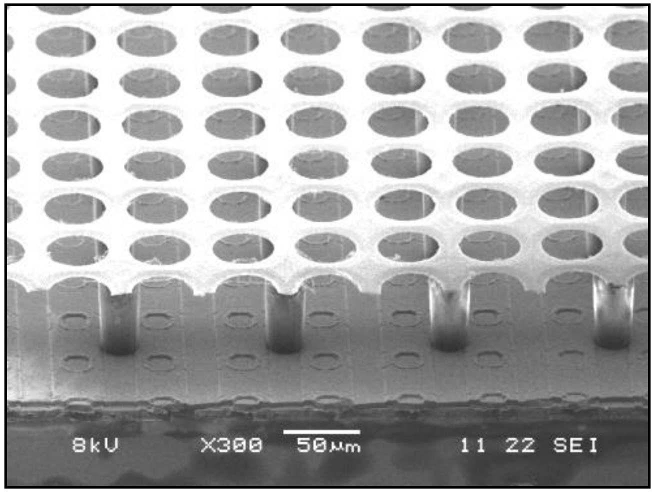
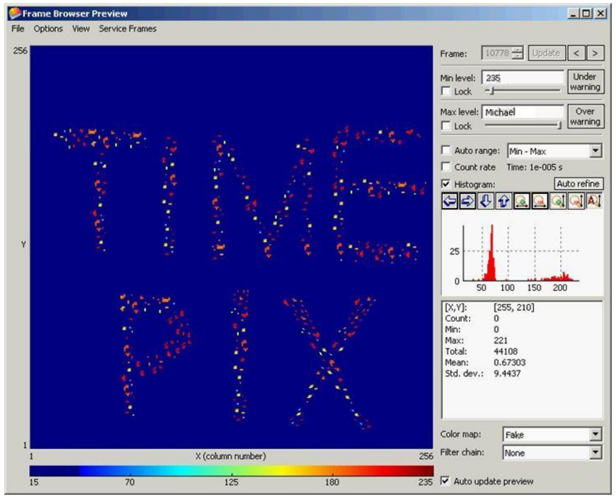




Study of gain fluctuations with InGrid and TimePix

Michael Lupberger

5th RD51 Collaboration Meeting

24-27 May 2010 Freiburg, Germany

Summary

- Hardware
  - Timepix Chip + InGrid
  - Experimental setup and calibration

- Fe55 Spectra
  - Resolution and Fano factor
  - Efficiency: Electron counting
  - Efficiency: Gain/Threshold

- TimeOverThreshold measurements
  - TOT spectra and Polya fits
  - Gain measurements
  - Influence of SiProt

- 8 Chip panel

Hardware

The Timepix Chip

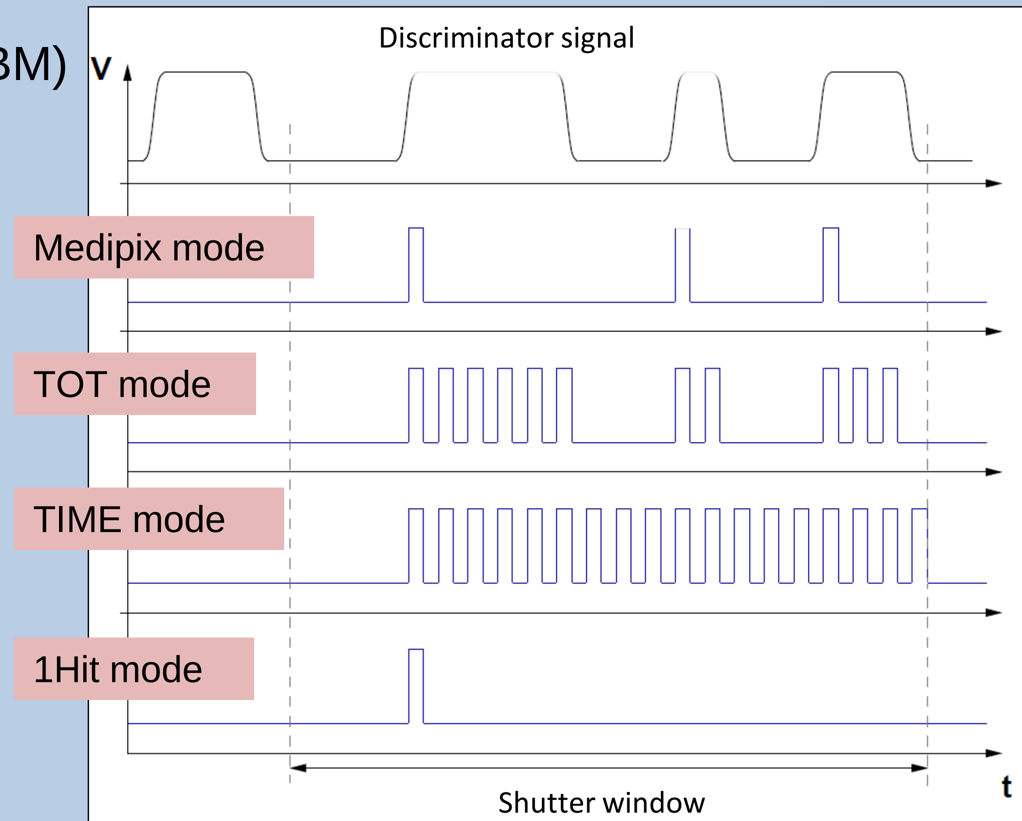
A modified MediPix2 Chip for TPC applications

Characteristics :

- 1,4 x 1,4 cm²
- matrix of 256 x 256 pixels (CMOS, IBM)
- 55 x 55 µm² per pixel
- Preamplifier/shaper (t_{rise} ~150 ns)

Motivation: knowing the time of arrival of avalanches at pixels
⇒use 14bits for counting clock cycles

- lower threshold
- clock up to 100 MHz in each pixel
- noise threshold ~ 500 e-
- digital output signal
- 4 different modes possible



Hardware

Timepix + Ingrid = Pixelated Micromegas

TimePix+Micromegas:

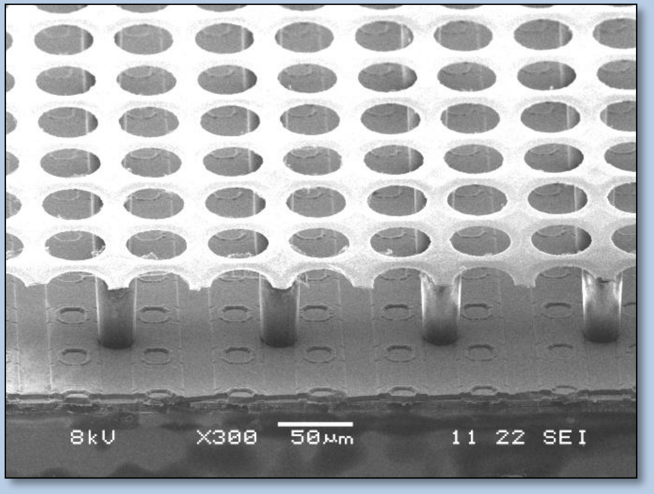
- No alignment between pixels and holes in grid
- pillars visible
- variation of distance between anode and grid
- irregular structure

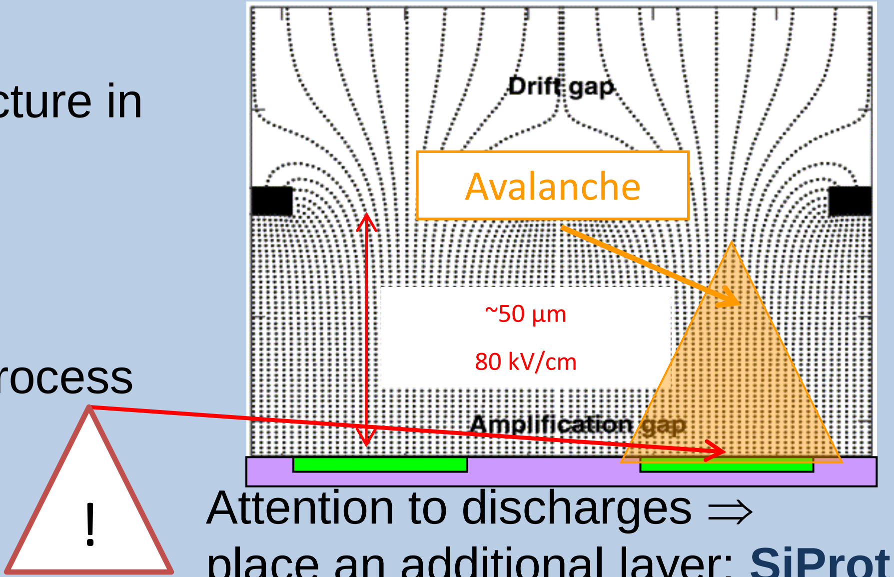
⇒ Gain inhomogeneities, Moiré effect

Solution:

GridPix: TimePix Chip with Micromegas structure in post-production (photolithography)

- alignment of grid
- flat surface
- regular structure
- possibility to vary grid parameters in post-process





Attention to discharges ⇒ place an additional layer: **SiProt**

Hardware

Setup

Gas box, volume: 1,5 l

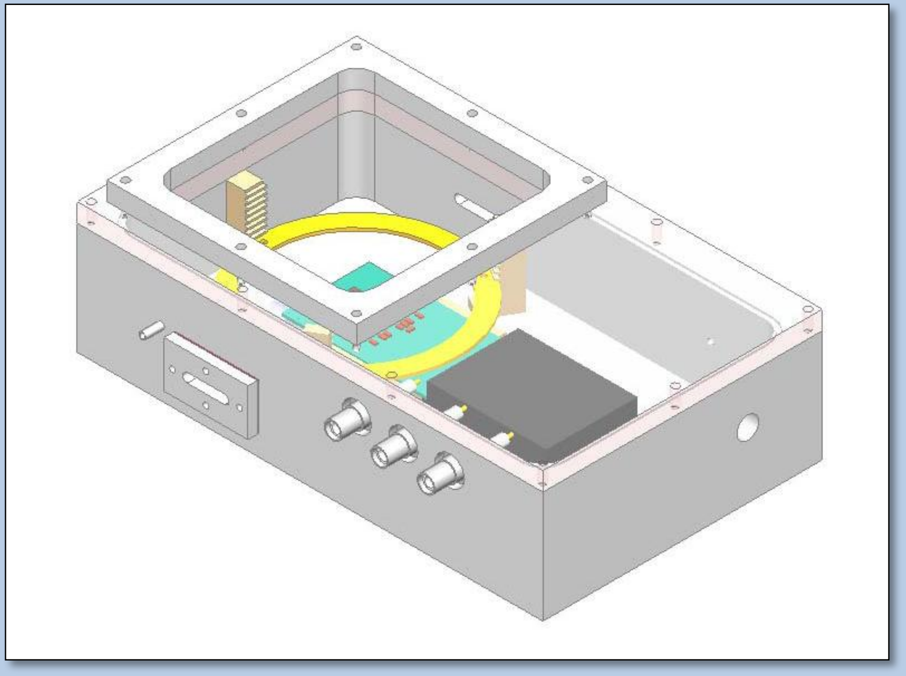
Source: Fe55, directly on cathode

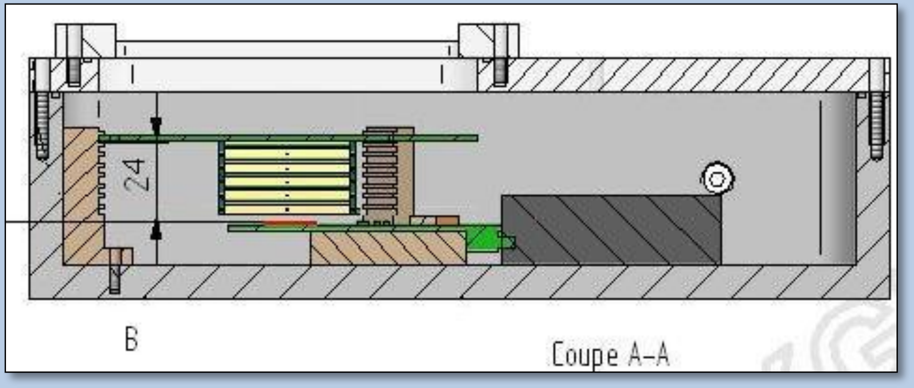
Gas: ArIso 95/5 (ArIso 80/20, P10, CF4)

