Development of a THGEM-based photon detector for RICH applications

Fulvio Tessarotto (INFN – Trieste)

on behalf of an Alessandria-CERN-Freiburg-Liberec-Prague-Torino-Trieste Collaboration

Introduction

Characterization of single THGEMs

Study of photoelectron extraction

Tests with multilayer THGEMs

Present status and perspectives

Motivations for this R&D program

At present the only economic way 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

No need of high space resolution (> 1 mm)

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

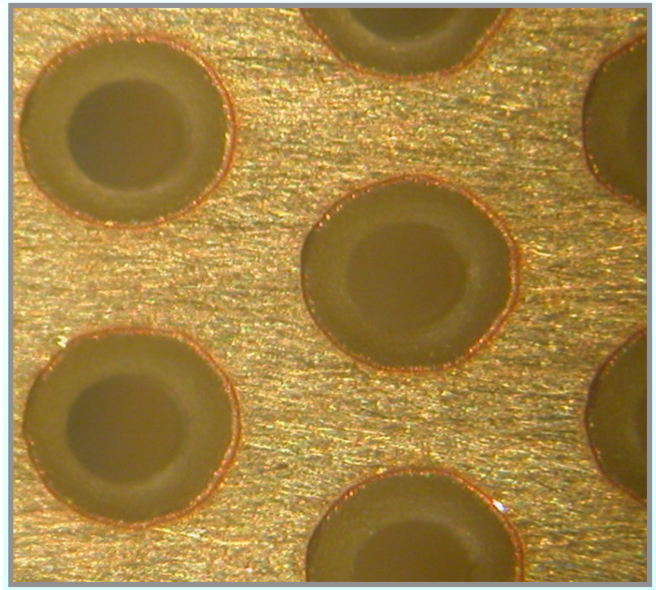
- industrial production (standard pcb)
- good stiffness
- very robust against discharge damages

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

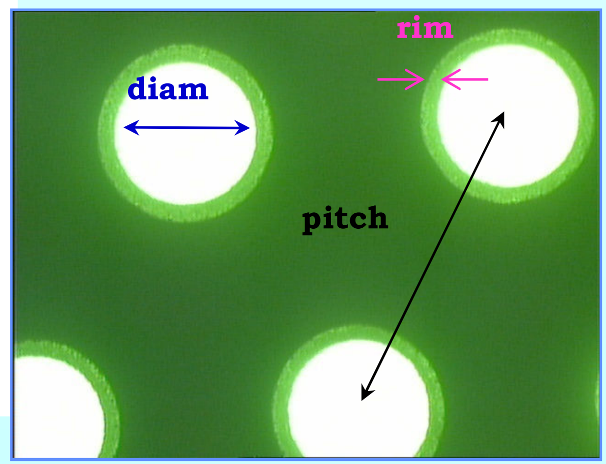


Picture at the microscope

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

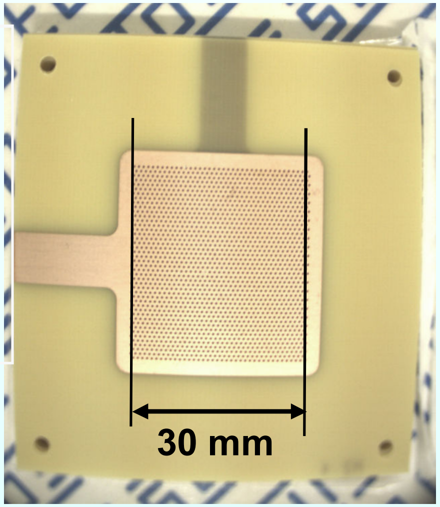
First step: testing the performances of THGEM's as electron multipliers:

- 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



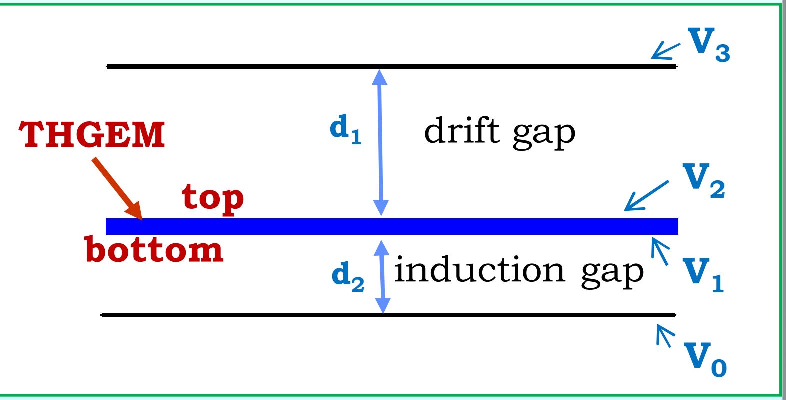
SETUP of the initial tests

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: <u>gain</u> 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

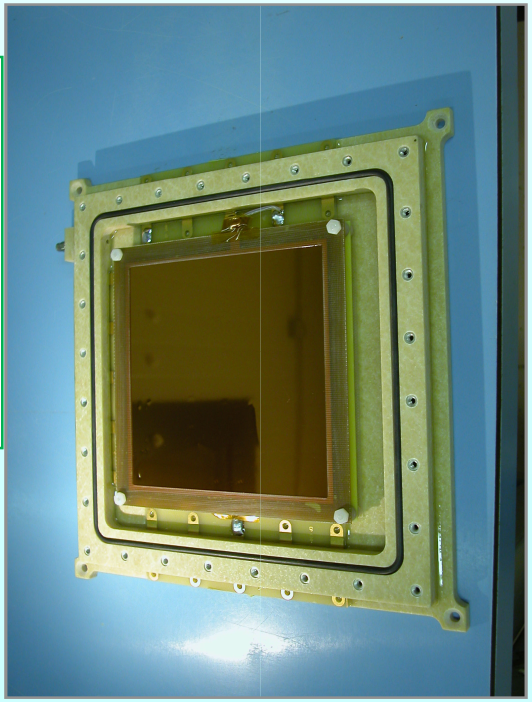
To detect ionizing particle :
$V_3 < V_2 < V_1 < V_0$

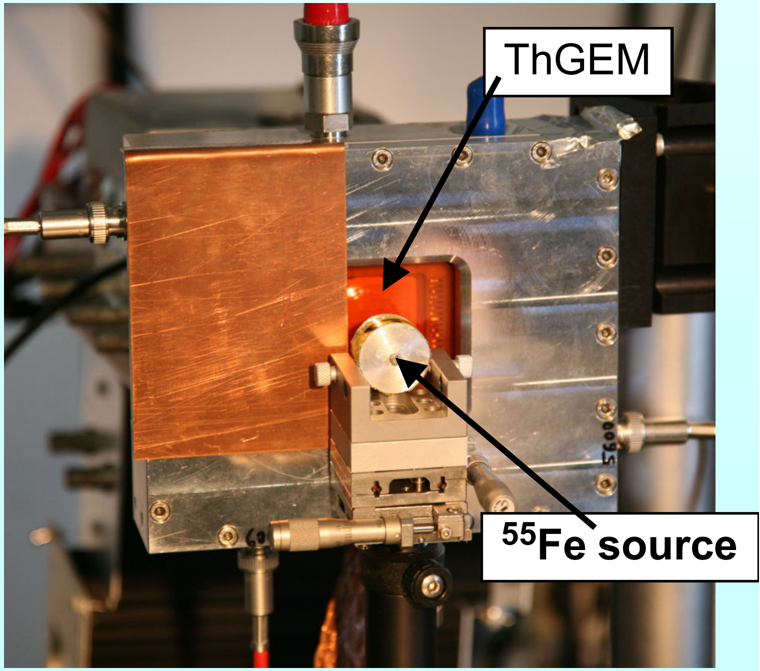


$$E_{drift} = (V_3 - V_2)/d_1$$

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

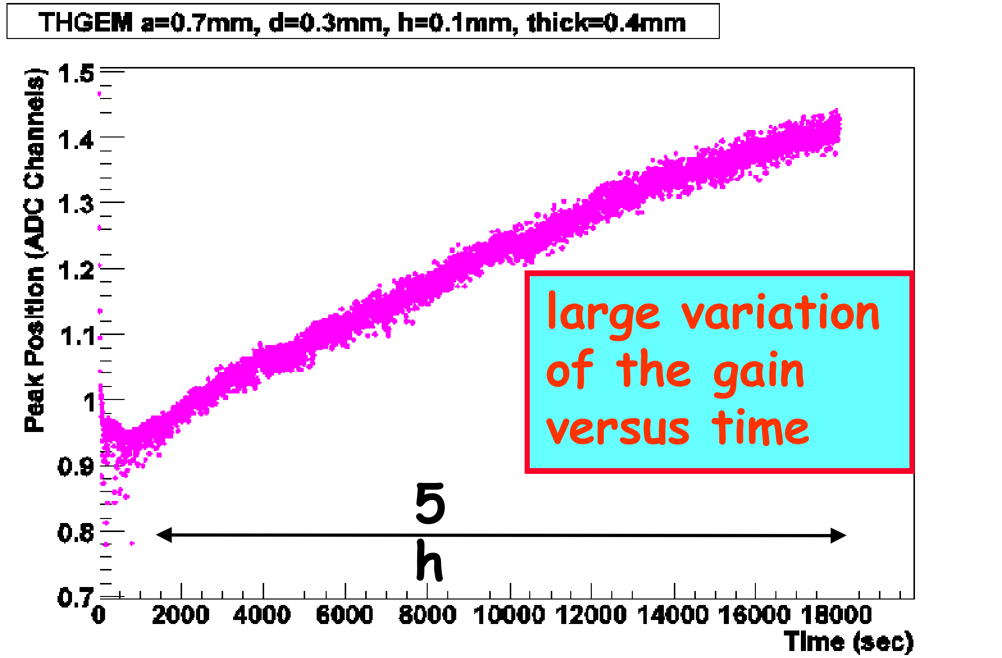
$$\Delta V = V_2 - V_1$$

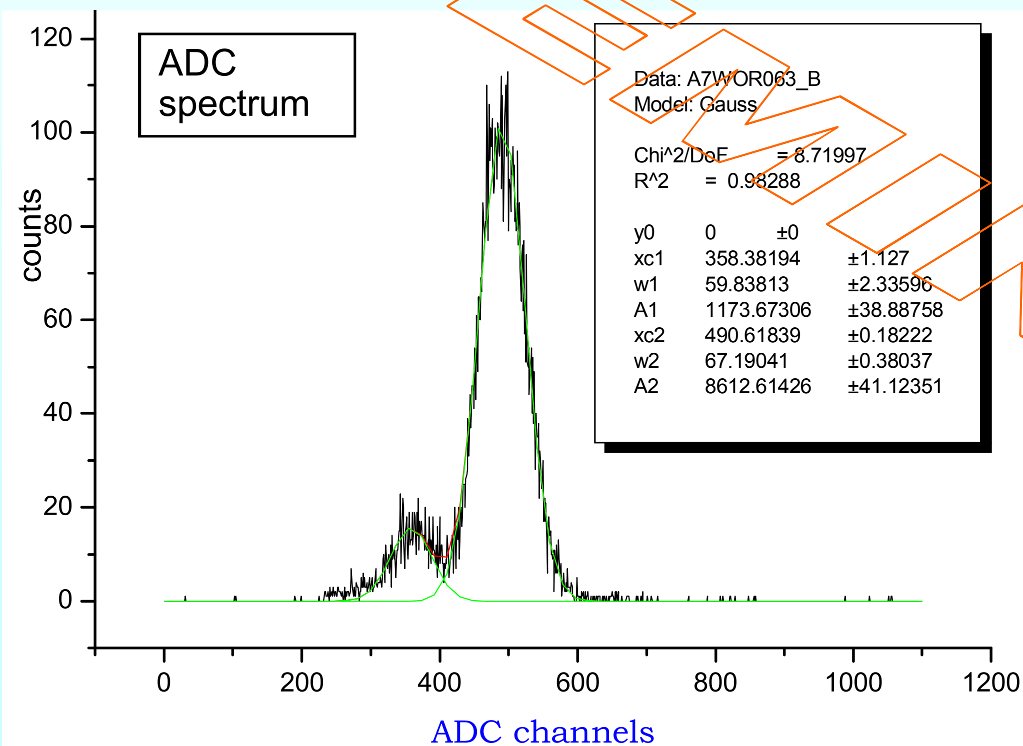


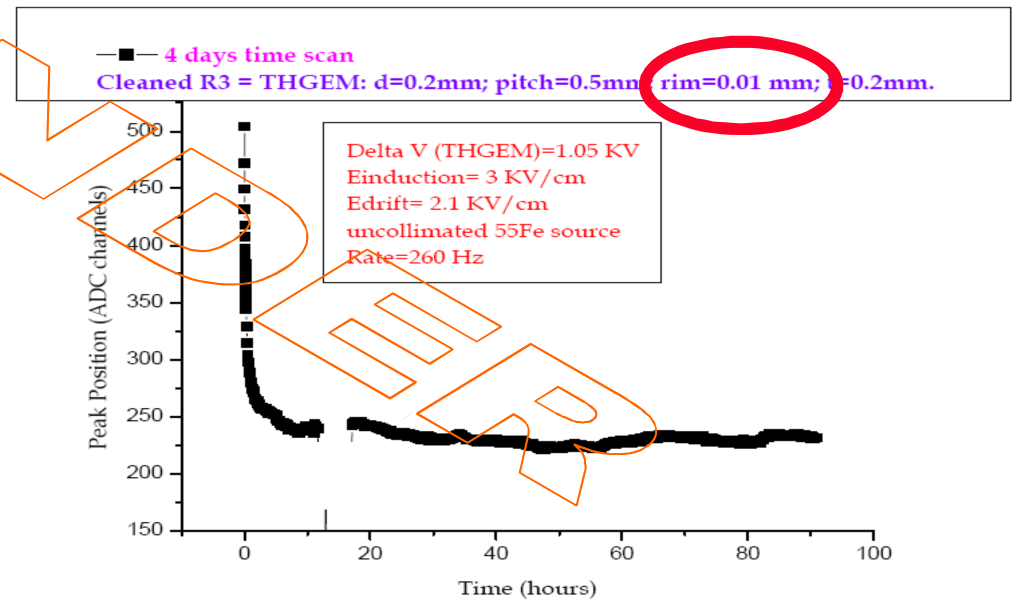


GAIN STABILITY (1)

