Pixel readout for a TPC

LCWS 2010 – Tracking TPC R&D session

27 March 2010

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On behalf of the Bonn/CERN/Freiburg/Nikhef/Saclay groups

Full post-processing of a TimePix

· Timepix chip + SiProt + Ingrid:

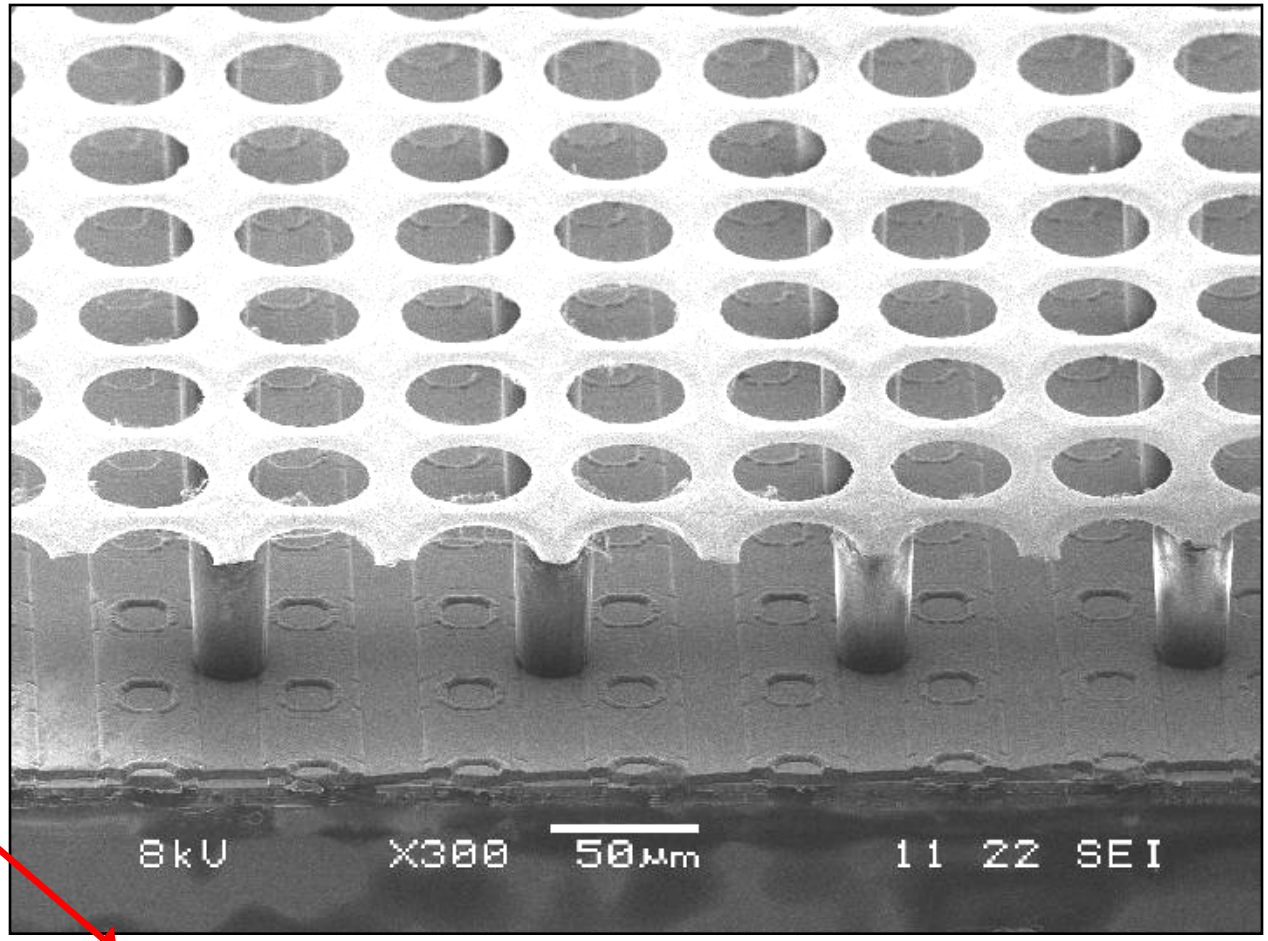
Timepix chip:

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

MESA+: Ingrid

IMT Neuchatel:

15 or 20 µm highly resistive aSi:H protection layer



Now also Si_3N_4 protection layers (7 µm)

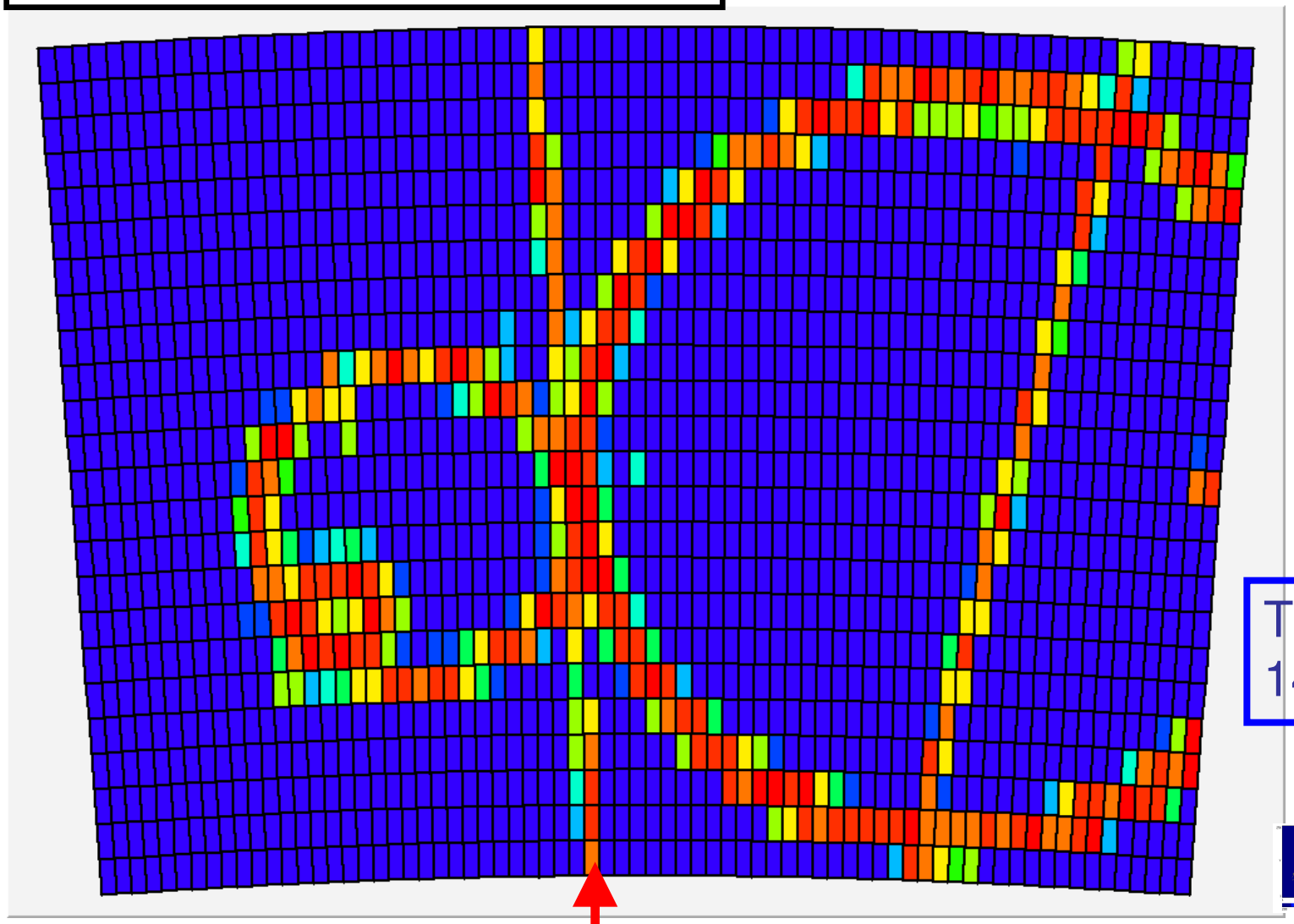
Pad readout vs. Pixel readout

- Pad size ~1x5 mm^2 or ~3x7 mm^2
- Timepix pixel size 55x55 $(\mu m)^2$

- Pad TPC ~ 10^6 pads; several 10^9 3D-voxels
- CMOS pixel readout ~ 2.10^9 'pads' (but 'only' ~ 4.10^4 chips); ~ 10^{12} 3D voxels

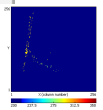
pads/pixels might be problem for software, but occupancy rather low

