R&D for a digital TPC
The SiTPC project

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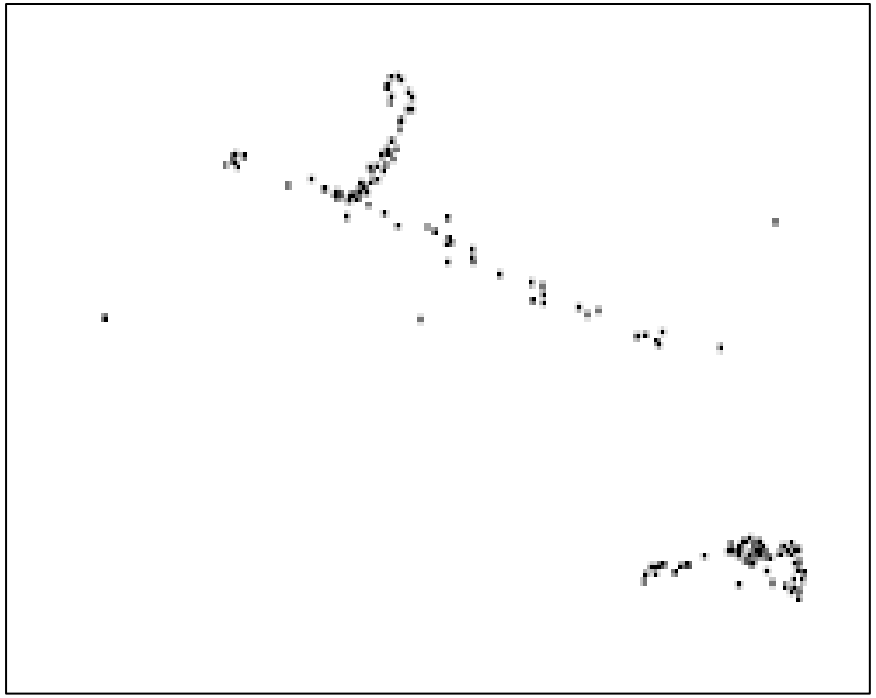
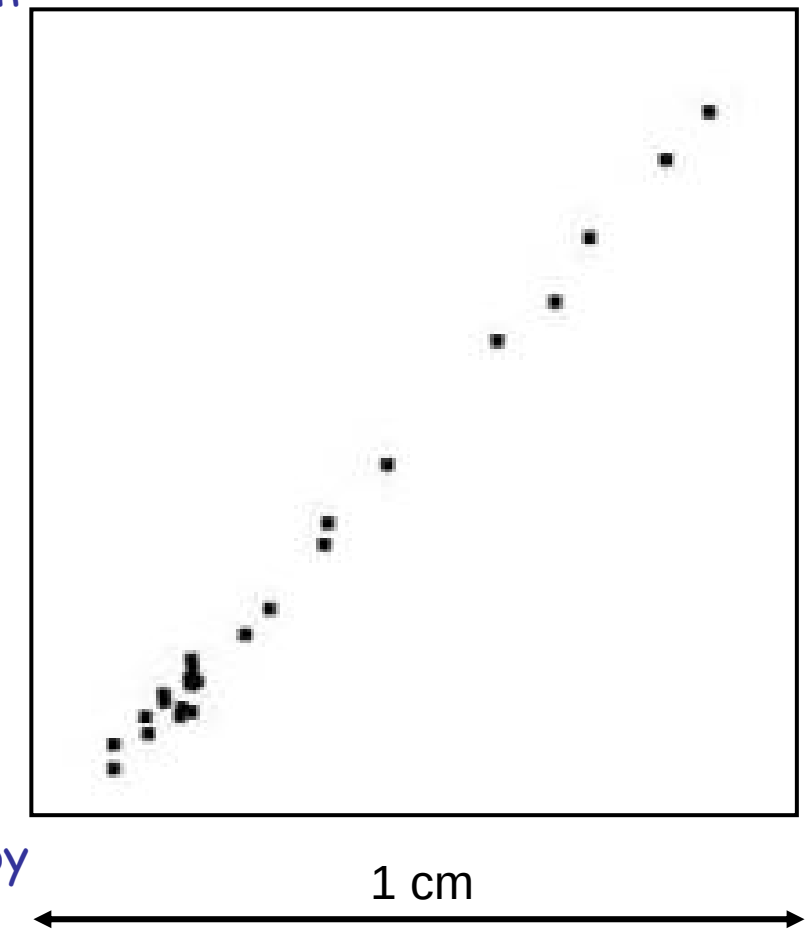
(CERN, Freiburg, MESA+/Twente, NIKHEF, Saclay)

- The digital TPC concept and advantages
- VLSI electronics: from Medipix2 to TimePix
- Micromegas and GEM achievements
- Integrated grid
- Protection issues
- Aging studies



The digital TPC concept

- Reconstruct a track electron by electron (or cluster by cluster)
- Optimally use this basic information:
  - Insensitive to gain fluctuations
  - dE/dx optimal resolution from cluster counting
- If you cover the whole TPC surface, $O(10^{8-9})$ channels instead of 10^6, but all digital (1/0)
- First costing attempts show it is comparable or cheaper than a standard readout
- Can consider replacing a few pad-rings by digital anode chips (gas club sandwich)

