R&D studies with resistive strip micromegas readouts

J. Galan[1]

Also contributed to this work

D. Attie[1], J. Burners[2], A. Delbart[1], J. Derre,
I. Giomataris, E. Ferrer-Ribas[1], F. Jeanneau[1], R. de Oliveira[2],
O. Maillard, P. Schune[1], A. Giganon[1]

1. CEA Saclay
2. CERN Geneva

Outline

Work motivation

1. Problems of sparks in gas based detectors.

2. Spark-resistant micromegas prototypes made of resistive strips.

Signal propagation model

3. Model to characterize charge difussion in resistive strips read-outs.

4. Results from charge difussion at different conditions.

New prototype designs for testing

5. Prototypes to characterize resistive properties and charge difussion.

6. Dedicated electronics to read-out resistive charge difussion signal.

Sparks and discharges in gaseous detectors

One of the main problems in high gain gas based detectors
is the **appearance of sparks**, and thus discharges in gas based detectors.

Sparks appear in the gaseous media when a critical high charge density is reached at the amplification region, given by the Raether limit (around $10^{7\text{-}8}$ electrons reached in the avalanche).

A simplified conceptual point of view is to understand this limit as
the probability to generate new secondary avalanches. When the number of secondaries generated is higher than the number of primaries which generated the original avalanche then the process **is non-STOP (as soon as the amplification field is present)**.

The consequence is the discharge of the mesh and the drop of the voltage provided by the power supply. **Three main disadvantages:**

1) gain limitation.
2) deadtime increased due to the HV recovery time.
3) detector reduced lifetime.

Sparks and discharges in gaseous detectors

In order to reduce sparks resistive materials were introduced **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

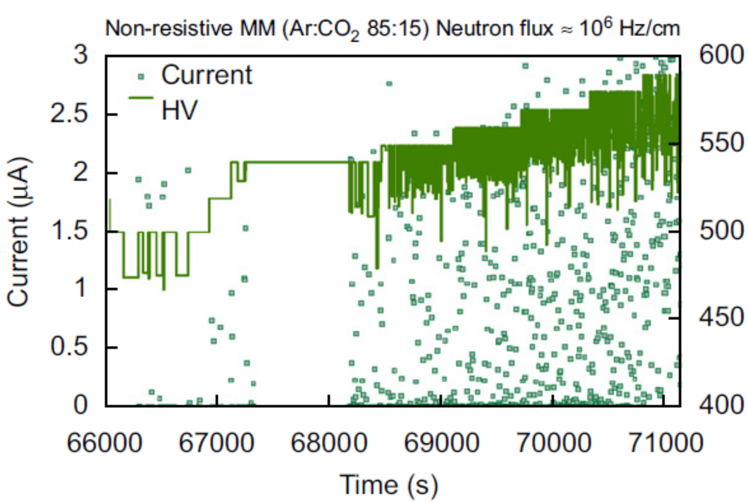
P. Fonte[a,b,*], N. Carolino[a], L. Costa[c], Rui Ferreira-Marques[a,d], S. Mendiratta[c], V. Peskov[e,1], A. Policarpo[a,d]

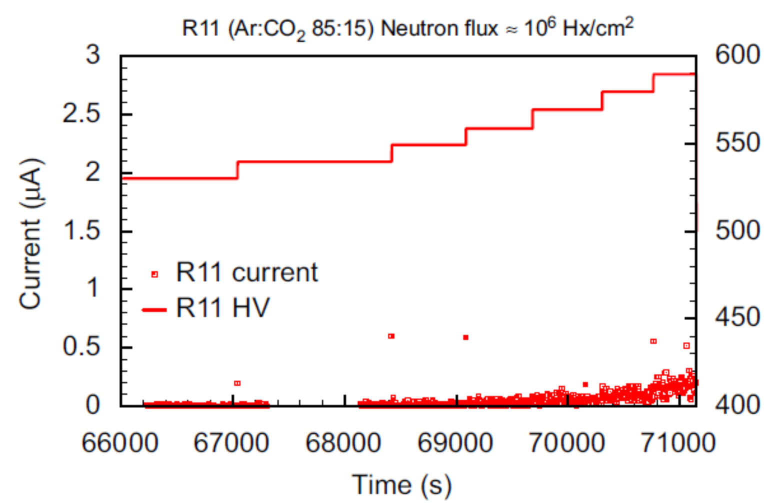
Recently this technique was also applied to Micromegas detectors by testing different resistive foils and strips topologies and proving good protection against sparks (development carried out within MAMMA collaboration for ATLAS muon chambers upgrades).

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,*]





Resistive strip micromegas topology

The trick at the resistive based technologies is **that the field is lost during a time long enough (in the order of us)** to allow charges drifting leave the gas.

The main advantages

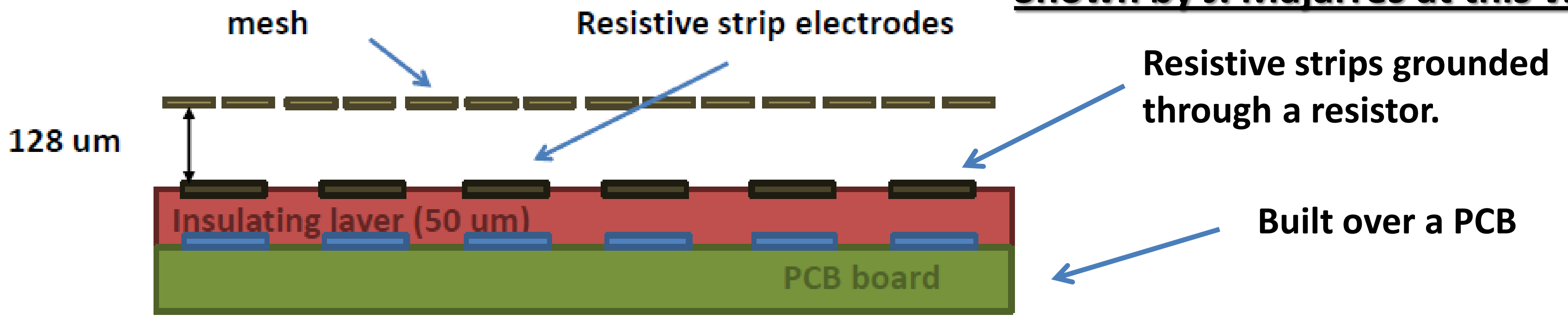
The spark does not evolve to its final state, the total discharge charge is well reduced and the power supply **voltage at the mesh is not affected.**

Field is lost only locally.

This leads to increased detector lifetime and reduced deadtime

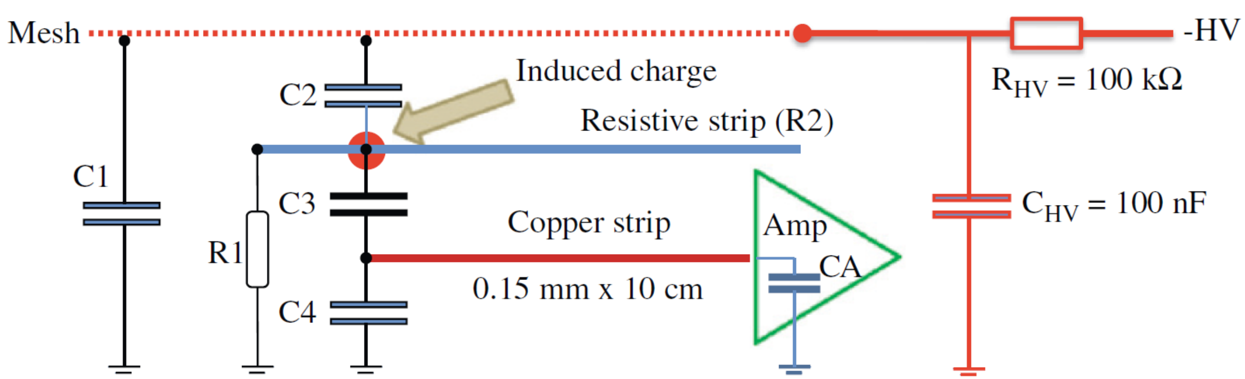
One of the topologies that better performance presented during tests at SPS beam at CERN

Shown by J. Majarres at this WS



A simplified electronic model to study resistive strip read-outs.

The same publication mentioned before gives the same **equivalent electronic model** which involves a resistive strip. Can be considered as the simplest model to take into account for a base study.



The present work is partially inspired on the previous work of Dixit & Rankin, where they obtain an analytical approach to the charge dispersion on a bi-dimensional resistive foil and the induction to electrode pads through an insulationlayer. Obtaining spatial read-out capabilities.

