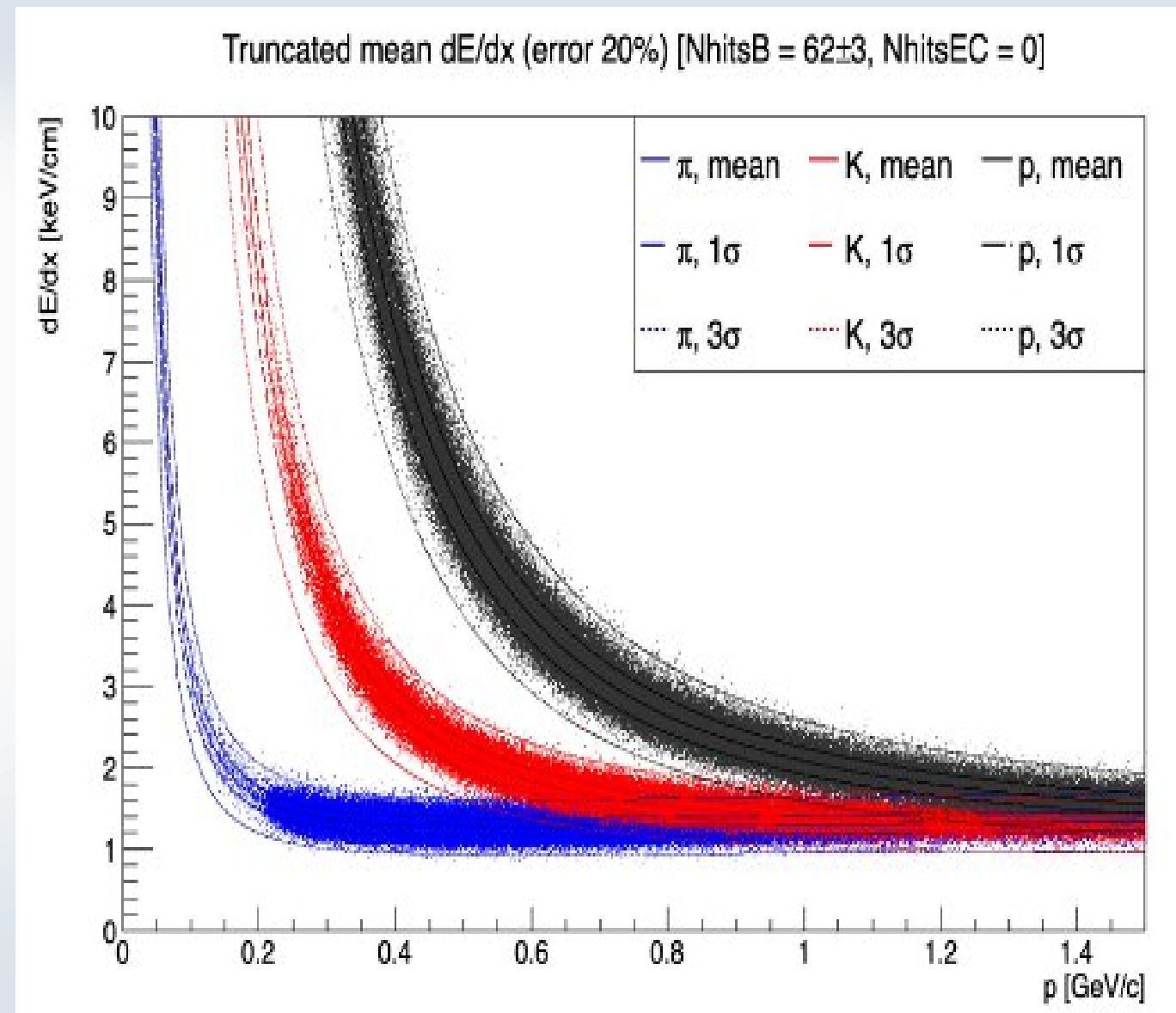


Garfield/LTSpice studies of the straw tube time and charge resolution for various readout parameters

S. Bulanova (NRC KI — PNPI) and A. Gurova (MEPhI, INP) on behalf of the StrawTrackerRD team

- Future experiments, such as DUNE and SPD, require not only particle tracking, but also particle identification for low momenta particles.
- Coordinate measurements → fast signal to reduce threshold crossing time fluctuations.
- Charge measurements → large peaking time to minimize energy loss fluctuations.



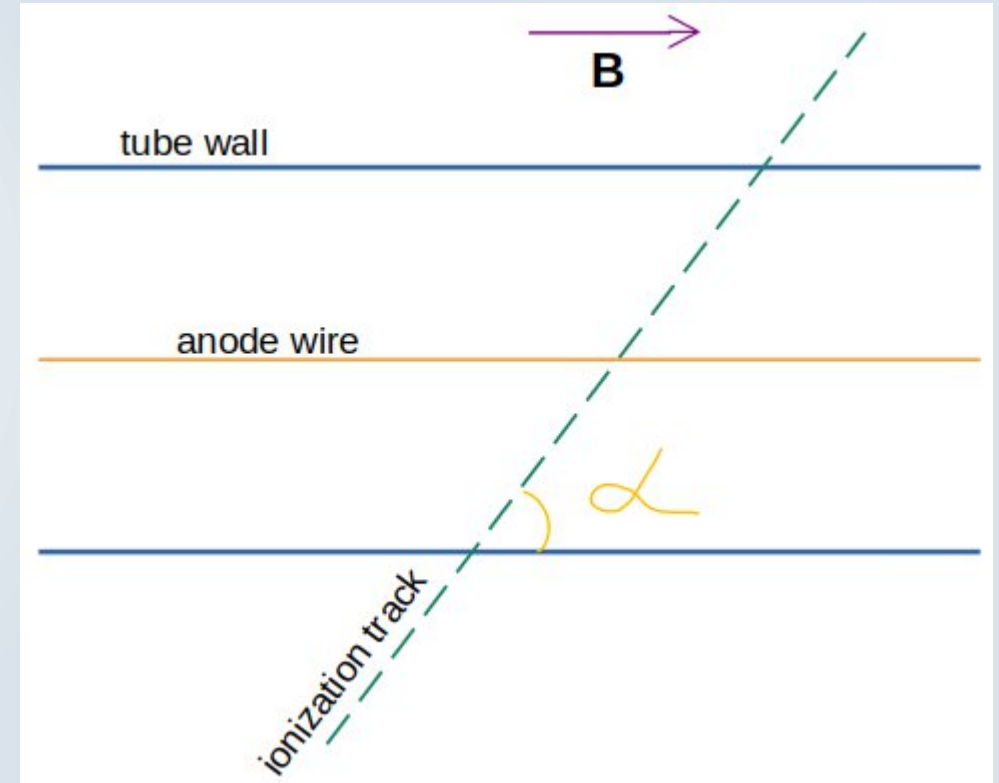
**MC only - ST barrel
SPD TDR**

Goals of simulation studies

- Prove charge resolution sufficient for PID;
- Check influence of the finite electronics dynamic range on tracker PID;
- Find optimal electronics parameters for both coordinate and charge measurements;
- For SPD experiment: provide input for SPDroot / SAMPO.

