The detection of single electrons using the MediPix2/Micromegas assembly as Direct Pixel Segmented Anode

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The TPC for the next Linear Collider (TESLA?)

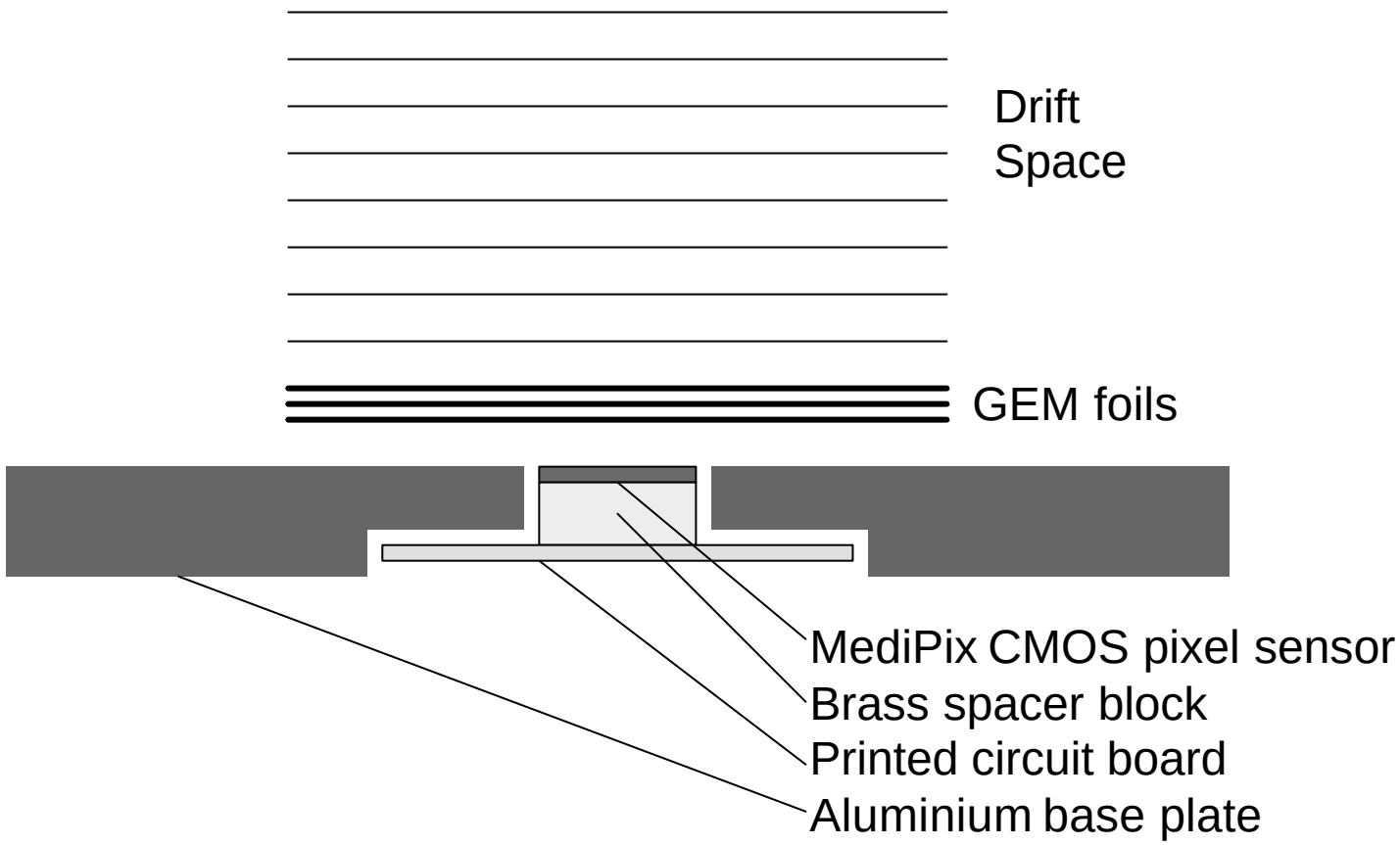
Ongoing R & D: use GEMs or Micromegas instead of wires

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 resisitive layer
- ‘Chevron’ pads
- many small pads: pixels

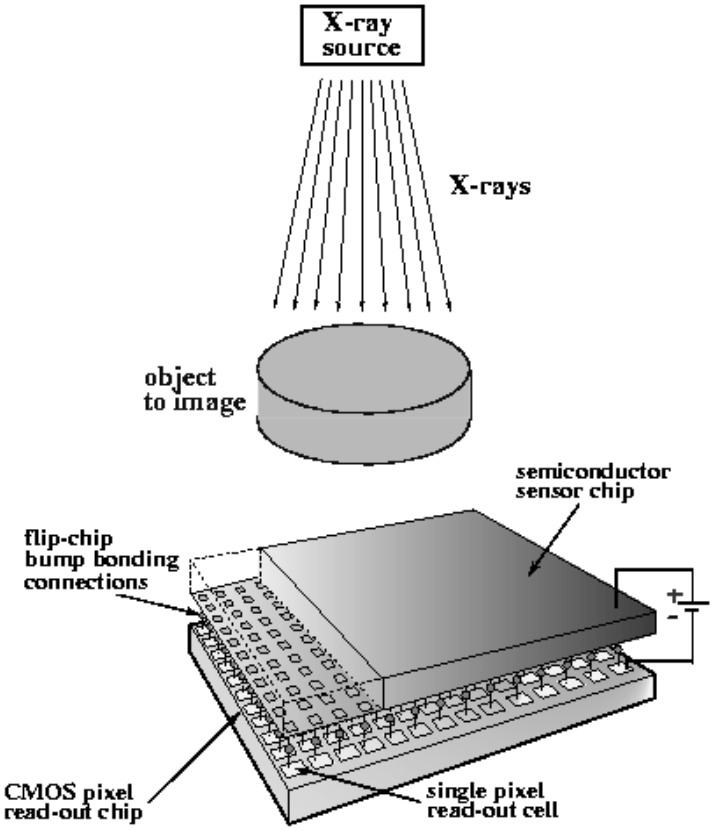
A new readout for the TESLA TPC:
Each GEM hole gets its own preamp/shaper/discriminator:

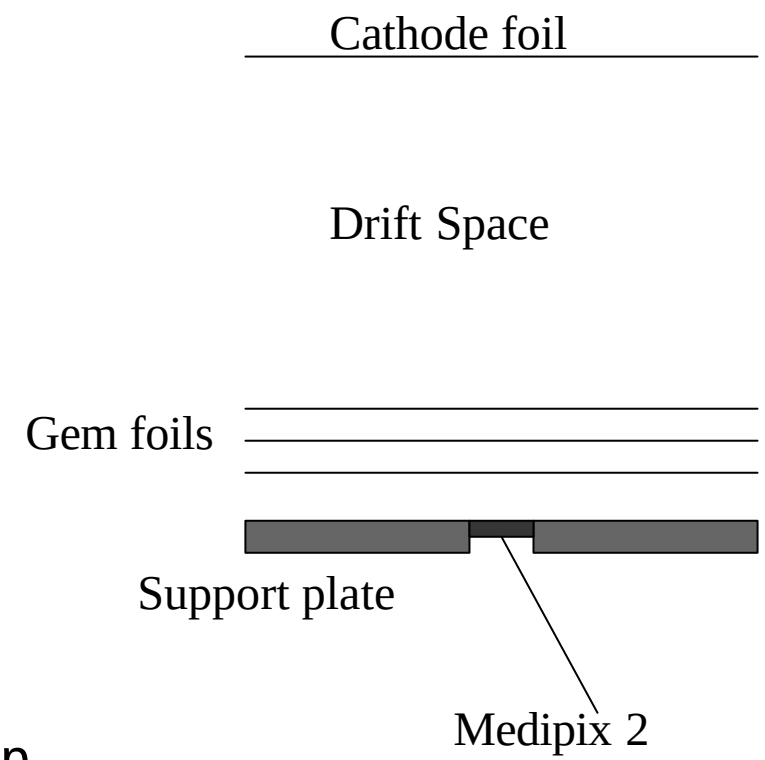


Our GEM-equipped TPC

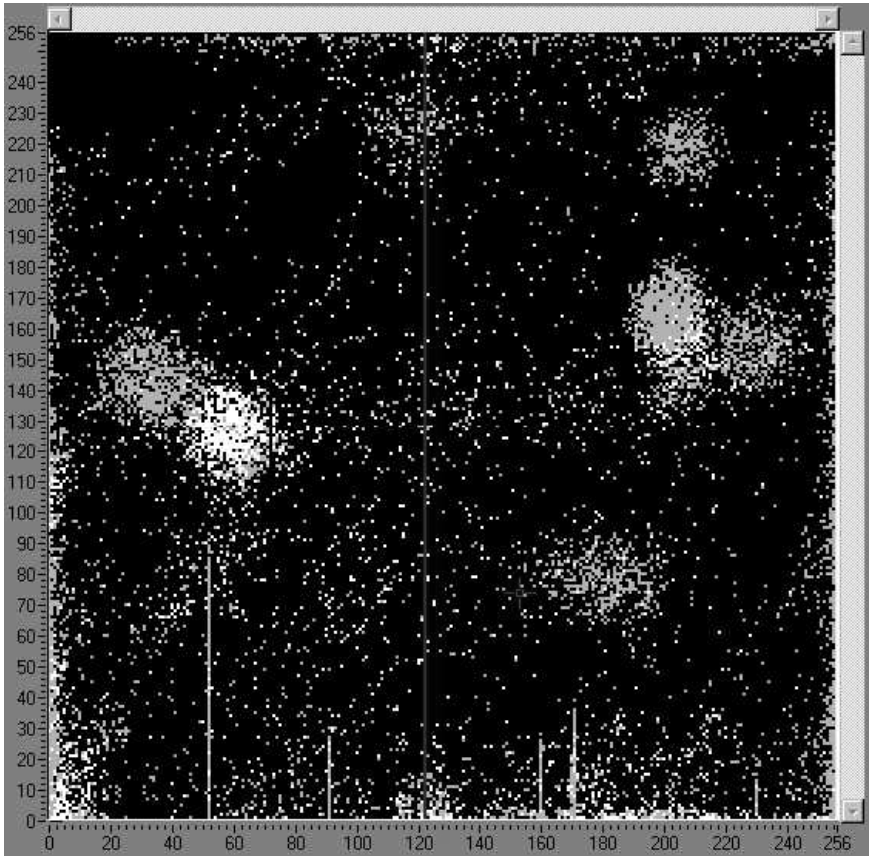
We have constructed a small test TPC equipped with three GEM foils which can be read out by means of the MEDIPIX2 CMOS pixel sensor.
The GEM foils were obtained from the CERN/Sauli/GEM group;
hole-to-hole distance (hexagonal geometry): 140 µm, hole diameter 85 µm,
fiducial surface 100 mm x 100 mm, thickness 50 µm.
The drift volume (vol. 100x100x100 mm^3) is surrounded by square wire loops, spaced 6.3 mm, put at decreasing potential. Three GEM foils are placed 7.4 mm behind the plane of the bottom wire loop; the distance between GEM foils is 1.6 mm.
The anode plane, at ground potential, is 6.6 mm below the third GEM foil.

