Garfield++/LTSpice simulation of straw tube response for different readout electronics models of the SPD Straw Tracker

S. Bulanova[1], V. Bautin[2], E. Kuznetsova[1]

[1]NRC KI PNPI (Gatchina)
[2]JINR (Dubna)

What is SPD straw tracker?

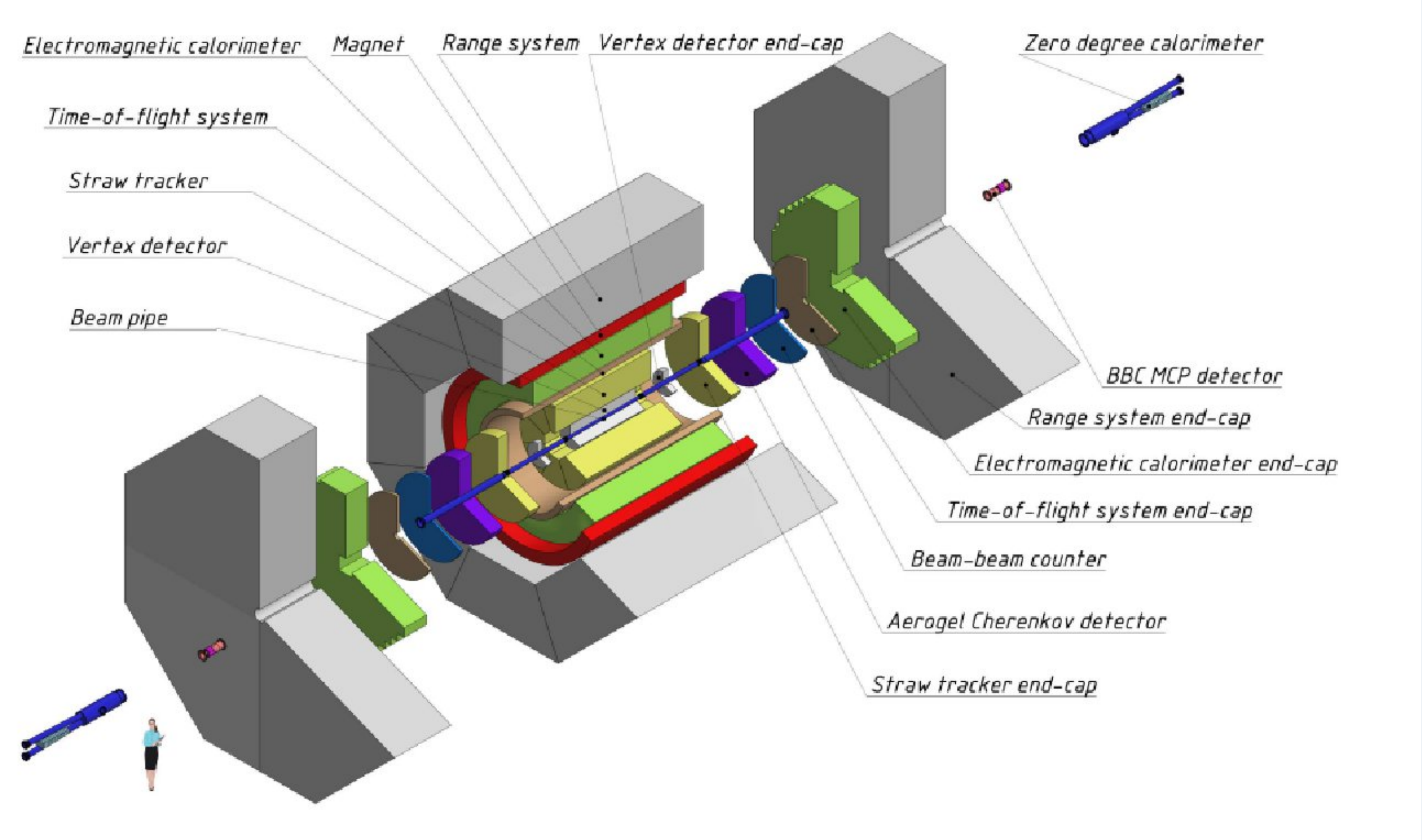


Fig. 1. Final layout of the SPD setup

What is Garfield++?

- Garfield++ is a toolkit for the detailed simulation of detectors which use gases or semi-conductors as sensitive medium.
- Migration from FORTRAN GARFIELD to Garfield++
- the straw signals obtained from Garlied++ simulation are used as an input for a readout electronics model. To emulate electronics response, the LTSpice (analog electronic circuit simulator computer software) software is used.
- As a baseline for the readout electronics we consider a VMM3-like model with the following parameters: amplification 3mV/fC; peaking time 25 ns, noise ENC 1500 e-

MOTIVATION

- Realistic simulation of a straw tube response is important for reliable SPDroot prediction of the SPD detector sensitivity to physics processes of interest;
- Readout electronics affects both the straw signal time (tracking) and charge (particle identification) measurements;
- Garfield++ (straw response) + LTSpice (readout) simulation allows to provide predictions even if no experimental measurements are available;
- Good input for both the hardware development and for the realistic tracker simulation in SPDroot.