72x24 pads of ~3x7 mm^2

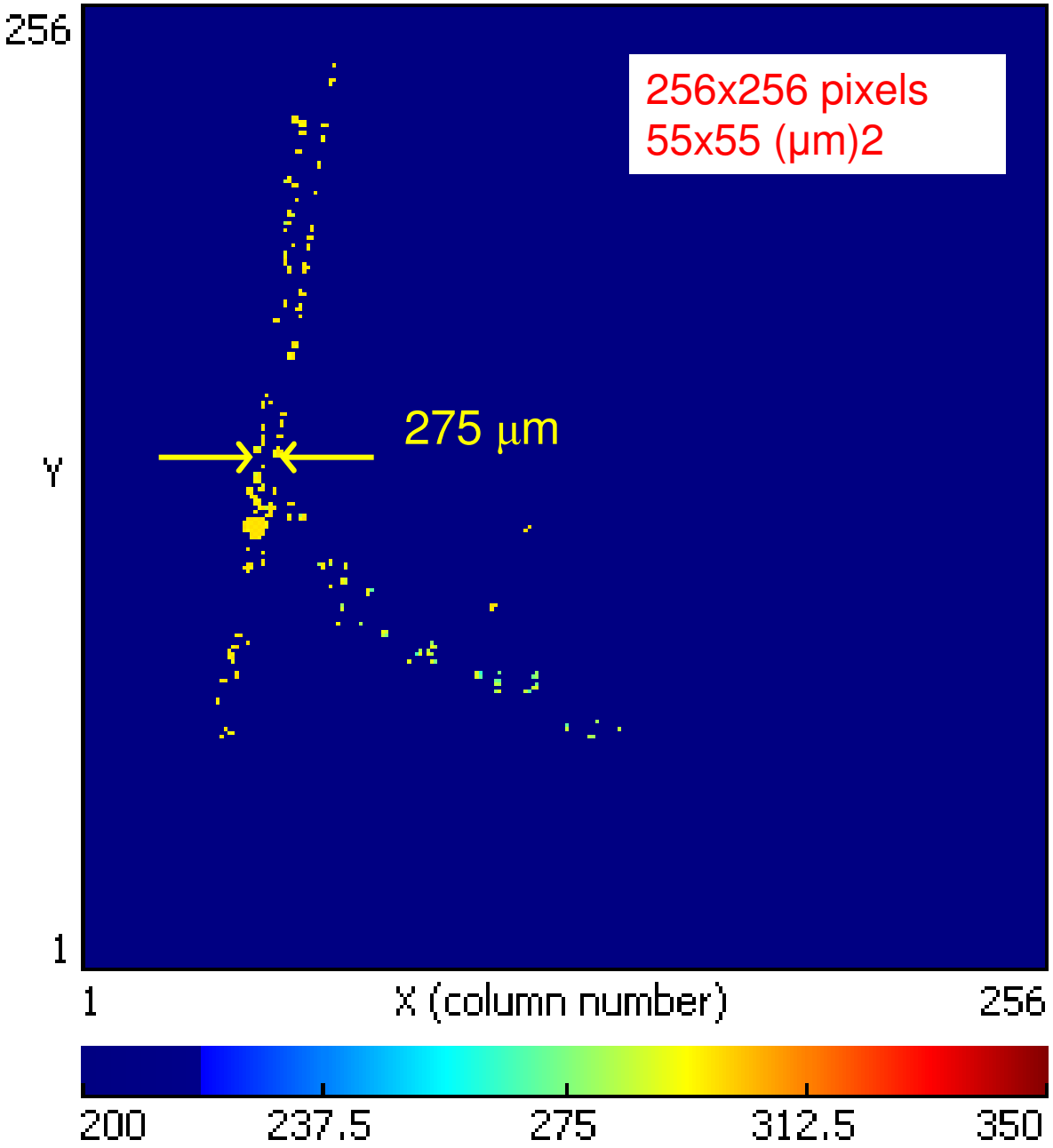


B = 1 T

TimePix chip
14x14 mm^2



5 GeV e^- beam



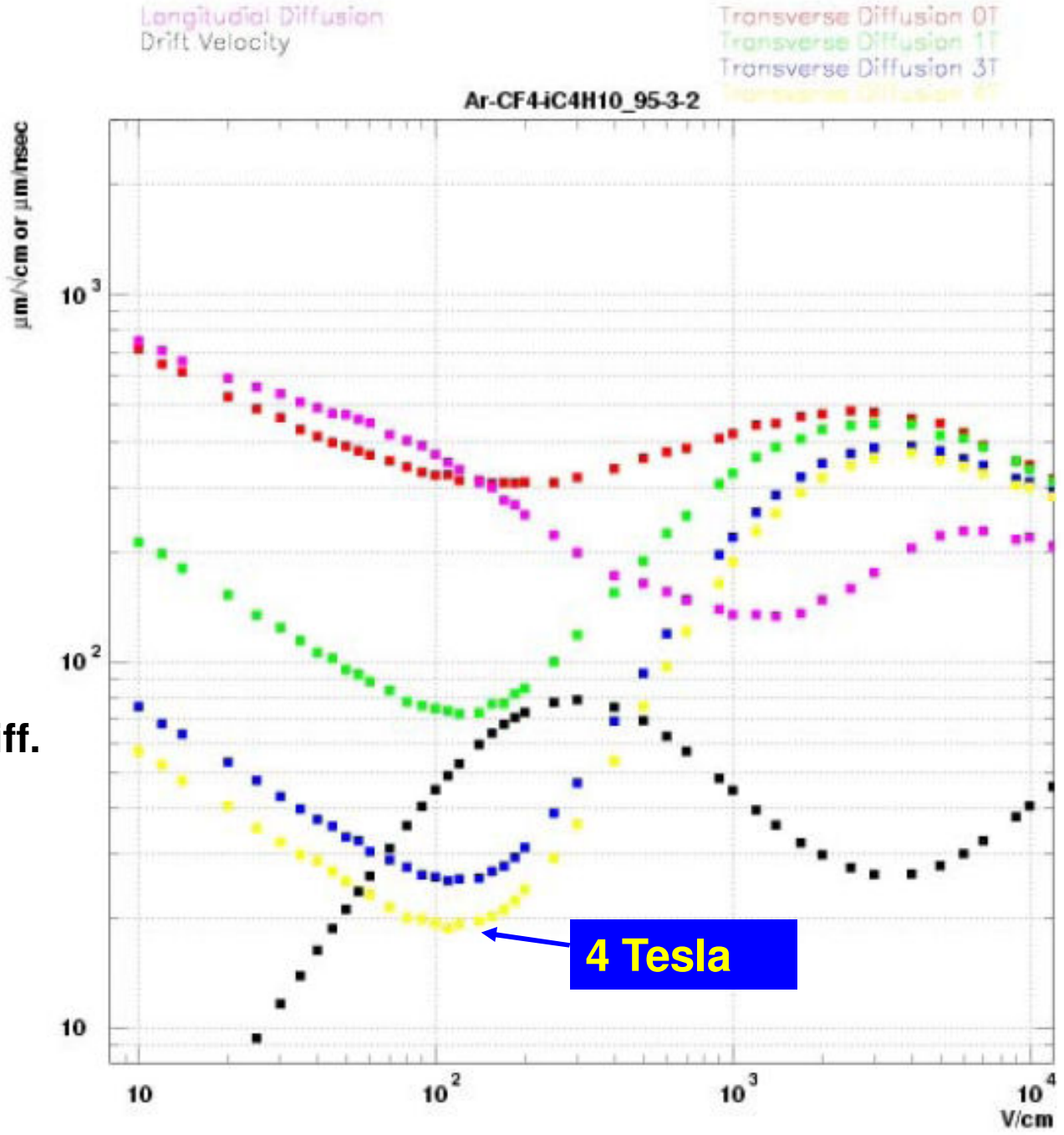
Two-track separation:

- Will be diffusion limited
- In this example:

5 pixels = 275 μm

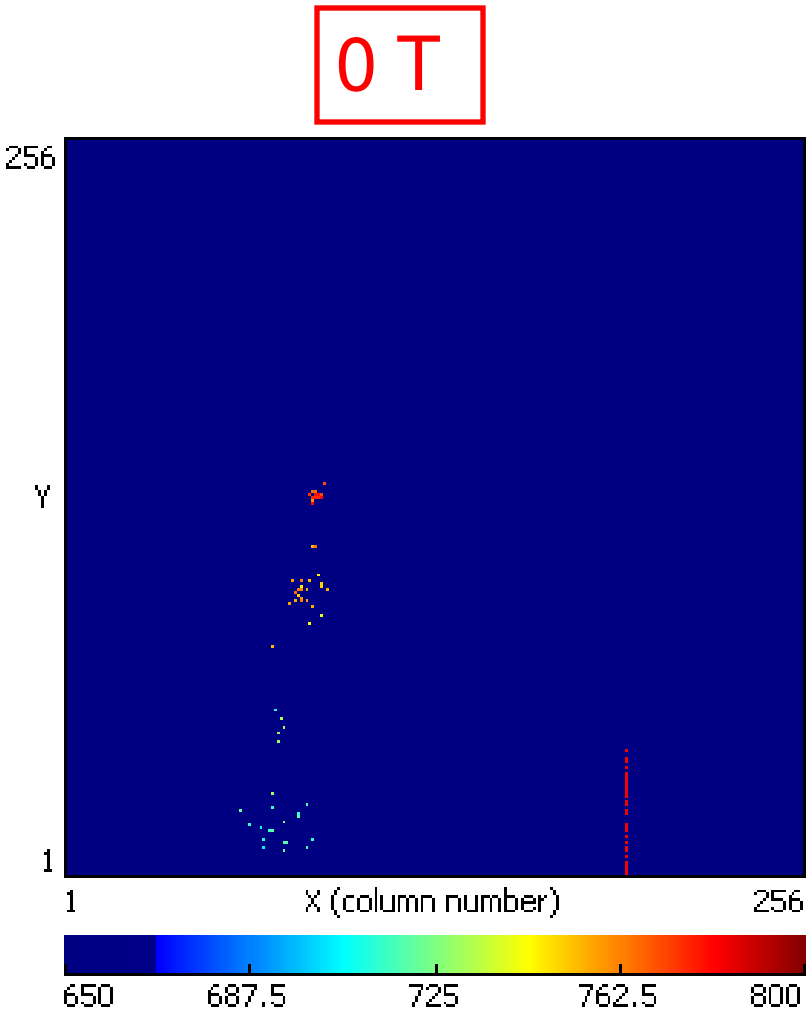
Diffusion at 4T in $Ar/CF4/iC_4H_{10}$ is

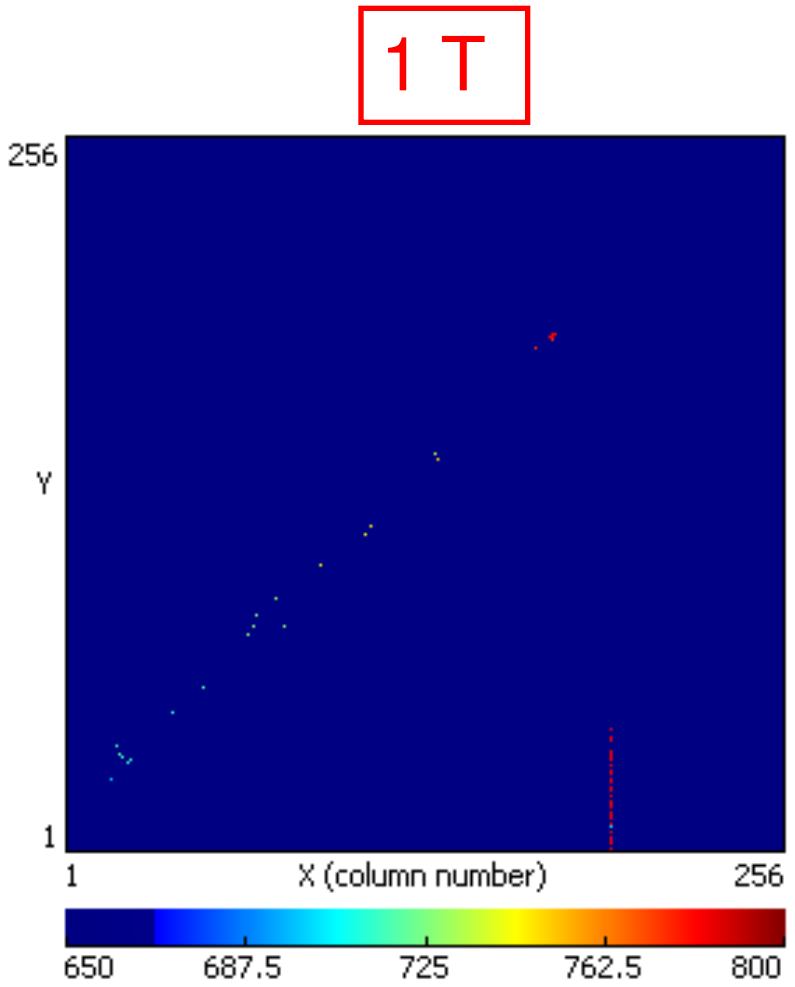
~ $20\sqrt{200}$ = 300 μm


Longitudial Diffusion
Drift Velocity
Transverse Diffusion 0T
Transverse Diffusion 1T
Transverse Diffusion 3T
Ar-CF4-iC4H10_95-3-2
µm/√cm or µm/nsec
10 3
10 2
10
10
10 2
10 3
10 4
V/cm
Long. Diff.
Transv. Diff.
Drift vel.
4 Tesla

Cosmic tracks traversing ~ 30 mm drift space

Ingrid and Ar-CF4-iC4H10 (95/3/2%)

