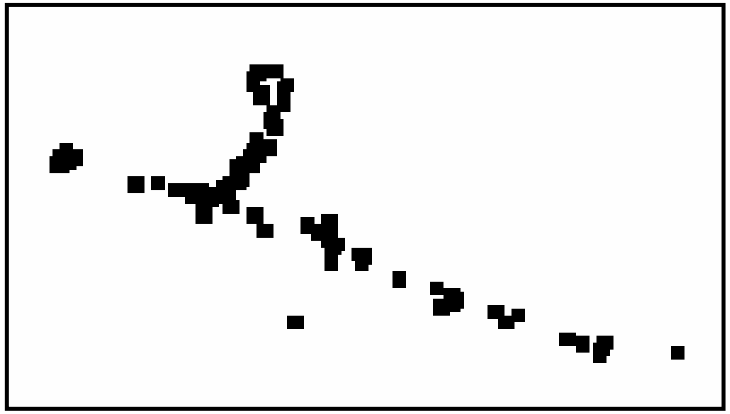
Recent developments for digital TPC readout

Jan Timmermans - NIKHEF

- Micro Pattern Gas Detector: GridPix
- Integration of grid and readout: InGrid
- 3D readout: TimePix
- Discharge protection
- Future developments



Goals

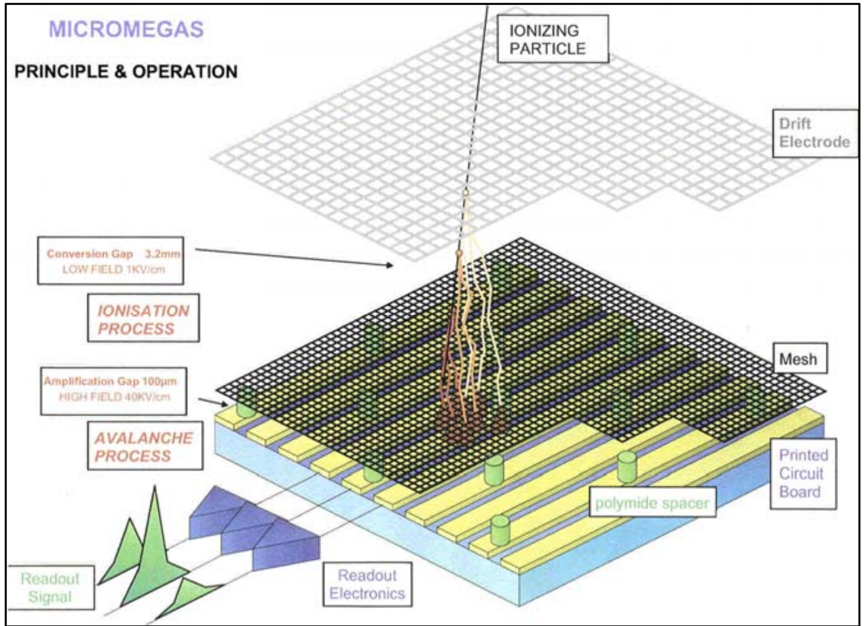
- Gas multiplication GEM or Micromegas foil(s)
- Charge collection with granularity matching primary ionisation cluster spread

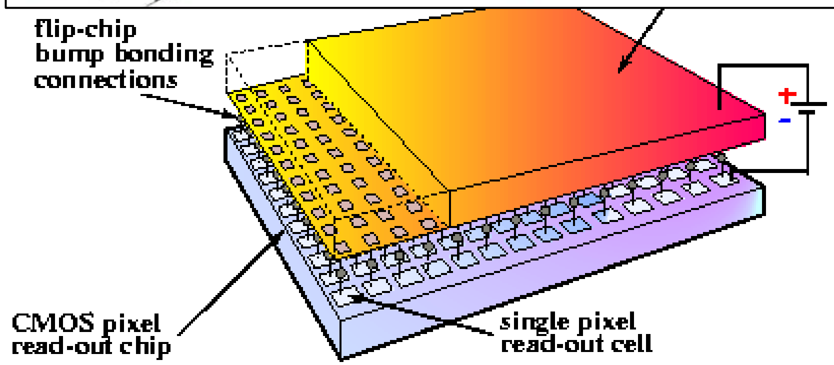
  (this needs sufficiently low diffusion gas)
- Investigate measurement dE/dx using cluster counting

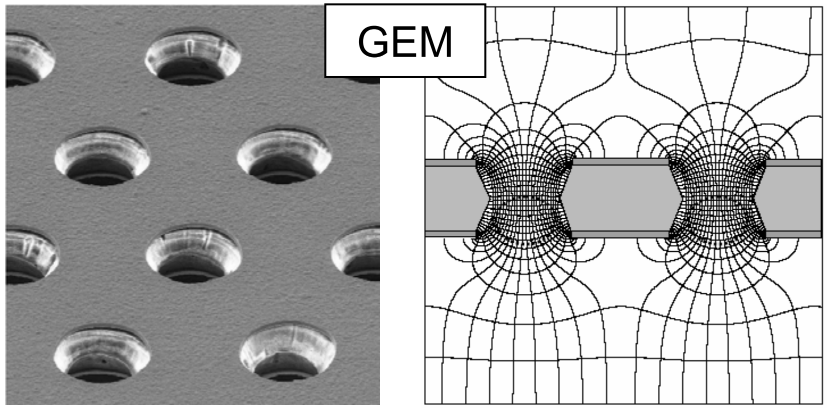
- 2D "proof of principle" based on existing Medipix2 readout chip: achieved
- Add 3rd coordinate: Medipix2 → TimePix
- Integrate grid with pixel chip: InGrid (new results)

