Determination of Track Properties Using GEM-TimePix Setup

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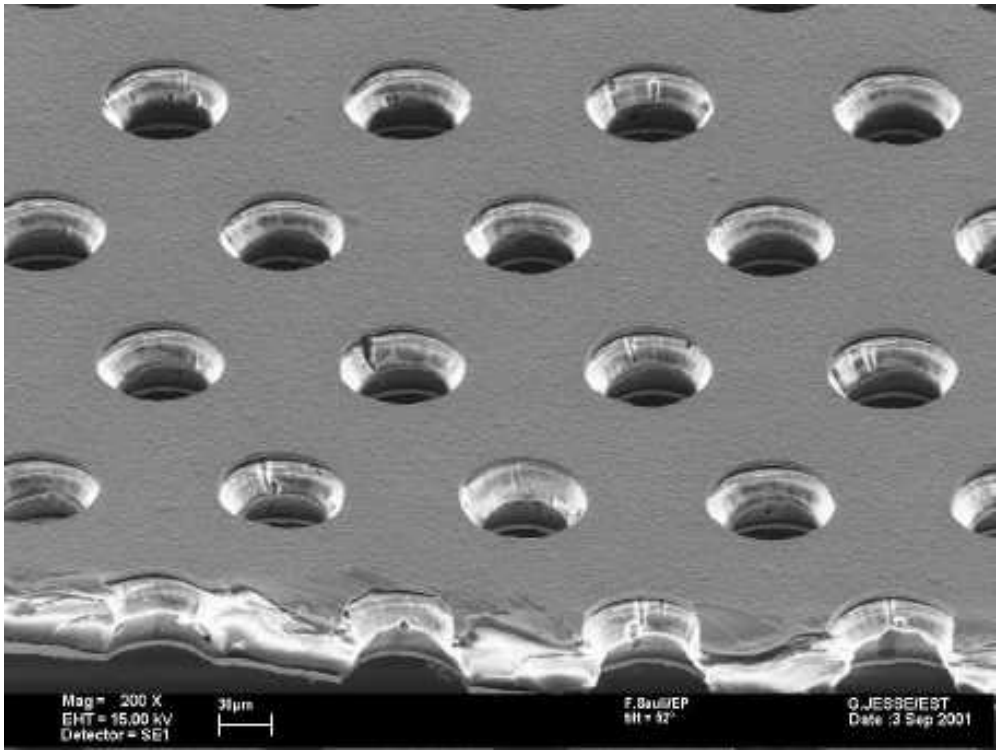
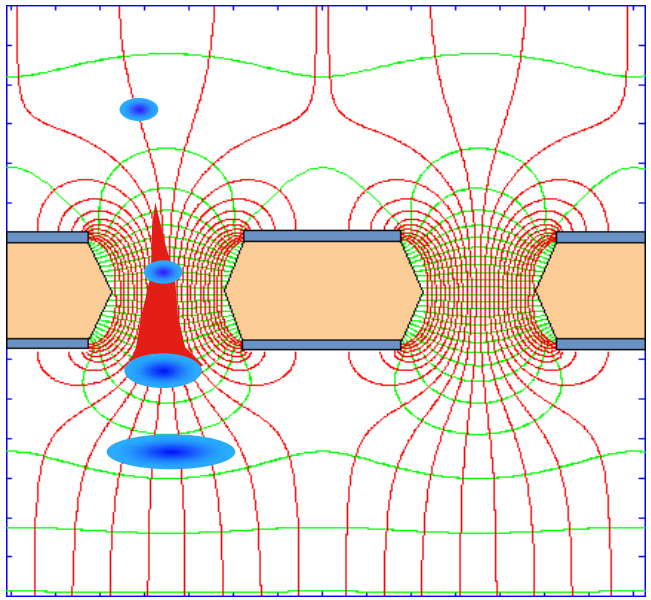
OUTLINE:

- ❑ DESY test beam setup
- ❑ Point resolution as function of drift length
- ❑ Results with different cluster algorithms
- ❑ (near) Future plans

GEM – Gas Electron Multiplier

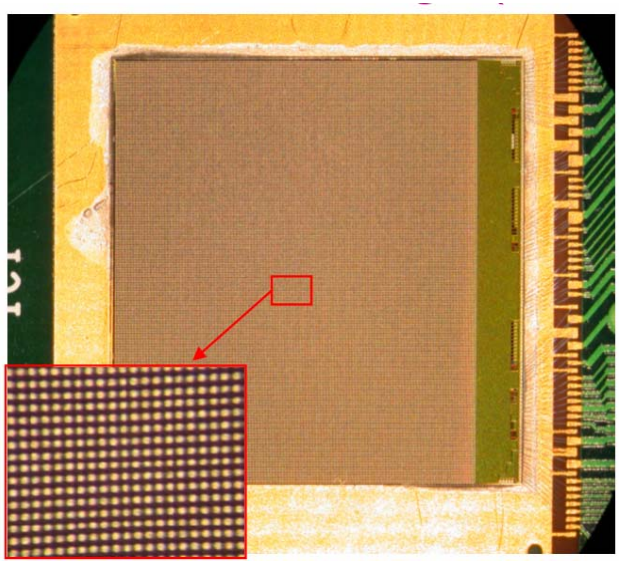


F. Sauli, Nucl. Instrum. Methods A386(1997)531
F. Sauli, http://www.cern.ch/GDD



- Thin metal-coated polymer foil chemically pierced to have high density of holes (technology developed at CERN)
- 5 µm Cu on 50 µm Kapton; 70 µm holes at 140 µm pitch
- gas amplification up to 10^5 achievable with Ar/CO_2 (7/3)
- minimised positive ion feedback

MediPix2 and TimePix chip

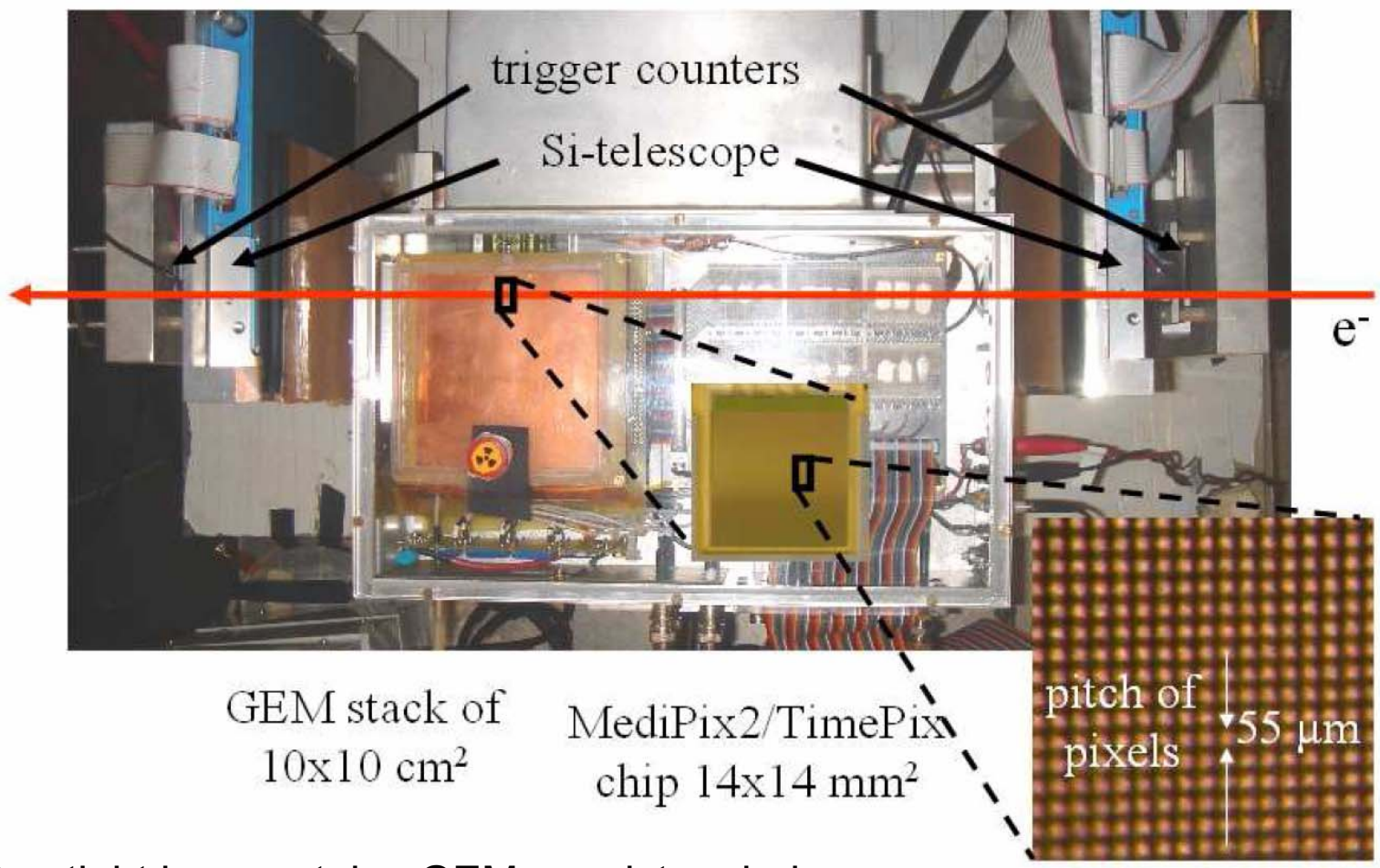


- MediPix2 and TimePix surface of 14x14 mm^2; pixel size of 55x55 μm^2
- TimePix clock distributed throughout the entire chip. Register on each pixel counts the number of clocks cycles depending on chosen mode - for each pixel this mode can be set individually

➢ In TIME-mode the cycles are counted from the point when signal crosses threshold till a common stop by gate signal (”Fast shutter”)
➢ ”Time-Over-Threshold” (TOT-mode) records clock cycles as long as the pulse is above threshold
➢ Mixed Mode (MM) – 50% of pixels in TIME and 50% in TOT-mode

