New tracker system for the MAGNEX focal plane detector at LNS - INFN within the NUMEN project

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INFN-LNS & University of Catania

For the NUMEN Collaboration

https://web.infn.it/NUMEN/index.php/it/

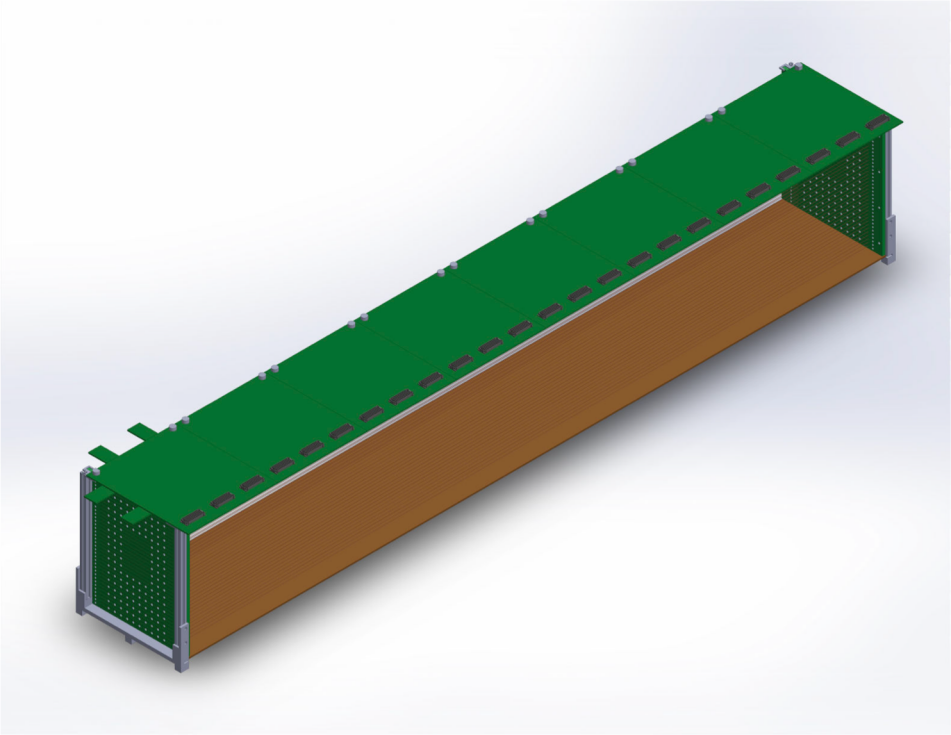
*NU*clear
*M*atrix
*E*lements for
*N*eutrinoless Double Beta Decay

Cross section measurements
of heavy-ion induced
Double Charge Exchange (DCE) reactions

Tiny value of cross sections demand
higher beam intensities

UPGRADE

More details in talks by
Dr. Calabrese
Dr. Brischetto



New tracker system

Gas Tracker for NUMEN

Limits of Wire-Based Detector:

Secondary effects ➔ Gain limits

Space charge ➔ Counting-rate limits (10^4 Hz/mm^2)

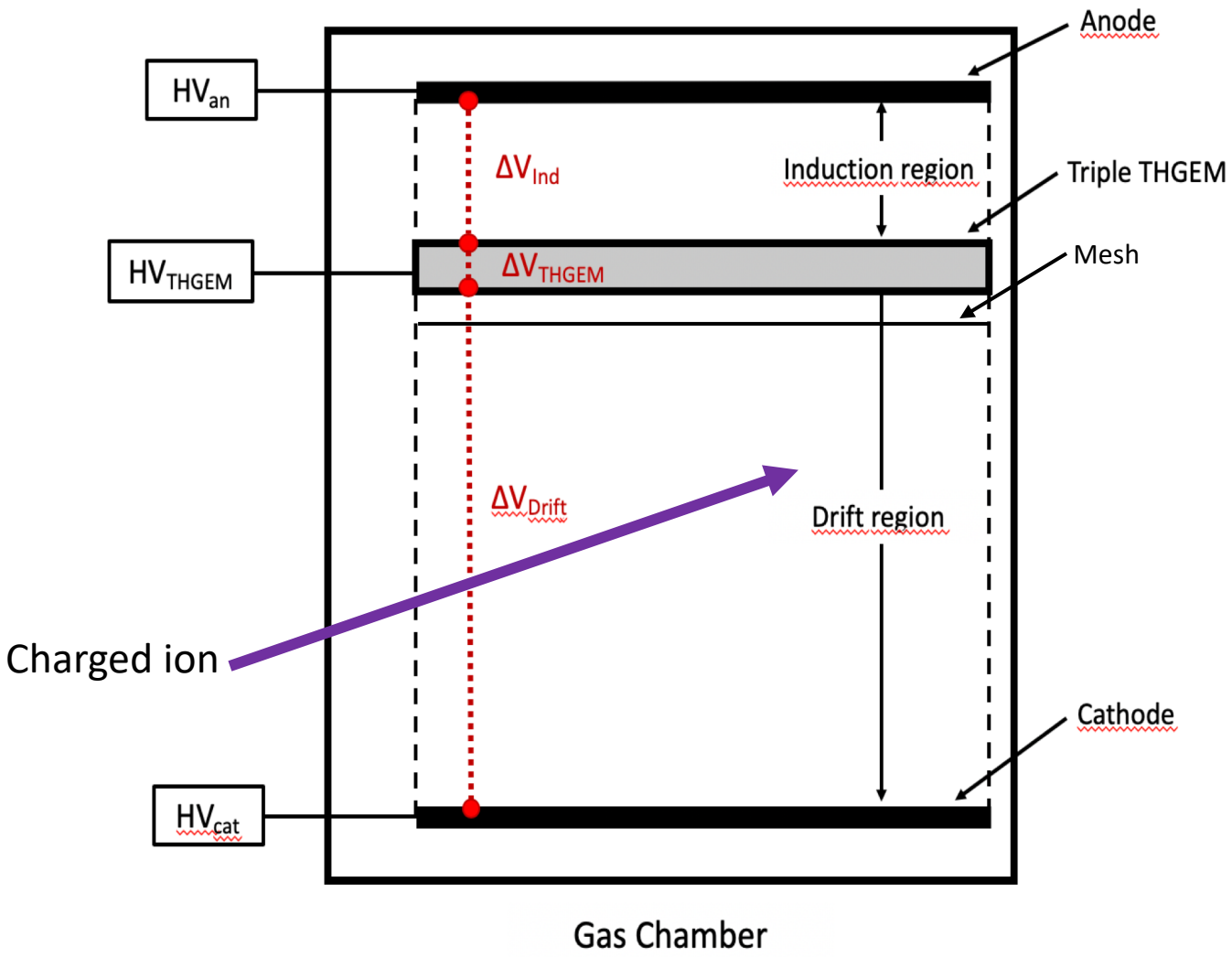
Aging ➔ Damage after long-term operation

Requirements for new Tracker system:

1) Ability to cope the **rates** of particles as high as **MHz**

2) **High resolution measurement** at the focal plane of the phase space parameters
   - horizontal position X_{foc} resolution **0.6 mm** (FWHM)
   - horizontal angle ϑ_{foc} resolution **0.5°** (FWHM)
   - vertical position Y_{foc} resolution **0.7 mm** (FWHM)
   - vertical angle φ_{foc} resolution **0.7°** (FWHM)

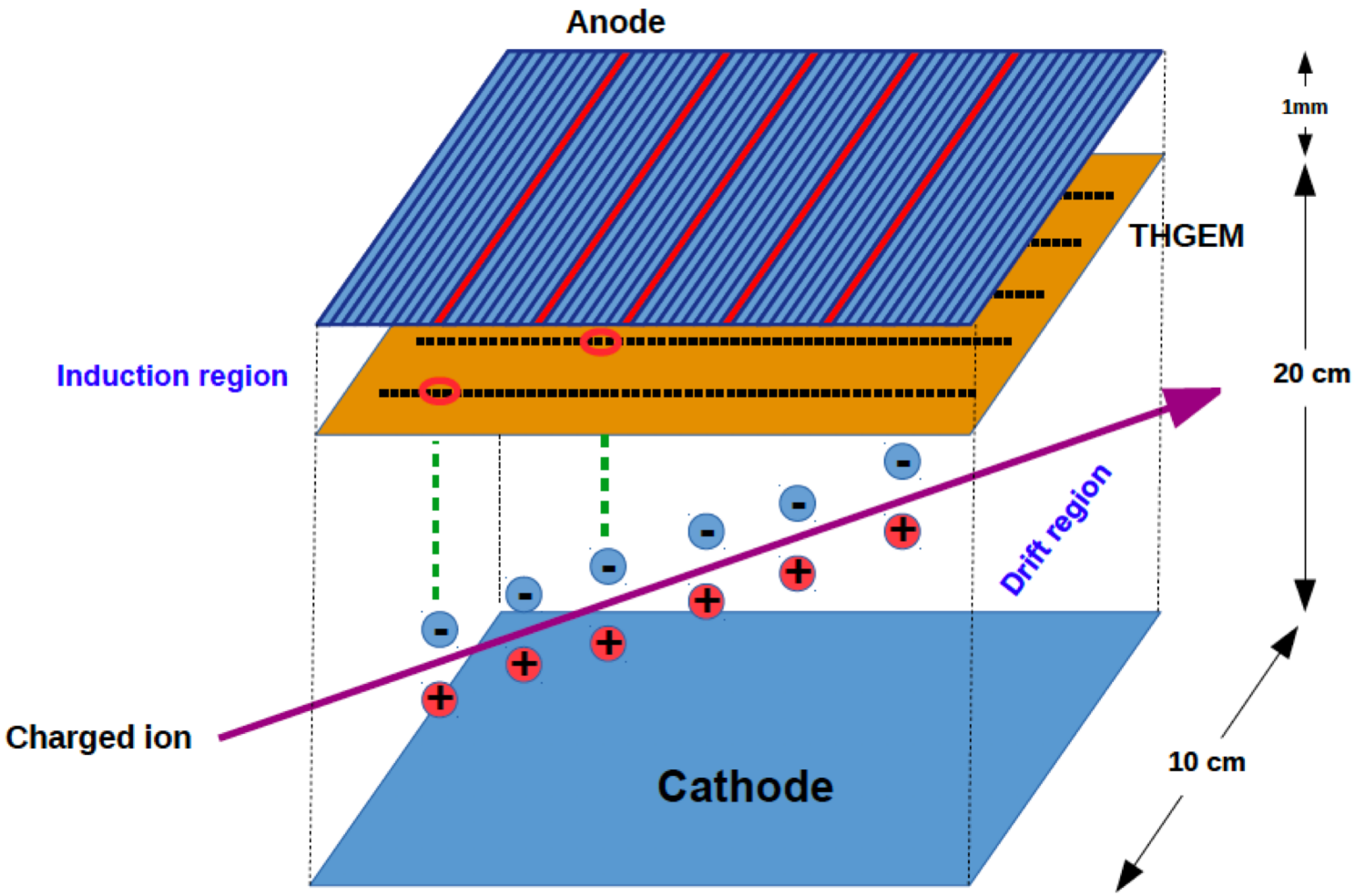
Gas Tracker for NUMEN

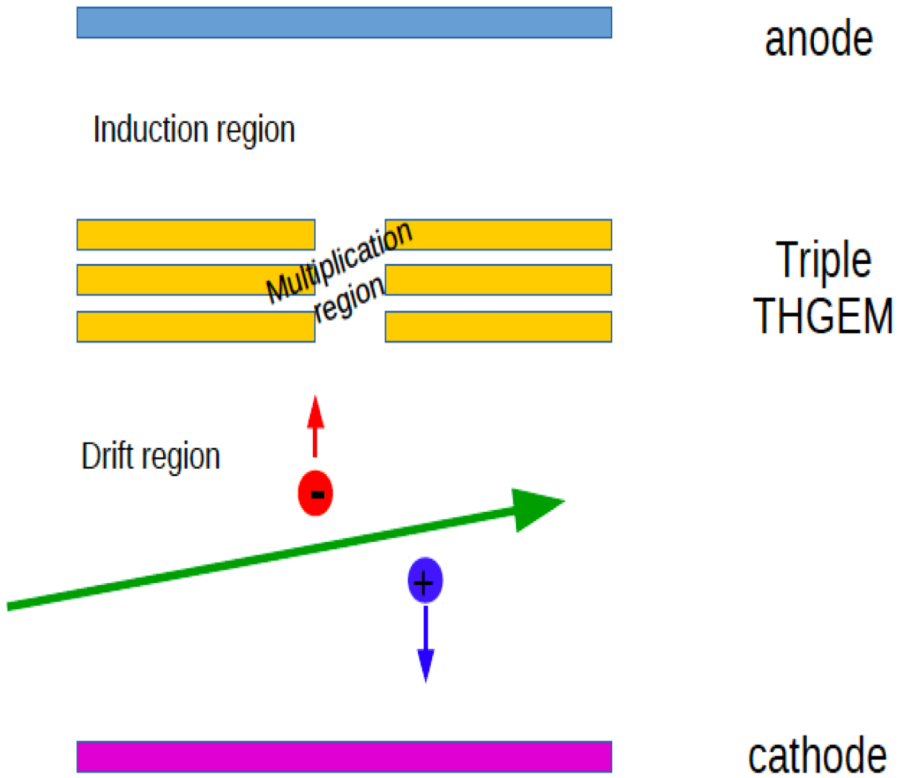


The new gas tracker (1122 x 185 x 108 mm^3 active volume) will consist of:

