Motivations for this R&D program

At present the <u>only economic way</u> to cover with photon detectors very large surfaces is to use gaseous photon detectors.

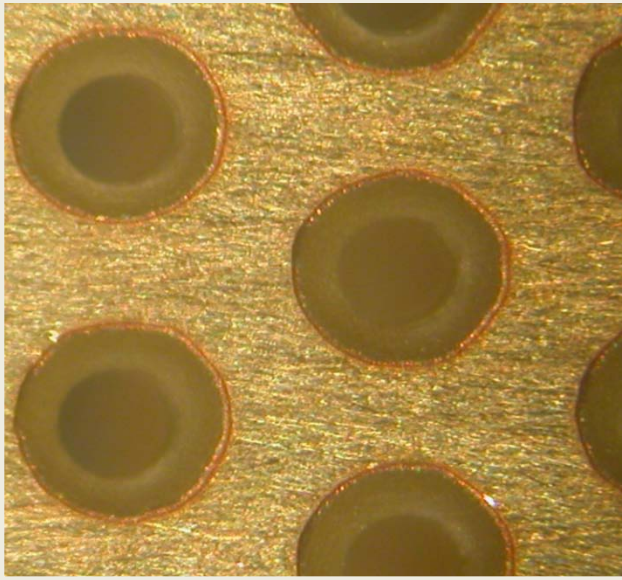
MWPC's with CsI are successfully used, but:

- **the effective gain is moderate (~10,000)**
- **the efficiency is challenged by aging (~1 mC/cm^2)**
- **the signal is slow, coming from the ions drift (~100 ns)**
- **the electrical stability in an experimental environment is limited and the recovery time after detector trip is long (~1 d)**

Performances in terms of rate capability and noise rejection cannot be increased without a change of technology, possibly in the direction of:

- **using a closed geometry to avoid photon feedback**
- **minimize ion backflow to the CsI layer**
- **detecting signals from electron drift (few ns)**
- **using simple and robust components**

We decided to try using THGEM's and reflective CsI photocathodes



Picture at the microscope

No need of high space resolution (> 1 mm)

Large area coverage (5.5 m^2 for COMPASS RICH)

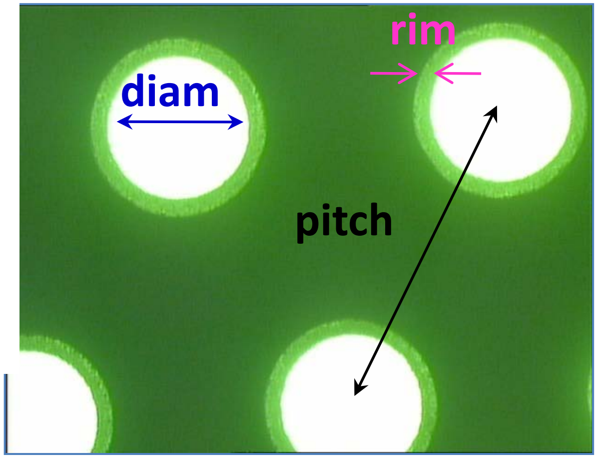
- **industrial production (standard pcb)**
- **good stiffness**
- **very robust against discharge damages**

For reflective photocathodes,

- **no need to keep the window at a fixed potential (2nm Cr →-20%)**
- **possibility of windowless geometry**
- **higher effective QE (larger pe extraction probability)**

→small photoconversion dead zones possible (~20%; GEM ~ 40%)

Large gain: > 10^6

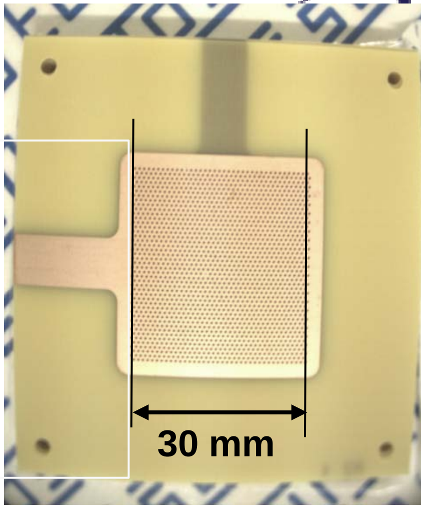


About two years ago we started a program to develop a suitable detector from existing experience and literature on THGEM's.

First step: testing the performances of THGEM's as electron multipliers:

- **range of attainable gains**
- **reproducibility and stability in time of the THGEM response**
- **role of the geometrical parameters:**
  thickness, hole diameter, pitch, rim size
- **dependence on THGEM material and production procedures**
- **performances in different operating conditions**

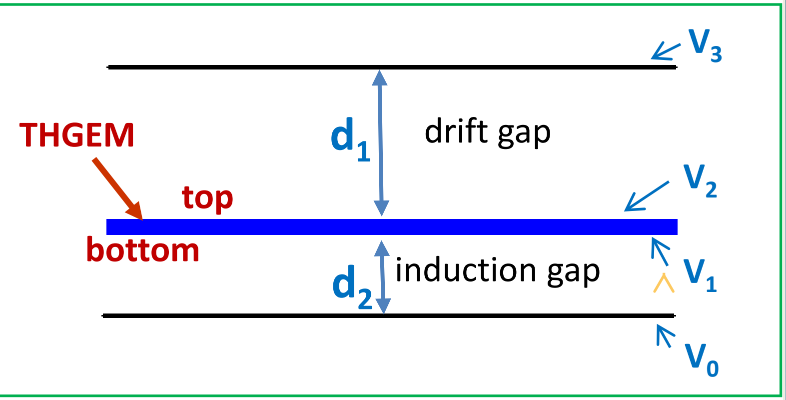
SETUP of the initial tests



Single THGEM layer in the chamber,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 approaches: gain from signal amplitude spectra
and from current measurements (pico-ammeters with resolution ~1pA)

tests performed at CERN MPGD Lab. and in Trieste:
more than 30 different THGEMs tested so far

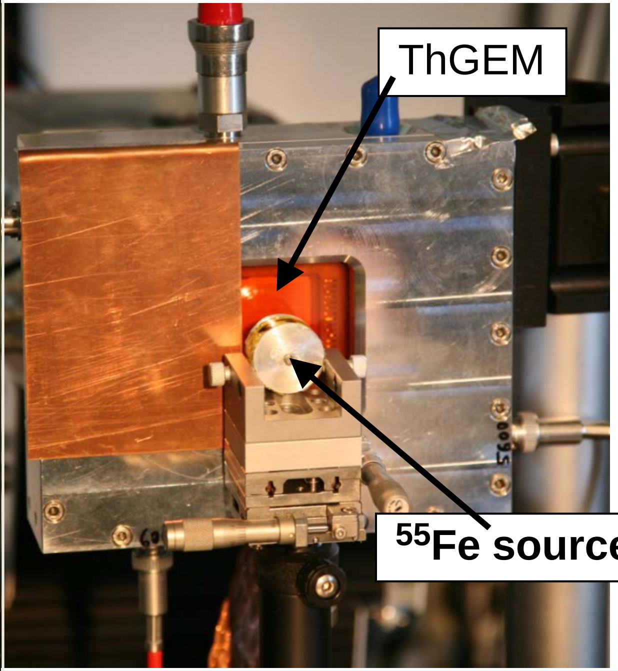
To detect ionizing particle :
$V_3 < V_2 < V_1 < V_0$



$E_{drift} = (V_3 - V_2)/d_1$

$E_{induction} = (V_1 - V_0)/d_2$

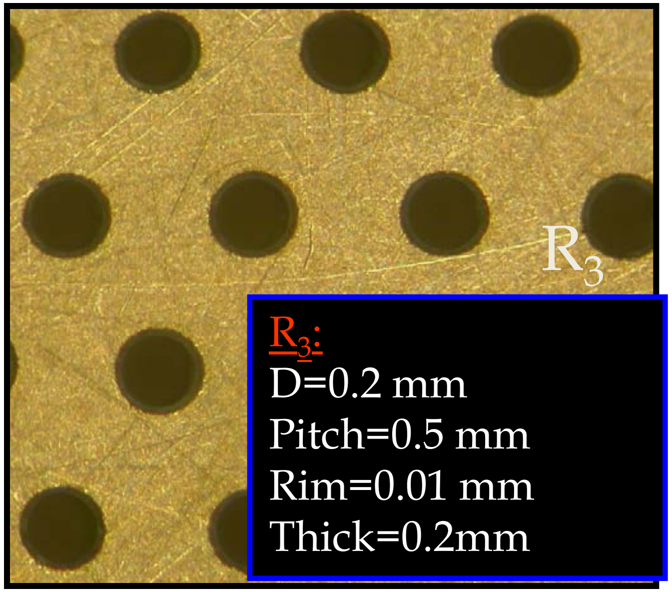
$\Delta V = V_2 - V_1$

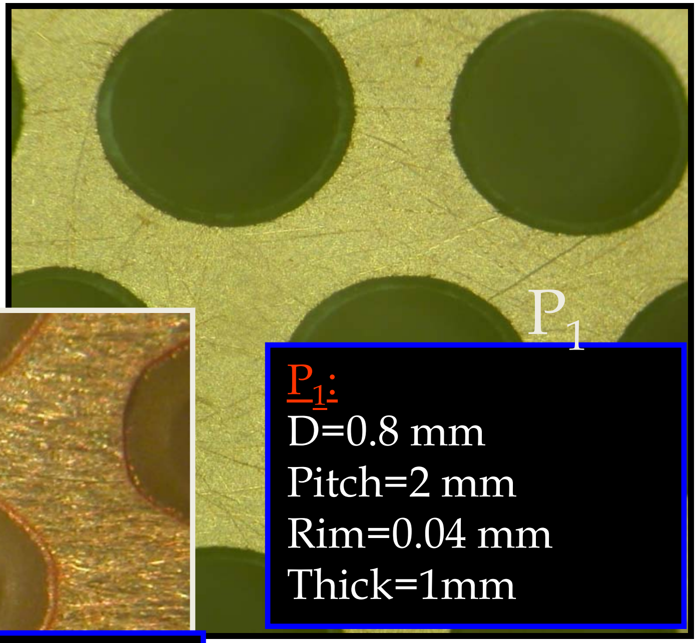


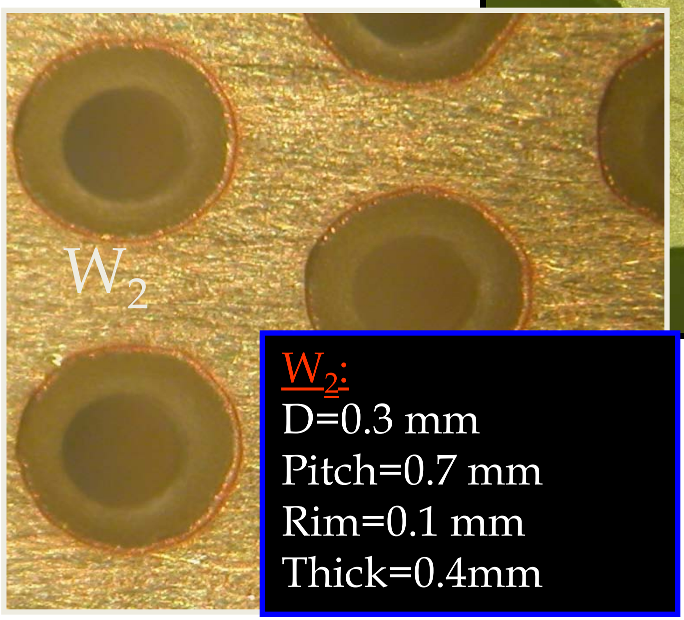
Characterization: 1- geometrical and production parameters

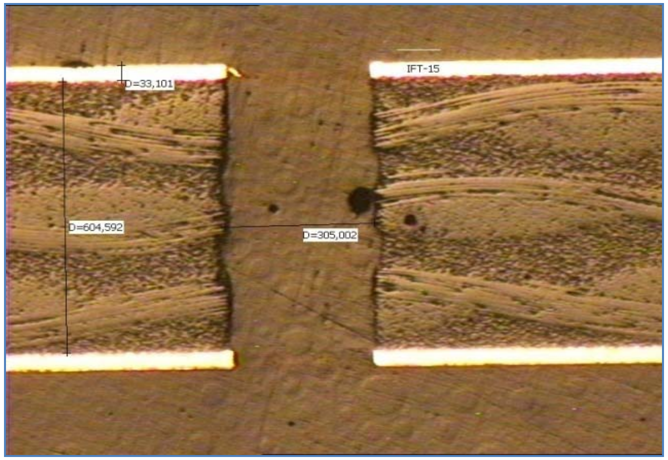
Multi parameter space exploration on **30 different THGEMs** allows to single out the role of

- diameter
- pitch
- rim
- thickness
- material
- production procedure









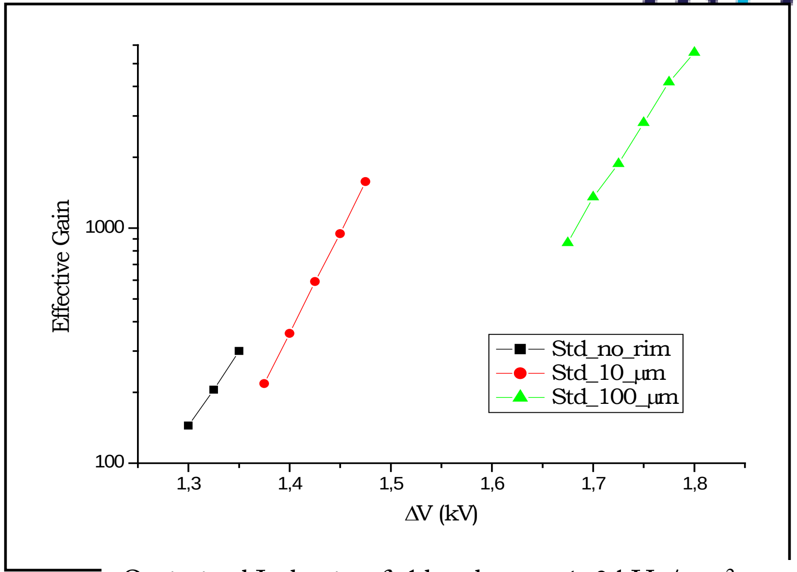
Characterization: 1- geometrical and production parameters: rim fundamental role

