Test of MPGD modules with a large prototype Time Projection Chamber

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On behalf of

The International Linear Collider

The International Linear Collider

ILC is a precision and discovery machine, operating initially at 500 GeV (CM). The 125 GeV Higgs and possibly other Higgses, can be produced at ILC.

International Large Detector

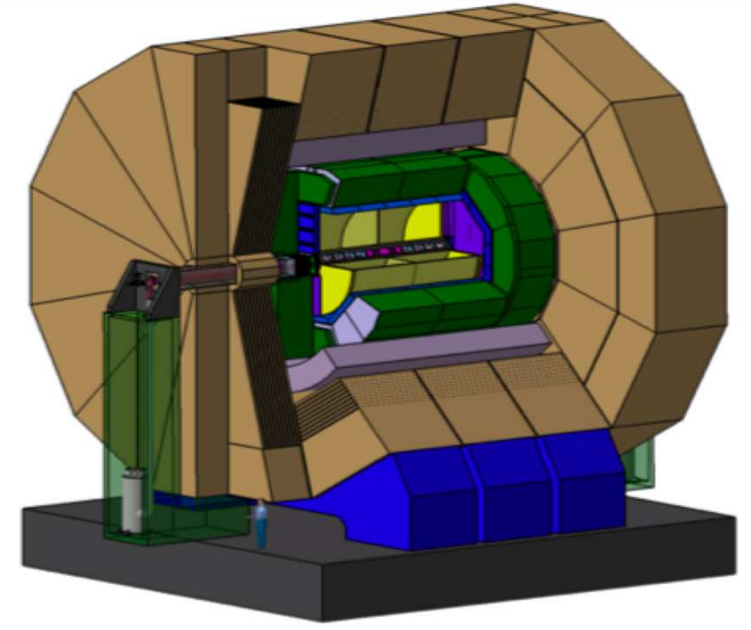


Figure 2: A schematic view of the International Large Detector concept (the TPC is the yellow cylinder inside the blue electromagnetic calorimeter).

LC-TPC dimension

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

A TPC as main tracker has the benefits of:

- ✓ Continuous, truly 3-D tracking.
- ✓ Robust pattern recognition.
- ✓ High efficiency tracking over large momentum range.
- ✓ Low material budget.

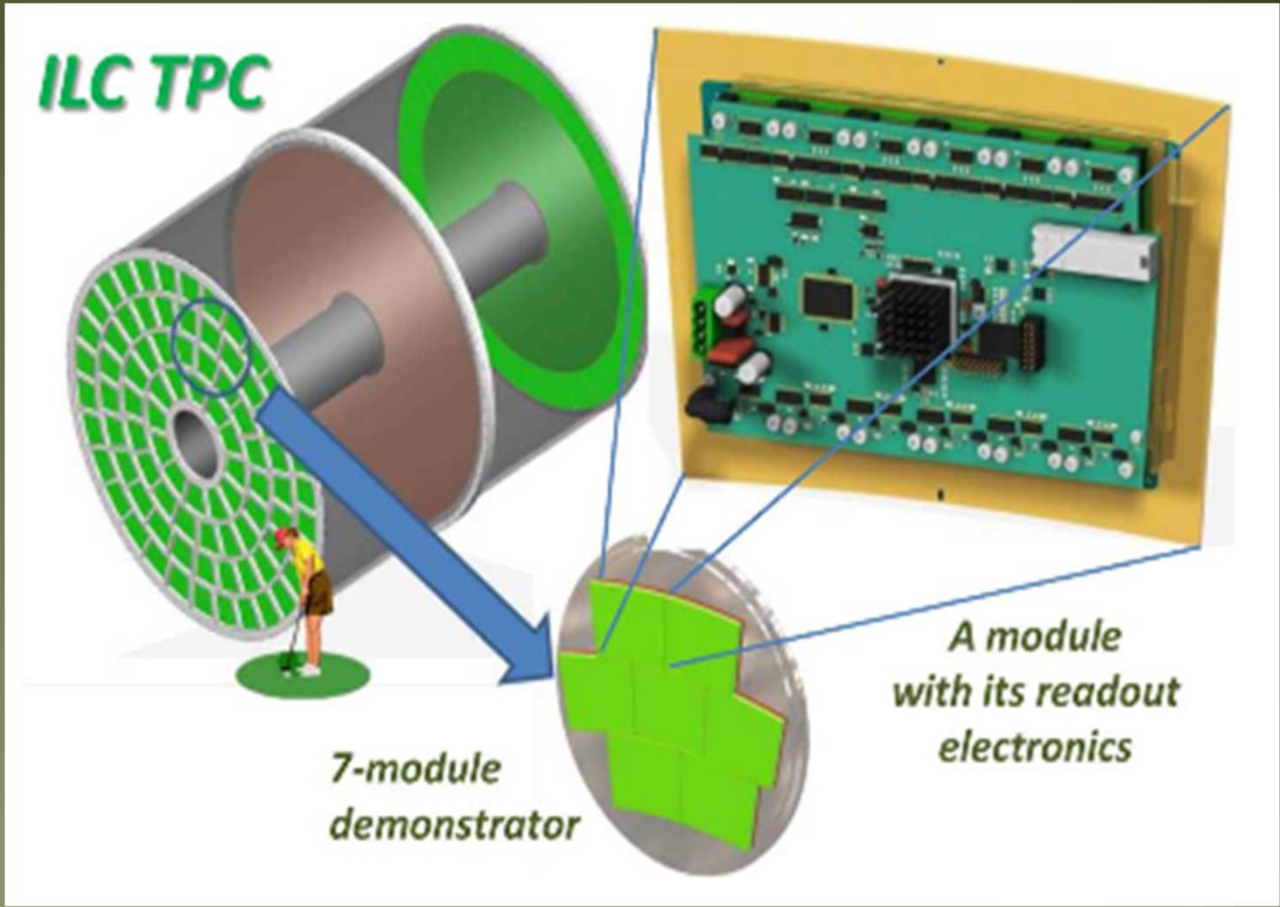
Resolution requirement

Physics goal sets the limit of r-phi resolution to be better than 100 micron over full drift length for 3.5 T magnetic field.

LC-TPC schematic (Large prototype demonstrator)

The four wheel model of the TPC endplate.

MPGD modules can be installed at the endplate.



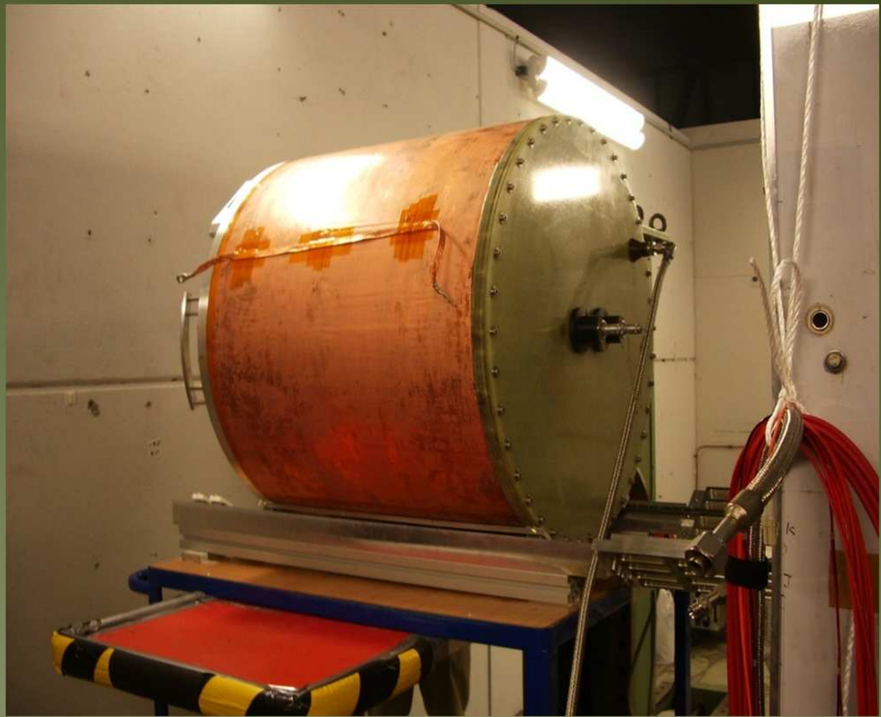
<u>The candidates are</u>

GEM
Micromegas

Besides pad-based read out, 'pixel read out' is also used (which applies GEM technology)

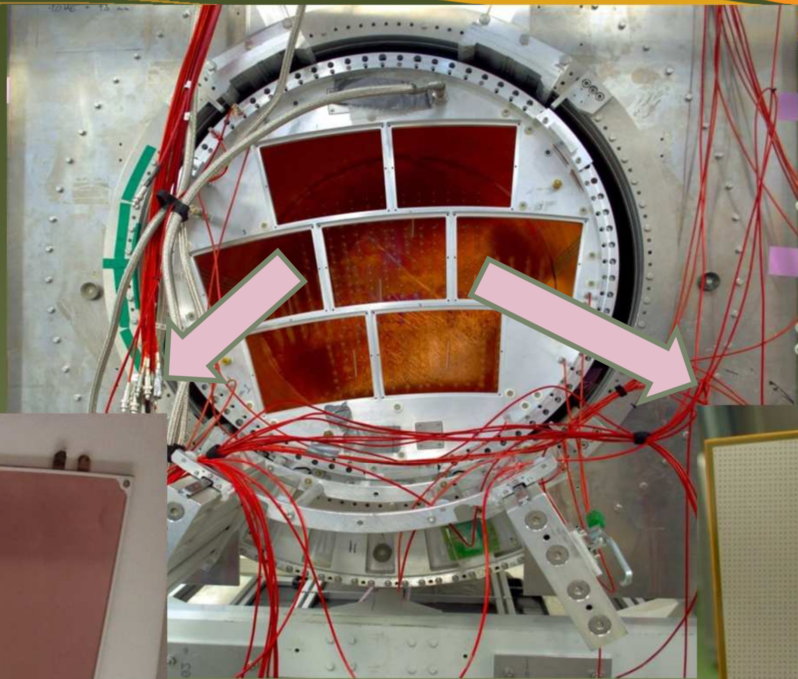
Large prototype TPC for ILC
at DESY

The movable stage and the 1T magnet.