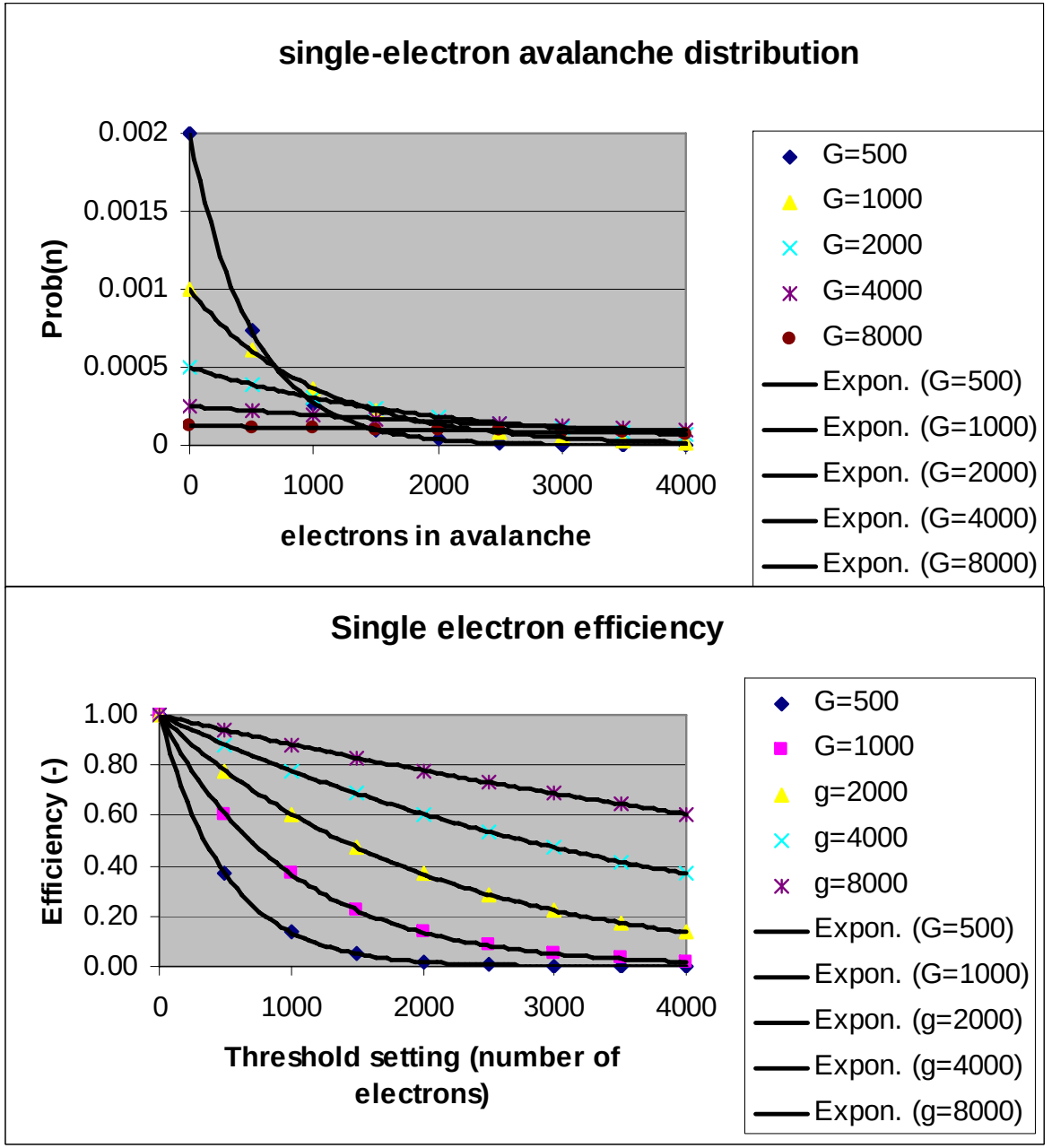


Gain fluctuations

- In first approximation, gain fluctuates exponentially in a parallel-plate chamber.
- In presence of noise, a 4 or 5 st.dev. cut costs in efficiency for single electron
- A gain of 19000 was necessary to see the single electrons with 90% efficiency
- Sparks destroy the chips

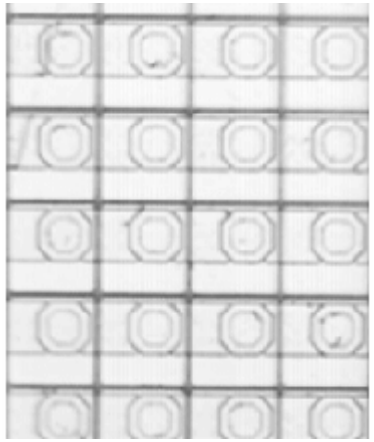
-> LOWER NOISE

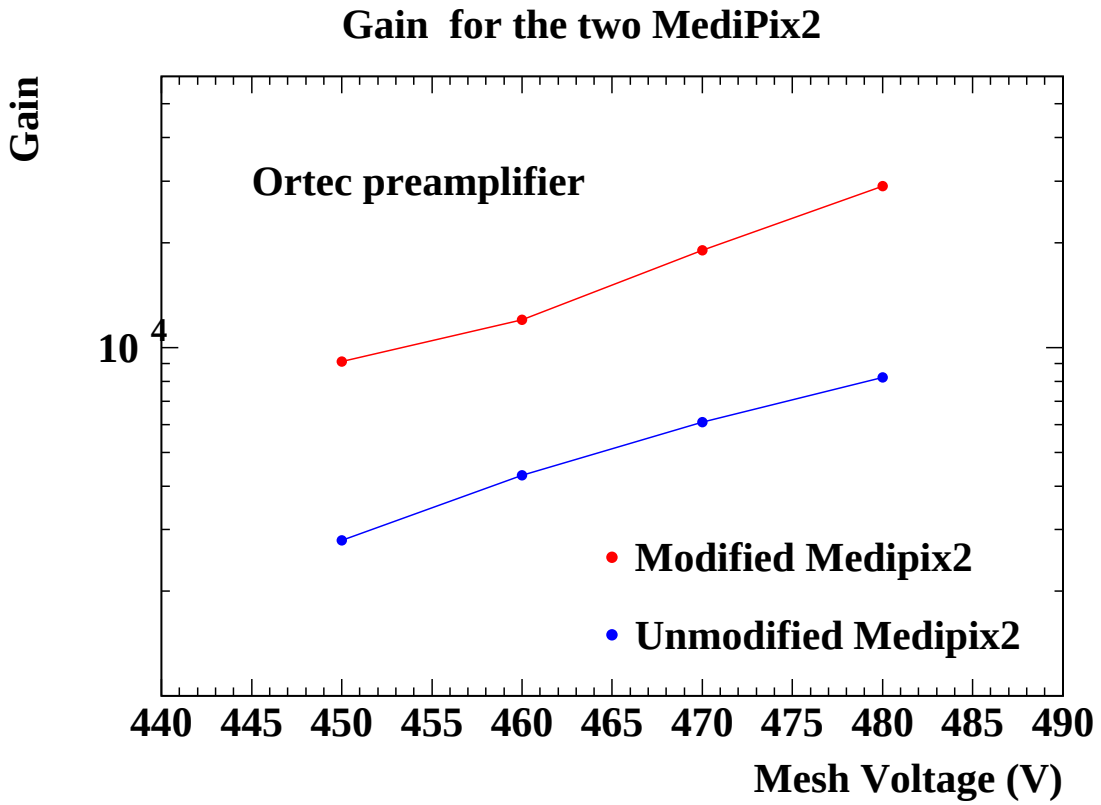
-> PROTECT CHIPS



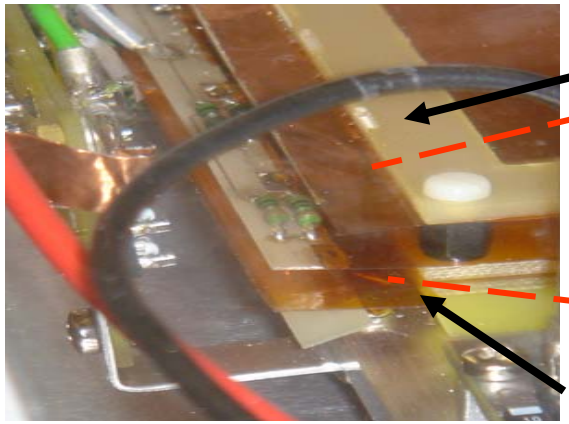
Gain with He+20% isobutane

- The gain with modified Medipix (80% conductive surface) is 3 to 4 times larger than with unmodified Medipix (20% conductive surface)





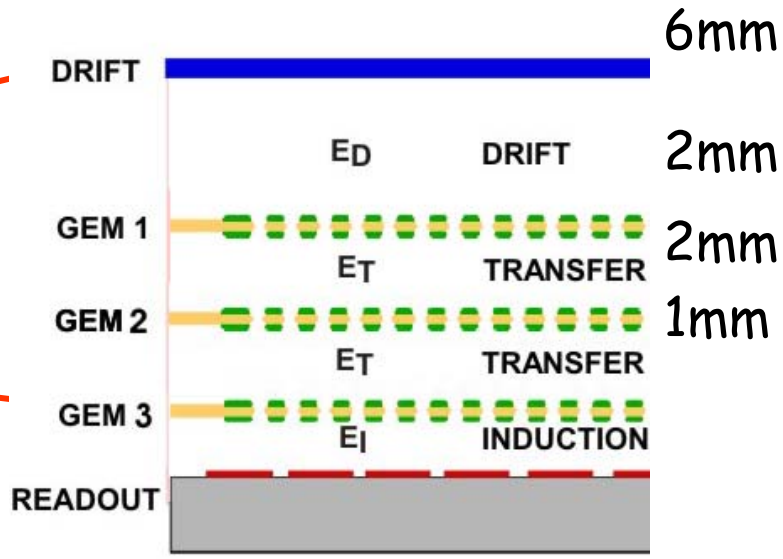
The Freiburg GEM setup



drift electrode

GEM 1
GEM 2
GEM 3

readout electrode



typ. potentials/fields:

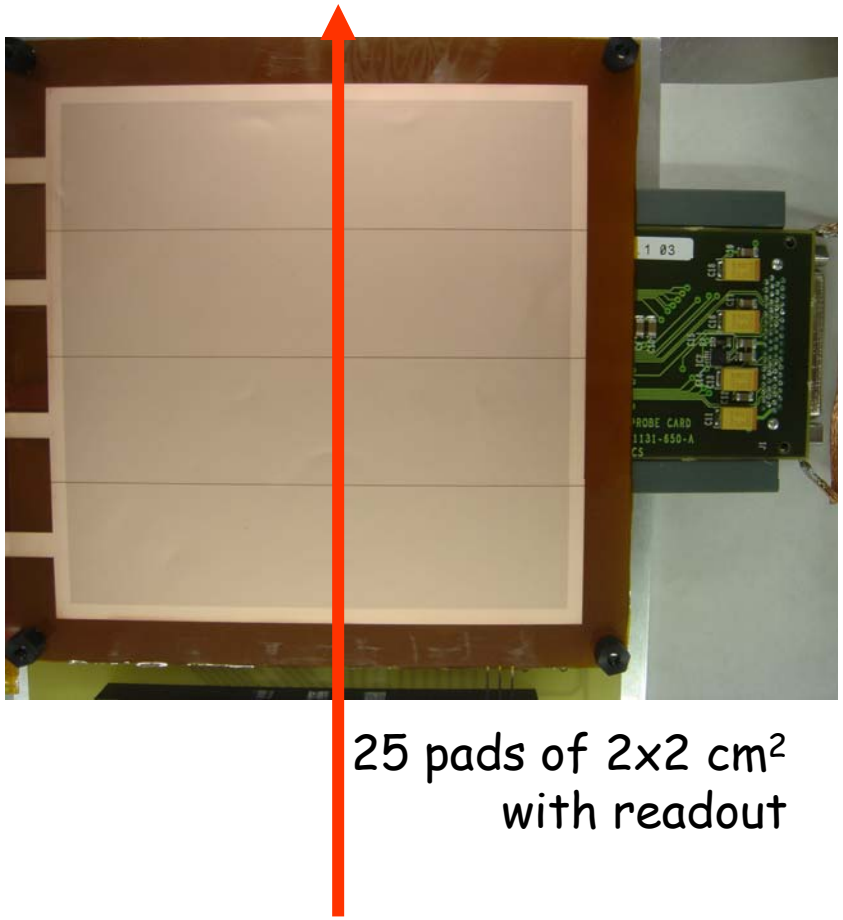
E_D= 1.1 kV/cm

ΔV_{GEM}= 404 V

E_T = 3.2 kV/cm

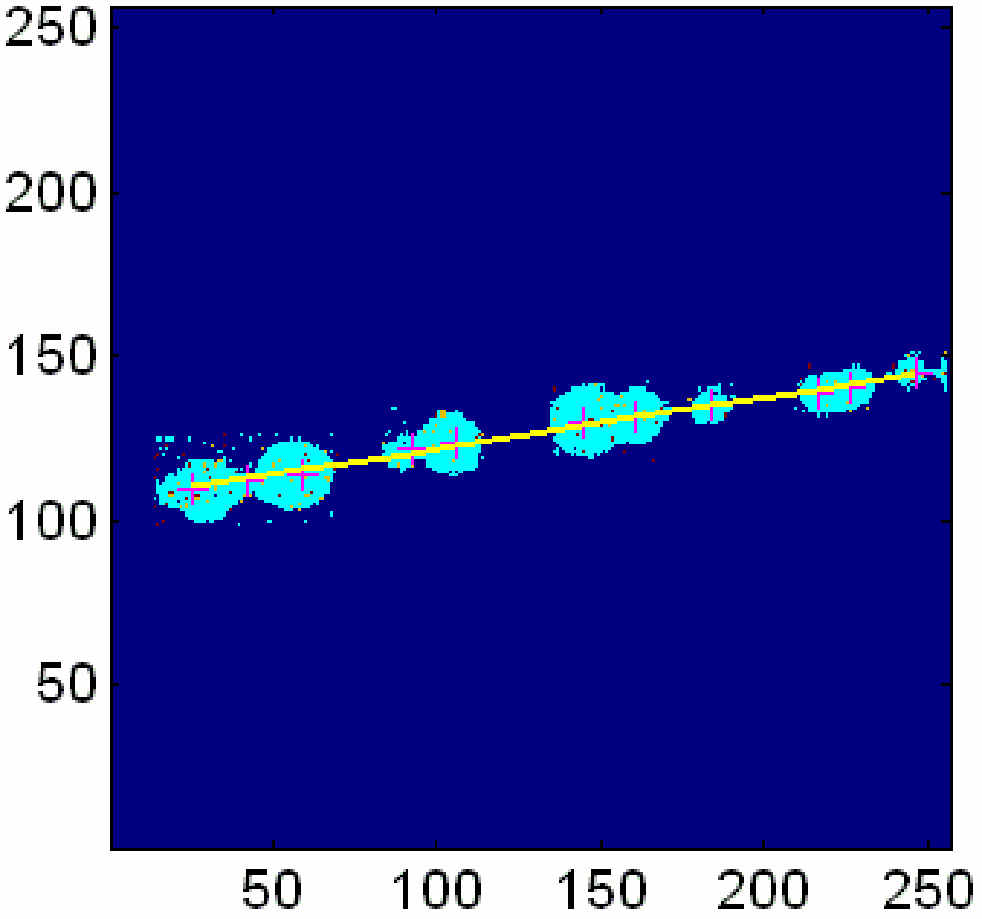
E_I = 4.0 kV/cm

The Freiburg GEM setup for point resolution measurement



25 pads of 2x2 cm^2 with readout

β^- source Ru106, 3.5 MeV from daughter Rh106 crosses 4 pads with MediPix2 in between

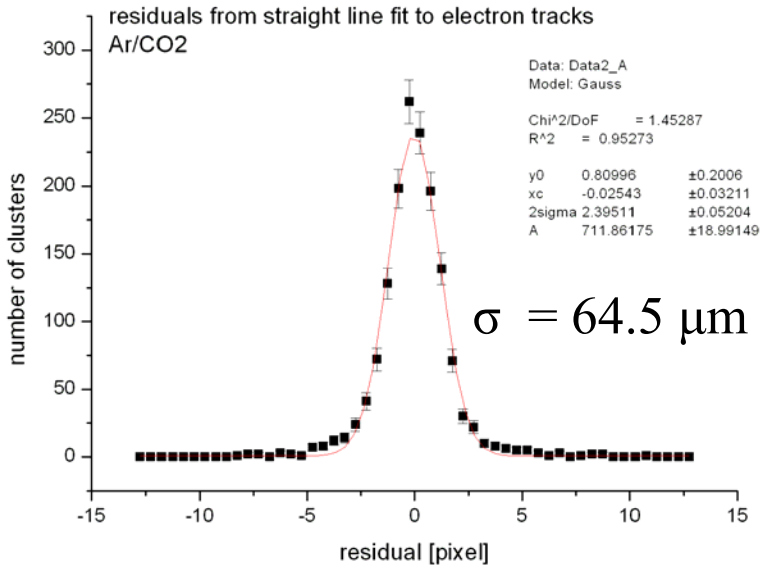


Resolution

Two methods:

residuals of a straight line fit
and triplet method

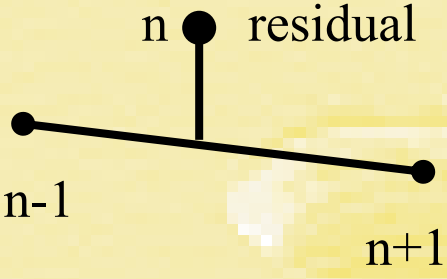
	Ar/CO2	He/CO2
residuals (str. line)*	65 ± 1.4 μm	51 ± 2.5 μm
Triplet meth resolution,	57 ± 1.3 μm	53 ± 2.8 μm



