Test of MPGD modules with a large prototype Time Projection Chamber

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On behalf of
LC-TPC

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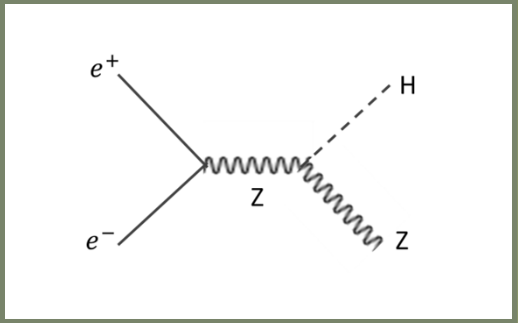
General Physics goal at ILC

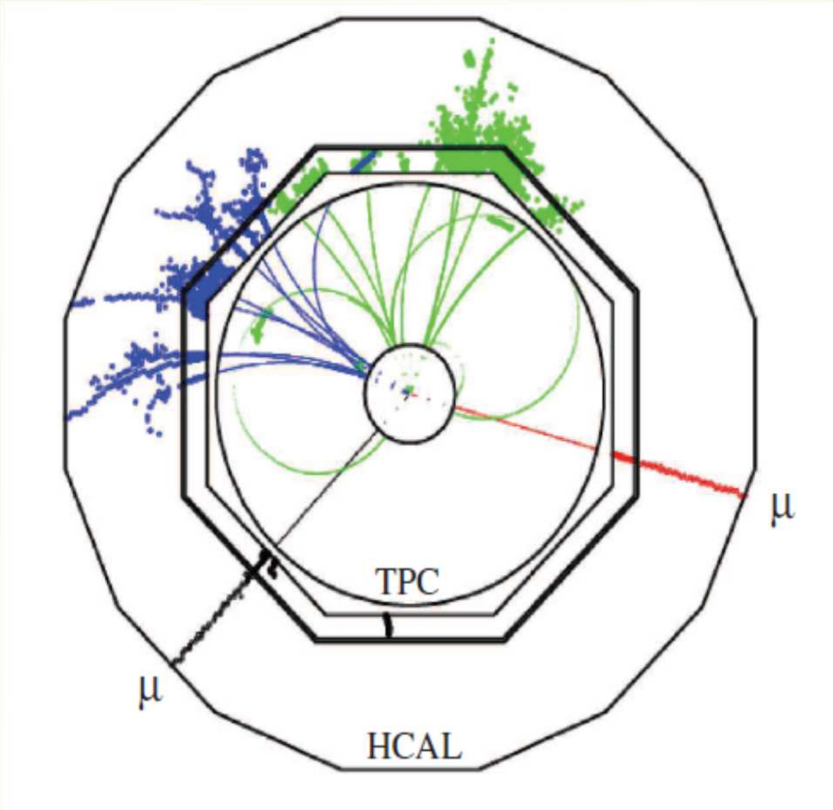
The 125 GeV Higgs and possibly other Higgses, can be produced at ILC by Higgs-stahlungs.

$HZ \rightarrow b\bar{b}\mu^+\mu^-$

Unbiased selection by Z recoils to measure mass and all possible decay modes.

Jet reconstruction also benefits from continuous tracking in a TPC.





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International Large Detector

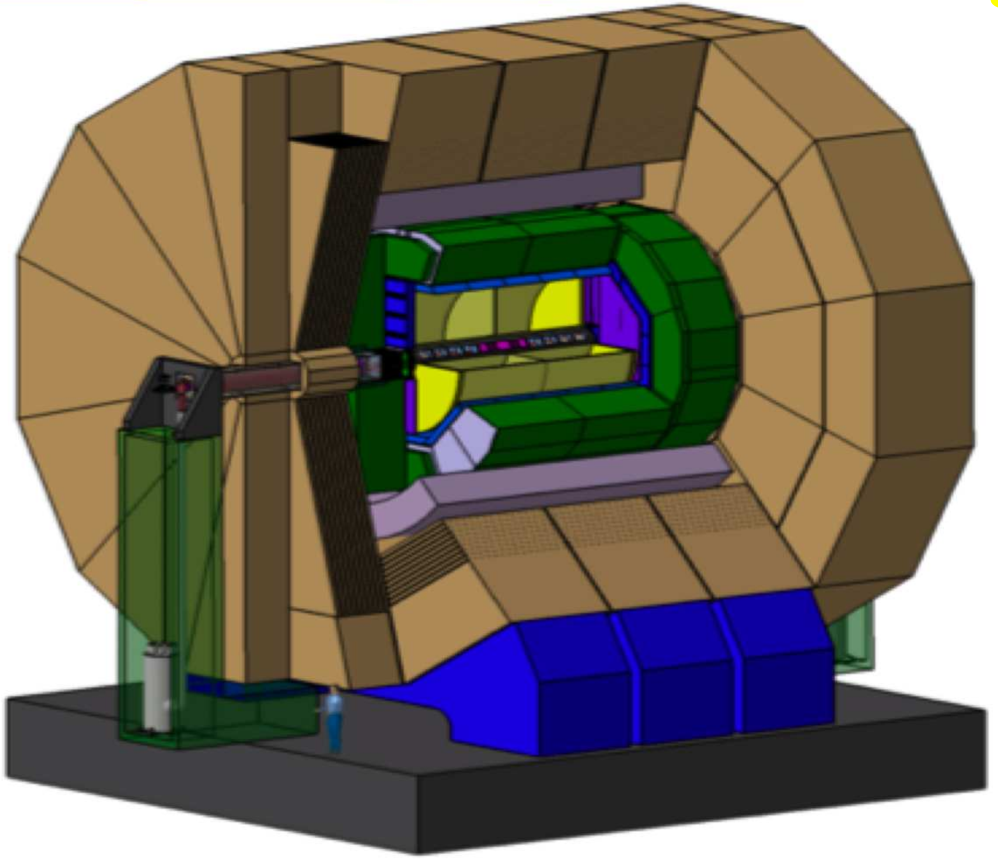
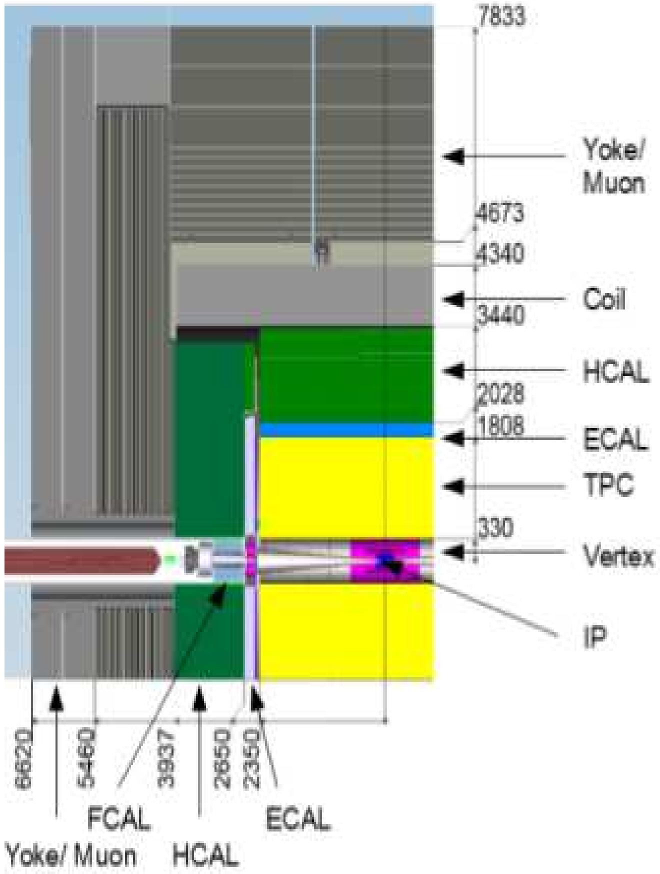


Figure 2: A schematic view of the International Large Detector concept (the TPC is the yellow cylinder inside the blue electromagnetic calorimeter).

ILD



Cross section

Length of the TPC ~ 4.6 m
Diameter of the TPC ~ 3.6 m
Magnetic field ~ 3.5 T

Physics goal sets the limit of r-phi resolution to be better than 150 micron

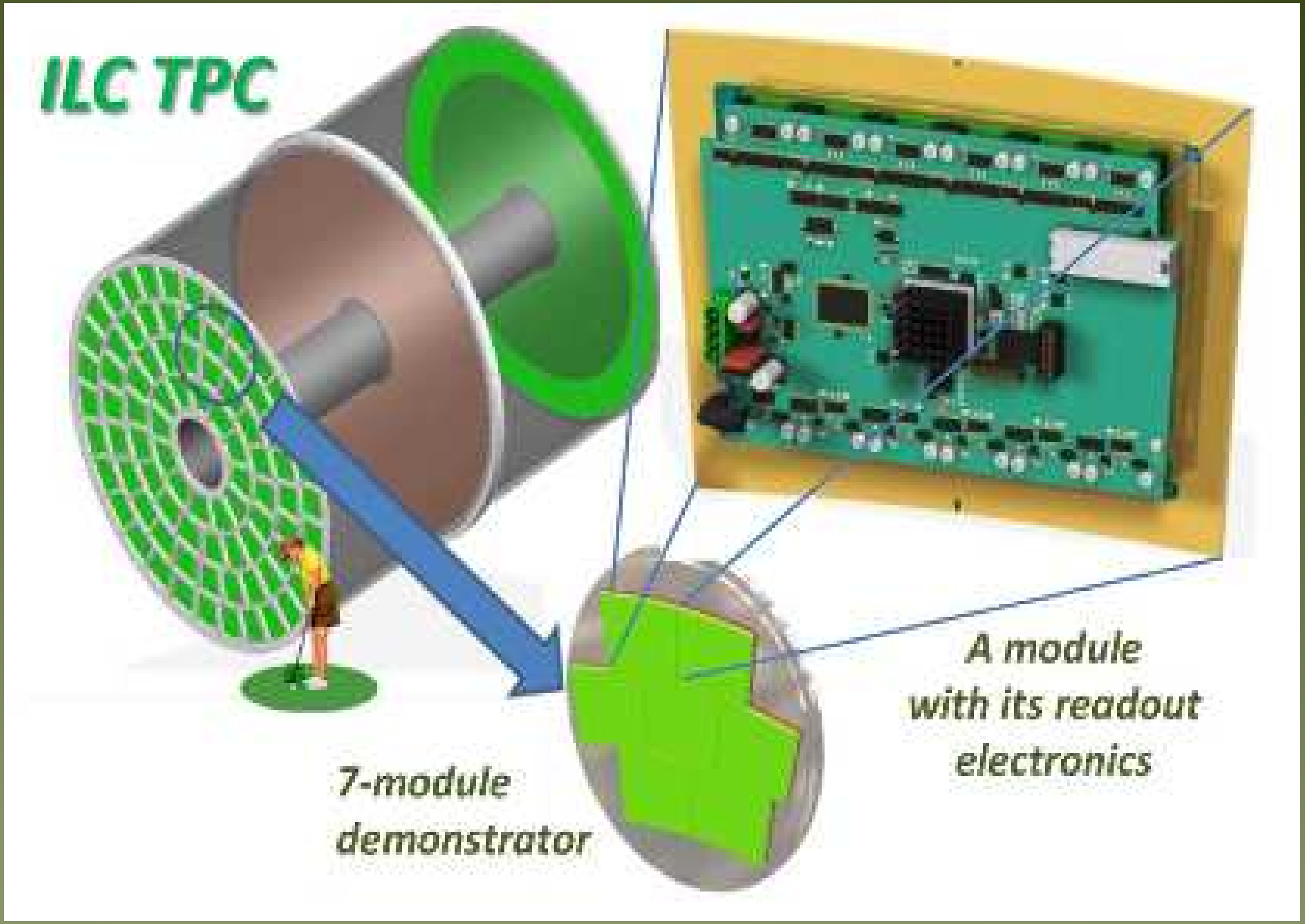
LC-TPC schematic
(Large prototype demonstrator)

The four wheel model of the TPC endplate.

MPGD modules can be installed at the endplate.

