Encapsulated Resistive-anode Micromegas TPC

test beam campaign
@ DESY 13/Nov ~ 28/Nov

preliminary plots

RD51 mini-work shop

4-6 December 2018 @ CERN

D. Attié, P. Colas, X. Coppolani, S. Emery-schrenk,

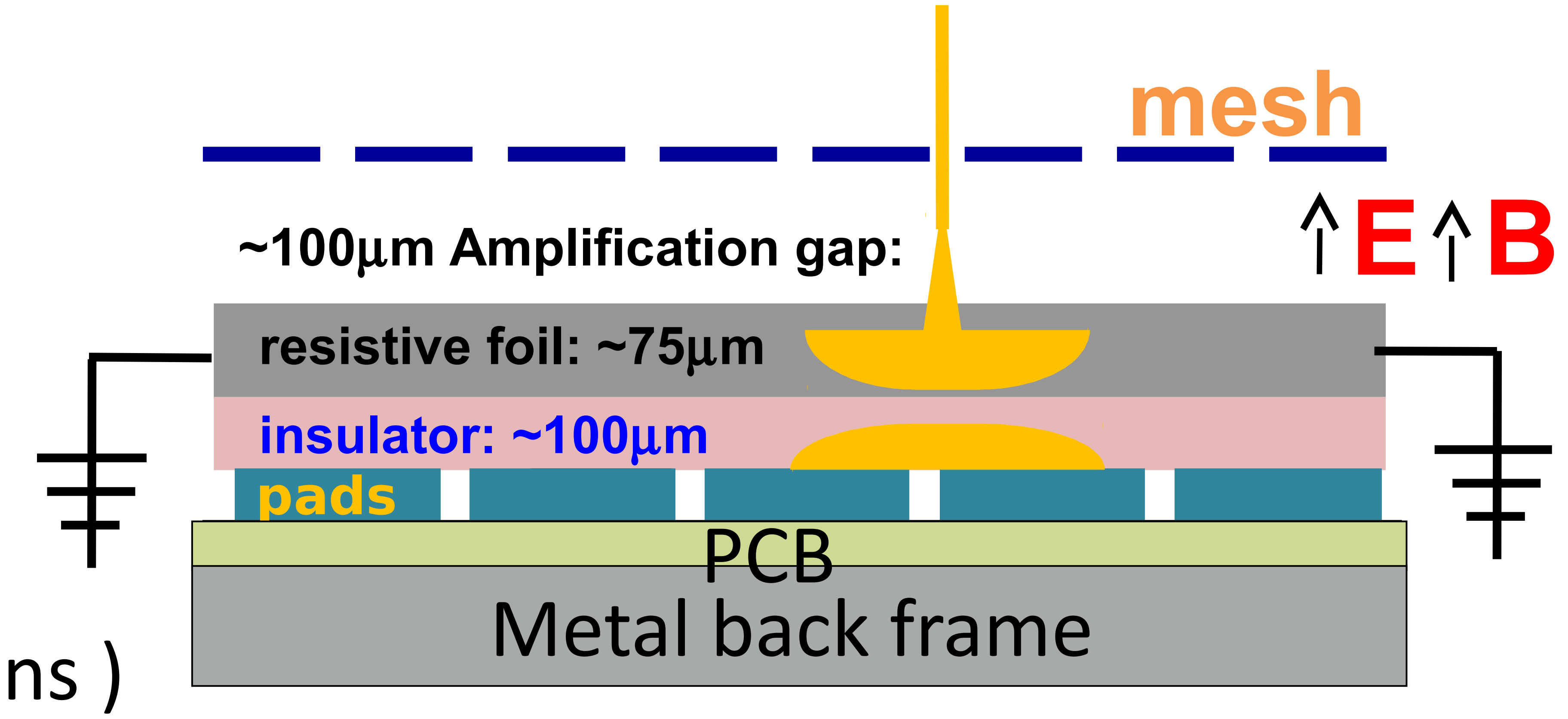
S. Ganjour, T. Ogawa, H. Qi, M. Riallot,

B. Tuchming, J. Timmermans, M. Titov,

and thanks to R. Diener, O. Schäfer, V. Prahl …

Encapsulated Resistive-anode Micromegas

- **Resistive-anode Micromegas**



Performance requirement for ILC : ~ 100 µm spatial resolution

"T2K" gas gives small transverse diffusion because of

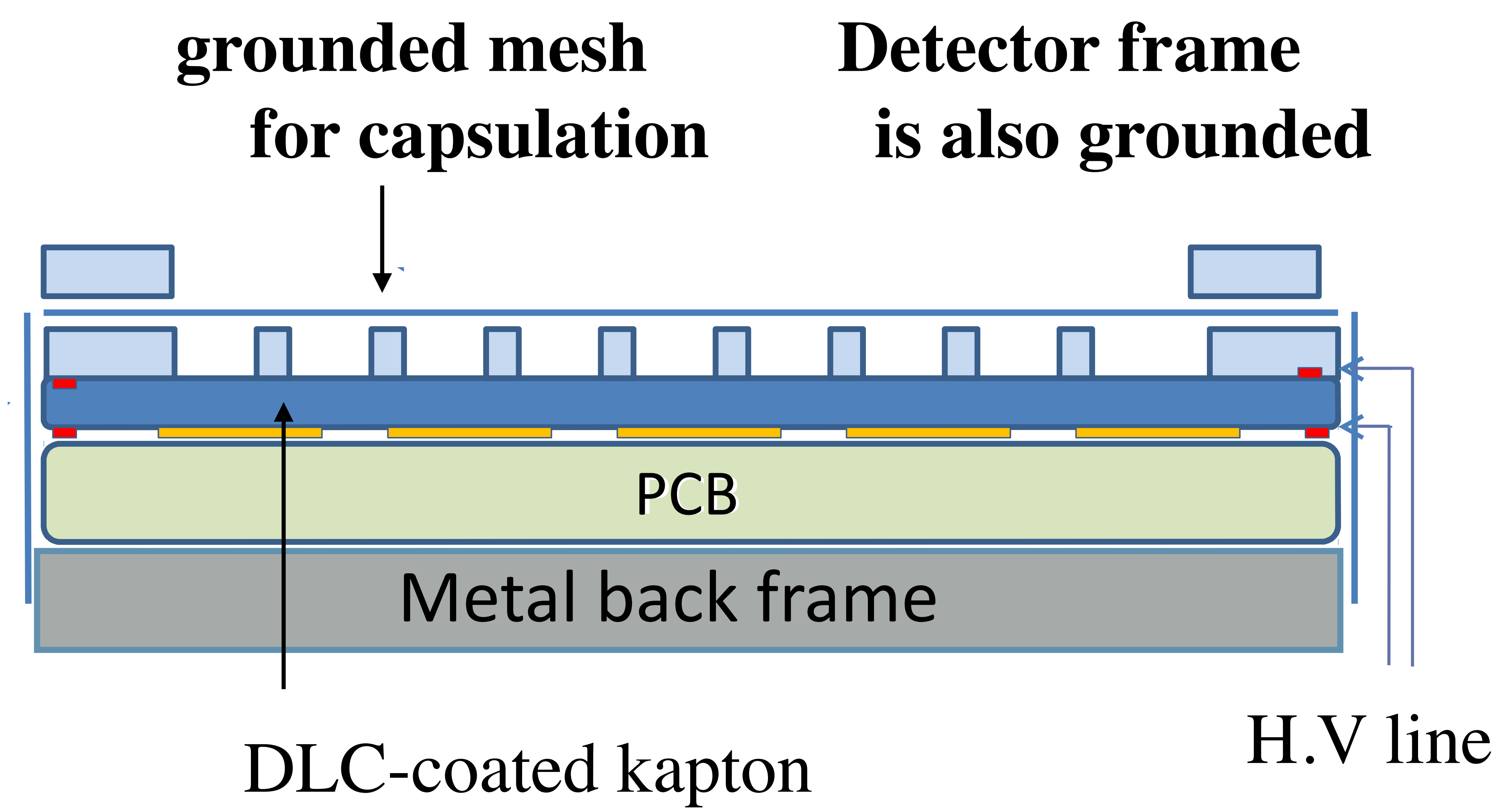
CF4 which can make τ large (τ: mean free time between collisions)

under 4T magnetic field Dt ~ 30 um/√cm (σ : limitation of pad size ~ width/√12)

Need sufficient #pads to get barycenter

=> spread charge and share with several pads.

- **Encapsulated Resistive-anode Micromegas**



Mesh is connected to ground.

Encapsulation shields against external noise

small signal can be acquired

Module-Module boundary keep homogeneity of E field ,

reduce ExB => Mitigates track distortions

Detector configuration

- **Module**
  - Module size: 22 cm × 17 cm
  - 24 rows × 72 columns (1726 Pads)
  - **Pad size: ~3 mm × 7 mm**
- **AFTER chip** produced by Saclay https://doi.org/10.1109/TNS.2008.924067

  for various kinds of detectors and **gas mixtures**

  different electronics gain

  25 MHz (50, 100 MHz) sampling frequency

  Peaking time 100 ns to 600 ns
- **Resistive anode** for dispersing charge

  ***Diamond Like Carbon*-coated kapton**

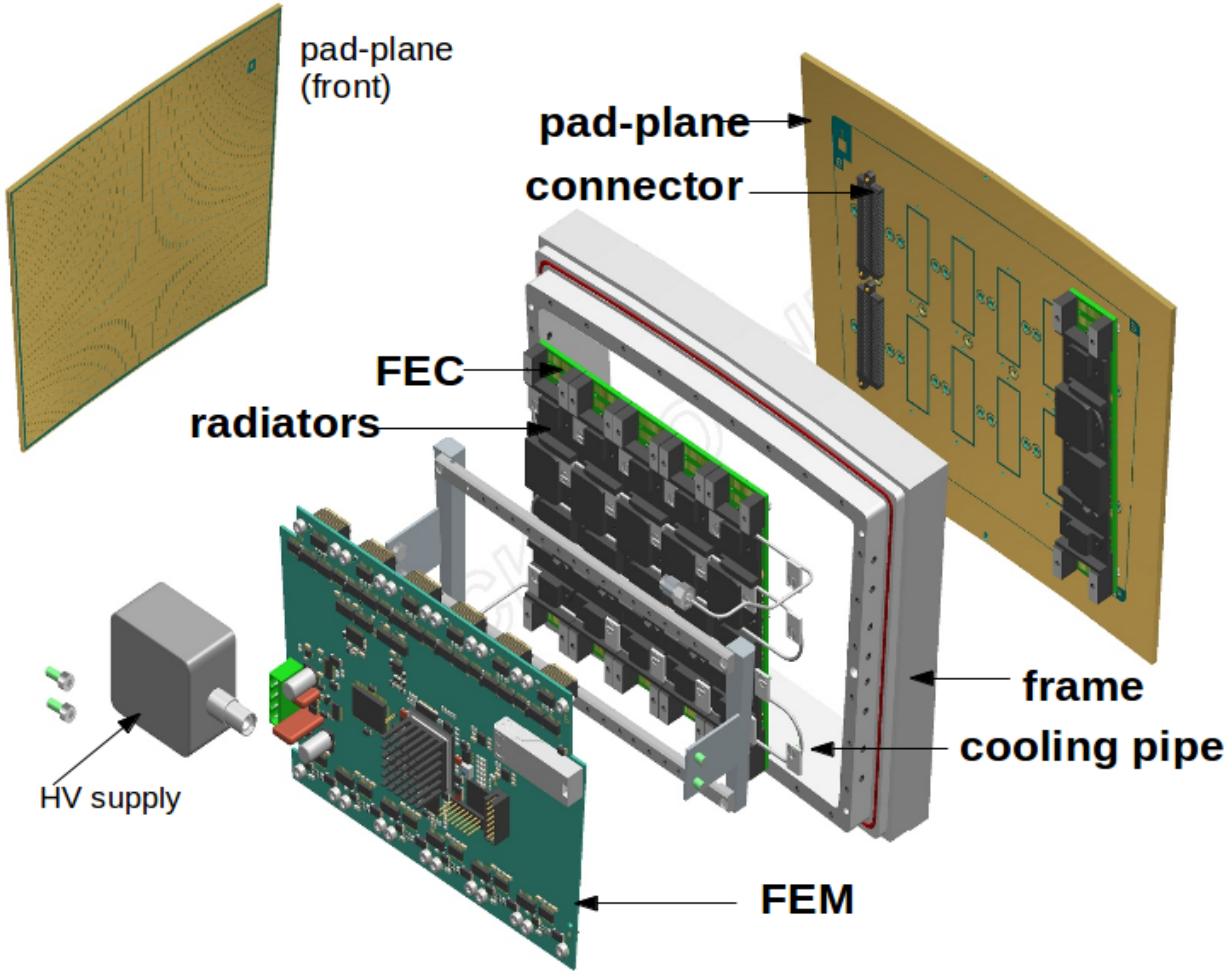
  Surface resistivity = 2.5 Mohm/sq

  is optimal when considering pad size,

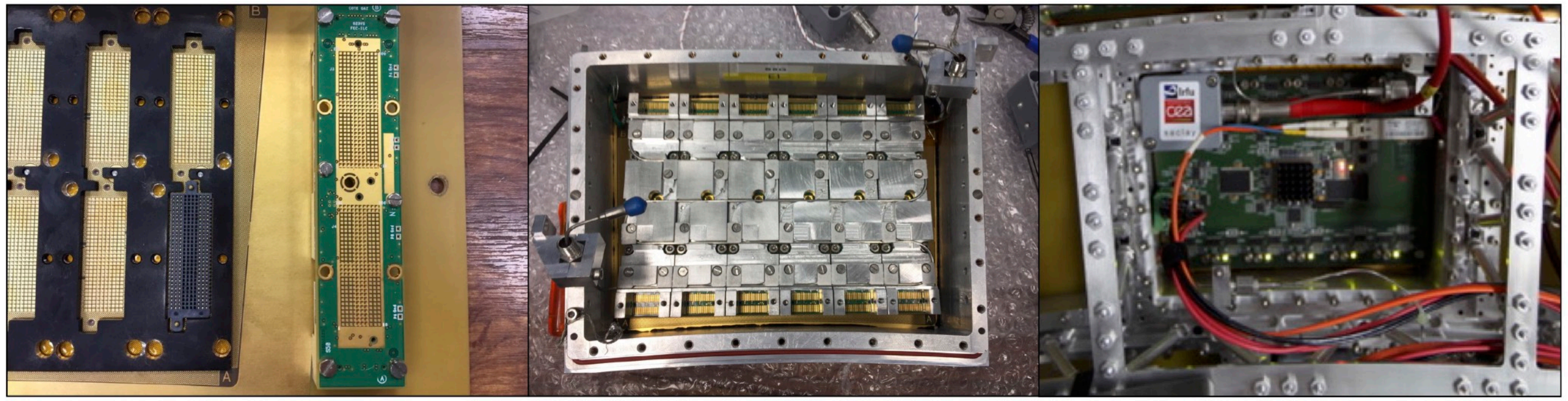
  insulator thickness , and shaping time …

  => sufficient charge spreading

  & protection for sparks



Stacking a module is easy !



- ***Carbon Loaded Kapton***
- ***Diamond Like Carbon***

comparison => *150119_D.S.Bhattacharya_AperoSPP*

The situation of beam test

- **with and without Magnetic-filed (B=1T)**

Performance test
& module alignment without ExB effect

Module scan for uniformity:
gain, $r\phi$ and z resolutions
Test of track distortions
by changing H.V of the center module

- **2PCO2 cooling with TRACI**

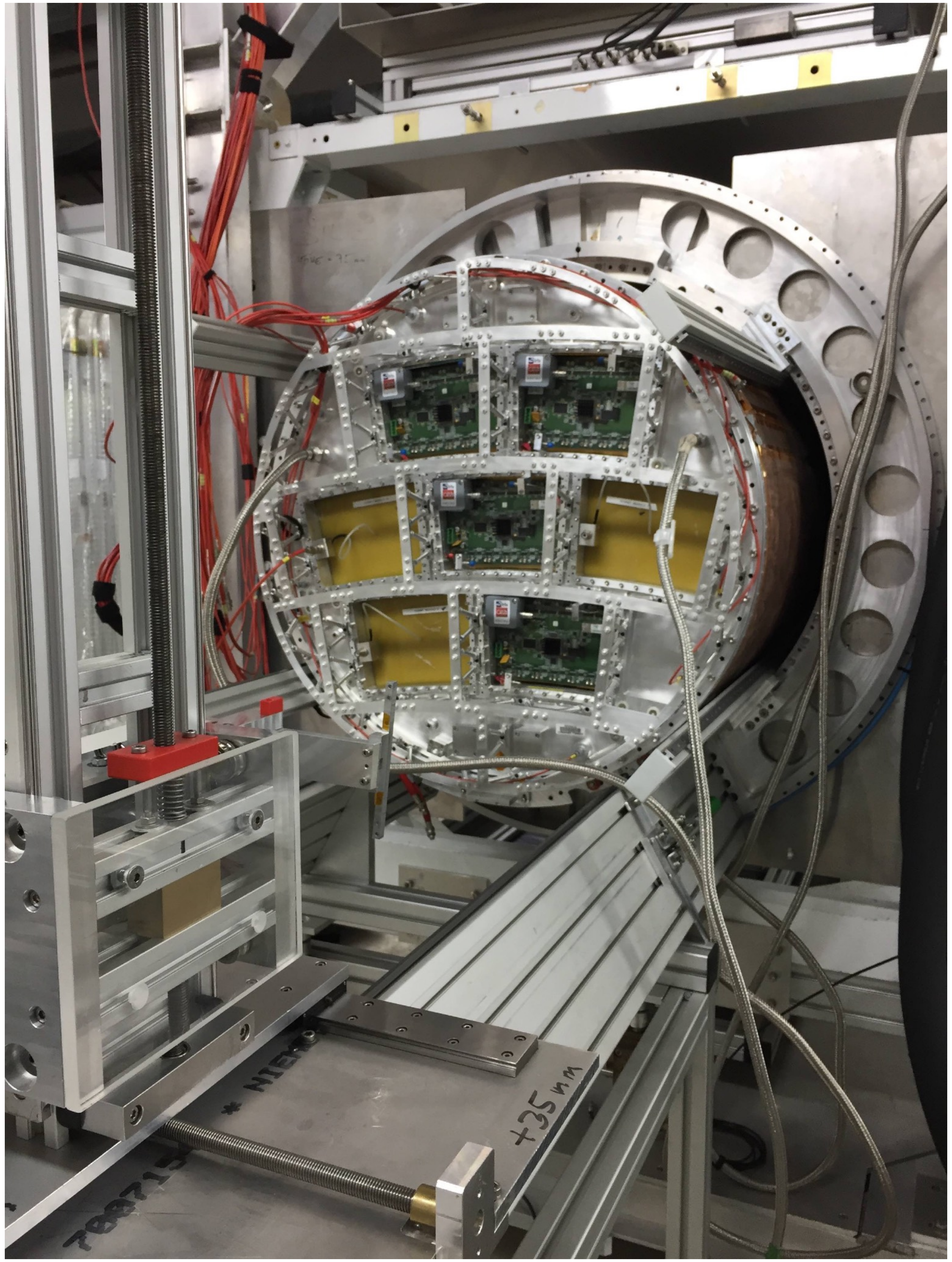
TRACI=Transportable Refrigeration Apparatus
for Co2 Investigation