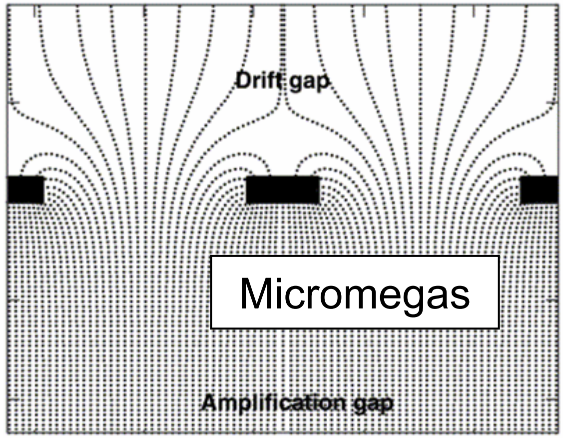
Micro Patterned Gaseous Detectors

- High field created by Gas Gain Grids
- Most popular: GEM & Micromegas





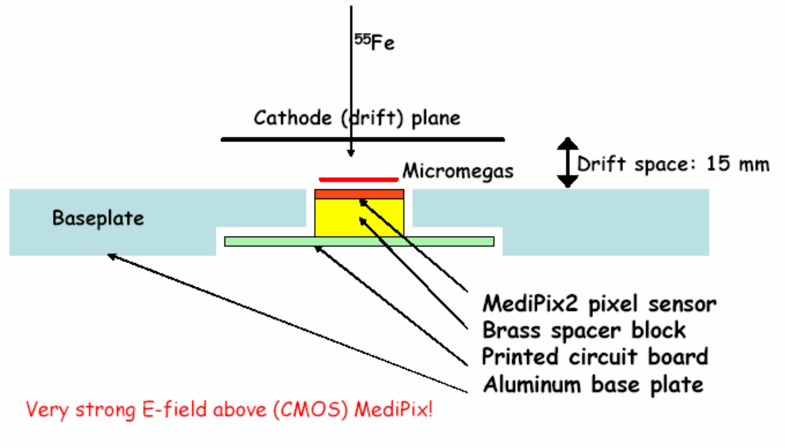




Use 'naked' CMOS pixel readout chip as anode

Results pixel readout gas detectors

NIKHEF-Saclay-CERN-Twente

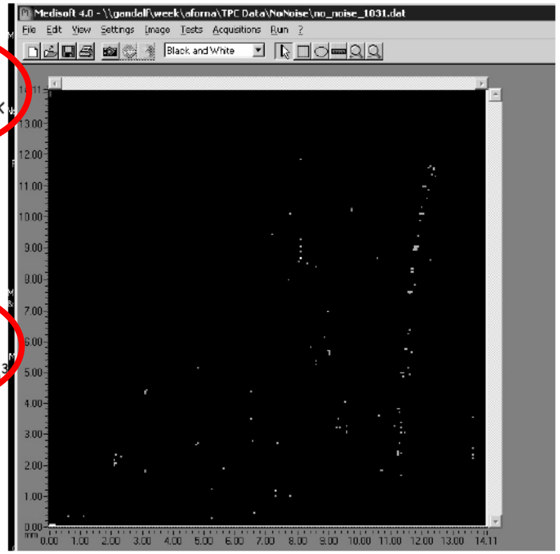


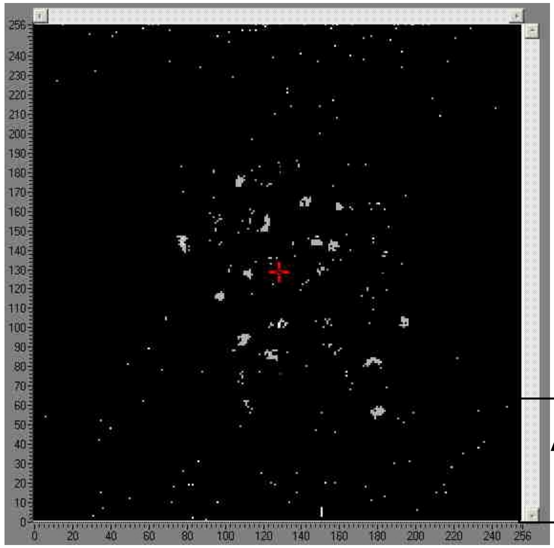
He/Isobutane
80/20
Modified MediPix

31 March 2004

Sensitive area:
14 x 14 x 15 mm³

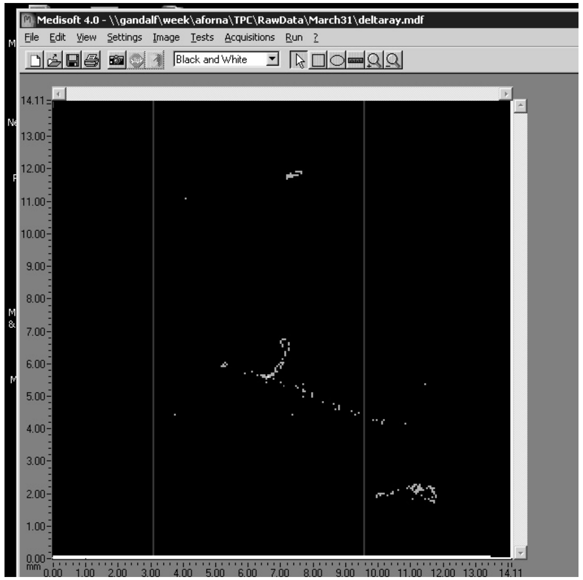
Drift direction:
Vertical
max = 15 mm





55x55 μm² pixels

Ar/isobutane
95/5



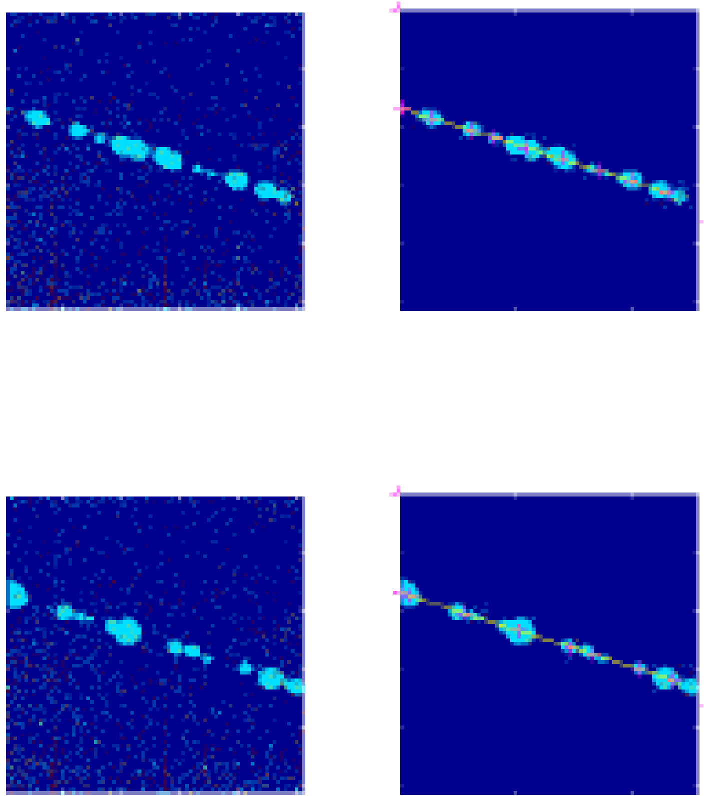
δ ray

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

NIM A540 (2005) 295 (physics/0409048)

Some events with fits (β source)

(from Freiburg GEM+Medipix setup - Andreas Bamberger)



Triple GEM

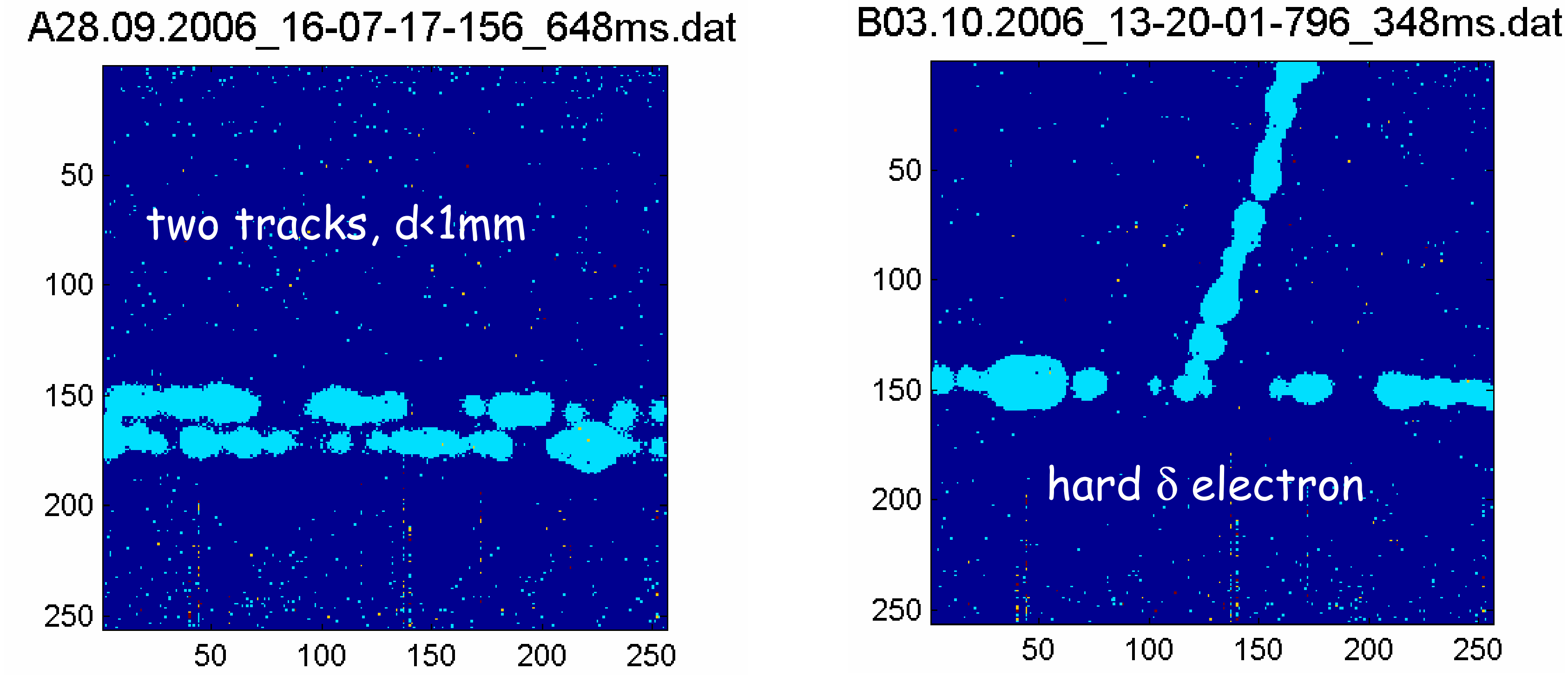
Total gain ~60k

~ 50 μm resolution

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

4. Testbeam at DESY: 3-GEM+Medipix

Freiburg
Bonn

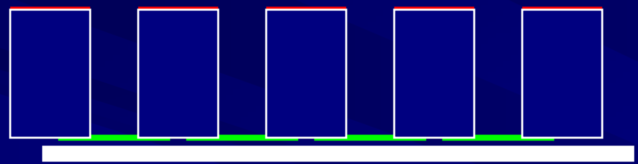


Lots of data to be analyzed
Still the same Medipix chip as 1.5 years ago
Prepare for Testbeam with Timepix in same setup a.s.a.p.

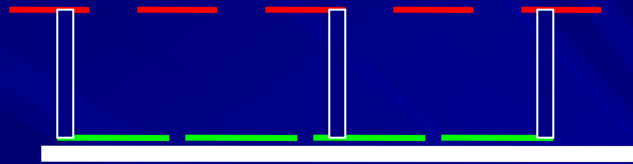
InGrid

Integrate GEM/Micromegas and pixel sensor

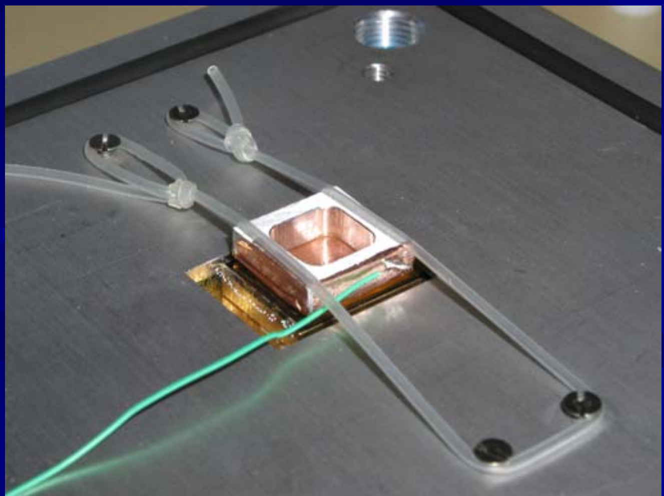
‘GEM’



‘Micromegas’



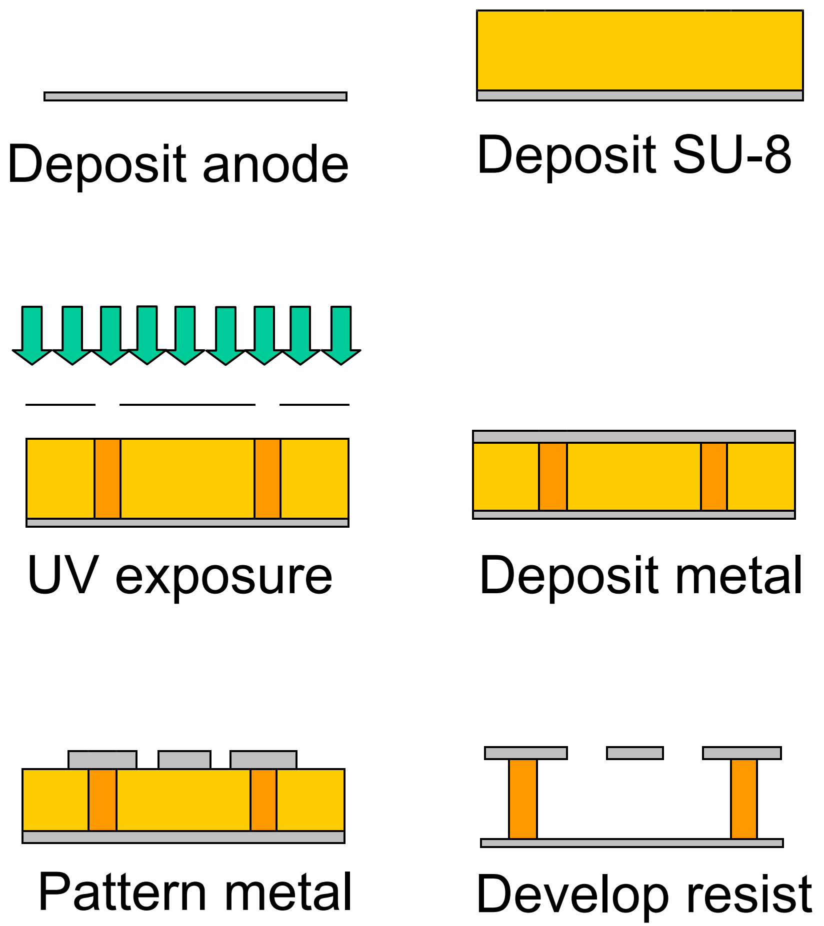
By ‘wafer post processing’

