The Silicon TPC System

EUDET Extended SC meeting

11 September 2006

Jan Timmermans

NIKHEF

JRA2 activity/task

- Silicon TPC readout ("SITPC")

  - development MediPix → TimePix chip
  - development diagnostic endplate module incl. DAQ

Purpose: a SiTPC based monitoring system

Partners:

ALU Freiburg, Bonn, CEA Saclay, CERN, NIKHEF

Associate: Bucarest

Goals in context of ILC

- Gas multiplication GEM or Micromegas foil(s)
- Charge collection with granularity matching primary ionisation cluster spread

  (this needs sufficiently low diffusion gas)
- Investigate measurement dE/dx using cluster counting?

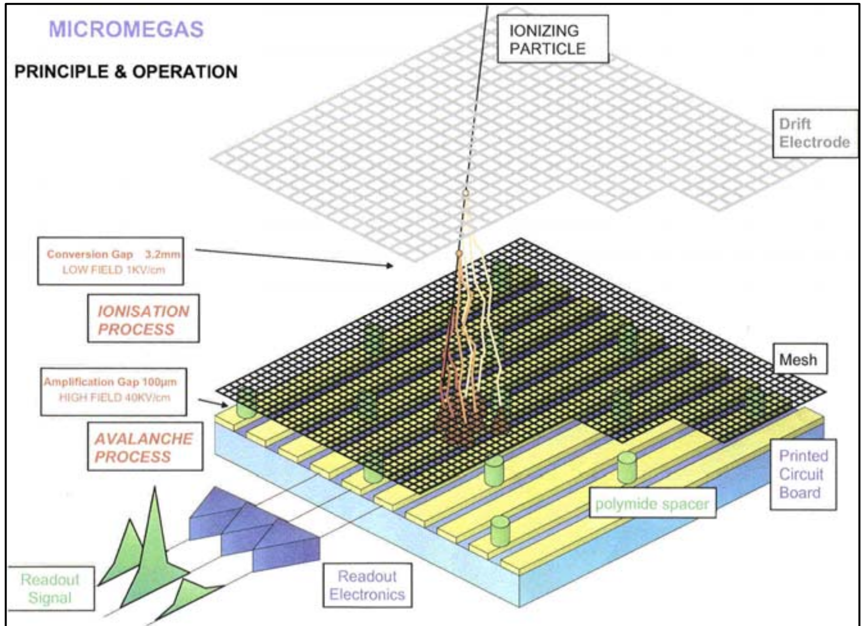
- 2D "proof of principle" based on existing Medipix2 readout chip: achieved (2004, 2005) by NIKHEF/Saclay, Freiburg
- Add 3rd coordinate: Medipix2 → TimePix (→2006/2007)
- Integrate grid with pixel chip: Ingrid (first results 2005)

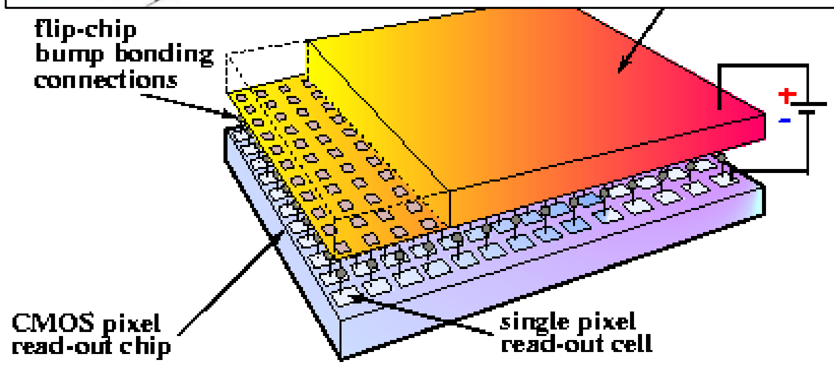
SITPC Tasks:

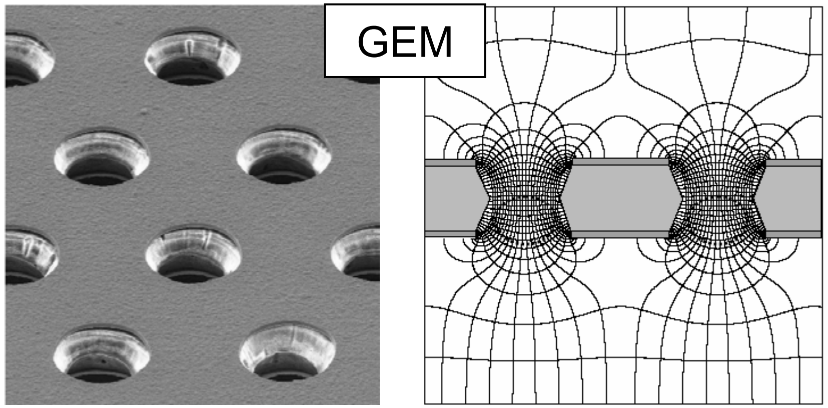
- Develop the Timepix chip that allows to measure the 3rd coordinate (drift time)
- Implementation of Timepix together with GEM and Micromegas into diagnostic endplate system
- Performance measurements in test infrastructure at DESY
- Develop simulation framework
- Develop DAQ system and integrate in overall DAQ of EUDET infrastructure

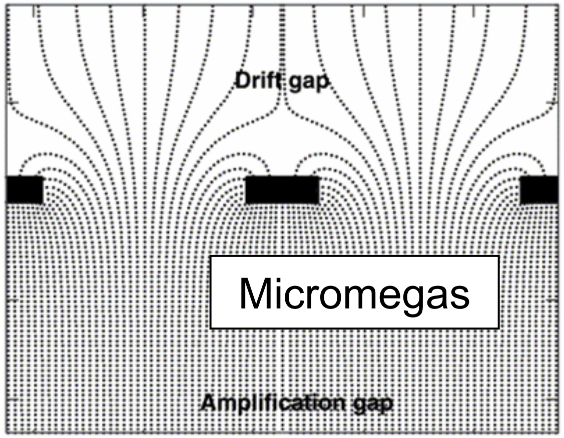
Micro Patterned Gaseous Detectors

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





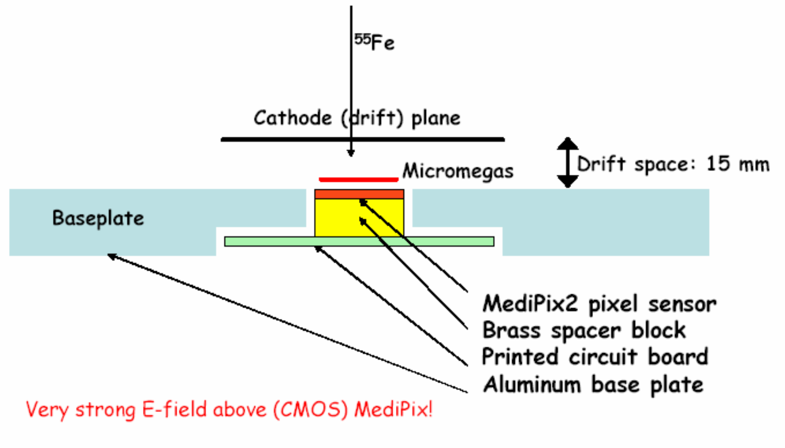




Use 'naked' CMOS pixel readout chip as anode

Results pixel readout gas detectors

NIKHEF-Saclay-CERN-Twente

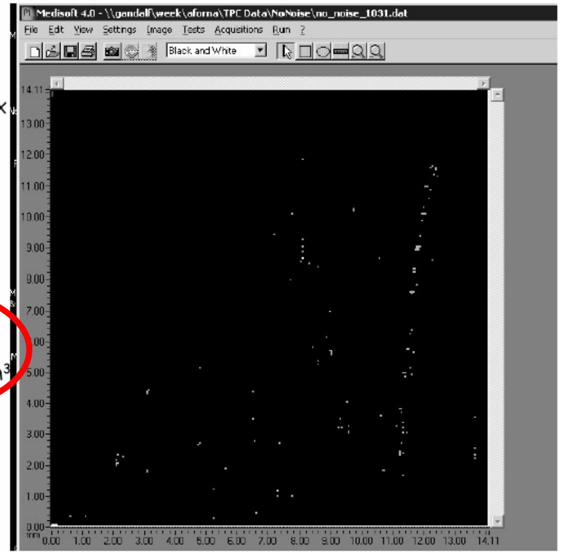


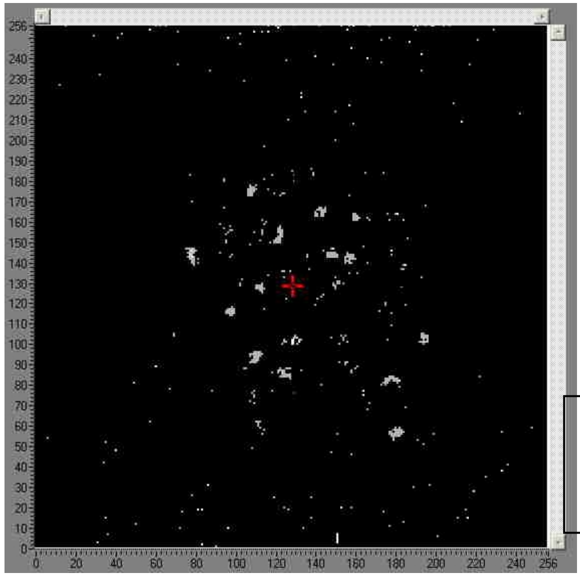
He/Isobutane
80/20
Modified MediPix

31 March 2004

Sensitive area:
14 x 14 x 15 mm³

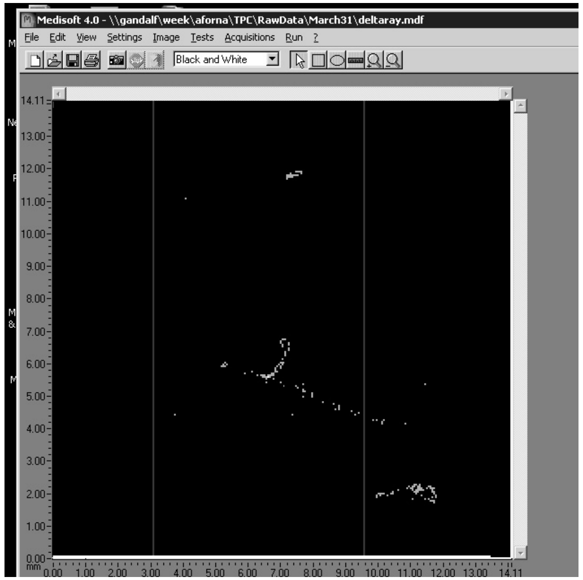
Drift direction:
Vertical
max = 15 mm





55x55 μm² pixels

Ar/isobutane
95/5



δ ray

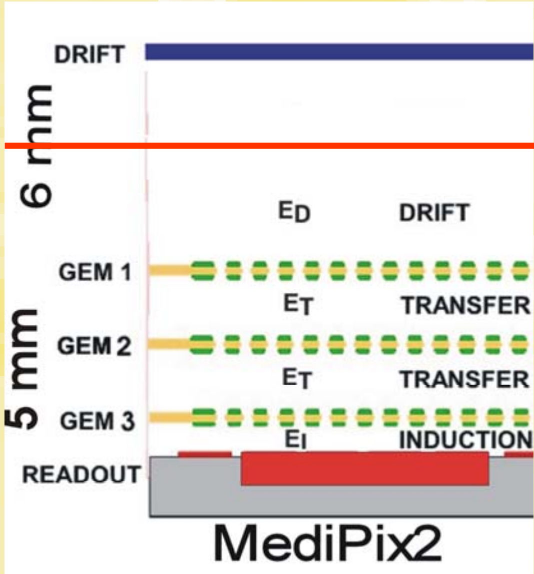
Observation of min. ionising cosmic muons: high spatial resolution + individual cluster counting !

