RD51 Collaboration Meeting

An update on the modelling of signal formation in detectors with resistive elements.

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Introduction

We want to use Garfield++ and COMSOL to model the signal formation in detectors with resistive elements.

Outline:

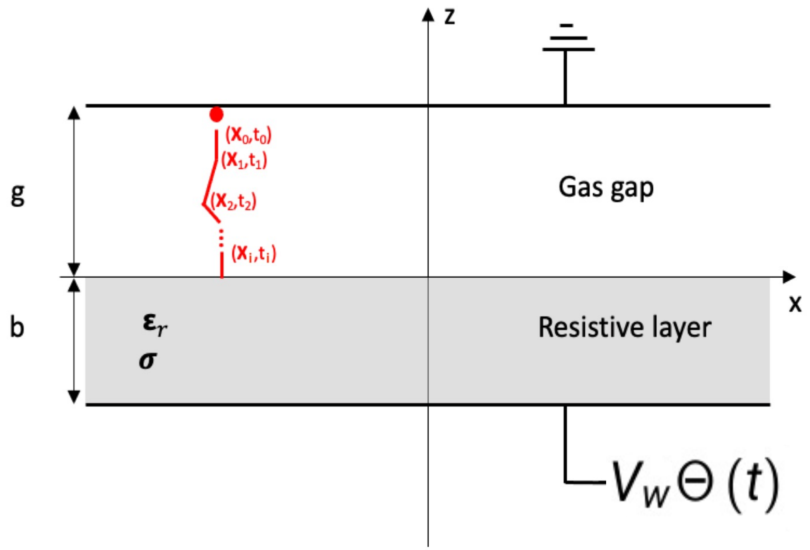
- Components of the dynamical weighting potential
- Simulating a MRPC
- Signal formation in an AC-coupled LGAD
- Signal formation in a MicroCAT readout structure
- Summary

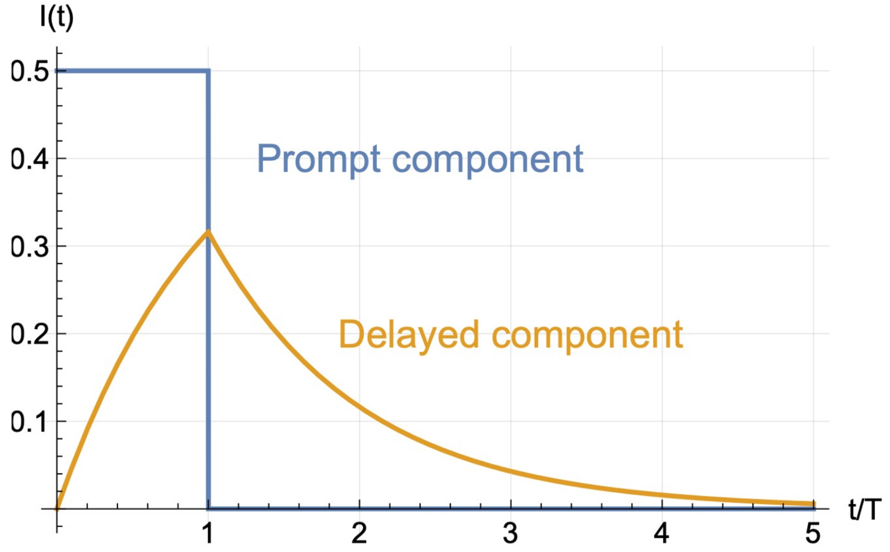
Garfield++: https://garfieldpp.web.cern.ch/garfieldpp/
COMSOL Multiphysics: https://www.comsol.ch

Components of the dynamical weighting potential

The time-dependent weighting potential is a superposition of a static *prompt* and a dynamic *delayed* component.

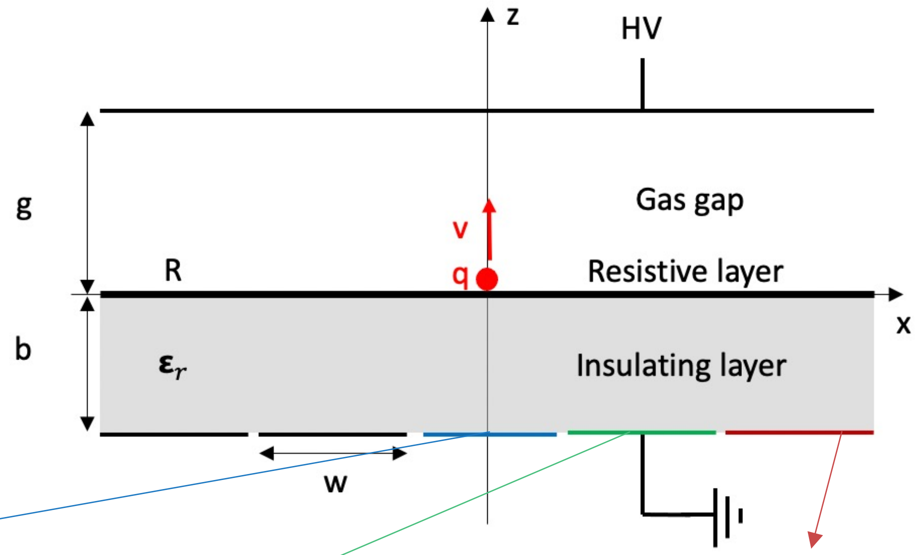
The prompt component of your signal is the instantaneous induction of current on the electrode source by the movement of the charge carrier.





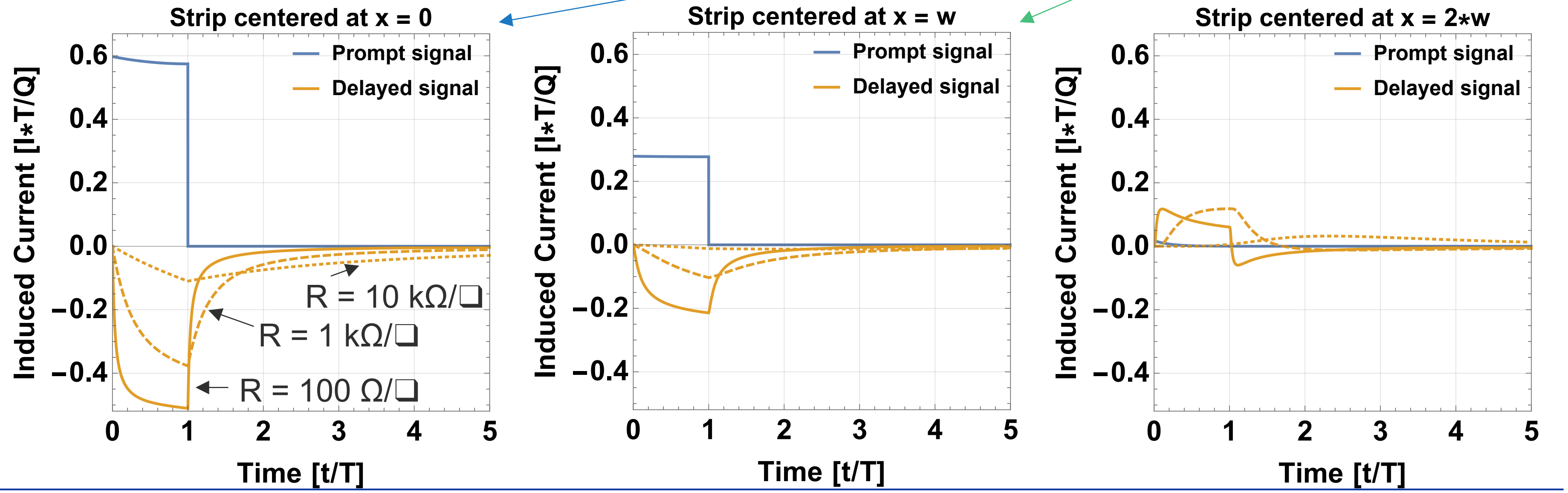
Components of the dynamical weighting potential

