GEM & TimePix

Larger Pixels, New Insights

A. Bamberger, M. Köhli, M. Lupberger, U. Renz, M. Schumacher

Albert-Ludwigs-Universität Freiburg

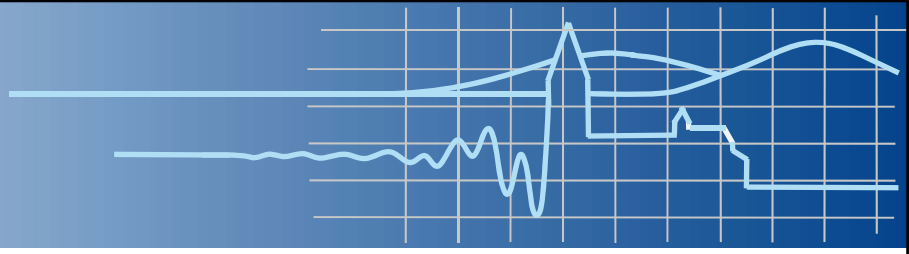
Physics Department

Albert-Ludwigs-
University Freiburg

Federal Ministry of Education and Research

UNI FREIBURG

Outline



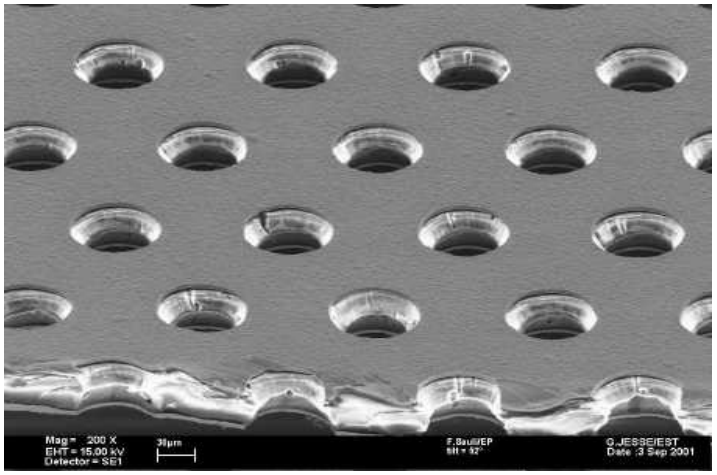
- Introduction
  - » GEMs
  - » Pixel enlargement
  - » Experimental setup
- Studies with 1x1 and 2x2 chips
  - » Comparison of effective threshold for both chips.
  - » Gain Estimation
  - » Studies with TOT calibration of individual pixels.
- Summary
- Future Plans

GEMs

Principle

- 2 layers Cu each 5 µm thick, separated from each other by 50 µm Kapton.
- Conical etched holes largest Ø70 µm, diagonal distance of holes 140 µm.

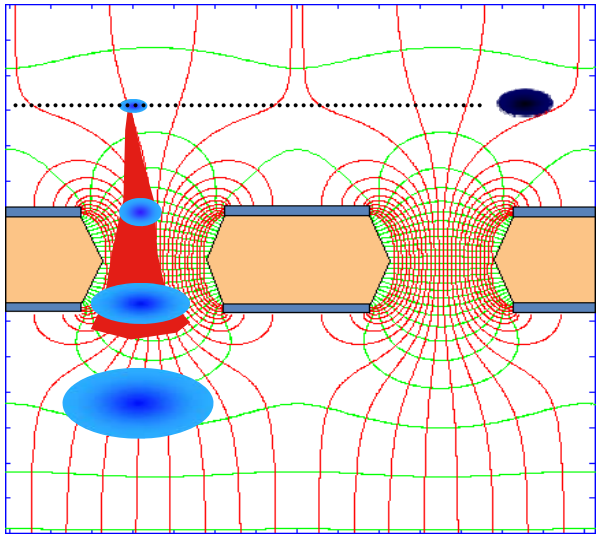
F. Sauli, http://www.cern.ch/GDD



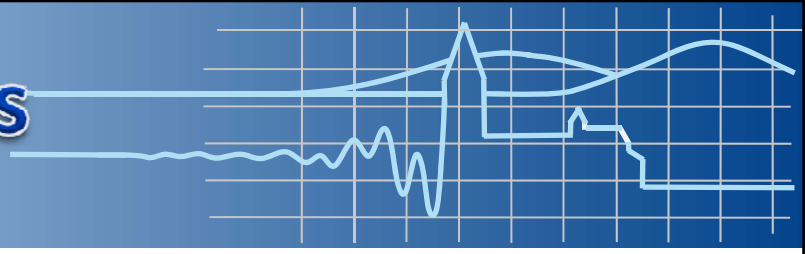
Triple-GEM-setup

- Gas gain up to 10^5 in $ArCO_2$

  ⇒Necessary because charge is typically spread over several pixels (>> 50 pixels)
- Minimizing the positive ion backdrift
- Localized region of amplification
- Reliable operation, only few sparks



Motivation for larger Pixels



- **Charge of cluster is spread over several pixels:**
  - **Reduces number of e^- per channel.**
  - **Increases effective threshold.**
  - **Requires high gas gain to detect minimum ionizing particles.**
- **Large pixels:**
  - **Collect more charge per pixel ⇒Reduce effective threshold.**
  - **Need less gas gain ⇒ Smaller number of positive ions.**
  - **Optimize pixel size versus spatial resolution.**
  - **Strong diffusion between cascaded GEM stack.**

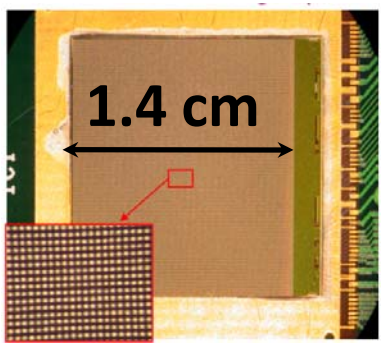
    ⇒Very small pixels not necessary

Pixel Enlargement IZM

TimePix is used as highly segmented charge collecting anode

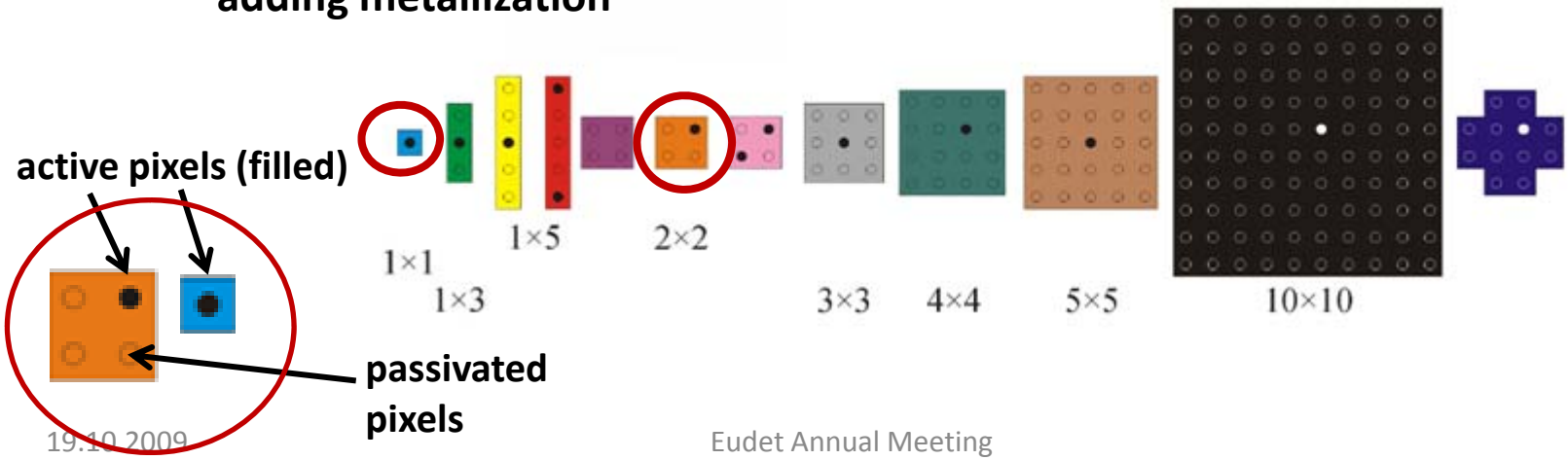
universitätbonn

- Post processing of complete *wafer from Bonn* group by IZM Berlin:
  - »Different pixel sizes
  - »Different pixel geometries
- Two post processed TimePix tested
  - **1x1:** pixel metallization extended from ≈20x20 µm² to 50x50 µm²
  - **2x2:** pixel size extended to 105x105 µm² by passivating 3 out of 4 pixels and adding metallization



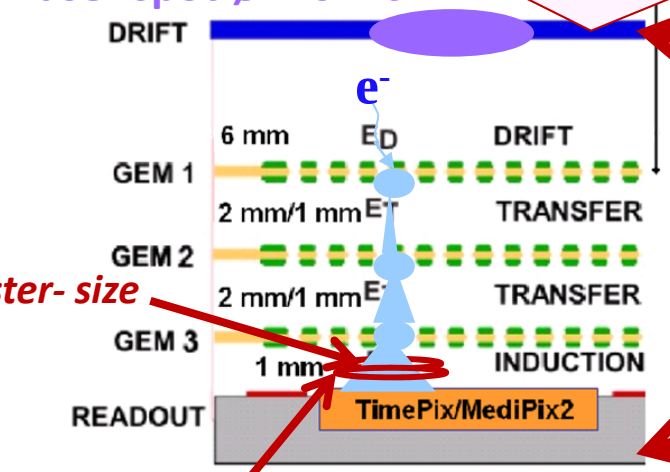
Dimensions & Features

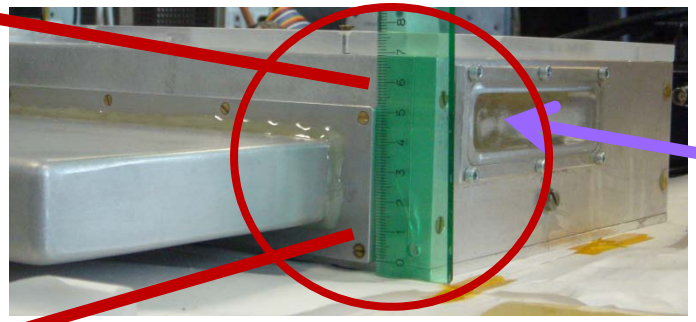
- 256 x 256 pixels²
- 55 x 55 µm² pixel size
- 14 x 14 mm² active area
- Measures Time Over Threshold (TOT)
- External test pulse can be injected in pixels



Test Setup

schematic view of the stack from side





$\sigma_{cluster-size}$

Transverse diffusion between GEMs leads to spread of charge across several pixel (>>50)

Potentials and fields:

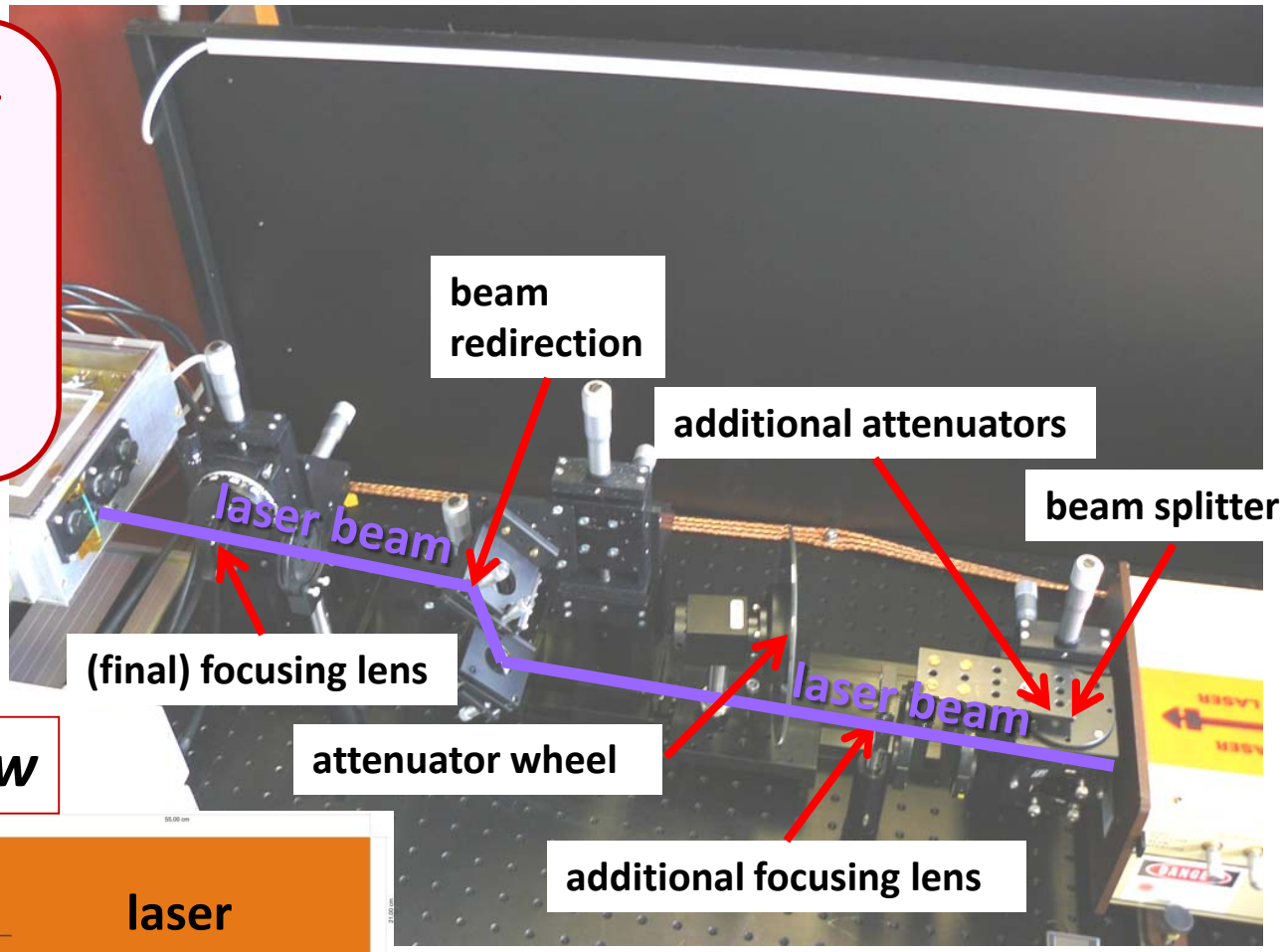
ΔV_{GEM} = 317 V:	ΔV_{GEM} = 375 V:
E_D= 0.85 kV/cm	E_D= 1.00 kV/cm
E_T = 2.54 kV/cm	E_T = 3.00 kV/cm
E_I = 3.57 kV/cm	E_I = 4,21 kV/cm

Voltage across GEMs (ΔV_{GEM}) equal for all three GEMs

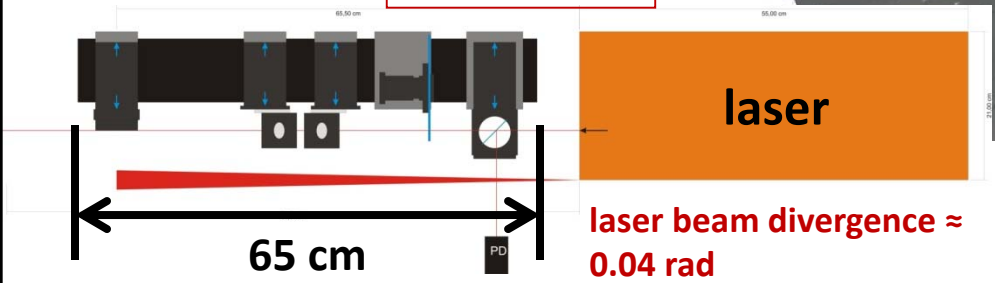
Test Setup with Laser

Readout interfaces:

- USB interface:
  - »80MHz clock
  - »Used for 2x2 chip
- Muros interface:
  - »37MHz clock
  - »Used for 1x1 chip



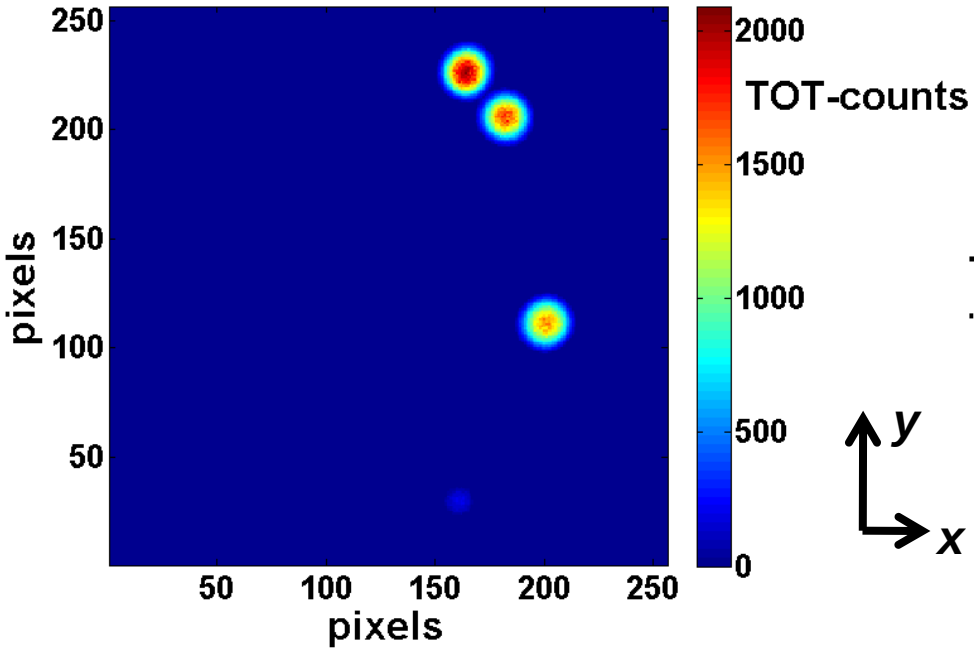
top view



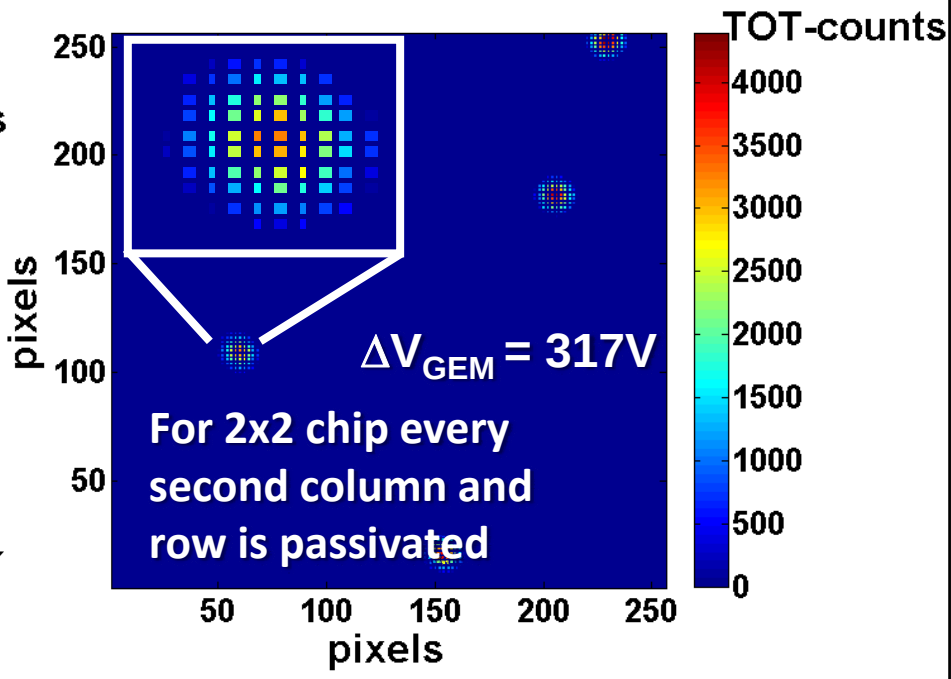
laser beam divergence ≈ 0.04 rad

Events with Iron Fe^{55}

Fe^{55} clusters with 1x1 TimePix (Muros)



Fe^{55} clusters with 2x2 TimePix (USB)

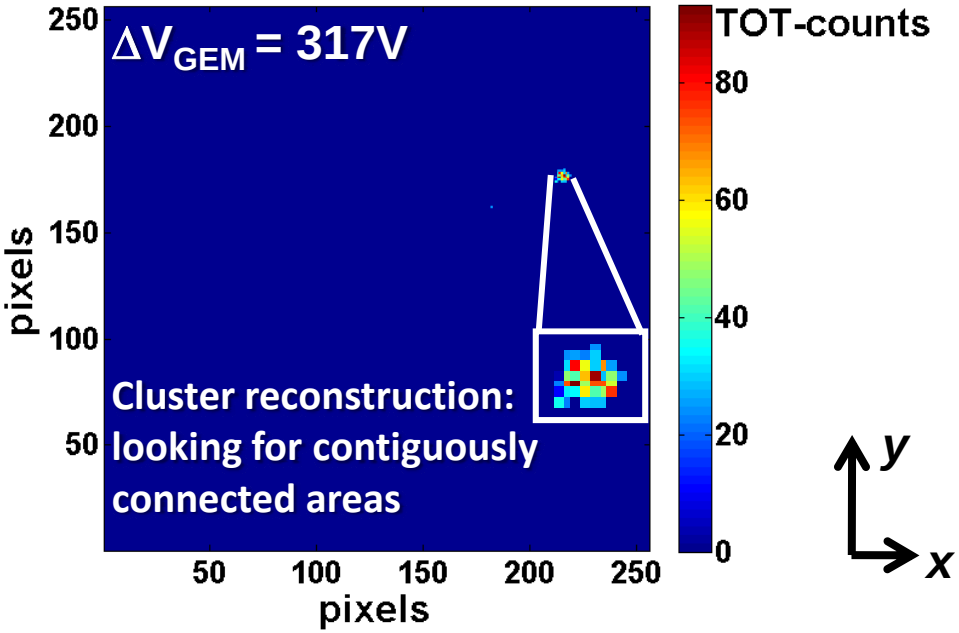


- USB (80MHz clock) used for 2x2
- Muros (37MHz) used for 1x1

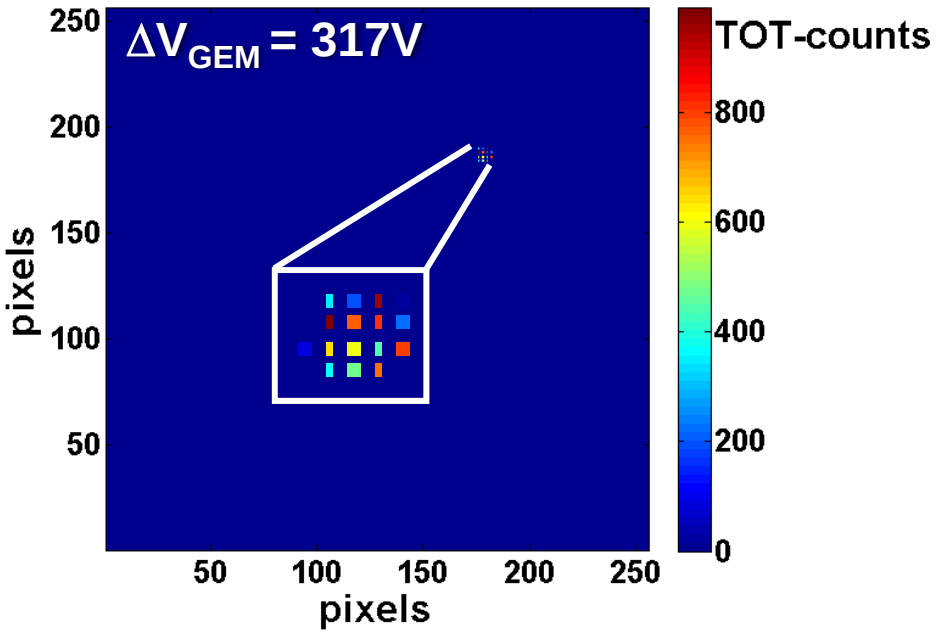
} TOT not directly comparable : has to apply factor 80/37 to 1x1 TOT values

