Investigation of the Properties of Thick-GEM Photocathodes by Microscopic Scale Measurements with Single Photo-electrons

(The Leopard Project : Trieste-Budapest)

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for the joint group of
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INFN Trieste
Wigner RCP Budapest

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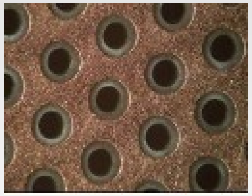
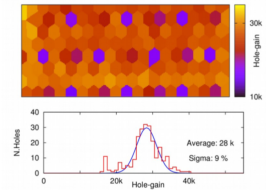
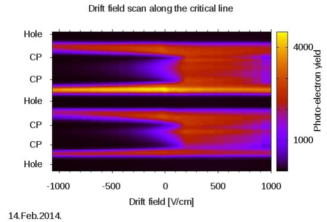
REGARD
RMKI ELTE Collaboration on Gaseous Detector Research and Development

Outline

- Micro-pattern RICH
- ThickGEM microstucture
- The Leopard system
- Trieste-Budapest setup
- Data and analysis
- Gain uniformity
- Drift field effects
- Summary







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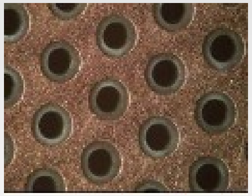
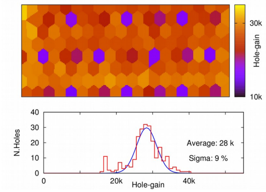
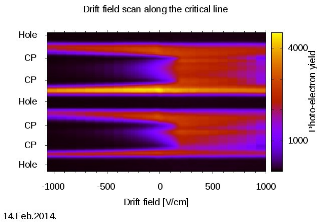


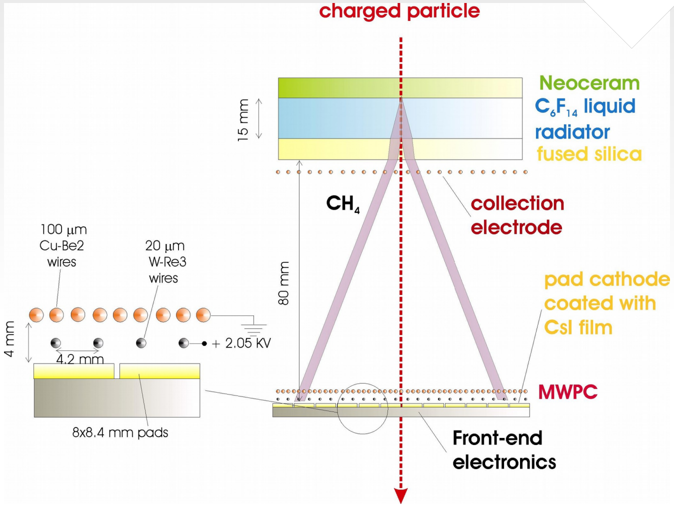




MPGD Based Cherenkov Detectors

See Review talk by Fulvio Tessarotto

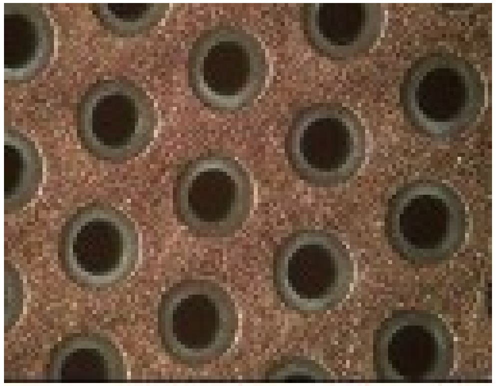
- Gaseous Photon Detectors for Cherenkov detectors
  - Large area at reasonable price
  - CsI cover for UV photon detection
- Advantages vs. MWPC based RICH
  - Reduction of ion back-flow
  - Fast response
  - High rate capability
  - Possibility for MIP suppression
  - No feed-back photons
- PHENIX, COMPASS, ALICE
- Triple GEM, TGEM, TCPD, TGEM+MM
  in all: GEM-type photoconverting plate
- Efficiency and microstructure ?



GEM based Cherenkov D.:
Talk by T.Hemmick
COMPASS RICH Hybrid :
Talk by S.Levorato
MIP Suppression :
Poster by G.Hamar

Microstructure of UV Sensitivity on ThickGEM Surface

- Holes are definitely blind spots
  (no photoconverter material is there inside)
- Highly non-uniform extraction field
  (high around the holes, lowest in symmetry points)
- Critical symmetry points (and lines)
- Side-effects of MIP suppression ?
- Large range for the geometrical parameters
  (diameter, pitch, rim, thickness)
- Choise of the filling gas



- Microstructure … ? → Map of response for single photons
  [simulations ?]

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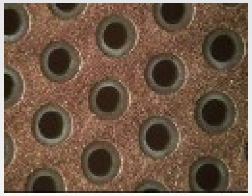
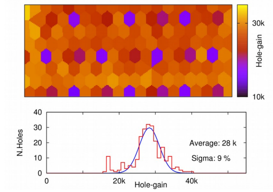
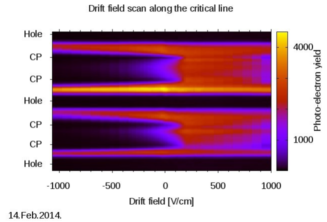
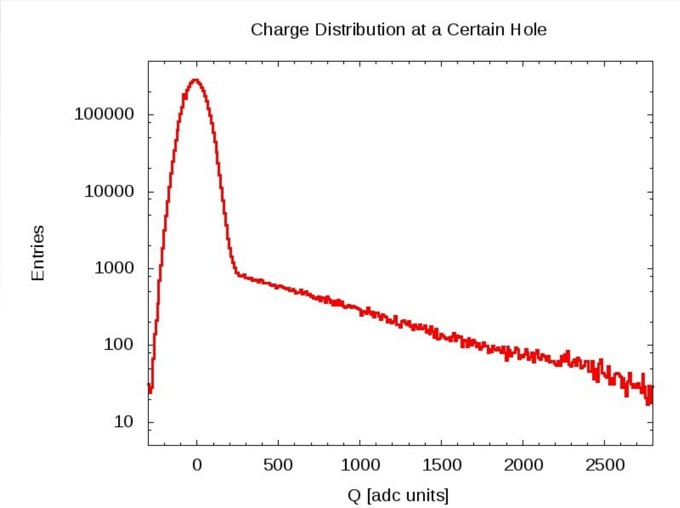






Strategy to Examine the Microstructure

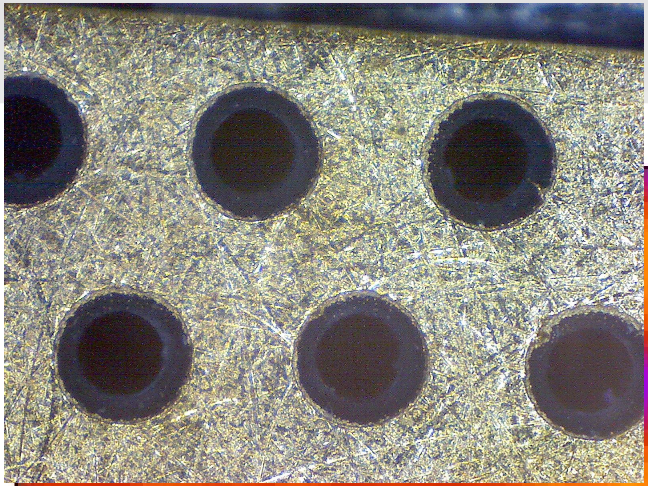
- Single photo-electrons
  PE yield and gain separation
- Focused UV light
- High resolution mapping
  should be better than 0.1mm!
- Combined (and fast) data acquisition

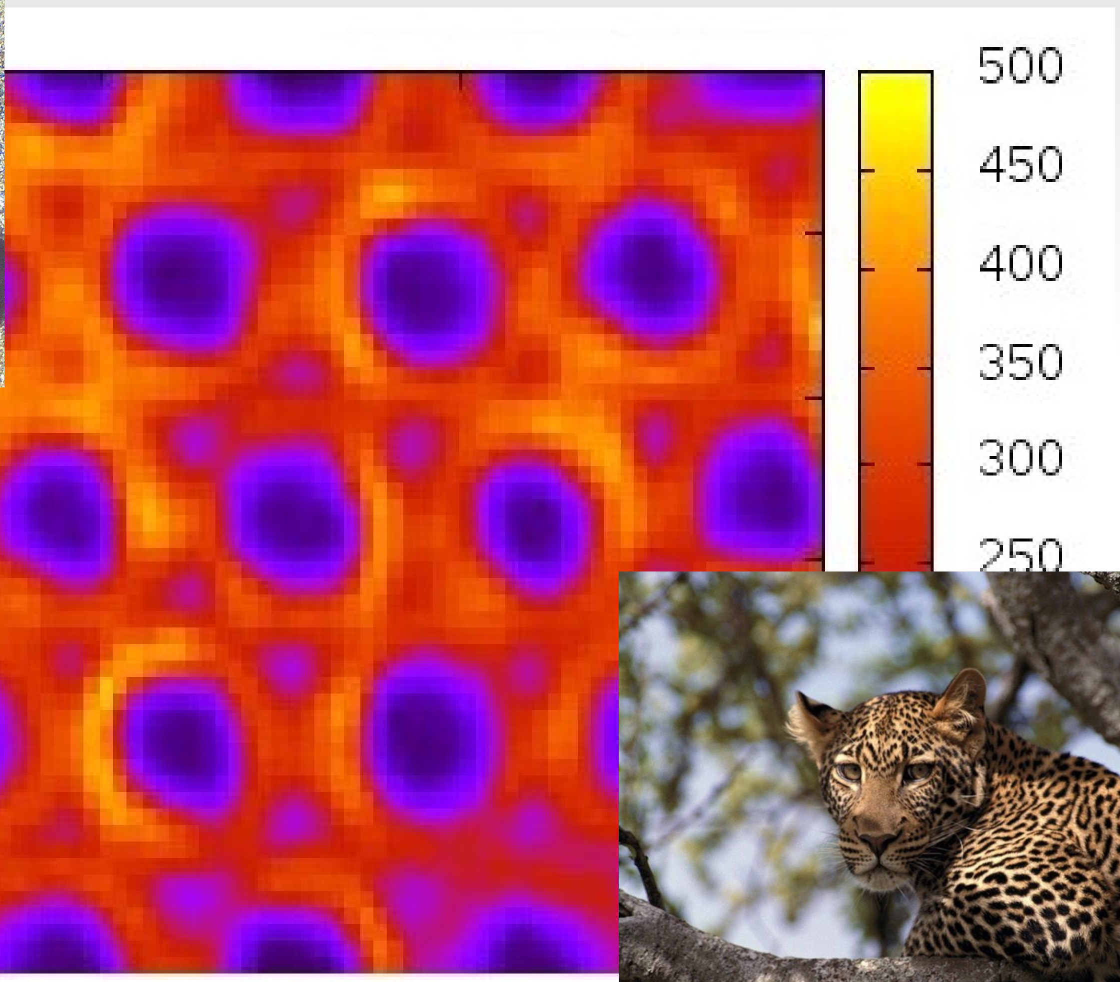


Targeted topics:

- Optimization (and parametrization)
  (hole geometry, voltages, gas mixtures, ...)
- Fine tuning for simulation

What could be seen?

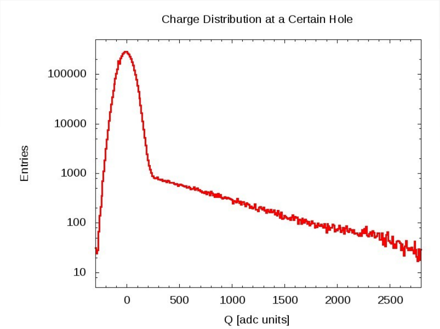




seems like a leopard...

Challenges

- Optical system : 20-100 μm spot size
  => 10^4 - 10^6 points (spectra) for an area
- Single photo-electrons:
  < 5% PE / event AND 100-1000 PE / point
  => 10^4 - 10^6 events in each points