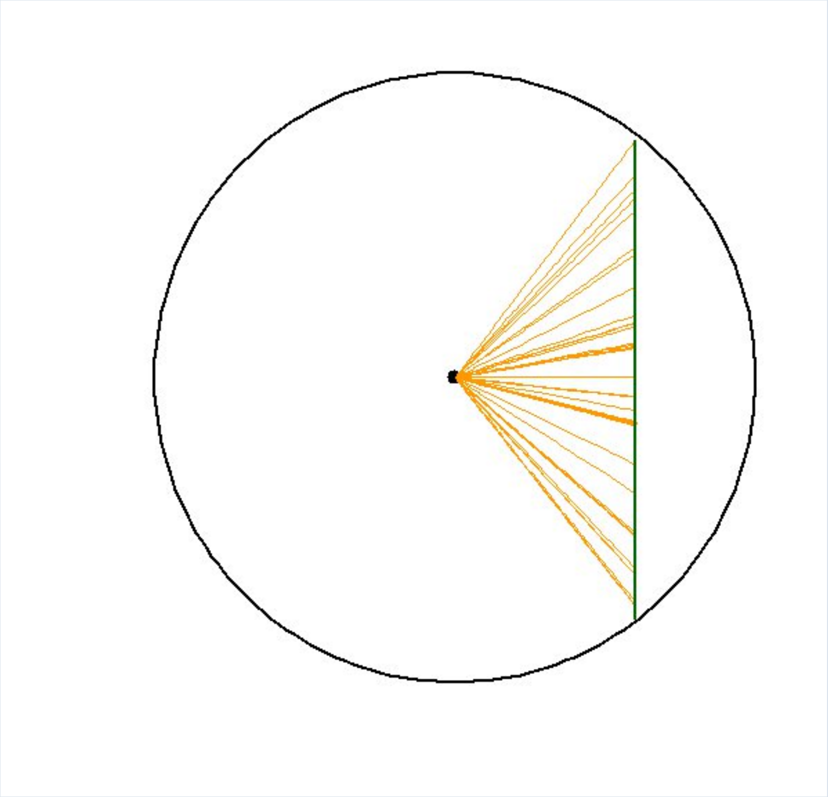


Fig. 2. A track of 1 GeV muon crossing the straw tube shown together with electron drift lines.

Simulation parameters (SPD setup)

- Straw diameter: 10 mm
- Anode diameter: 30 mkm
- HV: 1750 V
- Gas mixture: Ar+CO2 / 70:30%
- Gas mixture temperature: 20 celsius
- Gas mixture Pressure: 1 atmosphere
- Ionization particles: muon, proton, pion, kaon, electron. 0.1, 1, 10 GeV/c
- Track angle α: 90^0, 13^0, 26^0.
- Magnetic field: 0 T, 1.3 T
- Mean Gas Gain value is fixed to 4.5e4, the variation is described by Polya function

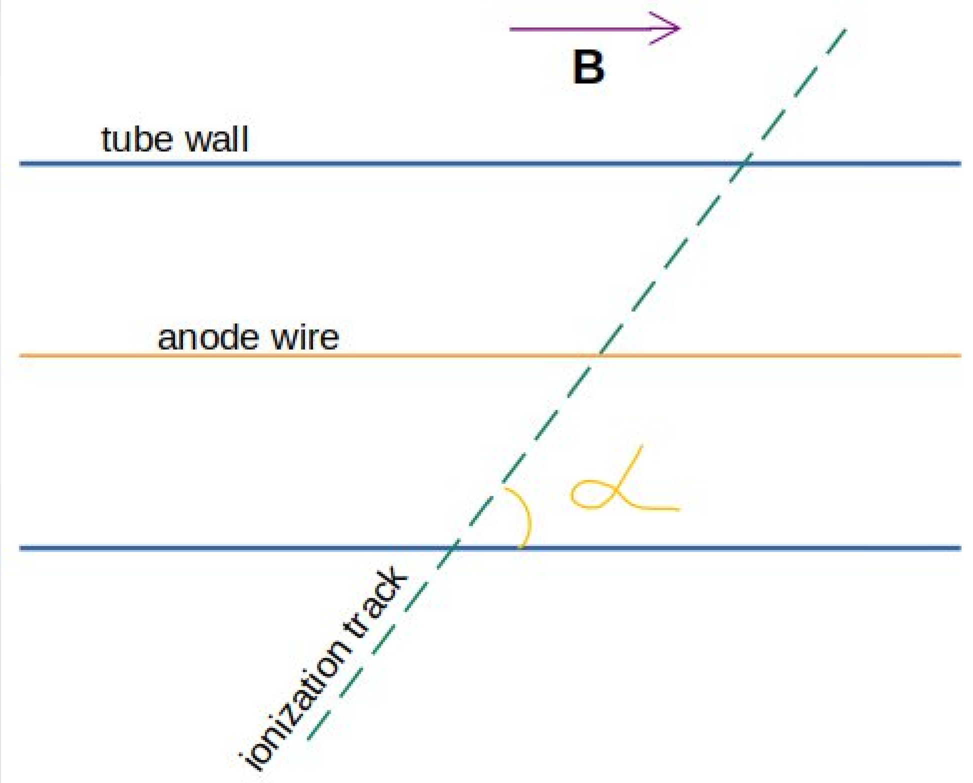
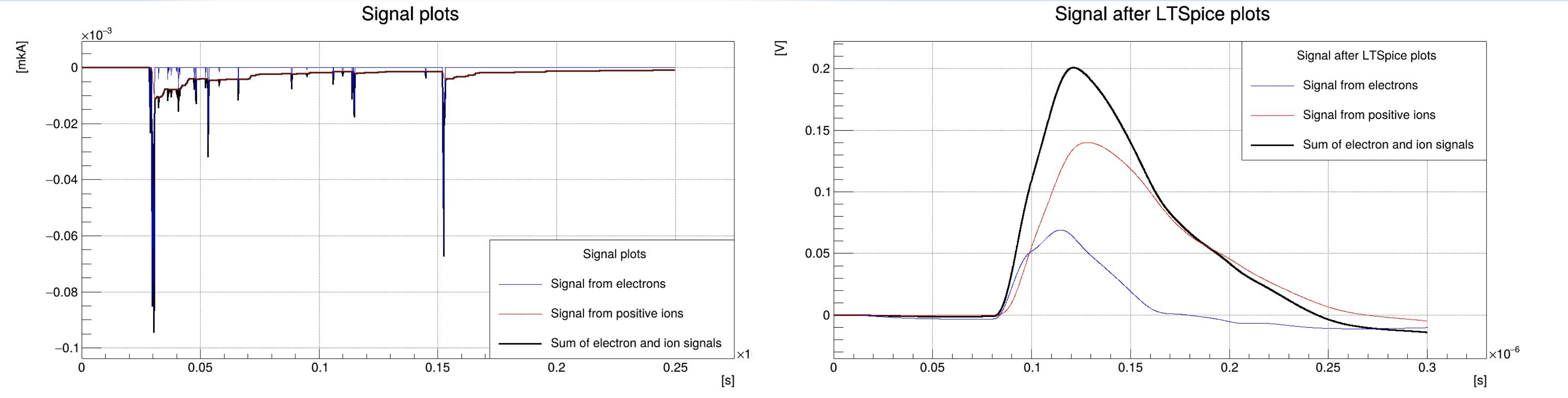


Fig. 3. Layout diagram of ionising particle, track angle, and magnetic field vector

Examples of the simulated signals



(a) (b)

Fig. 4. (a) The signal induced at the anode wire (black) by electrons (blue) and ions (red) as simulated by Garfield, (b) the corresponding signal after the LTSpice readout emulation for 25 ns peaking time, gain of 3 mV/fC and electronics noise of 1500 e.

