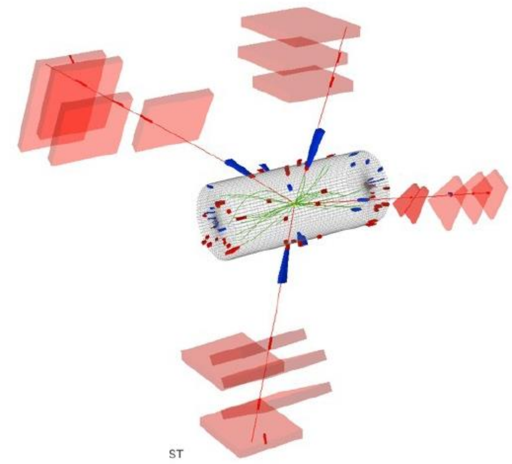
RPCs rate capability (let us calculate…)



M. Abbrescia

Let us start from…

… one of Santonicos's presentations:

- In the static limit the voltage applied to the chamber V_a is entirely transferred to the gas but for a working current i part of this voltage is needed to drive the current in the electrodes

$$V_{gas} = V_a - Ri = V_a - V_{el}$$

- The voltage transferred to the electrodes can be written as

$$\boldsymbol{V_{el} = \rho\, t\, r_u < Q >}$$

$\boldsymbol{\rho}$ is the bulk resistivity of the electrode material; $\boldsymbol{t}$ is the total thickness of both electrodes; $< \boldsymbol{Q} >$ is the average charge delivered in the gas for each count and $\boldsymbol{r_u}$ is the counting rate per unit surface

→ A high rate capability requires to keep V_{el} at a negligible value wrt V_{gas} even under heavy irradiation

What we learn from that formula

- ➢Gap thickness seems not to play any role
- ➢Electrode resistivity does influence rate capability
- ➢Electrode thickness does influence rate capability

It is not clear how much a reduction on V_{drop} has on the rate capability:

✓Anyhow bakelite thickness can account for a 25-50%(? Ex. from 2→1.5-1 mm) reduction on V_{drop}

✓Bakelite resistivity can account a 10 (or more) factor on V_{drop}

Electrode thickness seems to play a second order role.

About gap thickness:

… let us use something older and more elaborate

$$q_{\rm ind} = \frac{q_e}{\eta g} \Delta V_w \overbrace{\sum_{j=1}^{n_{\rm cl}} n_0^j M_j \left[e^{\eta(g - x_0^j)} - 1 \right]}^{Q}.$$

The trick is to increase q_{ind} keeping Q constant
ηg stays constant!

$$\Delta V_w = \frac{\varepsilon_r g}{n_g \varepsilon_r g + (n_g + 1)d}$$

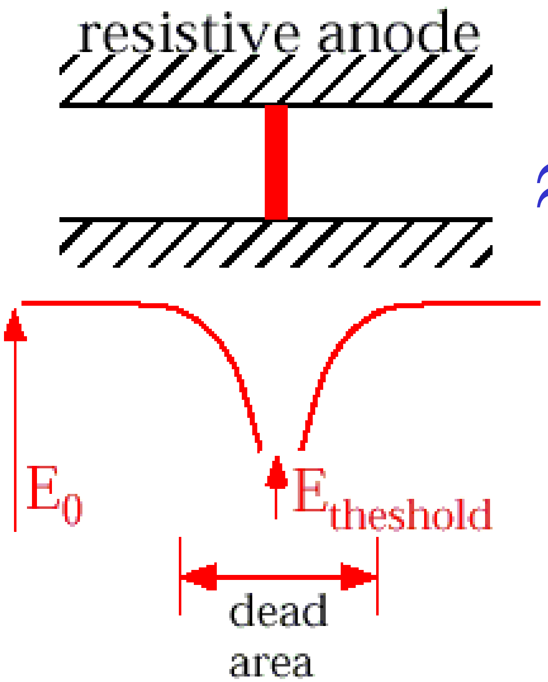
Here g is the gap thickness
- Decreasing the gap thickness <u>alone</u> reduces the induced charge (keeping Q constant)
- Worsen the rate capability

About gap thickness:

- The point is that if you reduce the gap thickness only the shielding electrostatic effect of the bakelite plates increases in proportion
- The voltage drop related to the weighting field should be as high as possible
- If you reduce the electrode thickness at the same time, the two effect cancel out, but you do not gain anything in rate capability

- ✓A lot of experimental data showing that wider gaps (9 mm) show a much higher rate capability
- ✓It would be strange that the 2 mm gap is the minimum

