The Silicon TPC System

EUDET Extended SC meeting

27 August 2007

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

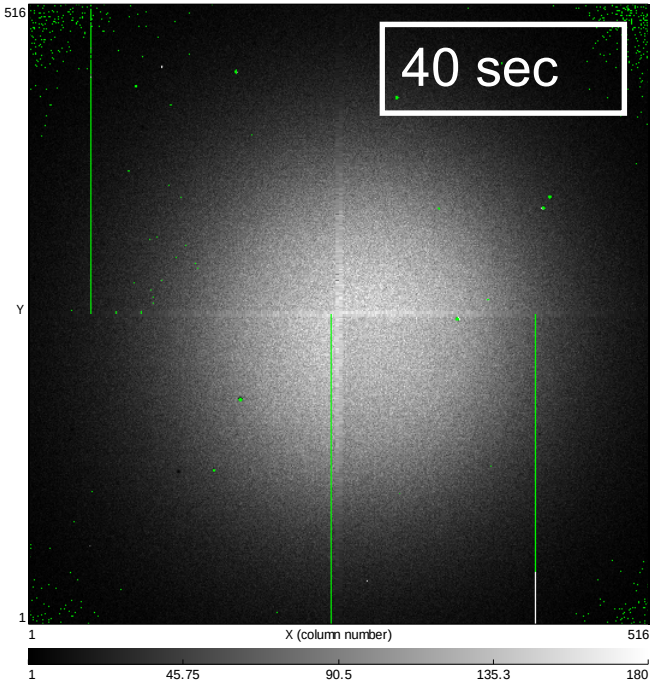
Associate: Bucarest

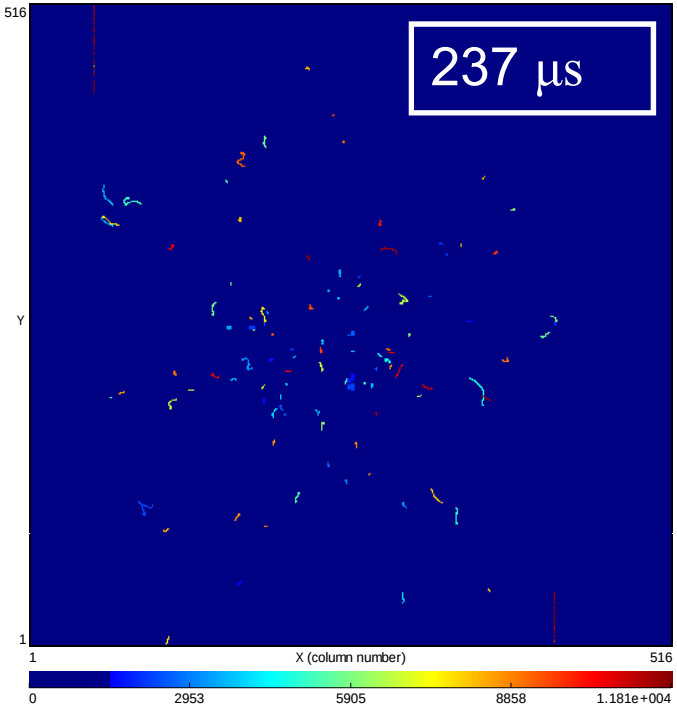
SITPC Tasks:

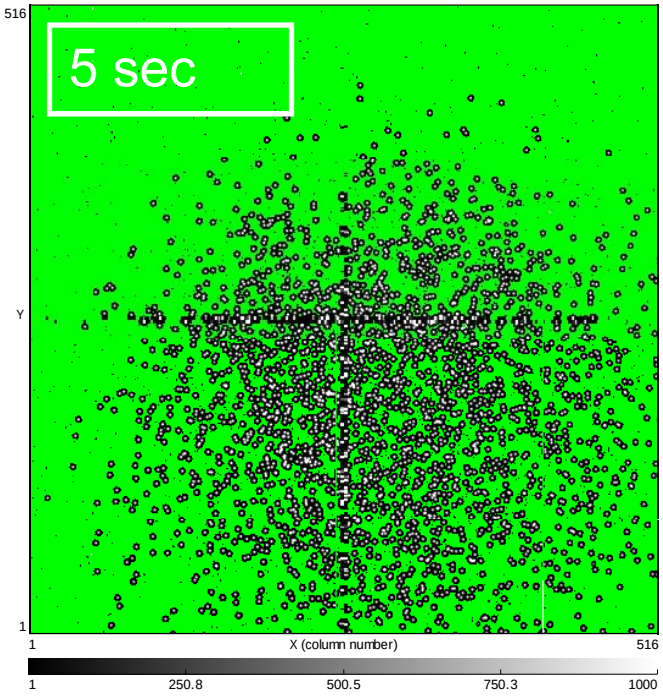
- ✓ Develop the Timepix chip that allows to measure the 3rd coordinate (drift time)
- ✓ Implementation of Timepix together with GEM and Micromegas into diagnostic endplate system (in progress)
- Performance measurements in test infrastructure at DESY
- Develop simulation framework
- Develop DAQ system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

CERN (Xavi Llopart/Michael Campbell): first Timepix quad (+ 300 μm Si sensor)

- Top-right: Medipix counting mode (^{55}Fe)
- Bottom-left: Time mode (^{90}Sr)
- Bottom-right: time-over-threshold (^{241}Am)

