EP R&D Day 2021

Resistive elements and signal induction: towards an accurate modelling of induced signals for different detector technologies.

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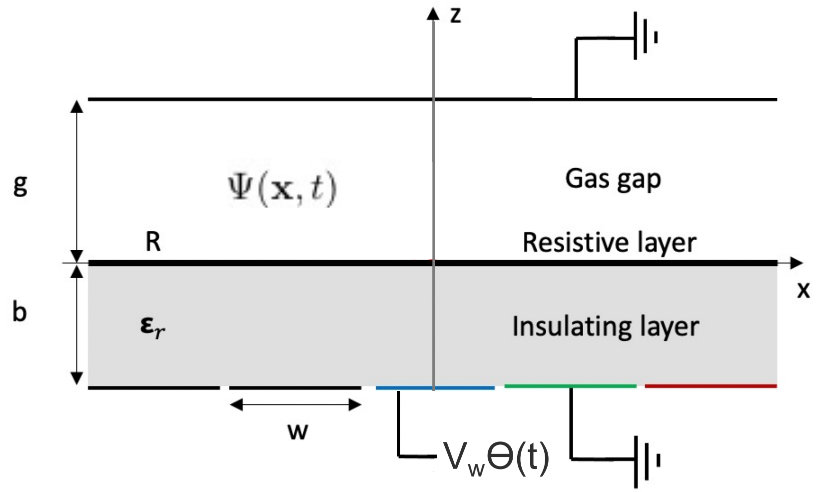
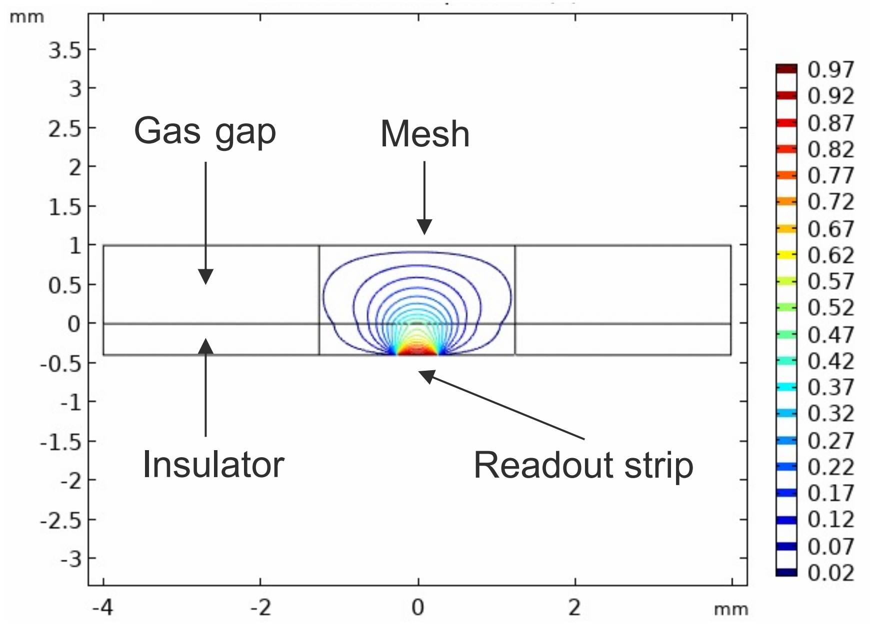
Ramo-Shockley theorem extension for conducting media