- a **gas drift region** delimited by a cathode and a Frish grid (or mesh plane) where the drift time and consequently the vertical position and angle will be measured
- an **electron multiplication region** (Multiple-Thick GEM)
- a **segmented read-out plate** where the horizontal position and angle will be measured

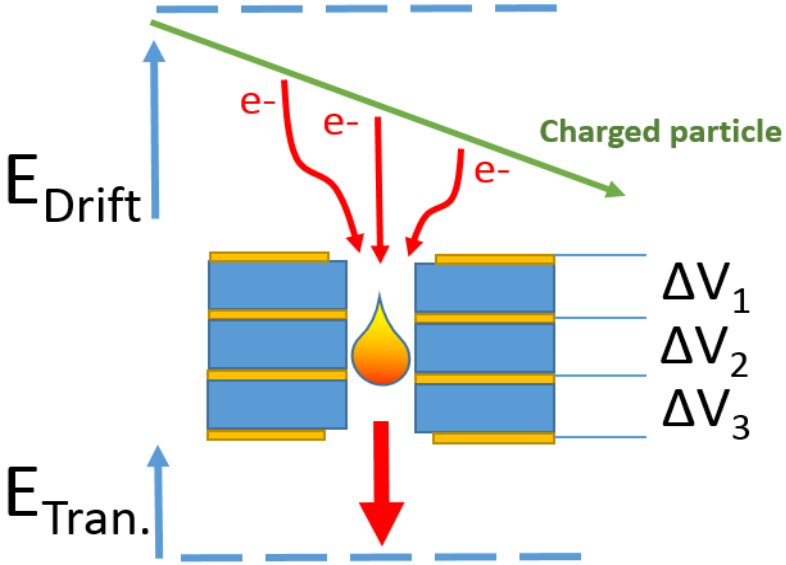
Working principles



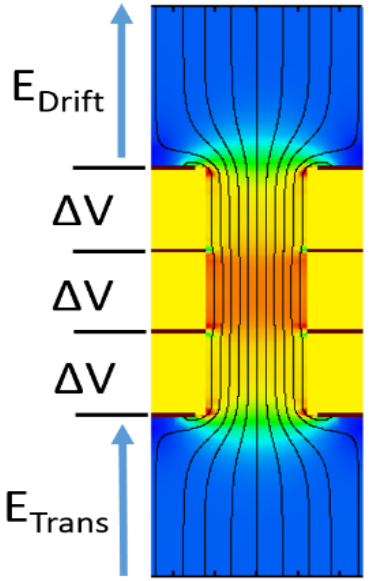


Multi-layer THGEM (M-THGEM)

Assembly of **Three THGEM** elements stacked together



3-layer THGEM

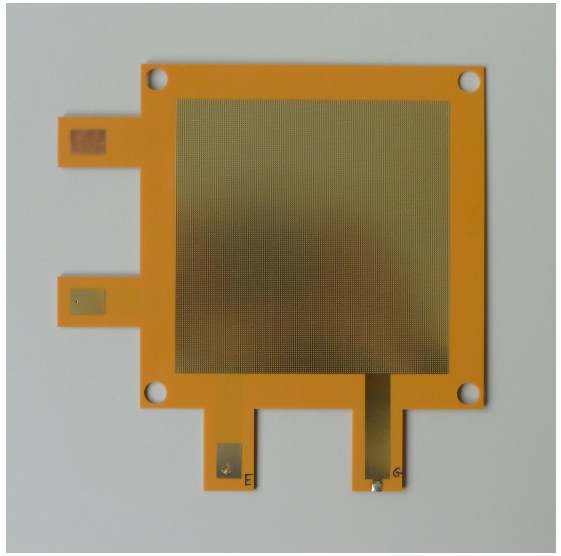


Cortesi M., et al., *Review of Scientific Instruments* 88.1 (2017): 013303.

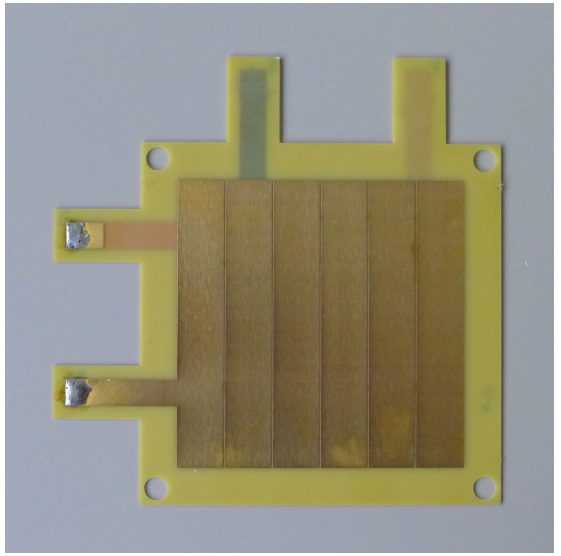
MHz/mm² rate capability

No loss of charge ➔ high gain @ low voltage
Robust avalanche confinement ➔ lower secondary effects
Long avalanche region ➔ high gain @ low pressure
Field geometry stabilized by inner electrodes➔ reduced charging up

THGEM characterization

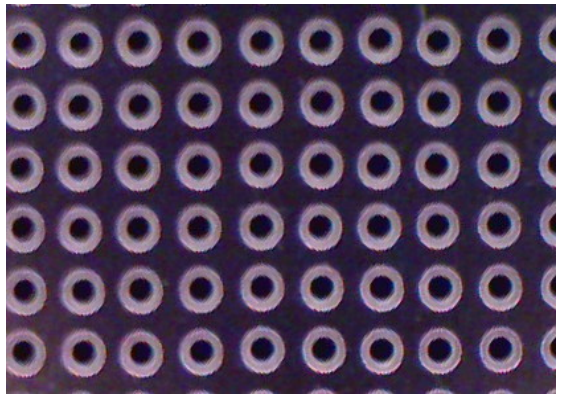


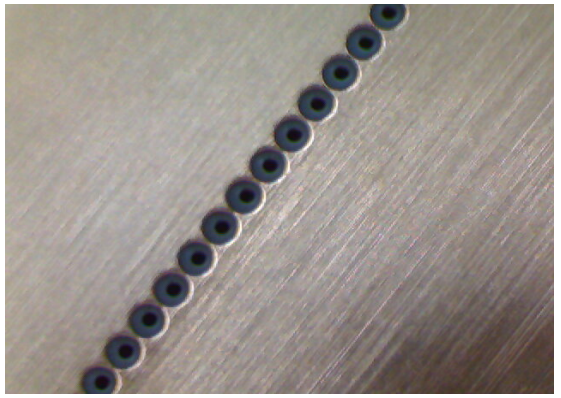
Full THGEM F10



ROW THGEM R1

	F10	R1
Substrate material*	Ceramic SD103K	PCB
Finish board thickness* [mm]	1.4 ± 0.1	1.28
Dimension [mm^2]	107×107	107×107
Rim size* [mm]	0.1	0.2
Rows	143×143	5
Holes	20449	143
Hole diameter* [mm]	0.30 ± 0.05	0.280
Hole spacing	0.75	0.75





Controlled parameters:

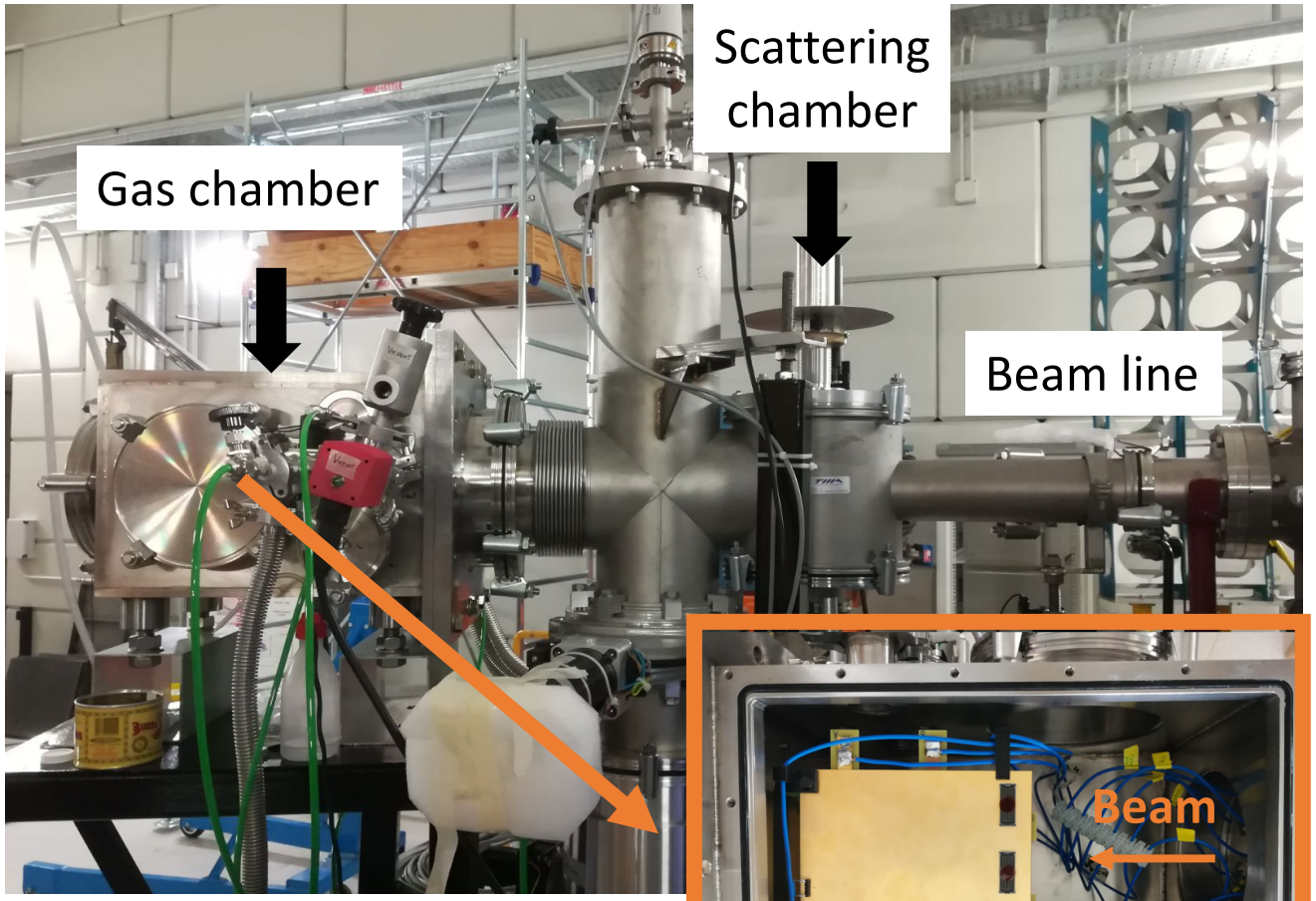
- Pressure of Isobutane gas (C_4H_{10})
- Voltage of THGEM
- Voltage of induction region
- Voltage of drift region

