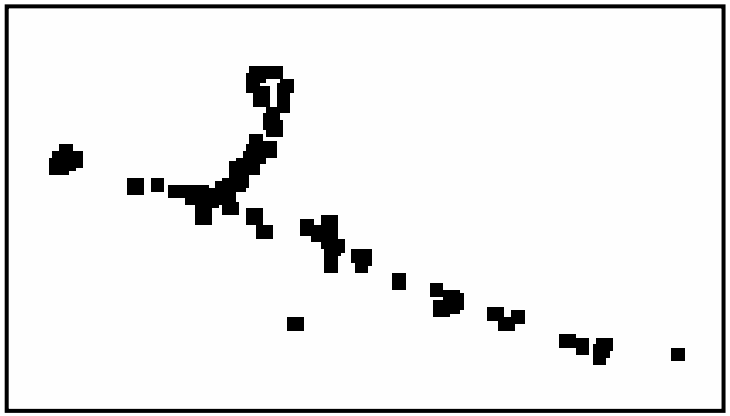
Silicon pixel readout for a TPC

Jan Timmermans - NIKHEF

- Reminder GridPix
- TimePix news
- First & new results InGrid
- First results on protection
- Future developments



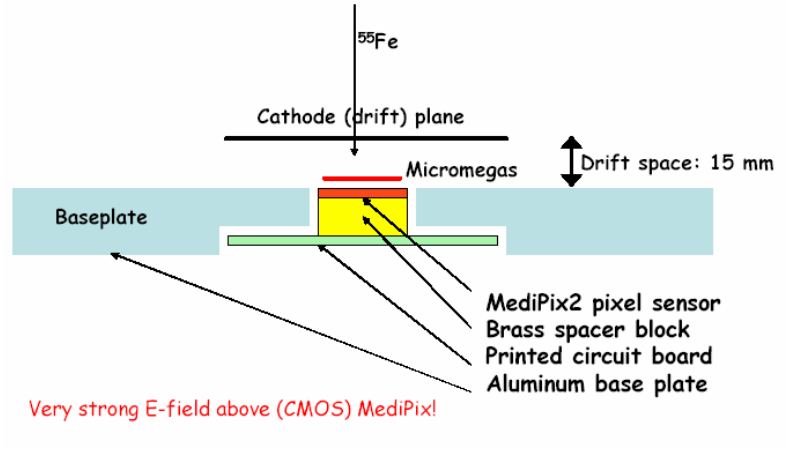
Goals

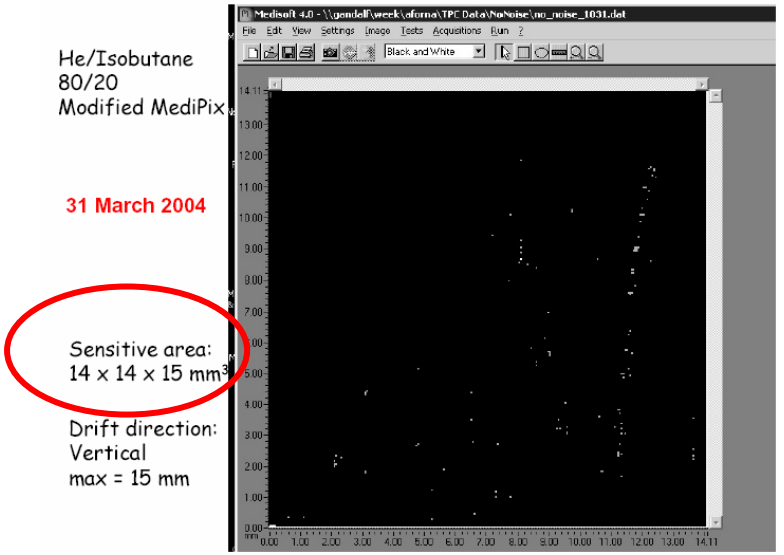
- Gas multiplication GEM or Micromegas foil(s)
- Charge collection with granularity matching primary ionisation cluster spread
- Needs sufficiently low diffusion gas
- dE/dx using cluster counting?
  ($\rightarrow$ M. Hauschild @ ECFA LC workshop Vienna)

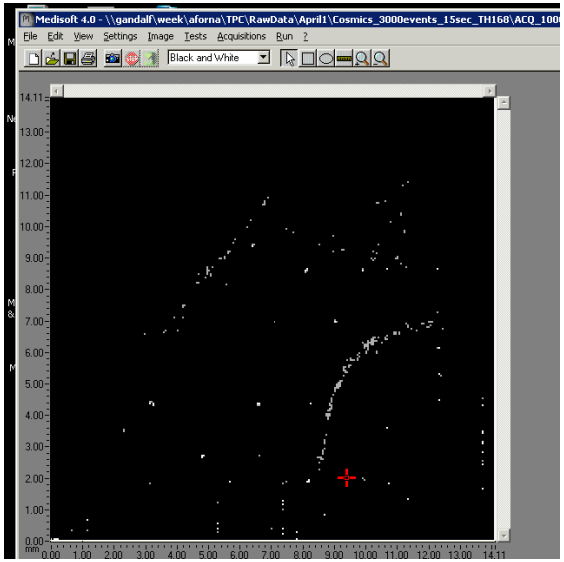
- Proof of principle based on existing Medipix2 readout chip: achieved
- Add 3rd coordinate: Medipix2 $\rightarrow$ TimePix ($\rightarrow$2006)
- Integrate grid with pixel chip: Ingrid (new results)

Results pixel readout gas detectors

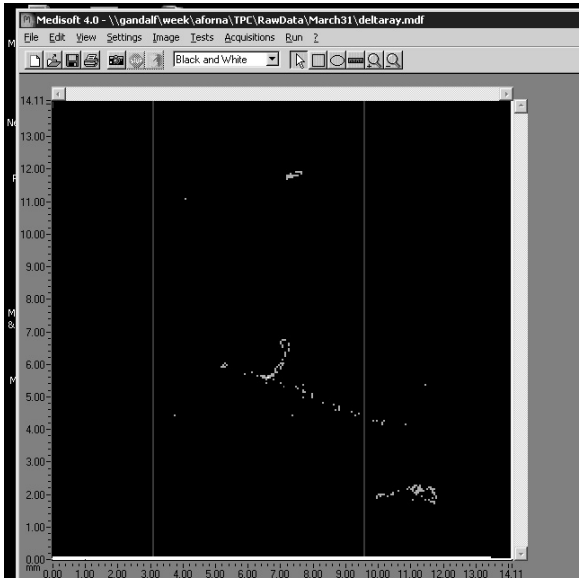
NIKHEF-Saclay-CERN-Twente







55x55 μm^2 pixels



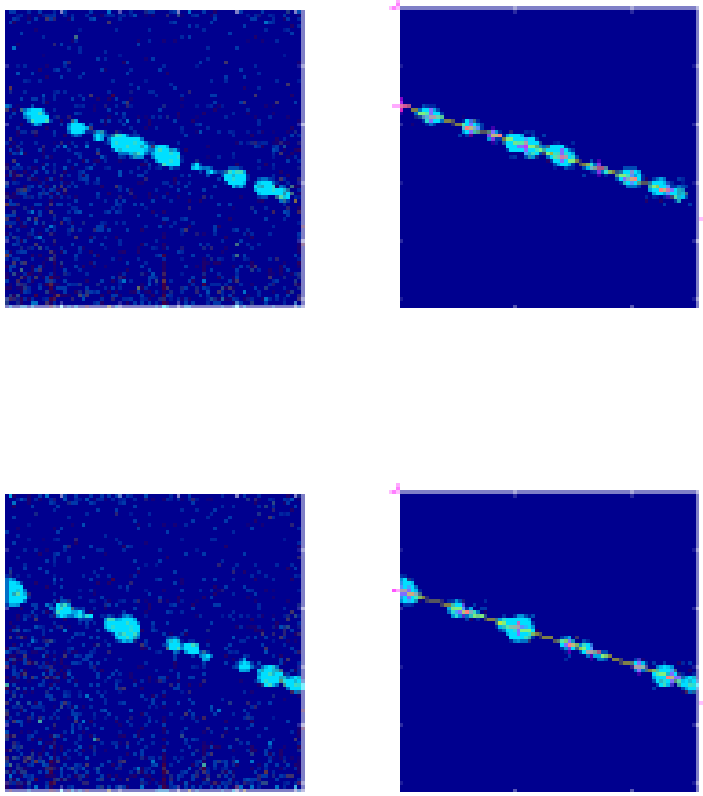
δ ray

Observation of min. ionising cosmic muons: high spatial resolution + individual cluster counting !