NIM A540 (2005) 295 (physics/0409048)

JRA2 GEM-TimePix Projekt

Institute of Physics, Albert-Ludwigs-Universität Freiburg

- Micro Pattern Gas Detectors (MPGD): high resolution readout and high rates
- pixelated readout offers high resolution Digital Bubble Chamber
- a TPC at the ILC needs excellent momentum resolution =>GEM-TimePix for end plate readout
- Cluster counting as a goal



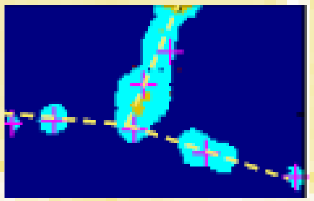
e^- from source /test beam

Chip surface exposed to moderate fields

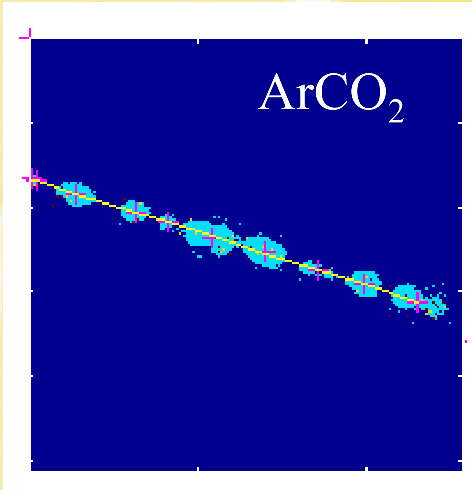
Still first chip since 1.5 y !

Results from MediPix Prototype setup:

For ArCO2 and HeCO2: point/cluster resolution determined with different algorithms between 50 - 60µm



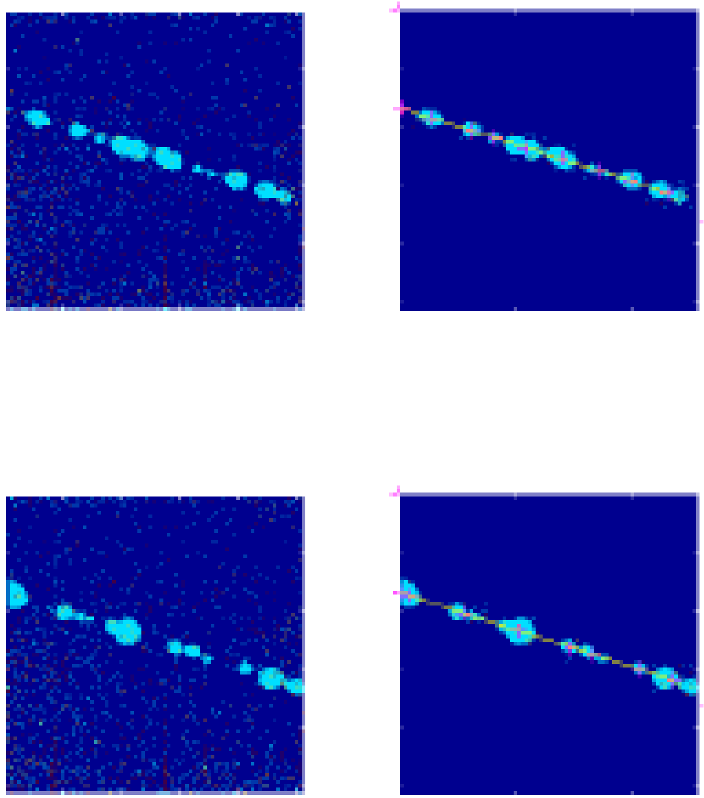
δ-electron in HeCO2



Charge depostion on the MediPix Chip electron track from ^{106}Ru source and straight line fit

Some events with fits

(from Freiburg GEM+Medipix setup - Andreas Bamberger)



Difference between Micromegas and GEM setup understood (simulation Michael Hauschild)

Results for point/cluster resolution

(from Freiburg GEM+Medipix setup)

	Ar/CO2	He/CO2
3-point method	58 ± 2 µm	53 ± 3 µm
$\sigma_{corrected}$*	54 µm	53 µm

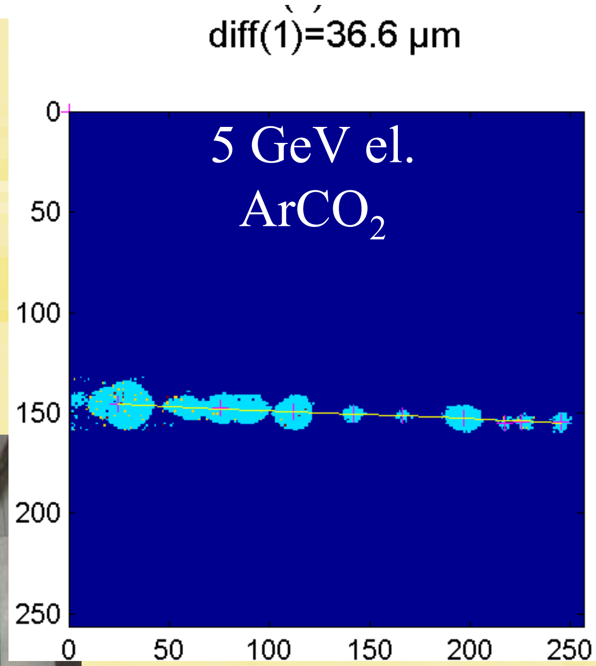
- **with few primary electrons per cluster !**
- * multiple scattering correction to be checked for systematics

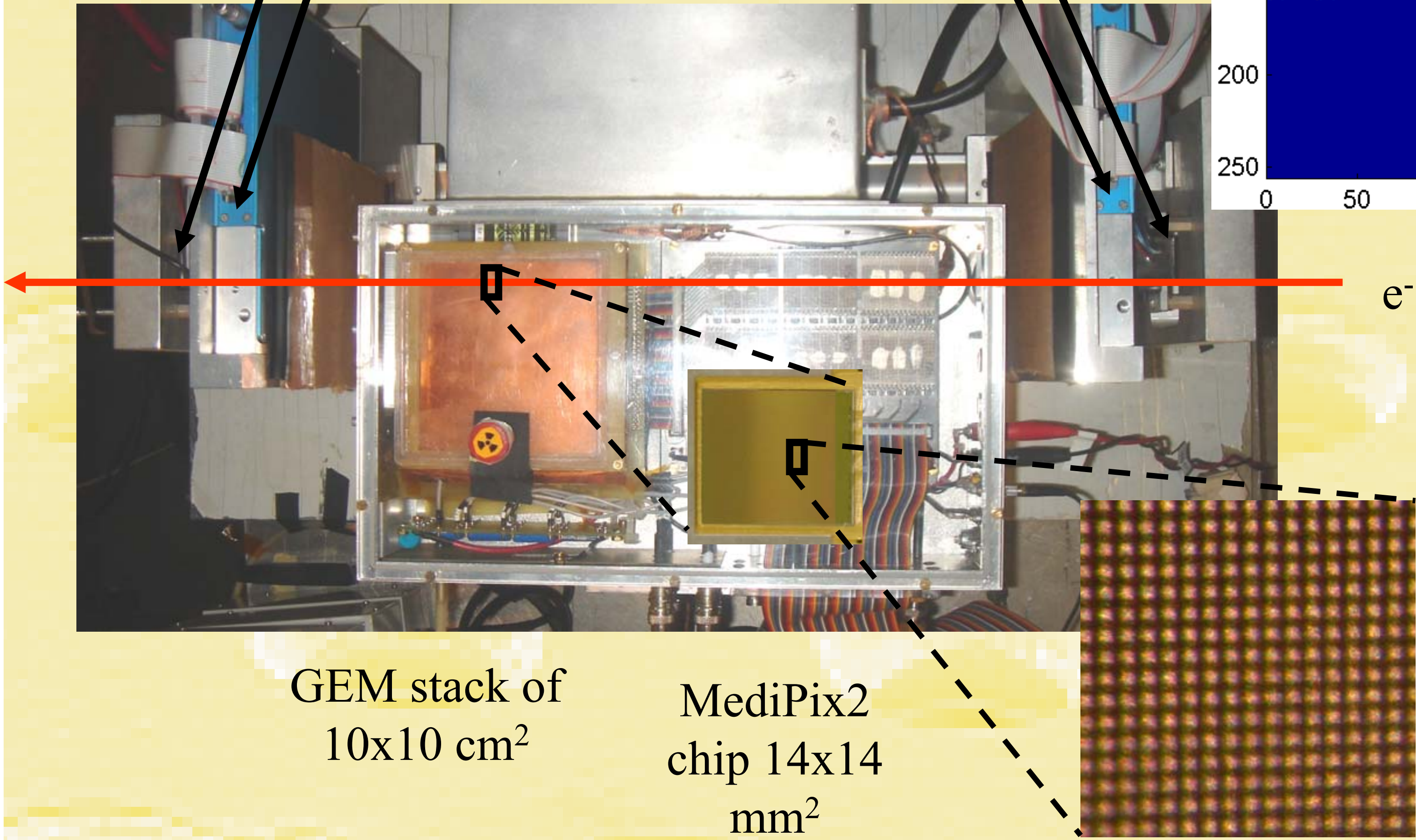
Test beam event

multiple scattering negligable on MediPix scale

trigger counters ~8 mm wide

Si telescope (~20 μm precision)





e⁻ from PETRA

GEM stack of 10x10 cm²

MediPix2 chip 14x14 mm²

pitch of pixels

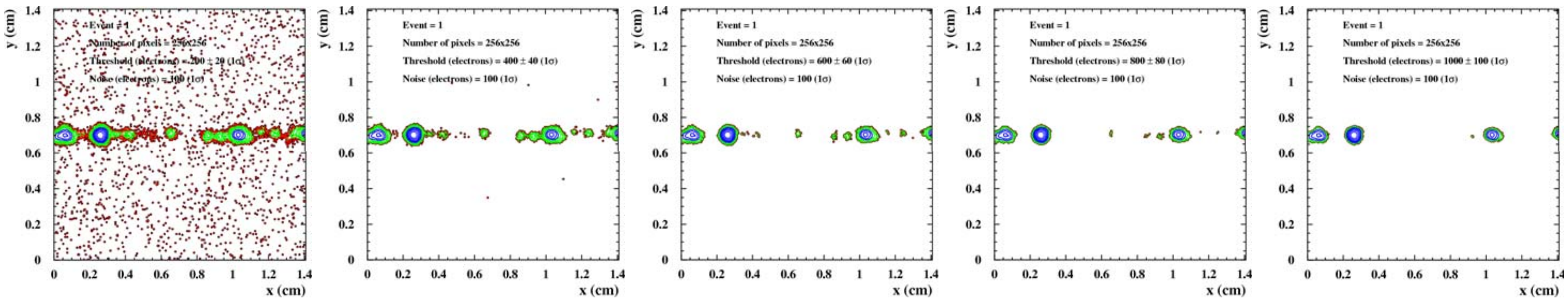
55 μm

Simulations (M.Hauschild): Threshold Scan

GEM

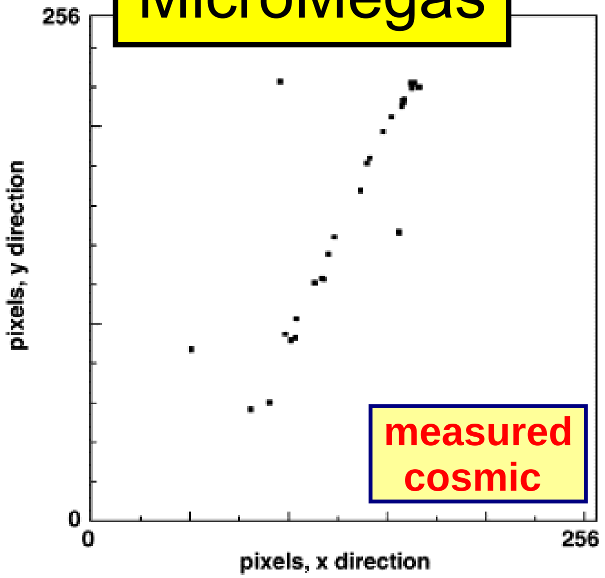
detection thresholds per pixel (allow 10% variation):

