Study of a multi-module Micromegas TPC prototype for tracking at the International Linear Collider

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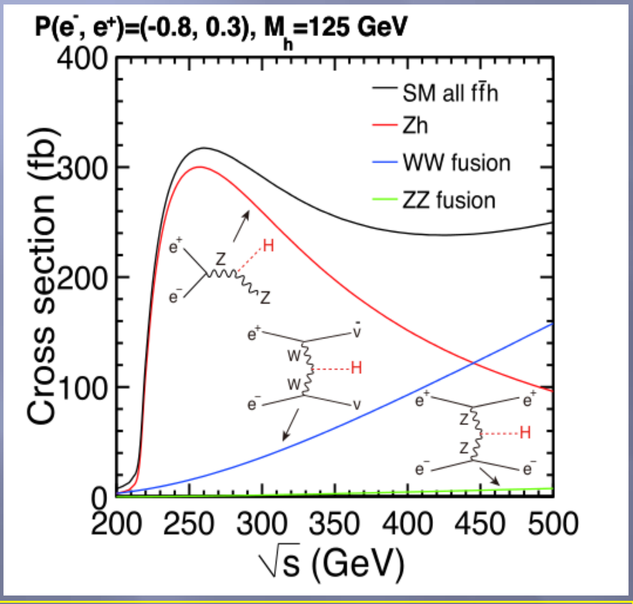
The International Linear Collider

general physics goals

- **At the ILC, e- e+ will collide initially in the range $\sqrt{s}$ = 240 – 500 GeV**
- **It is a precision measurement and discovery machine.**

Different production processes and decay modes of Higgs boson will be studied at different energy ranges.



Cross sections of three major Higgs production processes as a function of centre of mass energy*.

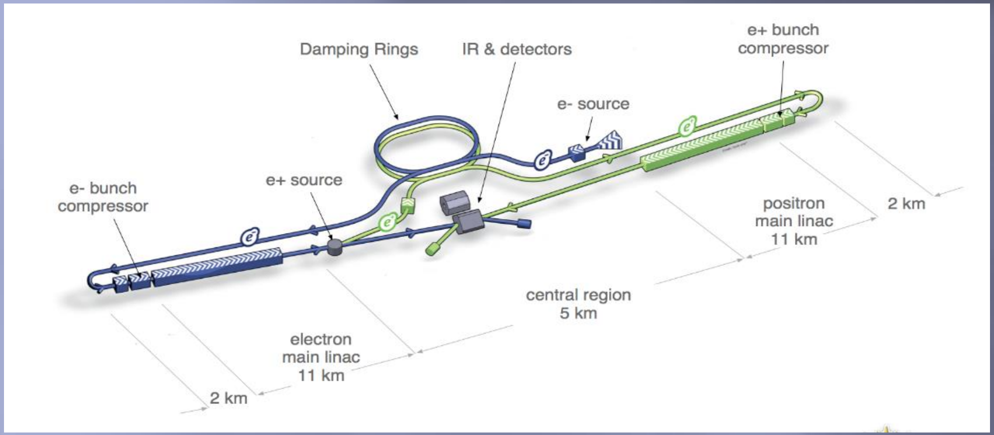
A major Higgs production process at $\sqrt{s}$ = 250 GeV is ***Higgs-strahlung*** : e- e+ → Z H, followed by Z → $\mu^+ \mu^-$

The advantages of Higgs-strahlung are:

- Identification of Z boson with a well defined energy corresponding to the kinematics of recoil against 125 GeV Higgs helps to identify a Higgs event even without studying the Higgs decay.
- Total decay width of the Higgs boson can be determined and the Higgs couplings can be studied with precision.
- Invisible decay modes can be studied.
- From the decay of Z boson, Higgs mass can be measured precisely.

*LCC Physics Working Group, arXiv:1506.05992v2 [hep-ex]

International Large Detector



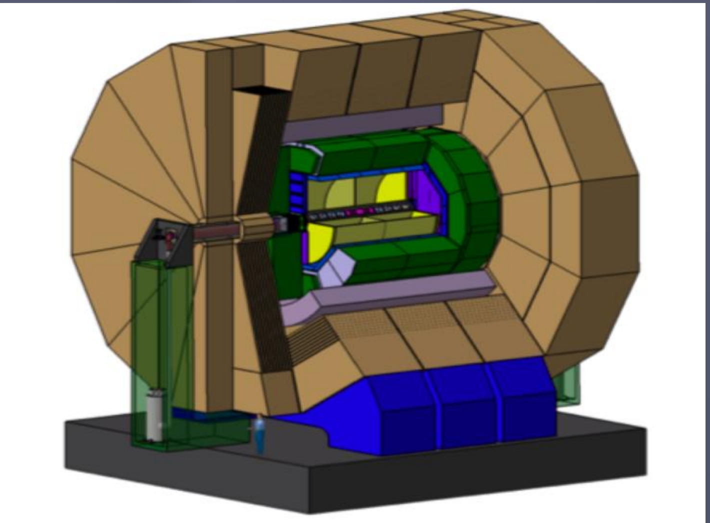


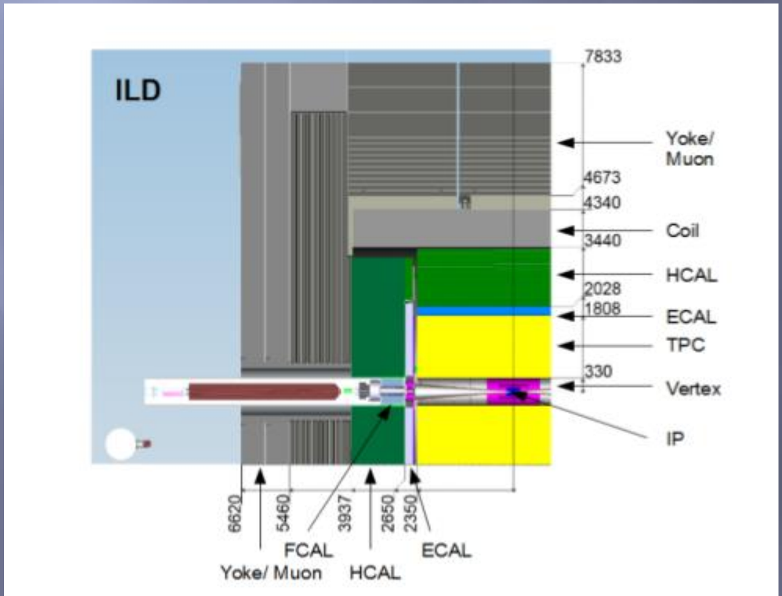
Figure 2: A schematic view of the International Large Detector concept (the TPC is the yellow cylinder inside the blue electromagnetic calorimeter).

ILD-TPC dimension

Length of the TPC ~ 4.6 m

Diameter of the TPC ~ 3.6 m

Magnetic field ~ 3.5 T



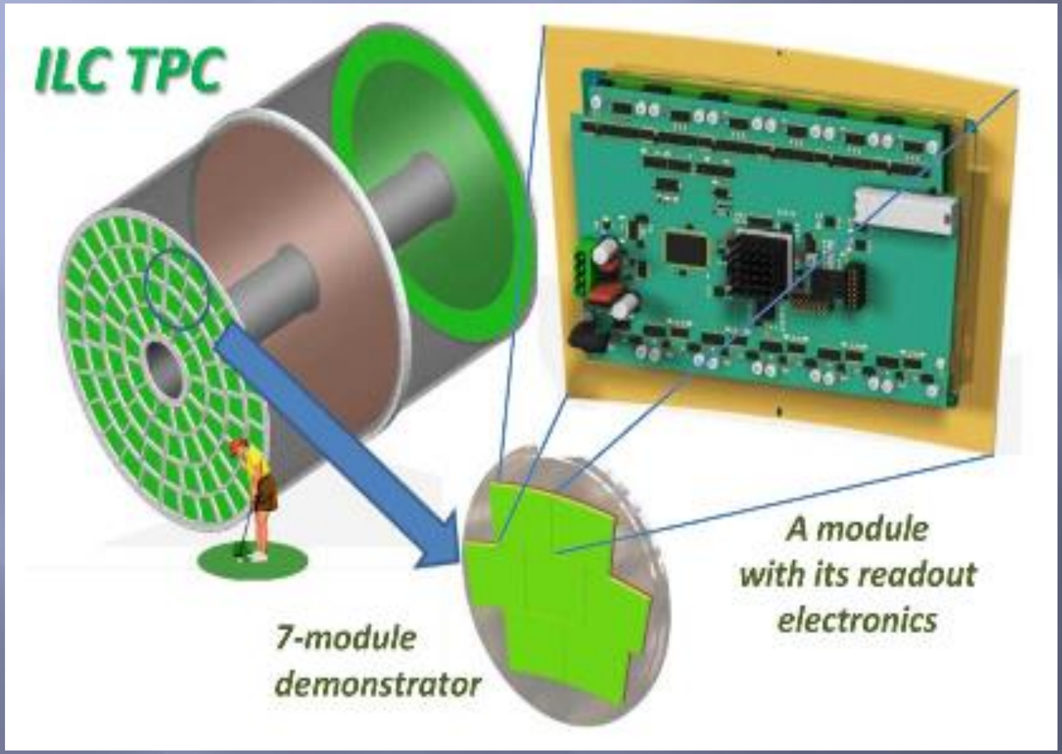
A TPC as main tracker has the benefits of:

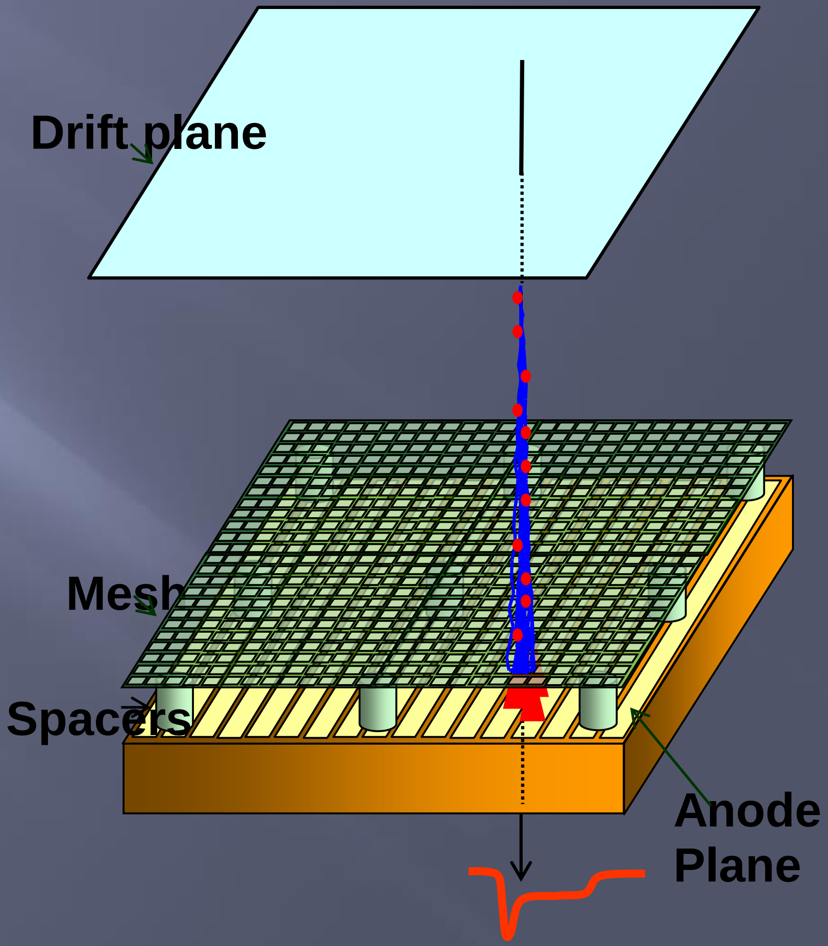
- ✓ Continuous, truly 3-D tracking.
- ✓ Robust pattern recognition.
- ✓ High efficiency tracking over large momentum range.
- ✓ Low material budget.

Resolution requirement

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

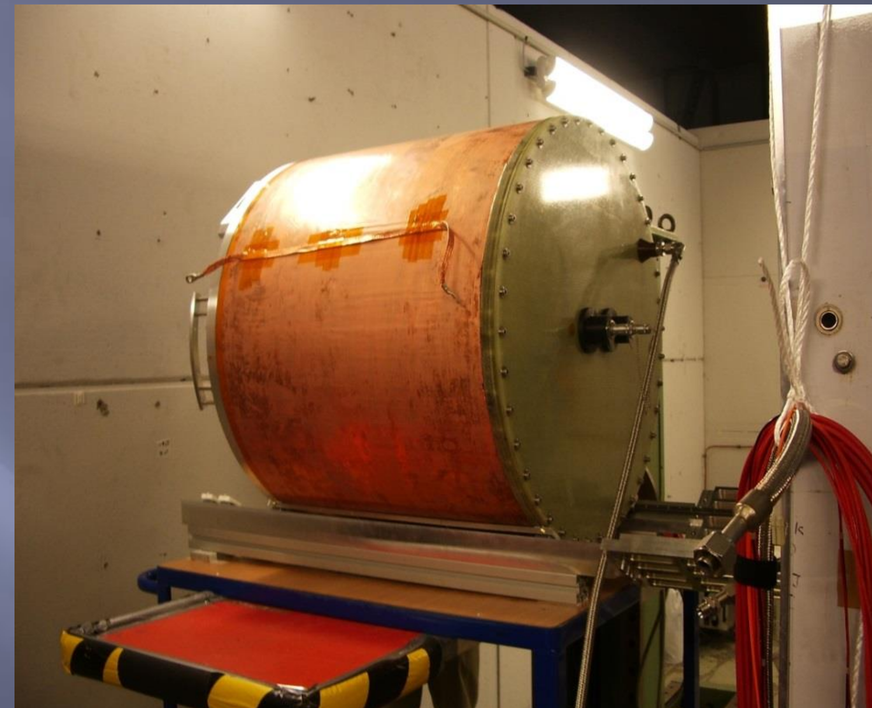
ILD-TPC schematic
(Principle of a TPC and Micromegas)





The Large prototype TPC for ILC at DESY

The movable stage and the 1T magnet.