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

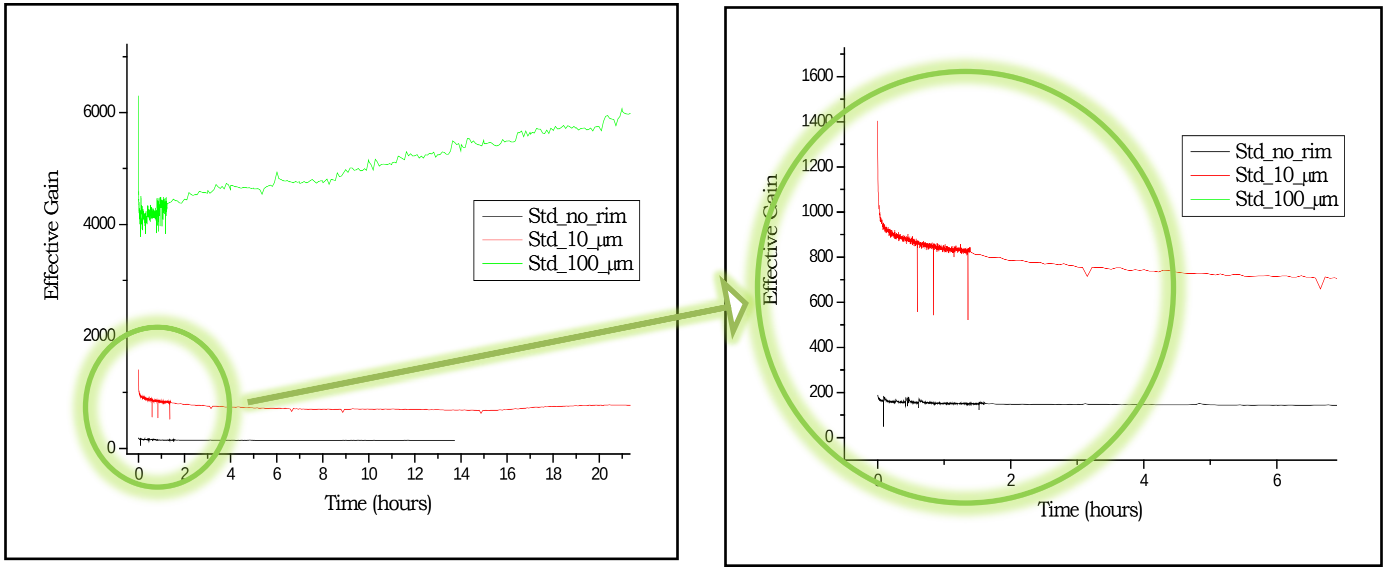
Important gain dependence vs. the rim size

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

Continuously irradiated with collimated X-Ray source



Optimized Induction field and rate ~ 1÷2 kHz/mm^2



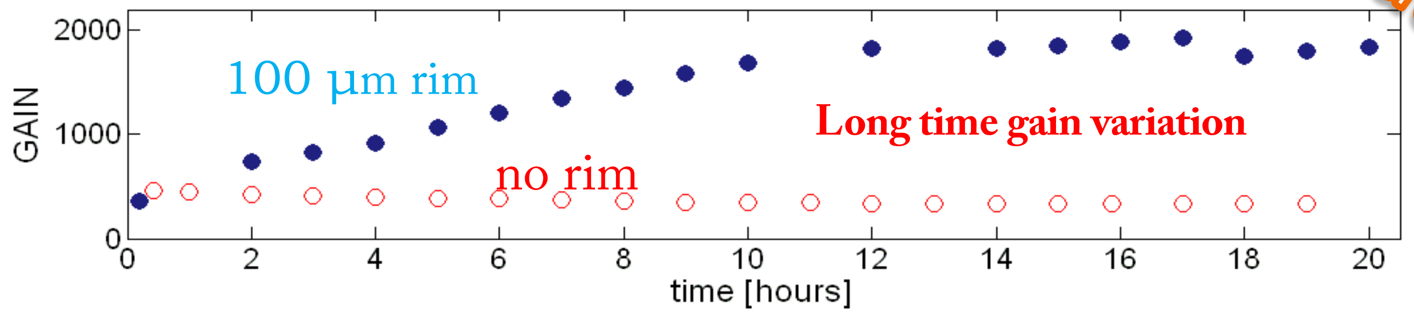
- A factor >>2 in gain variation between the initial drop and the stabilization;
- Different behaviour for THGEMs with and without (or small) rim.
- History dependent gain for THGEMs with rim

Characterization: 1- geometrical and production parameters: rim fundamental role

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

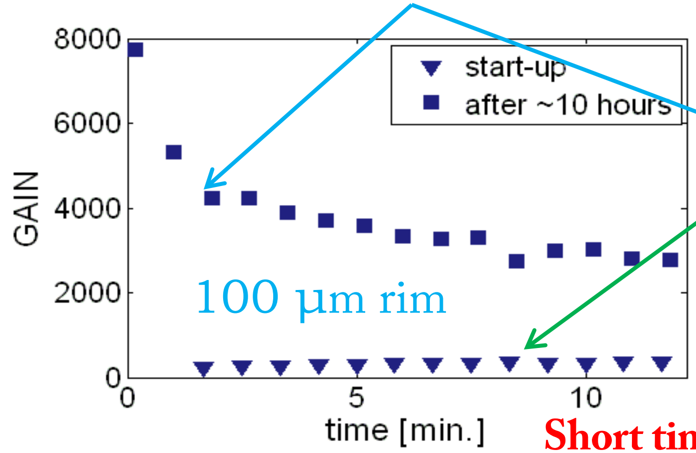
^{55}Fe source; uniform irradiation

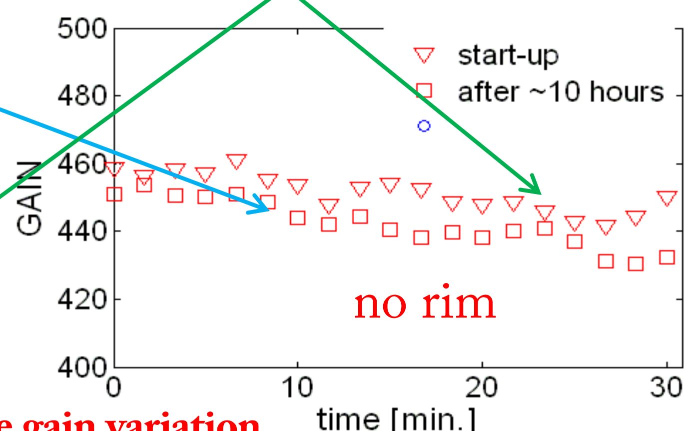
Reproducible



START IRRADIATING after ~10 hours at nominal voltage

Irradiation within HV switch on (after ~1 day with no voltage applied)

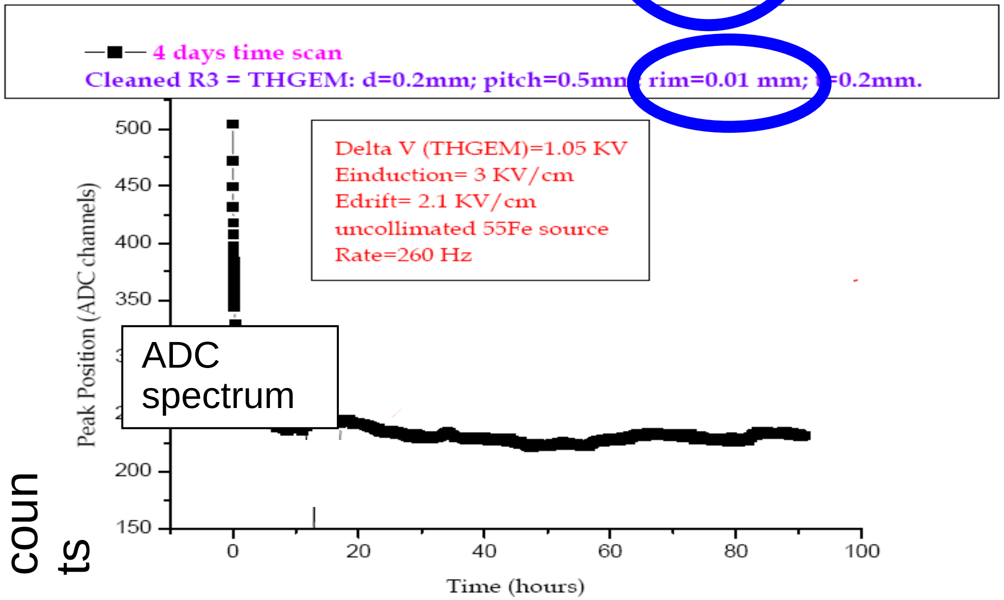


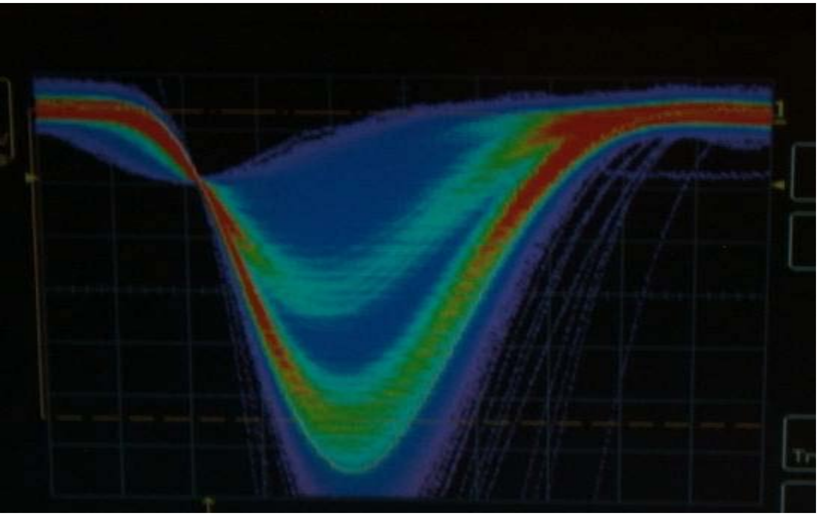


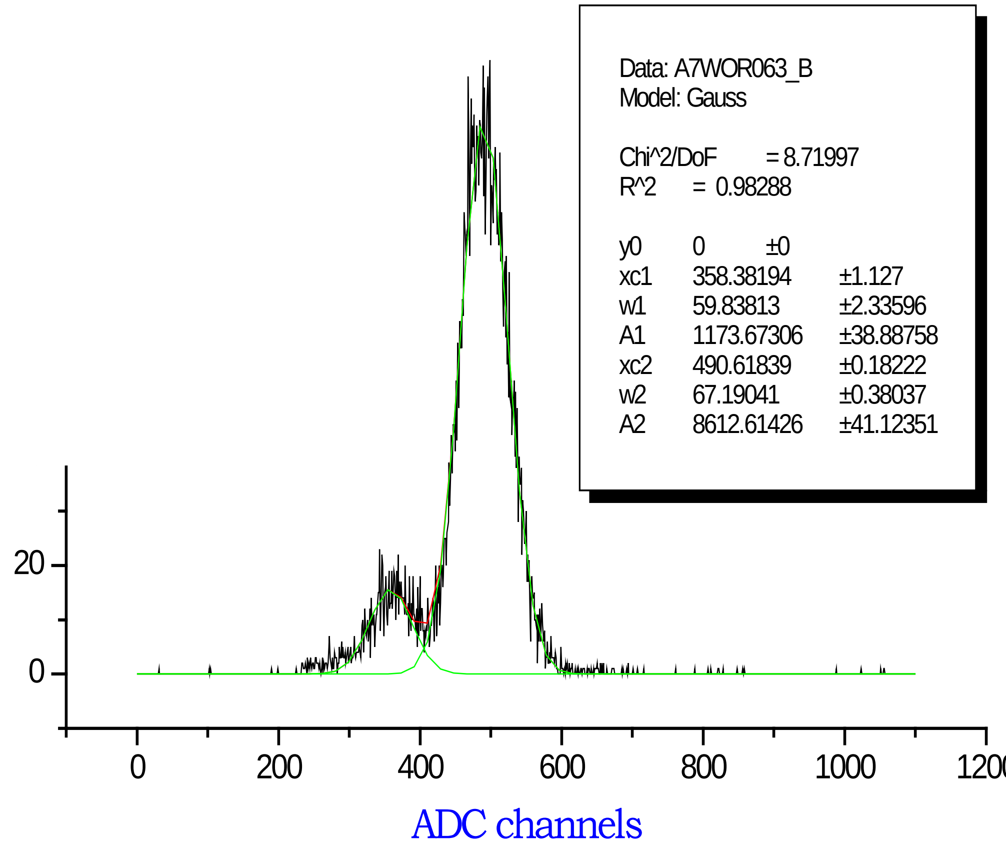
Short time gain variation

Good gain stability (within ~20-30%) is obtained with small rim (< 20 μm)

