REALISTIC SIMULATION OF THE MPD TIME PROJECTION CHAMBER WITH GARFIELD++ SOFTWARE

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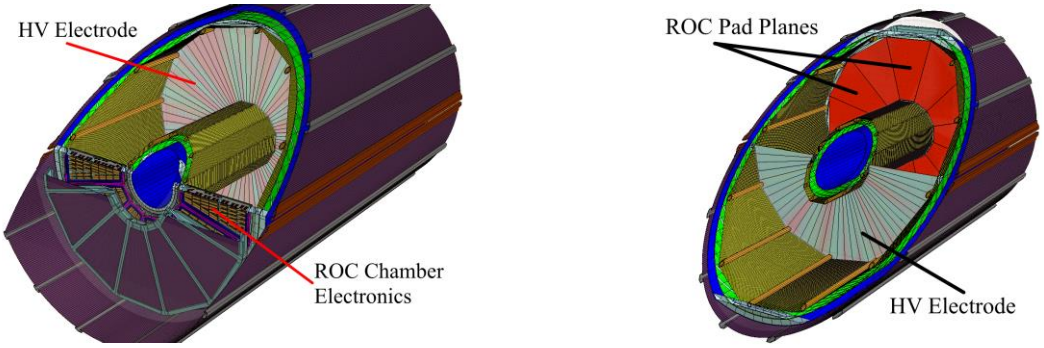
The detailed simulation of electron drifting in the MPD TPC was made with CERN Garfield toolkit for the simulation of gas particle detectors. For electron transporting, the 10% Ar + 90% CH4 gas mixture with impact of corresponding magnetic and electric fields from MPD TPC Technical Design Report (rev. 07) were used. Ionization processes were investigated in a wire planes area near Read-Out Chambers of the TPC. The Read-Out Chambers were modelled with some different values of gating grid voltage.

Keywords: NICA, MPD, TPC, Time Projection Chamber, Garfield, Detector Simulation

1. Introduction

Time Projection Chamber is a charged particle detector that performs a three-dimensional reconstruction of particle interactions and particle trajectories. TPC's are used in some physics experiments in high-energy physics with large particle multiplicity. Multi-Purpose Detector (MPD) of the NICA facility also makes use of TPC as the main detector for particle collisions reconstructions. MPD TPC is composed of cylinder divided in two sections by the high voltage (HV) electrode membrane. Each section has 163 cm length and 133 cm radius of drift gas volume [1]. At the endcap of each section, there are 12 read-out chambers (ROC) to gather data of events. Gas composition that fills drift volumes is a mixture of 90% of Argon and 10% of Methane. A detailed model with equivalents of ROC chambers electronics and thermal screen of the MPD TPC that is used for the current GEANT simulations for events reconstruction is shown in (fig. 1).



(a) (b)

Figure 1. Simulation Model of MPD Time Projection Chamber with ROC chambers electronics equivalents and thermal screen

2. MPD TPC Read-Out Chambers

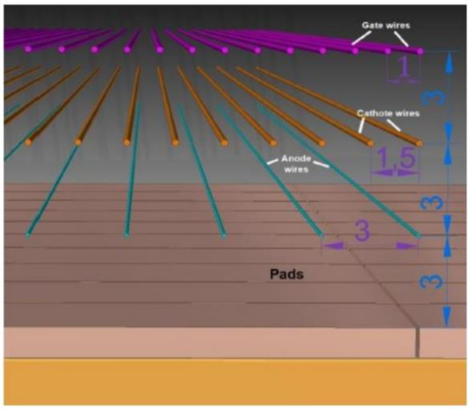
Twenty-four ROC chambers are used in the MPD TPC in total. Conceptual design of each ROC chamber is conventional. A pad plane of ROC chamber contains 27 rows of pad with the size of 5x12 mm at the inner area and 26 rows of pad with size of 5x18 mm at the outer area as a compromise of reasonable number of readout electronics channels. The pads have a rectangular shape, and the total number of pads in the TPC is 95232 [1]. ROC chamber parameters are shown in (fig. 2(a)). A ROC chamber has three wire grids: a gating grid, a shield grid and a sensing grid. Gating and shielding grid wires have diameter of 75 μm, sensing grid wires diameter is 25 μm respectively. A wire structure is shown in [fig. 3(b)]. Gating grid voltage is supposed to be -42.5V for the open gate and add ± 100V to each wire with an alternate pattern for the closed gate.