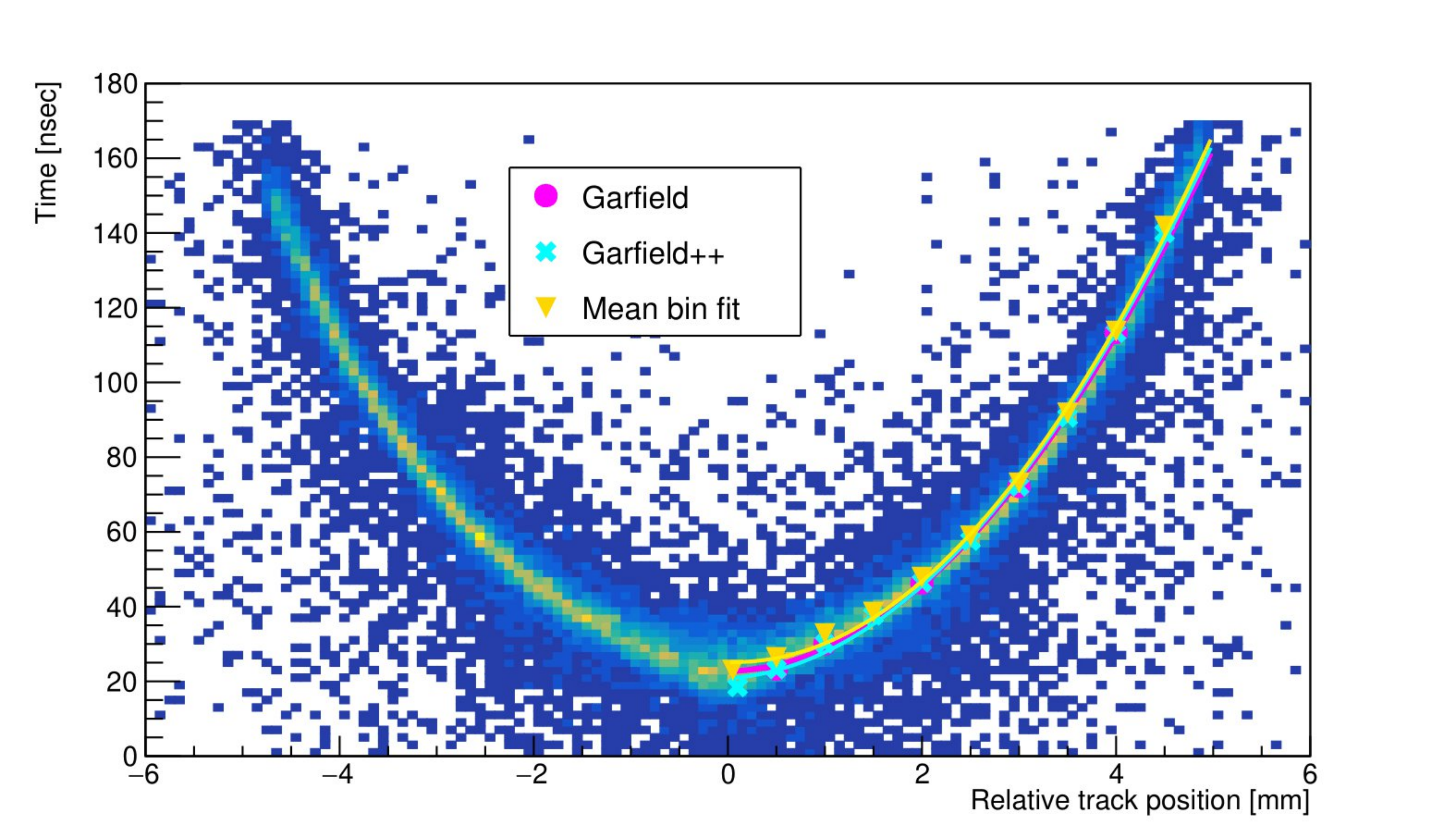


Fig. 6. Fortran Garfield and Garfield++ with VMM3 compared to NA62 data (CARIOCA chip)