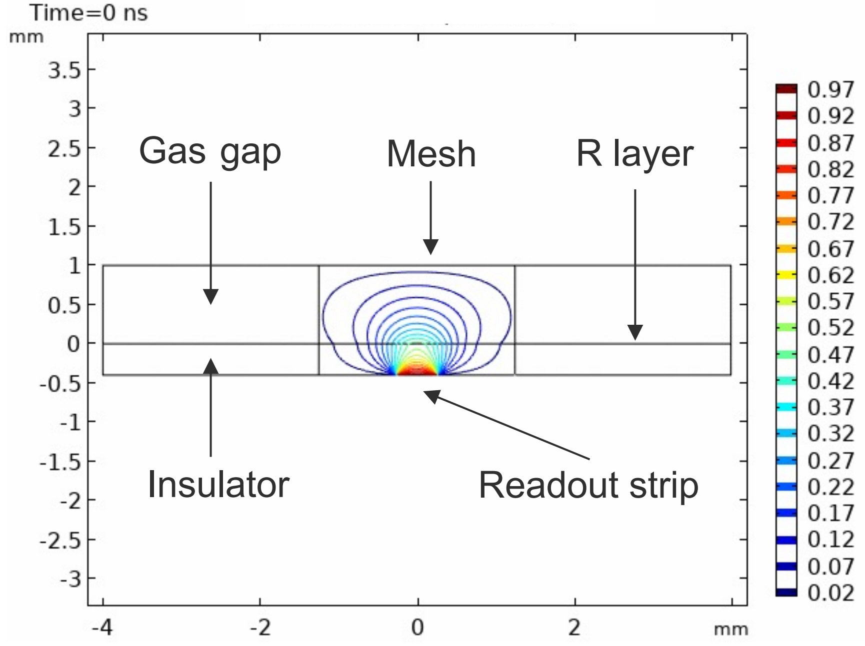
In this project the signals induced in detector structures with resistive elements is modeled by applying an extended form of the Ramo-Shockley theorem for several geometries.



Weighting potential for only perfect insulators and electrodes with infinite conductivity.



Weighting potential for a resistive layer separating the gas gap and insulating layer.



W. Riegler, Nucl. Instrum. Meth. A 535 (2004), 287-293.
W. Riegler, Signals in Particle Detectors, CERN's Academic Training Lecture Regular Programme (2019).

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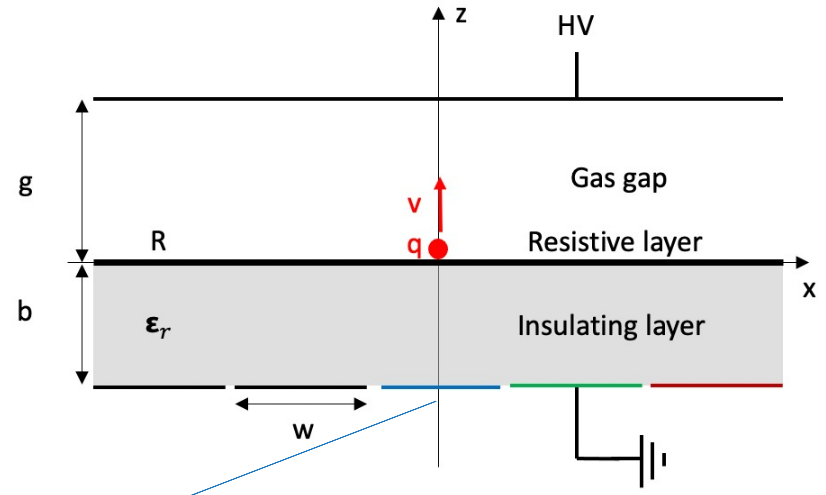
Ramo-Shockley theorem extension for conducting media