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







REMINDER

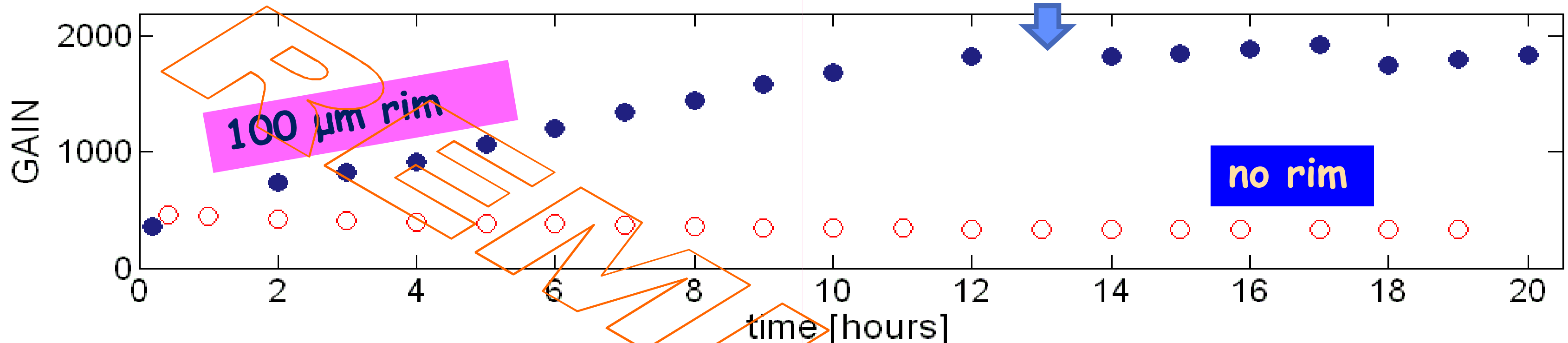
It is now clarified that the good stability (within ~20-30%) is obtained with small rim (< 20 μm)

GAIN STABILITY (2)

^{55}Fe source; uniform irradiation

	diam (mm)	pitch (mm)	rim (μm)	thick (mm)
	0.4	0.8	0	0.4
	0.4	0.8	100	0.4

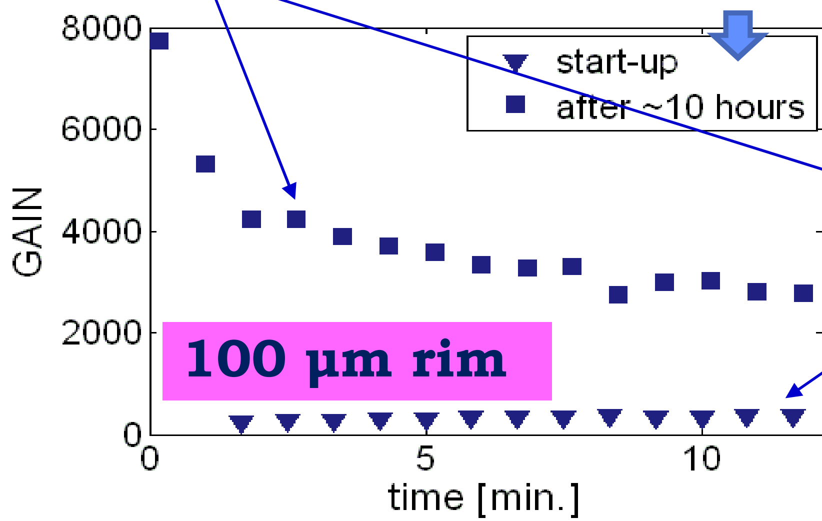
Long time gain variation

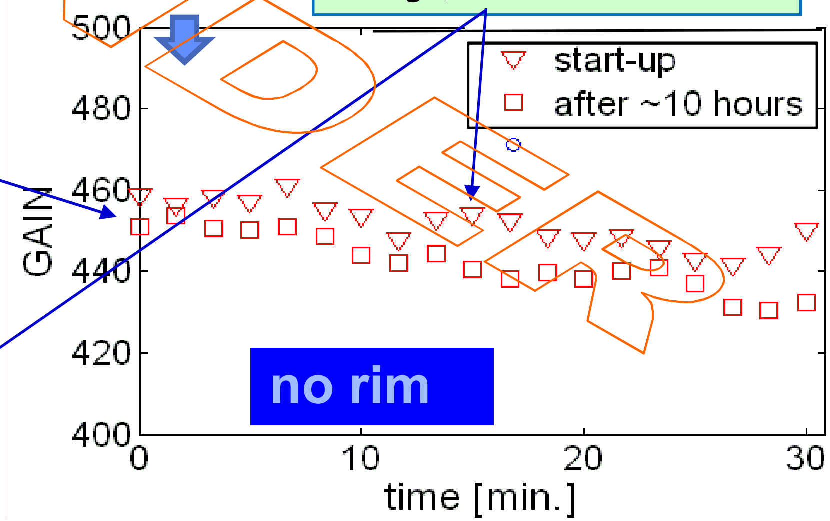


START IRRADIATING after ~10 hours at nominal voltage

Short time gain variation

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





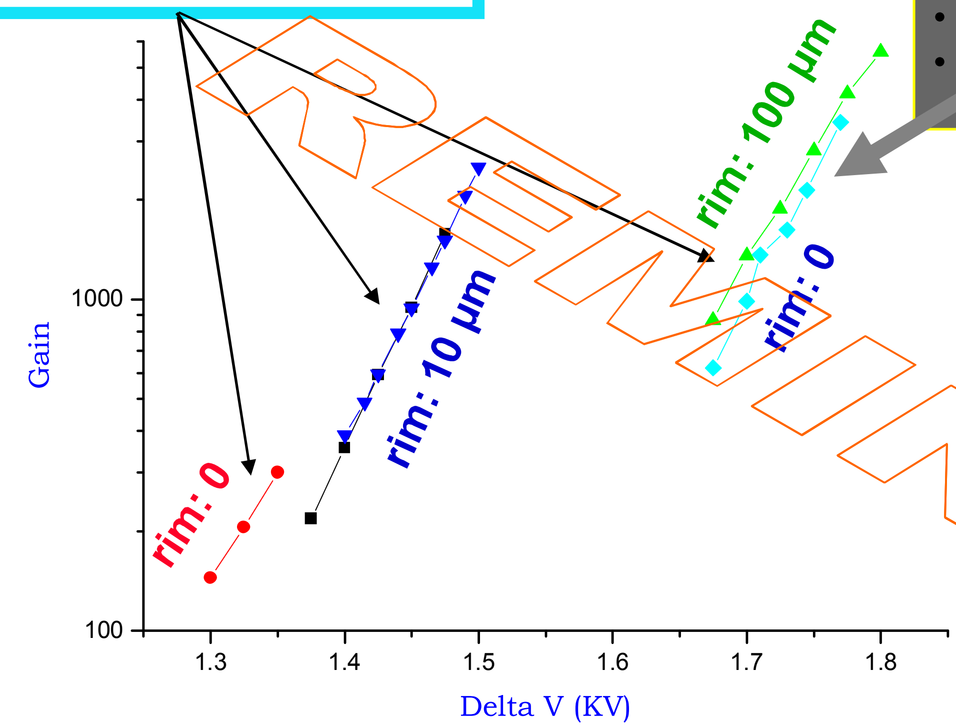
Gain ~ 4,000; rate capability ~ $10^7/mm^2$

PARAMETERS:
- Diameter = 0.3 mm
- Pitch= 0.7 mm
- Thickness = 0.4 mm

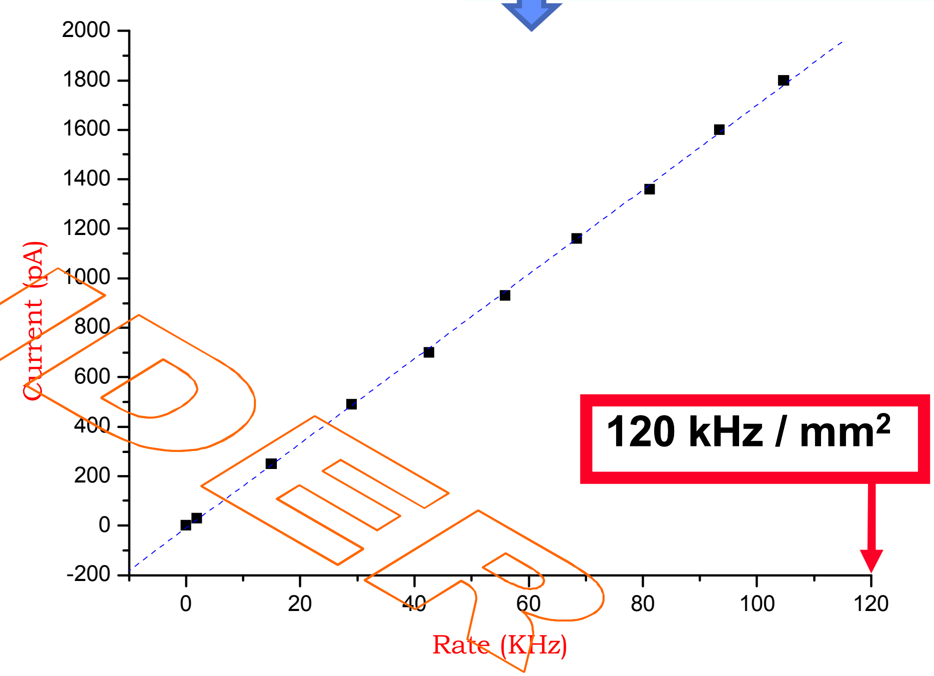
Ar/CO_2: 70/30

PARAMETERS:
- Diameter = 0.3 mm
- Pitch= 0.6 mm
- Thickness = 0.6 mm
- Rim = 0 mm
- Gas: Ar/CO_2 – 70/30

PARAMETERS:
- Diameter = 0.3 mm
- Pitch= 0.7 mm
- Thickness = 0.4 mm
- Rim = 0 mm
- Gas: Ar/CO_2 – 70/30



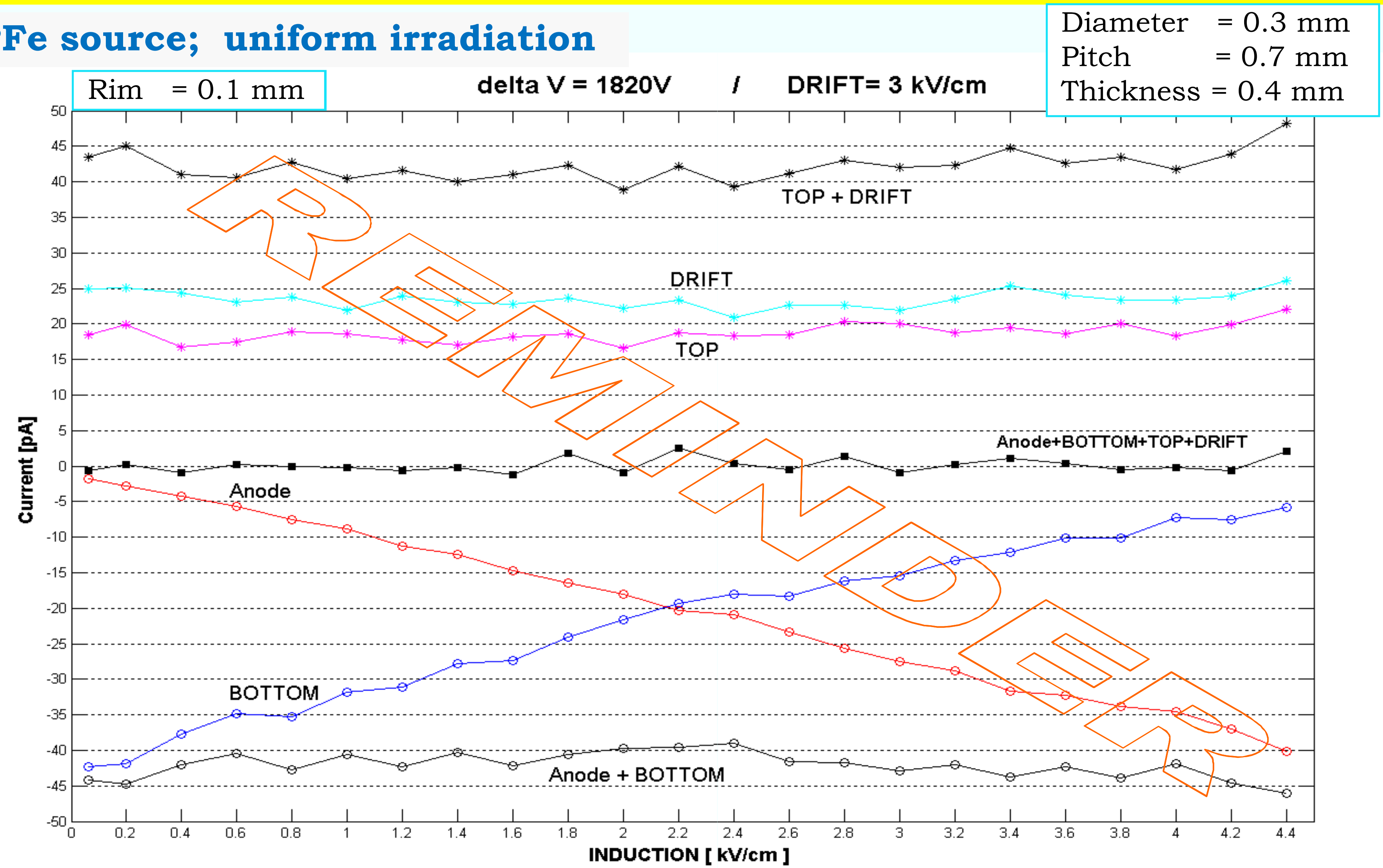
X-Ray Source: ~1 mm², rate ~1.7KHz.



