Gain stability: charging-up phenomena in **THGEM**-based detectors

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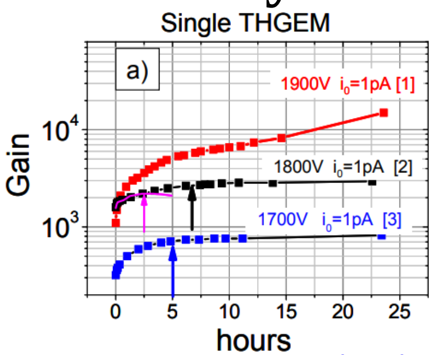
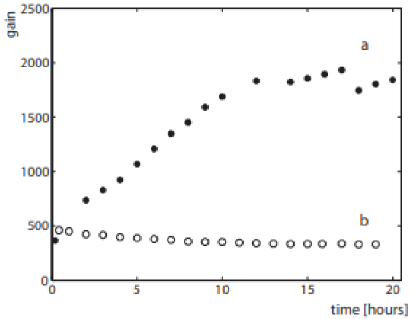
Motivation

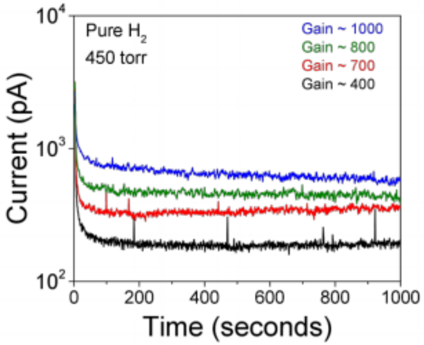
Gain stability in THGEM-based detectors was exhaustively studied in recent years:



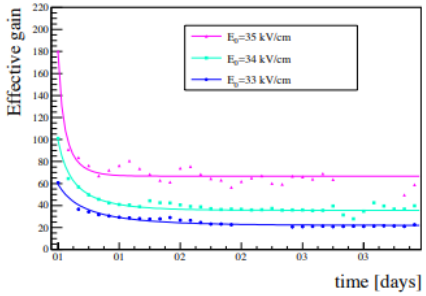
R. Chechik et al., C0604032 (2006) 0025



M. Alexeev et al., 2010 JINST 5 P02009



M. Cortesi et al., 2015 JINST 10 P09020



C. Cantini et al., 2015 JINST 10 P03017

- A new **methodology** by WIS for systematic study of gain stabilization in MPDGs:
  D. Shaked-Renous et al., 2017 JINST 12 P09036
- A new **simulation model** of charging-up phenomena in THGEM by the Aveiro & WIS:
  P.M.M. Correia et al., 2018 JINST 13 P01015

Here: study of **charging-up** phenomena in THGEM combining both approaches
MP et al., arXiv:1801.00533

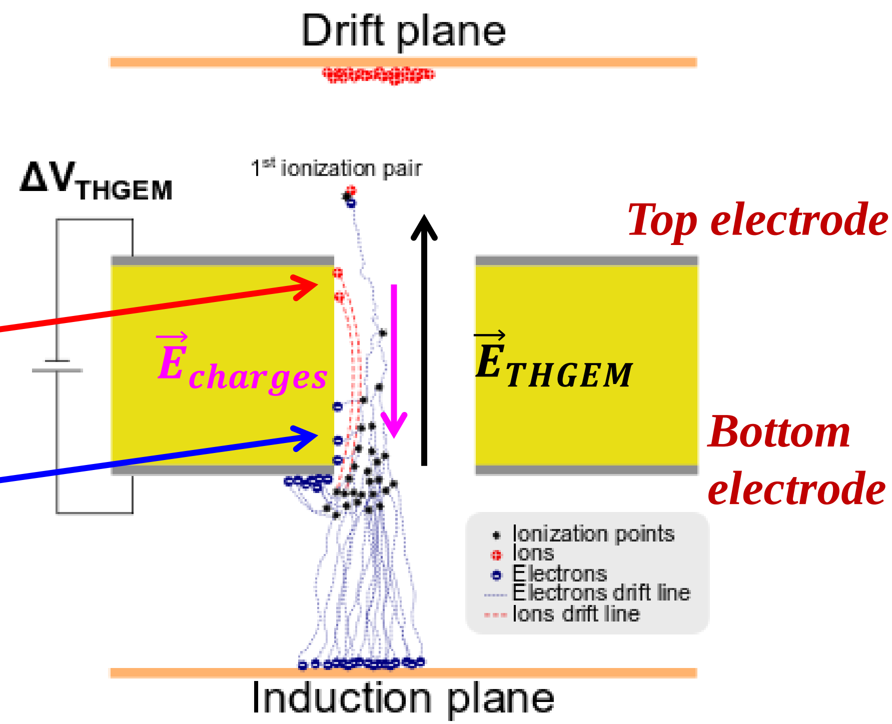
Charging up processes in THGEMs

THGEM without etched hole-rims

During the avalanche process, electrons and ions can end up attached to the THGEM hole walls.

