Implementation of task for calibration of TPC gas drift velocity

The XXVII International Scientific Conference of Young Scientists and Specialists
AYSS-2023

Alexander Bychkov
VBLHEP, JINR
abychkov@jinr.ru
November 2, 2023, Dubna, Russia

Time-Projection Chamber (TPC)

Reconstructed coordinates in 3D

- XY – pad position
- Z – calculates by electrons drift time and velocity

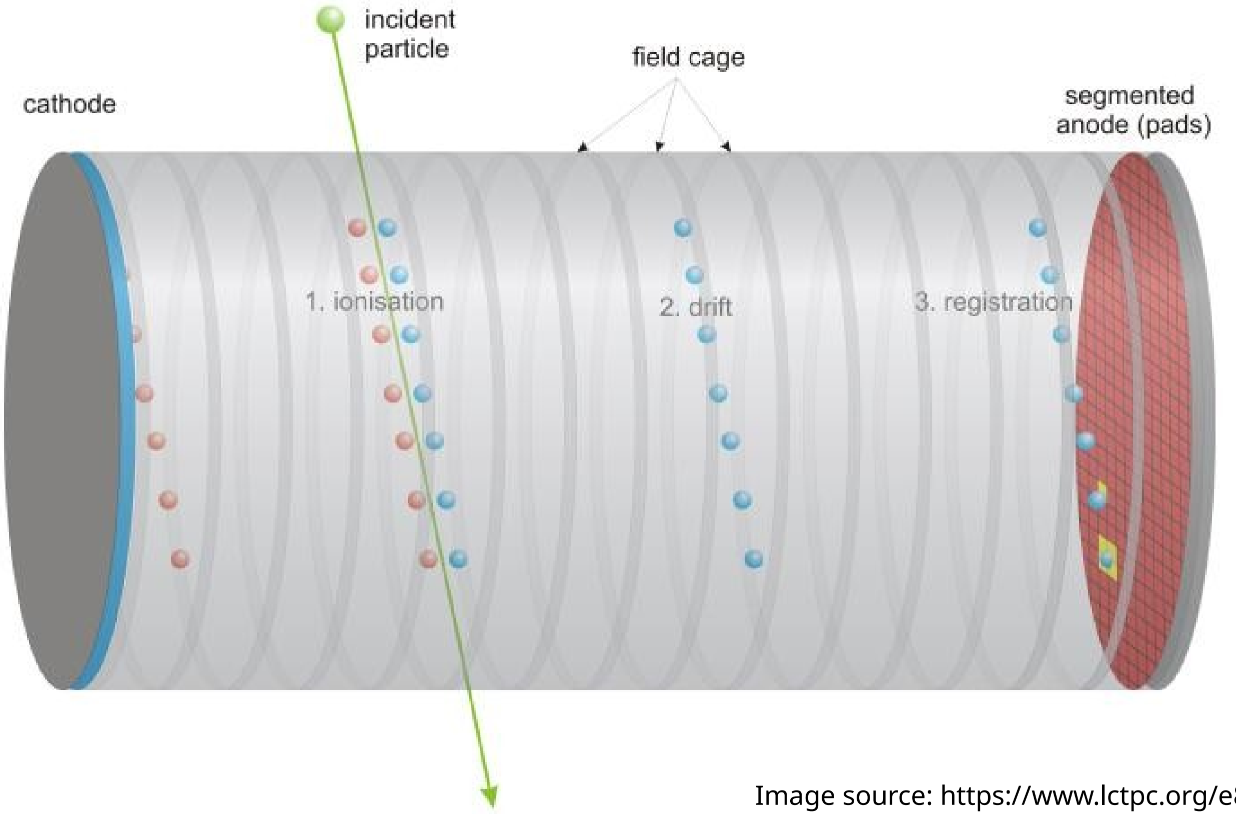


Image source: https://www.lctpc.org/e8/e57671

Electron Drift Velocity calculation problem

Impact on drift velocity

- Temperature
- Pressure
- Charged areas in gas volume

Read trigger delay

- Cumulative delay of all triggers before Read-Out Camera (ROC) starts gathering data
  - Delay between moment when collision event or laser pulse happens and starting of gathering data by ROC
- Time offset of all data

MPD TPC

TPC gas

Gas mixture 90% Ar + 10% CH_4

Operating pressure 2.0±0.1 mbar

(relative to atmospheric)