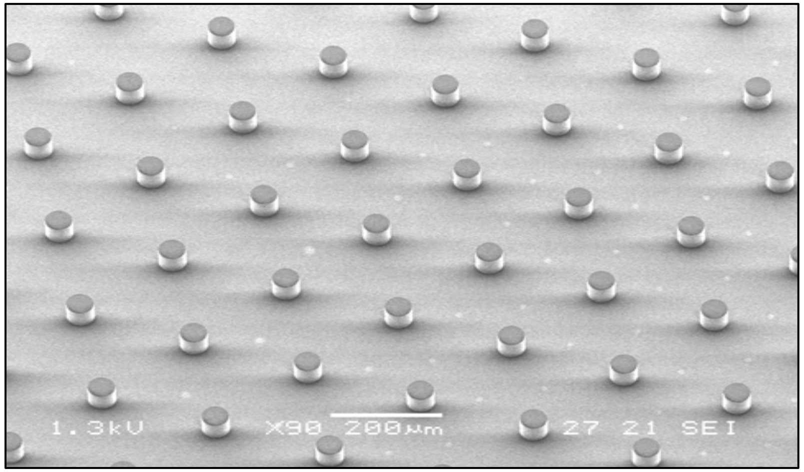


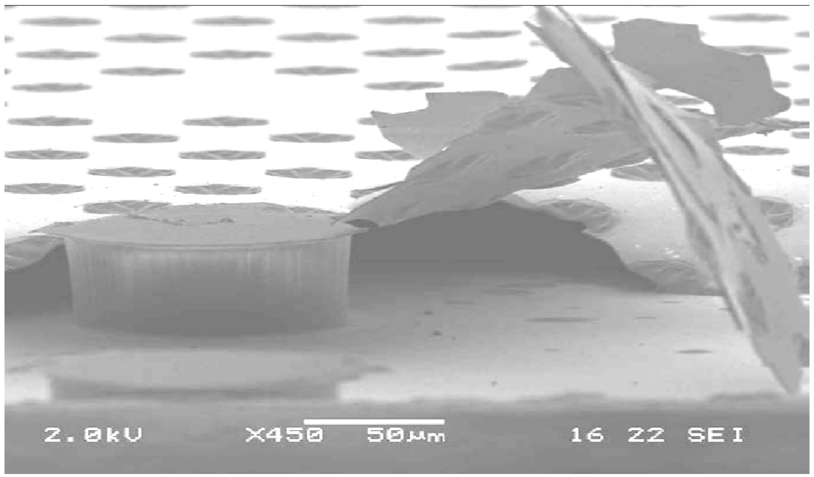
4” wafer

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

NIKHEF/Twente: InGrid (Integrated Grid)

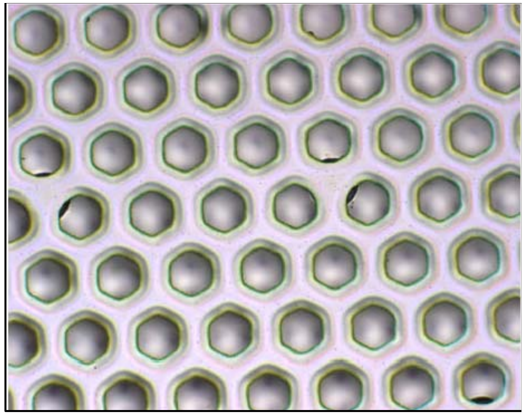






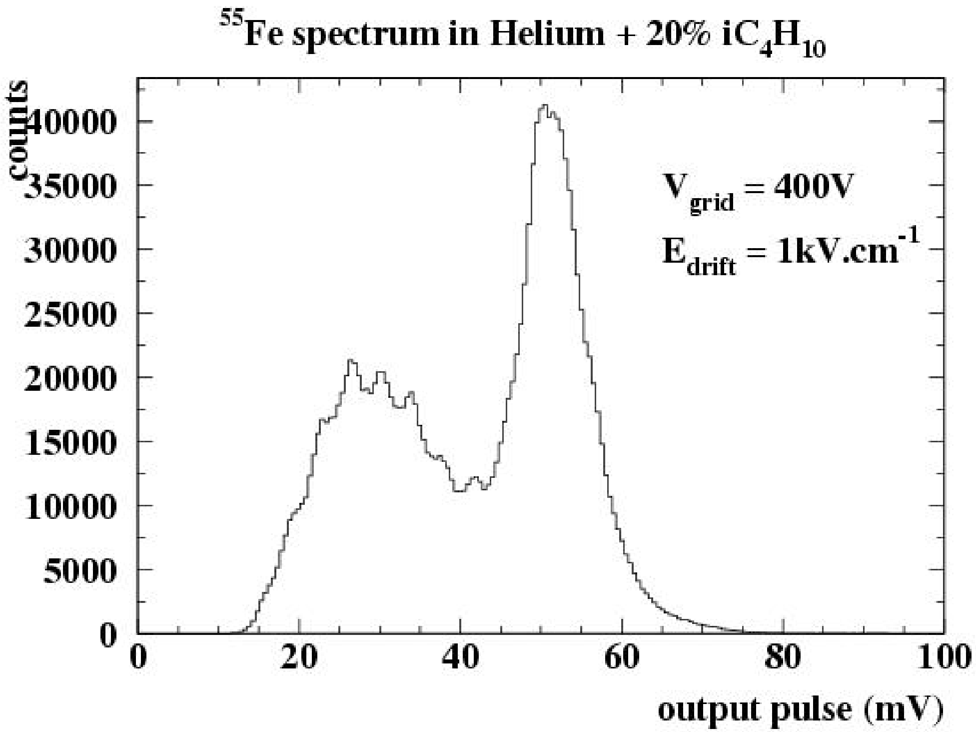
Measuring the InGrid signals

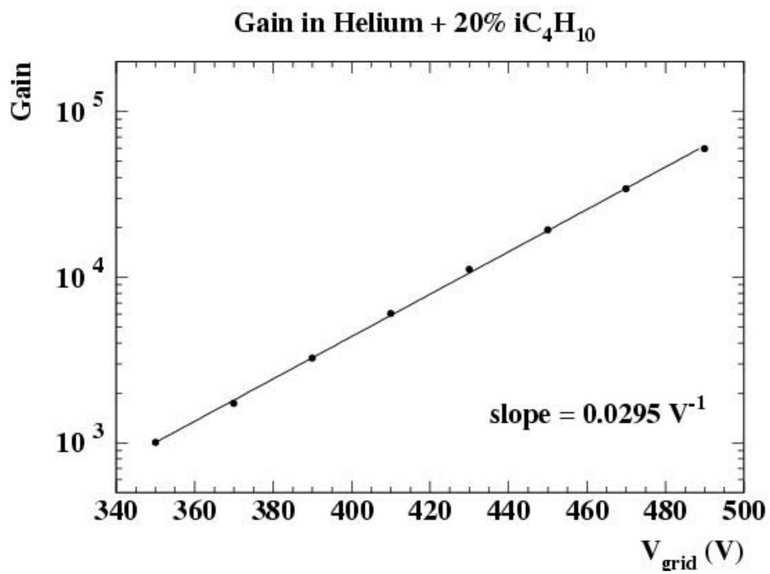
(NIM A556 (2006) 490)



(After 9 months of process tuning and unsuccessful trials)

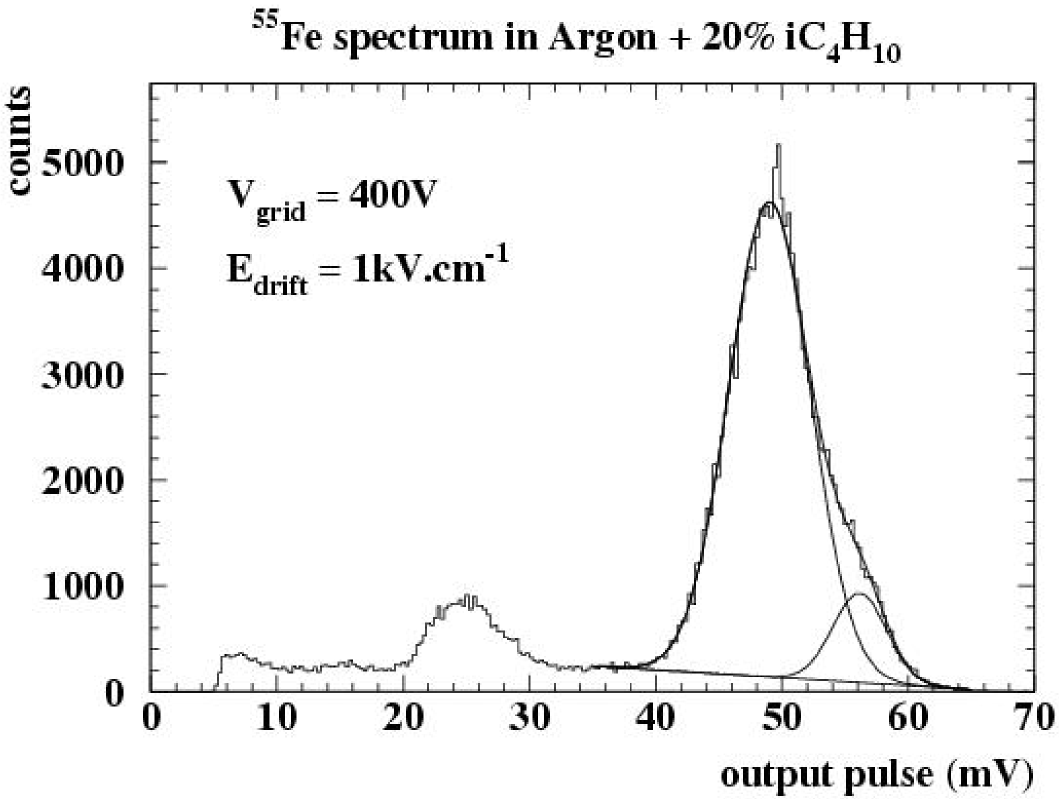
Pulseheight and gain: He + 20% iC_4H_{10}





