Track distortion in a Micromegas-based Large Prototype TPC for the ILC

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One of the two detector concepts for the ILC is the 'International Large Detector' (ILD).

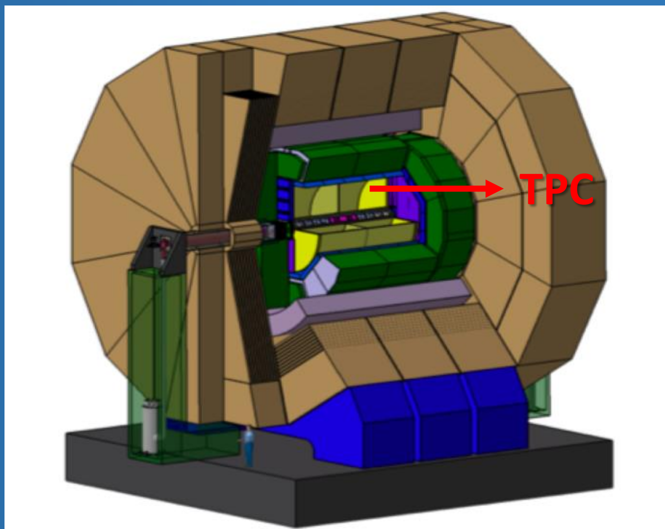
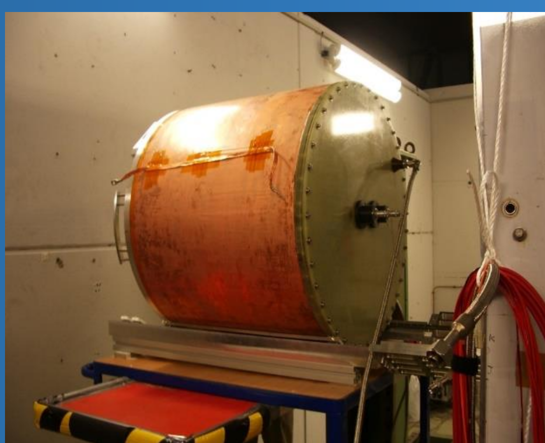


Figure 2: A schematic view of the International Large Detector concept (the TPC is the yellow cylinder inside the blue electromagnetic calorimeter).

The central tracking at the ILD will be based on a large TPC.

A Large Prototype of the ILD-TPC is installed at DESY to test different MPGD technologies.

The movable stage and the PCMAG.



The field cage of LPTPC

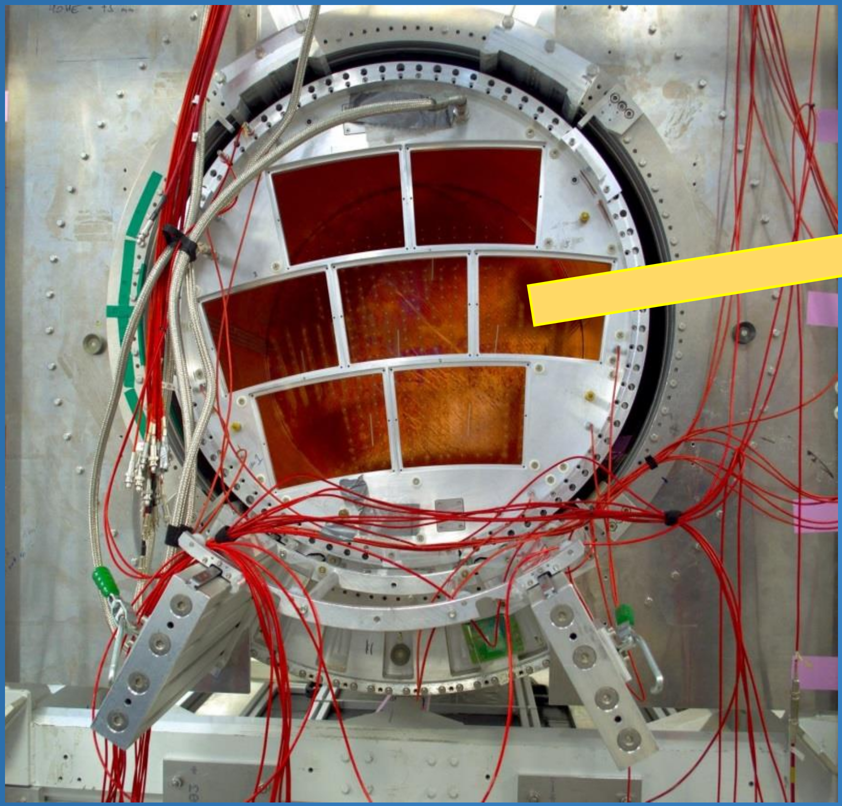
The field cage of the LPTPC

Drift length = 56.80 cm

Inner diameter = 72 cm

- **Electron beam of energy from 1 – 6 GeV**
- **Under a magnetic field of 1 T.**

Micromegas at the LPTPC



End-plate of the LPTPC

Seven Micromegas modules are commissioned at the LPTPC.

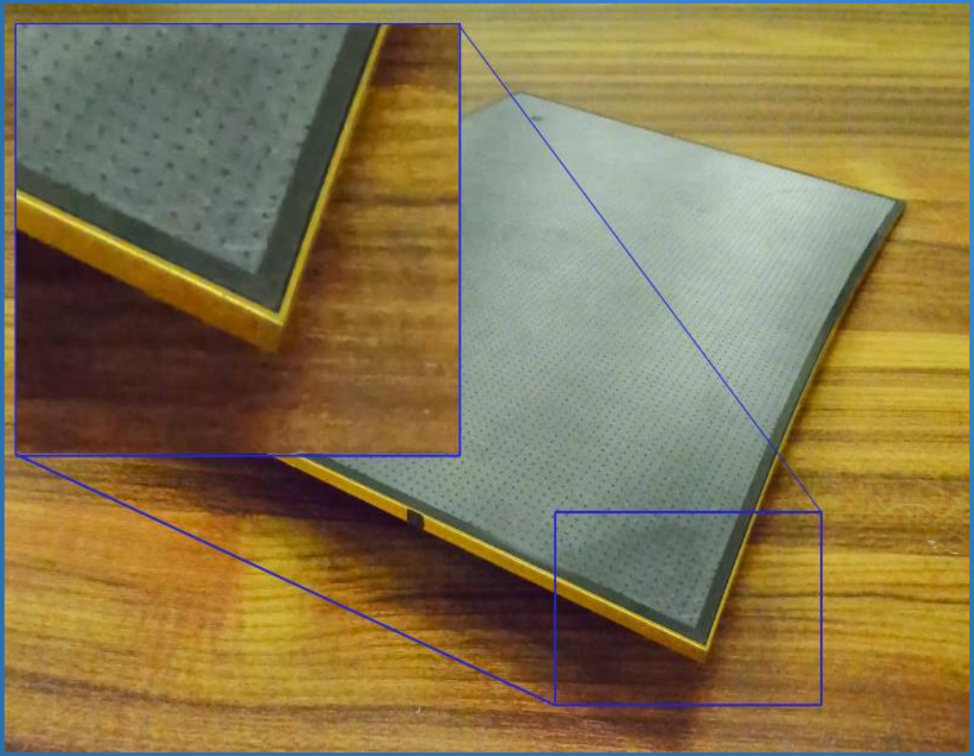
Micromegas module

- Module size: 22 cm × 17 cm
- Readout: 1728 Pads
- 24 rows
- Pad size: ~ 3 mm × 7 mm

Two challenges in track reconstruction

- ❖ Misalignment between the modules.
- ❖ Electric field distortion near the edges of the modules.

Misalignment occurs during the installation of the modules at the LPTPC end-plate.



A copper frame supports the readout and rests very close to the micro-mesh.

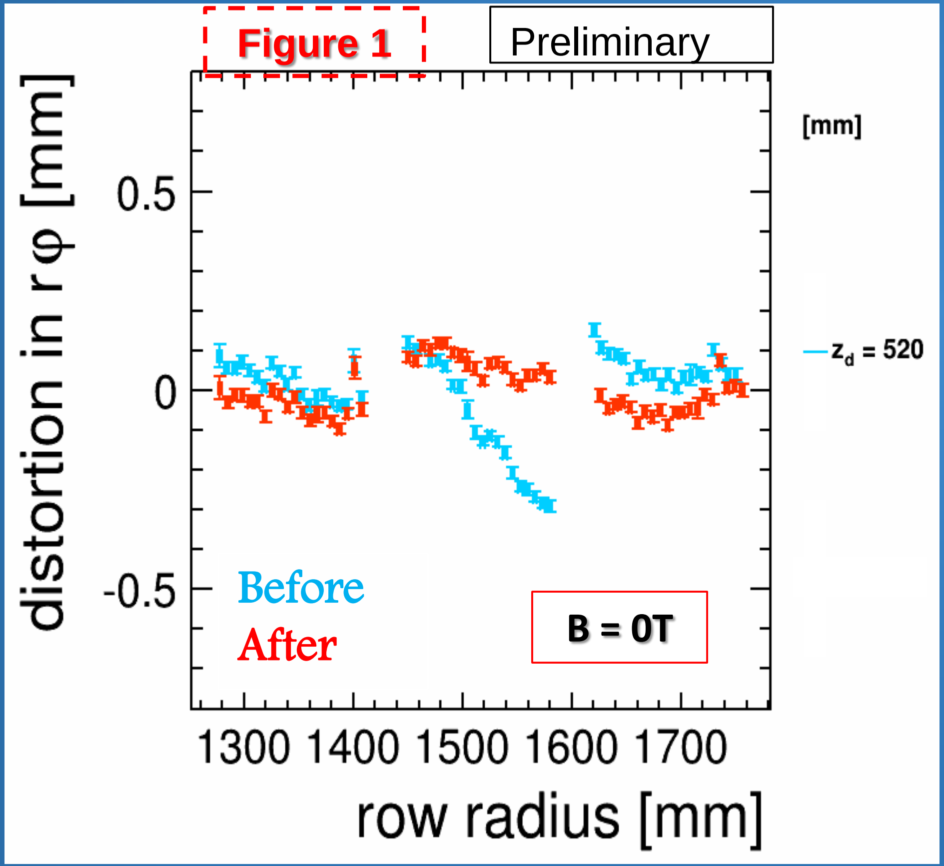
Since the frame is kept at ground potential, it introduces non-uniformity in the electric field near the edges of the modules at the vicinity of the anode plane.

The non-uniform electric field influences pad-hits.

