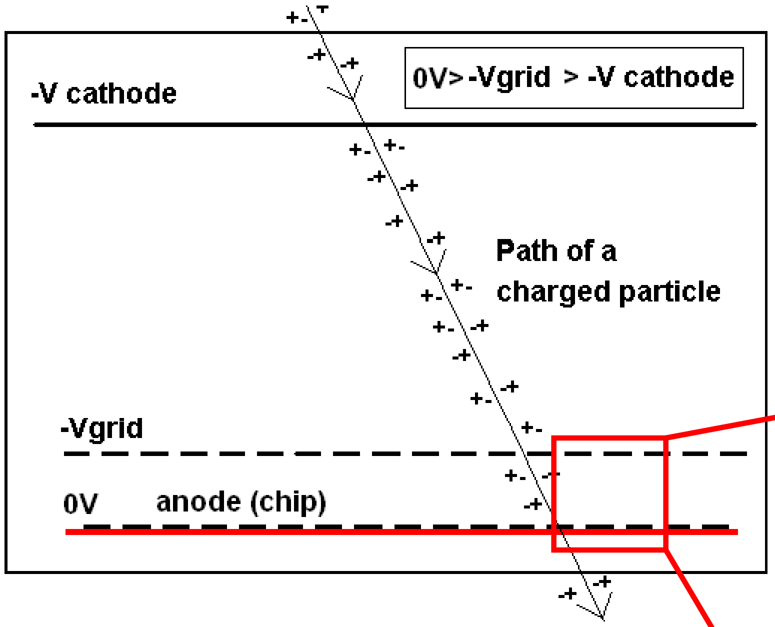
Report from WG2:
Common Characterisation and Physics Issues

Harry van der Graaf
2nd RD-51 Workshop, Paris, Oct 15, 2008

Discharge protection for MPGDs

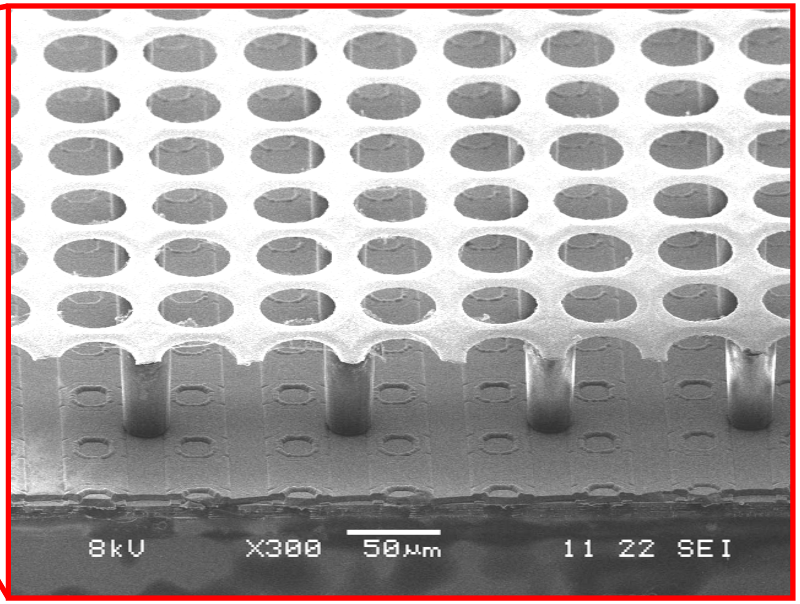
Martin Fransen, Nikhef

Gridpix detectors

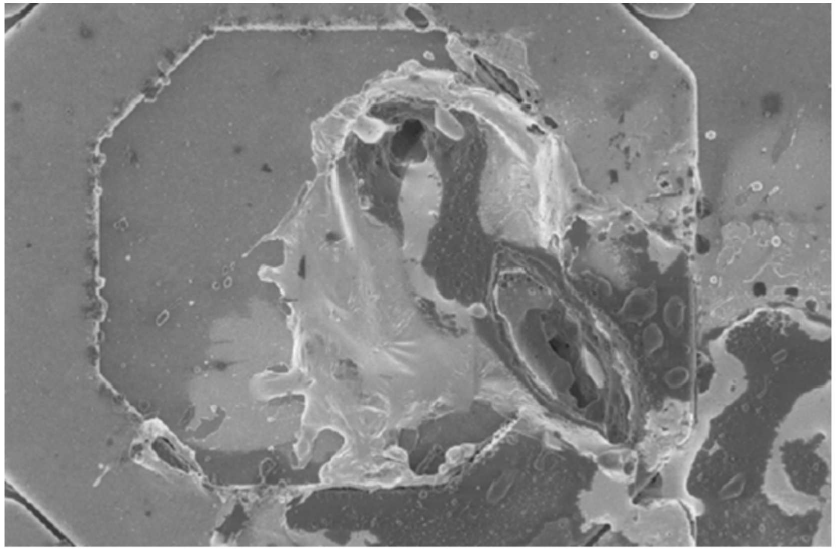


- Drift volume (1mm-1m).
- Grid.
- Gain region.
- Pixel readout chip.

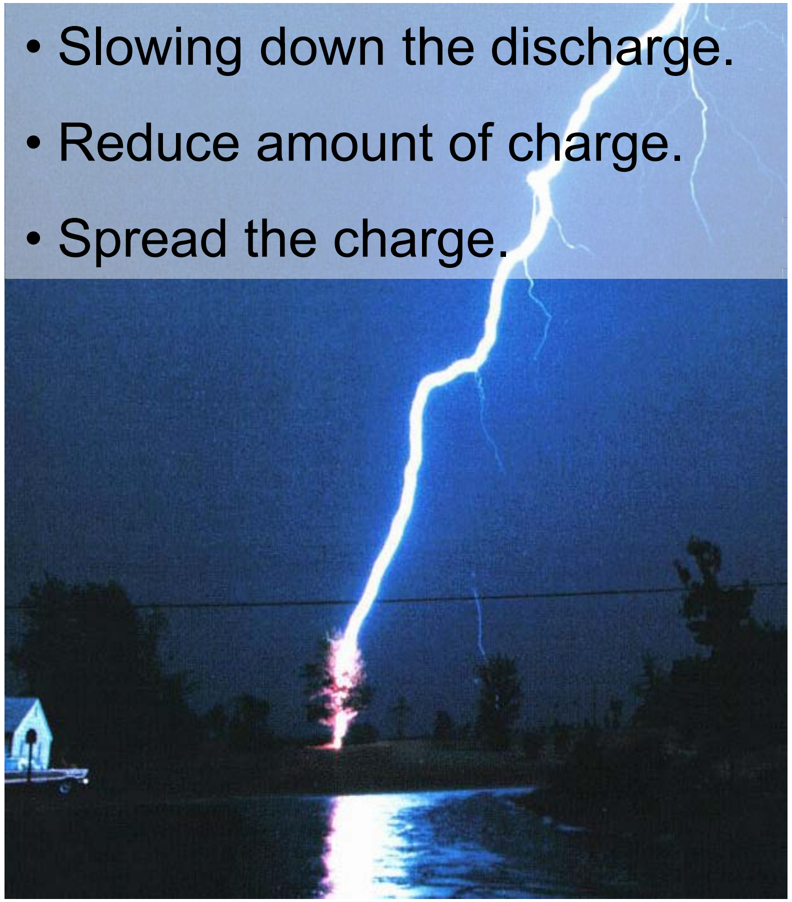
- Grid made by lithographic procedure. (University of Twente)



Gridpix detectors



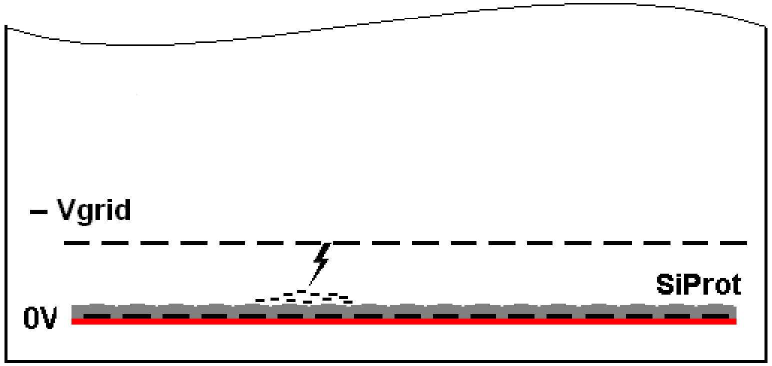
- Drift volume E= ~0.1-1kV/cm.
- Grid.
- Gain region E= ~80kV/cm
- Timepix chip.

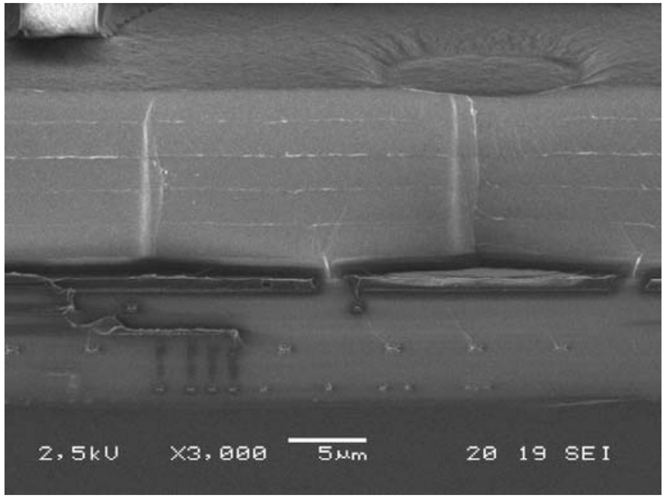


- Slowing down the discharge.
- Reduce amount of charge.
- Spread the charge.

High resistive coating

- Deposit on the chip without killing the electronics.
- Quenching of discharges.
- Some conductivity to prevent net charge build up.
- Amorphous silicon (IMT Neuchatel), SiProt.
- Si_3N_4 , silicon nitride (Twente), SiNProt.
- Provoke discharges with α radiation to test the layer.

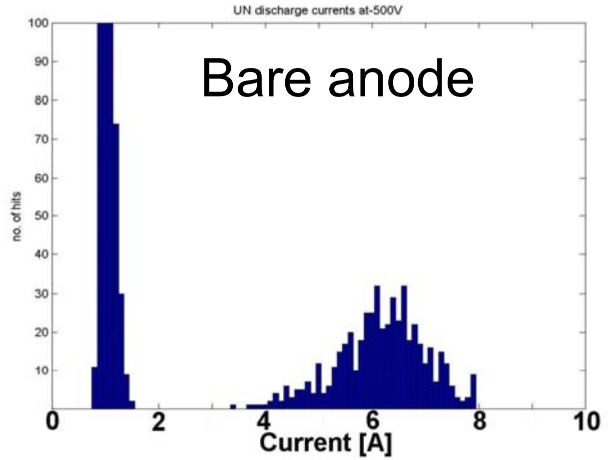


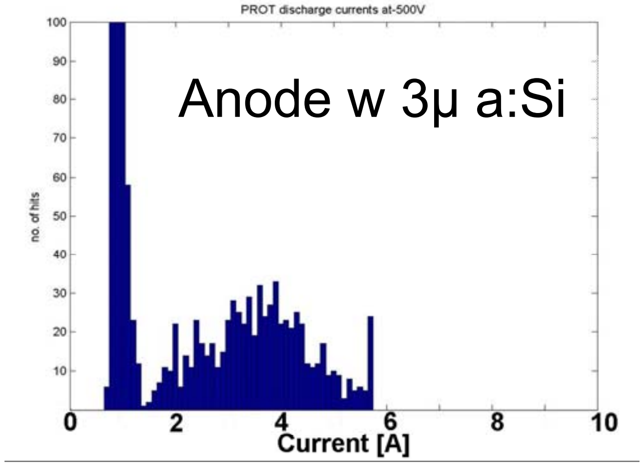


Discharge quenching

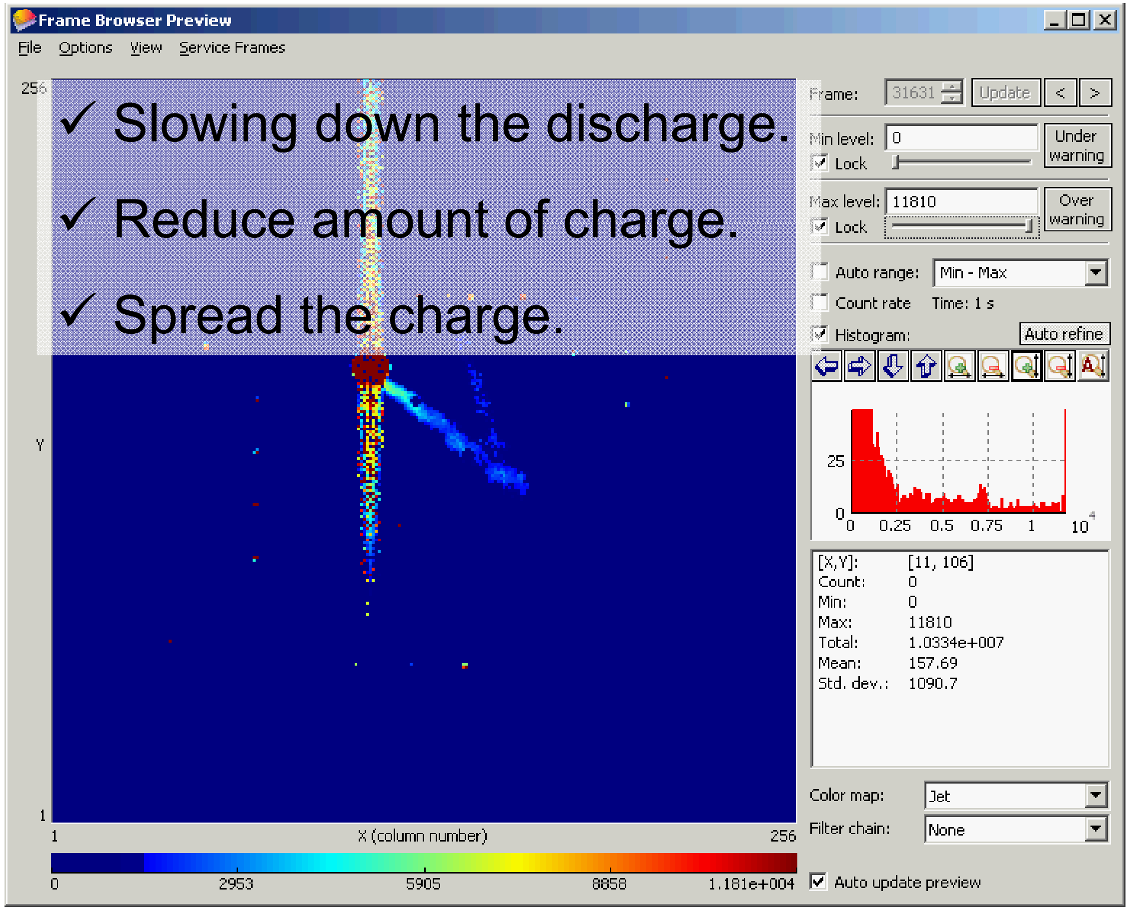
- 3 μm a-Si.
- Dummy anodes.
- Peak currents:
  - 6-7 amps on bare anode.
  - 3-4 amps on prot. anode.

- Reduced heat dissipation.





Discharge quenching



- ✓ Slowing down the discharge.
- ✓ Reduce amount of charge.
- ✓ Spread the charge.

Frame: 31631

Min level: 0
☑ Lock

Max level: 11810
☑ Lock

☐ Auto range: Min - Max
☐ Count rate Time: 1 s
☑ Histogram:

[X,Y]: [11, 106]
Count: 0
Min: 0
Max: 11810
Total: 1.0334e+007
Mean: 157.69
Std. dev.: 1090.7

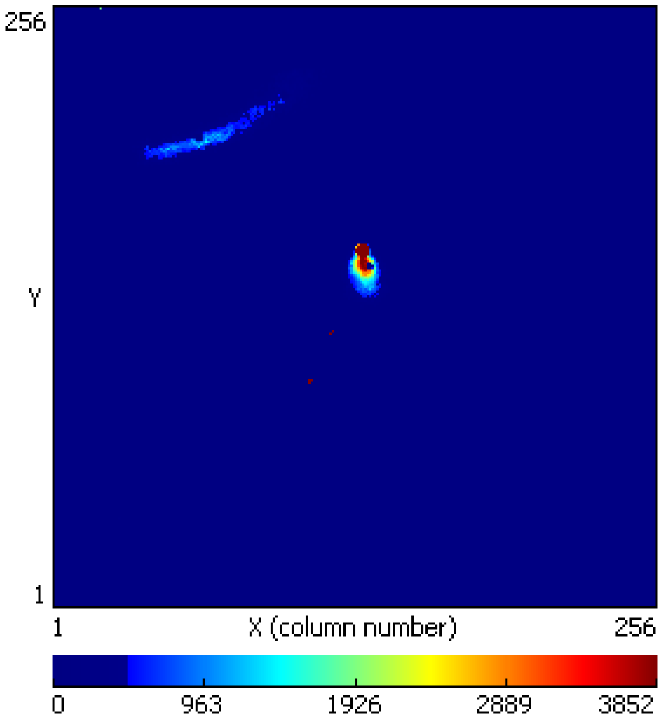
Color map: Jet
Filter chain: None

☑ Auto update preview

Pixelman software: IEAP, Prague

Recent developments

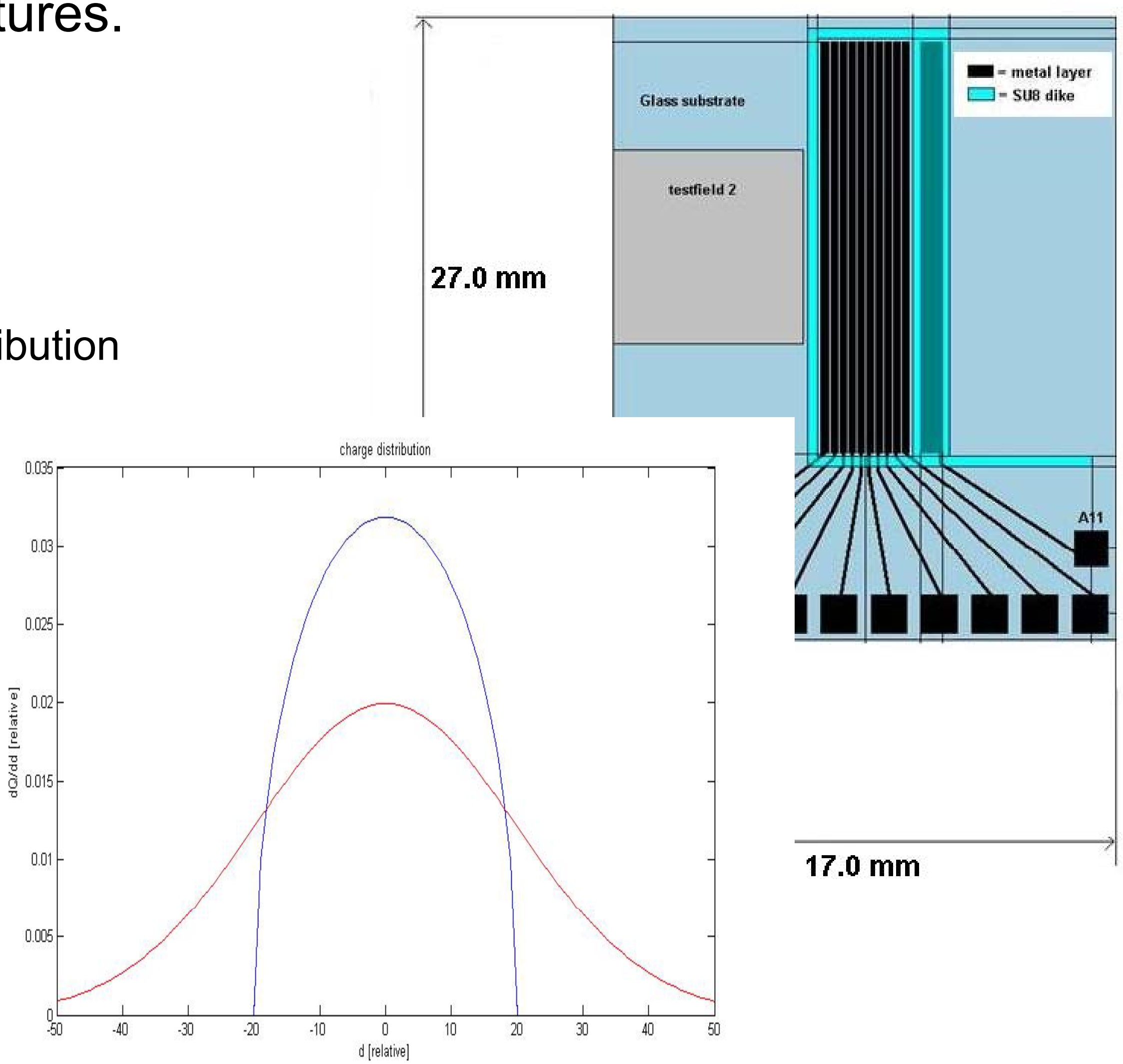
- Charge per pixel reduced to ~ pC →
- Medipix 3 with input protection.
- chip with 7 μ SiNProt still alive after >10 days.
- At Twente both Ingrid and SiNProt can be applied! → post processing faster and cheaper.



