Simulation of RPC detectors and comparison of their response at different gas gap lengths

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Resistive Plate Chambers (RPC)

Resistive Plate Chambers (RPC) are **gaseous detectors** composed of two parallel plates made out of a highly resistive material. A high voltage is applied to this plates, and between them exists a **gap** in which an easily ionizable **mixture of gases circulate**.

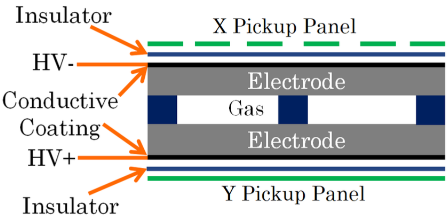
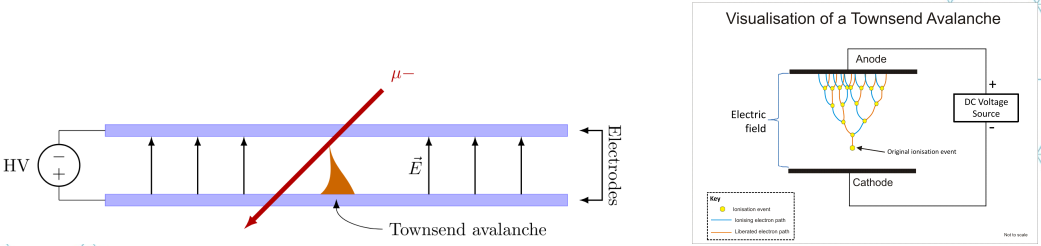


Figure 1: Basic diagram for an RPC. [Mondal, 2018]

Principle of operation

The gas is ionized by the passing of a **charged particle** generating electron-ion pairs that drift towards the anode under the influence of the electric field and gain energy doing so, generating more electron-ion pairs. This is called a **Townsend Avalanche**



(a) (b)

Figure 2: (a) Principle of operation of an RPC detector. [Van Assche, 2016] (b) Visualization of a Townsend Avalanche. [Français, 2017]

HEED track and first electron clusters

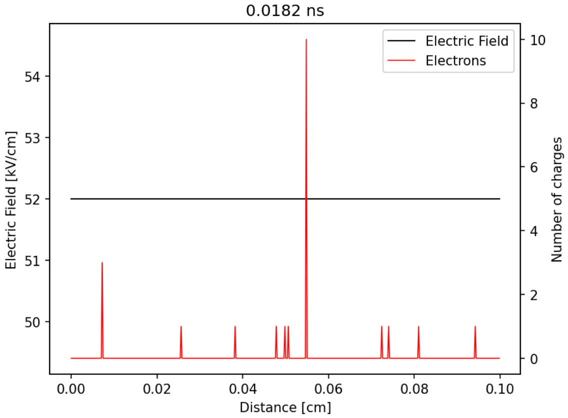


Figure 3: Electrons in the first time step of the simulation and the local electric field. Gap size is 0.1 cm divided in 500 steps, the magnitude of the applied voltage is 5.2 kV

Development of the electron avalanche

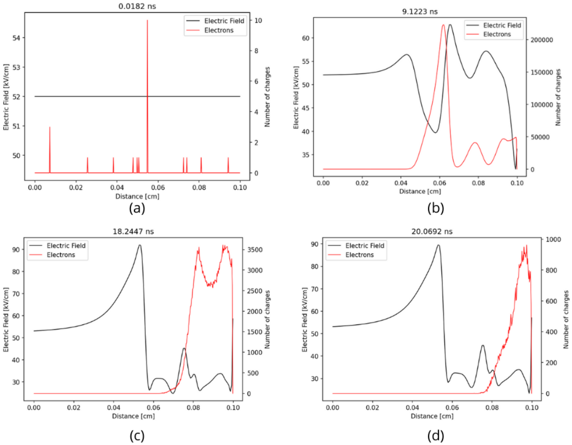


Figure 4: Evolution of the avalanche and space charge effect at different time steps.

Avalanche growth

Riegler-Lippmann-Veenhof model[Riegler, 2003][Lippmann, 2003]. The probability that there n electrons in the avalanche after it moves from z to $z + dz$ is given by

$$\begin{aligned} P(n, z+dz) = & P(n-1, z)(n-1)\alpha dz(1-(n-1)\eta dz) \\ & + P(n, z)(1-n\alpha dz)(1-n\eta dz) \\ & + P(n, z)n\alpha dz n\eta dz \\ & + P(n+1, z)(1-(n+1)\alpha dz)(n+1)\eta dz. \end{aligned} \tag{1}$$

Avalanche growth

Then, generating random numbers we can simulate the multiplication and the attatchment of the electrons, for this we use[Riegler, 2003][Lippmann, 2003]