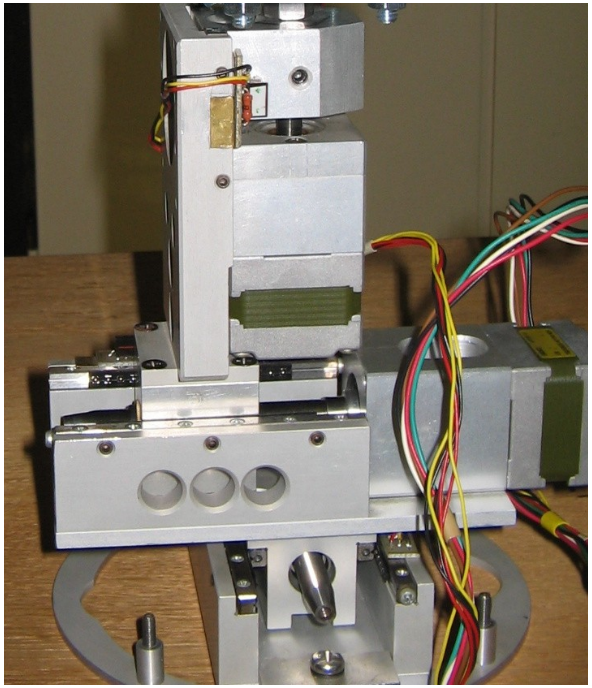


<u>Necessary system requirements :</u>

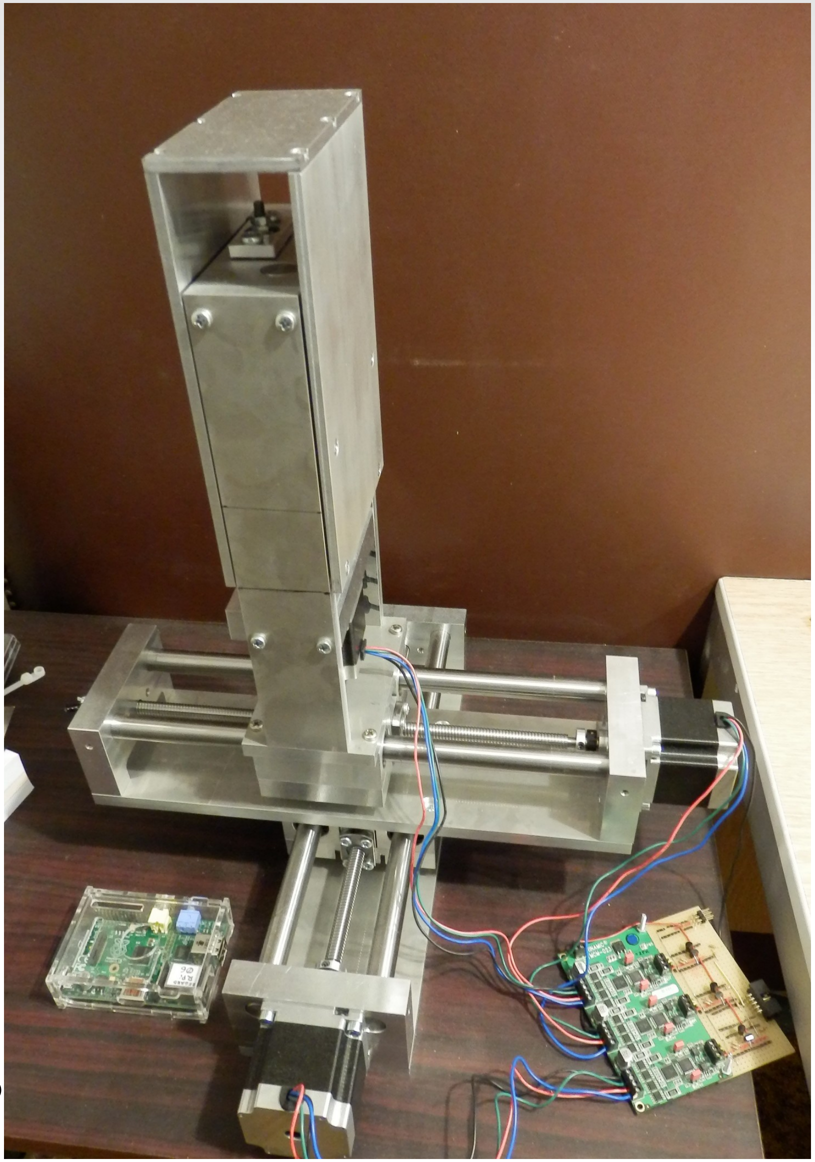
- Efficient focusing of pulsed UV light
- Actuator system (3D) : ~10 μm precision, 10ms response
- Fast ADC : >> 10 kHz
- Combined data acquisition system (ADC and actuator)

Actuator System

- Stepping motors for all axis
- Good resolution : 2.5 μm
- Direct control
- Mounted upside-down on a support table

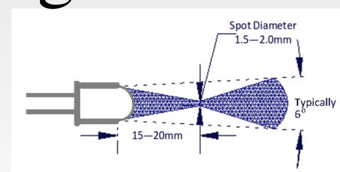


Larger (20cm) and faster version became ready recently

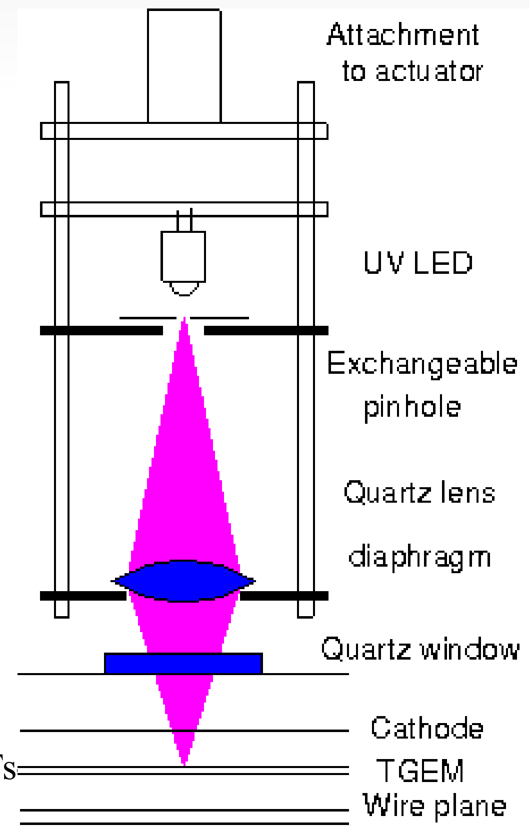


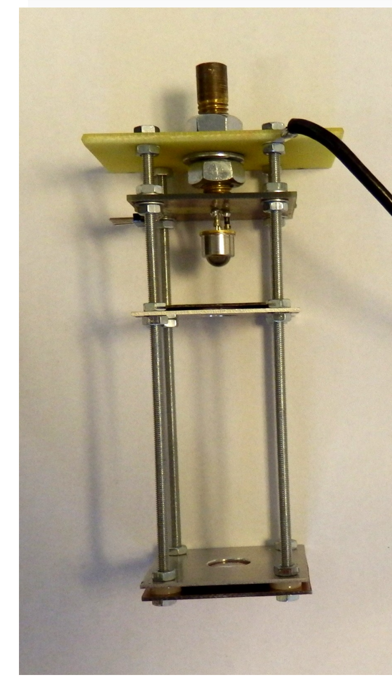
Optical Setup

- Pulsed UV source : UV LED : SETI UVTOP240
  peak: 243 nm, widths: 10nm
  Photo-electrons from gold surface
- Focusing ball lense cover



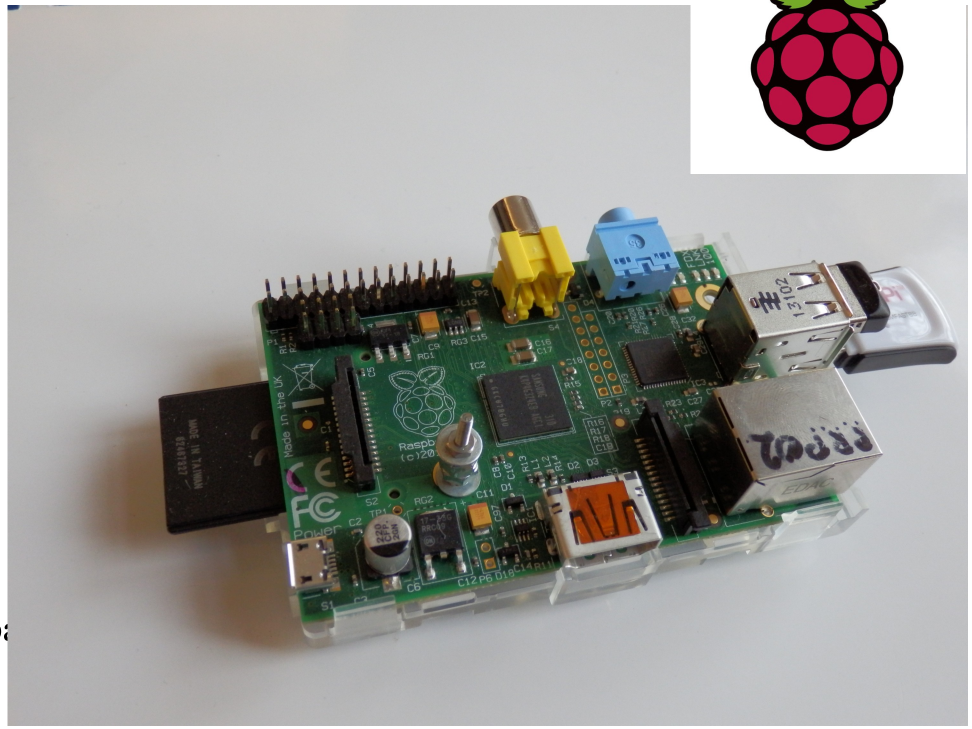
- Led Driver Unit
  adjustable oscillator
  trigger and LED output
- Pinhole (spot size x 2)
  150 µm => 70 µm spot
  Pinhole 30 µm for GEMs
- Quartz window
- Further improvements
  are still under tests





Data Acquisition : Machine

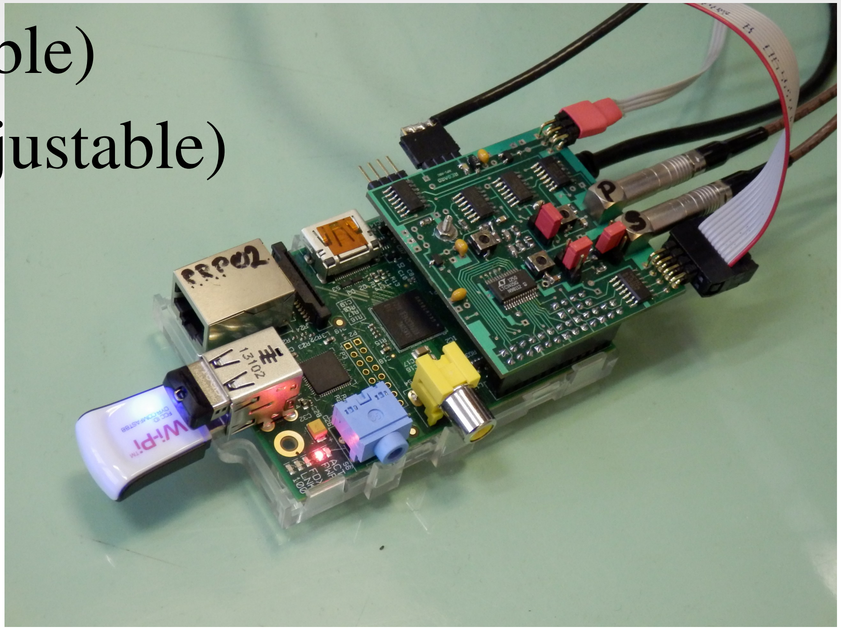
- Several options tested so far: Camac, PC+LPT
- Recent successfull implementation: RaspberryPi
- **Raspberry Pi** (is a tiny computer)
    - 700MHz ARM CPU + Broadcom 2835 chip
    - Periferials: USB, HDMI, SD, AV, Audio
- **GPIO pins (10MHz)**
- Low power consumption and low cost
- Raspbian **Linux** : Debian based OS
- WiFi connection



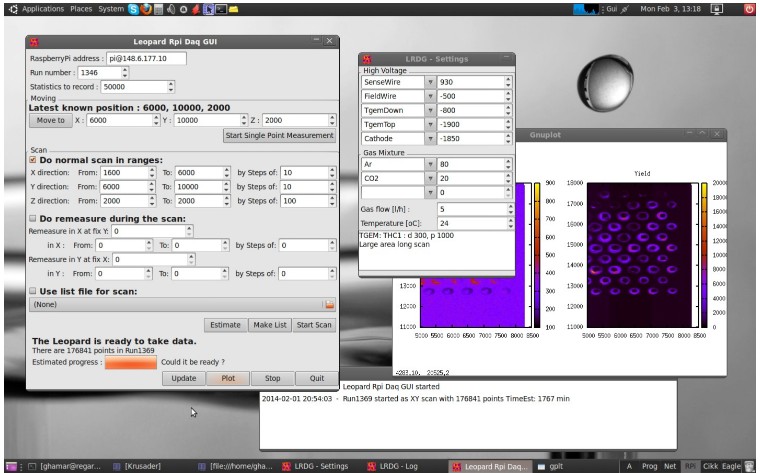
Data Acquisition : HW + SW

- Special **additional board**: fits to the GPIO pins
- Parallel-out single **ADC** (LTC1415)
- **Trigger** reciever and timing (adjustable)
- Signal shaping and amplification (adjustable)
- **Tagging** of rejected triggers
- **Direct actuator control**

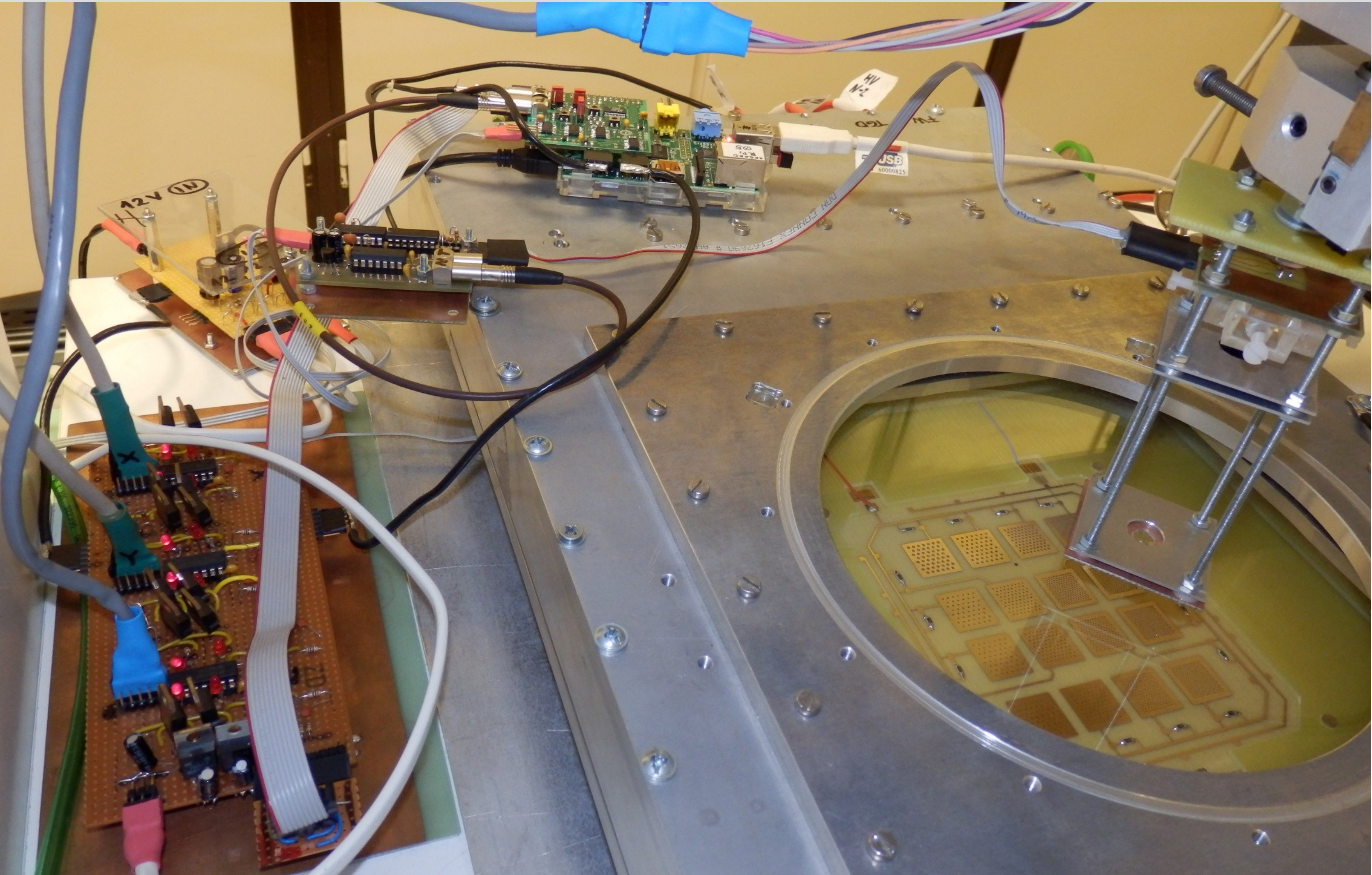
  (can be accomodated
  to any moving controls)