NIM A540 (2005) 295 (physics/0409048)

Some events with fits

(from Freiburg GEM+Medipix setup - Andreas Bamberger)



Difference between Micromegas and GEM setup understood (simulation Michael Hauschild)

Results for point/cluster resolution

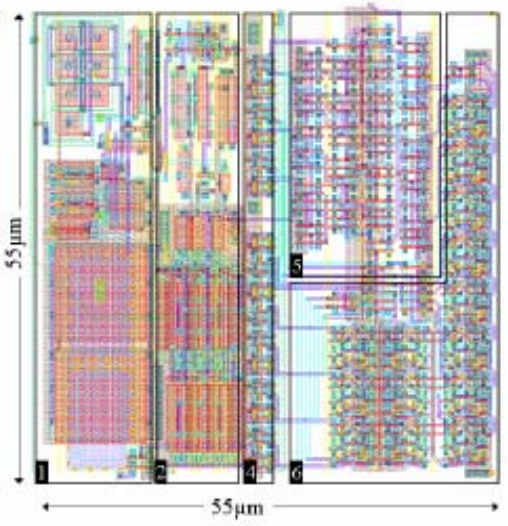
(from Freiburg GEM+Medipix setup)

	Ar/CO2	He/CO2
3-point method	58 ± 2 μm	53 ± 3 μm
$\sigma_{corrected}$*	54 μm	53 μm

- **with few primary electrons per cluster !**
- * multiple scattering correction to be checked for systematics

TimePix1 (EUDET: Freiburg, Saclay, CERN, NIKHEF)

- Distribute clock to full 256x256 pixel matrix (50-100-160MHz)
- Enable counting by first hit after 'shutter' opens, until 'shutter' closes (common stop); also time-over-threshold possible
- Dynamic range 2^{14} x 10 ns = 160 µs
- (for the time being) no zero-suppress to remain fully compatible with Medipix2
- Shaping time ~200 ns
- Extra static discharge protection for the could be considered later

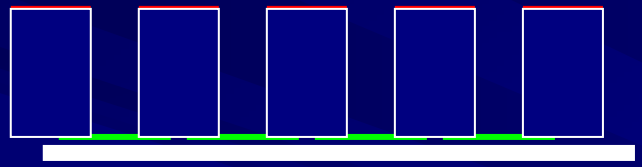


- Keep same chip-size, pixel-size, readout protocol
- 1st full reticle submit done July 2006

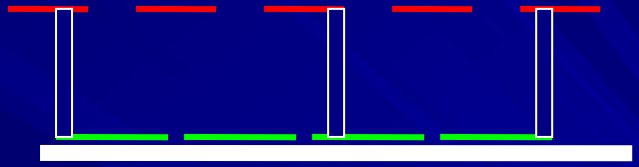
InGrid

Integrate GEM/Micromegas and pixel sensor

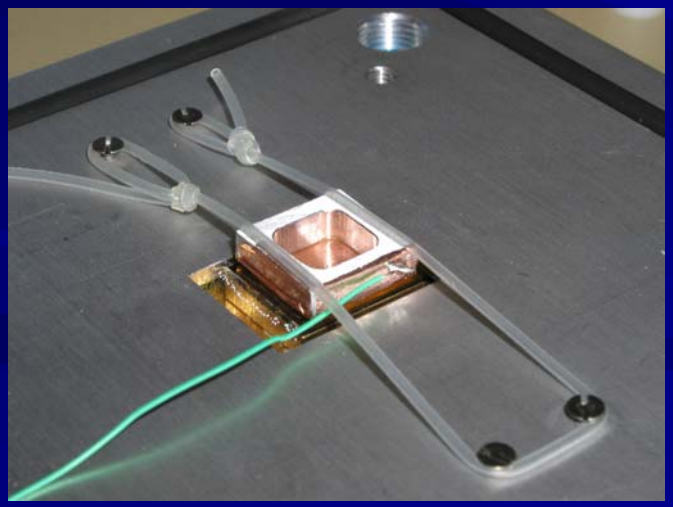
‘GEM’



‘Micromegas’



By ‘wafer post processing’

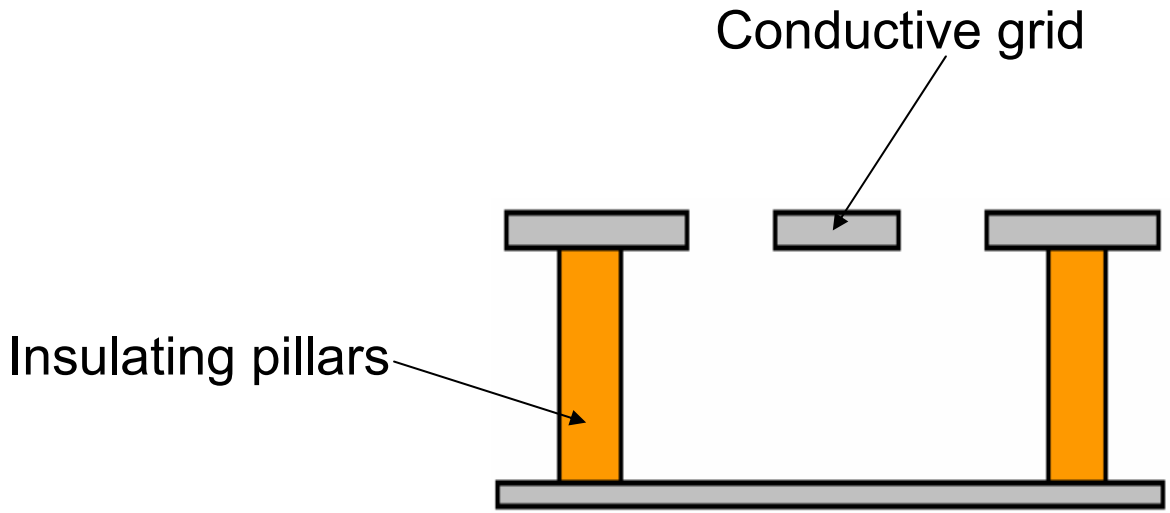


4” wafer

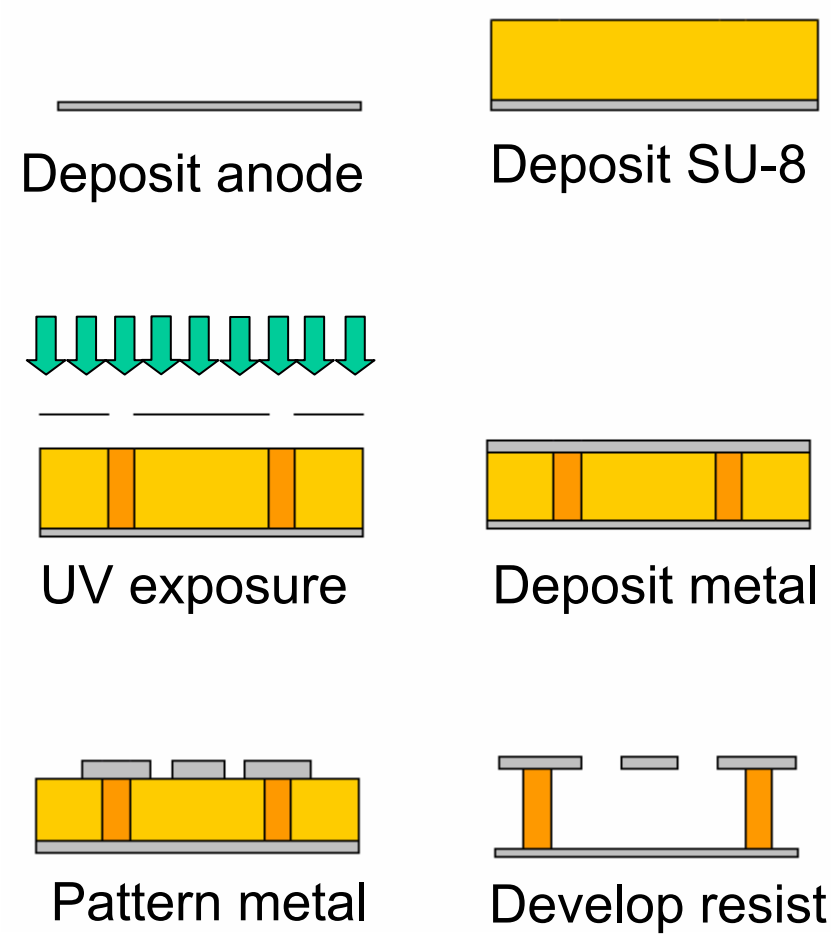
19 different fields of 15 mm Ø
2 bonding pads / fields

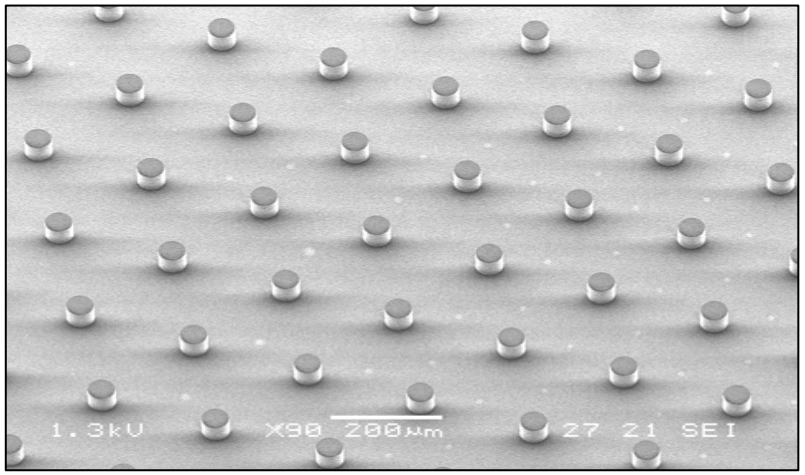
Materials for our structures

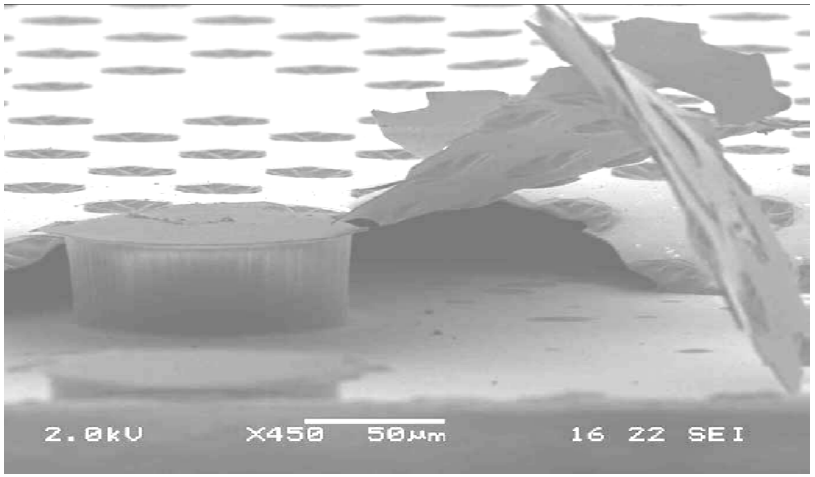
- SU-8 negative resist as insulating pillars
  - Easy to define structures
  - Wide range of thickness (5 μm to 250 μm)
  - High precision
- Aluminum as conductive grid
  - Commonly used in microelectronics
  - Easy to deposit
  - Easy to pattern