Readout: MUROS, 36MHz, Pixelman
Filter: > 10 Pixel per Frame

Drift distance: max. 2,4 cm
Amplification gap: 50µm
SiProt: 7µm

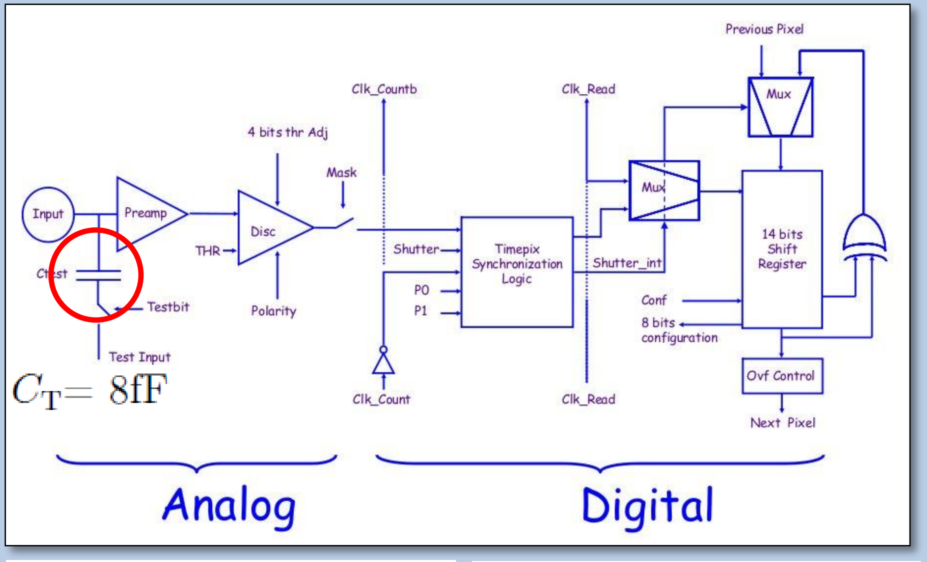
Field degrader
No anode plate around InGrid





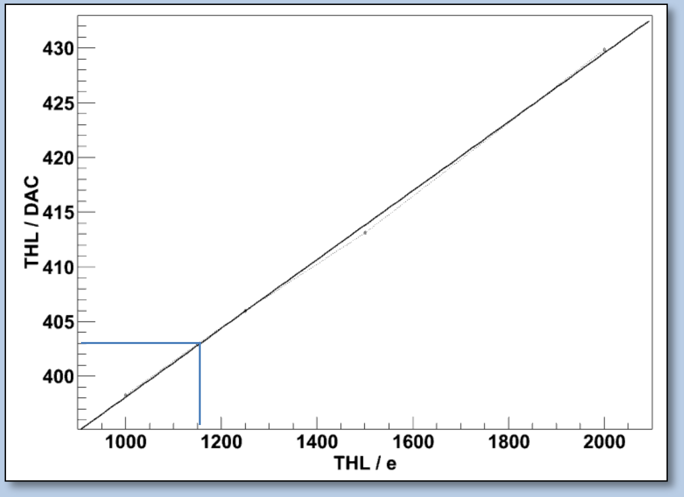
Hardware

Calibration



$$Q_{inj}\,[e^-] = 50 \cdot \Delta U_{inj}[mV] \qquad Q_{inj} = C_T \cdot \Delta U_{inj}$$

Threshold DAC → #e- calibration



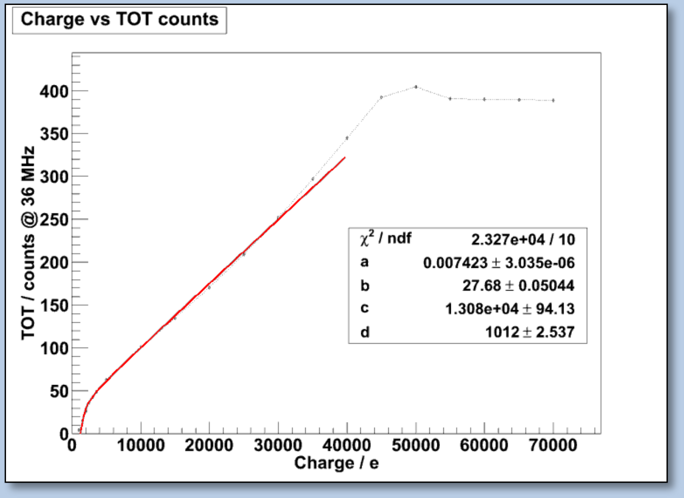
Internal test pulses applied to each pixel via MUROS

→ Known input charge into electronics

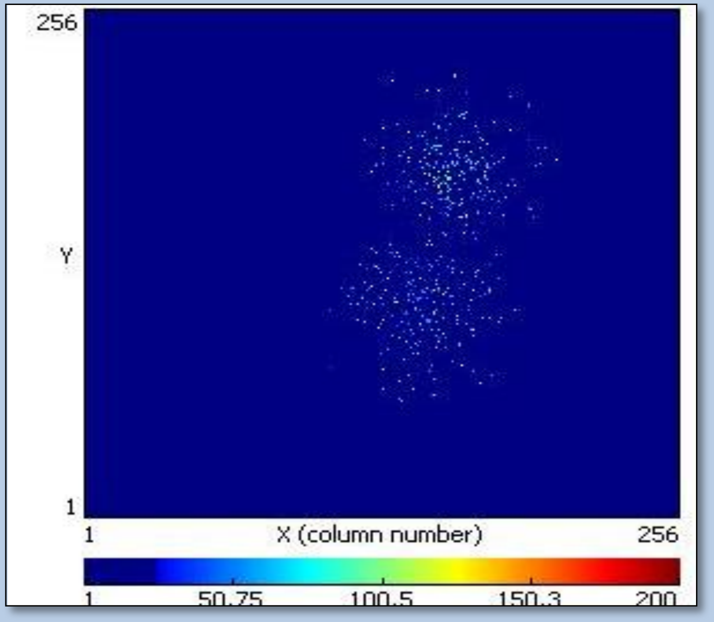
→ Threshold calibration

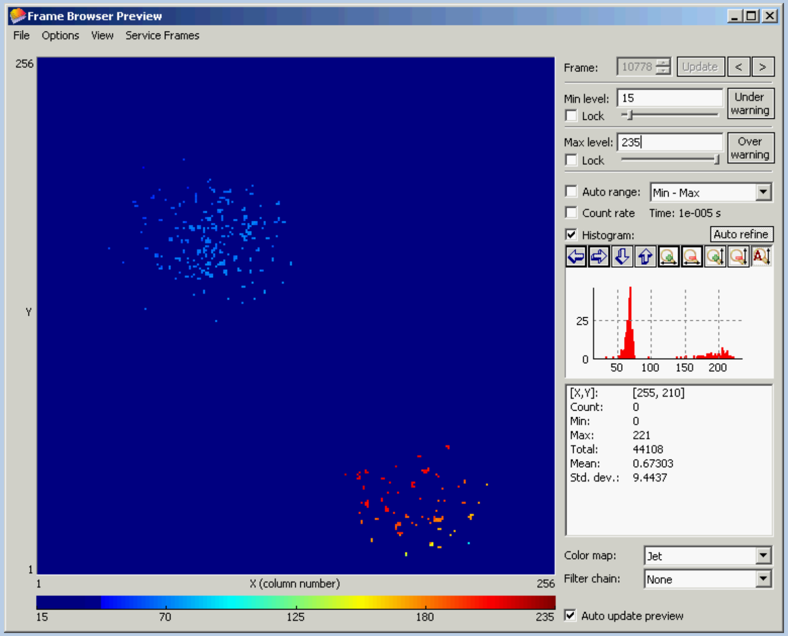
→ TOT calibration !Non linear for low charge

TOT → #e- calibration



Software
Analysis code





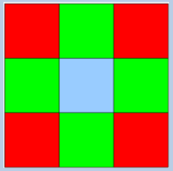
TOT Mode: 1. Check circularity of clouds

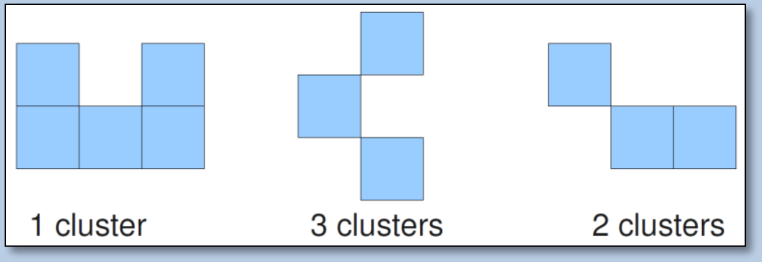
TIME Mode: 1. Separate clouds with time information

2. Check if cloud near center
3. Check cloud size RMS

Find clusters (group attached pixels)

→ Histograms, Fits, TOT to electrons …

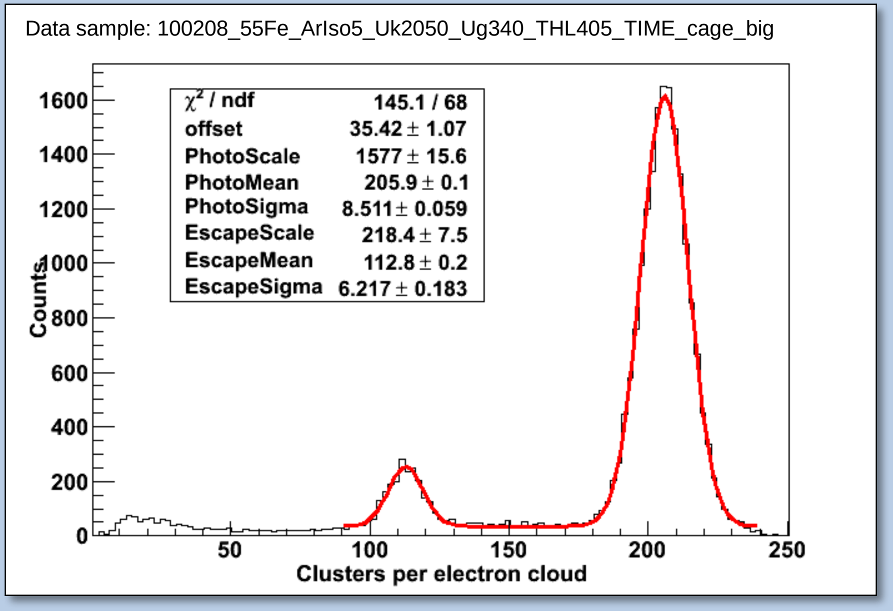




Fe55 Spectra
Resolution

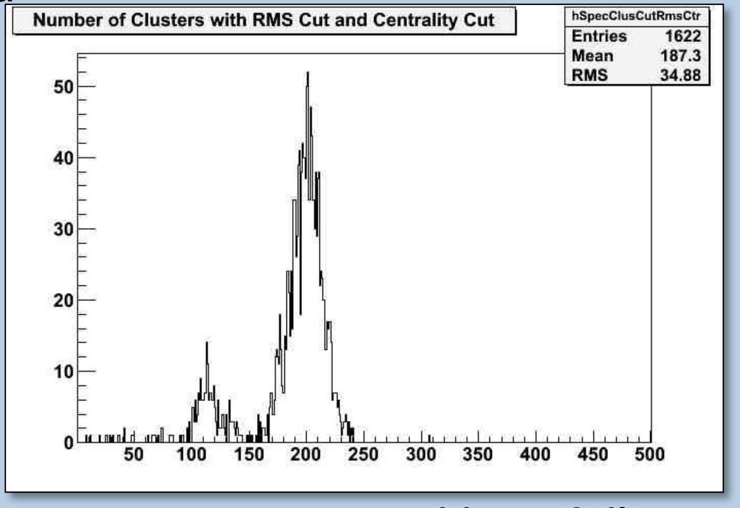
- Count number of hit pixels/clusters per electron cloud
- Chromium foil to absorb K_β photons
- long term measurement and hard cut on cloud size
- best resolution achieved: 4,1% (photo peak)

$$\left(\frac{\sigma_{N_d}}{N_d}\right)^2 = \frac{1}{N_p}\left(F + \frac{1-\frac{N_d}{N_p}}{\frac{N_d}{N_p}}\right) \text{ [1]} \Rightarrow F = 0.28$$

