LEOPARD: high resolution scanner for MPGD detector developments

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Lendület program

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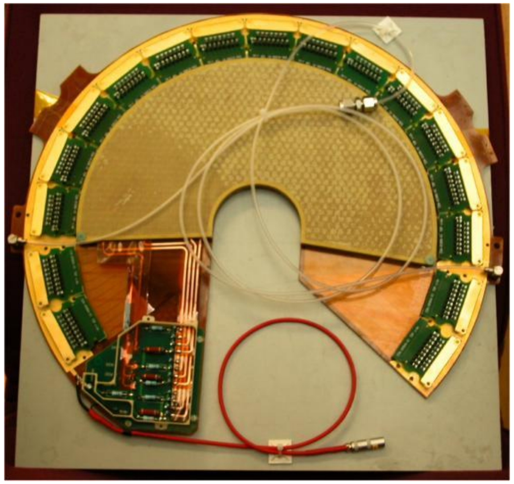
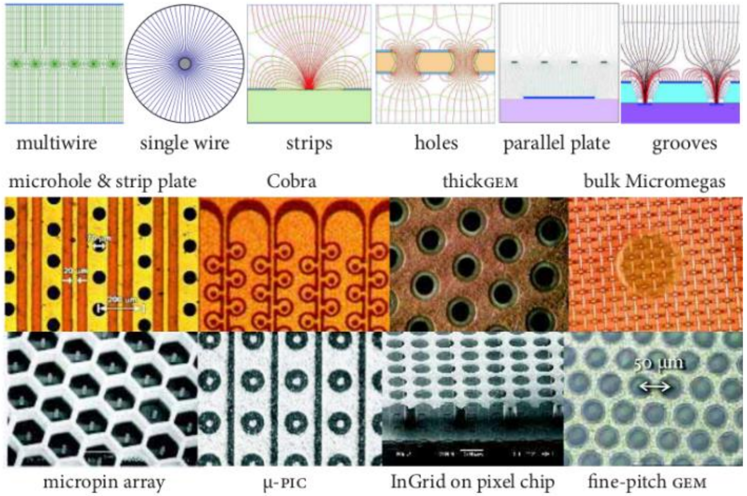
Outlook

1. **Introduction** of the MPGD type GEM
2. **The Leopard** scanning system
3. **Developments** on the Leopard system
4. **Latest results** of standard GEM measurements

1. Introduction
MicroPattern Gaseous Detectors (MPGD)

- Gaseous detectors: large area, low material budget
- Wire chambers limitations: rate, resolution, production
- MPGD: high electric field via microstructure PCBs eg.: GEM, Thick GEM, MicroMeGas etc…
- RD51 collaboration: active R&D
- Usage: tracking, TPC, RICH, …



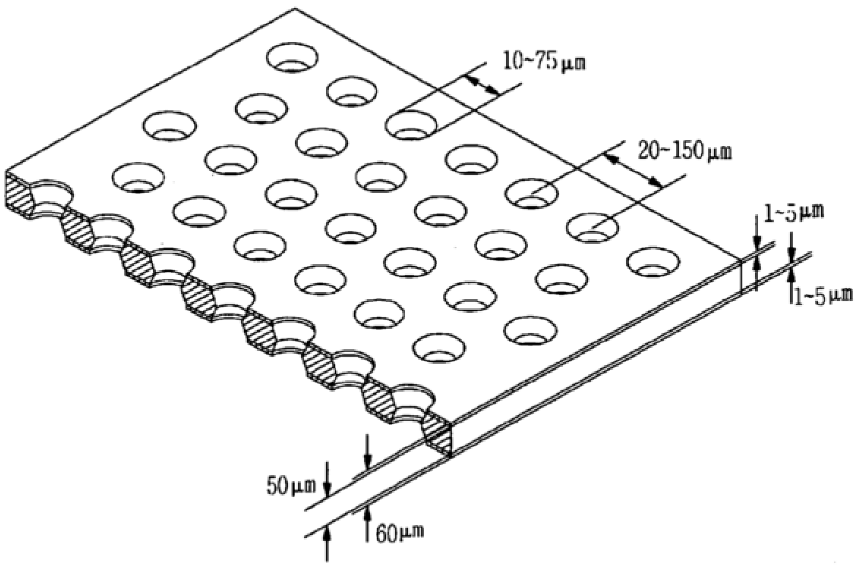


1. Introduction
The GEM Detector

GEM (Gas Electron Multiplier): a novel and widespread MPGD

- Insulator layer with metallic top and bottom side
- Holes (thin GEMs 10-70 μm, thick GEMs 300-400 μm diameter)
- Few 100 V between top and bottom side
- Electron avalanche through holes
- Gain 10-100, can be cascaded

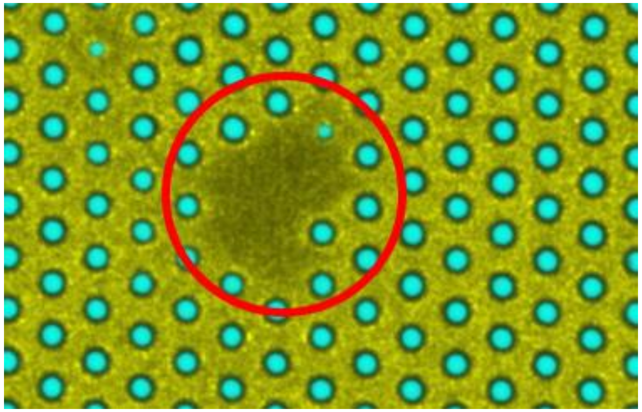
- High resolution
- High rate capability
- Upgrade projects eg.: ALICE-TPC, CMS-GE forward