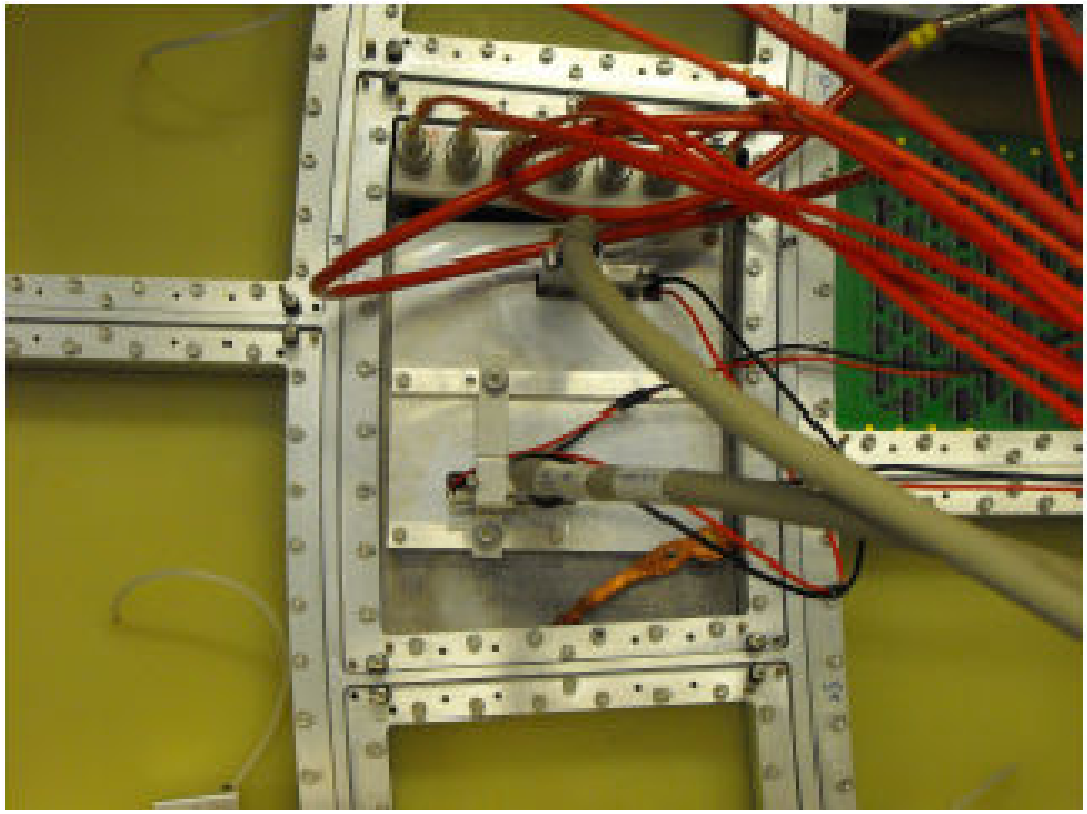




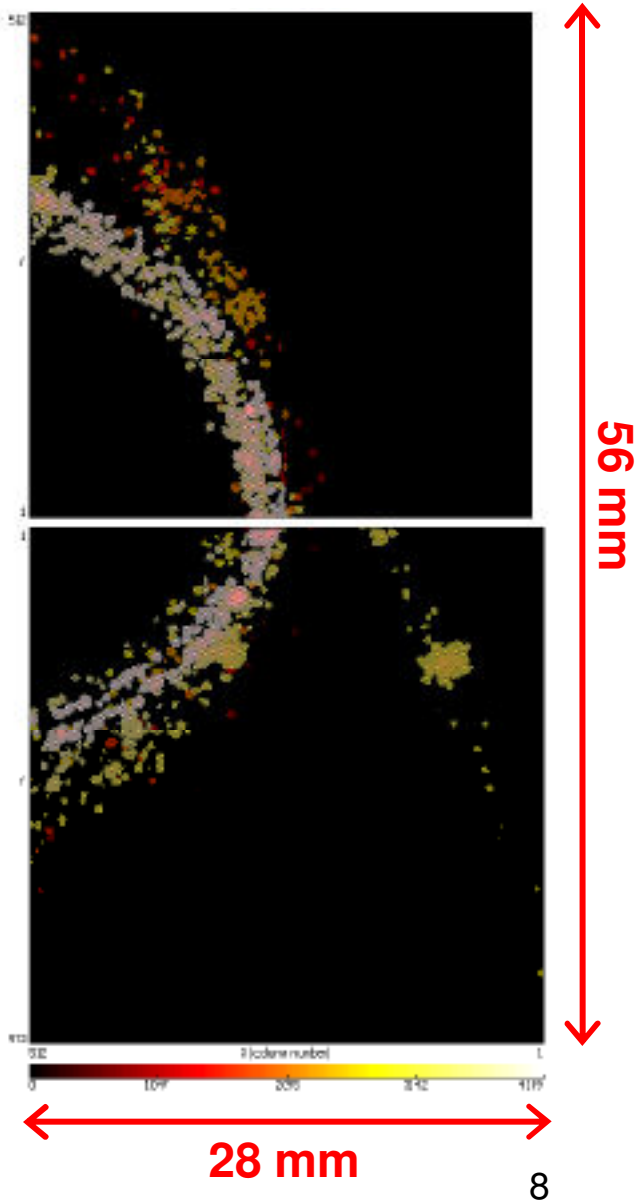
"large" diffusion

"little" diffusion

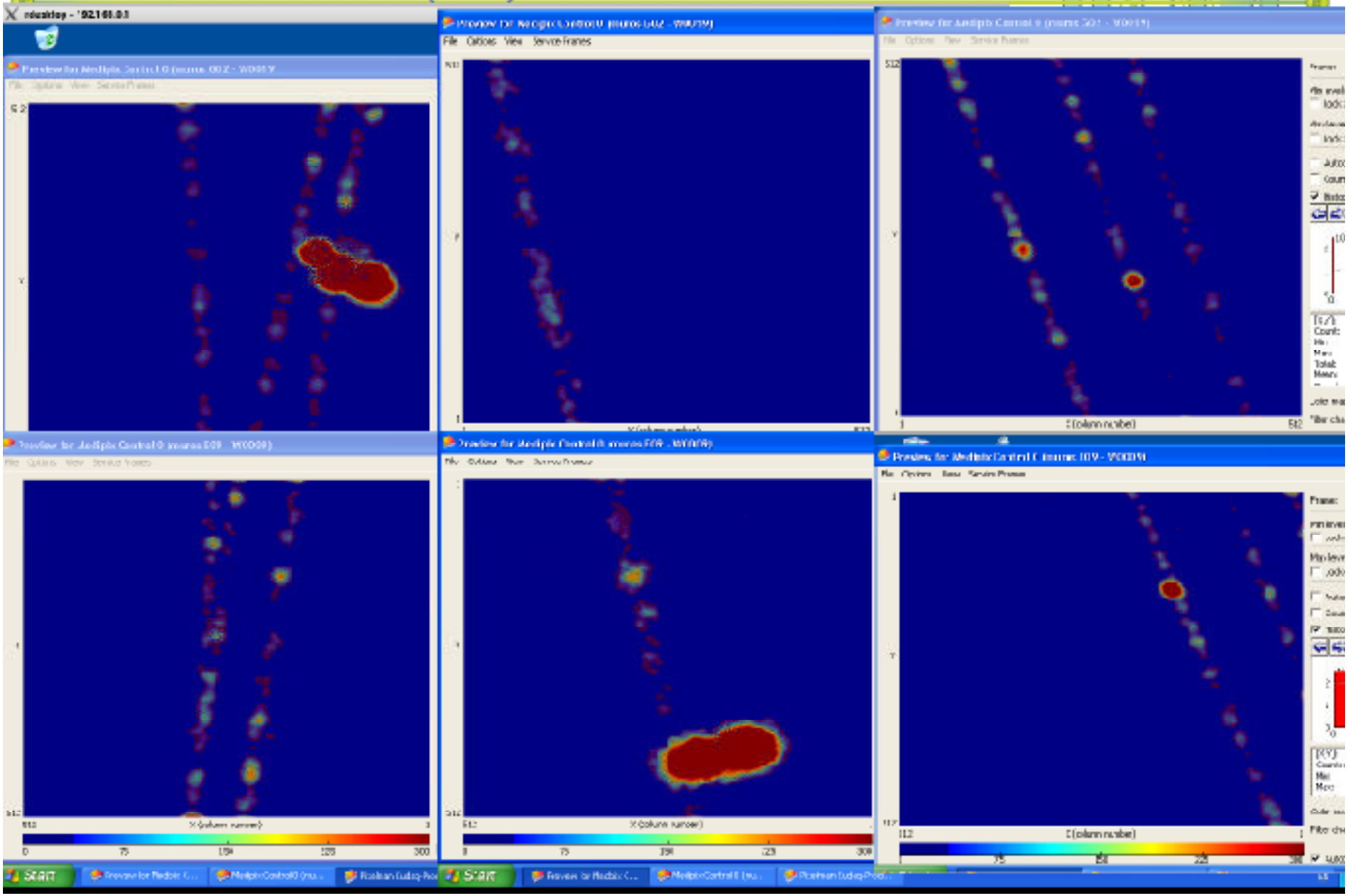
Triple-GEM module with readout by 8 Timepix chips: 16 cm2 active area, 0.5M channels



Bonn/Freiburg



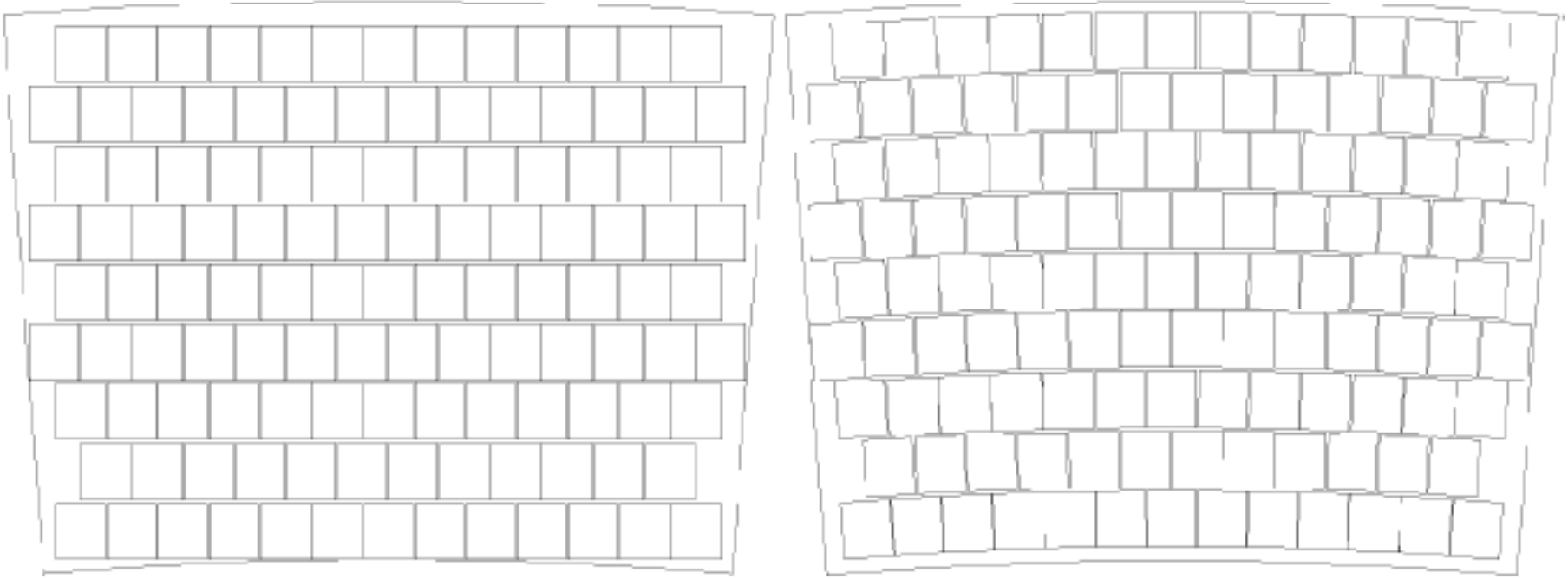
Some Pictures (III)



'Long-term' plans (end 2010)

LP1 module covered completely with Timepix modules

First ideas: 119 Timepix chips (more than 1 wafer, $\approx 7.8 \cdot 10^6$ channels)

