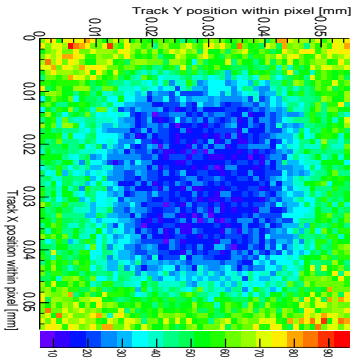
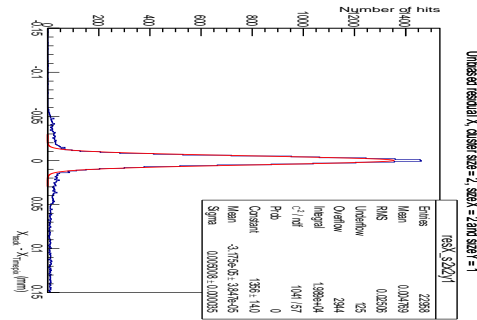


# Timepix test-beam results and Sensor Production Status

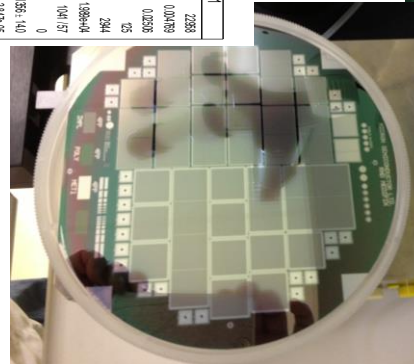
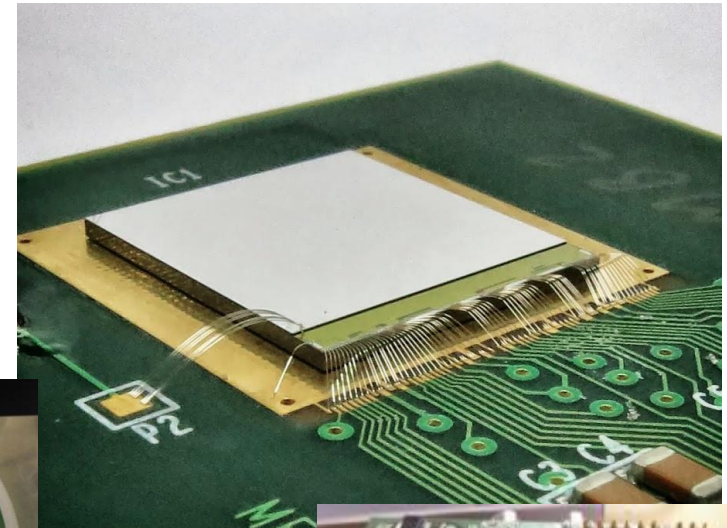
Mathieu Benoit, PH-LCD



Hit probability, cluster size 2



Unbiased residual X, cluster size = 2, size X = 2, size Y = 1



# Outline

- Sensor production and procurement
  - Micron Semiconductor Ltd. / IZM production
  - Advacam 50um Thickness active-edge assemblies
- Timepix/EUDET Telescope integration
  - Going fast : MiMTLU
  - Geometry Optimization for resolution enhancement
- August 2013 testbeam Results

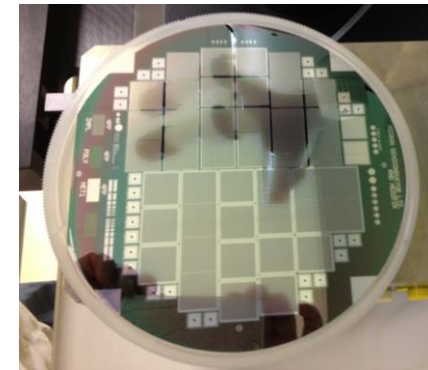
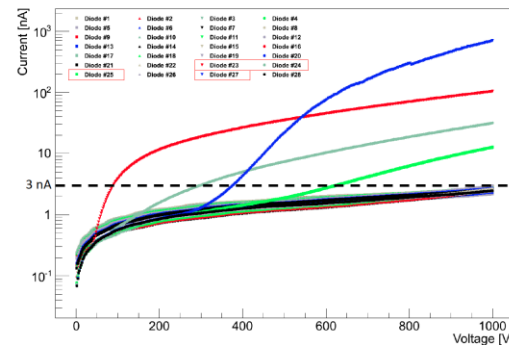
# Sensor production and procurement : Micron



A first sensor production was launched in 2012 to investigate with manufacturers the possibility to process very thin sensor wafer.

- First delivery from Micron Semiconductor Ltd. (UK) of 10 Timepix Sensor wafer end of 2012
  - 4 N-in-P, 6 P-in-N wafers
  - Thickness between 100  $\mu\text{m}$  and 300  $\mu\text{m}$
- Very good sensor quality
  - Visual inspection OK!
  - Current-Voltage curve on test diode show very good leakage properties and no breakdown up to 1000V

Wafer 3022-1 200  $\mu\text{m}$  - Diodes IV

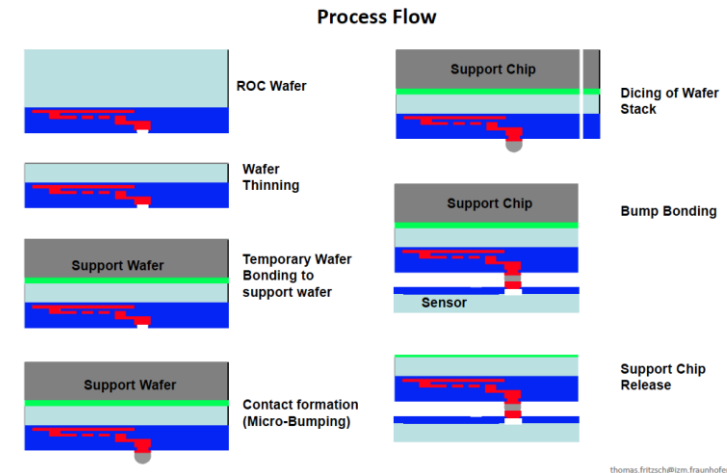


Number	Type	Thickness [ $\mu\text{m}$ ]
2929-22	N-type	300
2929-21	N-type	300
3022-1	P-type	200
3028-7	NTD-N	150
3027-13	NTD-N	100
3022-4	P-type	200
3022-3	P-type	200
2953-8	P-type	150
3029-8	NTD-N	150
2929-24	N-type	300

# Sensor production and procurement : Bumping at IZM

Micron Sensor Wafer were sent to IZM for Under-Bump Metallization and assembly to Timepix and Medipix3RX ASIC

- 6 Sensor wafers processed by IZM
  - wafer < 200 um thickness attached to handle wafer for processing
- 2 Timepix ASIC wafer processed with bumps for attachment to Micron sensors .
  - 2<sup>nd</sup> wafer thinned down to 100um and attached to handle wafer for production of very thin sensor assemblies
    - Target : 100 um Sensor on 100 um Timepix ASIC
- First Assemblies return to CERN and tested in August DESY Testbeam
- 100um Sensor wafer broke during handle wafer removal -> Most sensors OK !
- 100um ASIC wafer processed , now testing quality of the assemblies



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# Sensor production and procurement : Advacam

Production of assemblies with very thin sensors has also been investigated with Advacam (Finland)

- 7x50 um p-in-n Timepix thin assemblies delivered to CERN in July 2013
- Very good bump quality, only a few merged/unconnected bumps
- Depletion at 15V, good leakage current properties (~100nA @ 15V) , uniform on all tested chips , Breakdown @ ~85V
- 5 assemblies tested in August 2013  
DESY Testbeam

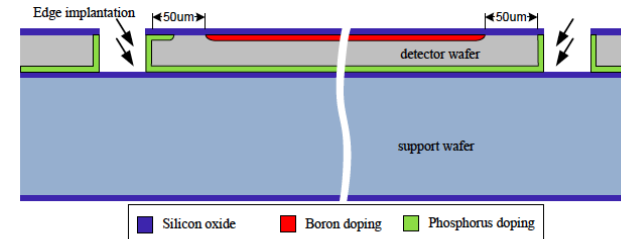
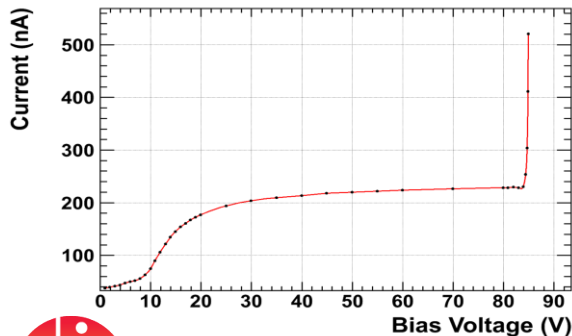
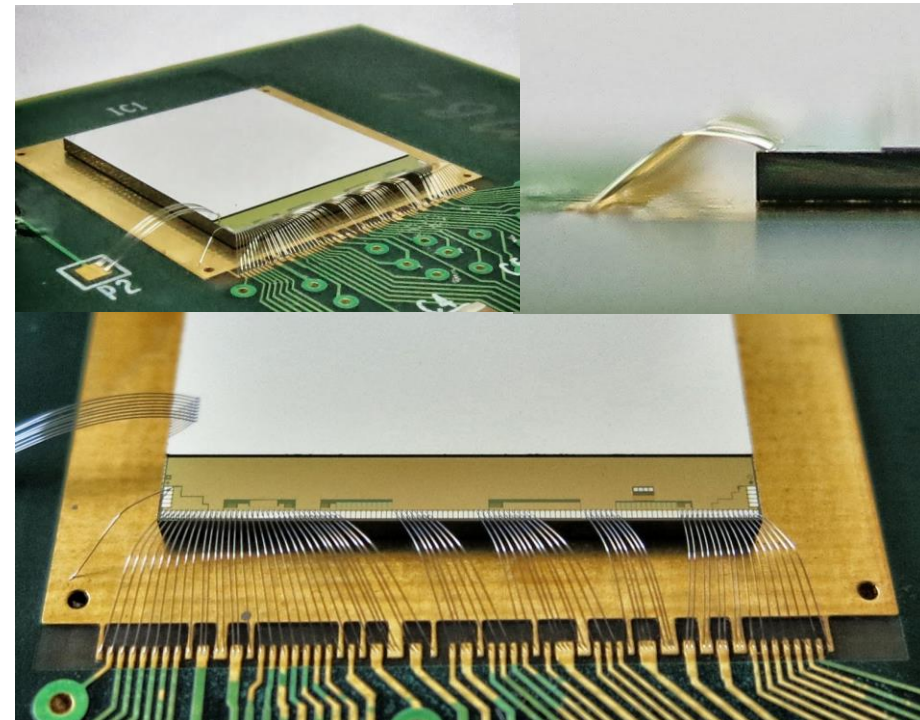


Illustration of the active edge approach with P-on-N structure



# Timepix/EUDET Telescope integration : Going fast with MiMTLU

Test beam infrastructure @ DESY:

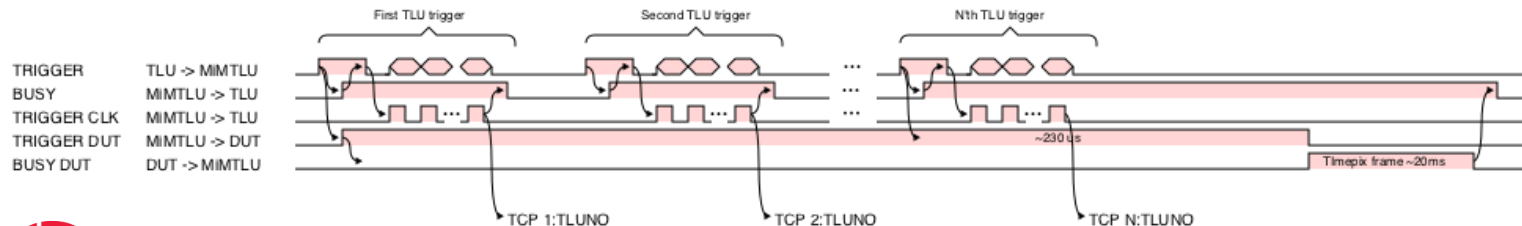
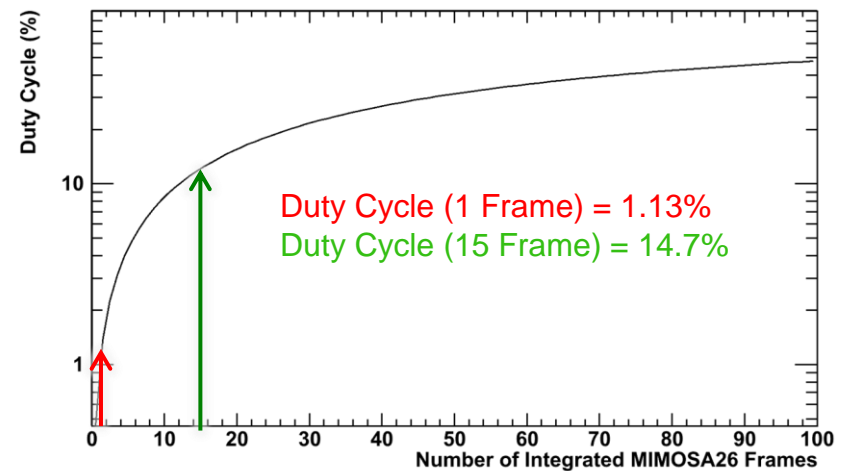
- Electron beam (energies up to 6 GeV)
- Telescope based on MIMOSA detectors
- DAQ framework provided:
  - EUDAQ (software)
  - Trigger Logic Unit (hardware)
  - Reconstruction and analysis software
  - Very good user support

The Timepix ASIC Fitpix Readout was integrated to the Telescope DAQ, providing online monitoring and full reconstruction framework . The Man-in-the-middle TLU device was developed to circumvent rate limitation imposed by Timepix Full-Frame Readout

Trigger Logic Unit (TLU)



MiM-TLU

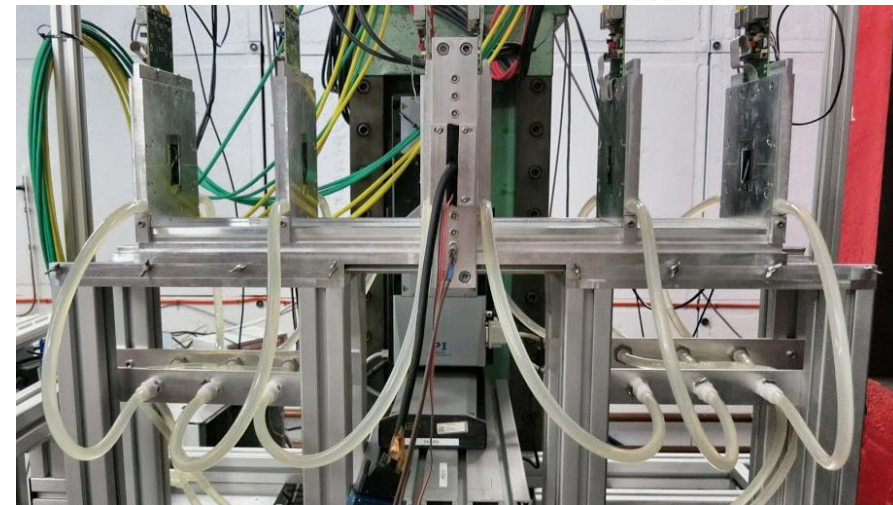
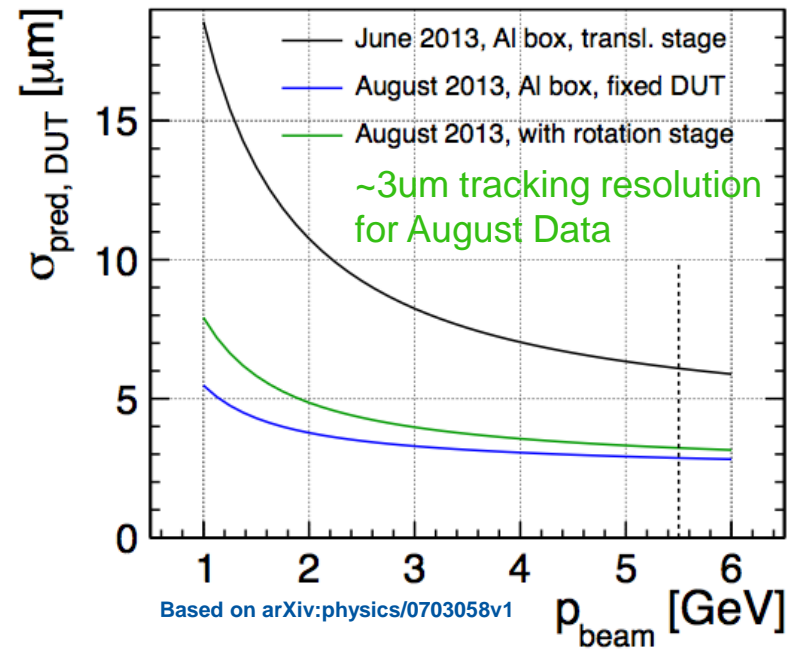


# Geometry optimization for resolution enhancement

DESY low energy electrons are subject to scattering and a careful optimization of Telescope and DUT positioning was conducted to minimize the tracking resolution at the DUT.

- Based on Analytical Track Fit by  $\chi^2$  minimization taking into account multiple scattering in the telescope, air.
- The conclusion is that best configuration is to bring telescope as close to DUT as possible and distance telescope planes to gain lever of arm

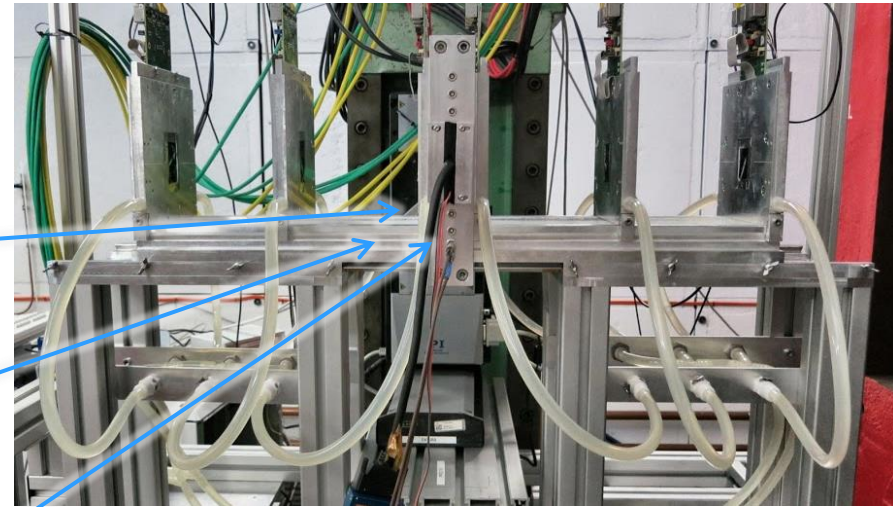
DATURA telescope DUT prediction resolution





# August 2013 testbeam Summary

- **61'632'783 trigger in 2 week, ~1.8 track per shutter**
- Measurement with and without DUT at 1.2-5.5 GeV for resolution and tracking studies
- Measurement with MIMTLU with Different Scaling factors
- Bias scan at 0 degree for each sample , 15 track per shutter (15-45V, 5-45V for thicker sensor)
- Angle and Bias Scan from 90 degree to 15 degree tilt , bias scan for 50um thin Sensor at 75 degree



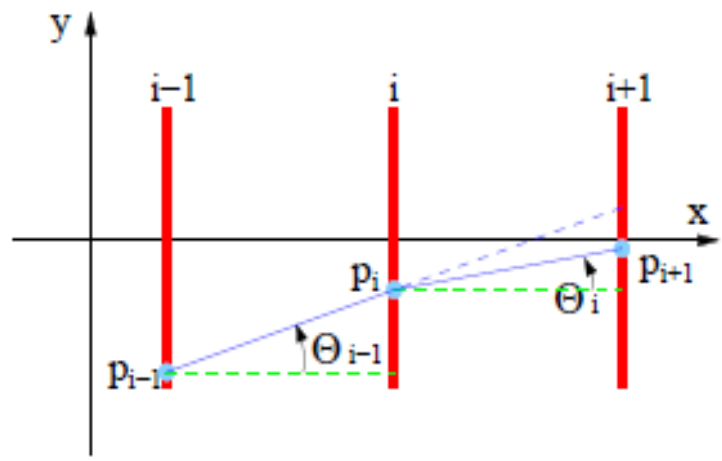


# Reconstruction

- The track fitting method takes into account multiple scattering
- Minimization of  $\chi^2$  (its derivatives can be calculated analytically) which has 2 contributions:
  - uncertainty of the position measurement ;
  - the track angle of particle multiple scattering in the plane.