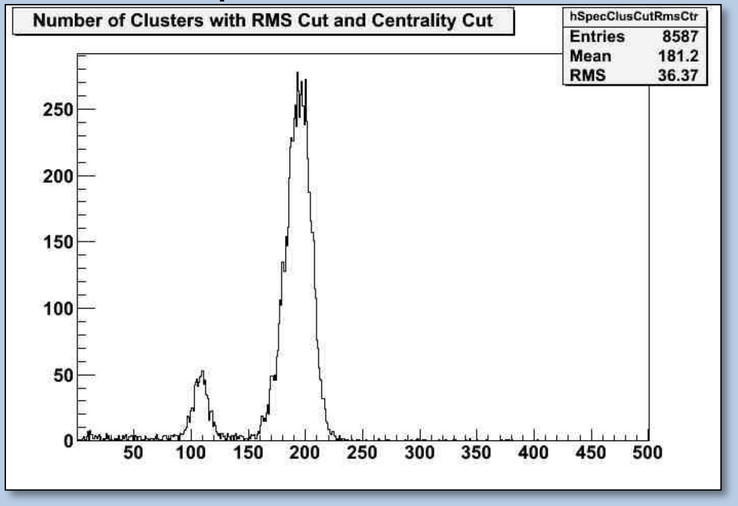


[1] Max Chefdeville, Development of Micromegas-like gaseous detectors using a pixel readout chip as collecting anode

Fe55 spectrum without Cr foil



Fe55 spectrum with Cr foil



Fe55 Spectra

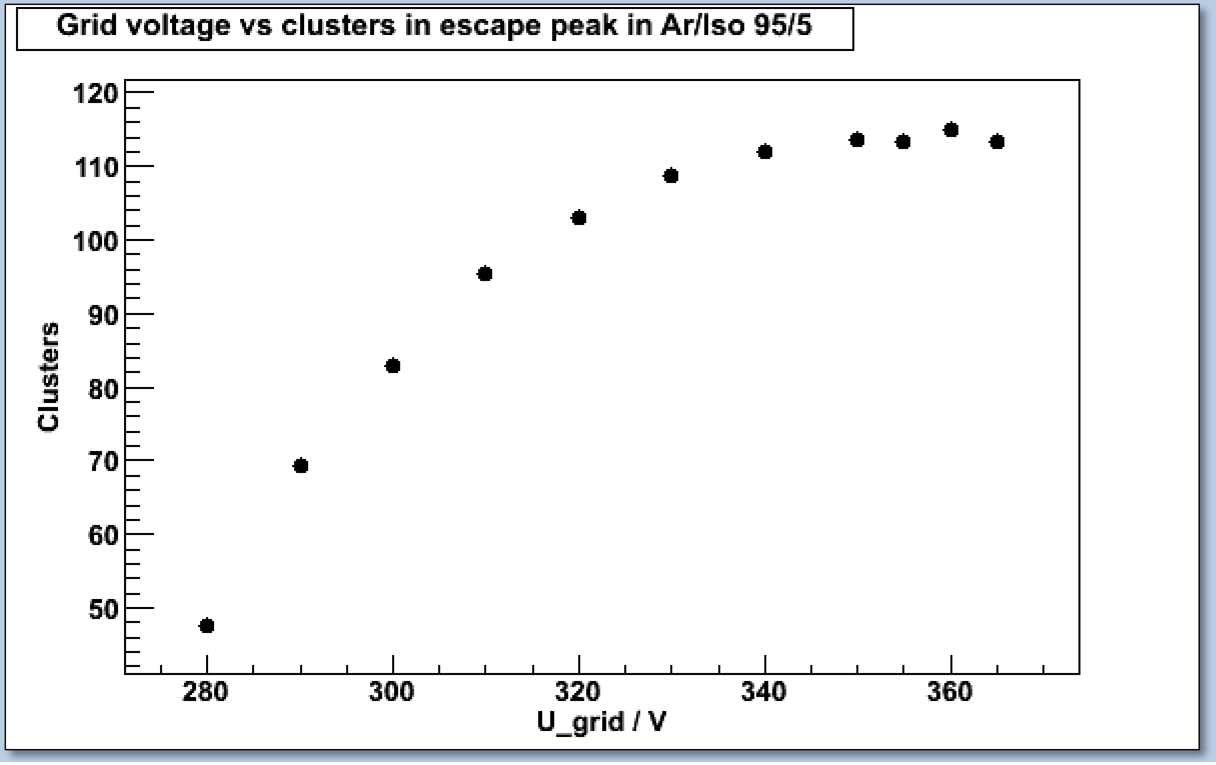
Clusters in escape peak

In ArIso 95/5:

- have a look on escape peak: less electrons, better separated by diffusion
- enough diffusion to arrive at plateau for escape peak: 115±1 cluster
- most clusters include just one pixel (almost no charge sharing)
  $\Rightarrow$ 1 cluster $\cong$ 1 primary electron at plateau
- applying harder cuts on RMS of electron cloud does not effect number of clusters

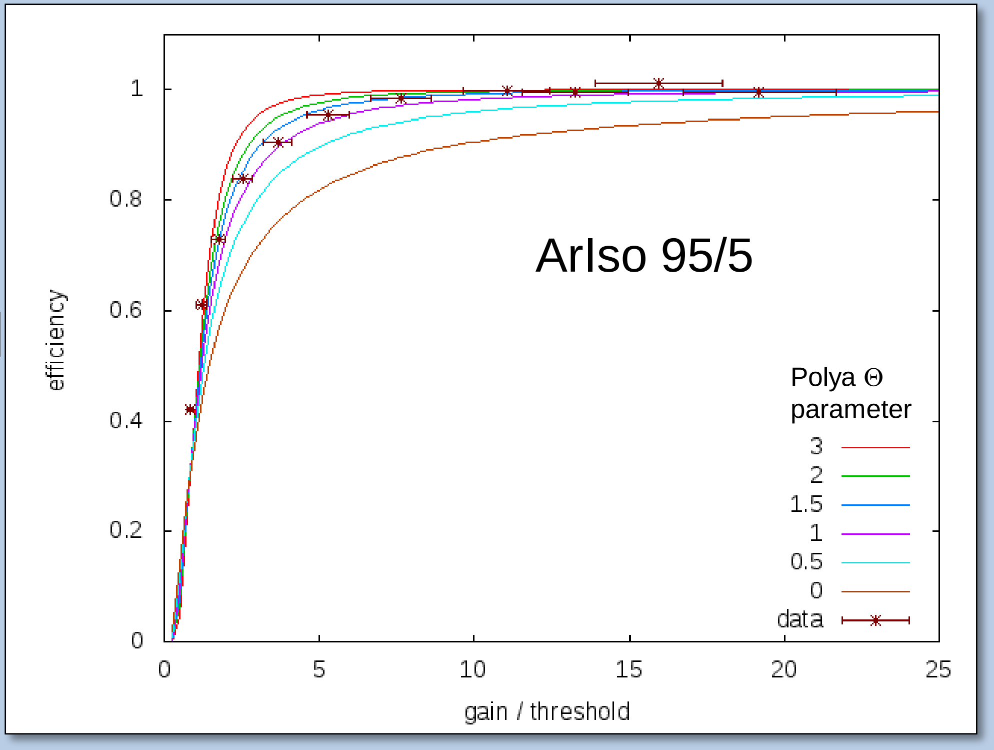
- escape peak at: 2,9 keV
- photo peak at: 5,899 keV

- $\Rightarrow$ 230 electrons expected in photo peak (max counted: 215 electrons)



Fe55 Spectra
Detection Efficiency

Comparison of theory and measurements assuming Polya distribution



Detection efficiency:

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

m=Θ+1

Threshold: 1150 electrons
Gain: from similar Micromegas detector

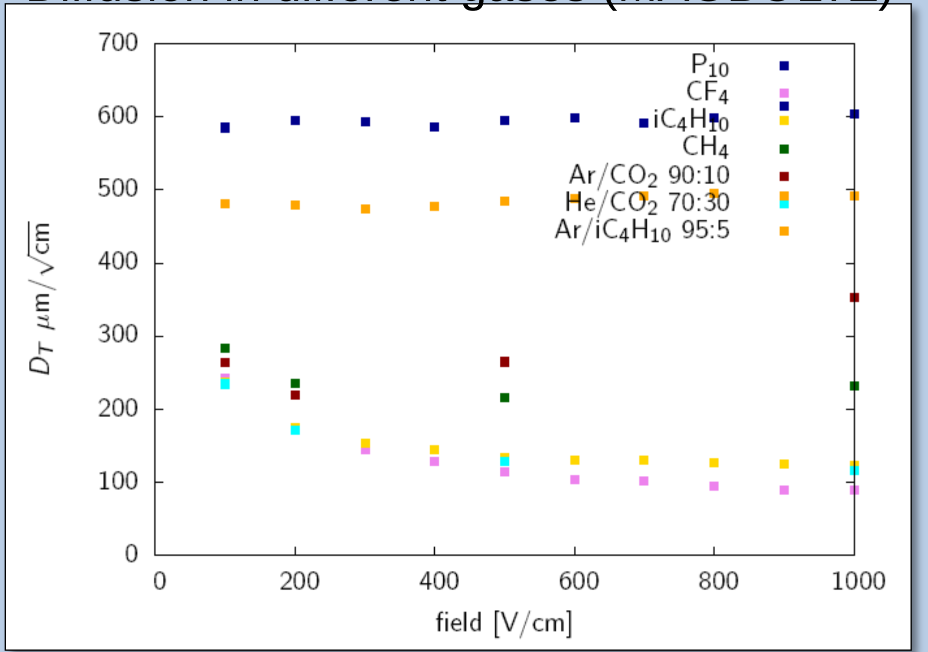
Primary electrons: assuming 115 in Escape peak

