Pixel readout of MPGD

Some recent results at NIKHEF

11 September 2007

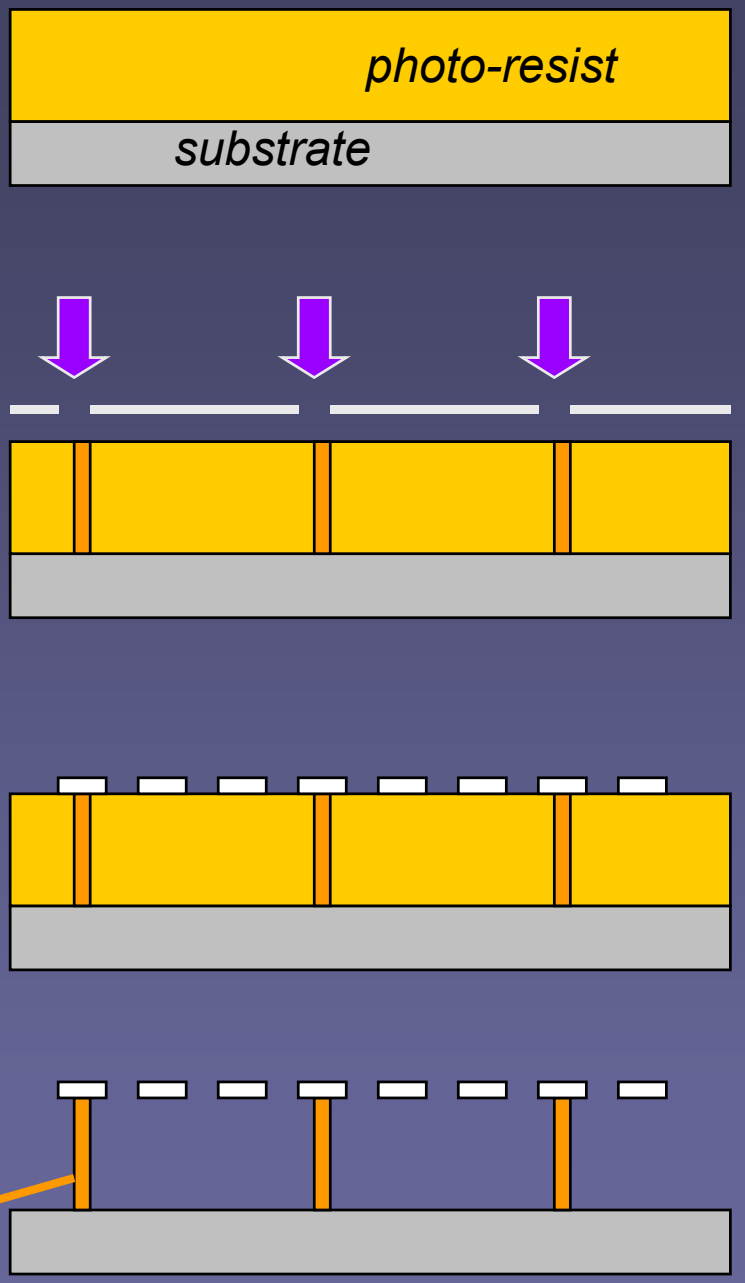
Jan Timmermans

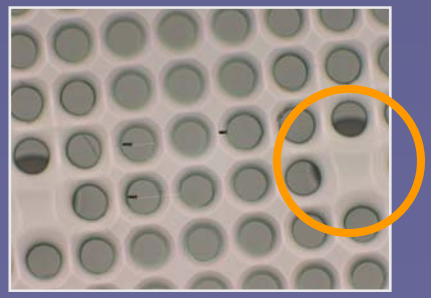
Overview

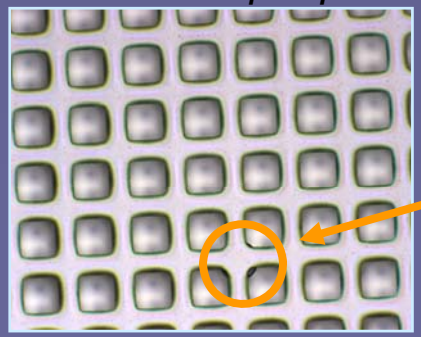
- Pixel readout of gaseous detectors using Micromegas-like structures
- Adding functionalities to pixel readout chips by wafer post-processing
  - Gas gain grids: Ingrid
  - Discharge protection: Siprot
- The Timepix chamber, a 65k channel μTPC
- Gossip (thin gaseous detector) and Gossip ageing results

Processing InGrids
(MESA+, Univ. Twente)

- Substrate can be:
  - Si wafer with a patterned anode
  - Pixel readout chip
- Photo-resist coating & exposure
  - Define the amplification gap (tens of μm)
  - Define the supports (pillars/walls)
- Metal film deposition & patterning
  - Define the grid geometry
- Dissolve the un-exposed resist
  - + some cleaning




20 μm pitch


50 μm pitch

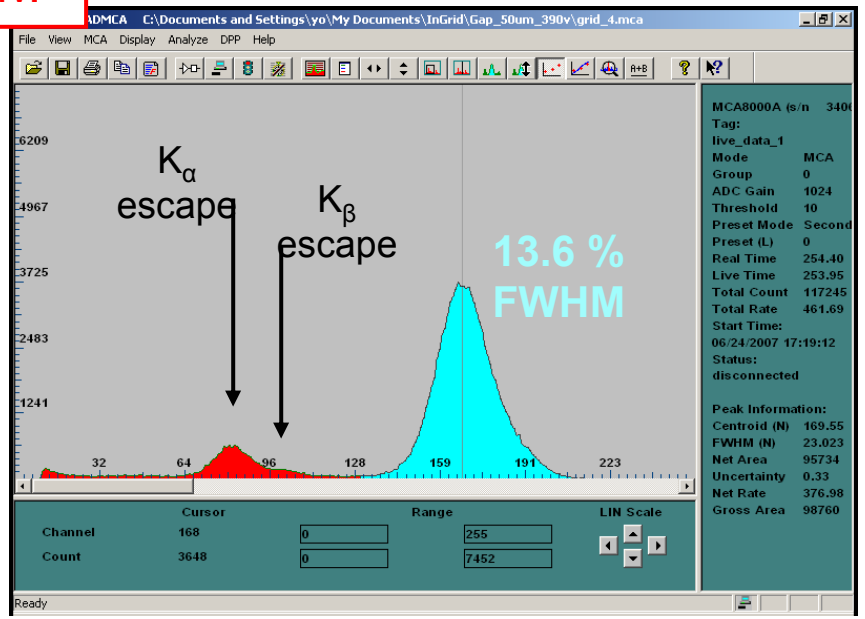
New InGrid developments and results

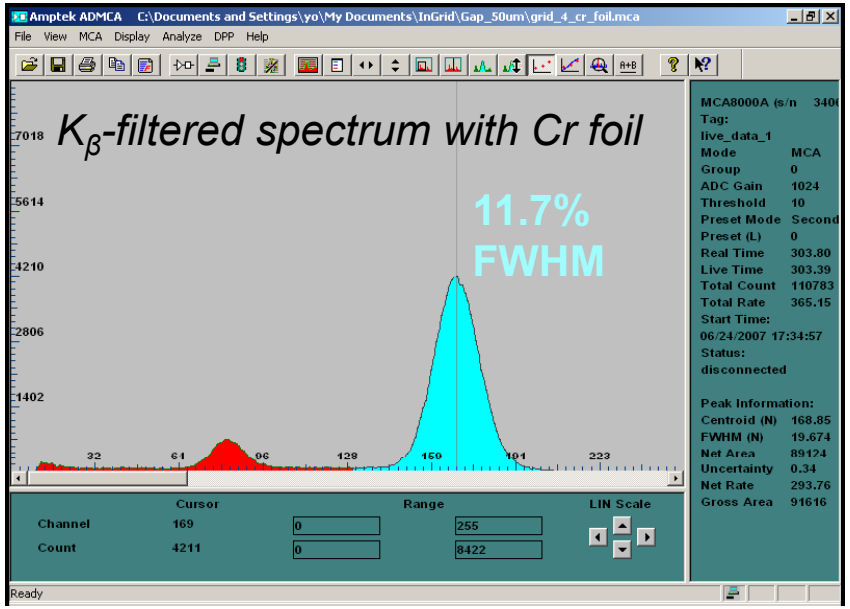
Max Chefdeville (NIKHEF/Saclay) + Twente Univ.

- 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**
  - With F=0.17 and Ne = 229 gain fluctuation ~ 0.5

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

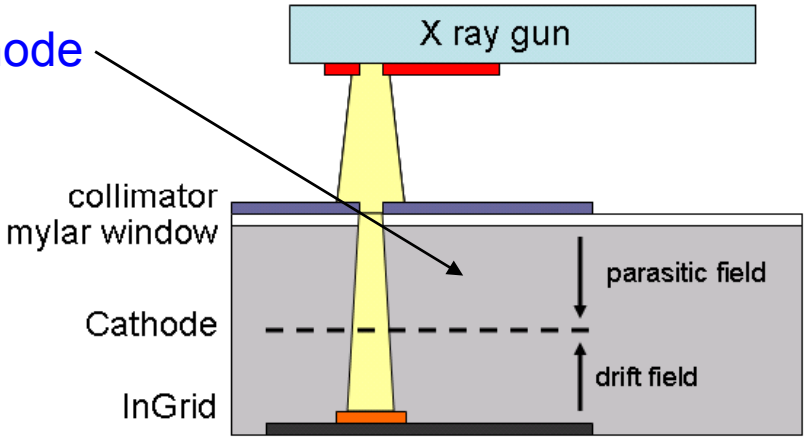
- Until now: 1 µm thin Al
  but can now be increased to 5 µm by electrolysis
  Expect less damaged from sparks





