Status of the c-τ factory drift chamber simulation

(first steps)

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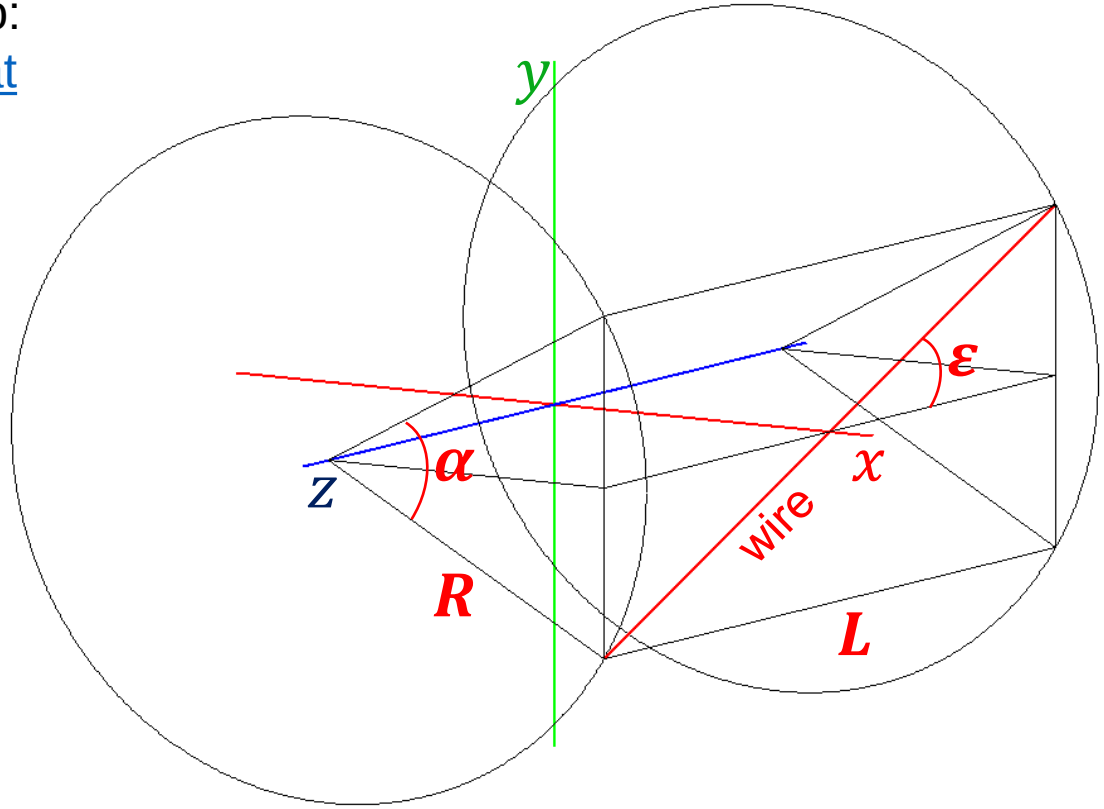
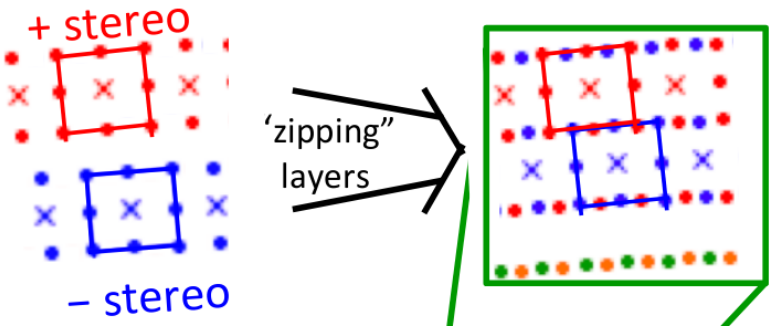
Drift Chamber Geometry

- We simulate the full-stereo drift chamber with the parameters, close to that proposed by F. Grancagnolo: https://indico.ijclab.in2p3.fr/event/4902/contributions/17030/attachments/13603/16389/SCTFDrift_Chamber.pdf

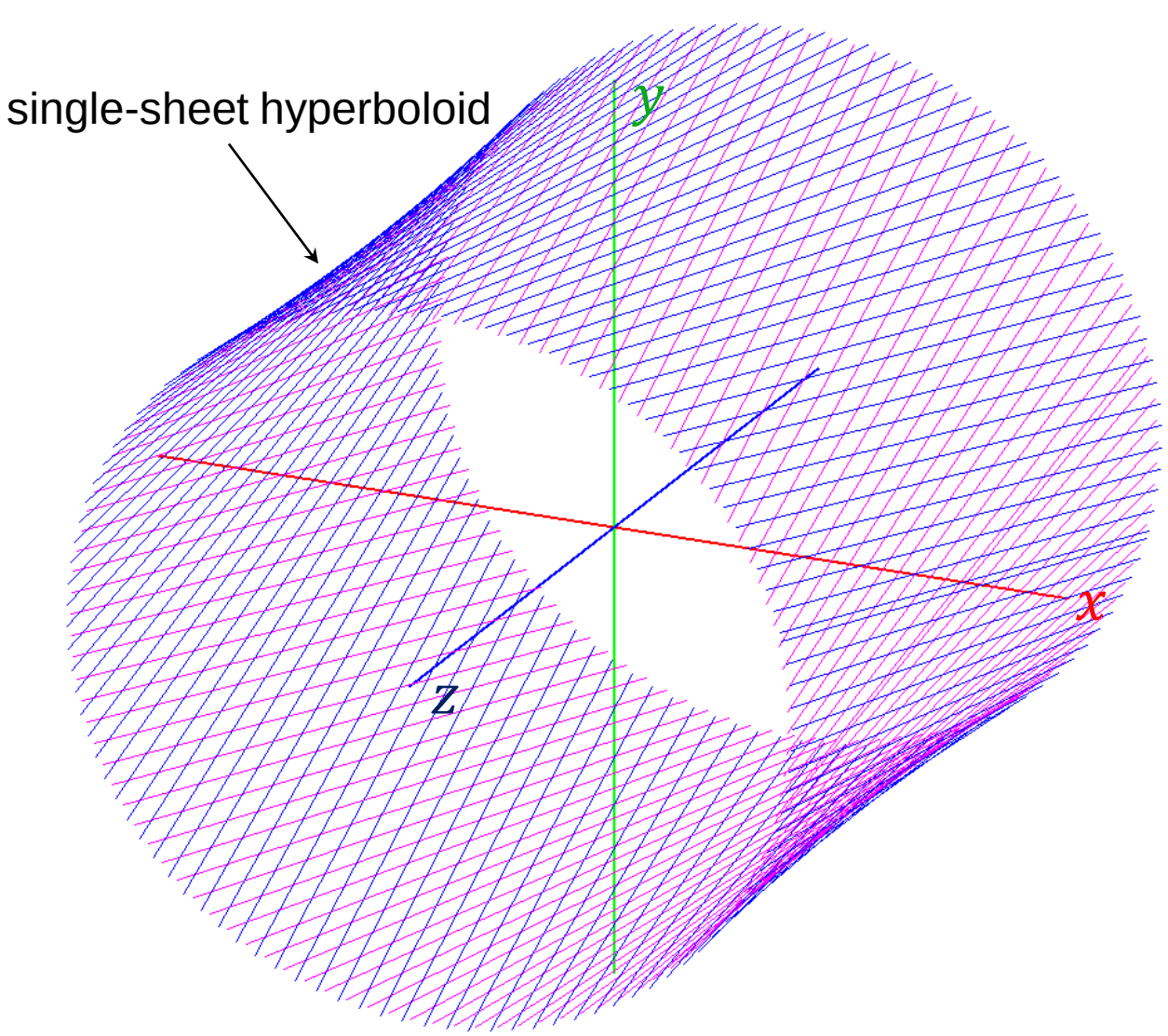
Parameter	Value
R_{in}, mm	200
R_{out}, mm	800
Length, mm	1800
Cell shape	Square
Cell size	~7-9 mm
α, rad	$\pi/6$
Stereoangle ε, rad	~60-220 mrad
$N_{superlayers}$	8
Layers in superlayer	8
Gas	90% He – 10% iC_4H_{10}
$N_{signal\ wires}$	21824
$N_{field\ wires}$	$\sim 5 \times N_{signal\ wires}$