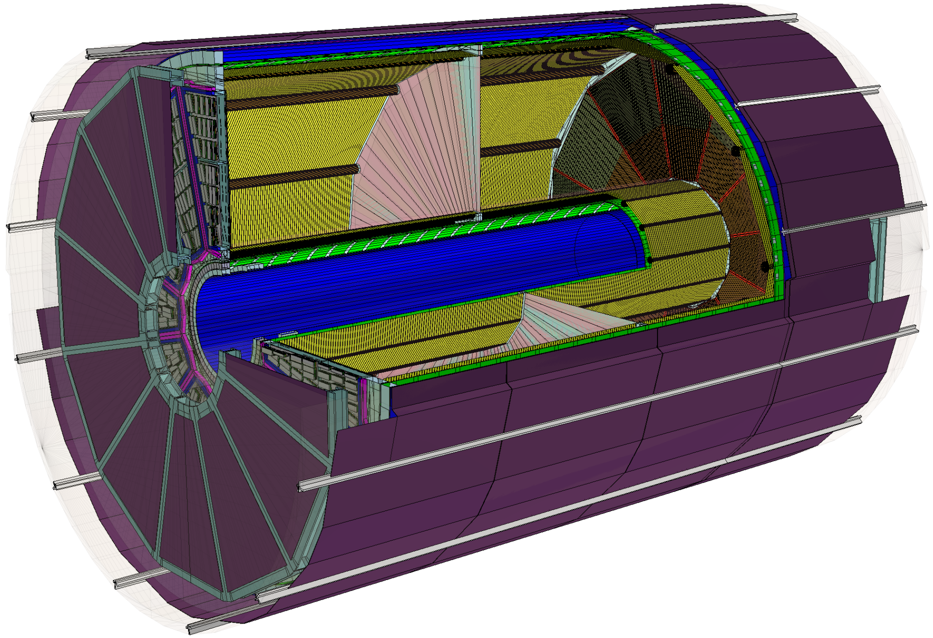
Temperature 25 °C

stability < 0.5 °C

Electron drift velocity in electric field 140 V/cm and magnetic field 0.5T

~5.53291 cm/μs +/- 0.01%

(Garfieg++ simulation)



According to TPC TDR v7

Simulation features for testing drift velocity calculations

Read-out channels details

- 100 ns – time bucket, 310 time buckets
- >95000 read-out channels in total
  - 24 Read-out Cameras - sectors

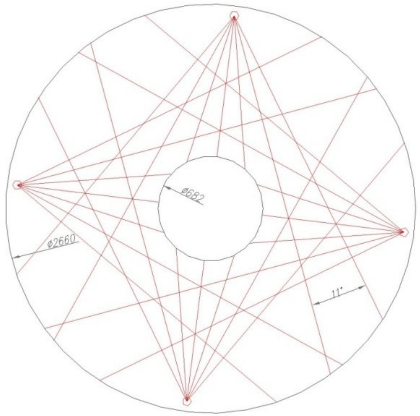
Electrons drifting + ROC response («Digitizing» task in MPDRoot software)

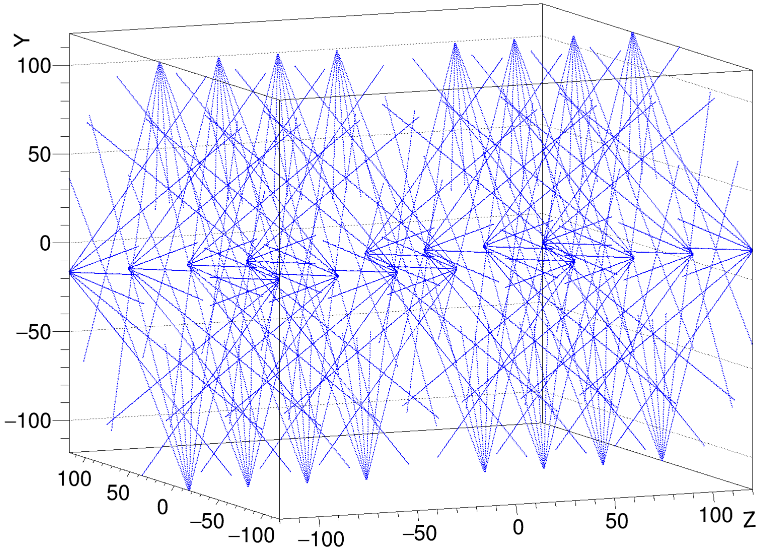
- Forming charge-in-time distributions for each pad of the TPC
  - Transferring electrons from MC track to Pad Plane of ROC with desired electron drift velocity
  - Adjust electron drift times taking into account read trigger delay
  - Remove electrons that reach ROCs plane before read trigger occurs

