Activity report of ILD-TPC Asia group

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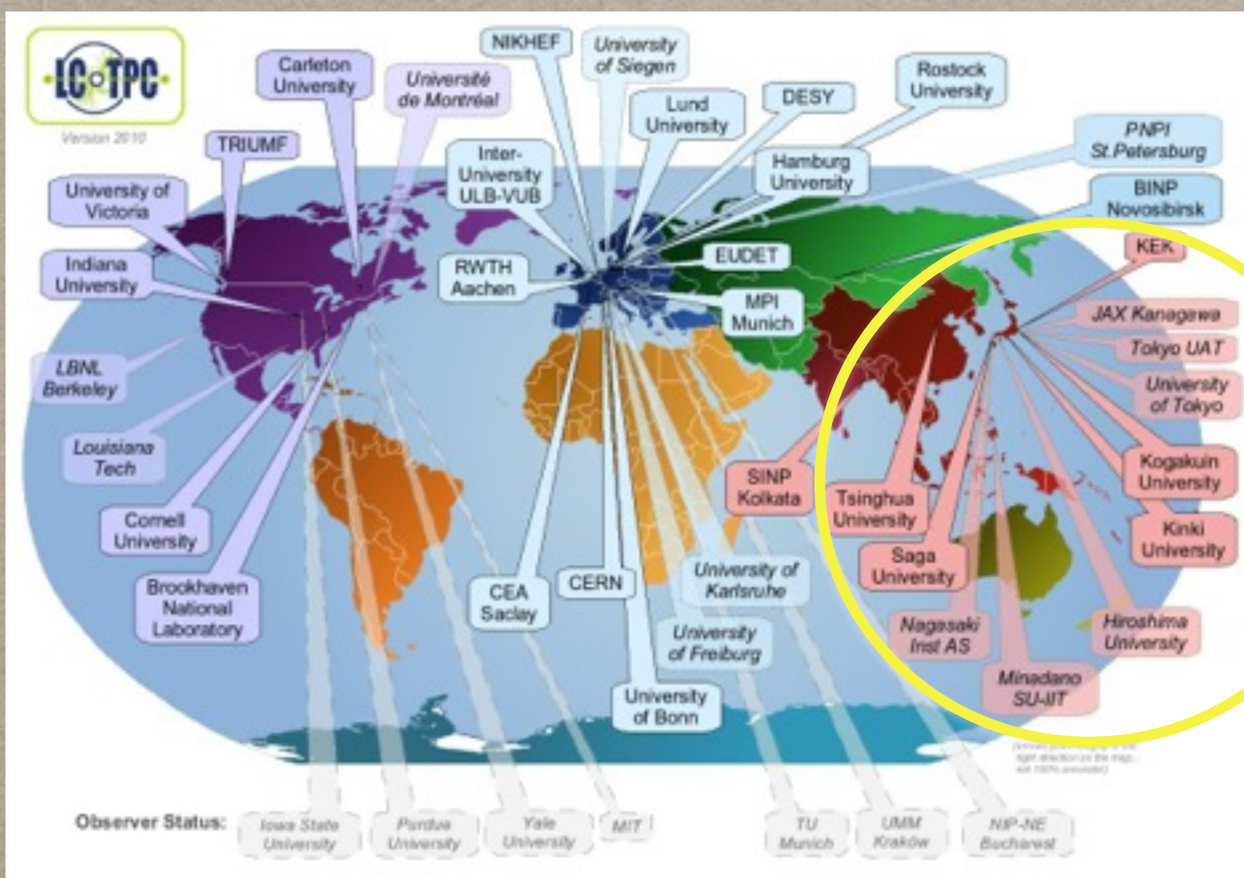
on behalf of ILD-TPC Asia group