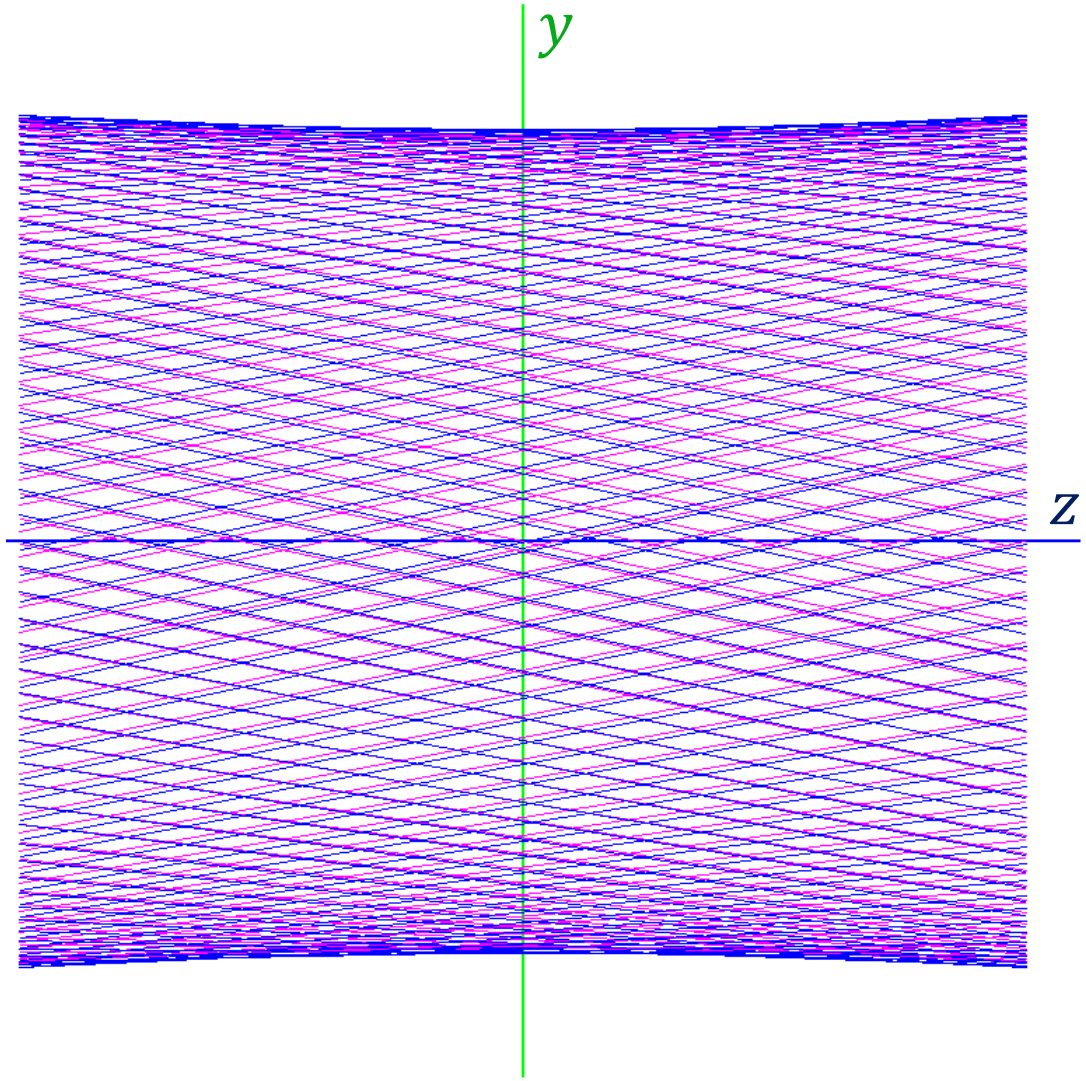


from proposal of F. Grancagnolo:



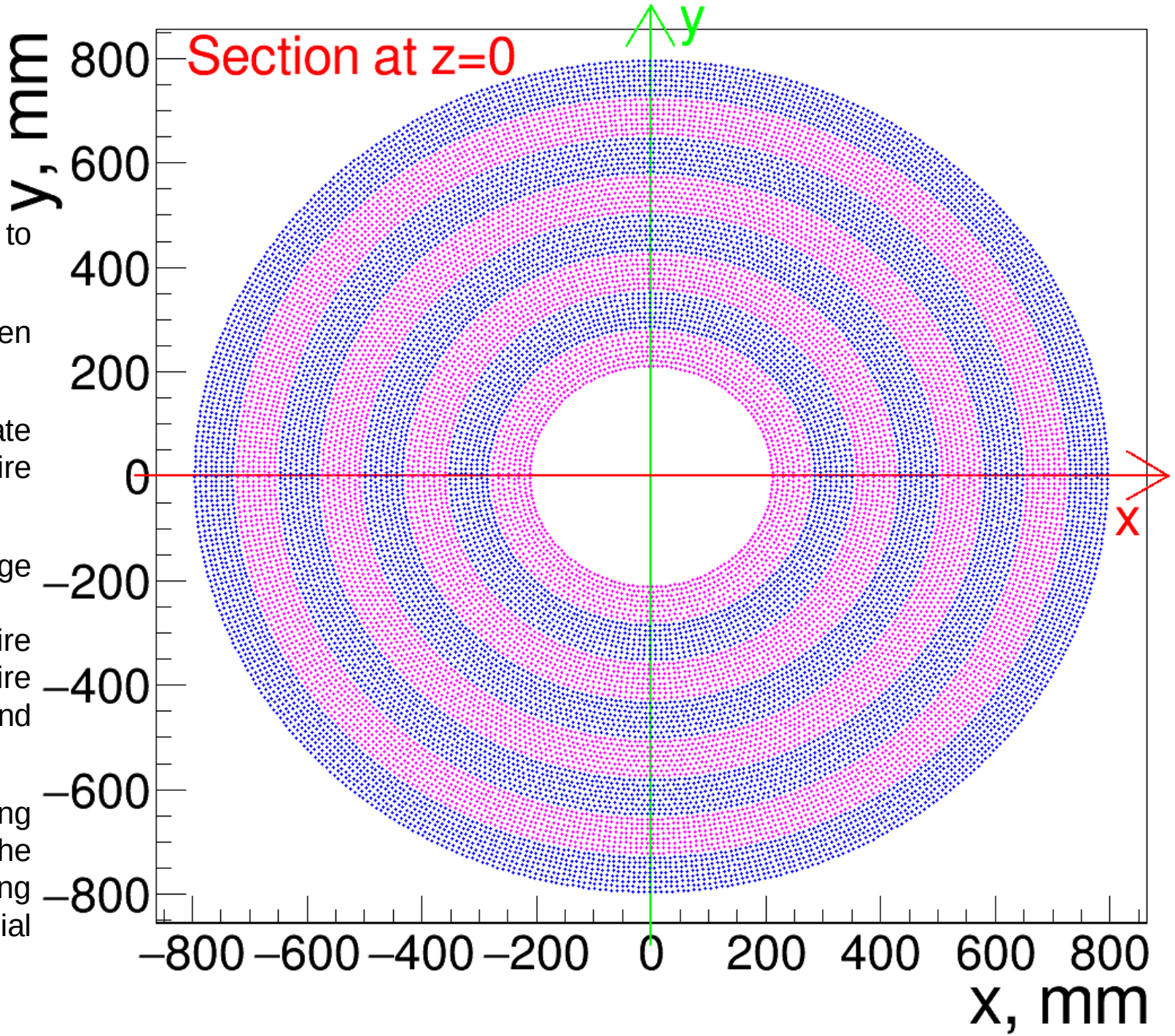
Drift Chamber Geometry





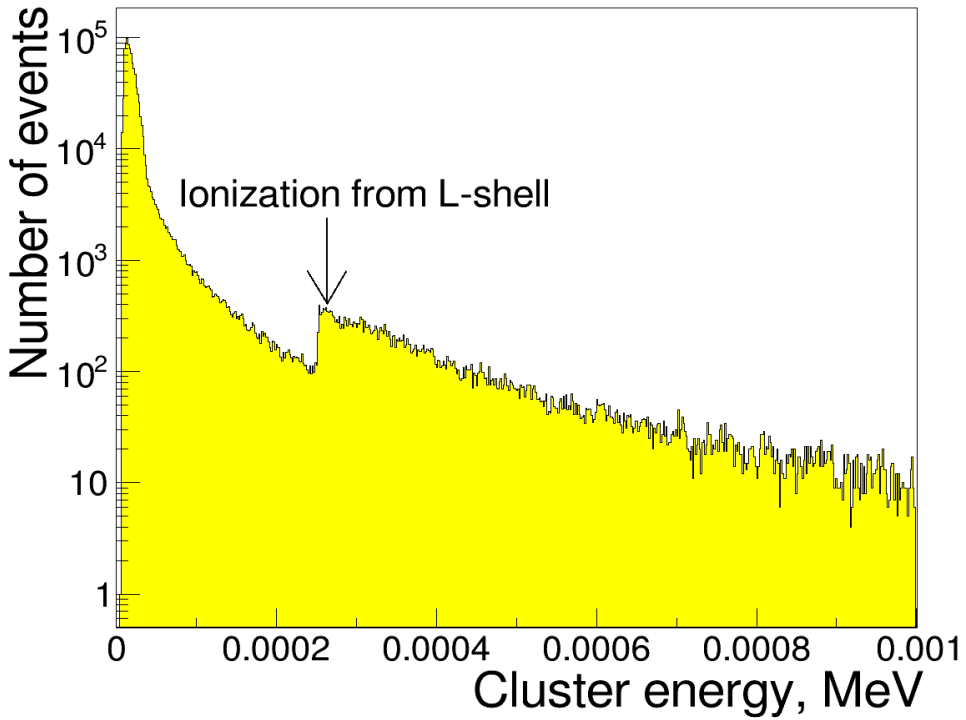
Drift Chamber Geometry

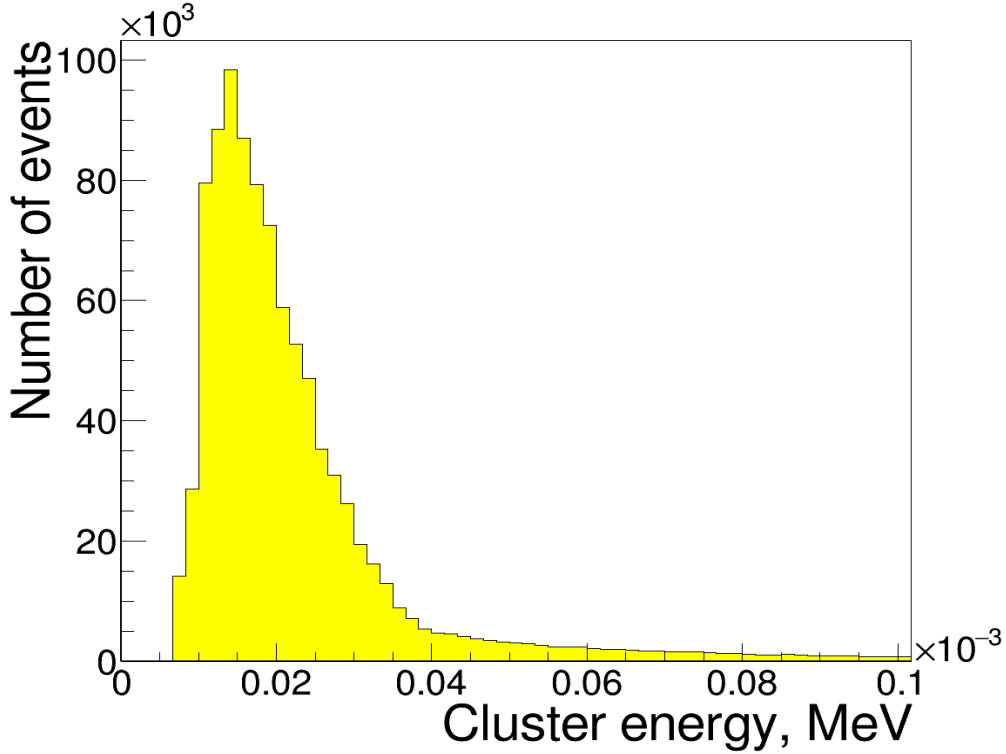
- The geometry of drift chamber is passed to **GEANT4** via the **DD4HEP** toolkit
- The material of wires is planned to be taken into account “on average”
- We do not use **DDSegmentation** to associate the **GEANT4** hits with the particular signal wire (as **FCCSW** does)
- Instead, we developed the separate package **DriftChamberFulStereoGeomGenerator**, doing all the geometry-related stuff (hit-to-wire association, translation from the lab to wire coordinate frames and back, drift time and charge division coefficients calculation etc.)
- We save the drift chamber geometry using **DD4HEP DataExtensions** and invoke the geometry whenever necessary during digitization and reconstruction via the special **Gaudi Tool**



Simulation of Ionization Clusters

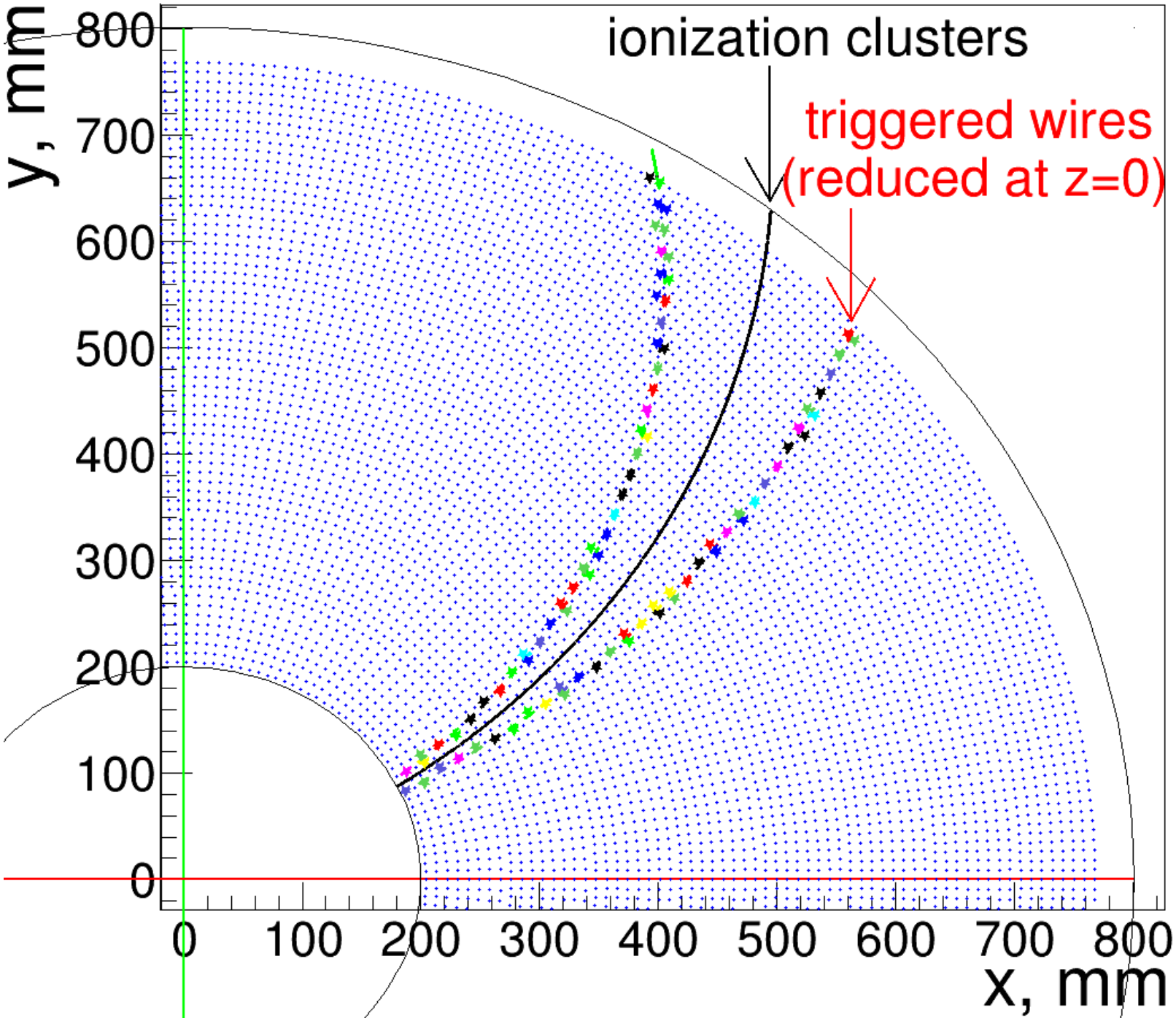
- On the *spiral* stretched between the beginning and the ending points of the GEANT4 hit (**G4Step**) we generate the ionization clusters until their total energy exhausts the hit energy
- Currently we are using the cluster energy spectrum for 80% Ar – 20% iC_4H_{10} mixture (taken from CMD-3)
- We are working to obtain the cluster energy spectrum for 90% He – 10% iC_4H_{10} mixture from Garfield++, as well as to get the distribution of the number of electrons in cluster depending on the cluster energy