Simulation studies suggest the following charge distribution across THGEM holes:

- Back-drifting ions: attached to the upper part of the hole walls
- Electrons: attached to the bottom part of the hole walls, once the avalanche expands



Visualization of charging up process

Charge accumulation on hole-walls → E decreases → lower gain

Charging up processes in THGEM

THGEM with etched hole-rims

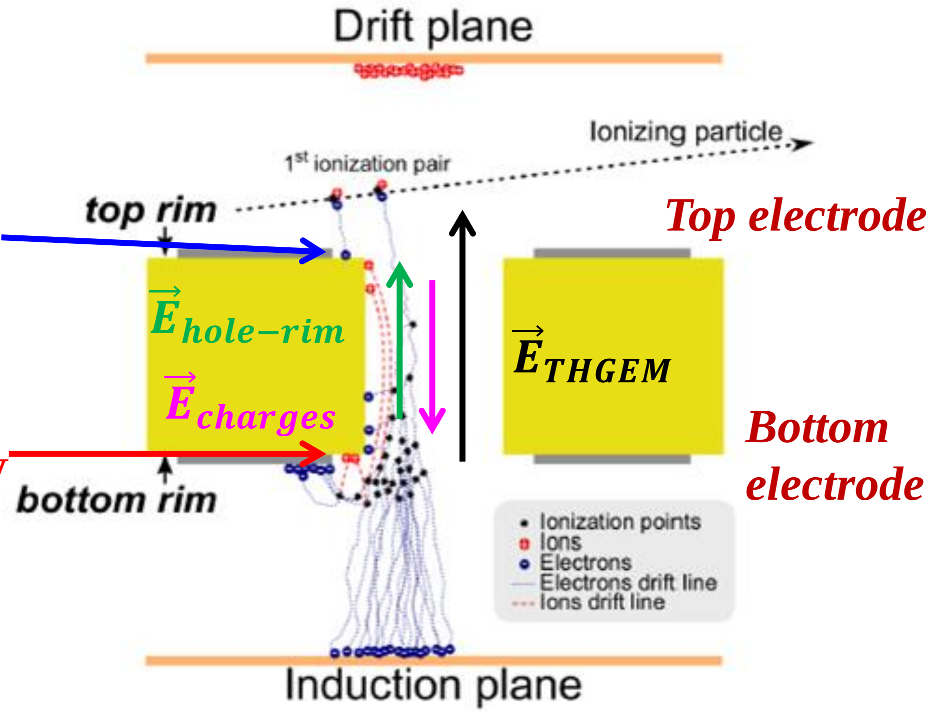
Simulation studies suggest, that the dielectric surface of the hole-rims is charged differently to the THGEM walls:

“top-rim”

Primary electrons, not focused to the THGEM holes can end up on the top-rim insulating surface

“bottom-rim”

Charge multiplication at the vicinity of the bottom-rim creates ions that are accumulated on the bottom-rim



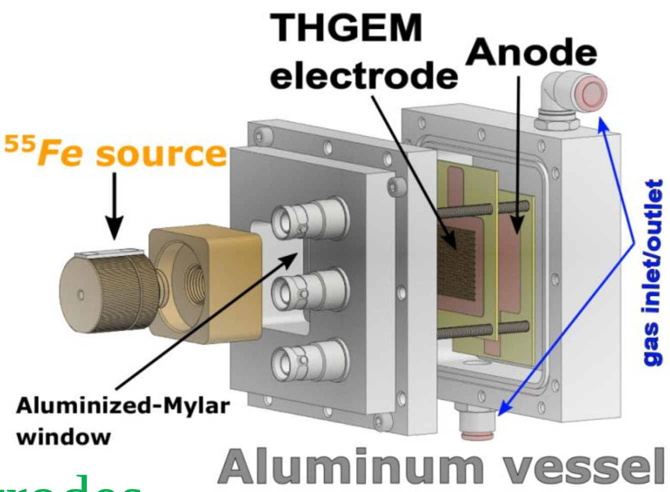
Visualization of charging up process

Charge accumulation on hole-rims → E increases → higher gain

Methodology of charging up measurements

Previous studies (D. Shaked-Renous et al., 2017 JINST 12 P09036) suggest several potential sources affecting gain stabilization other than charging up:

- Gas composition (outgassing, leaks, water vapors)
- Down-charging (due to electro-negative gas compounds)
- Previous electrode's history
- Temperature/Humidity variations