<u>The candidates are</u>

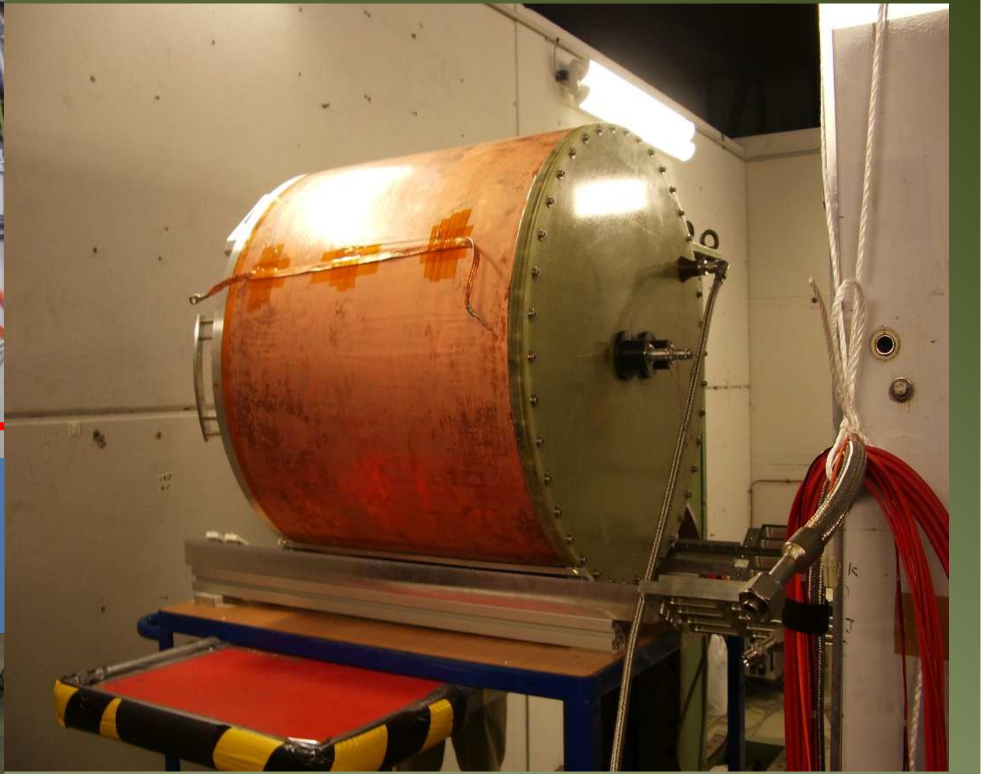
GEM
Micromegas
Timepix



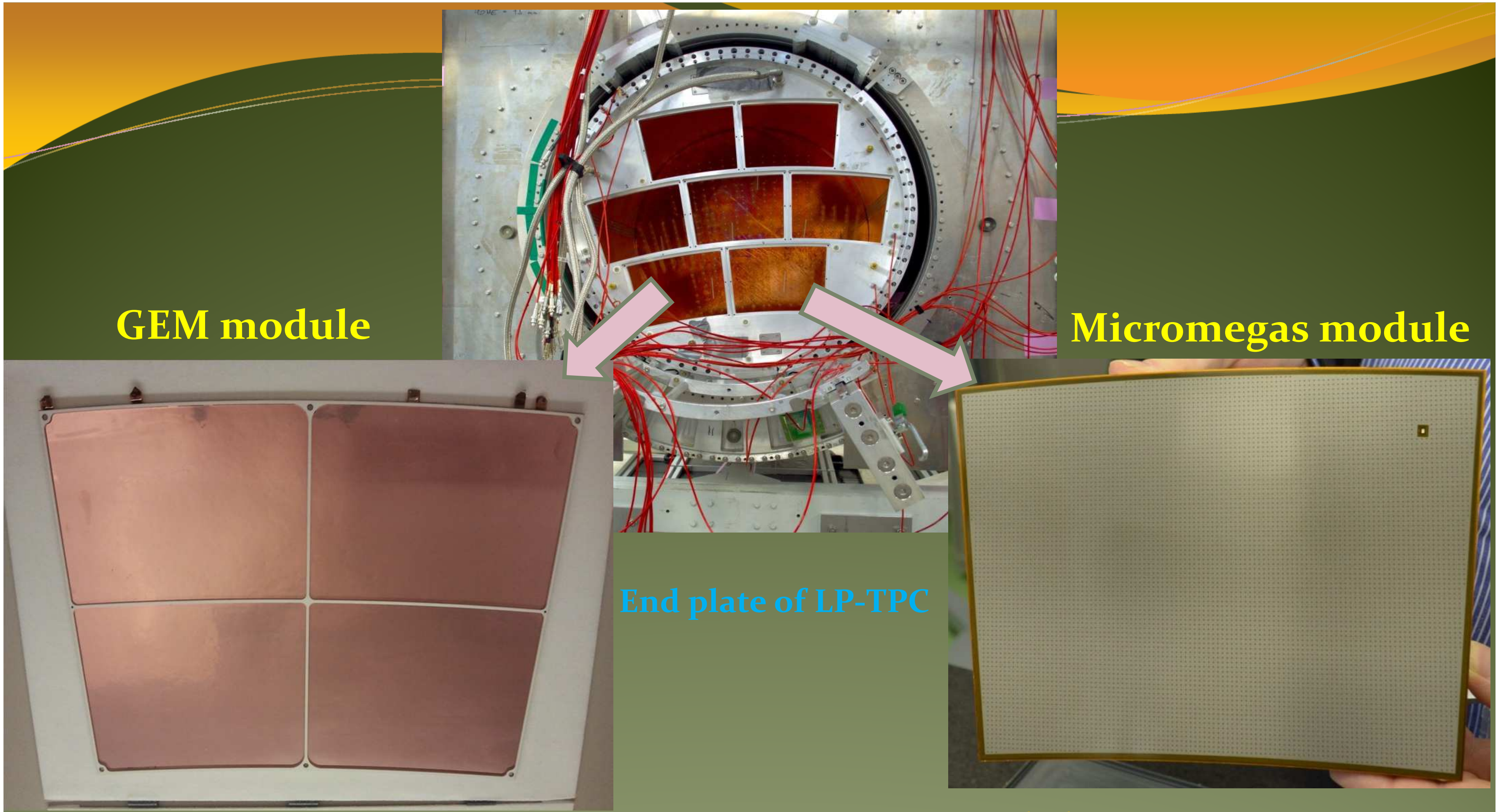
Large prototype TPC for ILC

at DESY

The 1T magnet.



The 60 cm long DESY field cage



GEM module

Micromegas module

End plate of LP-TPC

- Module size: 22 cm × 17 cm
- 28 rows × 72 columns
- Readout: 5000 Pads
- Pad size: ~1.26 mm × 5.85 mm

- Module size: 22 cm × 17 cm
- 24 rows × 72 columns
- Readout: 1726 Pads
- Pad size: ~3 mm × 7 mm

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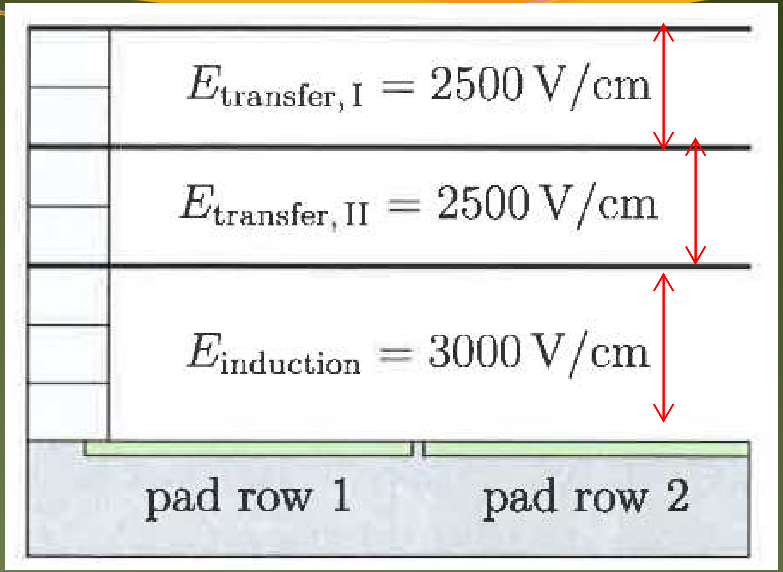
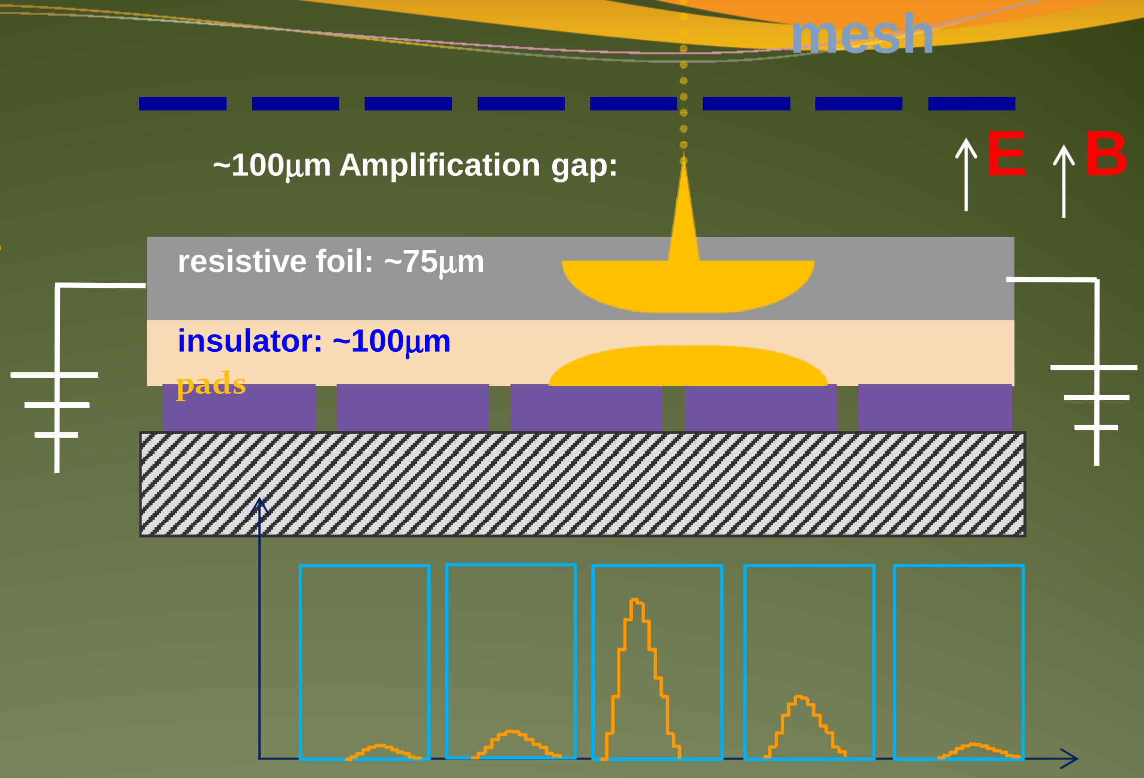
The GEM module

size: ~22x17 cm2



- Triple GEM stack → Stable operation at high gain
- The GEMs are divided into 4 sectors by the alumina bars → HV stability -> Field uniformity.
- Thin ceramic mounting structure → Good GEM flatness upto 100 micron + low material budget + minimal dead area

We are using resistive Micromegas



In standard Micromegas resolution is given by,

$$\mathrm{Resol} = w/\sqrt{12}$$

Charge is dispersed in Resistive Micromegas

$$\sigma = \sqrt{(2t/RC)}$$

R is the the surface resistivity of the resistive layer, C is the capacitance per unit area and t is the shaping time of the electronics.

Charge dispersion ≅ 2mm

- **Before we have been using *Carbon Loaded Kapton* which is now unavailable.**
- **A new resistive material, *Diamond Like Carbon* is available from Japan.**
- **We used both in the recent beam during test March 2015.**

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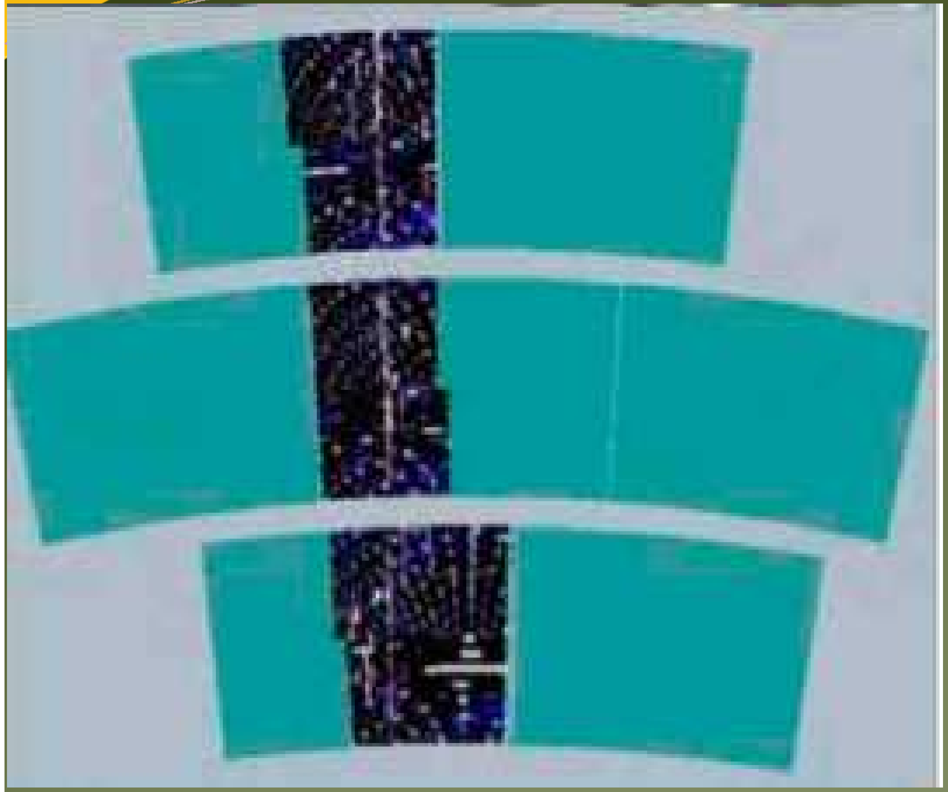
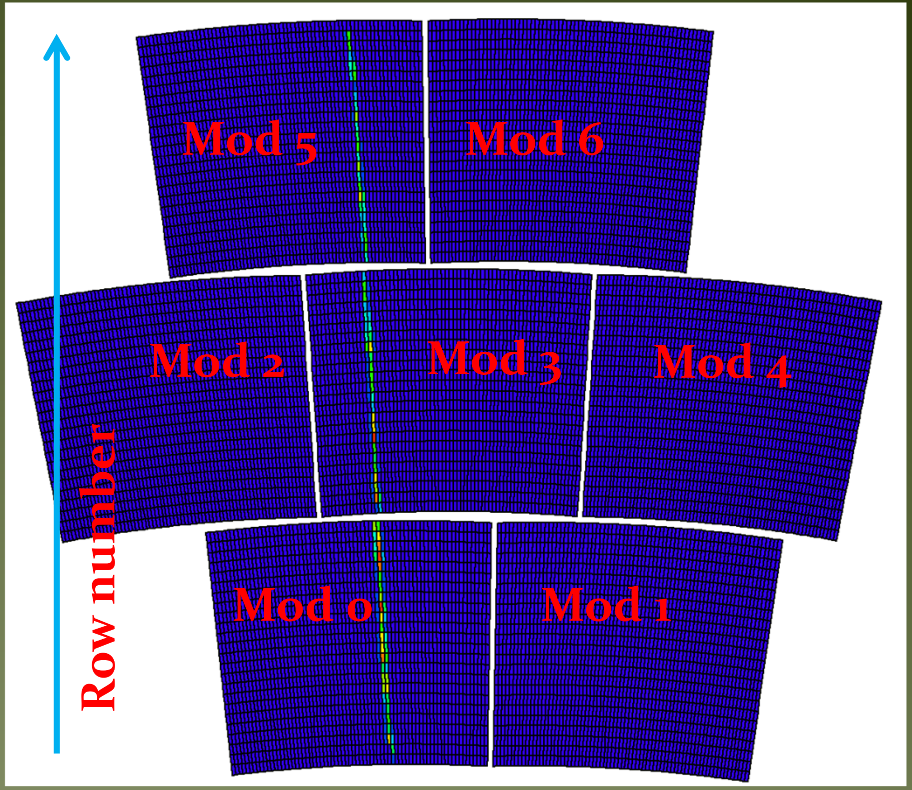
Track on GEM modules