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

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Signal propagation model

3. Model to characterize charge difussion in resistive strips read-outs.

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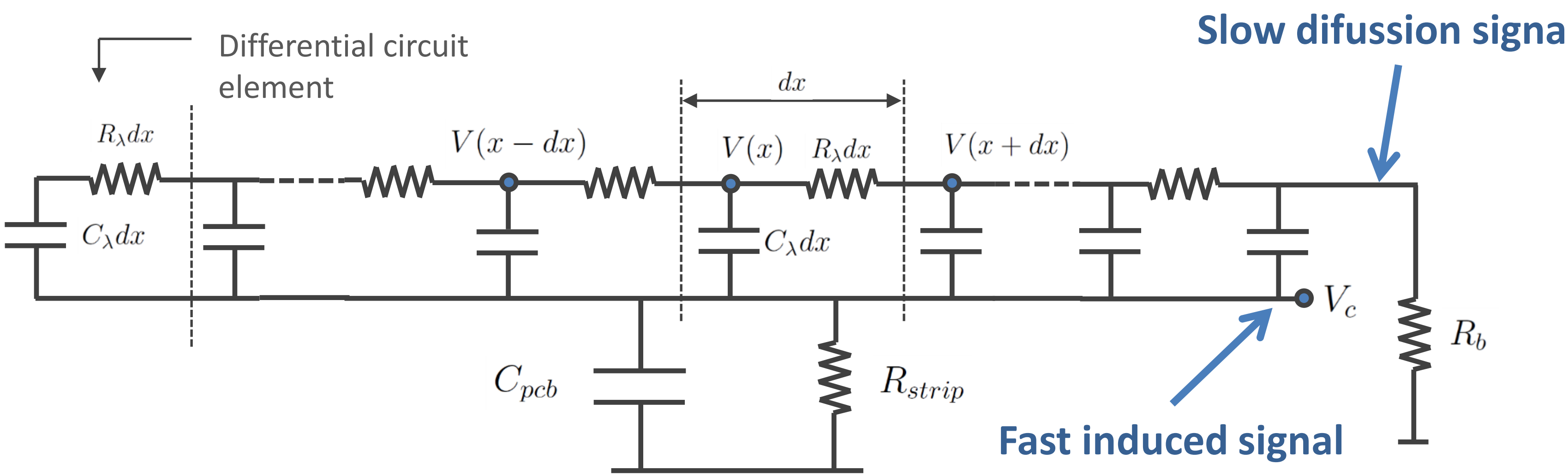
Resistive strip model to calculate charge difussion

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



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 to charge propagation

arXiv:1110.6640

These equation are solved by spatial discretization (standard and very well known method)

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

Which leads to a set of coupled differential equations

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

Which after some transformations allow to solve a set of N undependent equations.

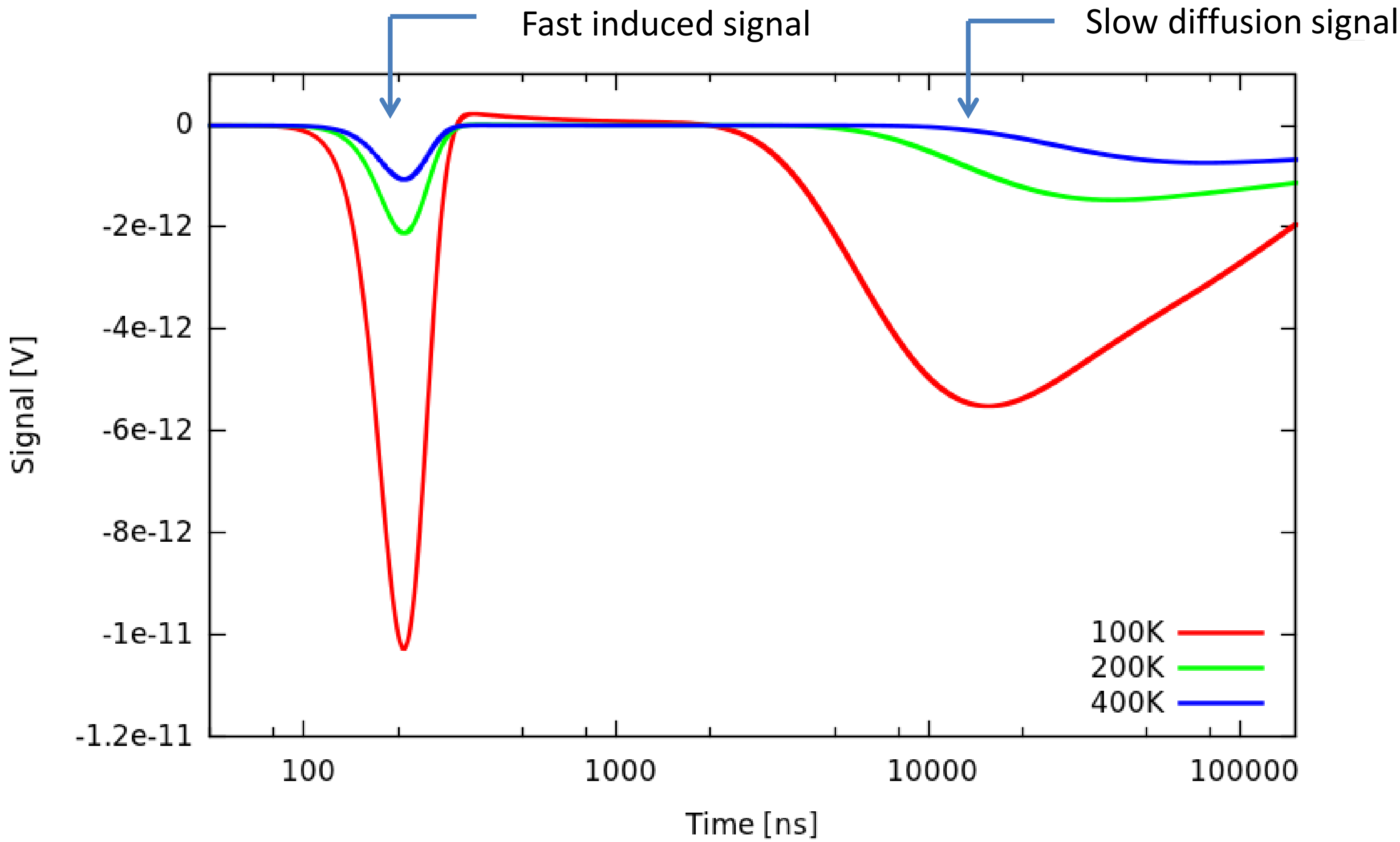
Diagonal matrix

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

Transformed potential

Current evolution at the boundary resistor Rb for different resistivity values (Logarithmic time scale)

The model shows a fast induced signal which is the common read-out signal, and additionally a second signal due to charge difussion through the resistive strip.



Different simulations 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

Cluster size simulations 100 um

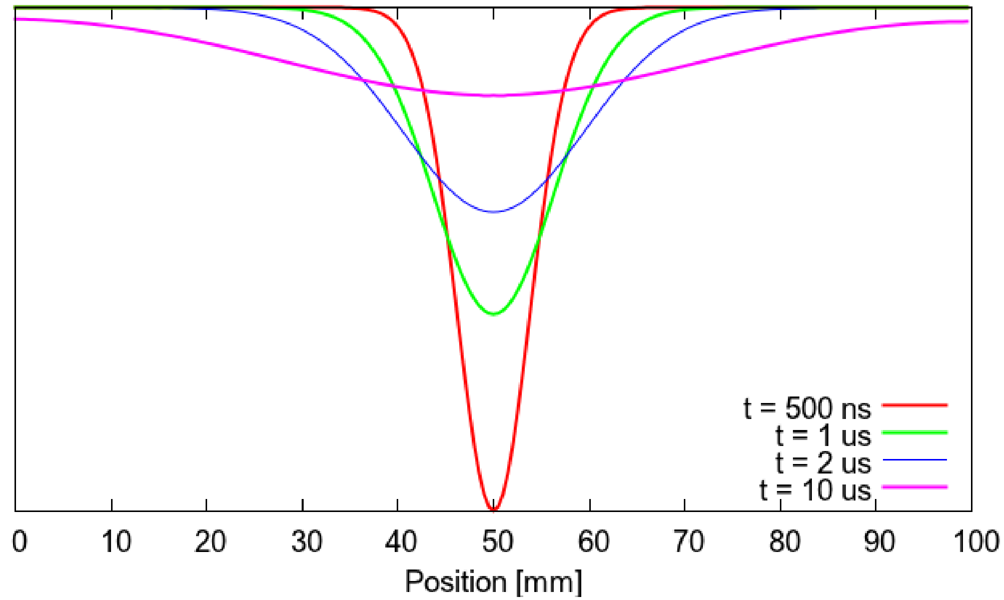
Contrary to fake intuition signal is not dependent **on transversal difussion**

Charge difusion at different periods of time

A gaussian charge signal is introduced at the center of the detector.

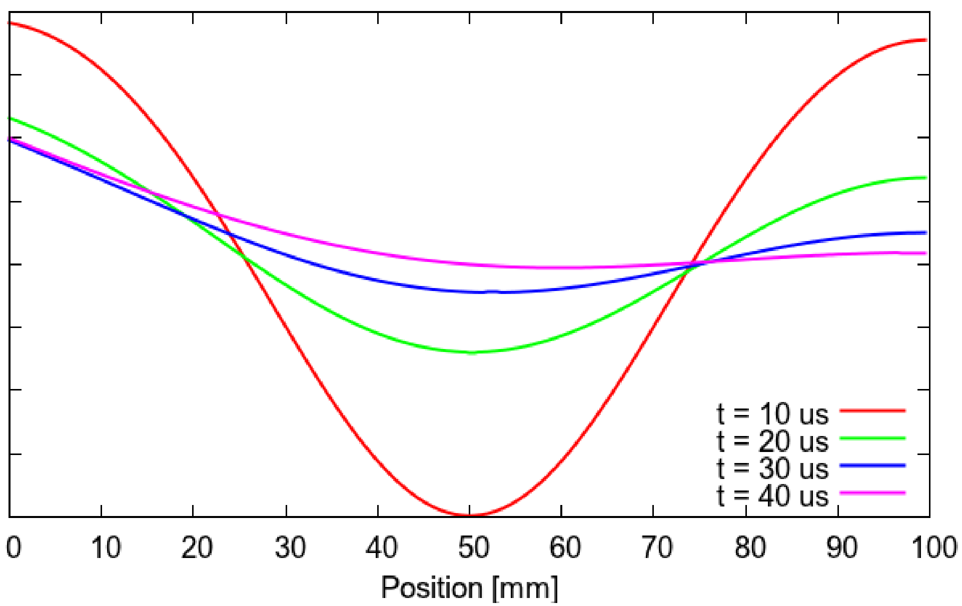
With highest value at 200ns and a sigma of 50ns distributed in few mm.

