Charge difusion through resistive strip read-outs.

Javier Galan, G. Cauvin, A. Delbart,
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CEA Saclay

RPC2012 - Frascati
7/Feb/2012

Outline

1) Motivation (R&D resistive micromegas)

2) Resistive strip model and first results.

3) Resistive strips detectors characterization

Work motivation — Effect of sparks in detector nominal operation

Some of the main problems induced by sparks in gaseous detectors

1. Intrinsic detector dead-time appears due to field loss.

2. Intense currents may damage electronic boards

3. Carbonization or cathode melting might cause deterioration of the detector itself.

First spark-protected detectors made of Resistive Plate Chambers (RPC).

Nuclear Instruments and Methods in Physics Research A 431 (1999) 154–159

A spark-protected high-rate detector

P. Fonte[a,b,*], N. Carolino[a], L. Costa[c], Rui Ferreira-Marques[a,d], S. Mendiratta[c], V. Peskov[e,1], A. Policarpo[a,d]

First micromegas made of resistive anode

Nuclear Instruments and Methods in Physics Research A 518 (2004) 721–727

Position sensing from charge dispersion in micro-pattern gas detectors with a resistive anode

M.S. Dixit[a,d,*], J. Dubeau[b], J.-P. Martin[c], K. Sachs[a]

Spark reduction implemented in micromegas technology

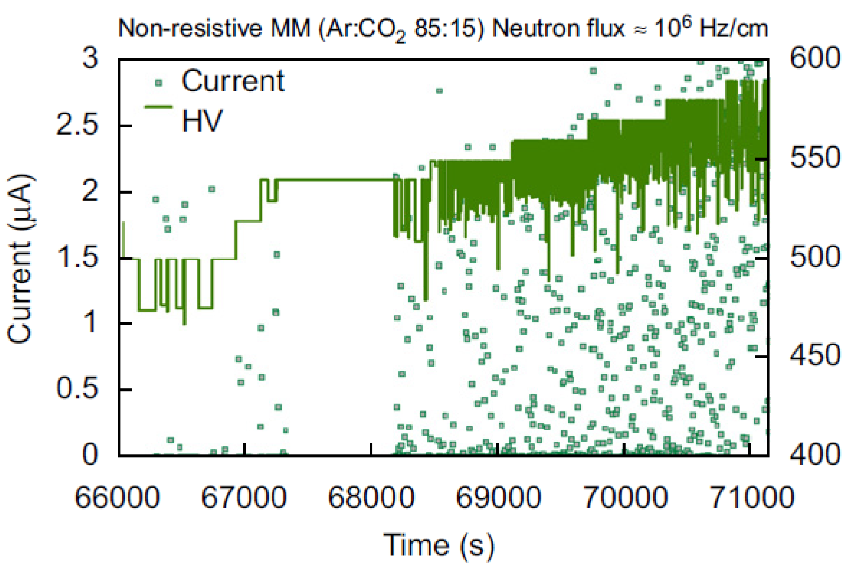
Recently this technique was also applied to Micromegas detectors by testing different resistive foils and strips topologies and proving good protection against sparks (development carried out within MAMMA collaboration for ATLAS muon chambers upgrades).

Nuclear Instruments and Methods in Physics Research A 640 (2011) 110–118

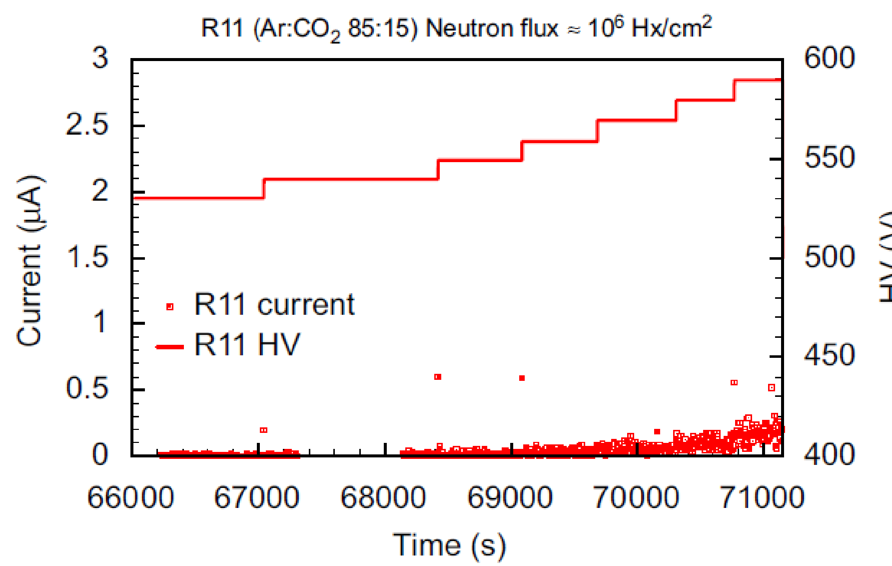
A spark-resistant bulk-micromegas chamber for high-rate applications

T. Alexopoulos [a], J. Burnens [b], R. de Oliveira [b], G. Glonti [b], O. Pizzirusso [b], V. Polychronakos [c], G. Sekhniaidze [d], G. Tsipolitis [a], J. Wotschack [b,*]

<u>Micromegas technology</u>

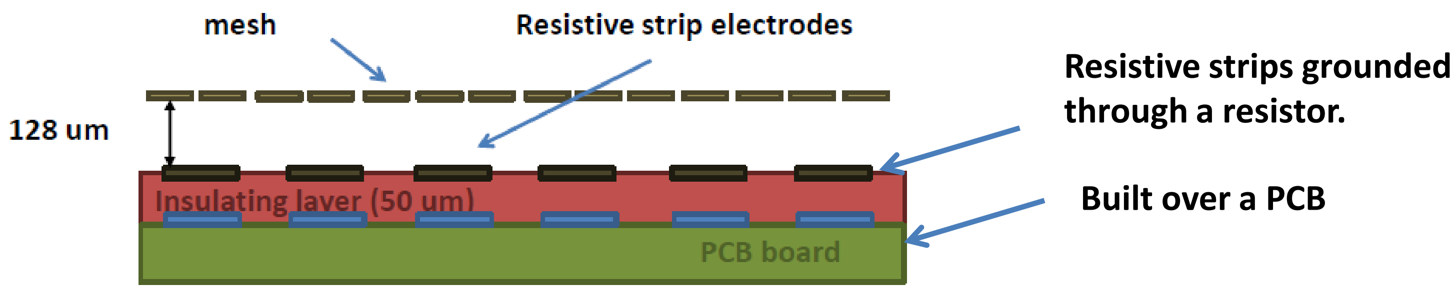


<u>Resistive micromegas technology</u>

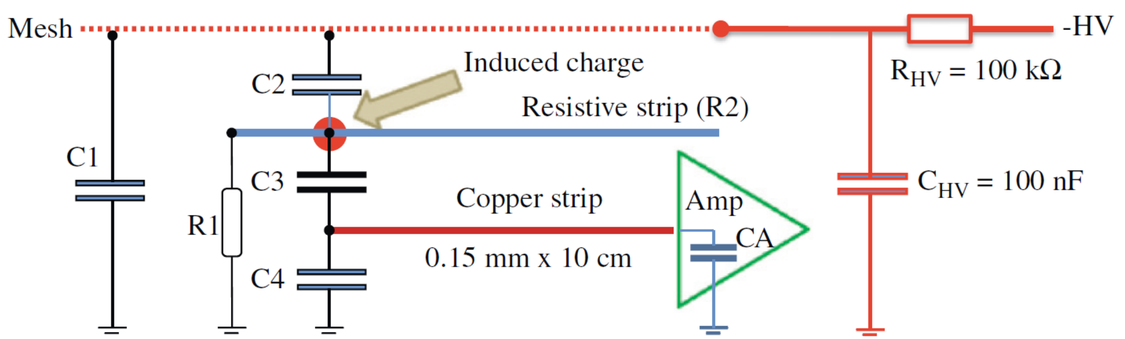


Resistive Micromegas electrical model

Detector transversal section



The electric model of this new resistive micromegas detectors is provided in the previous publication.