The **delayed component** **of your signal encodes the responds of the resistive material to the field lines of this charge carrier.**



Let us take a simple geometry to get an intuition:

- g = 50 µm
- b = 5 µm
- w = 200 µm
- T = g/v = 0.4 ns

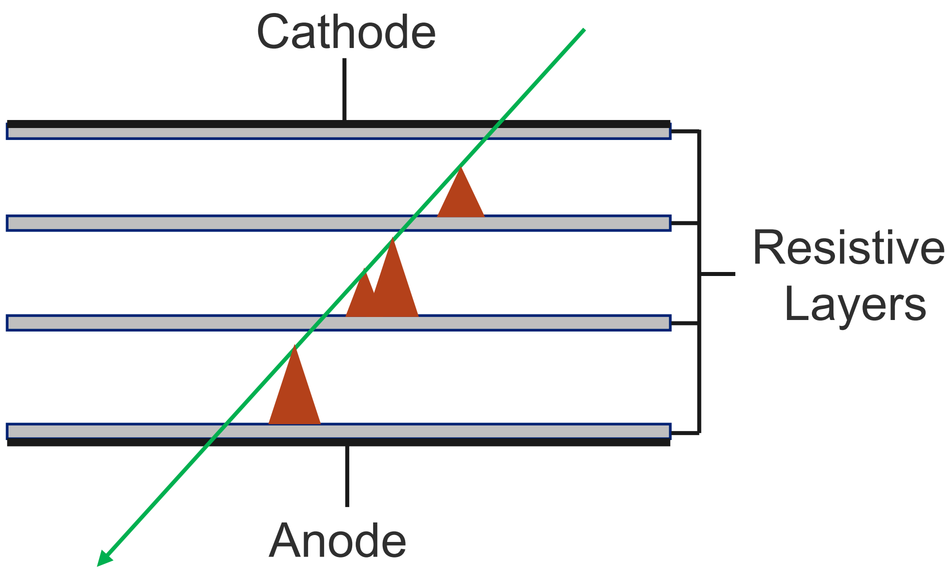


Simulating a MRPC

In order to relatively efficiently simulate a MRPC two separate questions ought to be addressed:

- A grid-based Monte Carlo simulation for the avalanche dynamics

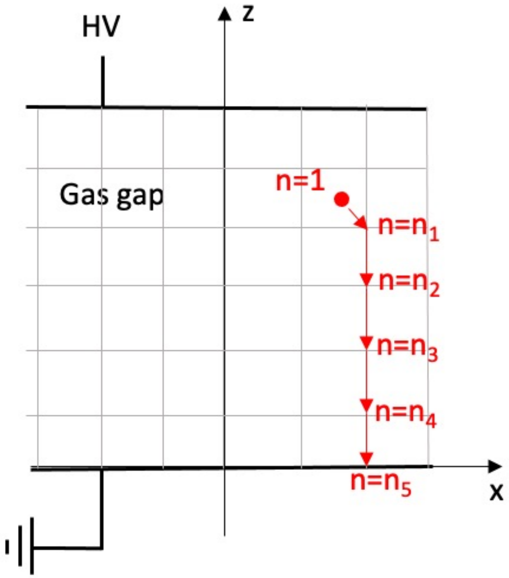
- The weighting potential of the readout electrodes.

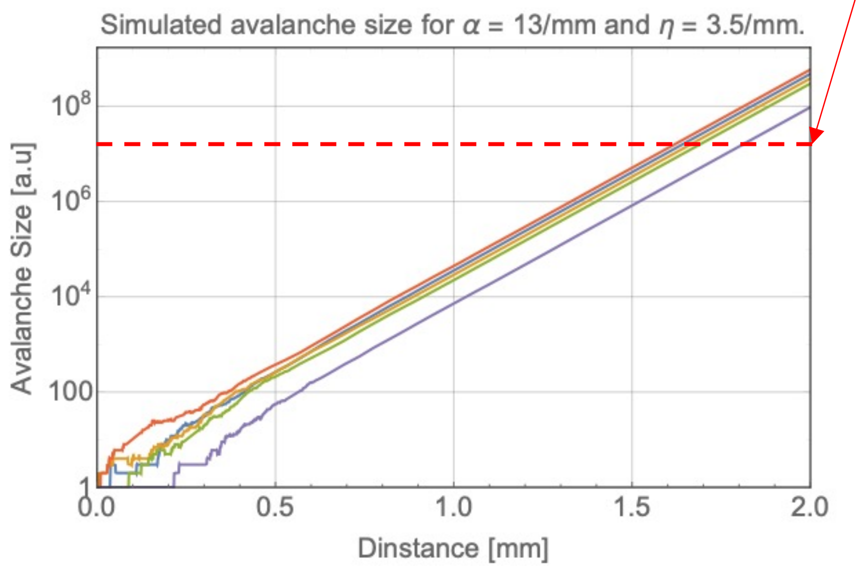


Grid-based avalanche dynamics calculations

When propagating electrons though notes of a lattice, the growth in its resulting effective Townsend avalanche can be done using a simple Monte Carlo method.

Due to space-charge effects there is a suppression of avalanche growth. → Saturation at 1.6*10^7 electrons.



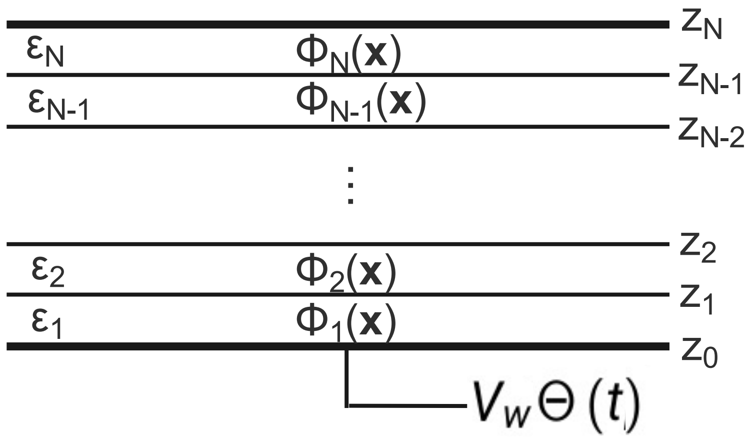


W. Riegler and C. Lippmann and R. Veenhof, Nucl. Instrum. Meth. A (2003).

Weighting potentials in a MRPC

On the question of the weighting potential: for a strip of width w_x centered at the origin when $z_{m-1} < z < z_m$ it is:

$$\phi_m(x,z) = \frac{2V_w}{\pi}\int_0^\infty \cos(kx)\sin\left(\frac{kw_x}{2}\right)\frac{h_m(k,z)}{k}dk\ .$$



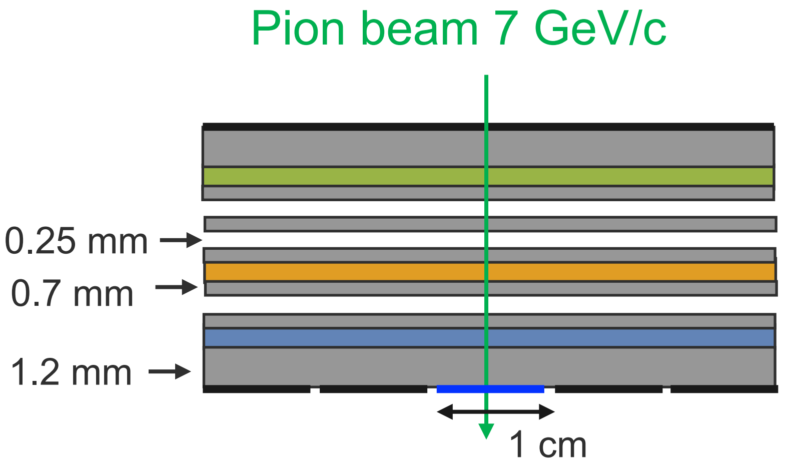
In the case of a readout plane the solution is:

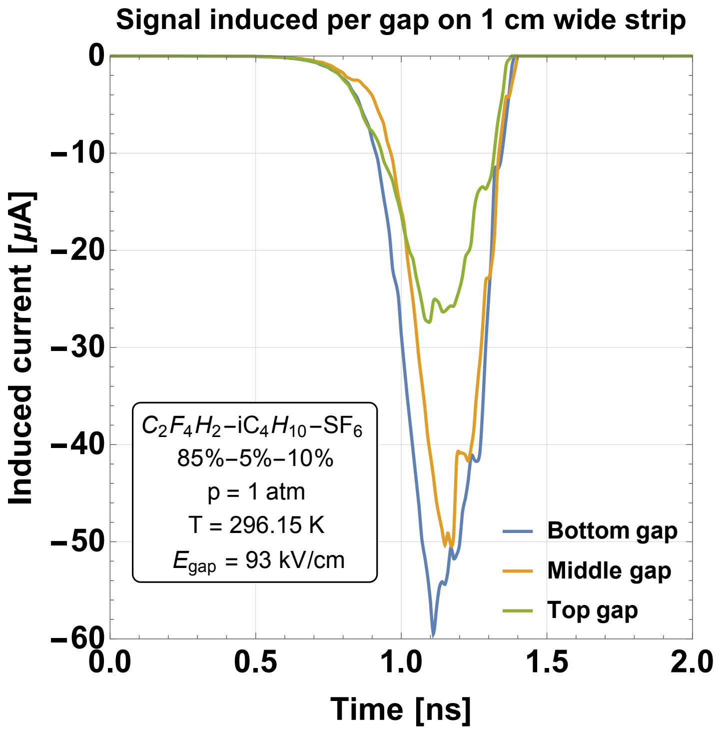
$$\phi_m(z) = V_w - \frac{V_w}{\sum_{l=1}^{N}\frac{z_l - z_{l-1}}{\varepsilon_l}}\left(\frac{z - z_{m-1}}{\varepsilon_m} + \sum_{n=1}^{m-1}\frac{z_n - z_{n-1}}{\varepsilon_n}\right)\ .$$

Strip width and the contributions of layers

In general, a readout strip's signal will not be comprised equally from that induced by each layer.

This is imbalance will decrease when the strip's width increases.





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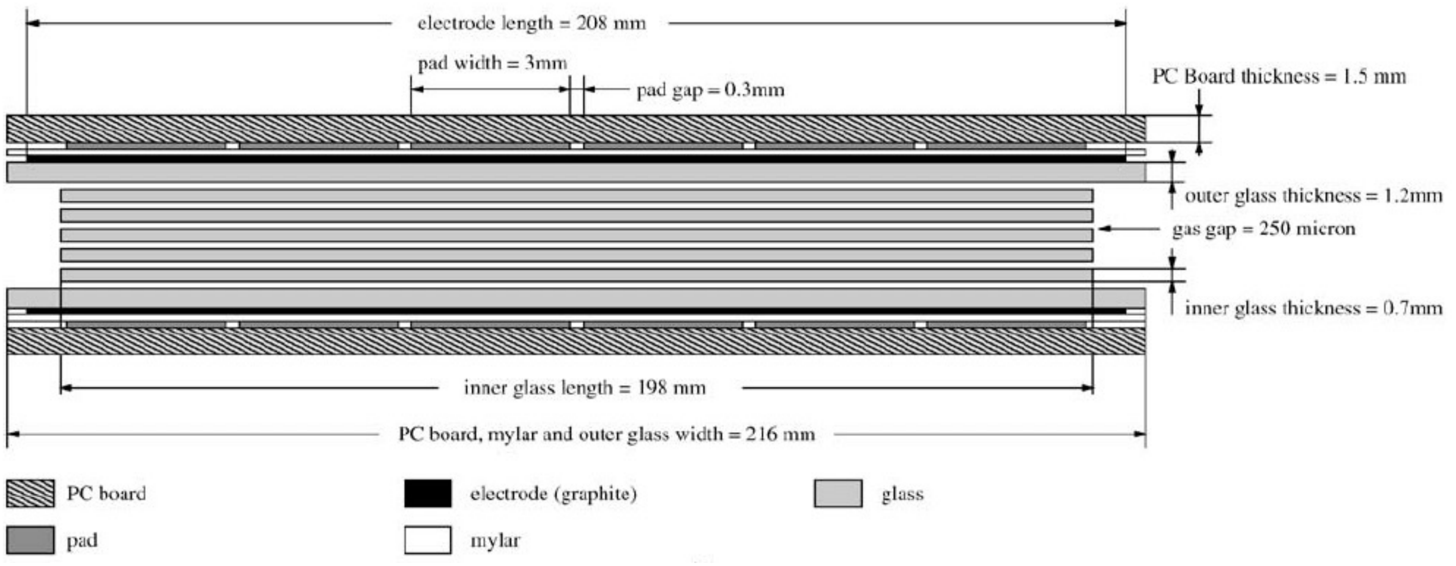
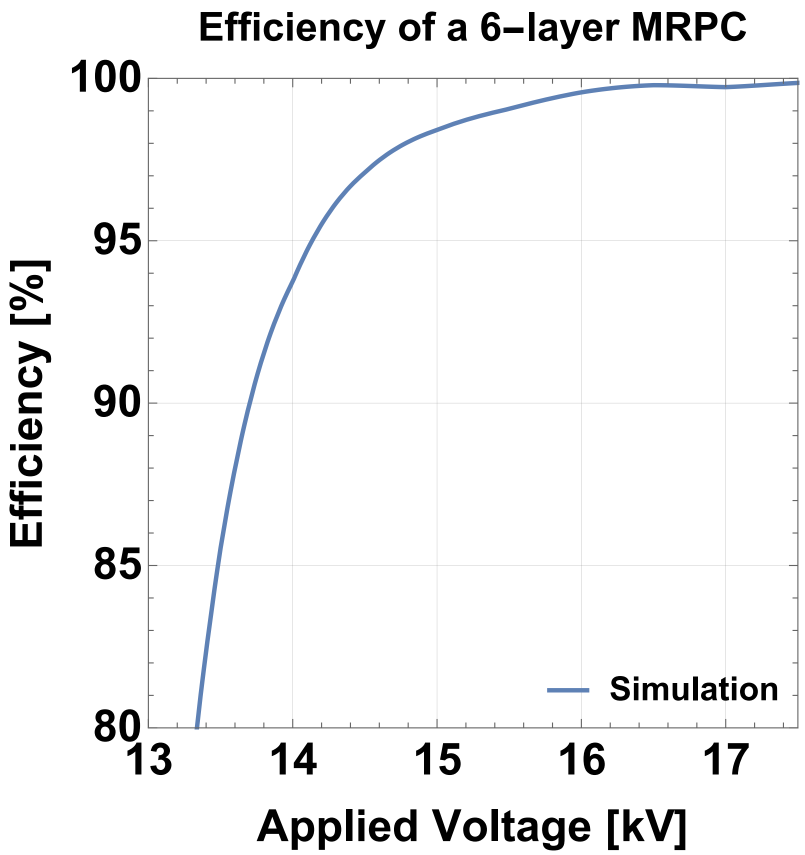
Preliminary

Next step: benchmark the simulations

We will do a first comparison of the efficiency and time to measurements taken with a MRPC

Here a discriminator threshold of 30 fC is assumed.





