New developments on integrated MPGD, ageing and protection

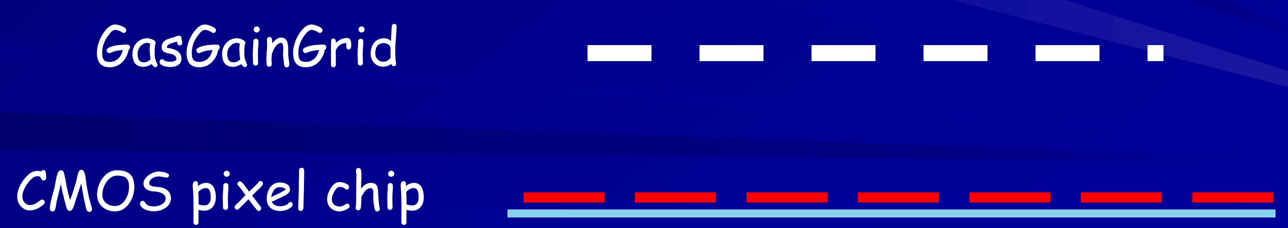
MPGD Workshop
CERN, January 20, 2006

Harry van der Graaf, NIKHEF, Amsterdam

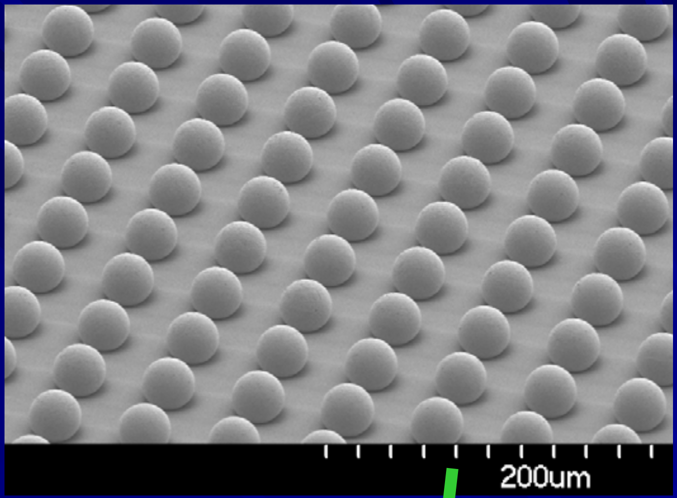
GridPix:

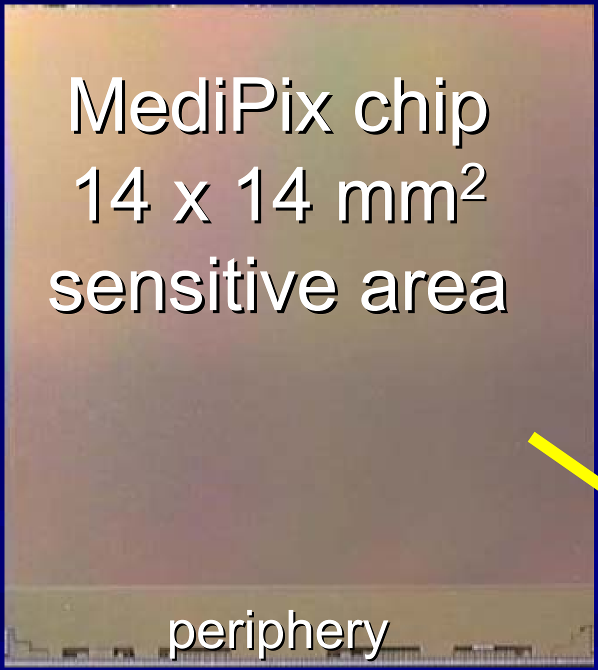
put active pixel sensor chip under MPGD:

integration of MPGD and FE electronics

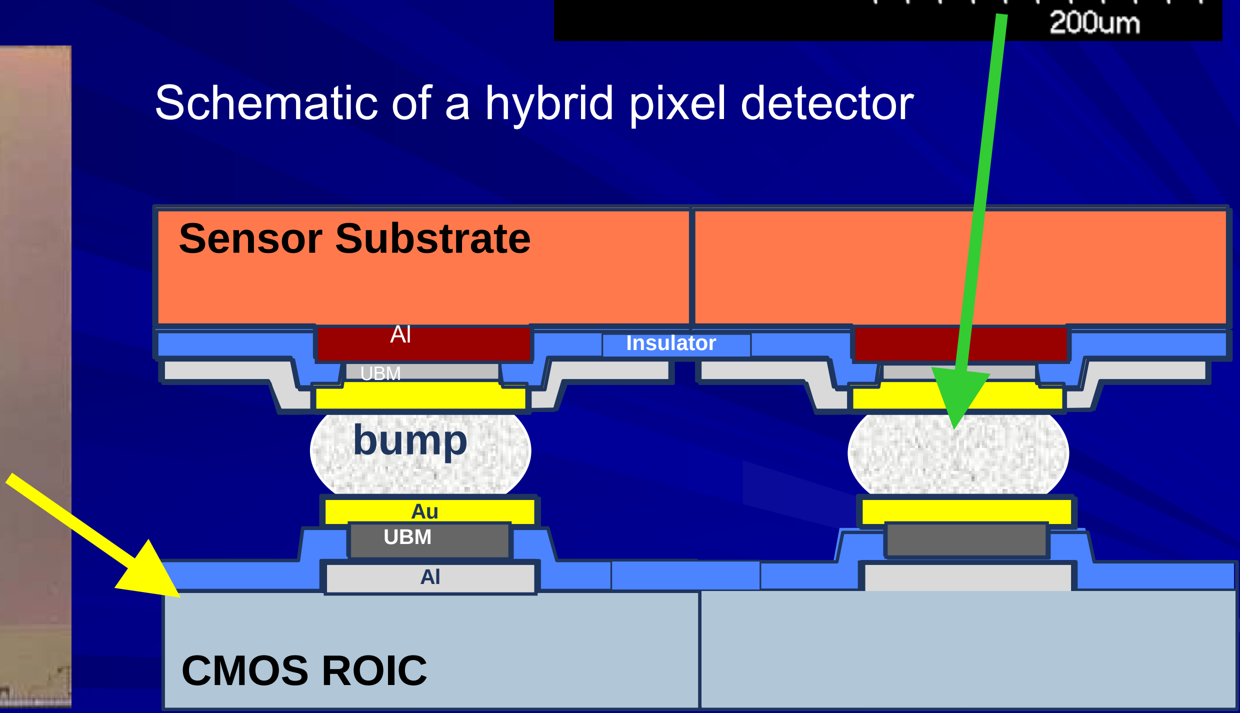


Medipix2:
Hybrid Pixels
CERN Medipix Consortium



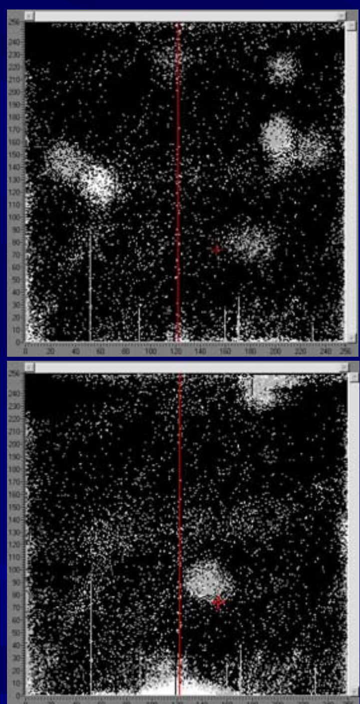


Schematic of a hybrid pixel detector

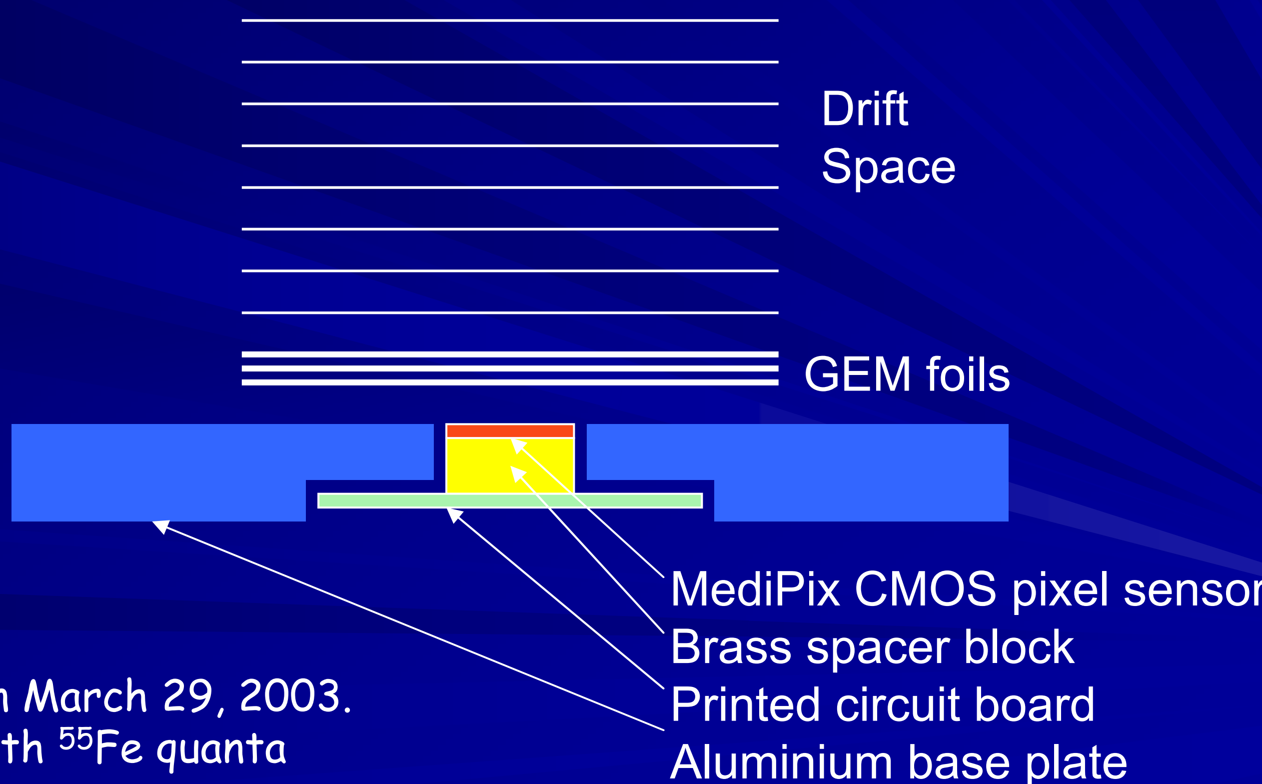


approved Eureka proposal

March 2003	Triple GEM + MediPix 2	NIKHEF
January 2004	Single GEM + PIXIE chip	INFN-Pisa
February 2004	Triple GEM + MediPix 2	NIKHEF
March 2004	Micromegas + MediPix 2	NIKHEF/Saclay/UnivTwente:
Oct 2004	Double GEM + MediPix 2	Freiburg
June 2005	Triple GEM + MediPix 2	Freiburg

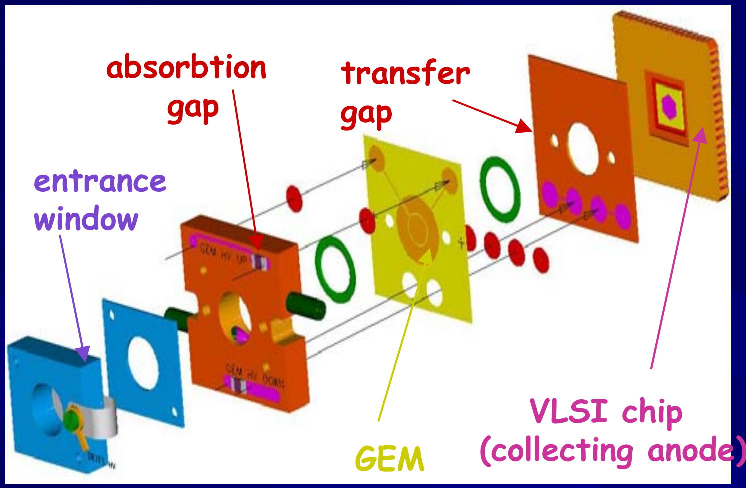


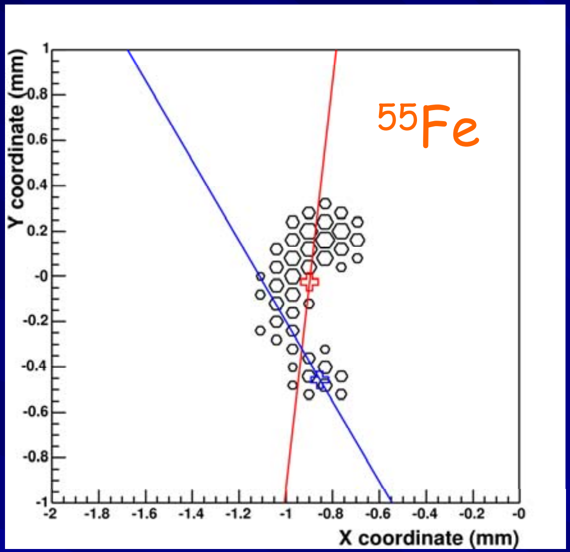
First events, recorded on March 29, 2003.
Drift space irradiated with ^{55}Fe quanta
Gas: Ar/Methane 90/10