First time steps



GND

Last time steps

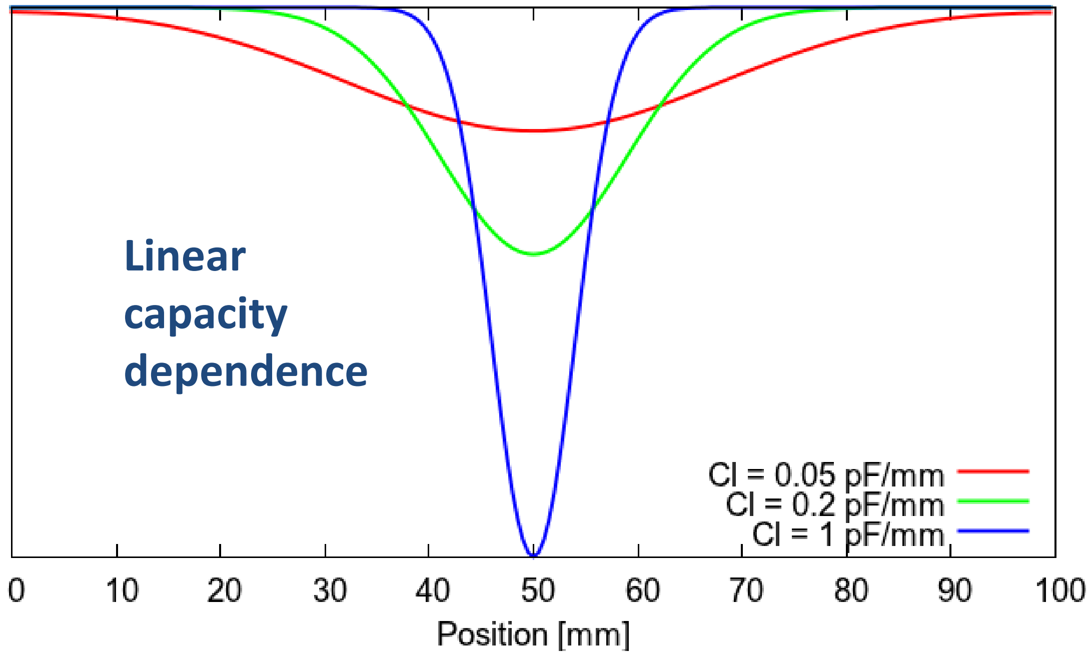


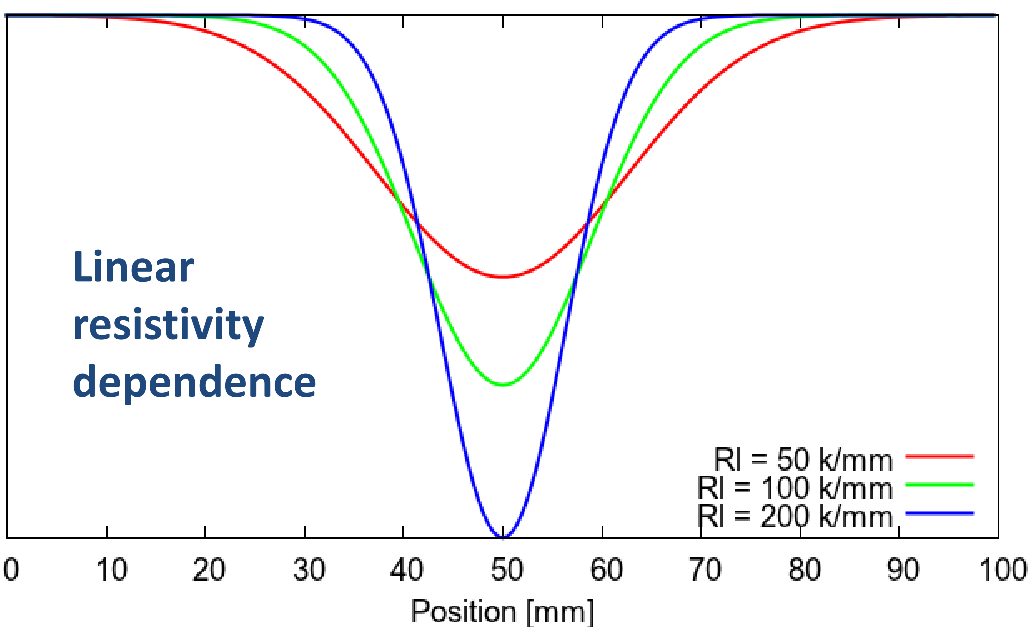
The effect of charges drifting to ground it is observed at the latter time steps.

Charge difussion at different resistivities and capacitances

For the same input signal the charge spread at different resistivities and capacitances values can be evaluated.

These results correspond to the charge spread after 1 us difussion





As expected higher capacitance and higher resistivity

↓

lower charge diffusion

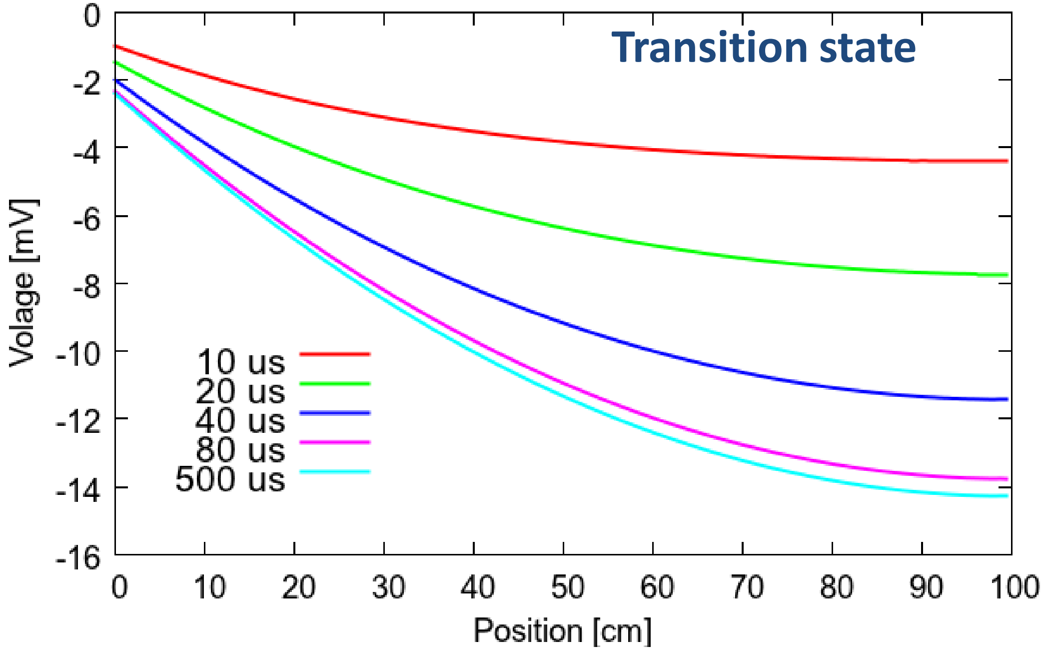
Simulating homogeneous illumination

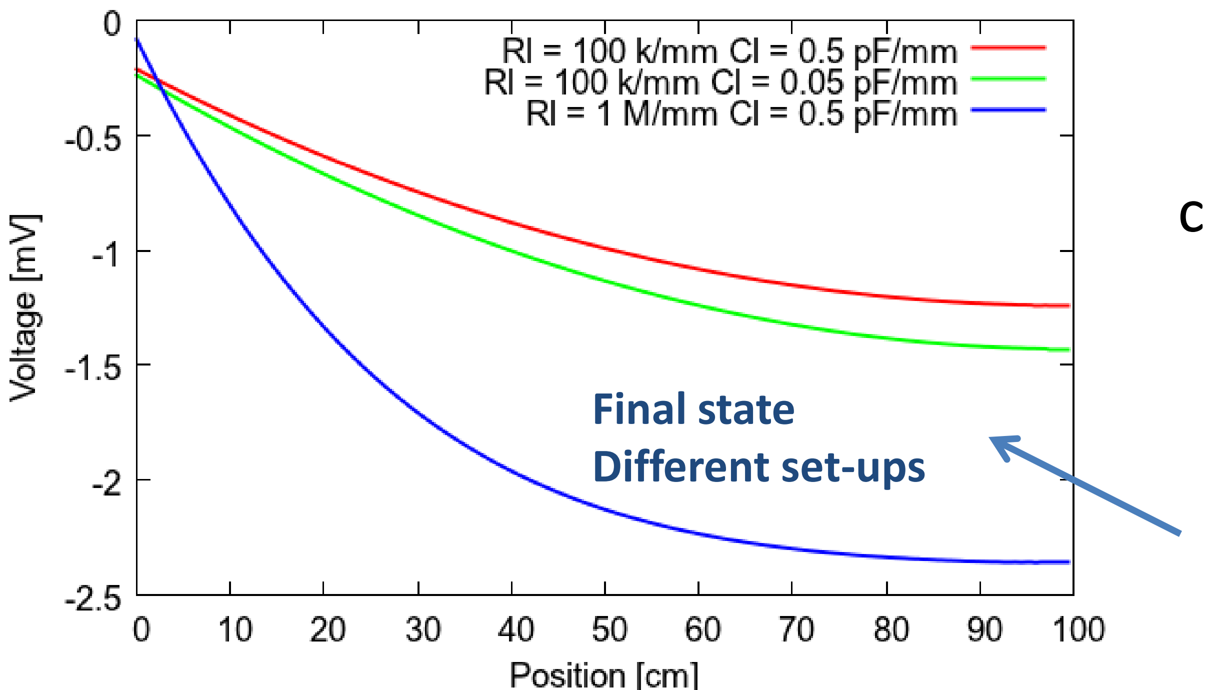
Instead of using a Gaussian signal an homogeneous current along the resistive strip is introduced