Laser Calibration System

UV laser system

- Two pulsed 130 mJ 5-7 ns Nd:YAG lasers
- ~1mm beam diameter
- 224 laser beams in total
- 112 “straight tracks” in each half of the TPC
  - 4 planes of laser beams
  - 30 cm between planes
- 10 Hz impulses





Drift velocity calculation algorithm

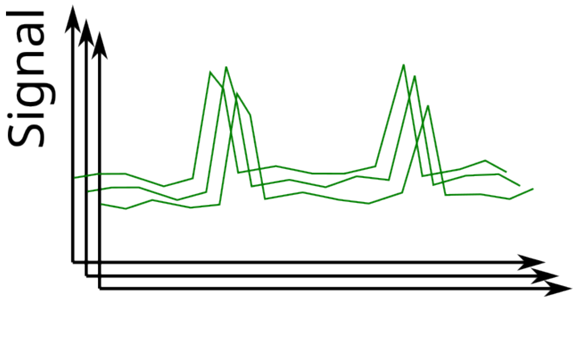
Based on cumulative signal-in-time distribution from all channels in sector (or half of TPC)

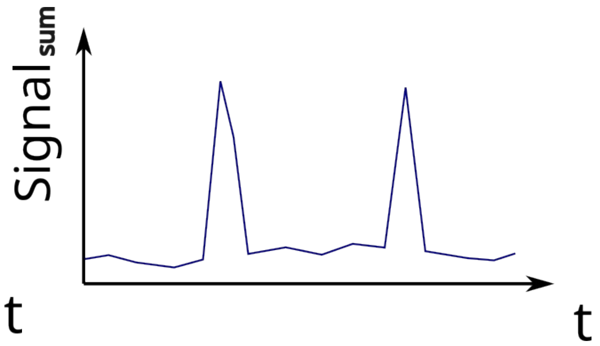
Laser grid planes forms high peaks in the distribution

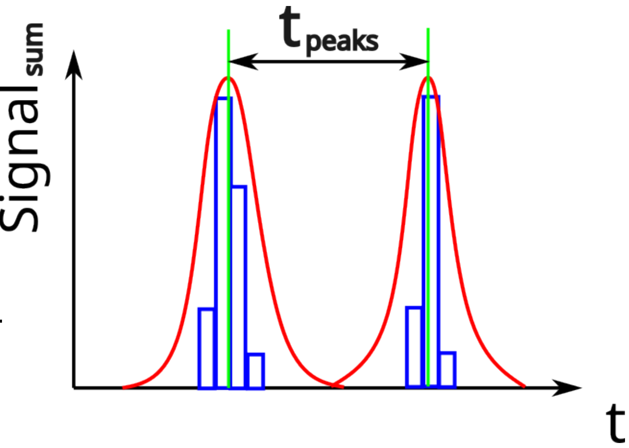
The peaks determines position of laser grid planes

Drift time between positions of laser planes provides velocity information

Difference between measured and «expected» position of laser grid provides trigger delay information