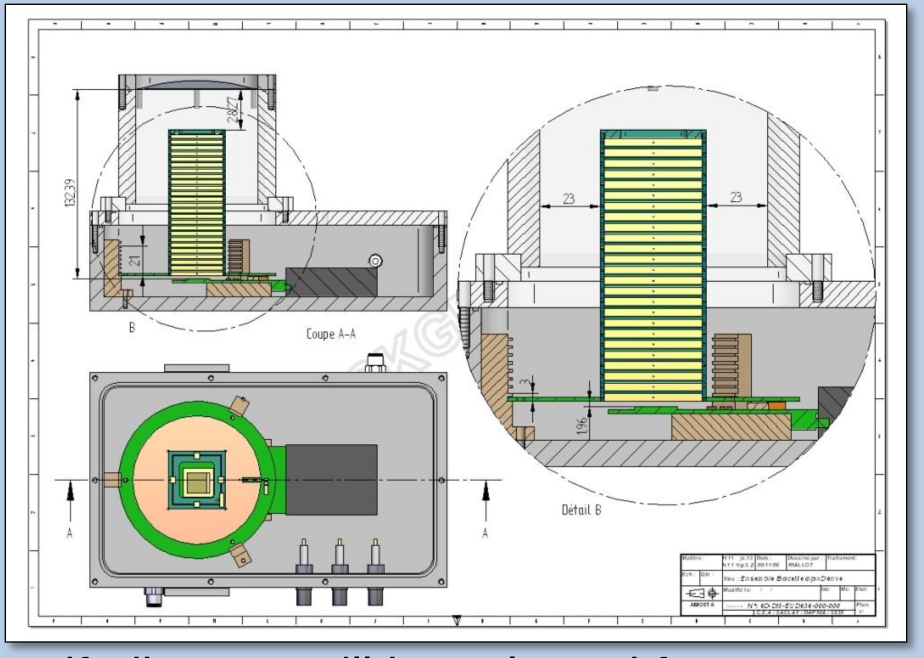
[1] Max Chefdeville, Development of Micromegas-like gaseous detectors using a pixel readout chip as collecting anode

Fe55 Spectra

Improvements to Setup

Diffusion in different gases (MAGBOLTZ)





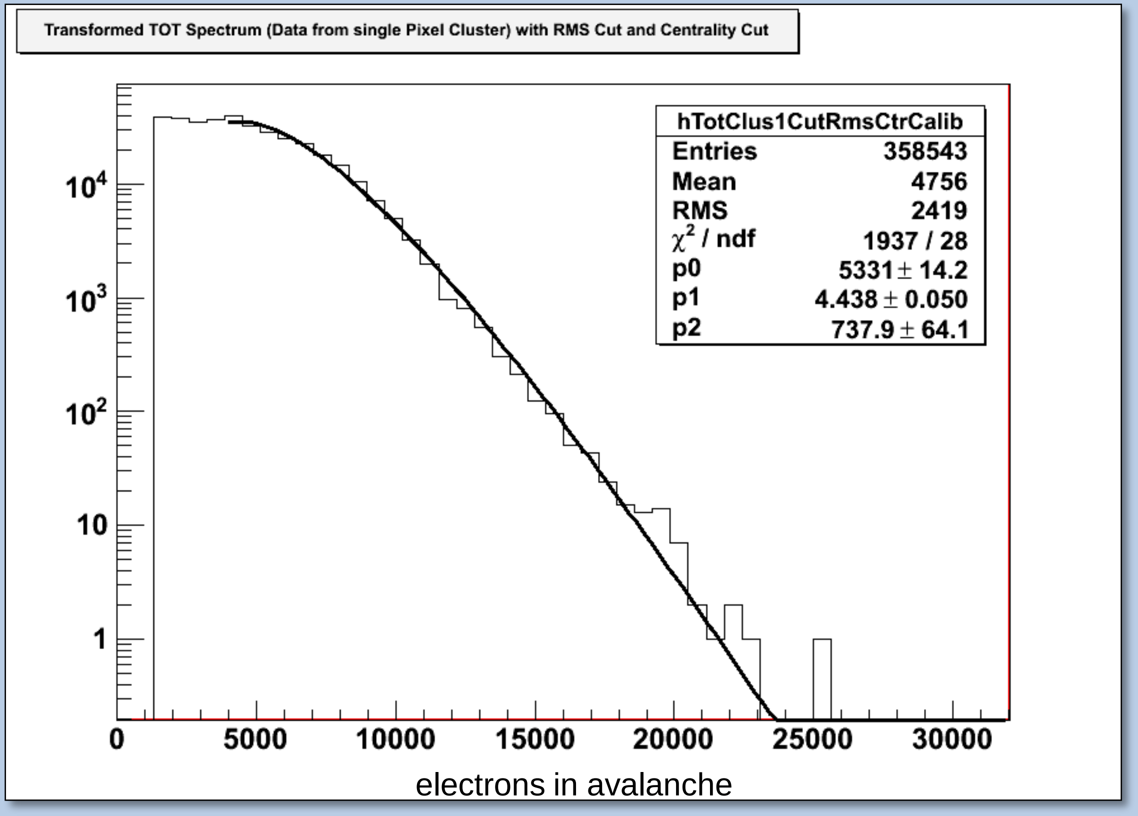
- ArIso95/5 is already gas with high diffusion
- P10 is dangerous for Chips
  - →Higher voltages needed
  - →Sparks more likely
- Diffusion for other gases to low
  - →Electron clouds to small
  - →Too low single electron det. Eff.

- Drift distance will be enlarged from 2,4 cm to ~ 10 cm
- Field degrader will be improved

TimeOverThreshold
TOT Spectra

Data sample:
U_{grid}=330 V

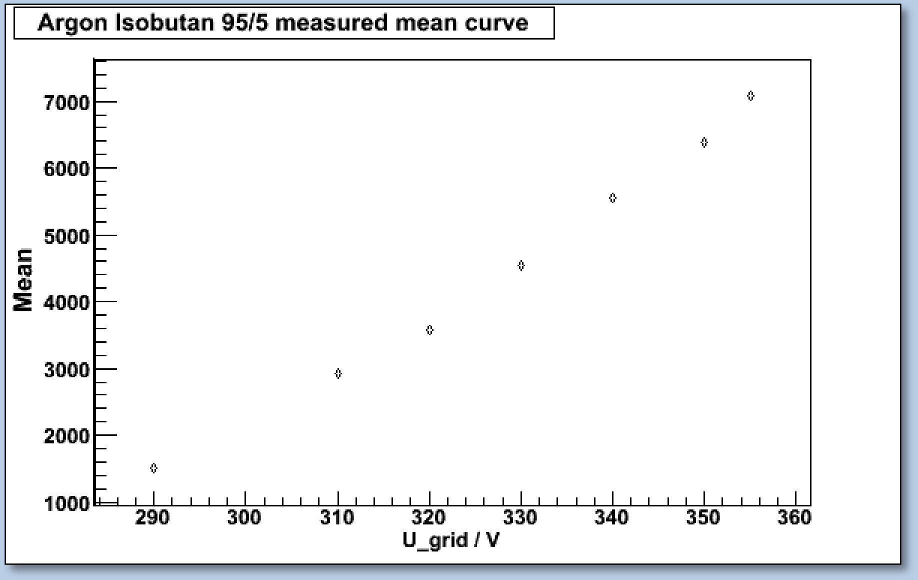
Polya fit forced starting from 4000
Advantages:
•TOT → #e- calibration reliable
Disadvantages:
•few data points for low voltages
•just tail fit



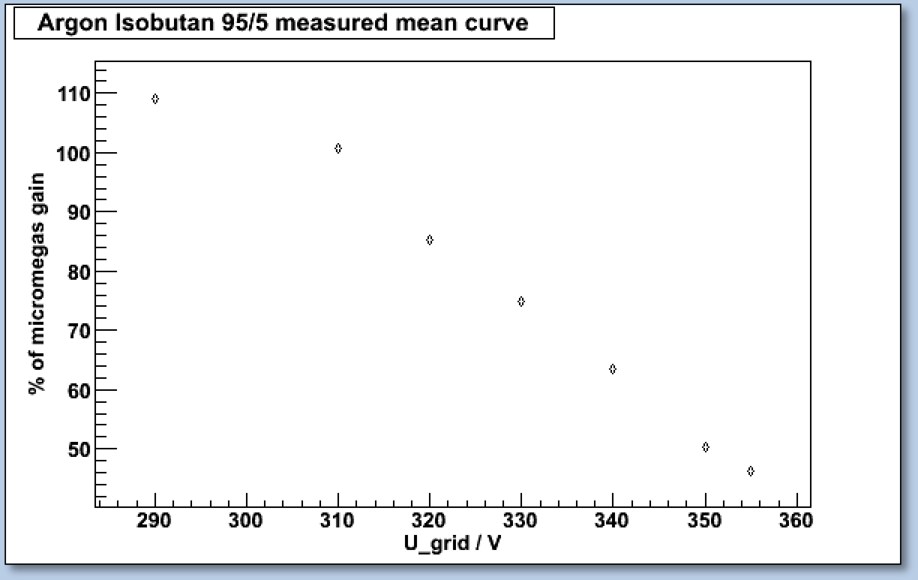
TimeOverThreshold

Gain Curve

Mean of Polya fit curve



Comparison to Micromegas results



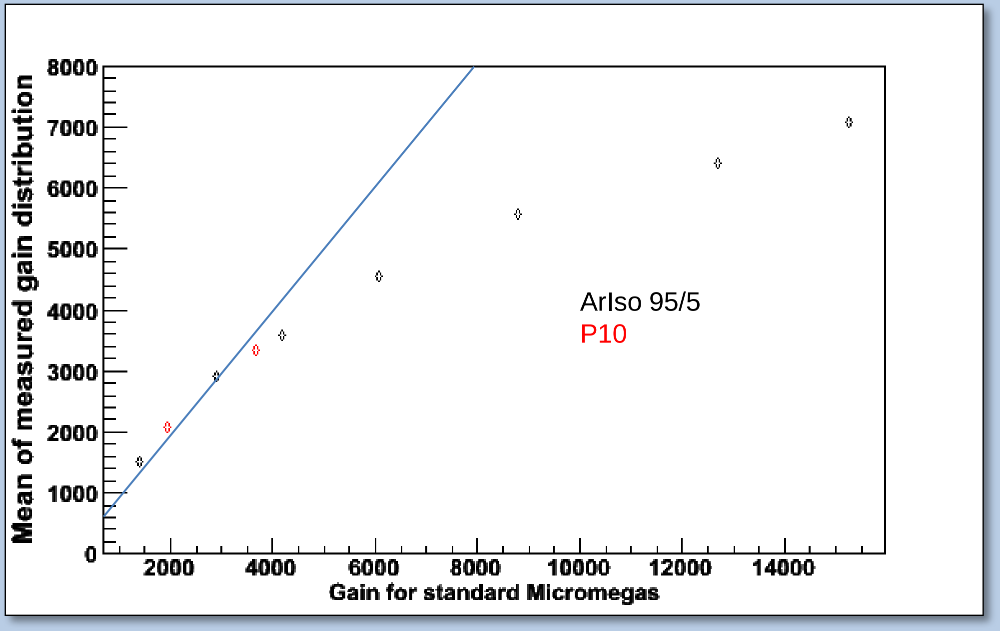
Use TOT → #e- calibration ⇒ gain curve
→ Not exponential at all
→ Very low gain at high voltages

→Higher gain at lower voltages?
→ lowest gain ≈ threshold
→ inaccurate calibration for low gains
→ Gain drop with voltage
→ difference to Micromegas: SiProt