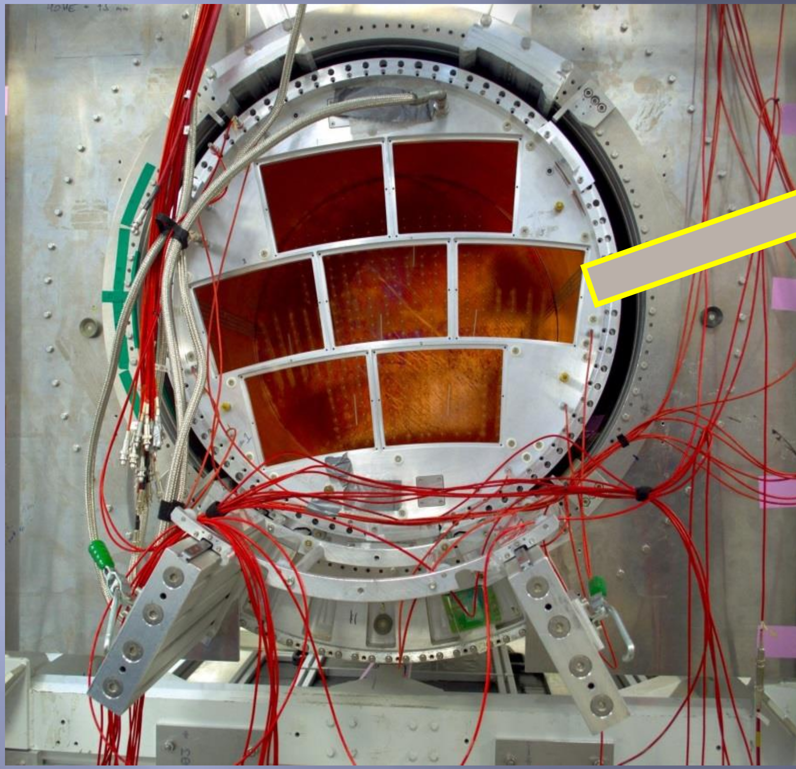
The field cage

- Drift length = 56.80 cm
- Inner diameter = 72 cm

AIDA

EUDET

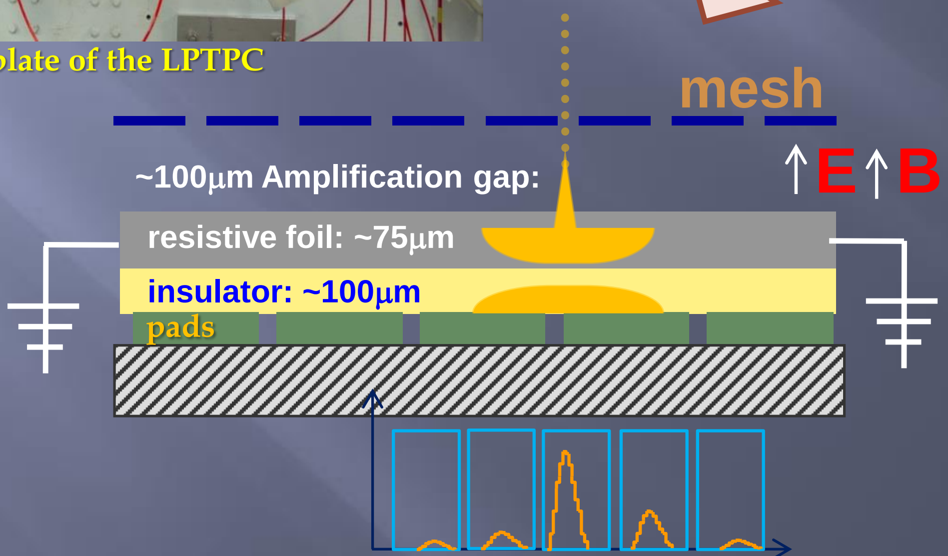
Pad-based resistive anode



End plate of the LPTPC

Micromegas module

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



The Resistive Micromegas

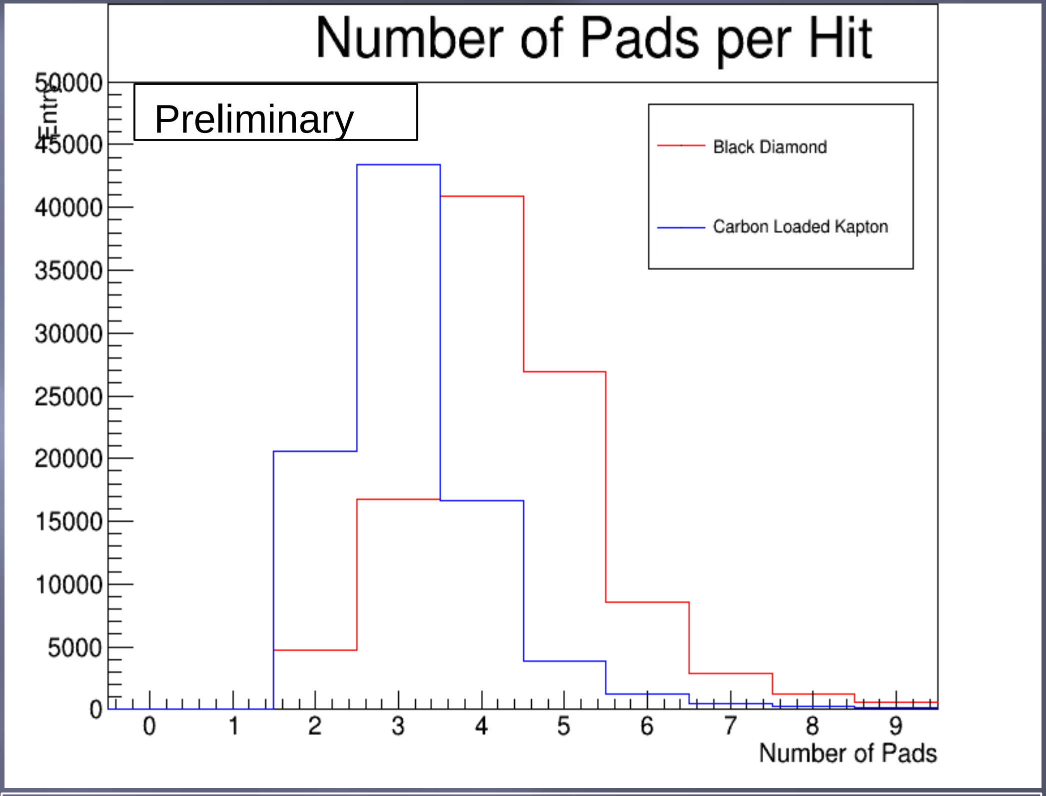
In standard Micromegas resolution is given by,

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

At LP-TPC,
Resistive Micromegas are used, where charge is dispersed on the resistive foil. It is glued on top of the pads.

σ of the charge distribution

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



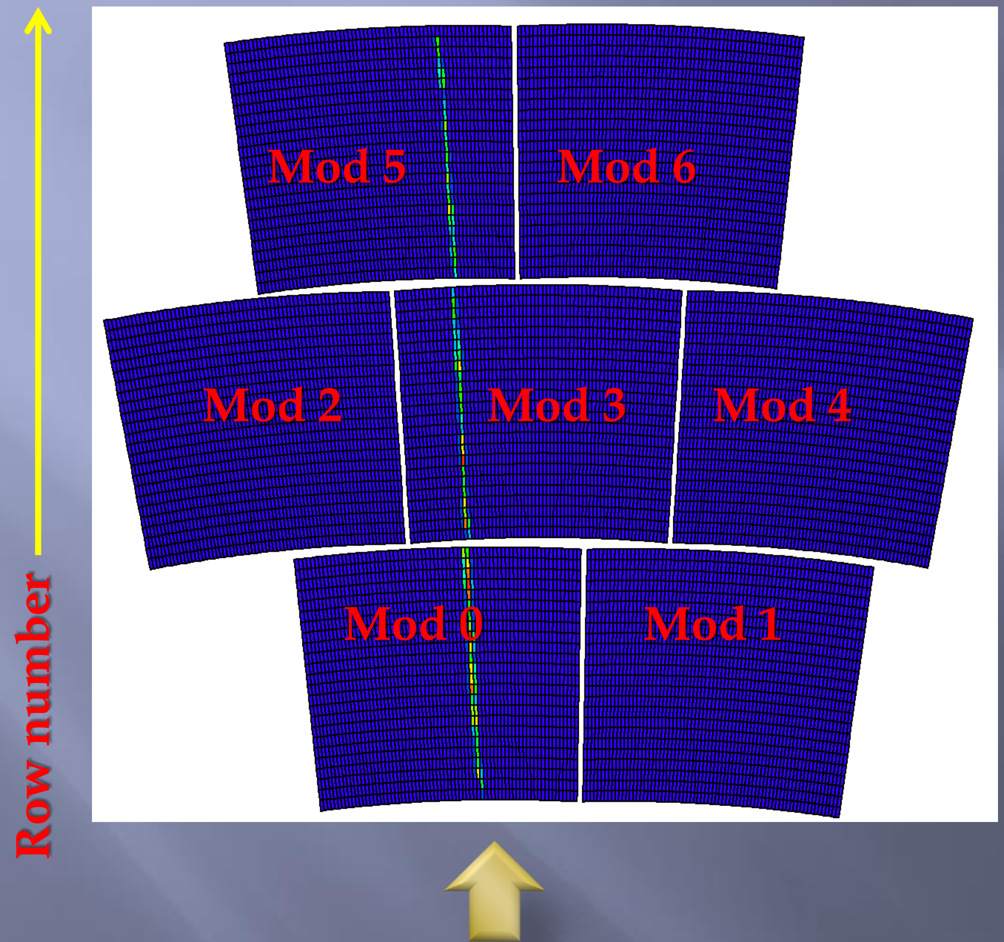
CLK => 3.13, BD => 4.33
More charge spreading in BD than in CLK

R -> the surface resistivity of the layer.
C -> capacitance per unit area and *t* is the shaping time of the electronics.

- **Commonly used *Carbon Loaded Kapton (CLK)* is unavailable now.**
- **A new resistive material, *Diamond Like Carbon (DLC)* is available from Japan.**
- **We used both in the recent beam test during March 2015.**

Study of different parameters

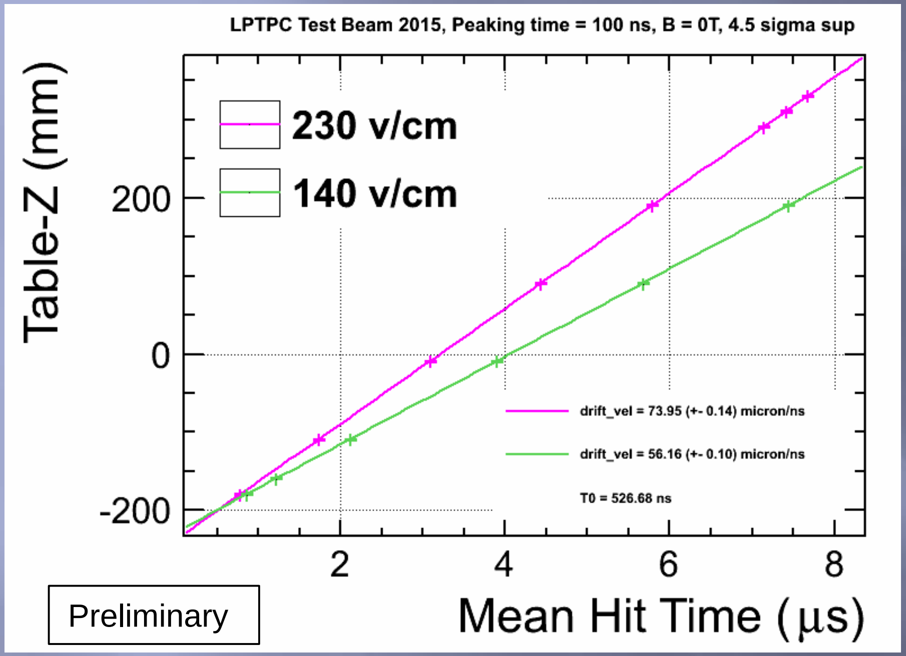
Track Micromegas modules



5-GeV electron beam

Studies	Range
At different drift distances	full available drift length of 60 cm
At different *phi (degree)*	0, 2, 4
At different *theta (degree)*	10 to 30 in steps of 5
At different X positions	'-40' mm to '30' mm
At different peaking time of the electronics.	100 ns to 1000 ns
At two different fields	140 V/cm, 230 V/cm
At different noise thresholds	3 sigma and 4.5 sigma
At two different magnetic fields	0 T and 1 T
At different momenta	1 GeV to 5 GeV
Cosmic rays	B = 1 T and B = 0 T

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 starting-drift (T_0).
- The drift time (or length) is calibrated from T_0.

Measured drift velocity is in very good agreement with simulation*.