Rate = 100 kHz

Gain = 10000

Primary electrons = 300





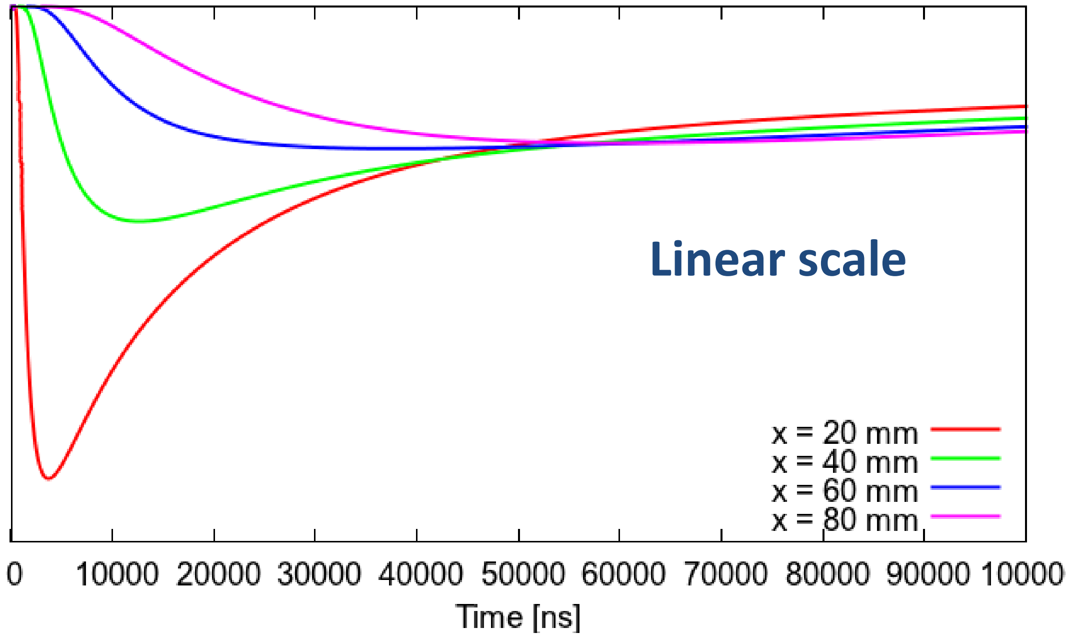
The resistive foil is charged-up and it could lead to gain inhomogeneities

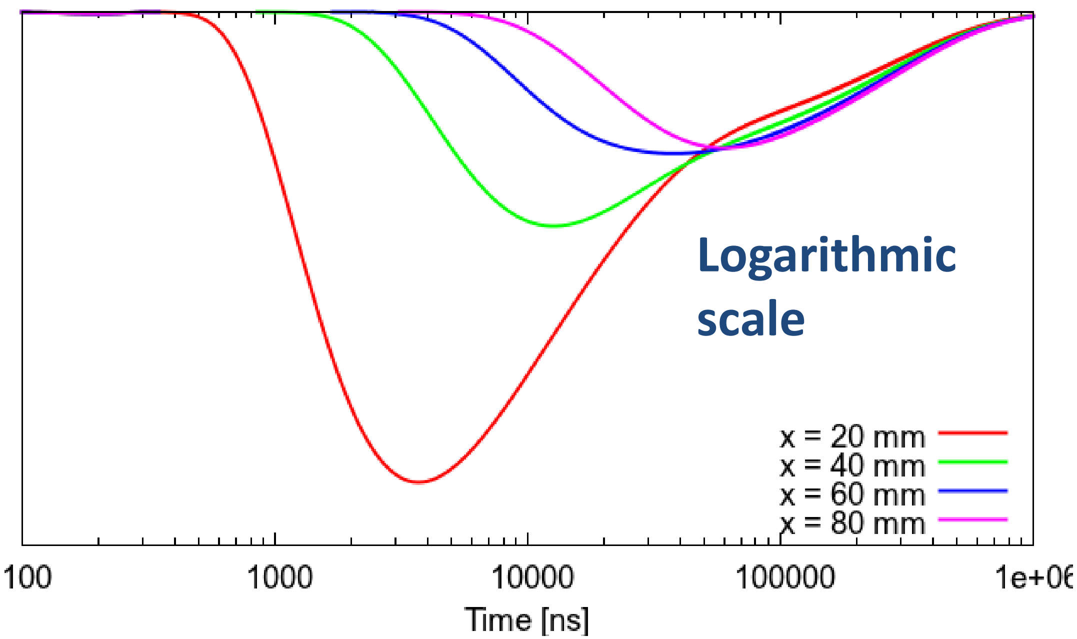
Relation with resistivity and capacitance at the final state.

Obtaining a signal through resistive at different positions

The **current at the boundary** resistor is plotted versus time for different positions every 0.5 mm **showing different pulse-shapes and delays**.

Closer to the ground higher is the signal and the most dangerous for read-out electronics.





<u>Gaussian current signal</u>

at 200 ns and sigma 50 ns

<u>Resistive strips parameters</u>

Rl = 100 k/mm

Cl = 0.2 pF/mm

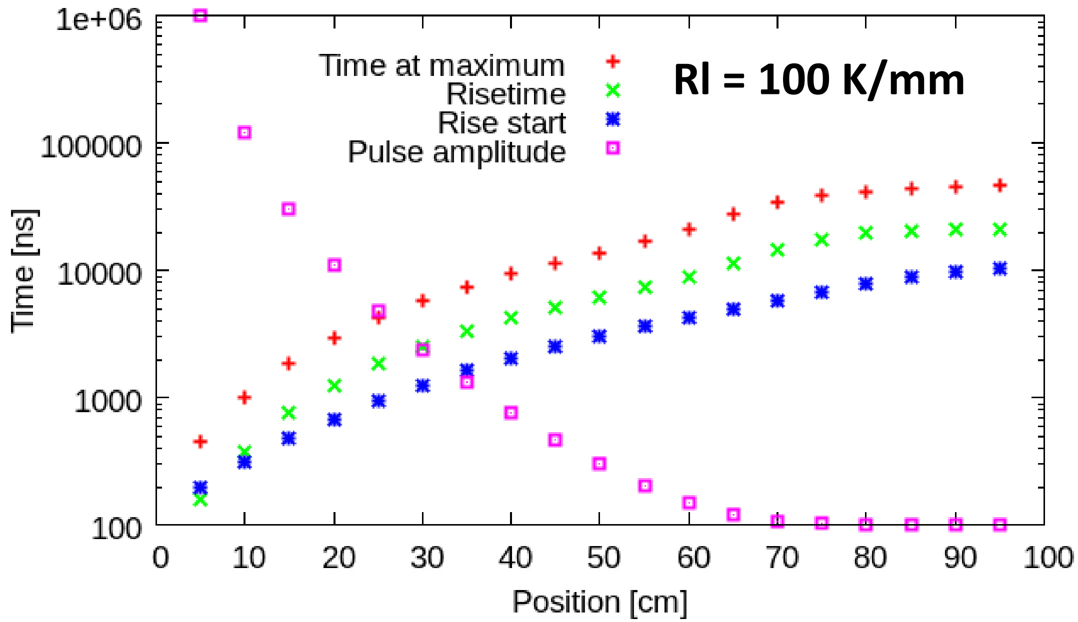
Rb = 5M

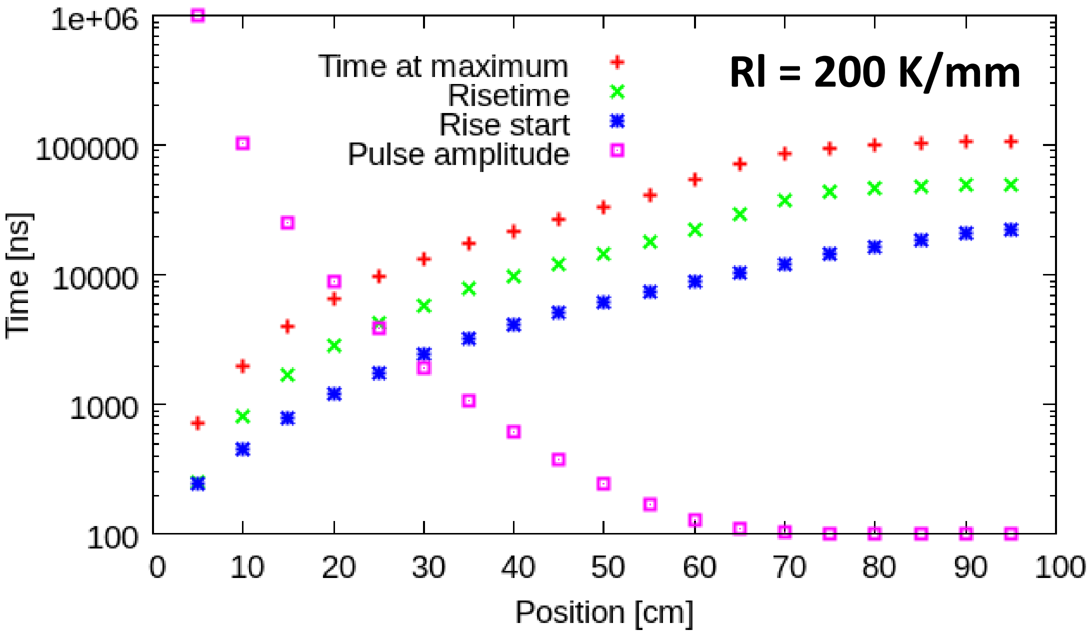
Pulse properties for different event positions