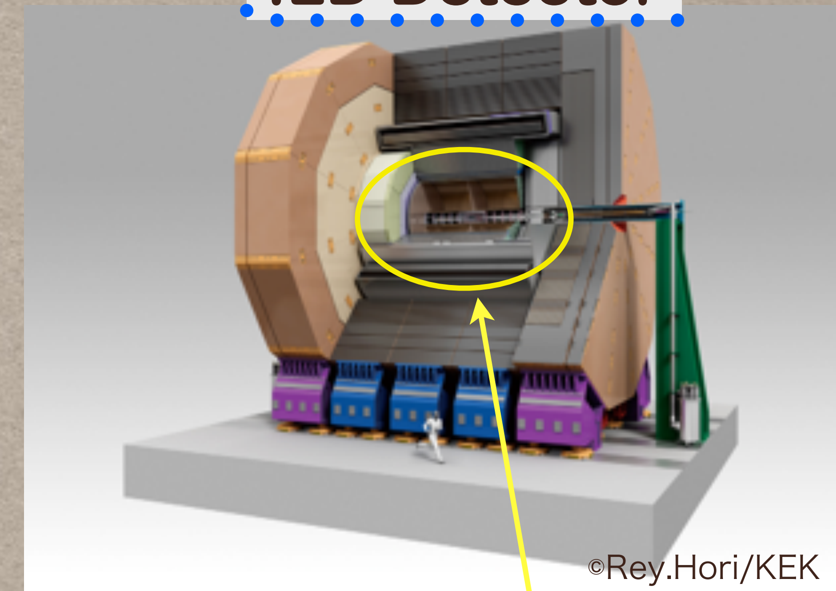
Contents

ILD-TPC Asia group

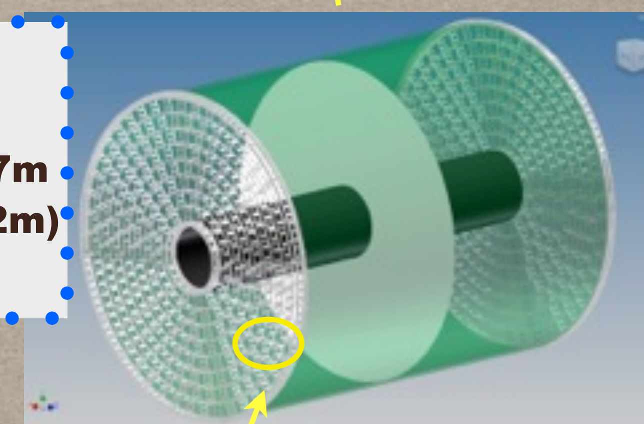
A group of ILD-TPC collaboration
- Japan, China, Philippines
- R&D of TPC with GEM

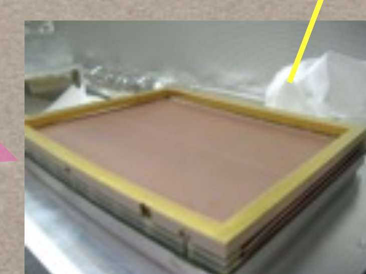


ILD Detector



ILD-TPC
- radius 3.6m length 4.7m (max drift distance 2.2m)
- B=3.5T





GEM module

Performance goal of ILD-TPC

✤ **Momentum Resolution**

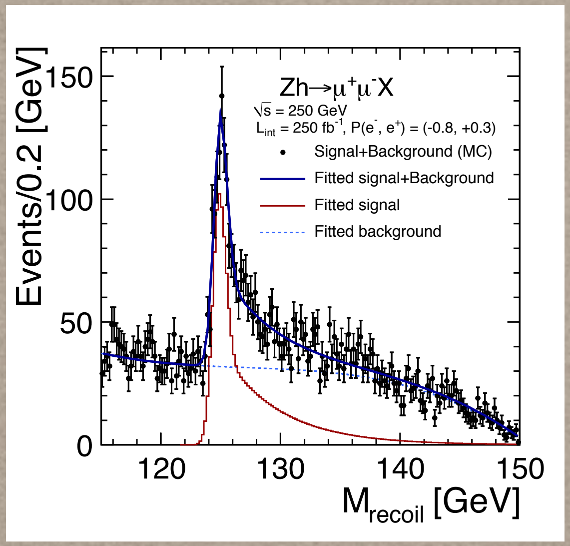
$\sigma(1/p_t) = 2\times10^{-5}$ (GeV^{-1}) >200 sampling points along a track with a spatial resolution better than **$\sigma_{r\varphi}$~100 μm** over the full drift length of >2m in B=3.5T (recoil mass, $H\rightarrow\mu^+\mu^-$).

✤ **High Efficiency**

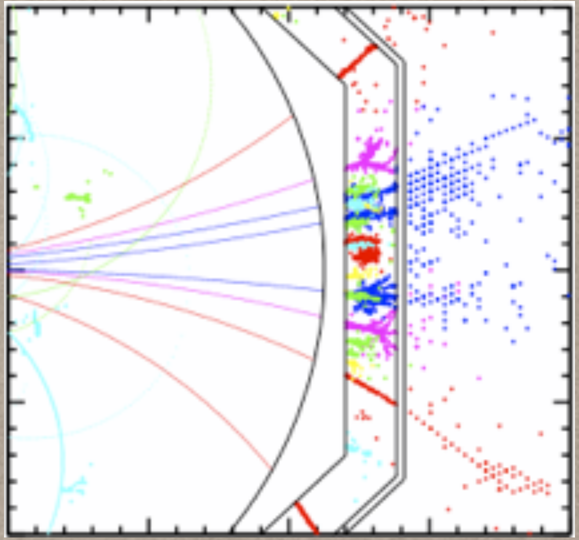
2-track separation better than **~2mm** to assure essentially 100% tracking efficiency for PFA in jetty events.High tracking efficiency also requires **minimization of dead spaces** near the boundaries of readout modules.

