

Tracking cosmics: recent results from a Micromegas-covered MediPix2 pixel CMOS readout circuit in a mini-TPC

Recent GridPix results: an Integrated Grid (InGrid) and an ageing test of a Micromegas chamber

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PSD7, Liverpool, UK, Sept 15, 2005



1906: Geiger tube

gaseous detector

ionisation: primary electrons

(central) anode wire

electron multiplication

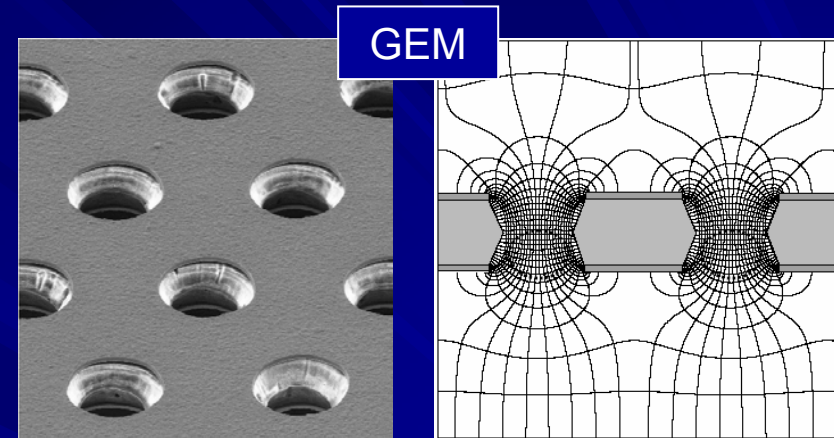
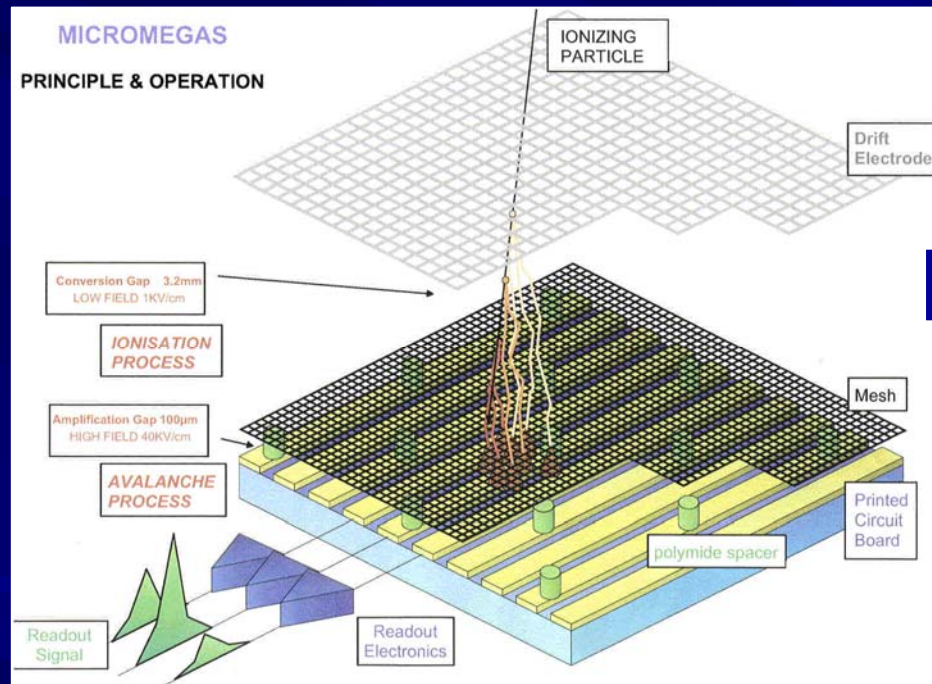
Geiger-Muller tube
Proportional tube
Multi Wire Proportional Chamber
Drift Chamber
Time Projection Chamber

1995 Micromegas (Charpak & Giomataris)

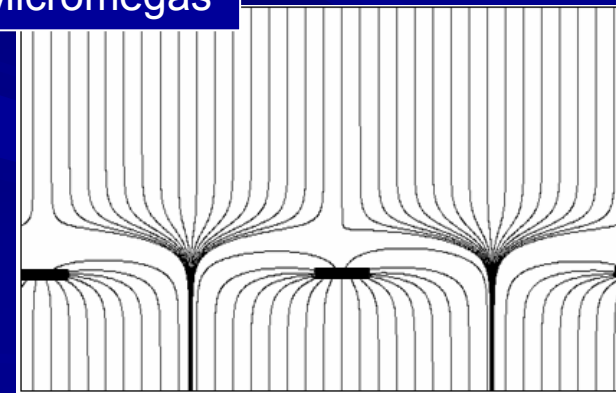
1996 GEM (F. Sauli)

Micro Patterned Gaseous Detectors

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



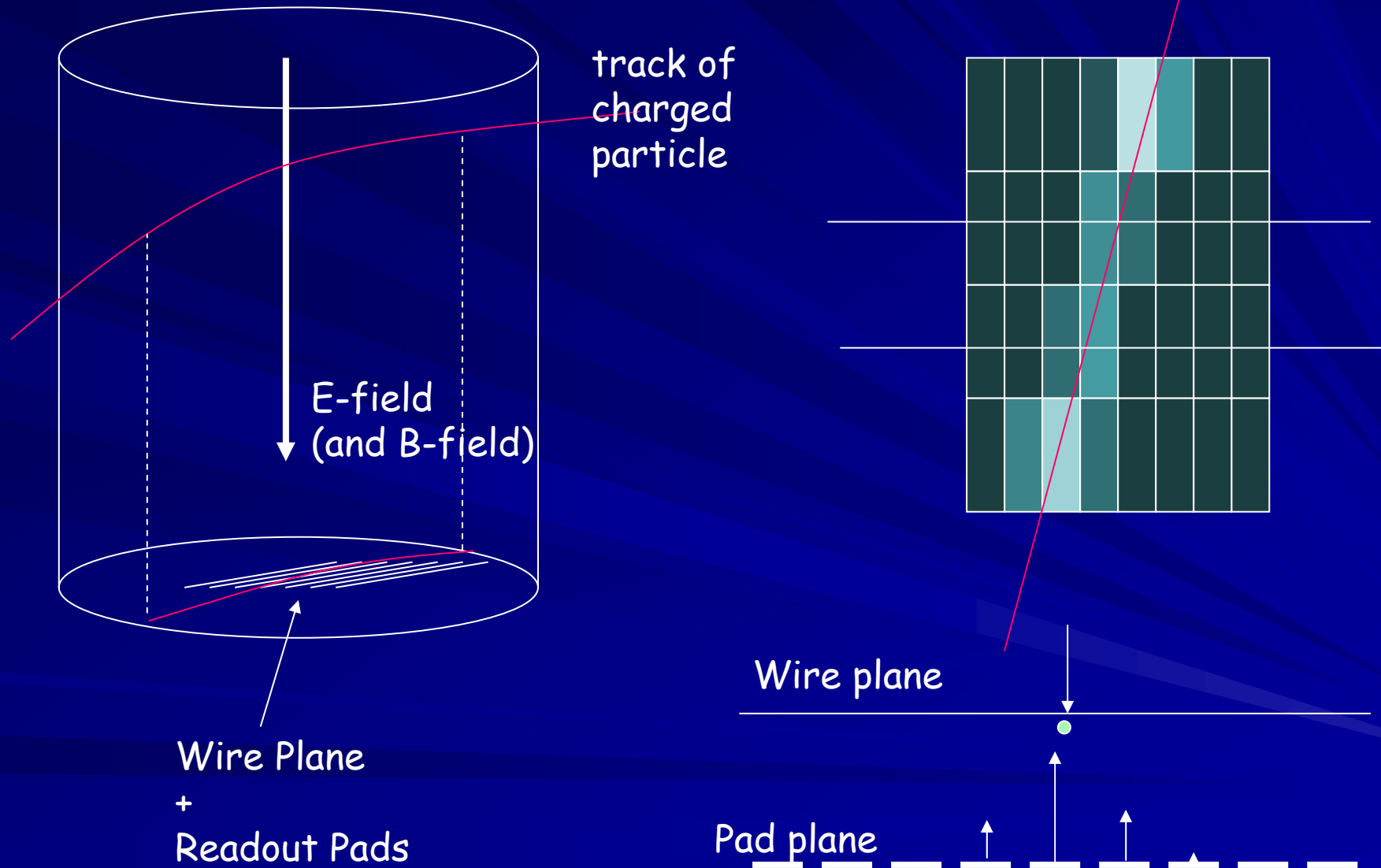
Micromegas



improved granularity: wire chambers react on COG of many electron clouds/clusters