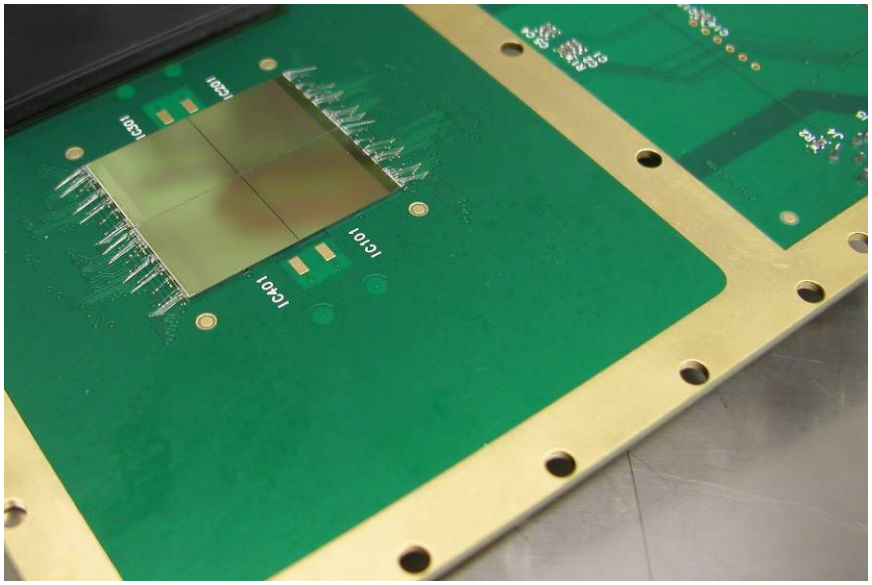


Gas amplification: triple GEM, possibly also InGrids

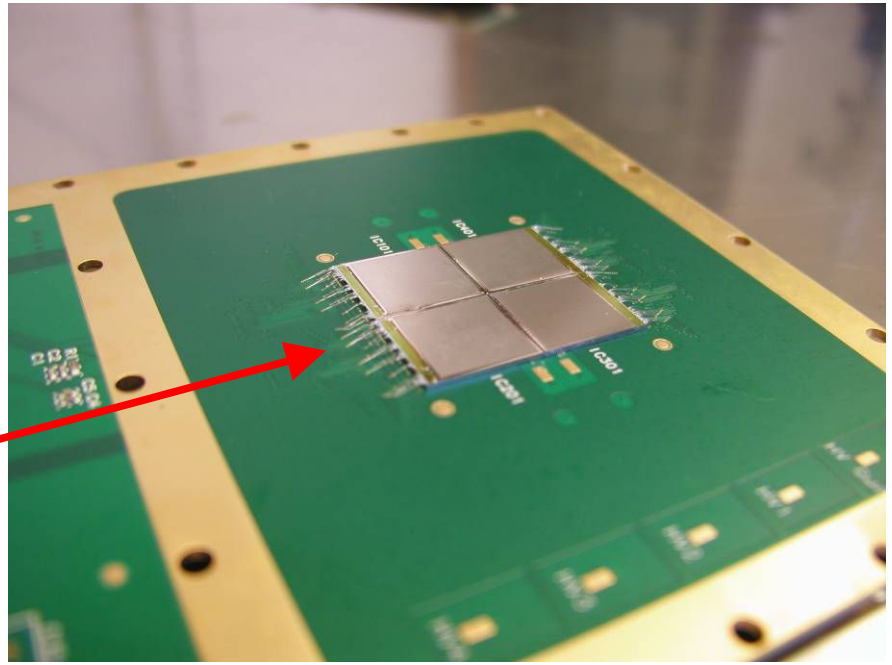
Readout electronics: 'Scalable Readout System' developed at CERN in the framework of RD-51

universitätbonn

NIKHEF: emphasis on Ingrids



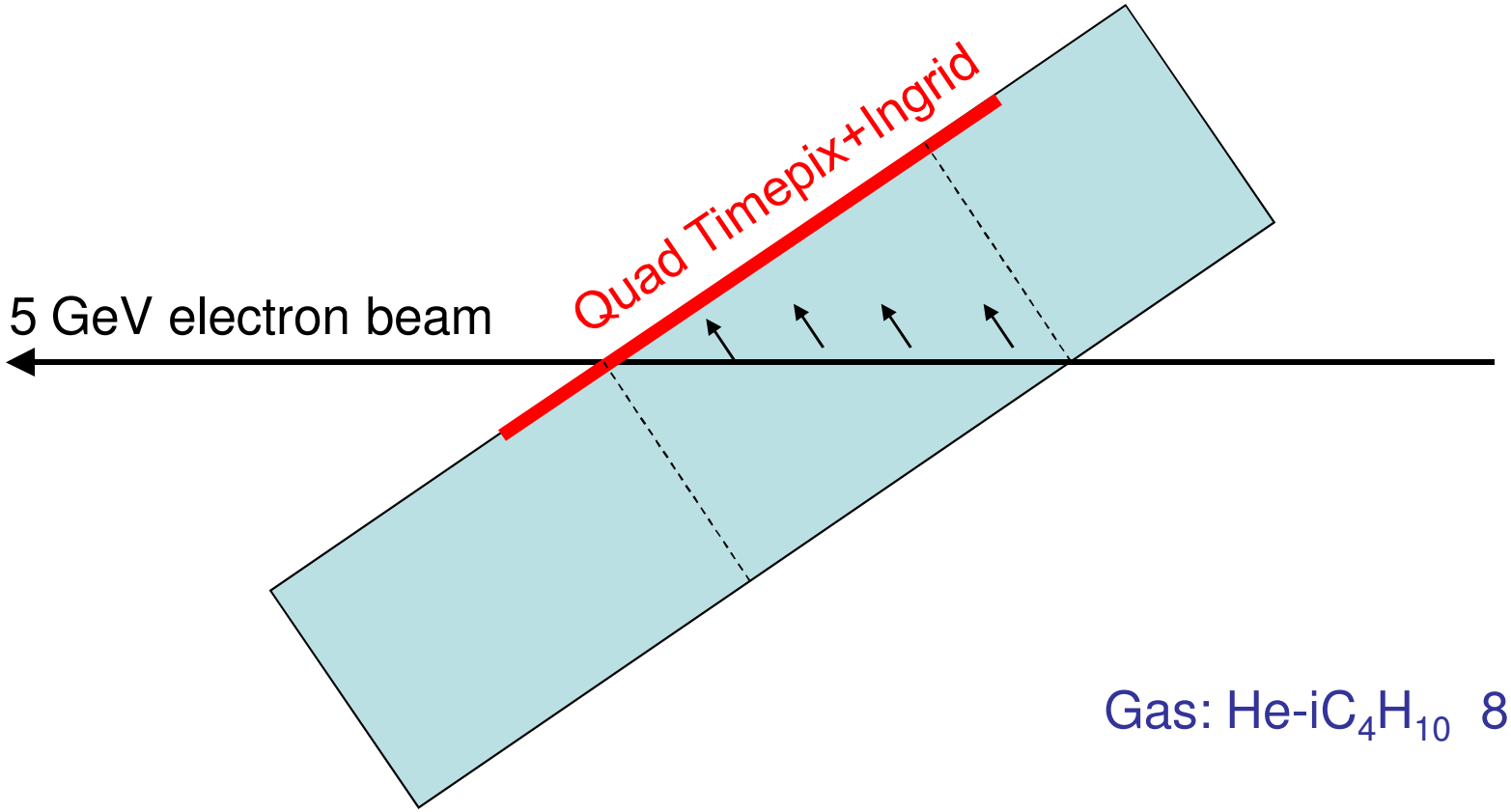
- within Relaxd project: 4x4 Medipix chips in compact mounting
- Will evolve in 8x8 Timepix chips for EUDET



- QUAD chips board tested OK in 2008
- Equiped with Ingrids in June ‘09
- Works with source and cosmics at NIKHEF in Nov’09 – Feb’10

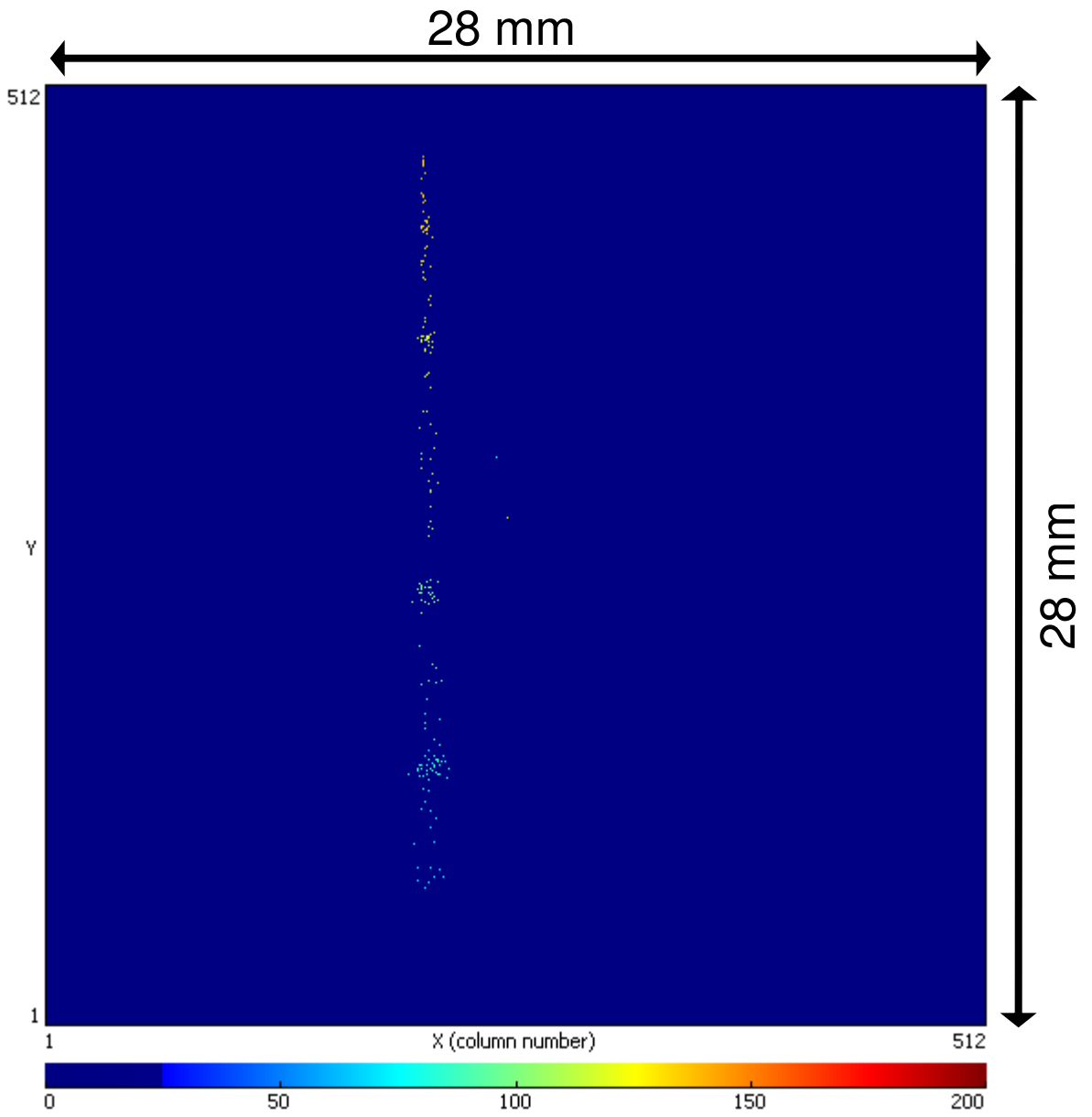
- Readout does NOT work at DESY (testbeam) in Dec’09 and Mar’10, except for 3 days in March’10