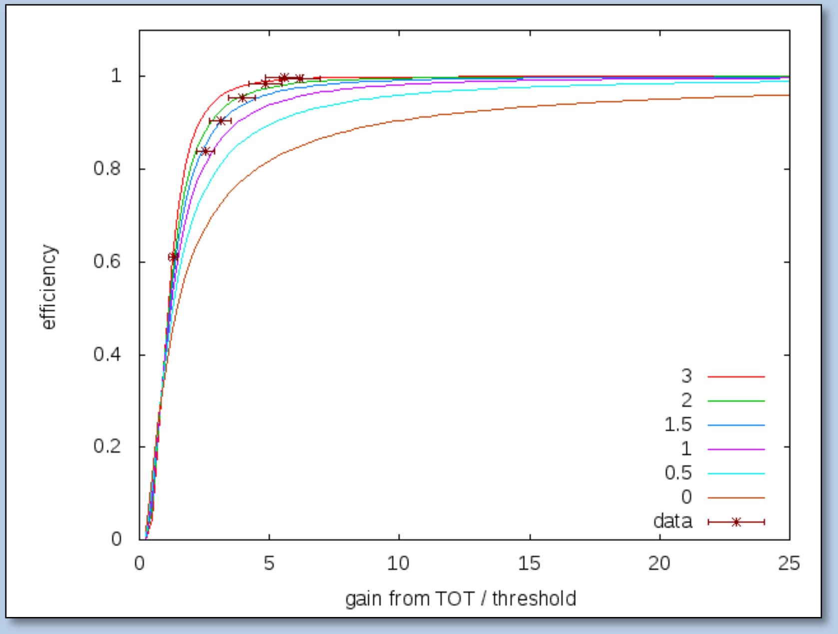
TimeOverThreshold

Influence of SiProt

Comparison of InGrid mean to Micromegas gain



Detection efficiancy with gain = mean



P10 gas: dangerous for Chip

→Sparks at 430 V / G_{mm} ≈ 10000

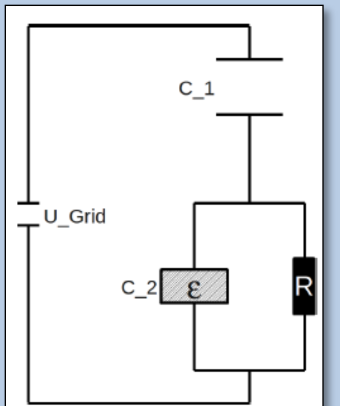
CF4 gas: not in this plot

Θ Going to higher values of ≈ 2

TimeOverThreshold

Influence of SiProt

Reason for lower gain: SiProt layer over anode. Look on single Pixel:
SiProt acts as capacitor that charges with avalanches and discharges over high resistance



$$\frac{dQ}{dt} = G\,f - \frac{Q}{RC}$$

$$G[C](U_{\mathrm{Si}}) = e\exp(A + B \times \Delta U)$$

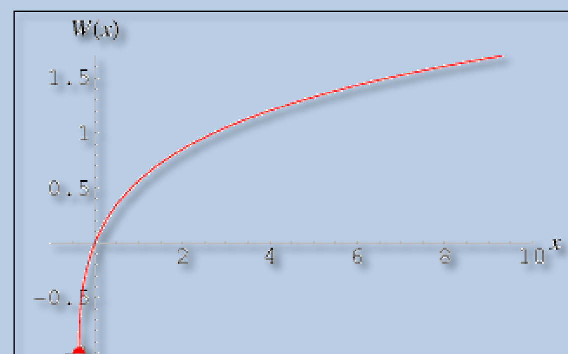
$$\Delta U = U_{\mathrm{grid}} - U_{\mathrm{Si}}$$

$$\frac{U_{\mathrm{Si}}(t\to\infty)}{R} = G(U_{\mathrm{Si}}(t\to\infty))\,f \Rightarrow \frac{U_{\mathrm{Si}}(t\to\infty)}{R\,f\,e} = \exp(A + B \times (U_{\mathrm{grid}} - U_{\mathrm{Si}}(t\to\infty)))$$

f = avalanche frequency, Q=C·U
G = number of electrons per avalanche
R = resistance of SiProt
C = capacitance of SiProt

$$U_{\mathrm{Si}}(t\to\infty) = \frac{W(B\,R\,f\,e\,\exp(A + B \times U_{\mathrm{grid}}))}{B}$$

W: Lambert W-function



$$\tau = RC = \varepsilon_0\,\rho\,\varepsilon$$

	a-Si:H	Si_3N_4
$\rho/[\Omega\,\mathrm{cm}]$	10^{11} [2]	10^{14} [3]
ε	11.8 [1]	7.5 [3]

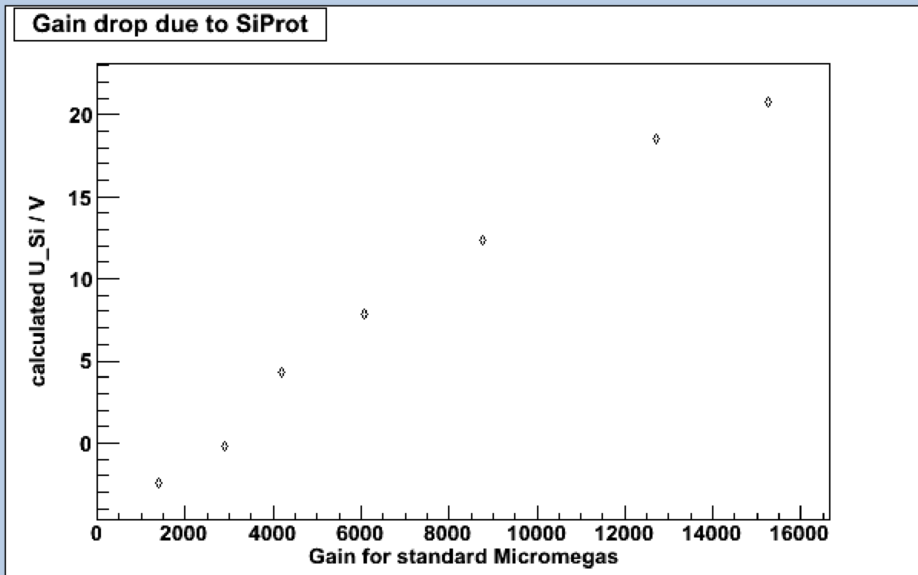
$\Rightarrow \tau \approx 1$ min

[1] S. C. Deane and M. J. Powell, Field-effect conductance in amorphous silicon thin-film transistors with a defect pool density of states, Journal of applied physics 1993, vol. 74, no11, pp. 6655-6666
[2] M.A. Chefdeville, Development of micromegas-like gaseous detectors using a pixel readout chip as collecting anode, Univ. of Twente, January 2009
[3] http://www.siliconfareast.com/sio2si3n4.htm

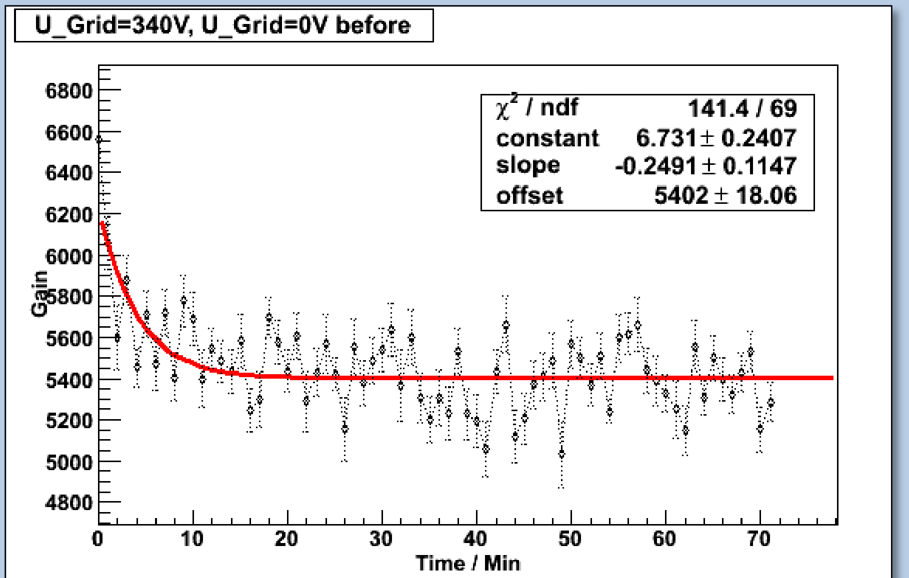
TimeOverThreshold

Influence of SiProt

Calculation of voltage on SiProt surface



Example for gain drop (charging of SiProt)



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

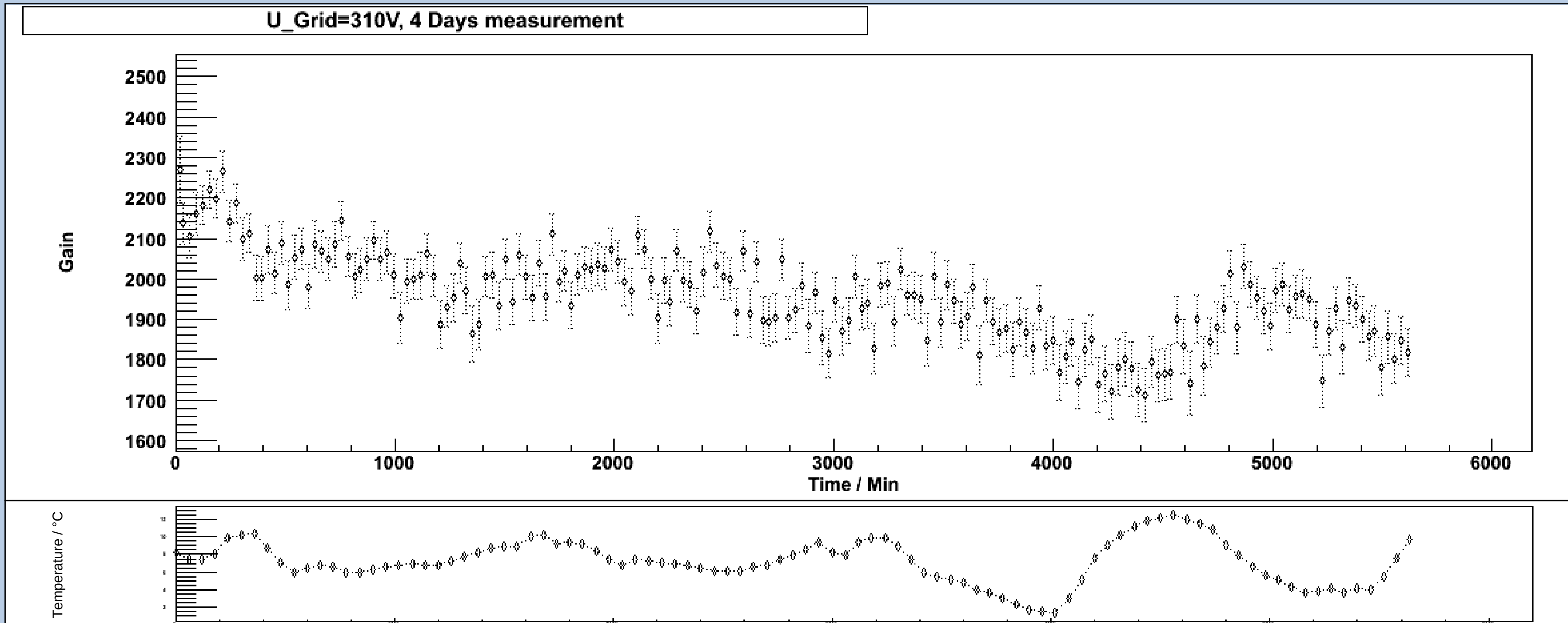
$$mean = G_{measured} = \exp(A + B \cdot \Delta U)$$

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

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

Analysis of gain in first minutes:
Gain drop from 6240 to 5402
with $\tau = 4 \pm 2$ min

TimeOverThreshold
Long term measurements



Long term measurements dominated by environmental conditions

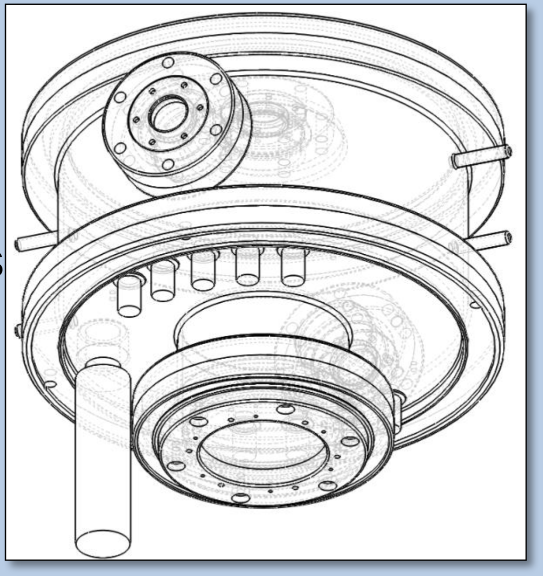
→ register pressure and temperature
→ try to keep them constant