Track Micromegas modules





5-GeV electron beam

5-GeV electron beam

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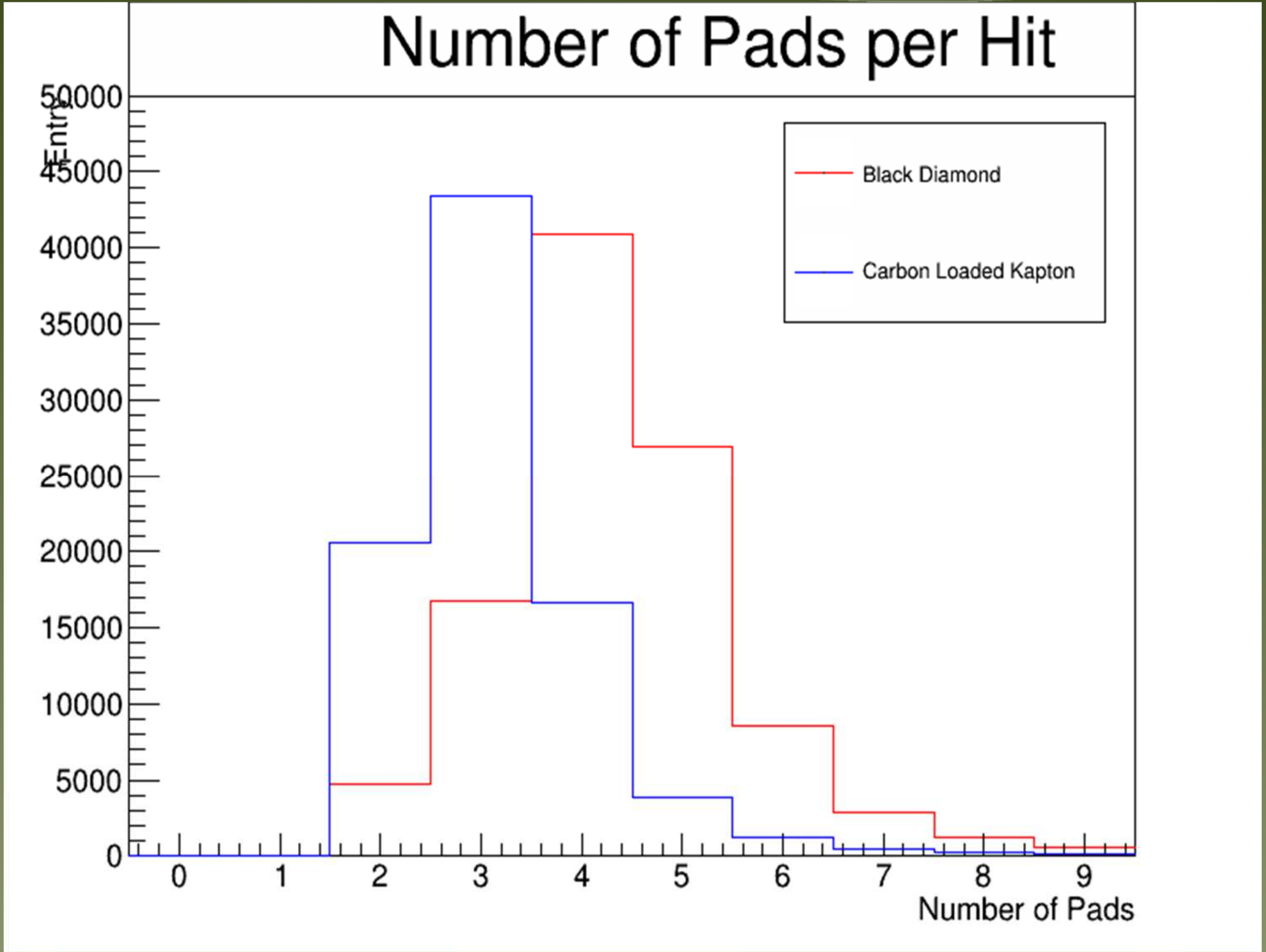
Comparison of charge spreading in two Micromegas modules



CLK => 3.13, BD => 4.33

Charge spreading of BD modules is slightly more than in CLK

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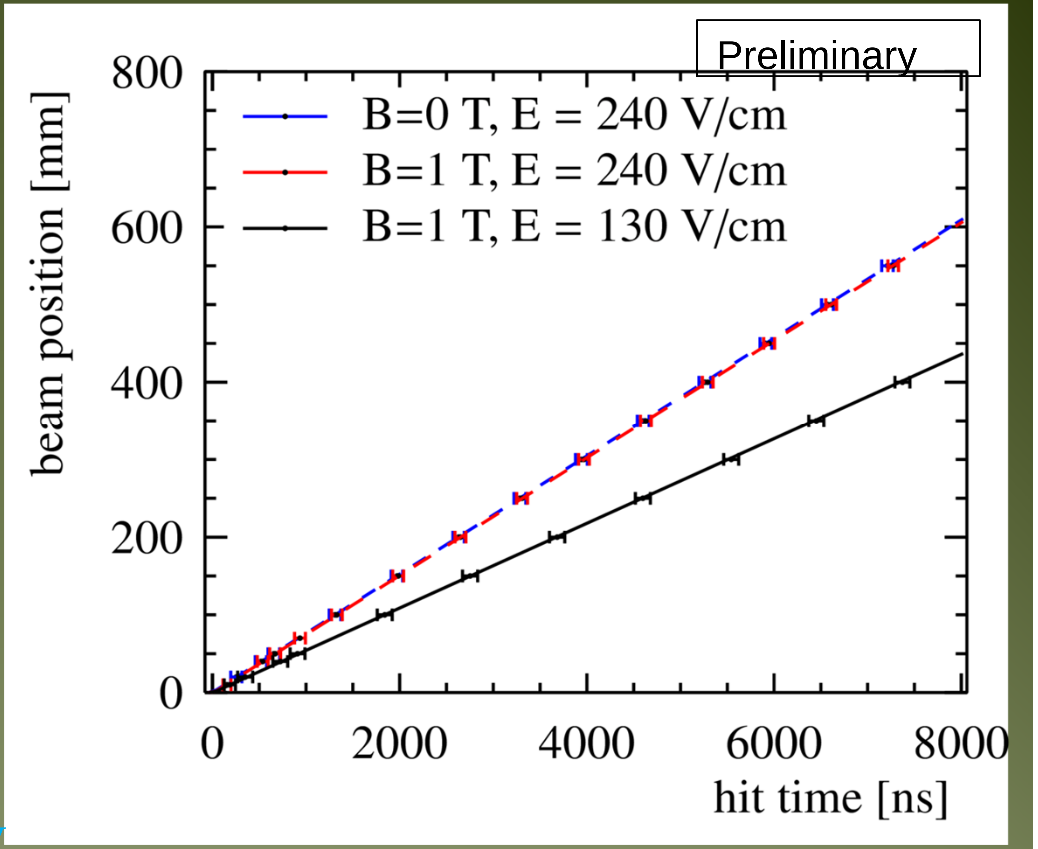
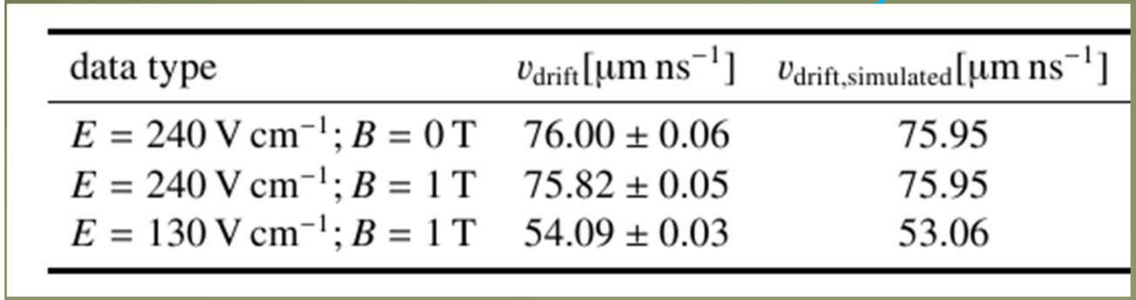
Drift velocity calculation (with GEM)

- ❖ The beam position on the TPC is plotted against reconstructed time.
- ❖ Slope gives the drift velocity.
- ❖ Intersection of two such curves for two different fields gives the time of zero-drift (To).
- ❖ The drift time (or length) is calibrated from To.



Measured and simulated drift velocity



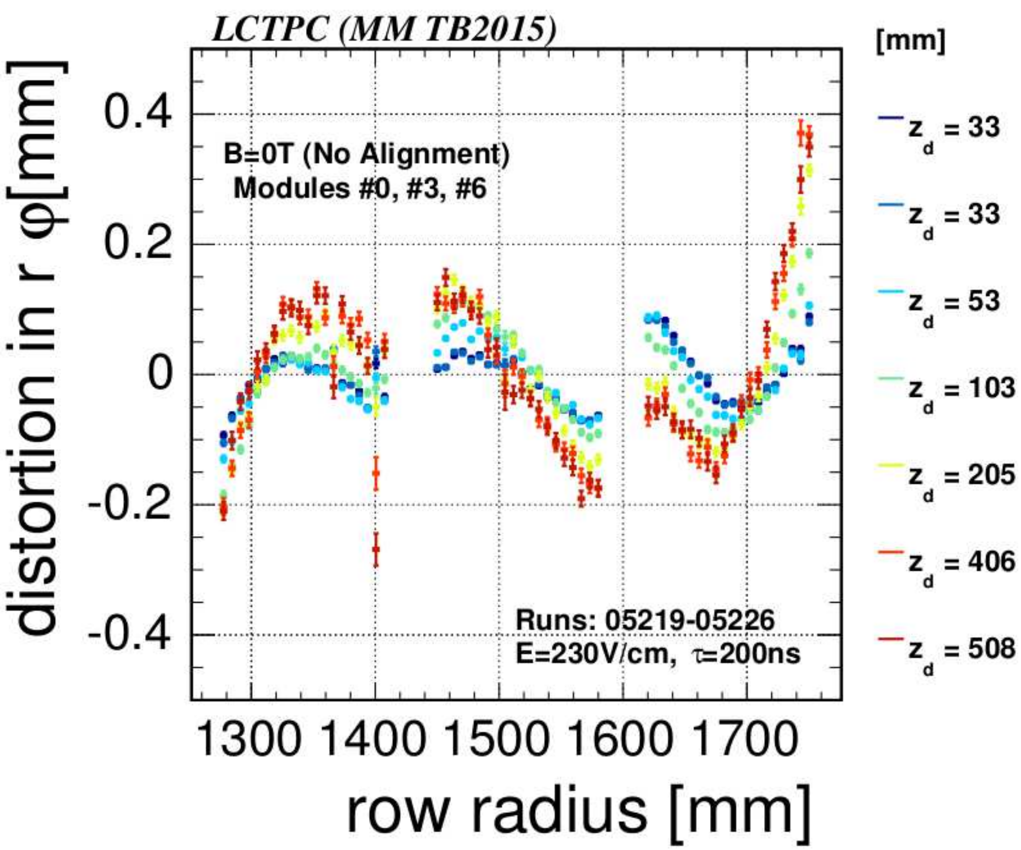
data type	$v_{\mathrm{drift}}[\mu\mathrm{m\,ns}^{-1}]$	$v_{\mathrm{drift,simulated}}[\mu\mathrm{m\,ns}^{-1}]$
$E = 240\,\mathrm{V\,cm}^{-1}; B = 0\,\mathrm{T}$	76.00 ± 0.06	75.95
$E = 240\,\mathrm{V\,cm}^{-1}; B = 1\,\mathrm{T}$	75.82 ± 0.05	75.95
$E = 130\,\mathrm{V\,cm}^{-1}; B = 1\,\mathrm{T}$	54.09 ± 0.03	53.06