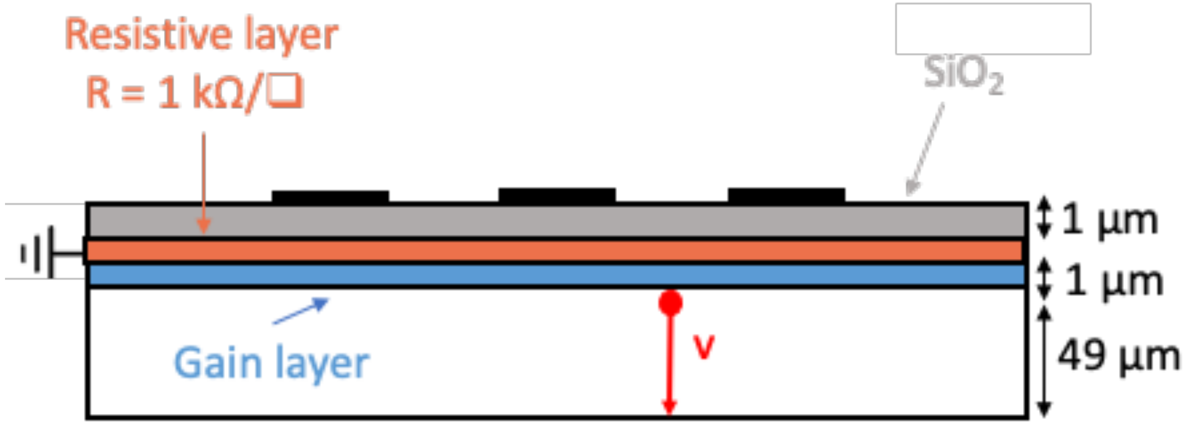
M. Shao, et al., Nucl. Instr. and Meth. A: Vol. 492, Issue 3 (2002) 344

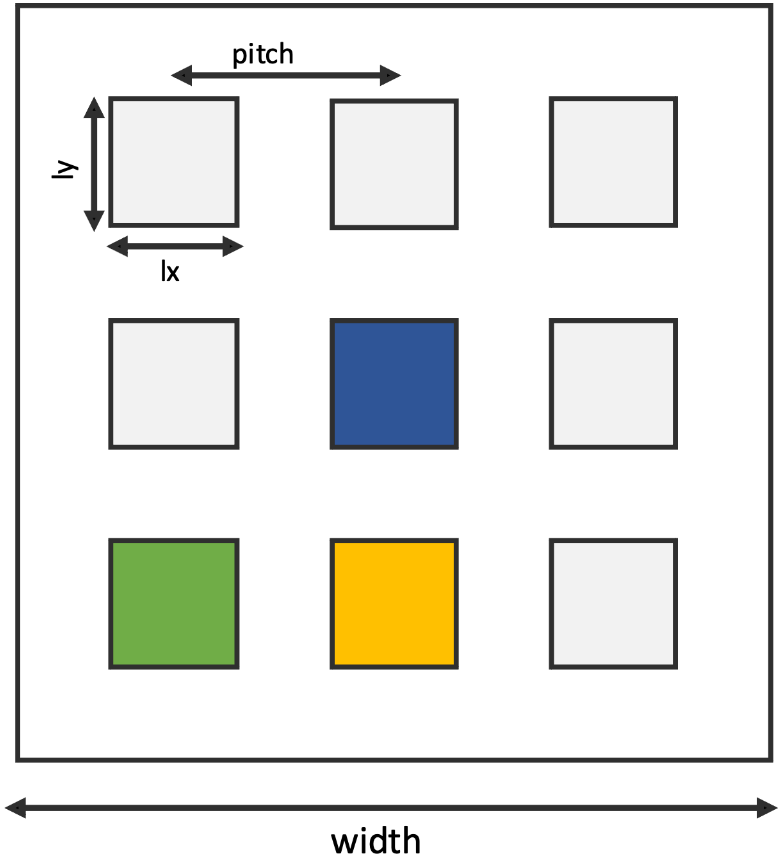
Preliminary

Weighting potential for AC-coupled LGAD

Using COMSOL the dynamic weighting potential can be calculated for the AC-coupled LGAD's readout system.

This has been done for five different geometries.

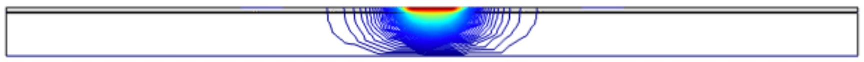




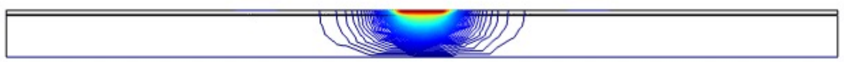
Evaluating signals for a 100-200 geometry

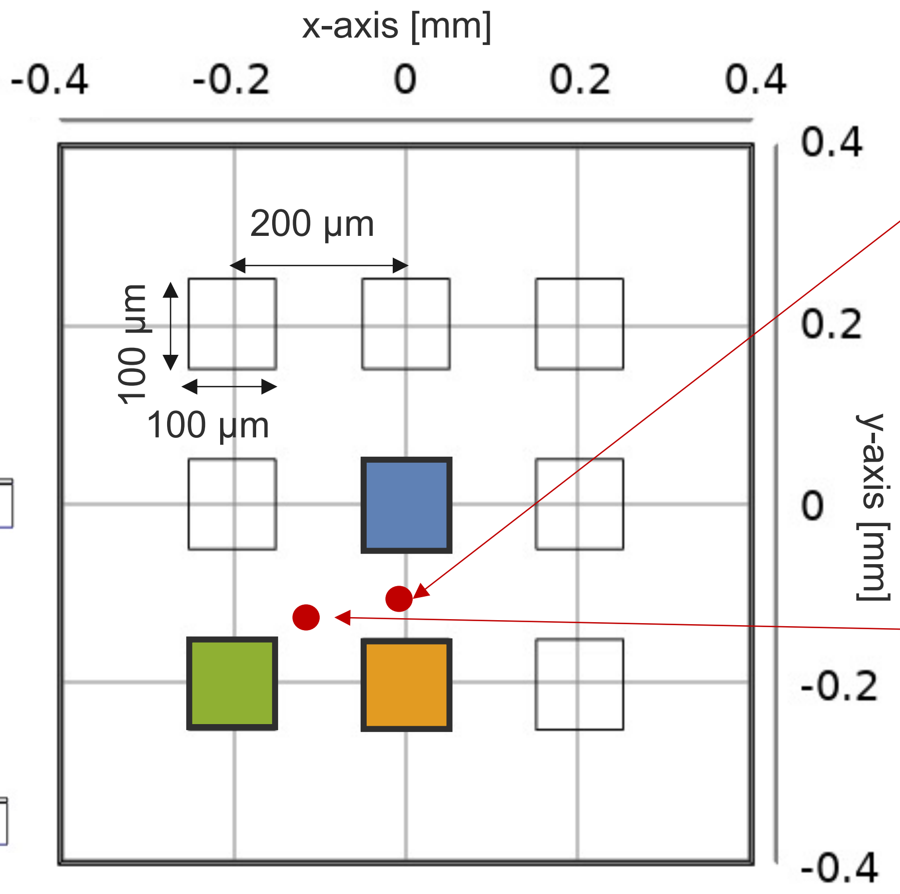
To understand the roll that the prompt component plays in this signal one can look at the central pad on the bottom row.