✤ **Minimum material**

for PFA calorimeters behind, also to facilitate extrapolation to the inner Si tracker and the vertex detector



Recoil mass measurement



Particle Flow Algorithm

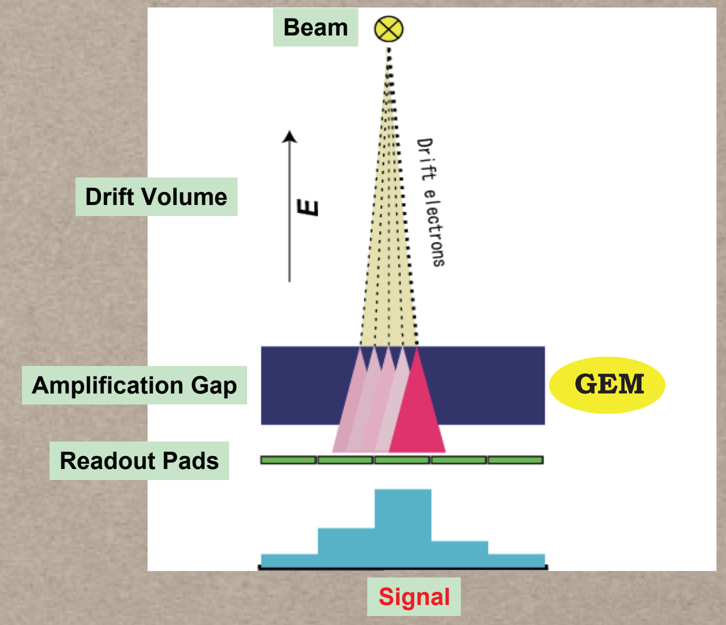
Why MPGD is good for ILD-TPC ?

MPGD (Micro Pattern Gas Detector)

MPGD is a gaseous detector with gas amplification by the 2D micro pattern structure.

Advantage of MPGD against MWPC

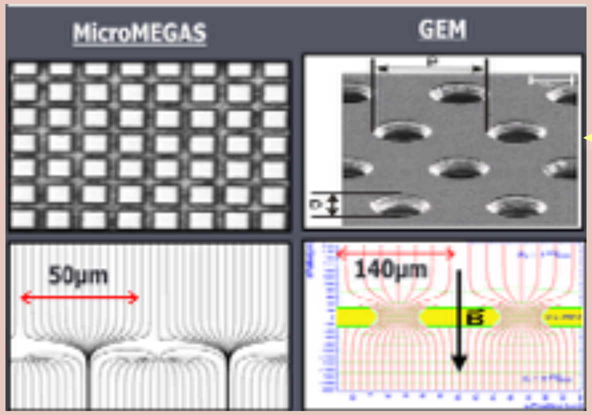
- less ExB effect to rφ resolution in the high magnetic field (B=3.5T)
- fine two-dimension structure of the O(100μm) can achieve O(100μm) resolution and two track separation
- small dead signal region by the support frame



operation principle of GEM-TPC

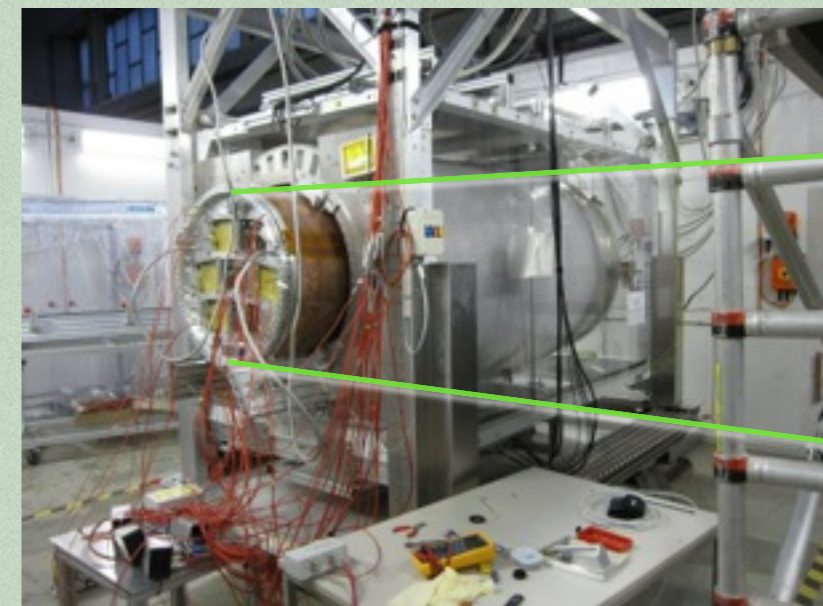
two MPGD candidates of ILD-TPC

- GEM
- micromegas



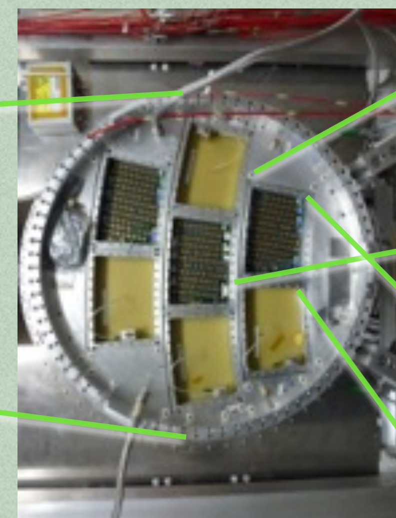
ILD-TPC Asia group have proposed to use GEM and been doing R&D.