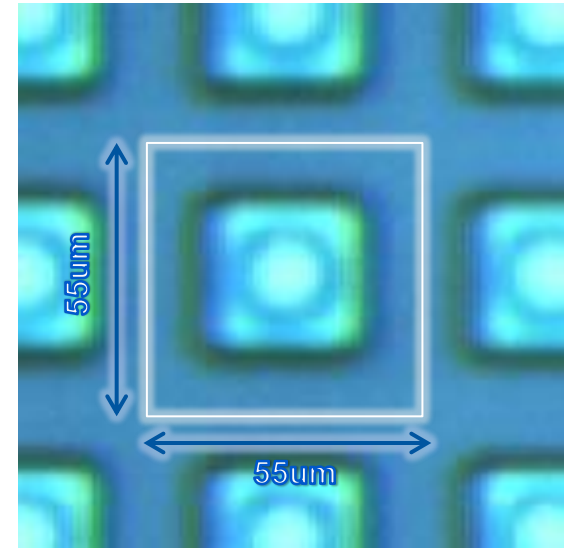
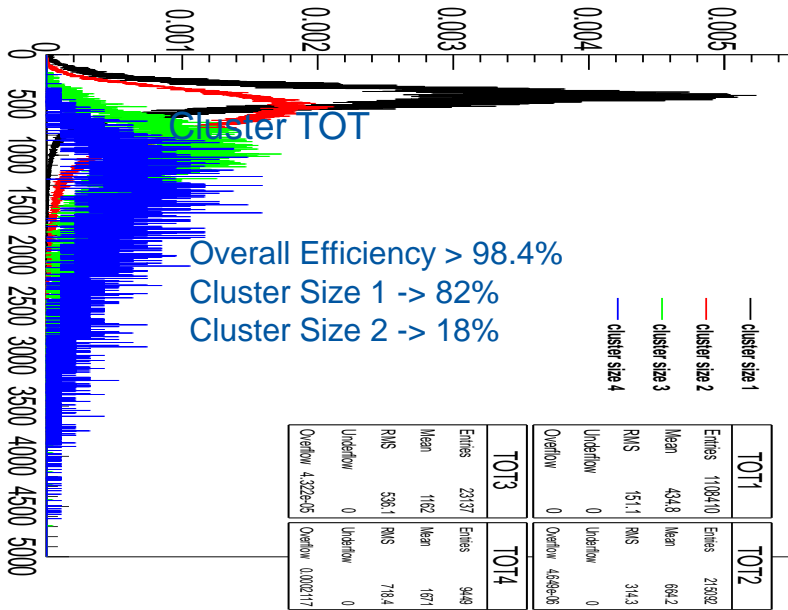
## Telescope :

- 6 x Mimosa26, 18x18 um pixels
- Digital Readout
- Reconstruction in ILCSoft
- Analysis in pyEudetAnalysis

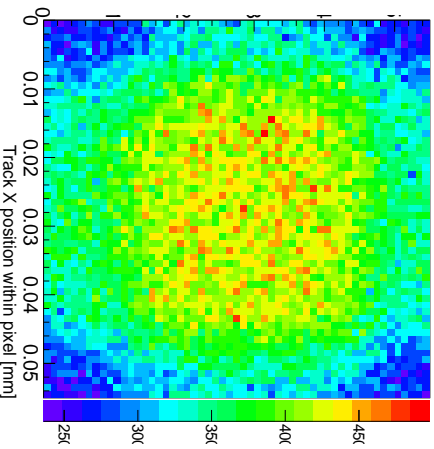


# August 2013 testbeam Results

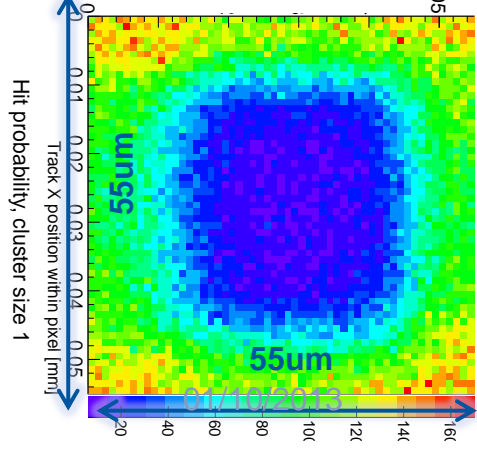
Advacam p-in-n 50um thin Timepix Assembly, 50um edges, ~100nA@15V :



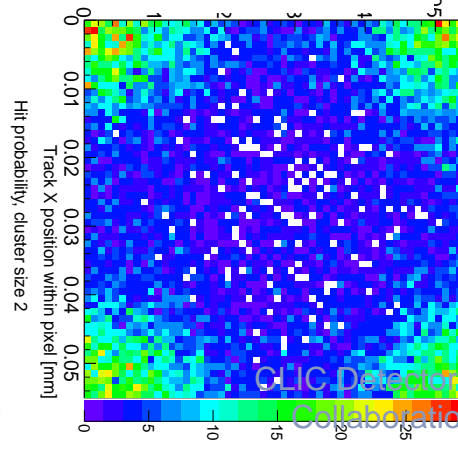
Cluster Size 1



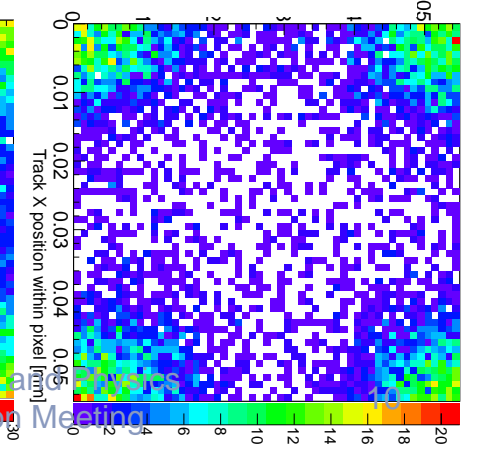
Cluster Size 2



Cluster Size 3

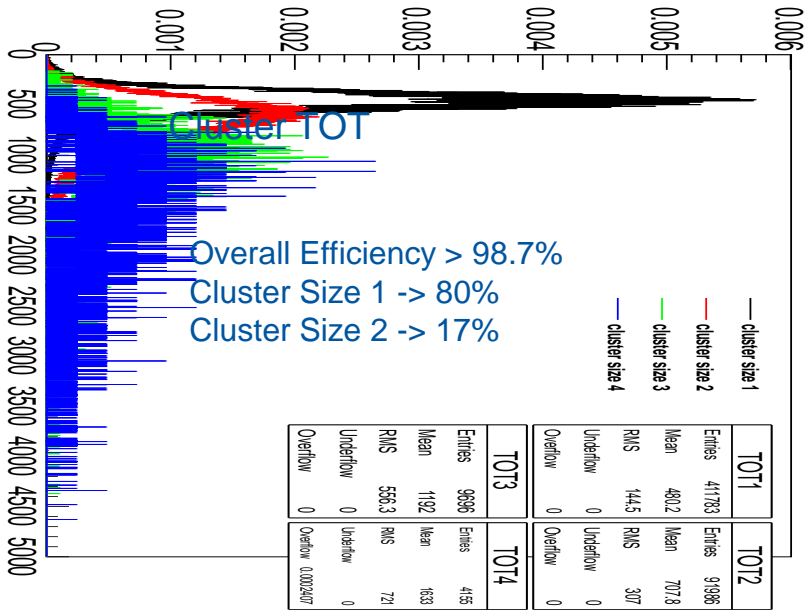


Cluster Size 4

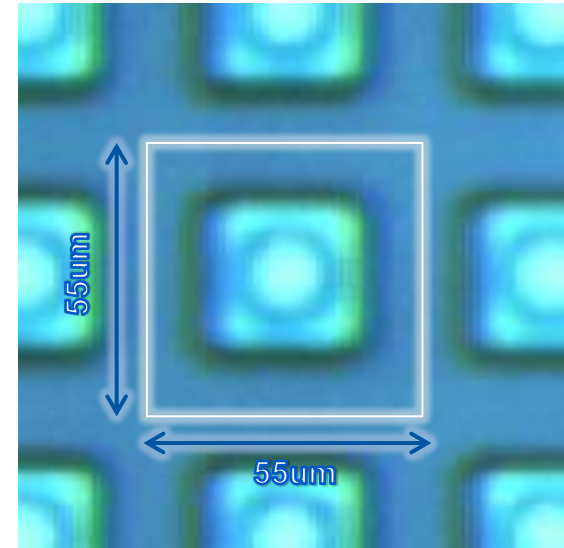


# August 2013 testbeam Results

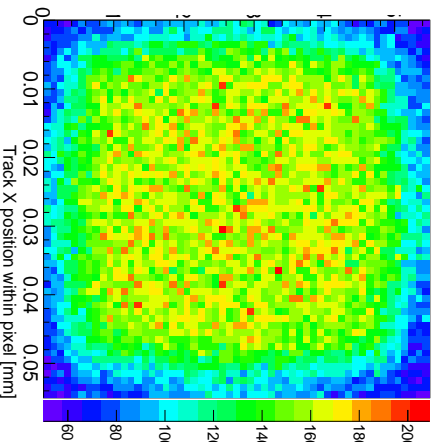
Advacam p-in-n 50um thin Timepix Assembly, 20um edges, ~100nA@15V :



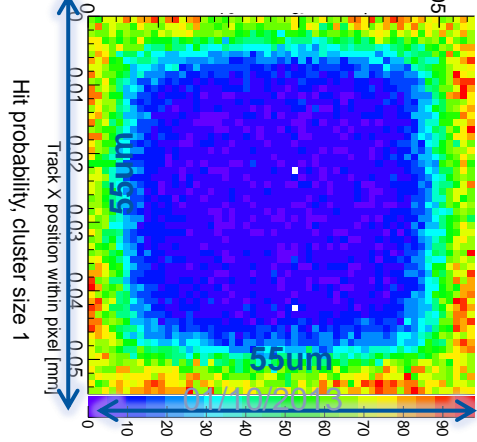
Energy Spectrum, cluster size = 1



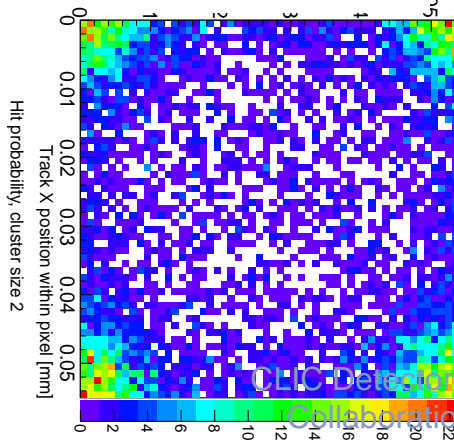
Cluster Size 1



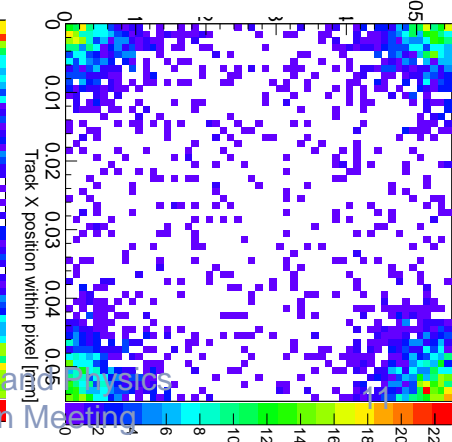
Cluster Size 2



Cluster Size 3

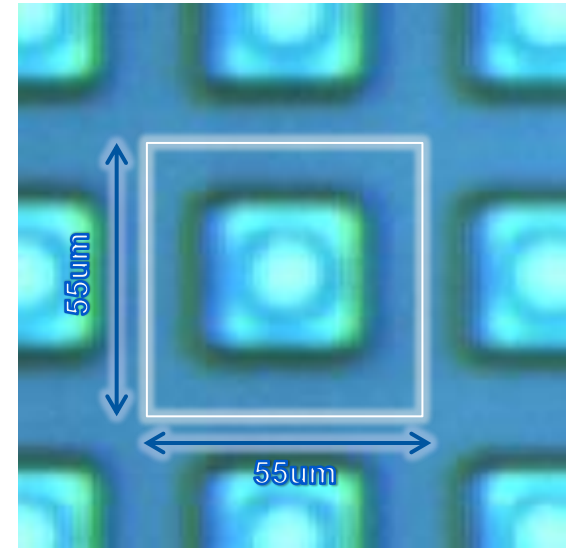
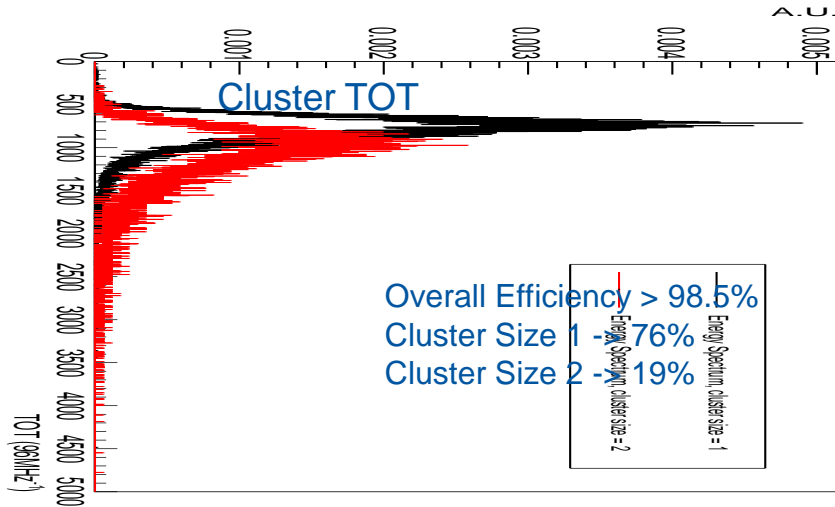


Cluster Size 4

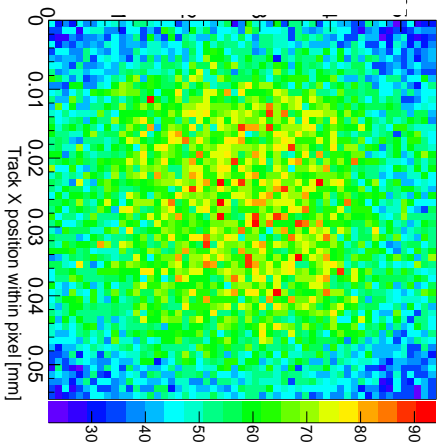


# August 2013 testbeam Results

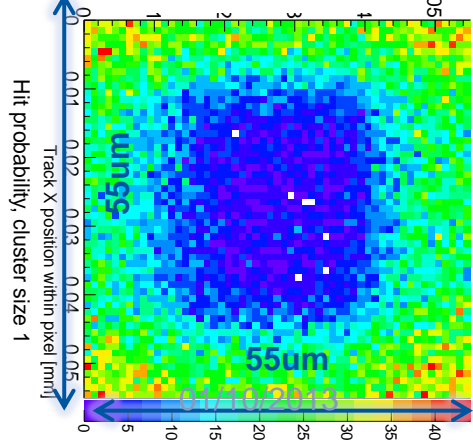
Micron p-in-n 100um thin Timepix Assembly, ~40nA@30V :



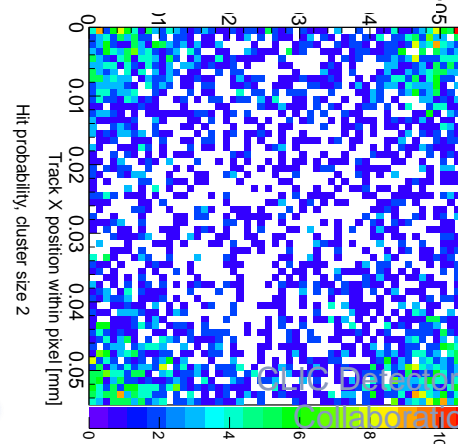
Cluster Size 1



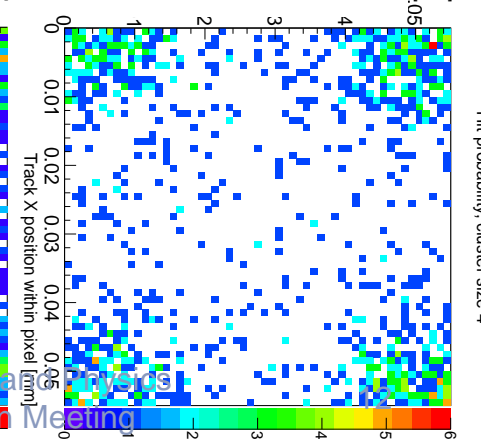
Cluster Size 2



Cluster Size 3



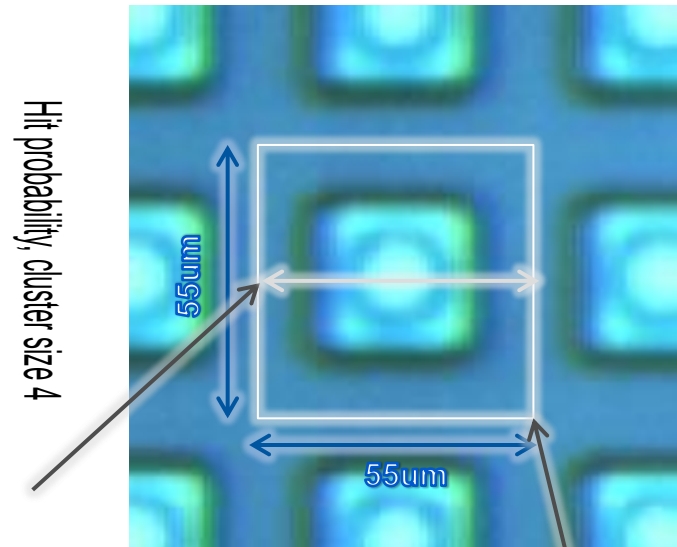
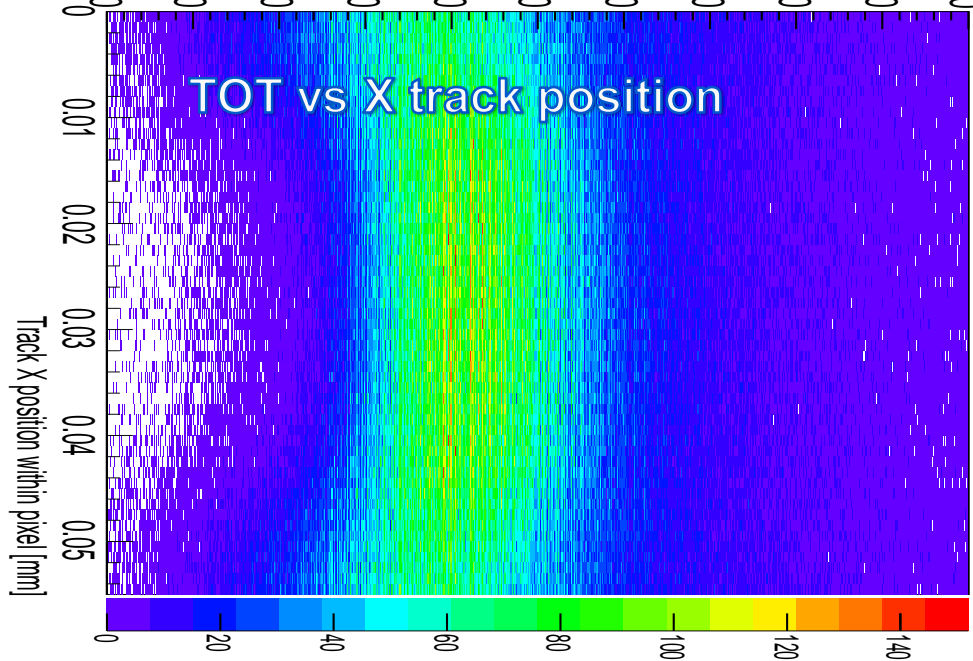
Cluster Size 4



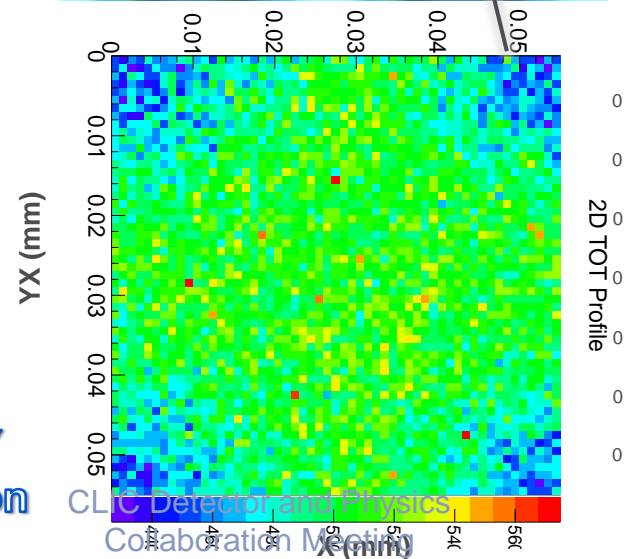


# August 2013 testbeam Results

Advacam p-in-n 50um thin Timepix Assembly, 50um edges, ~100nA@15V :