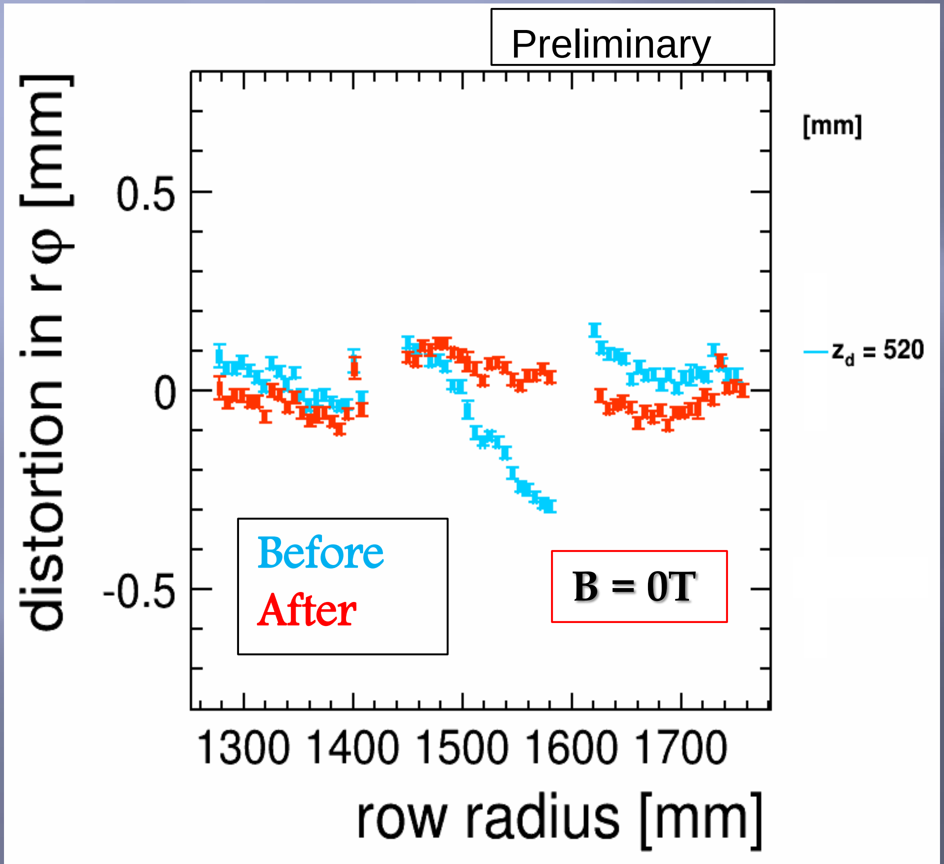
	E=140 V/cm	E=230 V/cm
V_d Data	$56.7 \pm 0.1 \mu m/ns$	$74.1 \pm 0.2\ \mu m/ns$
V_d Magboltz	$57.9 \pm 1.0 \mu m/ns$	$75.5 \pm 1.0 \mu m/ns$
$D_\perp$ Magboltz	$74.5 \pm 2.5 \mu m/\sqrt{cm}$	$94.8 \pm 3.1 \mu m/\sqrt{cm}$

*Magboltz is a simulation tool to compute different gas transport parameters in gaseous detectors

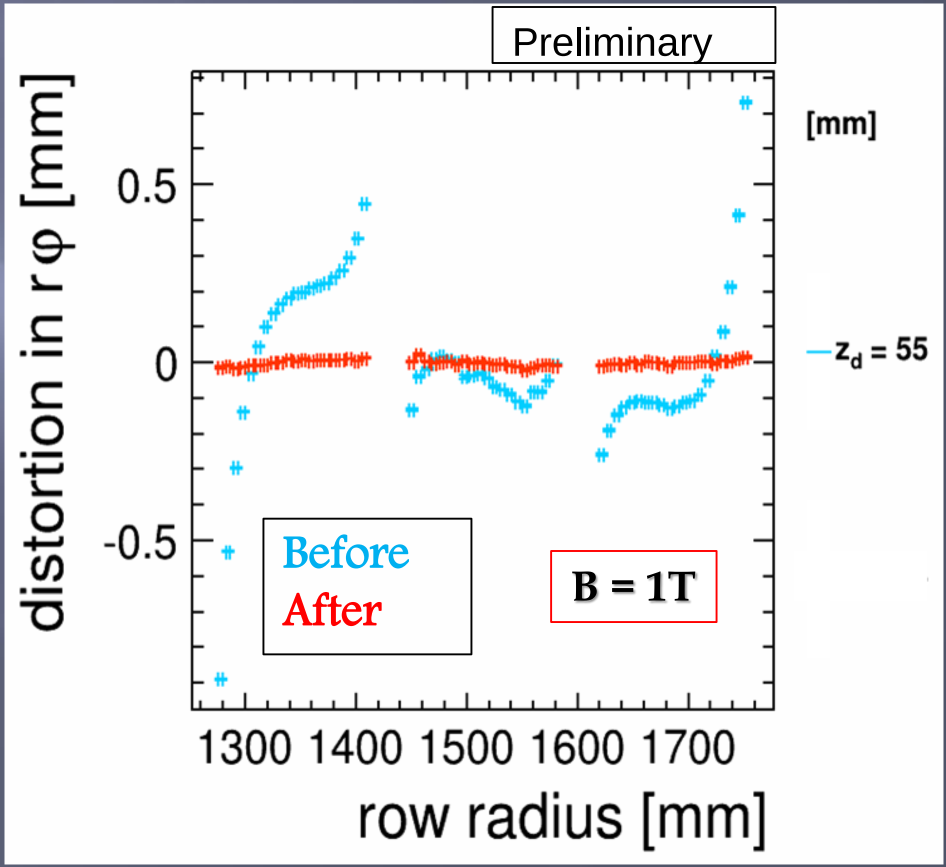
Track Distortion

- There could be misalignment between the modules during installation
- The grounded peripheral frame of the module creates localized electric field distortion

✓ Alignment correction and Distortion correction are done during analysis



Before and after *Alignment* correction

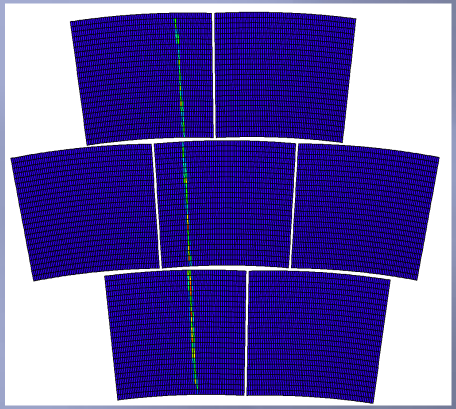


Before and after *Distortion* correction

Analysis is done in MarlinTPC frame work.

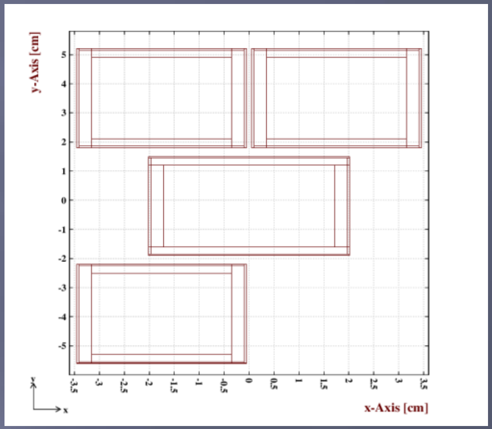
Investigation of Track distortion by Numerical Methods

<u>Simulation tool combines</u>
Garfield + neBEM + Heed + Magboltz



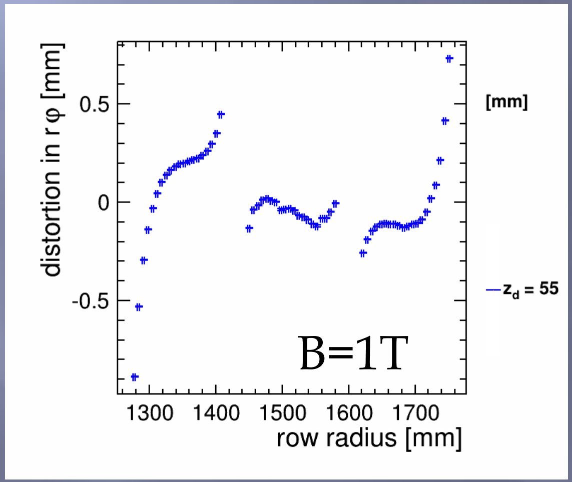
Micromegas modules on the <u>LPTPC endplate.</u>

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

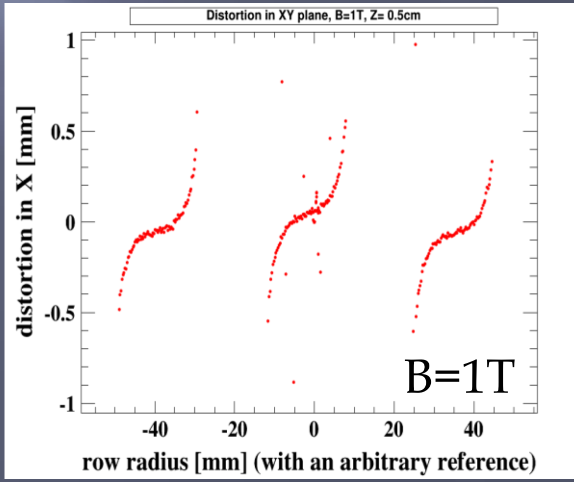


The <u>**simulated**</u> Micromegas modules

Module size:
3.4 cm × 3.4 cm.
reference frame is Cartesian.



