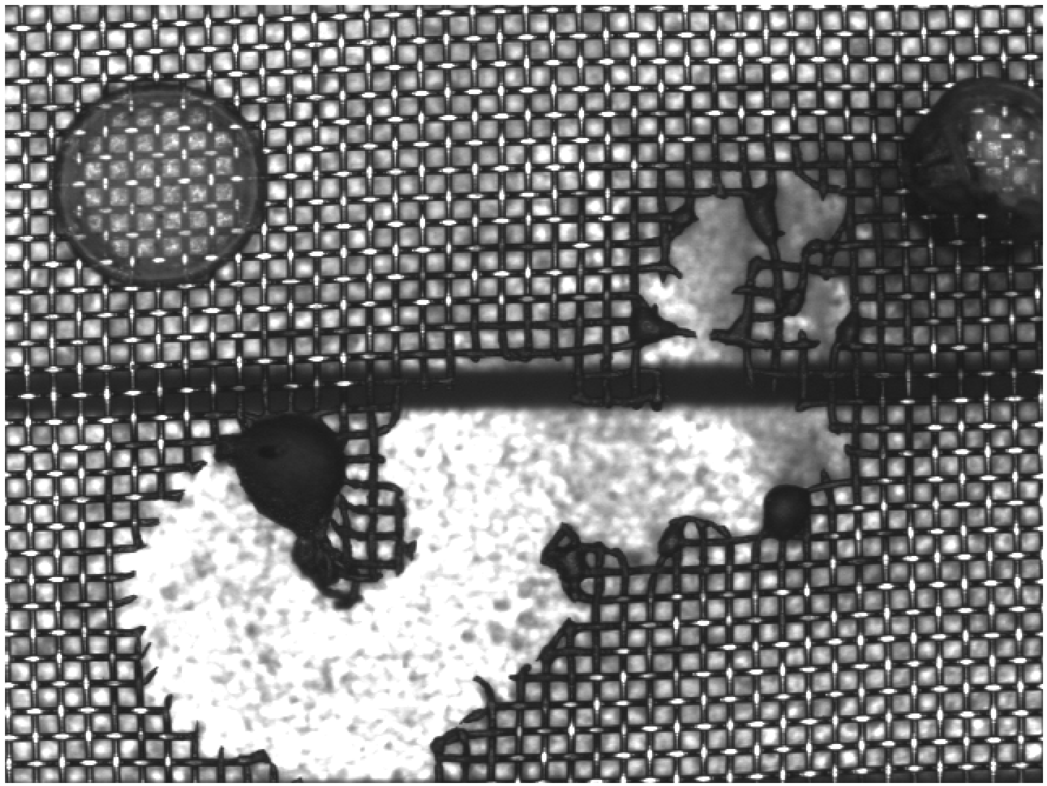
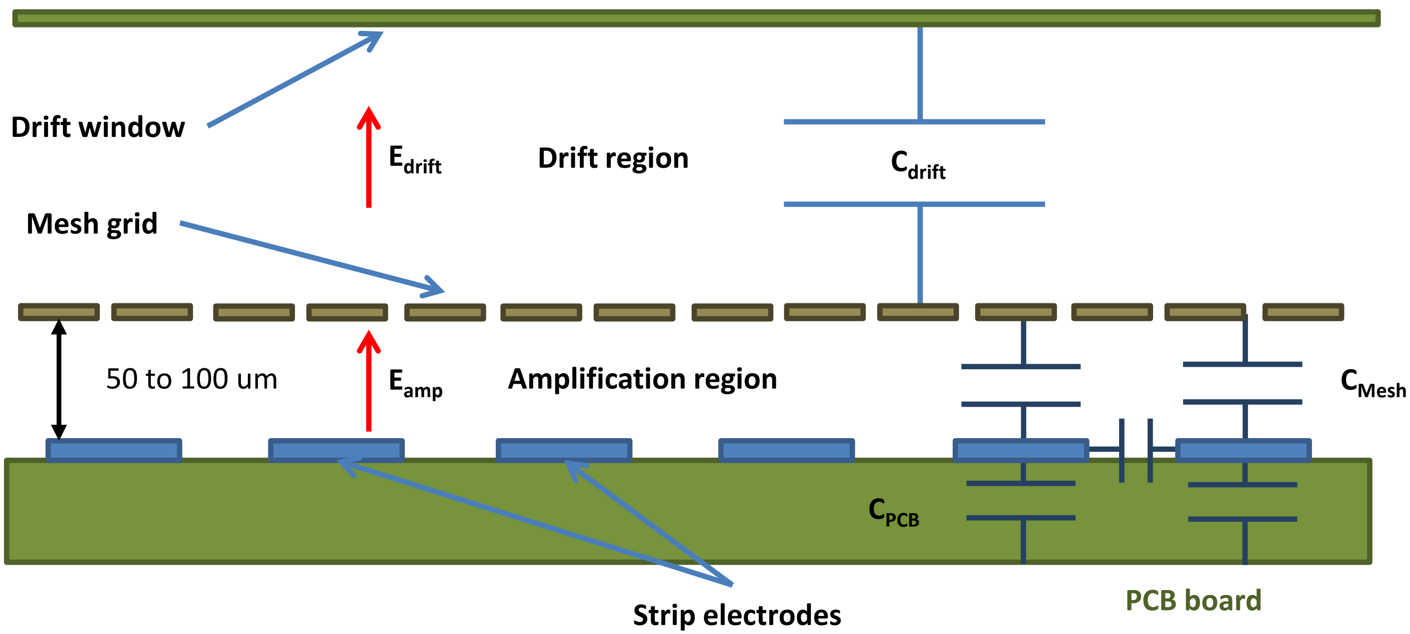
Characterization of the electrical response of Micromegas detectors to spark processes.



J .Galan
CEA-Saclay/Irfu
For the RD51 meeting

Spark measurements have been performed with a standard Micromegas detector



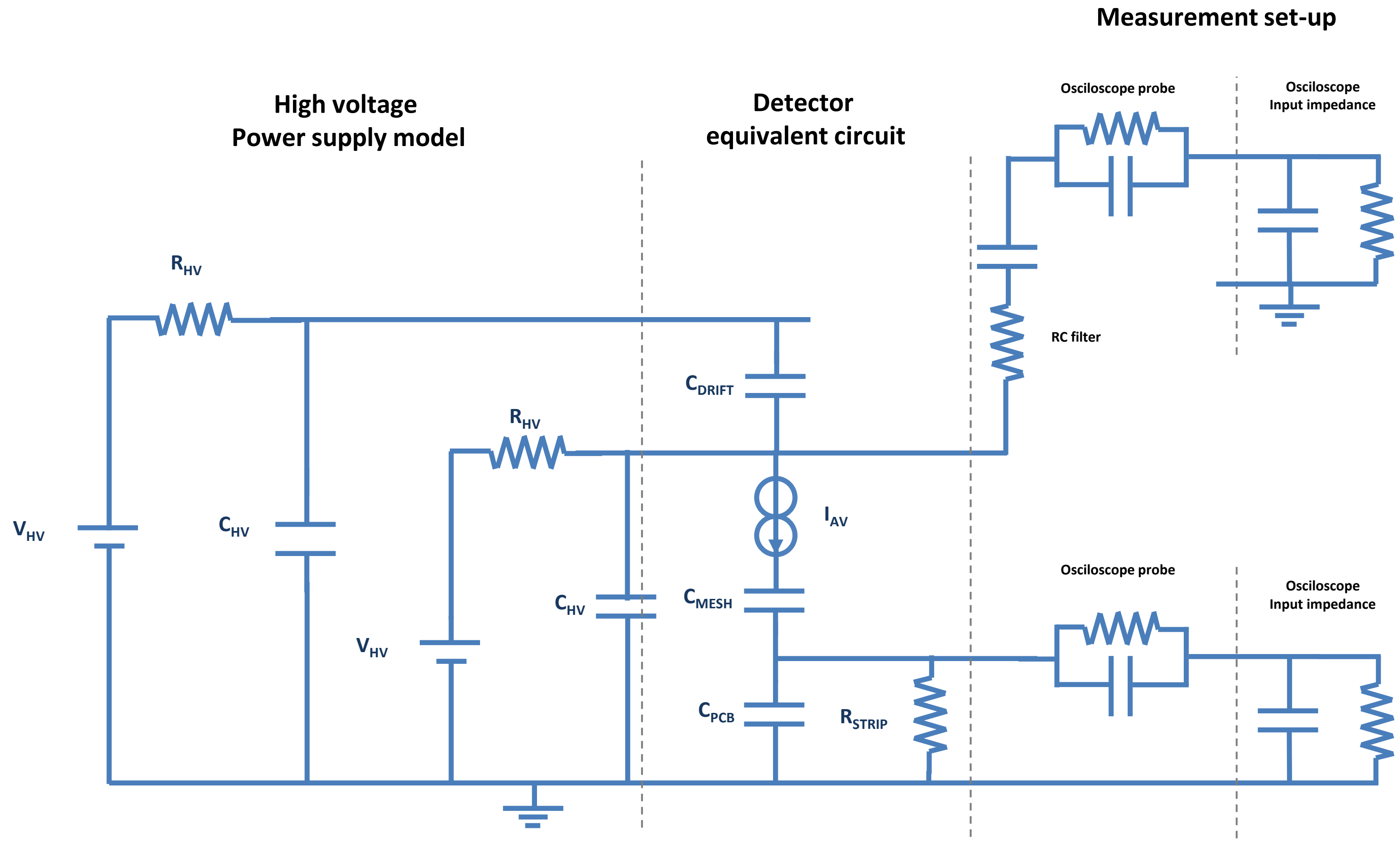
The aim is to establish a methodology and electrical modeling of sparking phenomena.

In order to understand the different electronic responses measured by the different read-out systems and prototypes under development.

Required modeling of spark + modeling of electrical response

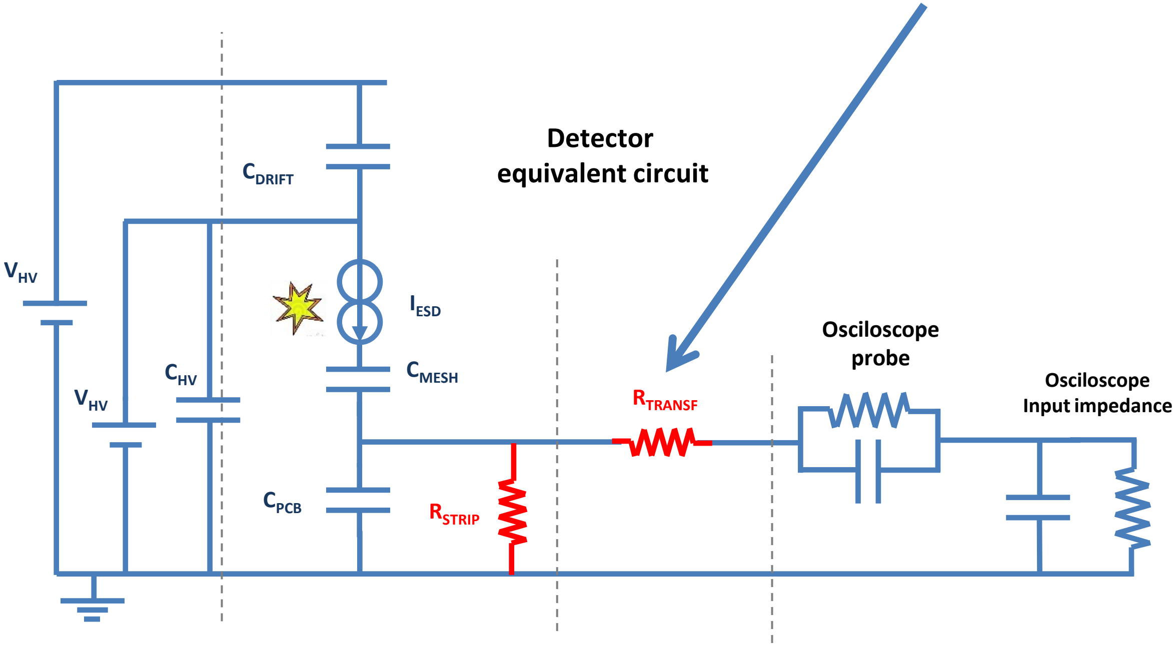
Full standard detector equivalent circuit

Here I draw all the components that could have (not that have) an influence in the electrical response. Just to have a global picture.