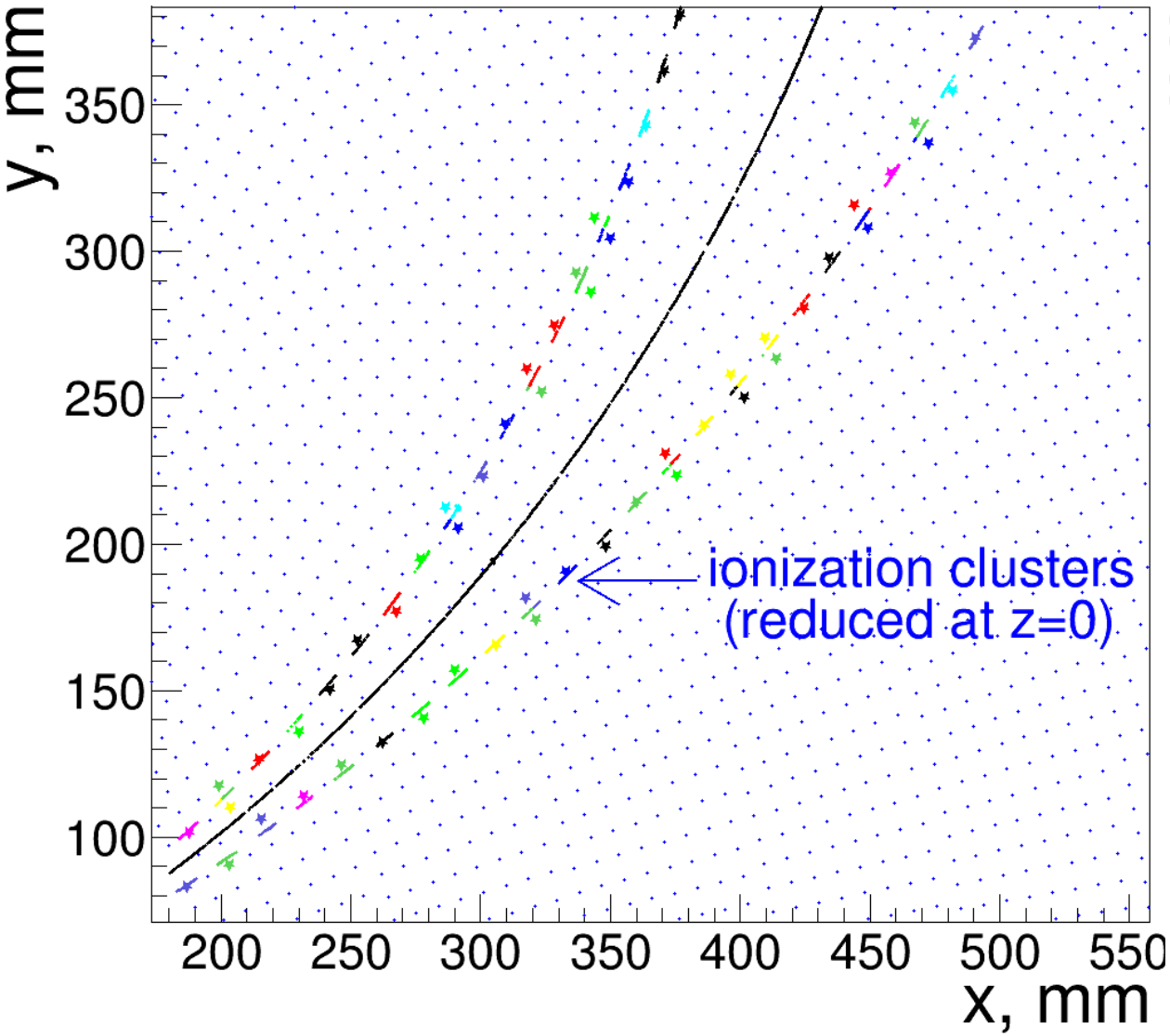


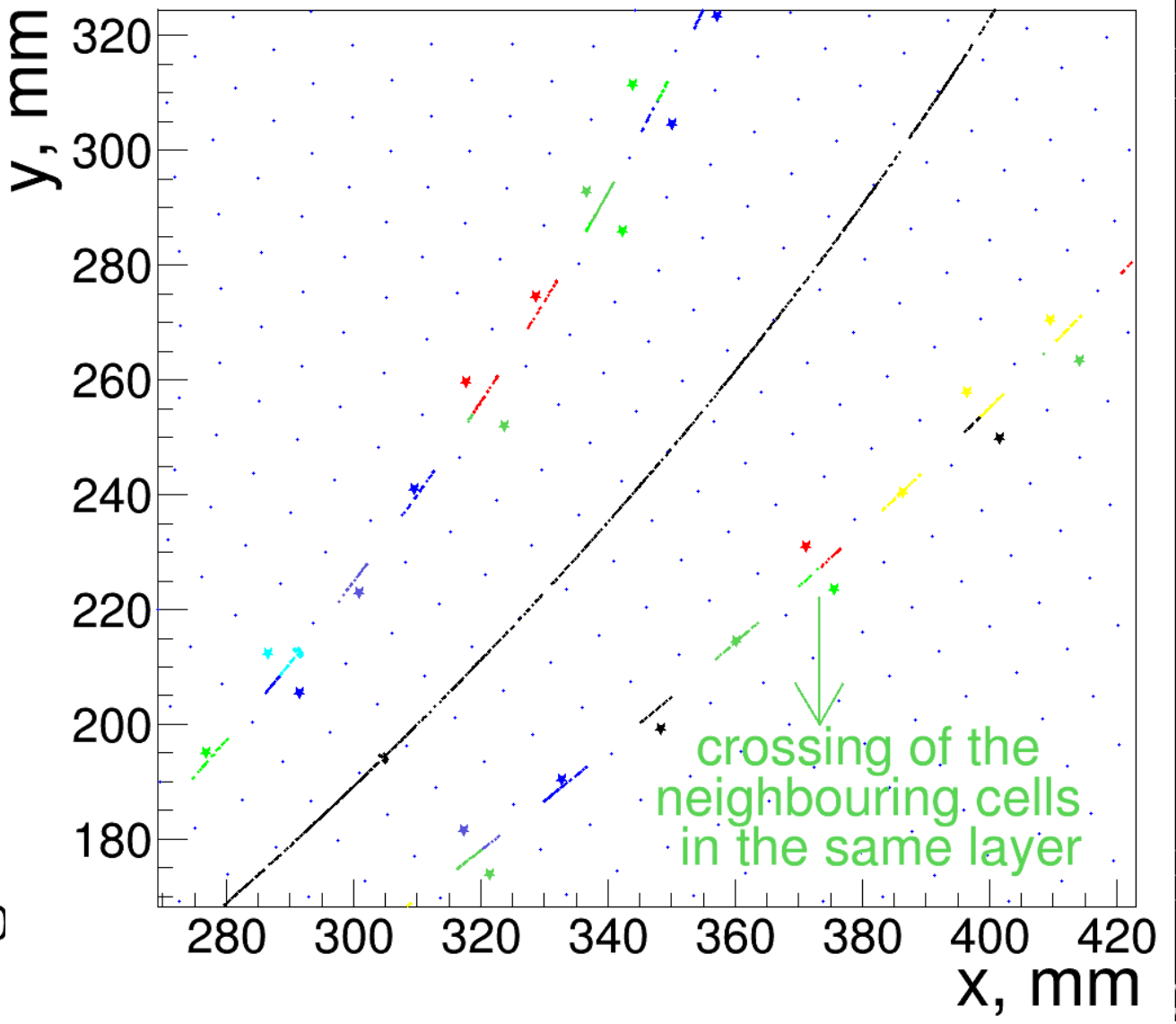
Association of Clusters with Wires

- At the first step of digitization each ionization cluster is associated with the closest signal wire
- For this purpose the reduction of cluster coordinates to the z=0 plane is performed



