# THGEM CHARACTERIZATION STUDIES

On behalf of the CERN, Torino, Trieste groups

Elena Rocco

RD51 Collaboration Meeting - Paris, 13-15 October 2008

# OUTLINE

Presentation of results about:

- time stability measurements;
- drift and induction scans and energy resolution
- gain;
- rate capability.

# MOTIVATIONS

Just a recall (discussed by Fulvio Tessarotto at the Amsterdam meeting).

- Our final goal :
  design, build and operate THGEM-based photon detectors;
- in these slides, the first step:
  understand and characterize the THGEM detecting ionizing particles.

# GENERAL INFORMATION

- The work presented has been performed in two labs (CERN and Trieste) with two similar setups.
- 30 THGEMs up to now characterized (here we present selected items).
- The pieces are different in geometry and in production techniques.

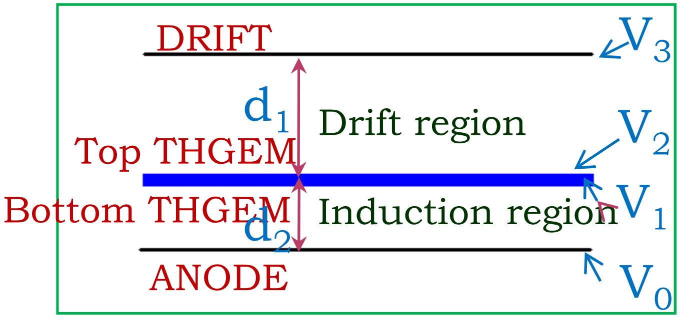
# THGEM AND SETUP

*Setup:*

•Single THGEM layer in the chamber (see sketch below);
•Active surface: 30 x 30 $mm^2$;
•Gas mixture Argon/$CO_2$ (70/30);
•Sources: X-Ray (Cu – collimated source) and $^{55}Fe$ (uniform irradiation);
•Two methods of measurement: pulse height mode (amplitude spectra) and current mode (pico-ammeters with resolution up to 1pA);

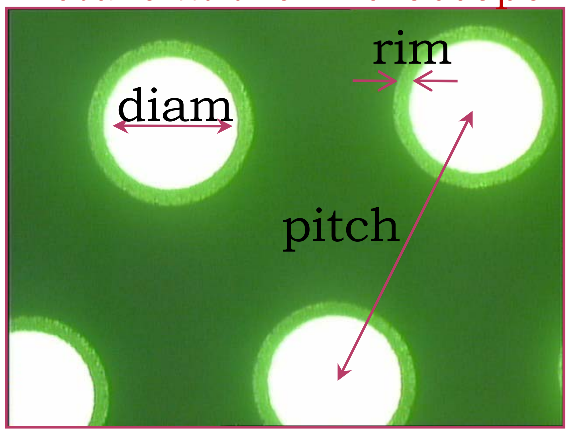
**GEOMETRICAL CONFIGURATION IN THE CHAMBER**

To detect ionizing particle :
$V_3 < V_2 < V_1 < V_0$

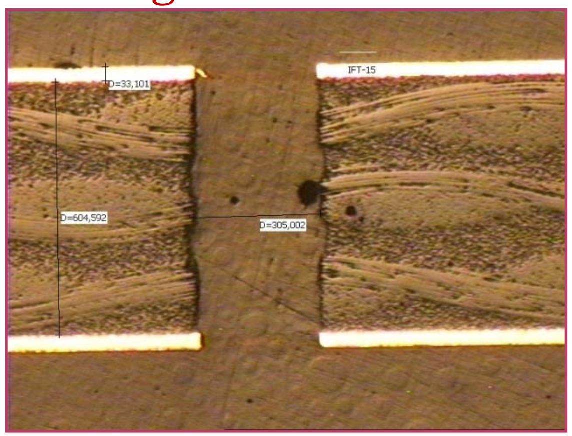



$E_{drift} = (V_3 - V_2) / d_1$
$E_{induction} = (V_1 - V_0) / d_2$
$\Delta V = V_2 - V_1$

Picture at the microscope



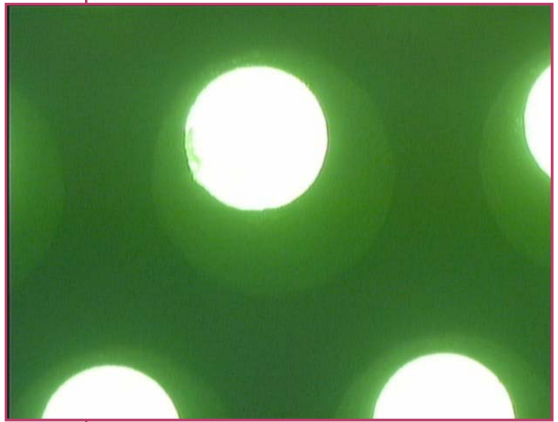

Metalografic section



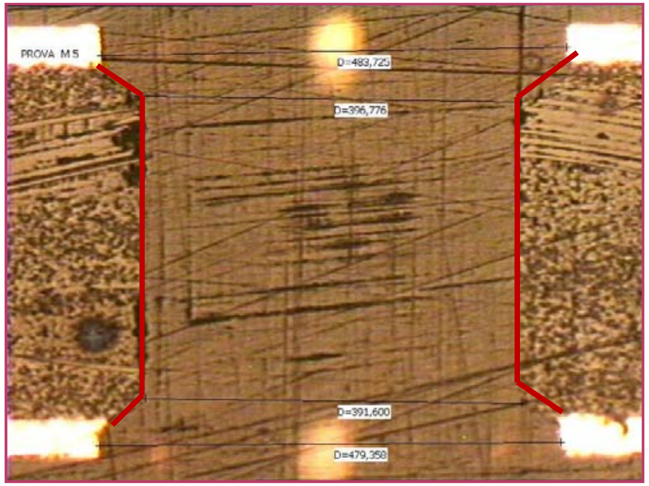
# RIM PRODUCTION TECHNIQUES

- 6 different protocols;
- See Fulvio Tessarotto's talk.