Garfield++ simulation parameters for SPD straws

- Straw diameter: 10 mm
- Anode diameter: 30 μm
- HV: 1750 V
- Gas mixture: Ar+CO₂ / 70:30%
- Gas mixture temperature: 20 celsius
- Gas mixture pressure: 1 atmosphere
- Ionization particles: μ , p , π^+ , e^- , K^+ .
- p : from 0.1 to 10 GeV/C
- Distance between track and the wire: 0.1 mm
- Track angle α : 90°
- Mean Gas Gain value: $4.5 \cdot 10^4$,

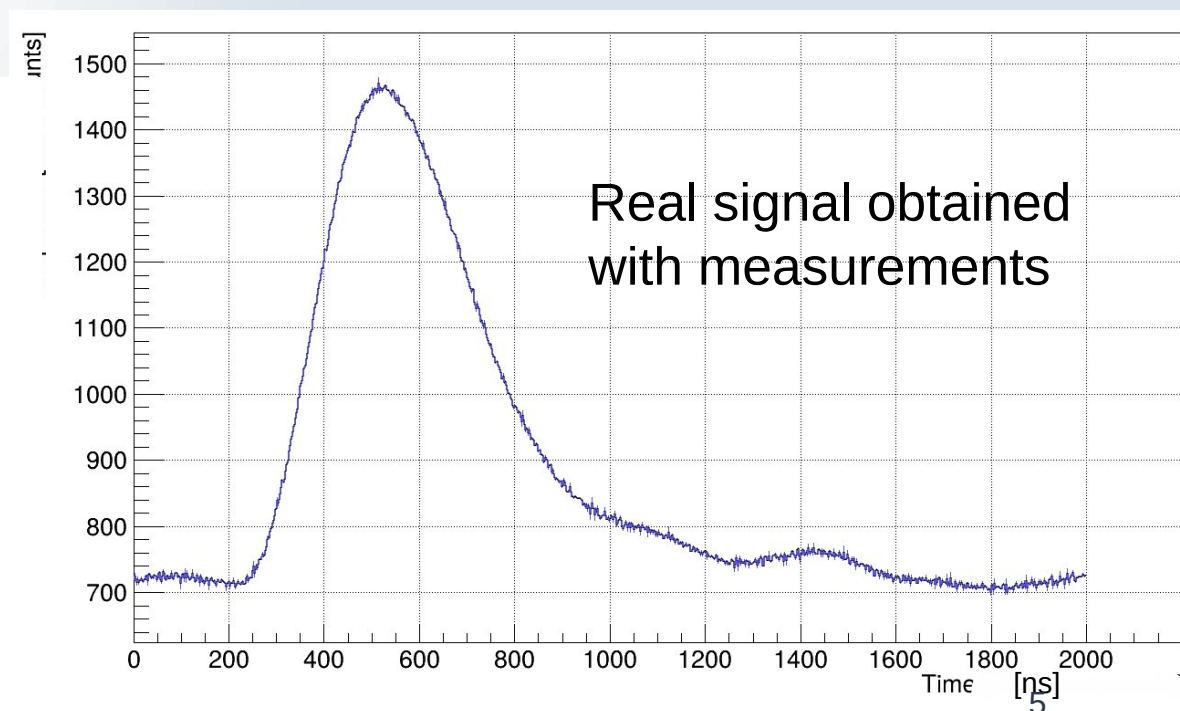
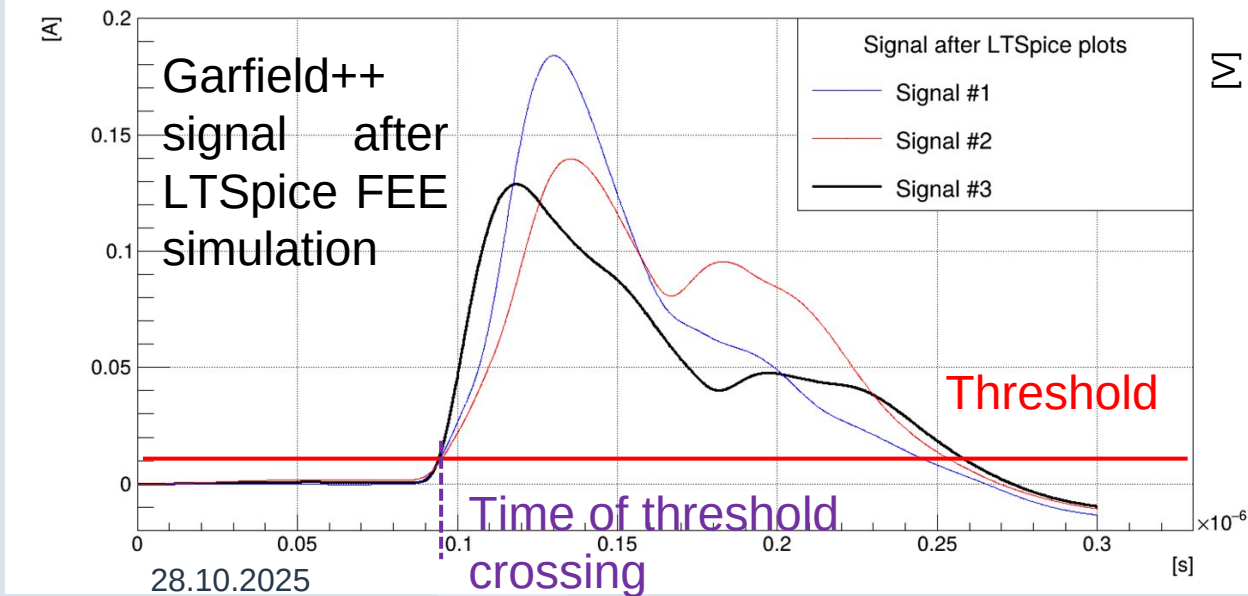
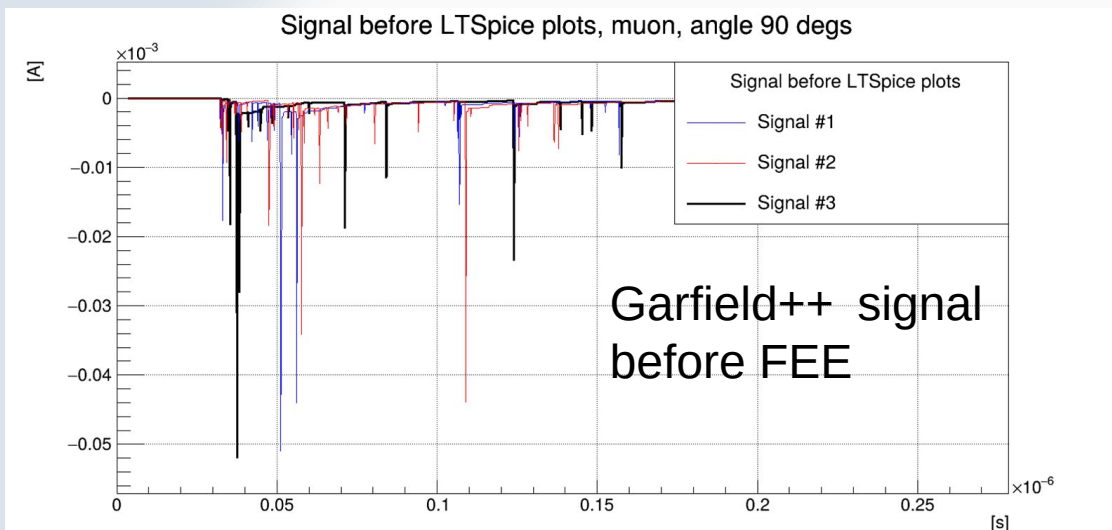


Layout diagram of ionizing particle, track angle, and magnetic field vector

Simulation instruments



Garfield++ is developed for detailed simulation of signal induced on electrodes of gaseous detectors and is used for direct straw signal. For precious front-end electronics simulation LTSpice toolkit is used.