- Software: C,C++ runs on the RPi
- ADC (w DSP), save spectra
- Control 3D table and HV system
- GUI on remote PC (wxWidgets)



Working Tabletop Setup



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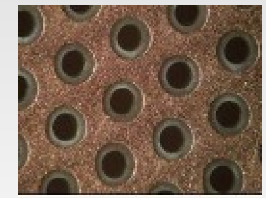
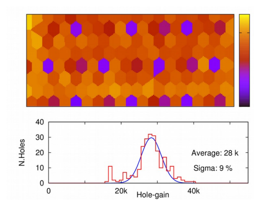
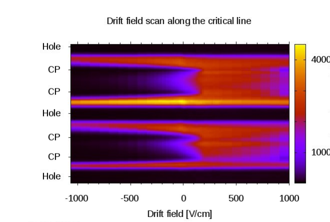






TGEM+MM Hybrid as Basic Setup in Trieste

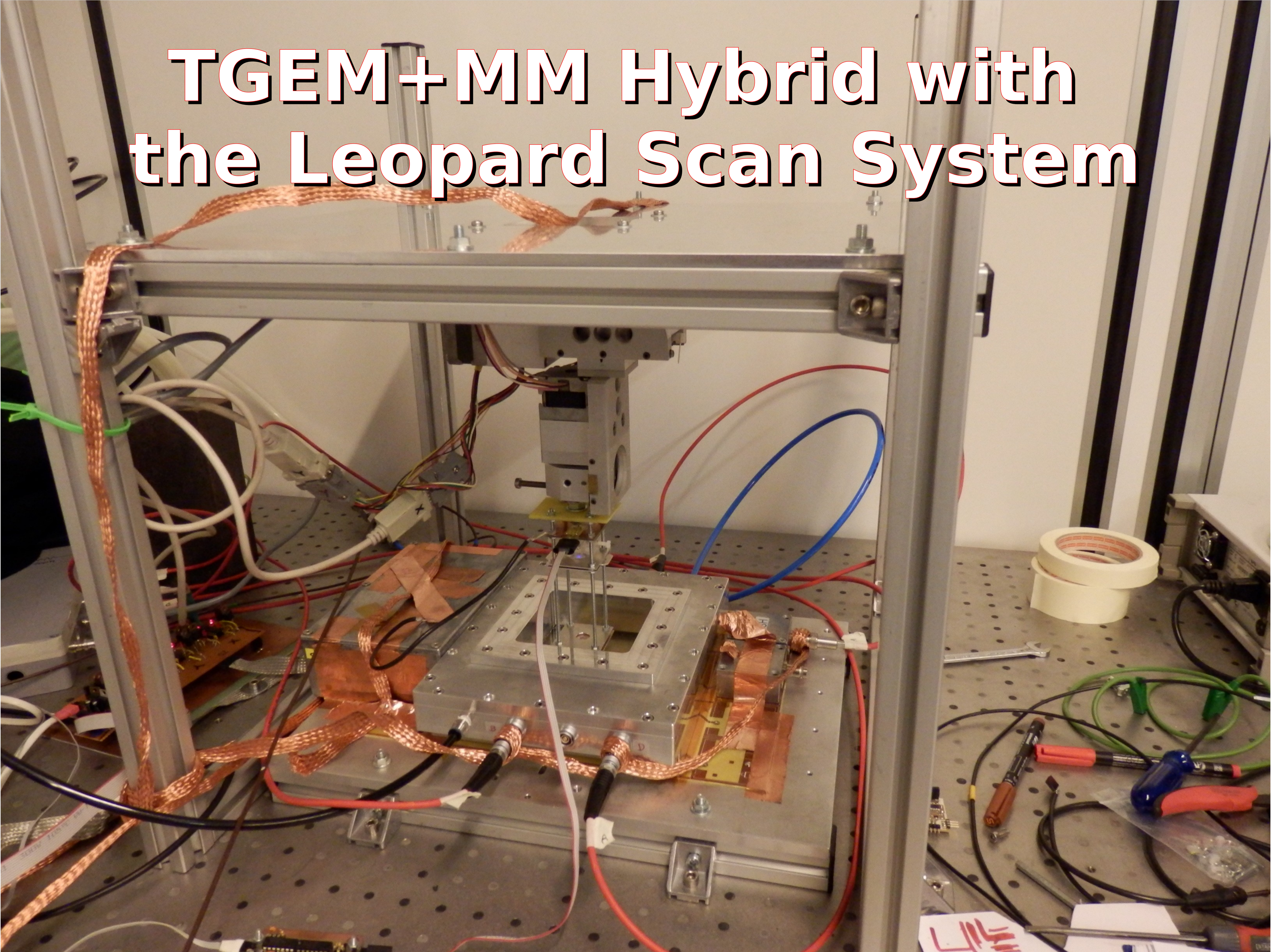
- To compate THGEMs „single THGEM layer" configuration should be used
- Used Hybrid (from photon view) :
  - Quartz window (for UV light)
  - Wire cathode : 100µm / 2mm spacing (along X axis)
  - TGEM in study
  - Bulk micromesh : 45/18 and 128µm for gap (CERN)
  - Padplane : 1D strips of 150/150 µm (alogn Y axis)
- Gas : Ar/CH_4 : 30/70

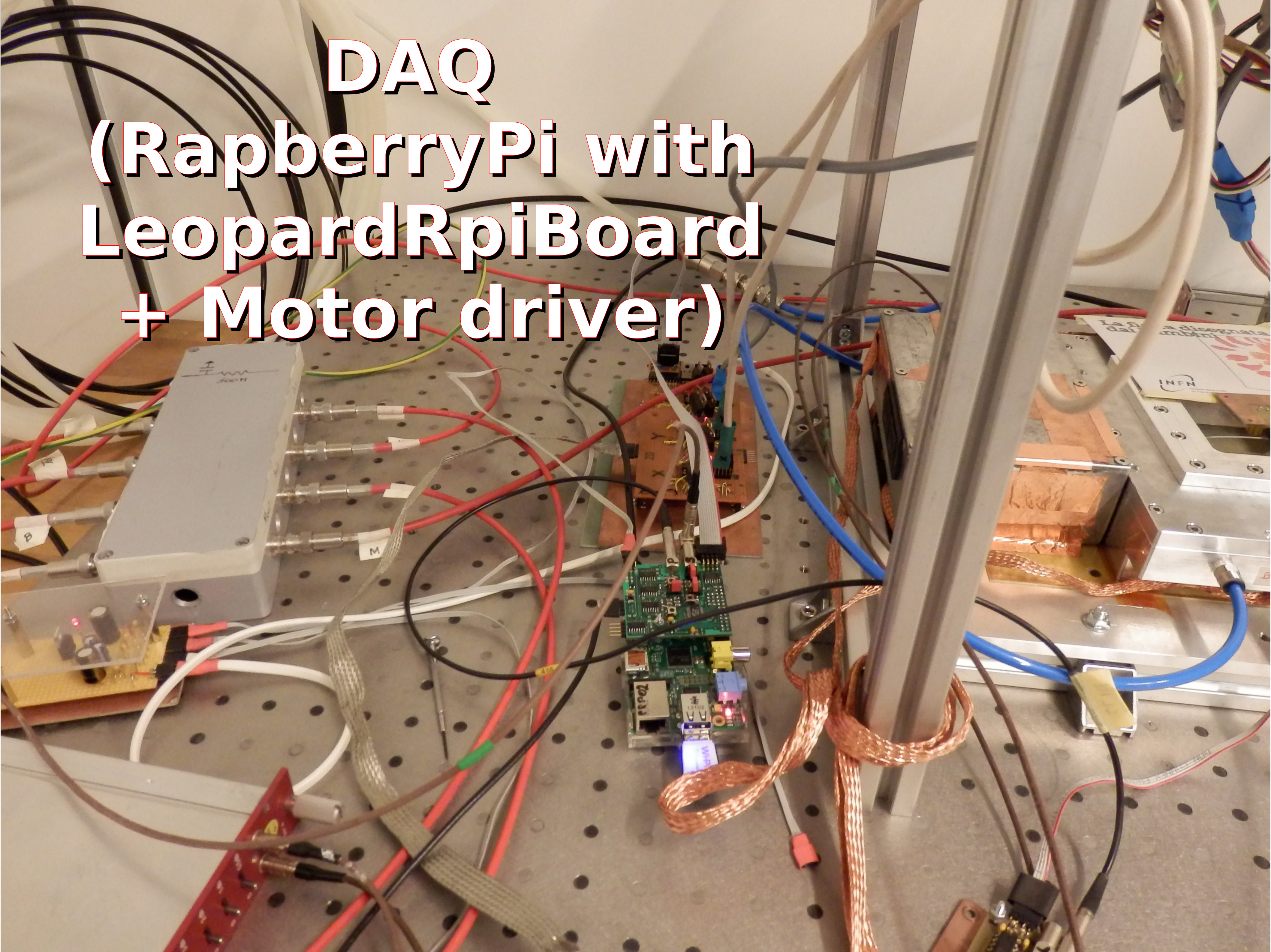
  and Ar/CO_2 for the long runs during the night

ThickGEMs in Study

- Based on the experience of the INFN Trieste group
- Several different TGEMs were sudied to compare:
  rim, thickness, hole size, production process
- All were gold plated (CsI was not required at this stage)
- Target issues:
  Uniformity
  Gain distribution
  Critical points
  Charge up

ThGEM Name	Hole [μm]	Pitch [μm]	Thickness [μm]	Rim [μm]
M1-III	400	800	400	0
DESTRO-I	400	800	400	5
C3HR-II	400	800	400	50
M2.4-G	400	800	600	0
M2.1-II	300	800	400	0


TGEM+MM Hybrid with
the Leopard Scan System


DAQ
(RapberryPi with
LeopardRpiBoard
+ Motor driver)
INFN

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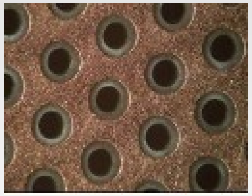
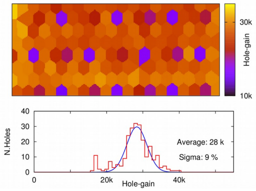
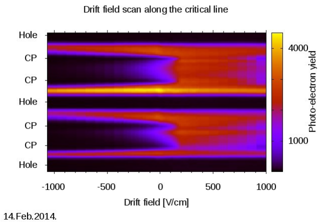
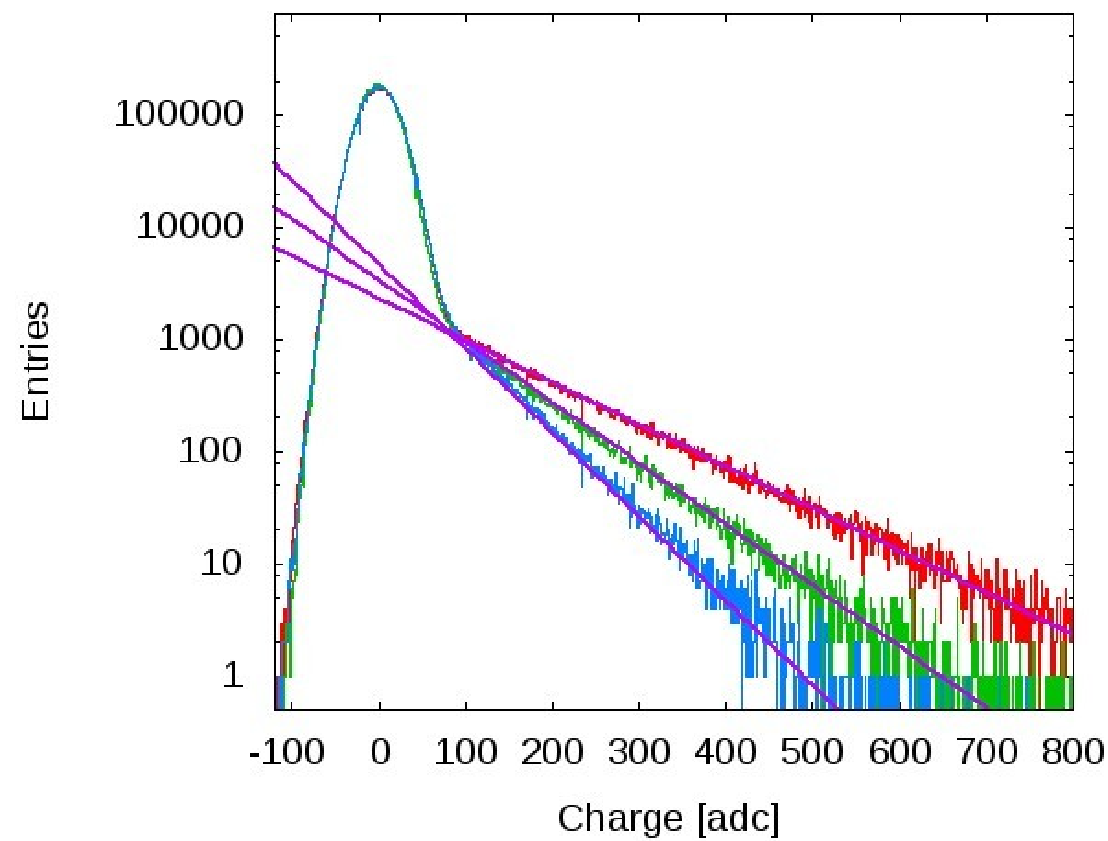