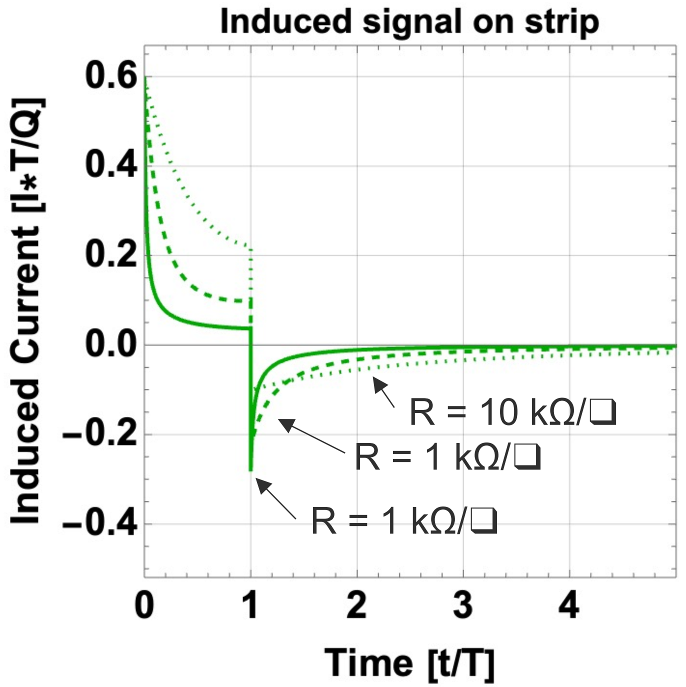


The time-dependent weighting potential is comprised of a static *prompt* and a dynamic *delayed* component.

$$I(t) = -\frac{Q}{V_w}\int_0^t \mathbf{H}\left[\mathbf{x}\left(t'\right), t-t'\right]\dot{\mathbf{x}}\left(t'\right)dt' \,,$$

$$\mathbf{H}(\mathbf{x}, t) = -\nabla\frac{\partial\Psi(\mathbf{x}, t)}{\partial t} \,.$$

- g = 250 μm
- b = 10 μm
- w = 400 μm
- T = g/v = 1 ns



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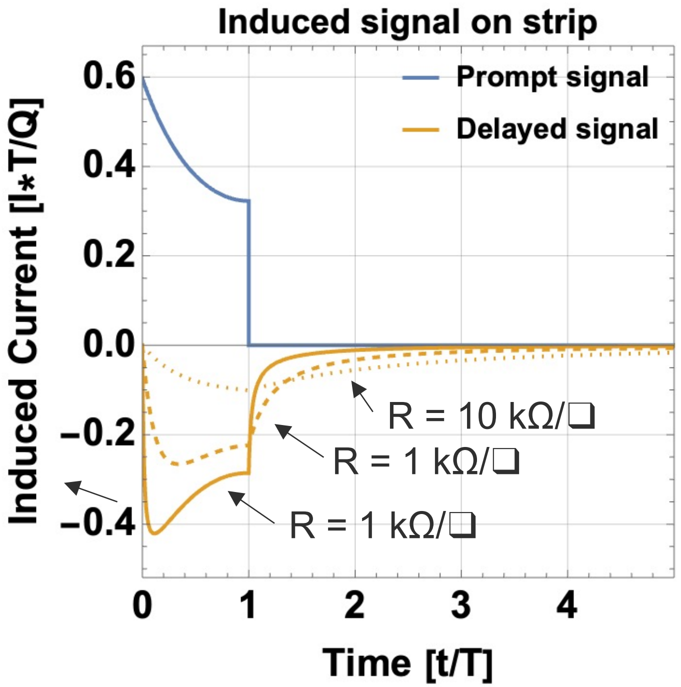

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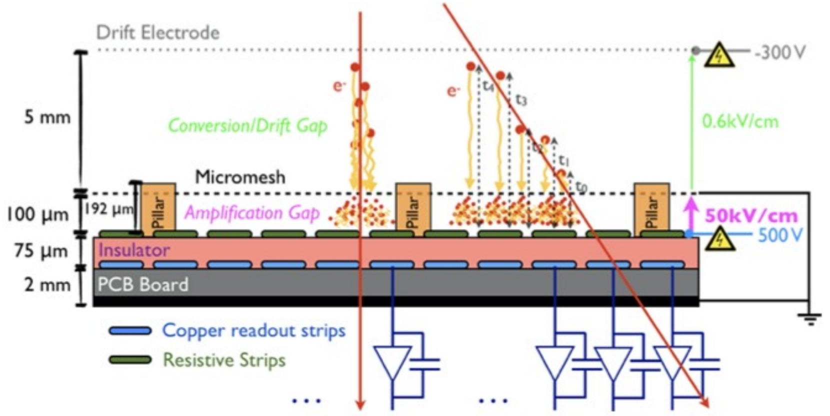
Some of the detectors containing resistive elements