Events with Laser

1x1 event



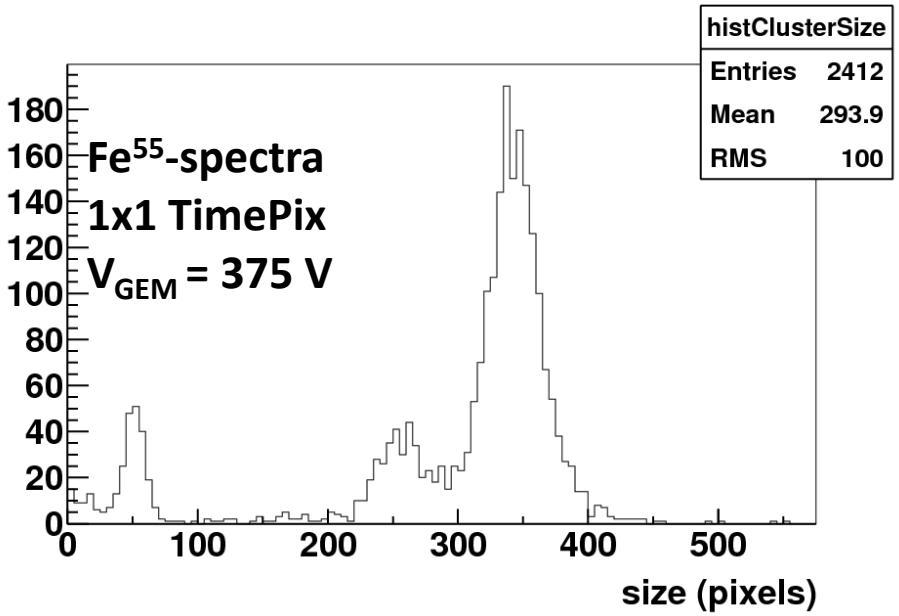
2x2 event



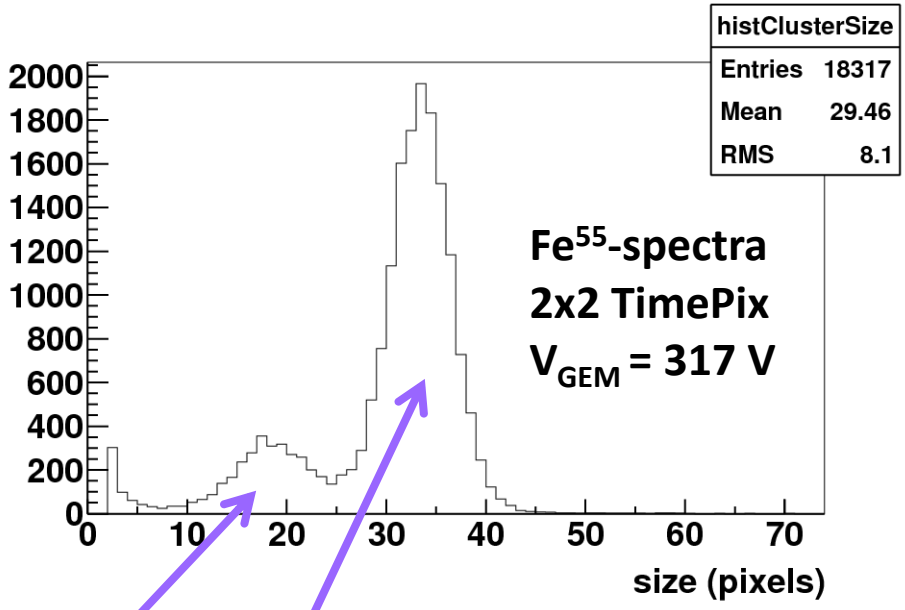
- Use Laser to characterize response of a test device using few or single primary e^-
- Following cluster information are reconstructed for *both sources:* Laser and Fe^{55}
  - »ClusterSize = number of pixels in a cluster
  - »ClusterCentroid = geometric center of cluster (x,y)
  - »TotVolume = sum of all TOT counts in a cluster
  - »TotAtCluster = TOT value at the cluster centroid
  - »Eccentr = eccentricity of a cluster

ClusterSize-Spectra

1x1 spectrum



2x2 spectrum

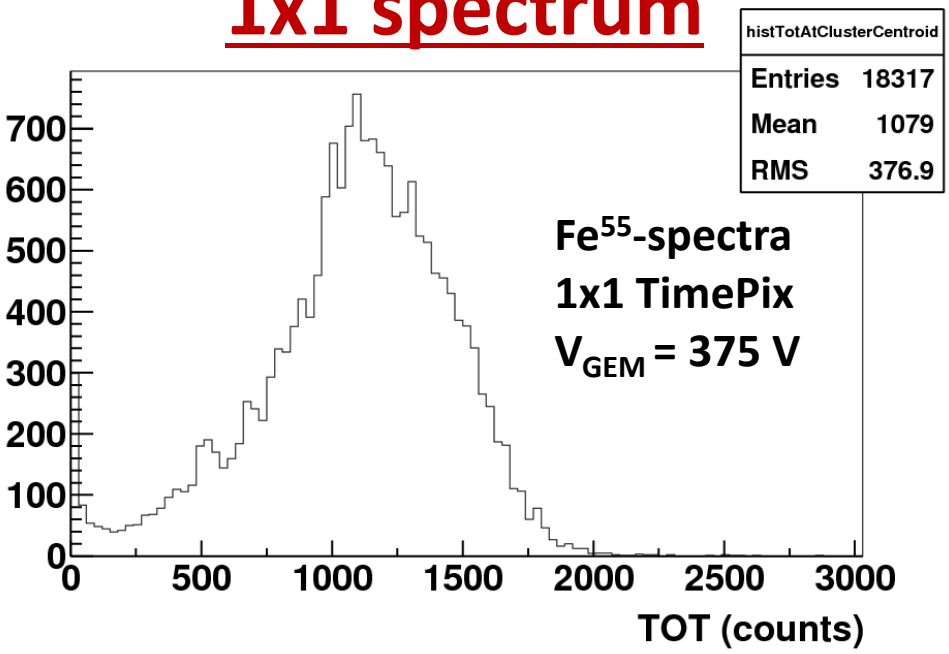


Typical argon spectra with *escape* and *photo peak*

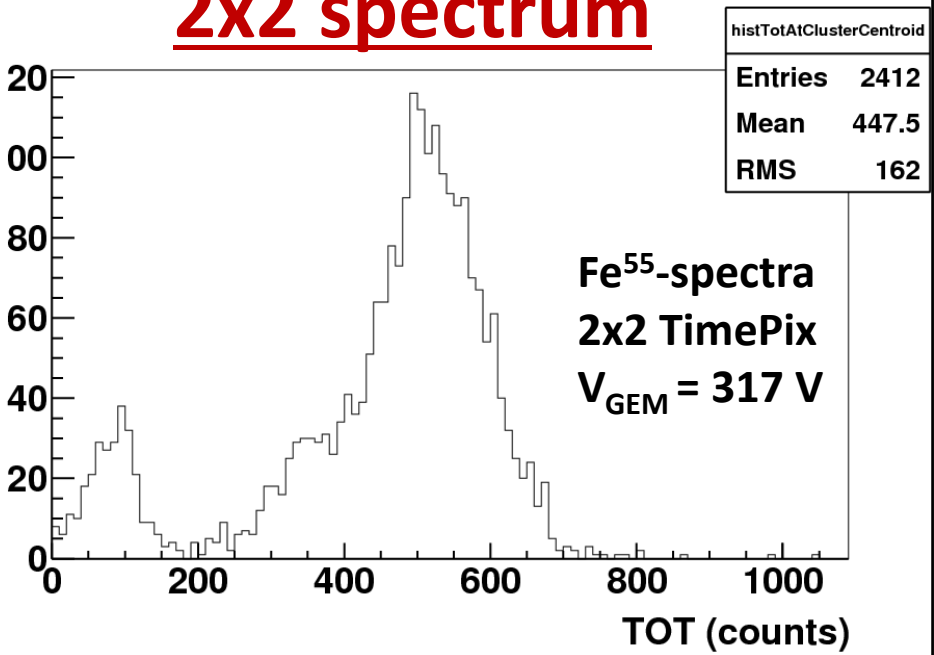
- Factor 10 difference in cluster size.
- For now: Take only TOT value at center of cluster to compare. effective threshold of 1x1 and 2x2 chips.
  ⇒ value independent of cluster size

TOT at Cluster Centroid-Spectra

1x1 spectrum

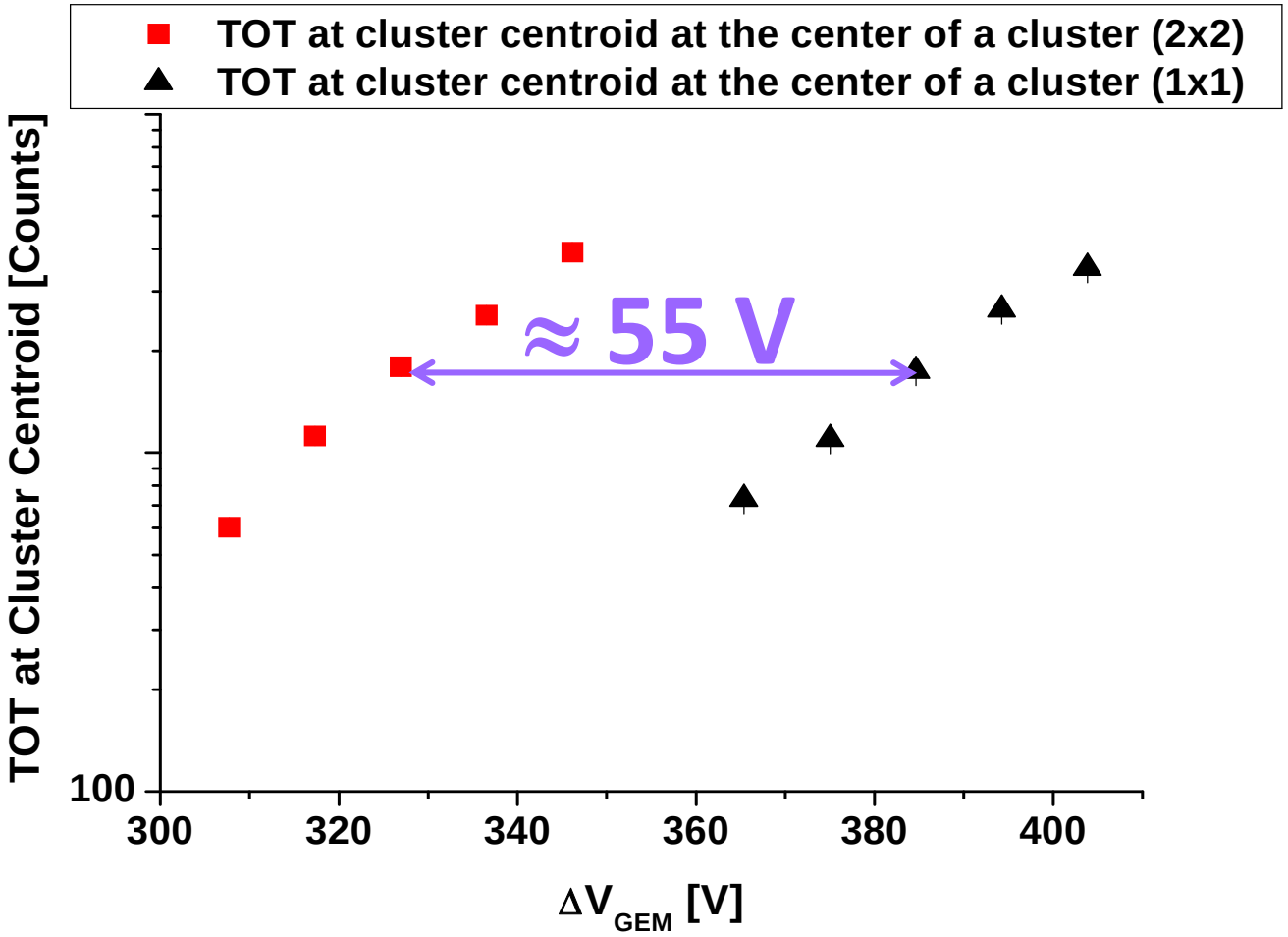


2x2 spectrum



- To compare 1x1 and 2x2: Determine peak position for different GEM voltages.
- Look for same TOT value of 1x1 and 2x2 and estimate difference in ΔV_{GEM}.
- Problem:
  - » Different thresholds for 1x1 and 2x2 TimePix
  - » Different readout interfaces $\Rightarrow$ different clocks must be corrected
  - » Other systematic uncertainties are investigated