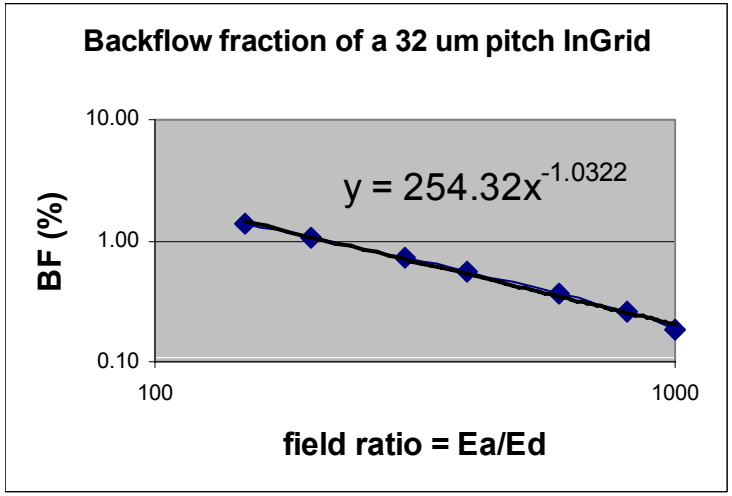
InGrid ion backflow measurements @ NIKHEF

- Measurements started in Saclay
- Main issues encountered:
  - Gas gap between detector window & cathode
    - "Parasitic" field
      Unwanted contribution to primary current
  - Small grid area
    - high X flux for significant primary current
      (recombination problem @ low drift field)
    - bad collection of "long" range photoe-

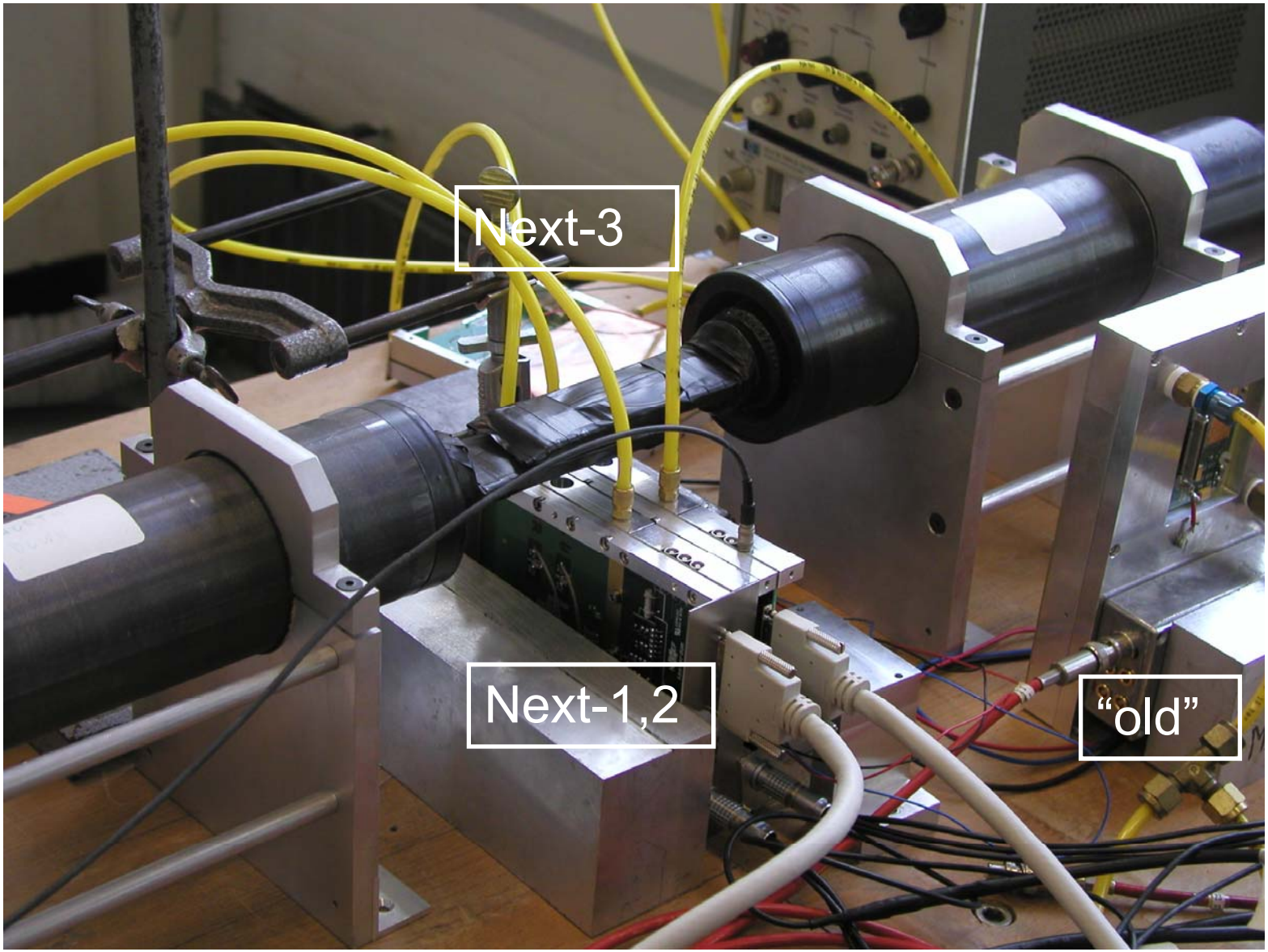


- Solutions:
  - Operate the detector with cathode at ground
  - Reduce X-ray energy (~ 9 keV) and flux

- Now:
  - measurement of the primary and backflow current accurate to the pA!
  - Good measurement up to field ratio of 1000: backflow fraction few 10^{-3} in P10 gas.



NIKHEF setup (on 24 Aug. 2007)



Status Timepix usage at NIKHEF

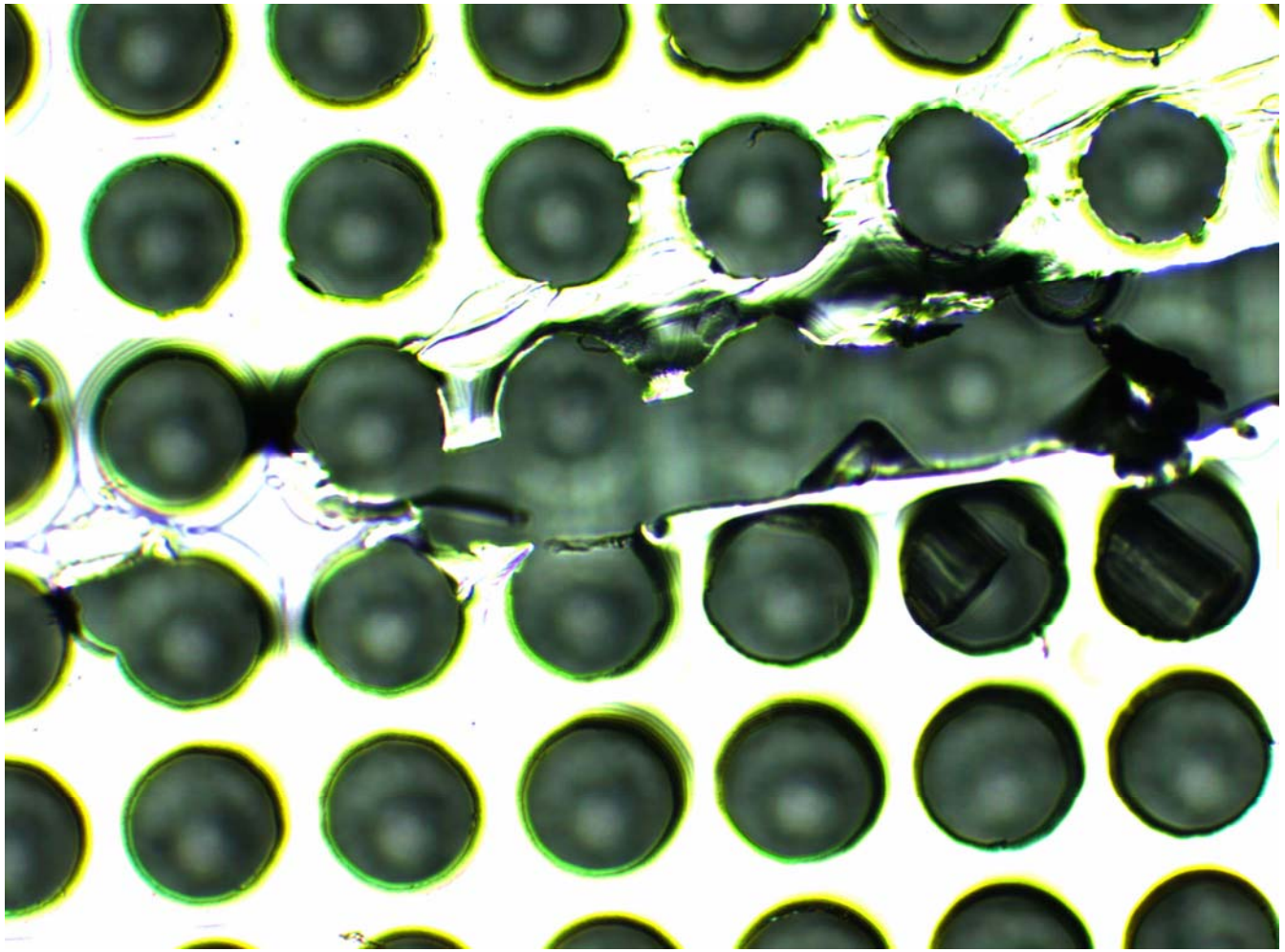
- 1st Timepix (with 3 μm Siprot) "under HV" Dec-Jan for 40 days He/isoButane 80/20; then died after ONE day with Ar/isoButane

- Timepix C08-W0014 (also 3 μm Siprot) was "under HV" since 24 April (for 3 months!) with He/isoButane 80/20 ("old")

- Timepix E09-W0014 (with 20 μm Siprot + Ingrid) under HV for >one month with He/isoB (detector Next-1)

- Detector Next-2: Timepix + 20 μm Siprot + Micromegas; just started on Ar/isoB.

- Next-3: Medipix2.1 + 30 μm Siprot + Ingrid: gain 200k reached



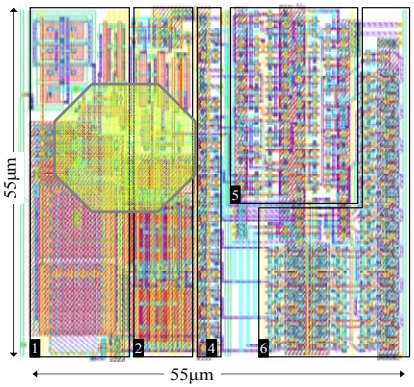
A “scratch” occurred during production Ingrid;

Loose parts removed. Ingrid working!

