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# The TOF Geometry Upgrade for the MPDROOT

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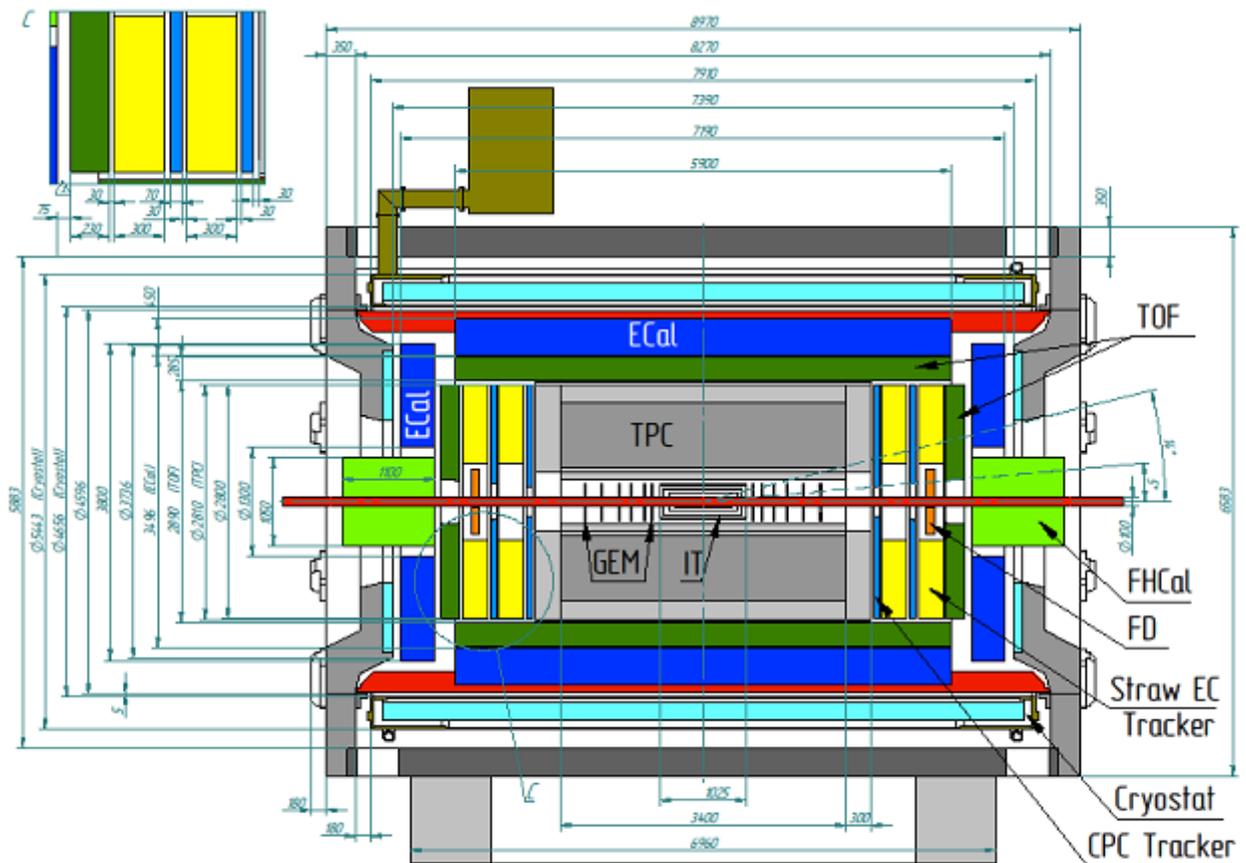
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# INTRODUCTION

The MPD is designed as a  $4\pi$ -spectrometer capable of detecting charged hadrons, electrons and photons in heavy-ion collisions in the energy range of the NICA collider [1, 2]. To reach this goal, the detector will include a precise 3D tracking system and a high-performance particle identification system based on time-of-flight measurements and calorimetry. At the design luminosity, the event rate in the MPD interaction region is about 6 kHz; the total charged particle multiplicity exceeds 1000 in the most central Au+Au collisions at  $\sqrt{s_{NN}} = 11$  GeV. As the average transverse momentum of the particles produced in a collision at the NICA energies is below 500 MeV/c, the detector design requires a very low material budget. The general layout of the MPD apparatus is shown in Fig. 1.1.