20 pixel masked ,  $k_{\text{rum}} = 1$ , Bias Voltage = 15V  
 Efficiency > 98.4% (edge included, track in mask pixel included)



TOT vs XY  
 track position

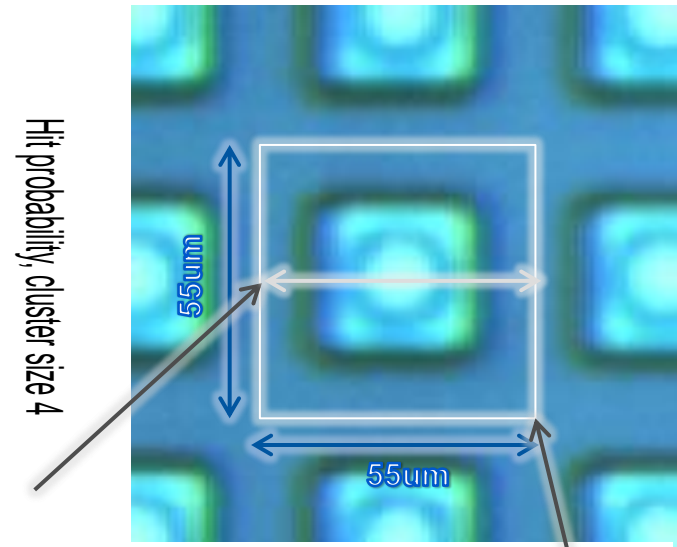
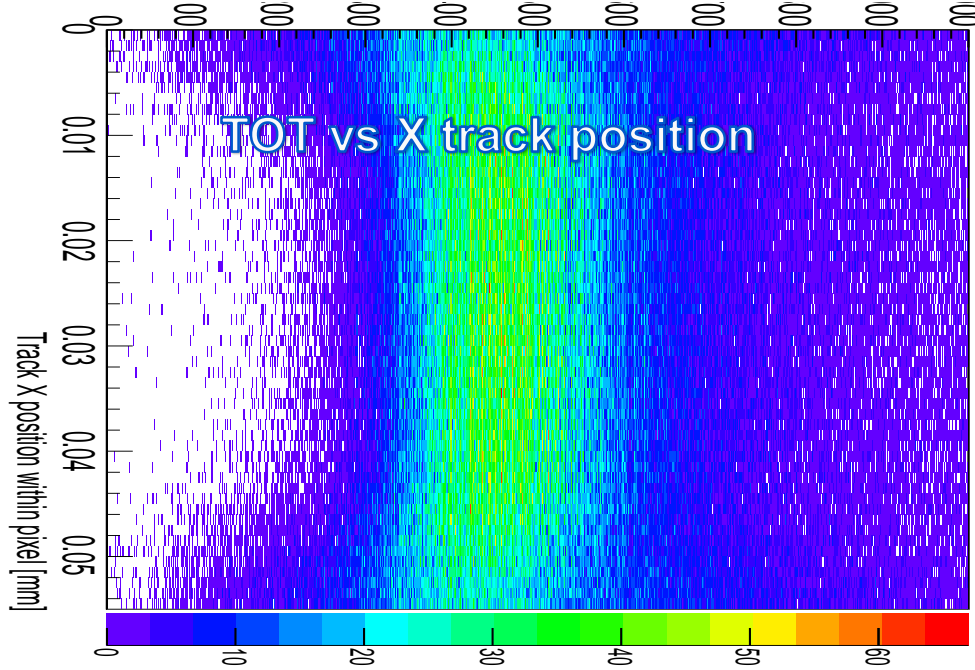
CLIC Detector and Physics  
 Collaboration Meeting



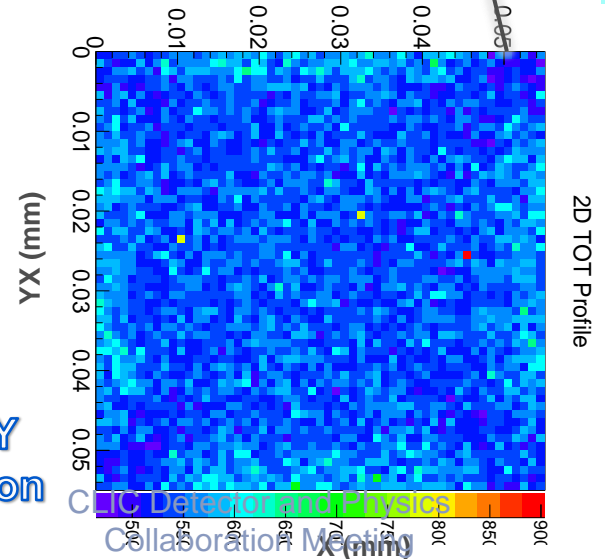
01/10/2013

# August 2013 testbeam Results

Advacam p-in-n 50um thin Timepix Assembly, 20um edges, ~100nA@15V :



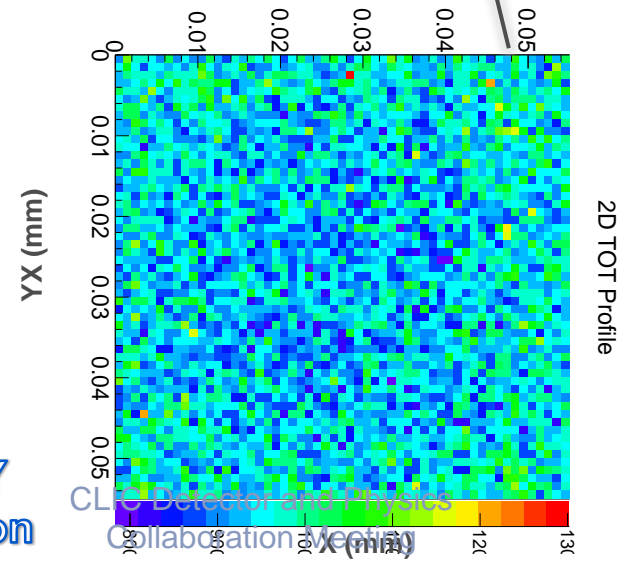
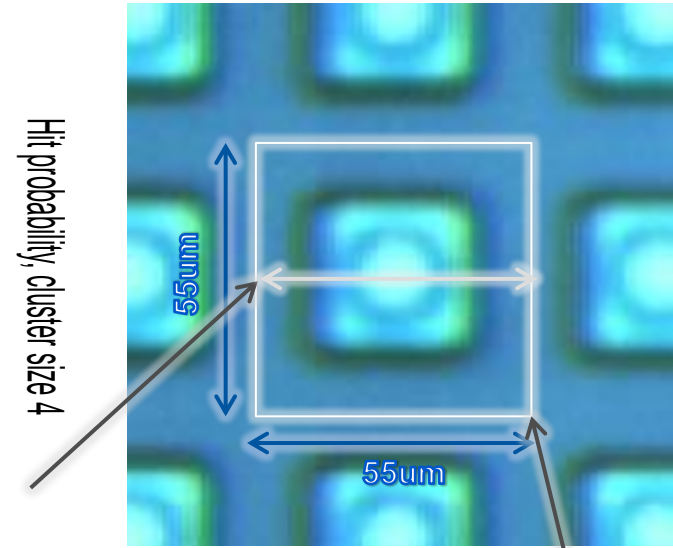
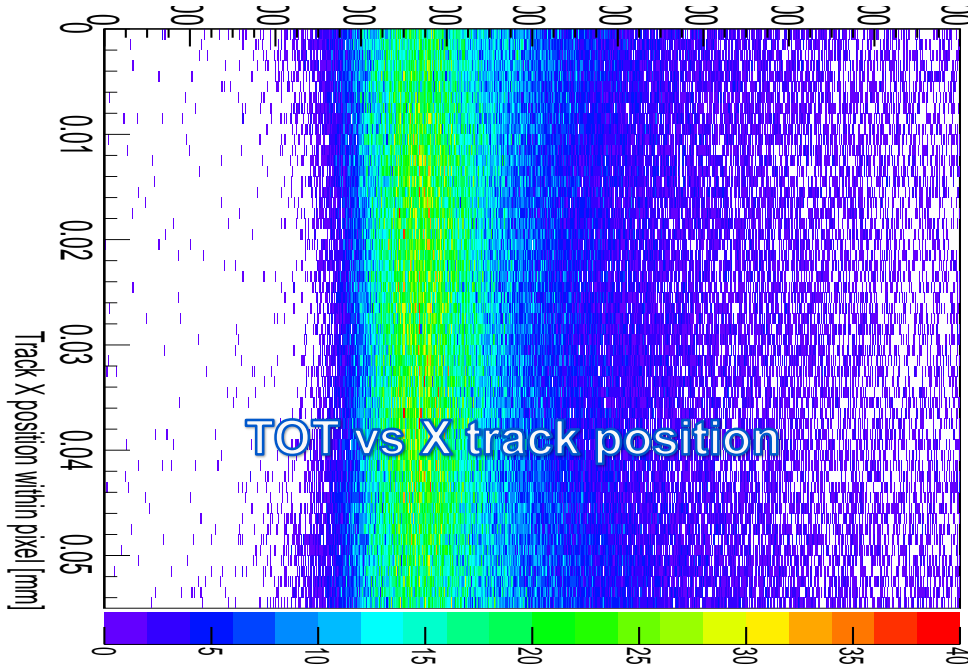
?? pixel masked , Ikrum = 1, Bias Voltage = 15V  
 Efficiency > 98.7% (edge included, track in mask pixel included)



TOT vs X/Y  
 track position

# August 2013 testbeam Results

Micron p-in-n 100um thin Timepix Assembly, ~40nA@15V :



?? pixel masked , Ikrum = 1, Bias Voltage = 35V  
 Efficiency > 98.5 % (edge included, track in mask pixel included)

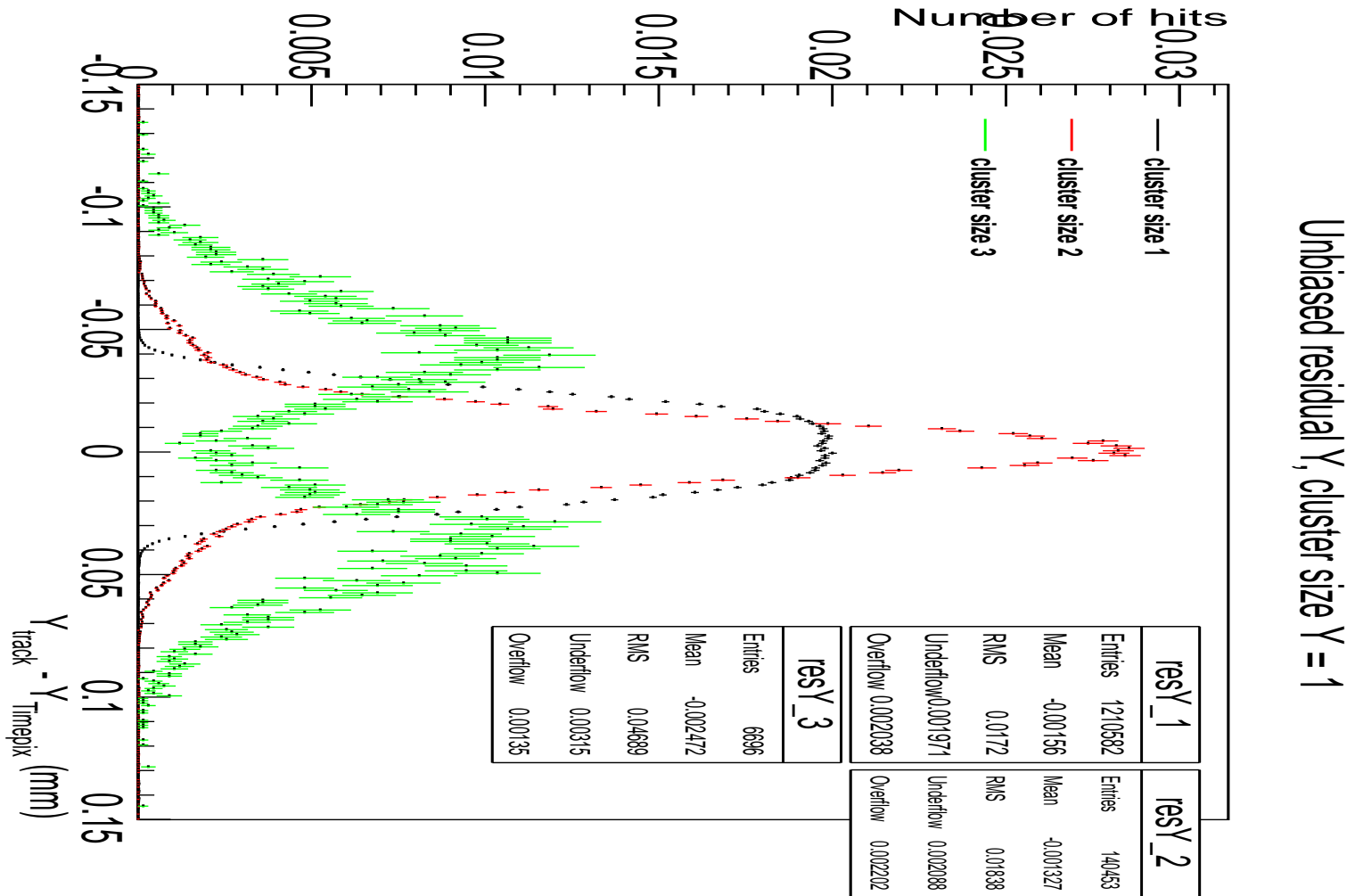
TOT vs XY  
 track position



01/10/2013

# August 2013 testbeam Results

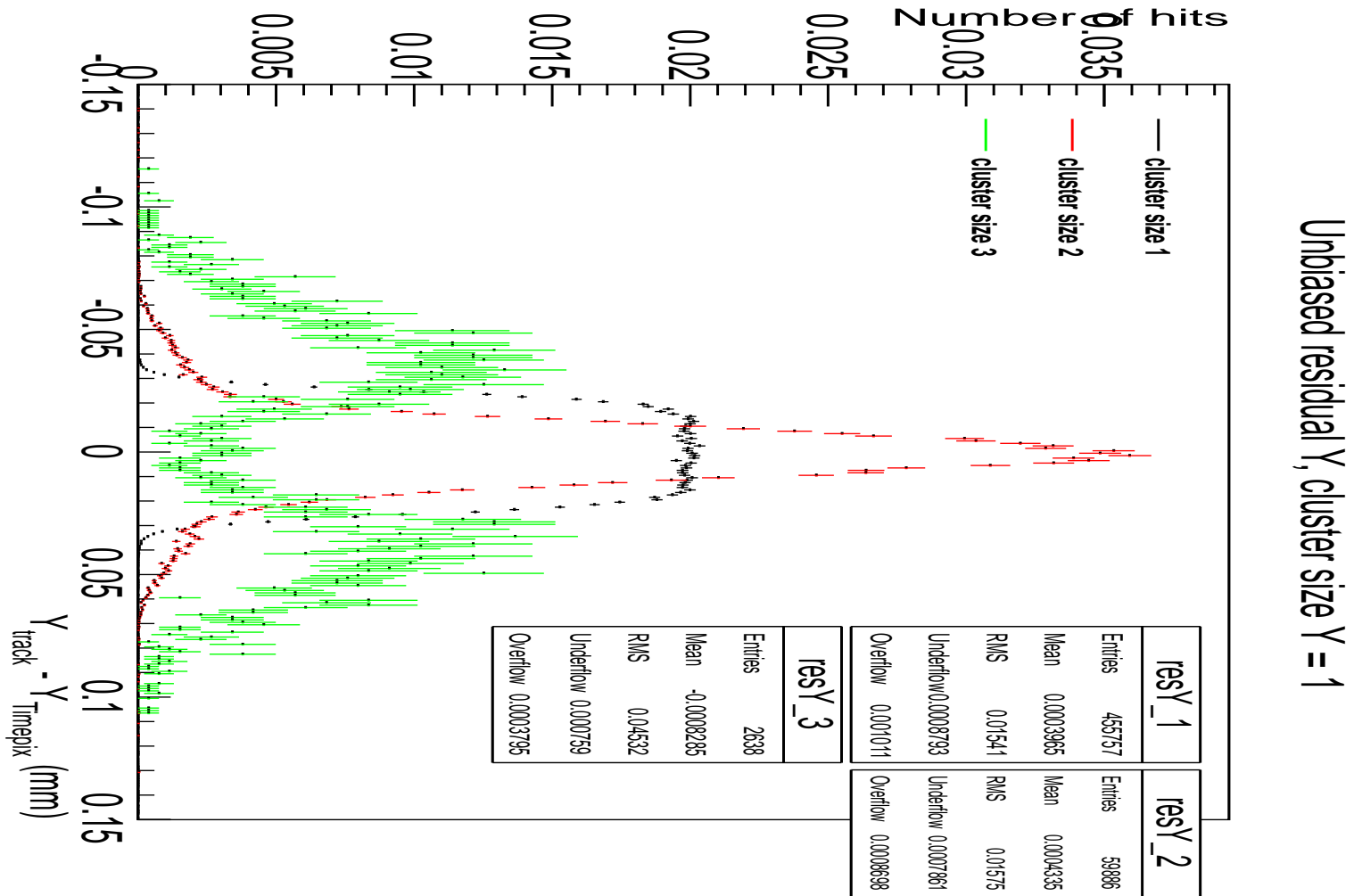
Advacam p-in-n 50um thin Timepix Assembly, 50um edges, ~100nA@15V :





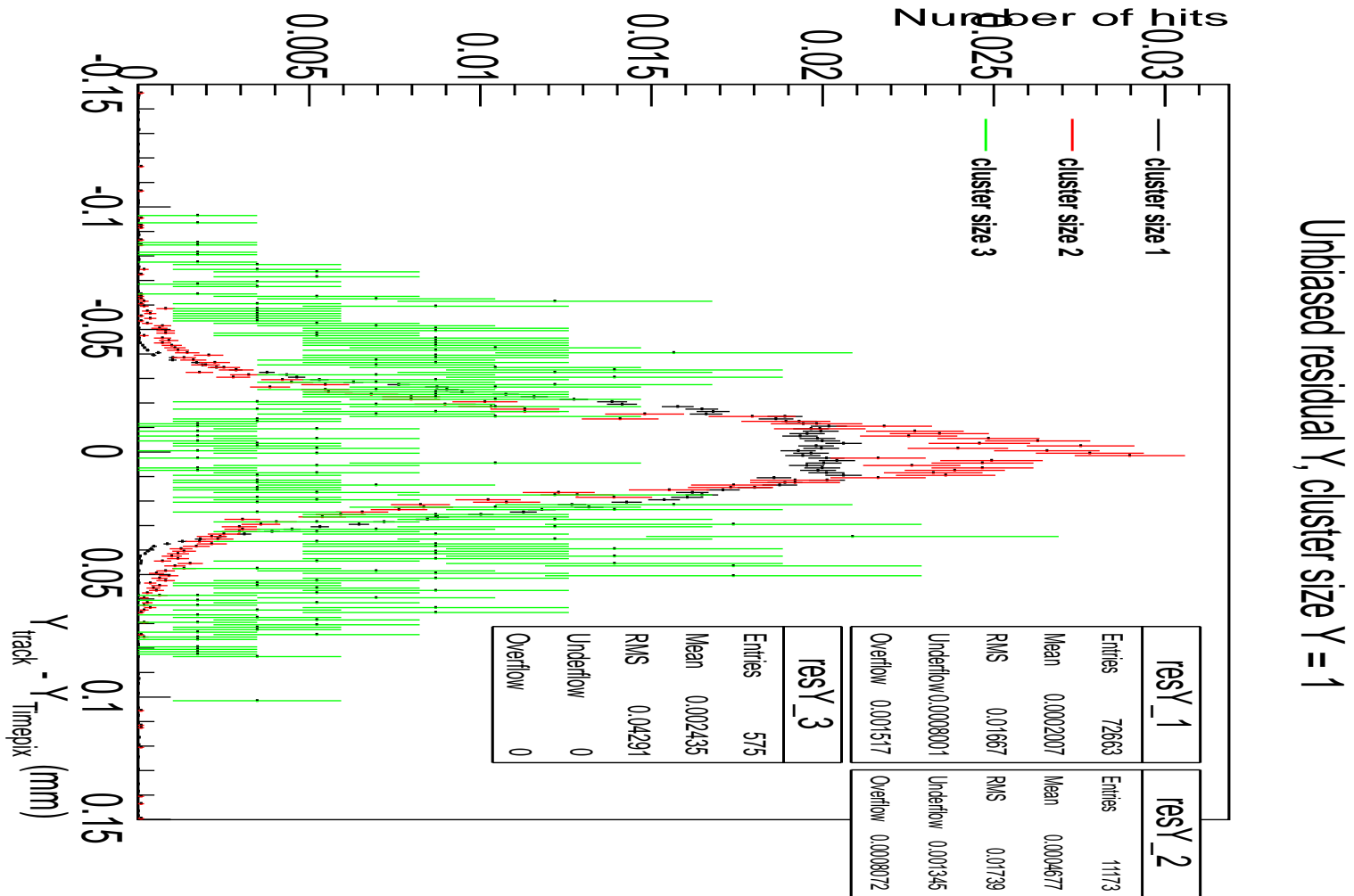
# August 2013 testbeam Results

Advacam p-in-n 50um thin Timepix Assembly, 20um edges, ~100nA@15V :