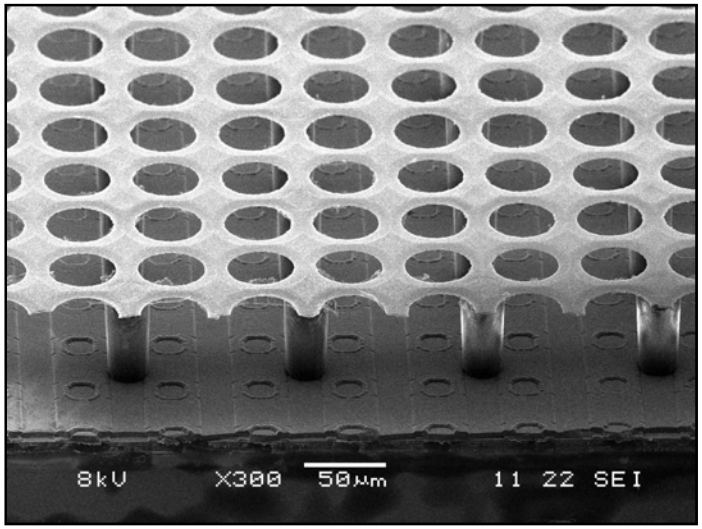
Timepix pixel

55x55 μm^2

CERN



Timepix + Siprot + Ingrid

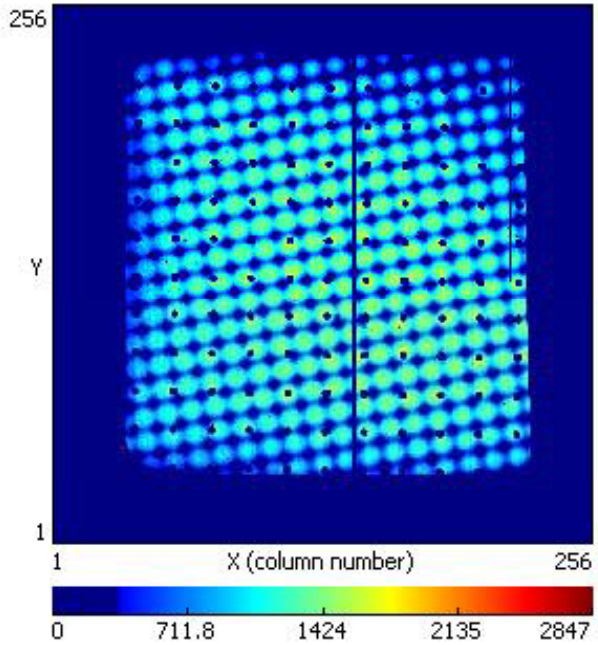


MESA+

IMT Neuchatel

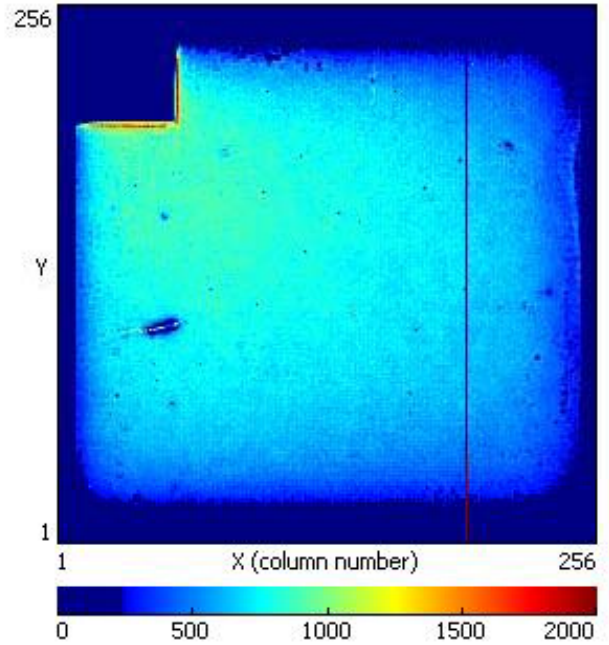
Timepix + Micromegas:

Moiré effects



Irradiation: ^{90}Sr

“uniform”



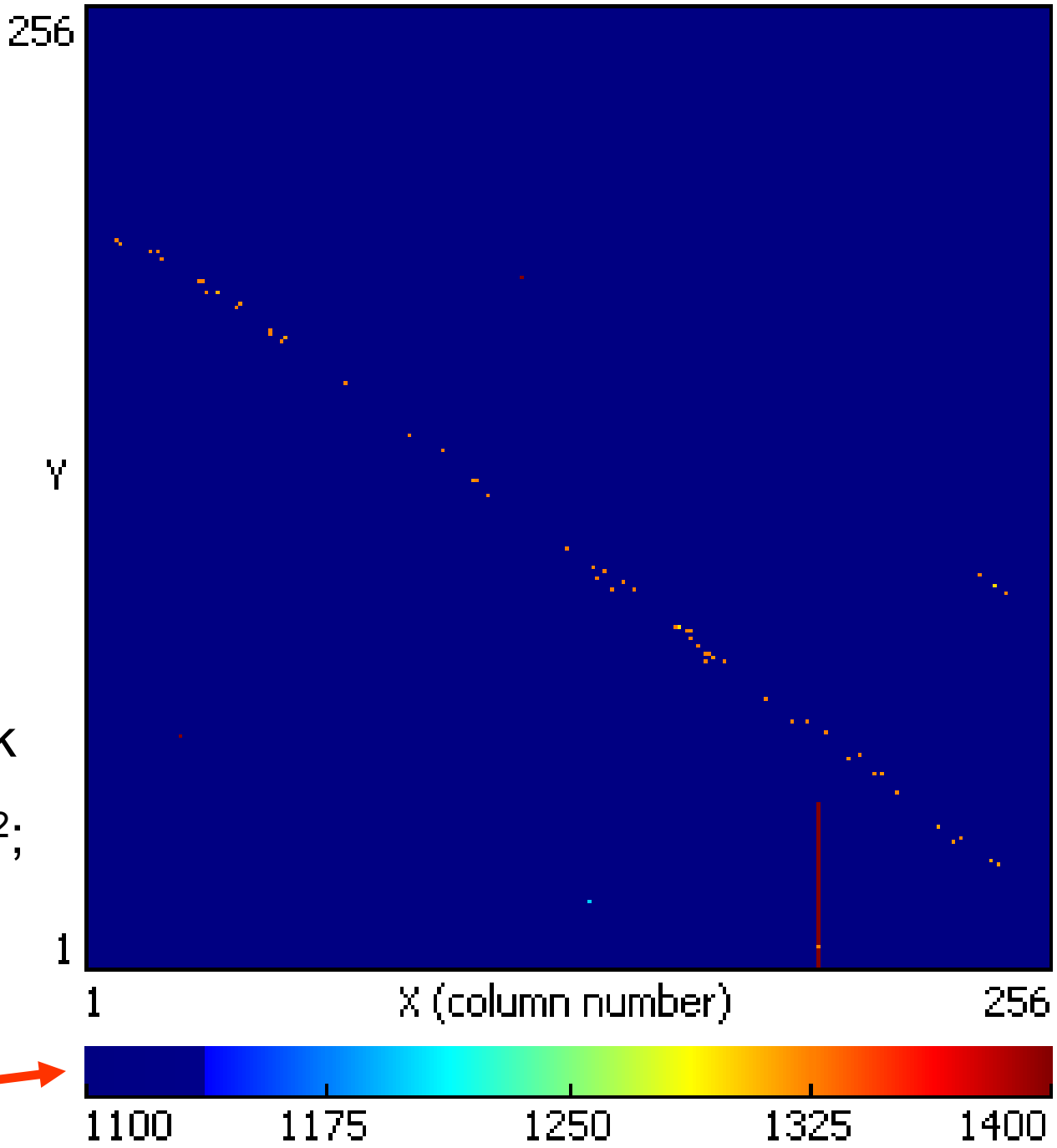
Timepix

+

20 μm thick Siprot

+

Ingrid



A “long” cosmics track

(picture is 14x14 mm^2;

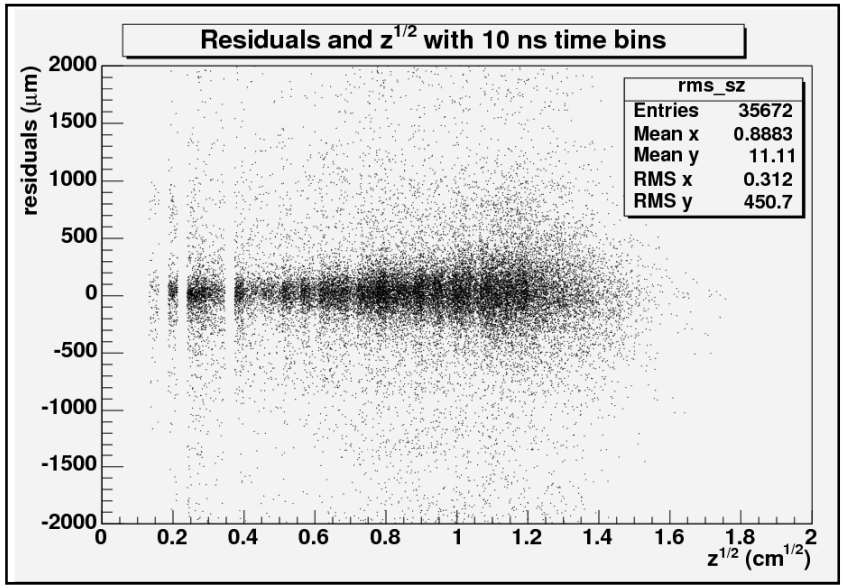
256x256 pixels)