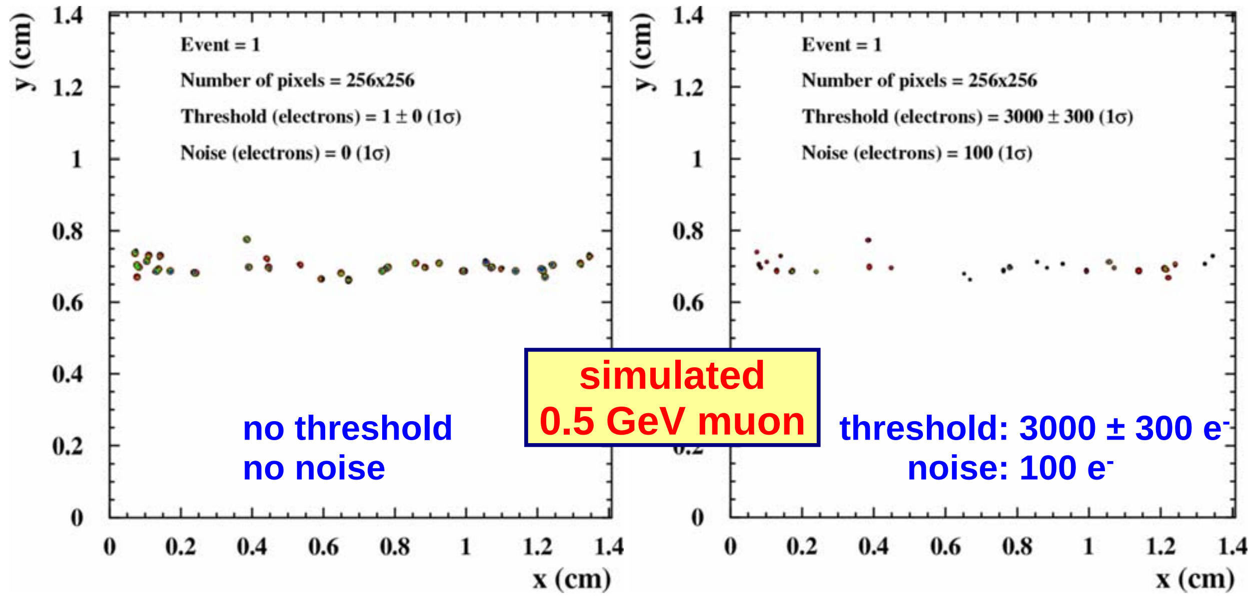
200 ± 20 e$^-$	400 ± 40 e$^-$	600 ± 60 e$^-$	800 ± 80 e$^-$	1000 ± 100 e$^-$



noise: 100 e$^-$

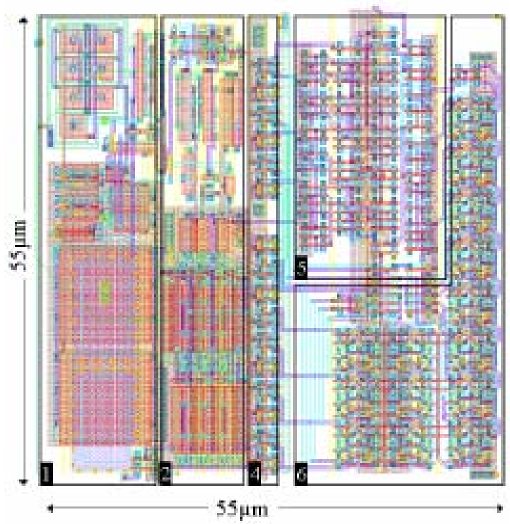
MicroMegas





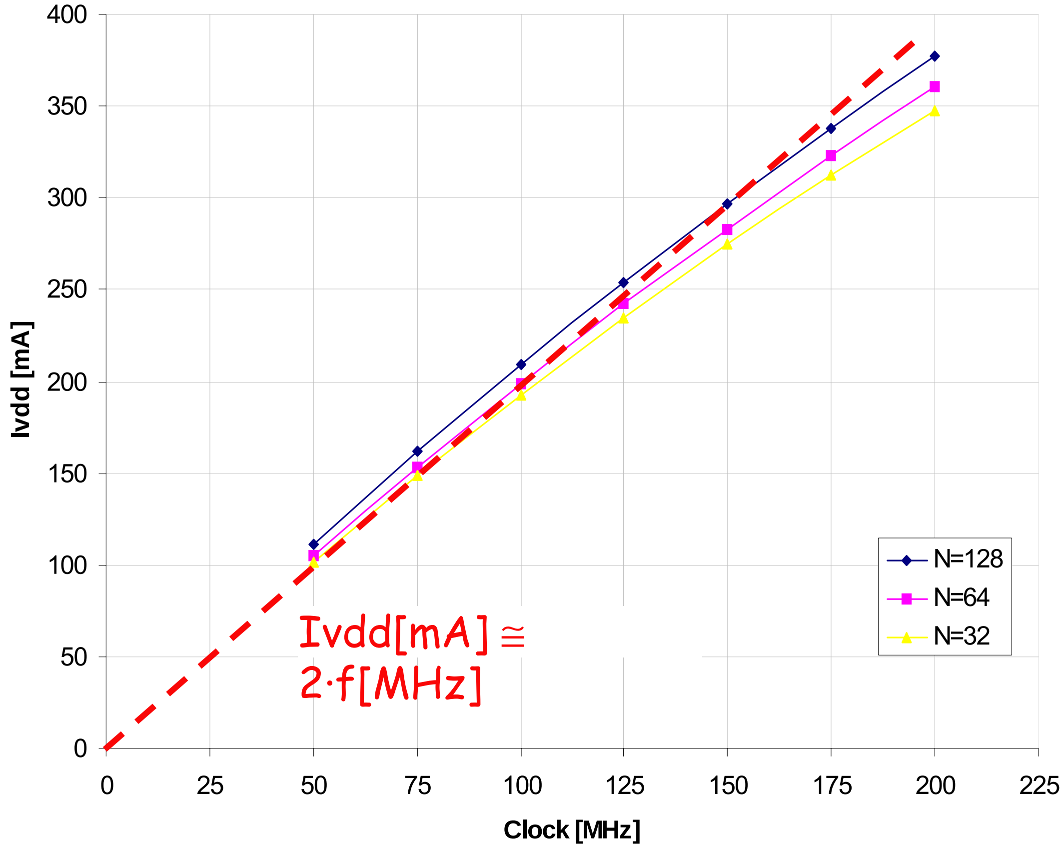
TimePix1 (EUDET: Freiburg, Saclay, CERN, NIKHEF)

- Distribute clock to full 256x256 pixel matrix (50-100-160MHz)
- Enable counting by first hit after ‘shutter’ opens, until ‘shutter’ closes (common stop); also time-over-threshold possible
- Dynamic range 2^{14} x 10 ns = 160 µs
- (for the time being) no zero-suppress to remain fully compatible with Medipix2
- Shaping time ~200 ns
- Extra static discharge protection for the could be considered later



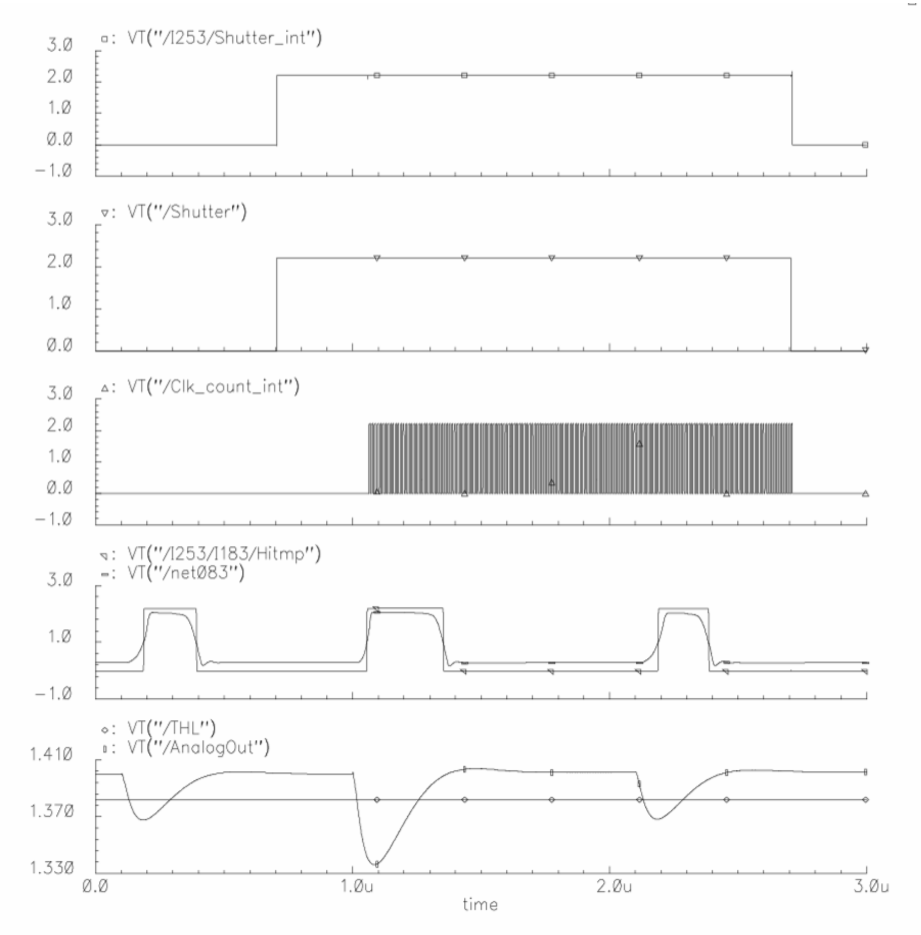
- Keep same chip-size, pixel-size, readout protocol
- 1st full reticle submit done July 2006

Expected digital power vs frequency

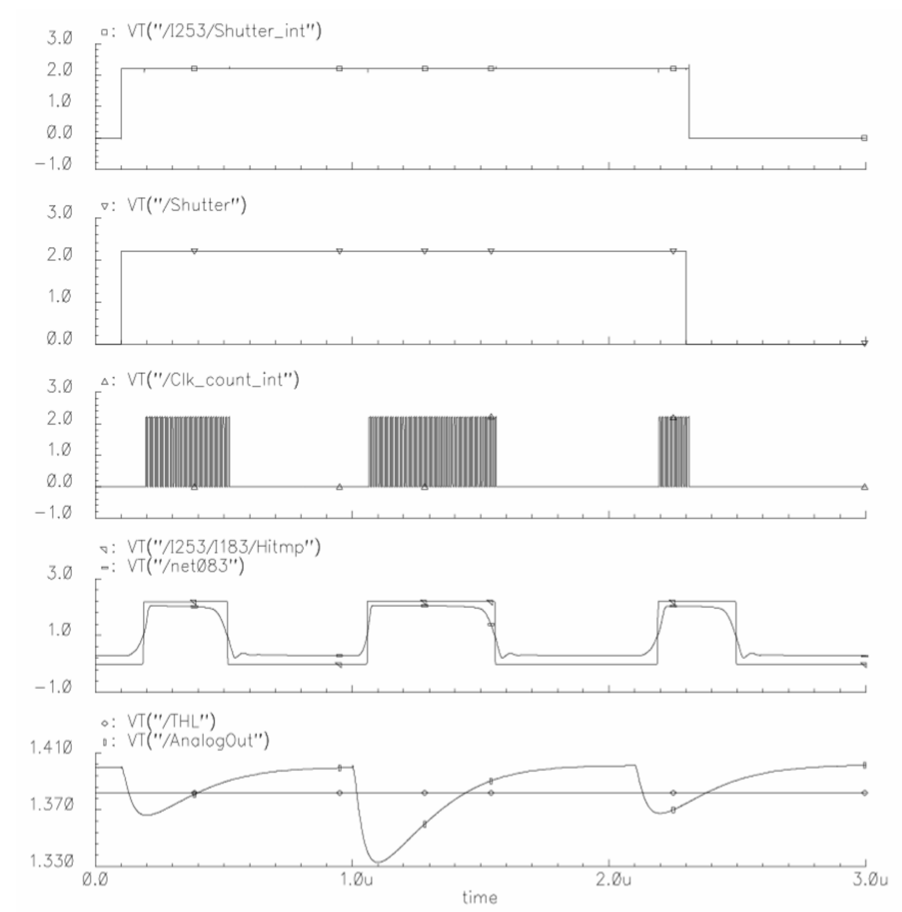


- $Pvdd = V^2 \cdot f \cdot Ctot$
- Simulation @ Vdd=2.2V but digital part could work to 1.8V (33% less power)