Discharge on a SiNProt covered Timepix chip.

Discharge test structure

- Foolproof test structures.
- To quantify:
    - Time of discharge
    - Amount of charge
    - charge density distribution
- As function of:
    - SiProt thickness
    - Gas mixture
    - Voltage



MPGD ageing

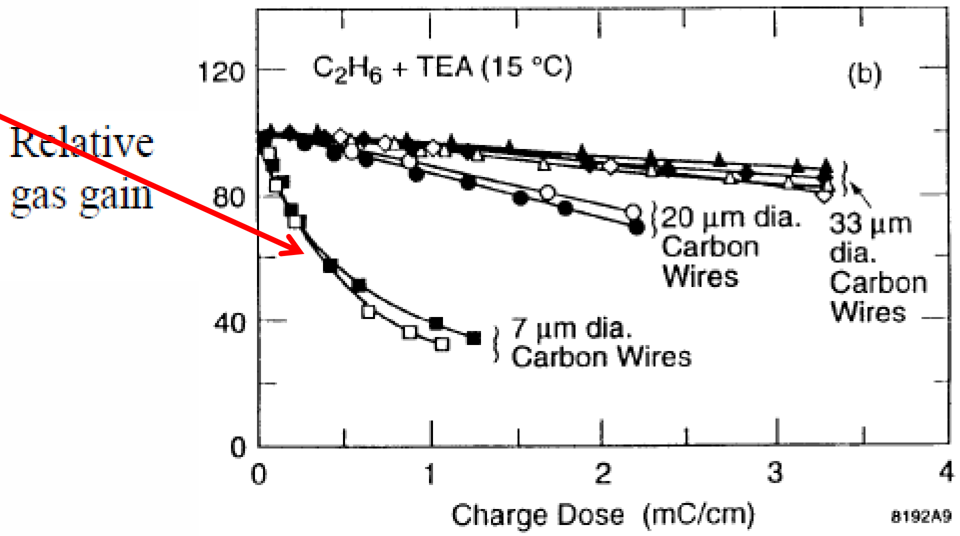
Fred Hartjes
NIKHEF

Magic or science?

2nd RD51 collaboration meeting
Paris, October 13 - 15, 2008

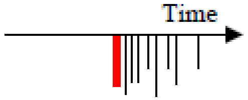
detector?

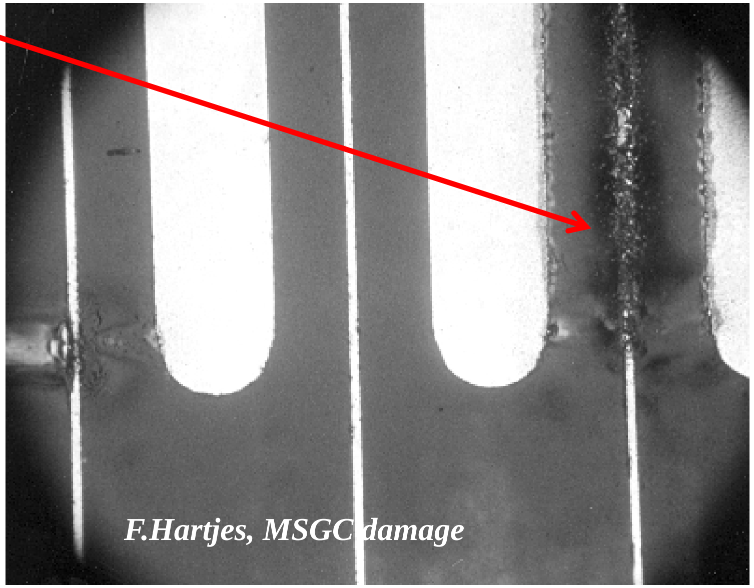
- Loss of avalanche gain
  - Rapid or slower



J. Va'vra, NIM A387(1997)183

- Broadening amplitude spectrum
  - => More variation gain





F.Hartjes, MSGC damage

- Increased

Loss of gain in gaseous detectors

- Figure of merit: accumulated **charge** on the anode surface
  - Kadyk (I. Juricic, J.A. Kadyk, Proceedings Workshop on Radiation Damage to Wire Chambers, Berkeley 1986, p. 141)

$$Q = G * D * n_e$$

$$R = \frac{1}{Q} * \frac{\Delta A}{A}$$

where

- Q is the accumulated charge per cm anode (wires or strips) or cm^2 (MPGD, PPC, ….)
- G is the gas gain
- D is the dose (particles per cm resp cm^2
- n_e is the primary ionisation per hit

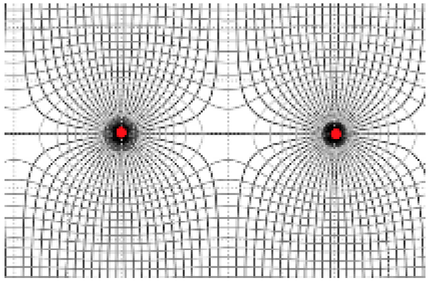
- Define the ageing rate R (%/C/cm) or (%/C/cm^2) as

Competition: ageing of silicon sensors

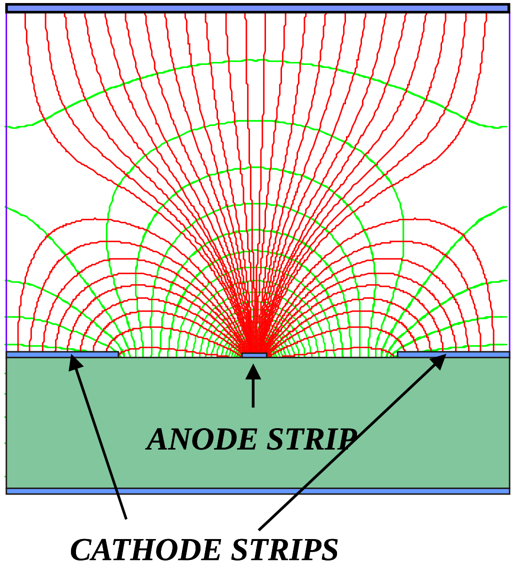
- Figure of merit: **n_{eq} dose**
  - Damage from applied radiation converted into damage from radiation caused by 1 MeV neutrons
  - => easy evaluation of radiation hardness
  - Often using neutrons from nuclear plant for ageing characterisation
- Nature of silicon sensor damage

gaseous detectors

Wire chamber: 1/R amplification field

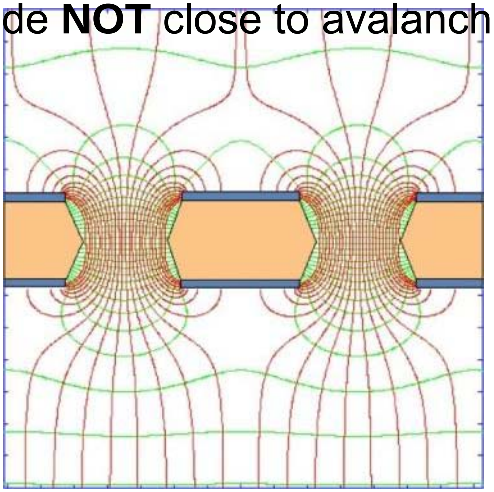


MSGC: dipole amplification field
Very high field at cathode edge



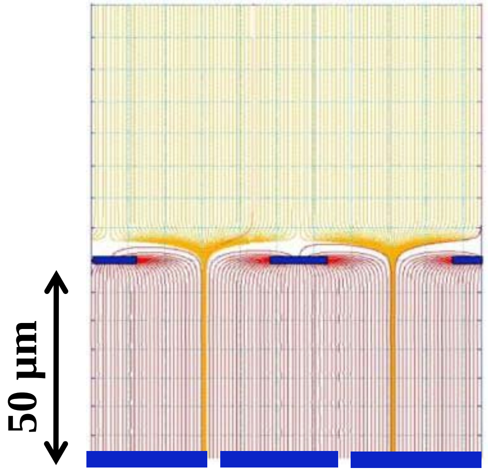
A.Oed, Nucl. Instr. and Meth. A263(1988)351

GEM: amplification field across ~ 25 μm (high at the edges of the hole)
Anode **NOT** close to avalanche



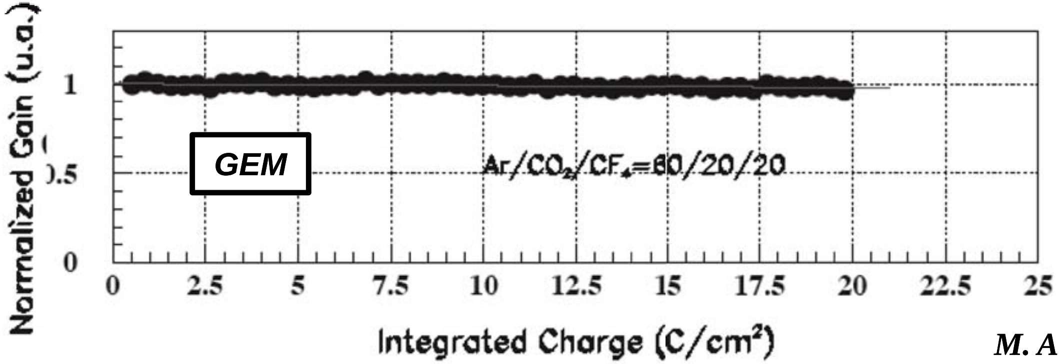
F. Sauli, Nucl. Instr. and Methods A386(1997)531

Micromegas: homogeneous amplification field across 50

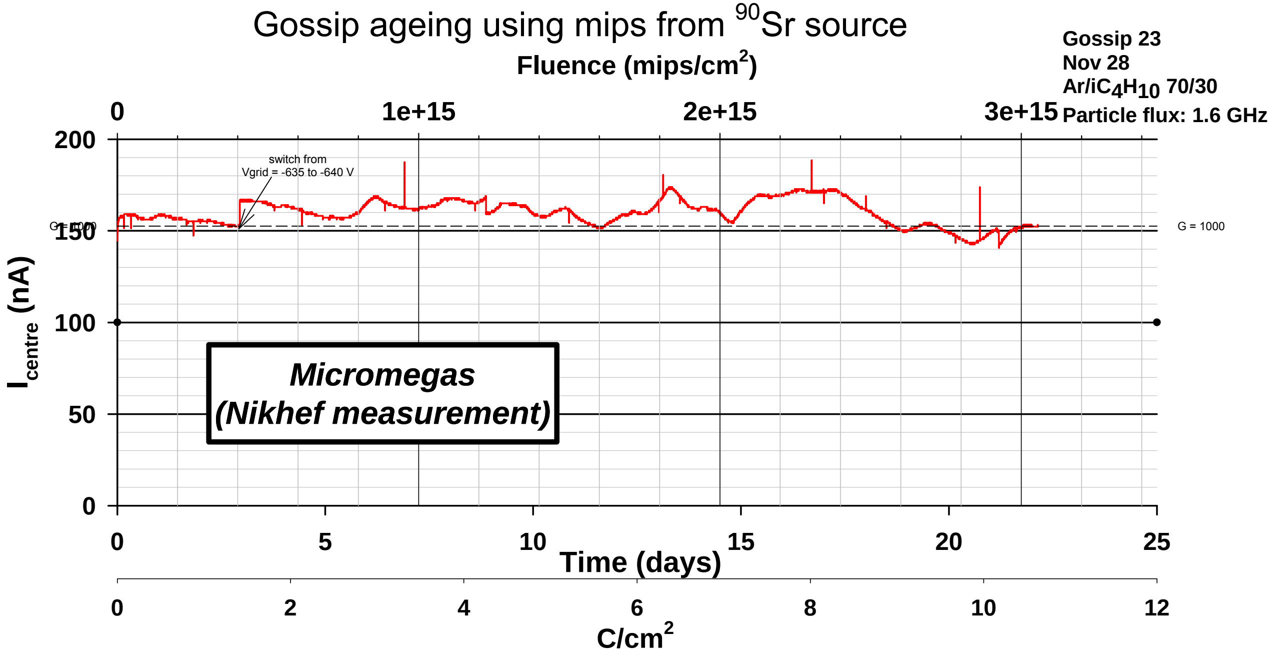


Y. Giomataris et al, Nucl. Instr. and Meth. A376(1996)239

Micromegas



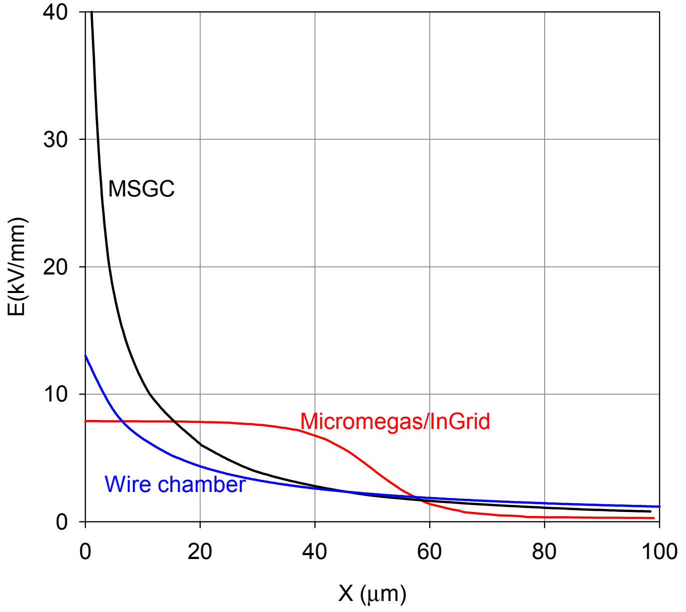
M. Alfonsi et al,
Nucl. Instr. and Meth. A518(2004)106

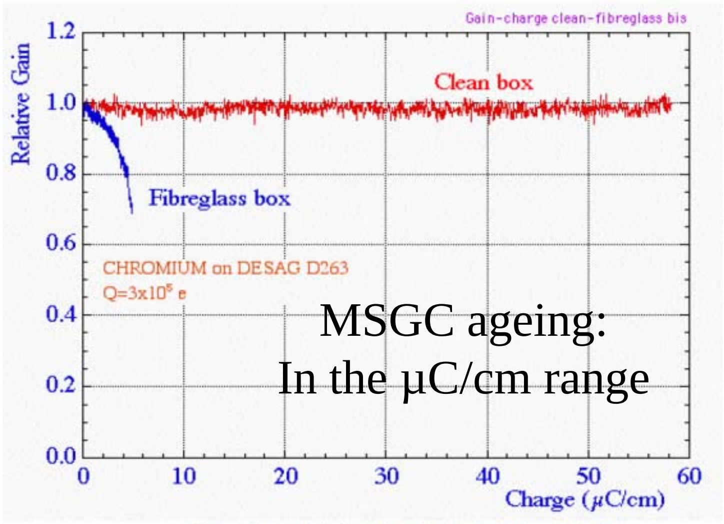


technology

- Polymerisation will be mainly at the end of the avalanche where the electron density is highest
  - A few µm away from the anode
  - Exception: GEM
- Key issue
  - Whta is the field at the anode surface?
  - High field => high avalanche temperature

Field strength (E) along the central drift path (X) to the anode for three different electrode geometries





MSGC ageing:
In the µC/cm range

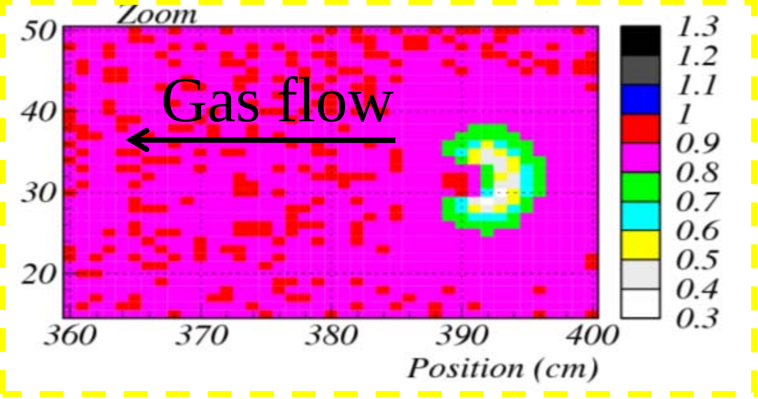
R. Bouclier et al, Nucl. Instrum. Methods A 381 (1996) 289

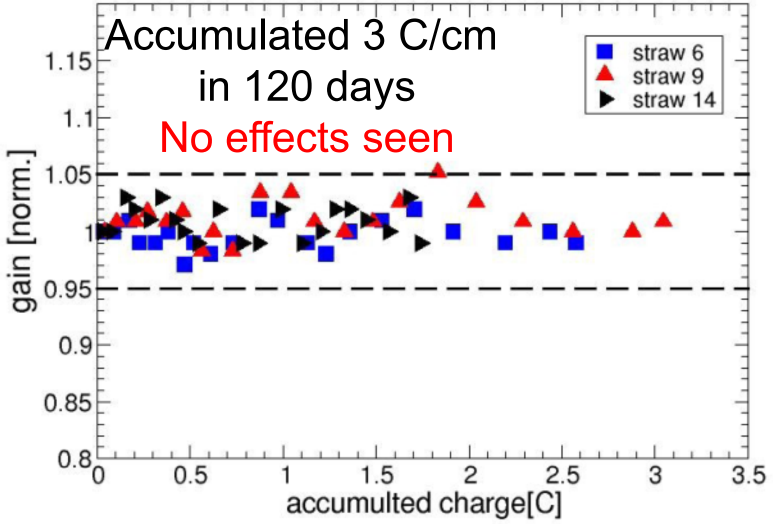
Result

- At accumulated charge **2.8 mC/cm** (peak value)

- Strong unexpected ageing effect
  - No ageing downstream

2nd scan /1st scan




Accumulated 3 C/cm in 120 days

No effects seen

Design recommendations

- Reduce field on cathode surface as much as possible
- Use the cleanest materials you can afford (NASA and CERN database)
  - But there’s no need getting bankrupt
- Add filter at the in coming gas close to the detector (molecular sieve 5A)
- Consider adding special ageing chamber for advance cleaning (see LHCB experience)
- **But** don’t expect this to be absolutely safe to prevent ageing
- Do as much ageing prototype tests as you can on as much different conditions to get an impression of the robustness of your detector
  - Different particles
  - Different irradiation rates
  - Different sites

Operational recommendations

- While running, monitor the chamber performance on a daily basis and take immediate action when observing ageing phenomena
- Don’t change from gas supplier while running an experiment
- Be prepared to apply additives
  - CF_4 + oxygen containing molecule like CO_2 or alcohols
  - Water (active moisture control and monitoring), don’t let it pass the 1% limit
  - **=> But be aware that these measures might worsen the situation in your specific case**

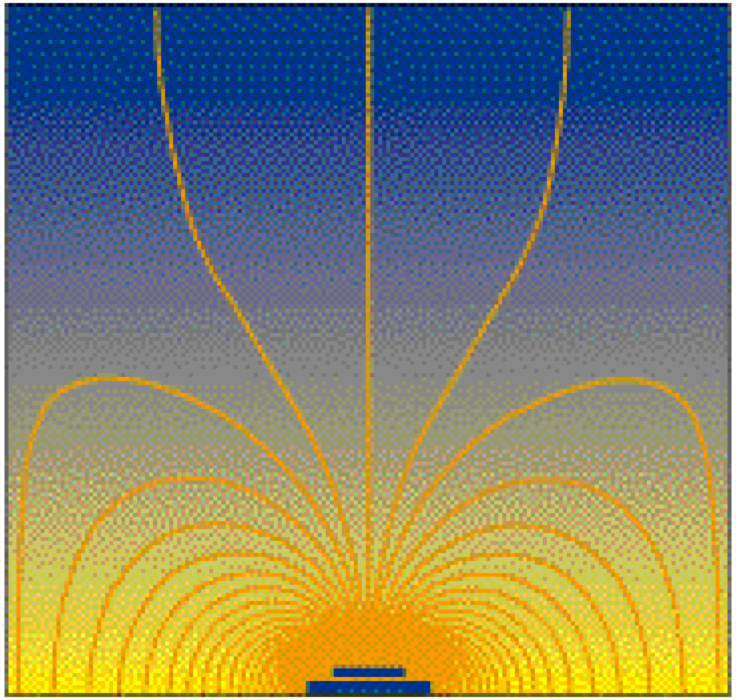
some thoughts on charging-up effects

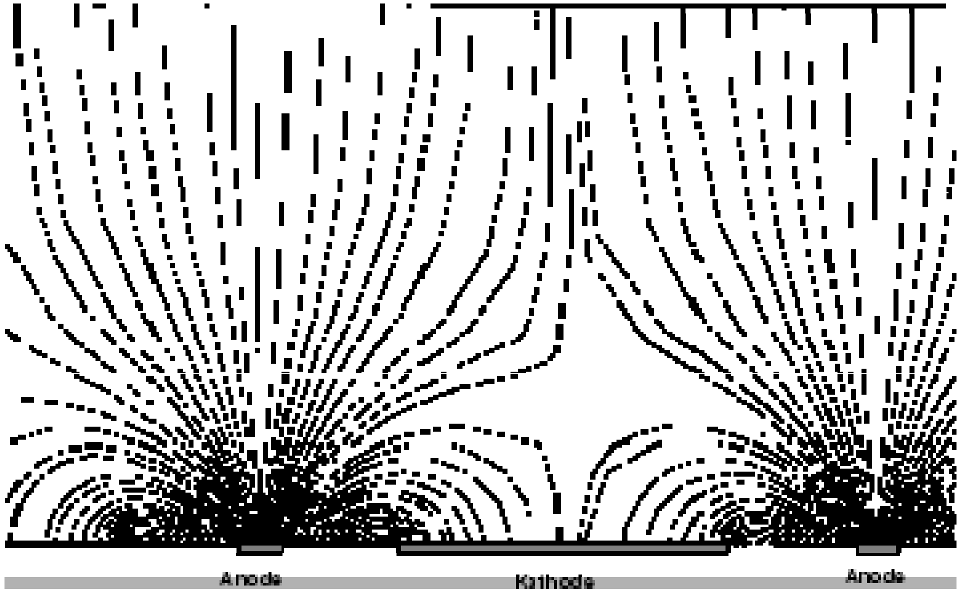
HvdG, Nikhef
RD51 Workshop, Paris, 2008

Micro Strip Gas Counters: hard to operate:

- discharges, ruining electrodes
- ageing

! Very strong electric field in insulator’s volume & surface !