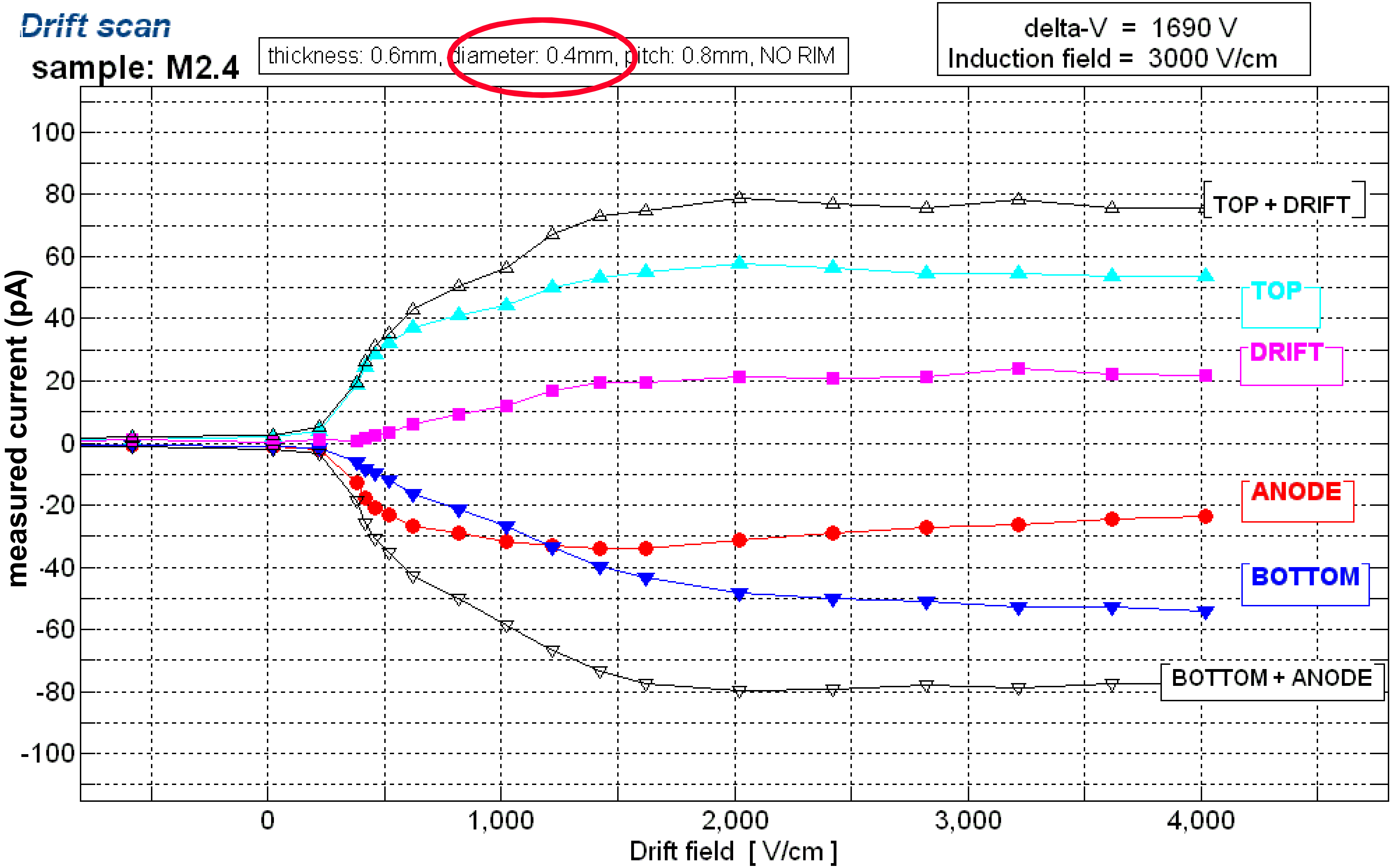
120 kHz/ mm², 300 e⁻ → single photoelectron rates of ~35 MHz/ mm²

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

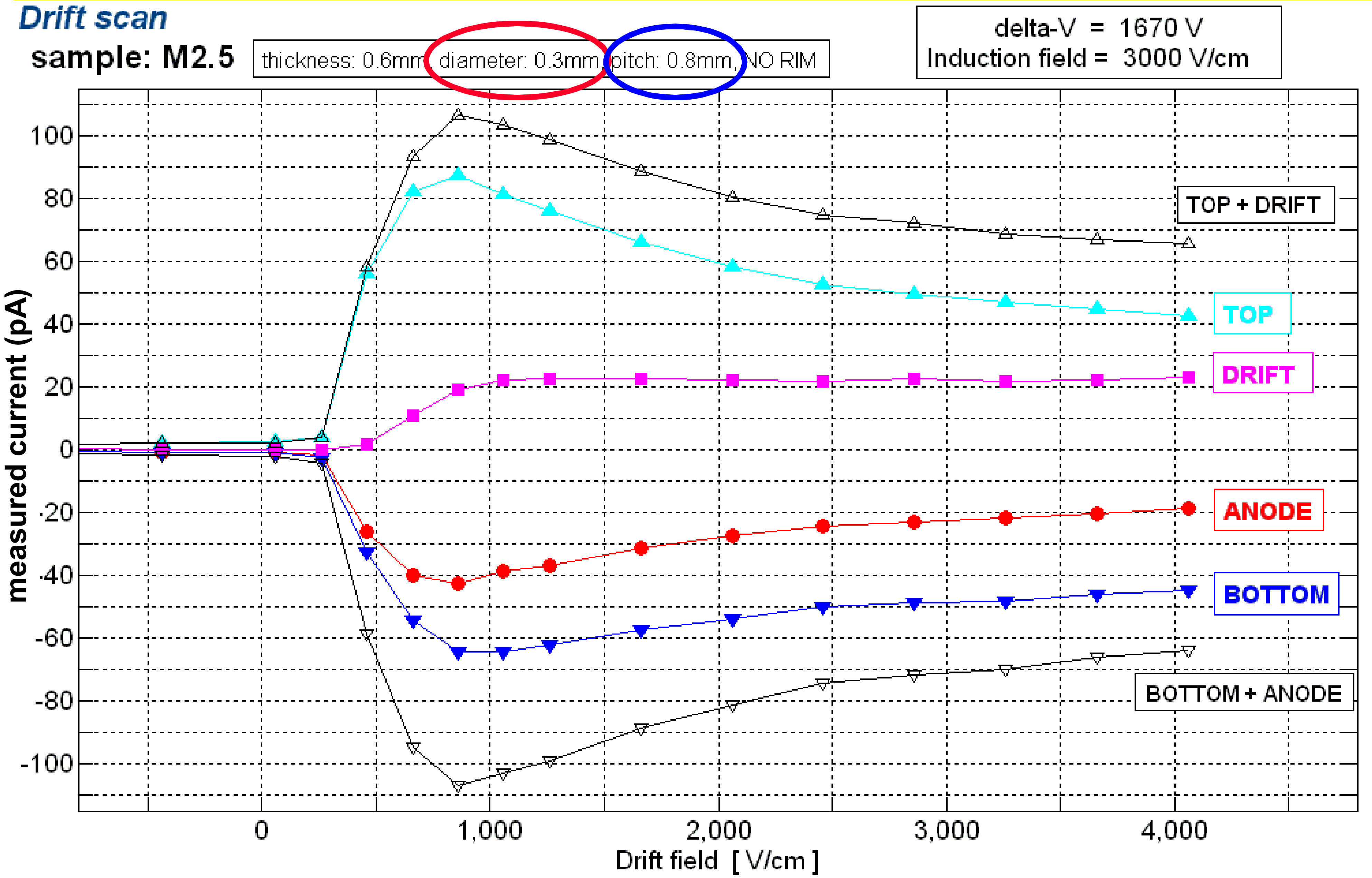
^{55}Fe source; uniform irradiation



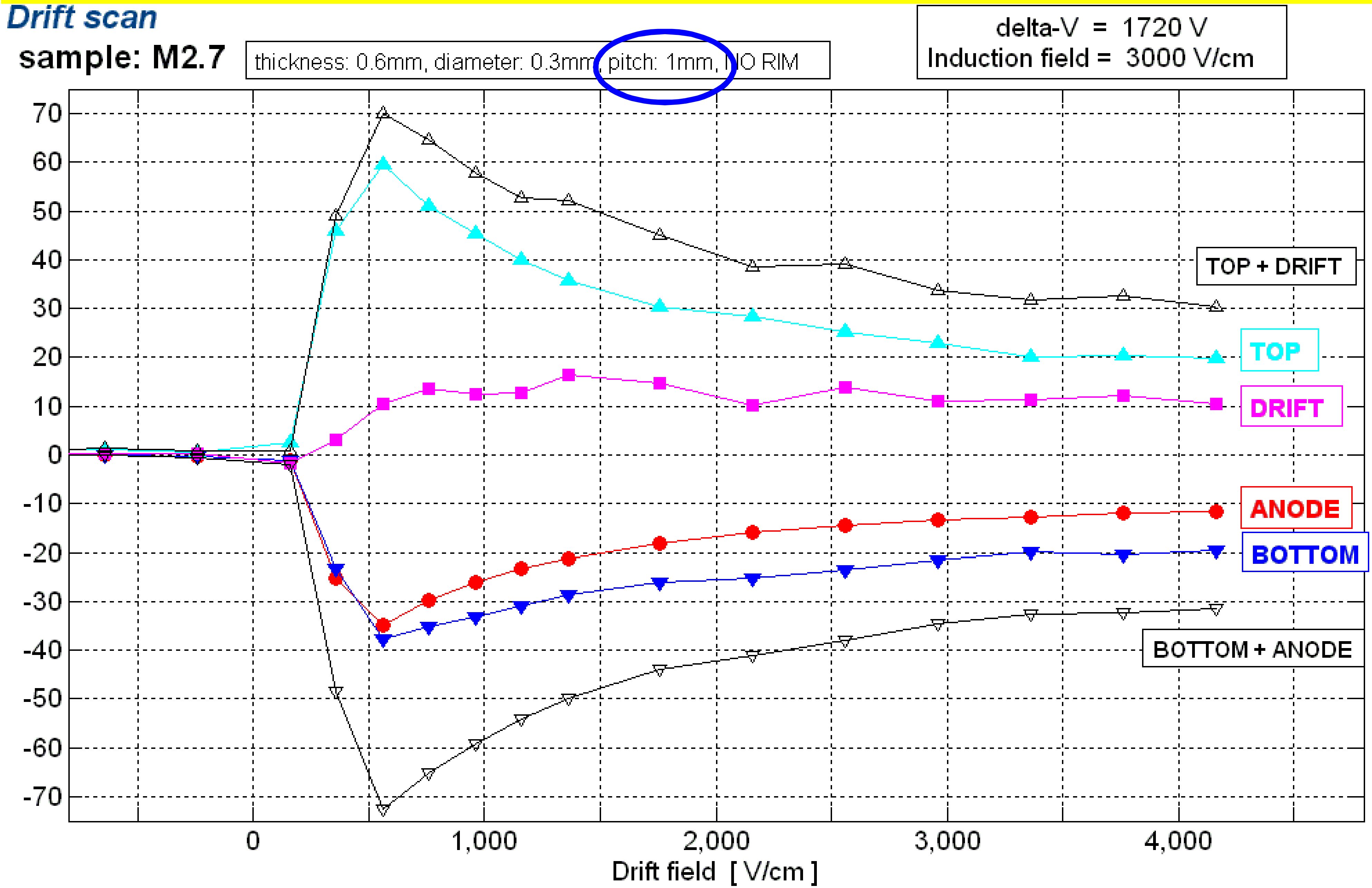
primary e^- collection efficiency vs E_{drift}



smaller holes: E_{drift} critical for e^- coll. eff.



e⁻ collection efficiency



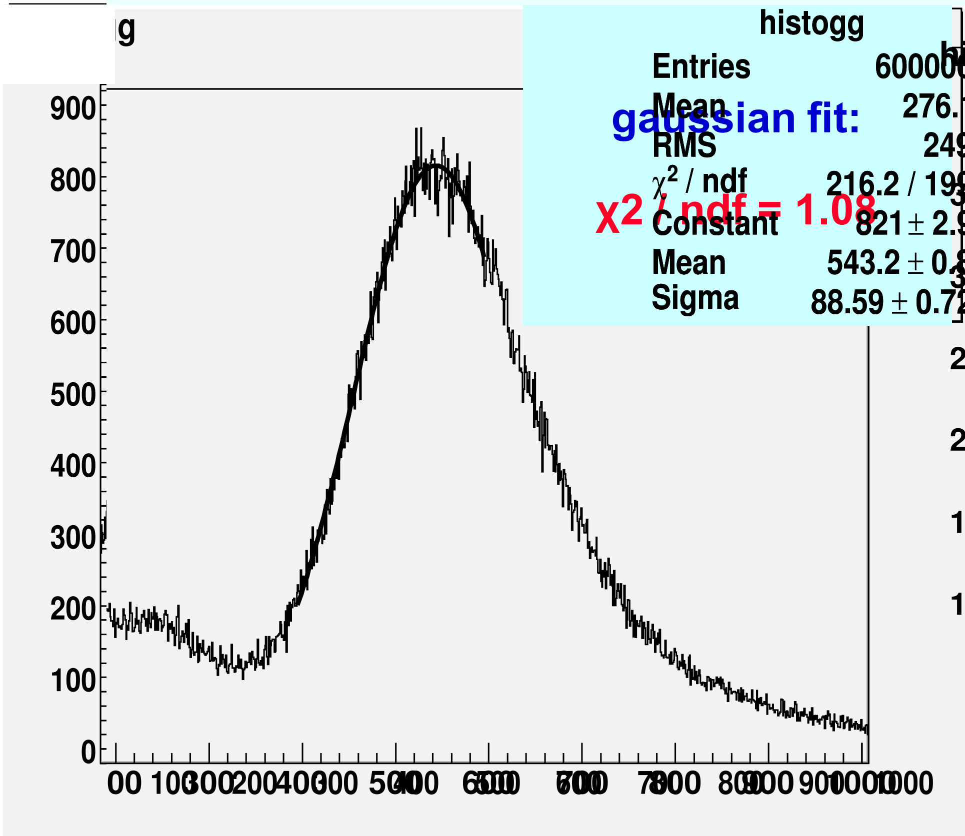
e⁻ collection efficiency

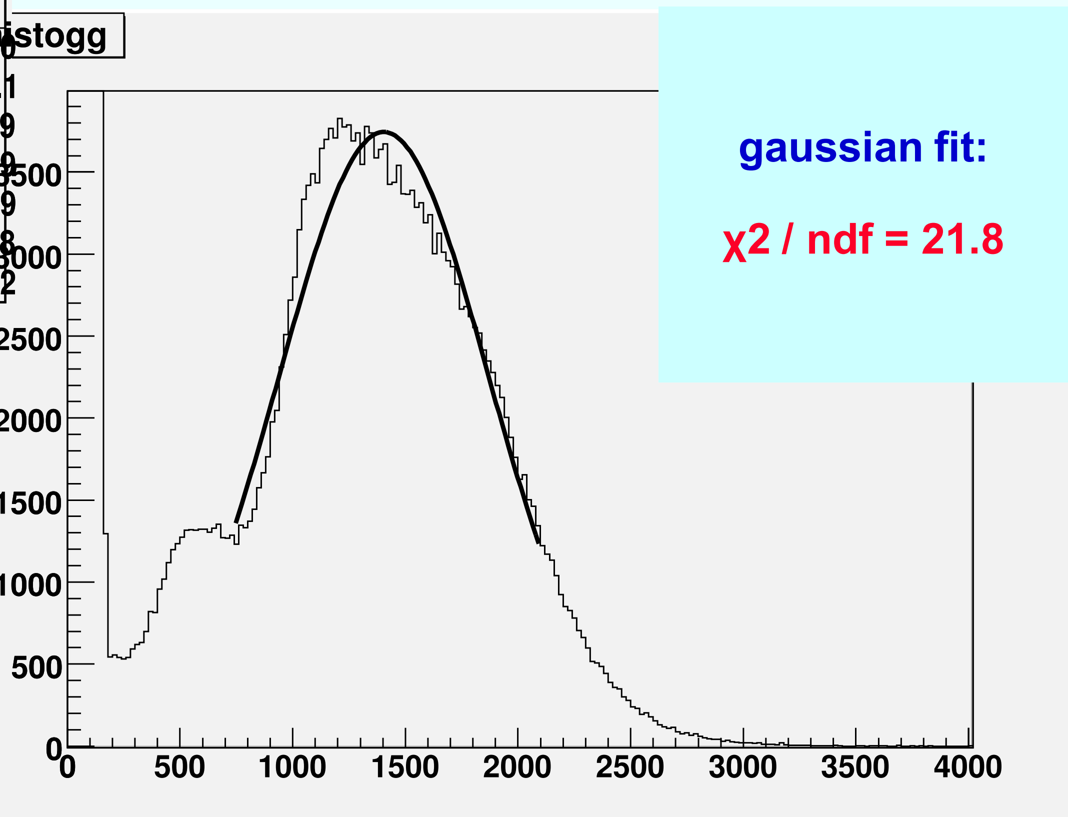
Single THGEM

For larger values of the drift field primaries are lost:

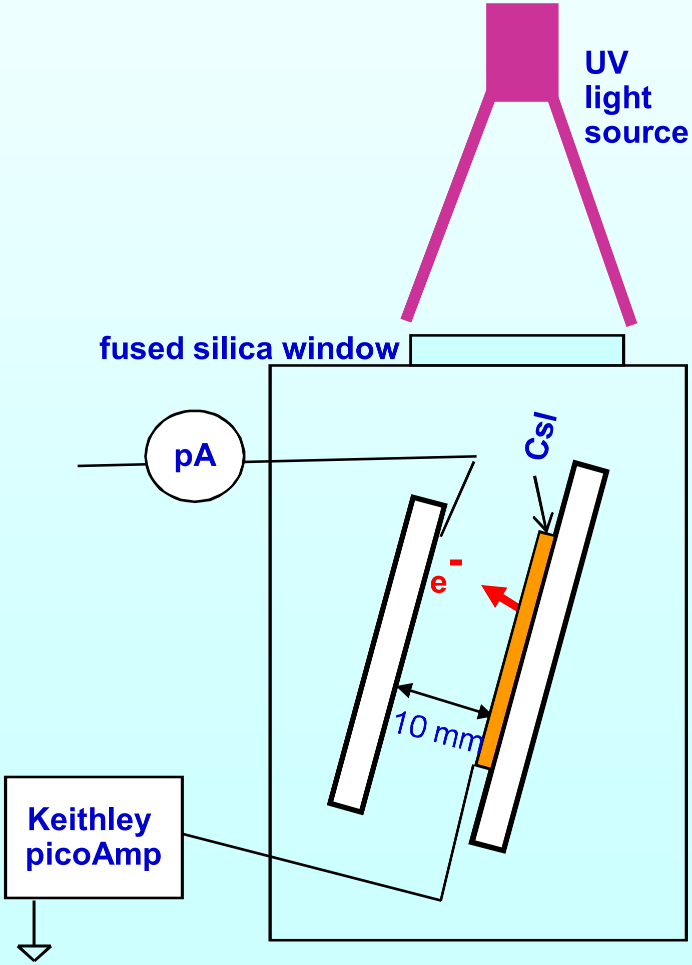
currents are lower and spectra become wider and distorted (not gaussian)

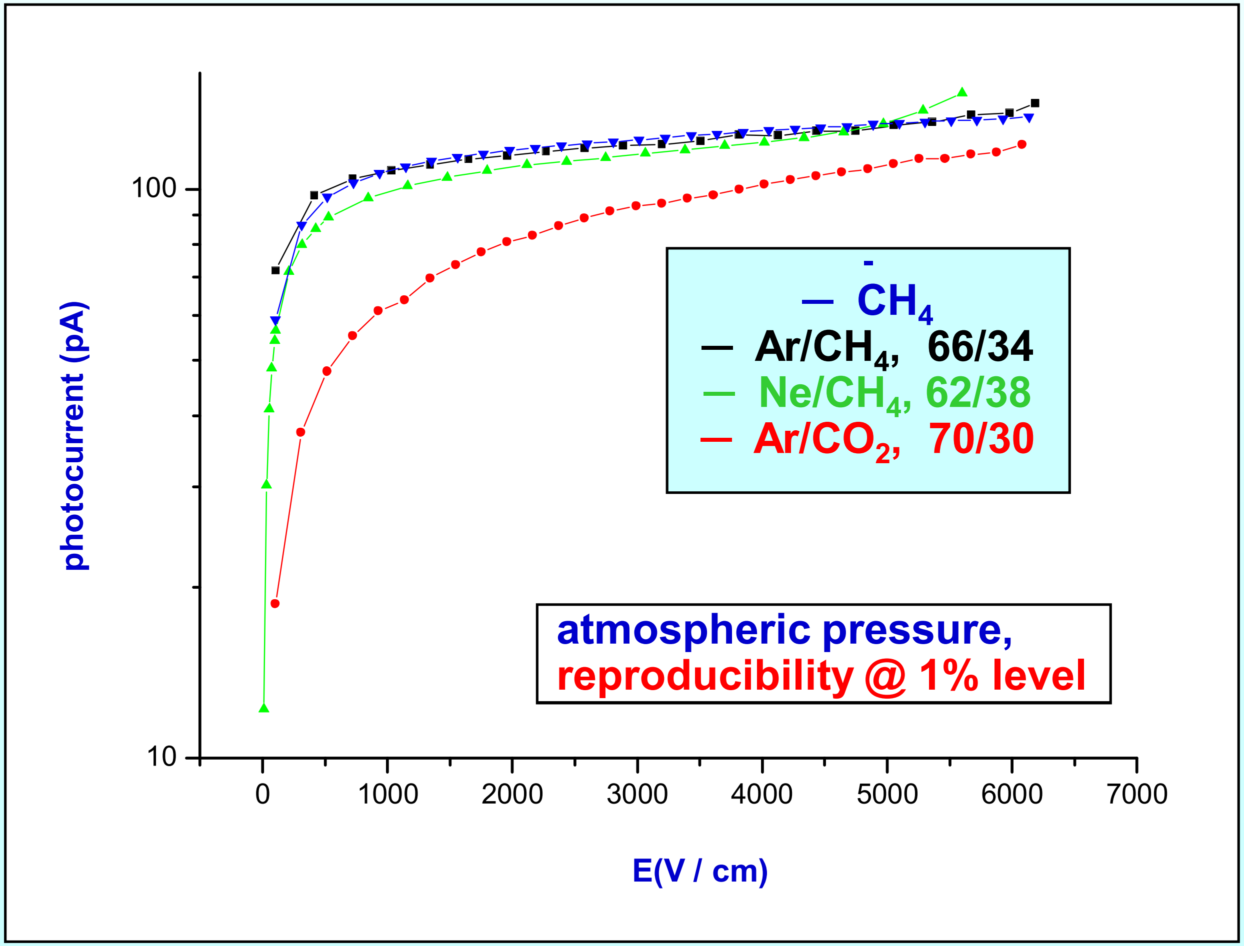
This effect is more critical for small values of the hole diameter and large values of the pitch





Photocurrent measurements in various gas atmospheres

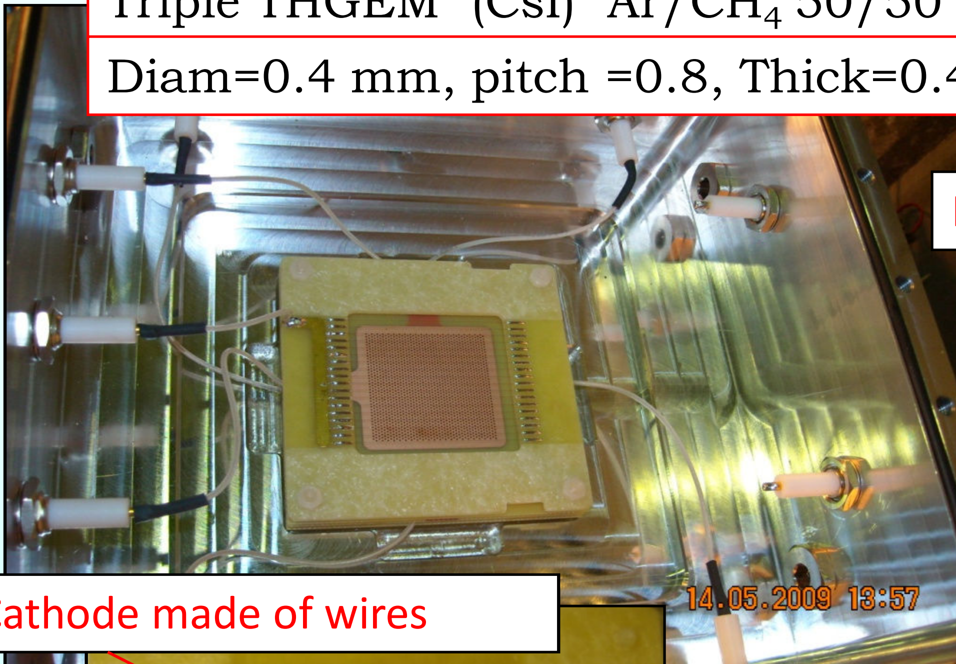




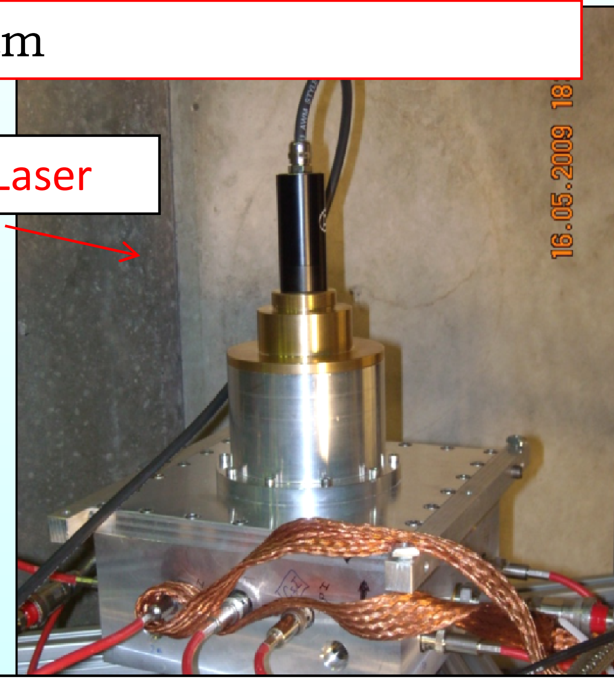
Setup for single photon detection test

Triple THGEM (CsI) Ar/CH_4 50/50

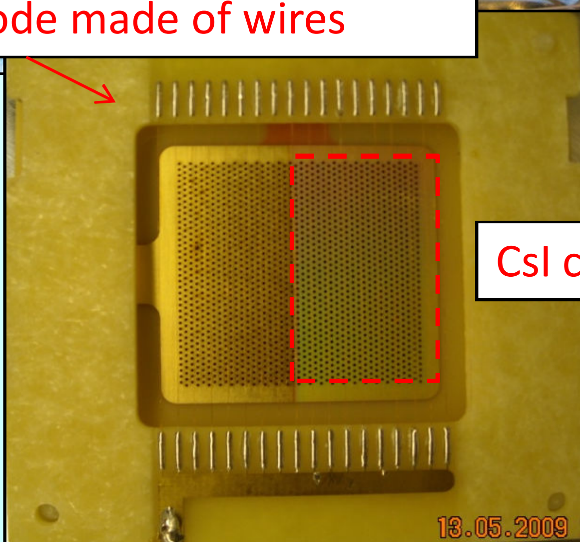
Diam=0.4 mm, pitch =0.8, Thick=0.4, rim ≤10 μm



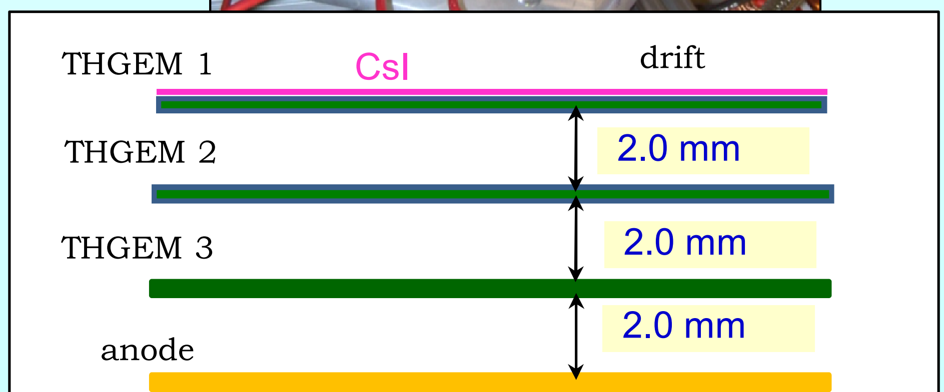
Pulsed Diode Laser



Cathode made of wires



CsI coating



Geometrical sketch inside the chamber

UV LIGHT PULSED SOURCES

1. **Model UV LED-255**

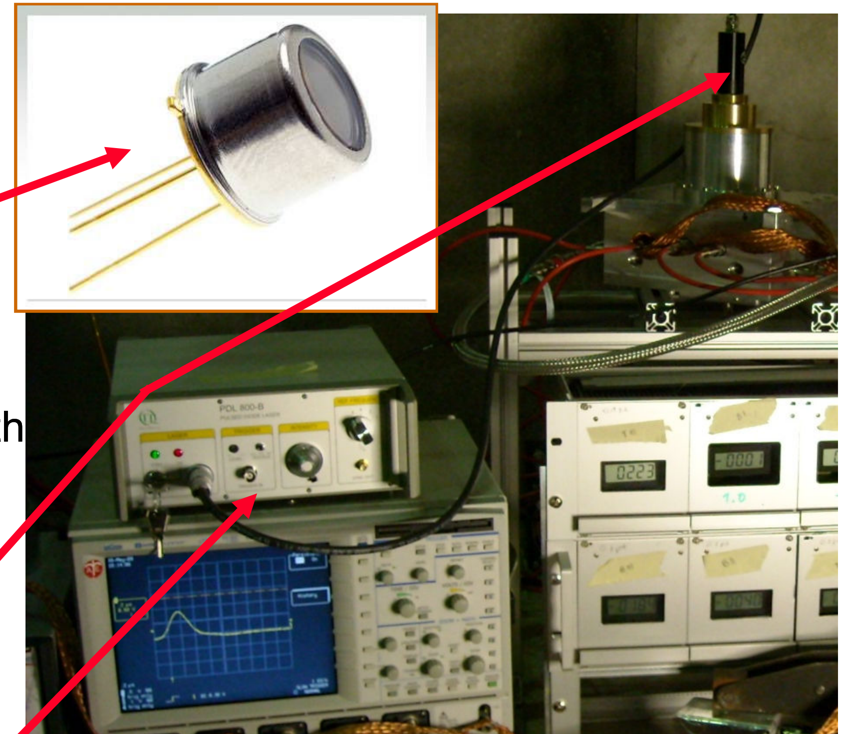
   by Seoul Optodevice Co., Ltd, Seoul, Korea (South

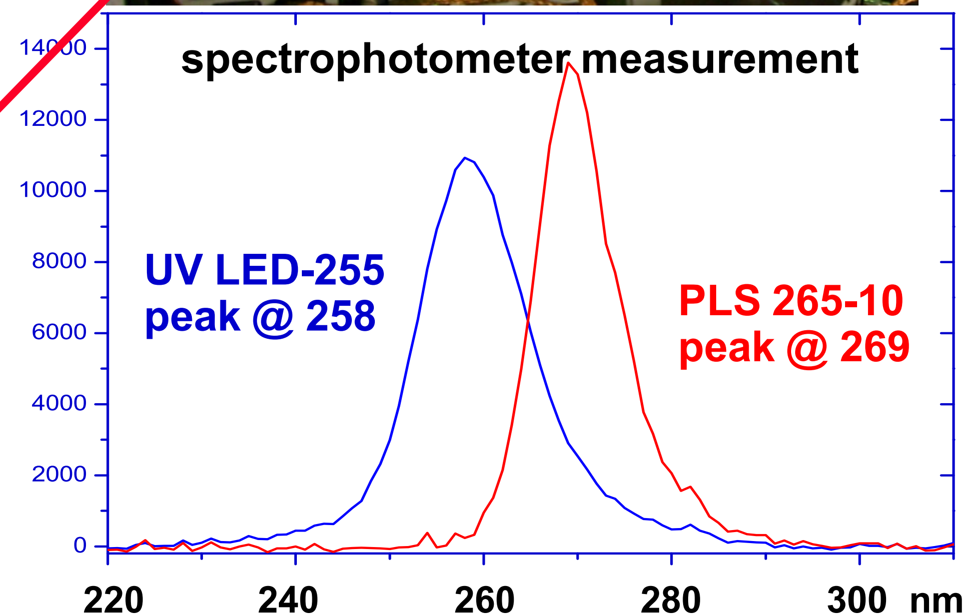
- **Central wavelength: 255 ± 10 nm**
- **Spectral line width: <20nm FWHM**
  - **also called germicidal ray (disinfection)**
  - **Applications: Water/Surface purification, Laboratory testing**