Detector equivalent circuit

The charge difussion model that I will present

is inspired on the previous work of "Dixit & Rankin" where analytical approach on a bi-dimensional resistive foil is presented.

Nuclear Instruments and Methods in Physics Research A 566 (2006) 281–285

Simulating the charge dispersion phenomena in Micro Pattern Gas Detectors with a resistive anode

M.S. Dixit[a,b,*], A. Rankin[a]

Outline

1) Work motivation (R&D resistive micromegas)

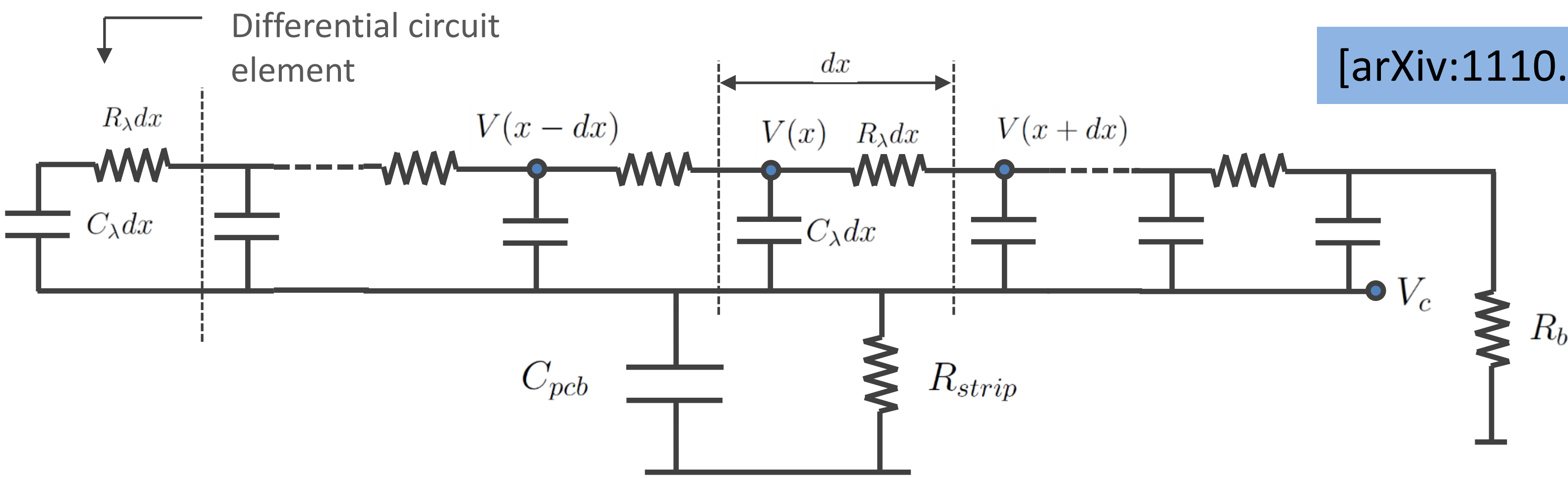
2) Resistive strip model and results.

3) Resistive strips detectors characterization

A simplified resistive strip model

The most simplified model of a resistive strip is obtained by replacing the strip by a transmission line.

[arXiv:1110.6640]



The propagation of the signal generated by a charge deposited at the resistive strip surface is described by the following expression.

$$\frac{\partial^2 V(x,t)}{\partial x^2} = C_\lambda R_\lambda \frac{\partial \left(V(x,t) - V_c(t)\right)}{\partial t} + R_\lambda \frac{\partial \rho(x,t)}{\partial t}$$

Which is moreover bounded by the electronic read-out connection

$$\frac{dV_c(t)}{dt} = \frac{C_\lambda}{C_{pcb} + x_L C_\lambda} \int_0^{x_L} \frac{\partial V(x,t)}{\partial t} dx - \frac{V_c(t)}{(x_L C_\lambda + C_{pcb}) R_{strip}}$$

Semi-analytical solution (I)

In order to solve the signal propagation, the strip is discretized in N finite elements, then we must solve a system of N+1 coupled partial differential equations

$$\frac{dV_j}{dt} = \frac{1}{\tau_\lambda \delta x^2}(V_{j+1} - 2V_j + V_{j-1}) + \frac{dV_c}{dt} - \frac{1}{C_\lambda}\frac{d\rho_j}{dt}$$

which acquires the following matrix equivalent description

$$\frac{d}{dt}\begin{bmatrix} v_1 \\ \vdots \\ v_n \end{bmatrix} = \frac{1}{\tau_\lambda \delta x^2}\begin{bmatrix} -2 & 1 & & & 0 \\ 1 & -2 & 1 & & \\ & \ddots & \ddots & \ddots & \\ & & 1 & -2 & 1 \\ 0 & & & 1 & -1 \end{bmatrix}\begin{bmatrix} v_1 \\ \vdots \\ v_n \end{bmatrix} + \frac{1}{\tau_\lambda \delta x^2}\begin{bmatrix} v_o \\ 0 \\ \vdots \\ 0 \end{bmatrix} - \frac{1}{C_\lambda}\frac{d}{dt}\begin{bmatrix} \rho_1 \\ \vdots \\ \rho_n \end{bmatrix} + \frac{dV_c}{dt}\begin{bmatrix} 1 \\ \vdots \\ 1 \end{bmatrix}$$

The potential at each point must be solved simultaneously, in order to decouple the equation system some algebra is applied and the calculation is done over the transformed potential.

Diagonal matrix

$$\frac{d\mathbf{u}}{dt} = \frac{1}{\tau_\lambda \delta x^2}\Lambda\mathbf{u} + \frac{1}{\tau_\lambda \delta x^2}\mathcal{X}\mathbf{v_o} - \frac{1}{C_\lambda}\mathcal{X}\frac{d\boldsymbol{\rho}}{dt} - \frac{\xi V_c}{C_\lambda R_{strip}}\mathcal{X}\,\mathbf{b}$$

Transformed potential

Semi-analytical solution (II)

Diagonal matrix

$$\frac{d\mathbf{u}}{dt} = \frac{1}{\tau_\lambda \delta x^2}\Lambda \mathbf{u} + \frac{1}{\tau_\lambda \delta x^2}\mathcal{X}\mathbf{v}_o - \frac{1}{C_\lambda}\mathcal{X}\frac{d\rho}{dt} - \frac{\xi V_c}{C_\lambda R_{strip}}\mathcal{X}\,\mathbf{b}$$

Transformed potential

Independent potential terms

We have now a set of **N+1 undependent and linear differential equations** which can be solved independently by applying a **Runge-Kutta method**.