GEM Production

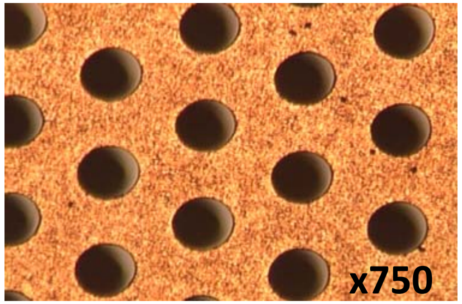
RIKEN/SciEnergy GEM

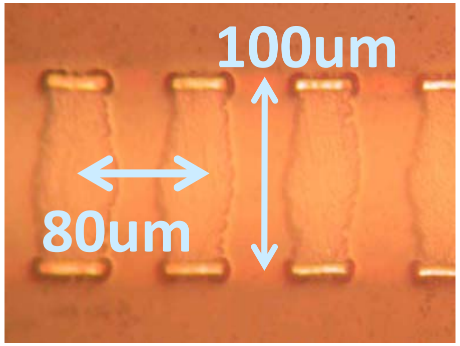
(thick-foil and fine-pitch)

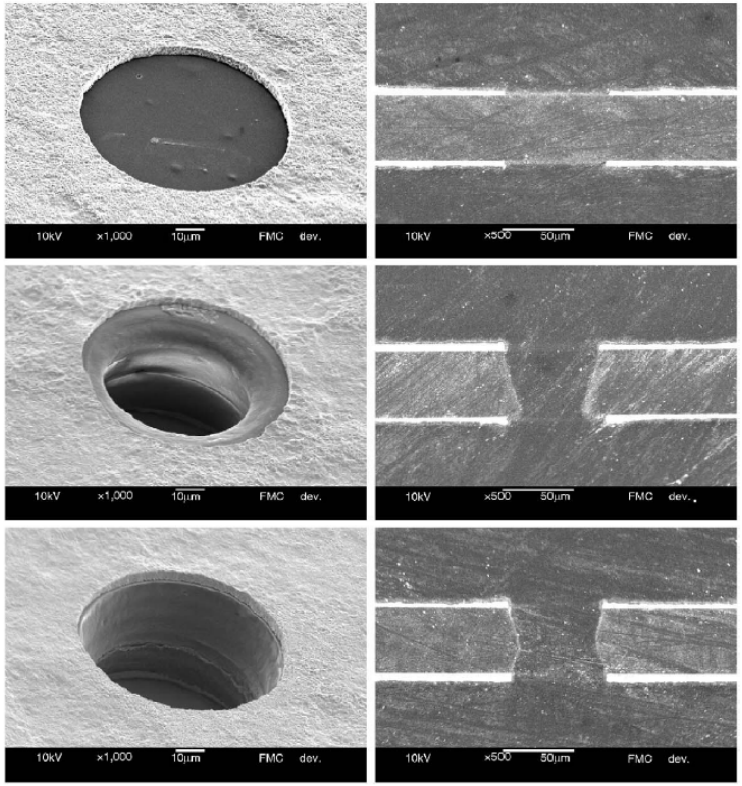
pitch 80um

hole 40um

thickness 100um







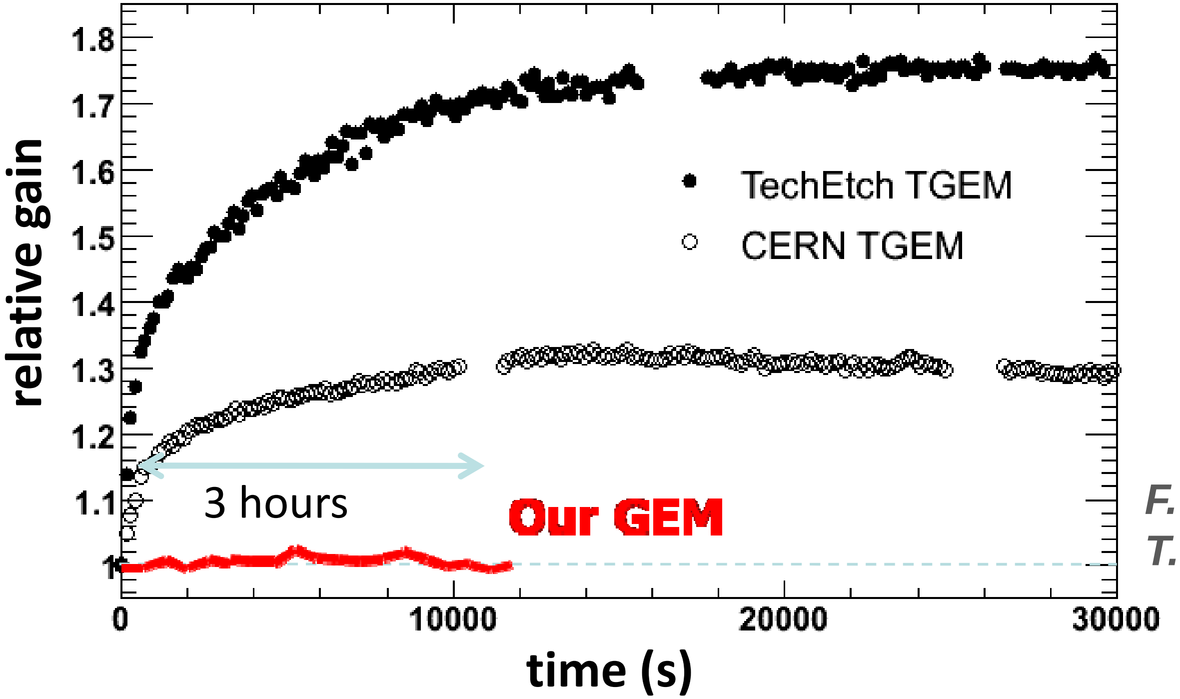
Remove copper by wet etching

Irradiate CO_2 laser

Remove remaining edge from the other side

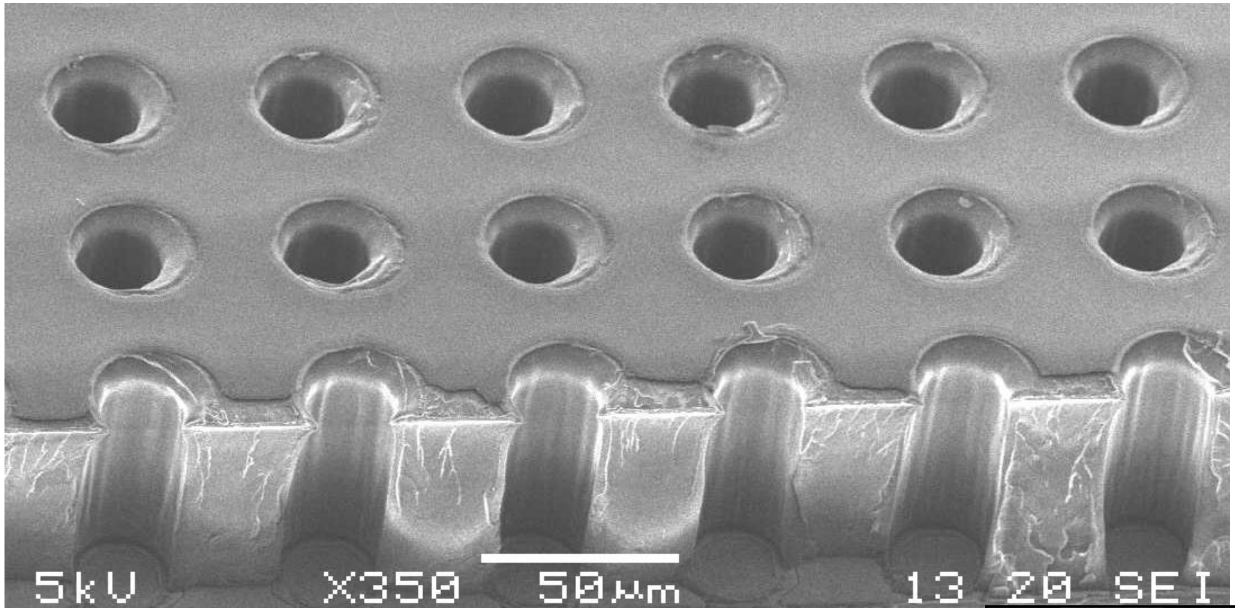
Gain instability (RIKEN GEM)

No increase and decrease just after HV on.



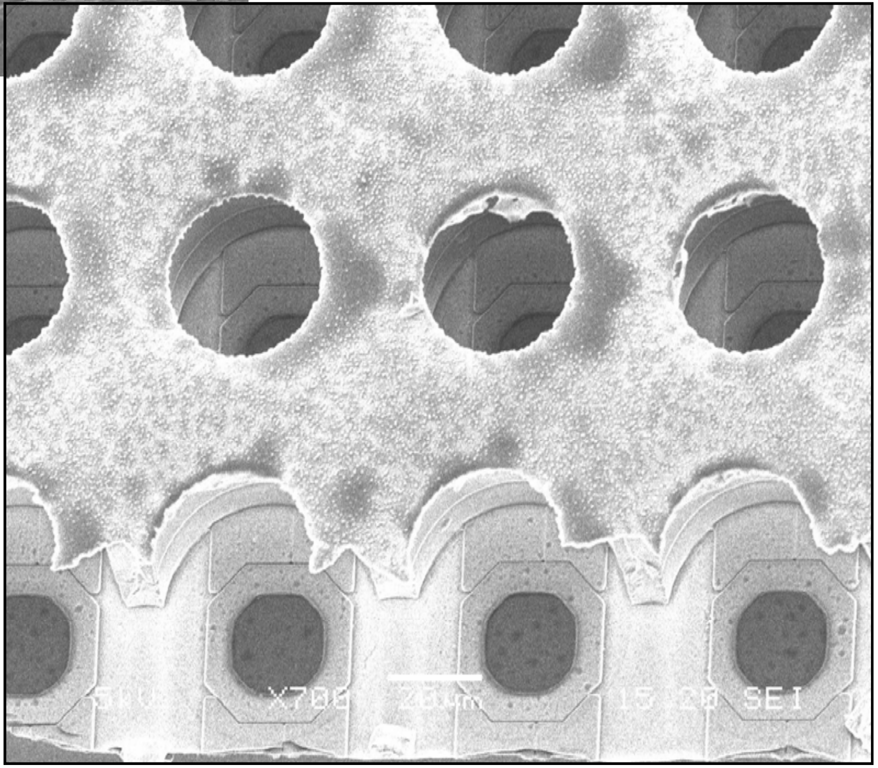
F. Simon (IEEE, 2006)
T. Tamagawa(IEEE,2007)

- **No gain increase in short measurements**
- **This is not for a special batch of GEMs but for all GEMs we produced**
- **Possible reasons;**
  - ✓**Less charging-up due to cylindrical hole shape**
  - ✓**Less polarization of Liquid Crystal Polymer**



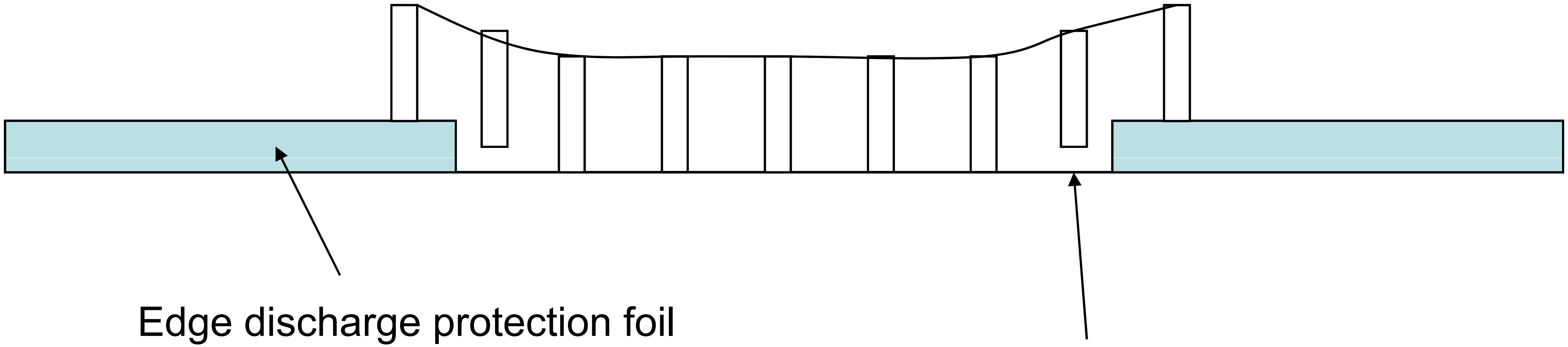
GemGrid 1

GemGrid 2



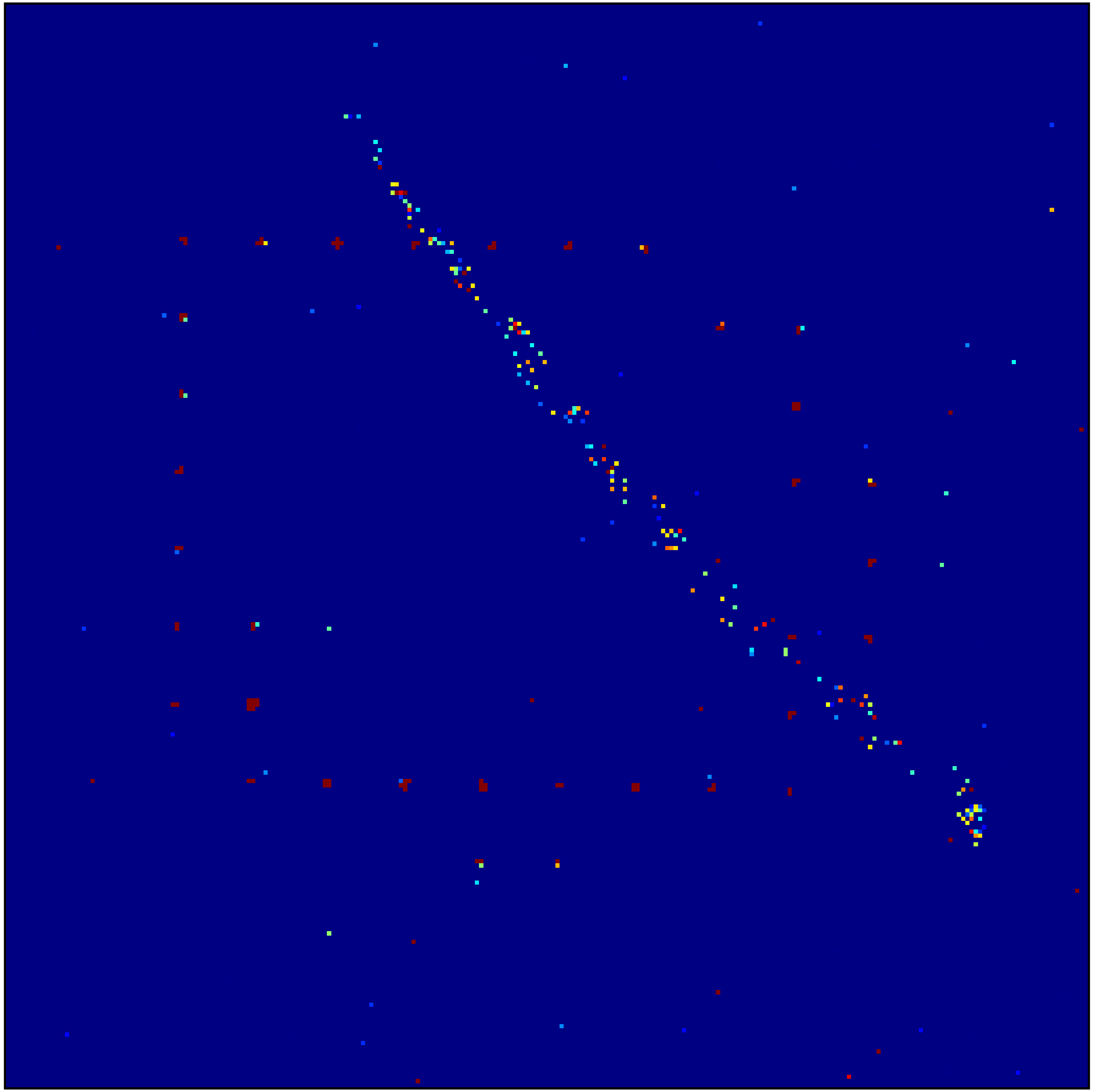
conductivity of kapton

Micromegas on pillars



Edge discharge protection foil

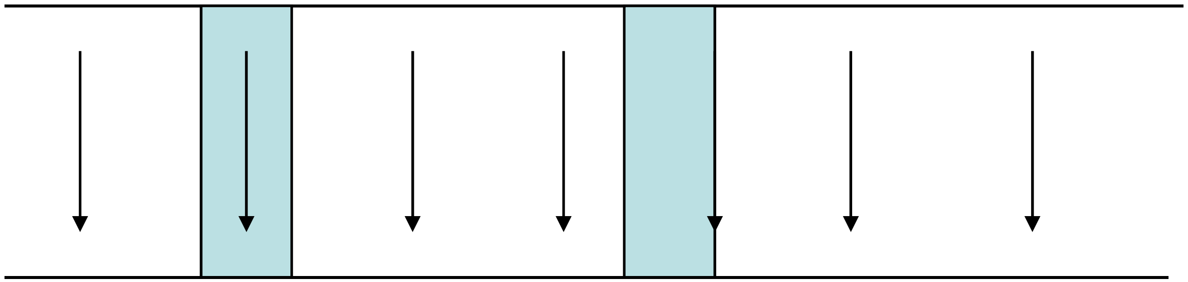
discharges + vibrations

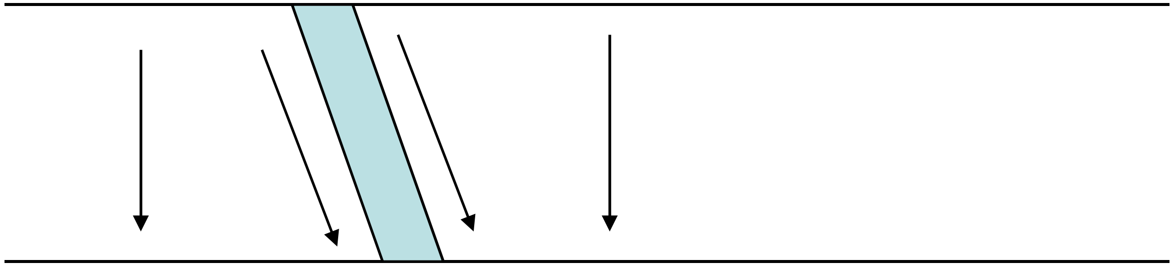


Charge-up effects

After (rapid) ramping of HV:

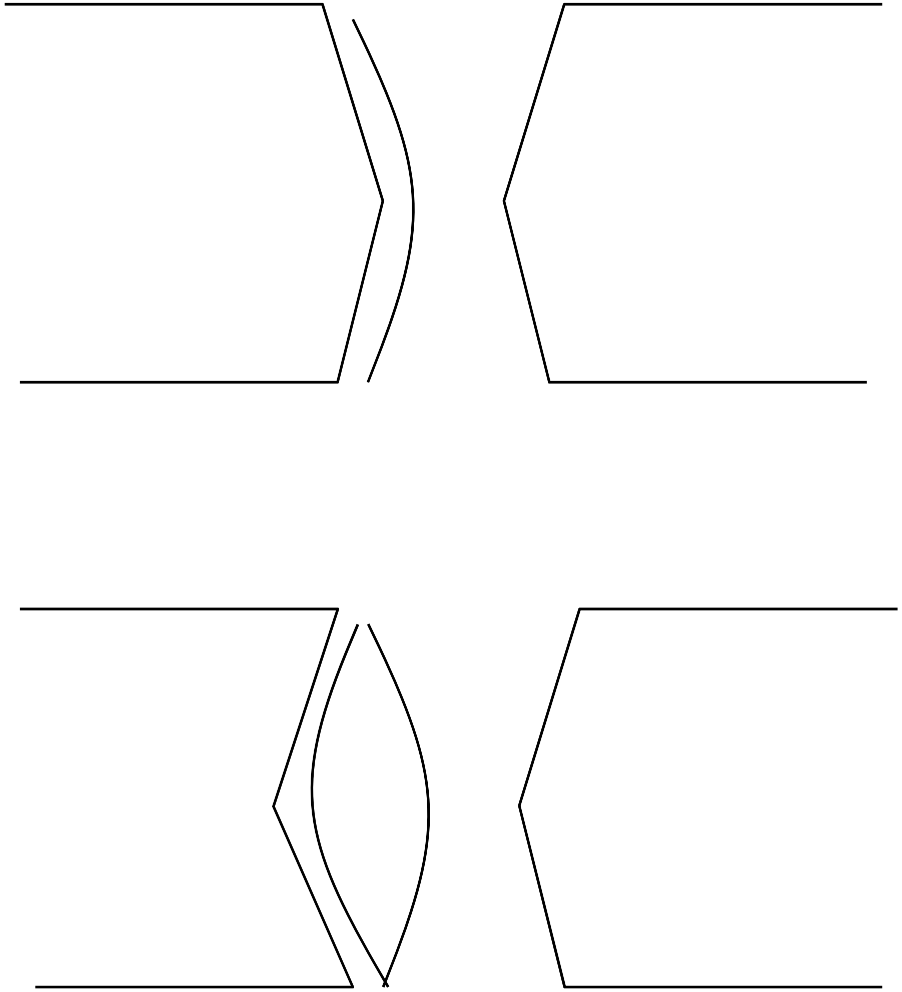
- polarisation: reduction of E-field in insulator (bulk) volume
  In homogeneous field with insulator // to field: nothing

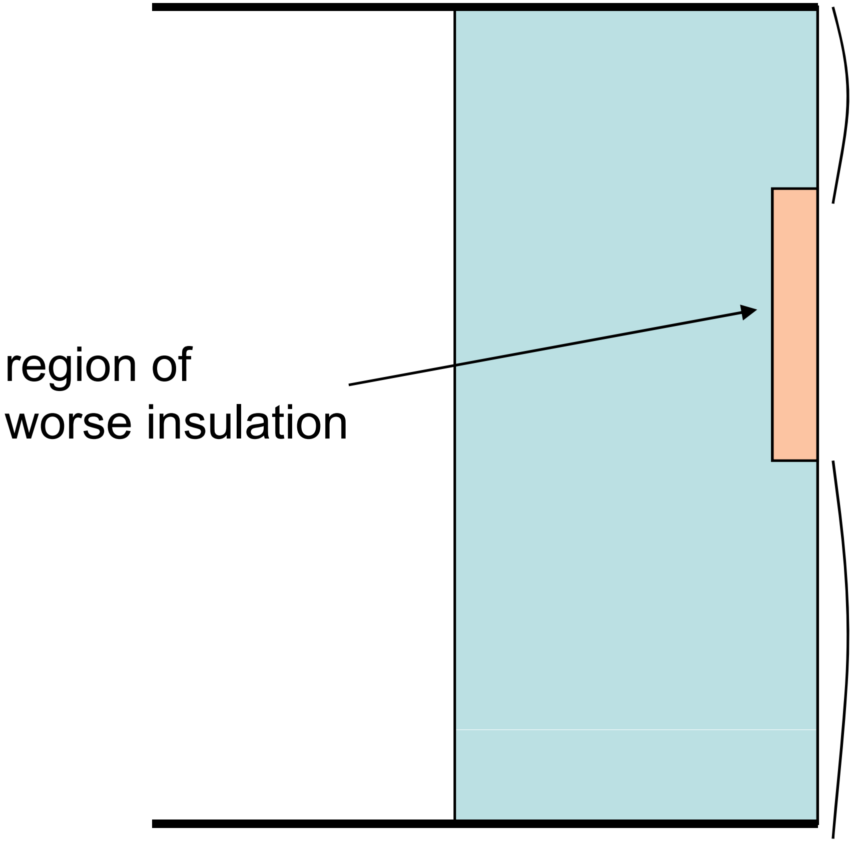




With E component perp. on insulating surface: modification of potential by hitting e- and/or ions until E // surface

GEM hole





region of
worse insulation

equalizing with water

Stronger effects for
good insulator

Very preliminary:

Use as little as possible insulating surfaces // strong E fields

Even more preliminary:

As for gain: GEMs perform les than (corresponding) Micromegas

Plans for

MPGD Radiation hardness tests for full detectors and components

Matteo Alfonsi,**Gabriele Croci**, Elena Rocco,
Serge Duarte Pinto, Leszek Ropelewski
CERN GDD Group

2nd RD51 Collaboration Meeting
Paris 13-15 October 2008
Working Group 2

Outline

- Full Detector Tests
  - Standard Triple GEM
  - Bulk MicroMegas
  - THGEM
- Components Tests
  - Standard Triple GEM components
    - Electrical Tests
    - Mechanical Tests

Method followed for Full Detectors

- Make a series of measurement before putting this detector in beam of ^{60}Co photons
- We would like to know if the performance of the detector is changed after strong irradiation (Total integrated dose of 10^6-10^7 Gy)

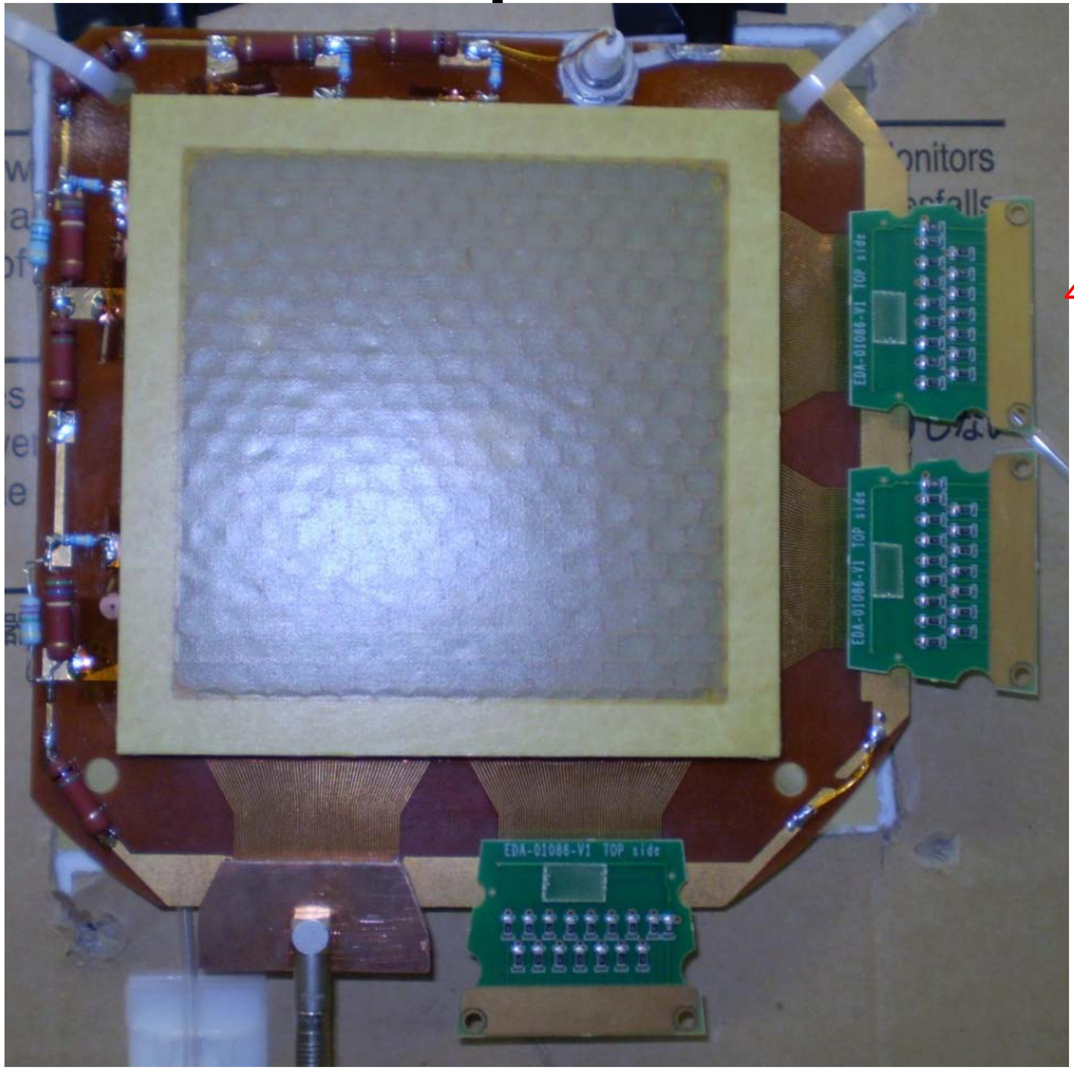
List of measurements

- Gain
- Rate Capability
- Discharge Probability
- Time Charging up Scan Type 1: Power on the detector and start to irradiate at the same time
- Time Charging up Scan Type 2: Power on the detector before starting the irradiation
- 2D Test (for Triple GEM)
- Test of uniformity over active area
- Counting plateau

What might happen after strong irradiation..

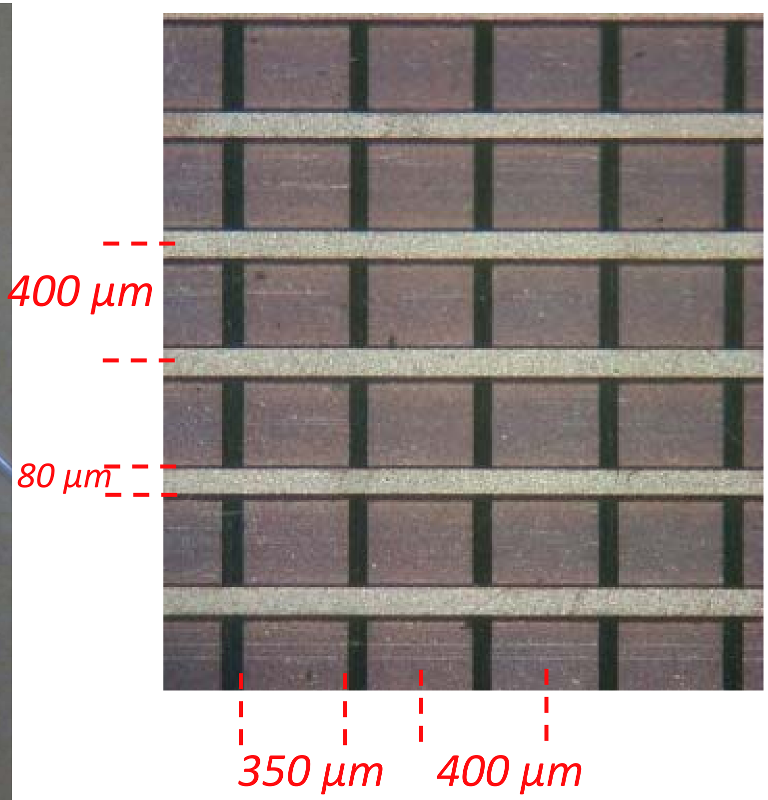
- Gain → For TGEM, if the kapton resistivity is changed we can have less gain than before at the same voltage; it may happen that this variation may only be on the irradiated spots.
- Gain variation with time → The detector can have different charging up proprerties
- .....

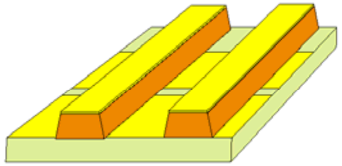
The Triple GEM Detector used



10 x 10 cm^2 Active Area

Gas Mixture used Ar/CO_2 70%/30%

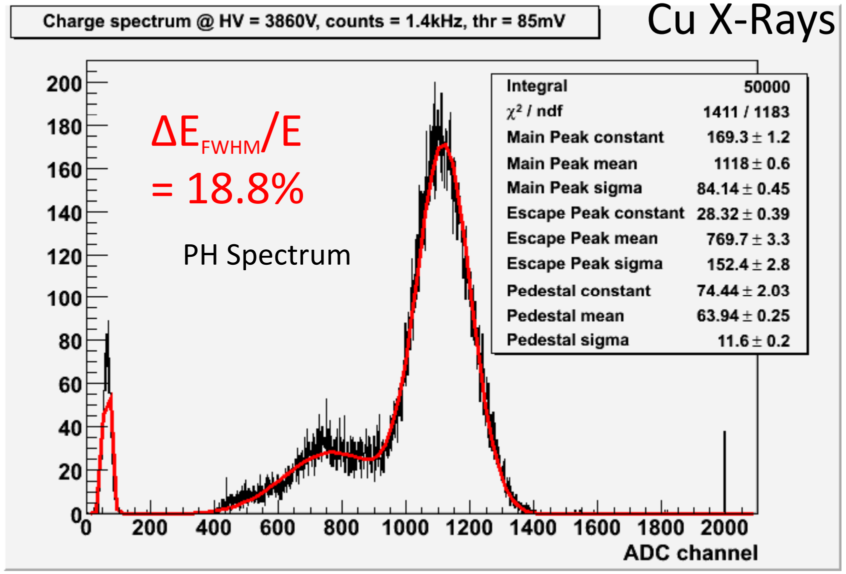




Cartesian 2D X-Y Readout

C. Altumbas et al, NIM A490(2002)177

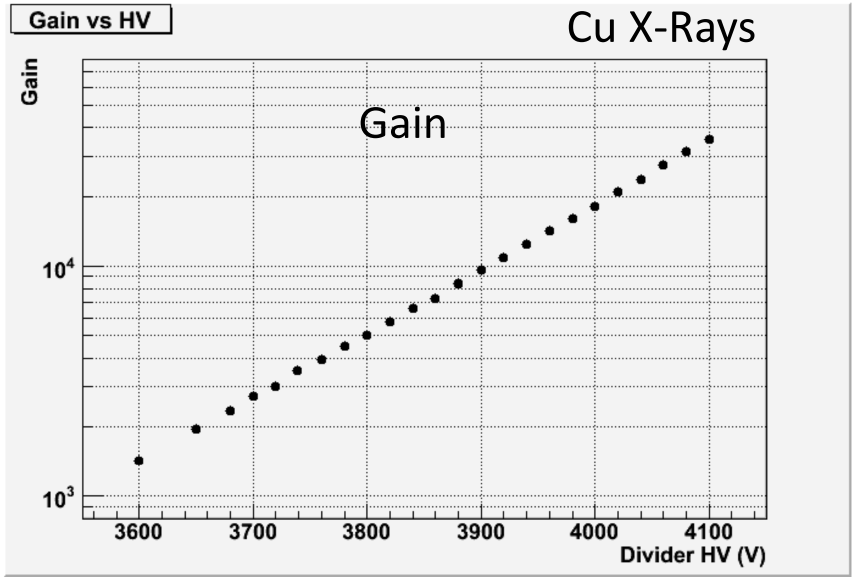
Measurements performed so far (before irradiation)



Cu X-Rays

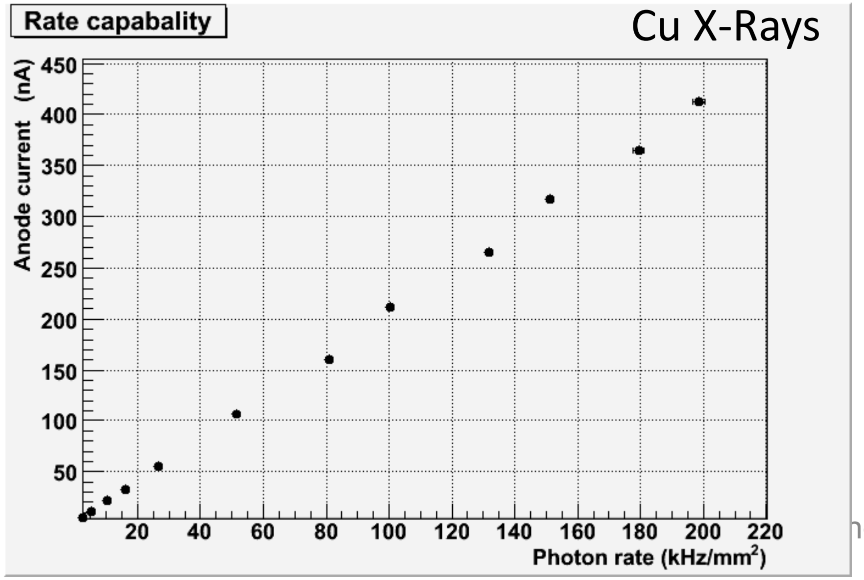
$\Delta E_{FWHM}/E$ = 18.8%

PH Spectrum

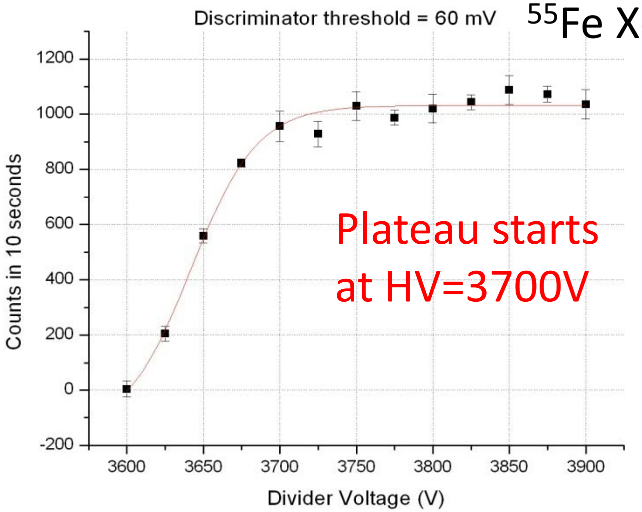


Cu X-Rays

Gain



Cu X-Rays



^{55}Fe X-Rays

Plateau starts at HV=3700V

Radiation Hardness tests of Triple GEM detector components

- Materials to be tested:
  - GEM Polyimide (Apical AV Kaneka)
  - Glue (Araldite AY103) + Hardener (HY951)
  - Frames Material (Permaglas)
- Tests to be performed
  - Electric Test
    - Measure kapton resistivity before and after gammas irradiation
  - Mechanical Tests: make mechanical tests on components that represent crucial part of detector assembly
    - Shear Test
    - Peeling Test