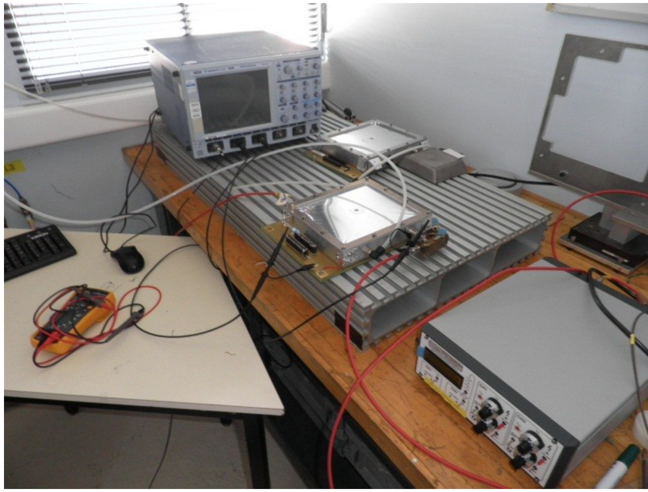


The million dollar question: There is room for any inductance in the model?

In this talk I present the effect on the pulse shape at different connection schemes



The set-up

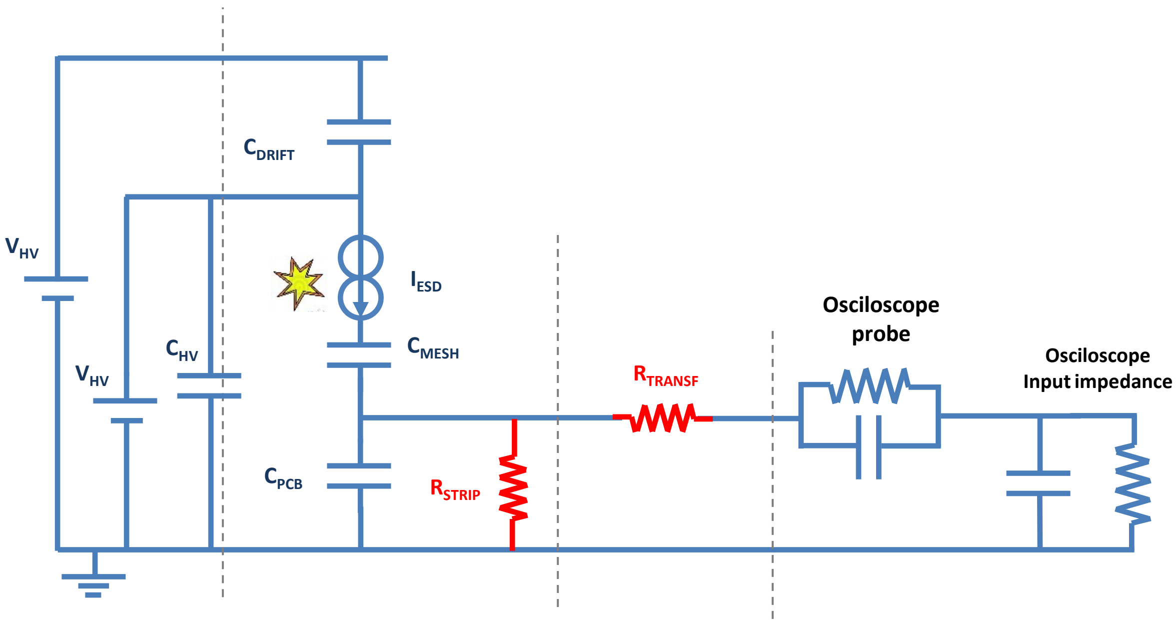


Recorded several pulses generated by sparks in the strips read-out.
In this set-up strips are interconnected to simplify and to integrate total signal.

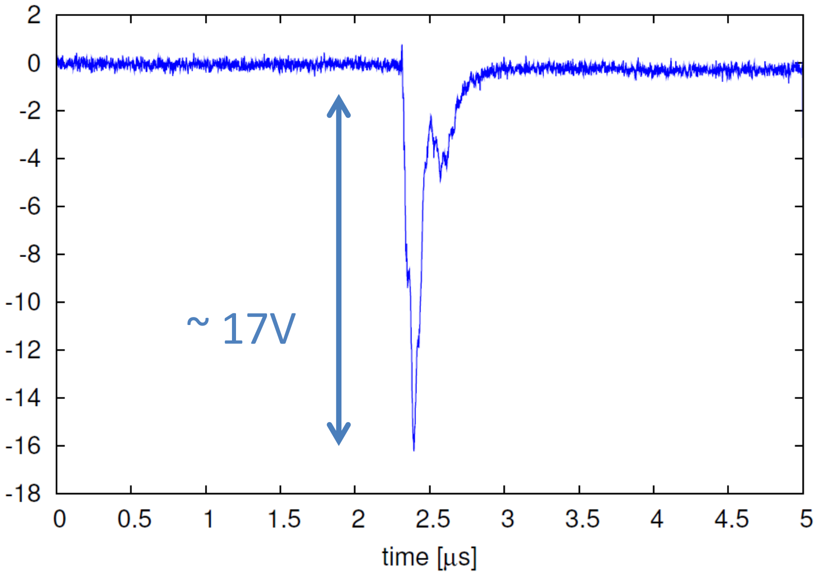
Combinations with the following values

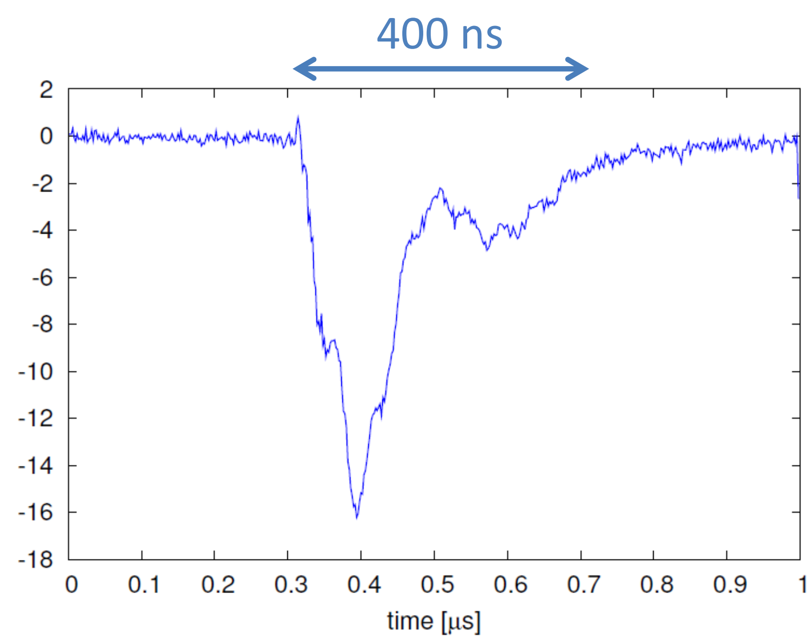
R_{strip} (Ω)	R_{transf} (Ω)
66.57	None
176.7	985.7k
890.6	9.94M