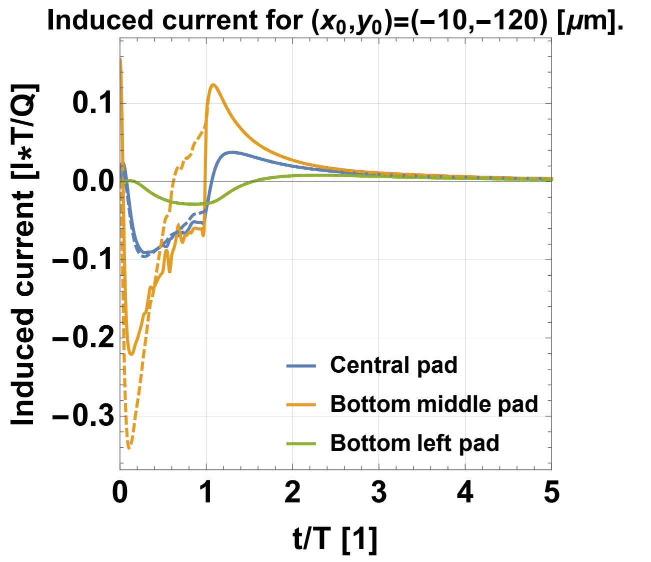
Prompt weighting potential:

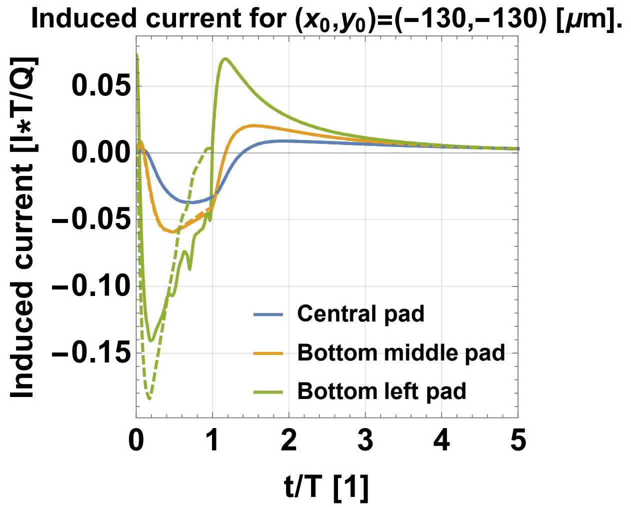


Full weighting potential:









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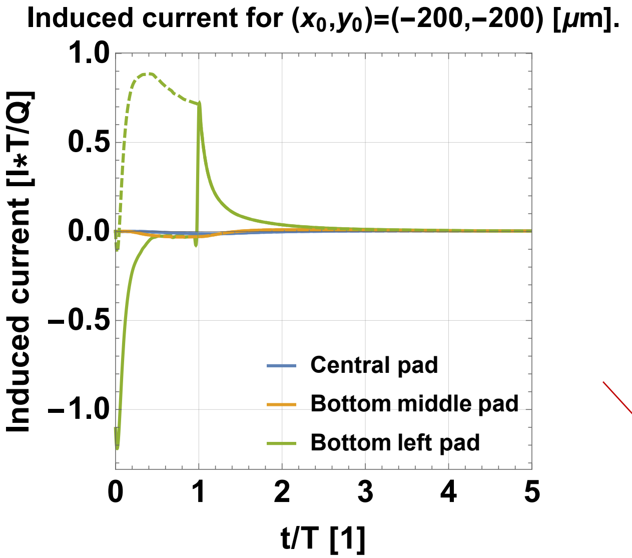
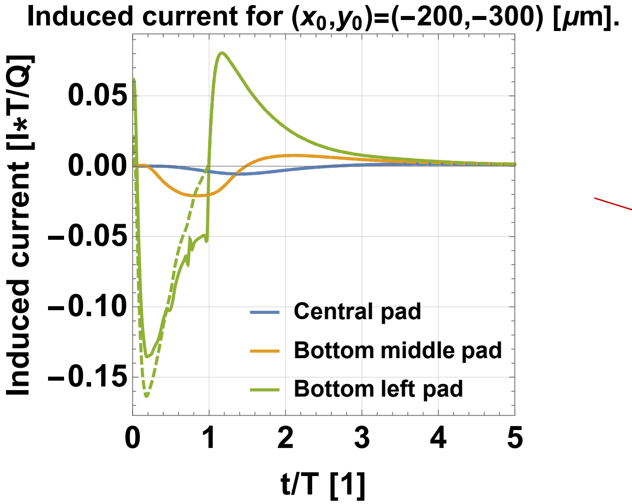
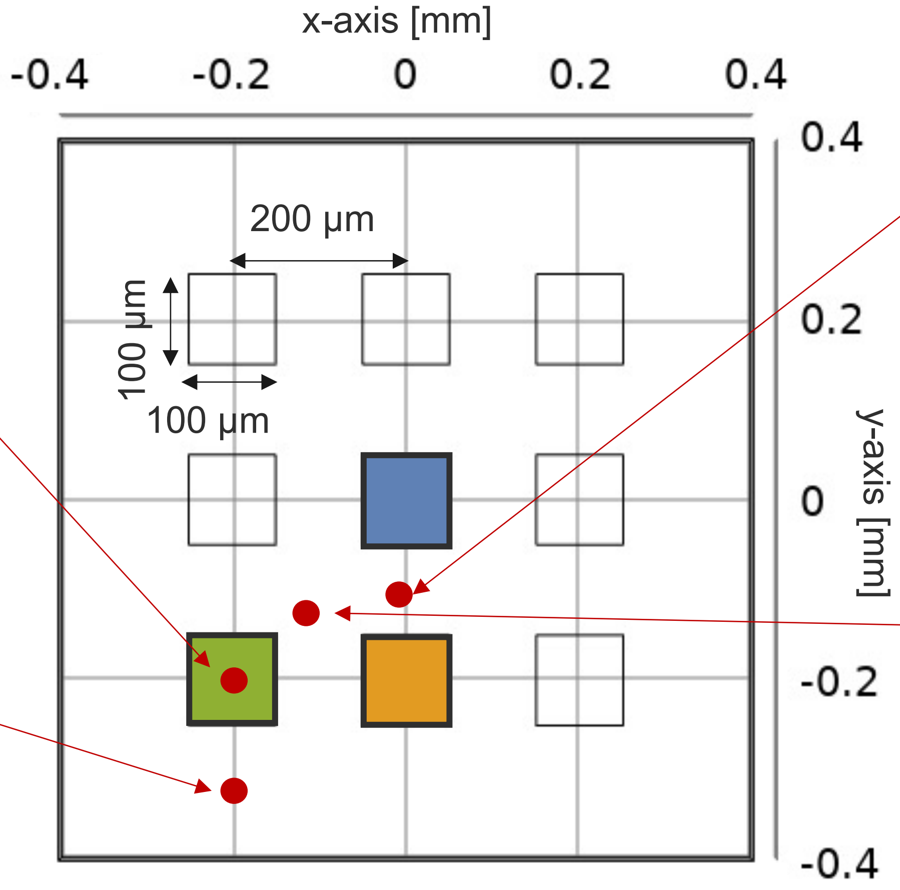
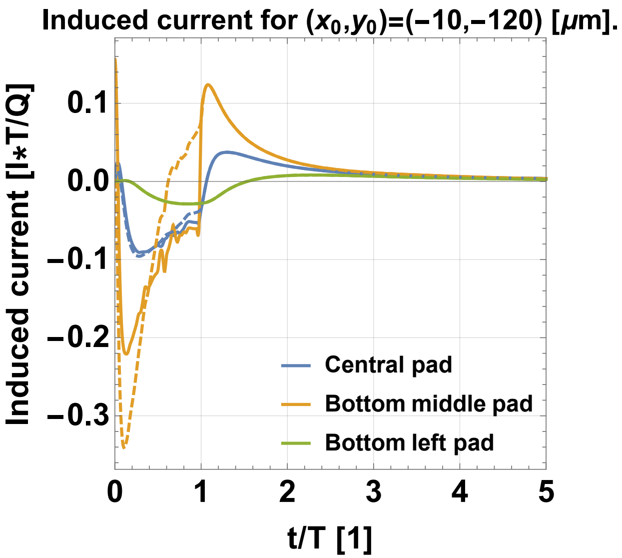
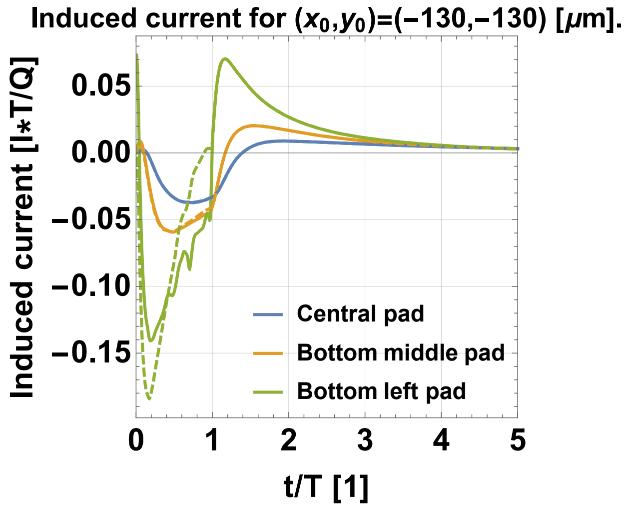
Evaluating signals for a 100-200 geometry