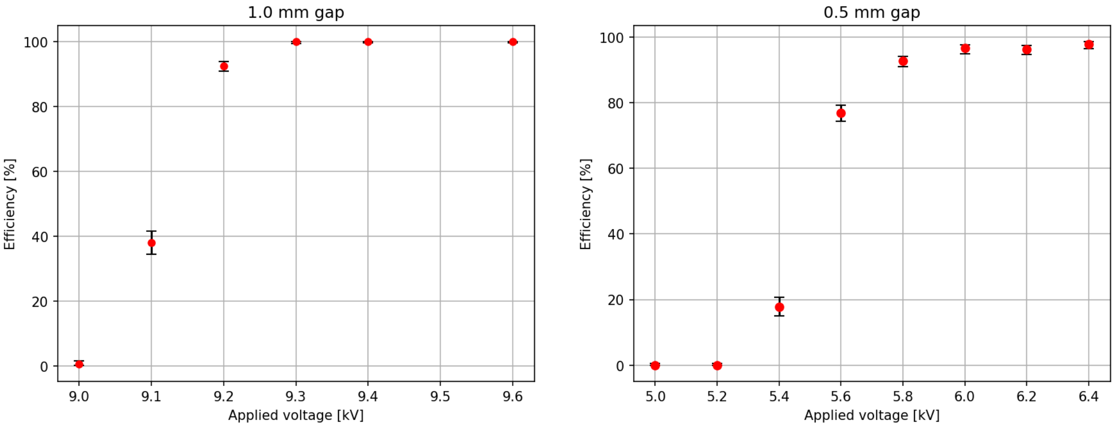
$$n = \begin{cases} 0, & s < k\frac{\bar{n}(z)-1}{\bar{n}(z)-k} \\ 1 + \ln\left(\frac{(\bar{n}(z)-k)(1-s)}{\bar{n}(z)(1-k)}\right)\frac{1}{\ln\left(1-\frac{1-k}{\bar{n}(z)-k}\right)}, & s > k\frac{\bar{n}(z)-1}{\bar{n}(z)-k} \end{cases} \quad \alpha, \eta > 0 \tag{2}$$

$$n = \begin{cases} 0, & s < \frac{\alpha z}{1+\alpha z} \\ 1 + \ln\left[(1-s)(1+\alpha z)\right]\frac{1}{\ln\left(\frac{\alpha z}{1+\alpha z}\right)}, & s > \frac{\alpha z}{1+\alpha z} \end{cases} \quad \alpha = \eta \tag{3}$$

$$n = \begin{cases} 0, & s < e^{(-\eta z)} \\ 1, & s > e^{(-\eta z)} \end{cases} \quad \alpha = 0 \tag{4}$$

where s is a random number from the interval $[0, 1)$.

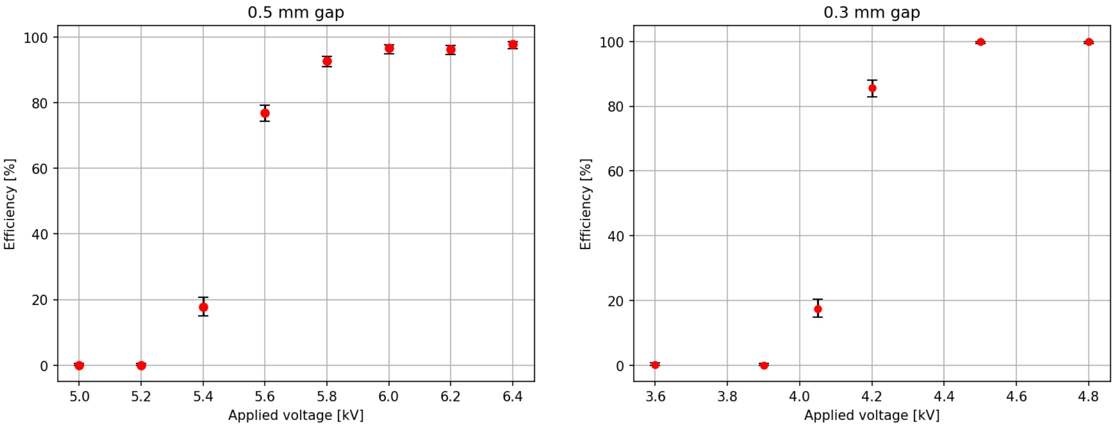
Results Efficiency



(a) (b)

Figure 5: Simulated detector efficiency at different magnitudes of the applied voltage.

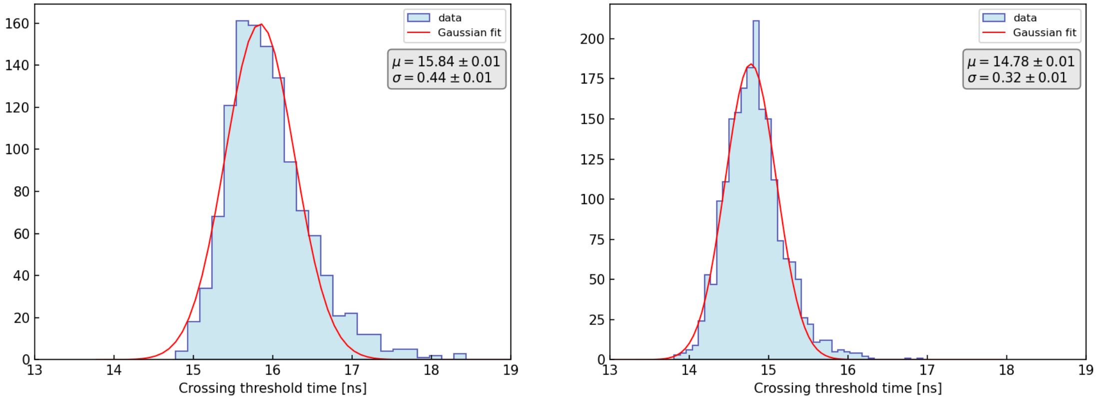
Results Efficiency



(a) (b)

Figure 6: Simulated detector efficiency at different magnitudes of the applied voltage.