- Gas gains 10^3 - $6{\cdot}10^4$

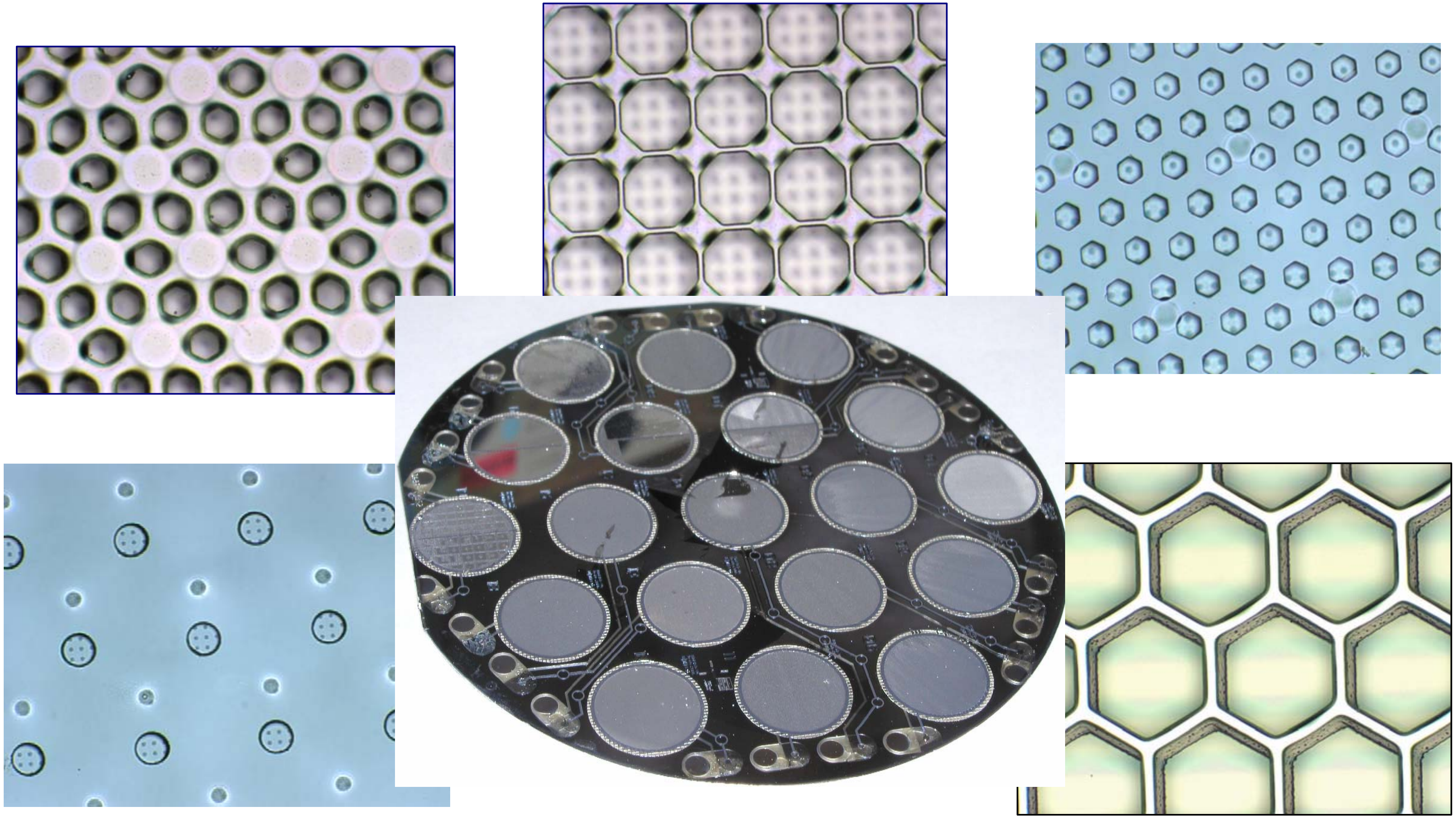
Energy resolution in Argon IsoC4H10 80/20



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

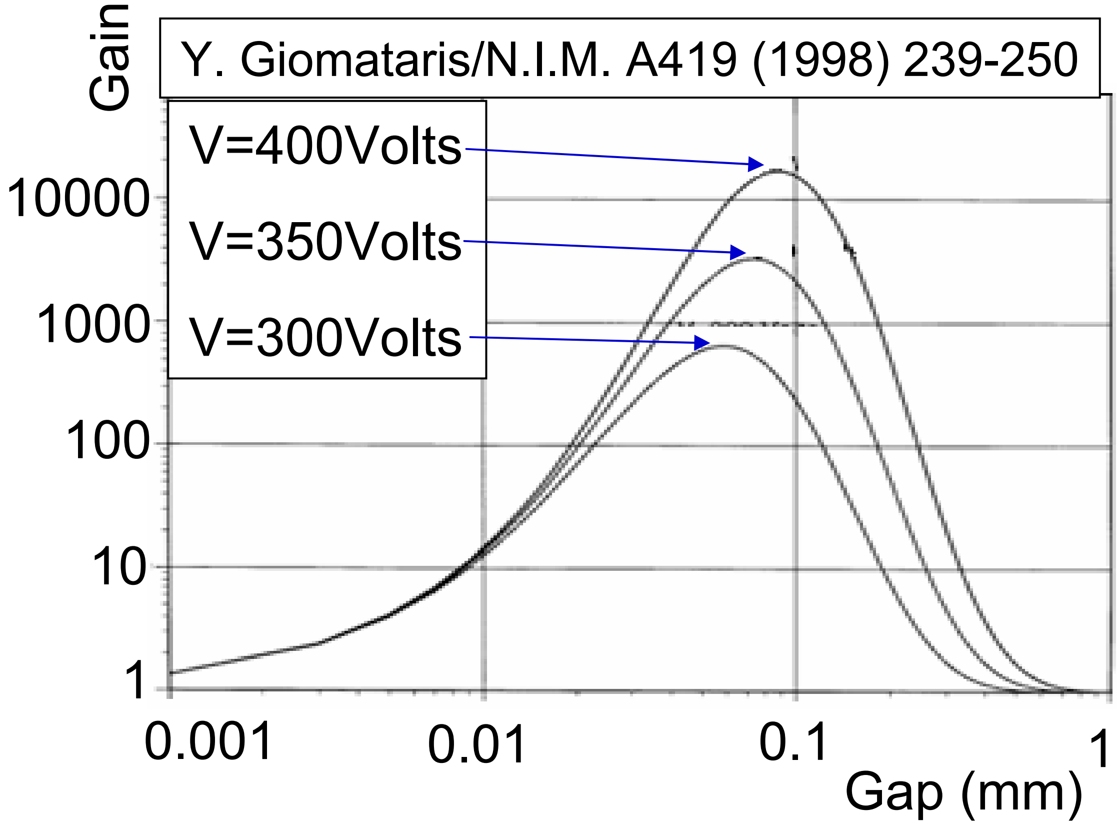
- Photo peak asymmetry seen
- Very good energy resolution