THGEM	Diameter (mm)	Pitch (mm)	Rim (mm)	Thick (mm)
W_2	0.3	0.7	0.1	0.4

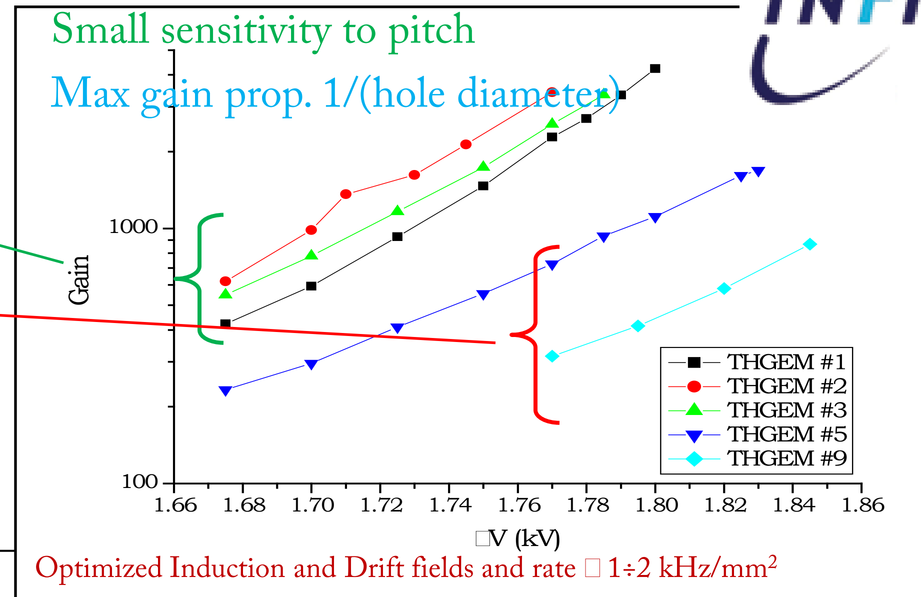


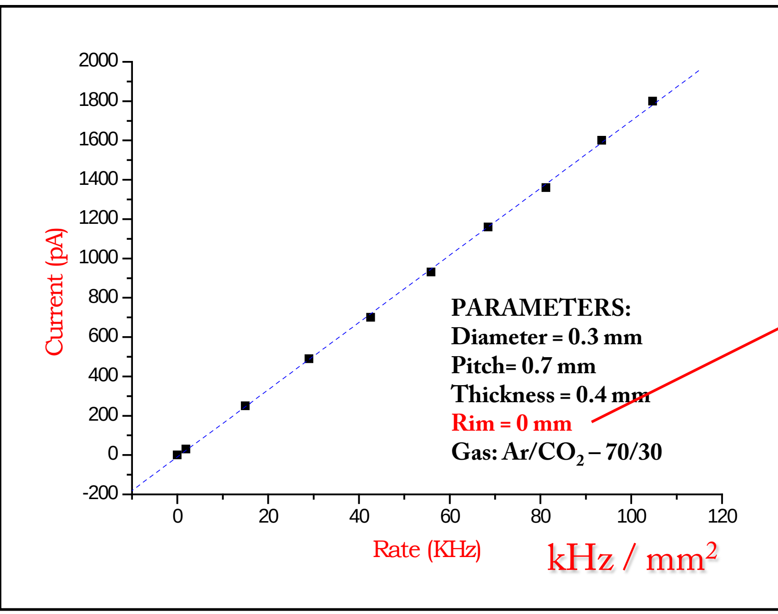


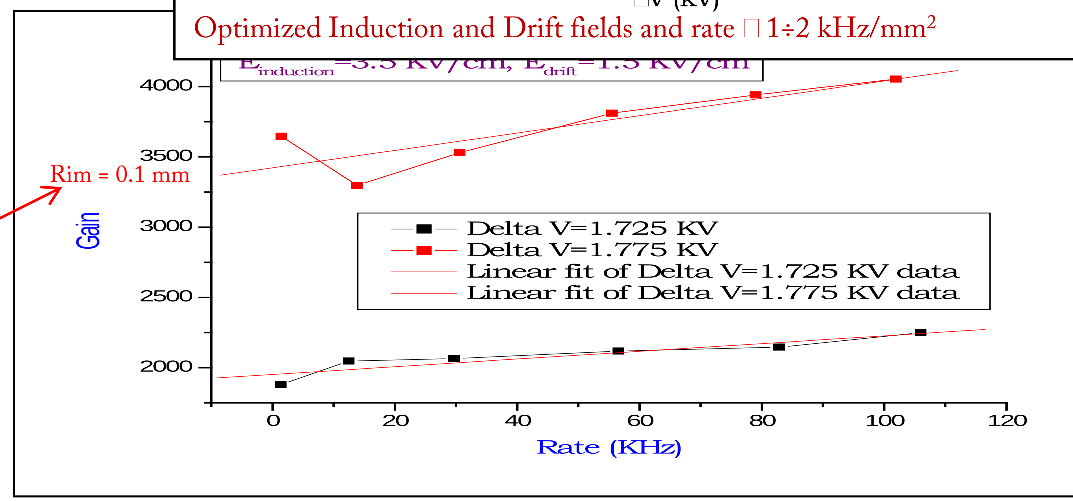


Characterization: 1- geometrical and production parameters

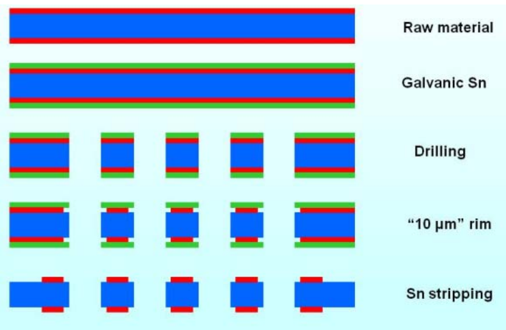
Name	Diam (mm)	Pitch (mm)	Rim (□m)	Thick (mm)
THGEM_1	0.3	0.7	0	0.6
THGEM_2	0.3	0.6	0	0.6
THGEM_3	0.3	0.5	0	0.6
THGEM_5	0.4	0.7	0	0.6
THGEM_9	0.5	0.7	0	0.6

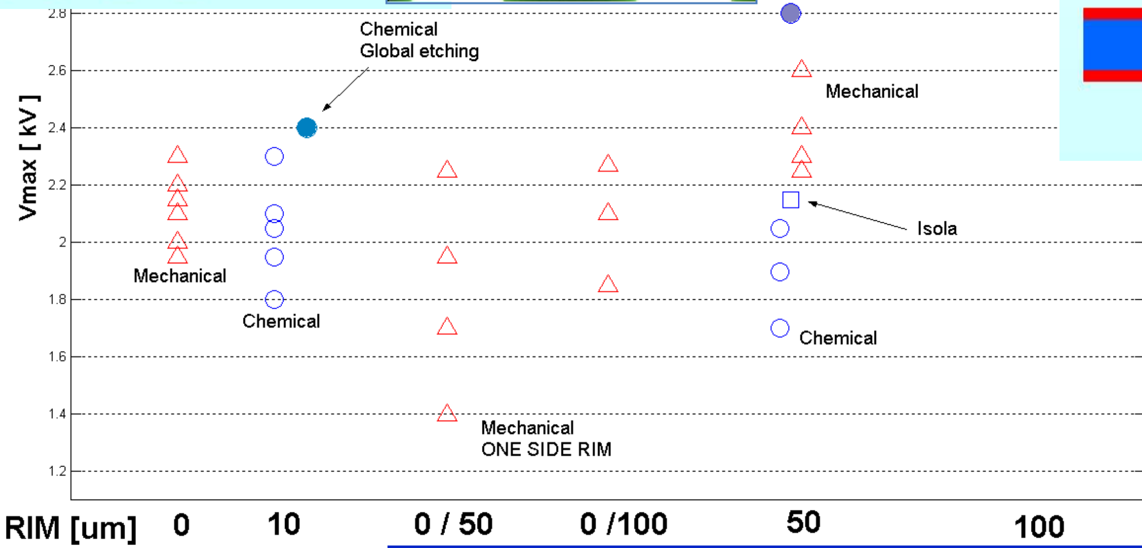


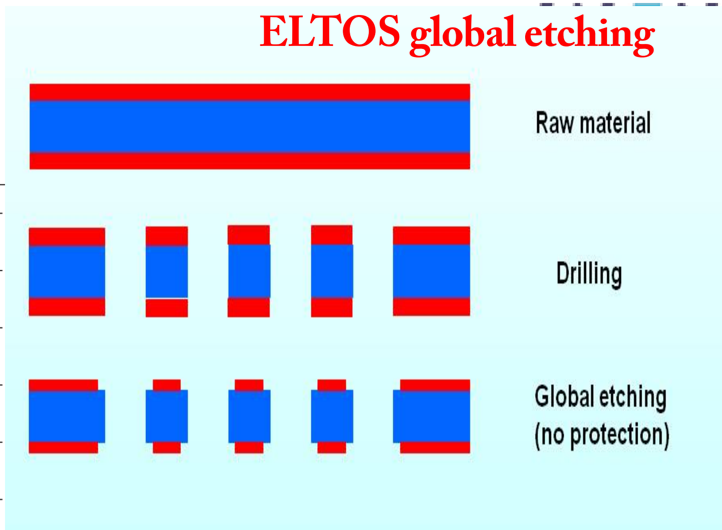




Characterization: 1- geometrical and production parameters: production techniques



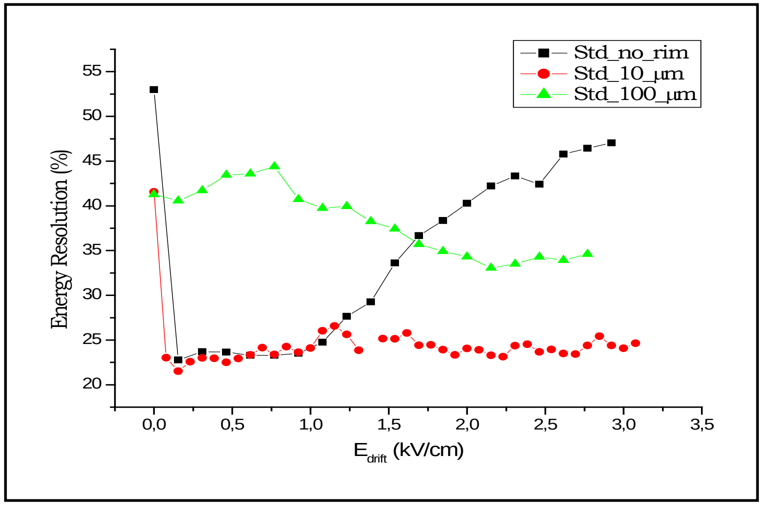




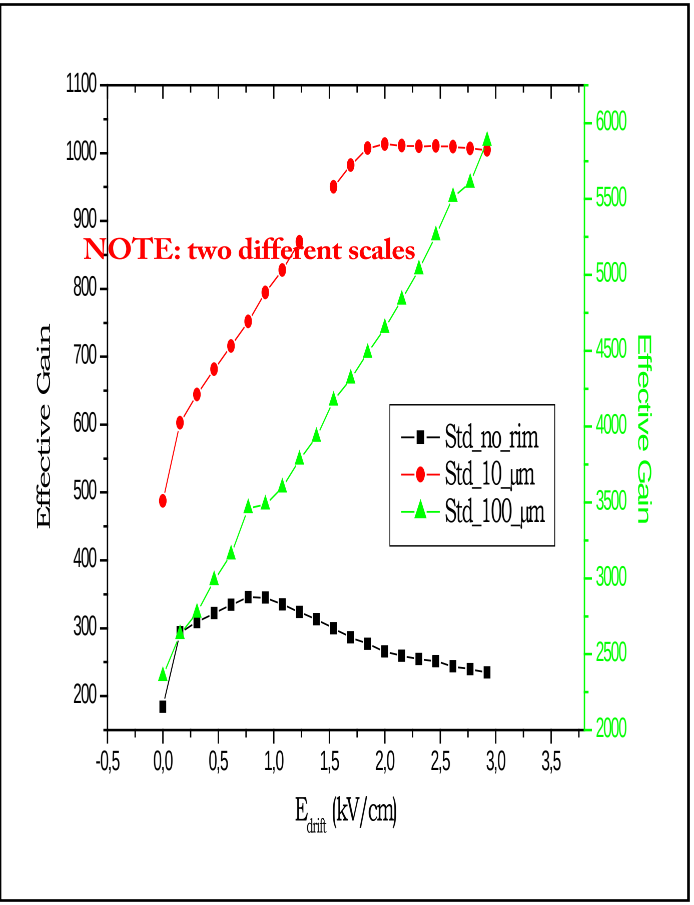
rim production techniques – 5 approaches tested

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

Poor energy resolution → not complete charge collection



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



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

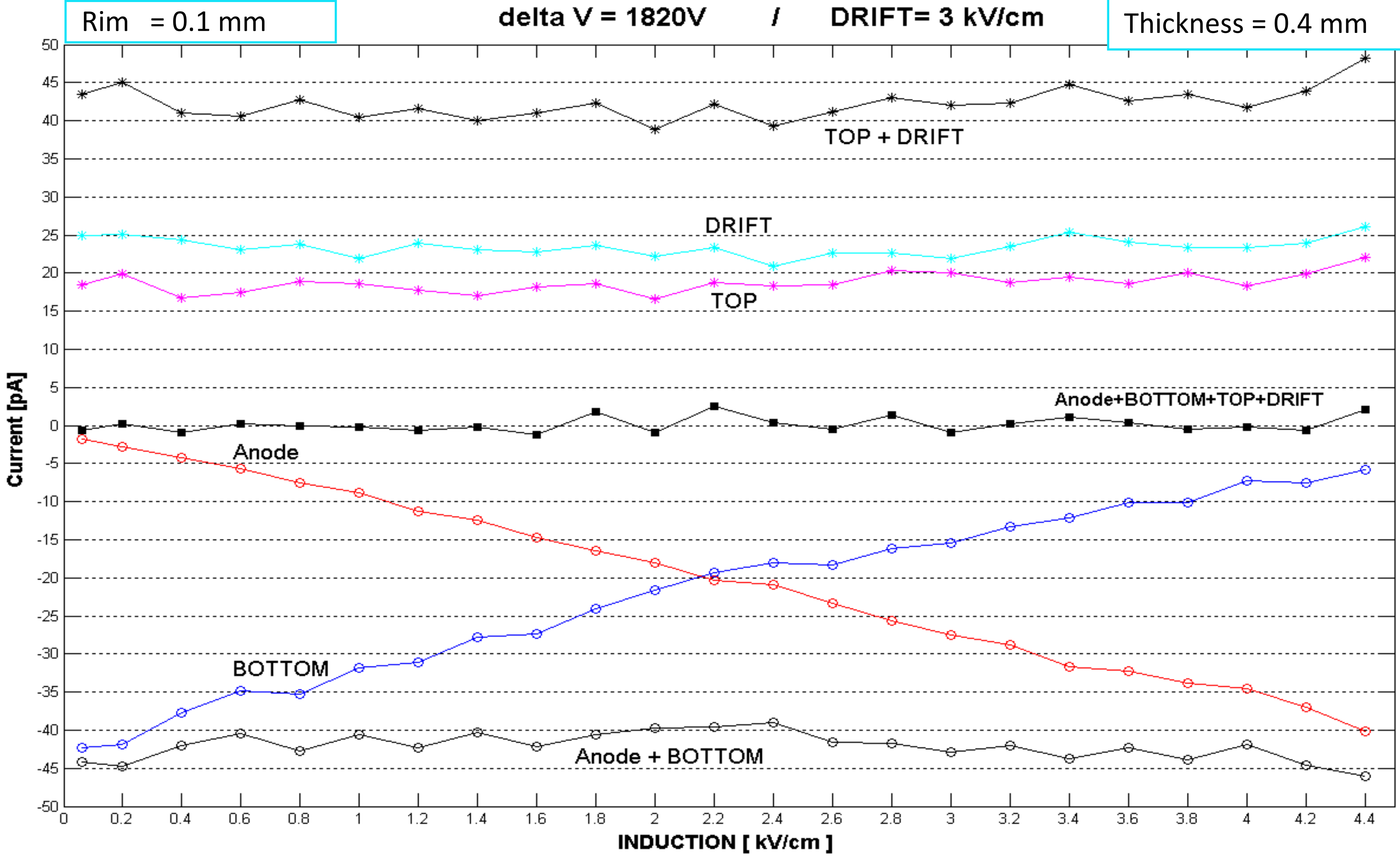
Contrary to the DRIFT scan, in the INDUCTION scan, the energy resolution is pretty constant. The values are included in a range between 22 ÷30 %