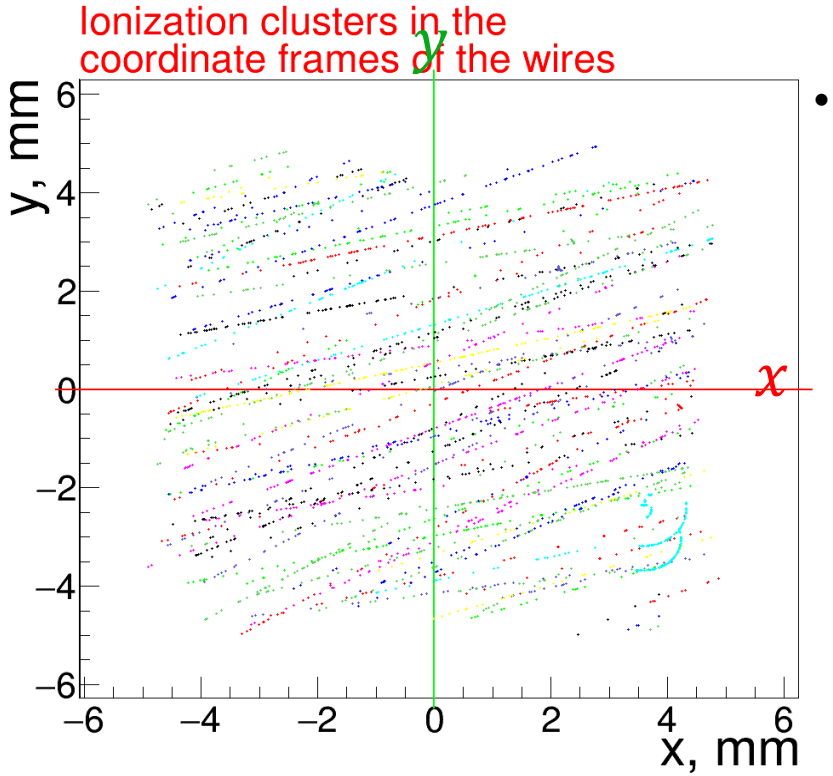
Association of Clusters with Wires



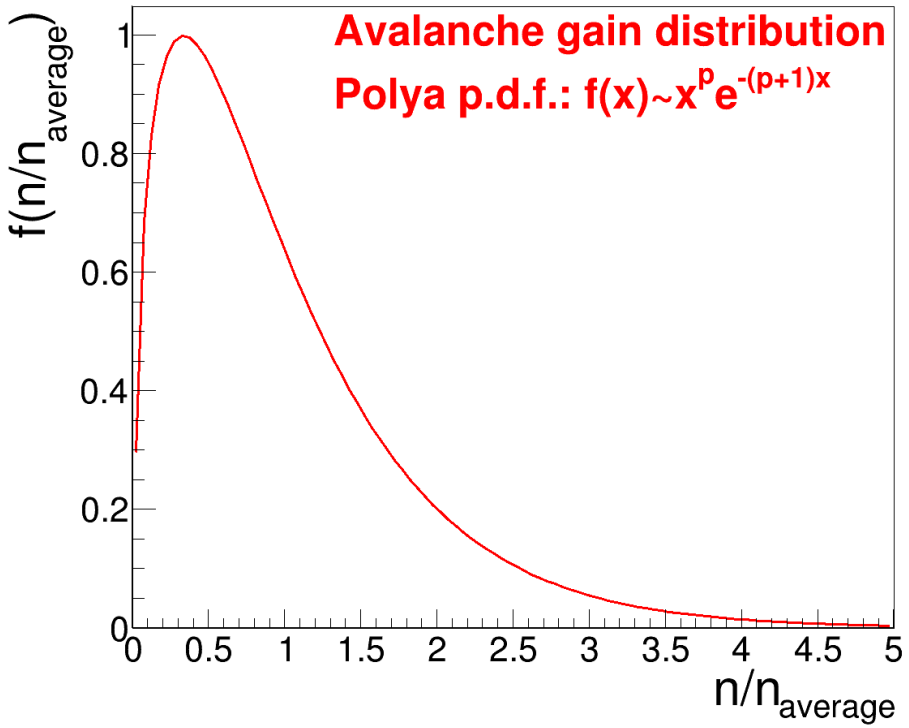


Digitization: From Clusters to Avalanches

- After the cluster-to-wire association the cluster coordinates are translated to the wire coordinate frame. The drift time, including diffusion, as well as the charge division coefficients are calculated
- Currently we use constant $v_{drift} = 2.3\ cm/\mu s$ and 2% time spread due to diffusion
- We are working to obtain from Garfield the isochrones for $10 \times 10\ \mathrm{mm}^2$ 2D square cell and are going to use them as the first approximation for all cells

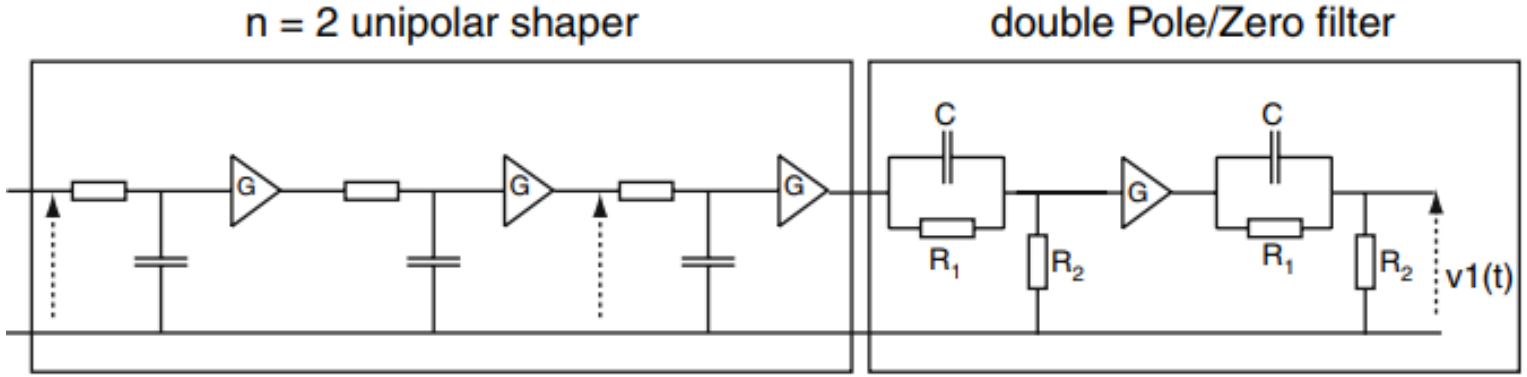


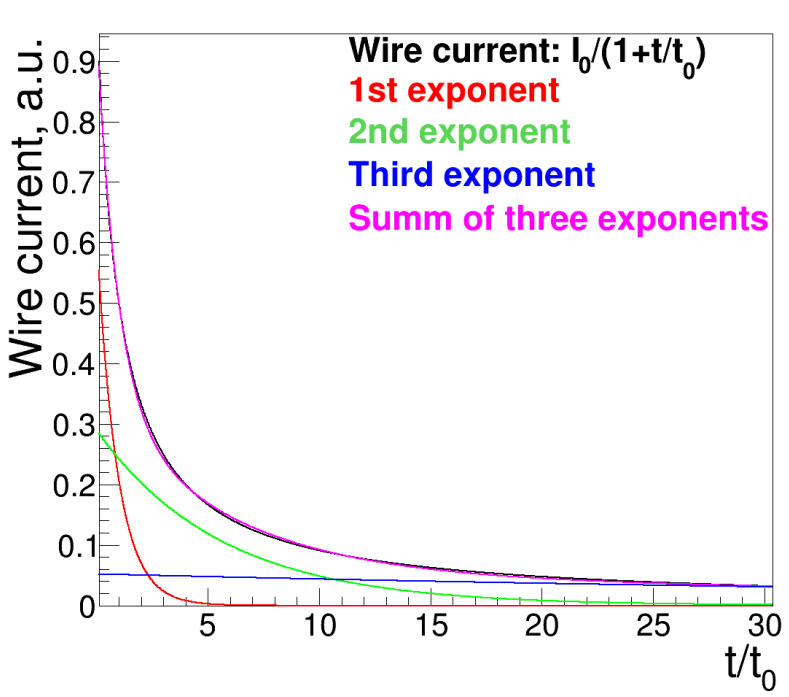
- The fluctuations of the avalanche gain are simulated according to the Polya distribution with the configurable parameter p (= 0.5 by default)

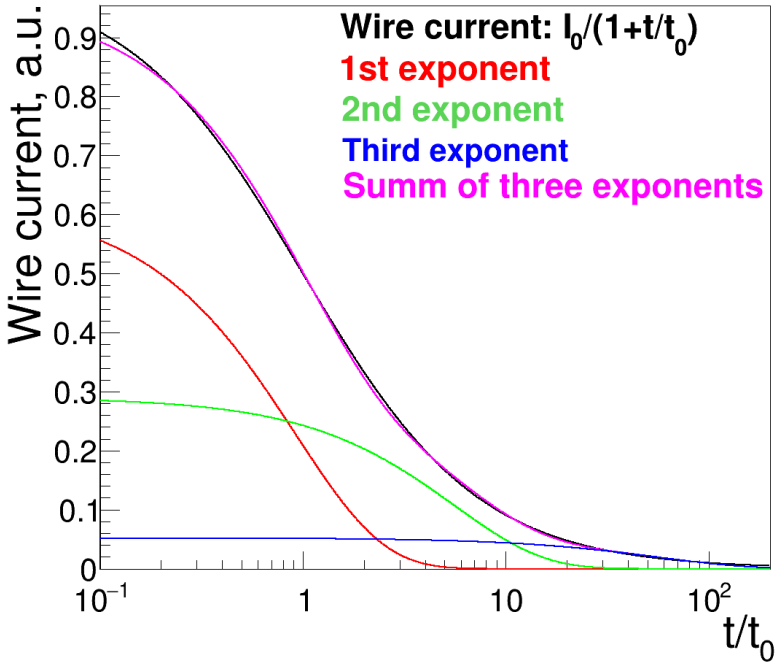


Digitization: Signal Shaping

- The wire current, induced by the flow of the ions, has the time dependence $I(t) = I(0)/(1 + t/t_0)$, where the characteristic decrease time $t_0 \sim 1$ ns is to be obtained from Garfield
- To cope with the pileup and make the cluster counting possible, the long signal tails should be suppressed/transformed. For this I use the cascade of n=4 unipolar shaper followed by the 2 pole-zero filters with the parameters, taken from the book of *L. Rolandi, W. Riegler, W. Blum „Particle Detection with Drift Chambers”*
- The wire current is approximated by the sum of three (or more) exponents, and the parameters of pole-zero filters are tuned to shorten the fall time of the slowly falling exponents