The **transformed potential is solved** for each time step iteration, and **the real potential and V_c are obtained** by applying the inverse transformation and the boundary expression.

The calculation is **implemented in a C code** where all the initial parameters can be defined in command line.

Different signal propagation set-ups

Simulations at different boundary resistors values.

R_b = 250K, 2.5M, 5M, 10M

R_λ = 100k/mm C_λ = 0.2pF/mm

Simulations at different strip resistivities R_λ = 50,100,200 k/mm

R_b = 10M C_λ = 0.2pF/mm

Simulations at different strip capacitances C_λ = 0.05, 0.2, 1 pF/mm

R_b = 10M R_λ = 100 k/mm

Simulations at different signal positions Δx = 0.5 mm

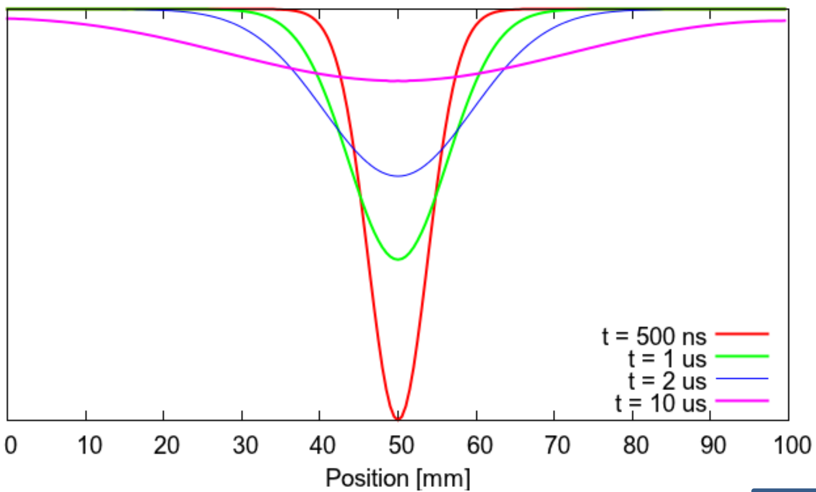
C_λ = 0.2pF/mm R_λ = 100 k/mm R_b = 5M

Homogeneous illumination versus beam illumination

Charge difussion along the resistive strip (Gaussian input signal)