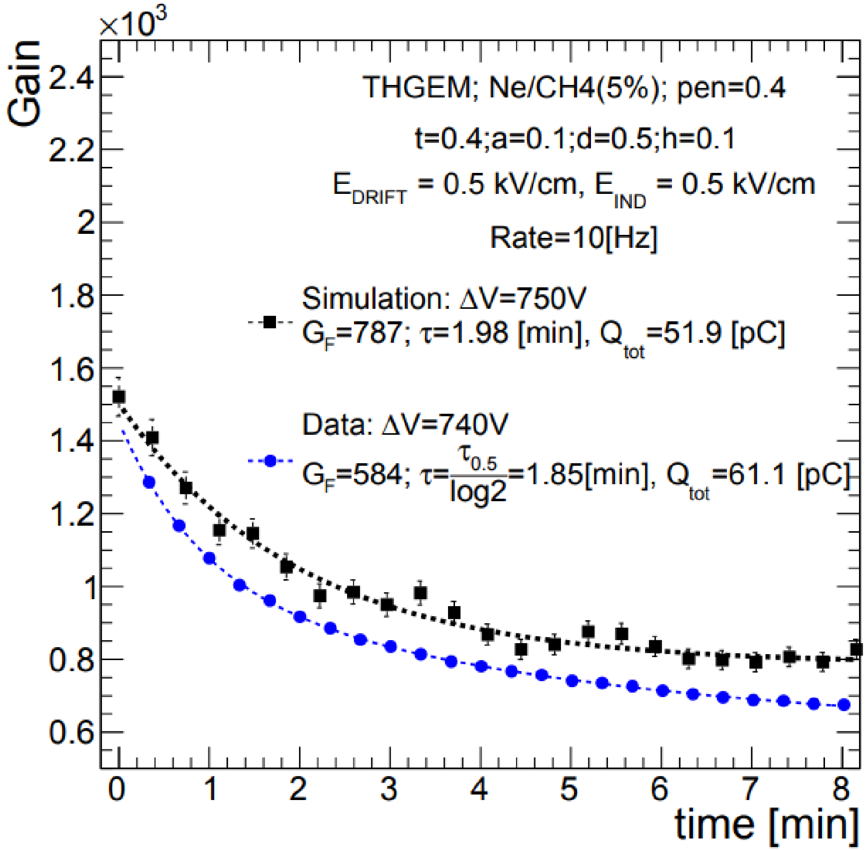


Methodology to overcome potential biases:

- Small hermetic vessel with $3 \times 3cm^2$ electrodes
- Most measurements done with pure, noble gasses (Ne, Ar)
- Prior each measurement the electrode history was "cleaned" with ionization gun; detector's vessel flushed for >1h
- Long-term measurements were performed multiple times

Validation of the charging up model

- Simulation result of gain stabilization was compared to measured data, in Ne/CH_4(5%) (with known Penning transfer rate).
- Qualitative comparison between characteristic quantities of the charging-up phenomena found to be **in fair agreement** with data.



Characteristic time:

Usually defined as the time for gain decrease to half of the total gain variation ($\tau_{0.5}$).
In case when gain variation fits exponential curve, $\tau = \tau_{0.5}/\log(2)$

Characteristic charge:

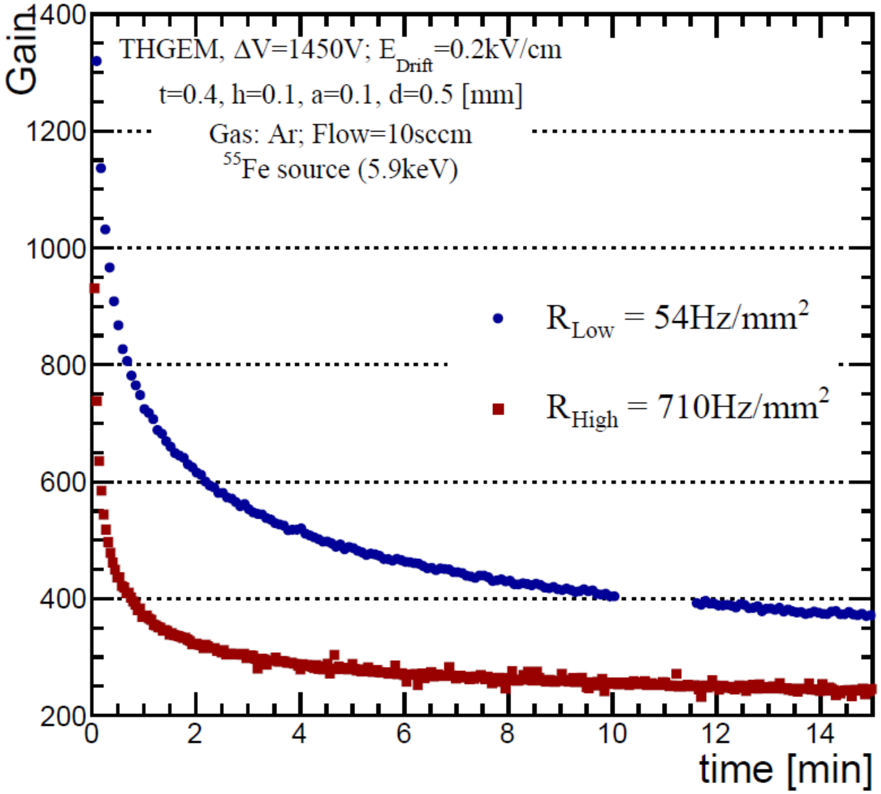
The total charge passes through THGEM holes during τ