Measured parameters:

- Max working voltage
- Gain
- *Ion Backflow* (IBF)

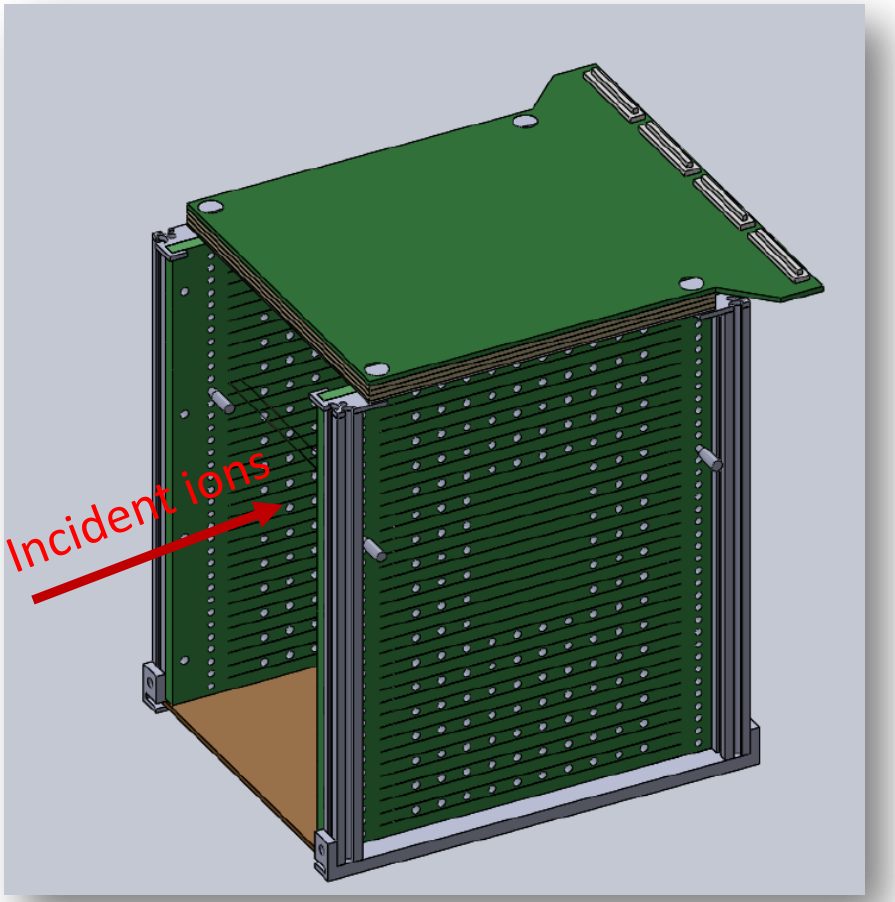
Tracker prototype

TeBe beam line @ LNS-INFN *Lateral view*

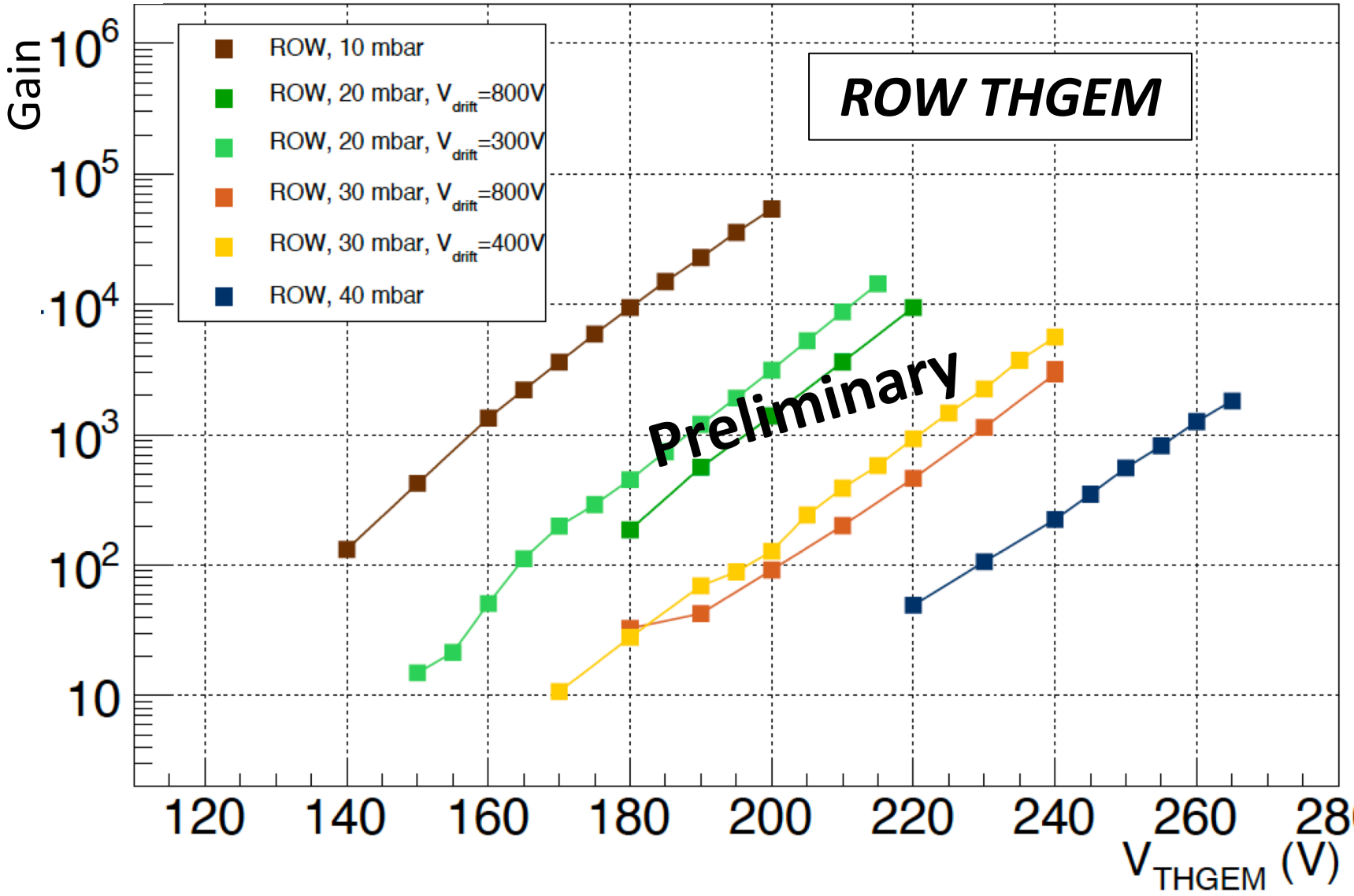


Top view

Active volume 107x107x185 mm^3



Measured parameters: *Gain*



Controlled parameters:

- Different pressures of Isobutane
- Different V_{DRIFT}

Results:

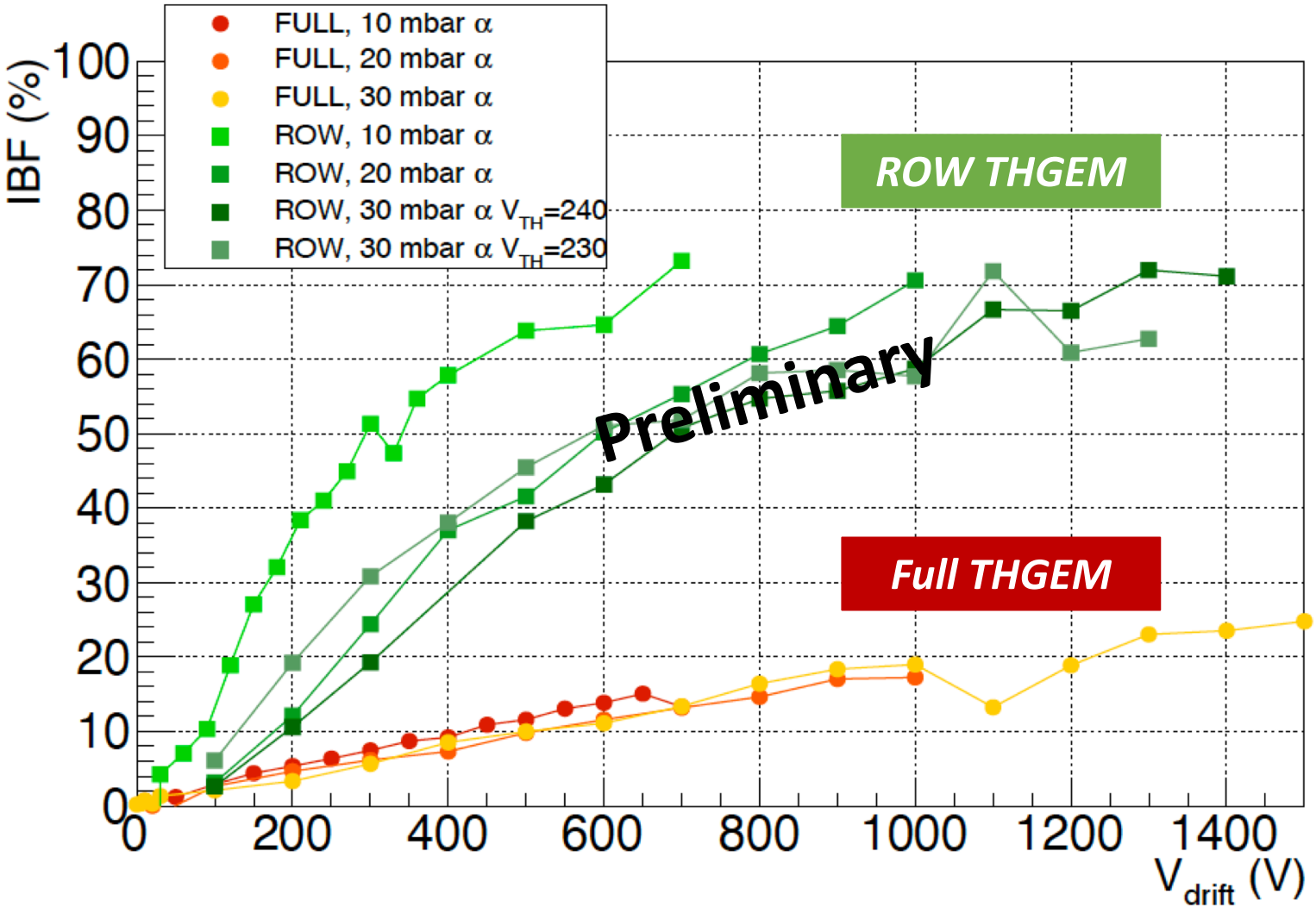
*Maximum reached Gain is **inversely proportional** to the pressure*

*Maximum reached Gain about **10^5***

Similar results with FULL THGEM

$$\text{Gain} = \frac{e^- at\ anode}{primary\ e^-}$$

Measured parameters: *Ion Backflow* (IBF)



Controlled parameters:

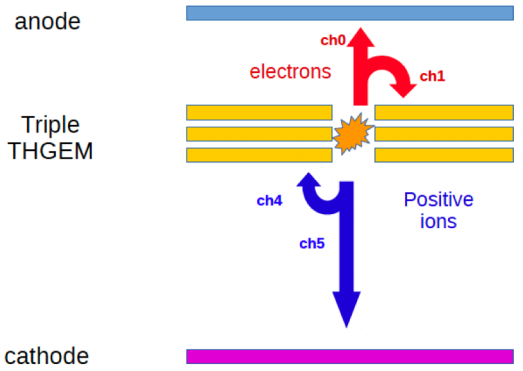
- Different pressures of Isobutane
- Different V_{THGEM}

Results:

*IBF is **higher** for ROW THGEM*

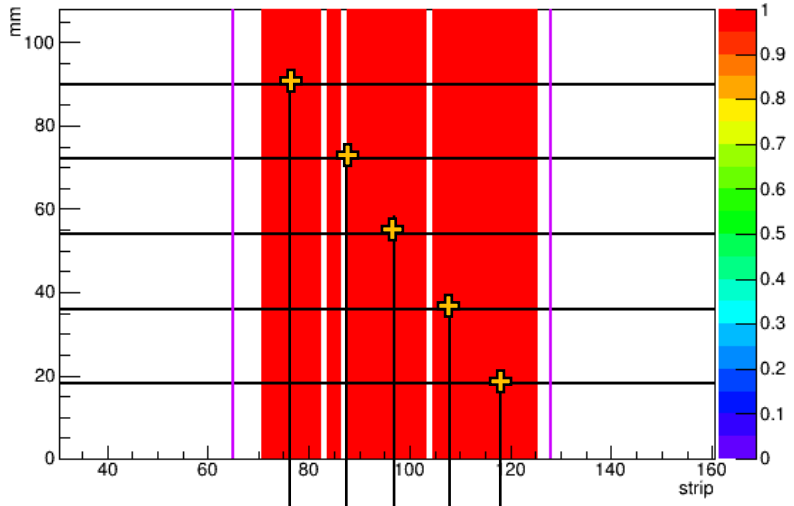
FULL THGEM

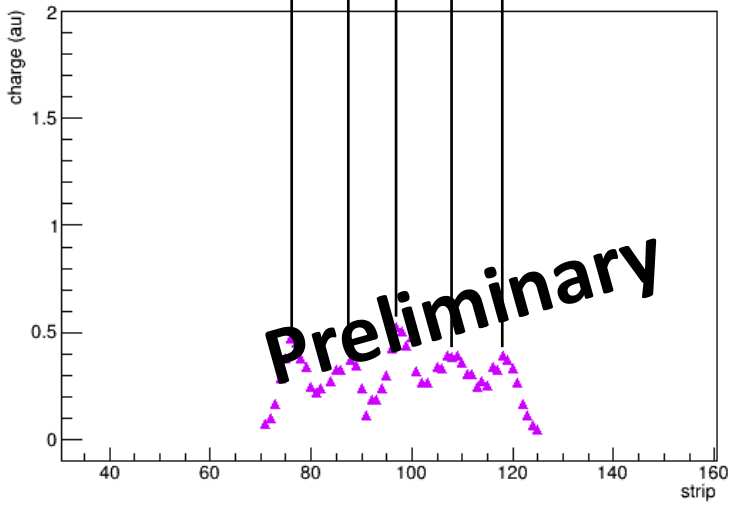
$$\text{IBF} = \frac{ions\ at\ cathode}{e^{-}\ at\ anode}$$



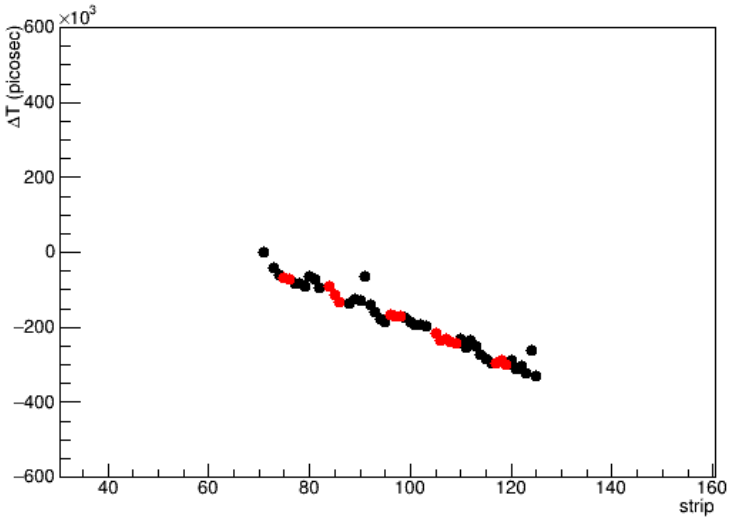
Example of an alpha track obtained with tracker prototype

Stripped anode hit map





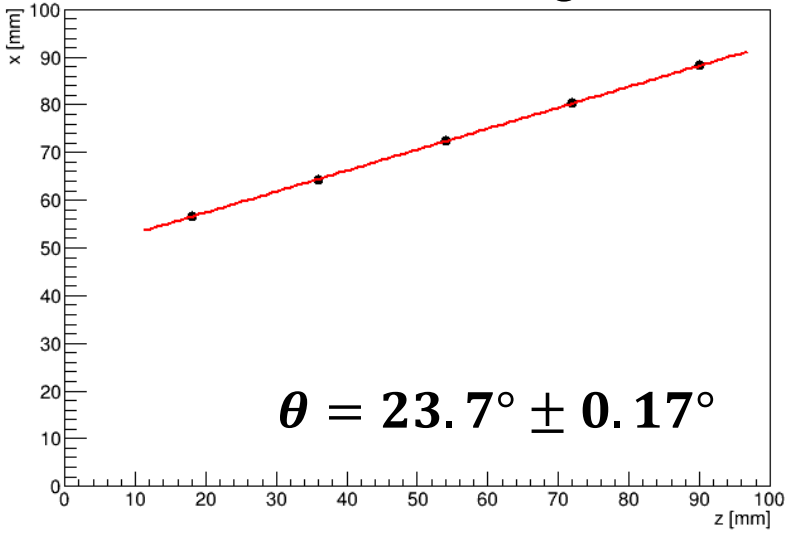
Charge vs strip

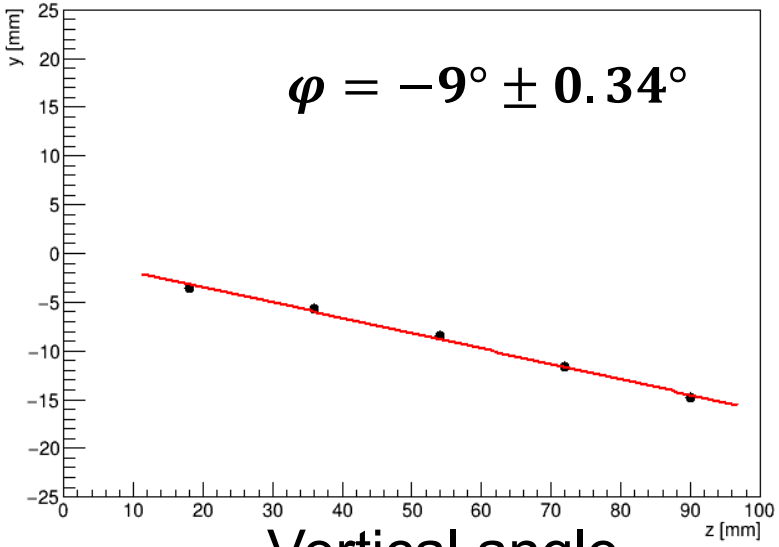


Time vs strip

*The **tests** performed with the reduced size tracker prototype, in terms of **resolution**, are **compliant** with the requests for NUMEN.*