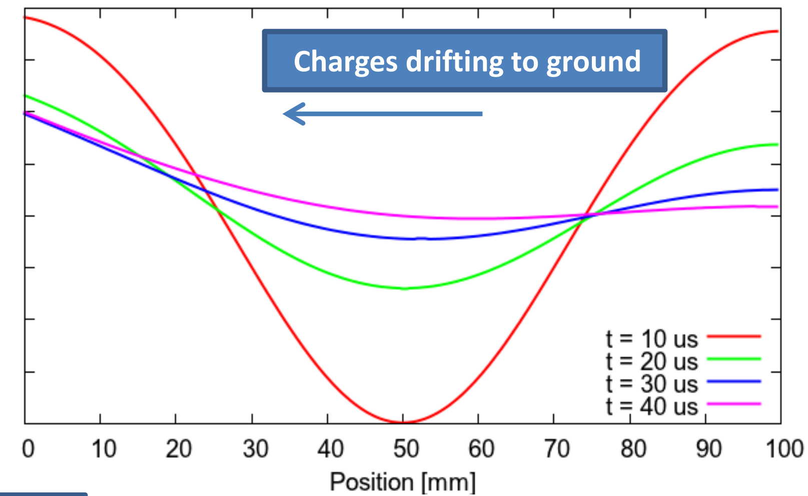
Same input signal at different times

First temporal frames



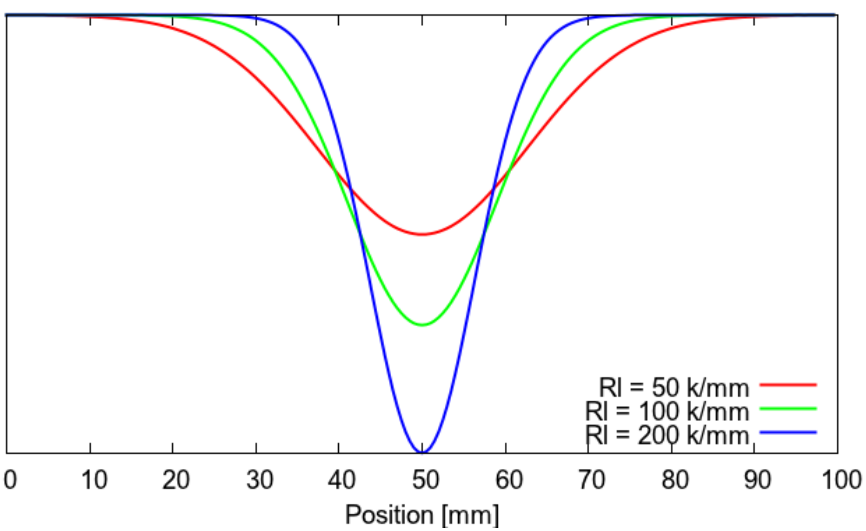
Last temporal frames

Charges drifting to ground

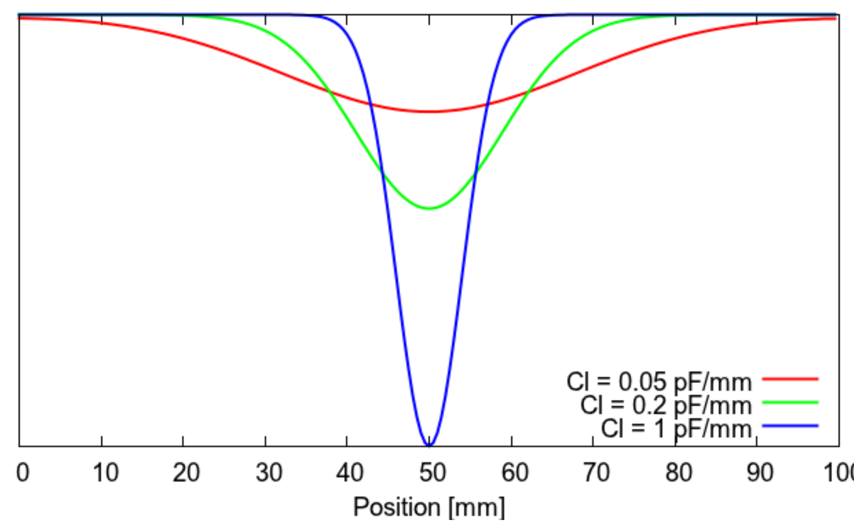


Same input signal after 1us diffusion

Linear resistivity effect on charge difussion



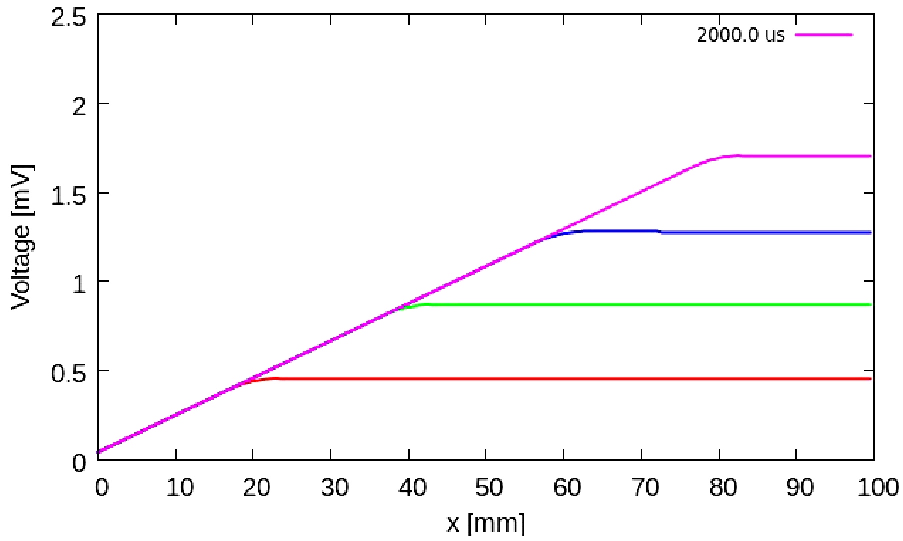
Linear capacitance effect on charge difussion



Full illumination and beam irradiation

4 independent input beam currrents

Each with same intensity and thickness



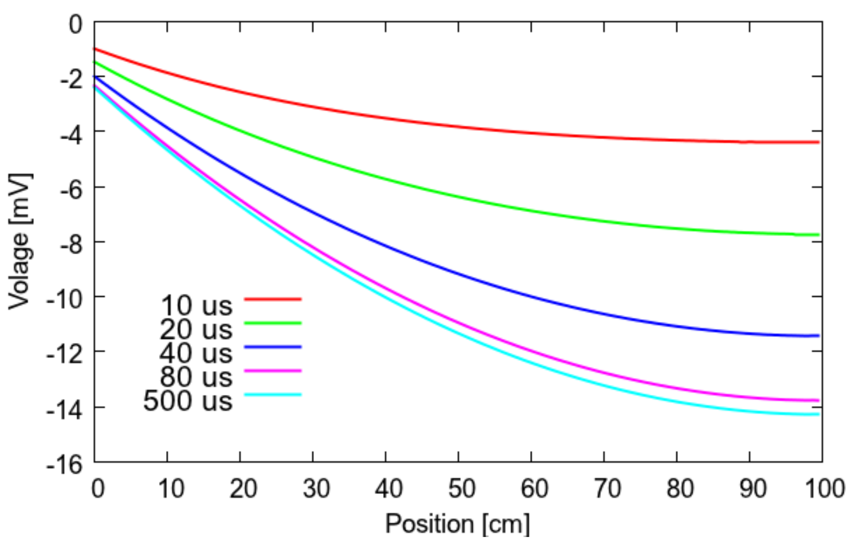
Homogeneous illumination

Rate = 100 kHz/cm^2

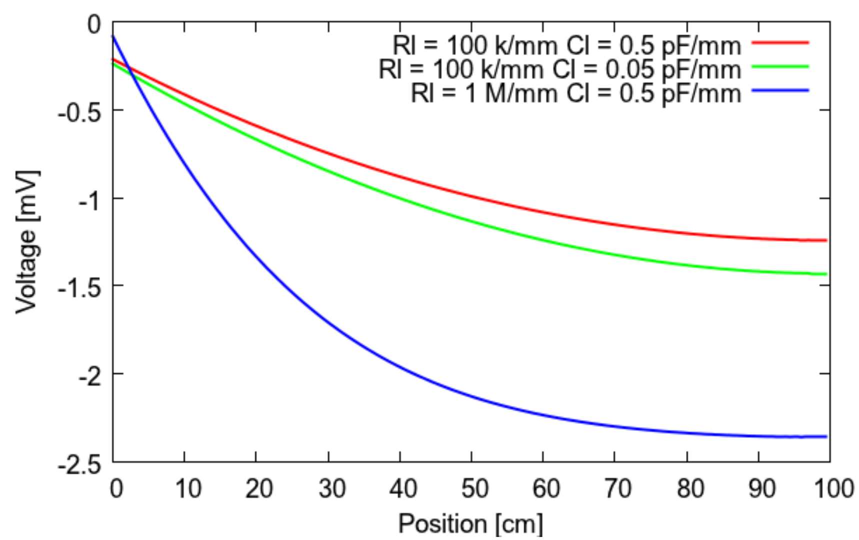
Gain = 10000

Primary electrons = 300

Transition state

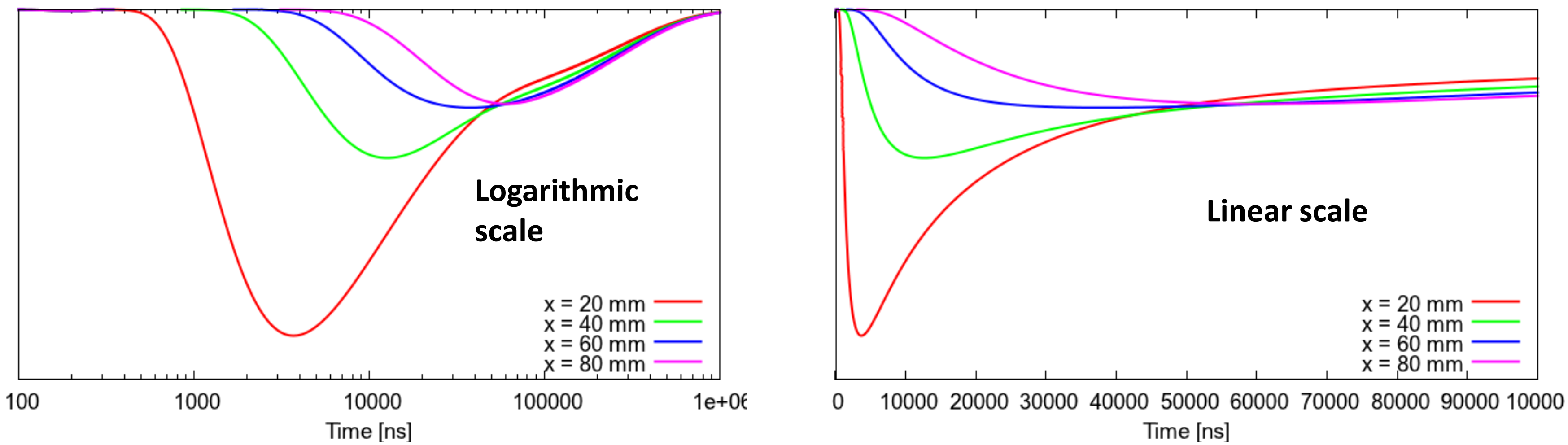


Final state (different values)