InGrid: Integrated Grid

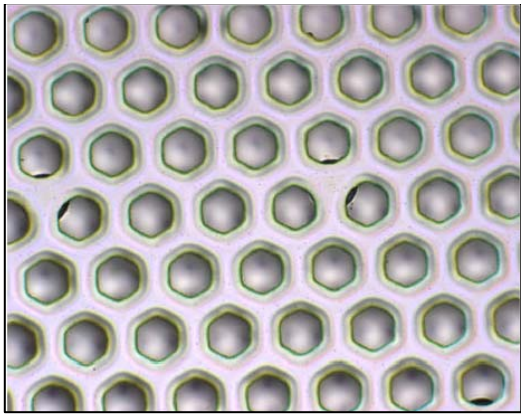






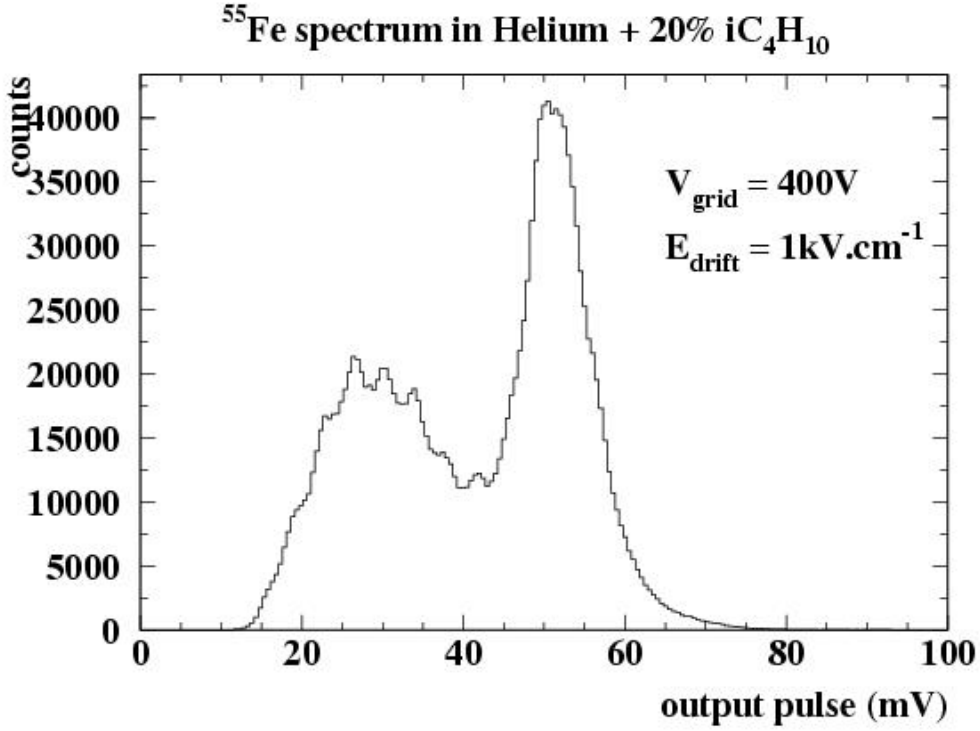
Measuring the InGrid signals

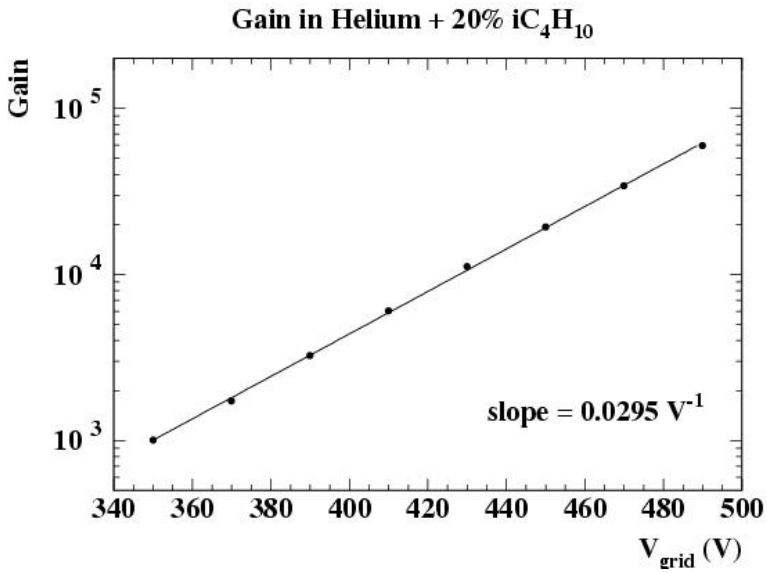
(NIM A556 (2006) 490)



(After 9 months of process tuning and unsuccessful trials)

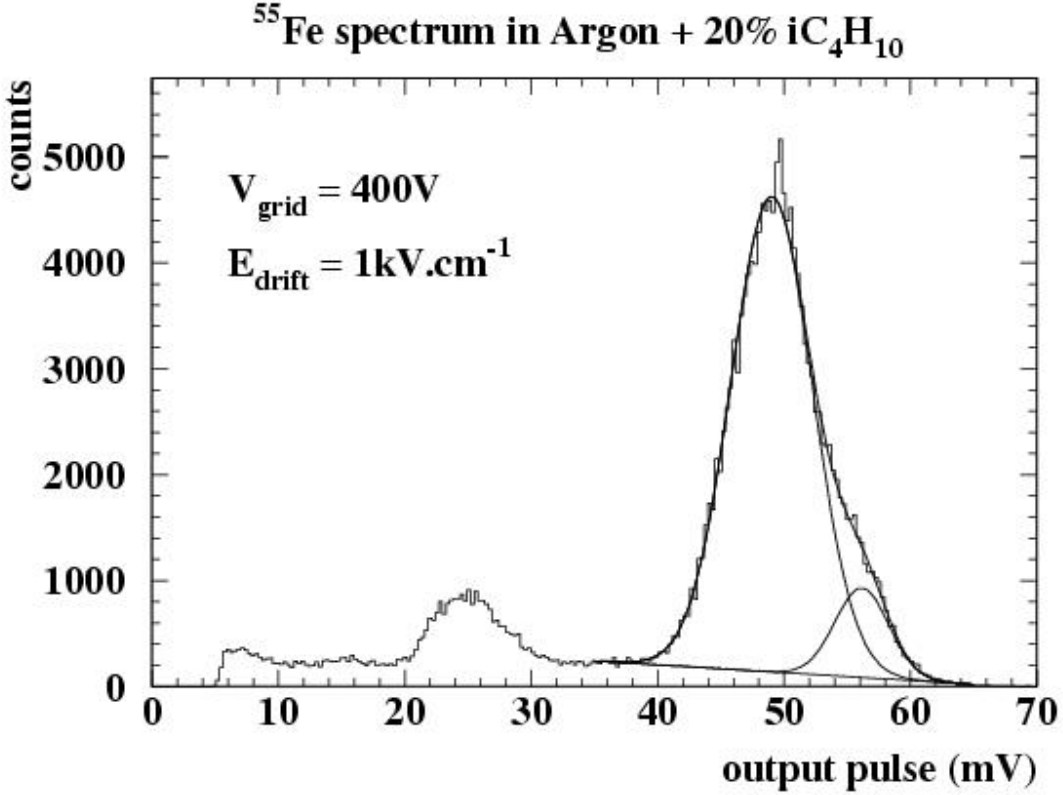
Pulseheight and gain: He + 20% iC_4H_{10}





•Gas gains 10^3 - $6 \cdot 10^4$

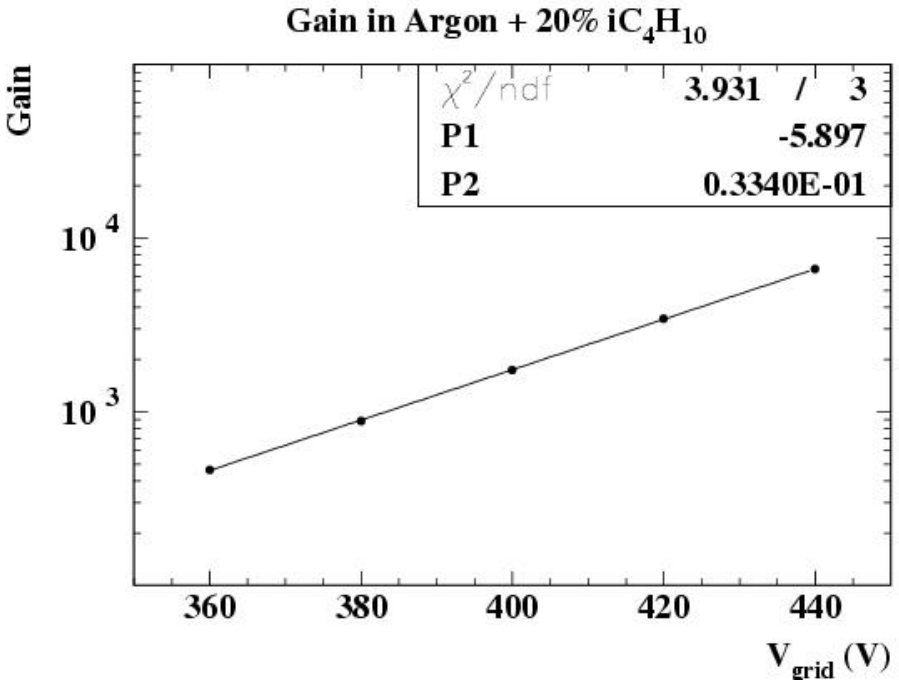
Energy resolution in Argon IsoC4H10 80/20