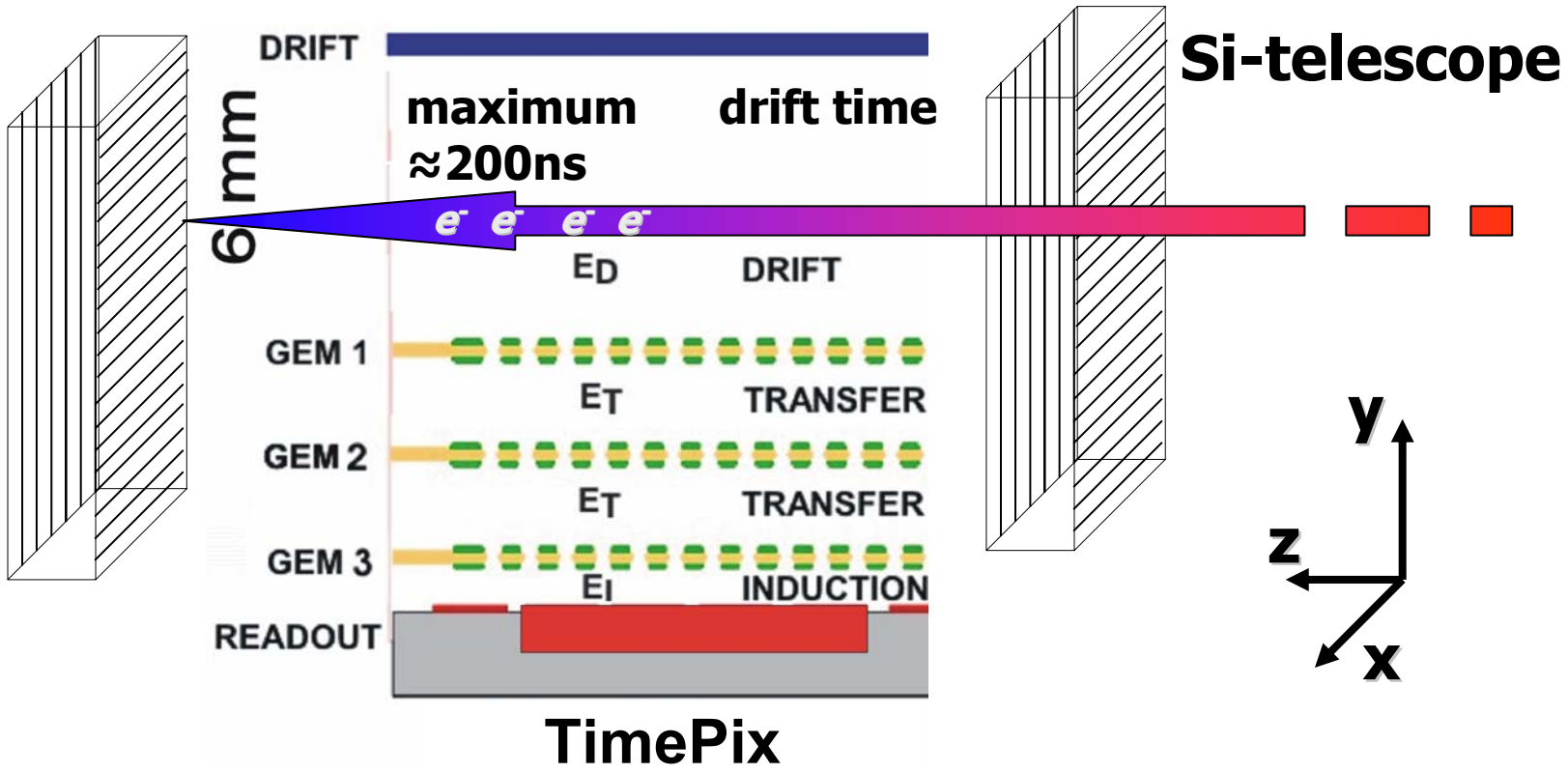
Maximum number of counts is limited in this measurement by chosen gate width of 12.6 μm or 600 counts at a given clock frequency of 48MHz

The Test Beam Setup



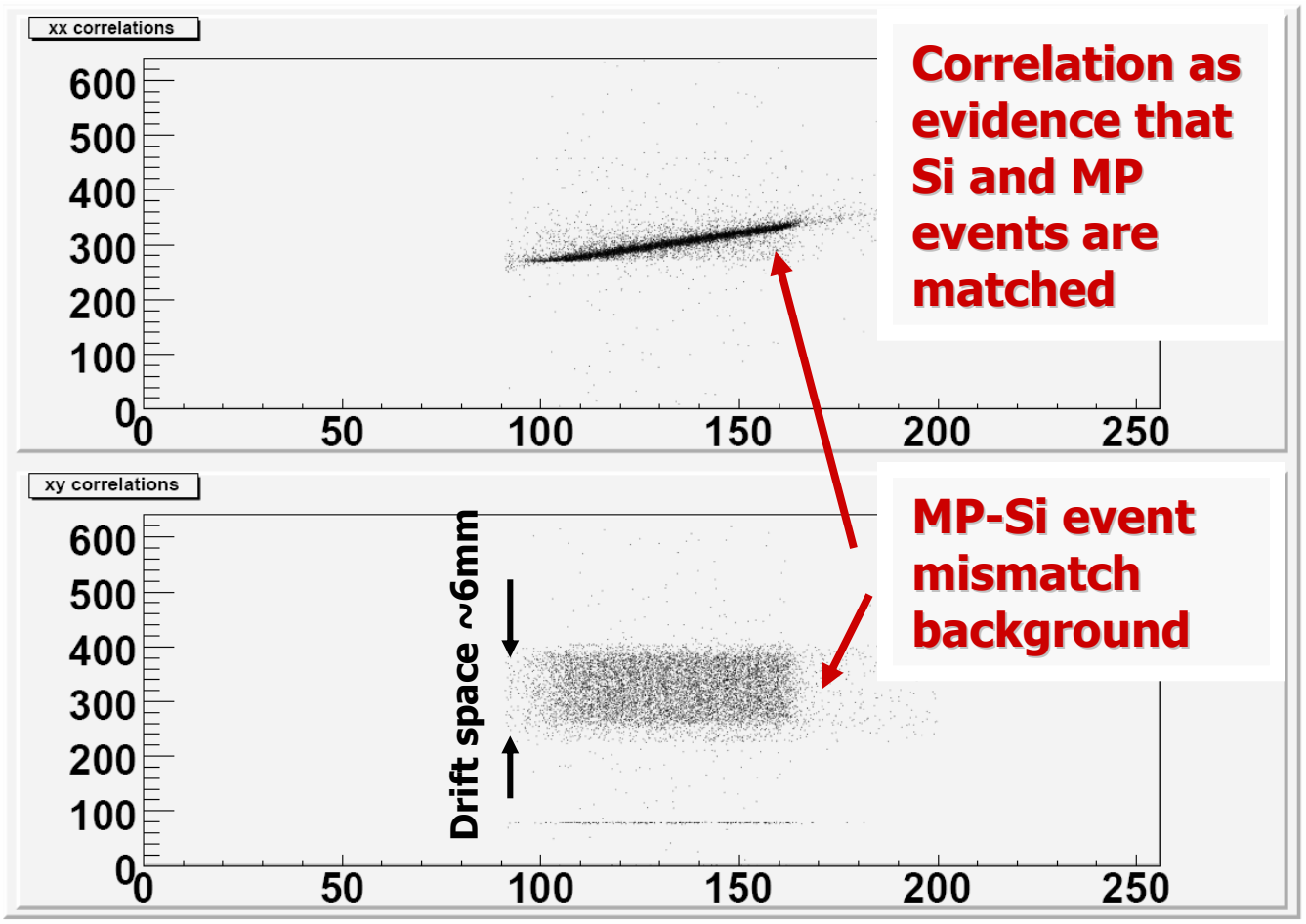
- Gas tight box contains GEMs, resistor chain, TimePix and MediPix2 chip and readout electronics of pads

Si-telescope



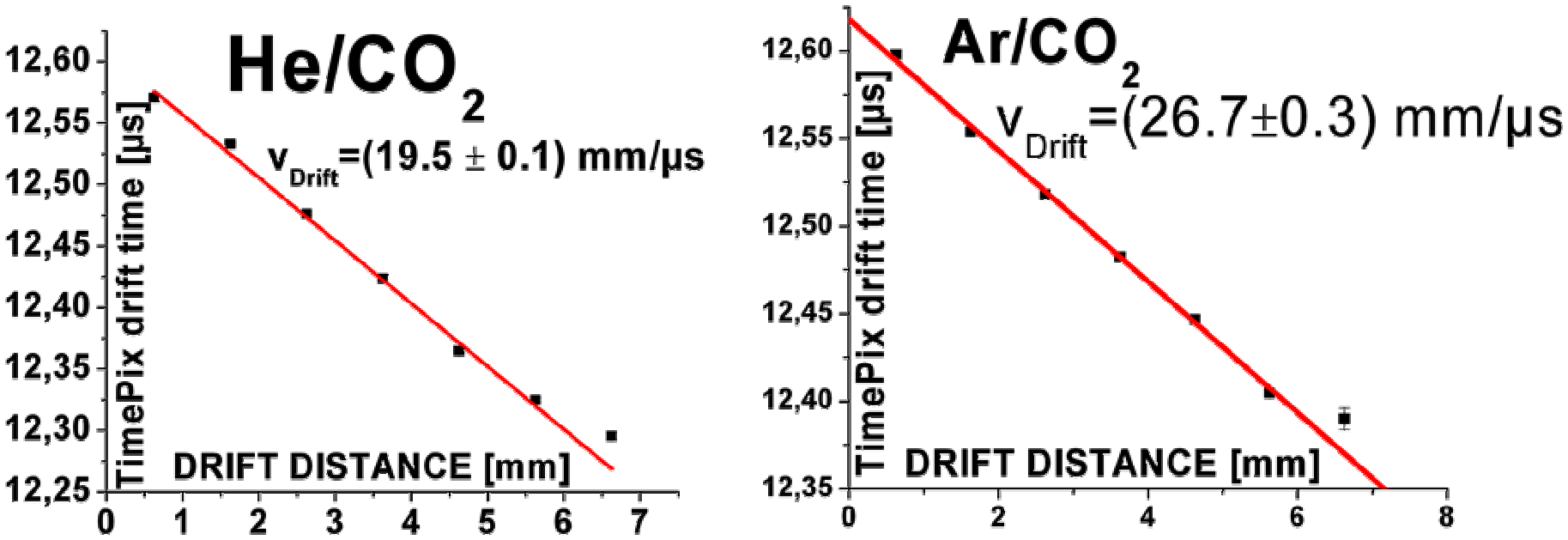
- The electron beam is defined by trigger scintillating counters of 1×1.5 cm^2 in size and a Si-telescope with 3 planes of strips allowing measurement of the x-coordinate in front and behind the GEM, and for the y-coordinate measurement in front of the detector
- The effective readout pitch of Si-telescope is 50 μm

Correlation of TimePix data and Si-telescope



Correlating the data acquisition of the beam telescope and the MediPix2 (x-axis) allows the determination of the resolution as a function of the drift distance