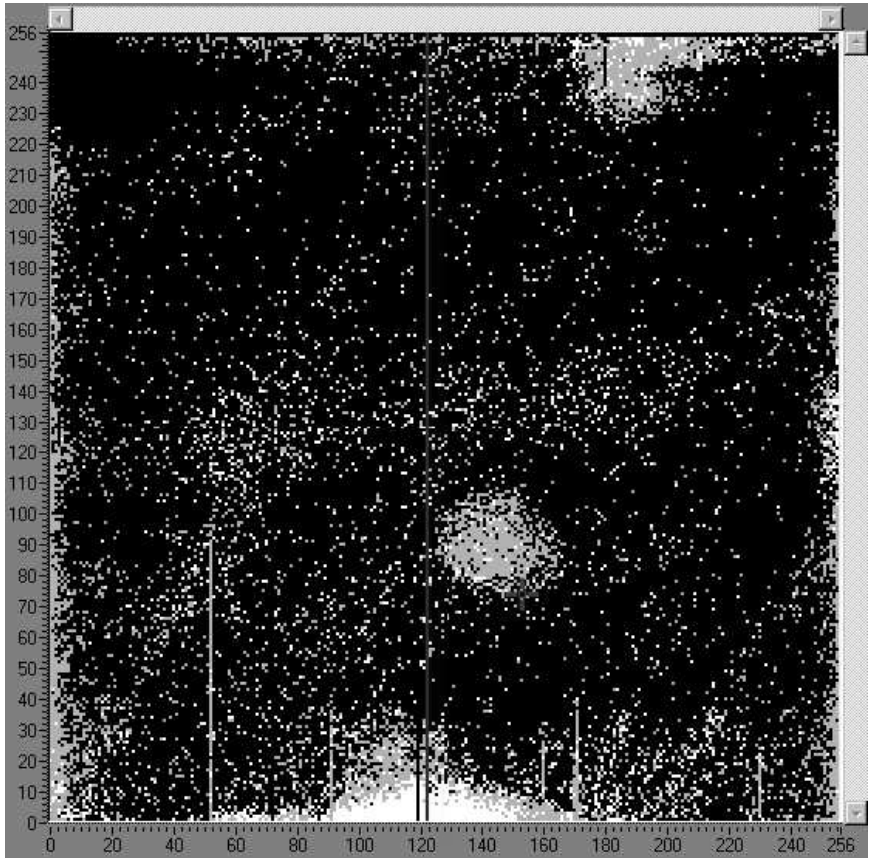
The MediPix2 pixel CMOS chip



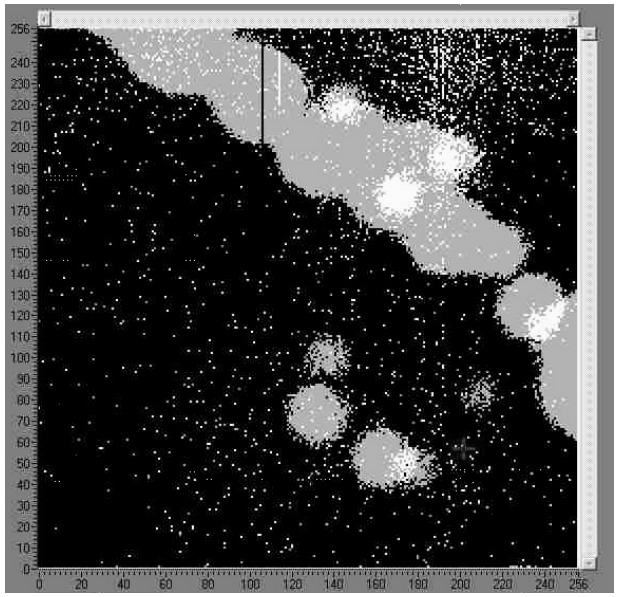


We apply the 'naked' MediPix2 chip without X-ray convertor!

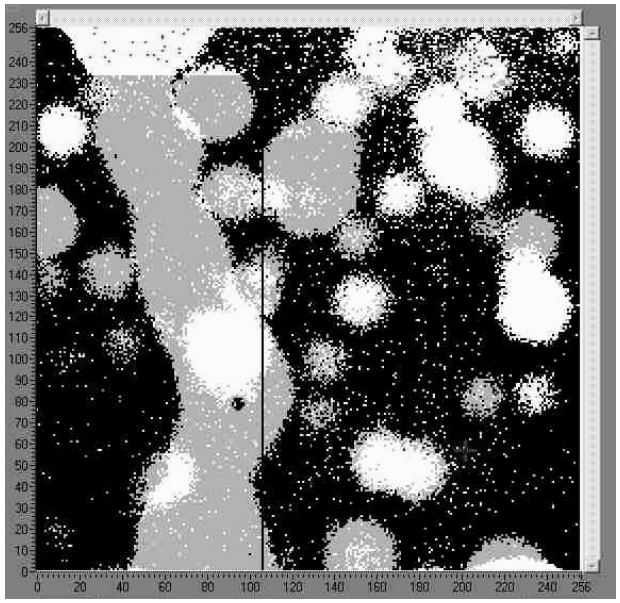




First events, recorded on March 29, 2003.
Drift space irradiated with ^{55}Fe quanta
Gas: Ar/Methane 90/10



No source; exposed 0.01 s



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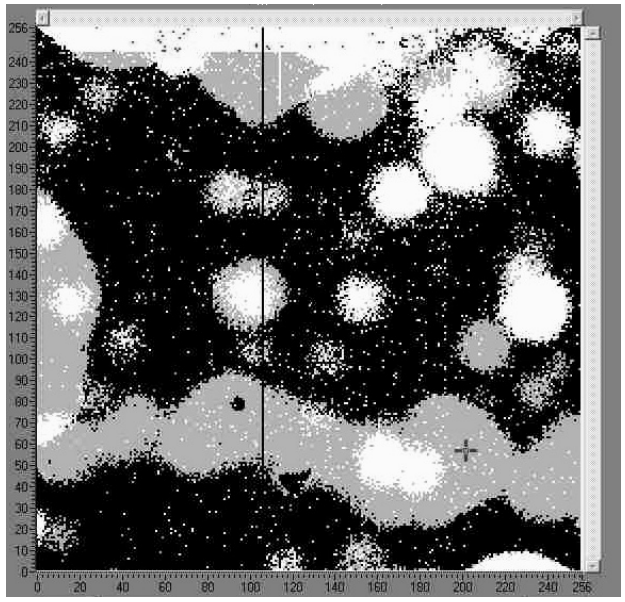

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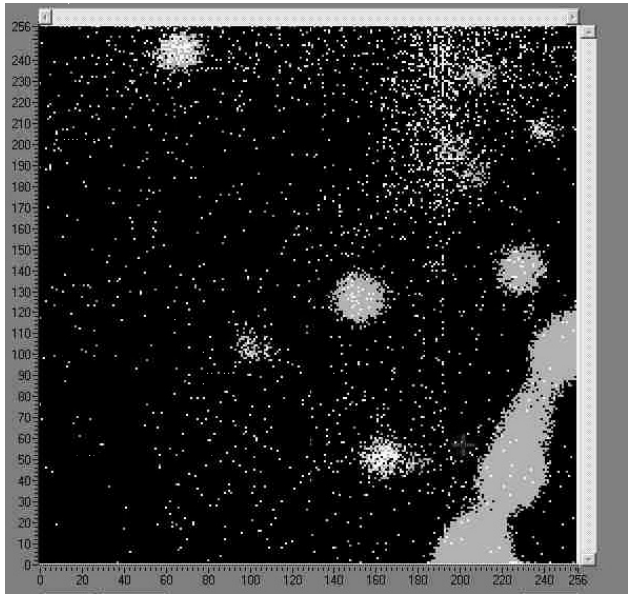
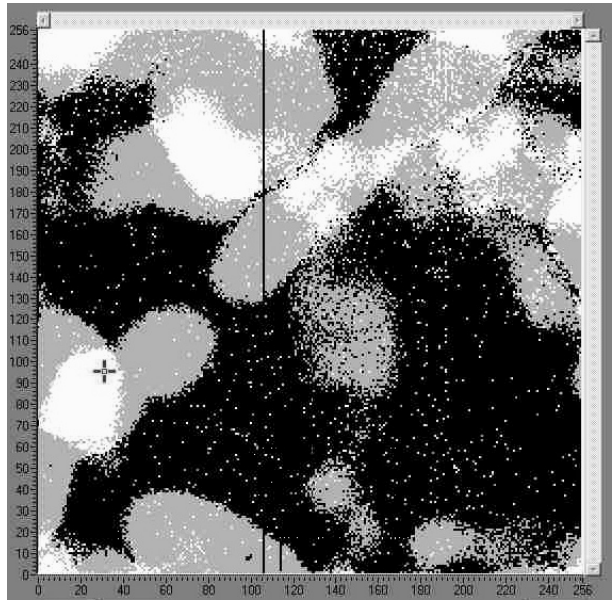


