The Silicon TPC System

The “final” status report

EUDET Annual meeting

30 September 2010

Jan Timmermans

NIKHEF/DESY

SITPC Tasks:

- ✓ Develop the Timepix chip that allows to measure the 3rd coordinate (drift time)
- ✓ Implementation of Timepix together with GEM and Ingrid into diagnostic endplate system:
  - with GEM working (2009), 2x4 Timepix
  - STOP PRESS: now also with 8x Ingrid working
- ✓ Performance measurements in test infrastructure at DESY (analysis GEM+Timepix data in progress)
- ✓ Develop simulation framework (and continues)
- ✓ Develop DAQ system and integrate in overall DAQ of EUDET infrastructure (first used in June'09; now also used with EUDET- and ZEUS MVD-telescopes)

Partners: ALU Freiburg, Bonn, CEA Saclay, CERN, NIKHEF

Final milestone/deliverable has 3 ‘legs’:

- one LP endplate module with triple-GEM (Bonn/Freiburg) read out by system of 2x4 Timepix chips; operational June’09 in T24; further test on LP maybe later this year
- one LP endplate module with 8 Ingrids, a Micromegas-like integrated grid (Saclay/Nikhef), on 8 Timepix chips; operational in gas test box, some HV instabilities in Ar/isoB (95/5); better with He/isoB (80/20); a new set of 8 Ingrids being prepared; test on LP-TPC later this year (?)
- One (or more) small detector(s) with ‘Quad’ Ingrids = “traveling infrastructure”; 1 detector with 4 Ingrids ready, RO problems being investigated

All groups have established contacts with outside institutions for 8” wafer scale post-processing:

- Freiburg Metallforschungszentrum (pixel enlargement)
- IZM Berlin: Ingrid/GEMGrid technology
  (first GEMGrid produced on dummy wafer)
- SMC (Scottish Microelectronics Centre) Edinburgh: Ingrid technology
- LAAS (CNRS) Toulouse (max. 6” wafers)

New stuff presented yesterday

- Impressive account of detailed measurements on avalanche statistics and single electron counting by Michael Lupberger Saclay/Freiburg (Master thesis work)

- NIKHEF 4xTimepix/Ingrid running and combined data taking 1xTimepix + ZEUS MVD telescope running EUDAQ (J.T.)

- Successful running of 8xTimepix/Ingrid in LPTPC module testbox (Paul Colas)

The “workhorse”

Timepix + Ingrid

or

Timepix + 3x GEM

Full post-processing of a TimePix

· Timepix chip + SiProt + Ingrid:

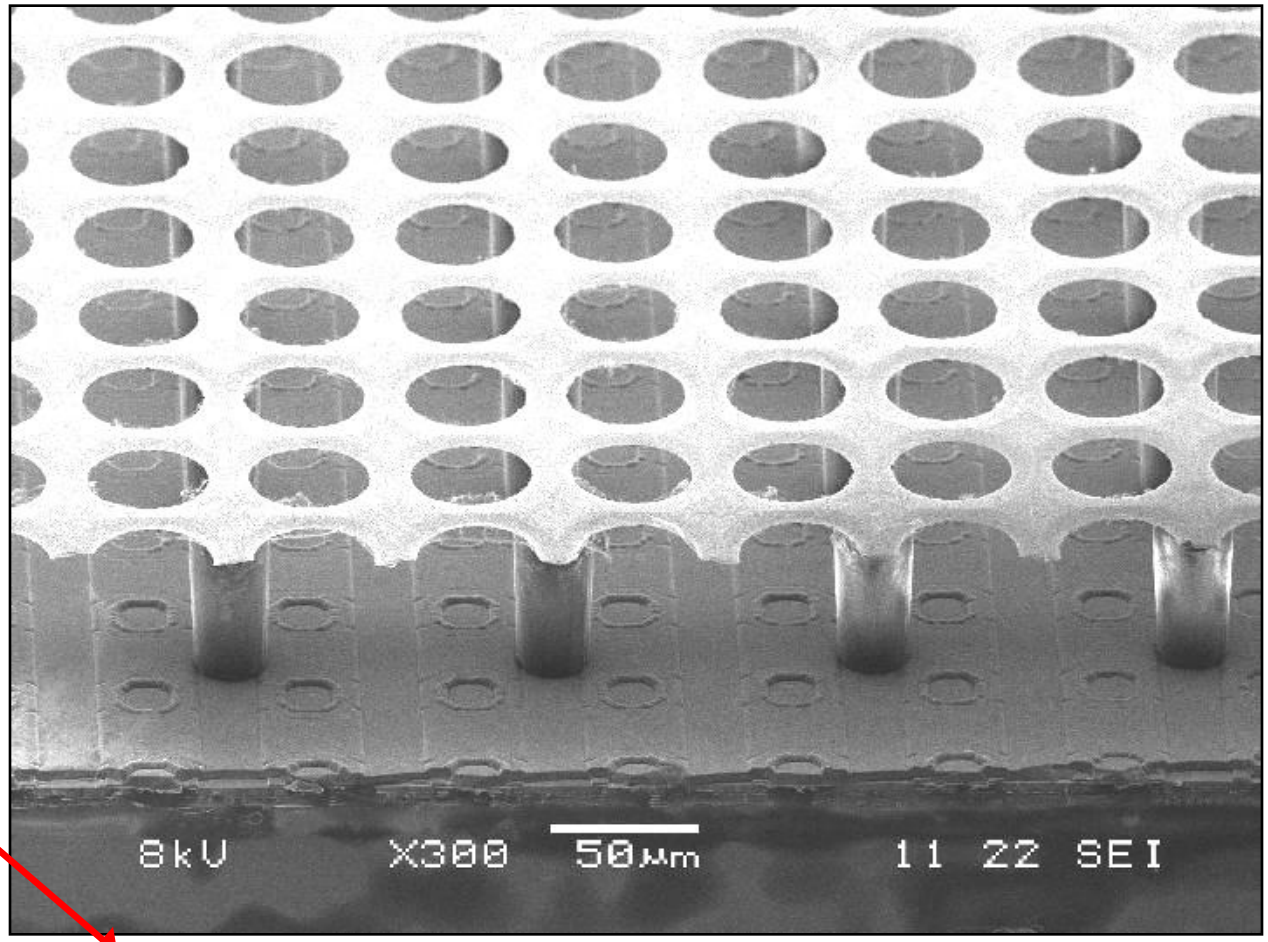
Timepix chip:

- 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



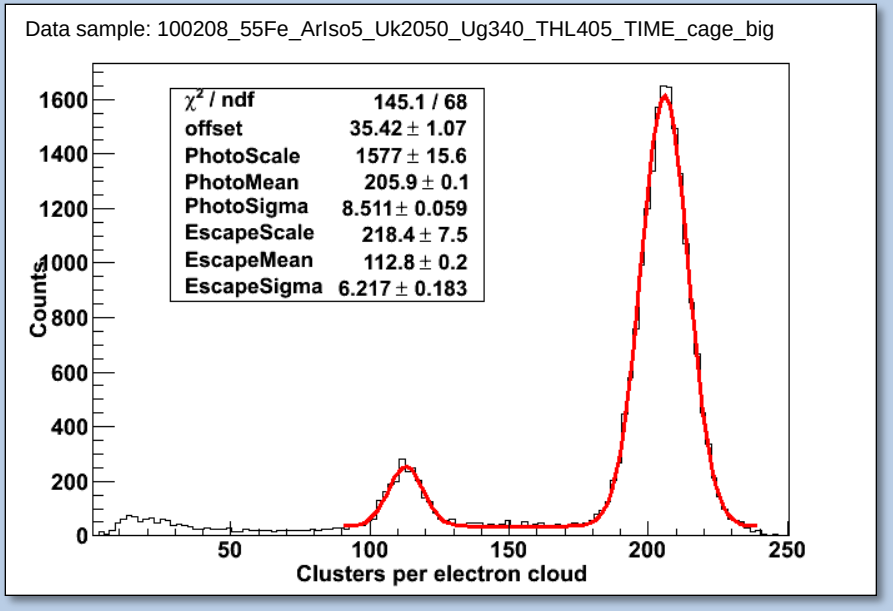
Now also Si_3N_4 protection layers (7 µm)

Fe55 Spectra

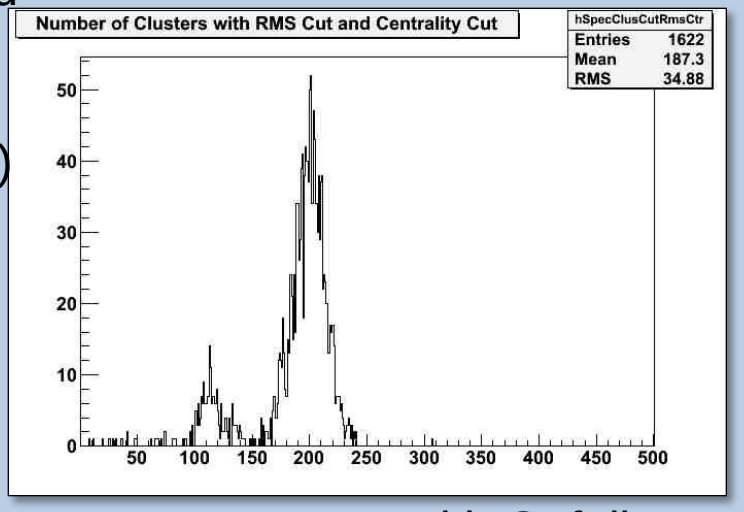
Resolution

- Count number of hit pixels/clusters per electron cloud
- Chromium foil to absorb K_β photons
- long term measurement and hard cut on cloud size
- best resolution achieved: 9,73% FWHM (photo peak)

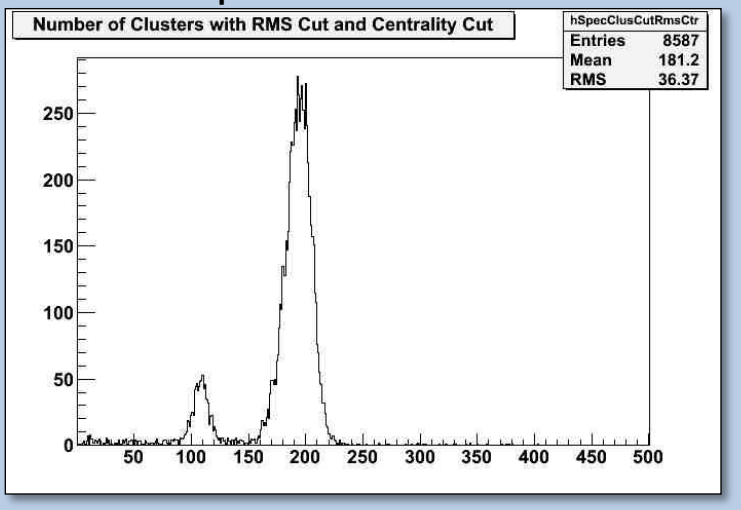
$$\left(\frac{\sigma_{N_d}}{N_d}\right)^2 = \frac{1}{N_p}\left(F + \frac{1-\frac{N_d}{N_p}}{\frac{N_d}{N_p}}\right)$$ [1] $\Rightarrow$ F = 0.26 (upper limit)



Fe55 spectrum without Cr foil



Fe55 spectrum with Cr foil

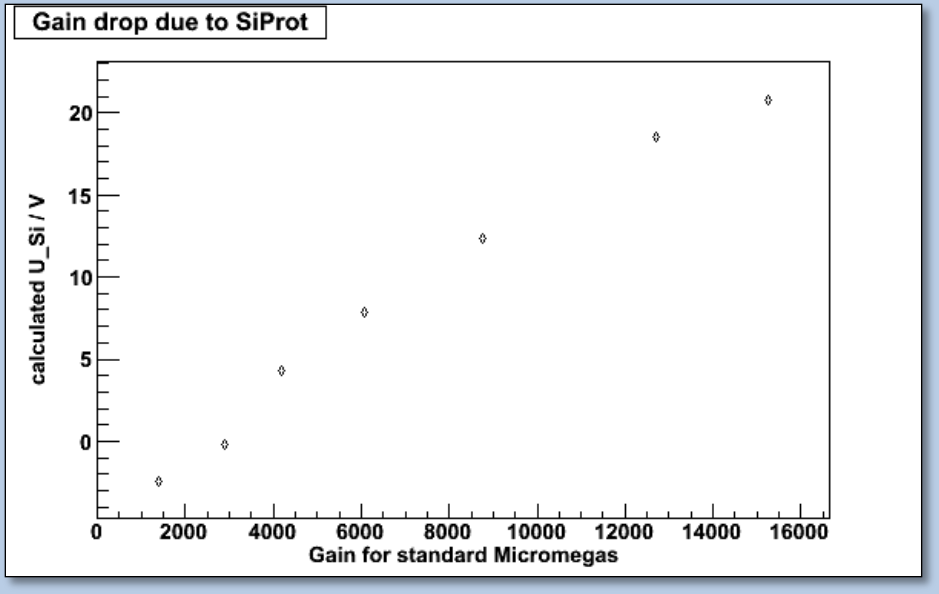


[1] Max Chefdeville, Development of Micromegas-like gaseous detectors using a pixel readout chip as collecting anode