Let us drop the static model



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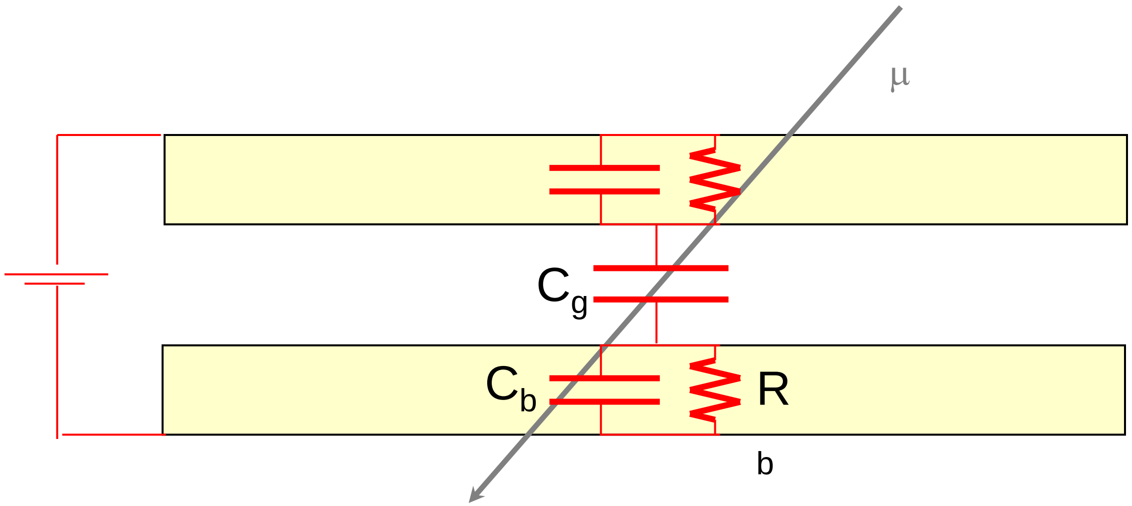


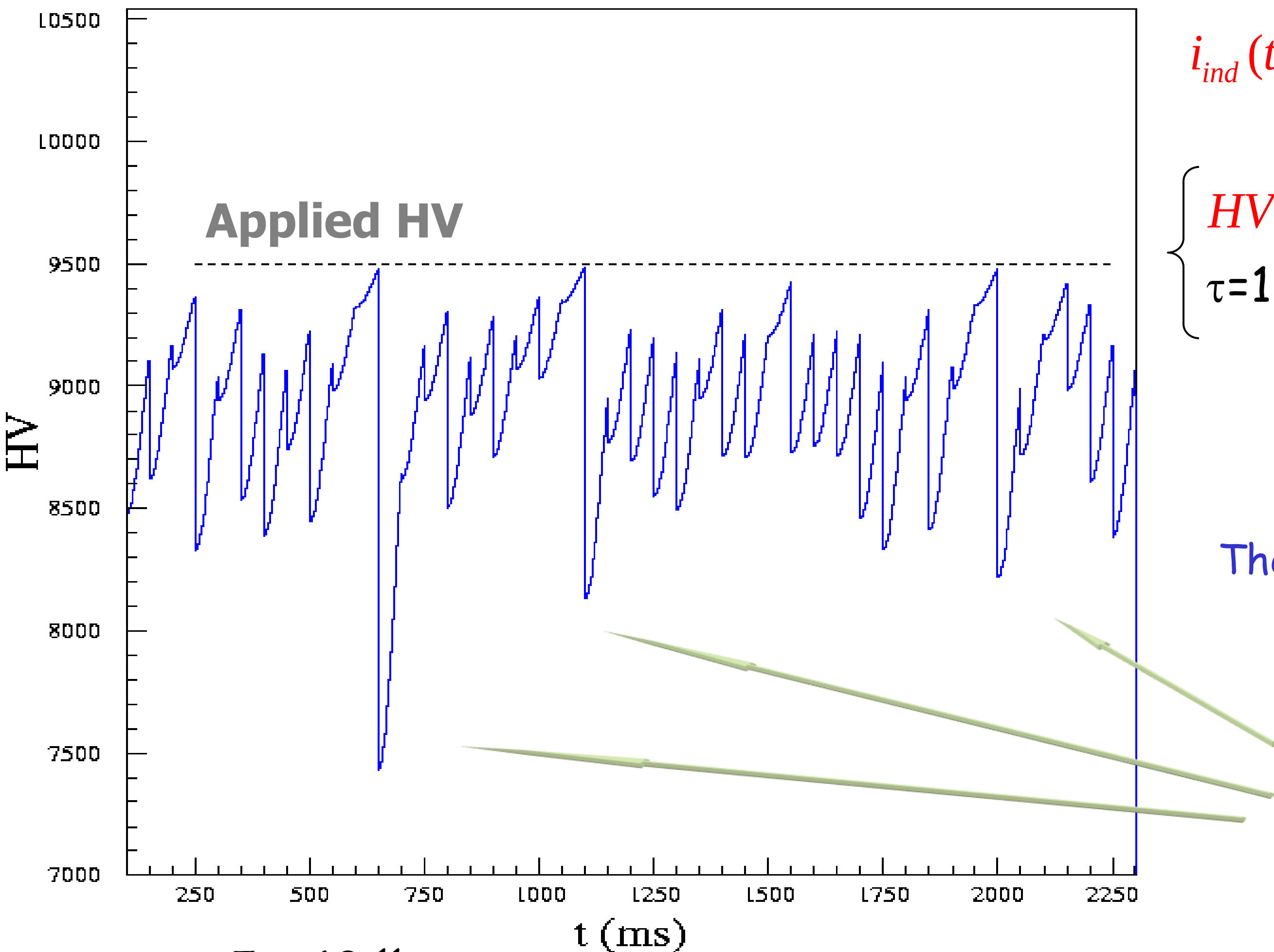
$$\tau = 2R_b\left(2C_b + C_g\right) = 2\rho_b\varepsilon_0\left(2\varepsilon_r + \frac{d}{g}\right)$$