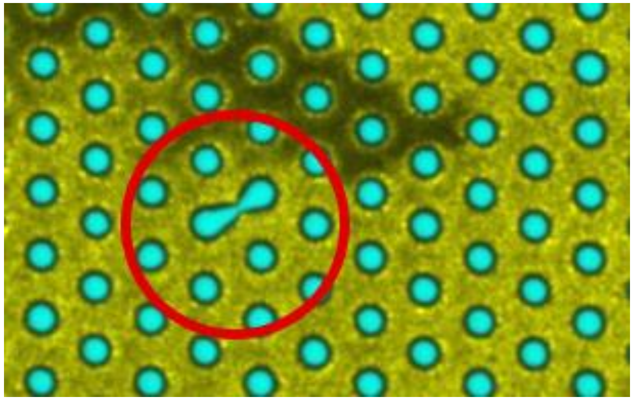


US Patent 2008/0283725 A1

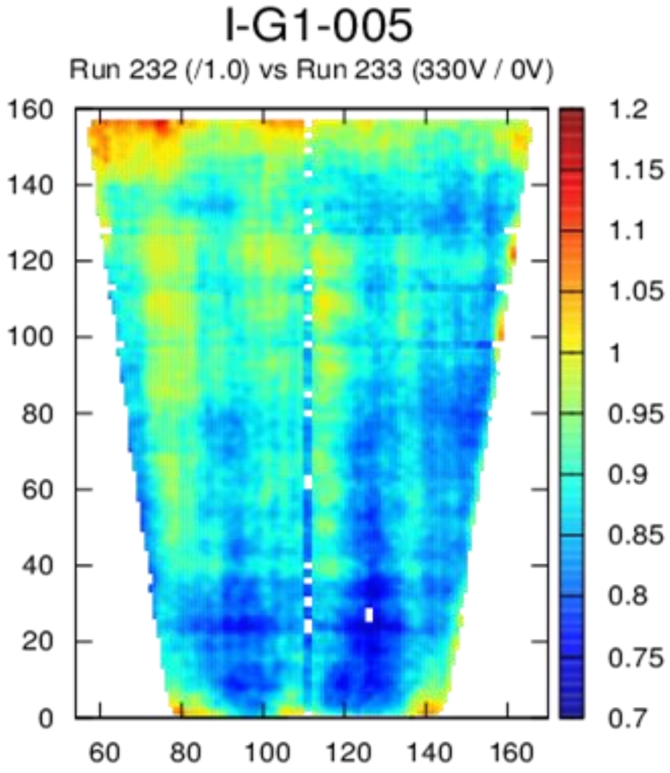
1. Introduction
The GEM Detector

Typical GEM production faults:





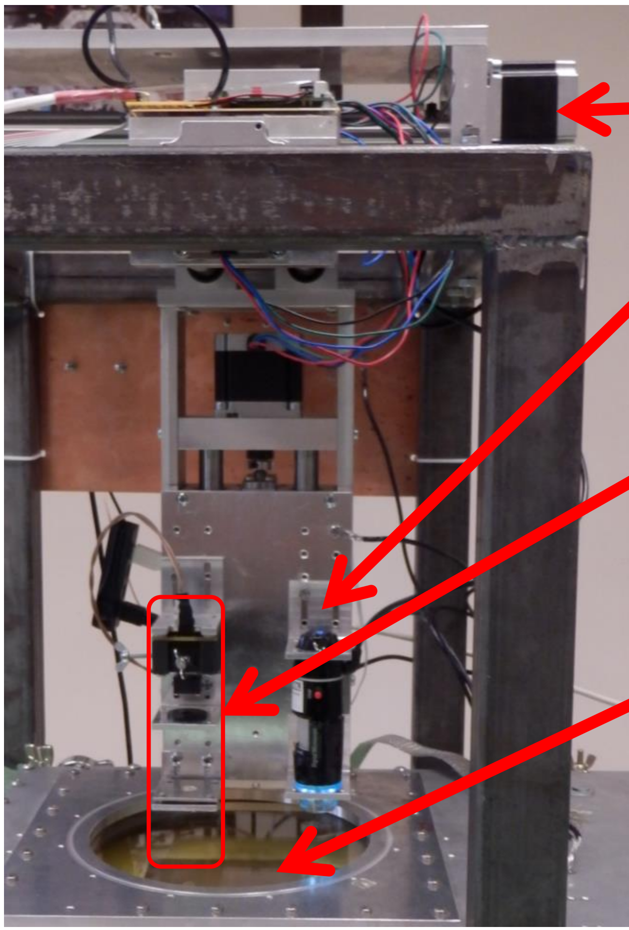
Gain inhomogeneity:



2. The operation of „Leopard” scanning system

Basic operation

Hole-by-hole gain mapping of micropatterns on 100 mm x 100 mm

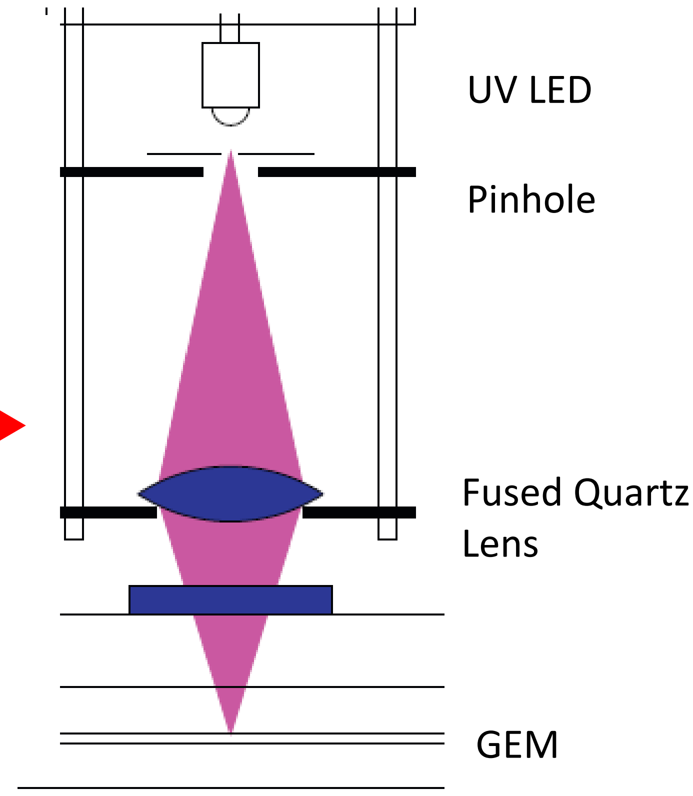


2.5 µm resolution stepper motors

USB Microscope Camera

UV Optical system
(UV source, pinhole, lens)