Simulation is done in Magboltz

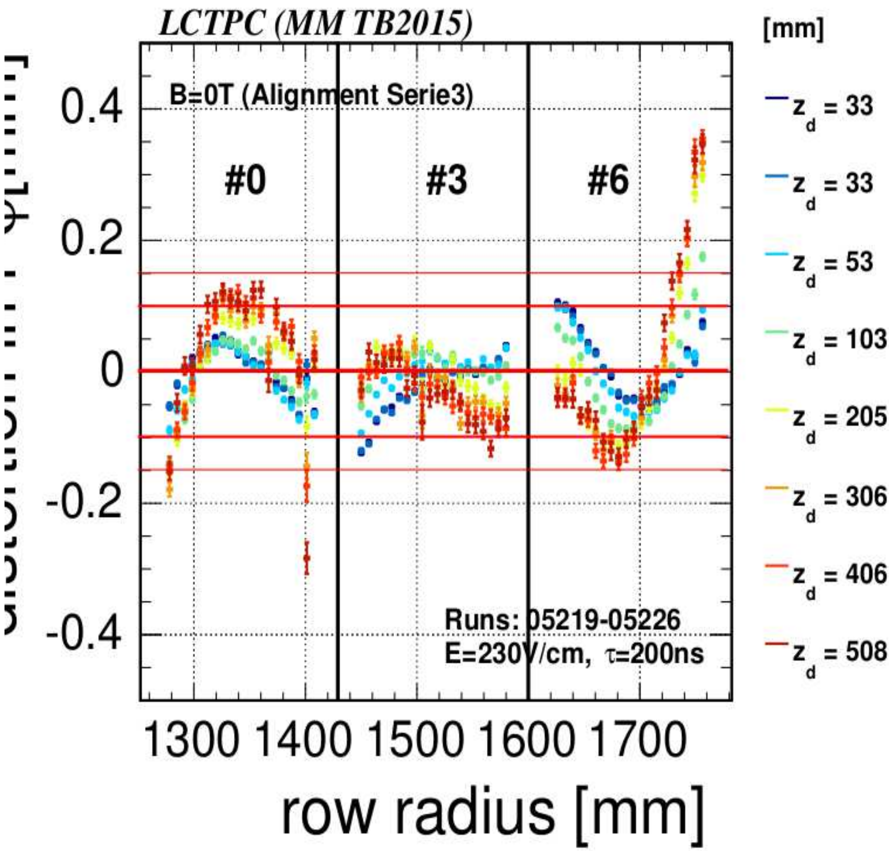
- ❖ **There could be misalignment between the modules during installation**

✓ Rotational and/or translational alignment correction is done during analysis

Alignment of Micromegas modules at B=0 T



Before alignment of the modules



After alignment of the modules

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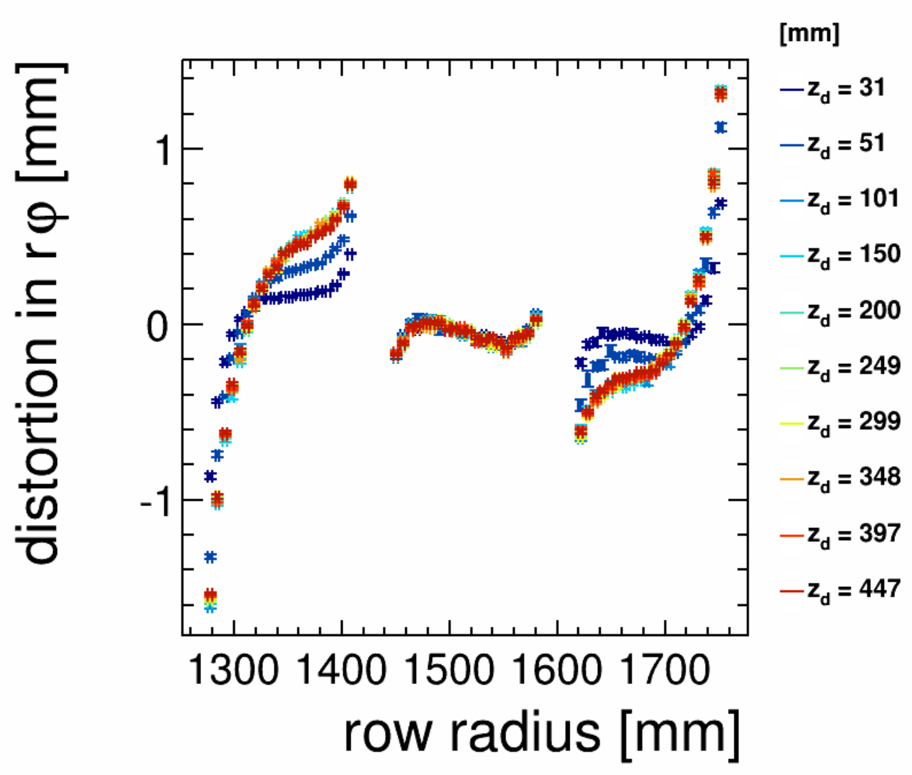
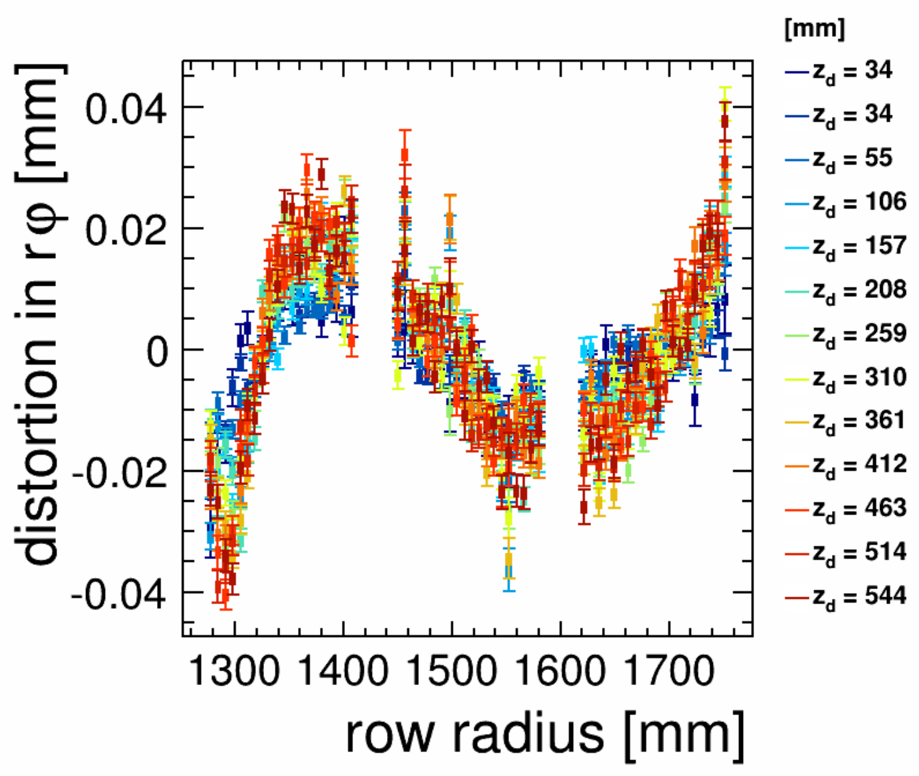
- **grounded or low potential surfaces near the edges of the module create localized electric field distortion**

- ✓ **Effect of distortion due to non-uniform field is also reduced during analysis**

Distortion in Micromegas, at B = 1 T



Before distortion correction



After distortion correction

The E×B effect can be seen near the edges

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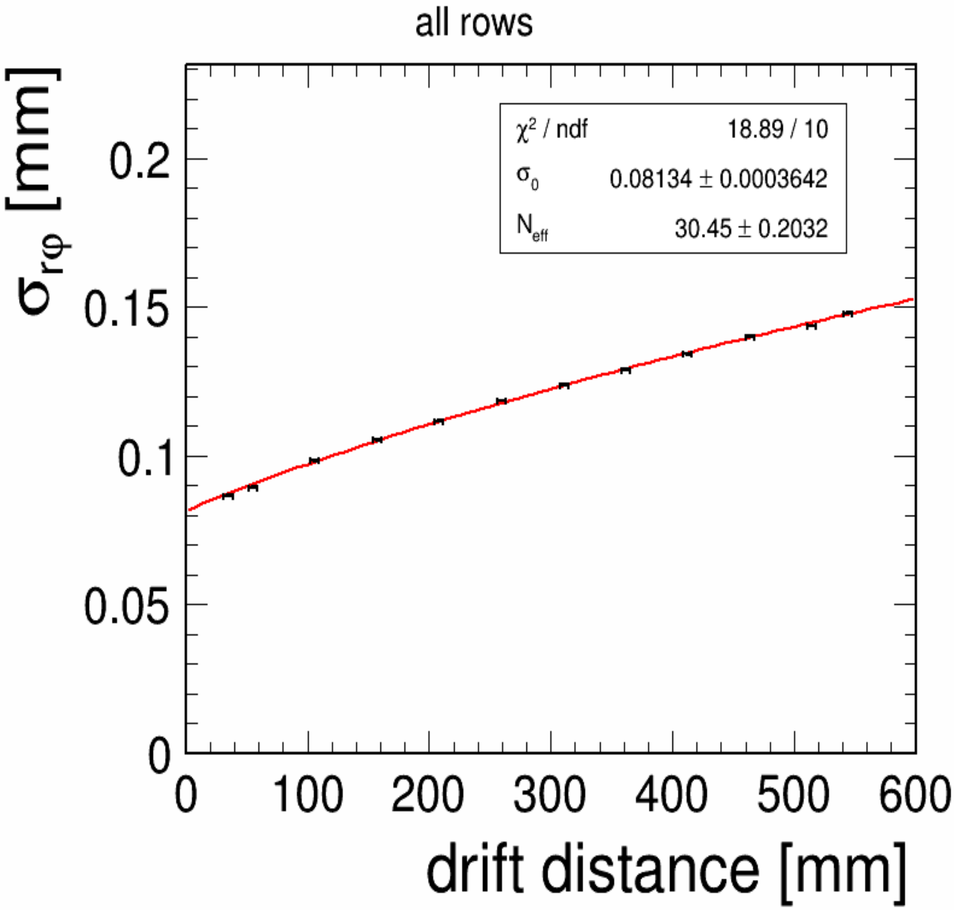
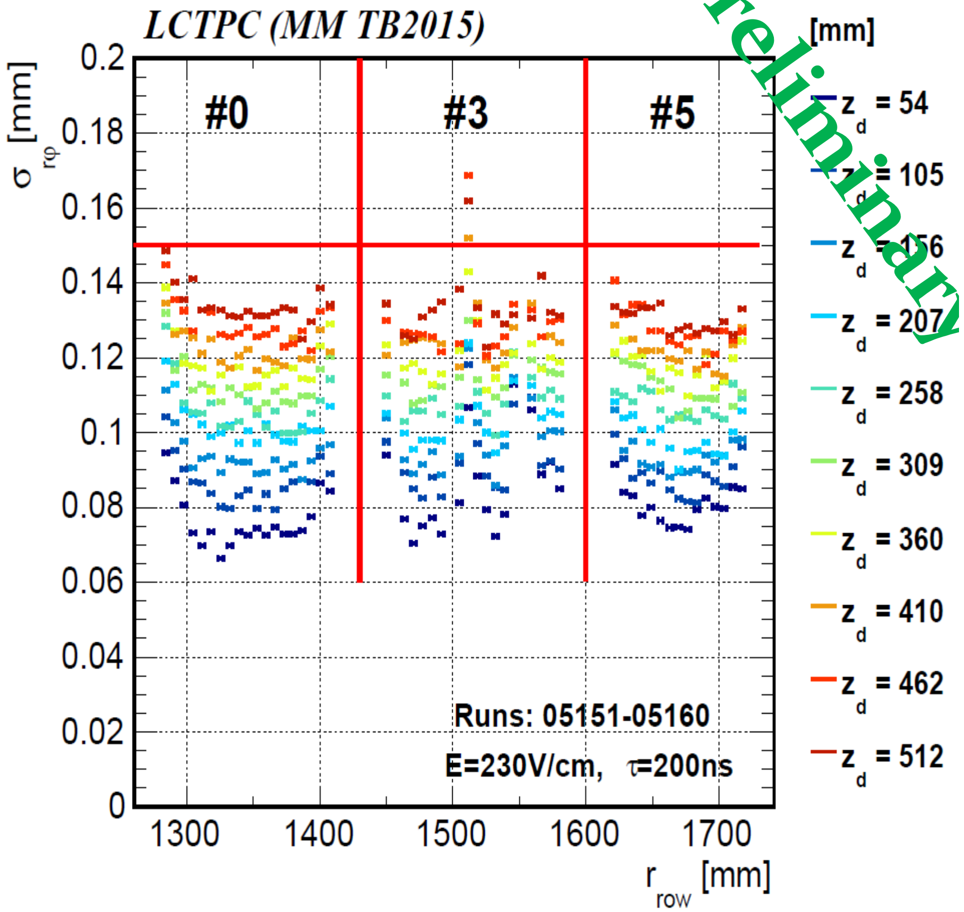
r-phi resolution of Micromegas

B=1T, peaking time = 200 ns, E=230 V/cm, phi = 0





r_phi resolution is below 150 micron for B = 1 T BD and CLK modules are closely comparable