Two resistivities shown at fixed linear capacitance and boundary resistor

Cl = 0.2 pF/mm

Rb = 10 M





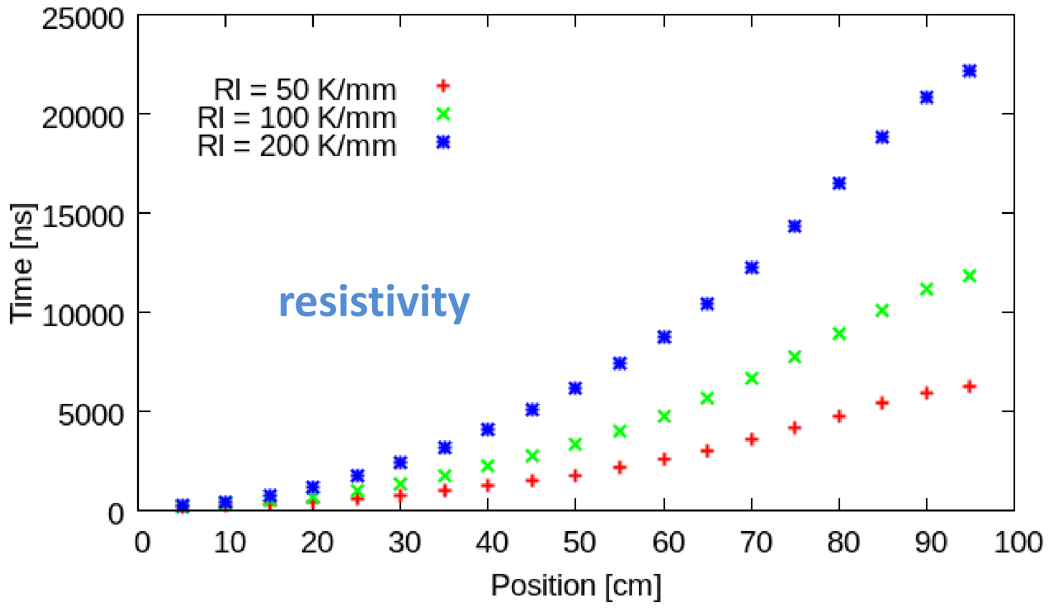
Pulse properties: risetime, width and rise-start changes along the resistive strip lenght.

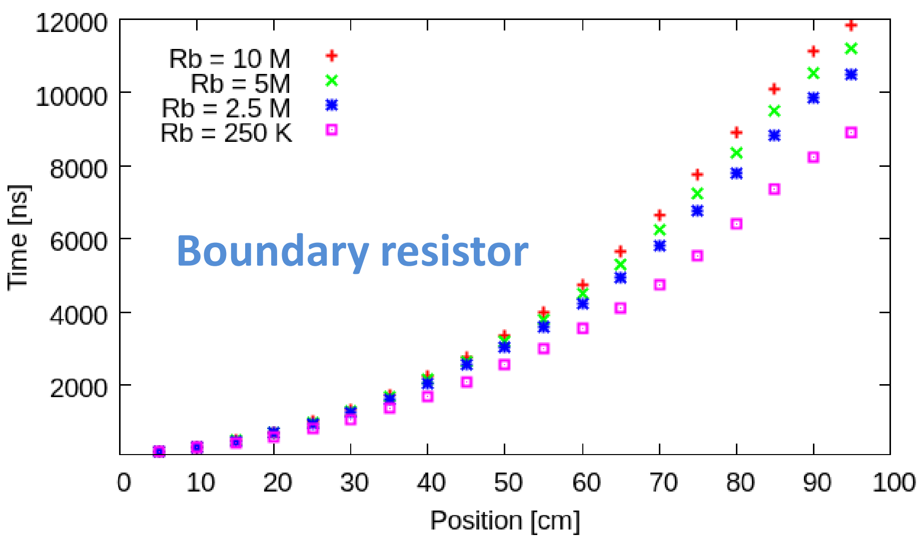
Opens the possibility to use these properties for event position recognition

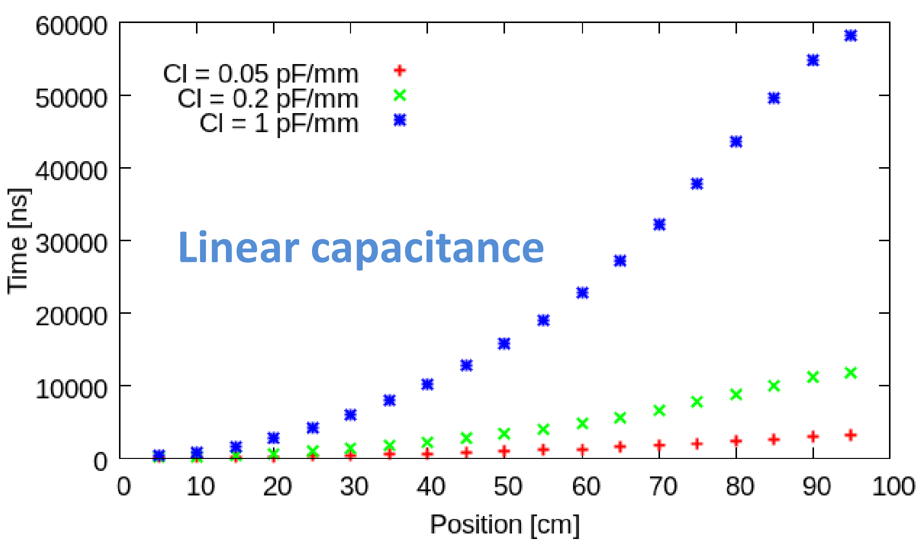
Risetime-start delay for different resistive strip model parameters

Signal delay is obtained for different linear resistivities, linear capacitances and boundary resistor values.

Signal shows NO big delay dependency with boundary resistor.