Effect on the pulse shape at different connection schemes

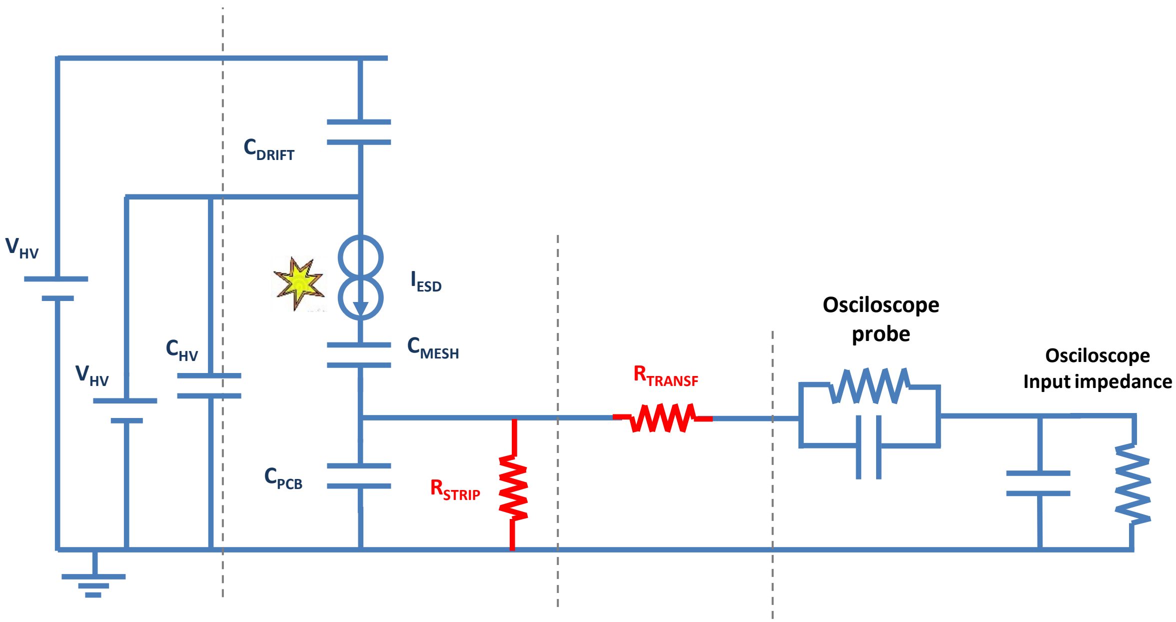


Low value	High value
R_{strip} (Ω)	R_{transf} (Ω)
66.57	9.94M

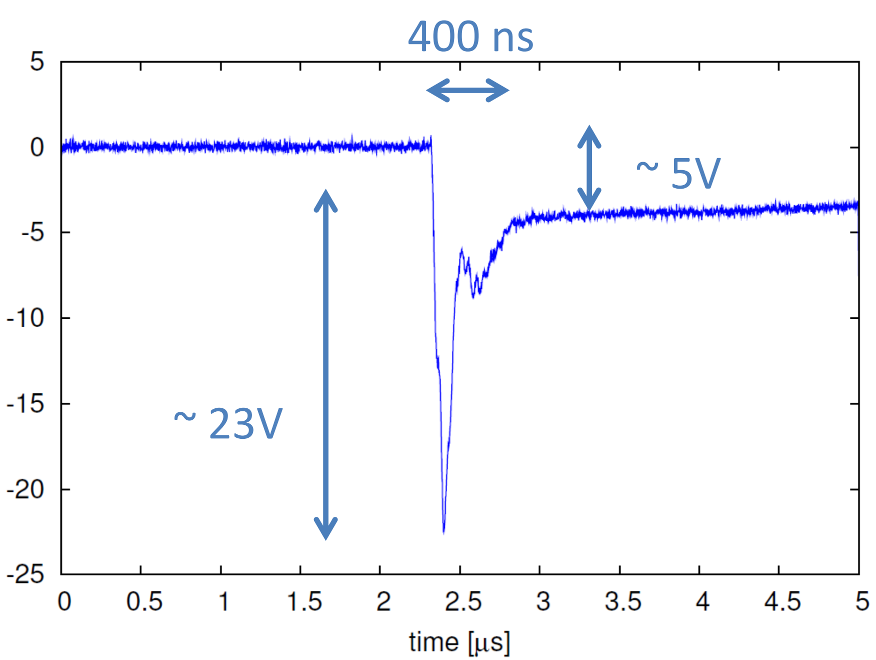


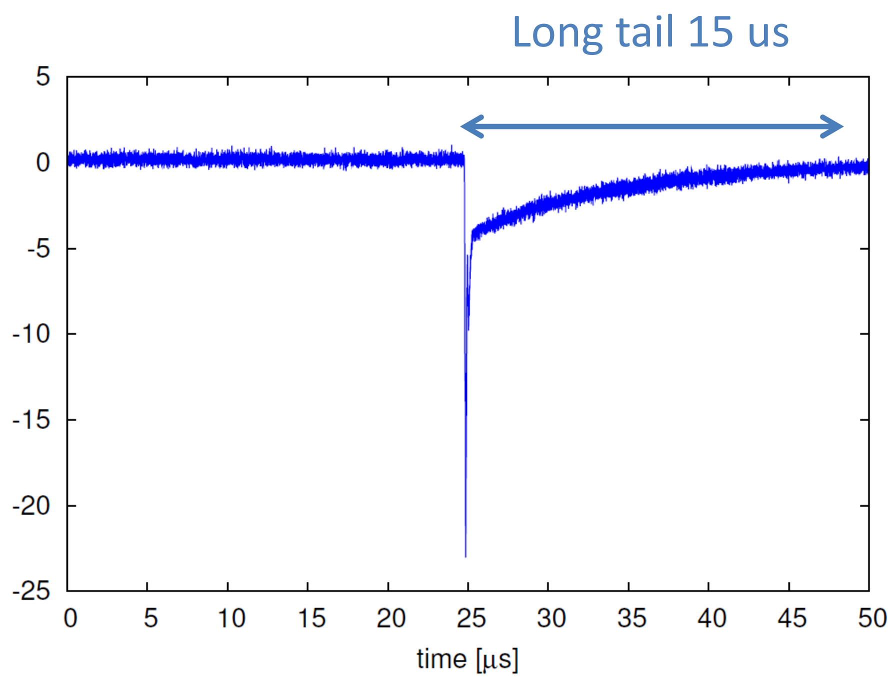


Effect on the pulse shape at different connection schemes

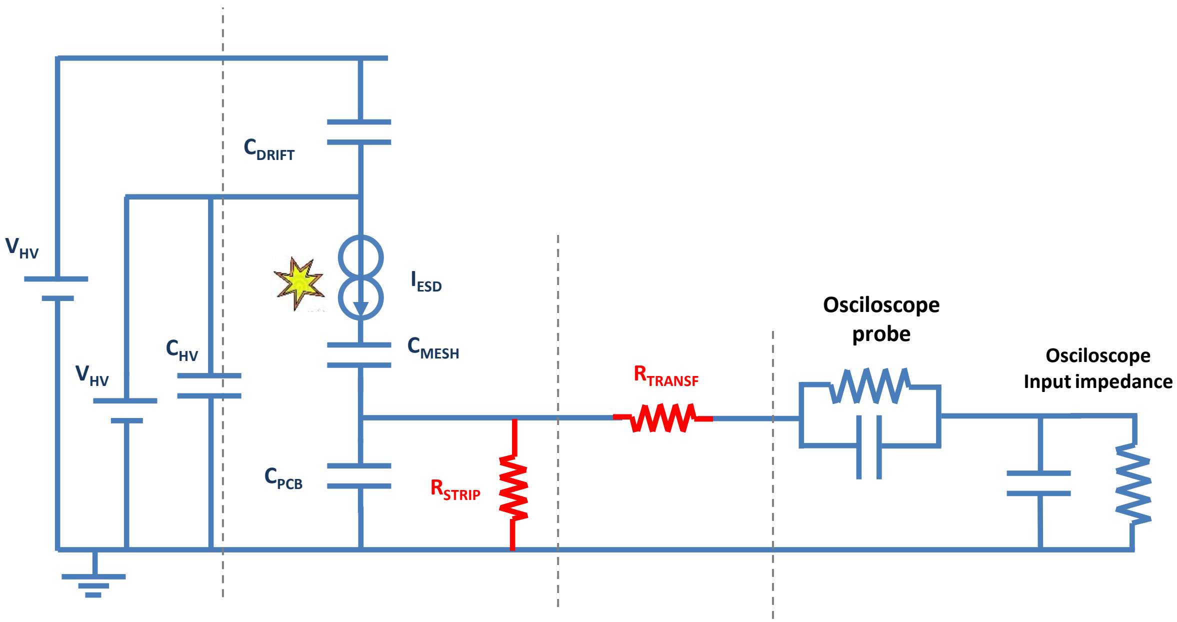


Low value	Mid value
R_{strip} (Ω)	R_{transf} (Ω)
66.57	985.7k

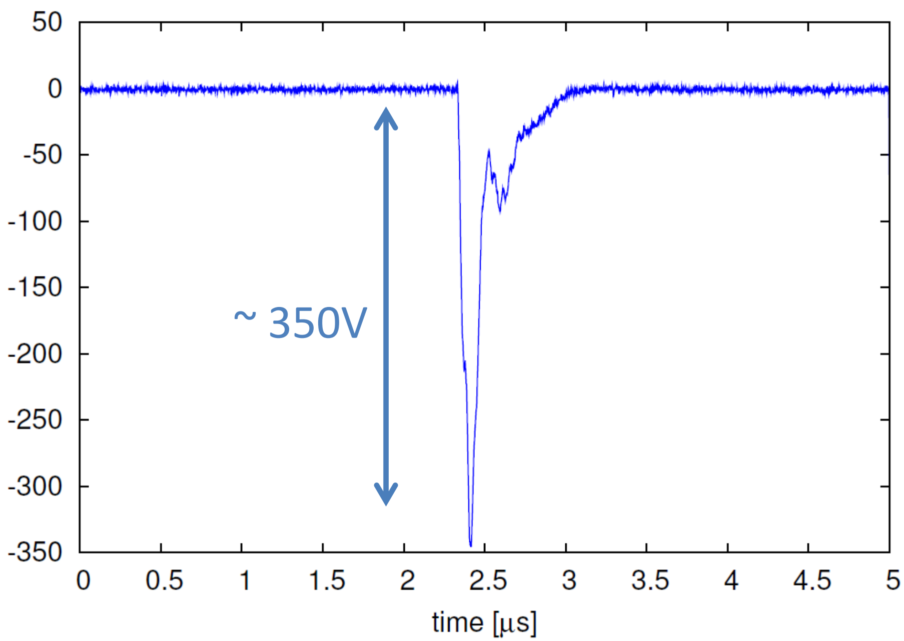


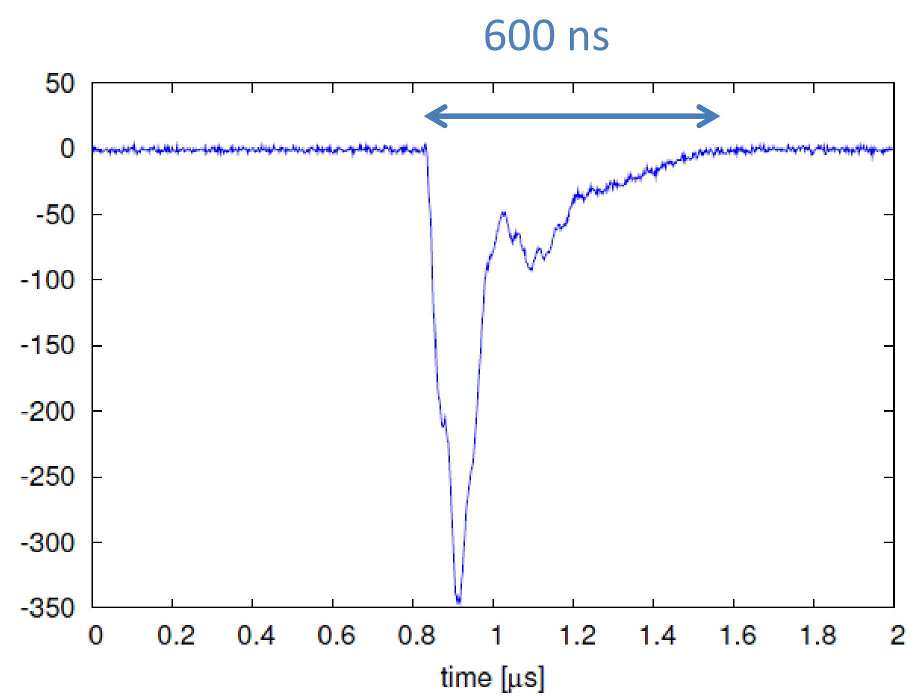


Effect on the pulse shape at different connection schemes

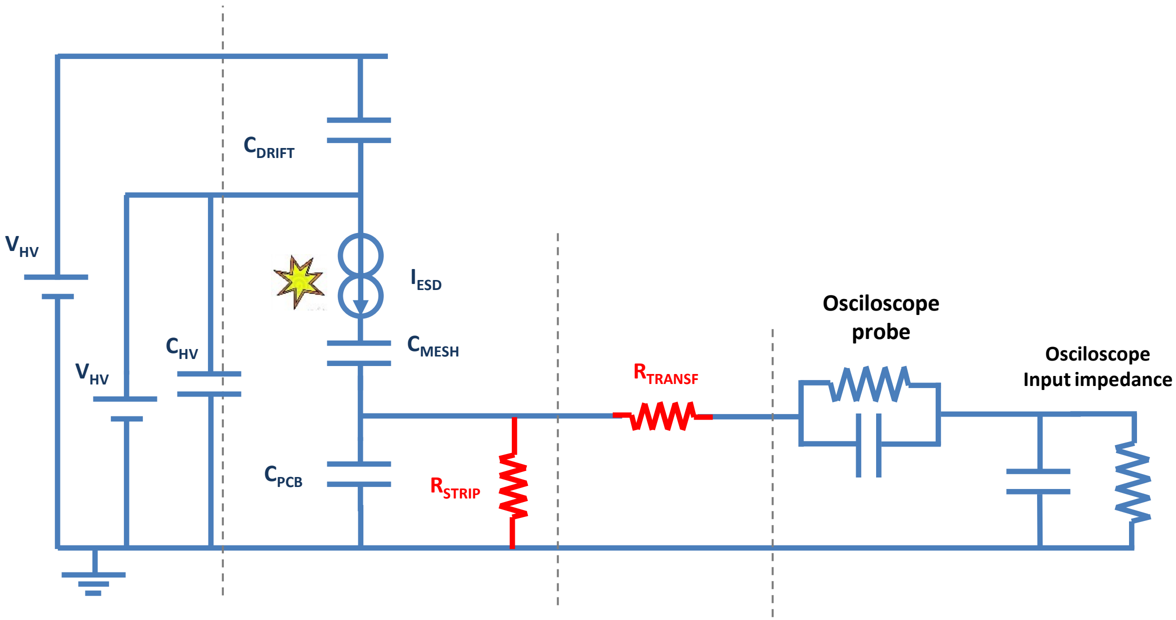


Low value	Direct conection
R_{strip} (Ω)	R_{transf} (Ω)
66.57	0

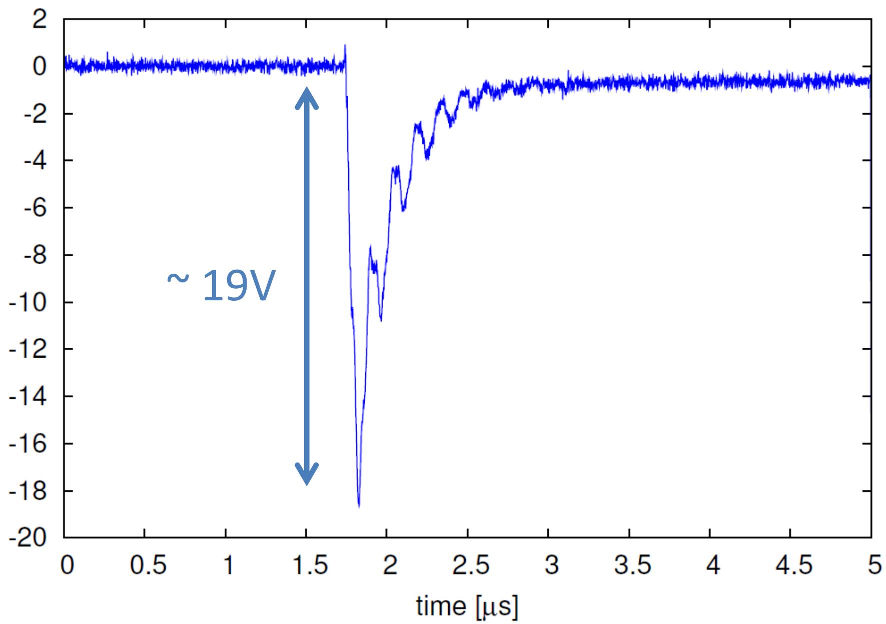


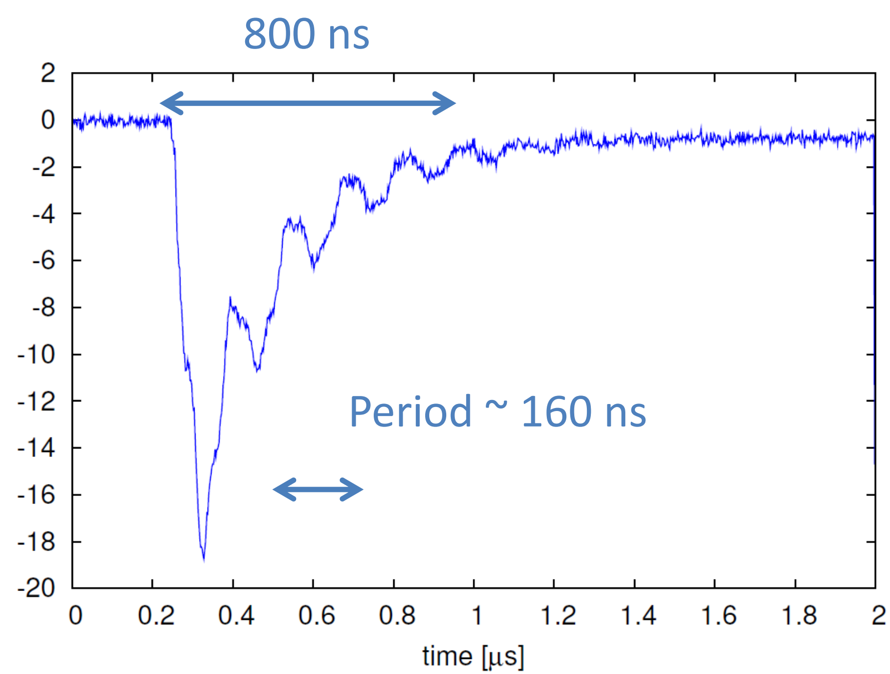