The value of E_{ind} defines the charge shearing between THGEM bottom and anode

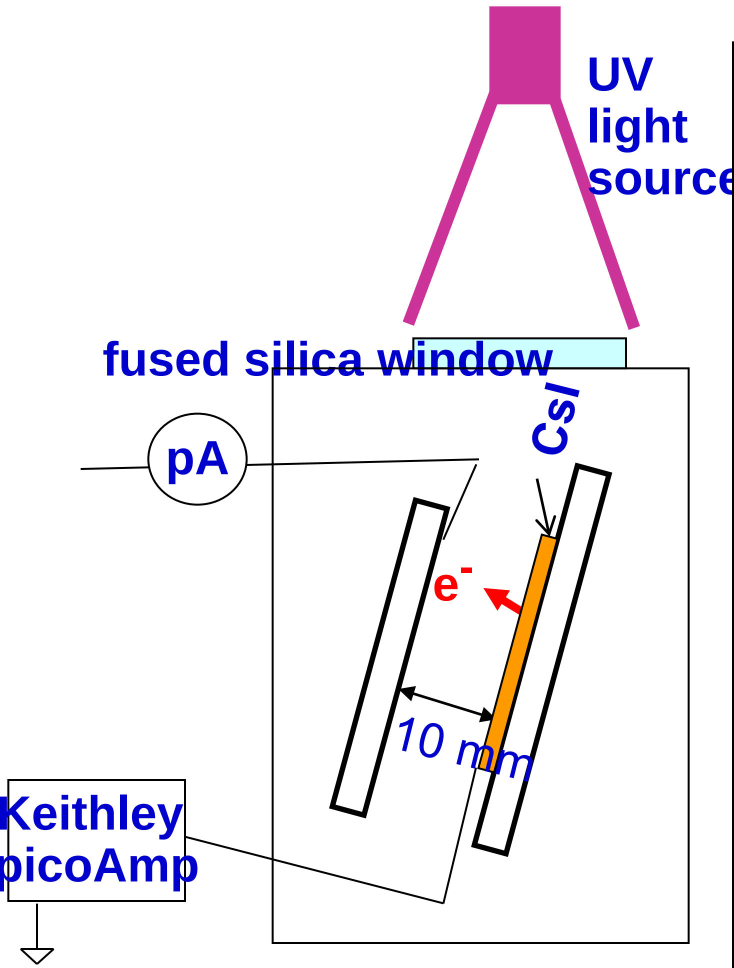
^{55}Fe source; uniform irradiation

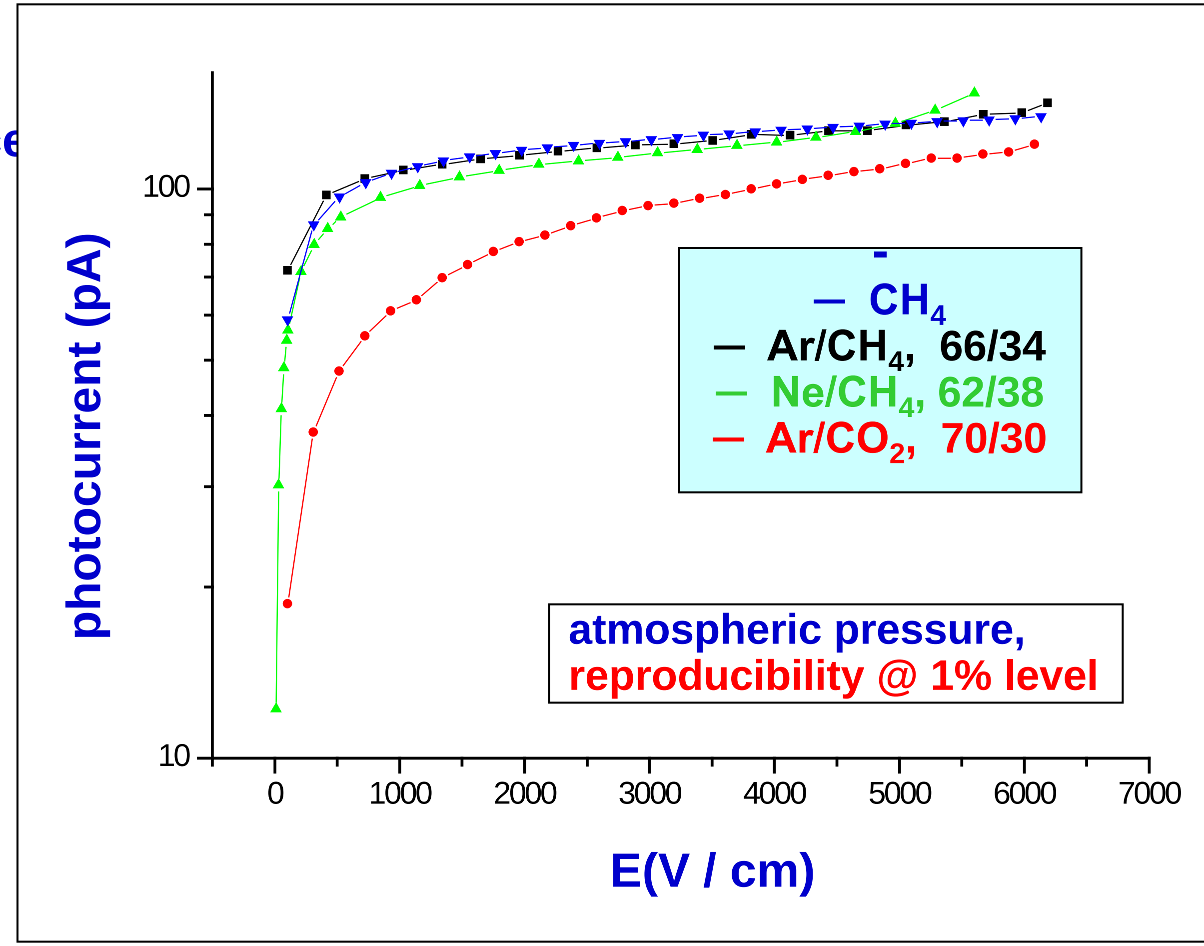
Diameter = 0.3 mm
Pitch = 0.7 mm
Thickness = 0.4 mm

Rim = 0.1 mm



Photocurrent measurements in various gas atmospheres

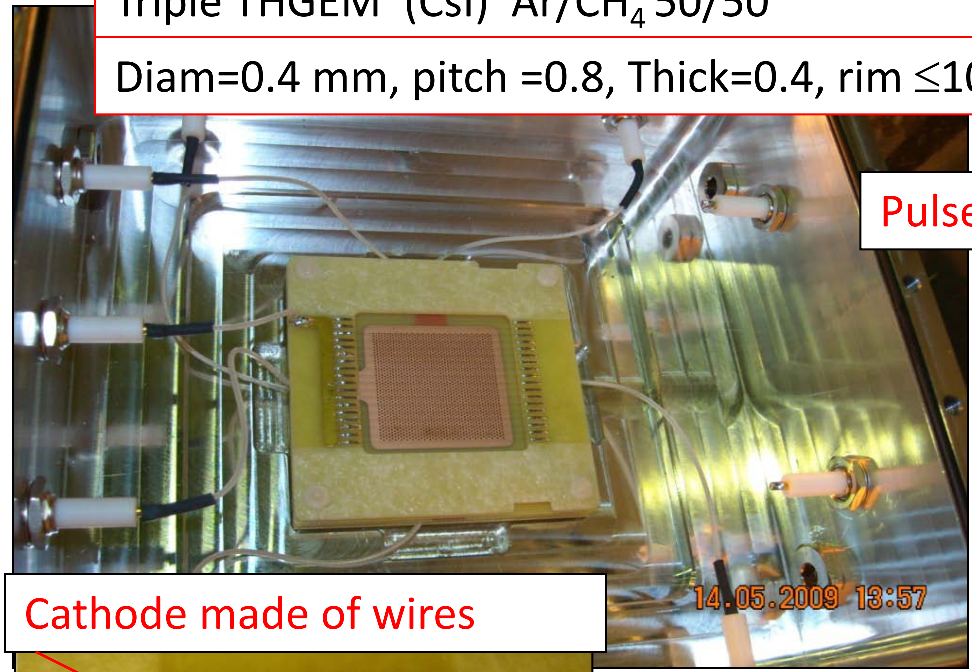




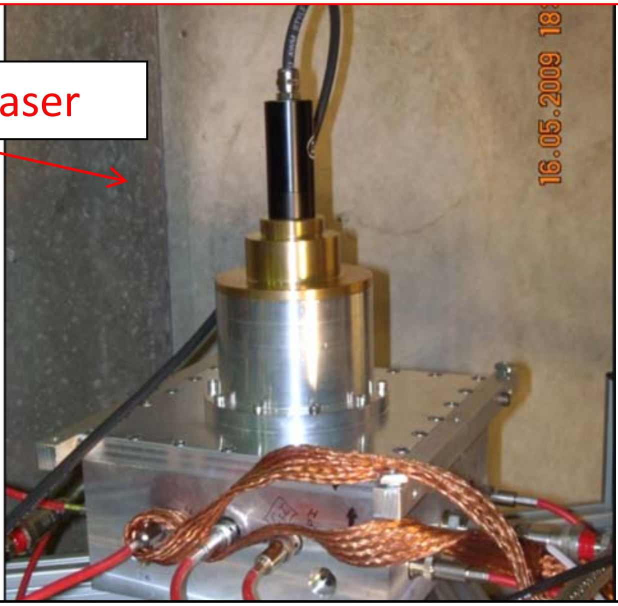
Setup for single photon detection test

Triple THGEM (CsI) Ar/CH_4 50/50

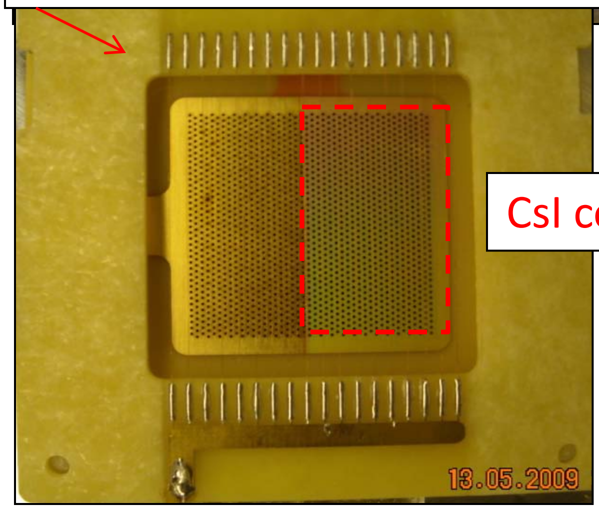
Diam=0.4 mm, pitch =0.8, Thick=0.4, rim ≤10 μm



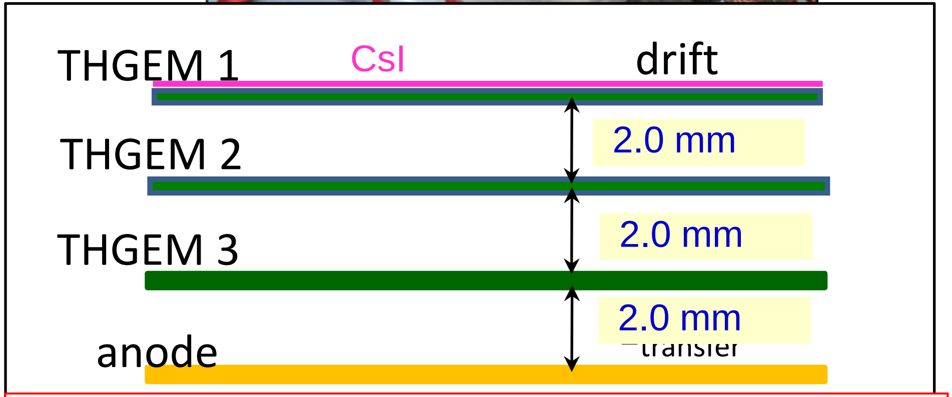
Pulsed Diode Laser



Cathode made of wires



CsI coating



Geometrical sketch inside the chamber

UV LIGHT PULSED SOURCES

1. Model UV LED-255

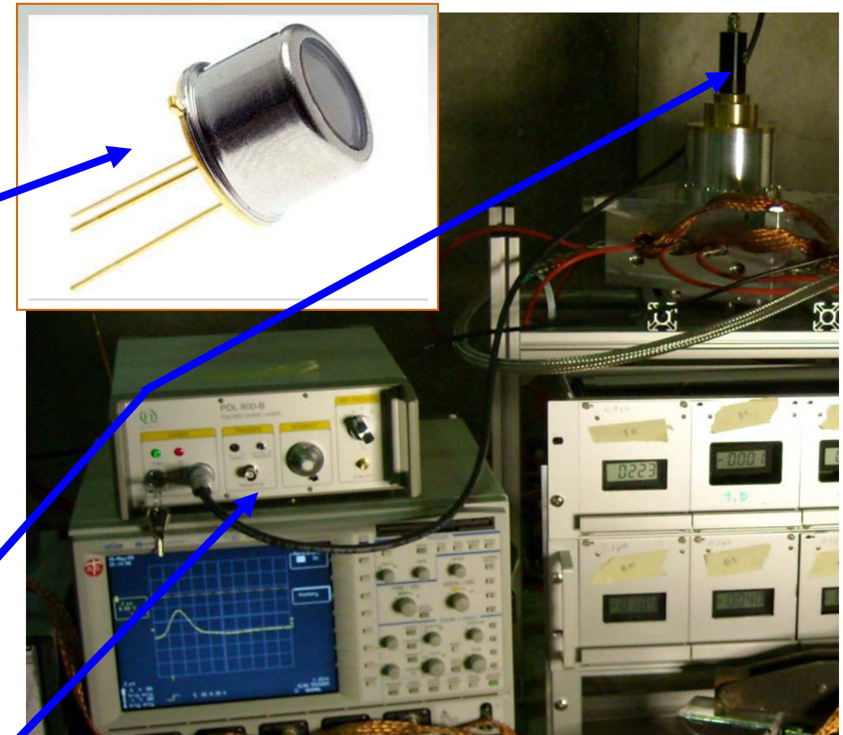
   by Seoul Optodevice Co., Ltd, Seoul, Korea (South)

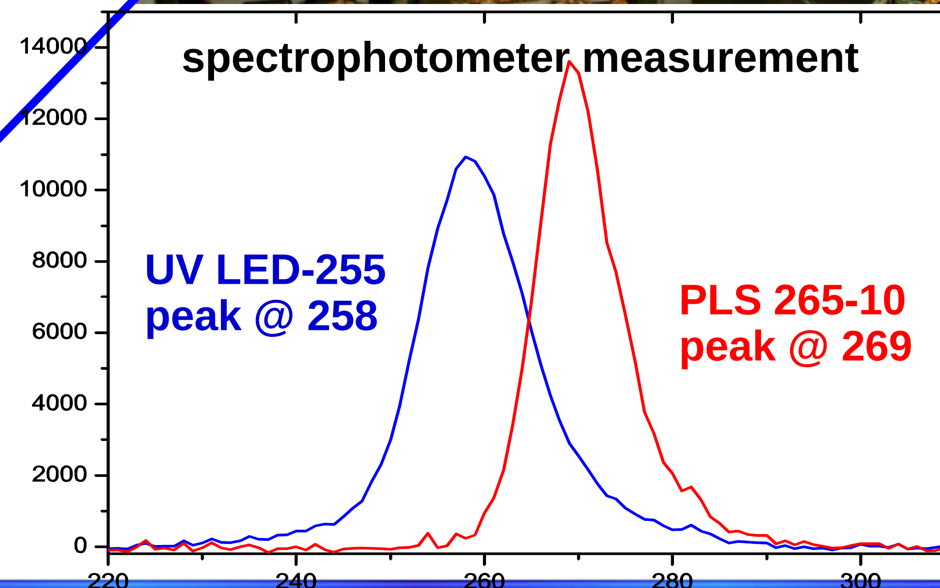
- Central wavelength: 255 ± 10 nm
- Spectral line width: <20nm FWHM
  - also called germicidal ray (disinfection)
  - Applications: Water/Surface purification, Laboratory testing

