Readout of a TPC using the Medipix2 CMOS pixel sensor

(detection of single electrons on a direct pixel segmented anode)

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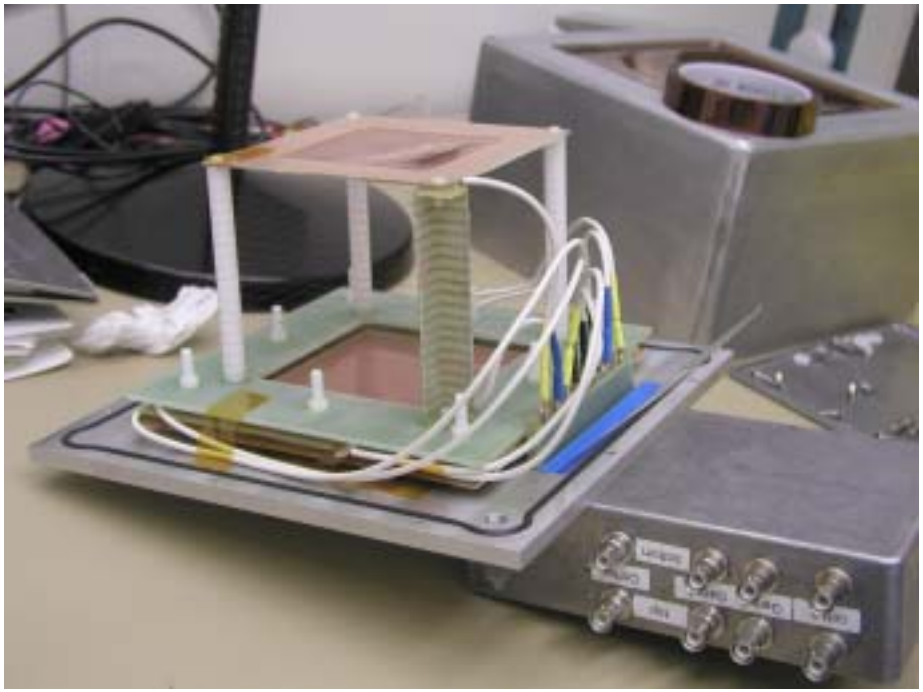
CERN/Medipix Collaboration: Erik Heijne

Thanks to: Wim Gotink
Joop Rovenkamp
Max Chefdeville

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)

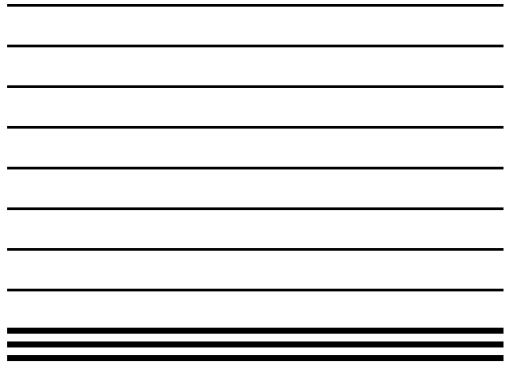
- Proof of principle based on existing Medipix2 readout chip

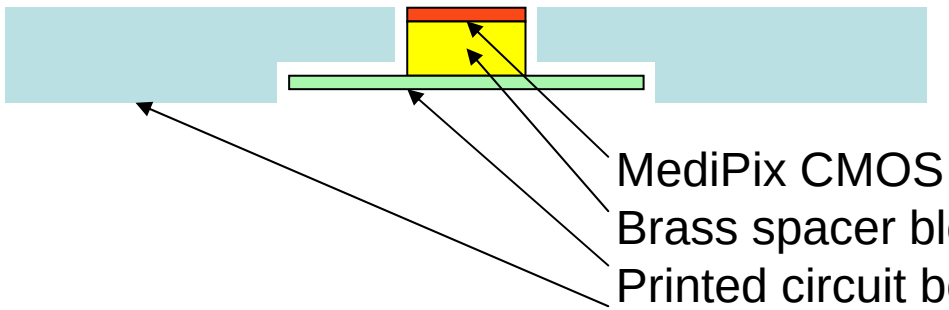


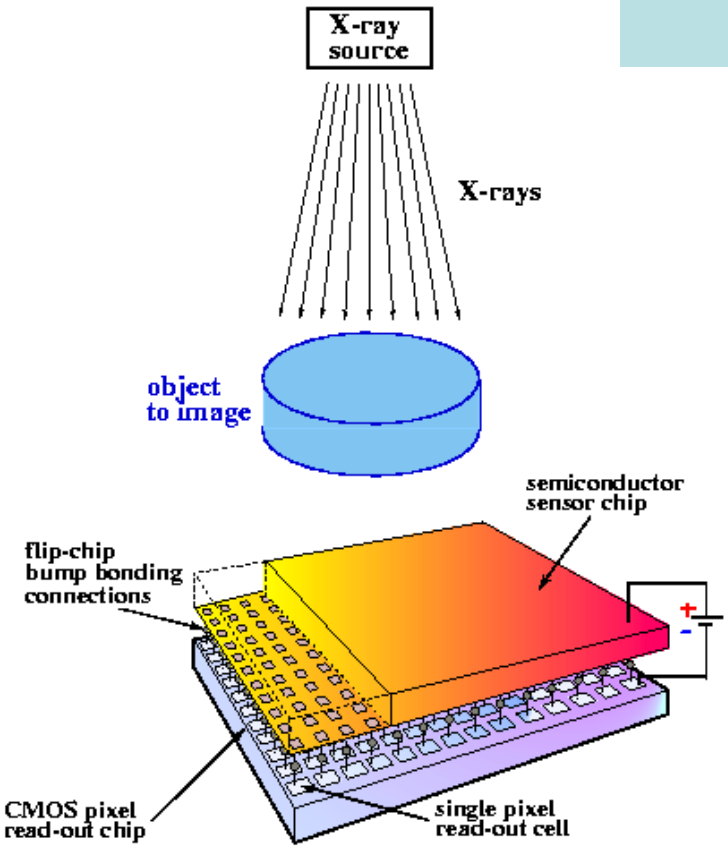
Our GEM-equipped TPC

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.

Drift length: 100 mm
Distance between GEMs: 1.6/2.6 mm
Distance bottom GEM/MEDIPIX: 6.6 mm