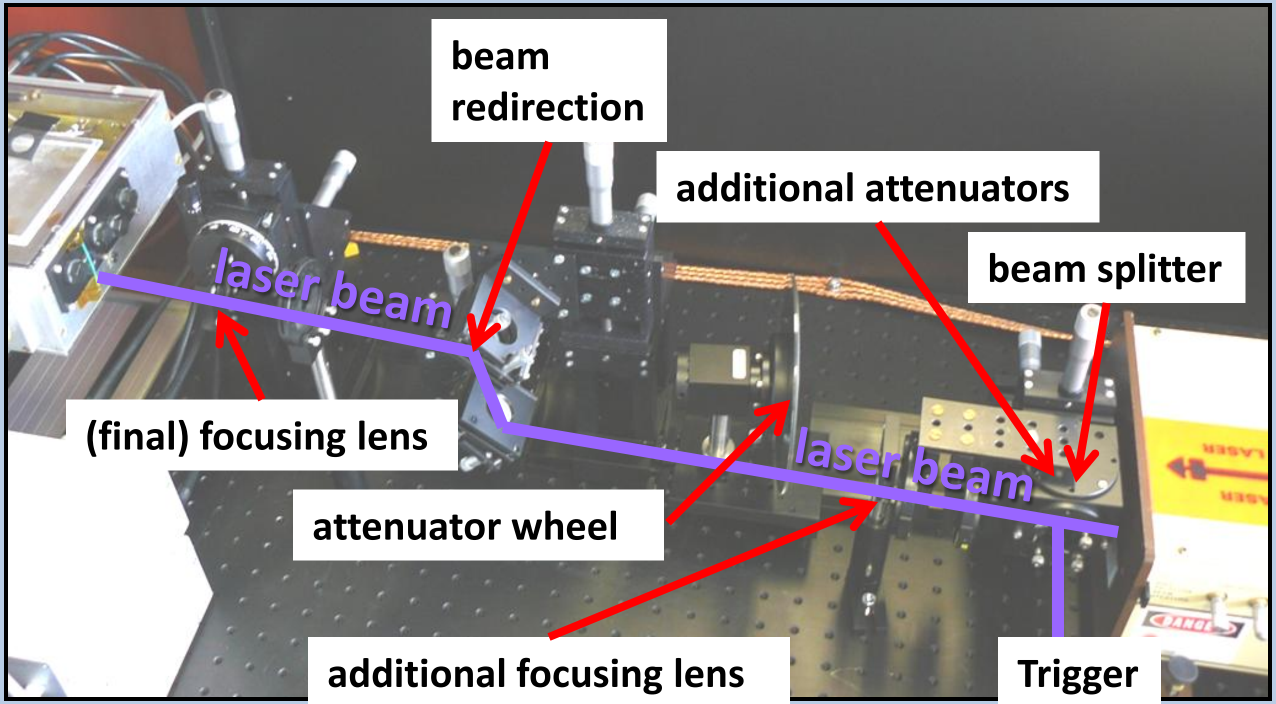
TimeOverThreshold

Laser measurements

Plans for next weeks:

- Use LASER test bench and gas box in Freiburg
  → photo effect on cathode, few electrons
  → defined frequency and position of primary electrons
  → temperature und pressure registration



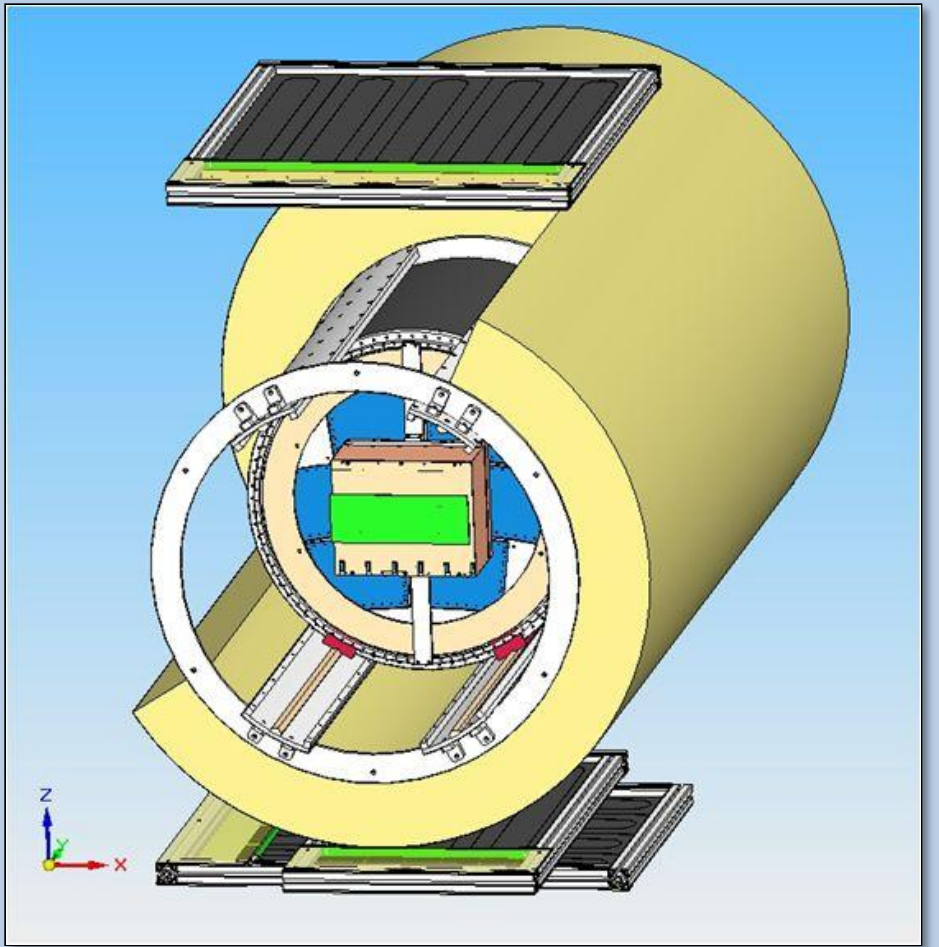


Measurement program:

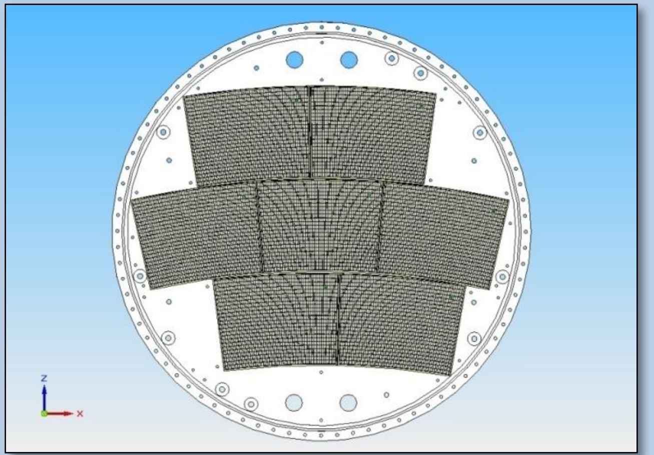
- TIME mode:
  → drift velocity
  → electron counting
- TOT mode:
  → charging effect of SiProt
  → surface scan

8 Chip panel
Large Prototype for LC TPC

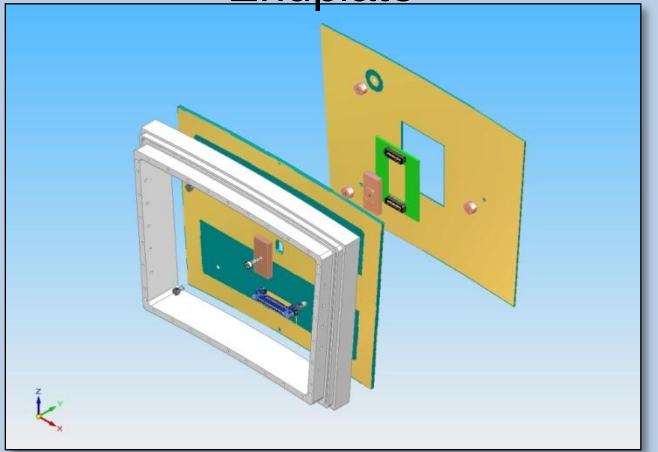
Aim: A panel with 8 TimePix InGrid Chips for the large TPC prototype