Recovery time independent of the cell dimension ...

A few numbers:

- typical avalanche radius: 100 μm
- typical avalanche charge: 1 pC
- typical external charge contained in 100 μm: 10 pC

What REALLY happens…



$$i_{ind}(t) = -\mathbf{v}_d \cdot \mathbf{E}_w q_e e^{\eta v_d t} \sum_{j=1}^{n_{cl}} n_0^j M_j$$

$$\begin{cases} HV(t) = HV_{ext}\left(1 - e^{-t/\tau}\right) \\ \tau = 1500 \text{ ms} \end{cases}$$

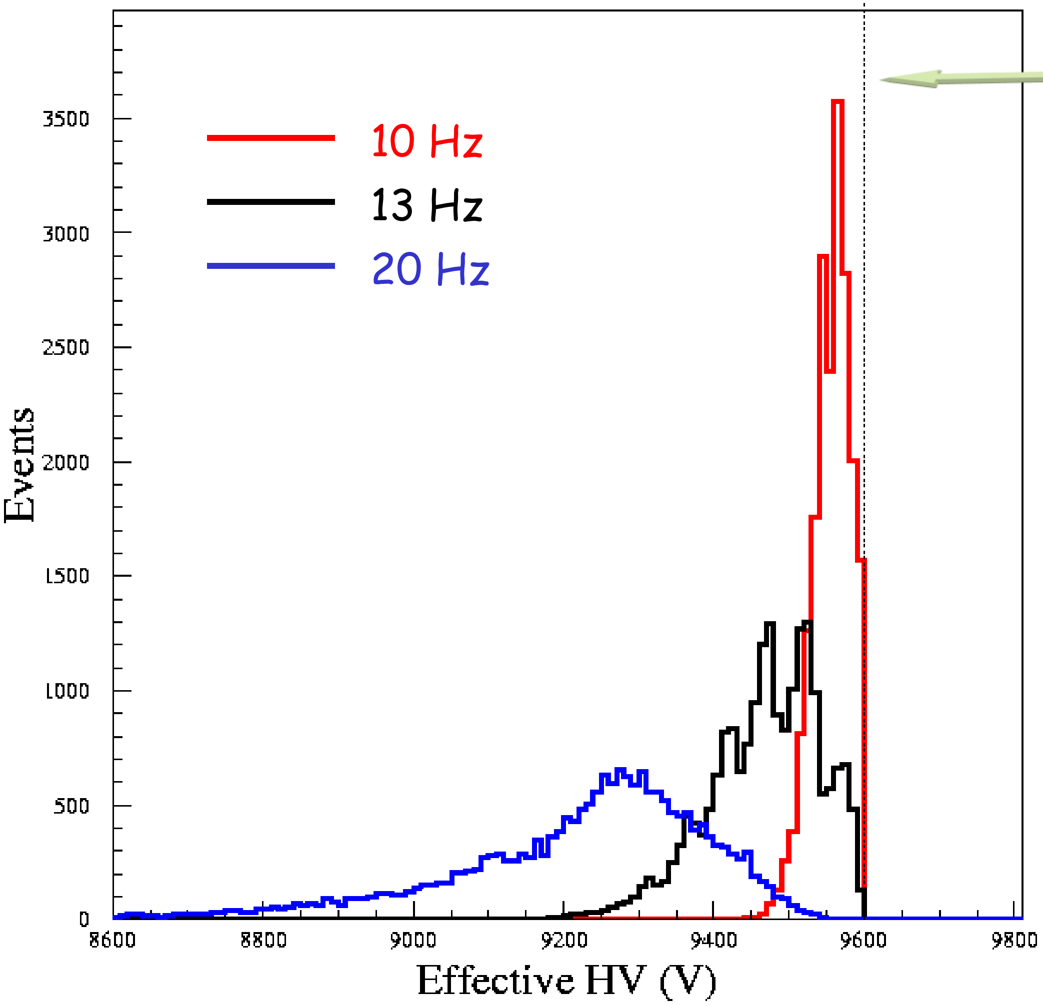
There is a sort of feedback …

High HV "at start"