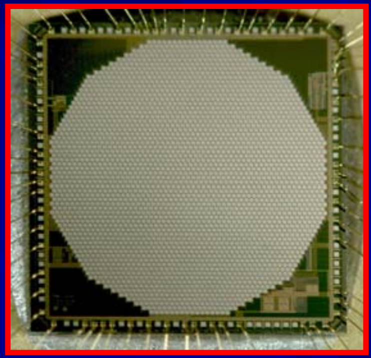


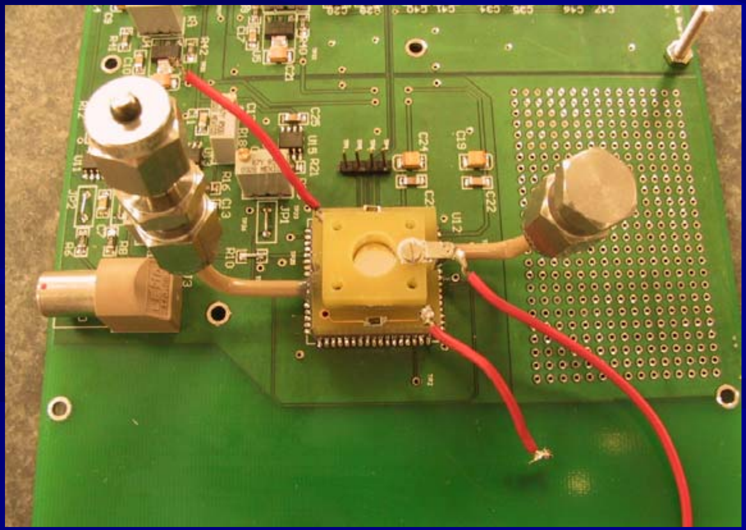
January 2004 Single GEM + PIXIE chip

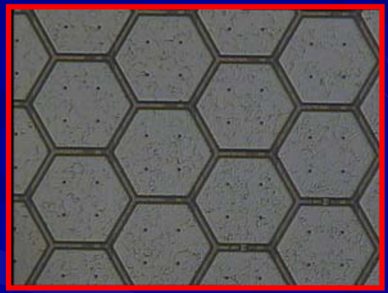
INFN-Pisa

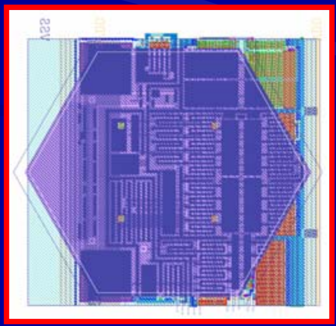






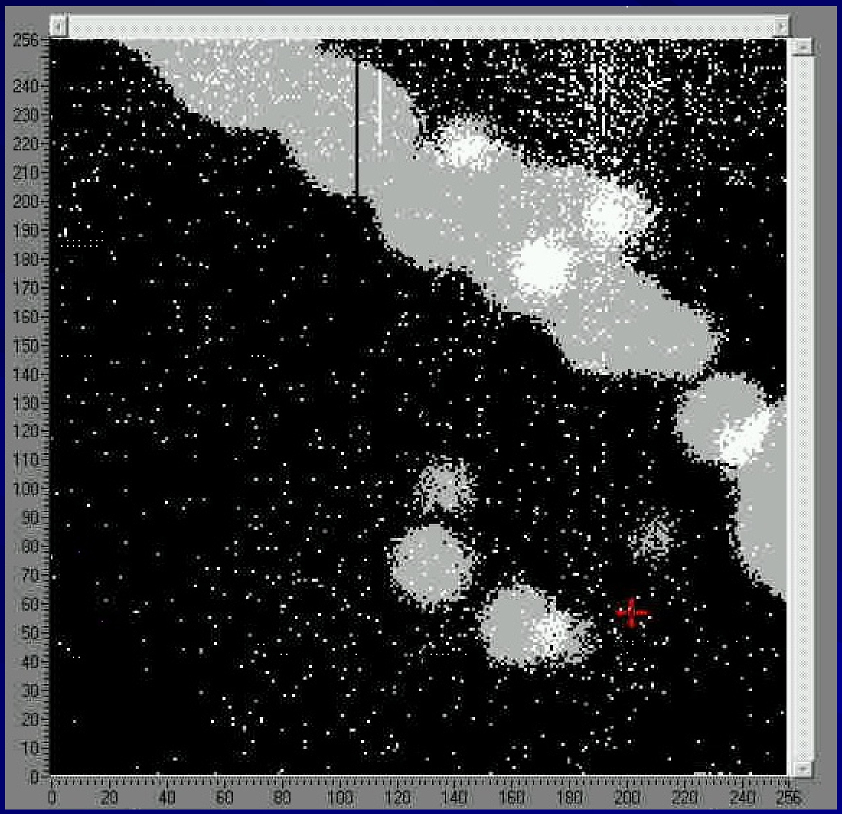


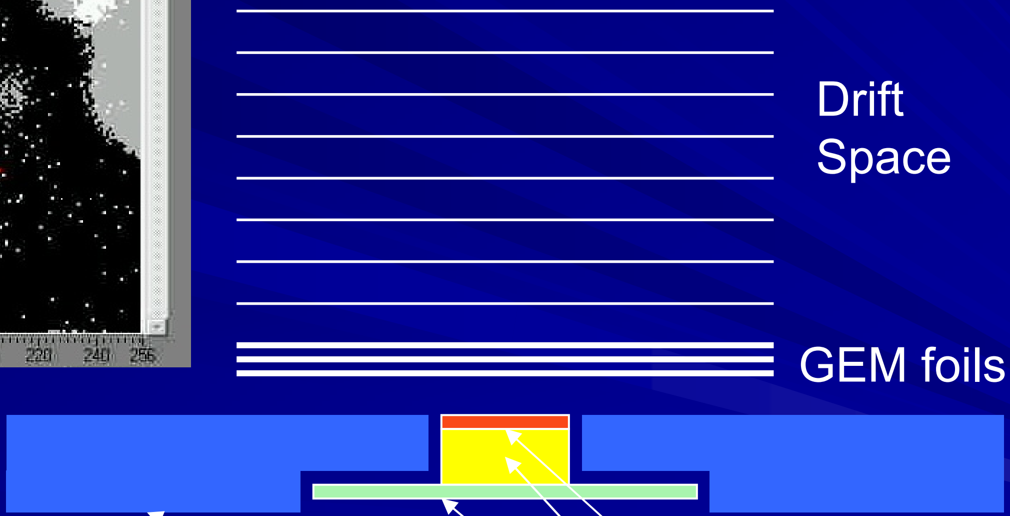




pixel electronics dimension:
80 μm x 80 μm in an
hexagonal array,
comprehensive of
preamplifier/shaper, S/H
and routing (serial read-out)
for each pixel
number of pixels: 2101

February 2004 Triple GEM + MediPix 2 NIKHEF

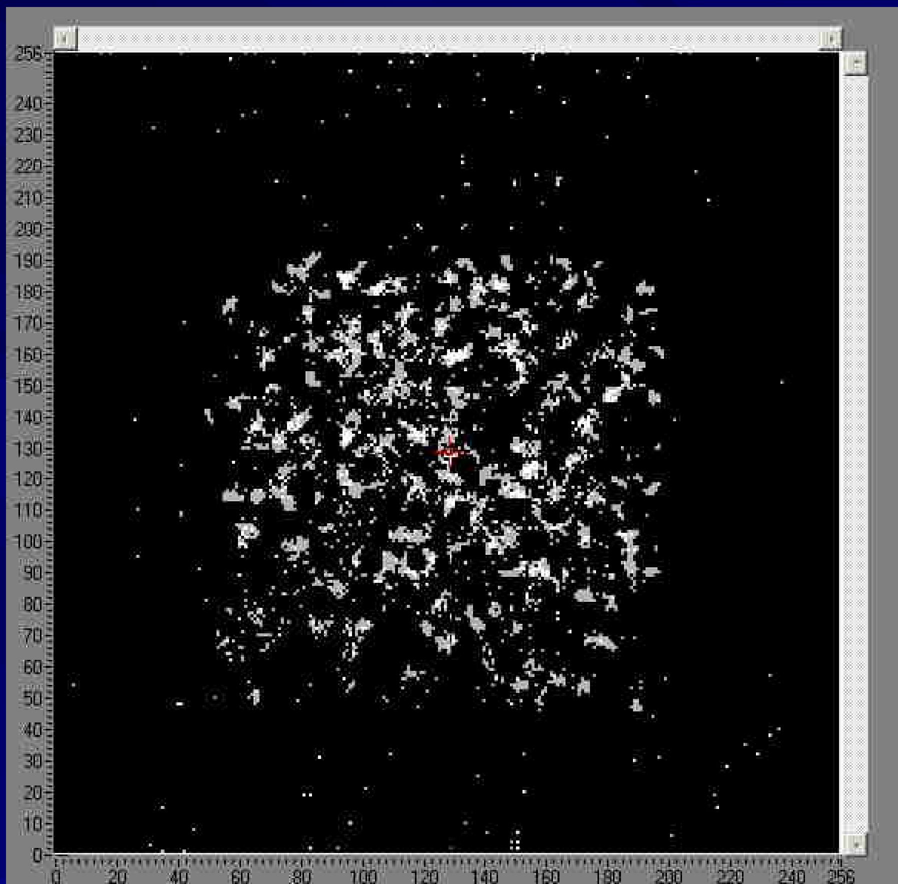




Gas: Ar/Isobutane 90/10

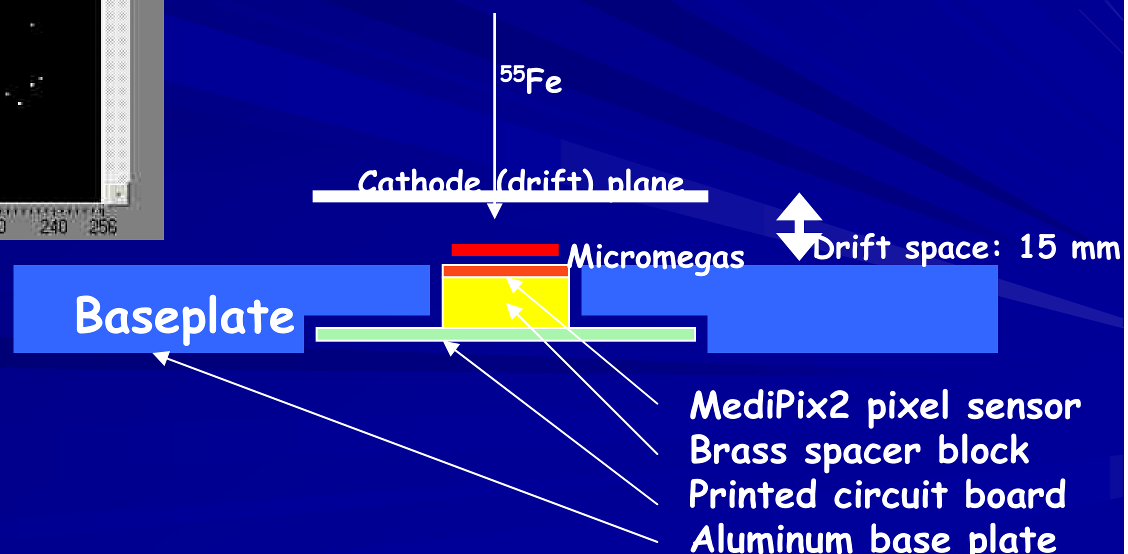
February 2004 Micromegas + MediPix 2

NIKHEF/Saclay/UnivTwente:

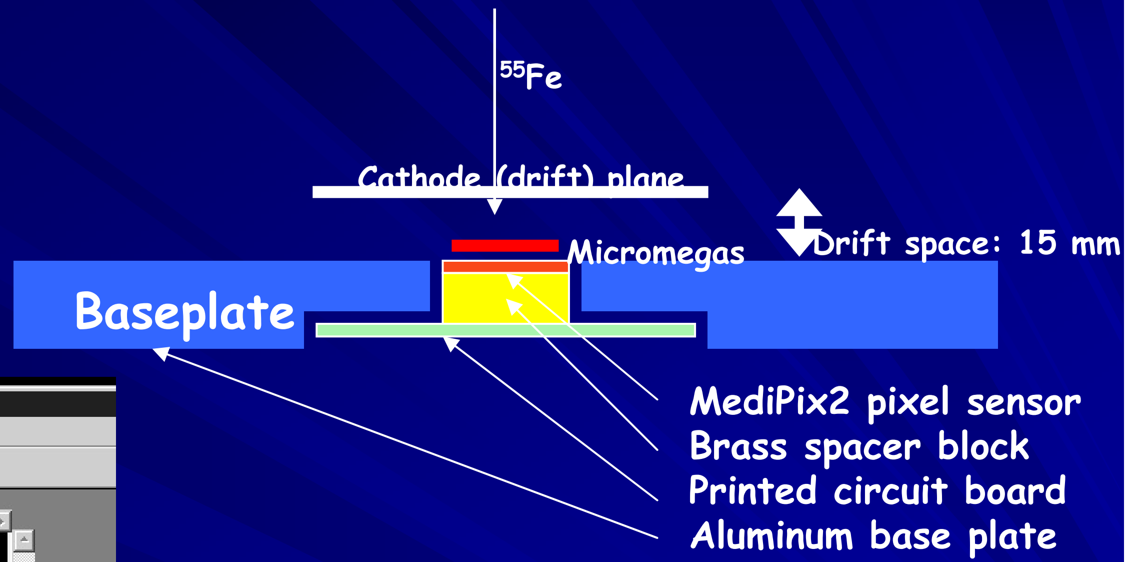


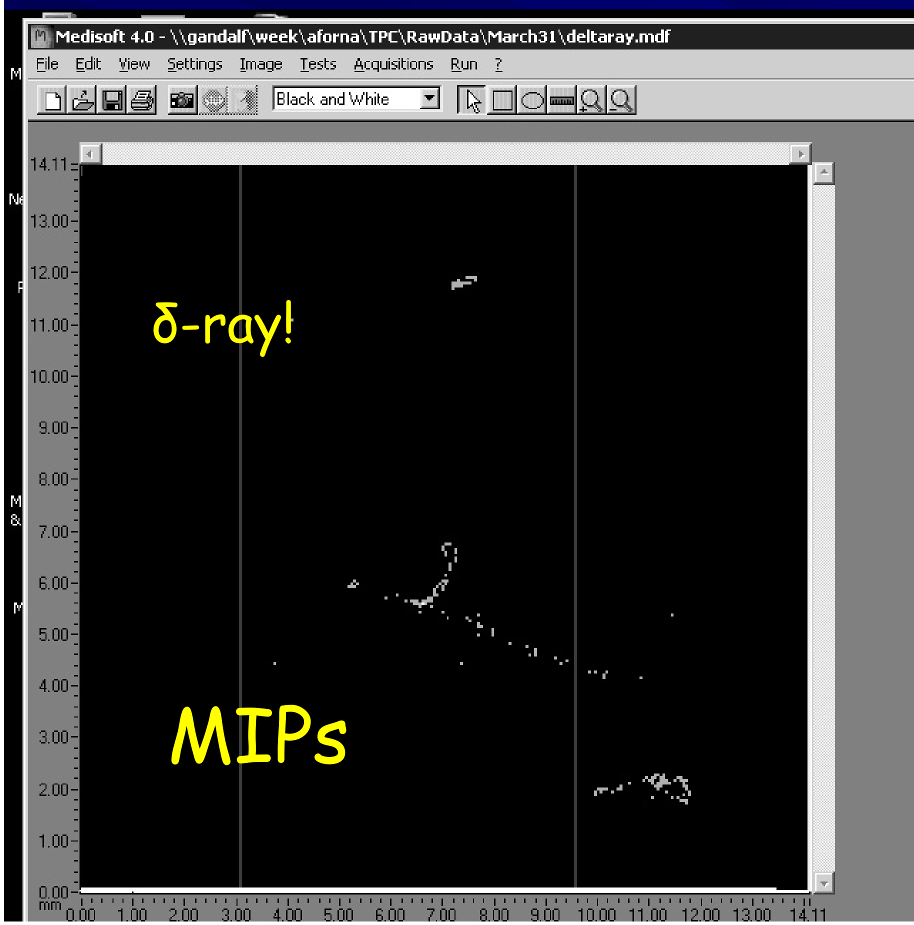
^{55}Fe

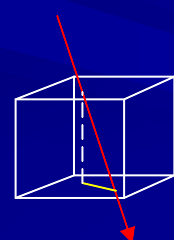
Very strong E-field above (CMOS) MediPix!



April 2004 Micromegas + MediPix 2 NIKHEF/Saclay/UnivTwente:

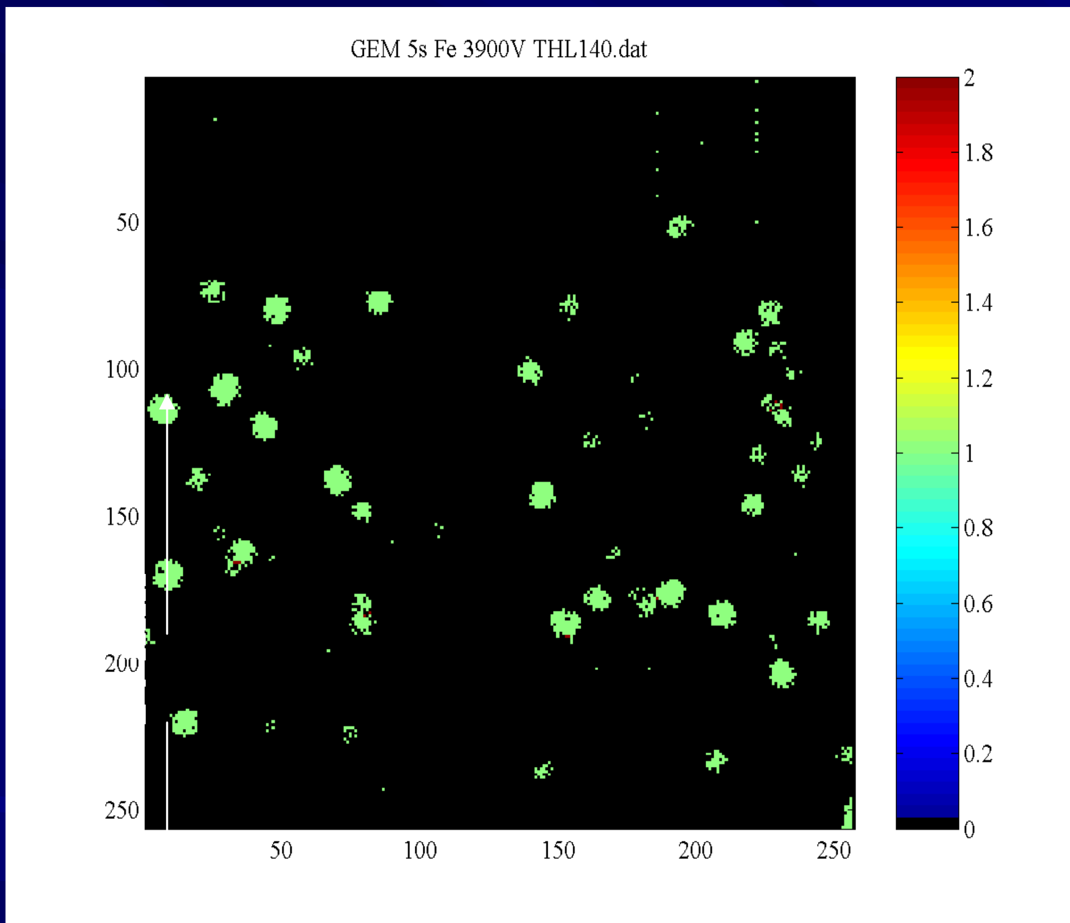




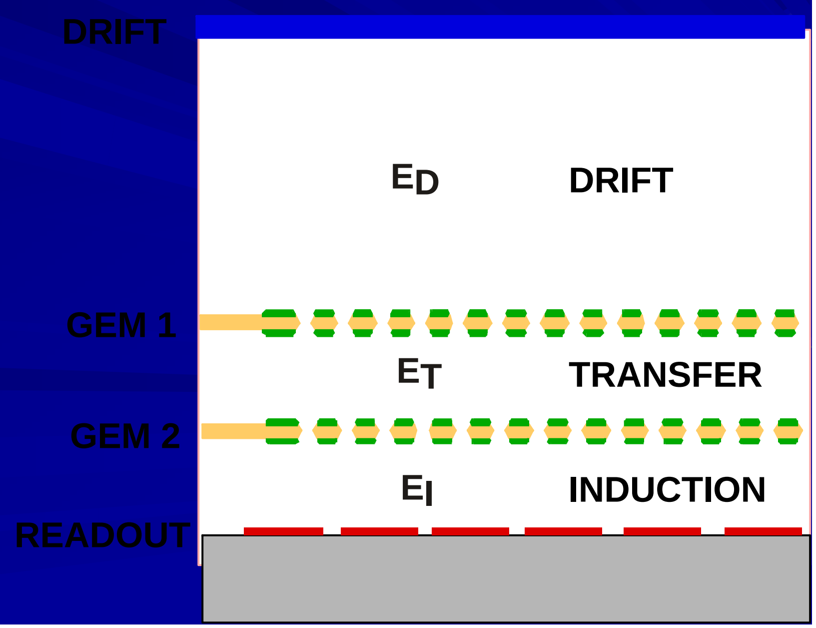


He/Isobutane
80/20
Modified MediPix

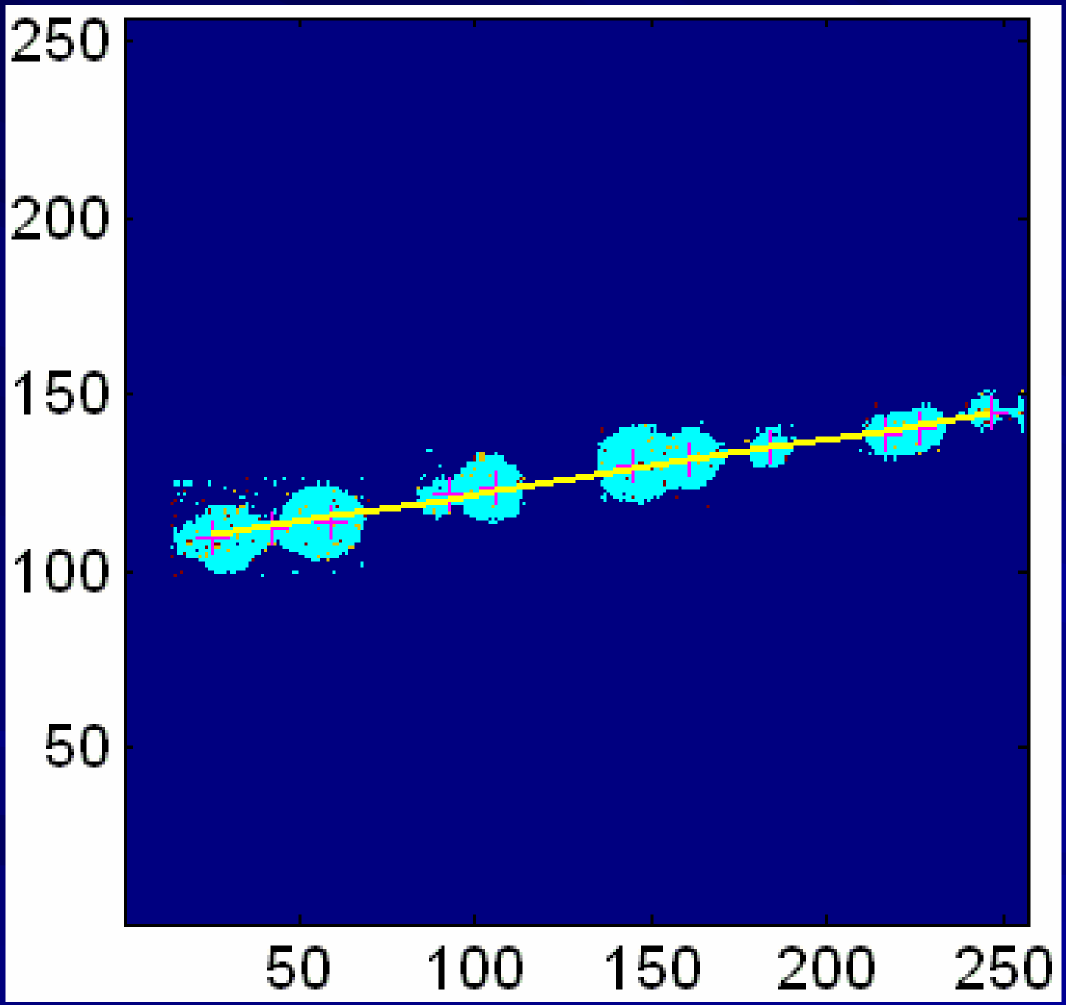
Jan 2004 Double GEM + MediPix 2 Freiburg