Garfield++ and Geant4 validation

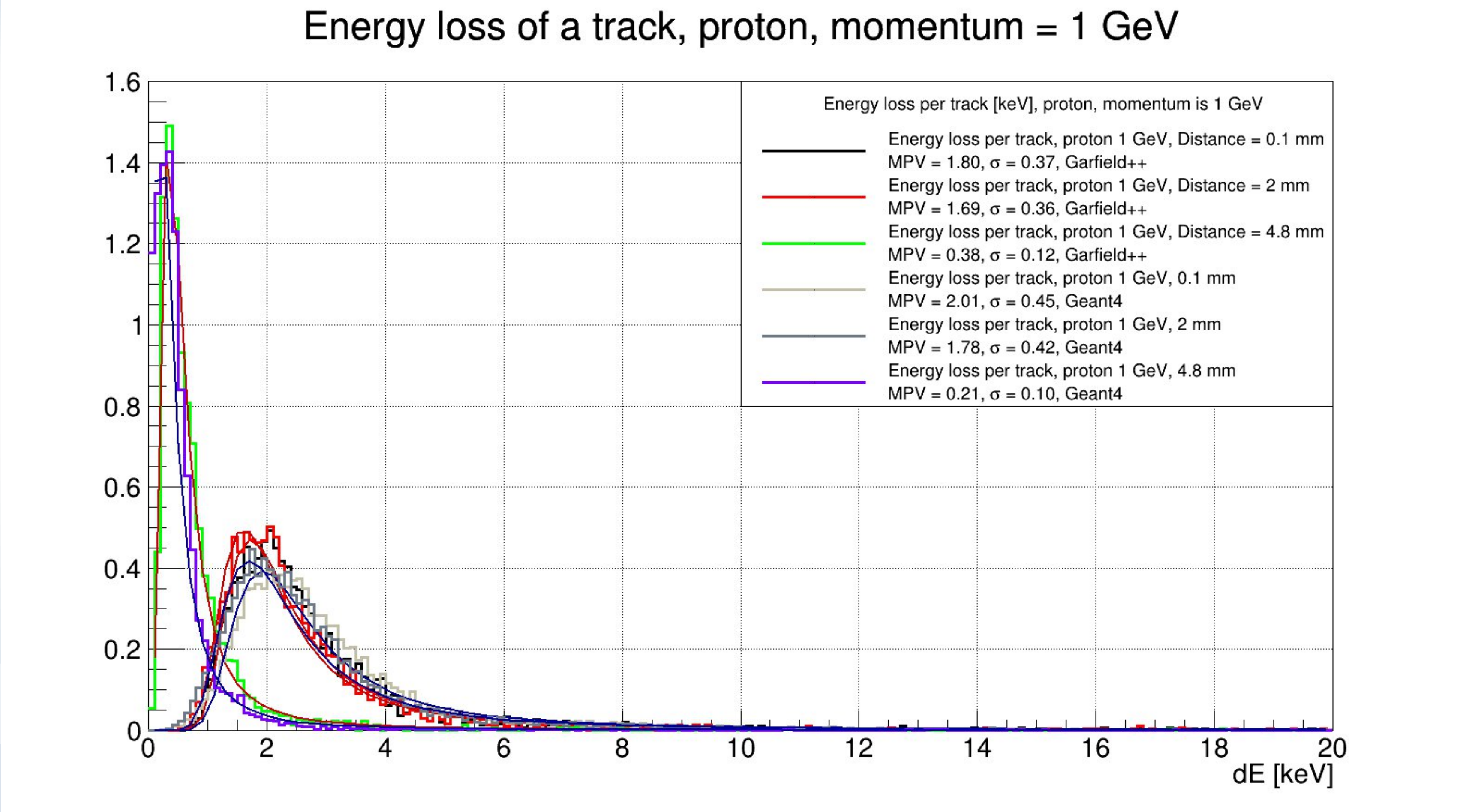
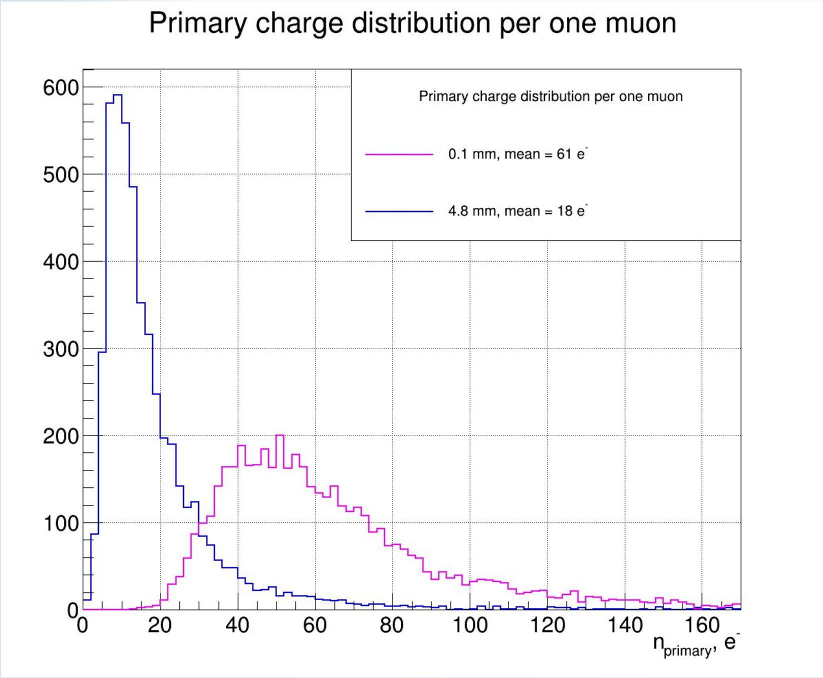


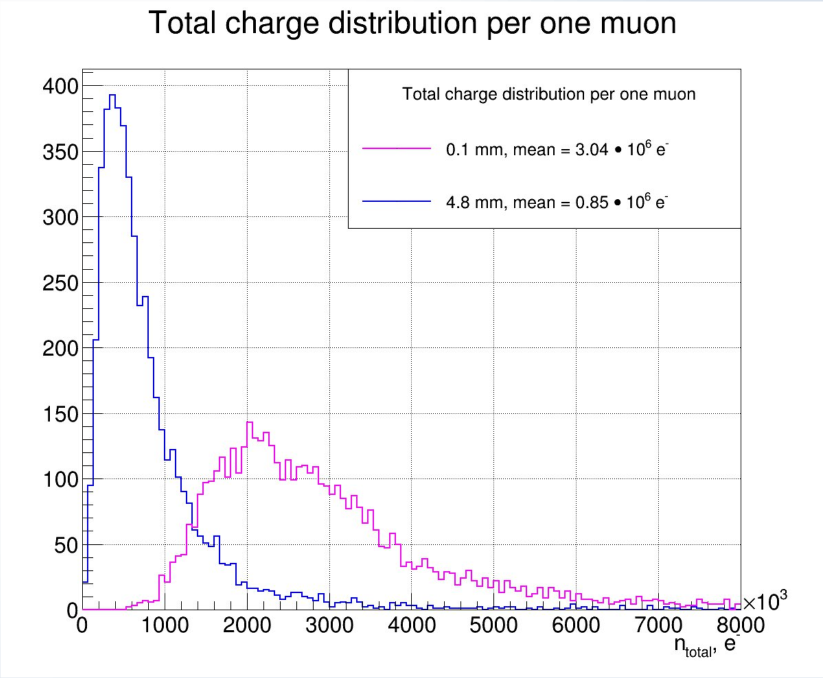
Fig. 5. Comparison of the energy loss predicted with Garfield++ and Geant4.