Medipix2: 256 x 256 pixels

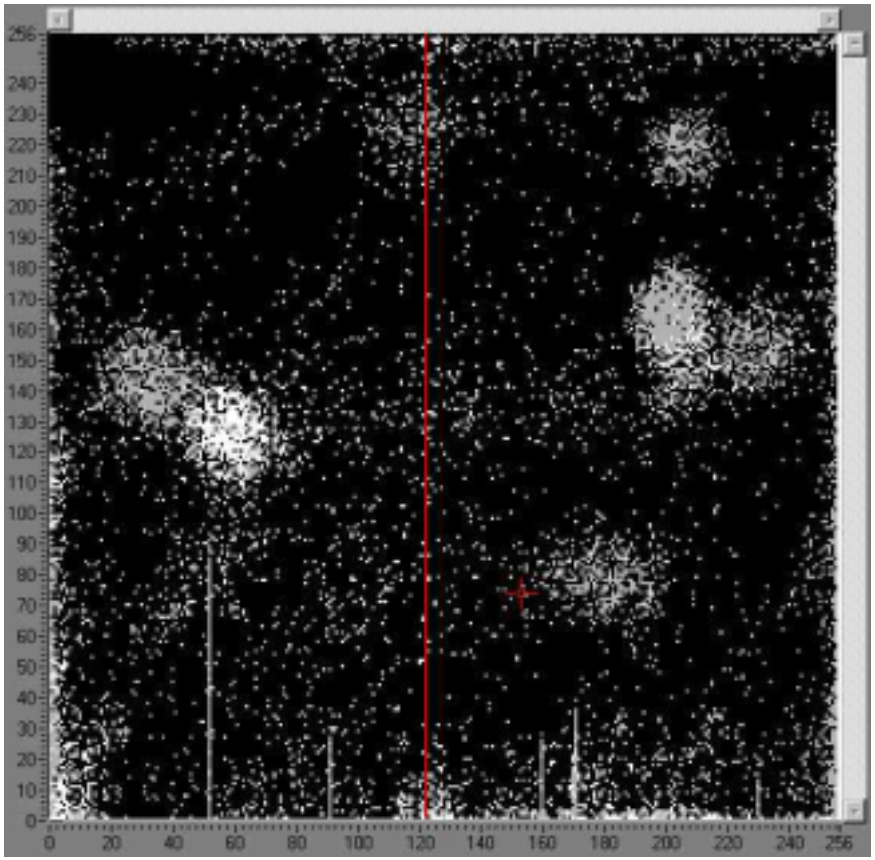
55 μm x 55 μm

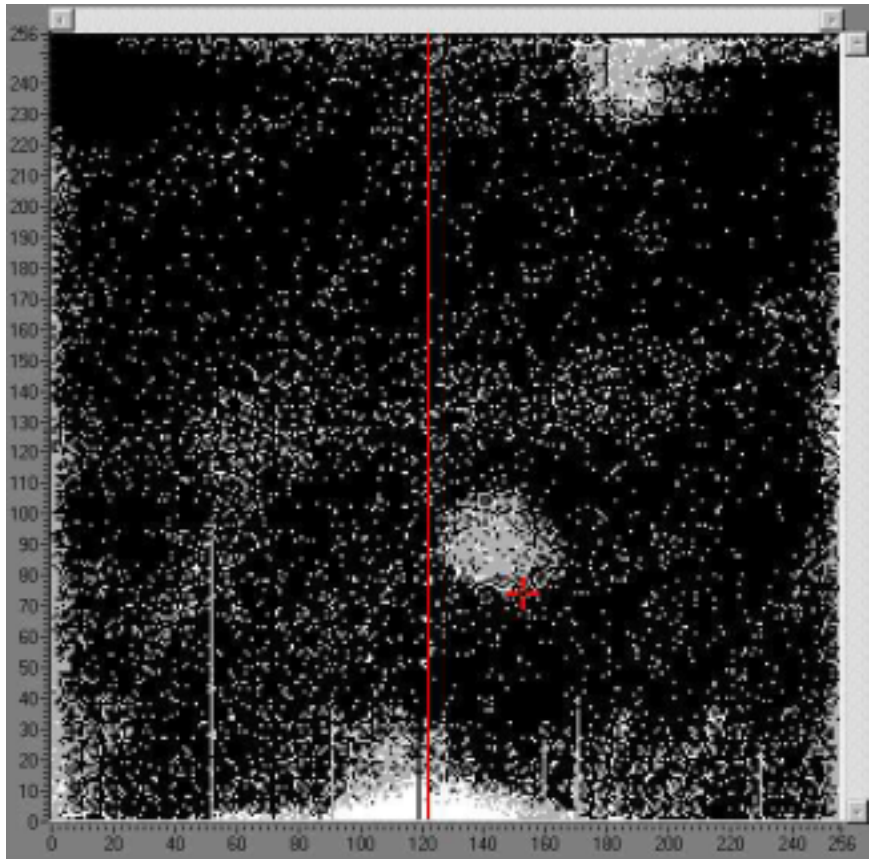
area 14 x 14 mm^2

each pixel: low-noise preamp,

discriminator, two threshold DAC,

13-bit counter, communication logic

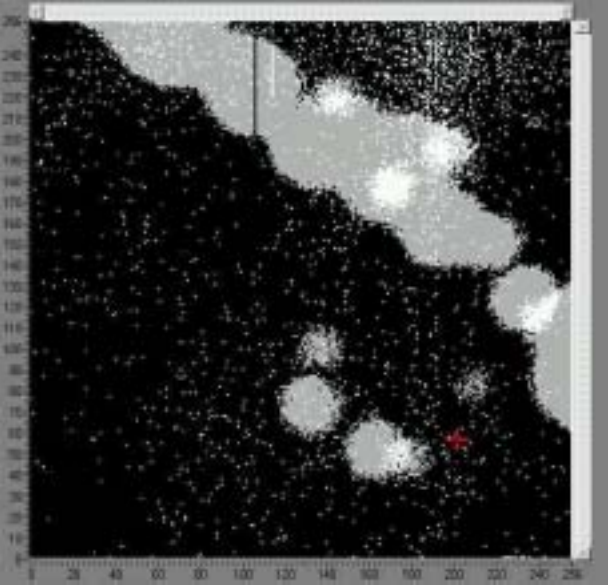




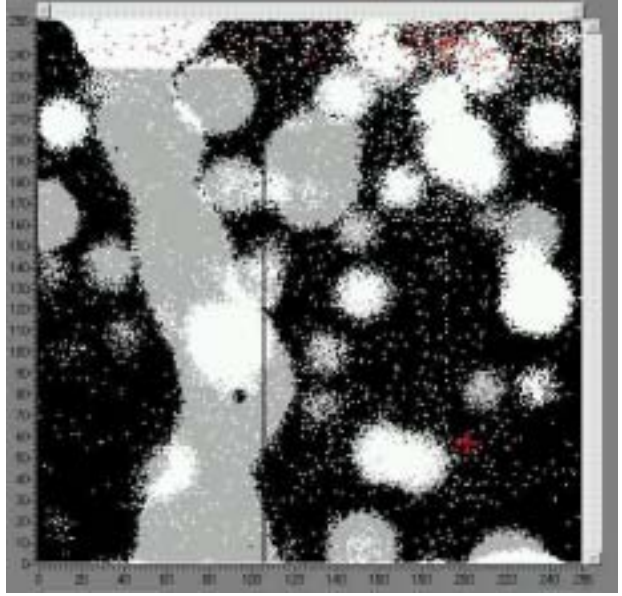
First events, recorded on March 29, 2003!
Drift space irradiated with ^{55}Fe quanta

Ar/CH_4 90/10

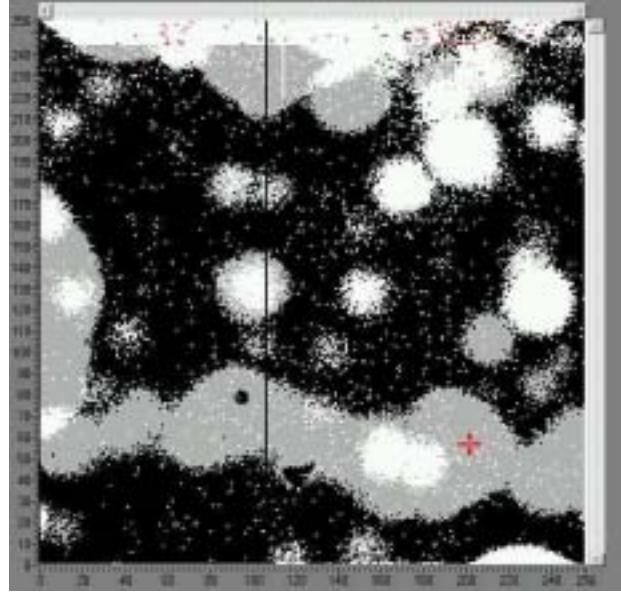
Not immediately understood. Now we do: conversion source ~0.3 mm, defocussing GEM ~0.5 mm, diffusion in driftspace ~1.5 mm