Drift Velocity



- Drift velocity determined using TIME mode and drift distance from Silicon Telescope for He/CO_2 and Ar/CO_2
- In TIME-mode time information for a cluster shows dispersion – start time depends on the pulse height. A ”time walk correction” is applied according to the cluster size, as it’s suggested by MM mode:

$$\Delta = 1/(A + B \cdot ClusterSize) + C$$

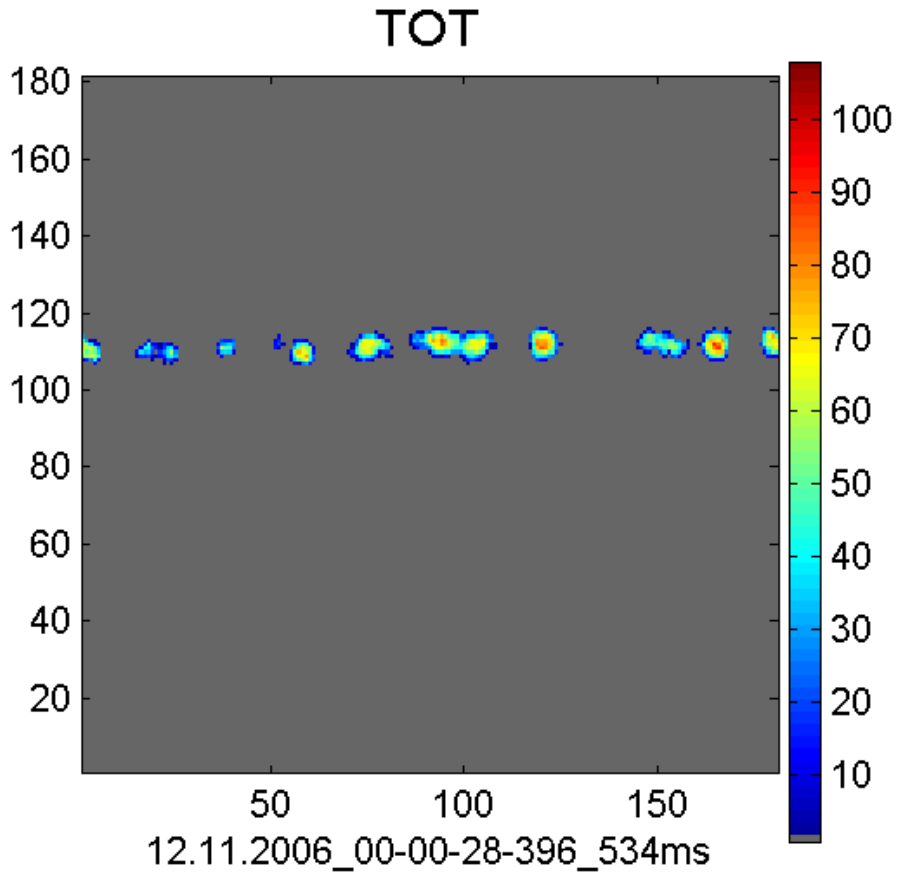
Cluster Reconstruction and Point Resolution

Three clustering methods:

- **Contiguous areas**: applicable for any mode - TIME or TOT
- Cluster definition using charge deposition:

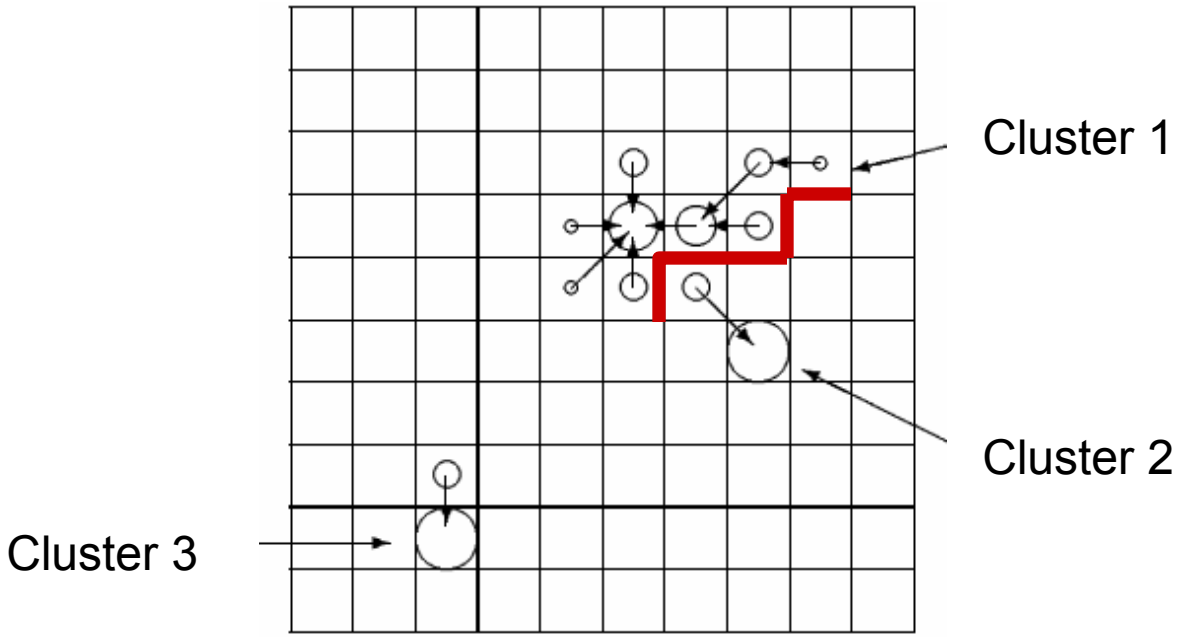
  - **"Saddle Point"**- point line for secondary maximum in projection transverse to track. Rectangular dividing line between merged clusters at the saddle point

  - **"island"** - clustering (exploited from ZEUS calorimetry); next slide



“Island” Clustering for TOT mode

- A pixel with the highest TOT count is the starting point
- Then the adjacent pixels with the highest nonzero counts are connected to the starting pixel if they have no neighbor with a higher TOT value. Also the pixels next to the nearest neighbors are connected
- The procedure is repeated for each pixel to produce a unique assignment of pixels to clusters