Any field structure feasible



Gain for different gap sizes

Maximum predicted in gain vs gap curve



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

d gap thickness

$$\alpha = pA\mathrm{e}^{-Bp/E}$$

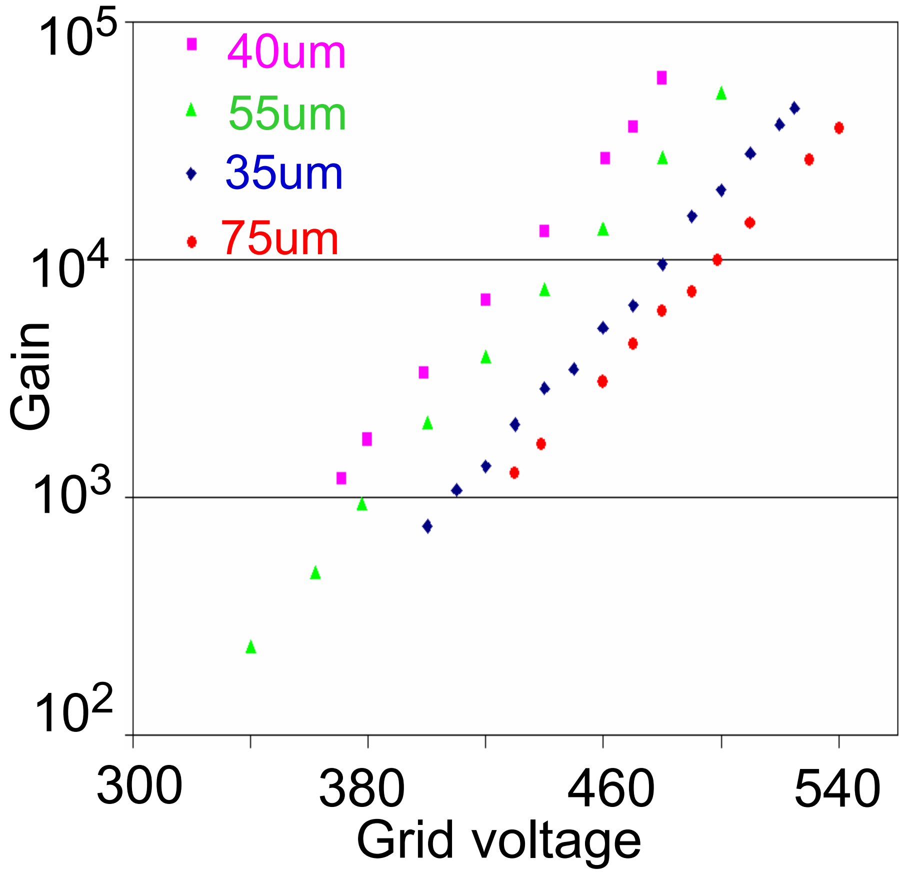
Rose & Korff

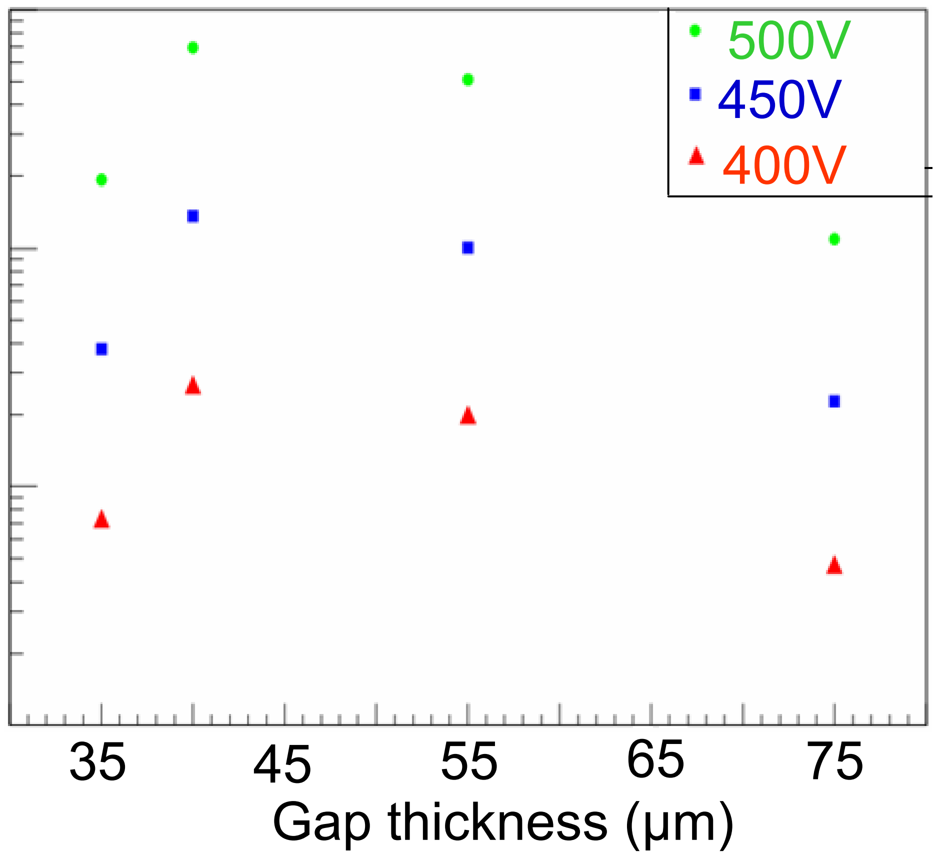
p pressure

A,*B* depend on gasmixture

Gain for different gap sizes

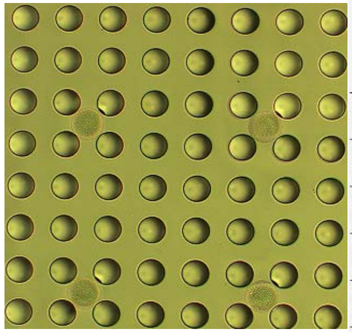
- But now we can make measurements

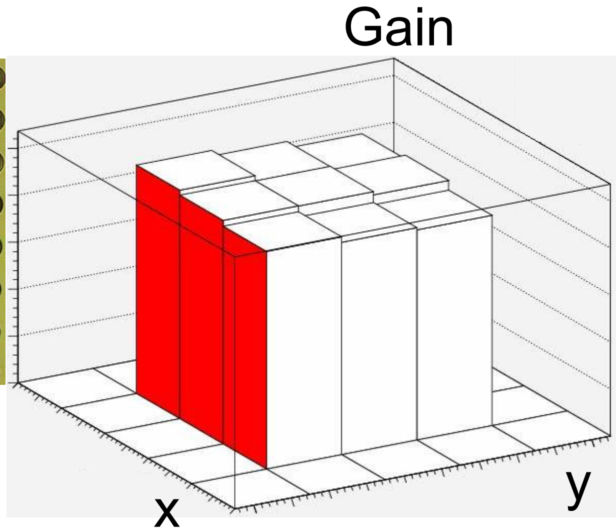


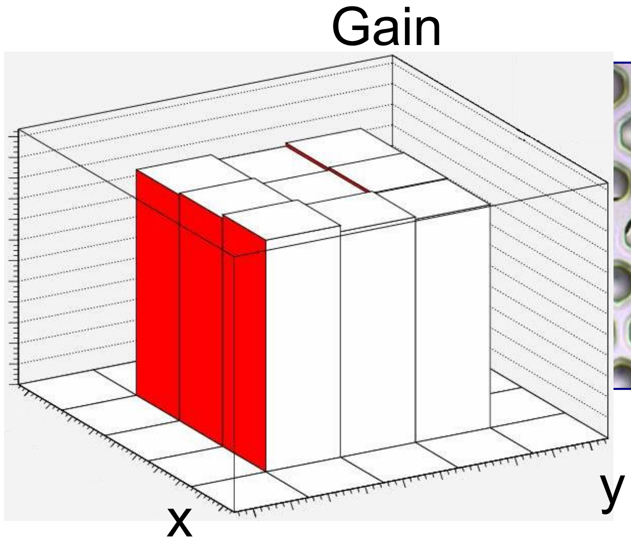


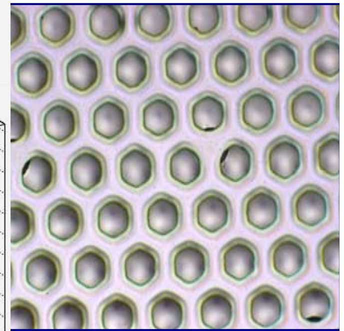
Homogeneity

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







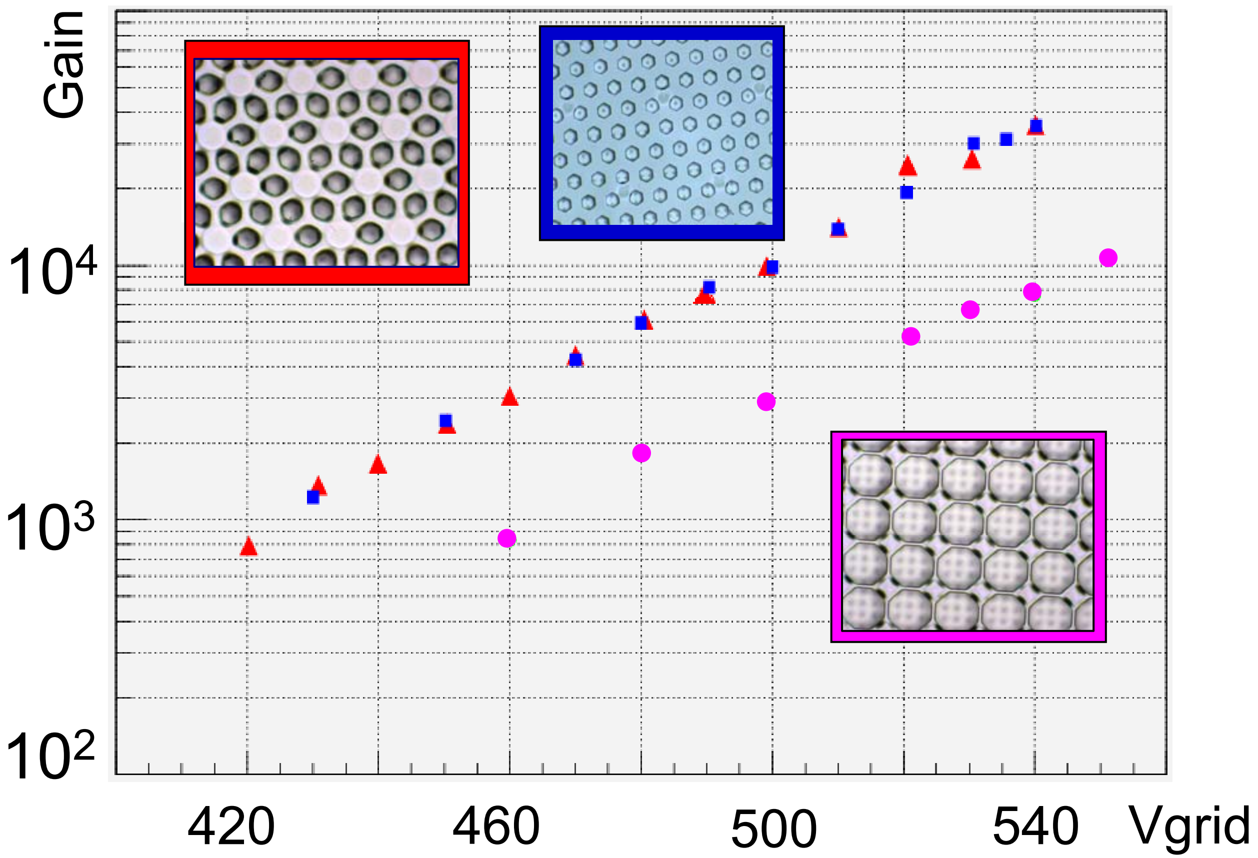


2.6 % RMS

1.6 % RMS

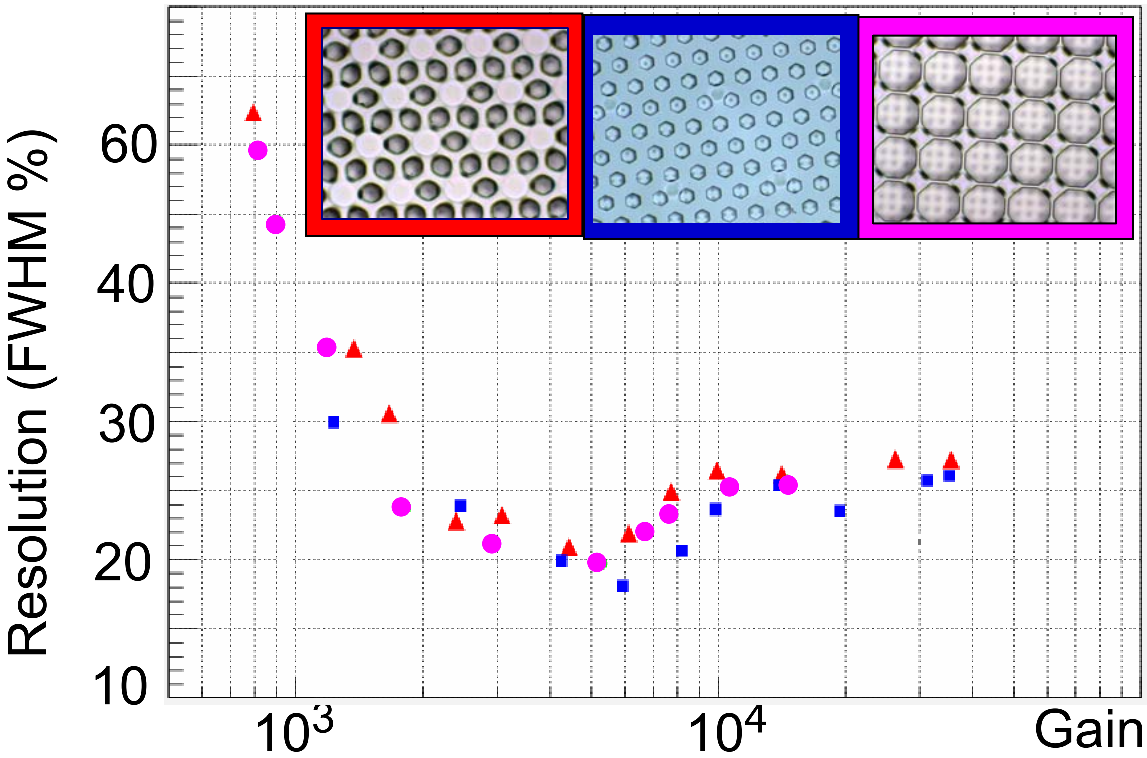
Measured gain for different hole size

And measurements confirm simulations



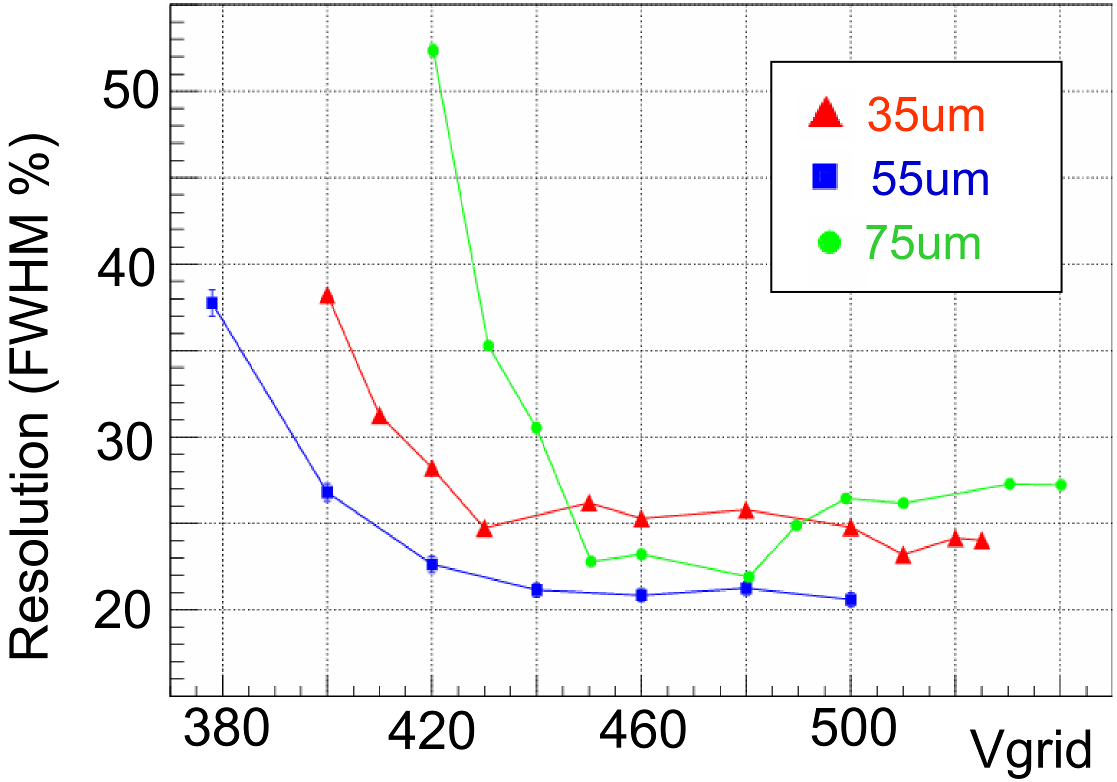