Difference understood:

Due to multiple scattering

triplet method:



residuals reweighted by a factor close to √(2/3)

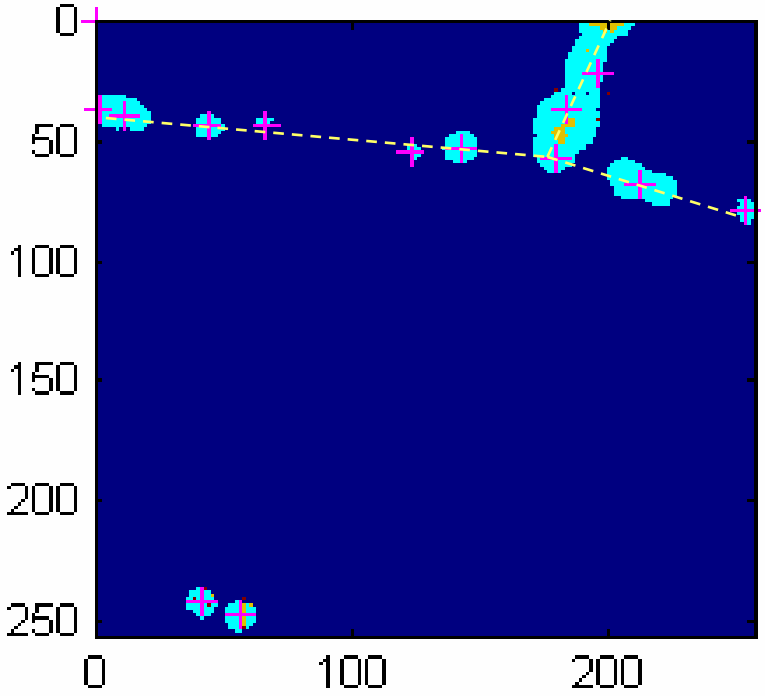
* slightly biased, still under investigation

a “fast” δ-electron

recoil electron of
> 23 keV
because track
length >3mm

angle close to 90°

incoming e-
from ^{106}Ru



outgoing
electron at ~ 10°

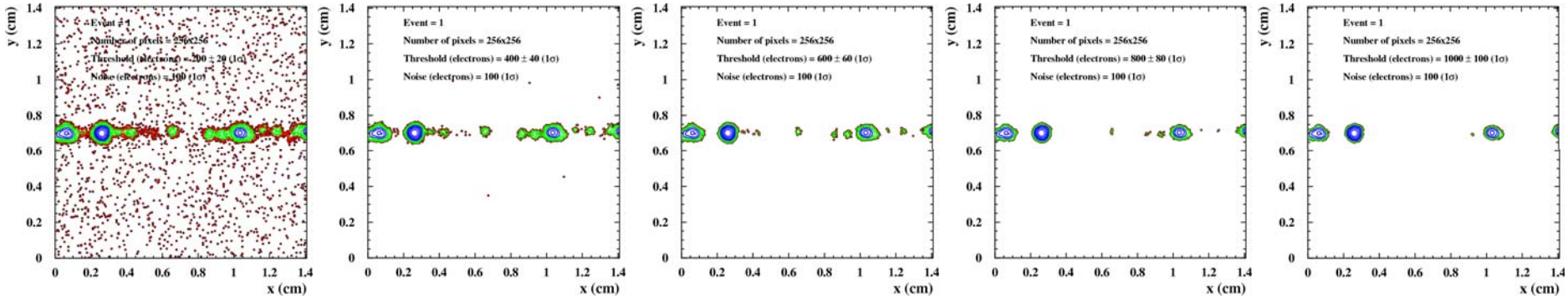
He/CO_2

Simulations at CERN: Threshold Scan

GEM

detection thresholds per pixel (allow 10% variation):

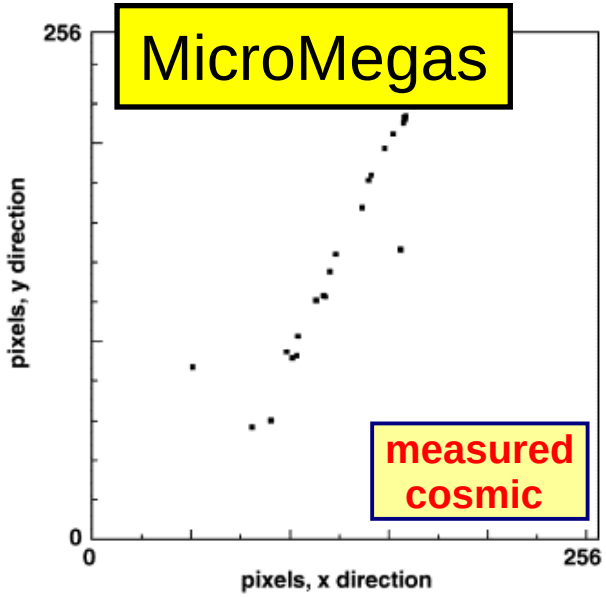
200 ± 20 e⁻ **400 ± 40 e⁻** **600 ± 60 e⁻** **800 ± 80 e⁻** **1000 ± 100 e⁻**