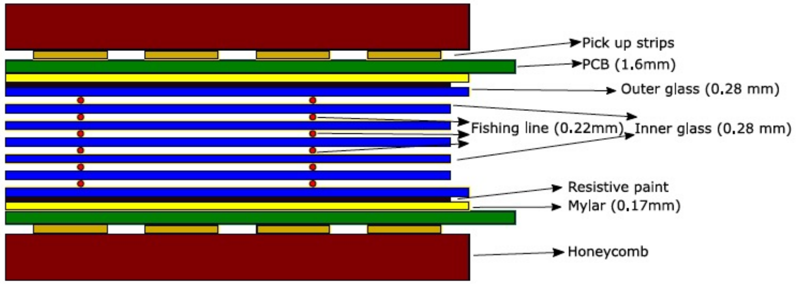
These weighting potentials can only be obtained analytically for a small subset of the larger group of existing detectors; thus, a numerical method is used.

- Resistive-strip bulk Micromegas
- Small-pad Micromegas
- μ-Resistive-WELL
- Resistive-Plate-WELL
- **MicroCAT's two-dimensional interpolating readout**
- Multigap Resistive Plate Chambers (MRPC)
- **AC-Coupled Low Gain Avalanche Detector**

Resistive-strip bulk micromegas



MRPC



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T. Alexopoulos et al., Nucl. Instrum. Meth. A **937** (2019).
Z. Liu et al., Nucl. Instrum. Meth. A **908** (2018).

Signal formation in a MicroCAT detector

The MicroCAT's two-dimensional interpolating readout structure allows for a reduced number of electronic readout channels without loss of spatial resolution.

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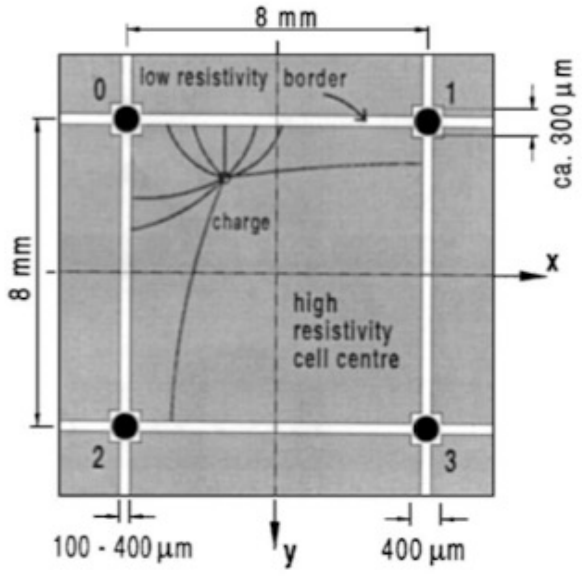
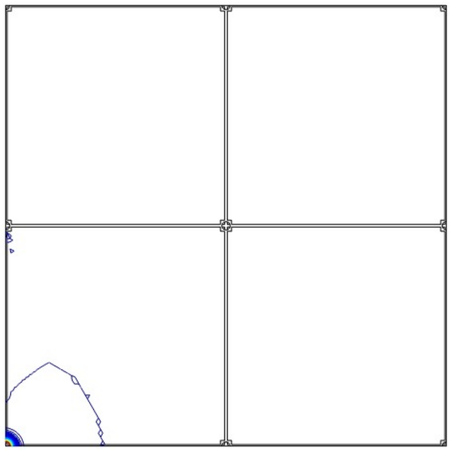
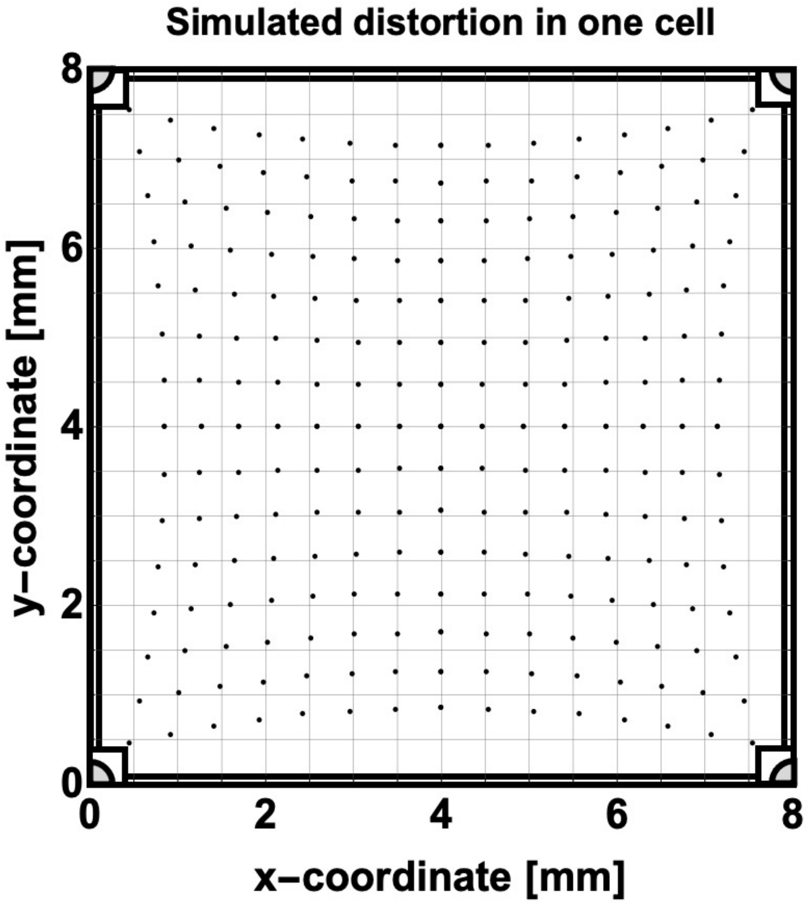
H. Wagner et al.
Nucl.Instrum.Meth. A 482 (2002) 334–346