The field cage
- Length 60 cm
- Diameter 72 cm

Pad-based anode



End plate of LP-TPC

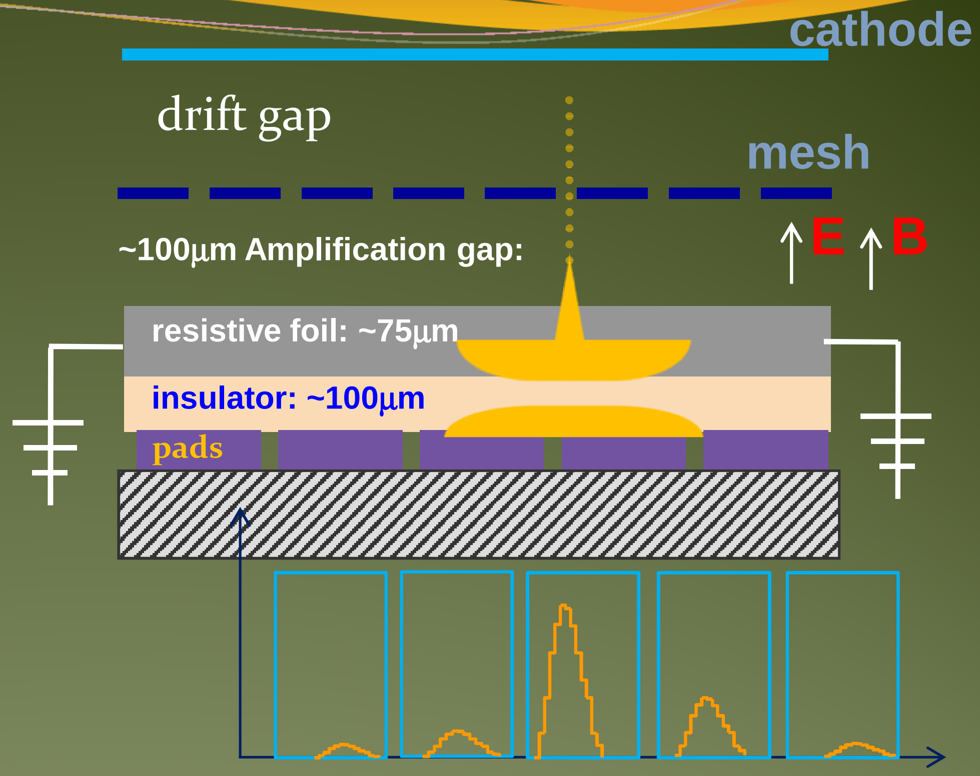
GEM module

- Module size: 22 cm × 17 cm
- 28 rows
- Readout: 4839 Pads
- Pad size: ~1.26 mm × 5.85 mm

Micromegas module

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

The Resistive Micromegas



In standard Micromegas resolution is given by,

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

Charge is dispersed in Resistive Micromegas

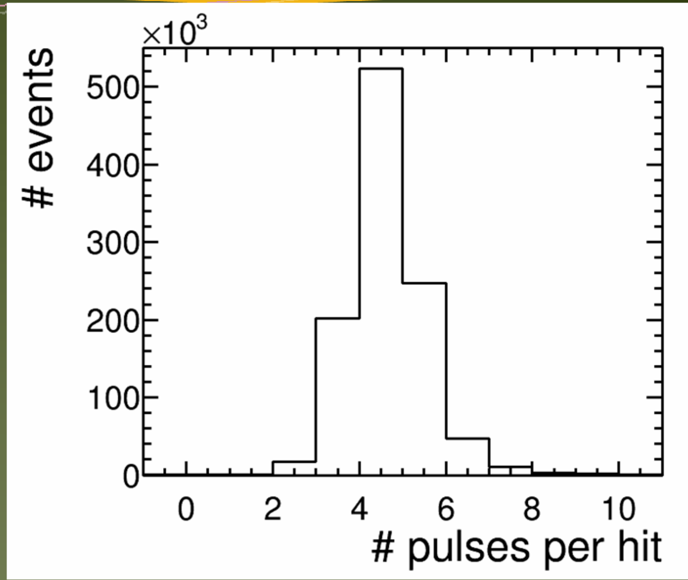
$$\sigma = \sqrt{(2t/RC)}$$

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 $\cong$ 2mm

- Commonly used *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.

The DESY GridGEM module



Pads per hit = 4.5

Triple GEM stack → Stable operation at high gain

The GEMs are divided into 4 parts→ HV stability.

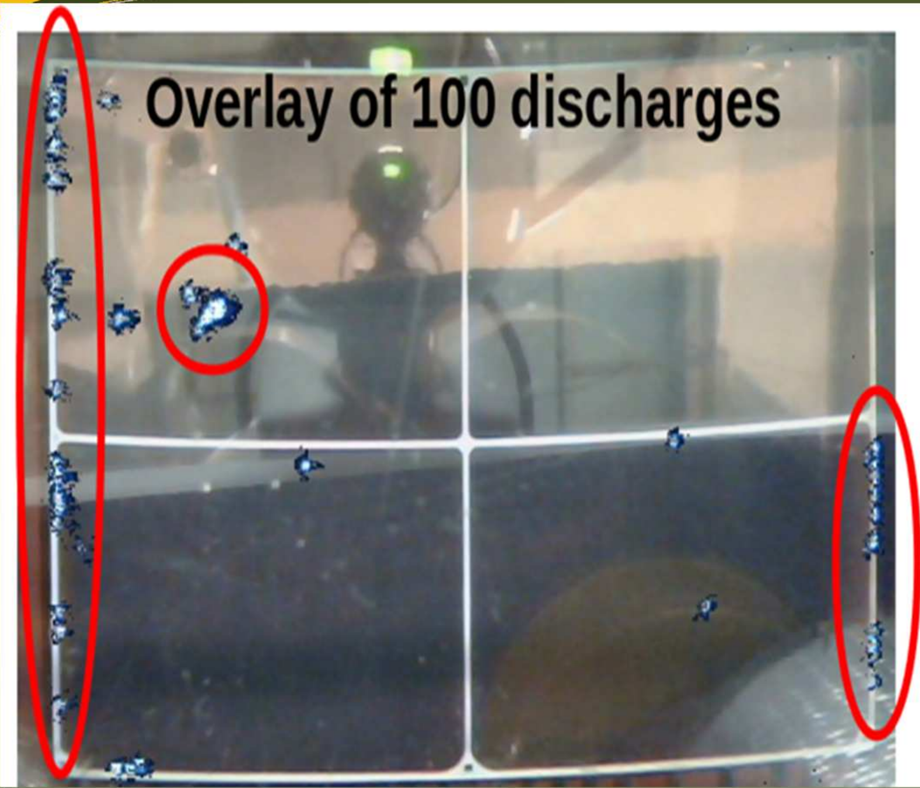
The ceramic bars provide mechanical

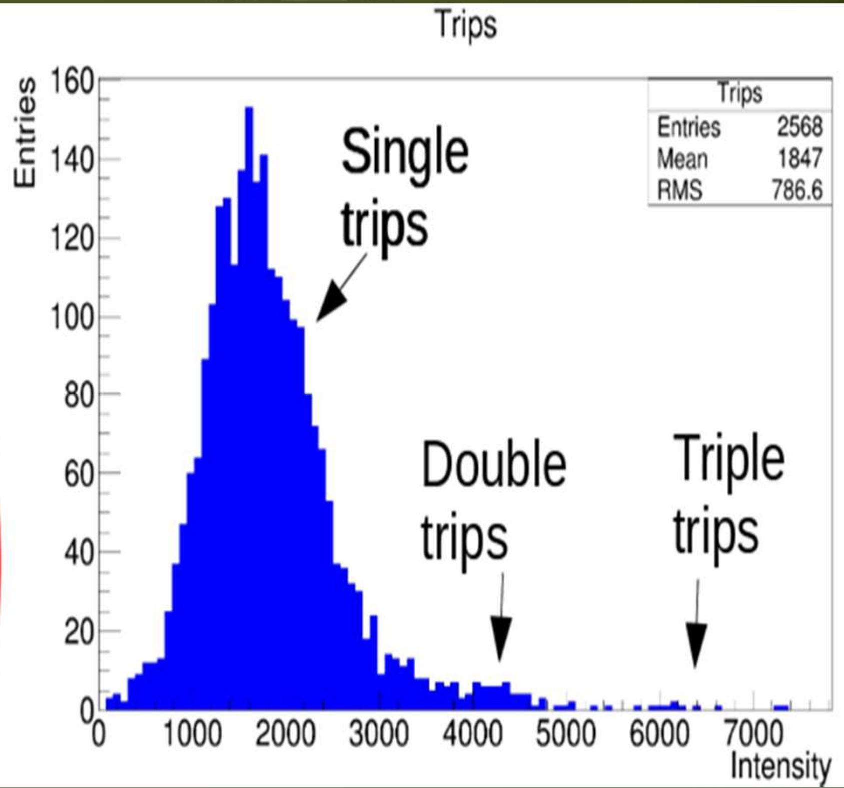
Support → light weight and flat + field uniformity.

Measured flatness < 100 micron undulations and minimum dead area.

Charge is spread during the amplification.
The spread is ~ 2 mm. This allows resolution
to be better than $\frac{w}{\sqrt{12}}$,
w being pad width.

Recent study with GEM module

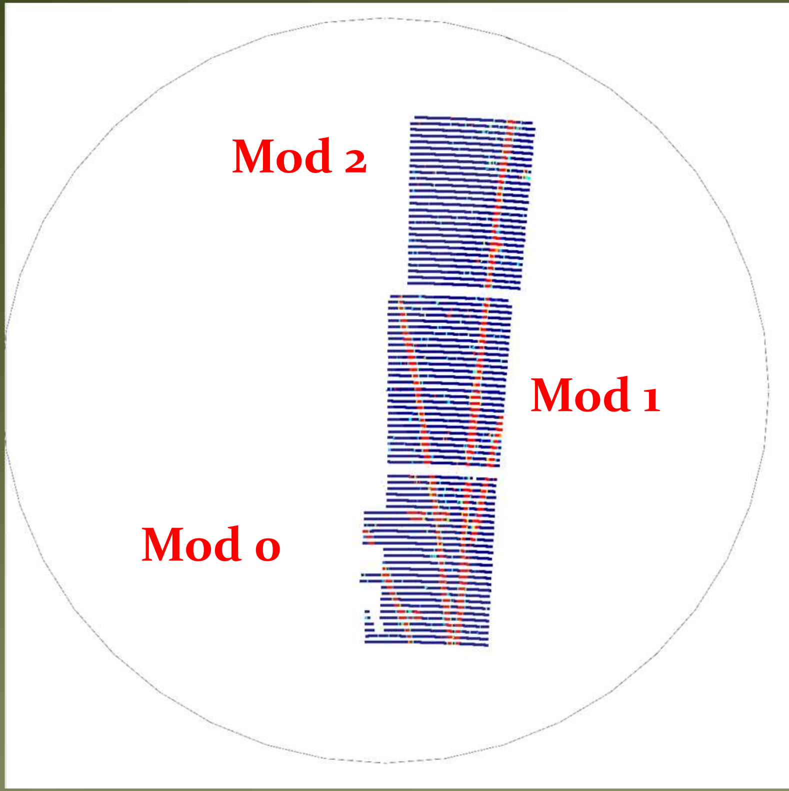




- In rare cases the trip in one sector triggers a second trip in other sector
- Only a combination of multiple trips pose a thread to destroy GEM
- Common ground of different sectors is identified as the probable reason for this.