Horizontal angle

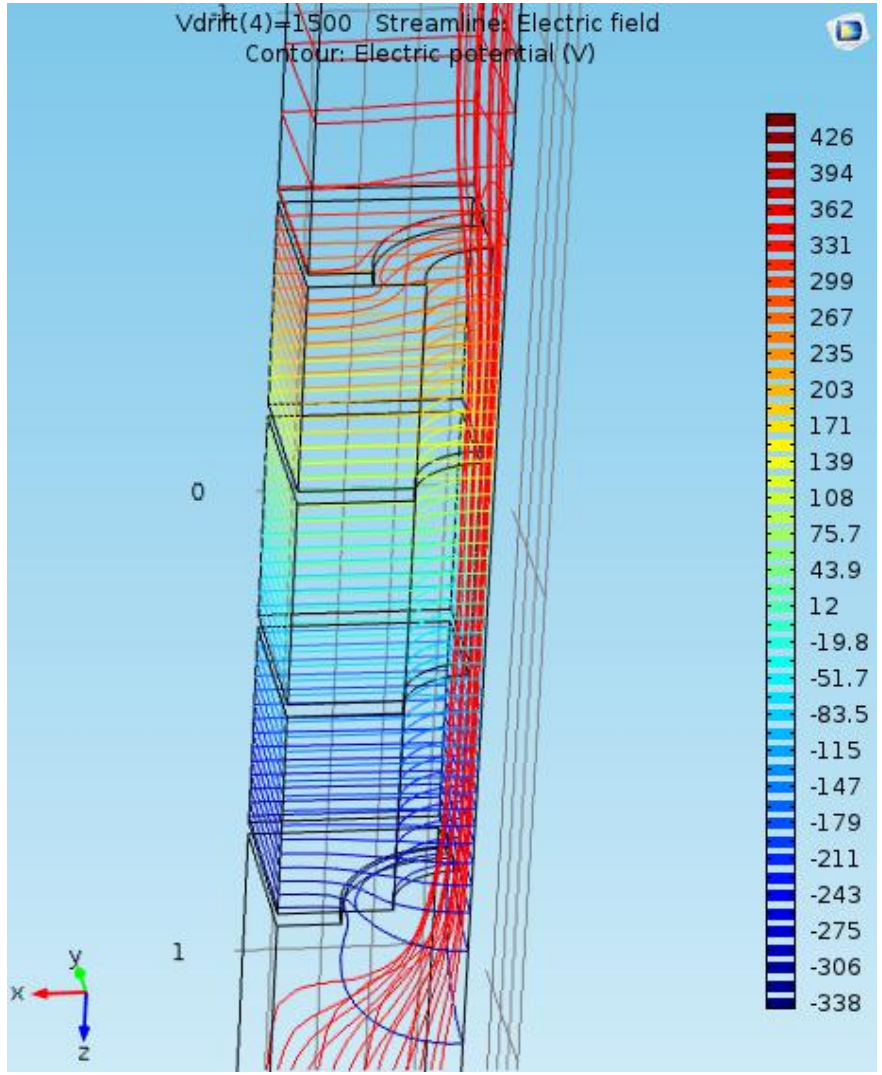




Vertical angle

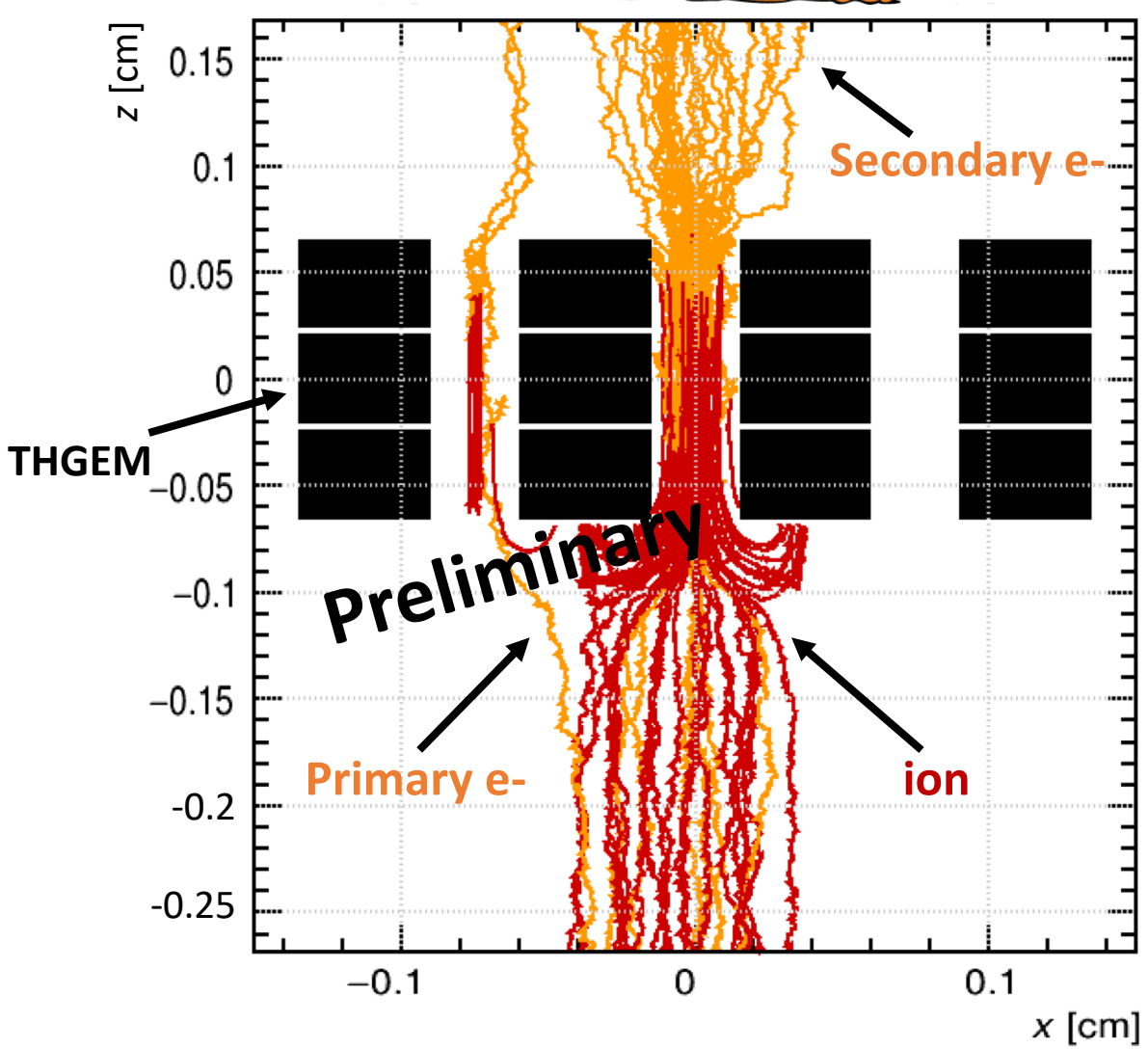
Simulations

COMSOL





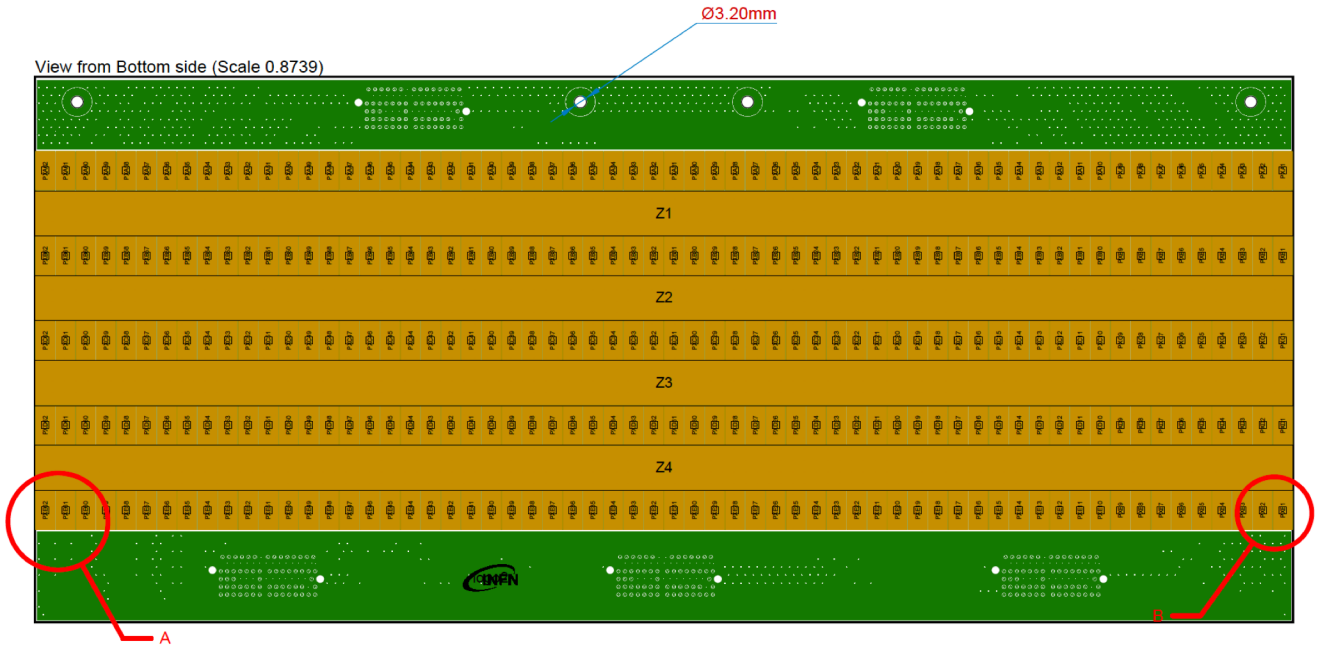
Garfield++

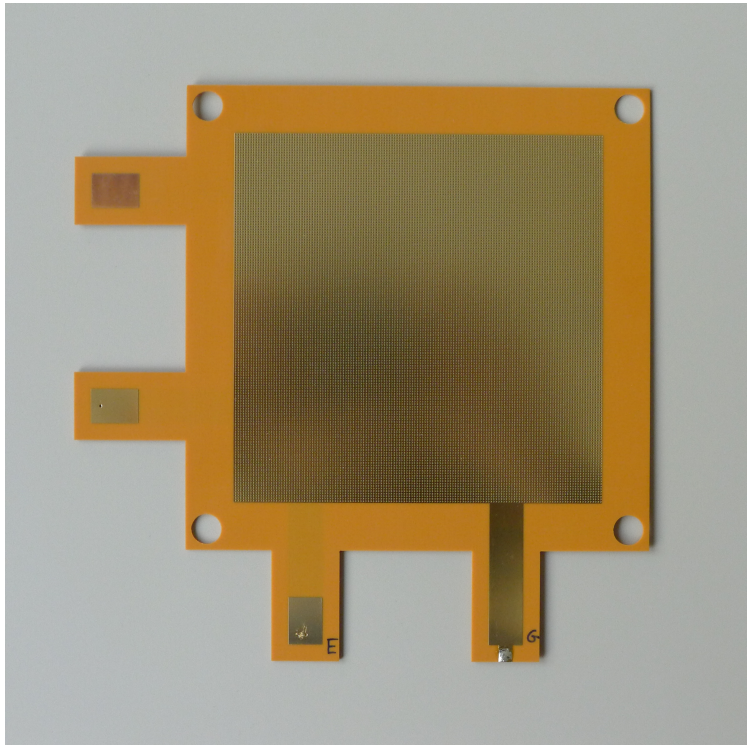


Prospects

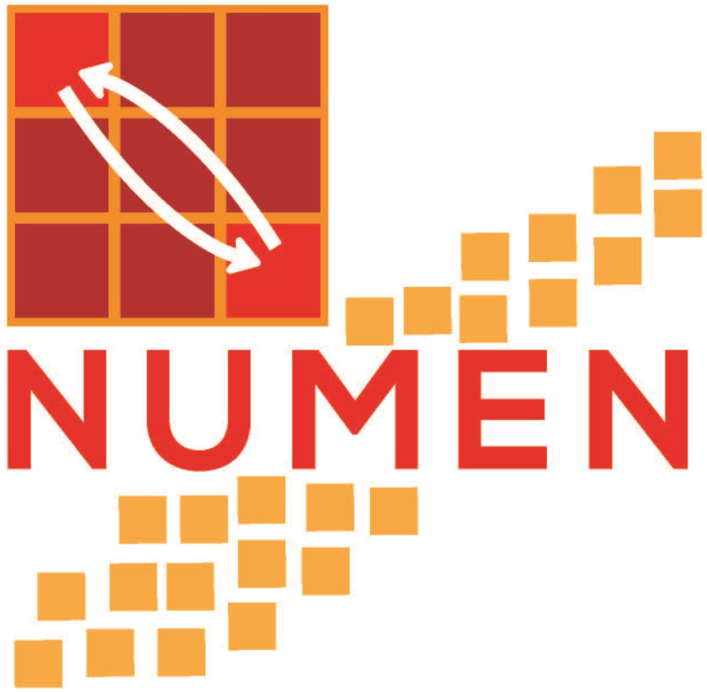
~~Anodic stripped plane~~ → Anodic pad plane