Timepix TOT



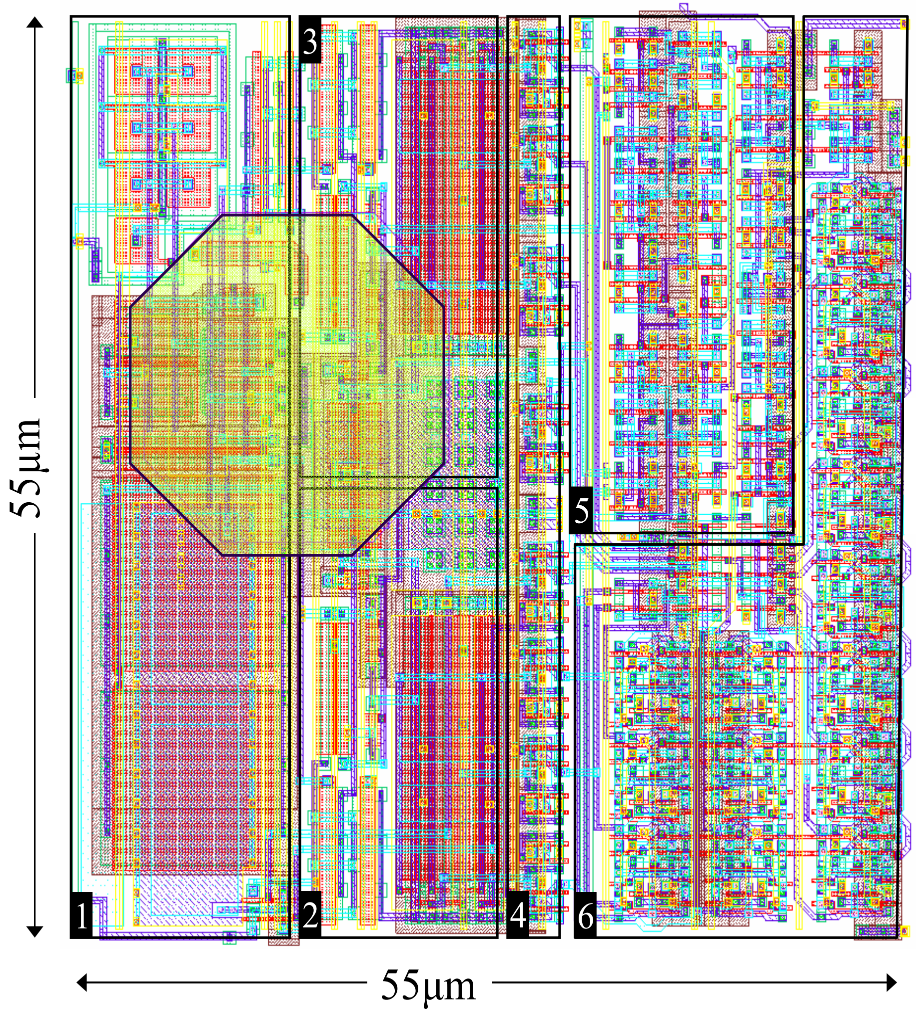
100MHz



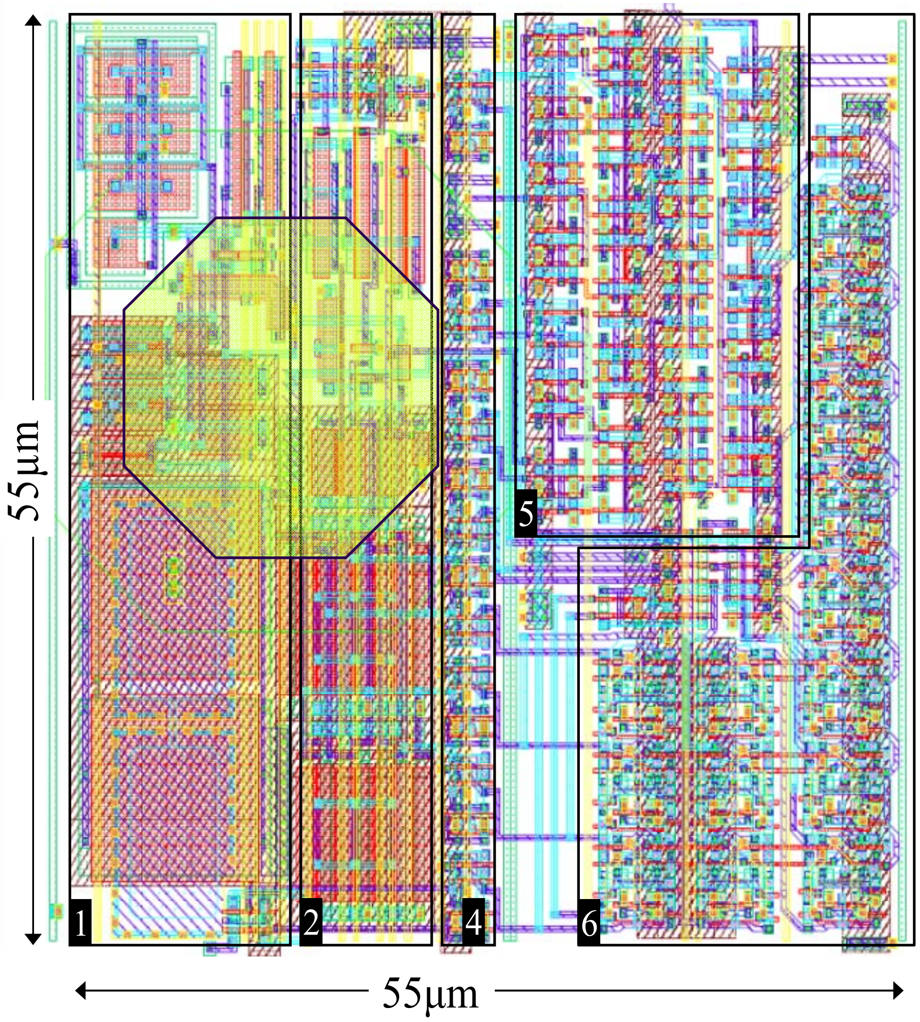
100MHz

Mpix2MXR20 vs Timepix Layout

Mpix2MXR20 layout



Timepix layout



Timepix summary

Physical dimensions	14.111 mm x 16.120 mm (like Mpix2MXR20)
IO PADs	127 (like Mpix2MXR20)
Charge collection	e^-, h^+
Pixel functionality	PhotonCounting, TOT, Timepix
Amplifier Gain	~18mV/Ke$^-$
Noise	~75e$^-$
Linearity	Up to 50Ke$^-$
Thresholds	1 (4bits adj)
σ equalized	~25e$^-$
Minimum Threshold	~500e$^-$ (expected)*
Counter Depth/Overflow	14-bits/Yes
Max Analog power	6.5µW/pix 420mW/chip (@2.2V Vdda)
Static Digital Power	440mW@100MHz (@2.2V Vdd)
Readout	Serial/Parallel
Readout compatibility	95% (Clock active when shutter ON)

Timepix: Next Steps

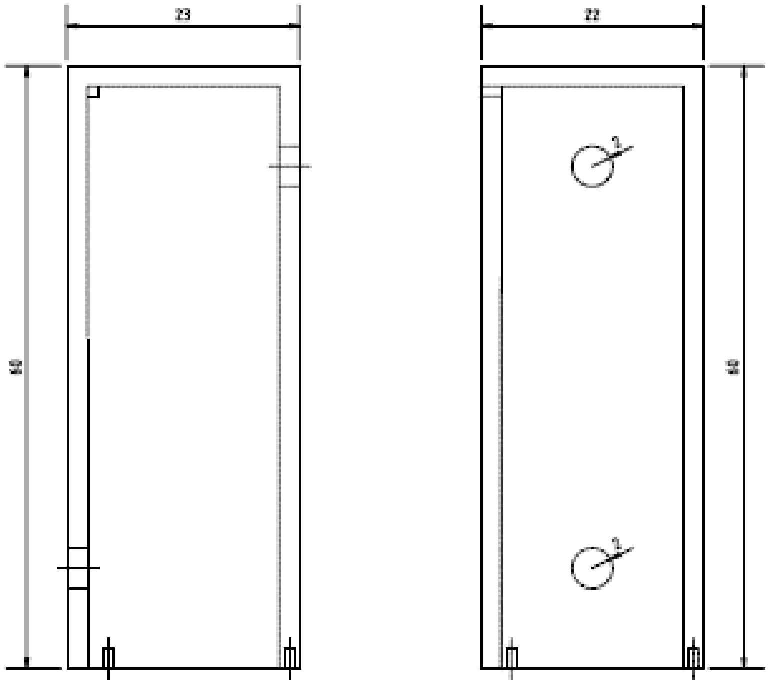
- Expected 12 wafers out of foundry by 19th of September $\Rightarrow$ 25th to 30th September delivered at CERN
- Testing of the chip on wafer using the Medipix2 probecard in the Silicon Lab clean room
- First version of Timepix firmware for the Muros2.1 readout is already prepared
- 1-2 month of chip characterization and wafer probing expected