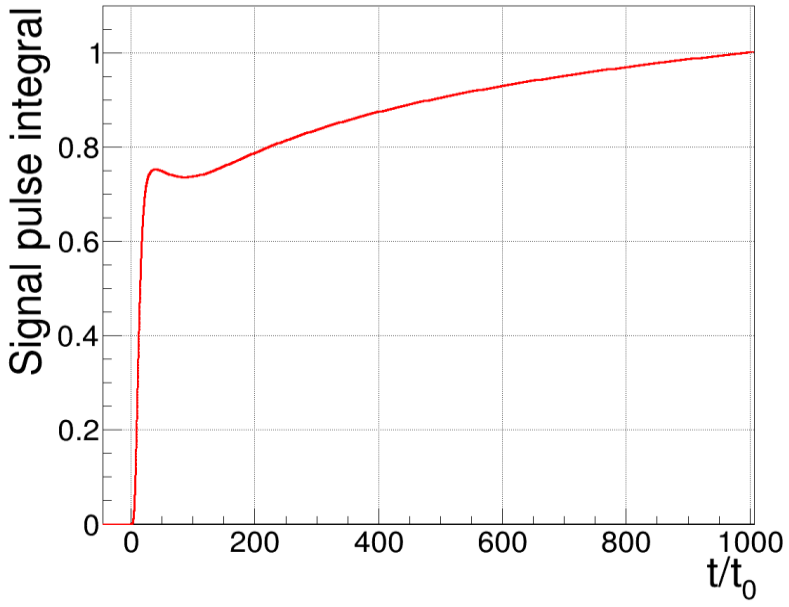


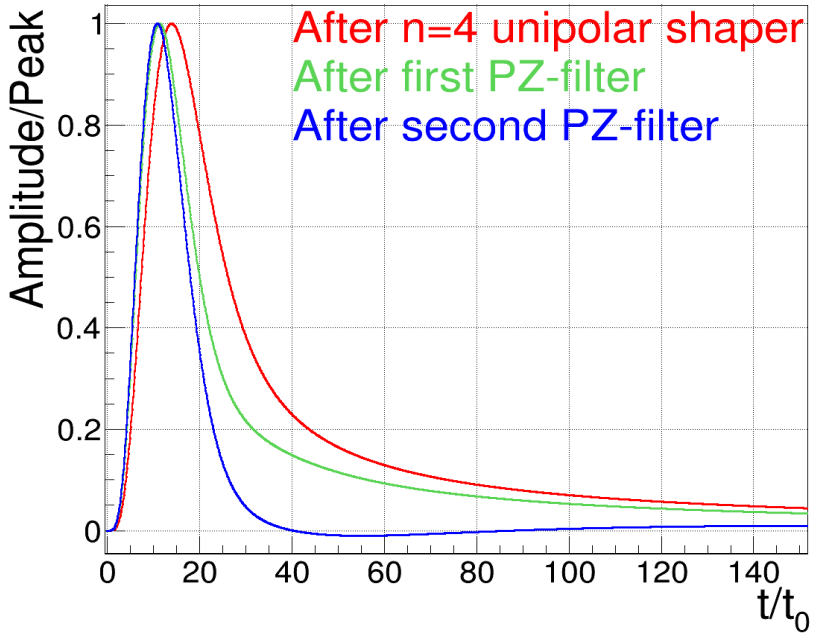


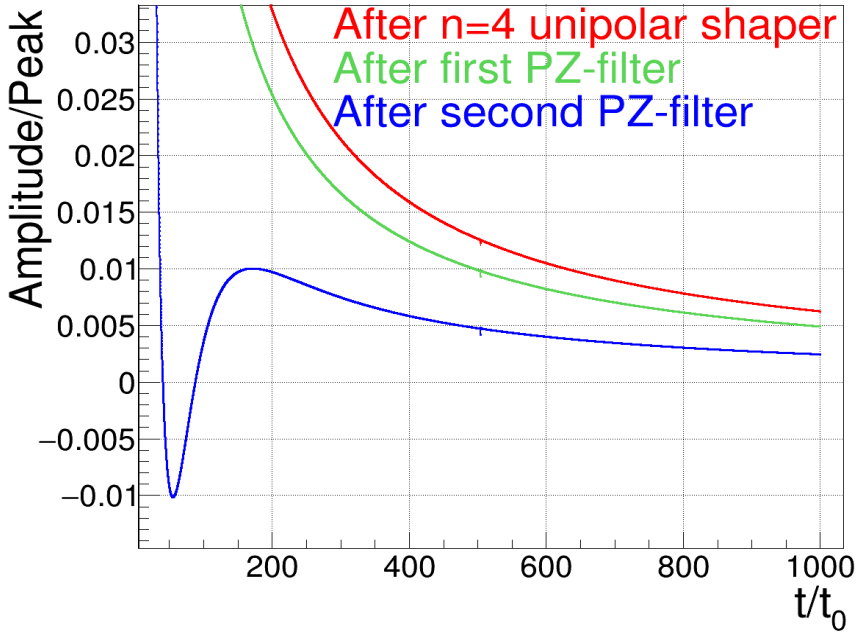


Signal Shaping

- The resulting signal peak has the duration of ~40 ns and is followed by the -1% undershoot and a very long <+1% tail
- The tail contains ~20% of signal charge, if integrated up to 1000 t_0
- In the presence of many ionization clusters the pedestal shift is prominent







from *L. Rolandi et. al.:*

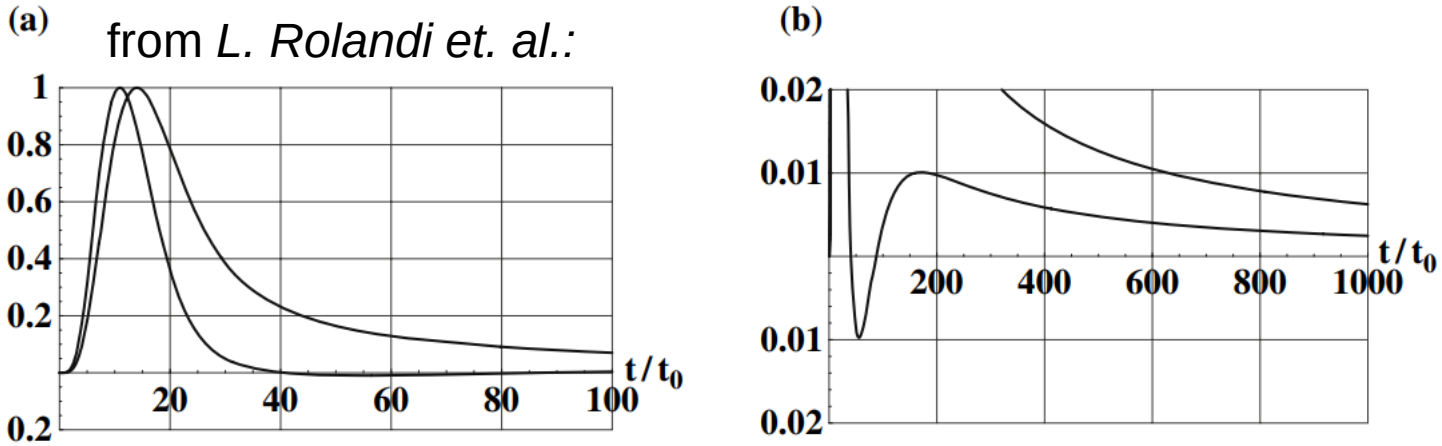


Fig. 6.19 (**a**) Wire chamber signal processed by a unipolar shaper of $n = 4$ and $t_p/t_0 = 10$ together with the same signal filtered by of two pole-zero filters. The pulse width is reduced to a length of $T \simeq 40t_0$. (**b**) The same signal on a smaller vertical scale, showing a tail with a height corresponding to about 1% of the chamber signal