$$V_{drift} = \frac{Z_{between\,laser\,planes}}{t_{peaks}}$$

Drift velocity calculation codes

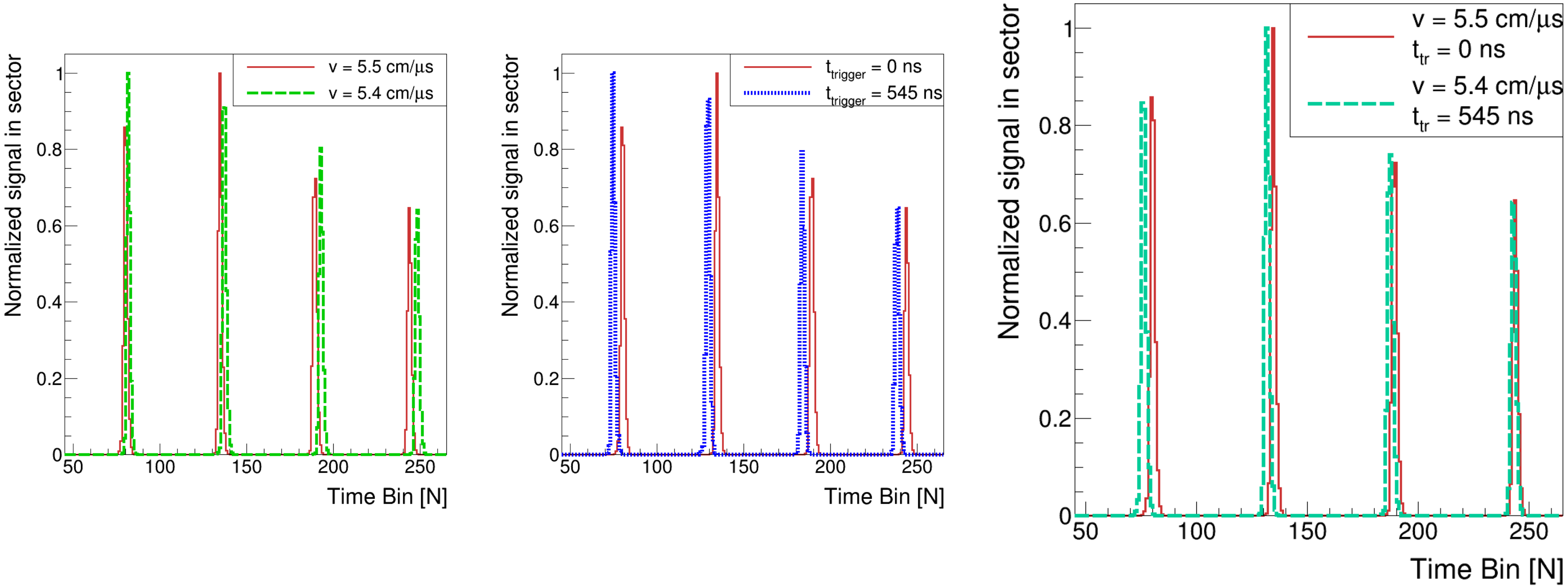
Points of interest

- Drift velocity calculation along all drift length
  - 3 points between pairs of laser planes
  - interpolated/extrapolated velocity value for each hit (quadratic polynomial now)
- Read trigger offset calculation
  - with taking into account actual drift velocity

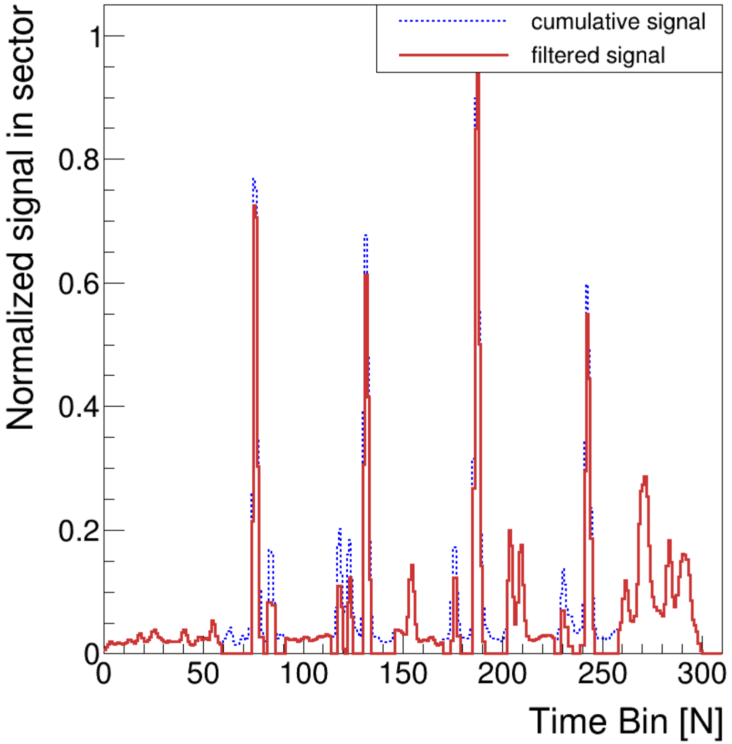
Fast algorithm

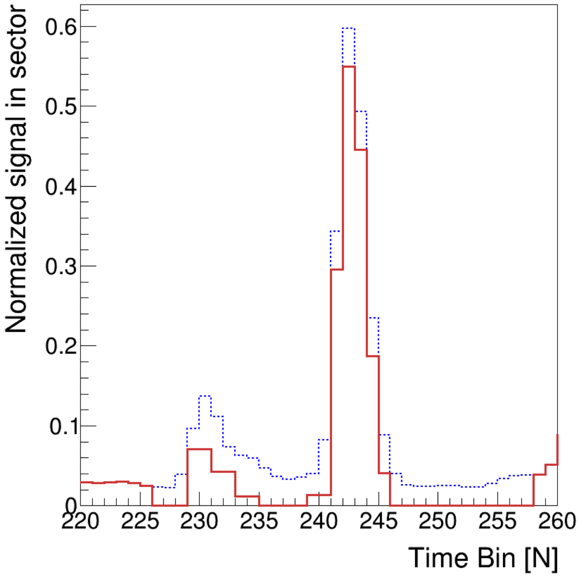
- Real time calculations for slow control and based on RAW data
- Calculations of velocity map of each event should takes less than 100 ms (10Hz)
  - now ~70-75 ms (Intel Core i7-8700) - single thread (codes also allow multi-thread per sector), velocity per sector, all sectors