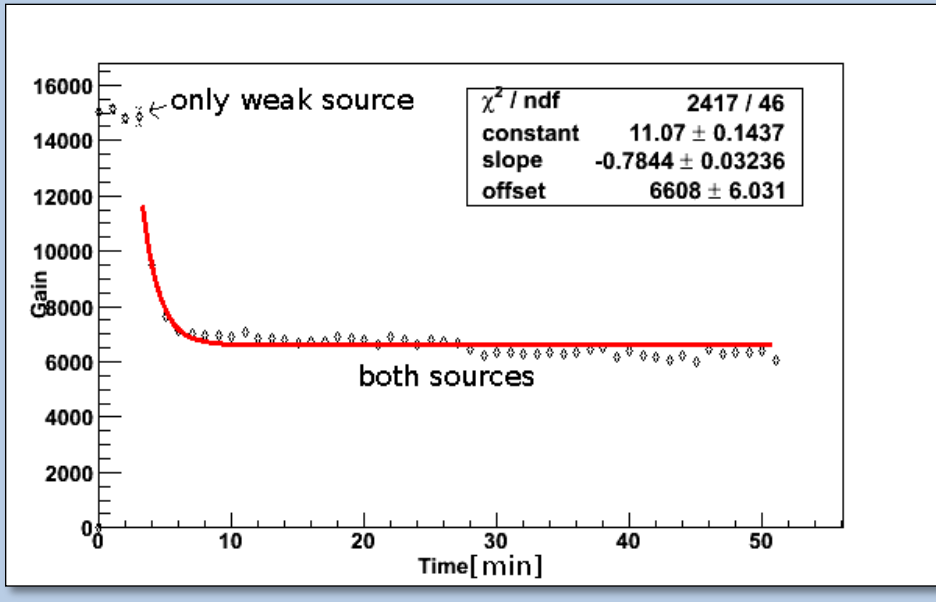
TimeOverThreshold

Influence of SiProt

Calculation of voltage on SiProt surface



Example for gain drop (charging of SiProt)



$$G = \exp\left(A + B \cdot U\right)$$

$$mean = G_{measured} = \exp\left(A + B \cdot \Delta U\right)$$

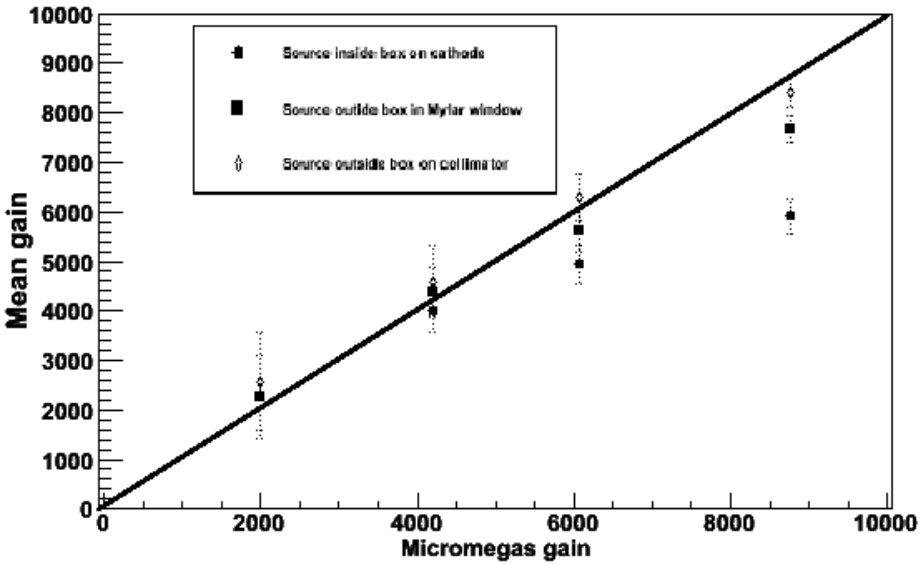
$$\Rightarrow \Delta U = \frac{\ln(mean) - A}{B}$$

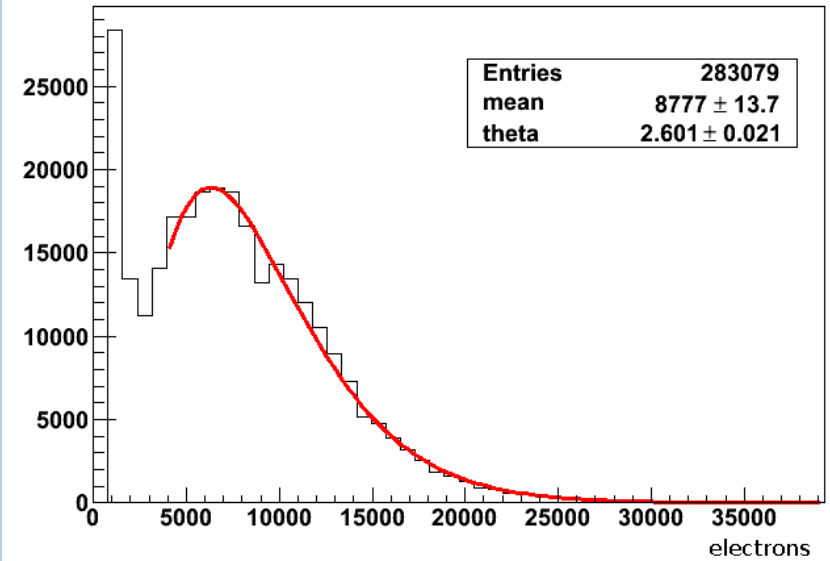
$$U_{Si} = U - \Delta U \qquad U_{Si} = \frac{W\left(B \cdot f \cdot R \cdot G\right)}{B}$$

Put on second, stronger source during measurements:
Gain drop from 15000 to 6600 with τ = 1.27±0.05 min

TimeOverThreshold

Low rate measurements





Place source further away from detector
-> inside detector (high rate)
-> outside detector box (low rate)
-> outside detector box + collimator (highest rate)

InGrid gain approaches Micromegas gain

Measurement at lowest rate
→ high gain
→ noise visible, as acq. time needs to be longer
→ $\Theta = 2.6$

Combined Measurement
Detection Efficiency

Comparison of theory and measurements assuming Polya distribution
Combine gain and primary electron measurements

From gain (TOT) measurements: Polya mean = gain

From primary electron (TIME) meas.:
number of prim. electrons,
117,9 electrons = 100 % det. Eff.

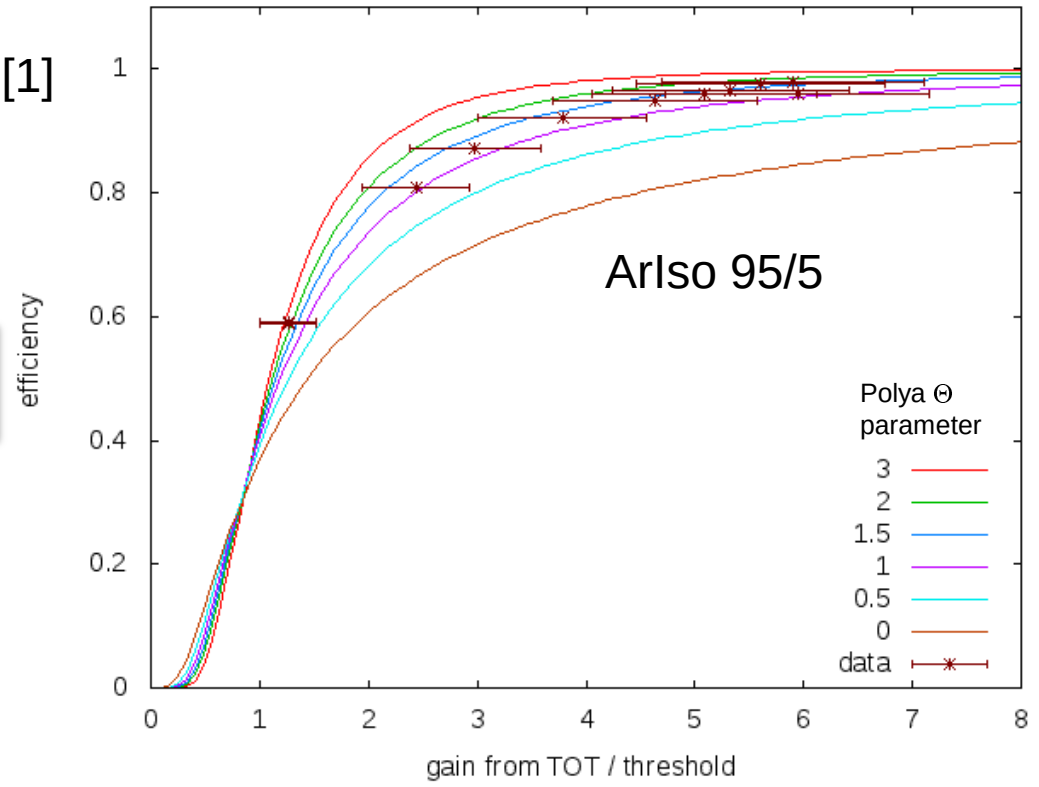
Detection efficiency:

$$\kappa(m,G,t) = \int_t^\infty \frac{m^m}{\Gamma(m)} \frac{1}{G} \left(\frac{g}{G}\right)^{m-1} \exp\left(-m\frac{g}{G}\right) dg$$