“Island” Clustering

Mixed Mode sample, Ar/CO_2

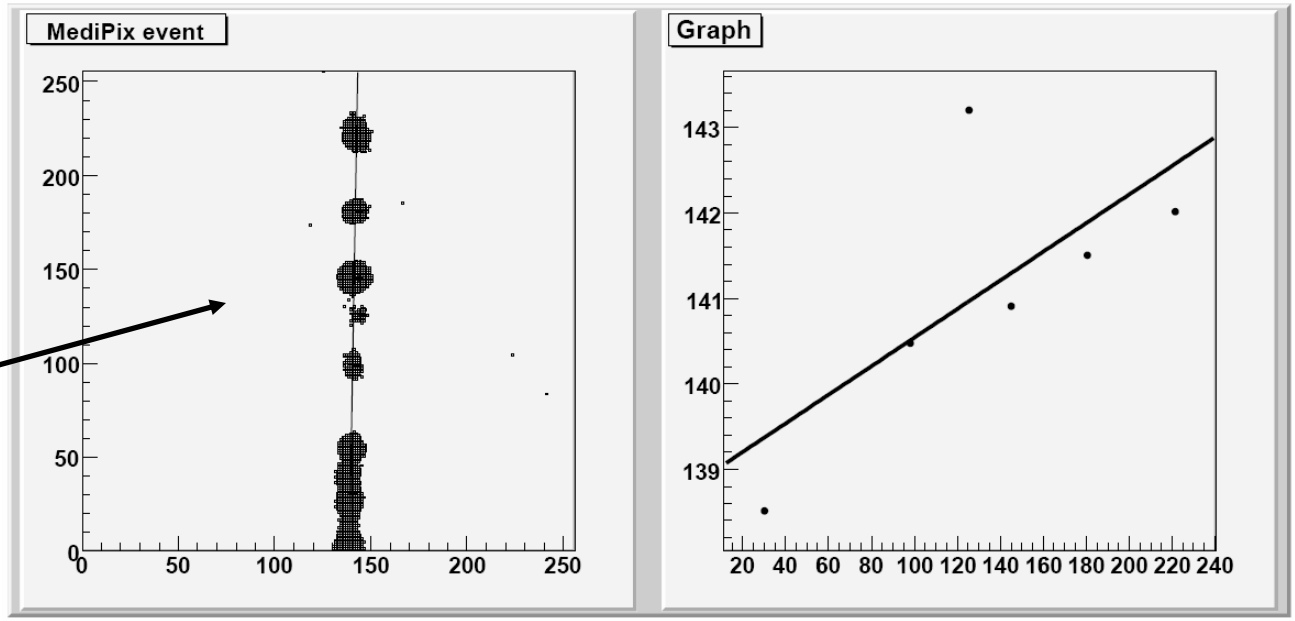
High statistics run

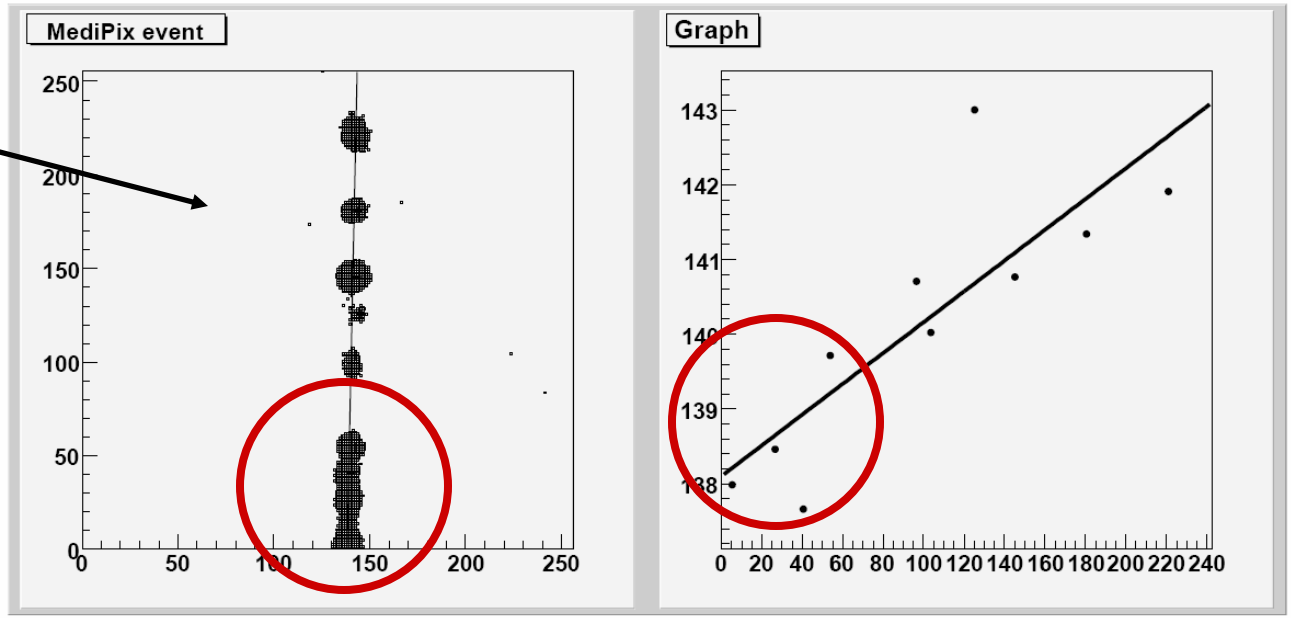
Contiguous area clustering

$<N_{clusters}> \sim 8$

“Island” clustering

$<N_{clusters}> \sim 12$



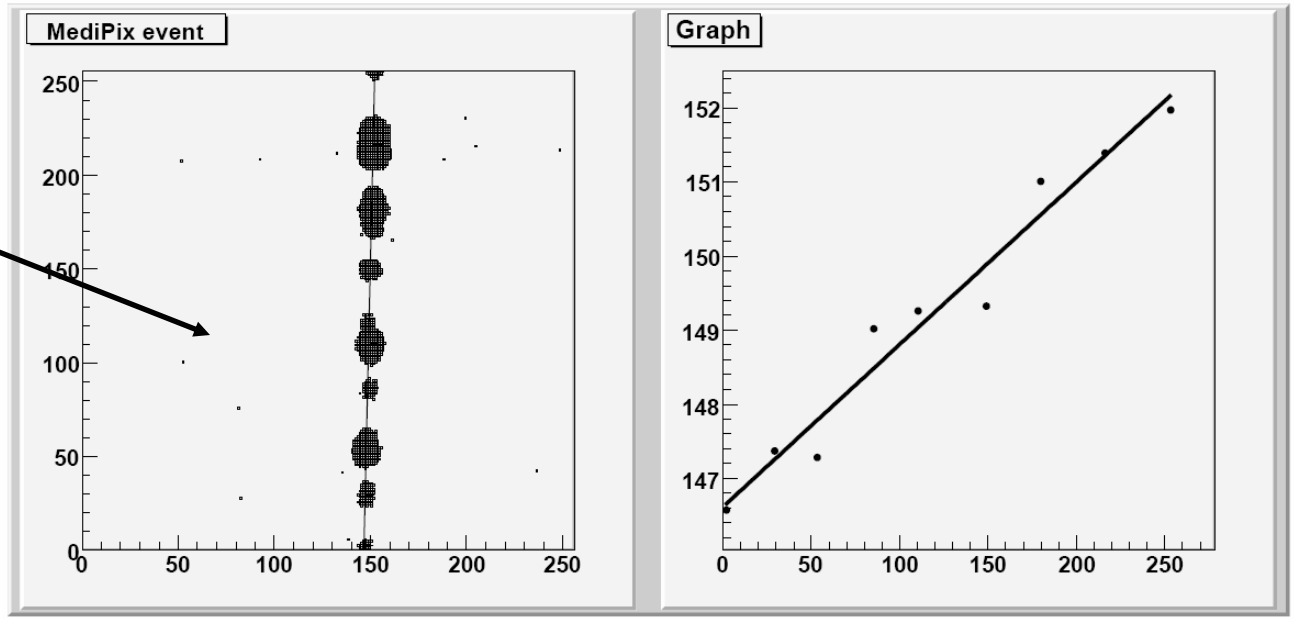


More clusters found; a power to resolve a single clusters on a contiguous tracks

02/06/2007

“Island” Clustering

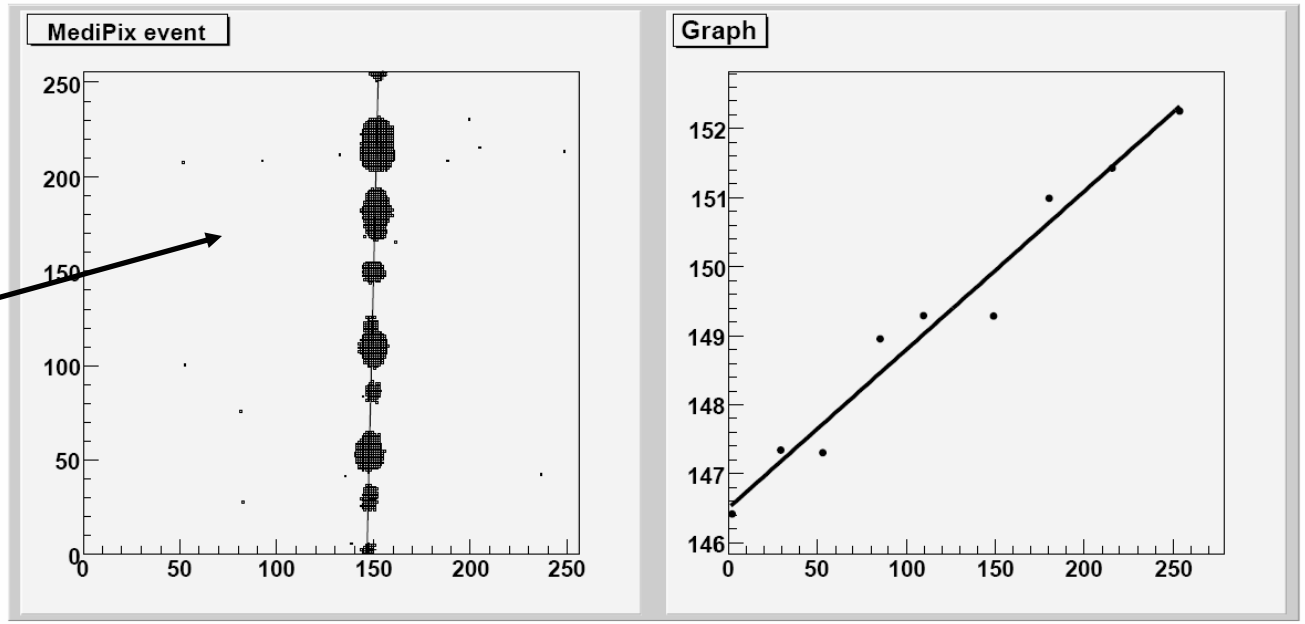
Contiguous area clustering



Next event;

The same number of clusters found with both clustering methods for the event

“Island” clustering



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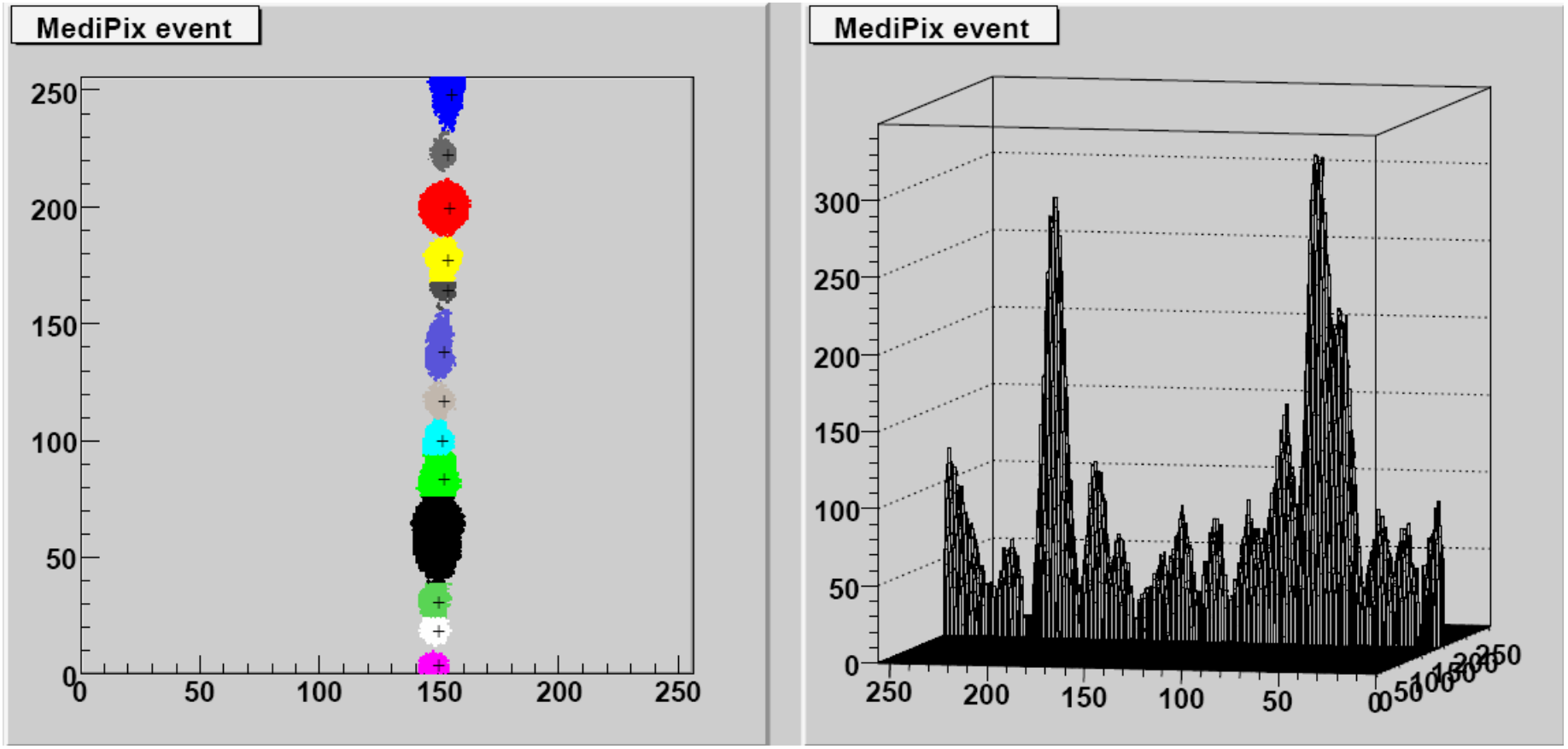
TOT Event Clustered with “Island” method