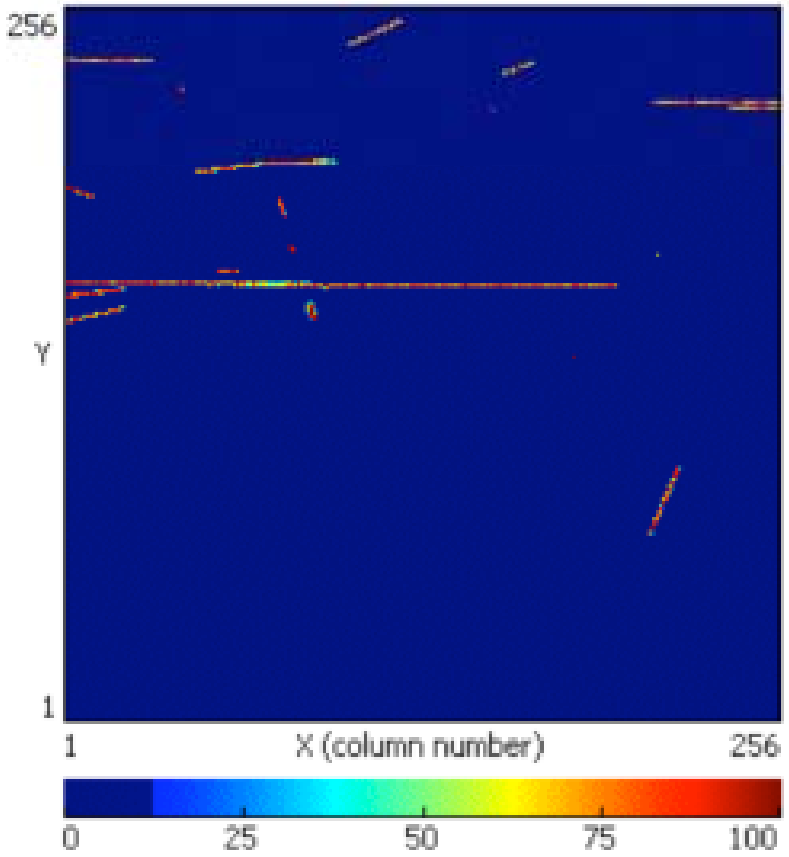






Erik Heijne: Timepix (single chip + Si sensor) parallel to beam

H6 120 GeV/c PION BEAM



ANALOG MODE TOT
TYPICAL SIGNAL ~80 counts

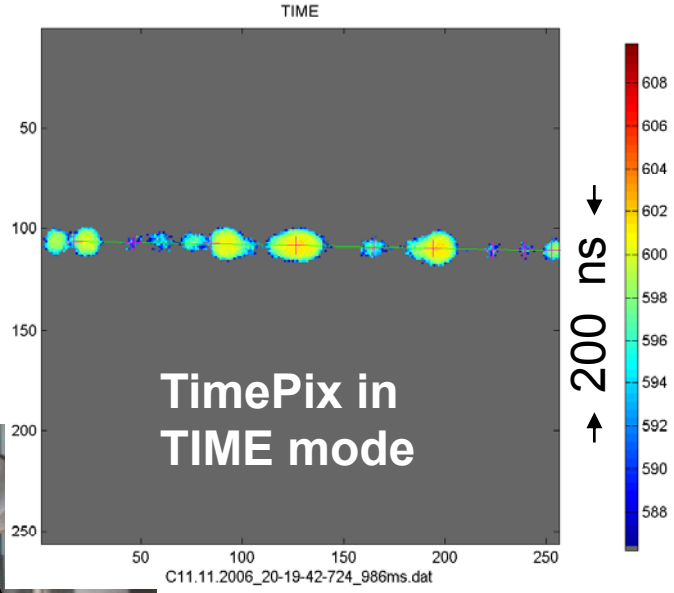
Test beam setup and event

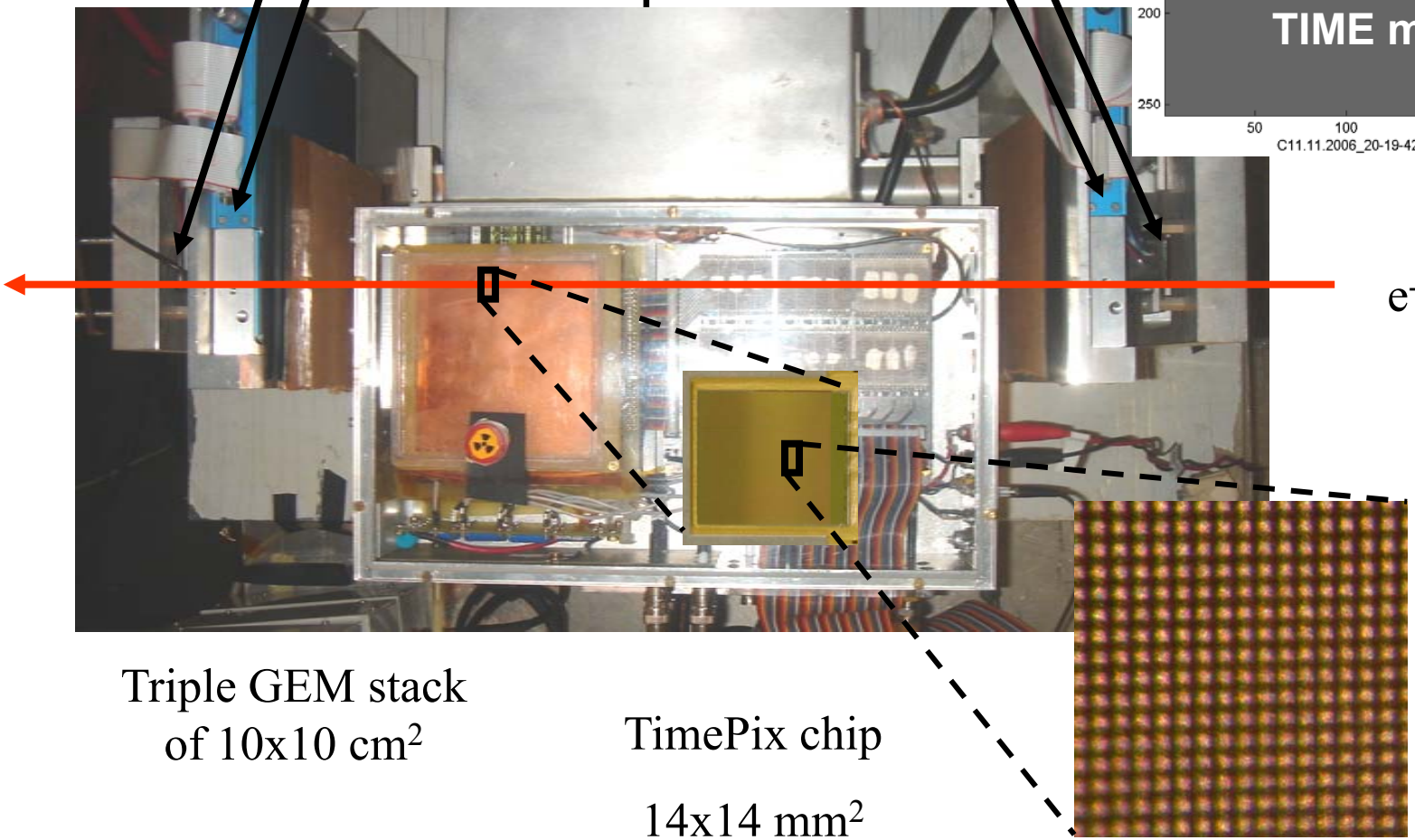
Freiburg

trigger counters ~ 1cm wide

Si telescope (y position ~20 μm precision)

- Test beam setup





e⁻ from DESY II

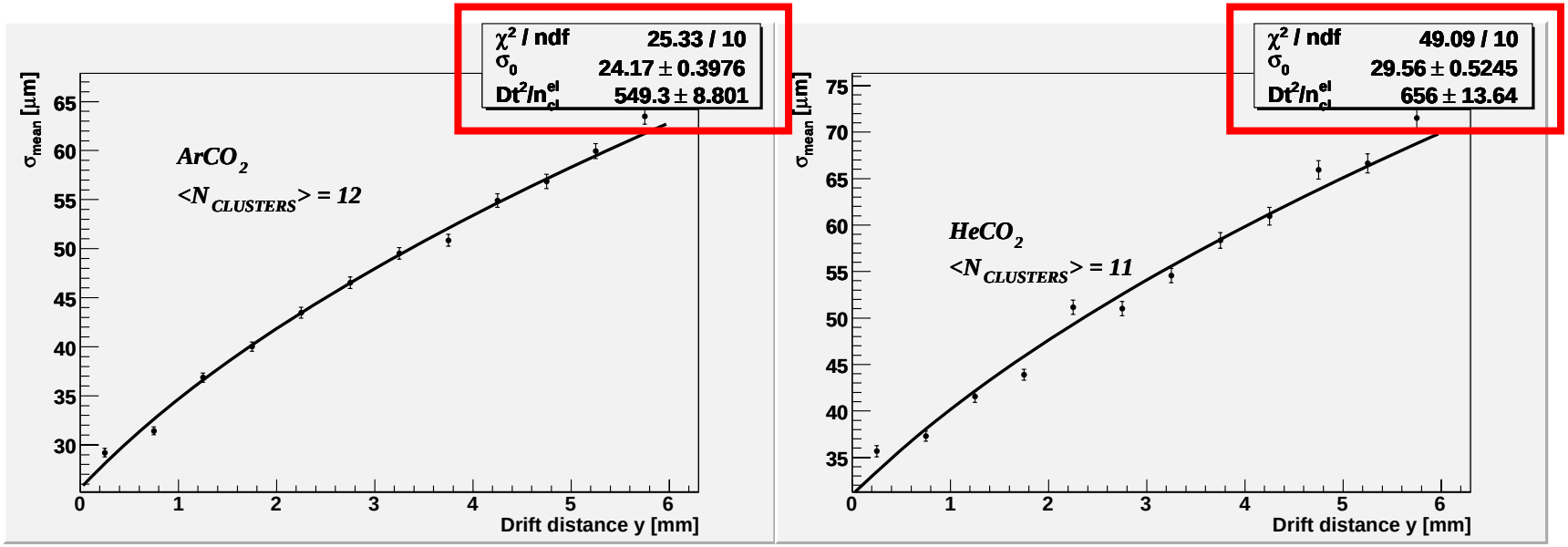
Triple GEM stack
of 10x10 cm²

TimePix chip

14x14 mm²

pitch of
pixels
55 μm

Highlight of TimePix results



High statistics runs with standard GEM (140 µm pitch).

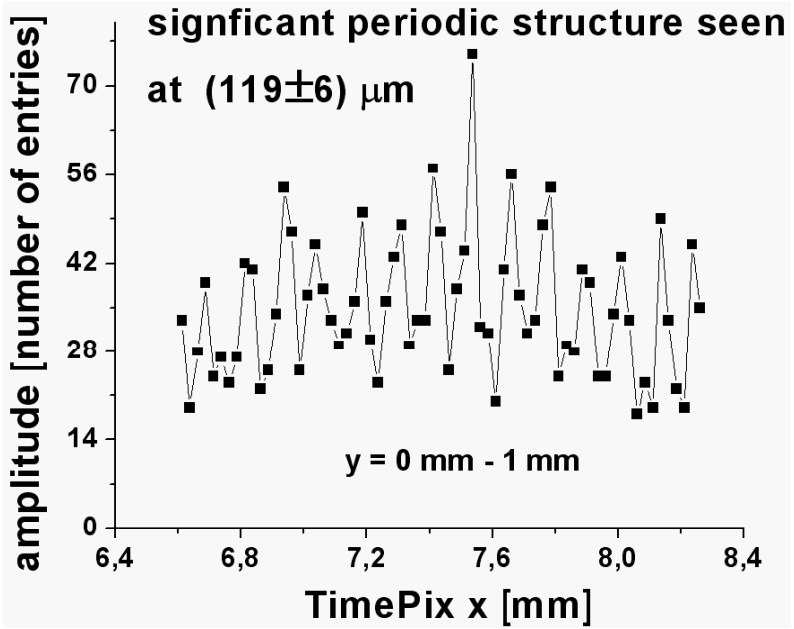
Mixed Mode setting of the TimePix: Every other pixel measures charge, the TIME is recorded for the other half of the pixels.

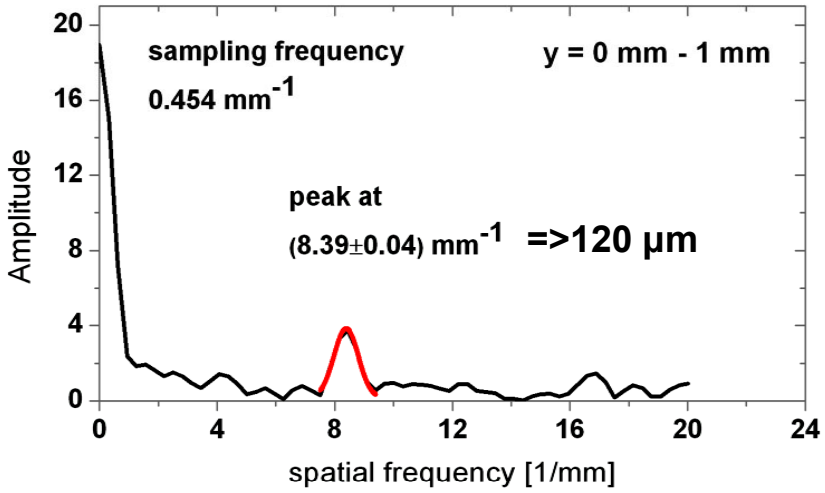
The following observations are made:

- **Different cluster separation algorithm are employed: the change for σ_0 is a few µm.**
- **The time information is corrected for the walk (dependence of the time of arrival measured on the amount charge deposited).**
- **A resolution in y of <16 ns/cluster is achieved (about 0.45 mm). The clock runs with 48 MHz.**
- **Additional cut on the time results in an improvement for σ_0 of about 1µm.**
- **A change of the slope parameter D_t^2/n_{eff} is observed as the cluster size increases due to merged primary clusters (increase of the effective number of electrons).**

Substructure due to GEM hole pitch

standard GEM





Is the resolution of a cluster yet affected by the finite pitch of the holes?

