Implementation of task for calibration of MPD TPC electron drift velocity
Реализация задачи нахождения скорости дрейфа электронов для MPD TPC

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Время-проекционная камера (TPC) - основной трековый детектор установки MPD. Координаты трека определяются по времени дрейфа электронов от положения трека до камеры считывания. Ввиду того, что скорость дрейфа электронов зависит от давления, температуры, пространственного заряда в чувствительном объеме детектора, скорость дрейфа должна измерятся в режиме реального времени. Для решения данной задачи будет использоваться лазерная калибровочная система. В статье представлен алгоритм рассчета скорости дрейфа электронов основанный на обработке временных распределений сигнала от лазерной системы калибровки.

The MPD Time-Projection Chamber (TPC) is the main tracking detector of the MPD experiment. Tracks coordinates are obtained by measurement of drift time of electrons from track position to readout chamber. The drift velocity of electrons can vary due to pressure, temperature, space charge effects, so it must be measured online. To solve this problem the laser calibration system is foreseen for this. The article presents an algorithm that provide drift velocity measurements and based on processing signal-in-time distributions.

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Introduction

The Time-Projection Chamber (TPC) is the main tracking detector of the MPD. The design and structure of the MPD TPC are similar to those that were used in the STAR, ALICE and NA49 experiments. The active gas volume of the TPC is bounded by coaxial field cage cylinders with a pad plane readout structure at both end-caps. The uniform electric field in the active volume required for drift electrons is created by a thin central HV electrode together with a voltage dividing network at the surface of the outer and inner cylinders and at the readout end-caps (see Fig. 1) [1].

The gas mixture of 90 % argon and 10 % methane (P10) is supposed to be used in the TPC. The developed system has to provide the constant pressure 2.0±0.03 mbar (relative to atmospheric) and temperature 25±0.5°C in the active volume of the TPC [1].

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The TPC readout system is based on the Multi-Wire Proportional Chambers (MWPC) with cathode pad readout (ROC). The end-cap readout plane is covered by 12 trapezoidal sectors of the readout chamber. The total number of pads in the TPC is >95000 [1].

The UV laser calibration system is a part of the test and calibration procedure designed to produce a grid of the laser beam tracks at well-defined angles and positions. The system will provide on-line monitoring of the value of drift velocity which depends on the drift gas pressure changes (caused by changes of atmospheric pressure), the temperature, E×B noncollinearity and space charge effects. The system powered by 2 UV pulse lasers (one for each half of the TPC) with 10 Hz pulse rate and 3-6 ns pulse duration. Each laser forms 112 beams in a half of the TPC via prisms and micro-mirrors system. Beams diameter is expected to be ∼1 mm. Laser grid consist of 4 planes with 28 beams each in a half of the TPC (see Picture 2) [1].

Electron drift velocity calculation

Reconstruction algorithm of electron drift velocity and its implementation meets the following requirements:

1. velocity value provides along all drift length,
2. on-line calculations to compatibility with slow control of detector.

Also the algorithm provides information about trigger delay value. Trigger delay is cumulative delay between calibration system pulse and time when ROCs starts collect data. Electrons drift during this time, so this leads to offset of all data.

The algorithm consist of the following steps (see also Picture 3):

1. accumulate signal-in-time distribution by addition signal-in-time data from all read-out channels - laser grid planes forms relatively high peaks in the distribution, this peaks determines position of laser grid planes,
2. velocity information is obtained from drift time between laser grid planes as $V_{drift} = \frac{Z_{between\ laser\ planes}}{t_{peaks}}$,
3. difference between measured and expected well-known position of laser grid provides trigger delay information.

The algorithm allows to work with data from a half of the TPC or a single sector to build a map of velocities. Calculation of drift velocity at any point along drift length implemented as interpolation/extrapolation by 3 points (there are 4 laser planes in sector/half of the TPC so this provides 3 points of velocities between them).

The algorithm and its implementation have only tested on simulations data because MPD TPC isn't finished yet. For test capabilities MPDRoot software is used [2]. A following features was added to digitization part (electron drifting and ROCs response) of MPDRoot:

1. transferring electrons from MC track to ROC with desired electron drift velocity,

2. adjust electron drift times or remove electrons taking into account trigger delay.

Implementation of drift velocity calculation algorithm bases only GSL and Boost libraries, so it's mostly independent from MPDRoot and can be easy integrated to slow control [4, 5].

The simulation data consists of 500 events of laser grid mixed with particles collision to provide noise effects. Simulations in Garfield++ software says that electron drift velocity with expected parameters of gas in MPD TPC is ∼5.5 cm/µs [3]. During tests electron drift velocity of 5.4 cm/µs and trigger delay of 545 ns are chosen. Initial rough laser plane peak finding and local wavelet filtering procure more accurate fitting of the peak position (see Picture 4). Calculations of drift velocity are made for 6 reference points in each of 24 sectors (144 points in total): 1 per laser plane, 1 near TPC central high voltage electrode, 1 near segmented surface of ROC. Calculations of trigger delay are made per sector too. Results of velocity and trigger delay calculations can be seen in Picture 5. While reconstruction of velocity is fair enough with error less than 0.5 mm/µs, reconstruction of trigger delay provides average offset of 5 ns, but in terms of position this offset less than 2 mm with taking into account reconstructed velocity values (calculated as a distance between expected and average reconstructed position of laser plane nearest to ROC surface).