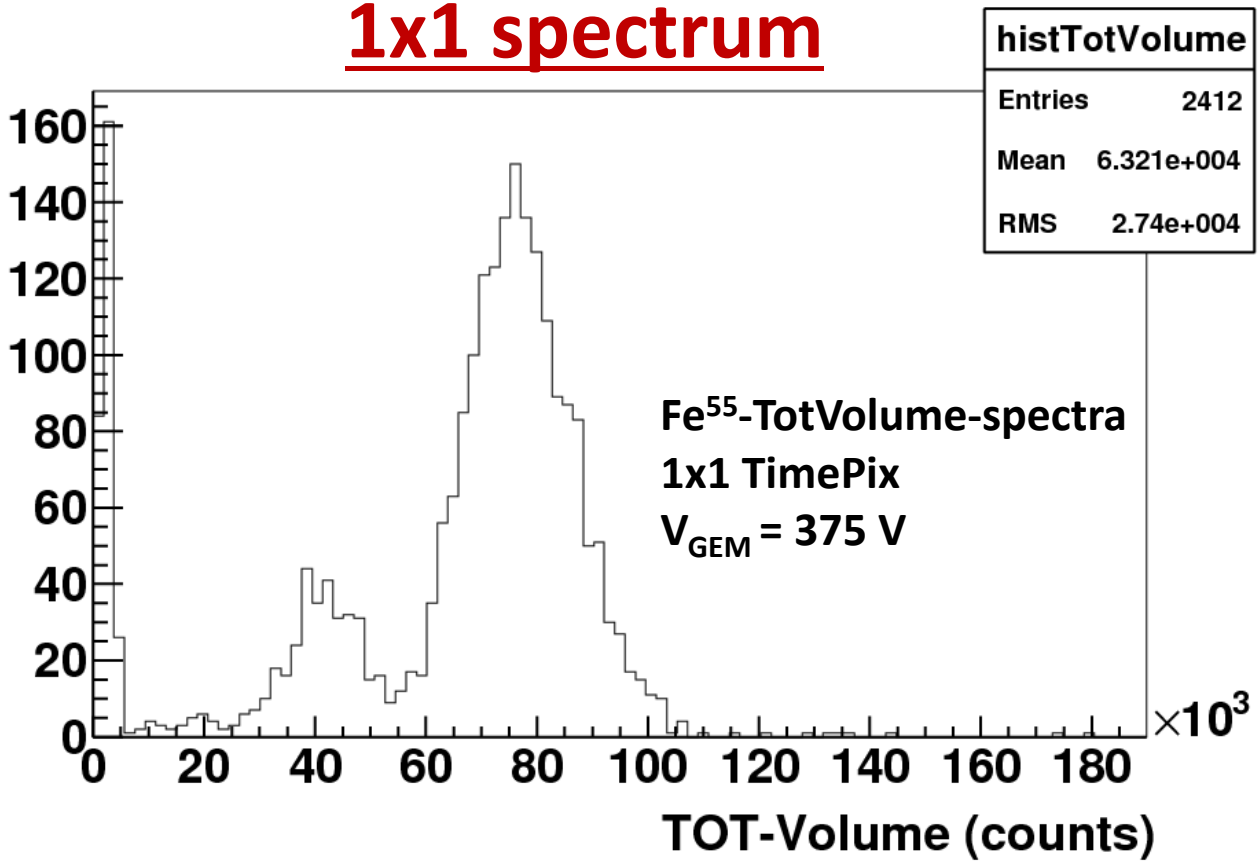
TOT Counts at Cluster Centroid vs. ΔV_{GEM}



- To account for different clocks 1x1 results are corrected with factor 80/37.
- For about same TOT value ≈55V smaller ΔV_{GEM}
- Lower effective threshold ⇒ Less backflow of positive ions into drift volume.

TotVolume-Spectra 1x1

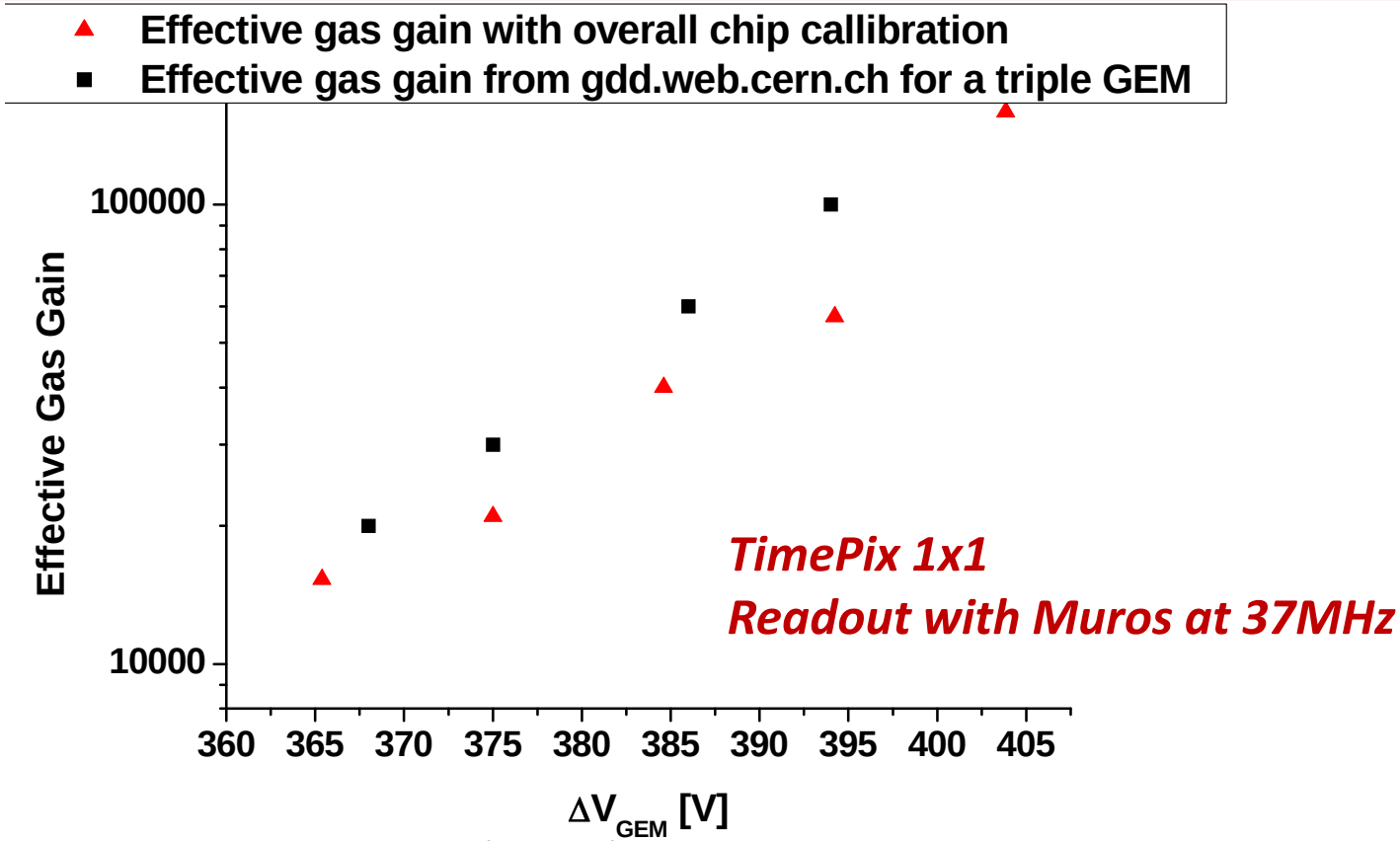
1x1 spectrum



- Goal: Measure effective gain ⇒ Determine TotVolume at photo peak.
- But: Need conversion from TOT to charge in e^- ⇒ calibrate TOT of TimePix using external test pulses.

Gain Estimation

- "Recipe" to calibrate TOT with test pulses:
  - » Charge of injected test pulses (TimePix-Manual): Q = 50[e^-/V] x TestPulse[V]
  - » Conversion factor from TOT count to charge ("chipwise").
- Estimate Charge deposition from TOT volume of a cluster.



New approach for calibration

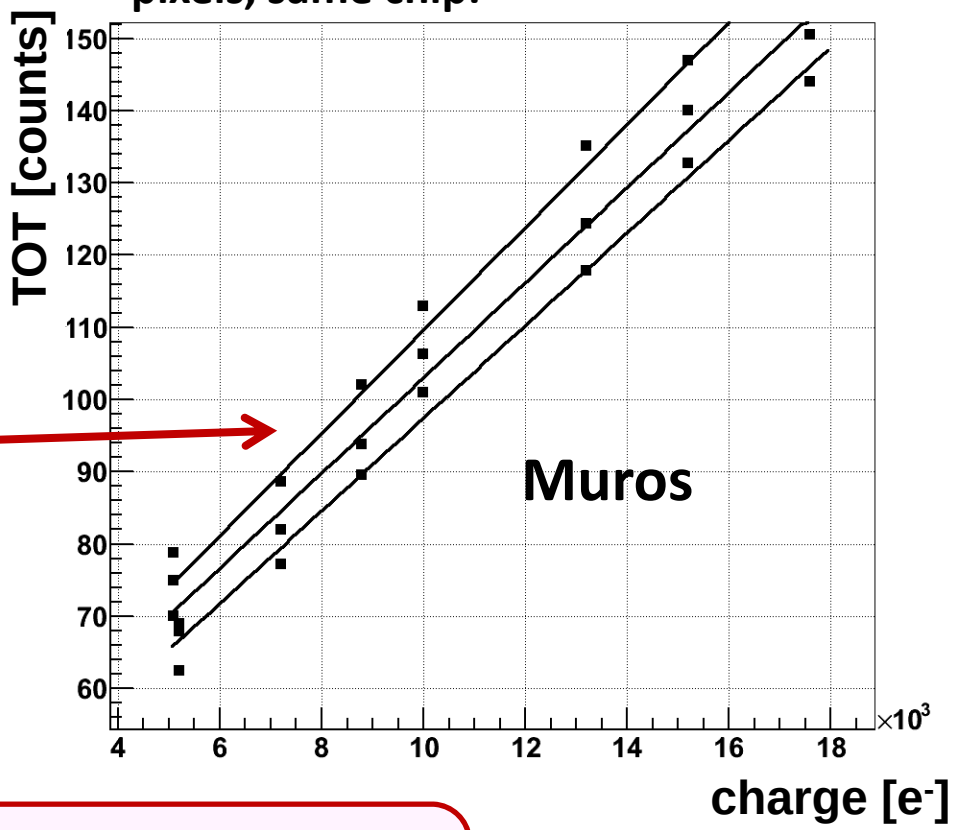
- TOT depends linear on the deposited charge Q:

$$\mathrm{TOT} = b \cdot Q + a$$

- Until now: Calibration with test pulses is done chipwise.

⇒ But every Pixel has its own response function

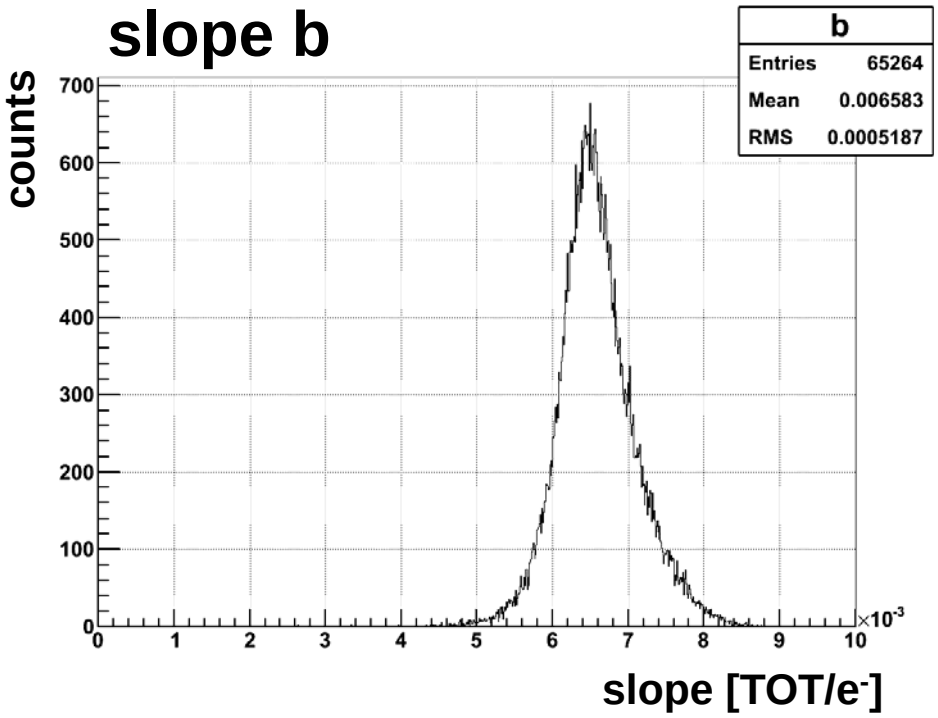
Calibration curves for three different pixels, same chip:

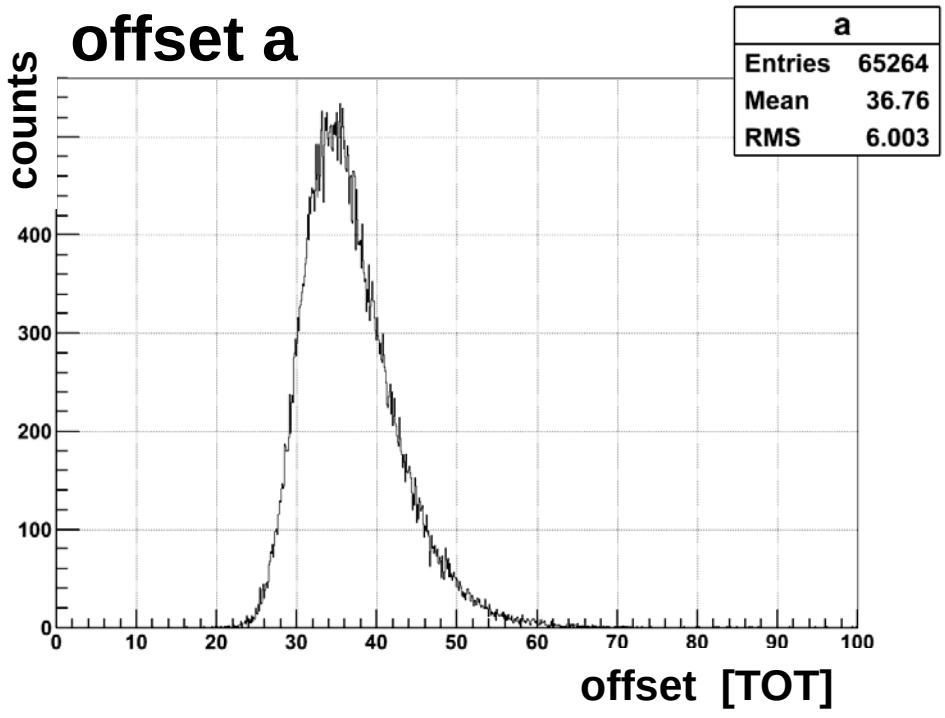


Is there a benefit in calibrating single pixels?

Is there a difference between USB and Muros?

Muros with Test Pulses





$$\mathrm{TOT} = b \cdot Q + a$$

- **Results indicate: Muros small variations in pixel response.**
- **Fluctuations for time being not separable from statistical deviations.**

Muros & USB - Comparison

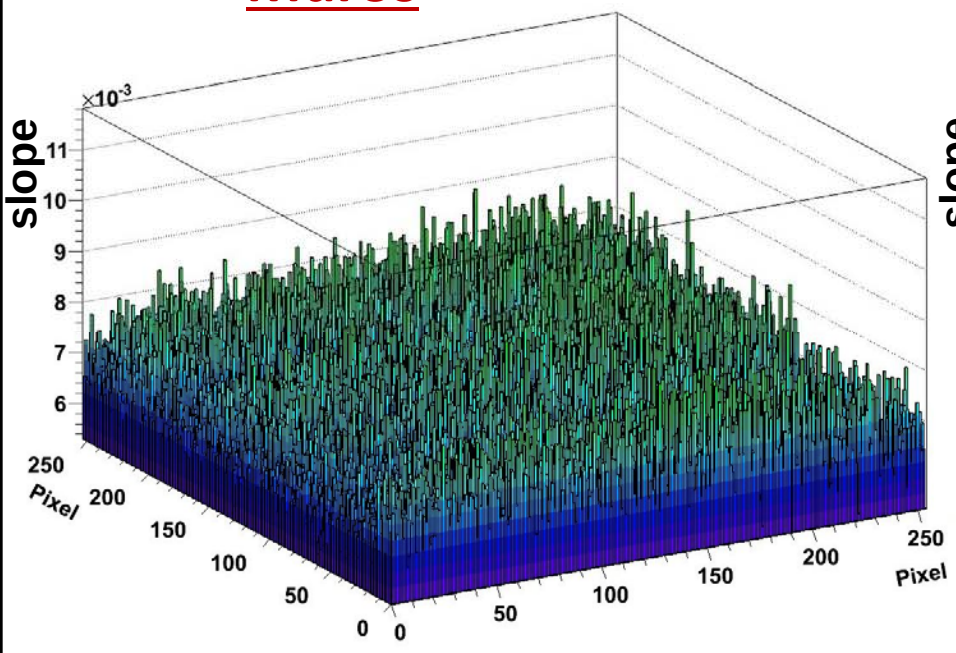
- **Are these distribution homogenous across the chip?**
- **Are these distributions the same for Muros and USB interfaces?**

Our expierence shows:

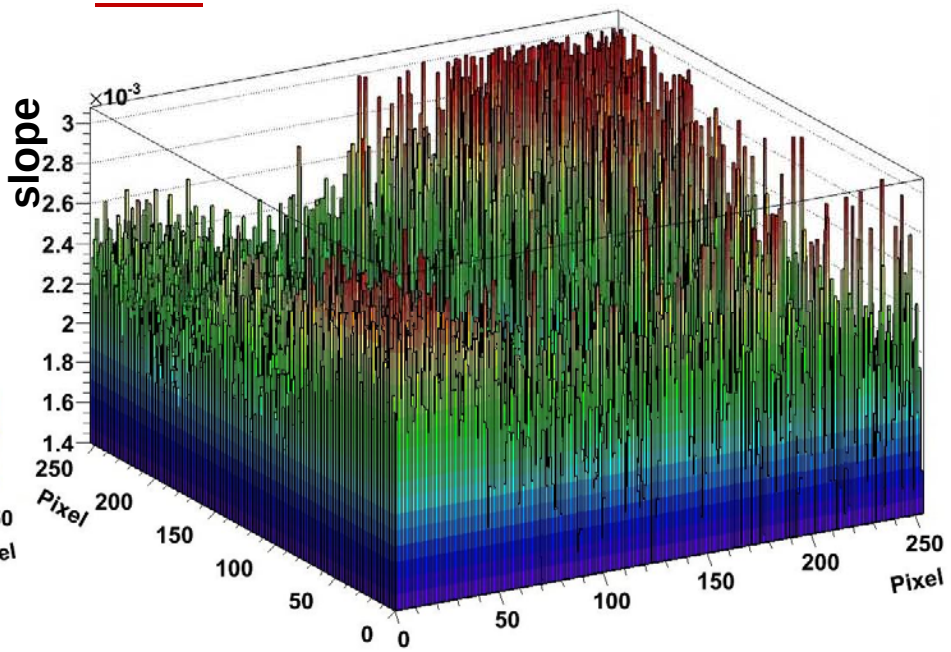
USB interface:

- **more noisy**
- **inhomogeneous pixel response**

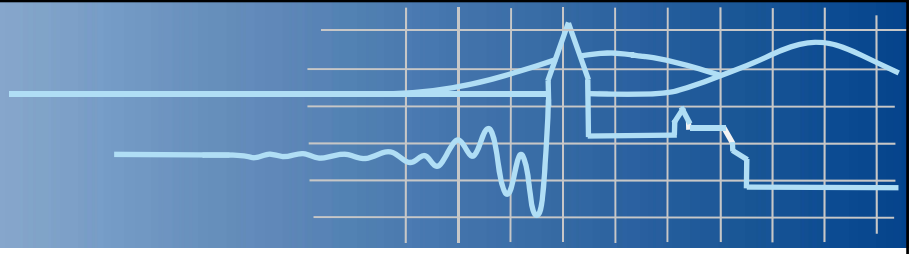
Muros



USB

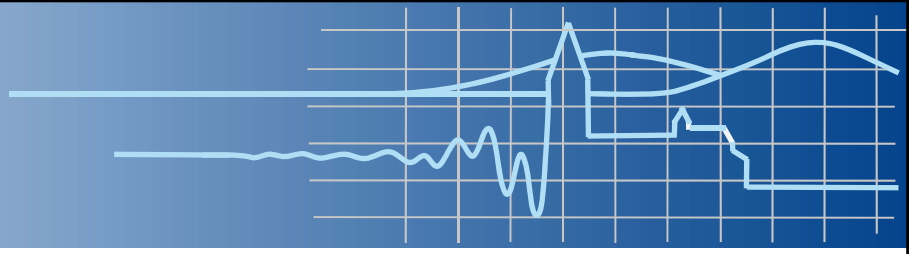


Summary

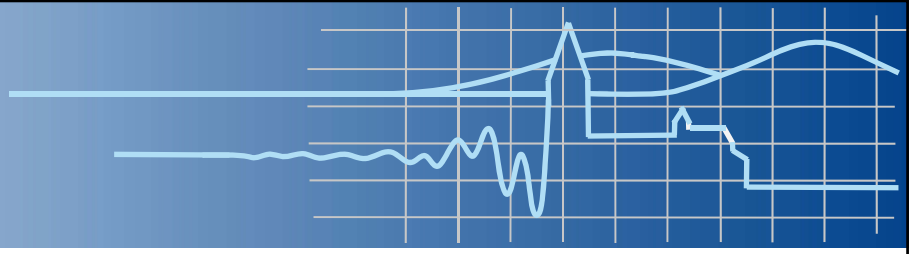


- Pixel enlargement **reduces effective threshold.**
- Gain measurement - nice agreement between reference from GDD at CERN and TimePix:
  - » Systematic errors are under study
  - » Calibration with TimePix 2x2 will be done soon
    - ⇒ Estimate gain at lower ΔV_{GEM}
- Problems with USB are only present for measurements with test pulses
- **Refined and more detailed analysis in progress**

Future Plans



- **Tests with new chamber and 8 Channel HV:**
  - » **Further study 1x1 , 1x3, 1x5, 2x2, 3x3, 4x4… TimePix chips**
  - » **Parameter scan to find optimal settings V_{GEM}, E_{Drift}, $E_{Transfer}$ and $E_{induction}$.**
  - » **Test ageing properties of material used for passivation, pixel enlargement and possibly Ingrids.**
- **New gate generator will create very stable shutter signal for TimePix**
  - » **Less than 1ns jitter**
  - » **Allows very exact determination of precision in time for any device under test (e.g. TOT or TIME like measurements for Gossip/TimePix2).**
- **Laser test bench together with radioactive sources allows accurate characterization of all possible combinations of MPGDs and pixel readout**