Event display demonstrates the different configurations of beam position

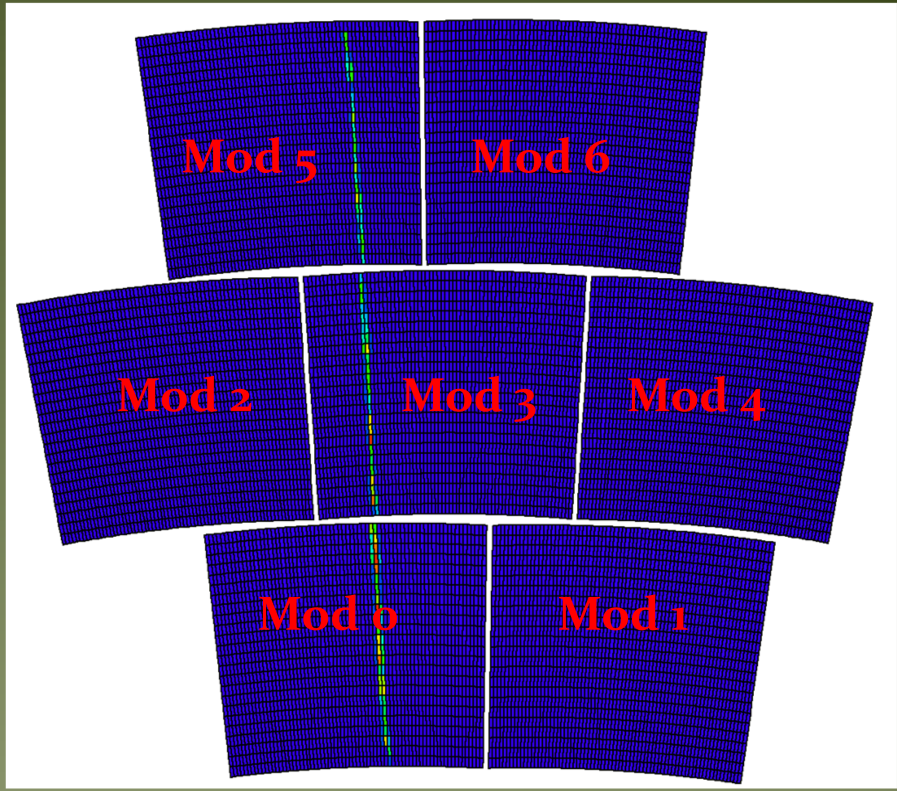
Track on GEM modules



5-GeV electron beam

Row number

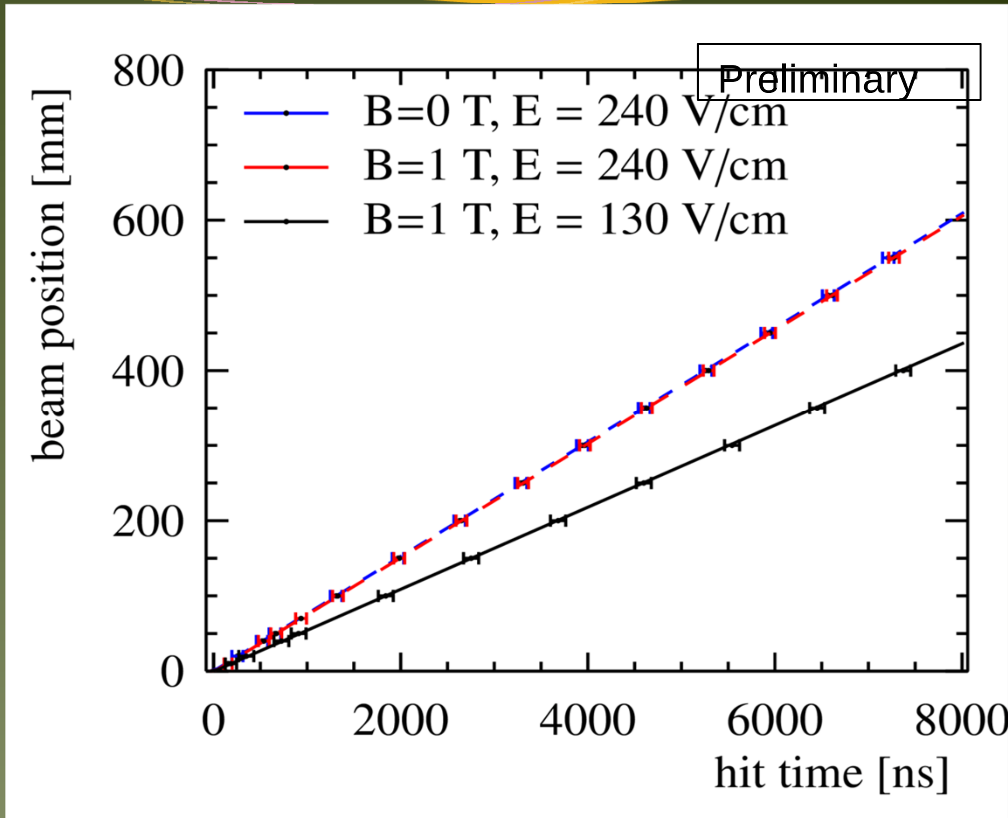
Track Micromegas modules



5-GeV electron beam

Drift velocity measurement

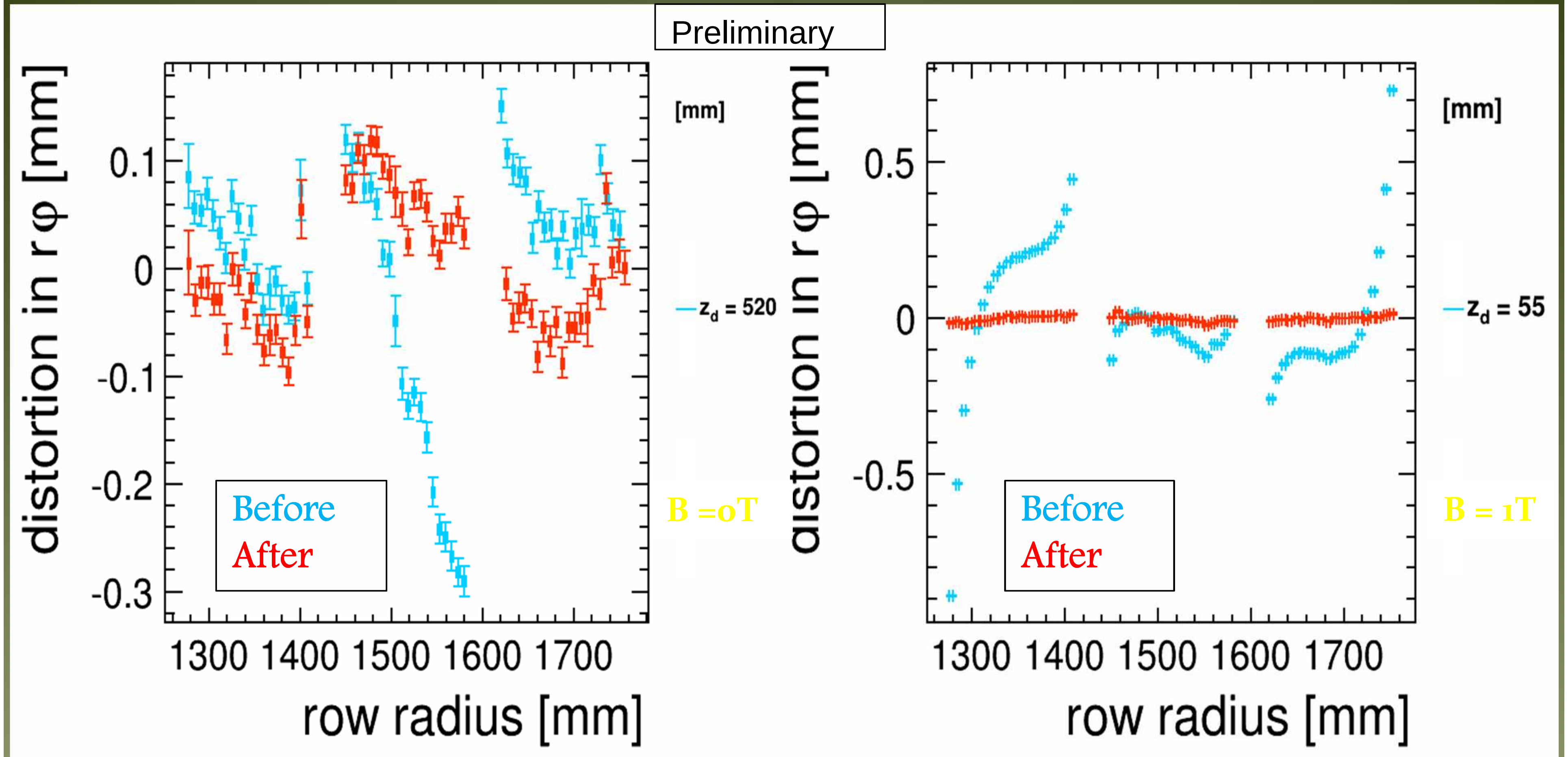
- The beam position on the TPC is plotted against reconstructed time.
- Slope gives the drift velocity.
- Intersection of two such curves for two different fields gives the time of zero-drift (To).
- The drift time (or length) is calibrated from To.



Measured drift velocity is in very good agreement with simulation.