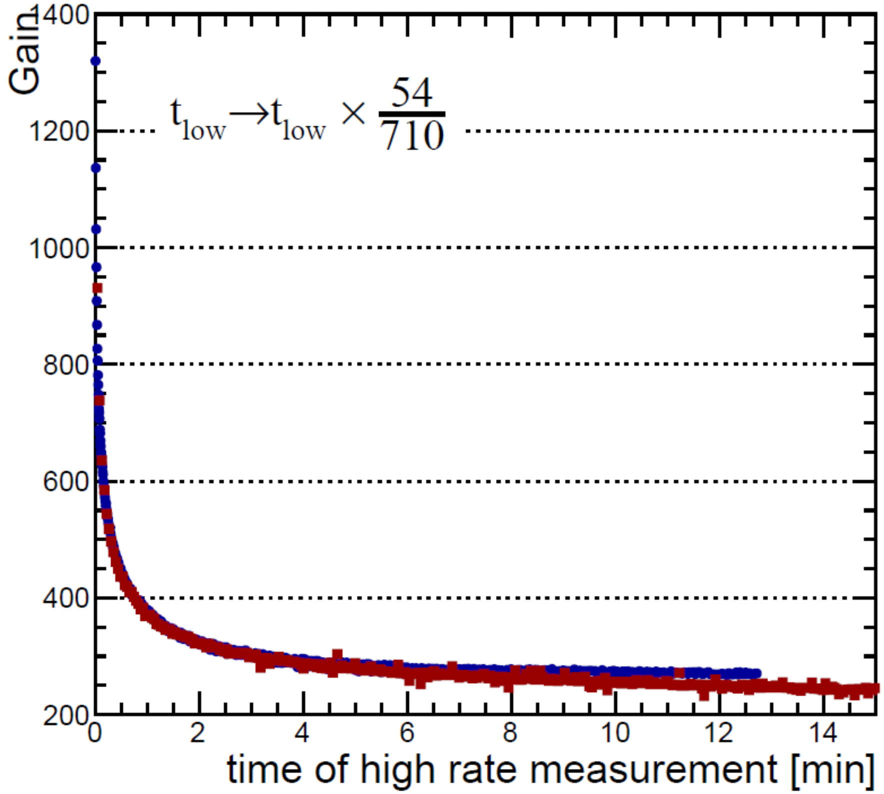
$$Q_{tot} = Q_0 \times R \times \int_0^{\tau} G(t)dt$$

Primary charge (Q_0) *Irradiation rate* (R)