2. **PLS 265-10 (pulsed LED) and controller**

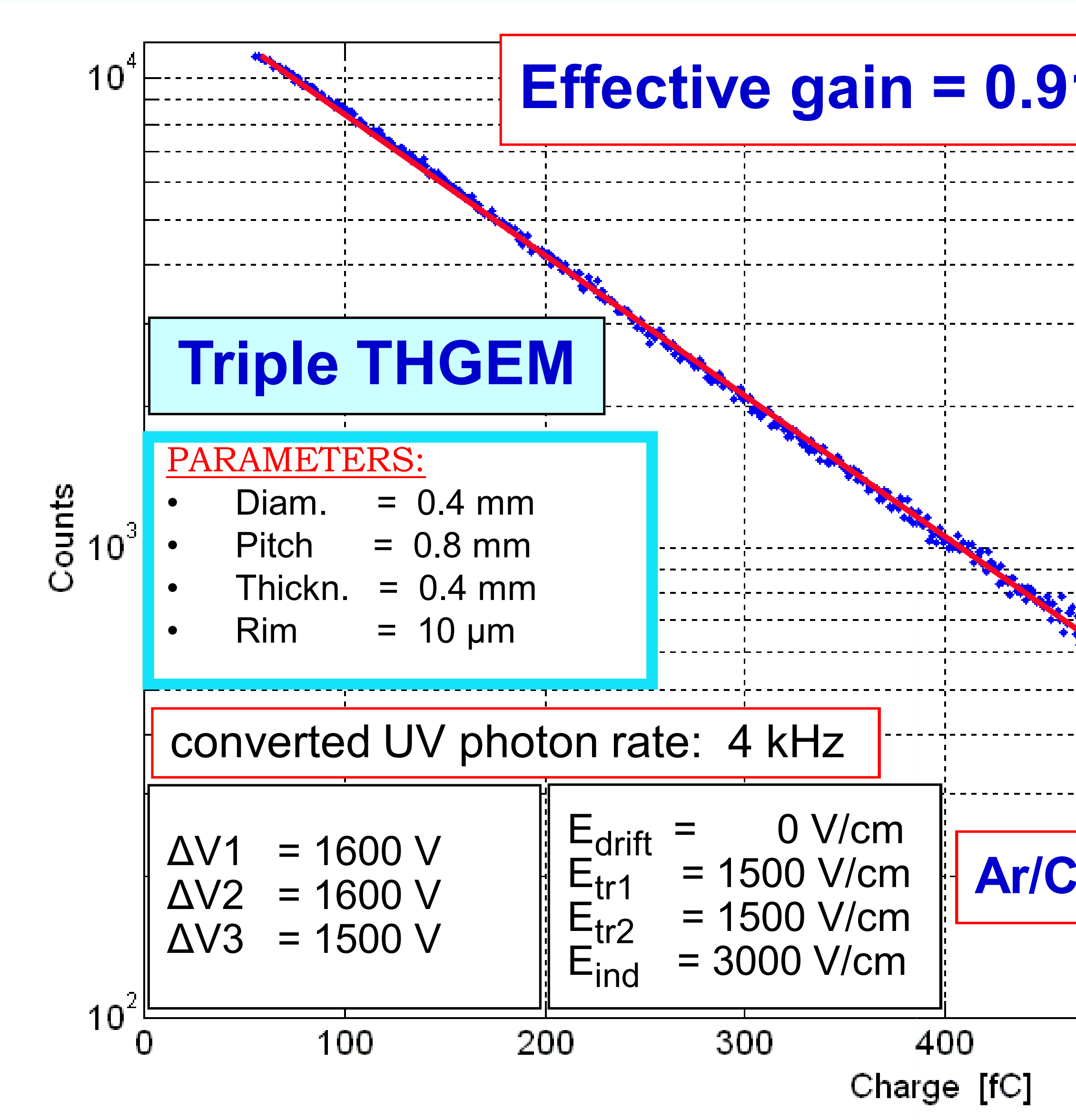
   by PicoQuant GmbH, Berlin, Germany

- **600 ps long pulses**
- **up to 40 MHz**





Amplitude distribution for single photon signals



stable detector behavior at gains approaching 10^6

It's the gain of a PMT!