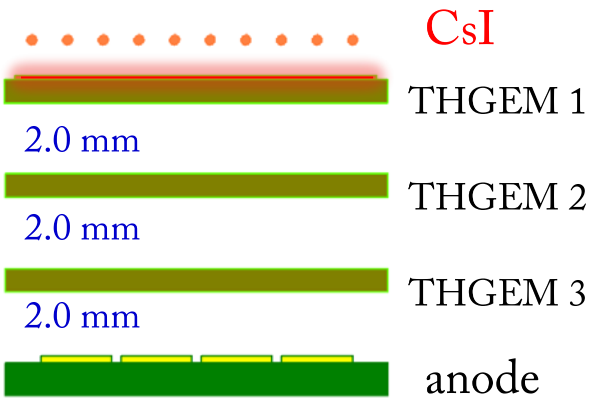
2. PLS 255-10 (pulsed LED) and controller

   by PicoQuant GmbH, Berlin, Germany

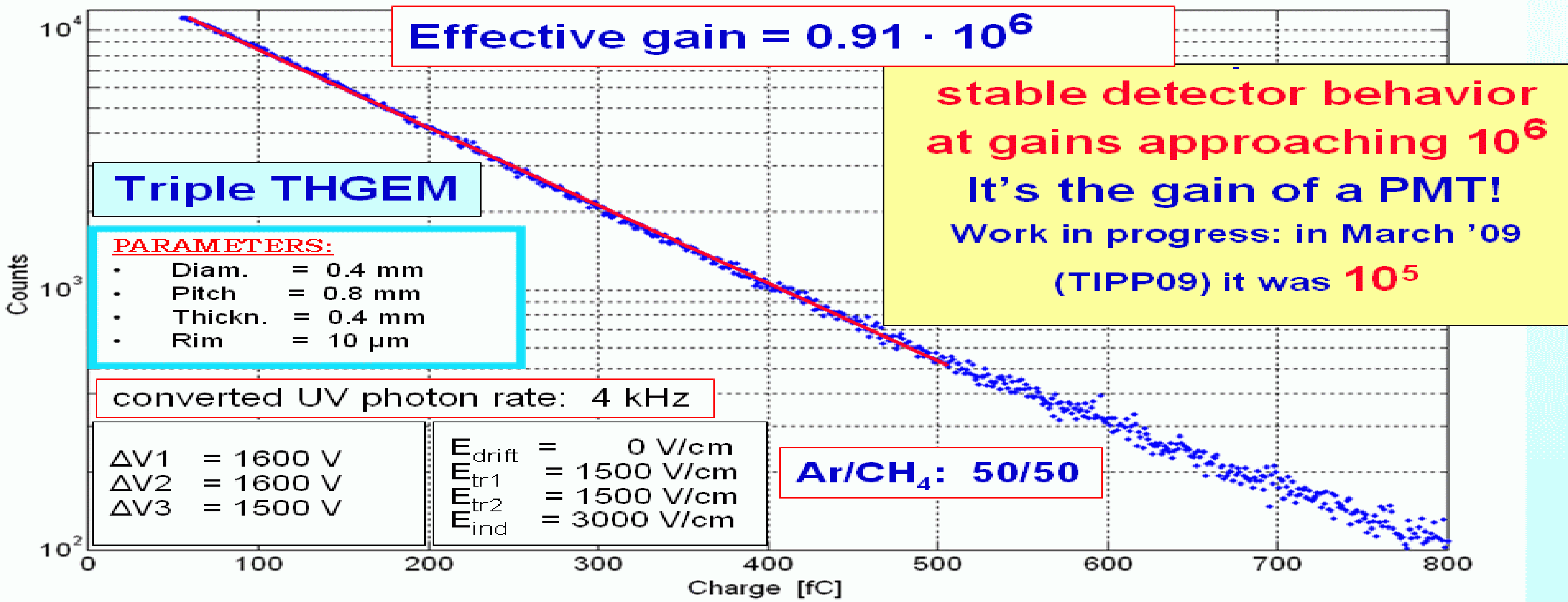
- 600 ps long pulses
- up to 10 MHz





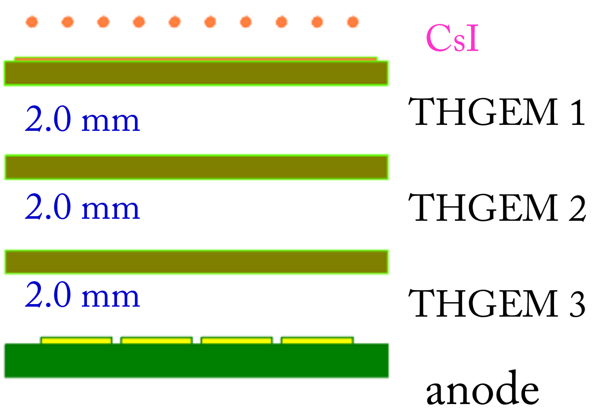


Amplitude distribution for single photon signals

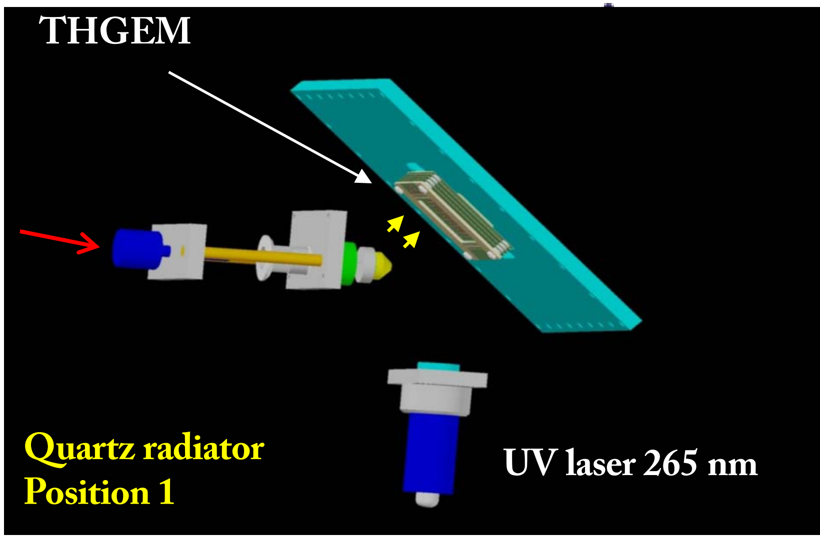


Our first detection of Cherenkov light

Triple THGEM (CsI) Ar/CH_4 50/50 Diam=0.4 mm, pitch =0.8, Thick=0.4, rim ≤10 μm (GE)

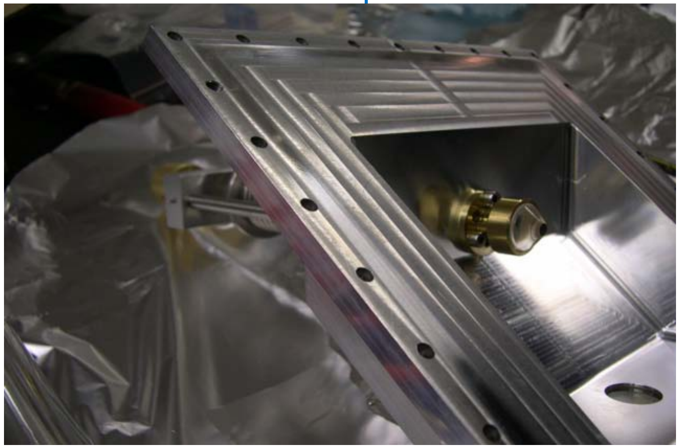


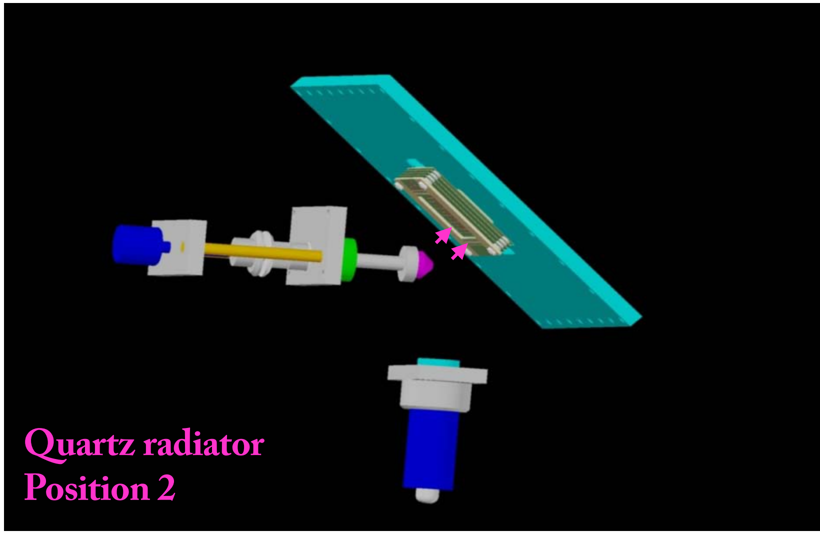
πBeam
p=150 GeV/c
Trigger AND 4 (2+2)
3mm x 3mm scintillators



-External illumination: pulsed UV laser, monitoring currents, analog readout, digital readout in single photon mode

- Adjustable quartz radiator – Cherenkov photons

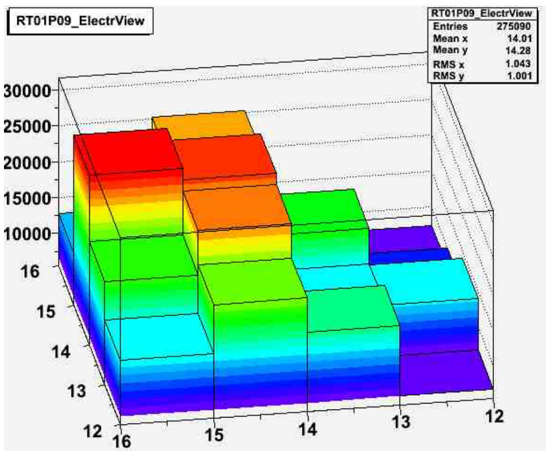




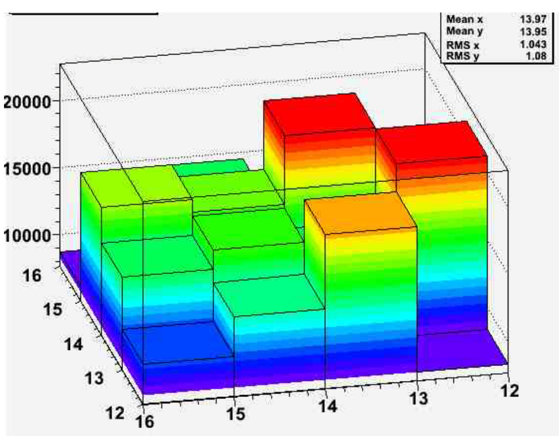
Detector behaves in the same way as in the LAB: Gain up to 10^6, good reproducibility, full control

Test beam 2009: result

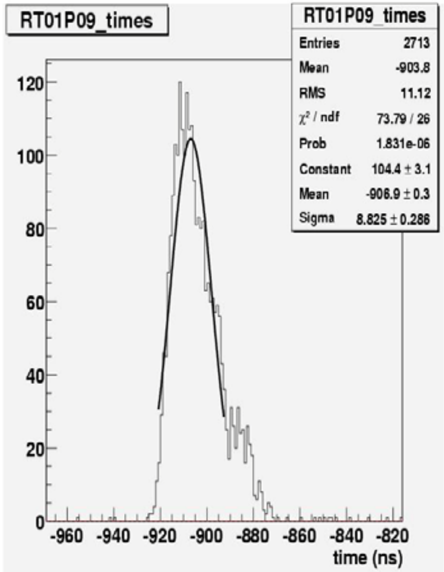
2 different positions of radiator (change of 20mm)



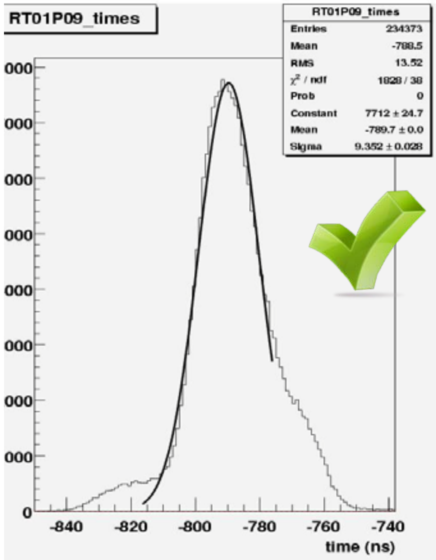
First indication of Cherenkov light



Timing properties



Laser (no beam)
σ=8.8 ns



High intensity beam
σ=9.3 ns

Max. sustainable gain for stable operation: ~ 10^5
More studies are needed in beam conditions
(mip ionization, Ion Back Flow….)

Photoelectron extraction

Electrostatic calculations are essential to optimize our THGEMs

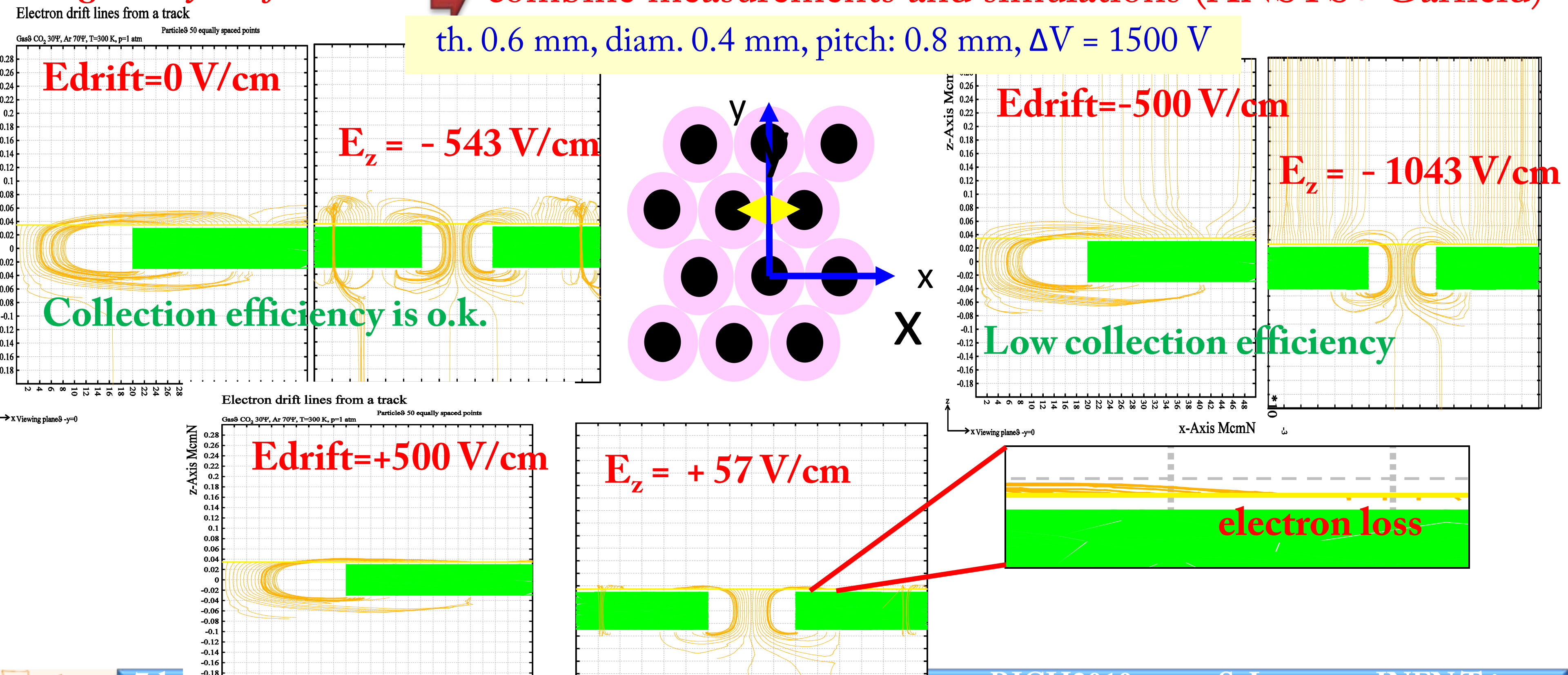
Critical points:

Effective CsI Q.E. depends on the *electric field at the CsI surface* and *e focusing* is done by dipole field

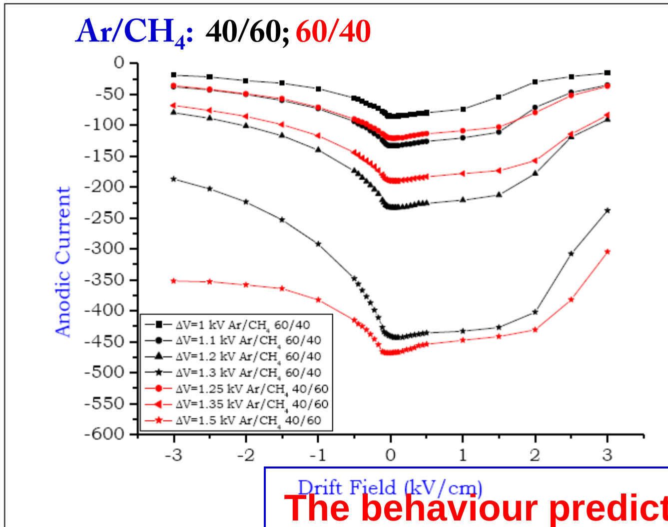
The backscattering effect depends on *the gas and on the field too*

The collection of photoelectrons in the holes for multiplication is difficult to measure and critically *depends on geometry and fields*

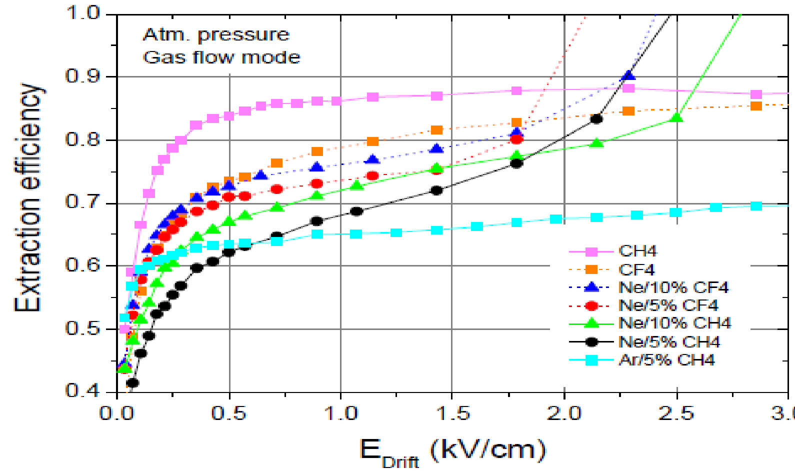
➡ combine measurements and simulations (ANSYS+ Garfield)



Photoelectron extraction

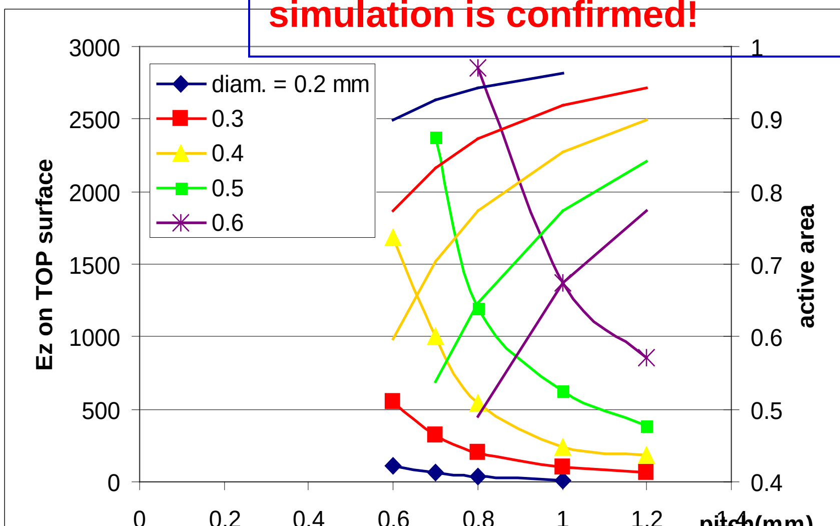


ΔV (kV)
1
1.1,
1.2
1.3
1.25
1.35
1.5

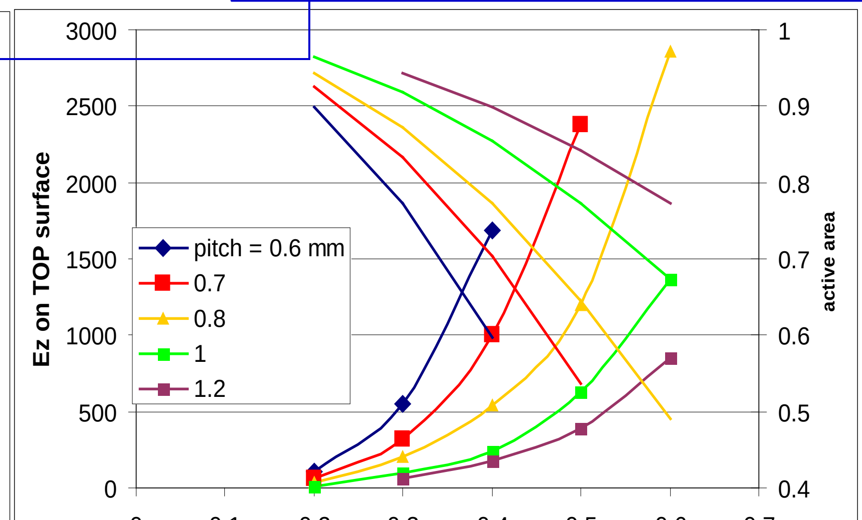


C. D. R. Azevedo et al., 2010 *JINST* 5 P01002

The behaviour predicted by the simulation is confirmed!



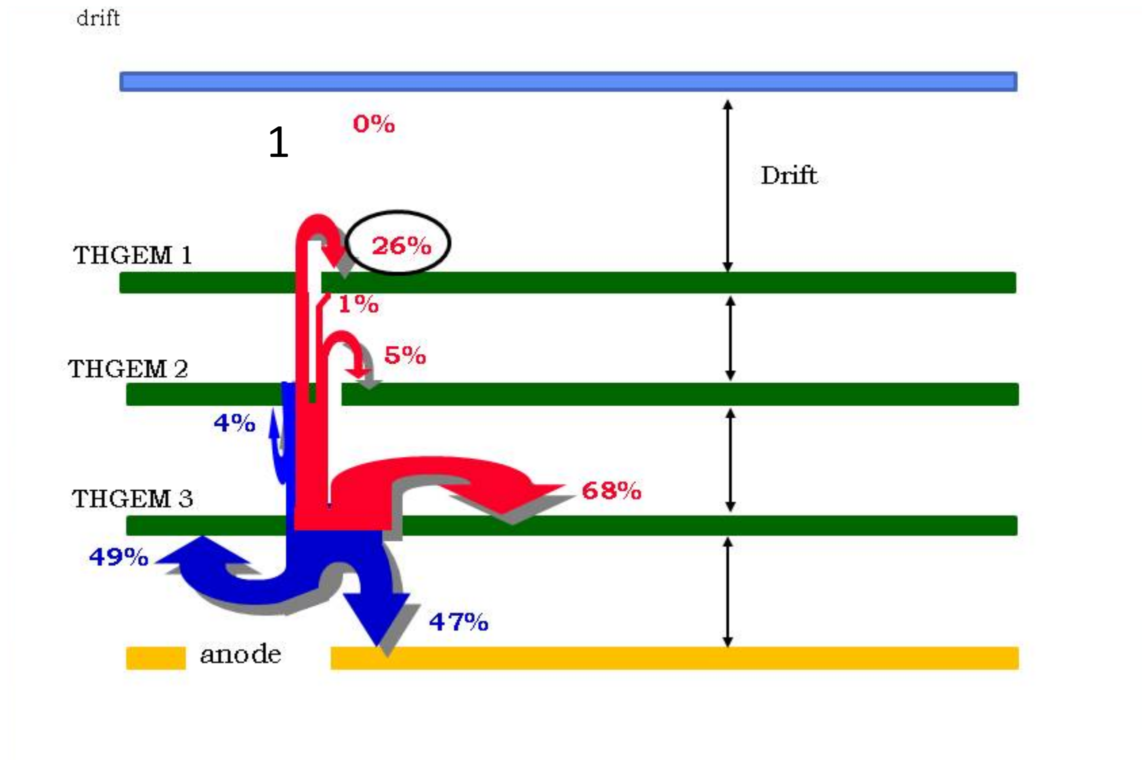
$E_z \sim 1/(\text{pitch})^4$



$E_z \sim \exp(\text{diam.})$

Ion Back Flow:

Main problem: Ions
-secondary *e* emission
-ion feedback
-gain & performance limitations in terms of instabilities /charge accumulation on PC



Ion Back Flow

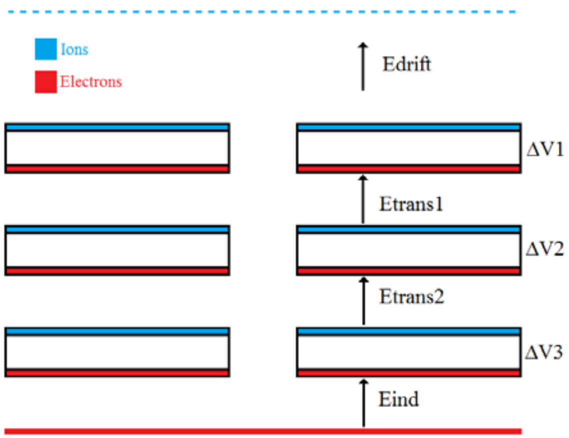
First trial: modify middle THGEM geometry

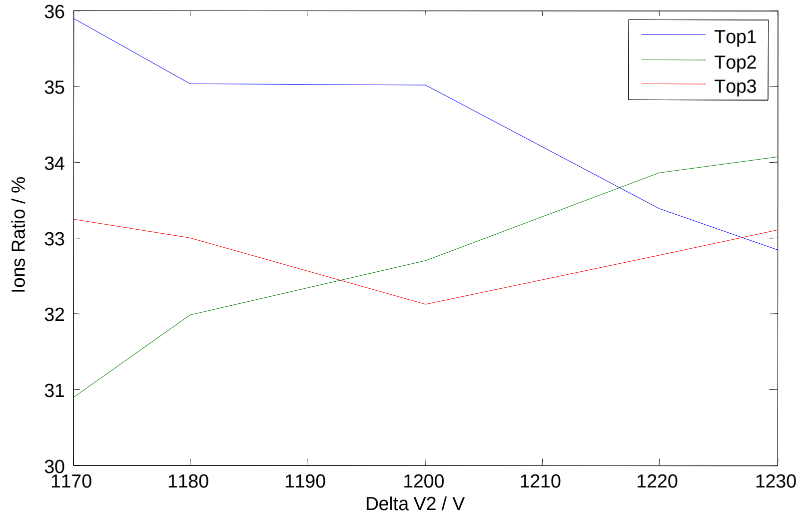
same pitch 0.8 mm and same thickness but holes from 0.4 to 0.2 mm

Induction Scan, Transfer field scan, ΔV scan and multiple combinations → *reduction possible in the order of few percent only*

E_D = 0 V/cm
E_{T1} = 500 V/cm
E_{T2} = 750 V/cm
E_I = 2500 V/cm

Δ V1 = 1050 V
Δ V2 = 1200 V
ΔV3 = 1000V

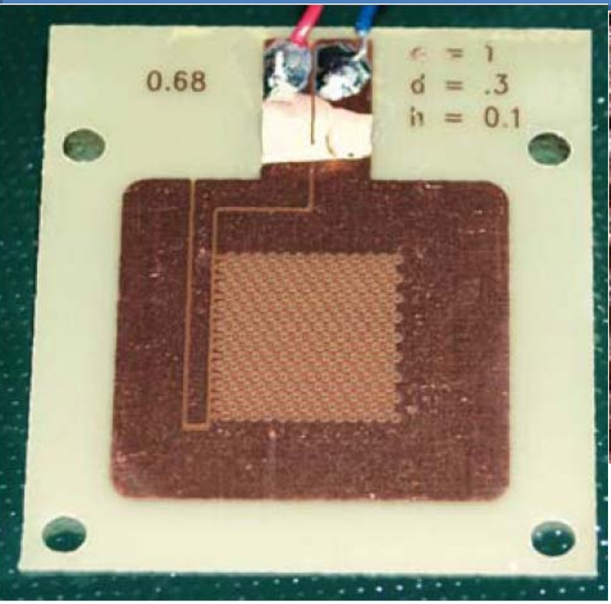


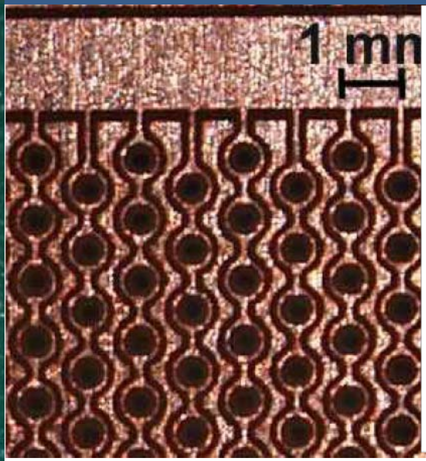


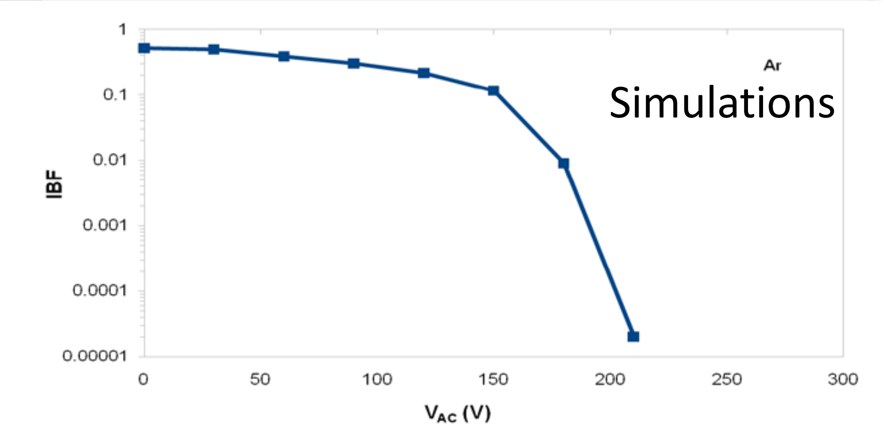
Simple geometrical solutions seem not to be sufficient, different approach needed !

Work done in collaboration with Carlos Santos (Thanks!)