Test runs are taken recently with different orientation with respect to the track and with smaller pitched GEMs (80μm).

Results are expected to be available soon.

SiTPC activities in BN

Status:

Work towards construction of a GEM-Timepix-Module for JRA2 Large Prototype

- test setup (Muros+Pixelman) running in Bonn
- single chip carrier for gluing into endplate produced and tested
- small prototype construction ongoing
- started design work for LP module (EUDET deliverable)

Plans:
- small prototype available in fall, then tests in lab + testbeam
- produce an initial 3-GEM module with (n>1) Timepix chips compatible with LP by end of year (to meet milestone)
- integration with JRA1 Trgger/DAQ system

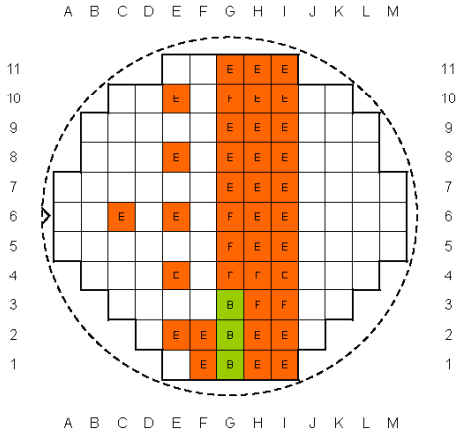
Financial:

Postdoc (M.Killenberg) 50% on JRA2/SiTPC, 50% on NA2/ANALYS
Cashflow as planned

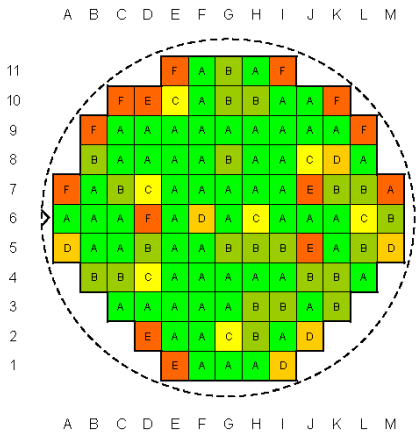
TimePix wafer tests

Wafers		Classes						Total
N°	ID	A	B	C	D	E	F	
11	ATFWTLX	59	22	7	6	5	8	107
24	GY11IKX	55	29	7	4	7	5	107
25	GW11H5X	-	3	-	-	31	7	41
26	GS11H9X	43	37	4	7	9	7	107
27	GH11G2X	65	28	3	2	7	2	107
Totals		222	116	21	19	28	22	428
Percentages (%)		51.9	27.1	4.9	4.4	6.6	5.1	100

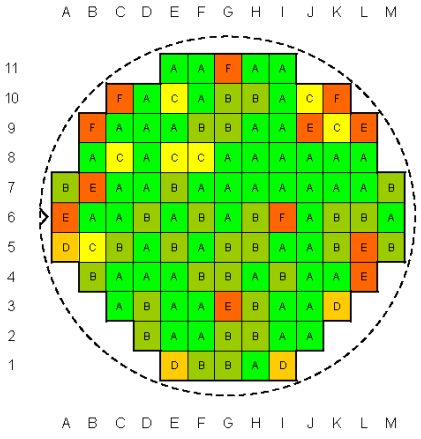
GW11H5X (25)



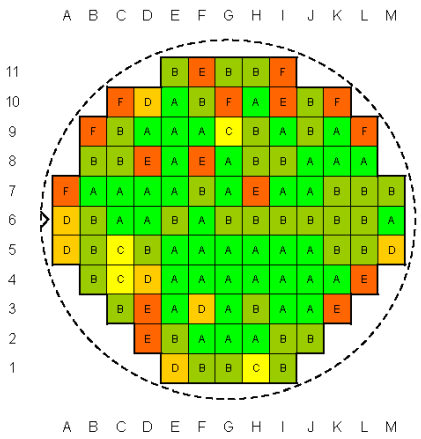
ATFWTLX (11)



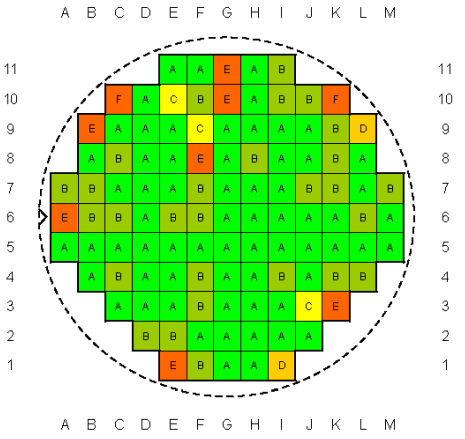
GY11IKX (24)



GS11H9X (26)



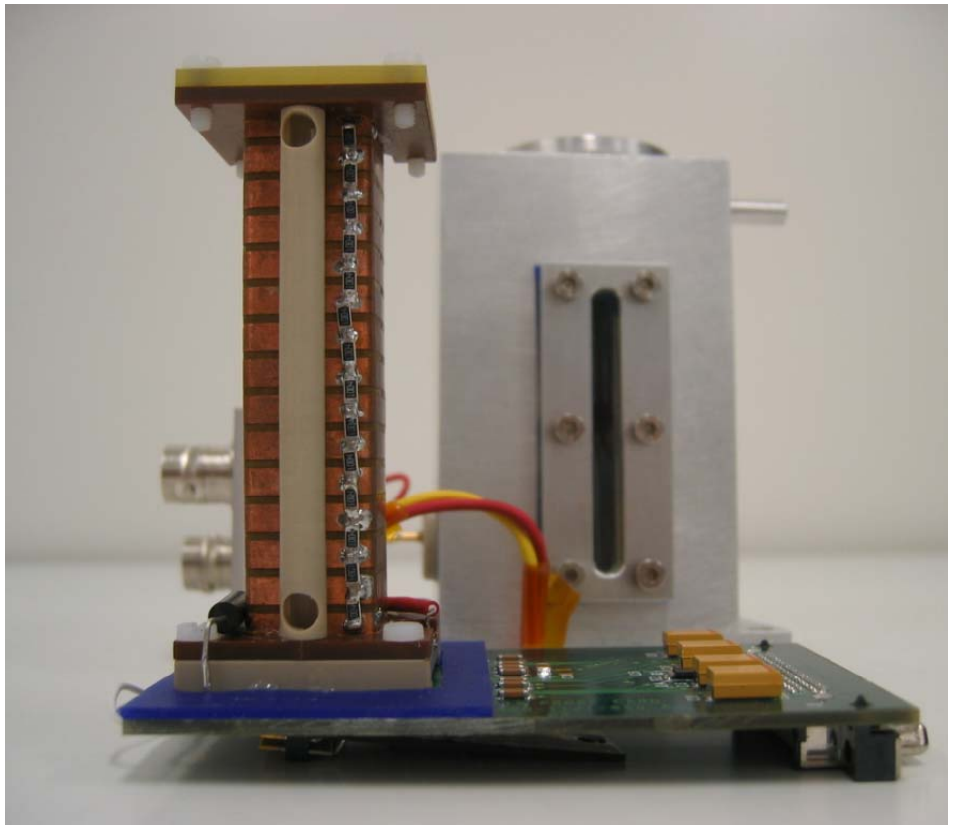
GH11G2X (27)



8 more wafers will be probed in mid-September

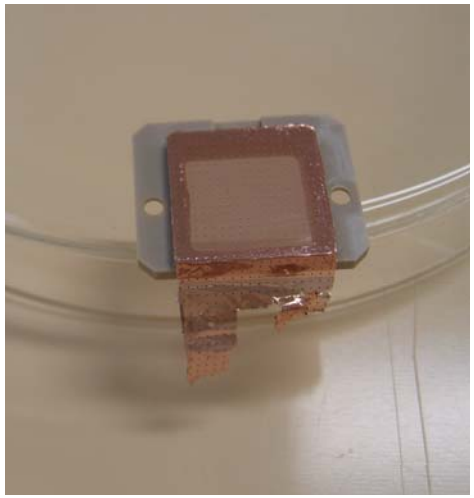
TimePix Chamber

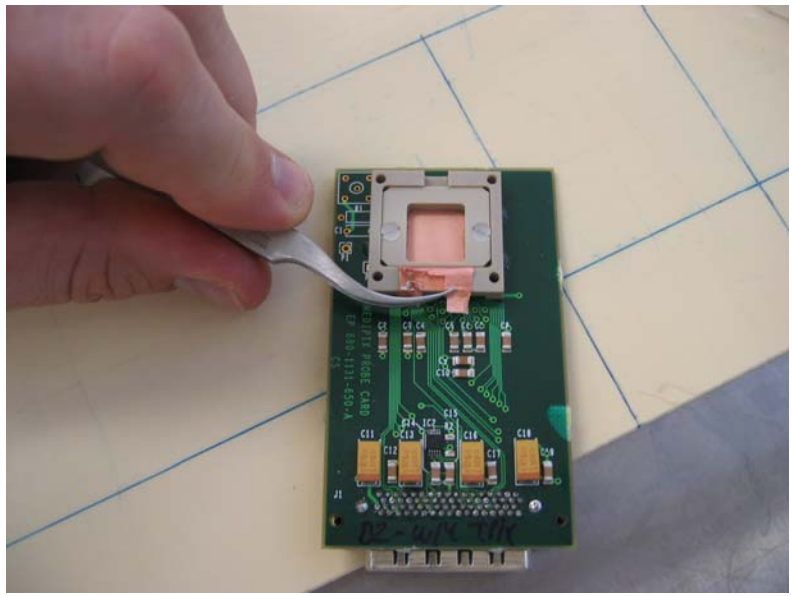
- Box mounted on TimePix board:



Mesh for TimePix Chamber

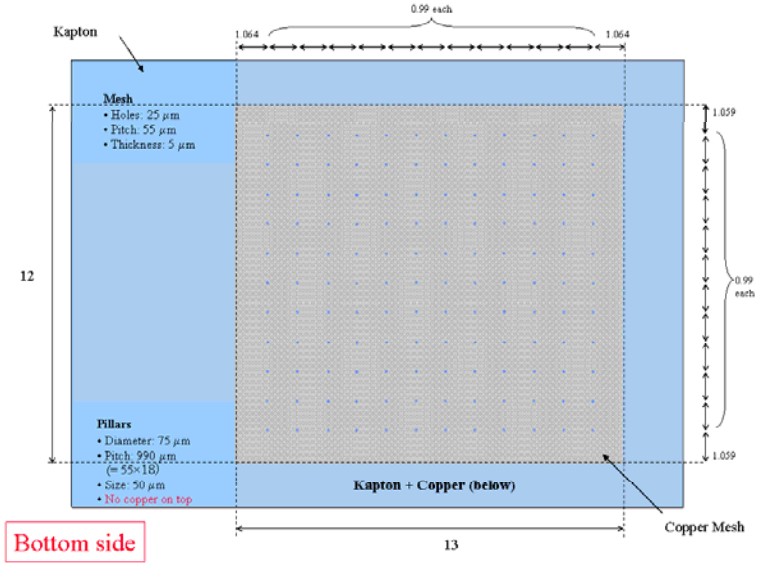
- Mesh made at Saclay of 12x12 mm² size





- Specific Micromegas meshes build at CERN should be available soon

→For now one TimePix & one Medipix are dead



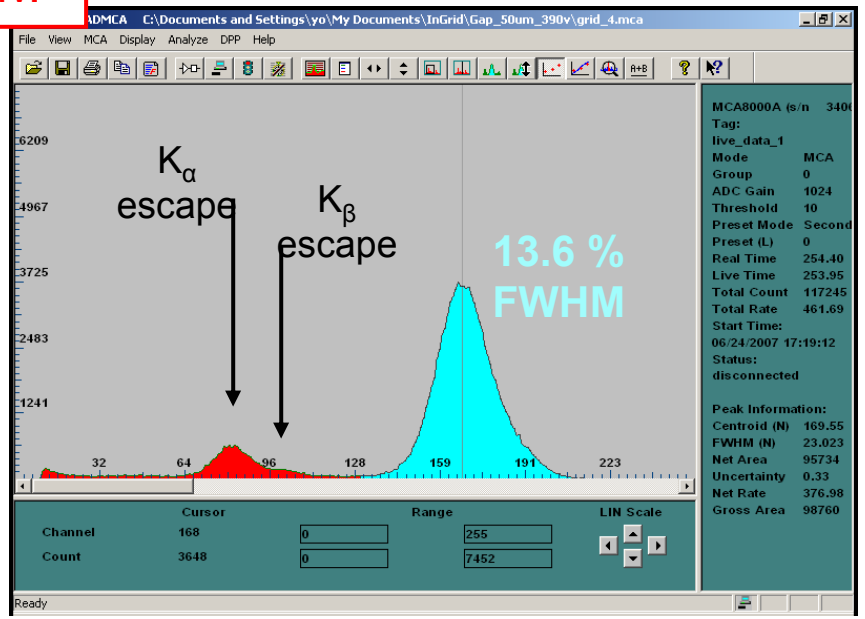
New InGrid developments and results

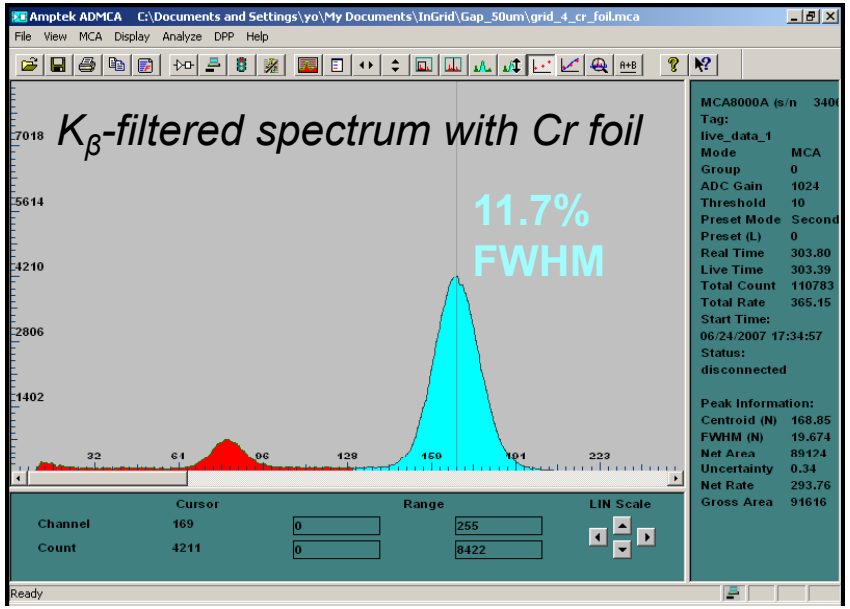
Max Chefdeville (NIKHEF/Saclay) + Twente Univ.

- 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

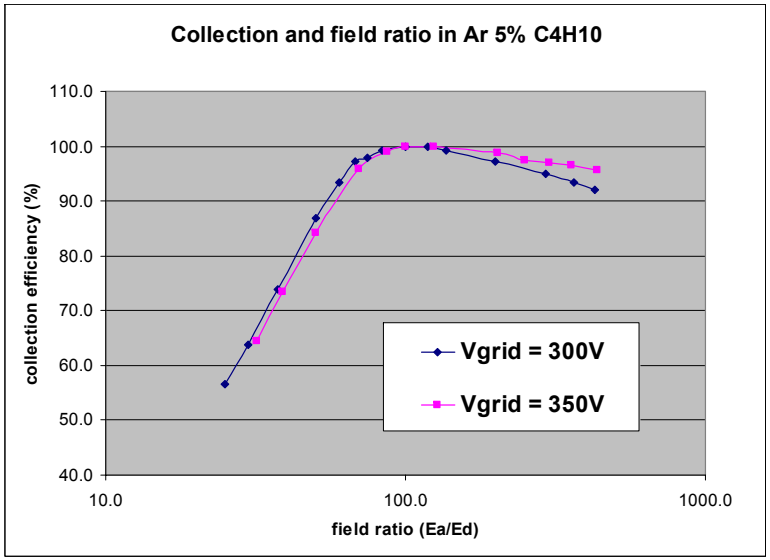
- Until now: 1 µm thin Al
  but can now be increased to 5 µm by electrolysis
  Expect less damaged from sparks