Implications of the phenomenological model

Stabilization time expected to be linear with the inverse of the rate

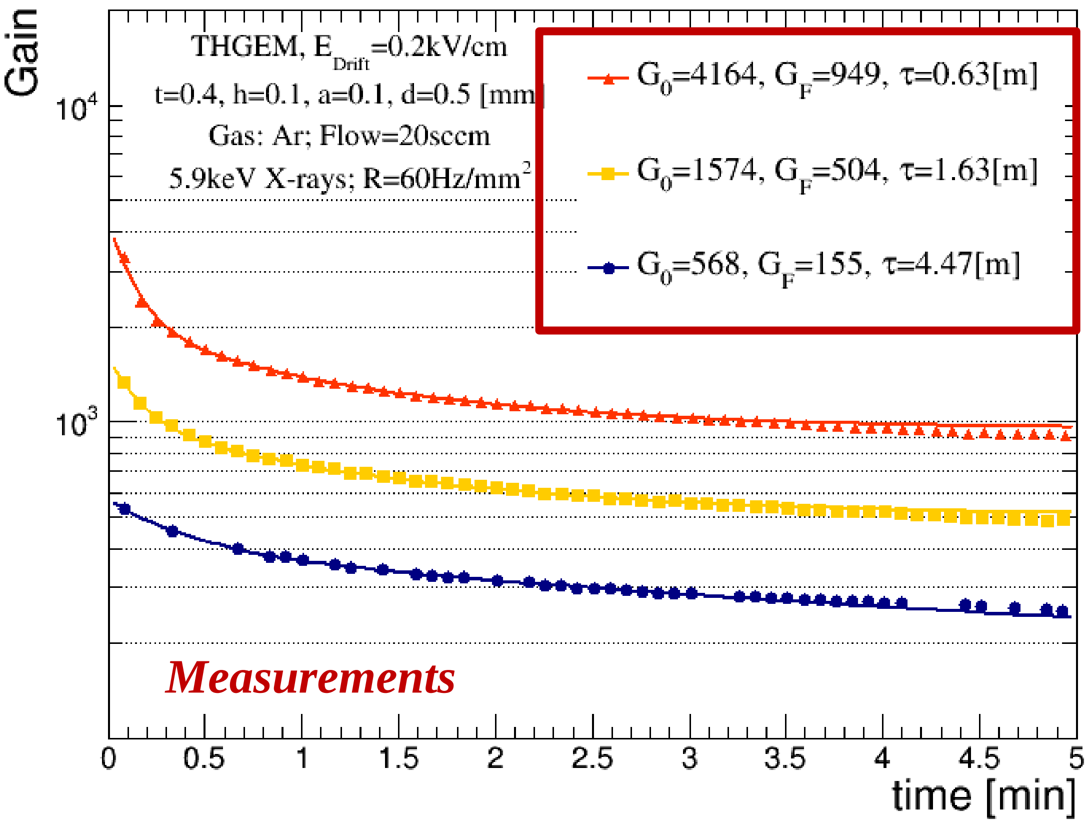


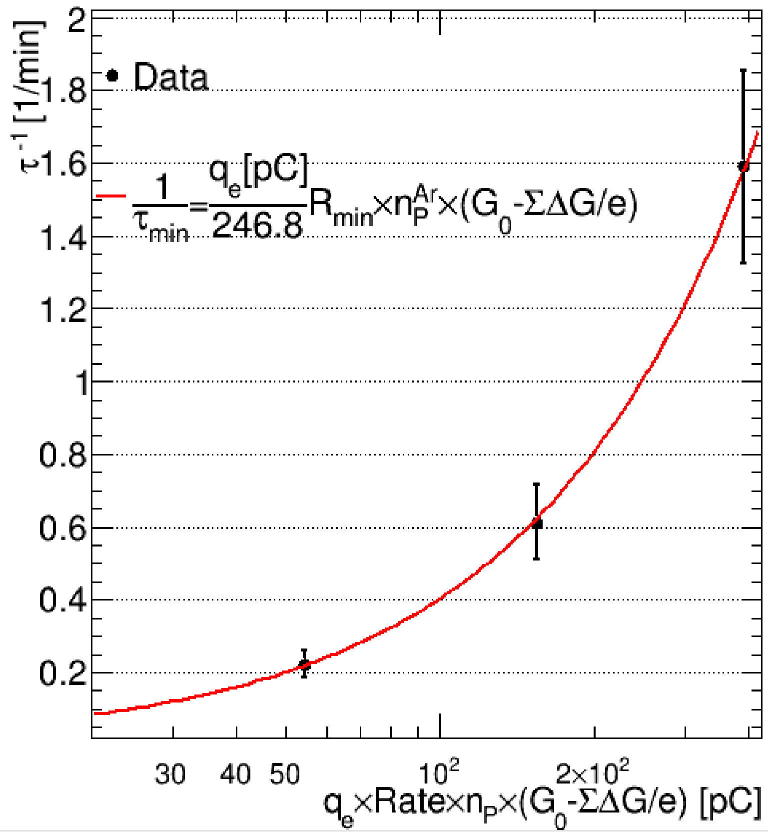


Low-rate measurement performed for >2h, then
Scale x-axis of the low-rate measurement by the rate ratio

Implications of the phenomenological model

Stabilization time decreases proportionally with increasing gain



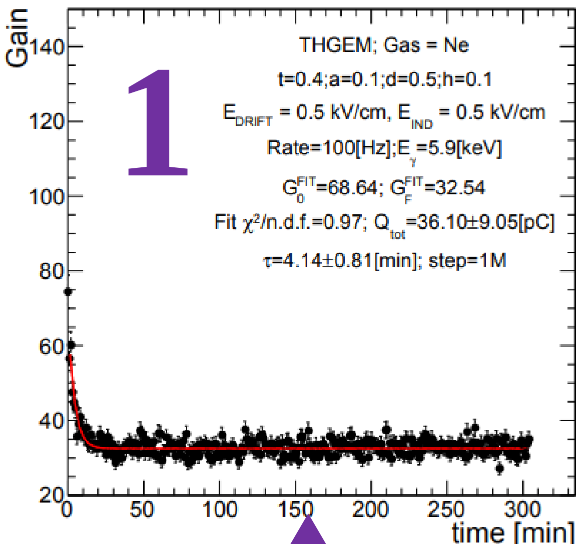


Characteristic charge Q_{tot} is constant regardless the detector's gain

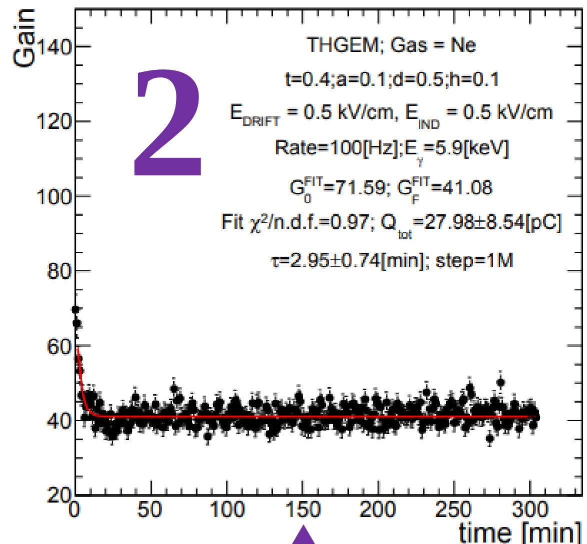
Study of the rim effect

Simulation shows that the charging up of hole-rims leads to an increase of the detector's gain, with different time constants