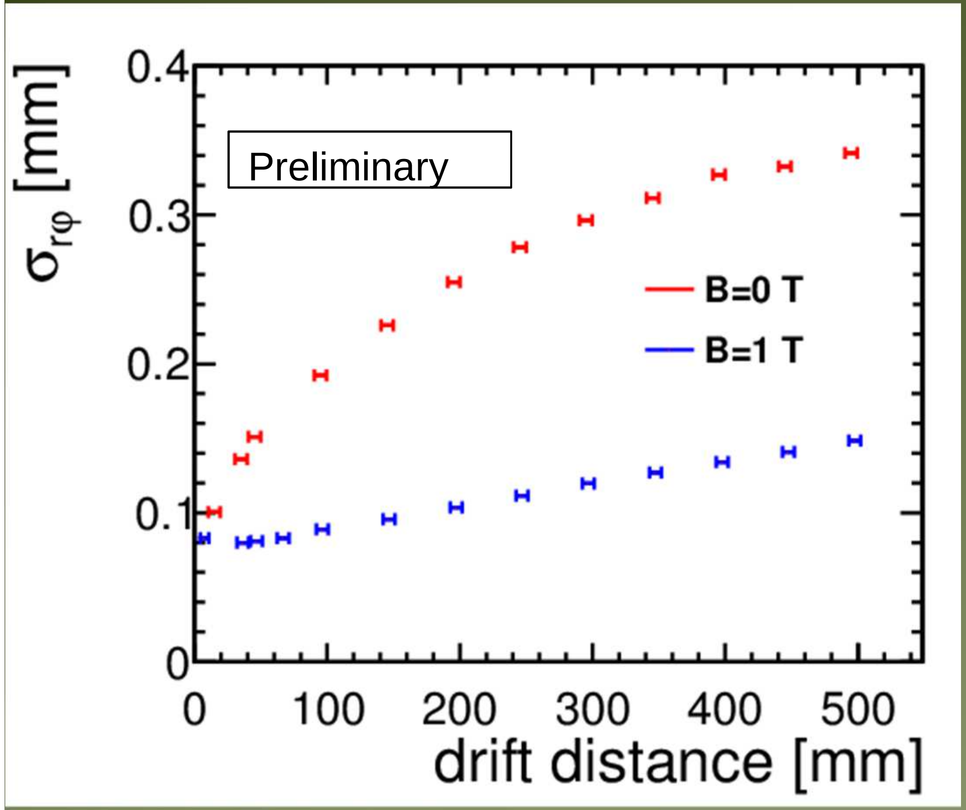
Fit formula: $\sigma = \sqrt{\sigma_0{}^2 + \frac{C_d^2 \cdot z}{N_{eff}}}$

σ_0 : the resolution at Z=0

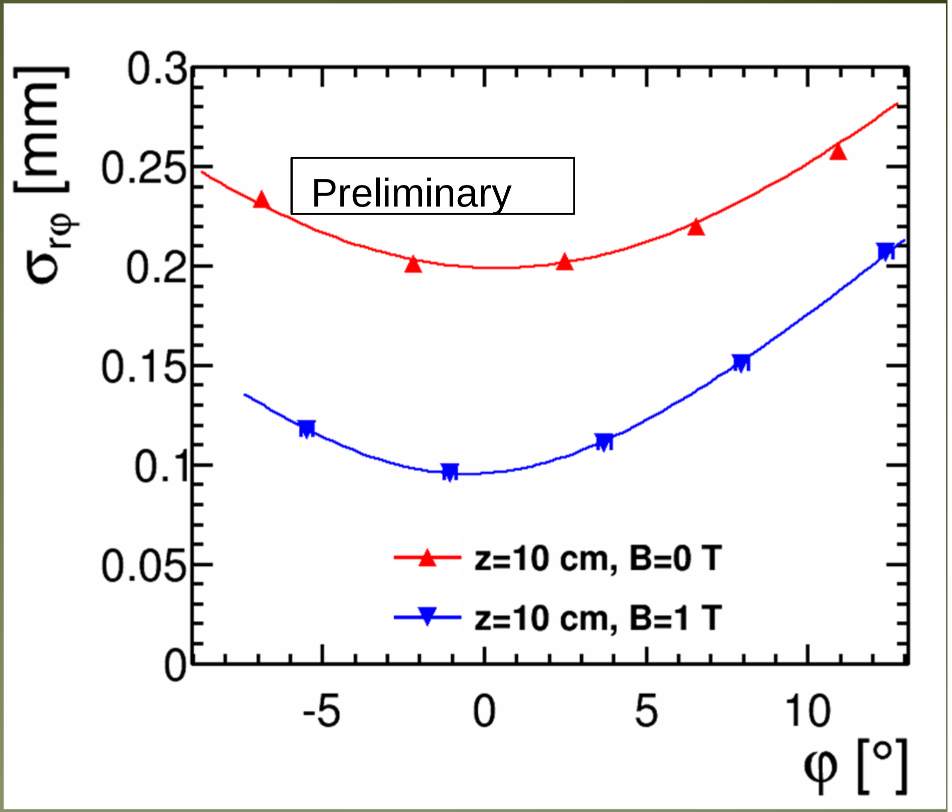
N_{eff} : the effective number of electrons

r-phi resolution (GEM)

r-phi resolution vs drift distance



r-phi resolution vs phi angle

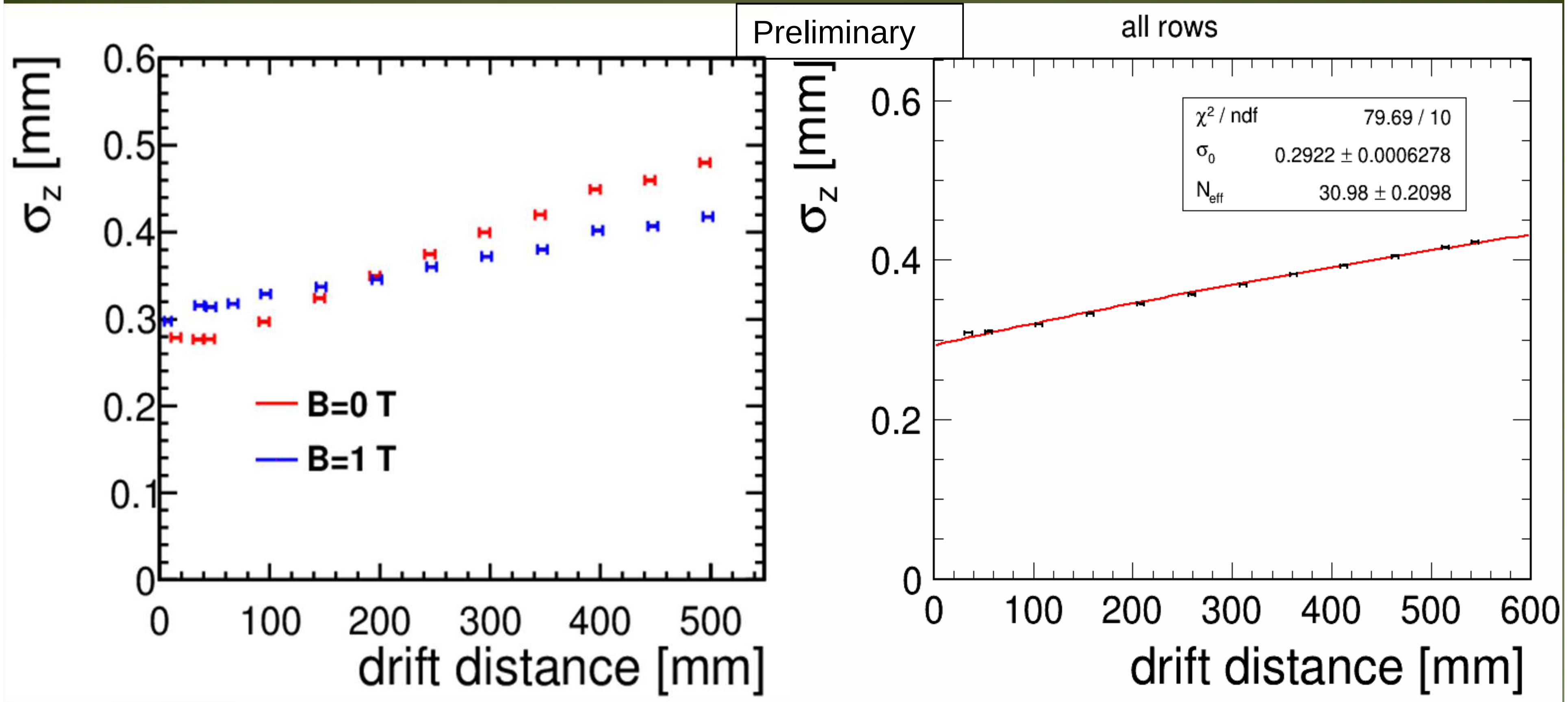


application of magnetic field improves the result

For 60 cm drift, r_phi resolution is below 150 micron for B = 1 T, which satisfies ILD criteria

Z resolution

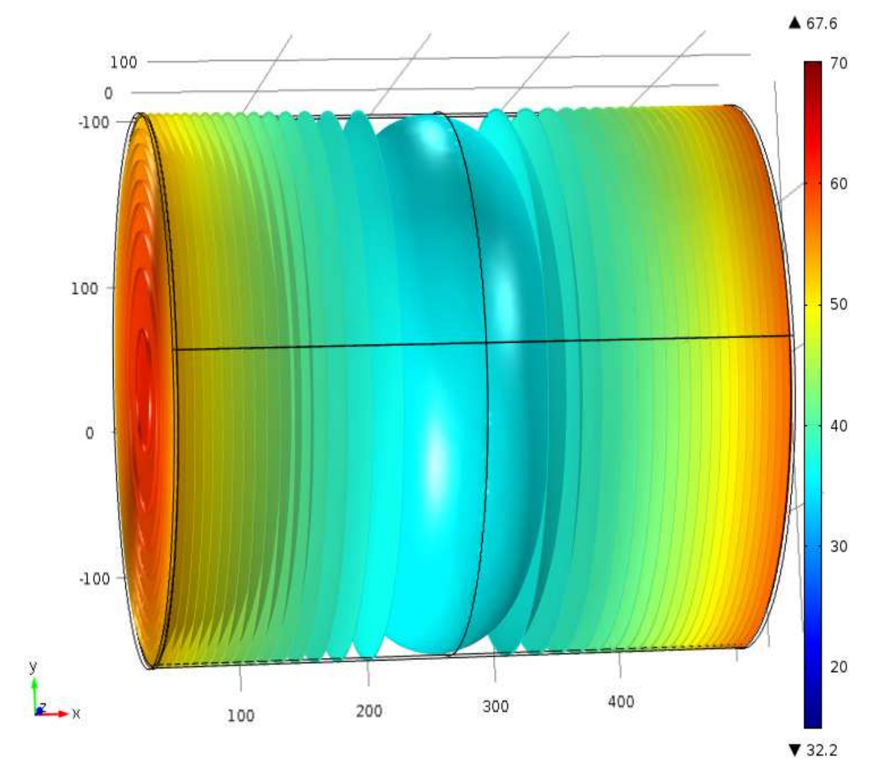
Z resolution vs drift distance



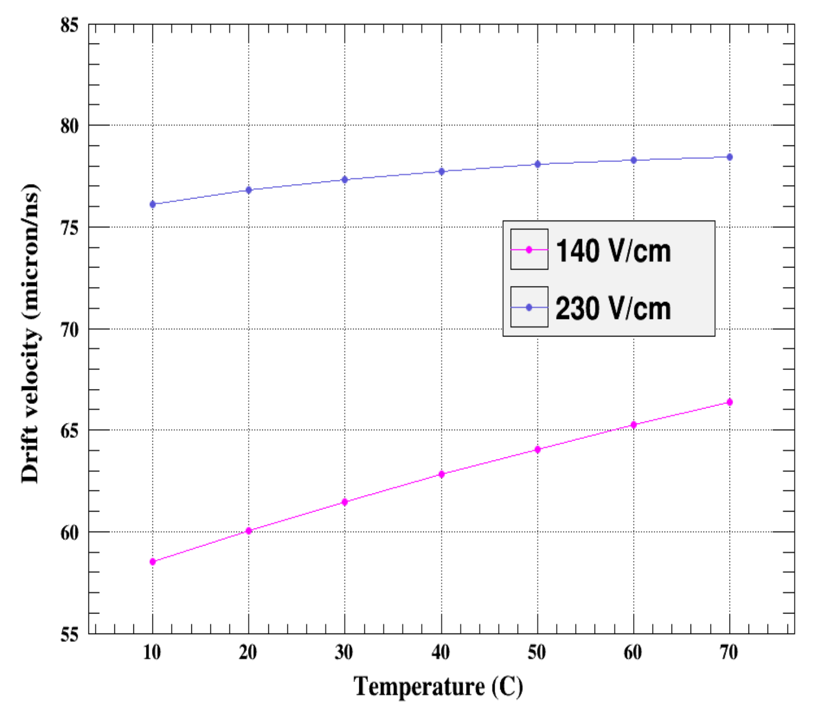
The Z resolution in 1 T magnetic field satisfies ILD requirement

Heating of electronics

- ❖ Each (Micromegas) electronic takes nearly 30 W of power.
- ❖ This rises the temperature of the detector up to 70 deg C
  - ❖ Electronics can be damaged if it runs for hours without cooling
  - ❖ Temperature gradient in TPC would occur if heat is not remoded