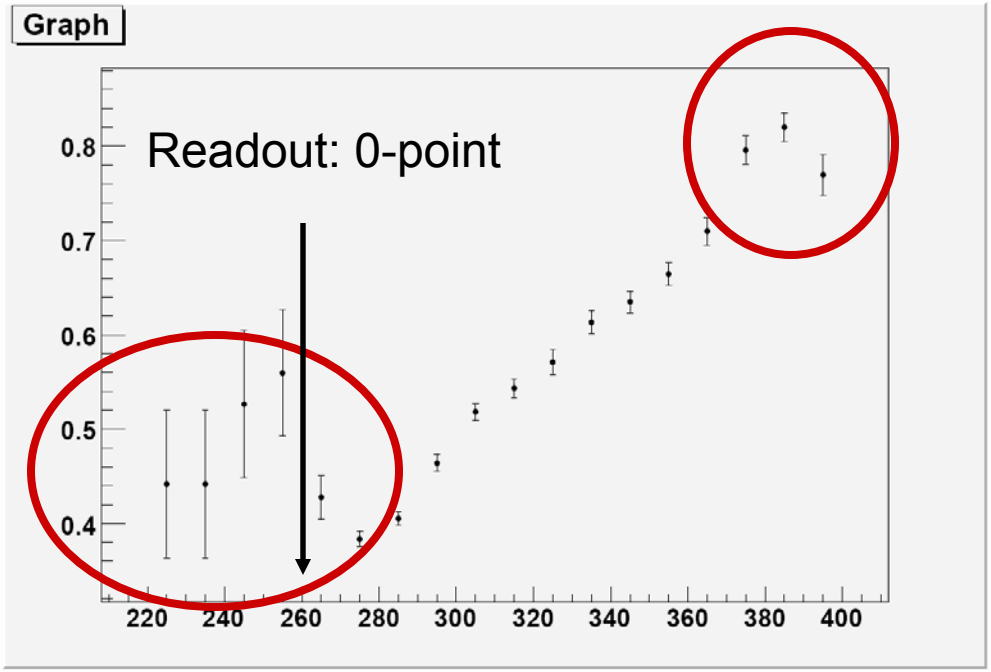


Dependence of Point Resolution from Drift Length

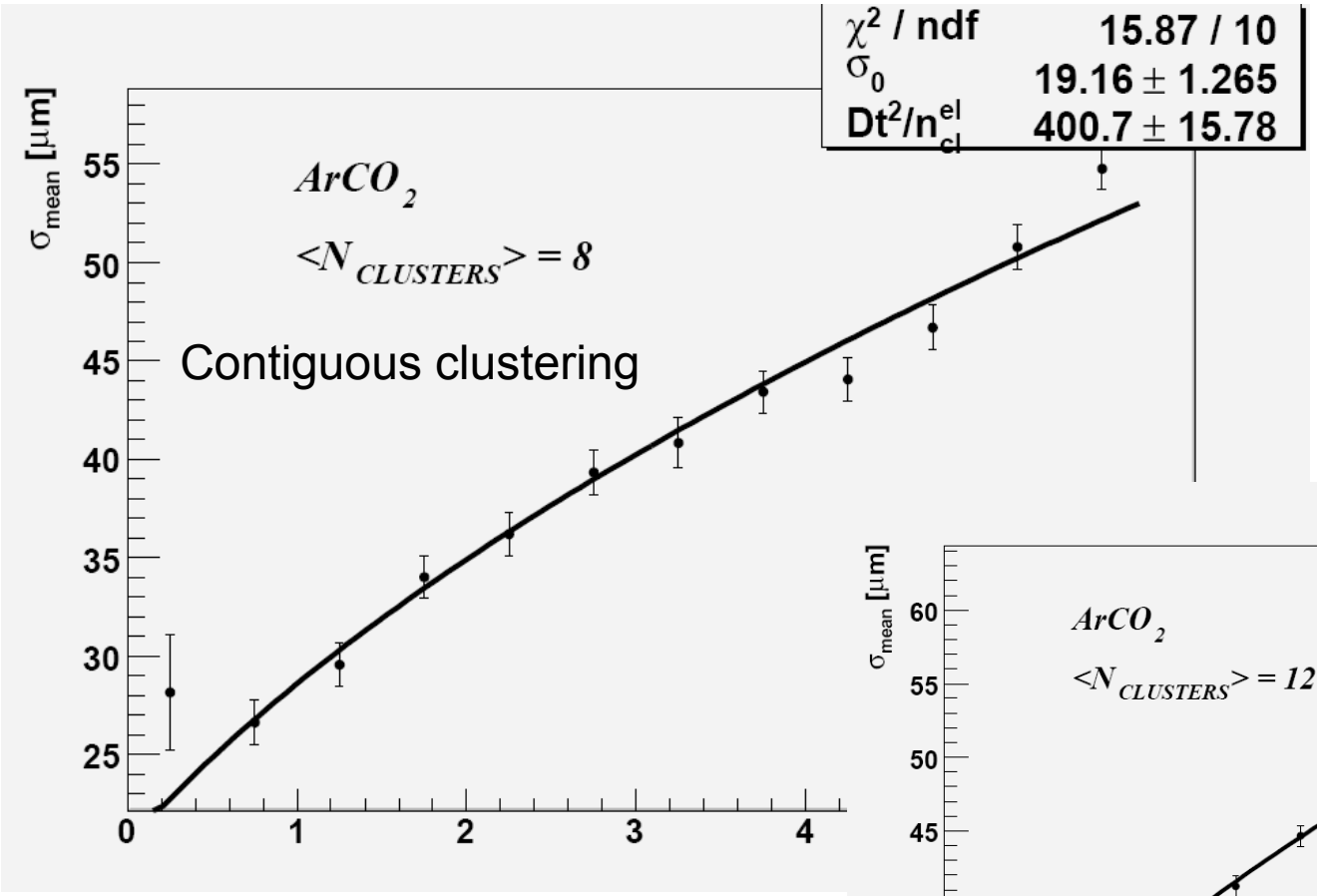
- σ_{mean} - variance of the mean position of ionization cluster centers
- D_t - transverse diffusion coefficient
- n_{cl}^{el} - number of primary electrons per cluster
- y - drift length
- **σ_0 - smallest achievable resolution** for a given configuration

$$\sigma^2_{mean} = \sigma^2_0 + \frac{D_t^2 \cdot y}{n_{cl}^{el}}$$

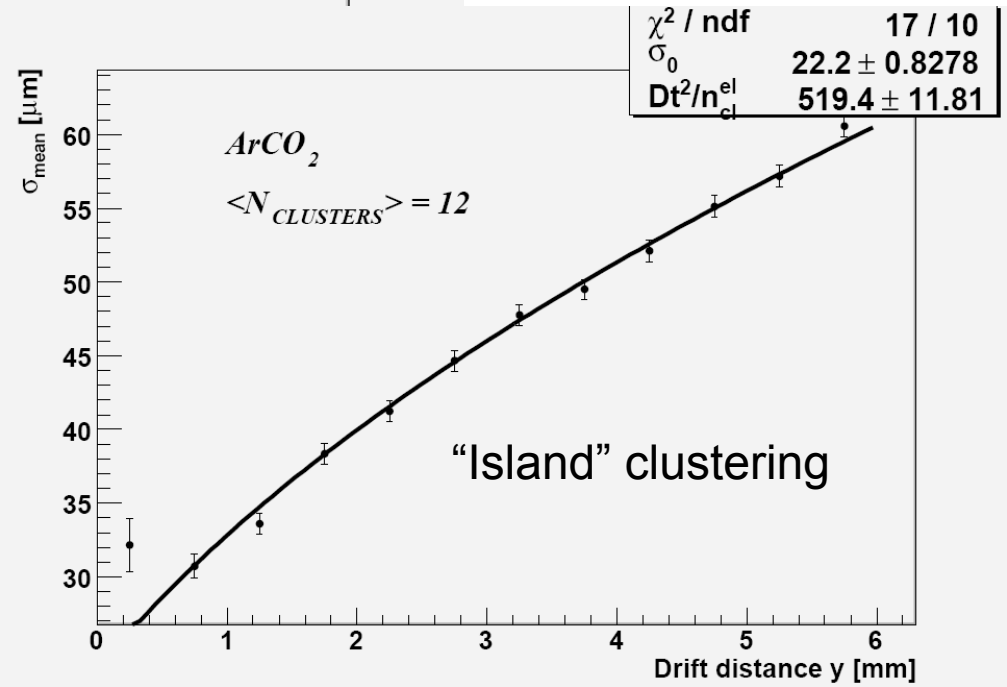
Border points are affected by remaining background



Point Resolution vs. Drift Length for Different Clustering Methods

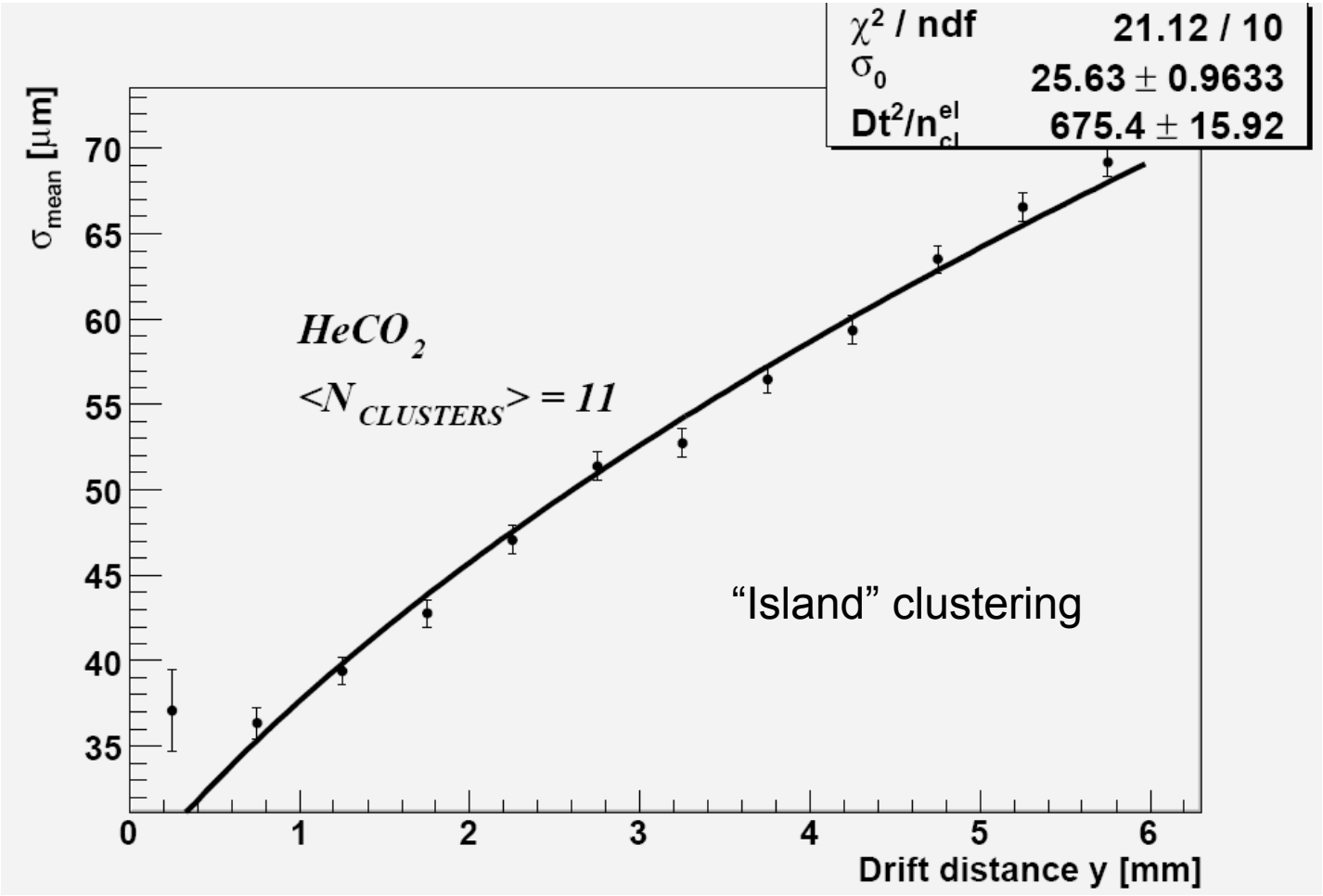


- High statistics runs
- Increase of number of clusters per track length



- By increasing the number of clusters the resolution per cluster goes up ~ $(12/8)^{1/2}$