No source; exposed 0.1 s

Feb 9, 2004

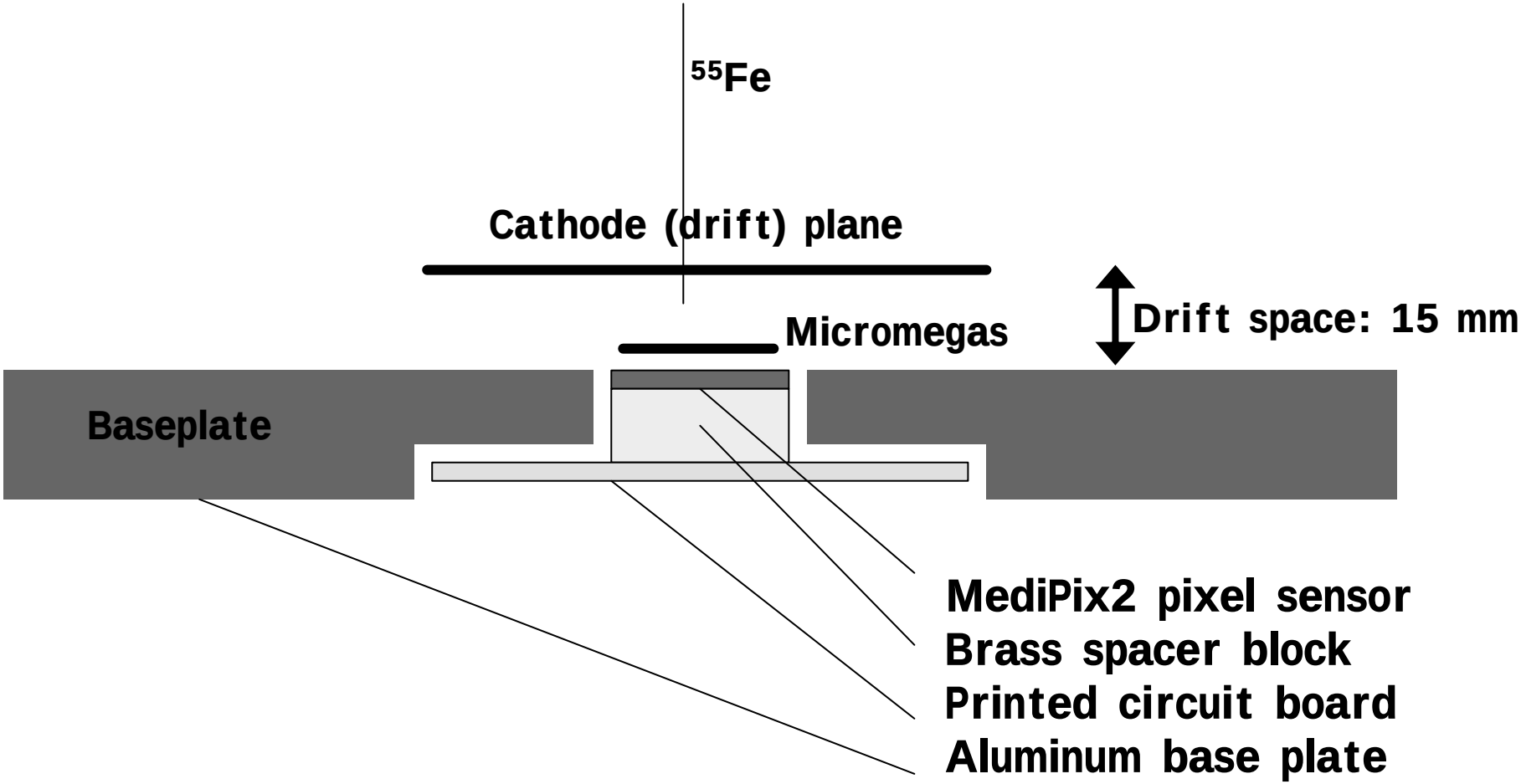
Fiducial field:
14 x 14 mm²

Collected ionisation
in 14 x 14 x 100 mm^3
during exposure time
Gas: Ar/Isobutane 90/10



