

# Recent InGrid Studies and DESY Test-Beam Results with Octopuce

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## OUTLINE:

- “Octopuce” Uniformity Studies in the Laboratory
- DESY Test-Beam Track Reconstruction with Octopuce
- Tests of IZM-3 InGrids
- Future InGrid Tests using Low Energy Electrons from PHIL at LAL

International Workshop on Future Linear Colliders  
University of Texas at Arlington, October 22-26, 2012

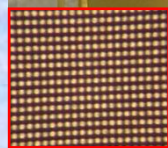
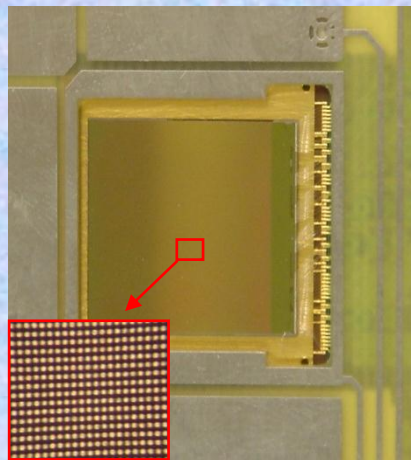
# Integrated Electronics: Pixel Readout of Micro-Pattern Gas Detectors

**3D Gaseous Pixel Detector** → **2D (CMOS pixel chip readout)** × **1D (drift time)**

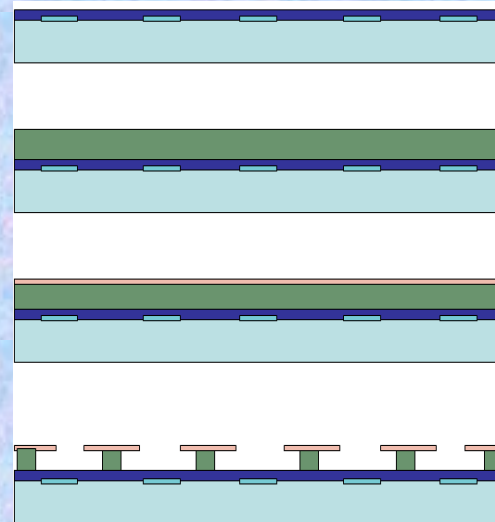
Bump bond pads for Si-pixel Detectors - Timepix or Medipix2 (256 × 256 pixels of size 55 × 55 μm<sup>2</sup>) serve as charge collection pads.

Each pixel can be set to:

- **TOT** ≈ integrated charge
- **TIME** = Time between hit and shutter end



Through **POST-PROCESSING INTEGRATE MICROMEGAS** directly **on top of CMOS chip**

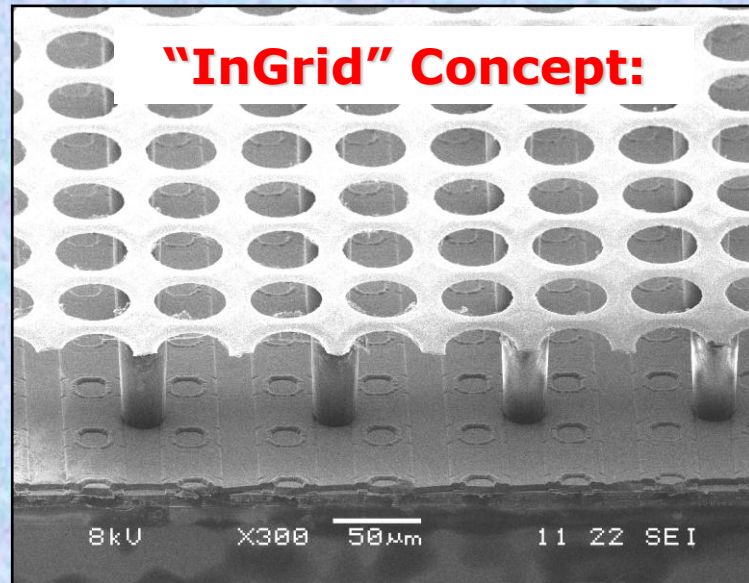
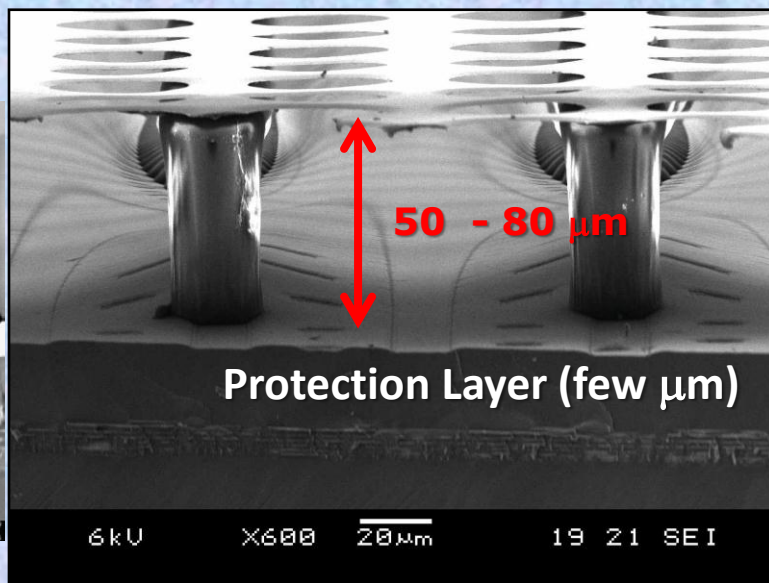
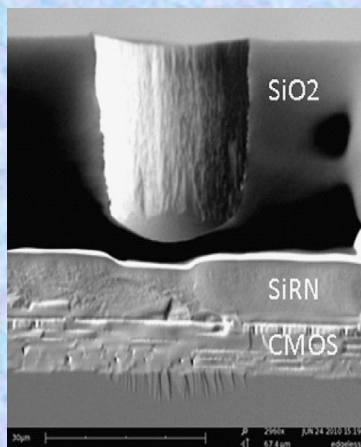


1. Formation of protection layer (e.g. Si<sub>3</sub>N<sub>4</sub>)

2. Deposition of spacer material (e.g. SU8)

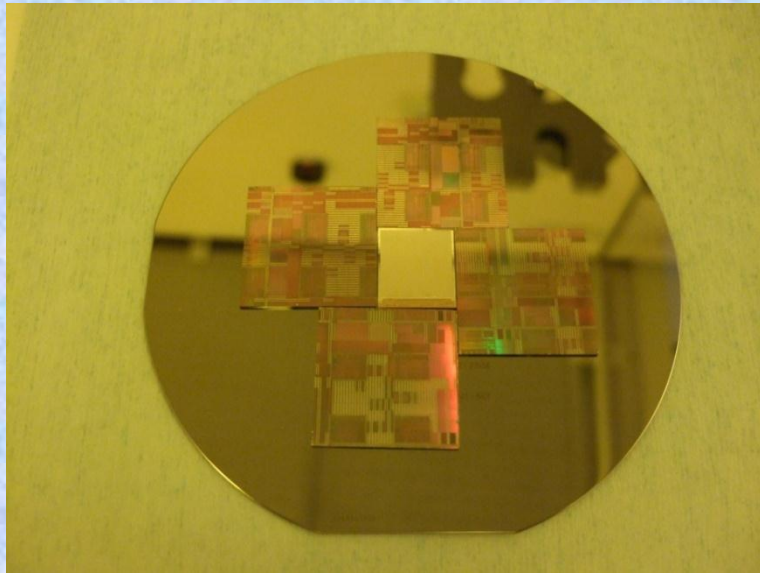
3. Deposition of the Grid material

4. Formation of structure "support" / grid

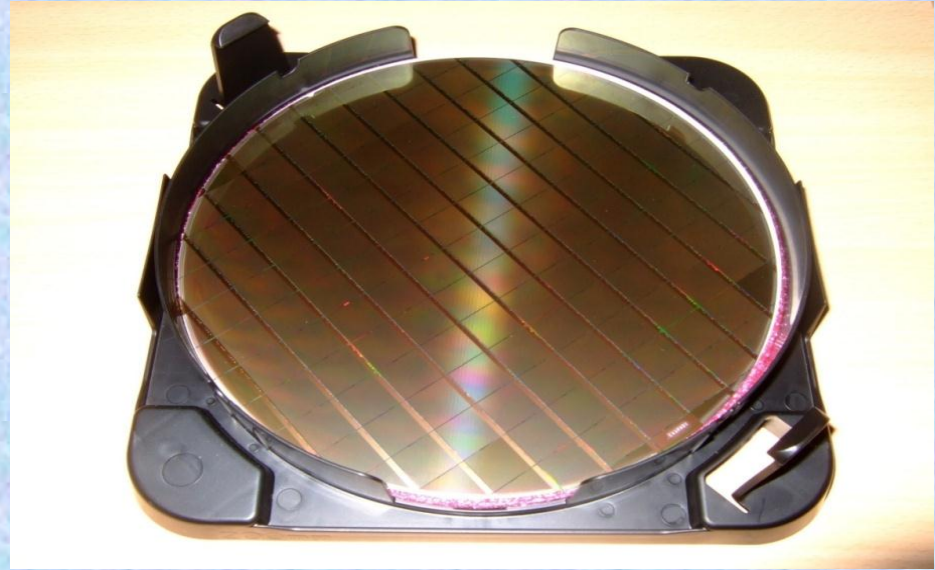


# "InGrid" Technology and "Driving" Developments

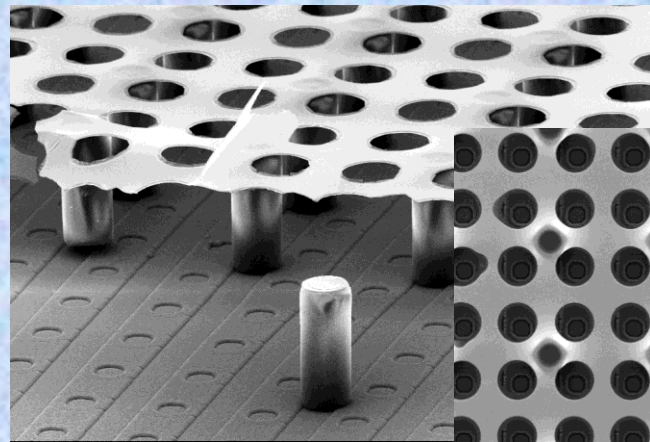
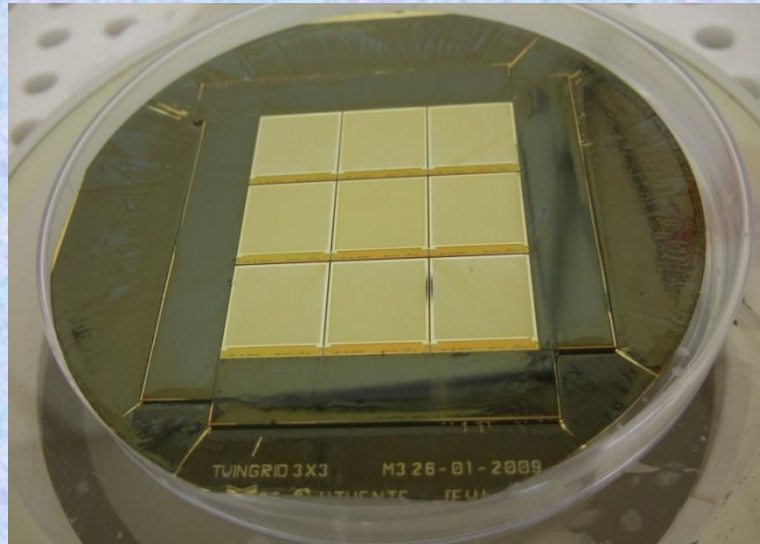
2005: Single "InGrid" Production



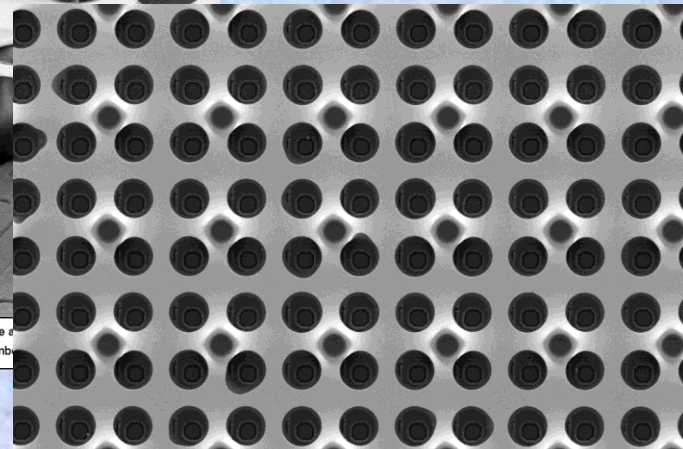
2011: Major Step Forward →  
InGrid Production on a wafer level (107 chips)