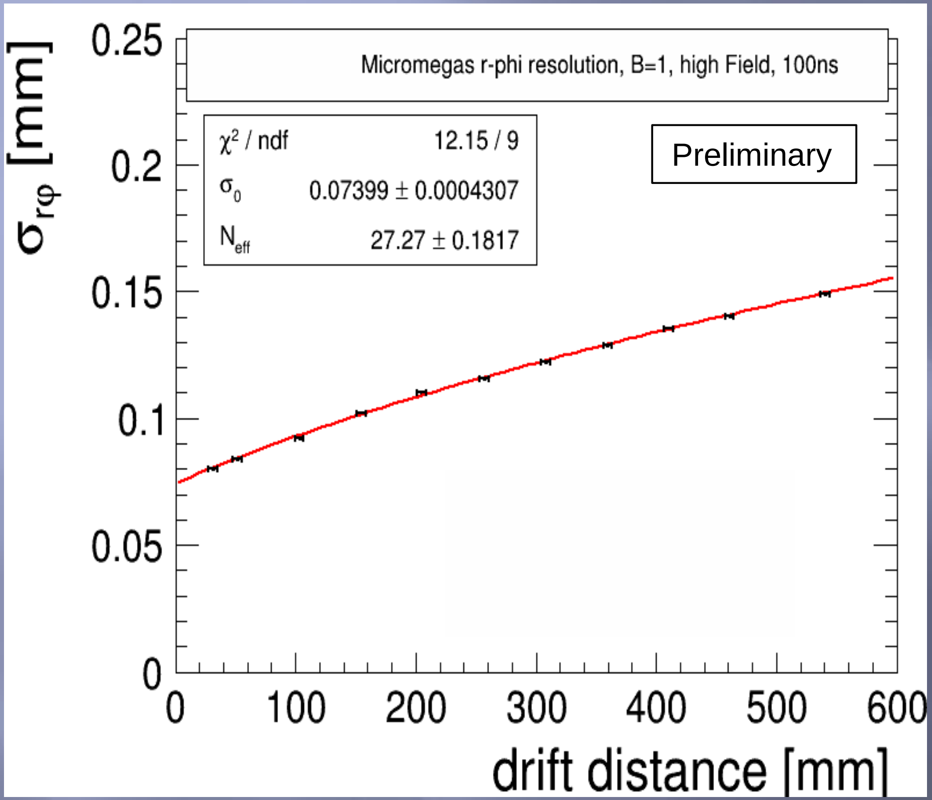
Distribution of the residuals as obtained in <u>**Experiment**</u> without alignment correction.

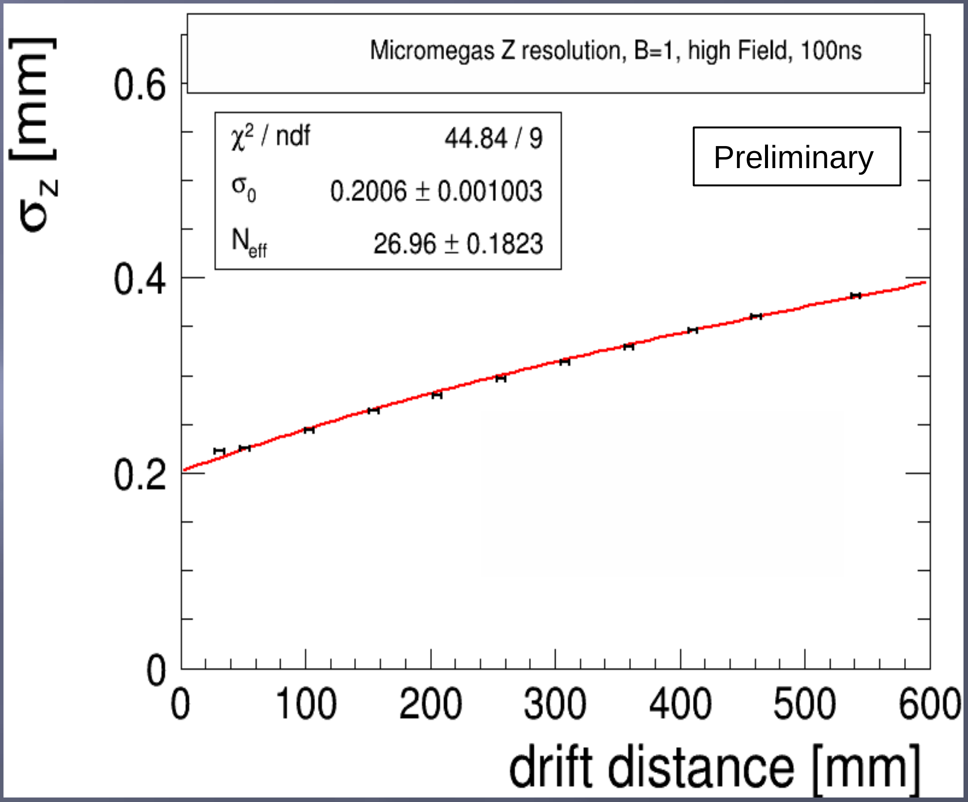


Distribution of the residuals as obtained in <u>**Simulation**</u>

Resolutions of Micromegas

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





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

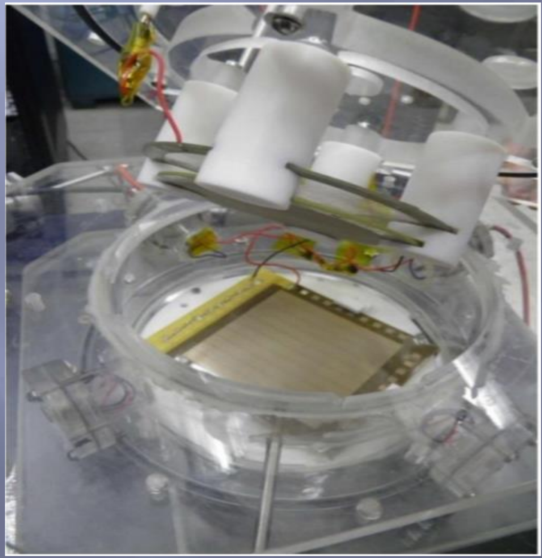
N_{eff} : the effective number of electrons

In 1 Tesla magnetic field, for ~ 60 cm drift length, the space and time resolutions of Micromegas corresponds to ILC requirements over full drift length, for 3.5 T magnetic field

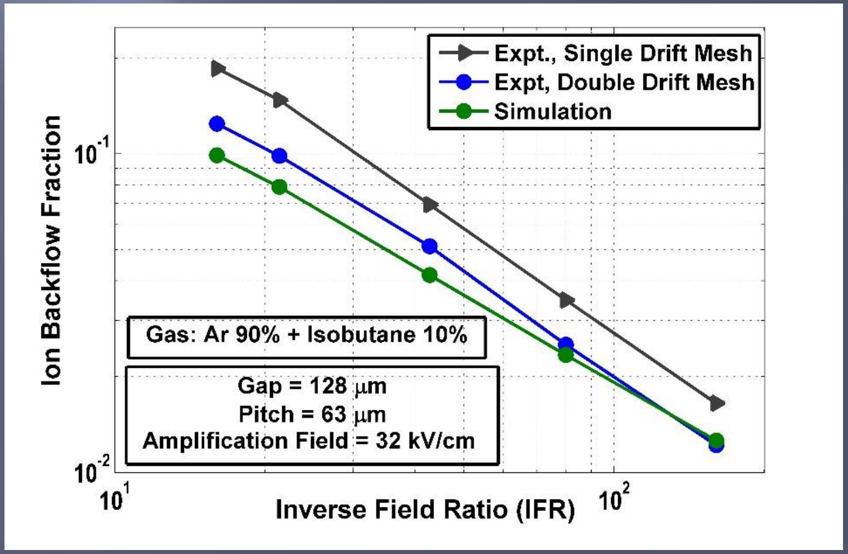
Investigation of Ion Backflow in Micromegas

- The positive ions created in the avalanche can flow back to the drift space, building up a charge density which affects the electron drift.
- Ion Backflow can affect the performance of a gaseous detector.
- In Micromegas, the backflow is intrinsically suppressed.

- The backflow fraction (IBF) is defined by: N_b/N_t
  where N_b is number of back flowing ions and N_t is the total ions produced.
- In experiment IBF is measured as: $I_C/(I_M+I_C)$,
  where I_C is current on the drift cathode and I_M is the current on the micromesh.
- In simulation IBF is calculated as : N_b/N_t .