Signal charge distribution

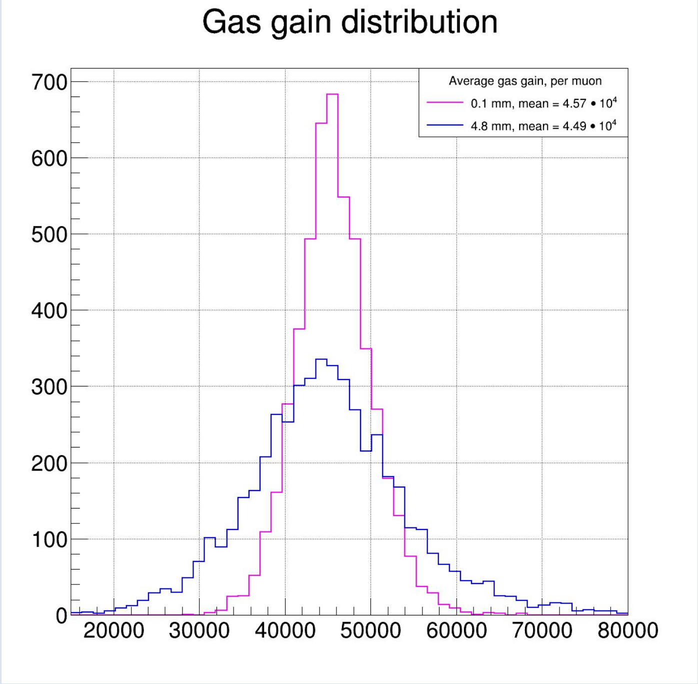
Fig. 7.
- Primary ionization => the number of primary electrons;
- Avalanche amplification => the total number of electrons;
- Signal formation => the charge induced on electrodes



a) Primary charge distribution per one muon

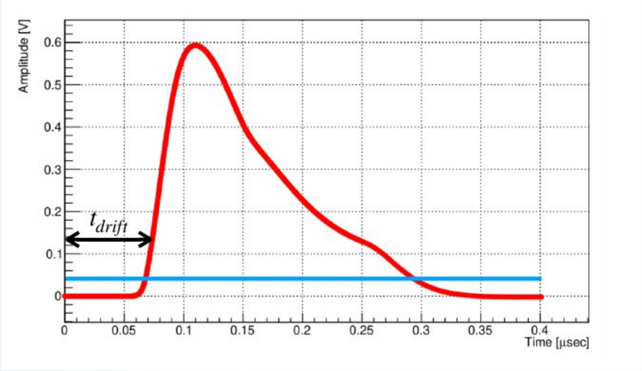


b) Total charge distribution per one muon



c) Total charge divided by primary charge (gas gain)