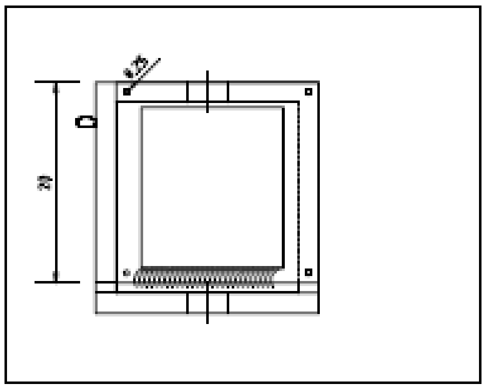
News in Saclay

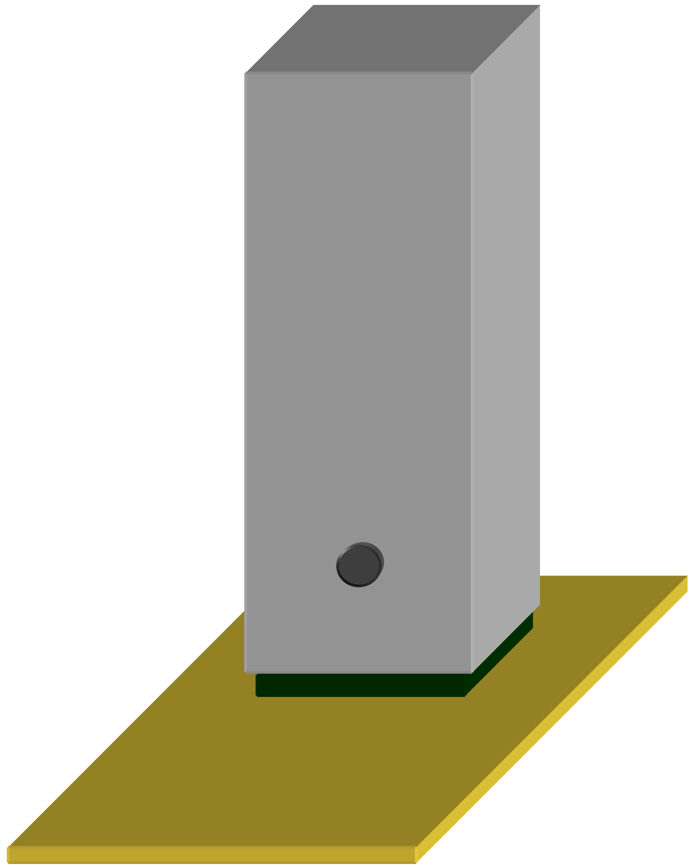
dapnia SPP
saclay

- MUROS arrived in Saclay
- Upgraded to the latest firmware of the Medipix2 USB Interface with a home-made cable : USB1.1 v1.0.6 -> USB1.1 v1.0.7
- Design of a small drift chamber for the chip
- Gain measurements using different gas mixtures with a Micromegas detector

Drift chamber for a Medipix2 chip

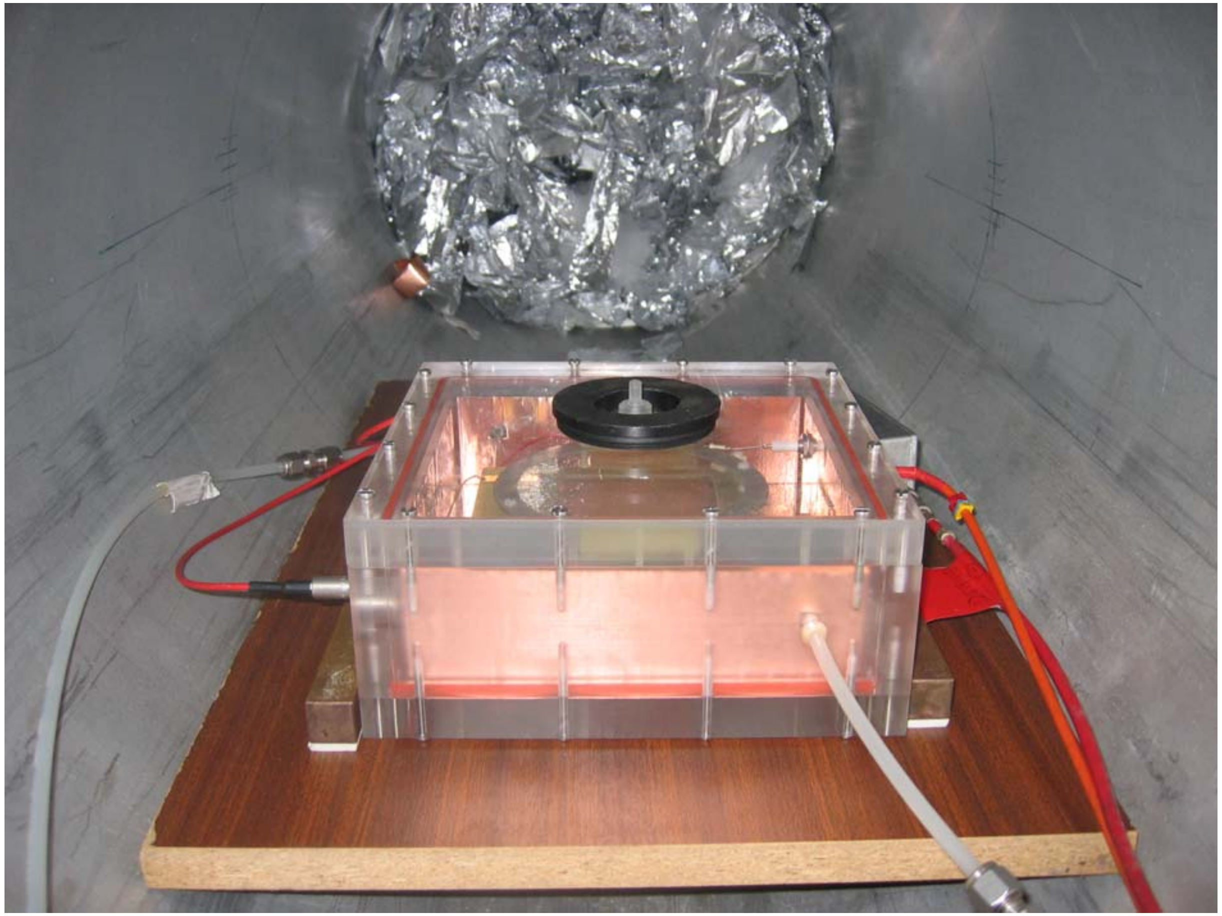






Gain measurements

dapnia SPP
saclay



• Aim : find a gas with a comfortable gain margin

• Using the same detector

• Transparent plastic box of 25cm x 25cm x 5cm size

• Sources :
- Fe 55 (5.9 keV)
- COOL-X (8.1 keV)

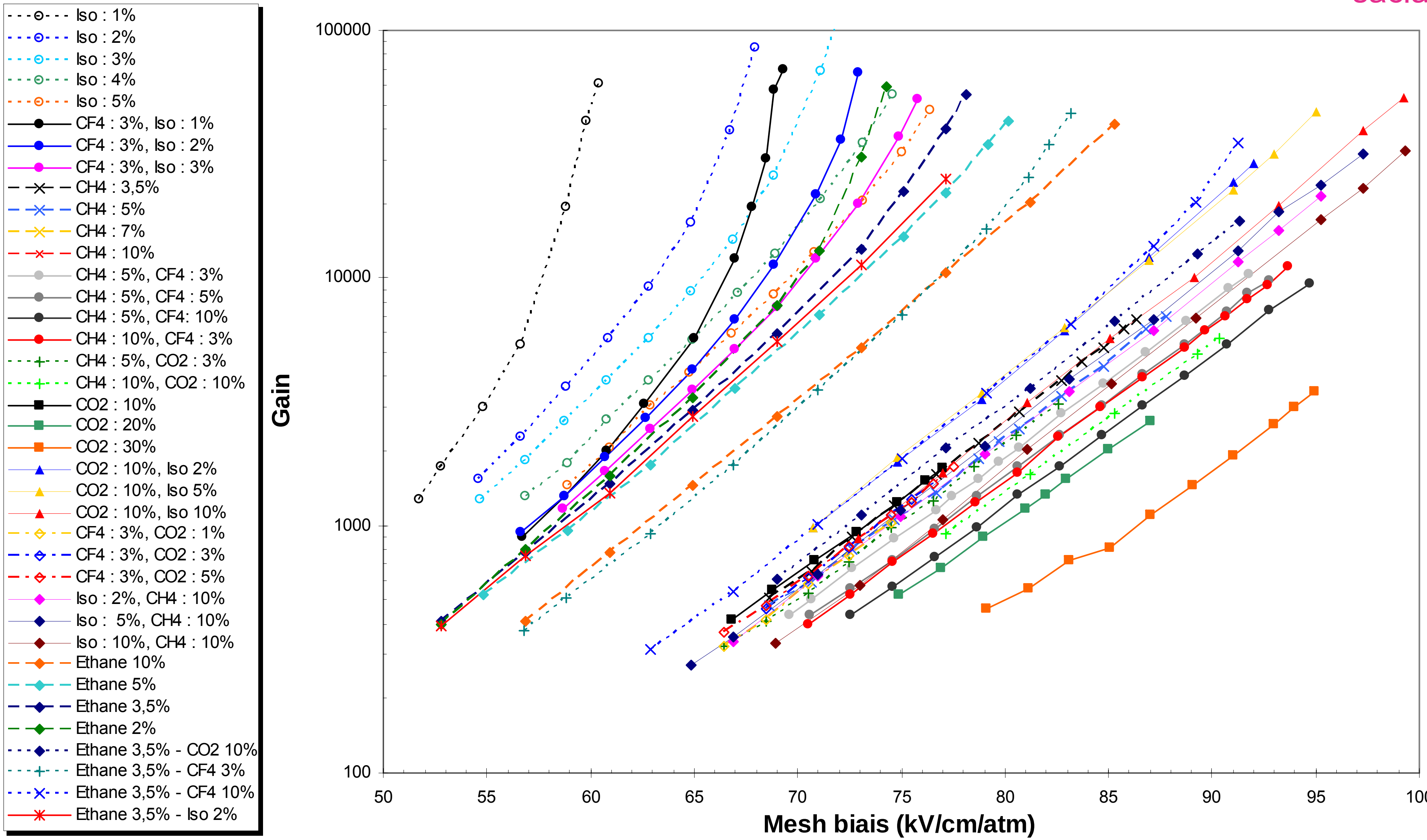
• Student : Michal Was (ENS)

