Simulation of the avalanche creation in resitive circular chambers

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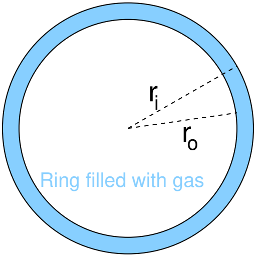
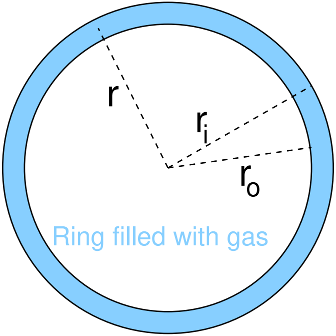
Motivation

- The new resistive cylindrical chambers (RCCs) offer many advantages compared to conventional planar RPCs.
- Obvious advantage of the new resistive cylindrical chambers (RCCs): operation at high pressure possible.
- Goal: Development of an RCC simulation as guidance for the RCC optimization.
- Approach chosen for this presentation: simulation using the Garfield++ toolkit.



Electrical potential between inner and outer cylinder

Simulation of a 300 μm RCC gap with 15 mm diameter



Electrical potential between inner and outer cylinder

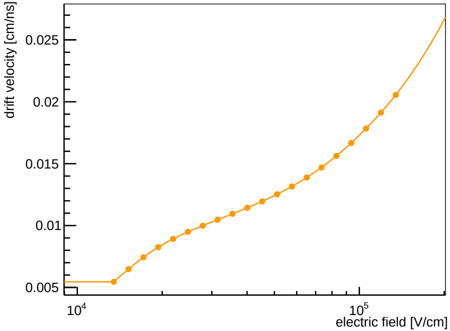
Configuration studied in simulation

- r_i =15 mm, r_o =15.3 mm.
- Ring filled with CO_2 at 3 bar and room temperature.
- Voltage U_0 between cylinders: ±4 kV.

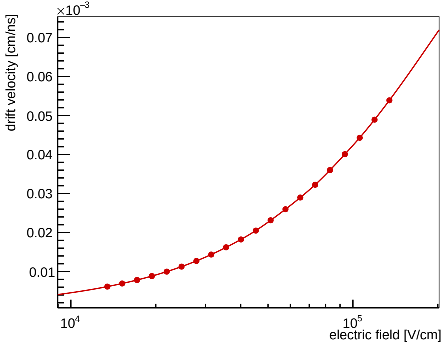
$\Rightarrow$ $|\vec{E}| \sim 10^5$ V cm^{-1}.

Magboltz prediction for drift velocities

Electron drift



Ion drift



- Electron drift velocity at 10^5 V cm^{-1}: 0.017 cm ns^{-1}.

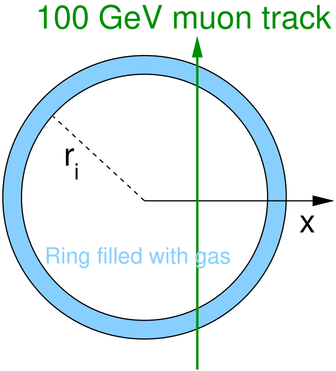
⇒ Time to drift across the gap: ∼2 ns.

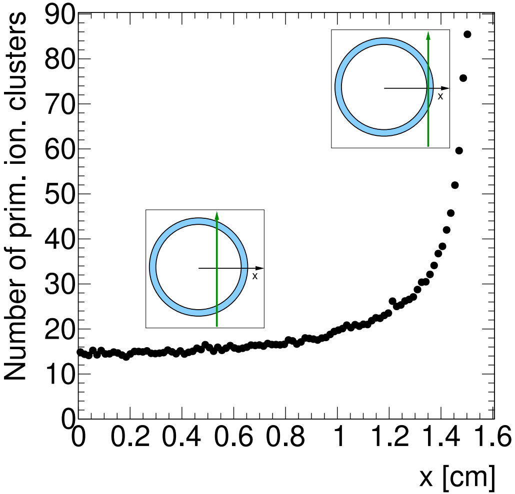
⇒ Very fast and short electron signal.

- Ion drift velocity at 10^5 V cm^{-1}: $0.042 \cdot 10^{-3}$ cm ns^{-1}.

⇒ Time to drift across the gap: ∼700 ns.

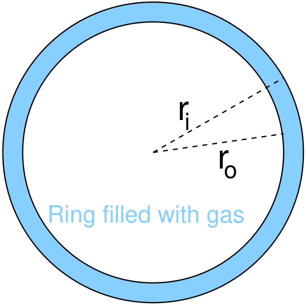
⇒ Much slower ion signal.





⇒ Small number of primary ionization clusters: ∼14 for $r \lesssim r_i$.