Time Projection Chamber (TPC): 2D/3D Drift Chamber

The Ultimate Wire (drift) Chamber



Problem

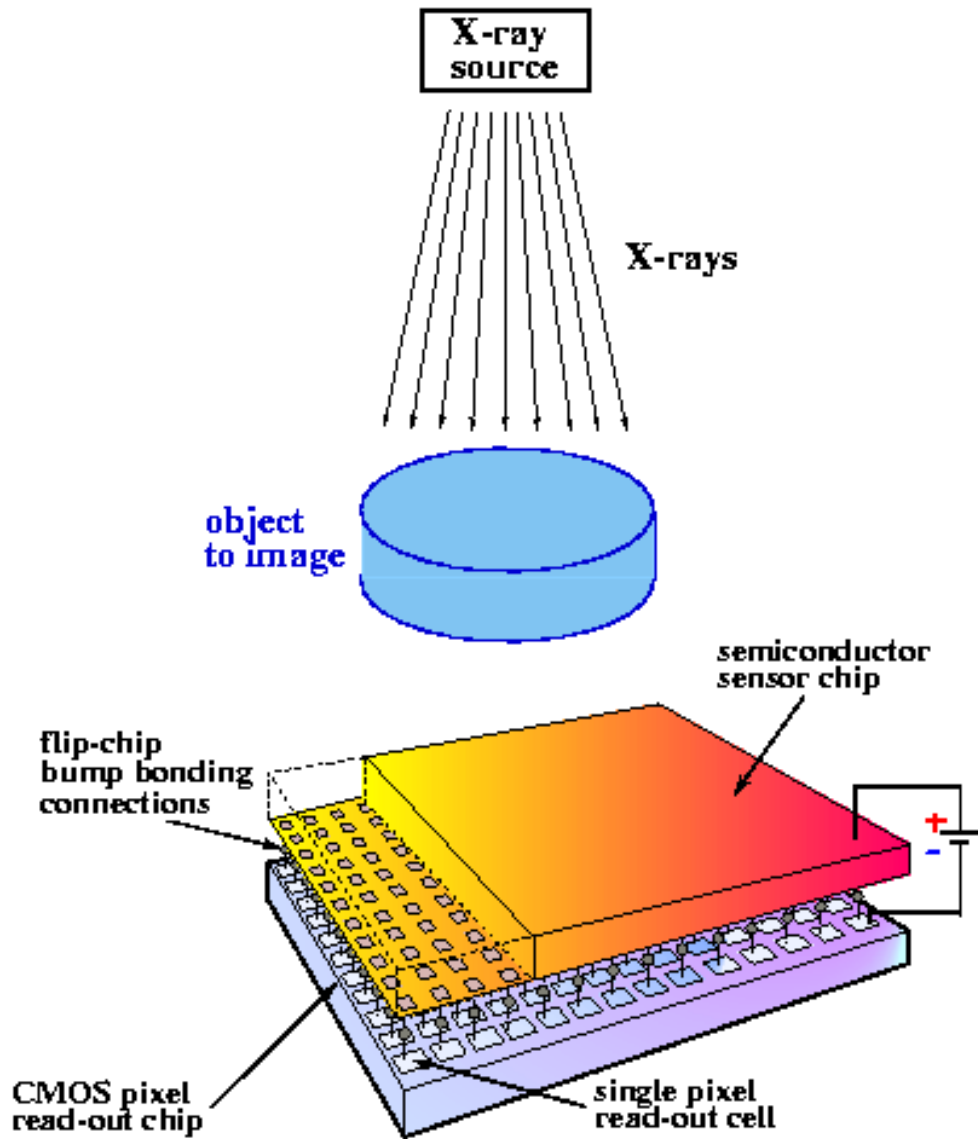
With wires: measure charge distribution over cathode pads:
c.o.g. is a good measure for track position;

With GEMs or Micromegas: narrow charge distribution
(only electron movement)



Solutions:

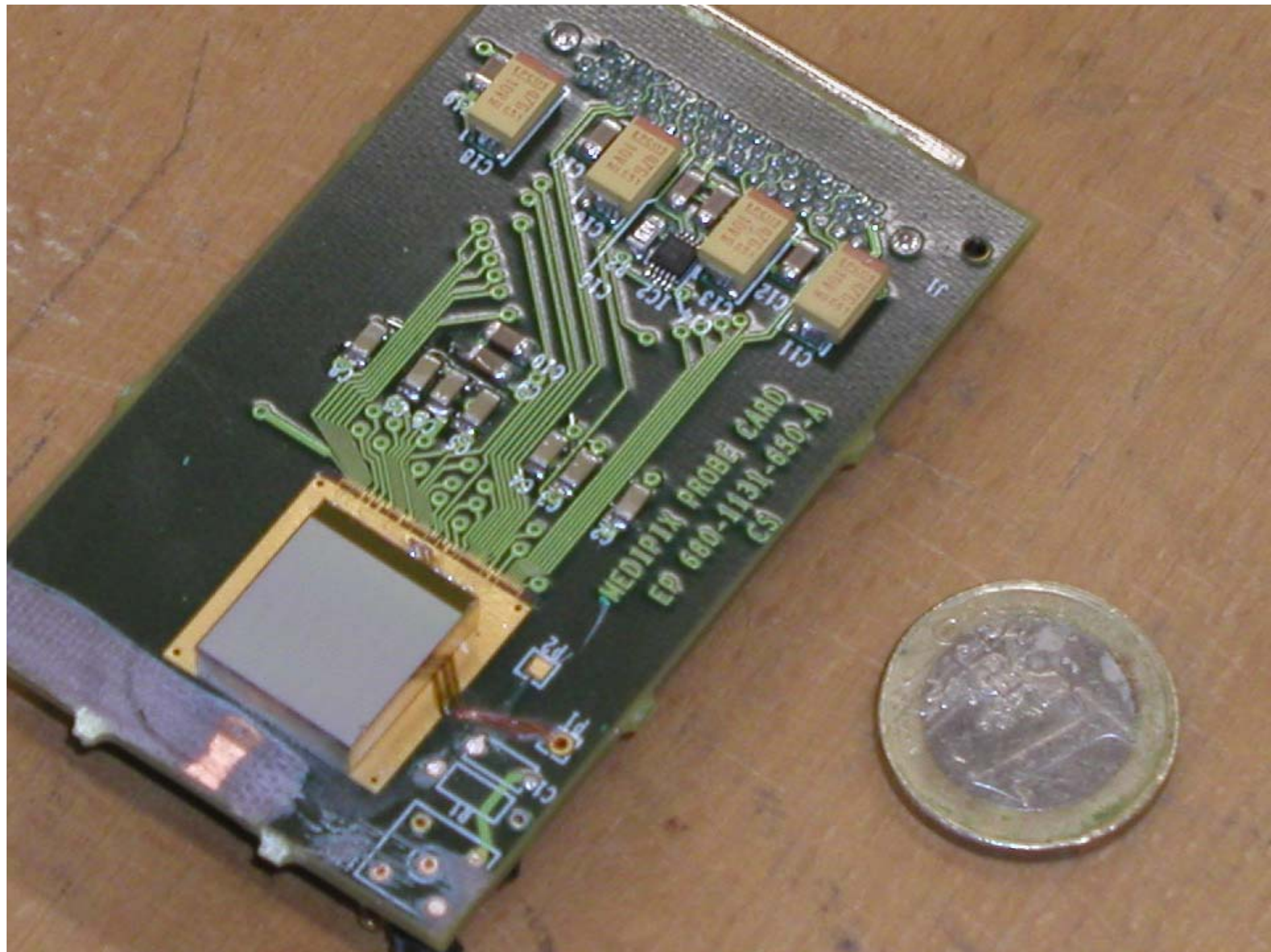
- cover pads with resistive layer
- 'Chevron' pads
- many small pads: pixels!