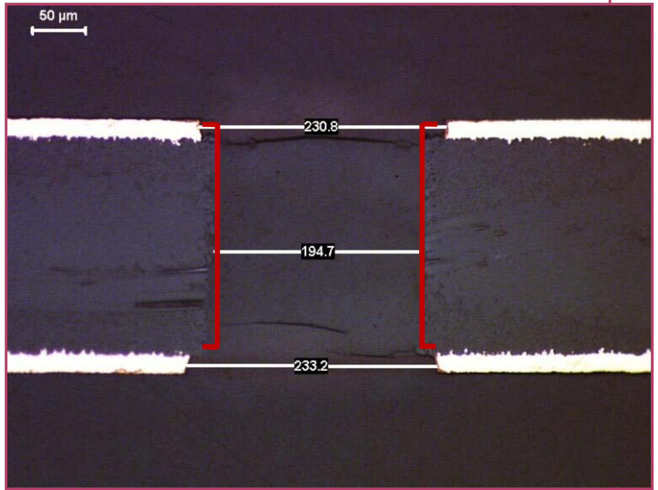
Some examples:



Weizmann technique




Eltos: mechanical drilling

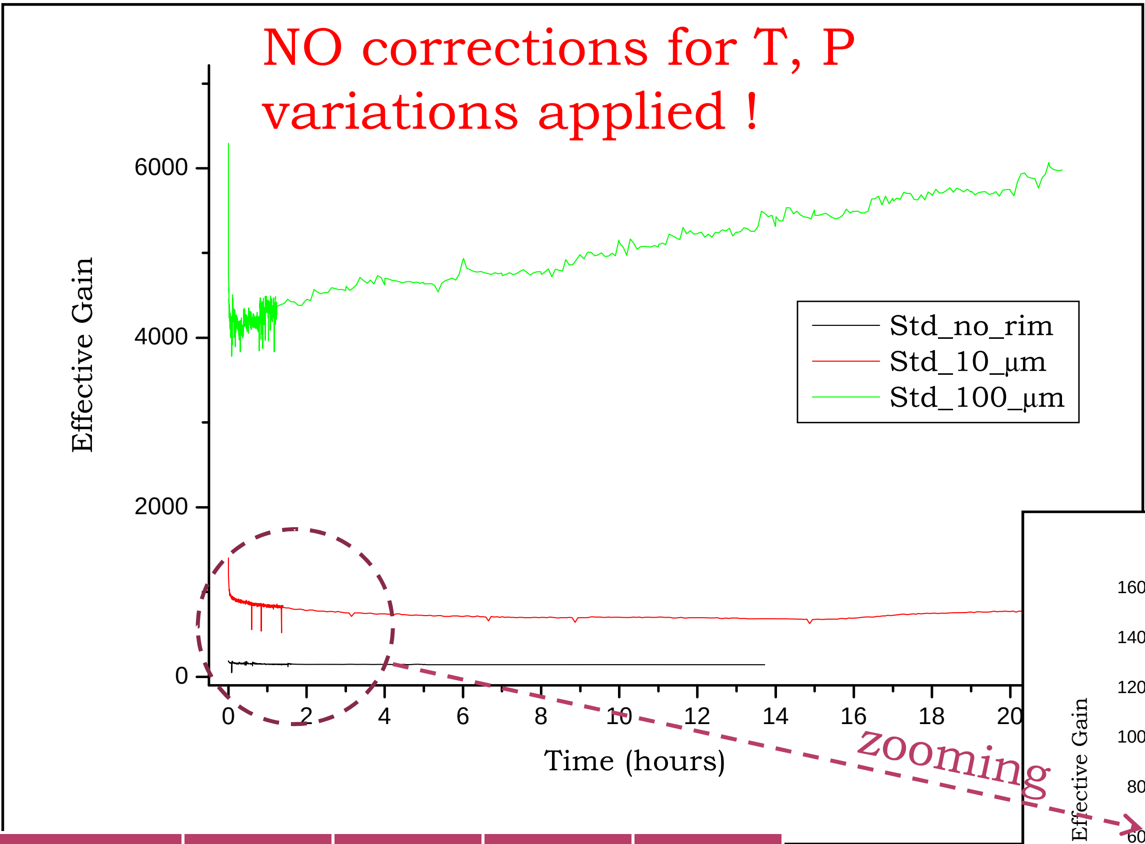



CERN etching production

## Geometrical parameters and production techniques of the THGEMs characterized (a sample)

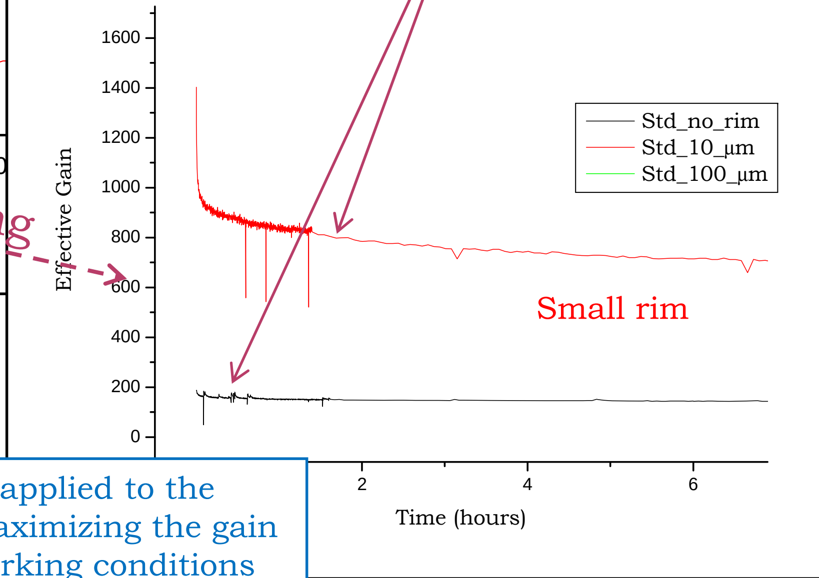
| Label | Diam (mm) | Pitch (mm) | Rim (μm) | Thick (mm) | Rim production | Company |
|---|---|---|---|---|---|---|
| THGEM_1 | 0.3 | 0.7 | 0 | 0.6 | --- | CERN |
| THGEM_2 | 0.3 | 0.6 | 0 | 0.6 | --- | CERN |
| THGEM_3 | 0.3 | 0.5 | 0 | 0.6 | --- | CERN |
| THGEM_5 | 0.4 | 0.7 | 0 | 0.6 | --- | CERN |
| THGEM_9 | 0.5 | 0.7 | 0 | 0.6 | --- | CERN |
| Std_no_rim | 0.3 | 0.7 | 0 | 0.4 | --- | CERN |
| Std_10_μm | 0.3 | 0.7 | 10 | 0.4 | Electro-chemical polishing | CERN |
| Std_100_μm | 0.3 | 0.7 | 100 | 0.4 | Standard etching | CERN |
| Std_0/100_μm | 0.3 | 0.7 | 0/100 | 0.4 | Standard etching | CERN |
| Rui_10_μm | 0.2 | 0.5 | 10 | 0.2 | --- | CERN |
| M1 | 0.4 | 0.8 | 0 | 0.4 | --- | ELTOS |
| M2 | 0.4 | 0.8 | 25 | 0.4 | Mechanical drilling | ELTOS |
| M5 | 0.4 | 0.8 | 50 | 0.4 | Mechanical drilling | ELTOS |
| C3 | 0.4 | 0.8 | 50 | 0.4 | Chemical etching | ELTOS |
| C4 | 0.4 | 0.8 | 100 | 0.4 | Global etching | ELTOS |
| C7 | 0.4 | 0.8 | 10 | 0.4 | Global etching | ELTOS |

# TIME STABILITY MEASUREMENT (1/3)




- A factor >>2 in gain variation between the initial drop and the stabilization;
- Different behaviour for THGEMs with and without (or small) rim.