Point Resolution vs. Drift Length for “Island” Clustering

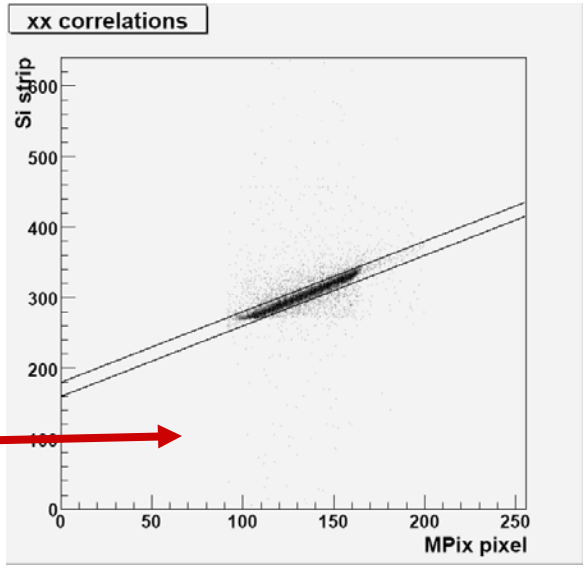


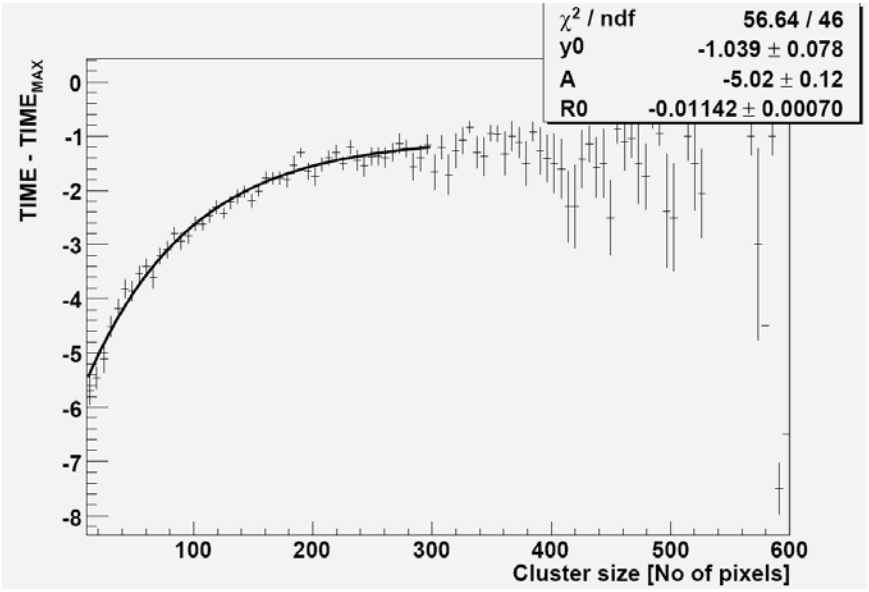
- Slope increases due to increase of frequency of primary one-electron clusters in He (expected ½)
- Higher efficiency of cluster reconstruction

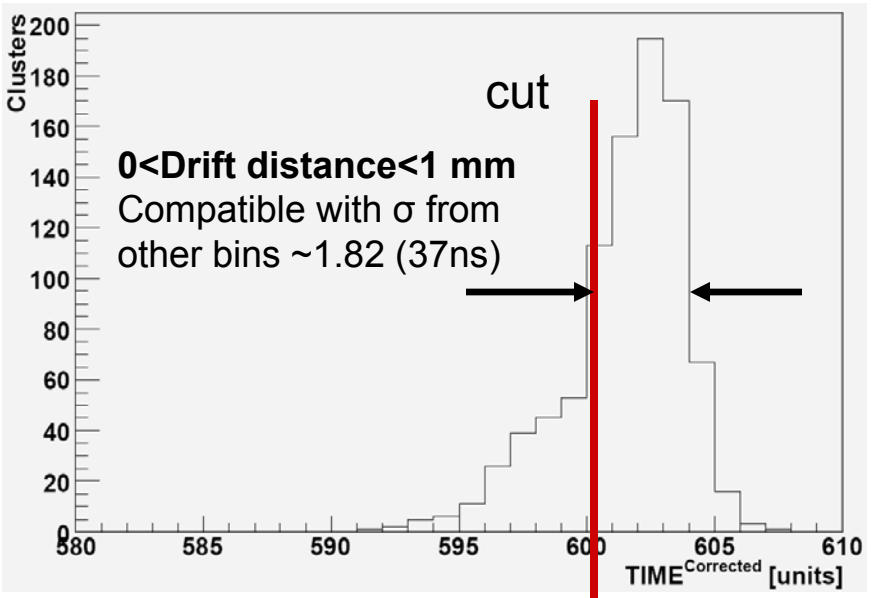
Cleaning Background Events

The major background type for analysis is double-track events at TimePix. Double track events mostly uncorrelated with Silicone telescope

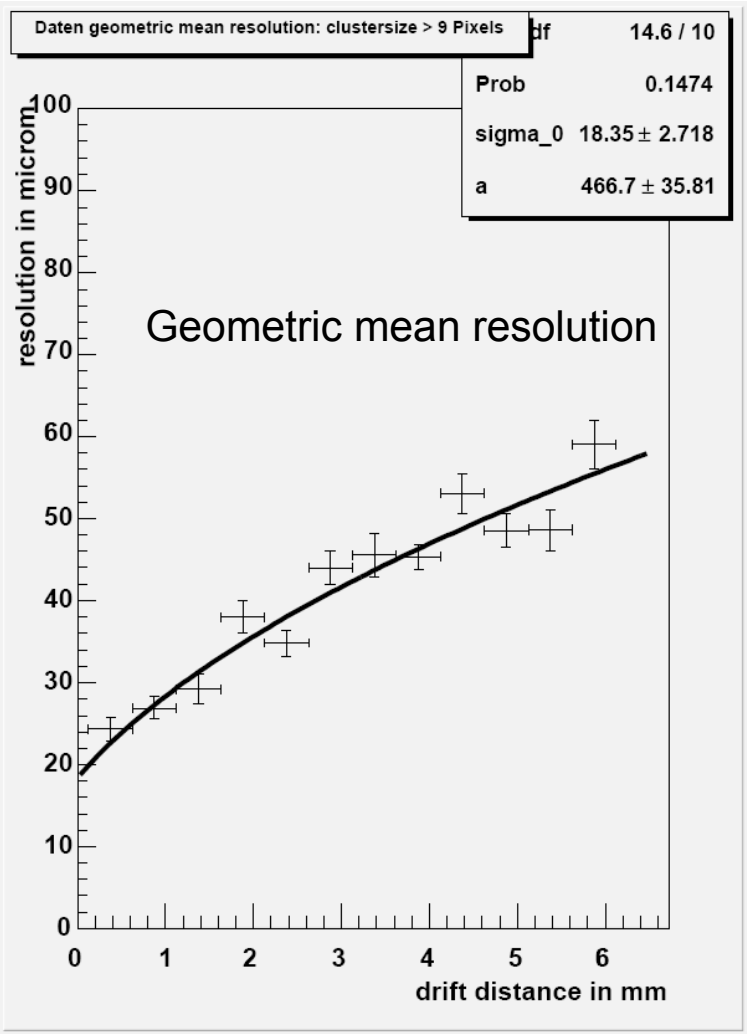
- Remove double-track events at TimePix with a projection along tracks
- Clean mismatch events using the “xx-correlation” between TimePix and Sil. tel.
- Using TIME information; was not used yet !

