MATERIAL BUDGET STUDY OF THE MPD DETECTOR AT THE NICA COLLIDER*

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The Multi-Purpose Detector (MPD) is the experiment at the NICA collider. Due to the nested construction of the collider experiments, the construction of the each inner detector of MPD has an effect on the working of the other outer detectors and should be studied very carefully to make proper estimation of its material. The material budget study of the Multi-Purpose Detector (MPD) is considered in details.

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1. Introduction

The Multi-Purpose Detector (MPD) experiment [1] at the Nuclotron-based Ion Collider fAcility (NICA) in Dubna [2] is designed to explore the QCD phase diagram of strongly interacting matter in the region of highly compressed and hot baryonic matter. Detectors for this experiment should work with the high track reconstruction efficiency ($> 95\%$) and good momentum resolution for charged particles ($< 3\%$) in the expected high-multiplicity events (~ 1000 tracks for Au–Au collisions at $\sqrt{s_{NN}} = 11$ GeV).

Such requirements limit the mass of vertex and tracking detectors for the collider experiments. To meet the conflicting goals of minimizing detector mass and also incorporating cooling, power distribution and supported constructions, an integrated system design approach is needed. The precision of the measured vertex and track parameters is degraded due to multiple scattering effects in the detectors materials. It is, therefore, crucial to carefully account and limit for every material contribution in the detector acceptance region. The magnitude of multiple scattering depends on the local material budget measured in units of the material constant X_0.

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2. MPD detector setup

The experimental set-up proposed for the MPD is shown in Fig. 1 (left). From inside to outside in the figure, the subdetectors are:

— Inner tracker (ITS). Primary goals of the ITS are the determination of the primary collision vertex and secondary vertices necessary for reconstruction of decaying particles. IT should provide tracking and identification of low-momentum particles not reaching the TPC, and improve the momentum and angular resolution of particles measures within the TPC.

— The TPC aimed to reconstruct and identify charged particles in the pseudorapidity region $|\eta| < 1$. The ionization energy loss ($\mathrm{d}E/\mathrm{d}x$) measurements in the TPC gas will give an additional capability for particle identification.

— The high performance time-of-flight (TOF) system based on RPC (resistive plate chambers) allows pion, kaon and proton identification in the broad rapidity range and up to the total momentum of 2 GeV/c. The TOF detector has a cylindrical shape, covering polar angles of $|\theta - 90°| < 63°$ degrees.

— The electromagnetic calorimeter (ECal) aims to measure the energy of particles mainly interacting by electromagnetic force. Those particles are electrons, positrons and photons. They are stopped by this detector and their deposit energy is measured then.

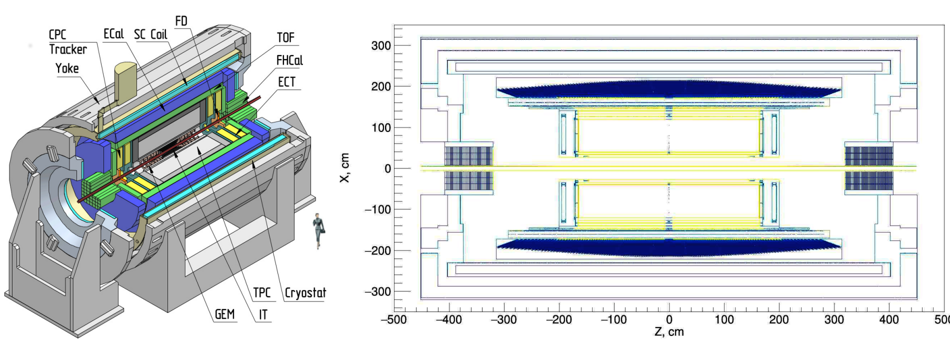

Fig. 1. Left: Setup of the MPD experiment. Right: Radiation lengths of MPD detectors.

— Forward Hadron Calorimeter (FHCal) is designed to measure the energy distribution of the projectile nuclei fragments (spectators) and forward going particles produced close to the beam rapidity. The FHCal consists of two hadron calorimeters with 45 towers each arranged symmetrically from the interaction point.

The first stage of the MPD consists of the time projection chamber (TPC) supplemented by the TOF detector, ECla and FHCal calorimeters and fast forward trigger detector FT. At the final stage of MPD, the setup considers the few endcap detectors placed between TPC and magnet endcap. Among them will be EndCap Tracker (ECT), cathode pad chamber (CPC) tracker and endcap TOF.

3. Material budget of the MPD subdetectors

Due to the nested MPD design, each detector has an impact on an outer one. For estimation of energy loss, material budget for all components of the MPD should be calculated.

For estimation of the radiational length of the detector material, the Geant4 version 10.5.1 package [4] provides a fictitious particle, geantino. The geantino accumulates the radiation length of the materials along its passage. These particles, generated uniformly over the pseudo-rapidity range, calculate the radiation lengths of total and individual contributions of the geometry elements.

The passage of the geantino through the material of the simulated MPD detector is tracked in Geant4, imaging the material distribution of the detector by plotting, for each step of the geantino's spatial trajectory, the fraction of the total radiation or hadronic interaction length of its trajectory, traversed in that step.

Figure 1 (right) shows the scan of the MPD detectors with the usage of geantino particles from Geant4 package. The picture clearly demonstrates the increasing of the material budget towards outer detectors so that tracking detectors have relatively small radiation lengths materials, and electromagnetic (ECal) and hadronic (FHCal) calorimeters have much larger radiation lengths.

Averaged material budget for the other subdetectors is shown in Fig. 2 (top).

The beam pipe and time projection chamber support wheels must also be included in the material budget. Figure 2 (bottom) shows the yield-to-radiation length from the material of tracking detectors (TPC, TOF) and pipe.

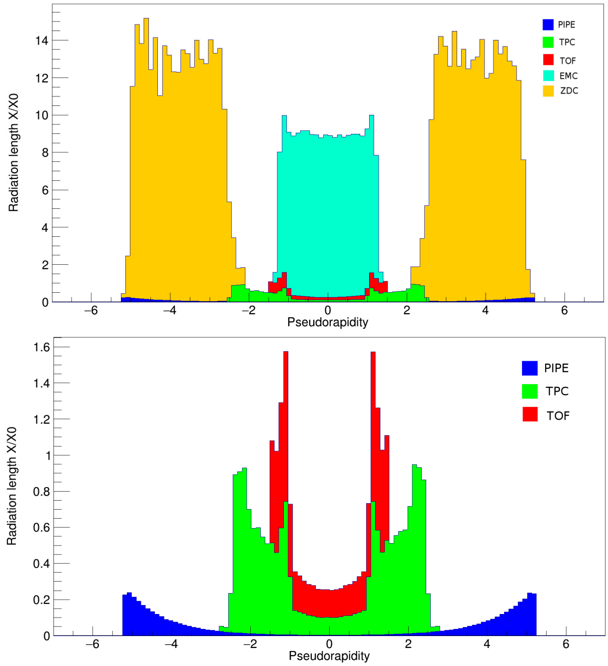

Fig. 2. Averaged material budget (top) for all MPD detectors, (bottom) for the pipe, TPC and TOF detectors.

4. Results

The material budget of the all of MPD detectors was estimated. The detailed simulation of MPD TPC was performed with thermoscreen and electronics. The next step will be including the detailed Inner Tracking System and TPC into material budget study of MPD.

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