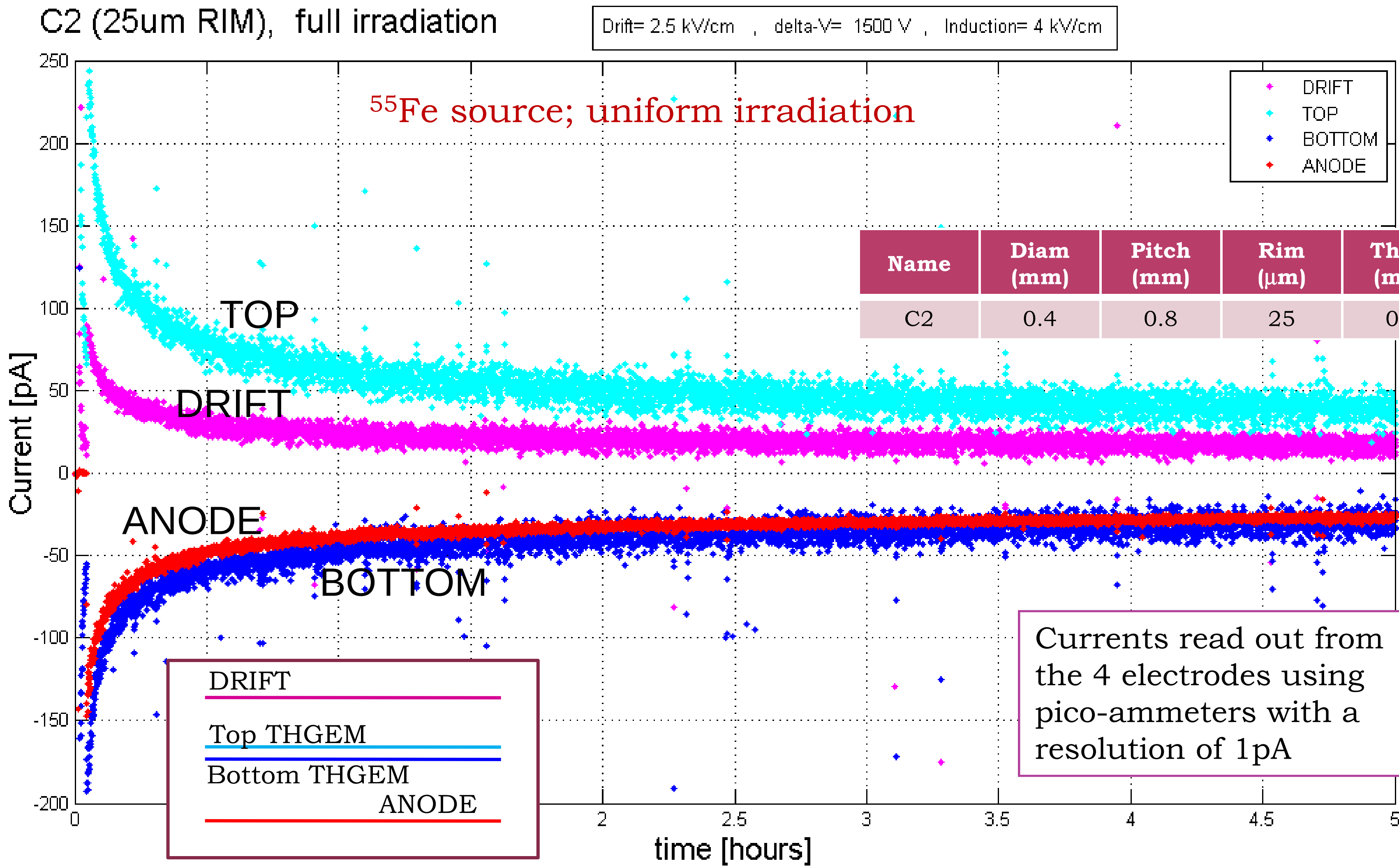
Continuously irradiated with collimated X-Ray source




| Name | Diam (mm) | Pitch (mm) | Rim (µm) | Thick (mm) |
|---|---|---|---|---|
| Std_no_rim | 0.3 | 0.7 | 0 | 0.4 |
| Std_10_µm | 0.3 | 0.7 | 10 | 0.4 |
| Std_100_µm | 0.3 | 0.7 | 100 | 0.4 |

Different ΔV applied to the THGEMs, maximizing the gain for stable working conditions

# Time stability measurement (2/3)




| Name | Diam (mm) | Pitch (mm) | Rim (µm) | Thick (mm) |
|---|---|---|---|---|
| C2 | 0.4 | 0.8 | 25 | 0.4 |

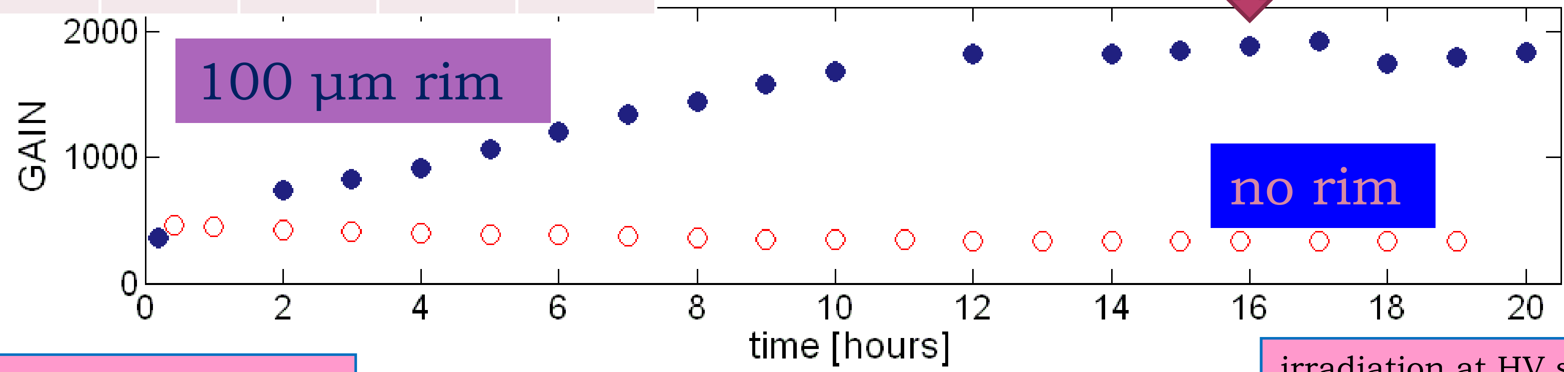
Currents read out from the 4 electrodes using pico-ammeters with a resolution of 1pA