Large prototype and test beam

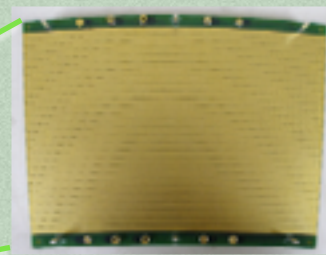


Large prototype

- radius 720mm, length 610mm
- B = 1T (PCMAG)
- placed on DESY T-24 area (5 GeV electron beam)



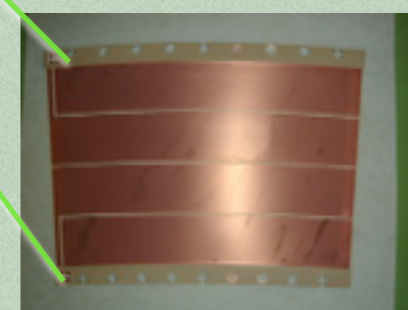
End plate



Pad plane

192 pads/row
178 pads/row
28 row/module

pad: (1.15〜1.25) mm W X 5.26 mm H
0.1 mm gap, staggered layout



GEM sheet

- two GEM made of 100μm thick LCP
- Φ - 70μm, pitch - 140μm

Purpose of Large prototype

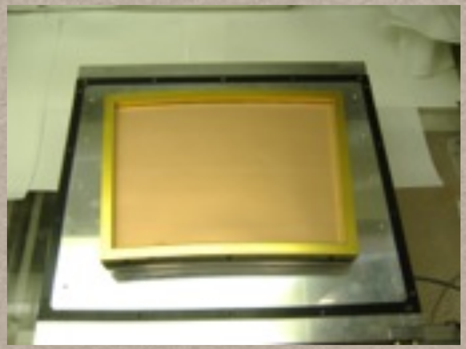
- estimate to the TPC performance under the near condition of the real TPC
- compare the performance of the various readout modules

Beam test 2010 and 2012

DESY II test beam line T24 (electron p_e = 5 GeV/c)
Sep.1 - Sep.26 2010 and Nov.19 - Dec.18 2012

2010 Data

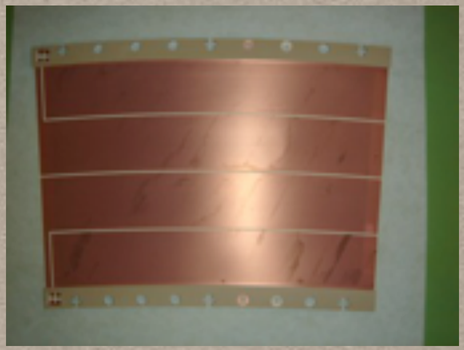
- B=1T
- z-scan: (5cm - 55cm)



2010 version

Increase the partitions (2-> 4) of GEM electrode to protect the readout electronics by discharge

2012 version



There were problems at 2010 beam test

1. NO data of short drift length and various beam angle
2. large distortion around the module boundary
3. damaged readout electronics by discharge

took below steps for 2012 beam test

1. optimize HV of field shaper
2. increase the partitions of GEM electrode
3. add protection circuit to readout electronics