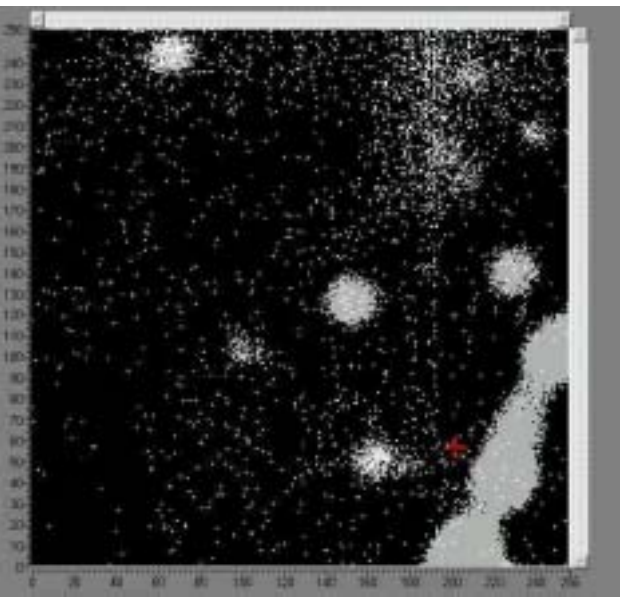
exposed 0.01 s



exposed 2 s



exposed 2 s



exposed 0.1 s

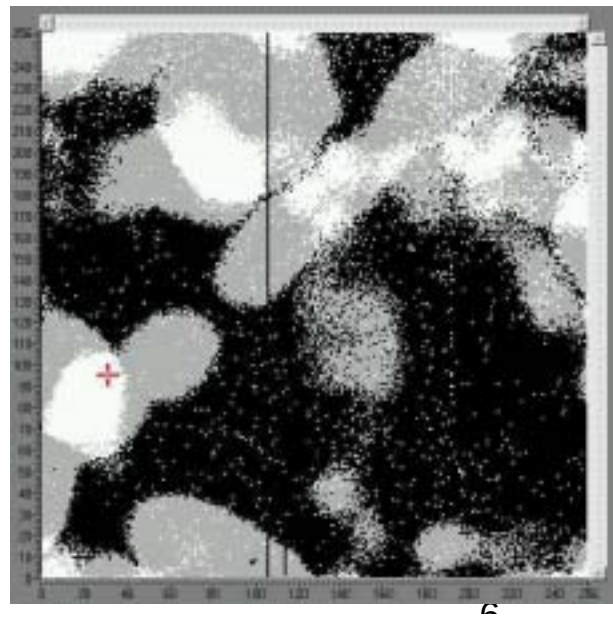
Feb 9, 2004

Ar/Isobutane 95/5

Fiducial field:
14 x 14 mm^2

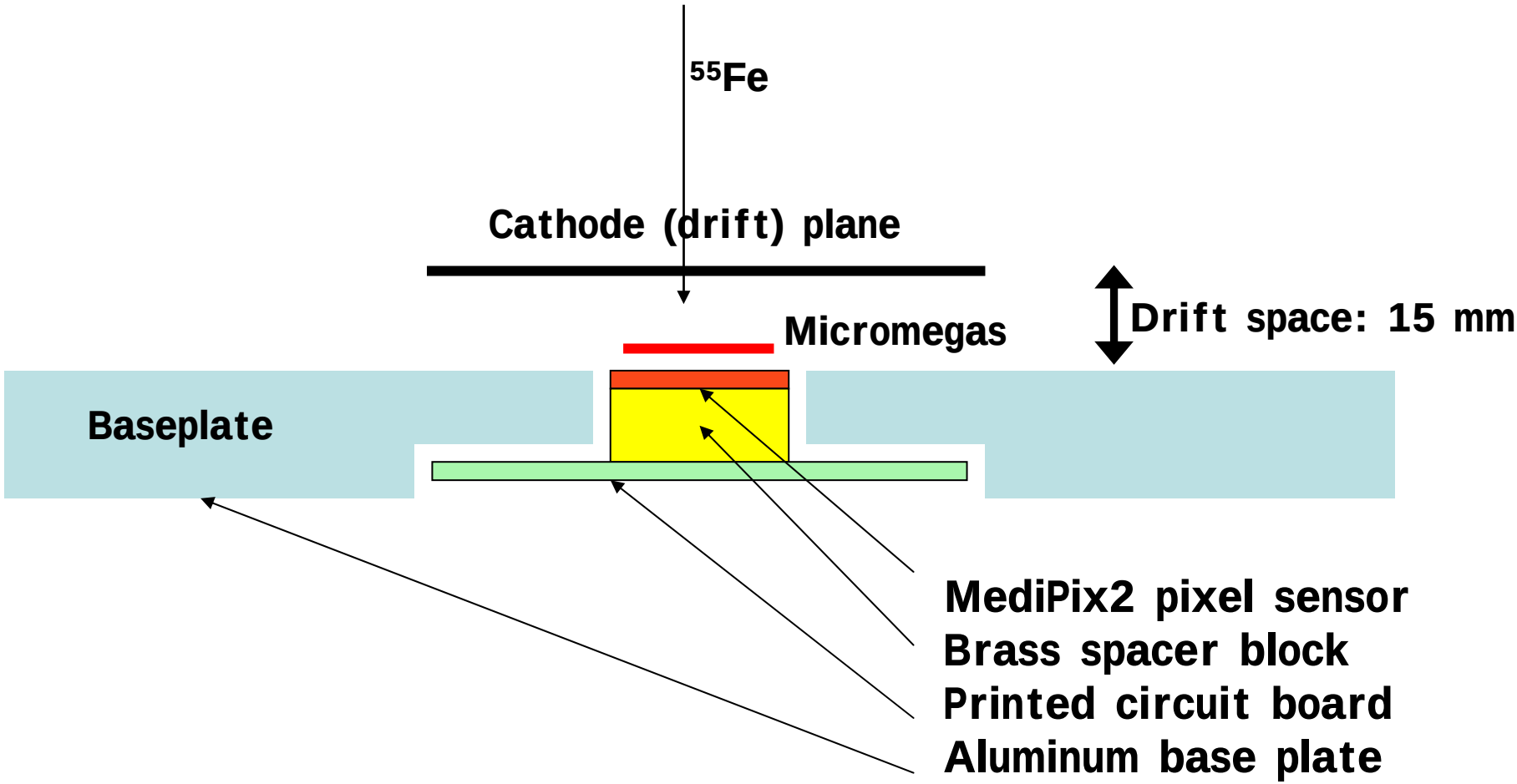
Collected ionisation
in 14 x 14 x 100 mm^3
during exposure time

LCWS 2004 Paris



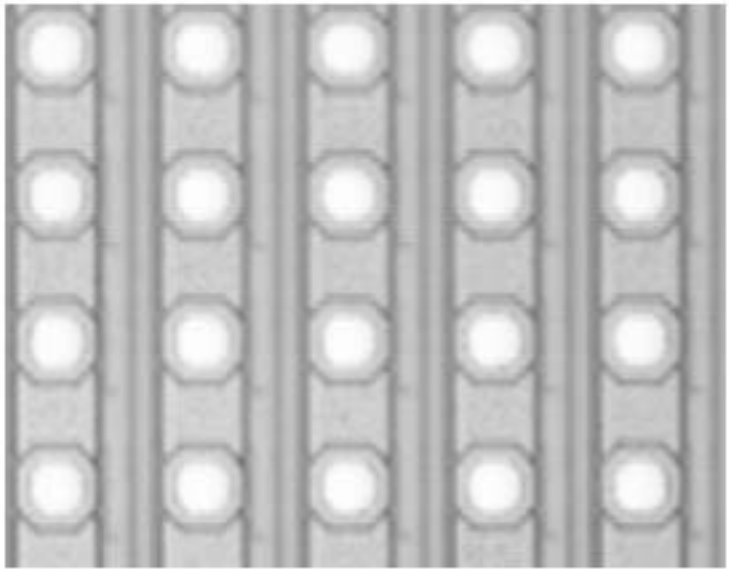
^{90}Sr source; exposed 0.01 s

With Paul Colas & Ioannis Giomataris: MediPix2 & Micromegas

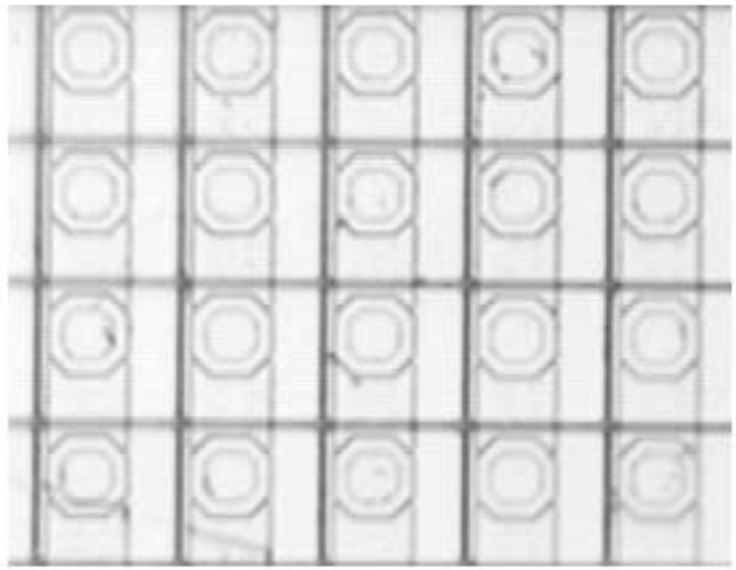


Very strong E-field above (CMOS) MediPix!

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



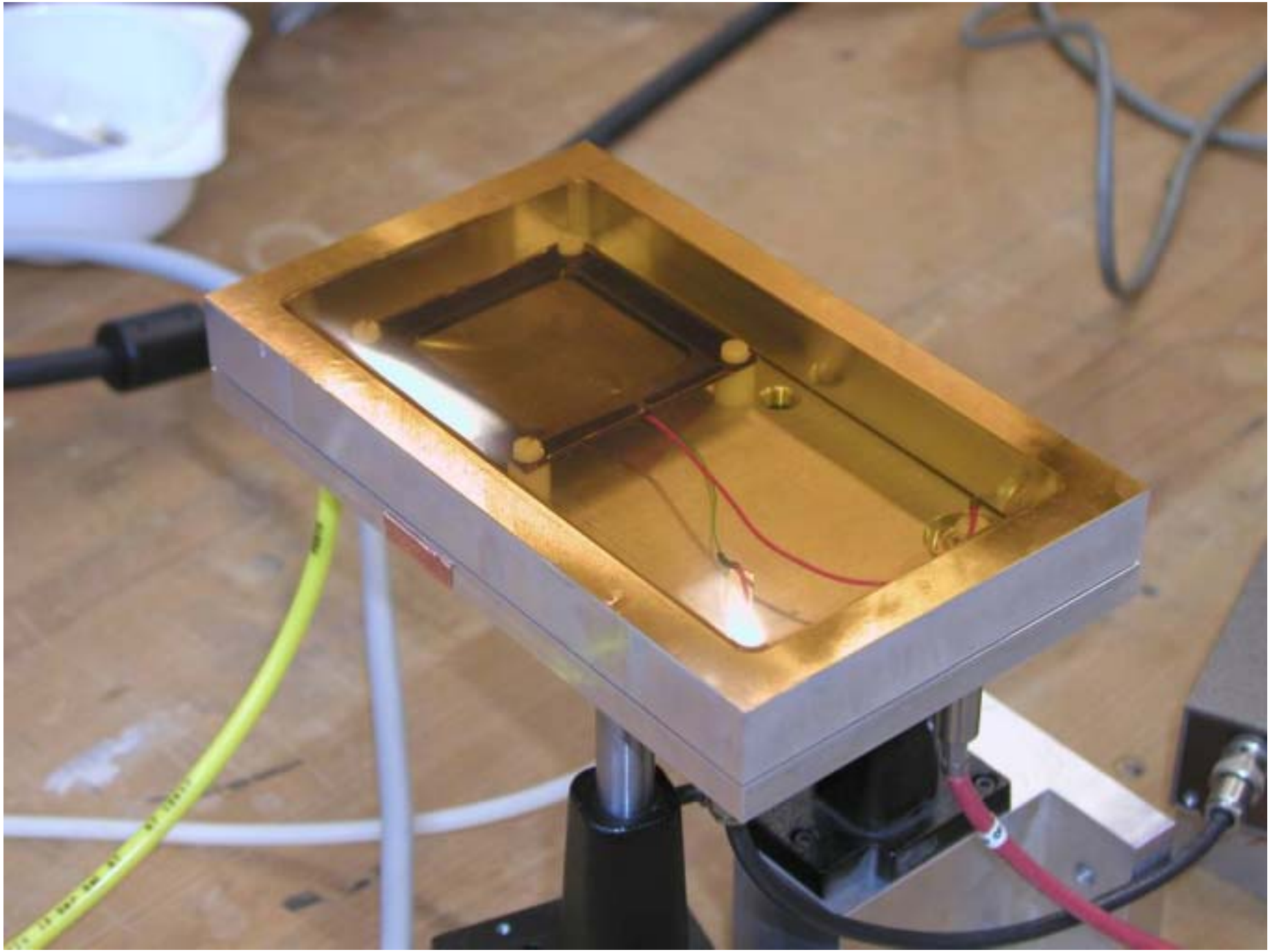
a)

