Straw signal modeling using Garfield++ interface to LTSPICE

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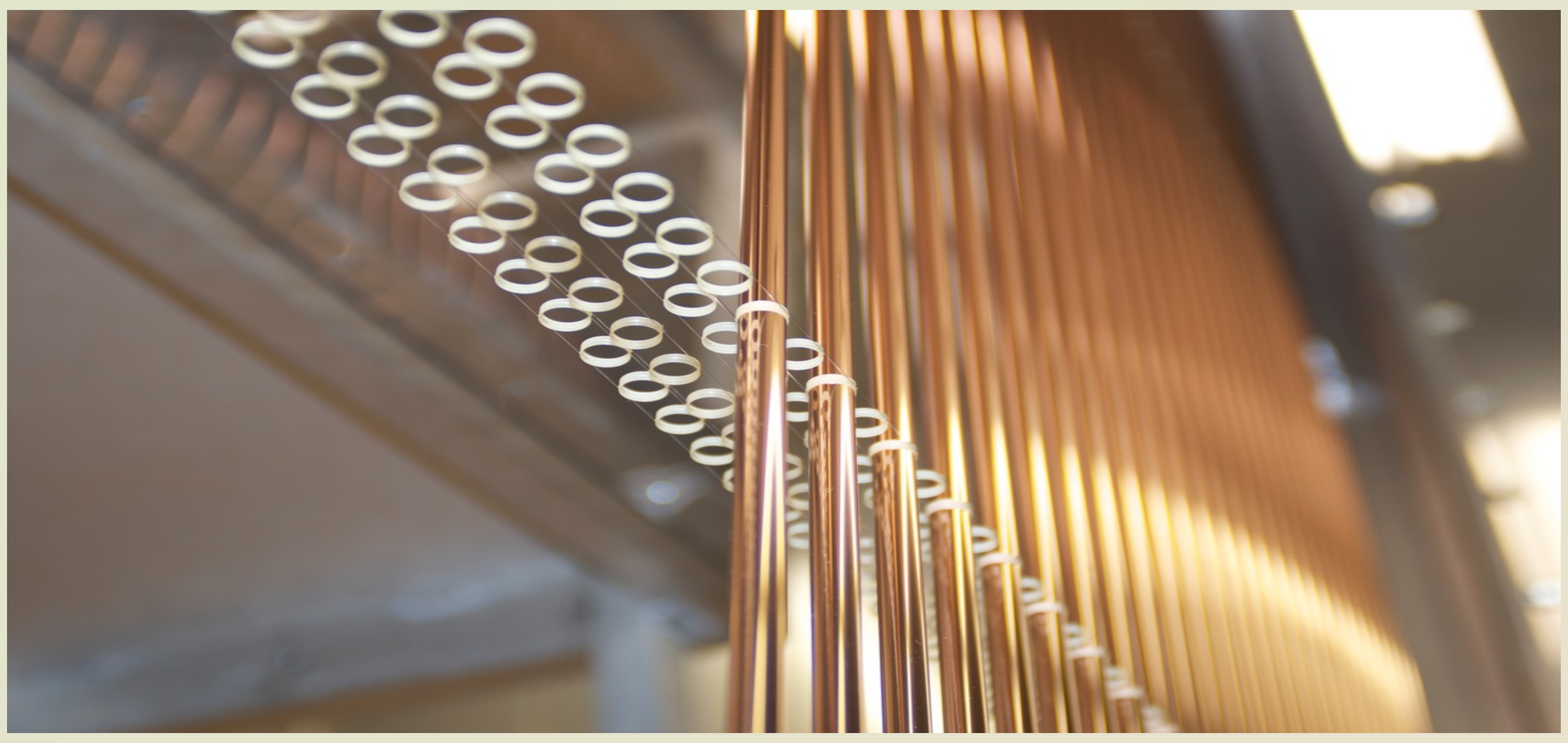
1. Motivation