Data and Quantities

- UV light focused onto a 50 μm spot (MP)
- Single photo-electron spectrum in every MP



Data and Quantities

- UV light focused onto a 50 μm spot (MP)
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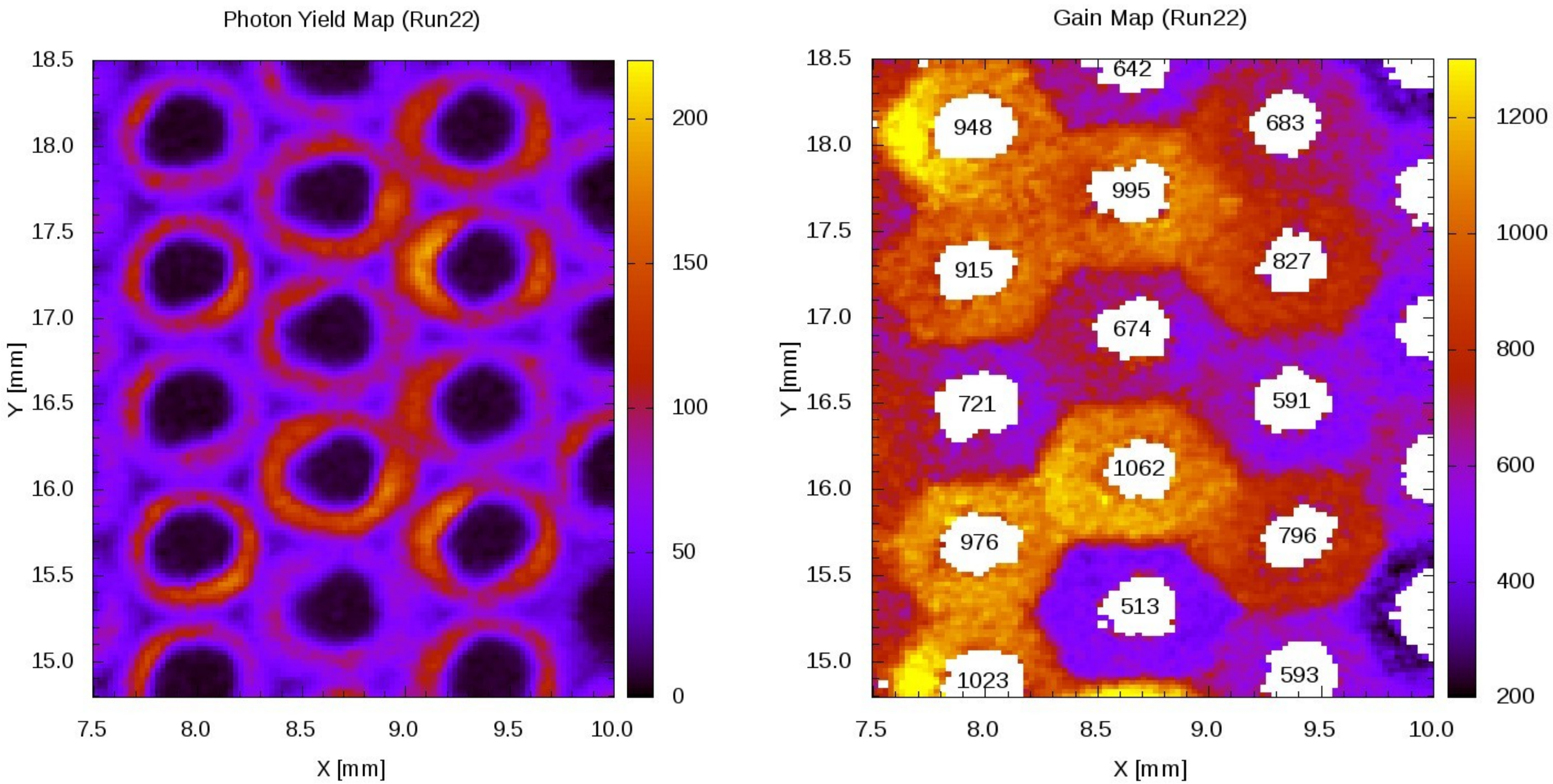
- Compute photo-electron yield and gain for every MP

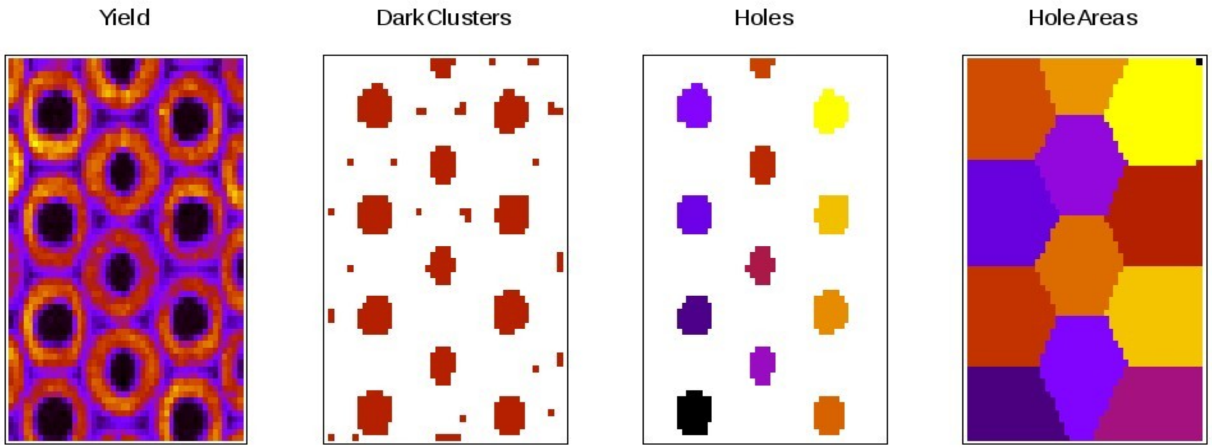


RICH2016

Data and Quantities

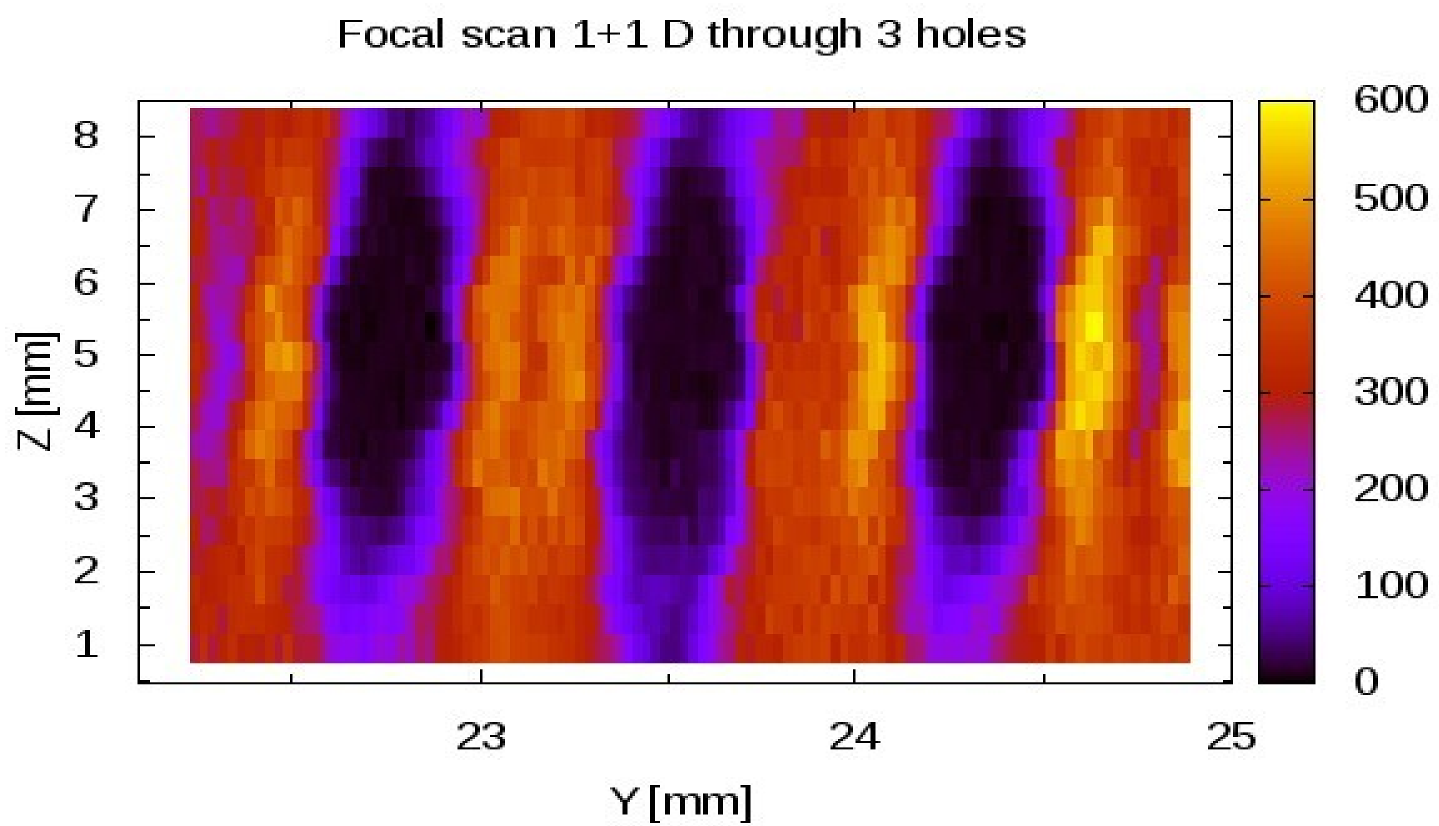
- UV light focused onto a 50 μm spot (MP)
- Single photo-electron spectrum in every MP
- Compute photo-electron yield and gain for every MP
- Search for holes, compute "hole-level" quantities

- Default plots:
  Yield map
  Gain map
  Hole-gain distr.



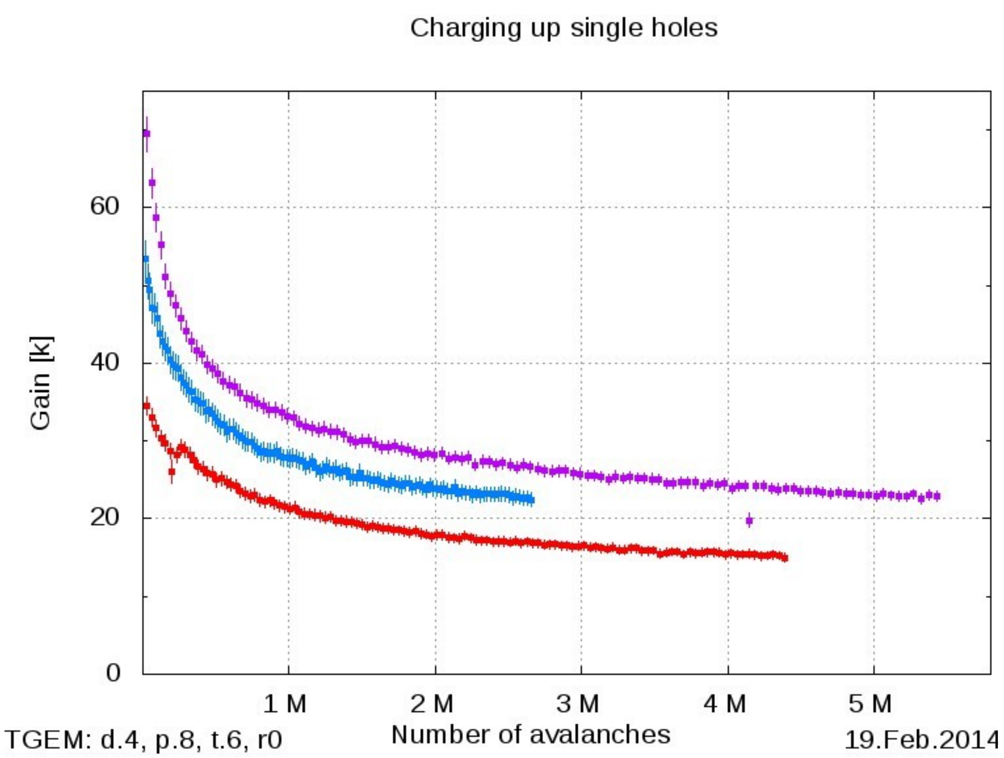
Setting the Focus

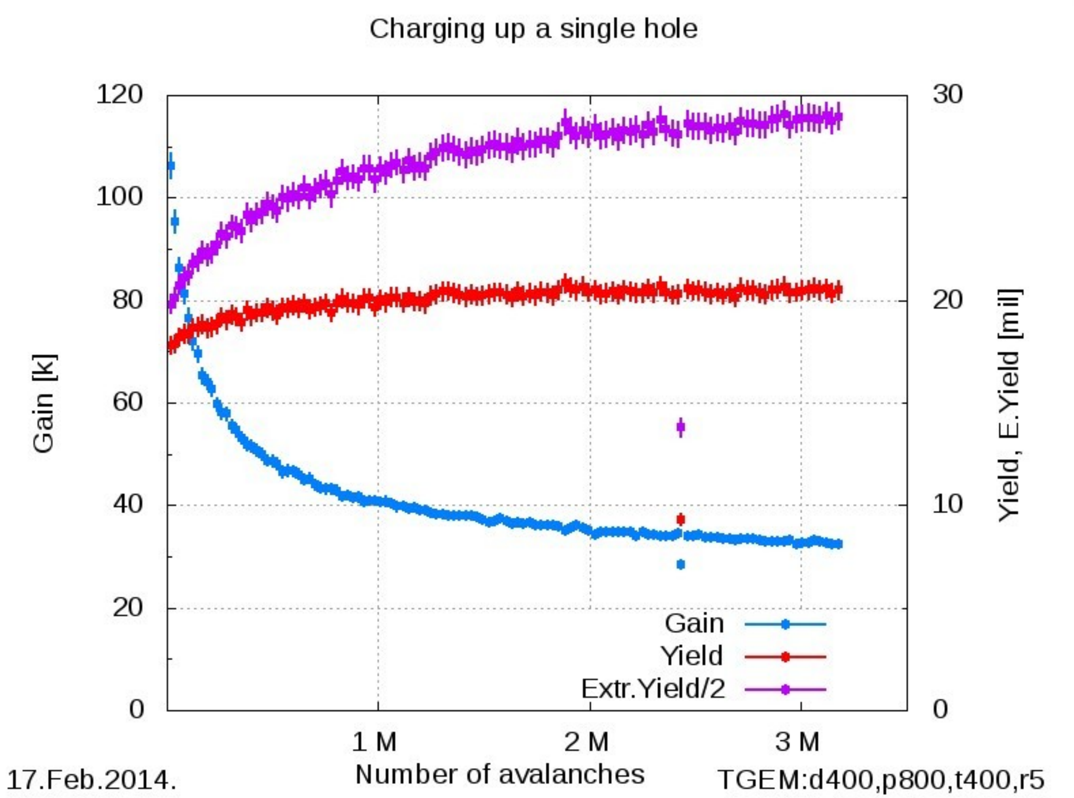
- Finetuning the focal distance with measuremets
- 1+1 (or 2+1) dimension scans
  → select the sharpest slice (image)