**Figure 1.1:** Cutaway side view of the MPD with dimensions.

The Multi-Purpose Detector consists of a barrel part and two endcaps located inside the magnetic field. The barrel part is a shell-like set of various detector systems surrounding the interaction point and aimed at reconstructions and identifying both charged and neutral particles in the pseudorapidity region of  $|\eta| \leq 1.4$ . The endcaps are aimed at the precise tracking over pseudo rapidity range ( $1.4 < |\eta| < 2$ ). The ion beams interact inside the beam pipe located along the  $z$  axis with the central interaction point at  $z = 0$  in the center of the detector. The interaction region covers an interval of  $|z| \leq 25$  cm.

The barrel part shown in Fig. 1.1 consists of a tracker and particle identification system. The principal tracker is the time projection chamber (TPC) supplemented by the inner tracker (IT) surrounding the interaction region. Both subdetectors (IT and TPC) must provide precise track finding, momentum determination, vertex reconstruction and pattern recognition. The time-of-flight (TOF) system must be able to identify charged hadrons and nuclear clusters in the broad rapidity range and up to total momentum of 2 GeV/c. The fast forward detectors (FD) will provide the TOF system with the start signal. The main goal of electromagnetic calorimeter (EMC) is to identify electrons, photons and measure their energy with high precision.

## **2. THE MPD TOF SYSTEM DESIGN**

The cylindrical part of the TOF MPD is in the barrel between the time-projection chamber (TPC) and the electromagnetic calorimeter (ECal). The TOF barrel internal radius is about 1.5 m from the beam axis and outer radius is 1.7 m (Fig. 3.6). The active surface of the barrel part of the MPD ToF covers the pseudorapidity range  $|\eta| \leq 1.4$ . The total surface of the barrel TOF system is about 52 m<sup>2</sup>. The TOF detector system is organized in a modular way.

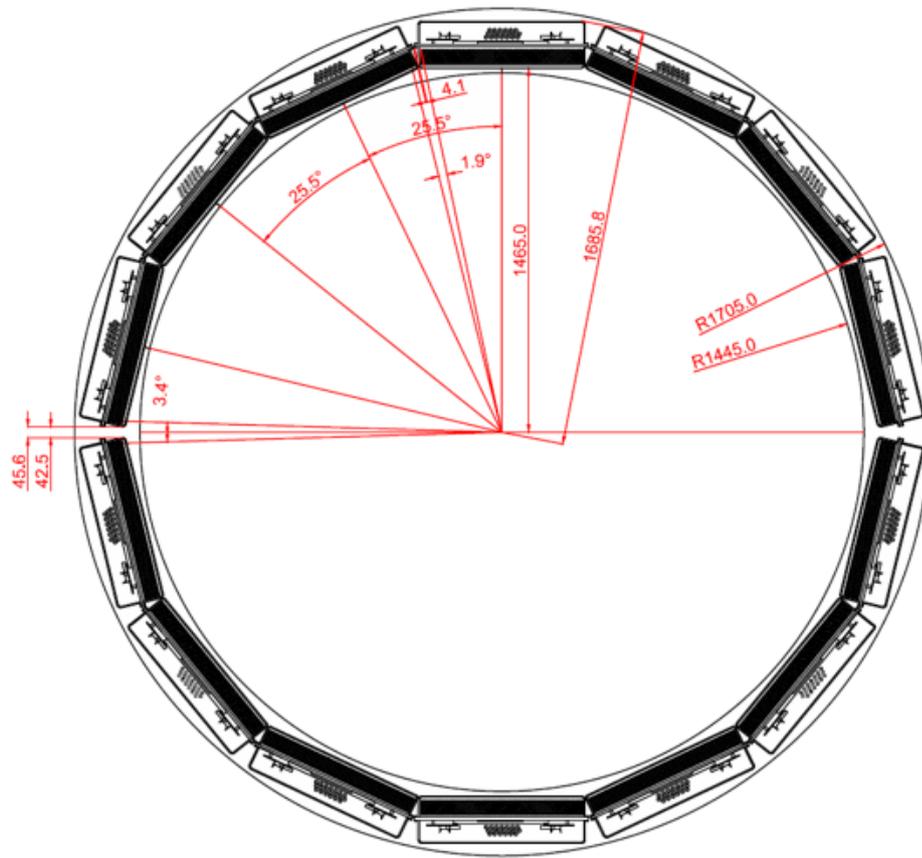


Figure 2. Dimensions of the TOF barrel in  $\phi$  direction.