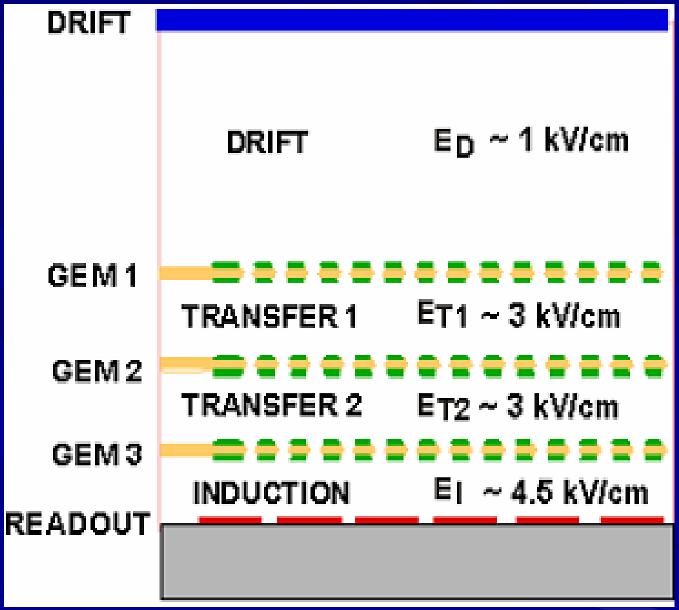


14 mm



June 2005 Triple GEM + MediPix 2 Freiburg

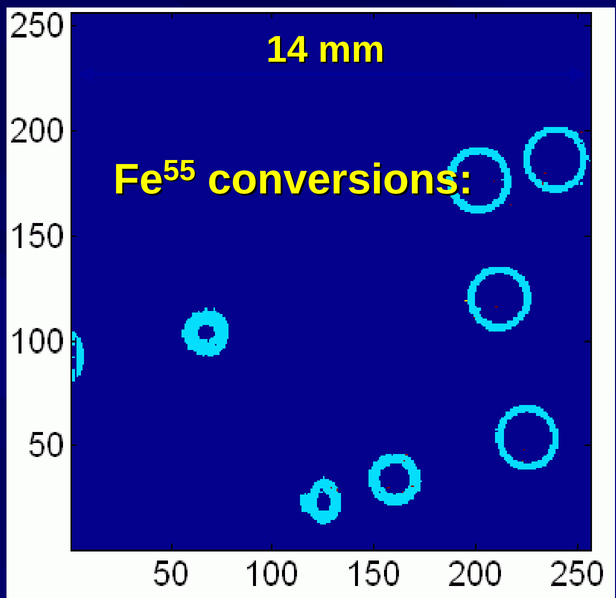


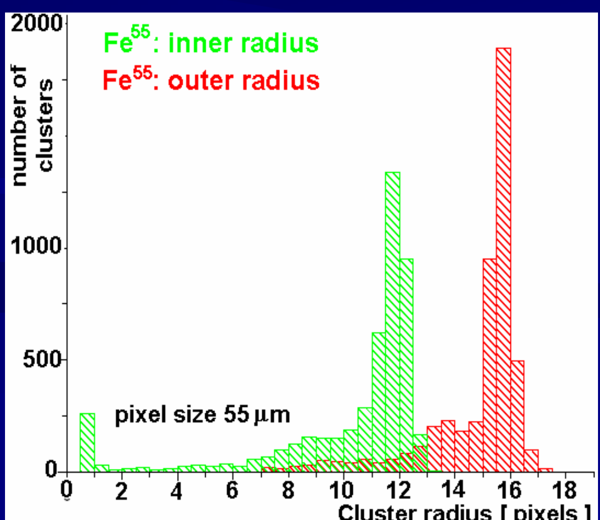


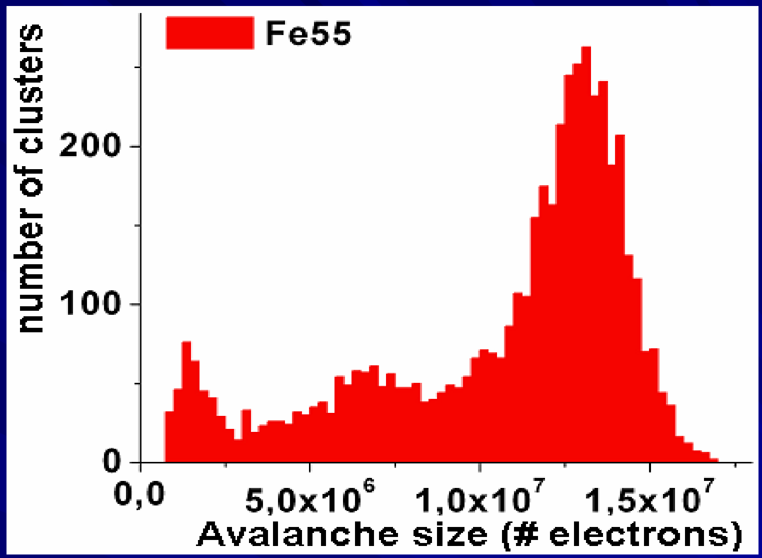
GEM and MEDIPIX2 Studies@ Freiburg

(A. Bamberger, K. Desch, J. Ludwig, U. Renz, M. Titov, N. Vlasov, A. Zwerger)

Ar/CO_2 (70:30)







Fe^{55} X-rays in Ar/CO_2:

Digital MEDIPIX2 chip,
low and high thresholds
(low discrim. thr ~ 1000 e^-)

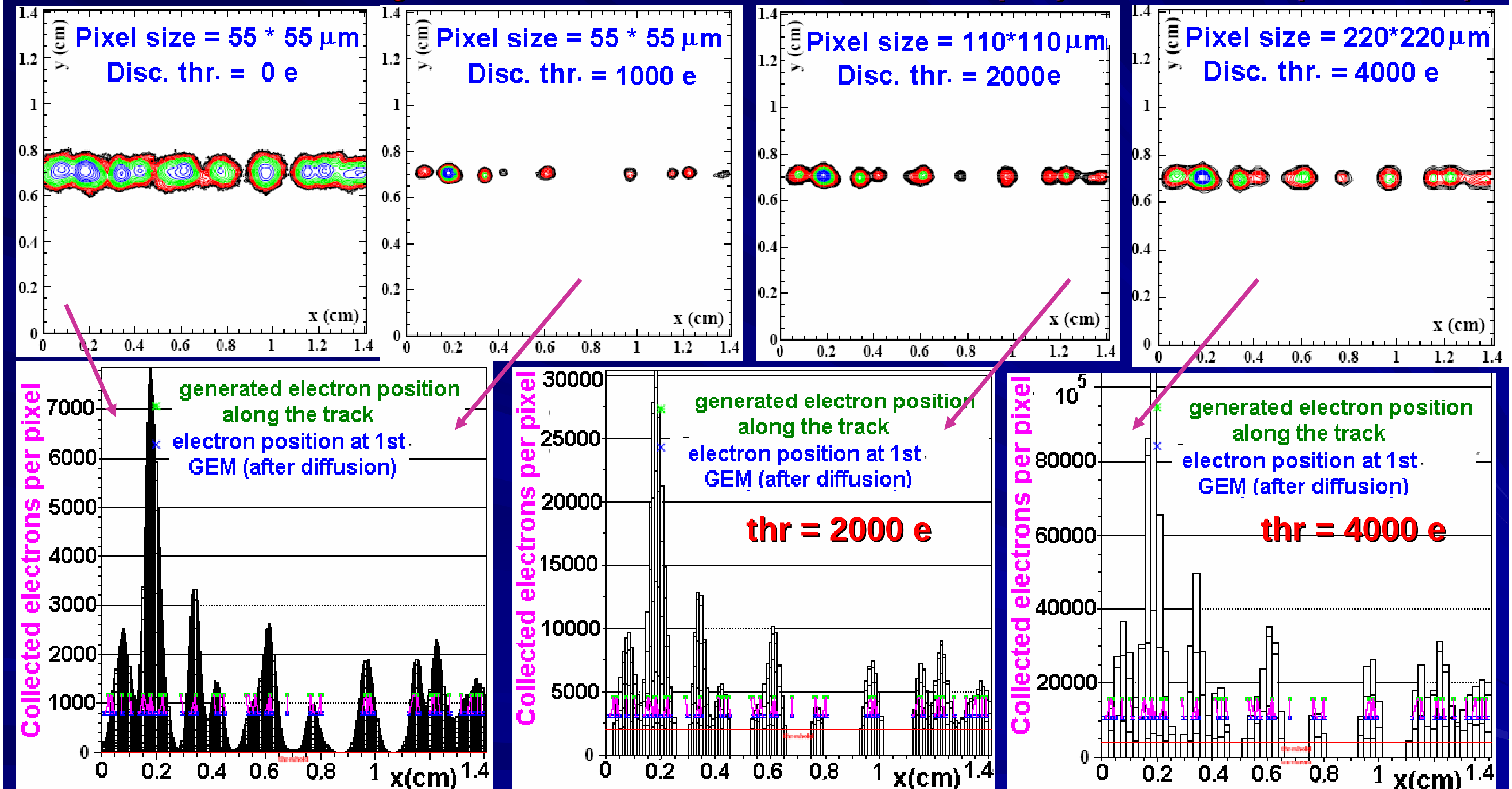
Chip calibration: DAC thr.
vs injected charge

Estimate Fe^{55} cluster
charge from inner / outer
cluster radius →
gain determination

GEM and MEDIPIX2 Simulation for Freiburg setup

Simulation studies were performed by Michael Hauschild (CERN)

• **Contour Plot of charge distributions on MEDIPIX2 surface (vary thresholds & pixel sizes)**



• Pixel size of 55 * 55 µm is too small for TGEM and gain ~ 4*10^4 → number of single electron clusters fall below the discriminator threshold (1000 e)

• **Use of larger pixels (220 * 220 µm) improves S/N ratio → more clusters are detected**