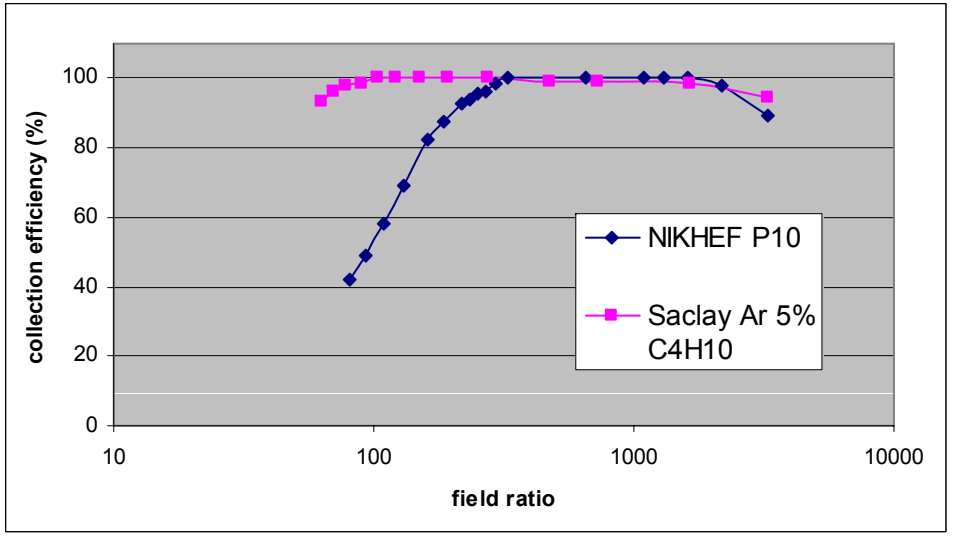


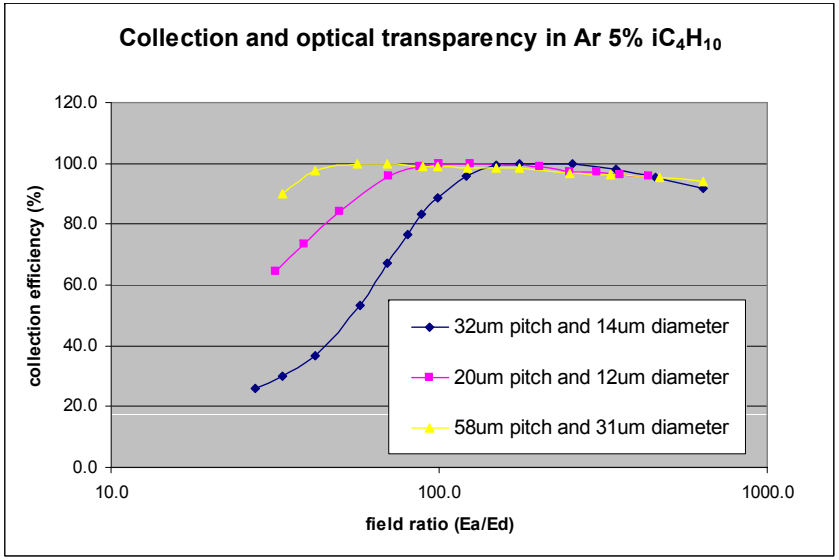


InGrid collection efficiency

- 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

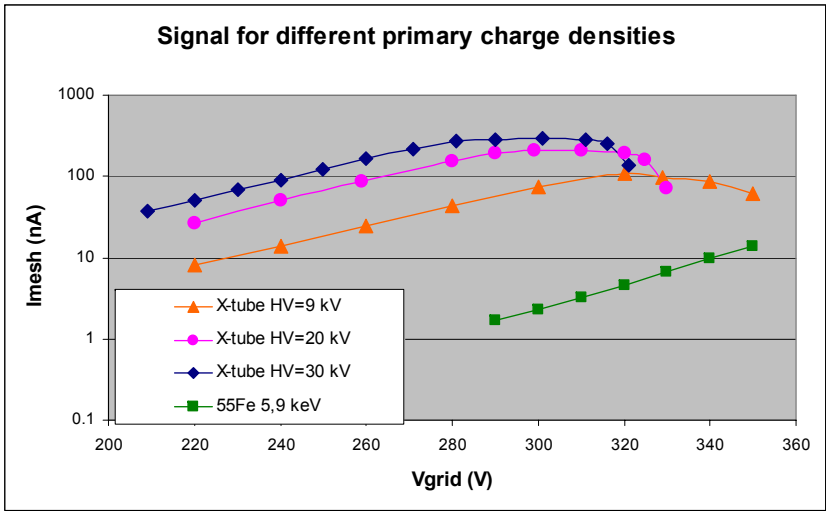


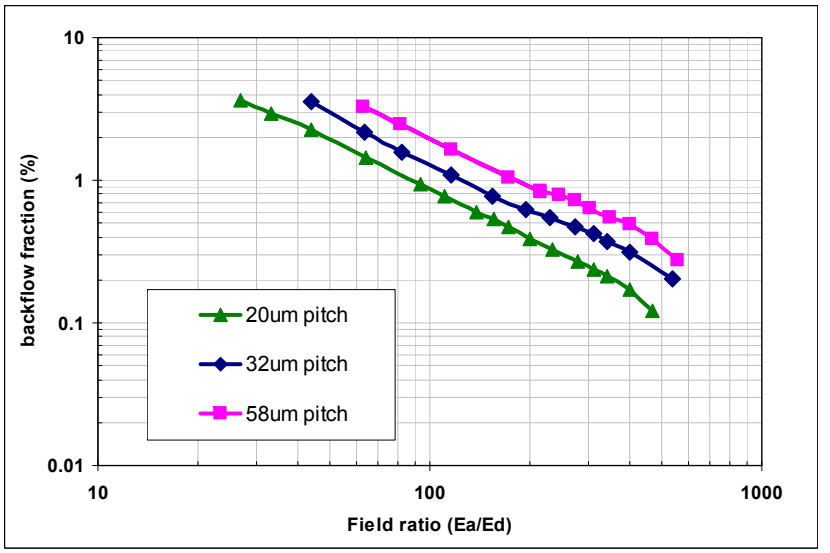




Ion backflow fraction
Preliminary results in Ar 5% C_4H_{10}

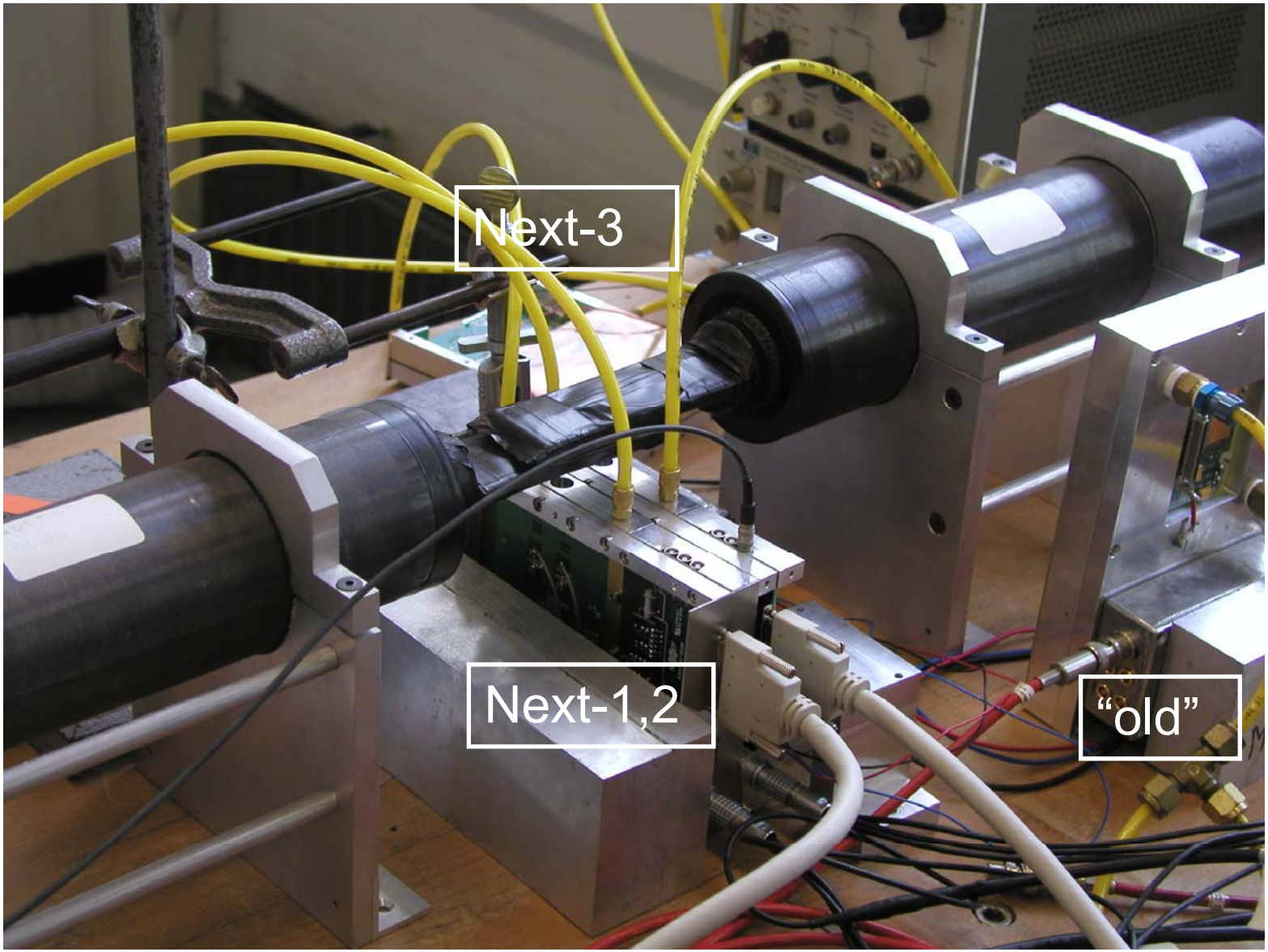
- Annoying feature: small InGrid area
  - requires high primary Q density to get significant I_0
  - Backflowing ions may recombine with primary e- !
  - Fine tuning of the collimation, the X-gun power (I_0 and Q density) and the gas gain
- Results
  - Curves follows 1/x trend
  - With σ ~ 14.2 μm over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