~~ROW THGEM~~ → Full THGEM



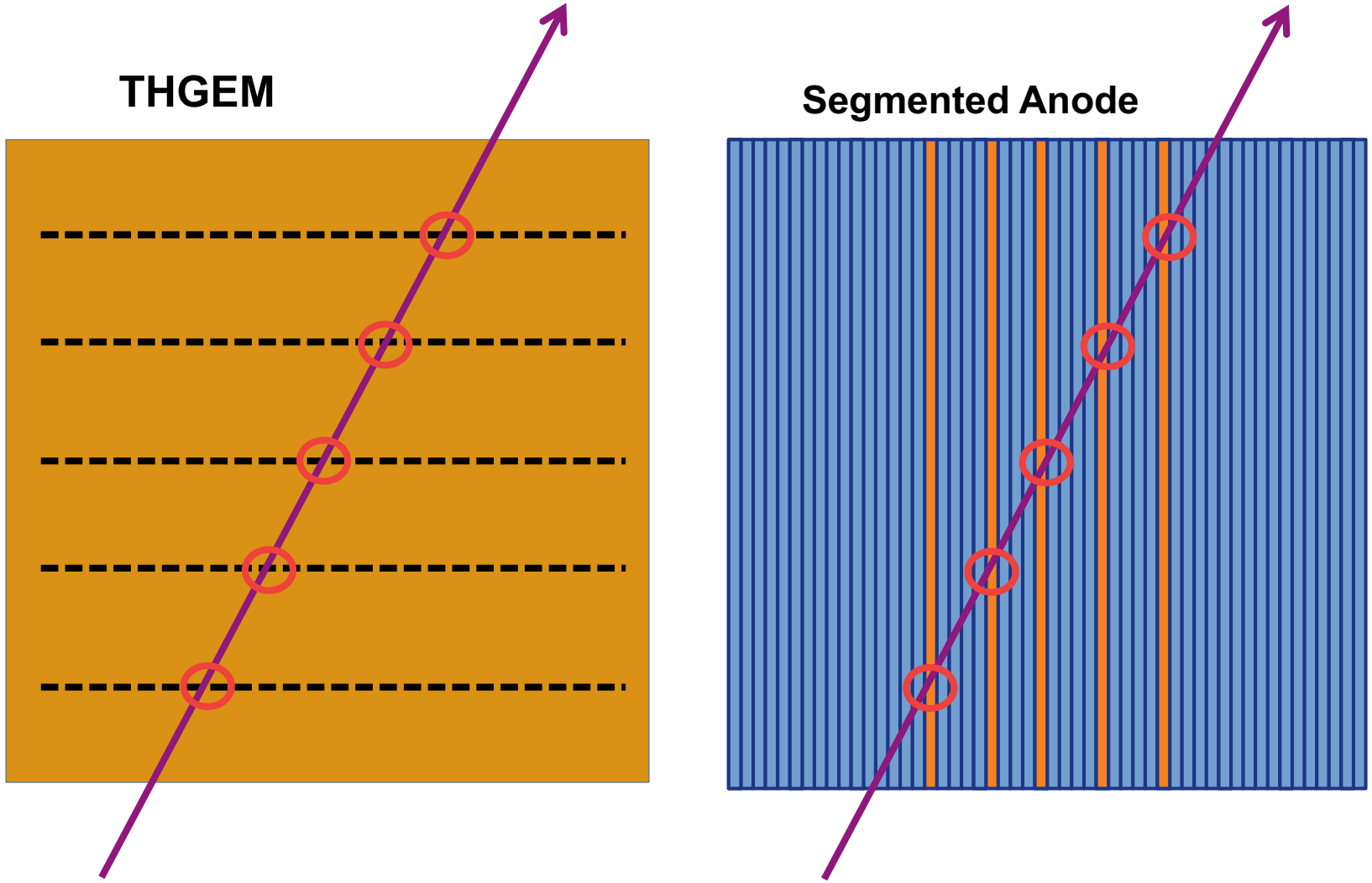


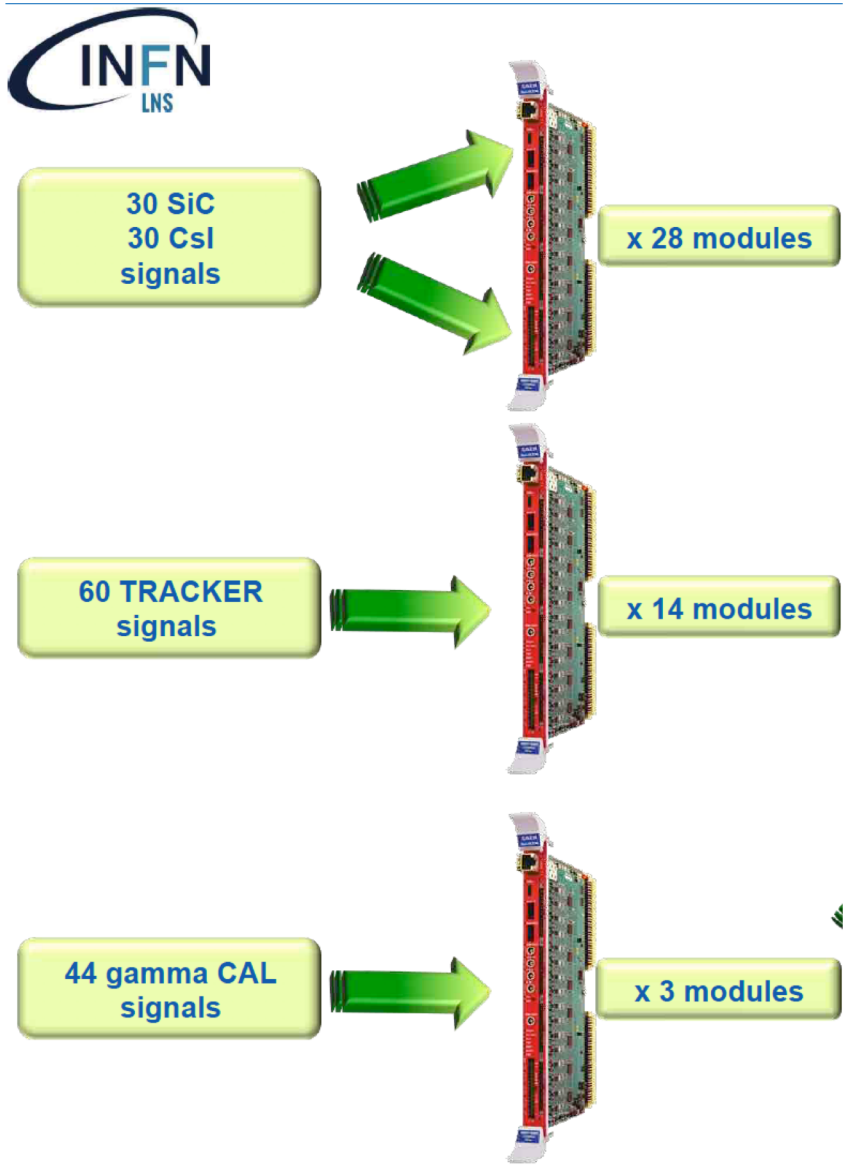
Work in progress…



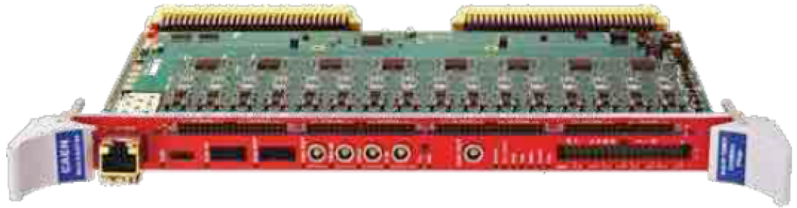
Thanks for your attention!

The working principle of the 5 rows configuration





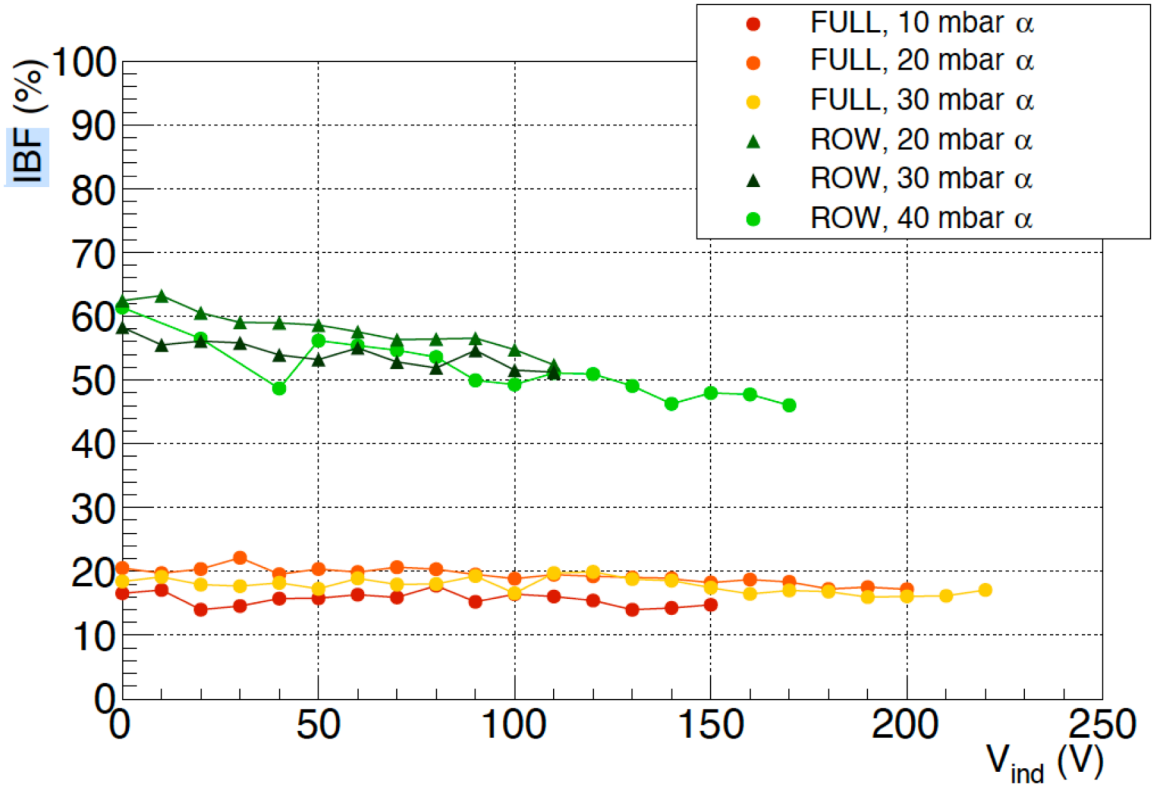
CAEN VX2740 digitizer module

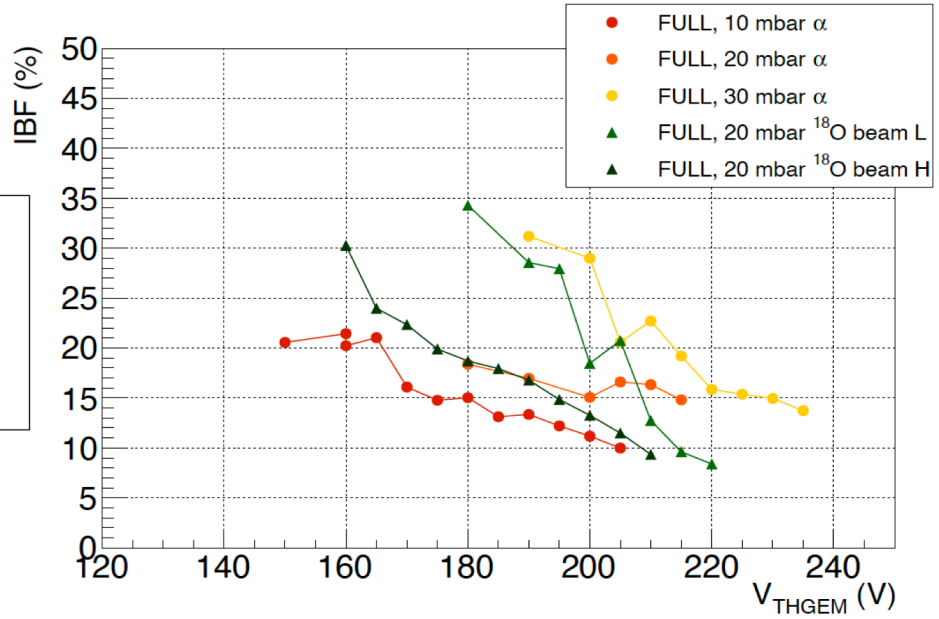


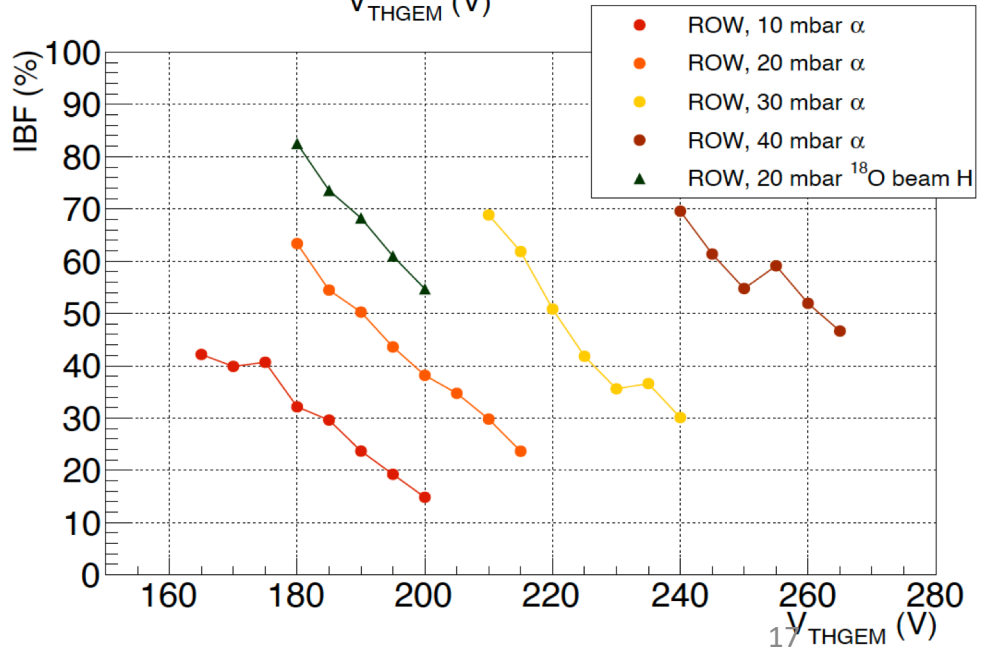
64 channels

- 125 MS/s sampling;
- uniform front-end and readout hardware architecture;
- reduction and simplification of the spares;
- programmable signal handling algorithm, tailorable to each detector type (FPGA);
- very good energy resolution, 16 bit conversion;
- very good timing capabilities, in 8 ps steps;
- pile-up detection and tagging;
- high data throughput;
- also chosen by INFN DARKSIDE experiment