Few tracks from ~3-day test at DESY with quad-Ingrid detector

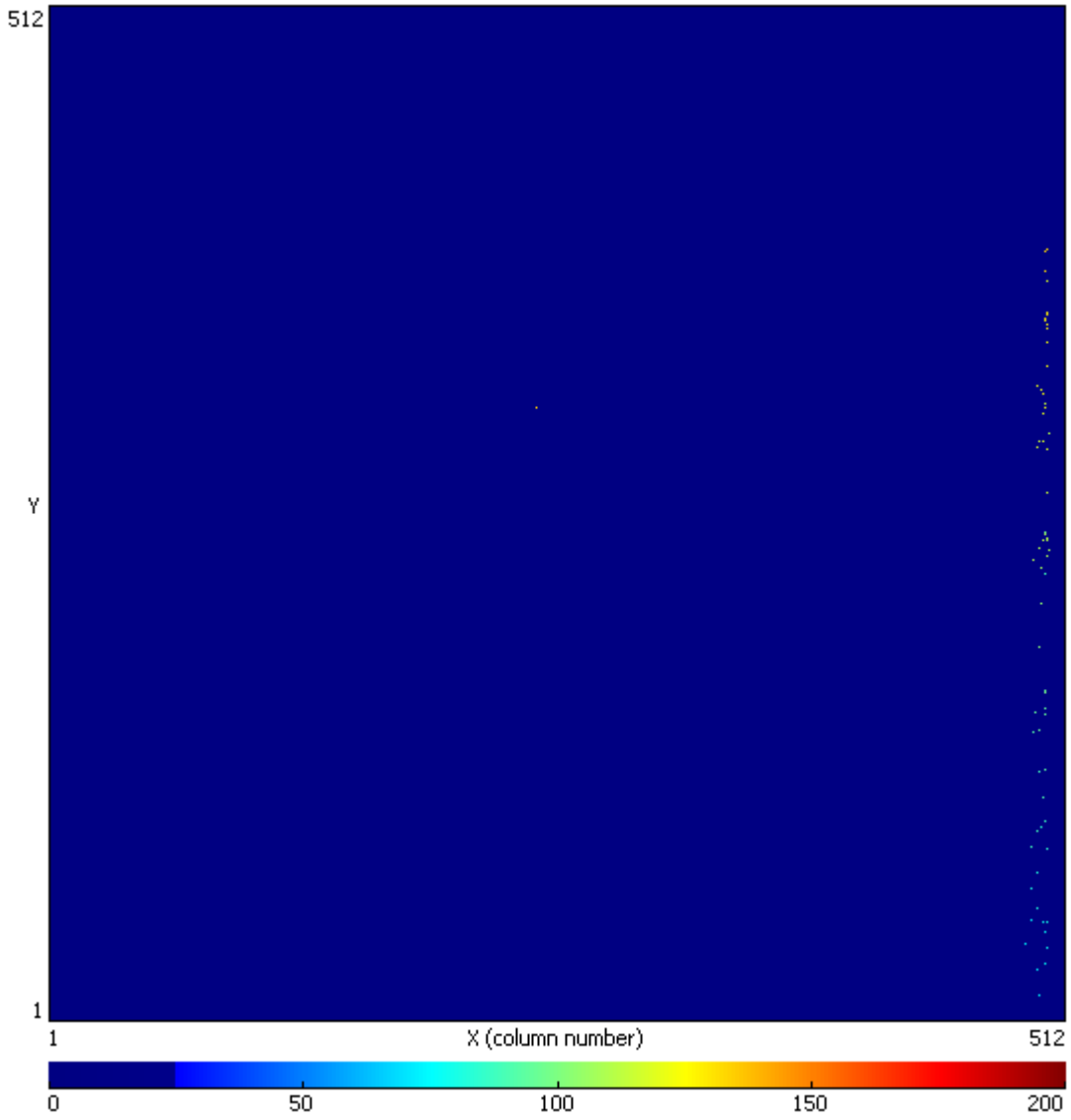


Gas: He-iC_4H_{10} 80/20

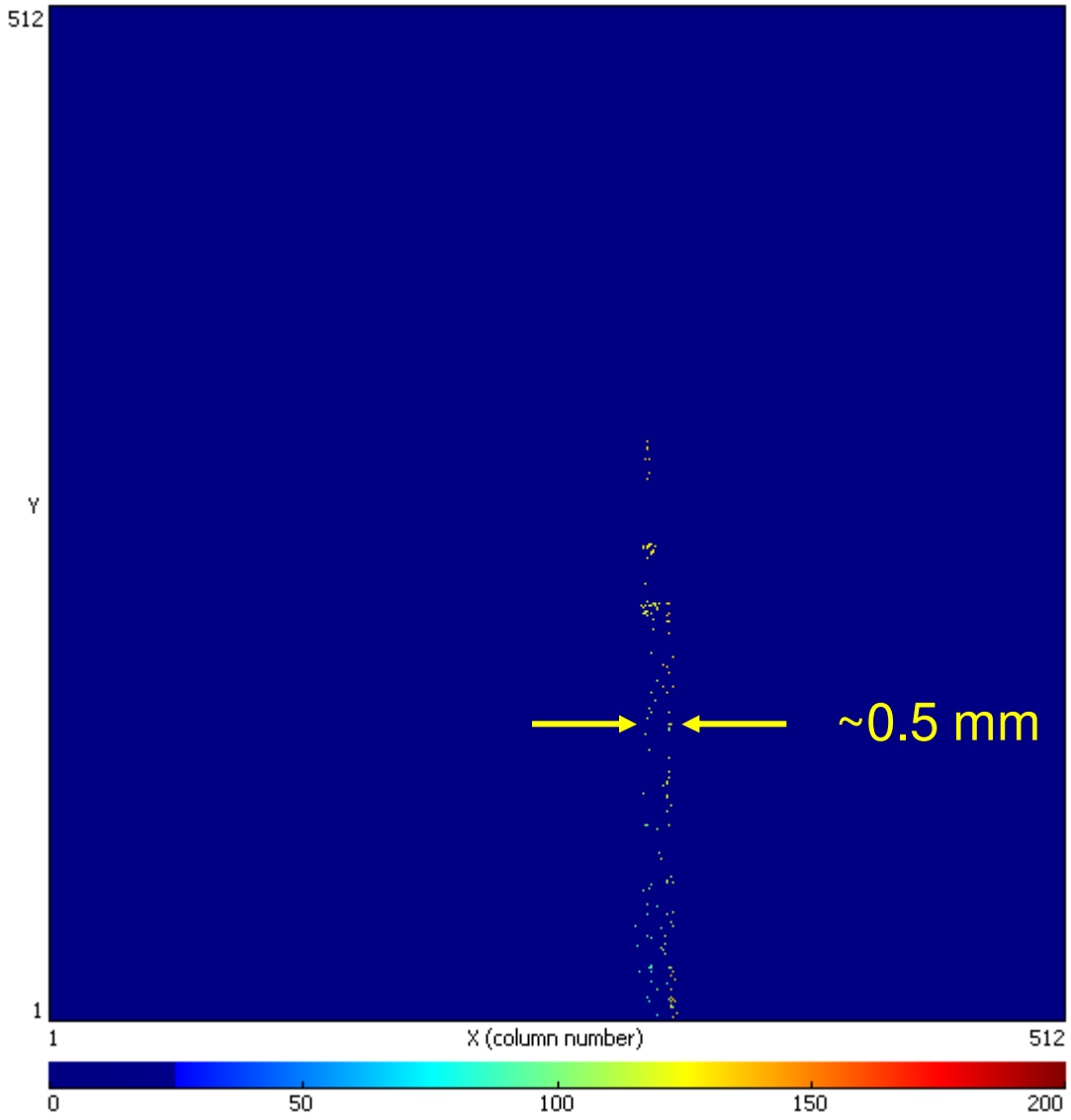
A normal track



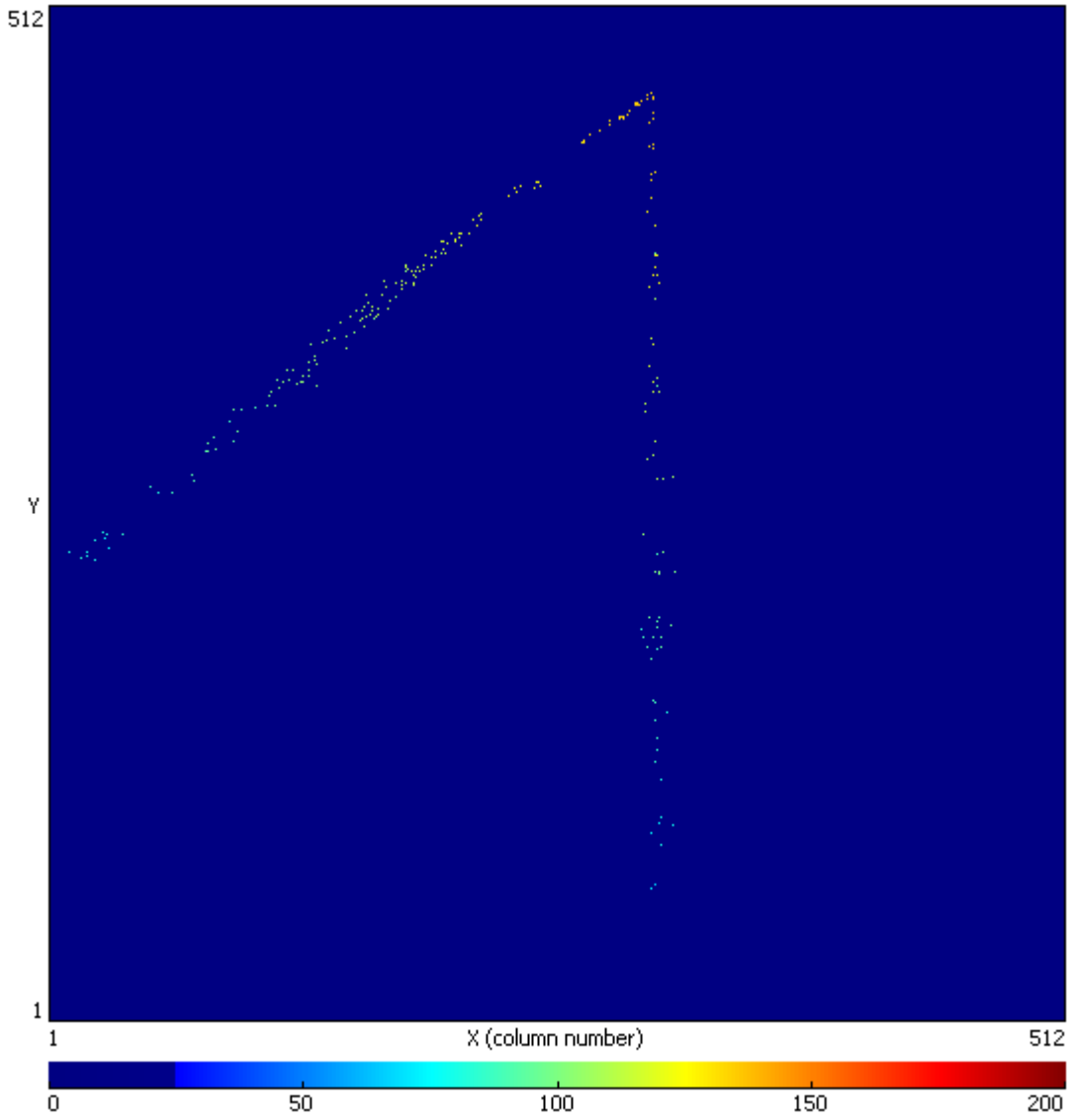
Track very close to border; there is 0.5mm ‘dyke’