The detector is segmented in  $\phi$  direction into 14 pairs of modules of  $\sim 5.9$  m length. The maximum distance between two boxes does not exceed 5 mm. The special shape of module minimizes the dead area inside the sector. The dead area between modules along  $\phi$  direction is due to the limited space along the radius of barrel.

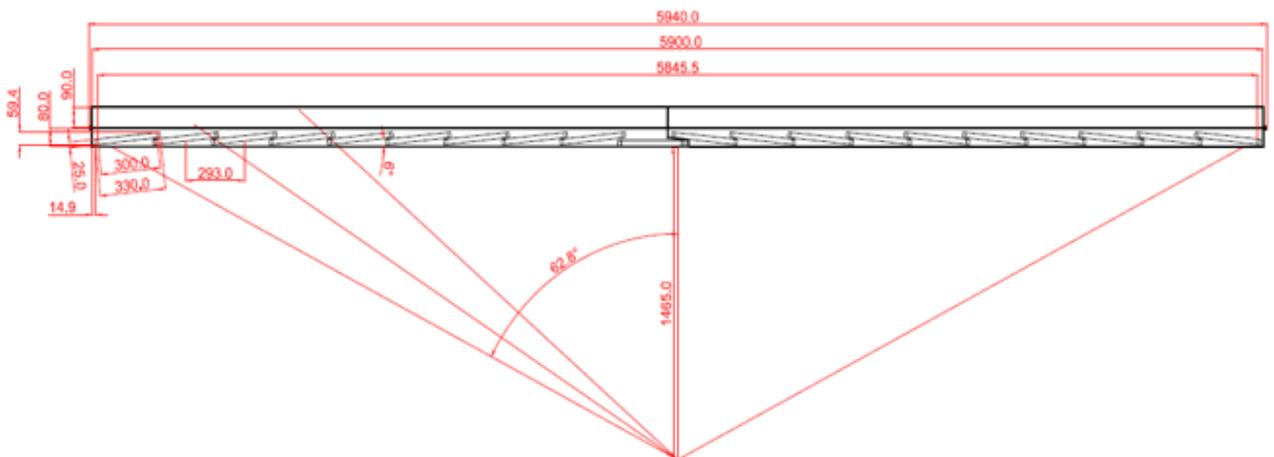


Figure 3. Arrangement of MRPCs inside the gas boxes along the beam direction.

A scheme of the MPD TOF detector is presented in Fig. 3.1. The detector consists of three stacks of 5 gas gaps each. As resistive electrodes common float glass is used. The outer glass electrodes have the thickness of 0.4 mm. The internal glass electrodes have the thickness of 0.270 mm. The fishing line as a spacer defines the 200  $\mu\text{m}$  gap between the all resistive electrodes [3].