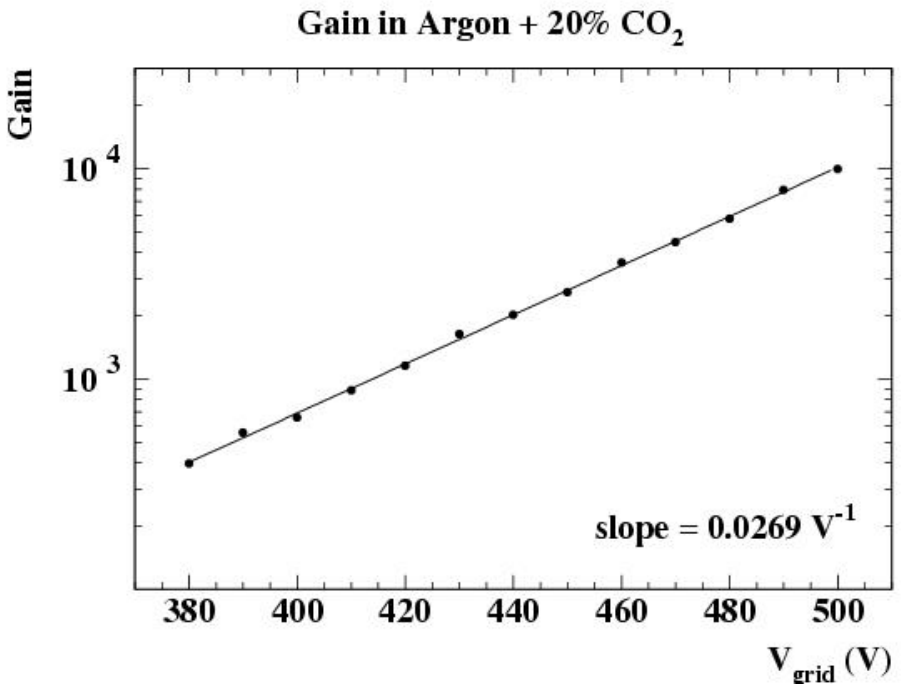


- Observation of two lines:
  - K_α at 5.9 keV
  - K_β at 6.4 keV
- Resolution σ_E/E = 6.5%
  - (FWHM = 15.3%)
- Gain variations < ±5%

- Photo peak asymmetry seen
- Very good energy resolution

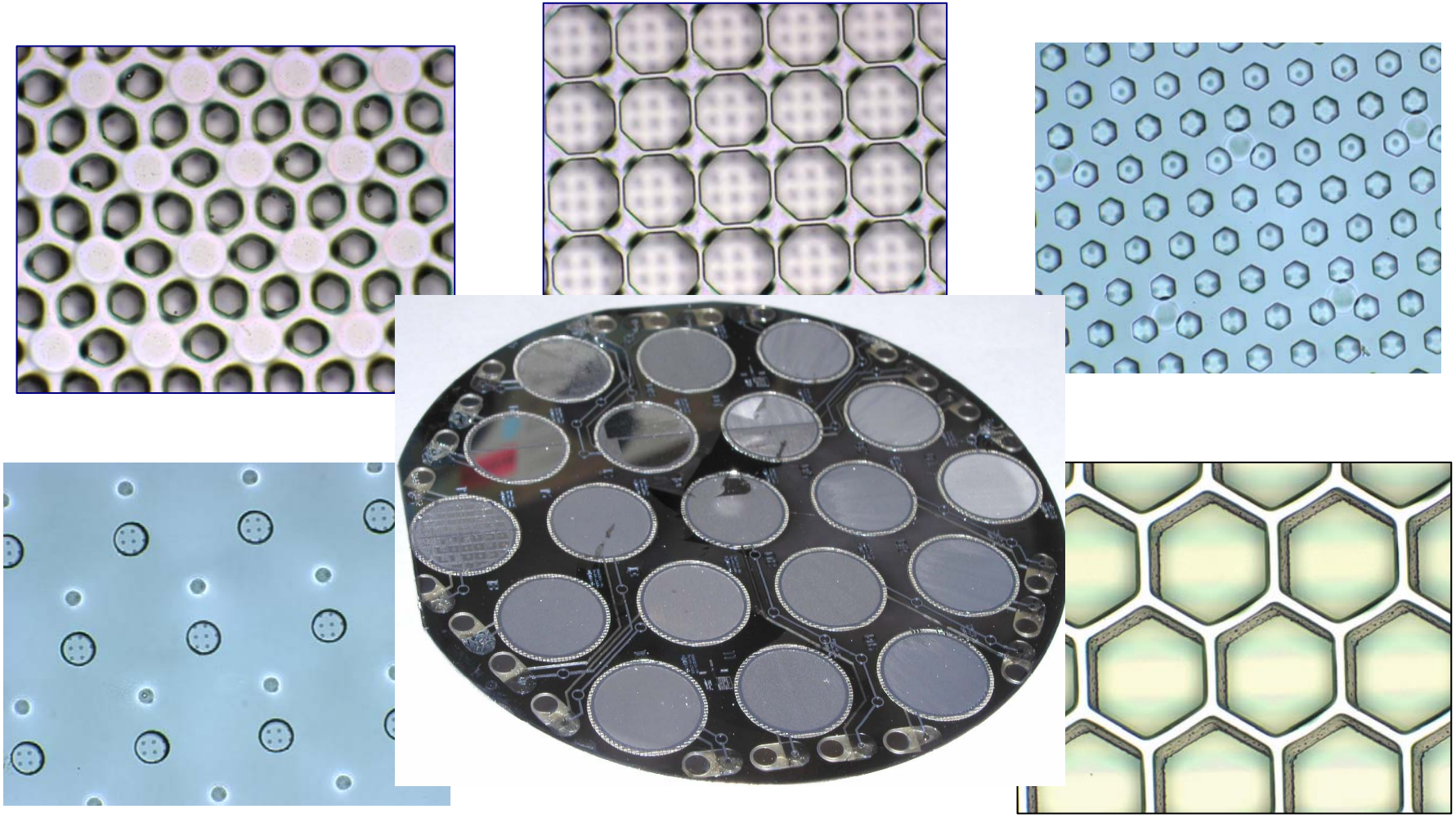
Gas gains in Argon





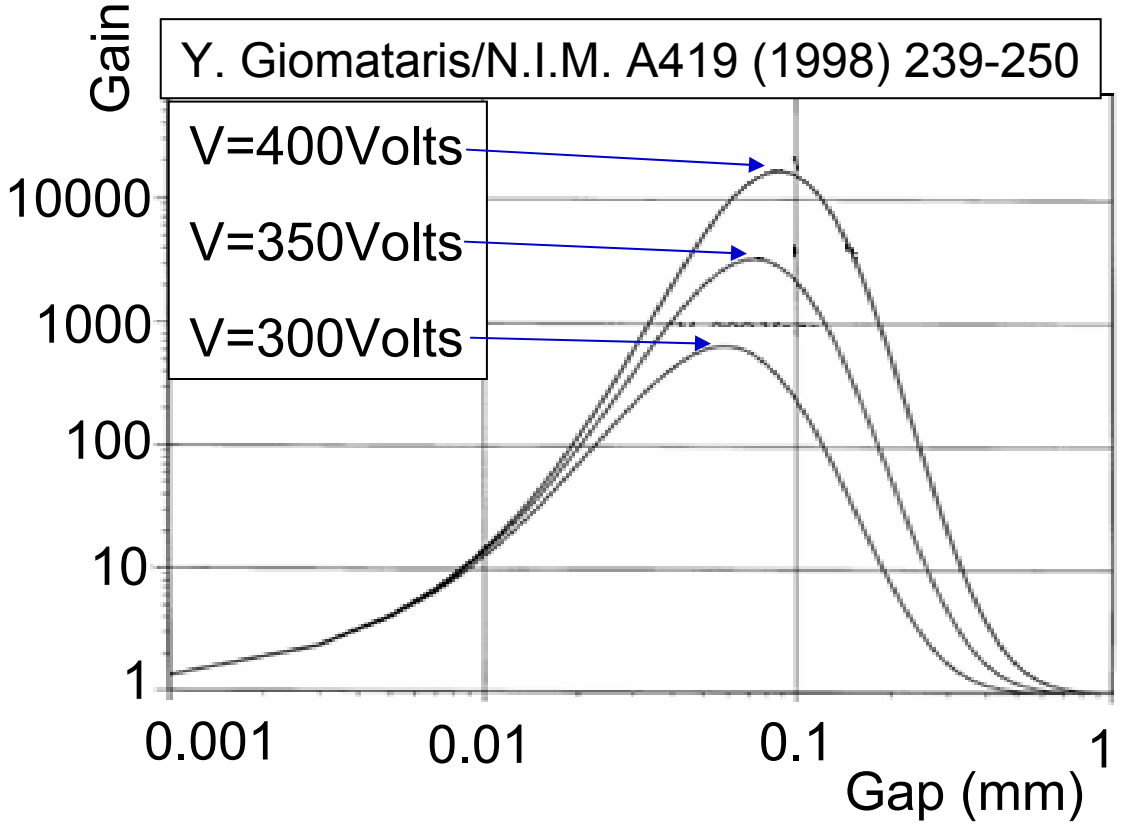
- Ar / CO_2 mixtures offer good ageing properties
- Gain of 10^4 reachable in Ar / CO_2 80/20
- Ageing studies in a reasonable amount of time (intense X-rays source)