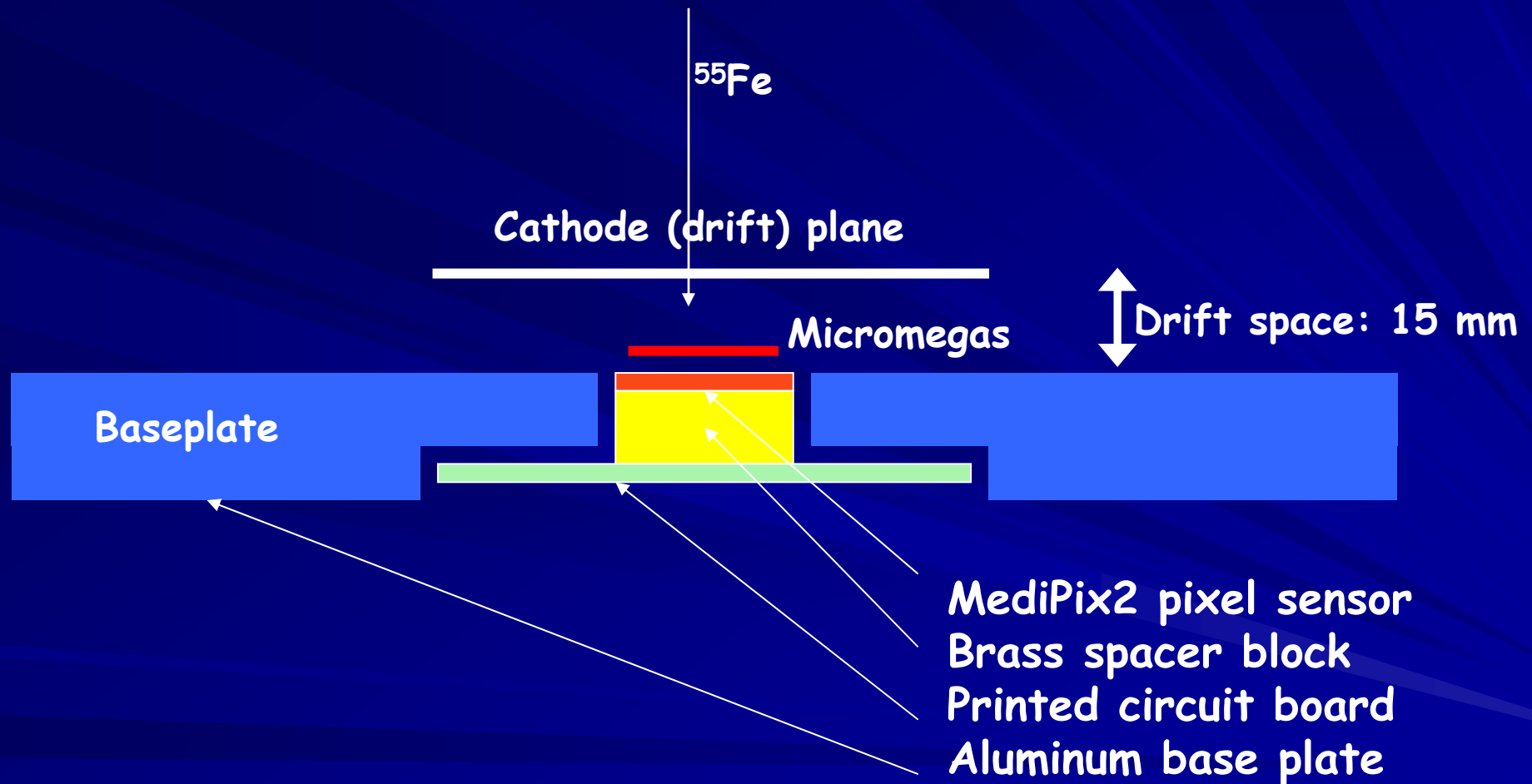
The MediPix2 pixel CMOS chip

- 256 x 256 pixels
- pixel pitch: $55 \times 55 \mu\text{m}^2$
- Within each pixel:
 - preamp + shaper + discr
 - 14-bits counter
 - discr. thresholds
- Developed by MediPix Consortium, CERN

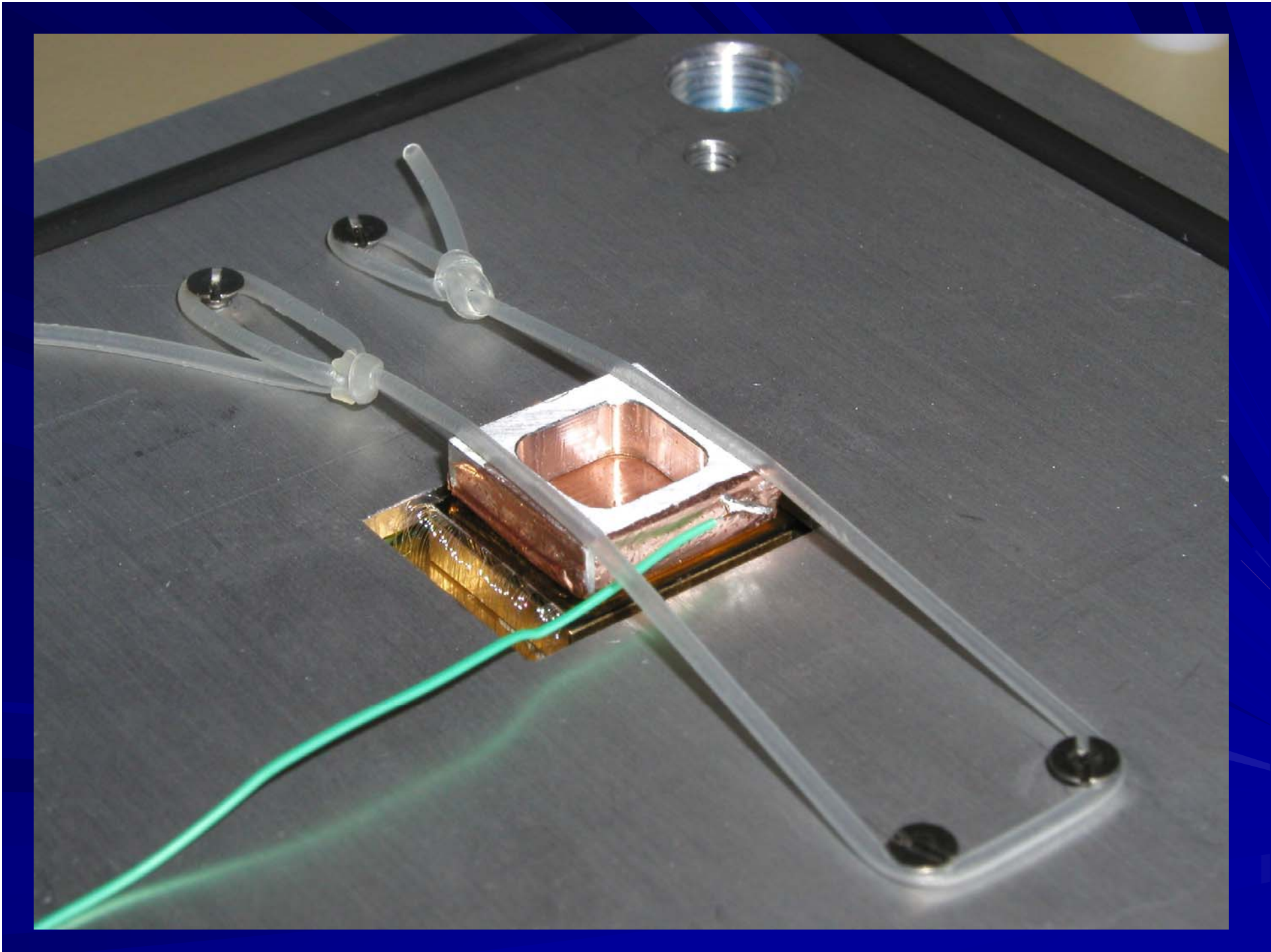
We apply the 'naked' MediPix2 chip without X-ray converter!