Threshold crossing time for the 10 mV



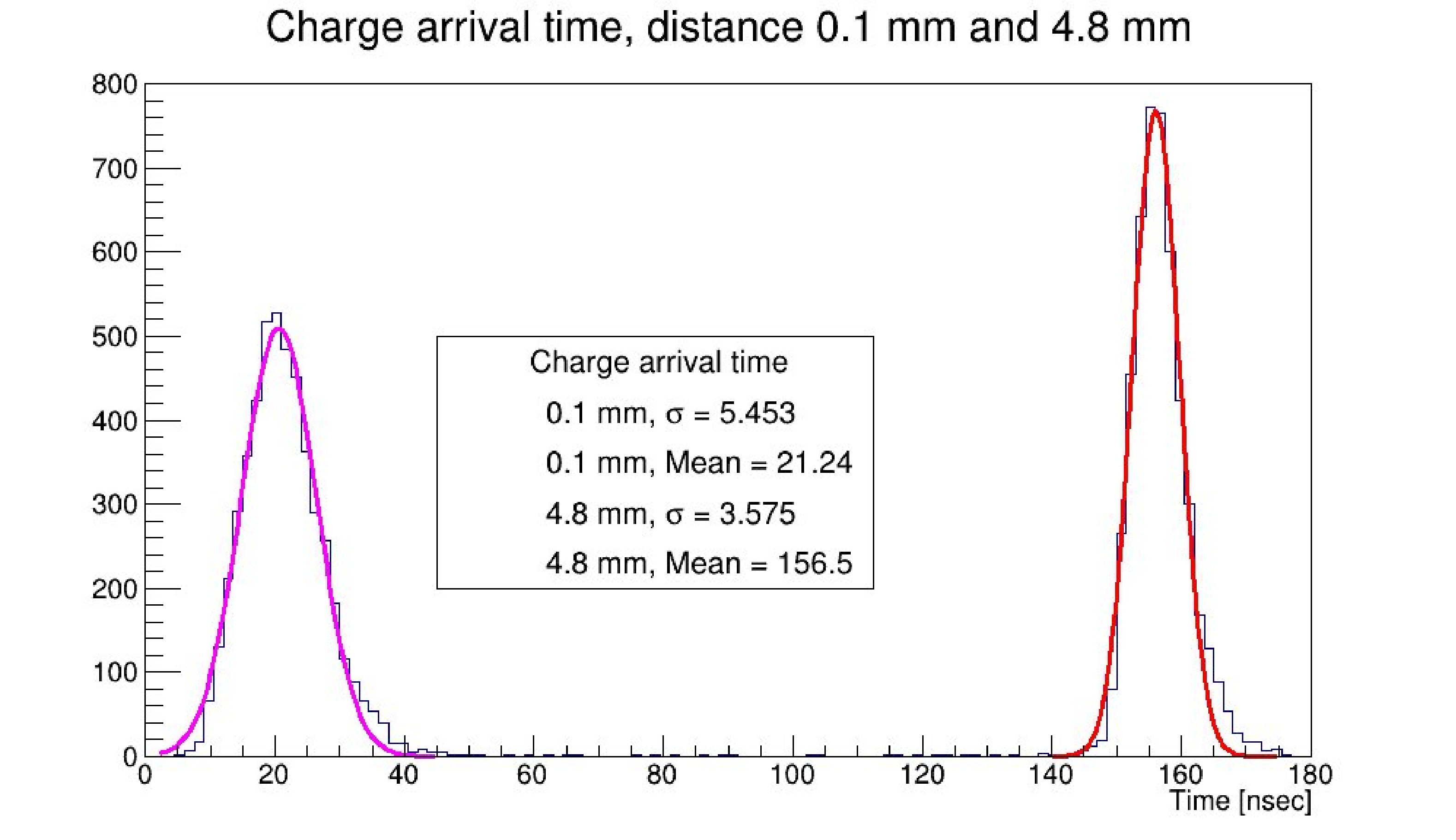
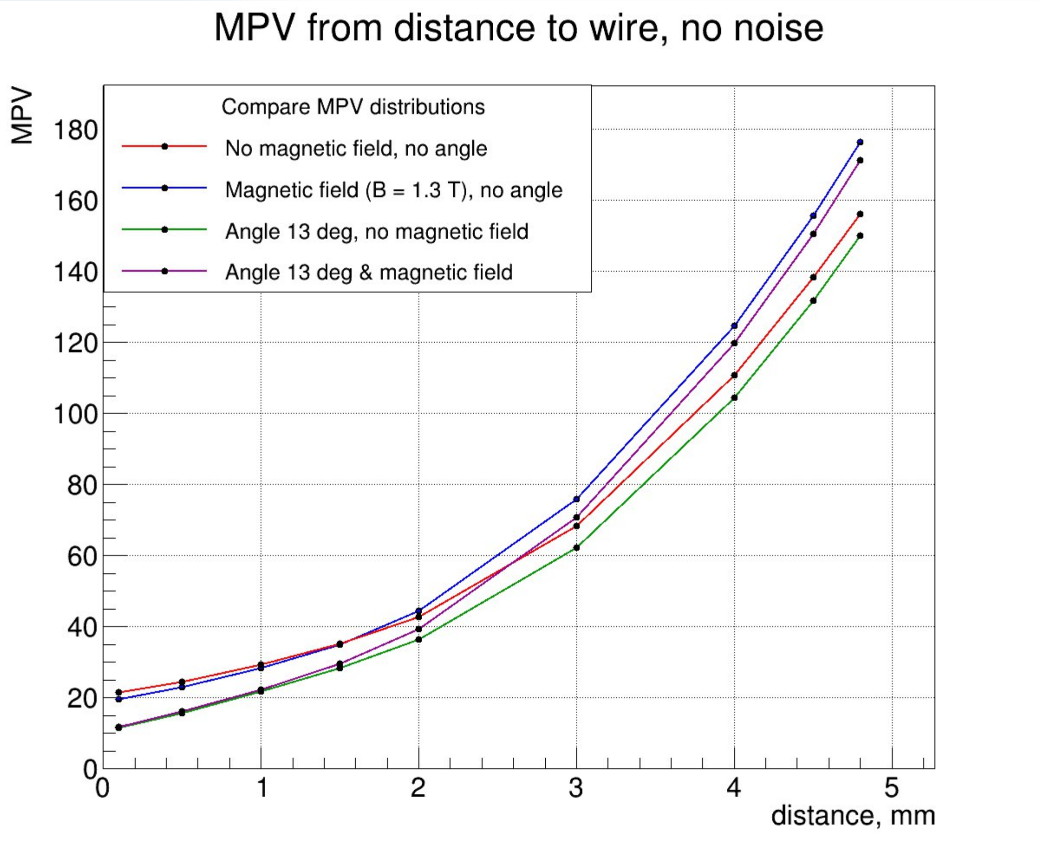
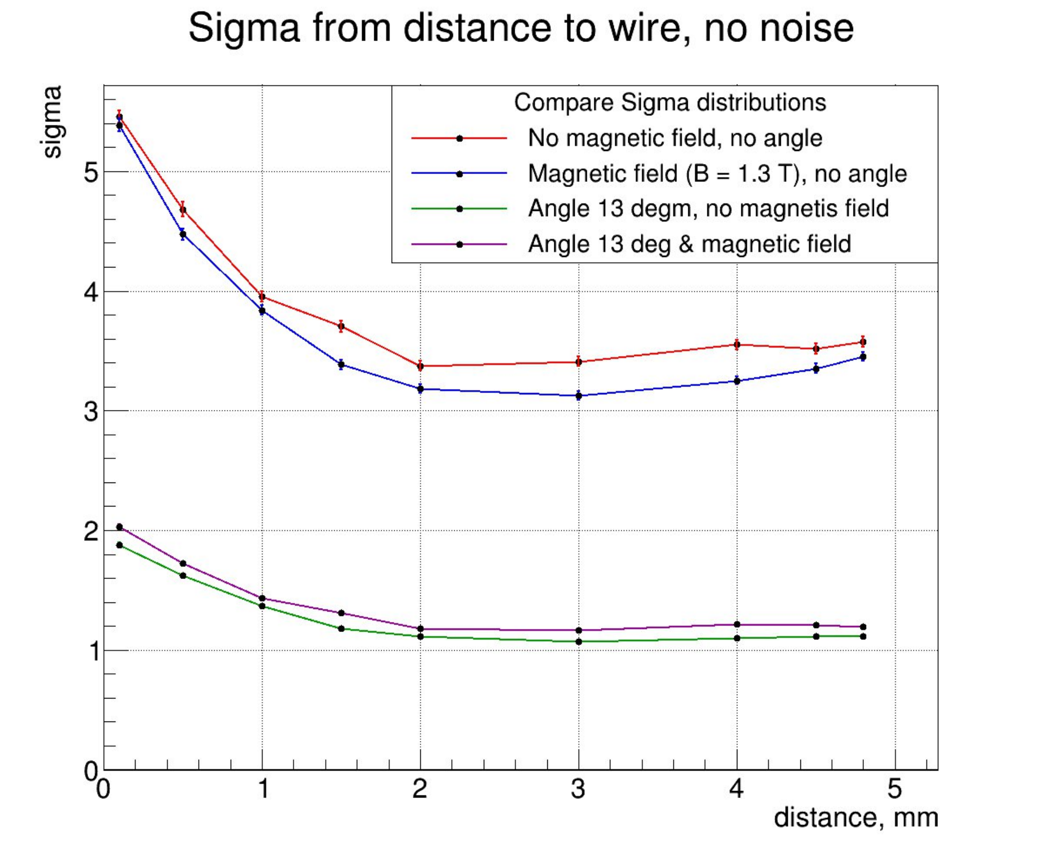