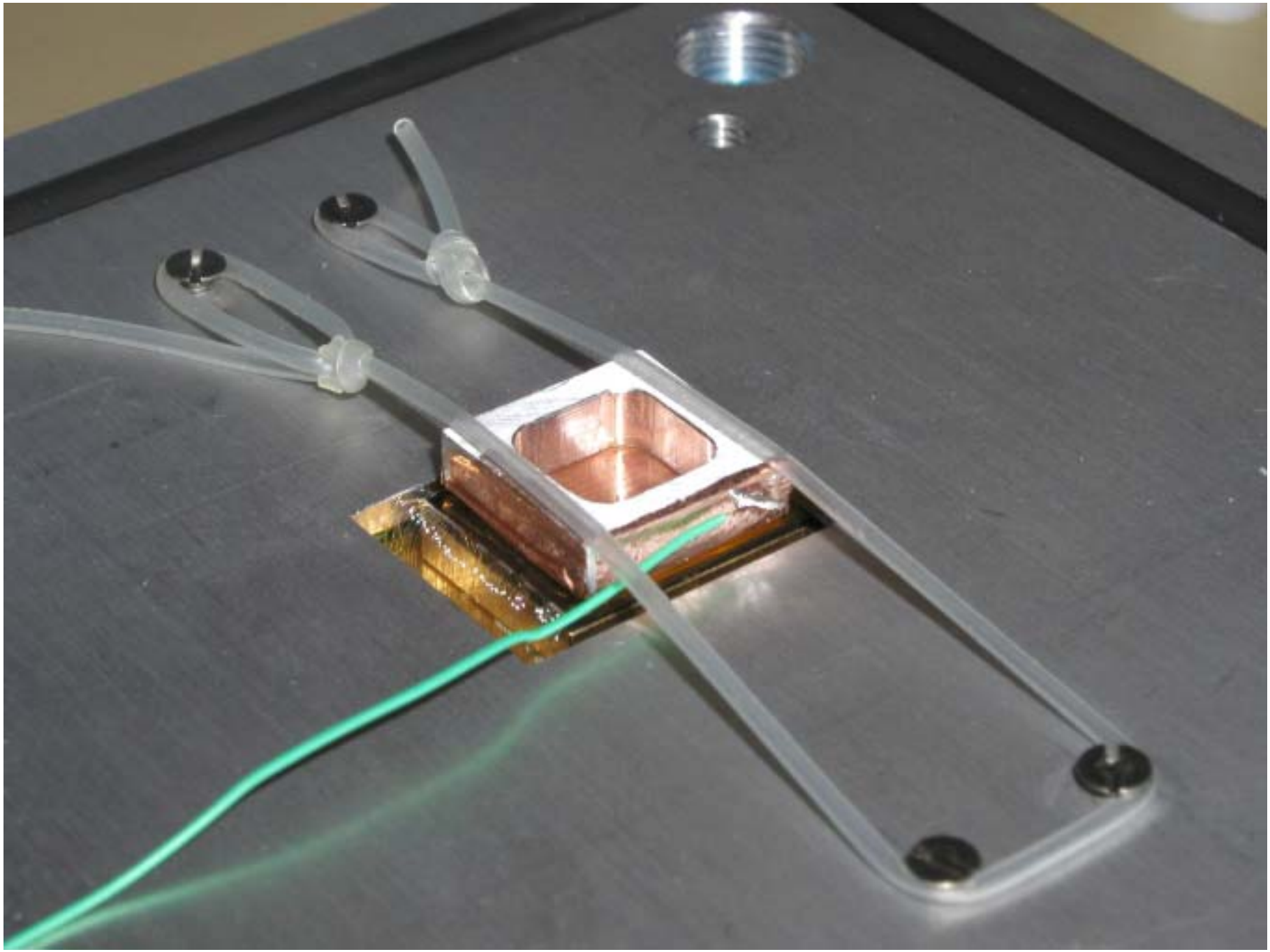


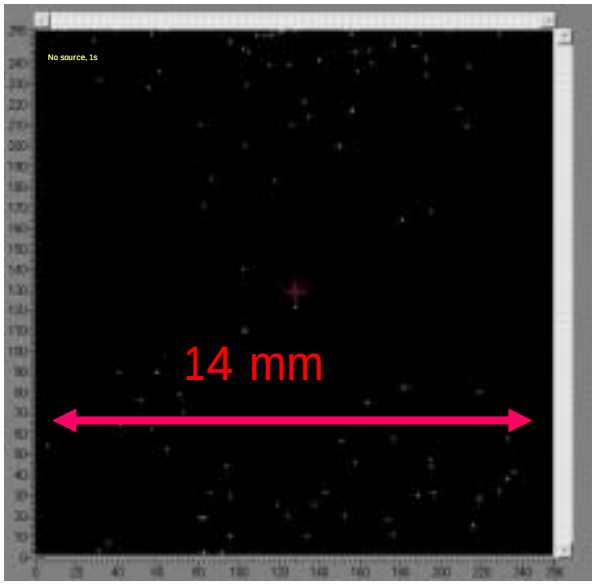
b)

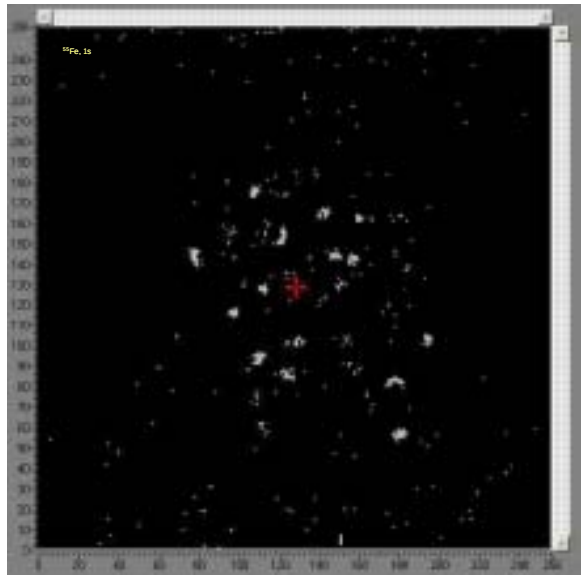
Pixel Pitch: 55 x 55 μm^2
Bump Bond pad: 25 µm octagonal
75 % surface: passivation SiN
New Pixel Pad: 45 x 45 μm^2

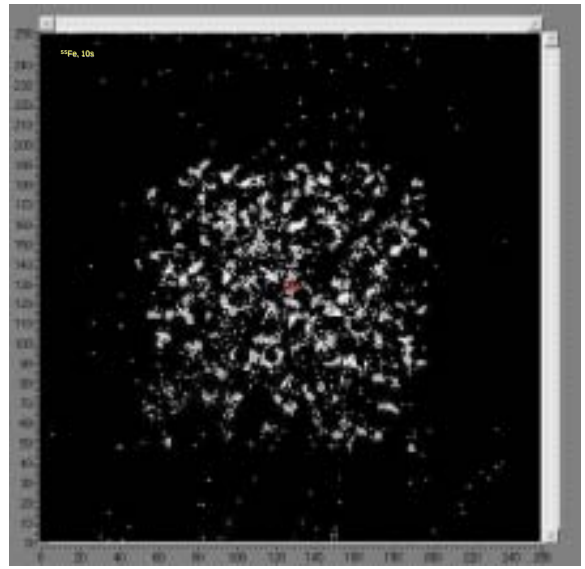
Insulating surface was 75 %
Reduced to 20 %







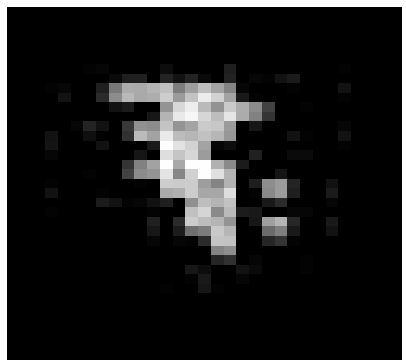


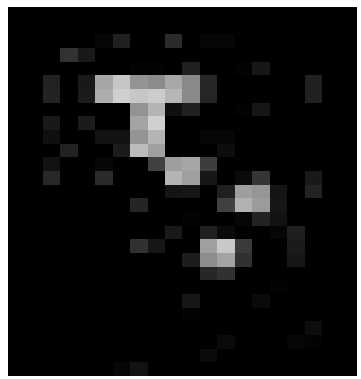


Friday 13 (!) Feb 2004: signals from a ^{55}Fe source (220 e- per photon); 300 μm x 500 μm clouds as expected

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

= 7 kV/mm !!