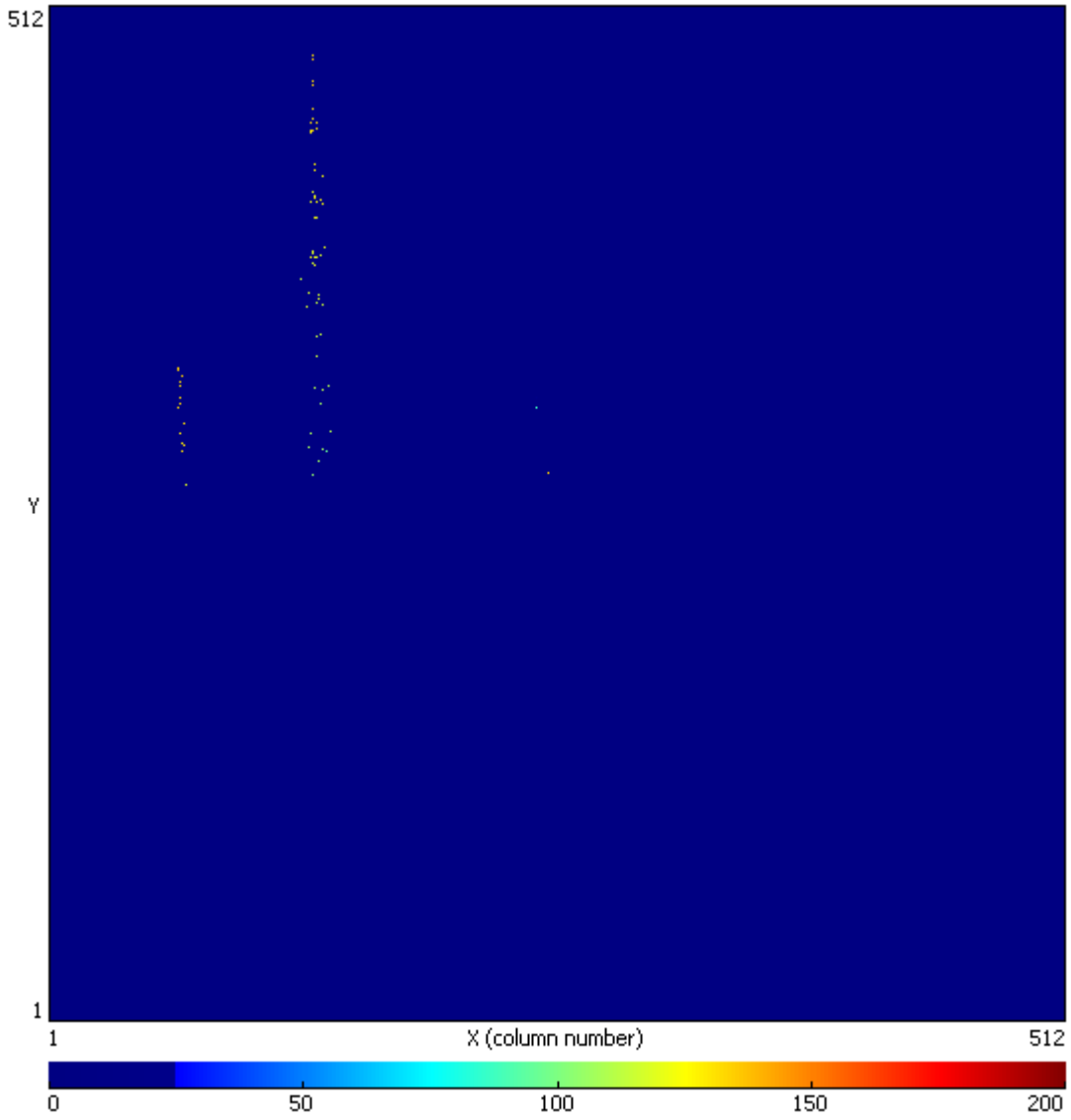
Two tracks about 0.5 mm apart in x



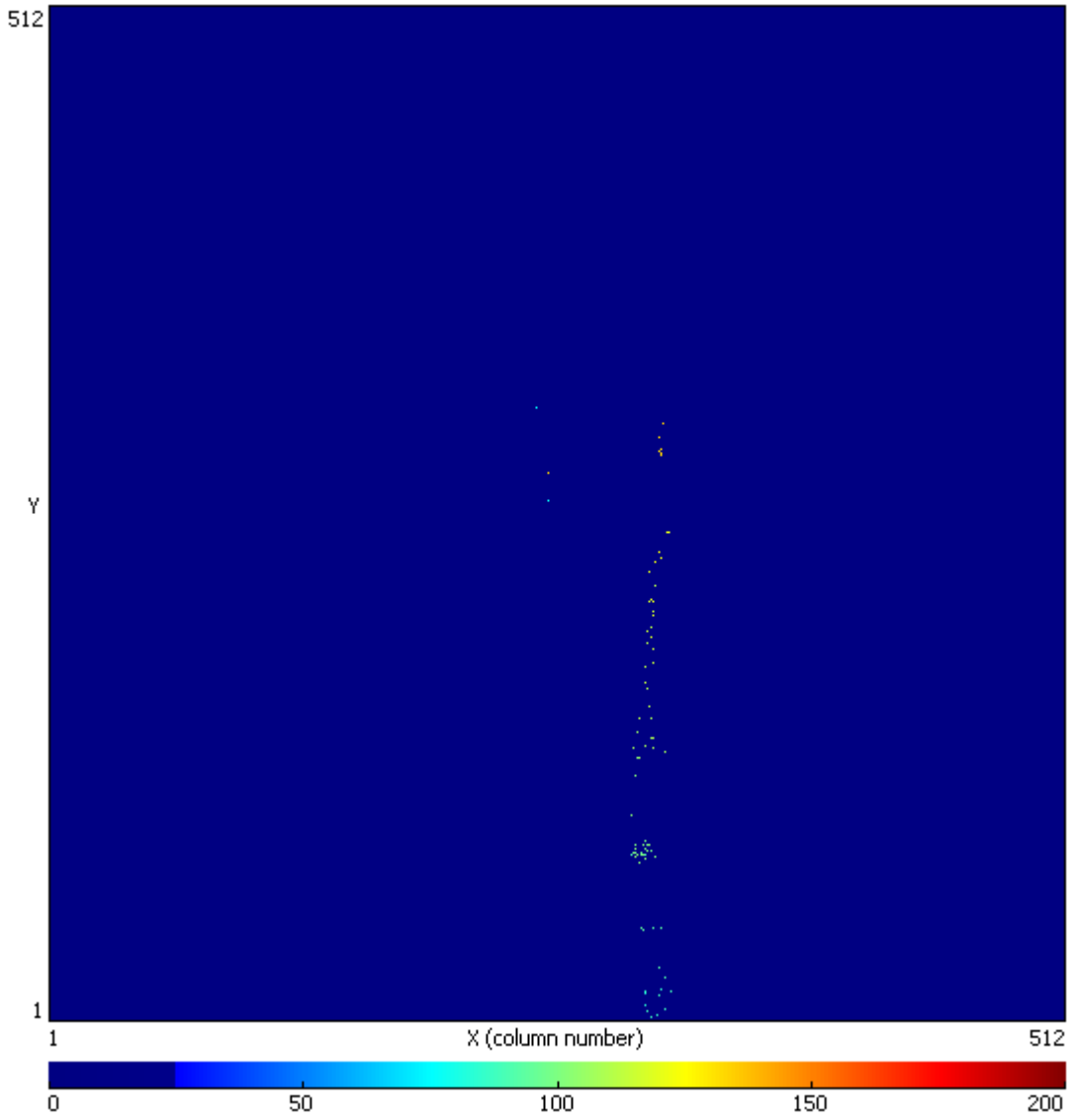
Track backscattering from chip (=anode)



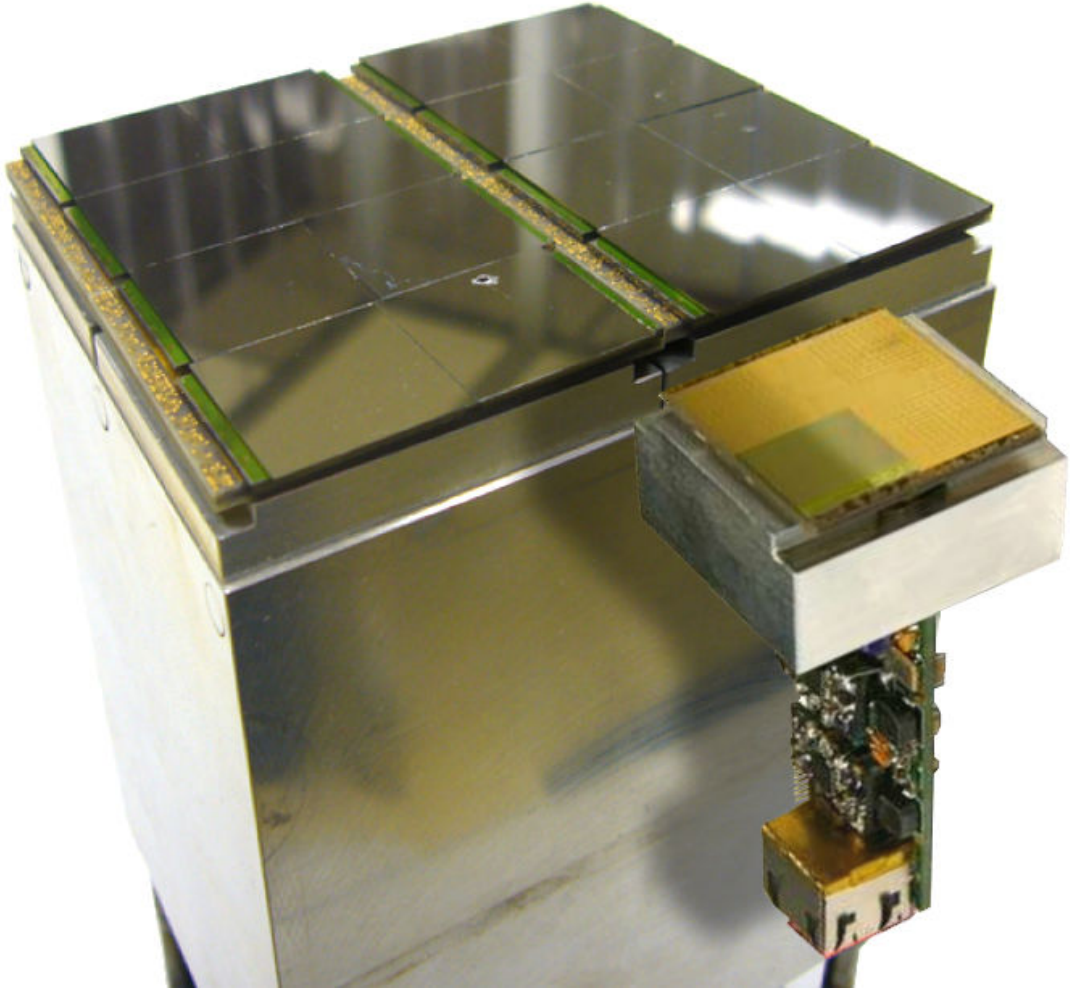
Two tracks; last day lower-left Ingrid lost HV connection