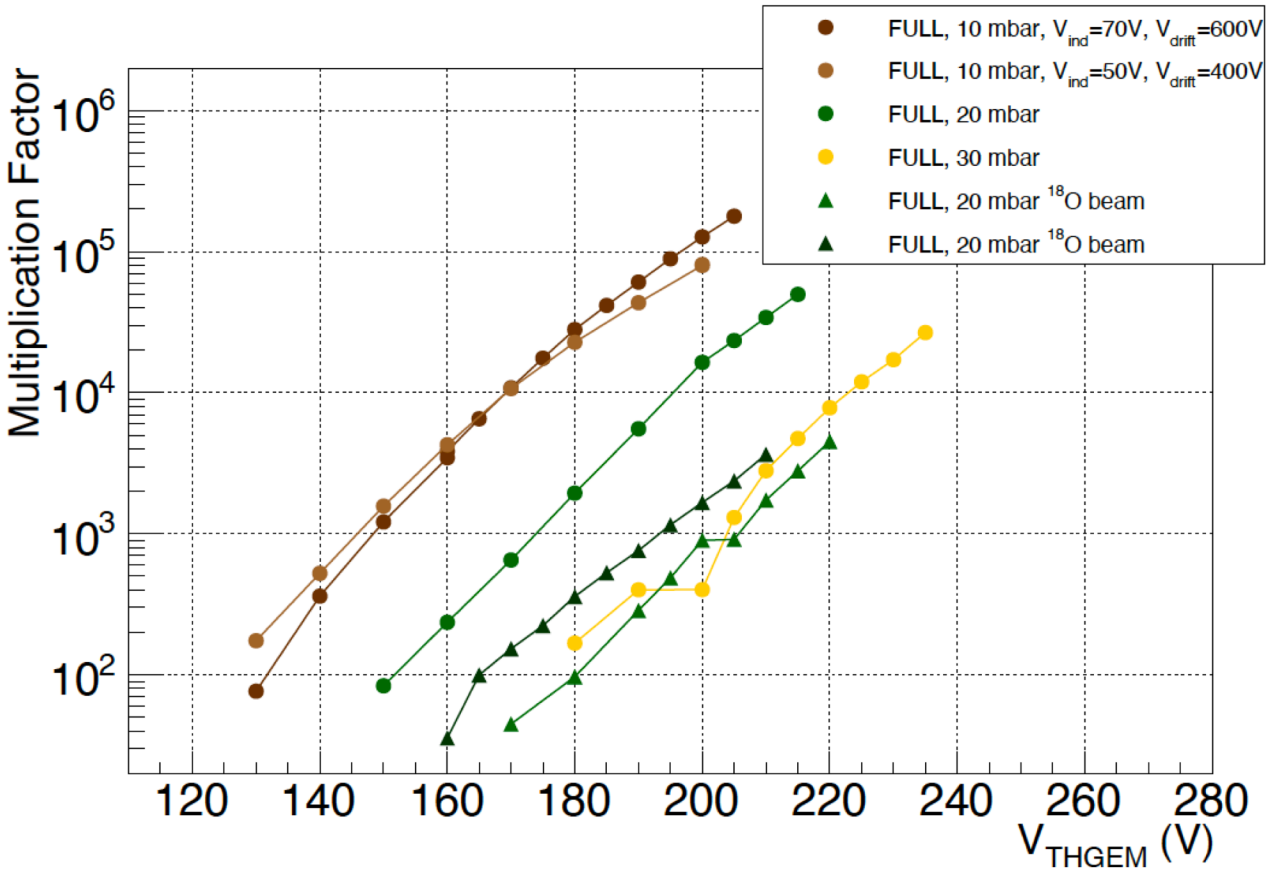
Measured parameters: *Ion Backflow* (IBF)