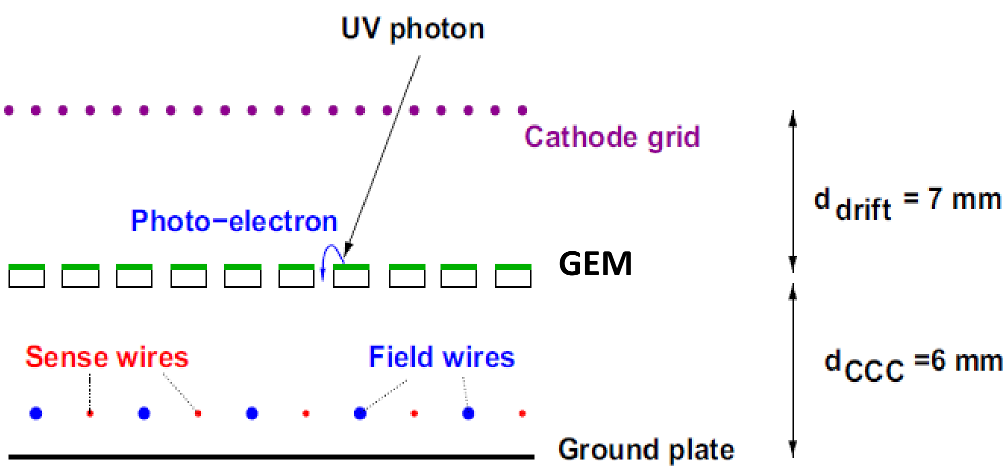
GEM detector



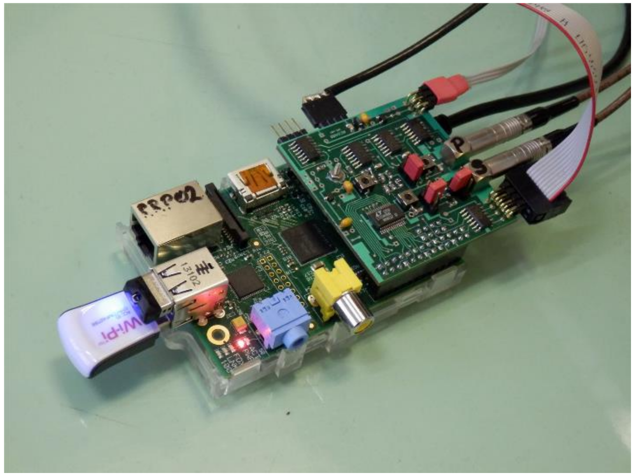
Nucl. Instr. and Meth. A 694, p 16-23, (2012)

2. The operation of „Leopard” scanning system
Basic operation

- Focused UV light excites the surface of the GEM
- The Photoelectron (PE) creates avalanche through the GEM hole
- Signal process with RasperryPi based DAQ system



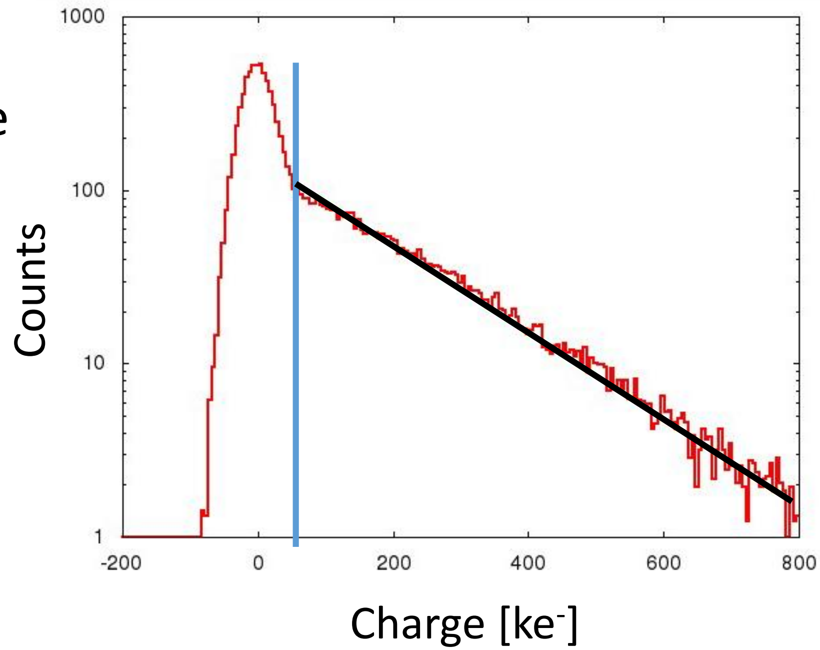
Nucl. Instr. and Meth. A 849 (2017)



RaspberryPi

2. The operation of „Leopard" scanning system
Data analysis

- Signal is proportional to amount of electrons at the end of the avalanche (Charge)
- Histogram of all measures contains the Gaussian noise and the exponential charge counts
- Density function: $f(q) = \frac{Y}{G} e^{-q/G}$
- **PE–yield**: $Y_c = \int_{q_c}^{\infty} f(q)\, dq$
- **Gain**: $G = \frac{\int_{q_c}^{\infty} q\, f(q)\, dq}{\int_{q_c}^{\infty} f(q)\, dq} - q_c$

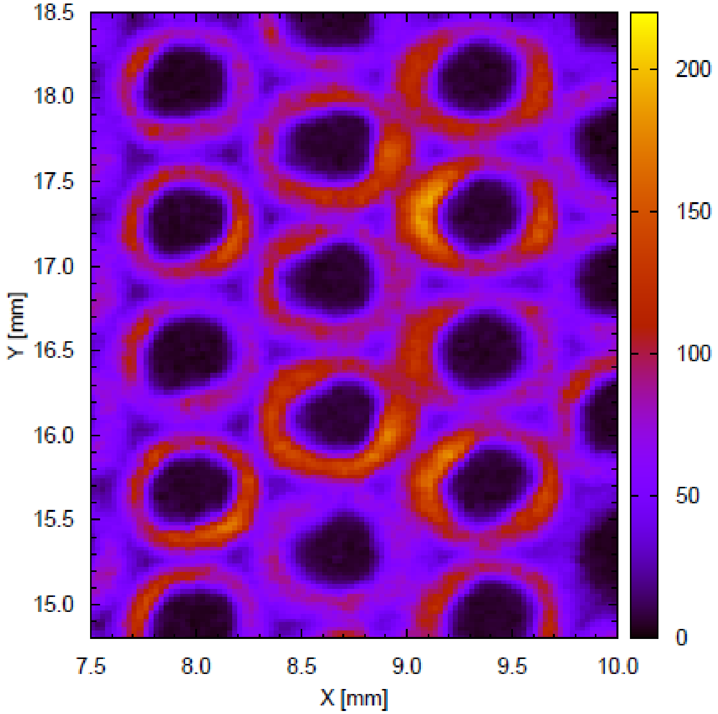


Nucl. Instr. and Meth. A 694 (2012)

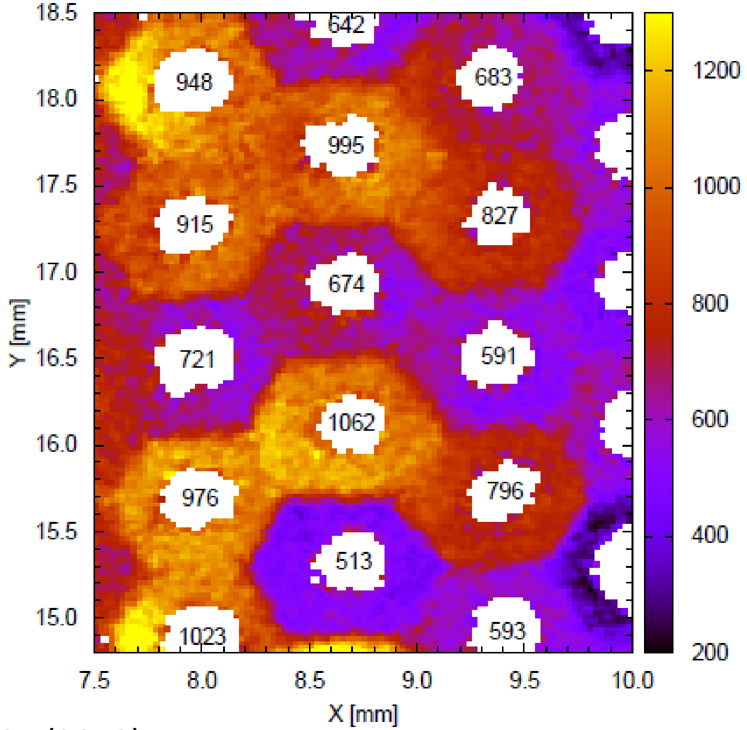
2. The operation of „Leopard” scanning system
Maps