2009: "InGrid" Production on a  
3 x 3 Timepix Matrix

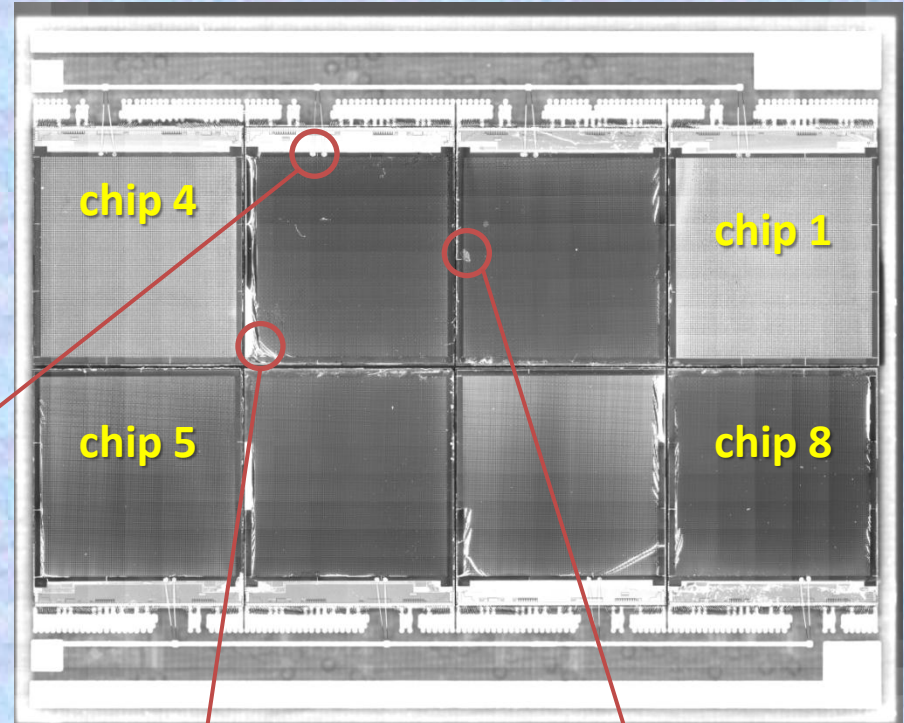
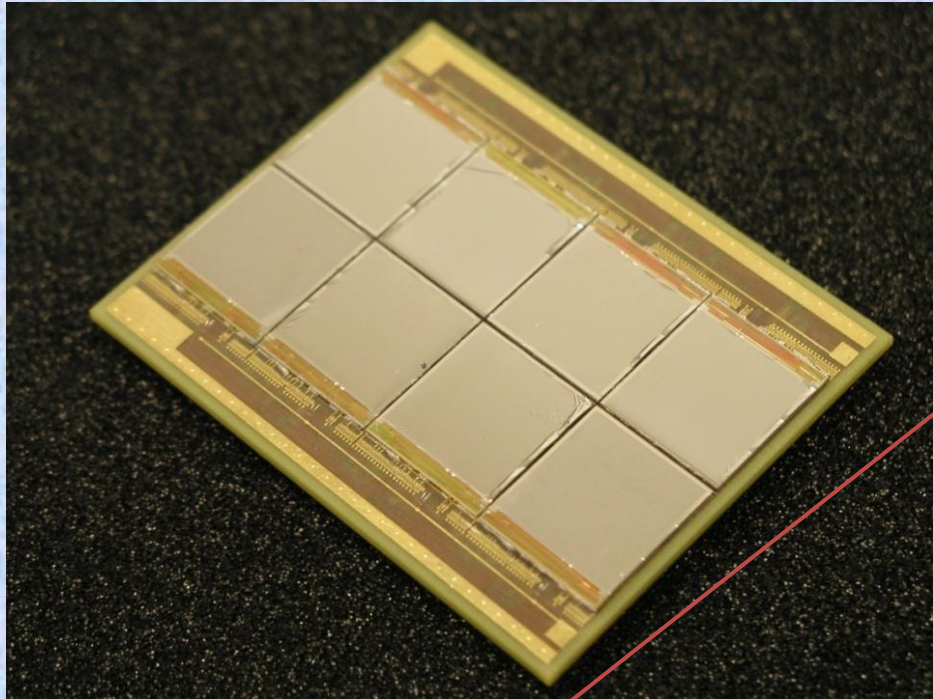


Mag = 303 X Signal A = SE2  
WD = 18 mm EHT = 20.00 kV  
20µm Stage at Chamber

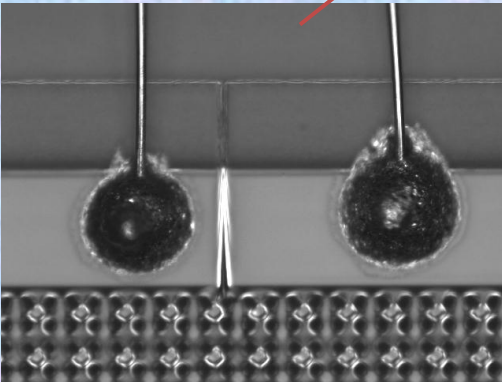


Mag = 174 X Signal A = SE2  
WD = 8 mm EHT = 20.00 kV  
100µm Stage at T = 0.0 ° Chamber = 1.31e-003 Pa Fraunhofer IZM

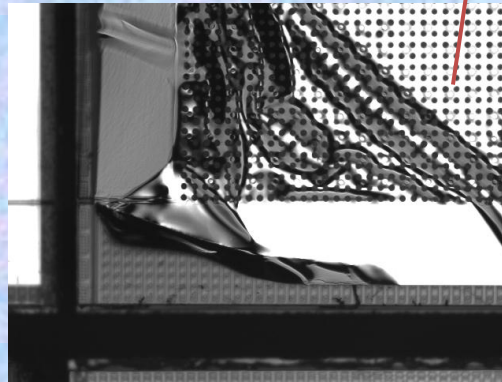
# The "Octopuce" (2009)



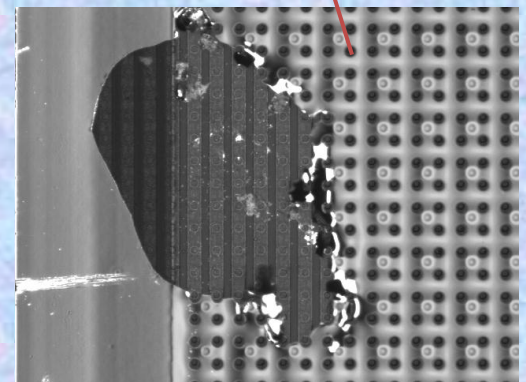
***Non homogeneous area on the mesh of different chips***



**HV connections**



**"Grid irregularities"**



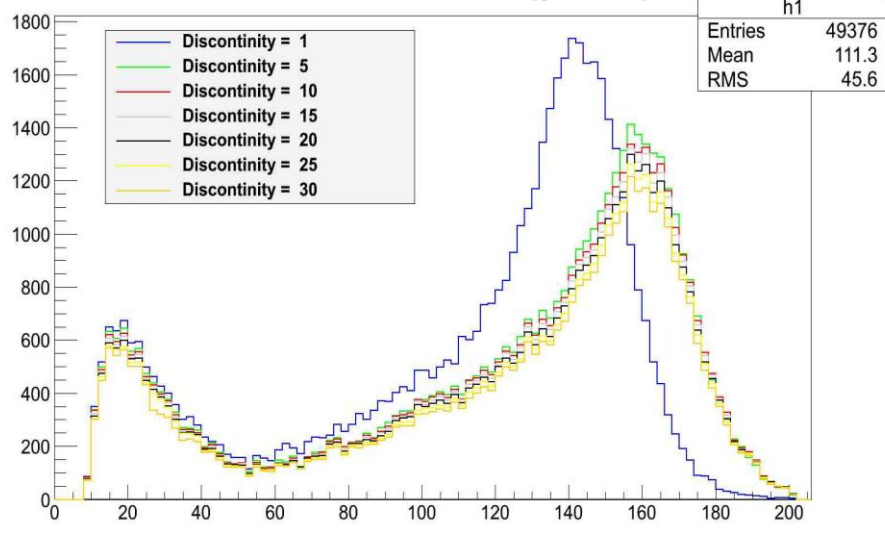
# Octopuce Studies & Fe55: Homogeneous Irradiation



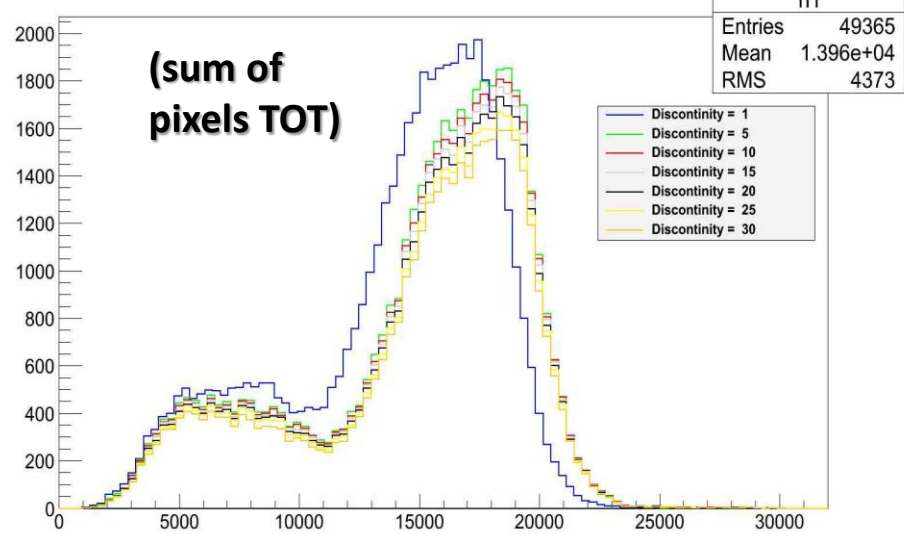
**Fe<sup>55</sup> Studies (26/07/2012):**  
**He/Iso 80/20**  
**Vmesh=390 V**  
**Vdrift =3000 V**

**Integrated picture for all 8 chips:**  
**(discontinuity = distance between pixels in the cluster)**

clusterSize (pixels)