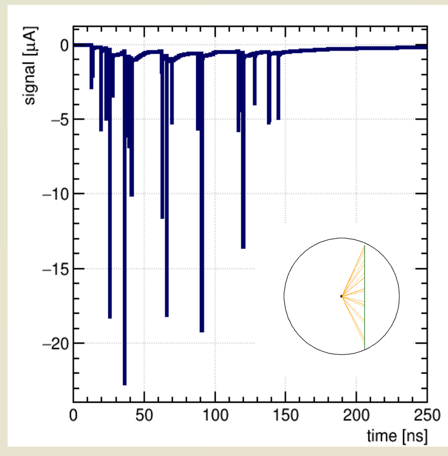
Track coordinates are reconstructed according to the measured signal arrival time defined by the drift time of primary electrons from the track to the anode wire. A number of operating and future experiments use Straw Tube detectors for precise tracking such as ATLAS TRT[1]. Example of successful operation of a large area Straw Tube Tracker made of straws produced by ultrasonic welding method: the NA62 [2] detector.

Small material budget and achievable large acceptance make Straw Tube Trackers attractive for the SPD [3] Experiment. When designing such large scale and complex detector it is of extreme importance to run precise simulations.

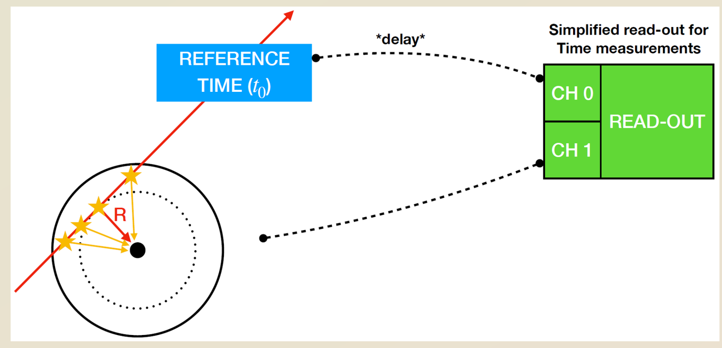
Garfield++ is an object-oriented toolkit for the detailed simulation of straw tubes that use a gas mixture or a semiconductor material as sensitive medium.

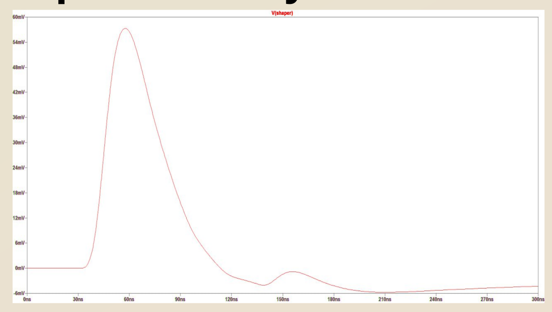
2. Simulation

Signal from straw tube simulated by Garfield++



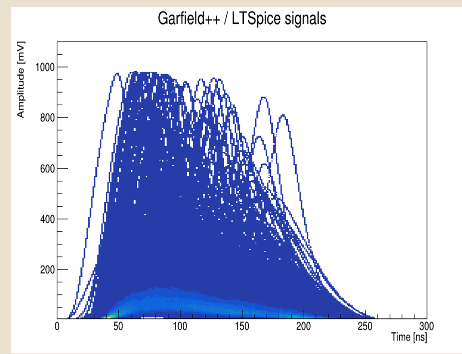
LTSpice response to the signal provided by Garfield++

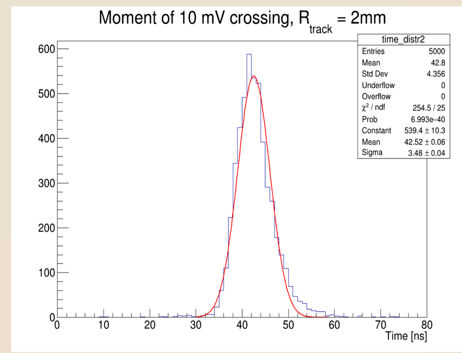




The signals obtained within Garfield++ simulation. Then this signal was processed by LTSpice. (LTSPICE is one of the best software for analysis and design of electronic schemes. It is an easy to use, widespread, and free product with very good convergence). Once the signal is processed by LTSpice one can use it for further analysis.