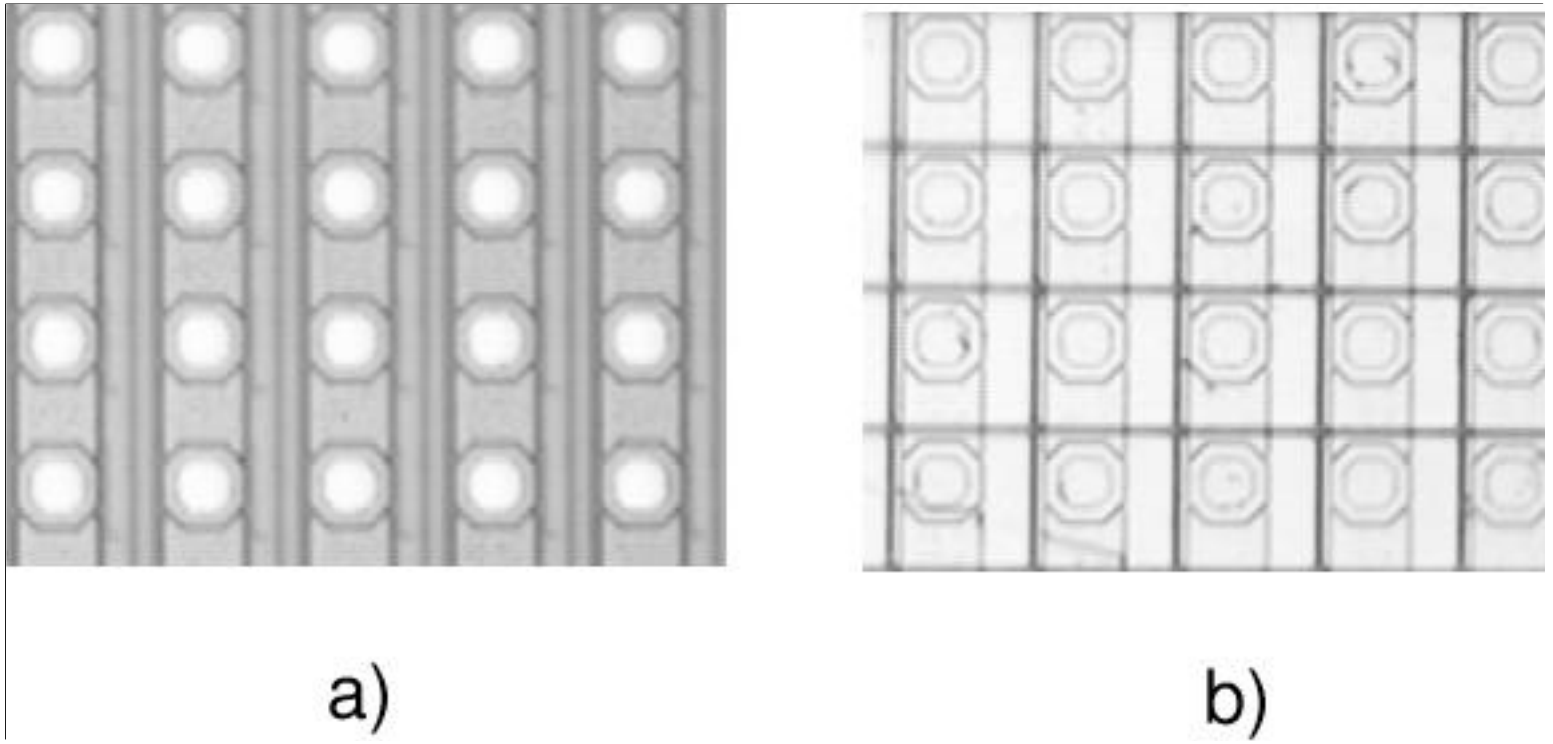
^{90}Sr source; exposed 0.01 s

With Paul Colas & Yannes Giomataris: MediPix2 & Micromegas



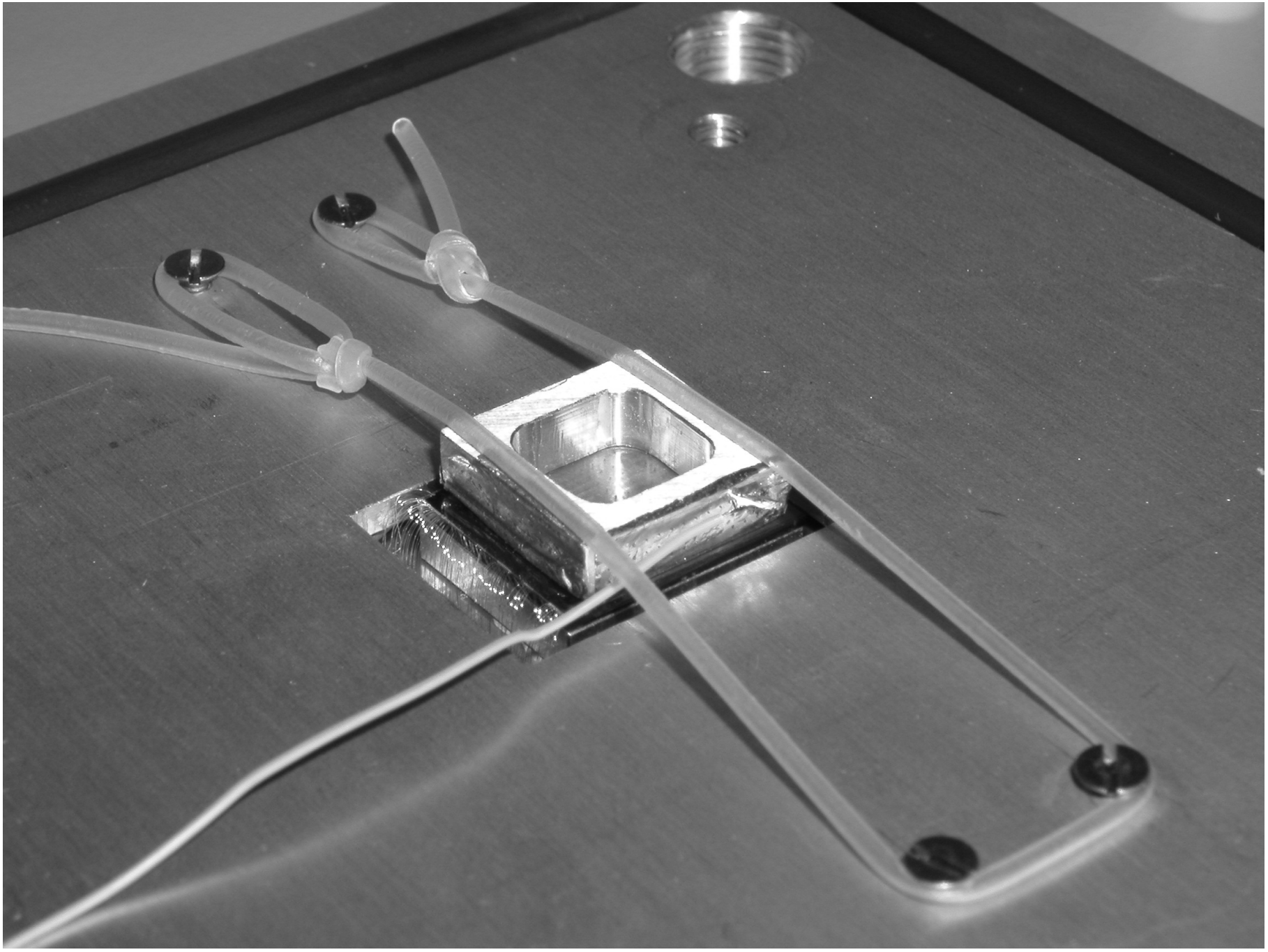
Very strong E-field above (CMOS) MediPix!

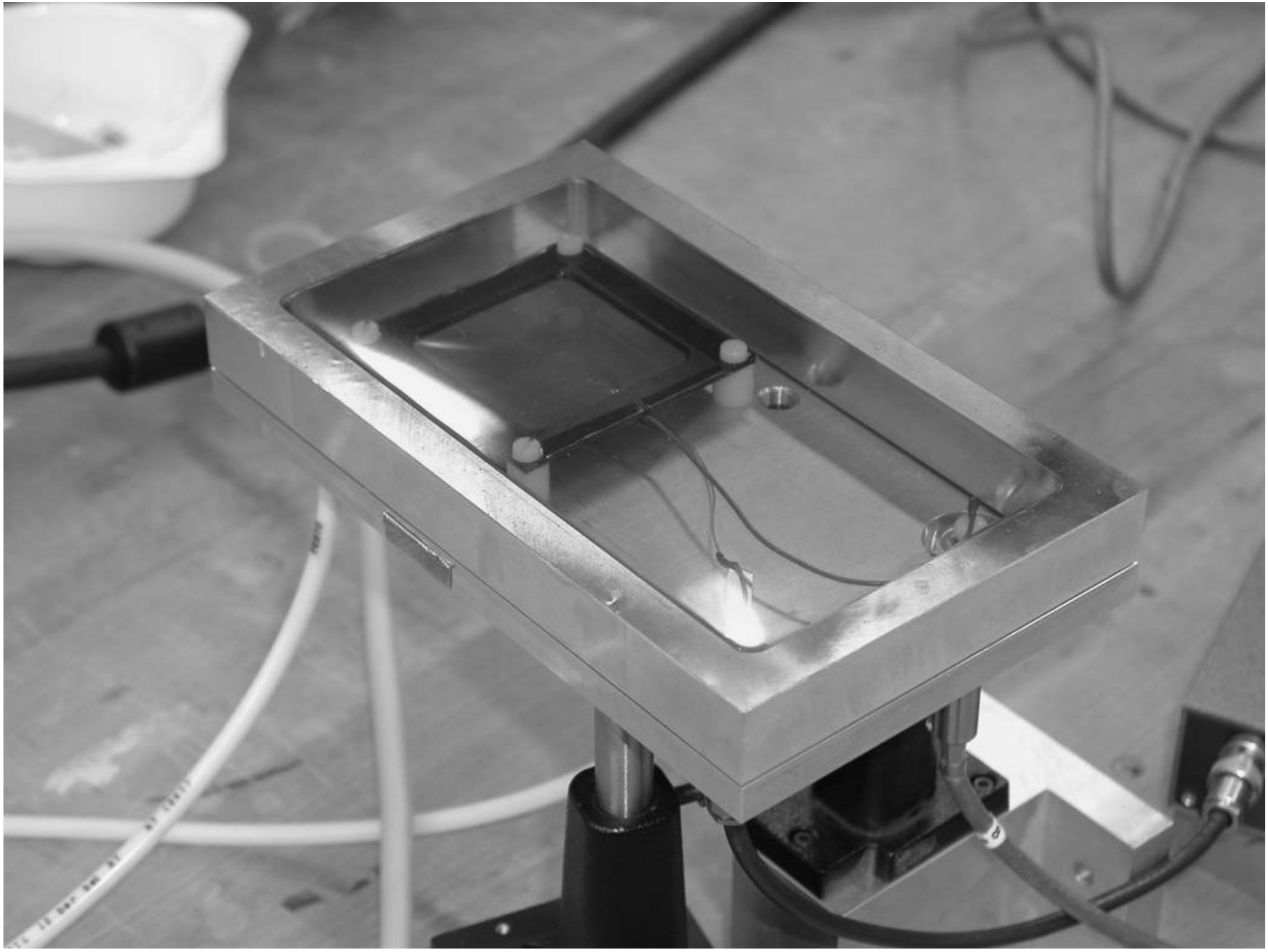
MediPix modified by MESA+, Univ. of Twente, The Netherlands

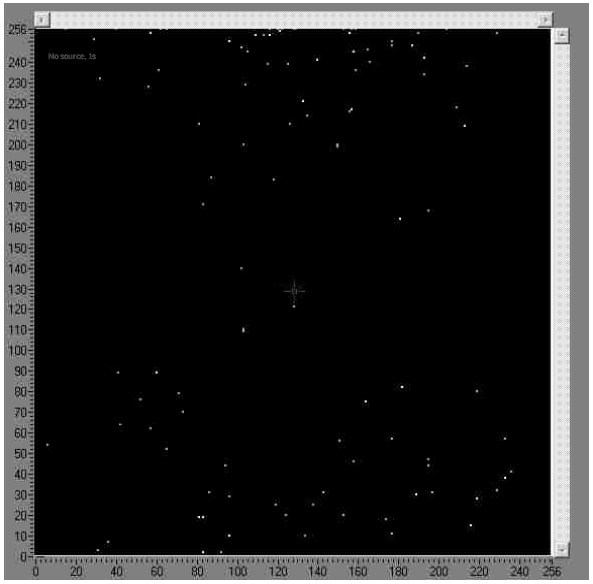


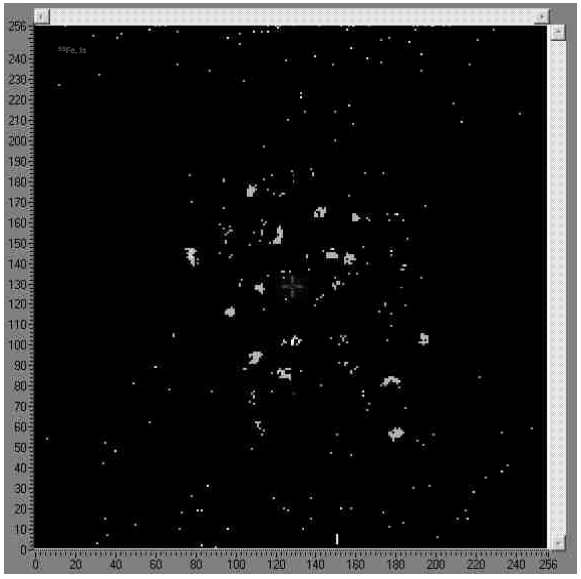
Pixel Pitch: 55 x 55 μm^2
Bump Bond pad: 25 µm octagonal
75 % surface: pacivation SiN
New Pixel Pad: 45 x 45 μm^2

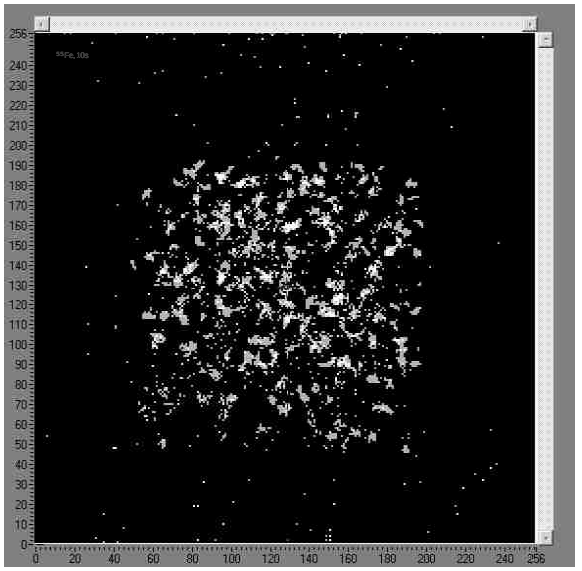
Insulating surface was 75 %
Reduced to 20 %