Previous measurements of gold plated Thick GEMs: one pixel of the map shows the gain or PE-yield from approx. a million measure in a color range

PE-yield map



Gain map



Nucl. Instr. and Meth. A 694 (2012)

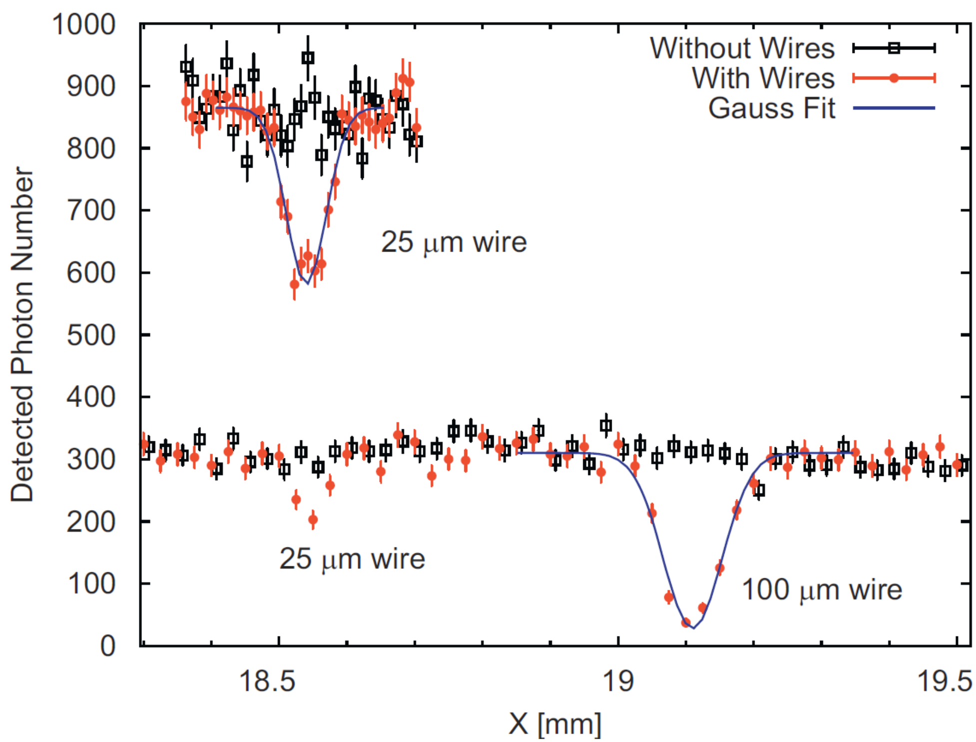
2. The operation of „Leopard" scanning system

Measuring resolution

Size of the focused light spot characterizes the resolution of the system

Determining:

- 1D PE-yield measurement perpendicular to thin wires
- Gaussian fit to the shadow of the wires
- FWHM of the fit is the resolution by definition



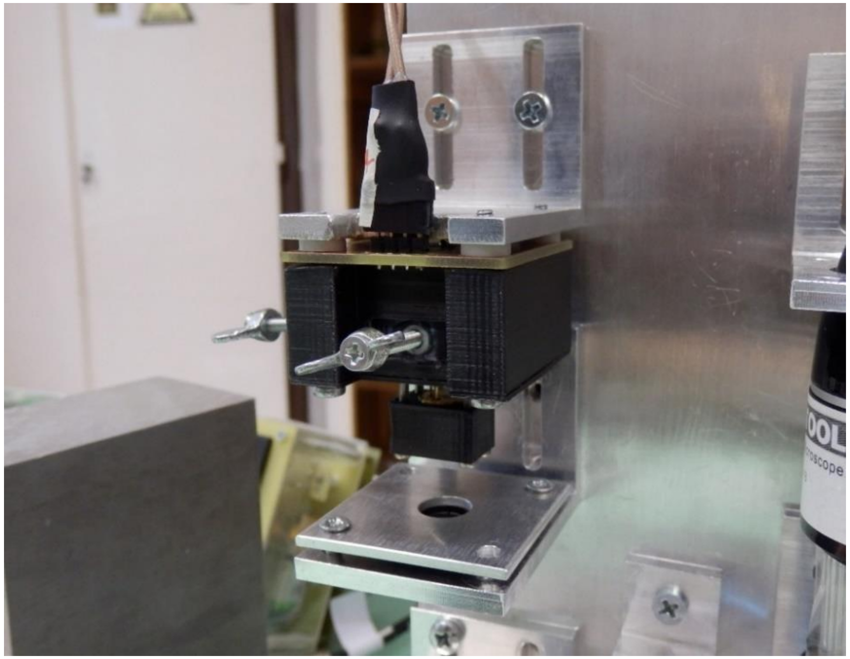
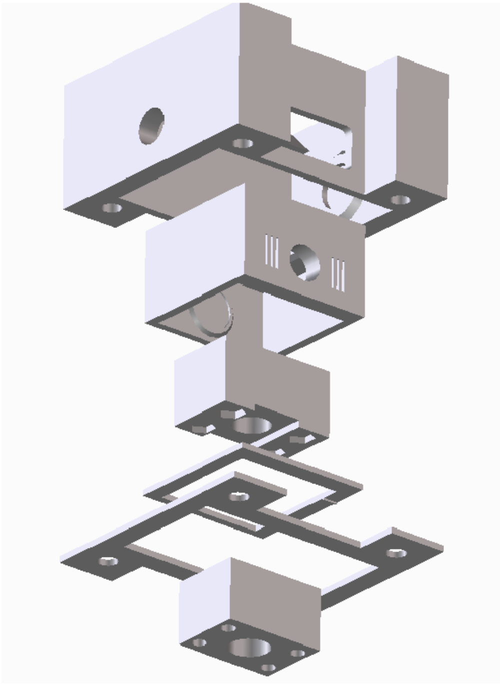
Nucl. Instr. and Meth. A 694 (2012)

3. Developments
Goals

- Leopard system upgrades:
  - Increase UV intensity → faster scanning, measuring lower QE copper GEMs
  - Increase Resolution → measuring standard GEMs (smaller hole diameters)
  - Simplifying calibration methods
- Checking time and space stability
- AIDA-2020 plans: Large size demonstrator for MPGD hole-by-hole gain map for QA purposes