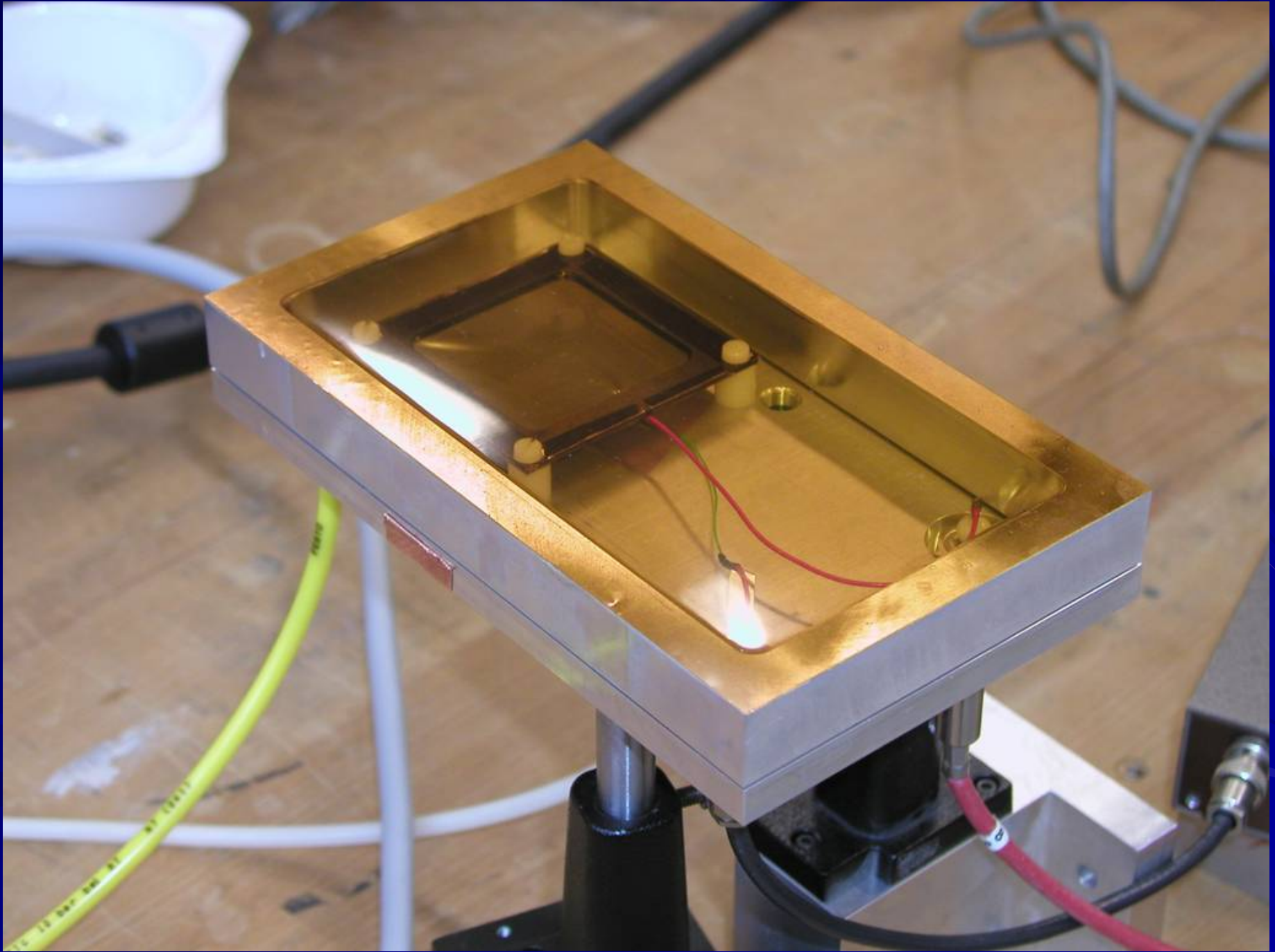


MediPix2 & Micromegas

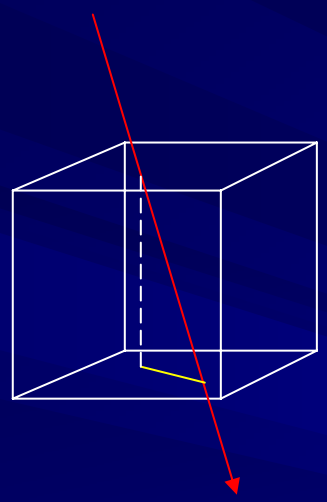


Very strong E-field above (CMOS) MediPix!



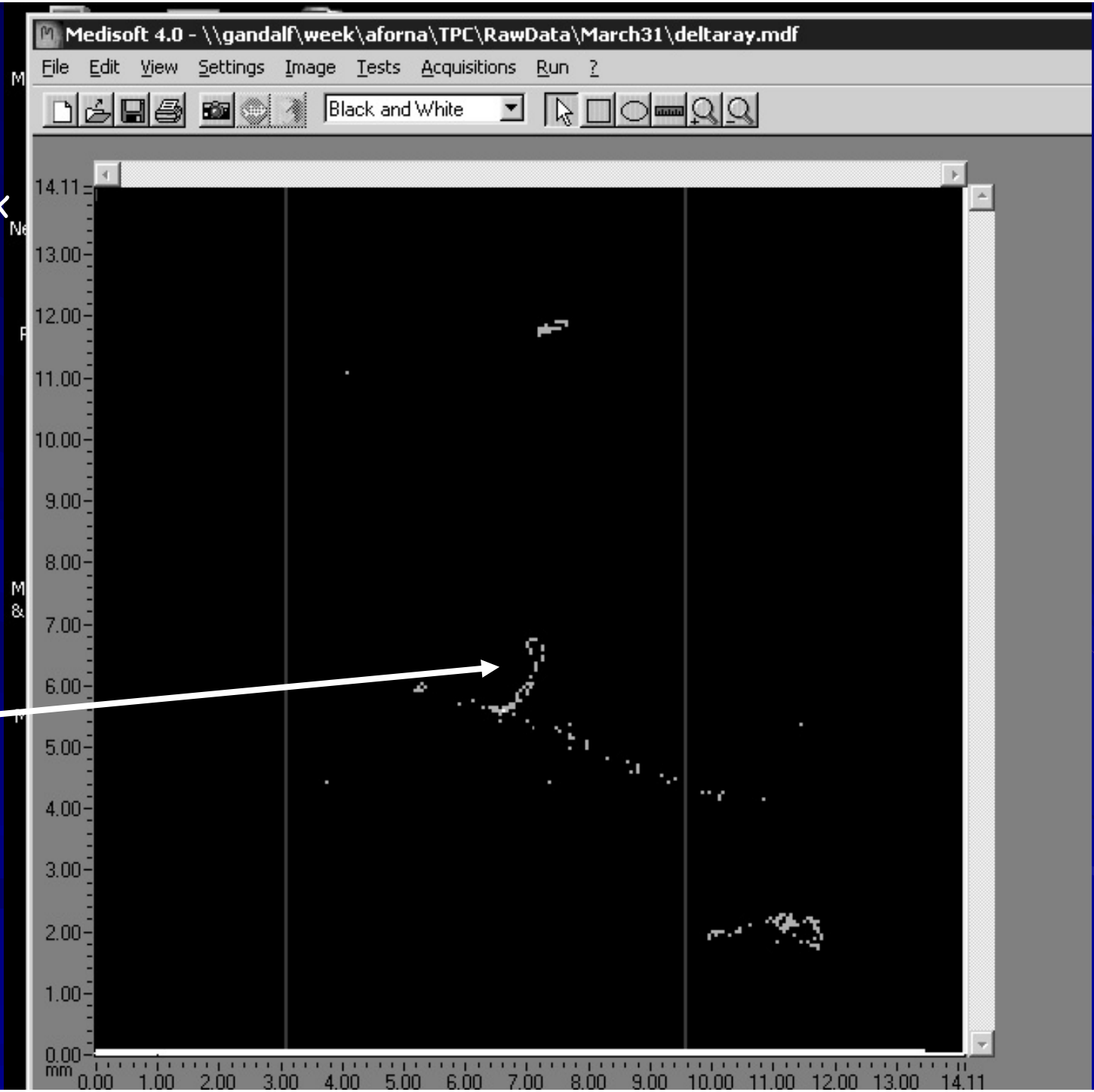


He/Isobutane
80/20
Modified MediPix



δ -ray!

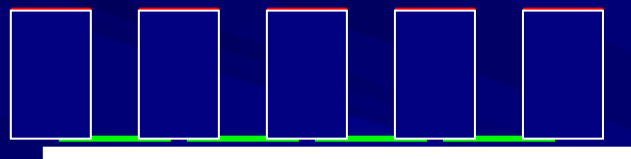
Efficiency for
detecting single
electrons:
< 95 %



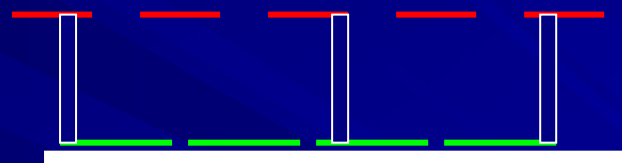
Integrate GEM/Micromegas and pixel sensor:

InGrid

'GEM'



'Micromegas'



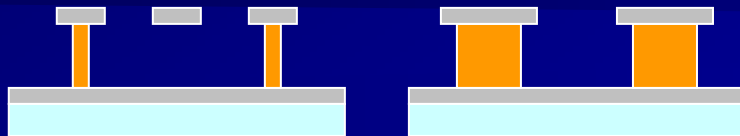
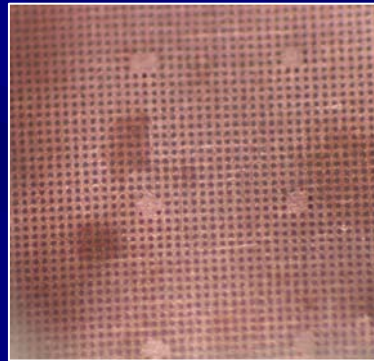
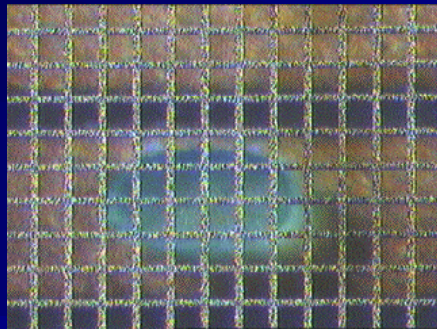
By 'wafer post processing'

InGrid VS Micromegas

Micromegas

Electroforming tech.