Prototype for LC TPC at DESY



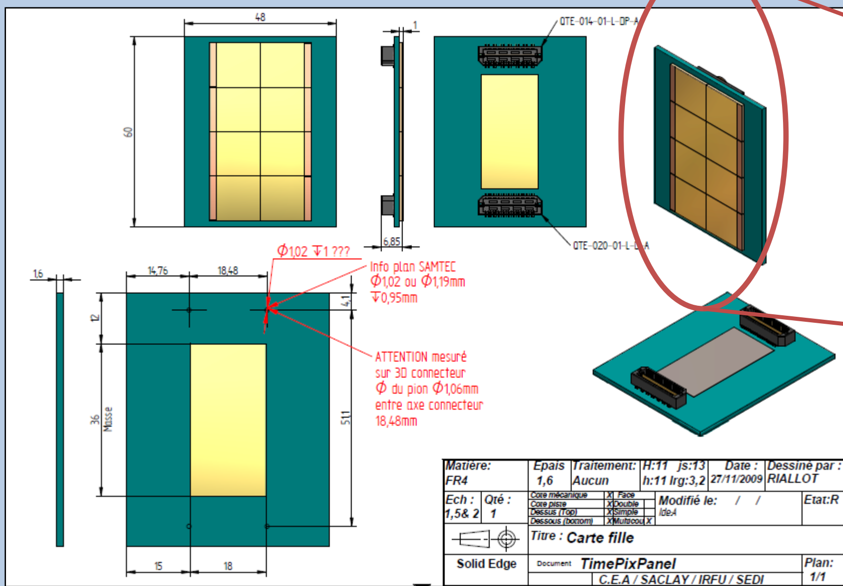
Endplate

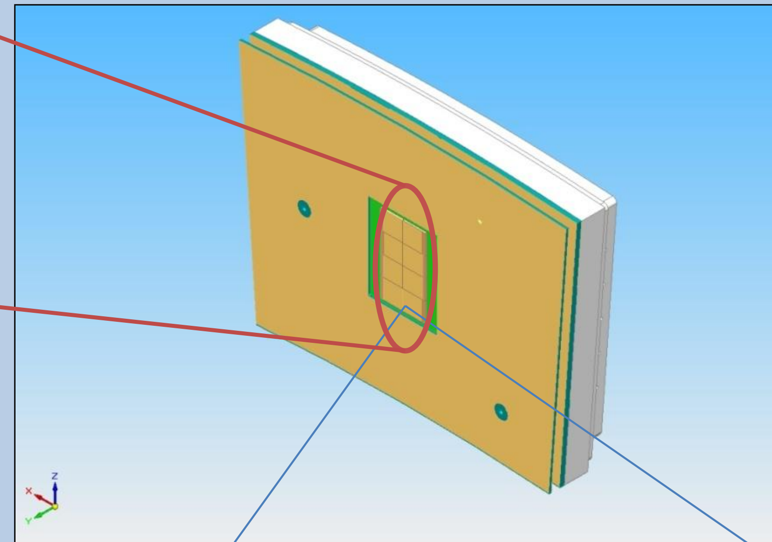


One module

8 Chip panel
Octopuce

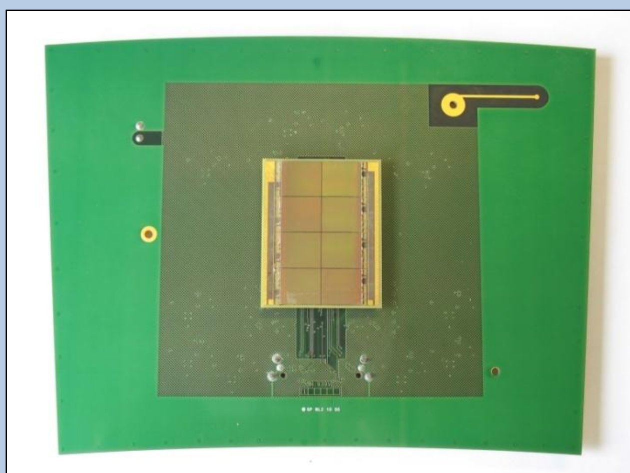
Board ready since ~April

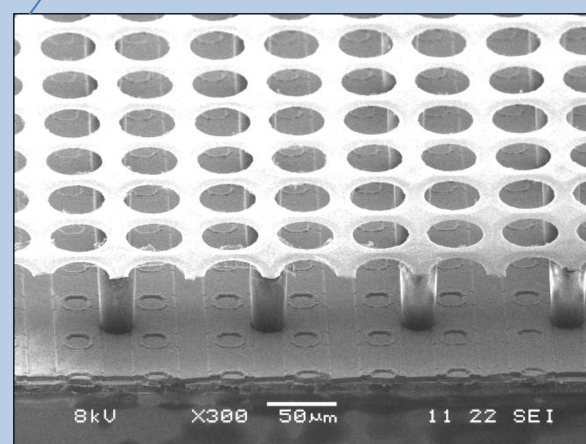




First equipped with 8 naked Timepix chips in NIKHEF bonding lab by Joop Rövekamp

⇒to ensure operability

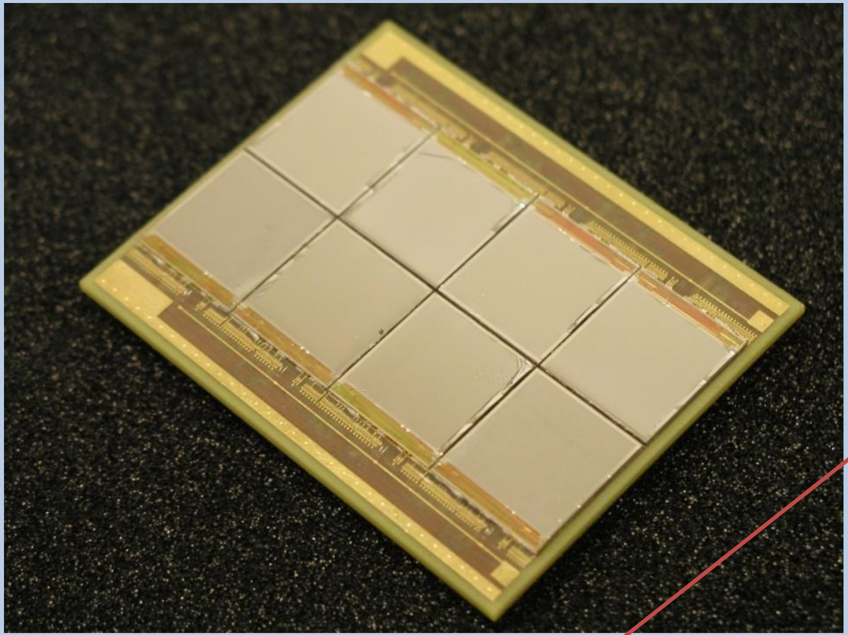


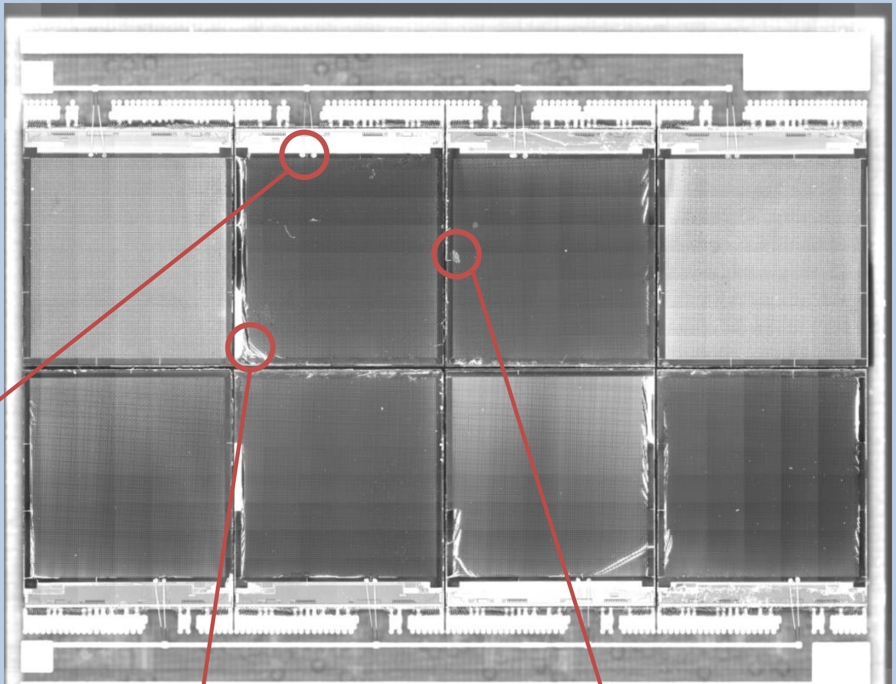


8 Chip panel

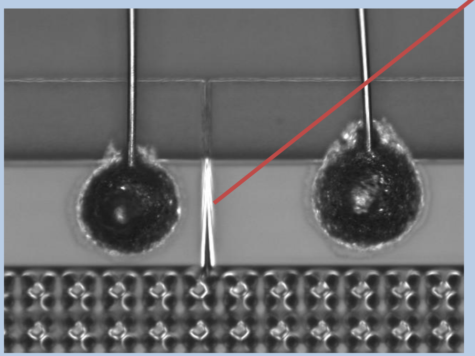
Octopuce

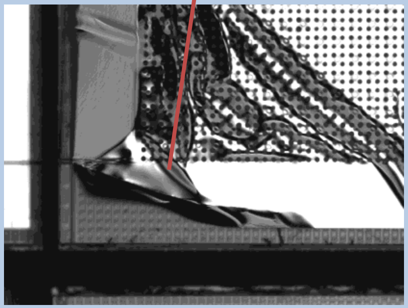
29.04.2010: 8 Tempi + Ingrid Chips glued and bonded daughterboard at NIKHEF

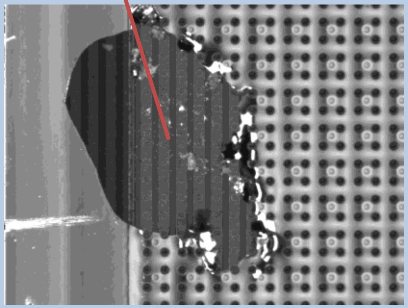




Microscope: Grids not perfect, but very good



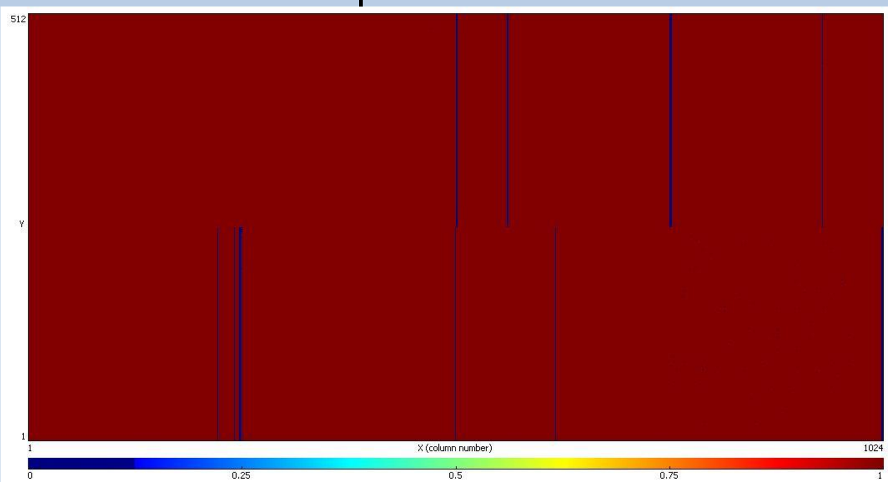




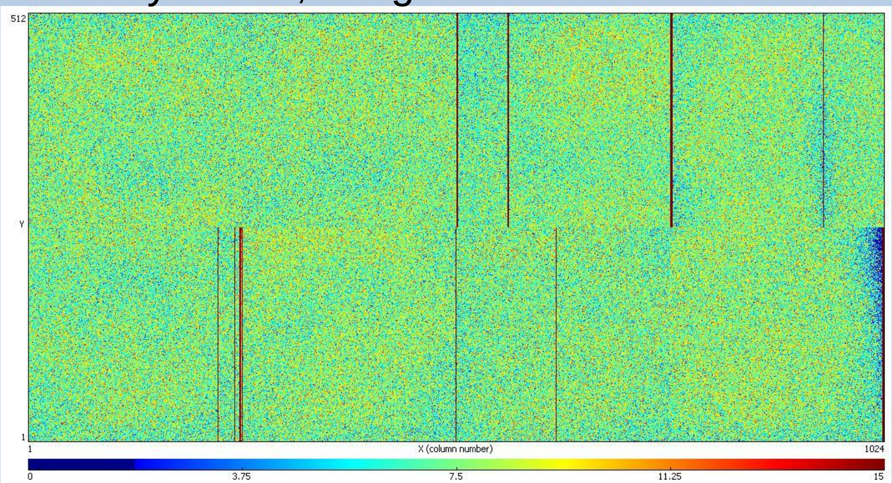
Grid HV bonds fixed with silver glue

8 Chip panel
Octopuce

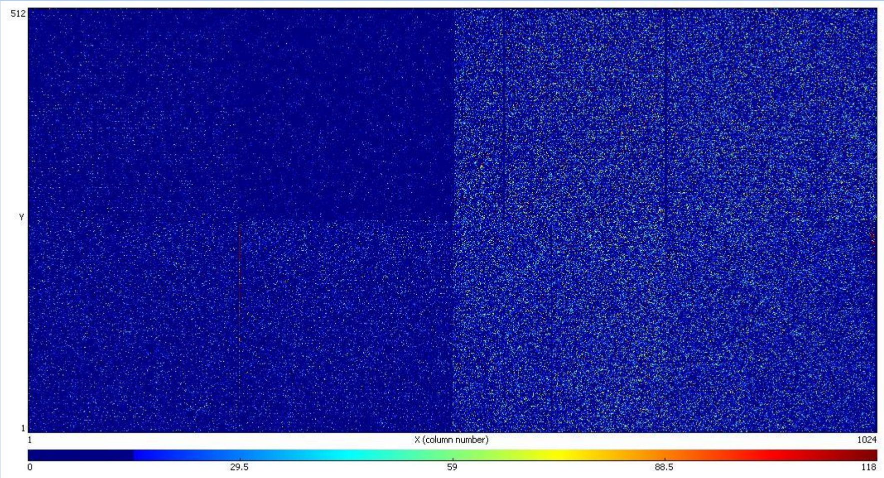
18.05.2010: all 8 chips detected on board and electronically tested, Images from Pixelman