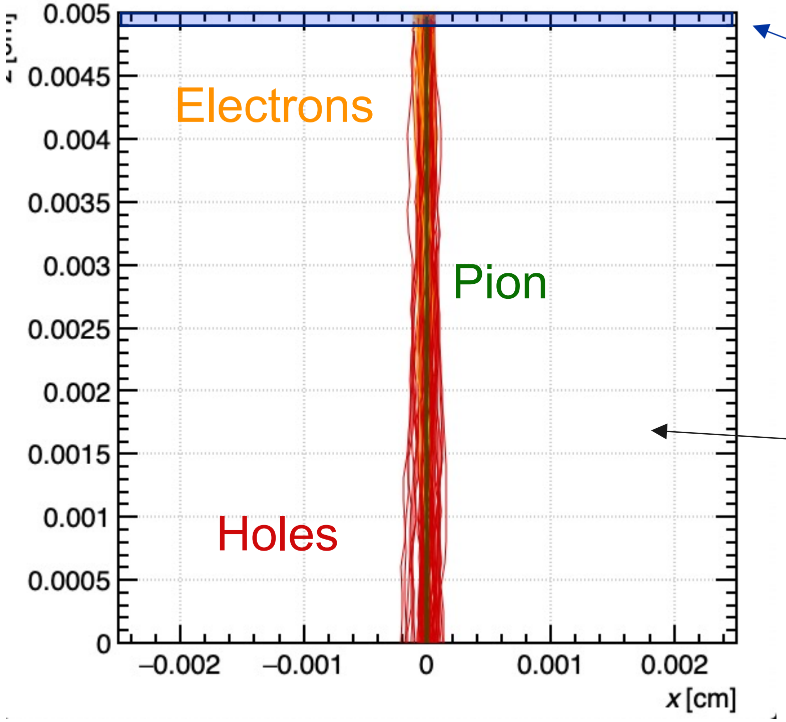




Induced current for an 18 GeV/c pion track

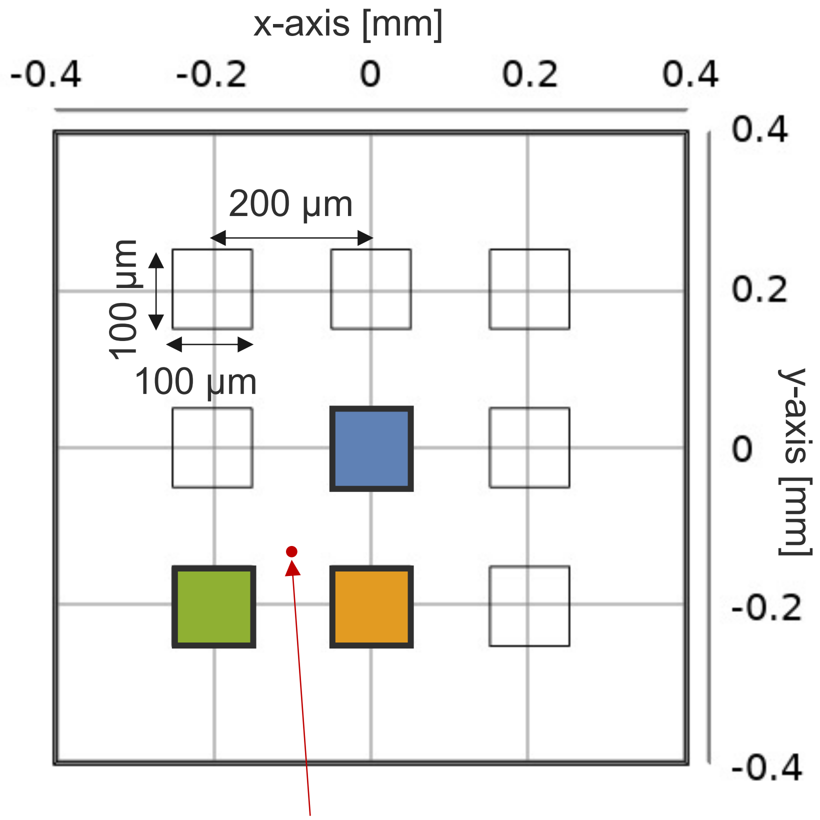
Given a pion tracking though the sensor the resulting signal can be calculated.

Simulation of 18 GeV/c pion track



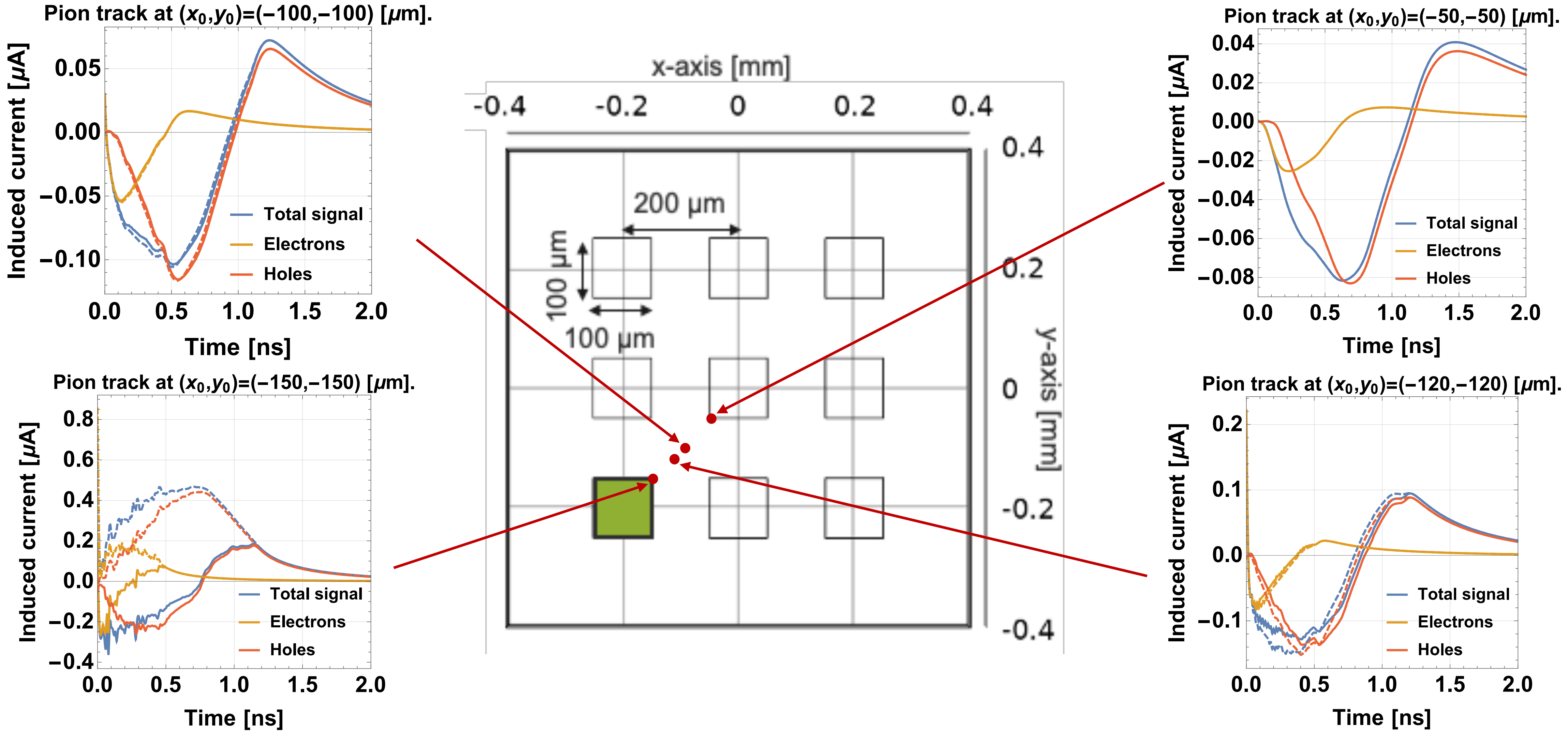
Gain layer of 1 μm thick with E = 300 kV/cm