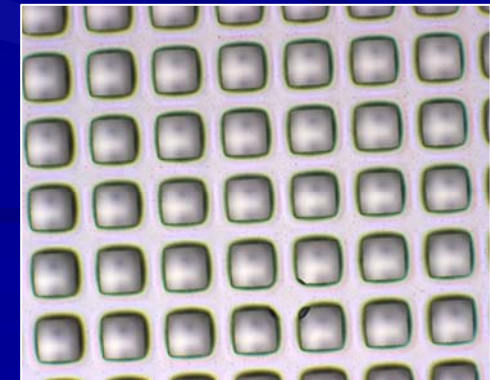
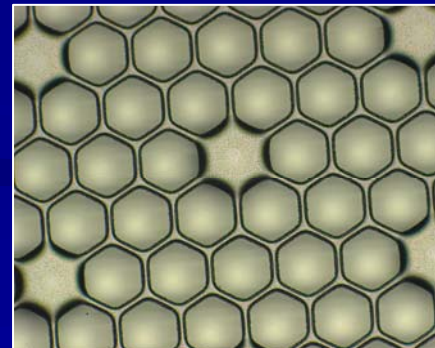
- Large areas
 - Large pillar \varnothing (250 μm)
 - Hybrid detector
- Manual mounting



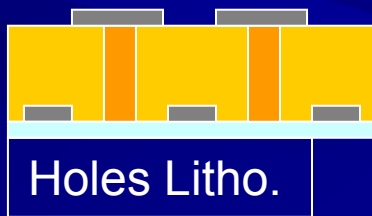
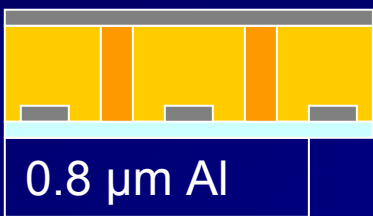
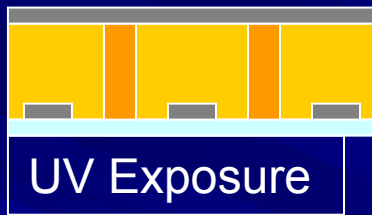
InGrid

Micro-electronic tech.

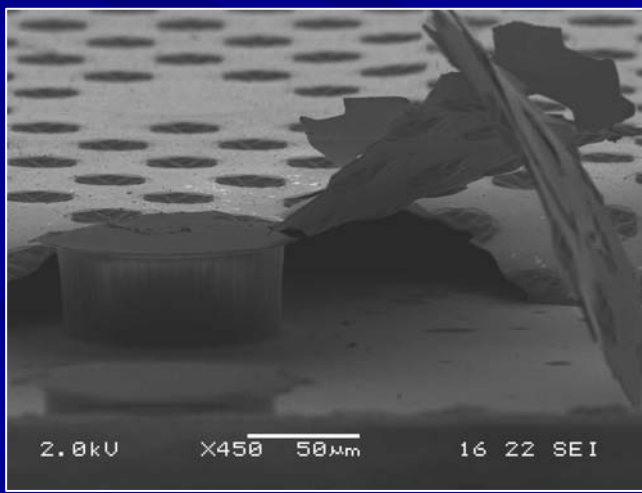
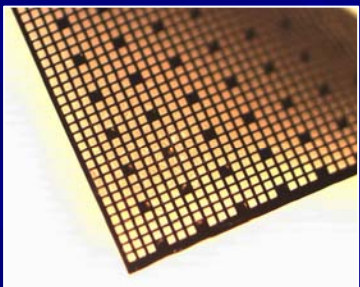
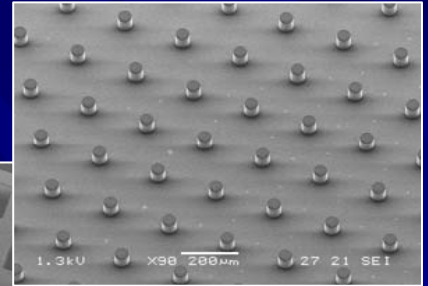
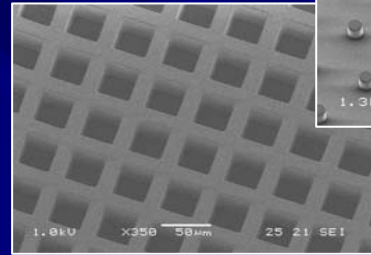
- Wafer scale areas
 - Minimum pillar \varnothing (30 μm)
 - Integrated detector
- Compact / Mass producible
- All geometric parameters accurately controlled
- Gap, Holes, Supporting structures