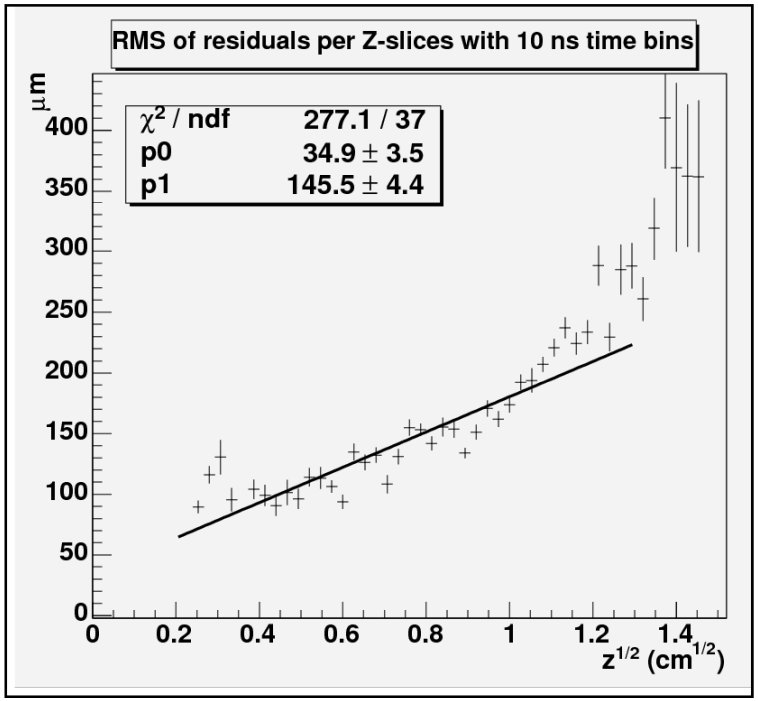
Residuals and drift length

- Standard deviation of residuals follows $\sigma_t^2 = \sigma_0^2 + D_t^2 \cdot z$
  with σ_0 spatial resolution at "0" drift distance and D_t diffusion coefficient.

- Straight line fit yields:
  D_t = 174 µm.√cm @ 660 V.cm^{-1} for t_{bin} = 25 ns
  D_t = 145 µm.√cm @ 660 V.cm^{-1} for t_{bin} = 10 ns

  D_t = 180 µm.√cm from MAGBOLTZ



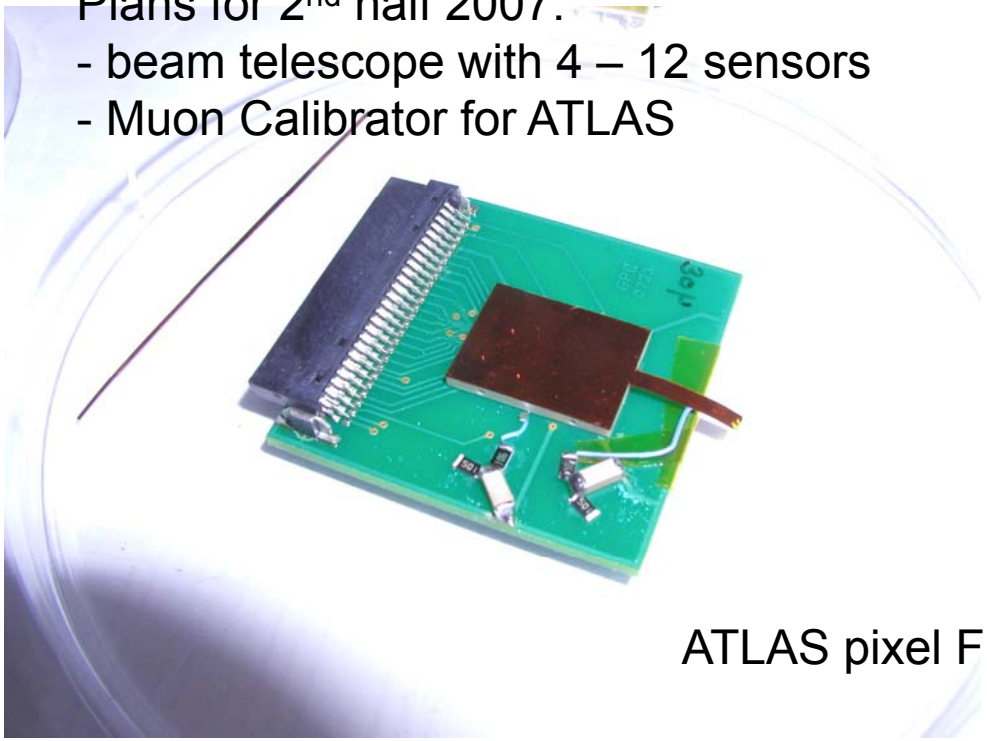


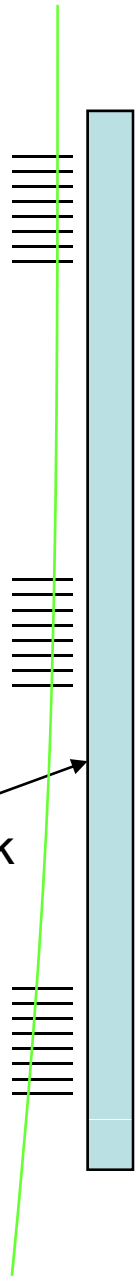
Gas On Slimmed Silicon Pixels **GOSSIP**

Replacement of Si (inner, pixel vertex) trackers
- **lighter**
- **require less power**
- **radiation hard**

First Gossip-Demo built (Univ. of Nijmegen): 1.2 mm drift gap with PSI-46 (CMS pixel) chip, Micromegas and SiProt

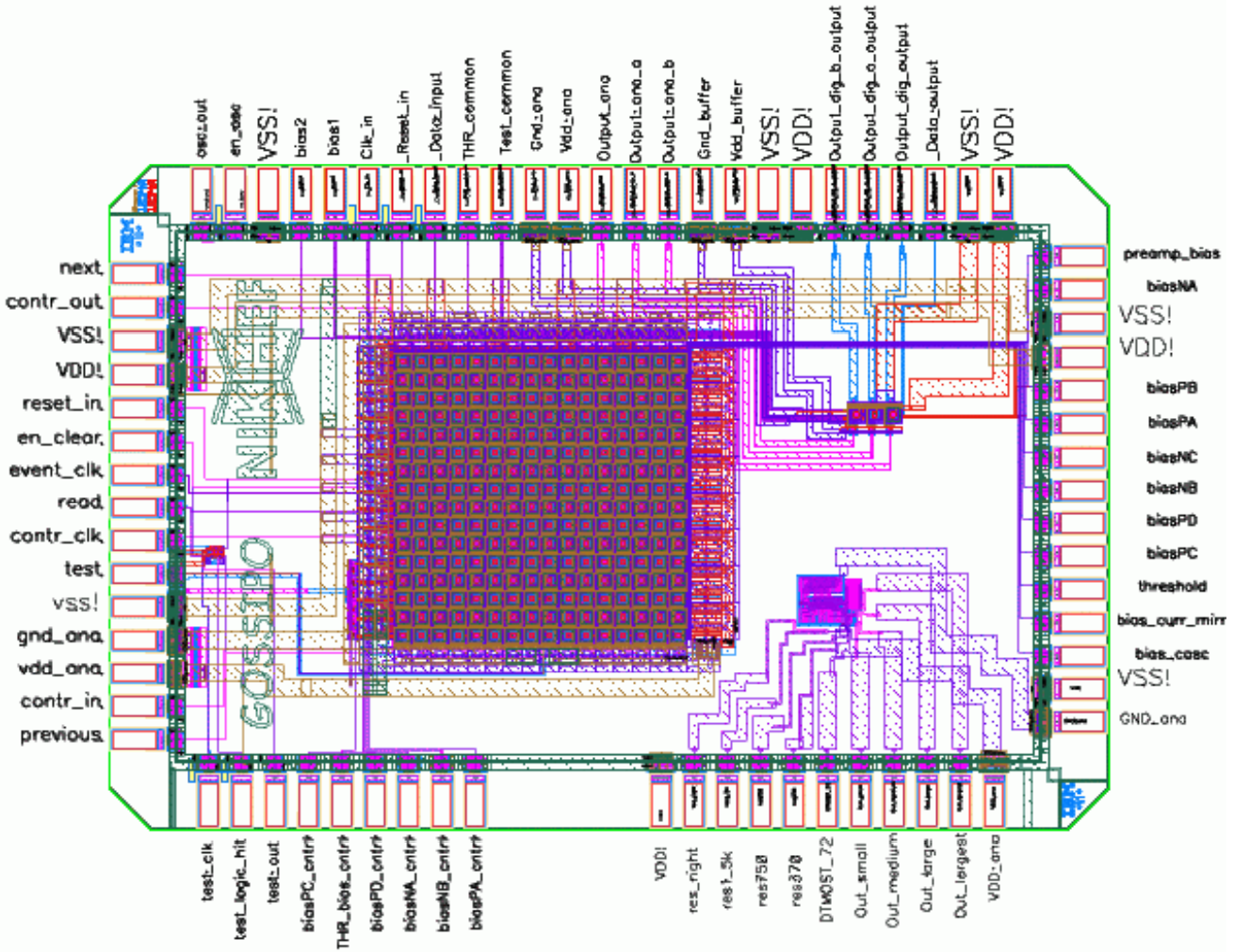
Plans for 2nd half 2007:
- beam telescope with 4 – 12 sensors
- Muon Calibrator for ATLAS





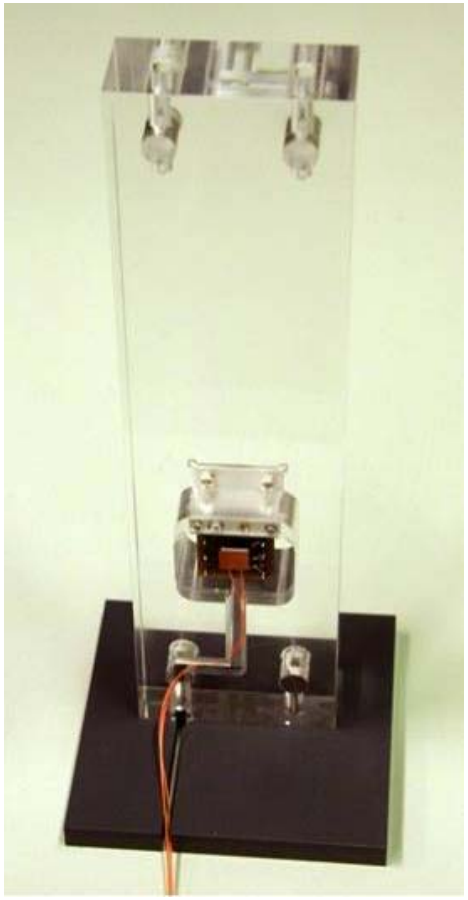
ATLAS pixel FE chip made available…..

