Update on Silicon Pixel Readout for a TPC at NIKHEF

TILC08 - Sendai

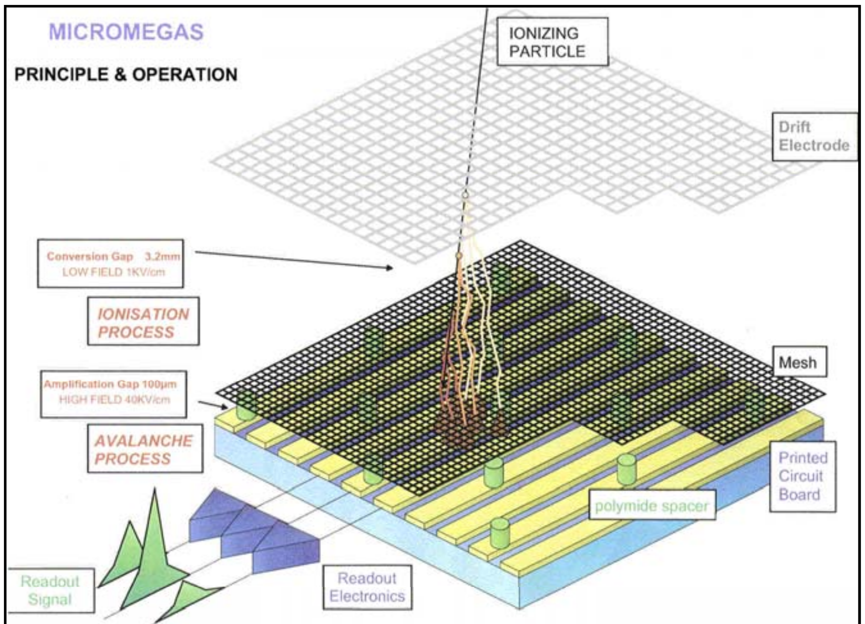
4 March 2008

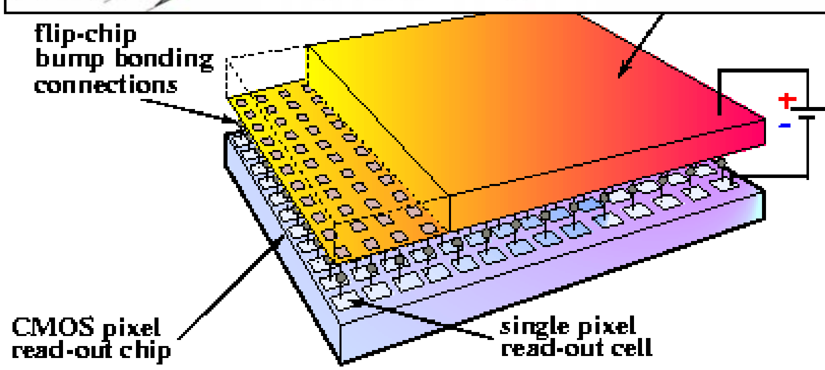
Jan Timmermans

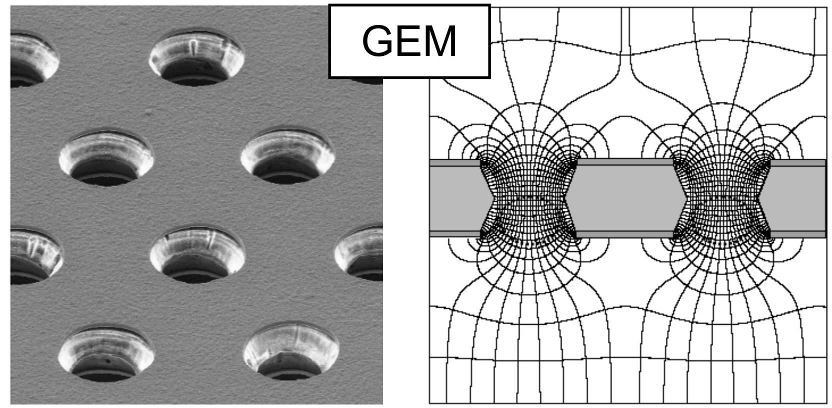
NIKHEF

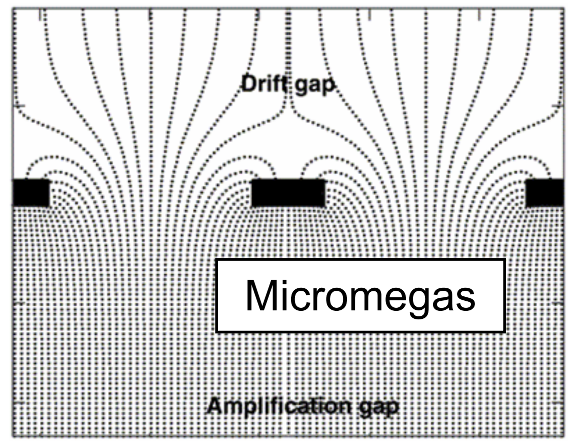
Micro Patterned Gaseous Detectors

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





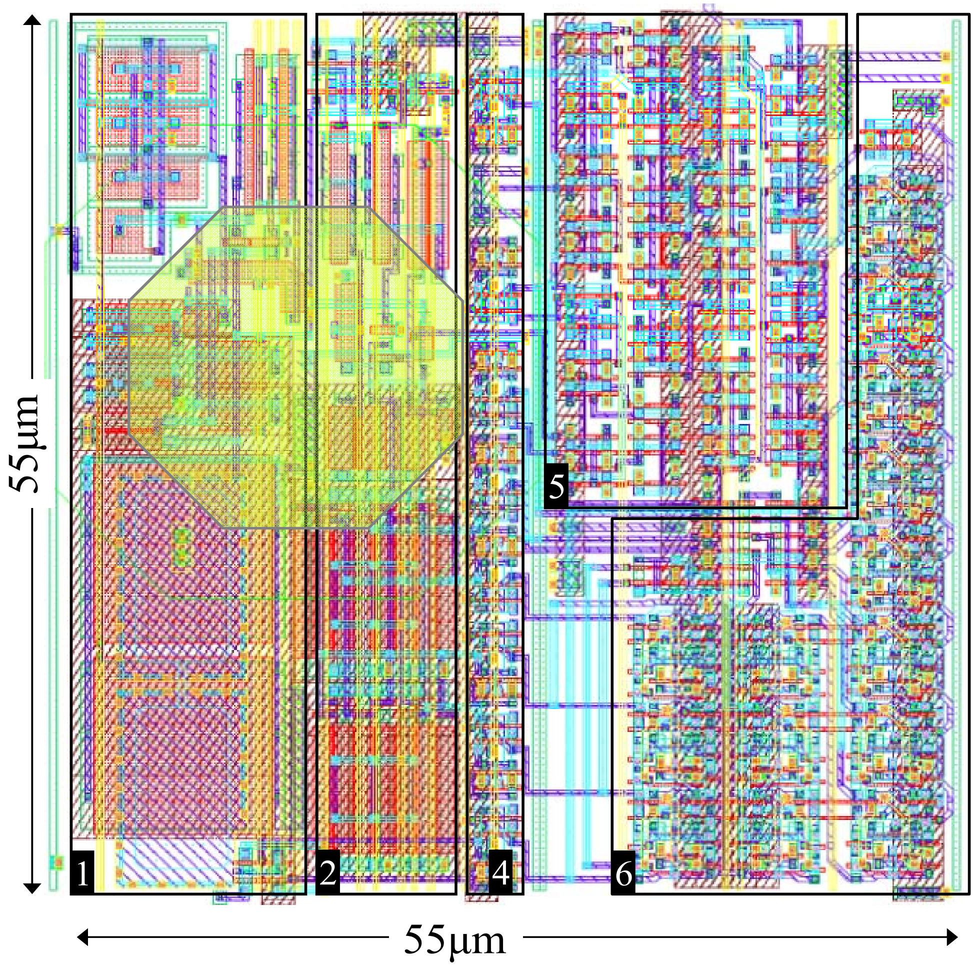




Use 'naked' CMOS pixel readout chip as anode

Timepix pixel

CERN



Timepix chip:

- 256x256 pixels
- pixel: 55x55 μm^2
- active surface: 14x14 mm^2

Timepix chip (1^{st} version) produced Sept. 2006

Available for use in detectors since Nov. 2006

Timepix in gaseous detectors

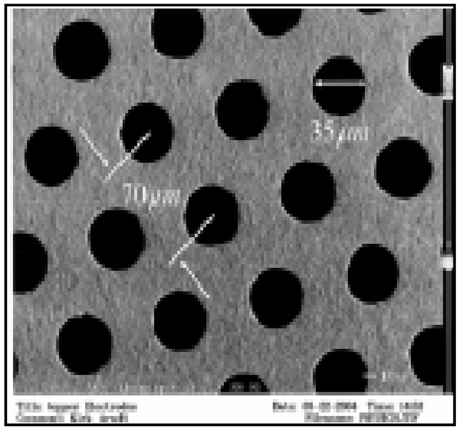
- With Micromegas grid or GEM stacks
- Wafer postprocessing:
  - Integrated grid (Ingrid)
  - Enlarged pixels (with GEMs @ Freiburg)
- Discharge protection:

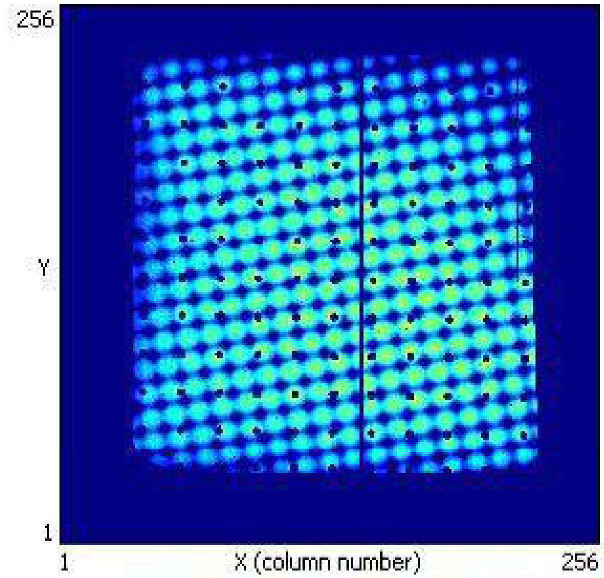
high-resistive (~10^{11}) Ω·cm amorphous Si layer (20 μm thick) on top of CMOS chip

(later maybe also high-resistive grid)

Full post-processing of a TimePix

· Timepix chip + Micromegas mesh:



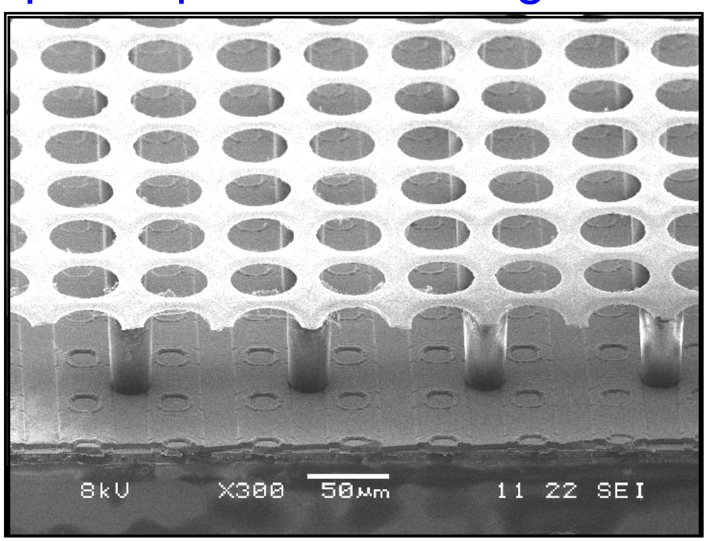


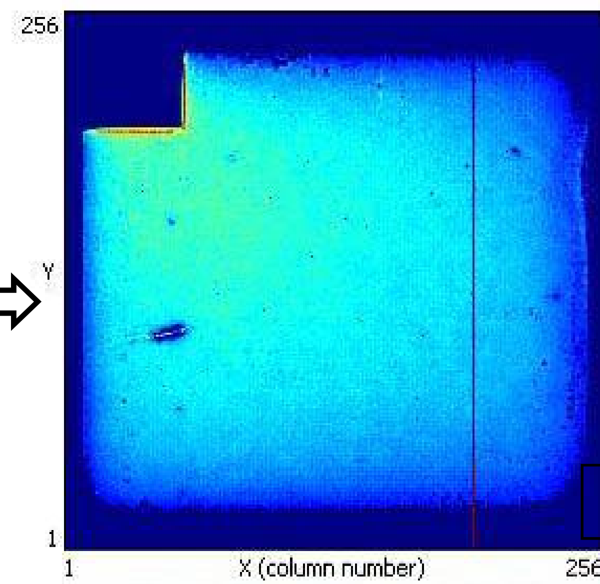
Moiré effects
+ pillars

· Timepix chip + SiProt + Ingrid:

MESA+

IMT
Neuchatel





"Uniform"

"counting" mode

“lifetime” of Medipix2/Timepix chips

- “naked” Medipix chips:

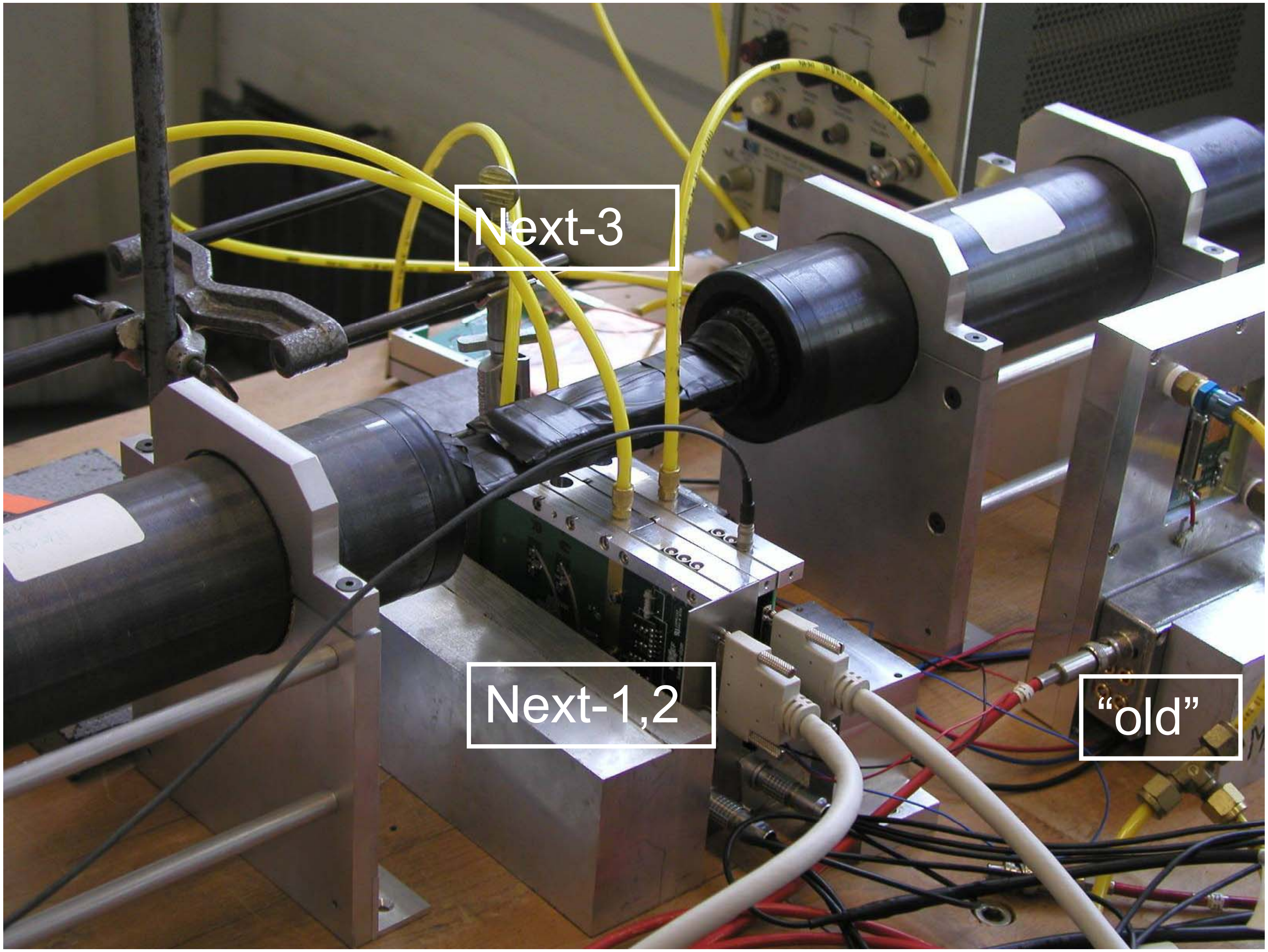
  up to few hours; sometimes very short!

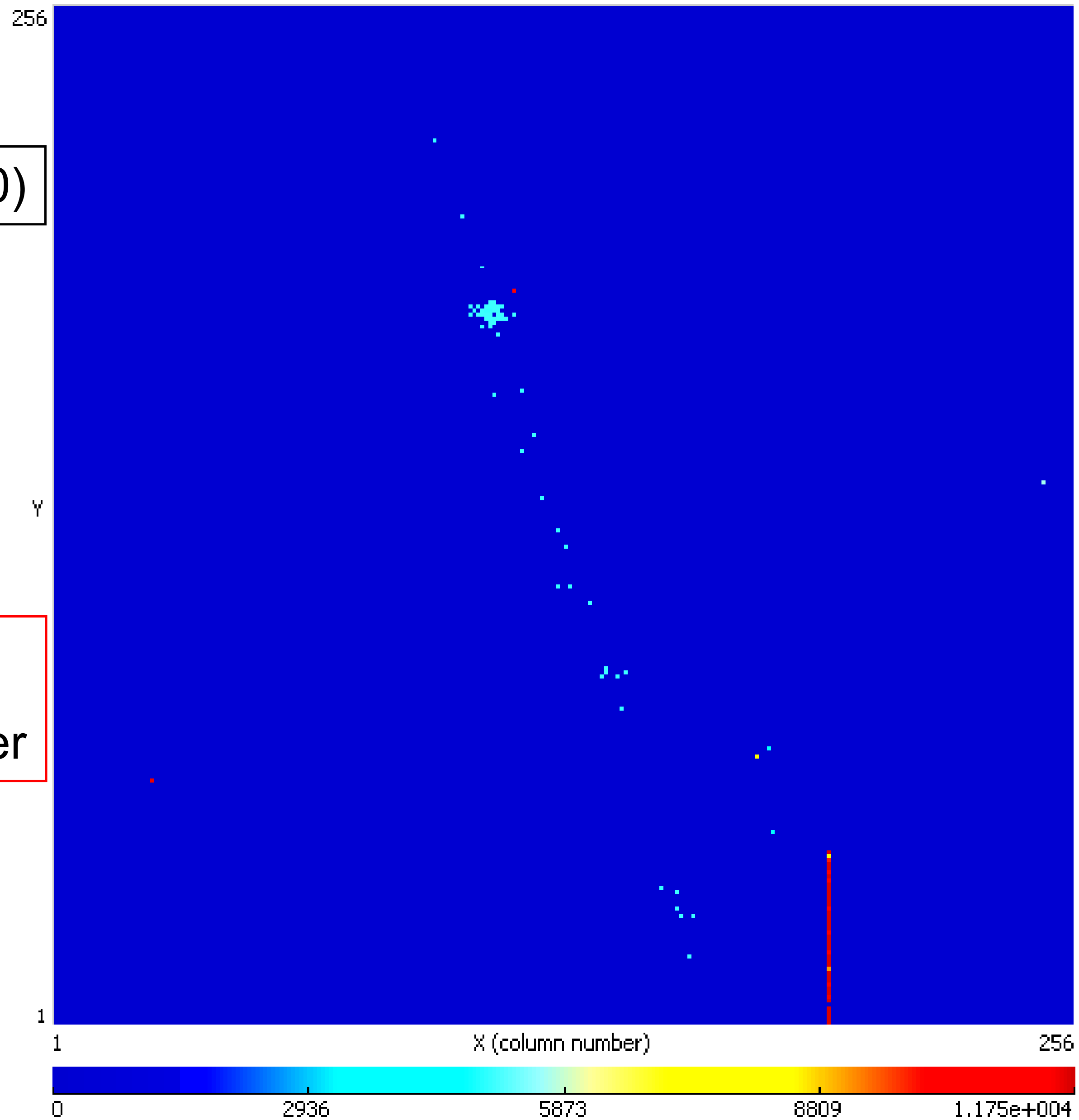
  (both in He and in Ar mixtures)

- With 4 μm amorphous Si:
  - in He/isobutane (80/20): > 3 months
  - In Ar/isobutane (80/20): ~ 1 day!

- With 20 μm protection layer ???