We found a very old paper on kapton irradiation…

R.G. Filho et al, "Induced conductivity Of Mylar and Kapton Irradiated by X-Rays", IEEE Transactions on Electrical Insulation Volume EI-21 No. 3, June 1986

Kapton Samples of 80 mm diameter with thickness varying from 6 to 75 µm were irradiated with W X-Rays for several hours; They saw a variation of the Kapton conductivity

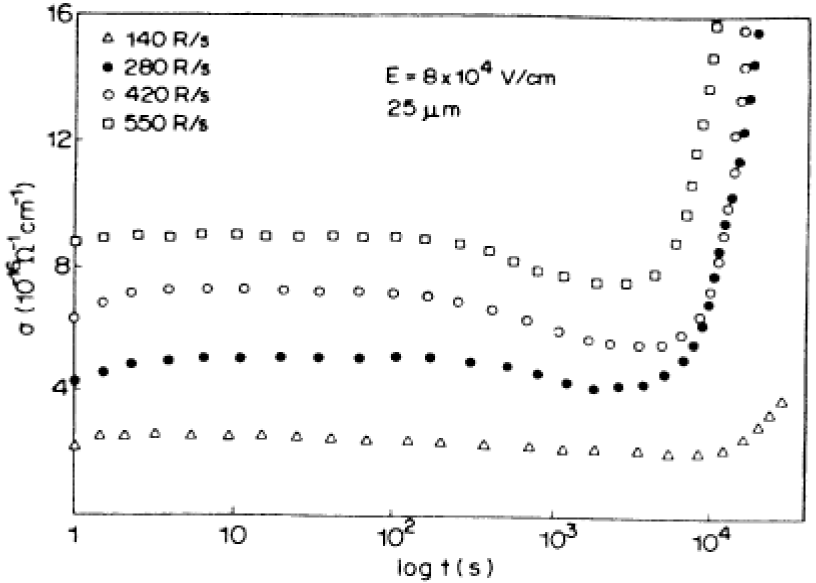
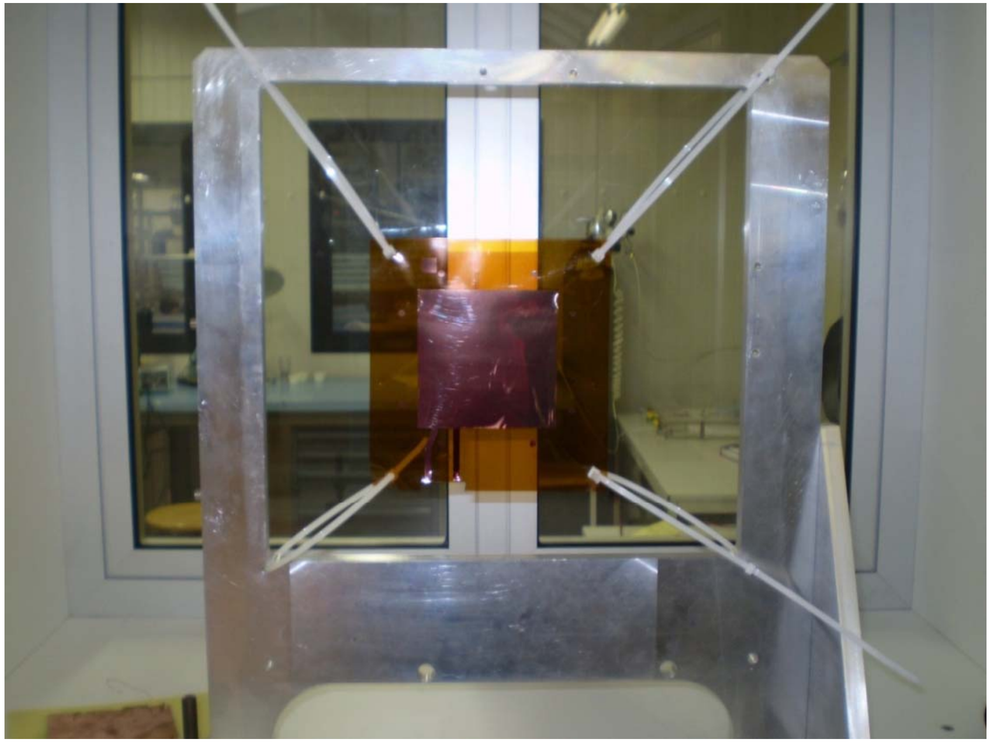


Fig. 14: Kapton: RIC as a function of time for different exposure rates.

First Lab Irradiation Test (prelim. results)

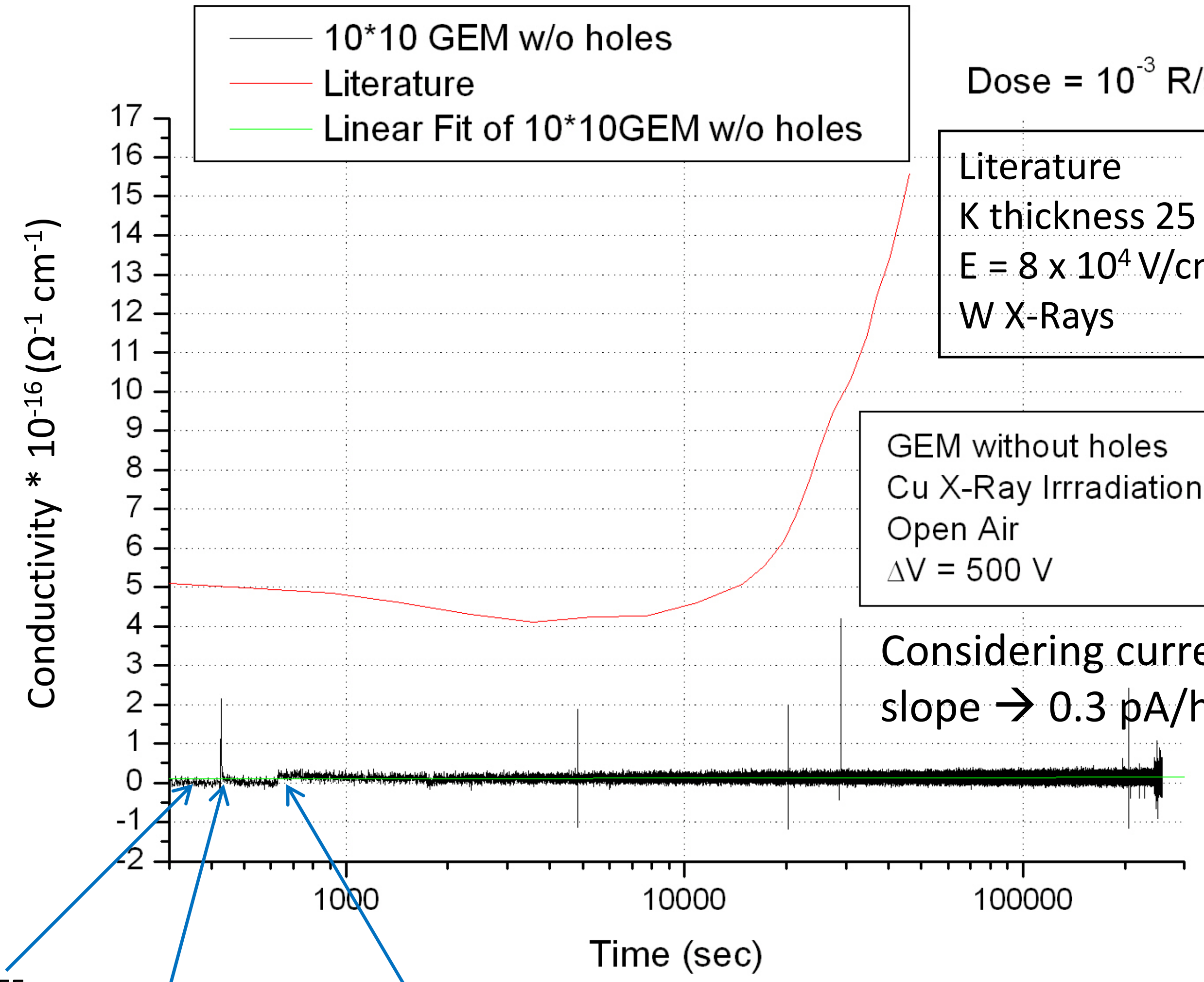
Measurement of Induced Conductivity inside a copper-clad 50 µm thick kapton foil **(GEM w/o holes)**

This copper-clad kapton foil was powered with 500 V and irradiated at very high rate in open air with Cu X-Rays to understand if irradiation will vary its conducibility.
Since measurement was performed in open air, air ionisation could be a problem.



The current flowing from the top to the bottom electrode was monitored during irradiation

Measurement of Induced Conductivity inside a copper-clad kapton foil (GEM w/o holes)



Dose = 10^{-3} R/sec*mm^2

Literature
K thickness 25 um
E = 8 x 10^4 V/cm
W X-Rays

GEM without holes
Cu X-Ray Irrradiation for 3 days
Open Air
ΔV = 500 V

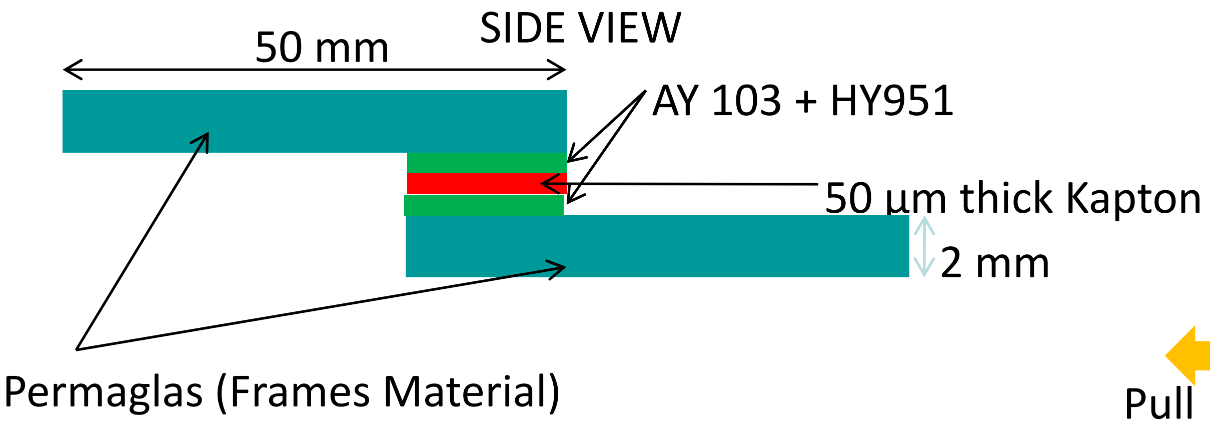
Considering current we found a slope → 0.3 pA/hour

HV OFF, X-RAYS OFF

HV ON, X-RAYS OFF

HV ON, X-RAYS ON

Shear Test Samples



SIDE VIEW

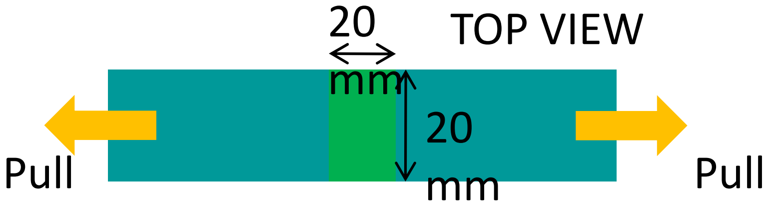
50 mm

AY 103 + HY951

50 µm thick Kapton

2 mm

Permaglas (Frames Material)



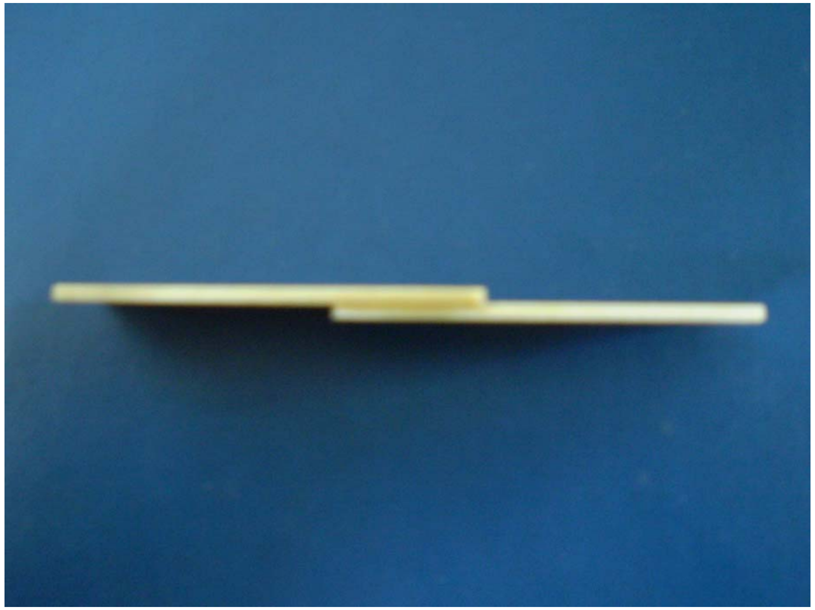
TOP VIEW

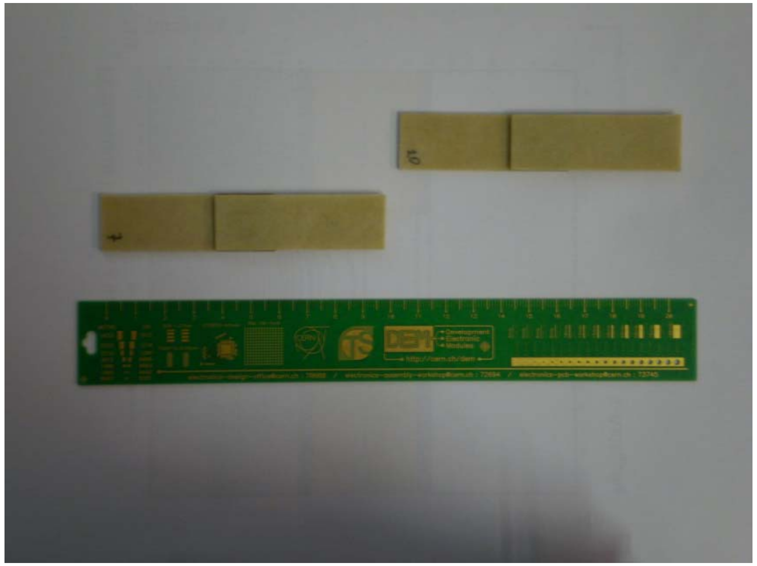
20 mm

20 mm

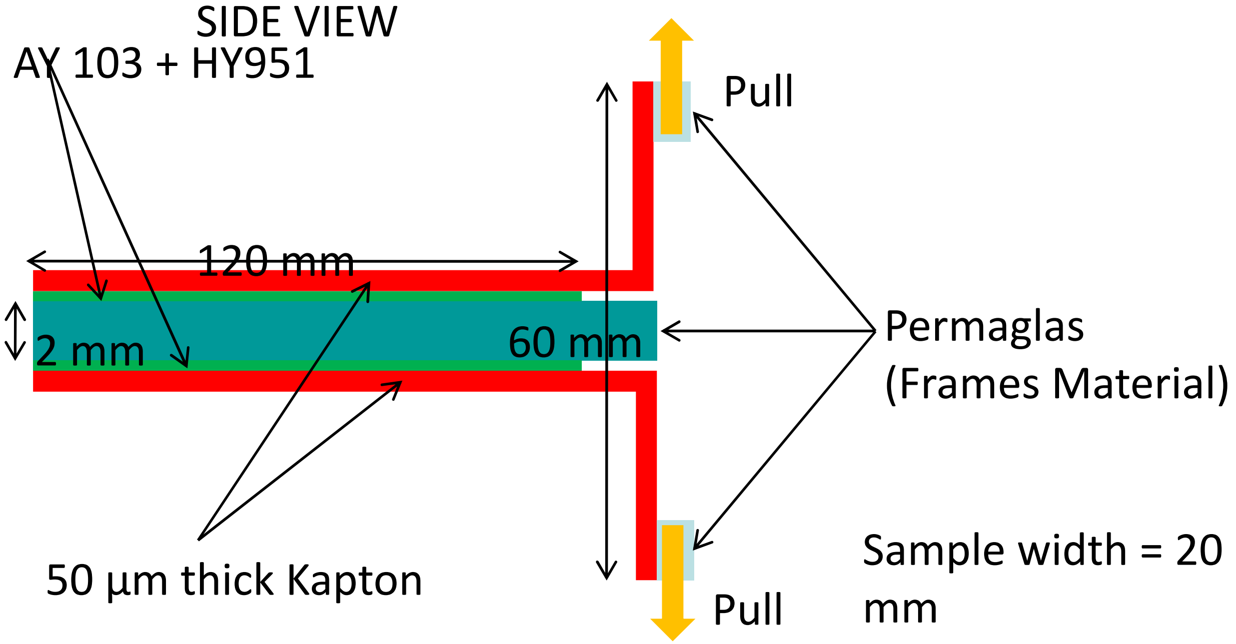
Pull

Pull

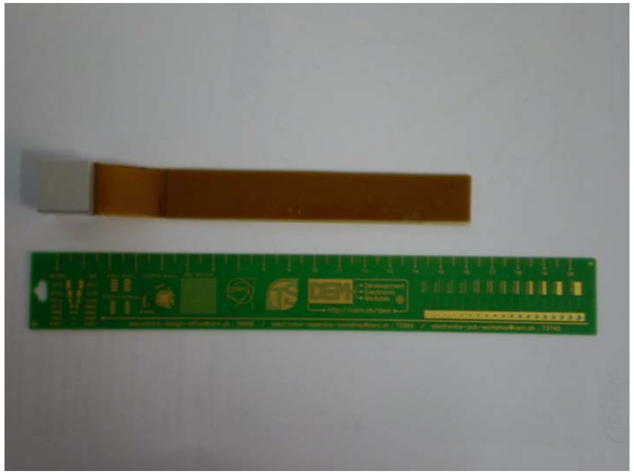




Peeling Test Samples



Sample width = 20 mm



Previous studies on Araldite AY103 +HY951

Material:	**Epoxy structural adhesive**	**ID No. M 523**
Type:	**Araldite AY 103/HY 951 (100/8)**	
Supplier:	**Ciba-Geigy**	

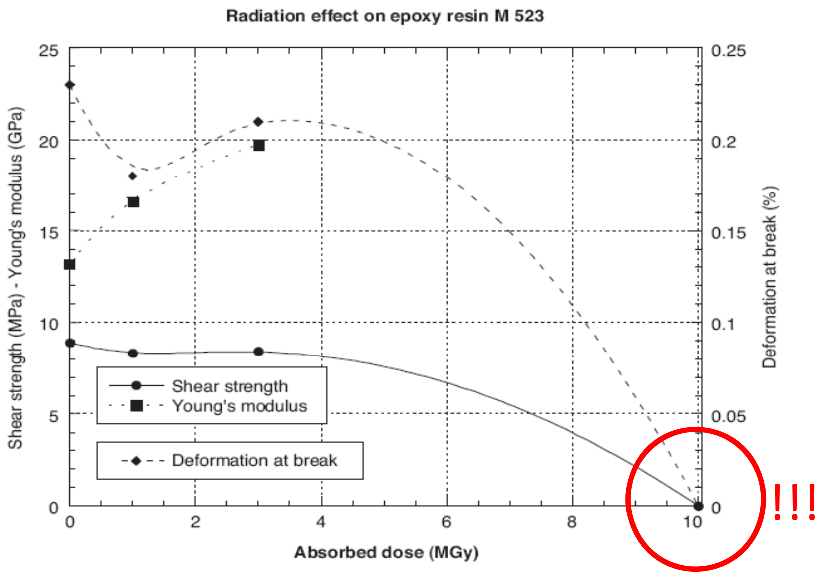
Test method:	**Shear test with aluminium samples**
Sample geometry:	**Equivalent to ASTM D 1876-93**
Surface treatment:	**Sand blasting**
Polymerization temperature:	**25°C**
Radiation source:	**Cobalt 60 and Switched-off reactor**

Absorbed dose (MGy)	Dose rate (kGy/h)	Shear strength (MPa)	Deformation at break (%)	Young's modulus (GPa)
0	0	8.9 ± 0.6	0.23 ± 0.03	13.2 ± 6.6
1	4	8.3 ± 0.5	0.18 ± 0.04	16.6 ± 1.1
3	4	8.4 ± 0.3	0.21 ± 0.01	19.7 ± 1.8
10	20	0.0	0.0	–

Critical property = deformation at break
Radiation index (RI) ~ 6.7 at a mean dose rate of 4 kGy/h

Studies made at CERN some years ago on the same glue used in Triple GEM detectors assembly

***Compilation of radiation damage test data**, 4. / Guarino, Francesco et al. CERN-2001-006. - Geneva : CERN, 2001. - 131 p.*



Present Situation

- We are performing the tests before irradiation **but now we need to find a ^{60}Co irradiation facility!!!!!**

ANY SUGGESTIONS?????