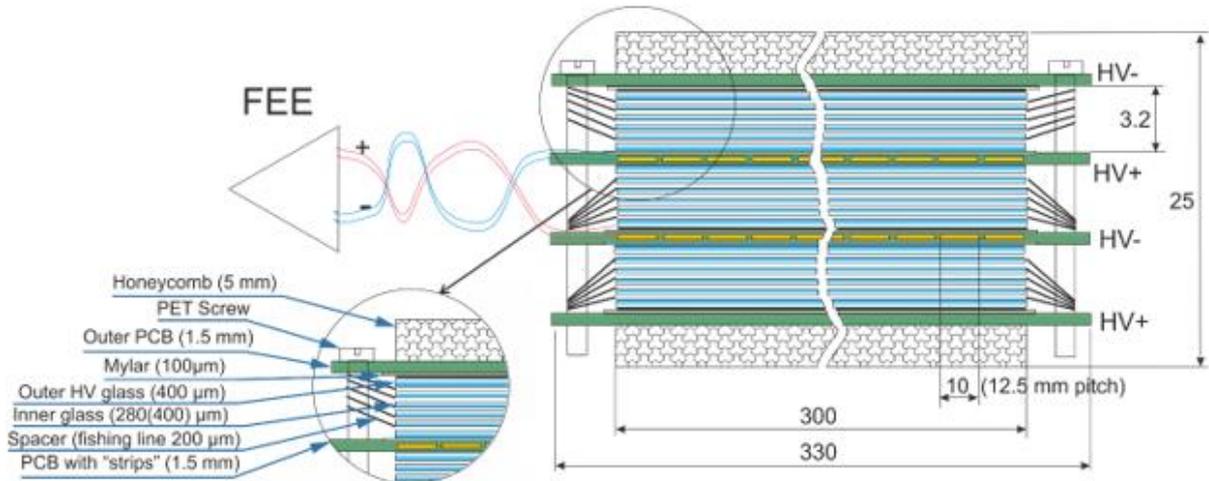


Figure 4. Scheme of the triple-stack MRPC with strip readout for TOF MPD.

### 3. ROOT GEOMETRY OF TOF MPD

#### 3.1. Development of geometry v8

The main goal of version 8 development is to make geometry much more detailed than version 7. It means inclusion of gas boxes, electric cables and detector mounts. Sizes of some parts were also changed.

MRPC detector itself has become more detailed in this version. Three layers of RPC glass and active gas are placed between PCB plates. Division of active areas into three layers allows to run more accurate simulations, compared with version 7 of MRPC, which contained only a single layer. Honeycomb plate was modelled as a pair of solid metal plates, each one has four times less thickness, than original one. Pictures of 7 and 8 versions of MRPC detectors in MPDROOT frameworks are presented in figure 5.

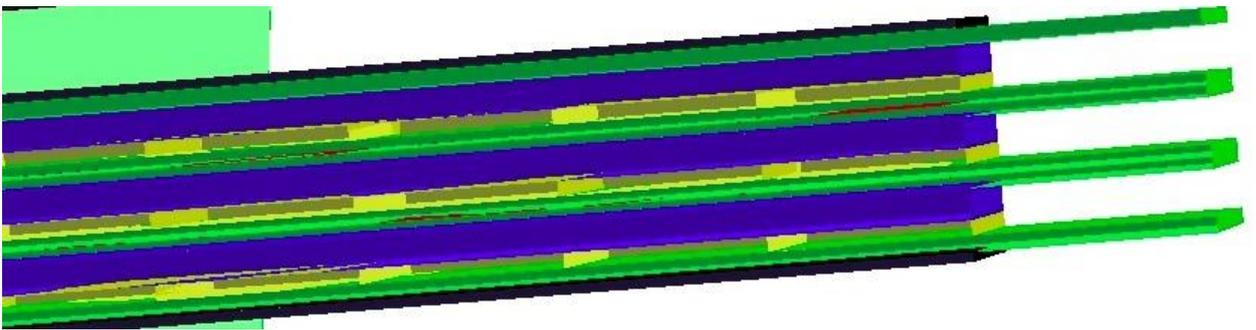
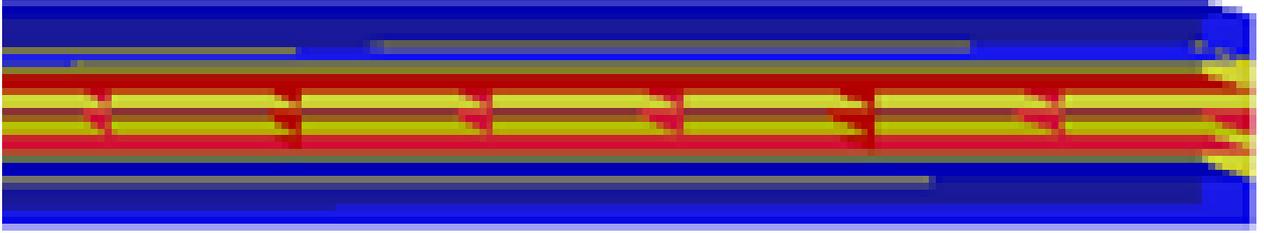


Figure 5. Comparison between MRPC v7 (top) and MRPC v8 (bottom).

Due to limited amount of shapes available in ROOT geometry, the gas boxes were modelled as several aluminum plates, placed in the shape of box. Inner volume of box is filled with gas. Detectors are placed inside the gas box. Each detector is attached to box with three pairs of mounts, which were also modeled in geometry. Central detector is placed at different angle and has its unique shape of mounts.