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

- ❖ There could be misalignment between the modules during installation
- ❖ grounded or low potential surfaces near the edges of the module create localized electric field distortion
- ✓ Alignment correction and Distortion correction are done during analysis



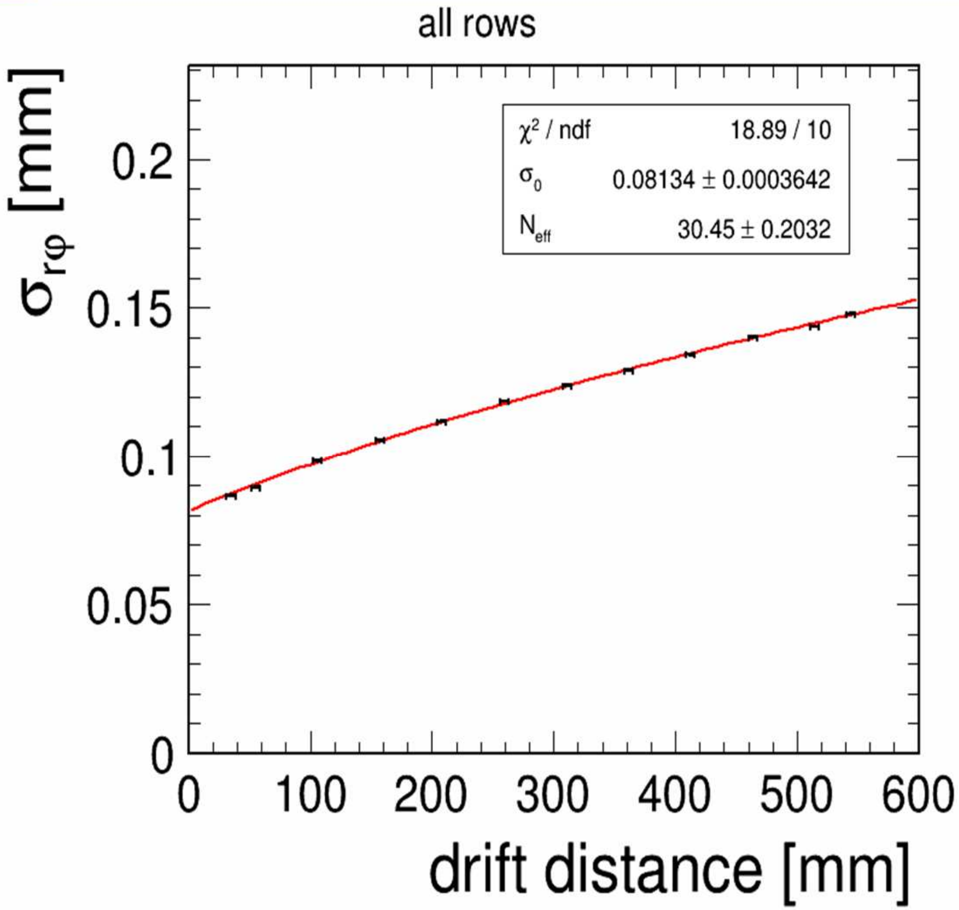
Alignment correction in Micromegas

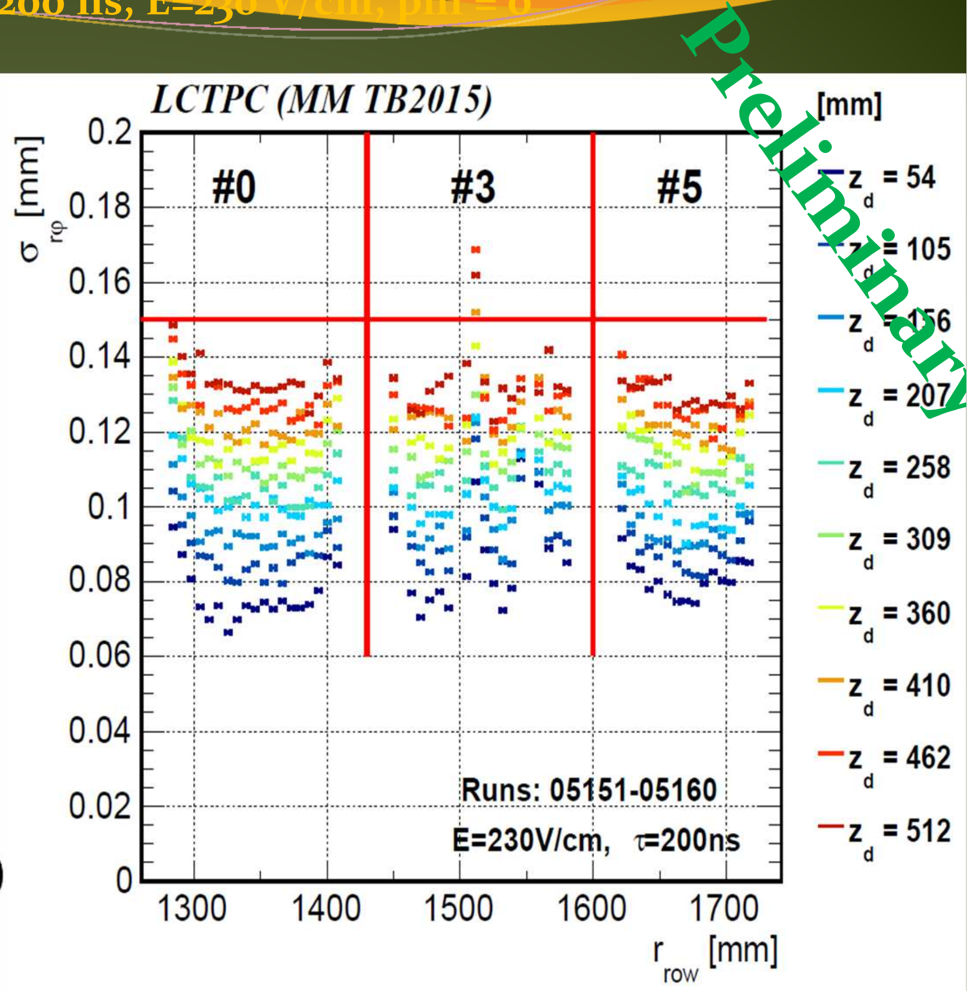
Distortion correction in Micromegas

Analysis is done in MarlinTPC frame work.

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

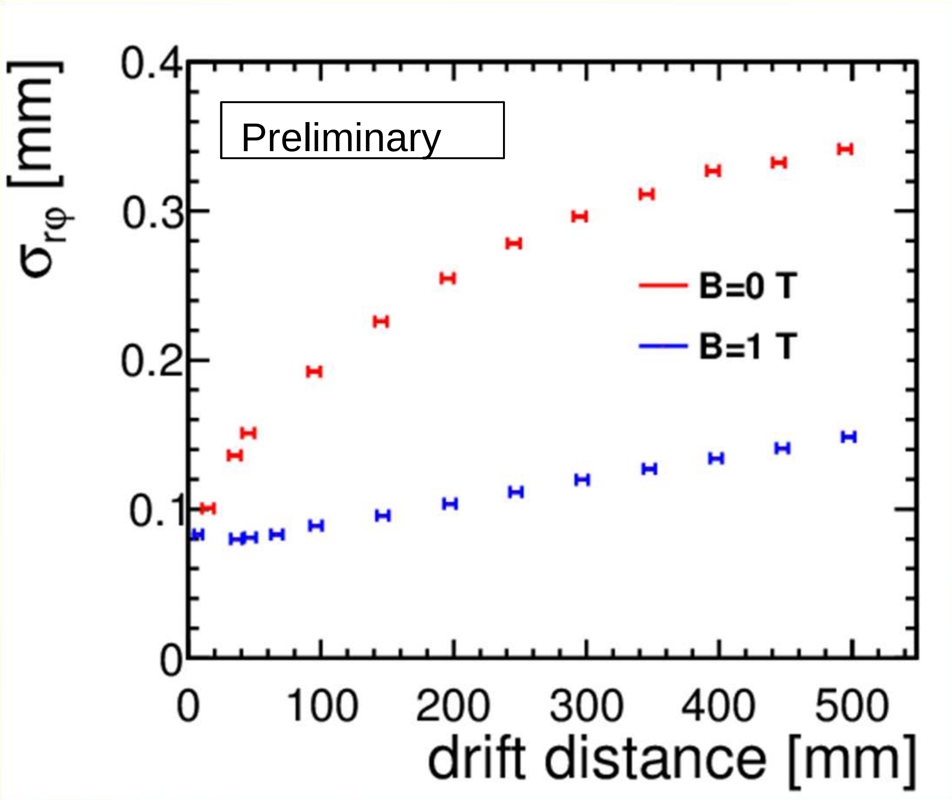
Fit formula: $$\sigma = \sqrt{\sigma_0{}^2 + \frac{C_d^2 \cdot z}{N_{eff}}}$$

σ_0 : the resolution at Z=0

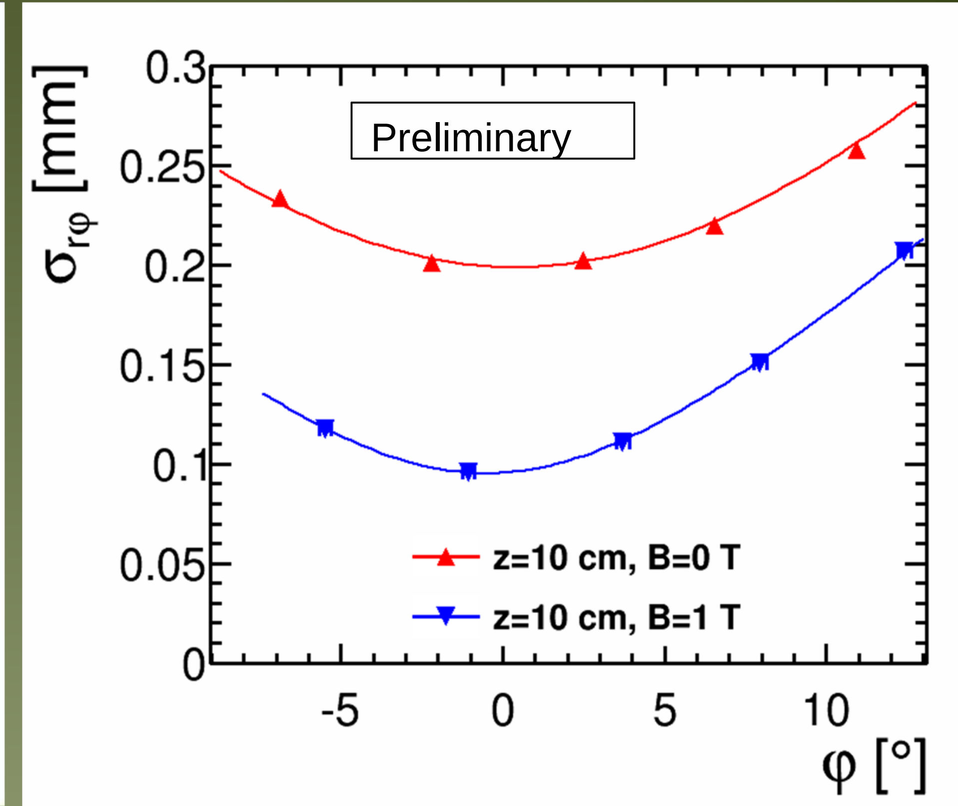
N_{eff} : the effective number of electrons