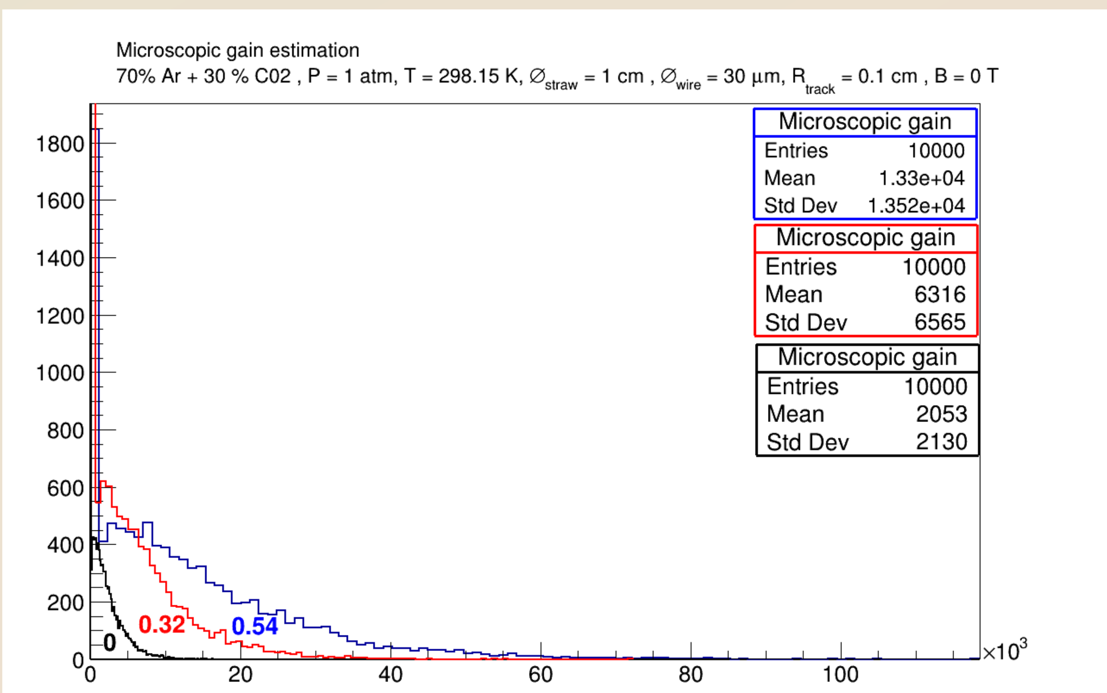
Simulation by Garfield++ after LTSpice





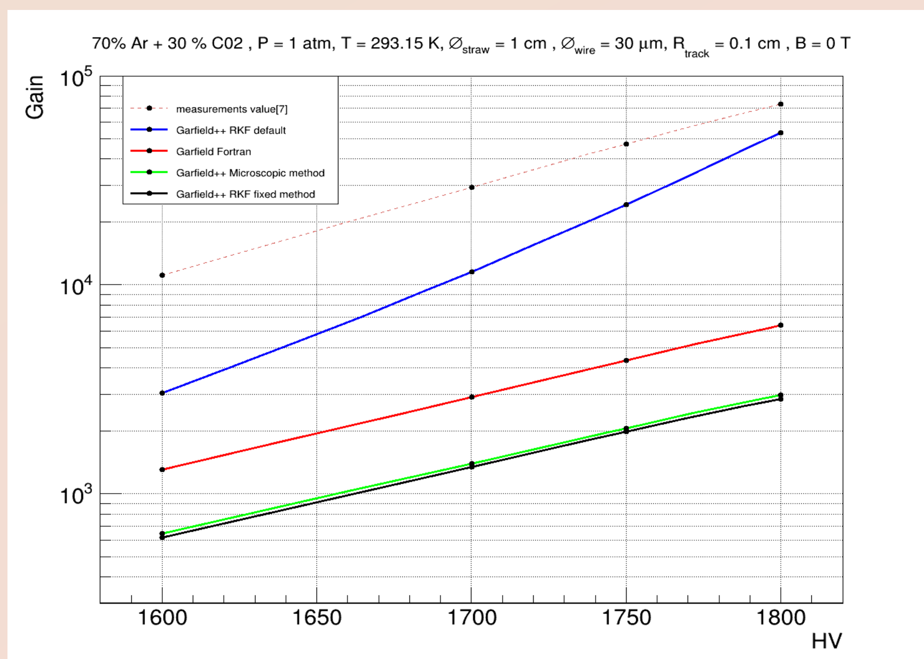
A combination of Garfield++ simulation of a straw tube response interfaced to the LTSpice electronics simulation package allows efficient optimization of the signal circuit path and VMM3[4] operation parameters, and supports performance studies for Straw Trackers operated in magnetic field and with different gas mixtures. The straw response to a muon track passing at the distance R from an anode wire is fed into an LTSpice model of the VMM3. One can also use VMM3/3A because analog part of the chip is almost similar for both of ASICs.

3. Gas gain. Microscopic gain and Runge-Kutta-Fehlberg integration



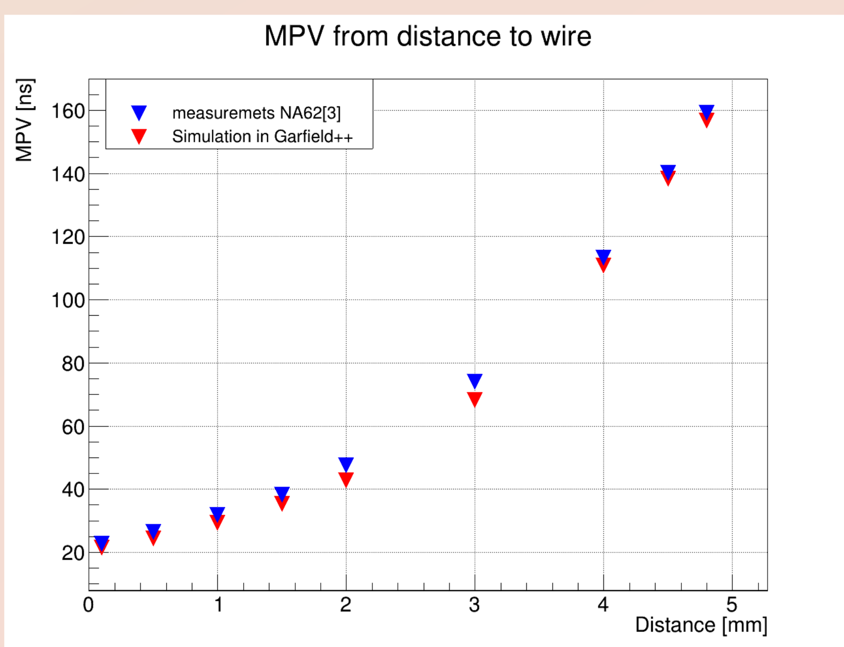
Garfield++ uses 2 ways to predict gas gain when simulating electron avalanche amplification - microscopic (detailed simulation) and Runge-Kutta-Fehlberg function based (fast simulation) methods. In some gas mixtures besides the "direct ionization" atoms can also be ionized in the process when an atom or molecule of the gas is excited to a state which excitation energy is higher then ionization potential of another gas atoms, so de-excitation can cause additional ionization. Such process is known as Penning Effect[5]. Since the Penning Effect is directly related to the gas gain prediction equation, it is important to estimate its contribution to the gas gain value. These estimations has been done in the figure. The plot demonstrate the gas gain predictions obtained with the microscopic methods for Penning coefficient[6] of 0, 0.32 and 0.54. The expected value for 70%Ar+30%CO2 gas mixture is 0.54.