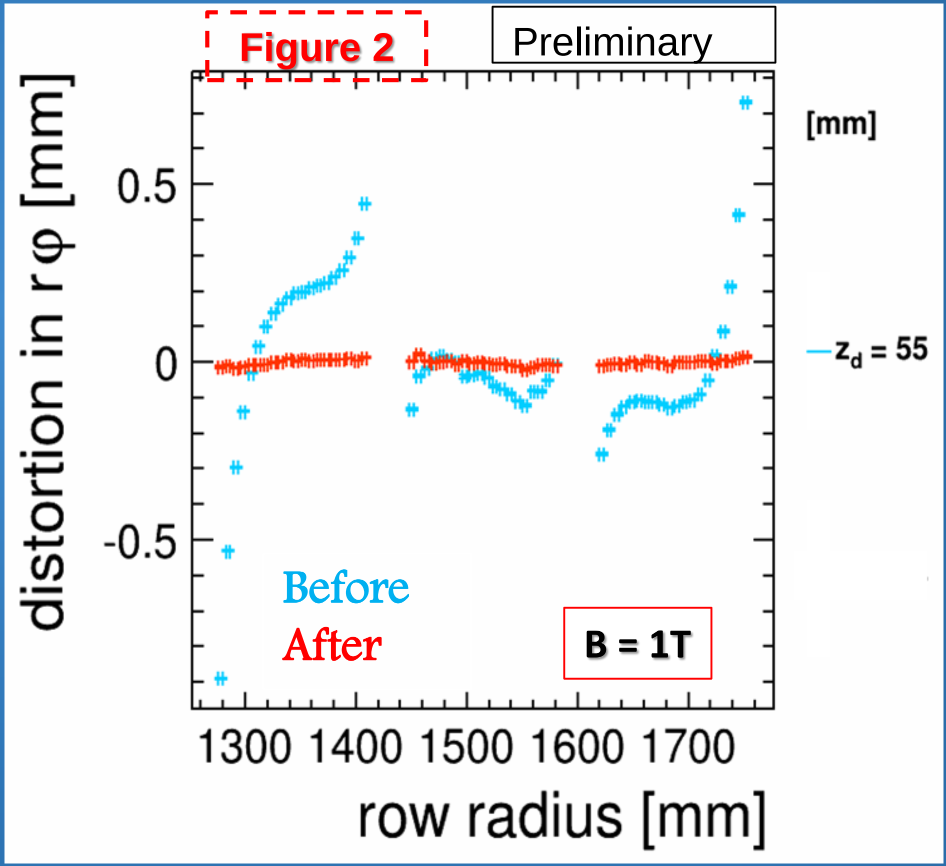
Two challenges in track reconstruction

✓ **Aalignment correction and Distortion correction are performed during analysis**

residual, $\Delta = X_{hit} - X_{track}$



Before and after *Alignment* correction

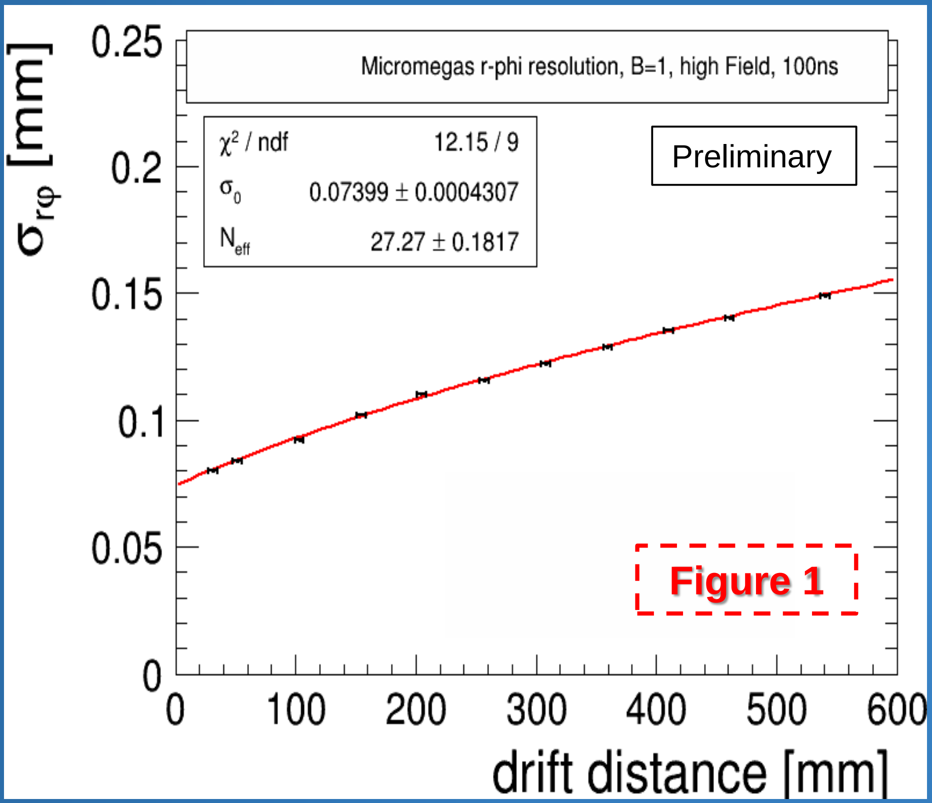


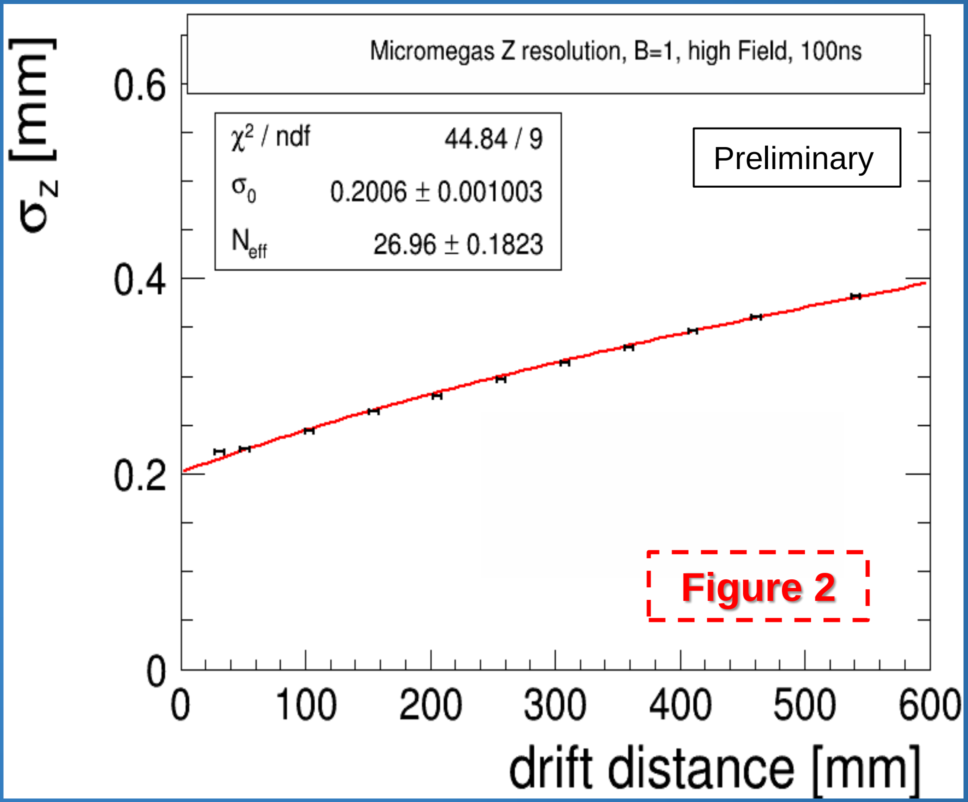
Before and after *Distortion* correction

Analysis is done in MarlinTPC frame work.

Resolutions of Micromegas After Distortion Correction

B=1T, peaking time = 100 ns, E=230 V/cm, phi = 0





at 60 cm drift, r-phi resolution is below 150 μm for B = 1 T

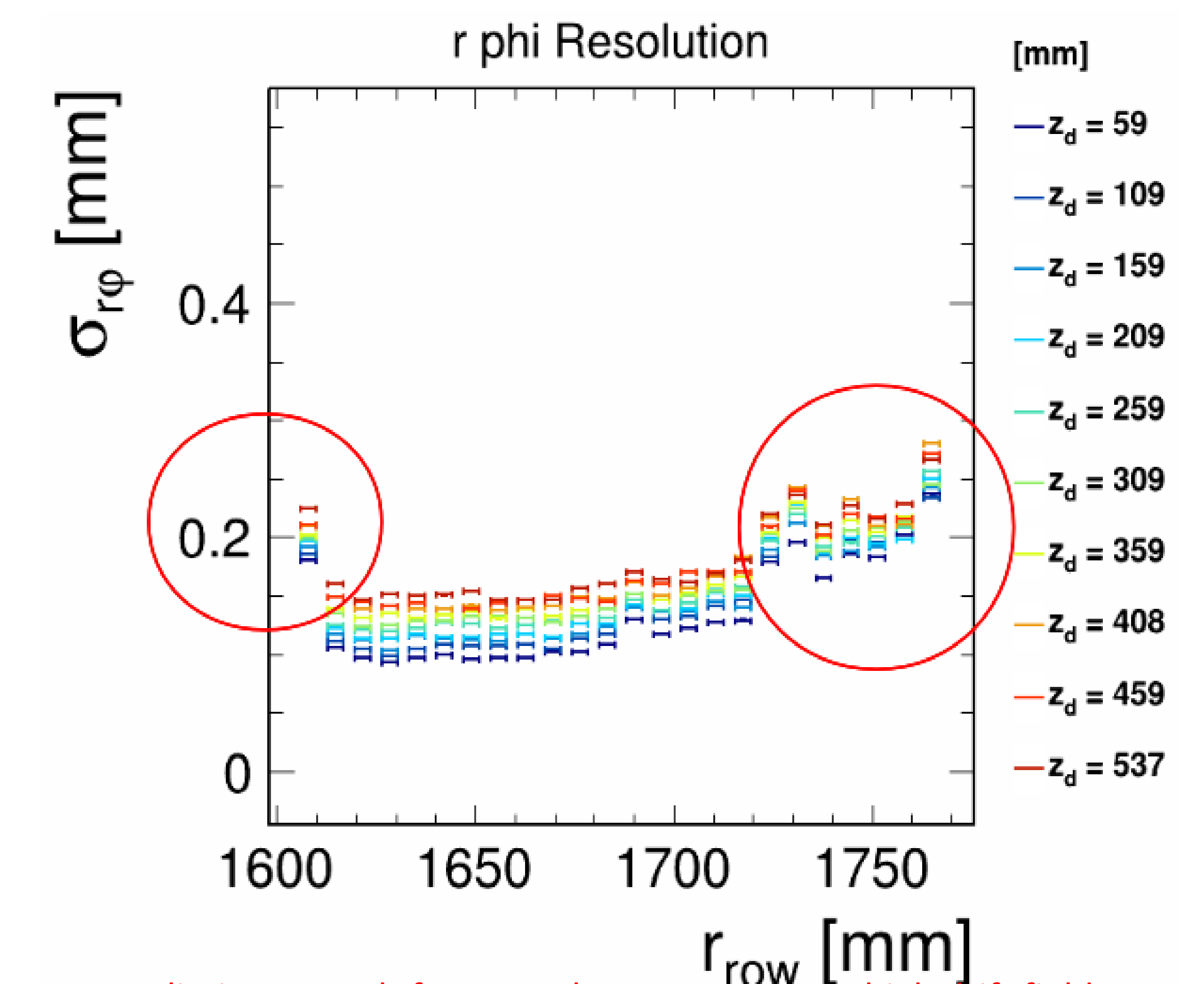
at 60 cm drift, Z resolution is below 0.4 mm for B = 1 T

Fit formula: $\sigma = \sqrt{\sigma_0{}^2 + \frac{C_d^2 \cdot z}{N_{eff}}}$

σ_0 : the resolution at Z=0
N_{eff} : the effective number of electrons

In 1 Tesla magnetic field, for ~ 60 cm drift length, the space resolution in r-phi and in z of Micromegas corresponds to ILC requirements over full drift length, for 3.5 T magnetic field.

without Distortion correction, the performance degrades



Preliminary result from Test beam 2015, B =1, high drift field.