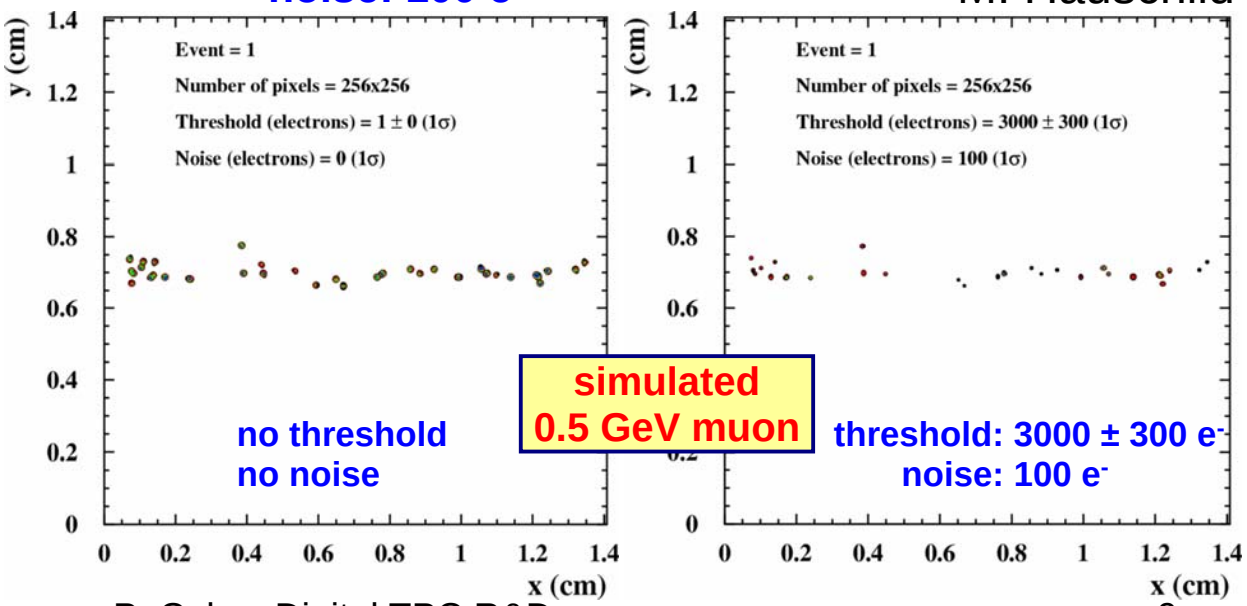


noise: 100 e⁻

M. Hauschild

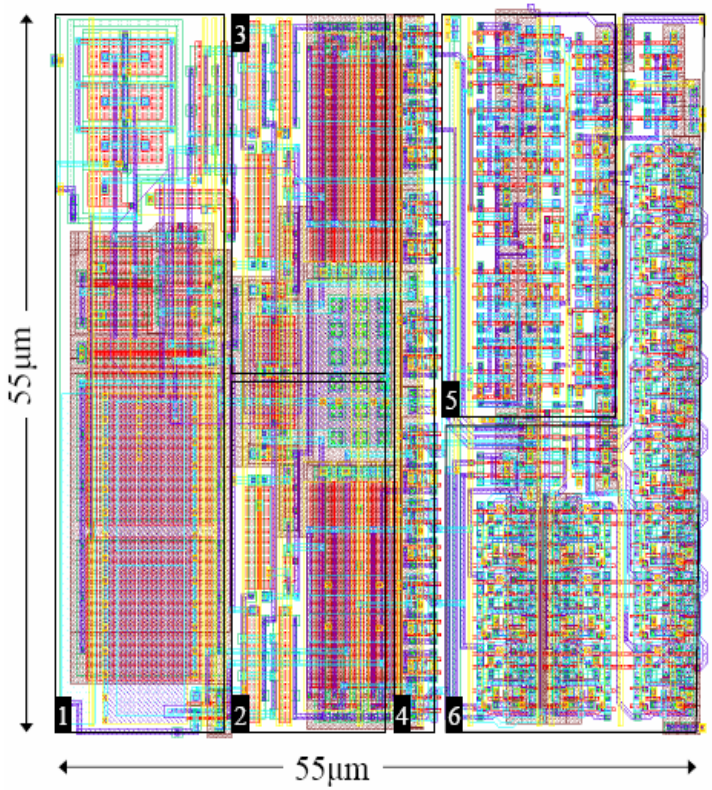
MicroMegas





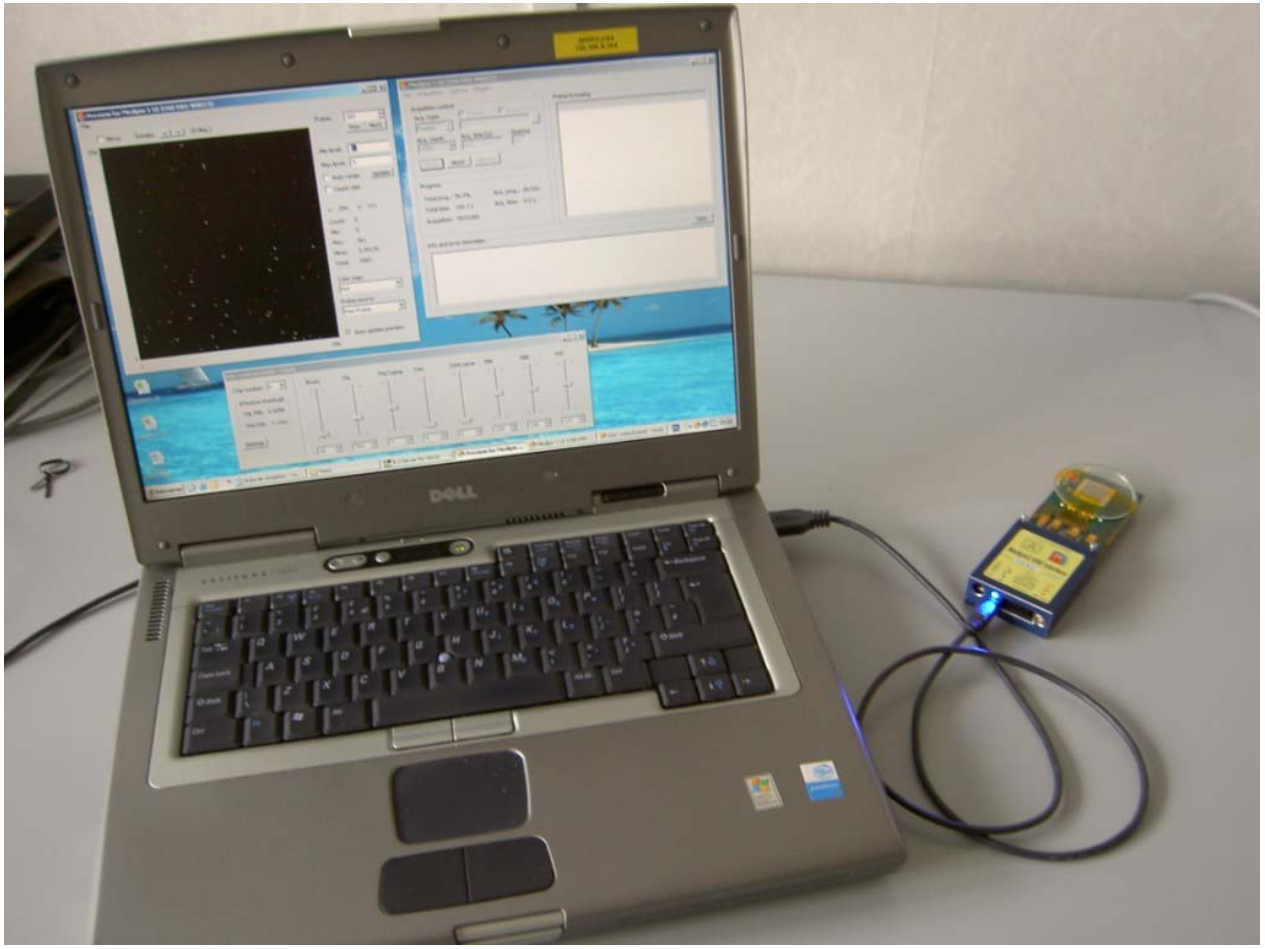
From Medipix2 to Timepix

- Medipix collaboration: 17 institutes, since 1999
- CMOS chip, 0.25µ technology, 65000 pixels on 2cm^2
- Upgrade of Medipix2: MXR version, less sensitive to temperature, finer setting of the pedestals pixel by pixel
- Also new readout board/card: USB (so far 6x slower than MUROS board)