Effect on the pulse shape at different connection schemes

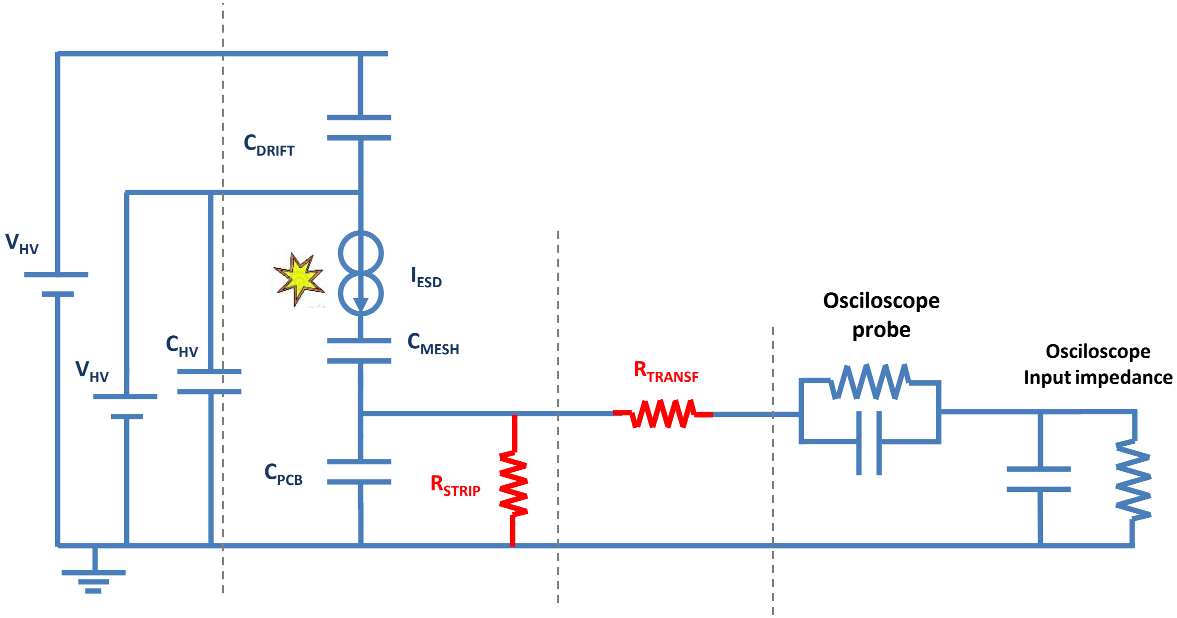


Mid value	High value
R_{strip} (Ω)	R_{transf} (Ω)
176.7	9.94M

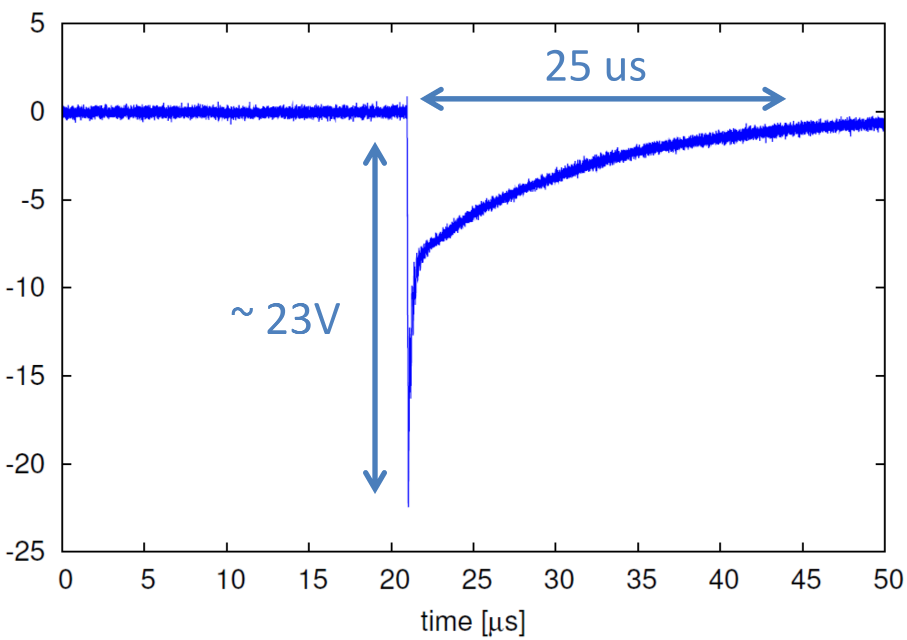


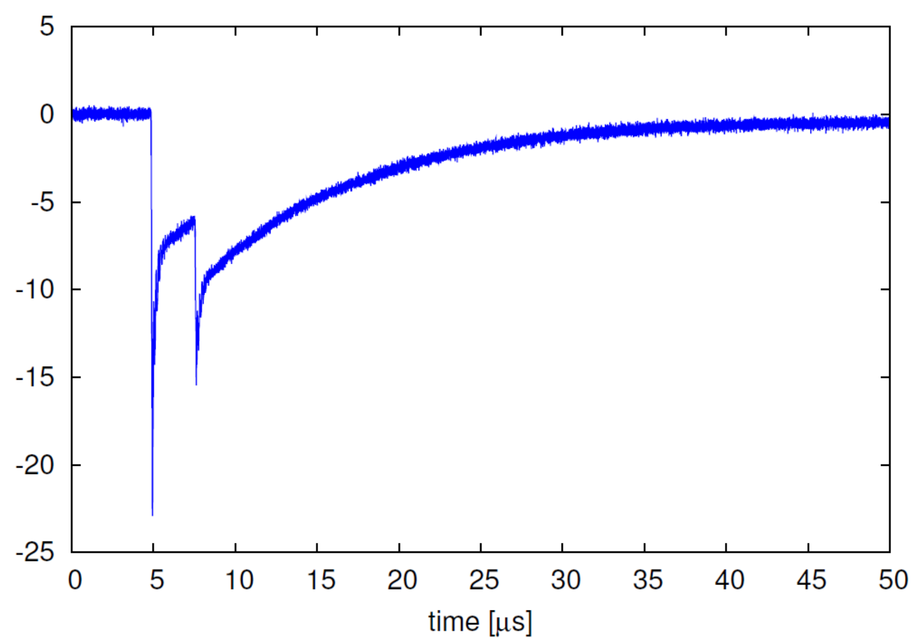


Effect on the pulse shape at different connection schemes

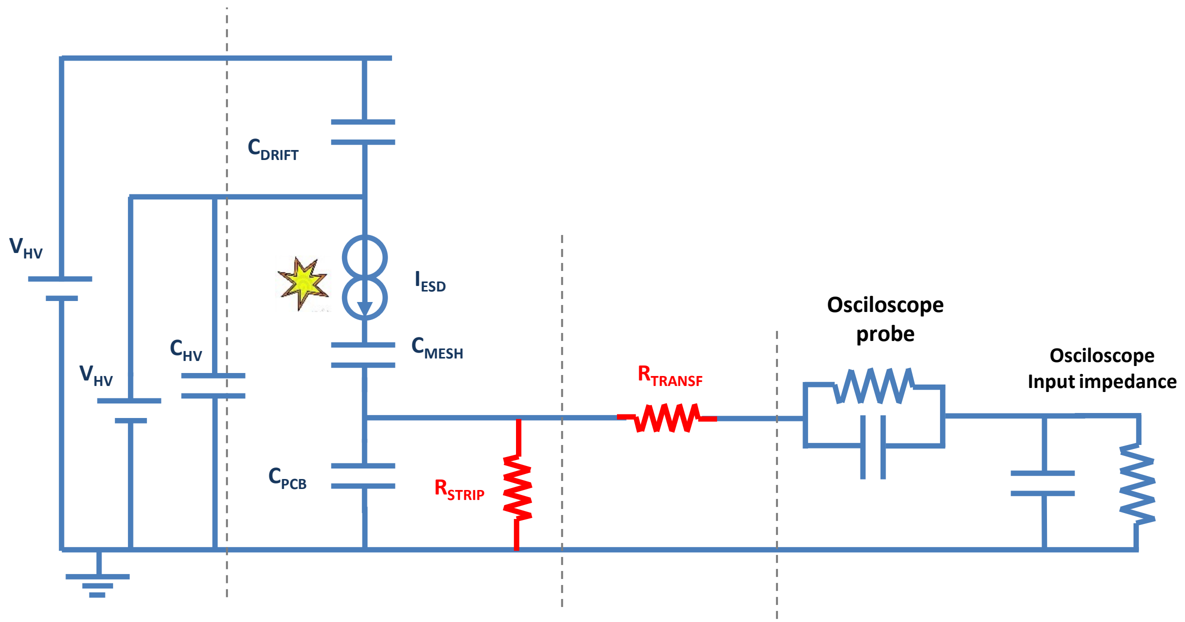


Mid value	Mid value
R_{strip} (Ω)	R_{transf} (Ω)
176.7	985.7k

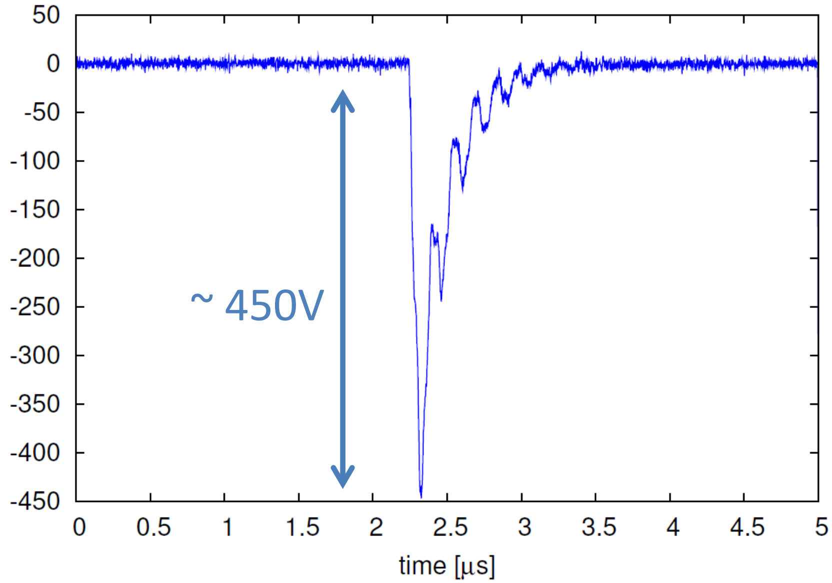


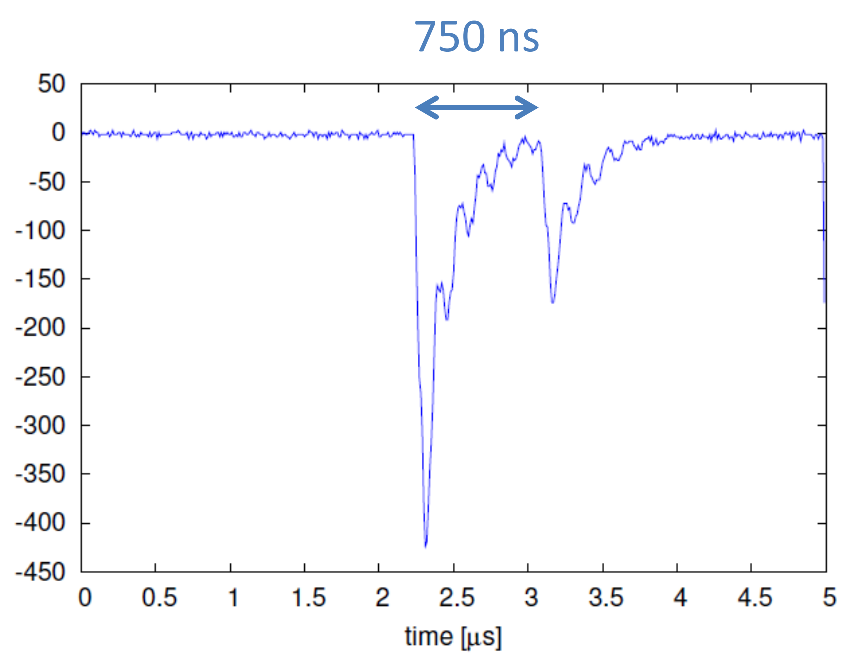


Effect on the pulse shape at different connection schemes

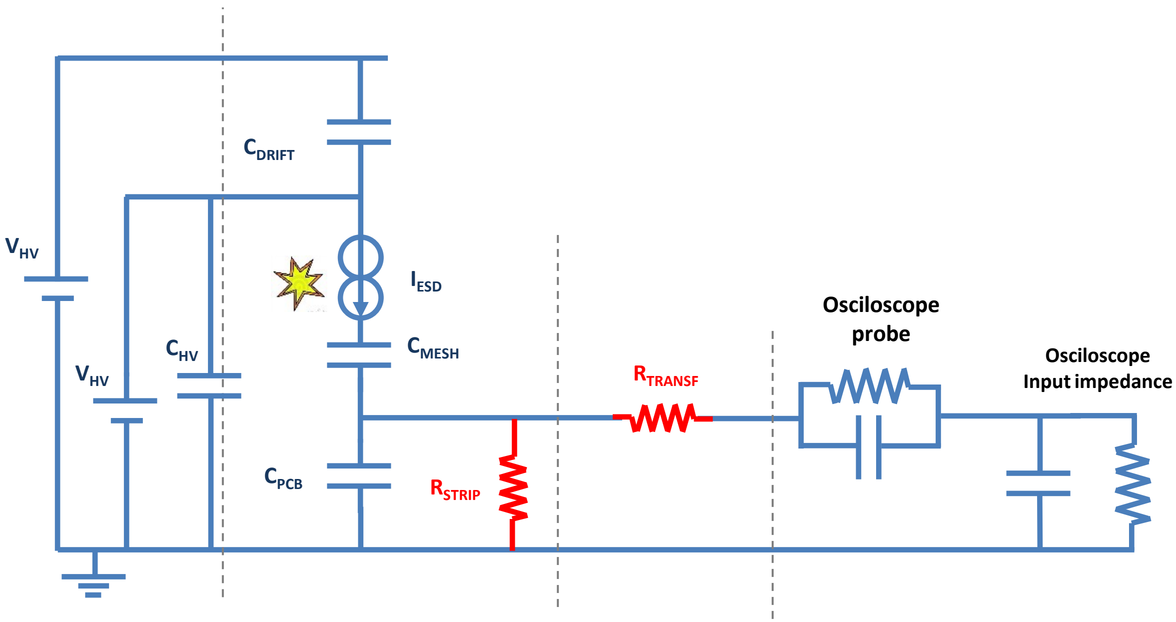


Mid value	Direct conection
R_{strip} (Ω)	R_{transf} (Ω)
176.7	0

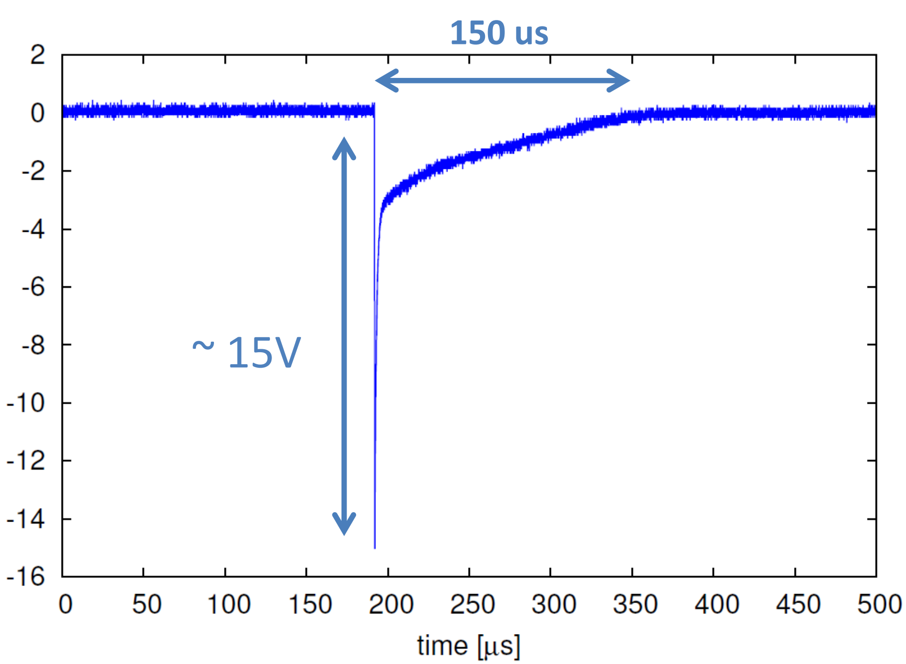


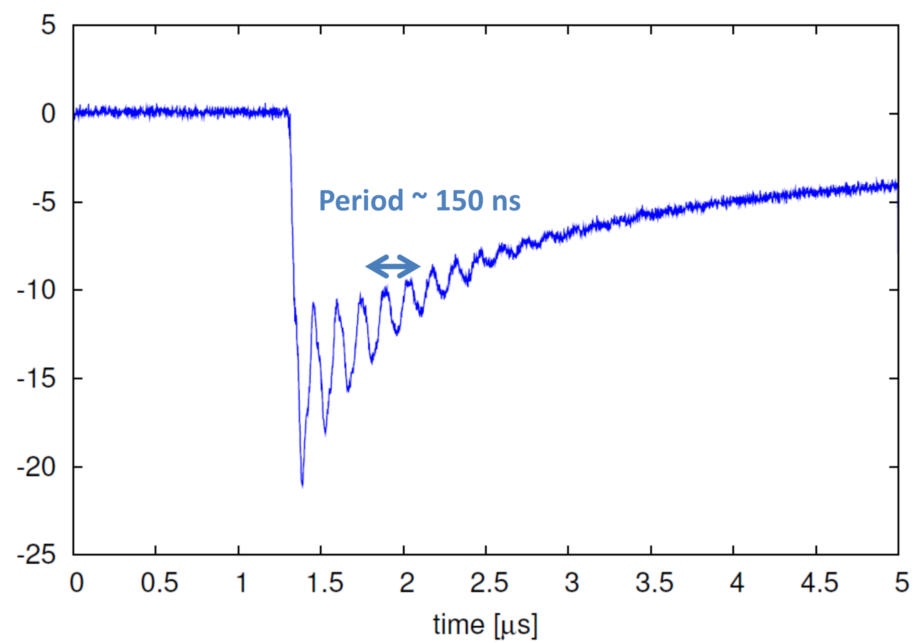