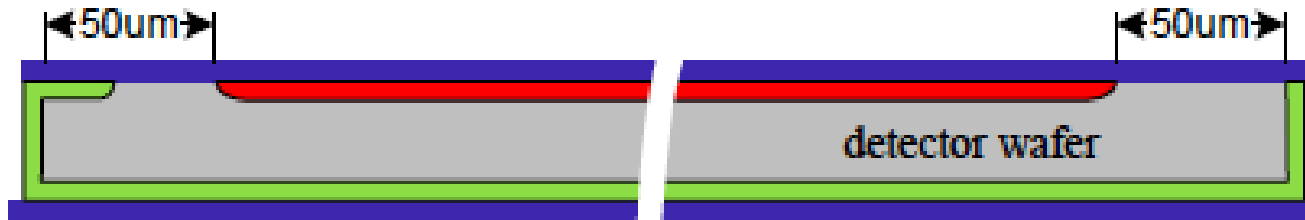
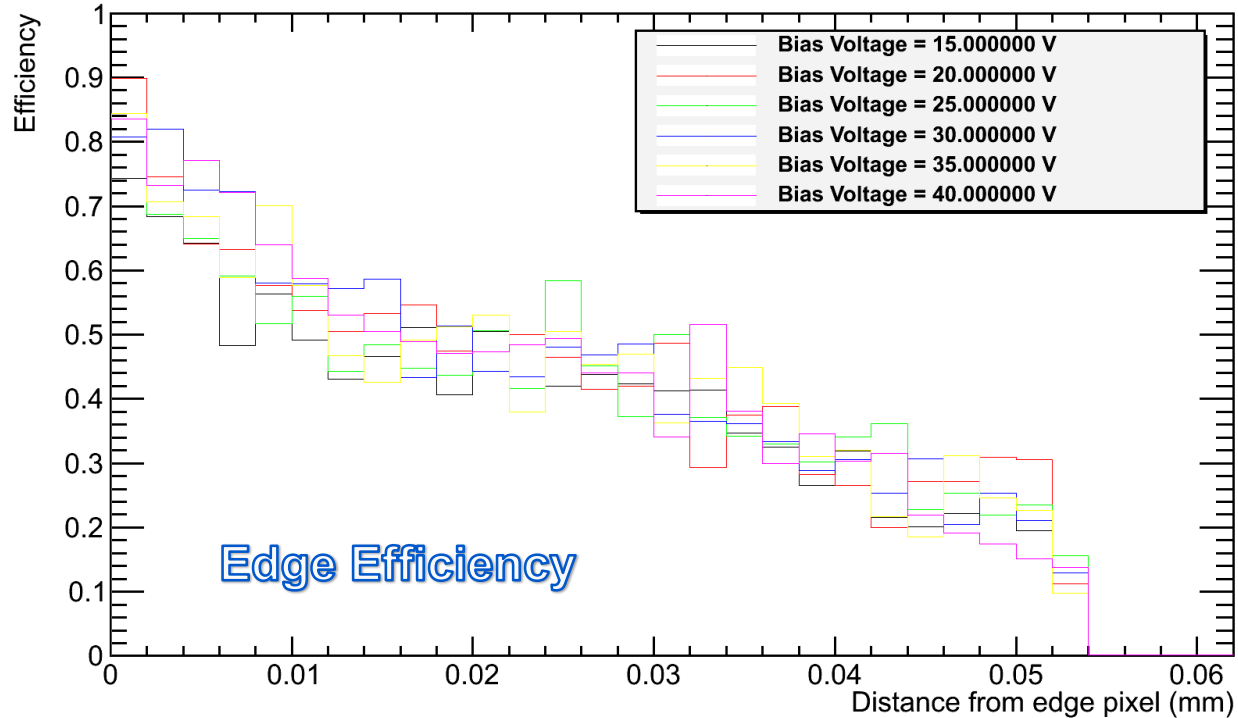
# August 2013 testbeam Results

Micron p-in-n 100um thin Timepix Assembly, ~40nA@35V :



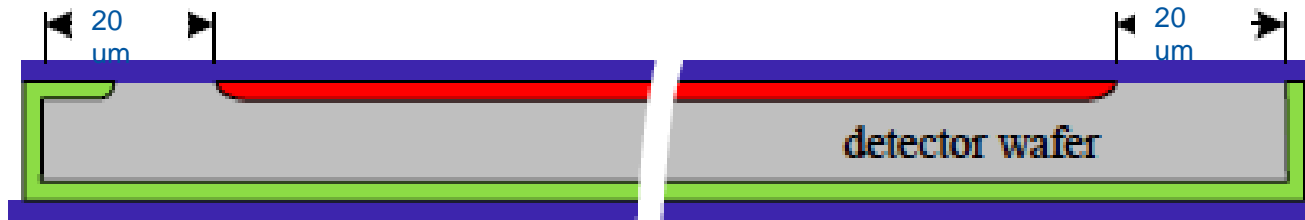
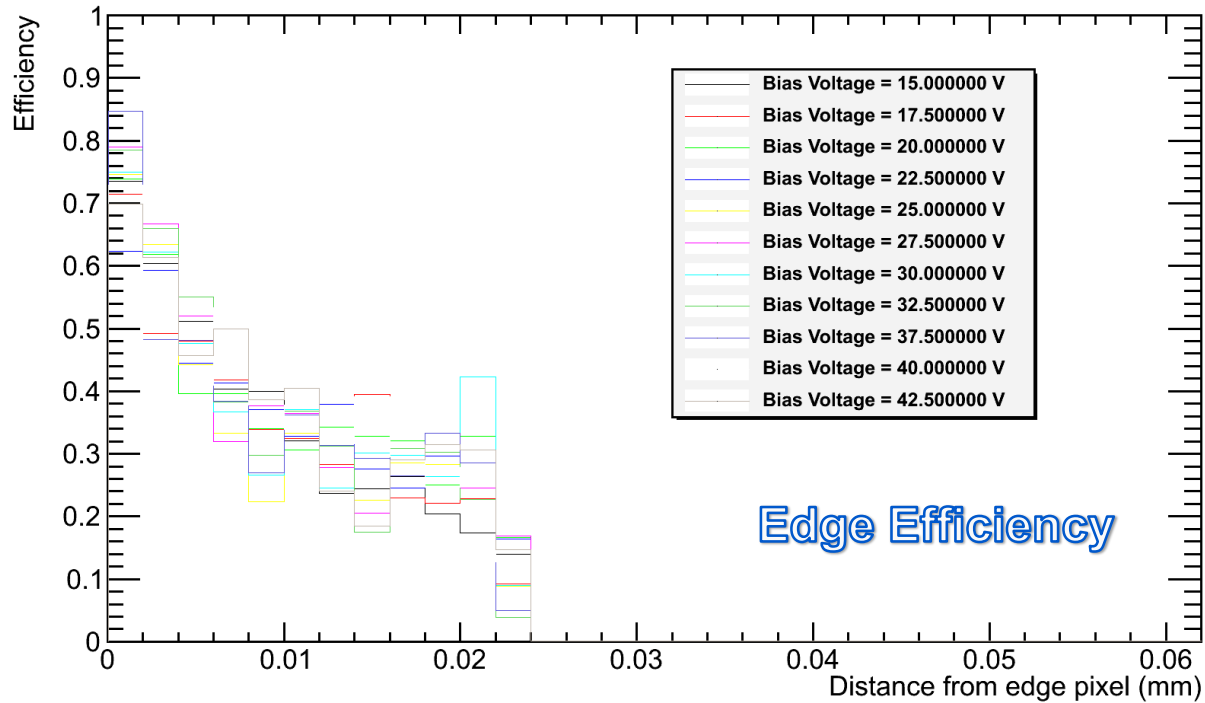
# August 2013 testbeam Results

Advacam p-in-n 50um thin Timepix Assembly, 50um edges, ~100nA@15V :



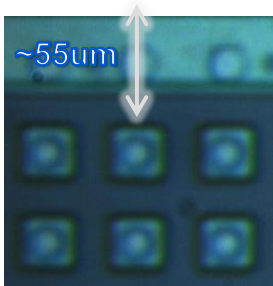
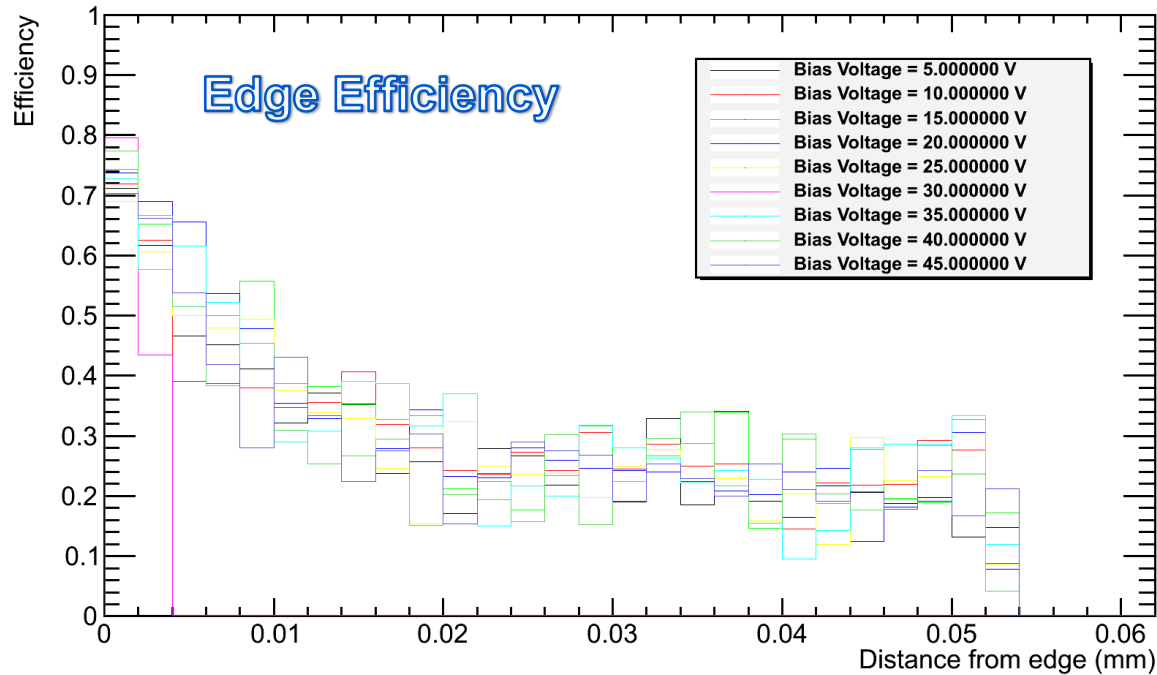
# August 2013 testbeam Results

Advacam p-in-n 50um thin Timepix Assembly, 20um edges, ~100nA@15V :





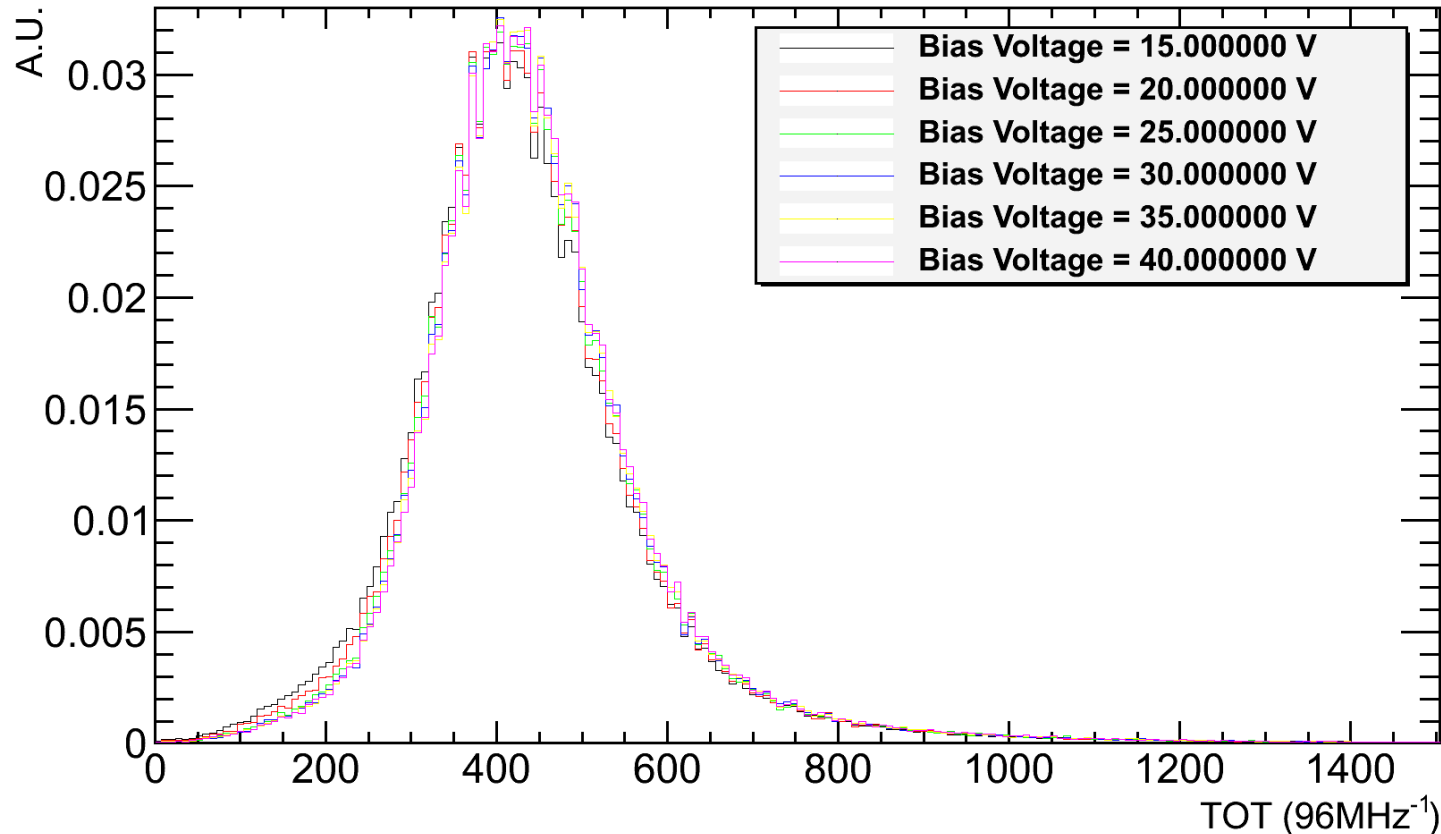
# August 2013 testbeam Results



Micron p-in-n 100um thin Timepix Assembly, ~40nA@35V :

# August 2013 testbeam Results

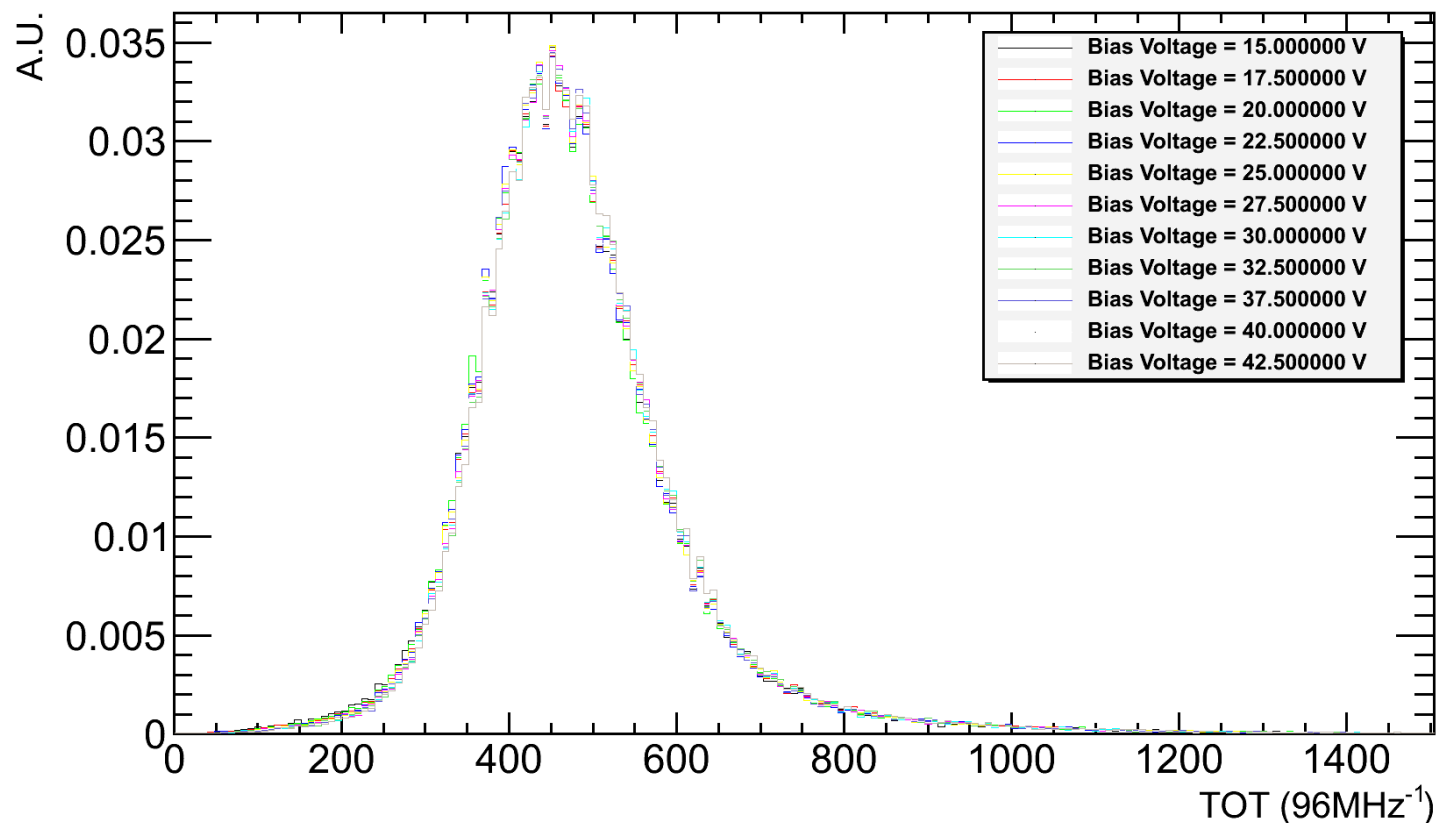
Advacam p-in-n 50um thin Timepix Assembly, 50um edges, ~100nA@15V :



TOT Distribution, 1 pixel clusters

# August 2013 testbeam Results

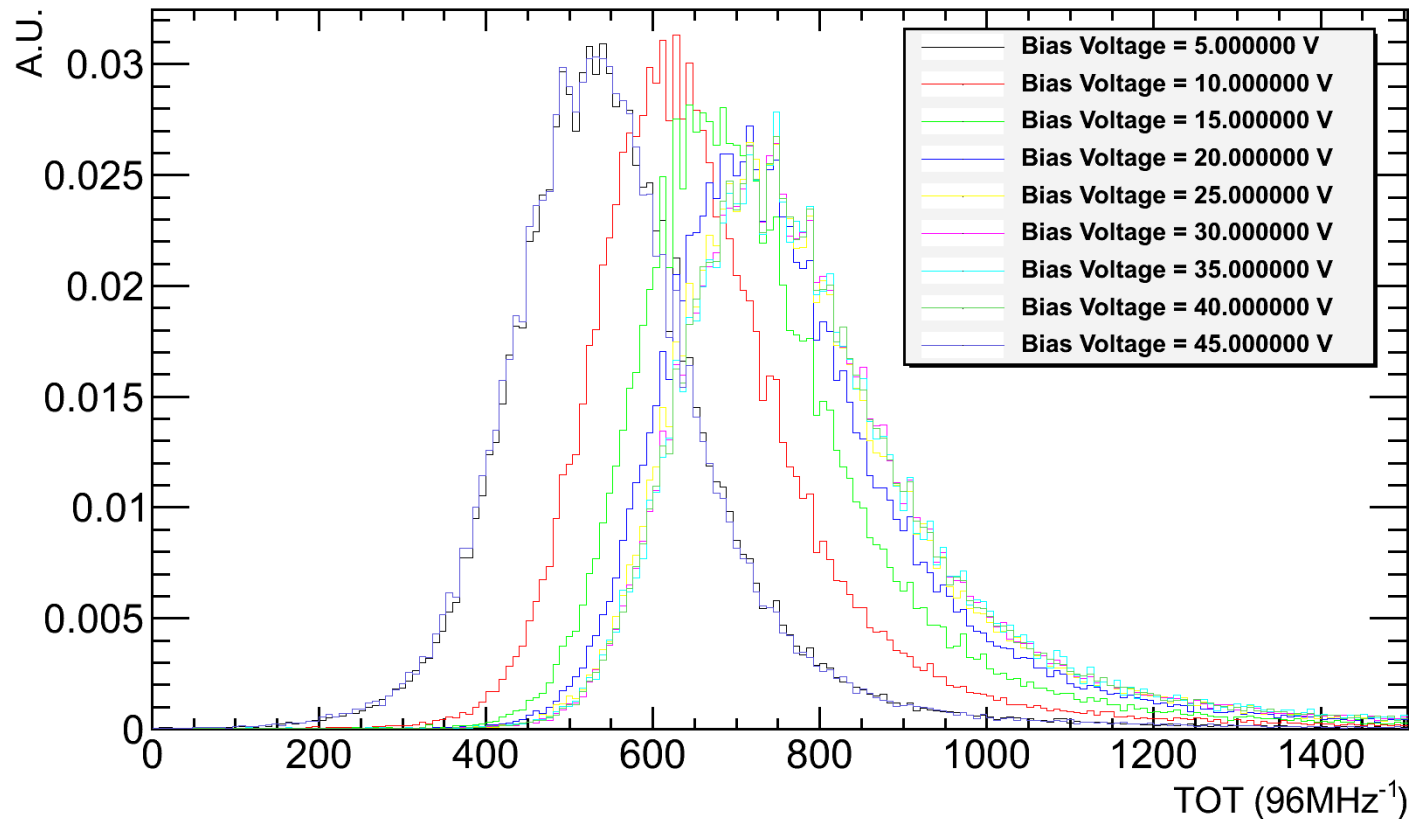
Advacam p-in-n 50um thin Timepix Assembly, 20um edges, ~100nA@15V :