Any field structure feasible



Gain for different gap sizes

Maximum predicted in gain vs gap curve



$$M = e^{\alpha d}$$

d gap thickness

$$\alpha = pAe^{-Bp/E}$$

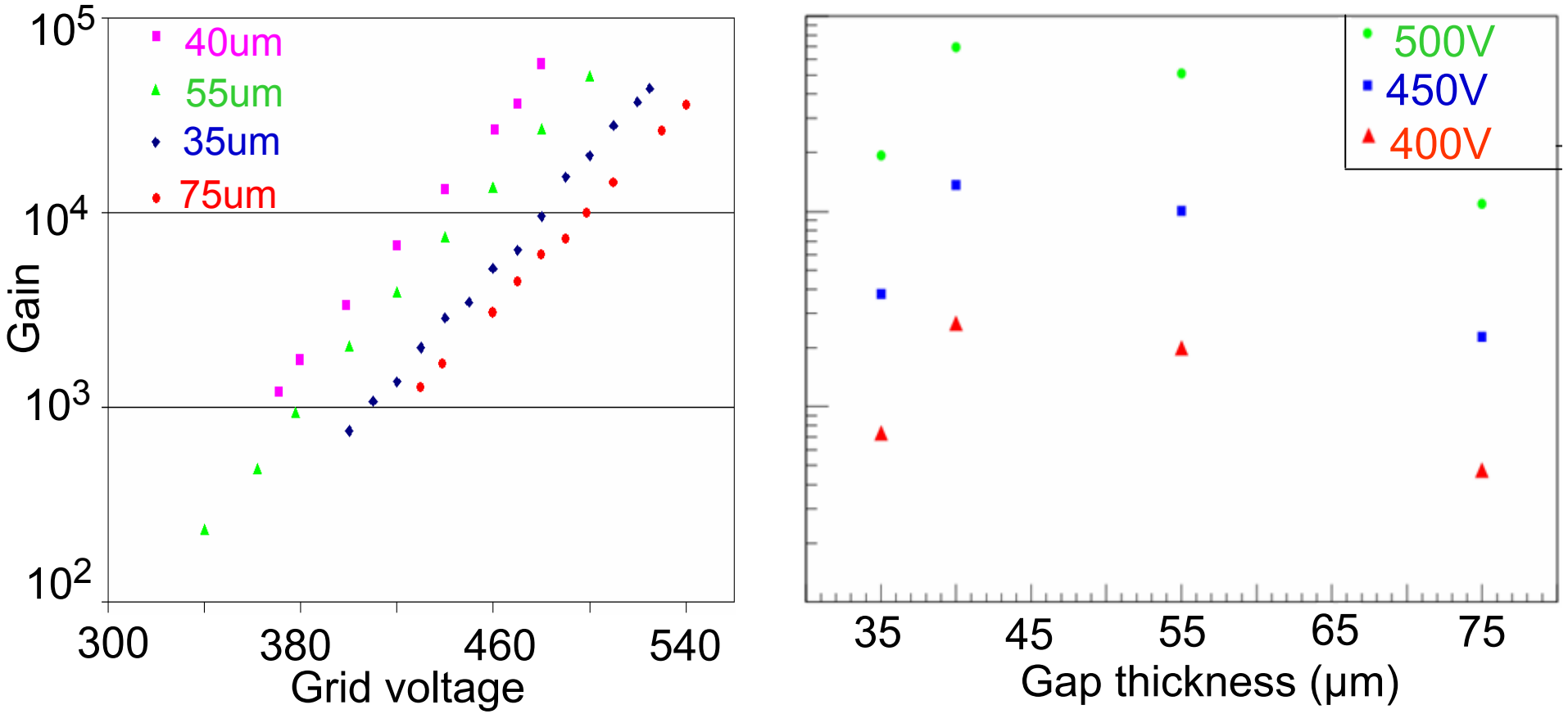
Rose & Korff

p pressure

A,B depend on gasmixture

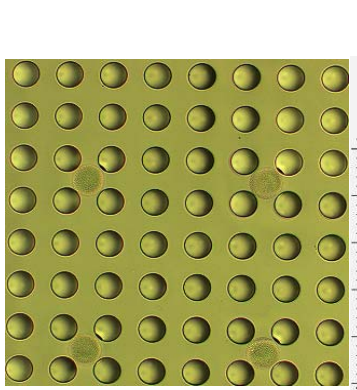
Gain for different gap sizes

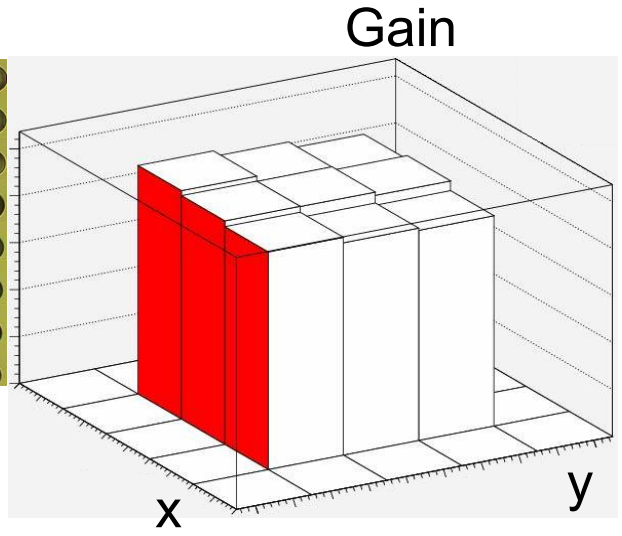
- But now we can make measurements



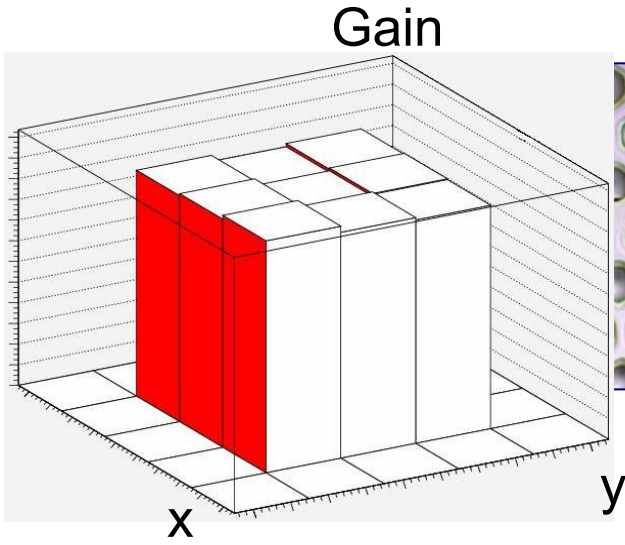
Homogeneity

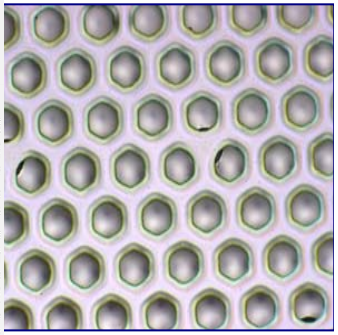
- Gain measurements scanning the surface of the detector
- Homogeneity given by grid quality