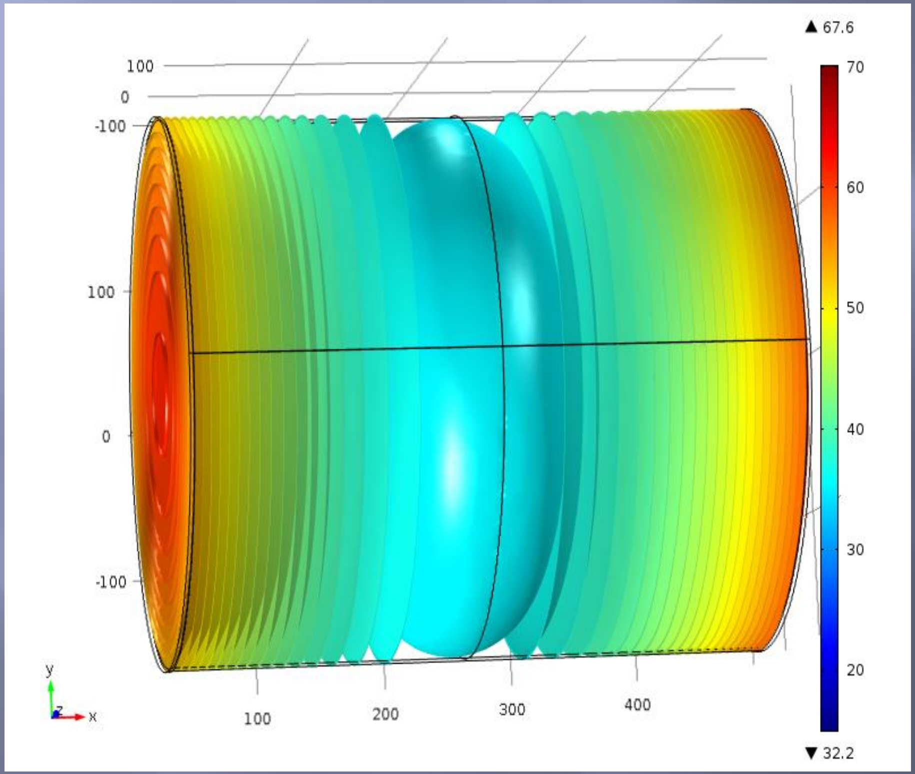
Experimental setup for IBF measurement

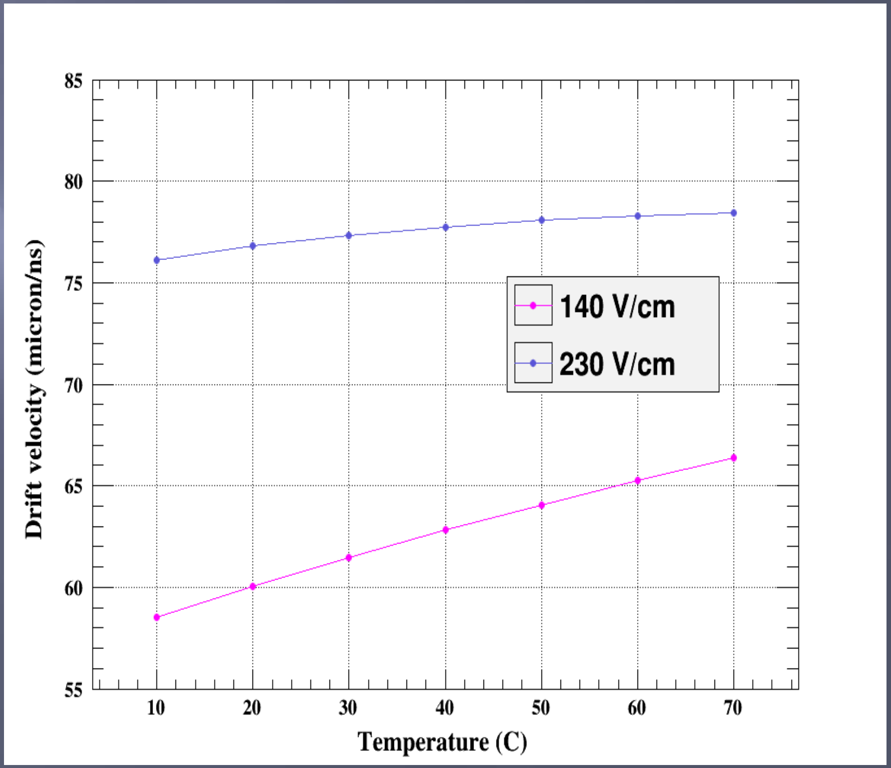


Experimental and Simulation results

Heating of the electronics

- Each (Micromegas) electronic takes nearly 30 W of power.
- This increases 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 removed



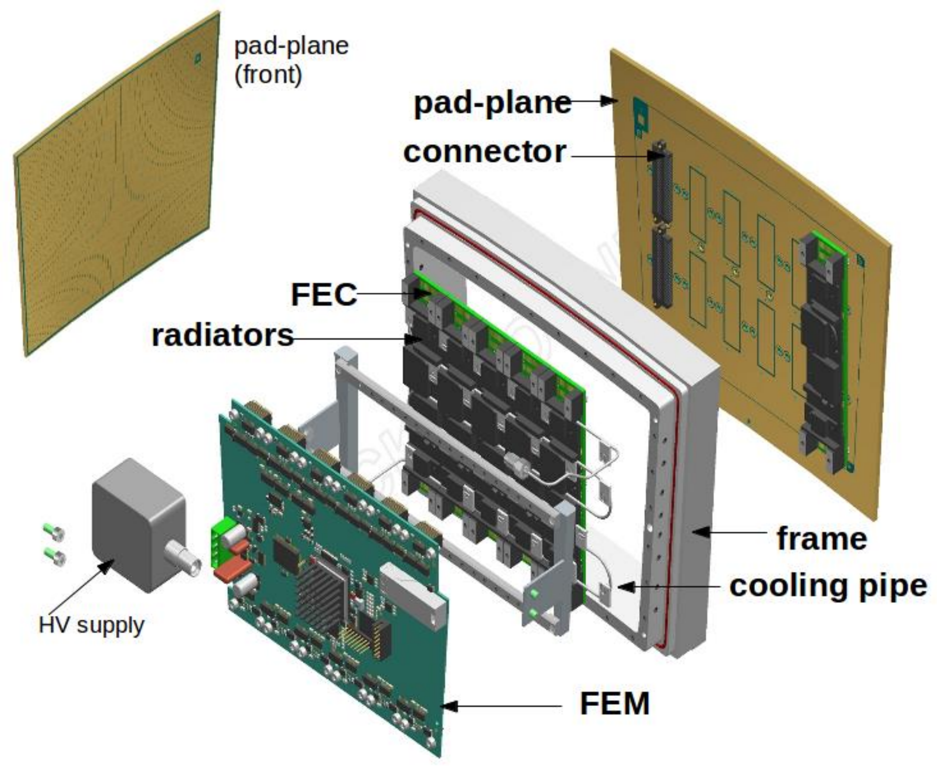


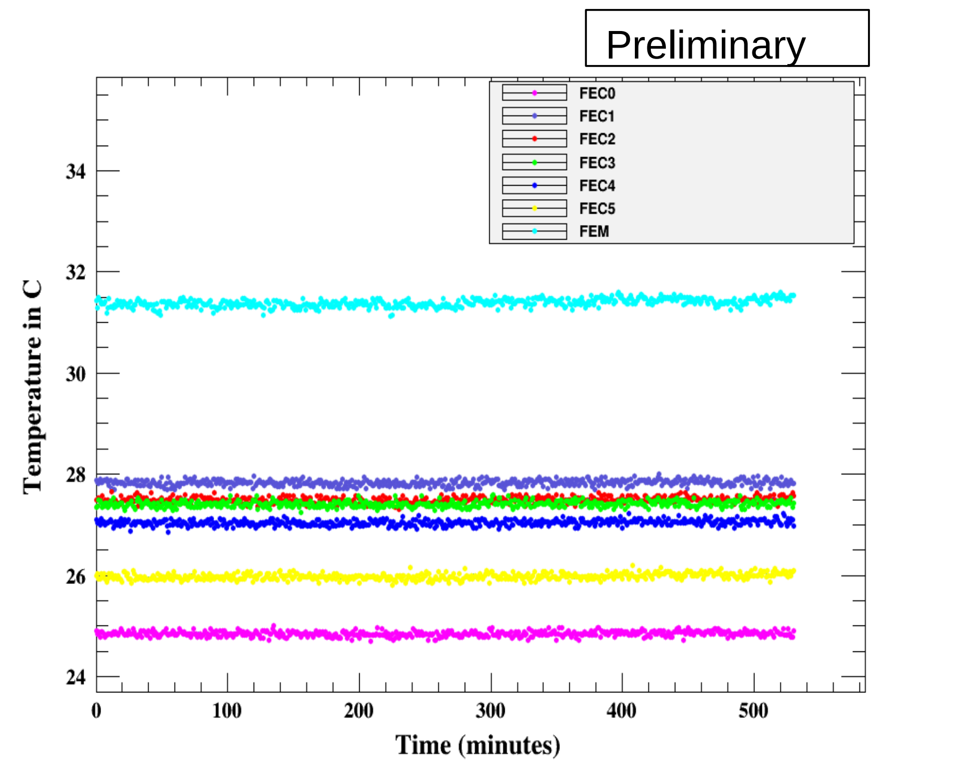
Temperature gradient in ILD-TPC
Simulation with COMSOL

Drift velocity Vs Temperature
Simulation with Magboltz

Two-phase CO2 cooling during 2015 beam test

During cooling, temperature is below 28 deg C and stable within 0.2 deg C.





Micromegas electronics and cooling setup **Stable temperature during cooling**

List of publications

- **Test of Micro-pattern Gaseous Detector modules with a large prototype Time Projection Chambers.**
  *Deb Sankar Bhattachary**, On behalf of LCTPC collaboration.
  Proceeding [PoS(EPS-***HEP 2015***)277] *The European Physical Society Conference on High Energy Physics,*
  22-29 July 2015, Vienna, Austria.

- **Investigation of ion backflow in bulk micromegas detectors.**
  P. Bhattacharya*, *D. Sankar Bhattacharya*, S. Mukhopadhyay, S. Bhattacharya, and N. Majumdara.
  [2015 JINST 10 P09017]

- **Measurement and simulation of two-phase CO2 cooling in Micromegas modules for a Large Prototype of Time Projection Chamber.**
  *Deb Sankar Bhattacharya**, David Attié, Paul Colas, Supratik Mukhopadhyay, Nayana Majumdar, Sudeb Bhattacharya, Sandip Sarkar, Aparajita Bhattacharya and Serguei Ganjour.
  [2015 JINST 10 P08001].

- **Test of a two-phase CO2 cooling system with a Micromegas modules.**
  *Deb Sankar Bhattacharya**, Paul Colas, David Attié.
  [LC-DET-2014-005].

In progress

- **Track Distortion in the Large Prototype of a Time Projection Chamber for the International Linear Collider.**
  *Deb Sankar Bhattacharya** , Purba Bhattacharya, Supratik Mukhopadhyay, Nayana Majumdar, Sudeb Bhattacharya, Sandip Sarkar, Paul Colas, David Attie, Serguei Ganjour and Aparajita Bhattacharya.
  [Proceeding of 'XXVII IUPAP Conference on Computational Physics 2015', IIT Guwahati, Assam, India.]