Very stable operation during beam test.
Keep the modules 28~30 °C

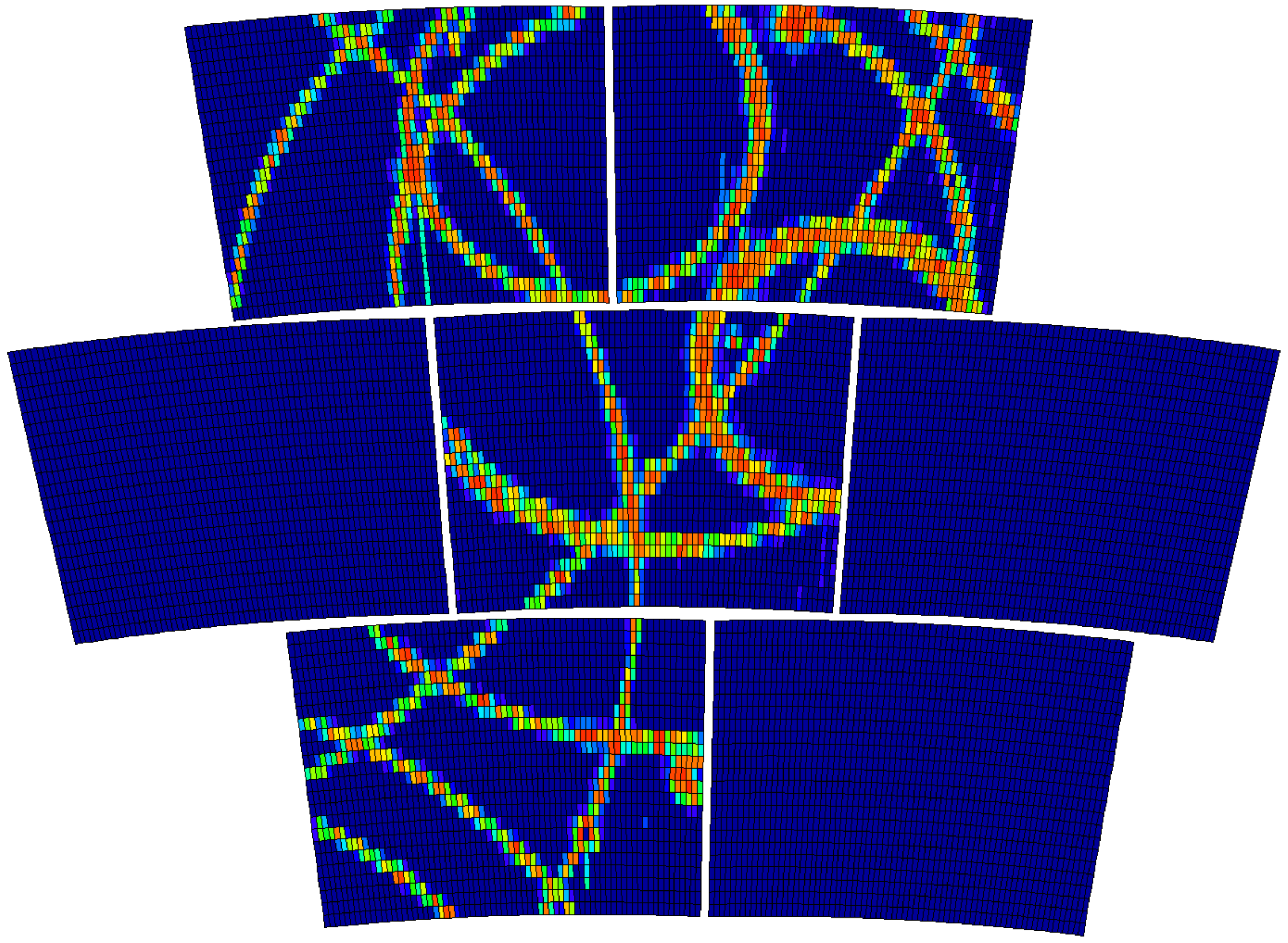
CMS CO2-100W
Mini Cooler

PH-DT-PO

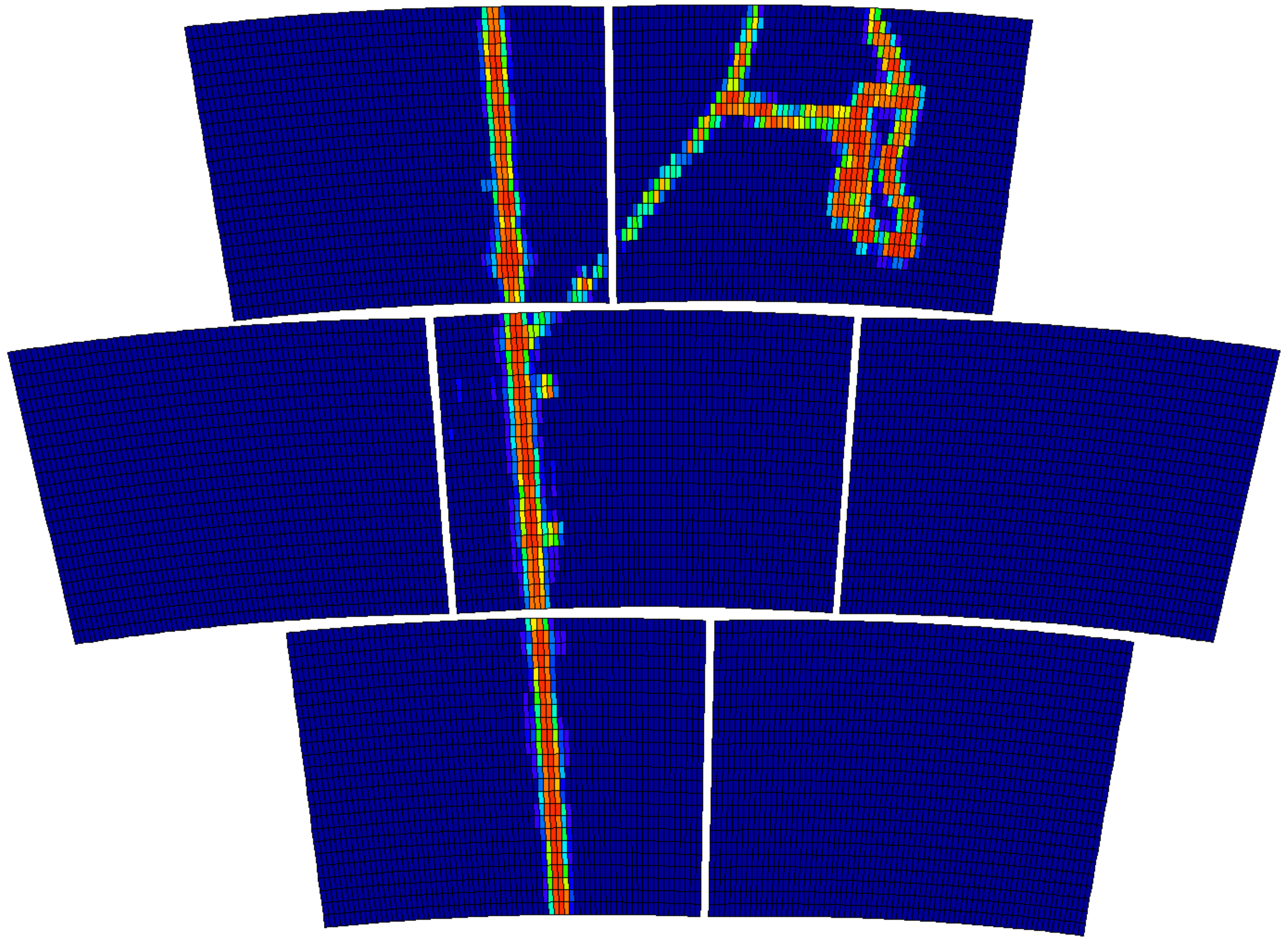
FILE: x:\students\kkapusniak\TRACI\co2_100w_cms\Latest\CO2_100W_CMS_electr.vsd



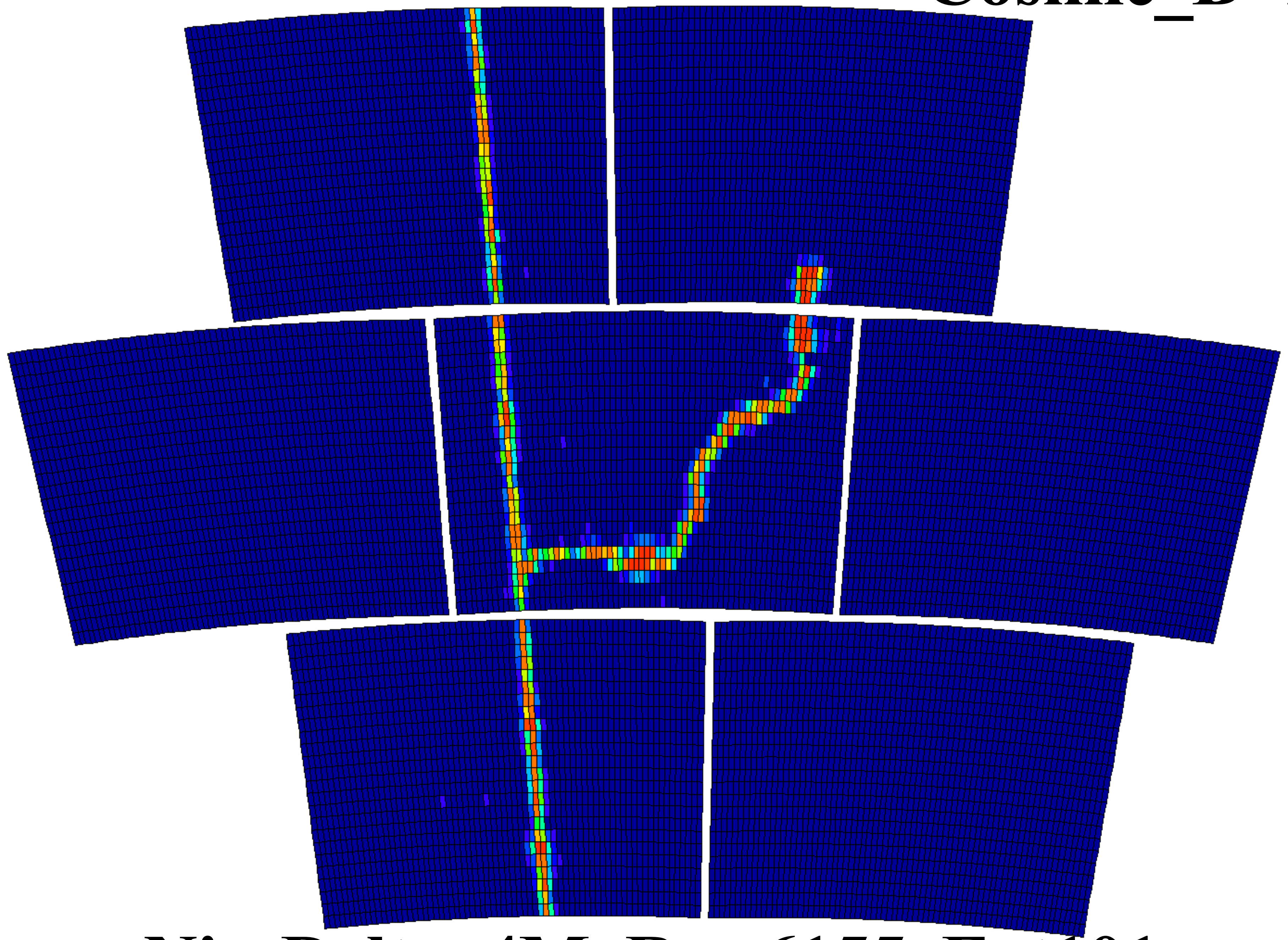
Nice events



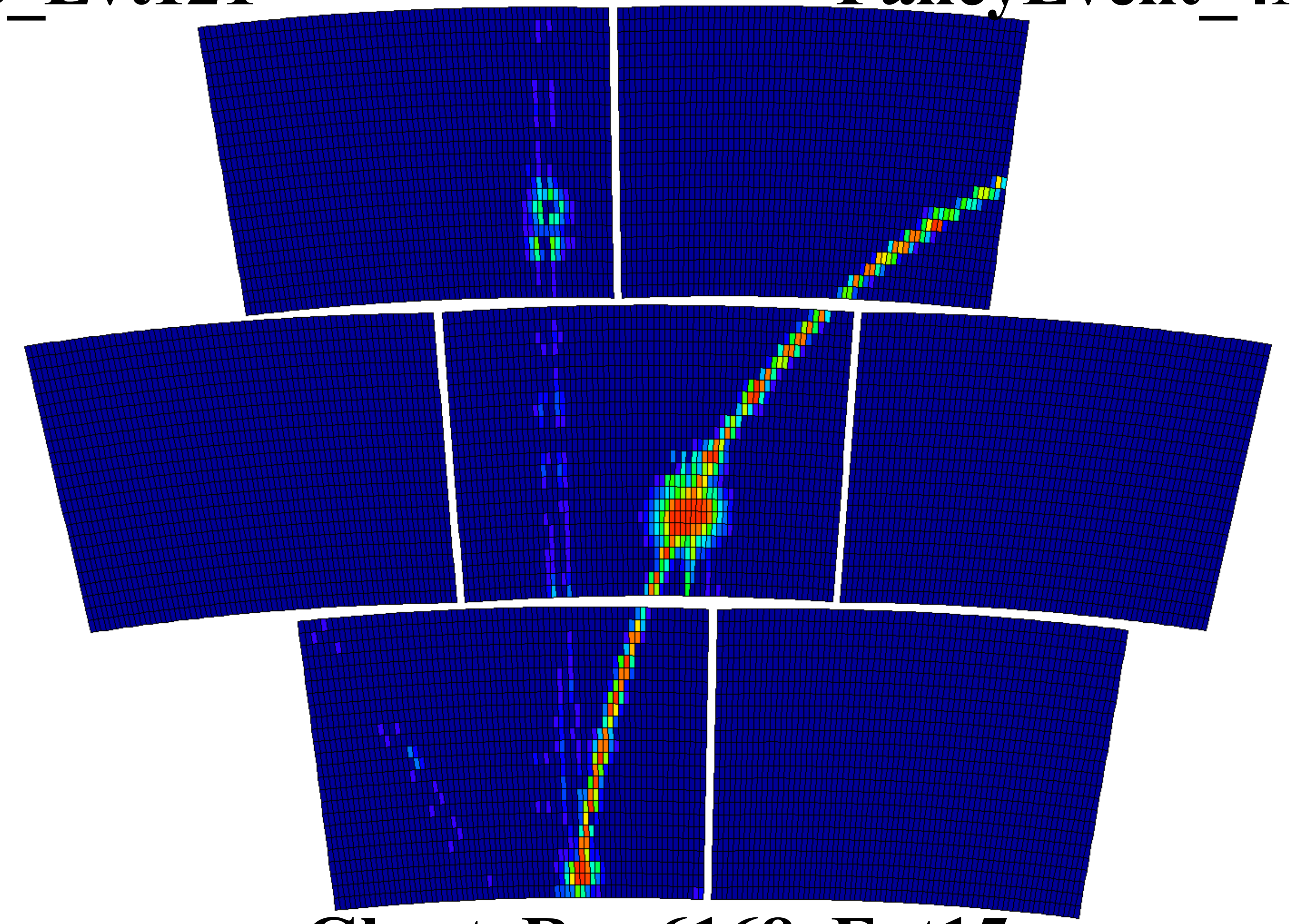
Cosmic_B=1T_Run6138_Evt121



FancyEvent_4M_Run6160_Evt46



NiceDelta_4M_Run6155_Evt101



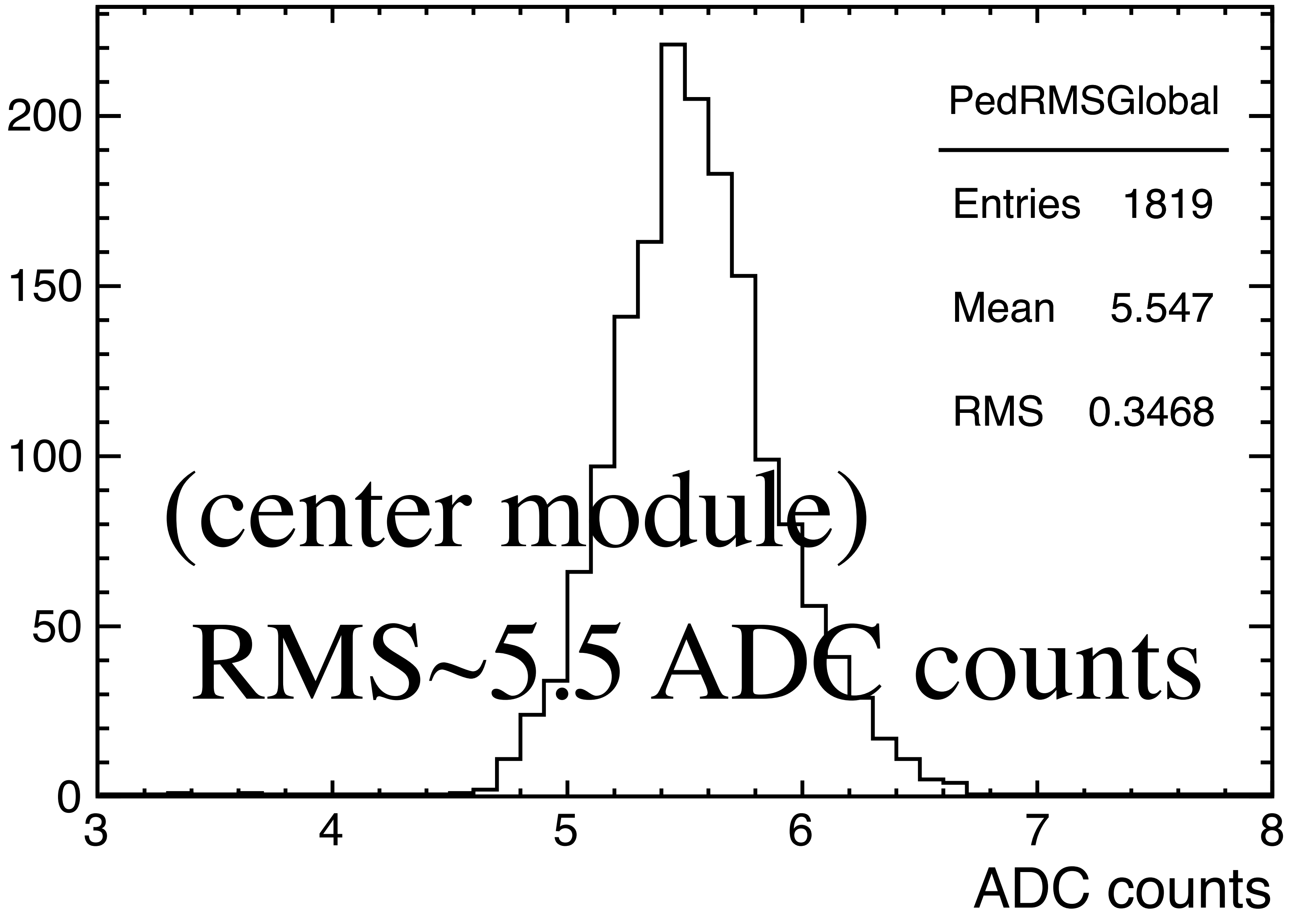
Ghost_Run6168_Evt15

Module status

- **Less noise contribution**

  Dynamic range is 4024 ADC counts

  Pedestal-RMS dist. measured under B=1T

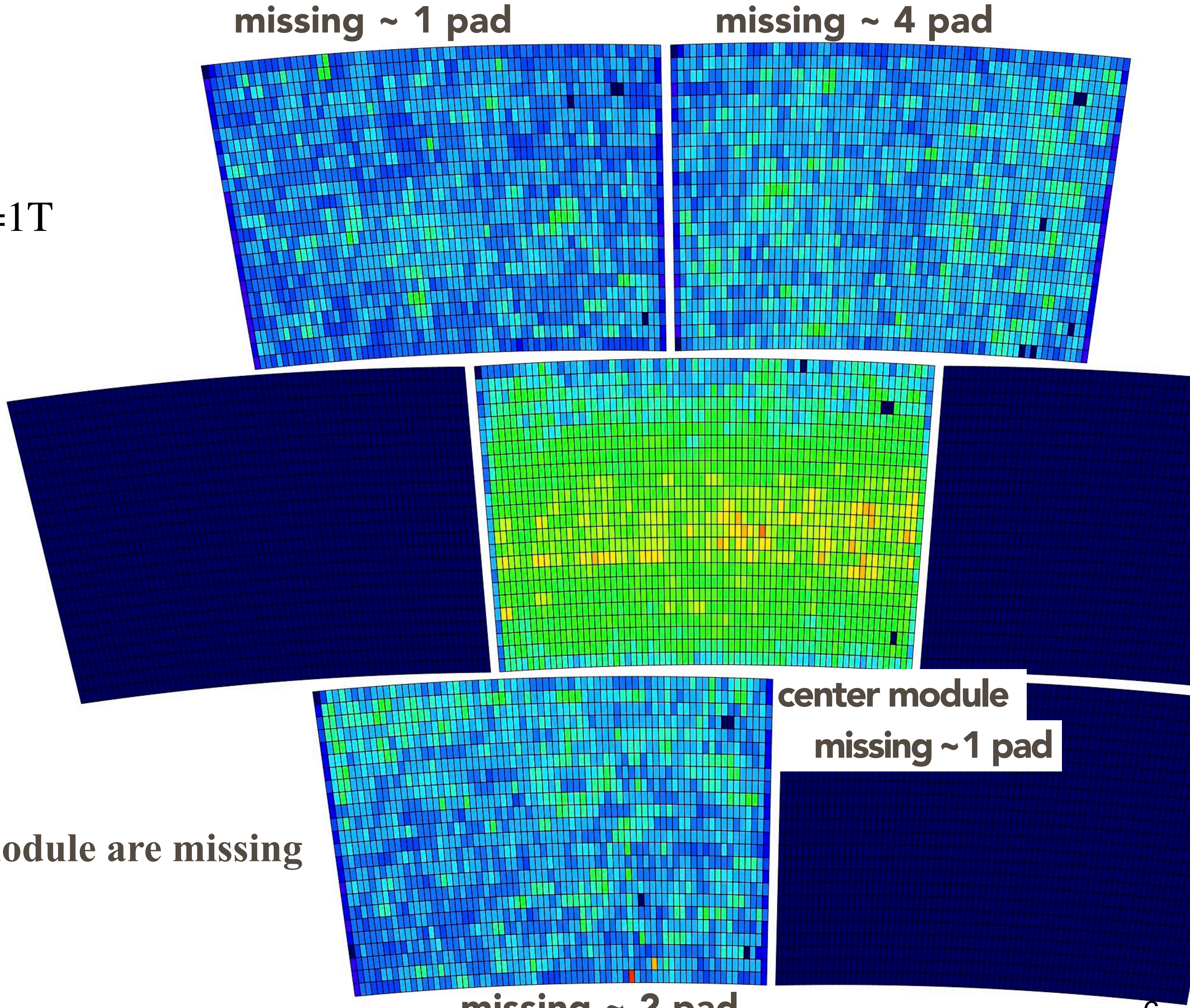


- **~99.9% channels are active**

  Due to electric circuit error 2pads in each module are missing
  => can be modified in next production

  1 ~4 missing pads because of disconnection

Accumulation of cosmic events



Charge spreading

https://indico.cern.ch/event/698927/contributions/2872364/

$$\rho(r,t) = \frac{RC}{2t}\exp\left[-\frac{-r^2RC}{4t}\right]$$

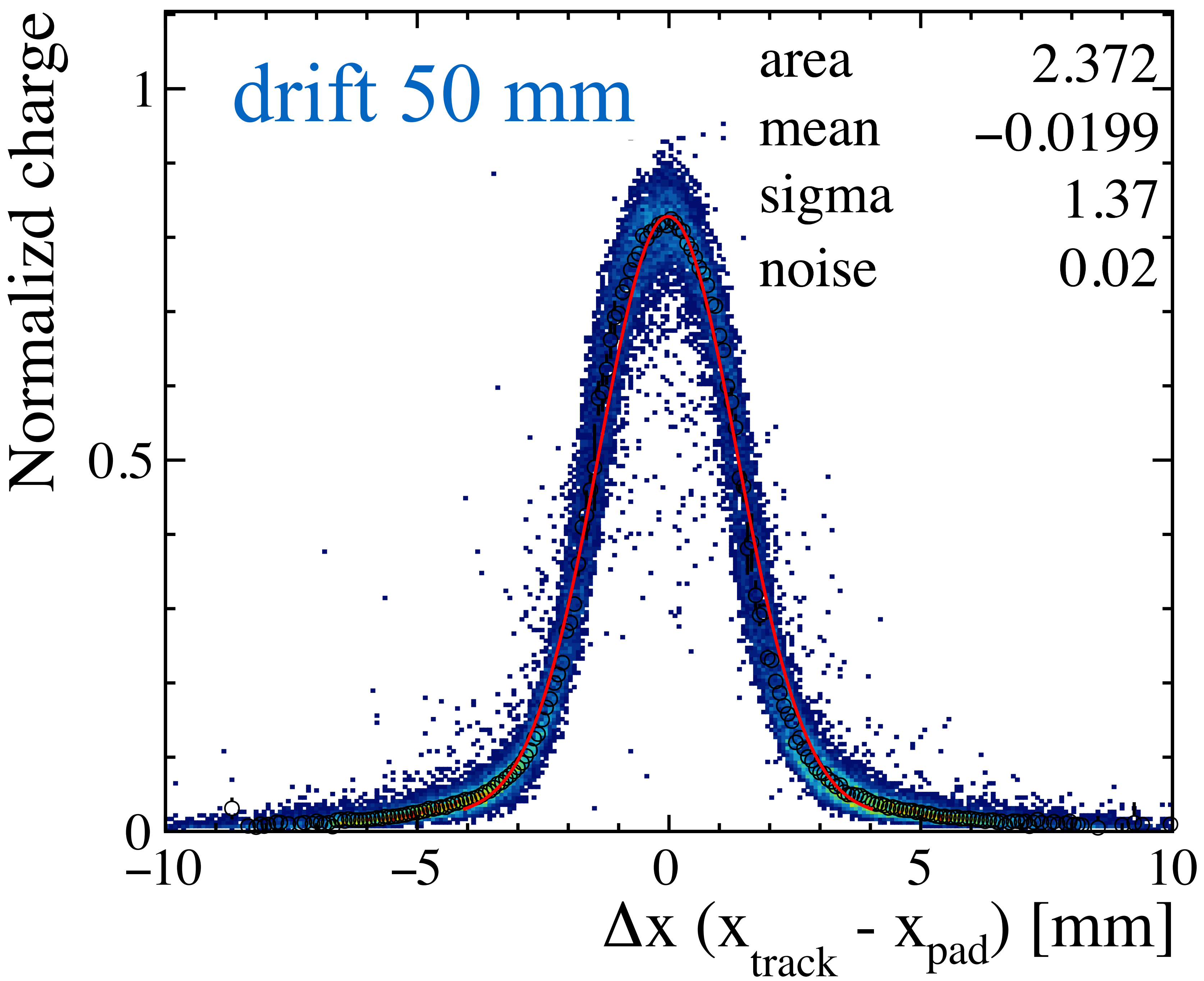
R- surface resistivity
C- capacitance/unit area