r-phi resolution (GEM)

r-phi resolution vs drift distance



r-phi resolution vs phi angle



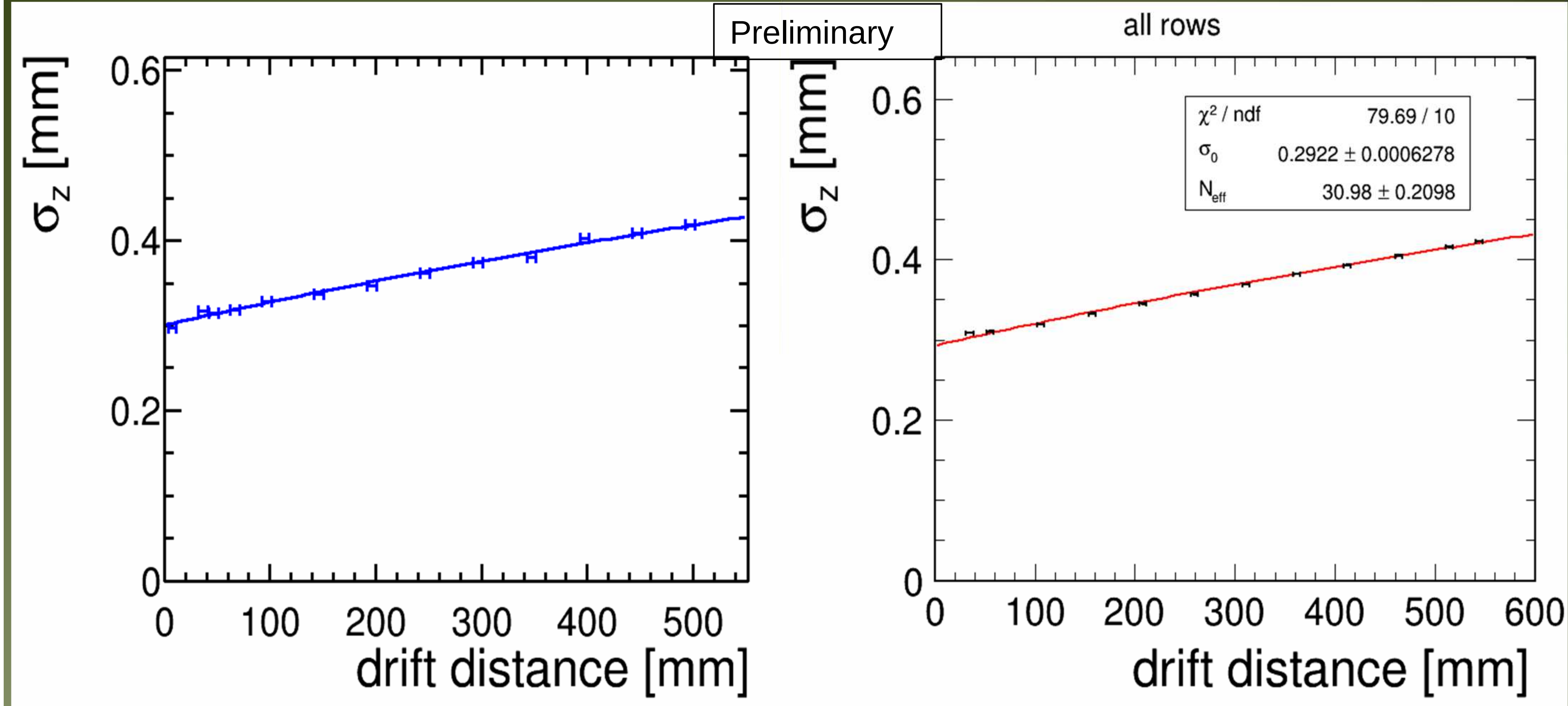
application of magnetic field improves the result

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

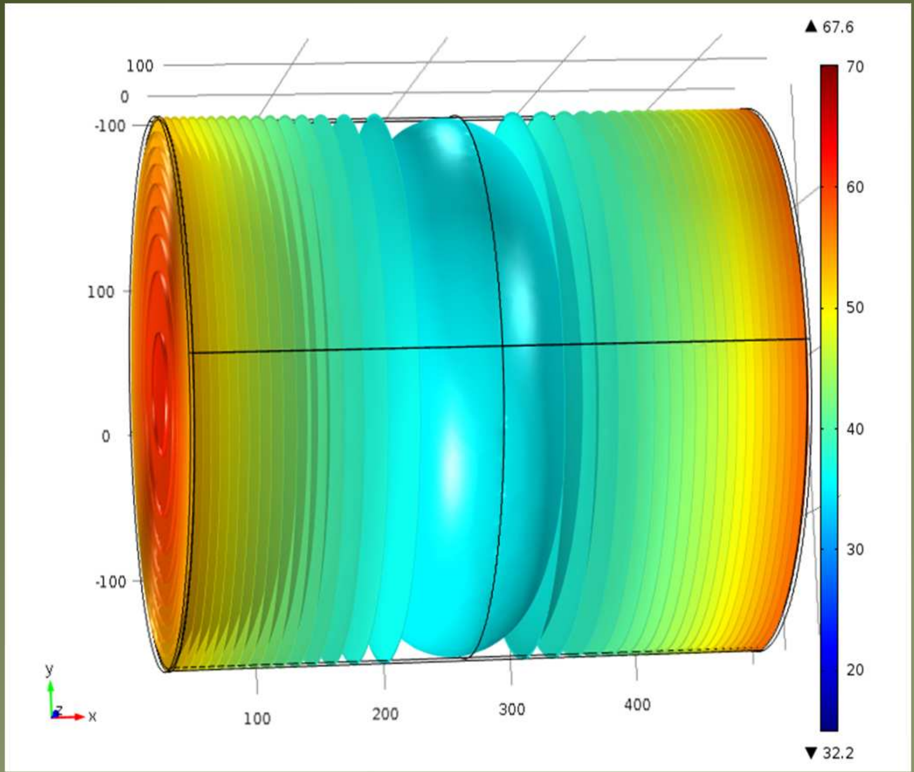
GEM | **Micromegas**



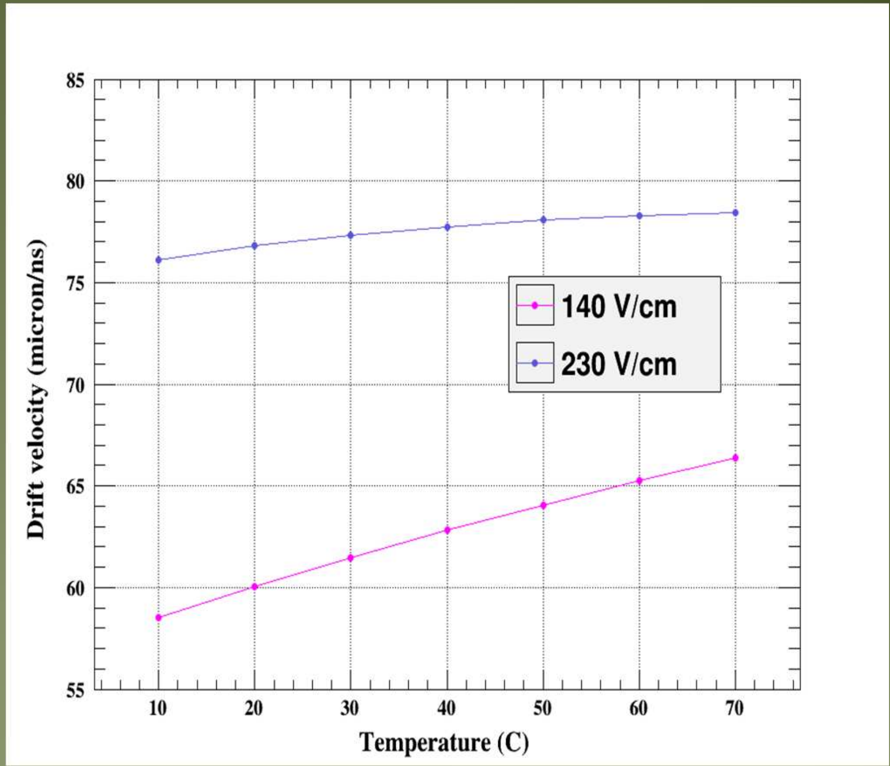
The Z resolution in 1 T magnetic field satisfies ILD requirement

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



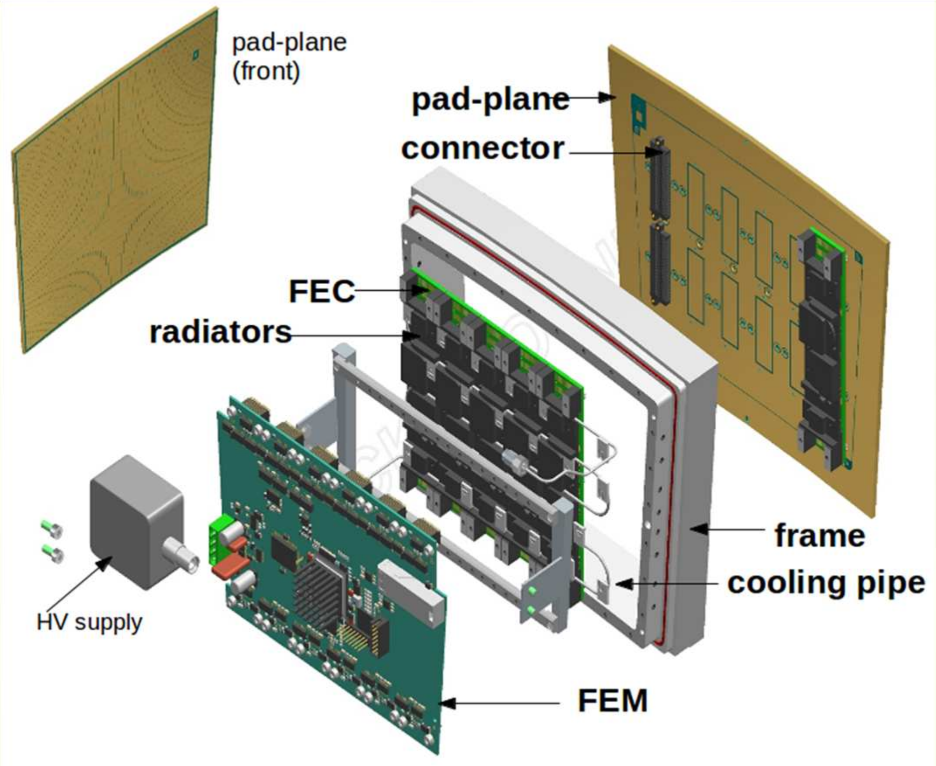
Temperature gradient in ILC-TPC
Simulation with COMSOL