The Charge-Up Effect

- Charge up : an <u>area</u> or a <u>**single hole**</u>
- The **decrease of gain** has been seen
- Significant increase of the photon yield has been measured
  (Time constant is diffentent from the one in the change of gain)
- Eliminating the charge-up effects:
  Before the scan the area was shone with high luminosity





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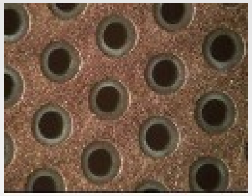
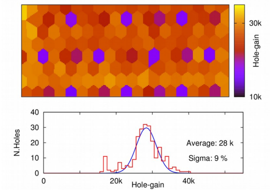
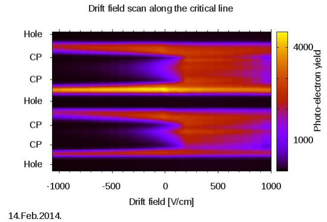
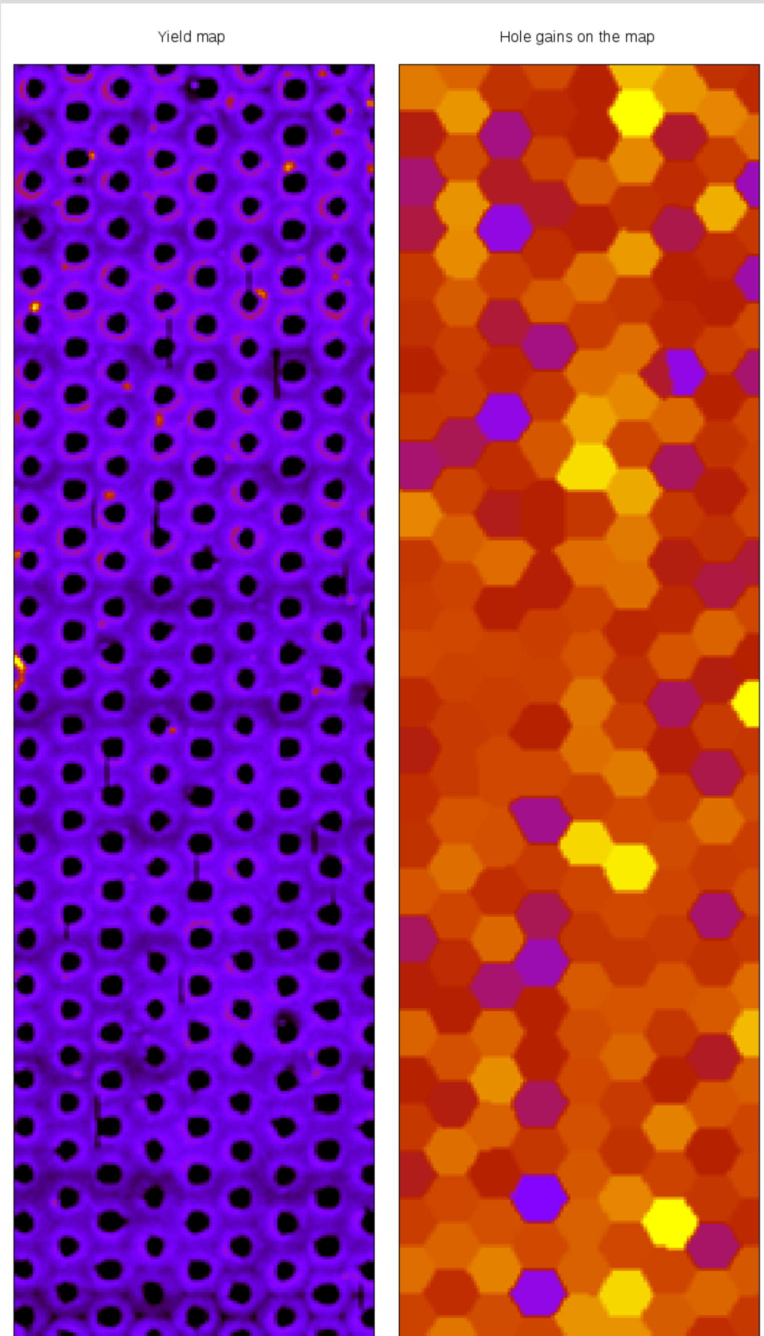


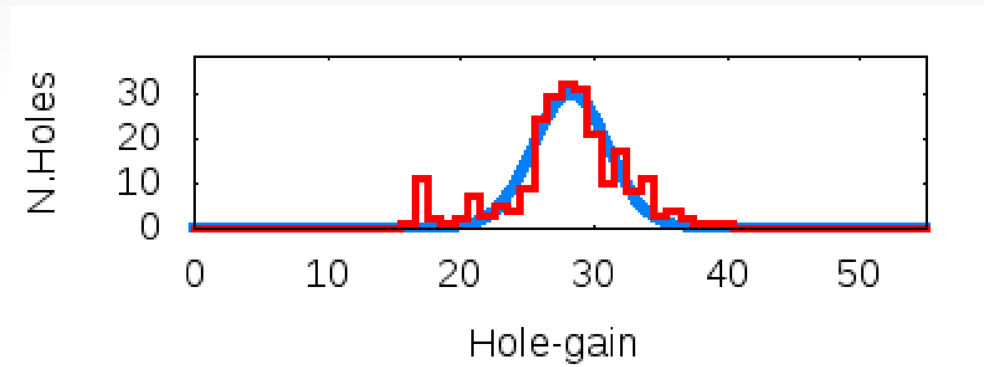




Gain Uniformity Studies



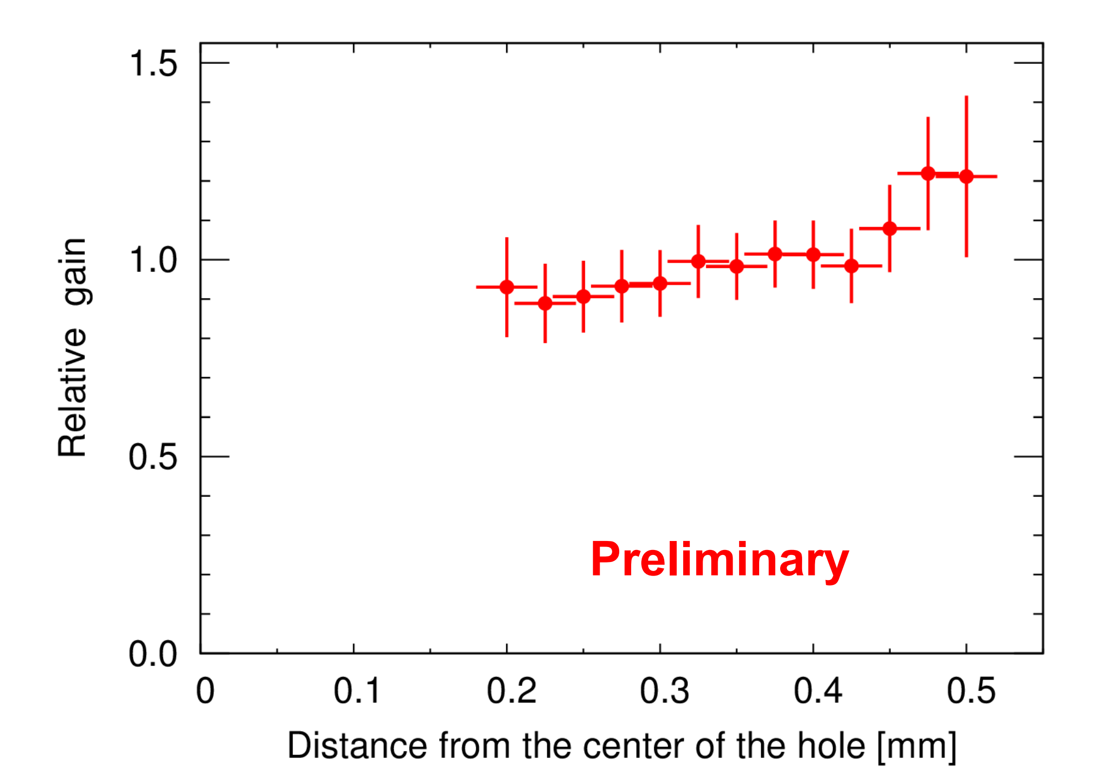
- Long runs for statistics on large areas
- Evaluation of the "hole-gain" distribution
- Comparative test for every THGEMs



ThGEM Name	Applied averge gain	Standard deviation	Number of used holes
M1-III	39900	12.0%	317
DESTRO-I	24100	11.0%	194
C3HR-II	47100	21.6%	247
M2.4-G	76200	21.2%	268
M2.1-II	24000	8.3%	323

Avalanche Size

- Does the size of the electron avalanche
  depend on the point the electron enters into the hole ?
- Leopard :
  Place of PE emission
  < = ? = >
  point of entering
- Diffusion ...
- Preliminary results
  with DESTO-I
  are compatible with
  a flat distribution (?)



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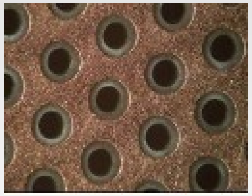
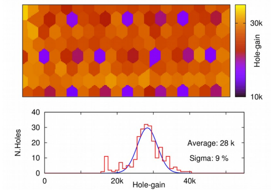
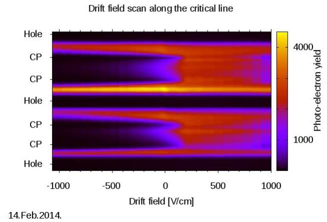
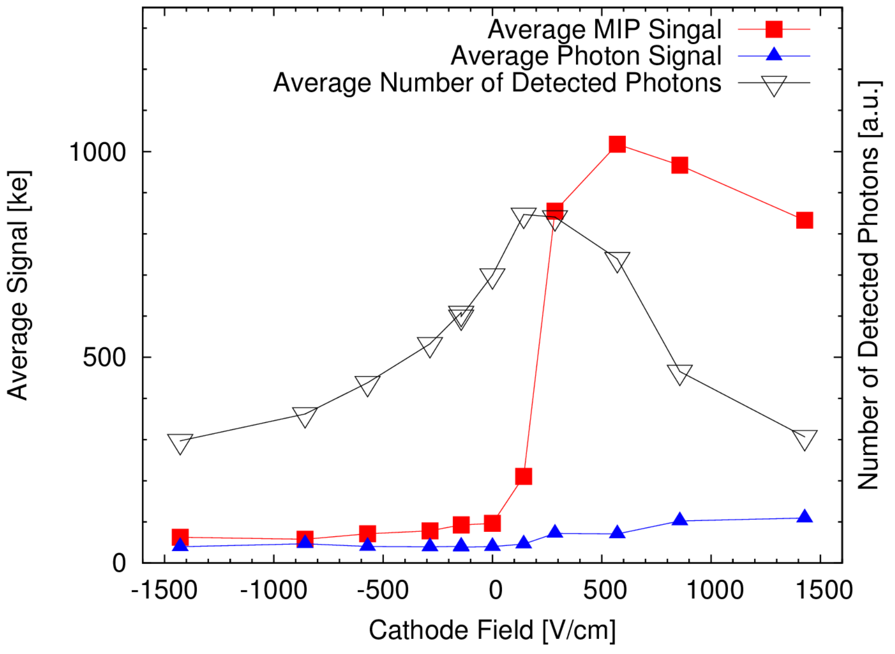