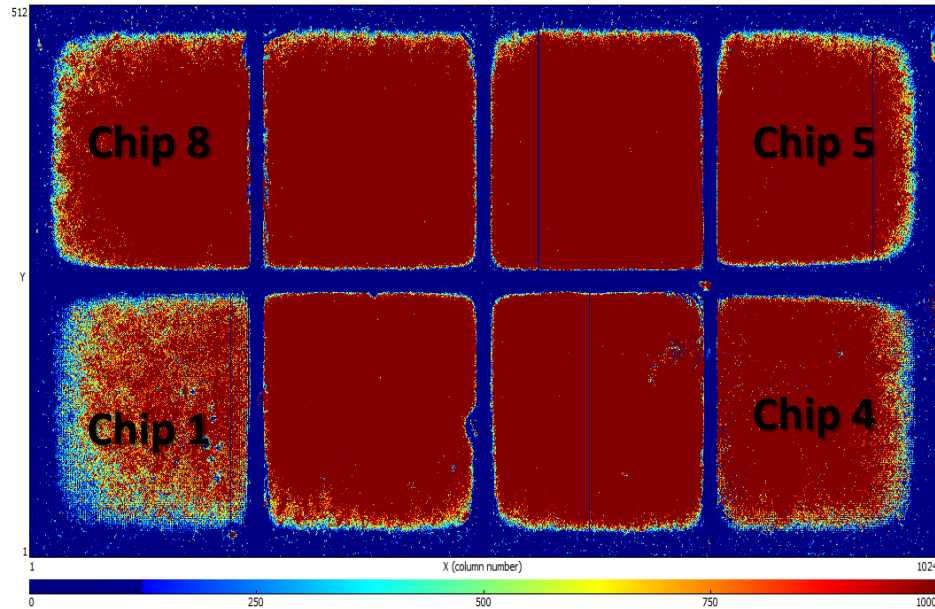


totalClusterCharge

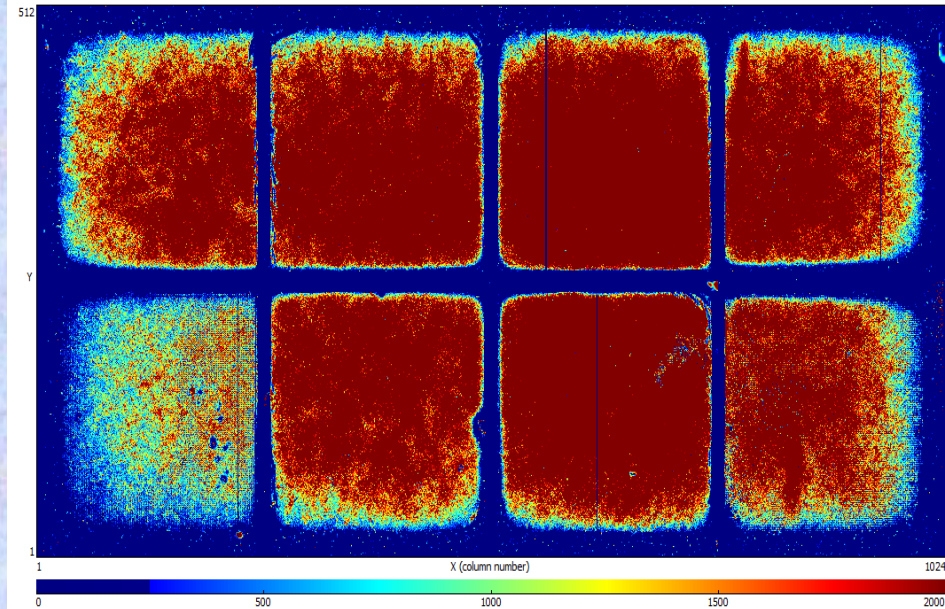


# Octopuce: Uniformity of the Response (I)

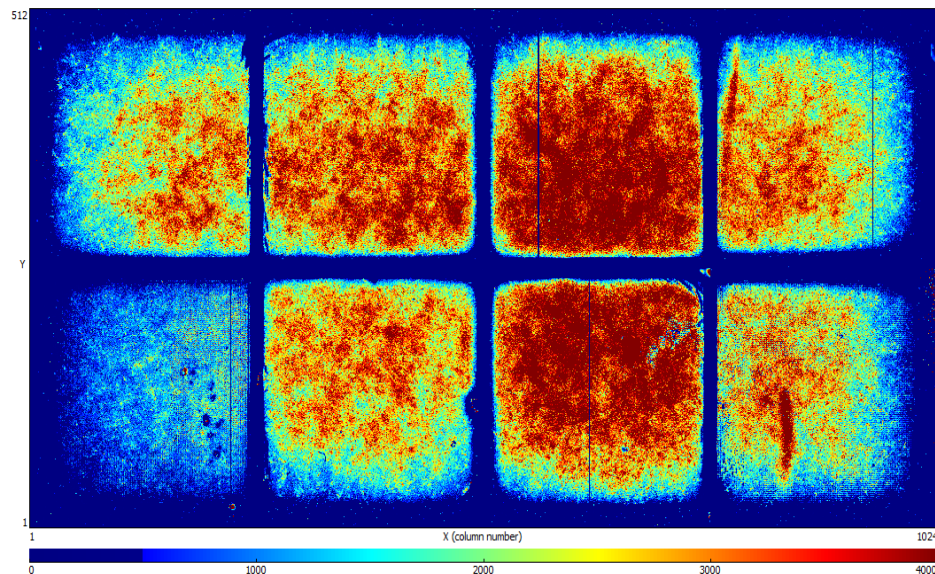
**THRESHOLD = 1000 COUNTS**



**THRESHOLD = 2000 COUNTS**



**THRESHOLD = 4000 COUNTS**



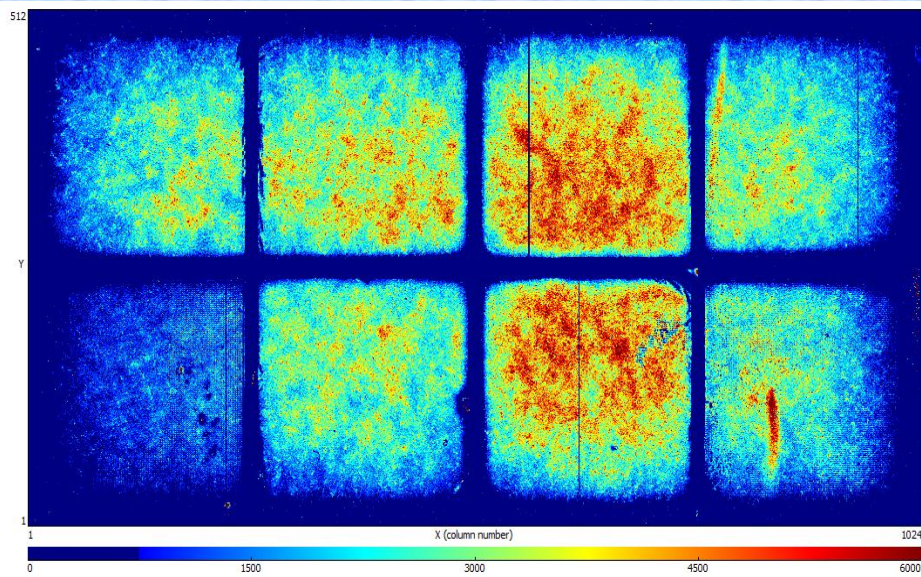
**Non-sensitive ( $\sim 1.5$  mm)  
areas between chips**

**Fe<sup>55</sup> Studies (26/07/2012):**

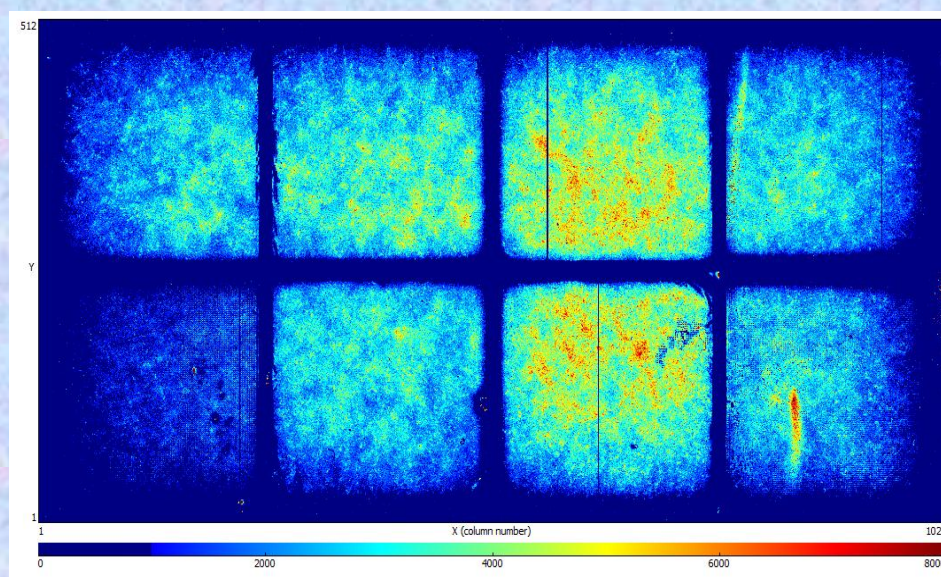
**He/Iso 80/20  
Vmesh=390 V  
Vdrift =3000 V**

# Octopuce: Uniformity of the Response (II)

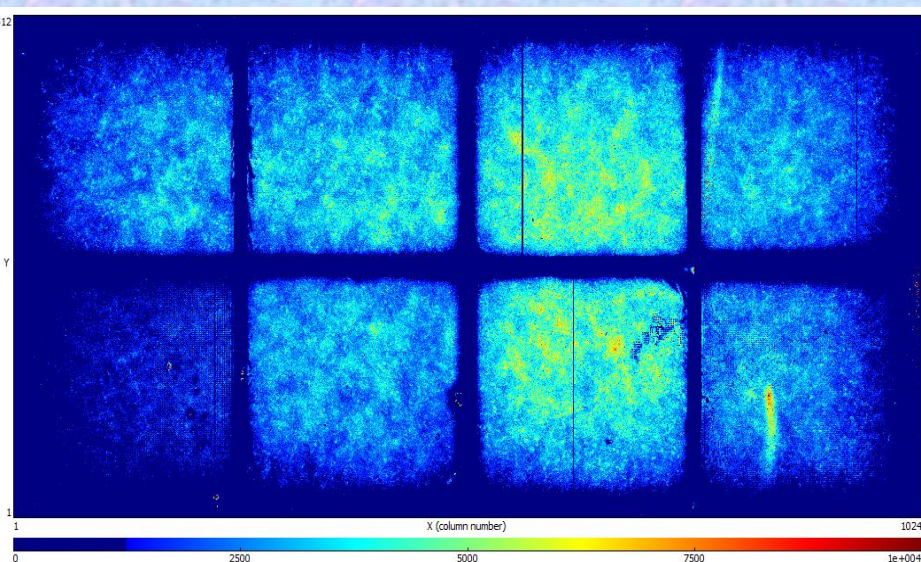
**THRESHOLD = 6000 COUNTS**



**THRESHOLD = 8000 COUNTS**



**THRESHOLD = 10000 COUNTS**



**Non-sensitive ( $\sim 1.5$  mm)  
areas between chips:**

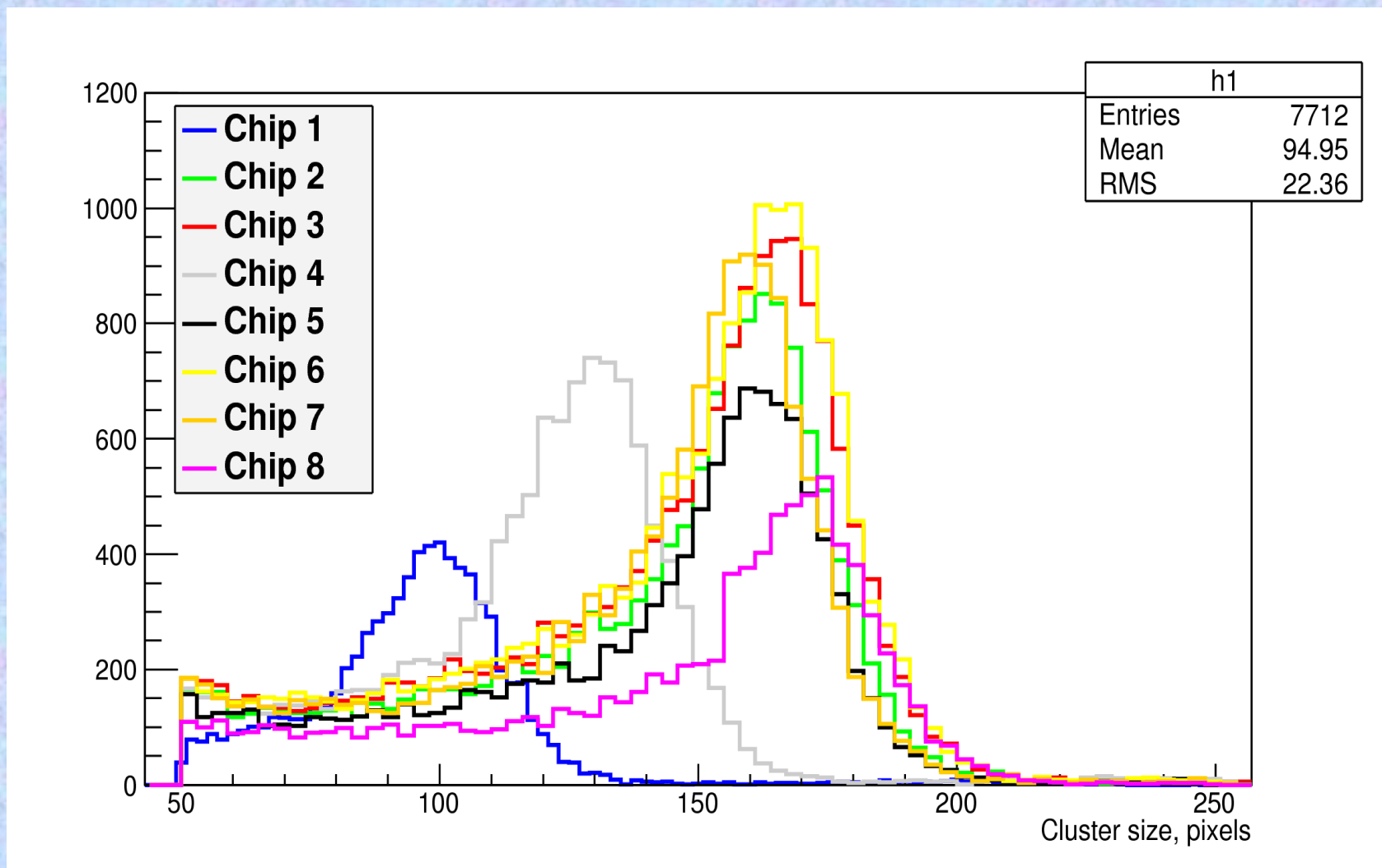
**More studies required to understand:**

➤ if “dead” areas between chips decreases with increased drift field;

➤ “dead” area on the outer edge as a function of the guard voltage

# Octopuce: Cluster Size Distribution

**Single electron sensitivity is very high for all (but 1 and 4) chips**



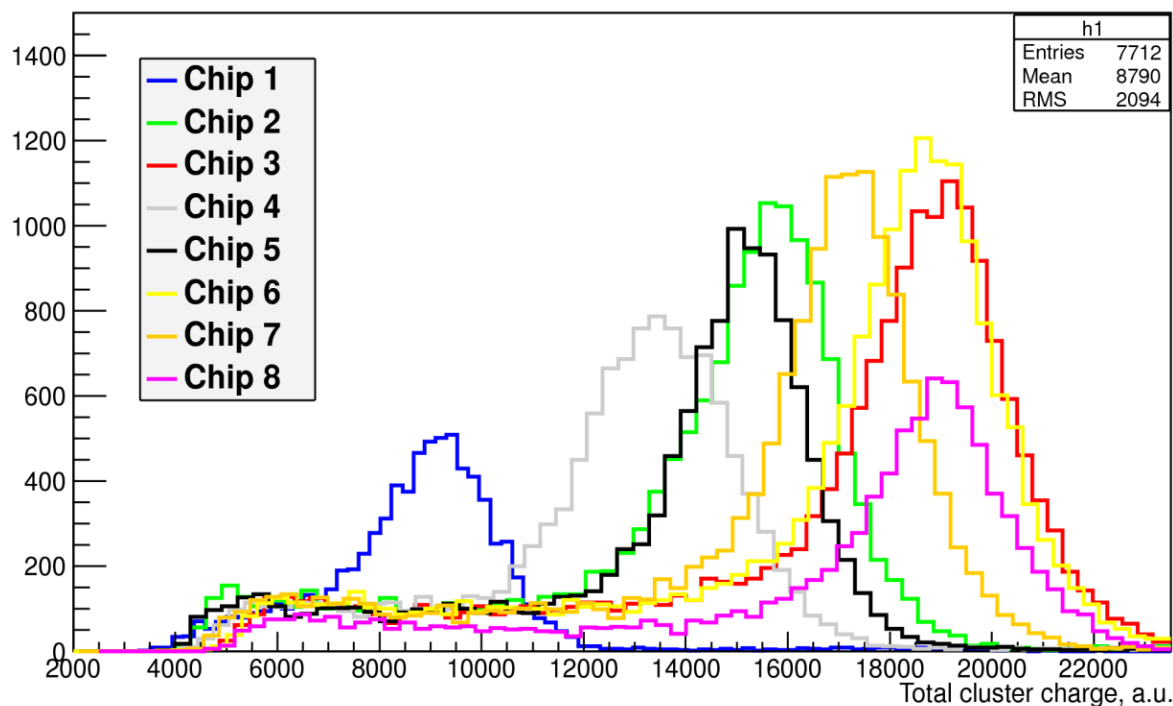
**Expected number of primary electrons in He/Iso (80/20)  $\sim$  165**