1. **Only HOLE-WALLs are charged → gain drop of >50%**
2. **HOLE-WALL + BOTTOM-RIM are charged → smaller gain drop**
3. **HOLE-WALL + BOTH-RIMs are charged → long-term time gain variation**



☑ **Hole-Walls**
☒ **Top-rim**
☒ **Bottom-rim**



☑ **Hole-Walls**
☒ **Top-rim**
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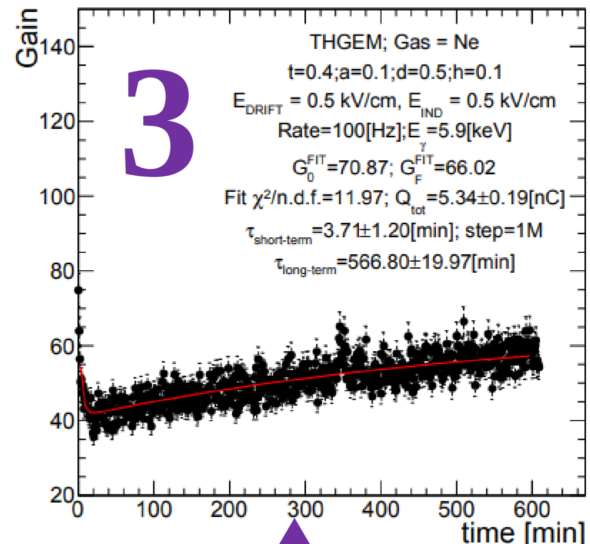
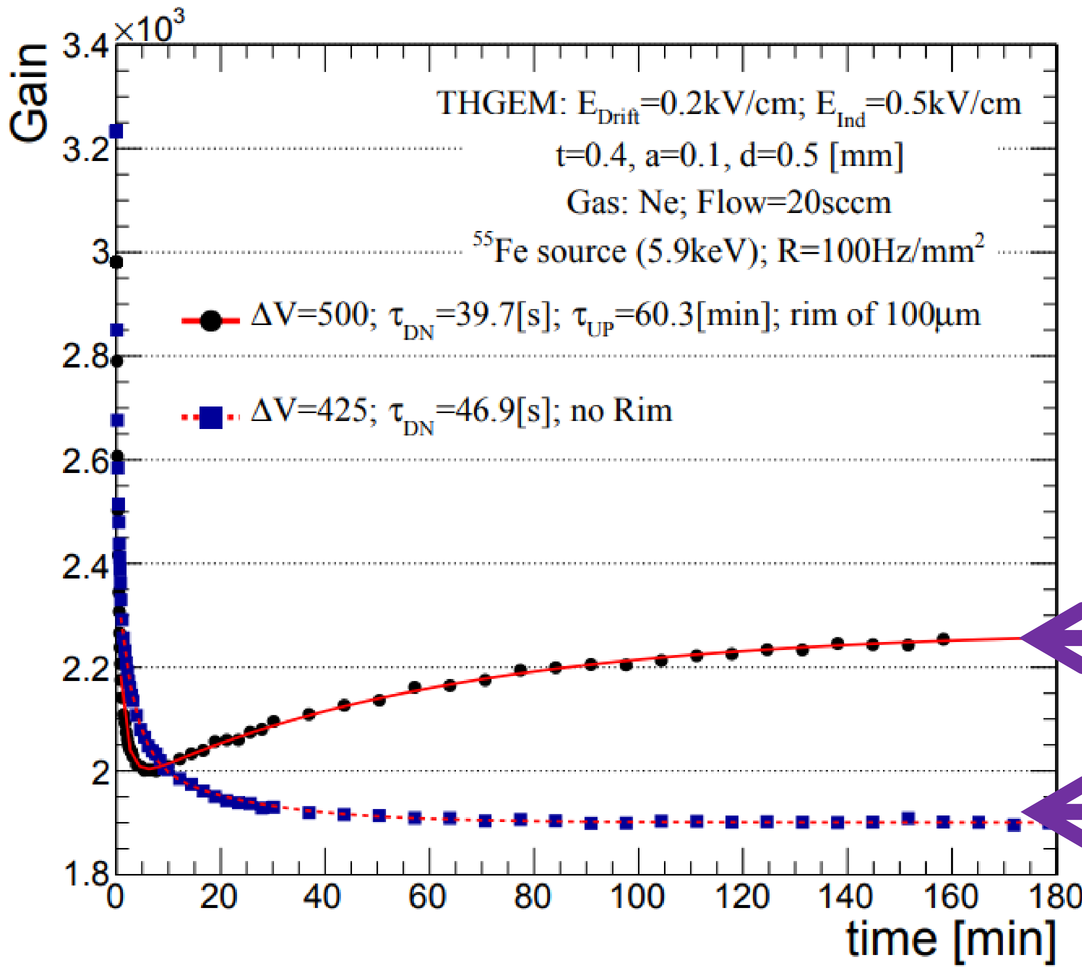
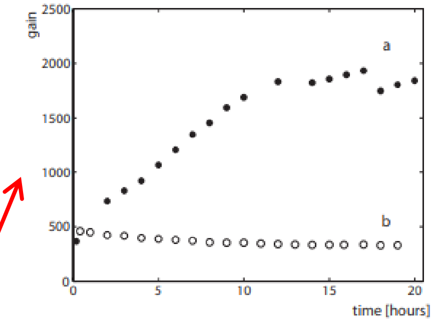