Charge resolution studies

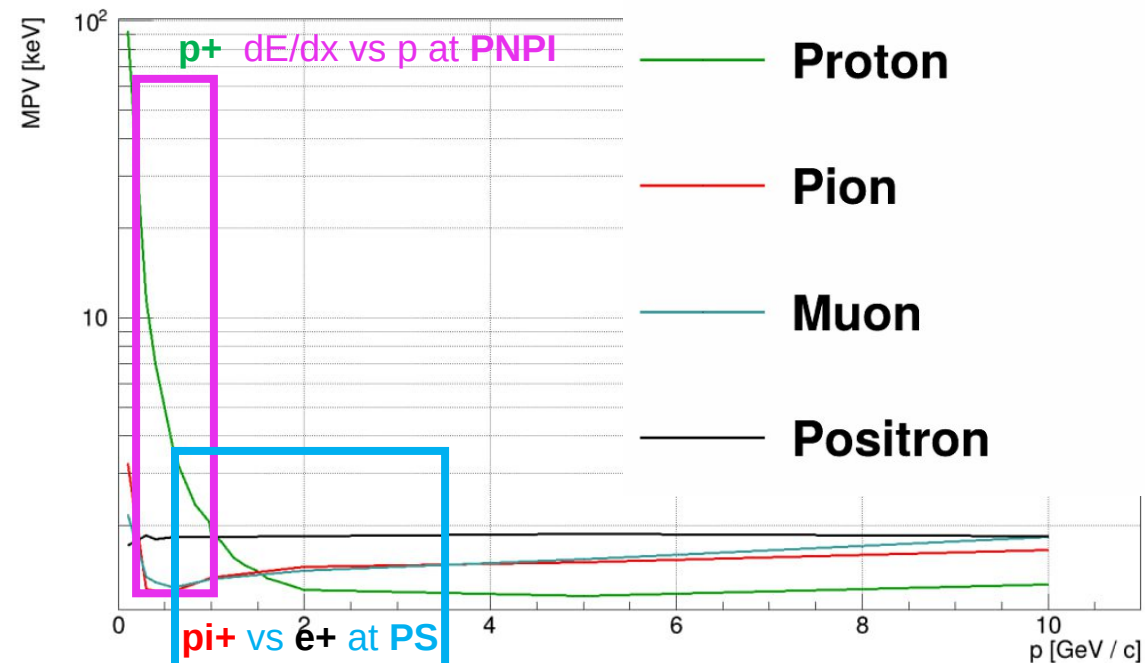
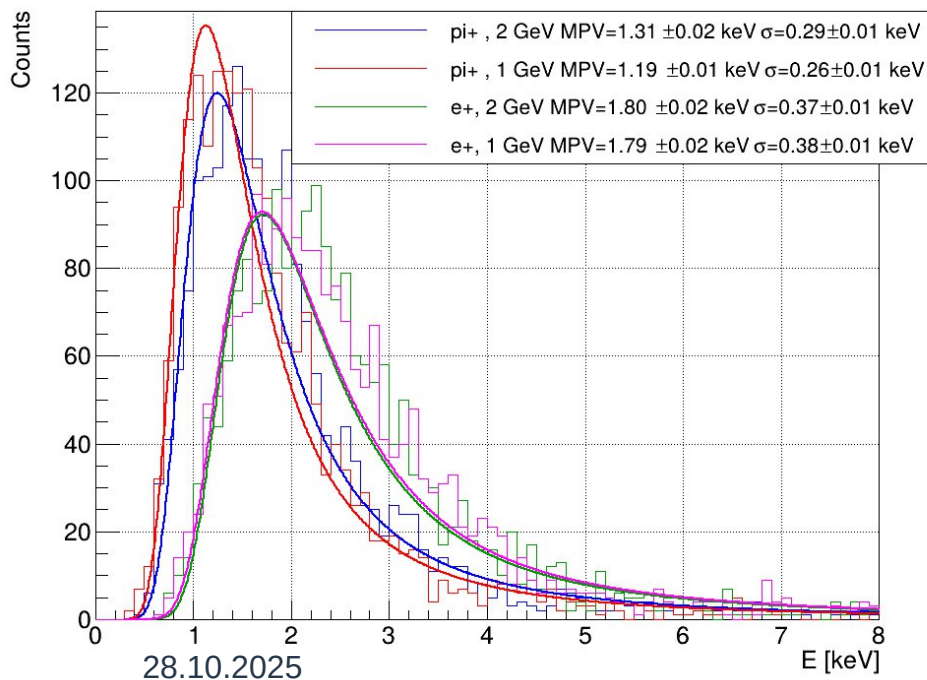
Garfield++ allows us to access particle ionisation energy losses. We provide simulations to support TB measurements. Ionisation energy losses are taken into account.

Latest Test Beams (TB) measurements:

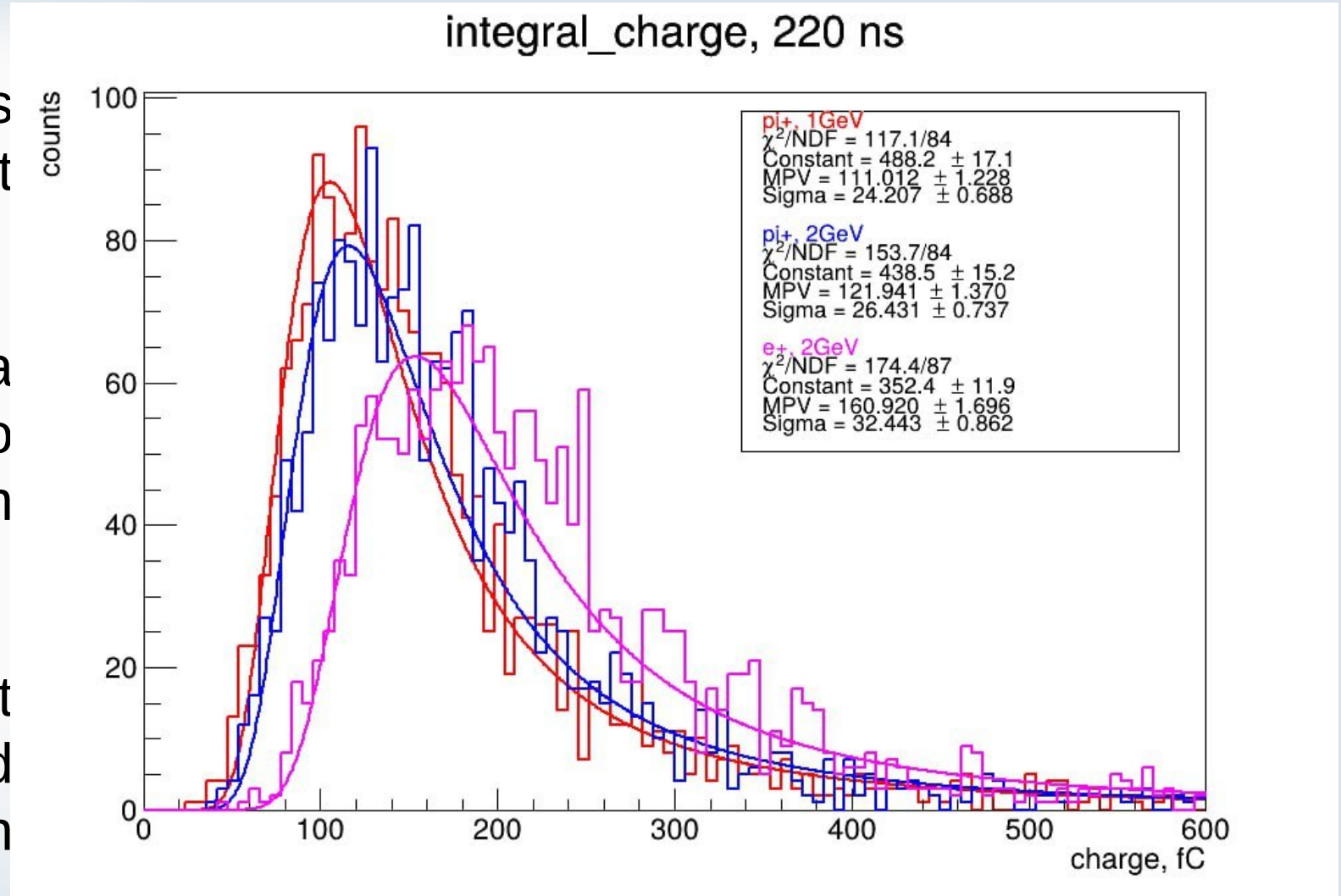
PS Test Beam (CERN) — dE/dX measurements for e and π in the range of 0.5-5 GeV/c - **charge resolution**

Synchrocyclotron SC 1000 (PNPI, Gatchina) — dE/dX vs **proton** momentum for the range 0.4-1.8 GeV/c - **charge resolution, + testing the necessary dynamic range**

Energy deposit

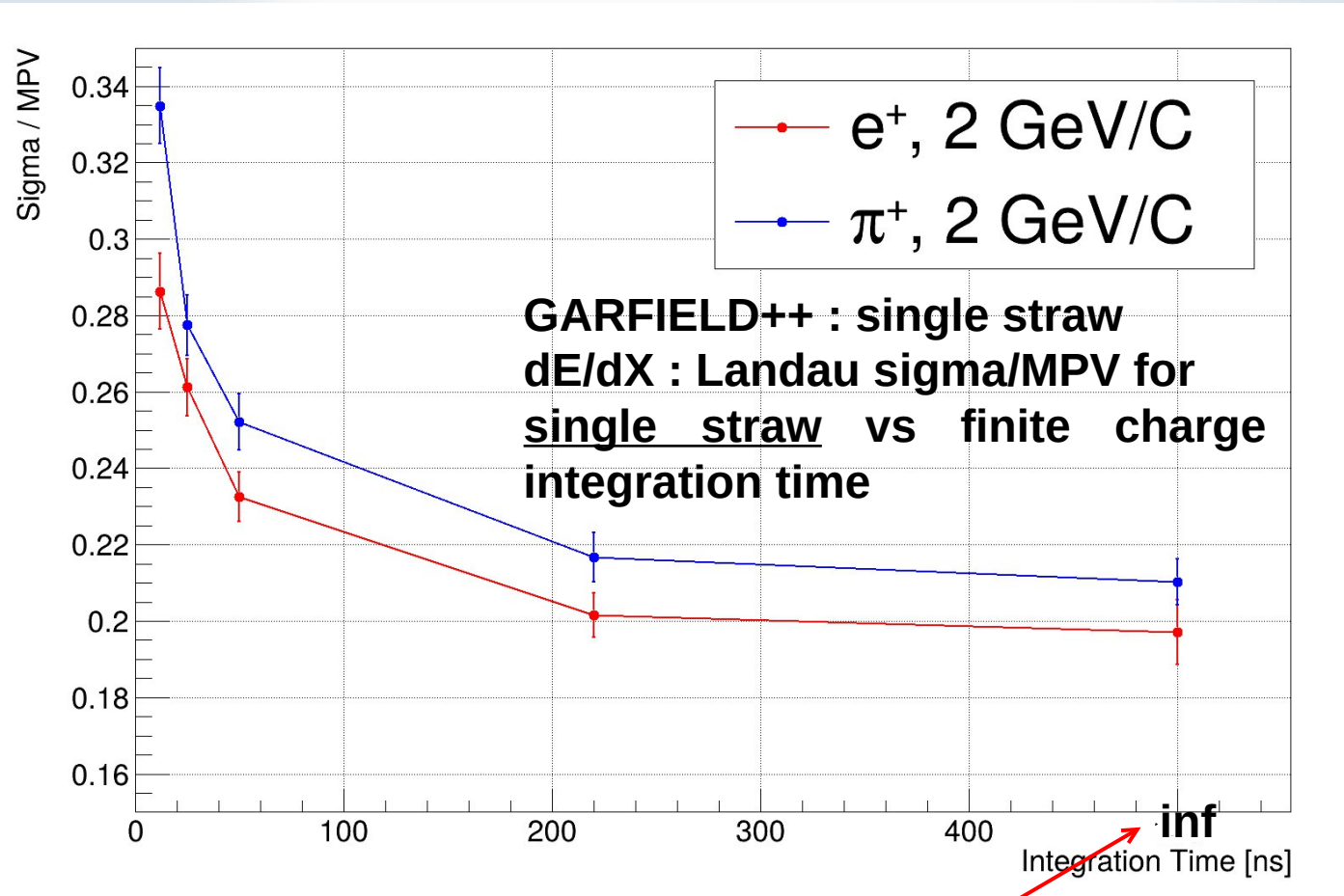


- Signals have a continuous long ion tail, which can last for microseconds.
- Garfield++ provides us a tool to get partial signal to integrate the signal within given range.
- Landau distribution most probable value (MPV) and width (Sigma) depend on the integration time.



Integrated charge distributions for various beam composition and energies. Integration time is set to 220 ns as an example.

Influence of the electronics peaking time



Preamplifier is used with limited shaping time, so dependence of the collected charge as a function of signal collection time was studied.

There is a strong resolution dependence of the charge integration time.