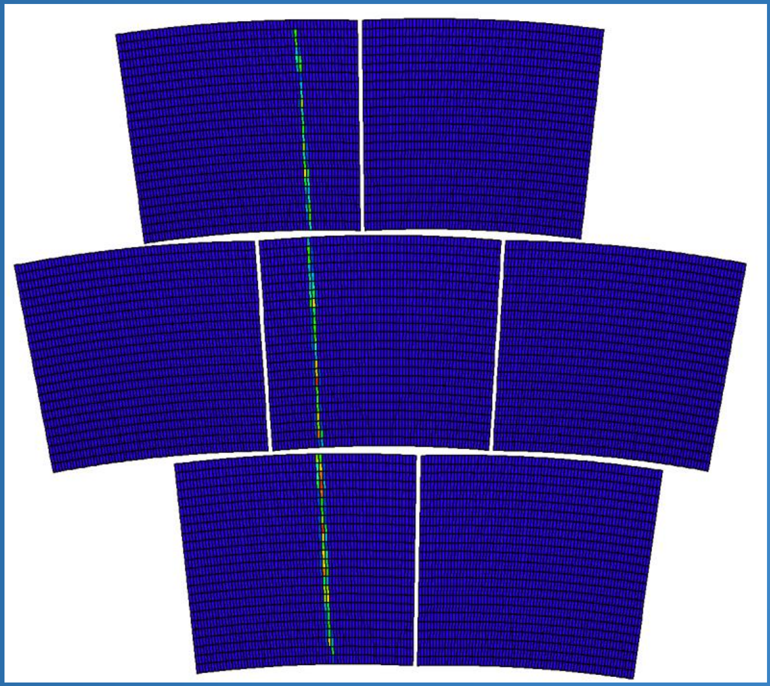
row-wise space resolution is plotted for a Micromegas module.
The colour band indicates different drift distances.

Resolution near the edge of the module can be seen to to have higher values.

Effect of distortion degrades the performance of the TPC.

Investigation on Track distortion by Numerical Methods

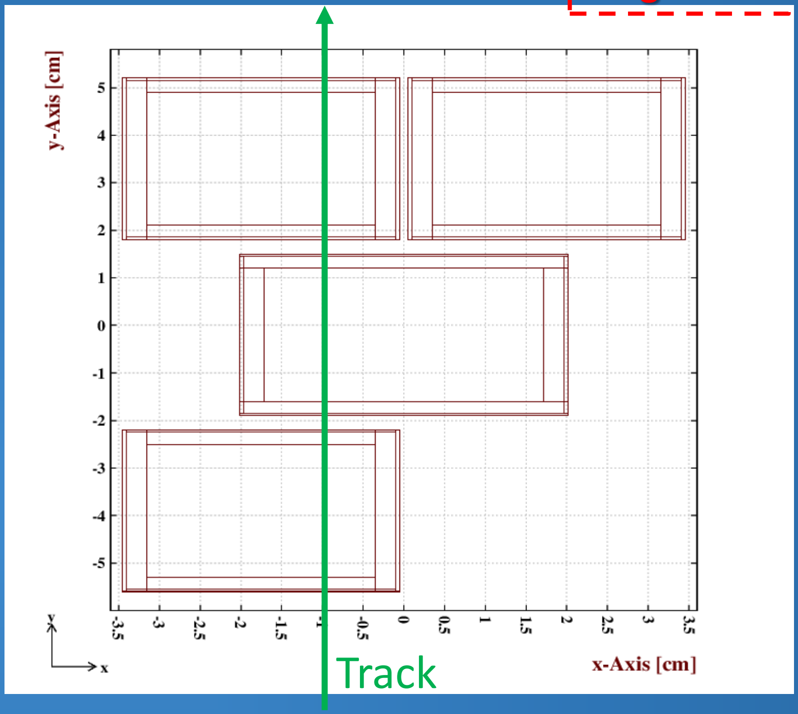
Figure 1



Micromegas modules on the **LPTPC endplate.**

Module size: 17 cm × 22 cm.
Reference frame is in r-phi system.