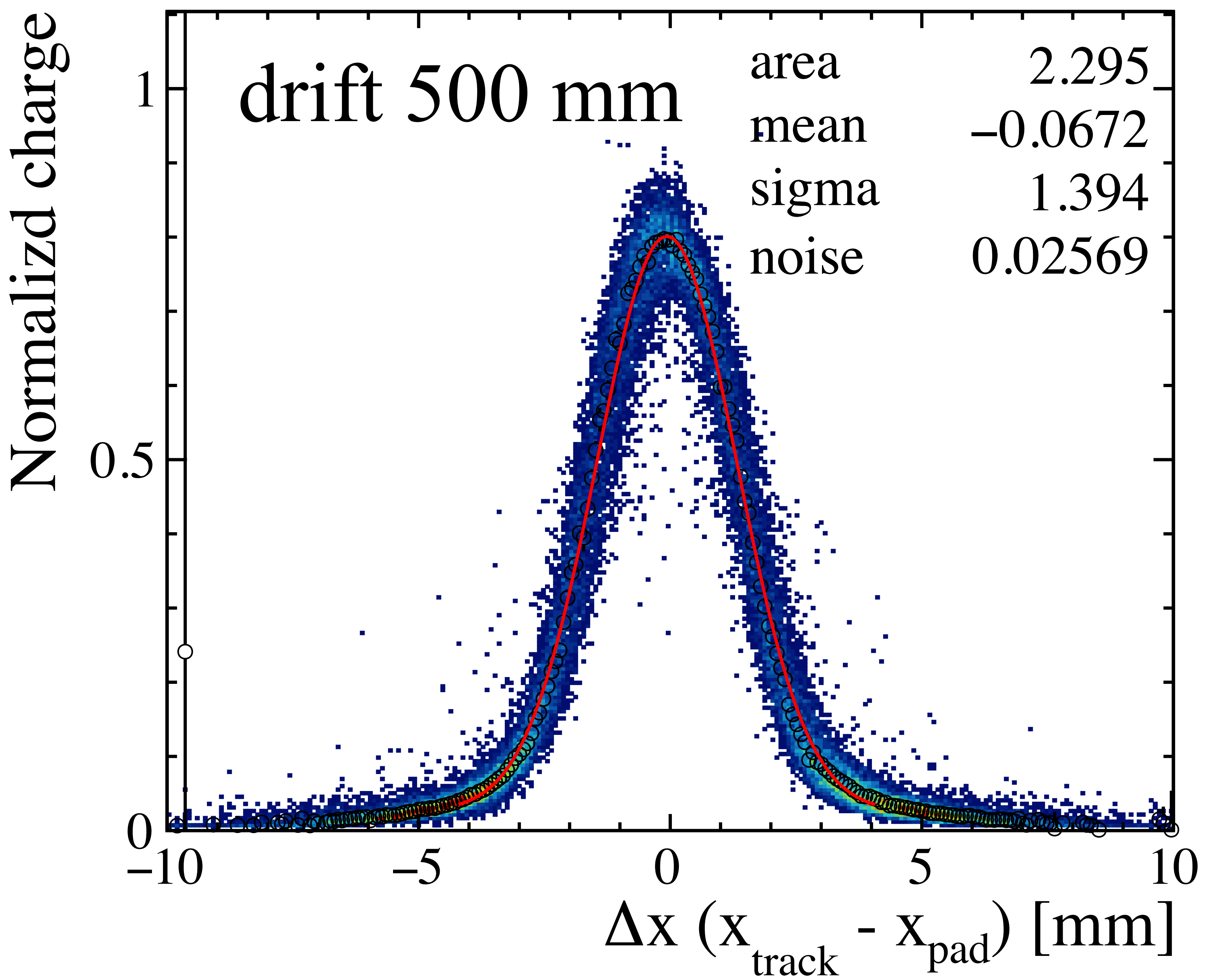
→ Gaussian spreading as a function of time with σ_r = sqrt(2t/RC)

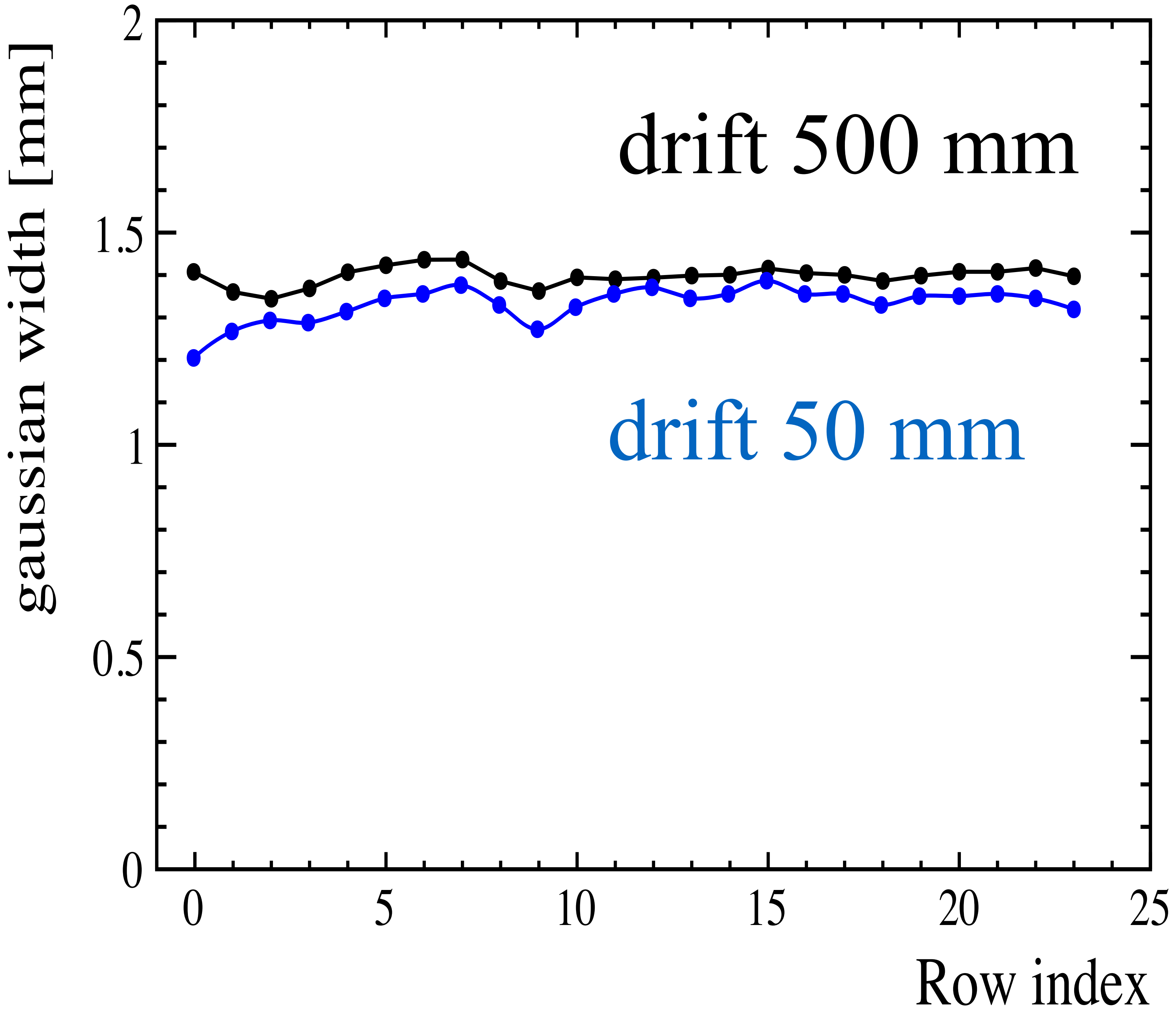
- **Pad Response Function**

σ = 1.4 mm well suited for 3mm-wide
to share amplified charge with a few pads

For R= 2.5 Mohm/sq, shaping 200 ns, 200 μ insulation in addition to the 50 μm kapton,
one obtains sigma ~ 1.4 mm







Dt under B=1T ~ 95 um/√cm

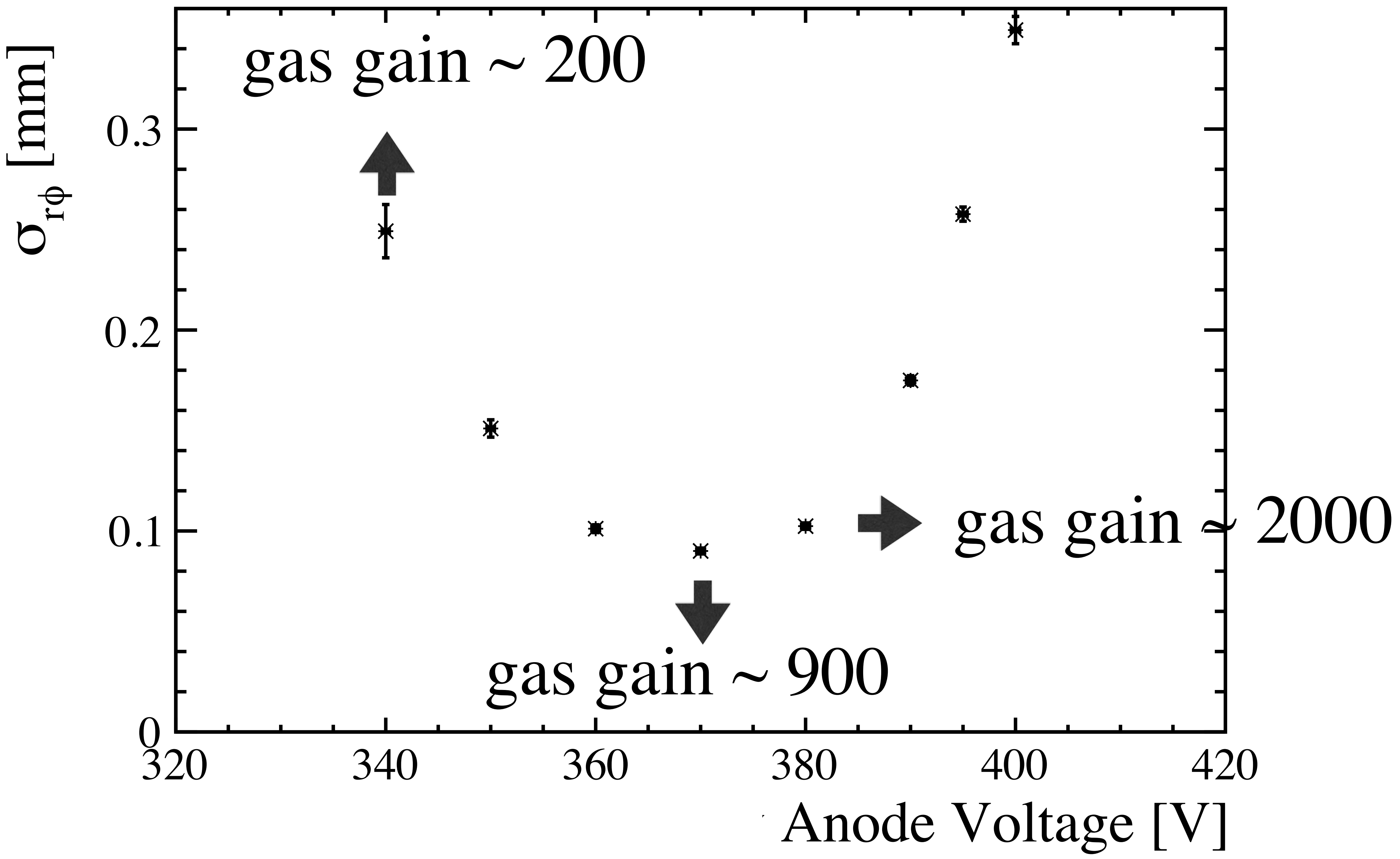
H.V scan (optimization)

- **σrφ as a function of anode voltage (amplification)**

σrφ : width of a $\Delta = x_{track} - x_{hit}$ distribution

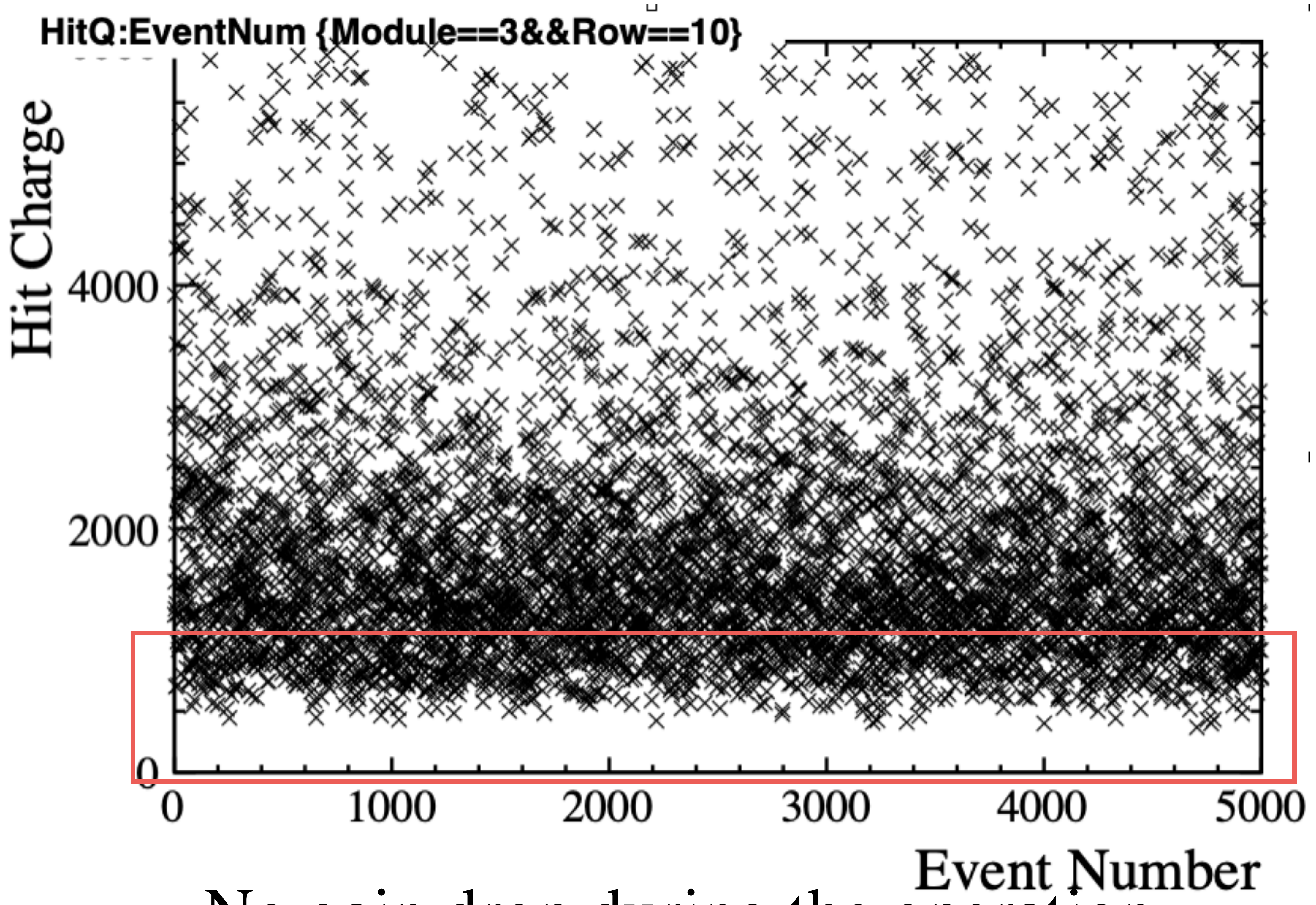
Charge is insufficient

large saturation
barycenter can not
be measurable



Hit charge vs Event Number
with anode voltage = 370V

a sample run (~12 mins)



No gain drop during the operation

(No any micro discharges)

gain : reference Figure 5-2 in PhD:WANG_WENXIN (Fig 7-3 with 5GeV) .

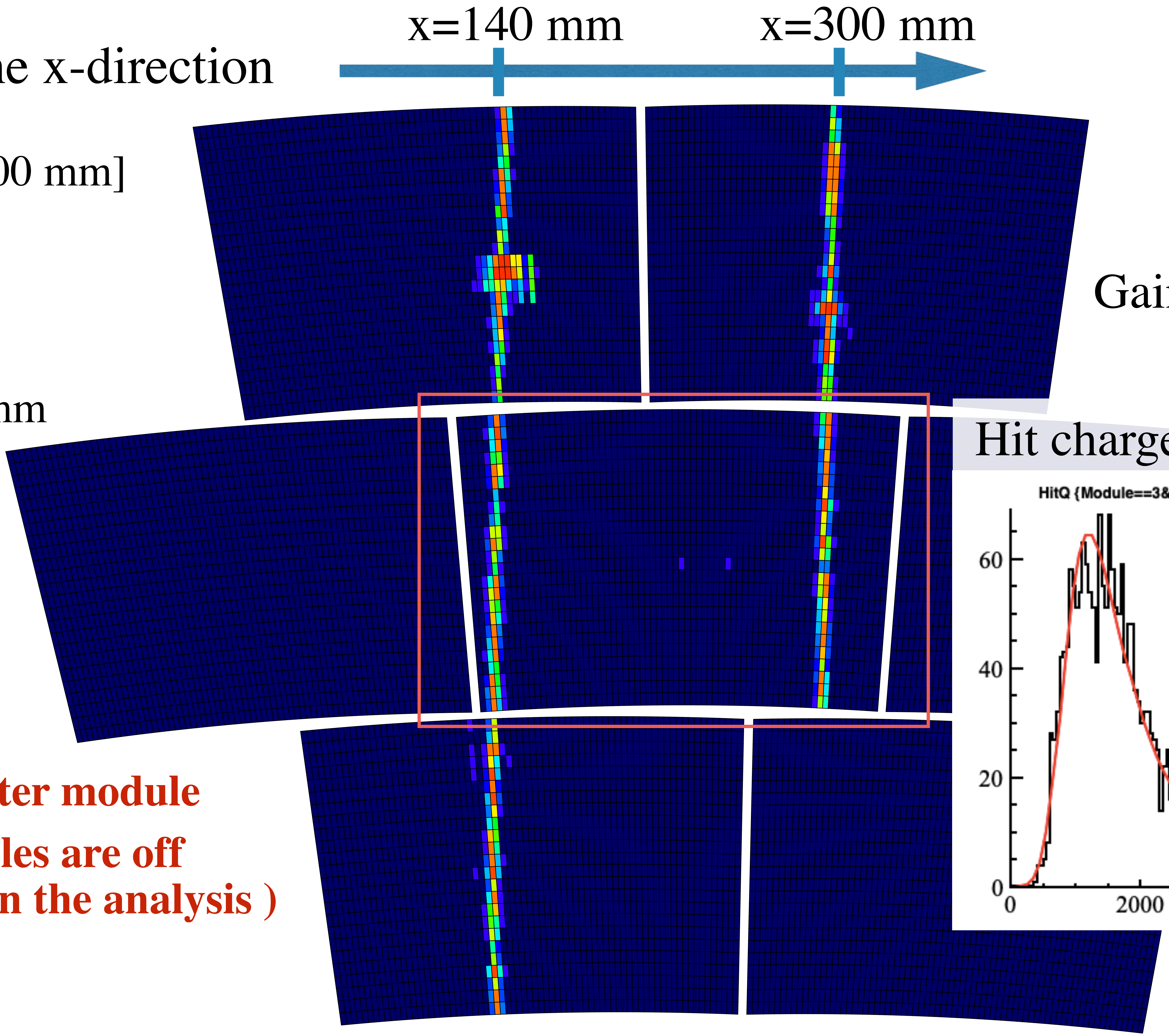
Uniformity of gain & point resolution over the module

- Scan along the x-direction

x=[120 mm ~ 300 mm]
10 points

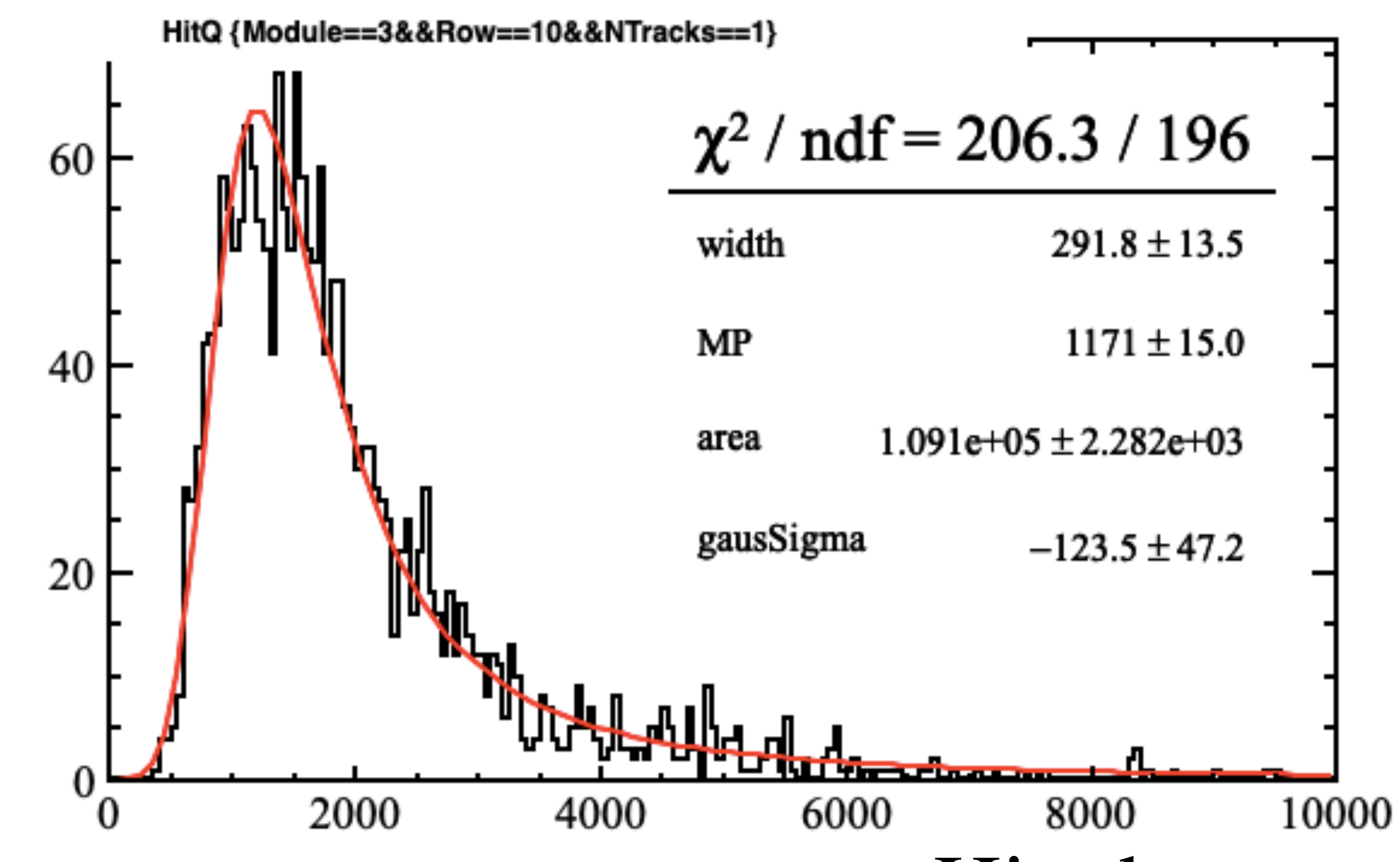
B=1T,
Drift length ~ 70 mm
to avoid being
washed out
by diffusion

- **Focus on the center module**
(the other modules are off in the analysis)



Gain : MP of gaussian conv. landau function.