Effect on the pulse shape at different connection schemes

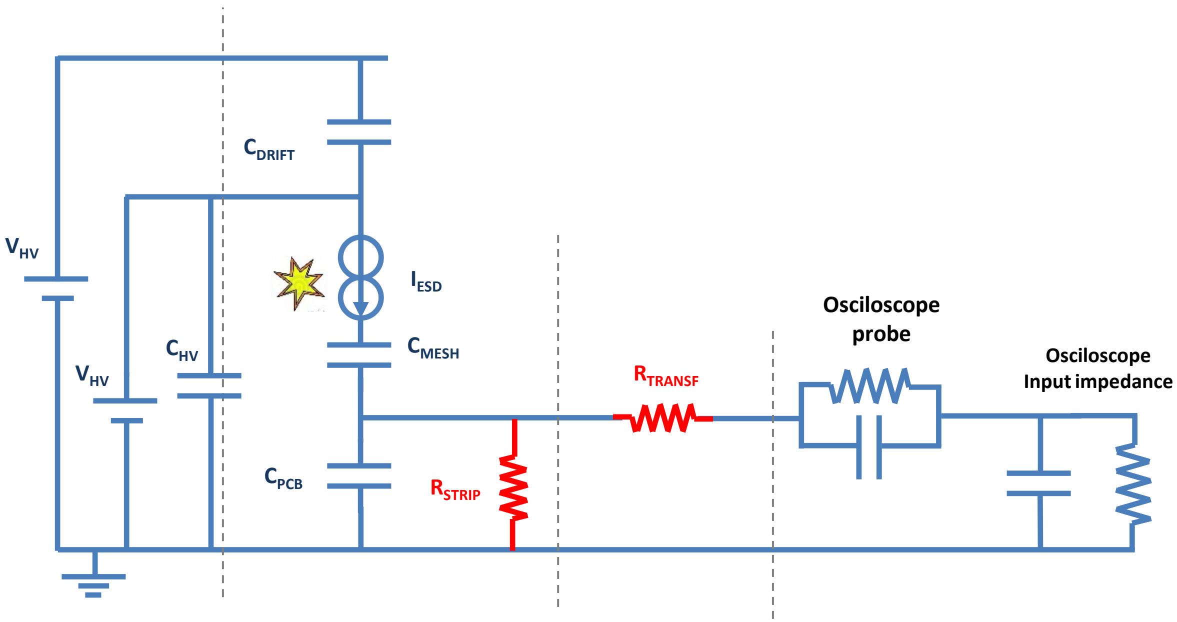


High value	High value
R_{strip} (Ω)	R_{transf} (Ω)
890.6	9.94M

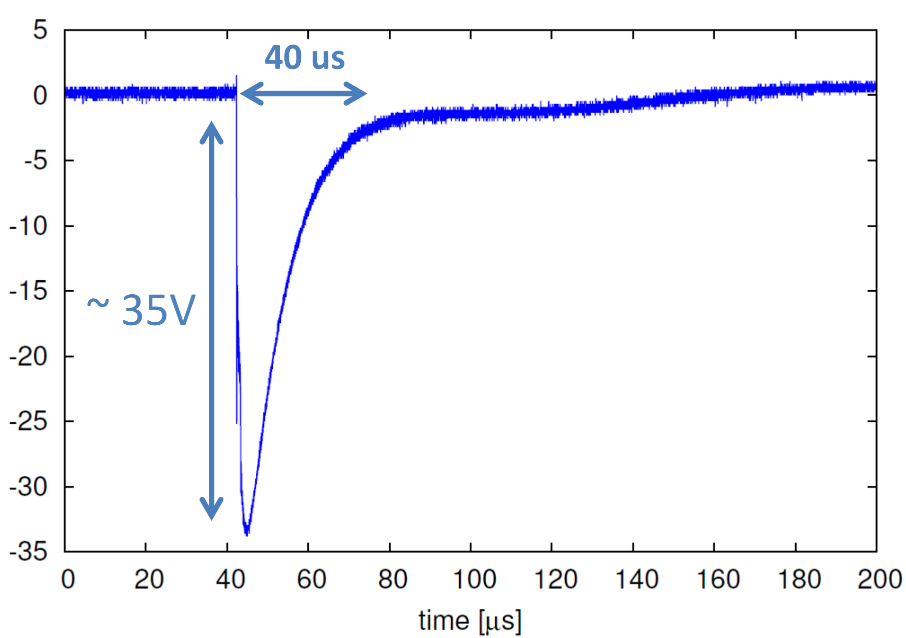


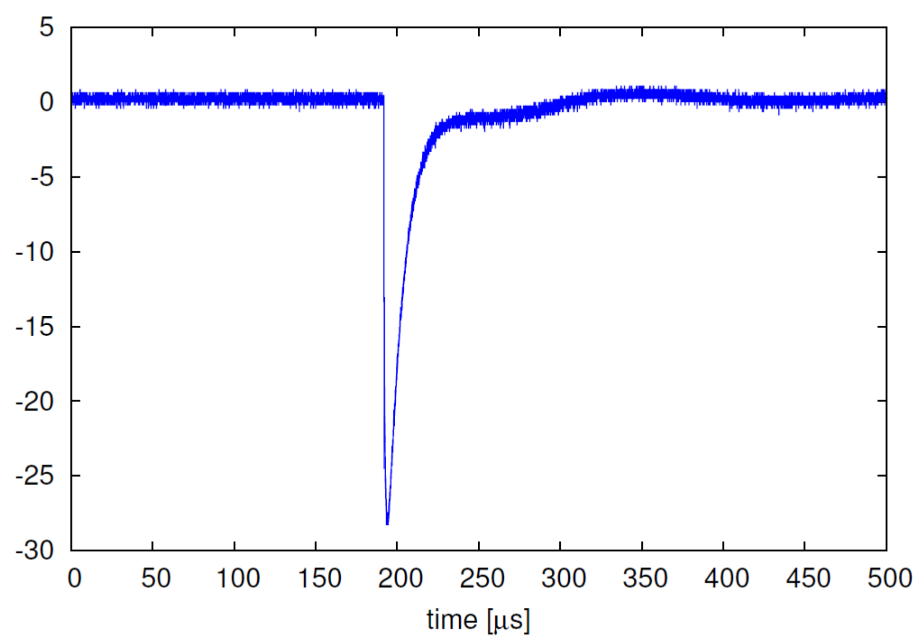


Effect on the pulse shape at different connection schemes

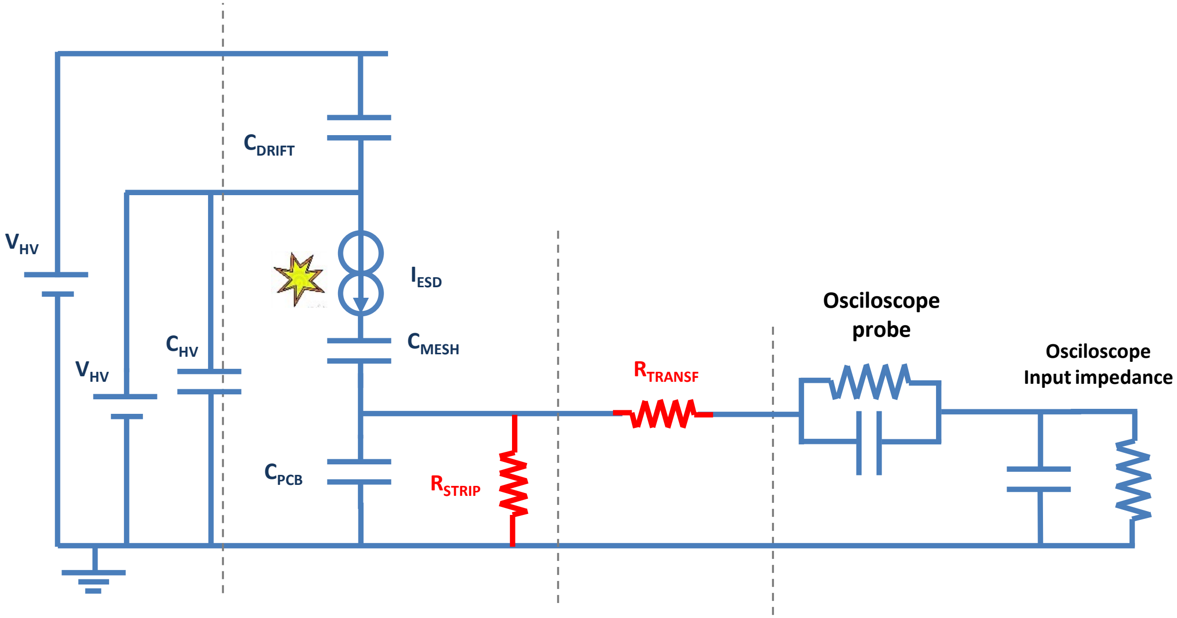


High value R_{strip} (Ω)	Mid value R_{transf} (Ω)
890.6	985.7k



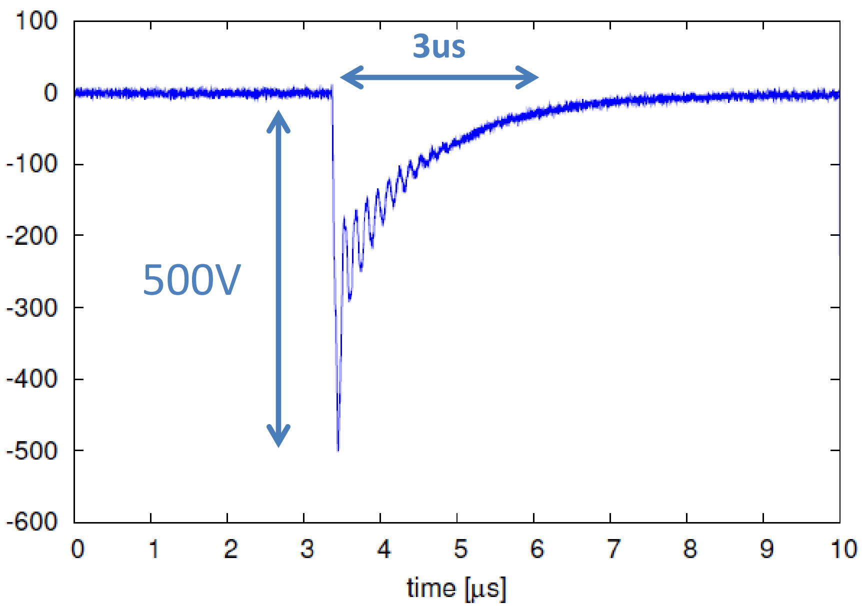


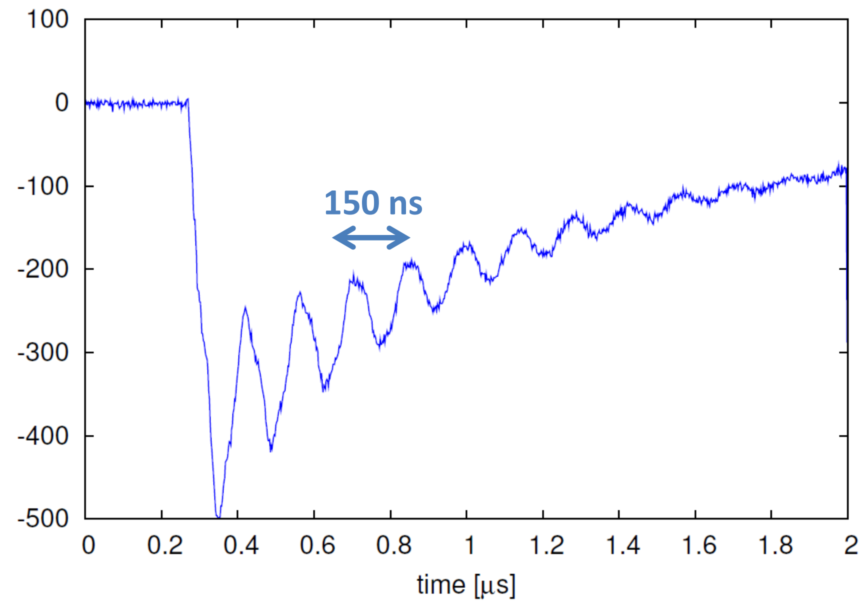
Effect on the pulse shape at different connection schemes



High value | Direct conection

R_{strip} (Ω)	R_{transf} (Ω)
890.6	0





Remark

- All these pulses were recorded without using an alpha source.

Mesh voltage required to start sparking process : V_{mesh} = -387.5 V

- When using an alpha source (Am^{241}) the sparking voltage decreases.

Mesh voltage required to start sparking process : V_{mesh} = -344.0 V

Pulses were also recorded using alphas in all the previous configurations Rstrip - Rtranf.

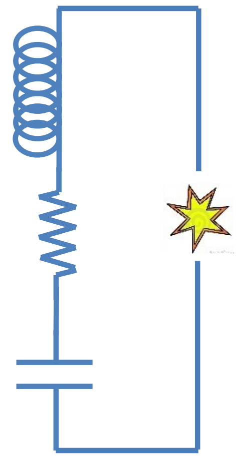
The shape of the pulses remains the same in each configuration.

The only difference resides in the **amplitude of the pulses**.

Related with the voltage reached in the mesh which leads to higher charge.

A simple model to start with …

Electrostatic Discharge (ESD) model



From reference:
Advanced Simulation Methods for ESD Protection Development.
ElSevier. 2003. K.Esmark, H. Gossner, W. Stadler

RLC description of spark phenomena.