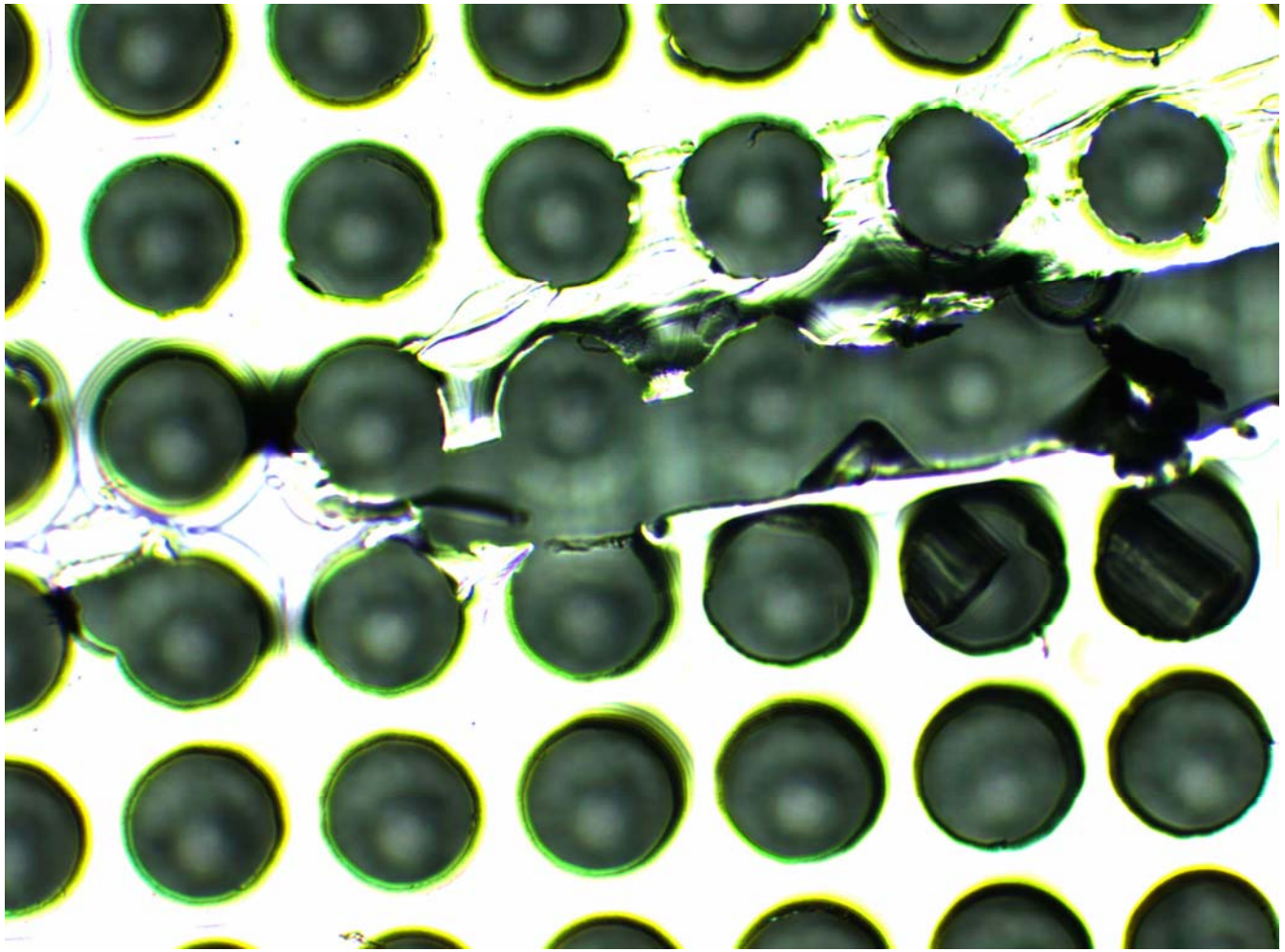
Pitch (um)	σ/p	C (model)	C (measure)
20	0.71	1	0.9
32	0.44	1.2	1.3
58	0.25	2.5	2

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
- Timepix E09-W0014 (with 20 μm Siprot + Ingrid) under HV for one month with He/isoB (detector Next-1)
- Collecting cosmic m.i.p.'s in triggered mode (external shutter)
- Clock frequency 40 MHz and 100 MHz
- Pixelman: now writing "zero-suppressed" frames (< ~1 Kb) in "filtered" mode (only when >10 hits present)
- Detector Next-2: Timepix + 20 μm Siprot + Micromegas; will go on Ar/isoB. next week
- Next-3: Medipix2.1 (dead) + 30 μm Siprot + Ingrid: gain 200k



A “scratch” occurred during production Ingrid;

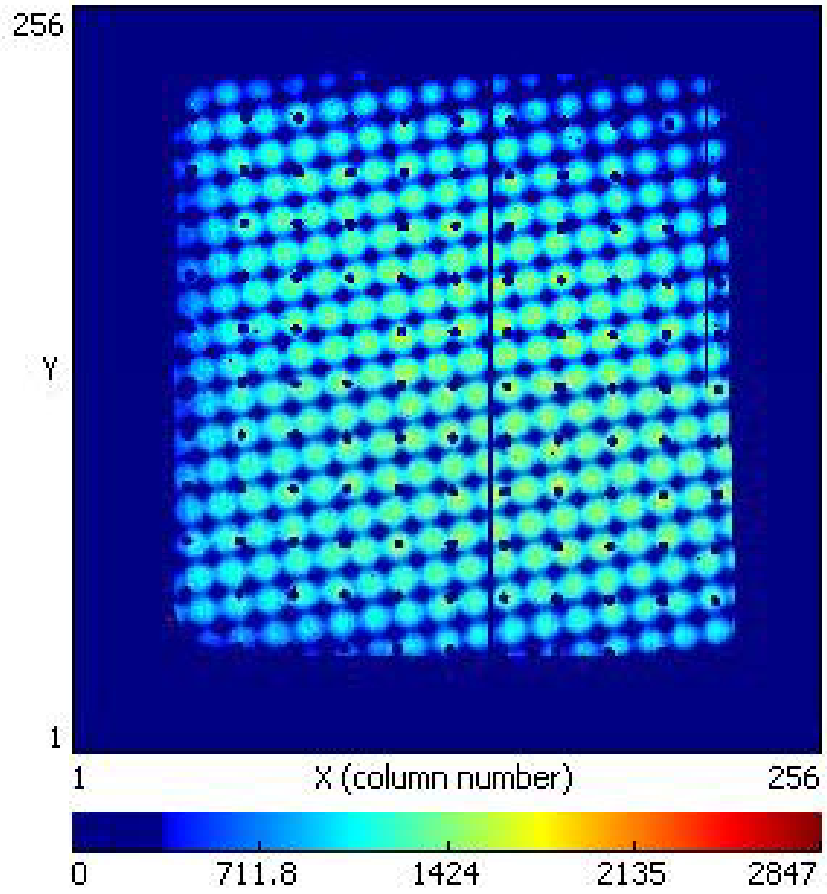
Loose parts removed. Ingrid working!

Timepix + Micromegas

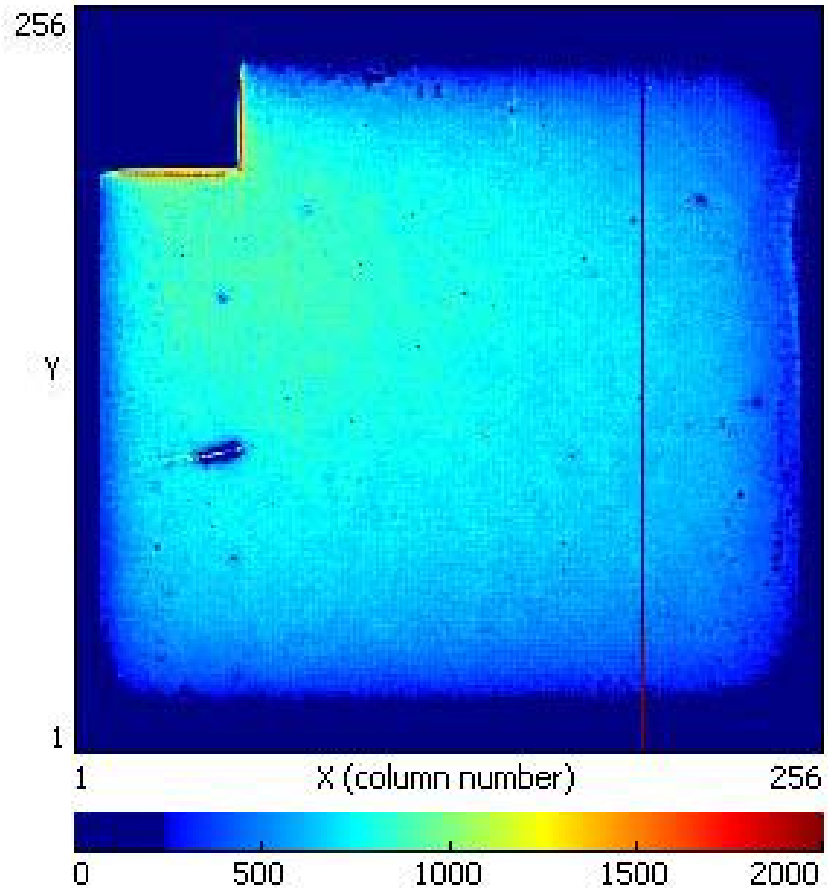
Timepix + Ingrid

(in “counting” mode; 60 sec resp. 100 sec with ^{90}Sr source)

Moire effects



“uniform”