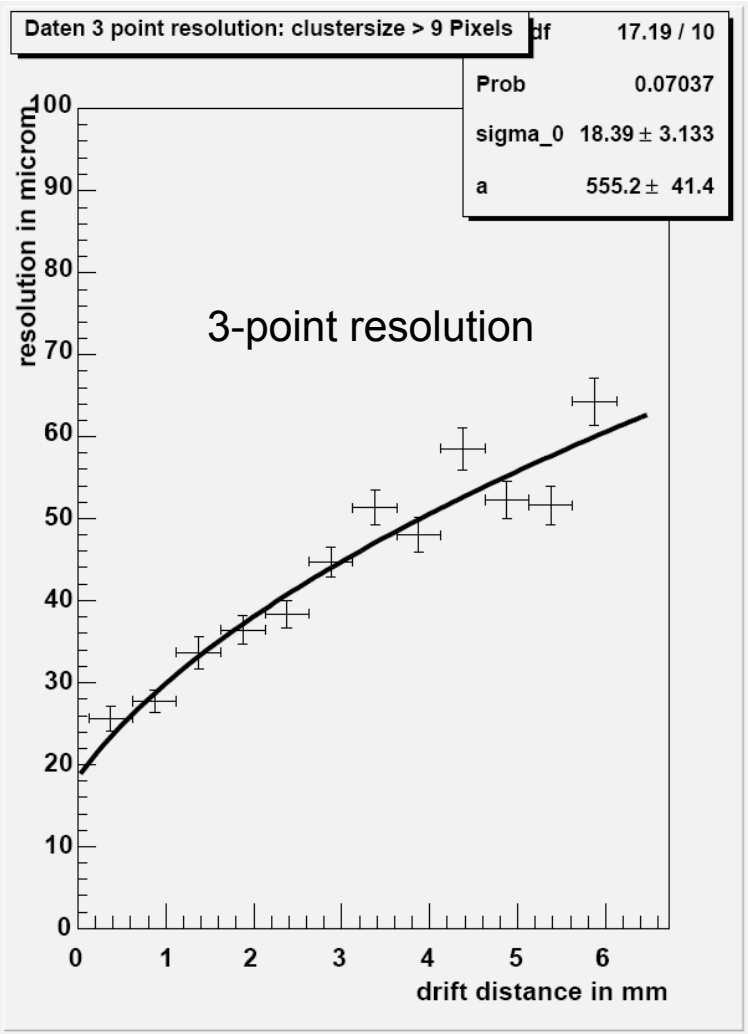






Point Resolution vs. Drift Length for “Saddle Point” Clustering





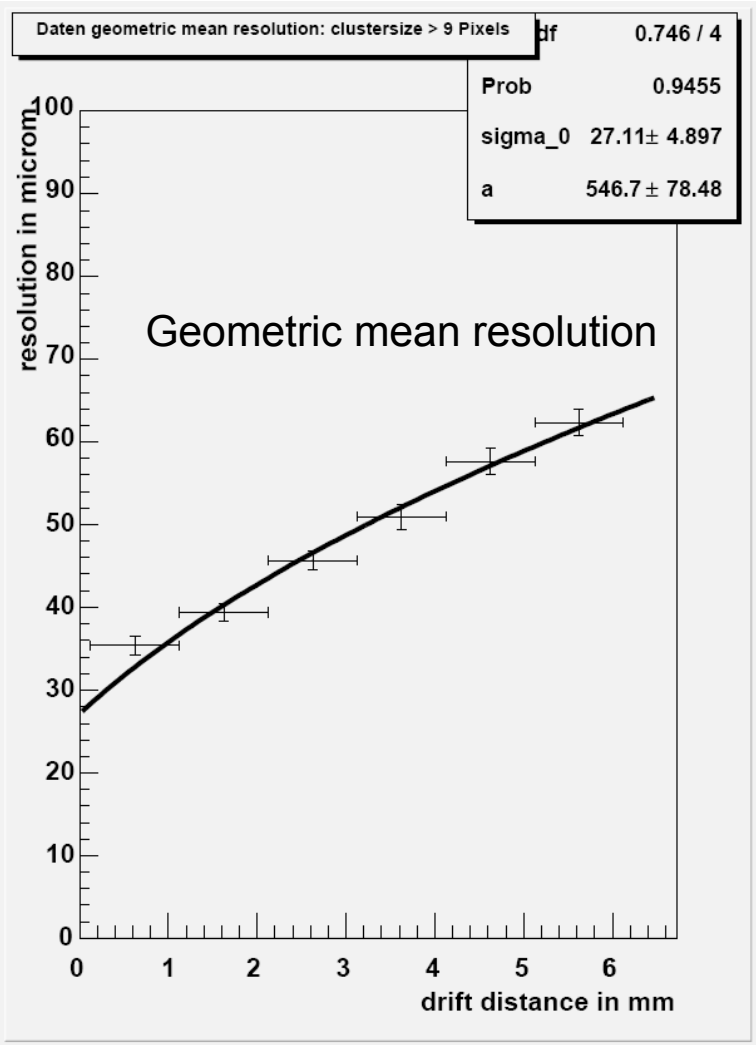
Ar/CO_2

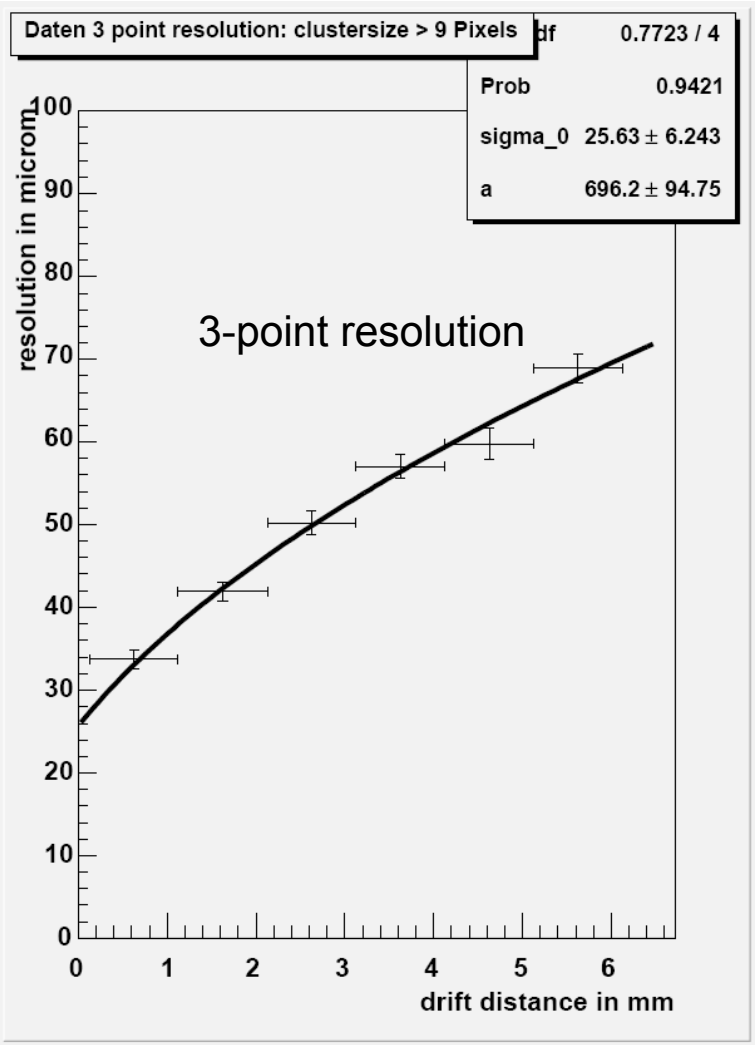
$a = D_t^2/n_{el}^{cl}$

- 3-point resolution is less sensitive to kinks in the track
- Good agreement between both methods

Mean number of clusters ~ 12

Point Resolution vs. Drift Length for “Saddle Point” Clustering





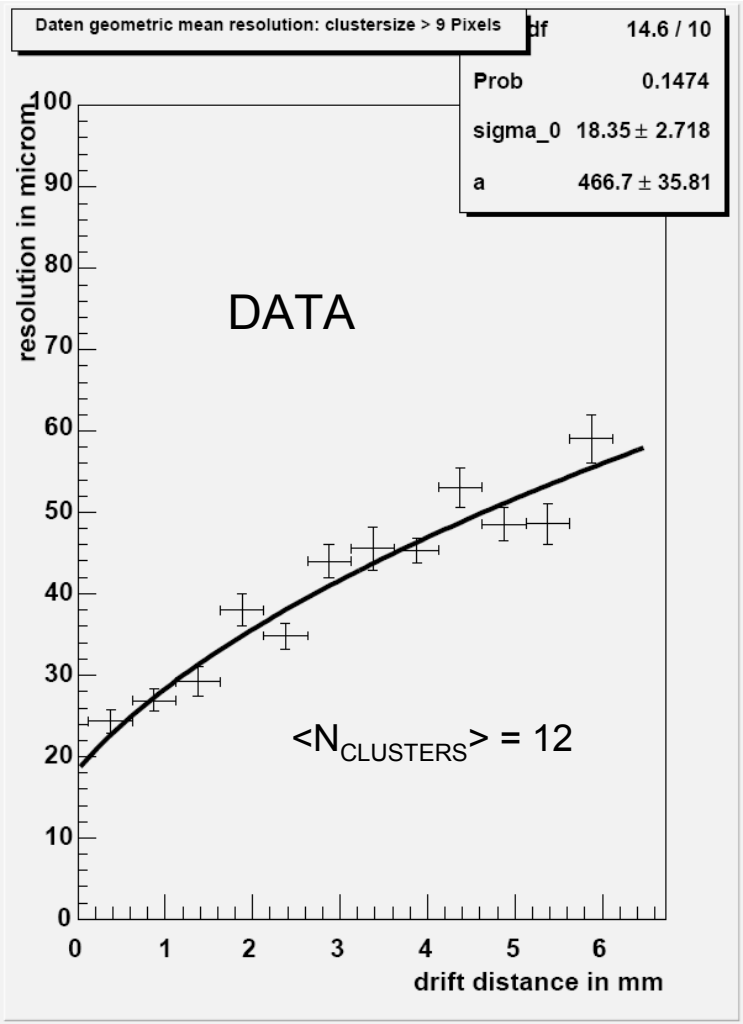
He/CO_2

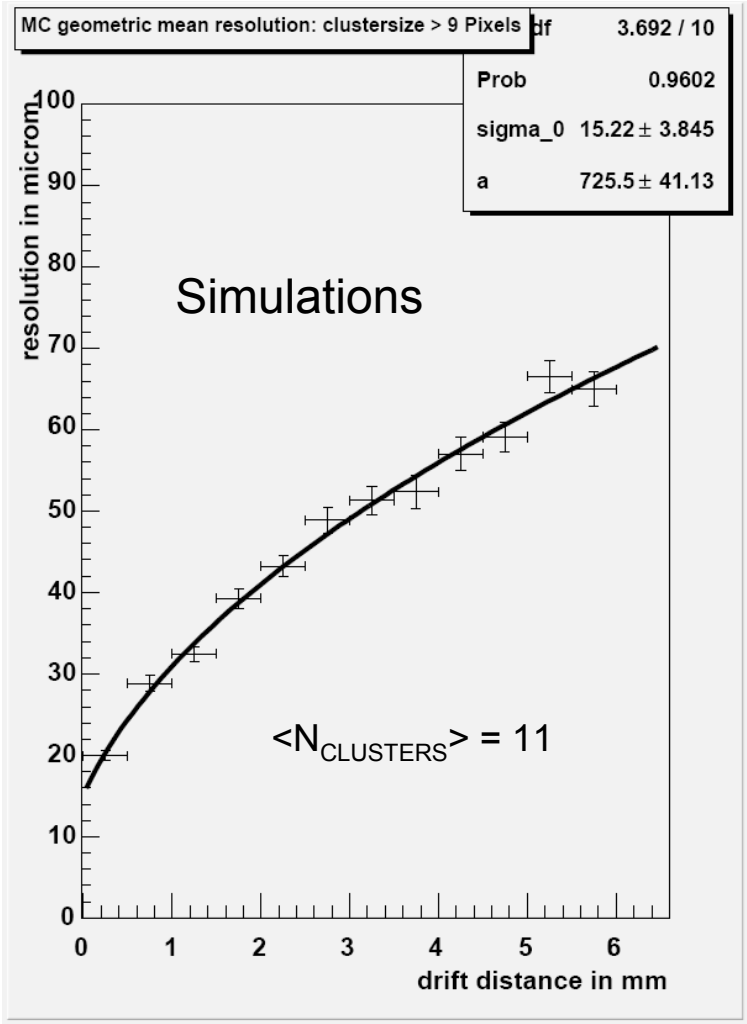
$a = D_t^2/n_{el}^{cl}$

- Agreement between both methods

Mean number of clusters ~ 12

DATA vs. Simulations (Ar/CO_2)