Is anybody interested in irradiating other detectors or components ???

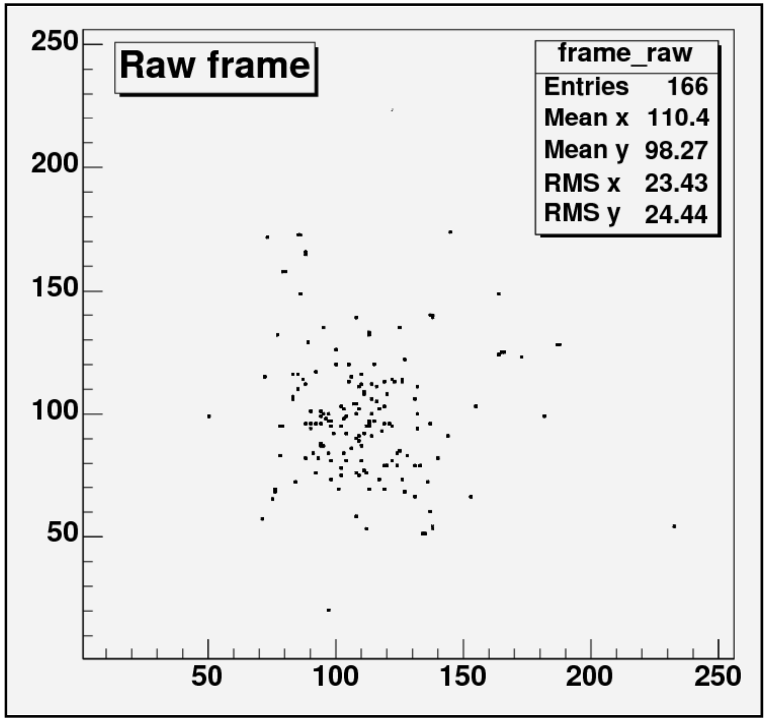
Digital primary electron counting: W, Fano Factor, Polya vs Exponential

M. Chefdeville, NIKHEF, Amsterdam

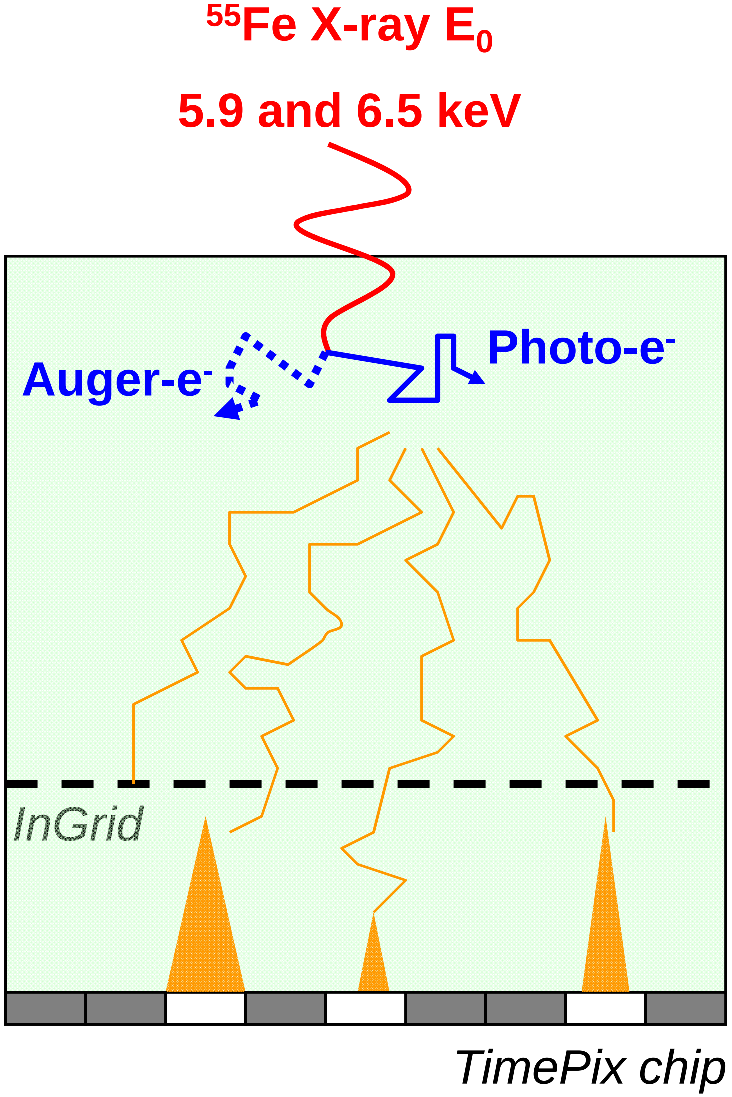
RD51, Paris, 13-15 October 2008

^{55}Fe quanta conversions seen by GridPix

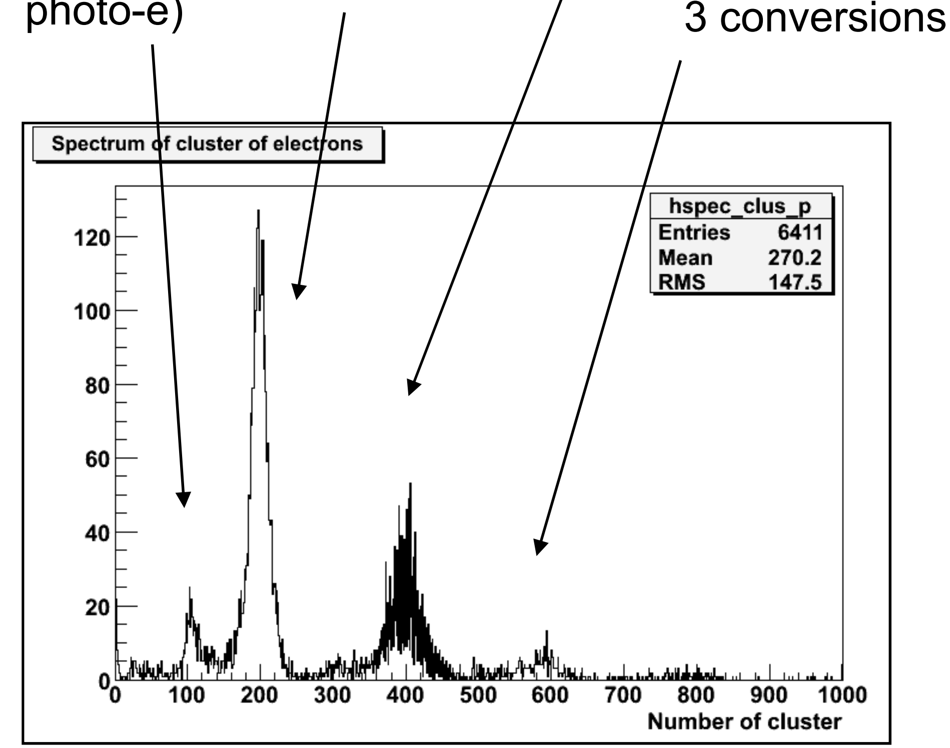
After large drift distance, primary e$^-$ separate and can be counted



Gas mixture: Ar/iso 95/5



^{55}Fe quanta conversions seen by GridPix



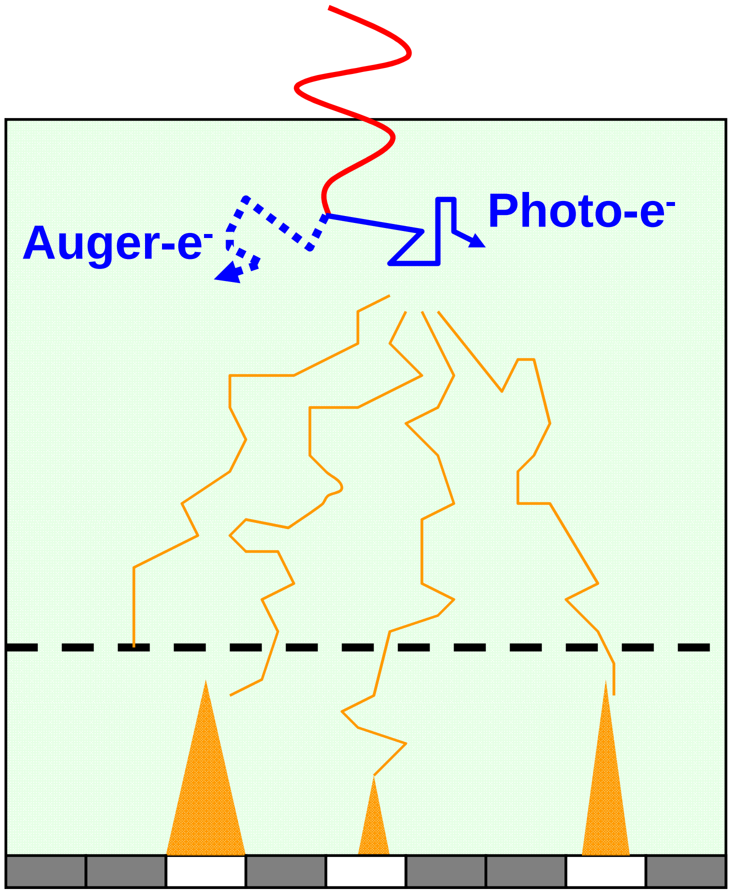
Escape peak (only photo-e)

Photo-peak (photo-e and Auger-e)

2 conversions

3 conversions

Raw spectrum



^{55}Fe X-ray E$_0$

5.9 and 6.5 keV

Auger-e$^-$

Photo-e$^-$

TimePix chip

Look at the escape peak only (smallest number of primary electrons)

Measurements of W and F

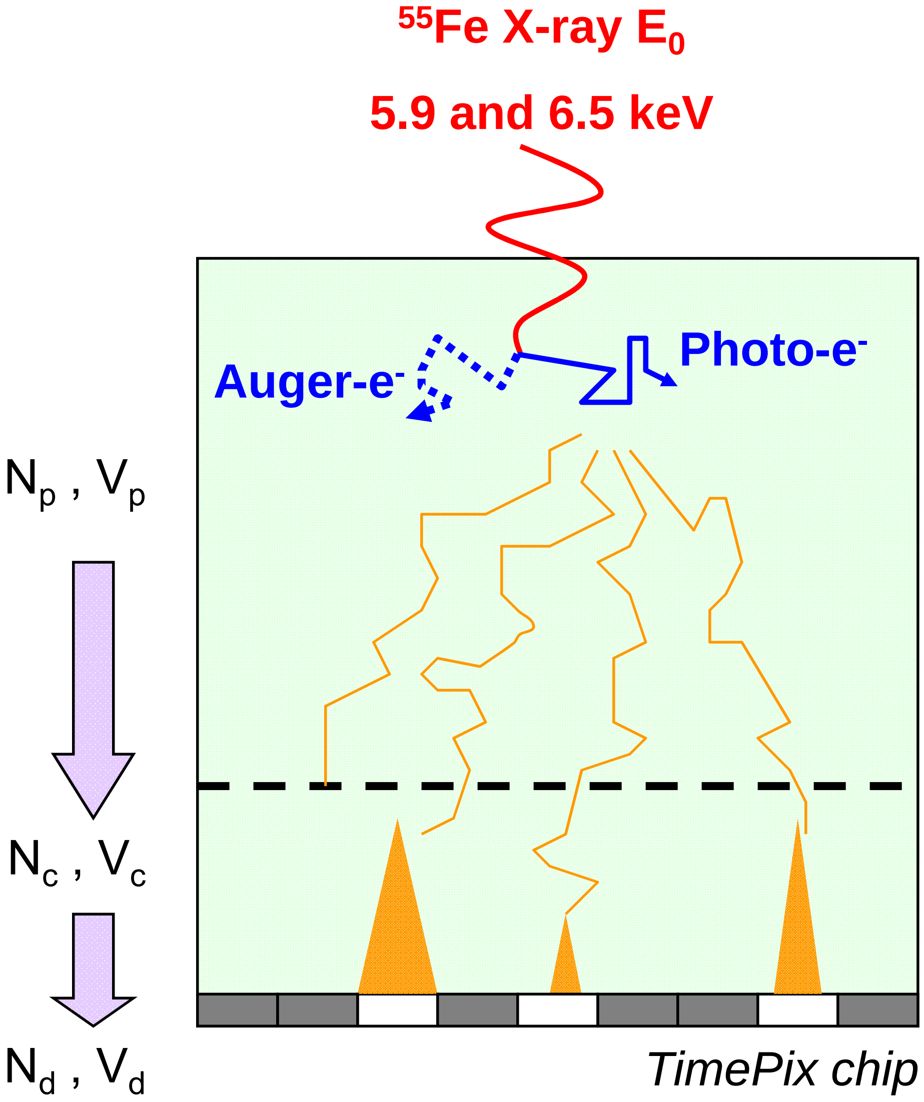
What is measured is the mean and variance of the number of detected electrons (N_d, V_d)

Correction for limited collection and detection efficiencies yield N_p and V_p

$W = E_0 / N_p$

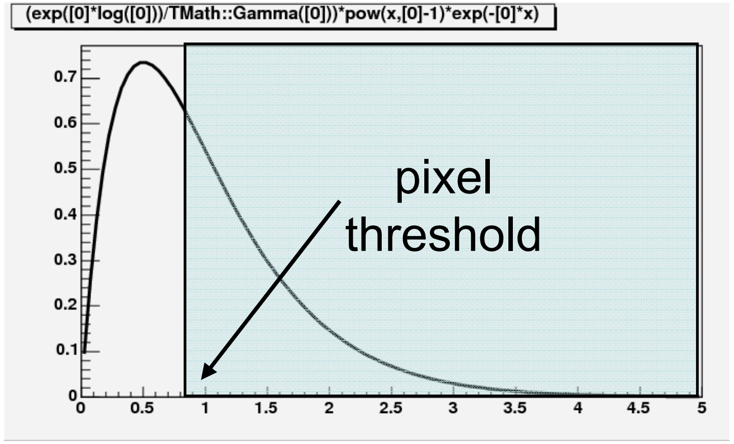
$F = V_p / N_p$

Collection and detection eff. should be known



Detection efficiency

$$\kappa = \int_t^\infty p(g).dg$$



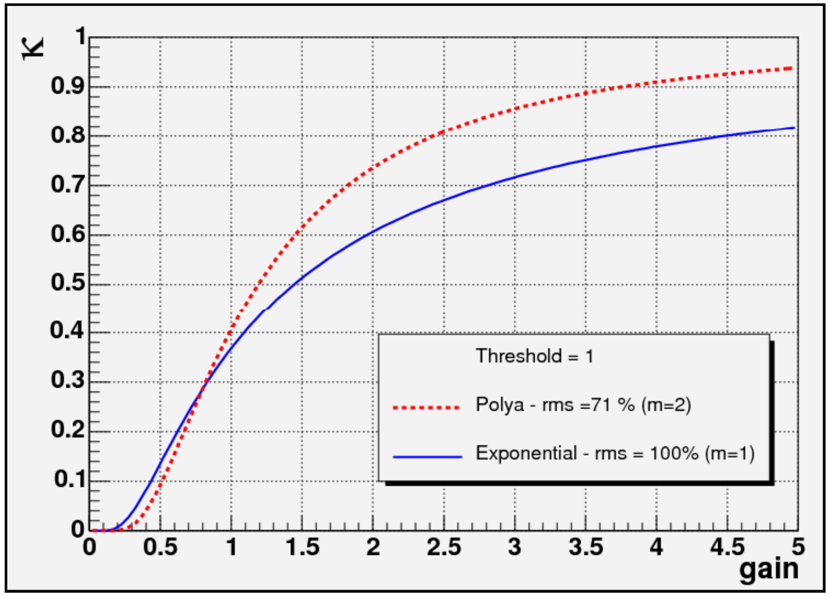
pixel threshold

Exponential fluctuations:

$\kappa(g) = \exp(-t/\langle g\rangle)$

Polya-like fluctuations:
parameter m=1/b ~ 2
with $\sqrt{b}$ the relative rms

$\kappa(2,g) = (1+2.t/\langle g\rangle) . \exp(-2.t/\langle g\rangle)$

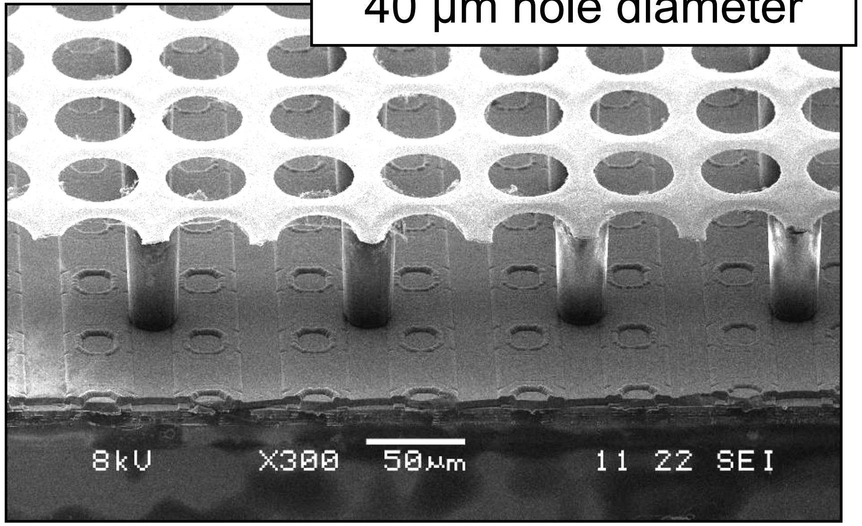


Detection efficiency will be determined by fitting κ(g) to (N_d, V_{grid}) data points

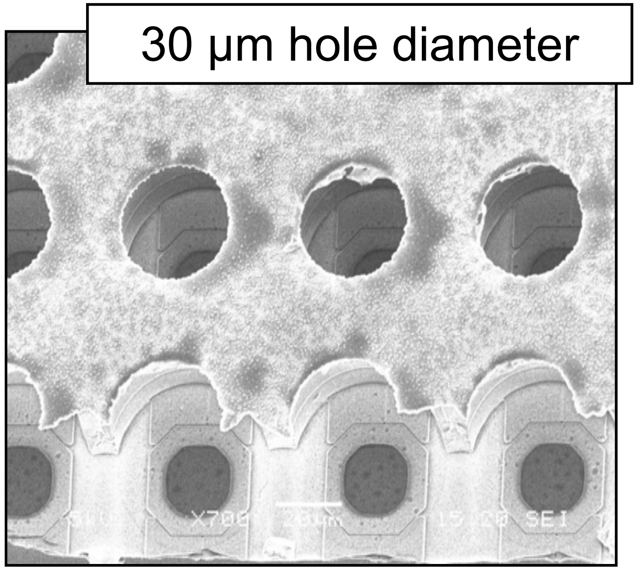
Detectors

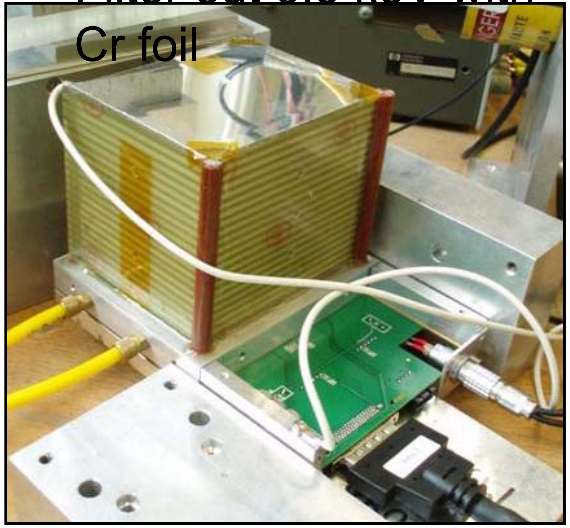
Two measurement periods

Timepix chip # 1:
- Standard InGrid
- Low event statistics


40 µm hole diameter

Timepix chip #2 :
- Increased event statistics
- New GEMGrid structure
- Filter out 6.5 keV with Cr foil