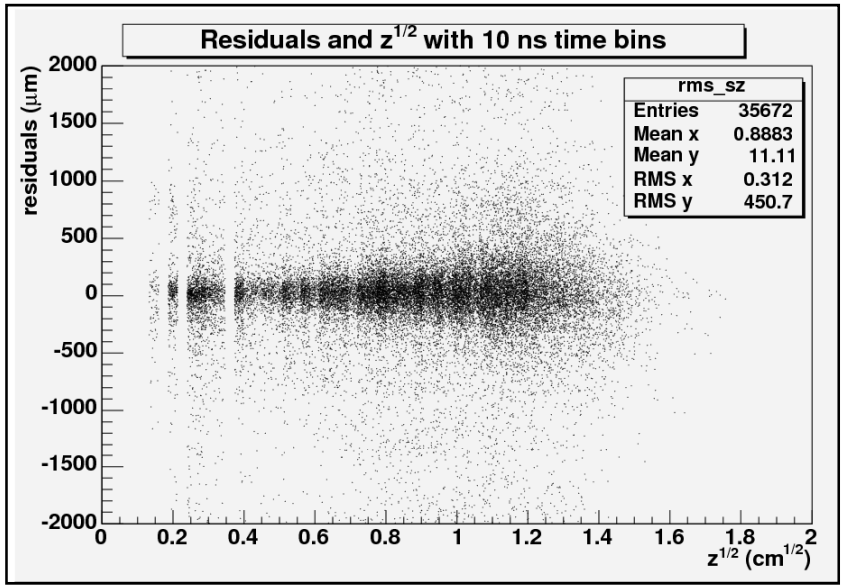


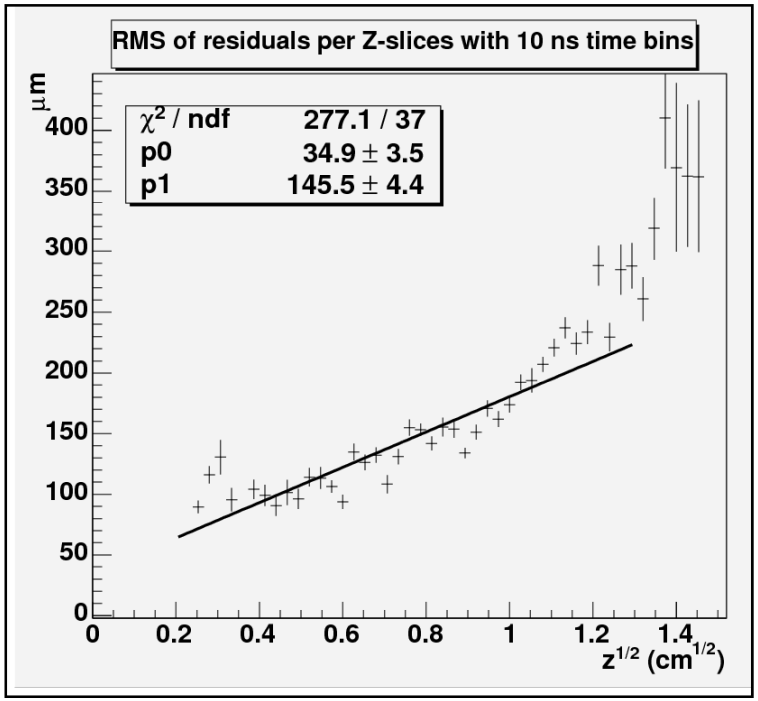
Residuals and drift length

- 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

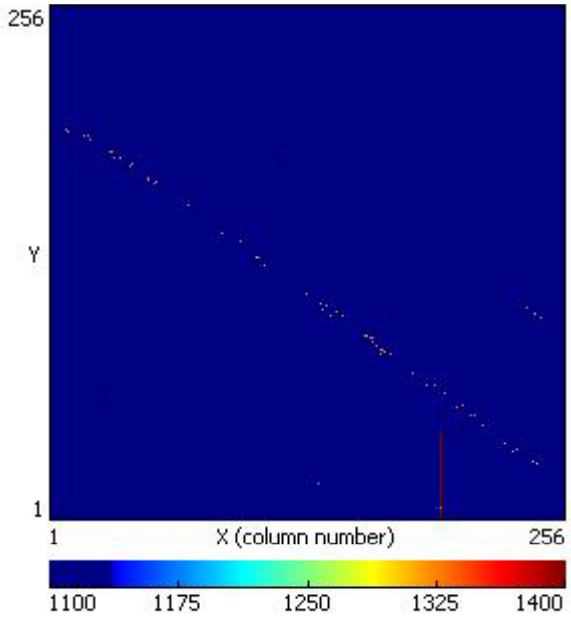
  D_t = 180 µm.√cm from MAGBOLTZ

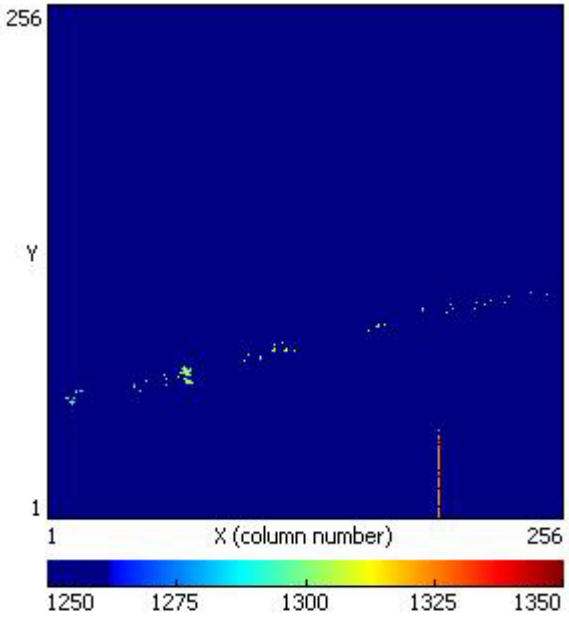


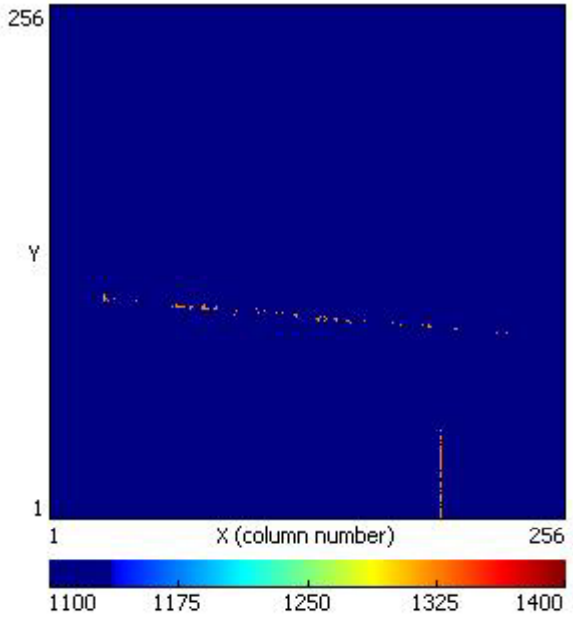


A few example cosmics tracks taken in triggered “arrival time” mode

(Timepix + 20 μm thick Siprot + Ingrid)