2.6 % RMS

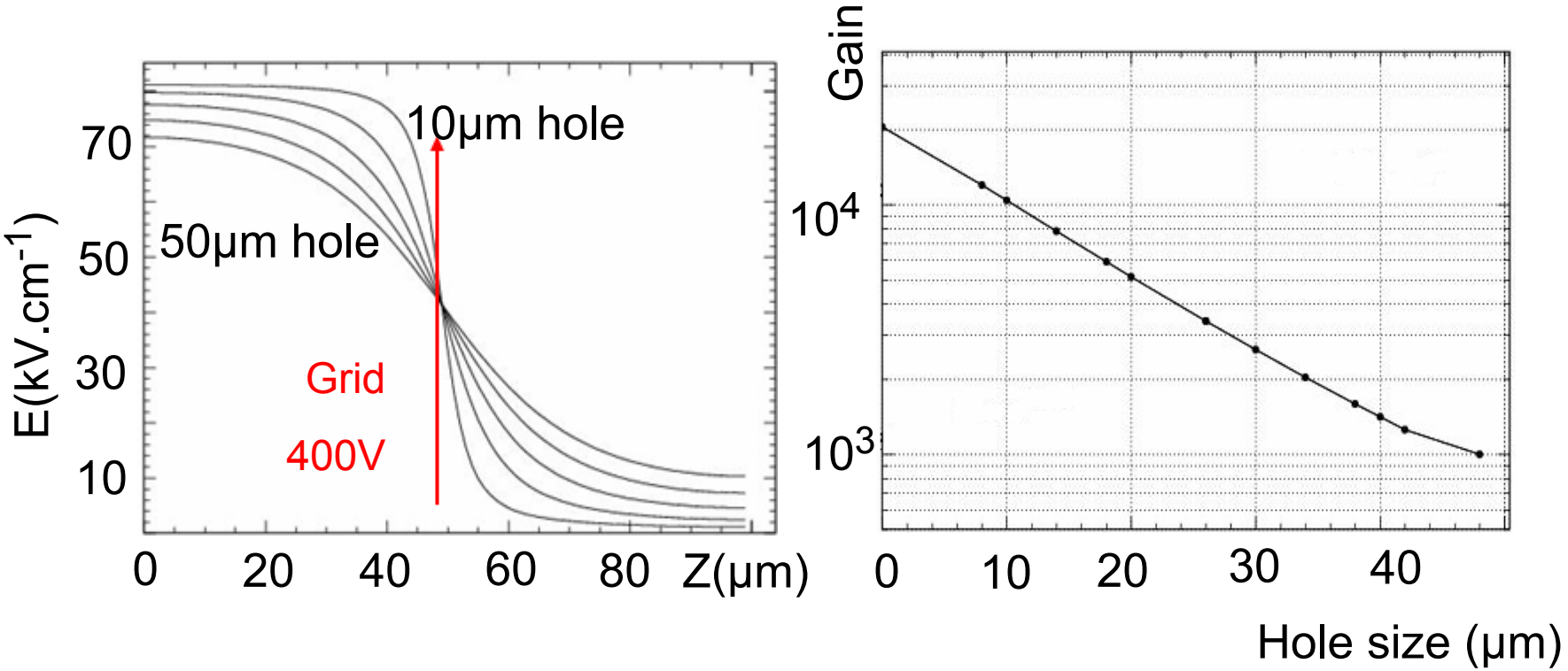




1.6 % RMS

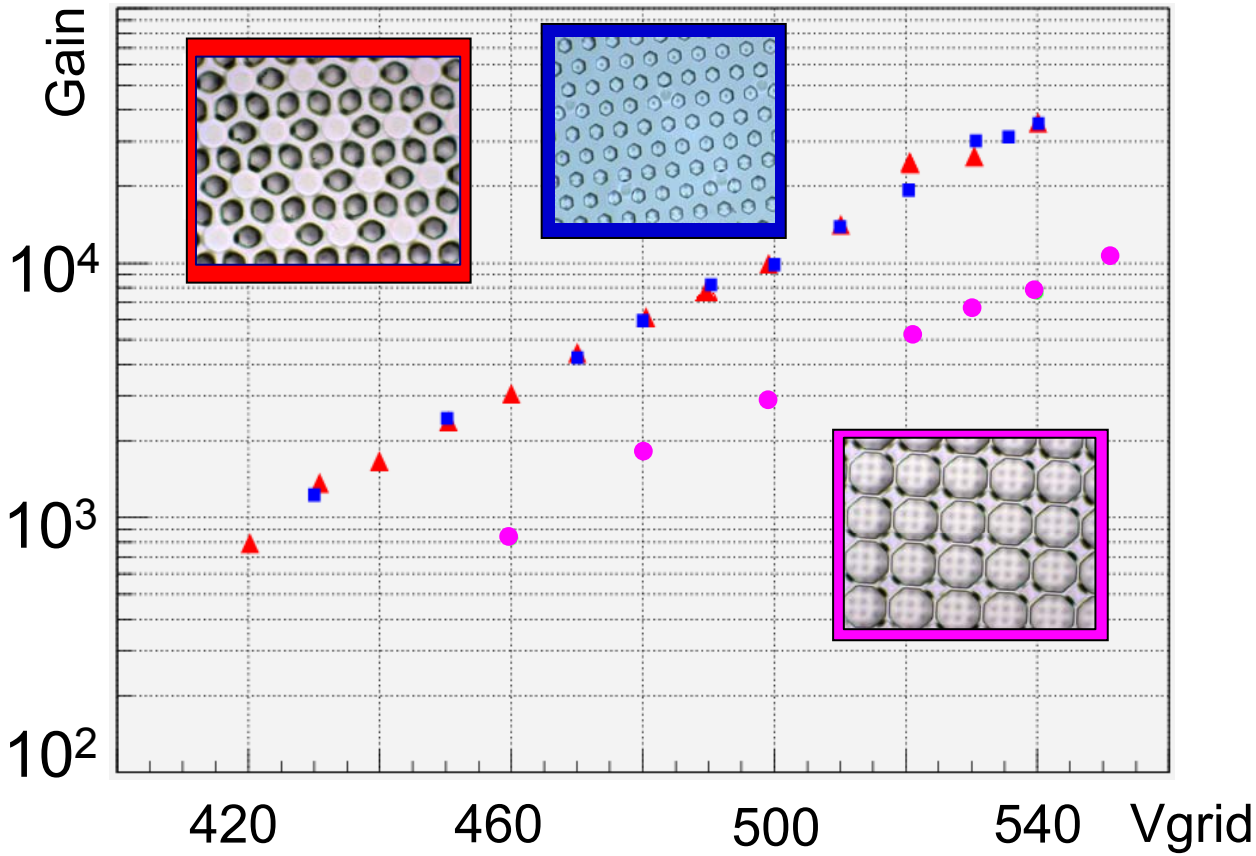
Simulated gain for different hole size

- Electric field along z axis decreases with hole size
- Different gain expected for different hole size