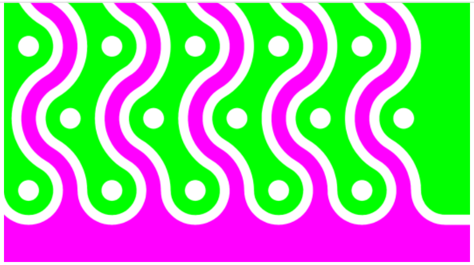
Ion Back Flow reduction







New Thick Hole-Structures for Gaseous Detectors, João Veloso RD51



Single photon detection efficiency strongly affected by

Active area (electrode) / Dead area (holes) → limits on the geometry of 1th THGEM

E field on the surface → geometrical parameters of the 1th THGEM

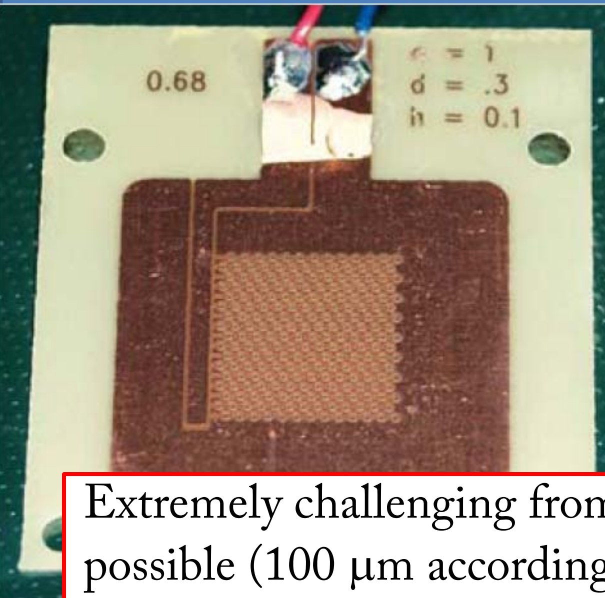
$E_z \sim \exp(\text{diam.})$

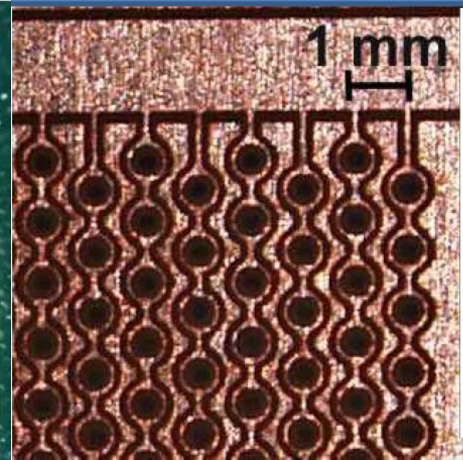
$E_z \sim 1/(\text{pitch})^4$

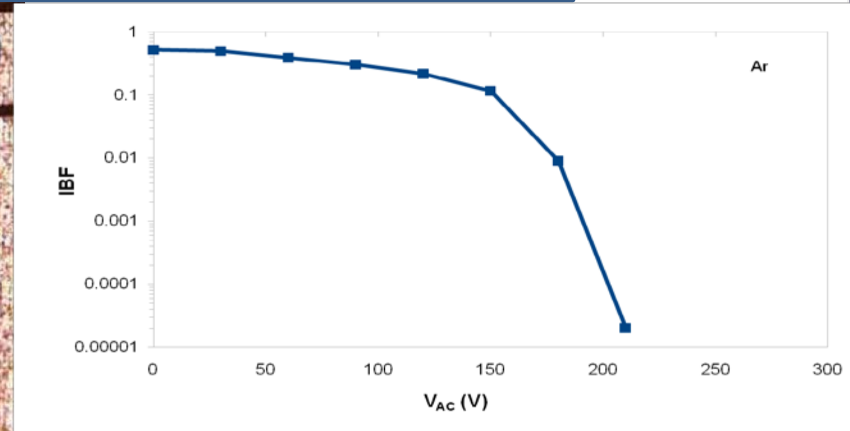
Impose constrains on the maximum space between electrodes for THCOBRA → pitch and hole size

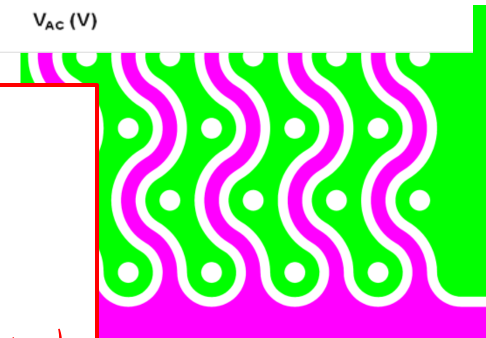
Hole	Ering	Clearance	Cobra Electrode	Pitch
400	2X80	2X80	80	800

Ion Back Flow reduction









Si

THGEM

Extremely challenging from the technological point of view
possible (100 μm according to PCB producers suggestion is feasible)

-expensive

-parameter control for large surfaces is very difficult

-reduction of Cu thickness → detector robustness is affected (discharges see later)

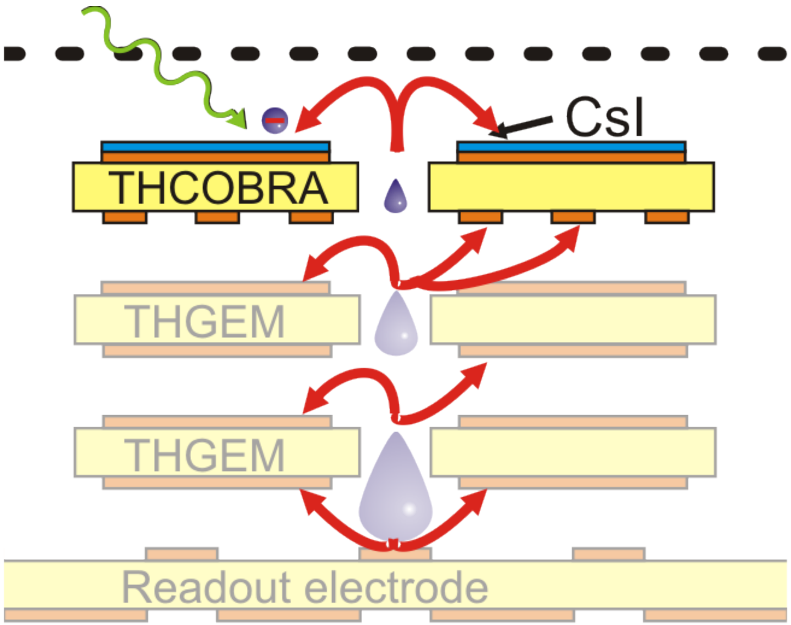
$E_z \sim \exp(\text{diam.})$

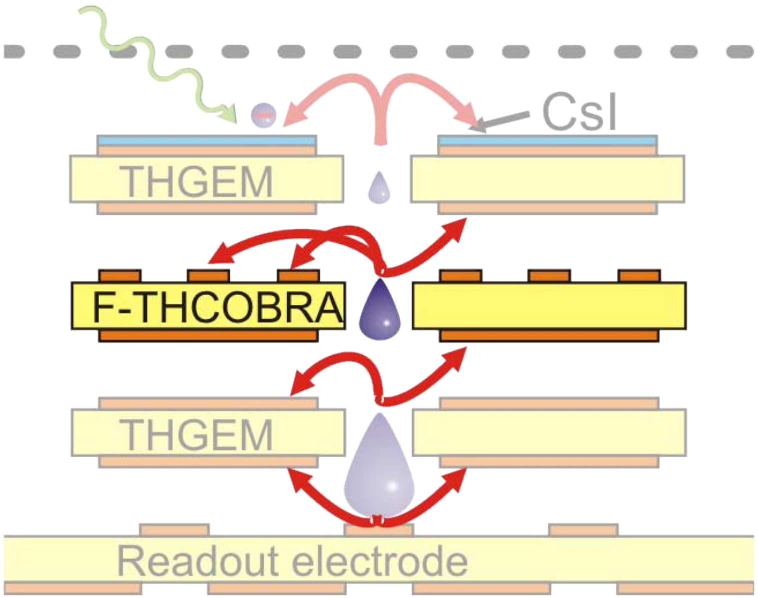
$E_z \sim 1/(\text{pitch})^4$

Impose constrains on the maximum space between electrodes for THCOBRA → pitch and hole size

Hole	Ering	Clearance	Cobra Electrode	Pitch
400	2X80	2X80	80	800

THGEM-THCOBRA



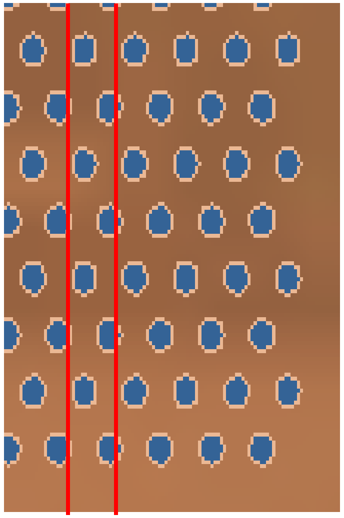


- Position:
  - 1st stage

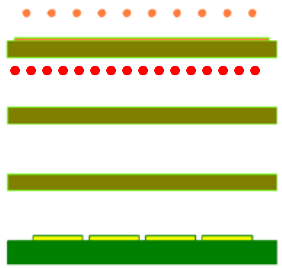
- Position:
  - 2nd stage, 3rd, ...

Ion Back Flow reduction

To get rid of geometrical constrains -> plane of wires facing the 1th bottom electrode

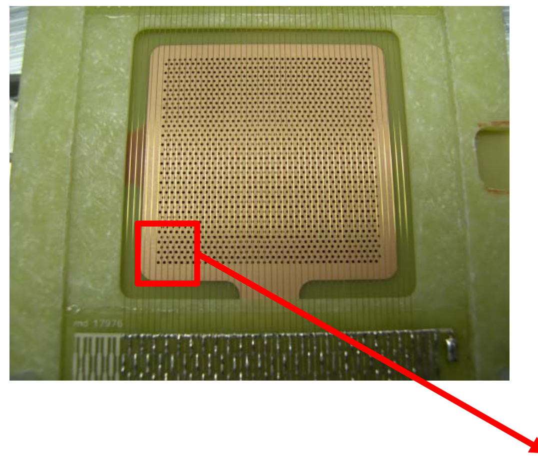


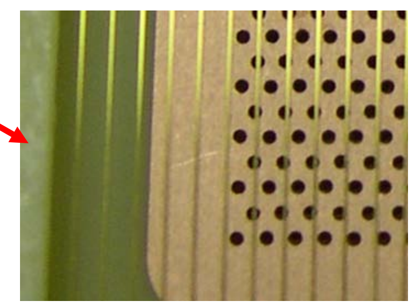
Distance from the bottom plane 500 μm
Wires spacing according to pitch of the THGEM

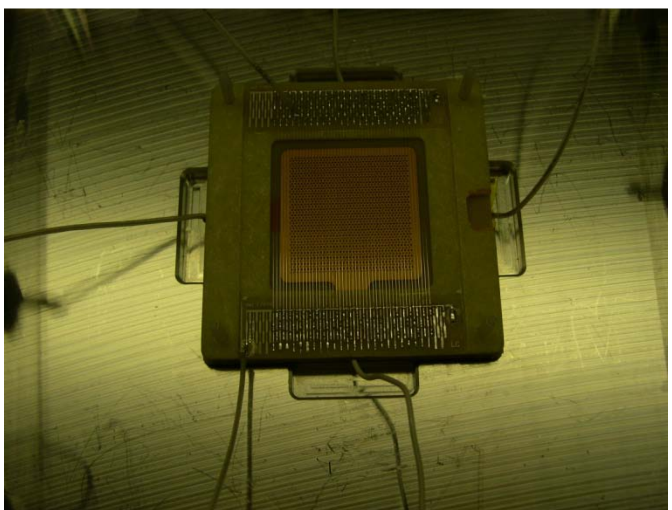


Its realization
100 μm wires

Very firs trial!



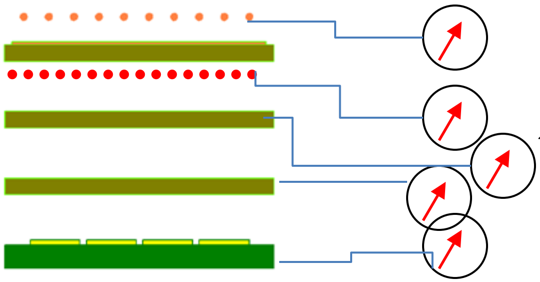




Ion Back Flow reduction

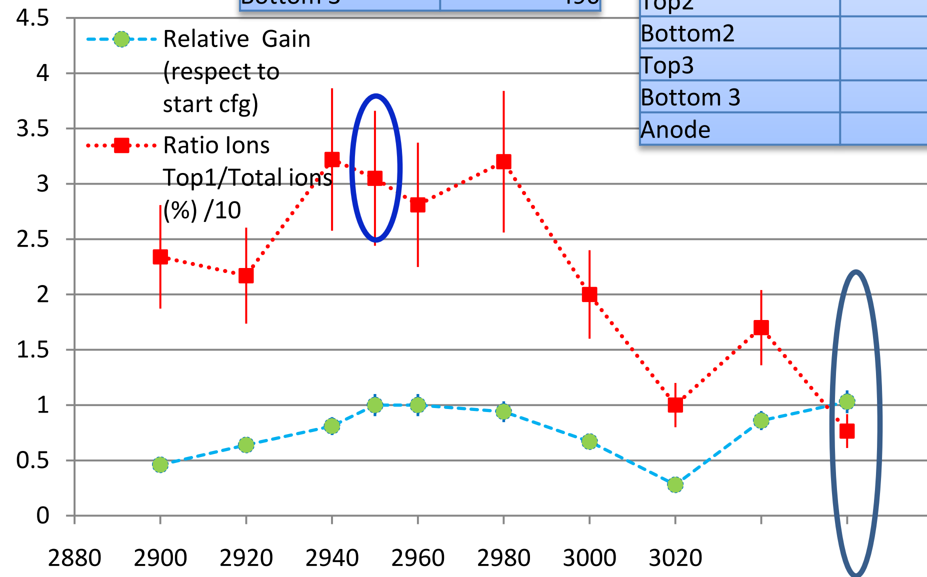
HV	Volt
Drift	4100
Top1	4100
Bottom 1	2956
Cobra wires	3020
Top2	2807
Bottom2	1650
Top3	1510
Bottom 3	490

Anode	0
Drift	4100
Top1	4110
Bottom 1	3150
Cobra wires	3220
Top2	3000
Bottom2	1650
Top3	1510
Bottom 3	500
Anode	0



1 pA for each layer, 2mm spacing

HV	Volt			E (V/cm)	Current measured
Drift	4015	Cfield	0	0	-10
Top1	4015	DV1	1059	2647.5	30
Bottom 1	2956	Edrift	16	40	0
Cobra wires	2940	Trans1	133	886.6667	0
Top2	2807	DV2	1157	2892.5	27
Bottom2	1650	Transf2	140	700	-8
Top3	1510	DV3	1020	2550	46
Bottom 3	490	Induction	490	2450	-35
Anode	0				-63



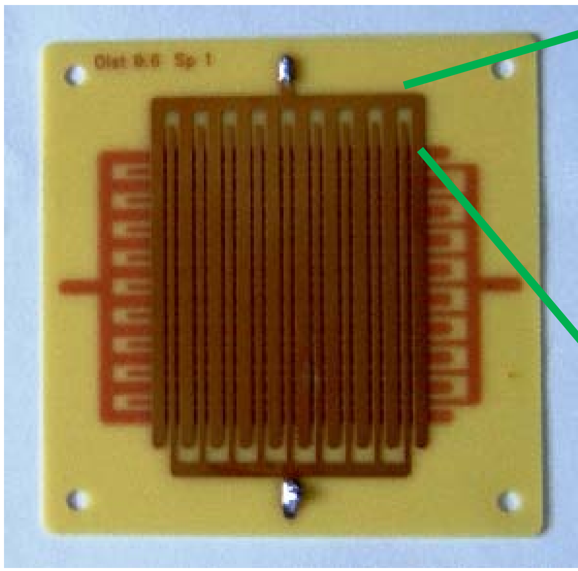
Increasing Second THGEM ΔV (200V)

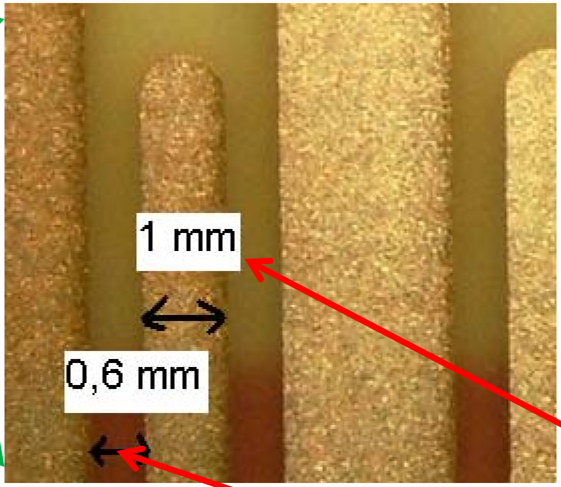
Very first trial!