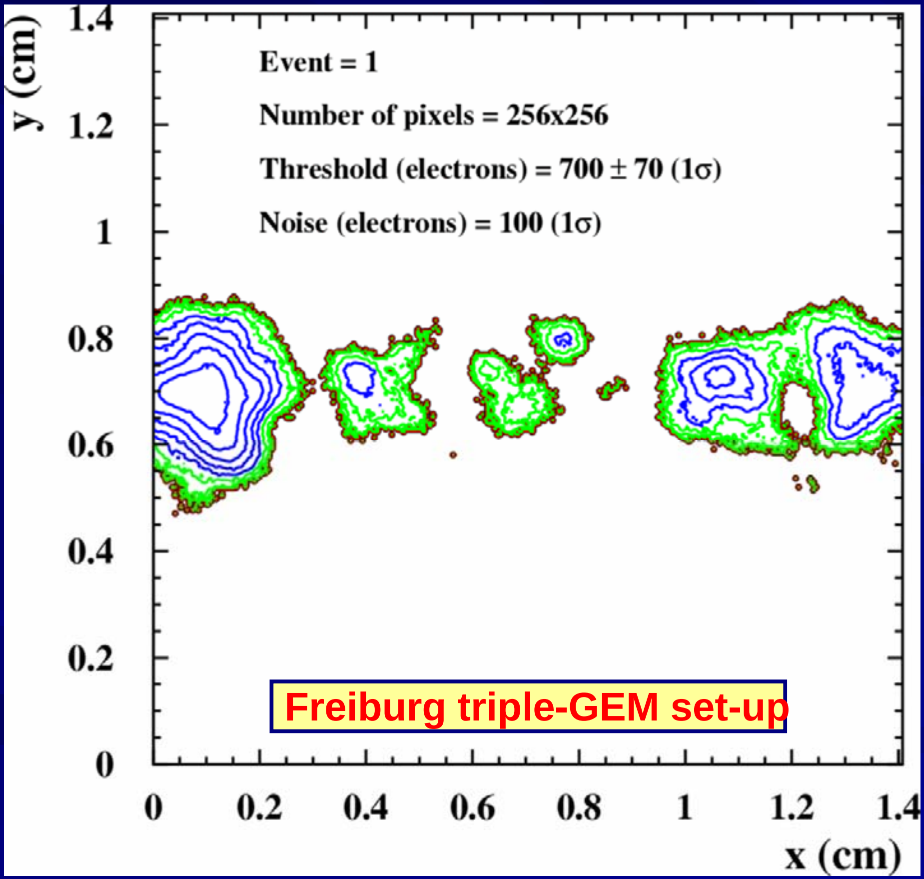
M. Hauschild's conclusions

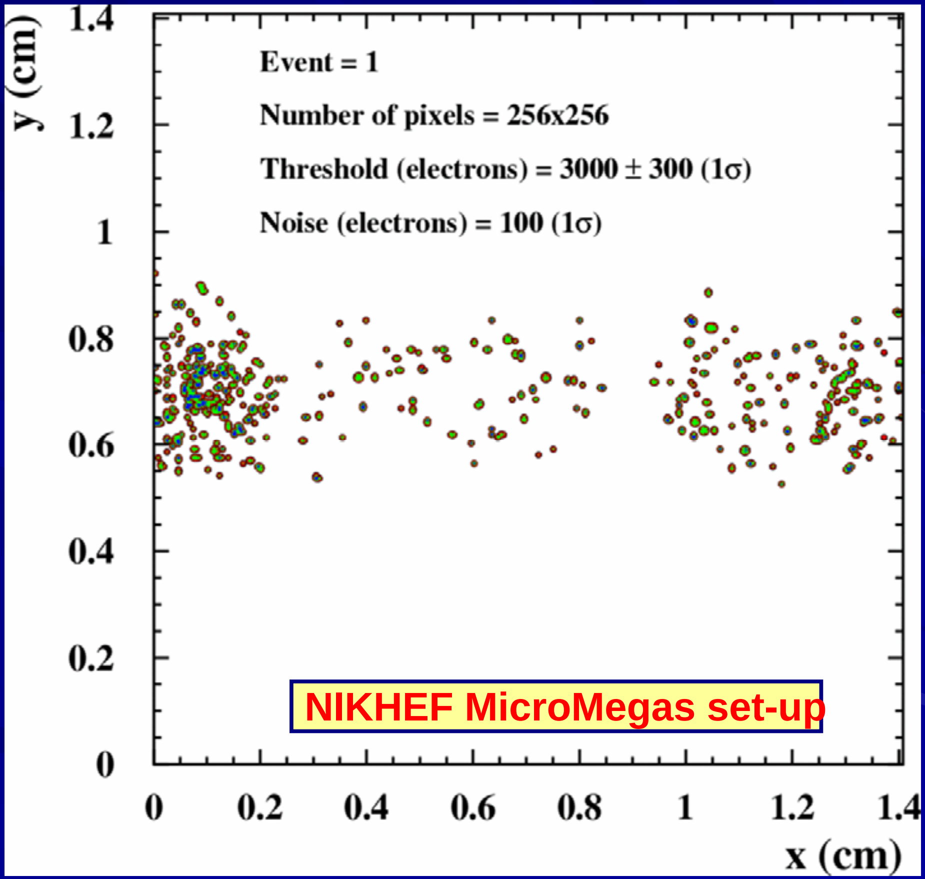
- GEMs + MediPix
  - large "blobs" because of large diffusion among GEMs and to MediPix
    - electron cloud diluted over too many pixels, many pixels below threshold, single electrons clusters mainly undetected
  - solutions
    - reduce diffusion (optimize gas, E-field, GEM set-up)
    - use larger pixels, granularity still good enough for large "blobs"
- MicroMegas + MediPix
  - rather small "blobs" because of low diffusion between MicroMegas and MediPix
    - efficient to detect individual electrons, need to keep small pixel size
- GEMs vs MicroMegas
  - GEMs good to detect whole clusters, Micromegas single electrons
  - What do we need?
    - e.g. dE/dx needs cluster counting, not counting of electrons

Outlook

- ...at the ILC...
  - 100 GeV muon, B = 4 T, TESLA-TDR gas, 100 cm drift

identical events: same generated primary clusters/electrons





- The matching of the granularity of an MPGD may require a short distance (< 1 mm) between the 1st GasGainGrid and the anode plane.

- With a single GasGainGrid placed at a distance of 50 μm from the anode plane, individual electrons can be detected within a (MediPix2)pixel (and future TimePix voxel). The maximum amount of information of the primary electrons can be extracted, only affected by diffusion.

- If the resolution of a track position measurement is limited by diffusion, then the information of all individual electrons will not result in a better resolution.

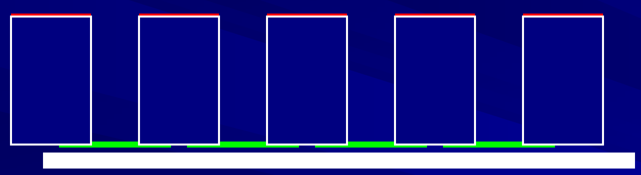
- If single electrons can be associated with primary clusters, then the dE/dX measurement can be based on cluster counting

- Optimising single electron-sensitive MPGD requires new algorithms for recognition of clusters, δ-rays, scattering, as well as a low-diffusion gas with large cluster distance

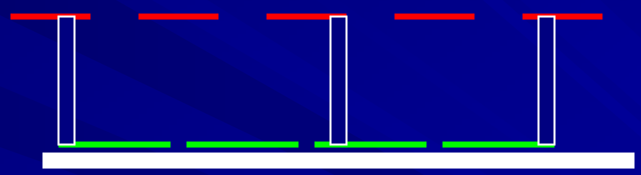
Integrate GEM/Micromegas and pixel sensor:

InGrid

‘GEM’



‘Micromegas’



‘wafer post processing’

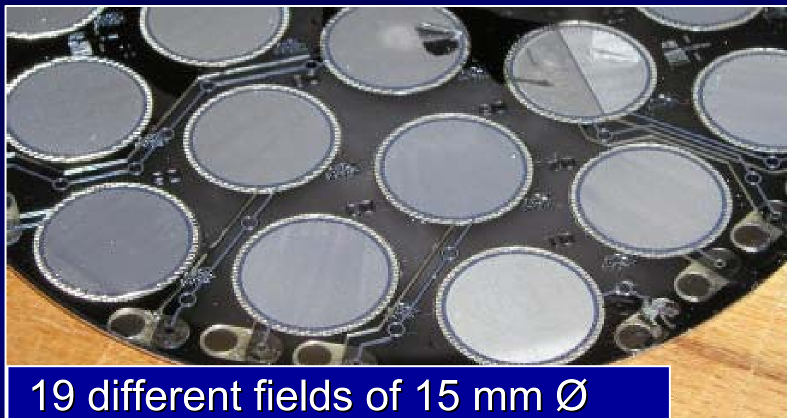
by

Univ. of Twente, MESA+

approved VICI proposal

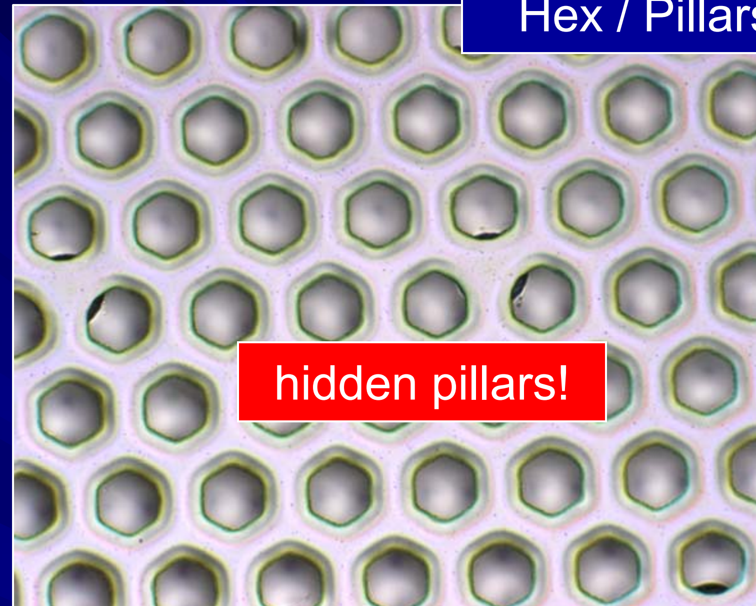
‘there is plenty of room at the top’

Prototypes

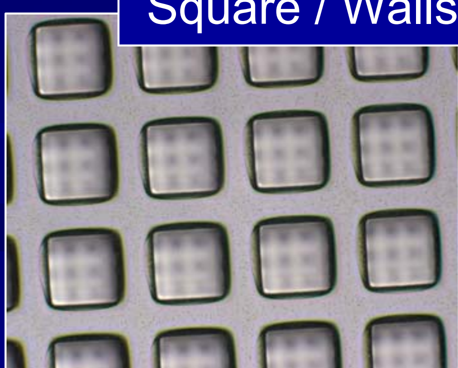


19 different fields of 15 mm Ø
2 bonding pads / fields

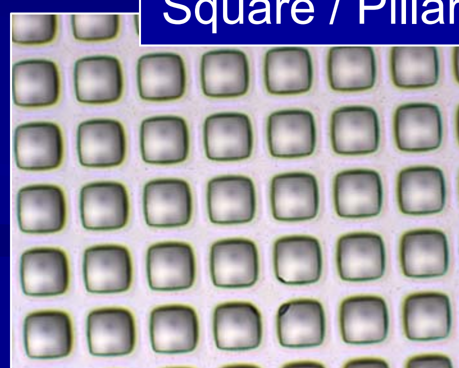
Hex / Pillars



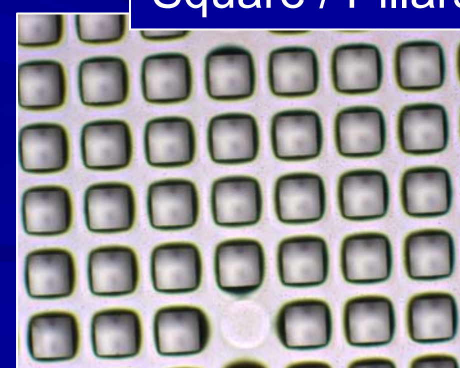
Square / Walls



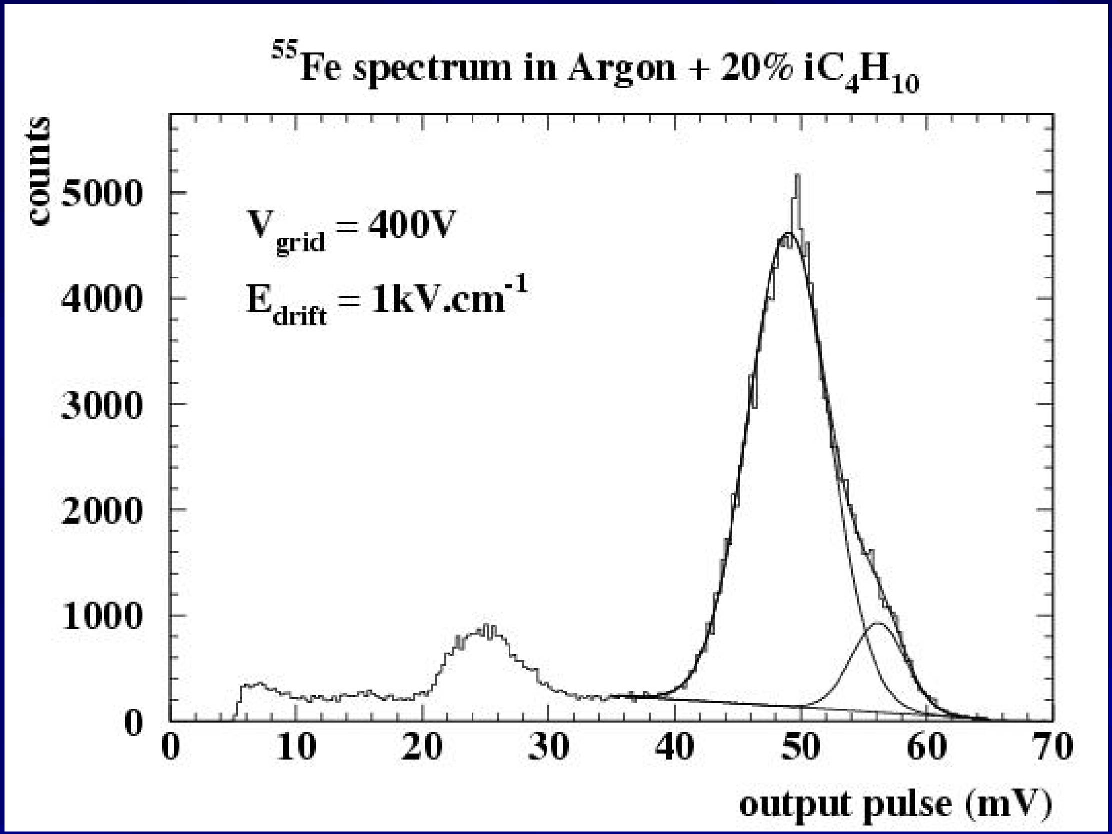
Square / Pillars



Square / Pillars



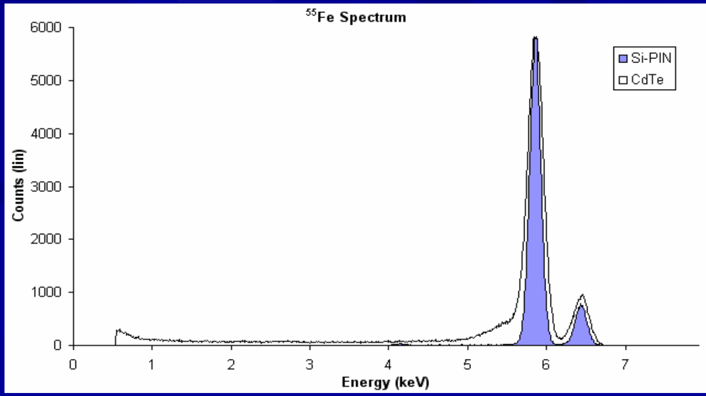
Energy resolution in Argon IsoC_4H_{10} 80/20