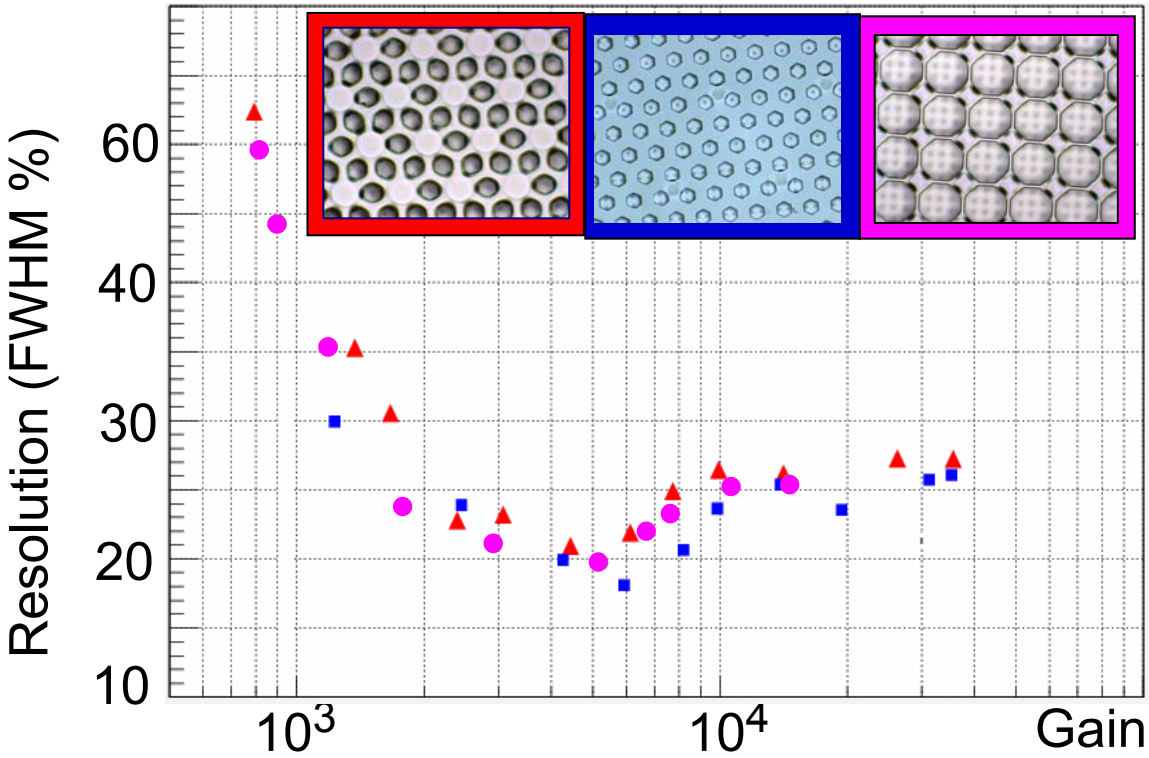
Measured gain for different hole size

And measurements confirm simulations



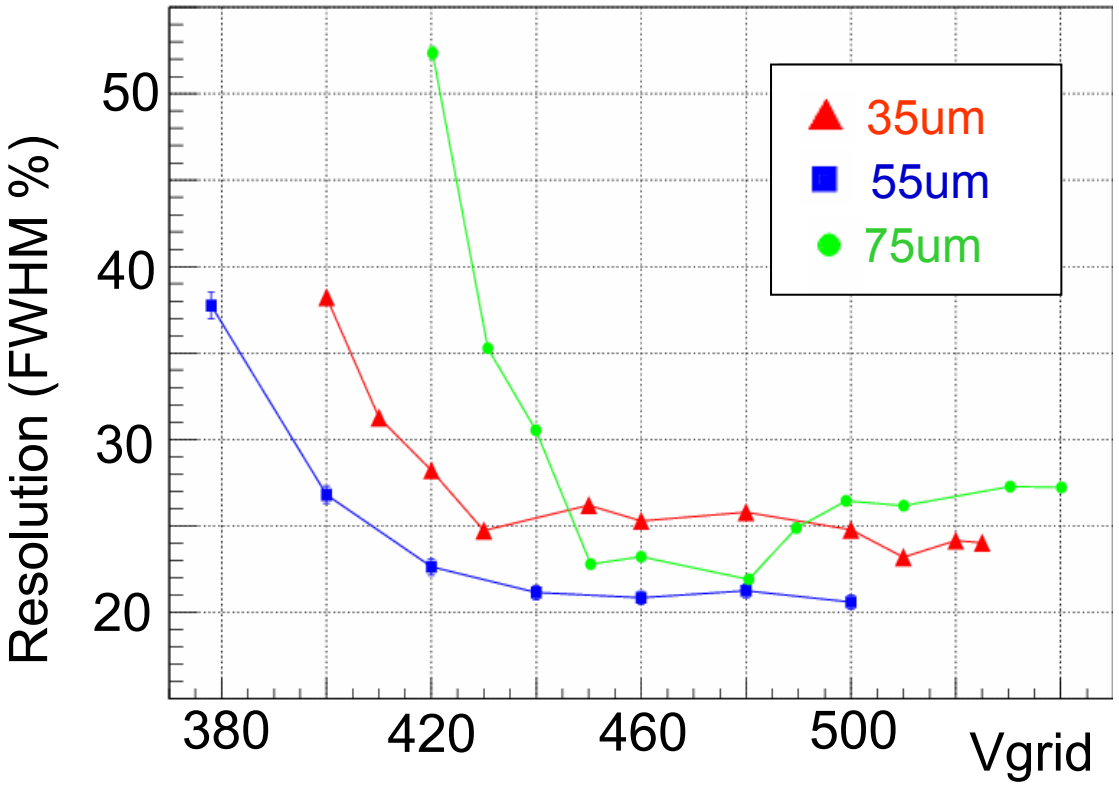
Energy resolution

- Resolution depends on
  - Primary,attachment,T,P
  - Collection efficiency (field ratio)
  - Gain homogeneity & transverse diffusion

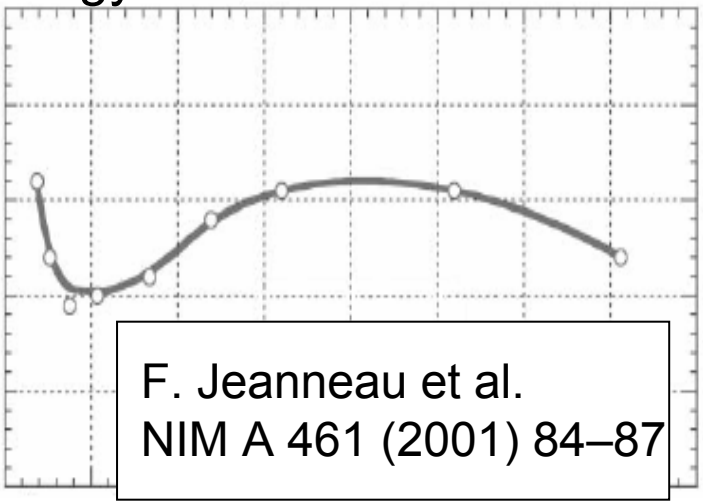


Resolution as function of gap

- Why a parabolic behavior ?



Energy resolution

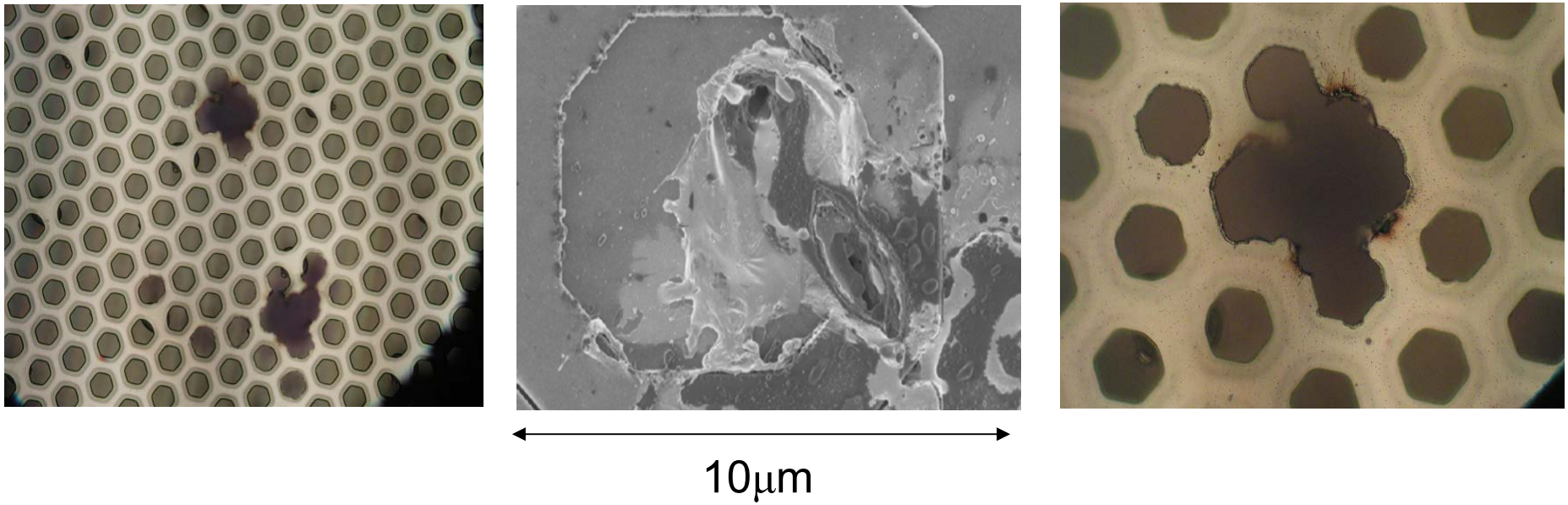


F. Jeanneau et al.
NIM A 461 (2001) 84–87

Gain

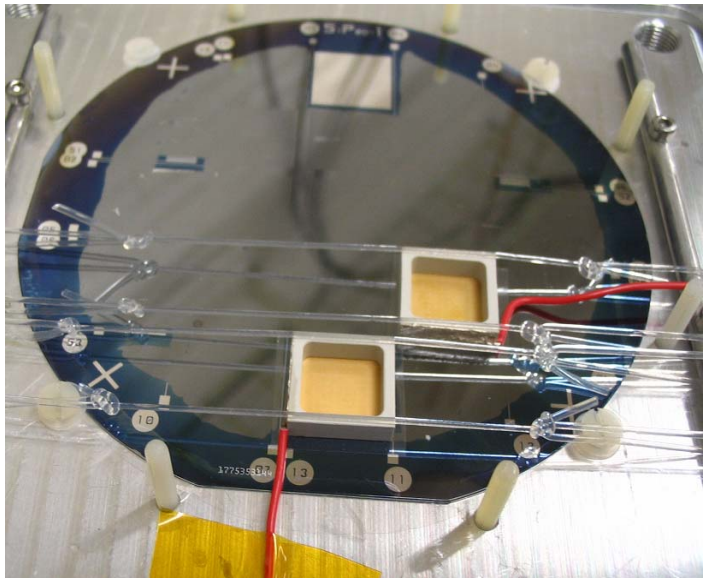
Sparking

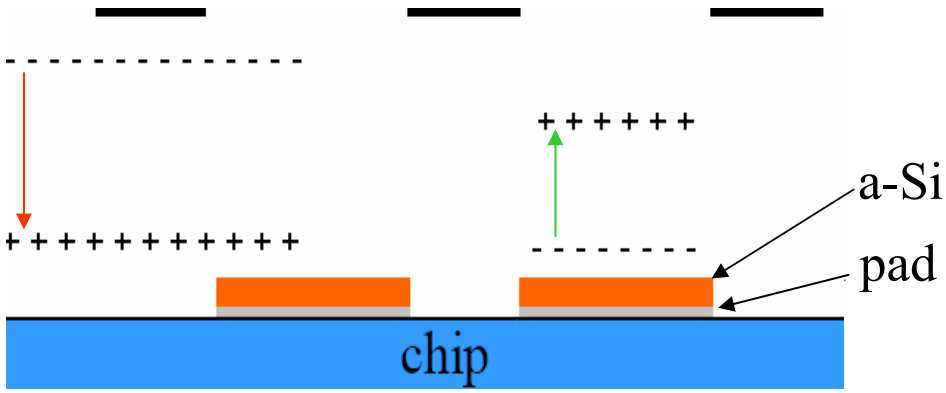
- Chip faces 80kV/cm with no protection (unlike the GEM setup)
- Degradation of the field, or total destruction of grid but also CMOS chip



Solution:high resistive layer

- Resistive plate chamber principle
- Amorphous silicon deposited
  - 4um thickness,resistivity ~$10^{11}\Omega$.cm,temperature~250 °C
- 2 fields with Micromegas: one protected, one unprotected
- First signals recorded; they look the same