Other implementation possible Up to a factor 5 in ions reduction wit no gain loss! To be investigated !!! (simulations are needed)

A small step towards big dimensions

Problem: *large surfaces* to be covered means *high capacity (~1nF for 100 cm^2)*
and accumulated energy : segmentation is needed .
Test of the minimum space separation requirements
to avoid in case of trip/discharge the involvement of the very next segmented area





10 different distances between strips have been tested
0.1 0.2 0.3 0.4 0.6 0.8
0.15 1 1.5 2 mm
for 3 strip thickness
0.1 0.2 1 mm

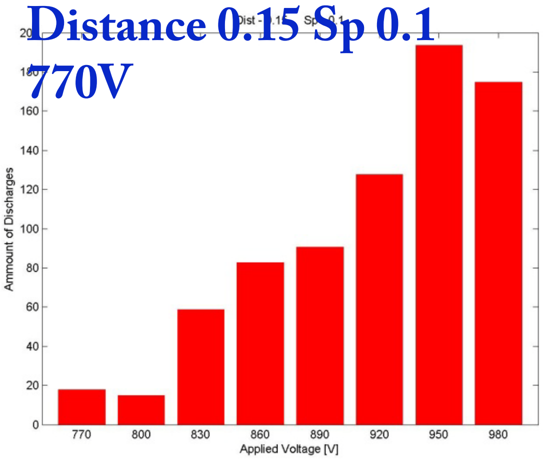
Strip thickness

Distance between strips

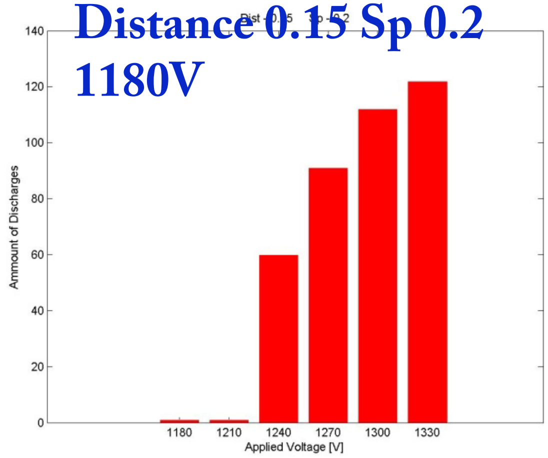
Nitrogen atmosphere, increasing potential difference applied , discharge counting system implemented

A small step towards big dimensions

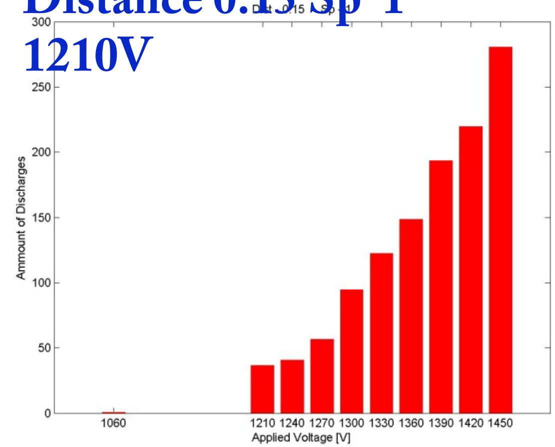
Distance 0.15 Sp 0.1
770V

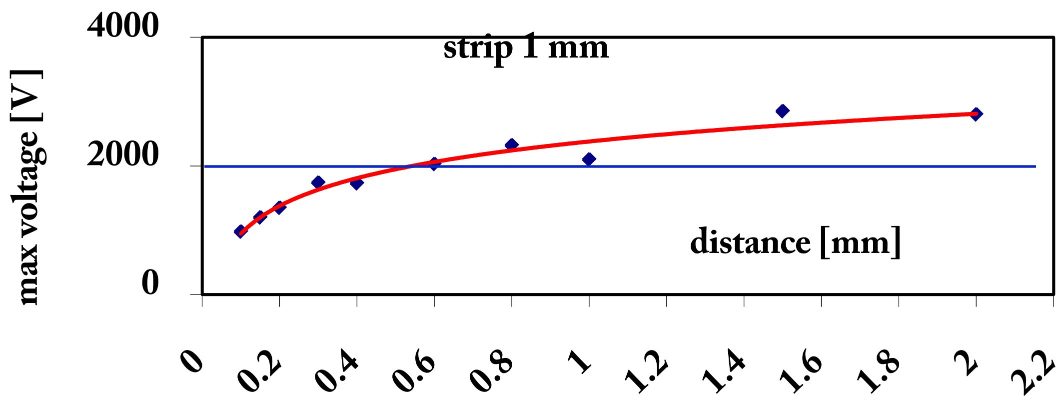


Distance 0.15 Sp 0.2
1180V



Distance 0.15 Sp 1
1210V





Extracted the Maximum ΔV (discharge) for the two parameters:
strip distance **and**
strip thickness

Can be helpful in large detector parameter modelisation!

Concerning the photon detectors

GOALS:

Operate a "*large*" THGEM based photon detector in beam condition and *see* Cherenkov rings

Perform a E field scan (Drift, Induction, Transfers) thanks to the new HV system (not possible last year) and check the detector response.

Test the behavior of the FE electronic coupled to a larger capacitance device with a new electronic protection circuit to save CMAD chips from damages when sparks occur

2010 new setup

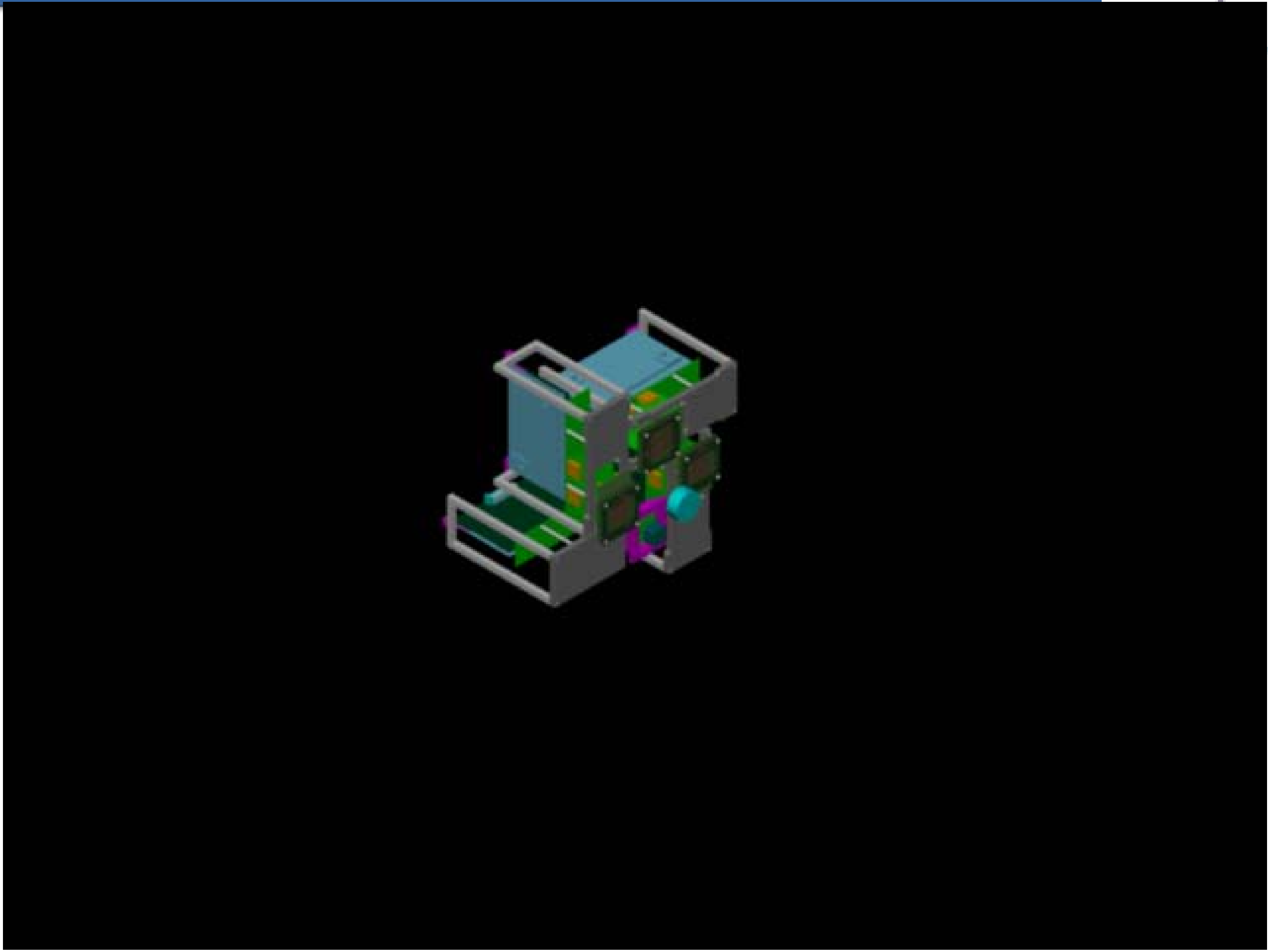
A completely new photon detector system has been designed and it's in preparation.

It consists of a newly designed and machined radiator lens (160 mm Cherenkov diameter) . It can be equipped at the same time with 3 independent 30mmx30mm THGEM PDs
A MAPMT R7600 will be permanently installed too.

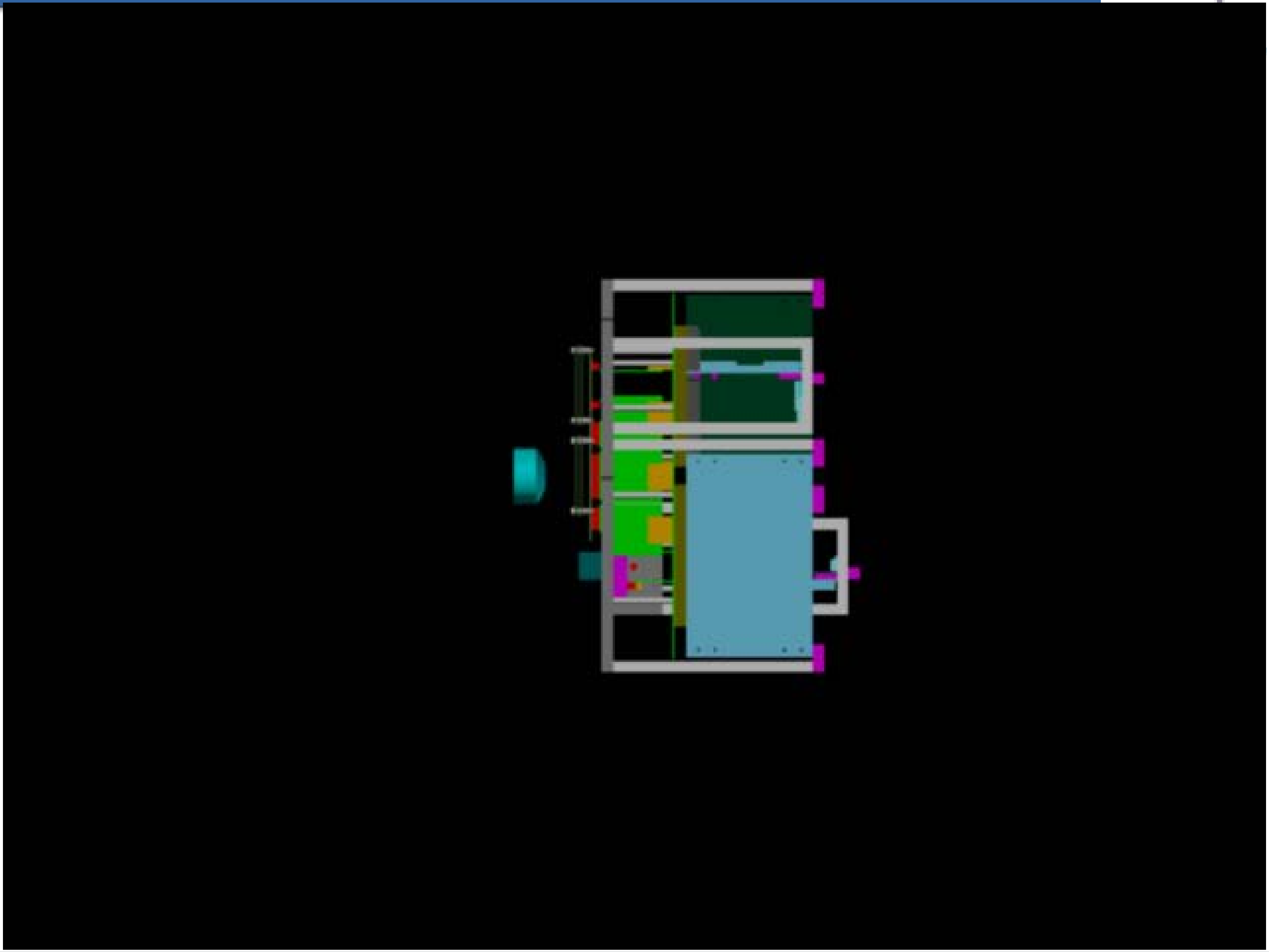
GOALS
-Perform photon counting and extract THGEM photon detection efficiency by comparison with pmt.
- Test a possible solution for IBF reduction with one of the 3 THGEM detectors adding a dedicated electrode.

2010 new setup

2010 new setup



2010 new setup



CONCLUSIONS

• Characterization of the THGEM has proven to be fundamental in understanding the role of the different parameters and in their choice

Towards THGEM based single photon detector

Achievements

• Cherenkov light has been detected, large stable gain in laboratory (10^6),
• Nice time resolution <10 ns
• Photoelectron extraction understood

Open points

• IBF reduction: first encouraging tests using an ad hoc electrode
• Gain reduction in presence of ionizing particles: to be further studied
• Engineering studies for large size started

2010 test beam will shade light on important aspects!