Work in progress: in March '09 (TIPP09) it was 10^5

Time distribution for single photon signals

Triple THGEM

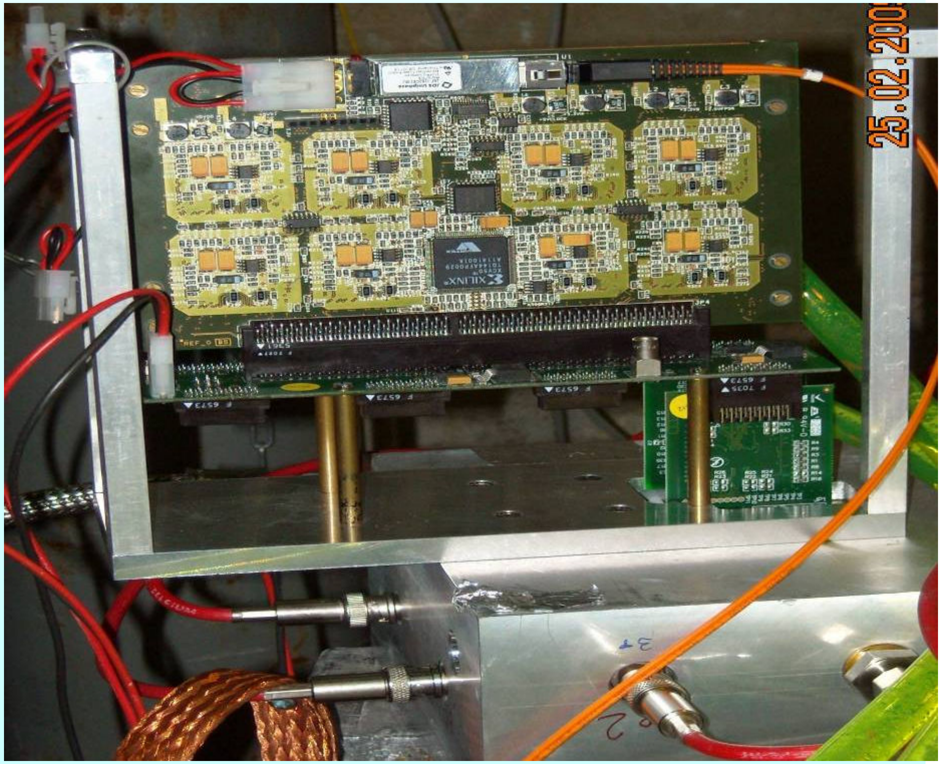
Ar/CH_4: 50/50

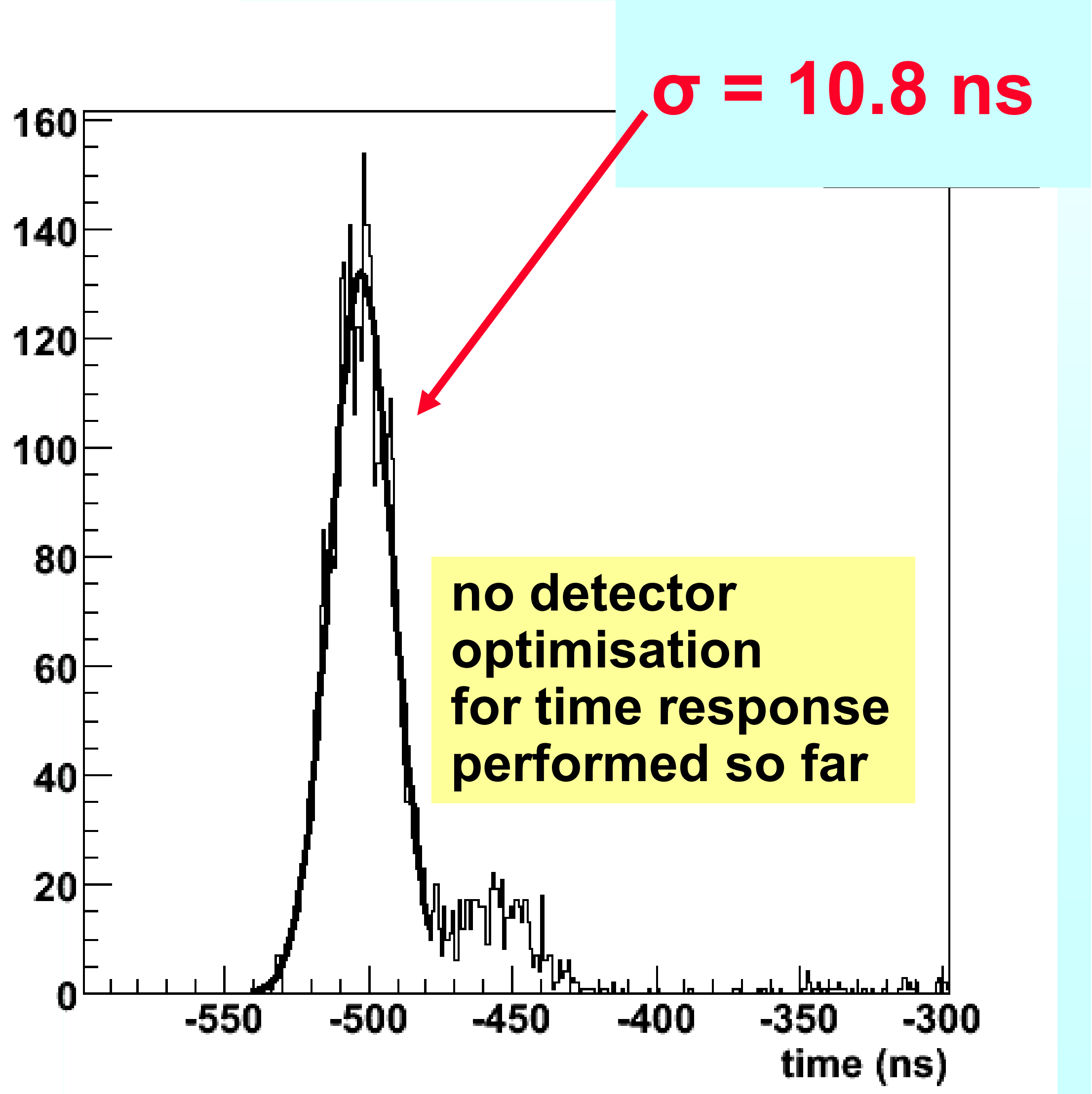
gain ~ $5 \cdot 10^5$

PARAMETERS:
Diam. = 0.4 mm
Pitch = 0.8 mm
Thickn. = 0.4 mm
Rim = 10 µm

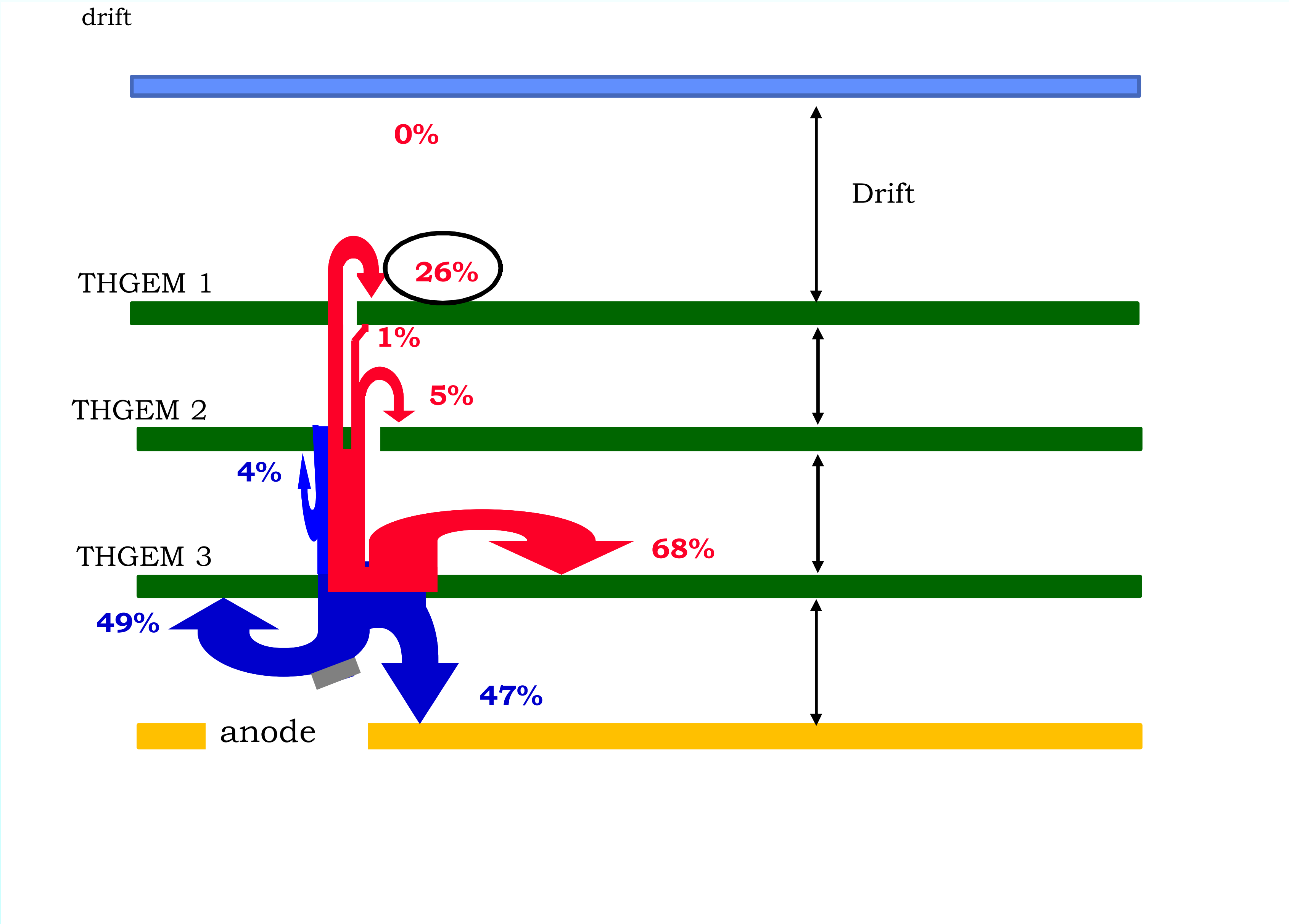
converted UV photon rate: 3 kHz

TDC bin size: 108 ps
pulse width: 600 ps





presently typical charge sharing

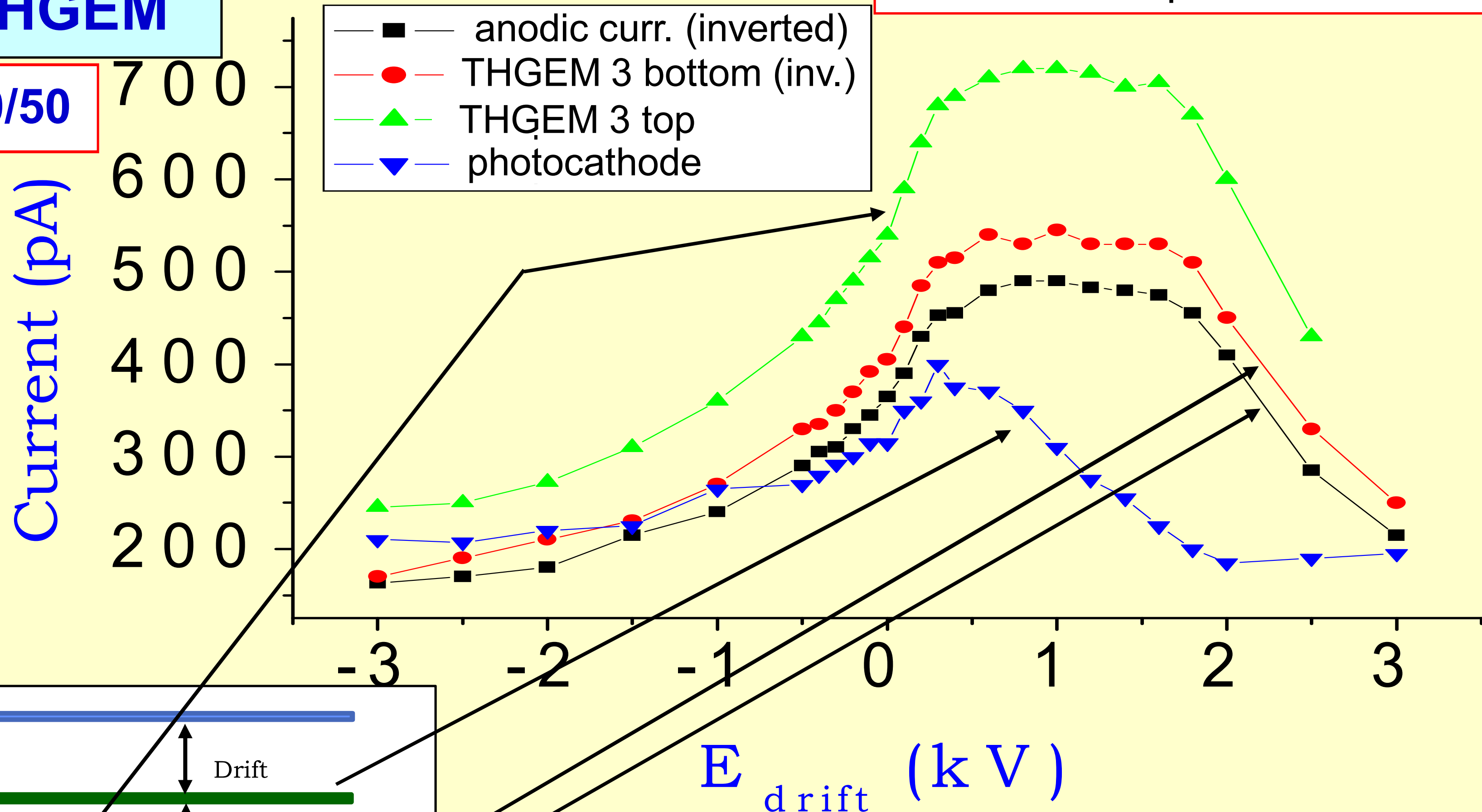


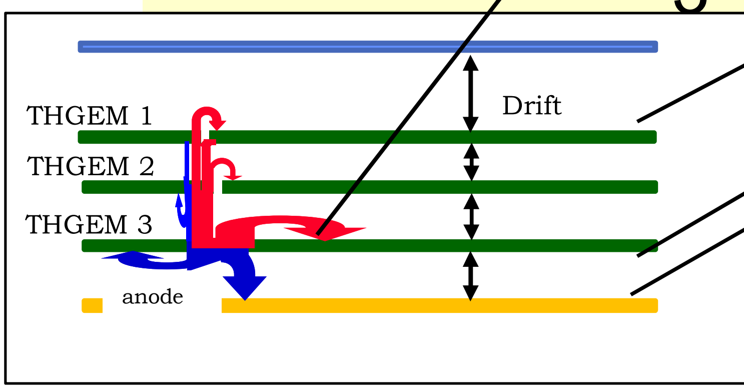
currents as function of E_{drift} at gain ~10^6

Triple THGEM

Ar/CH_4: 50/50

converted UV photon rate: 4 kHz





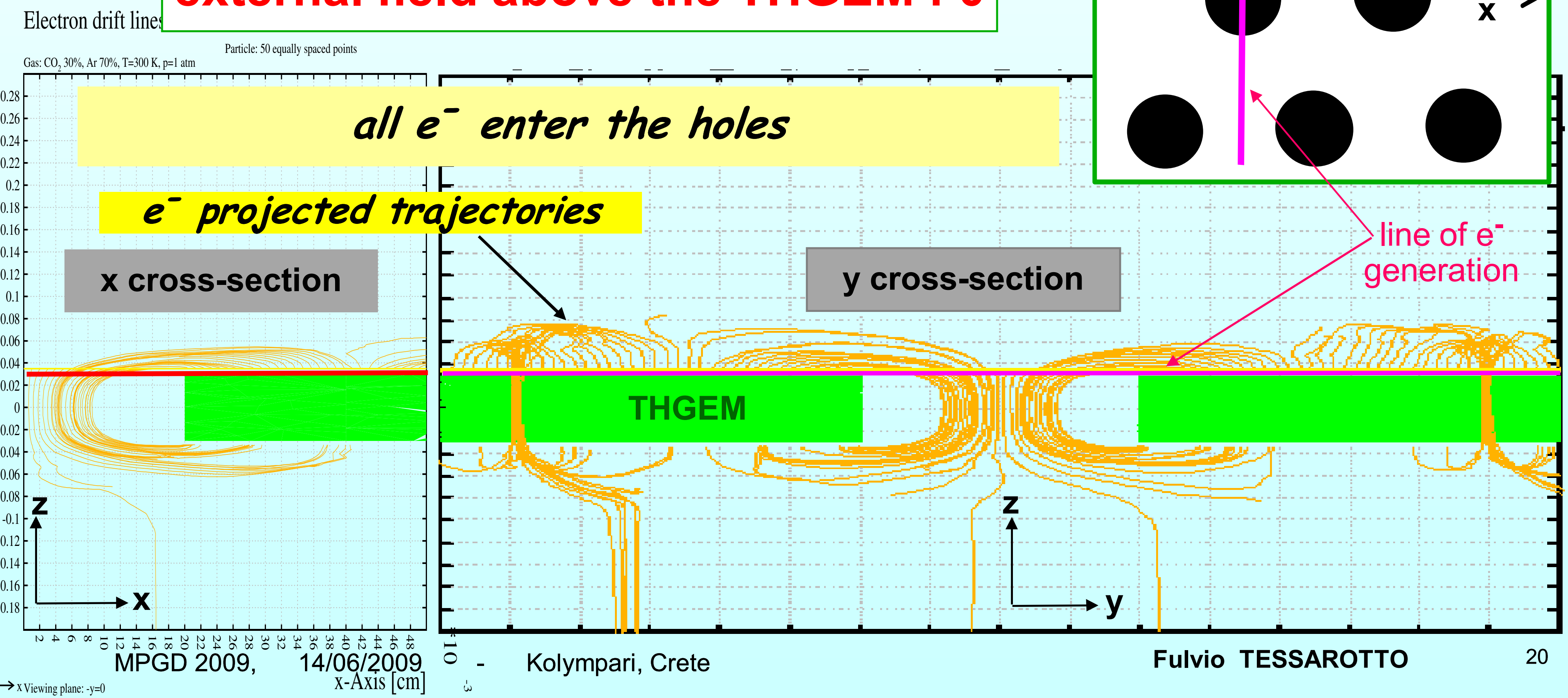
"plateau" of anodic current at large gain too

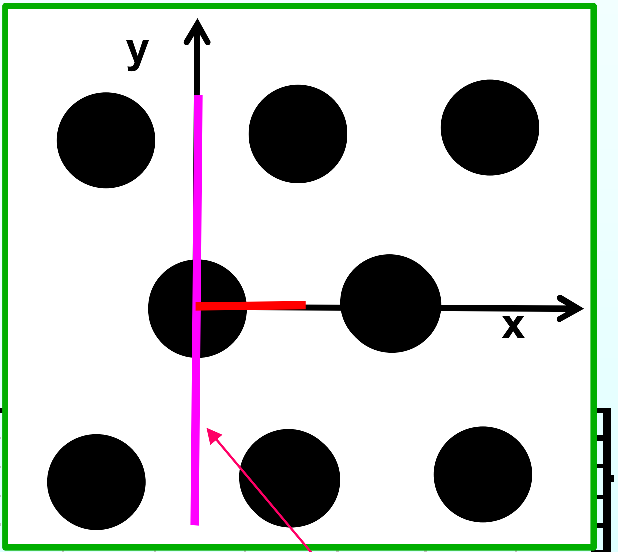
simulation of photoelectron extraction, E_{drift}=0

photoelectron trajectories from a THGEM photocathode,_multiplication switched off

thickness 0.6 mm, diam. 0.4 mm, pitch: 0.8 mm, ΔV = 1500 V

external field above the THGEM : 0



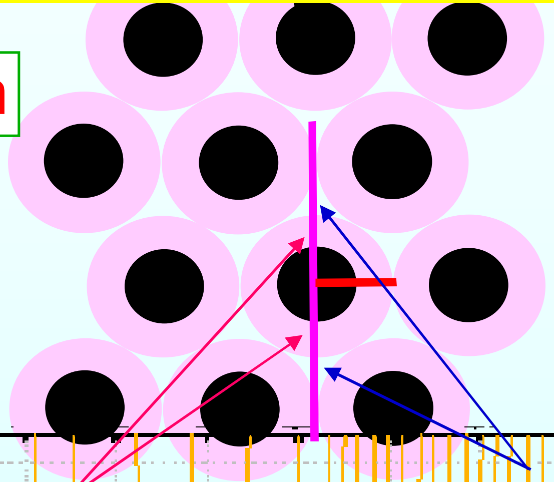


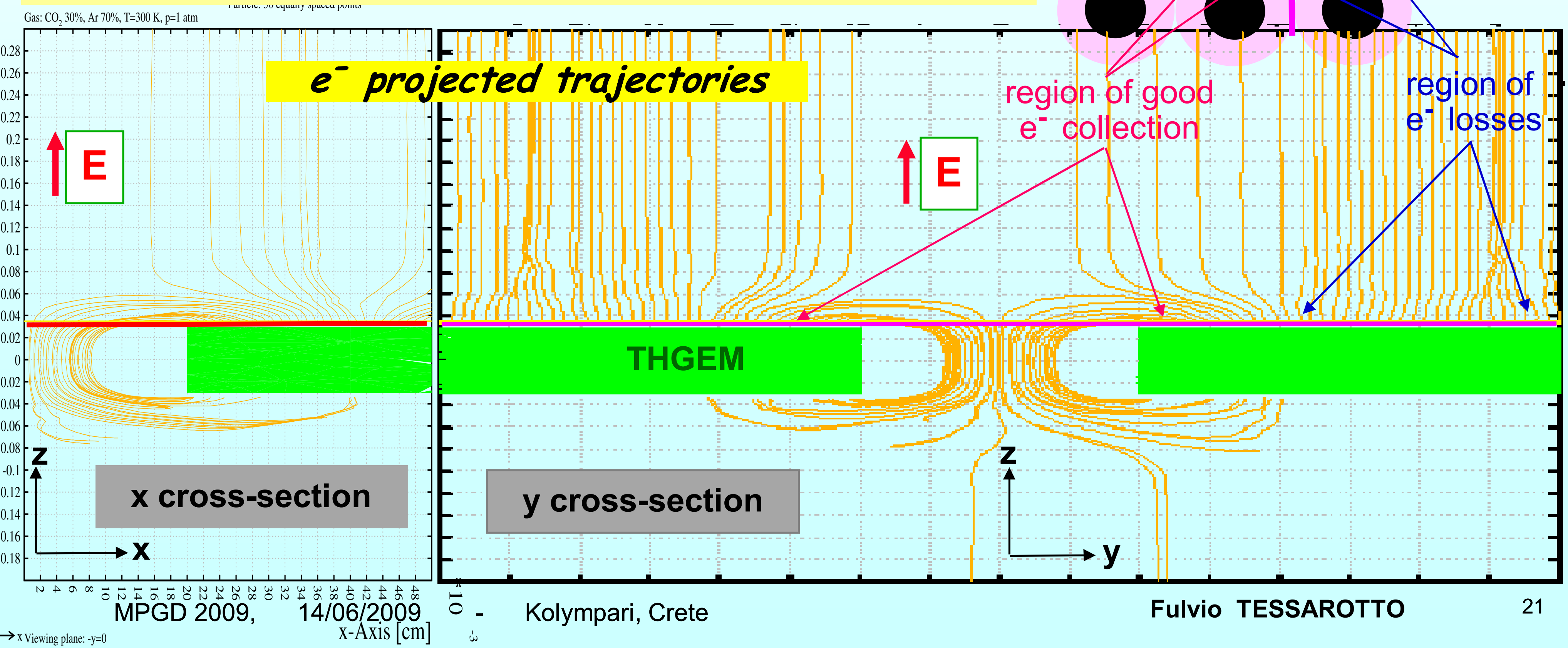
photoelectron trajectories, E_{drift}=-500 V/cm

external field above the THGEM : - 500 V/cm

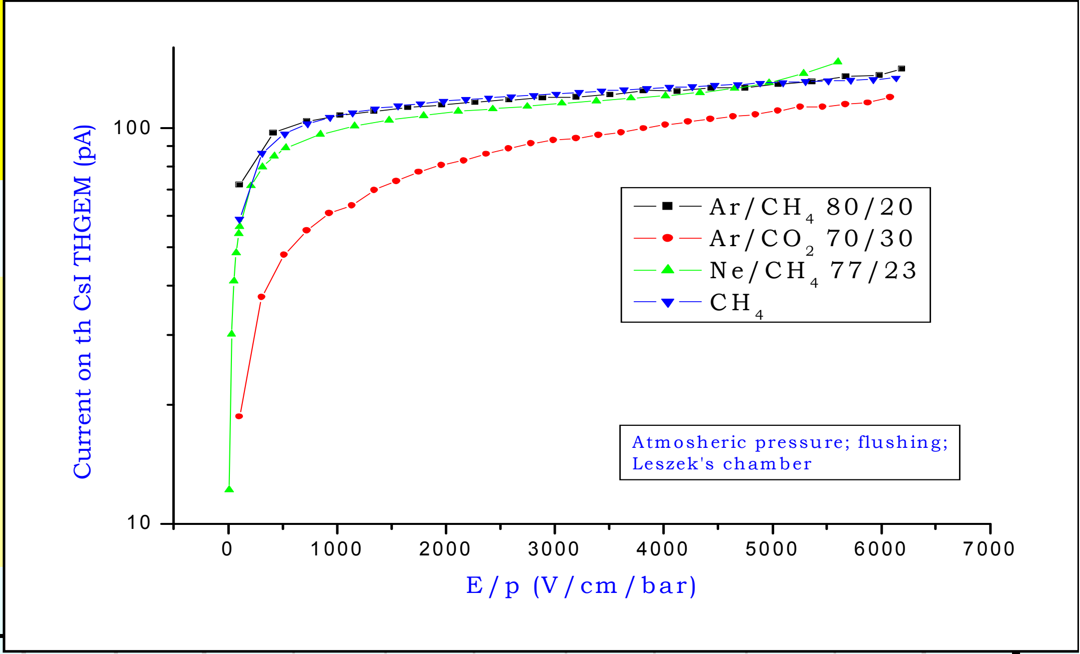
better photoelectron extraction from the CsI

