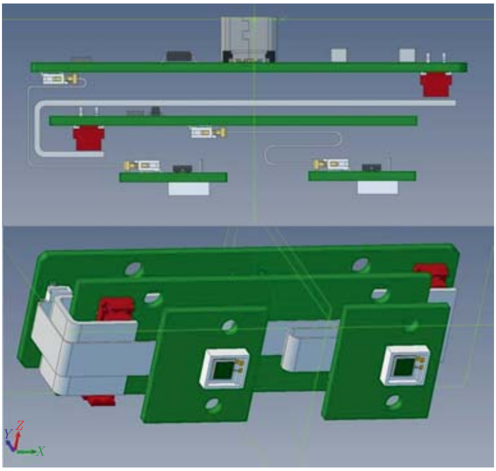

Fig. 5. The separated electronic PCBs with SiPMs, amplifier and power supply

Fig. 6. MicroTCA4 crate with 12 slots PICMG

switched fabric computer systems in a small form factor [6]) (Fig. 6). The TCA standard allows one to install up to 12 AMC cards (Advanced Mezzanine Card). Industry standard AMC–FMC carriers will be used for MCORD system. FMC (FPGA Mezzanine Card) is an ANSI standard that provides a standard mezzanine card form factor, connectors, and modular interface to an FPGA located on a base board (Fig. 7). For more information about light production and propagation, analog and digital electronic system, see [7, 8].

Fig. 7. Left: the example of FPGA board; right: the example of FMC card

The scintillators size will be about $1620 \times 72 \times 22$ mm. The time difference in light propagation through the fiber embedded into plastic will be used to find the particle interaction position along the scintillators module, whereas the width and thickness of the plastic slab will give upper limits on the muon track position in the plane perpendicular to the long detector axis. Application of fiber for light collection along the scintillating bars allows for using small SiPM photodetectors (1.3×1.3 mm).

MCORD detector modules will be arranged in a barrel shape around the shielding of the MPD detector (Fig. 2). Each module will be installed on the MPD shielding surface separately (Fig. 8). Signals induced by muons will be processed in the FPGA basing on coincident hits from different detector layers

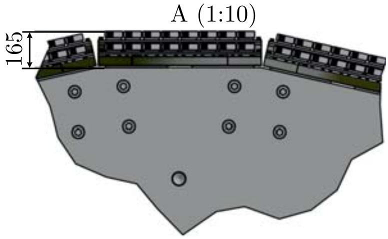

Fig. 8. MCORD modules on the MPD surface

allowing for particle tracking. The fast and low latency process of the muons trajectory identification will be based on the muon trajectory processor. The original concept for the Overlap Muon Track Finder can be found in [9, 10], while the CMS muon trigger system is described in [11].

SUMMARY

This work is a part of the activities of the NICA-PL Consortium. It presents the current concept of a modular cosmic muon trigger system for the MPD detector at the NICA facility. Detection system is based on low-cost elements (plastic scintillators with SiPM photodetectors). The digital analysis system will be based on the MicroTCA standard with FPGA modules. The proposed hardware can be modified upon requests to change the required number of channels or spatial resolution.

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