☑ **Hole-Walls**
☑ **Top-rim**
☑ **Bottom-rim**

Study of the rim effect

Measured data confirms simulation results





M. Alexeev et al., 2010 JINST 5 P02009

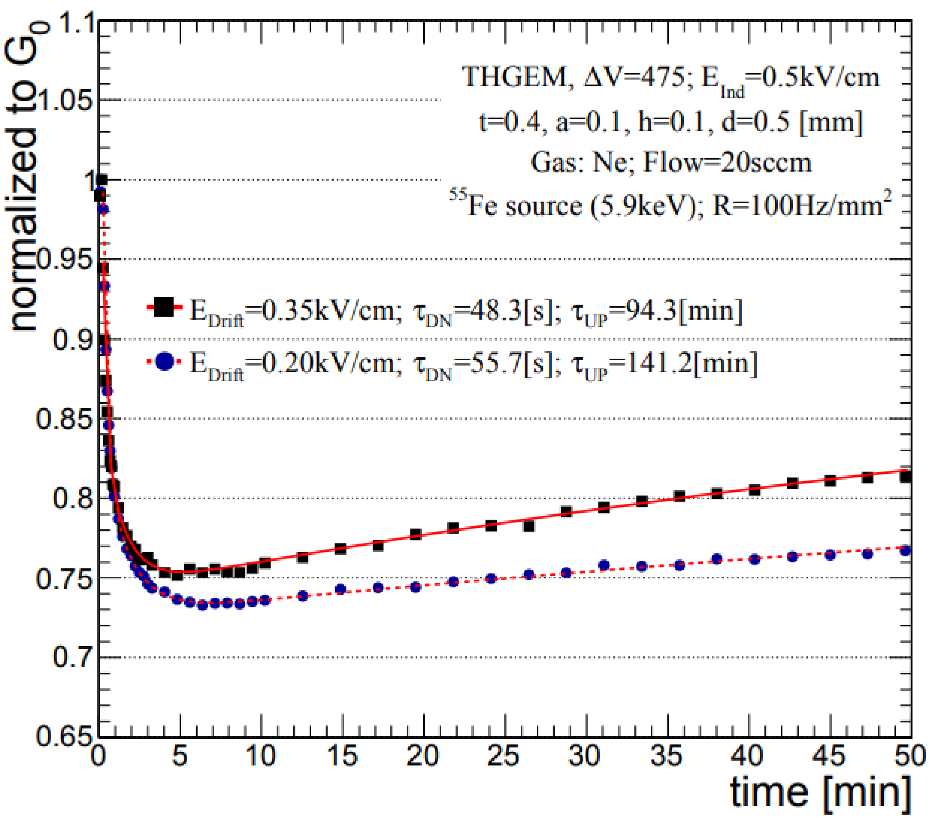
- Already observed (**not new**)
- Here this first shown phenomenologically (**NEW**)
- THGEM is stable with top-rims (**NEW**)

Electrode with an etched hole-rim of 0.1mm

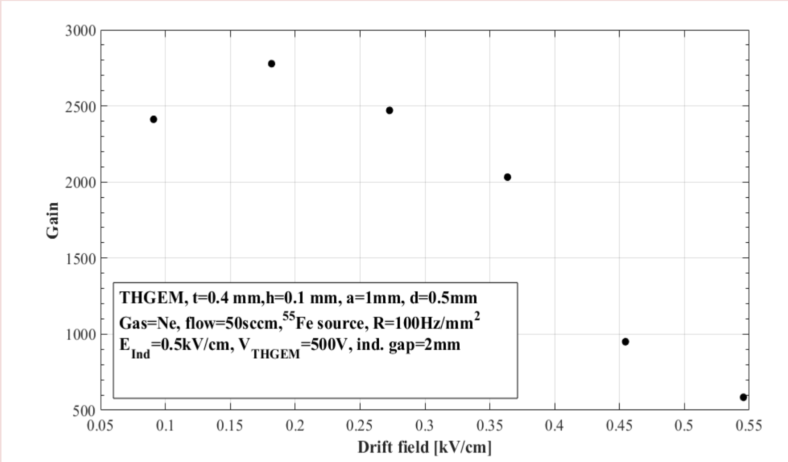
Electrode without hole-rim

Study of the **top-rim** effect

The rate of charging-up of the **top-rim** can be modified:
higher **drift field** → lower electron collection efficiency into holes → more electrons end up on the "top-rim"