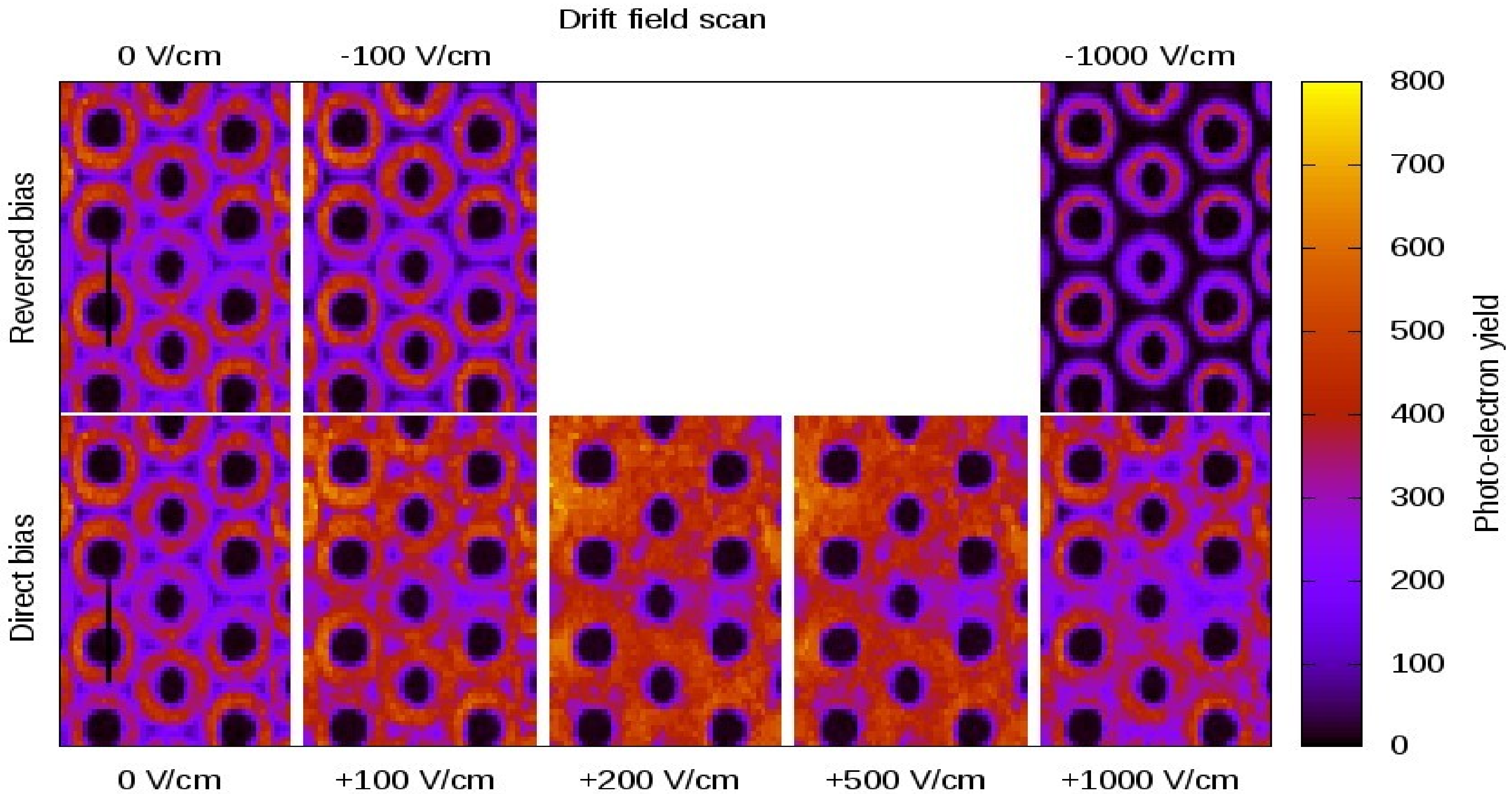


Effects of the Drift Field

- Optimization of drift field could be crucial
  - MIP suppression needs reversed drift field
  - PHENIX HBD : close to zero field
  - For the critical symmetry points : non-zero normal drift is needed
- With the Leopard setup the point-by-point and integrated photo-electron yields can be examined

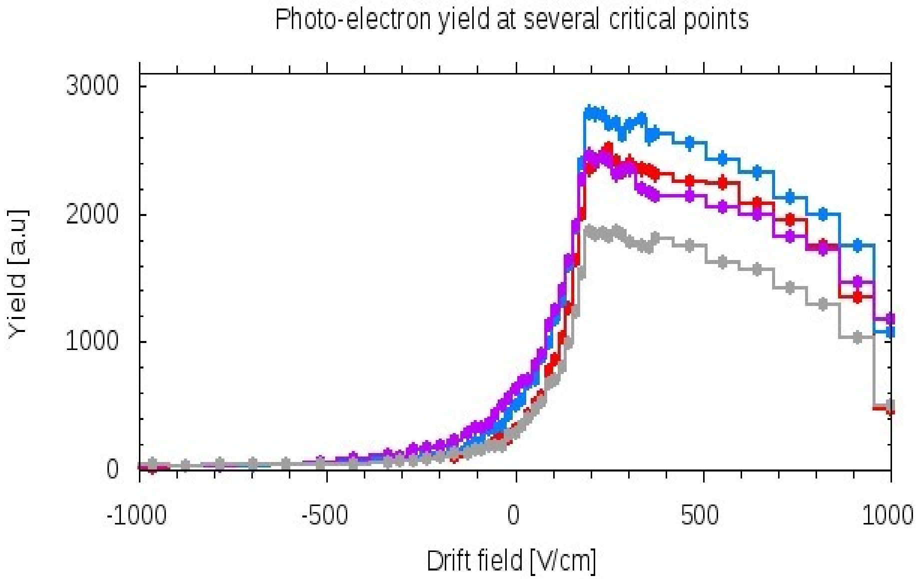


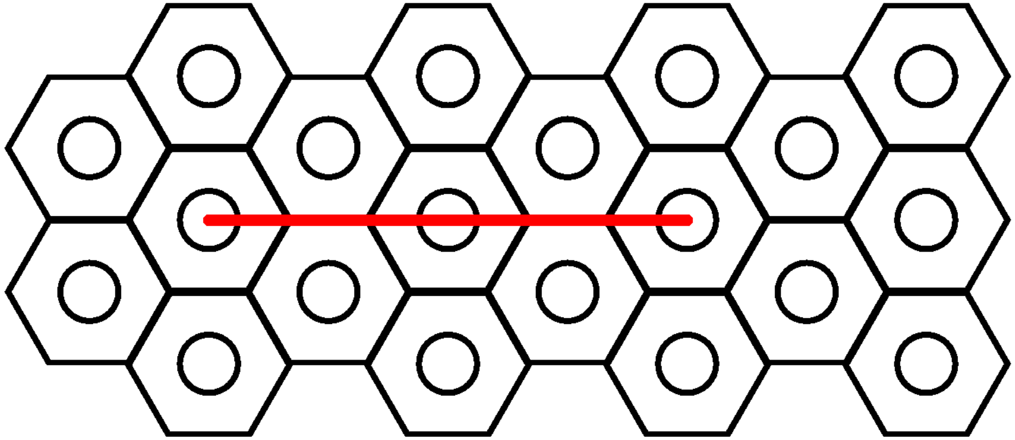
Drift Field Scan



"Critical Line" Scan

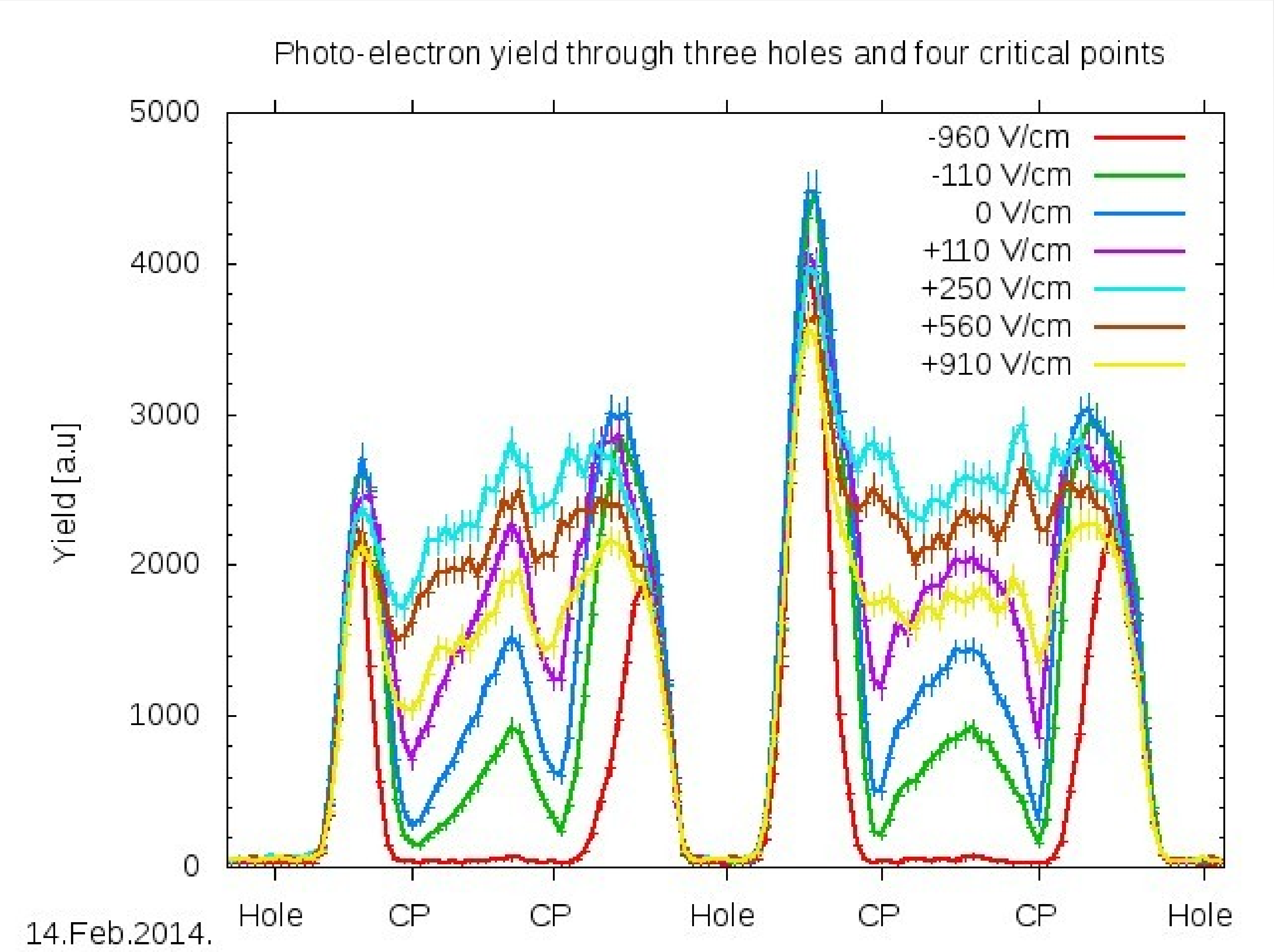
- Critical symmetry points and symmetry lines are most the effected by the drift field
- Dependance in the crytical point is measurable (Focused light + HV scan)
- Systematic studies on these kind of points with comparision to the standard points ?
  → 1 dimension scan along a line (with several voltage settings)



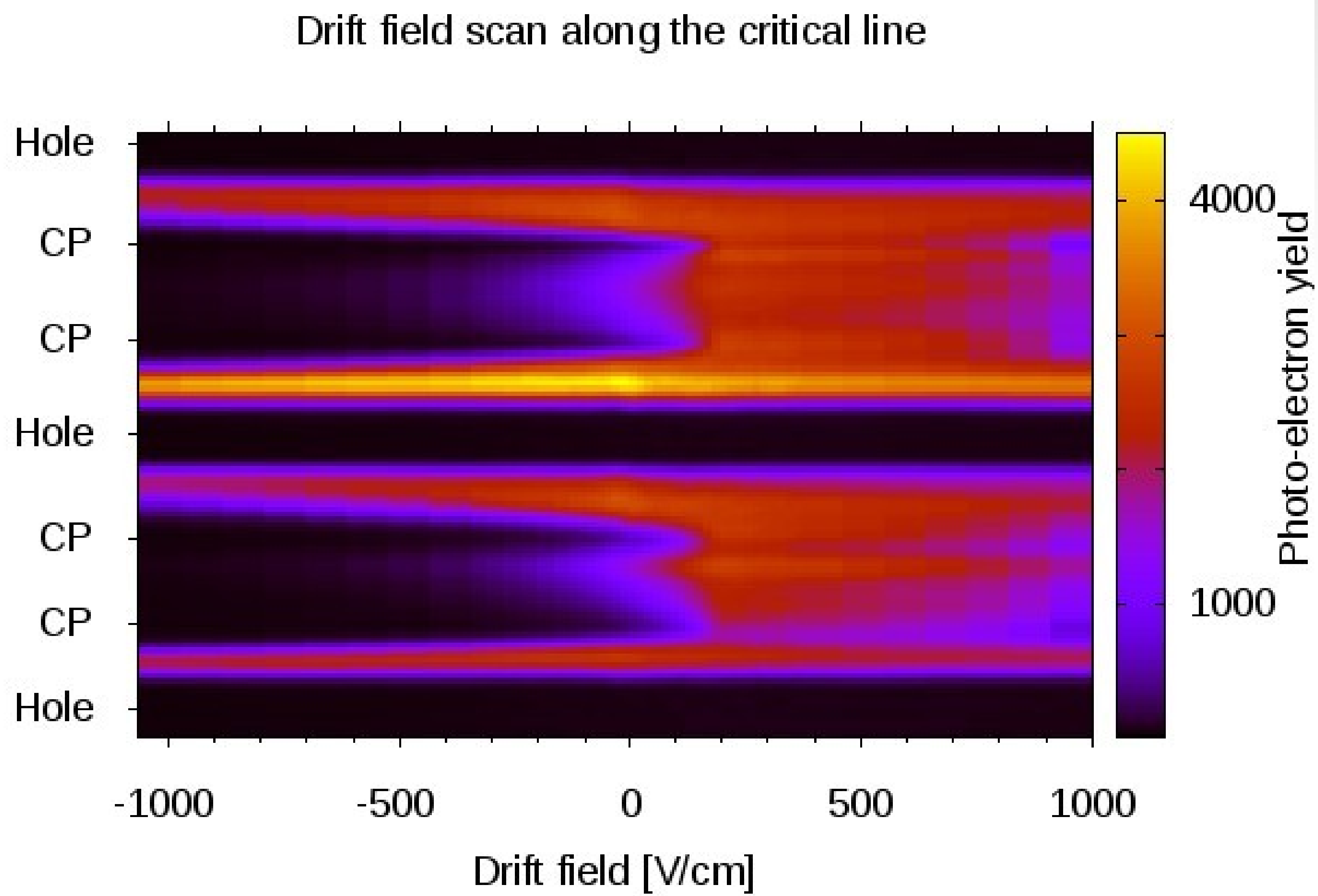


Critical Line Scan : Samples

- Critical points are clearly visible
- Evolution as expected from former measurements