3. TPC Simulation with Garfield++

Some parameters such as electron drift velocity, longitudinal and transverse diffusion are necessary for realistic simulations of TPC. A Garfield++ software is used to obtain these parameters. The Garfield++ software is a toolkit for a detailed simulation of detectors, which uses gases or semi-conductors as a sensitive medium. Garfield++ provides: ionization calculation by a HEED program, electric fields calculations with different mathematical techniques, transport and avalanches of electrons by a Magboltz program [2]. 100 millions of collisions is used to calculate these parameters.

The obtained values are 5.538 cm/μs for electron drift velocity, 0.0347 cm1/2 for longitudinal diffusion and 0.0228 cm1/2 for transverse diffusion. Values errors are ±0.018%, ±2.5% and ±3.2% respectively.

Gas composition	Ar 90% + CH_4 10%
Temperature	293.15 K (20° C)
Pressure	Atmospheric + 2 mbar
Magnetic field	0.5 Tesla
Electric field	140 V/cm
HV electrode voltage	-23 kV
Shielding grid (anode) voltage	0 V
Sensing grid (cathode) voltage	1400 V
Gating grid voltage (expected)	-42.5 V ± 100 V



(a) (b)

Figure 2. Physical parameters TPC Read-Out Chamber (a) and wire grids structure (b)

Garfield++ is utilized for calculations of electric field maps for ROC chambers and ion drift times as well. Gating grid voltages are applied for these calculations -42.5 V for the open and -42.5 V ± 100 V for the closed gating grid accordingly. Electric fields in ROC chambers is presented in [fig. 3(a)] for the opened gating grid and in (fig. 3(b)) for the closed gating grid. Example of calculated electron and ion drift paths is shown in (fig. 4).

Minimum value of ion drift times starts from 60 μs and maximum time is up to 800 μs for expected gating grid voltages. Times are gathered by calculation for 10^4 ions paths. Signal on ROC chamber pad plane is shown (fig. 5). Other gating grid voltages such as -42.5 V ± 250 V and -42.5 V ± 1000V are gathered for investigation purposes (fig. 6). Increasing voltage for the closed gate did not give a significant impact on decreasing ion drift times.

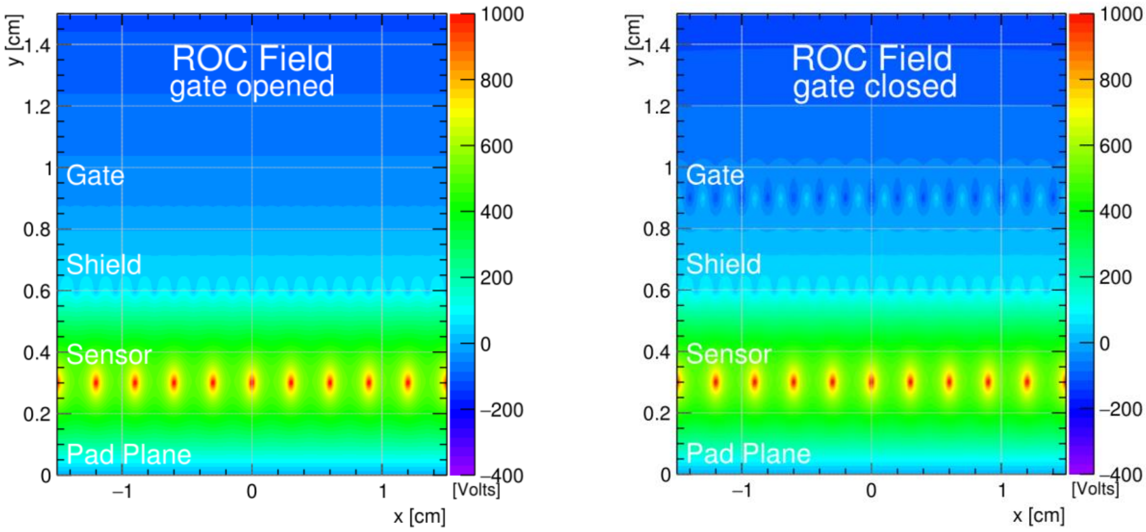


Figure 3. Electric fields in ROC chambers for opened gating grid (a) and closed gating grid (b)

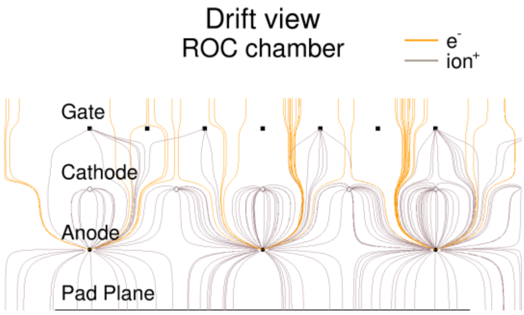


Figure 4. Example of calculated electron and ion drift paths. Electron paths calculated for opened gating grid, ion paths calculated for closed gating grid