NIKHEF setup (> 22 Aug. 2007)





^{90}Sr

He/Iso (80:20)

Time mode

118 µs shutter

Timepix
+
20 µm Siprot
+
Ingrid

in Next-1

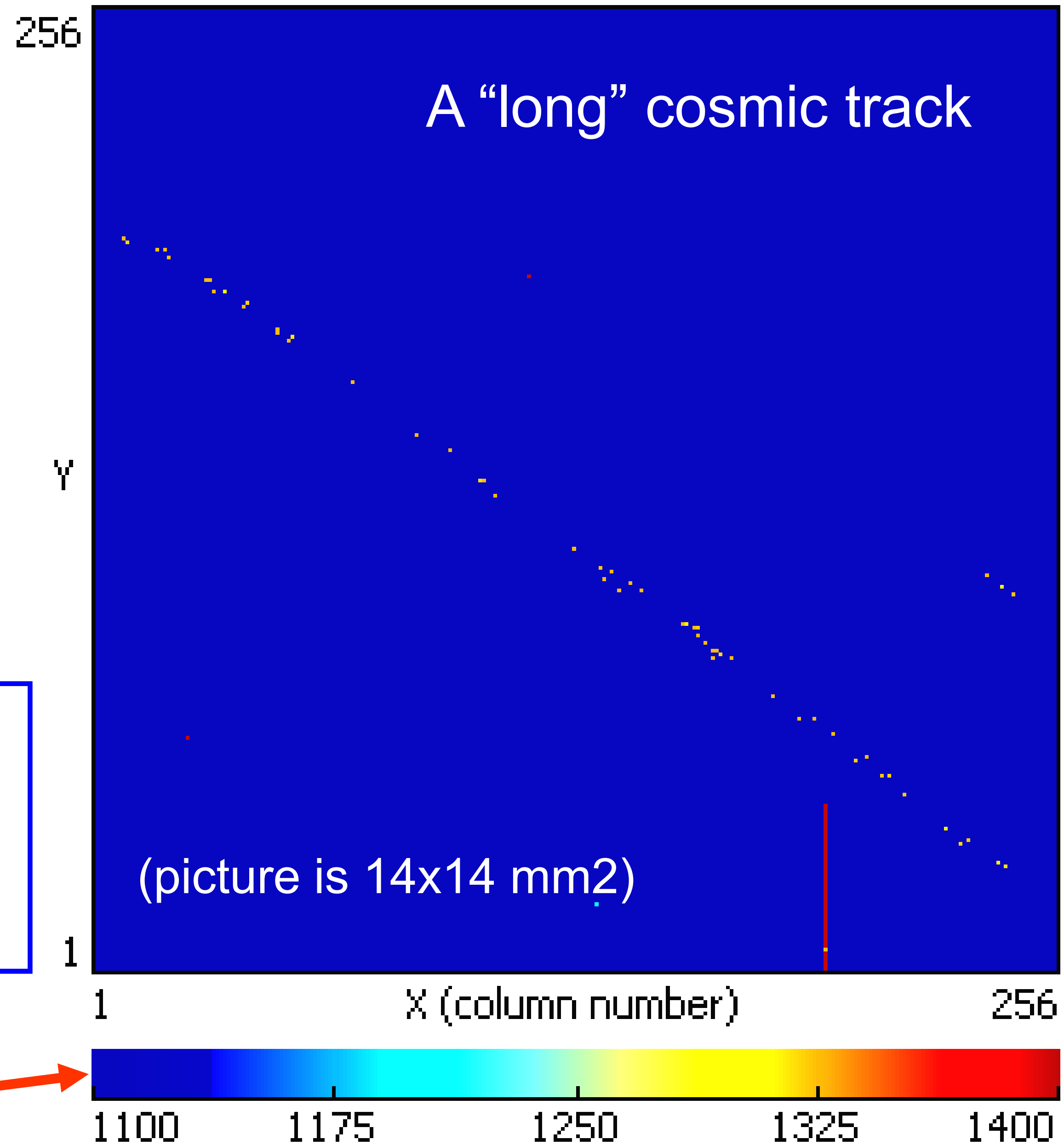
courtesy David Attié

The "typical" track

Timepix
+
20 μm thick Siprot
+
Ingrid

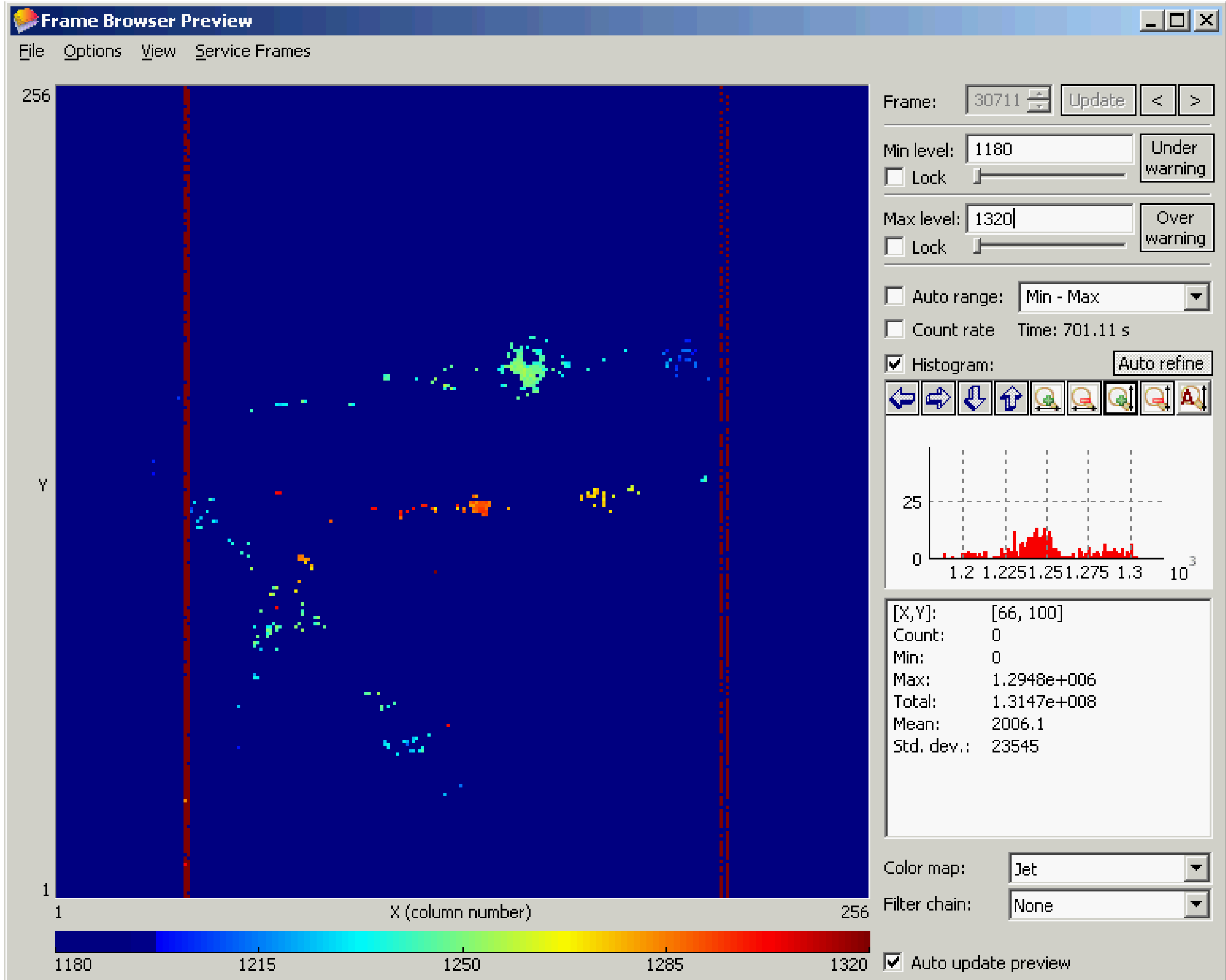
Stable operation in He iC4H10

Will 20 μm SiProt be enough to operate in Ar?



Stable operation in Argon too!