Bulk with E = 38 kV/cm



An example of the position of the pion track

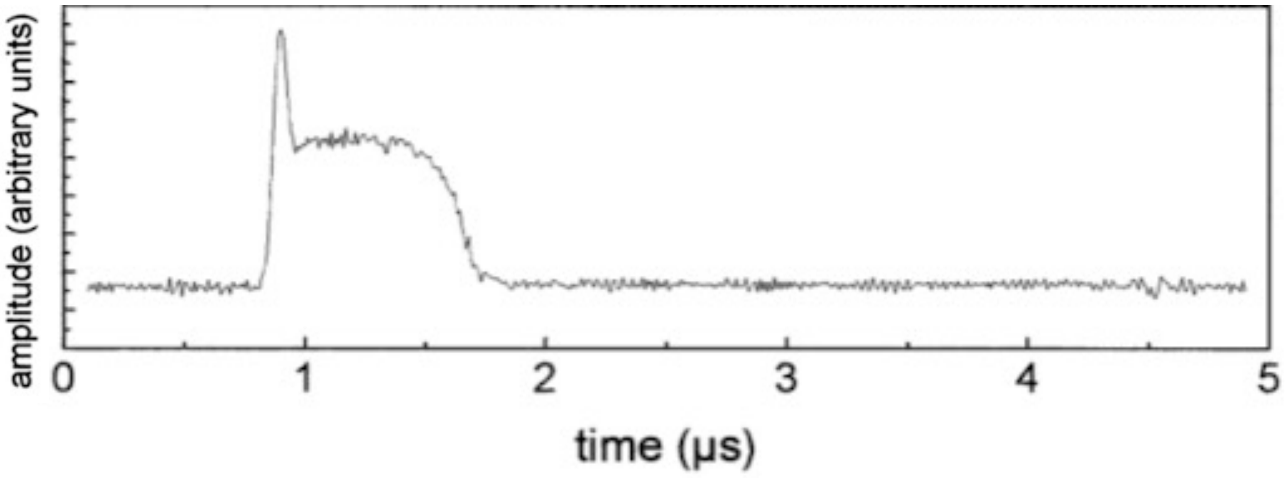
Induced current for an 18 GeV/c pion track

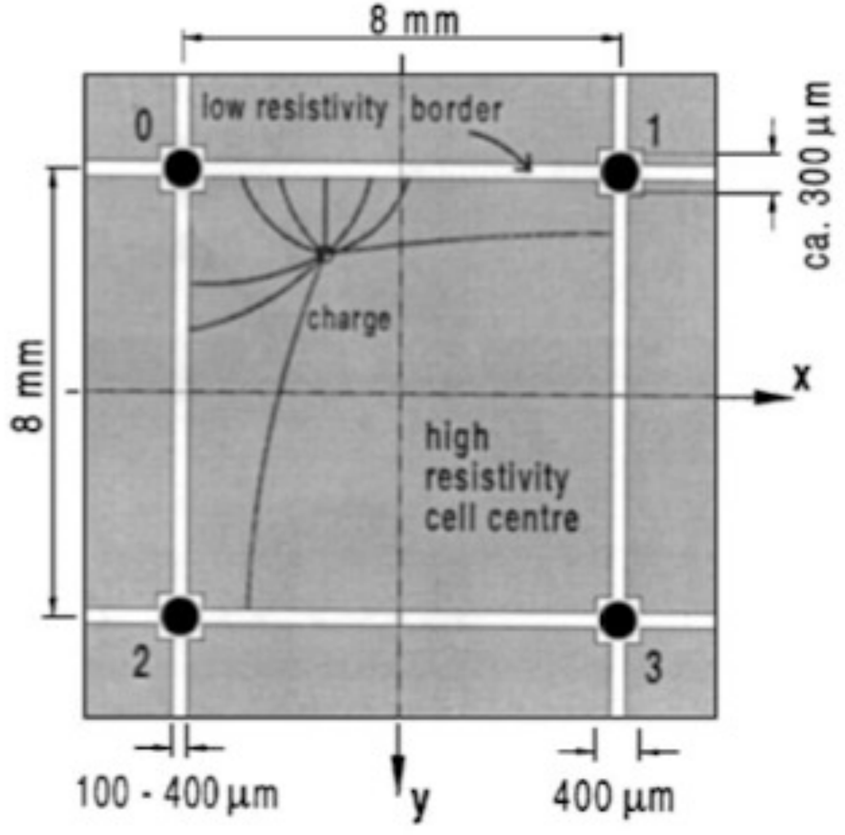


Signal formation in a MicroCAT detector

As an further example we take the MicroCAT's two-dimensional interpolating readout structure.

A reduced number of electronic readout channels nevertheless reaching a spatial nevertheless reaching good spatial resolution by using the delayed component of the signal.





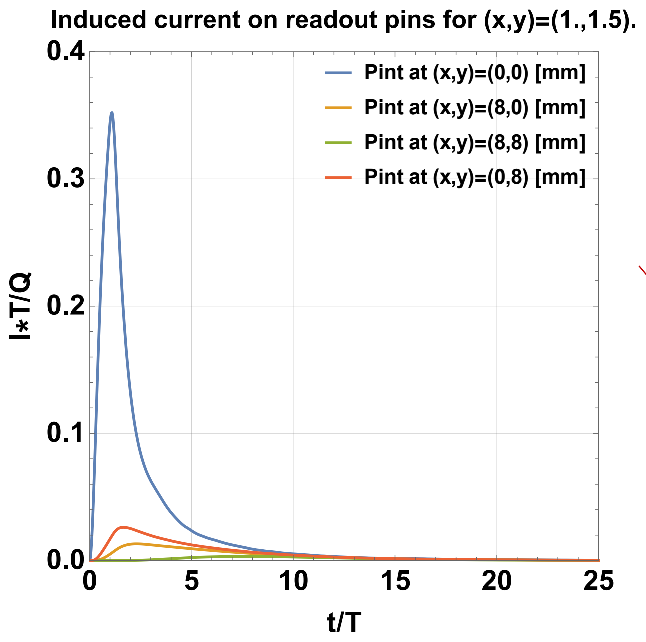
H. Wagner et al. Nucl.Instrum.Meth. A 482 (2002) 334–346