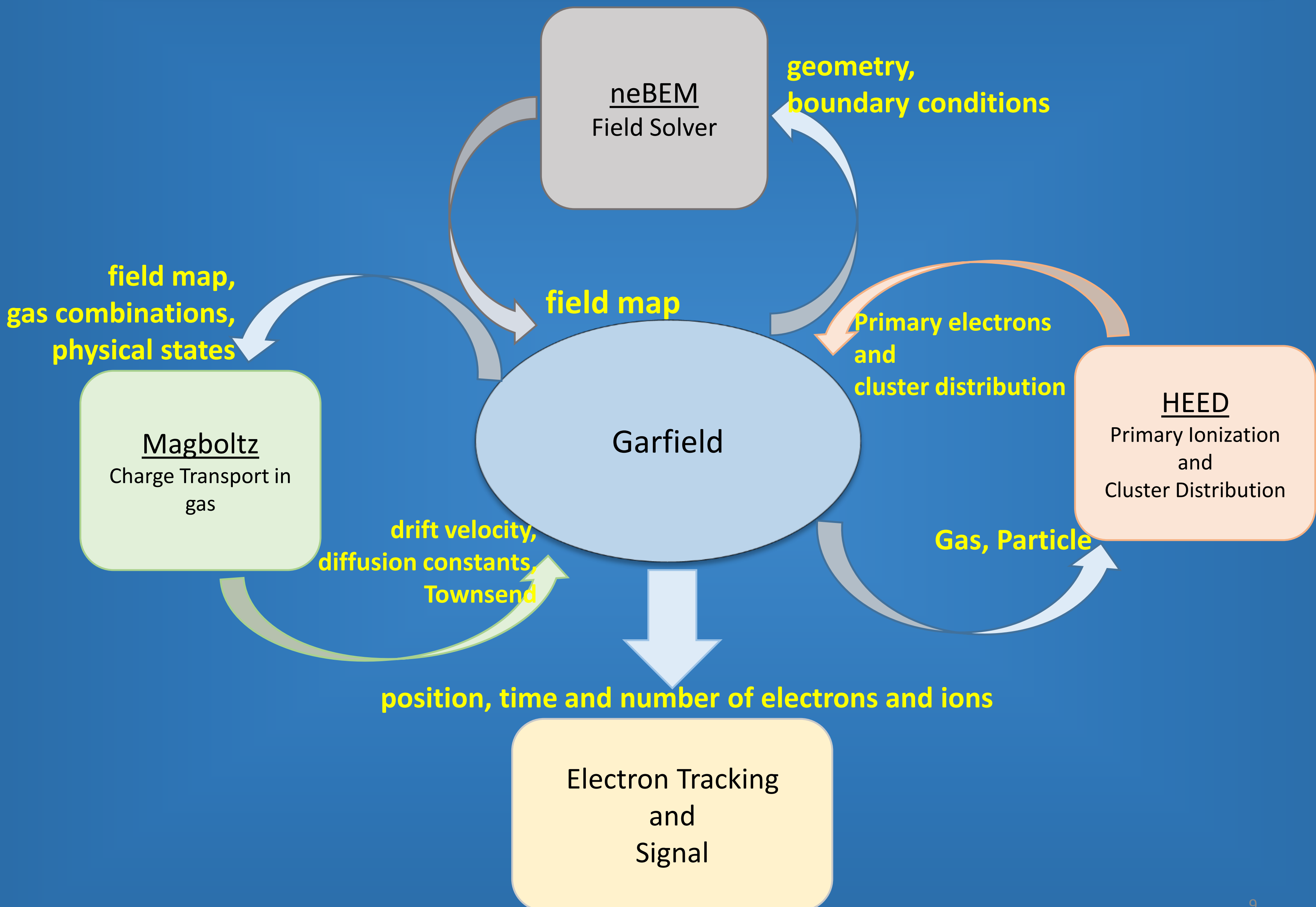
Figure 2



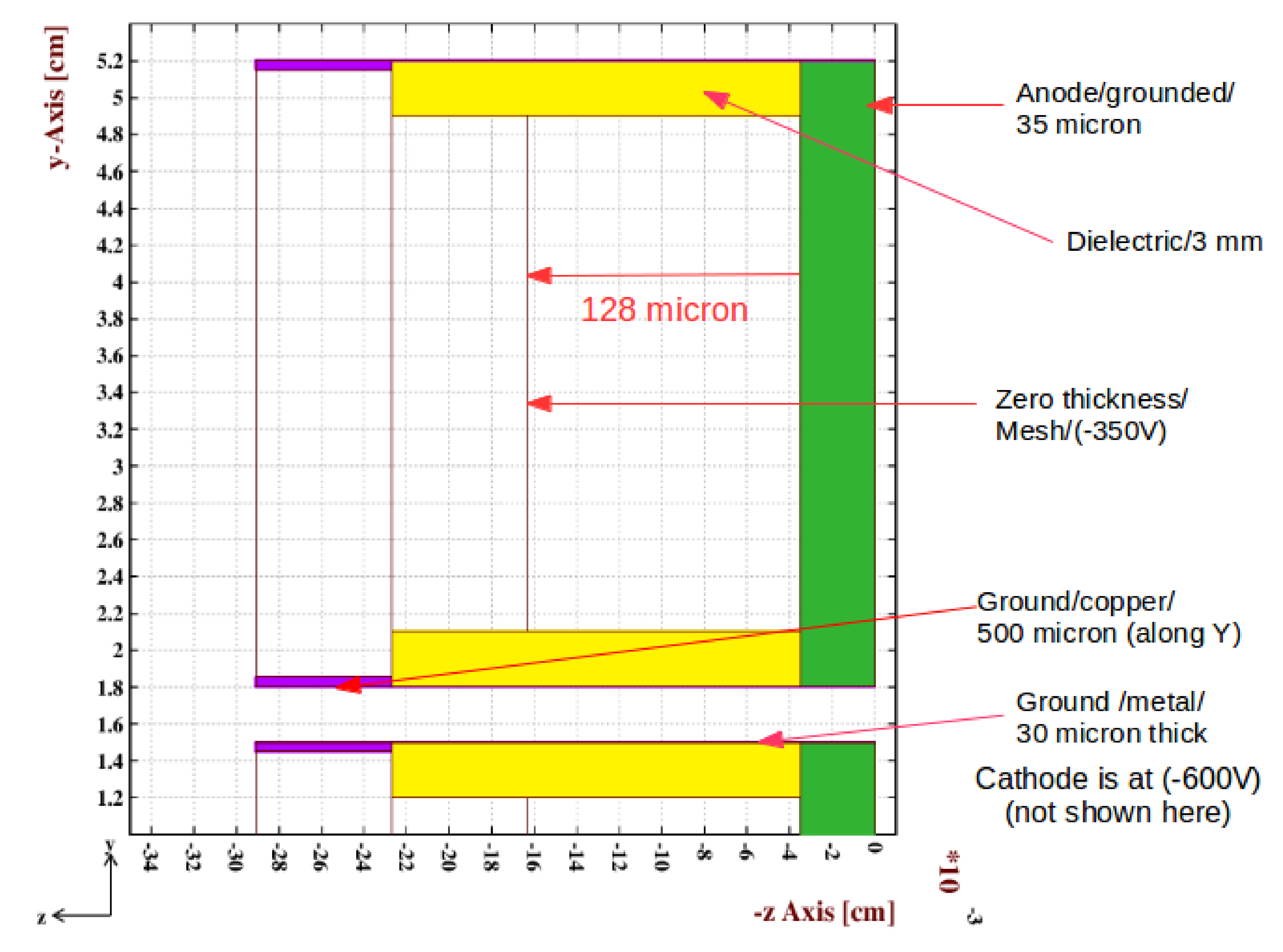
The **simulated** Micromegas modules

Module size: 3.4 cm × 3.4 cm.
Reference frame is in Cartesian.

Simulation Framework



Geometry of the Simulated model



The electron drift lines

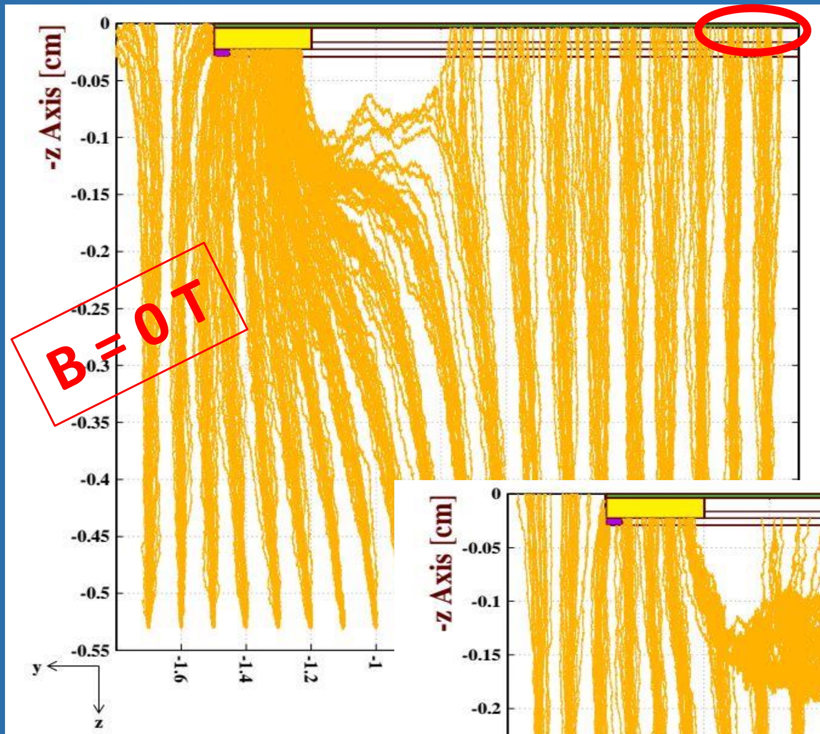


Figure 1

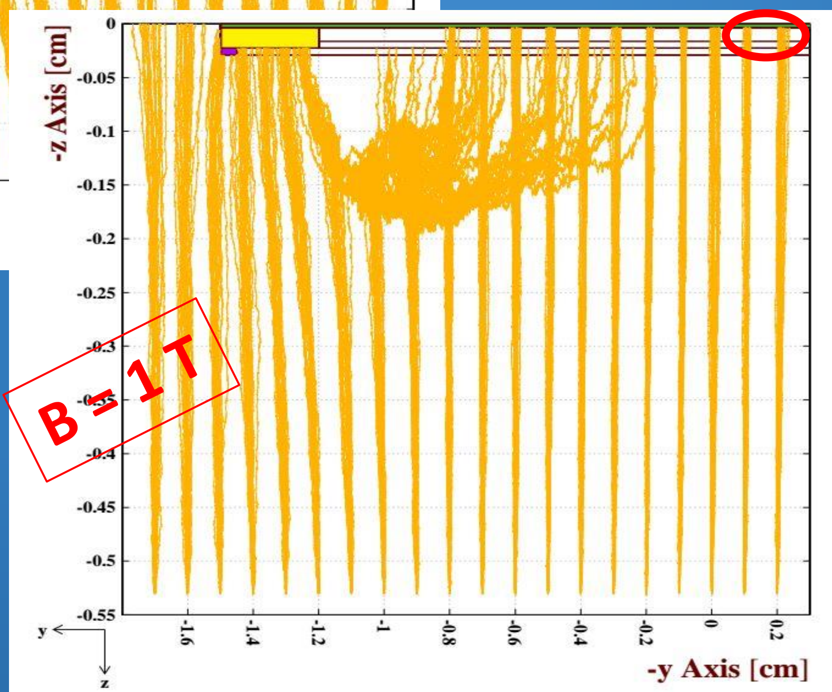


Figure 2

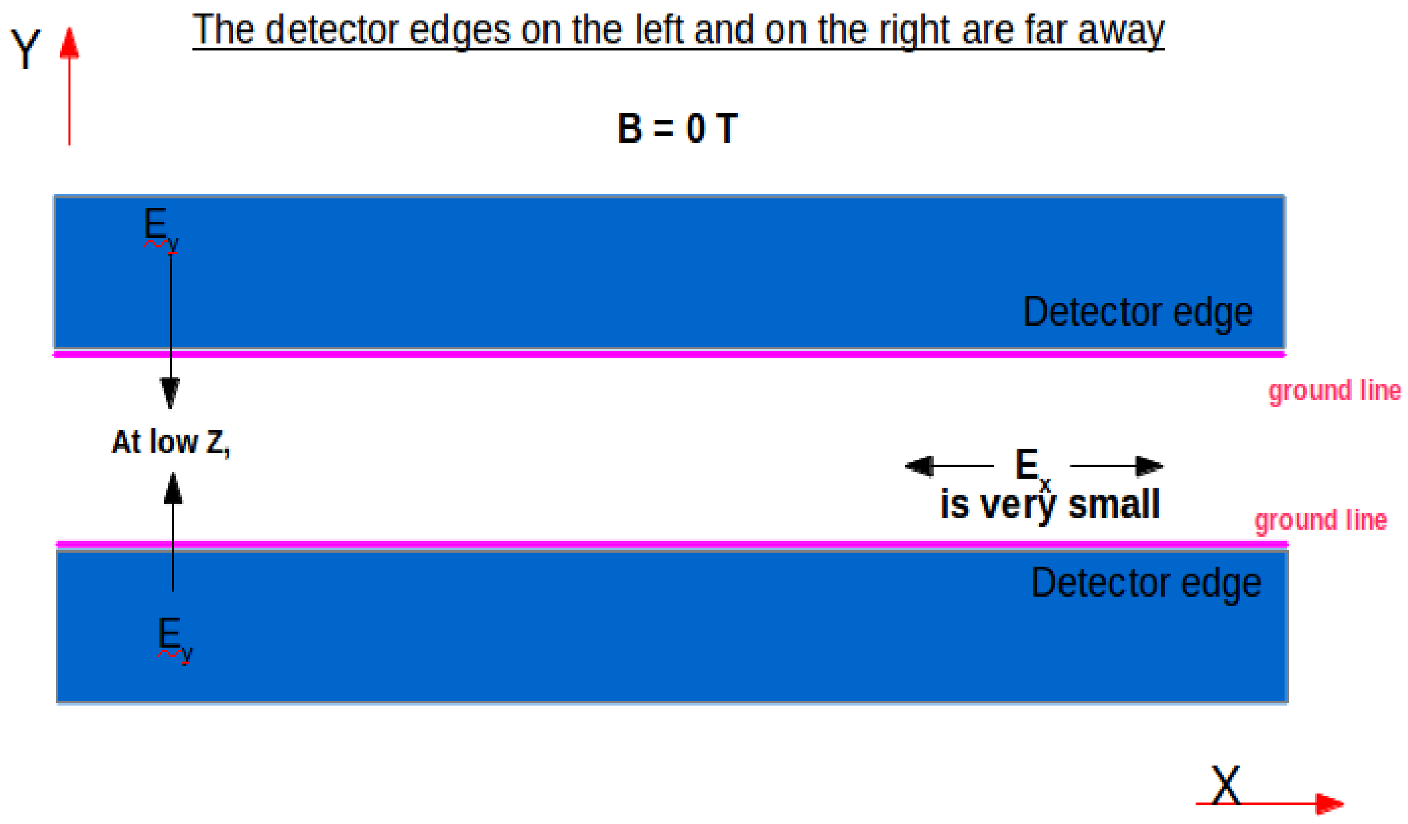
One electron is released from each of the 456 equidistant points that constitute a track. Monte-Carlo method is used to track the electrons.

The track is repeated over 50 times to gather enough statistics.

Diffusion in gas is reduced by by applying Magnetic field.