Ar/Isobutane 95/5

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

New trial: March 30 - April 2

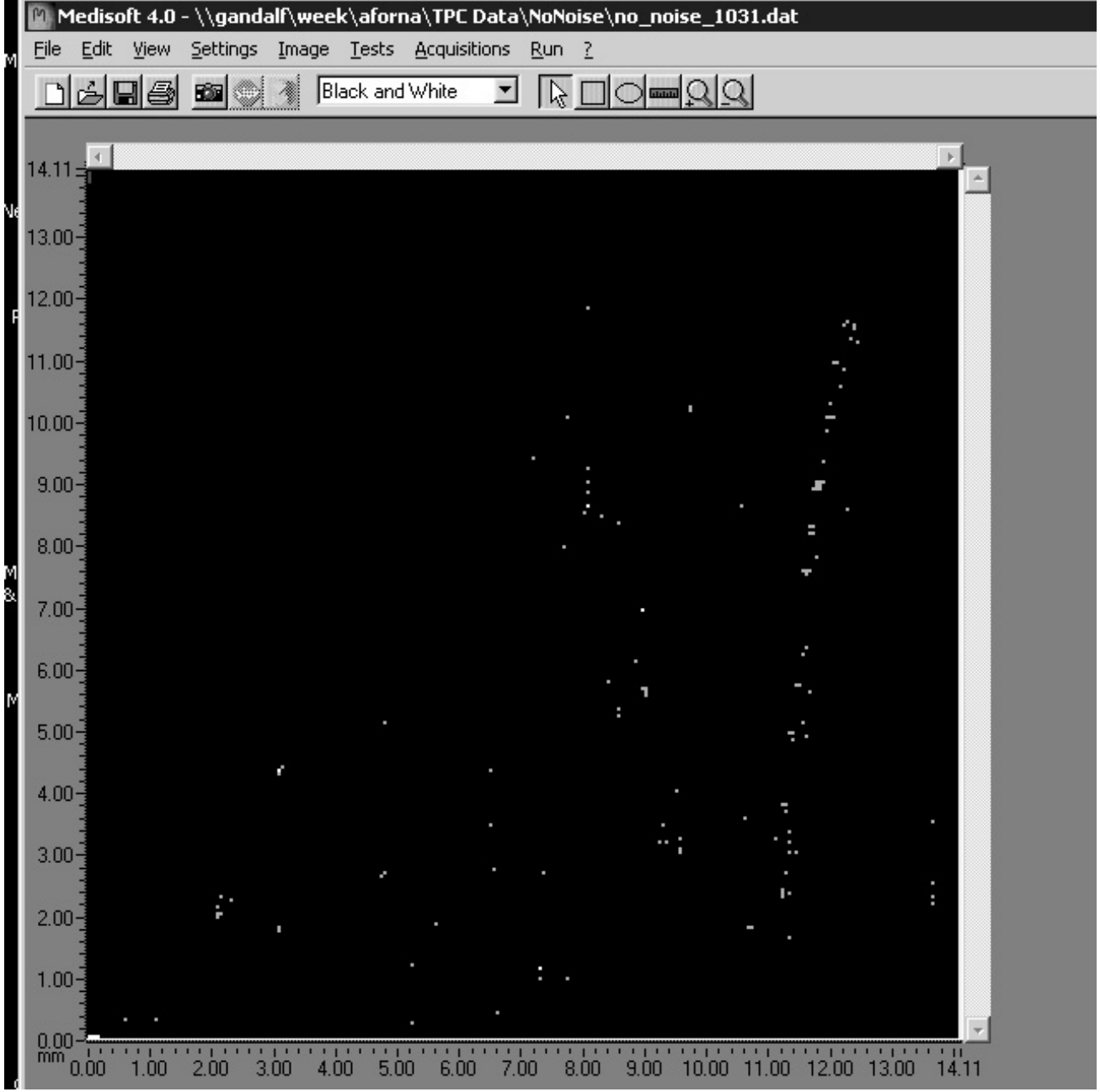
try to see single electrons from cosmic muons (MIPs)

- New Medipix
- New Micromegas (holds >500 V over 50 μm in …..)
- He/Isobutane 80/20 (gas gain 10,000 – 20,000)
- Pixel preamp threshold: ~3000 e^-
- Required gain: 5,000 – 10,000

….. it works !