TOT Distribution, 1 pixel clusters

# August 2013 testbeam Results

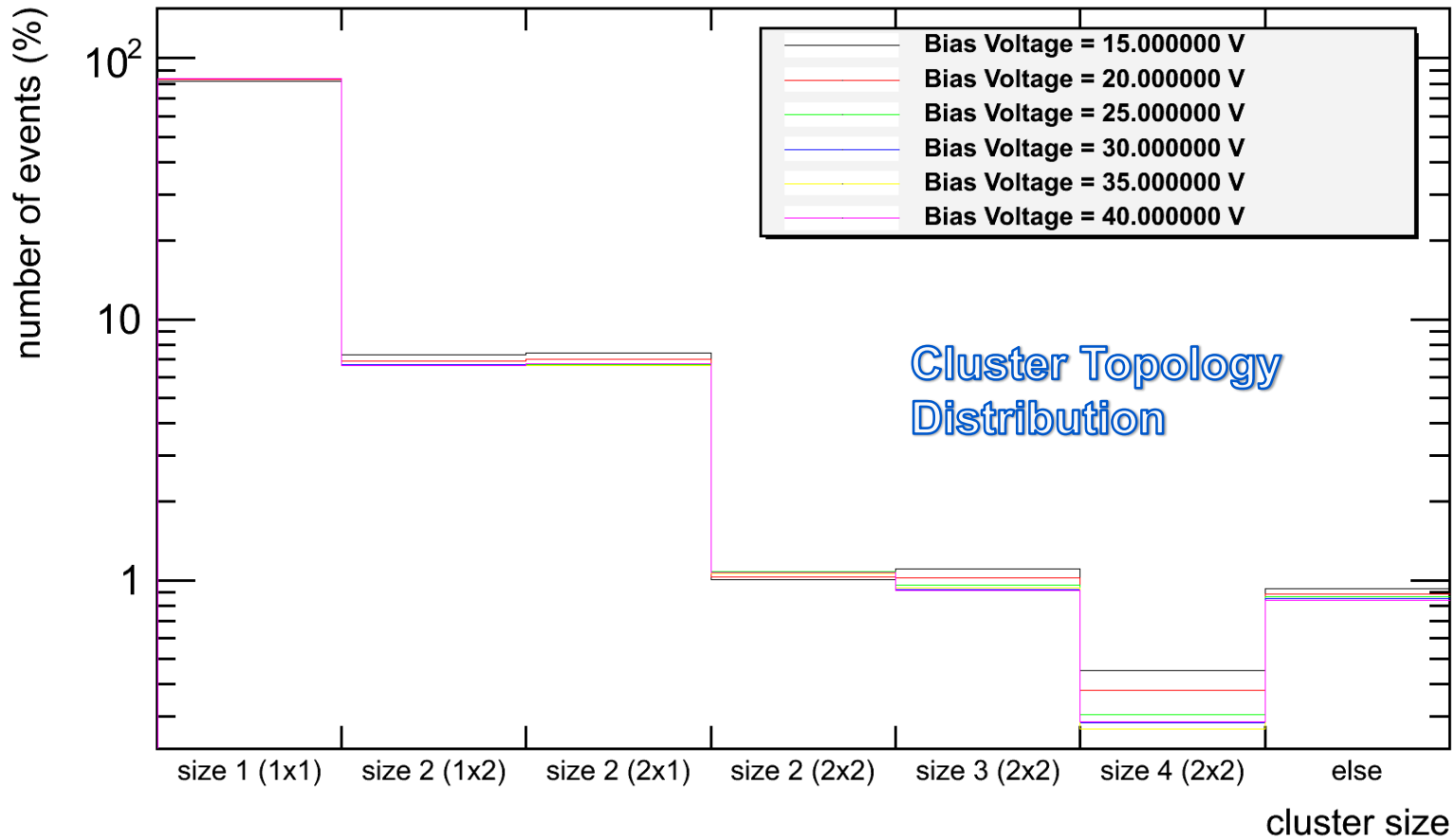
Micron p-in-n 100um thin Timepix Assembly,  $\sim 40\text{nA}@35\text{V}$  :



TOT Distribution, 1 pixel clusters

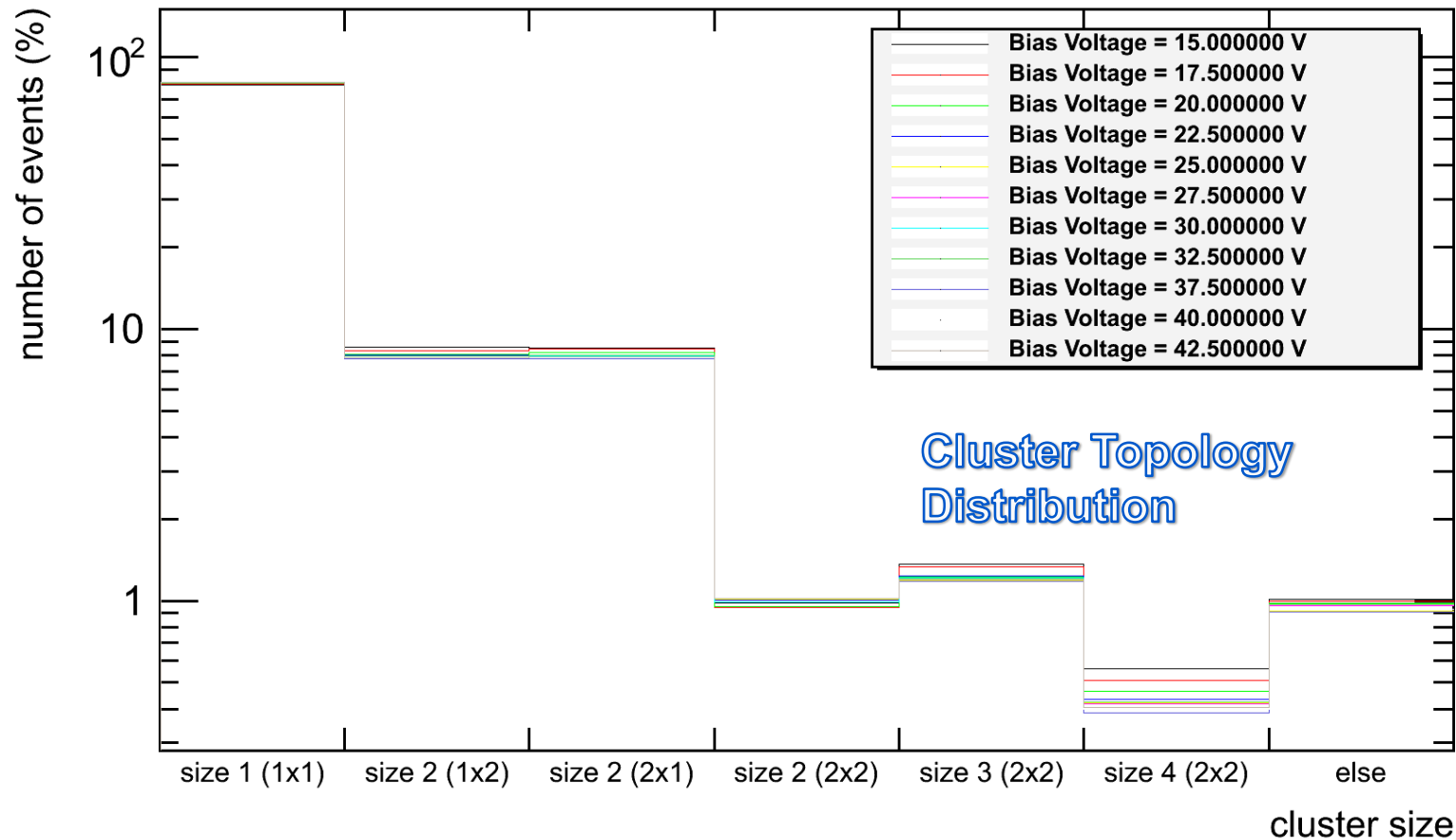
# August 2013 testbeam Results

Advacam p-in-n 50um thin Timepix Assembly, 50um edges, ~100nA@15V :



# August 2013 testbeam Results

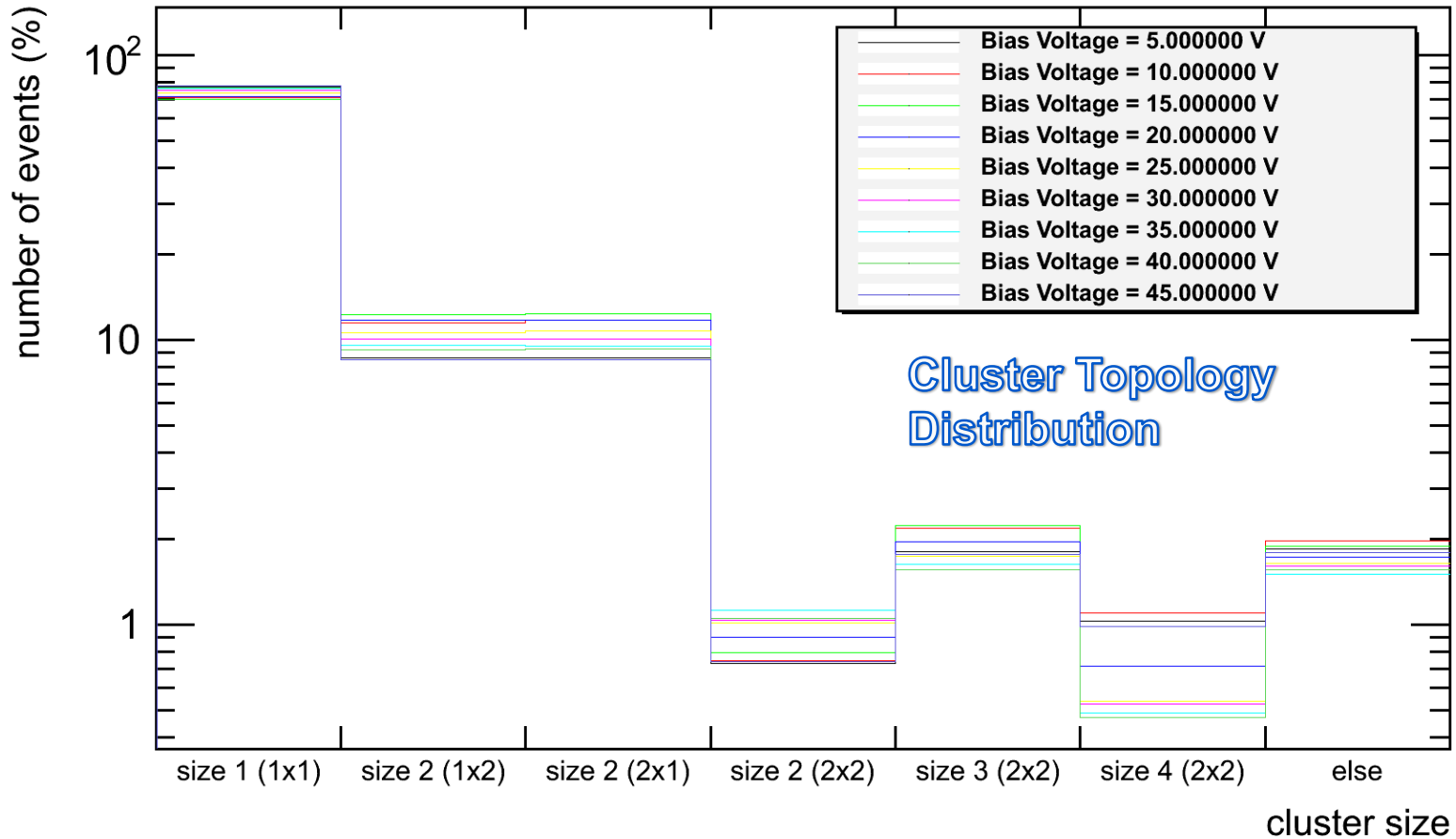
Advacam p-in-n 50um thin Timepix Assembly, 20um edges, ~100nA@15V :





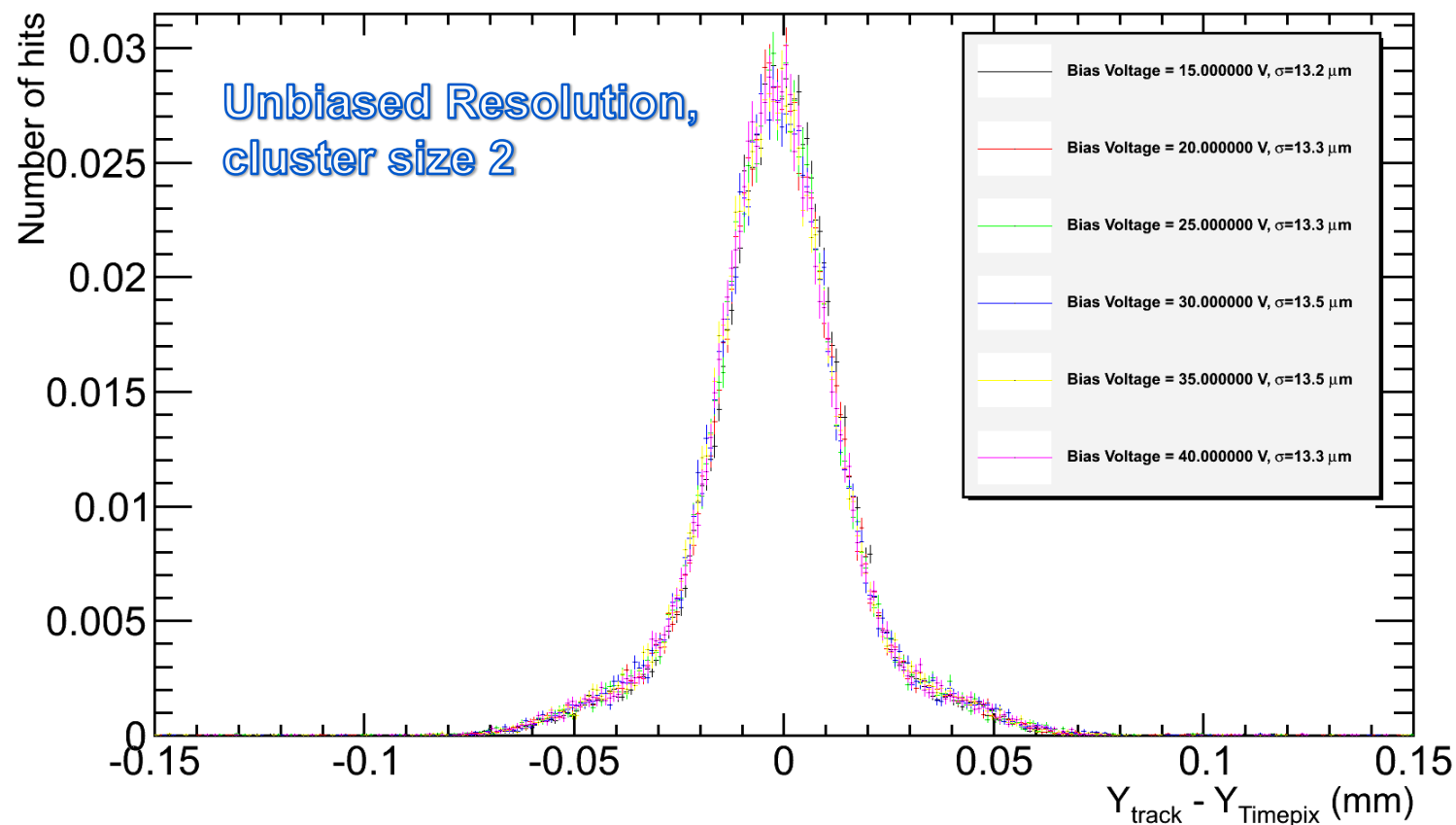
# August 2013 testbeam Results

Micron p-in-n 100um thin Timepix Assembly, ~40nA@35V :



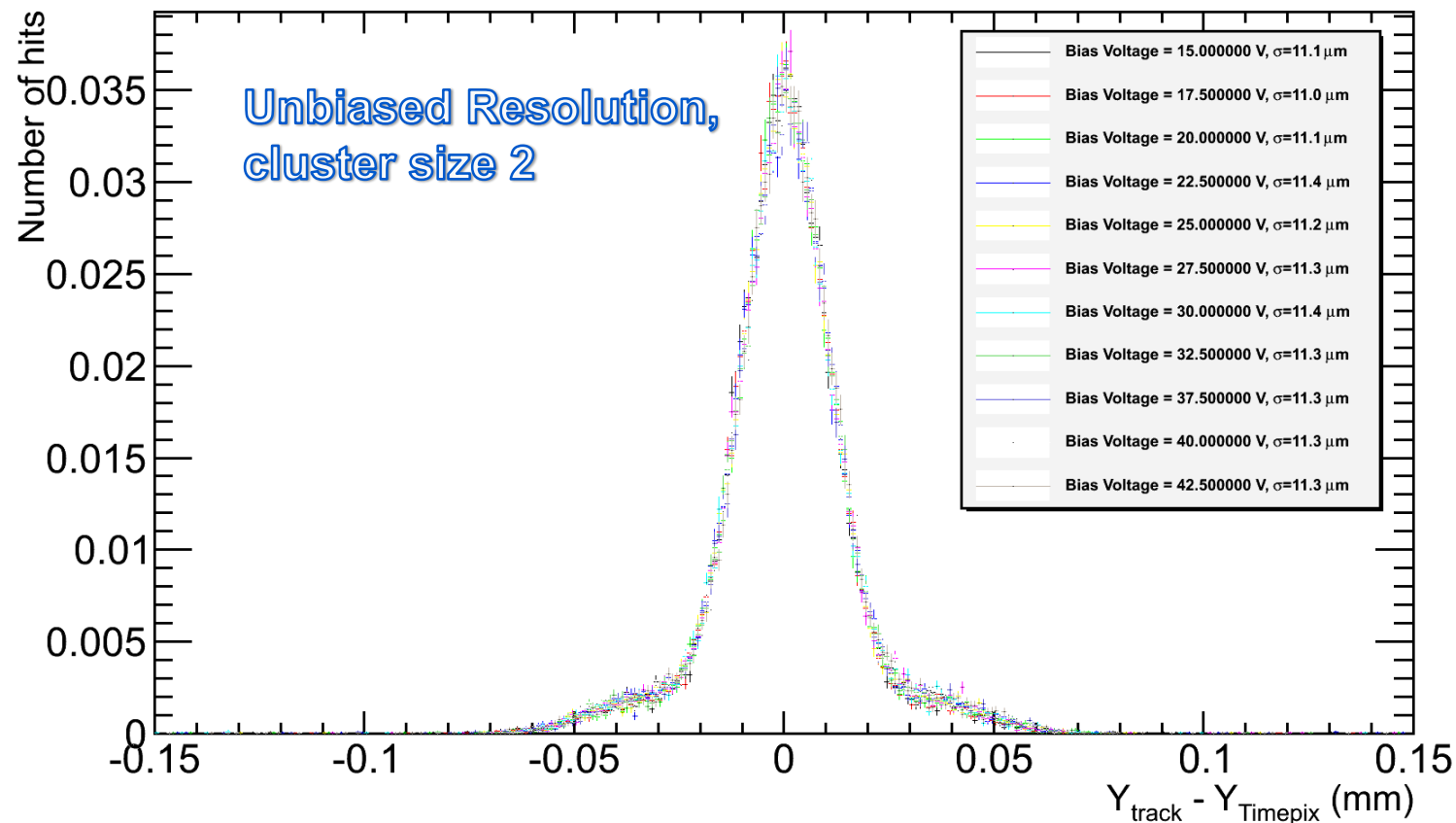
# August 2013 testbeam Results

Advacam p-in-n 50um thin Timepix Assembly, 50um edges, ~100nA@15V :