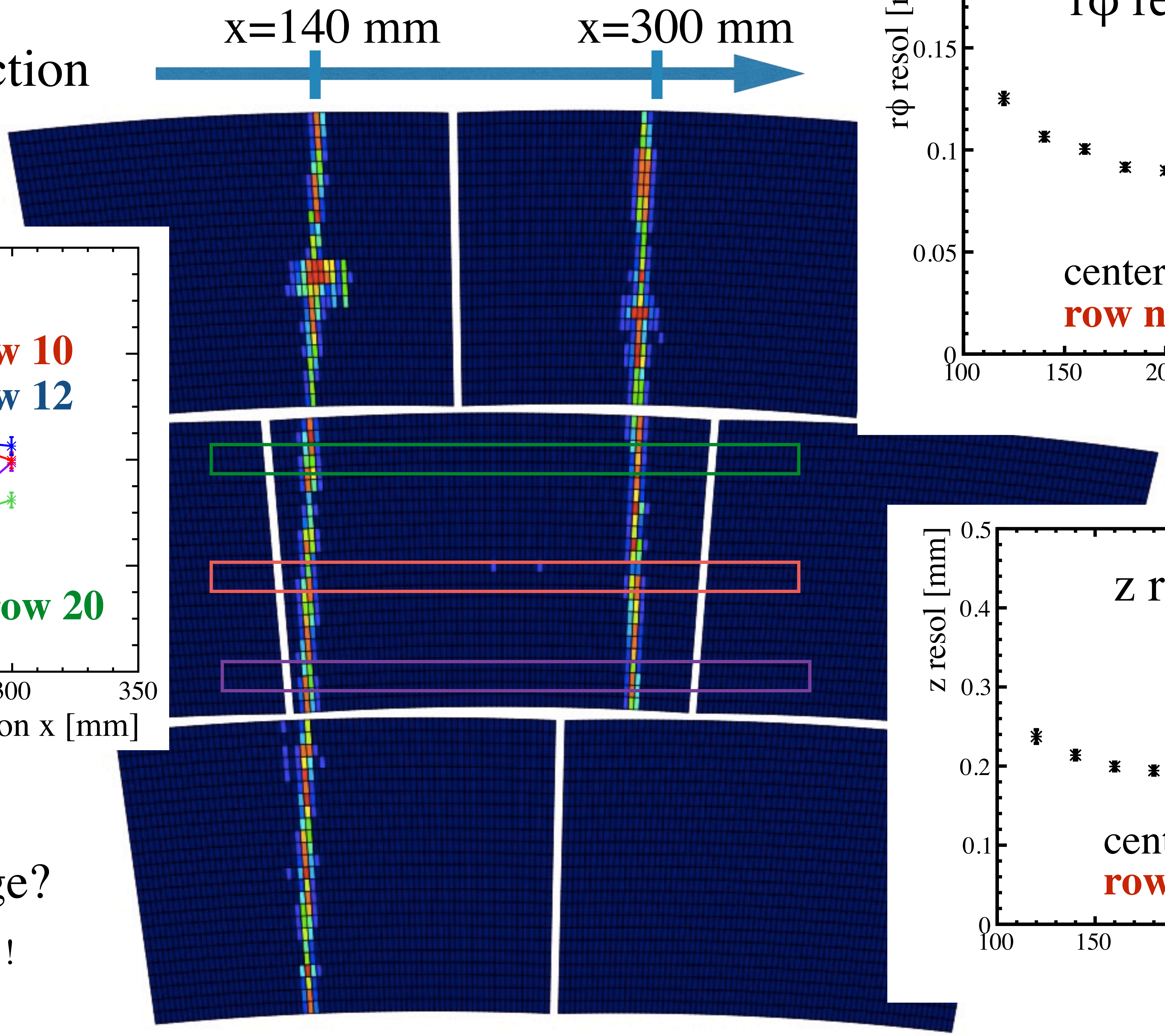
Hit charge distribution



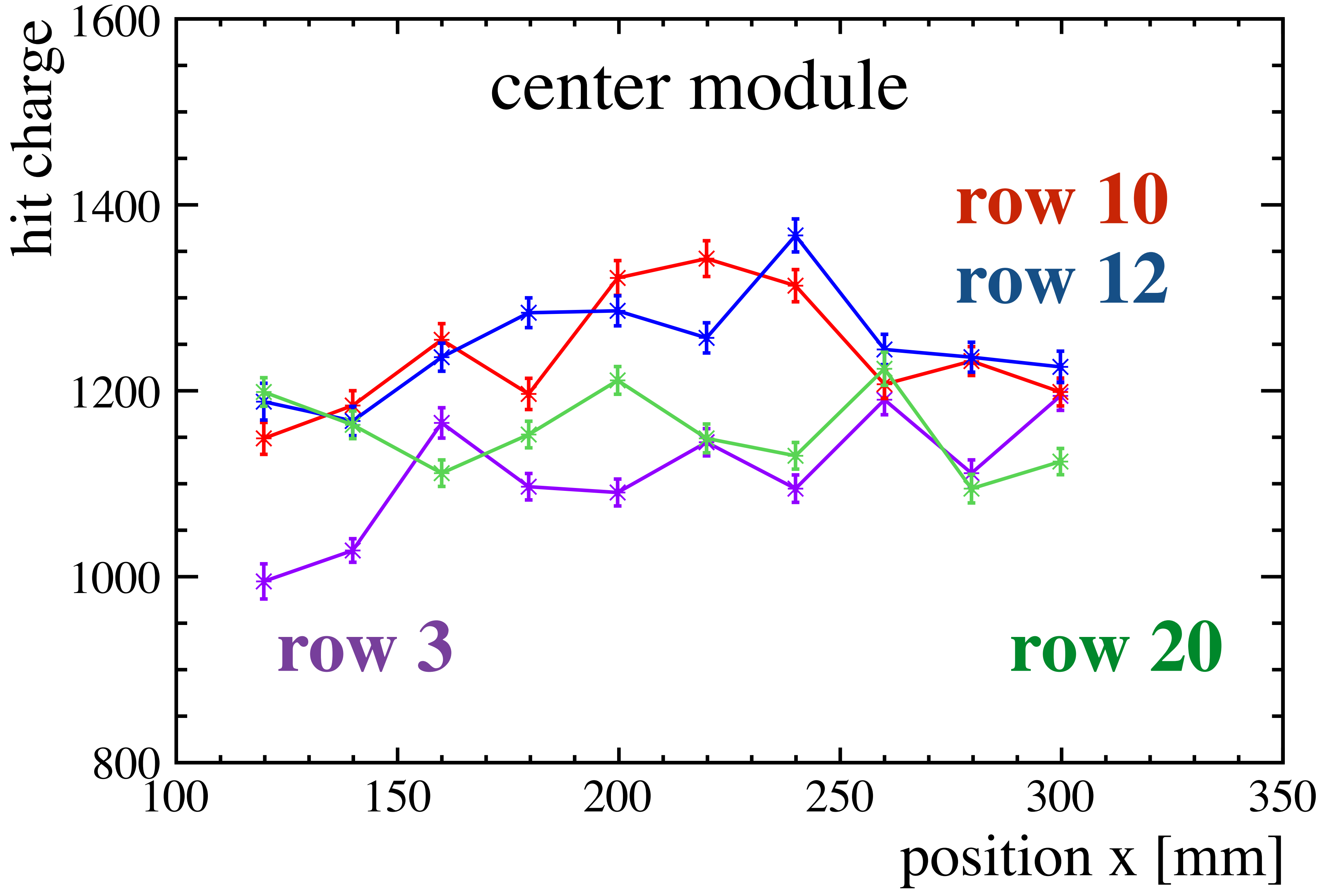
Hit charge

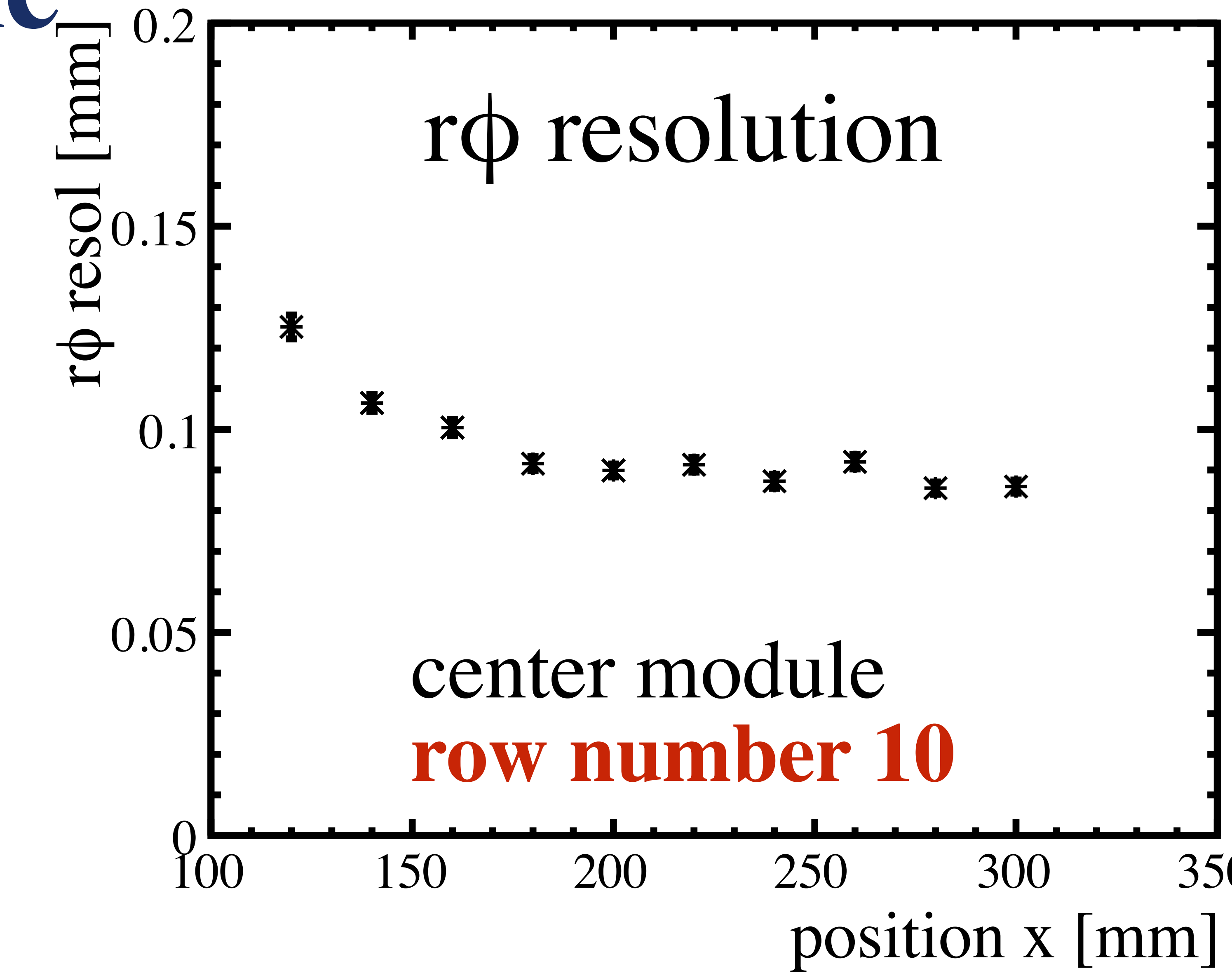
Uniformity of gain & point resolution over the module

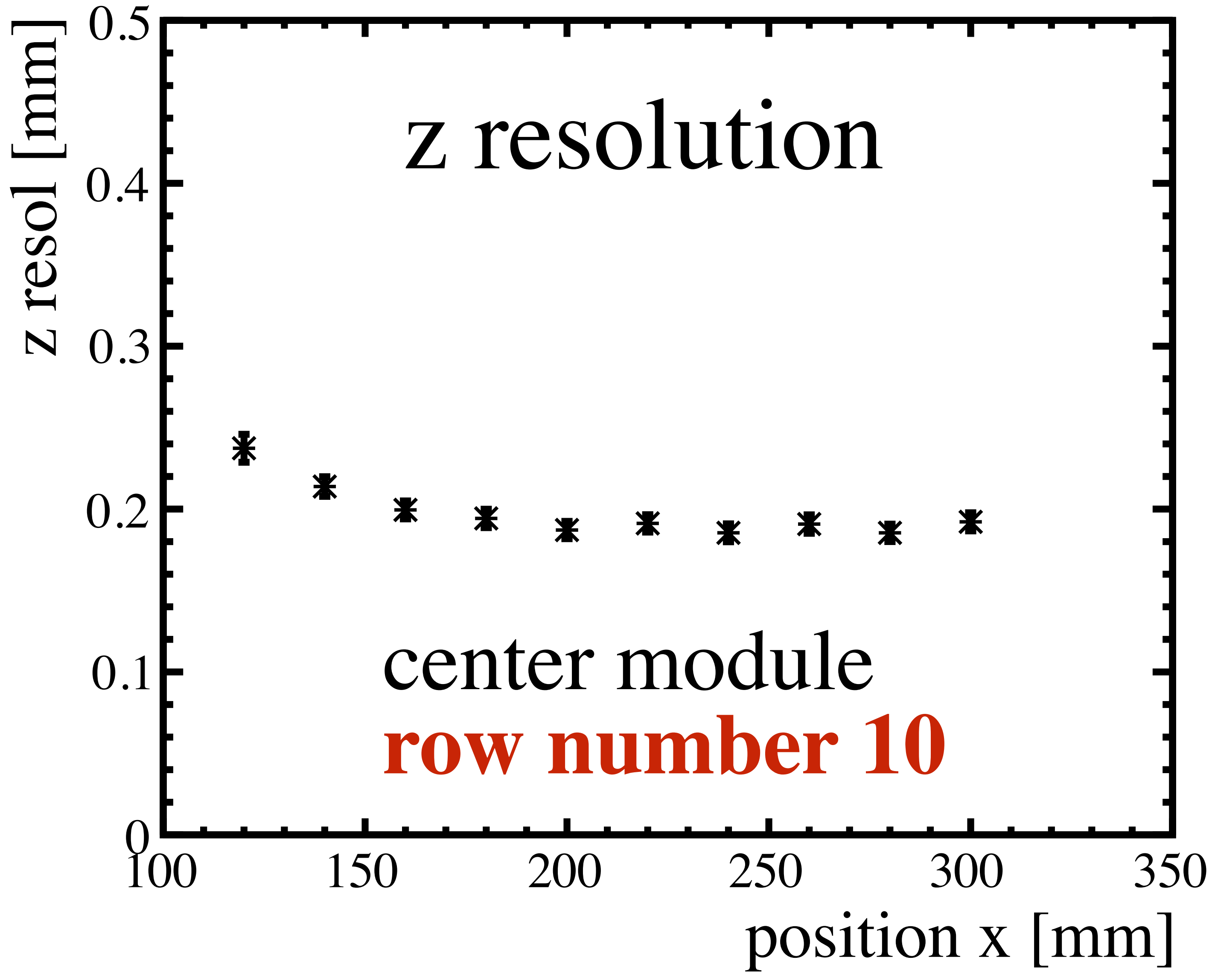
- Scan along the x-direction



Hit charge uniformity







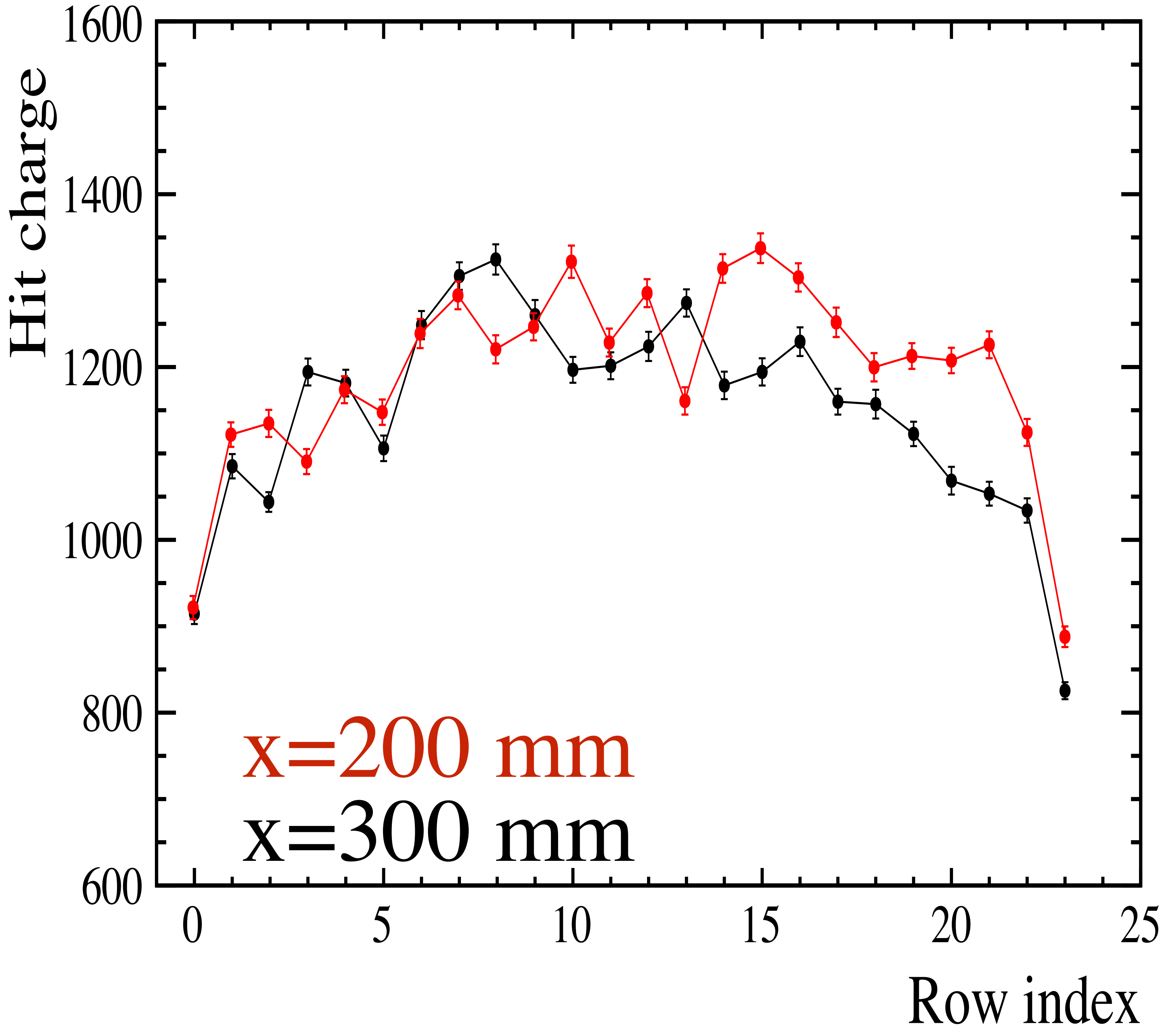
Center region observes relatively higher charge?

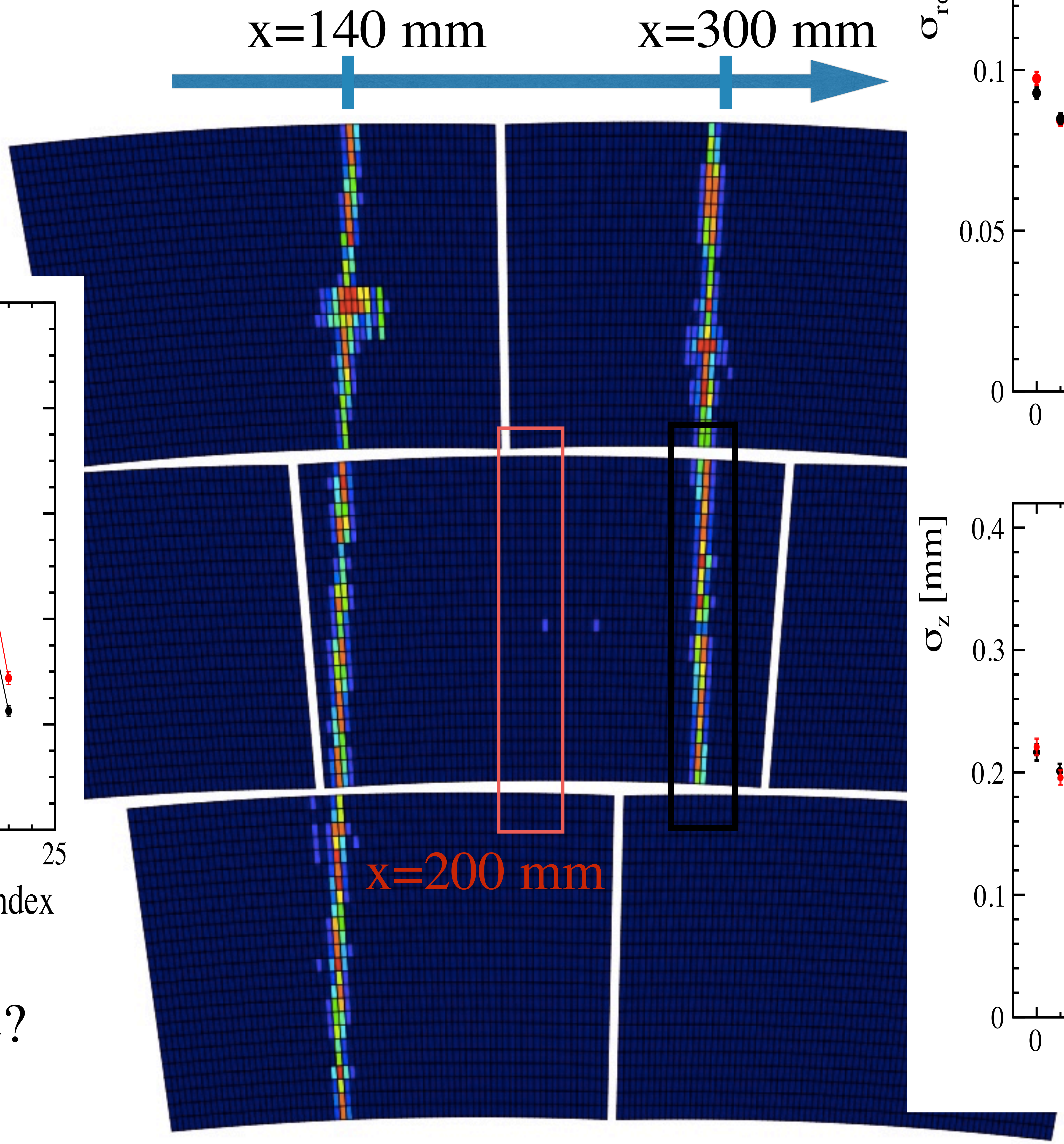
angle correction is not applied !