Time mode

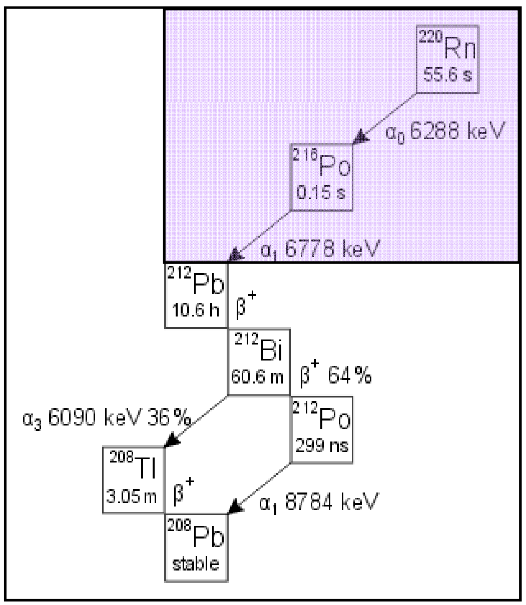


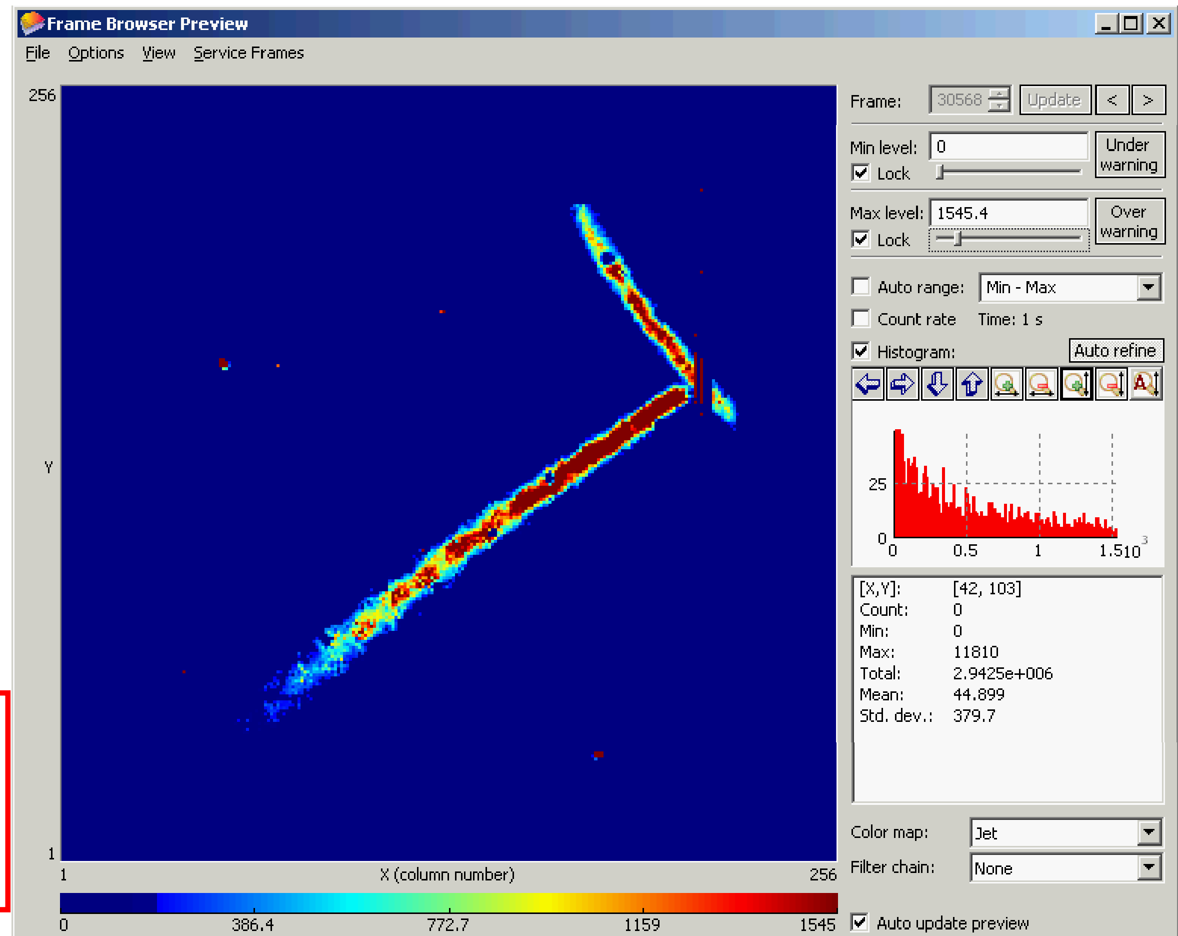
After 2 weeks of cosmic event recording, it was time for a definitive assessment whether 20 μm SiProt is enough to protect against discharges…

Final assessment: spark-proofness

- Provoke discharges by introducing small amount of Thorium in the Ar gas
  - Thorium decays to Radon 222 which emits 2 alphas of 6.3 & 6.8 MeV
  - Depose on average $2.5.10^5$ & $2.7.10^5$ e- in Ar/iC_4H_{10} 80/20 at -420 V on the grid, likely to trigger discharges

Charge mode





During ~3 days, some 5.10^4 alpha events recorded in 1% of which …

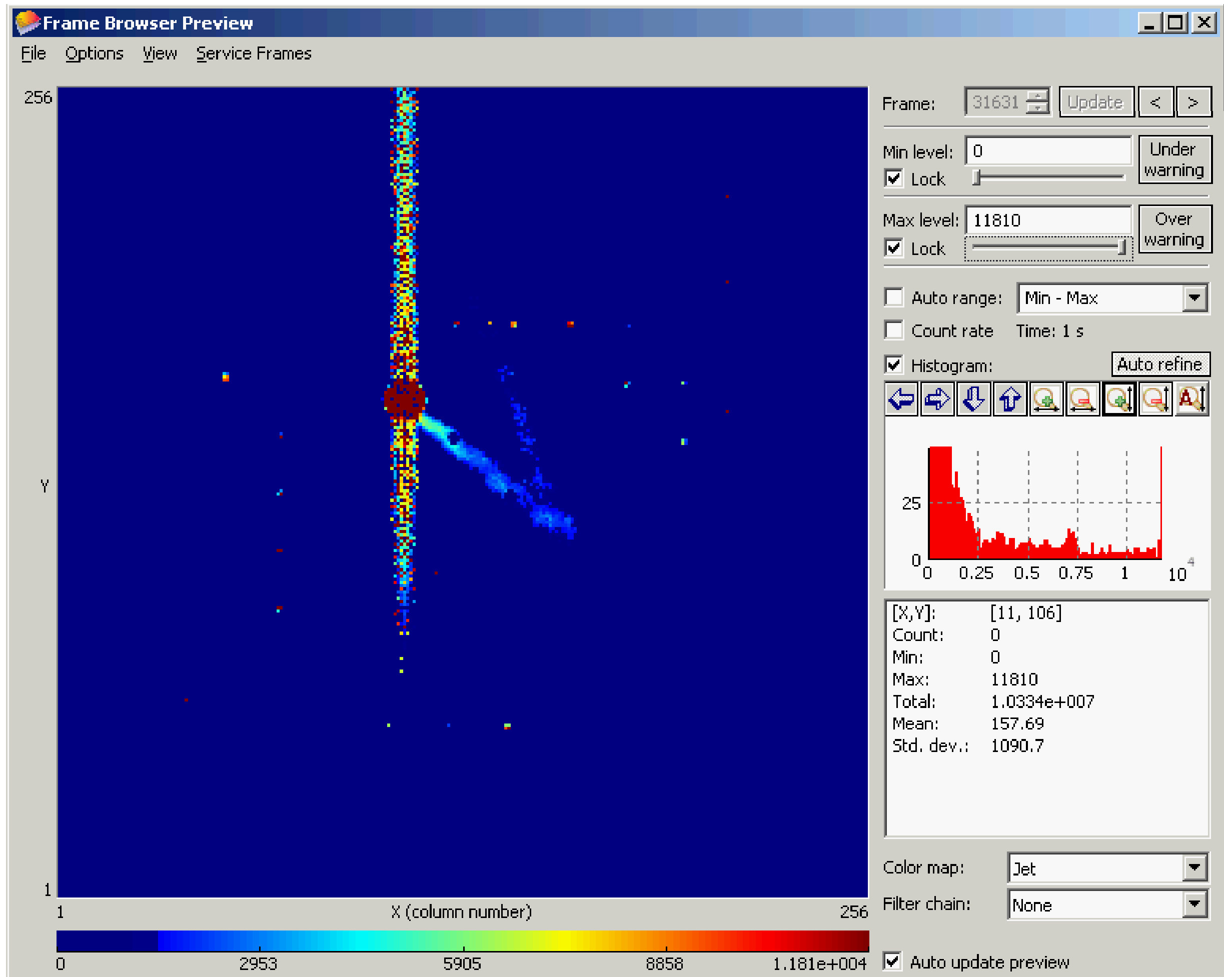
… discharges are observed !