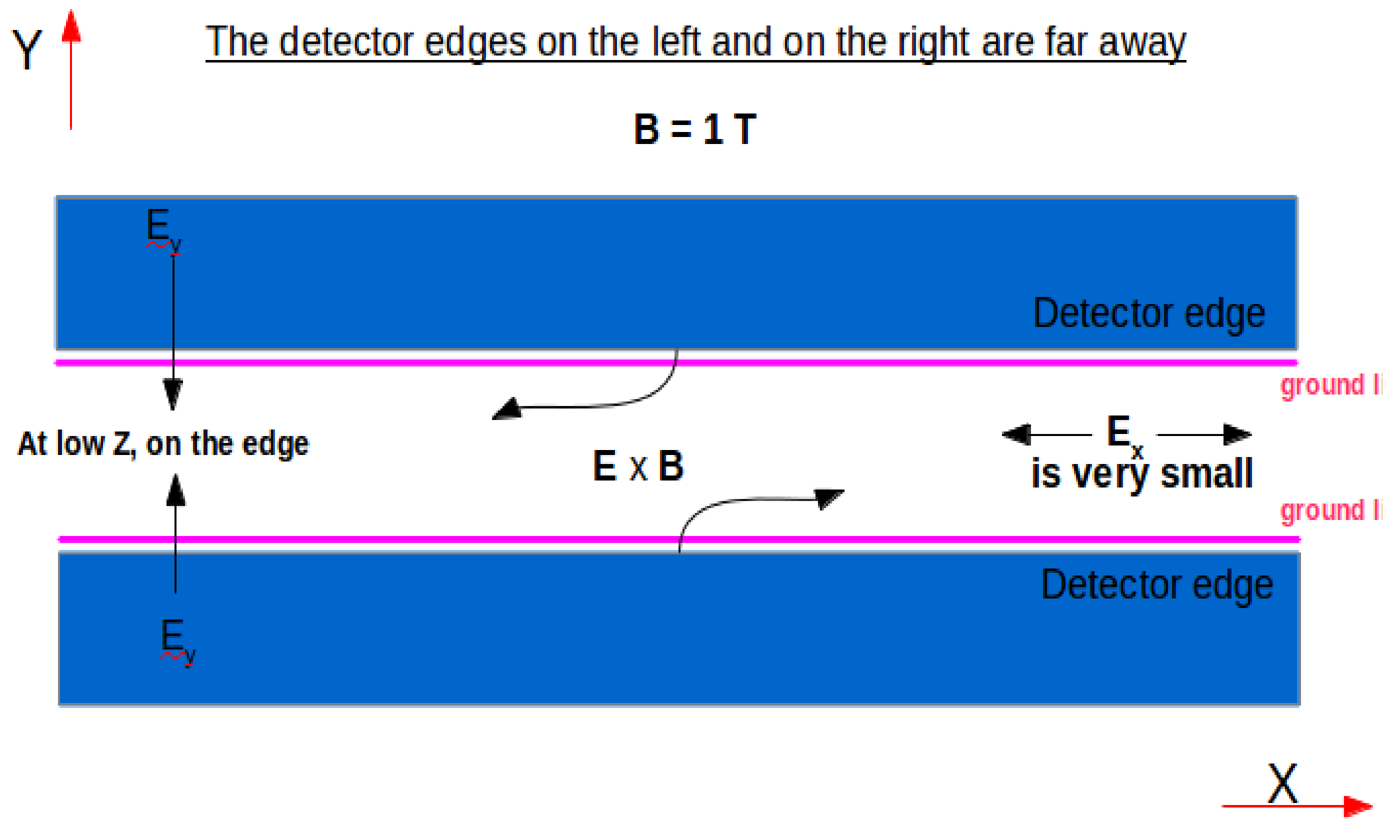
On the edges of the detectors, significant signal loss may be noticed as they hit the dielectric pillar because of the grounded frame.

How are the field lines distorted ?



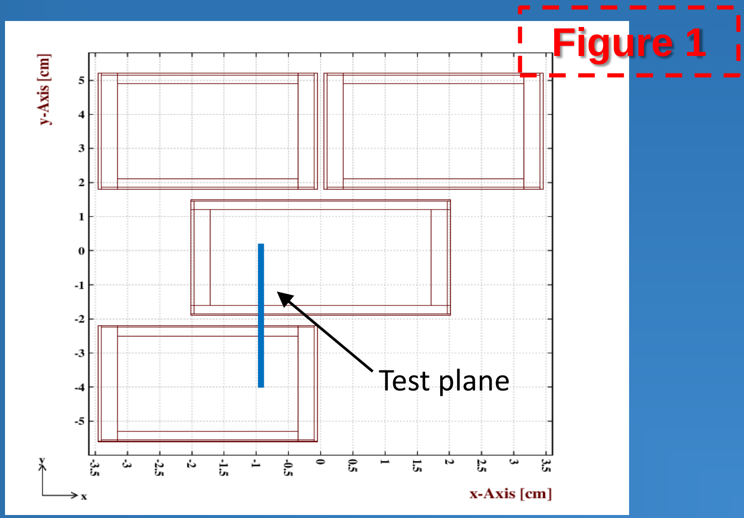
At the middle of the modules, **E field** is perpendicular to this plane

How are the field lines distorted ?

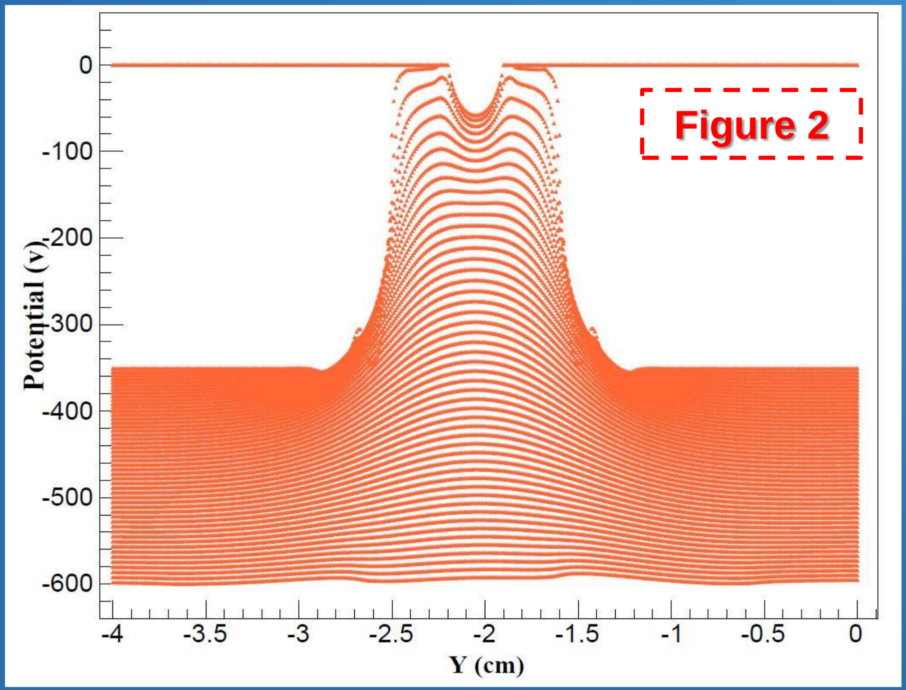


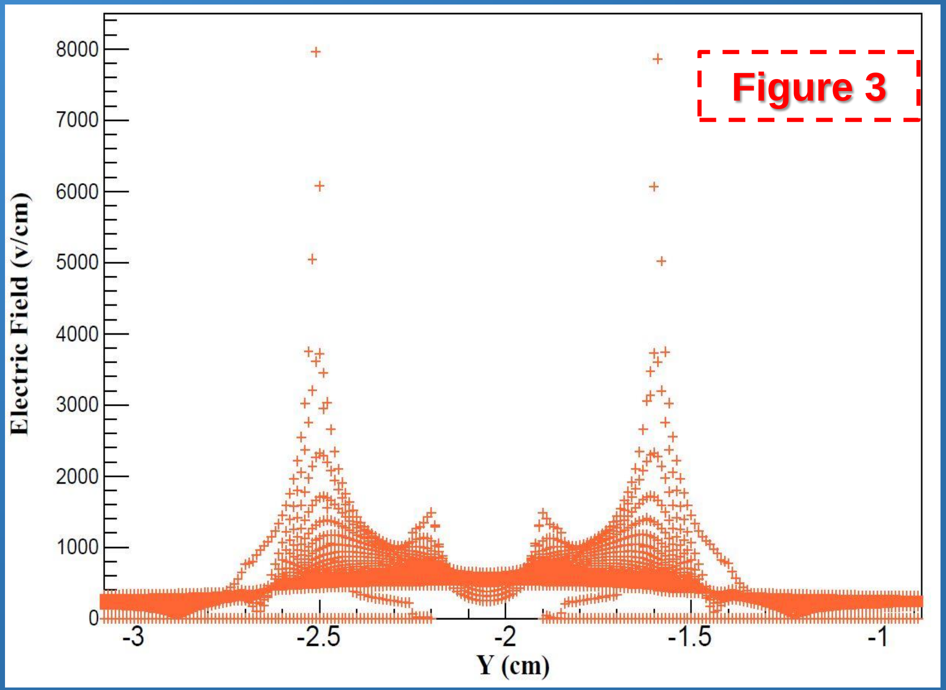
At the middle of the modules, E field and B field are perpendicular to this plane