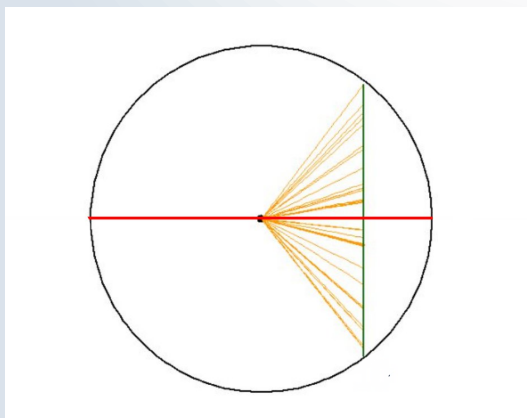
Infinite integration time (total charge, all charge was collected)

28.10.2025

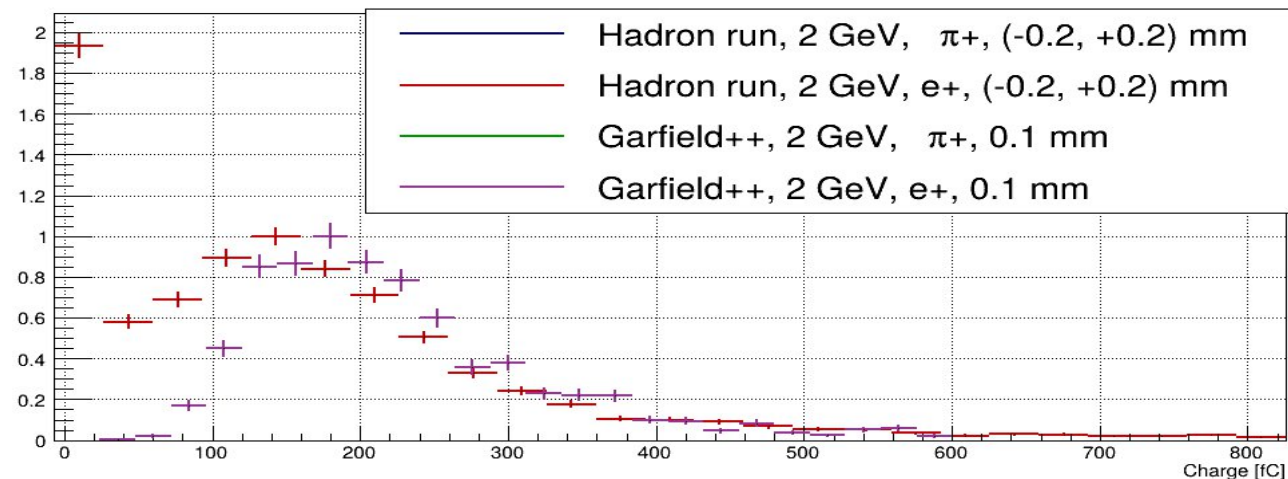
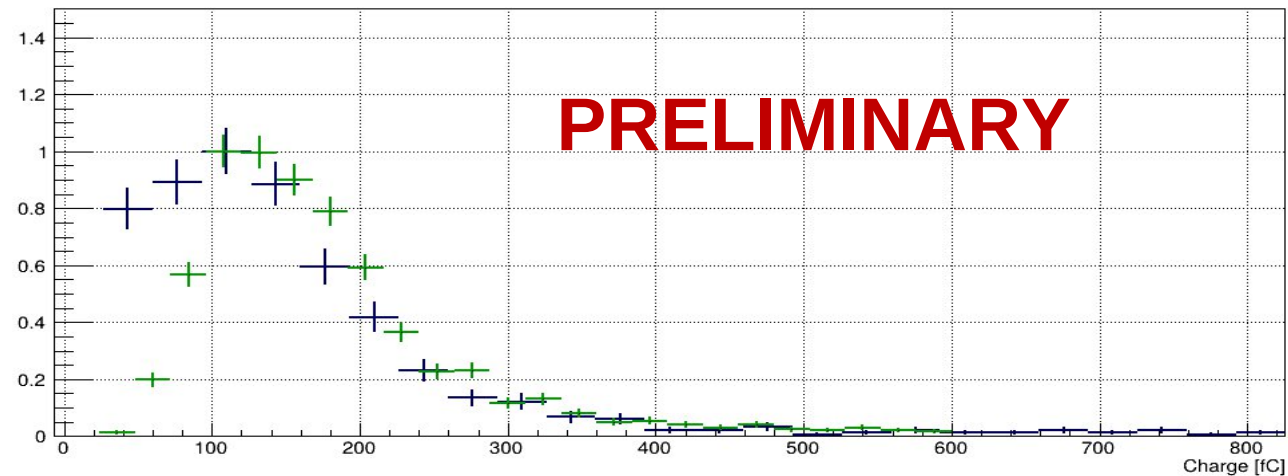
S. Bulanova and A. Gurova on behalf of the
StrawTrackerRD team

Test Beam simulation support

We have performed preliminary analysis of PS test beam data. There were taken tracks with distances $[-0.2; +0.2]$ mm between the wire and track.



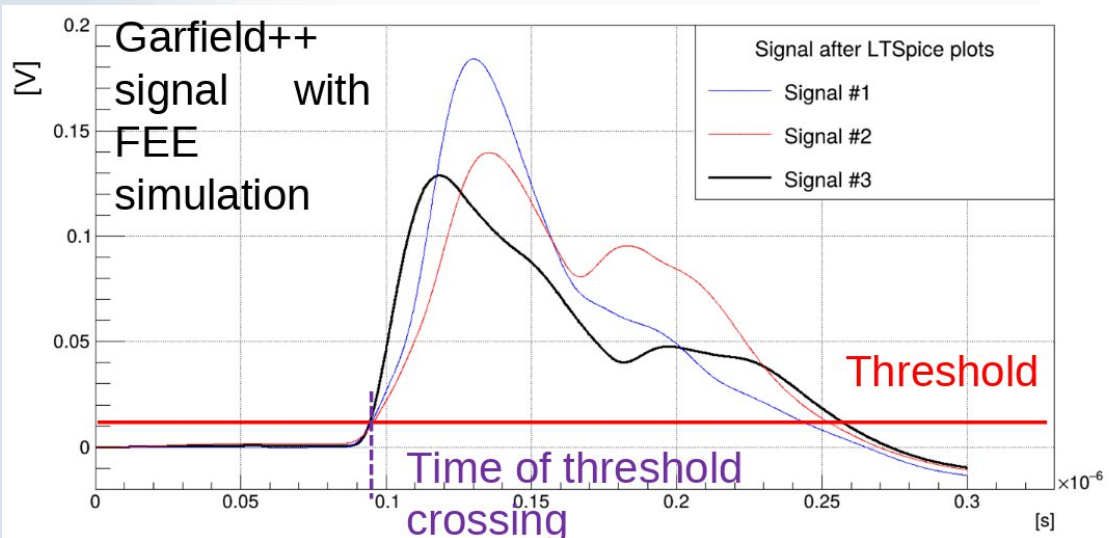
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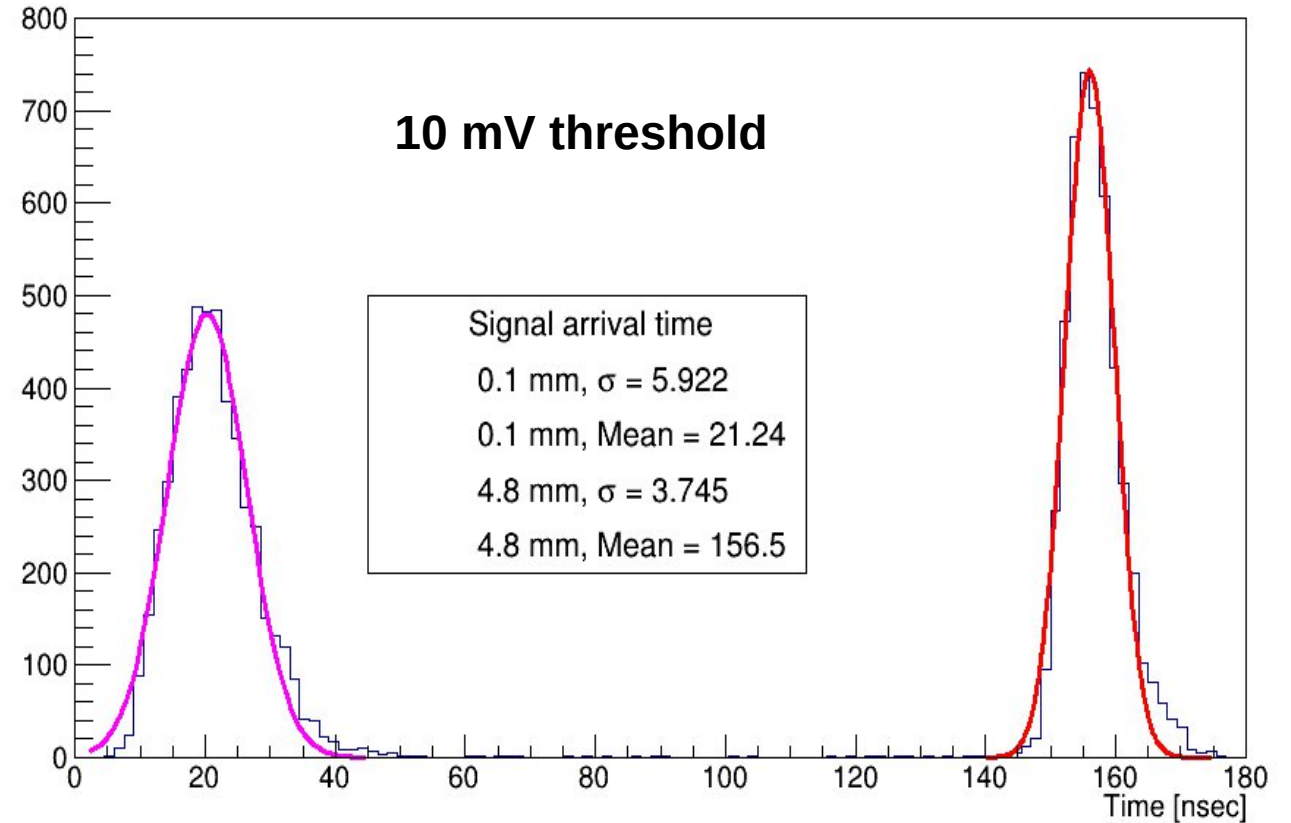
Spatial resolution studies