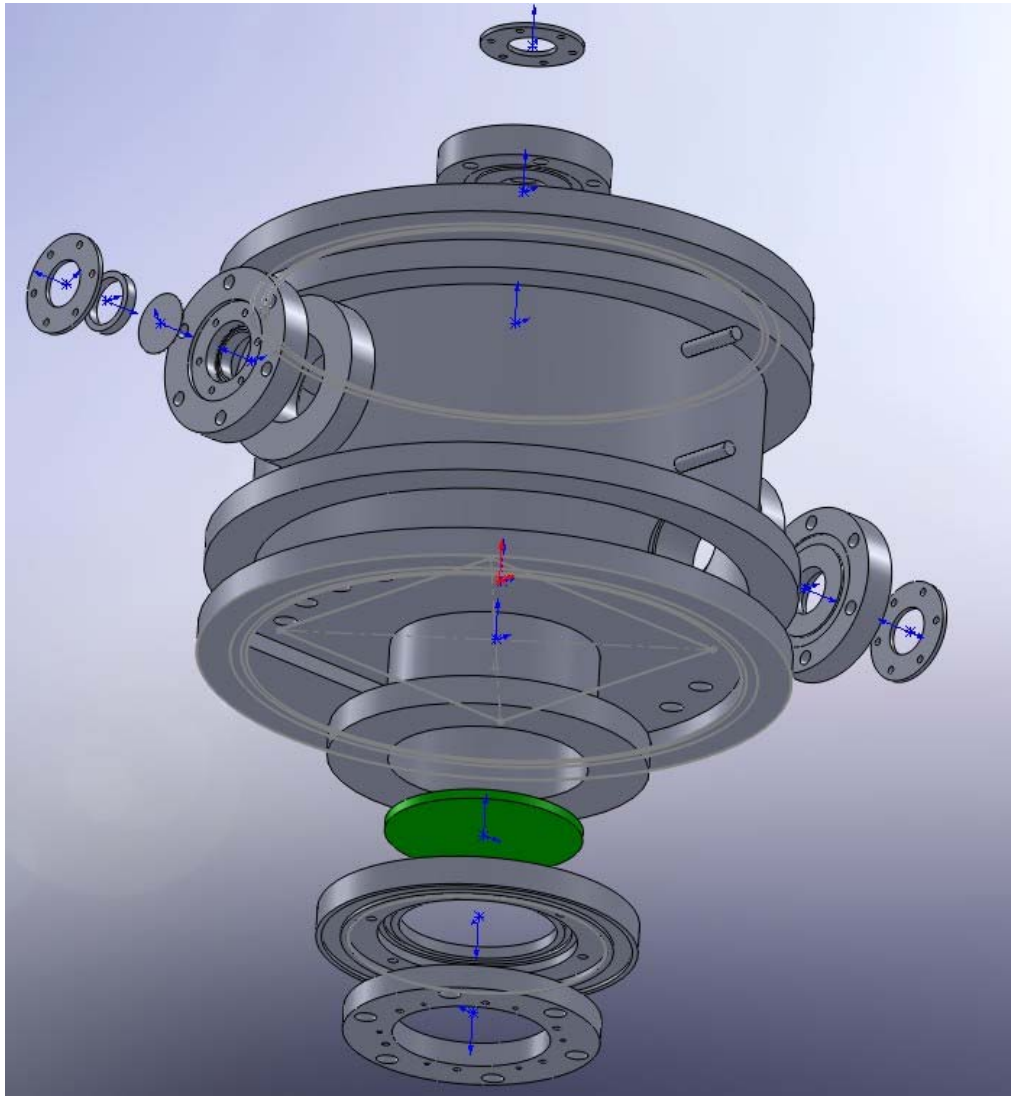


Backup Slides

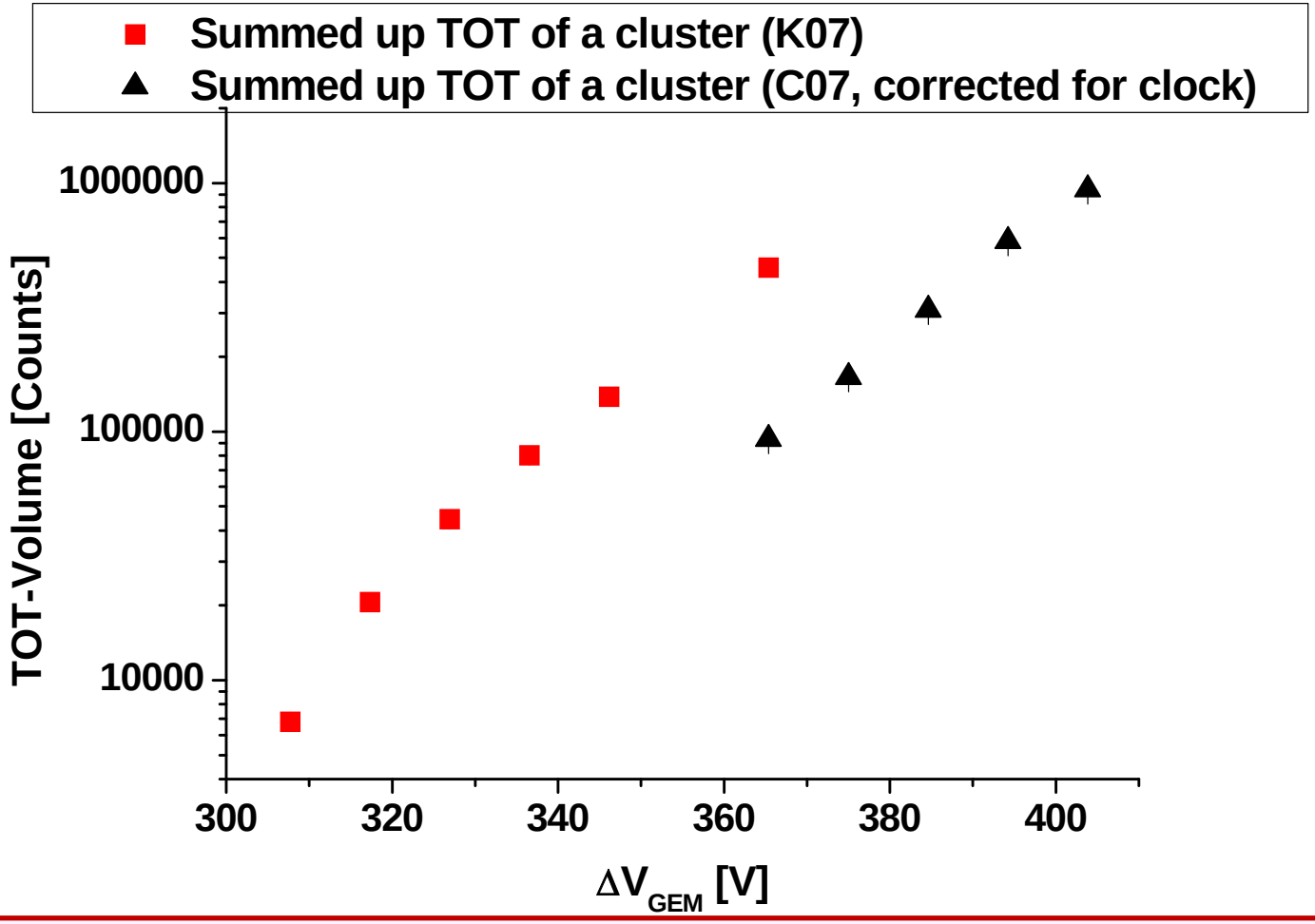
New "Box"

Features

- Modular construction with (adapted) standardized components.
- Avoiding of outgassing components or glue-
- 1" windows for tests with laser, beam or radioactive sources.
- Gas in- & outlets
- 9 SHV channel-feedthroughs
- Electronics connected through a customizable board.
- Sensors for pressure, humidity and temperature.

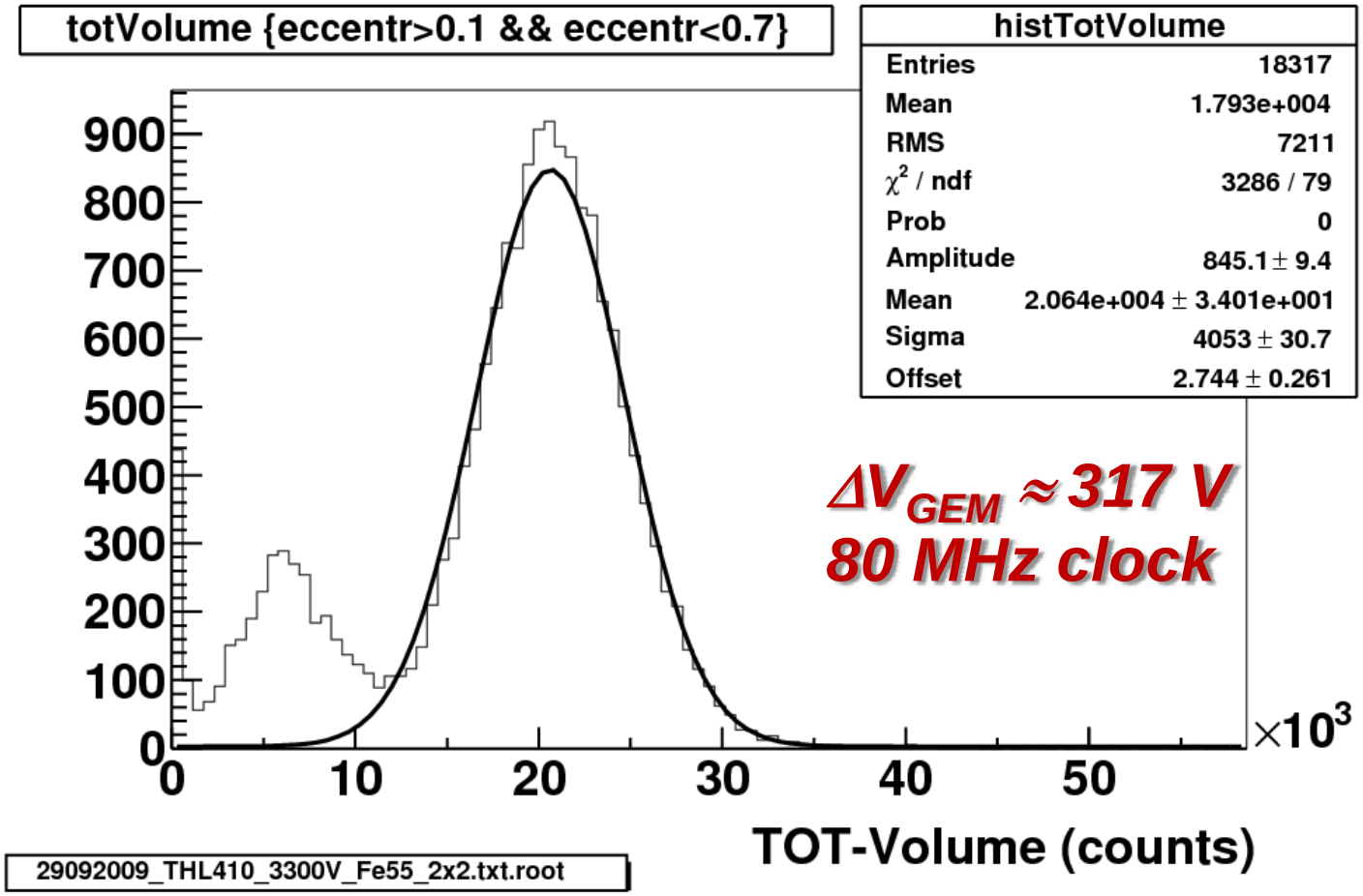


Tot Volumes vs. ΔV_{GEM}



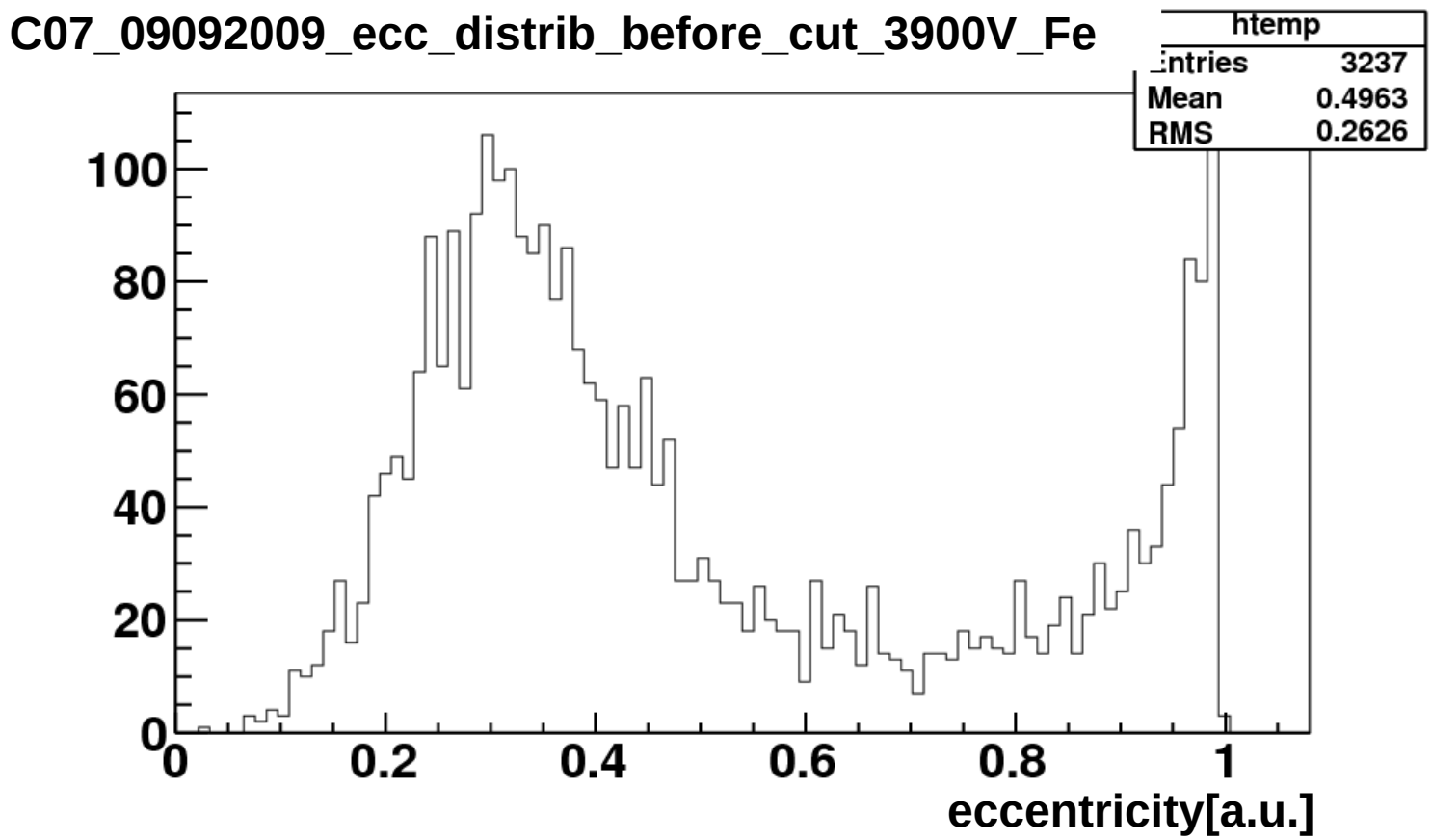
- Values corrected for different clock use with 2x2 (USB/80MHz) and 1x1 (MUROS/37MHz).
- Summed TOT (=TOT Volume) of a cluster proportional to total charge in clusters.
- For comparison different cluster sizes and thresholds must be taken into account.