Fig. 10. Threshold crossing time for 0.1 mm and 4.8 mm distances. B = 0 T, α = 90° (Mean (ns) is the most probable value (MPV), σ (ns) is the distribution width)

MPV & σ distributions for different cases



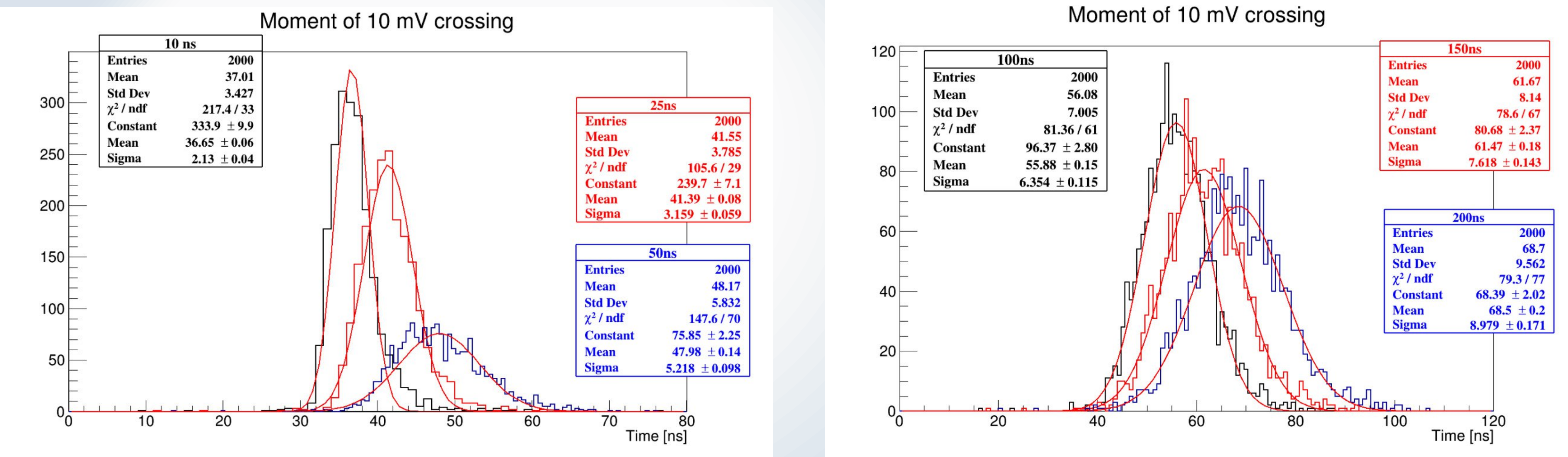
(a)



(b)

Fig. 11. (a) MPV (ns) from distance to wire (b) Sigma (ns) from distance to wire

Threshold crossing time for 10 mV



(a) (b)

Fig. 12. Threshold crossing time for 2 mm distance. (a) Peaking time 10, 25 and 50 ns (b) Peaking time 100, 150, 200 ns. Electronics parameters: signal amplification 3 mV/fC, noise implemented here is 1500e, threshold 10 mV. VMM-based model