3. Developments
3D printed LED positioner

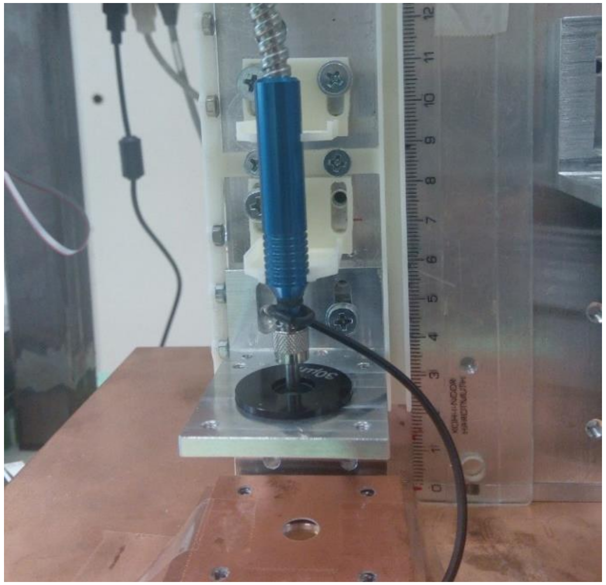
- UV intensity depends on how much photon gets through the pinhole
- The number of photons depends on the precise position of the LED below the pinhole
- Precise positioning is possible thanks to 3D printed device
- The LED can be positioned easily and precisely, LED is removable

Left: the 3D printed positioner device. Right: exploded view of the parts

3. Developments
UV photon yield increase by deuterium source

- Until now a 130 kHz pulse signal triggered the measures, but the deuterium lamp can work only on continuous operation → self-trigger operation has been implemented
- Advantage: 30-50 x faster measuring
- Disadvantage: cutting of noise needs extra measure

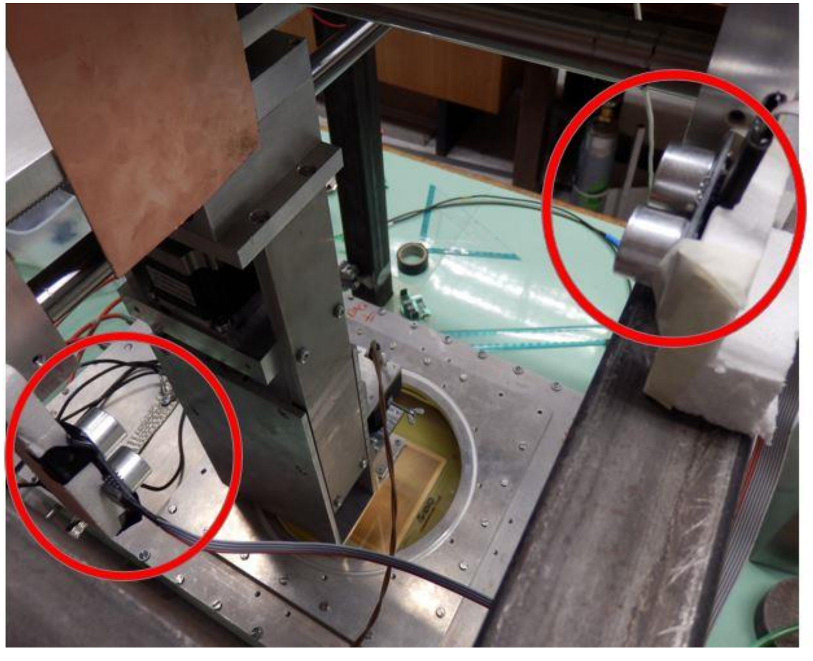


Left: the deuterium lamp from INFN Trieste. Right: connection of optical cable to Leopard

3. Developments

Position feedback with ultrasonic sensors

- The stepper motors are 2,5 μm precise, but we had no feedback into the software until now → For example origo calibration was manual
- With the new sensors this process could be automated and error checking is simpler



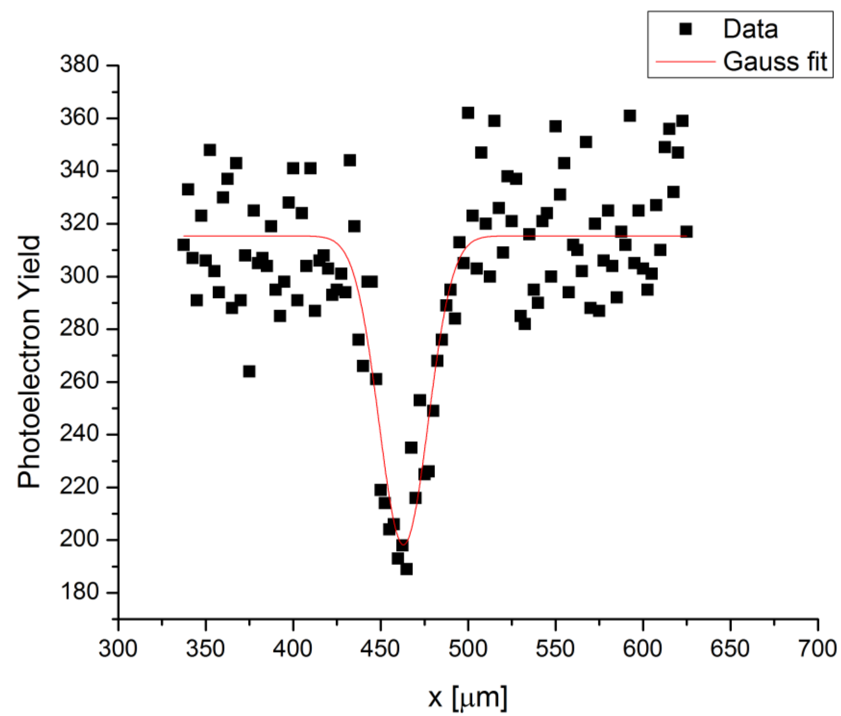
The ultrasonic sensors

3. Developments

Increasing resolution

- Reducing the light spot size
- Because of higher photon yield: smaller (30 µm) pinhole can be used
- Avoiding spherical aberration: aspherical lens and smaller blende
- Subject and image distance optimized
- Slower movement, delay time before measurements to avoid the effect of vibrations
- => **New resolution is 30 µm** (down from 70 µm)