- **Numerical Study of Electrostatic Field Distortion on LPTPC End-Plates based on Bulk Micromegas Modules.**
  Purba Bhattacharya*, Deb Sankar Bhattacharya, Supratik Mukhopadhyay, Nayana Majumdar, Sudeb Bhattacharya, Paul Colas and David Attie.
  [Proceeding of 'MPGD 2015, 12-17 October 2015', Trieste – Italy]

- **Beam tests of single Micromegas TPC modules for the linear collider.**

Acknowledgement

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I sincerely thank Prof. Sudeb Bhattacharya, Prof. Nayana Majumdar, Prof Sandip Sarkar, Dr. David Attie, Dr. Serguei Ganjour, Prof. Satyajit Saha and Dr. Sandrine Emery.

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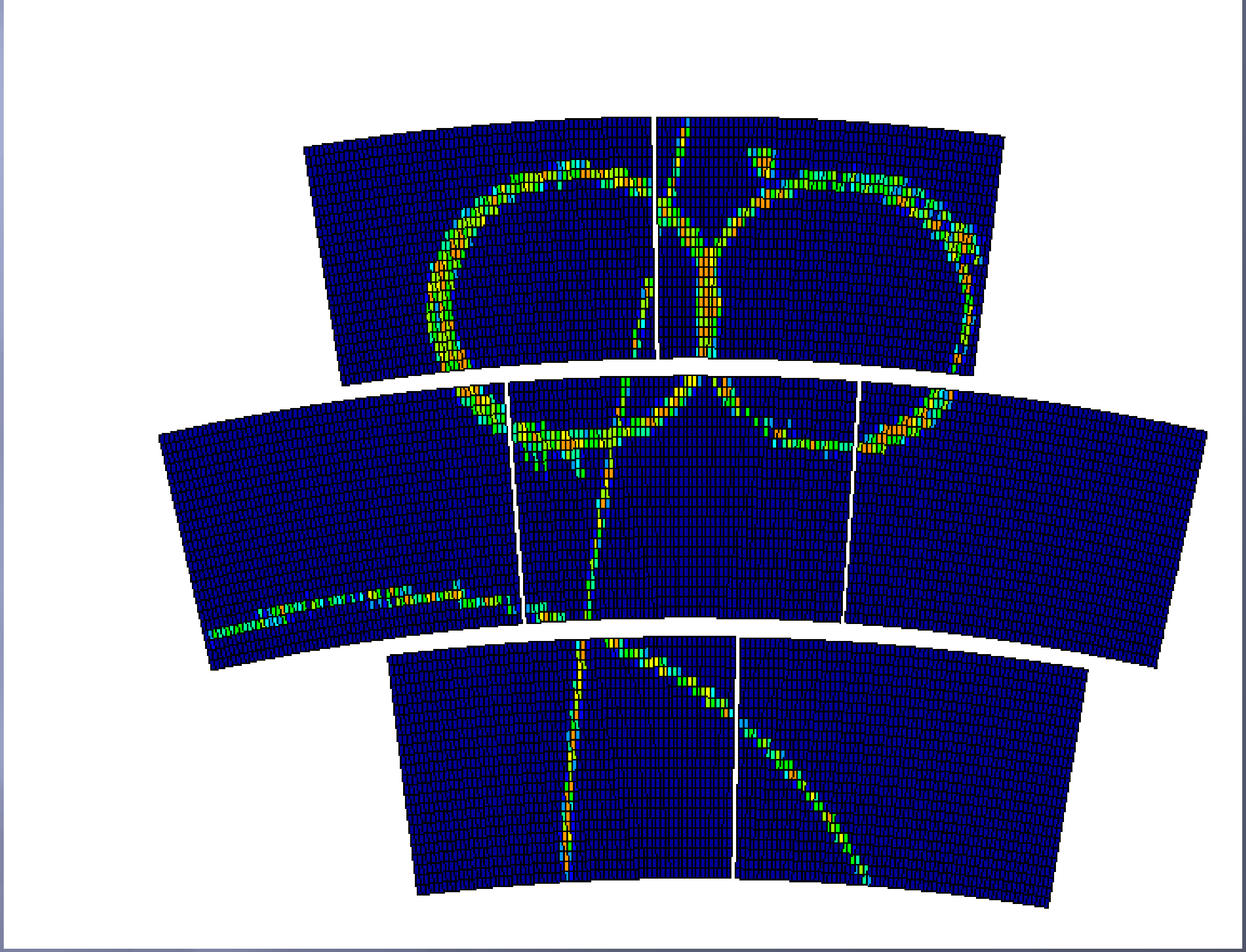
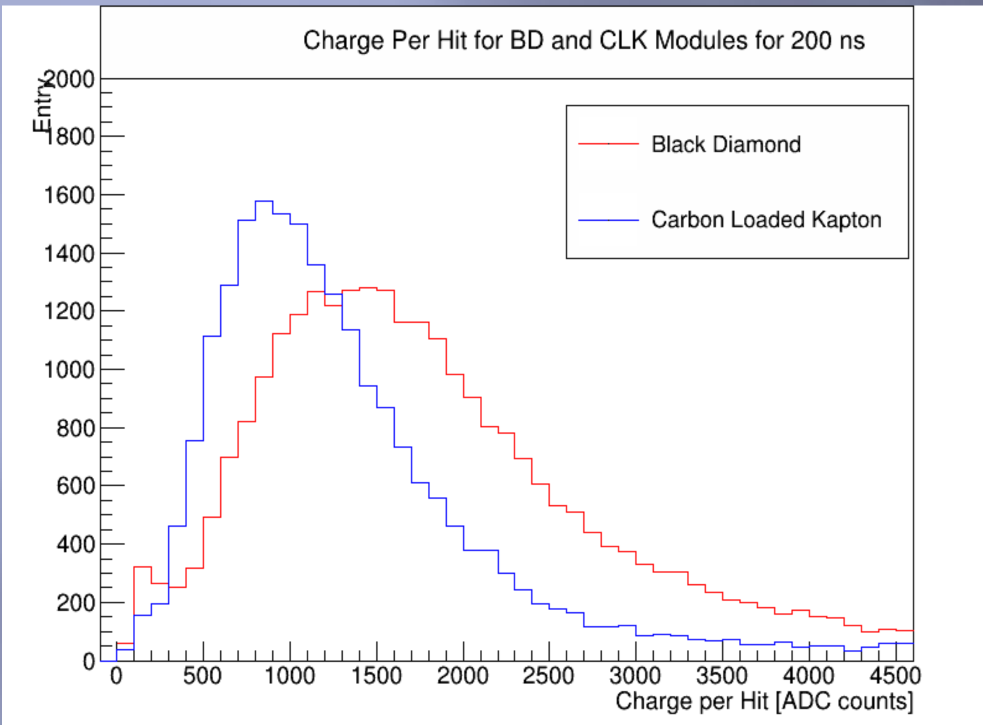
I am thankful to the scientific assistants of SINP and CEA, to the members of LCTPC collaboration and RD51 collaboration and to the IFCPAR/CEFIPRA (Project 4304-1).