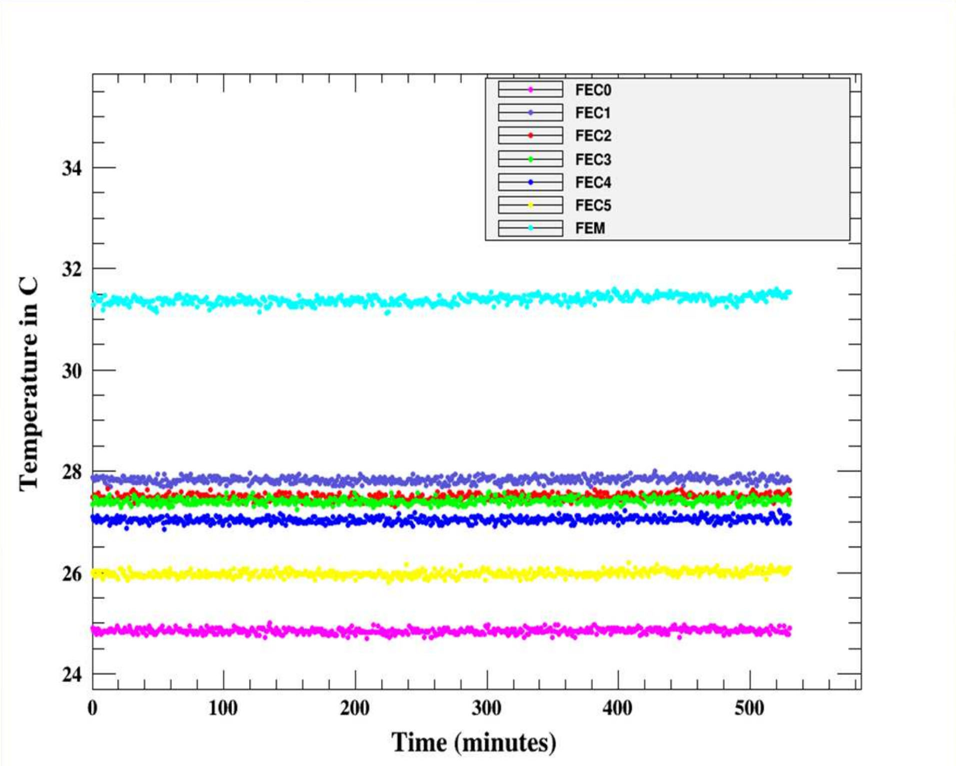


Drift velocity Vs Temperature
Simulation with Magboltz

Two-phase CO_2 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

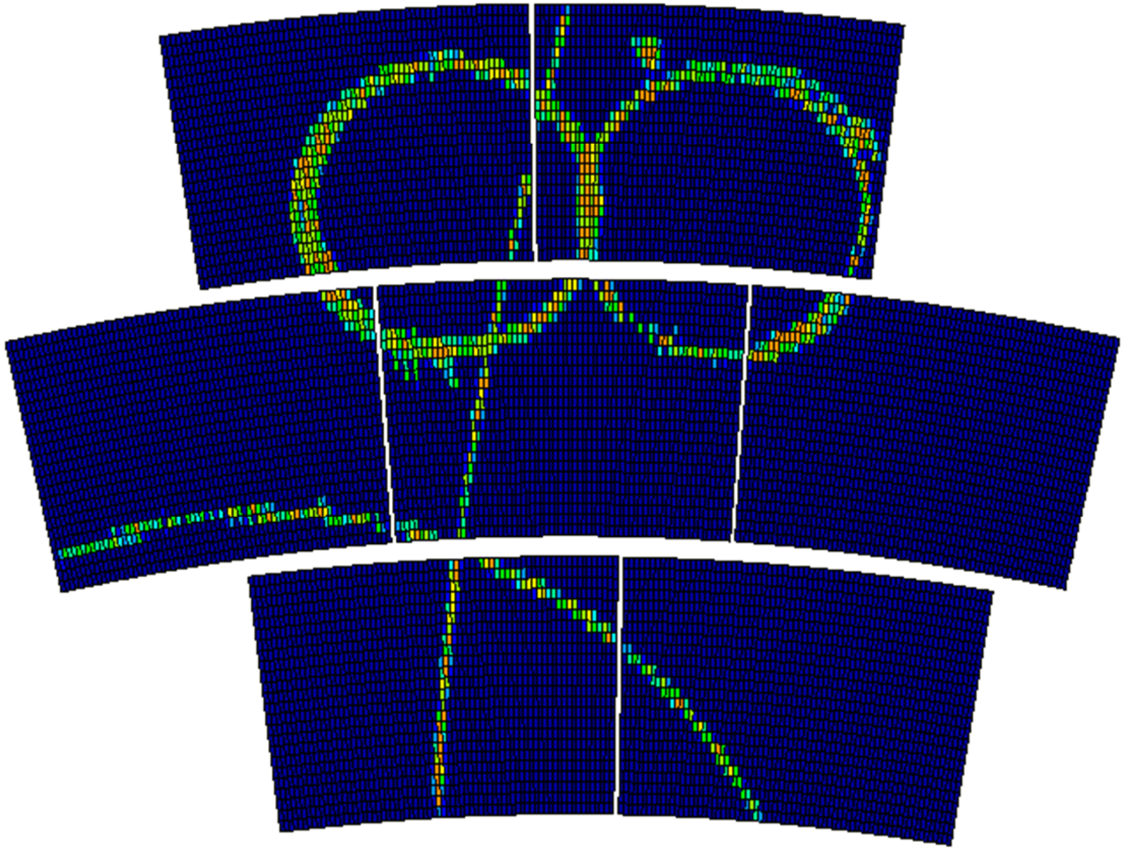
Summary

- 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.