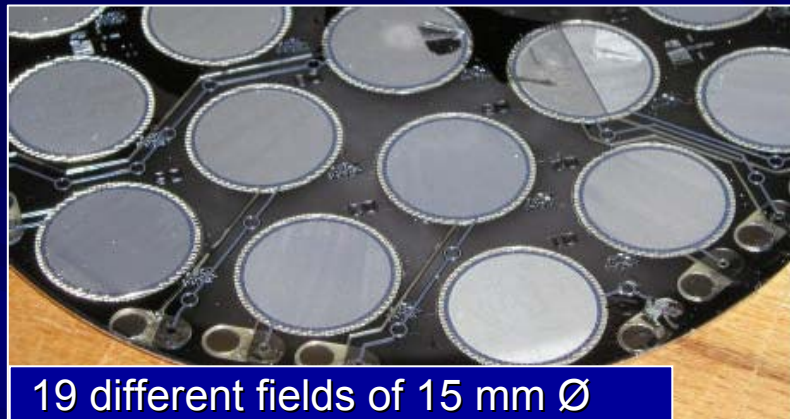
Processing InGrids



Suspended membrane 50 µm above the wafer

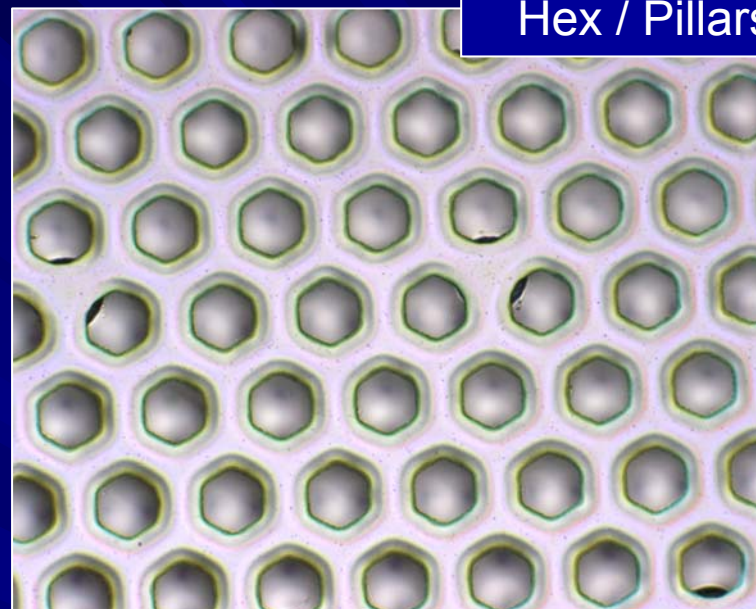


Prototypes

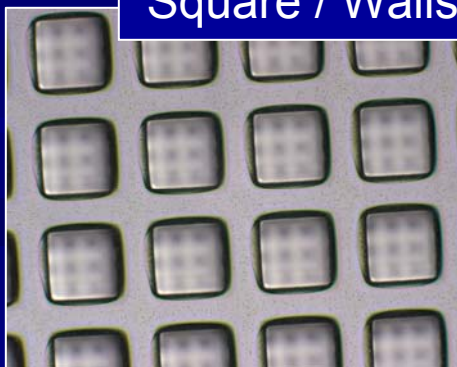


19 different fields of 15 mm \varnothing
2 bonding pads / fields

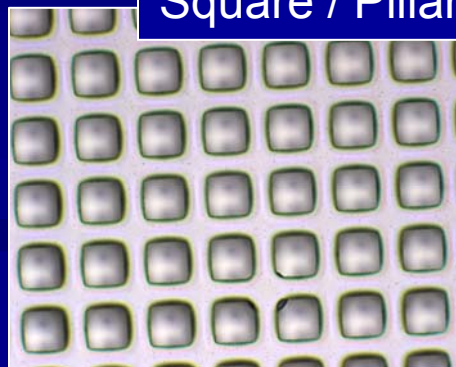
Hex / Pillars



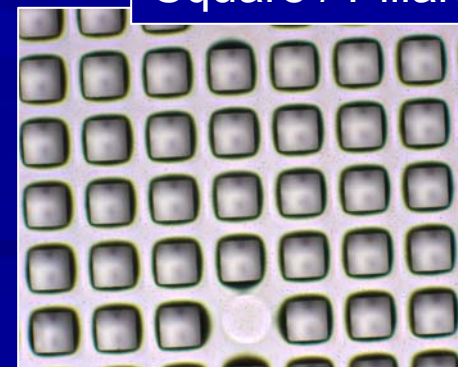
Square / Walls



Square / Pillars



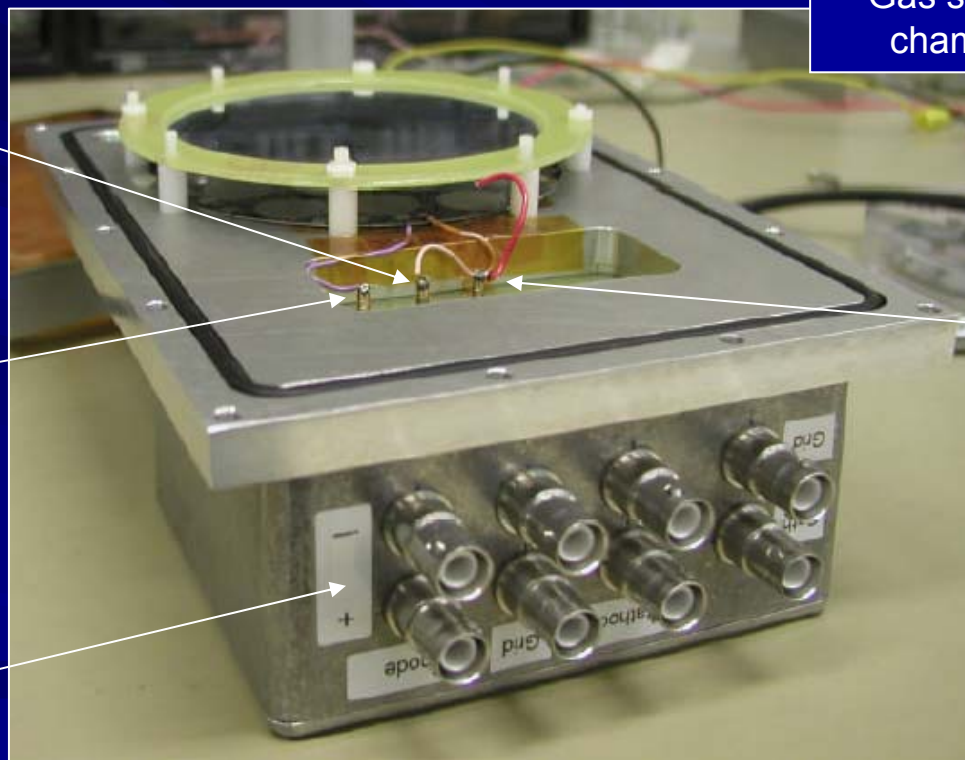
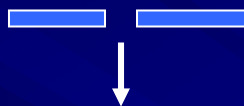
Square / Pillars



Experimental Setup



^{55}Fe collimated source



Gas sealed chamber

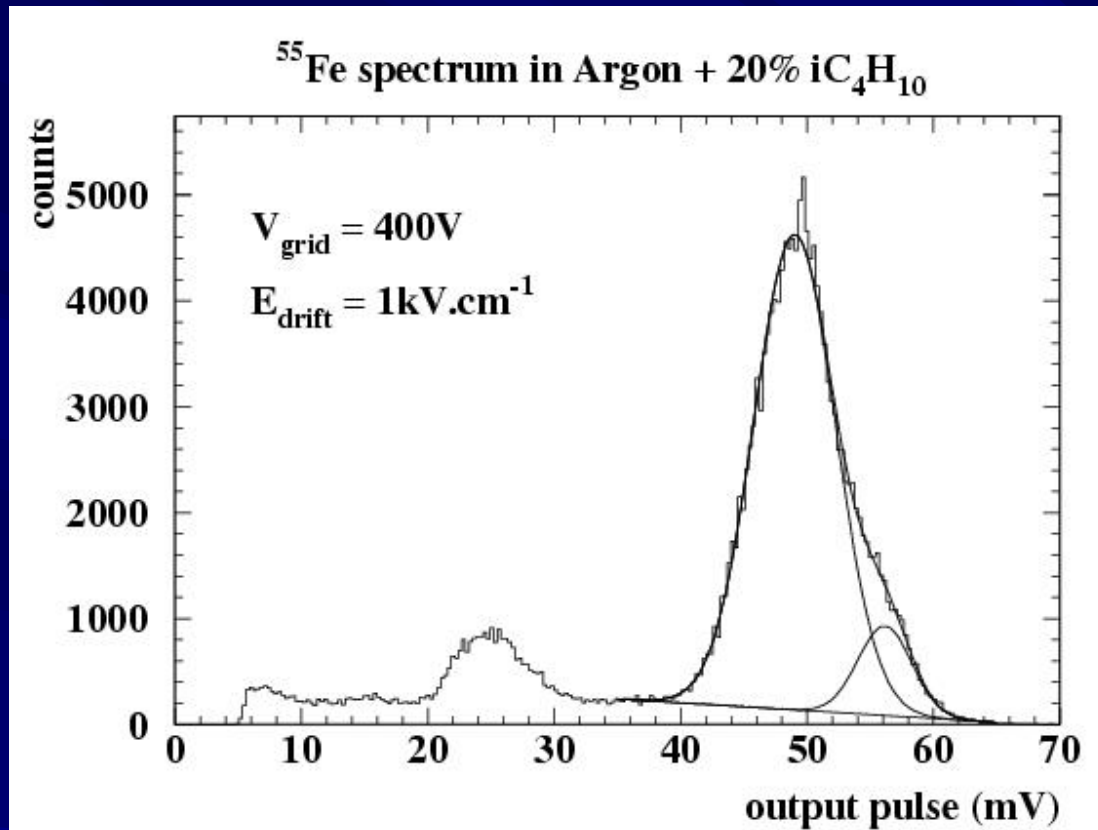
Grid to HV

Anode to ground

Connectors to 10 M Ω resistors in series with electrodes

Cathode to HV

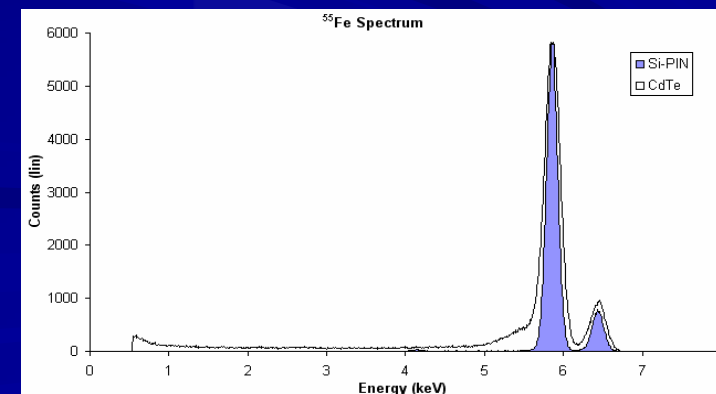
Energy resolution in Argon IsoC₄H₁₀ 80/20