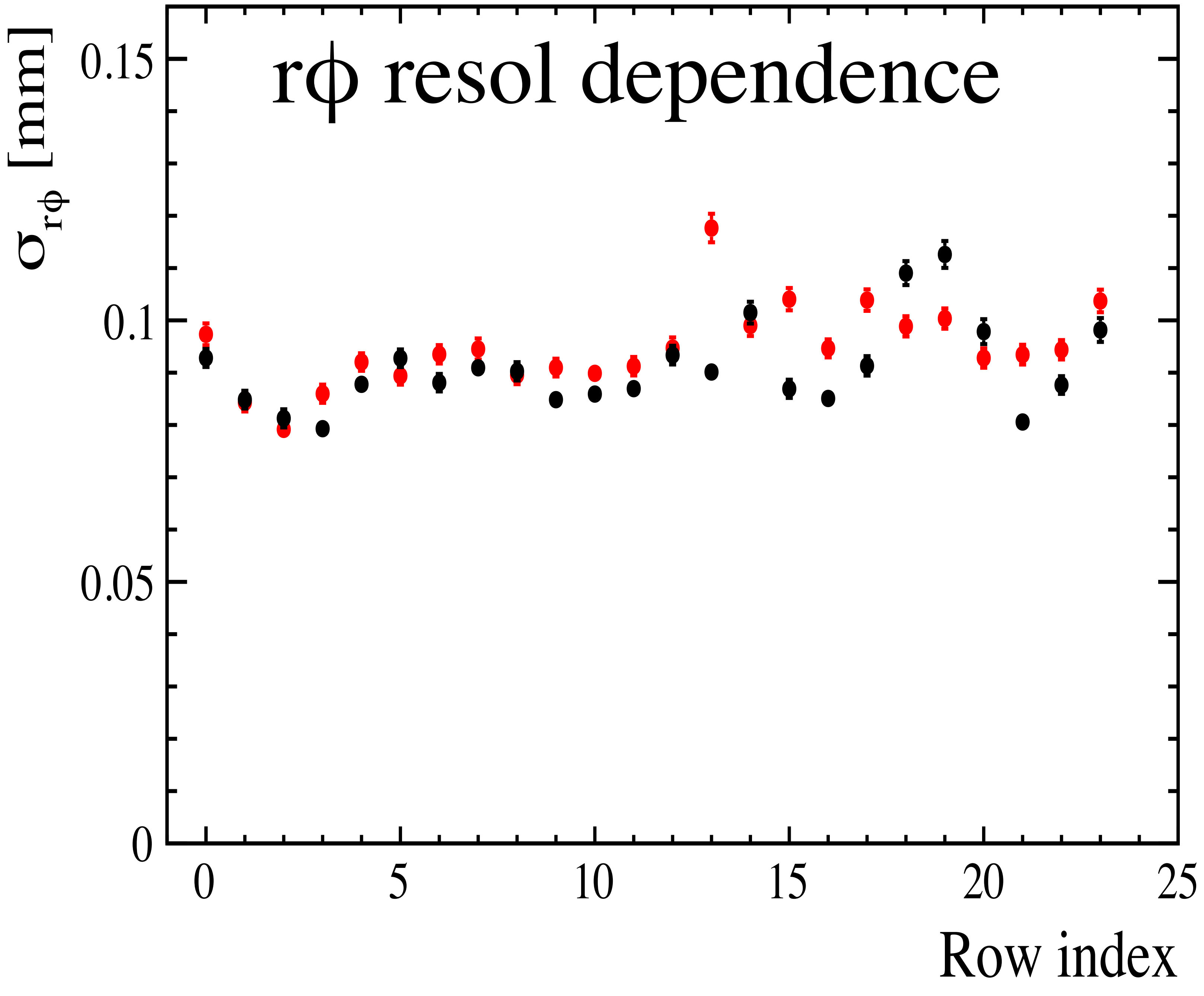
Uniformity of gain & point resolution over the modu

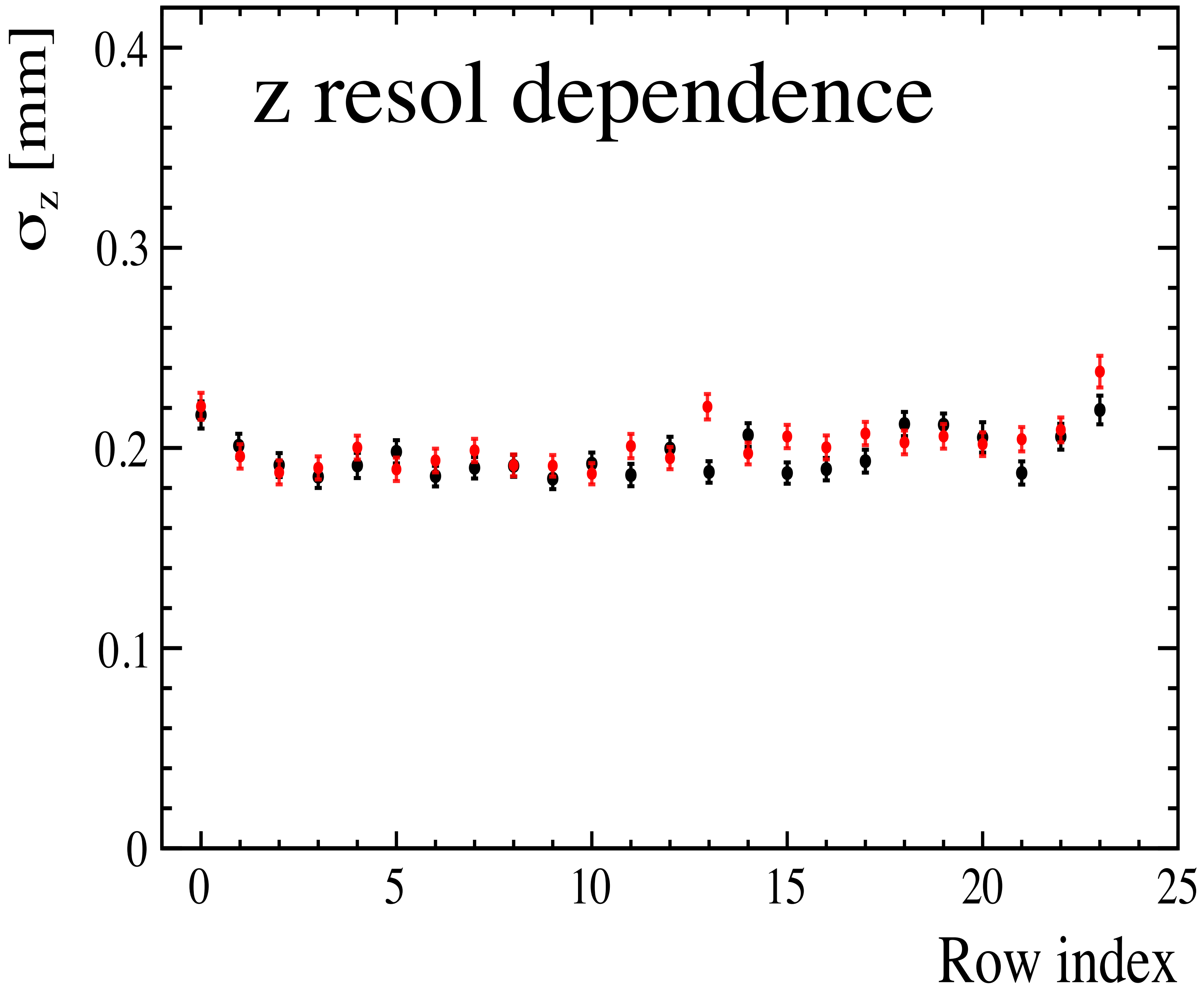
- Dependence along the row direction

Hit charge dependence









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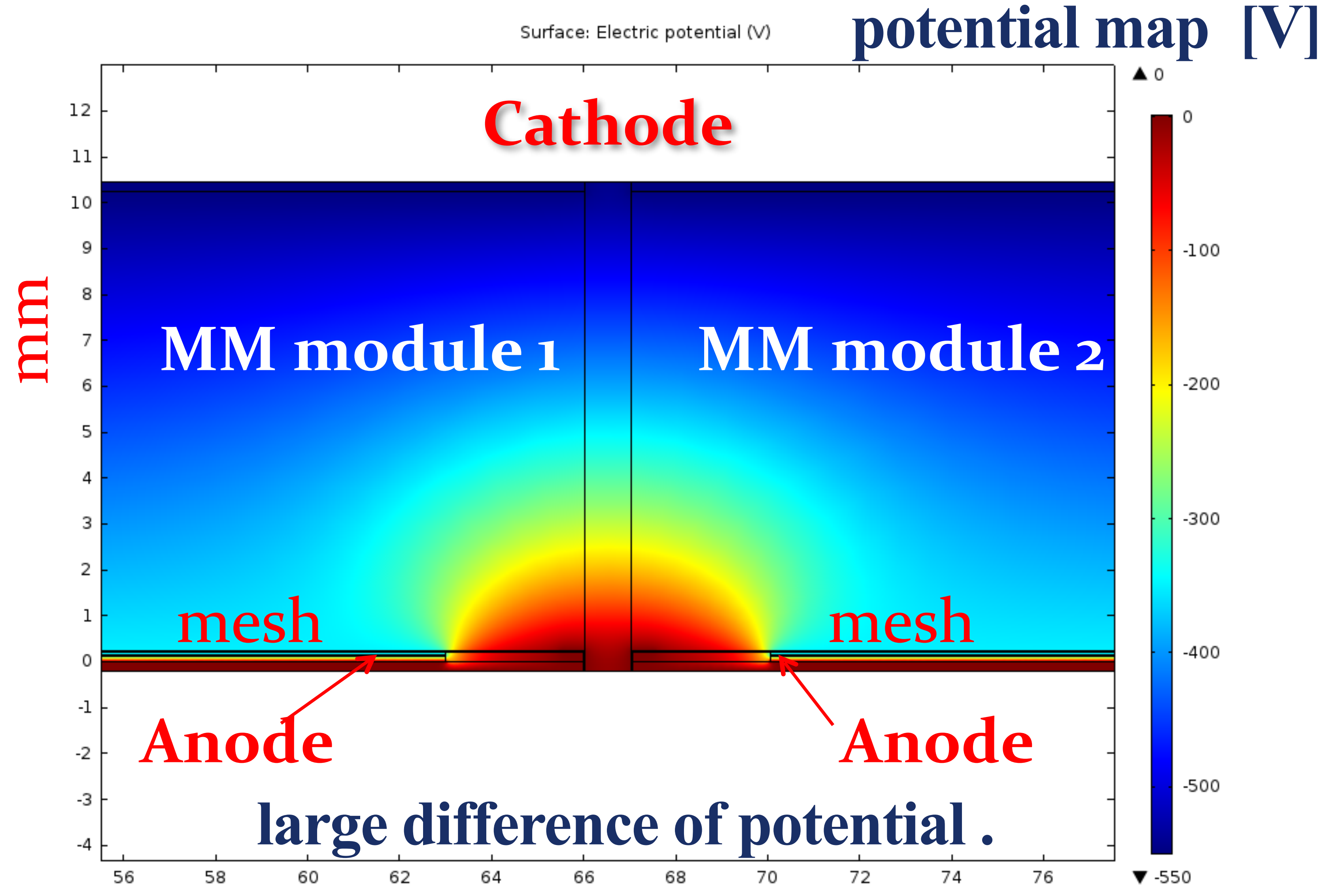
angle correction is not applied !

Track Distortions (2015 RA-MM beam test)

=> 150119_D.S.Bhattacharya_AperoSPP



The inhomogeneity of

the magnetic field (non-uniformity of material budget of magnet)

the electric field in the detector (the anode/ module gaps)

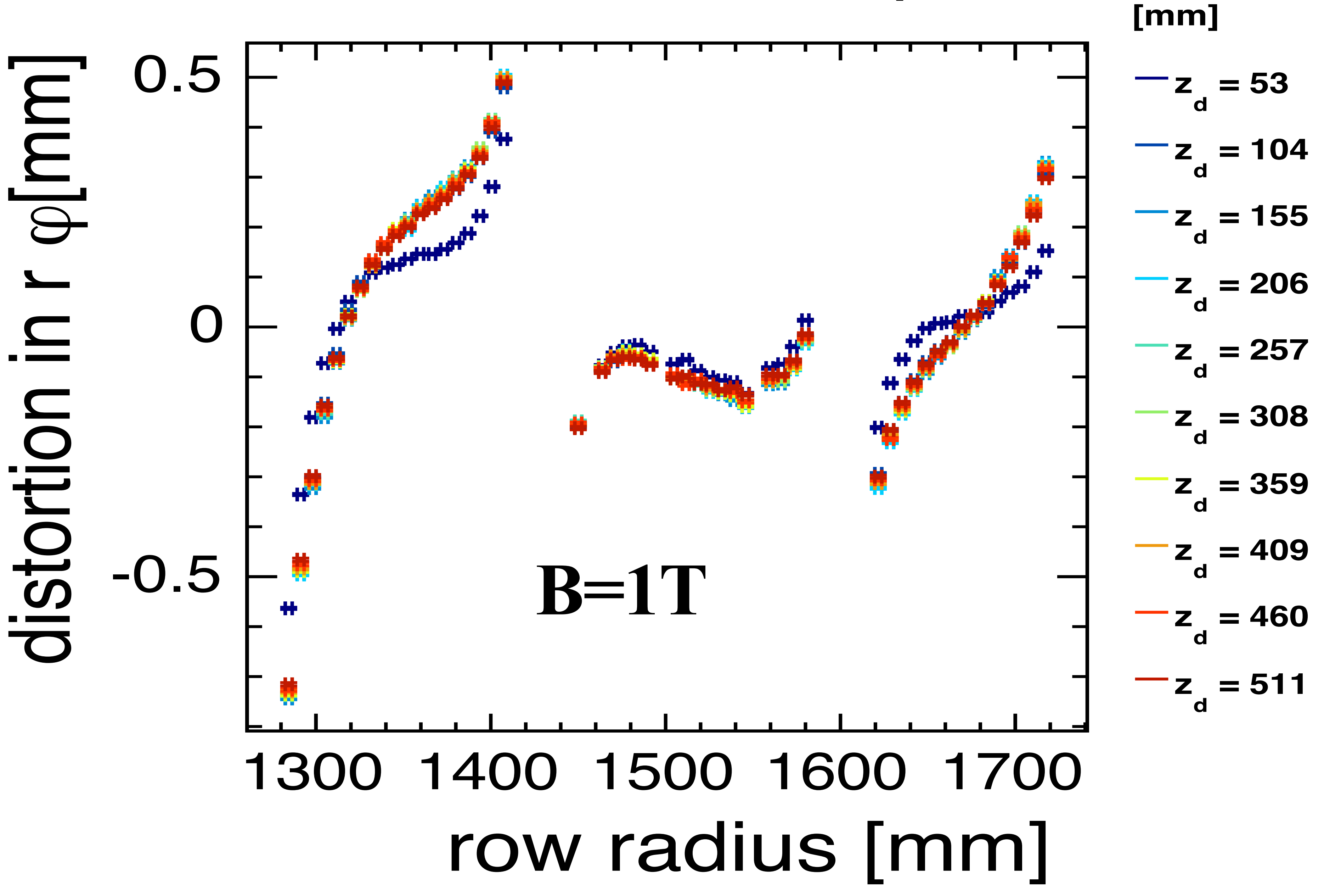
=> induce ExB effects

=> alter paths of drift electrons strongly.

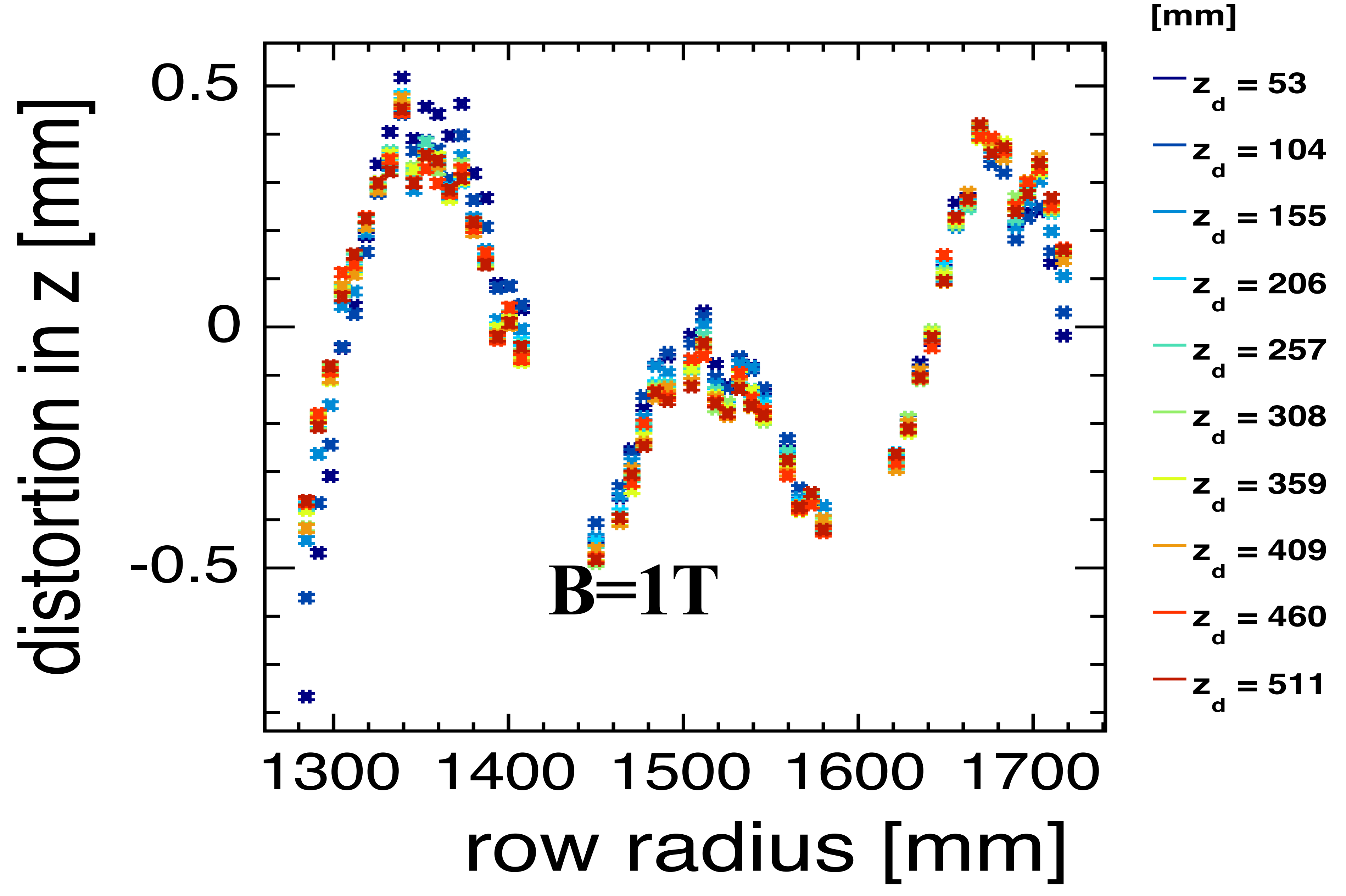
Big distortion between module boundaries ~ 1 mm