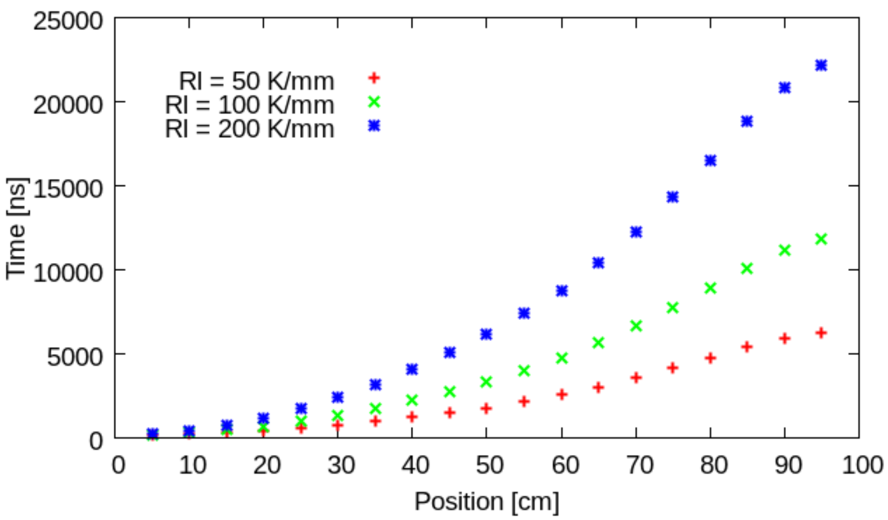


Event position effect on output signal

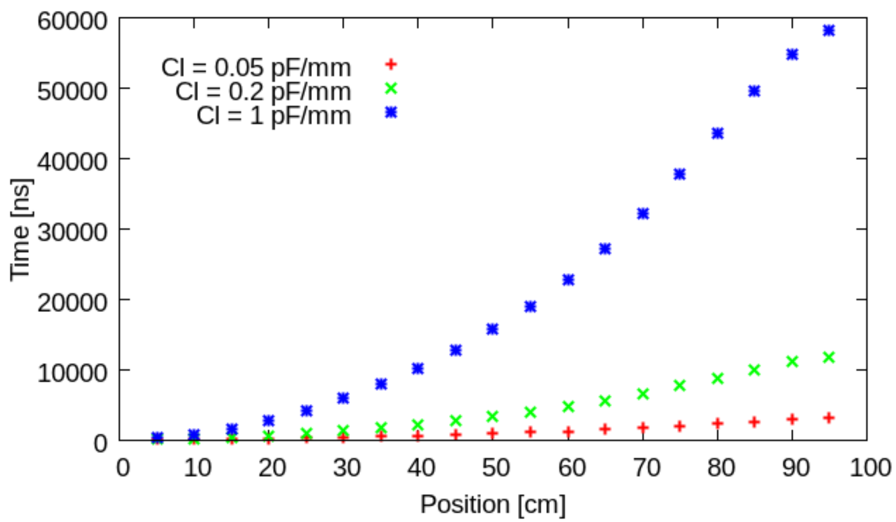
Input gaussian current at 200 ns and sigma 50 ns calculated at different strip positions



Pulse rise starts (dependency with resistivity)



Pulse rise starts (dependency with capacitance)



Outline

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2) Resistive strip model and first results.

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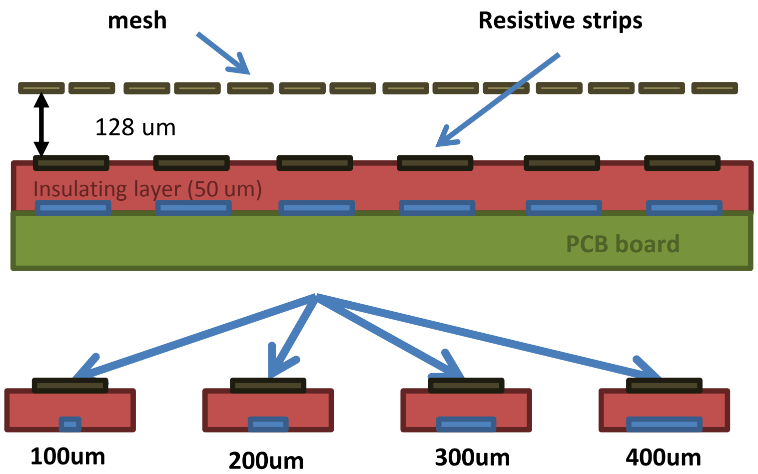
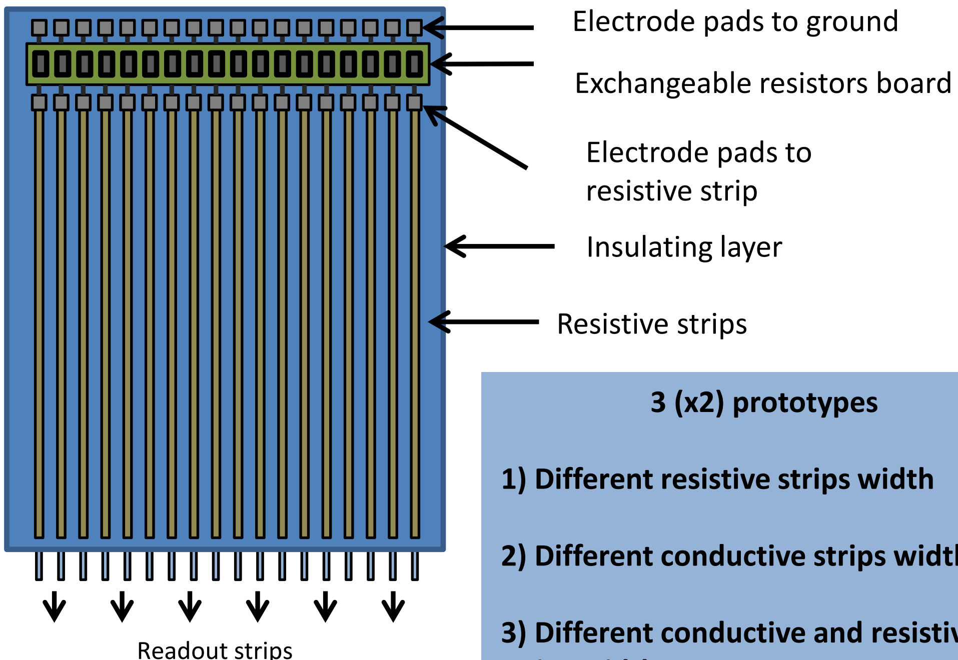
Resistive micromegas prototypes with different geometries





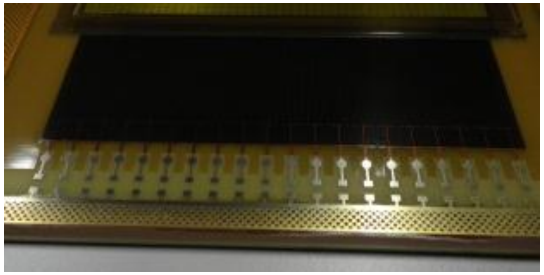
3 (x2) prototypes

1) Different resistive strips width

2) Different conductive strips widths

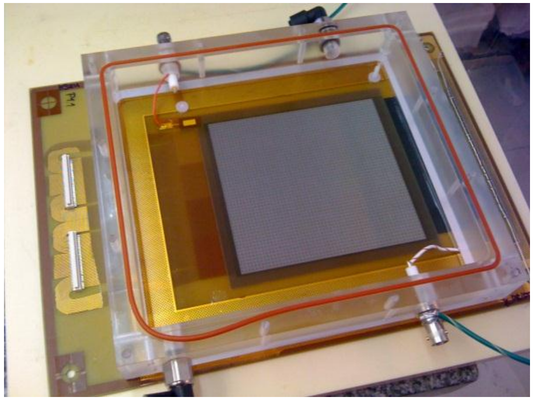
3) Different conductive and resistive strips widths