# TIME STABILITY MEASUREMENT (3/3)

| Name | Diam (mm) | Pitch (mm) | Rim (µm) | Thick (mm) |
|---|---|---|---|---|
| M1 | 0.4 | 0.8 | 0 | 0.4 |
| C4 | 0.4 | 0.8 | 100 | 0.4 |

$^{55}Fe$ source; uniform irradiation

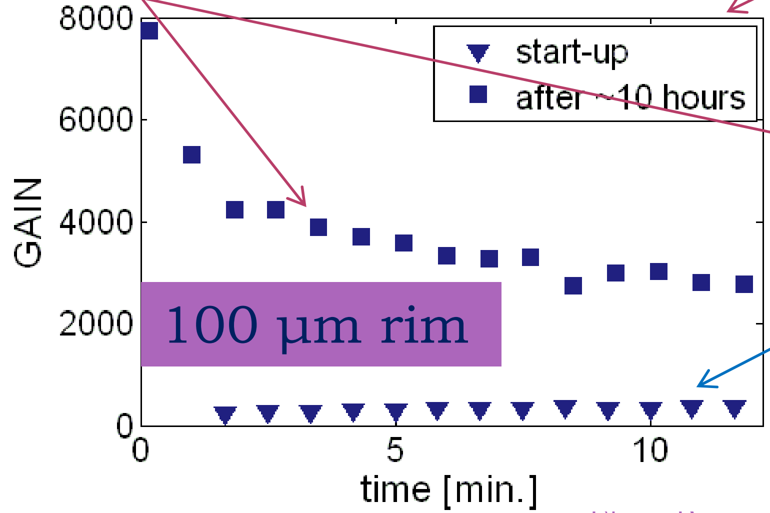
Long time gain variation

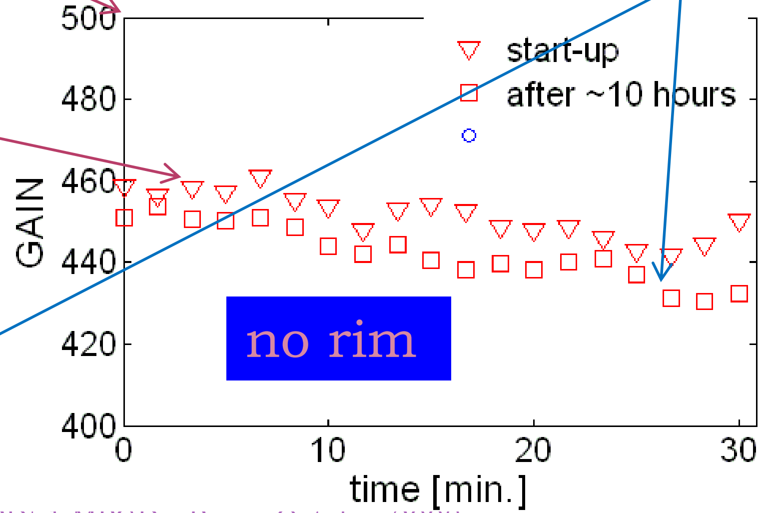



START IRRADIATING after ~10 hours at nominal voltage

Short time gain variation

irradiation at HV switch on (after ~1 day with no voltage)



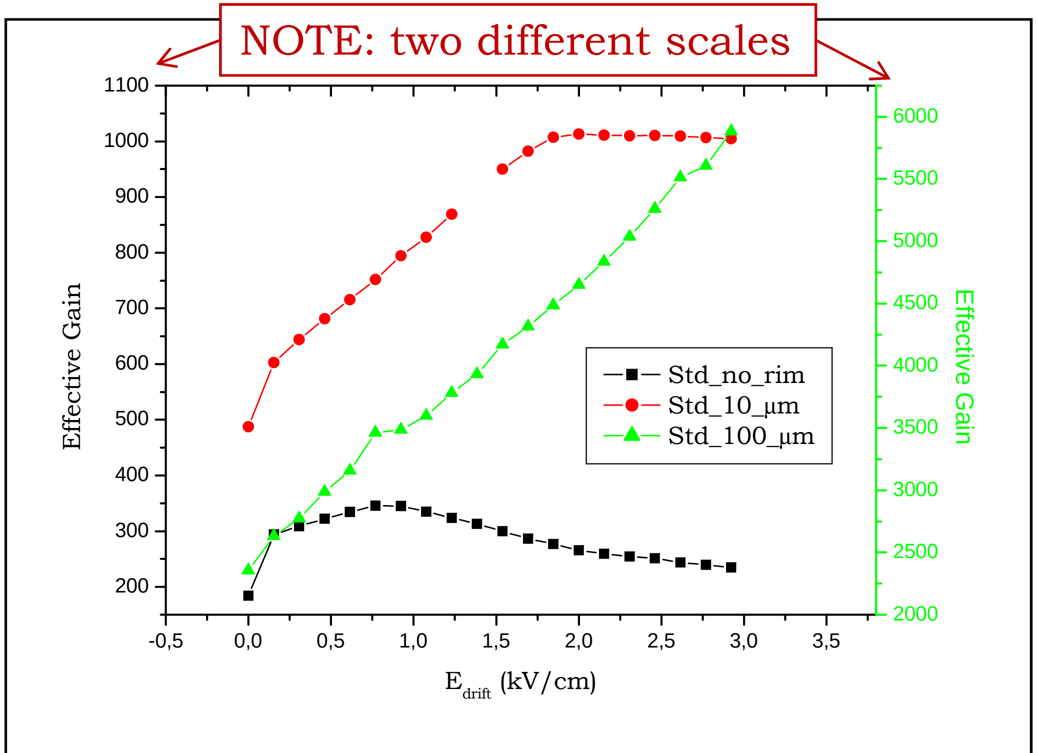
# Rim and Gain Stability, what we have learned

GAIN VARIATION (CONTINUOS IRRADIATION)