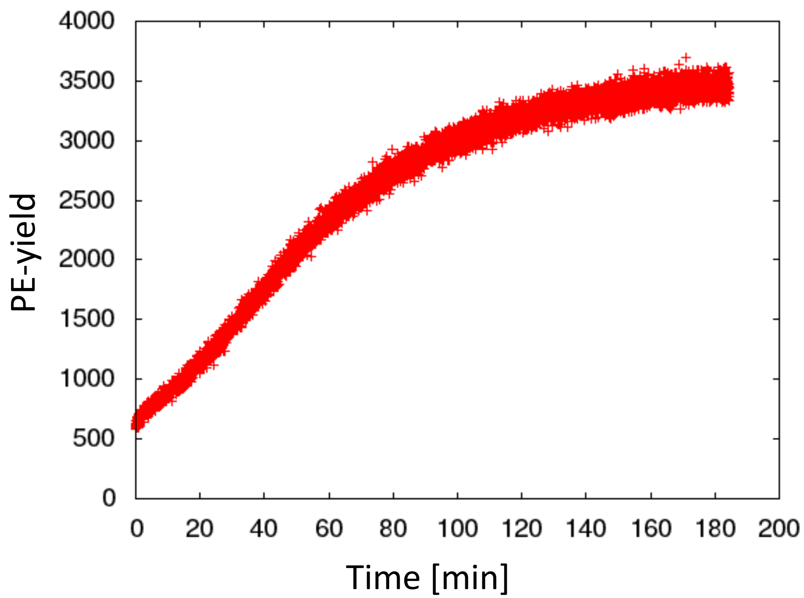
$$315-\frac{1640}{11\sqrt{\pi/2}}e^{-\frac{1}{2}\left(\frac{x-17400}{11}\right)^2}$$

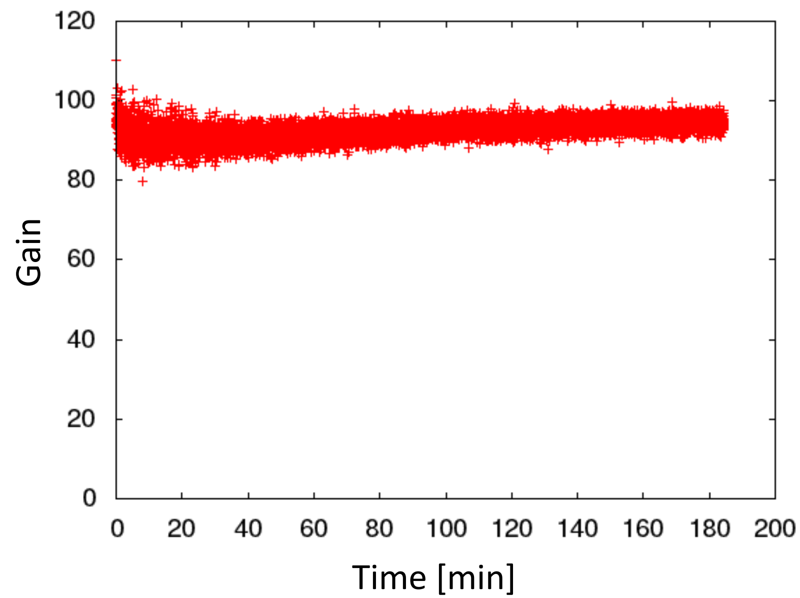


4. Latest results on standard GEMs

Chargeup

- On long-time measurements gain and PE-yield change can be observed
- Positive ions left from the avalanche flows back to the insulator → chargeup
- Gain saturation time can be determined → after this time, the gain is stable

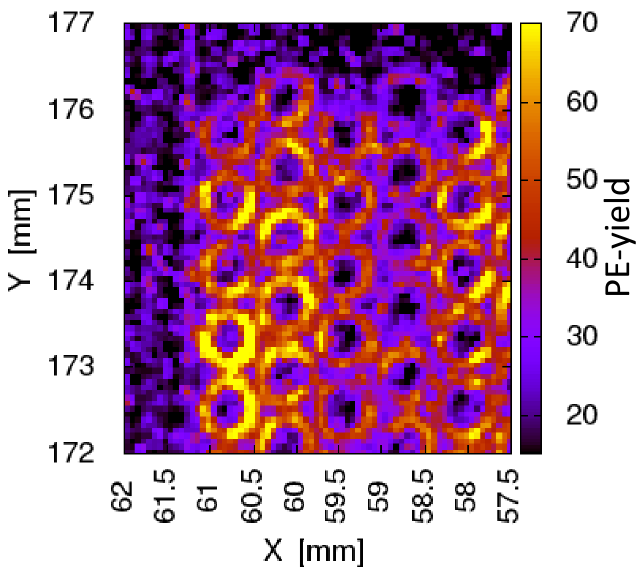


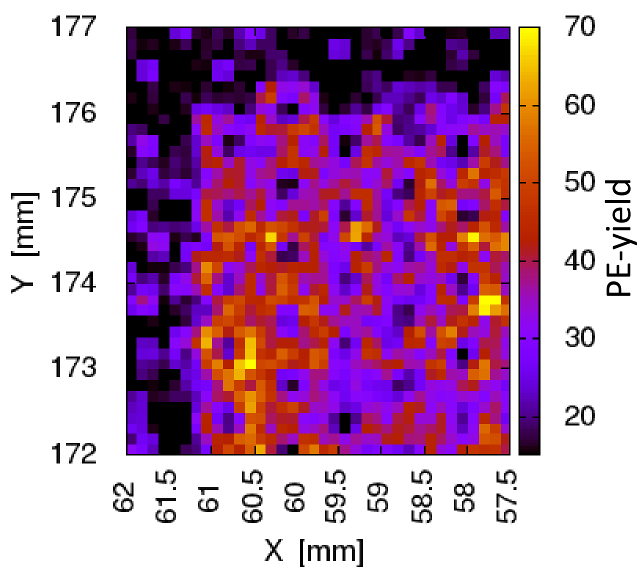


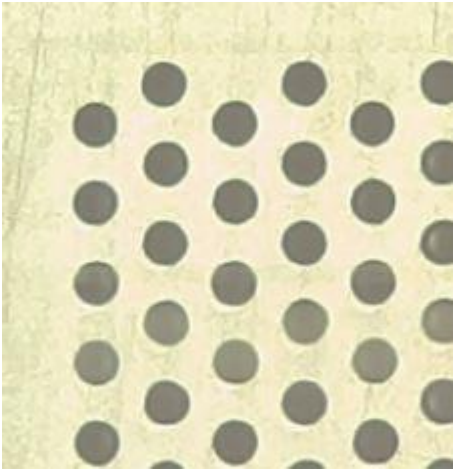
4. Latest results on standard GEMs

Position stability

- Goal is to check spacial restore accuracy
- Same corner area measured multiple times with different step sizes
- Corner hole coordinates were compared with each other and with microscope camera picture
- The pointing error had 15 μm