Resistive strips connectors



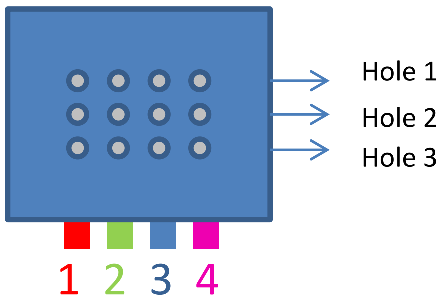
Resistive strip widths

Detector chamber mounted

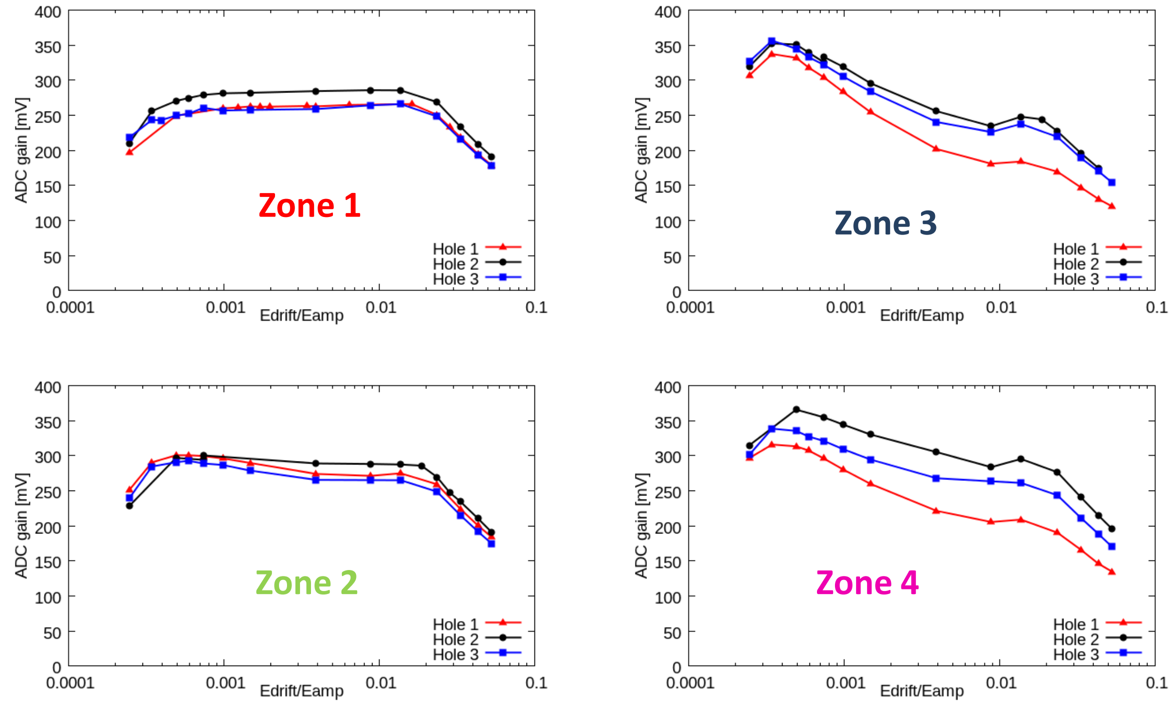


First prototype characterization. Different resistive strips widths

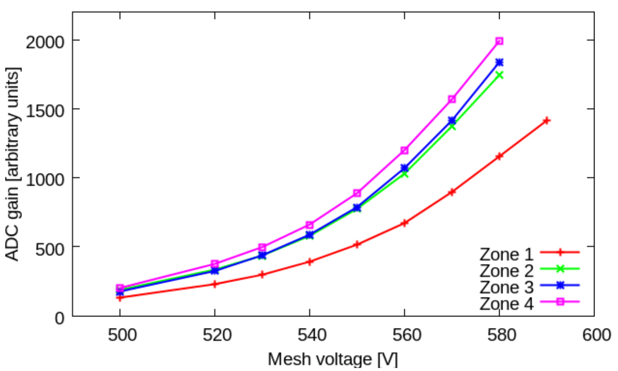
Mask was used to irradiate different areas



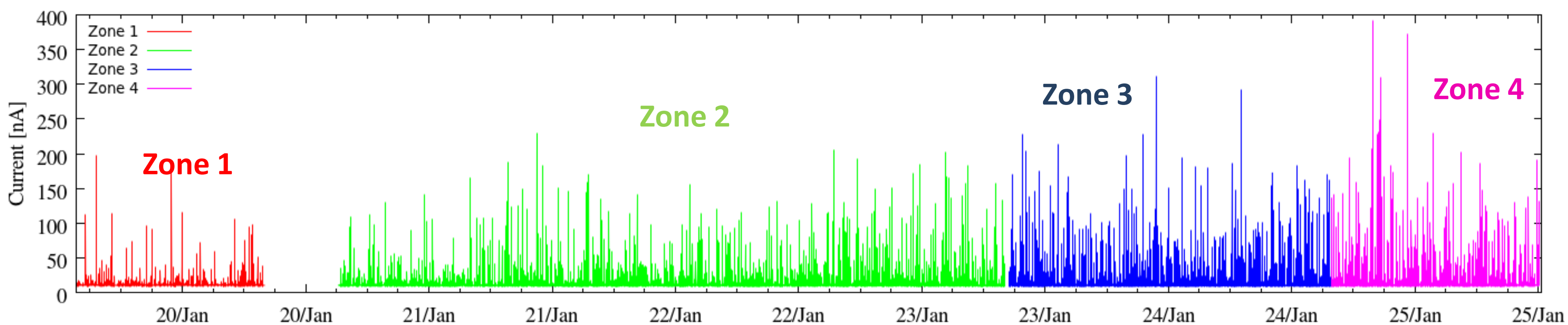
Transparency curves for each zone



Gain curves for each different zone



Spark production at each different region



Resistive strip signal read-out

Nuclear Instruments and Methods in Physics Research A 646 (2011) 118–125

Longitudinal resistive charge division in multi-channel silicon strip sensors

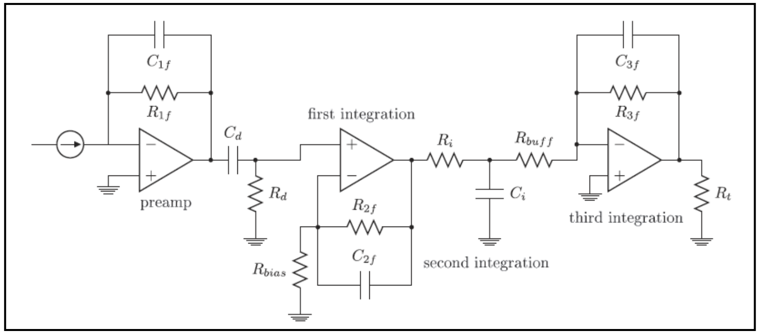
Jerome K. Carman[a], Vitaliy Fadeyev[a], Khilesh Mistry[a], Richard Partridge[b], Bruce A. Schumm[a,*], Edwin Spencer[a], Max Wilder[a]