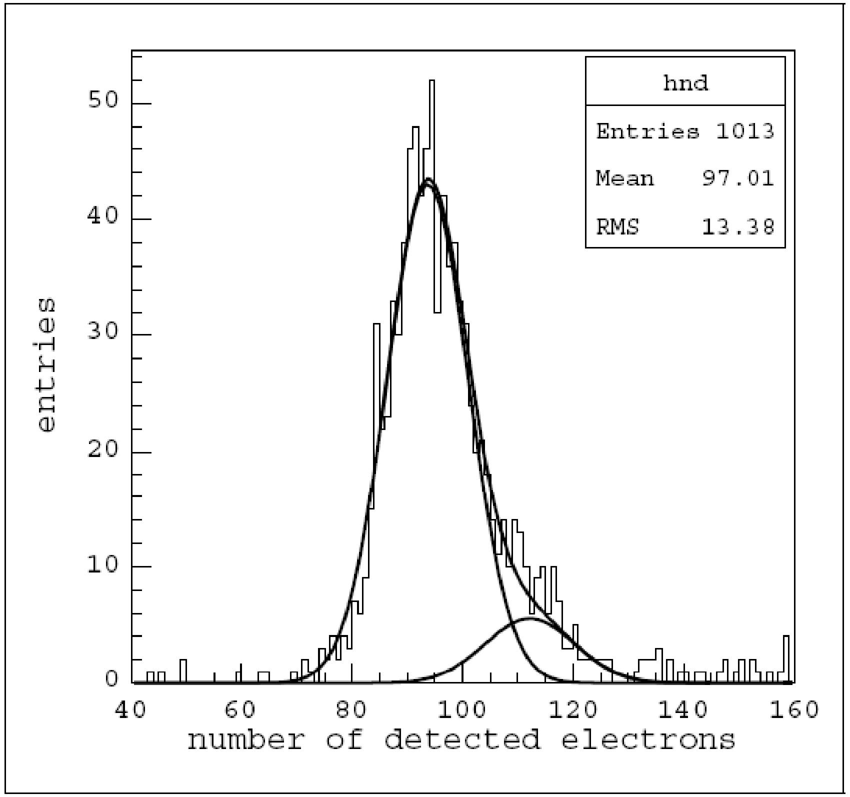

30 µm hole diameter

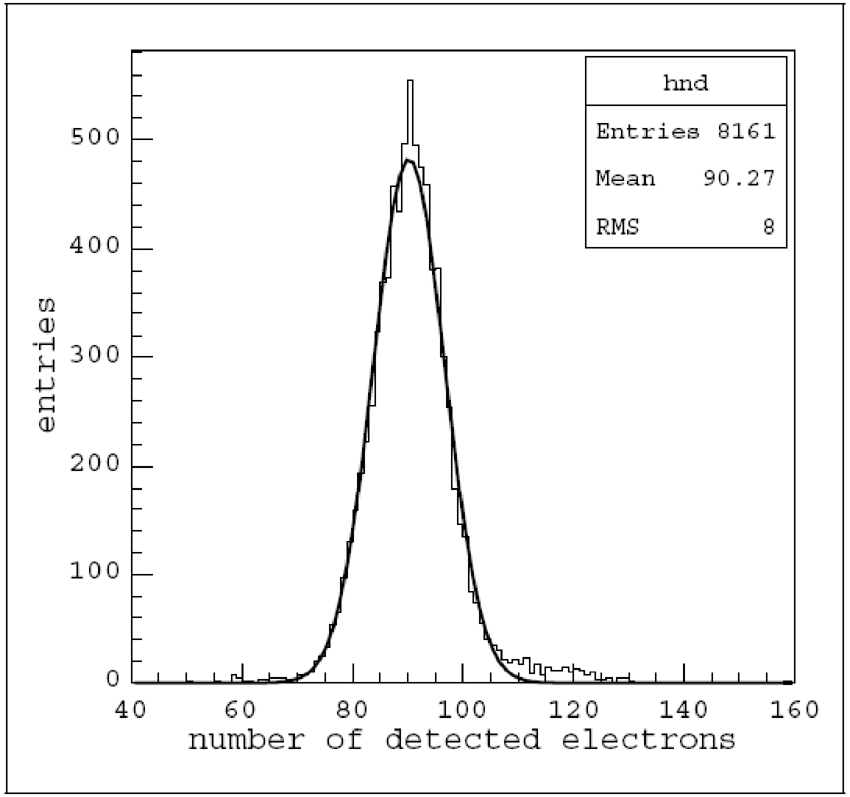


Chamber geometry:
- 10 cm field cage
- Guard electrode surrounding the chip (inside chamber)

Measured spectra at -330 V

- Timepix #1
- Timepix #2





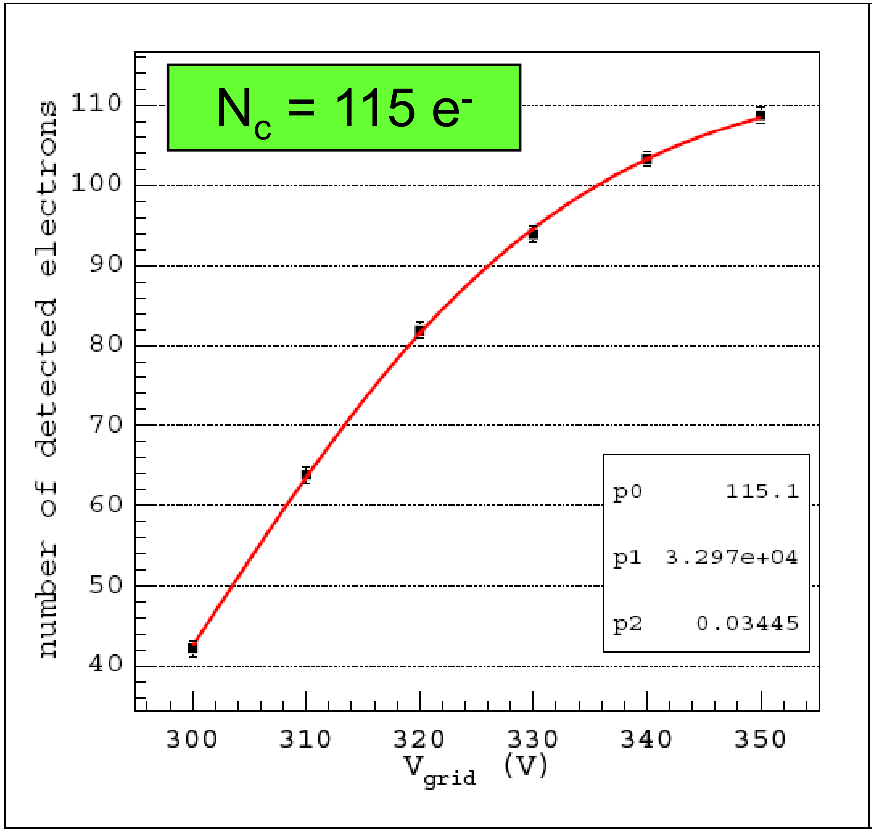
5.9 and 6.5 keV escape events
(event ratio ~ 7:1)

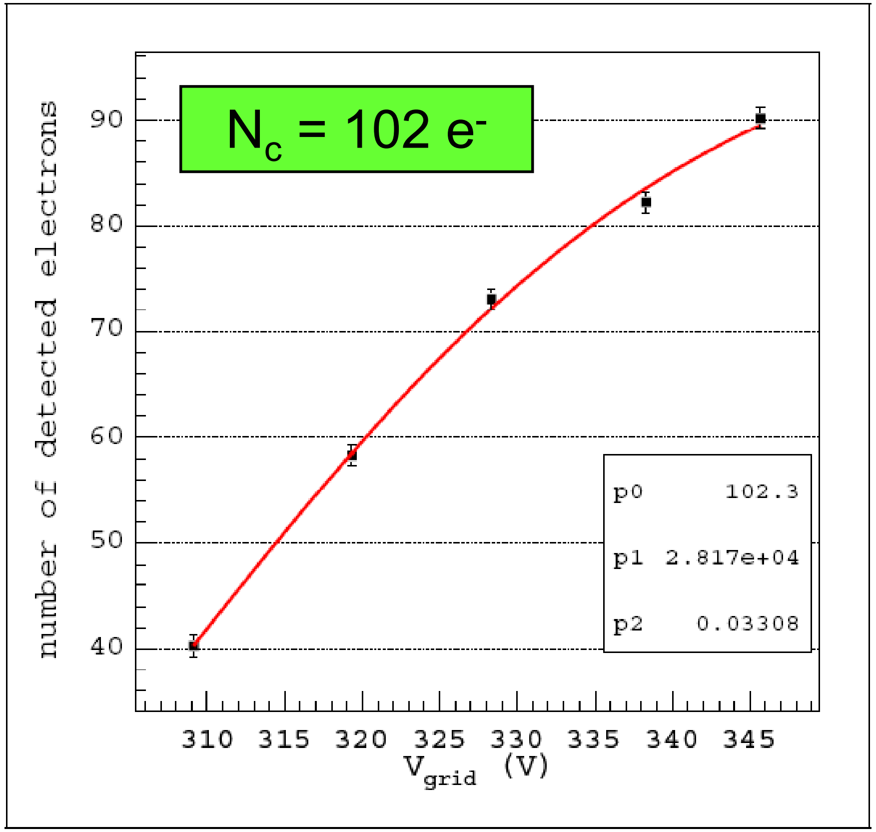
5.9 and 6.5 keV escape events
(event ratio ~ 50:1)

Peak position and grid voltage

Asymptotic value of N_d gives the number of collected electrons N_c

Polya fit works very well where exponential one (not shown) fails!





- Compatible with the smaller hole diameter of InGrid #2
- Contribution from collection efficiency to peak width now known

W and F in Ar/iso 95/5 at 2.9 keV

Assume full collection efficiency of detector #1

$N_p = N_c = 115 \pm 2$ e-

→ W = 25.2 ± 0.5 eV

Extrapolation to 5.9 keV photo-peak straightforward

$N_p = 230 \pm 4$ e-

Peak width measured with detector #2 corrected for detection and collection eff. (87 %)

$\mathrm{RMS}(N_p) \sim 4.3$ %

→ F = 0.21 ± 0.06

Compatible with literature

W = 25.0 ± 0.6 eV

F = 0.250 ± 0.010

Ar/iso 20/80 – 1253 eV X-rays

from Pansky. *et al.*

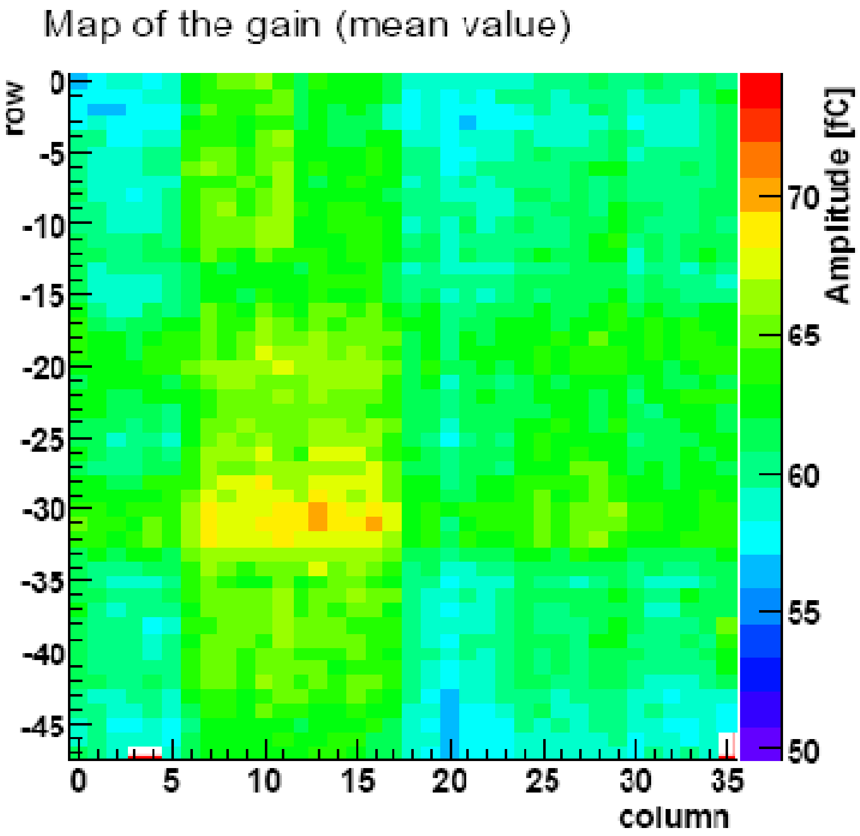
J. Appl. Phys. **79** (1996) 8892

T2K Test Bench results on uniformity and reproducibility of Micromegas production

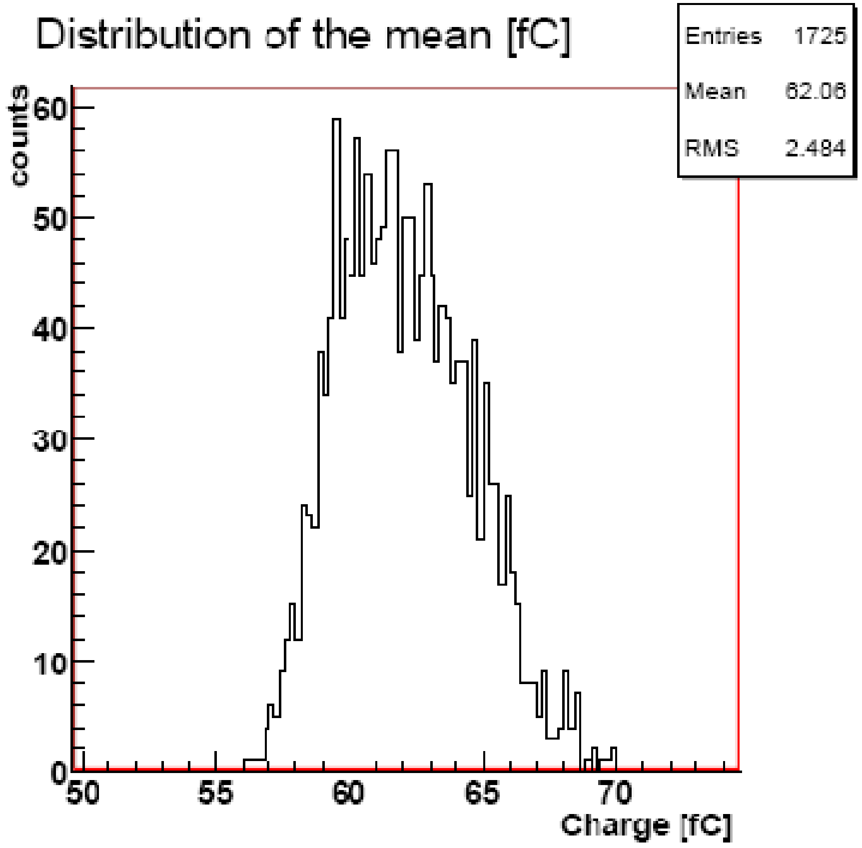
A. Ferrero*

for TRIUMF, University of British Columbia, University of Victoria, IRFU-CEA/Saclay, RWTH Aachen University, INFN Italy, Barcelona University, Valencia University and University of Geneve*

RD51 Collaboration Meeting, October 14 2008



Map of the gain (mean value)



Distribution of the mean [fC]

- Measurements performed at the nominal mesh voltage of -350V
- Each bin in the 2D map represents one pad (36 × 48 matrix)
- Signal amplitude dispersion: ∼4% RMS

Scintillation Readout From THGEMs operating in xenon

Joaquim M.F. dos Santos

University of Coimbra; University of Aveiro

Weizmann Institute of Sciences

Universidad Autónoma de Barcelona/ Universidad Politécnica de Valencia

2nd RD51 collaboration meeting
13-15 Oct. 2008, **Paris**

Recent Relevant Applications of Optical TPCs

Double Beta decay Experiments

NEXT – Neutrino Xenon TPC

Dark Matter search

XENON, LUX, ZEPELIN, WARP experiments

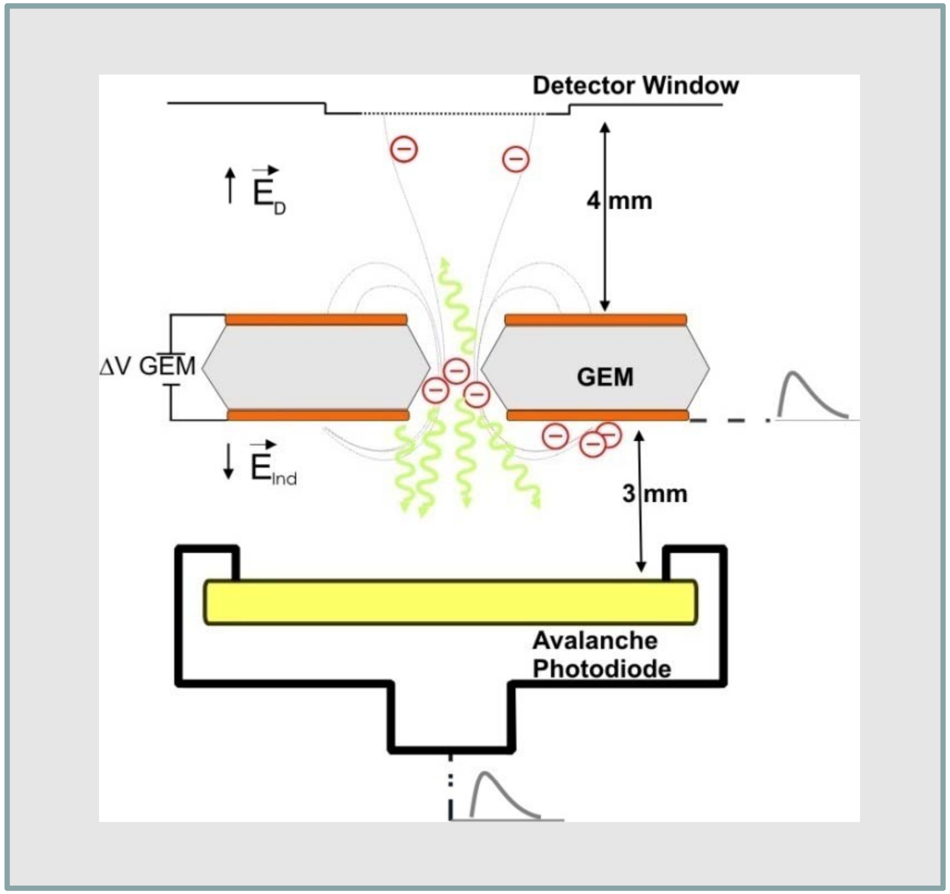
- **Secondary scintillation amplification, for higher sensitivity, with PMT/LAAPD readout**
  - **Double mesh, uniform field scintillation gap**

    e.g. secondary scintillation yield of

    466 photons/e^-/cm @ 4.1 kV/cm/bar

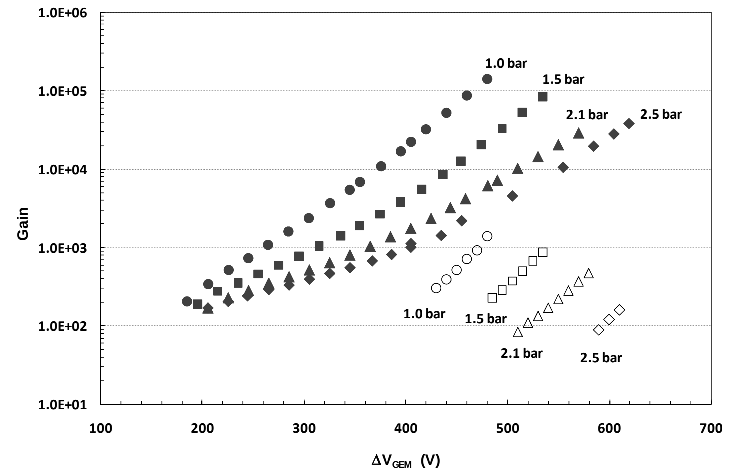
    (C.M.B. Monteiro et al., J. Inst. 2 P05001)
  - **Scintillation in hole-type microstructures, e.g. THGEMs**