The electric Field and potential near the gap between the modules

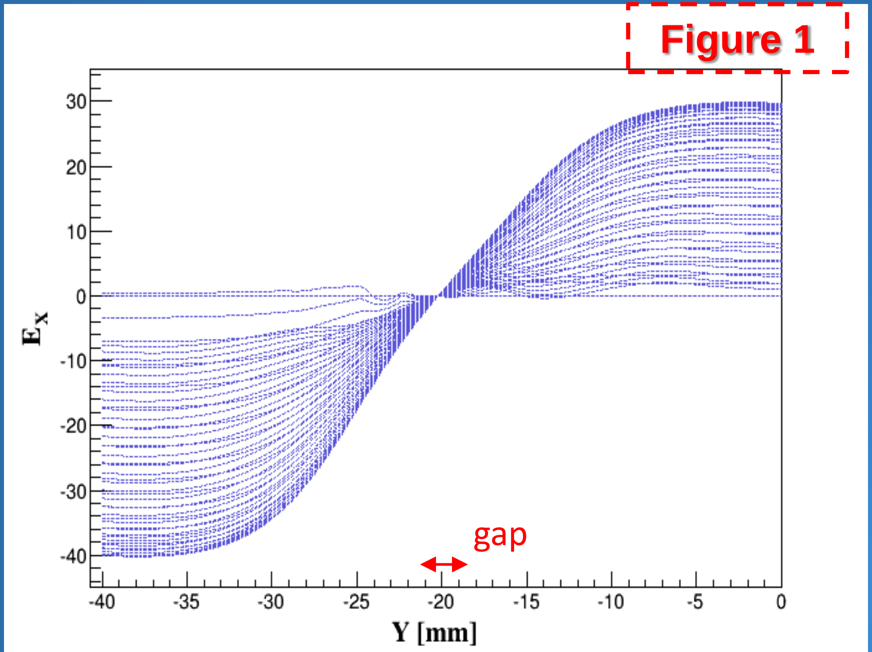


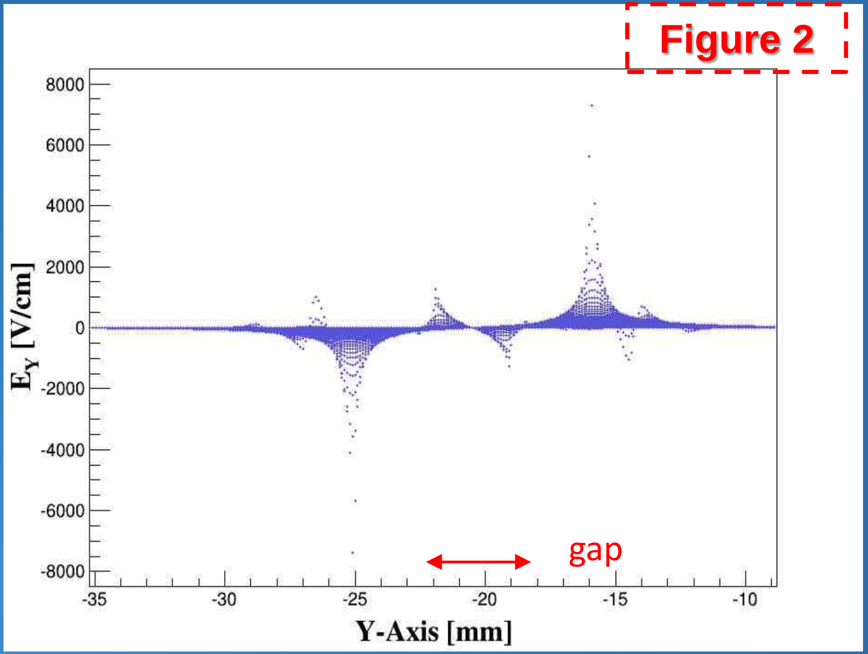
- A test plane is chosen at X=-1.0 cm, Y= -4.0 cm to 0.0 cm, Z= 0.0 cm to 1.0 cm.
- The centre of the gap is around at Y= -1.8 cm.
- The iso-potential lines are distorted around the gap.
- The resultant field is non-uniform around the gap.

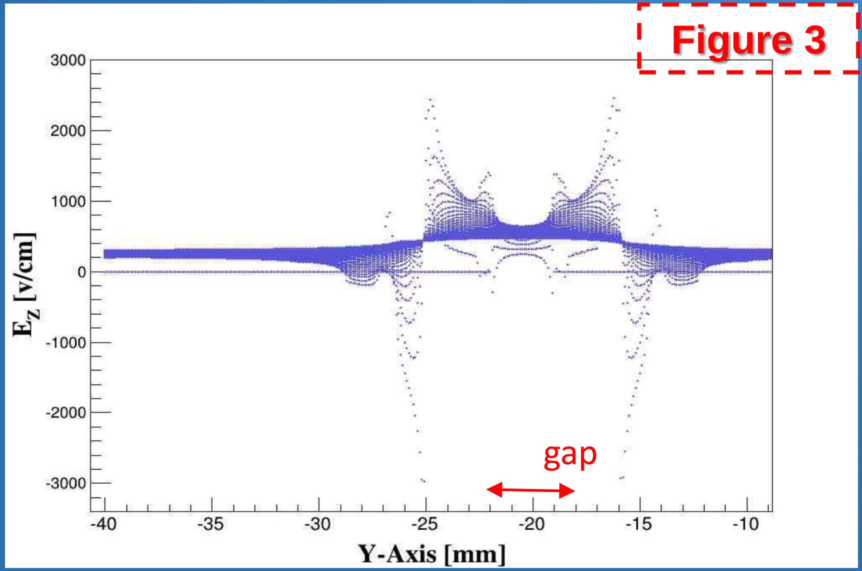




The components of the electric field

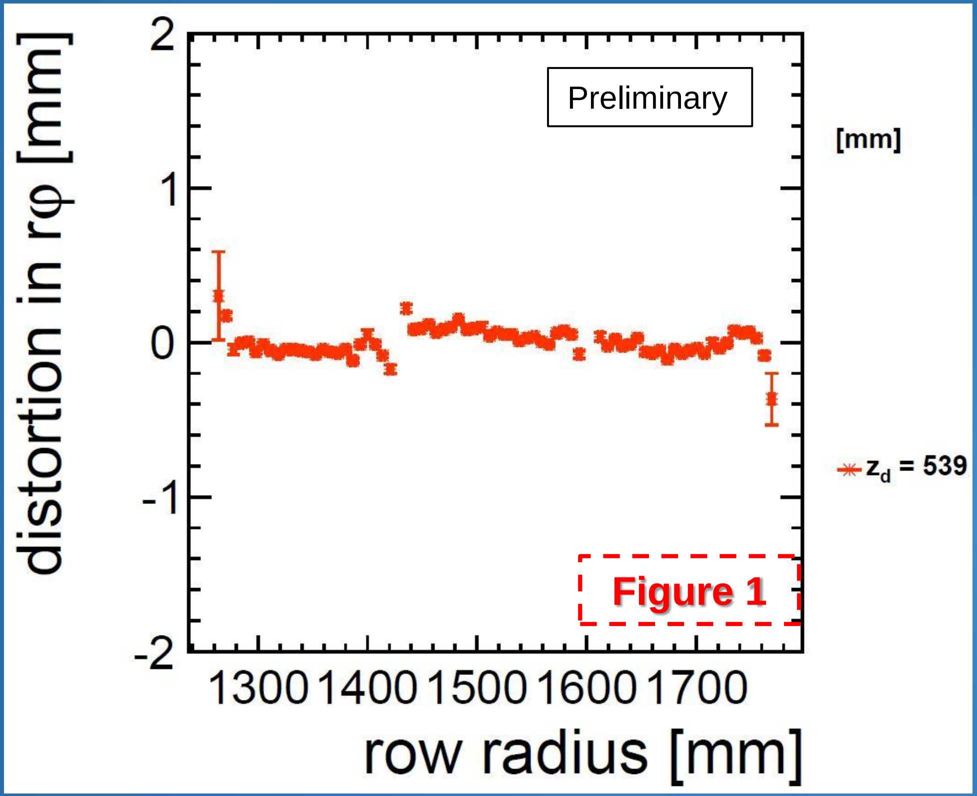






- The centre of the gap is at around -20 mm.
- Around the centre, the components of the electric field are changing sign.
- Also the components of the field has larger values around the gap.
- E_Y has larger values than E_Z.

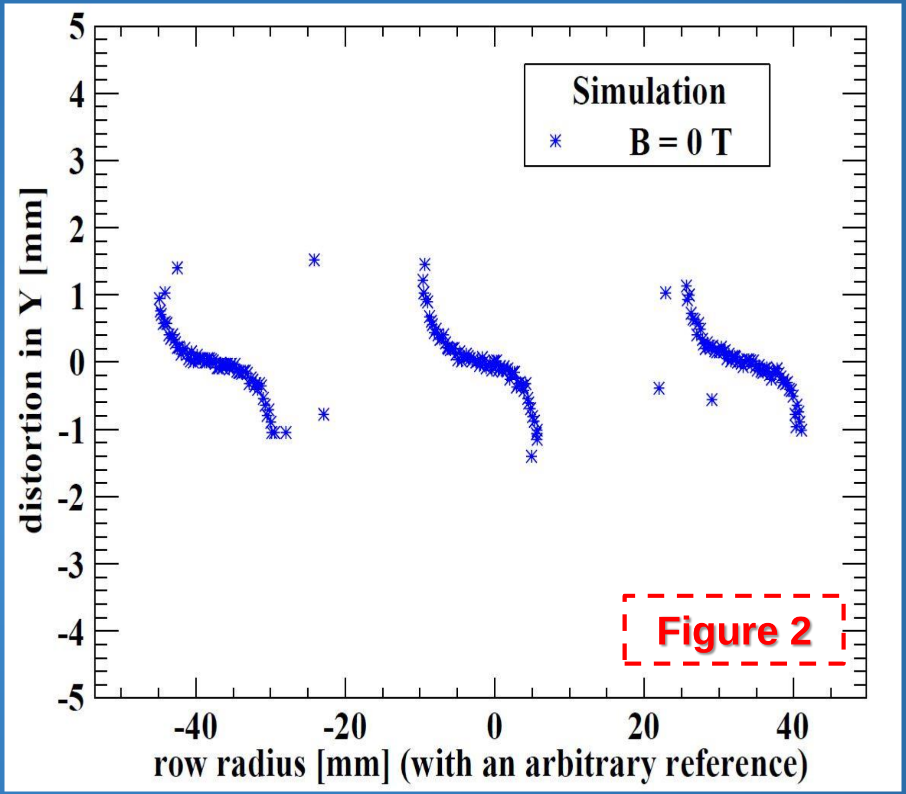
Comparison of distortion between experiment and simulation



For the Micromegas modules on the **LPTPC endplate.**

B=0T

Distribution of the residuals as obtained in **Experiment** *after* alignment correction.