Systematic effect on position determination in each row is corrected

track distortion rφ



track distortion z

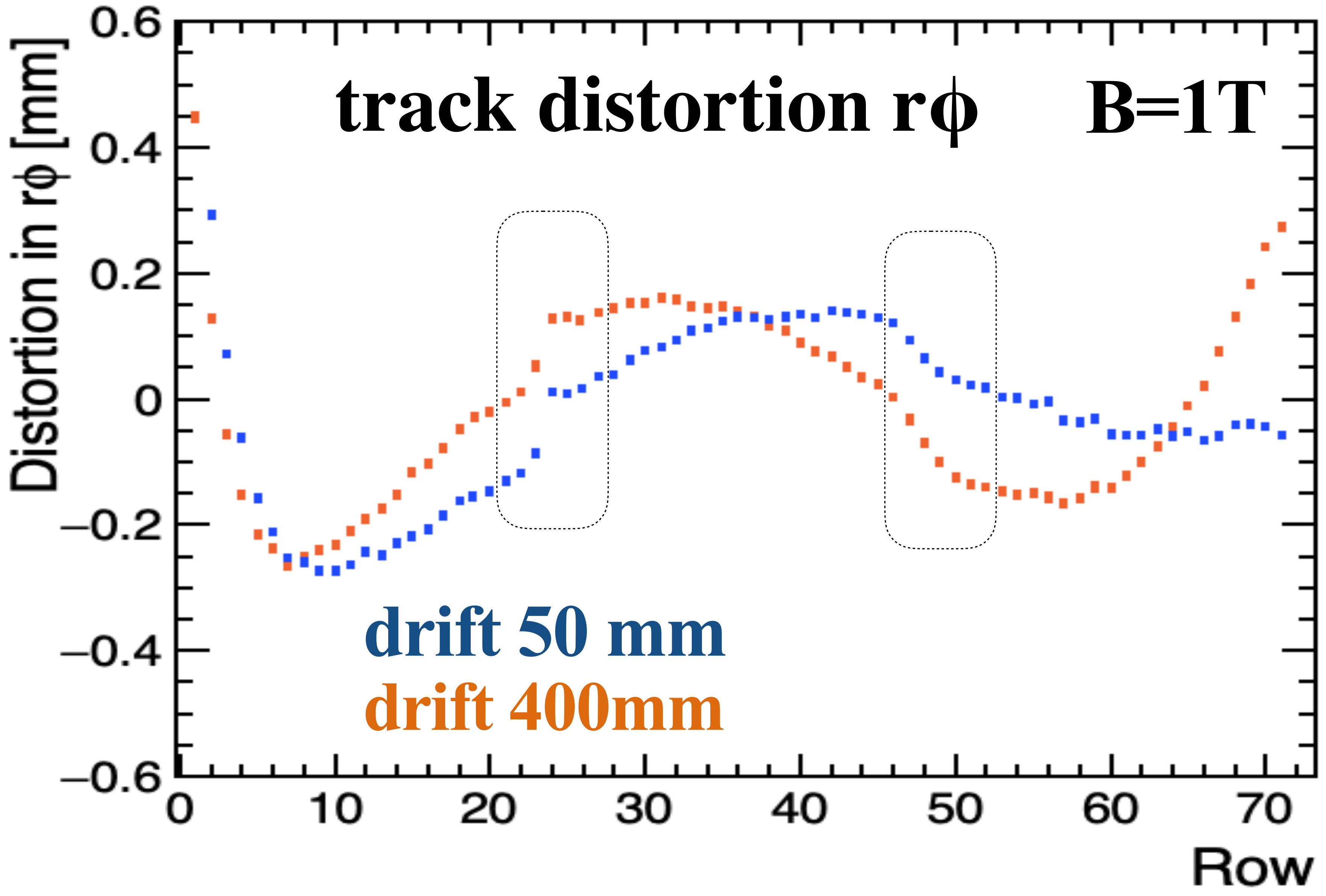


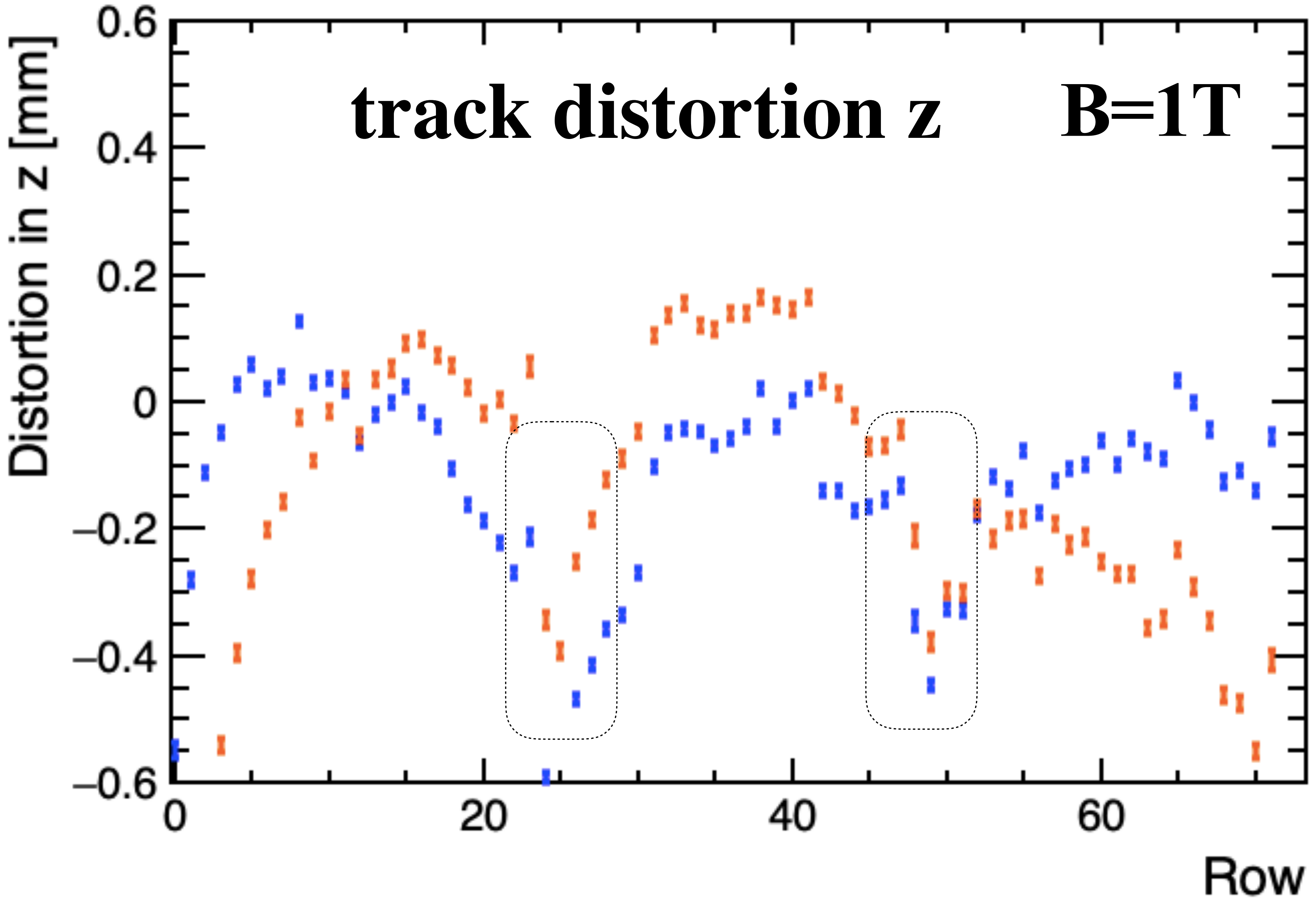
Track Distortions (2018 Encapsulated RA-MM)

2018 beam test data

same analysis condition

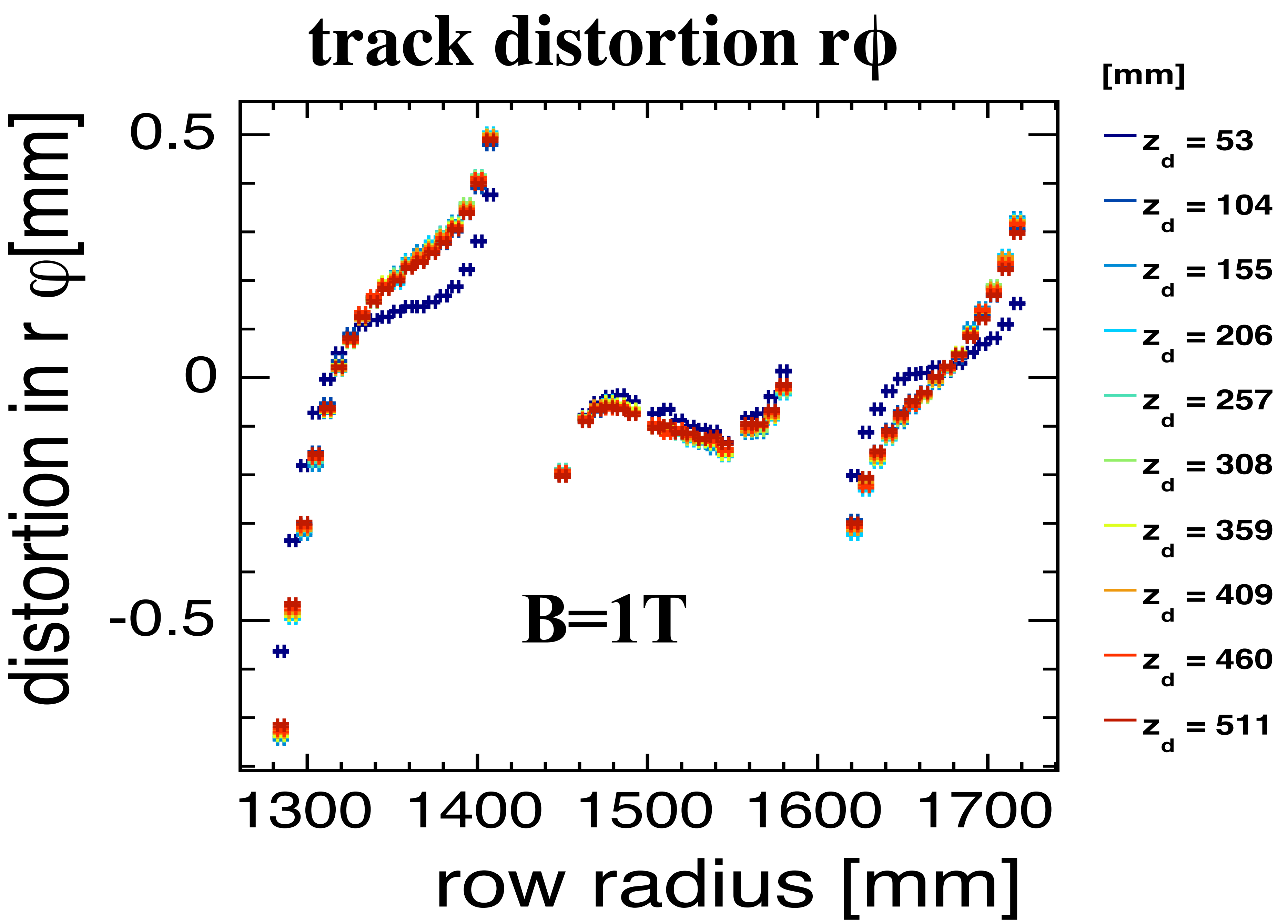
good connection between boundaries ! huge improvement !

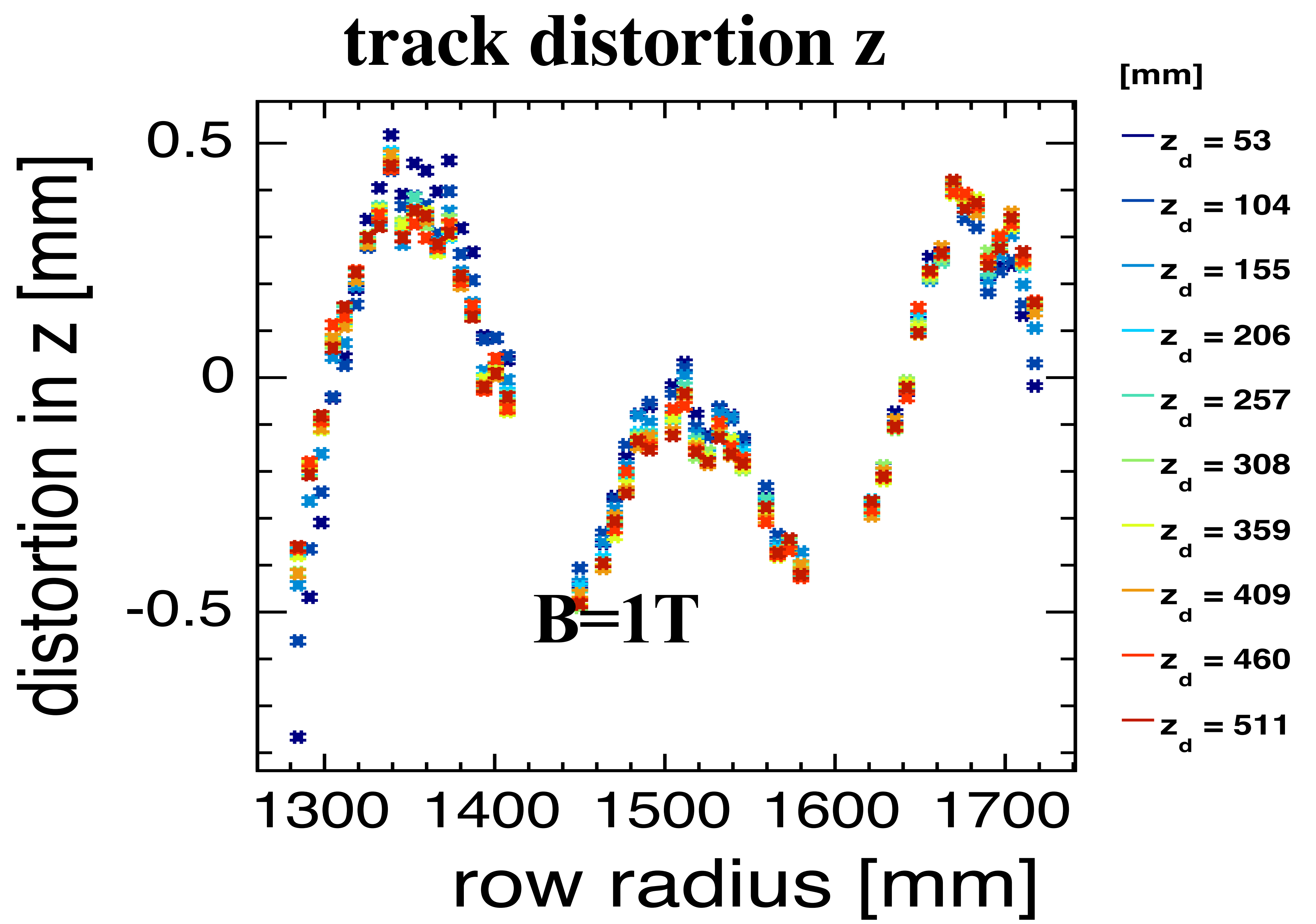




Big distortion between module boundaries ~1 mm

Systematic effect on position determination in each row is corrected





Summary for now

- **Performance test with the new high voltage scheme was tested**
  @ test beam campaign in DESY during 13/Nov ~ 28/Nov
  for the shielding electronics, mitigation of the track distortions
  and flexibility of the HV settings.
- **4 detectors were almost perfectly working with the small noise contribution**
  and without any gain drop due to micro discharges (for physics runs) .
- The structure is observed on the uniformity of the hit charge distribution.
  This is non-uniformity of the resistive-anode, or other reason? under investigation…
- **Huge improvement was observed for the track distortions as expected**
- **Analysis was just started !**

See you next time …

hopefully, for ILC-TPC development

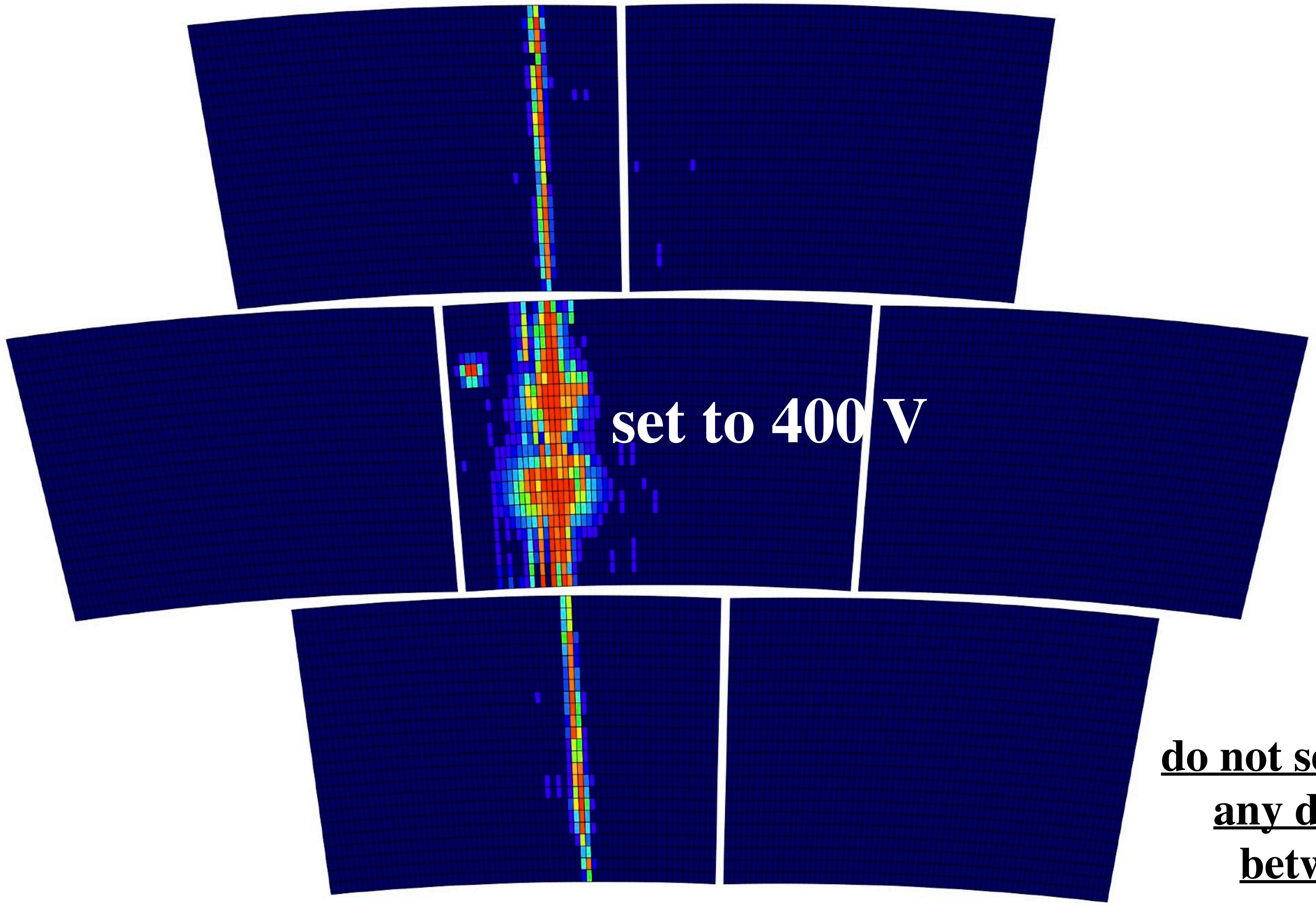
Track Distortions (2018 Encapsulated RA-MM)

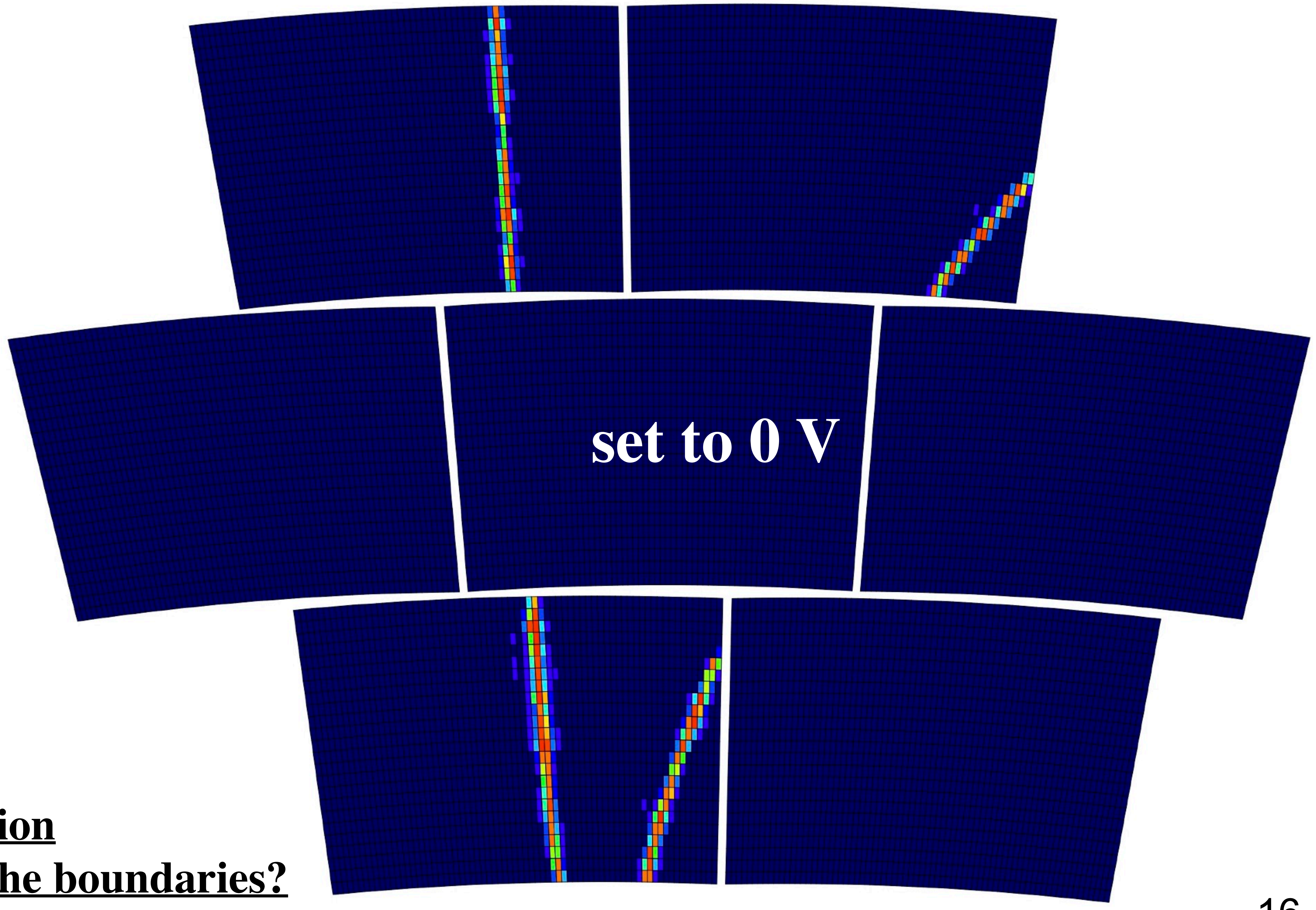
H.V of the center module was altered or killed (set to 0 V)

to make sure how large distortion appear => large difference of potential is created.