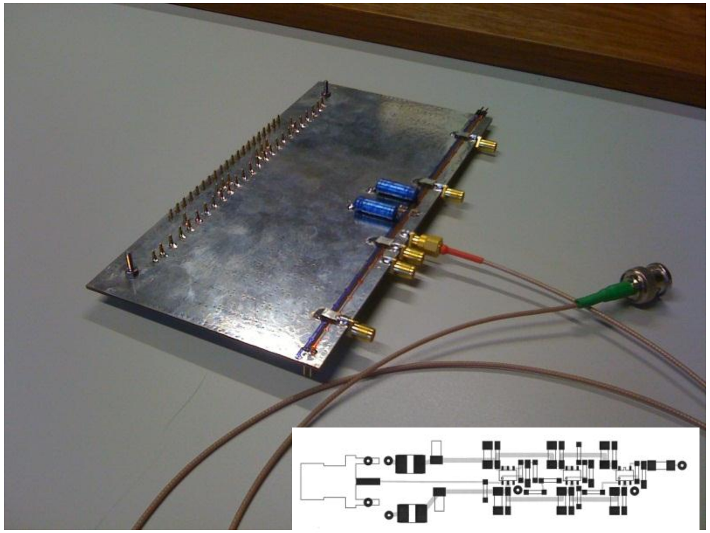
3-stage preamplifier

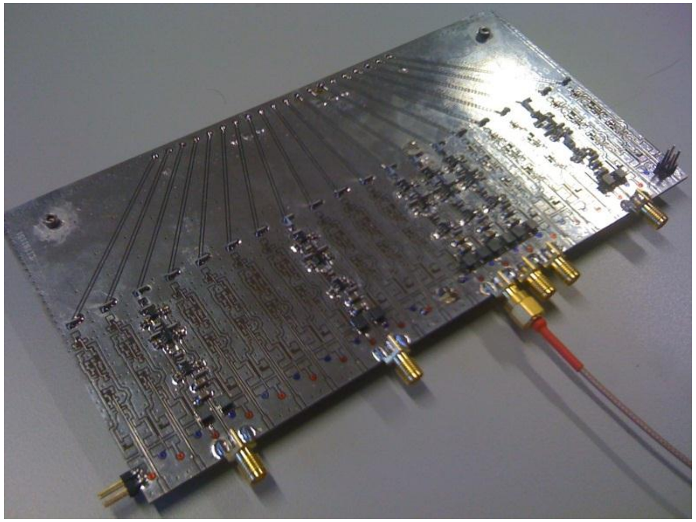
Printed circuit board developed at SEDI

Card is actually under test

Shaping time about 1us, test detector with shaping times Higher than 10-100us







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Summary and conclusions

- Resistive micromegas technology has proven good reliability under extreme conditions (high intensity pion, neutron, high intensity x-ray beams, …). However this new technology still requires further study for a complete understanding of the detector response.

- A simple model and the methodology to solve it has been introduced. This model can be considered as a first step towards a more complex structure. The full mathematical description could allow to connect with field solvers.

- Characterization of different prototype geometries undergoing will allow to increase our understanding and optimize key parameters.

- Resistive strip signals to be read using dedicated electronic read-out, peaking time to be optimized for each read-out group.

Backup slides

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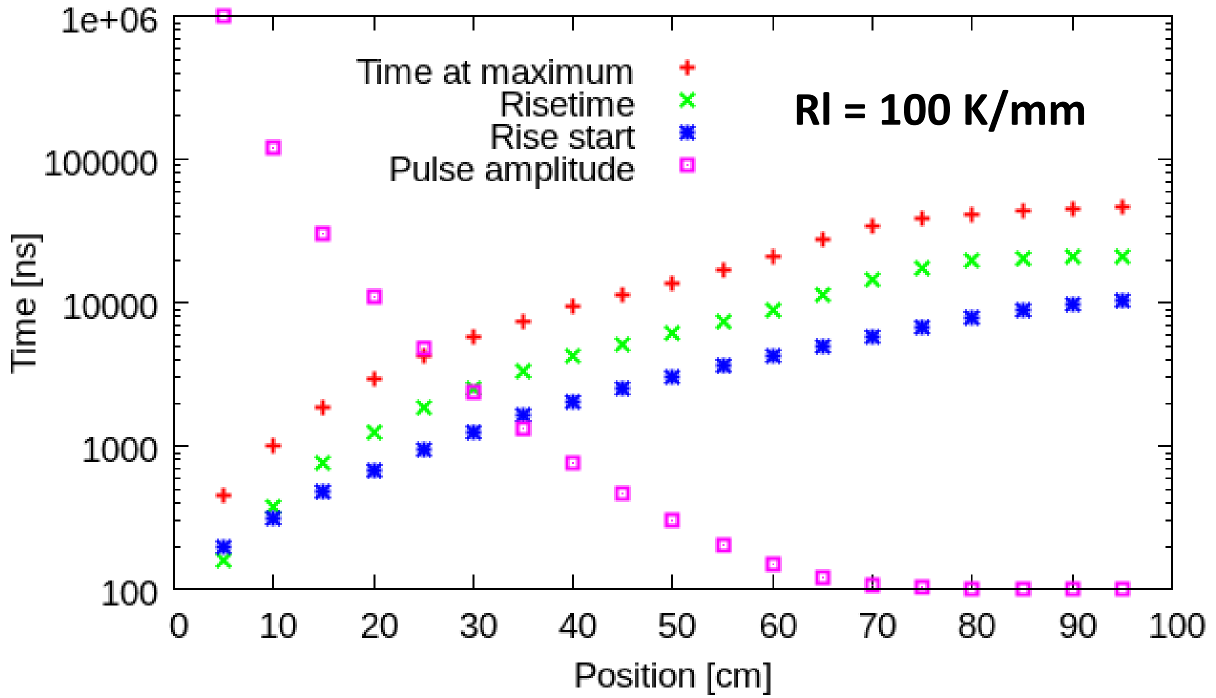
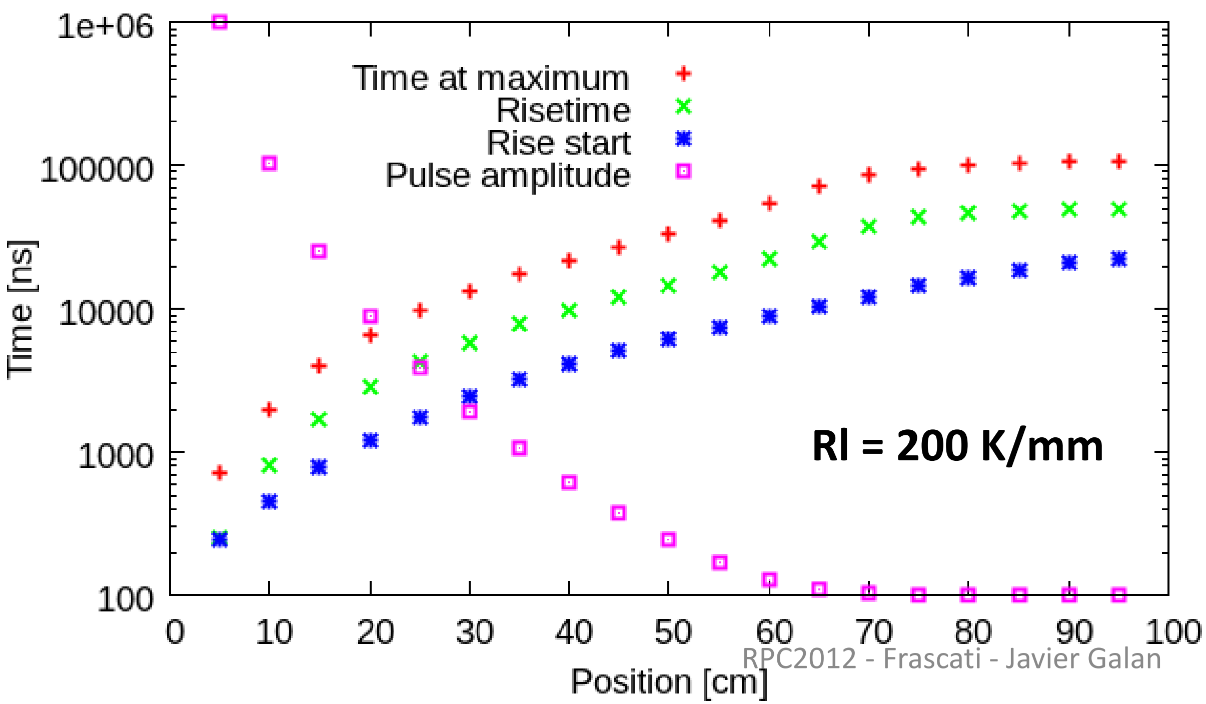
Pulse properties are obtained for different hit positions.