Results

Algorithm of electron drift velocity calculation is developed and implemented. The implementation allowed to calculate drift velocity map along electron drift length per sector or per half of MPD TPC. The implementation is adapted to use in slow control or offline data processing. Also additional features of MPDRoot TPC response simulation algorithms are added such as varying of electron drift velocity and read trigger delay.

REFERENCES

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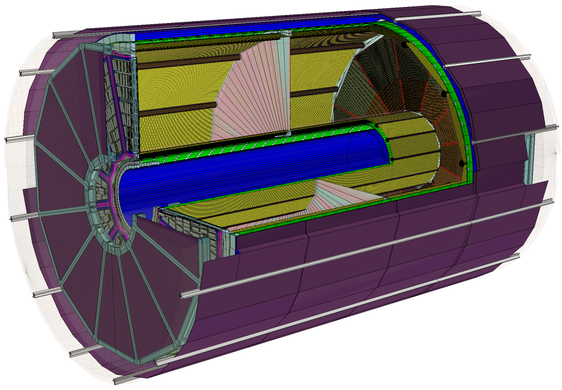

Fig. 1: MPDRoot Time-projection chamber geometry

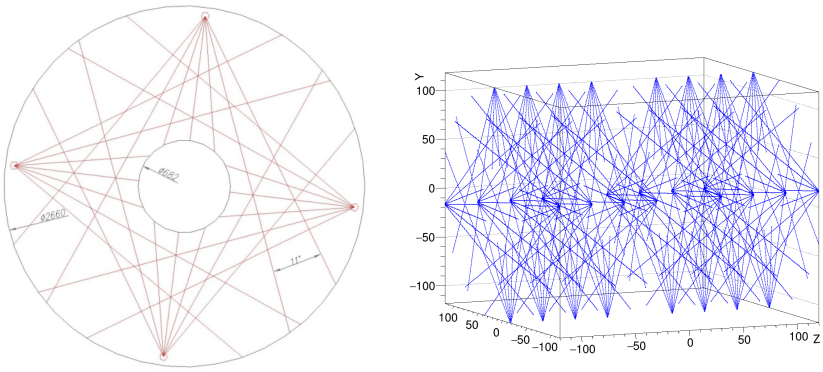

Fig. 2: Laser calibration system grid

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5. Boost / Boost C++ Libraries — URL: https://www.boost.org/.

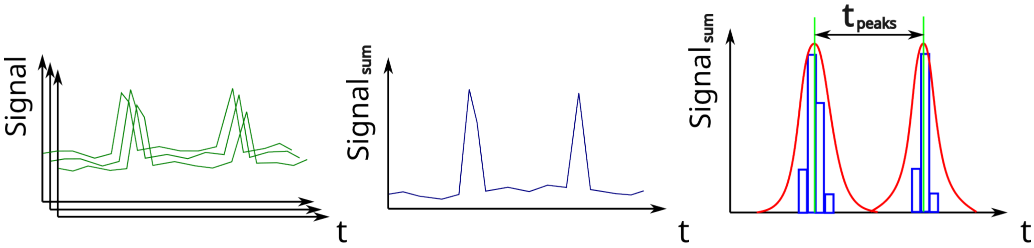
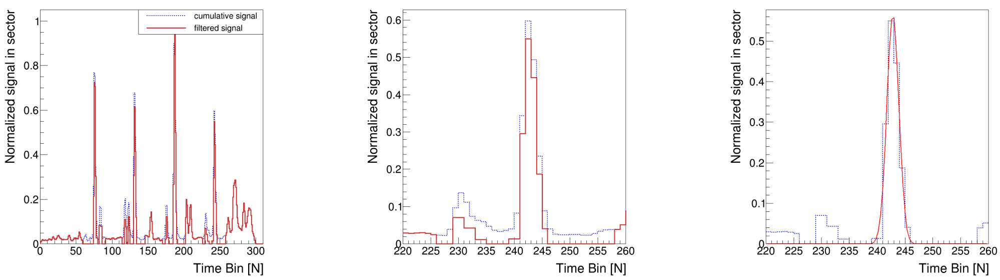
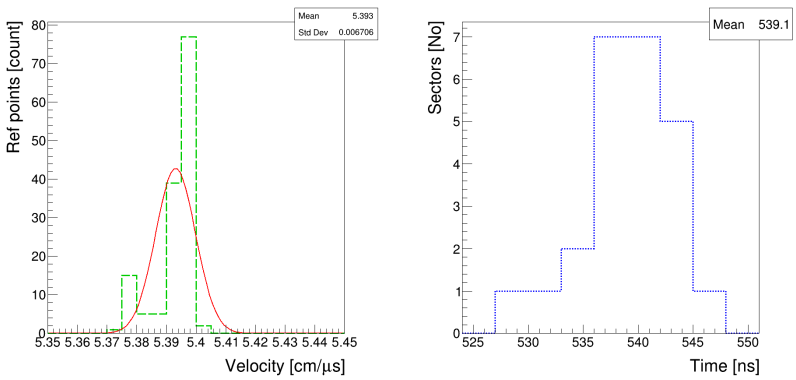


Fig. 3: Electron drift velocity calculation algorithm steps



(a) Signal-in-time (b) Single laser plane peak (c) Fitting of laser plane peak

Fig. 4: Example of electron drift velocity calculation



(a) Drift velocity calculations (b) Trigger delay calculations

Fig. 5: Quality of electron drift velocity calculations