(center module is set to 340V ~ 400V and 0V, drift distance 50 mm)

<u>The other modules are set to 380V</u>





<u>do not see any distortion between the boundaries?</u>

Track Distortions (2018 Encapsulated RA-MM)

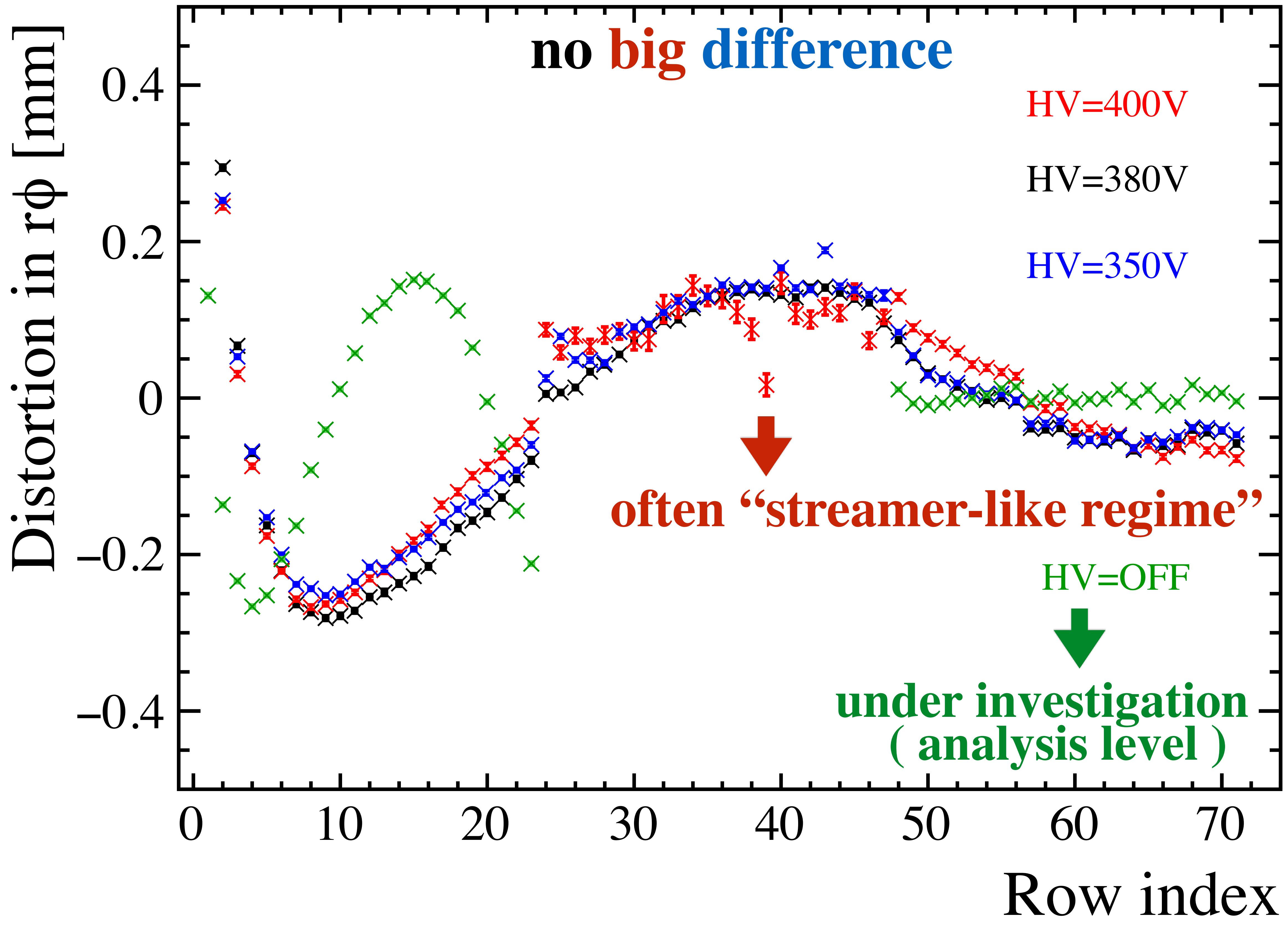
H.V of the center module was altered or killed (set to 0 V)

to make sure how large distortion appear => large difference of potential is created.

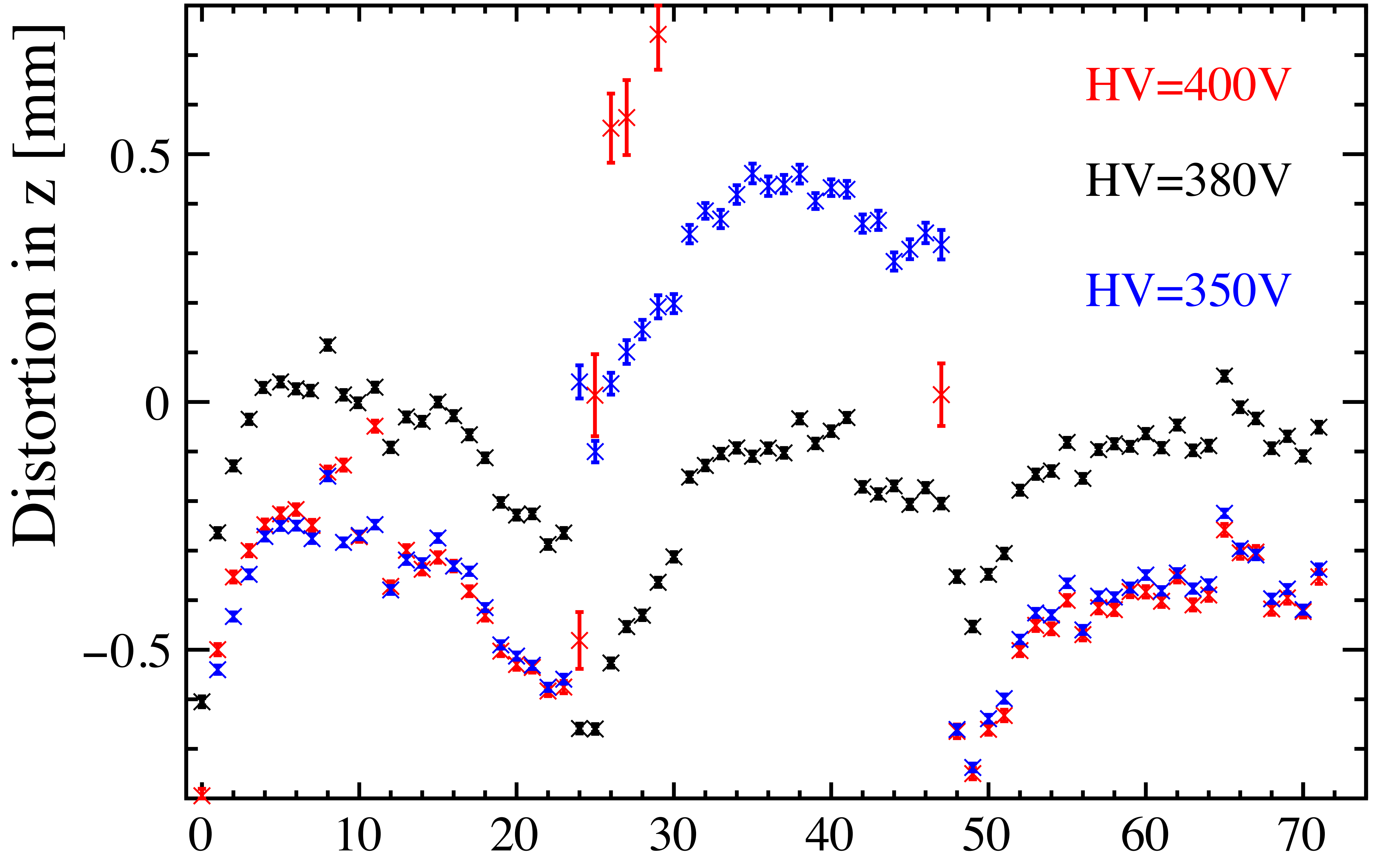
(center module is set to 340V ~ 400V and 0V, drift distance 50 mm)

<u>The other modules are set to 380V</u>

track distortion rφ



track distortion z



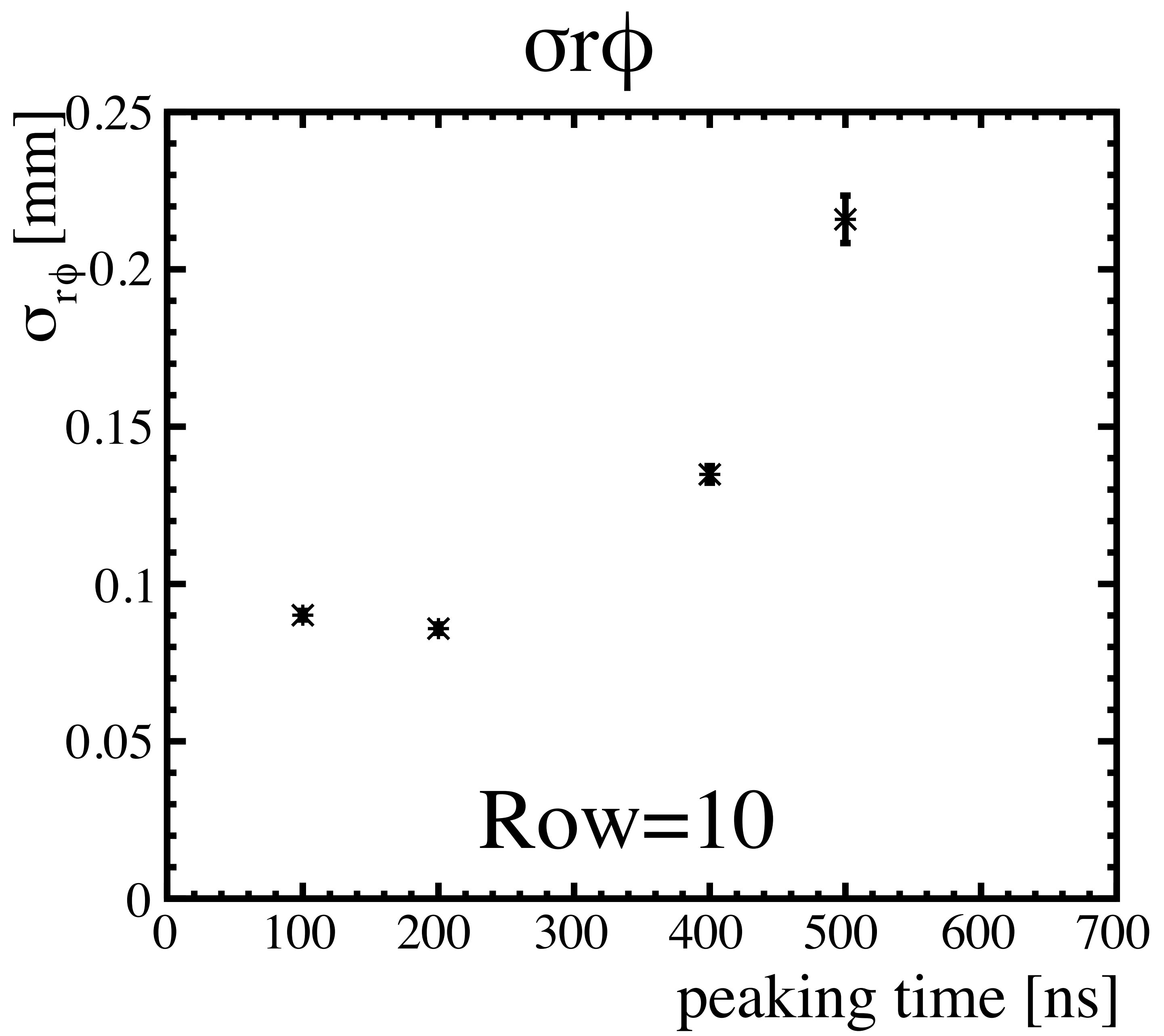
streamer-like regime, time estimation × ?

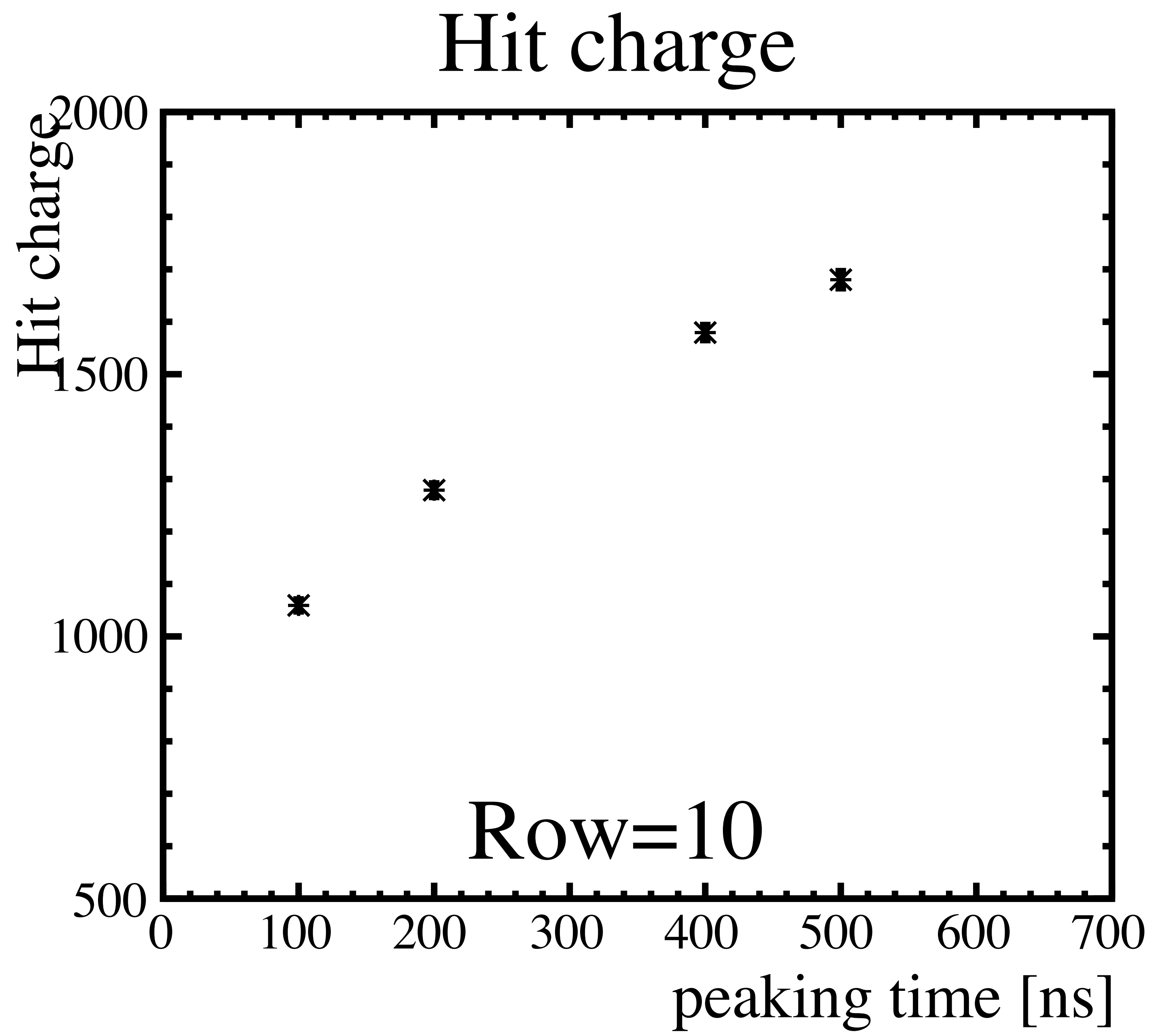
small signal, time estimation × ?

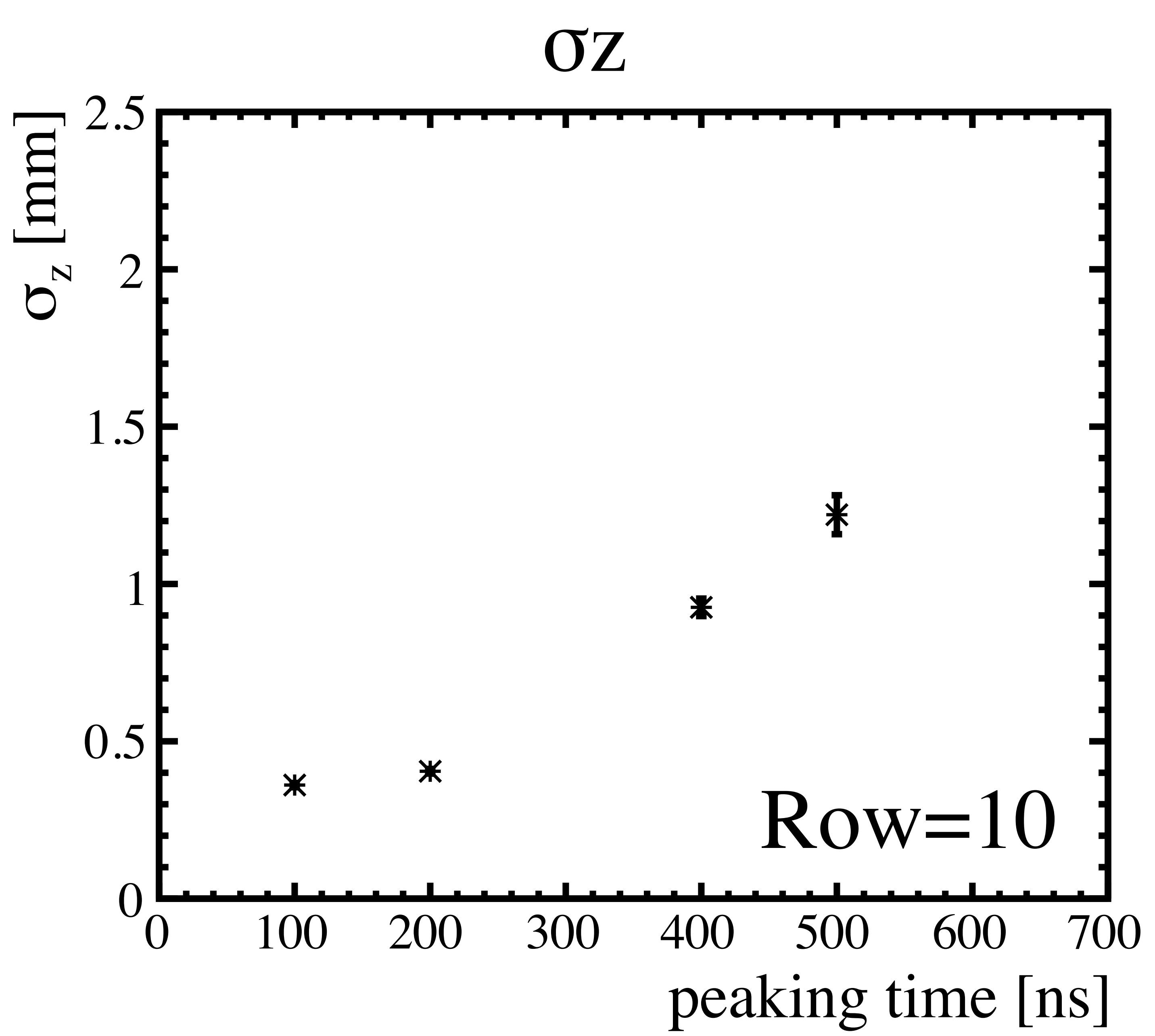
Peaking time scan (optimization)

`Drift length Z= 5 cm, B=1 T,  Ed=230V/cm`

Direct comparison is not easy due to different pulse shape
it is necessary to tune parameters for pulse finding …







σrφ : width of a $\Delta = x_{track} - x_{hit}$ distribution

σz : width of a $\Delta = z_{track} - z_{hit}$ distribution

Things to do

Gas condition :   drift velocity , diffusion constant (not easy for transverse due to RA …)

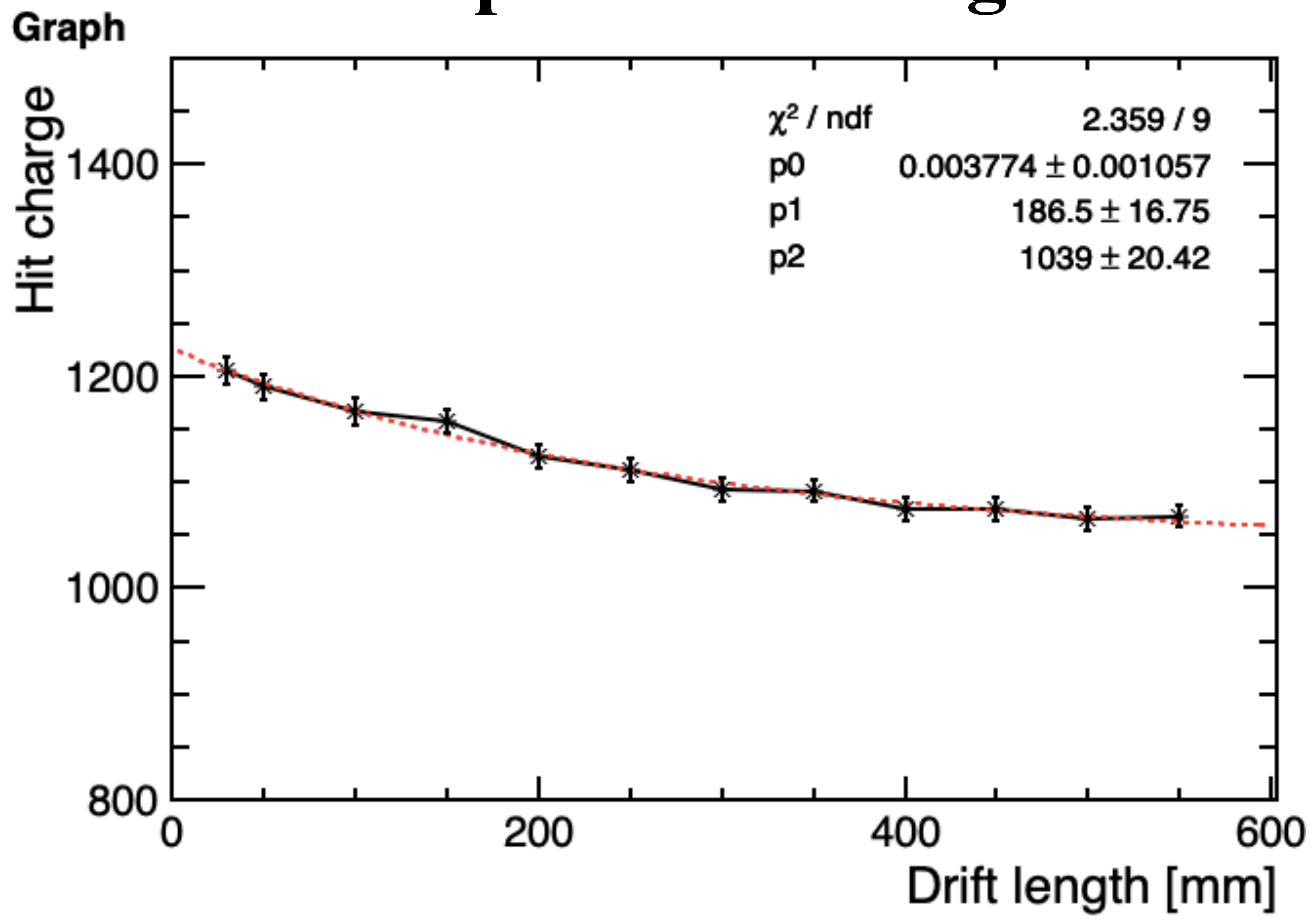
absorption of seed electrons …   phi angle dependence…