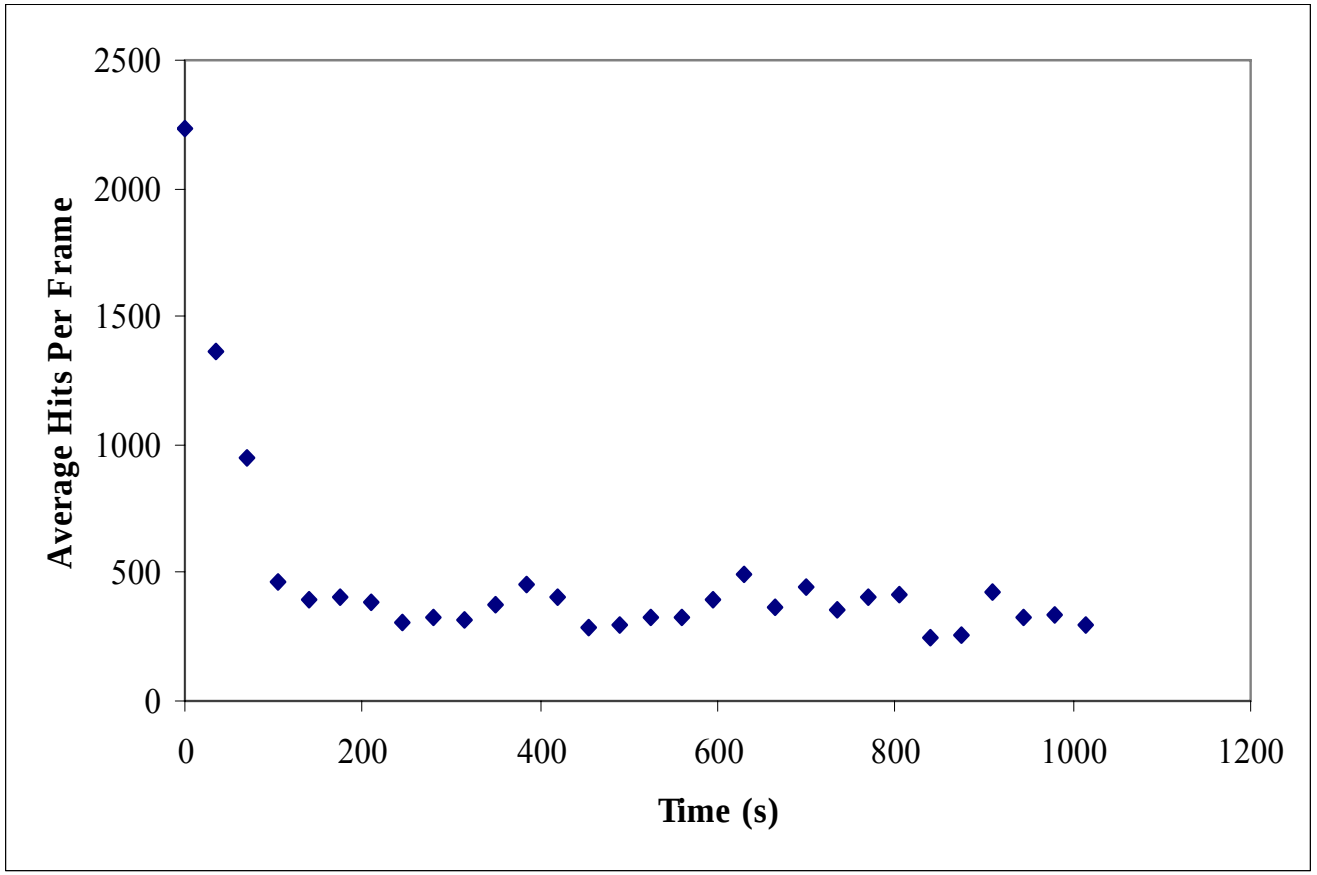
1 pixel = preamp (1)+ 2discri (2,3) + 8-bit DACs (4)+ 14-bit counter (6)

New Medipix2/MXR under study at Saclay



New Medipix2/MXR under study at Saclay

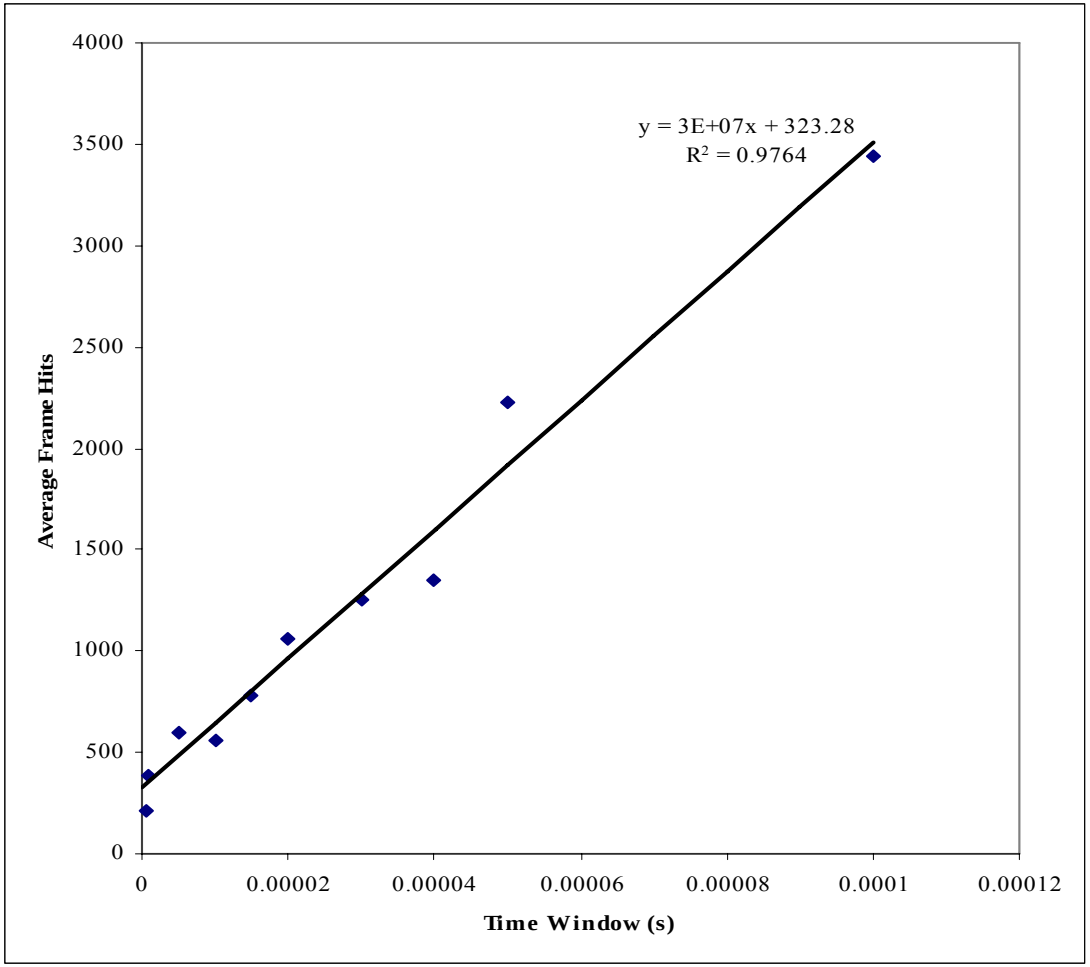
Noise vs. Running Time (from cold)
Medipix2/MXR Chip J07



New Medipix2/MXR under study at Saclay

Average number of hits vs time, for threshold at median noise:

Slight offset

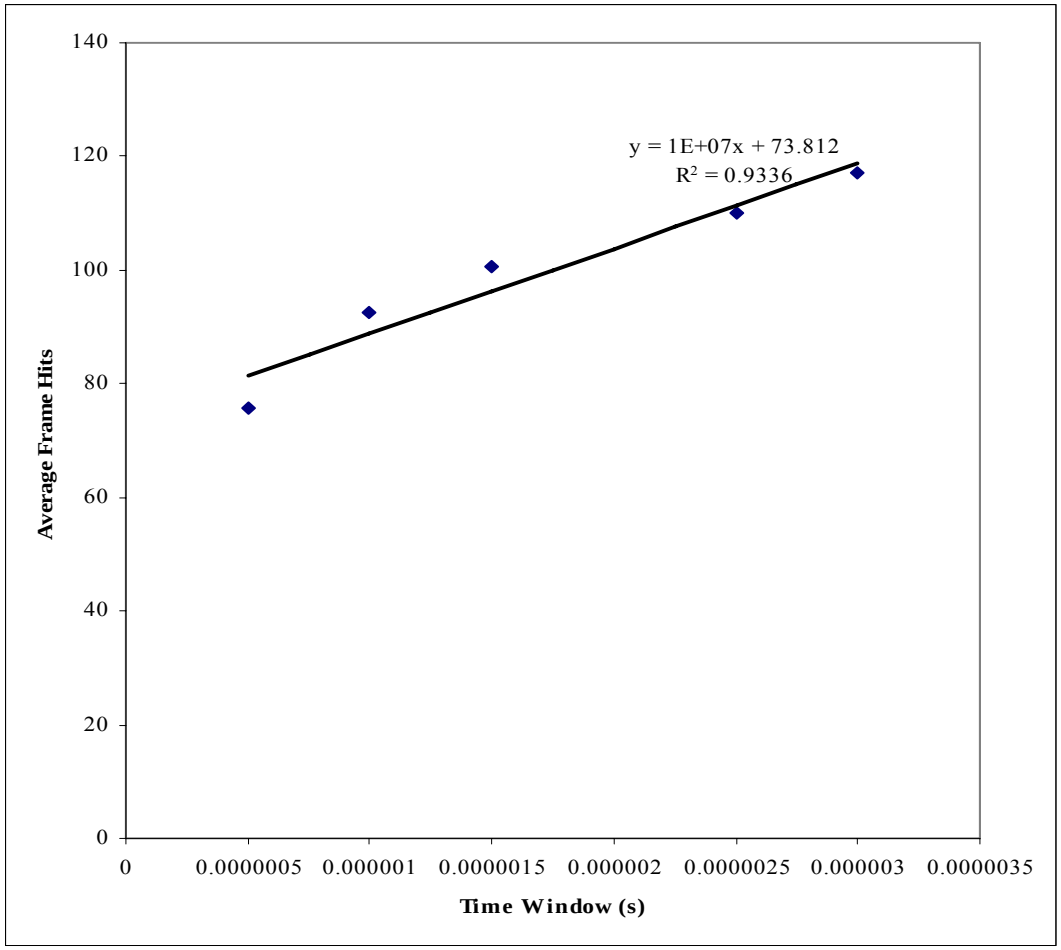


New Medipix2/MXR under study at Saclay

Average number of hits vs time, for threshold 1 step higher

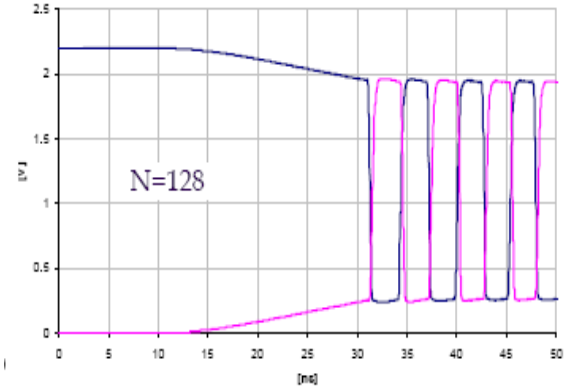
Offset larger in relative value

This means that there is correlated noise, thus room for improvement



From Medipix2 to Timepix

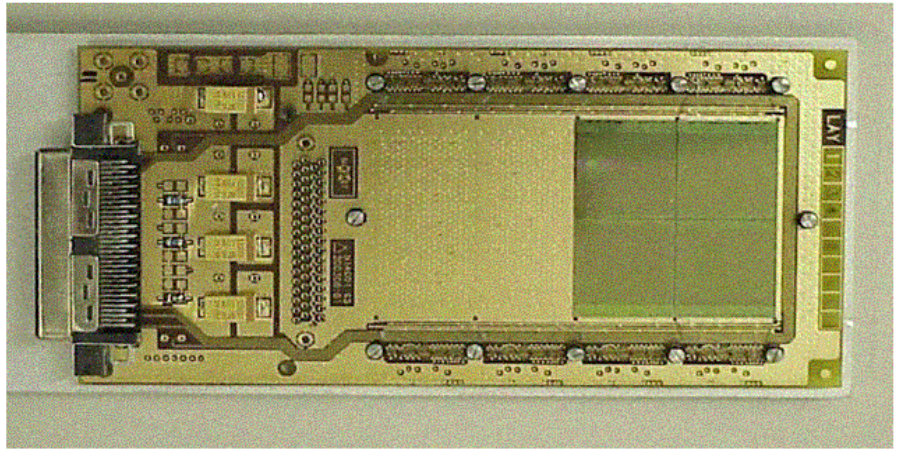
- Minimize changes to limit risks
- Provide a time measurement : distribute the clock (10 to 100 MHz) on every pixel (a clock per pixel was envisaged, but clock frequency is a function of power)
- Columns of ring oscillators with current starving are used for this (column buffered clock)
- Switchable Time-Over-Threshold (provides spectral capability) pixel by pixel.
- Provide protection by a resistive layer (3 microns of hydrogenated amorphous silicon, $10^{10\text{-}12}$ Ω.cm), equivalent to a O(100 MΩ) resistor which discharges slowly the mesh and lowers HV locally
- OK for our signals $1/C\Omega \ll R$ (C~20 fF)
- TEST IN PROGRESS



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)



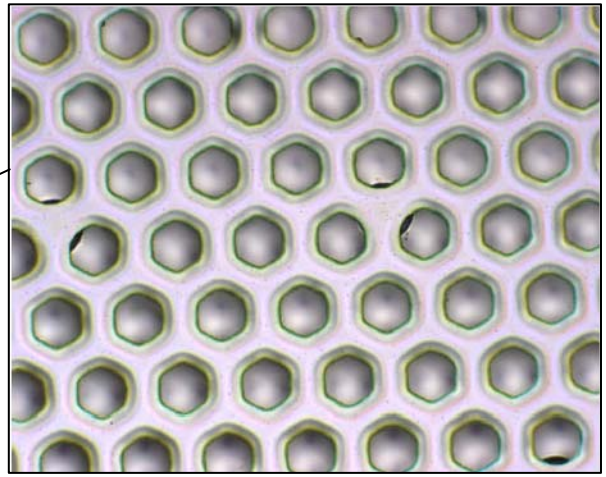
Further development:InGrid (MESA+/Twente,NIKHEF)

Integrating the Micromegas by Silicon wafer post-processing allows:

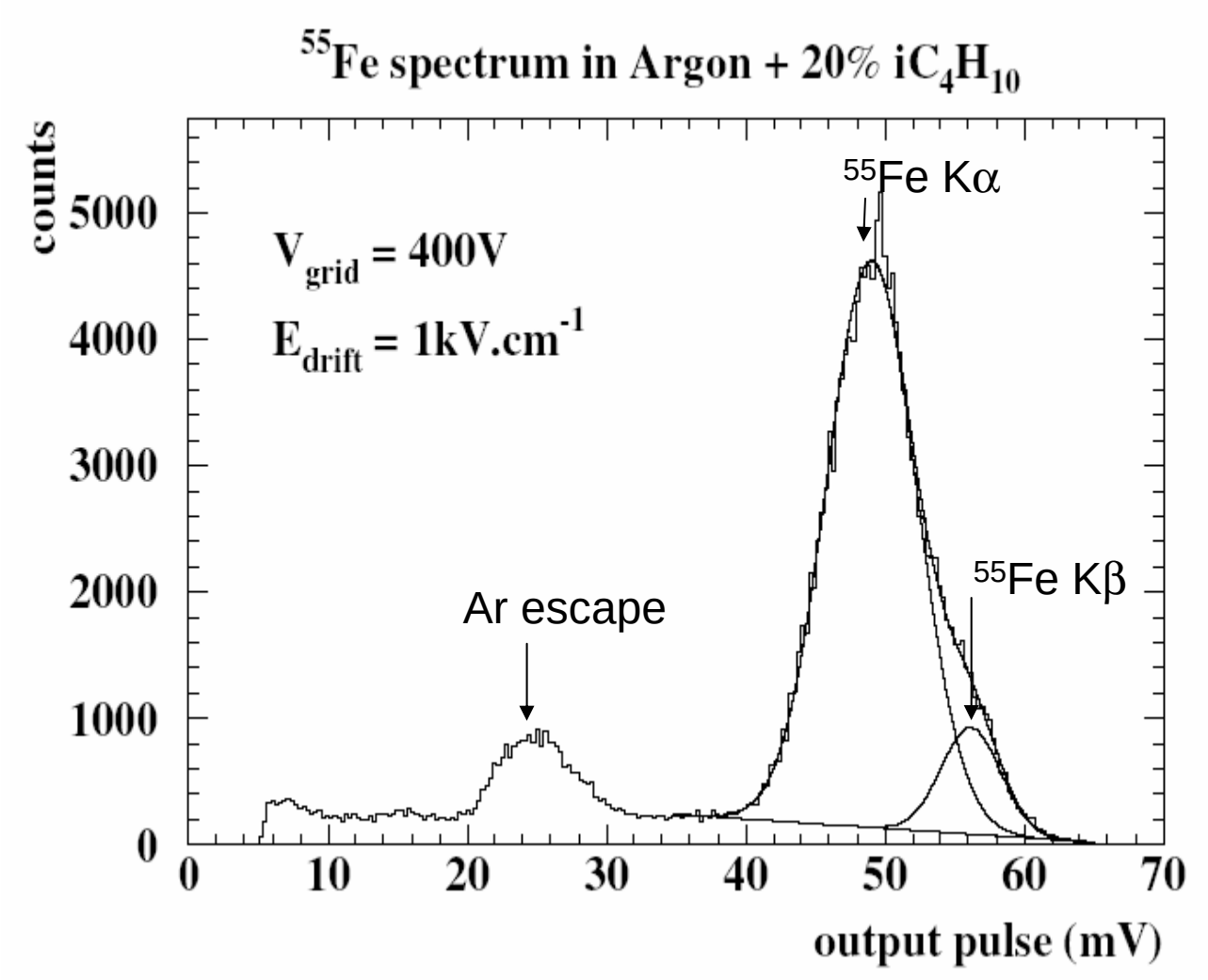
to avoid Moire effects (perfect alignment) and gap variations

to avoid dead areas, like frames (even hidden pillars)

to segment the mesh (lower noise, more reliability)



Results with Argon + 20% isobutane



^{55}Fe 5.9 keV line and escape line in Ar clearly visible.

Unprecedented resolution: σ_E/E = **6.5%.**

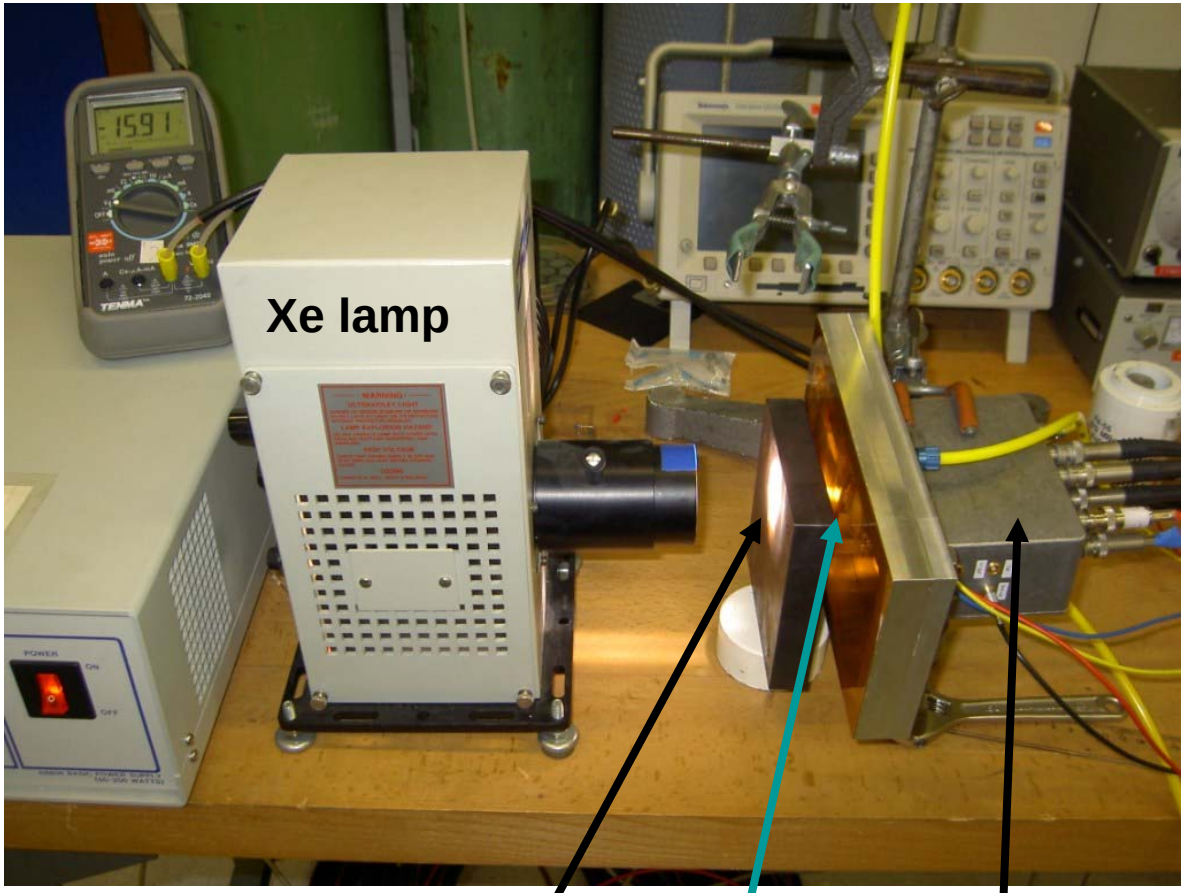
(FWHM=15.3%)

Kα and Kβ (6.5 keV) lines are separated by the fit.

More tests in progress with **smaller gaps** (40 μ successful)

Study of the **gas gain fluctuations** in progress

Aging studies in NIKHEF and Saclay



January 2006 at NIKHEF:

Use a Xe lamp to produce photo-electrons on a mesh

Broke record of current in a MPGD: 150 micro-Ampere on 65 mm^2 !

(equivalent to 5 years of LHC at 30cm from the beam in one hour)

Aging studies continue, with this Xe lamp in NIKHEF and with a X-ray gun in Saclay

Future: EUDET/SiTPC

- Kick-off meetings held at NIKHEF and DESY in January and February ’06. Clear milestones with deliverables 2006 through 2009
- CERN-Freiburg-NIKHEF-Saclay (+ soon Bonn? Bucarest?), open to newcomers. 2M€+, of which 850 k€ allocated by EC.
- TimePix design at CERN (until June 2006)
- Develop post-processings for protection and mesh integration
- Return from submit this summer, then perform tests (and iterate?)
- Build a detector (deliverable in 2 years)
- Watch the outcome of 130 nm and 90 nm technologies (CERN)