m=Θ+1
Threshold: t=1150 electrons

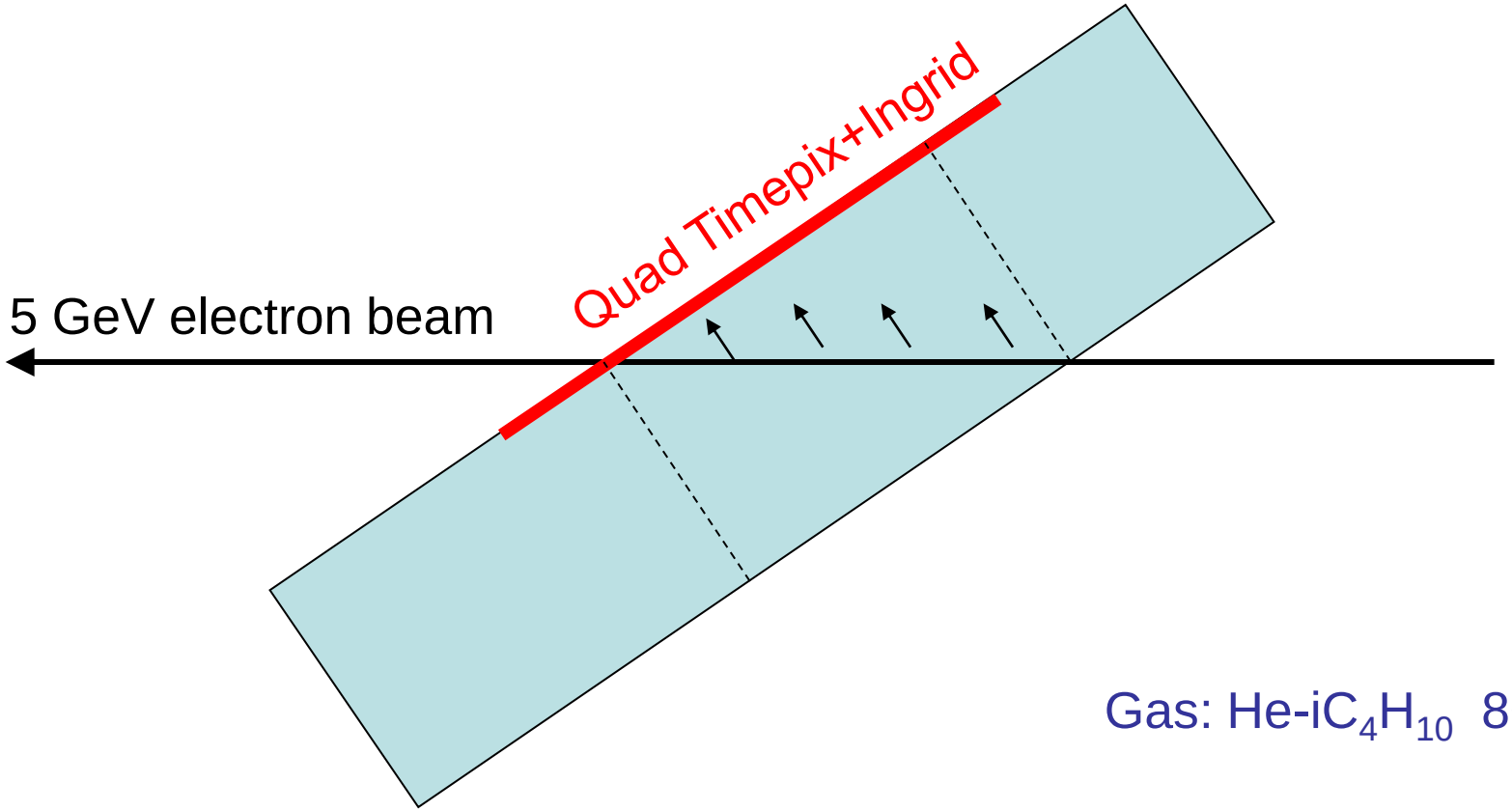
$\Rightarrow$ 0.5 < Θ < 2

[1]



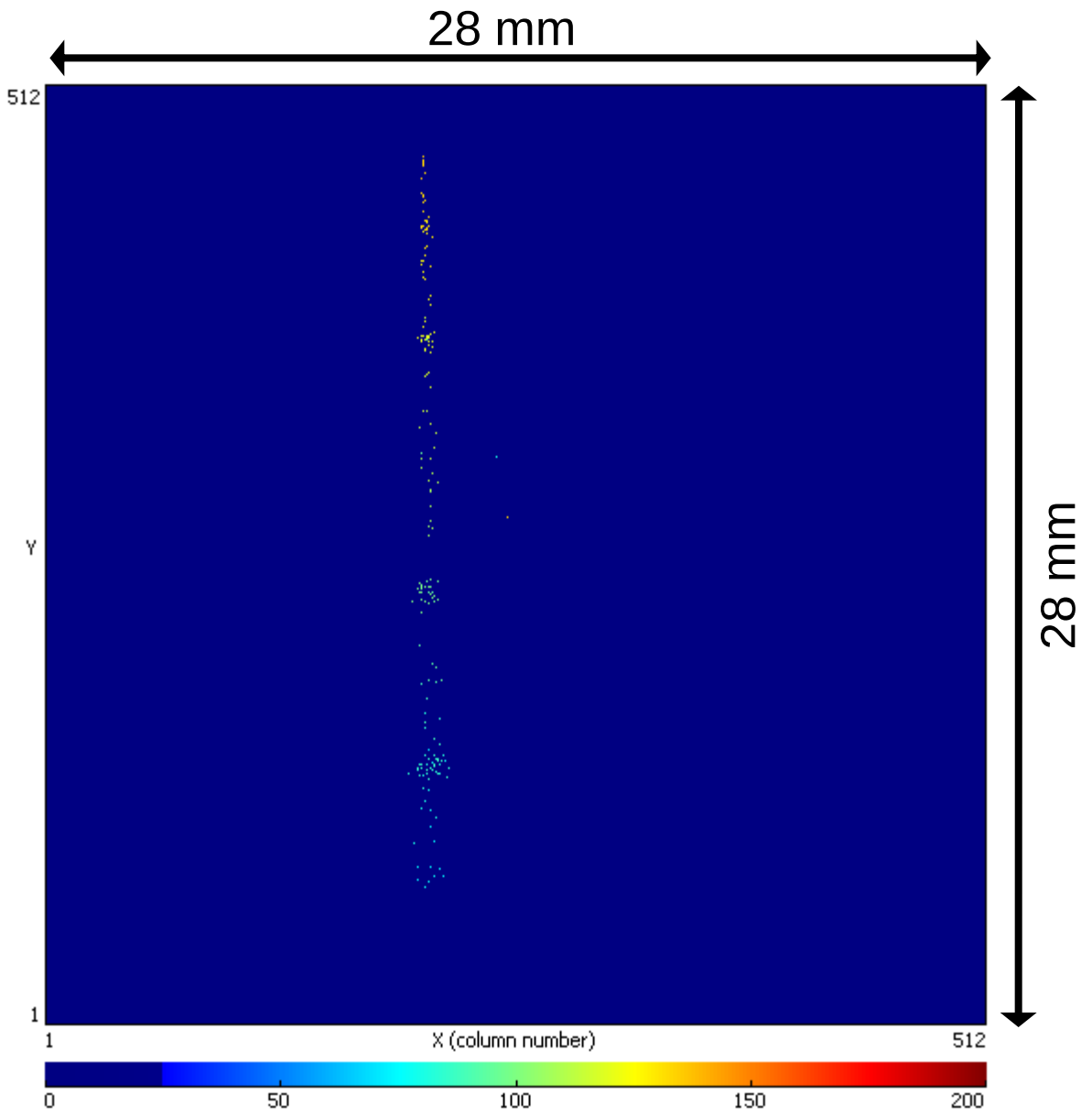
[1] Max Chefdeville, Development of Micromegas-like gaseous detectors using a pixel readout chip as collecting anode

Few tracks from ~3-day test at DESY with NIKHEF 4x Ingrid detector (March 2010)

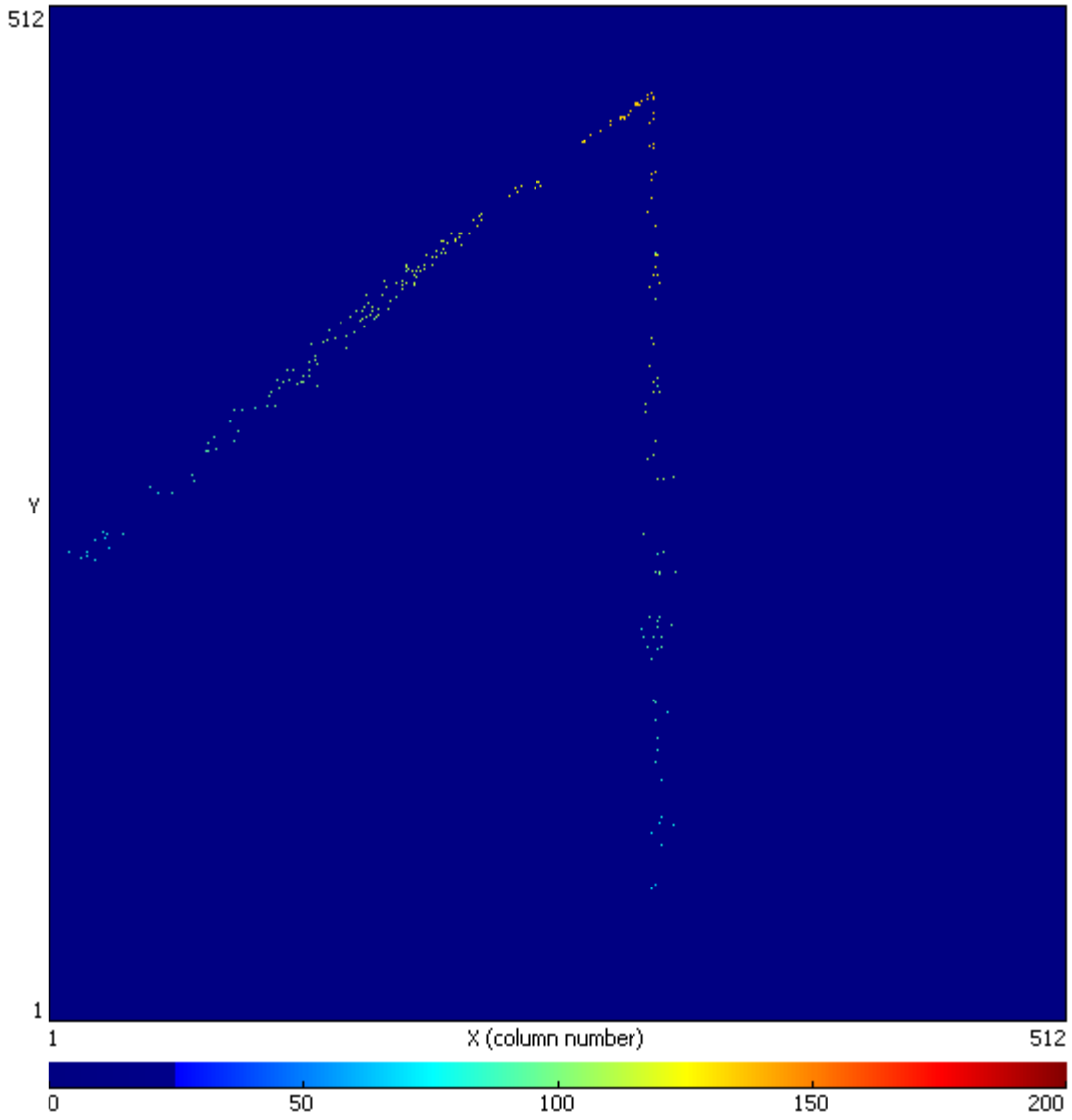


Gas: He-iC_4H_{10} 80/20

A normal track



Track backscattering from chip (=anode)



Handshaked Pixelman operation

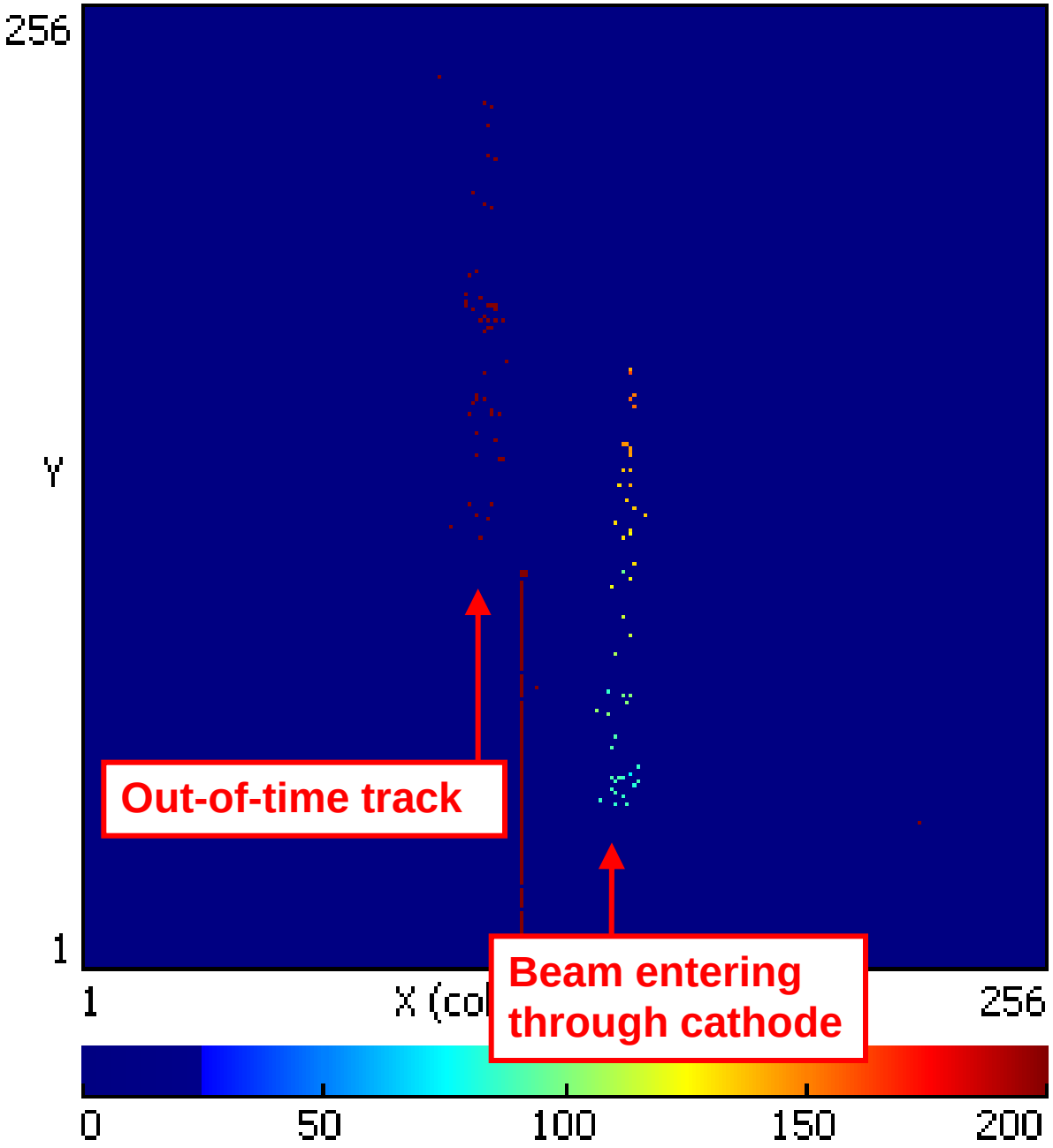
based on Uwe Renz Pixelman plugin

Work performed with Uwe Renz (and Martin Killenberg support) and with DESY summerstudent Bonnie Chow