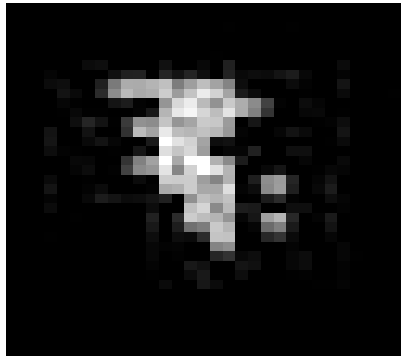


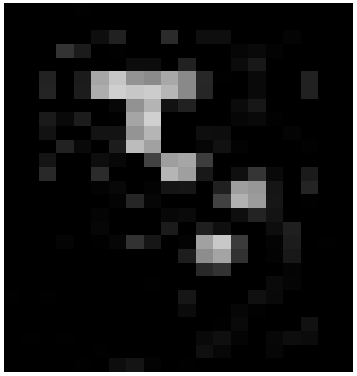


Friday 13 (!) Feb 2004: signals from a ^{55}Fe source (220 e- per photon); 300 ?m x 500 ?m clouds as expected

The Medipix CMOS chip faces
an electric field of 350 V/50 µm

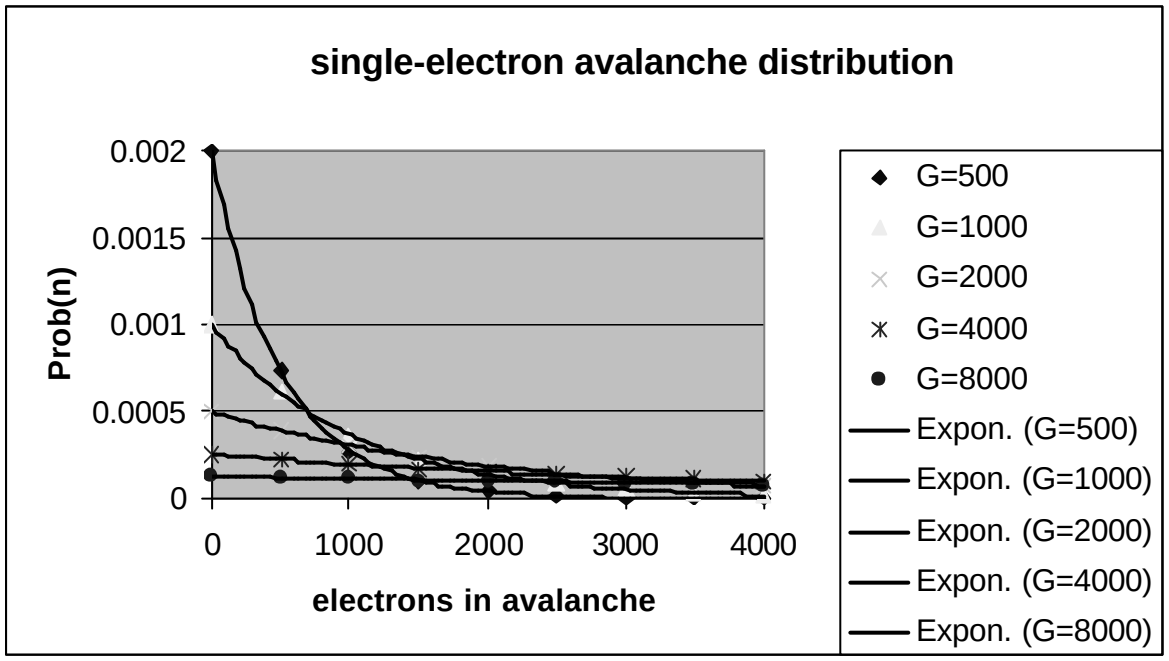
= 7 kV/mm !!





We always knew, but never saw: the conversion of ^{55}Fe quanta in Ar gas

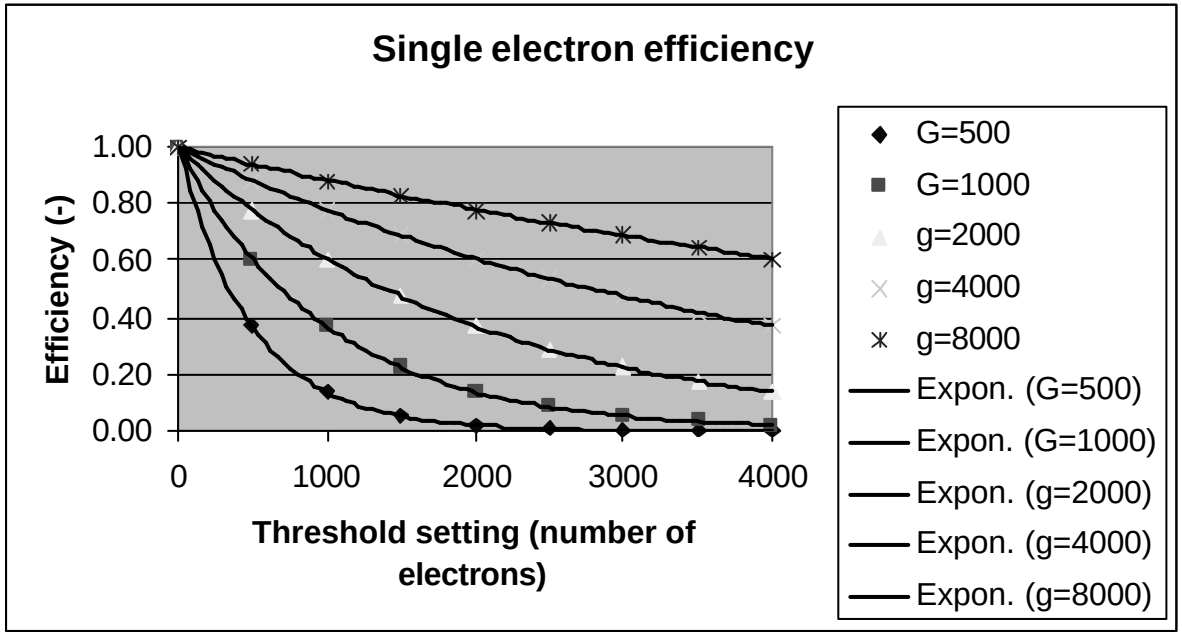
Single electron efficiency



- no attachment
- homogeneous field in avalanche gap
- low gas gain

No Curran or Polya distributions but simply:

$$Prob(n) = 1/G \cdot e^{-n/G}$$



$$Eff = e^{-Thr/G}$$

Thr: threshold setting (#e-)
G: Gas amplification

New trial: NIKHEF, March 30 – April 2, 2004
Essential: try to see single electrons from cosmic muons (MIPs)

Pixel preamp threshold: 3000 e-
Required gain: 5000 – 10.000

New Medipix
New Micromegas

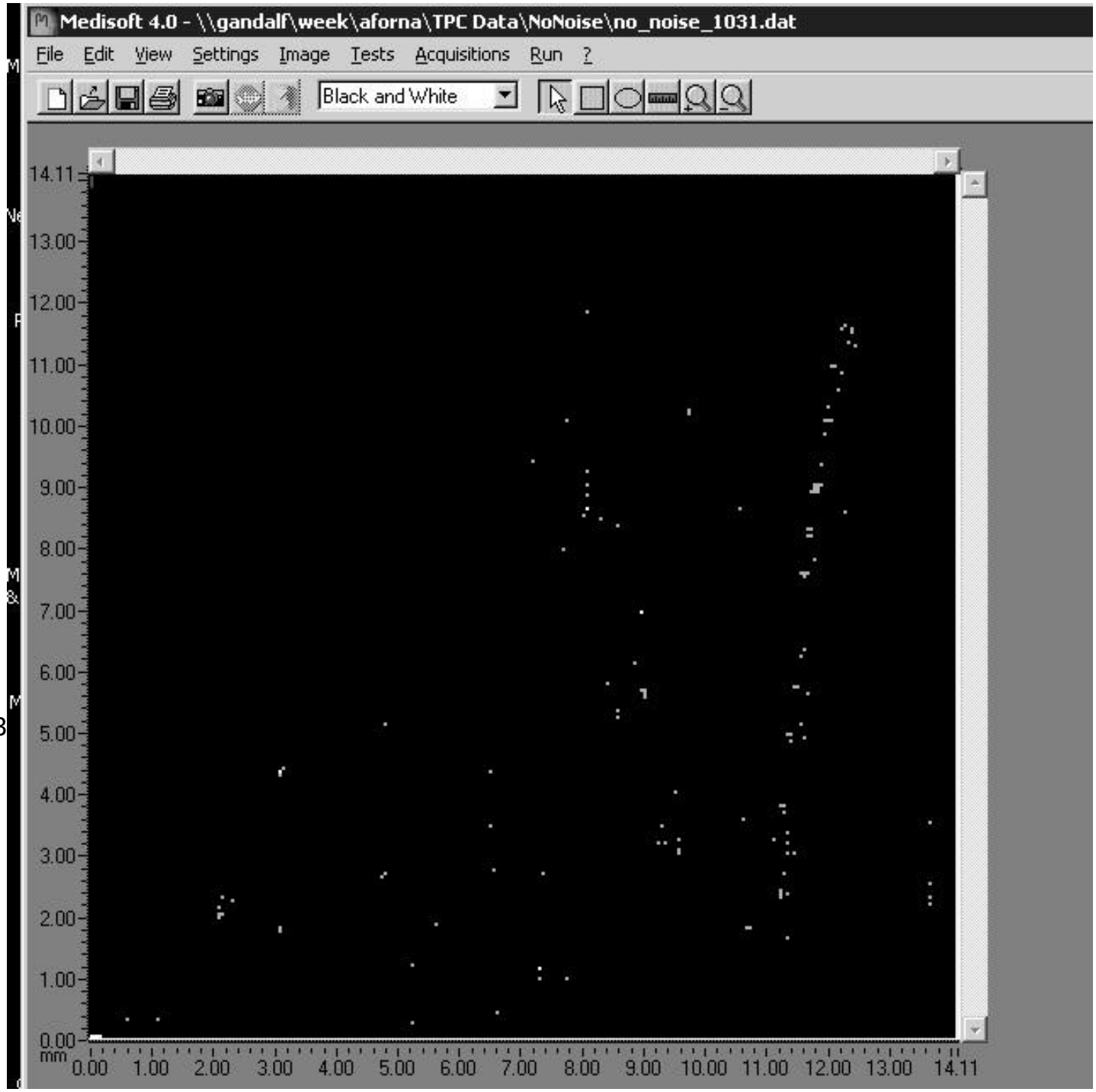
Gas: He/Isobutane 80/20
Ar/Isobutane 80/20
He/CF4 80/20

…… It Works!