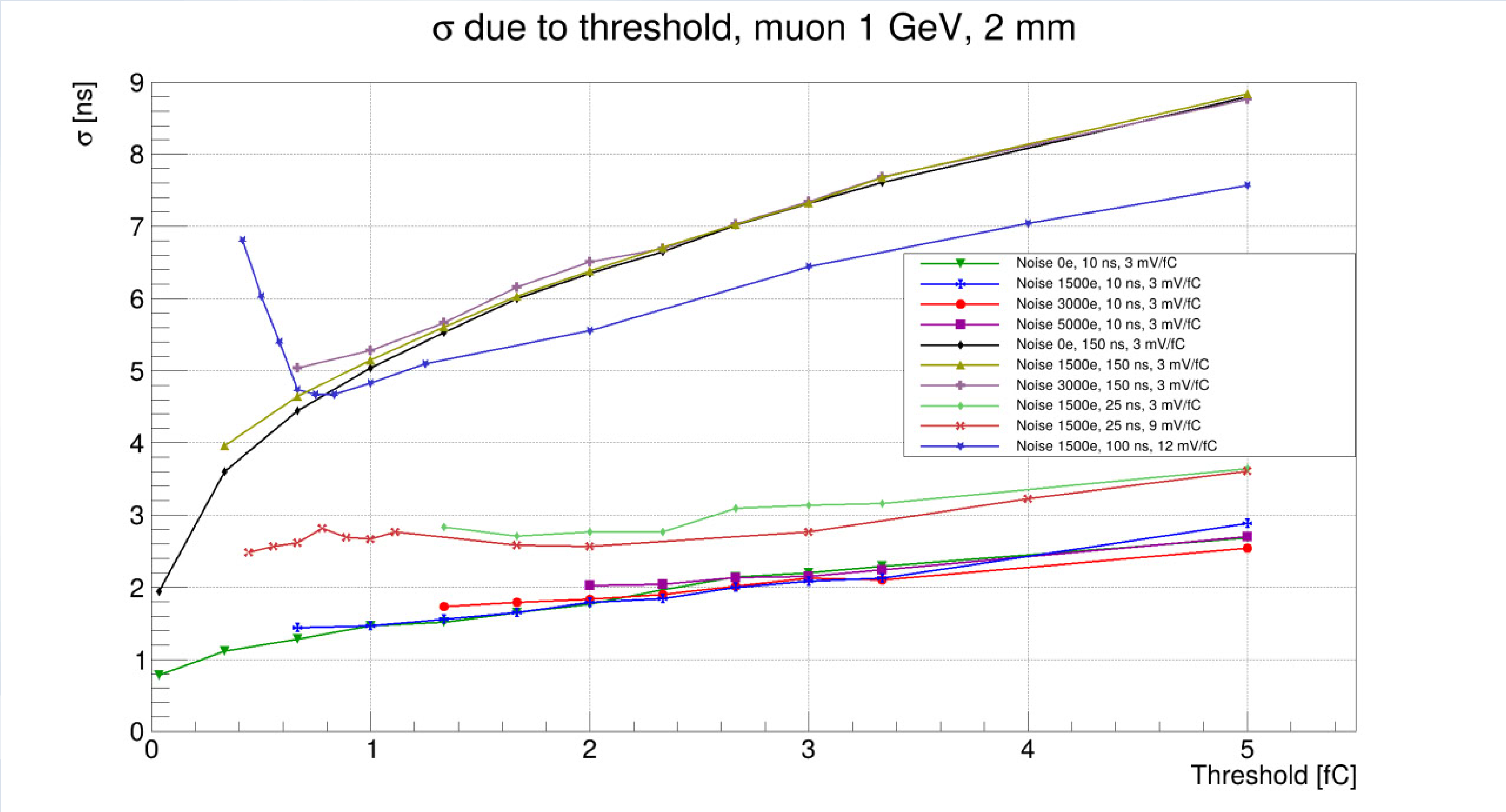


Fig. 13. σ of threshold crossing time due to threshold [fC] for 10 ns, 25 ns and 150 ns peaking time. Provided 9 mV/fC and 12 mV/fC amplifications

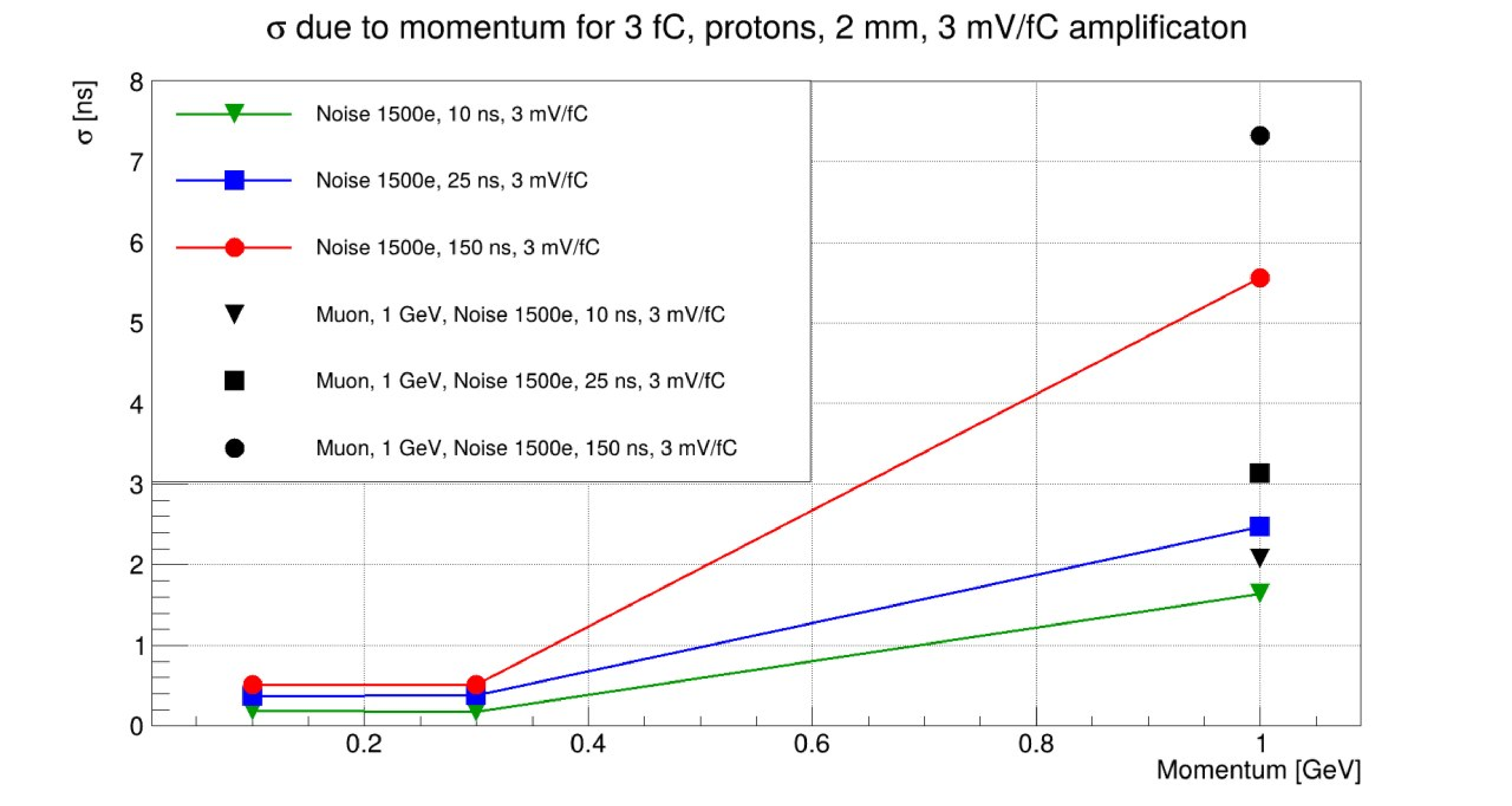


Fig. 14. σ of threshold crossing time due to particle momentum [GeV] for 10 ns, 25 ns and 150 ns peaking time. Muon and proton, 1500e noise

What is next?

Next steps need to be done to perform cross-check with the first testbeam measurements for electrons and pions of 0.3 – 5 GeV:

- ...to define the most optimal peaking time of the readout electronics;
- ...to perform the full chain simulation including the LTSpice signal processing for a given option of the readout electronics
- ...to provide the charge parametrization of the straw response for SPDroot