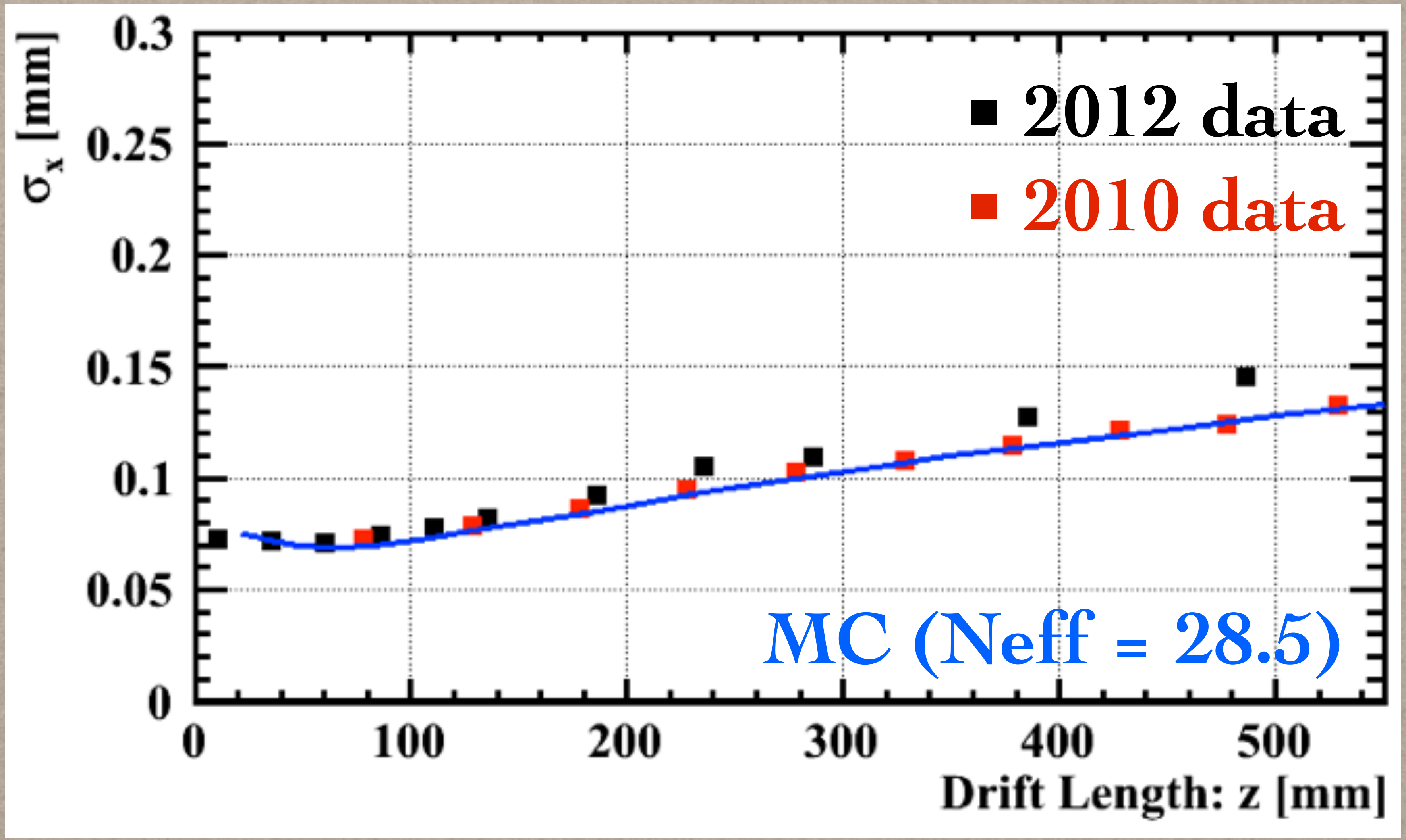
2012 Data

- B=0T, B=1T
- z-scan: (2.5cm - 50cm)
- x-scan: (-2cm - 2cm)
- theta-scan: (-10˚,10˚)
- phi: (-10˚,10˚)
- different gains, shaping times

more various data than 2010 beam test

Result of beam test

xy-resolution (central module, row 17)



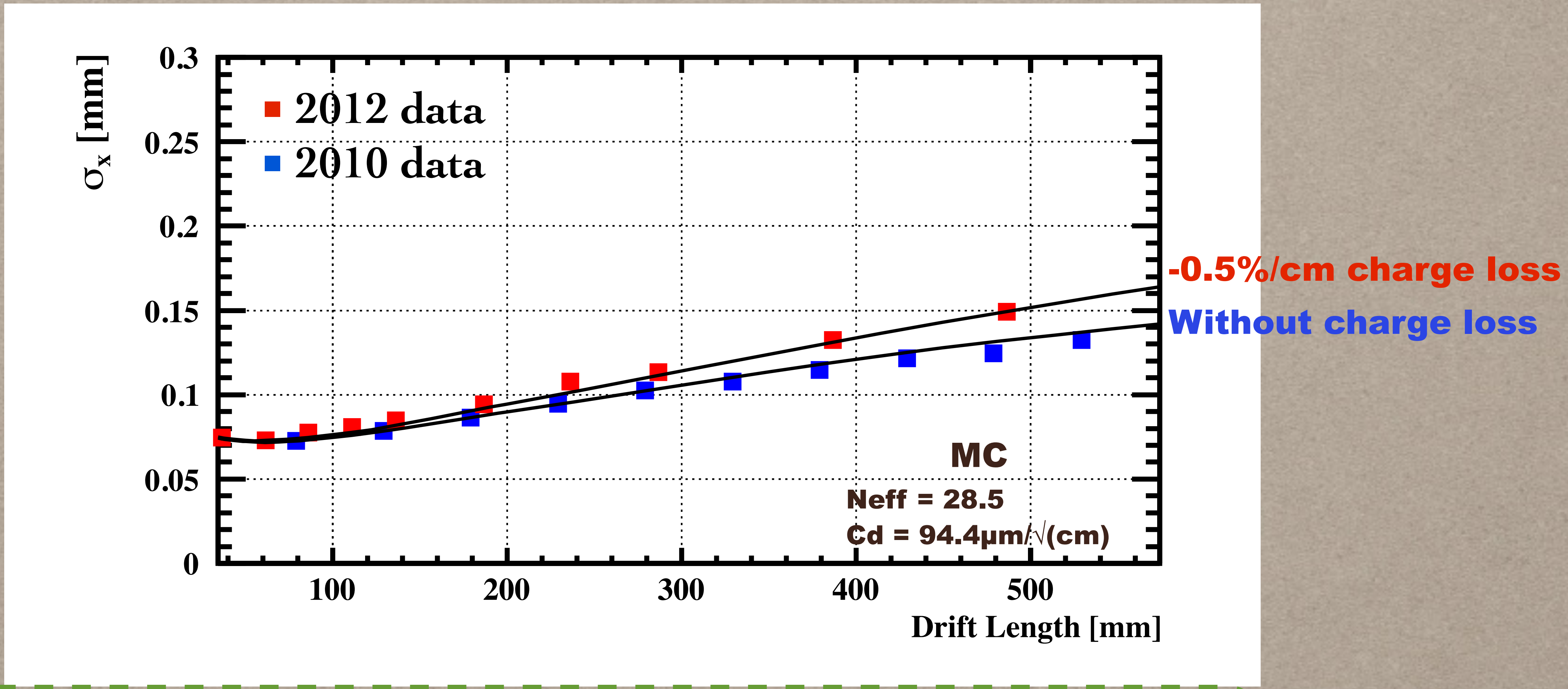
2012 data is consistent with 2010 data at short drift distance