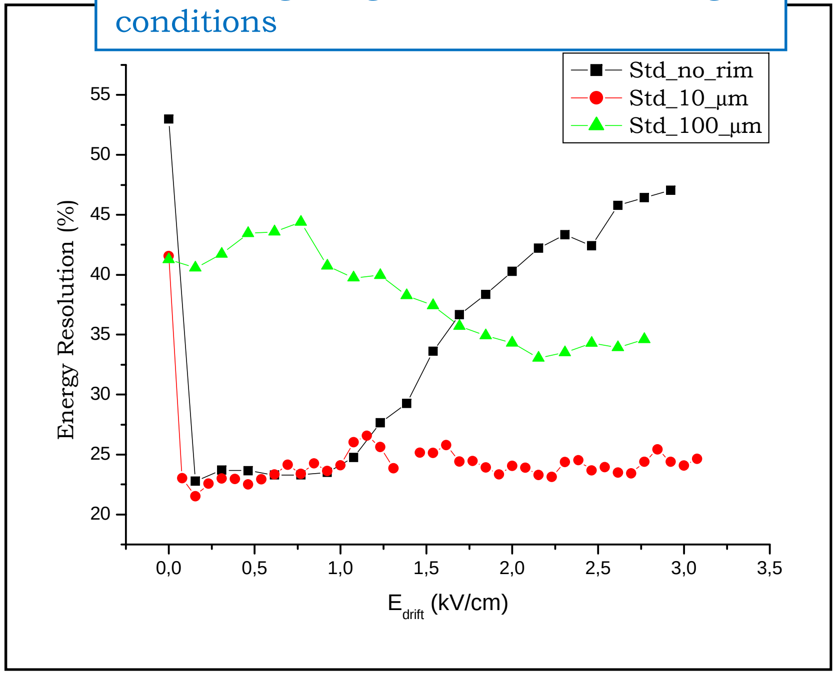
| | | |
|---|---|---|
| 100 μm chem. rim | ➔ | increase of ~ 400% |
| 25 μm chem. rim | ➔ | decrease of ~ 70% |
| 10 μm chem. rim | ➔ | decrease of ~ 50% |
| no rim | ➔ | decrease of < 30% |

- The time to reach stabilization is shorter for smaller rims
- For large rims, strong dependence of the gain on the irradiation history of the THGEM

# DRIFT SCAN VS RIM (1/2)




Different ΔV applied to the THGEMs, maximizing the gain for stable working conditions

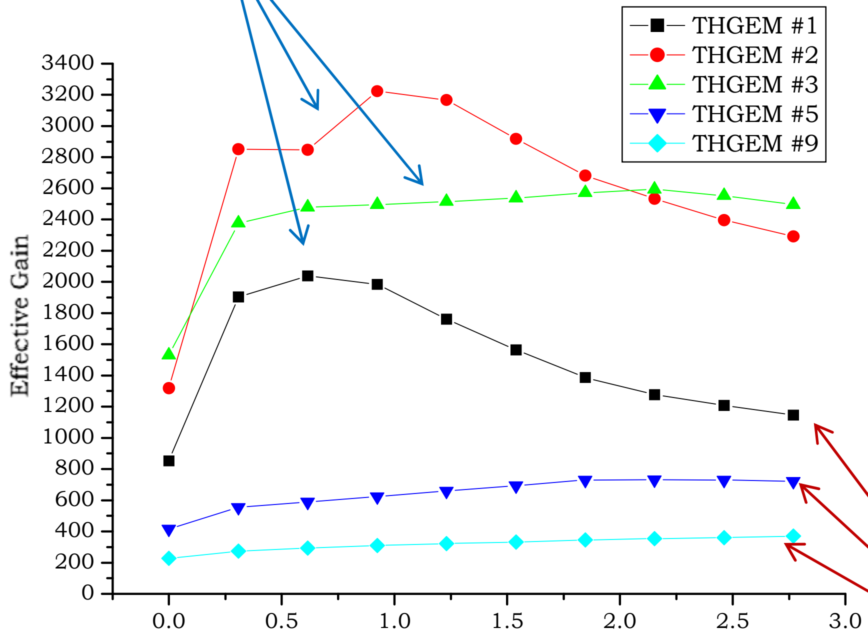



| **Name** | **Diam (mm)** | **Pitch (mm)** | **Rim (µm)** | **Thick (mm)** |
|---|---|---|---|---|
| Std_no_rim | 0.3 | 0.7 | 0 | 0.4 |
| Std_10_µm | 0.3 | 0.7 | 10 | 0.4 |
| Std_100_µm | 0.3 | 0.7 | 100 | 0.4 |

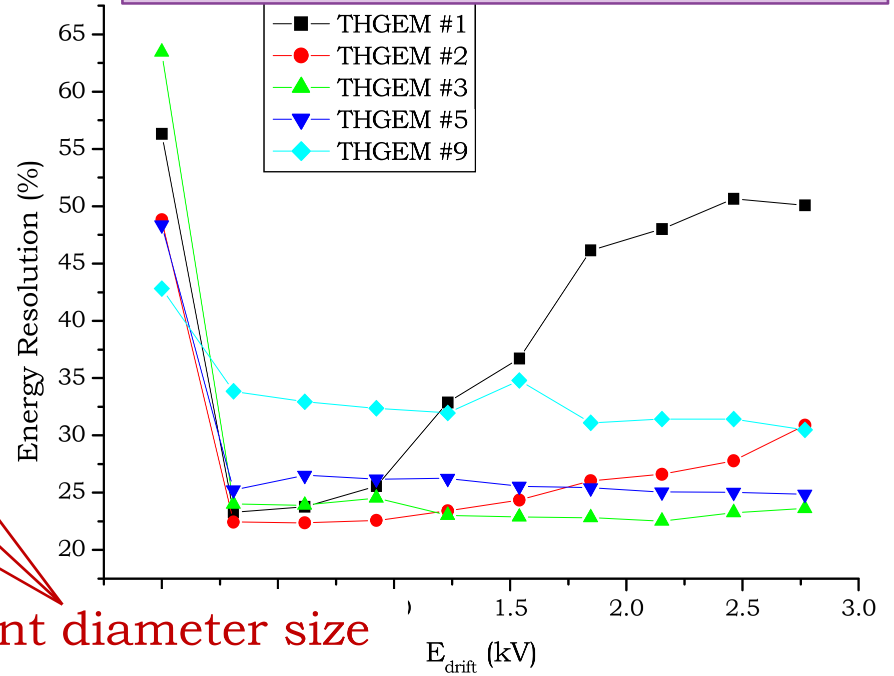
*CONCLUSIONS:* increasing the rim size the plateau region is displaced at high drift field or never reached for reasonable field values!!!