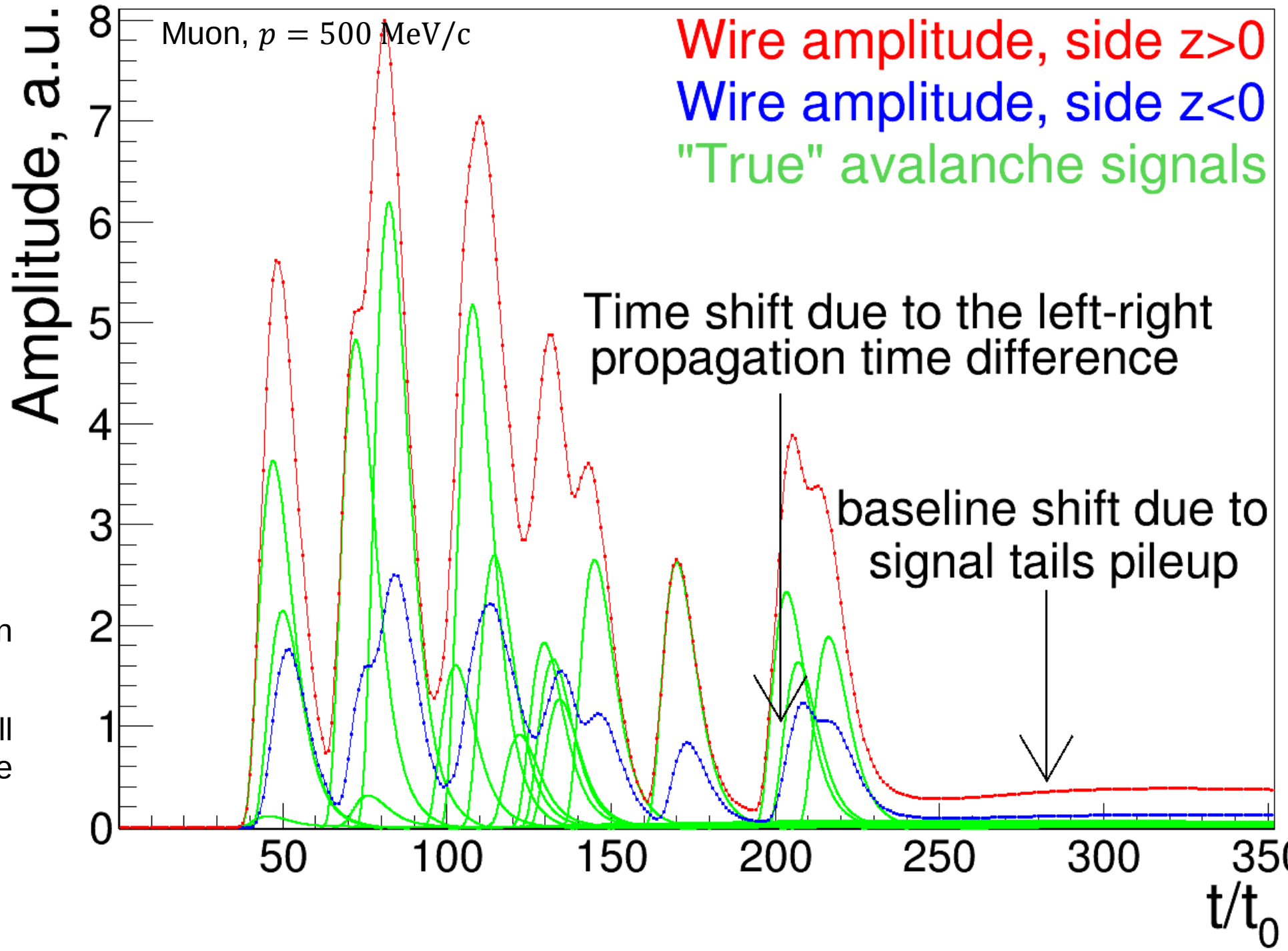
2 variants of digitization

- We created two variants of digitization:

1) 1-2 GHz waveform scan (for cluster counting)

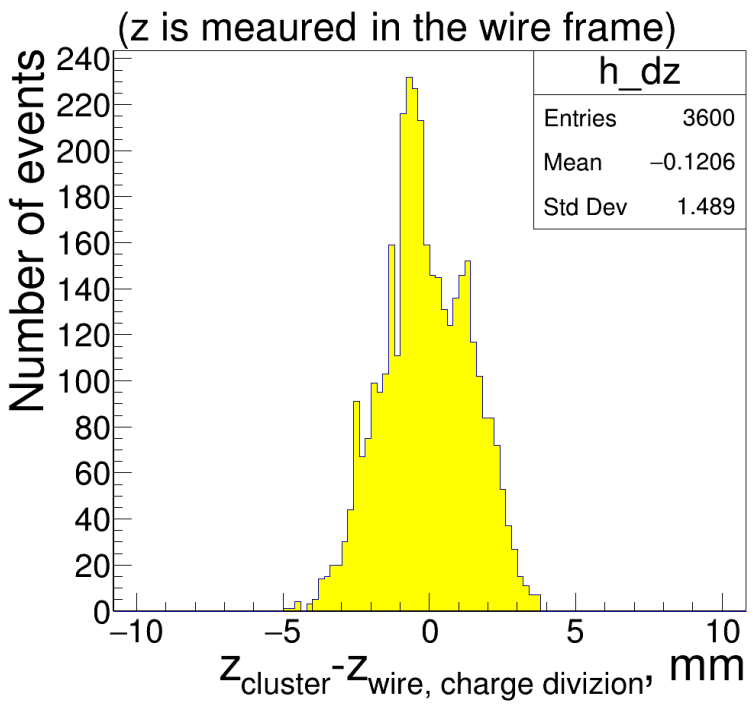
2) Digitizer with simple charge integration, starting from the discriminator threshold crossing

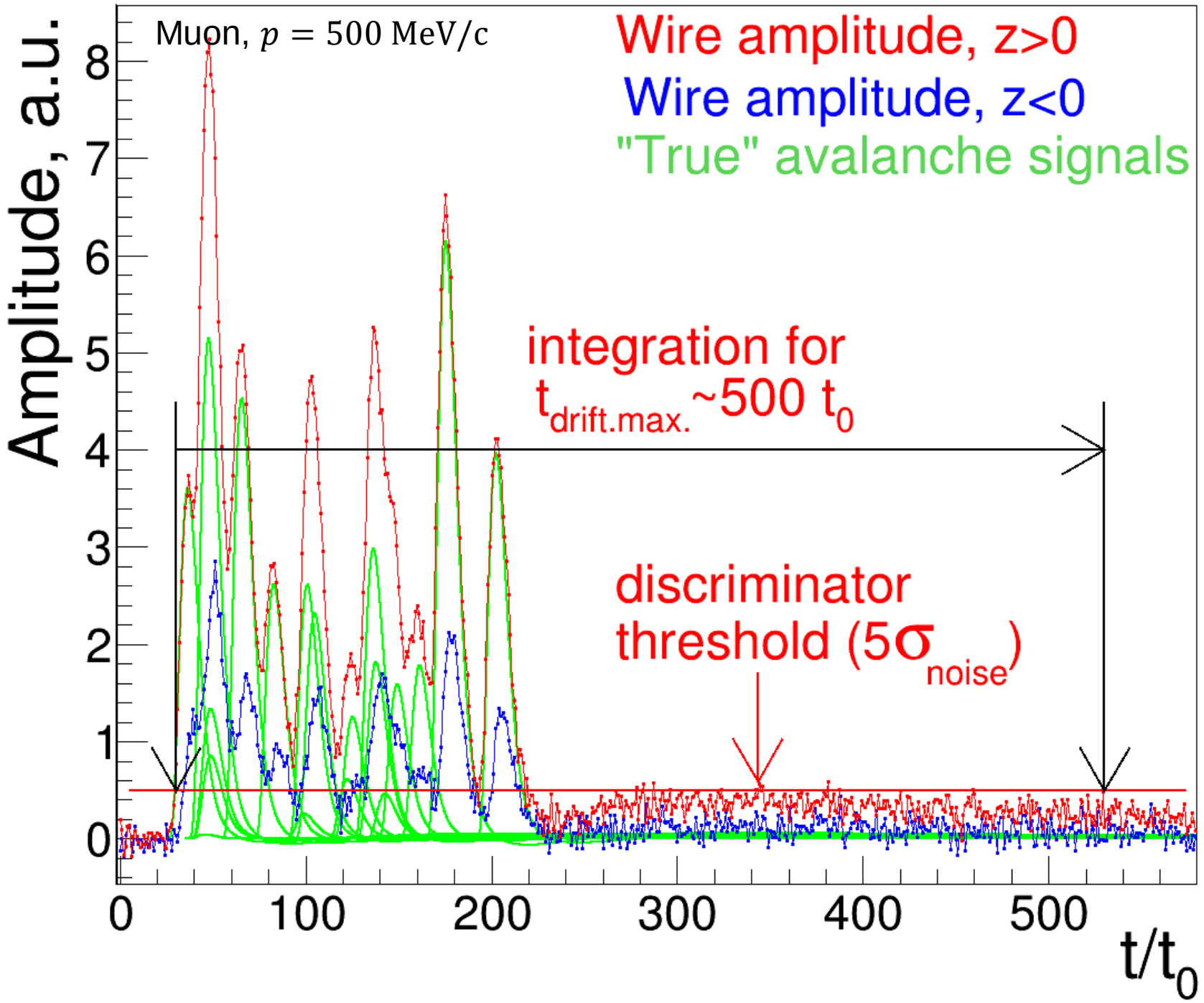
- The signal shape is taken the same in both cases
- At first we plan to go all the way with the simple charge integration option