but a fraction of the e⁻ are lost

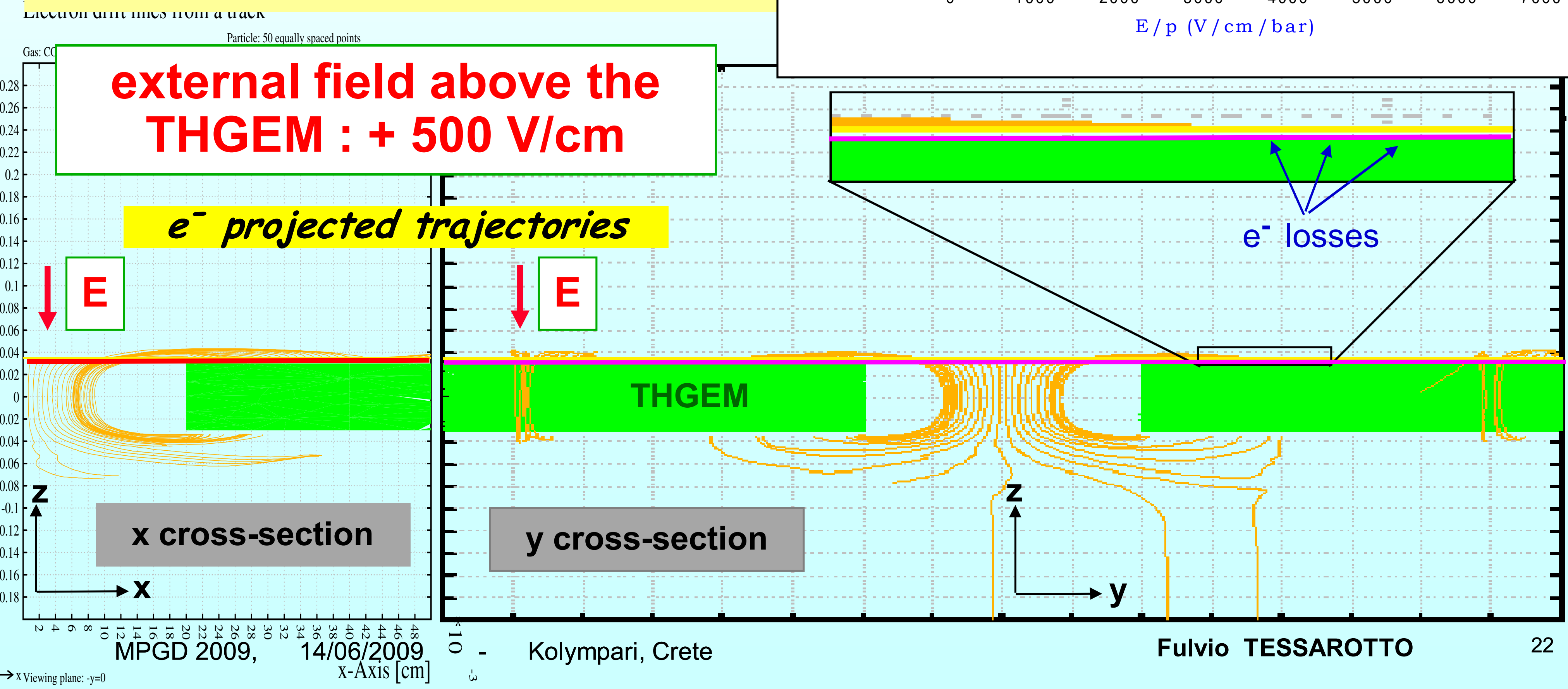




photoelectron traj. E_{drift}=+500 V/cm



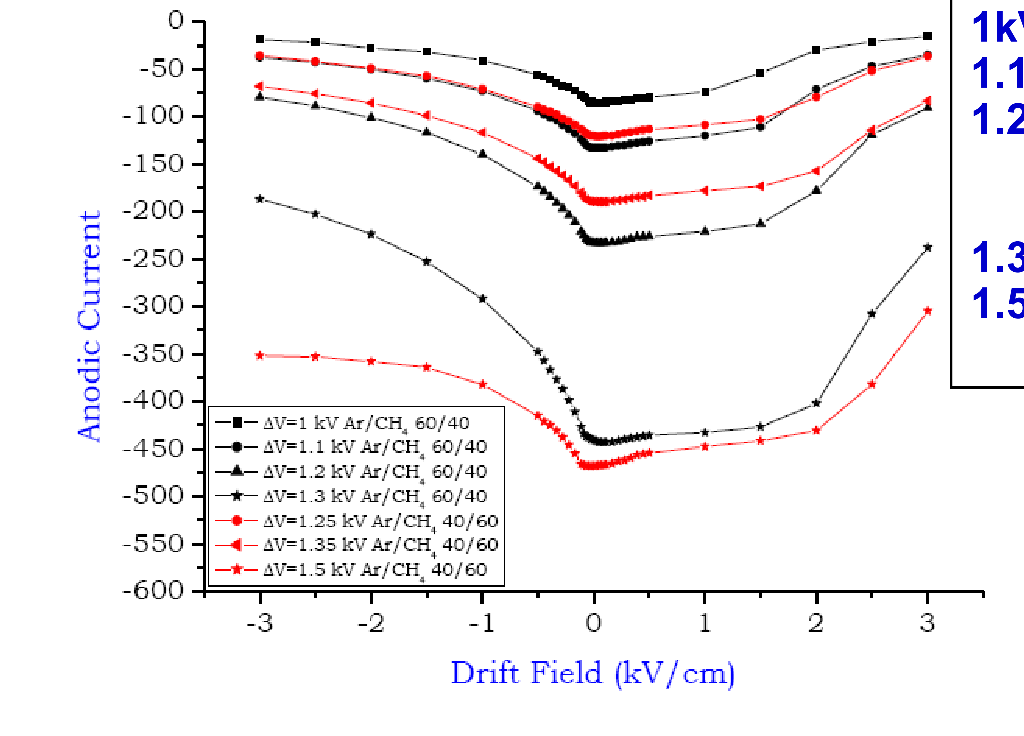
lowering field intensity: problematic photoelectron extraction from CsI



Photoelectron extraction at low THGEM gain

Anodic current in a THGEM detector versus the external electric field applied , a measurement

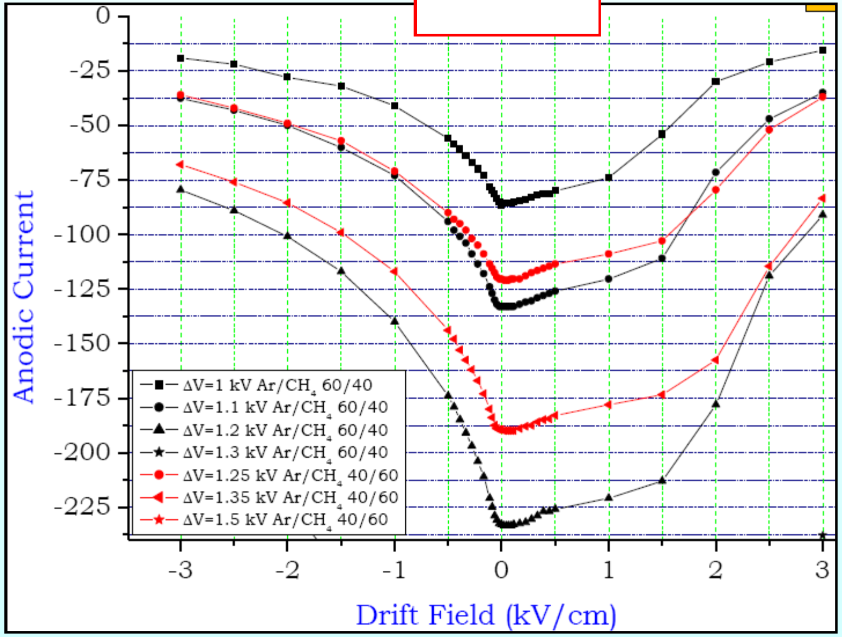
Ar/CH_4: 40/60; 60/40



ΔV = 1kV 1.1, 1.2 1.25, 1.3

1.35 1.5

ZOOM



The behaviour predicted by the simulation is confirmed!
→A clear suggestion to optimise the detector design

Perspectives

- optimize the parameters of the THGEM with photoconverting CsI layer to achieve the maximum photoelectron collection efficiency

- optimize the parameters for the two THGEMs to be used for the amplification of the signal to provide large and stable gain

- minimize the ion feedback to the CsI photoconverter

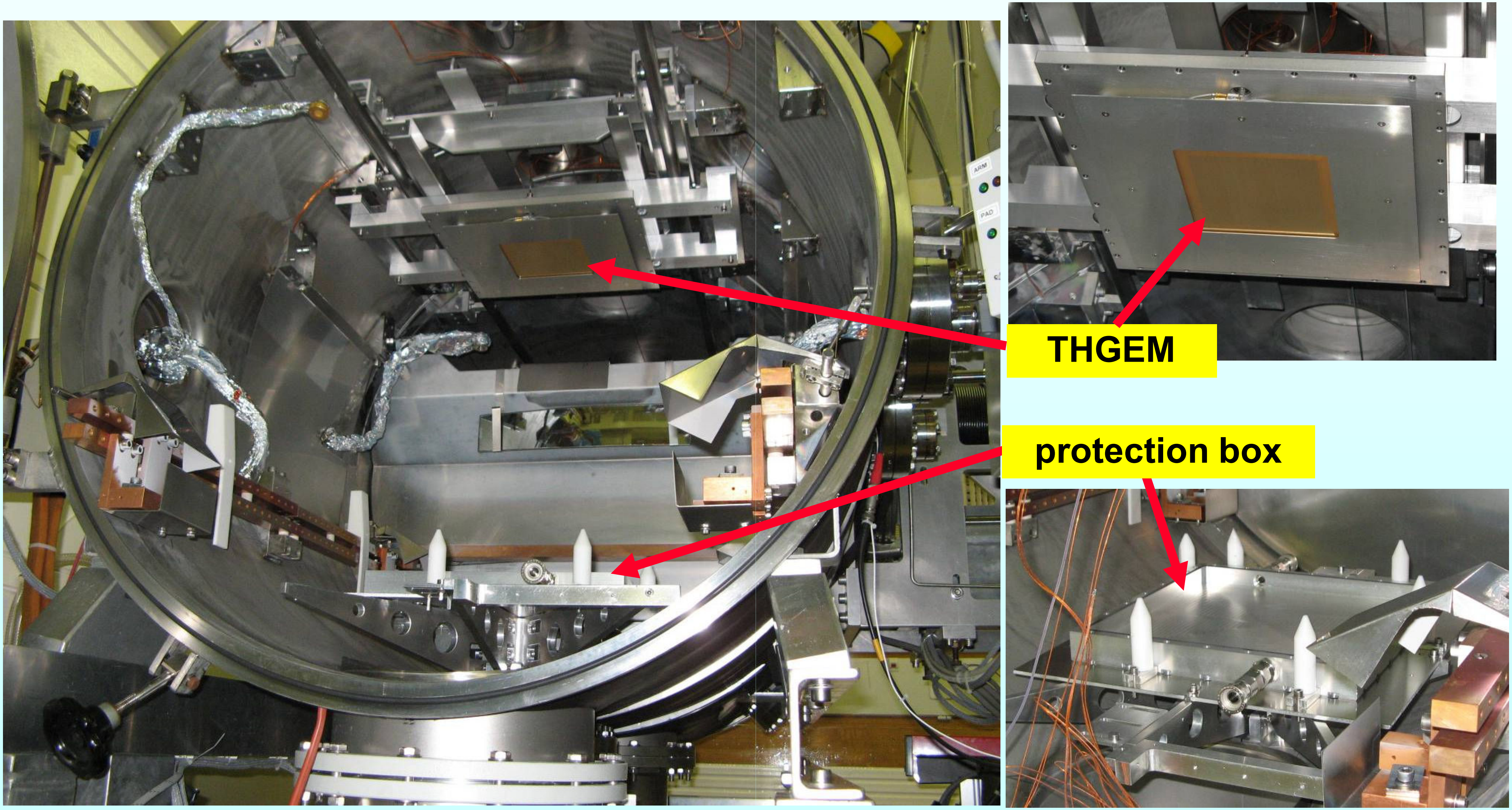
- test the chamber with 100 x 100 mm^2 THGEMs in a real experimental environment

- find solutions for the engineering problems related to the construction of a 600 x 600 mm^2 test prototype