# DRIFT SCAN VS GEOMETRY (2/2)

Different pitch size




***NOTE :***
Poor energy resolution ↔ not complete charge collection



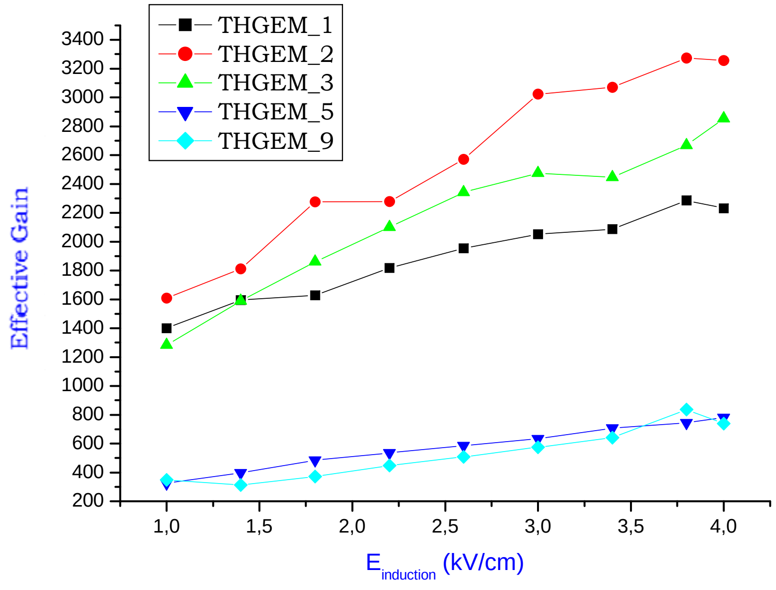

| Name | Diam (mm) | Pitch (mm) | Rim (µm) | Thick (mm) |
|---|---|---|---|---|
| THGEM_1 | 0.3 | 0.7 | 0 | 0.6 |
| THGEM_2 | 0.3 | 0.6 | 0 | 0.6 |
| THGEM_3 | 0.3 | 0.5 | 0 | 0.6 |
| THGEM_5 | 0.4 | 0.7 | 0 | 0.6 |
| THGEM_9 | 0.5 | 0.7 | 0 | 0.6 |

Different diameter size

Optimized Induction field, $\Delta V$=1.77 kV applied to all THGEMs, Rate ~ 1.6 kHz/mm$^2$

# INDUCTION SCAN (1/2)

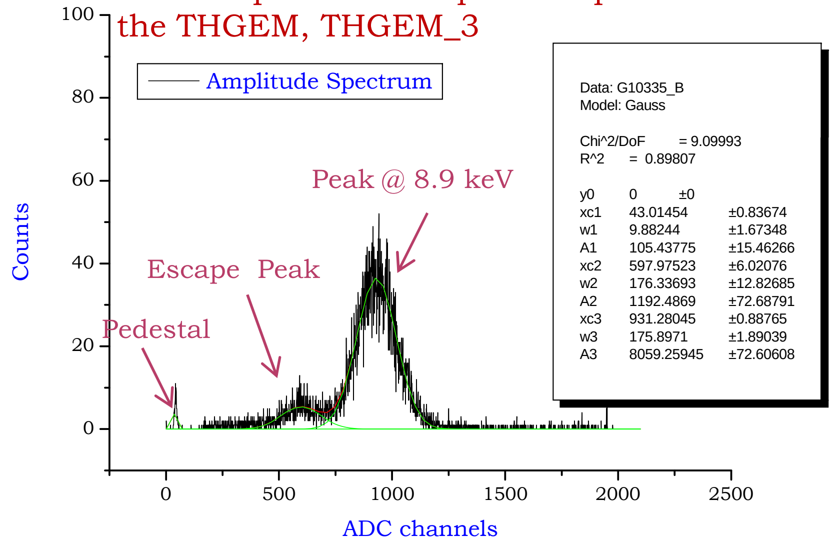
Optimized drift field and ΔV=1.77 kV




- Contrary to the DRIFT scan, in the INDUCTION scan, the energy resolution is pretty constant.
- The values are included in a range between 22   30 %

| Name | Diam (mm) | Pitch (mm) | Rim (μm) | Thick (mm) |
|---|---|---|---|---|
| THGEM_1 | 0.3 | 0.7 | 0 | 0.6 |
| THGEM_2 | 0.3 | 0.6 | 0 | 0.6 |
| THGEM_3 | 0.3 | 0.5 | 0 | 0.6 |
| THGEM_5 | 0.4 | 0.7 | 0 | 0.6 |
| THGEM_9 | 0.5 | 0.7 | 0 | 0.6 |

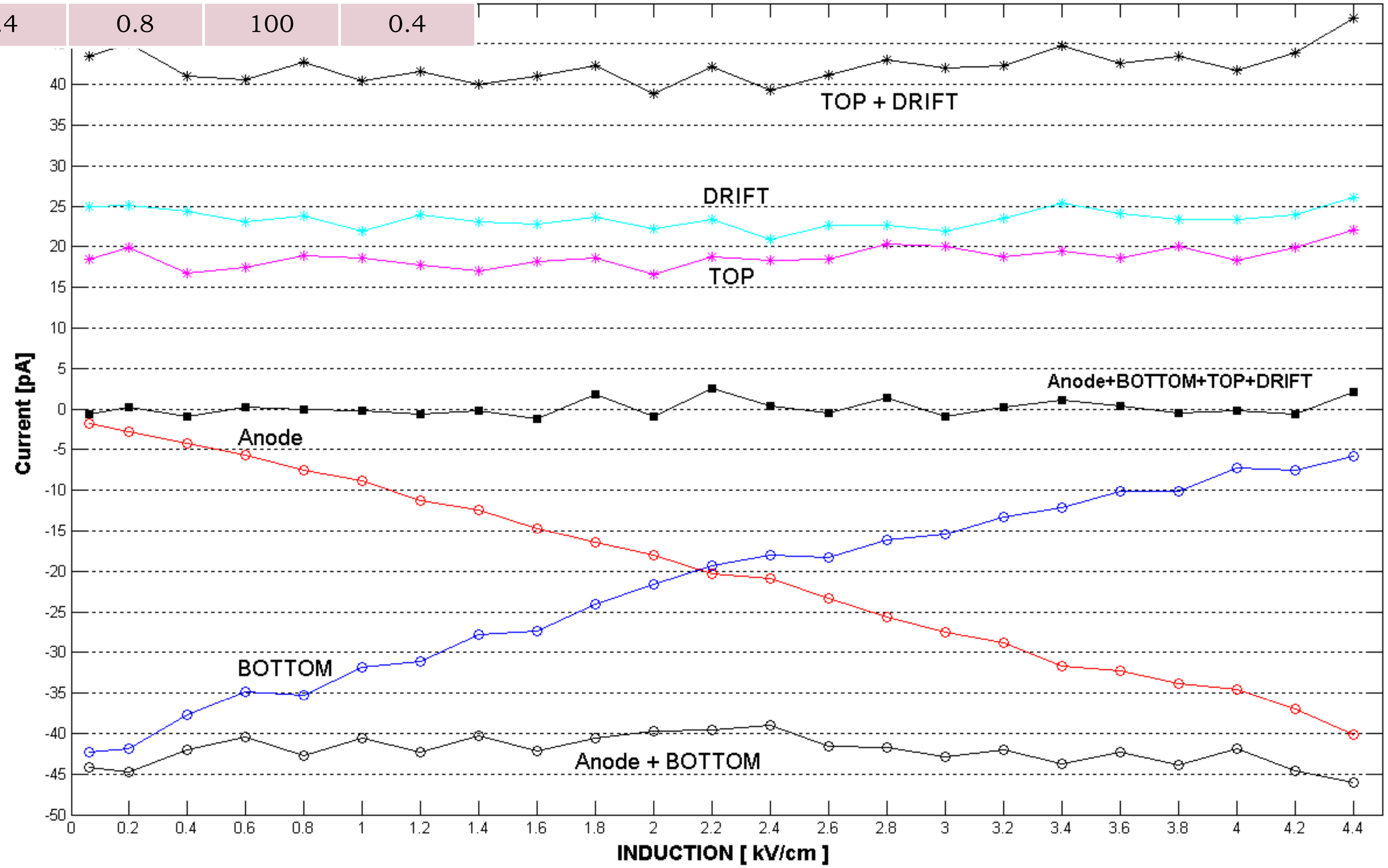
An example of the amplitude spectrum for the THGEM, THGEM_3