Capacitor is charged initially at a given voltage V_{esd}

$$L_{esd}\frac{d^2i}{dt^2} + R_{esd}\frac{di}{dt} + \frac{1}{C_{esd}}i = 0$$

Total ESD charge

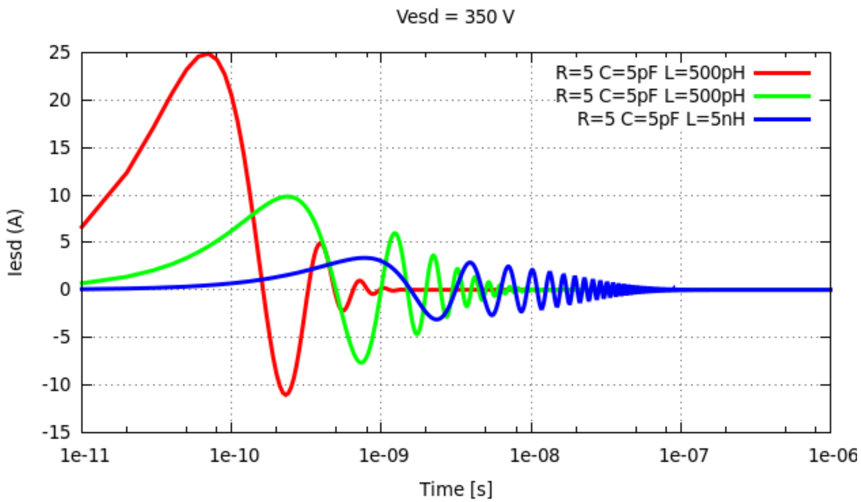
$$I_{esd}(t) = V_{esd}C_{esd}\frac{\omega_o^2}{\alpha^2 - \omega_o^2}\, e^{-\alpha t}\sinh\left(\sqrt{\alpha^2 - \omega_o^2}\, t\right) \quad \text{for } \alpha > \omega_o$$

$$I_{esd}(t) = V_{esd}C_{esd}\frac{\omega_o^2}{\omega_o^2 - \alpha^2}\, e^{-\alpha t}\sin\left(\sqrt{\omega_o^2 - \alpha^2}\, t\right) \quad \text{for } \alpha < \omega_o$$

2 Typical frequencies are involved

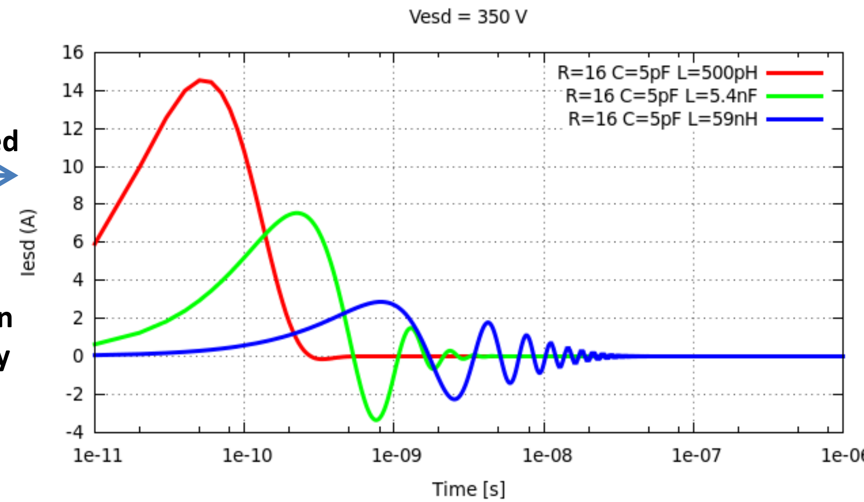
$$\alpha = R_{esd}/2L_{esd} \qquad \omega_o = 1/\sqrt{C_{esd}L_{esd}}$$

Discharge current for a set of RLC parameters

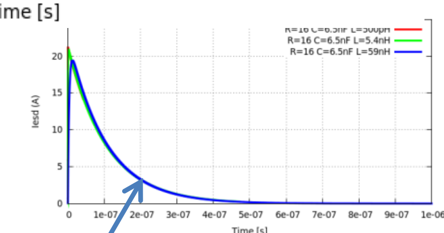


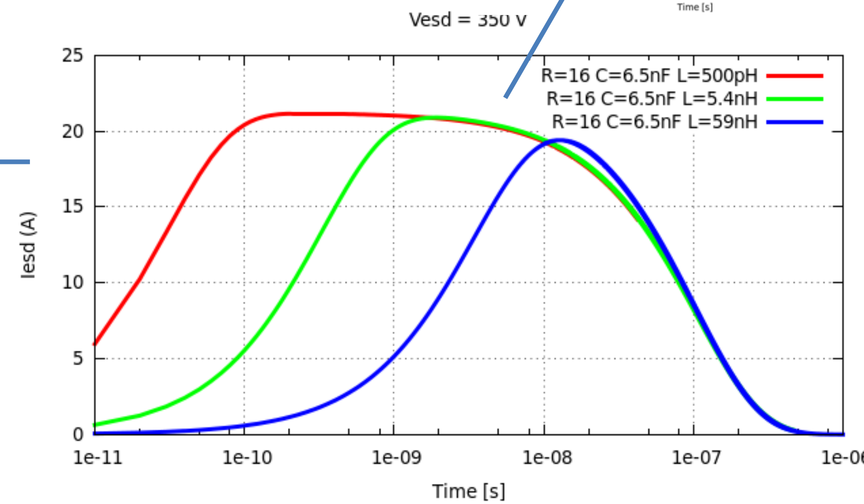
R increased

Oscillation frequency reduced



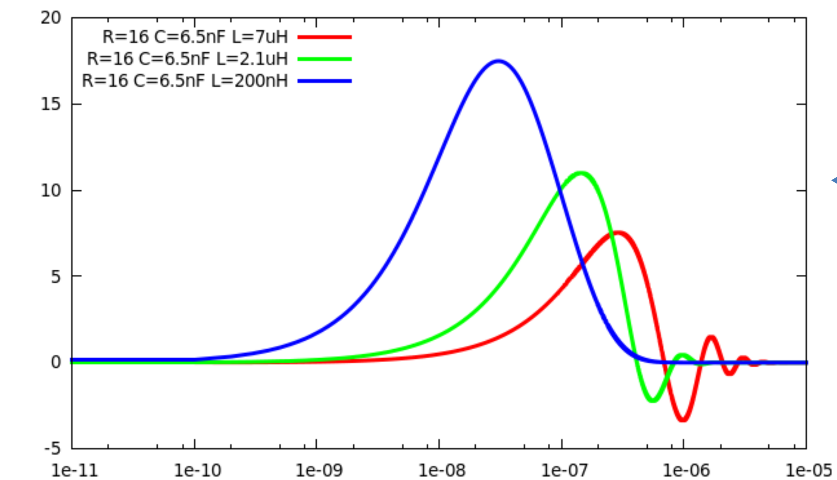
C increased
Integration effect





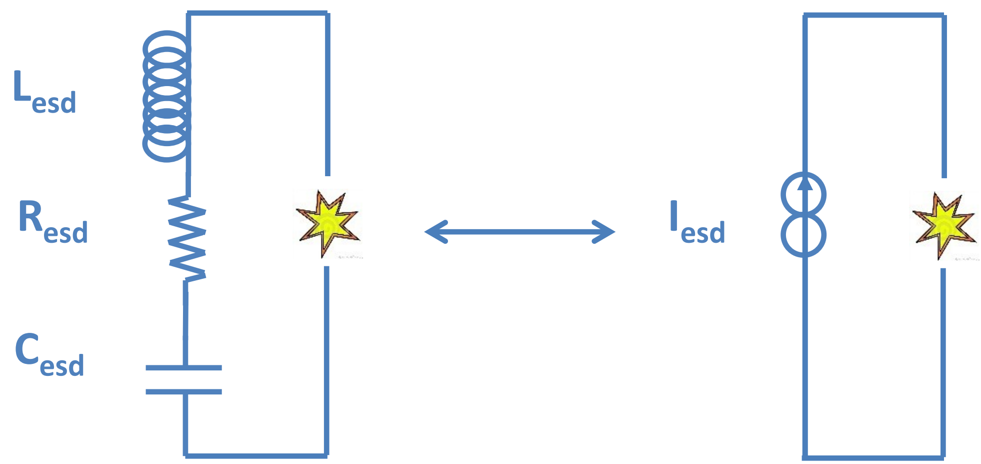
L increased

Recovered oscillations with signal delay

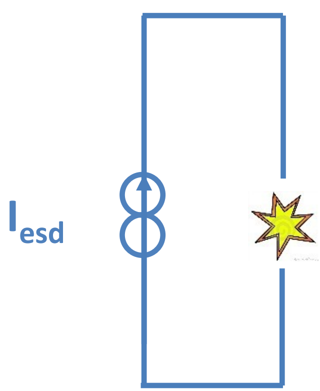


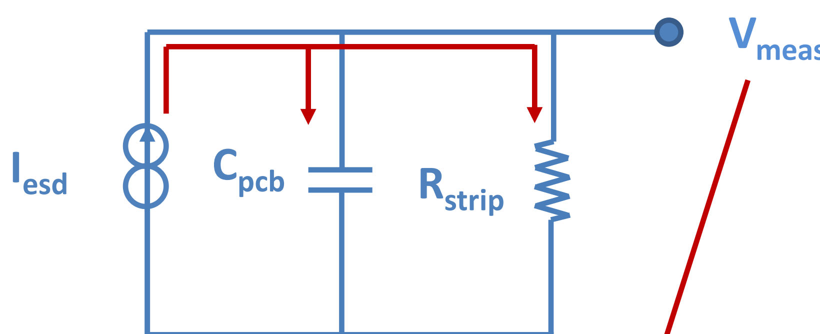
A modeling idea to test and fit the pulses acquired

Electrostatic Discharge (ESD) model ⟷ Current generator



Then the measured response is the result of spark current through: **R_{strip} // C_{pcb}**





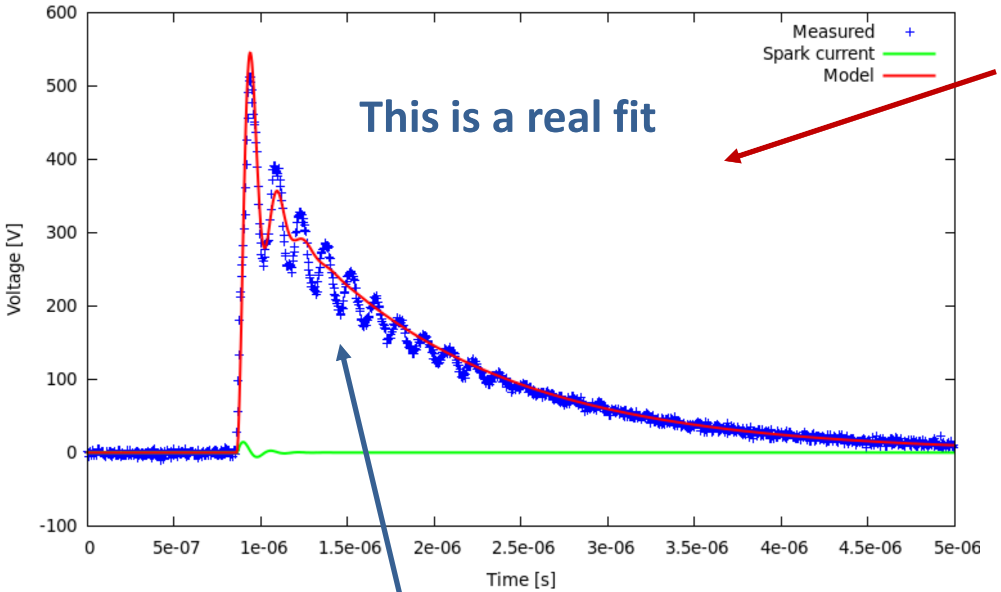
Allows analytical calculation and so montecarlo fitting

Can be solved using RK4.

$$I_{esd}(t) = V_{esd}C_{esd}\frac{\omega_o^2}{\alpha^2-\omega_o^2}\,e^{-\alpha t}\sinh\left(\sqrt{\alpha^2-\omega_o^2}\,t\right)\quad \text{for } \alpha > \omega_o$$

$$\frac{dV_{meas}(t)}{dt} = \frac{i_{esd}(t)}{C_{pcb}} + \frac{V_{meas}(t)}{R_{strip}C_{pcb}}$$

First tests to fit the sparks response



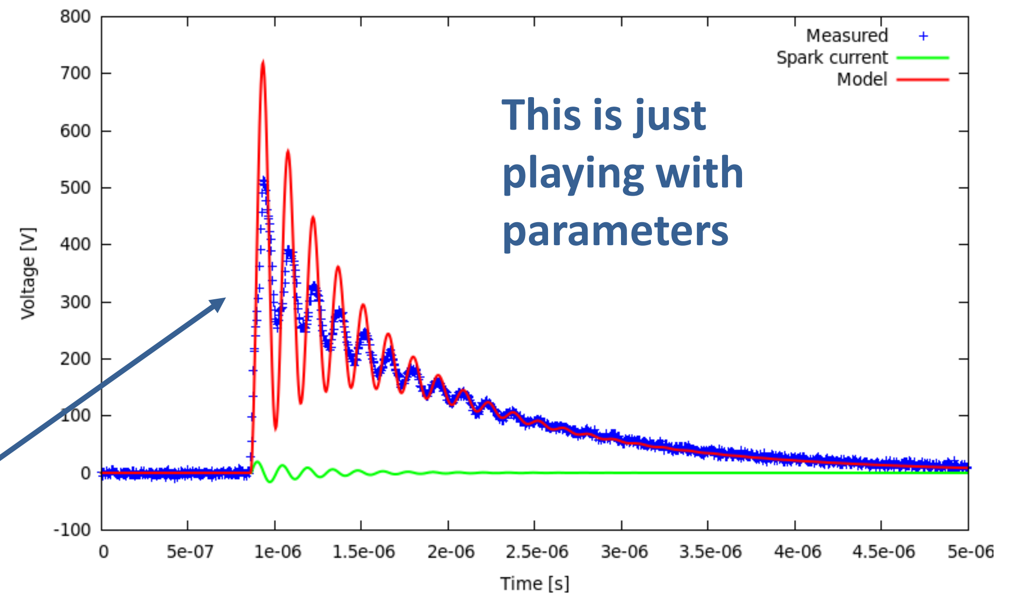
Using the model presented **the best approach** using minimum square method is given by the following curve.