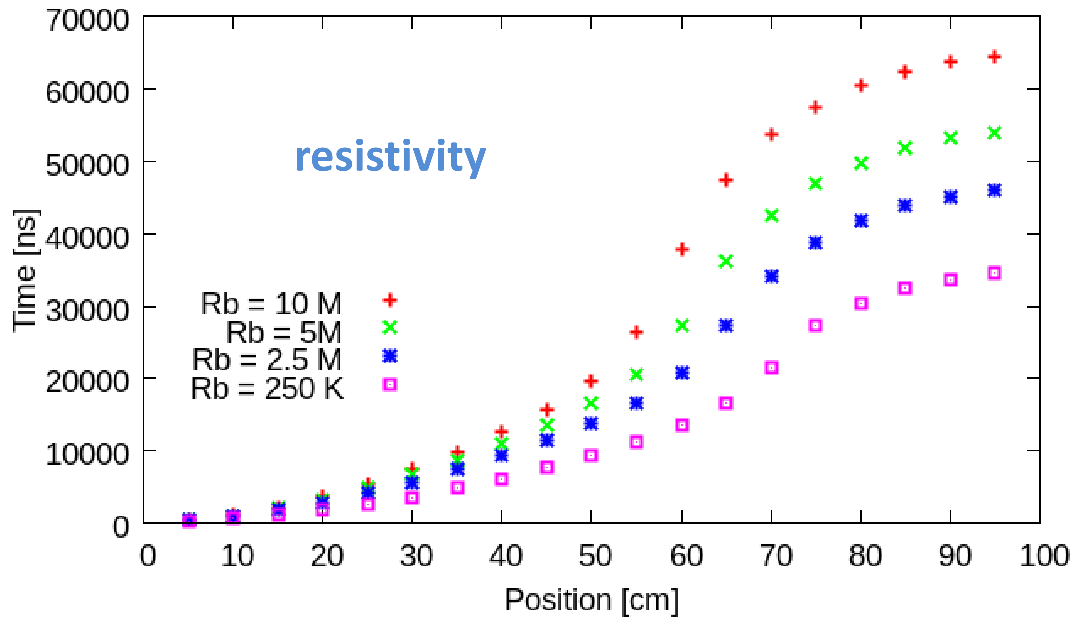


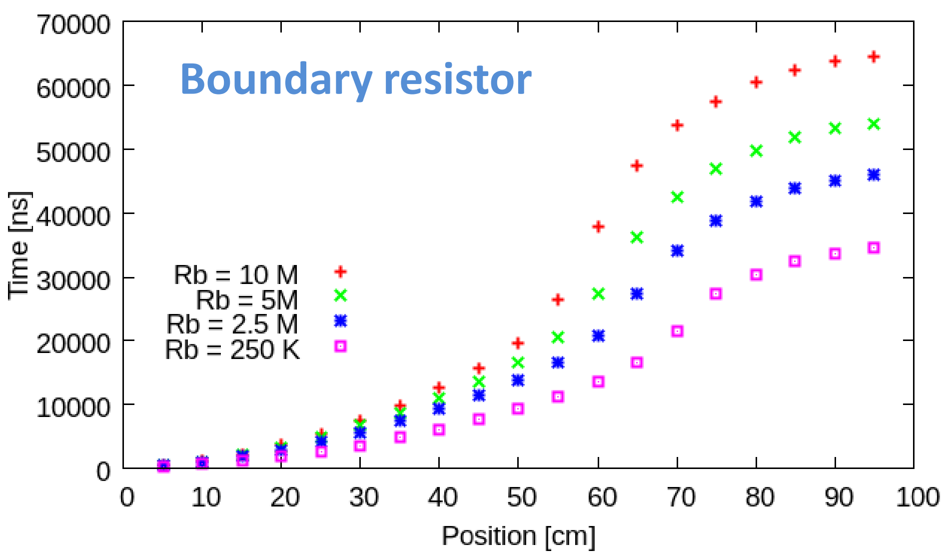


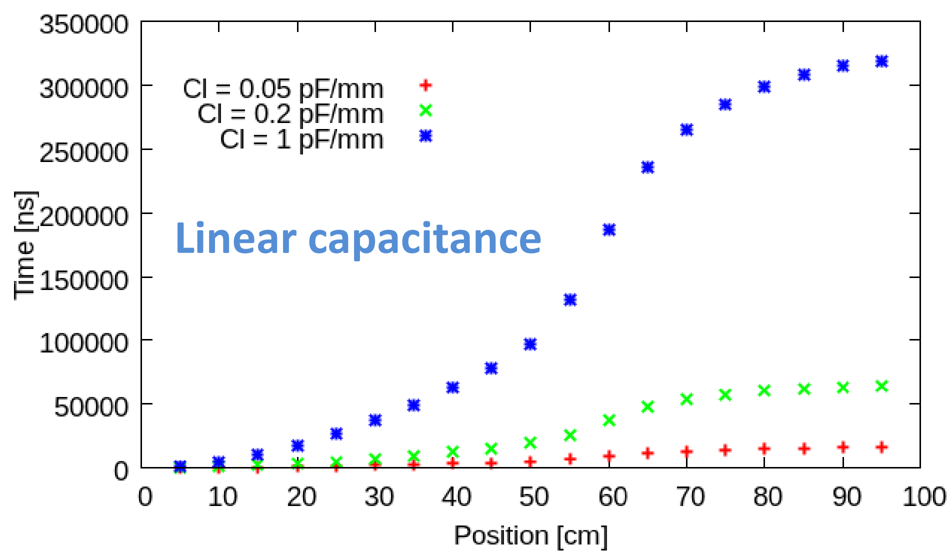
Maximum peak delay with event position

Maximum peak delay is obtained for different linear resistivities, linear capacitances and boundary resistor values.

Linear capacitance is crutial in the time delay.







Future studies related with resistive strip read-out

Use **a beam current at different positions to study gain unhomogeneity** due to dependency on charge distribution.

Introduce gain dependency (through Townsend parameters) in the description of the input current, and calculate **gain relation with input current**.

Change the potential of Vc to different fixed values to check **effect on the gain**, tests at different Vc values to be done experimentally.

Study the **effect of the strip length in gain homogeneity**.

Resistive strip model is implemented in C code allowing to integrate a future more complex simulation (with i.e. Garfield, neBEM, etc)

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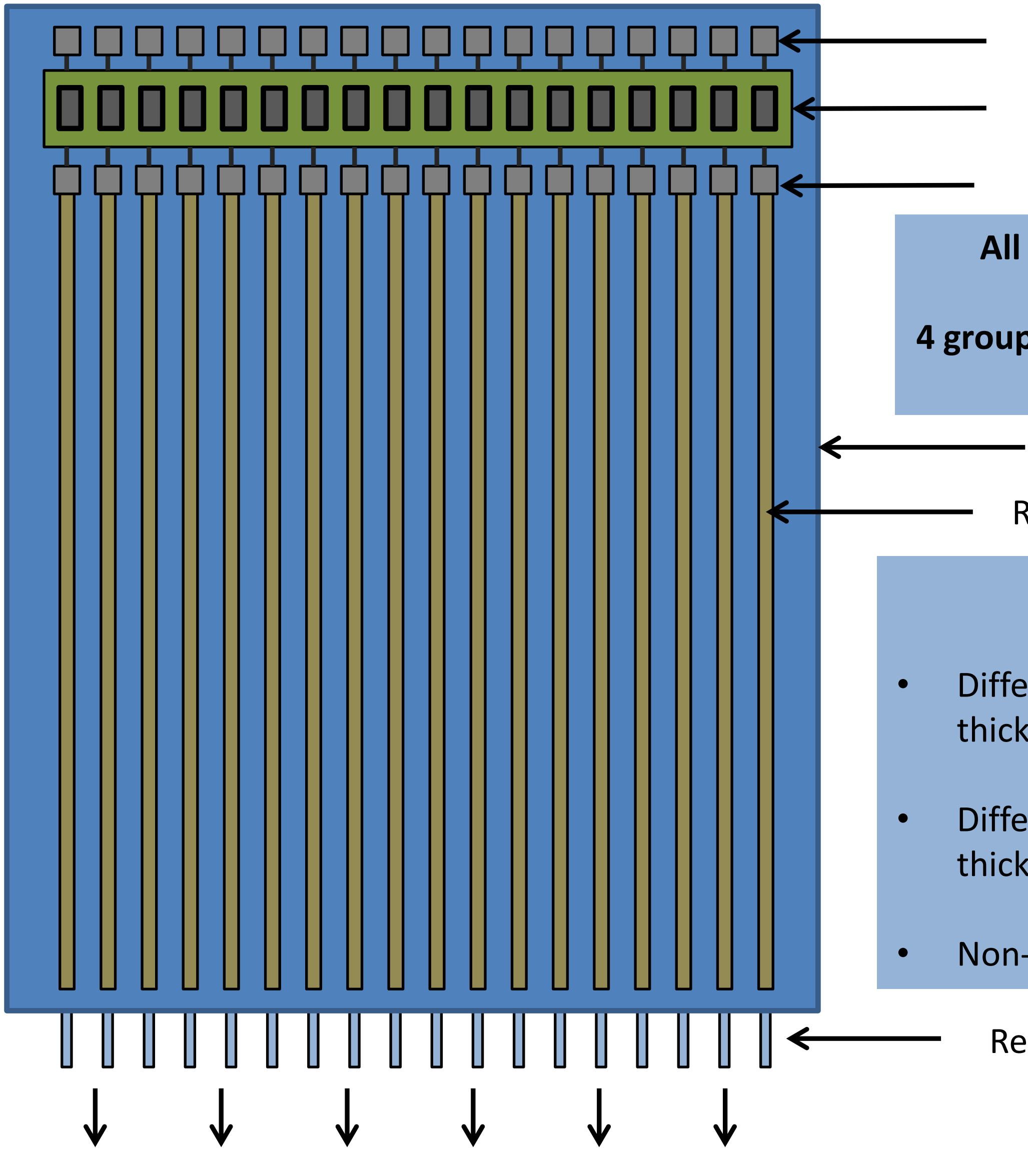
General resistive prototypes
1-D readout (2-D capabilities?)



All prototypes with 100 lines of 1 mm pitch

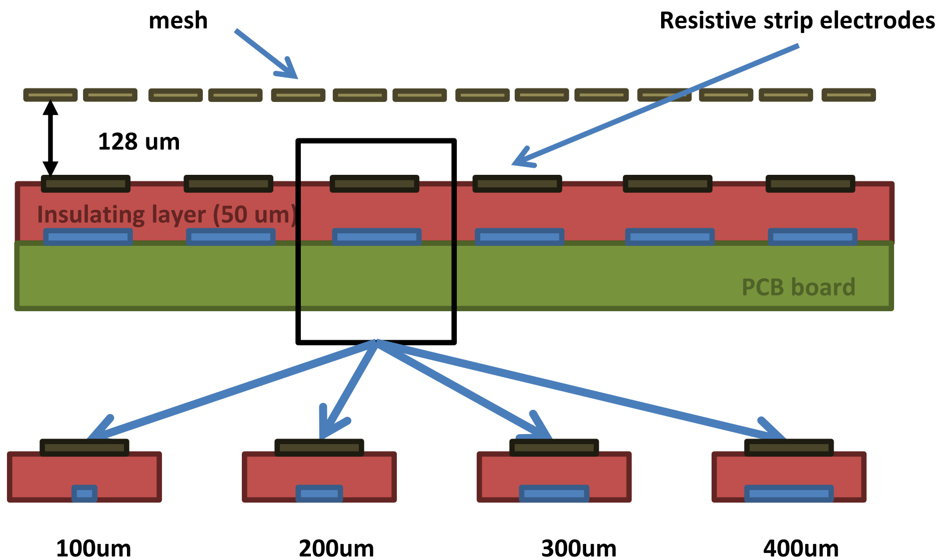
4 groups of 25 strips built-in the same detector with diferent geometries (strip width).