# Octopuce: Total Cluster Charge

**Chips 1 and 4 have a lower response (same trend as for the cluster size distribution) →**

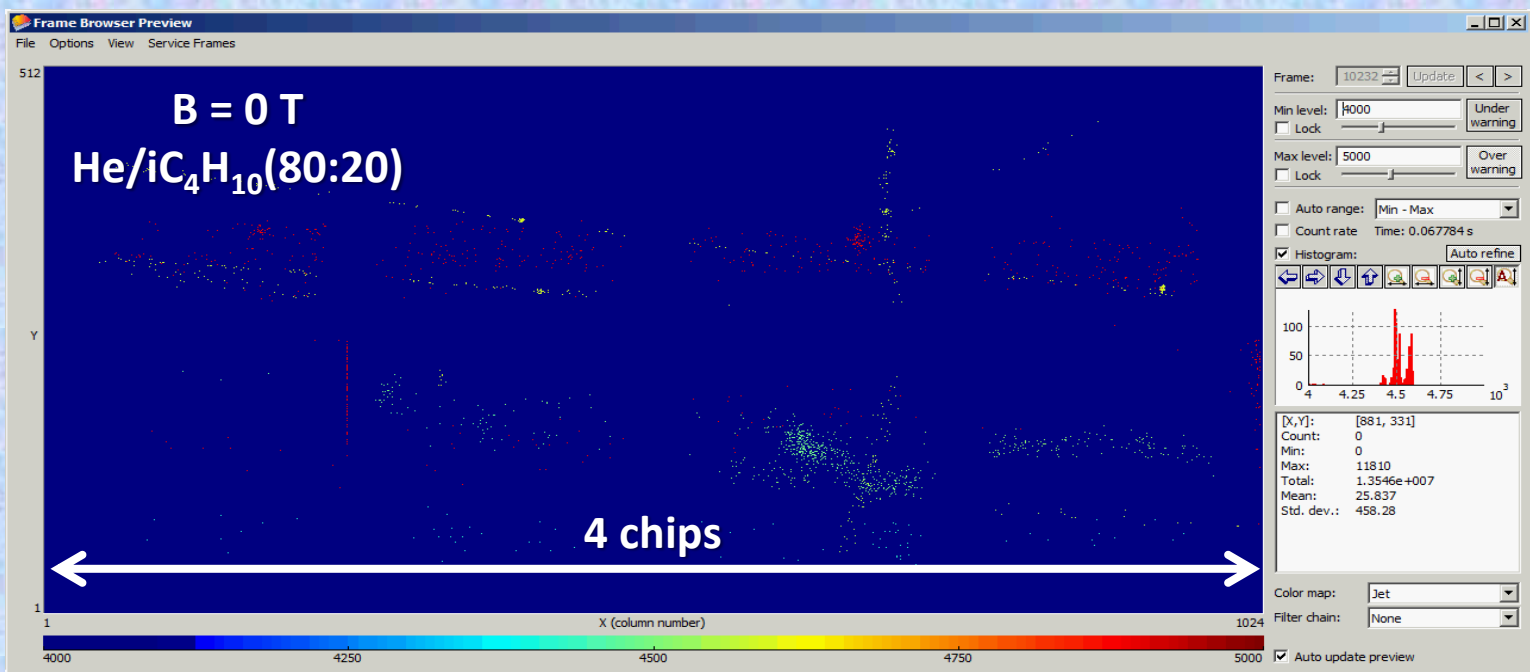
- **Difference in amplification gap**
- **Difference in threshold (too big to explain differences between 1 & 4 and others)**



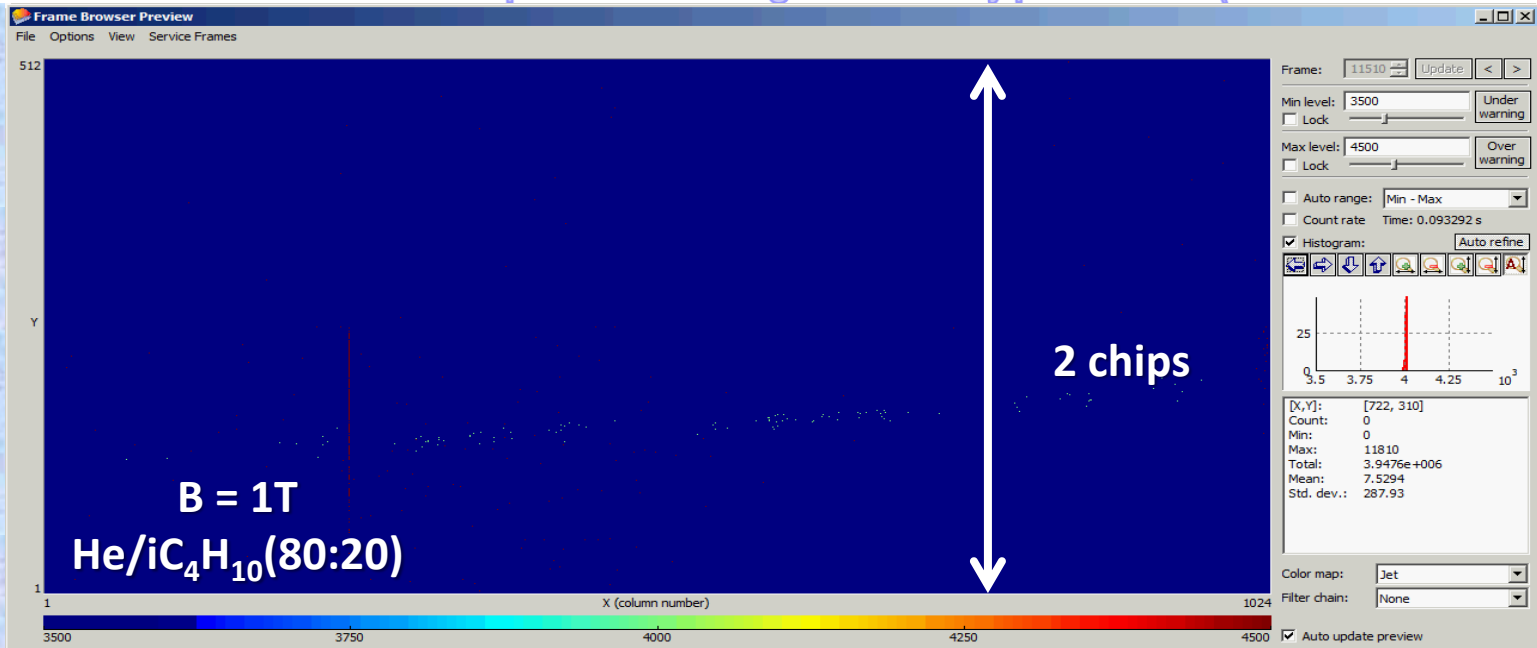
**After equalization:**

Chip number	Threshold level
<b>1</b>	<b>337</b>
<b>2</b>	<b>335</b>
<b>3</b>	<b>340</b>
<b>4</b>	<b>335</b>
<b>5</b>	<b>330</b>
<b>6</b>	<b>327</b>
<b>7</b>	<b>330</b>
<b>8</b>	<b>320</b>

**Some differences in amplification gaps between different chips are seen by microscope (studies are not conclusive, might come from different thickness of the glue under the chips)**

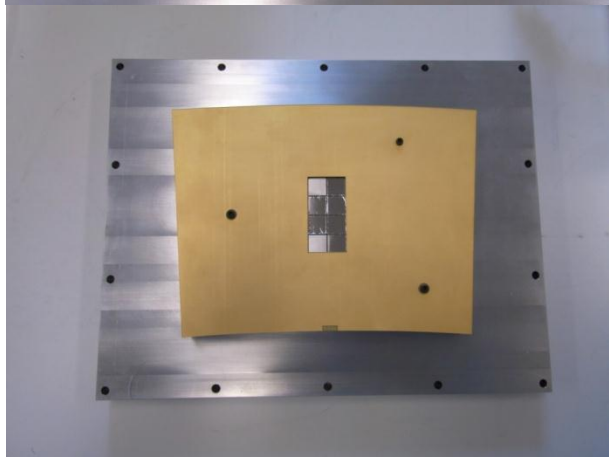
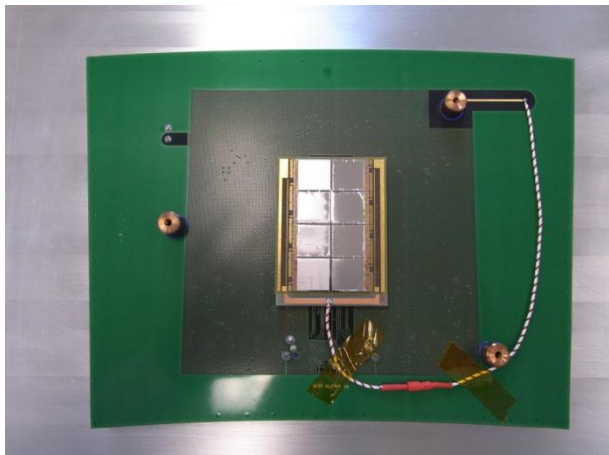


# DESY Test-Beam with Octopuce & Large Prototype TPC (December 2010)

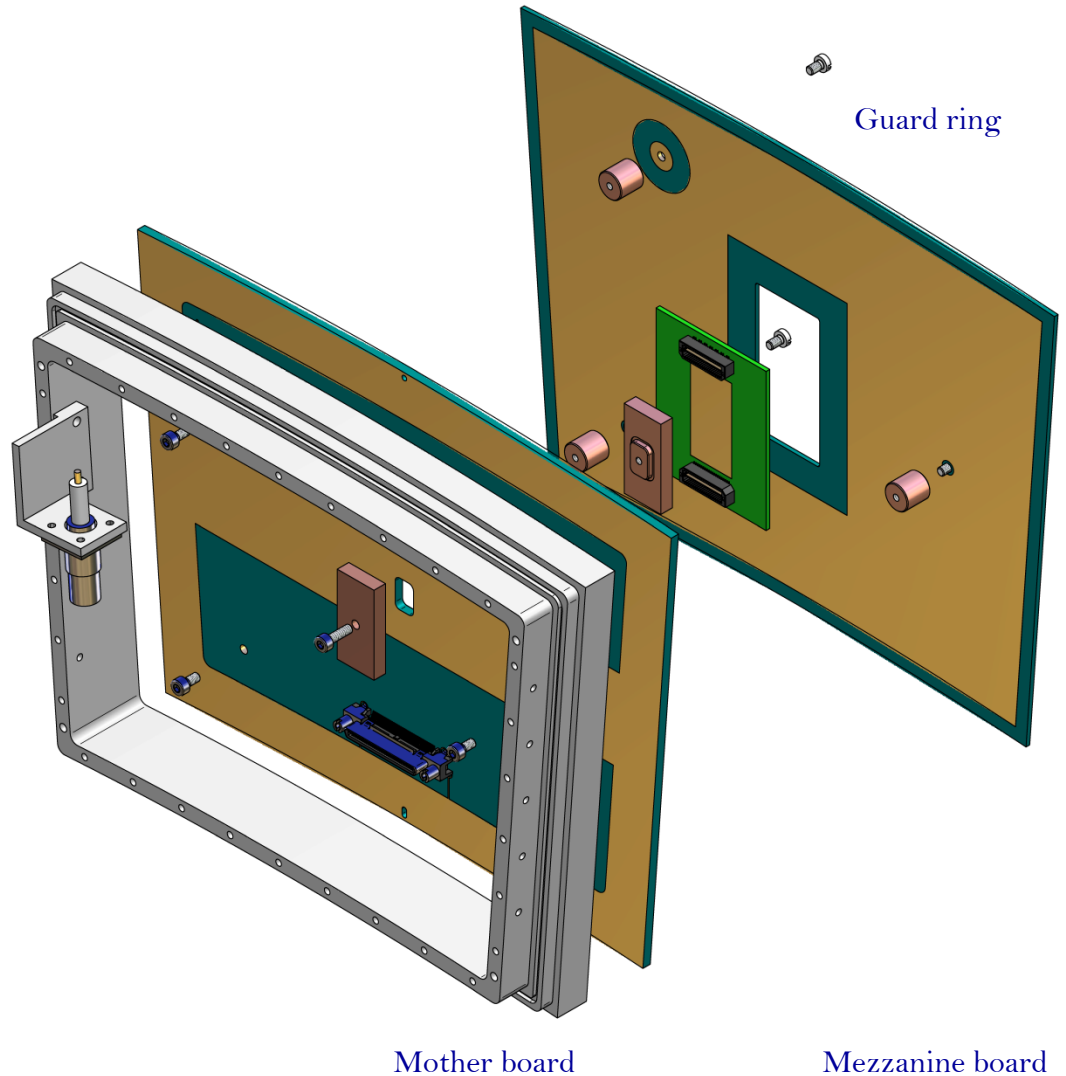


# “The Octopuce” in the Large Prototype TPC

- Chips on a mezzanine board making wire bonding easier
- Large Prototype compatible
- Heat dissipator