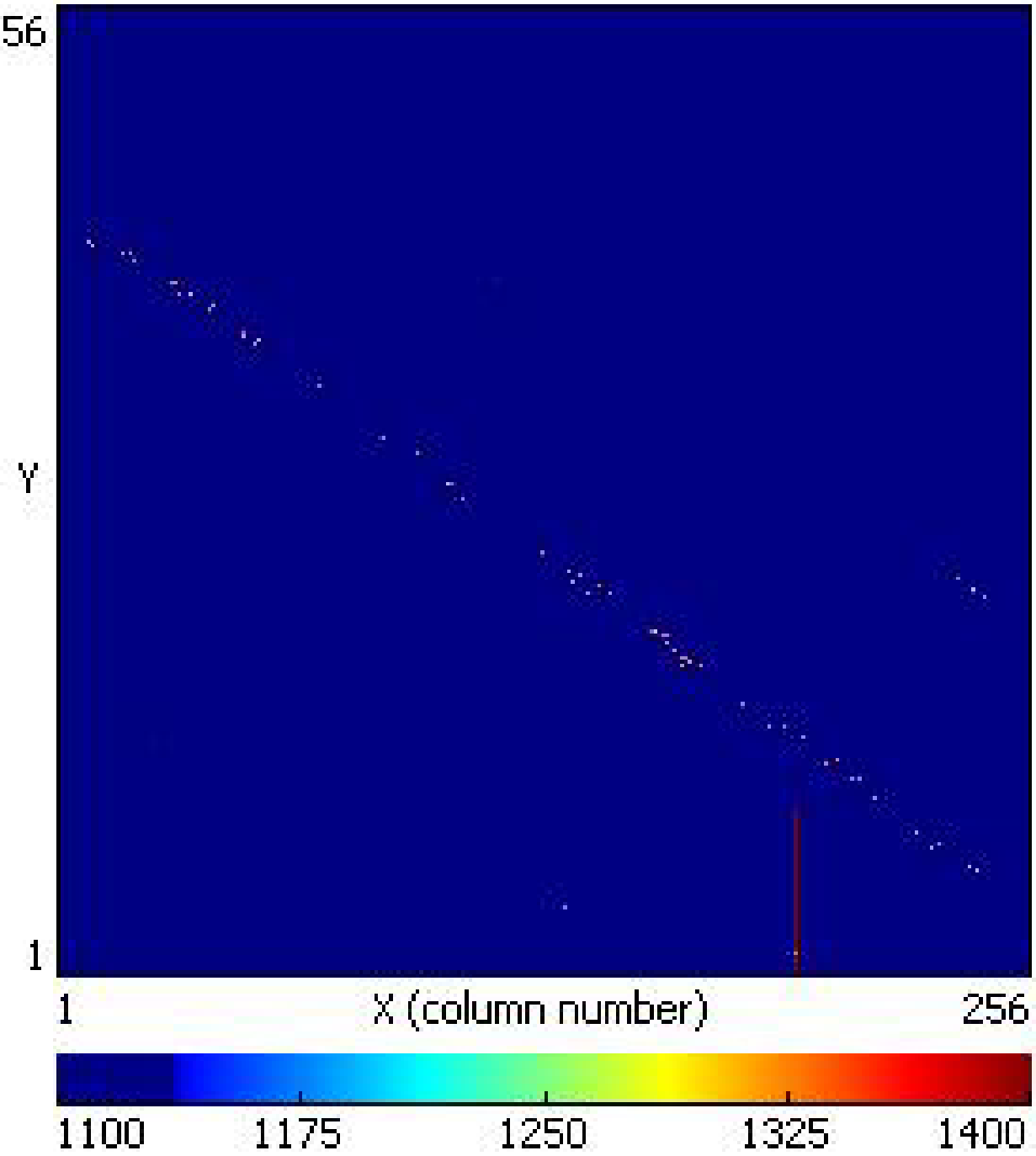




A “long” track

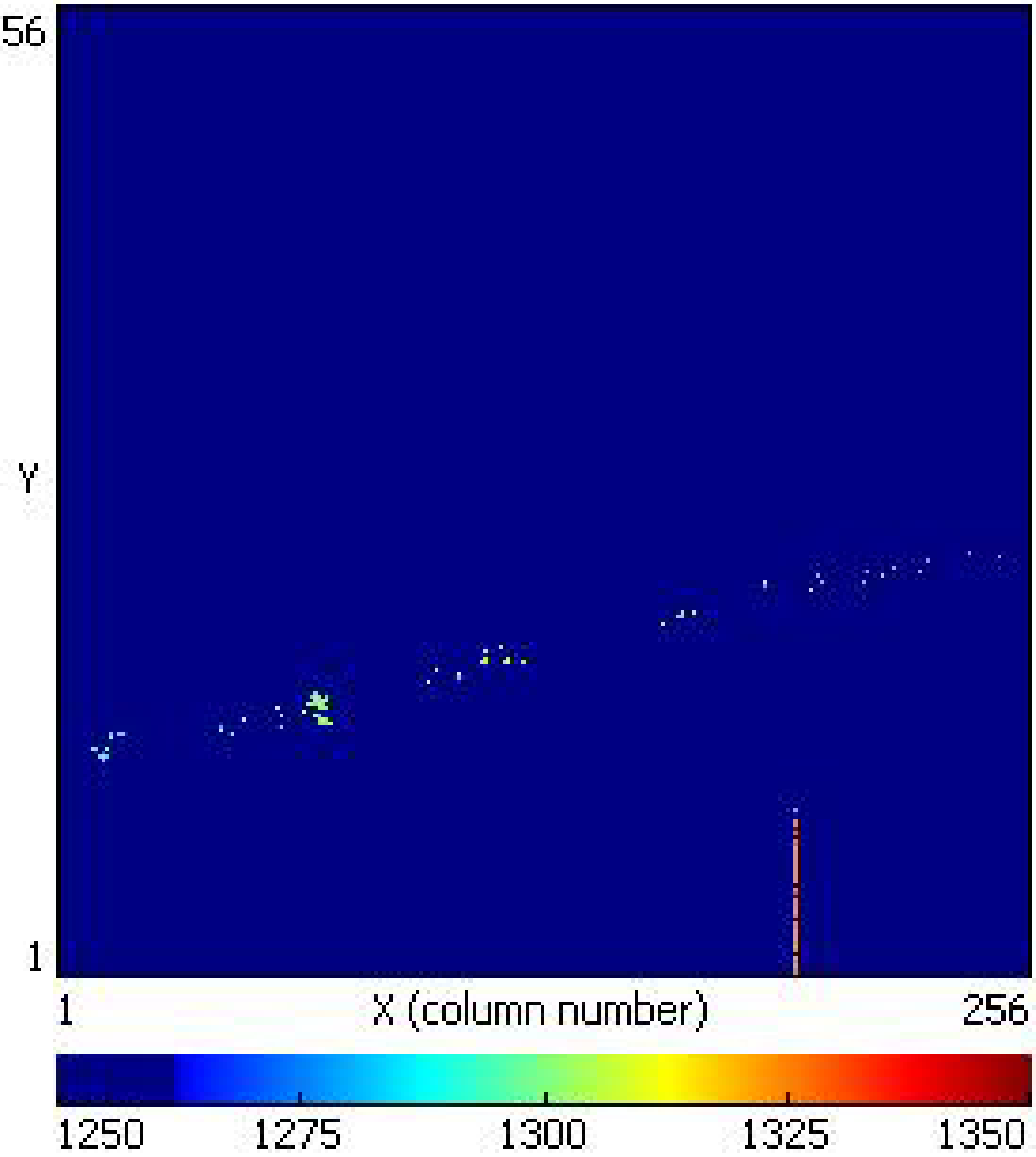
(picture is 14x14 mm^2)

Ingrid @ -420V



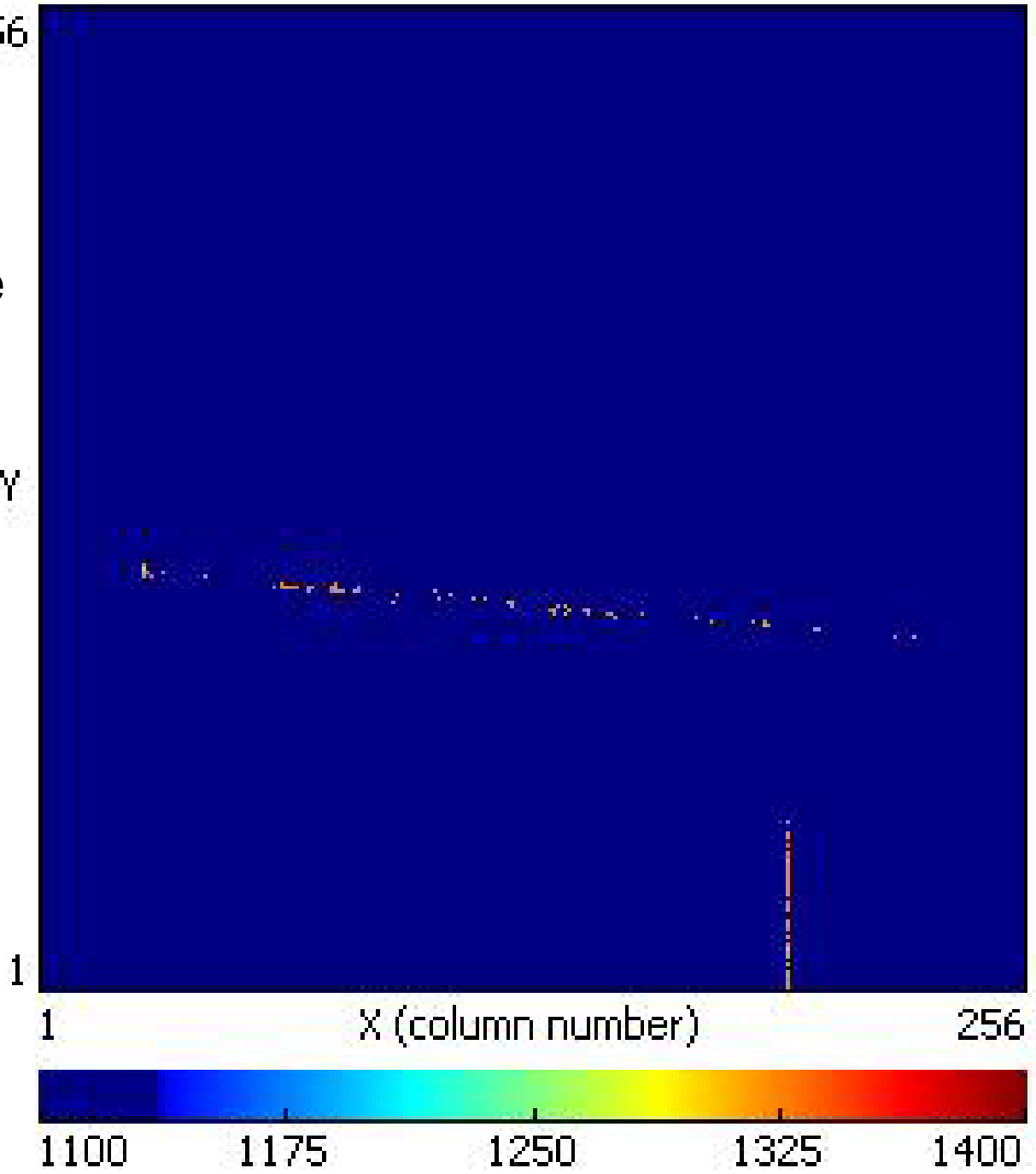
A “dipping” track

(Ingrid @ -450V)



"Multi-pixel" hits due to 20 μm thick Siprot layer

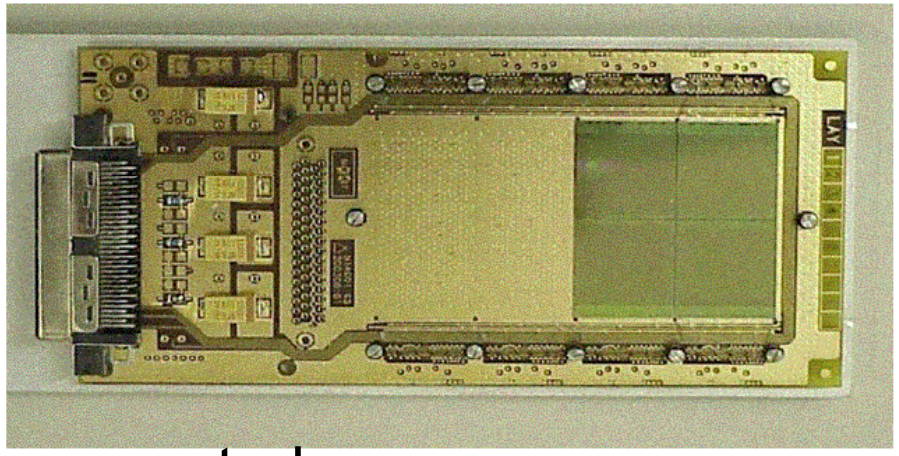
Ingrid @ -450V



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)



Somewhat slower progress than expected:

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

In summary: timetable

- ✓ 1st version Timepix operational: ~~1/2007~~ 9/2006
- ✓ First m.i.p. signals with Timepix: ~~~4/2007~~ 11/2006
- Gain experience with Timepix during 2007
- Development 2nd iteration Timepix ~~during 2007~~ → 3/2008
- Endplate infrastructure: 1/2008
- Full SITPC infrastructure incl. DAQ available: 1/2009

Financial status

Freiburg:

- from 17 month/person available for share of ALU about 4.5 will be spent this year
- consumables: ~½ still available
- all travel provisions spent

Bonn:

- Postdoc 50% JRA2/SiTPC, 50% NA2/ANALYS
- Cashflow as planned

FOM/NIKHEF:

- Postdoc (Yevgen Bilevych) since 1 April ’07
- Consumables ~1/2 spent

CEA Saclay:

- Postdoc (David Attie)
- Consumables ~ 1/2 spent

CERN:

- All SiTPC money ~ spent