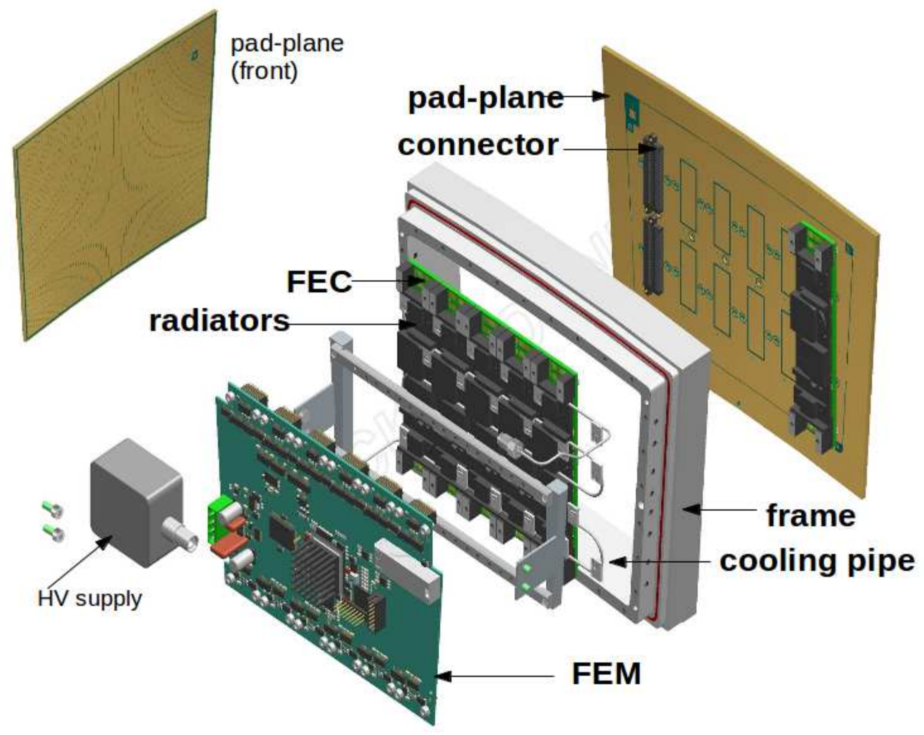
Temperature gradient in ILC-TPC
Simulation with COMSOL



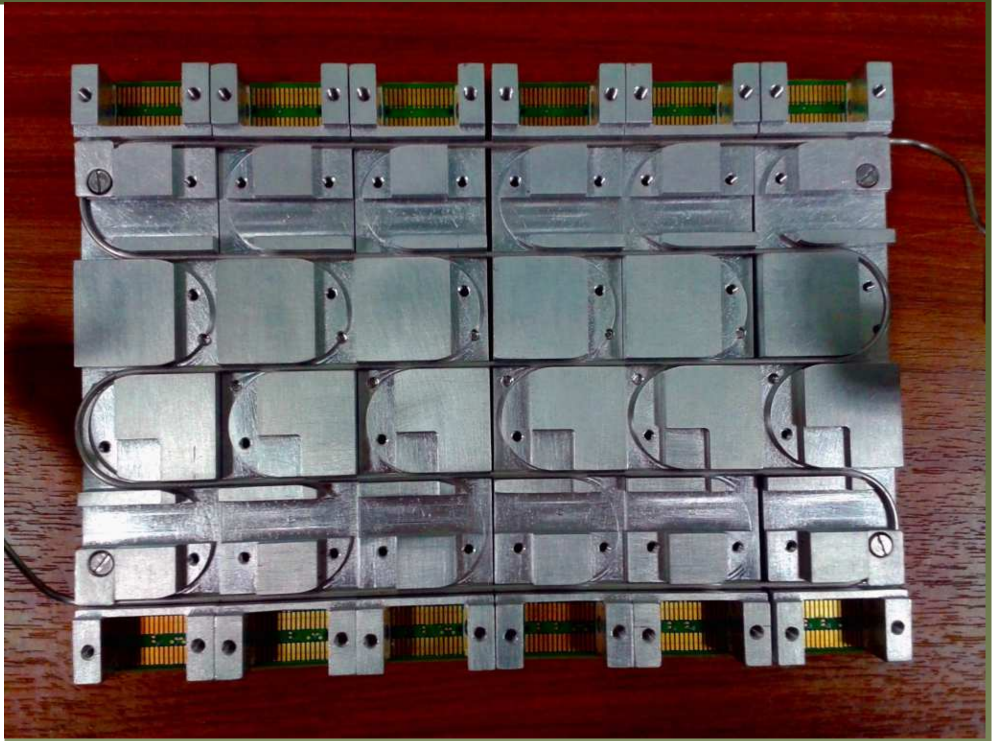
Drift Distance Vs Temperatur
Simulation with Magboltz

Two-phase CO2 cooling

Benefit of two-phase CO2 cooling is that the cooling happens during phase change which ensures uniform cooling at constant temperature.



General lay out of the MM module



The radiators and the cooling pipe

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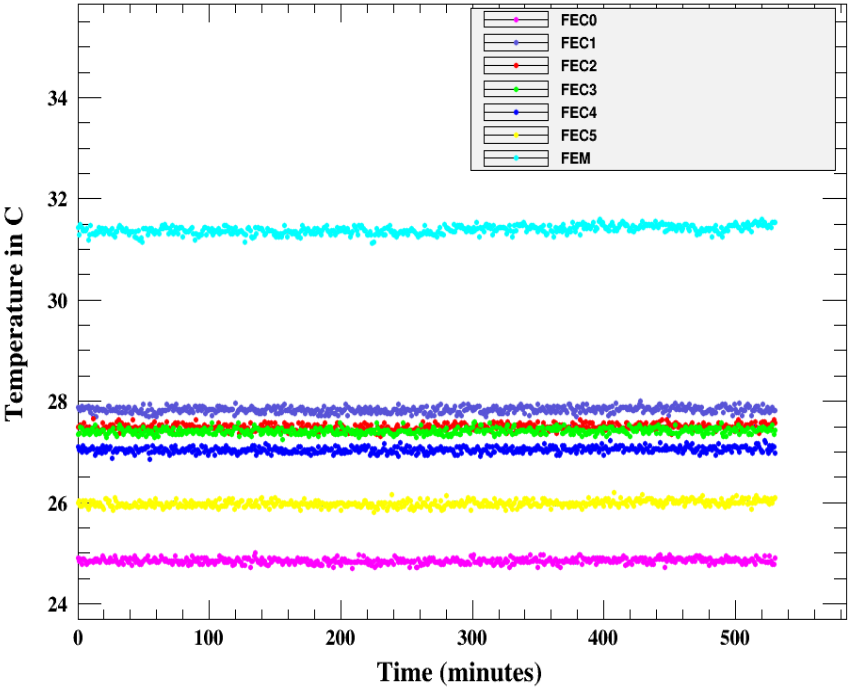
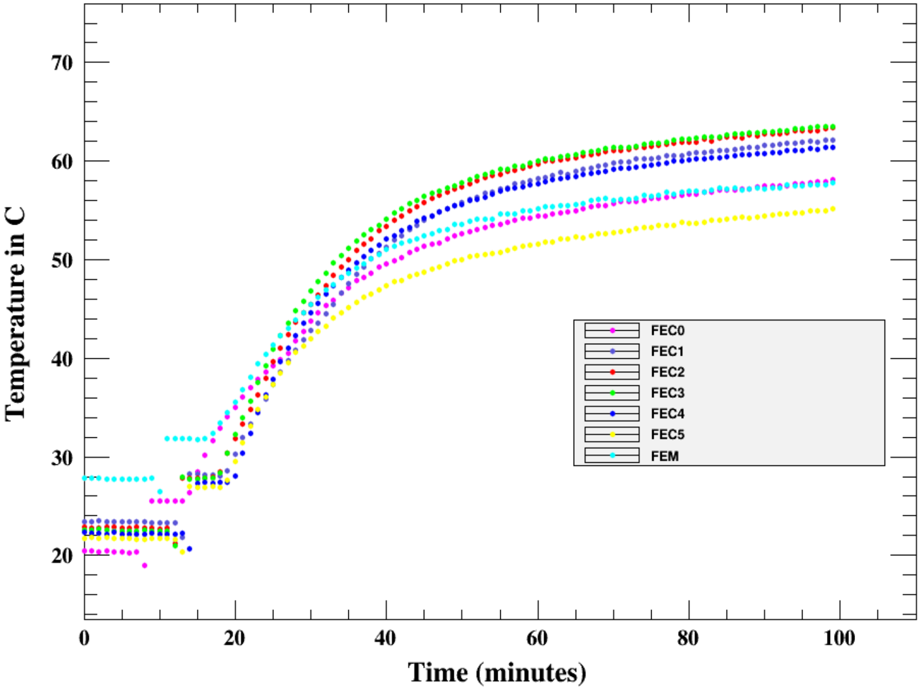
Two-phase CO2 cooling during 2015 beam test

During cooling, temperature is below 30 deg C and Stable within 0.2 deg C.



Stable temperature during cooling



Temperature rises when cooling is stopped

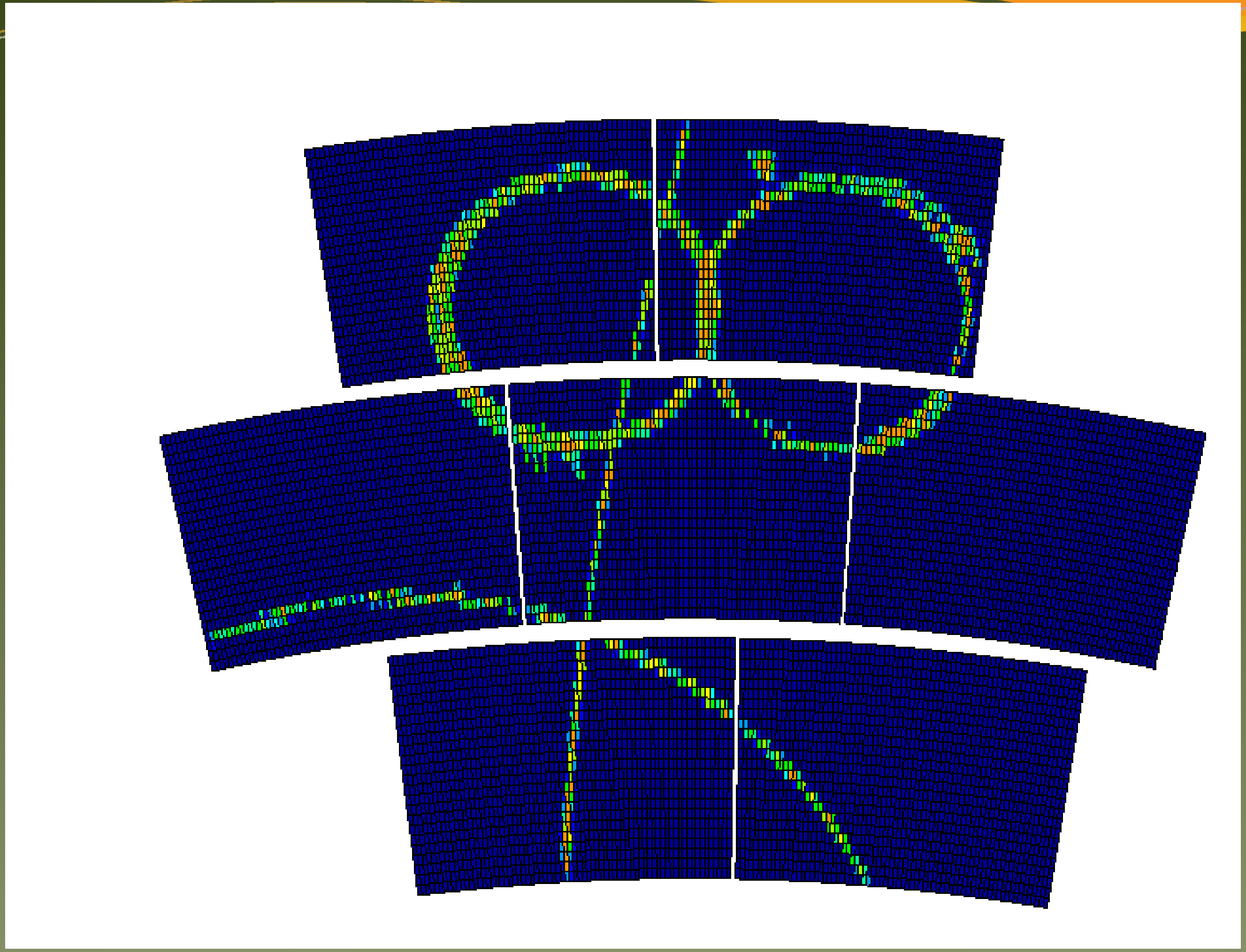
Summary

- ☐ Different studies have been carried out with Micromegas and GEM modules at Large Prototype TPC since 2008.

- ☐ In 1 Tesla magnetic field, for 60 cm drift length, the space resolutions of both Micromegas and GEM are below 150 micron. This satisfies ILC requirement.

- ☐ Two new Micromegas modules (from Japan) with resistive layer of 'Diamond Like Carbon' (DLC) have been tested in March 2015. Result is satisfactory. Problems due to unavailability of 'CLK' resistive layer is solved.

- ☐ Two-phase CO2 cooling is used uninterruptedly for more than 80 hrs. Temperature of individual Front End Cards (FECs) is stable within 0.2 degree C during the beam test.