Gossipo2



- Only “Slow” clock distribution, 40 MHz
  “Fast” clock from local oscillator per pixel, 560MHz
- 4 bit TDC & latency counter > **1.78 ns resolution** & 350 ns range

Gossip ageing results

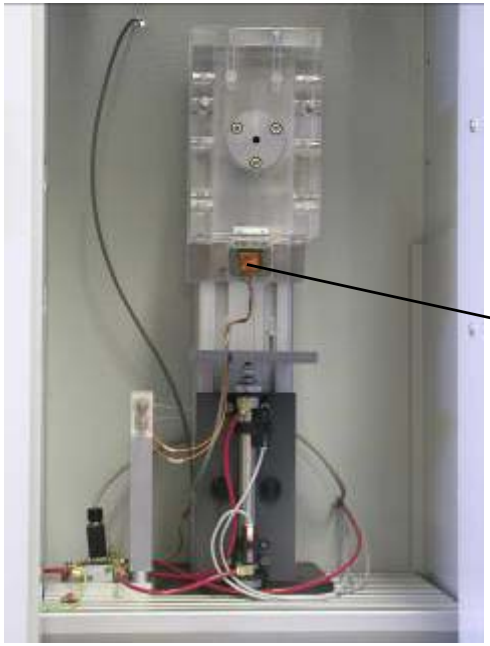


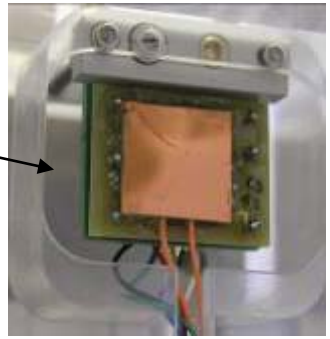
Fred Hartjes
NIKHEF

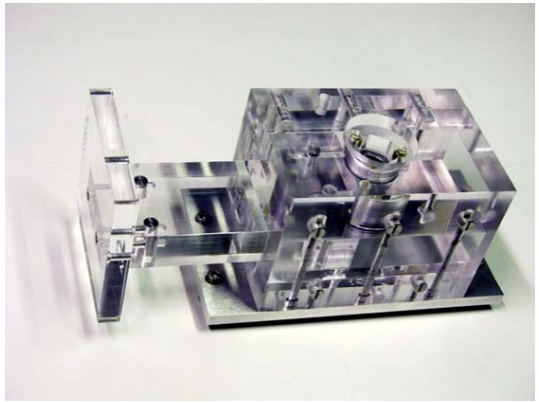
MPGD workshop
CERN, September 10-11, 2007

Ageing by mip irradiation

- Using ^{90}Sr source 5 GBq
  - 1 – 2 MeV electrons (mips)
  - Mip rate up to 1.8 GHz
- Source set-up
  - Source mounted in Perspex block
  - Sample moved by stage towards source (remotely controlled)

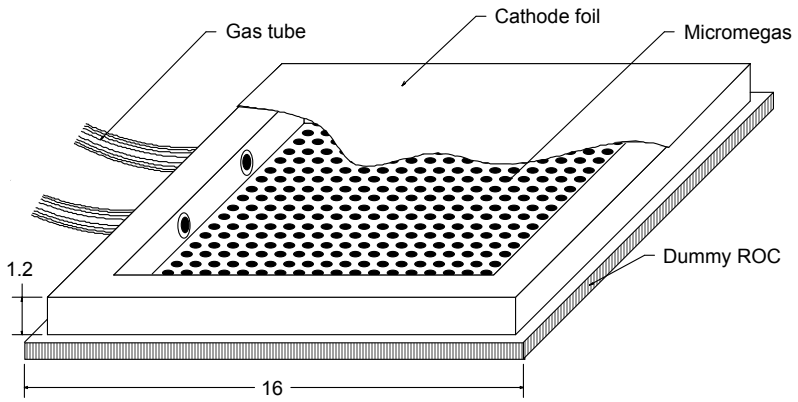


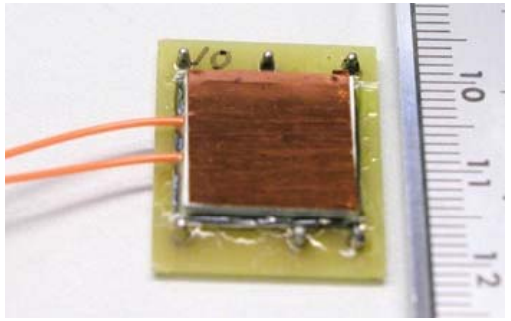




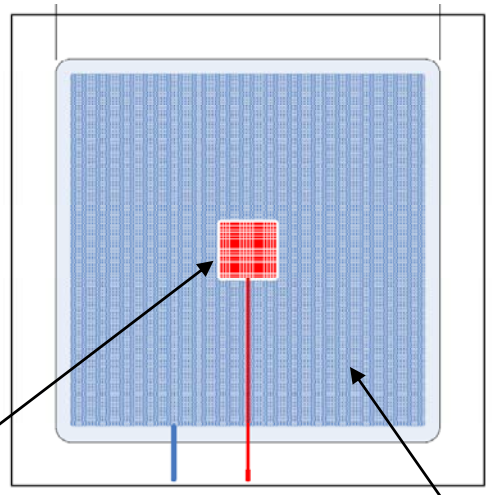
Source housing

Detector: GOSSIP 21 chamber





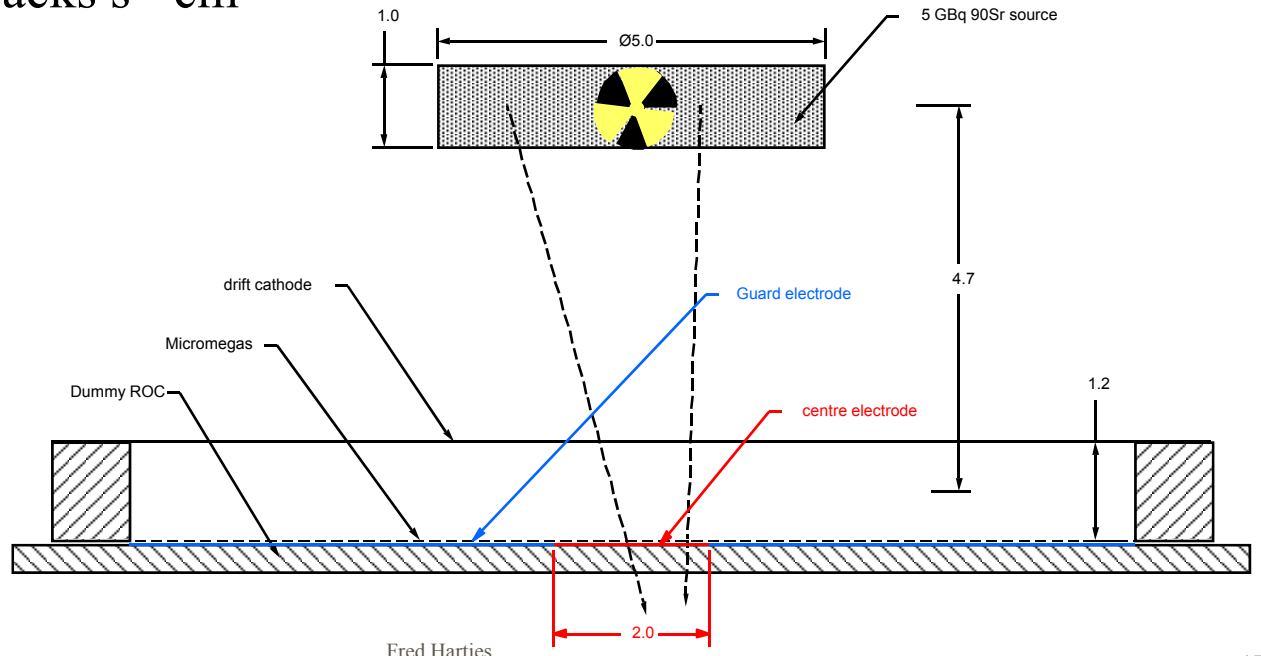
- Sample mounted on small PCB
- Drift volume 13 x 13 mm, 1.24 +/- 0.01 mm high
- Closed gas volume of 210 µl
- Signal electrode: 2 x 2 mm structure of 1089 pads (red) on matrix having 60 x 60 µm pitch
- Surrounding structure (guard) read out as well
- Micromegas has circular holes on same pitch



What do we expect?

- Distance (centre source to centre drift volume) 4.7 – 25 mm
- => maximum theoretical rate 1.8 x 10^9 tracks s^{-1} cm^{-2}
  - 7.2 x 10^7 tracks s^{-1} on 2 x 2 mm detection surface (1089 pixels)

- Reference: SLHC rate
  - Assume 2 x 10^{16} mips cm^{-2} over 5 year
  - => 4 x 10^8 tracks s^{-1} cm^{-2}



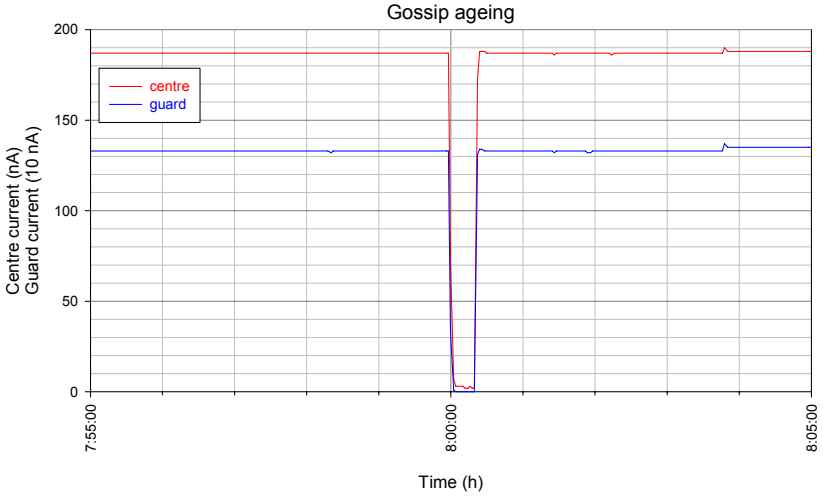
Experimental conditions and results

- Gas: He/iC_4H_{10} 78/22
  - Drift gap 1.2 mm
  - => 5.9 ionisations over drift gap
  - **=> expected ionisation current on detection surface <u>67.9 pA</u>**