Detector used is the (2009) “8 um” Ingrid

Some events …

- Handshaked mode
- Early shutter opening, so you will see “out-of-time” tracks
- He/iC_4H_{10} 80/20
- E_{drift} = 450 V/cm
- V_{grid} = 420 V


256
Y
1
Out-of-time track
Beam entering through cathode
1
X (co
256
0
50
100
150
200

Common data taking with Zeus MVD telescope on 8 Sept. 2010

- Using TLU for TRIGGER and BUSY synchronisation
- Writing of data using EUDAQ with Pixelman Timepix Data Producer plugin and Timepix Data Collector in EUDAQ computer
- Data transfer via TCP-IP
- ~ 4000 triggers written
- Possible problem still with “Endianness”
- Analysis awaiting

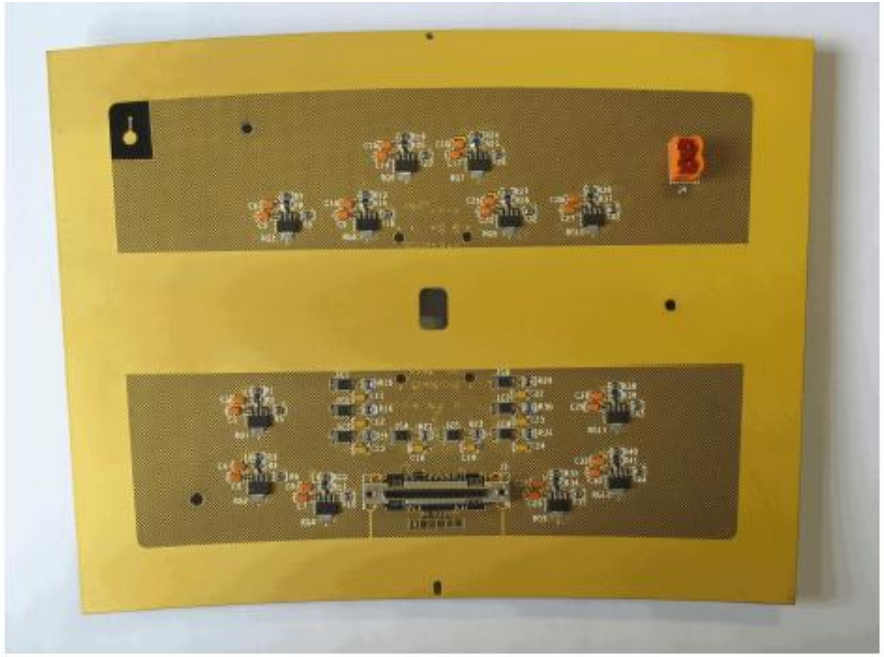
irfu

cea

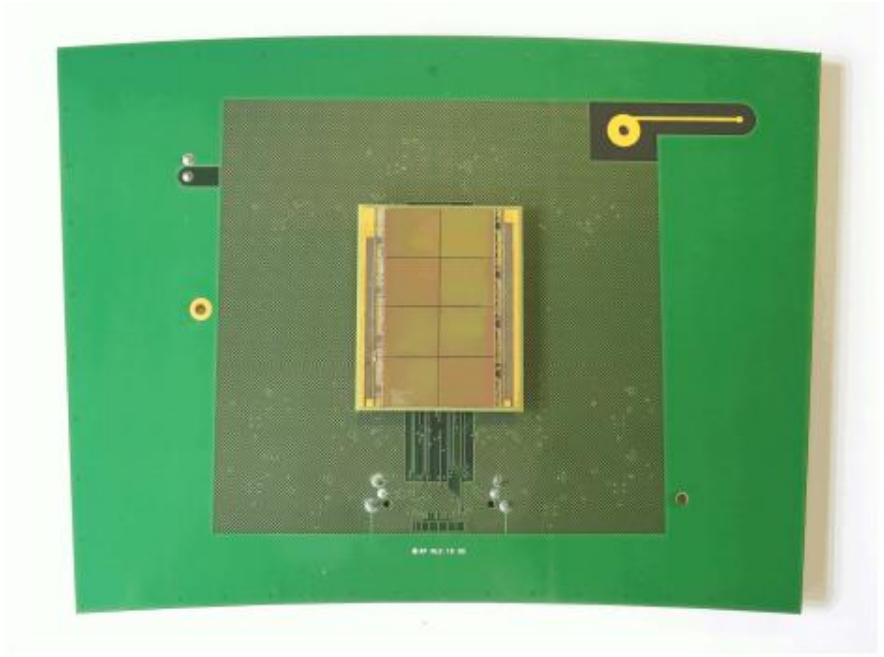
saclay

Design and operation of an 8-TimePix chip TPC Endplate

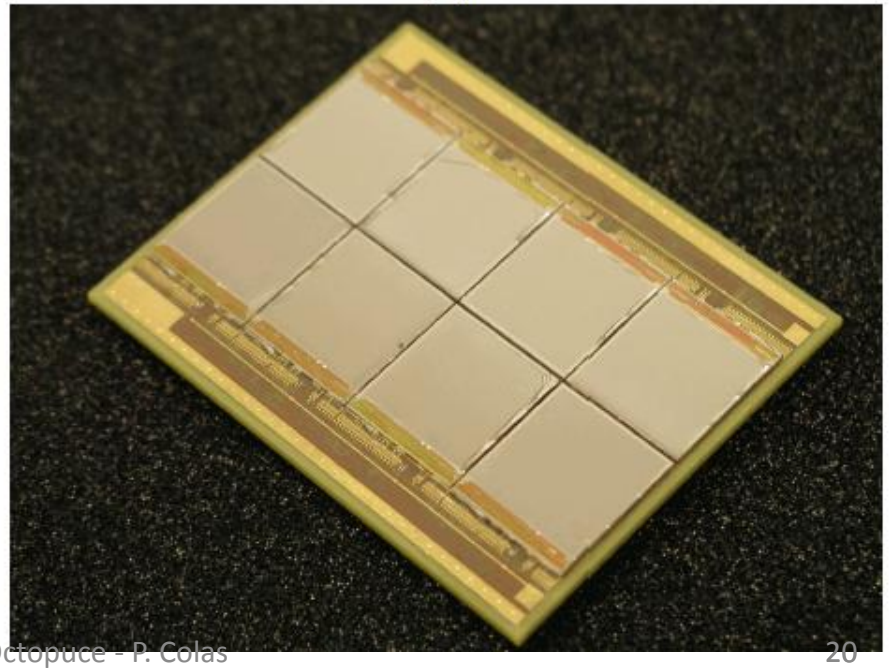
D. Attié, P. Colas, X. Coppolani, E. Delagnes, M. Lupberger, M. Riallot



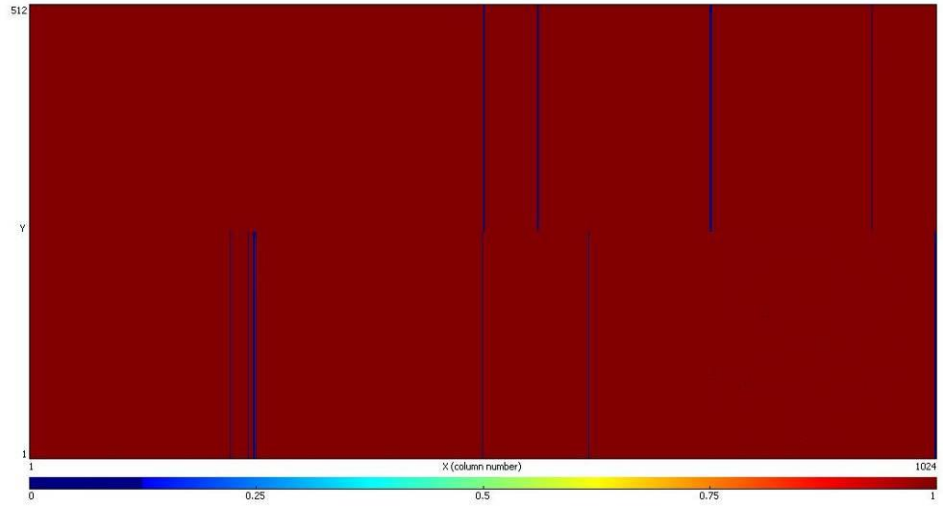
(1)



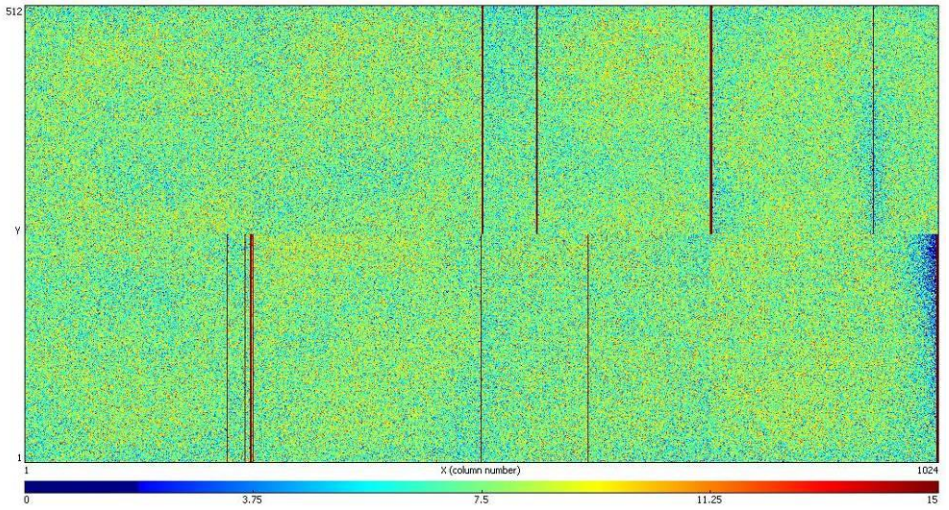
(2)