- 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%

Very good energy resolution:

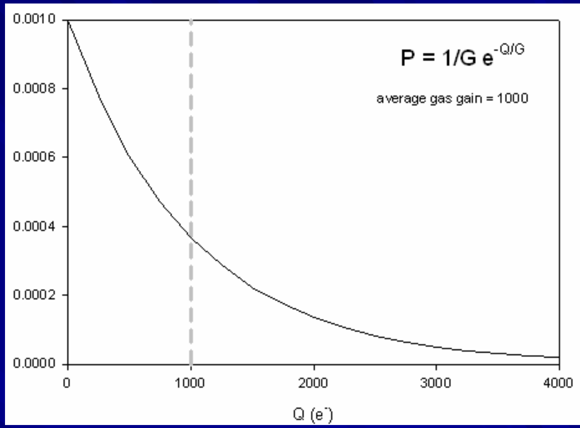
Very precise dimensions d < 0.1 μm



The exponential distribution?

(in single electron response)

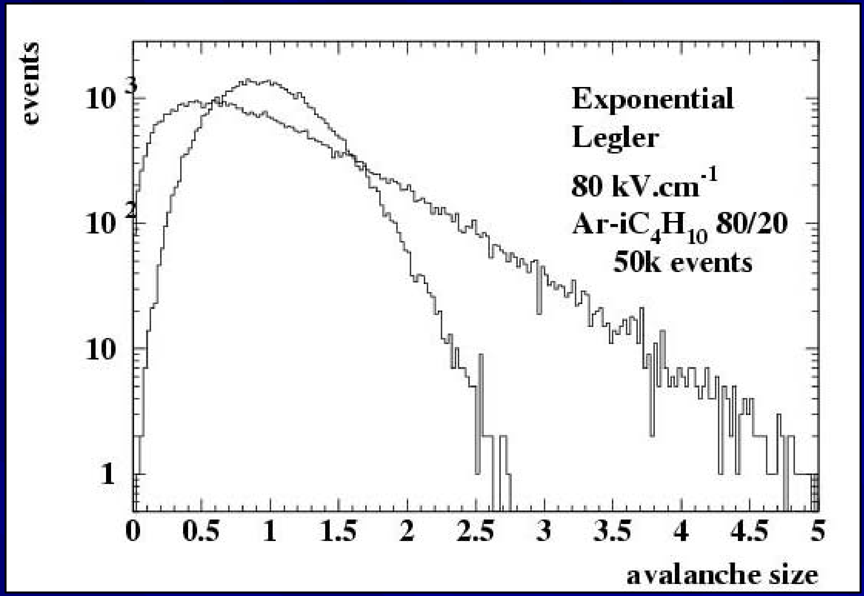
- Basic assumption
  - Ionization probability constant
    Townsend theory: $P_{ion}(dx) = \alpha.dx$
- Analytic form
  - $P(n,x) = \langle n\rangle^{-1} . (1 - \langle n\rangle^{-1})^{n-1}$
  - $\langle n\rangle = e^{\alpha.x}$
  - $P(n,x) \sim \langle n\rangle^{-1} . e^{n/\langle n\rangle}$ @ large n
  - $\sigma = \langle n\rangle$

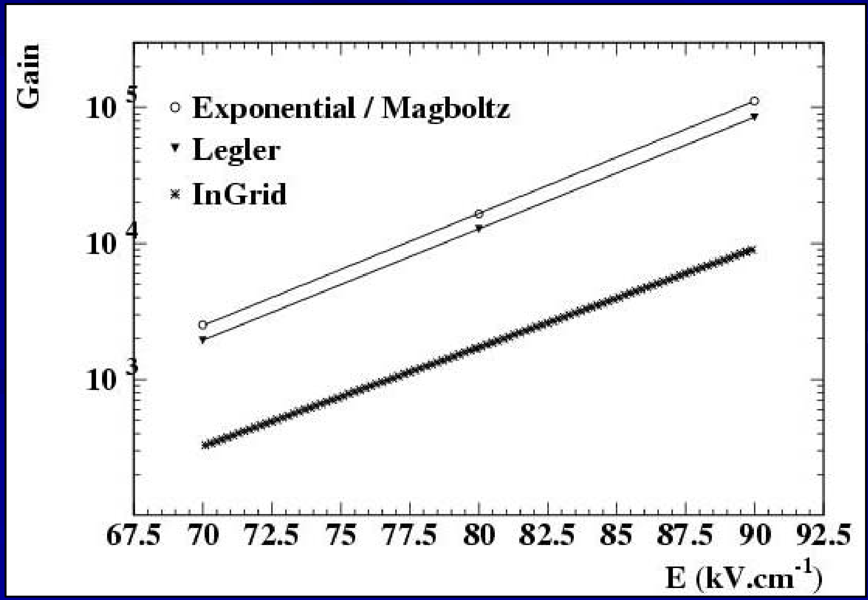


- For 220 e- from ^{55}Fe in Argon
  - Exp model: FWHM = 15.8 % multiplication only
  - InGrid: FWHM = 14.9 % all contributions
- Avalanche fluctuations overestimated

1D Avalanche Model @ constant E

- Input
  - E = 80 kV/cm
  - Gap = 50 um
  - α from MAGBOLTZ (1950 cm^{-1})
  - a_0 from Legler
  - "0" energy after ion.
- FWHM
  - 6.4 %   Legler
  - 15.8 %   Exp.
  - 13.4 %   InGrid (max)
- Gain @ 80 kV/cm
  - InGrid = 1750
  - Exp = 17500 !
  - Legler = 12800 !





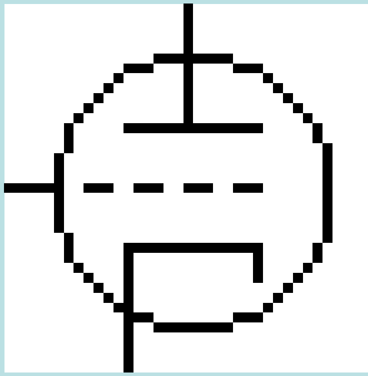
Smaller avalanche gap: we expect

- better energy resolution
- single electron response:
  - smaller RMS
  - better efficiency
  - lower gain required

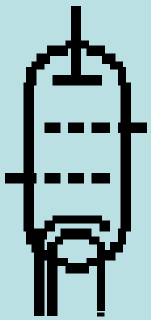
Downscaling hole pitch
hole diameter
avalanche gap
thus granularity, seems feasible

InGrid in preparation for MediPix
TimePix (approved EUDET: 300 kE!)
PSI 46 wafers

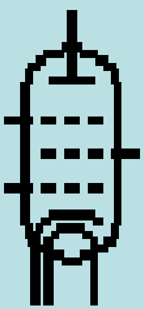
InGrid



triode



tetrode



pentode

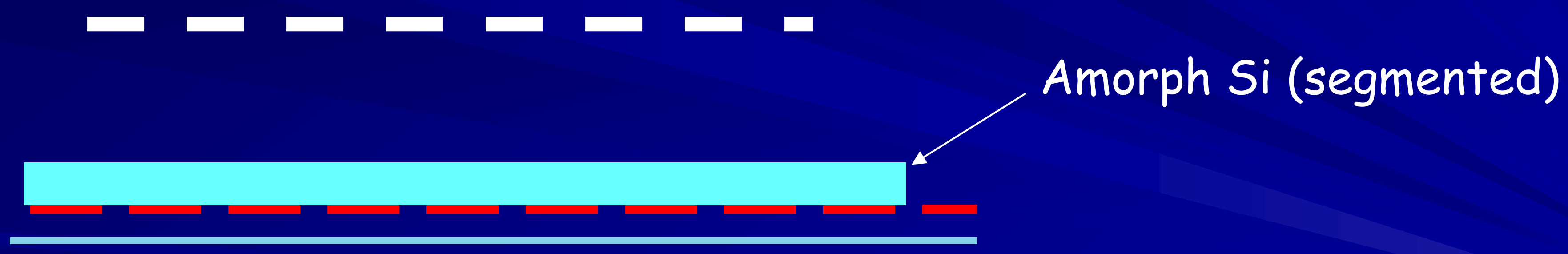
'there is plenty of room at the top':

- single GasGainGrid looks like Micromegas
- dual grid: (much) lower field above fragile pixel chip: looks like GEM
- reduction of ion feedback may require 3rd grid...

There may be MPGDs in the future,
without GEMs or Micromegas!

CMOS Chip protection against

- discharges
- sparks
- HV breakdowns
- too large signals



Emperical method:
Try RPC technology

- RPC principle: reduction of local E-field (Werner Riegler)
- Avalanche charge: electrostatic induction towards input pad
- Specific resistance:
  - high enough to 'block' avalanche charge
  - low enough to compensate signal current
  - layer thickness 4 μm, R_{vol} = 0.2 GΩ/cm
- Segmentation of A – Si may be required to prevent preamp-preamp coupling

Technology

- A-Si deposits possible in general, but wafers may get too hot
- Univ. of Neuchatel/IMT/P. Jarron (CERN) uses this for integrated X-ray sensor/convertor on MediPix 2
- pre-poster post processing before application of InGrid

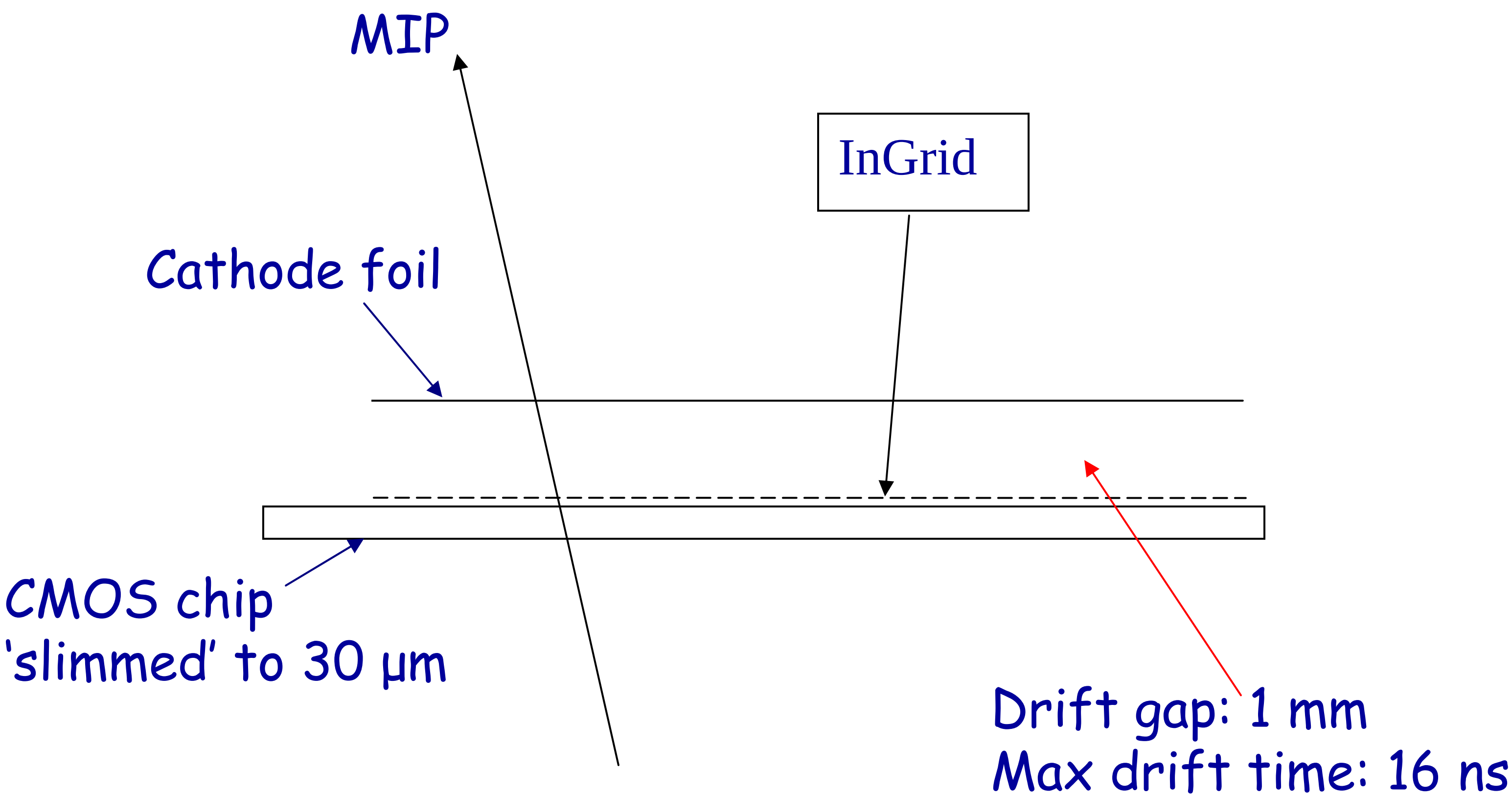
Applications of GridPix:

- Large TPC: L_{drift} = 2000 mm
- μ-TPC: L_{drift} = 200 mm
- Transition Radiation Detectors: L_{drift} = 20 mm
- GOSSIP: hi rad vertex detector: L_{drift} = 1 mm

Same principle:

- readout plane, including GasGainGrid + FE electronics
  - ultralight
  - low power (gas cooling!)
  - low cost (5 Euro/cm^2)
  - # readout channels: not a cost issue

- drift space: application specific



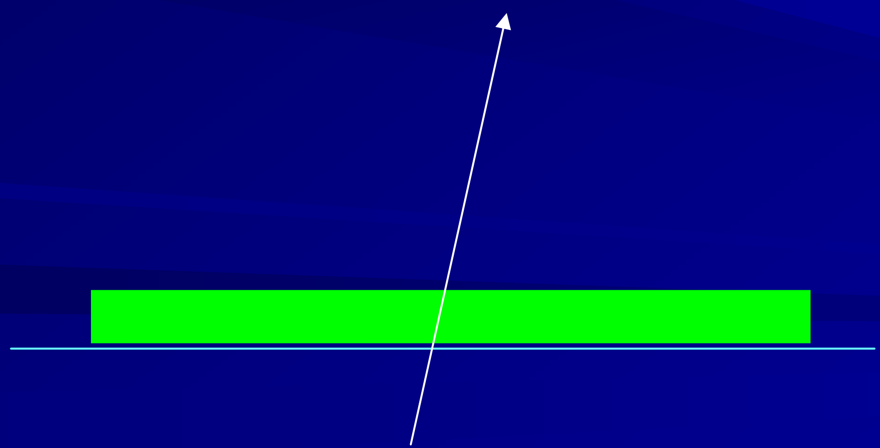
GOSSIP: Gas On Slimmed SIlicon Pixels
new vertex detector!

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
- Little power dissipation of preamps
- No detector bias current
- Ultra light detection layer (Si foil)
- less sensitive for background radiation (X-rays, n, gammas)



Vertex detectors:

- gas filled until 1980
- Domain of Si: strips, CCDs, pixels, MAPs
- back to gas-filled MPGDs!

Gossipo: MultiProjectWafer submit (0.13 μm technology) for ASD

Aging

Less aging of a GridPix detector versus wire chambers:

- Ratio of anode surface: thin wire surface versus anode plane (~20x)
- Low gas gain (1 k) due to fast signal and low source capacity (~20x)

total factor: 400x

- E-field near (flat) anode factor ~3 less than E-field near wire surface

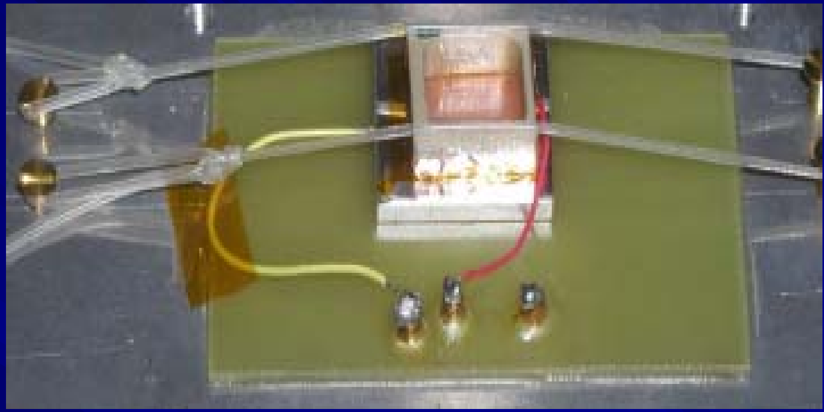
So: no issue for ILC-TPC
So: application as GOSSIP vertex detector in Super LHC seems feasible

First try

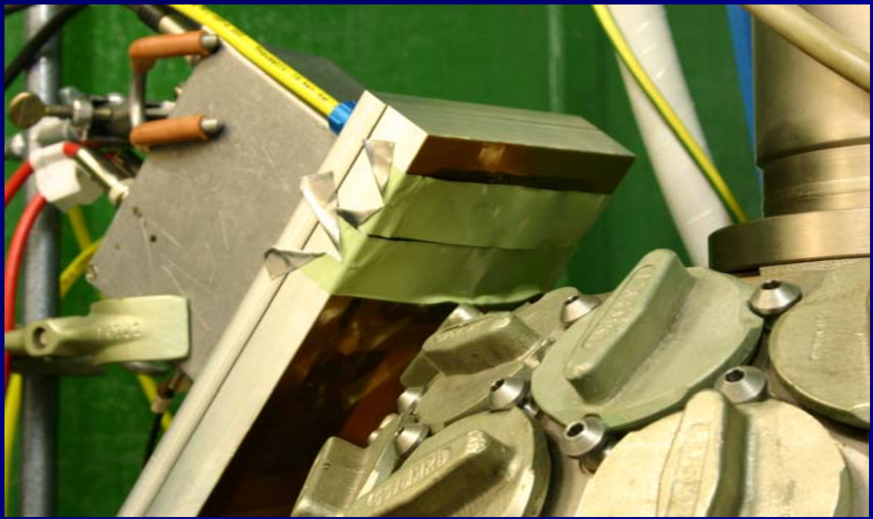
Aging test (remember MSGCs….!)

Half the GridPix was irradiated with 8 keV X-rays.

Gas: normal Ar/Methane90/10
Many plastics included.

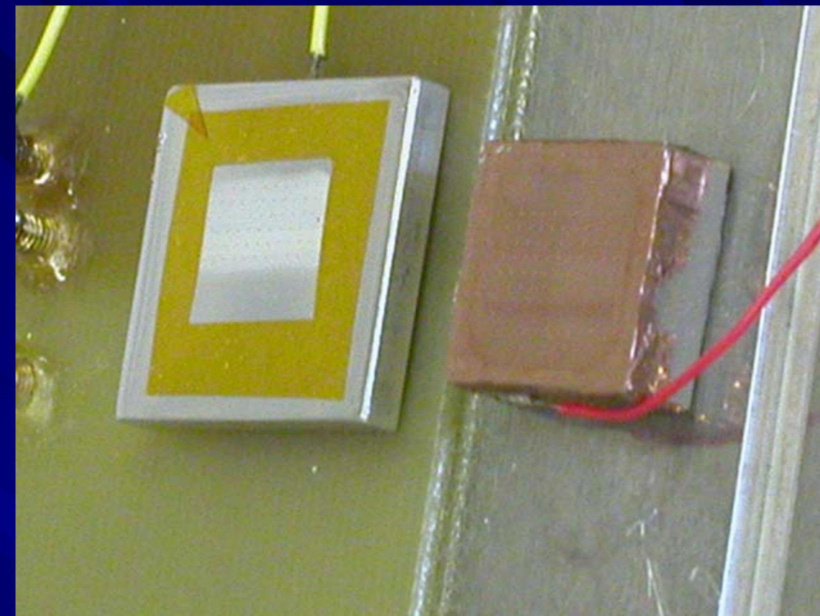


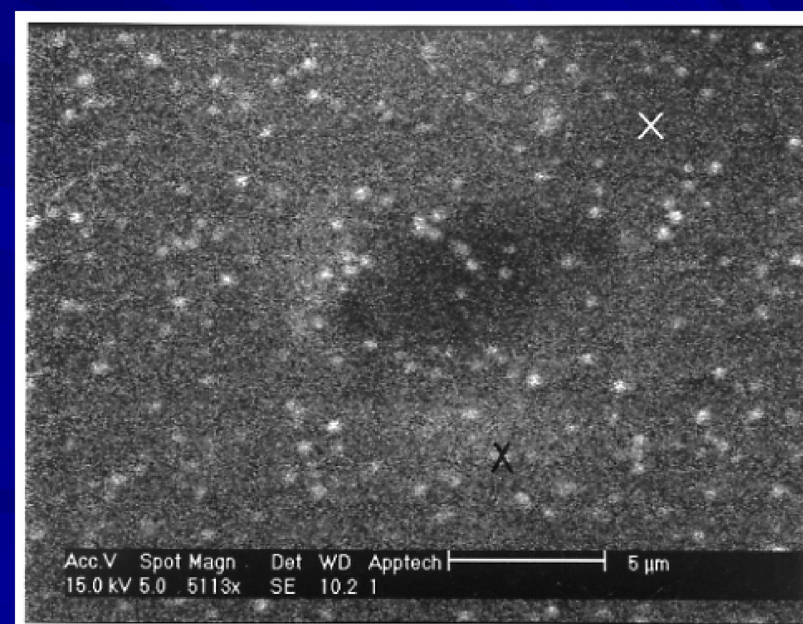
Chamber: Same as GridPix, but with polished Al plate as anode instead of MediPix



No rate effects up to anode current density of 0.2 μA / mm2

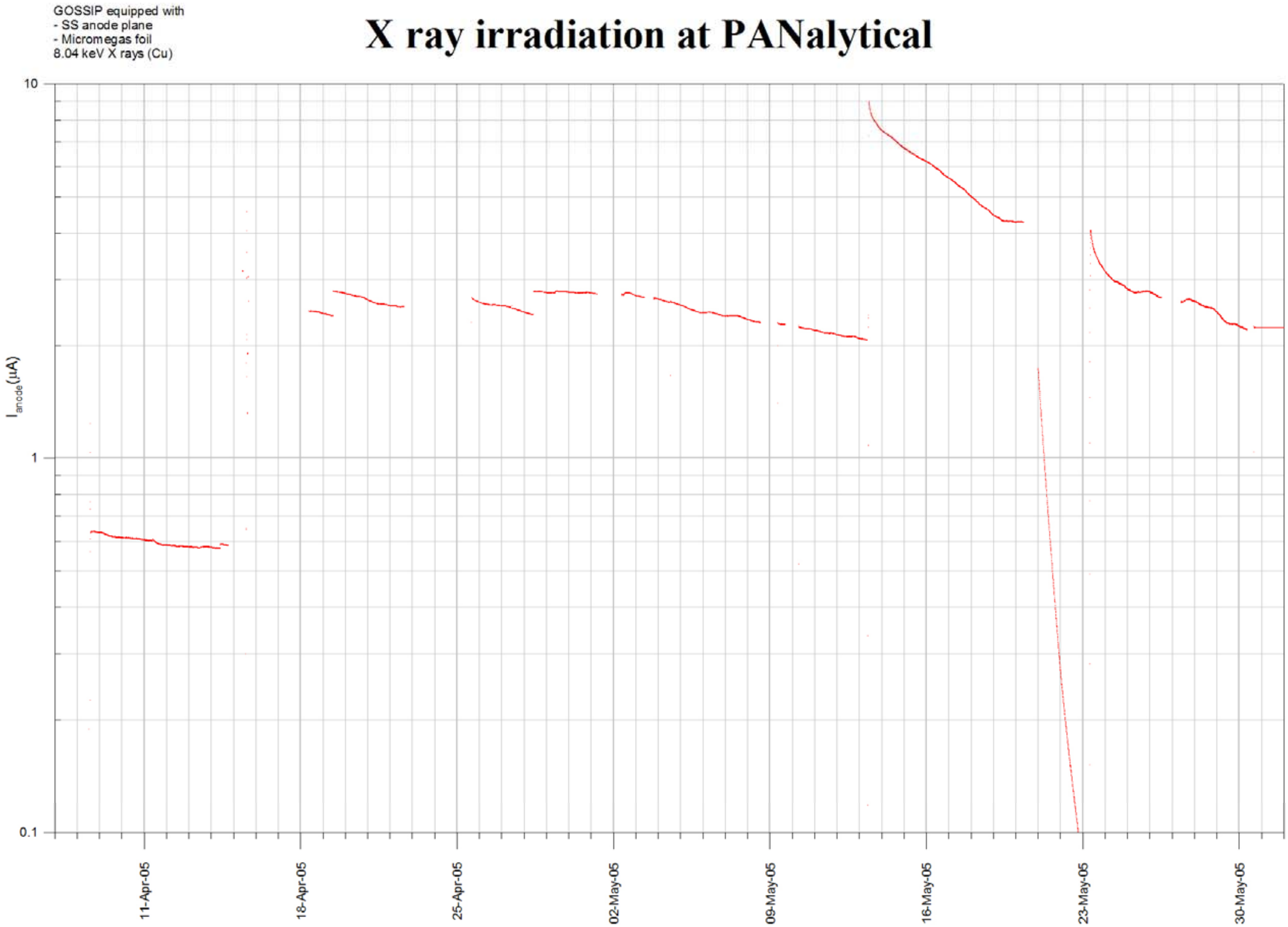
After 0.3 Coulomb/mm2, deposit of carbon polymer on anode is clearly visible.
Micromegas is clean (!?)
Little deposit on cathode