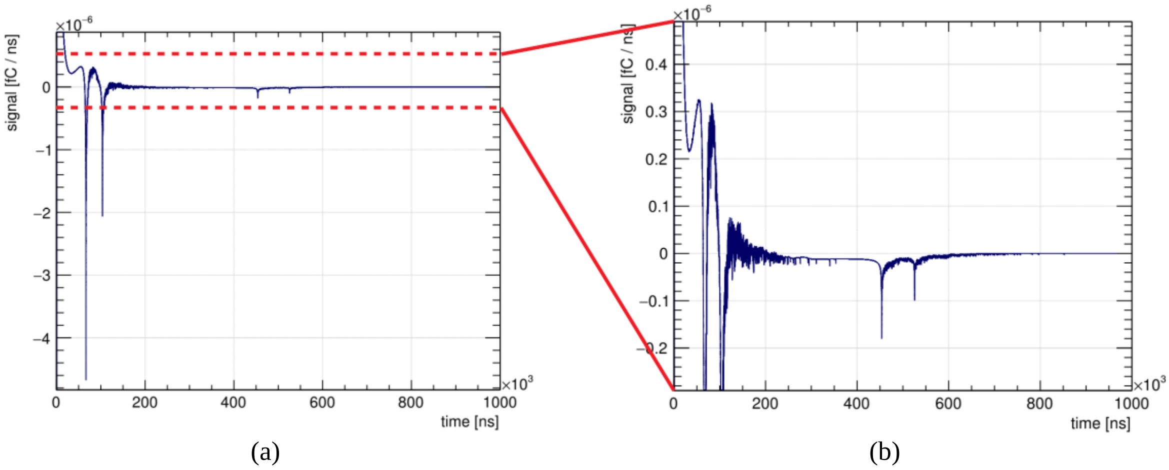


Figure 5. MPD TPC pad plane signal (induced current), 10^4 drifted ions

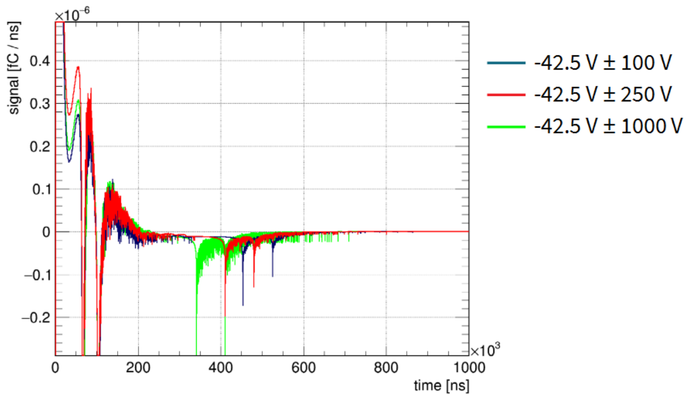


Figure 6. MPD TPC pad plane signal (induced current) for different closed gate voltages, 10^4 drifted ions

ASIC SAMPA was adopted in Front-End Electronics [1]. Simulation of electronics response (fig. 7) based on following transfer function [4] with parameters N = 4, sensitivity A = 20 mV/fC and peaking time τ = 160 ns [1]:

$$f(x) = A\left(\frac{x-t}{\tau}\right)^N e^{-N\left(\frac{x-t}{\tau}\right)} \qquad (1)$$

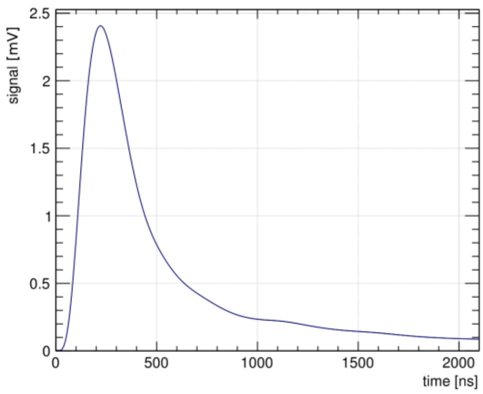


Figure 7. SAMPA-electronics response simulation

4. Conclusion

A detailed simulation of electrons drifting in the TPC volume is highly necessary to investigate the performance of the MPD TPC detector. Simulation of ion drifting in ROC chambers allows estimating the MPD TPC event rate. Electron drift parameters in Ar 90% + CH4 10% gas composition were updated and refined for the MpdRoot software package [4, 5]. Additional simulations of electric fields in ROC chambers and SAMPA-electronics responce help confirming expected parameters of ROC chambers.

5. Acknowledgement

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