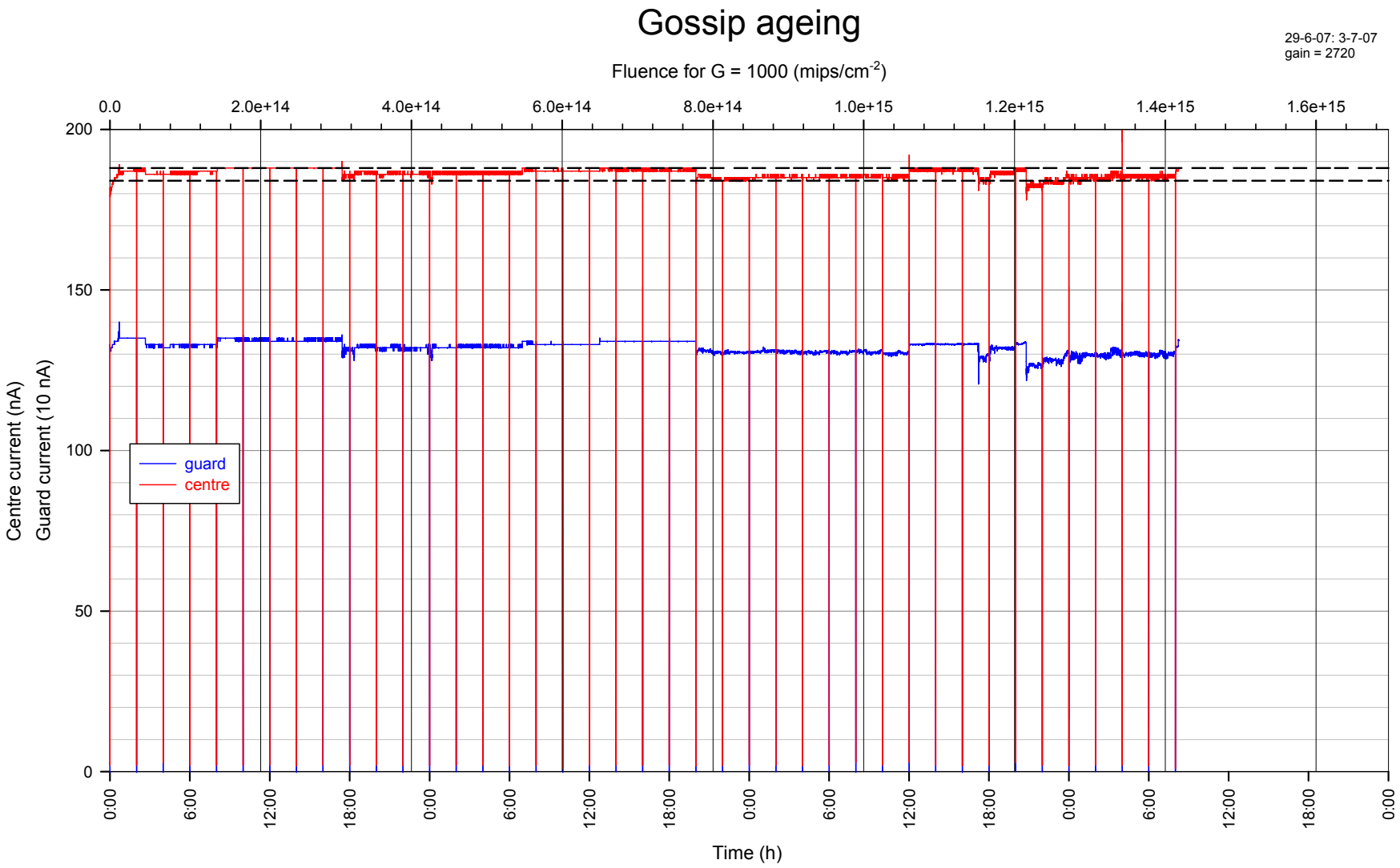
- For the gas system standard non-clean components were used mostly from brass, copper, Teflon/Peek tubing

- Measured current 185 nA at V_{grid} = -470 V
  - **=> gain = 2720**

- Zero current was automatically checked by moving the sample from the source every two hours



- After 0.8 x 10^{14} mips/cm^2 (at G = 1000) tripped
- After 1.4 x 10^{14} mips/cm^2 (at G = 1000) tripped again
  - Could not be brought into same gain (trip as soon the sample was moved to the source)


Gossip ageing
29-6-07: 3-7-07
gain = 2720
Fluence for G = 1000 (mips/cm-2)
0.0
2.0e+14
4.0e+14
6.0e+14
8.0e+14
1.0e+15
1.2e+15
1.4e+15
1.6e+15
200
150
100
50
0
Centre current (nA)
Guard current (10 nA)
guard
centre
0:00
6:00
12:00
18:00
Time (h)

Conclusions this ageing test

- GOSSIP ageing is practically absent for fluences up to 1.4 x 10^{15} mips/cm^2 at G = 1000
  - Decrease of gain between 0 and 1%
- Suggesting operation far beyond 10^{16} mips/cm^2

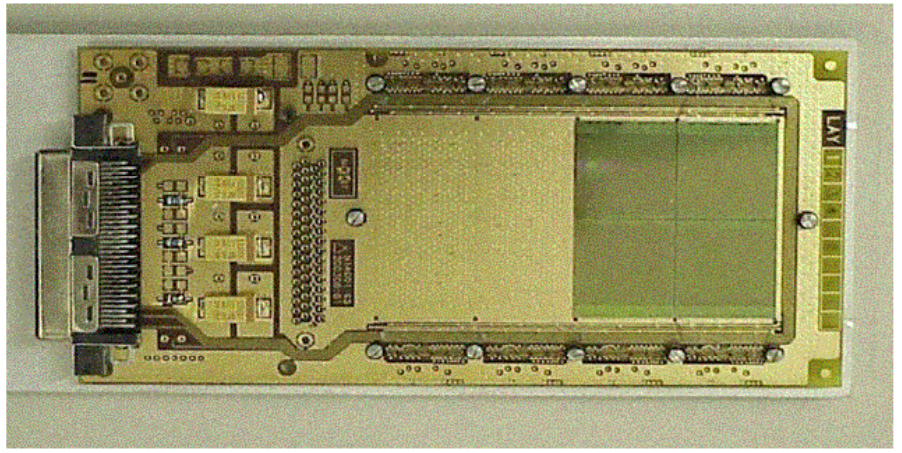
- This result does not correspond to an earlier measurement* using an Argon based counter gas and excitation by gammas where 18% decay in signal current was seen after a charge corresponding to the same fluence at G=1000
- Possible reasons are
  - Different counter gas (He vs Ar)
  - Different ionisation (mips vs 8 keV gammas)
  - Other chamber materials
  - ……
- More measurements are needed (other gases, test beam) to confirm these resuslts

* H. van der Graaf et al., GridPix: an Integrated Readout System for Gaseous Detectors with a Pixel chip as Anode, presentation at the IMAGING 2006 conference, June 27-30, 2006, Stockholm, Sweden. Submitted to the proceedings of IMAGING 2006 in Nucl. Instr. and Meth. A.

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)

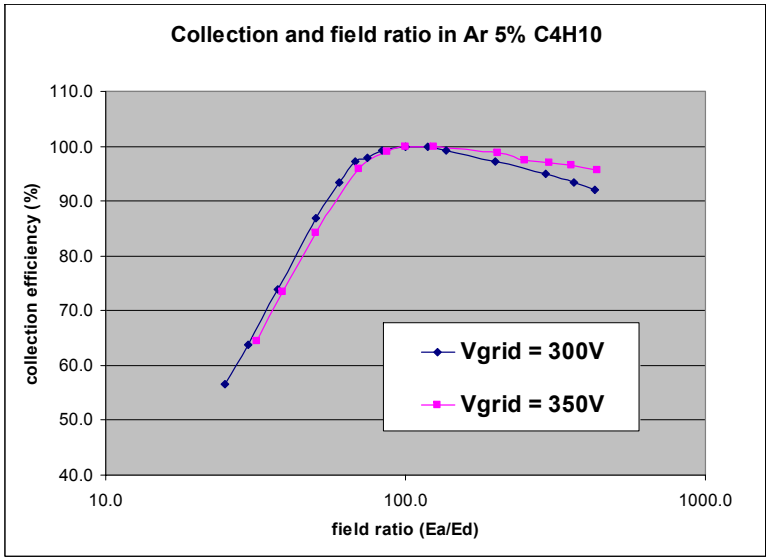


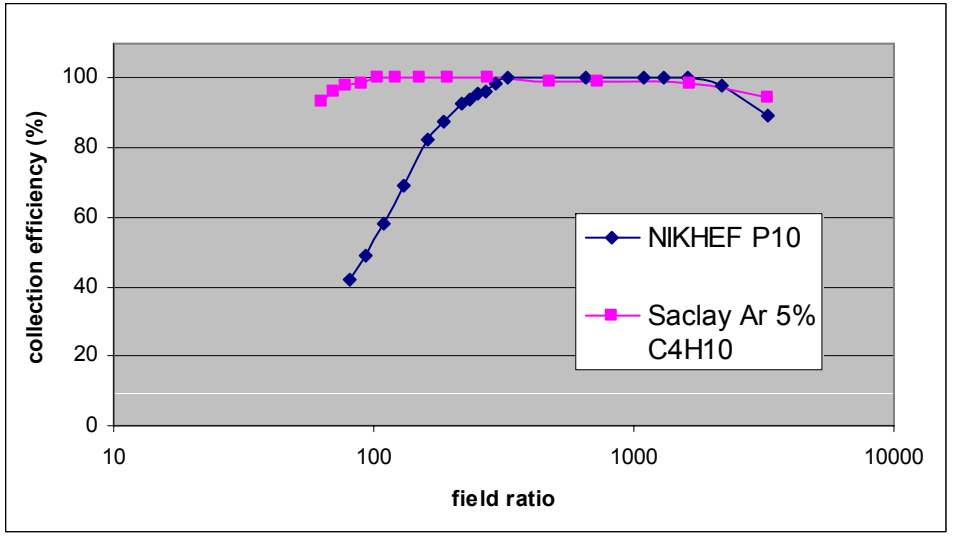
Hope for “through Si vias” (with Medipix chips) later this year!