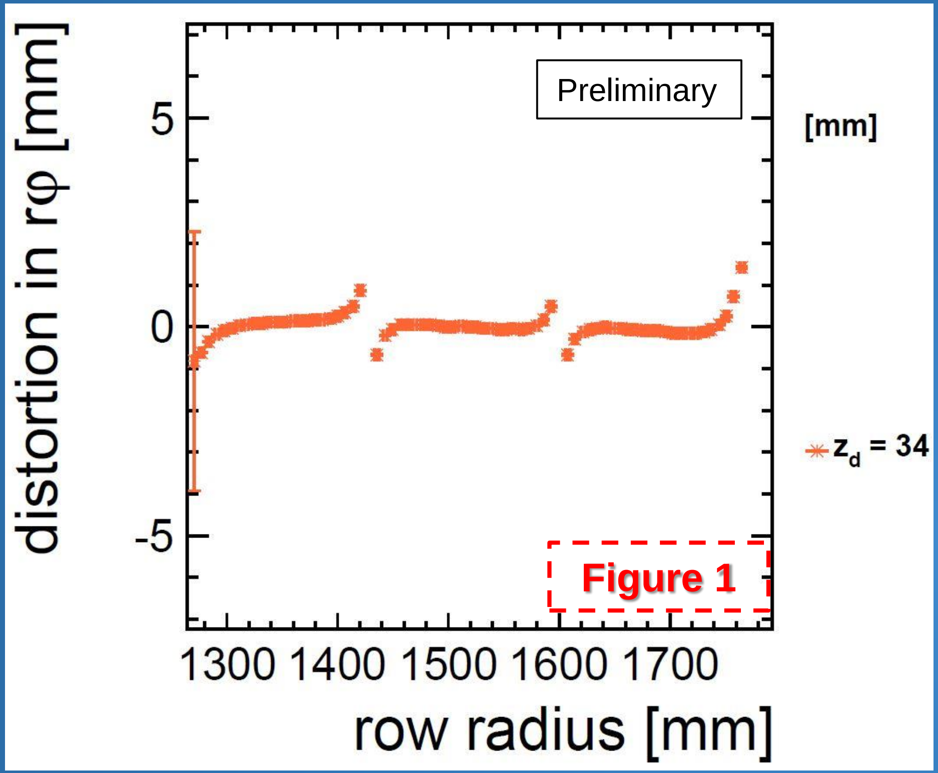


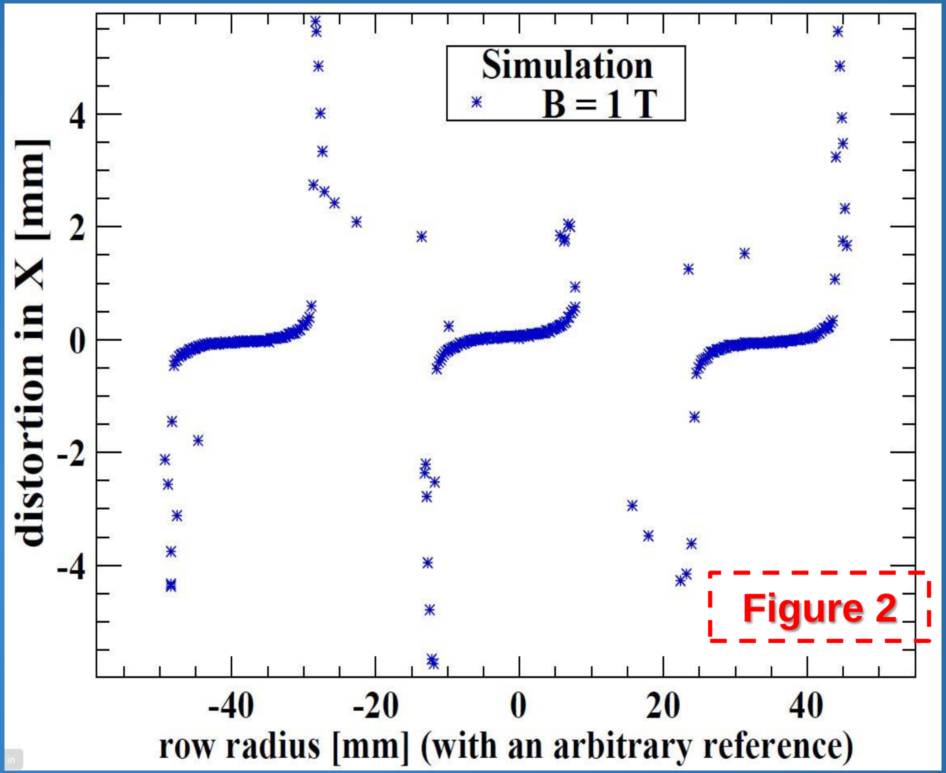
For the **simulated** Micromegas modules

B=0T

Distribution of the residuals as obtained in **Simulation**

Comparison of distortion between experiment and simulation





For the Micromegas modules on the **LPTPC endplate.**

B=1T

Distribution of the residuals as obtained in **Experiment** *without* alignment correction.

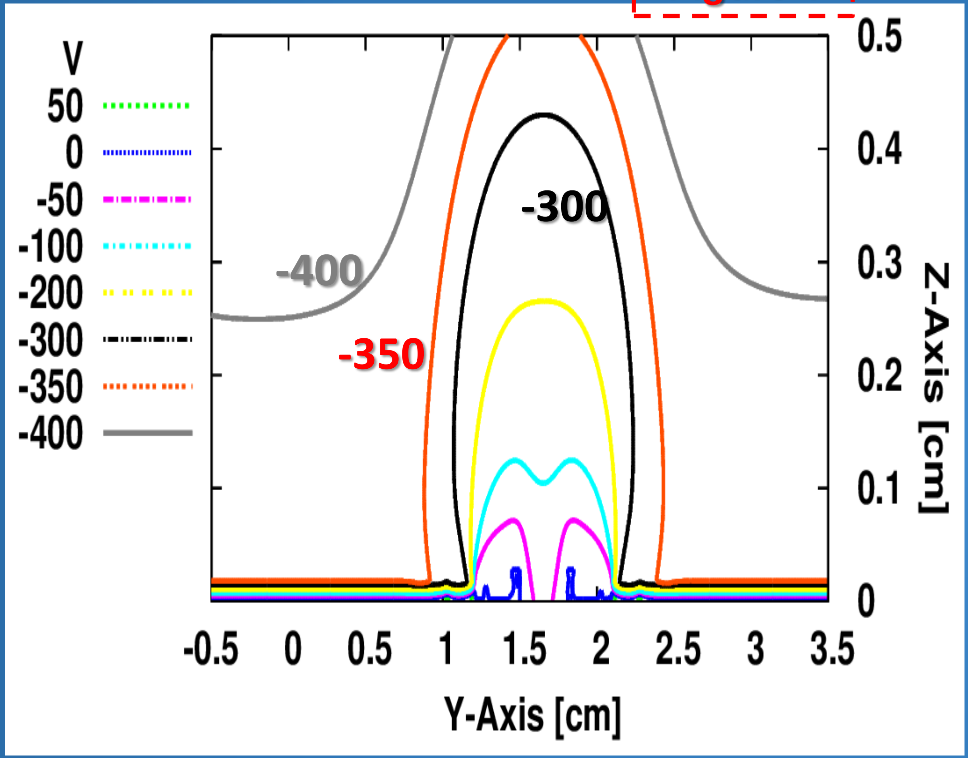
For the **simulated** Micromegas modules

B=1T

Distribution of the residuals as obtained in **Simulation**

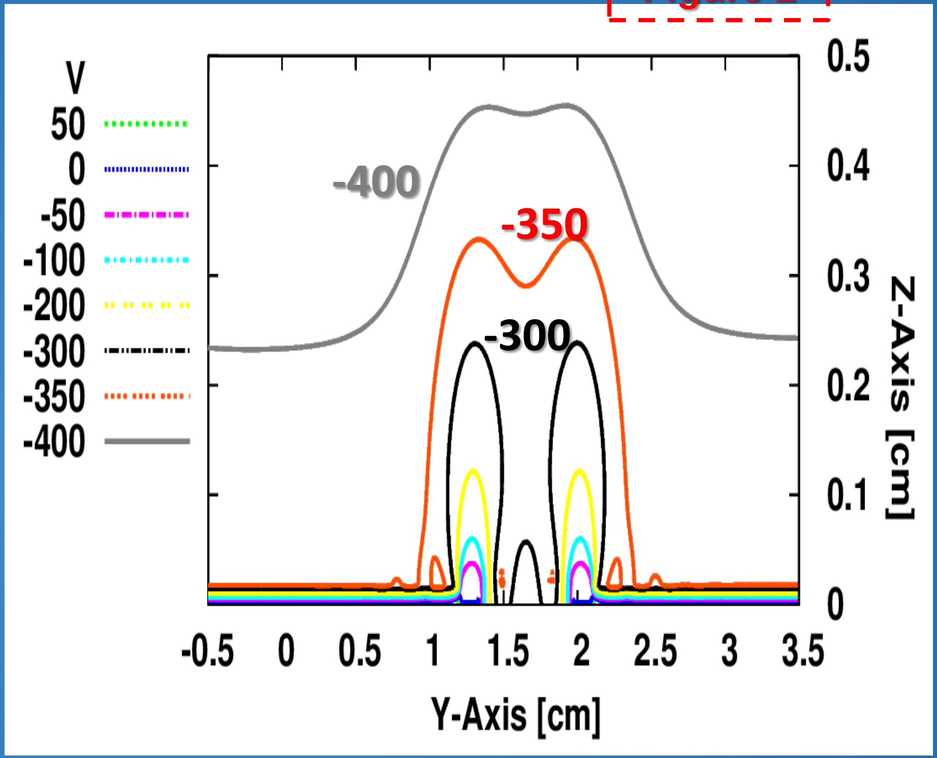
The potential of the copper frame is raised to -350 V

Figure 1



Copper frame is at 0 V

Figure 2



Copper frame is at -350 V

The potential of the copper frame is raised to -350 V

Figure 1

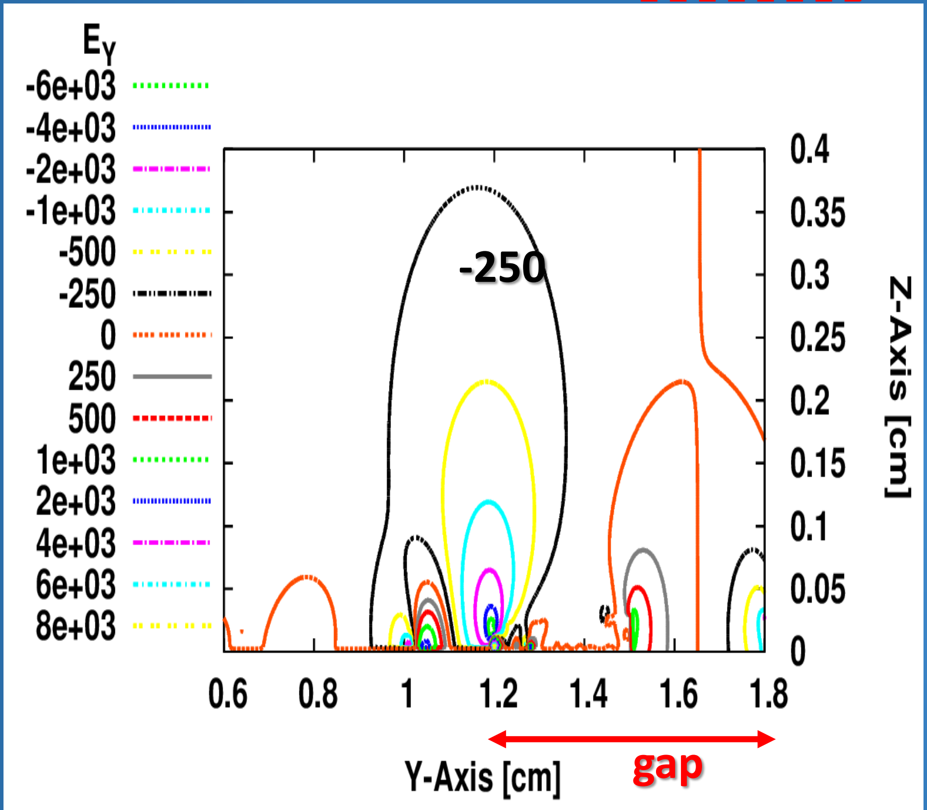
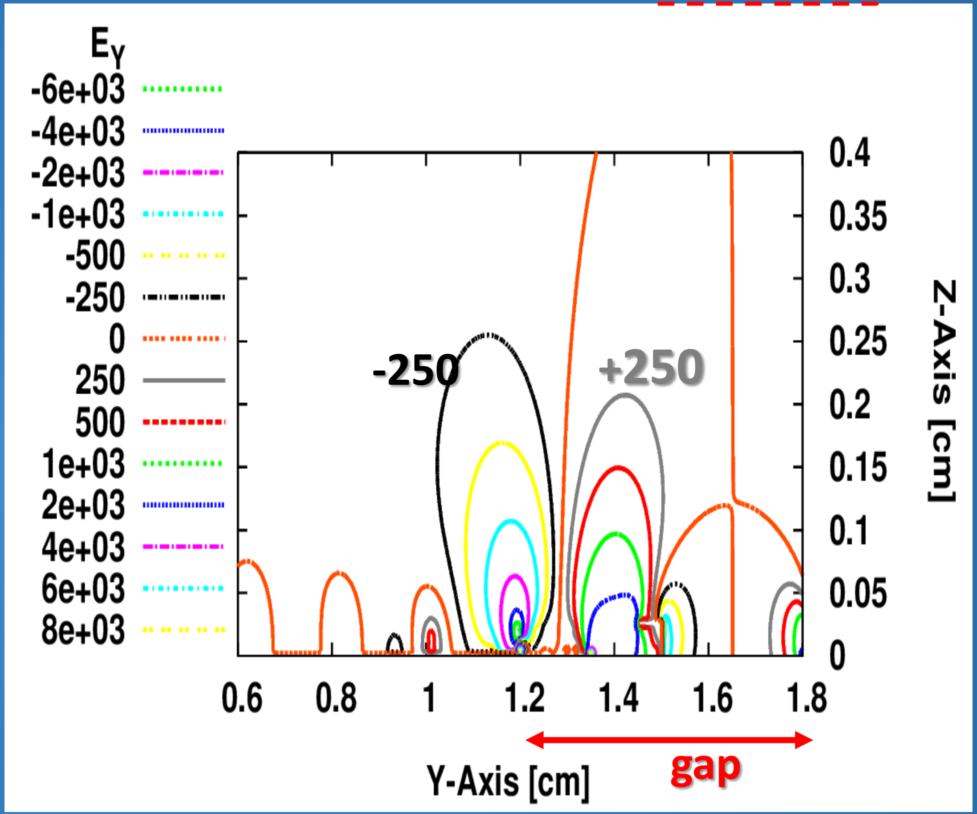