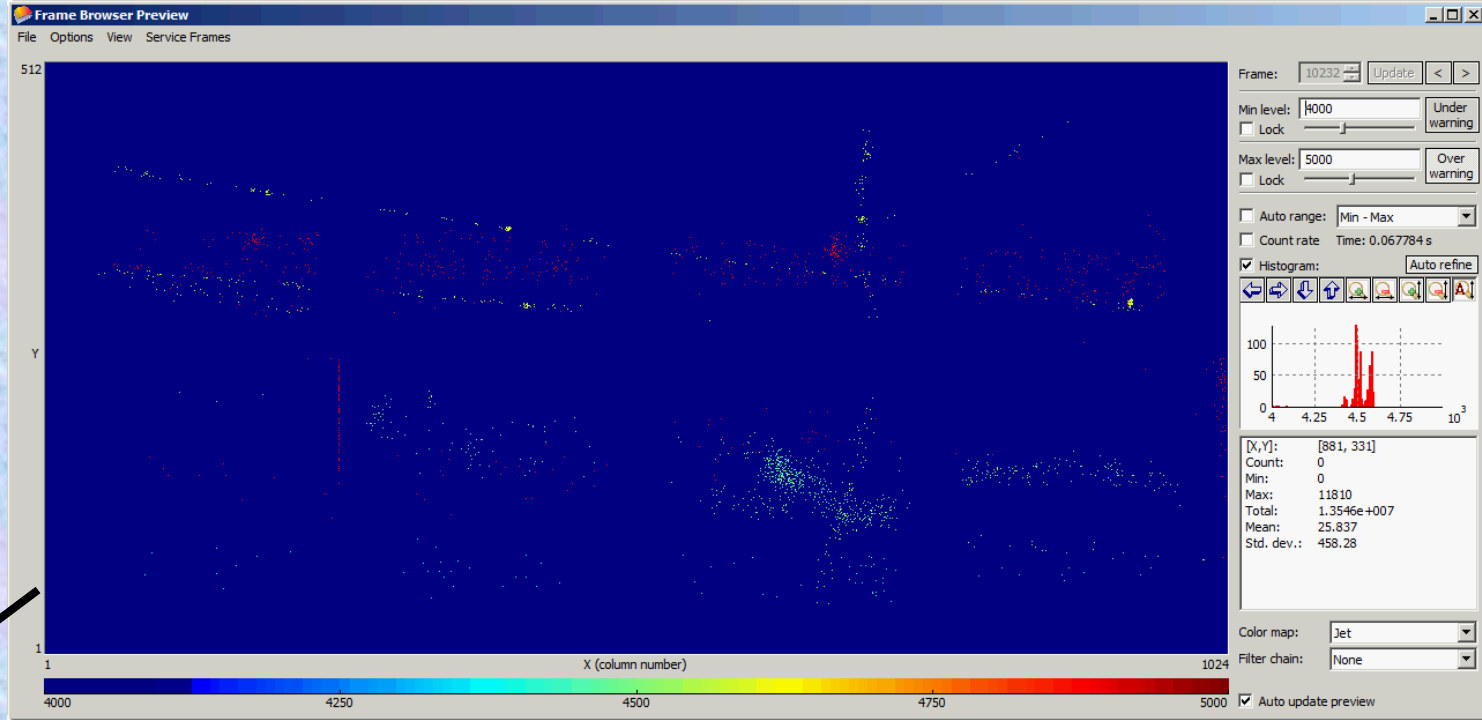
Timepix pane for Large Prototype TPC



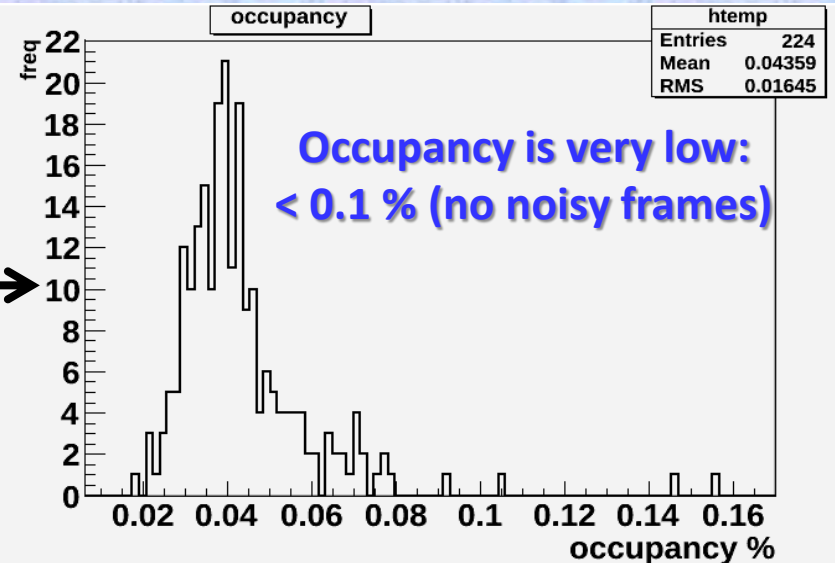
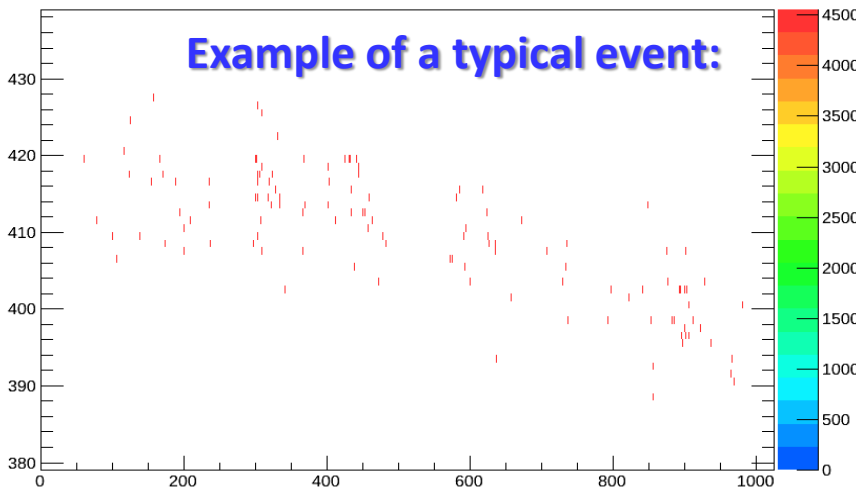
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# Octopuce in the Large Prototype TPC at 0 T

- He/Iso 80/20
- $V_{\text{mesh}} = 380\text{V}$
- Time mode
- Shutter Time: 100  $\mu\text{s}$ , start given by beam trigger



Example of a typical event:



# MAFalda: Medipix Analysis Framework

**ROOT based analysis package developed by John Idarraga (LAL)**

- C++ classes including processors:
  - OctoCEA (define in a few minutes)
  - Pattern recognition of tracks for low threshold

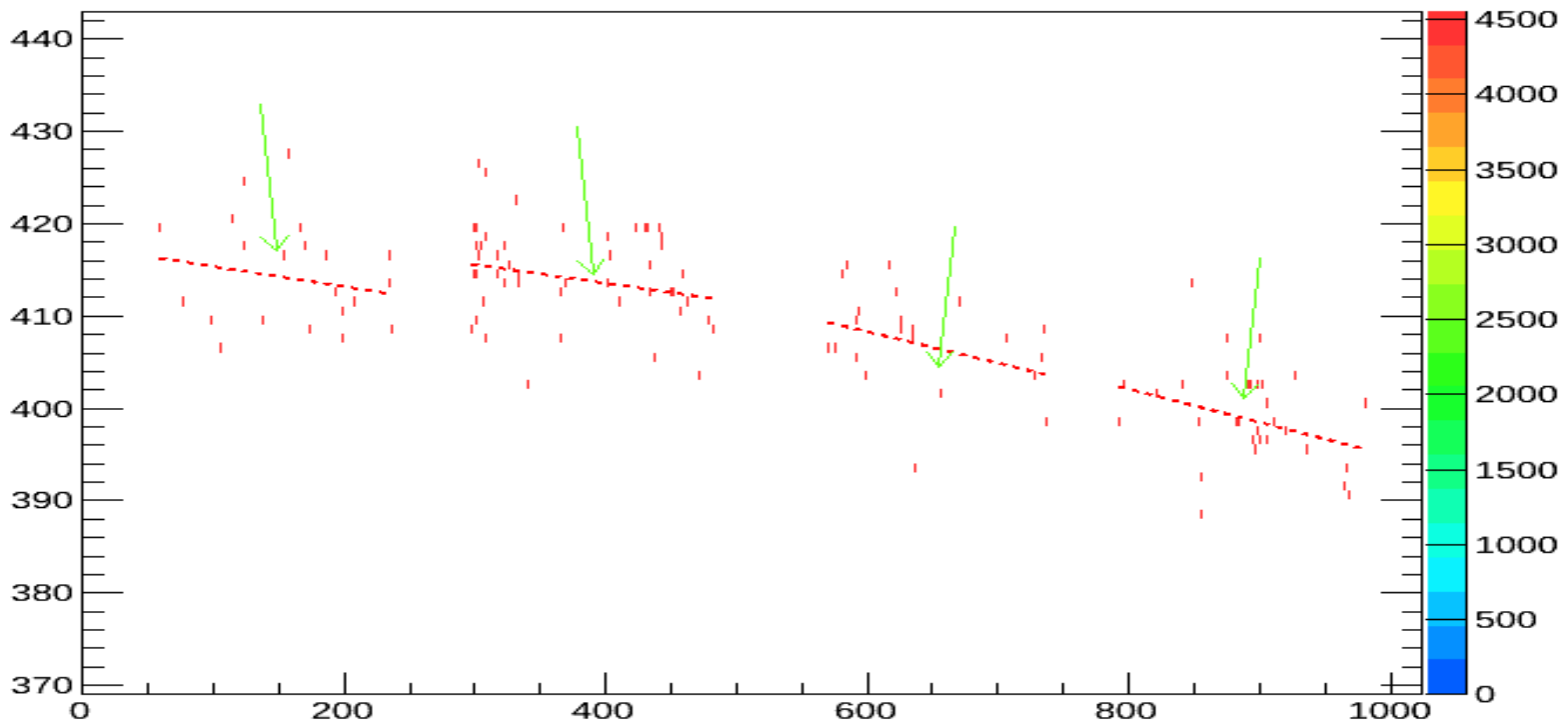
The screenshot displays the MAFalda software interface. On the left, a terminal window shows the execution of the OctoCEA processor. The output lists track parameters such as cut values, slopes, and container indices. For example, it shows tracks with cut values of 254.63, 564.062, 243.473, 357.231, 164.819, 443.514, 175.404, 690.223, and 286.239. The terminal also indicates the number of blobs found (11) and multiple mip clusters (6).

On the right, the MAFalda Viewer displays a 2D plot of particle tracks. The plot shows a distribution of points with several tracks overlaid. The tracks are color-coded by time, with a scale from 0 to 7000. The viewer includes a control panel with various settings for the BlobsFinder and OctoCEA processors. The BlobsFinder settings include border (0), discontinuity (30), and M1cut (-1). The OctoCEA settings include joinSlopeAngleTolerance (5), joinCutPixelTolerance (20), minNPixels (5), minNPixelsClouds (300), and minClusterSize (20). The PRBasi:Species settings include circleToEllipseMin (1.4), circleToEllipseMax (6), mindistanceToLine (15), fractionOfPixelsAtMindistance (0.8), minNInnerPixels (2), longGammaMax (3), minNPixelsMip (3), and maxNPixelsCurly (50). The control panel also includes buttons for Reprocess, Save config, Disconnect, and Quit, as well as a search bar and a jump to button.

