Garflied++/LTSpice studies of the straw tube response

S. Bulanova [1], V. Bautin [2], T. Enik [2], E. Kuznetsova [1], E. Mosolova [1], A. Mukhamejanova [2, 3, 4], D. Myktybekov [2, 3, 4].

[1]NRC Kurchatov Institute - PNPI [2]Joint Institute for Nuclear Research, Dubna [3]Institute of Nuclear Physics, Almaty, Kazakhstan [4]Al-Farabi Kazakh National University, Almaty, Kazakhstan

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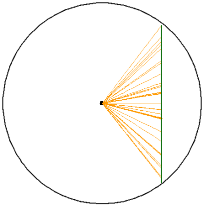
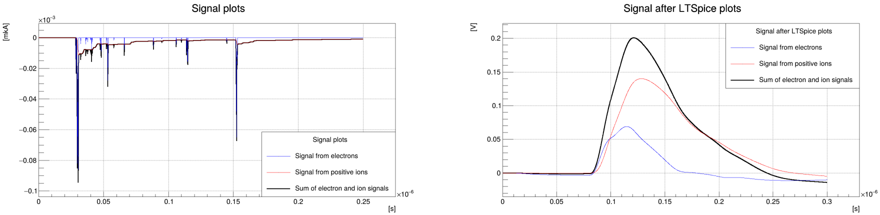
Motivation

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



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

Examples of the simulated signals



a) b)

Figure: (a) The signal induced at the anode wire (black) by electrons (blue) and ions (red), (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.

Study of the time resolution with a 25 ns peaking time readout – reported last year, the proposed parametrisation is being implemented in SPDroot. Link: https://indico.jinr.ru/event/3575/contributions/20512/

Roadmap for charge measurements studies

1. Validation of Garfield++ ionization energy losses with a stand-alone Geant4 simulation for e-, mu, K-, pi-, p in the momentum range of 0.1-10 GeV/c;
2. Validation of the charge distribution of the straw response;
3. Comparison with the data collected at the recent PS test beam;
4. Check of the magnetic field influence;
5. Choice of the peaking time, dynamic range and resolution for a baseline electronics model;
6. Signal emulation with LTSpice;
7. Signal charge parametrisation for SPDroot

Garfield++ and Geant4 validation

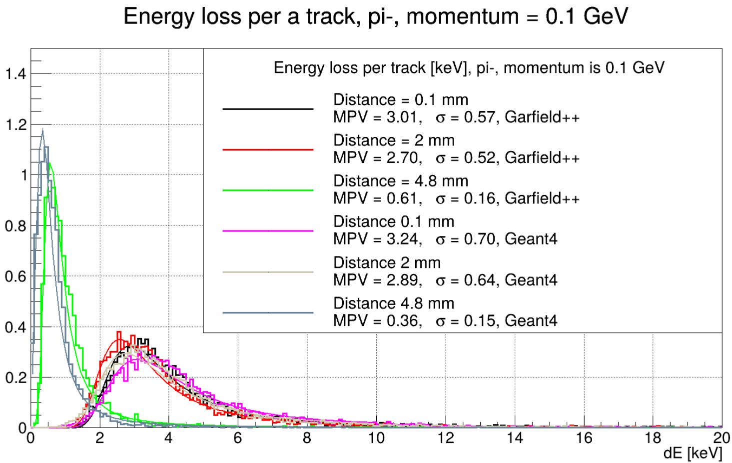


Figure: Comparison of the energy loss predicted with Garfield++ and Geant4.

Rough dynamic range estimate with ionization energy losses

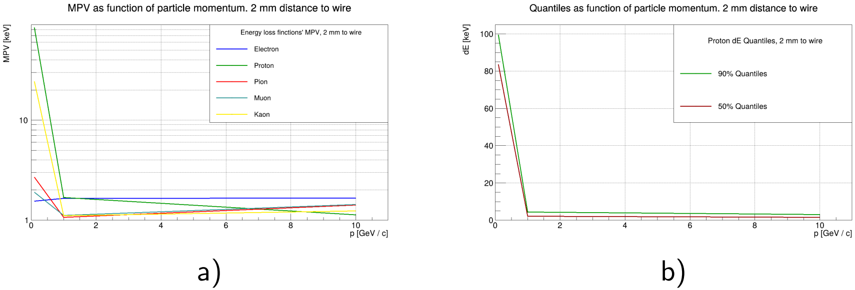


Figure: (a) MPV as functions of energy momentum, (b) 50% and 90% quantiles for proton, estimated range is about 100 keV. 2 mm distance

More detailed studies to be done with straw signal charges.

Signal charge distribution

Steps in Garfield++ simulation:

1. Primary ionization → the number of primary electrons;
2. Avalanche amplification → the total number of electrons;
3. Signal formation → the charge induced on electrodes

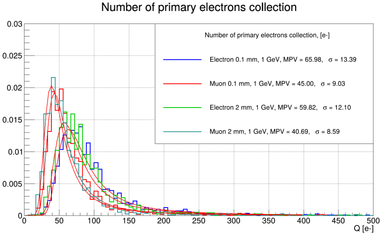
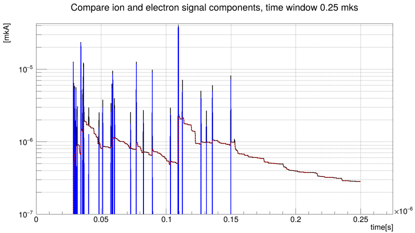


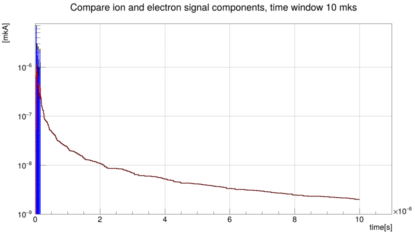
Figure: The number of primary electrons for few cases (electron 0.1 & 2 mm, muon 0.1 & 2 mm) [e-].

The values are in a good agreement with the energy loss divided by average energy per one electron-ion pair in Ar (27 eV). The statistical fluctuation in the number of e-ion pairs is negligible for the central part of the straw, so the sigma/MPV stays similar to the energy loss fluctuations.

Induced charge



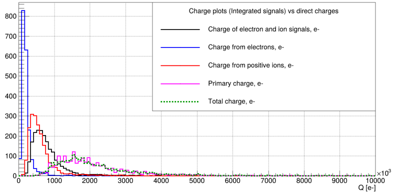
a)



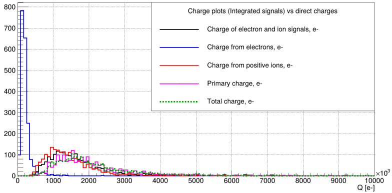
b)

Figure: The inverted signal induced on the anode wire (black) by electrons (blue) and ions (red) in logarithmic scale shown for first 250 ns (a) for 10 us (b) time scale.

Integration time influence



a)



b)

Figure: The fraction of measured charge is defined by the signal integration time (peaking time). The choice of the peaking time may be a compromise between the charge precision measurements and the maximal bandwidth.

Summary

1. The signal charge measurements are important for particle identification with the Straw Tracker;
2. Simulation studies with Garfield++ are ongoing;
3. Next steps need to be done to perform cross-check with the first testbeam measurements for electrons and pions of 0.3 – 5 GeV;
4. ...to define the most optimal peaking time of the readout electronics;
5. ...to perform the full chain simulation including the LTSpice signal processing for a given option of the readout electronics;
6. ...to provide the charge parametrization of the straw response for SPDroot