For the 1st time: image of discharges are being recorded

Round-shaped pattern of some 100 overflow pixels

Perturbations in the concerned column pixels
- Threshold?
- Power?

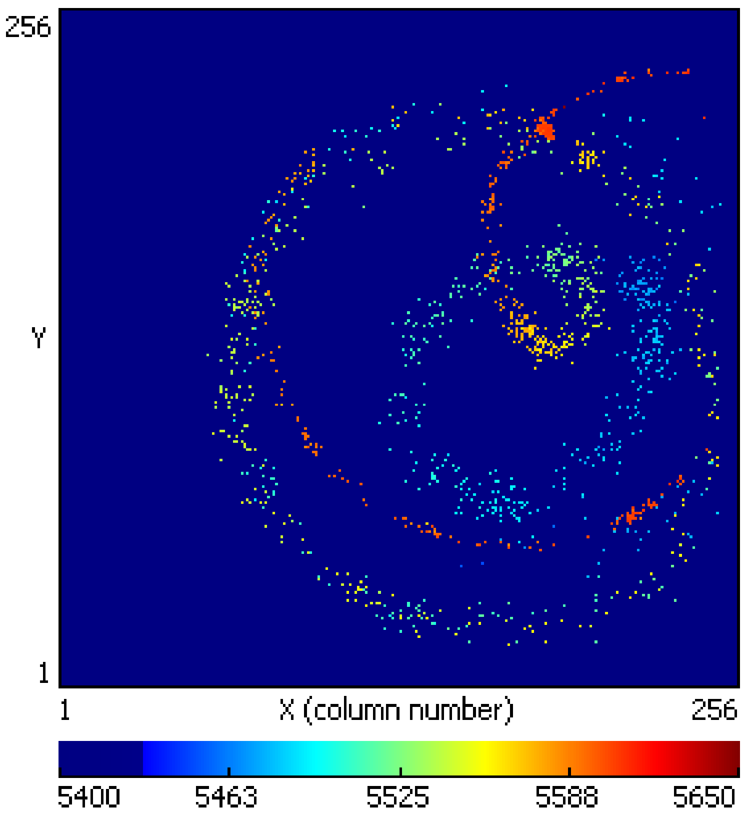
Chip keeps working !!

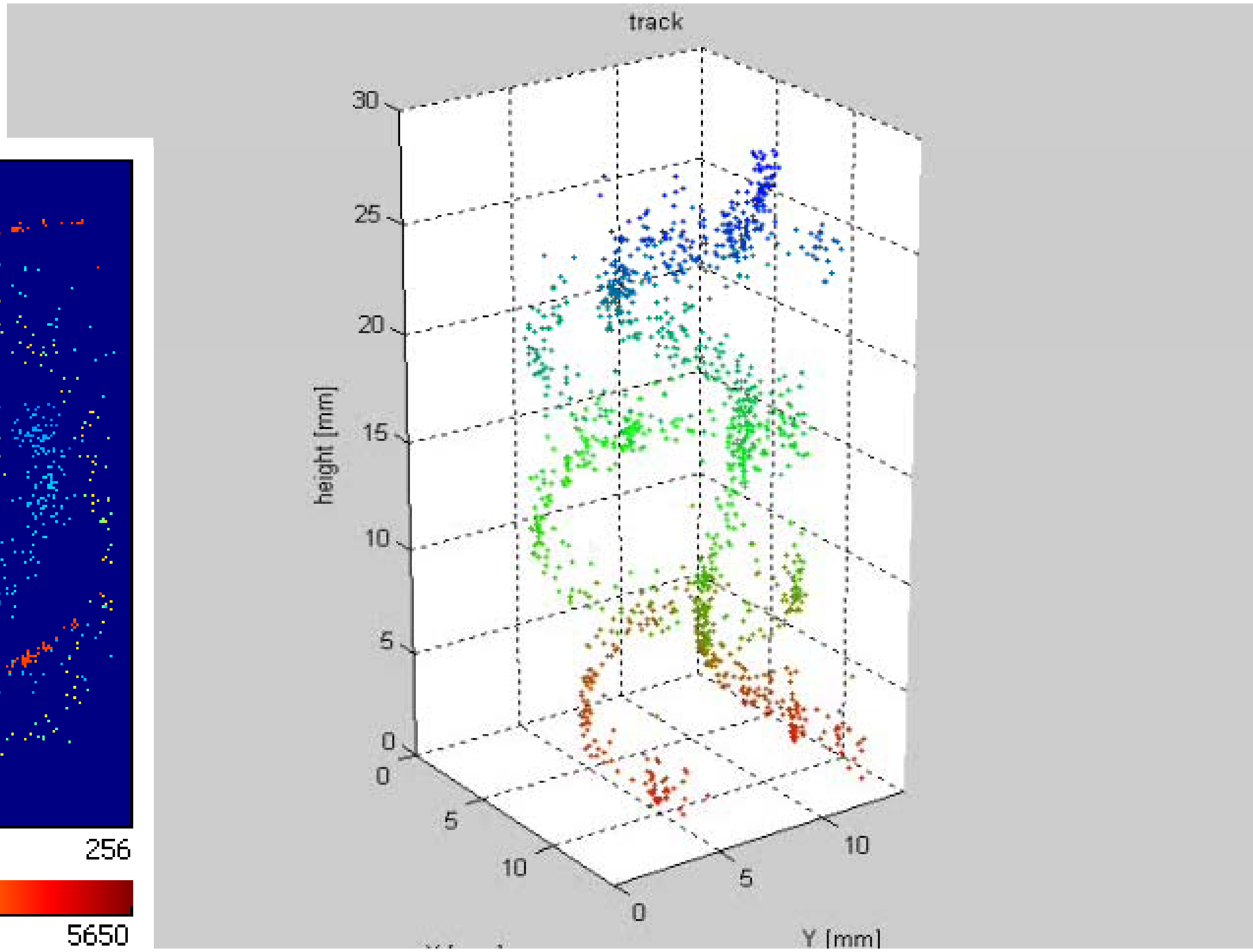


Sofar with 20 μm no more Timepix chip damaged by discharges

A 5 cm^3 TPC (two electron tracks from ^{90}Sr source)

B = 0.2 T





Pixel systems sofar….