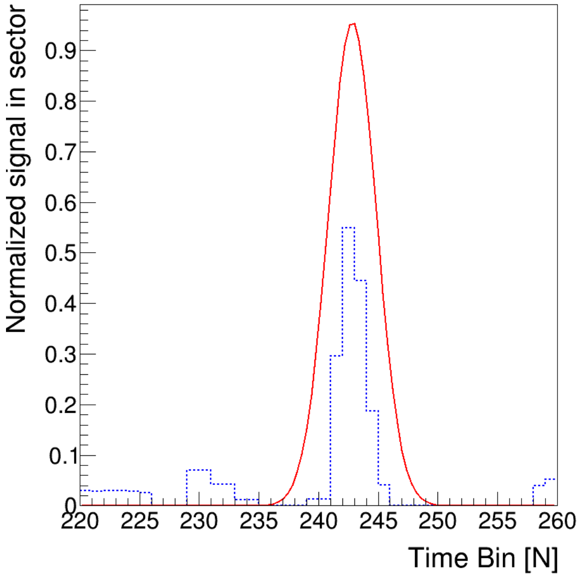
Simulations – laser grid only



Simulations – laser grid mixed with event







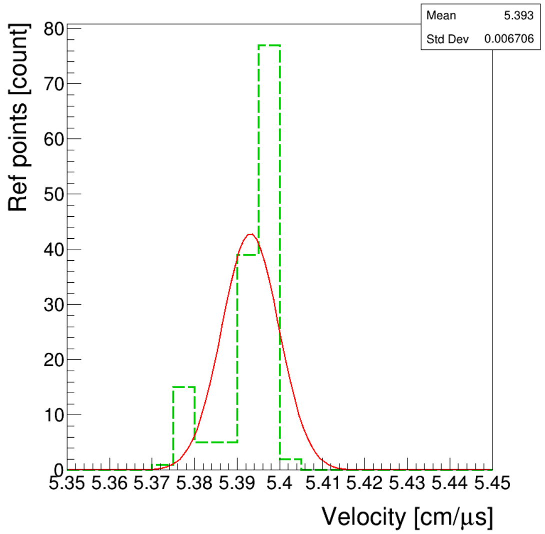
Simulations – laser grid mixed with event (2)

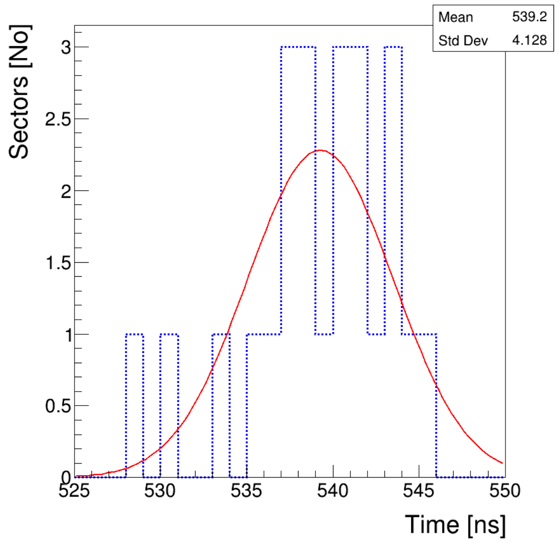
Statistics - 500 events of laser grid

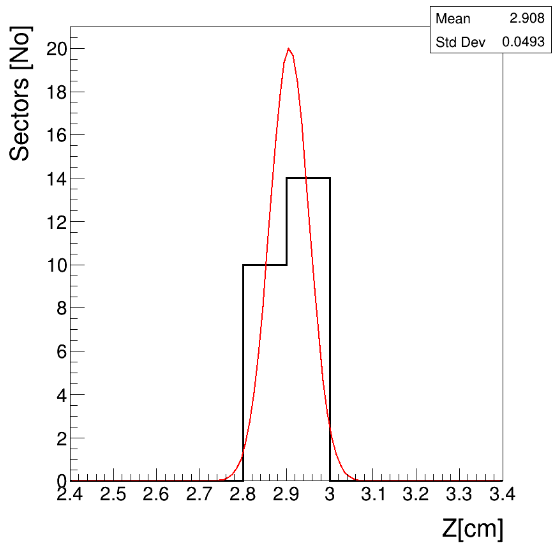
V_{drift} = 5.4 cm/μs $t_{trigger}$ = 545 ns (~ 3 cm offset)