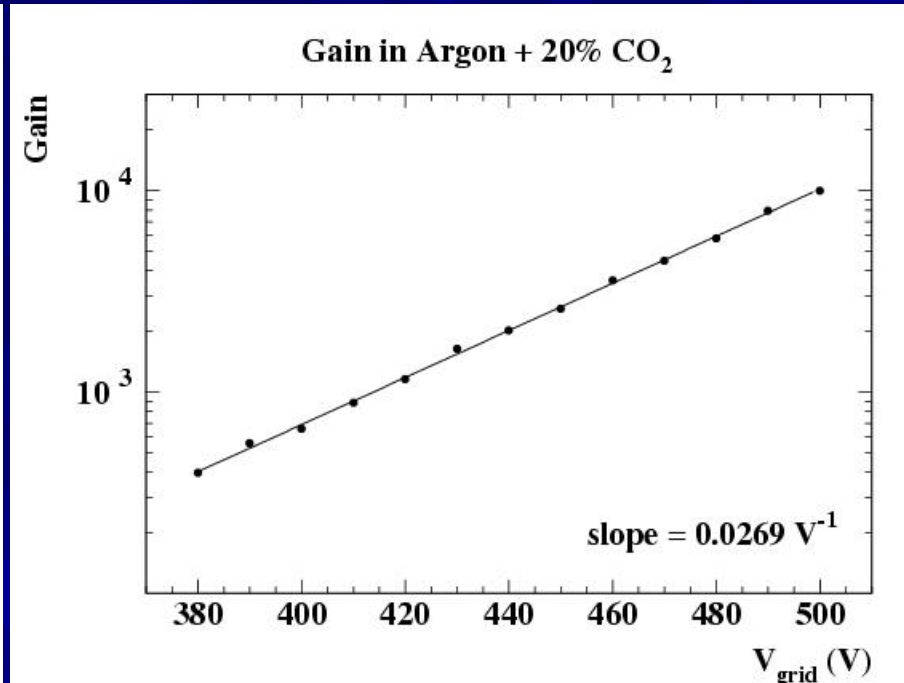
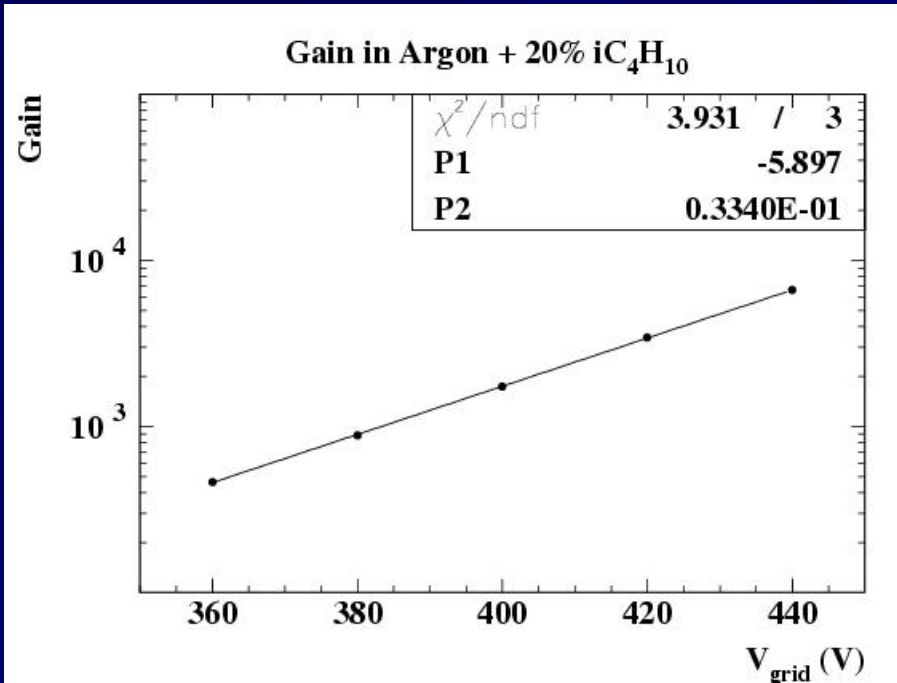
Very good energy resolution:

Very precise dimensions $d < 0.1 \mu\text{m}$

- Observation of two lines:
 - K_{α} @ 5.9 keV
 - K_{β} @ 6.4 keV
- FWHM of the K_{α} distribution
16.7 %
- Gain fluctuations
< 5%



Gains in Argon



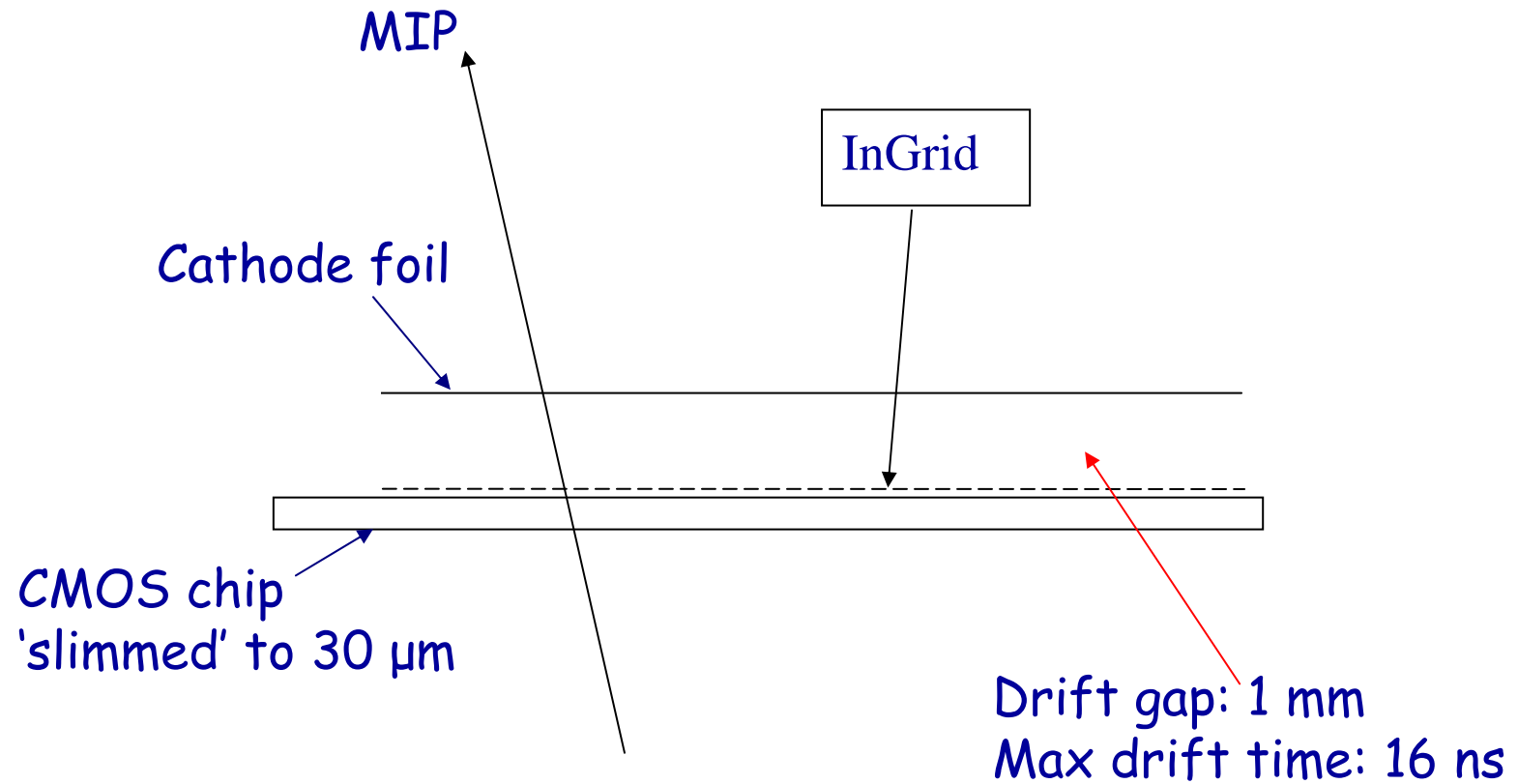
Argon / CO_2 mixtures offers good ageing properties (GOSSIP gas)

Gain of 10^4 reachable in Argon CO_2 80/20

Ageing studies in a reasonable amount of time (intense X-rays source)

Other applications of GridPix:

- μ -TPC
- Transition Radiation Detectors
- GOSSIP: tracker for intense radiation environment



GOSSIP: Gas On Slimmed Silicon Pixels

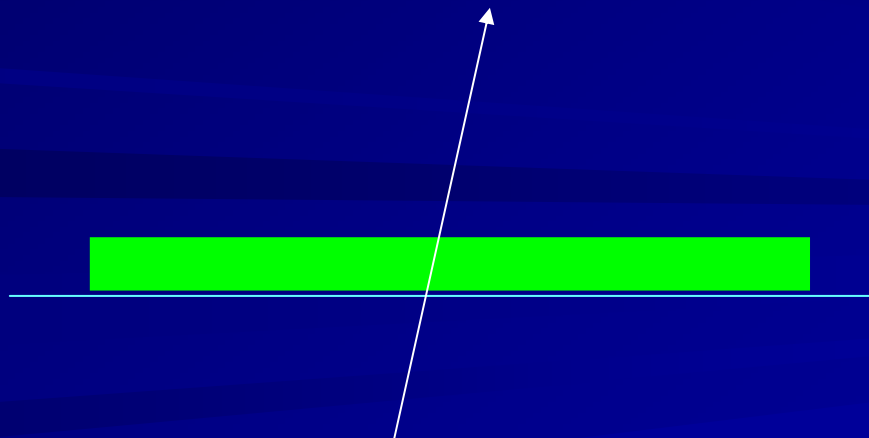
Essentials of GOSSIP:

- Generate charge signal in gas instead of Si (e⁻/ions versus e⁻/holes)
- Amplify # electrons in gas (electron avalanche versus FET preamps)

Then:

- No radiation damage in depletion layer or pixel preamp FETs
- No power dissipation of preamps
- No detector bias current
- Ultralight detection layer (Si foil)

1 mm gas layer + 20 μm avalanche gap + CMOS (almost digital!) chip
After all: it is a TPC with 1 mm drift length (parallax error!)