xy-resolution turns worse as drift length become long ⇐ another group using large prototype at 2012 observed same trend

Result of beam test (MC with real charge loss)

If there is a real charge loss by some reasons, can the real charge loss explain the xy-resolution of 2012 data ?

→ Compare 2012 data and MC simulation with Neff = 28.5 (consistent with 2010 data)



-0.5%/cm charge loss can explain the change for worse of xy-resolution on 2012 data

charge loss may be caused by gas leak or bad O_2 monitor…

Analytic formula of spatial resolution

Ref. Ryo Yonamine's Ph.D thesis

$$\sigma_x^2(z; w, L\tan\phi, C_d, N_{eff}, \hat{N}_{eff}, [f]) = [A] + \frac{1}{N_{eff}}[B] + [C] + \frac{1}{\hat{N}_{eff}}[D]$$

Analytical explanation is important to understand the relation to drift distance and spatial resolution in TPC. The four elements can be make influence of the spatial resolution.

(A) systematics due to finite pad readout
(B) diffusion effect
(C) electronic noise effect
(D) primary cluster fluctuation

(D) makes effort to resolution of inclined track

$$[D] := \frac{L^2 \tan^2\phi}{12}$$

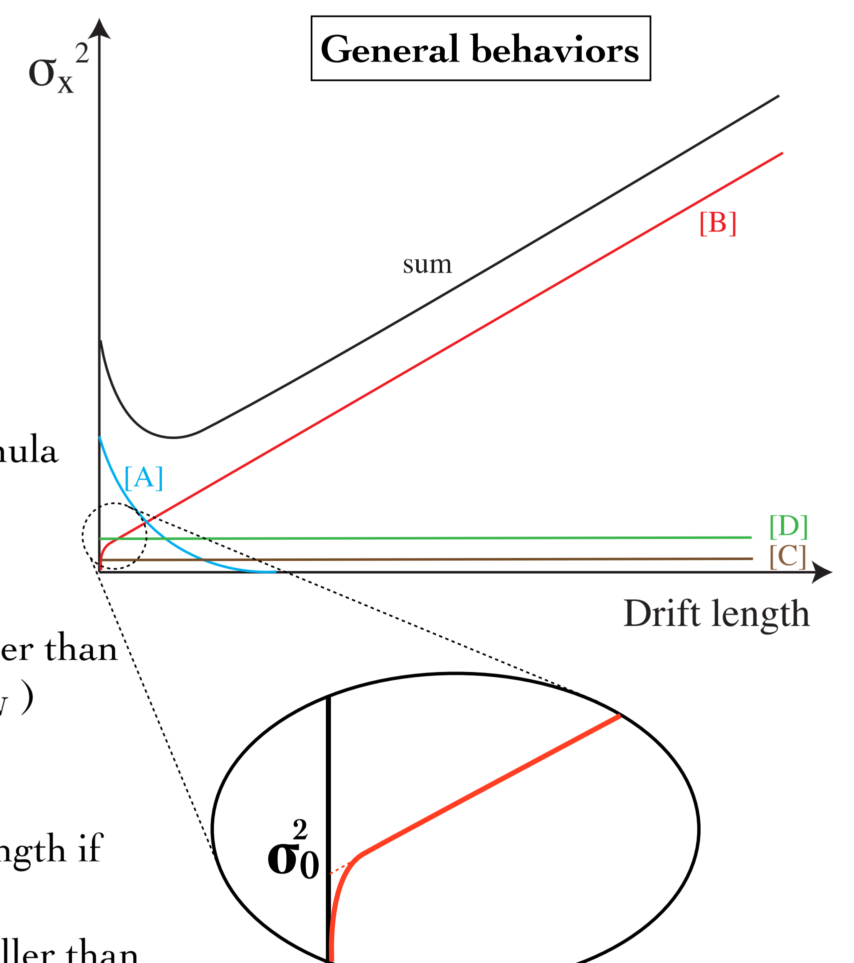
Obtained Knowledge

- Spatial resolution consists of 4 components.
- [A] : systematics due to finite pad readout.