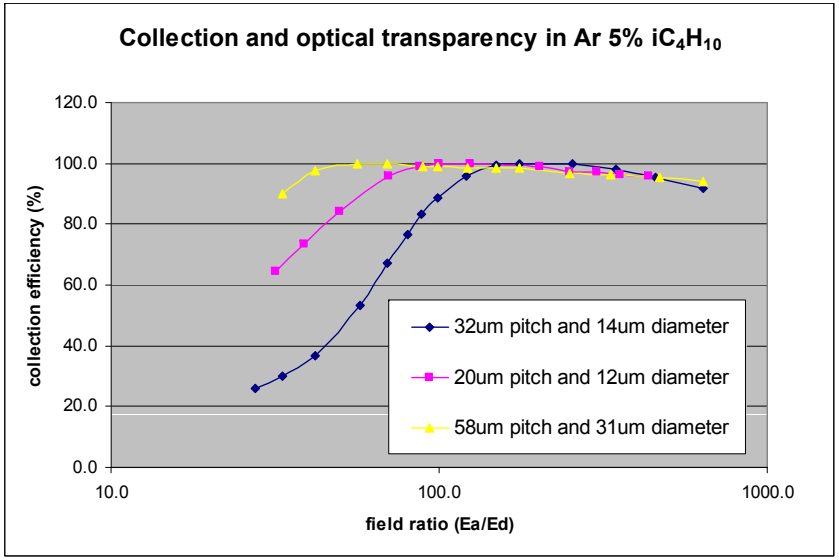
Backup slides

InGrid collection efficiency

- Increase with field line compression (E_a/E_d) and reach a plateau
- More compression for lower optical transparency grids
- Effect of the gas diffusion at the hole entrance: more compression for larger diffusion gas

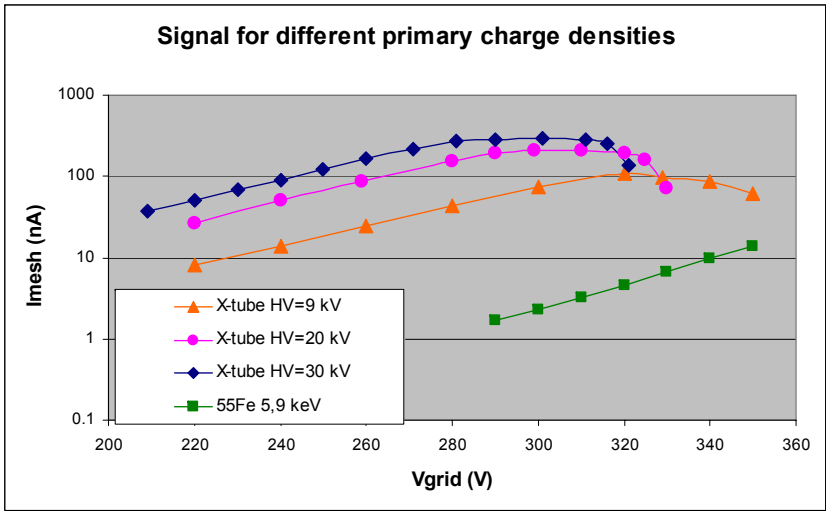


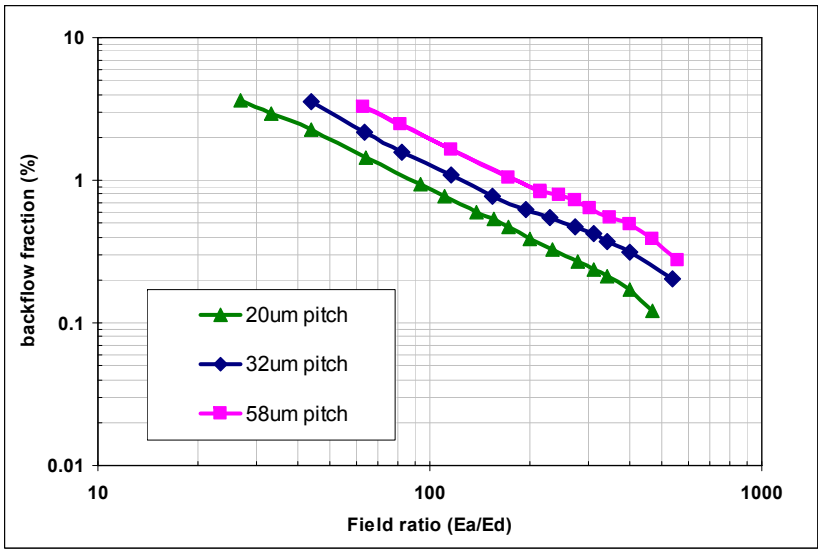




Ion backflow fraction
Preliminary results in Ar 5% C_4H_{10}

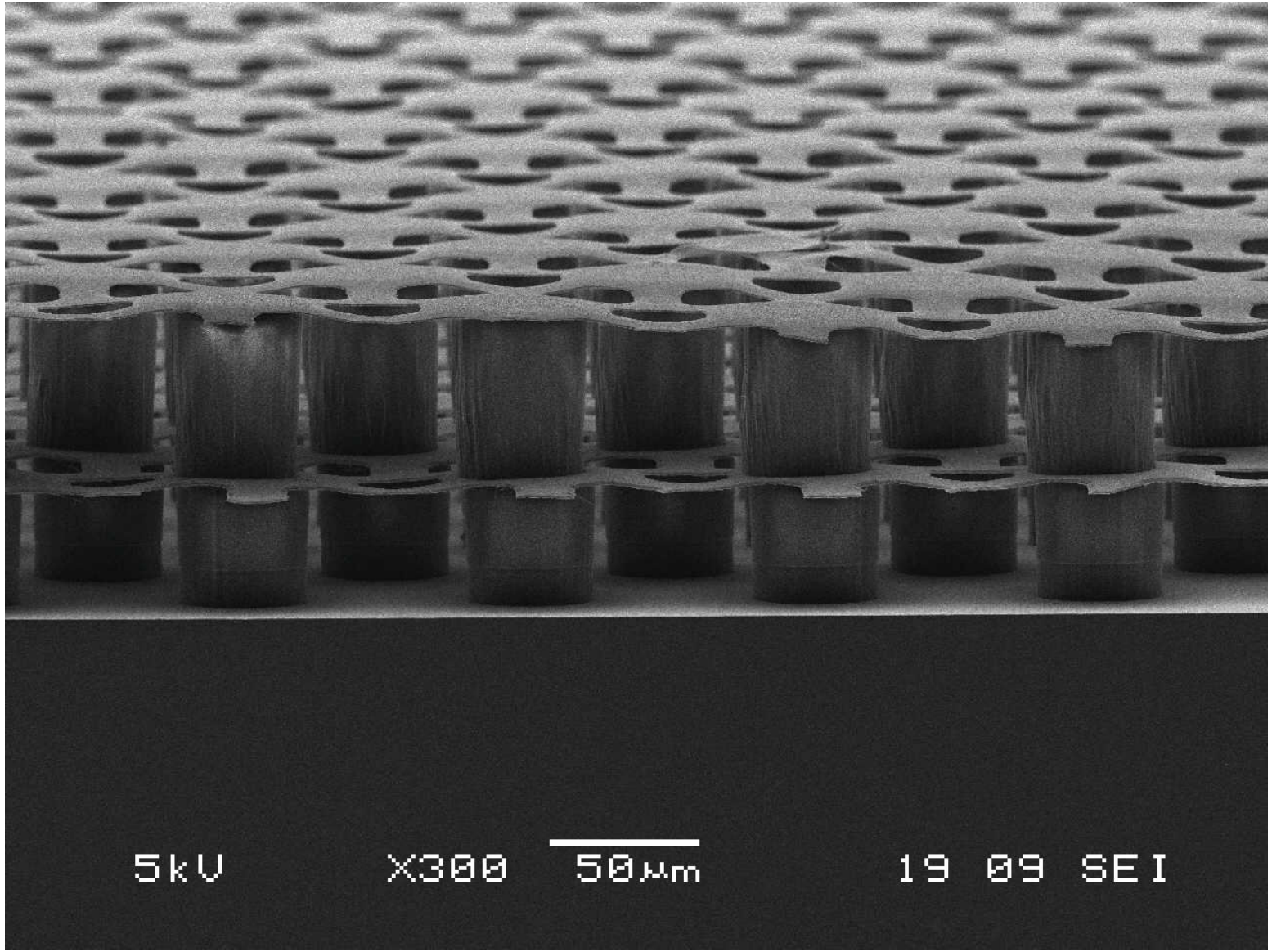
- Annoying feature: small InGrid area
  - requires high primary Q density to get significant I_0
  - Backflowing ions may recombine with primary e- !
  - Fine tuning of the collimation, the X-gun power (I_0 and Q density) and the gas gain
- Results
  - Curves follows 1/x trend
  - With σ ~ 14.2 μm over the 70 μm gap