Gain measurements : results

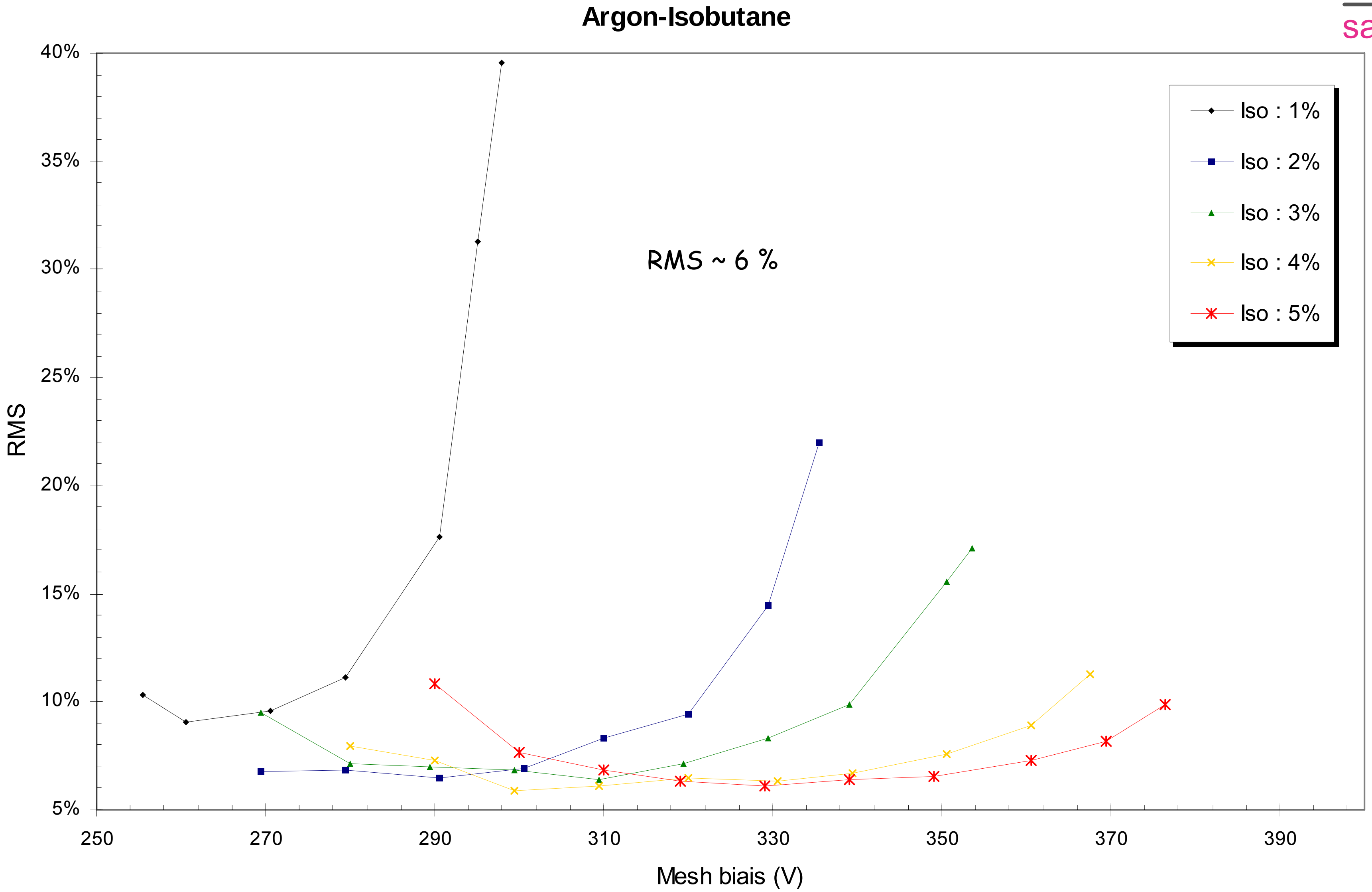
dapnia SPP

saclay

Mixtures of gases containing argon



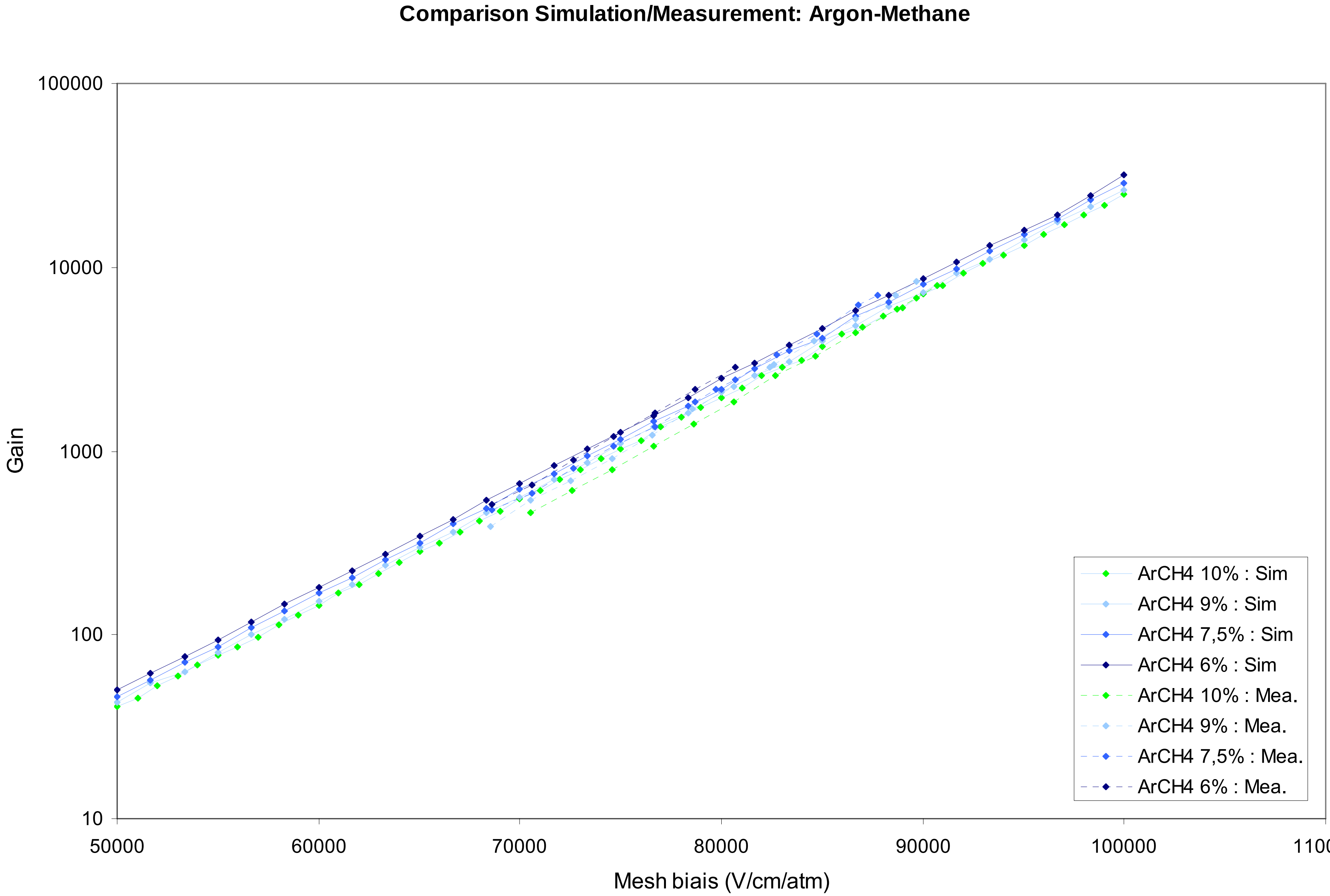
Gain measurements : results



Gain measurements : comparison with simulations

dapnia SPP

cea saclay

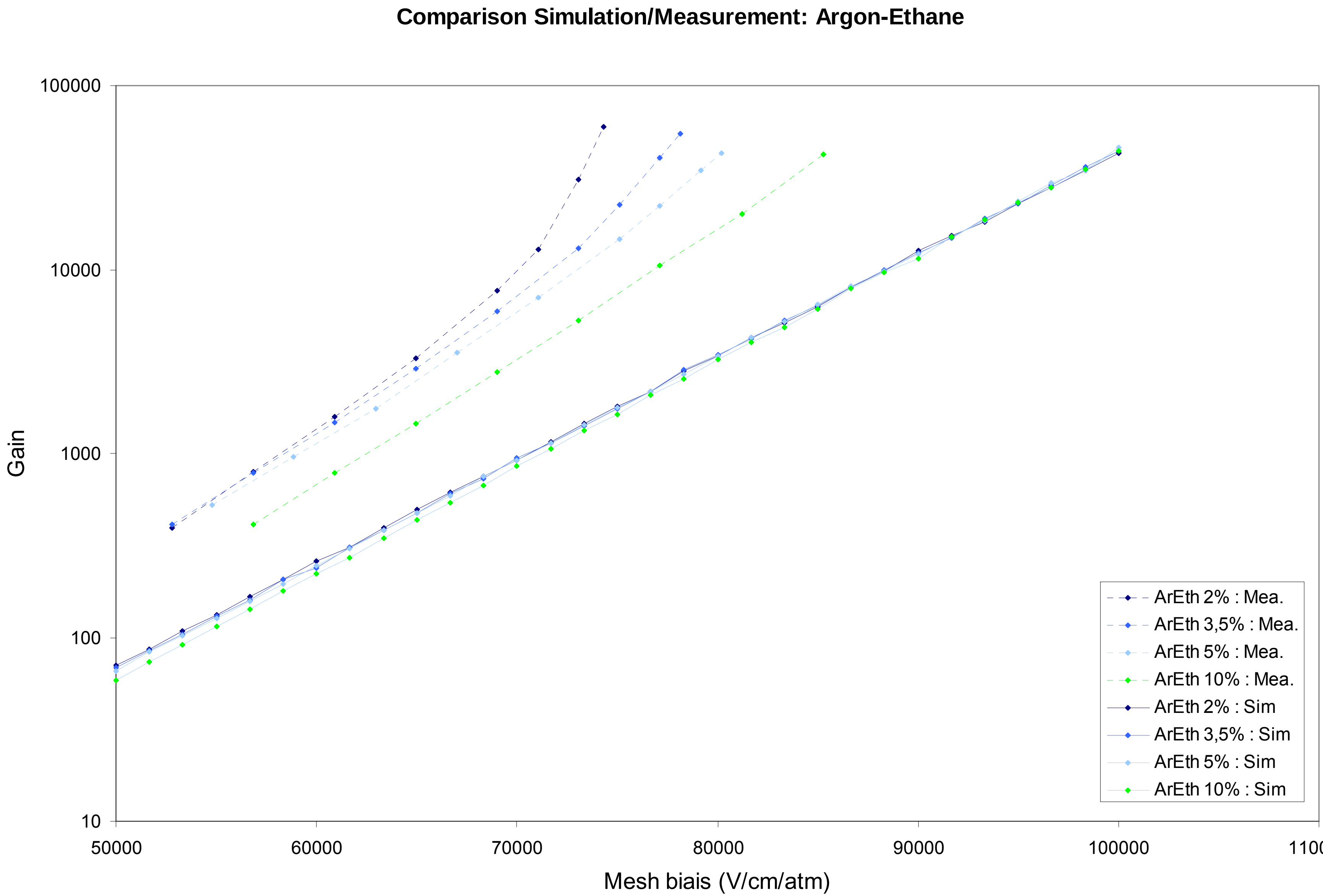


Simulations from GARFIELD/MAGBOLTZ