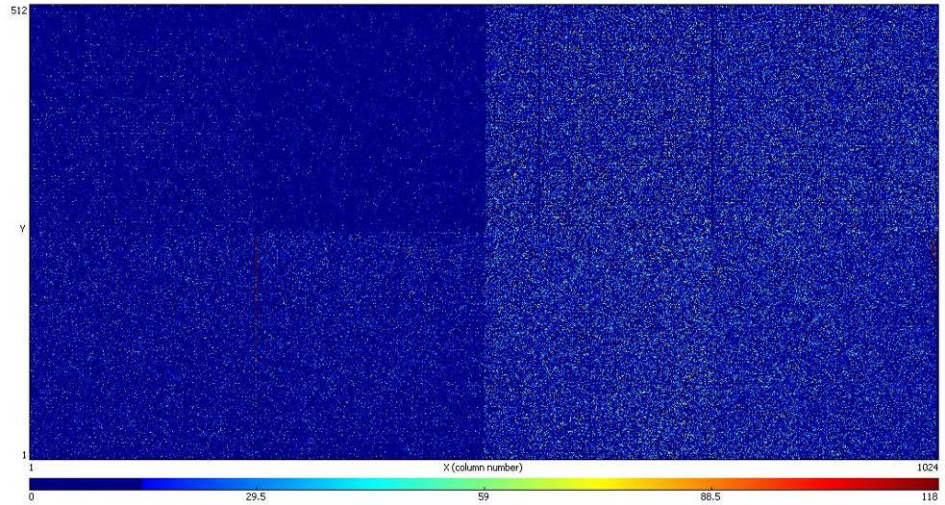
18.05.2010: all 8 chips detected on board and electronically tested
Images from Pixelman



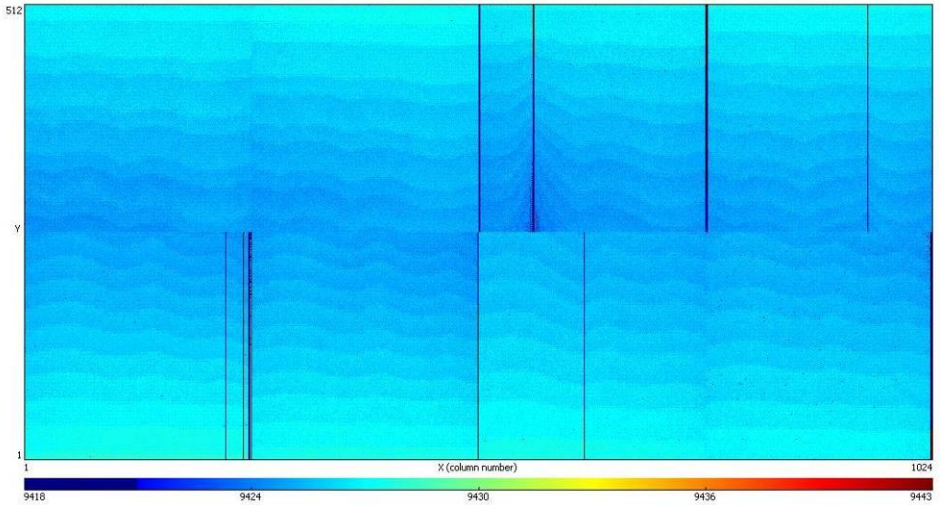
Mask map:4352 pad pixels⇒519937 channels



Threshold adjustment map

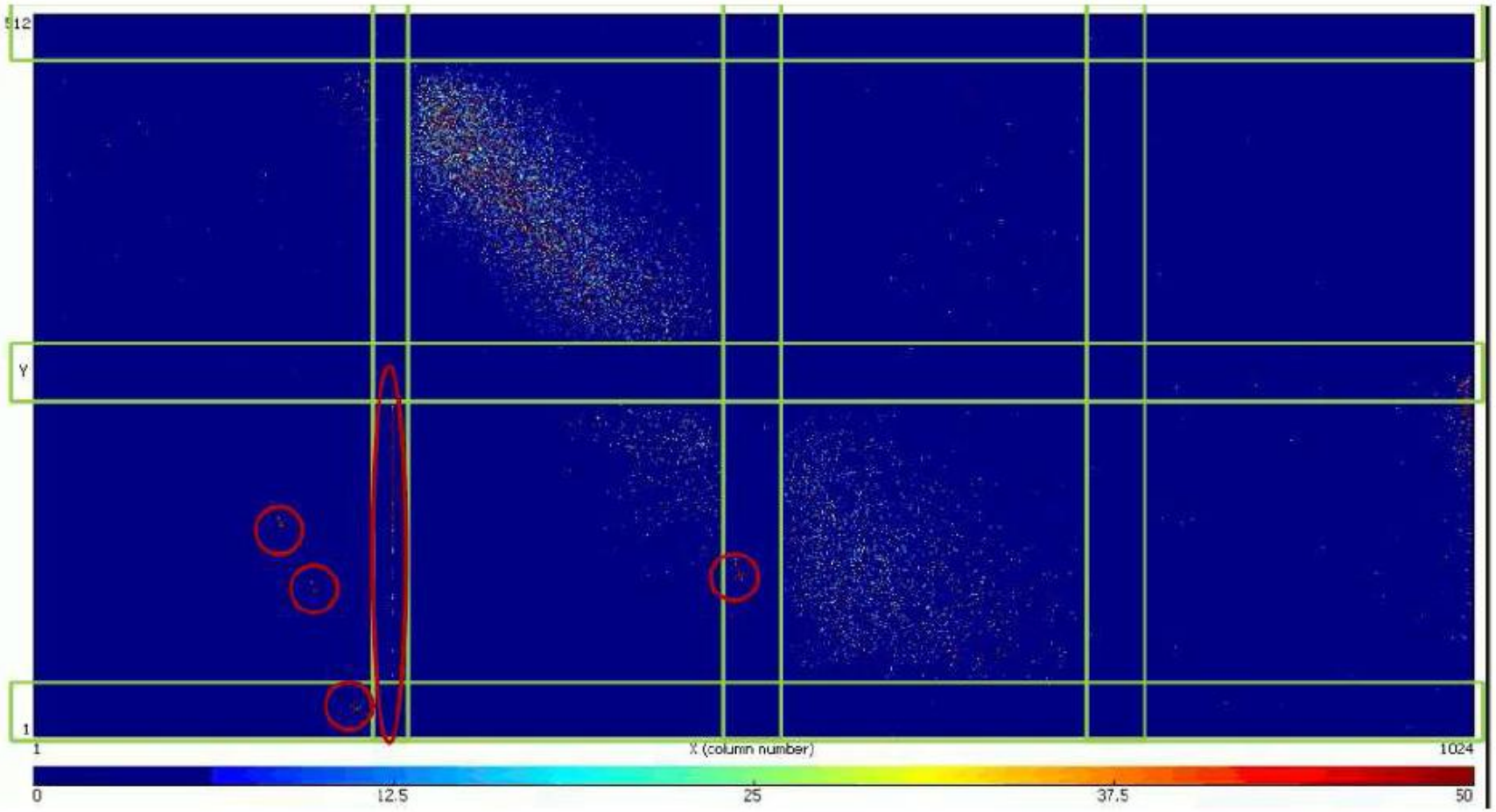


Noise (different threshold for chips to see them)