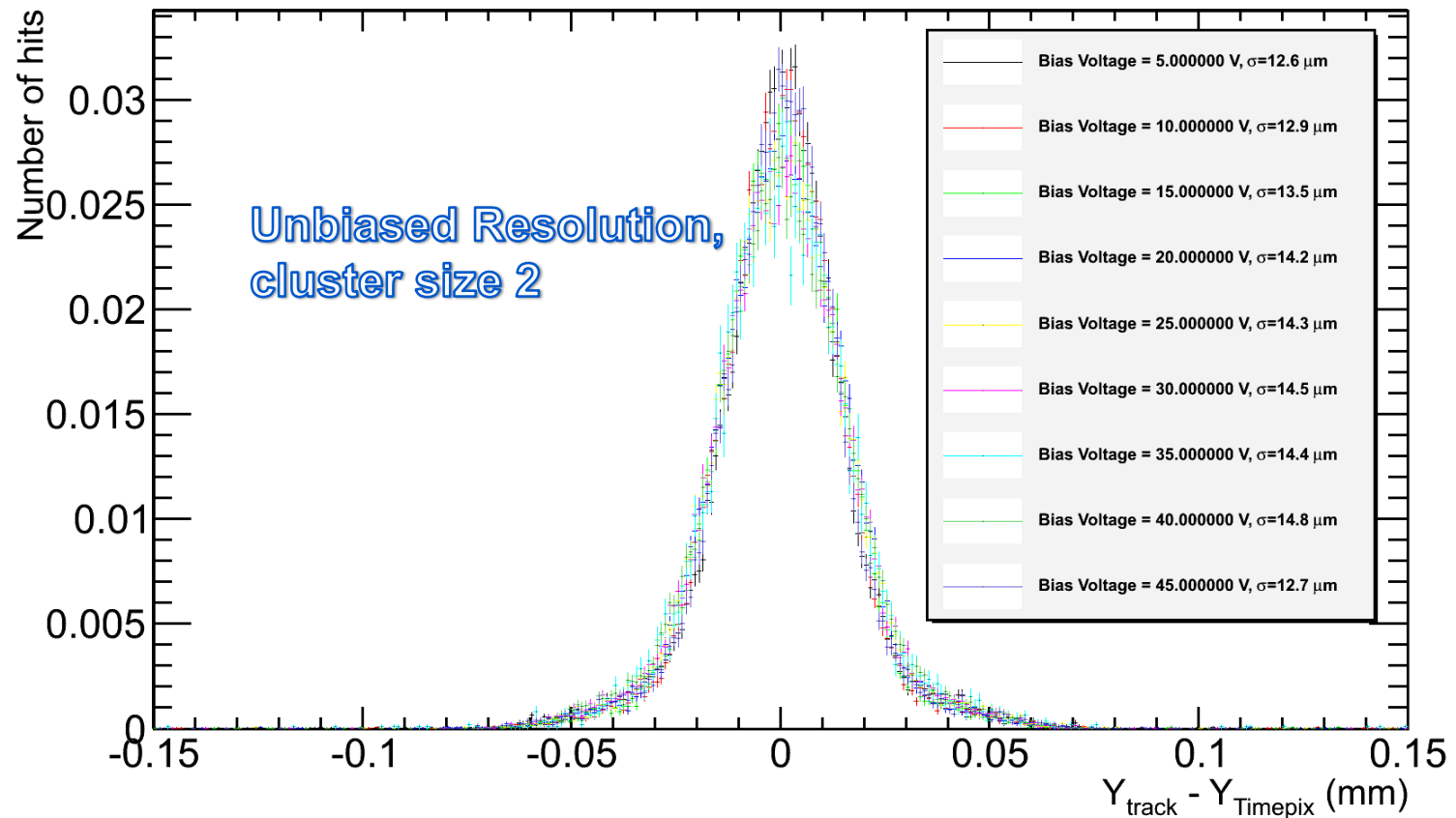
# August 2013 testbeam Results

Advacam p-in-n 50um thin Timepix Assembly, 20um edges, ~100nA@15V :



# August 2013 testbeam Results

Micron p-in-n 100um thin Timepix Assembly,  $\sim 40\text{nA}@35\text{V}$  :



# Benefits of Eta Correction

50um thin p-in-n 50um active edges  
Advacam Assembly  
 $\sigma_{\text{tracking}} = 2.9 \text{ um}$



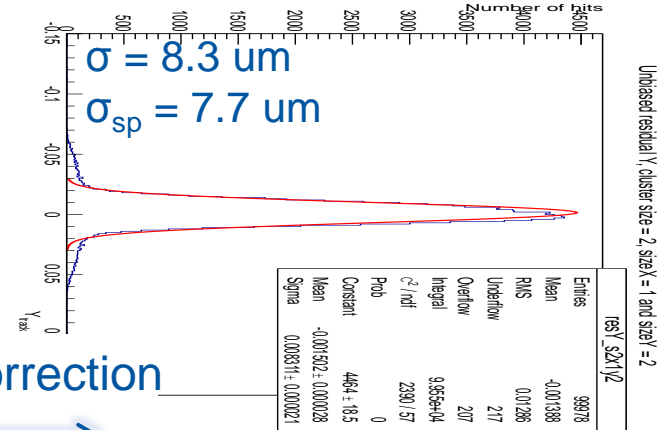
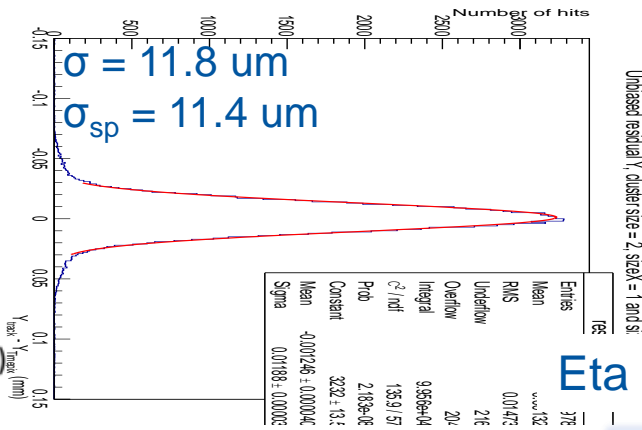
Size 2 (1x2)



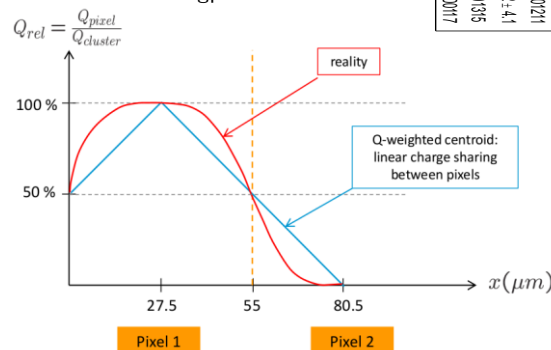
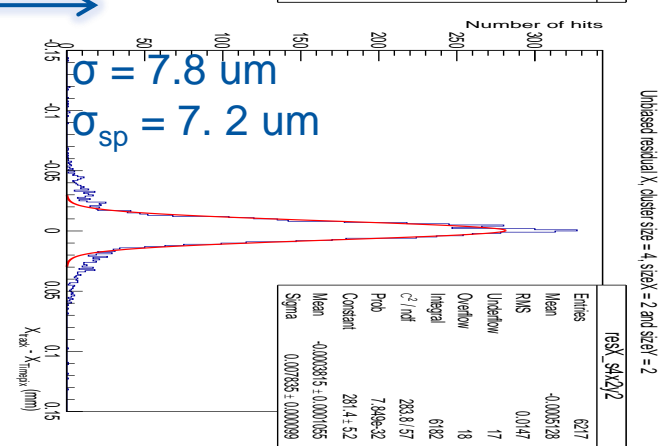
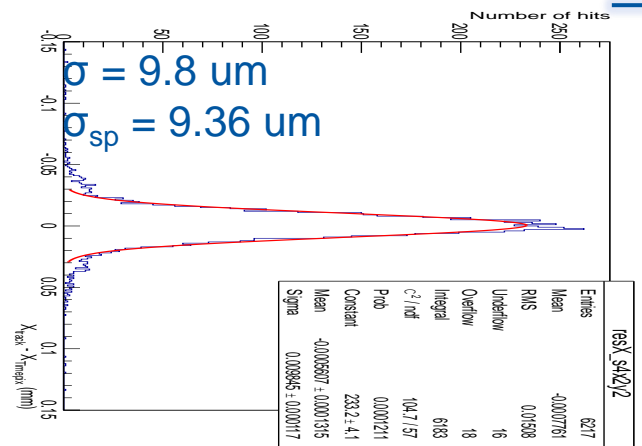
Size 2 (2x1)



Size 4 (2x2)



Eta Correction



Using TOT Information, it is possible to correct for non-linearities in Charge sharing between pixel and gain up to a factor 2 in single-point resolution for cluster size > 1. For 50um thin sensor, this represent only 20% of data, we need smaller pixel size ASIC with TOT measurement

# Benefits of Eta Correction

50um thin p-in-n 20um active edges  
Advacam Assembly  
 $\sigma_{\text{tracking}} = 2.9 \text{ um}$



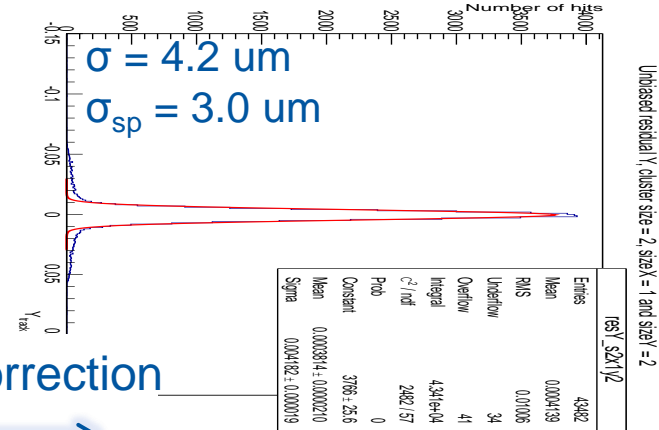
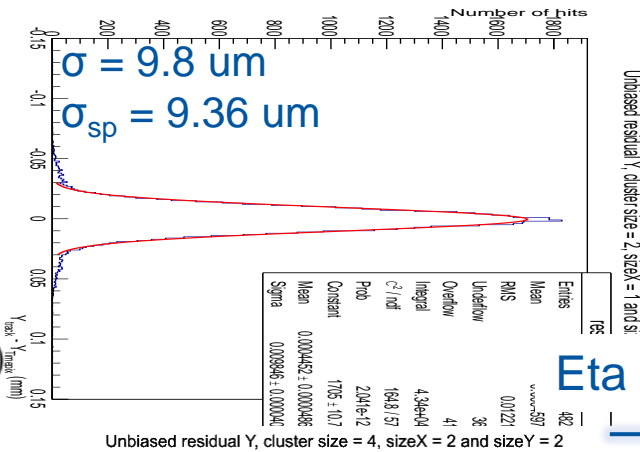
Size 2 (1x2)



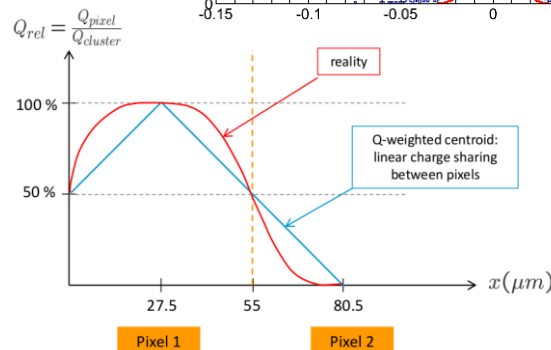
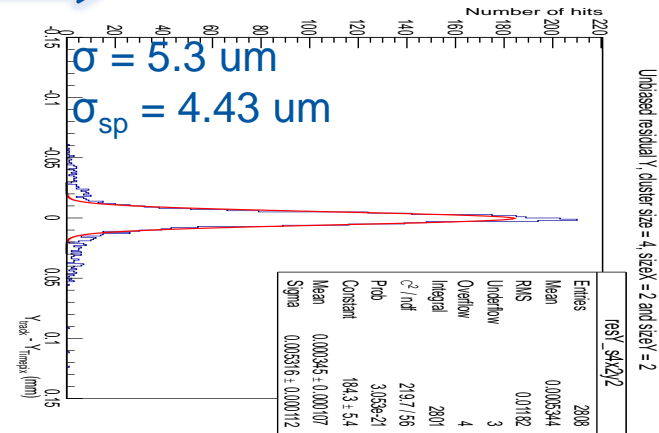
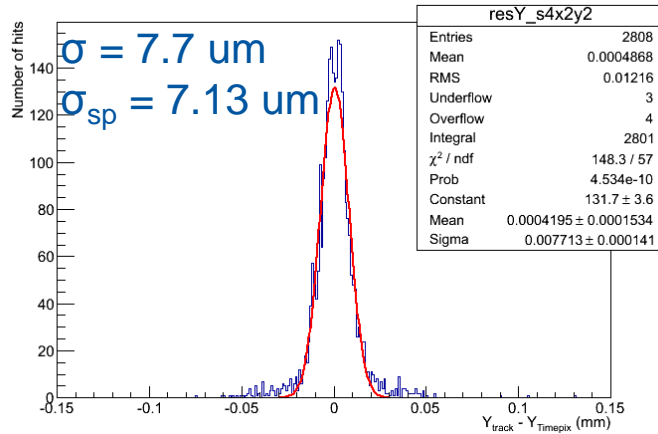
Size 2 (2x1)



Size 4 (2x2)



Eta Correction



Using TOT Information, it is possible to correct for non-linearities in Charge sharing between pixel and gain up to a factor 2 in single-point resolution for cluster size > 1. For 50um thin sensor, this represent only 20% of data, we need smaller pixel size ASIC with TOT measurement



# Benefits of Eta Correction

Micron 100um thick sensor  
 $\sigma_{\text{tracking}} = 2.9 \text{ um}$



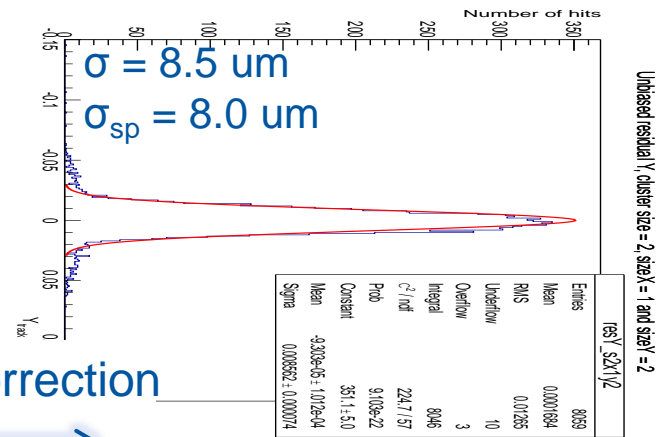
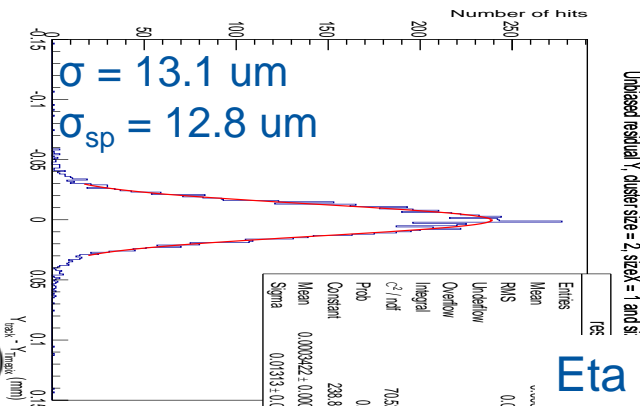
Size 2 (1x2)



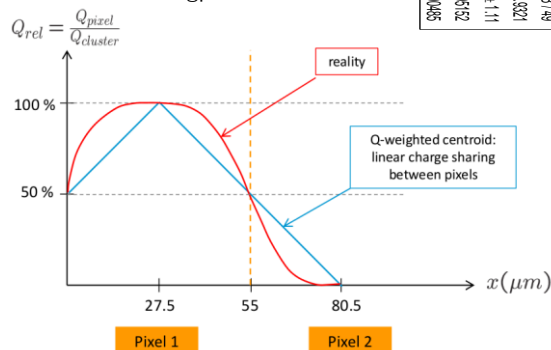
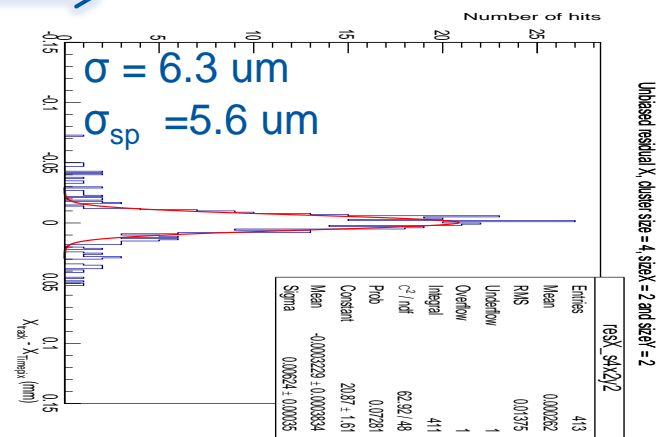
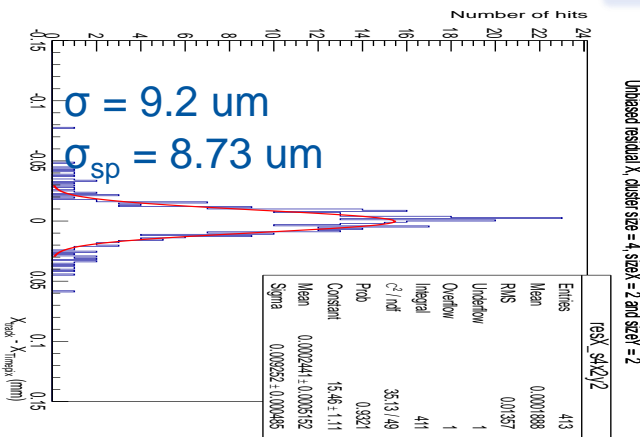
Size 2 (2x1)



Size 4 (2x2)



Eta Correction



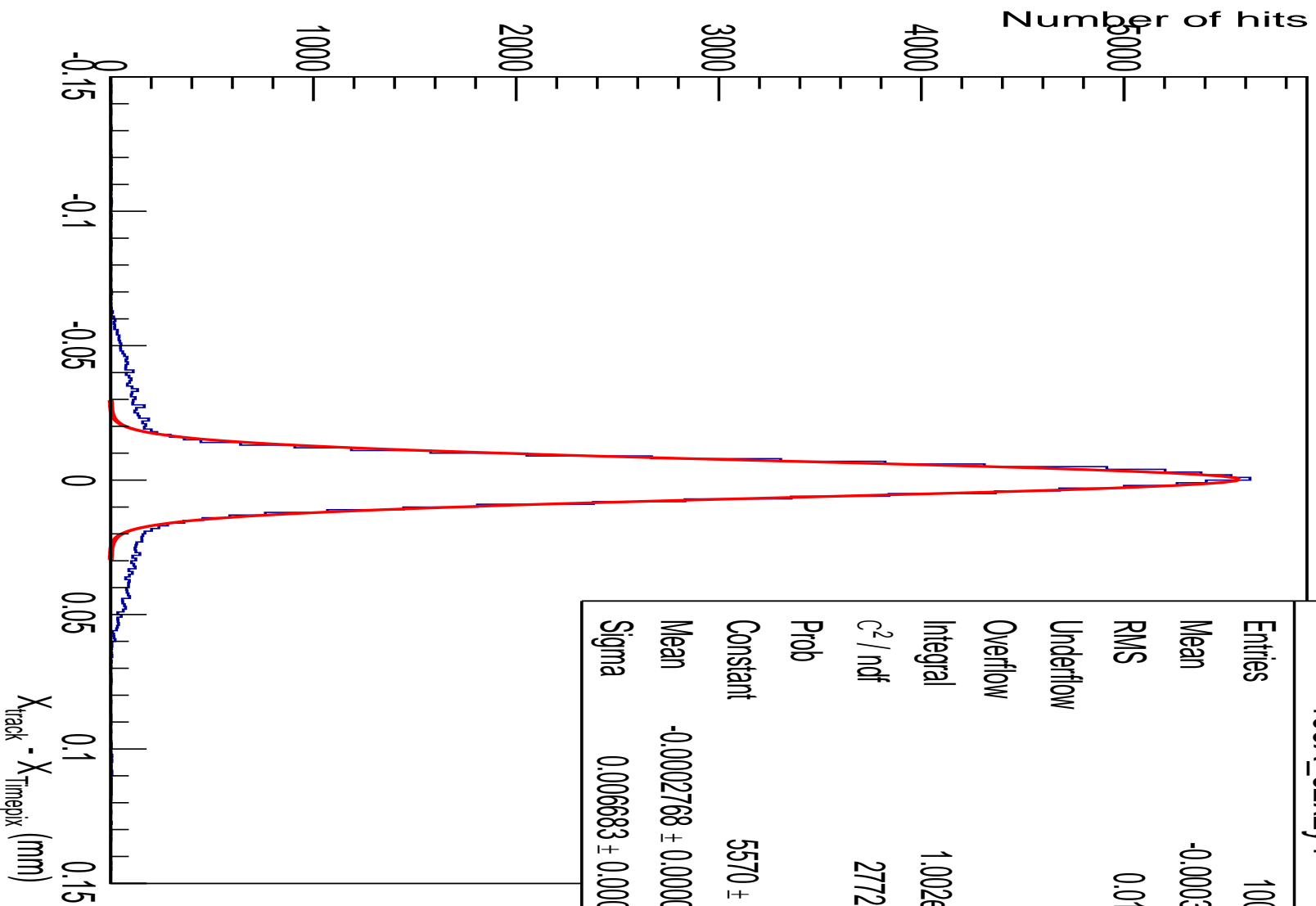
Using TOT Information, it is possible to correct for non-linearities in Charge sharing between pixel and gain up to a factor 2 in single-point resolution for cluster size > 1. For 50um thin sensor, this represent only 20% of data, we need smaller pixel size ASIC with TOT measurement