Time-dependent weighting potential map for one readout node





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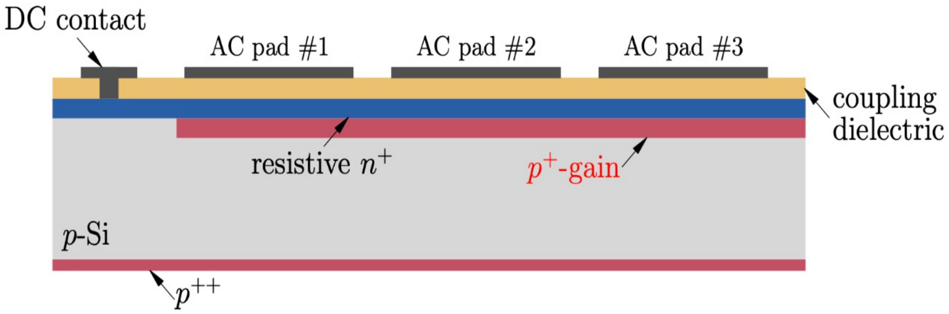
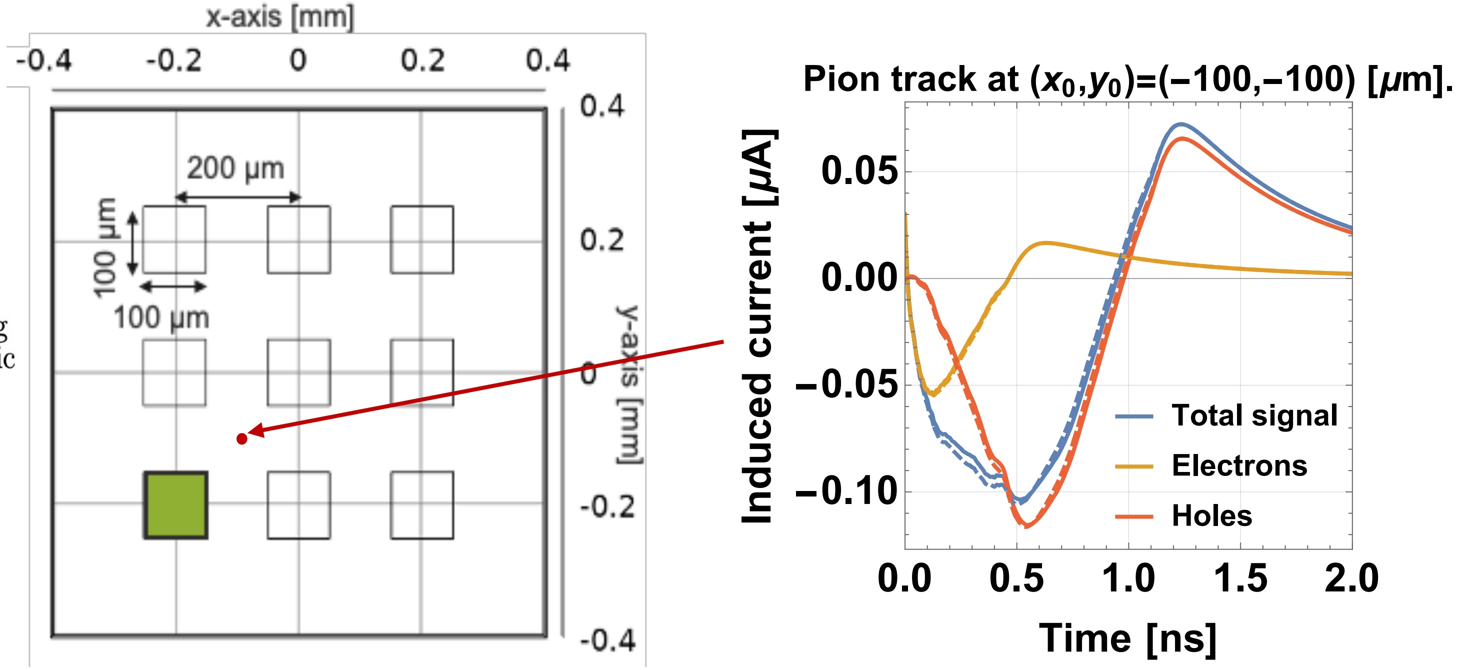
F. Bartol et al. J. Phys. III France, 6 (1996), p. 337
A. Sarvestani et al., Nucl. Instrum. Meth. A 410 (1998) 238–258
A. Sarvestani et al., Nucl. Instrum. Meth. A, 419 (1998) 444

Signal formation in other resistive particle detectors

With the INFN Torino group of N. Cartiglia we are currently looking at simulating the AC-Coupled Low Gain Avalanche Detector geometry.





M. Tornago, R. Arcidiacono, N. Cartiglia et al., Nucl. Instrum. Meth. A **1003** (2021).

Overlook of the methodology

COMSOL® :

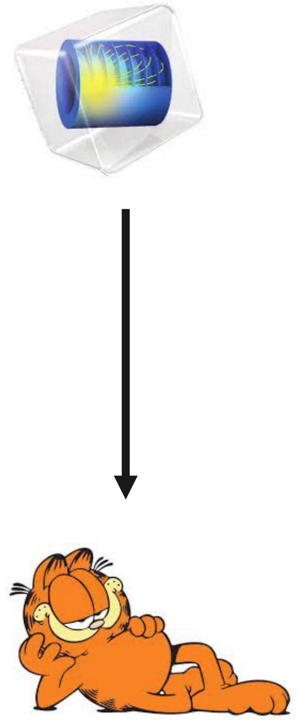
- Numerically obtain the dynamic weighting potential.

Garfield++:

- Detailed microscopic simulation of particle detectors based on ionization measurements in gases or semiconductors.

SPICE® :

- A general-purpose circuit simulation program to describe the front-end electronics.



Garfield++: https://garfieldpp.web.cern.ch/garfieldpp/
COMSOL Multiphysics: https://www.comsol.ch
SPICE: http://bwrcs.eecs.berkeley.edu/Classes/IcBook/SPICE/

Conclusion

In addition to deepening the understanding of existing structures, these studies are important for the design and optimization of the next generation of particle detectors and their application to specific needs driven by HEP experiments and other applications.

Thank you for your attention!