  disappears if $\sigma_{PR}/w \gtrsim 0.4$
  (long drift length or inclined tracks)
- [B] : diffusion effect

  - Gas property
  - We found that σ_0^2 in the asymptotic formula
    $$\sigma_x^2 = \sigma_0^2 + \frac{C_d^2}{N_{eff}} z$$
    can be written as $\sigma_0^2 = [A]_{z=0}/N_{eff}$.
  - We understood why Neff is much smaller than average of seed electrons. ($N_{eff} \ll \langle N \rangle_N$)
- [C] : electronic noise effect
- [D] : primary cluster fluctuation

  almost constant as a function of drift length if ϕ is fixed. It vanished for ϕ=0.
  - We understood why $\hat{N}_{eff}$ is much smaller than effective number of seed electrons. ($\hat{N}_{eff} \ll N_{eff}$)



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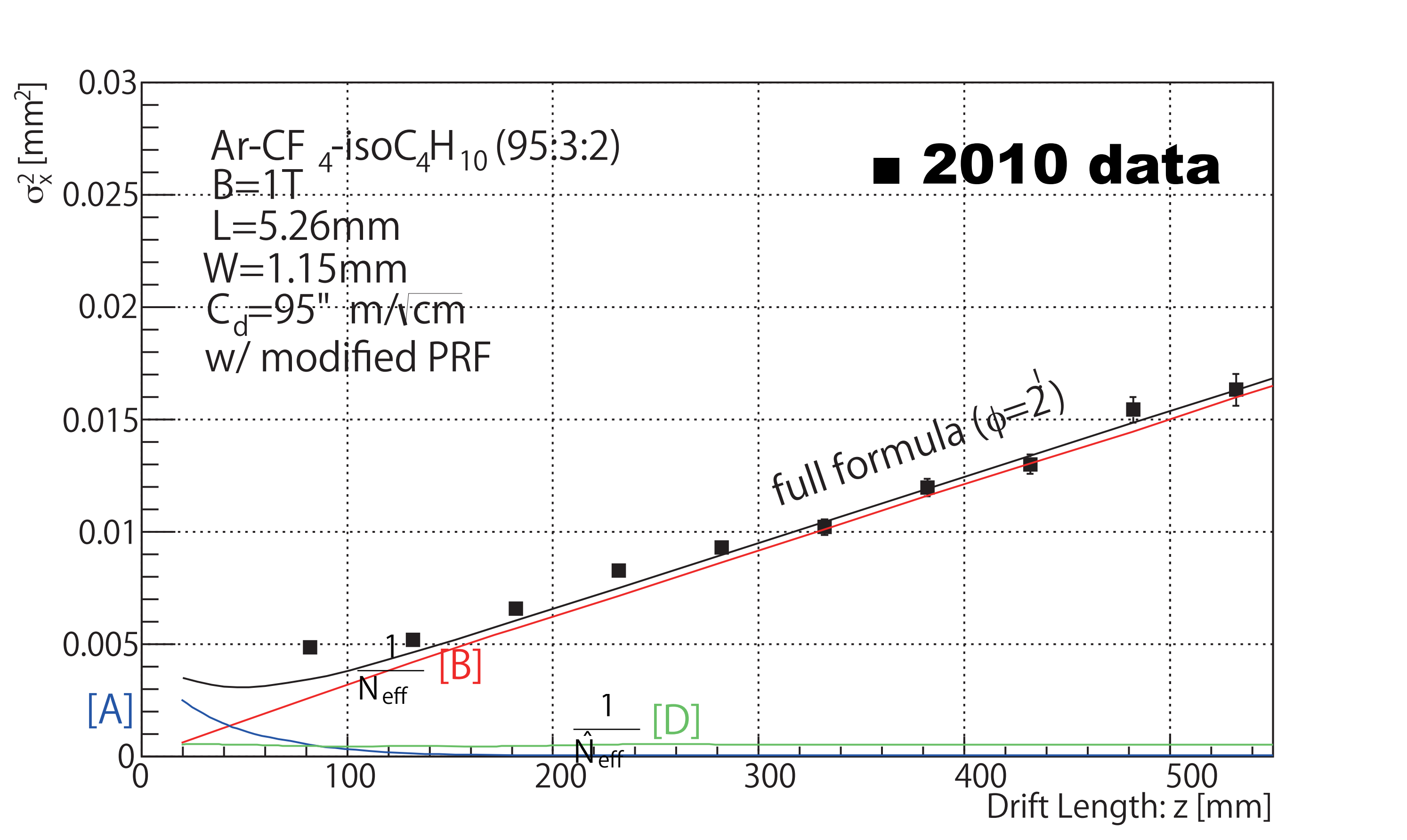
Slide by R.Yonamine