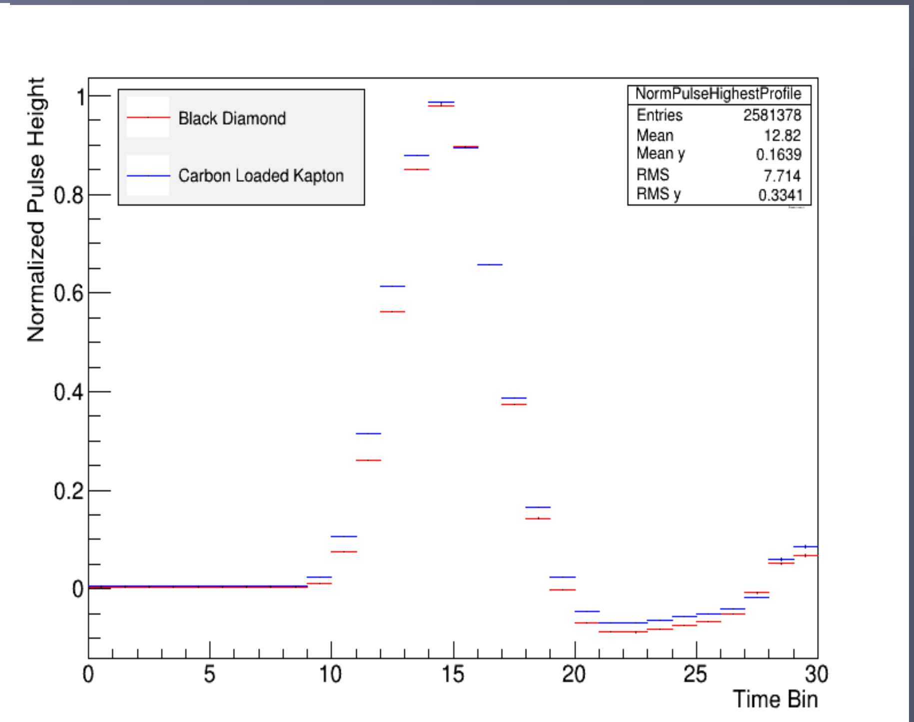
THANK YOU

Backup Slides

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



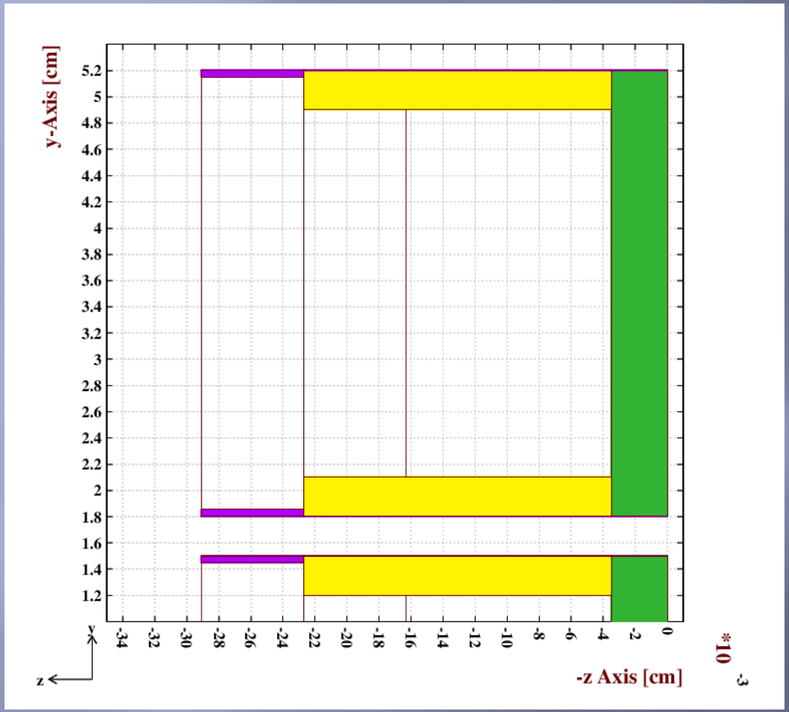
Normalised main pulse for BD and CLK



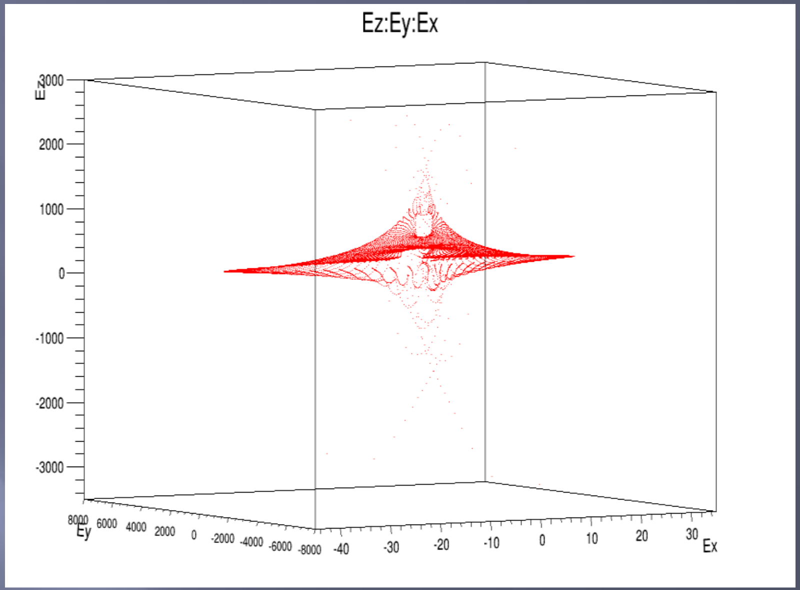
Charge per cluster in BD is slightly more than CLK.
This is because, BD has slightly larger capacitance than CLK.

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

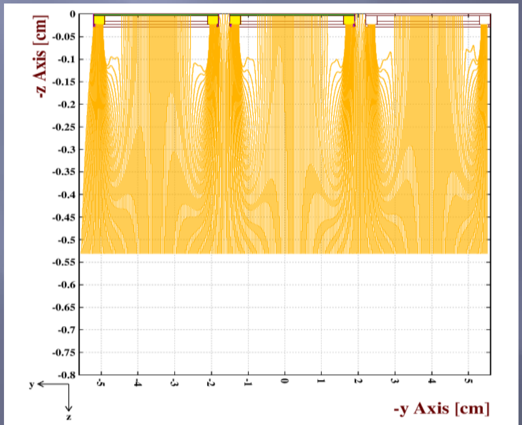
Investigation on Track distortion by Numerical Methods



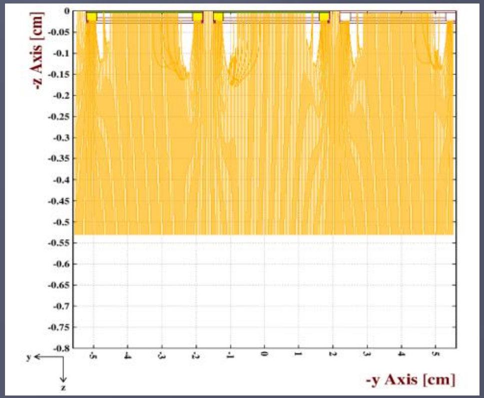
Simulated Micromegas modules



E_x, E_y and E_z components are plotted.
Large values of E_x and E_y at the module edge explains electric field distiortion.



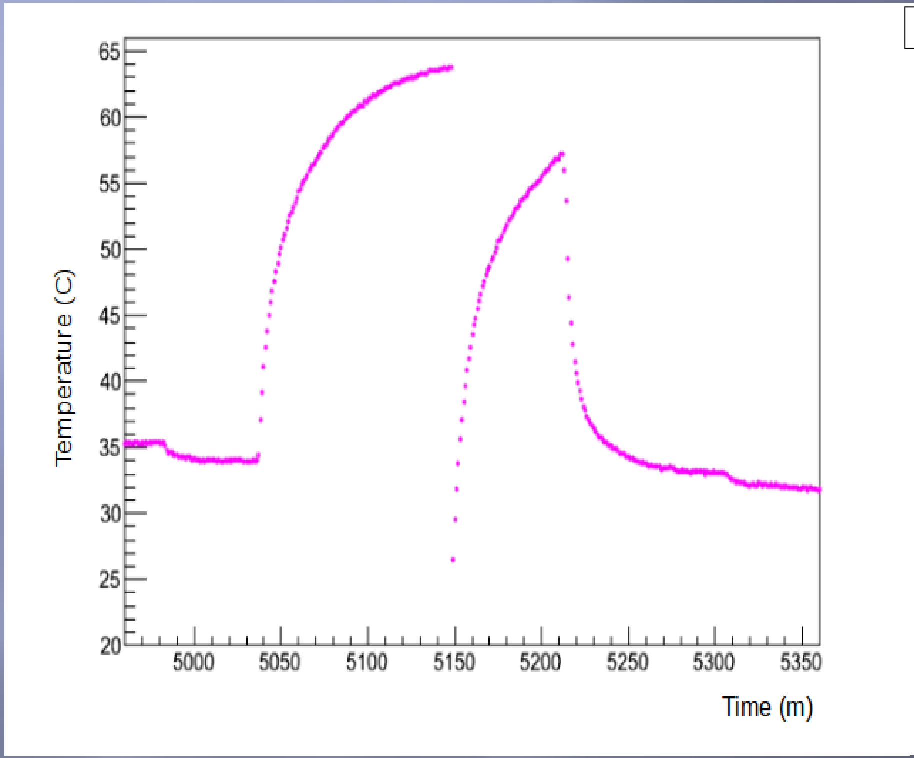
Electrons are drifting at B=0T

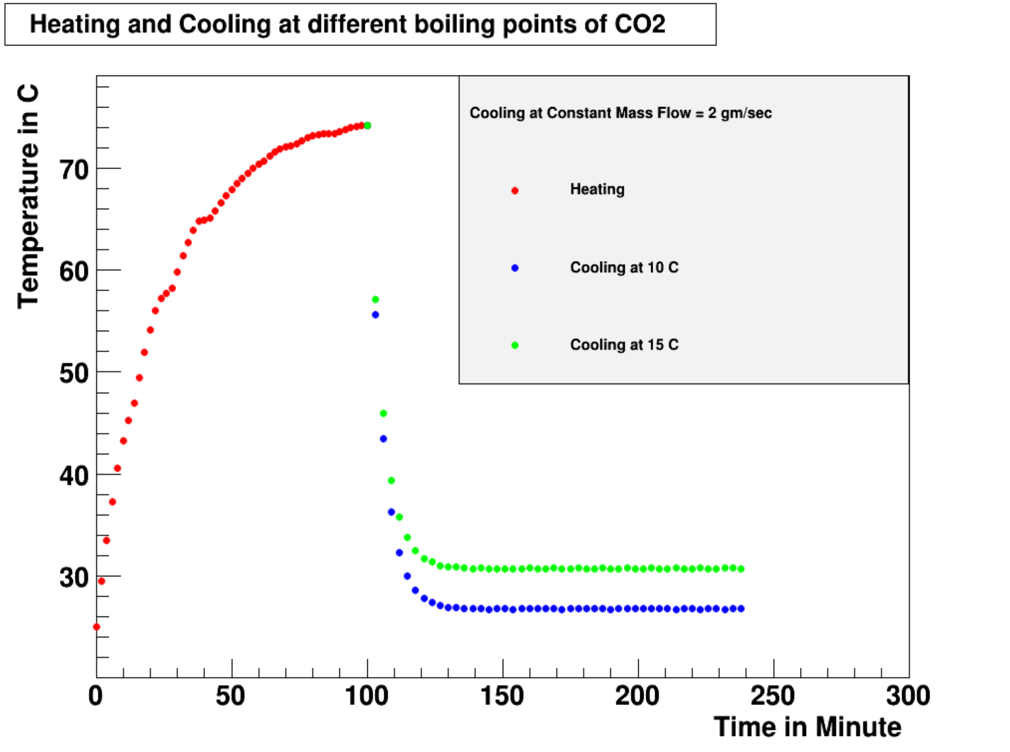


Electrons are drifting at B=1T

Two-phase CO2 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

Two-phase CO2 cooling

simulated model (COMSOL) shows how cooling works