# Conclusion

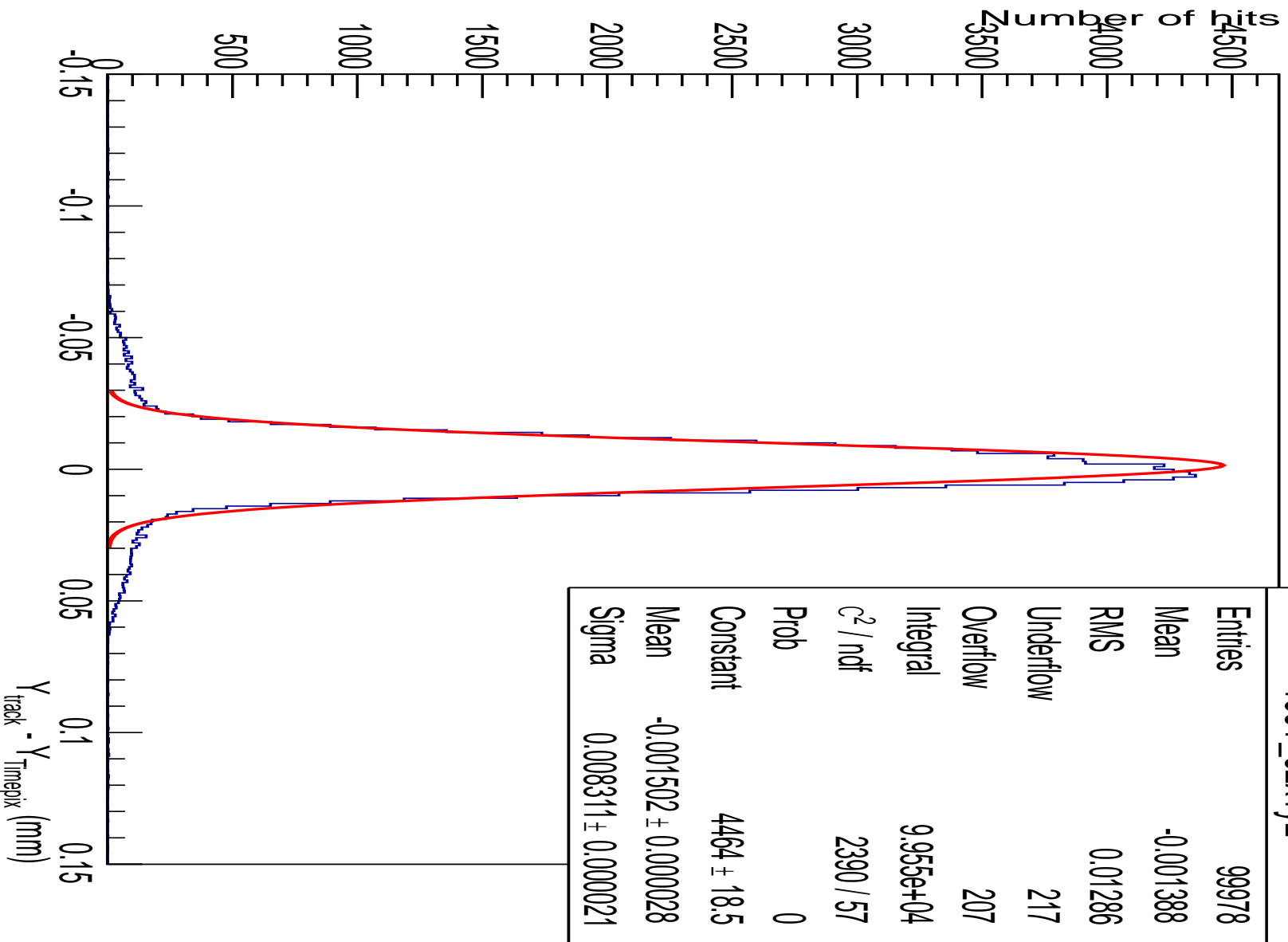
- First sensor assemblies have been received by CERN and tested in DESY electron beam using the EUDET Telescope
- **Good tracking efficiency and tracking performance demonstrated for both 50um Advacam sensor and Micron Semiconductor Sensor with 100 um sensor thickness**
- Charge Sharing the limiting factor for resolution, **smaller pixel needed ! (See CLICPix presentation, Pierpaolo Valerio)**
- More samples to be analysed soon, Data with various incident angles also to be analysed
- **100um-on-100um Timepix assemblies in production** , halfway to ultimate CLIC goal, 50-on-50 um assemblies!
- New sensor production with more aggressive thickness distribution planned for production of CLICPix sensors, for test with various pixel layout

# Backup

Unbiased residual X, cluster size = 2, sizeX = 2 and sizeY = 1



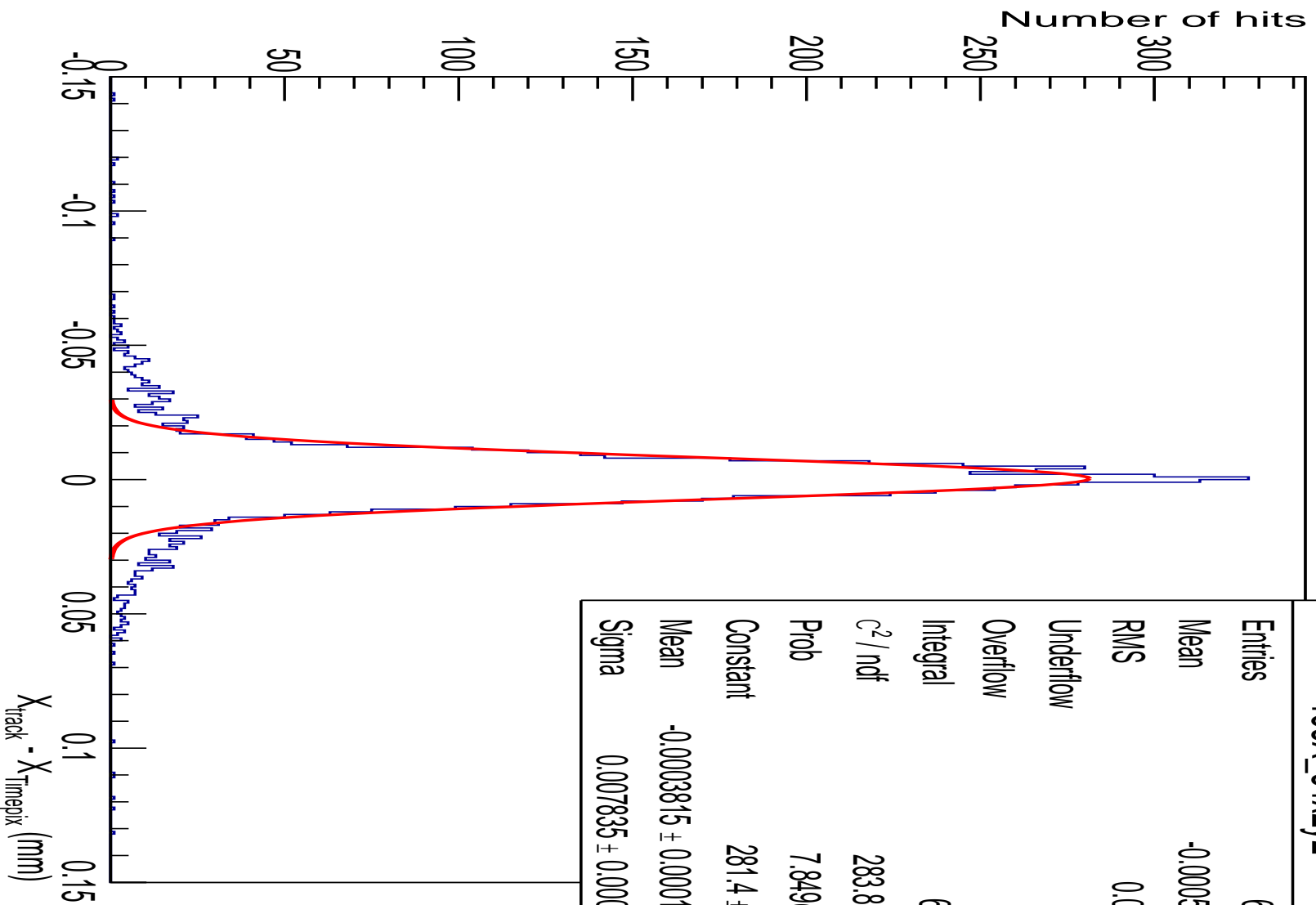
Unbiased residual Y, cluster size = 2, sizeX = 1 and sizeY = 2



Advacam p-in-n 50um thin Timepix Assembly, 50um edges

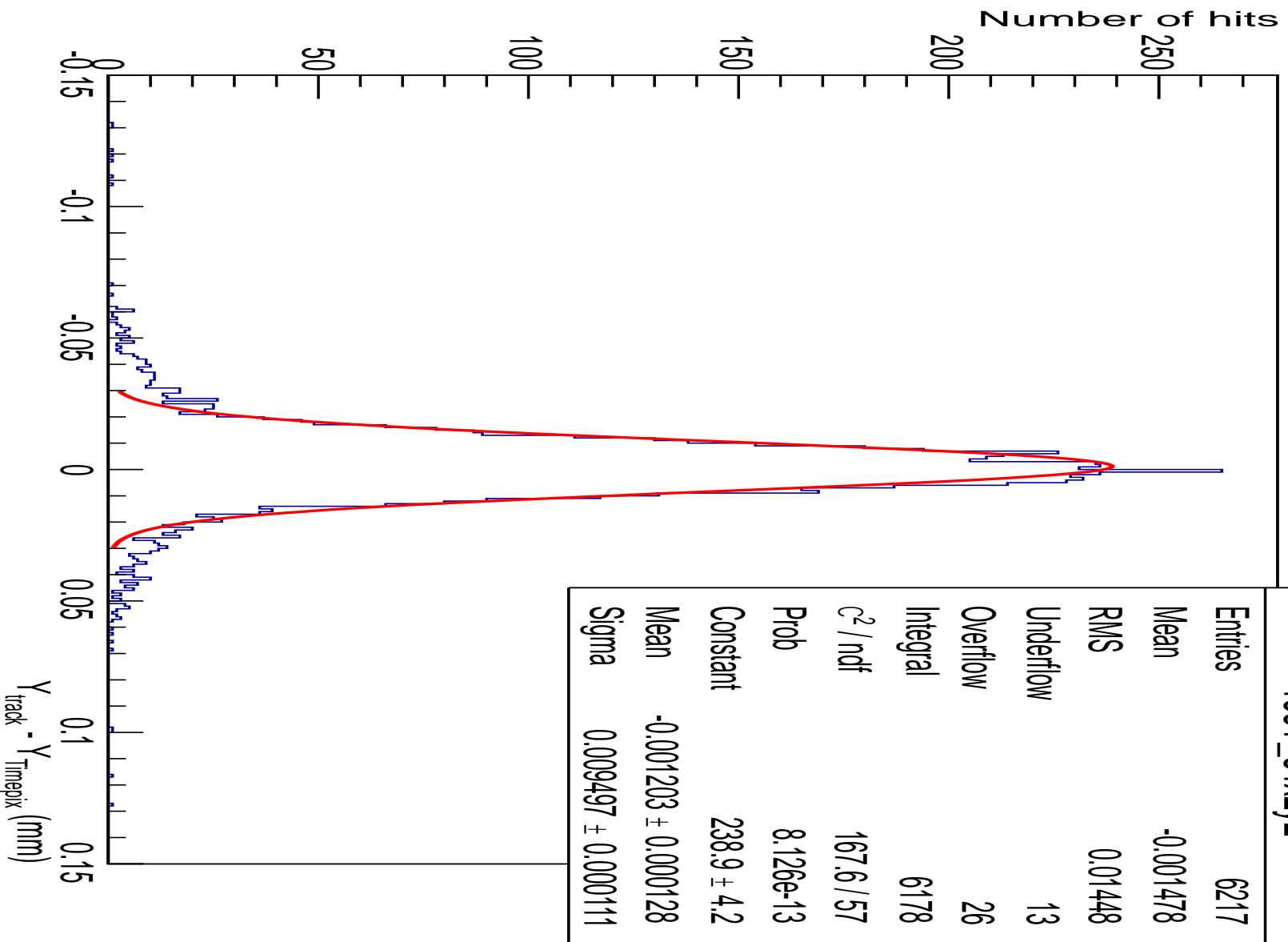


Unbiased residual  $X$ , cluster size = 4, size $X$  = 2 and size $Y$  = 2

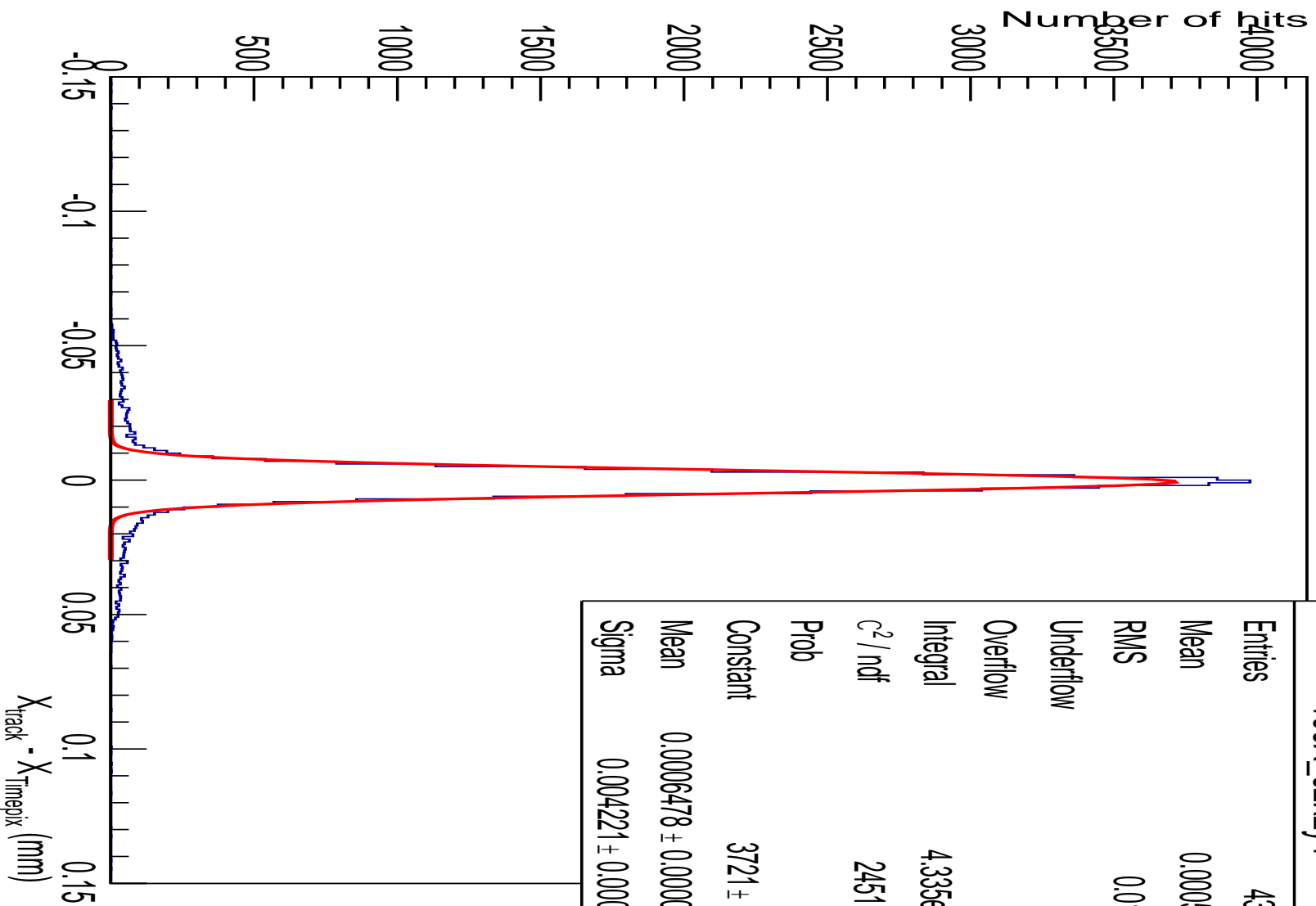




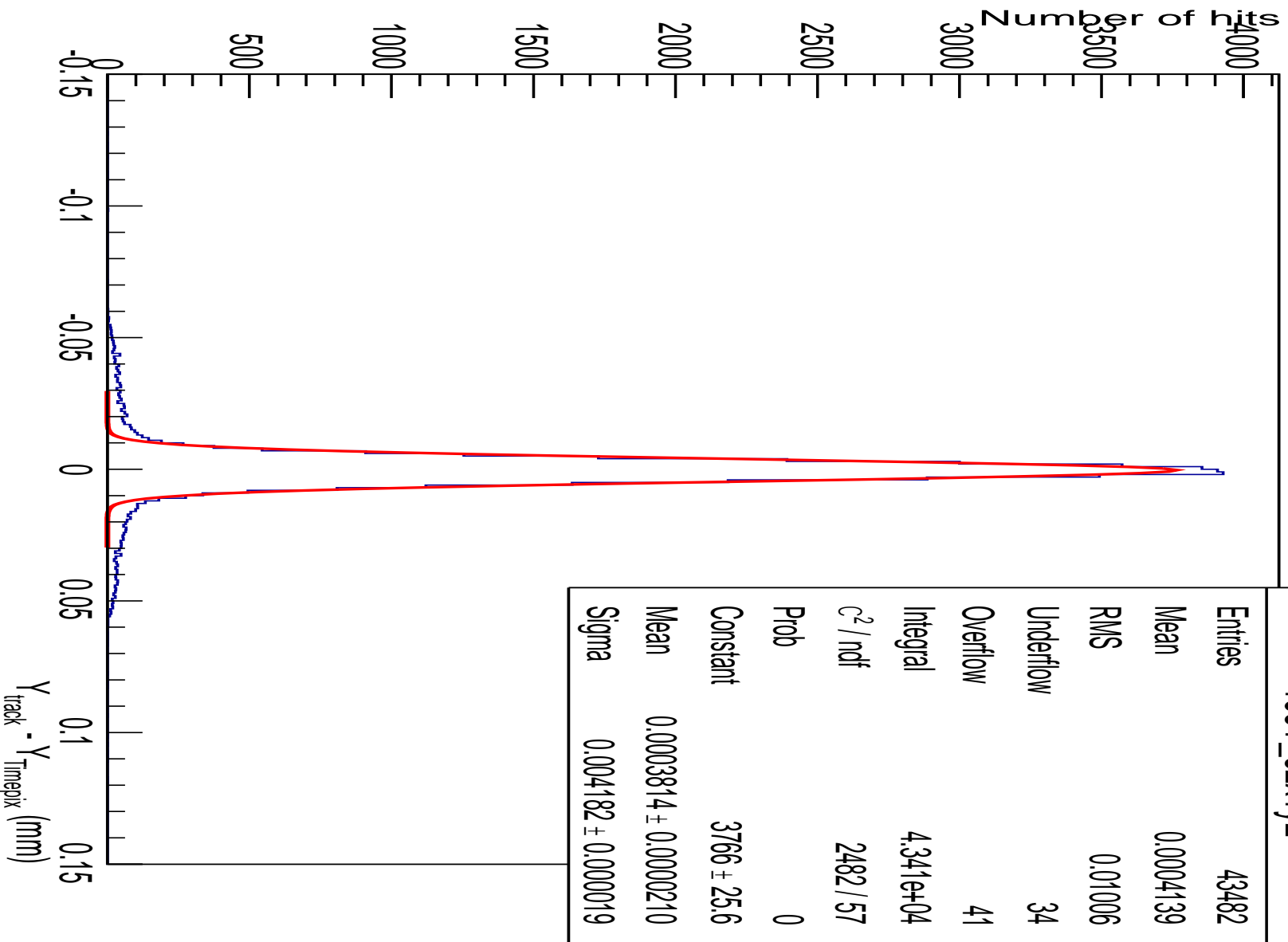
Unbiased residual  $Y$ , cluster size = 4, size $X$  = 2 and size $Y$  = 2