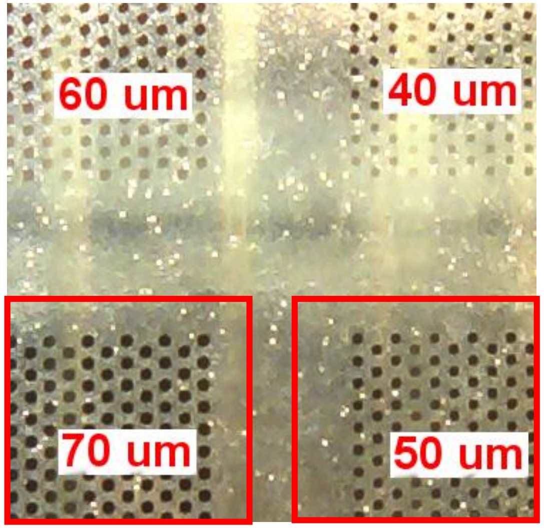




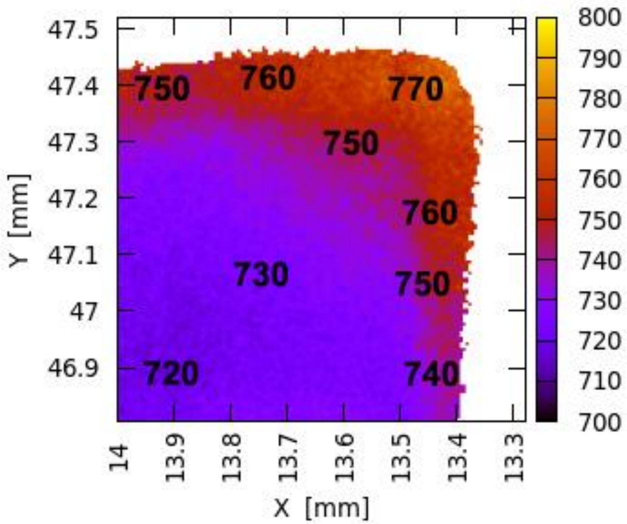


4. Latest results on standard GEMs
Edge-effect

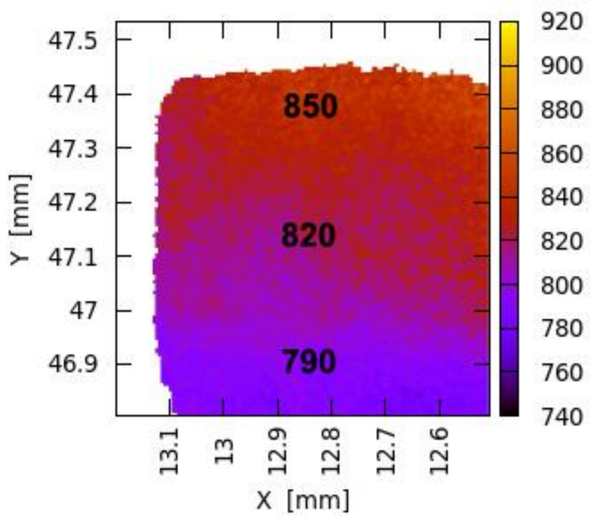
- Standard copper thin GEM with different hole size were examined
- Edge-effect: more electric field strength near edge, because those holes have fewer neighbor holes → 7-8% higher gain
- Larger hole size → lower gain, sharper edge-effect
- Smaller hole size → different edge-effect in X and Y direction
- Needs more investigation…



Gain at 70 µm [ADC]



Gain at 50 µm [ADC]



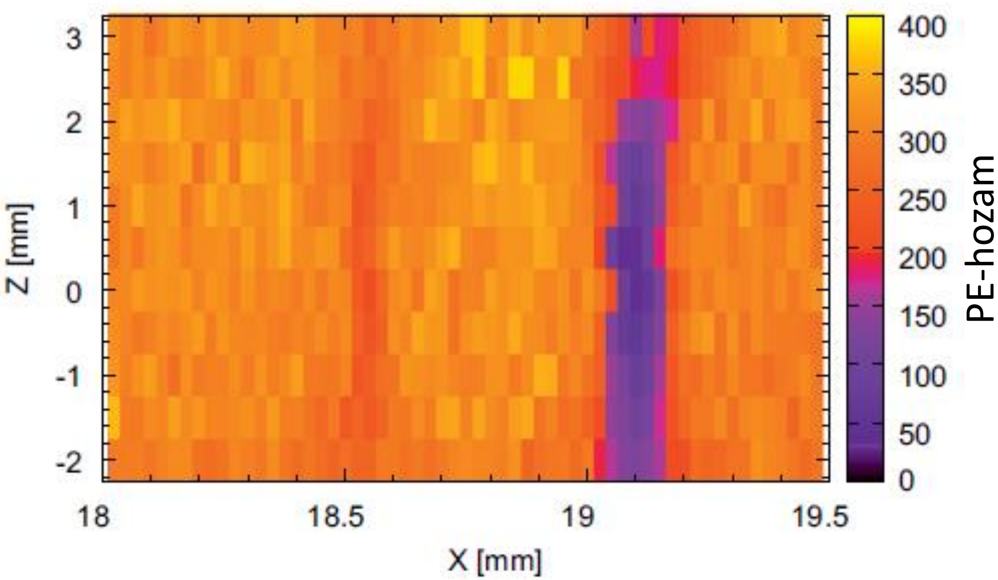
Summary

- Novel gaseous detectors: MPGDs
- Most used MPDG: GEMs (ALICE, CMS, PHENIX, TOTEM, …)
- Microstructure gain mapping with Leopard system
- Latest developments → we are able to measure standard thin copper GEMs
- Special effects measured: chargeup, edge-effect
- Multiple open questions ahead (eg.: effect of GEM faults)
- The Leopard system is ready for QA on 100 mm x 100 mm GEMs
- Development plans: vibration analysis, hardware and software upgrades, scaling the system to larger size, etc…

Thank you for your attention!