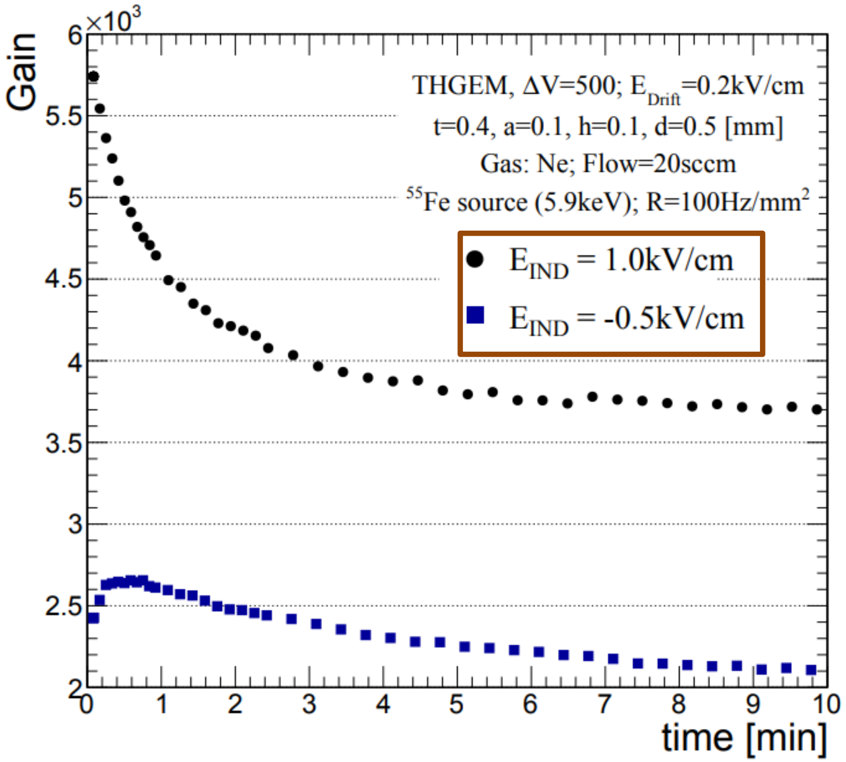


In Ne, the optimal drift field is 0.2kV/cm
Higher drift fields lead to a lose of primary charges on the top electrode, including the top-rim.
Higher drift field → lower resolution

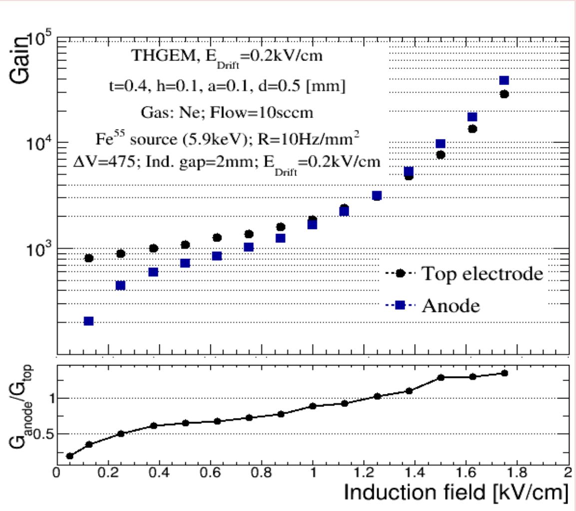


Study of the **bottom-rim** effect

The rate of charging-up of the **bottom-rim** can be modified:
Inversed **induction field** → avalanche confined at the bottom electrode → more ions created at the bottom-rim vicinity



E_{IND}=1kV/cm – high avalanche transfer to the anode
E_{IND}=-0.5kV/cm – avalanche collected on the bottom electrode



Summary and discussion

- We tested experimentally the phenomenological charging up model for the **first time.**
- Emphasize was given to **charging up** effects by mitigating possible charging down mechanisms.
- Stable gain is reached once the amount of charge ($\propto \boldsymbol{Q_{tot}}$) needed to fully charge up the detector's insulator passes through the detector
  - Both electrodes with and w/o hole-rims reached **stable operation**.
  - The presence of **top-rim** results in **slow gain stabilization** (usually few orders of magnitude slower than the fast component)
  - The presence of **bottom rim** mitigates the initial gain drop

  (affecting also THGEM-based geometries w/o induction gap, like THWELL, etc.)
- These charging-up transients: are **not affect** the detector's long-term operation under ***stable environmental conditions.***

Back up