Max. drift length: 1 mm

Max. drift time: 16 ns

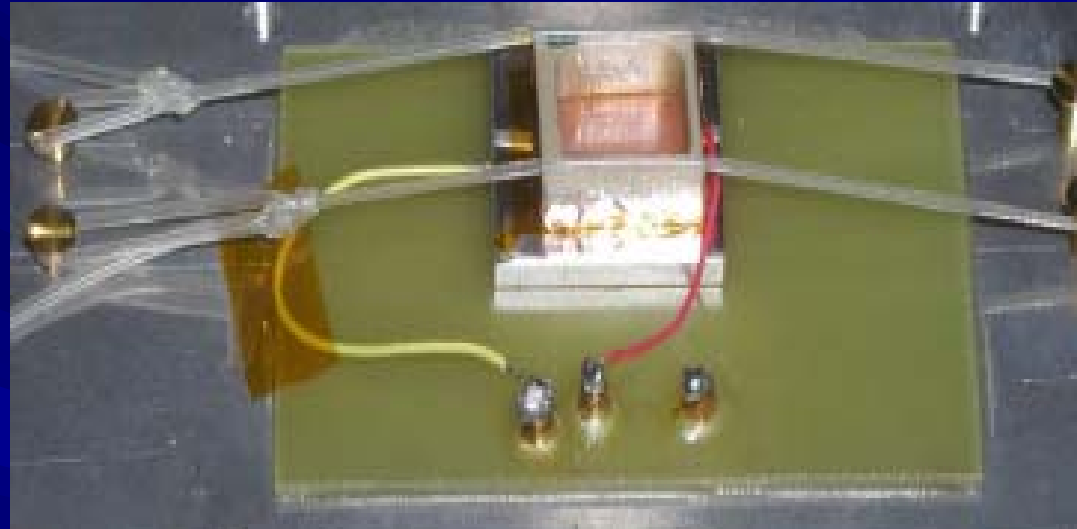
Resolution: 0.1 mm \rightarrow 1.6 ns

Ageing
Efficiency
Position resolution
Rate effects
Radiation hardness
HV breakdowns
Power dissipation
Material budget

Aging test (remember MSGCs....!)

■ Effects of high radiation environment on GOSSIP:

- Rate
- Current
- Deposits



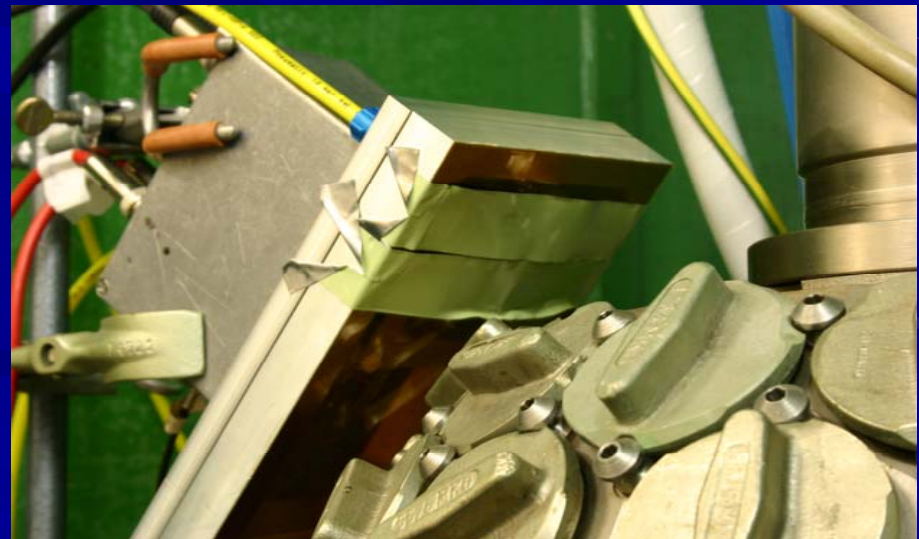
Chamber: Same as GridPix, but with polished Al plate as anode instead of MediPix

Rate effects

Anode current (*gas gain*) due to ^{55}Fe quanta calibrated with gas gain G and X-ray intensity N_x :

$$I_{\text{anode}} = G \cdot N_x \cdot 220 e^- \cdot q_e$$

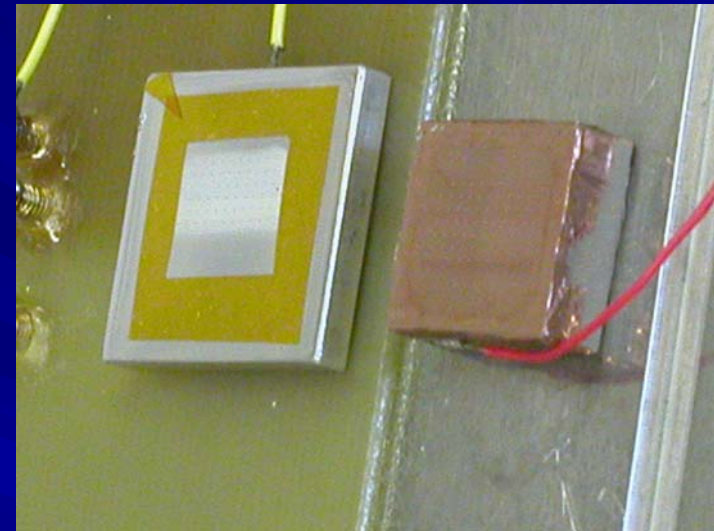
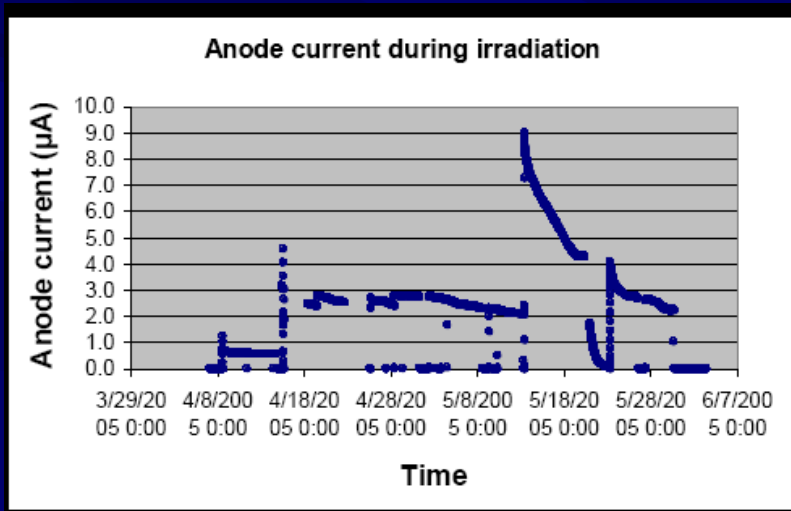
Irradiation with X-ray tube:
No deviation from current proportionality was observed up to 44 MHz of 8 keV X-ray quanta on a detector surface of 100 mm².



Aging test

Half the GridPix was irradiated with 8 keV X-rays. Gas: Ar/Methane 90/10

After 0.3 Coulomb/mm², deposit of carbon polymer on anode is clearly visible. Micromegas is clean (!)



Reduced aging of a GridPix detector versus wire chambers:

- ratio of anode surface: thin wire surface versus anode plane (~20x)
- low gas gain due to fast signal and low source capacity (~20x)

So: no issue for ILC-TPC

So: application as GOSSIP vertex detector in Super LHC seems feasible

Next

InGrid

Study the geometry influence on Resolution, Gain, Ion back flow

Optimise detector geometry

Protect the chip from discharges

High resistive grid, or separated grid segments

Apply InGrid on MediPix2, (TimePix!), PSI 46 pixel chips

GridPix (TPC for ILC)

TimePix: modify MediPix 2 chip: TDC clock over pixel matrix

EUDET (Nikhef-Saclay-Freiburg et al) granted \$\$\$!

GOSSIP

repeat aging test with Ar/CO₂

Gossipo: MPW submit for low-noise preamp ($C_s = 30$ fF)

Test with PSI 46 FE pixel chip *equipped with InGrid*

NIKHEF

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CERN

Erik Heine
Medipix Consortium

GridPix: the electronic bubble chamber