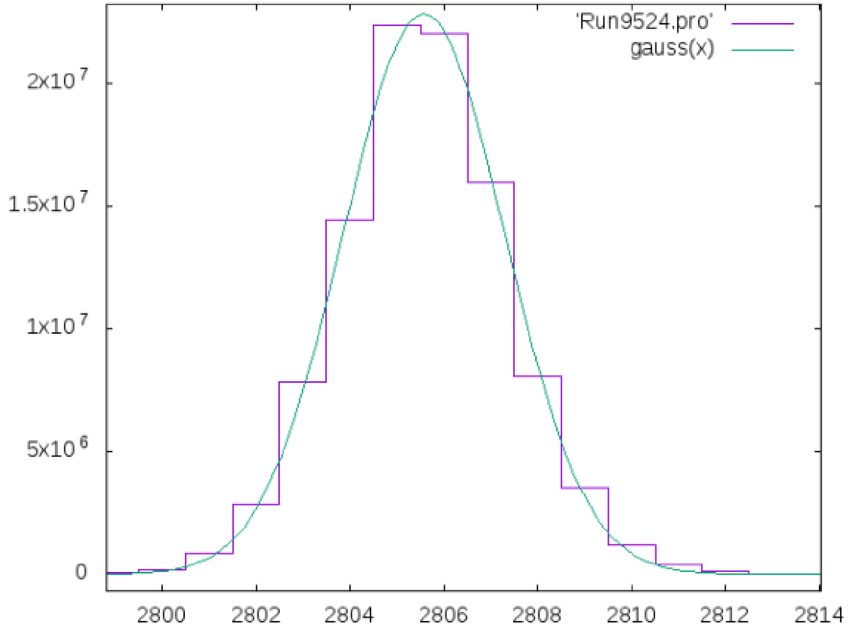
Backup slides

Microscope focusing



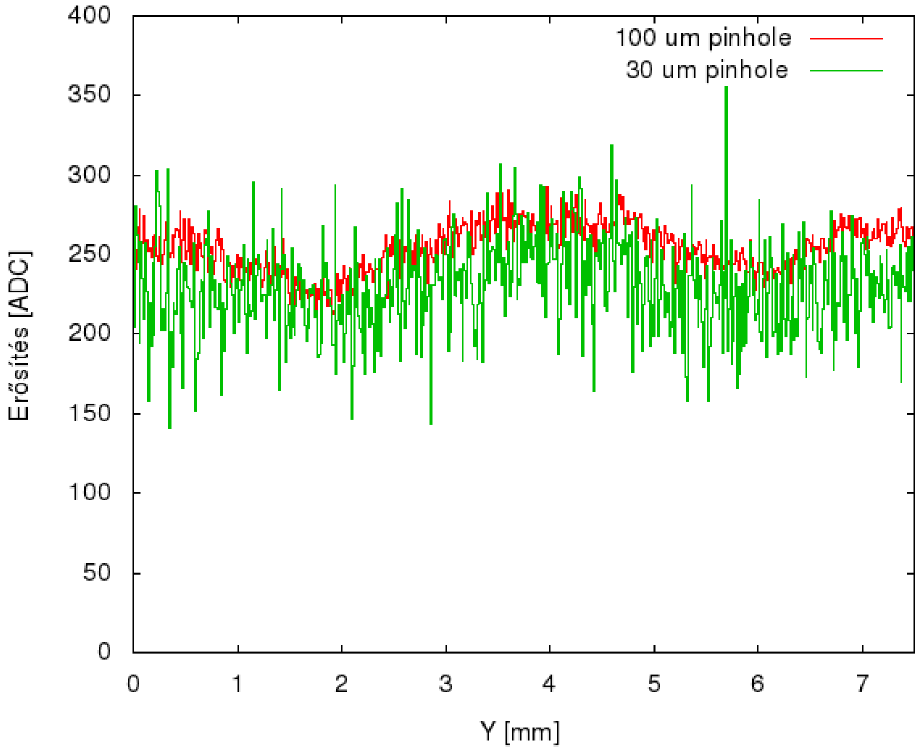
Noise

$$\int_{2820}^{\infty} 2{,}3 \cdot 10^7 e^{-\frac{1}{2}\left(\frac{x-2805}{3}\right)^2}\, dx \cong 50$$

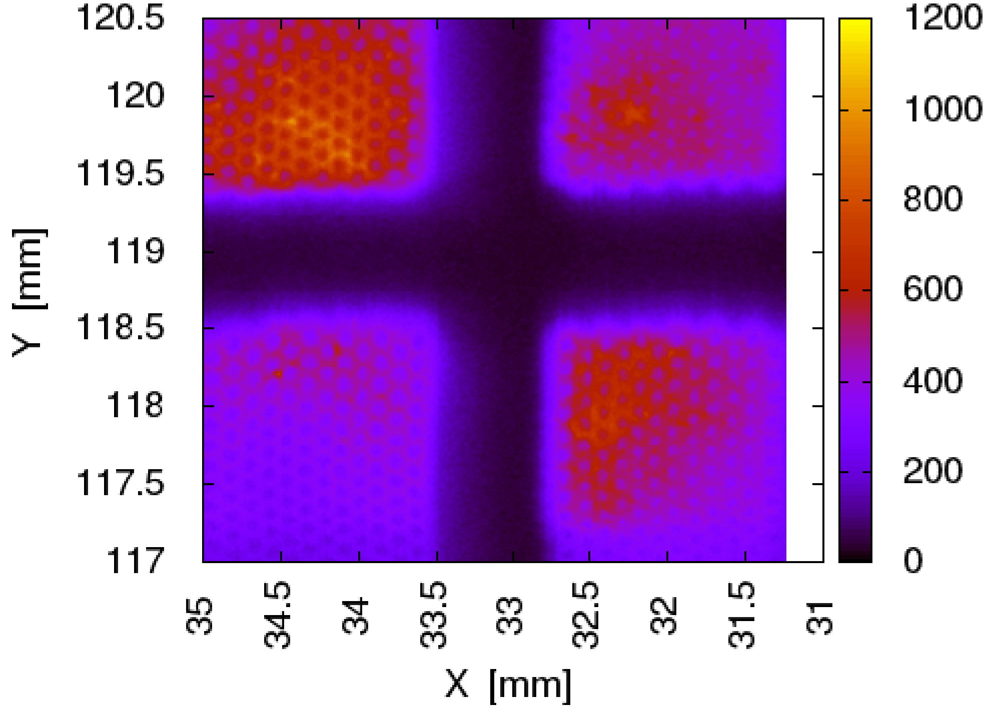


Forrás: G. Galgóczi

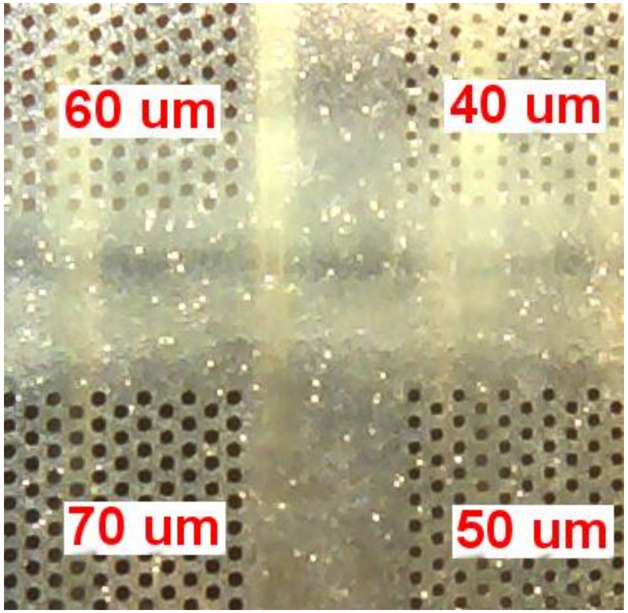
Gain stability



GEM PE-maps



120.5
120
119.5
119
118.5
118
117.5
117
Y [mm]
35
34.5
34
33.5
33
32.5
32
31.5
31
X [mm]
1200
1000
800
600
400
200
0



60 um
40 um
70 um
50 um

GEM gain maps