14 gas boxes are placed in shape of cylinder around the beam direction with angles, like ones displayed in figure 2. Overall look of TOF MPD geometry is displayed in figure 6.

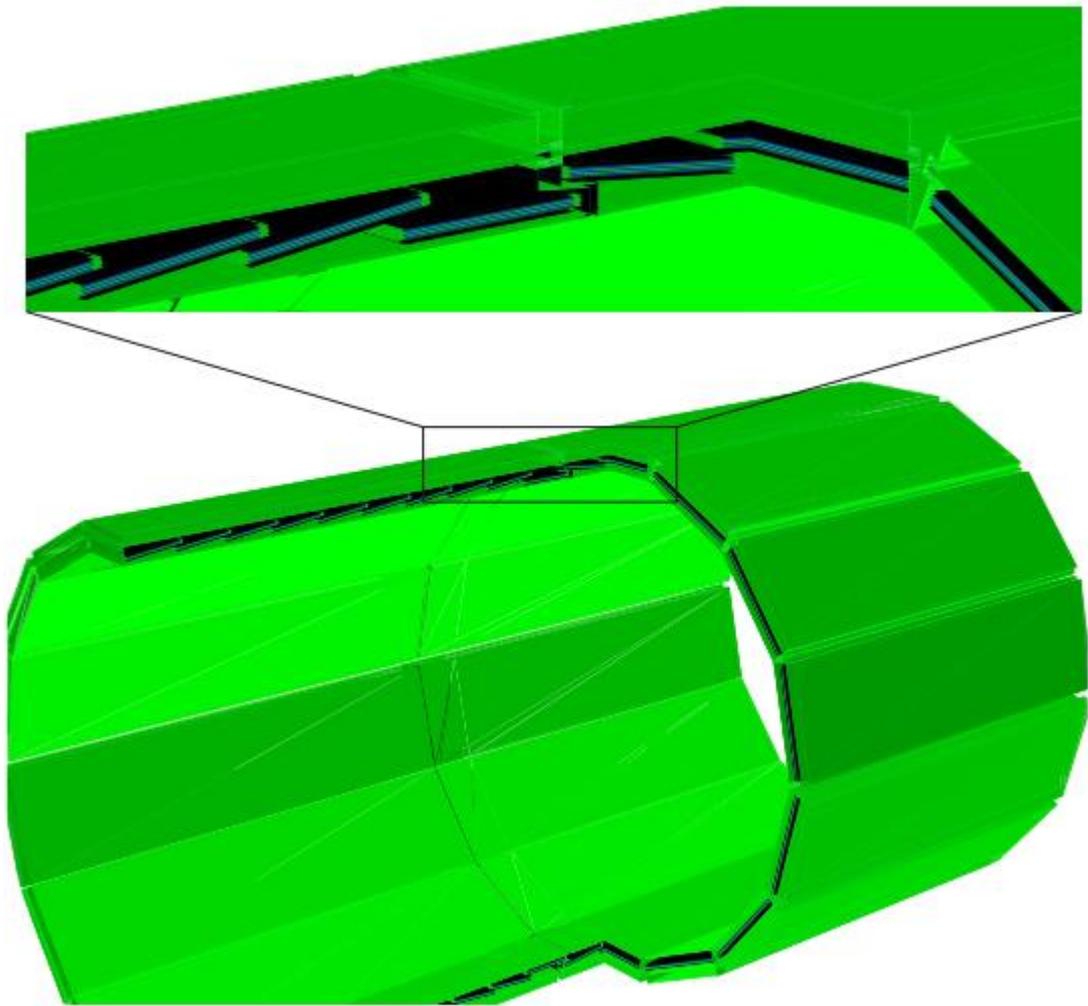


Figure 6. TOF MPD system in MPDROOT framework.

### 3.2. Geometric efficiency of the TOF MPD.

Monte Carlo simulation has been performed using the MPDROOT framework based on the CERN ROOT software. The MPDROOT framework has interfaces to several event generators (UrQMD, QGSM, HIJING, etc.) and includes all algorithms for MPD reconstruction and analysis, thus providing a complete set of instruments to simulate ion-ion collisions. For the purposes of this work we used LAQGSM event generator.