Track distorted by HV disconnected from lower-left Ingrid



NIKHEF

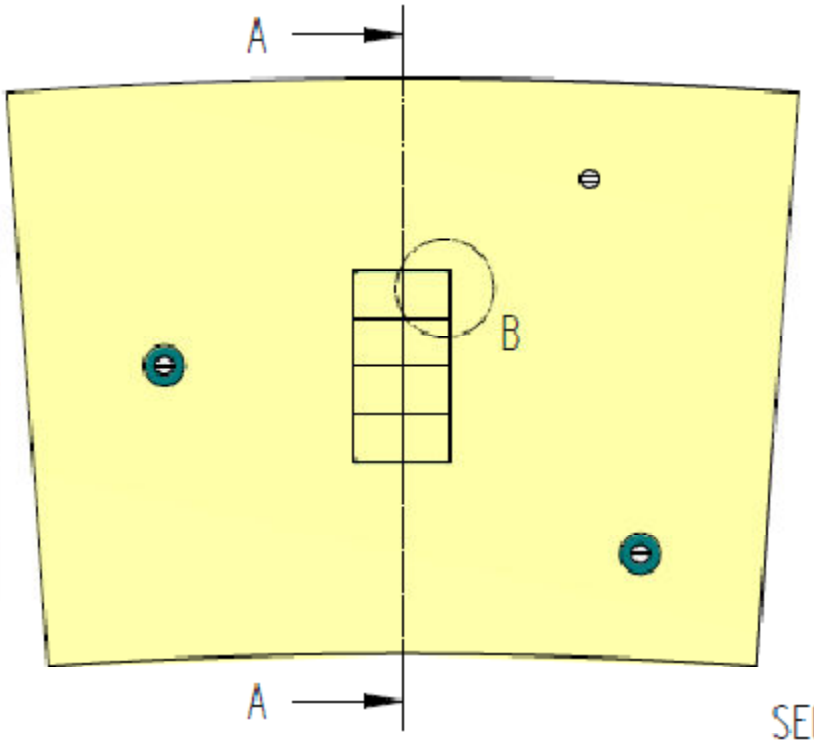


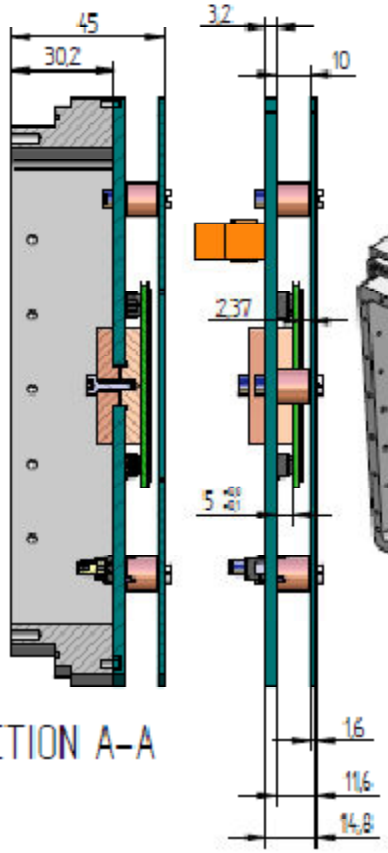
- within Relaxd project: 4x4 Medipix chips in compact mounting
- Will evolve in 8x8 Timepix chips for EUDET/LCTPC

Pixel readout activities at Saclay

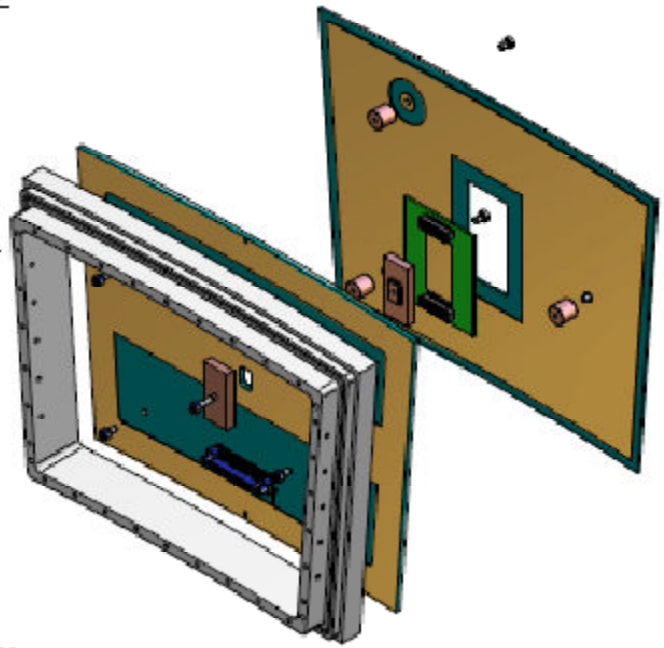
- Production of LP module with 8 Timepix+Ingrid chips (Saclay+Nikhef)
- Module (mother) board + ‘mezzanine’ board carrying chips produced by Saclay
- Timepix+Ingrid chips produced by Nikhef/Univ. Twente
- Readout working for 8 ‘naked’ Timepix chips
- Mounting of 8 Timepix+Ingrid chips soon

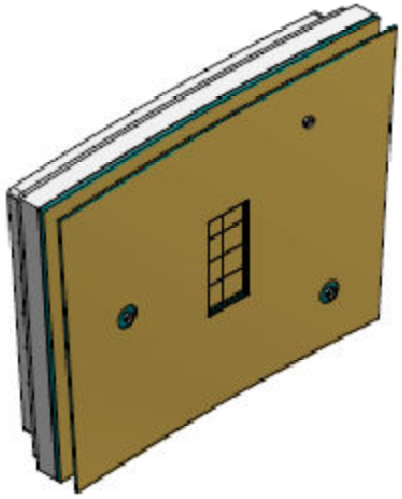
2×4 TimePix/InGrid matrix module for the LPTPC