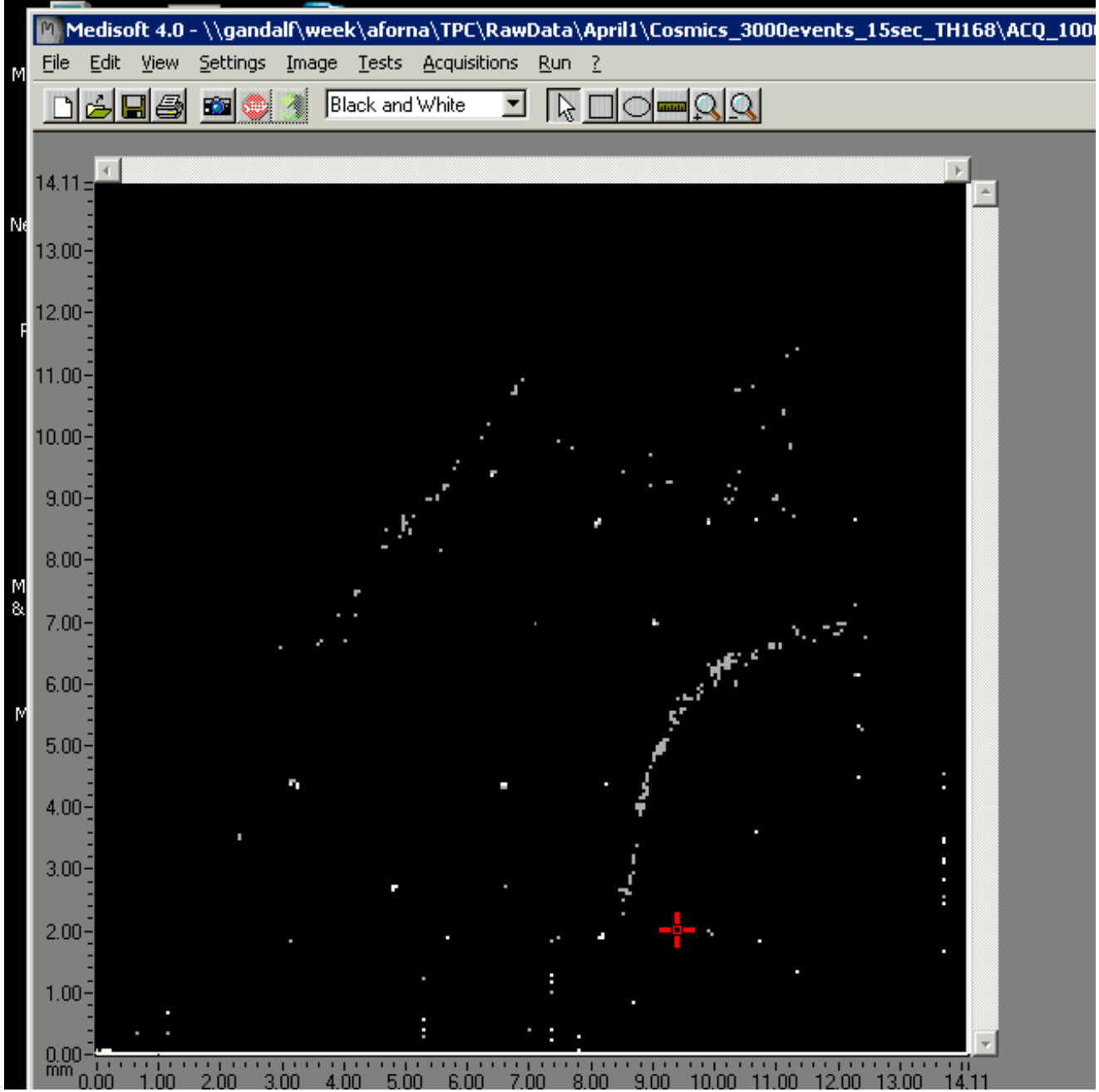
He/Isobutane
80/20
Modified MediPix

31 March 2004



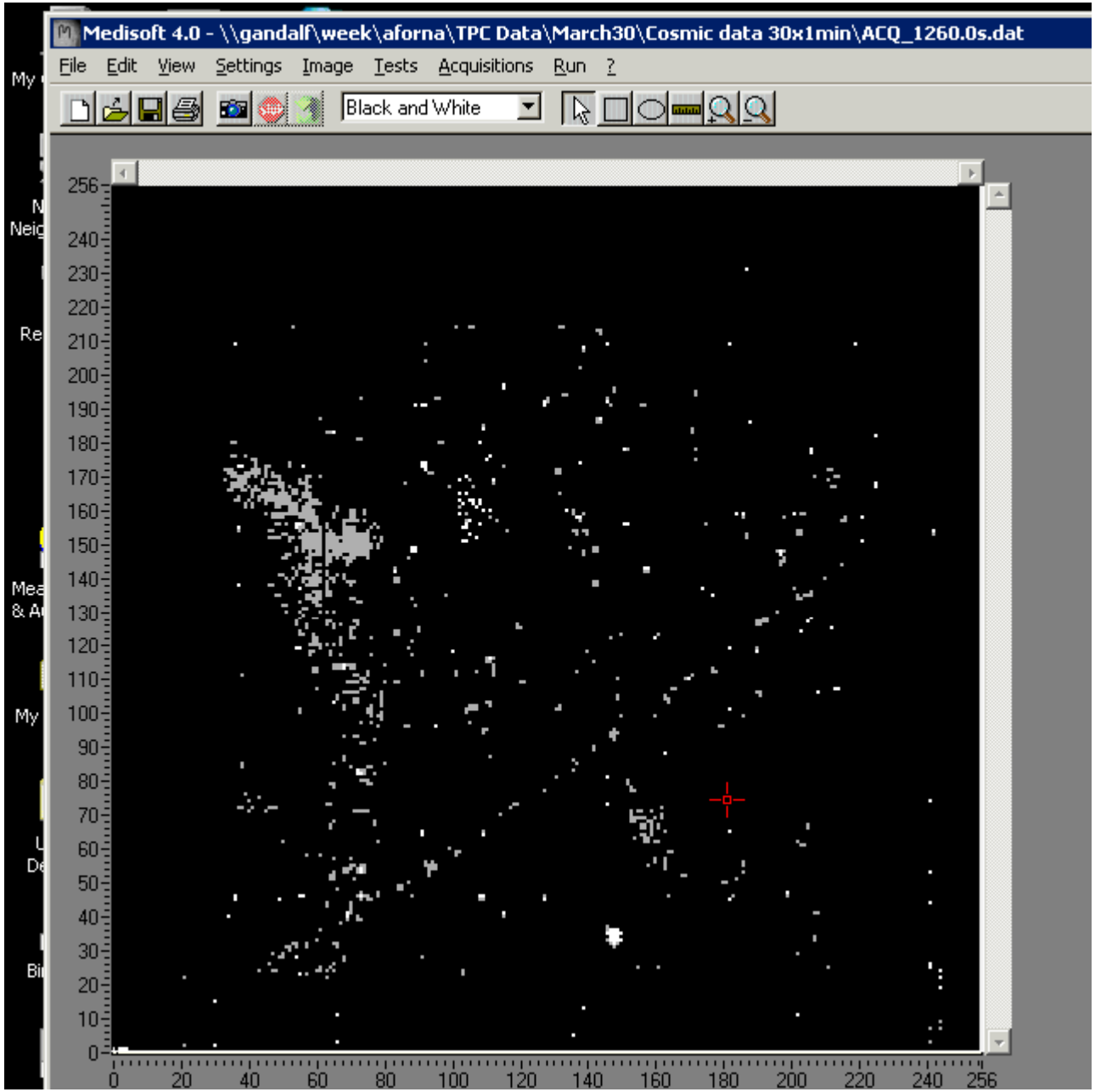
He/Isobutane
80/20
Modified MediPix

31 March 2004



He/Isobutane
80/20
Modified MediPix

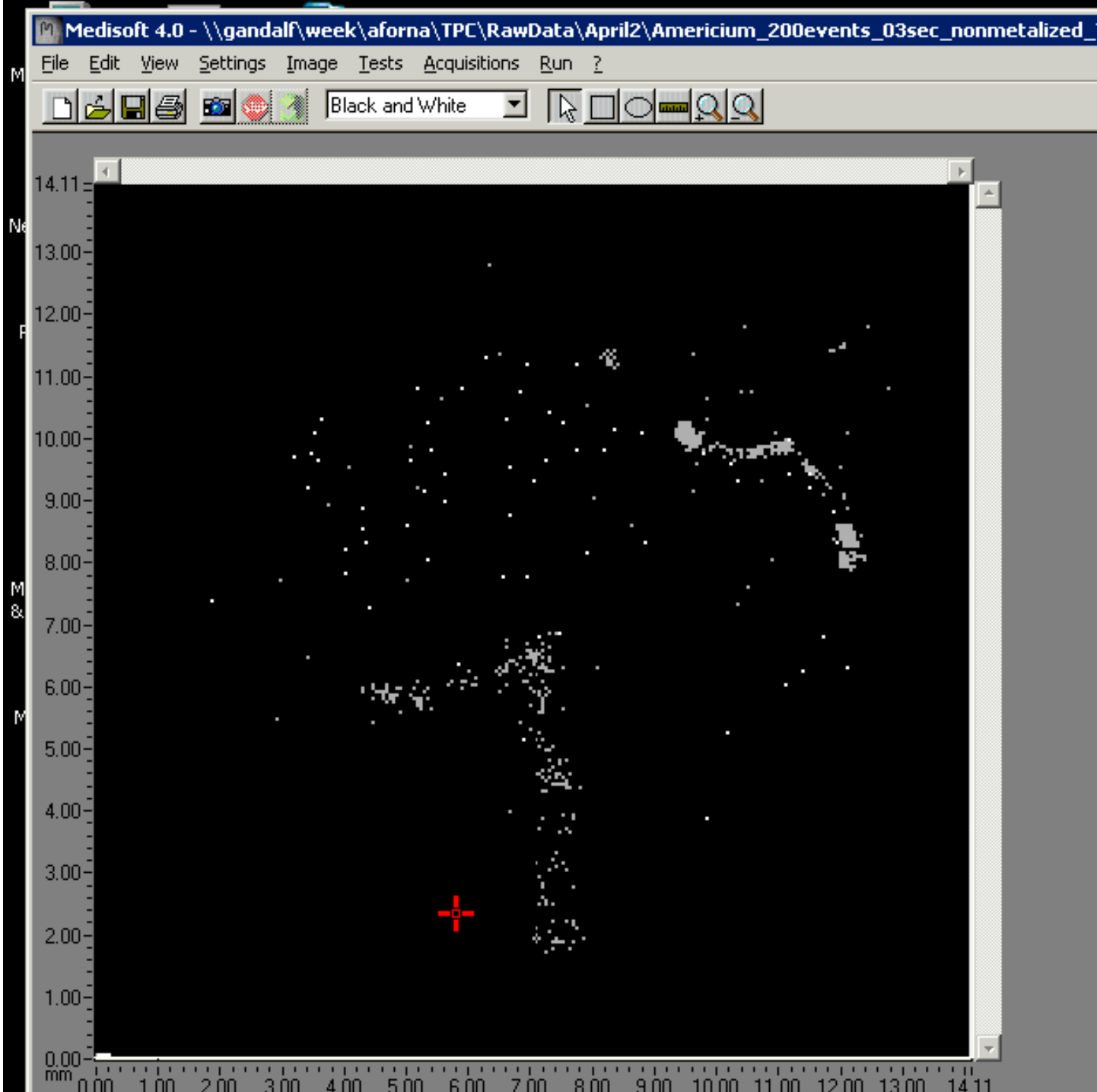
31 March 2004



He/Isobutane
80/20
Non Modified
MediPix

Amaricium Source