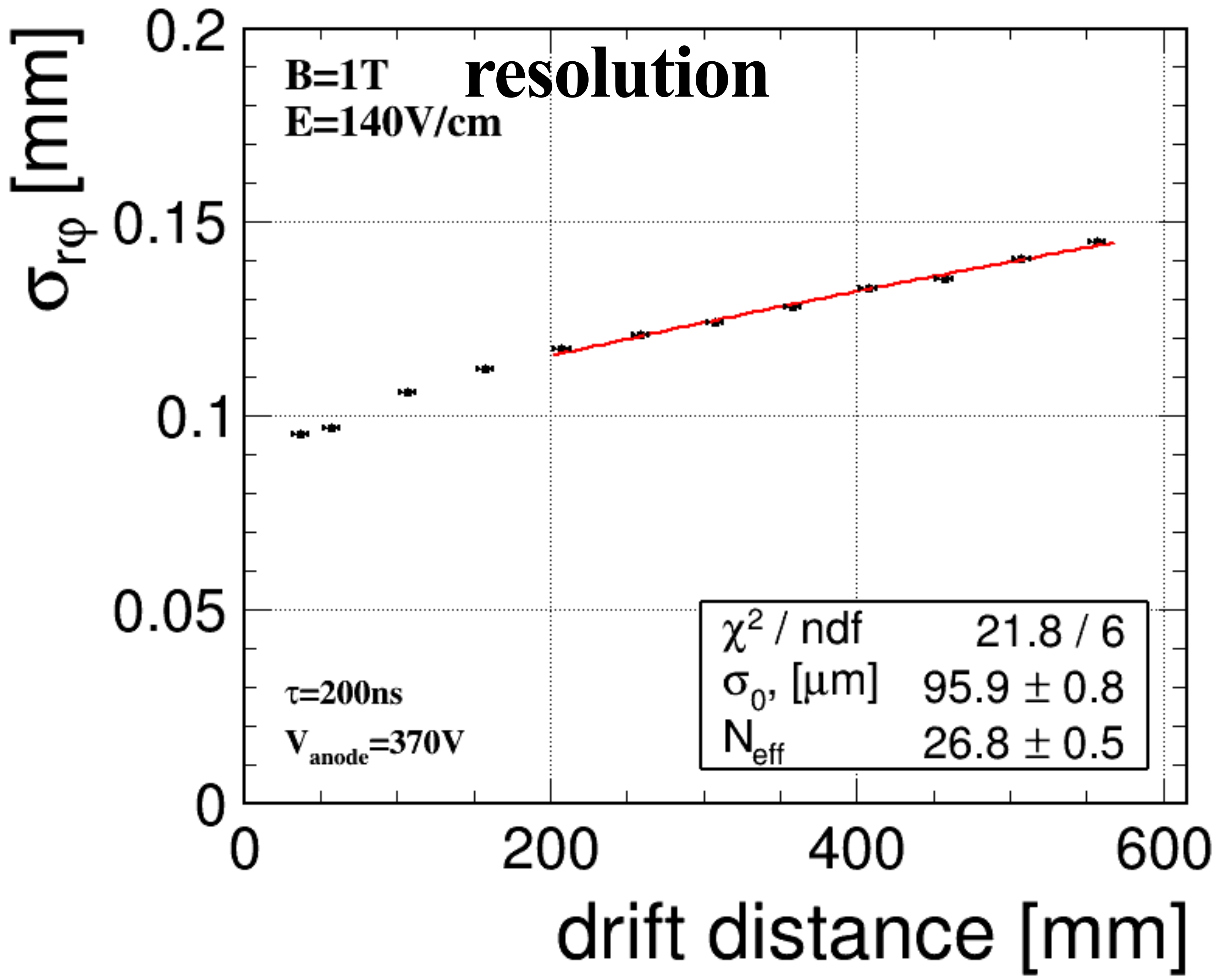
Resolutions , and Neff which is #of electrons associating to resolution

Uniformity for module boundary (upper 2 modules)

Alignment of the modules without B filed,   dependence of each module, systematics …

Absorption Hit charge

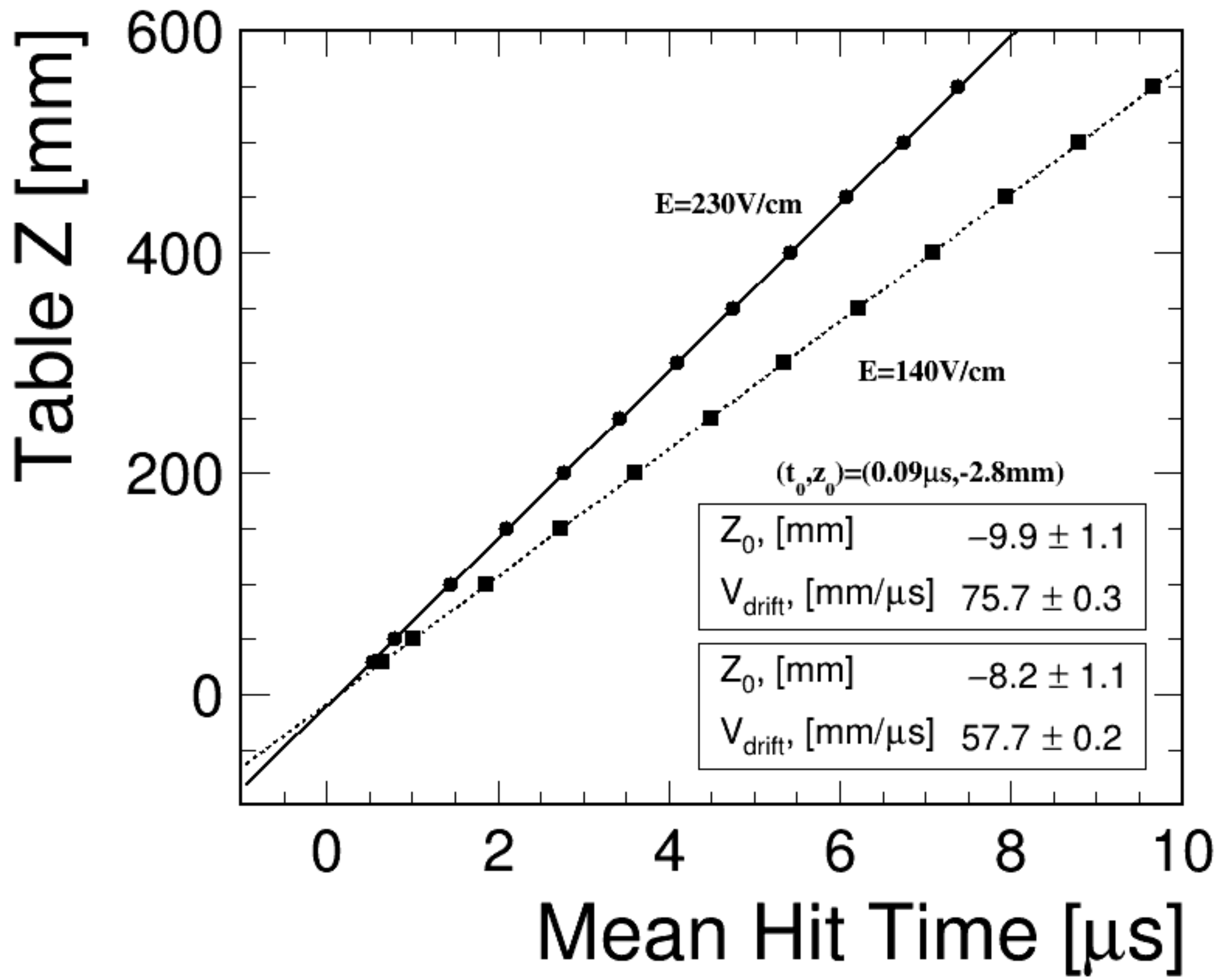


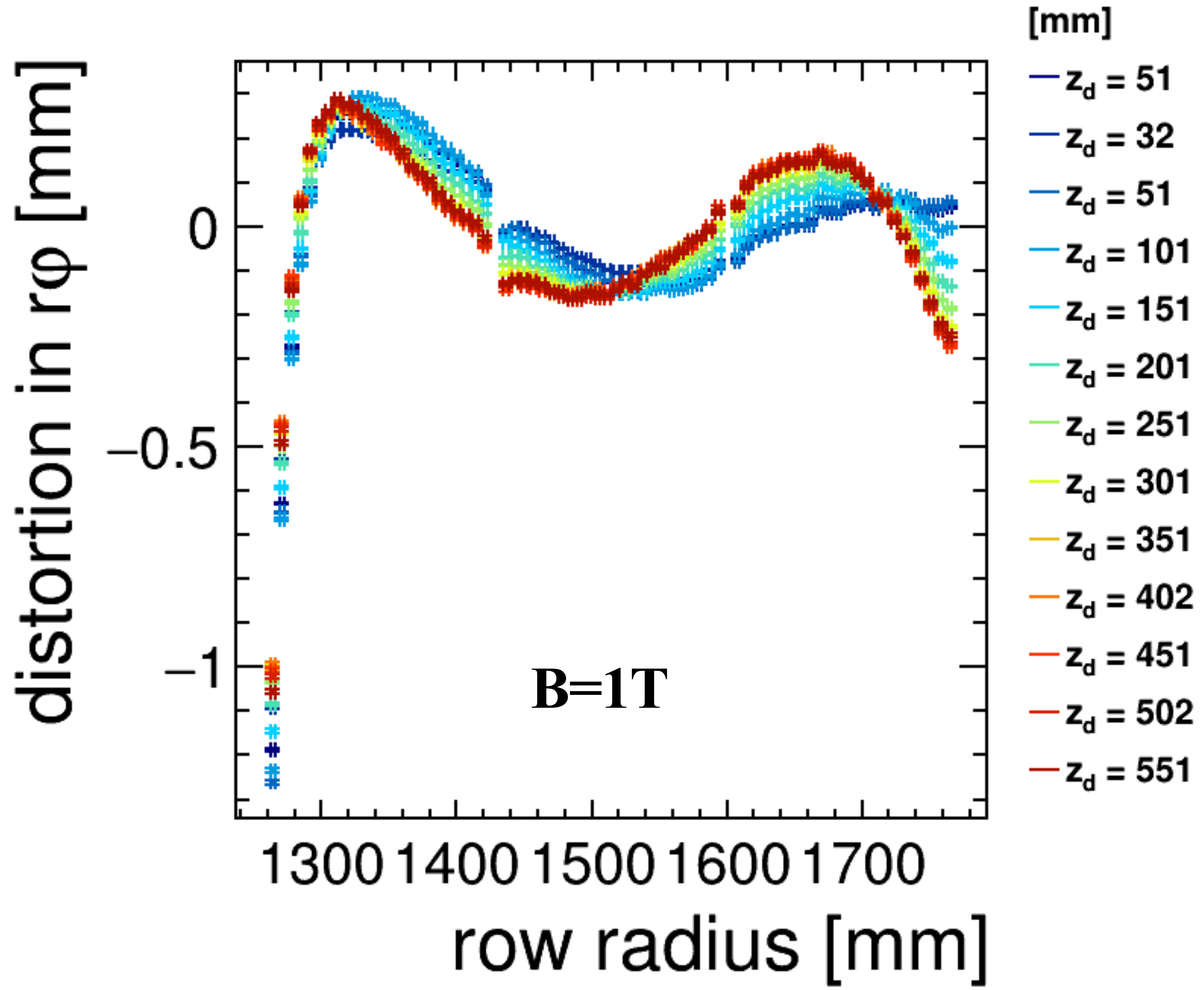


module difference

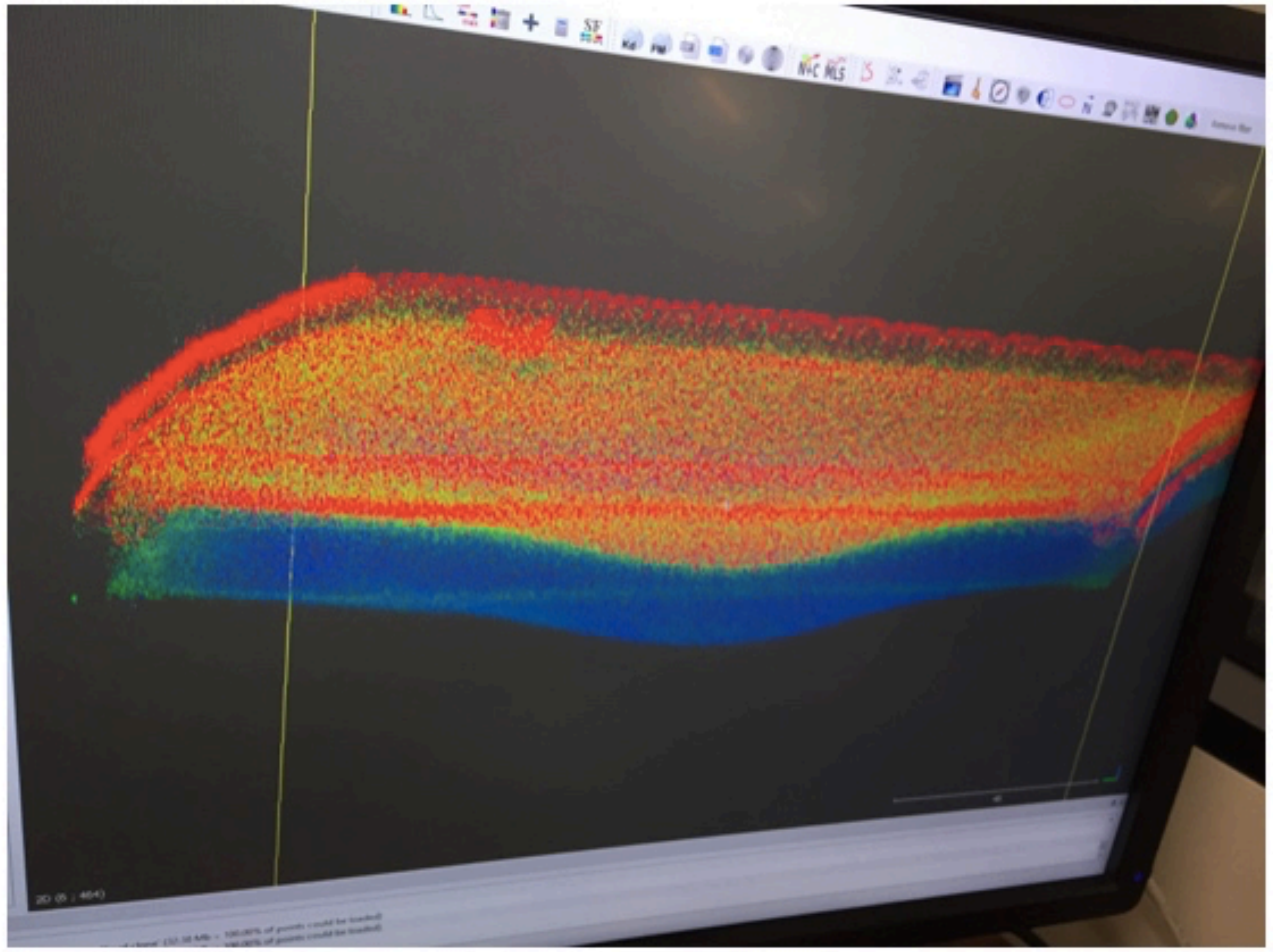
T0 (Z0) determination and drift velocities

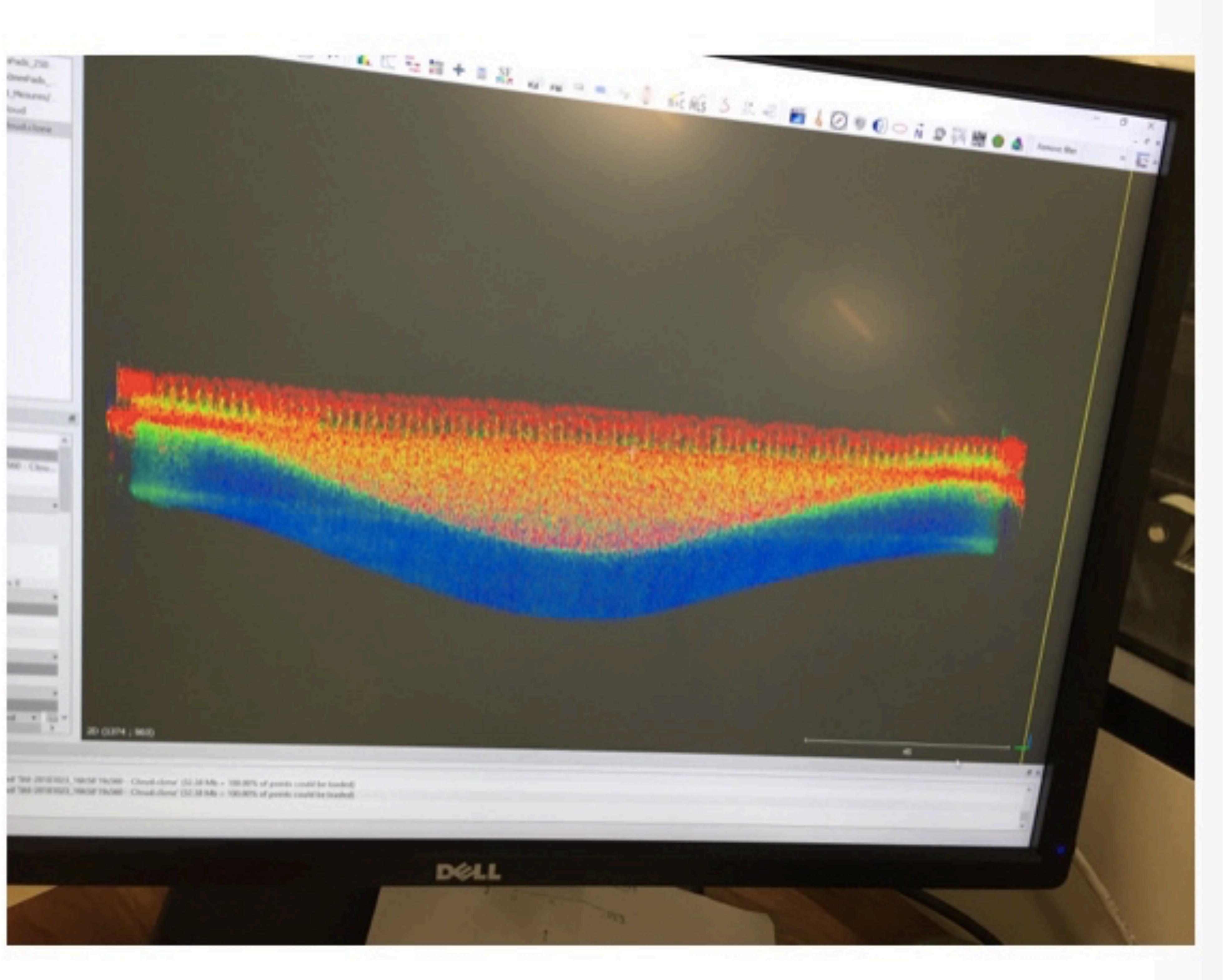
	E=140 V/cm	E=230 V/cm
V_d Magboltz	$57.9 \pm 1.0\mu m/ns$	$75.5 \pm 1.0\mu m/ns$
$D_\perp$ Magboltz	$74.5 \pm 2.5\mu m/\sqrt{cm}$	$94.8 \pm 3.1\mu m/\sqrt{cm}$



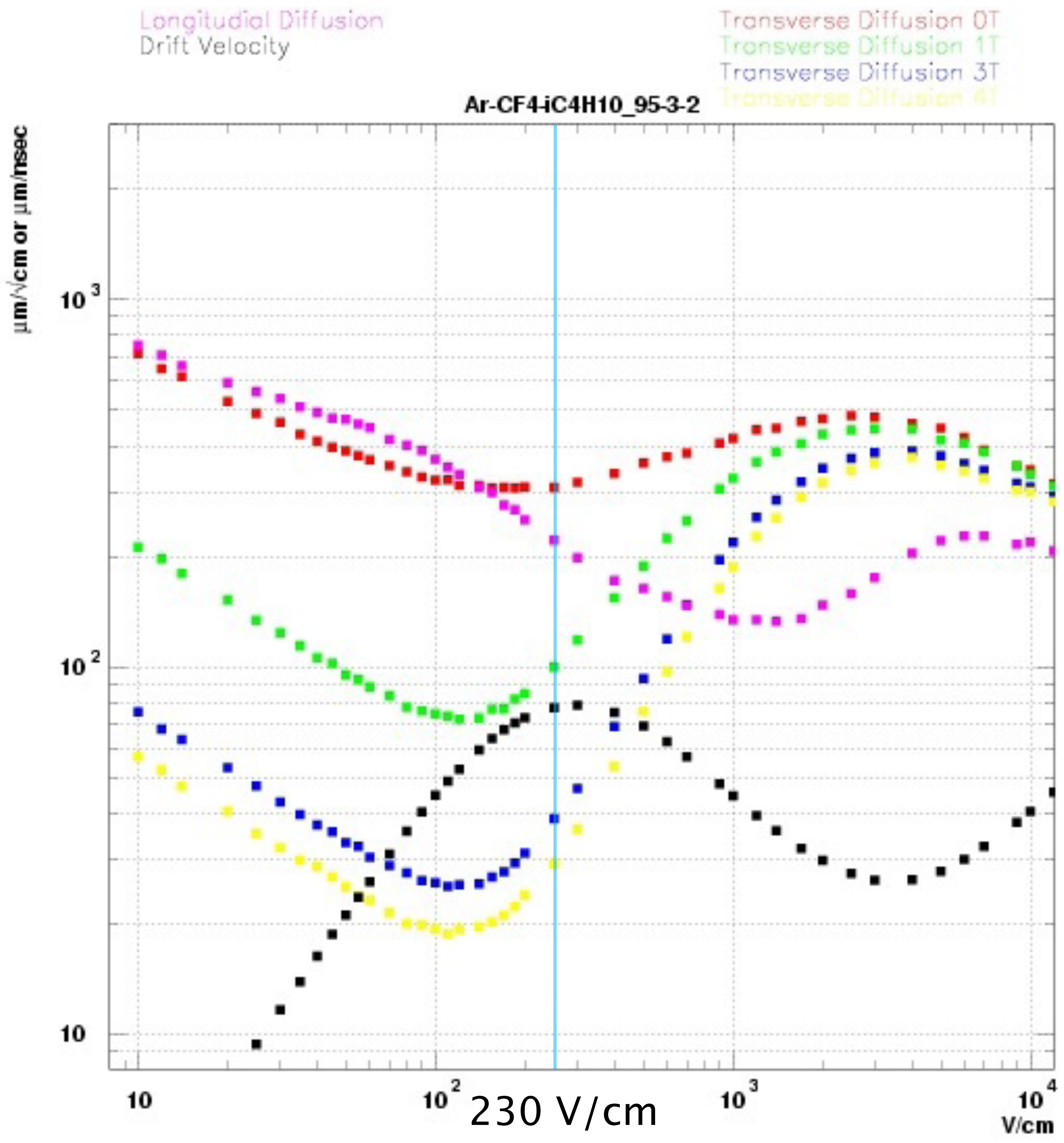


Geometry scan (old module)





Drift velocity and diffusion (T2K gas)



If we require the azimuthal resolution of 100 µm at z = 200 cm the diffusion constant (D), which is essentially the only free (controllable) parameter depending on the choice of gas mixture, needs to be smaller than 30 µm/√cm.

The diffusion constant of drift electrons under the influence of an axial magnetic field (B) is given by $D(B) = D(B = 0)/\sqrt{1 + (\omega\tau)^2}$, where $\omega \equiv e \cdot B/m$, the electron cyclotron frequency, and τ is the mean free time of drift electrons between collisions with gas molecules. Therefore we need a gas mixture in which $D(B = 0)$ is small (cool) and τ is fairly large (fast) under a moderate drift field (E)!

- The diffusion constant D is related to the diffusion coefficient (D^*) through $D2 = 2D^*/W$, where W is the electron drift velocity.
- The electron drift velocity is given by $W = e \cdot E/m \cdot \tau$ with e (m) being the electron charge (mass). A large value of τ, therefore, means a fast gas.

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