- Timepix (also Medipix2) with triple-GEMs (Freiburg, Bonn)
- Timepix (also Medipix2) with single Micromegas (NIKHEF, Saclay)

Now:

- Timepix + amorphous Si (highly resistive) + integrated grid (Ingrid) (NIKHEF), soon also Saclay

  Will compare performance different thickness of protection layer: 0, 5, 10, 15 and 20 μm
- larger drift lengths, up to 100 mm

- Sofar single-chip systems used
- Soon (Eudet deliverable) small multi-chip systems:
  - Bonn: two 4-chip boards → on endplate module
  - Saclay: one 8-chip board → on endplate module
  - NIKHEF: 4-chip board, fitting single-chip detector mechanics and drifter (could become endplate module)
- Later (~3/2009): aim for a 64-chip system (NIKHEF; may be too ambitious; bottleneck could be production of sufficient # Ingrids)

Summary

- A lot of progress made in last ‘year’; not mentioned many details on track resolution studies and on signal development
- Part of the technology is ready:
  - Very good energy resolution for Ingrid devices
  - Ion backflow at the few per-mil level at high field ratio
- Discharge protection seems working for Ingrid (and Micromegas) devices
- Robust operation with GEM devices (without protection)

Next:

- Build larger multi-chip detector systems with fast readout

Backup slides

Status of Timepix usage at NIKHEF

13 dec.	**B05** with 3 µm SiProt & Micromegas in He 20% iC4H10	TPX operated 1 month in He iC4H10
24 jan.	Switch to Ar 20% iC4H10, chip died after 2 days	
20 mar.	**MediPix2** with 3 µm SiProt & InGrid operated 4 days in He	1st fully post processed MPX
17 apr.	**C08** with 3 µm SiProt & Micromegas & guard electrode (G.E.) in He	TPX operated 3 months in He iC4H10
25 jul.	Stop **C08** after 3 months of continuous operation in He	
	E09 with 20 µm SiProt & InGrid placed in NEXT-1 chamber in He	1st fully post processed TPX
22 aug.	**A06** with 20 µm SiProt & Micromegas placed in NEXT-2 chamber in He	
04 sep.	Flush NEXT-2 (**A06**) with Ar, stable operation for >40 days!	TPX operated in Ar iC4H10
23 sep.	Flush NEXT-1 (**E09**) with Ar, same nice results	
26 sep.	Introduce Thorium in NEXT-2 (**A06**), provoke discharges Recording alpha's tracks & even more…	

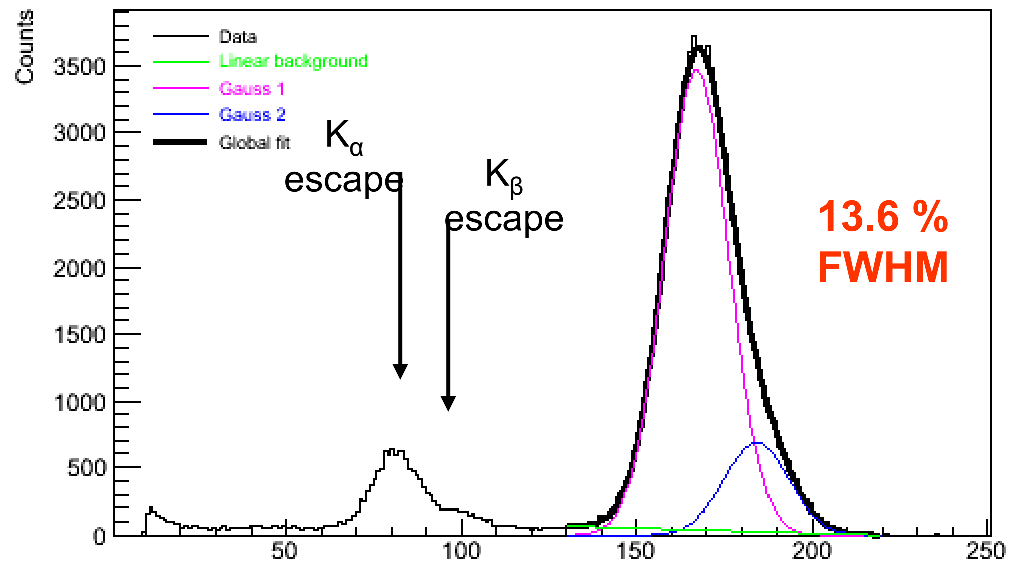
ALL STILL WORKING !!

New Ingrid developments and results

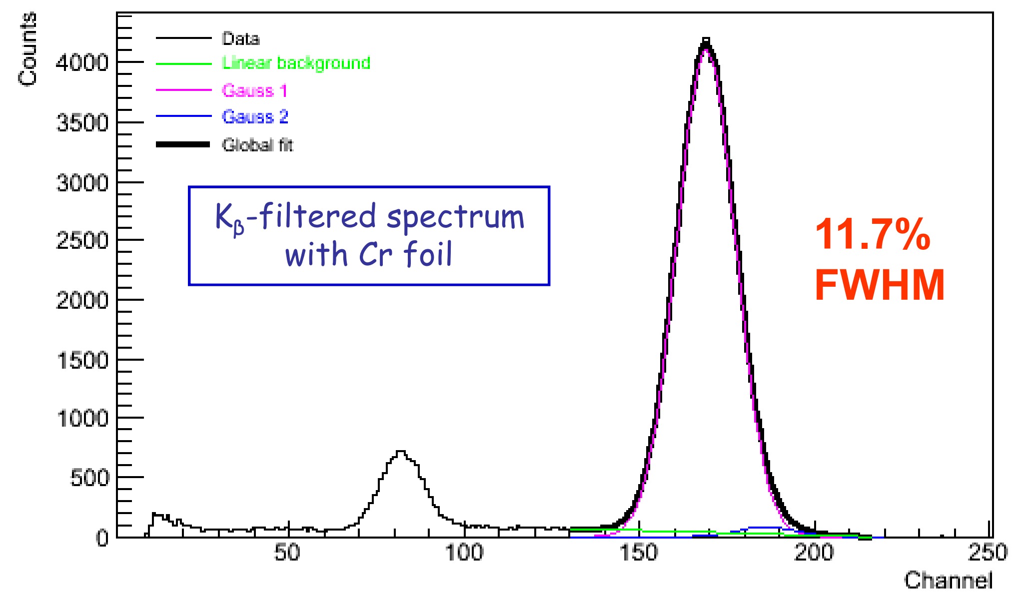
- Process improvement: grids much flatter
  - Extremely good energy resolution:
    13.6 % FWHM with ^{55}Fe in P10
  - Removal of K_β 6.5 keV line:
    11.7 % @ 5.9 keV in P10

- New wafer masks:
  hole pitches down to 20 µm
  with various diameters and gaps
  - Investigate Micromegas geometry
  - Test of the ion backflow theory

- Until now: 1 µm thin Al
  but can now be increased to 5 µm by electrolysis
  Expect less damaged from sparks