Big pulses

$\rho \approx 5 \times 10^{11}\ \Omega\text{cm}$

Some of the differences



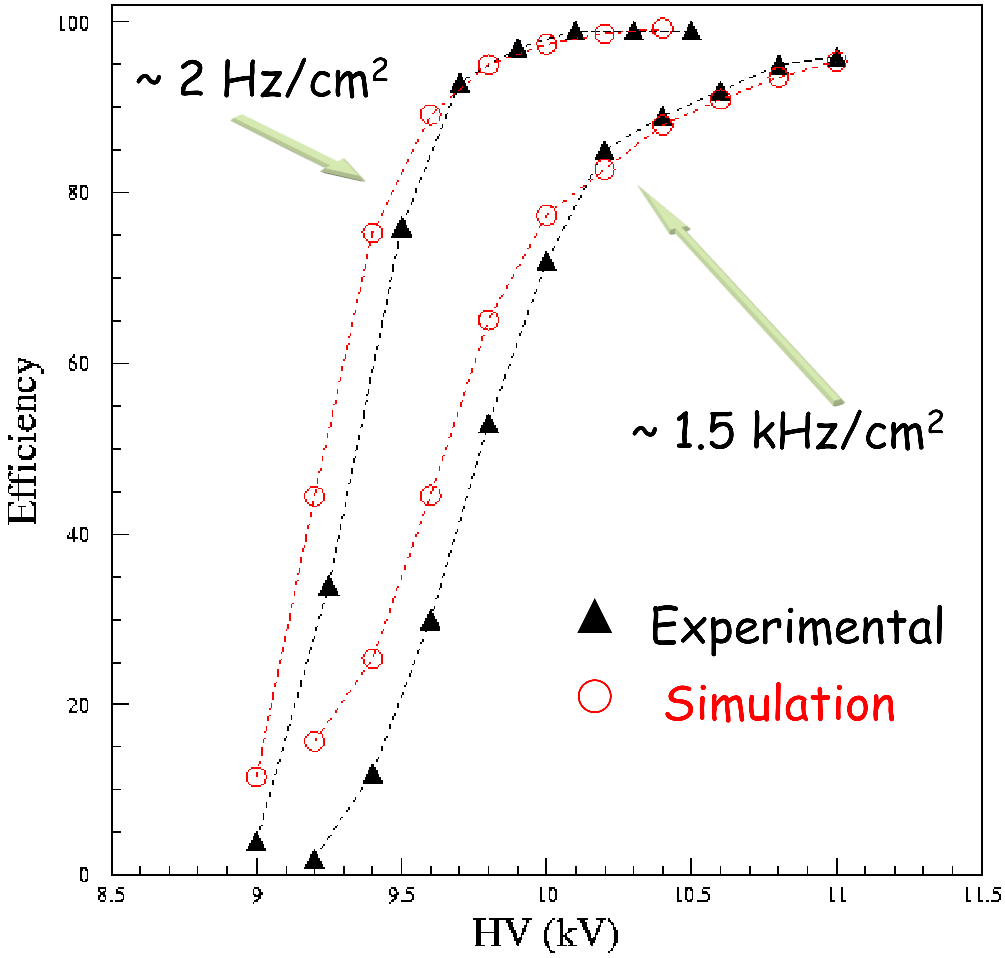
Applied HV

The effective HV diminishes and its distribution is broader.

(...until HV_{eff} is too low)

Two consequences:
- lower HV at high rate
- greater HV variations at high rate

Some comparison with data



Very good agreement

$$\varepsilon = 1 - e^{-\lambda\left[g - \frac{1}{\eta}\ln\left(\frac{q_{thr}}{A} + 1\right)\right]}$$

$$A = \frac{q_e \Delta V_w M n_0}{\eta g}$$

Data from G. Aielli et al., NIM A 478(2002) 271-276

(Some) Conclusions

- The static model used in the discussions (presentations!) is a really rough approximation of what is happening
  - Like putting a straight line where a complex phenomenon is happening
- Moreover it is wrong! You are assuming a pure resistive behaviour when the capacitive effetcs are predominant
  - Leads to not correct results
- Anyhow dependance on electrode thickness seems to be a second order effect
- Reducing the gap thickness alone has a negative effect on rate capability

More calculations are welcome