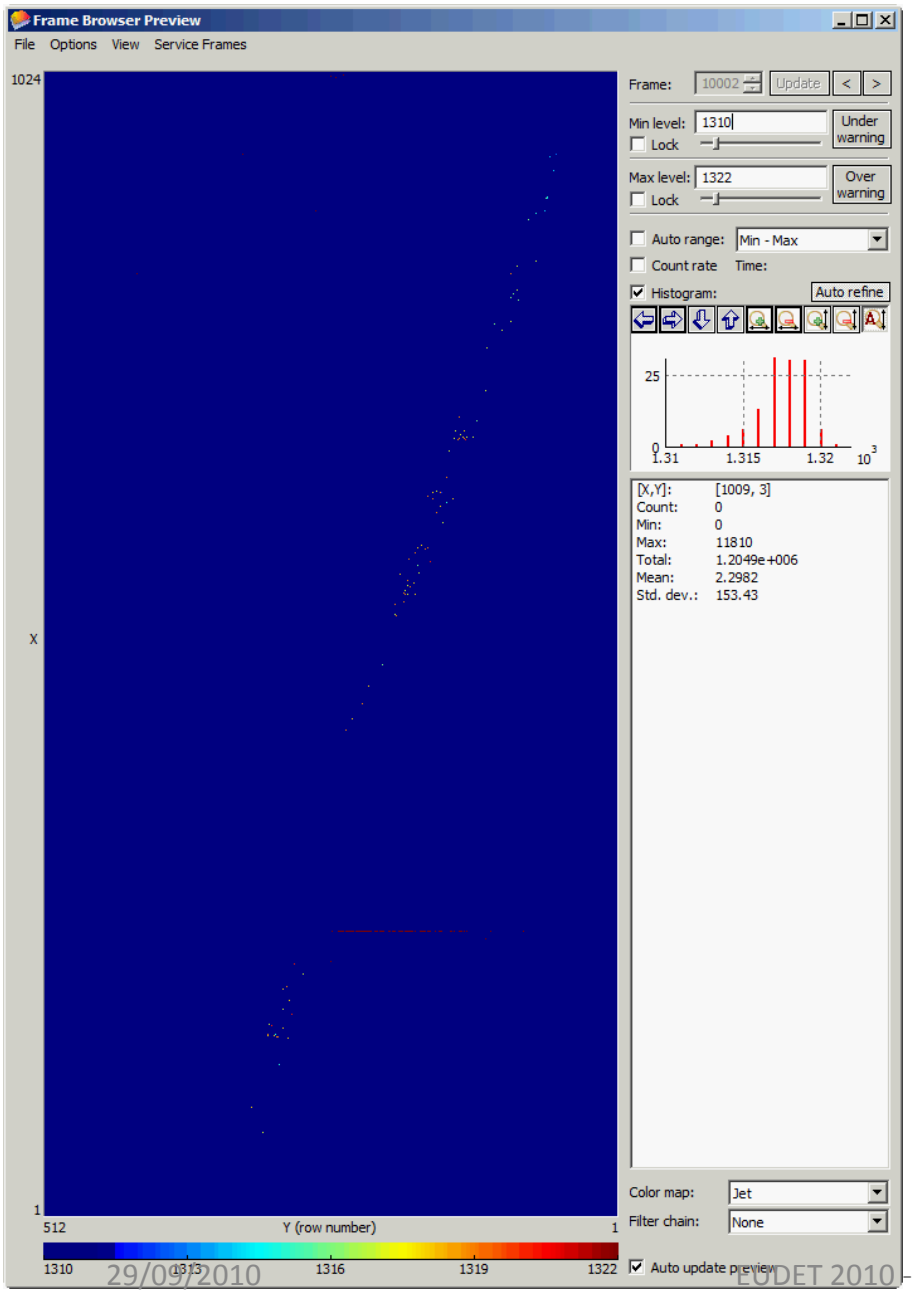


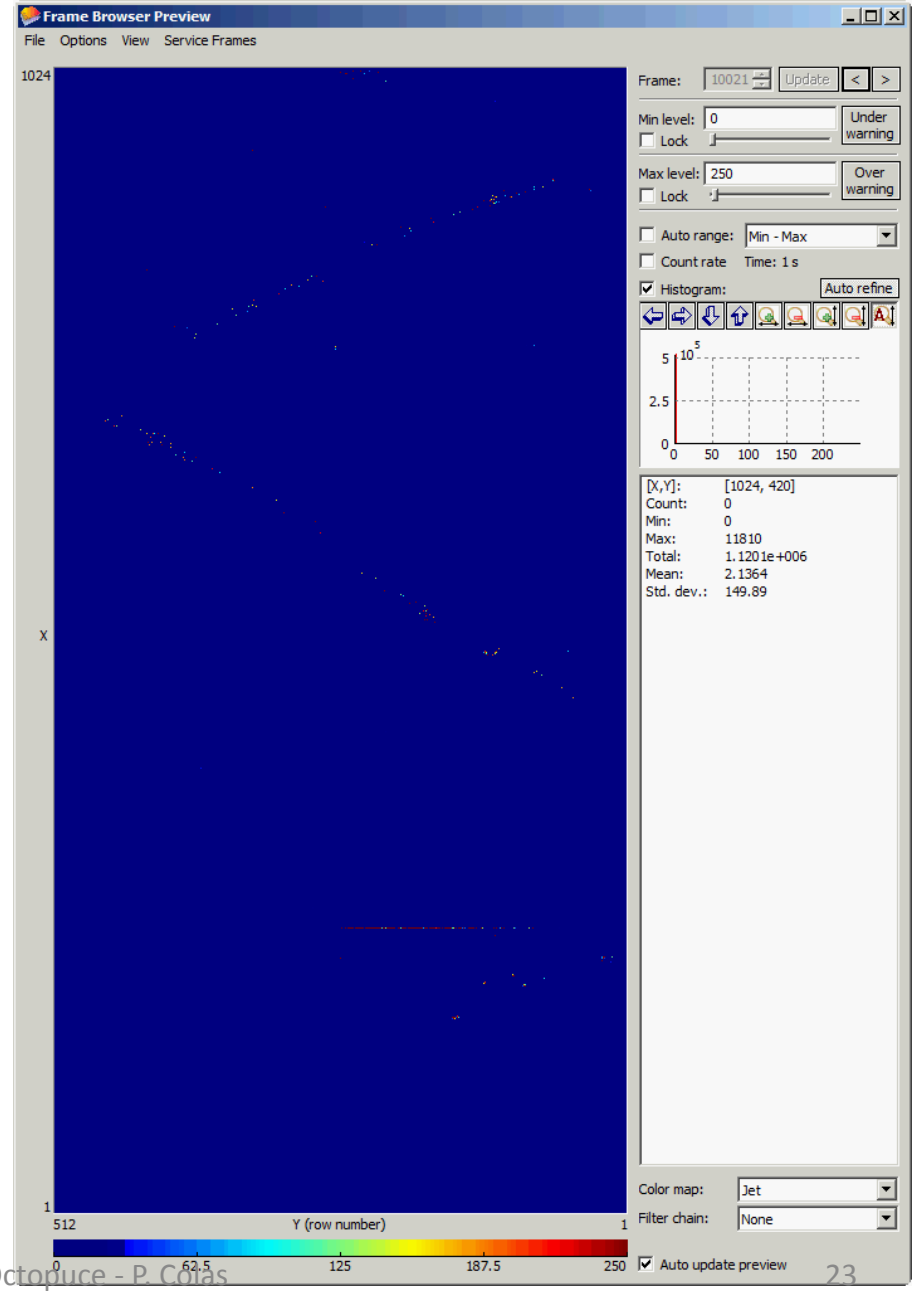
Test pulses in TIME mode

An alpha particle in the octopuce with Ar+5%isobutane at 275 V



Data taken in He + 20% isobutane at 375 V

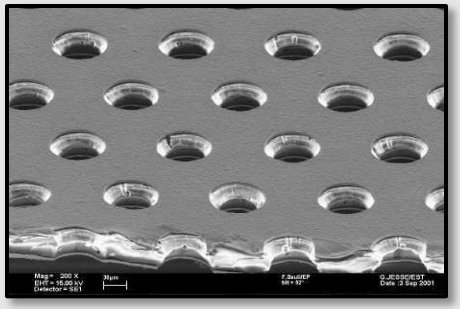


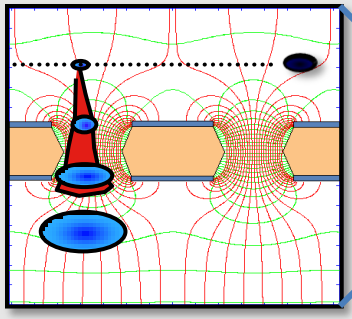


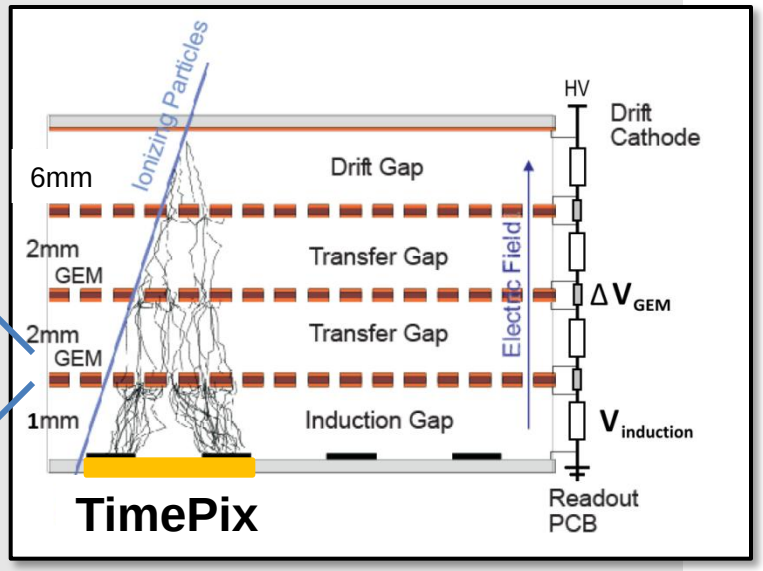
Some results presented at meetings earlier in 2010

Test Setup

GEM Setup





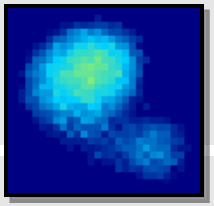


GEM+TimePix

charge is spread over *several pixels* *(>50)*

Consequences

- few e^- per channel (strong diffusion effects within the GEM-stack)
  high gas gain necessary for detection of *MIPs*



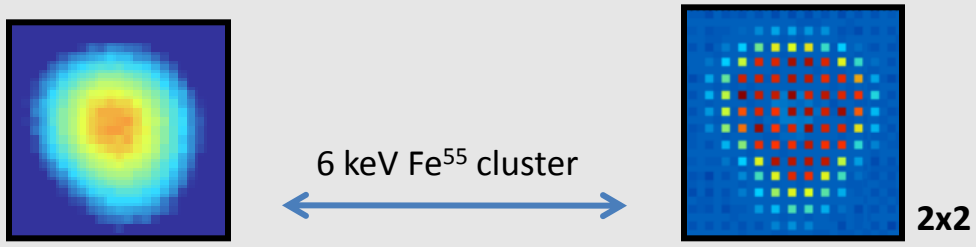
Post Processed chips

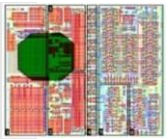
Postprocessed chips (IZM)

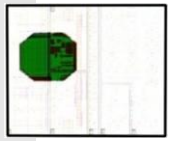
- **1x1:** metallization extended from ≈20x20 µm² to ≈50x50 µm²
- **2x2:** 3 of 4 pixels passivated, then metalized pixel size 105x105 µm²

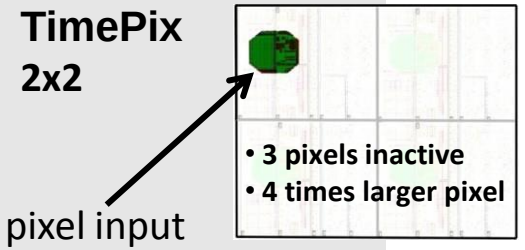
Motivation: enlarged pixels

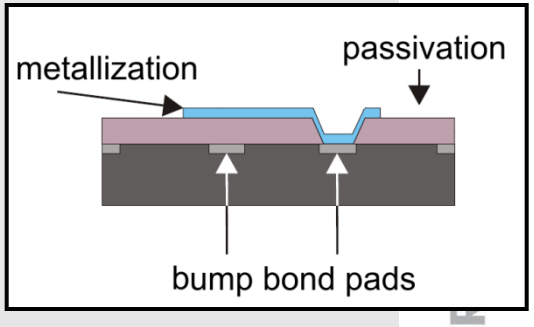
- more charge per pixel
  → higher probability of detection
- less gas amplification needed → fewer positive Ions
- optimization of spatial resolution vs. pixel size











profile of postprocessed pixels

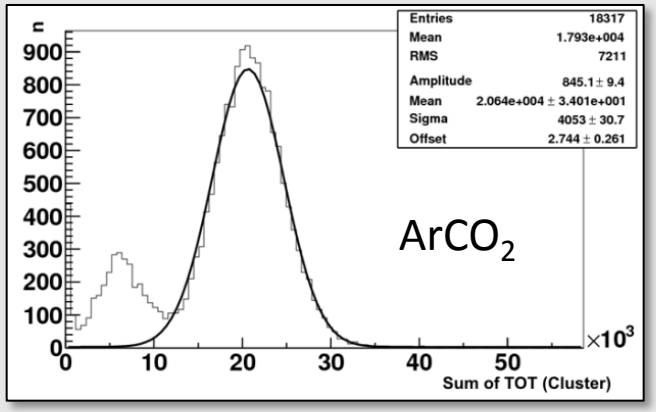
universitätbonn

UNI FREIBURG

Gain studies and Crosstalk

Setup

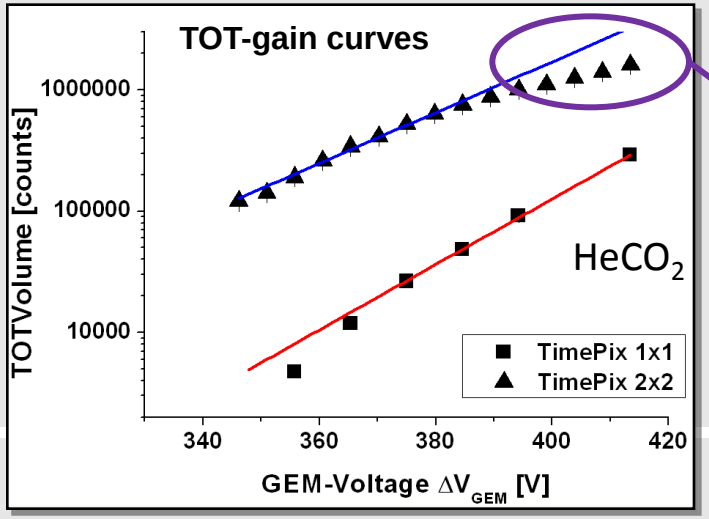
- gas: $HeCO_2$/ Fe55 (6 keV photons)
- 1x1 and 2x2 with similar thresholds

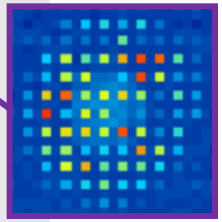


Procedure

- find clusters
- sum up the *TOT* values of the pixels (TOT - counts clock cycles above a chosen threshold)
- fit gauss (peak)
- take mean = *TOTVolume*

drop caused by crosstalk of pixels





Fe55-source
Volt./GEM: 385V
2x2 all pixels

Conclusion

with pixel enlargement:

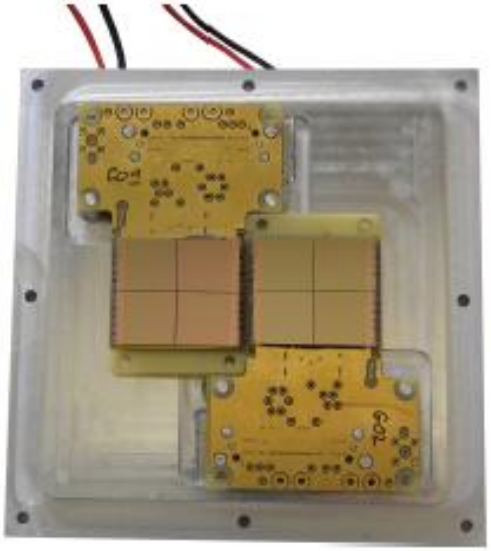
→ less gas gain needed

Detector Module

Bonn + Freiburg

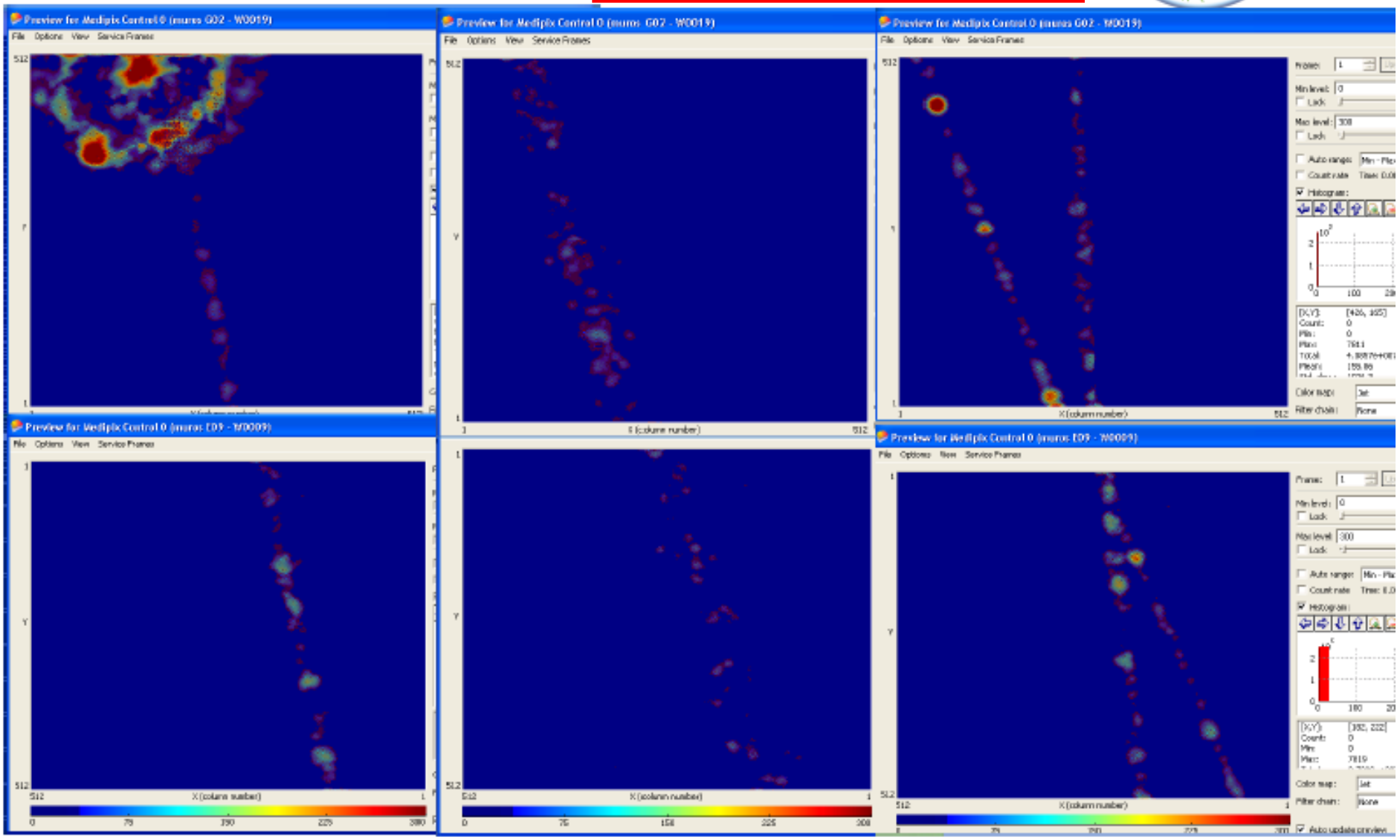
Gas Amplification Stage: stack of 3 GEMs
Readout: 8 Timepix chips + 2 MUROS
Gas Mixture: He:CO_2 70:30 and Ar:CF_4:iButan 95:3:2

A large set of data was taking varying the track inclination, particle momentum, drift distance, gas gain and magnetic field.



Example Tracks

Bonn + Freiburg



Drift Distance 10 cm

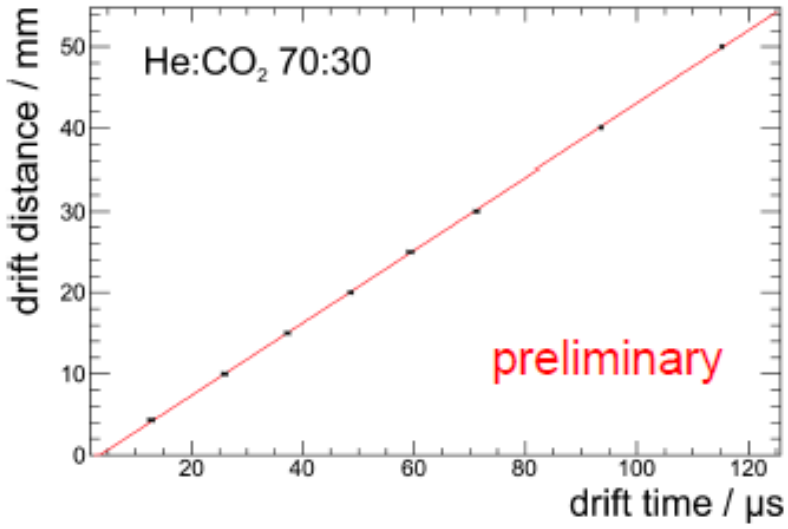
Drift Distance 50 cm

Drift Distance 4 cm

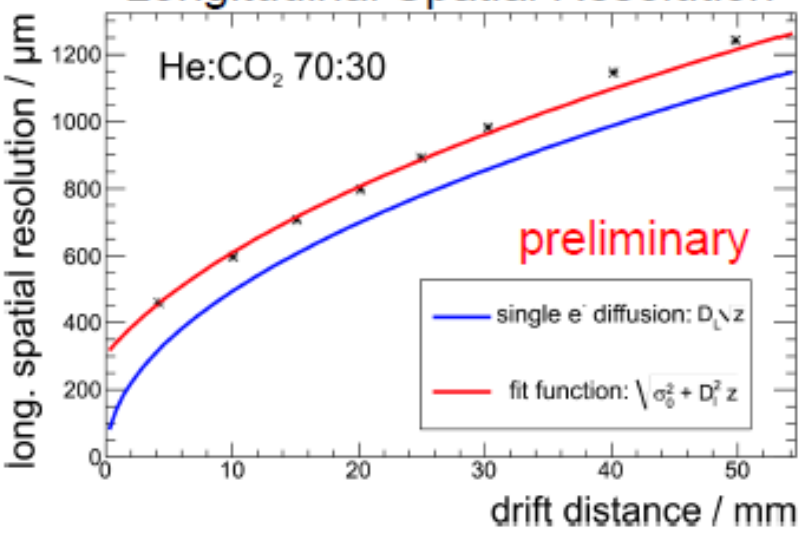
Results

Bonn + Freiburg

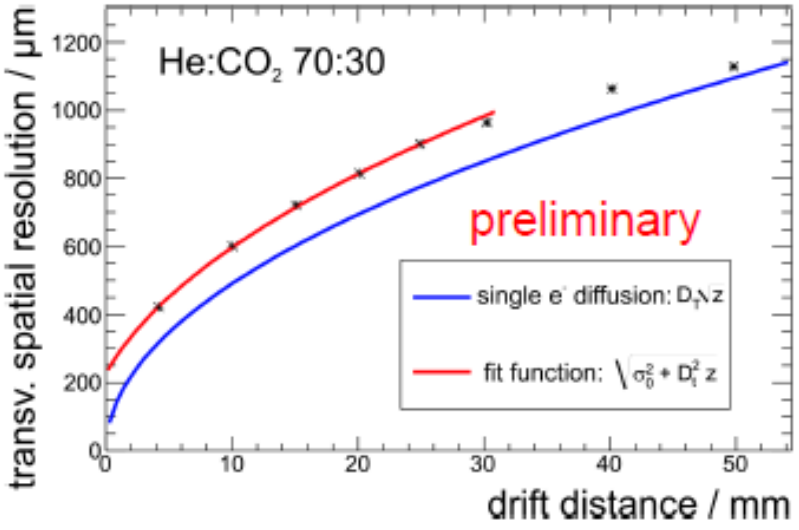
Determination of Drift Velocity

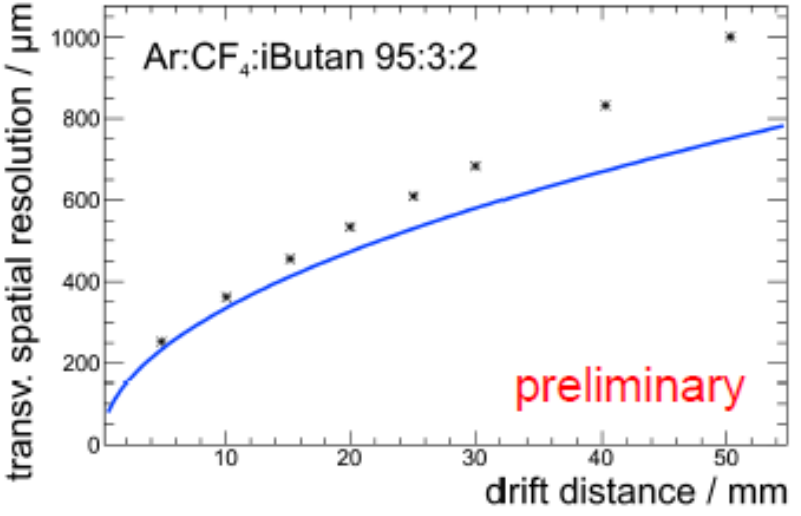


Longitudinal Spatial Resolution



Transverse Spatial Resolution





Outlook

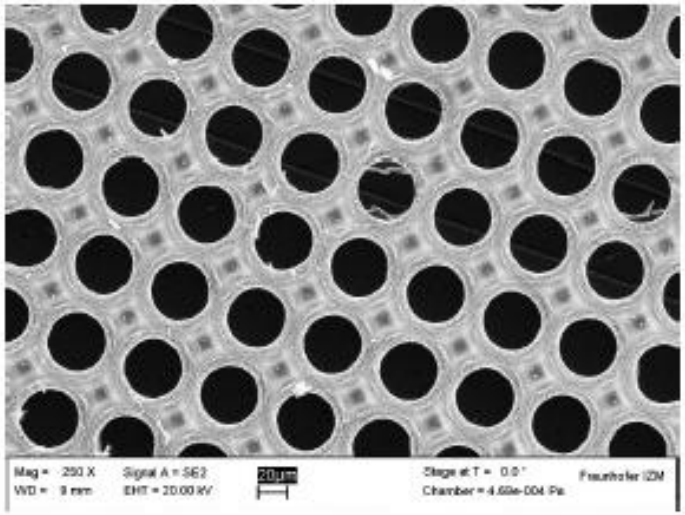
Bonn + Freiburg

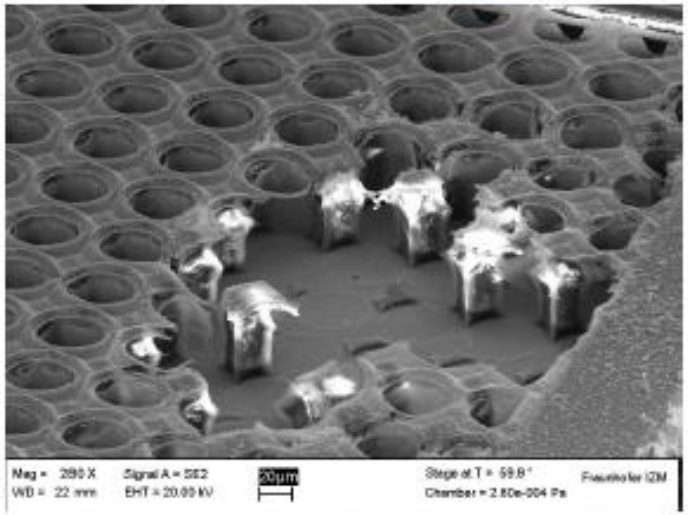
Detector was damaged after last run.
Repair work has been finished,
the chips are now being calibrated,
the detector will be reassembled soon and then shipped to DESY.

Another test beam campaign is under consideration to benefit from the improved LP setup.
(i.e. get rid of magnetic field inhomogeneities)

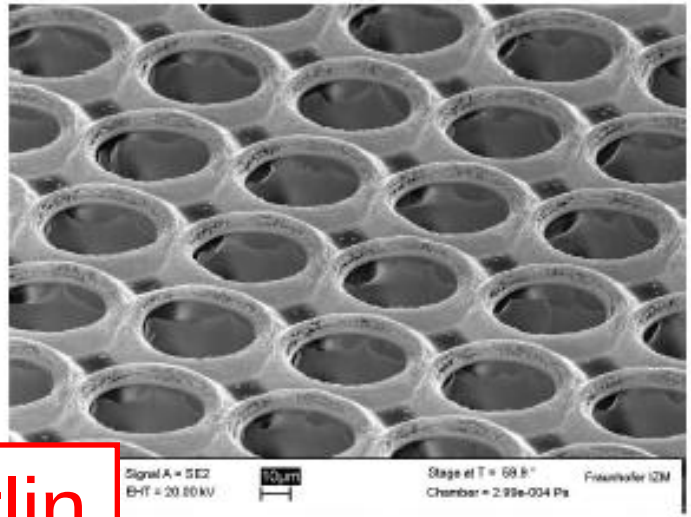
SEM-Pictures of First Dummies

GEMGrid





Pitch of the holes is 55 µm.