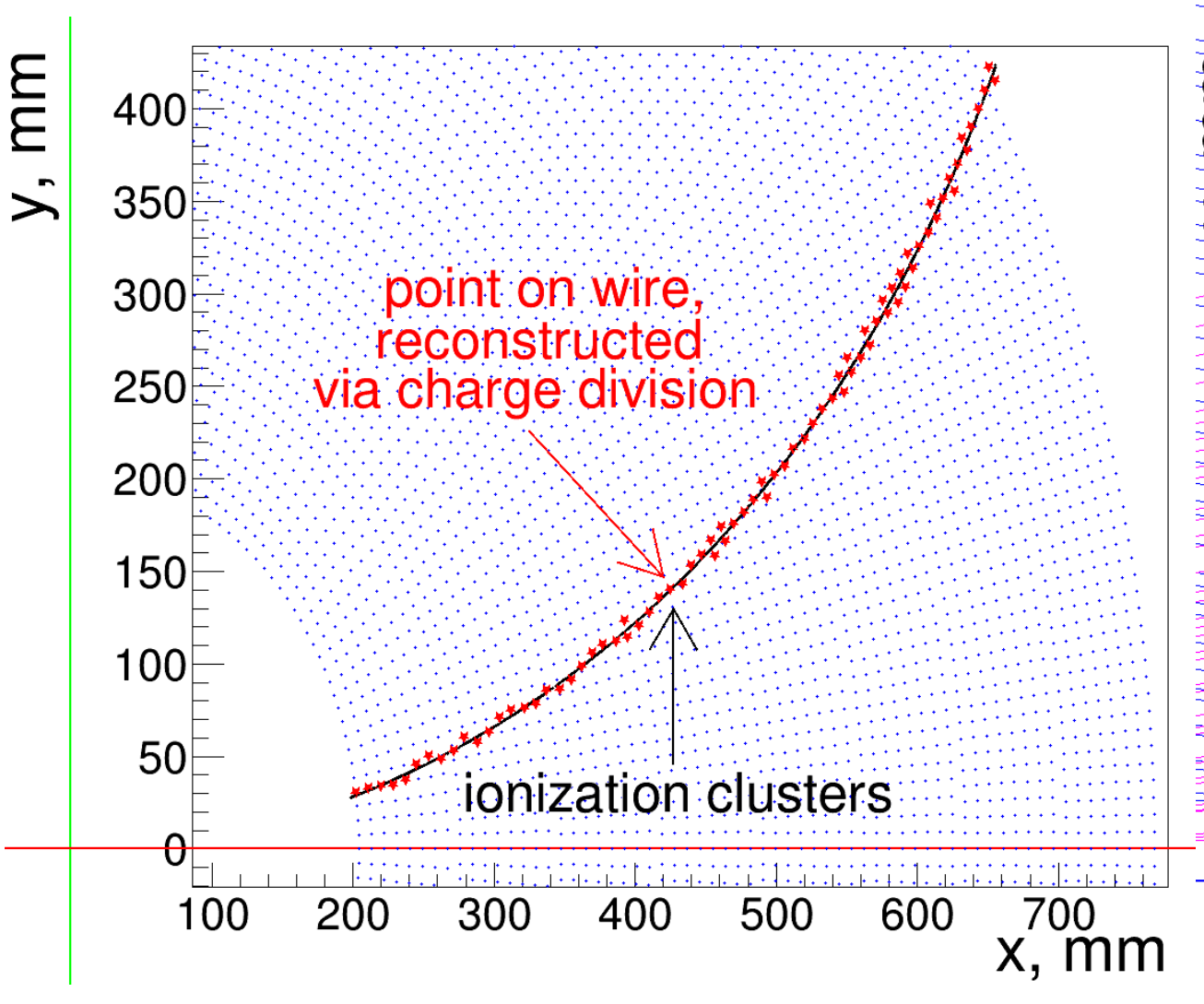
Digitization: Simple Charge Integration

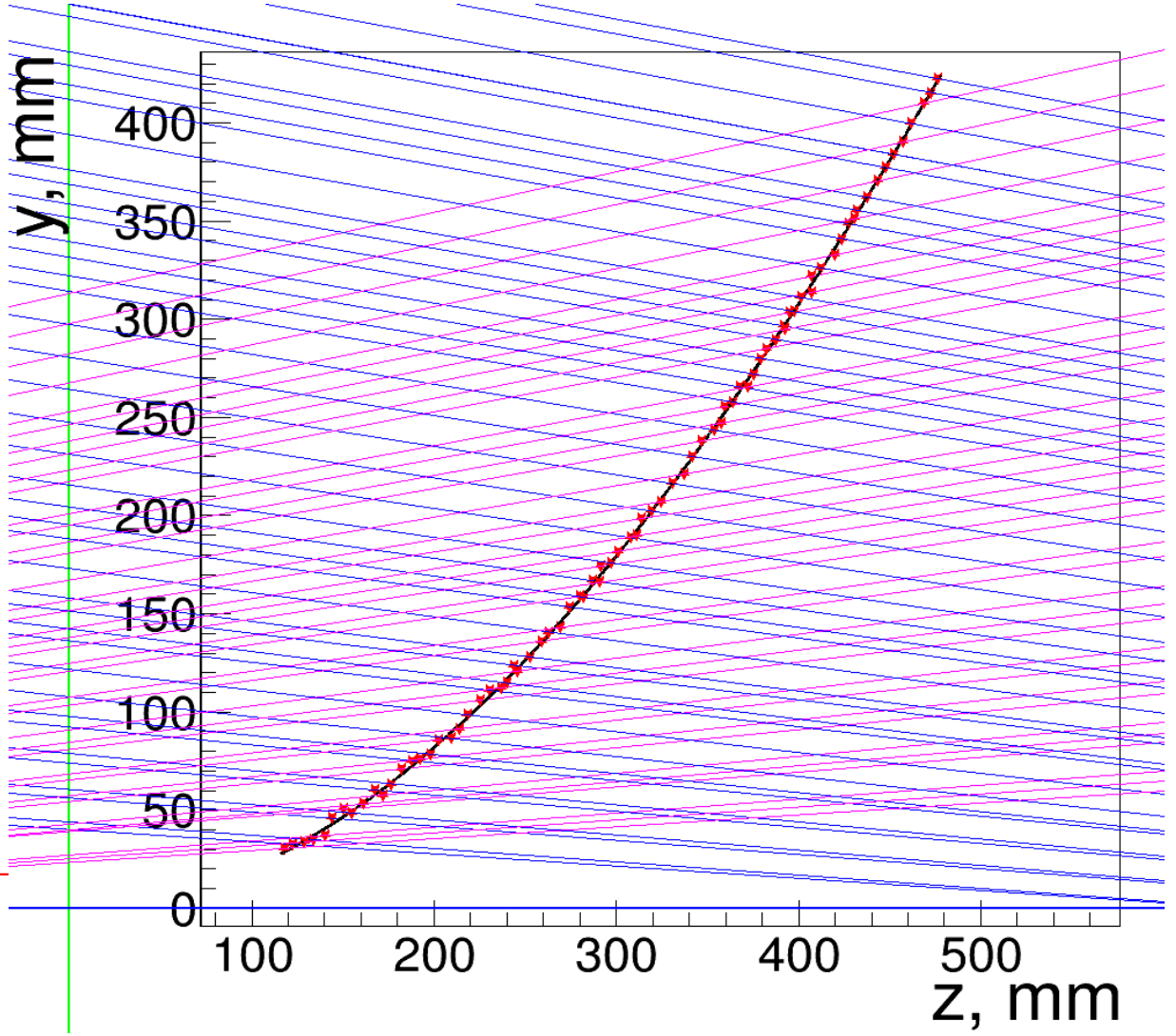
- z – coordinate of the hit on wire is reconstructed via the charge division formula, taking by default $R_{in,amplifier} = 75\ \Omega$, $\rho_{wire} = 1.5\ \Omega/\mathrm{mm}$





Reconstructing the wire hit via charge division formula





Plans

- From Garfield++ we plan to get:

1) The cluster energy spectrum for 90% He – 10% iC_4H_{10} and the distribution of number of electrons in cluster depending on the cluster energy (for different particle types)
2) The shape of the wire current and characteristic time t_0
3) The isochrones, diffusion and attachment coefficients for the $10 \times 10\ \mathrm{mm}^2$ 2D square cell (to be used as the first approximation for all cells)

- Single track fit using ACTS

→ **by the end of 2020**

- Develop the algorithm of track finding (the Italian colleagues are welcome to share with us the KLOE/KLOE2 experience on this)
- Write a memo/diploma

→ **first half of 2021**

- Vertex reconstruction
- Kinematic fit with TPC & Calorimeter
- Wave form analysis, cluster counting & cluster timing ?

→ **???**