3 (x2) prototype proposals

- Different resistive strips width values + usual thickness
- Different electrode strips width values + usual thickness
- Non-resistive strips + insulator thickness (X4)

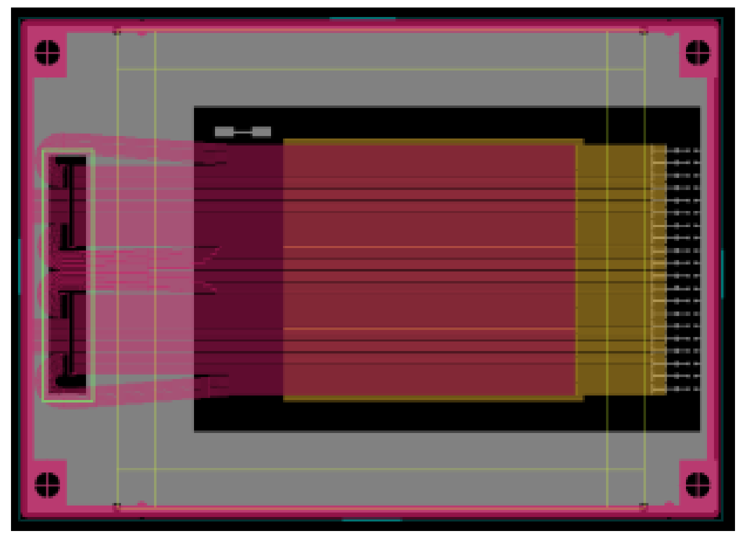
General resistive prototypes
1-D readout (2-D capabilities?)

Different strip widths schematic

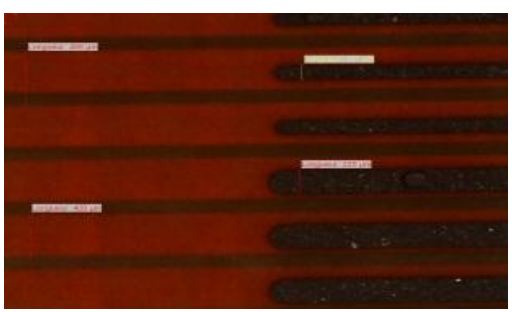


Prototypes designed and built at CERN PCB Workshop

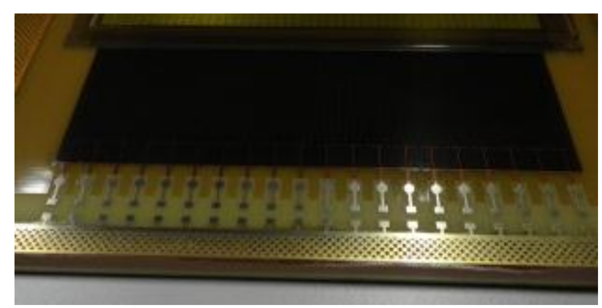
R. de Oliveira, J. Burners
based on MAMMA prototypes



Microscope picture



Resistive strips read-out pads picture



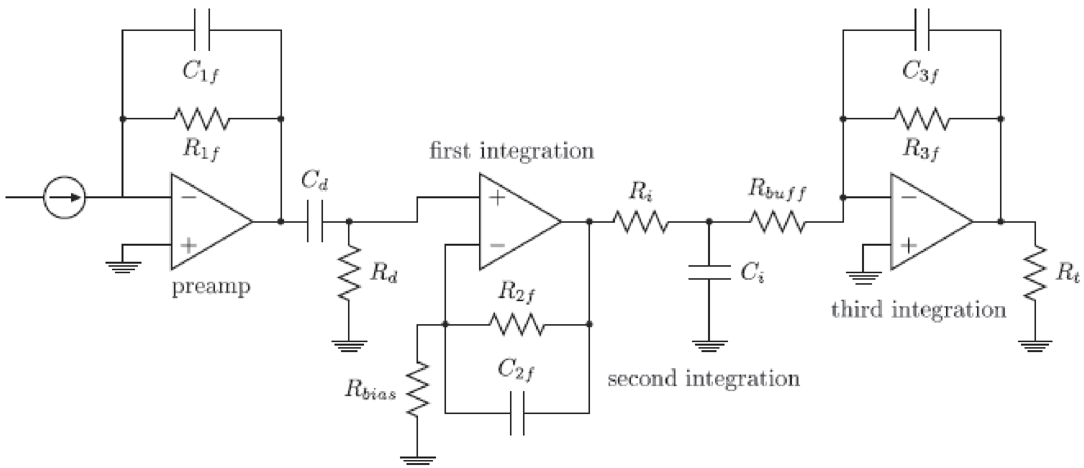
Electronic read-out to couple to high-impedance

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]

<u>Preamplification stage + 3 integration stages.</u>



"Optimum signal to noise ratio is given when the number of integration stages approaches infinity, **with a total integration time equal to the differentiation time".** Three stages are choosen just for simplicity.

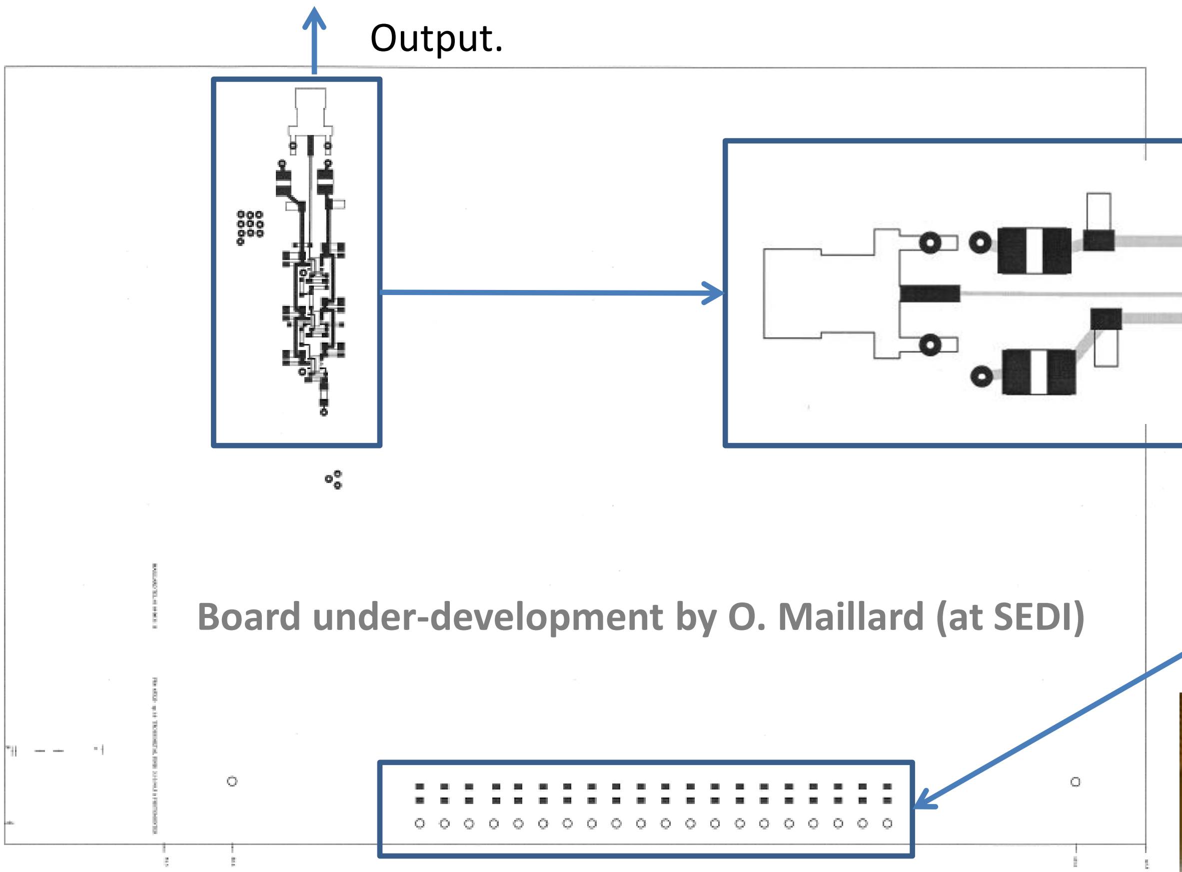
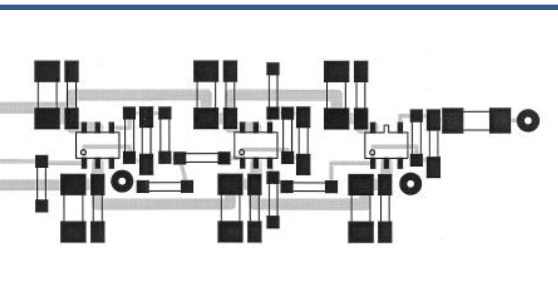
Thus, once the integration time is constrained it is also constrained the differentiation time.

Shorter shaping times than signal duration -> charge will be lost
On the other hand, parallel noise is proportional to the shaping time.
Shaping time should be a compromise and thus must be optimized.

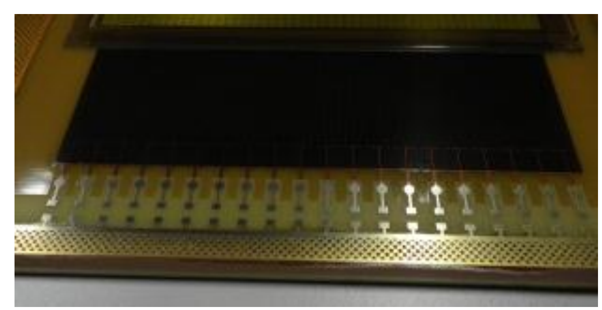
PCB read-out board

In order to read-out the resistive read-out signals at each line (20 lines) a PCB board is under design at SEDI (O. Maillard).

In principle SMA connector will be used in order to read-out with scope. Future solution to read-out 20 lines to be implemented.