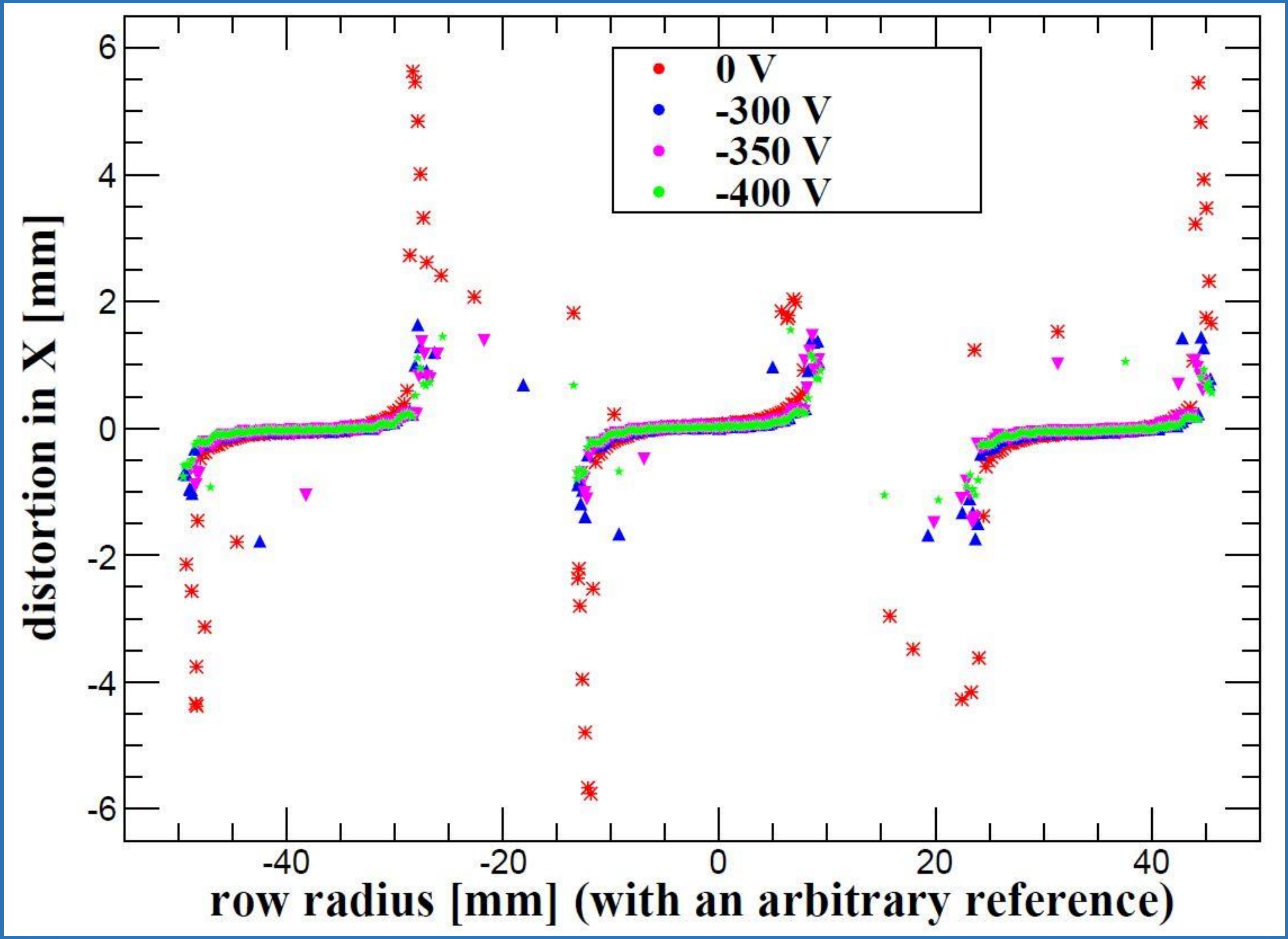
Figure 2



Copper frame is at 0 V

Copper frame is at -350 V

The potential of the peripheral frame is varied



Changing the potential of the copper frame has reduced the residuals of the pads near the edges.

Summary

- Track distortion has impact on the overall performance of a TPC.
- Distortion has been studied during analysis and also by means of numerical methods.
- The numerical study is done with a number of simplifications in geometry of the detector. Hence a direct comparison with experiment may not be applicable.
- The intrinsic detector parameters are, however, taken true to the experimental setup.
- Simulation matches the experimental trends and explains the behavior of distortion.
- The possibilities to mitigate distortion by biasing the peripheral frame has been tested in simulation.
- Further studies are in progress to improve the performance of the modules.

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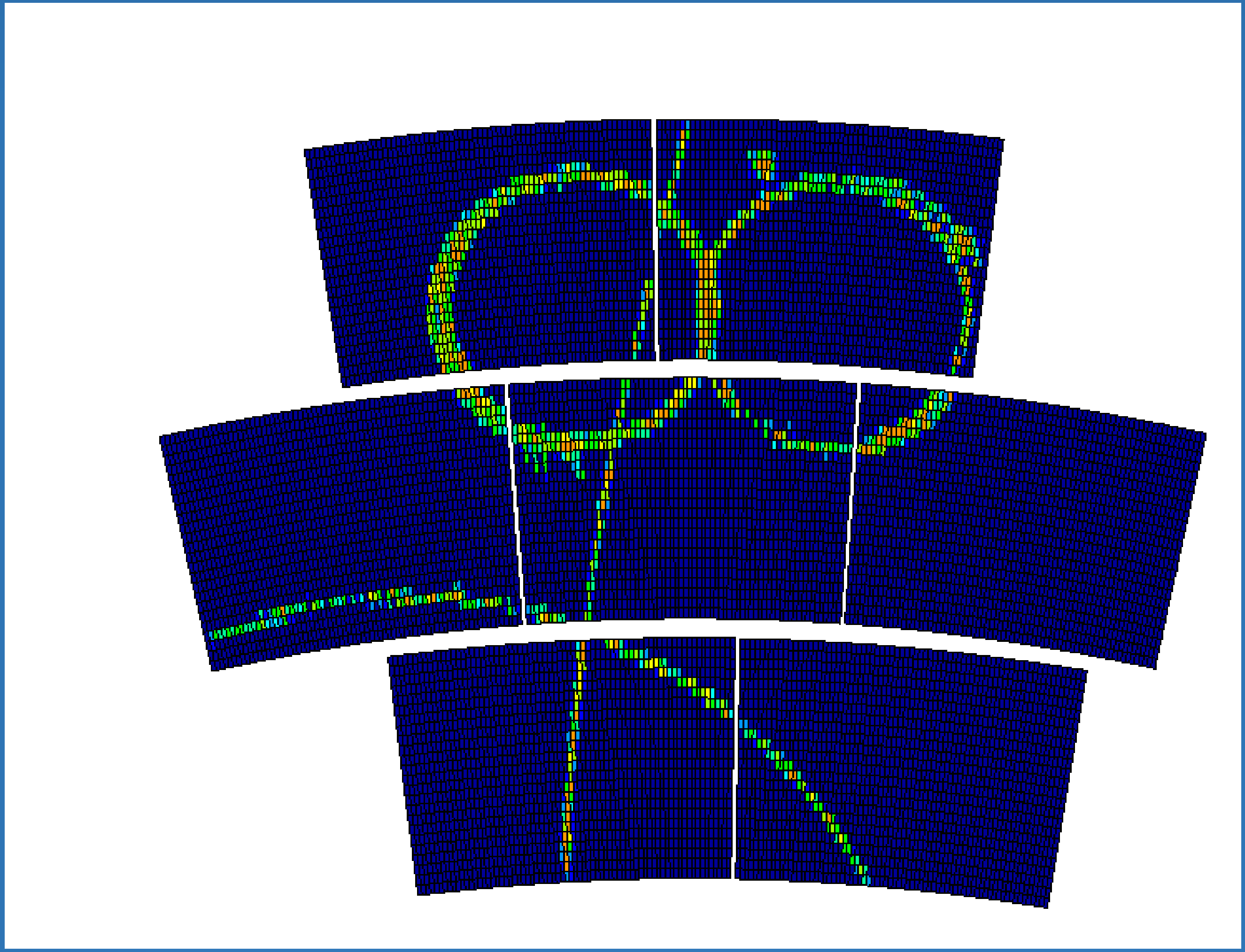

THANK YOU