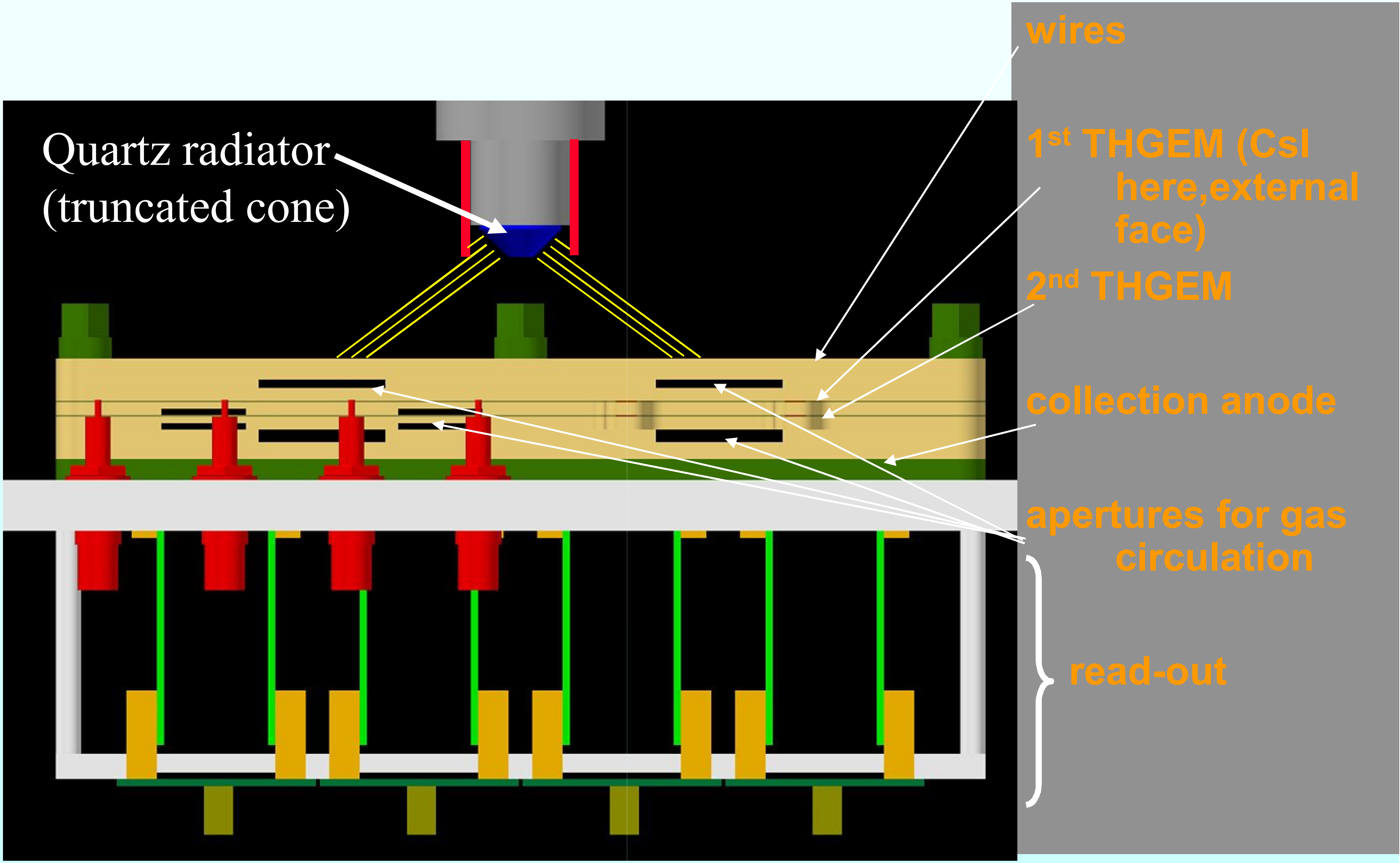
- assemble and test a first complete "full size" prototype chamber

CsI evaporation on 100 mm x 100 mm THGEM

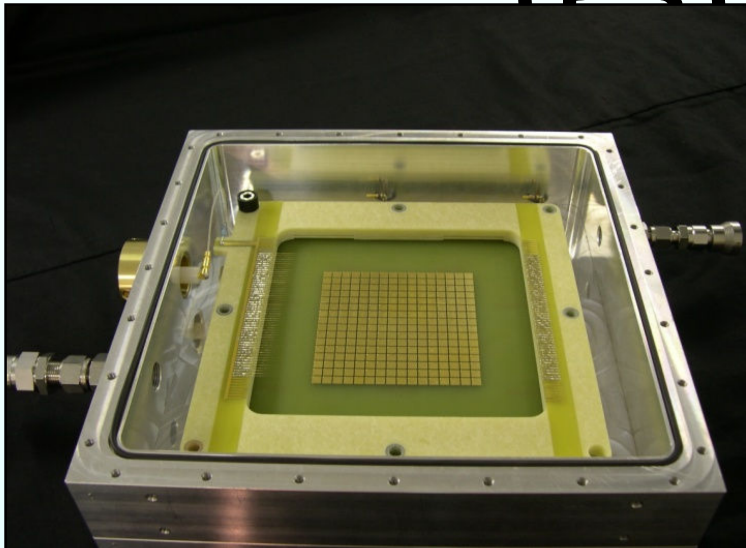
(A. Braem, C. David, M. van Stenis)

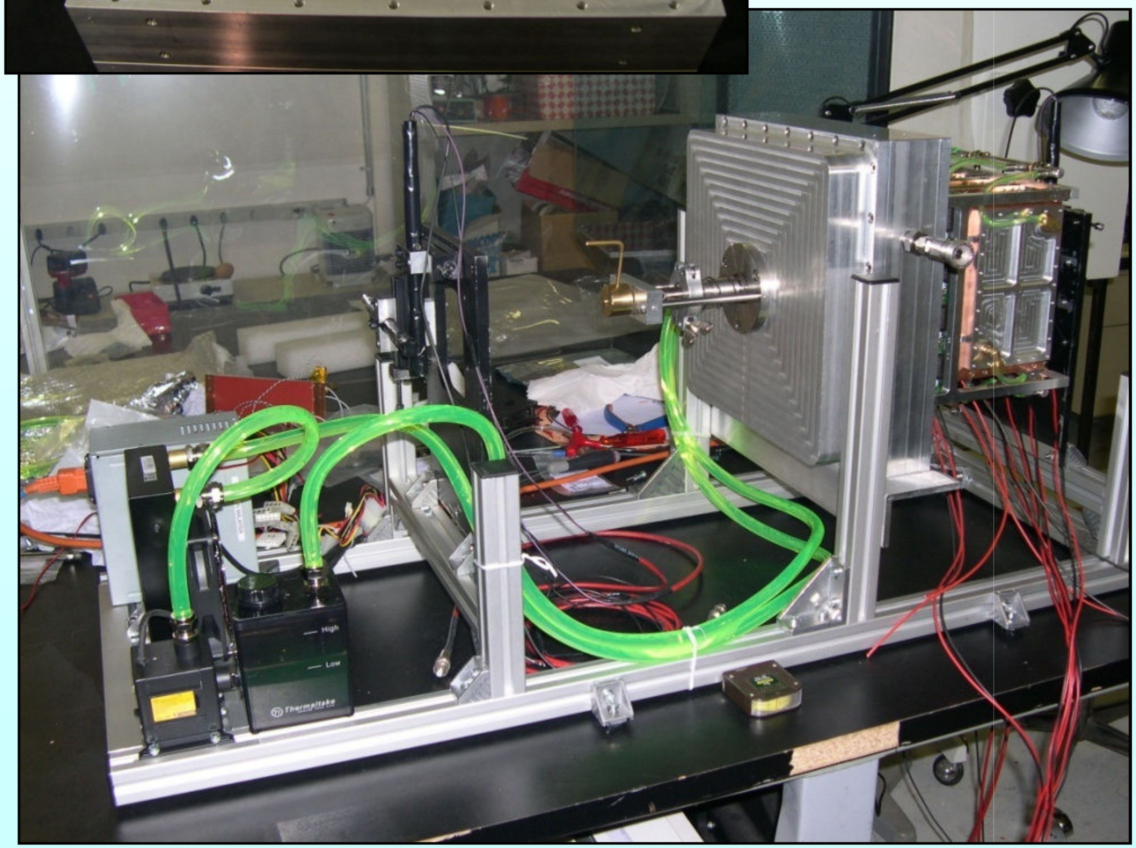


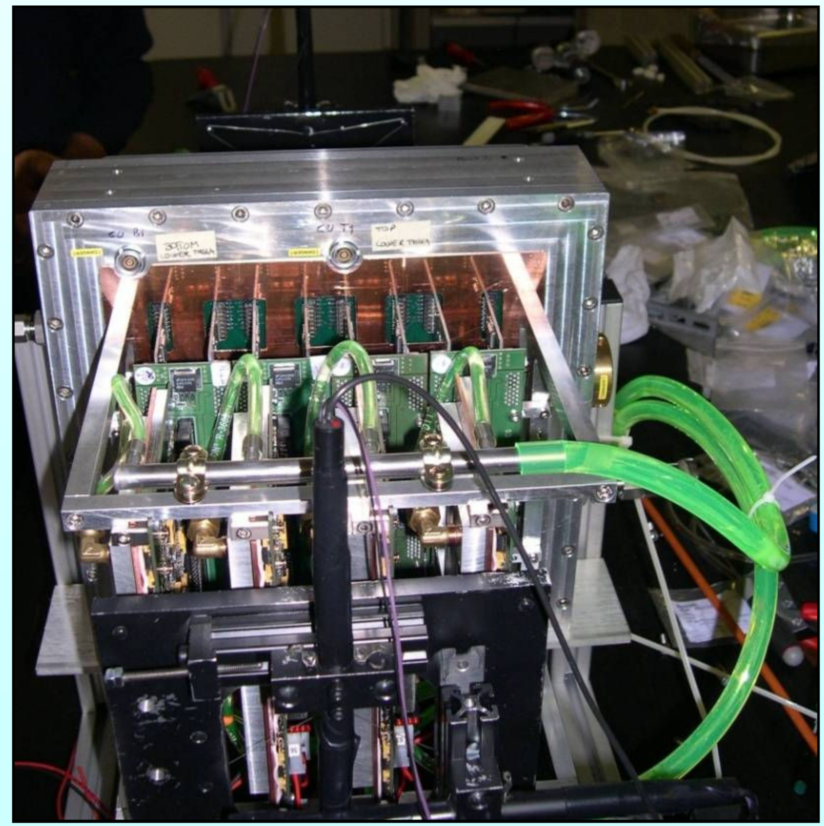
THE 100 x 100 PROTOTYPE STRUCTURE



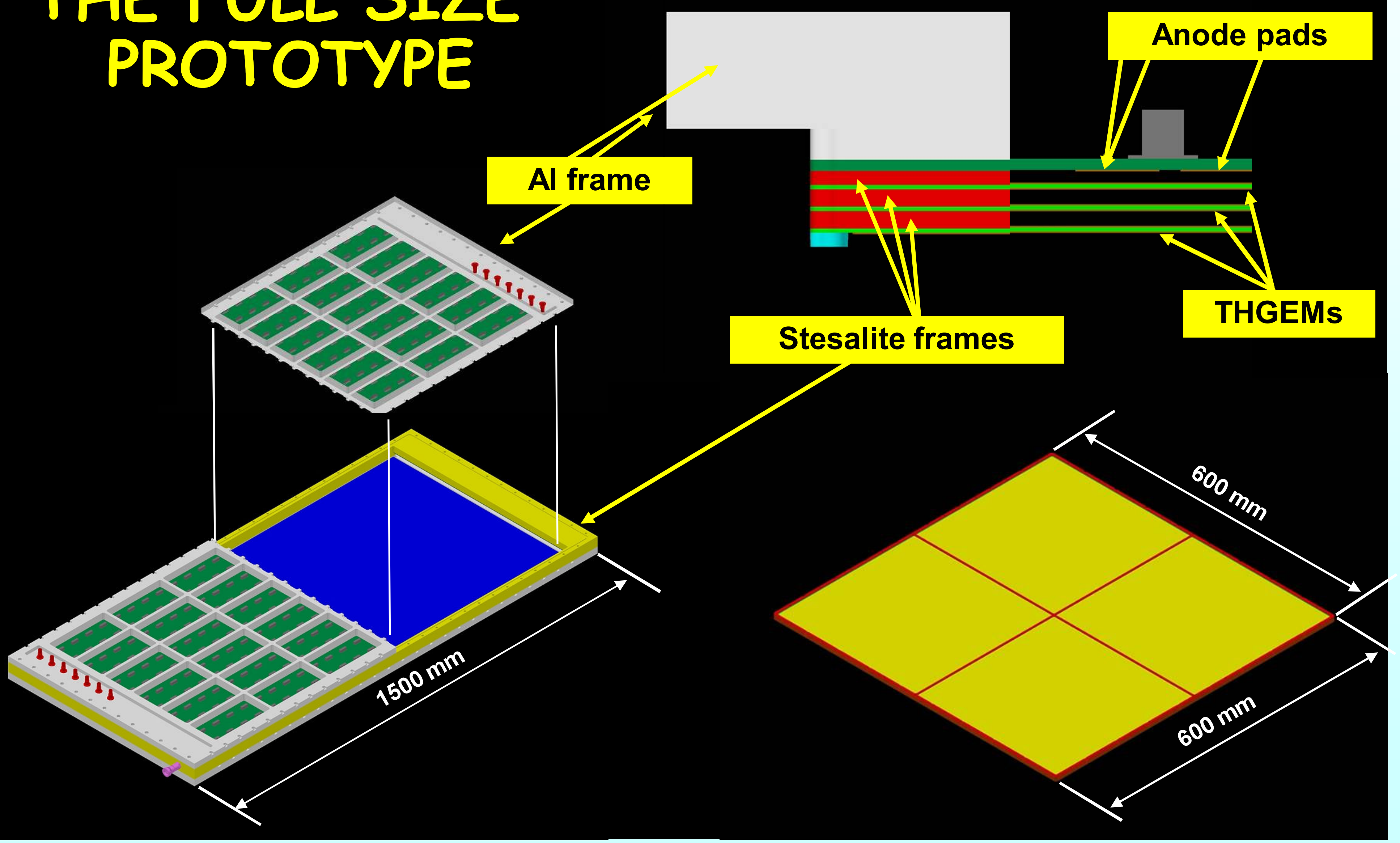
TEST BEAM SET-UP
00 mm x 100 mm
ROTOTYPES







THE FULL SIZE PROTOTYPE



Conclusions

- Intense R&D activity towards THGEM-based photon detectors.
- The systematic characterization of more than 30 different THGEM's with X-rays allowed to approach the definition of the best parameters.
- Detection of single photons:
  - gains between 10^5 and 10^6 in electrically stable detectors with 10 μm rim and a triple layer structure
  - time resolution ~ 10 ns
  - effective photoelectron extraction seems possible in methane-rich mixtures
- NO STOPPING POINTS DETECTED, even if still a long way to go
- Medium and large size prototypes are in production

this work is progressing thanks to many colleagues…

M. Alexeev[a], R. Birsa[b], F. Bradamante[c], A. Bressan[c], M. Chiosso[d], P. Ciliberti[c], G. Croci[e], M. Colantoni[f], S. Dalla Torre[b], S. Duarte Pinto[e], O. Denisov[f], V. Diaz[b], N. Dibiase[d], V. Duic[c], A. Ferrero[d], M. Finger[g], M. Finger Jr[g], H. Fischer[h],G. Giacomini[i,b], M. Giorgi[c], B. Gobbo[b], R. Hagemann[h], F. H. Heinsius[h], K. Königsmann[h], D. Kramer[j], S. Levorato[c], A. Maggiora[f], A. Martin[c], G. Menon[b], A. Mutter[h], F. Nerling[h], D. Panzieri[a], G. Pesaro[c], J. Polak[b,j], E. Rocco[d], L. Ropelewski[e], F. Sauli[e] , P. Schiavon[c], C. Schill[h], M. Slunecka[j], F. Sozzi[c], L. Steiger[j],M. Sulc[j], M. Svec[j], S. Takekawa[c], F. Tessarotto[b], H. Wollny[h]

a INFN, Sezione di Torino and University of East Piemonte, Alessandria, Italy
b INFN, Sezione di Trieste, Trieste, Italy
c INFN, Sezione di Trieste and University of Trieste, Trieste, Italy
d INFN, Sezione di Torino and University of Torino, Torino, Italy
e CERN, European Organization for Nuclear Research, Geneva, Switzerland
f INFN, Sezione di Torino, Torino, Italy
g Charles University, Prague, Czech Republic and JINR, Dubna, Russia
h Universität Freiburg, Physikalisches Institut, Freiburg, Germany
i University of Bari, Bari, Italy
j Technical University of Liberec, Liberec, Czech Republic