For realistic readout electronics simulation taking into account various FEE parameters (peaking time, amplification, noise) LTSpice model was developed.

The model accepts straw tube signals as input and outputs corresponding signals from electronics.

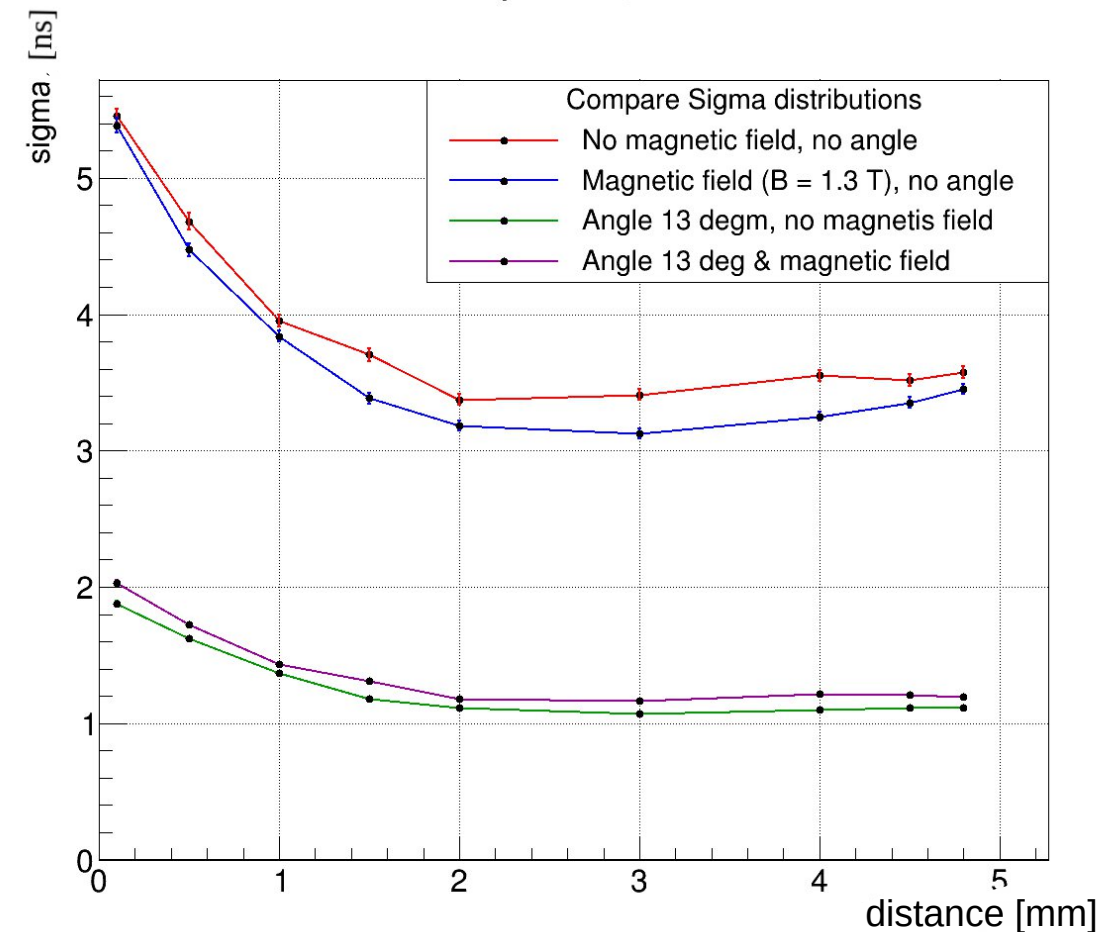
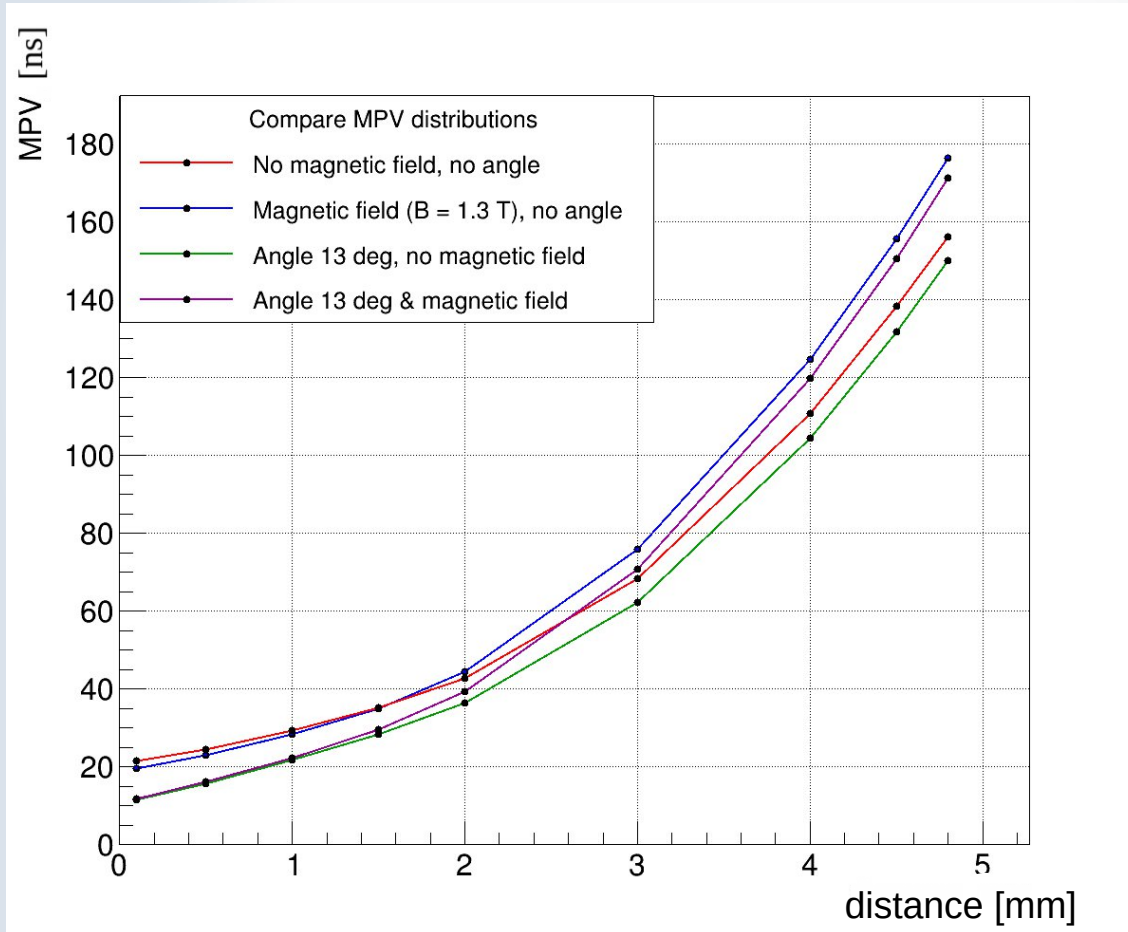