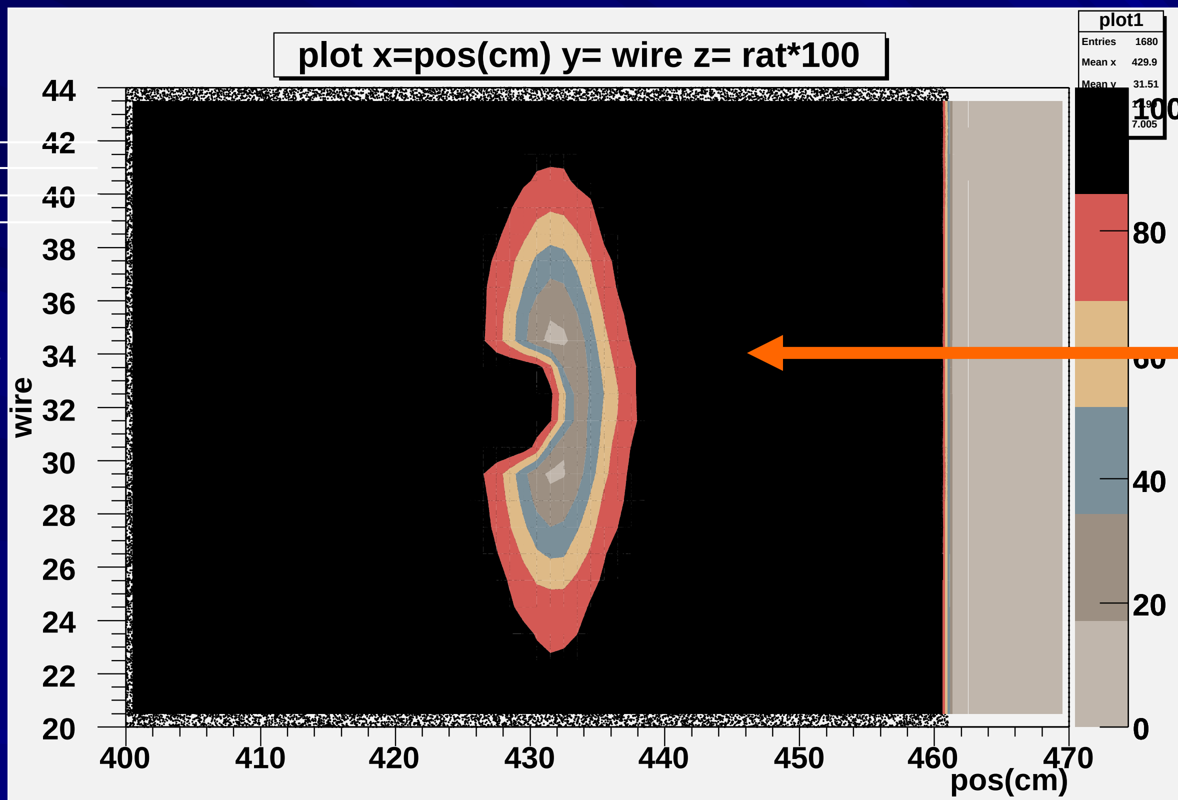
Very stable operation during exposure; current decrease significant after 24 h.

X ray irradiation at PANalytical



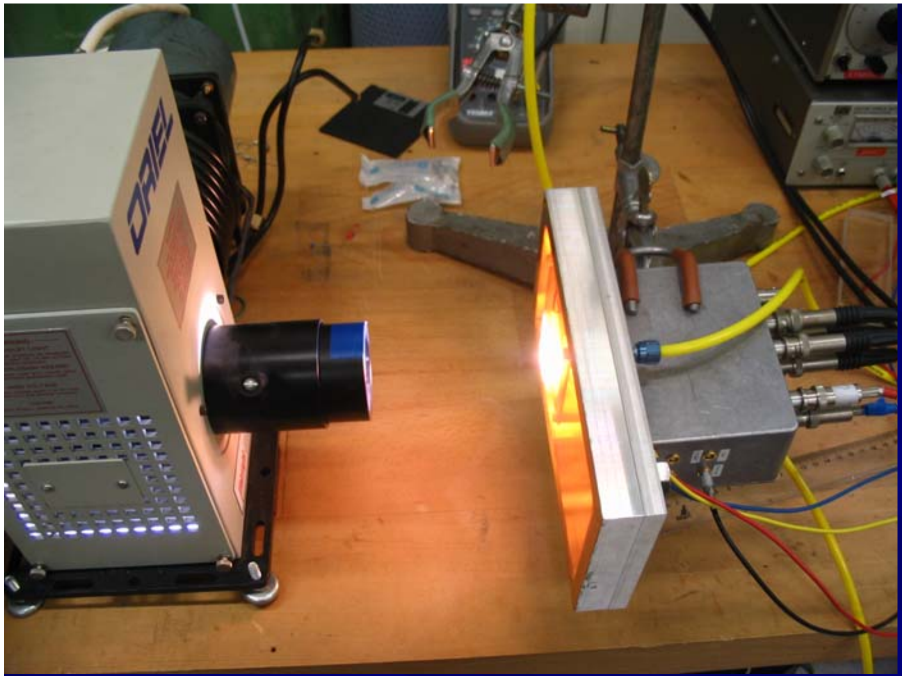
F.Sauli in NIM A 515 (2003) 358-363:
' ….a way to clean the gas…'

anode wires
pitch 5 mm



gas flow

LHCb chamber

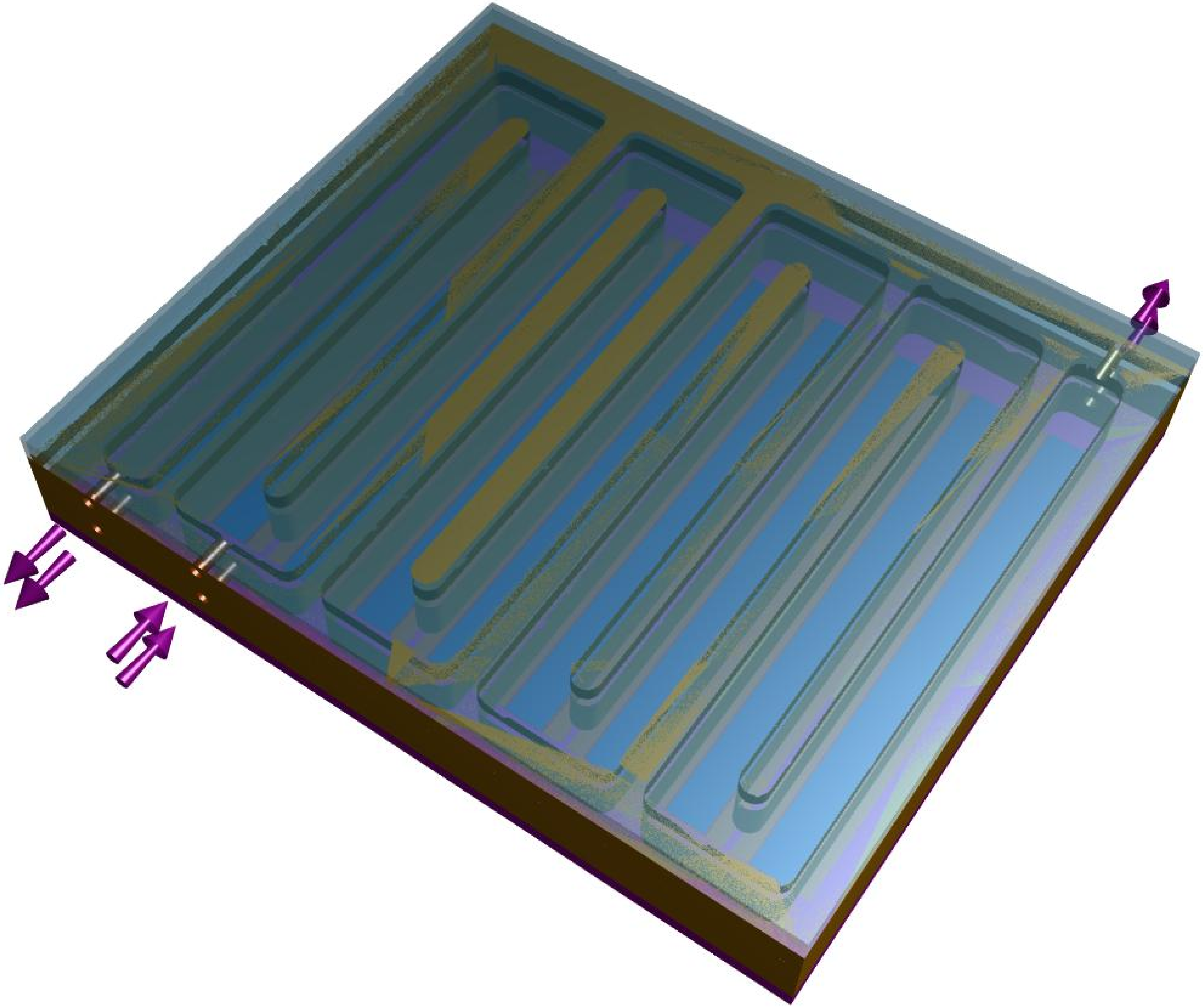


New attempt to solve/fight/learn about ageing

Ageing-free system: modify until there is *No Ageing!*
- construct GridPix chamber from non-ageing materials
- apply closed loop gas system (Ar/CO_2/DME)
- irradiate cathode (mesh) with UV light (Xe lamp) ➔ 1 µA/mm2 anode current

Add (traces of) suspected compounds to chamber gas
- SiO_2, SiH_4, $CSiH_6$
- outgassing Teflon, Viton, G10, epoxy, ethanol, H_2O etc

If ageing compound(s) are found:
- measure absorption efficiency
- apply active filters



As interaction material for detectors for charges particles, gas has certain advantages. New high-granularity, readout-integrated concepts may be preferred above Si detectors in the near future.

The stability of the gas gain process is better if there are as little as possible insulating materials facing the (avalanche) region with strong electrical field

The mail building block of a GridPix detector is a CMOS chip. Chip design manpower is required (highest level: ana-digi mix) in this period of detector R & D. The FE and DAQ electronics can not be separated from the detector, as has been the case so far. Example: Gossipo: PreampShaperDiscriminator MPW submit on 0.13 μm tech.

The present MPGD Detector R & D is NOT driven by LHC results. Always required: better resolution, better dE/dX, lighter, less power, radiation hard, no ageing, cheaper

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Univ. Twente/Mesa+
Jurriaan Schmitz
Cora Salm
Sander Smits
Victor Blanco Carballo

CERN
Erik Heine
Medipix Consortium

Thanks to:
Wim Gotink
Joop Rovenkamp

GridPix: the electronic bubble chamber