Electrode-pads interface to connect the board to detector by using Spring Pin Connectors.



Summary, conclusions and future work.

Is a fact that **resistive technology** (RPC and rMPGD) **do prevent sparking** processes at the detector.

In the framework of the last resistive micromegas detectors produced for MAMMA, a **simplified resistive-strip model** was used to derive results in different detector conditions.

First results show

- possible inhomogeneity's in the gain due to charge difussion.
- Pulse-shape dependdency with position.

Future results

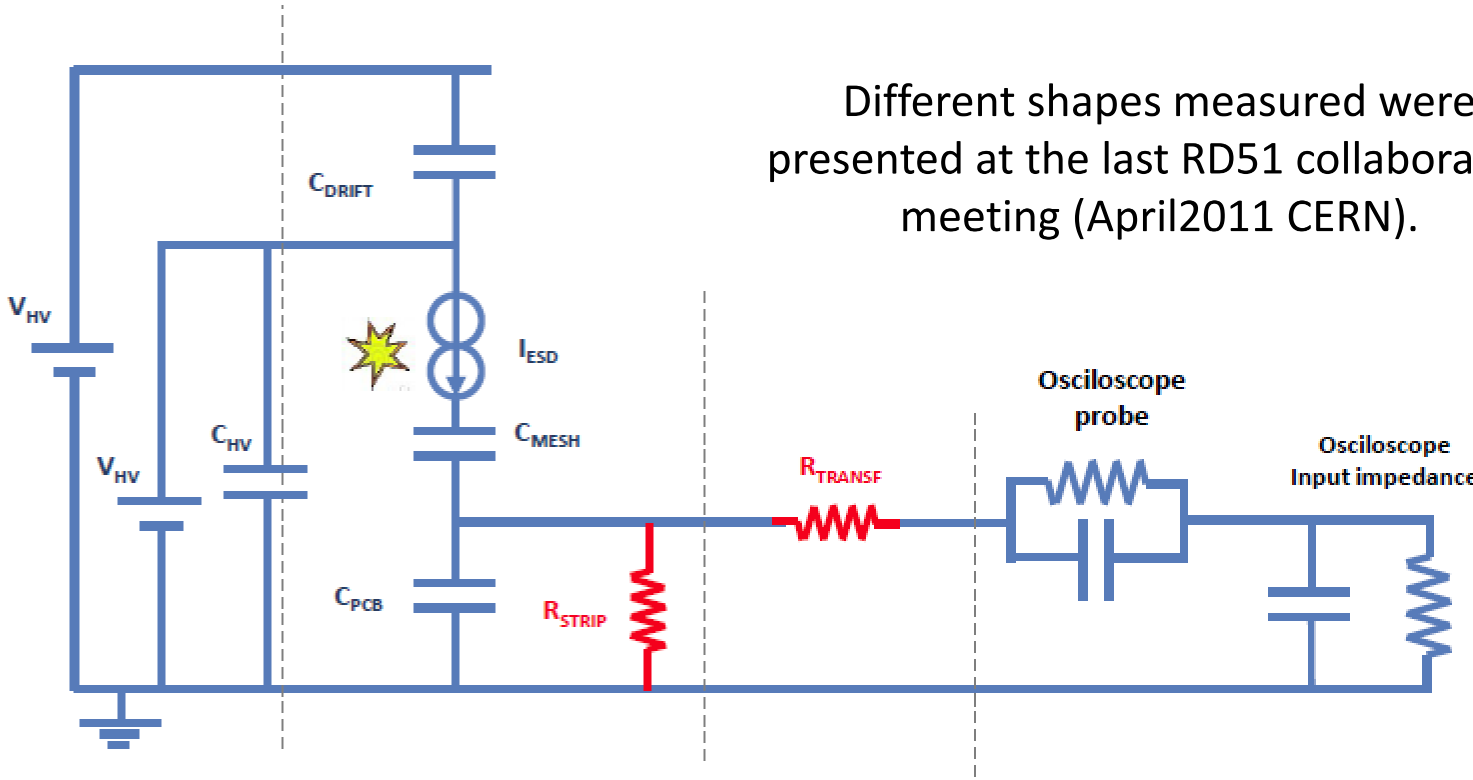
- Gain dependency with particle flux rate
- Gain versus mesh voltage curve for a fixed current

Prototypes ready for testing, characterization of resistive propagation will allow to measure signal delay and charge produced by different kind of events, included sparks.

3. Transient measurement at different connection schemes

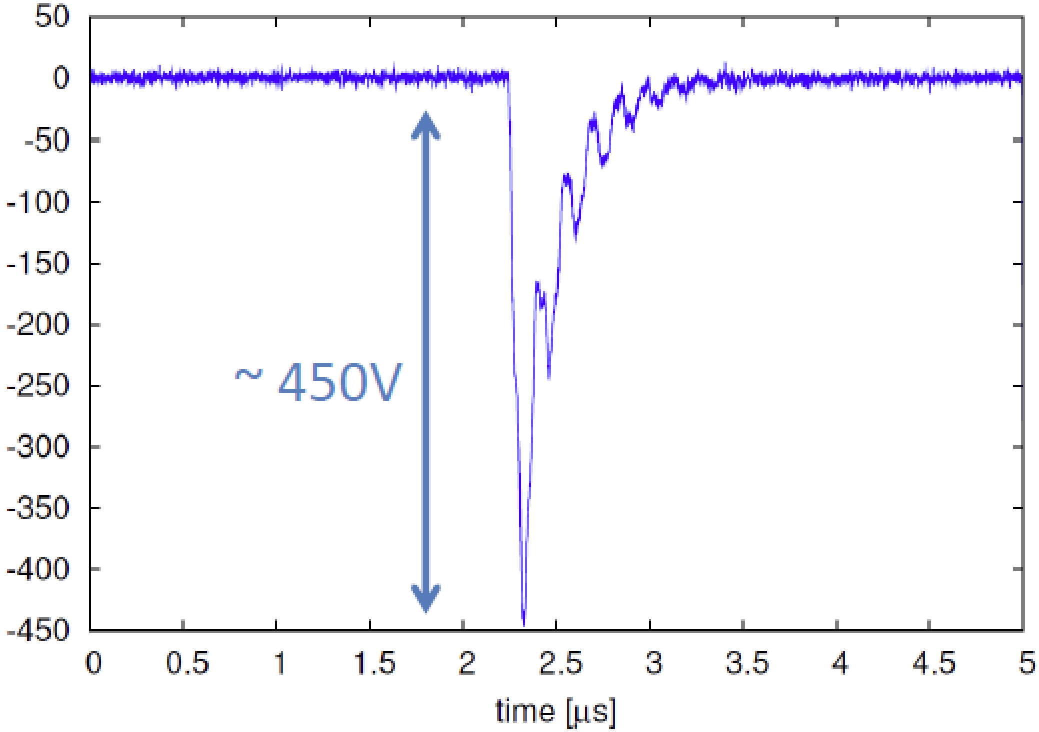
Transient measurements were taken at different connection schemes.

Different shapes measured were presented at the last RD51 collaboration meeting (April2011 CERN).

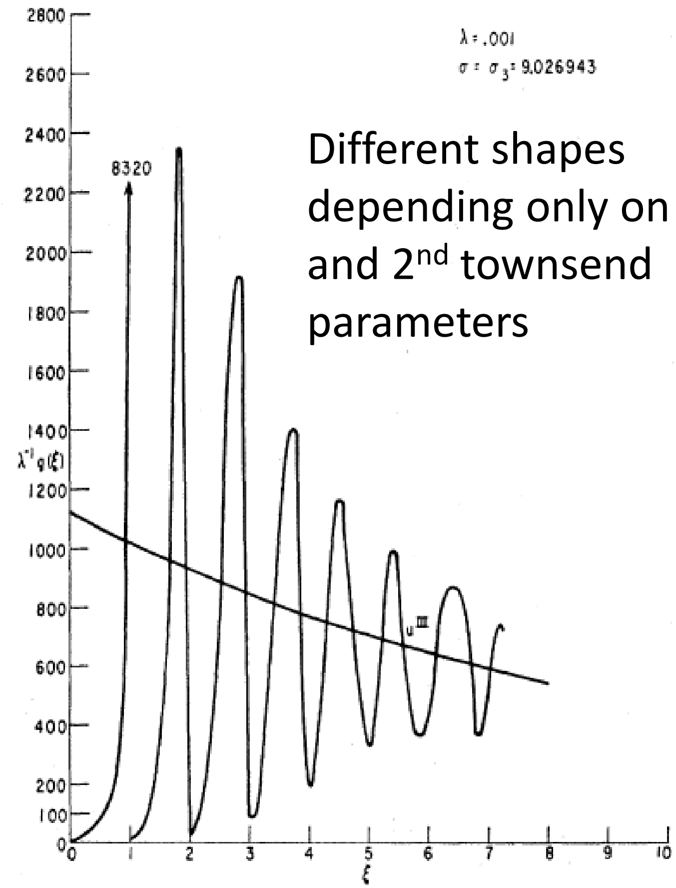


Interesting oscillations and shapes recorded which depend on the read-out configuration.

“Transient analysis of the townsend discharge”, P. Auer



Theoretical calculation



(b)

Different shapes depending only on 1st and 2nd townsend parameters

Such oscillations could be related with the ion transient time in the amplification gap.

Theoretical oscillation periodicity is given by the transient time.

In order to proof such thing one can check the periodicity dependency with high voltage and gas mixture.

Planning to extend the measurements presented at RD51 by using new configuration schemes including resistive type detectors.