Energy resolution

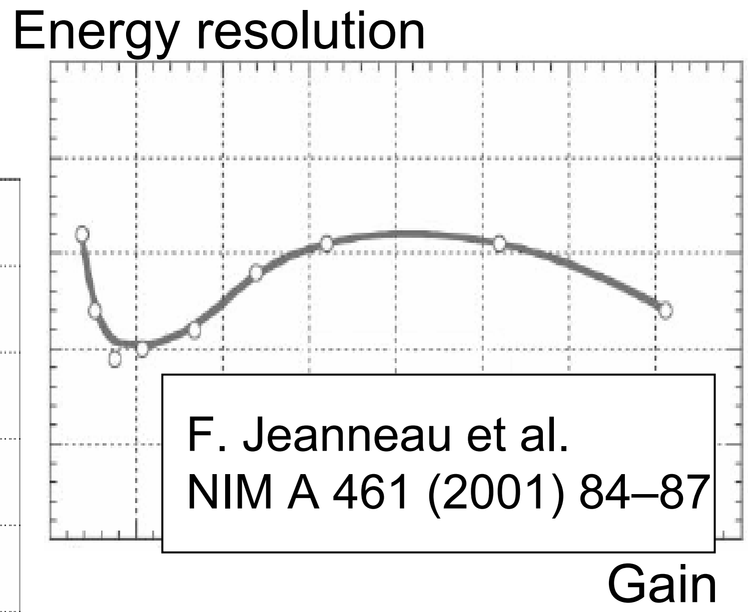
- Resolution depends on
  - Primary,attachment,T,P
  - Collection efficiency (field ratio)
  - Gain homogeneity & transverse diffusion



Resolution as function of gap

- Why a parabolic behavior ?





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

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

•Distribute clock to full 256x256 pixel matrix (50-100-160MHz)

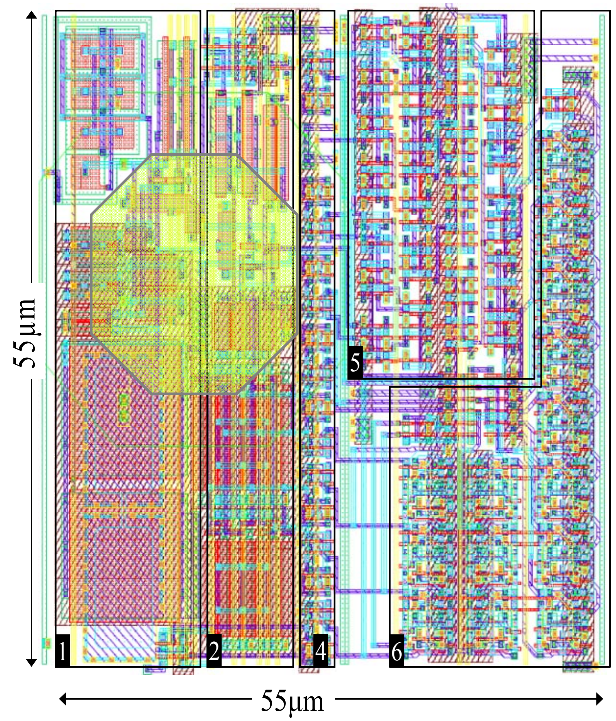
•Enable counting by first hit after ‘shutter’ opens, until ‘shutter’ closes (common stop); also time-over-threshold possible

•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

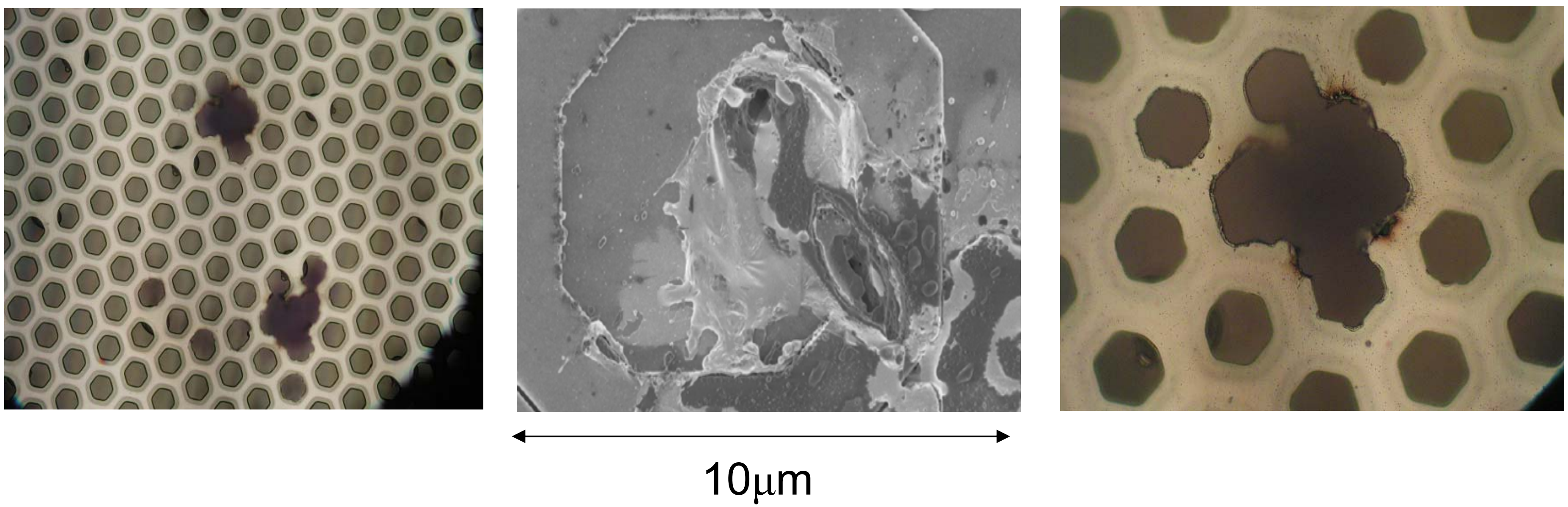
•Keep same chip-size, pixel-size, readout protocol



•1st <u>full reticle</u> submit done July 2006;
IT WORKS! Now preparing/doing tests in gas detectors.