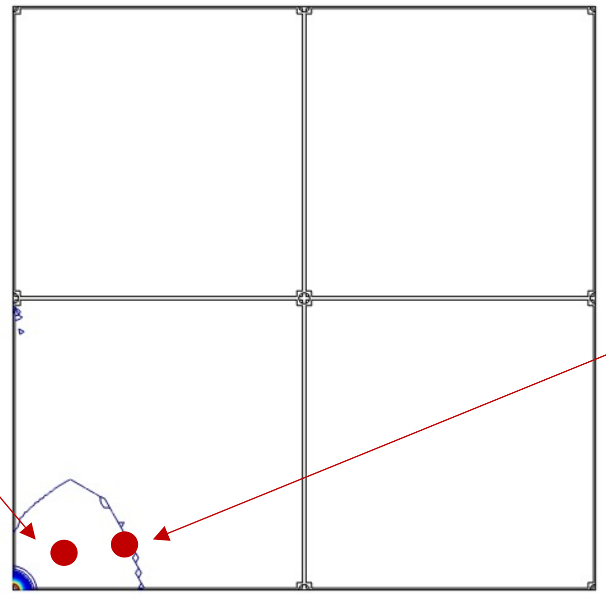
F. Bartol et al. J. Phys. III France, 6 (1996), p. 337
A. Sarvestani et al. Nucl.Instrum.Meth. A 410 (1998) 238–258

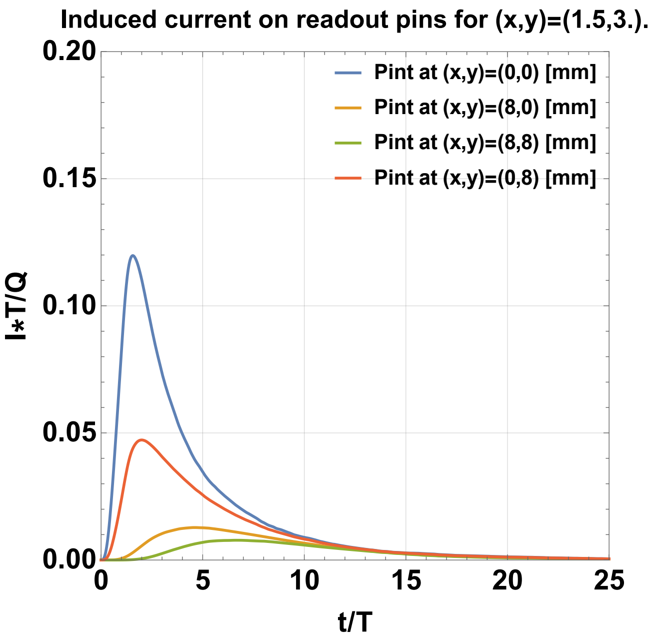
Signal formation in a MicroCAT detector

The induced current on the readout pins on one pad has been calculated for a charge carrier traversing an induction gap of 200 µm downwards in T = 4 ns. The surface resistivity is:

- R_{pad} = 100 kΩ/❑
- R_{strip} = 1 kΩ/❑







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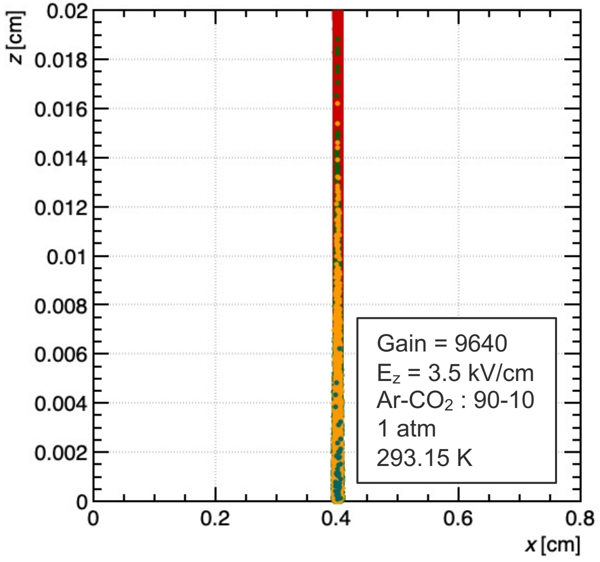
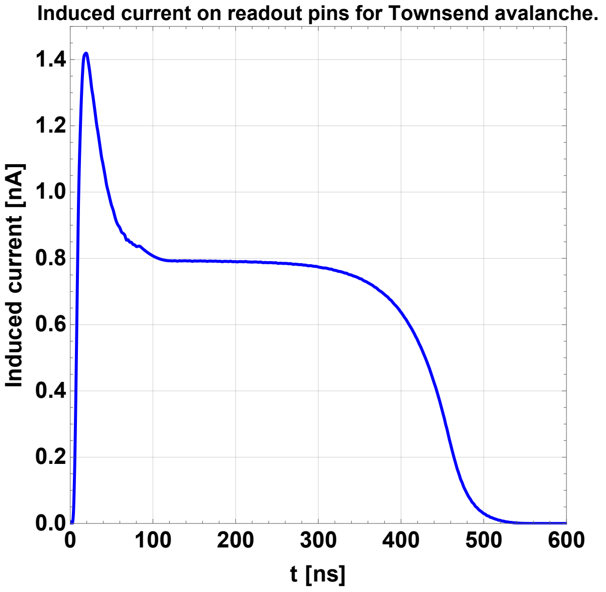
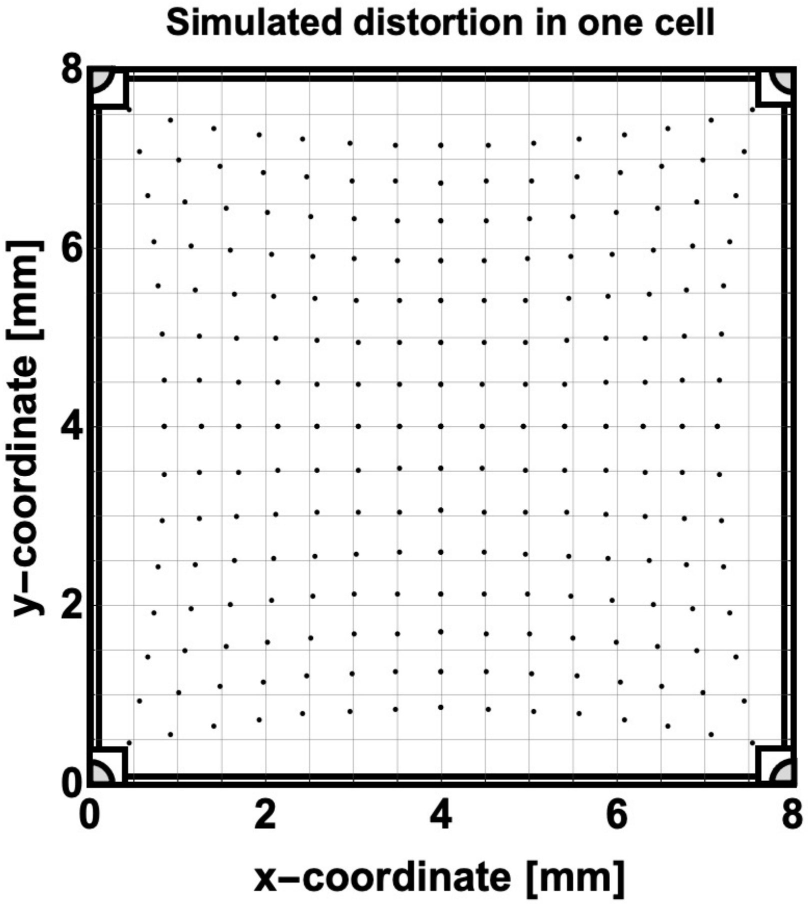
Signal formation in a MicroCAT detector

The same can be done for a Townsend avalanche.

Here a single electron has been placed in a uniform electric field, starting on the top of the induction gap.







Summary

We want to use Garfield++ and COMSOL to model the signal formation in detectors with resistive elements.

- Efficient multigap resistive plate chamber simulations will soon be possible in Garfield++.
- The tools developed during the project allow us to make a full description of the signal of:
  - The MicroCAT readout,
  - The AC-coupled LGAD.

Outlook:

- Benchmarking MRPC simulations against measurements.
- Using the developed tools to look at more detectors with resistive elements.

Thank you for your attention!