THANK YOU

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Backup Slides

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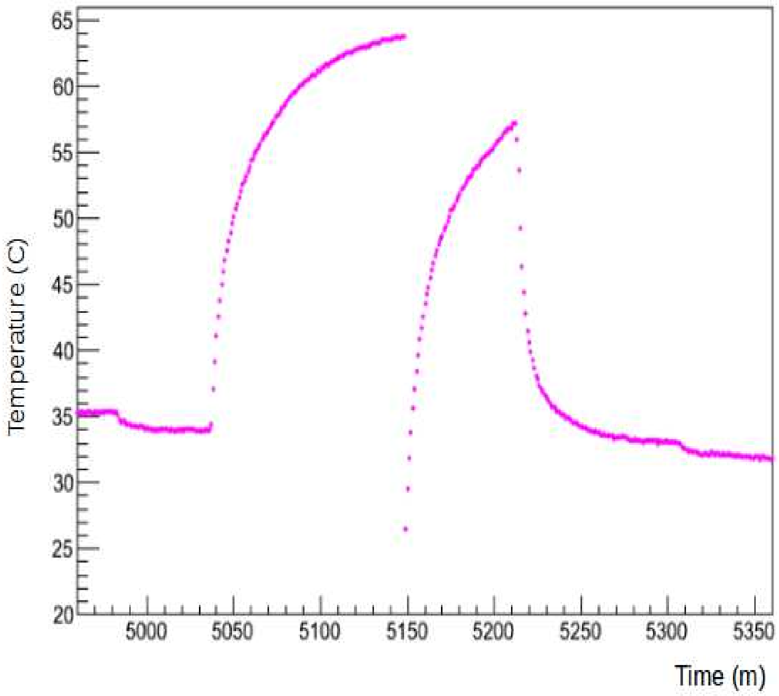
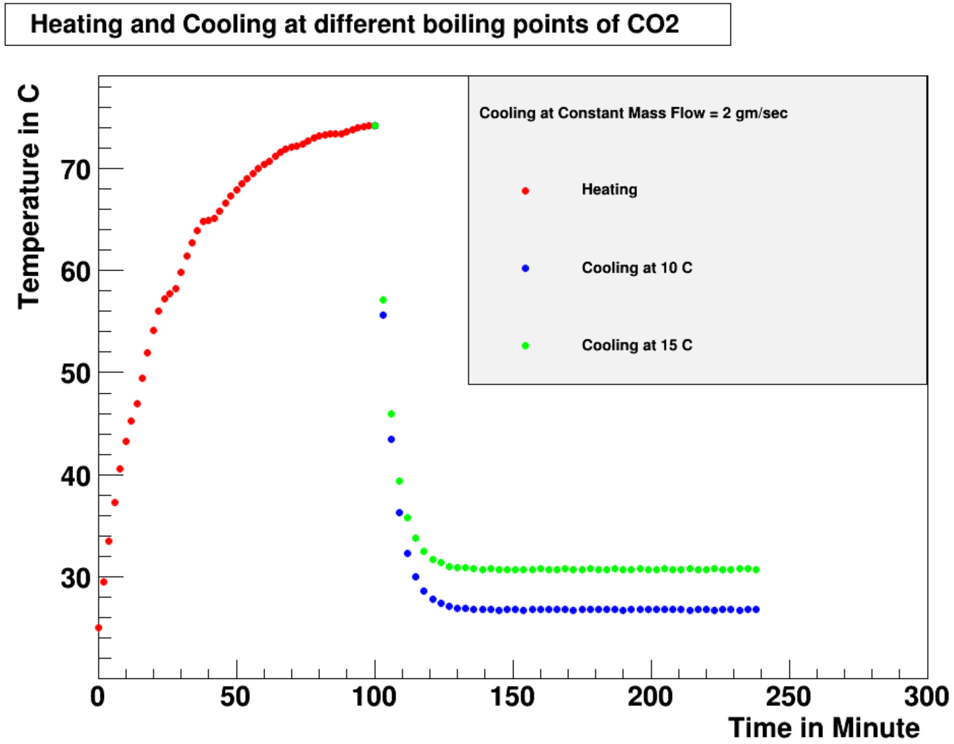
Two-phase CO_2 cooling

Experimental and simulation result for one MM module shows heating and cooling





Experimental result with one module
Shows the heating and cooling

Simulated result for one module
Shows heating and cooling

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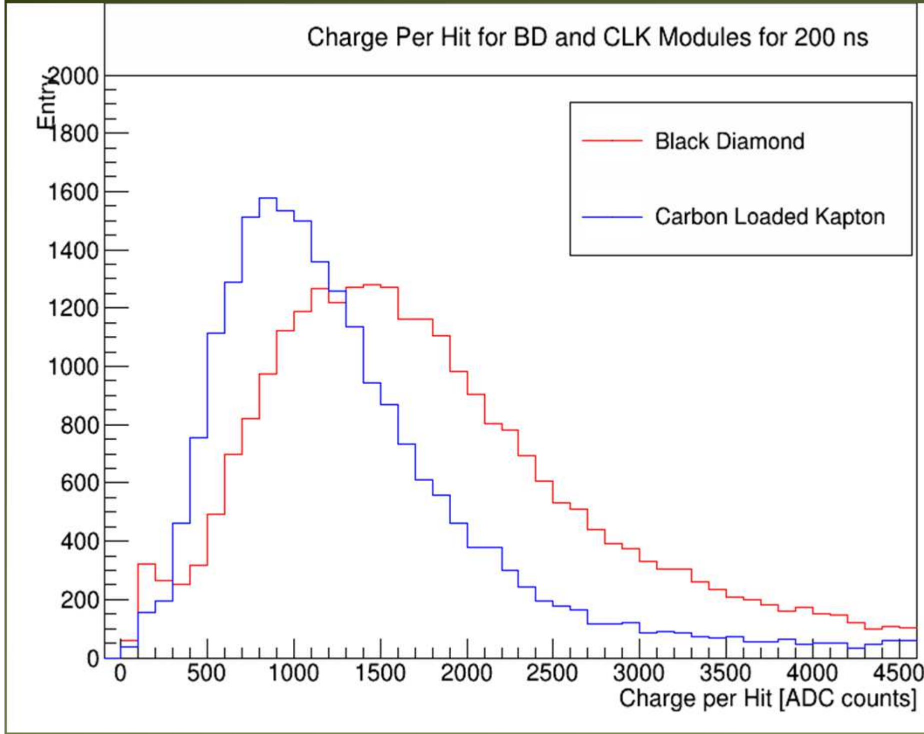
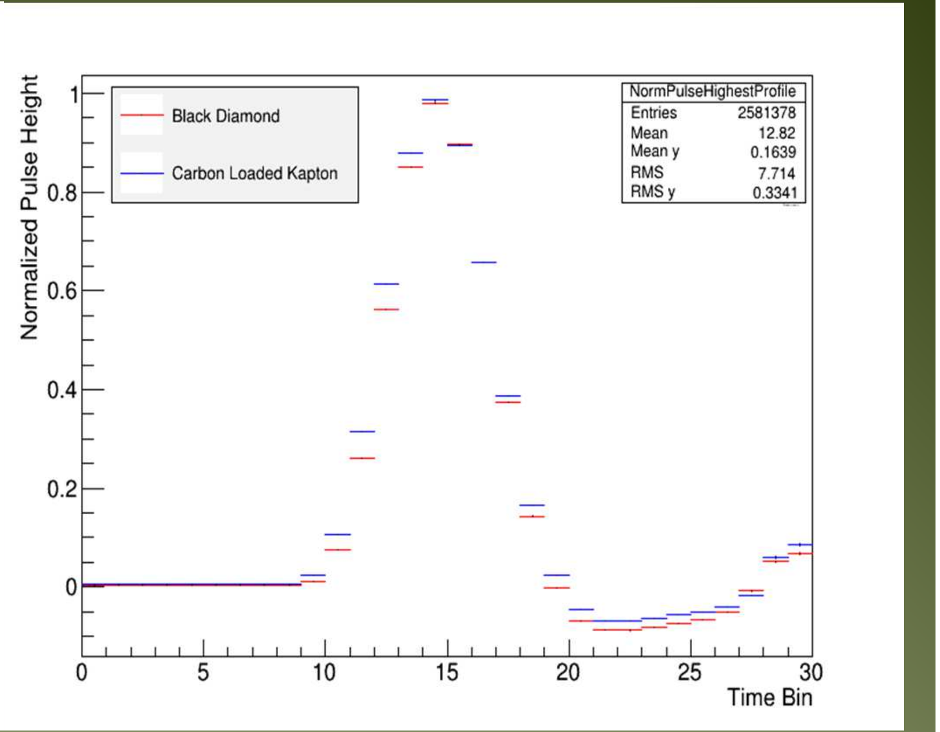
Charge per Cluster for CLK and BD modules at 200 ns peaking time of the electronics

Normalised main pulse for BD and CLK

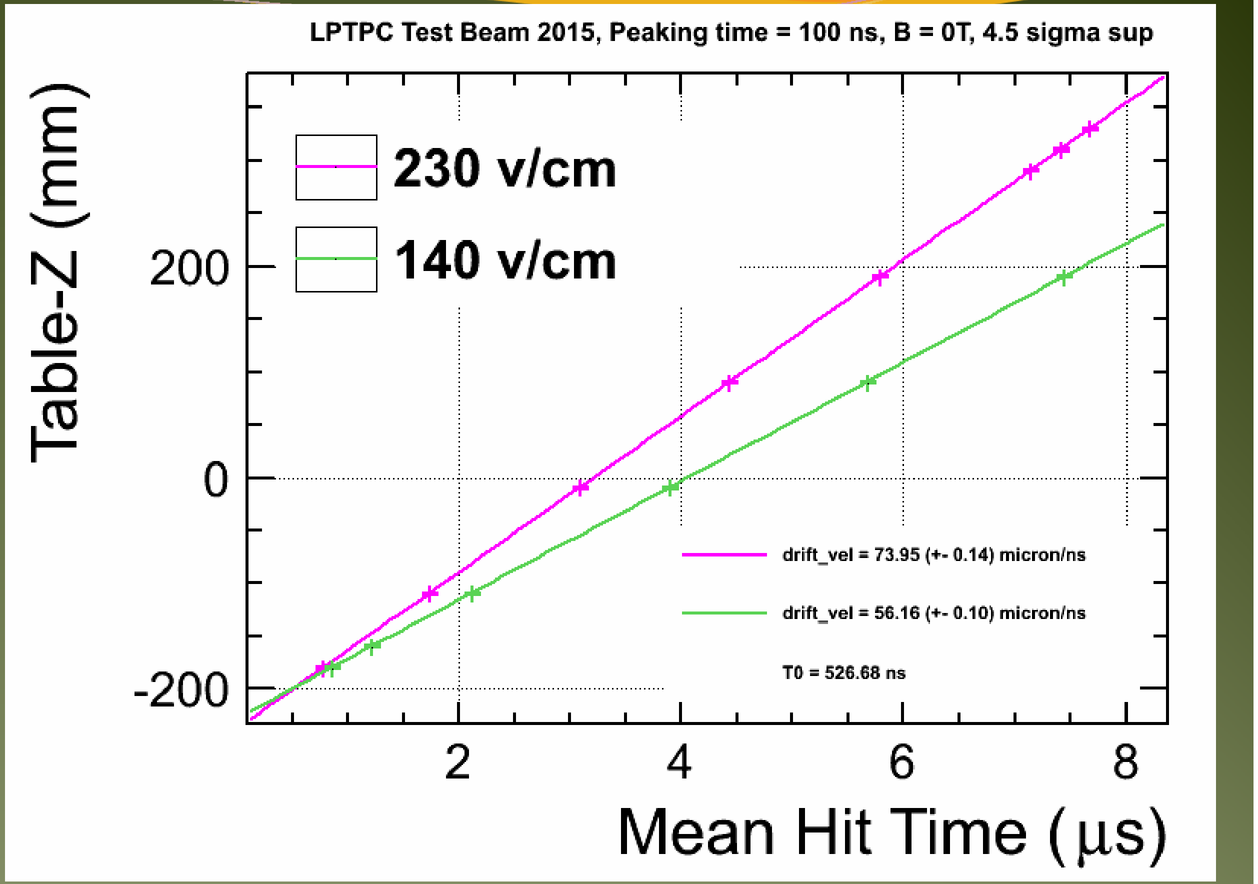




Charge per cluster in BD is slightly more than CLK.
This is because, BD has slightly larger capacitance than CLK.

The pulse shape of both detectors are nearly same.
DLC modules are good substitute for CLK

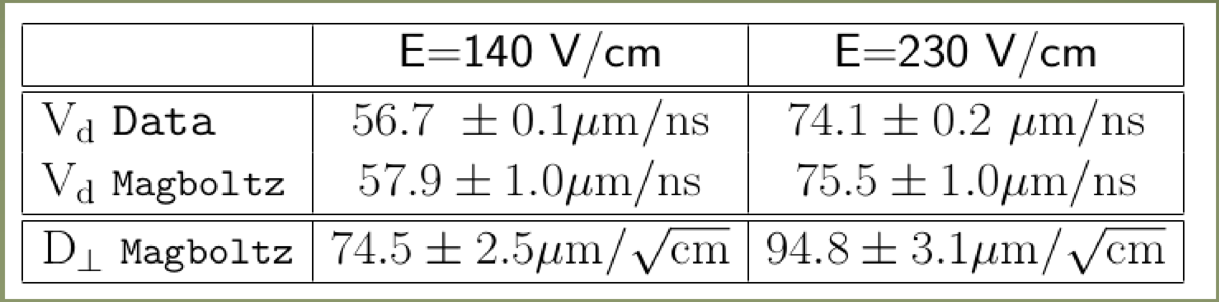
Measurement of drift velocity with Micromegas



The slope gives drift velocity.

The intersection point gives the time of zero drift (To).

Calibration of drift length (or time) is done from To.