Signal arrival time, distance 0.1 mm and 4.8 mm



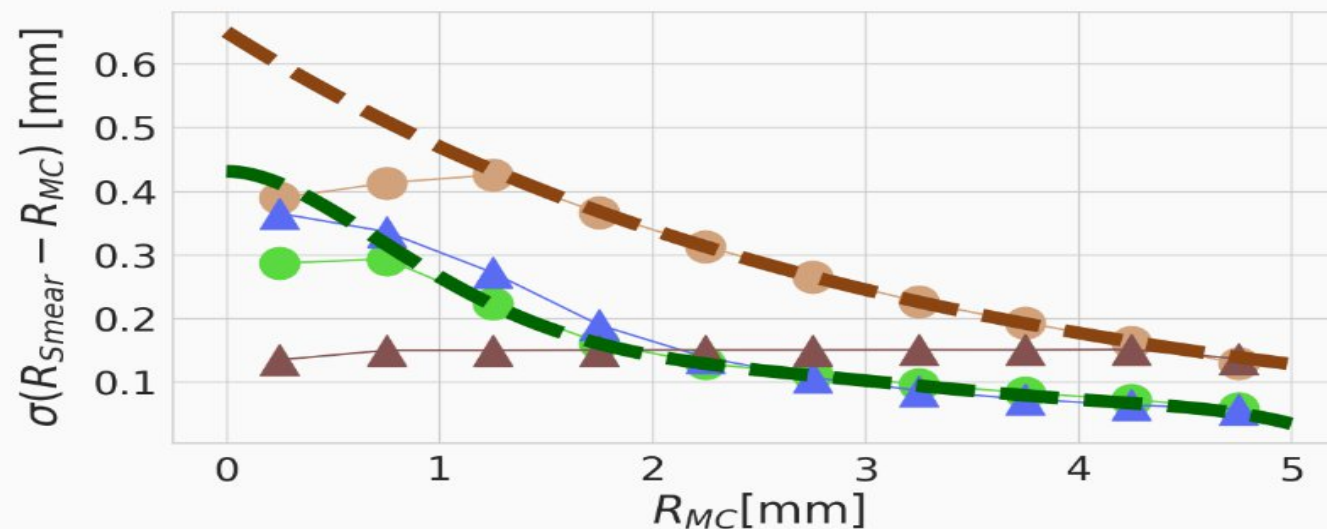
Signal crossing threshold time has a Gaussian distribution with certain MPV (most probable value) and σ (distribution width)

SPDroot realistic simulation implementation



The most probable value and width (σ) of the fitted Gaussian function describing the time distribution of the Garfield++/LTSpice simulated signals crossing the threshold of 10 mV as functions of the track position and the wire obtained with and without magnetic field

The variance of smearing hit
from SPDROOT simulations
[P = 1.0GeV, pdg=13(muon), $\theta= 90^\circ$]