# INDUCTION SCAN (2/2)

| Name | Diam (mm) | Pitch (mm) | Rim (µm) | Thick (mm) |
|---|---|---|---|---|
| C4 | 0.4 | 0.8 | 100 | 0.4 |

delta V = 1820V / DRIFT= 3 kV/cm

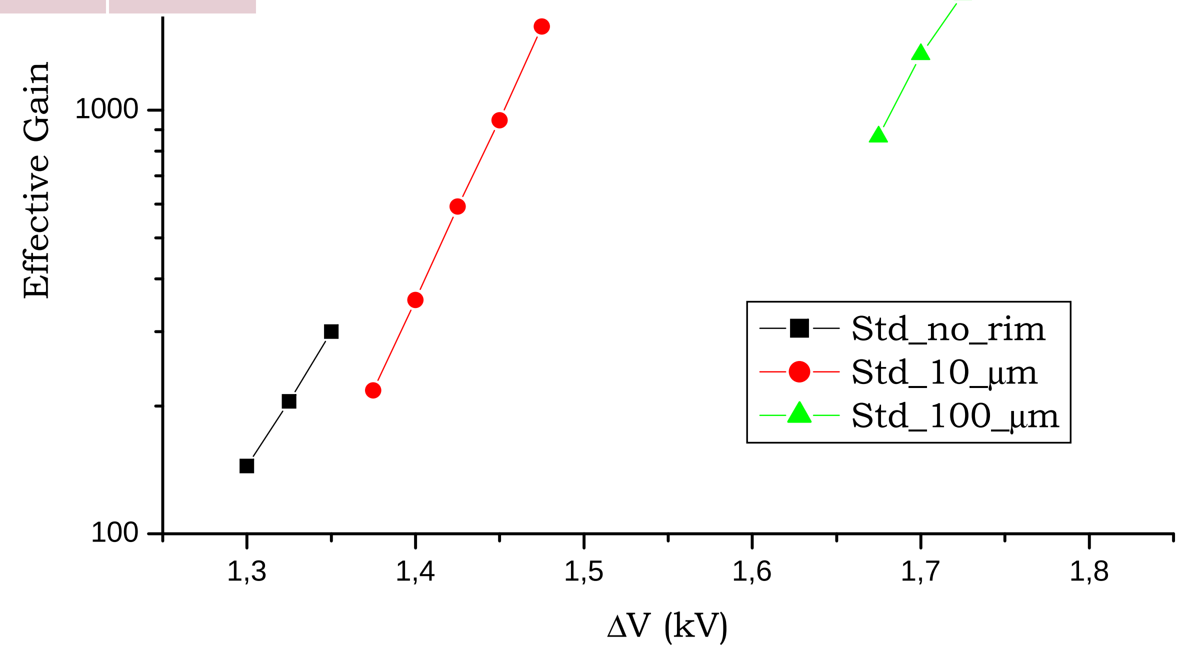



$^{55}Fe$ source; uniform irradiation

# GAIN OVERVIEW VS RIM (1/2)

| Name | Diam (mm) | Pitch (mm) | Rim (µm) | Thick (mm) |
|---|---|---|---|---|
| Std_no_rim | 0.3 | 0.7 | 0 | 0.4 |
| Std_10_µm | 0.3 | 0.7 | 10 | 0.4 |
| Std_100_µm | 0.3 | 0.7 | 100 | 0.4 |

important gain dependence vs the rim size




Optimized Induction field and rate ~ 1÷2 kHz/mm²

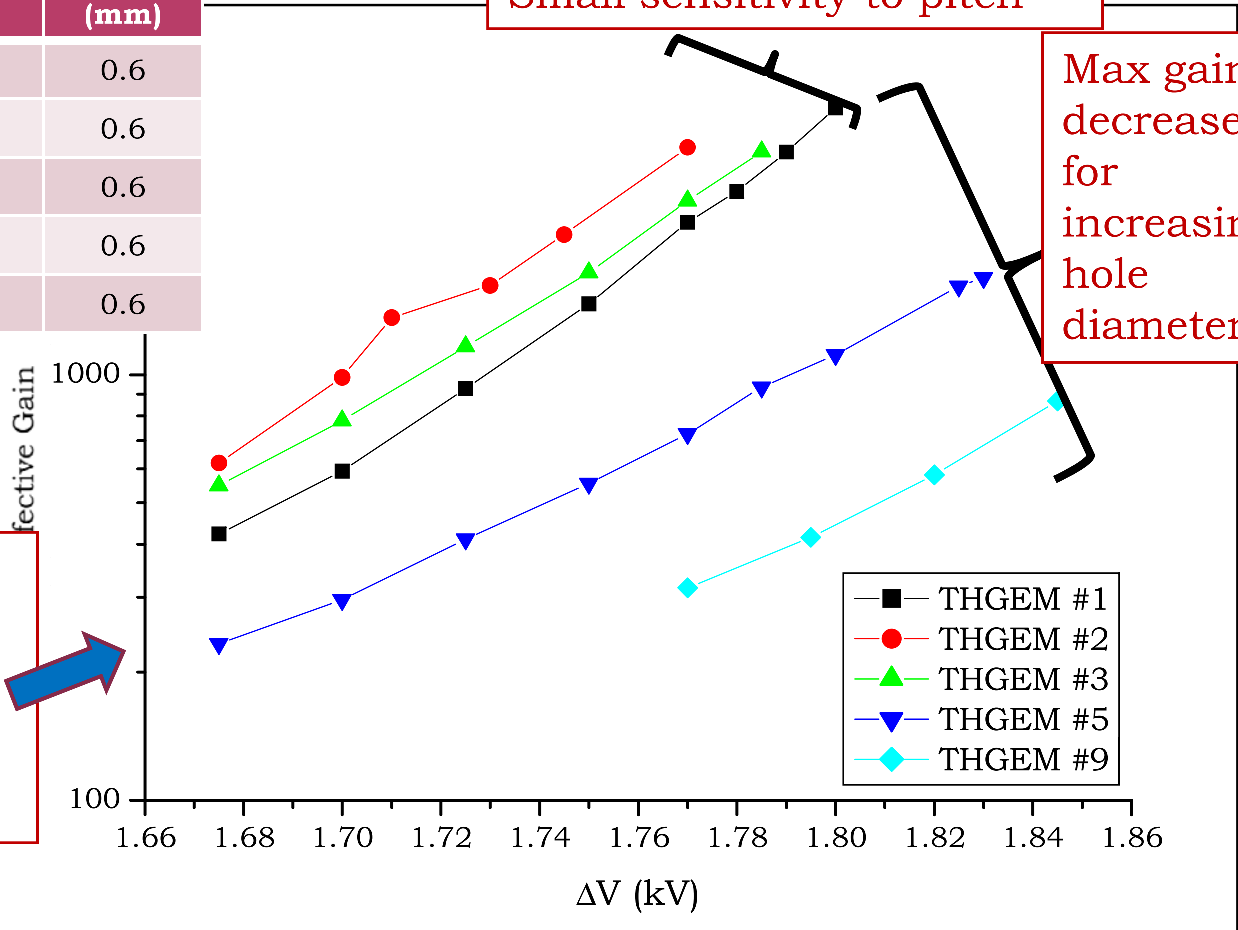
# GAIN OVERVIEW VS GEOMETRY (2/2)