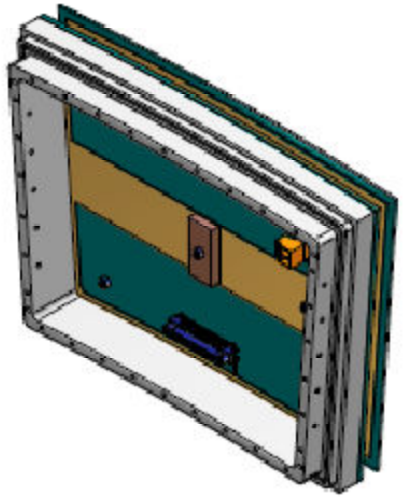


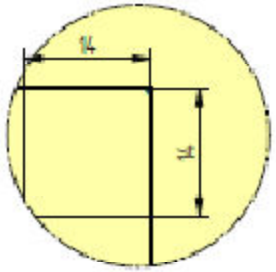


SECTION A-A



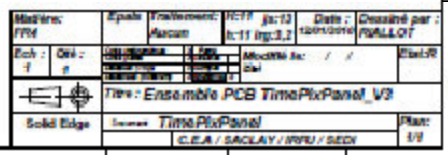






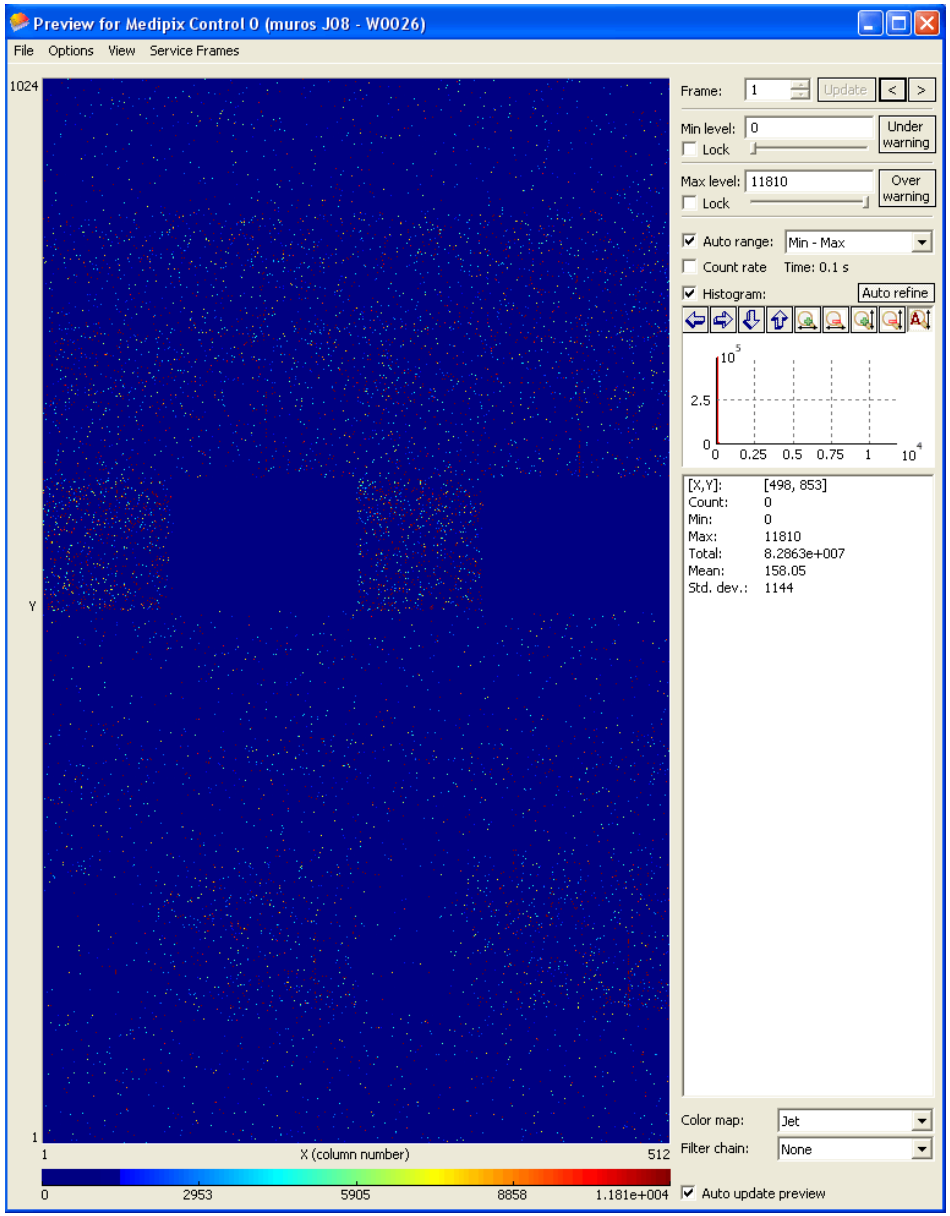
DETAIL B

- Mother card
- Mezzanine card
- Guard ring card
- Heat dissipation block



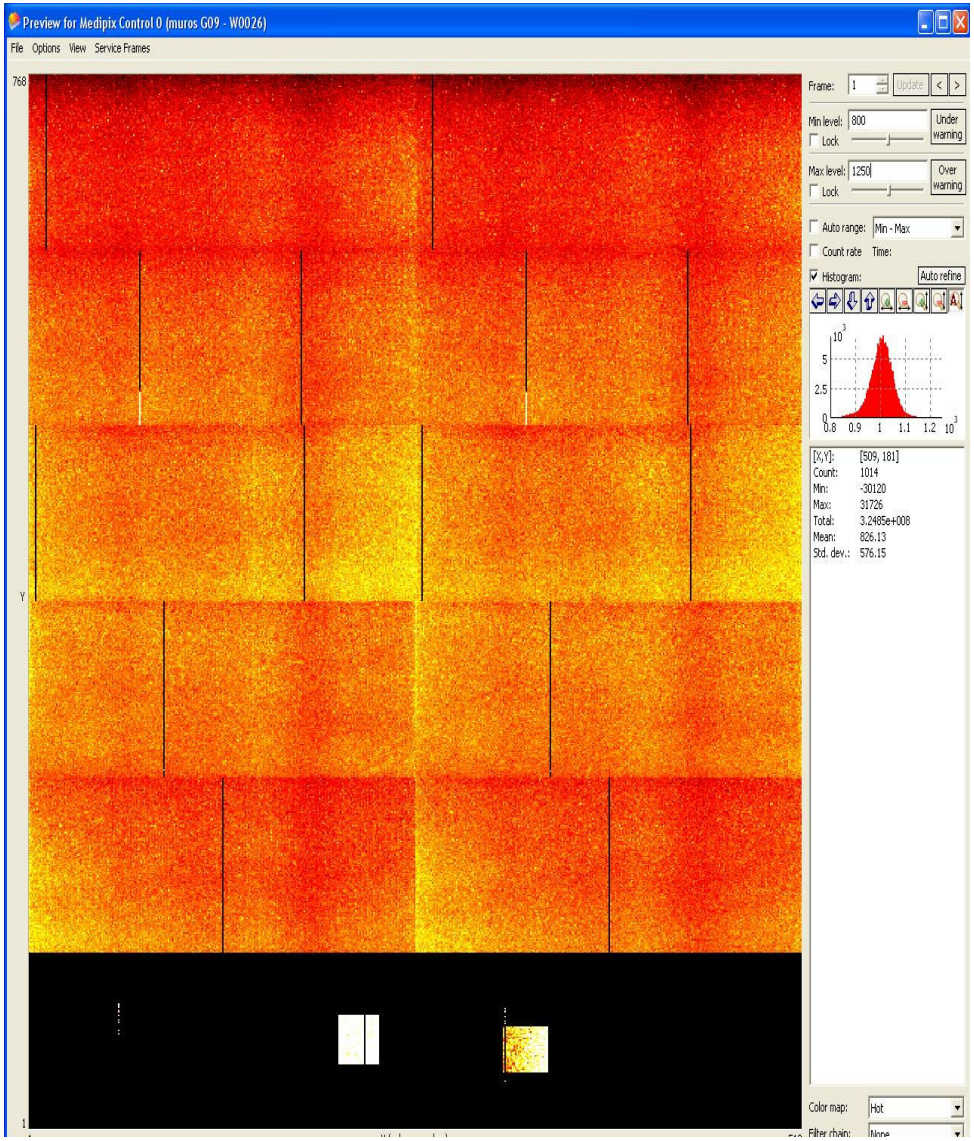
First light of the « Octopuce »

- 8 naked TimePix chips have been bonded on the octopuce card by Joop in Nikhef last month.
- For the first time, 8 chips have been recognized by Pixelman
- The mezzanine card works electrically using power regulators
- During operation, the total power consumption is 20 watts
- Pixelman display issue found and has to be fixed



Next steps

- The chip bypass has been tested
- The equalization was done and the test pulsers do the job
- Next month, 8 Ingrids could be mounted and tested in gas
- Next beam test in the Large Prototype of TPC in DESY before summer.
- To be continued…



Conclusions

- EUDET-SITPC final infrastructure available for 3-GEM + 8 Timepix chips – analysis beam data in progress
- LP module with 8 Timepix+Ingrid chips in preparation. Readout working with 8 ‘naked’ chips. Module mounting with Ingrids soon.
- Quad-Ingrid detector for standalone tests having readout problems at DESY (works at NIKHEF)

- Longer term: working on larger systems of 64 and 119 chips for Ingrids and GEMs.

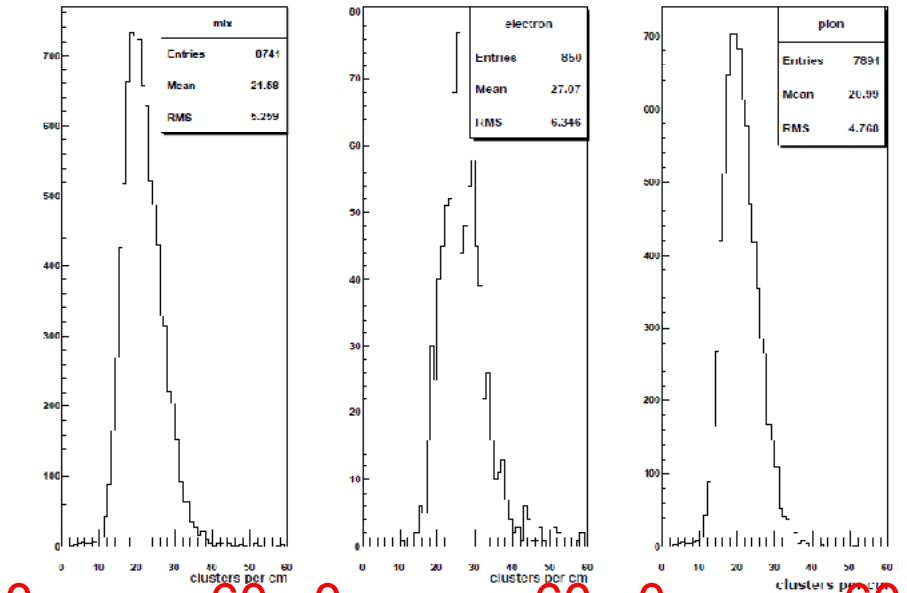
Backup

Performance goals and design parameters for a TPC with standard electronics at the ILC detector

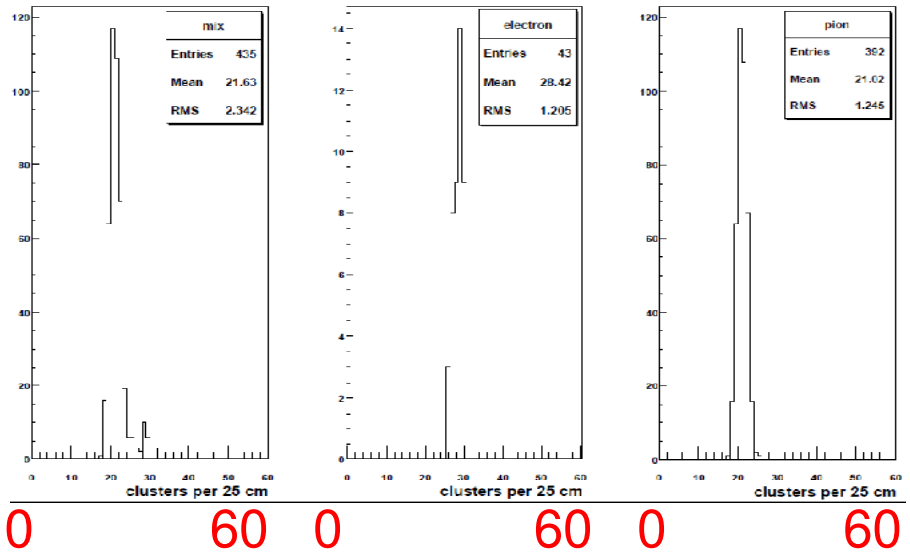
Size	$\phi = 3.6$m, L = 4.3m outside dimensions
Momentum resolution (3.5T)	$\delta(1/p_t) \sim 9 \times 10^{-5}$/GeV/c TPC only ($\times$ 0.4 if IP incl.)
Momentum resolution (3.5T)	$\delta(1/p_t) \sim 2 \times 10^{-5}$/GeV/c (SET+TPC+SIT+VTX)
Solid angle coverage	Up to $\cos\theta \simeq 0.98$ (10 pad rows)
TPC material budget	$\sim 0.04 X_0$ to outer feldcage in r
	$\sim 0.15 X_0$ for readout endcaps in z
Number of pads/timebuckets	$\sim 1 \times 10^6$/1000 per endcap
Pad size/no.padrows	$\sim$ 1mm$\times$4–6mm/$\sim$200 (standard readout)
σ_{point} in $r\phi$	$< 100\mu$m (average over $L_{sensitive}$, modulo track ϕ angle)
σ_{point} in rz	~ 0.5 mm (modulo track θ angle)
2-hit resolution in $r\phi$	~ 2 mm (modulo track angles)
2-hit resolution in rz	~ 6 mm (modulo track angles)
dE/dx resolution	~ 5 %
Performance	$> 97\%$ efficiency for TPC only ($p_t > 1$GeV/c), and
	$> 99\%$ all tracking ($p_t > 1$GeV/c) [82]
Background robustness	Full efficiency with 1% occupancy,
	simulated for example in Fig. 4.3-4(right)
Background safety factor	Chamber will be prepared for 10 $\times$ worse backgrounds
	at the linear collider start-up

with MPGD

Cluster counting distribution in He/iC4H10



all electrons pions



- Using 1 cm tracklength

Electrons:

Avg=27.1/cm rms=6.3

Pions: 21.0/cm 4.8

- Using 25 cm tracklength

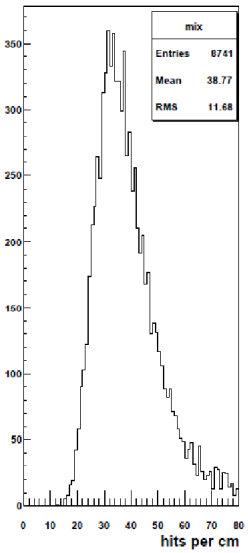
Electrons:

Avg=28.4/cm rms=1.2

Pions: 21.0/cm 1.2

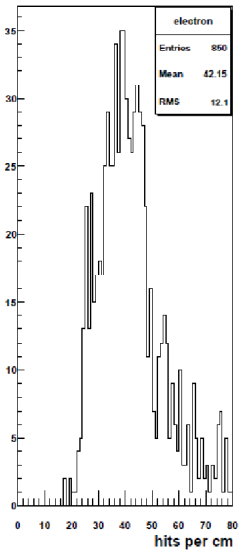
4.4 σ difference

Single hits counting distribution in He/iC4H10



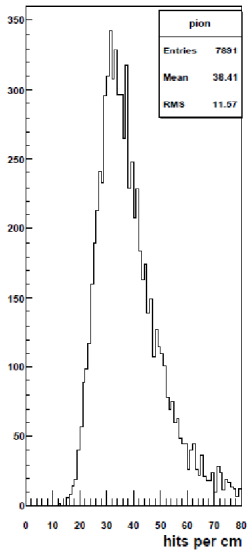
0 80

all



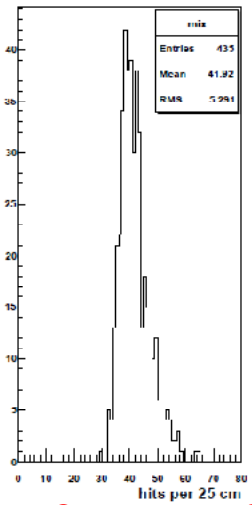
0 80

electrons



0 80

pions



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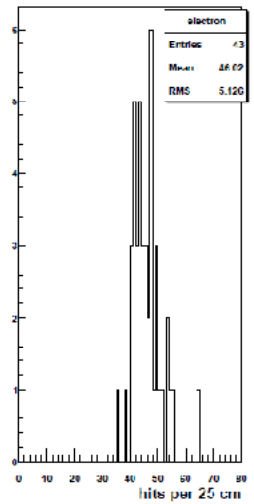

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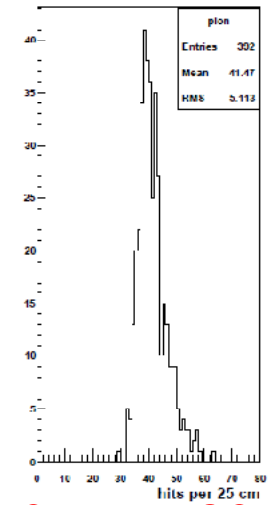

0 80

- Using 1 cm tracklength

Electrons:

Avg=42.2/cm rms=12.1

Pions: 38.4/cm 11.6

- Using 25 cm tracklength

Electrons:

Avg=46.0/cm rms=5.1

Pions: 41.5/cm 5.1

0.6 σ difference