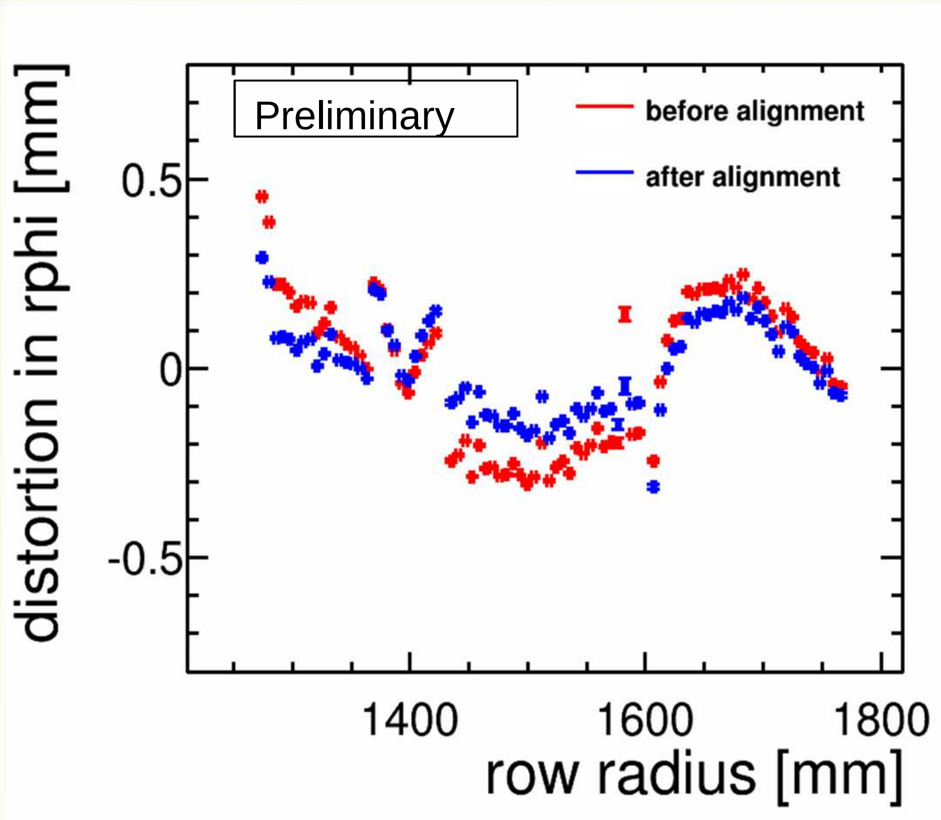
	E=140 V/cm	E=230 V/cm
V_d Data V_d Magboltz	$56.7 \pm 0.1 \mu m/ns$ $57.9 \pm 1.0 \mu m/ns$	$74.1 \pm 0.2\ \mu m/ns$ $75.5 \pm 1.0 \mu m/ns$
$D_\perp$ Magboltz	$74.5 \pm 2.5 \mu m/\sqrt{cm}$	$94.8 \pm 3.1 \mu m/\sqrt{cm}$

Alignment for (GEM)

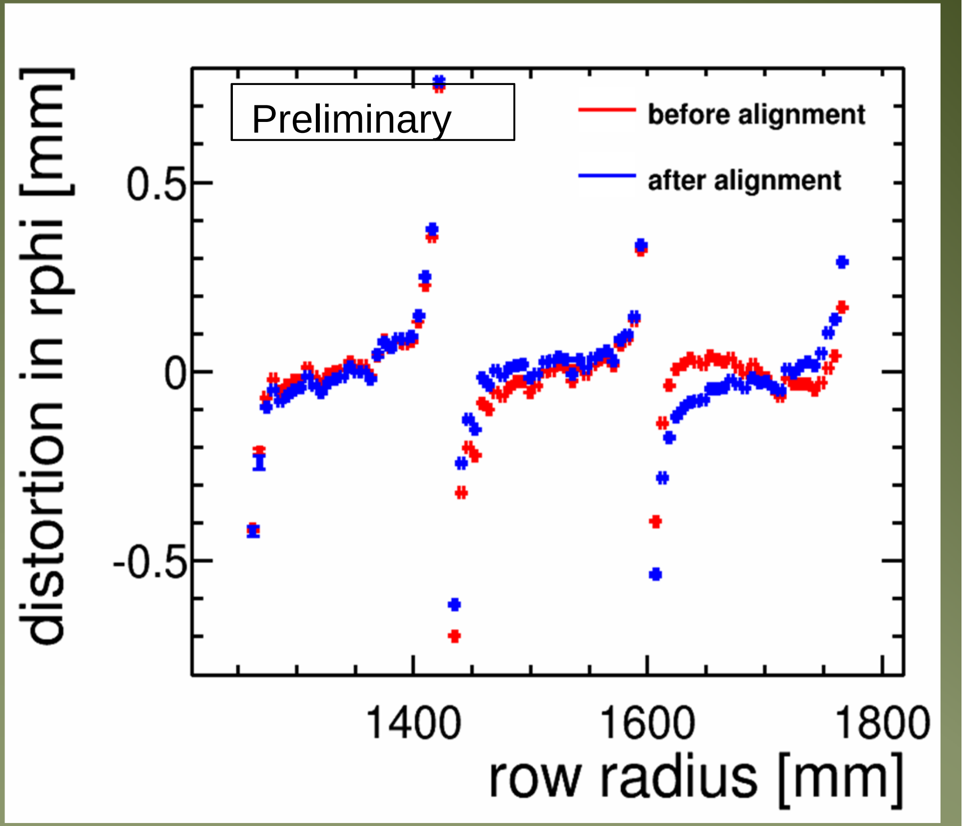
Alignment may occur during installation of the modules.

The effect is reduced by alignment correction during analysis.

B = 0 T

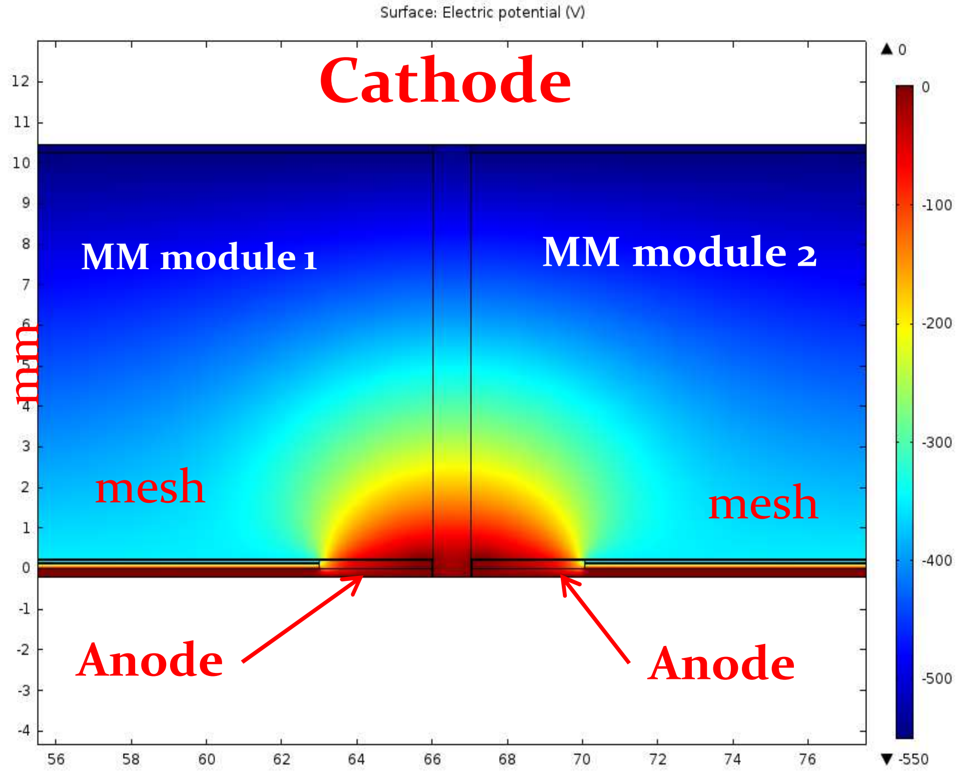


B = 1 T

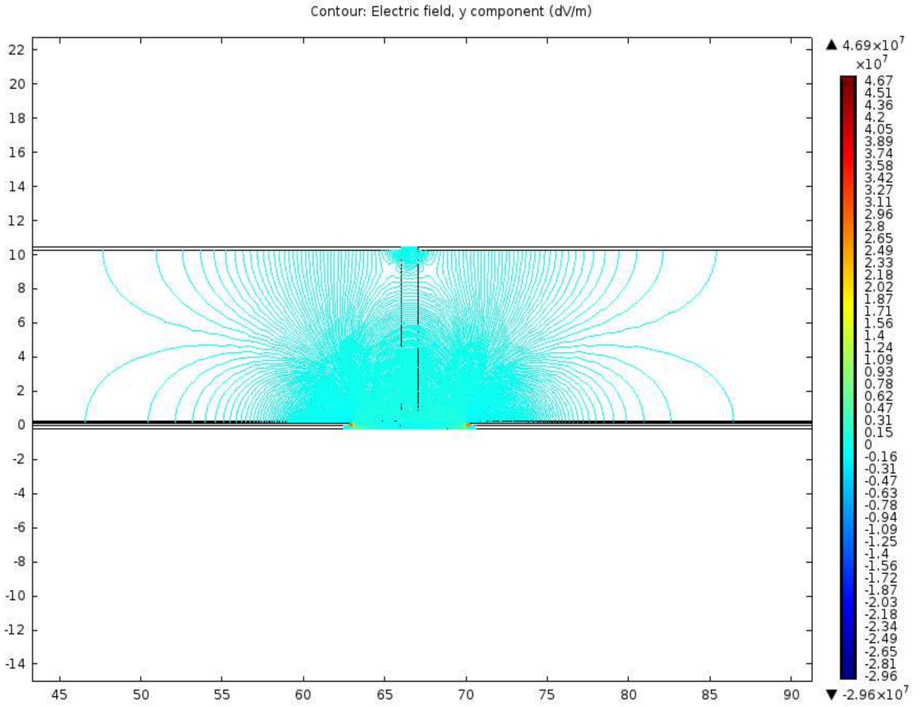


Micromegas

Potential distribution

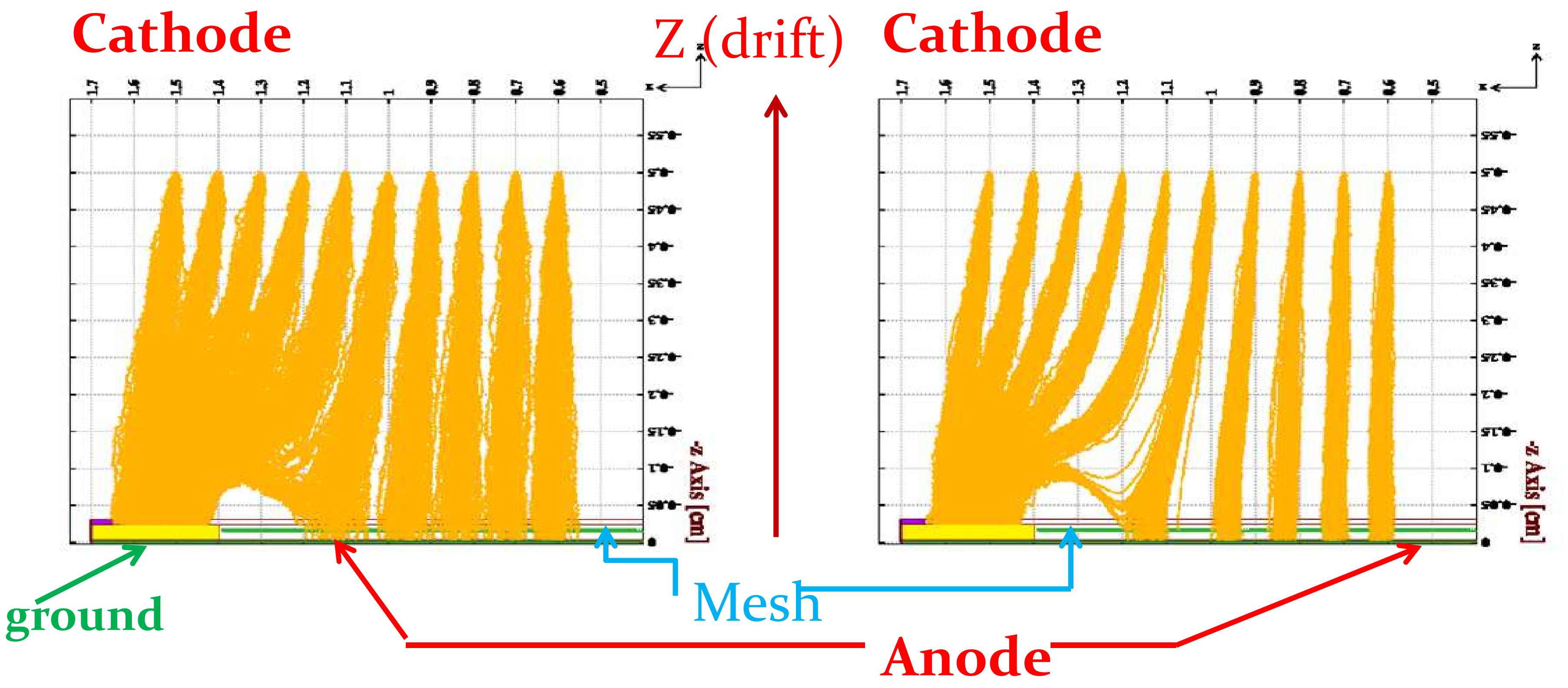


Field distortion (Micromegas)



Simulation with COMSOL

Drift of the electrons



B = 0

B = 1

Simulation with Garfield

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Two-phase CO2 cooling

simulated model (COMSOL) shows how cooling works