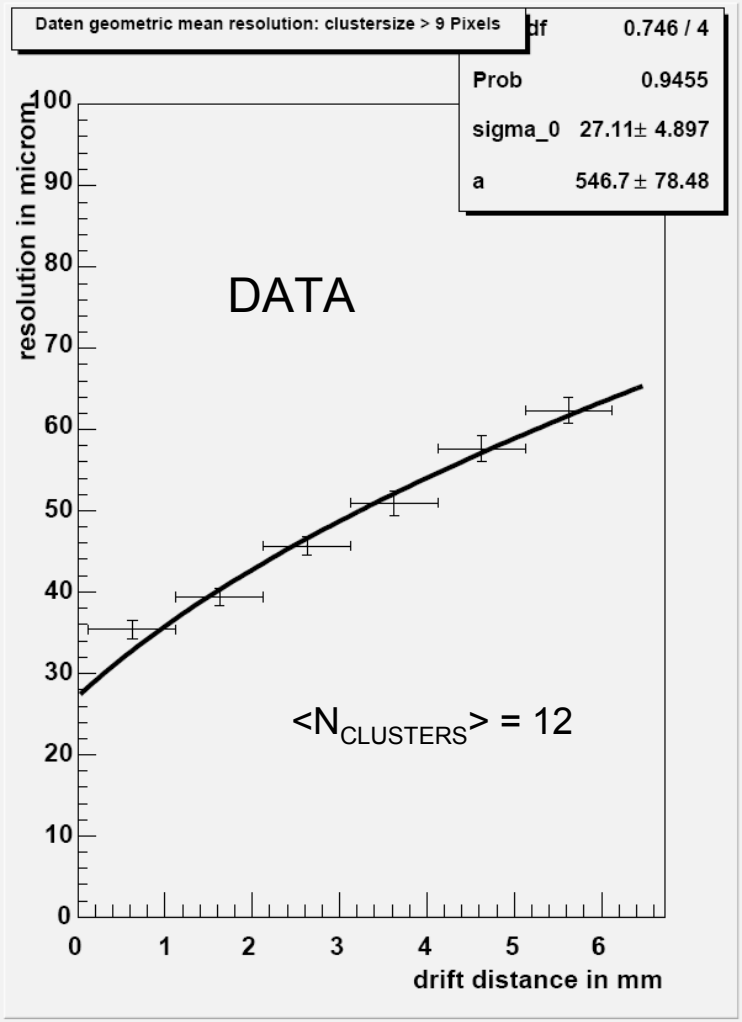
Ar/CO_2

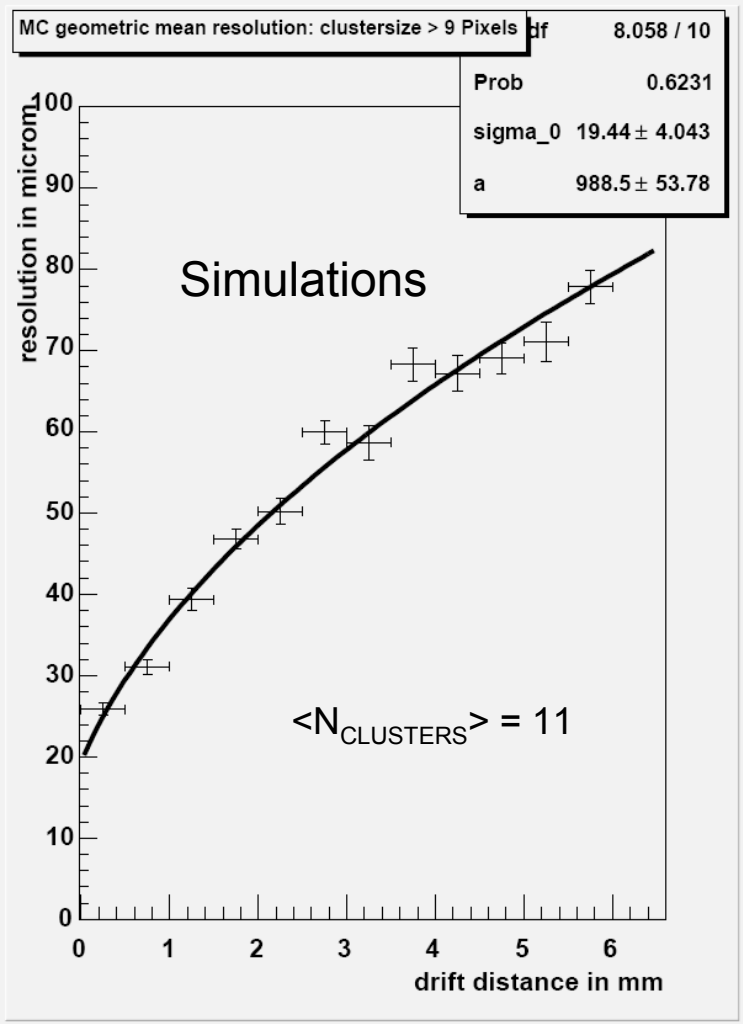
$a = D_t^2/n_{el}^{cl}$

"Saddle Point" clustering

Largest disagreement at highest drift distance ~ 15 %

DATA vs. Simulations (He/CO_2)





He/CO_2

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"Saddle Point" clustering

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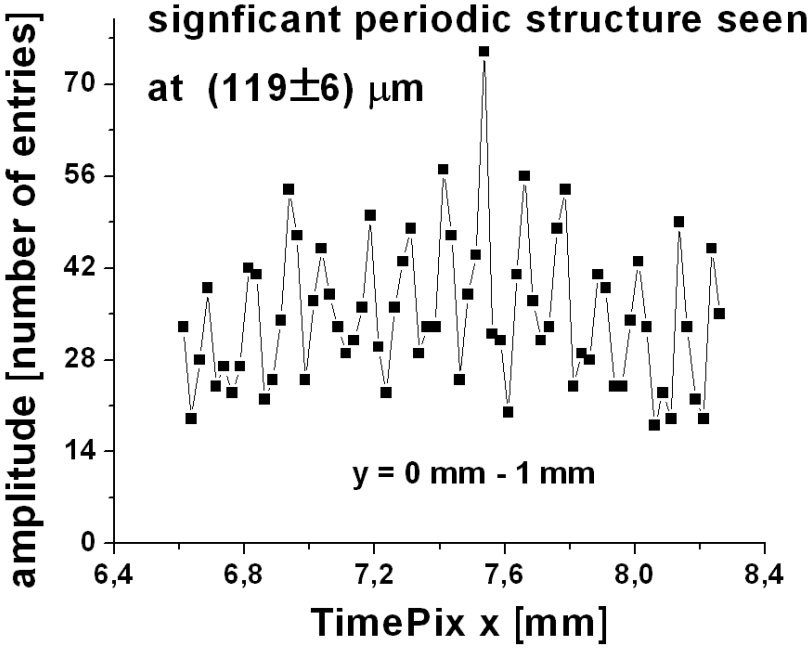
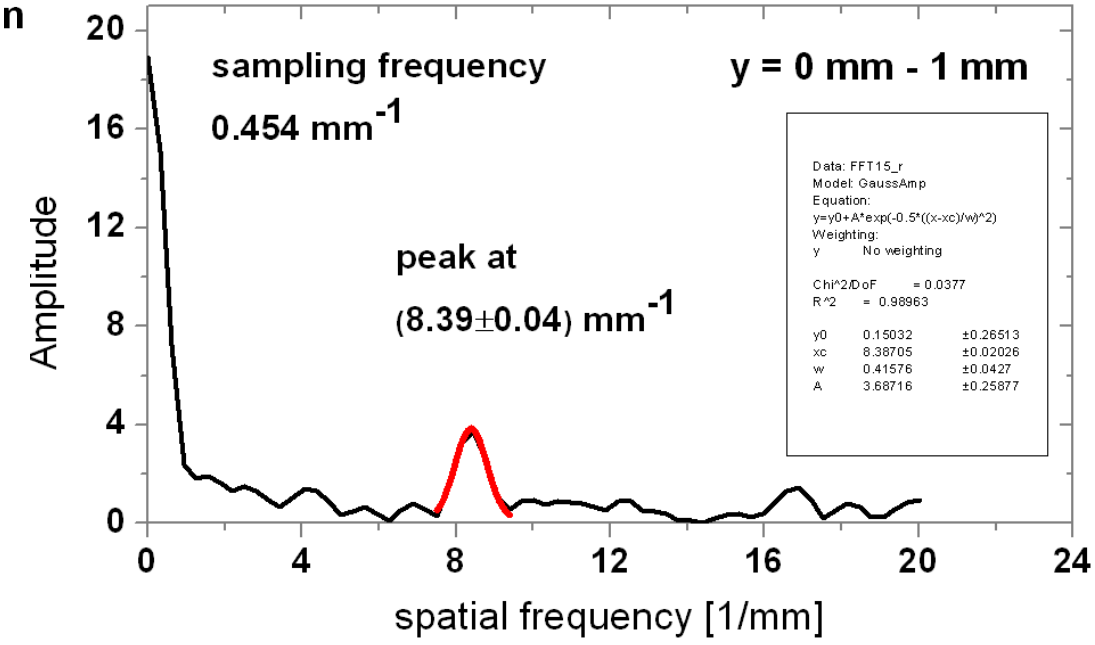
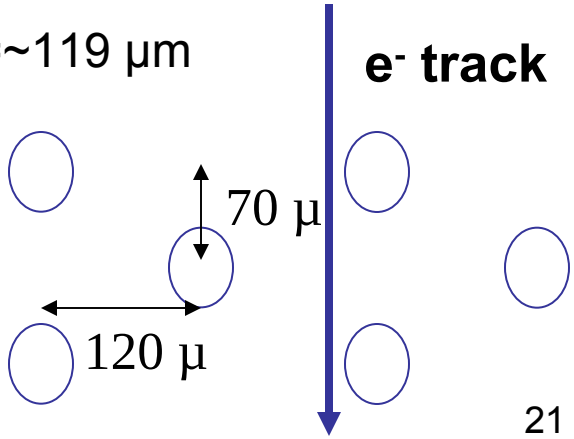
GEM Substructure





- Projection along the track (x-projection); first drift bin near upper GEM
- Use Fourier transforms – periodic structure at 1/8.39=~119 μm
- No structure for higher drift distances (> 1 mm) has been observed
- No structure has been observed for transverse to beam projection (pitch here is 70 μm) !



Analyses Result Summary

		DATA		Simulations	
	Gas	σ_0	D_t^2/n^{el}_{cl}	σ_0	D_t^2/n^{el}_{cl}
"Island"	Ar	22.2+/-0.8	519+/-12	-----	-----
	He	25.6+/1.0	675+/-16	-----	-----
"Saddle Point"	Ar	18.4+/-2.7	467+/-36	15.2+/-3.8	726+/-41
		18.4+/-3.1	555+/-41	15.8+/-4.8	866+/-52
	He	27.1+/-4.9	547+/-78	19.4+/-4.0	989+/-54
		25.6+/-6.2	696+/-95	22.4+/-4.2	1167+/-65

* 3-point resolution method

Conclusions and Future Plans

- Excellent performance of TimePix and very good stability of GEM-MediPix2/TimePix setup at test beam condition
- Two clustering methods have been established to resolve more clusters per track. The tracks are getting more contiguous with an increase of HV; therefore it's important to decompose overlapping areas
- The results of spatial resolution measurement with different methods are giving basically the same result
- New test beam séance in DESY with different GEM orientation is necessary to ensure that achieved resolution (σ_0) is still dependant on pitch discreteness of GEMs. Check if achieved σ_0 can be improved by:

  - using proper orientation of GEM with respect of tracks and/or reducing pitch of GEM holes

- The disagreement with simulation is to be investigated further