Garfield++ gives a good prediction for the drift time for a given high voltage, however the gas gain prediction from both the microscopic and Runge-Kutta-Fehlberg (RKF) methods differ from the experimental data. Nevertheless the microscopic method allows to obtain a good prediction for gas gain fluctuation and the RKF method allows to use this distribution together with the most probable gas gain values obtained in the measurements. That allows us to provide a good prediction for both the signal shapes and the amplitudes Microscopic method allows one to describe gas gain fluctuation whereas Runge-Kutta-Fehlberg fixed method allows to use given shape, for instance the one that is obtained by microscopic method with fixed drift time mean value. We use the experimental drift time mean value and fast Runge-Kutta-Fehlberg method thus this allows us to obtain signal shapes that are comparable with the real drift time mean values.



4. Drift time

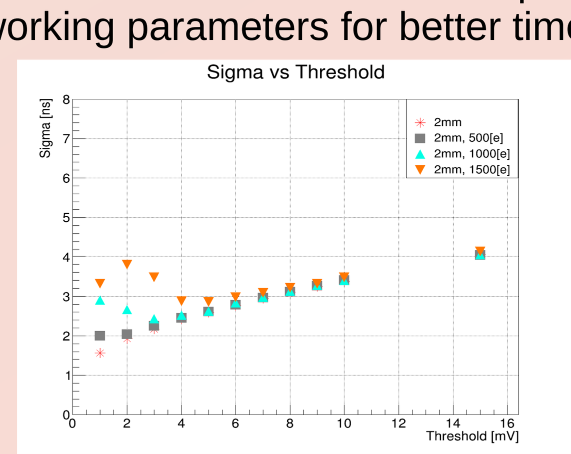
As can be seen from this figure the data obtained in our Garfield++ simulations reproduce the drift time data measured in the NA62 experiment[4]. The straw parameters used in simulations are as follows: gas mixture – 70%Ar+30%CO2, wire and tube diameters – 30 μm and ~10 mm respectively. Thus the calculated drift time coincides with the one obtained experimentally.

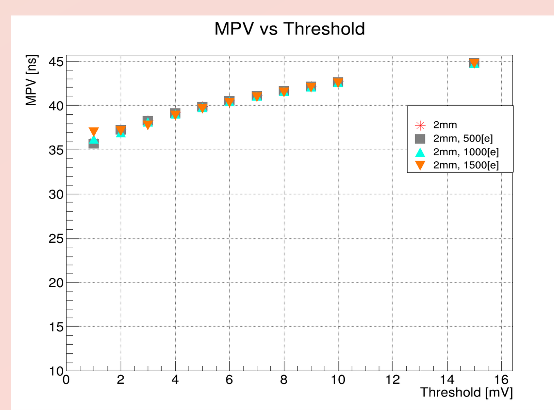


5. Noises by LTSPICE

To improve the realistic front-end electronics (FEE) model, additive white Gaussian noise (AWGN) simulation was added. The equivalent noise charge (ENC) of 500e (VMM3 nominal value), 1000e and 1500e was simulated. Figure below shows how the time measurements are affected with the noise for different threshold levels.

Careful noise simulation can improve real FEE performance studies and help to chose optimal working parameters for better time and spatial resolution.





6. Conclusion

- The gas gain values calculated by two different methods (microscopic and Runge-Kutta-Fehlberg for a given most probable value of the gas gain) are the same
- Garfield++ drift time prediction looks reasonable and describes well NA62 measurements[4] for the same type of straw
- Garfield++ with bug fix allows to reliably predict drift time and shape signal, which is important for further modeling of electronics for SPD Straw Tracker.

7. References

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