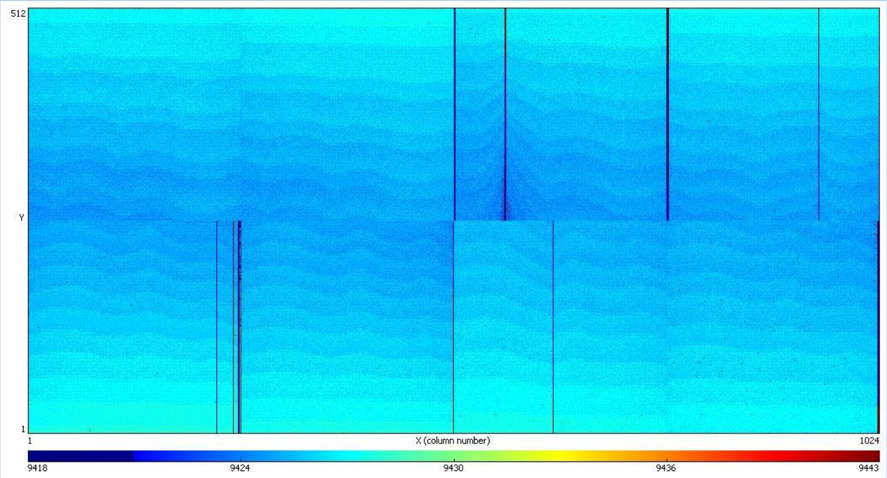
Mask map:4352 pad pixels⇒519937 channels



Threshold adjustment map



Noise (different threshold for chips to see them)



Test pulses in TIME mode

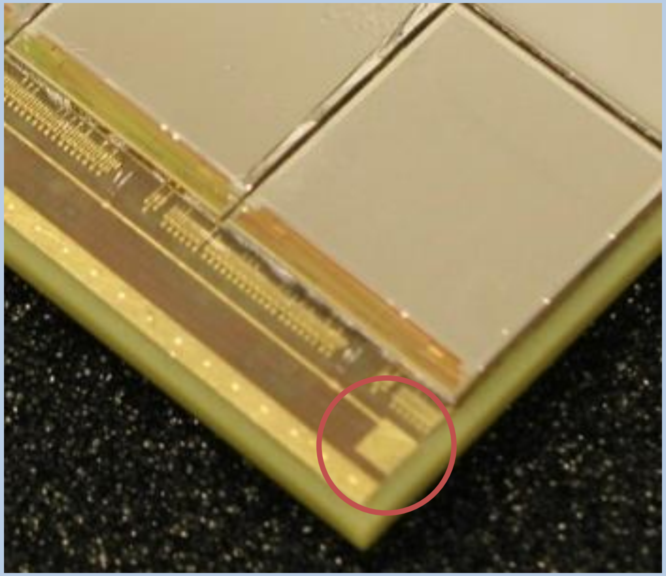
8 Chip panel
Octopuce

Next steps:

- Connect HV ring

- Apply voltage to the grid

- Hope that there is no current between a grid and a chip



- Calibrate chip (noise, threshold, TOT↔#e- calibration)
- Tests in lab with cosmics and Fe55 (gas chamber is ready)

- Go for test beam at LP TPC

Conclusion

Fe55 spectra:

• 100% single electron detection efficiency was reached in ArIso 95/5 with 115±1 electrons in escape peak

• comparing with theory the measured detection efficiency indicates a Θ close to 2 for a Polya model of gain fluctuations

TOT mode:

• TOT measurements can be used to obtain the gain of a TimePix InGrid detector

• The effects of the SiProt layer needs to be taken into account, which lowers the gain. The layer can be modeled by a not perfect capacitor.
More detailed studies are needed to compare the theory with measurements.
In particular the frequency and the position of the avalanches needs to be fixed.

8 Chip panel:

• In the next weeks a panel with 8 TimePix InGrid detector will be ready

• cosmics will be detected in the lab, tracks will be recorded in beam test at the LCTPC Prototype at DESY

Thanks

David Attié, Paul Colas, Xavier Coppolani,
Marc Raillot, Maxim Titov

Ian McGill, Xavier Llopart,
Heinrich Schindler, Rob Veenhof

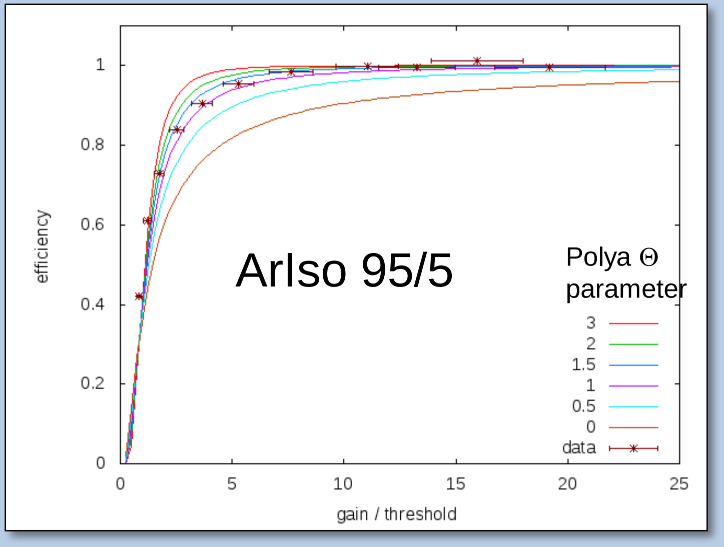
Markus Köhli, Uwe Renz, Markus Schumacher

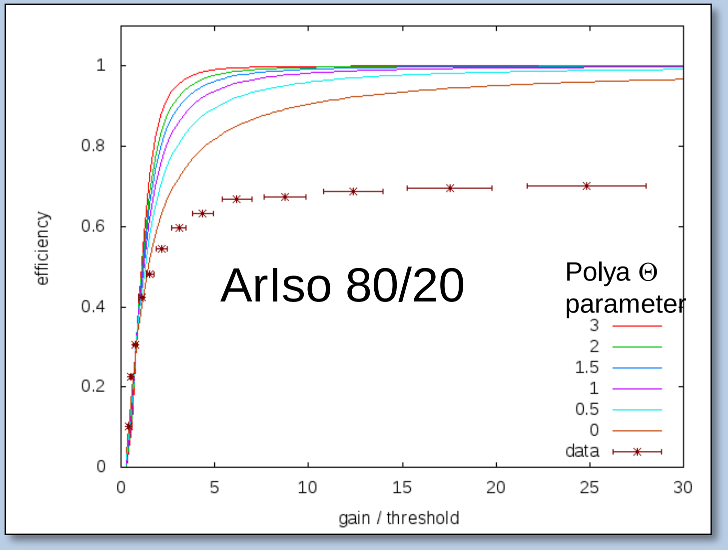
Maximilien Chefdeville

Yevgen Bilevych, Martin Fransen, Harry van der Graaf,
Joop Rövekamp, Jan Timmermans

Fe55 Spectra
Detection Efficiency

Comparison of theory and measurements assuming Polya distribution





Detection efficiency:

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

m=Θ+1

Assuming 100 % single electron detection efficiency

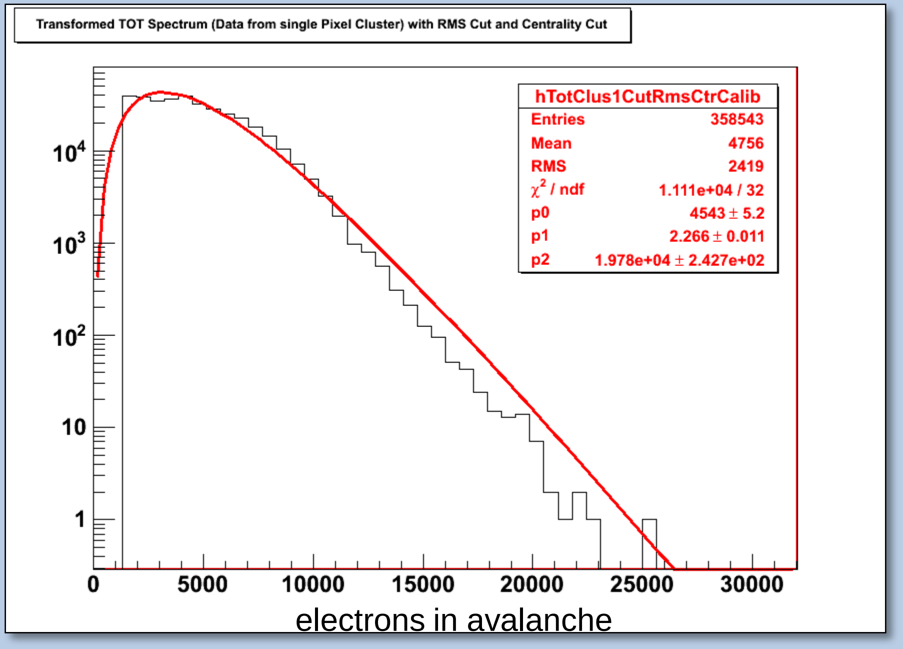
⇒ electron clouds are to small to separate all the electrons
⇒ diffusion not enough for given drift distance

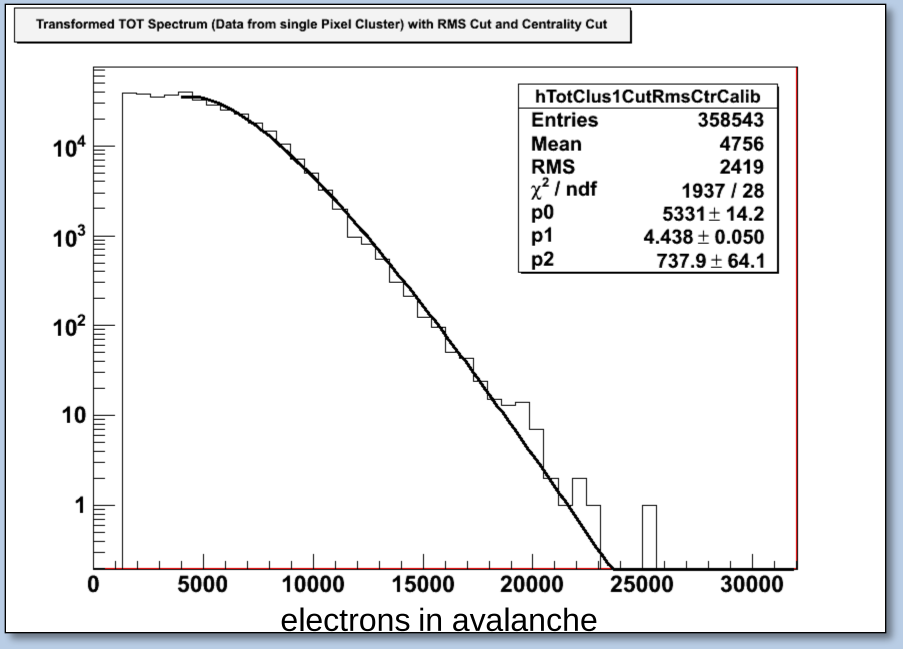
[1] Max Chefdeville, Development of Micromegas-like gaseous detectors using a pixel readout chip as collecting anode

TimeOverThreshold

TOT Spectra

Data sample: 100129_55Fe_ArIso5_Uk2040_Ug330_THL405_TOT_cage_Calib





Polya fit forced starting from 0

Advantages:

- curvature at low gain taken into account
- stable fit at low voltages

Disadvantages:

- gain calibration not accurate at low voltage

Polya fit forced starting from 4000

Advantages:

- TOT → #e- calibration reliable

Disadvantages:

- few data points for low voltages
- just tail fit