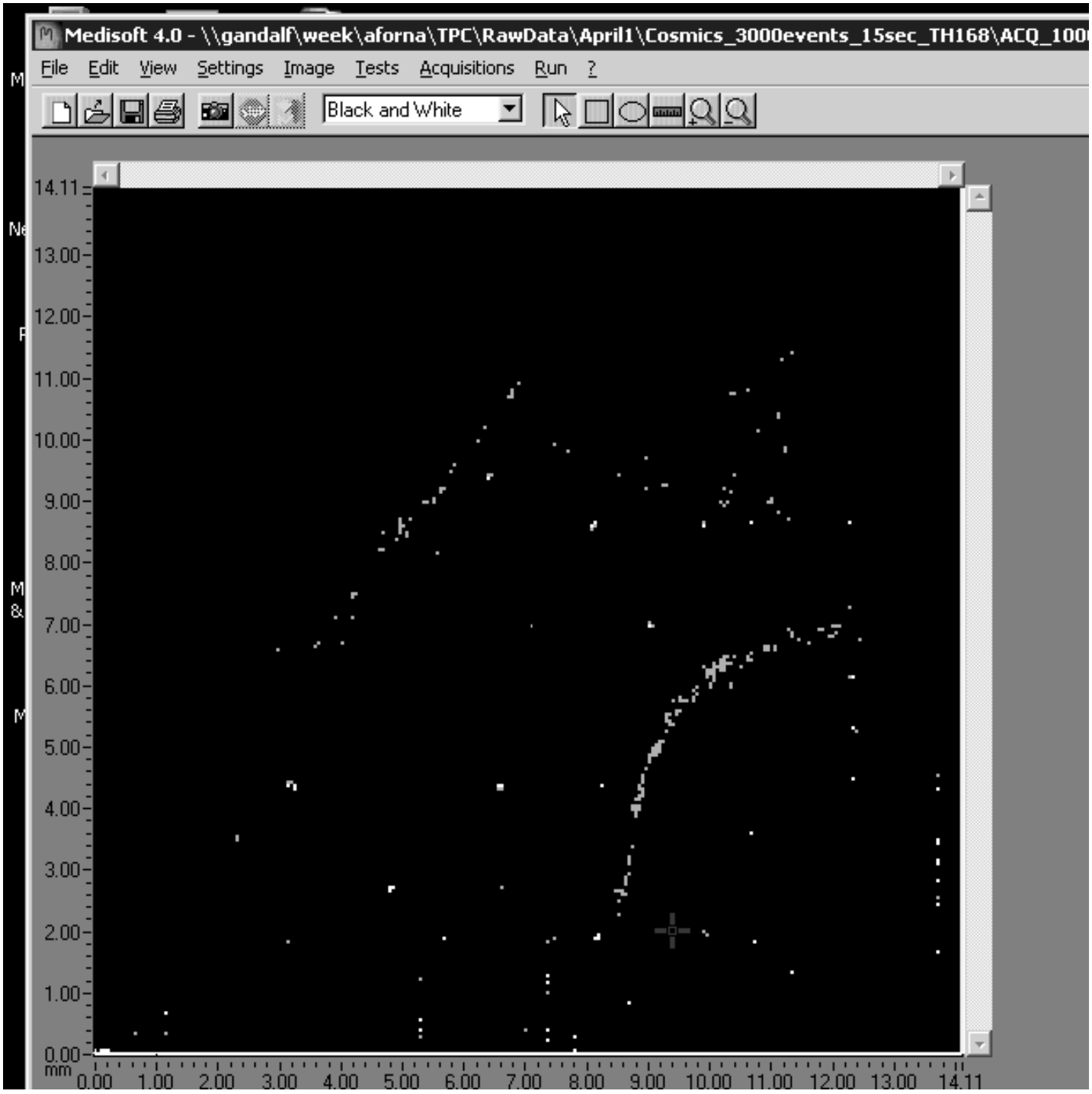
He/Isobutane
80/20
Modified MediPix

Sensitive area:
14 x 14 x 15 mm^3

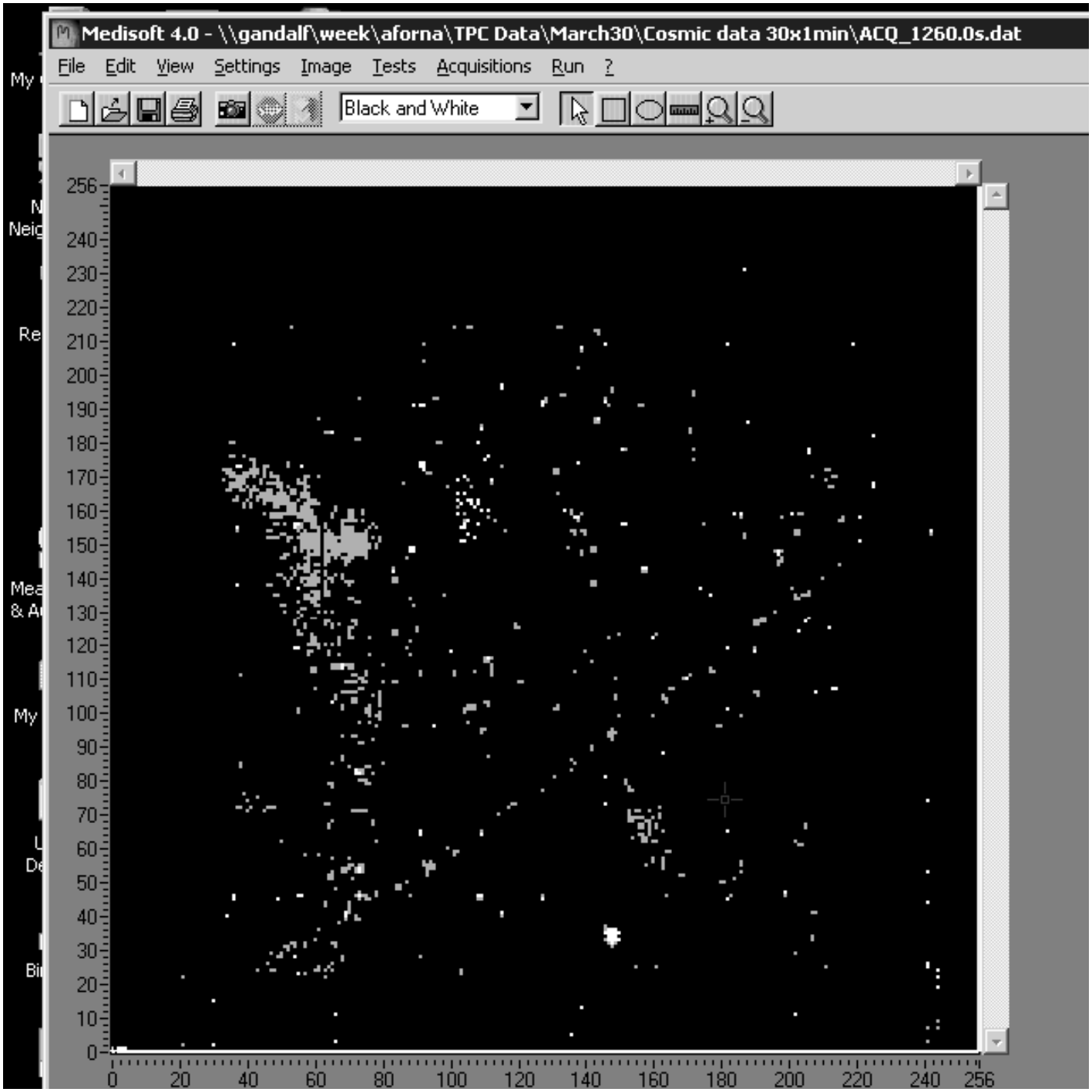
Drift direction:
Vertical
max = 15 mm



He/Isobutane
80/20
Modified MediPix

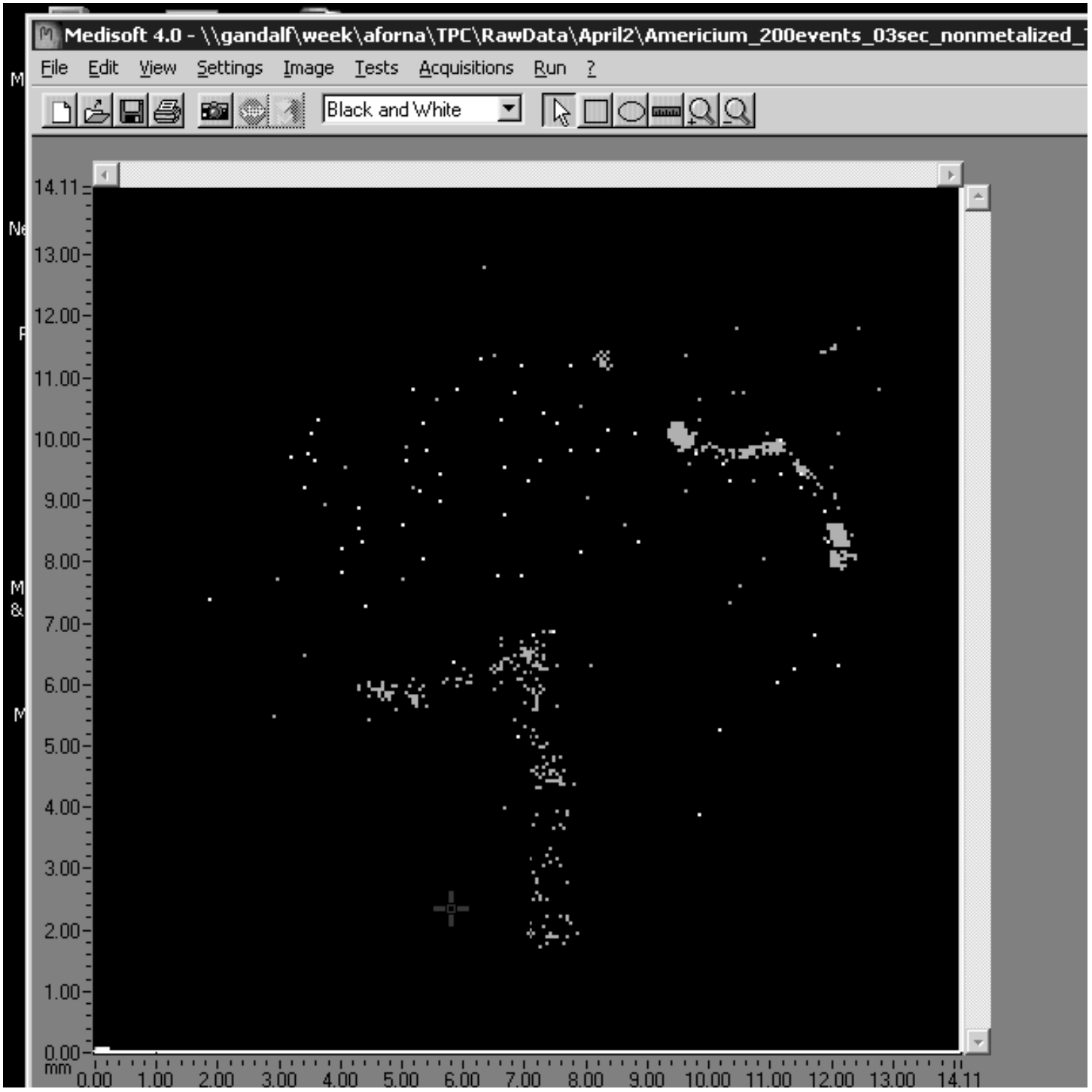