The barrel of the MPD TOF system is a cylinder covering the region of polar angles  $|\theta - 90^\circ| < 63^\circ$  ( $|\eta| < 1.4$ ) [3]. The structure of the TOF, the inner structure of each module and MRPC detectors have been described in the GEANT 4 package. All simulations have been done for geometry presented in the previous chapter.

To calculate geometric efficiency, we placed cylinder of active gas around the TOF barrel (Figure 7 a). This cylinder detects particles with 100% probability, so we divide number of hits in it on number of hits in TOF detectors for each area.

The efficiency in Figure 7 b is differential efficiency ( $d\epsilon/dZ$ ) along the  $Z$  direction, averaged over the angle  $\varphi$ .

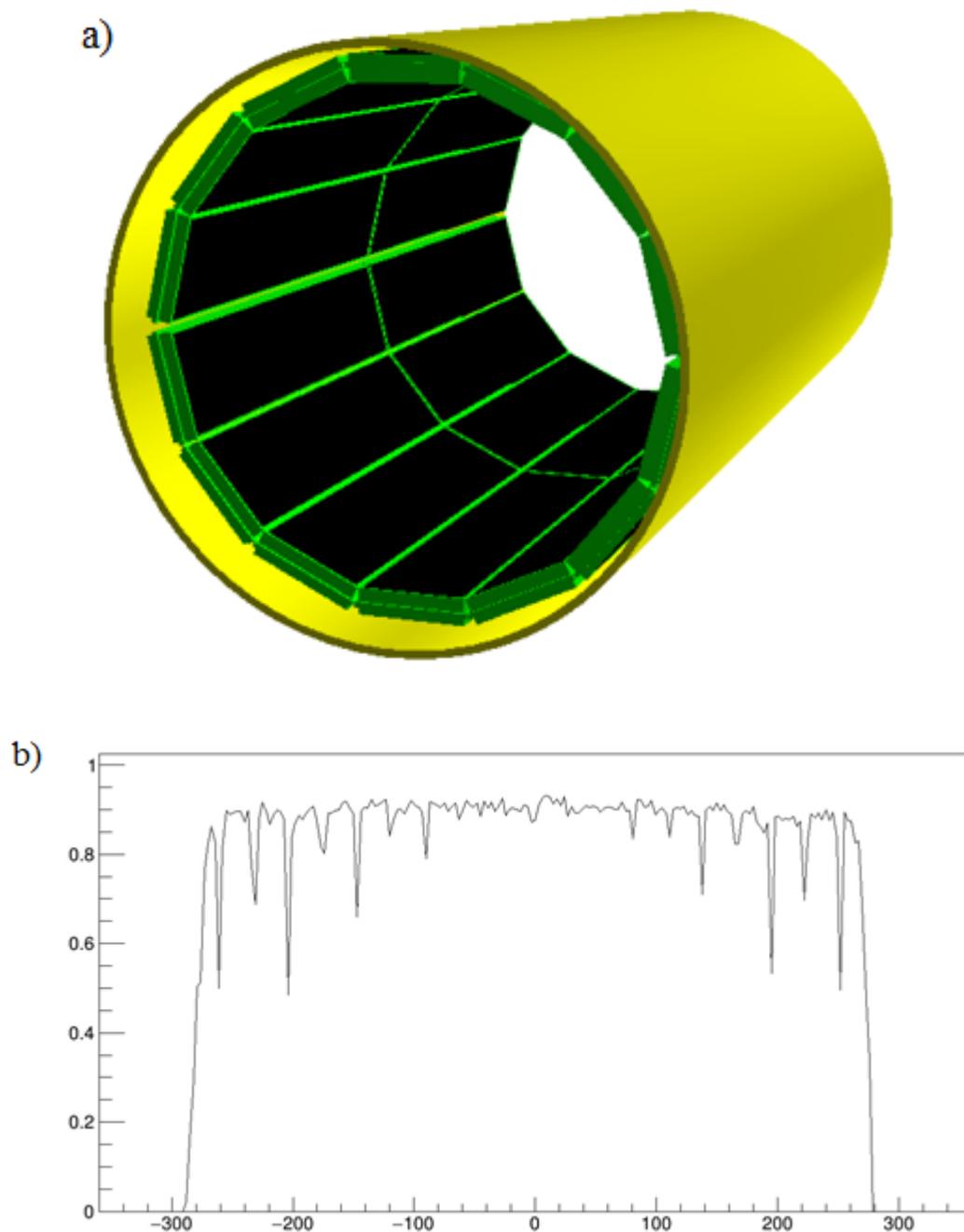


Figure 7. a) TOF barrel with active gas cylinder around it, b) distribution of geometric efficiency along  $Z$  direction, integrated over azimuth angle (preliminary result).