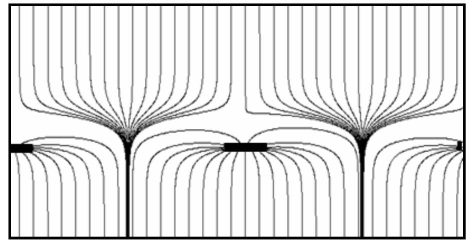


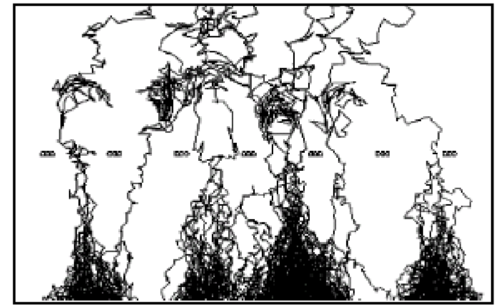
Gap: 50 µm; Hole picth: 32 µm,Ø: 14 µm

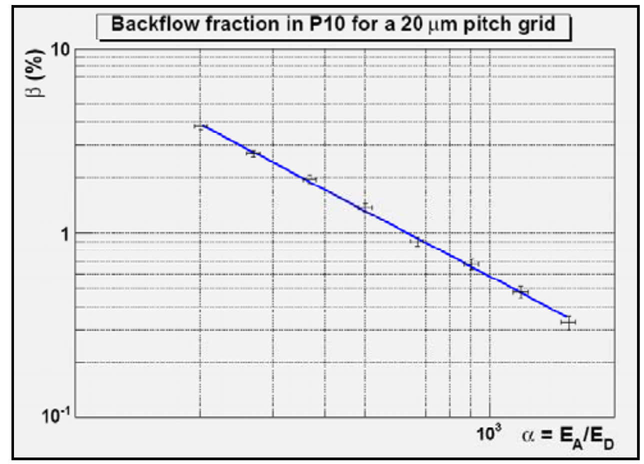


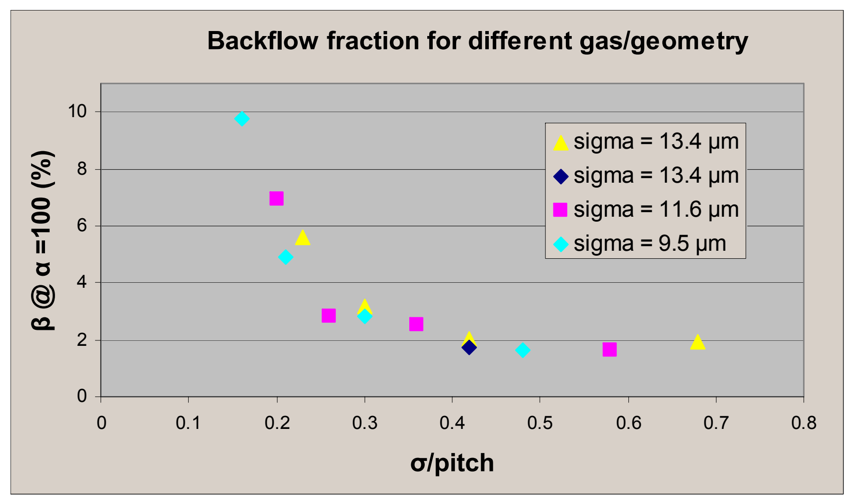
InGrid ion backflow measurements

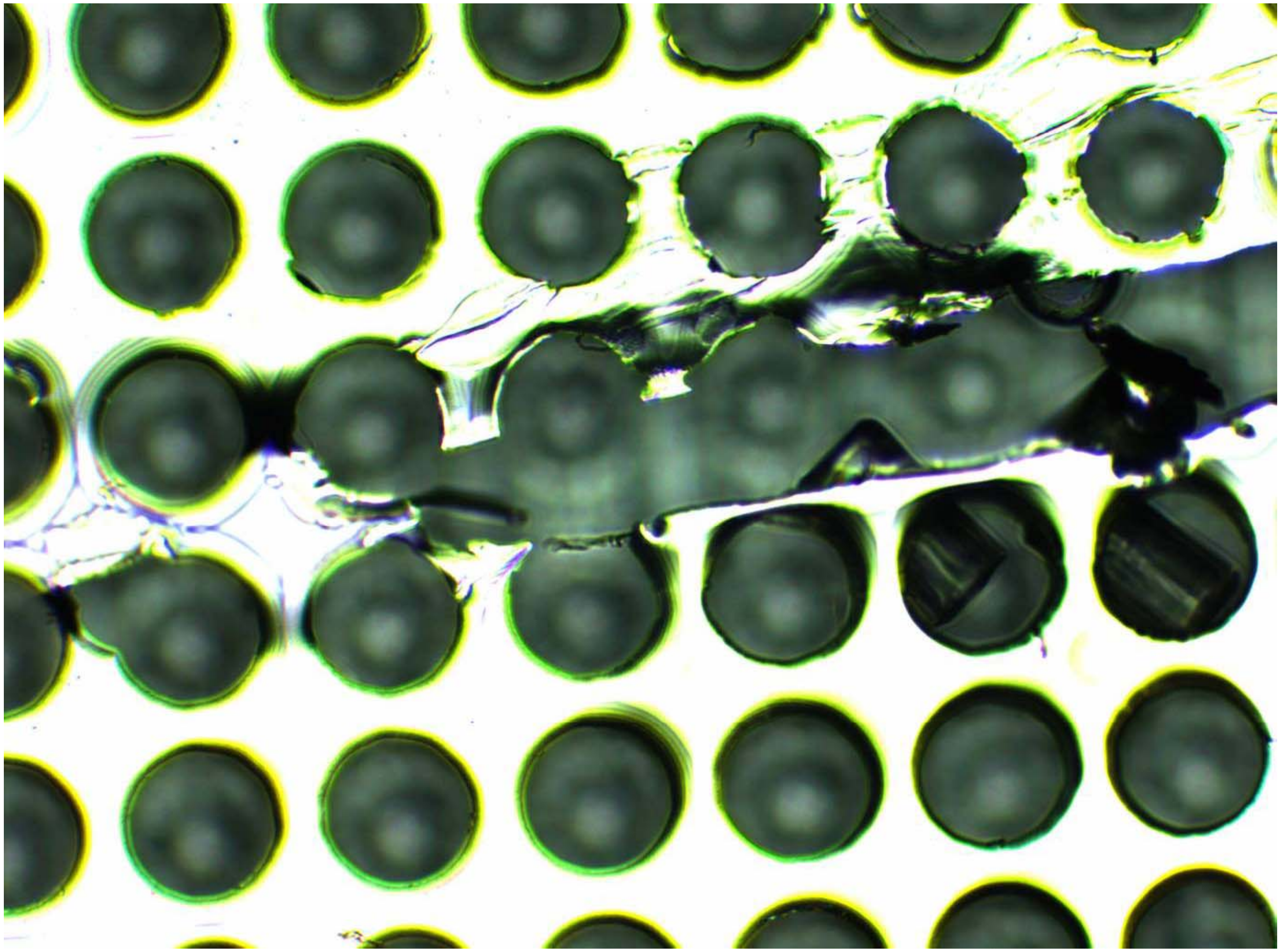
- Phenomenon depends on:
  - Avalanche charge distribution
  - Funnel size
- therefore on the gas and grid geometry
  - Q density in the funnel decreases with the avalanche transverse diffusion
  - Funnel size decreases with the field ratio and hole pitch
- Backflow fraction reaches a (minimum) plateau
  - Occurs when ions backflow through neighboring holes
  - Simulation predicts this to occur at σ/p = 0.5











A “scratch” occurred during production Ingrid;

Loose parts removed. Ingrid working!

Measurement of discharge "spectrum"
(signal from Ingrid recorded on digital scope)