144 velocity reference points = 24 sectors * 6 reference points

4 points — each laser plane, 1 point — HV electrode, 1 point — ROC pad plane

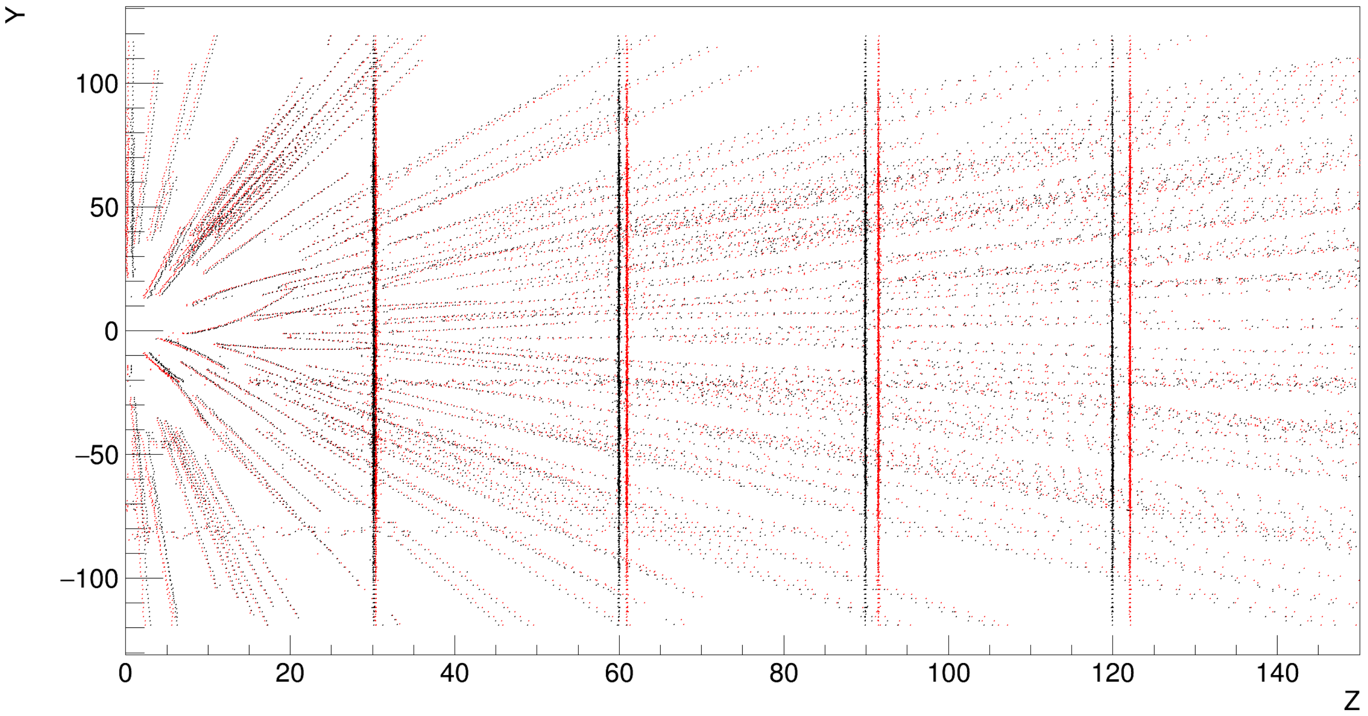






Simulations – laser grid mixed with event (3)

Example correction v_{drift} = 5.4 cm/µs $t_{trigger}$ = 545 ns



Conclusions

Main results

- Developed and implemented algorithm of electron drift velocity calculation
  - Calculations of drift velocity map (velocity per sector) or drift velocity in half of the TPC
  - Implementation adapted for real-time/offline execution

Additional results

- Extended features of MPD TPC response simulation algorithms
  - New additional features for electron transferring in sensitive volume

Thank you
for attention!

The XXVII International Scientific Conference of Young Scientists and Specialists
AYSS-2023