TOT-Volume 2x2

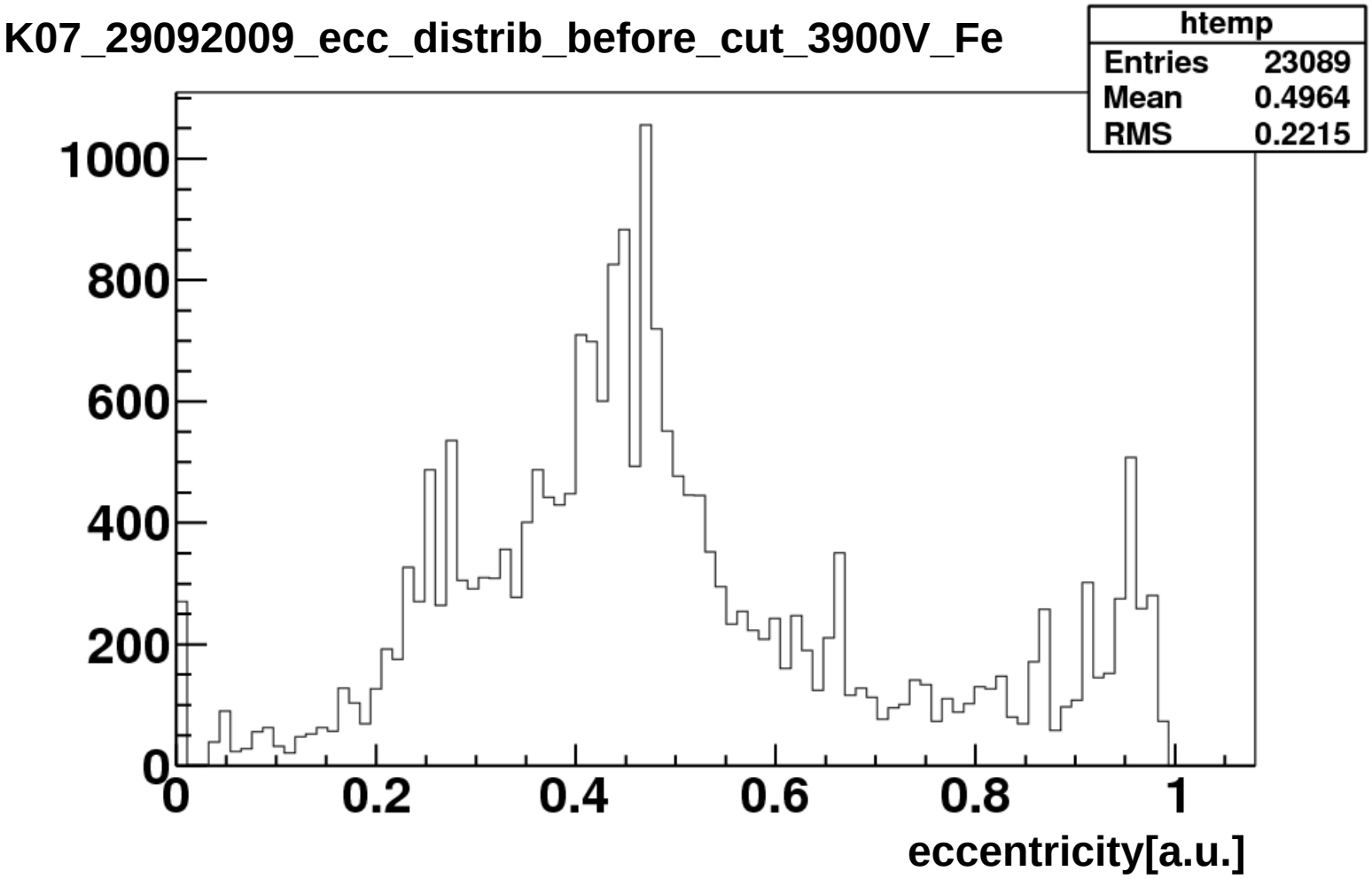


K07 "2x2" TimePix: 16 384 pixels of 110x110 µm²
⇒average cluster size ≈ 33 pixels

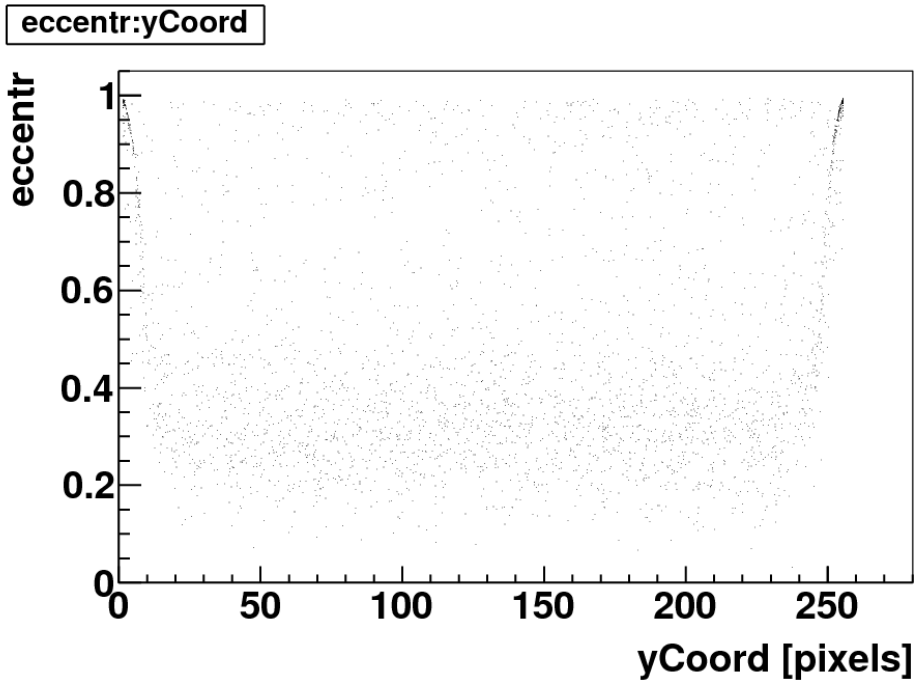
Eccentricity for 1x1

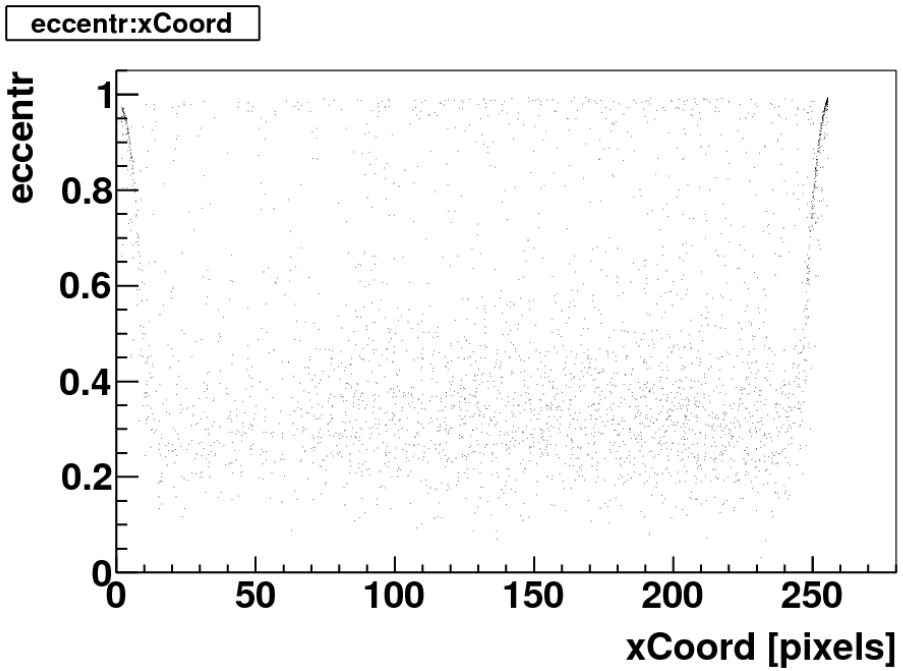


Eccentricity for 2x2

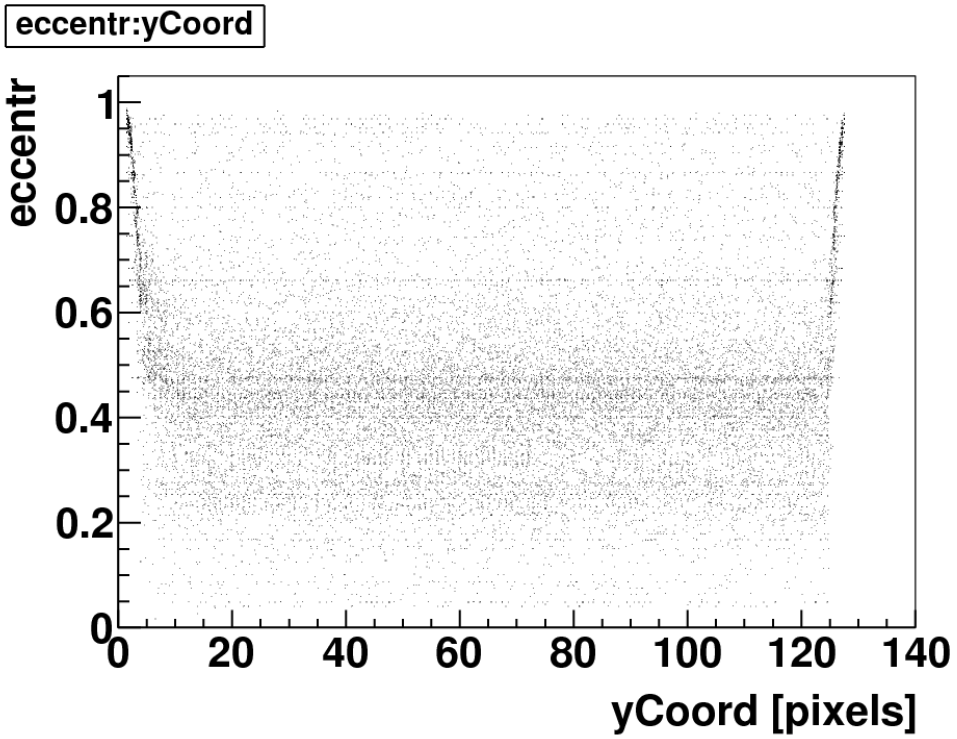


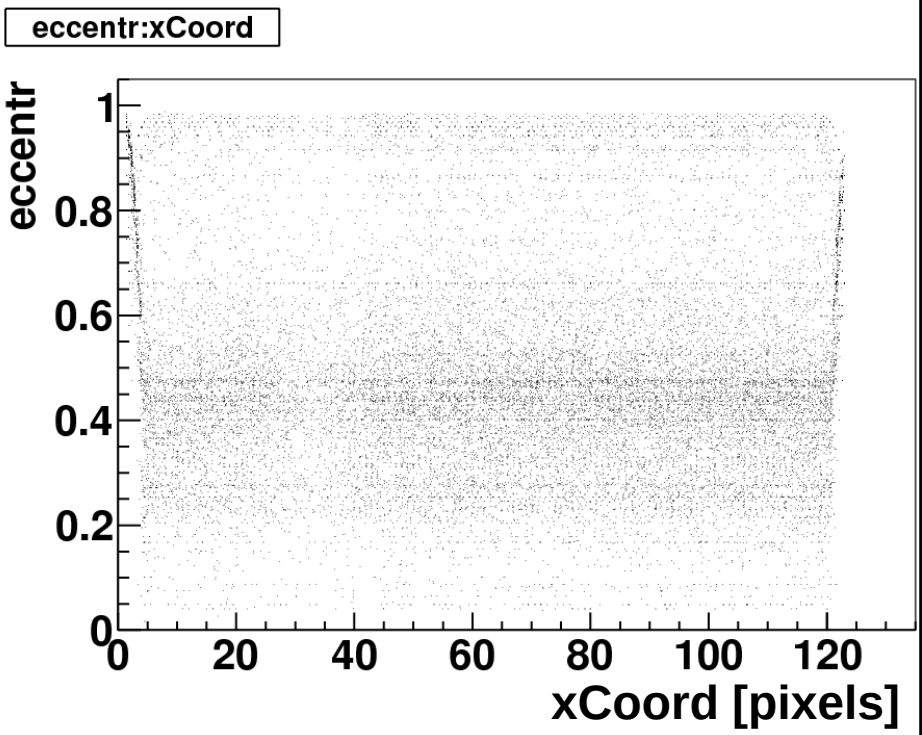
Eccentricity-Position Correlation: C07 3900V