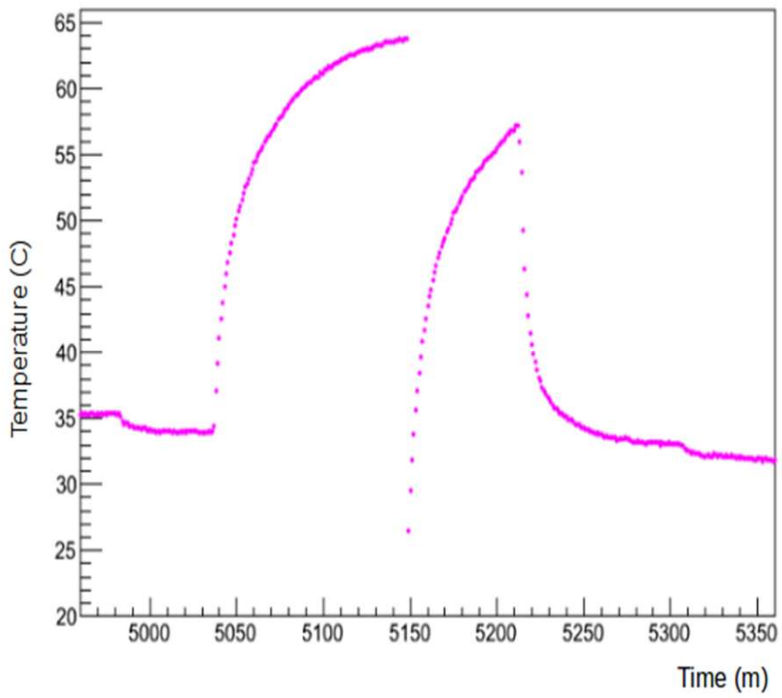


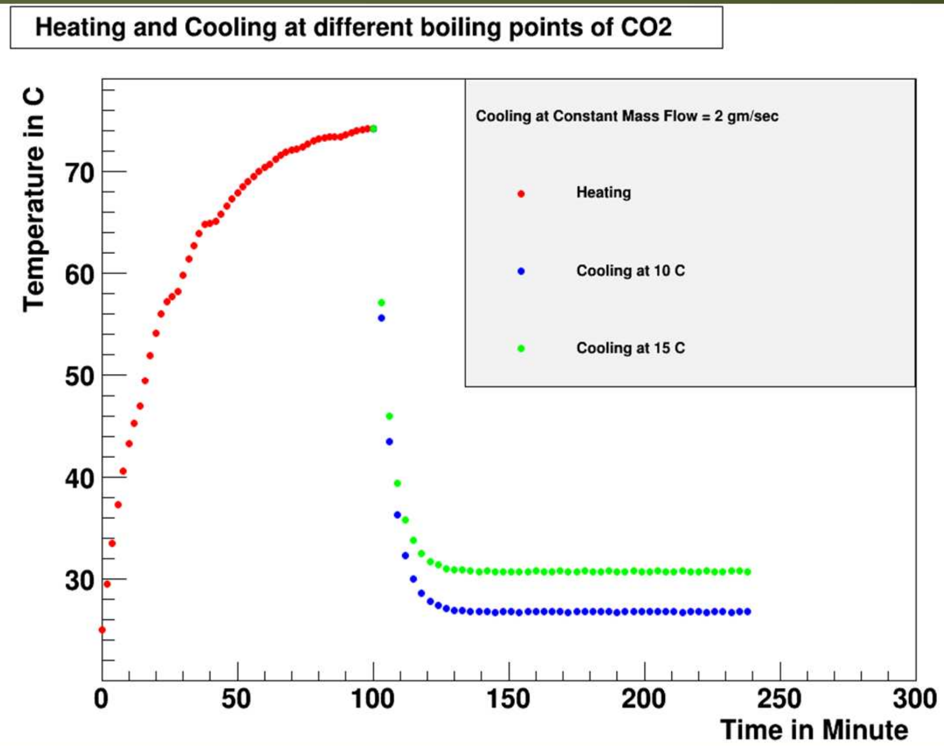
THANK YOU

Backup Slides

Two-phase CO_2 cooling

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

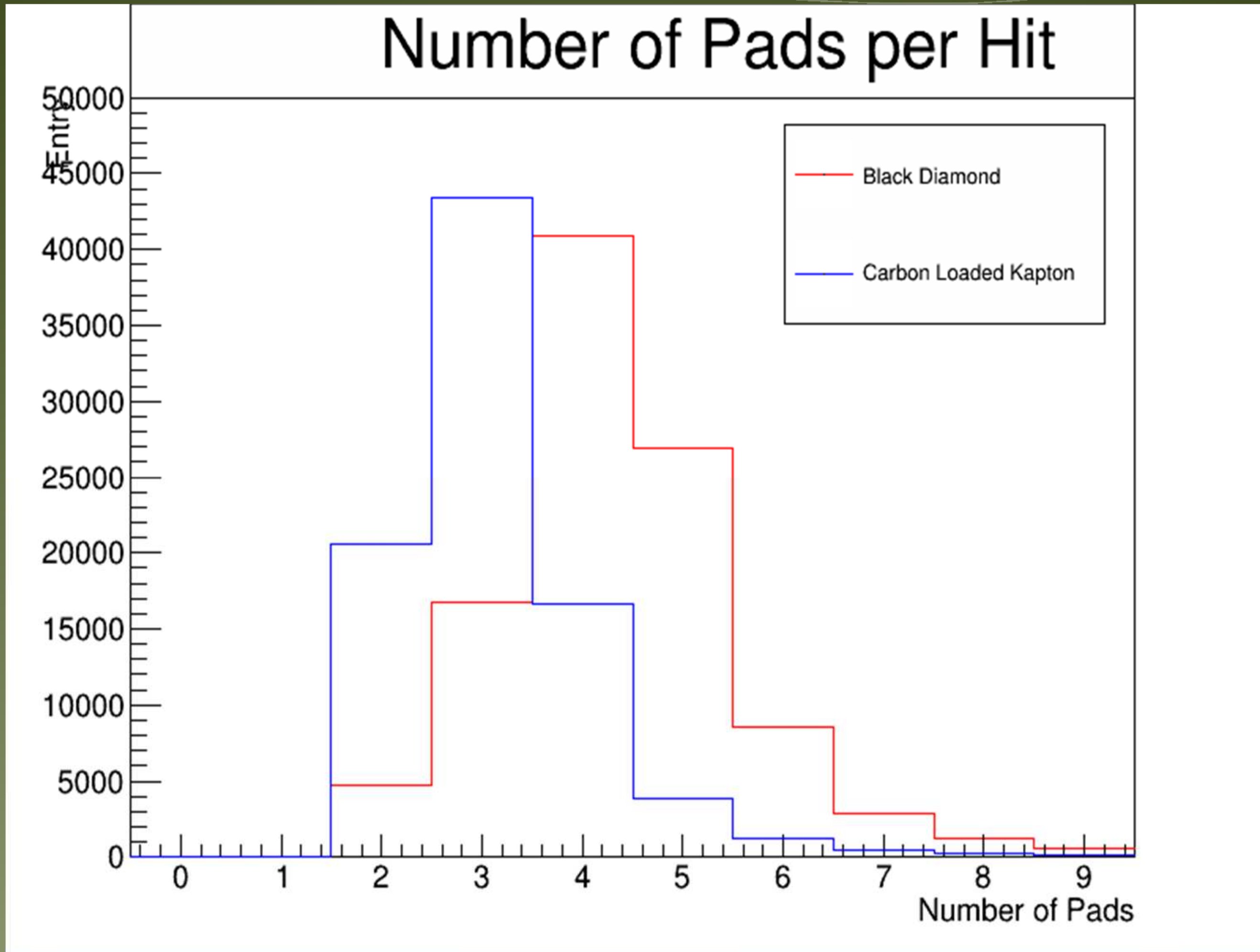




Experimental result with one module
Shows the heating and cooling

Simulated result for one module
Shows heating and cooling

Comparison of charge spreading in two Micromegas modules

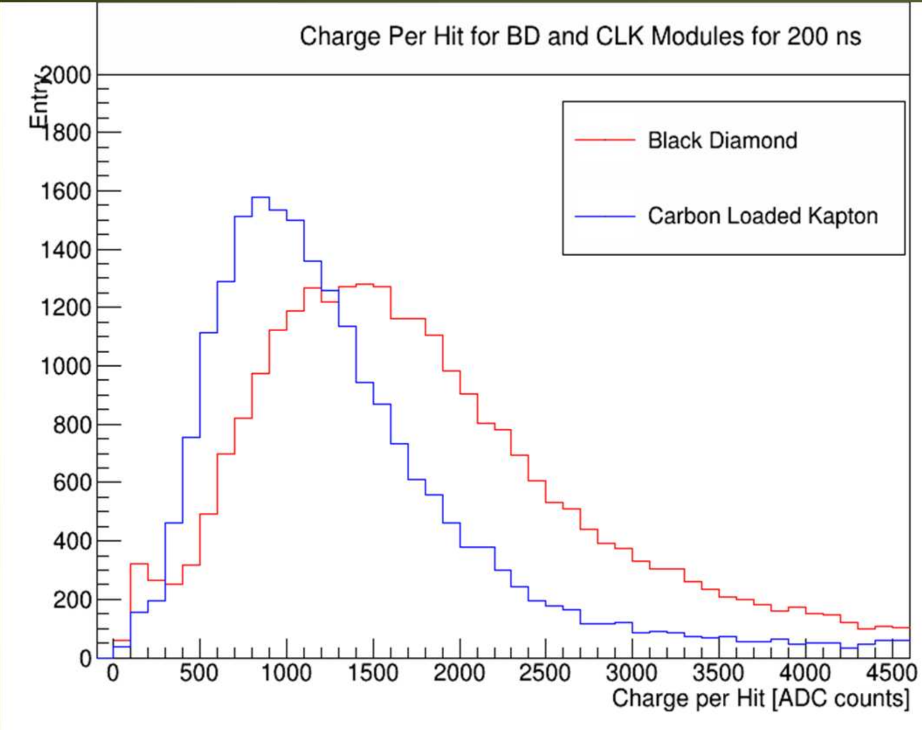


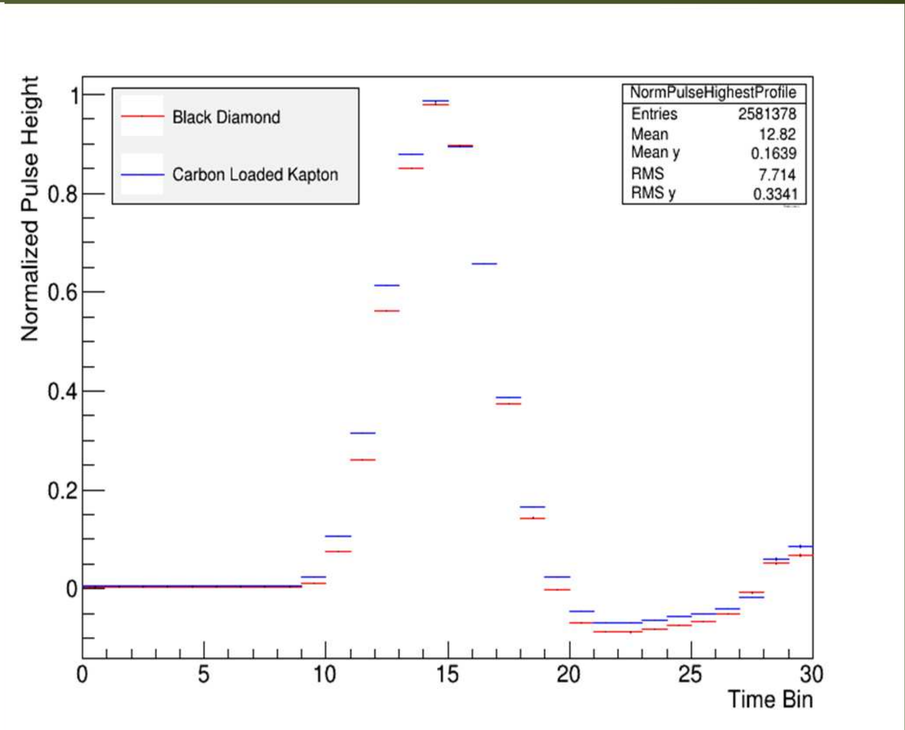
CLK => 3.13, BD => 4.33

Charge spreading of BD modules is slightly more than in CLK

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.

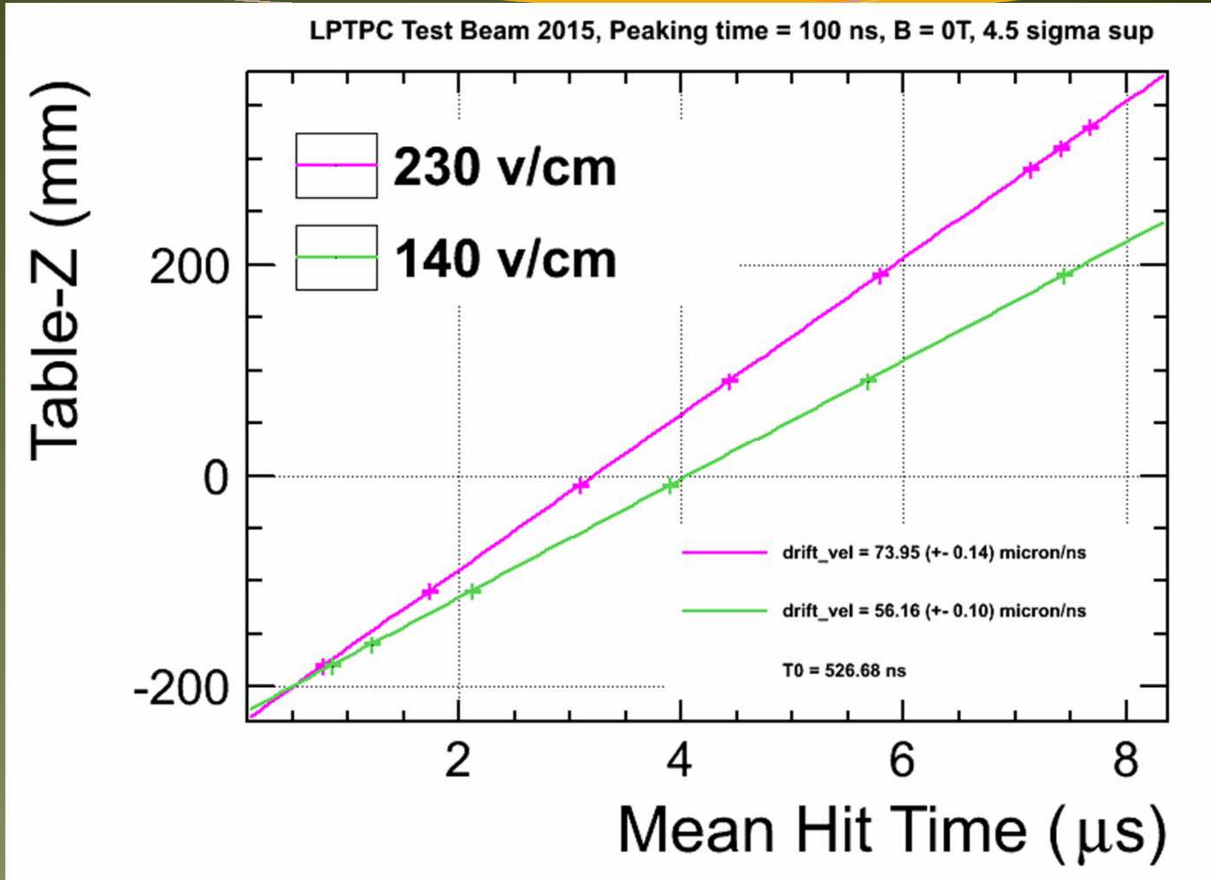
The pulse shape of both detectors are nearly same.
DLC modules are good substitute for CLK