Gain measurements : comparison with simulations

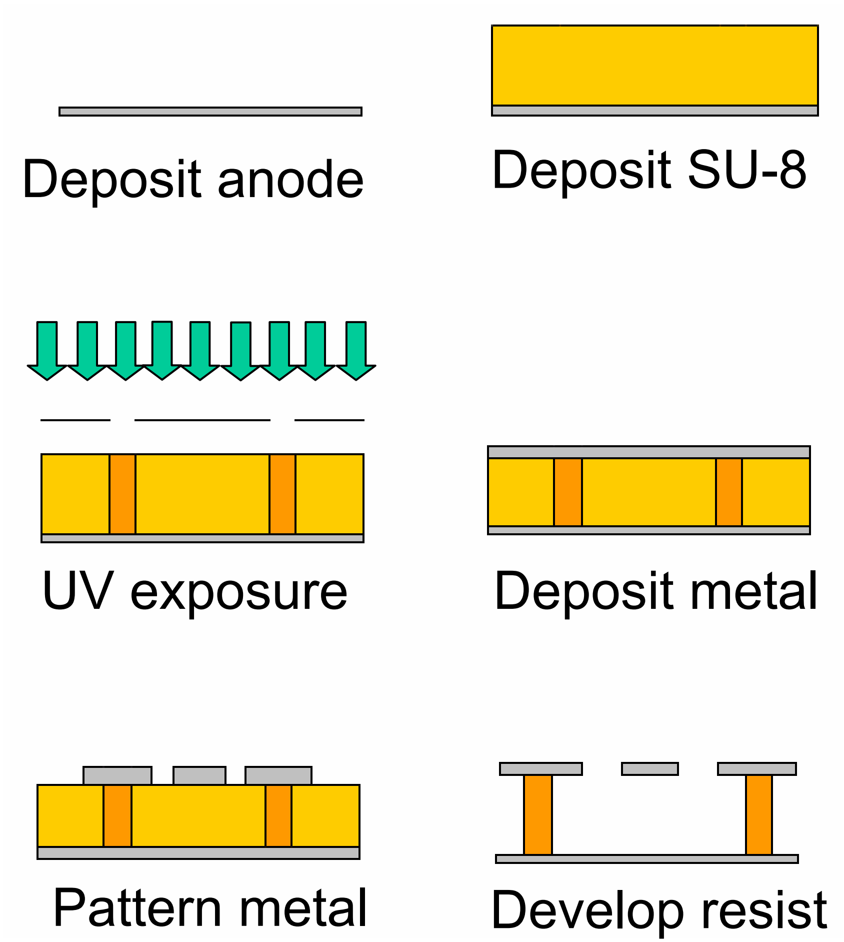
dapnia SPP

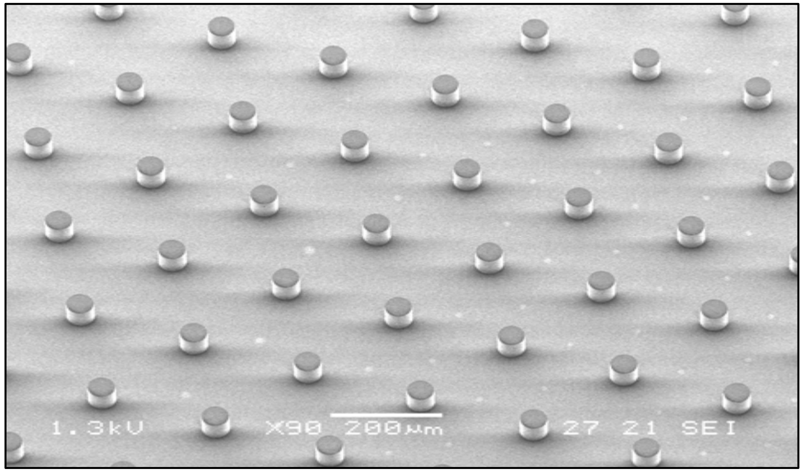
cea saclay

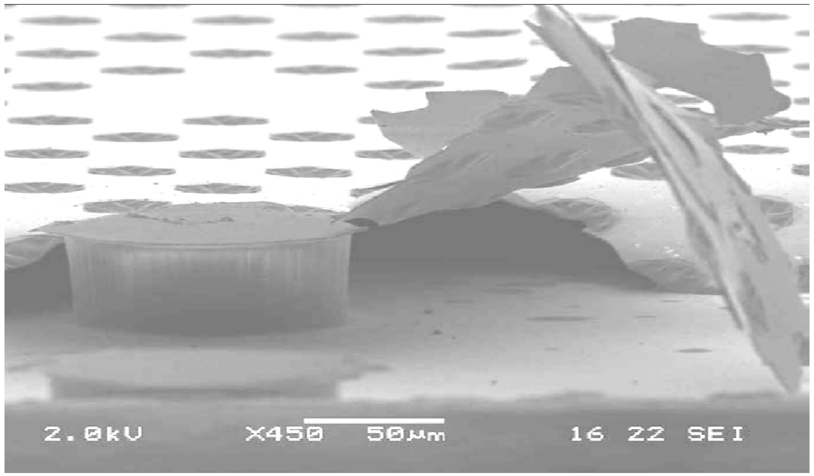


Simulations from GARFIELD/MAGBOLTZ

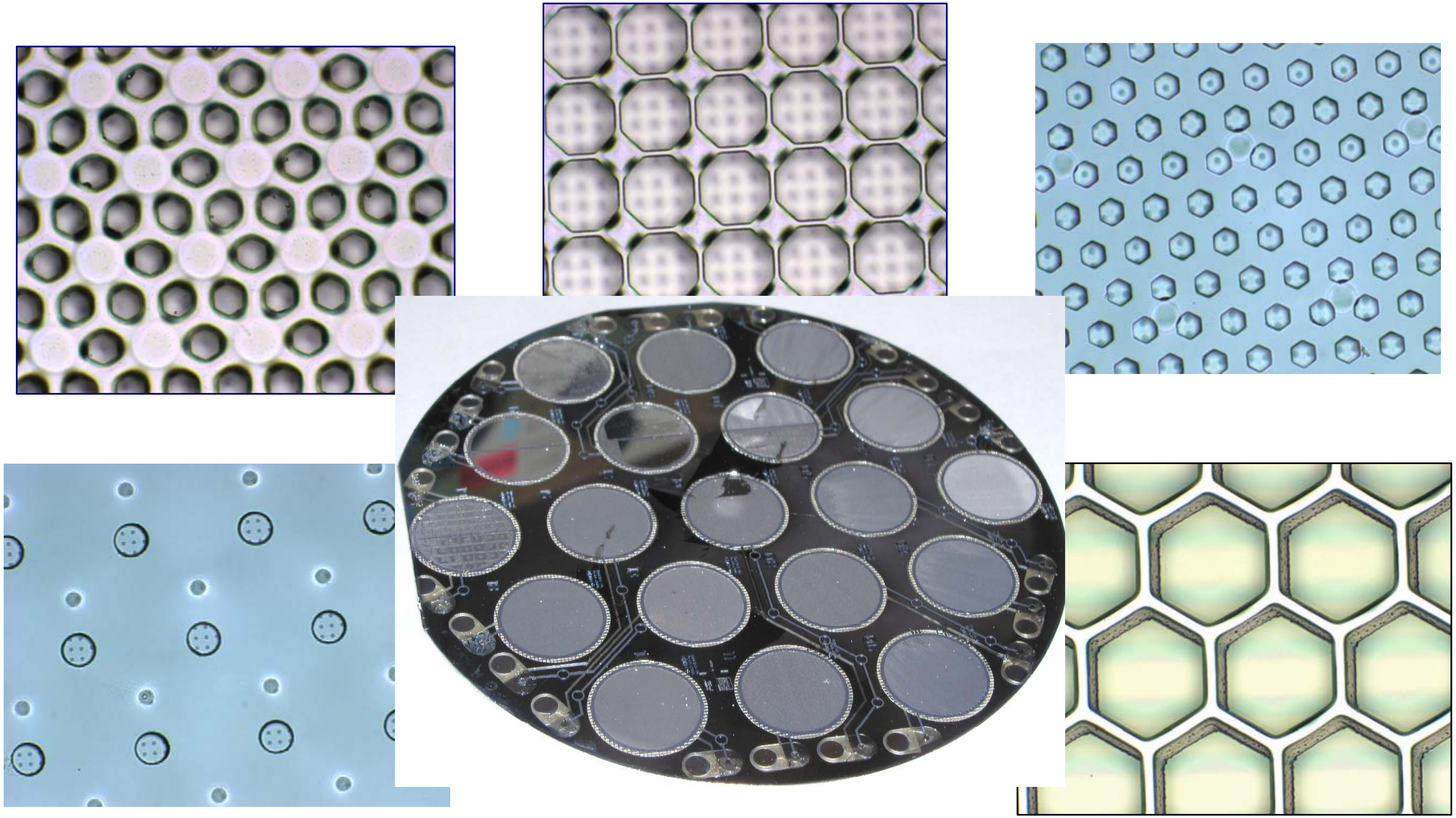
NIKHEF/Twente:
InGrid (Integrated Grid)