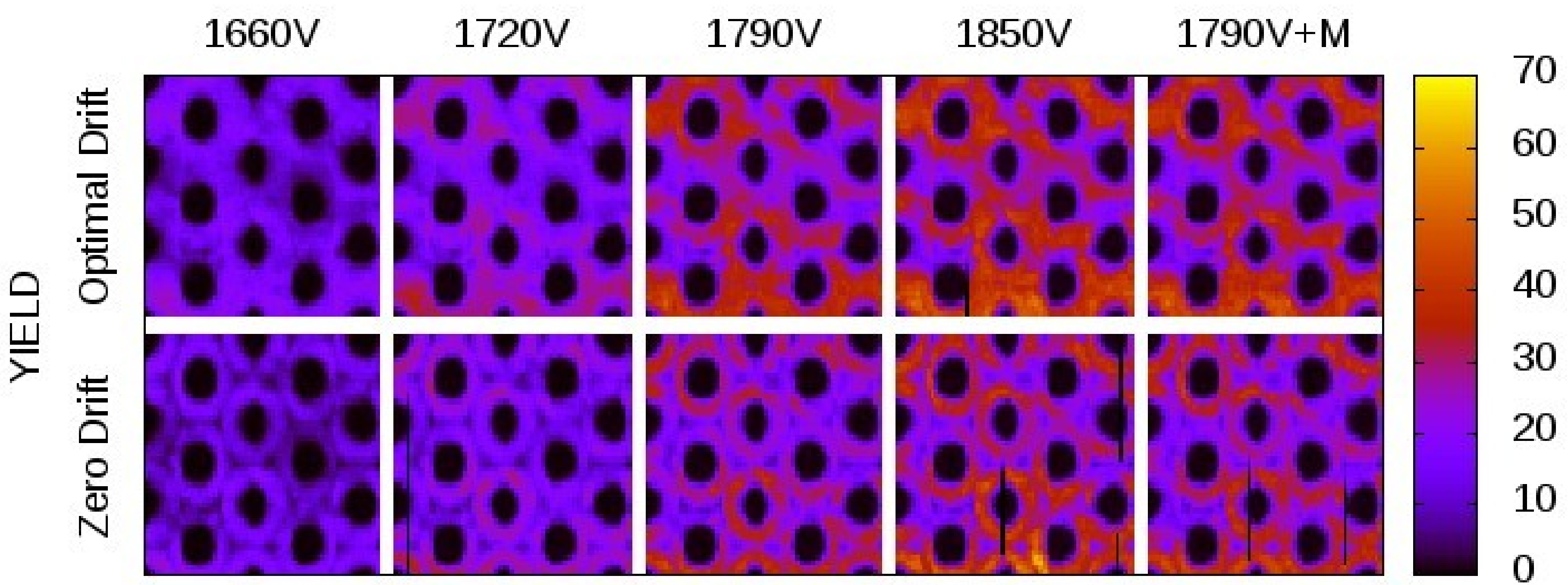


Critical Line vs. Drift



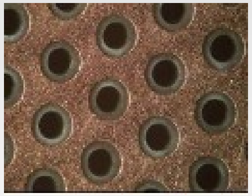
TGEM Voltage and Yield

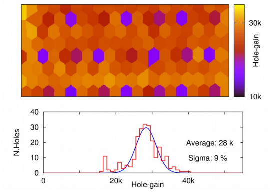
- Higher U_{TGEM} means higher field on the top
- What is the minimal necessary voltage (to have max yield without sparks)

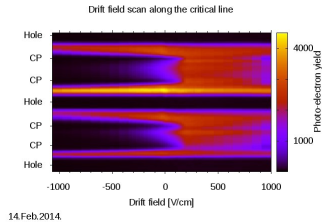


Outline

- Micro-pattern RICH
- ThickGEM microstucture
- The Leopard system
- Trieste-Budapest setup
- Data and analysis
- Gain uniformity
- Drift field effects
- **Summary**

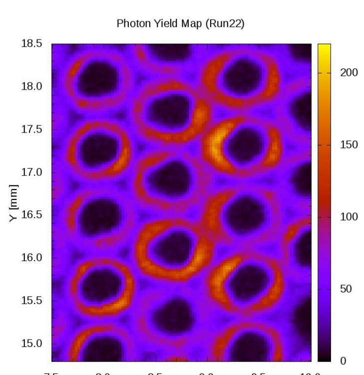


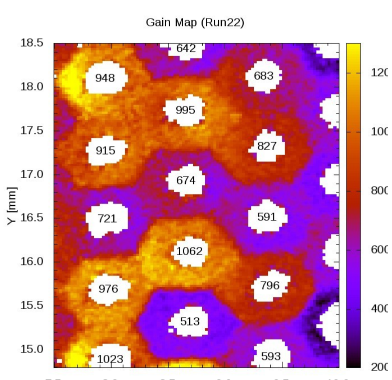


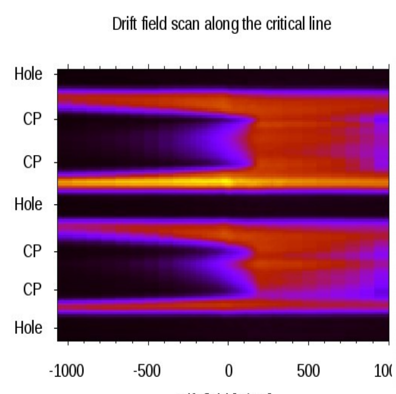


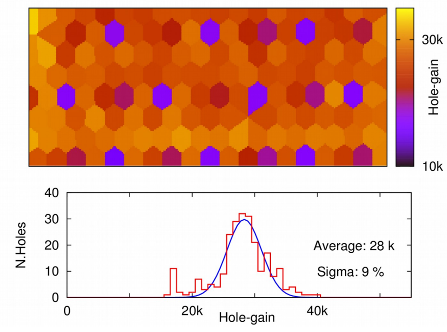
Summary

- Leopard System
  - Examine microstructure of MPGD
  - Realized as table-top setup
- Yield+Gain map, Hole-level behaviour → Simulations
- Optimization : Detailed Studies on ThickGEMs
  - Hole-gain distribution, comparision of different geometries
  - Optimization methods for voltage settings,
    Critical point/line behaviour
- Applicability for other gaseous devices as well
- Characterization → Novel device for quality assurance
- Upgrades and steps towards a large are device