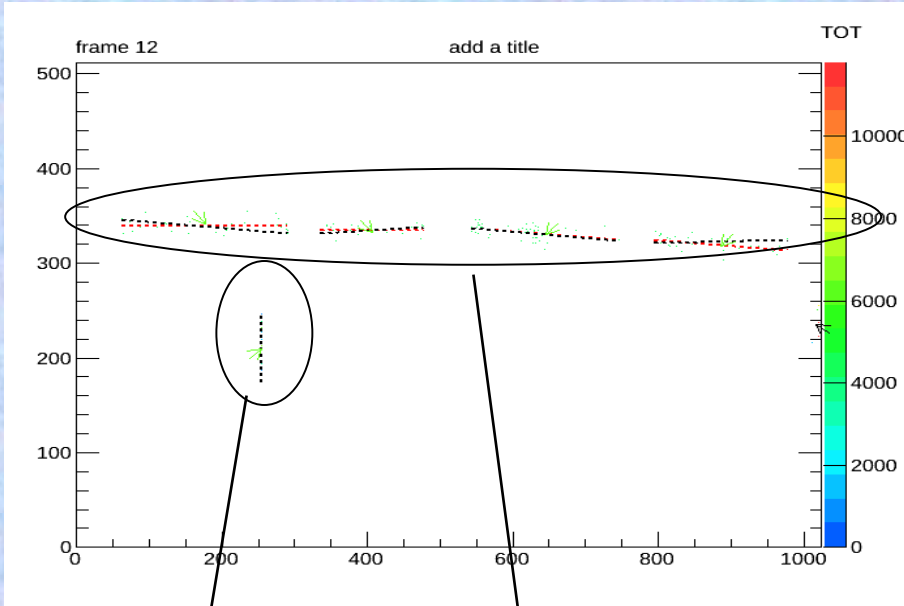
**Use MAFalda as the first step → implement reconstruction algorithm in Marlin TPC**

# MAFalda: Cluster Finding and Track Segments (I)

- Form cluster from the pixels with “discontinuity” < 40 pixels (each cluster should contain > 12 pixels)
- Calculate the linear regression with all points in the cluster (**red dotted line**)
- Calculate residuals from the red line to each point (if > 80 % the points are within 20 pixels – **this is the “track segment”** !)



# MAFalda: Cluster Finding and Track Segments (II)

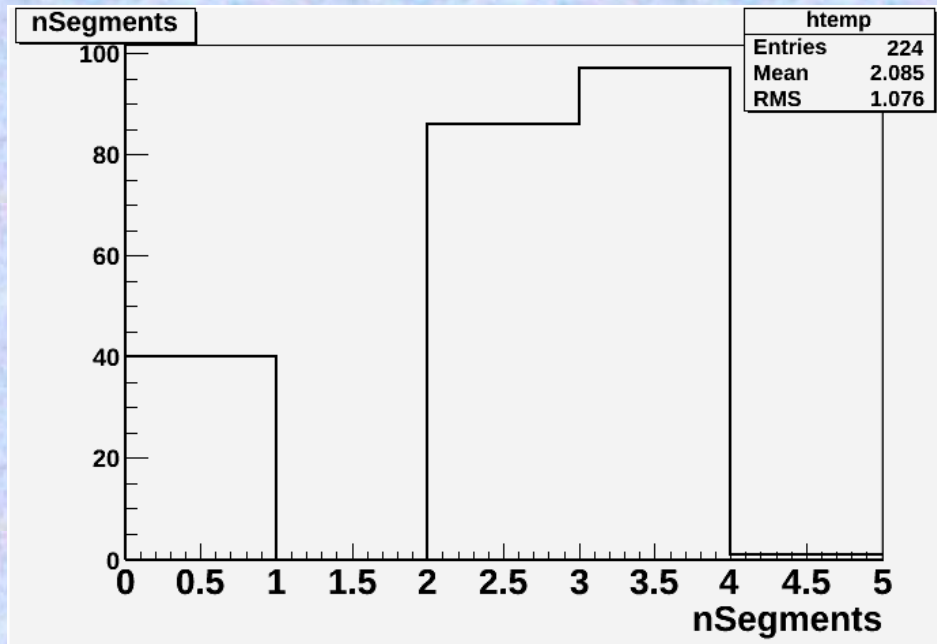
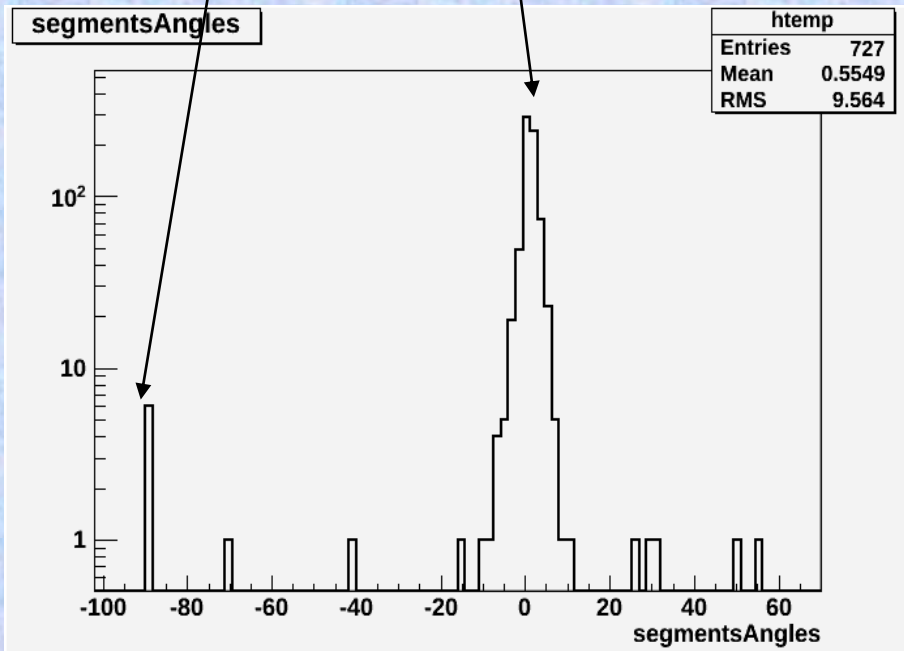


**Check incident angles of track segments**

**→ Take segments within +/-10 degrees  
(electron beam is in the horizontal direction)**

**Number of segments  
per reconstructed track**

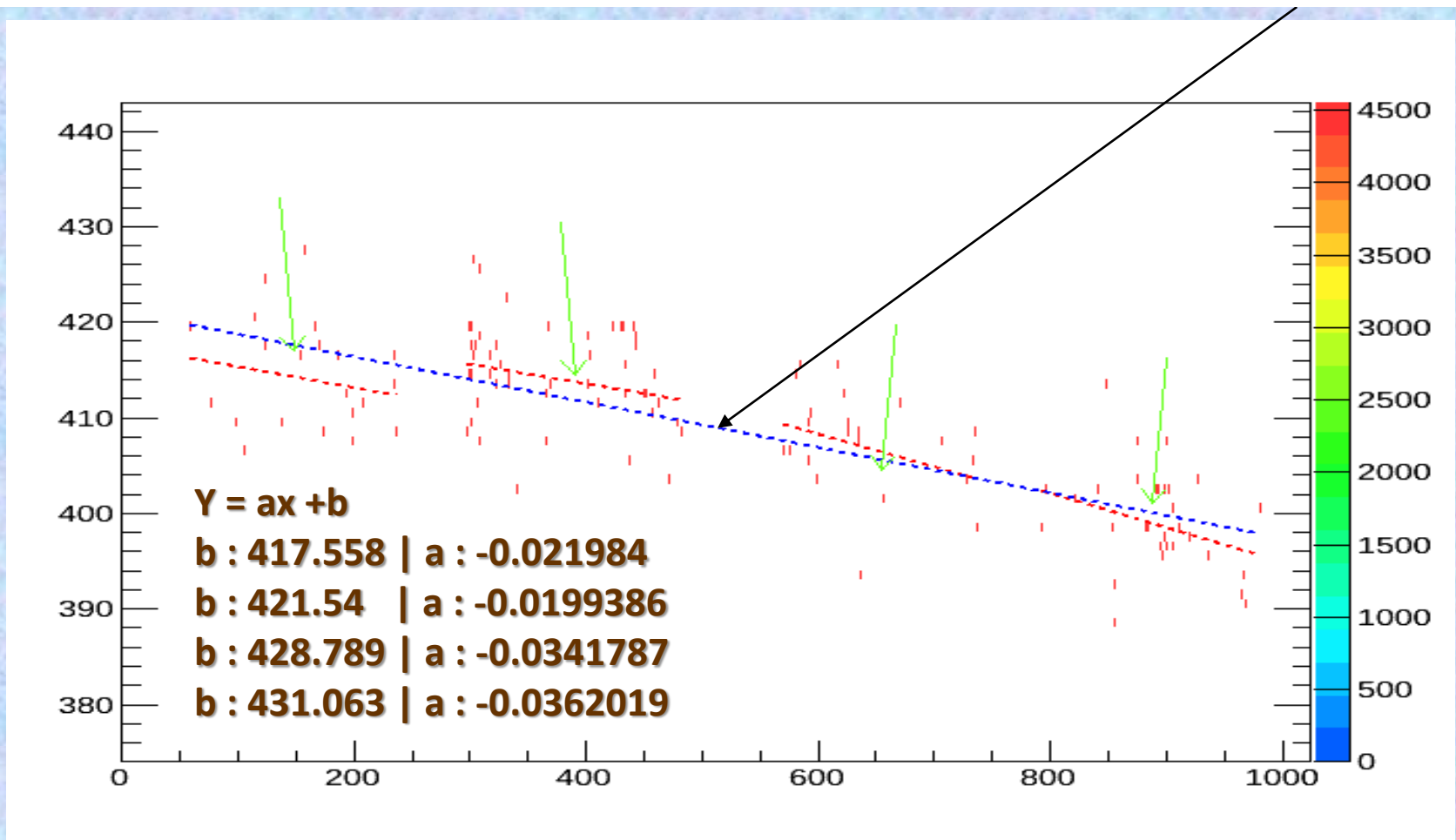
**(most tracks consists of  
2-3 segments):**



# Track Reconstruction

**Reconstruct track from track segments (if more than 2 segments):**

- Apply data quality cuts to make sure all segments correspond to a given track
- Perform a linear regression for all pixels on a track → **reconstructed track (blue dotted line)**





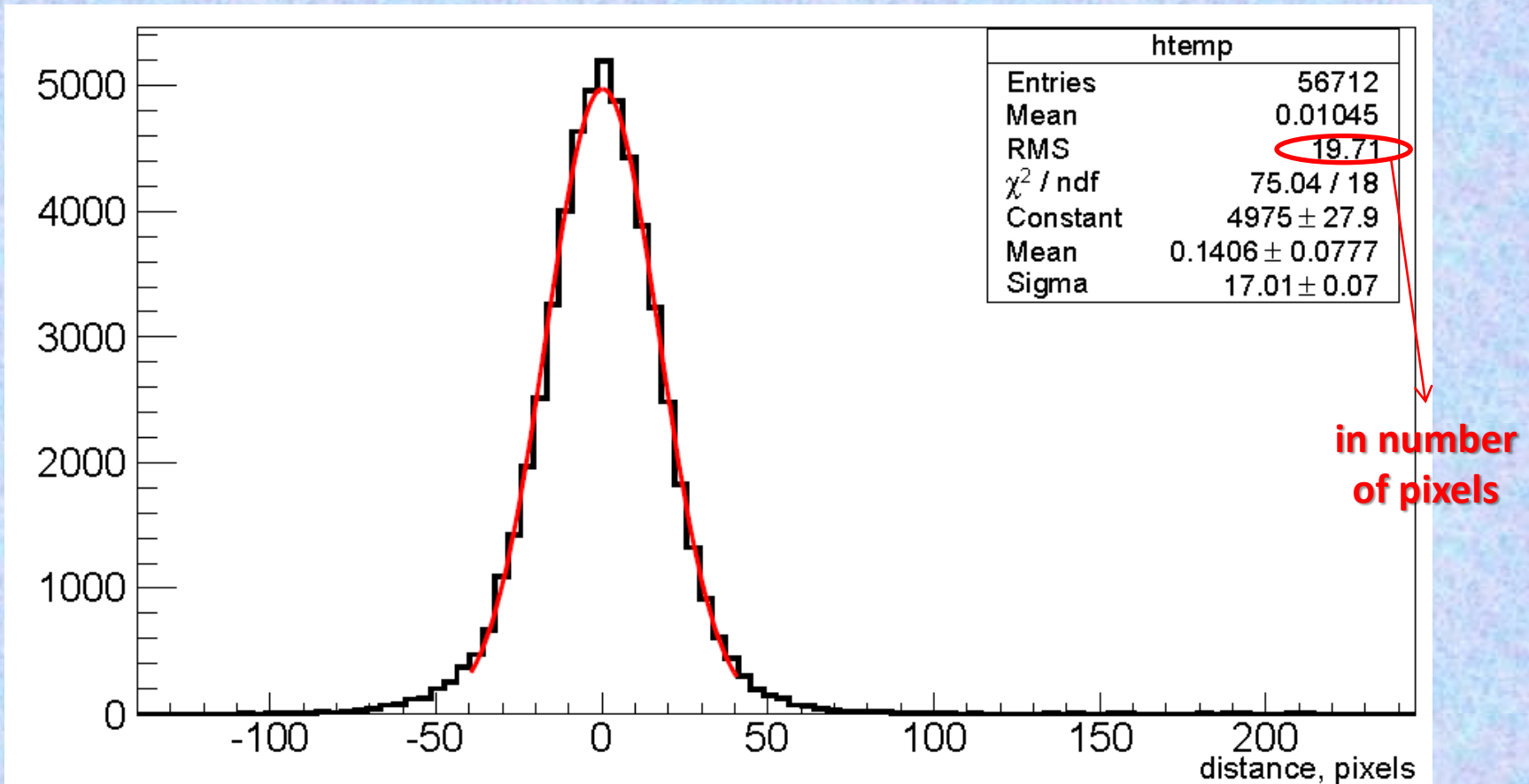
# Track Reconstruction: Residuals

An unbiased estimate of the single point resolution:  $\sigma = \text{Sqrt}(\sigma_1 * \sigma_2)$ :