However work is going on, montecarlo fitting does not assure to obtain the best solution, perhaps still some fine tuning required. If not, the model must be modified.

R_{esd} = 9.41Ω L_{esd} = 424 nH C_{esd} = 1.38 nF

R_{strip} = 890.6 Ω C_{pcb} = 1.0 nF

R_{esd} = 2Ω L_{esd} = 378 nH C_{esd} = 1.4 nF

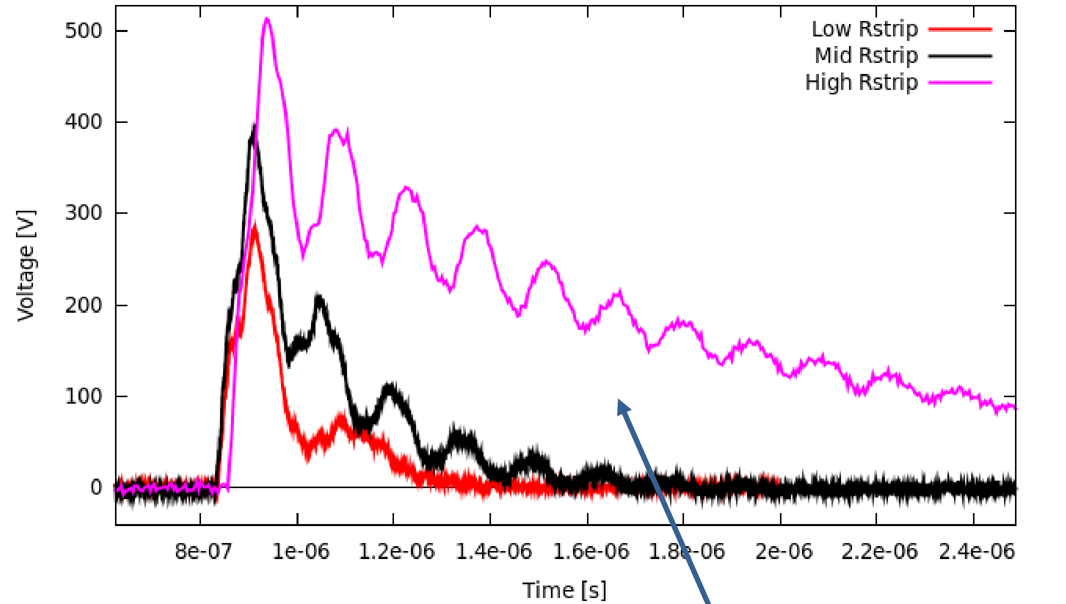


First tests to fit the sparks response

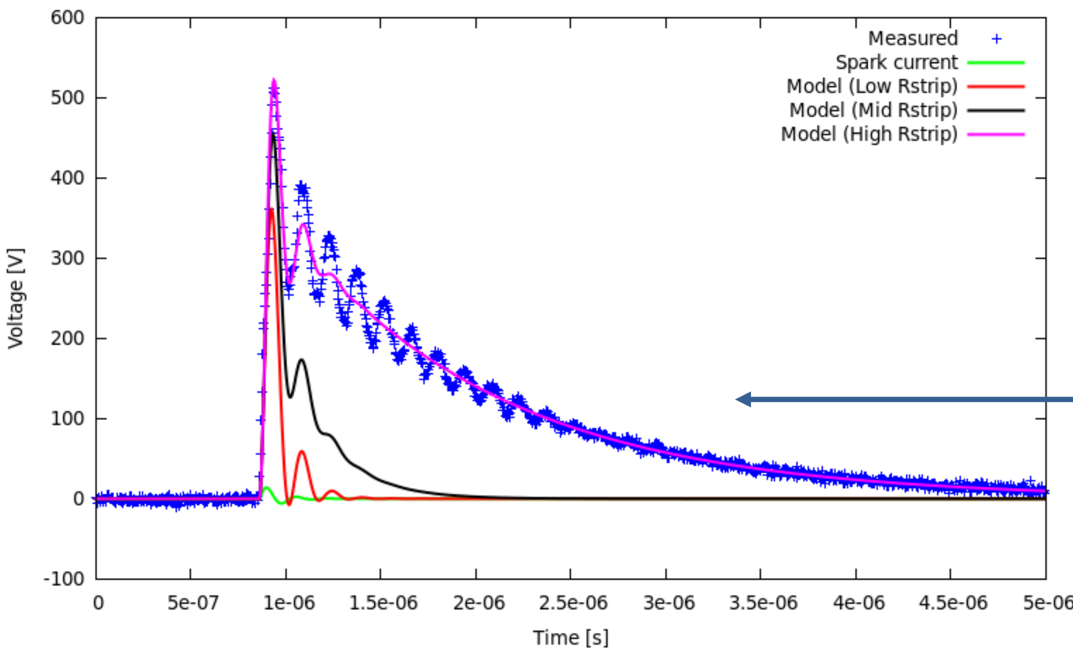
Still the model is not good enough to explain all the experimental shapes observed.

However it seems to be not far away.

The effect of R_{strip} in the model seems to be playing the proper role.



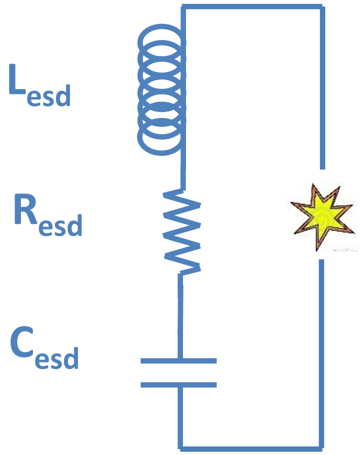
Pulse shapes with $R_{transf} = 0$



Pulse shapes obtained with the model, and changing R_{strip} to the experimental values.

Next steps

Electrostatic Discharge (ESD) model



The final goal:

Is to understand the origin of the detectors sparks response in order to prevent ageing, to optimize dead time, and to protect read-out electronics.

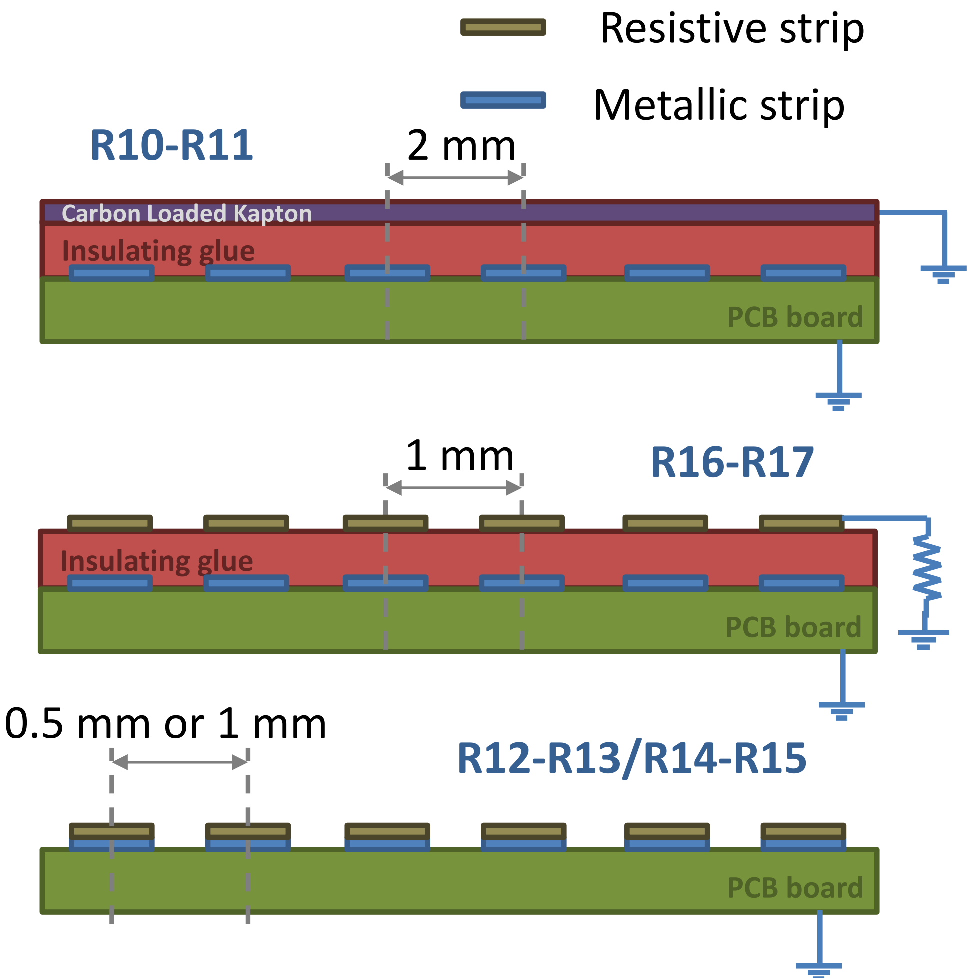
And to understand the differences observed in different prototypes in order to optimize construction parameters.

The different values used in **Rstrip and Rtransf** can help to crosscheck the validity of the model (R_{esd} - L_{esd} – C_{esd}).

$$I_{esd}(t) = V_{esd} C_{esd} \frac{\omega_o^2}{\alpha^2 - \omega_o^2} e^{-\alpha t} \sinh\left(\sqrt{\alpha^2 - \omega_o^2}\, t\right) \quad \text{for } \alpha > \omega_o$$

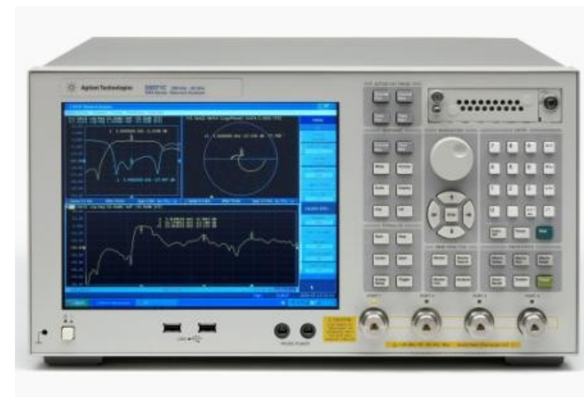
Problem : How to differentiate residual inductances and capacitances in the measurement from the model.

Planning to measure impedances in frequency domain at the different sLHC prototypes available



Measuring system

E5071C ENA Network Analyzer



Up to 10 GHz scanning

In order to determine

Influence of inductive effects at high frequencies

Equivalent impedance for each prototype

Influence on the measurements when doing modifications in the original set-up.

The end

Mesh readout