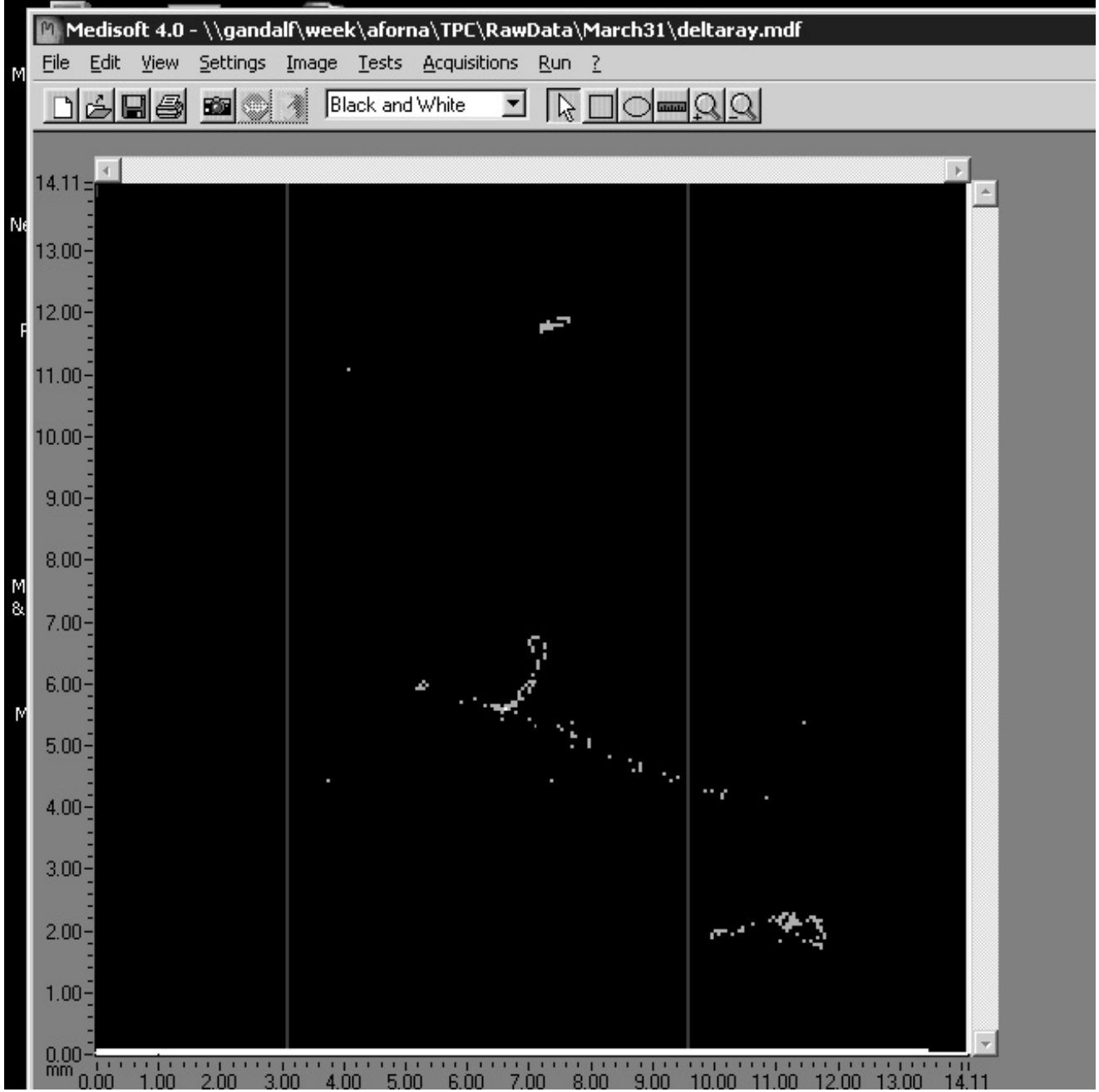
1 April 2004



21 April 2004

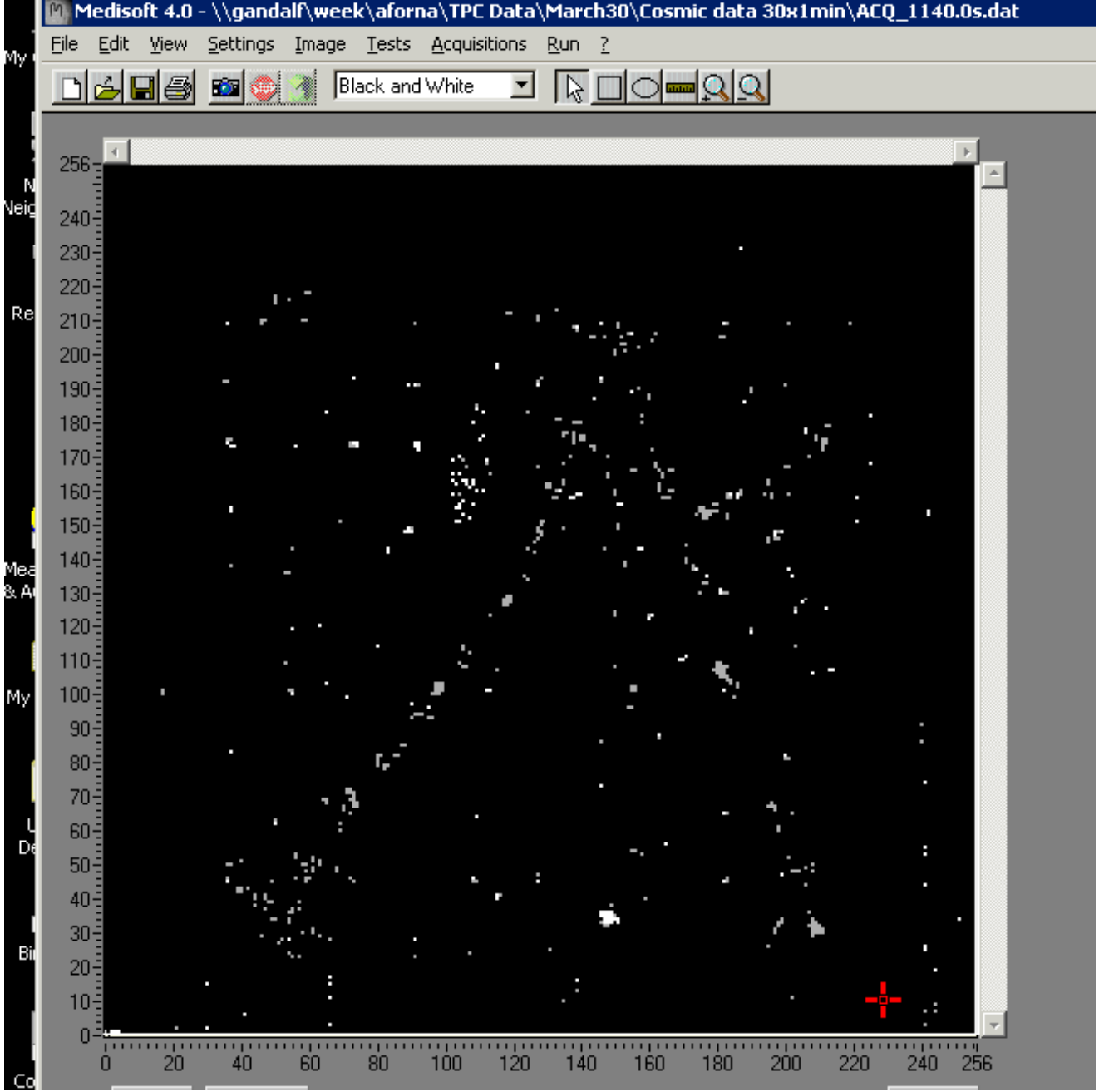
He/Isobutane
80/20
Modified MediPix

31 March 2004



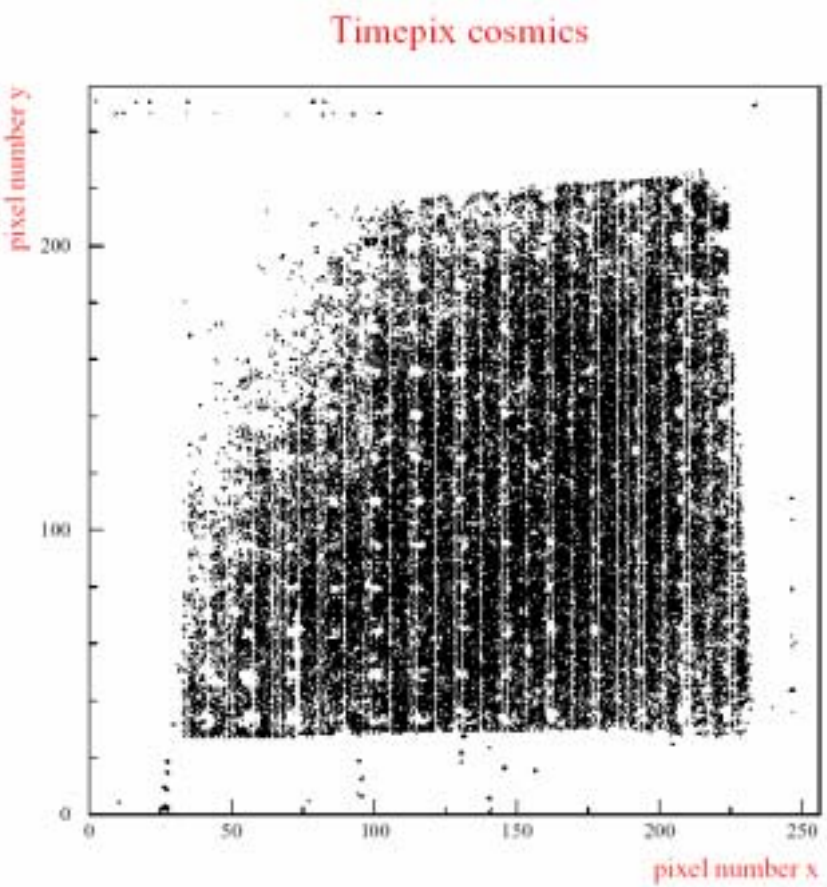
He/Isobutane
80/20
Modified MediPix

31 March 2004

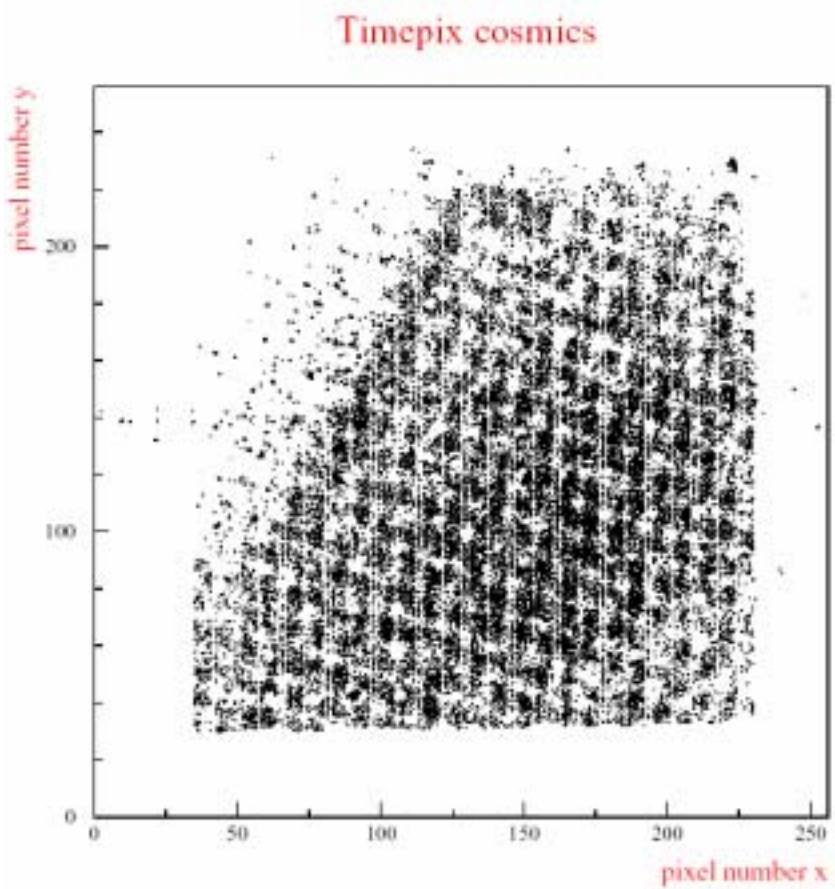


Data analysis cosmics ongoing …….