Perform fit to all pixels and calculate the distance between each pixel and the position of the point of closest approach along the fitted track:

$\sigma_1$  = Gaussian fit, when all pixels are included in the track fit

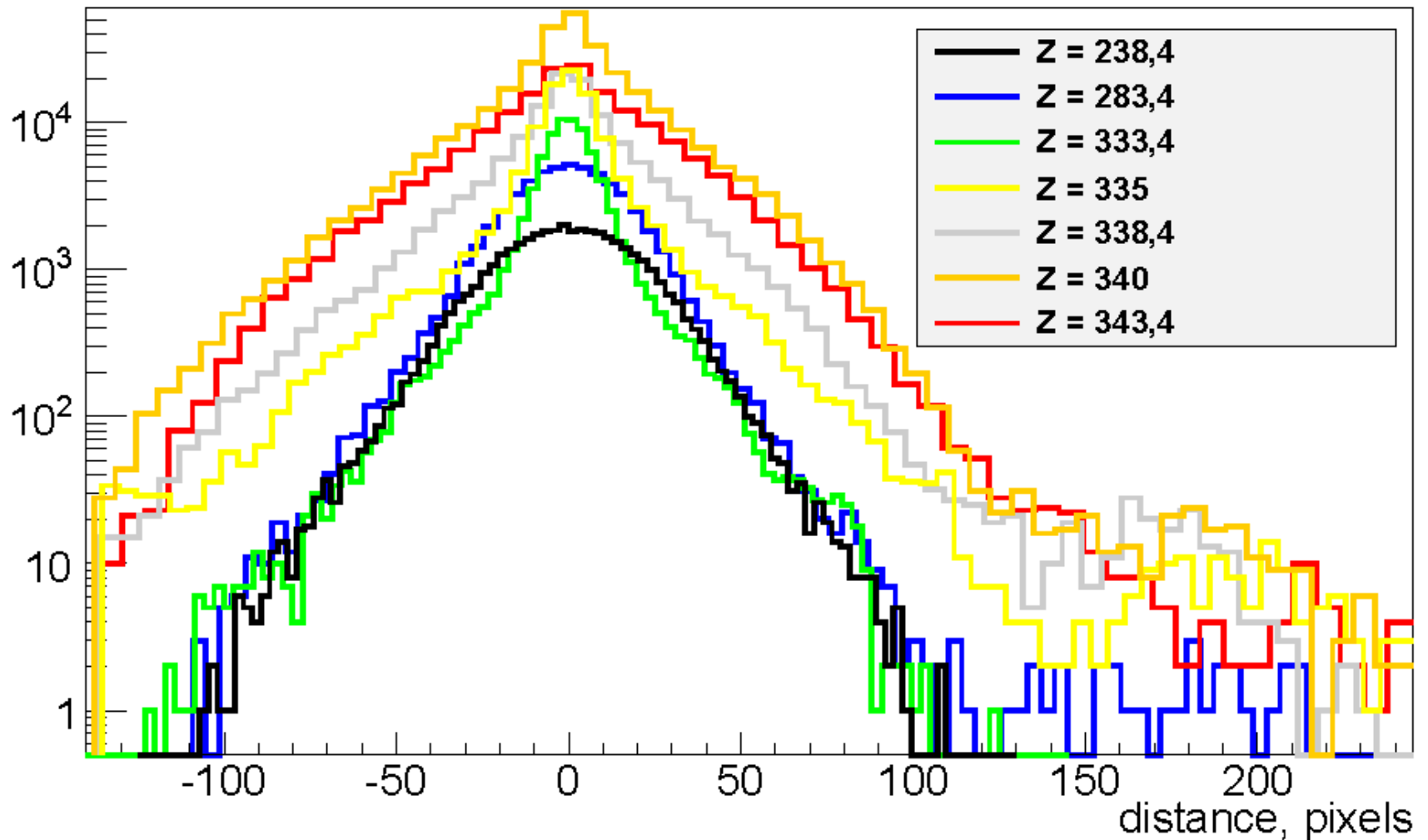
$\sigma_2$  = Gaussian fit, omitting pixel under consideration from the track fit



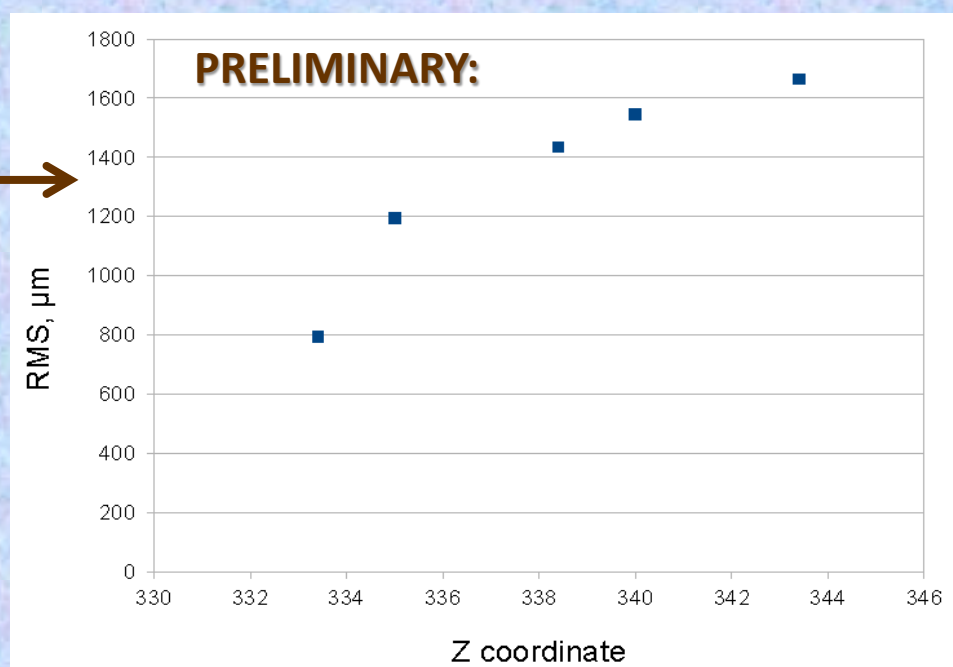
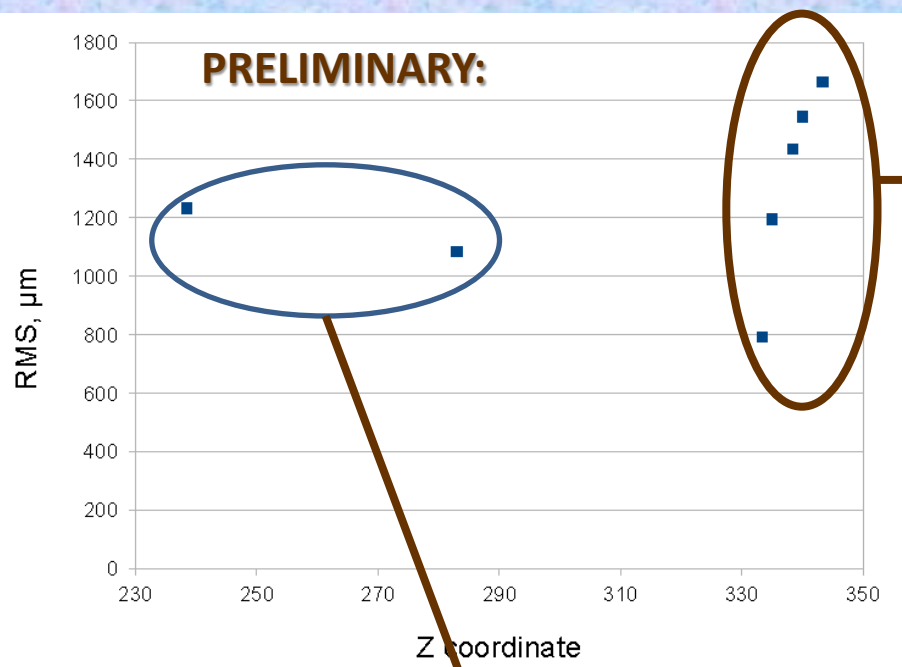
# DESY Test-Beam: Track Residuals

**Summary of residuals ( $\sigma = \text{sqrt}(\sigma_1 * \sigma_2)$ ) for different Z-coordinates:**

**(corresponds to the different positions of electron beam passing through the Large Prototype TPC)**



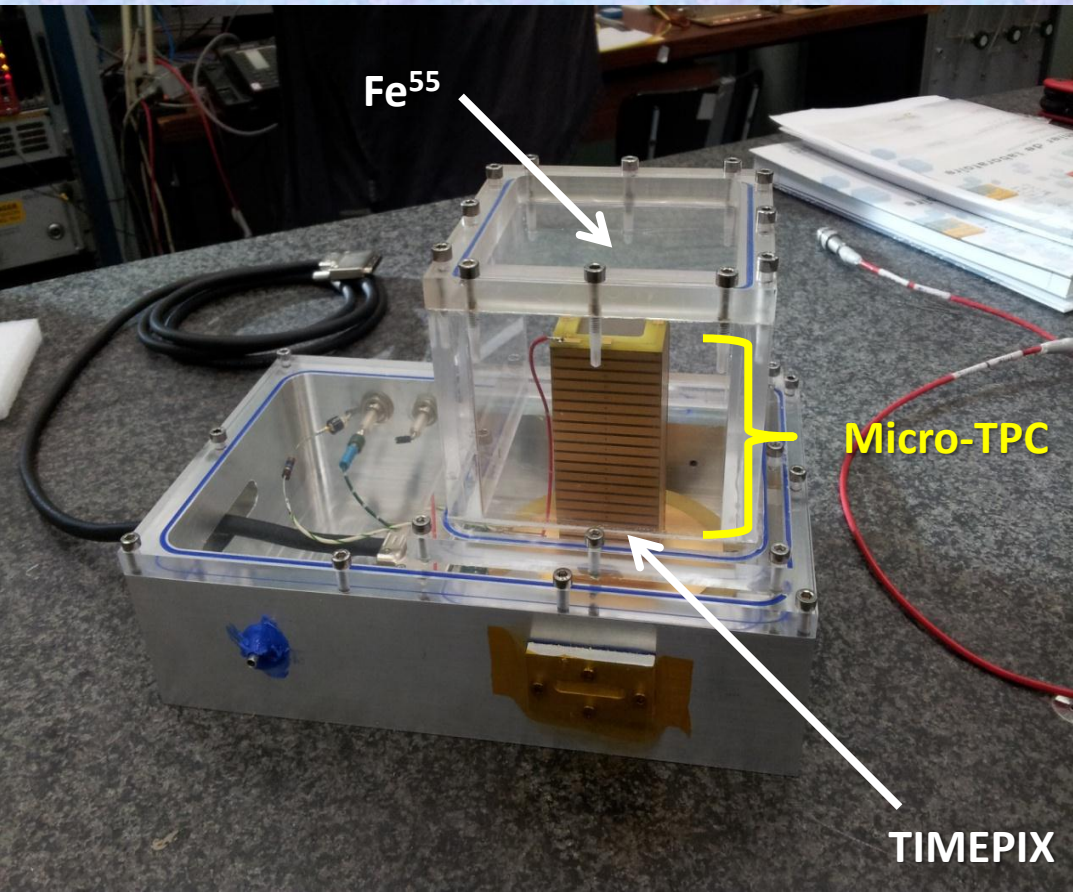
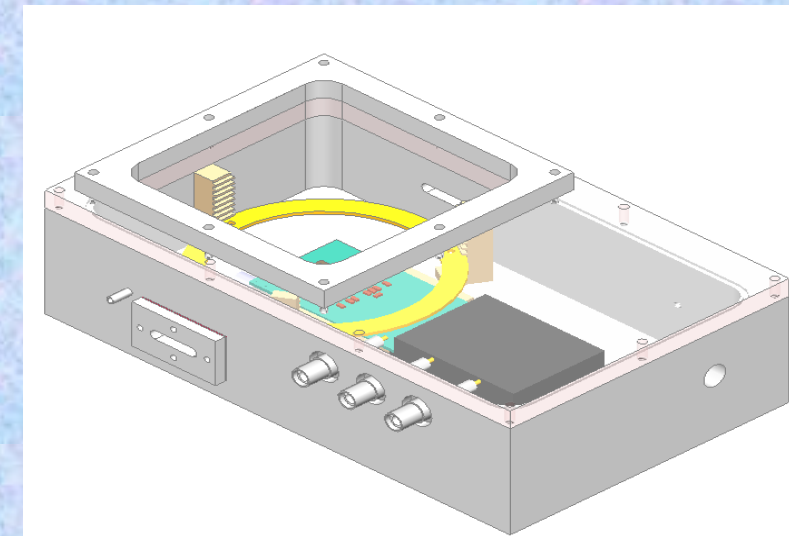
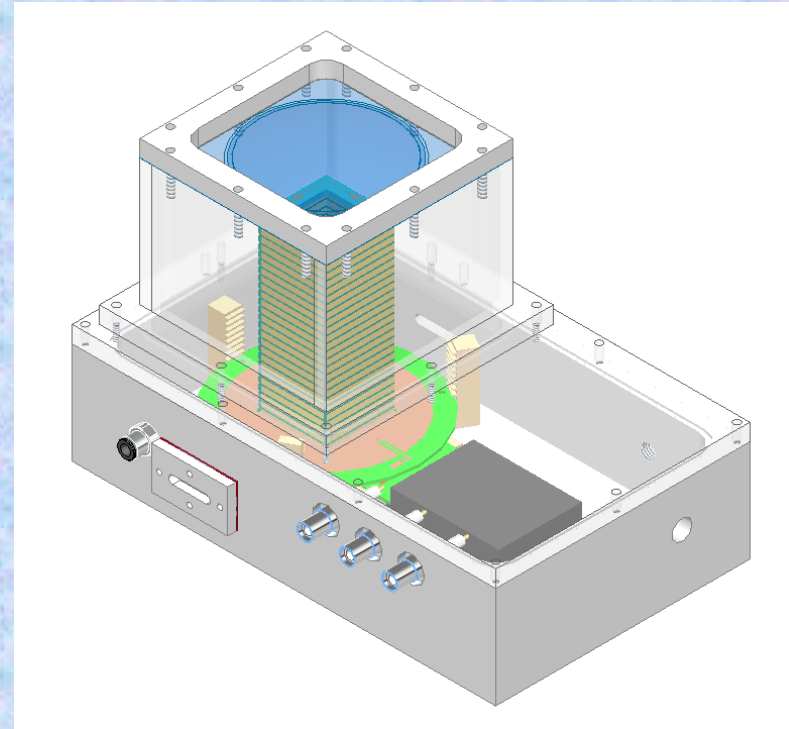
# DESY Test-Beam: Track Residuals as a function of Z (Large Prototype TPC)