He/Isobutane
80/20
Modified MediPix

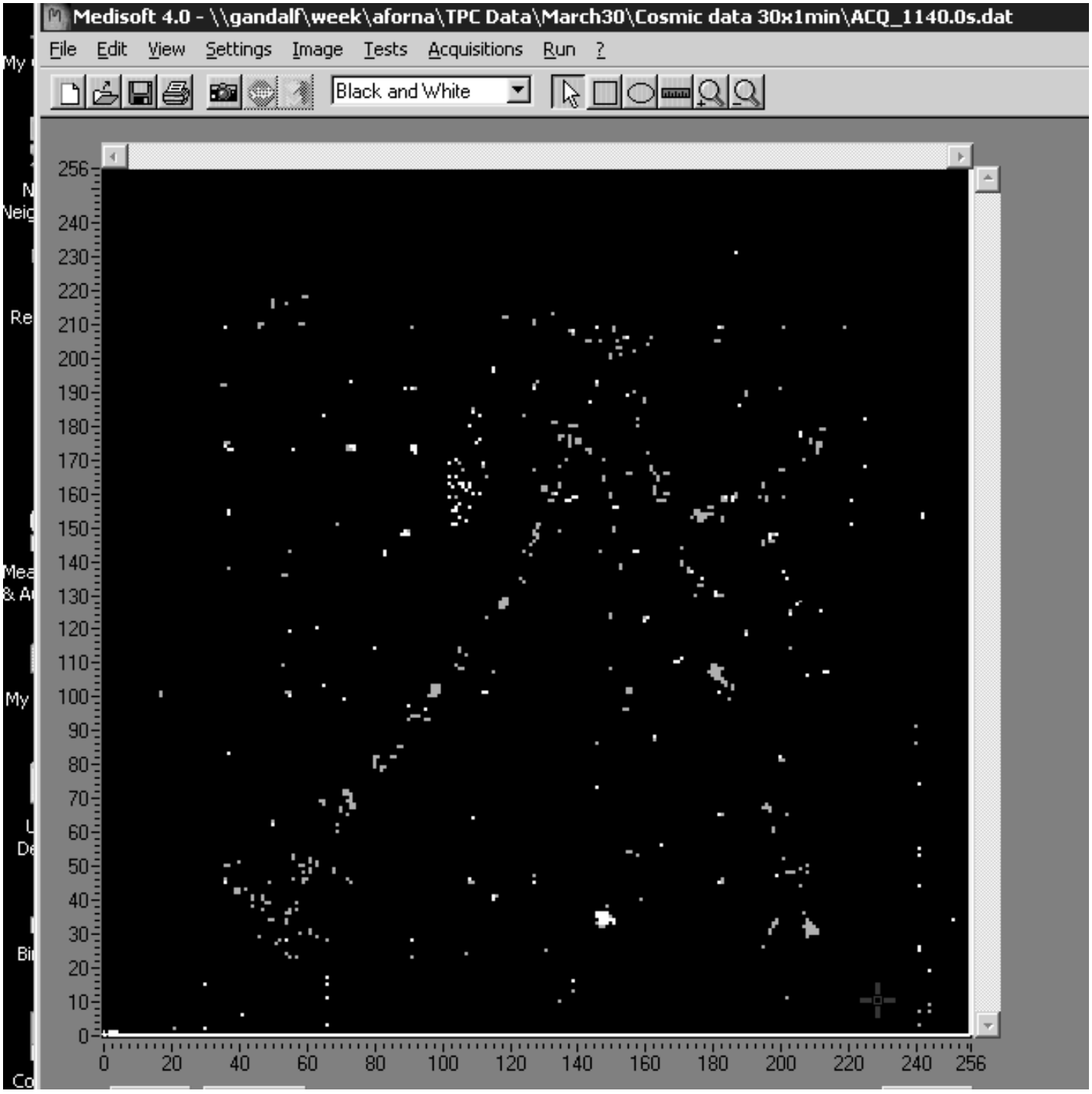


He/Isobutane
80/20
Non Modified
MediPix

Amaricium Source

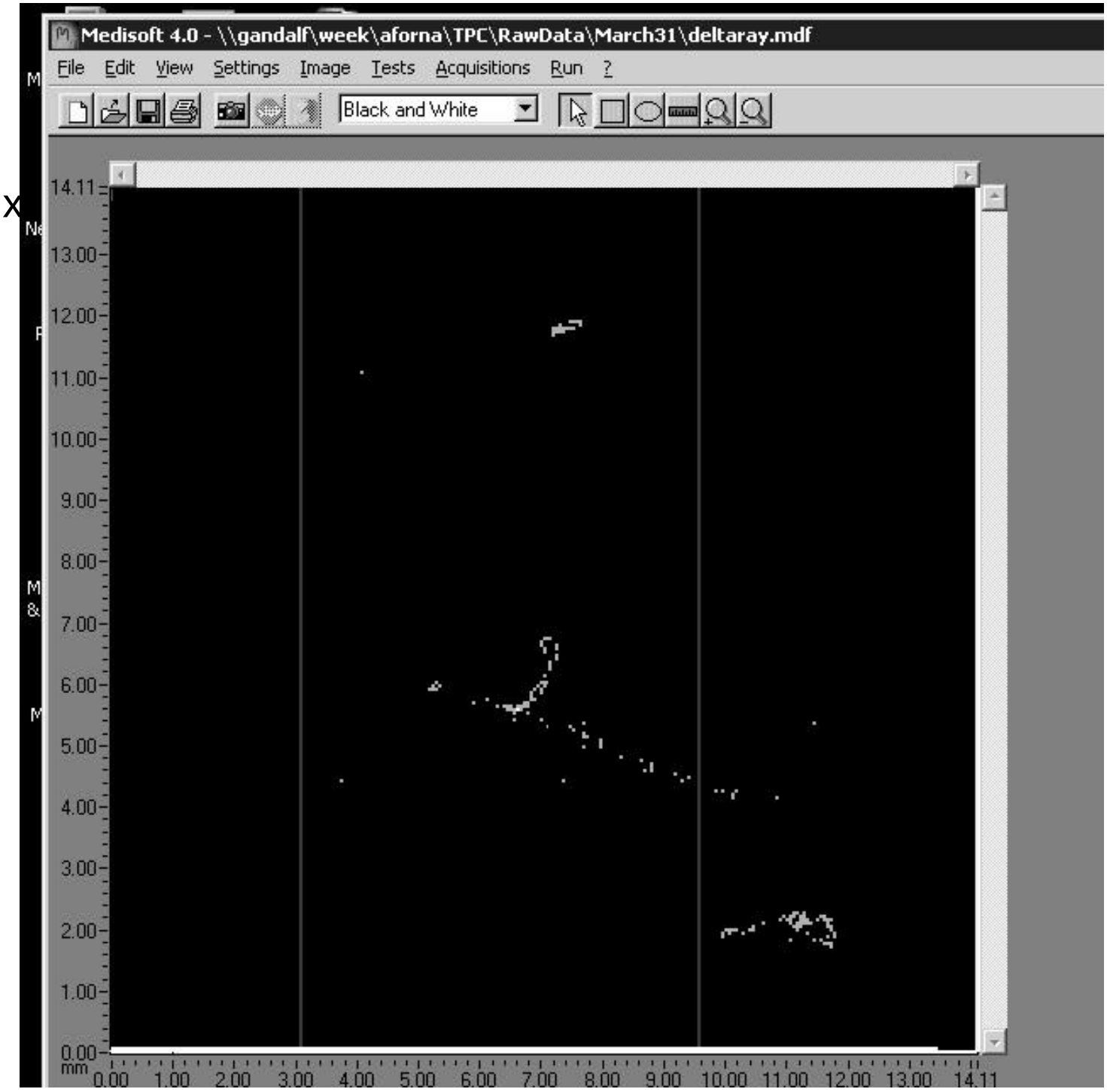


He/Isobutane
80/20
Modified MediPix



He/Isobutane
80/20
Modified MediPix

d-ray?