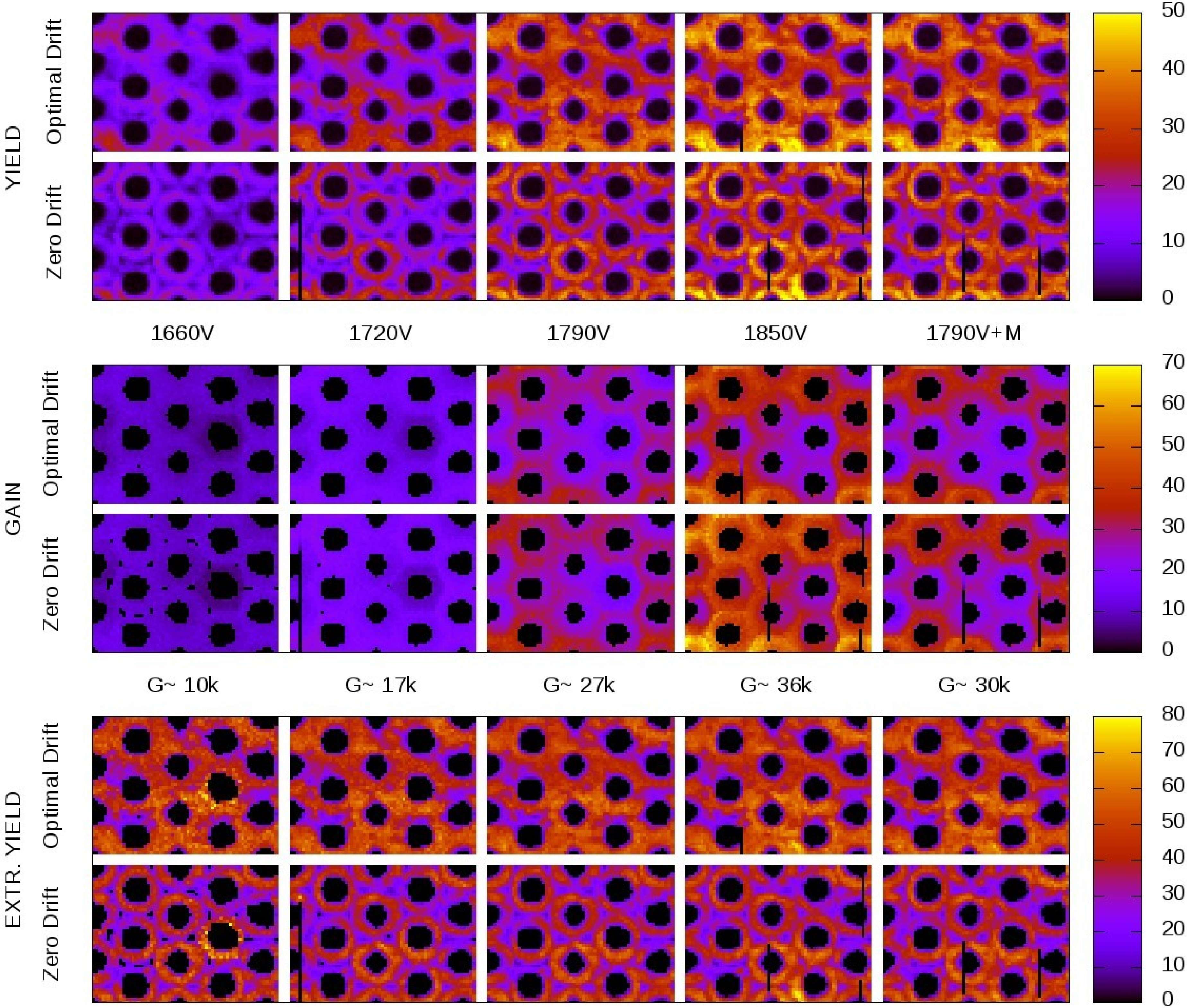




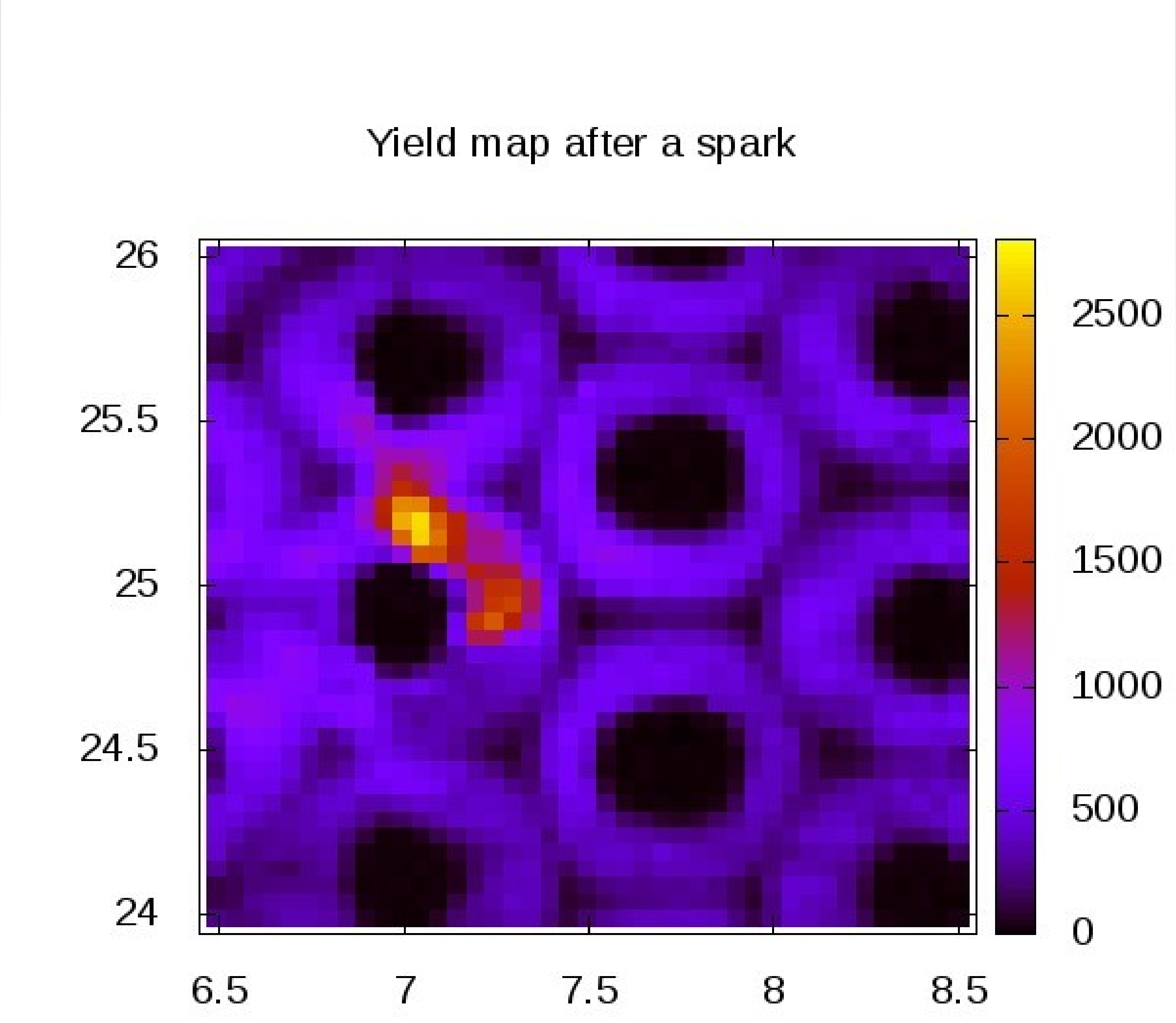


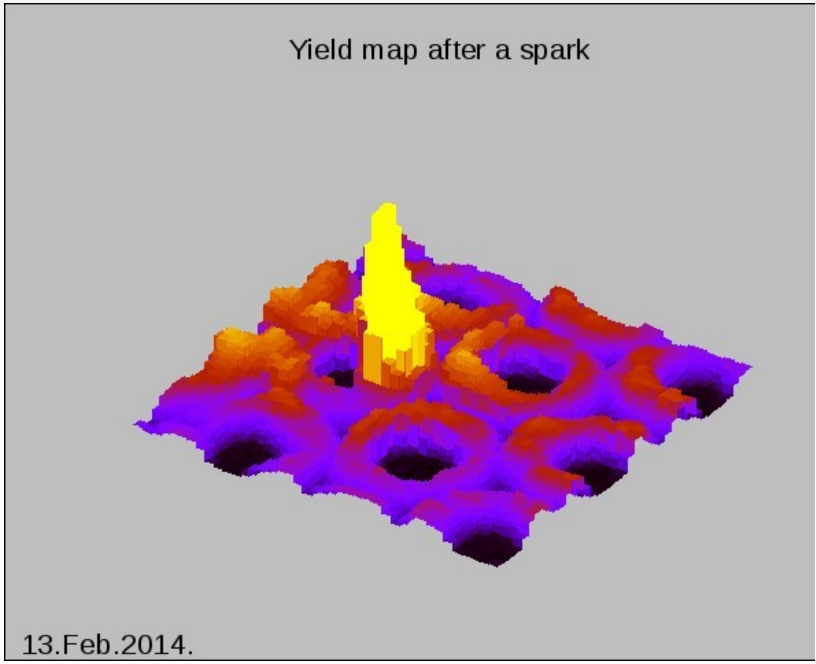


Extra slides

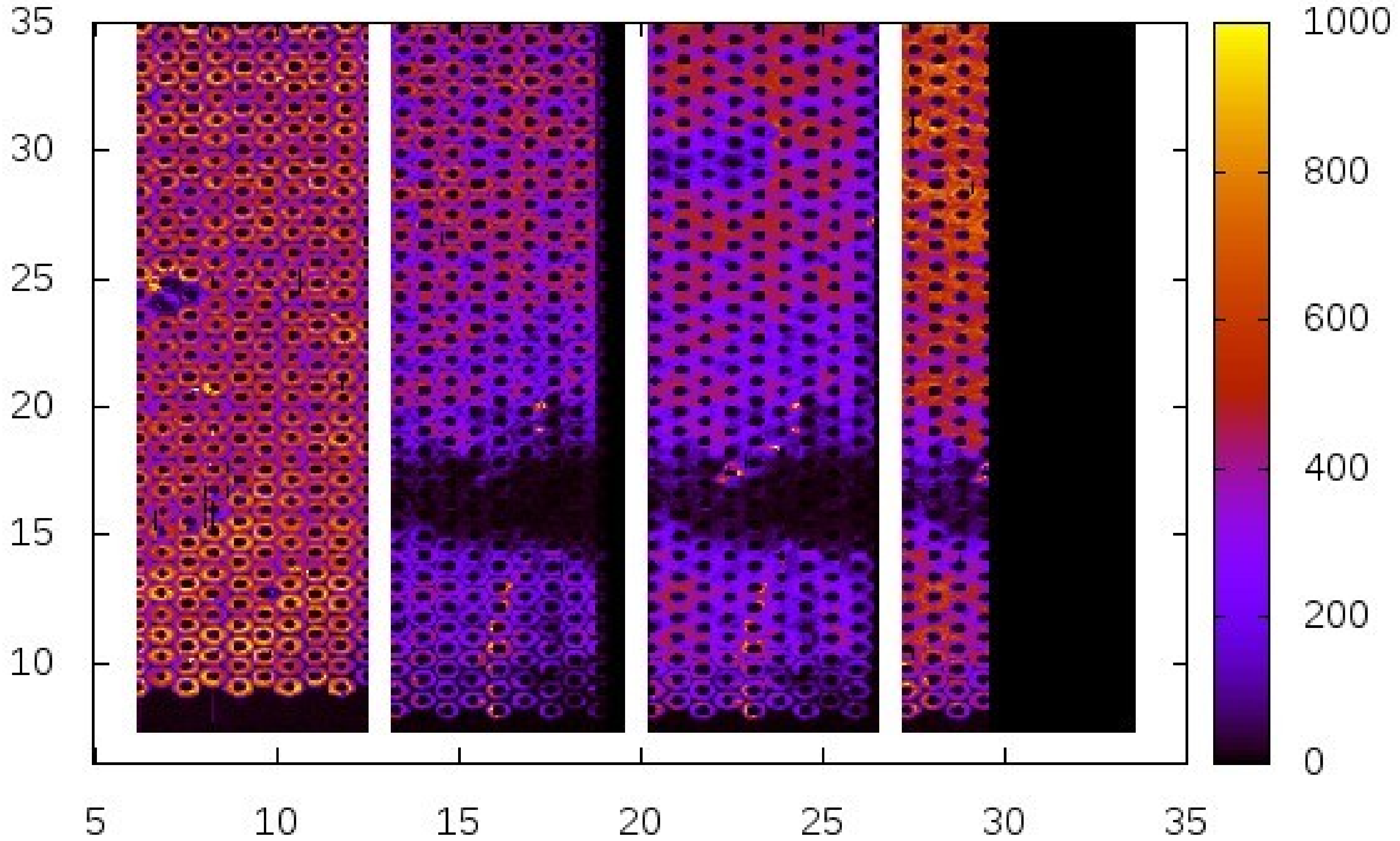

YIELD
Optimal Drift
Zero Drift
1660V
1720V
1790V
1850V
1790V+M
50
40
30
20
10
0
GAIN
Optimal Drift
Zero Drift
G~ 10k
G~ 17k
G~ 27k
G~ 36k
G~ 30k
70
60
50
40
30
20
10
0
EXTR. YIELD
Optimal Drift
Zero Drift
80
70
60
50
40
30
20
10
0

Sparks

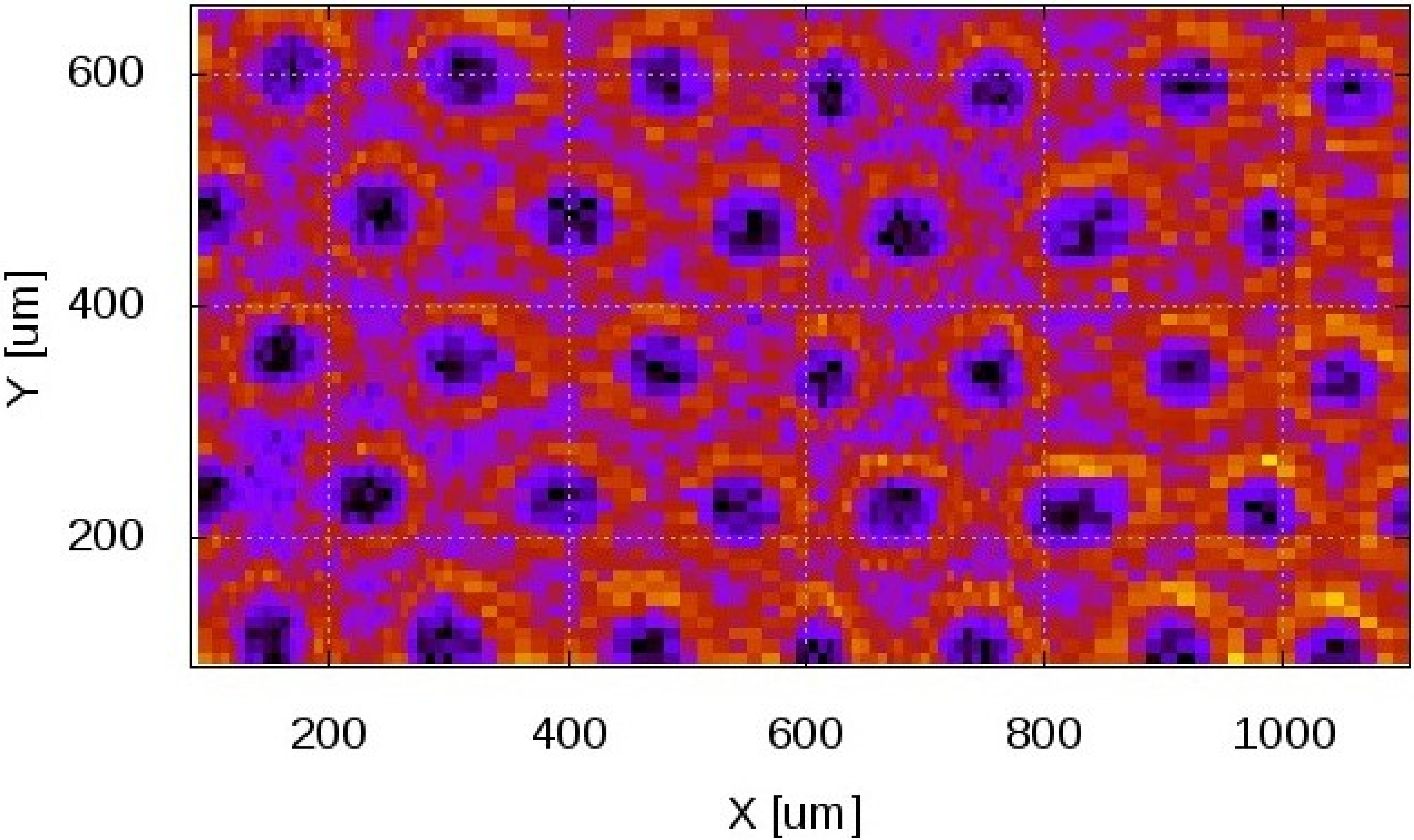

Yield map after a spark
26
25.5
25
24.5
24
6.5
7
7.5
8
8.5
2500
2000
1500
1000
500
0


Yield map after a spark
13.Feb.2014.

Long runs during nights with Ar/CO_2

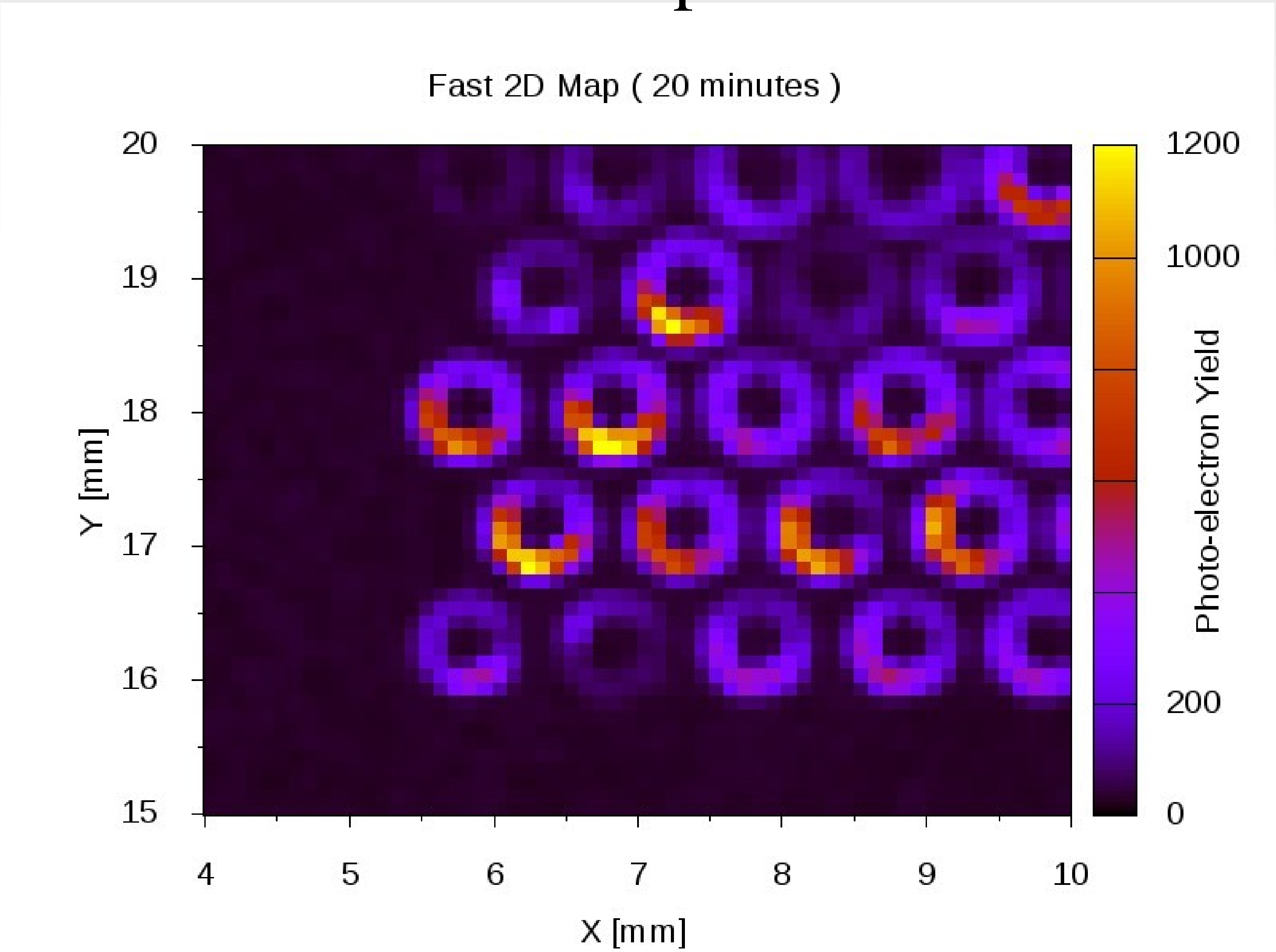


Normal GEM Foil



Speed : 20 min run

- DAQ rate : 120 kHz achieved with 99.5 % events accepted



Gain sharing and separation

- Single TGEM examination
- Underlying structure (post amplification stage) is measureable via shining **through the holes**