| Name | Diam (mm) | Pitch (mm) | Rim (μm) | Thick (mm) |
|---|---|---|---|---|
| THGEM_1 | 0.3 | 0.7 | 0 | 0.6 |
| THGEM_2 | 0.3 | 0.6 | 0 | 0.6 |
| THGEM_3 | 0.3 | 0.5 | 0 | 0.6 |
| THGEM_5 | 0.4 | 0.7 | 0 | 0.6 |
| THGEM_9 | 0.5 | 0.7 | 0 | 0.6 |

Small sensitivity to pitch

Max gain decrease for increasing hole diameter

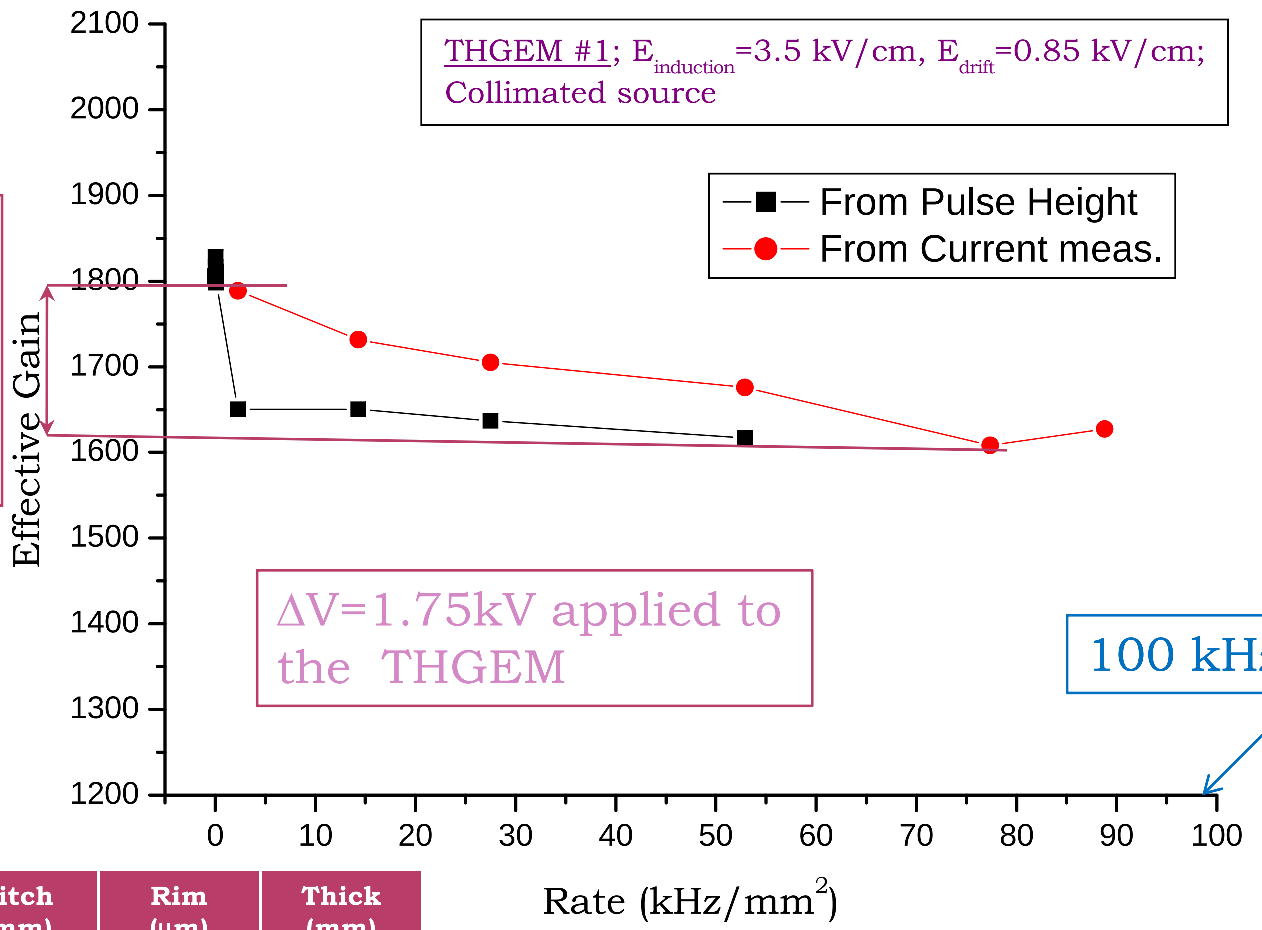
Look at the gain dependence on the diameter and pitch variation fixing one at time.




Optimized Induction and Drift fields and rate ~ 1÷2 kHz/mm$^2$

# RATE CAPABILITY

Gain variation <10 % over ~3 orders of magnitude in rate variation




100 kHz / mm$^2$

| Name | Diam (mm) | Pitch (mm) | Rim (µm) | Thick (mm) |
|---|---|---|---|---|
| THGEM_1 | 0.3 | 0.7 | 0 | 0.6 |

# CONCLUSIONS:

- The rim implies huge gain instabilities vs time, radiation history;
- With large rim poor energy resolution and doubts about complete charge collection;
- The plateau region for drift field seems to be reached for high voltage applied to the drift → no possible application in an experiment with big rim.
- Hints that the diameter is a key parameter for optimization of the THGEM performance for fixed thickness.
- The rate capability is not a limiting factor for applications at high rates.