The geometrical efficiency depends on the geometry of whole TOF system and arrangement of the MRPCs in the TOF. Higher values correspond to the lower edge of the detector in adjacent modules. In this position the active regions of adjacent modules are closest to each other. Therefore, more particles are recorded at this location.

### 3.3. Misalignments simulation for TOF geometry

The TOF geometry in MPDROOT is based on 3D model of this system and represents its ideal state. In reality, it is nearly impossible to assemble TOF modules with such precision. This leads to an inconsistency of results between simulation and native experiments because of different locations of MRPC modules and its active areas. To avoid that we made a simulation of randomly generated misalignments in TOF geometry. Based on that, there will be an algorithm, which will convert hit coordinates into such in ideal model.

Misalignments were simulated for MRPC's, their mounts and gas boxes. Values are generated in range of tolerance for each part to avoid overlapping. An example of randomly generated misalignment is presented in Figure 8.

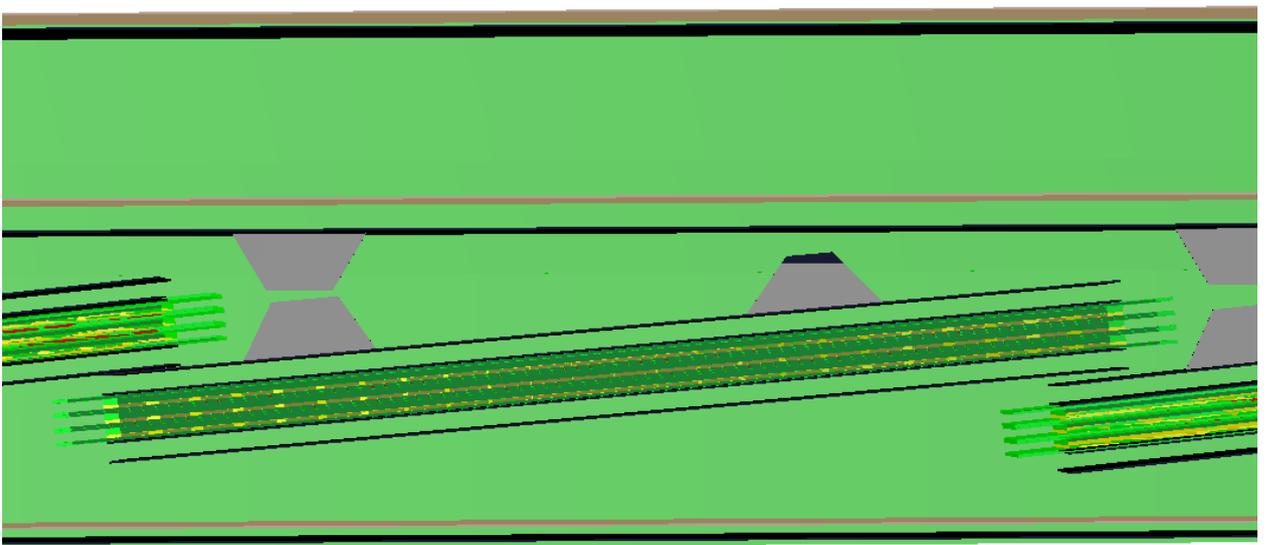


Figure 8. Detector plate, placed with randomly generated misalignments in TOF geometry for MPDROOT

## **RESULTS**

The new (eight) version of MPD Time Of Flight system geometry for MPDROOT contains more details of TOF system than version 7. The gas boxes and detector mounts were added. Combined with new, more detailed representation of MRPC, it allows to run more accurate simulations, compared with old version. Misalignment simulation provides to include randomly generated shifts into TOF geometry, to simulate installation inaccuracies of detectors and gas boxes. The next step is to make an algorithm to convert particle hit coordinates into such in ideal model.

Development of the eight version of Time Of Flight system geometry for MPDROOT. Misalignments simulation and geometric efficiency.

## REFERENCES.

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