[VMM3 readout, testbeam August 2023]
Resolution = 288

[Uniform 150 mkm]
Resolution = 147

[ASD readout, testbeam September 2024]
Resolution = 151

Parameterisation according to
test beam data August 2023
Mean = 321

[Parametrisation from GARFIELD++/LTSpice]
Resolution = 168

Parameterisation according to
test beam data September 2024
Mean = 163

SPDroot simulation using
Garfield++/LTSpice
straw signal paramanetrization

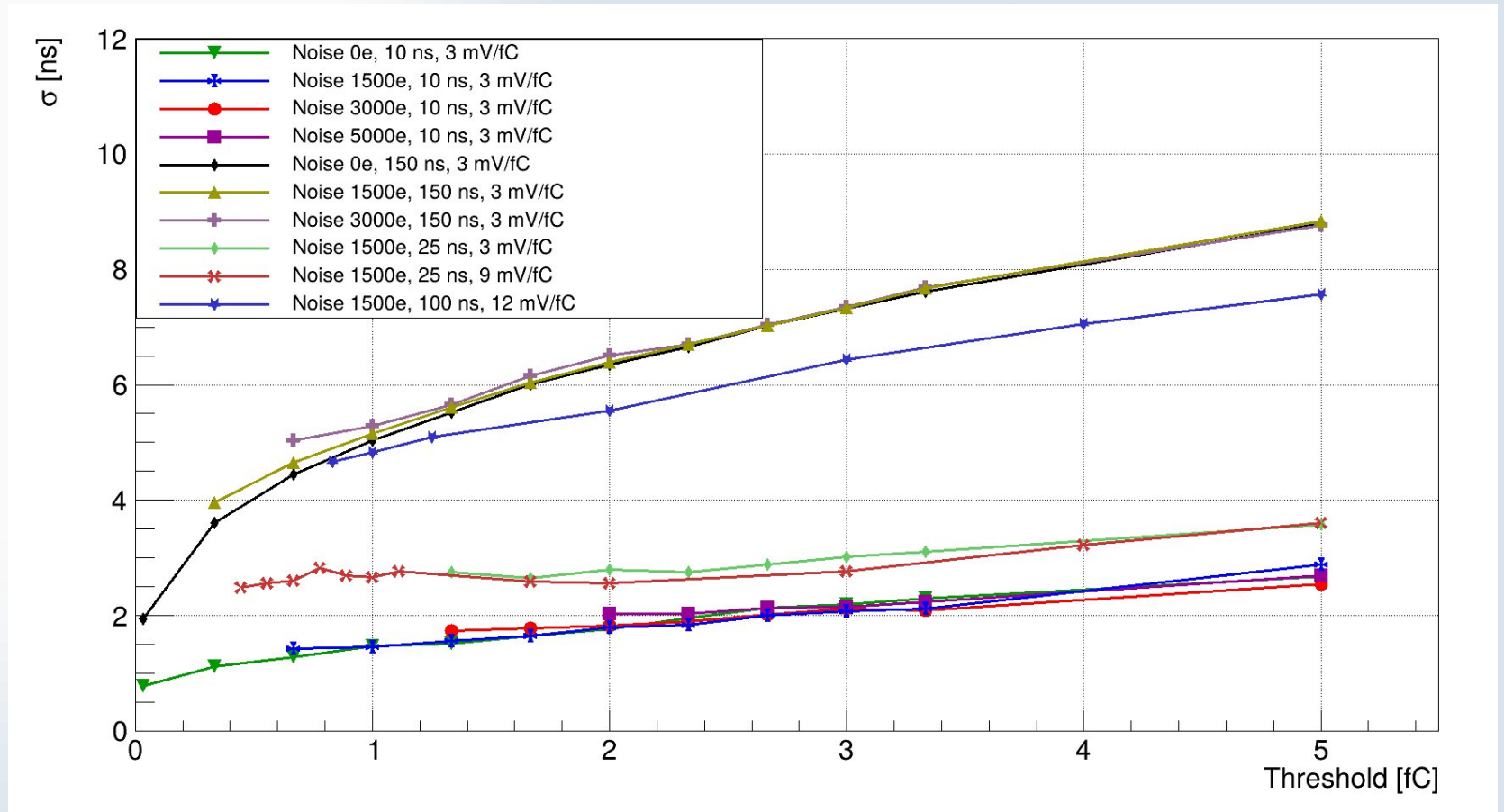
recent testbeam measurements

Electronics parameters simulation studies

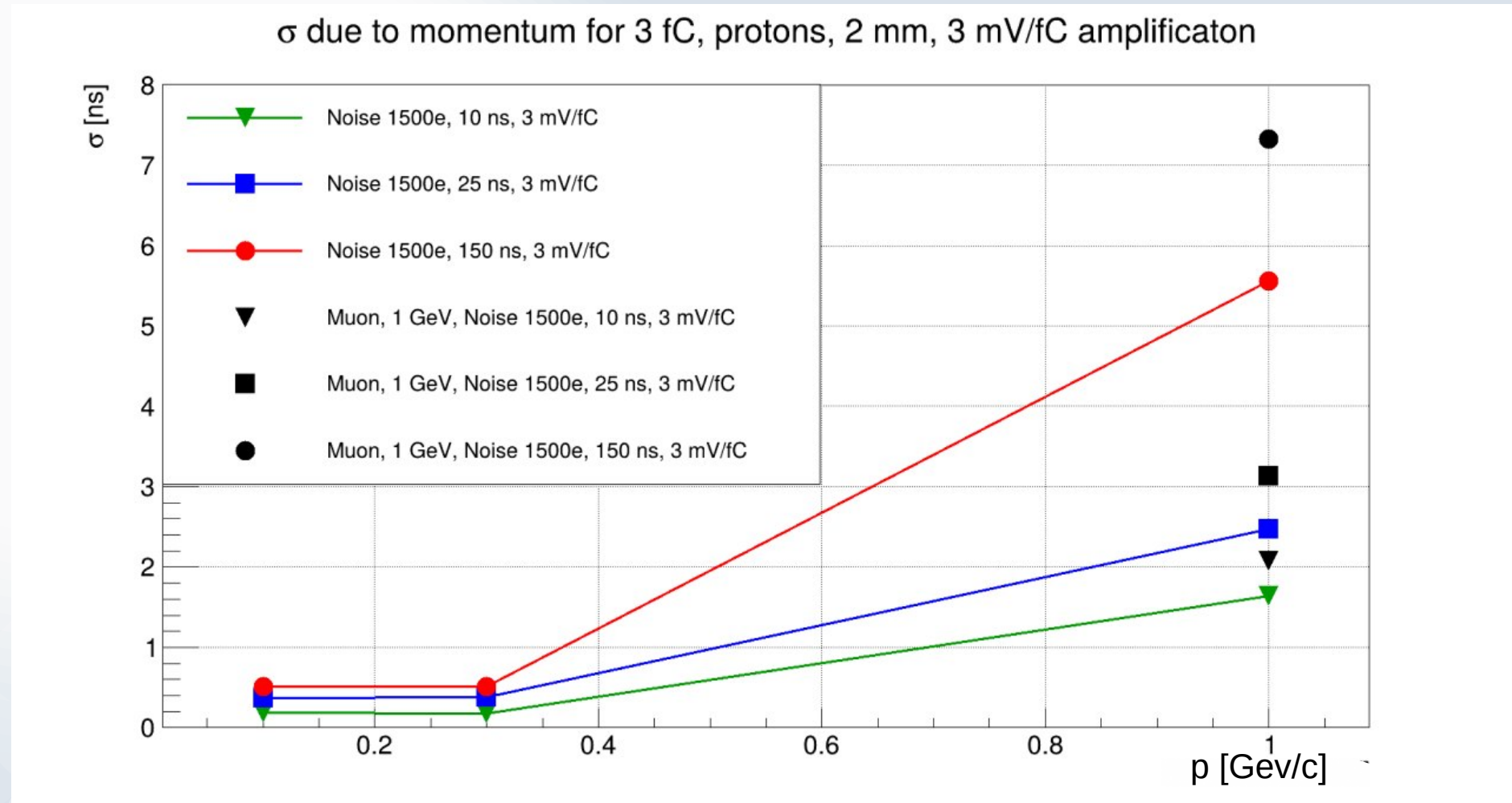
The time resolution of a 1 GeV/c muon is represented, considering:

- different values of peaking time (10, 25, 100, and 150 ns),
- gains of 2, 9, and 12 mV/fC.
- The noise of readout electronics was chosen to have the equivalent noise charge of 0, 1500, 3000 and 5000 electrons.

The results are shown only for the data samples with > 75% of the electronics response corresponded to the real signal.



The time resolution as a function of proton energy for 10 ns, 25 ns and 150 ns peaking time. Muon and proton are presented



Conclusion

- We performed Garfield++/LTSpice simulation studies of charge and spatial resolution of straw tubes as functions of various readout electronics parameters, in particular peaking time. The charge resolution degrades with shorter peaking time while improves spatial resolution and vice versa.
- Simulation studies of spatial resolution have been validated with the experimental data obtained with a μ beam for a small straw tracker prototype. Measurements of the charge resolution performed with e^+/e^- , π and p beams of low momenta are being analyzed for further comparison to the simulation results.
- Results of Garfield++/LTSpice modeling are being implemented as parameterized straw response into the simulation packages of SPD experiment.