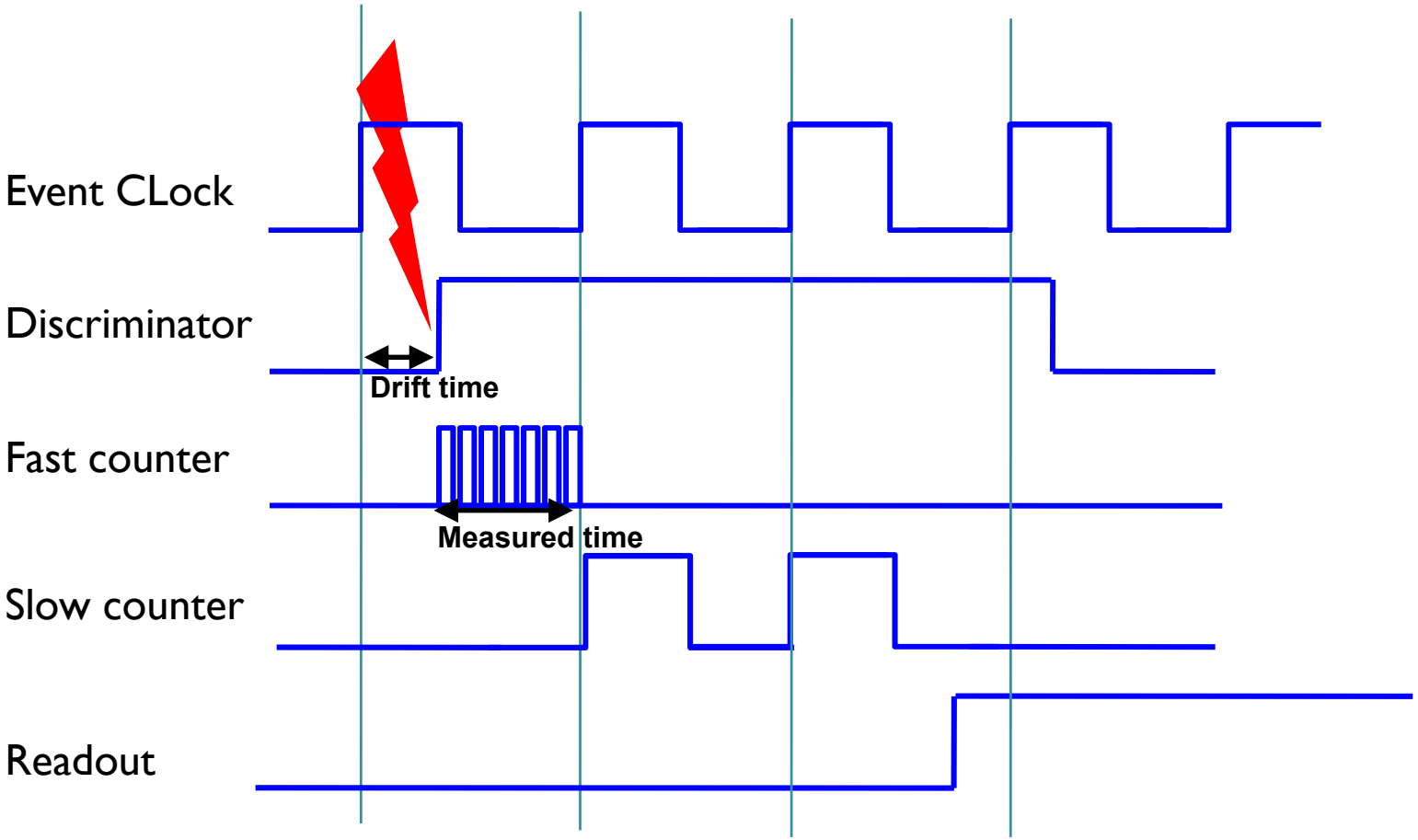


Pitch (um)	σ/p	C (model)	C (measure)
20	0.71	1	0.9
32	0.44	1.2	1.3
58	0.25	2.5	2

Alternative: TwinGrid



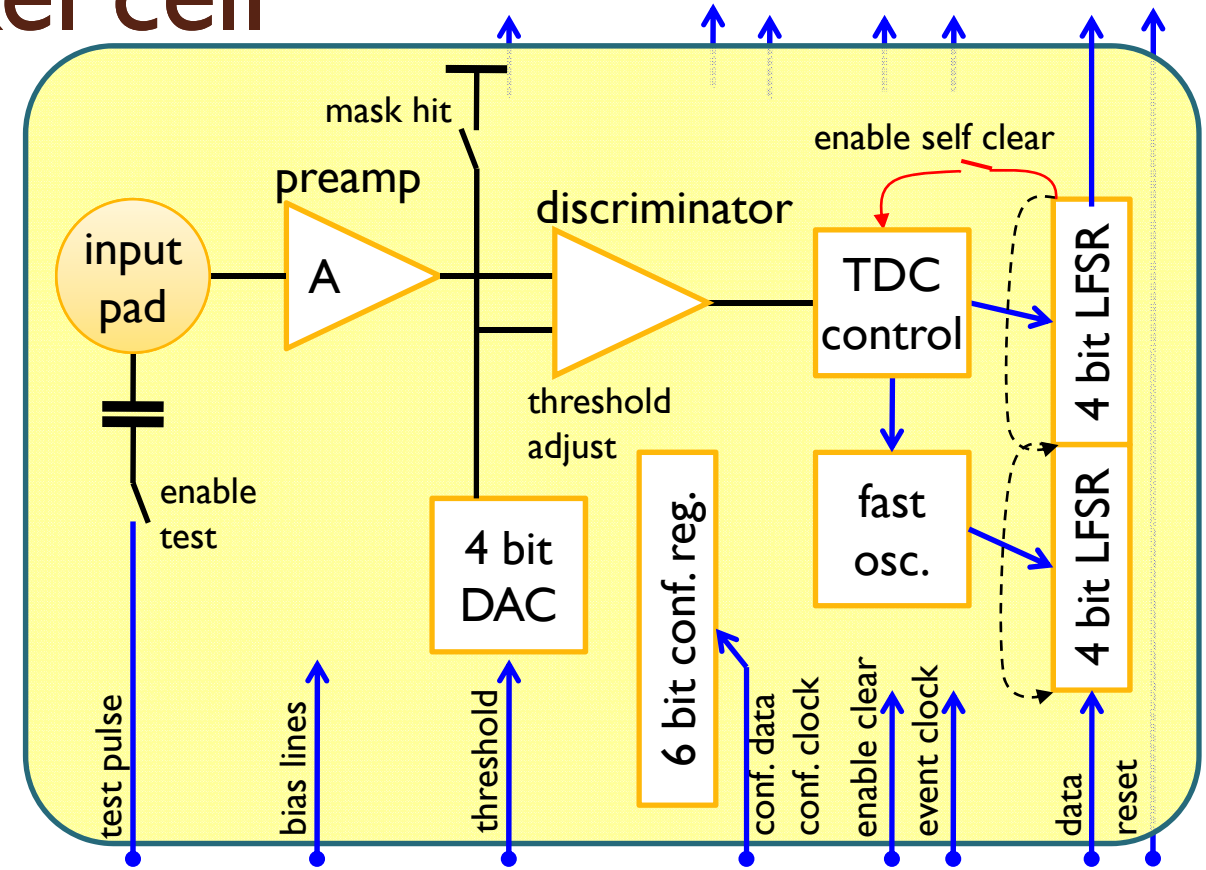
Drift time measurement



Focus on **LHC** (ATLAS) : **40 MHz** clock & timing

R. Kluit
Nikhef
Amsterdam

Pixel cell



- Only "Slow" clock distribution, 40 MHz
  "Fast" clock from local oscillator per pixel, 560MHz
- 4 bit TDC & latency counter > **1.78 ns resolution** & 350 ns range.
- 4 bit DAC for threshold tuning
- control register for masking, test-pulse enable and DAC

R. Kluit
Nikhef
Amsterdam

Example

- Gas: Kr/DME 74/26
- Measured histogram with fitted convoluted Poisson
- Cluster density calculated from **two** independent methods

1. Magnitude pedestal peak

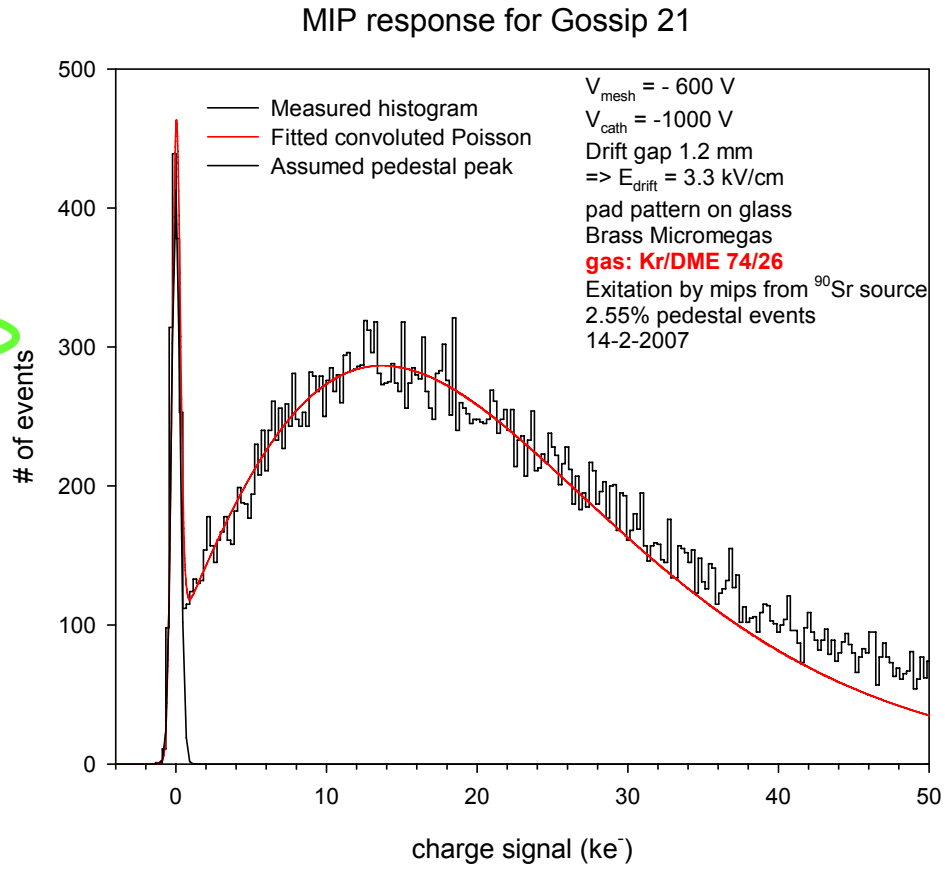
2.55 +/- 0.07 % pedestal events

=> cluster density 39.1+/-0.8 cm^{-1}

2. Fitting convoluted Poisson to experimental data

Using pdf =1 the best fit occurs at

38.2 +/- 2.6 cm^{-1} ¥



Literature

Cluster density Kr/DME 74/26: 40.2 cm^{-1}

¥Note that this number depends on the pdf value