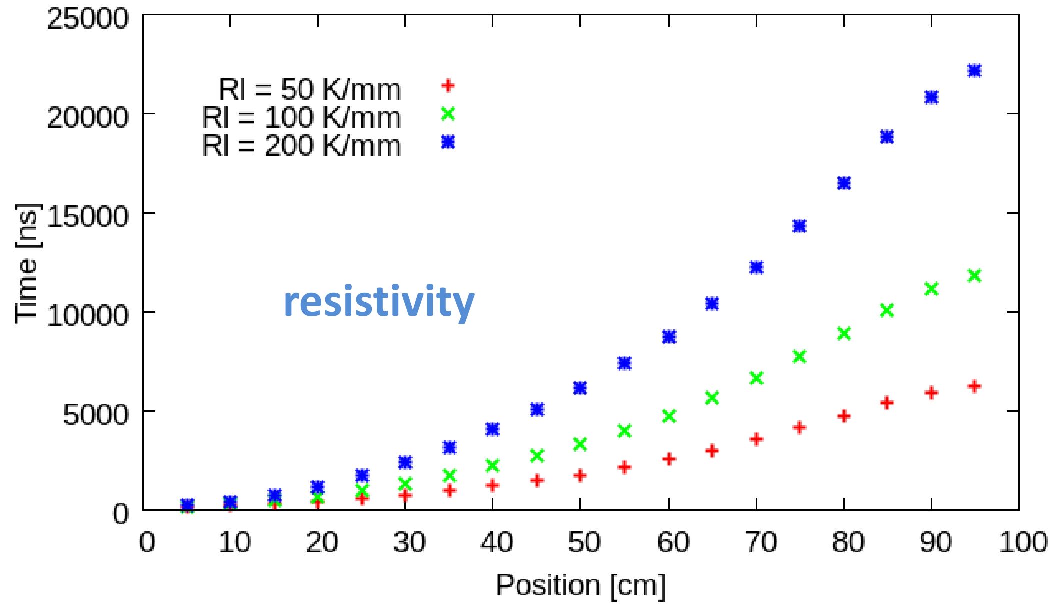


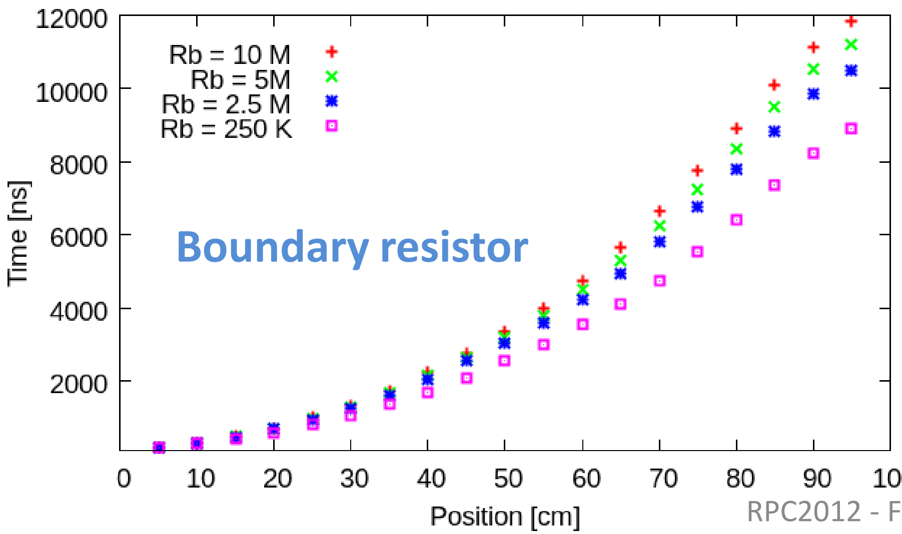
Typical signal times and amplitude

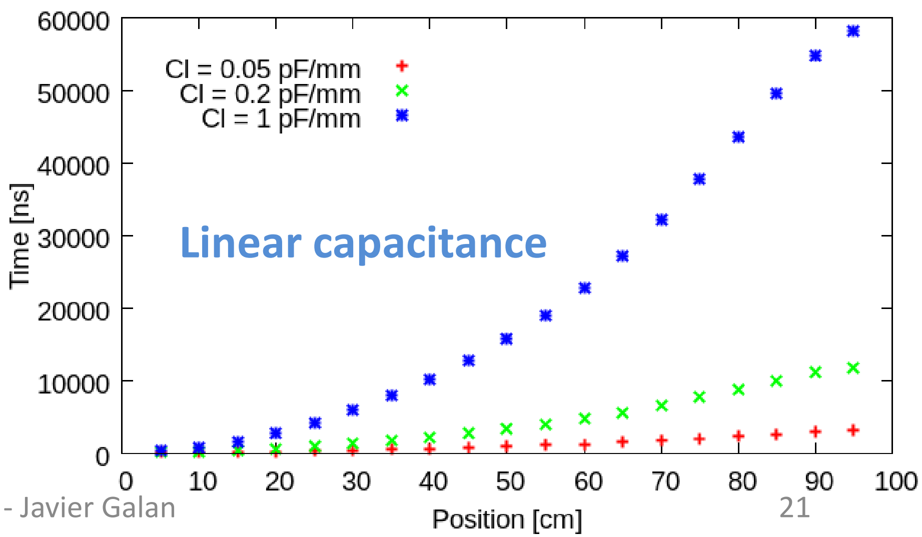
Cl = 0.2 pF/mm

Rb = 10 M

Risetime start delay for different resistivity and capacitance values.







Maximum peak position delay for different parameter values