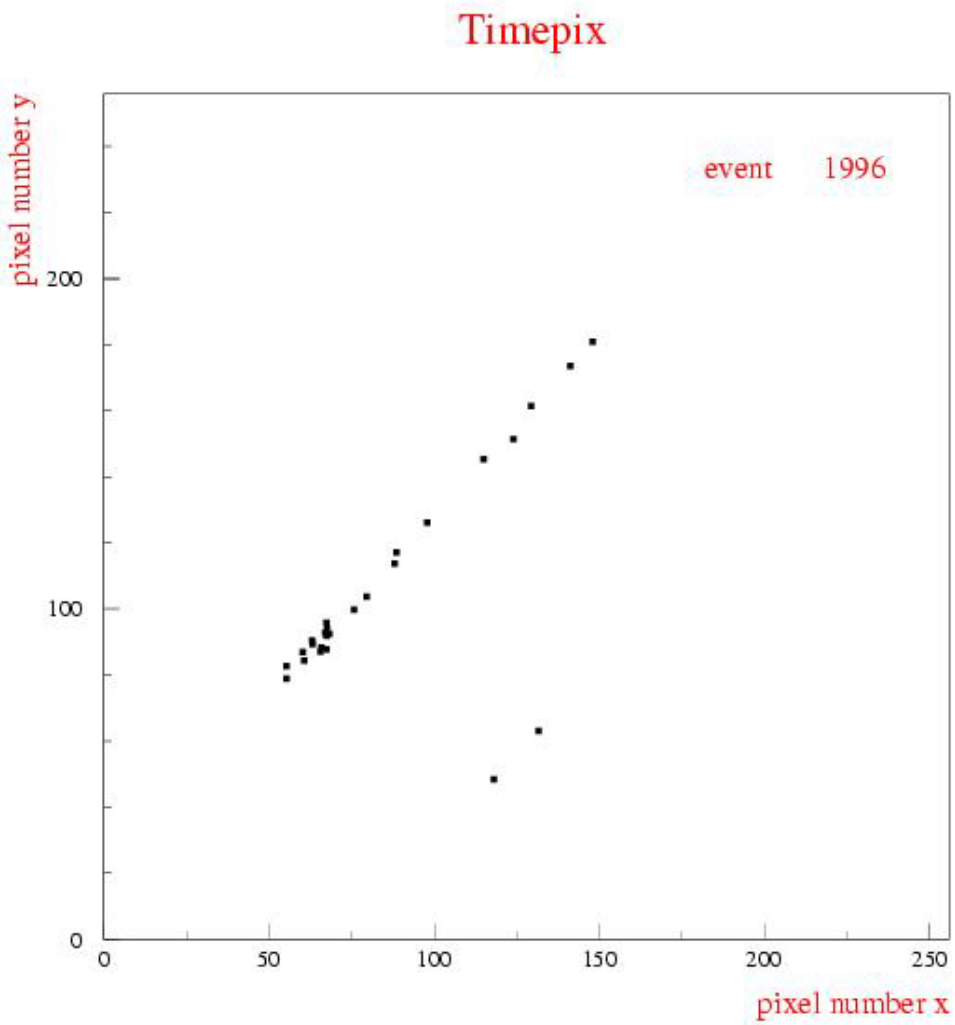
Modified Medipix



Non-modified Medipix



Example of a track reconstructed



(very preliminary)

This track:

- #hits = 24
- #clusters = 11
- length (3d) = 16.8 mm
- 1.4 e^-/mm; 0.65 cl./mm

On average:

- 1.7 e^-/mm; 0.5 cl./mm

- Proof of principle done!
- Can reach sufficiently high gas gains in He based gases (will try other ones)
- The Medipix2 chip can withstand strong E-fields (100kV/cm!)
- Accidental discharges destroy chip immediately (we broke 4 chips in 4 days!) Need protection!
- Analysis in progress: single electron efficiency, #clusters and #e^- per mm and comparison with expectations

Plans for coming weeks:

- Add cosmic trigger; Medipix2 can not be triggered, but can run in “stop” mode
- Try other gases: Ar/Isobutane 80/20

  He/CF4 80/20
- Single electron efficiency vs HV

Later this year beam tests (dE/dx (?): e^-, μ, π, …

A lot of work ahead:

•Form collaboration to develop TimePix CMOS pixel chip

(add time stamping); submit costs ~150 kEuro for 6 wafers.

YOU ARE WELCOME TO JOIN and ADD Euros/$s/Yens

•Develop discharge protection

•At NIKHEF/Mesa+: try to integrate Micromegas and pixel sensor by 'post-wafer' processing: InGrid $\rightarrow$ TimePixGrid

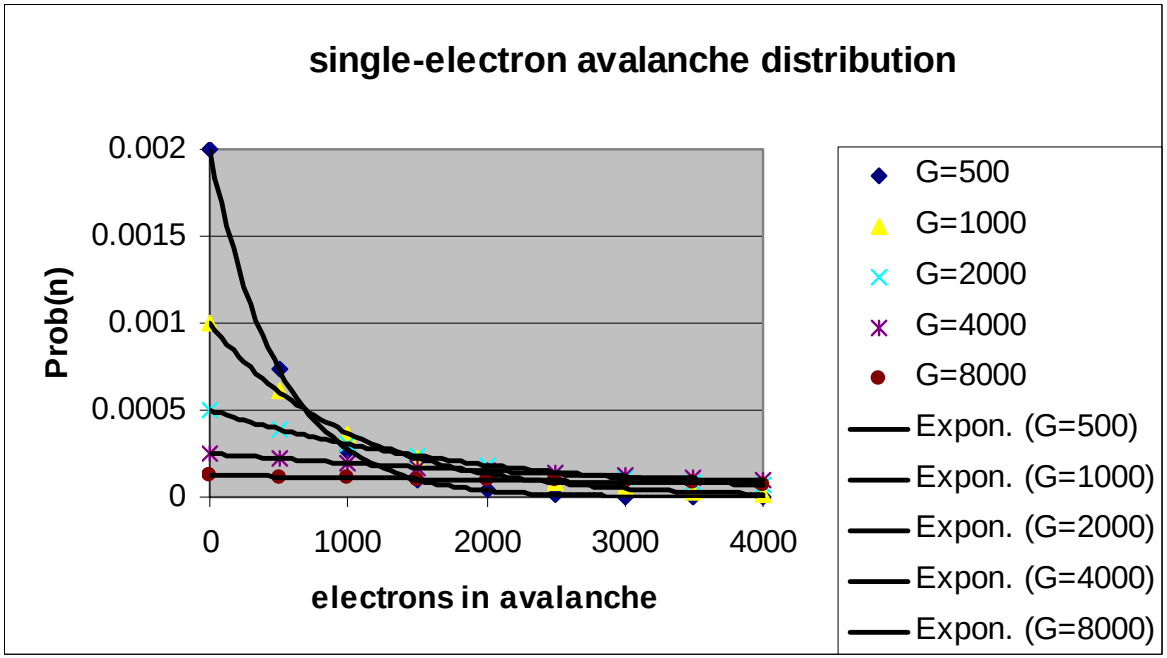
•Lots of simulations to study TPC performance in view of single electron detection: JOIN IN, no Euros needed

Backup slides

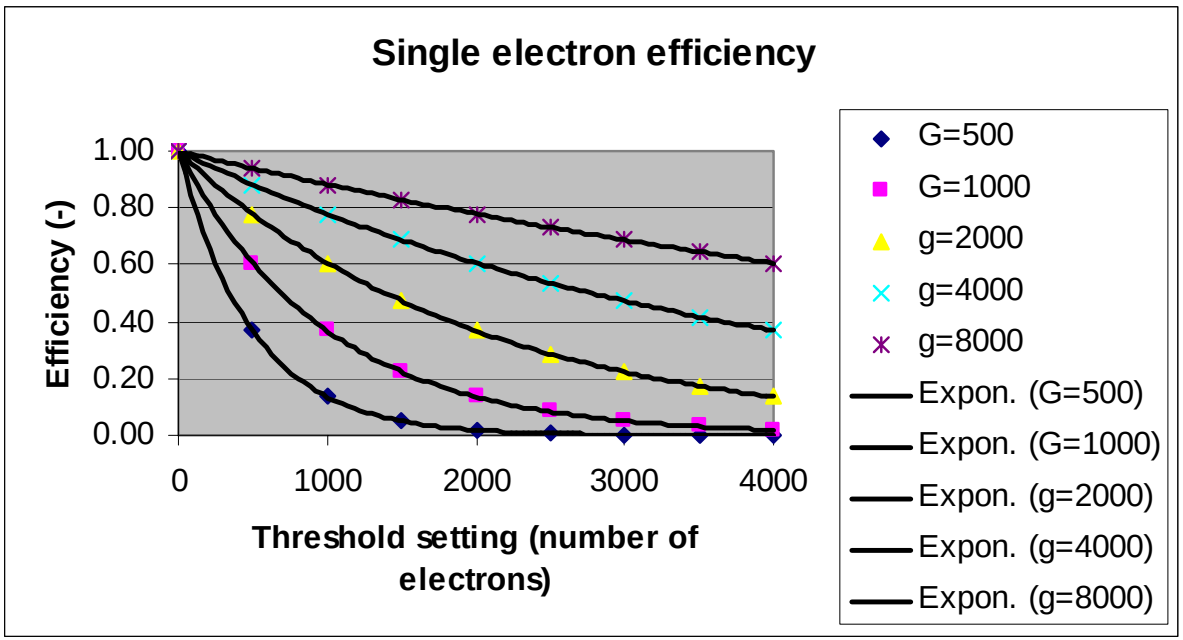
Top Drifter	5700 V
Bottom Drifter	3473 V
Top GEM 1	2813 V
Bottom GEM 1	2462 V
Top GEM 2	1876 V
Bottom GEM 2	1524 V
Top GEM 3	938 V
Bottom GEM 3	586 V

In the base plate of the chamber, a hole was cut out for the MEDIPIX2 chip: its pixel surface was flush with the (anode plane) base plate plane. The MEDIPIX2 chip contains 256 x 256 square pixels with pitch 55 µm x 55 µm giving a total fiducial sensitive area of 14.08 mm x 14.08 mm. Each pixel is equipped with a low-noise charge preamp, discriminator, two threshold DACs, a 13-bit counter and communication logic.
Since a triggering system had not been implemented, we operated the MEDIPIX2 sensor by enabling the counters manually, and stop the counting after a pre-set time interval (0.1 - 10 s). After that, the counts of each pixel are read out.

Drift length: 100 mm
Distance between GEMs: 1.6/2.6 mm
Distance bottom GEM/MEDIPIX: 6.6 mm



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



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

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