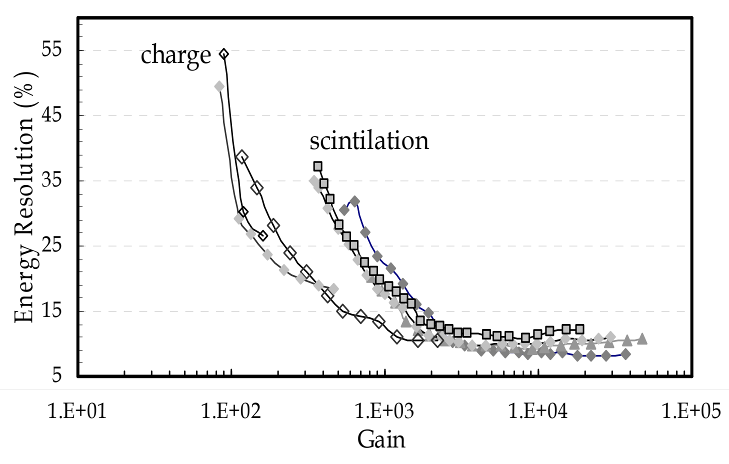
MPGD scintillation vs. charge readout



A.S. Conceição, et al., J. Inst. 2 P09010

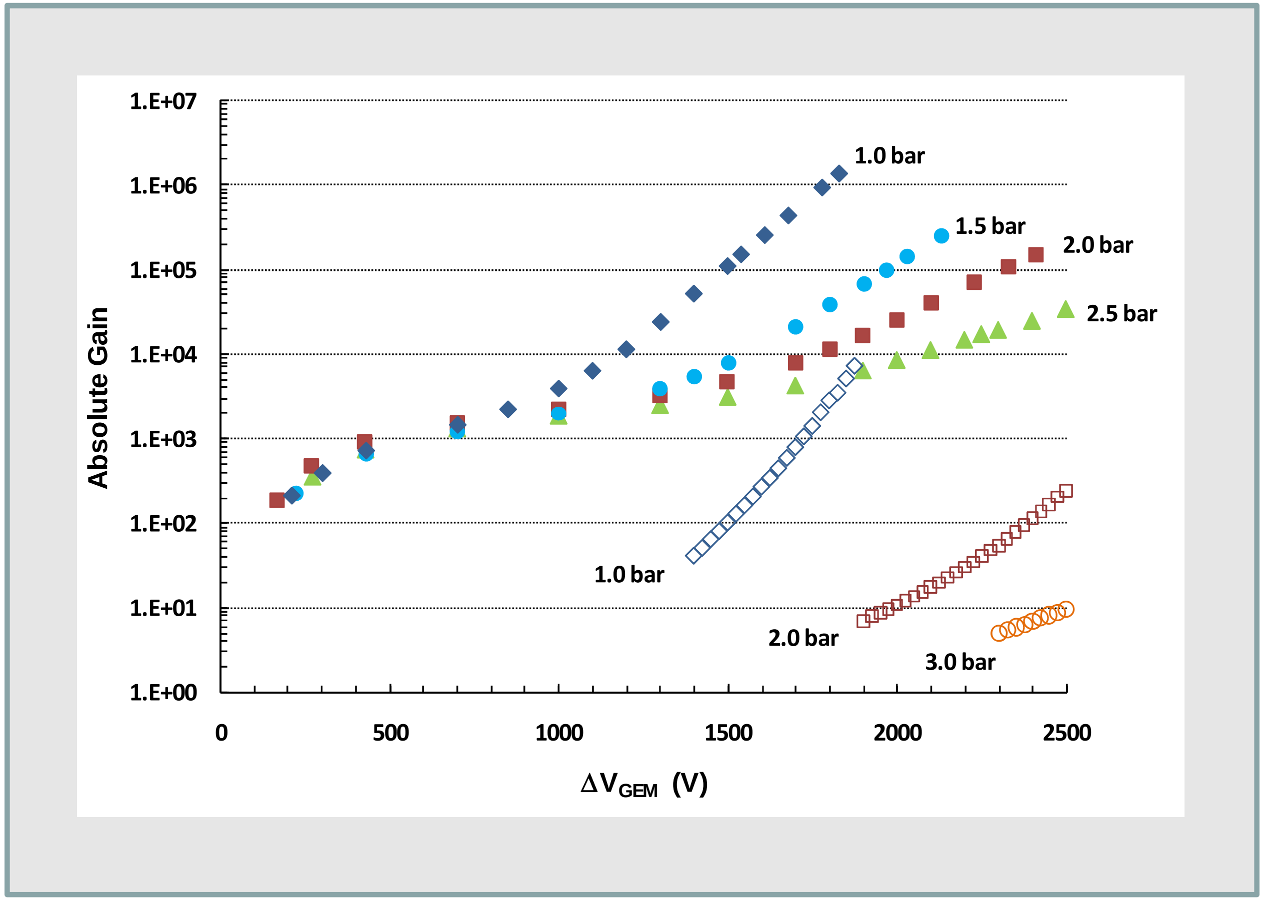
GEM scintillation vs. charge readout





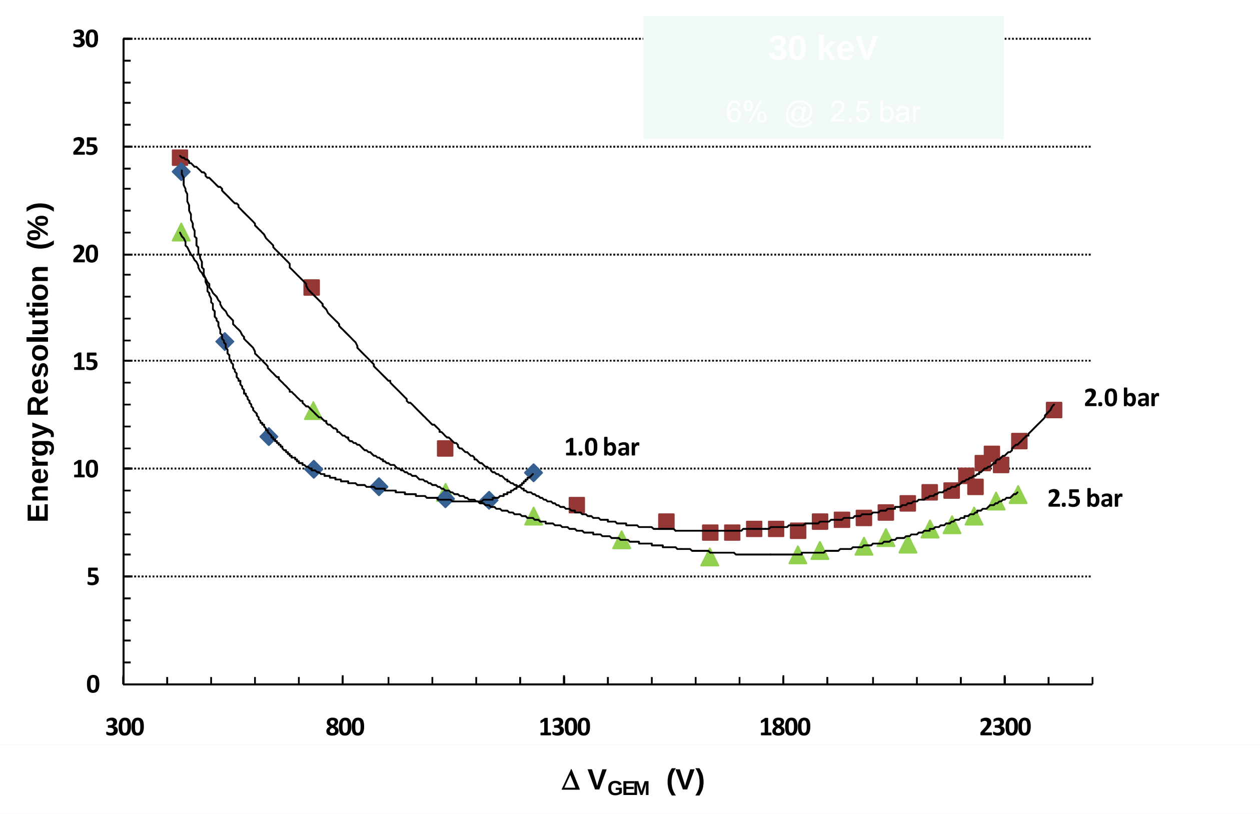
LAAPD gain ~130 - 150

THGEM scintillation vs. charge readout



LAAPD gain ~130 - 150

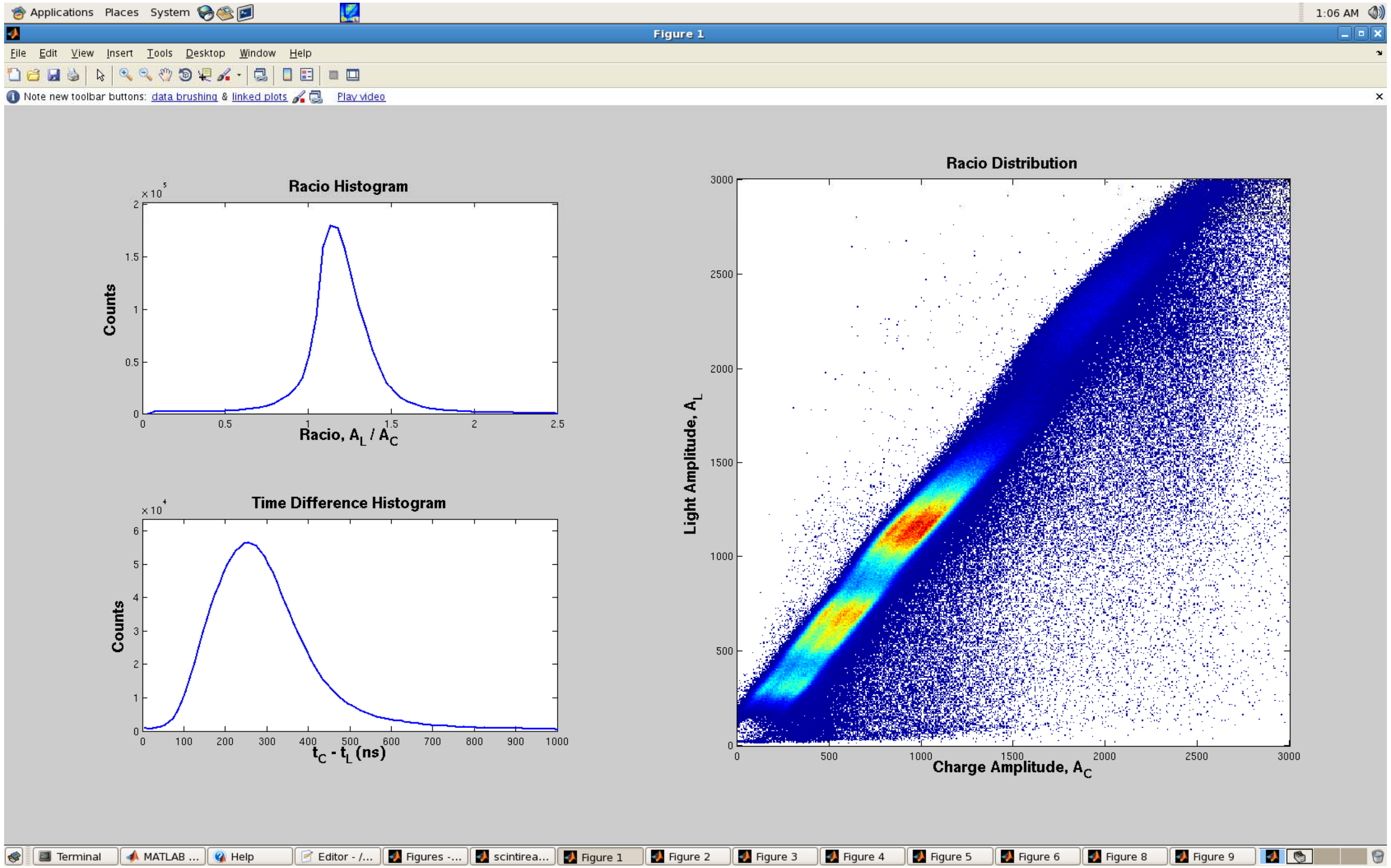
THGEM scintillation – Energy Resolution



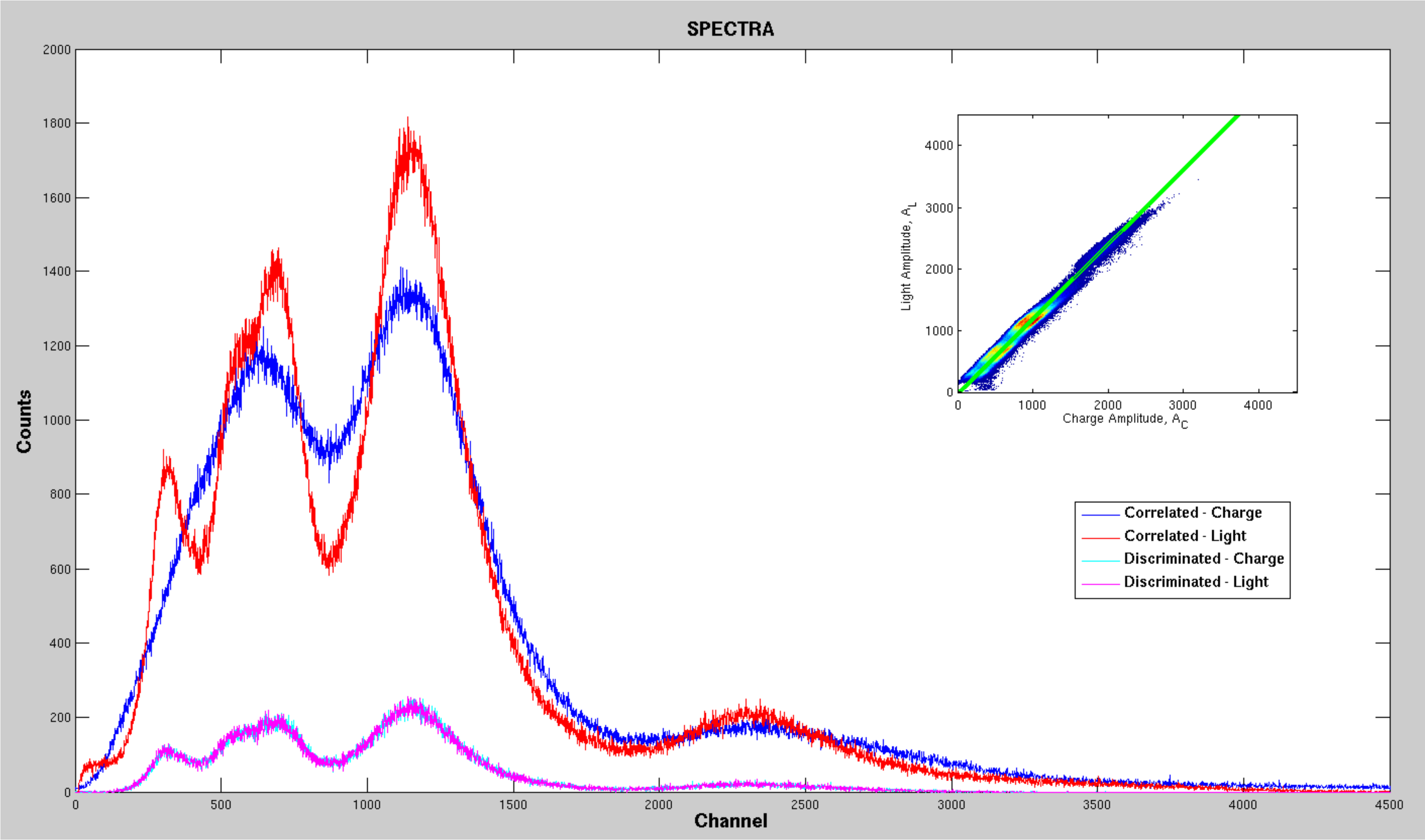
30 keV

6% @ 2.5 bar

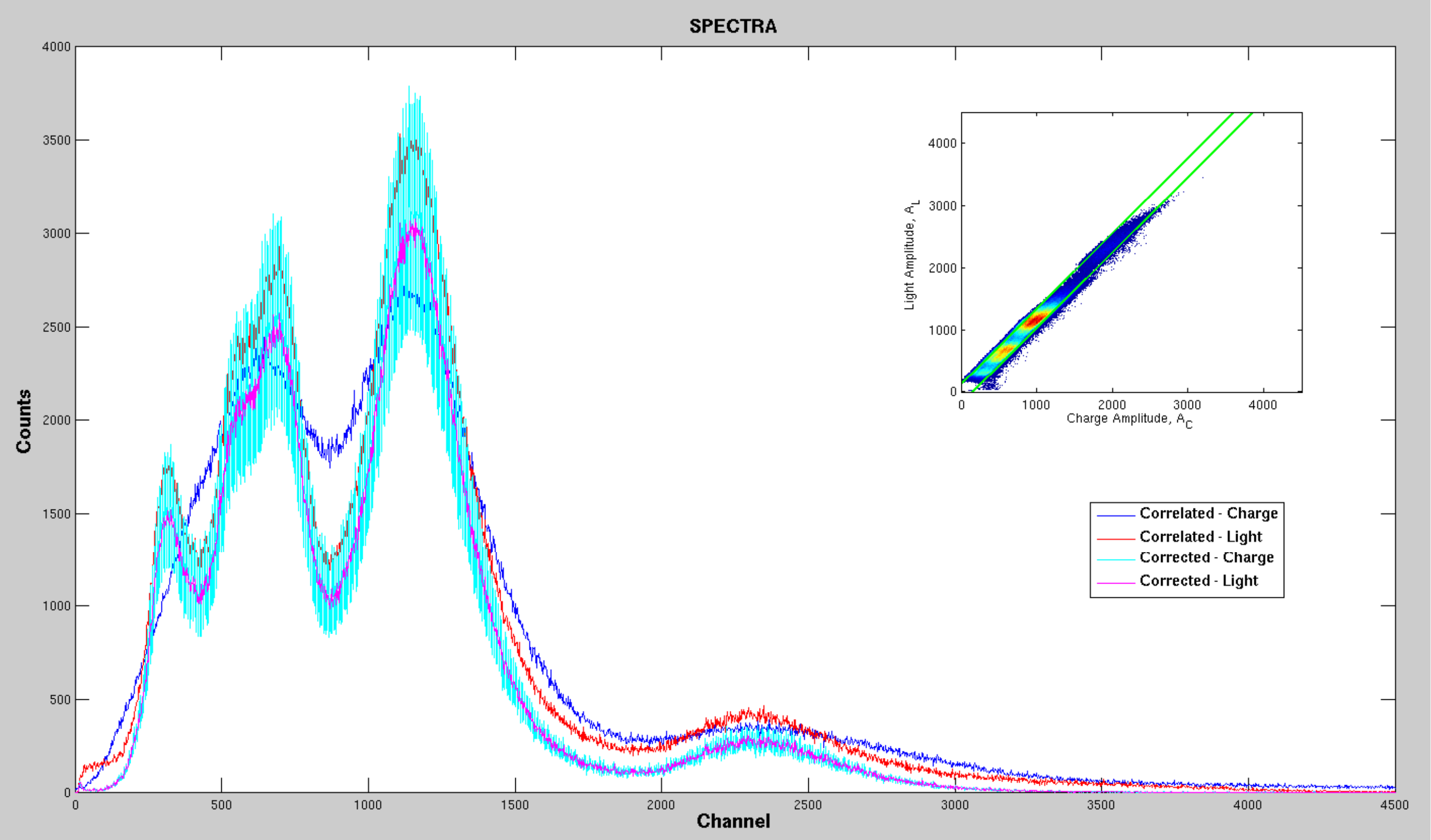
Scintillation and charge pulses correlation



Scintillation and charge correlated spectra



Scintillation and charge corrected spectra



Test Beam Measurements for a TGEM Based Trigger Detector

ELTE, **MTA KFKI RMKI** Collaboration
(Budapest, Hungary):
G. Bencze, L. Boldizsár, G. Hamar,
L. Kovács, P. Lévai, D.Varga

RD51 Collaboration Meeting, 13-15.10.2008., Paris