SiProt

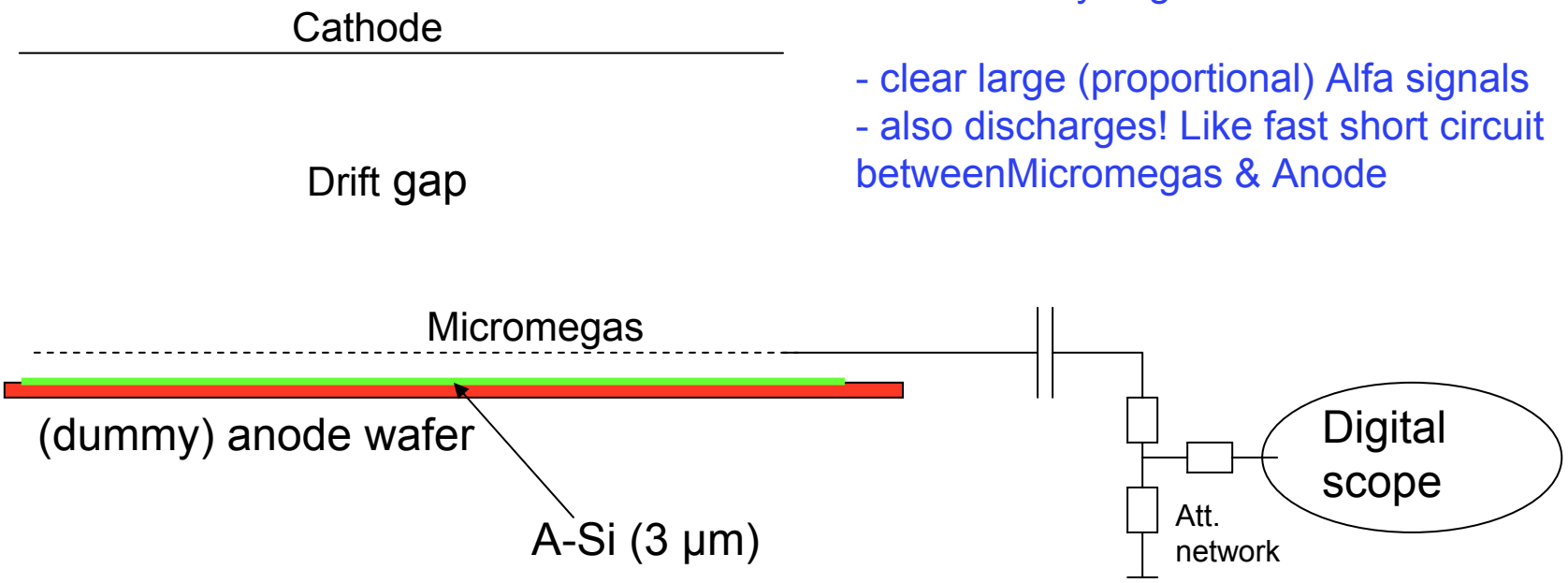
Protection of CMOS Pixel chip against discharges (sparks)

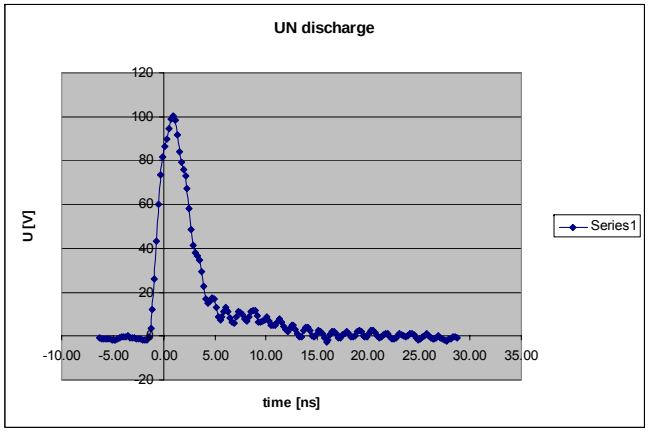
Method: apply high-resistive layer onto chip:
Principle: Resistive Plate Chamber

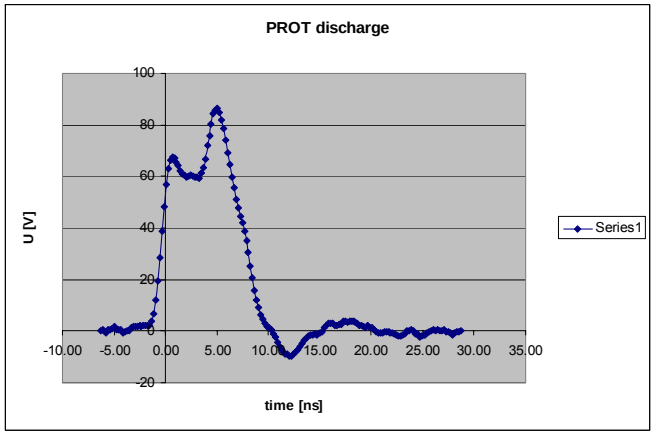
Univ. of Neuchatel (IMT): 3 μm of Amorphous Silicon
without heating the Si wafer too much…..

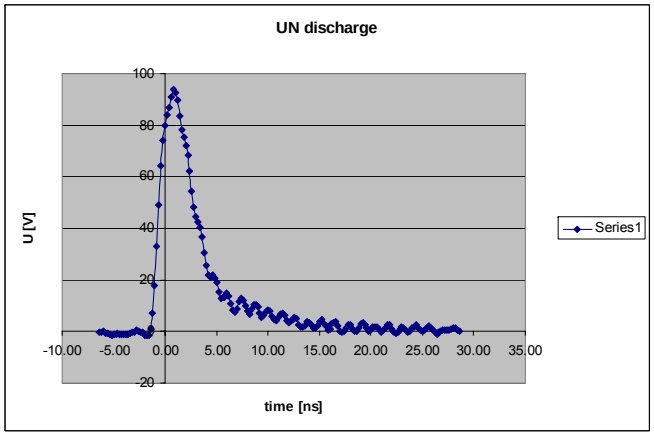
Put Thorium in gas line:
➔ Radon gas
➔ Alfa decay in gas

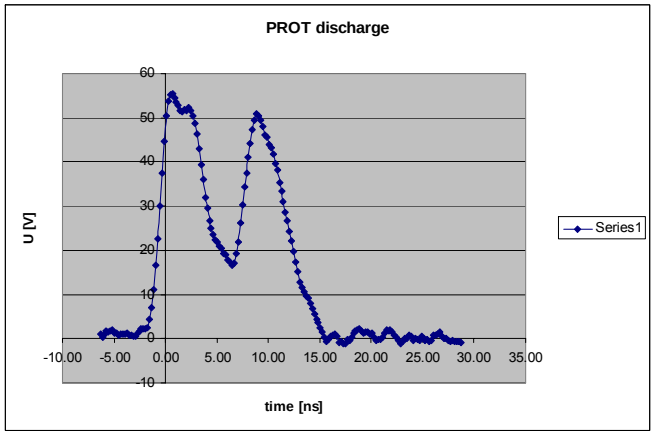
- clear large (proportional) Alfa signals
- also discharges! Like fast short circuit betweenMicromegas & Anode





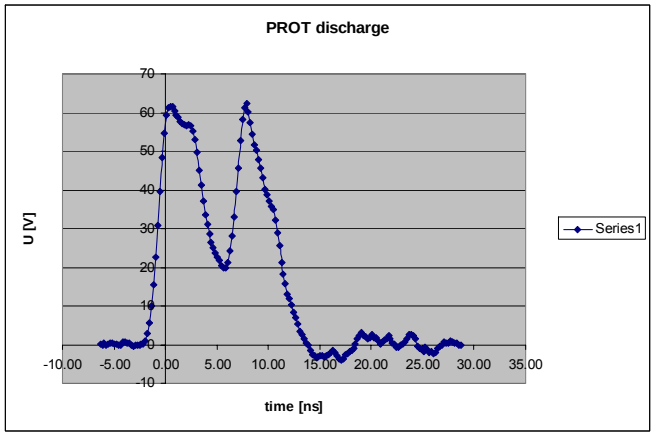






Unprotected: no A-Si layer

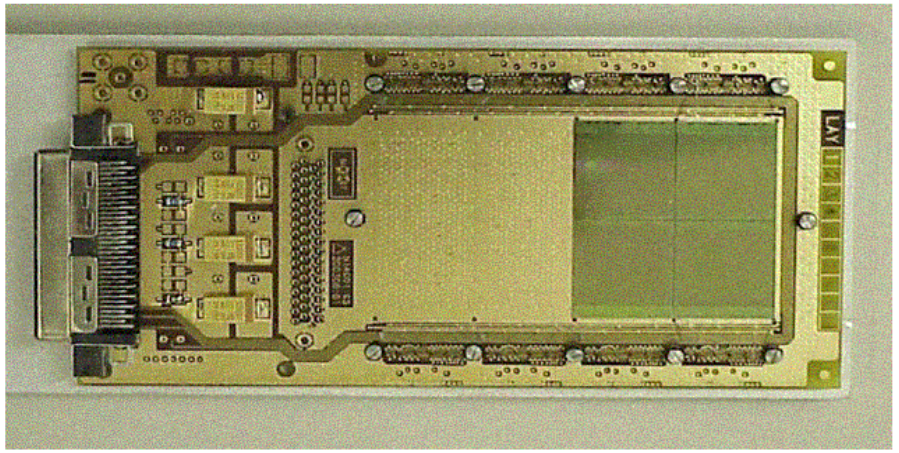
With protective A-Si layer



- smaller initial charge;
- 2nd discharge due to charge spread over surface?
➔ segmentation of A-Si layer in 'pixels'

Further Tests and Developments

- Investigate possible use of CMS (or Atlas) frontend pixel chip
- GOSSIP: very thin gas/pixel detectors as Vertex Detector (LHC/ILC) (TIMEPIX2 with ~1 ns resolution)
- Further ageing tests (Gossip)….
- Chip tiling: large(r) detector surfaces (2x2, 2x4 chips)
- Through Si connectivity: avoiding bonding wires
- Fast readout technology
  (~5 Gb/s)
- Discharge protection!



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