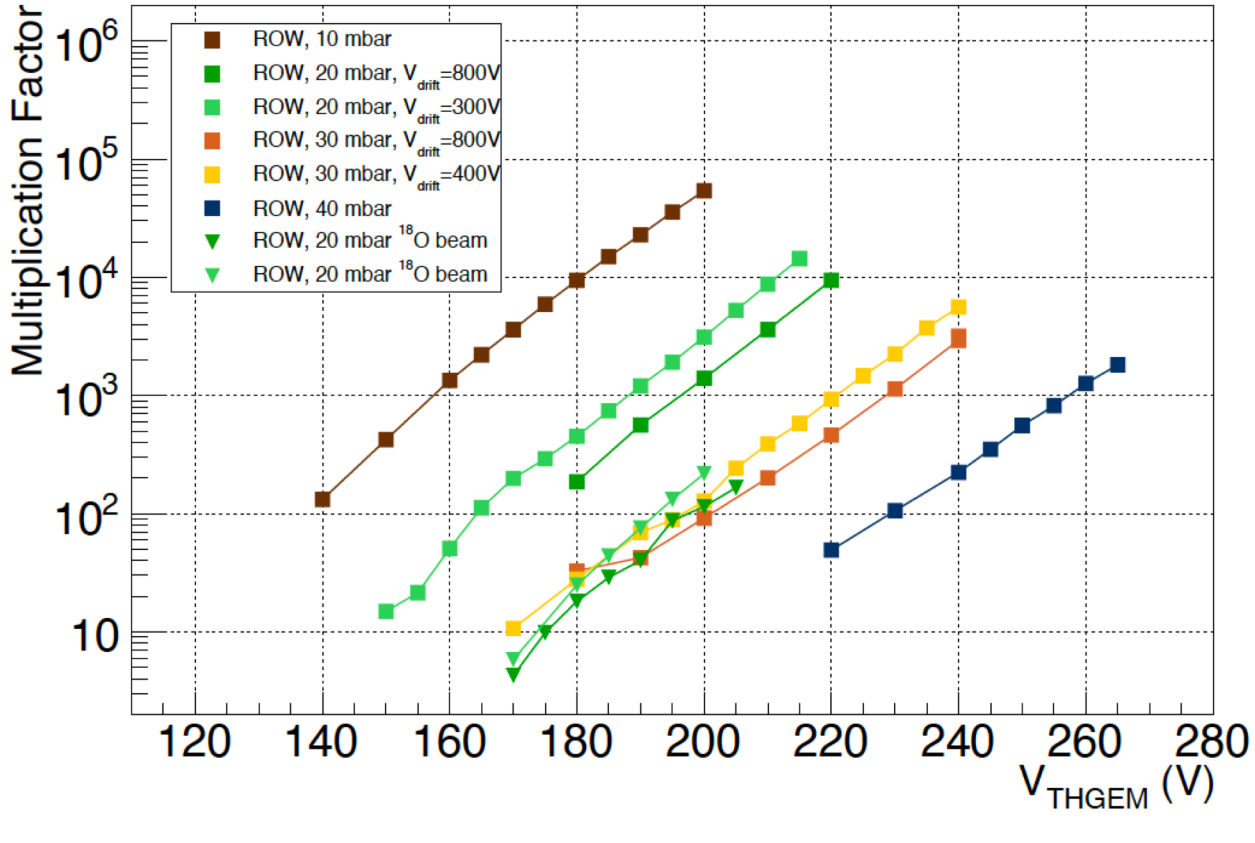




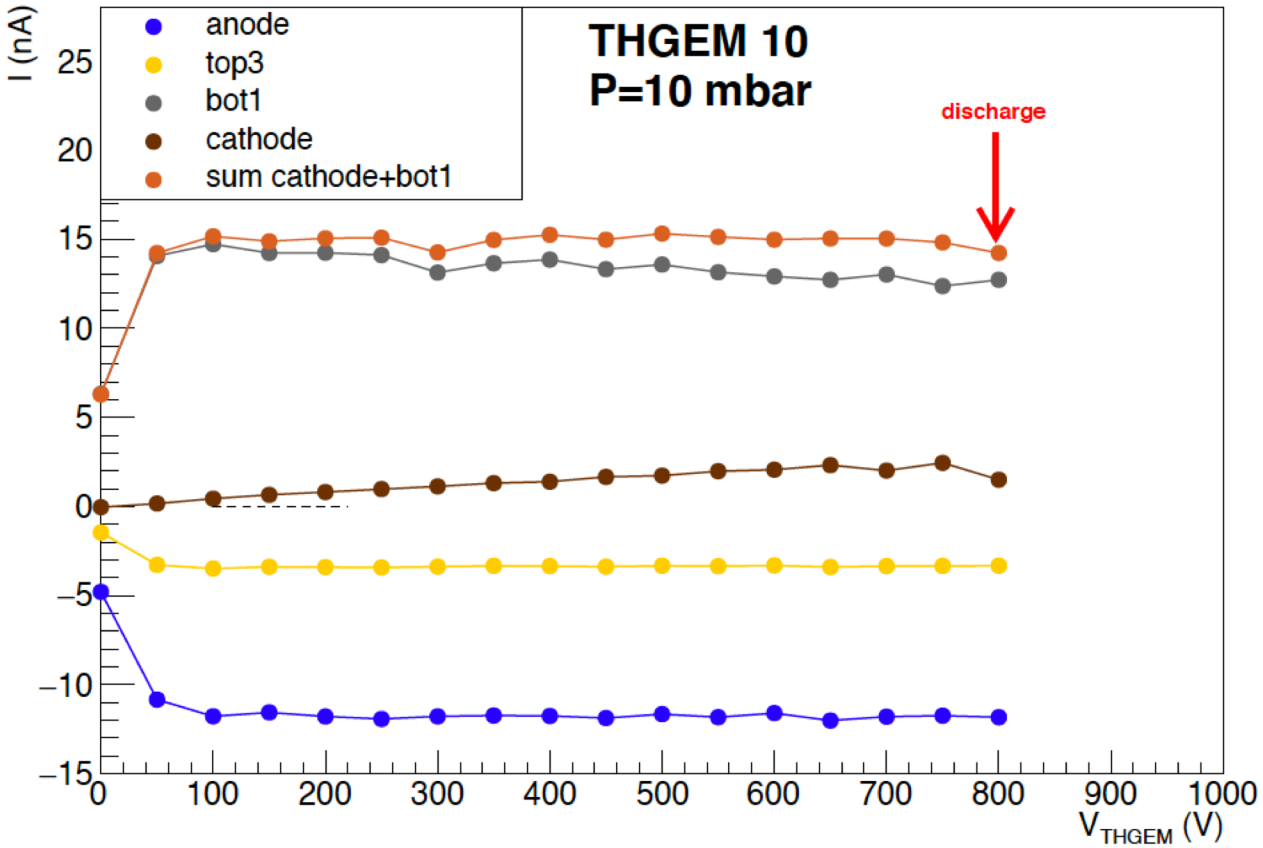
Measured parameters: Gain

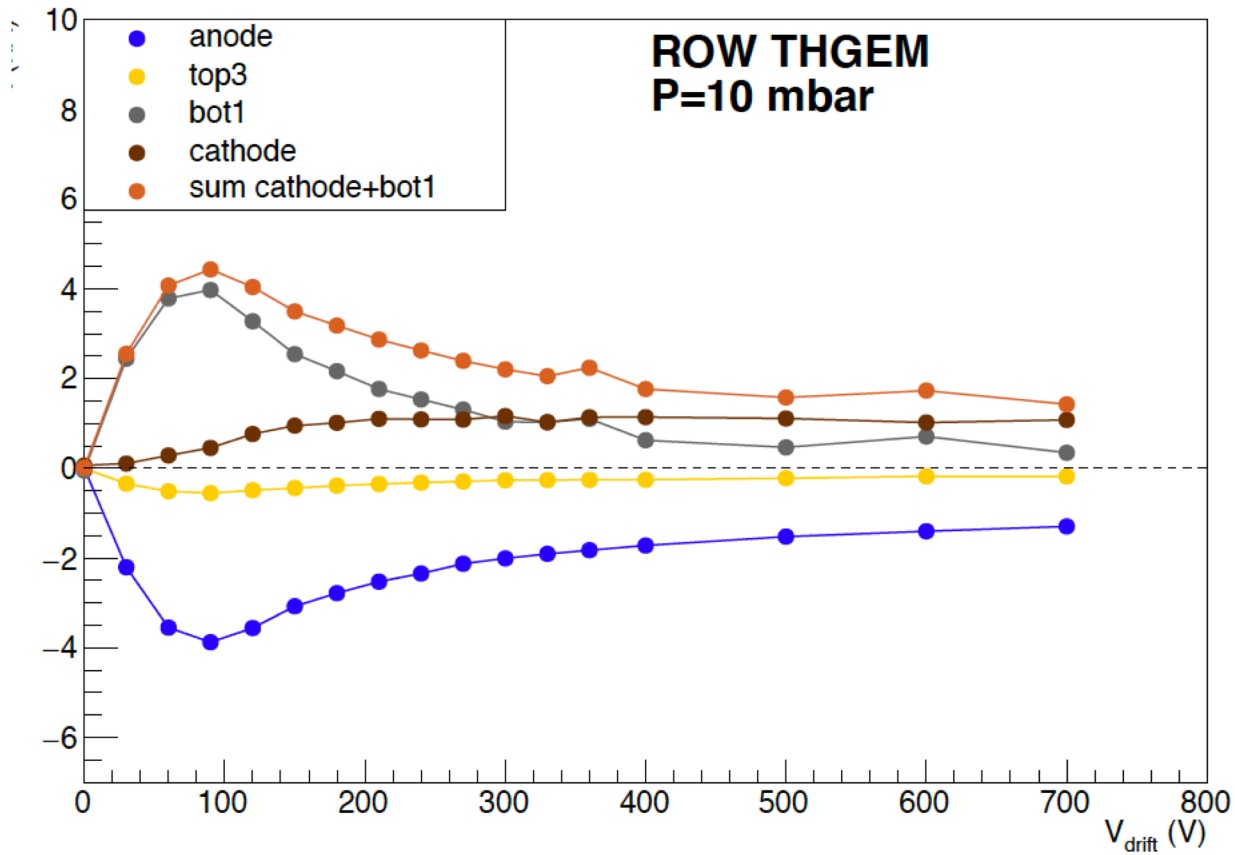


Full THGEM F10

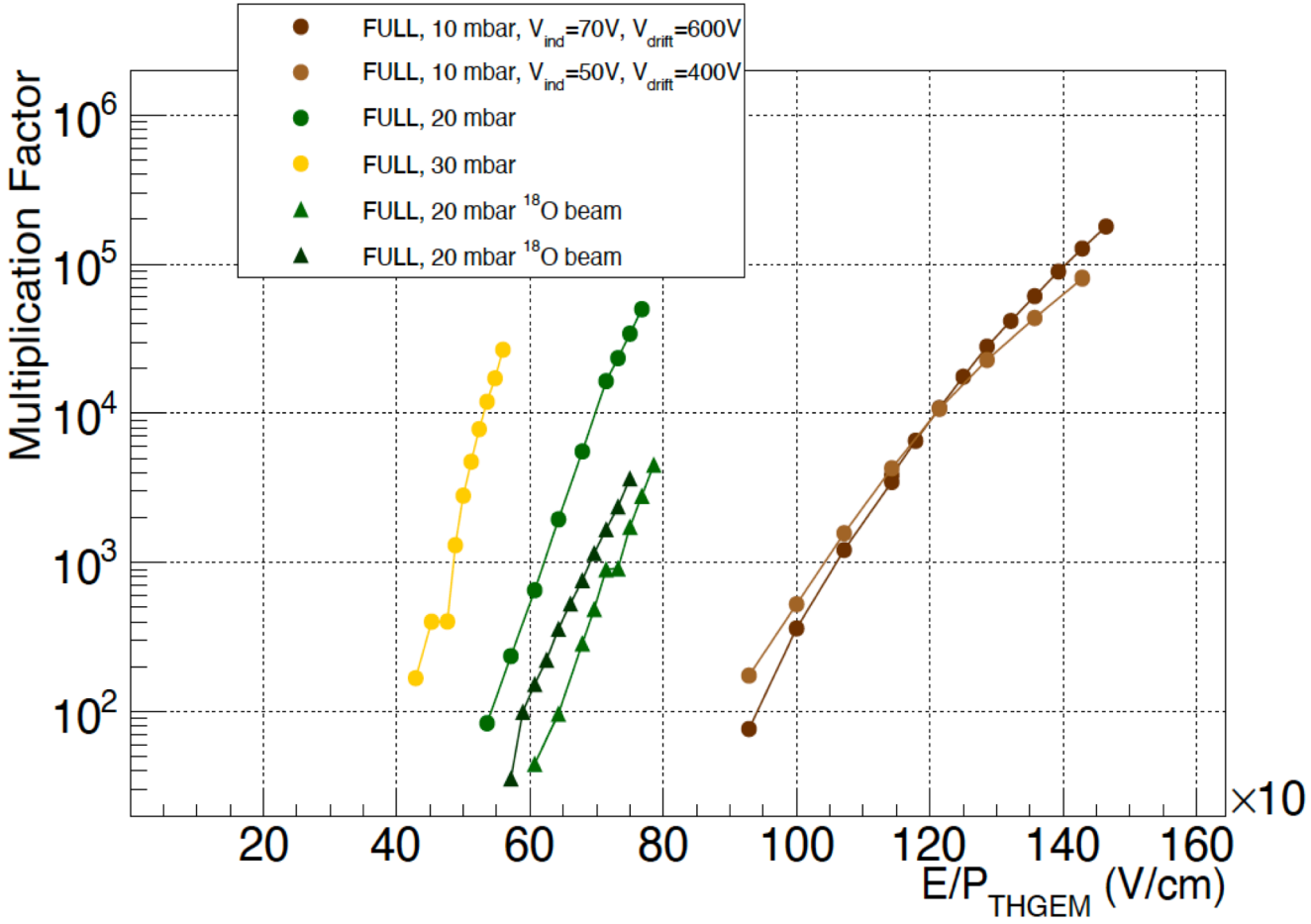


ROW THGEM R1

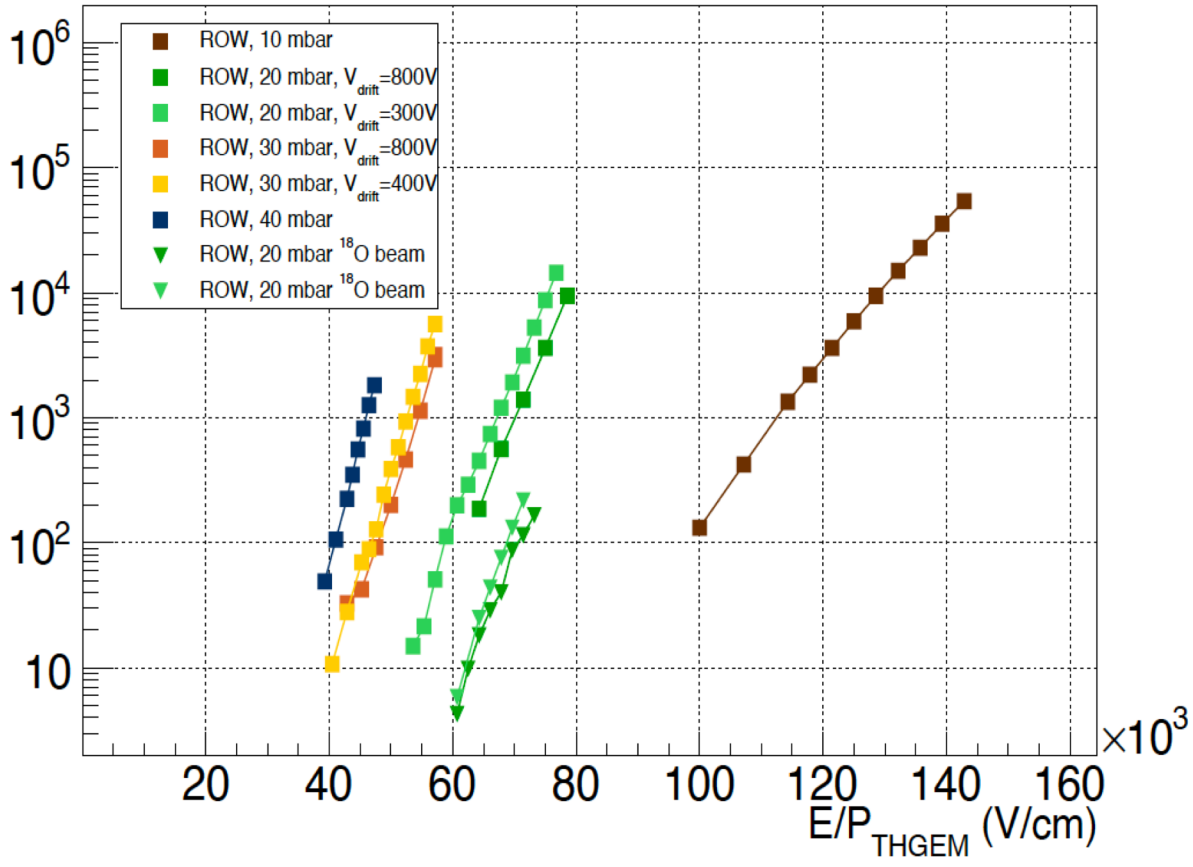

THGEM 10
P=10 mbar
discharge
anode
top3
bot1
cathode
sum cathode+bot1
I (nA)
V_THGEM (V)


ROW THGEM
P=10 mbar
anode
top3
bot1
cathode
sum cathode+bot1
V_drift (V)

Measured parameters: *Gain*



Full THGEM F10



ROW THGEM R1

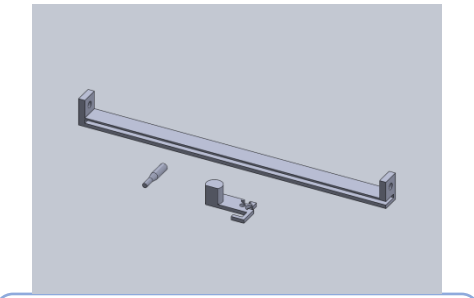
Mechanical design of gas tracker prototype

Connector to FE chip

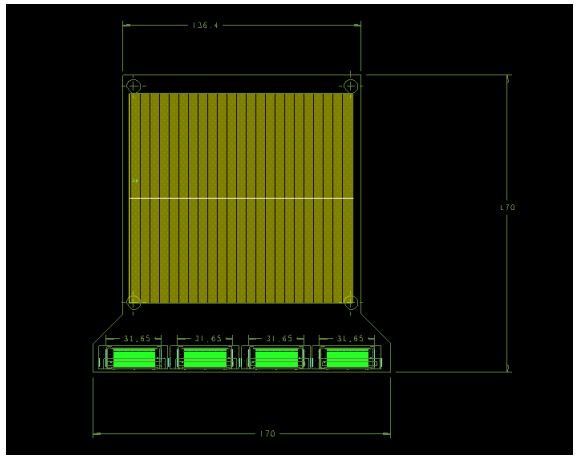
Multiple Thick-GEM



Aluminium profiles



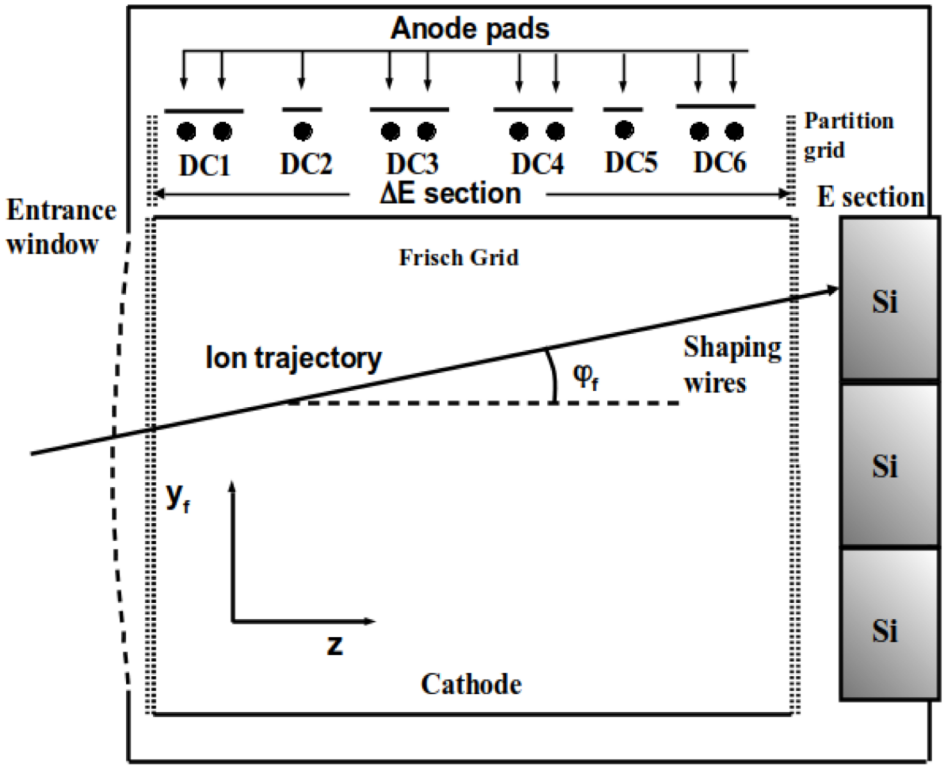
Plastic part created with 3D printers



PCBs

D. Bonanno et al.

Section view



60 Silicon Detectors
→ E_{res}

6 Proportional Wires
→ ΔE

Ion identification

6 Induction Strip
→ X_1, X_2, X_3, X_4
→ X_{foc}, θ_{foc}

6 Drift Chamber (DC)
→ Y_1, Y_2, Y_3, Y_4
→ Y_{foc}, ϕ_{foc}

Ray-reconstruction

Top view