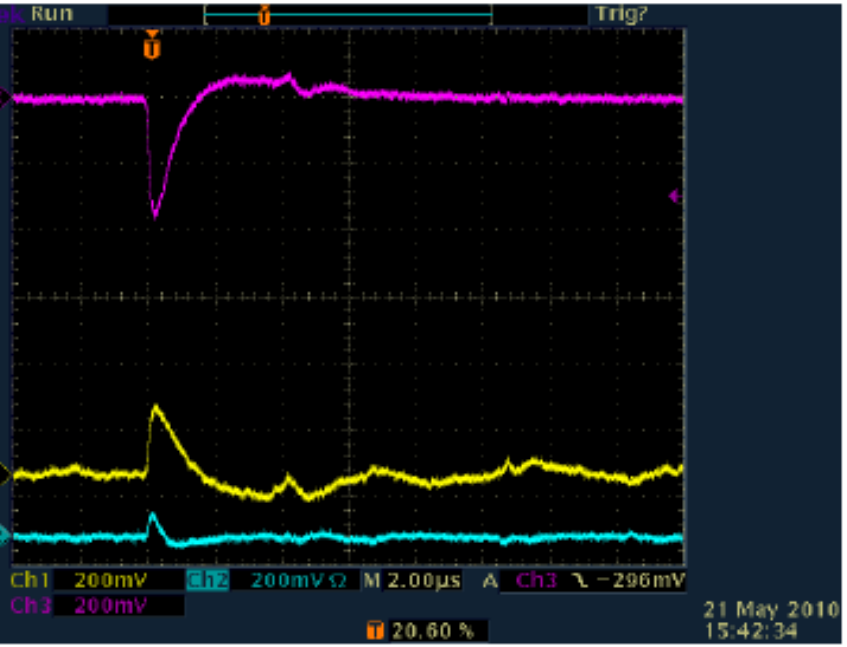


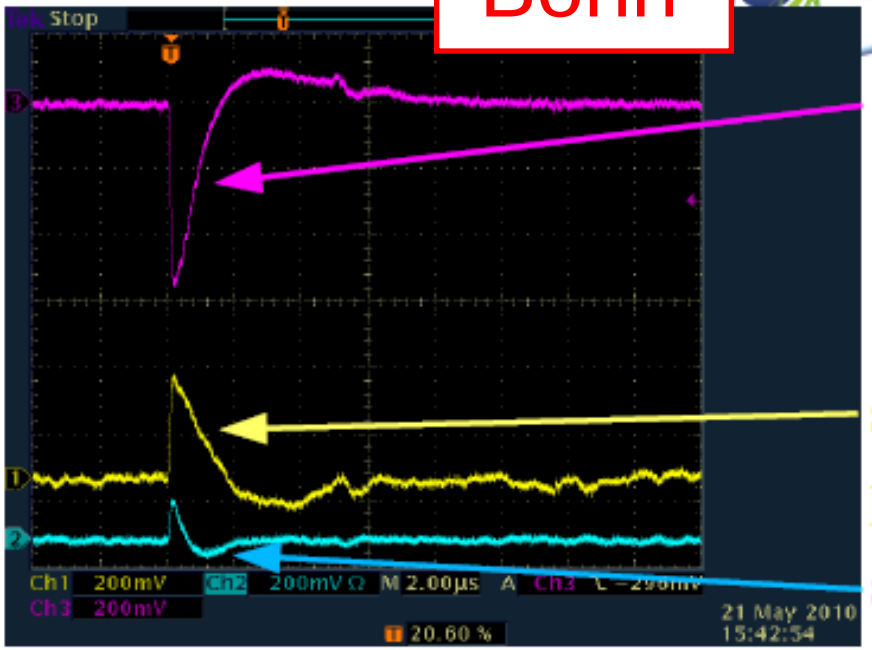
Small walls (2-3 µm) around the holes.

Bonn + IZM Berlin

First Signals with ^{90}Sr-source

Bonn

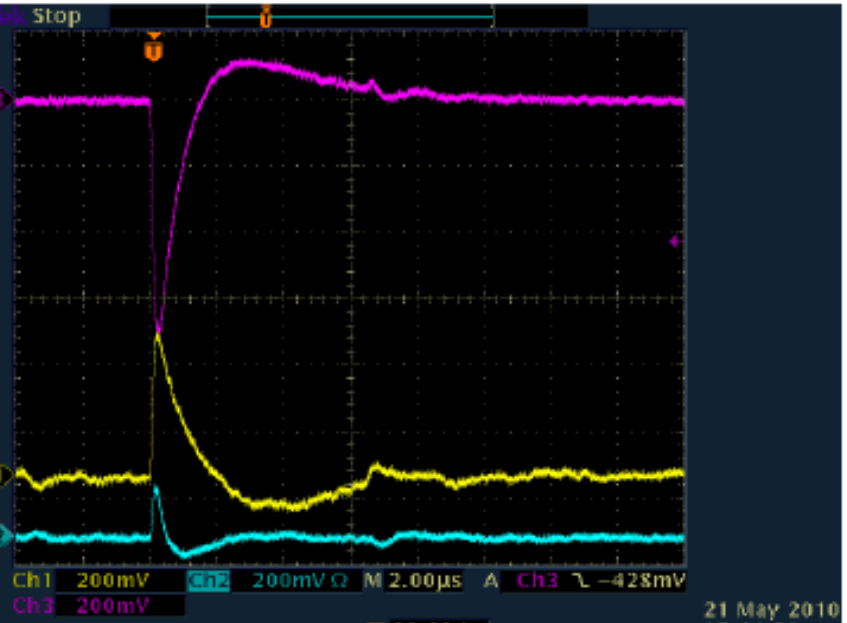


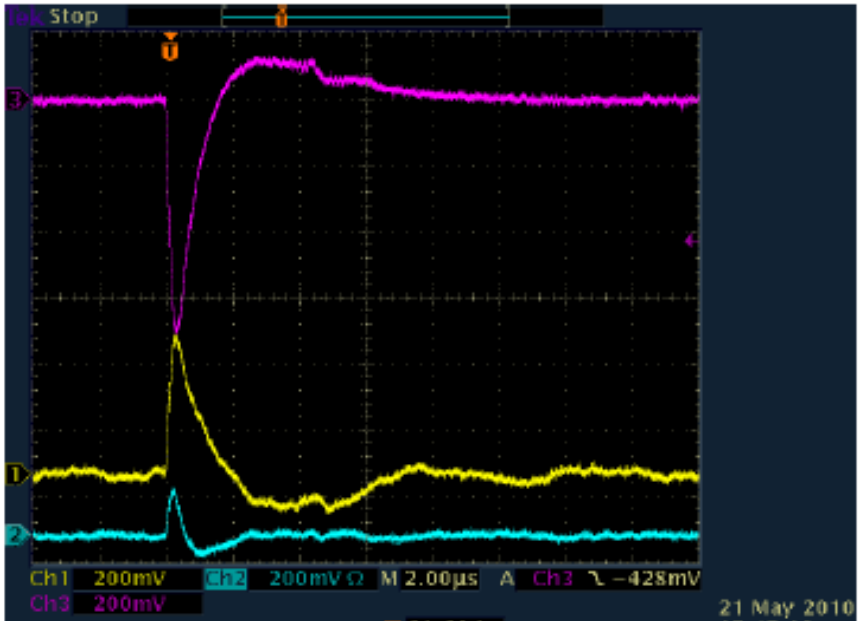


signal o
grid

signal o
pad

signal o
ring

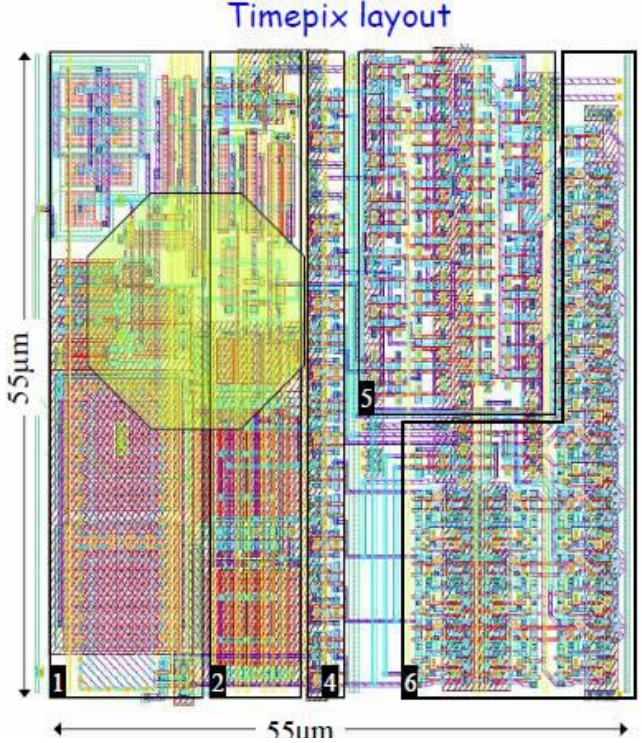




Rate
highly
correlate
with rad
source!

Summary of highlights

(the “deliverables”)



Full post-processing of a TimePix

· Timepix chip + SiProt + Ingrid:

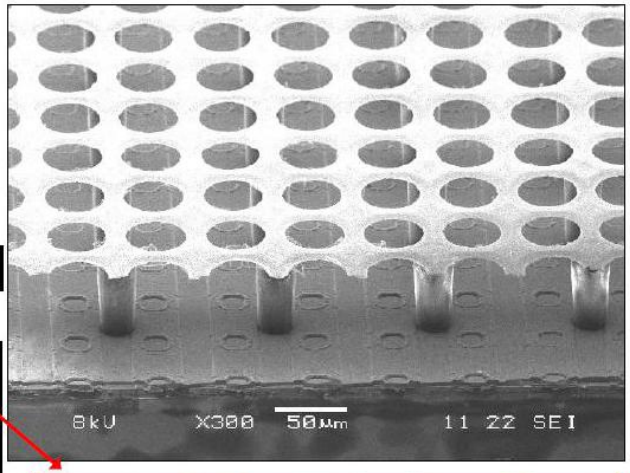
Timepix chip:

- 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



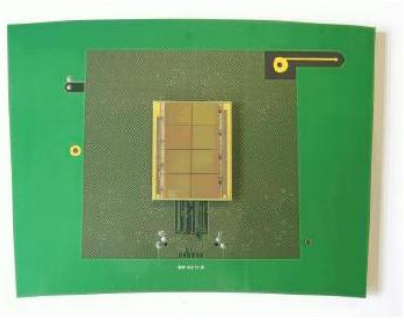
Now also Si_3N_4 protection layers (7 µm)

Detector Module

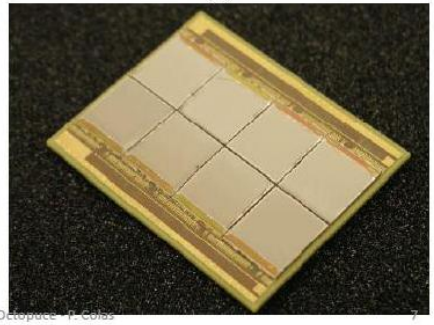
Gas Amplification Stage: stack of 3 GEMs
Readout: 8 Timepix chips + 2 MUROS
Gas Mixture: He:CO_2 70:30 and Ar:CF_4:iButan 95:3:2

A large set of data was taking varying the track inclination, particle momentum, drift distance, gas gain and magnetic field.

(1)



(2)



Conclusions

- EUDET-SITPC final infrastructure available for 3-GEM + 8 Timepix chips. New test at LP foreseen in fall 2010.
- LP module with 8 Timepix+Ingrid chips produced. Some HV problems with Ar mixtures. Operational with He/iC4H10. Test at LP late(?) 2010.
- Quad-Ingrid detector for standalone tests having readout problems; being investigated.
- All (or most) EUDET money is spent; some groups ‘overspent’ own contribution.
- Longer term: working on larger systems of 64 and 119 chips for Ingrids and GEMs or GEMGrids.
- Despite some problems, consider JRA2/SITPC very successful.