**Very low statistics, behavior needs to be understood**

# Saclay Micro-TPC with Timepix

- Two micro-TPC boxes have been built
- Drift distance in micro-TPC ( $\sim 10$  cm) is large enough to allow study of single electron response from  $\text{Fe}^{55}$  source



# Studies of new IZM-3 InGrids in the Saclay micro-TPC

**2011: Major Step Forward → InGrid Production on a wafer level**

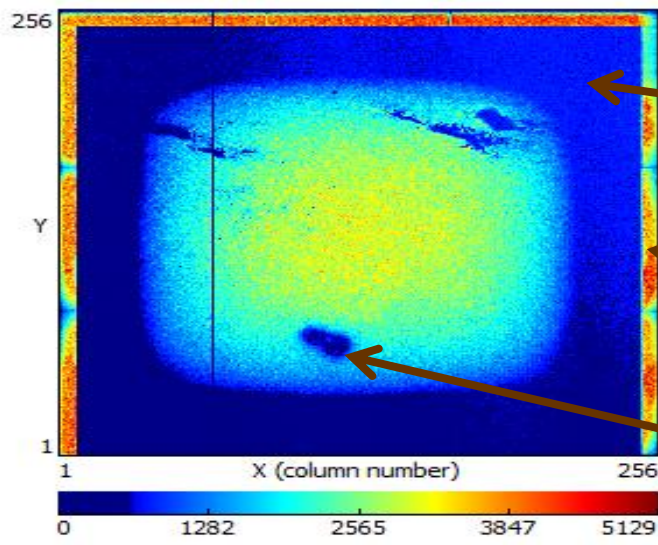
**2013: 3rd IZM production run to post-process Timepix chips on a wafer level**



➤ Received 6 IZM-3 InGrids in Saclay (earlier studies with IZM-3 InGrids have been performed in Bonn, NIKHEF)

➤ Four chips are mounted on PCB (one does not work)

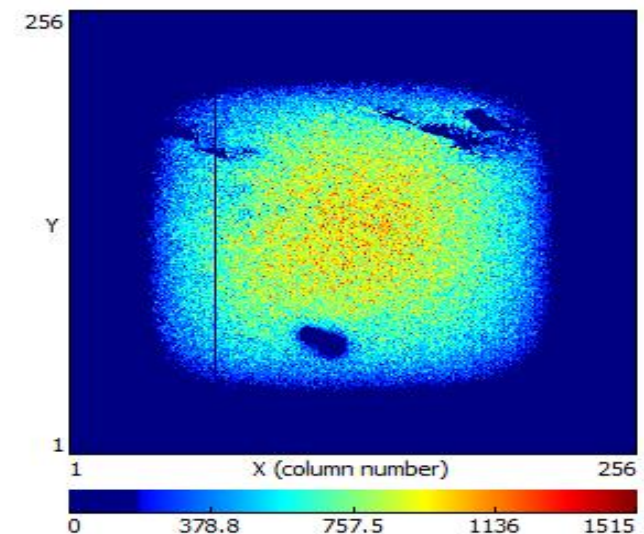
**One InGrid is tested → in general, good behavior**



Guard ring problem in micro-TPC

Some noise and/or discharges

Some local grid issues



# Proposal of a Flexible Detector Setup using Low Energy Electrons from PHIL at LAL

PHIL provides electrons with momentum 5 MeV/c and  $10^9$  particles per bunch

**Goal:** obtain samples of “monochromatic” electrons

- with energy between 1 and 5 MeV and energy spread of better than 10%
- with adjustable intensity down to  $10^4$  electrons per bunch

**Study  $dE/dx$  by cluster counting using InGrid detectors  
the electron range 1-5 MeV**

**(earlier simulation results by M. Hauschild & NIKHEF  
experimental studies)**

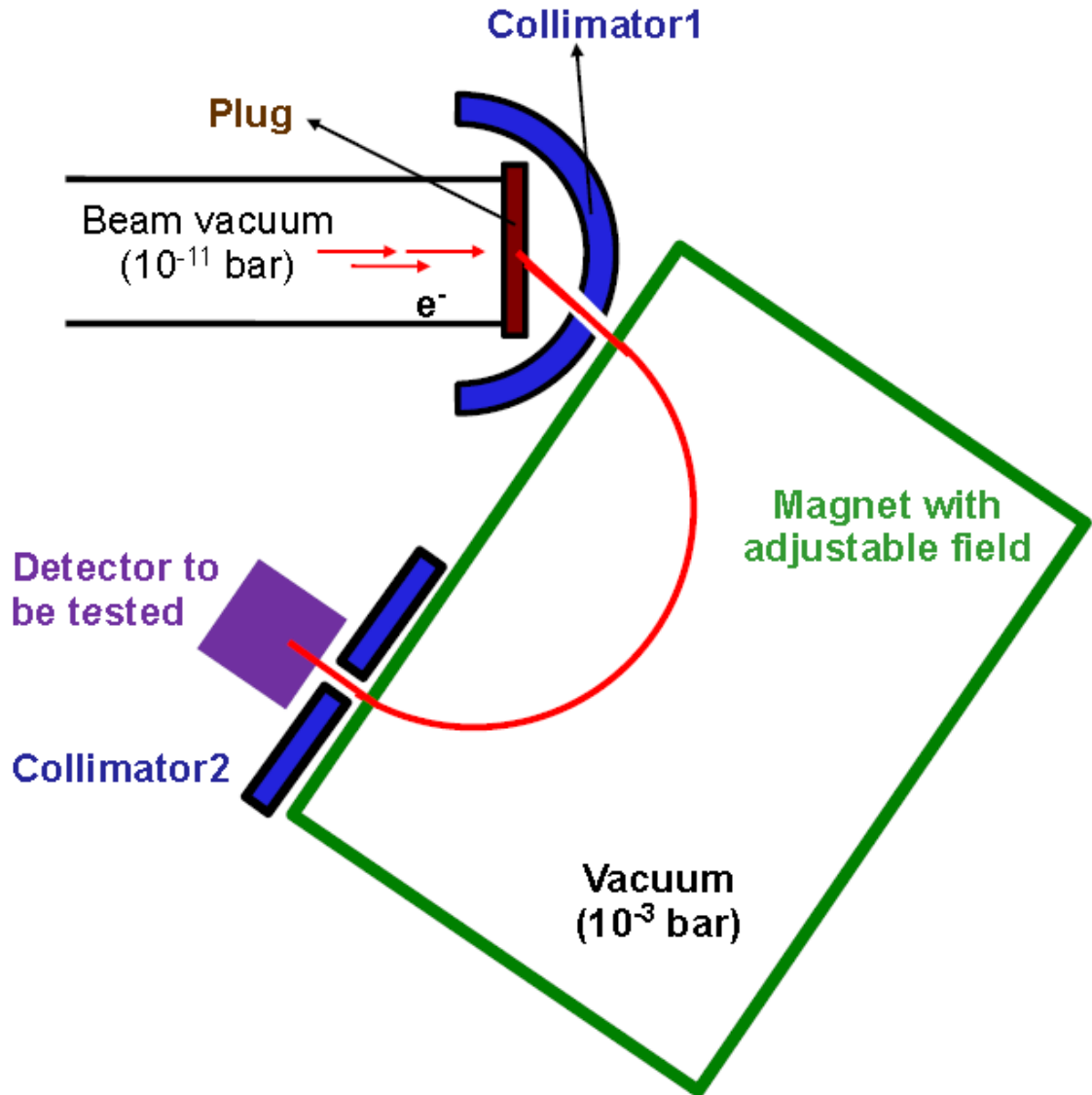
Joint proposal LAL & IRFU

LAL contribution from S. Barsuk, L. Burmistrov, H. Monard, A. Variola

# Spectrometer to sample “monochromatic” low energy electrons

## Setup idea:

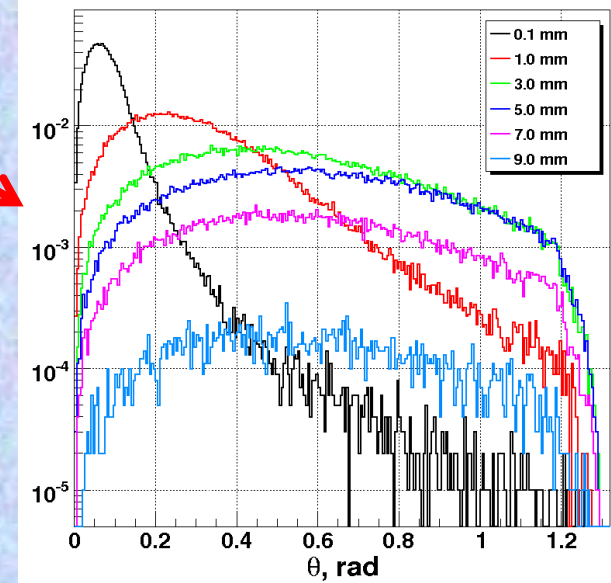
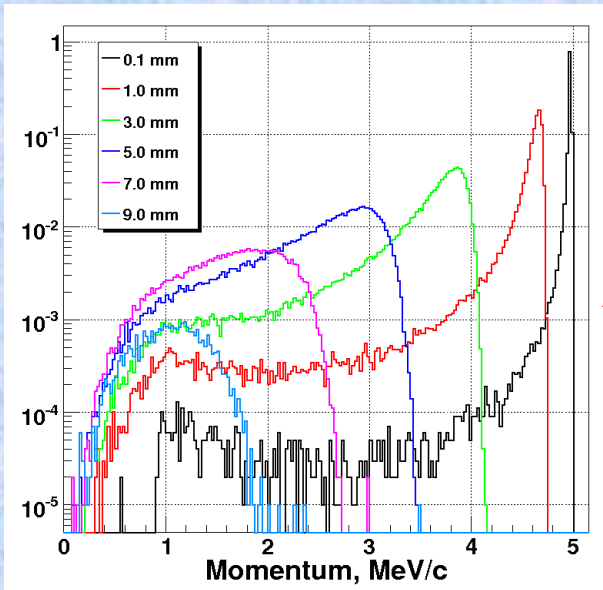
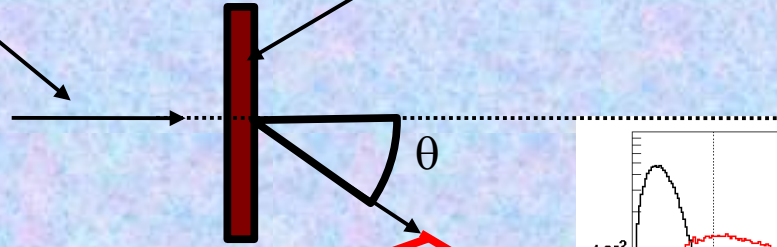
- ❑ Use electrons from PHIL
- ❑ Reduce energy/intensity using Al plug
- ❑ Select unique direction for electrons passing the plug with collimator 1
- ❑ Select required energy by half-turn of electron in the magnetic field (position of collimator 2)
- ❑ Adjust intensity/energy spread using collimator 2, positioned in front of tested detector



# Momentum and angular spectra of electrons passing through the Al plug, depending on the plug thickness : Geant4 simulation

5 MeV/c electron

Aluminum plug



Example of sampling 1 MeV electrons from 5 MeV beam: from simulated  $10^8$  electrons a sample of  $\sim 10^3$  electrons and momentum spread of  $\sim 10\%$  are obtained with collimator opening of 6 mm.