Electric field within the ring



Electrical potential between inner and outer cylinder

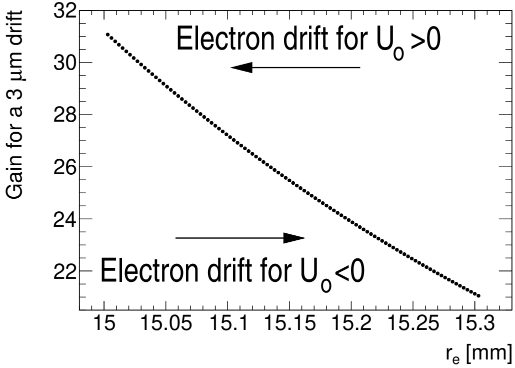
$$r_o - r_i \ll r_i :$$
$$E(r) = \frac{U_0}{\ln\frac{r_o}{r_i}}\frac{1}{r} \approx \frac{U_0}{r_i \ln\frac{r_o}{r_i}} - \frac{U_0}{r_i \ln\frac{r_o}{r_i}}\frac{r - r_i}{r_i}.$$

- Electric field almost constant within the ring.
- Electric field slowly decreasing with increasing r.

Question: What is the influence of the decreasing field?

Electron drift within the ring

Garfield++ used to determine how many electrons are created by a single electron drifting through a 3 μm thick ring at a given radius r.

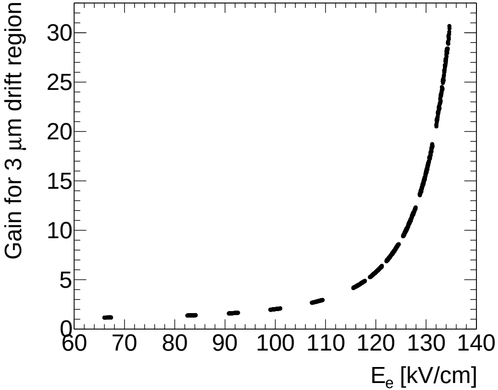


- For both field configurations (field point inwards or outwards) the gain is the same within the shell as the the magnitude of the electric field is the same.
- For $U_0 > 0$ the electron is moving into higher field regions.
- For $U_0 < 0$ the electron is moving into lower field regions.

$\Rightarrow$ Faster drift and more ionization in case of $U_0 > 0$ leading to higher and steeper signals.

Gain within a 3 μm ring as a function of E

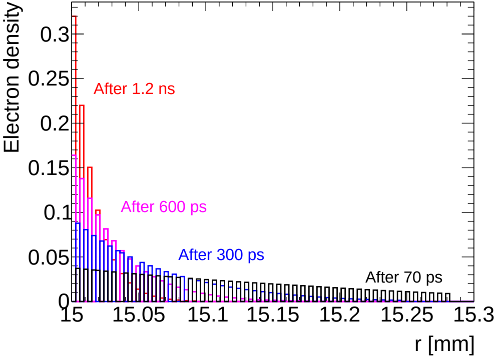
Dependence of the gain for an electron drifting through a 3 μm thick ring on the electric field strength.



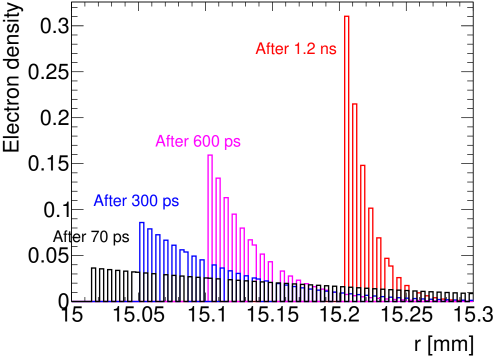
- Significant gain only for $E \gtrsim$120 kV/cm (corresponding to $U_0 \approx 3.7$ kV.
- The plotted dependence is needed to simulate the full avalanche taking into account the change of the electric field due to the built-up of space charge in the evolution of the avalanche.

Evolution of the shape of the avalanche

$U_0 > 0$, electron drifting inwards



$U_0 < 0$, electron drifting outwards



- Compression of the electron distribution for both drift directions.
- $U_0 > 0$: Highest electron density at the front of the electron cloud.
- $U_0 < 0$: Highest electron density at the tail of the electron cloud.
- ~ 5 times higher number of electrons for $U_0 > 0$ than for $U_0 < 0$.

Summary

- Garfield++ used to determine basic properties of an RCC (primary ionization, drift velocities).
- Garfield++ used to study the evolution of the avalanche for inwards and outwards pointing electric fields.
- No advantage for inwards points electric fields was observed.

⇒ Field configuration like in drift tubes preferable as this lead to faster and higher signals than the opposite configuration.

- Next steps: Simulation of the signals.