Measurement of drift velocity with Micromegas

The slope gives drift velocity.

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

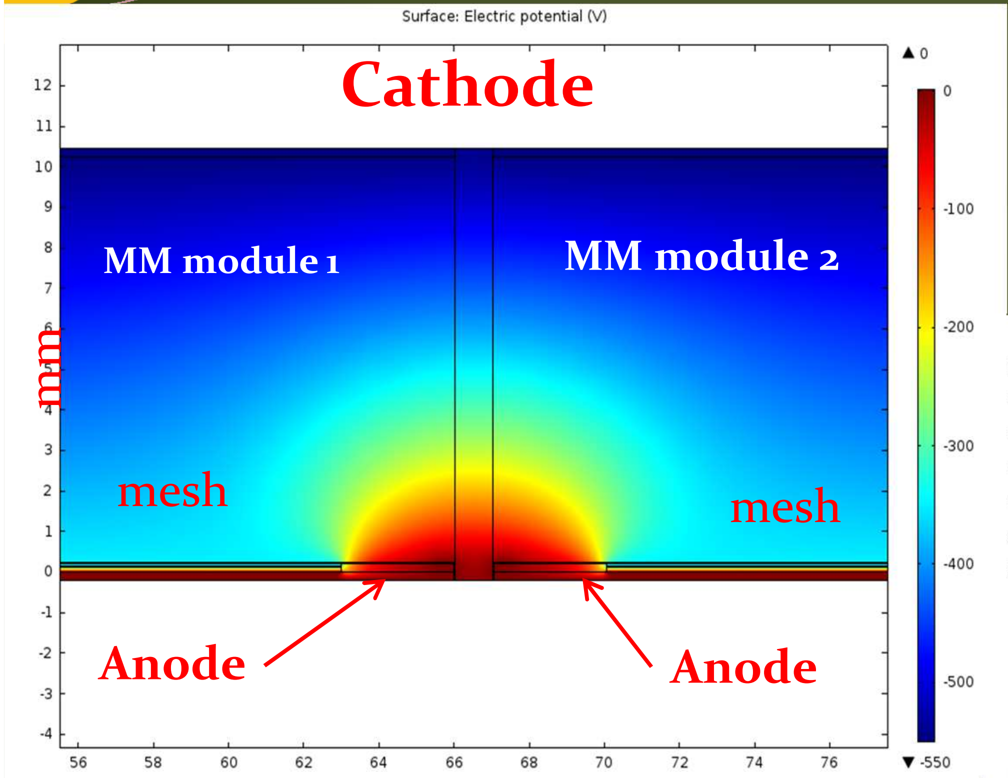
Calibration of drift length (or time) is done from To.



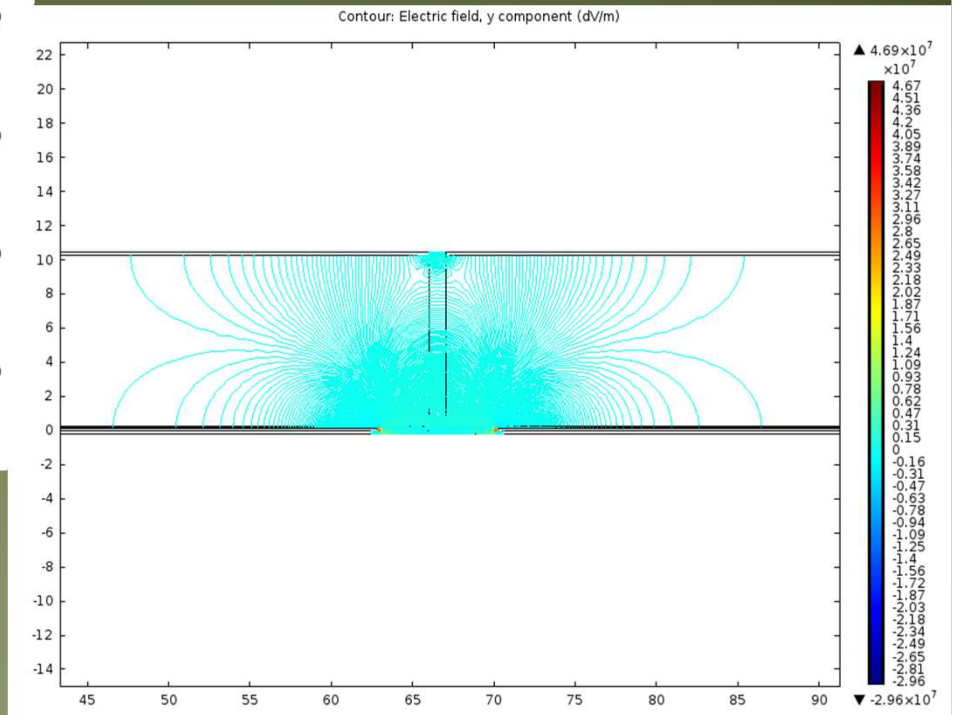
	E=140 V/cm	E=230 V/cm
V_d Data	$56.7 \pm 0.1 \mu m/ns$	$74.1 \pm 0.2\ \mu m/ns$
V_d Magboltz	$57.9 \pm 1.0 \mu m/ns$	$75.5 \pm 1.0 \mu m/ns$
$D_\perp$ Magboltz	$74.5 \pm 2.5 \mu m/\sqrt{cm}$	$94.8 \pm 3.1 \mu m/\sqrt{cm}$

Micromegas

Potential distribution

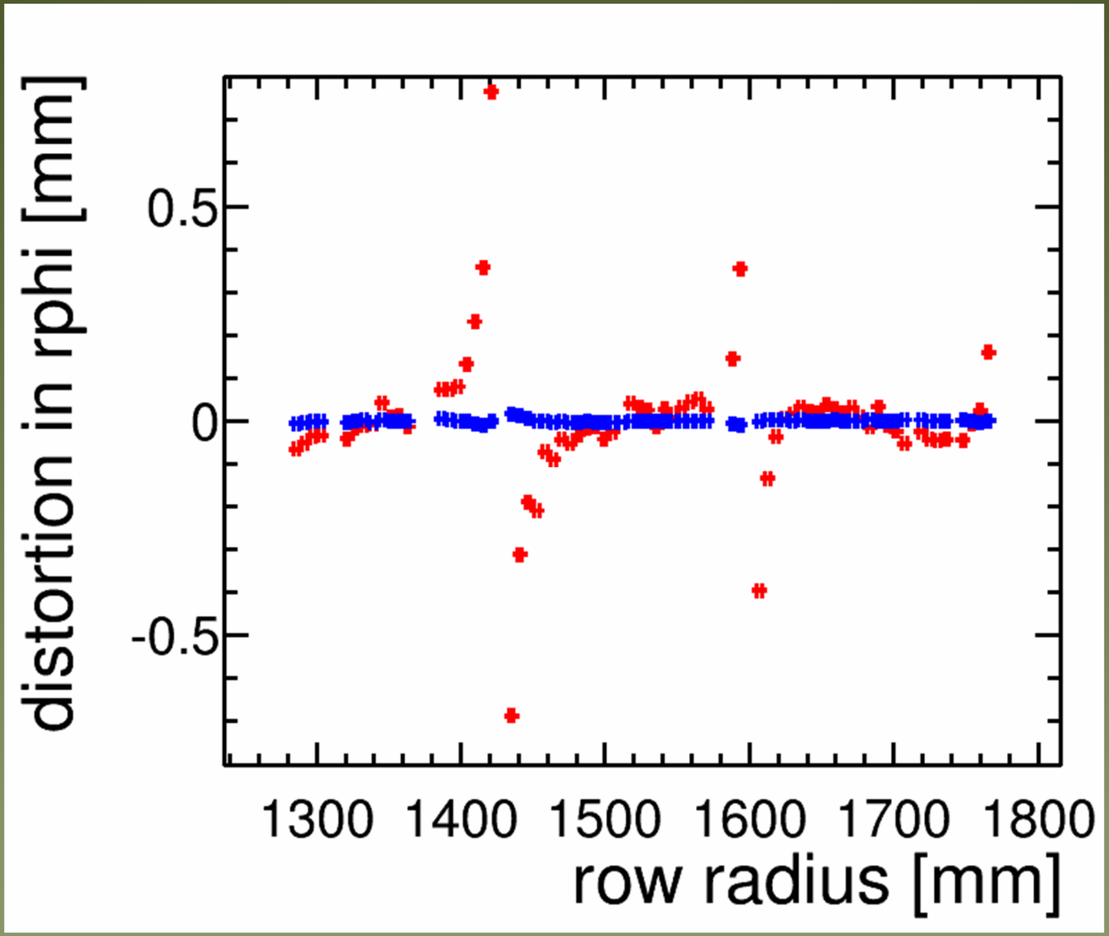


Field distortion (Micromegas)



Simulation with COMSOL

Distortion correction in GEM modules



Two-phase CO_2 cooling

simulated model (COMSOL) shows how cooling works