Nice!

- We can reach very high gas gains with He-based gases (> 100k!)
- The MedPix2 chip can withstand strong E-fields (10 kV/mm!)
- Discharges ruin the chip immediately (broke 4 in 4 days!)
- Efficiency: looks like > 0.9; consistent with high gain
- Seen MIPs, clusters, d-rays, electrons, a 's.....

Analysis is in progress:
- expected number of clusters in used gas (theory, literature)
- spectral distribution of number of electrons per cluster
- single electron efficiency as a function of gain: calibration

Plans for the next weeks:
- Add Cosmic Ray Trigger (two scintillators + absorber) to make efficient MIP data taking possible
- Single electron data from cosmic MIPs: vary:
  - HV (gain)
  - Gas composition (Ar/He, Isobutane/CF4)

in 2004: Beam tests (dE/dX: e-, pions, muons,.....)

For TPC group:

- Simulations: TPC performance in view of single electron detection:
  - spatial resolution (= momentum resolution)
  - precision dE/dX by cluster counting (M. Hauschild)
  - multi track separation
  - corrections for scattering
  - d-ray suppression

  Low diffusion
  low number of clusters?

- Form collaboration to develop TimePix CMOS pixel chip:
  - based on MediPix: change pixel counters into TDCs
  - require full scale! Submit costs 150 kE for 6 wafers...
  - MediPix Consortium (CERN based) likes to design TimePix1

Integrate GEM/Micromegas and pixel sensor: InGrid

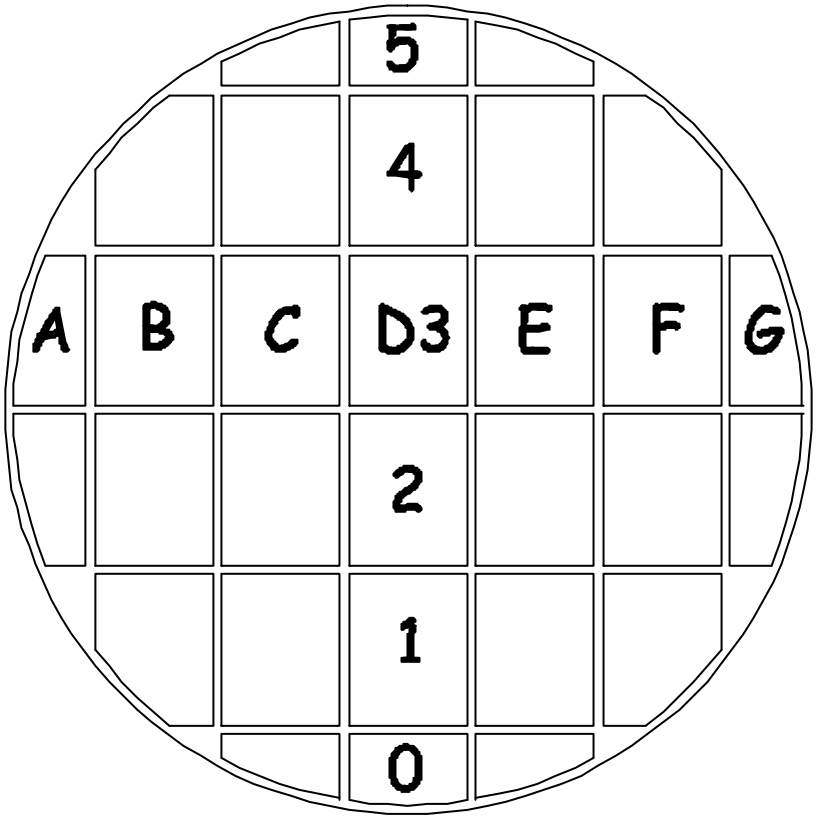
‘GEM’

‘Micromegas’

By ‘wafer post processing’

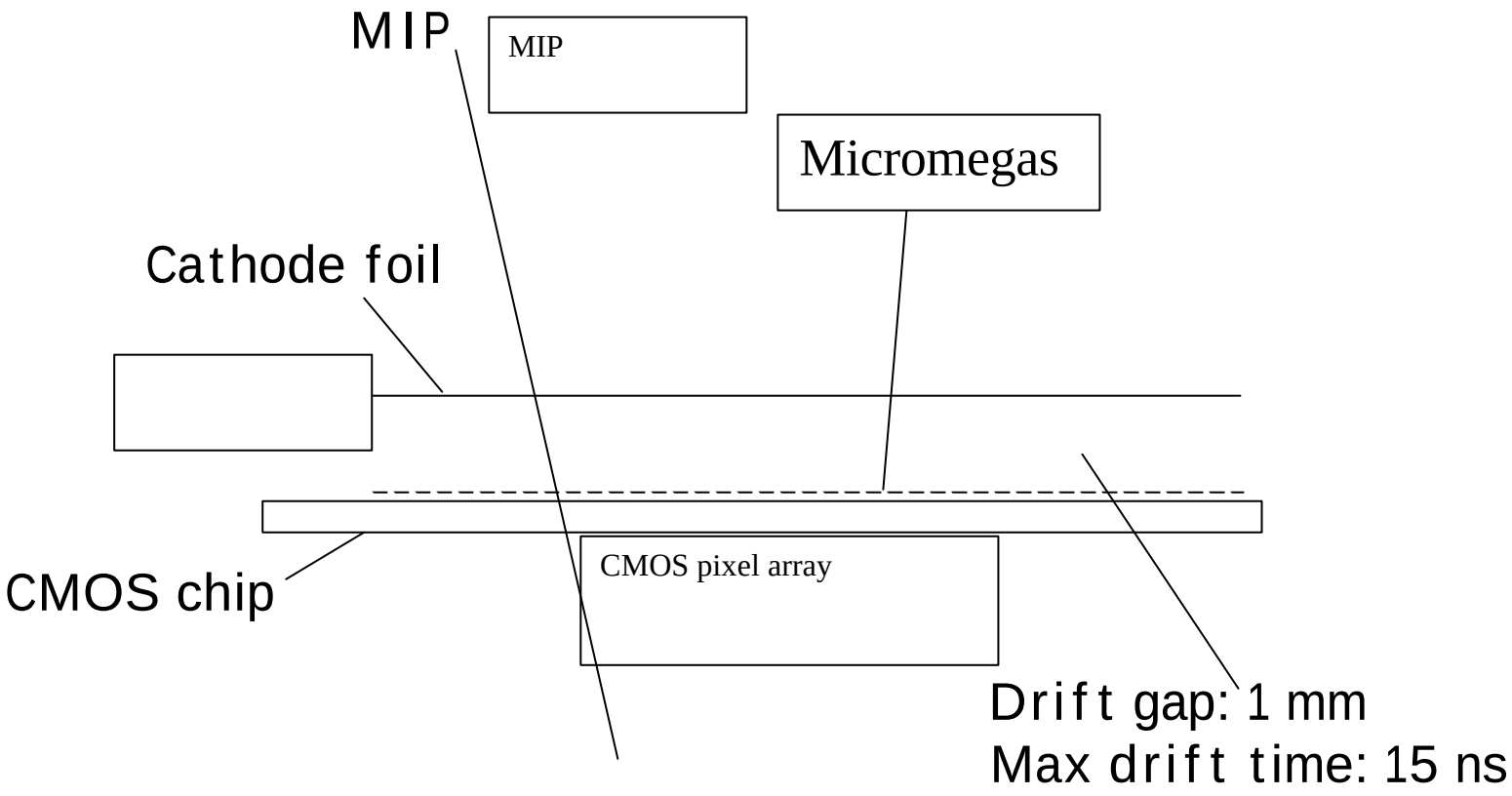
First InGrid expected in June

Wafer dia.: 100 mm
30 fields with variety of pillar geometry



Other applications of TimePixGrid:

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



GOSSIP: Gas On Slimmed SIlicon Pixels

Ageing: GEMs & Micromegas do not age (Alfonsi, Colas)

Spatial resolution: pixels down to 20x 20 μm^2

After all: TPC! 3D track info

Counting rate: 10 tracks/ (cm^2 25 ns): ions reach grid within 30 – 50 ns

Radiation hardness:
- Replace electron-hole pair generation in Si by gas + gas amplification
- Sufficient signal charge to eliminate low-noise amplifiers in pixels
- CMOS readout circuit: only digital gates (130 nm technology)

Material budget: slimmed Si (40 µm), 1 mm gas, 2 µm alu foils

Cooling: CMOS chip power < 0.1 W/cm^2: use gas flow as cooling…..

If it works: interesting for ATLAS, CMS, LHCb, ALICE, D0 etc