Results 1mm gap



(a) **(b)**

Figure 7: Crossing threshold time for a simulated dual gap RPC with gap lengths of 1 mm. The threshold is 0.1 pC. The applied voltage on the electrodes are (a) 9.3 kV and (b) 9.4 kV.

Results 0.5mm gap

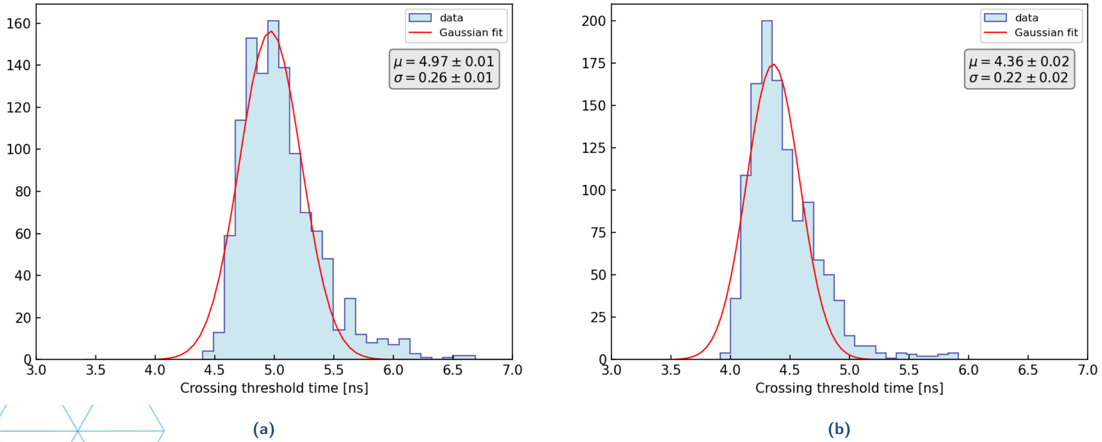
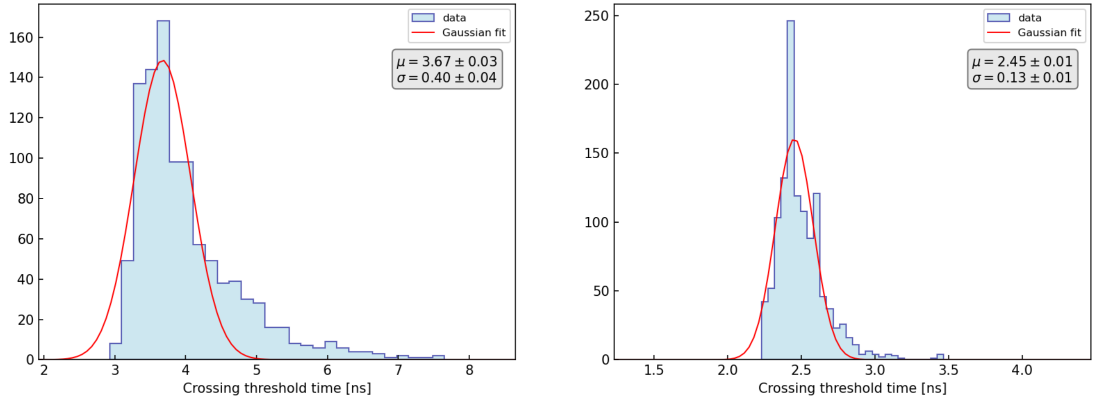


Figure 8: Crossing threshold time for a simulated dual gap RPC with gap length of 0.5 mm. The threshold is 0.1 pC. The applied voltage on the electrodes are (a) 6.2 kV and (b) 6.4 kV.

Results 0.3mm gap



(a) (b)

Figure 9: Crossing threshold time for a simulated dual gap RPC with gap length of 0.5 mm. The threshold is 0.1 pC. The applied voltage on the electrodes are (a) 4.2 kV and (b) 4.5 kV.

Overview

- So far we've obtained result that correlate with the physics of the detector.
- Increasing the applied voltage reduces de average crossing threshold time.
- Reducing the gap length makes the detector reach a high efficiency with less applied voltage and also reduces the threshold crossing time significantly.

Future work...

- Make a comparison of the simulated results and real results obtained in the laboratory.
- Get more data to increase the statistical significance of our results.

BUAP

- END -

Thanks for your attention

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