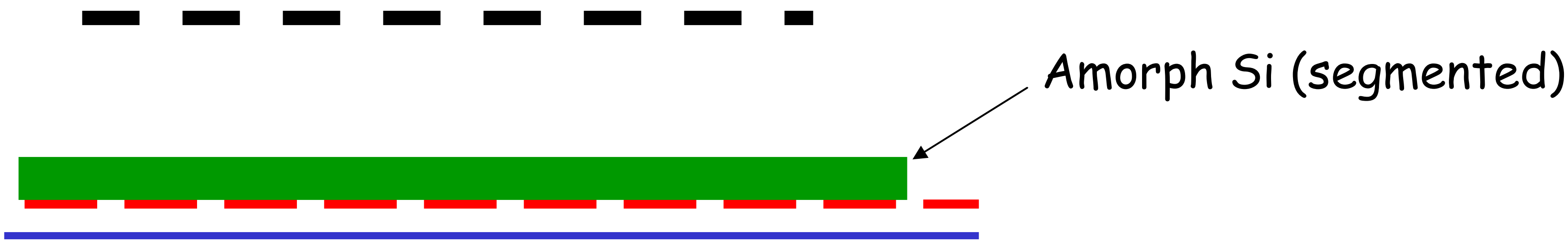
Sparking

- Chip faces 80kV/cm with no protection (unlike the GEM setup; 1.5 yr using same chip)
- Degradation of the field, or total destruction of grid but also CMOS chip

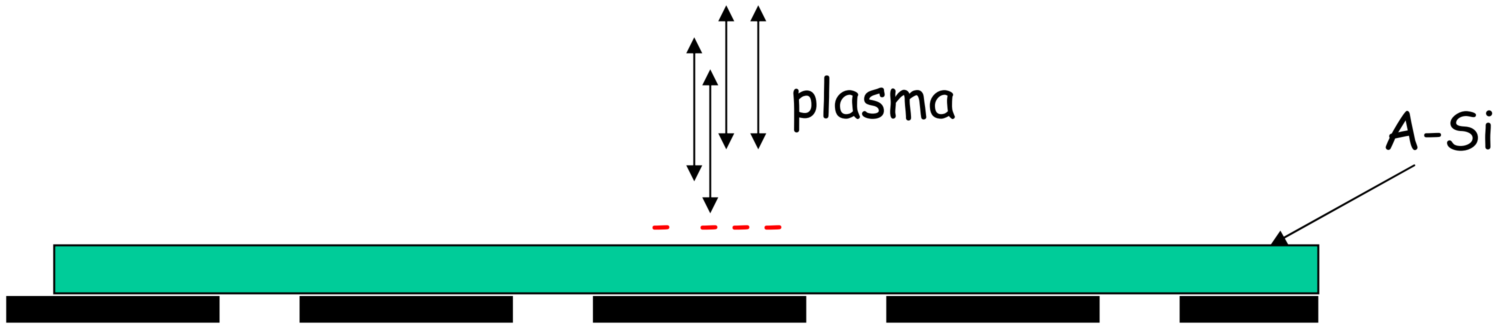


CMOS Chip protection against
- discharges
- sparks
- HV breakdowns
- too large signals

Silicon Protection: SiProt



Empirical method:
Try RPC technology



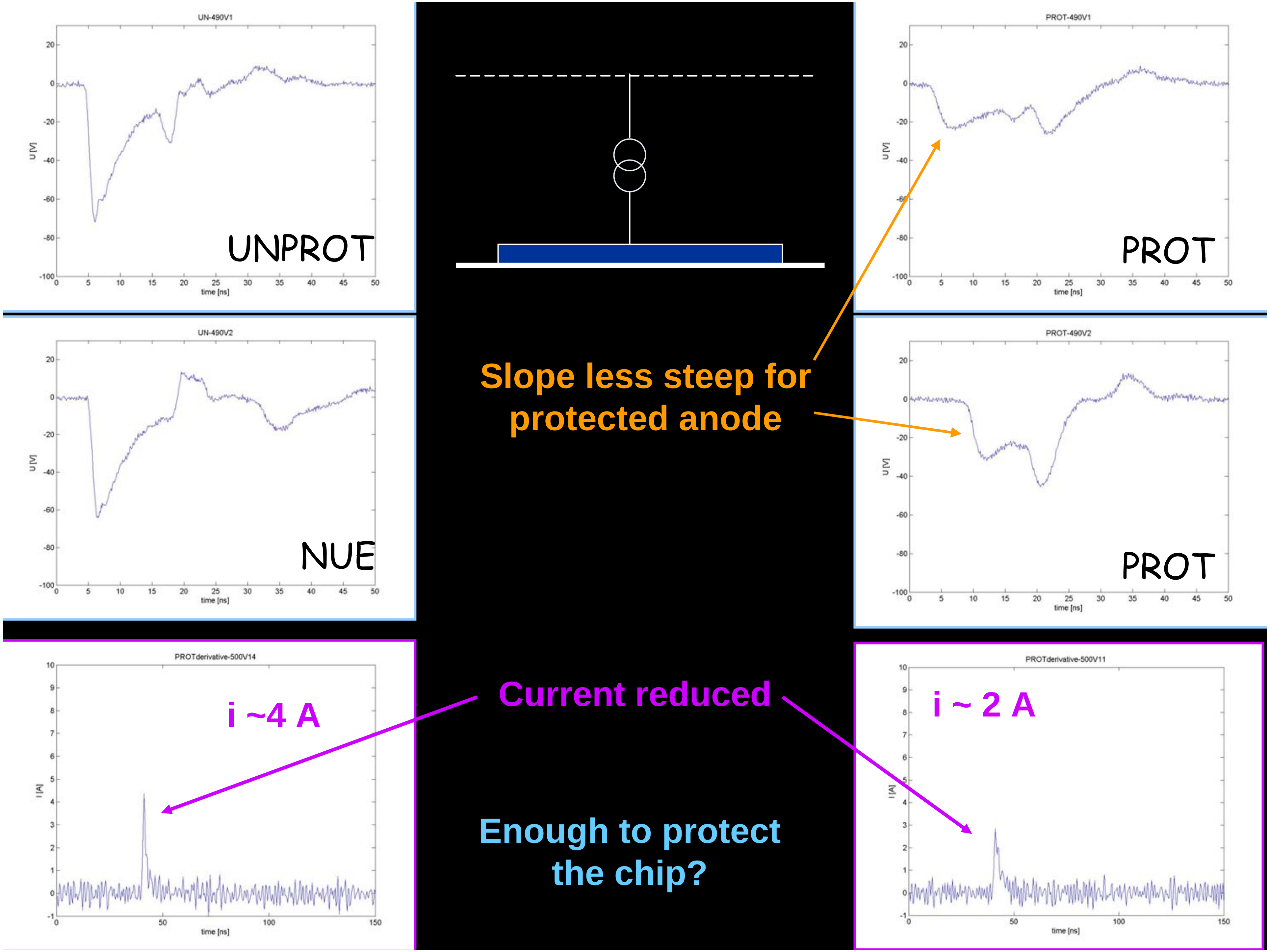
- RPC principle: reduction of local E-field
- Avalanche charge: electrostatic induction towards input pad
- Specific resistance:
  - high enough to 'block' avalanche charge
  - low enough to flow signal current
  - layer thickness 4 μm, R_{vol} = 0.2 GΩ/cm

Technology

A-Si deposit possible in general; avoid wafers get too hot

☺ Univ. of Neuchatel/IMT/P. Jarron (CERN) uses this for integrated X-ray sensor/convertor on MediPix 2

Test: put Thorium in gas: Radon α-decays:
- large (proportional) signals
- Discharges: like short circuits



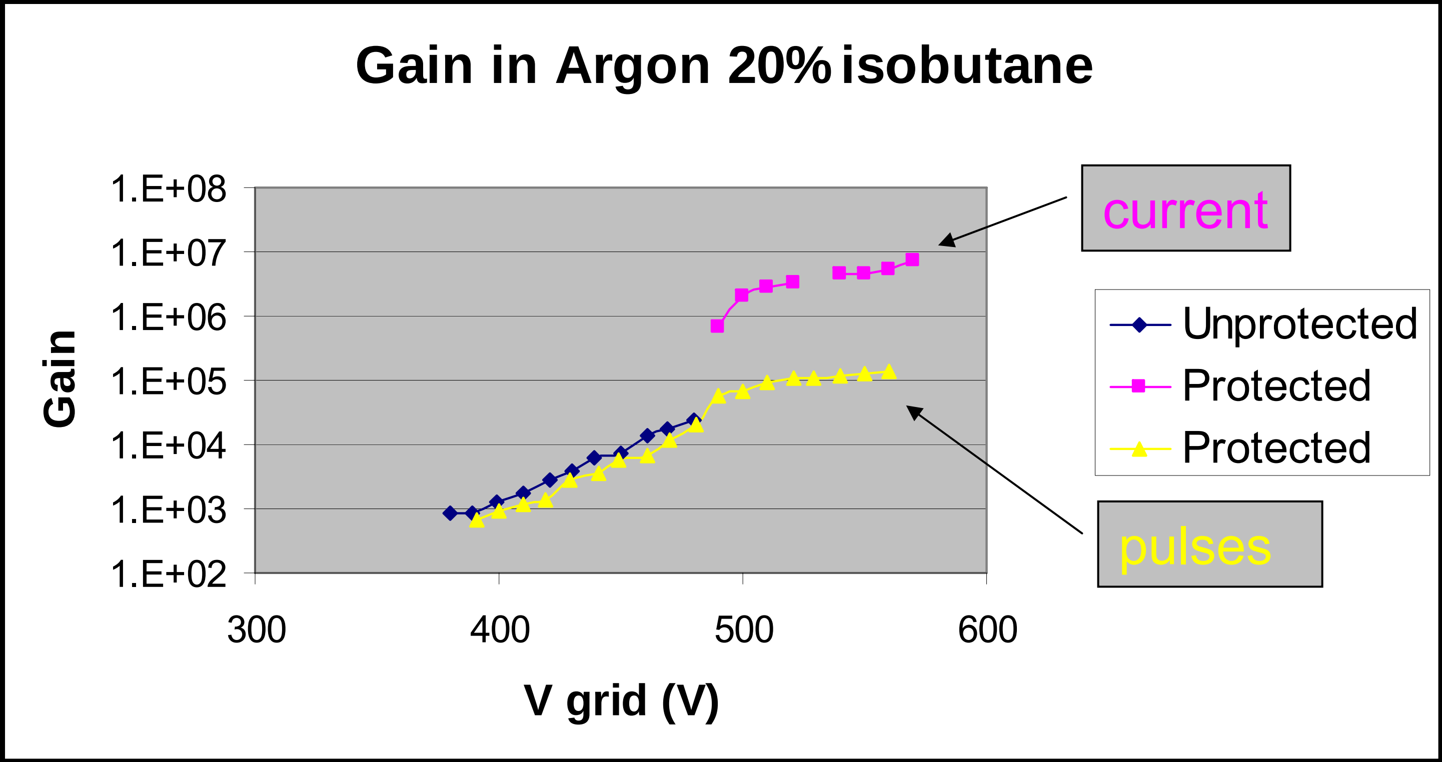
UN-490V1
U [V]
time [ns]
UNPROT
PROT-490V1
PROT
UN-490V2
NUE
PROT-490V2
PROT
Slope less steep for protected anode
PROTderivative-500V14
I [A]
i ~4 A
Current reduced
PROTderivative-500V11
i ~ 2 A
Enough to protect the chip?