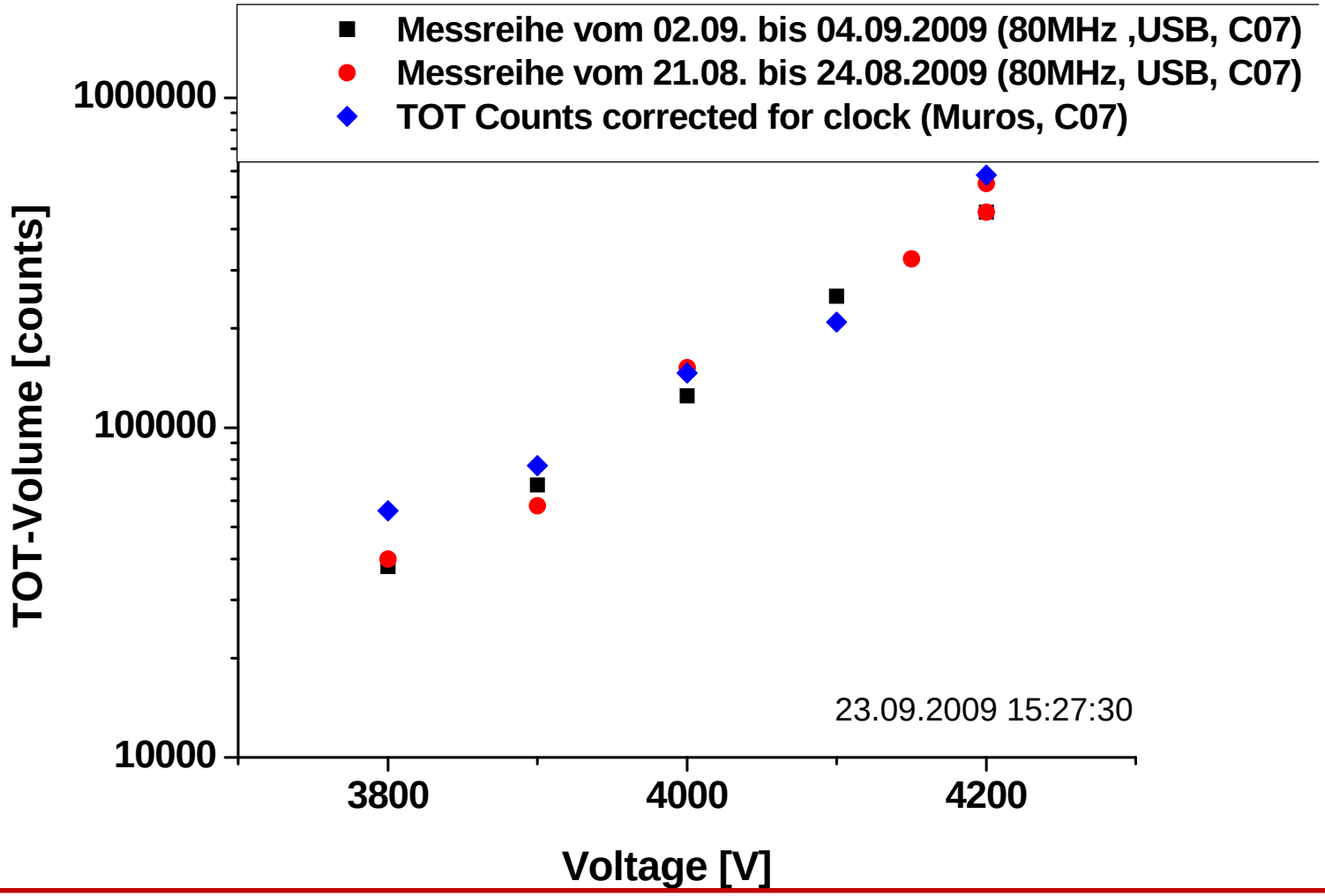


Eccentricity-Position Correlation: K07 3300V



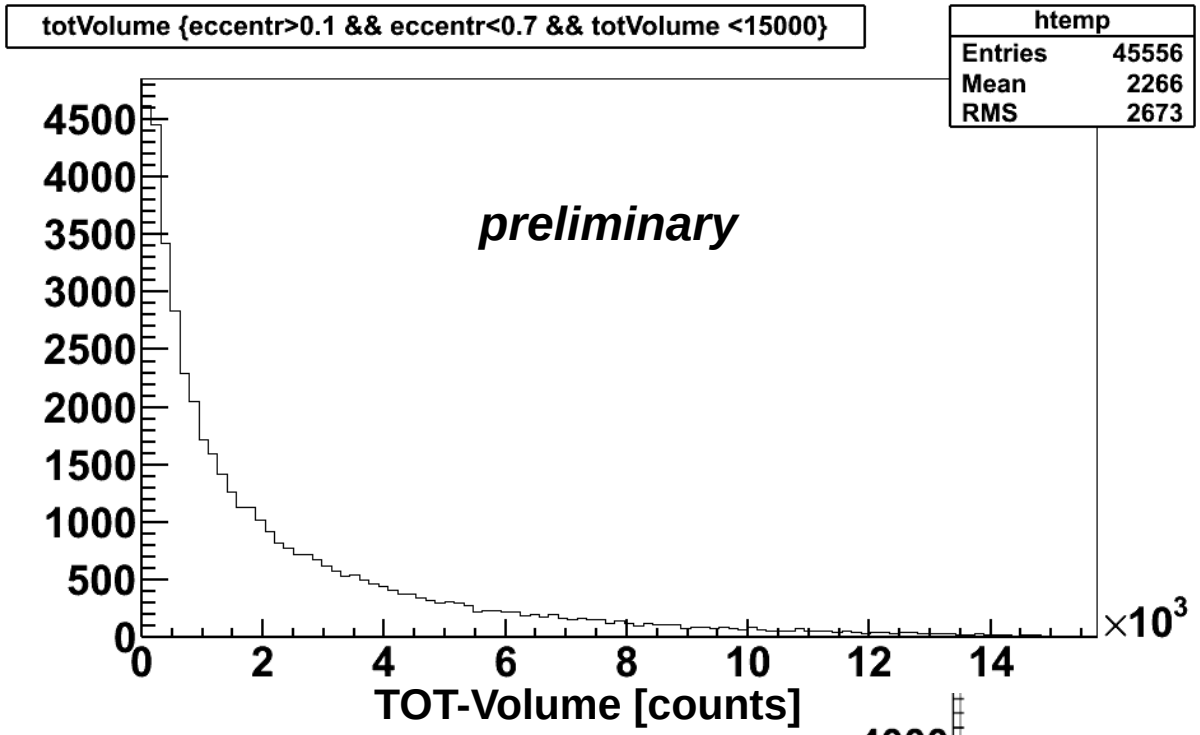


Comparison of Measurements between Muros and USB

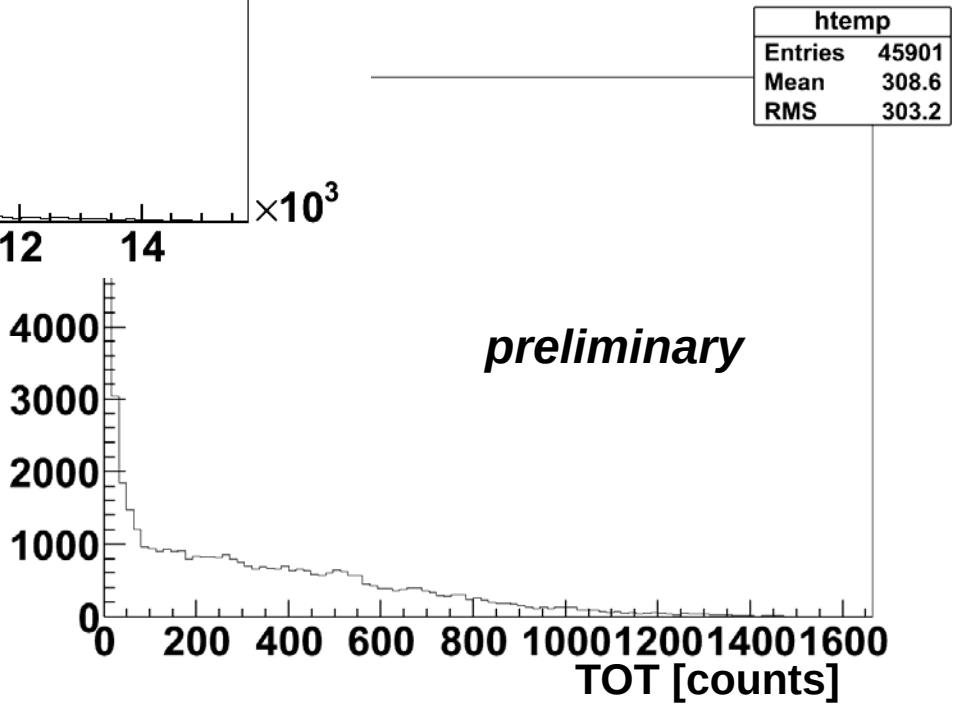


No significant difference between USB and Muros in measurements without test pulse

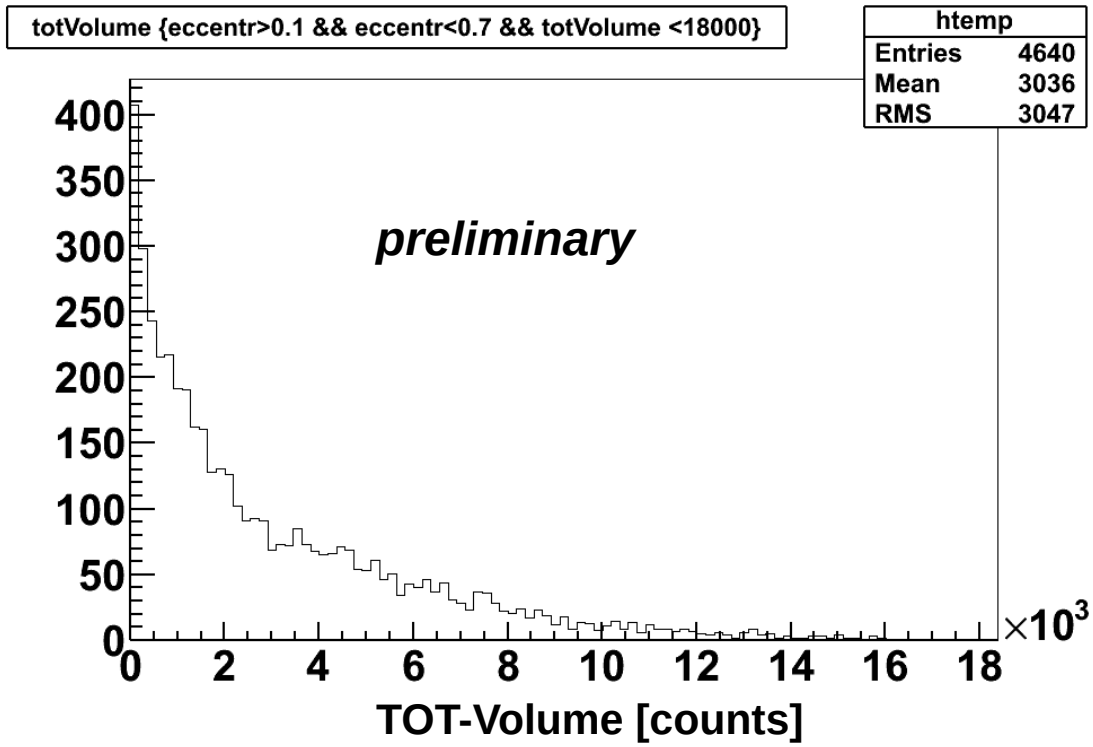
Laser-Spectra 2x2



$\Delta V_{GEM} \approx 317$ V
80 MHz clock



Laser-Spectra-C07 2x2



$\Delta V_{GEM} \approx 375$ V
37 MHz clock