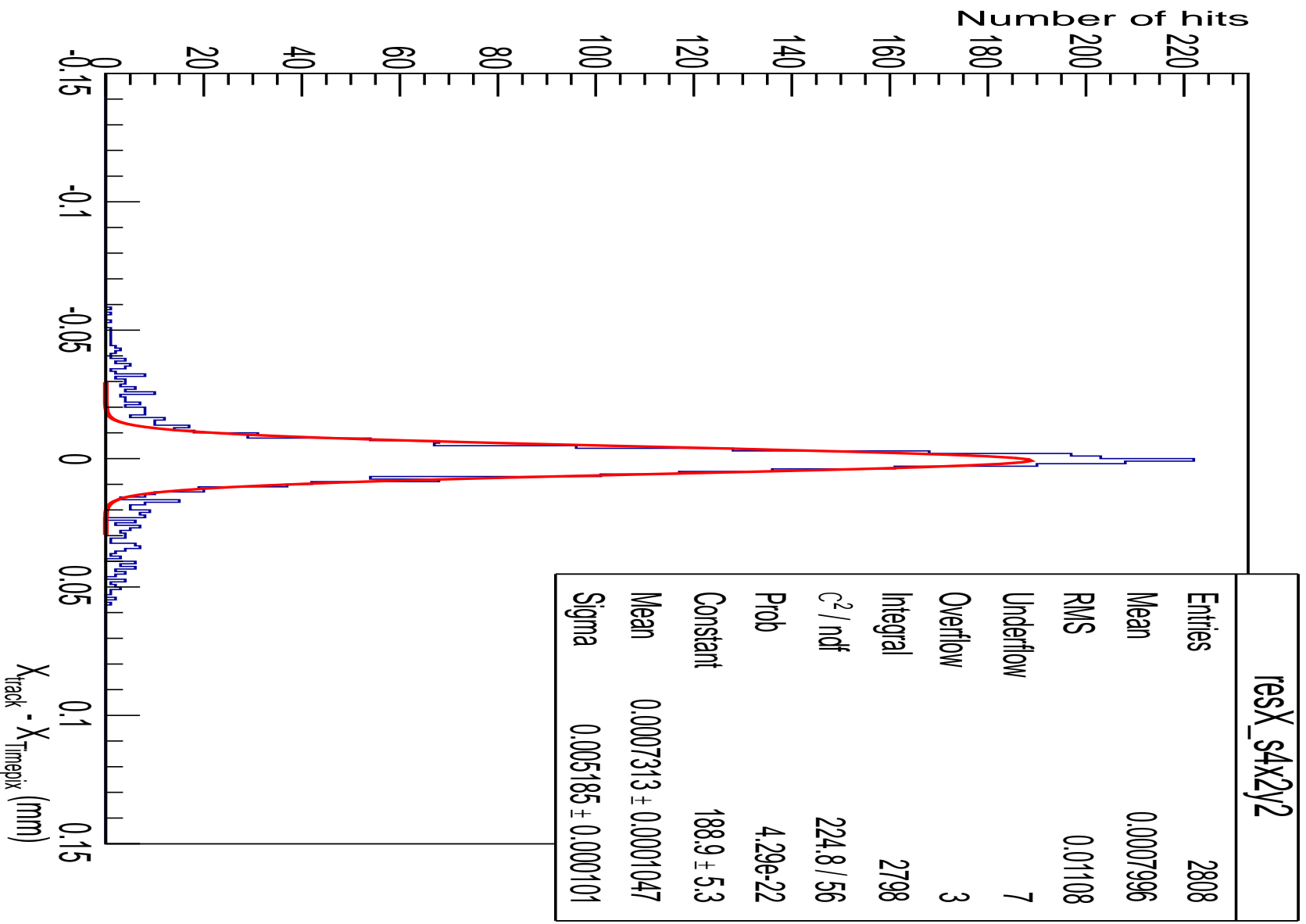
Unbiased residual  $X$ , cluster size = 2, sizeX = 2 and sizeY = 1



Unbiased residual Y, cluster size = 2, sizeX = 1 and sizeY = 2



Unbiased residual X, cluster size = 4, sizeX = 2 and sizeY = 2



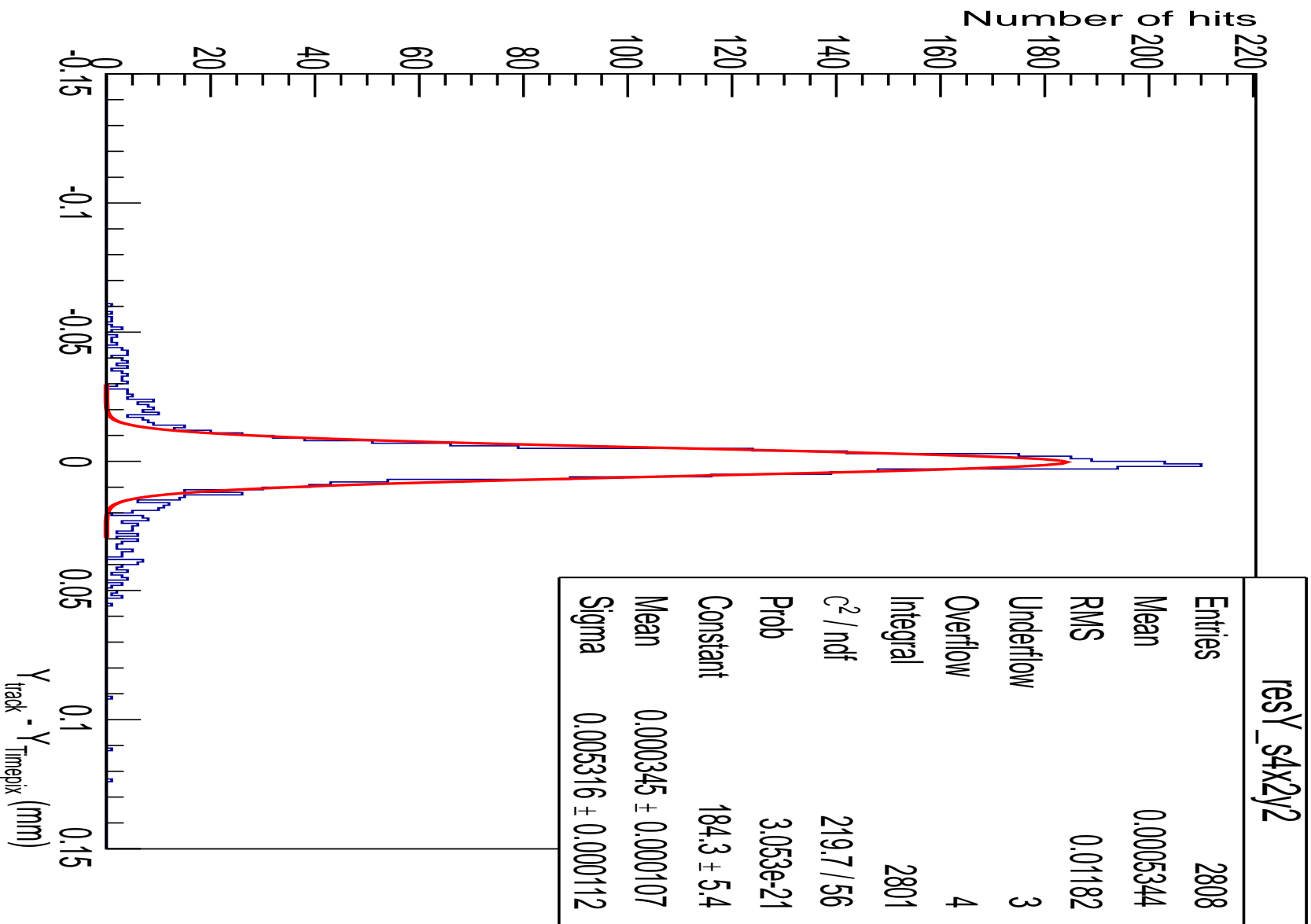
Advacam p-in-n 50um thin Timepix Assembly, 20um edges

01/10/2013

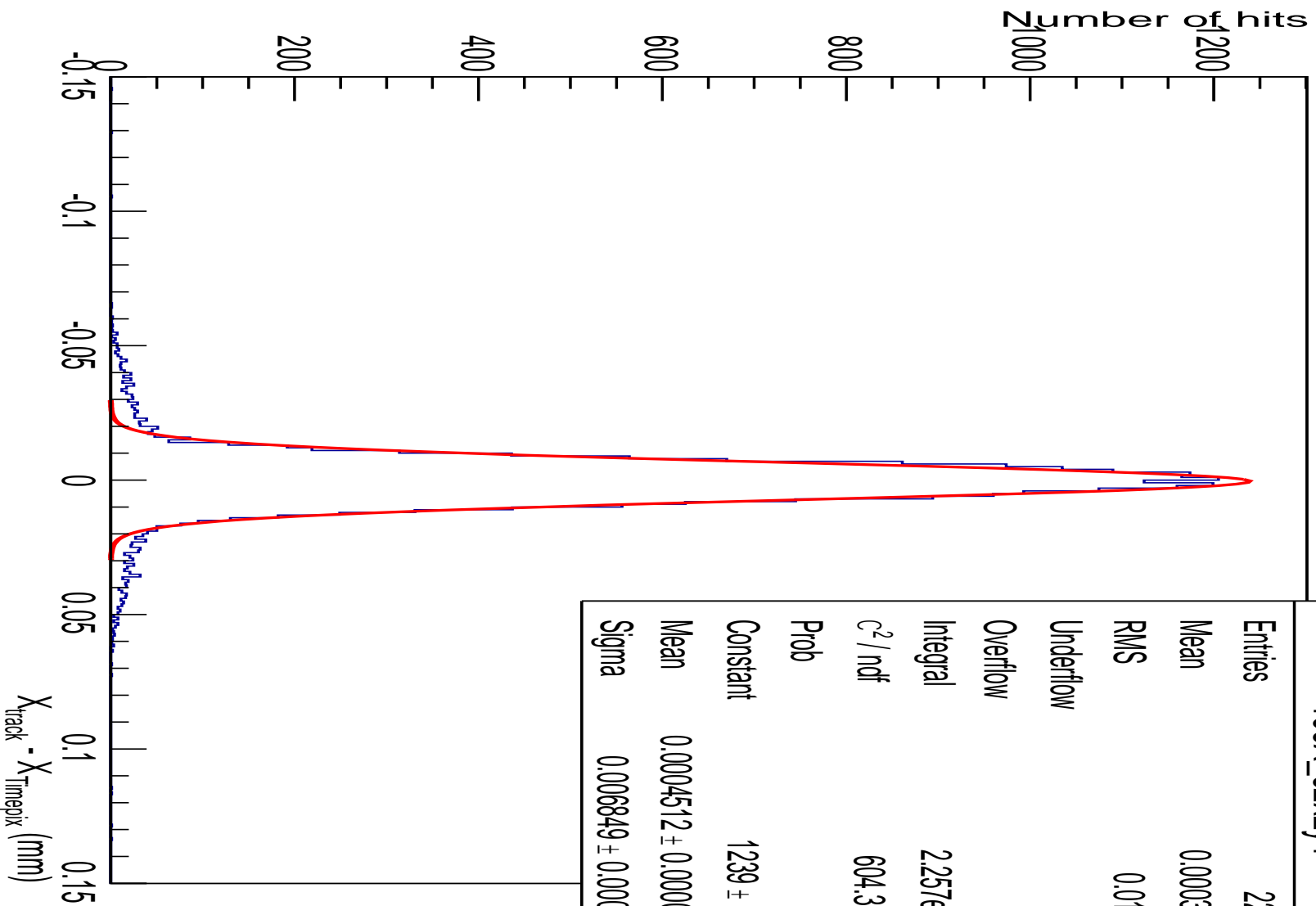
CLIC Detector and Physics  
Collaboration Meeting



Unbiased residual  $Y$ , cluster size = 4, size $X$  = 2 and size $Y$  = 2

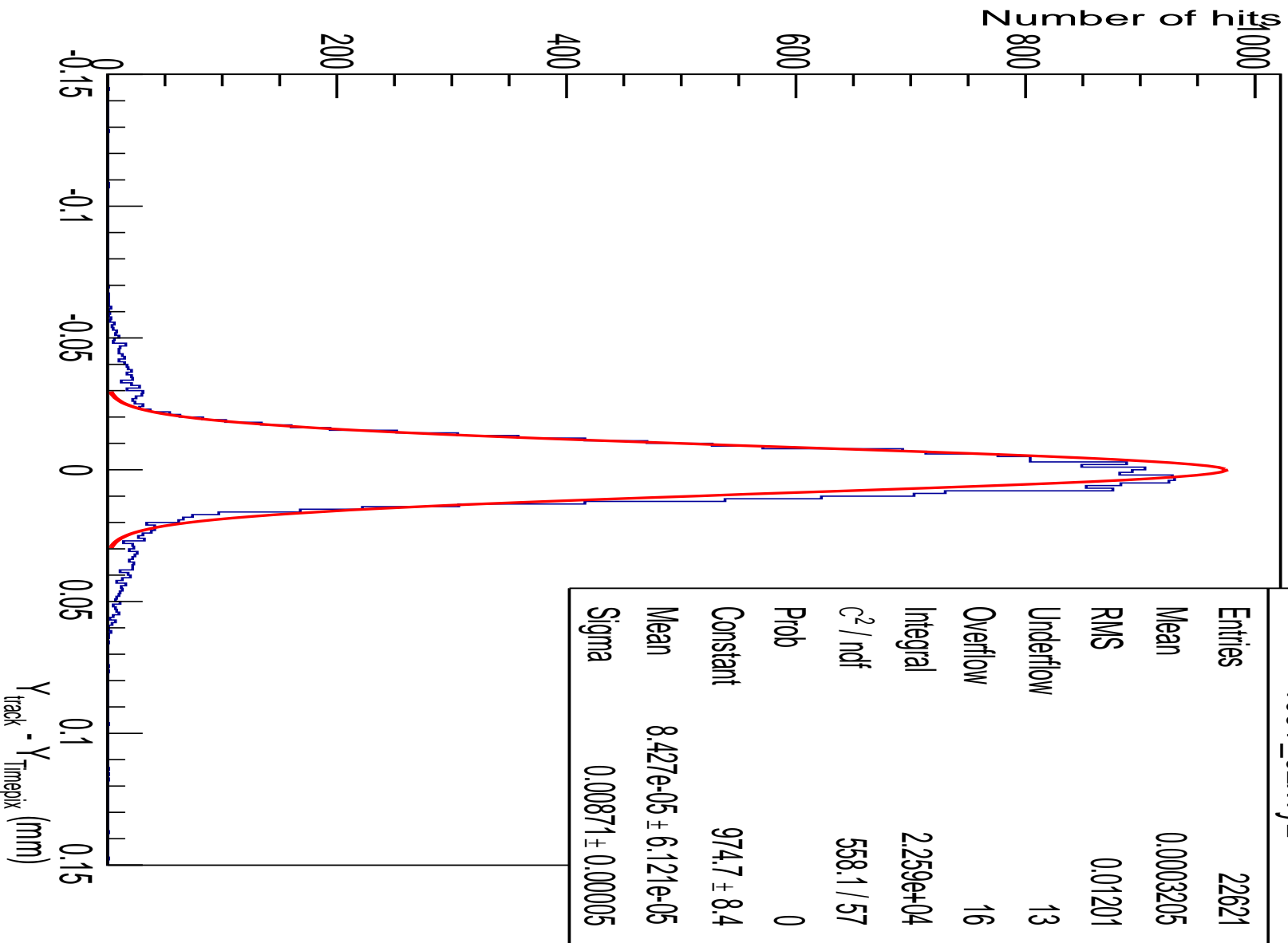


Unbiased residual X, cluster size = 2, sizeX = 2 and sizeY = 1





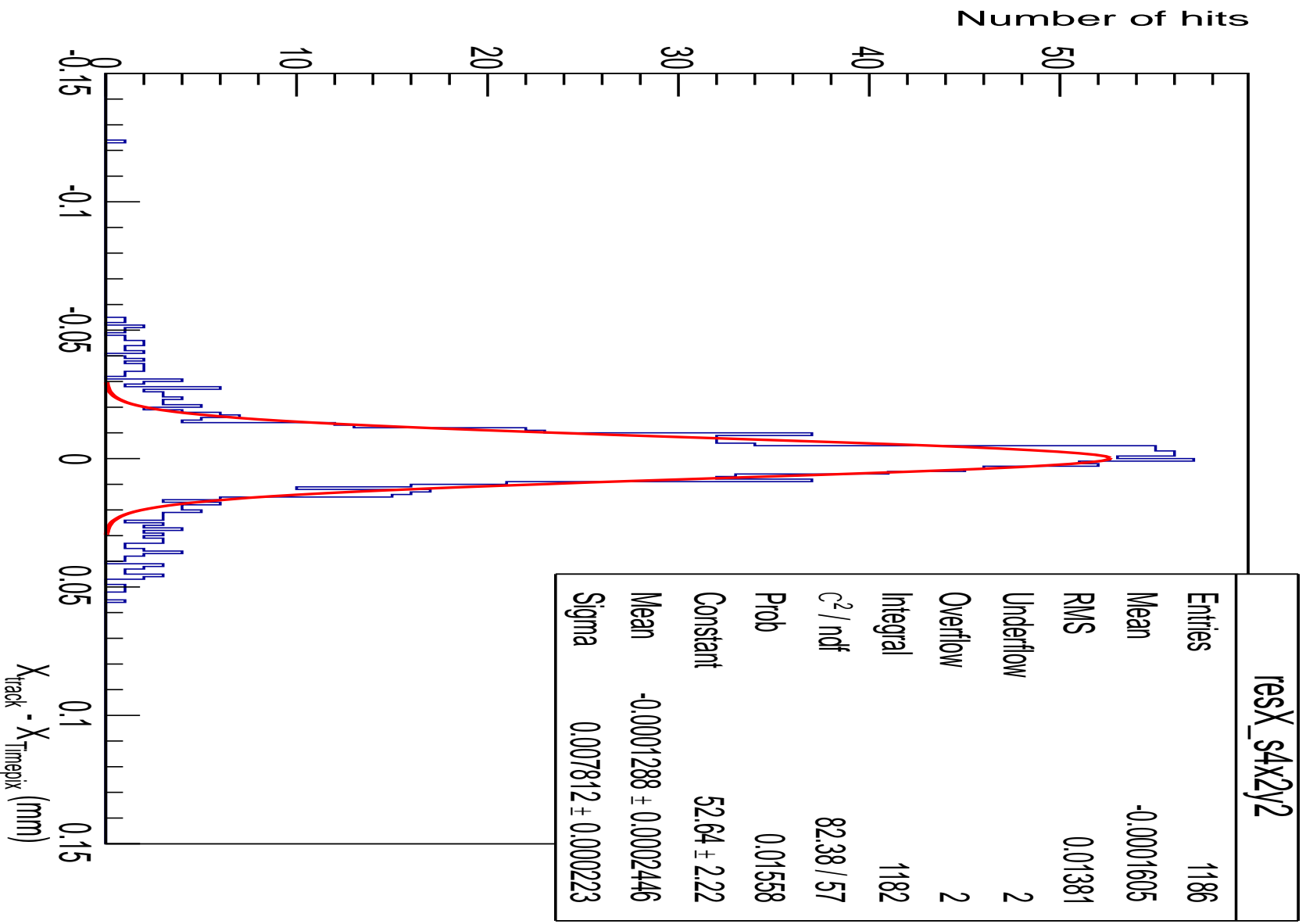
Unbiased residual  $Y$ , cluster size = 2, size $X$  = 1 and size $Y$  = 2



Advacam p-in-n 50um thin Timepix Assembly, 20um edges



Unbiased residual X, cluster size = 4, sizeX = 2 and sizeY = 2



Advacam p-in-n 50um thin Timepix Assembly, 20um edges



Unbiased residual  $Y$ , cluster size = 4, size $X$  = 2 and size $Y$  = 2