Gain

Iron 55 source

Look at the pulses from a pre amplifier (low grid voltage)

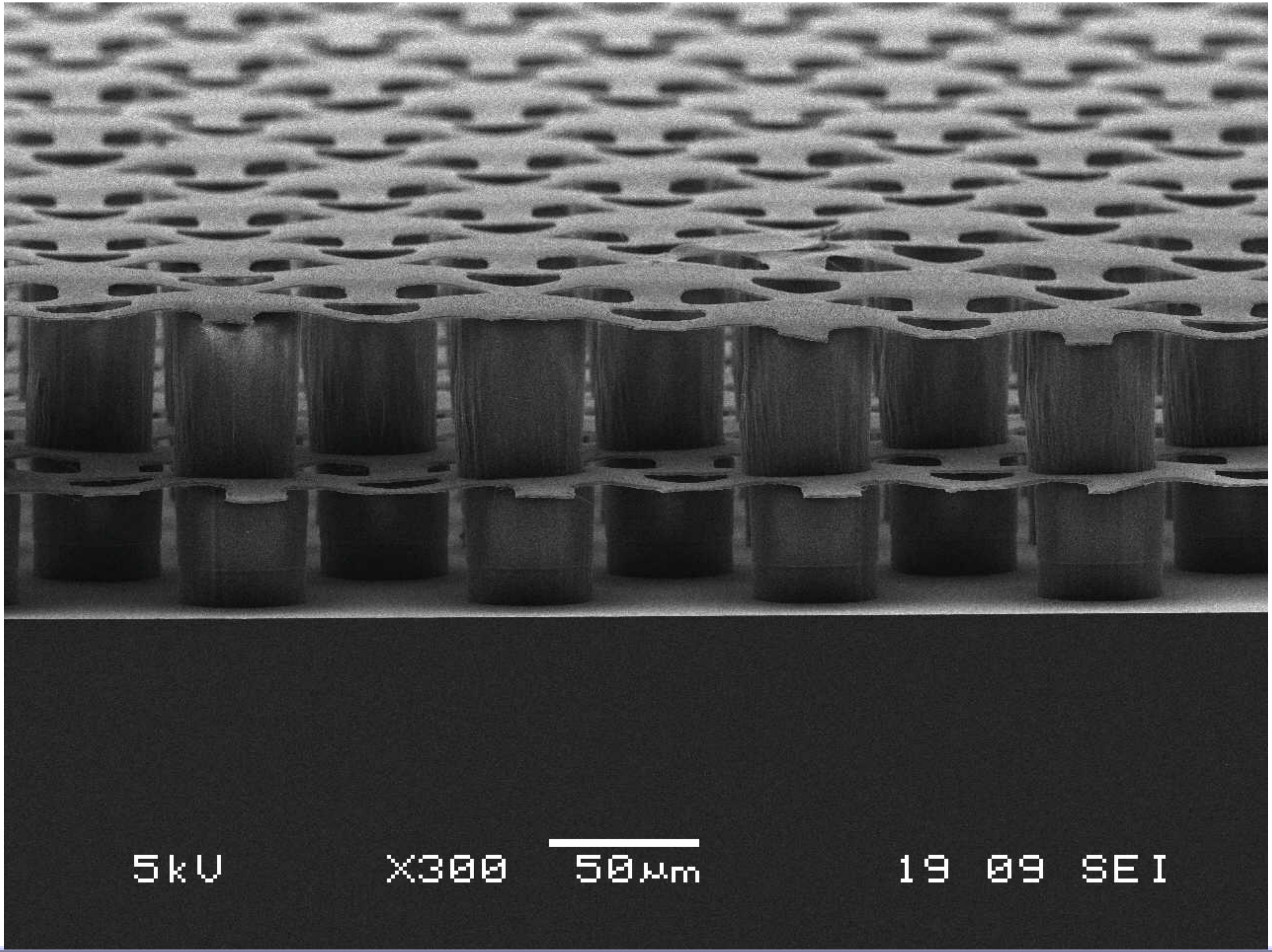
Look at the current flowing through the power supply (high grid voltage)



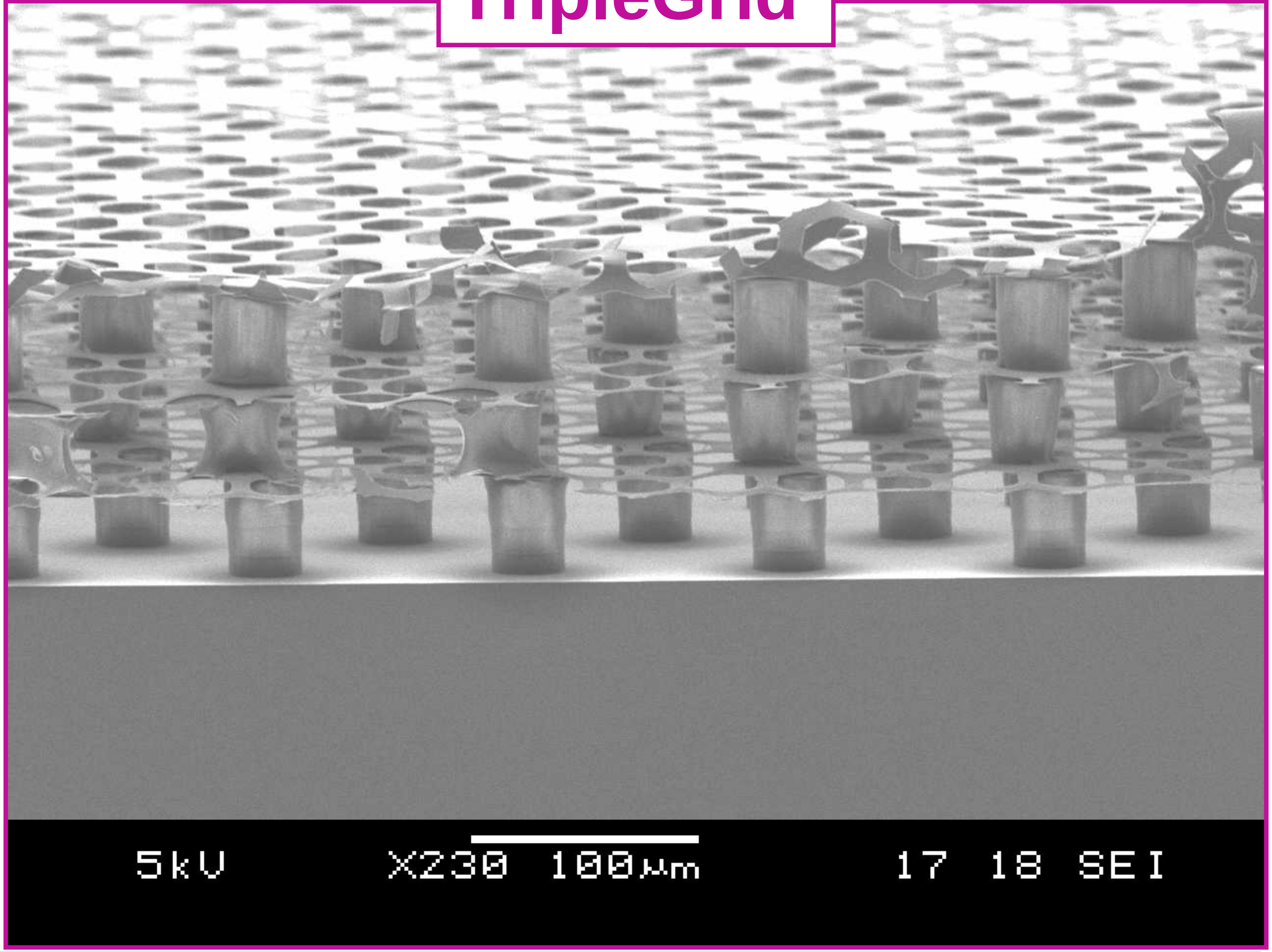
No sparks up to 570 V on the grid !

Burn the grid above 570…

Alternative: TwinGrid



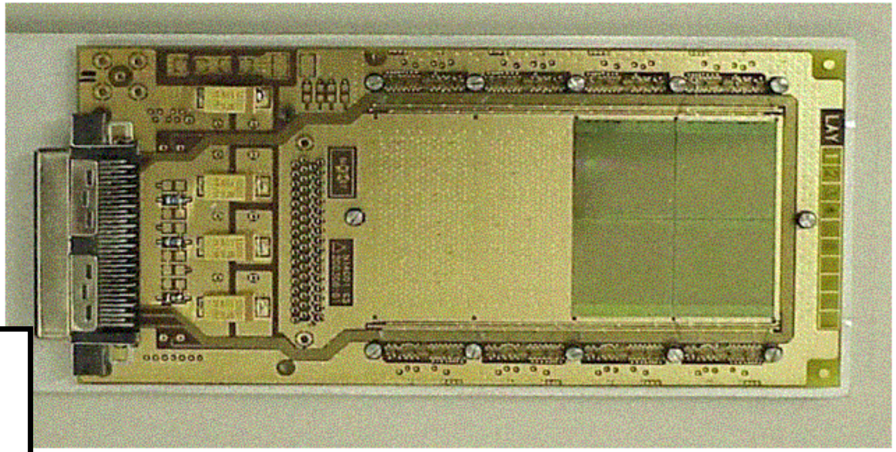
TripleGrid



Further Developments

RELAXD project (Dutch/Belgian)
NIKHEF,Panalytical,IMEC,Canberra:

- Chip tiling: large(r) detector surfaces
  (2x2, 2x4 chips)
- Through Si connectivity: avoiding bonding wires
- Fast readout technology
  (~5 Gb/s)



- Octal chip board:
  56 mm x 110 mm
  12-layer pcb

NIKHEF	Harry van der Graaf Jan Timmermans Jan Visschers Maximilien Chefdeville Martin Fransen Vladimir Gromov
Saclay CEA DAPNIA	Paul Colas, David Attié Dan Burke,Yannis Giomataris Arnoud Giganon, Marc Riallot
Univ. Twente/Mesa+	Jurriaan Schmitz Cora Salm Victor Blanco Carballo Sander Smits
CERN	Michael Campbell,Erik Heine Xavi Llopart

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Joop Rovenkamp

GridPix: the electronic bubble chamber