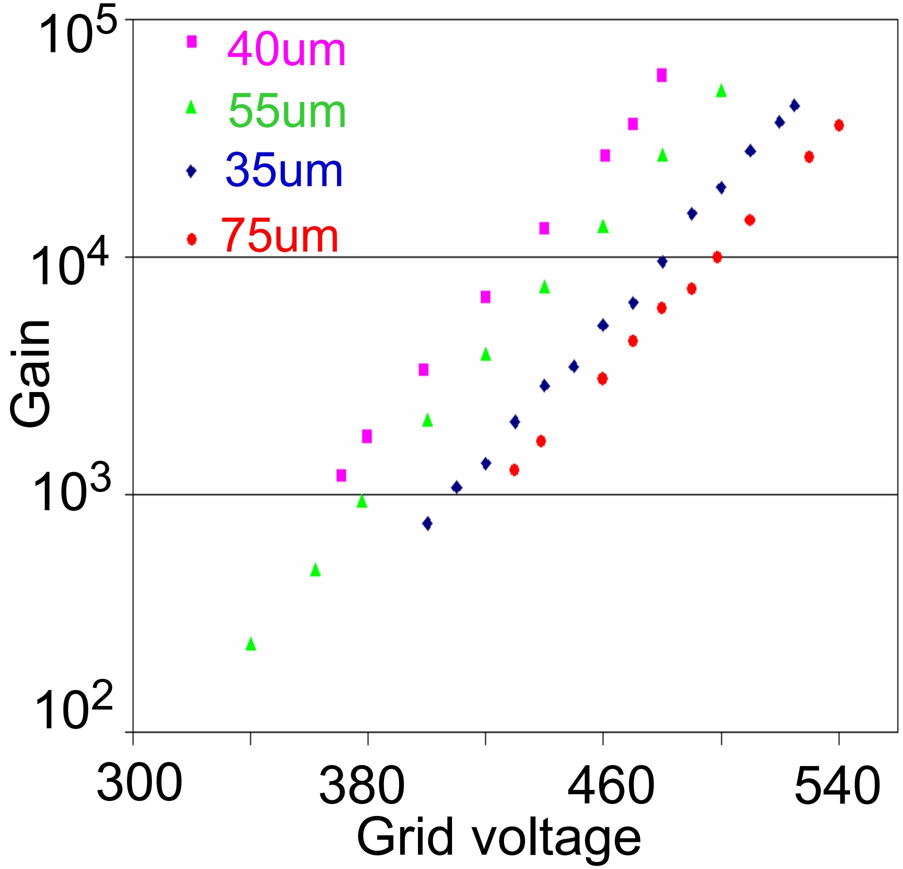


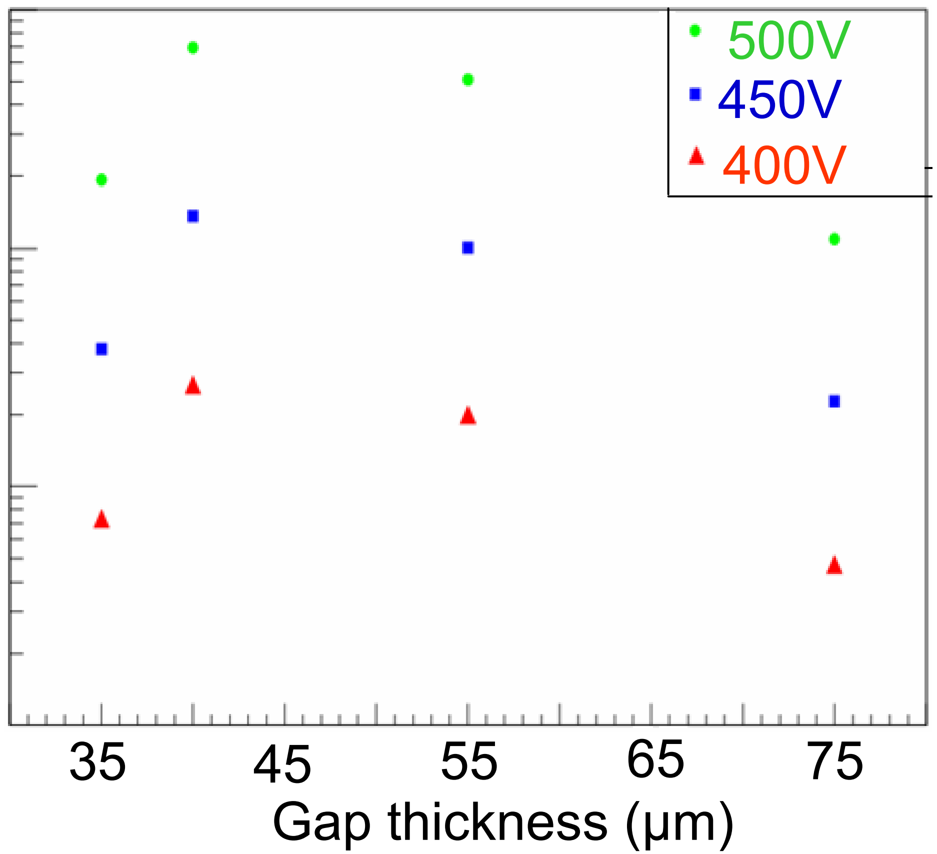
Any field structure feasible



Gain for different gap sizes

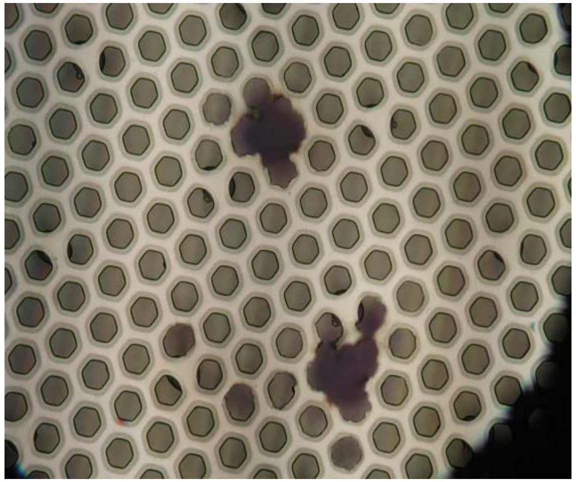
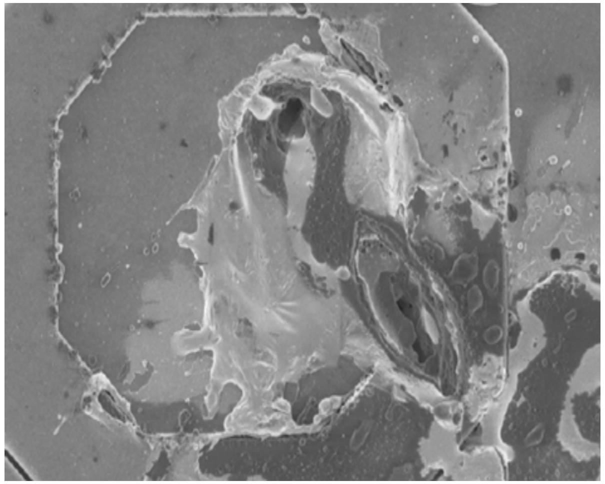
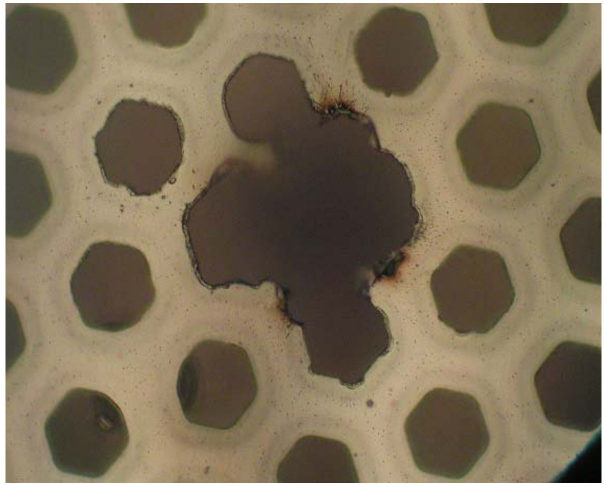
+ many other measurements (homogeneity, gain vs. hole size, energy resolution)





Sparking

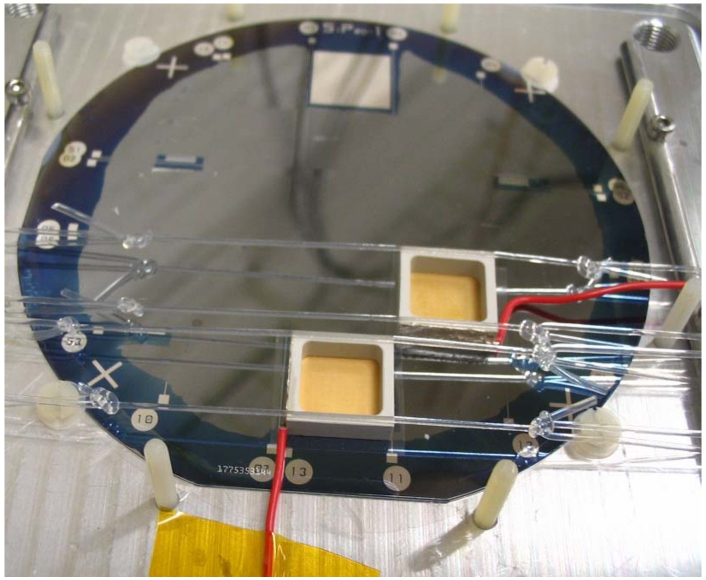
- Chip faces 80kV/cm with no protection (unlike the GEM setup)
- Degradation of the field, or total destruction of grid but also CMOS chip

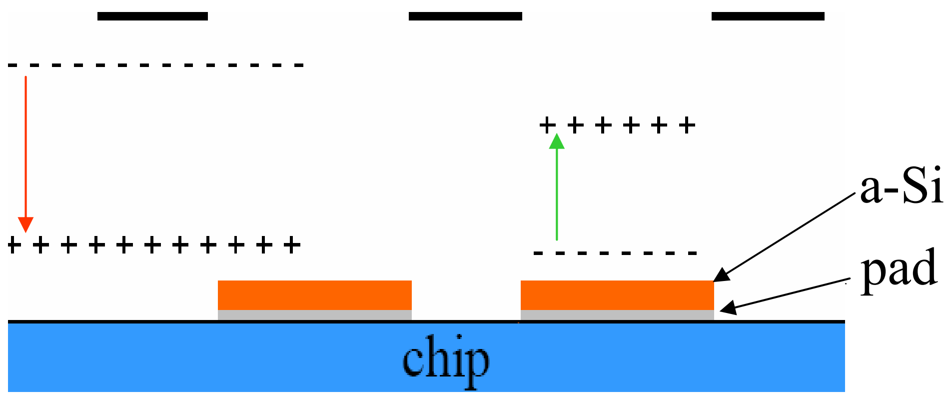




10μm

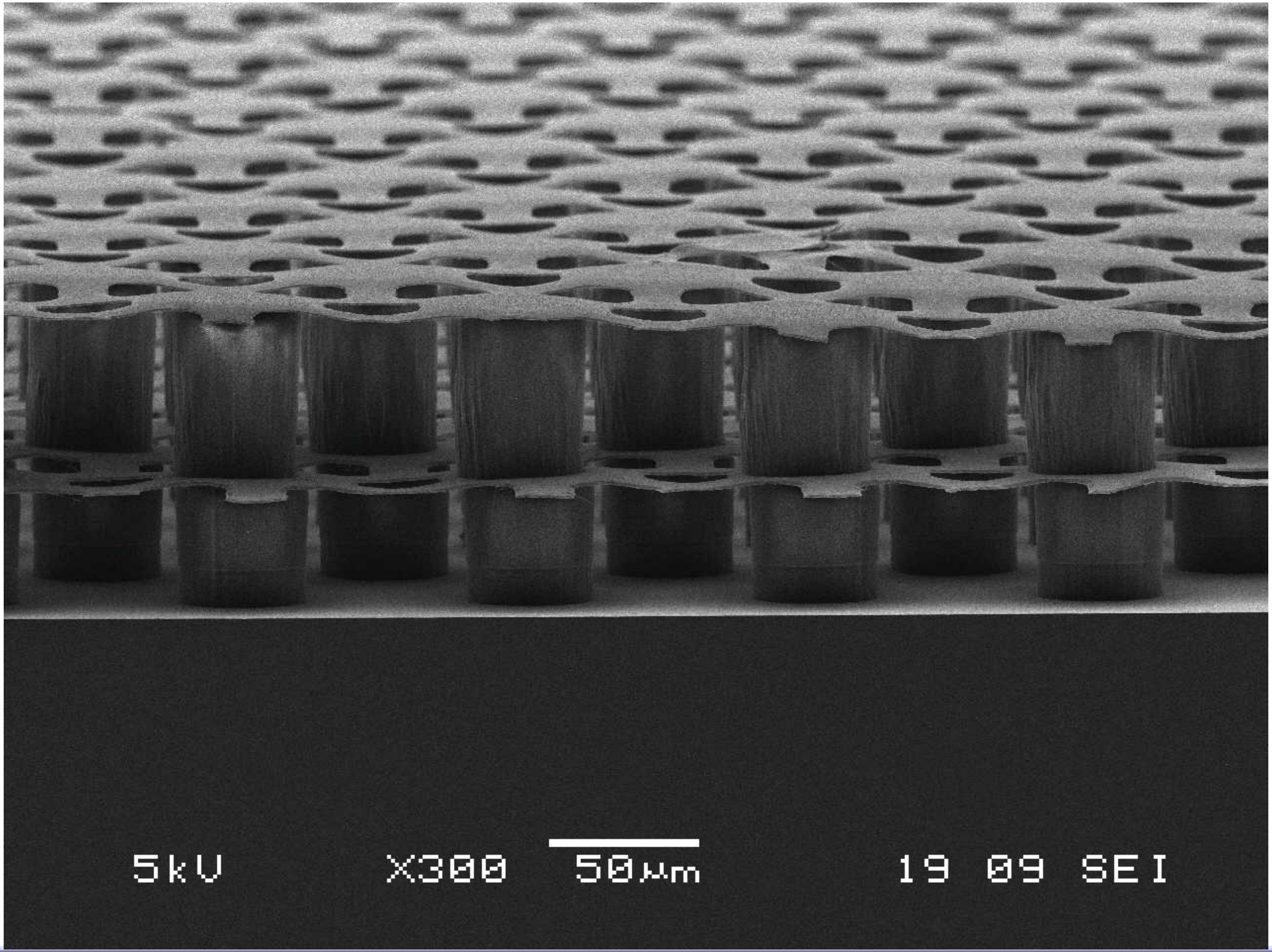
Solution:high resistive layer

- Resistive plate chamber principle
- Amorphous silicon deposited
  - 4um thickness,resistivity ~$10^{11}\Omega$.cm,temperature~250 °C
- 2 fields with Micromegas: one protected, one unprotected
- First signals recorded; they look the same





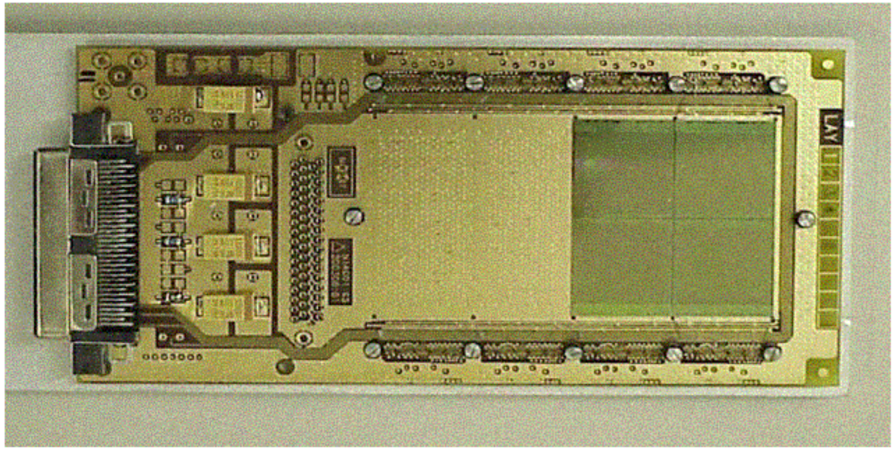
First Twingrid's



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)



In summary: timetable

- 1st version Timepix operational: 1/2007
- First m.i.p. signals with Timepix: ~4/2007
- Development 2nd iteration Timepix during 2007
- Endplate infrastructure: 1/2008
- Full SITPC infrastructure incl. DAQ available: 1/2009

FINANCES:	pers.	mat.	travel	total	
FREIBURG:	20.993	25.725	0.500	47.218	budget
	11.885	41.000	3.000	65.885	spent 2006
CEA Saclay:	48.333	32.300	3.000	83.633	
	34.236	32.300	3.000	69.536	
(comm.	60.000	~7.000		67.000)	
CERN:	60.450	21.000	2.000	83.450	
	(72.785	27.848		100.633	CERN table)
	(68.354	21.519		89.873	,, ,,)
NIKHEF:	22.500	40.000	1.000	63.500	
	0.0	38.000	1.000	39.100	
(comm.	86.500	4.000		90.500)	