Analytic formula of spatial resolution

Ref. Ryo Yonamine's Ph.D thesis

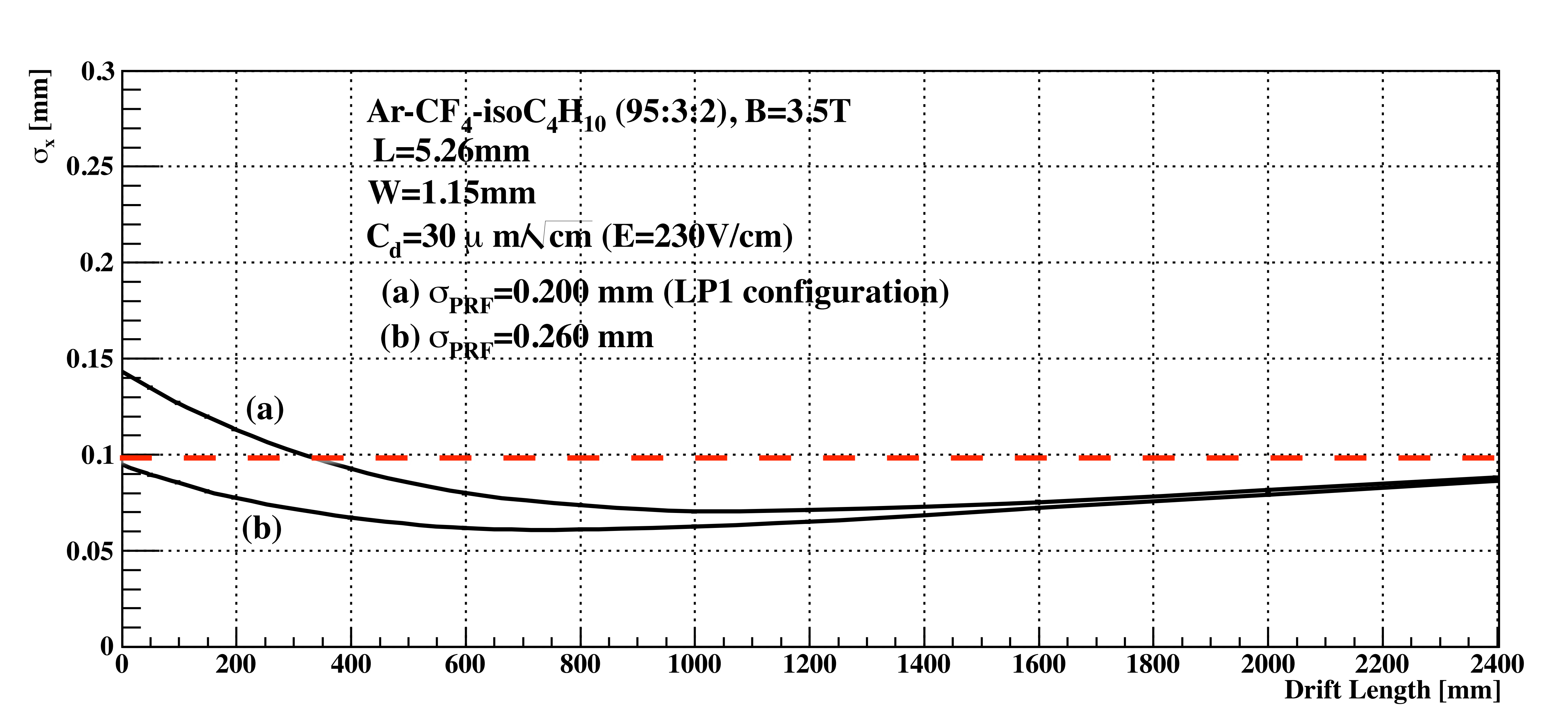
Compare analytic formula and 2010 test beam data
(noise effect is assumed to negligible small)



Analytic formula is consistent with test beam data

The spatial resolution for the drift length can be understood. We can estimate the performance of the real TPC using the results of large prototype measurement.

Extrapolation to the ILD-TPC



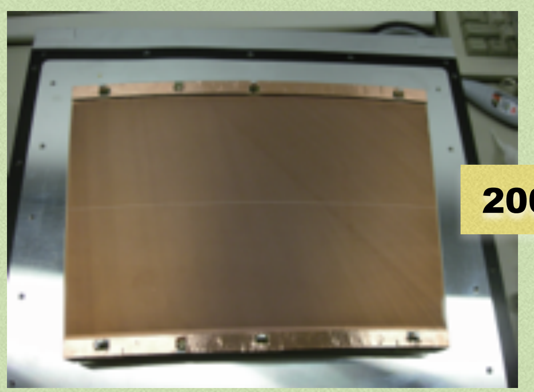
The expect performance by test beam is satisfied with the requirement of ILD-TPC

Local field distortion

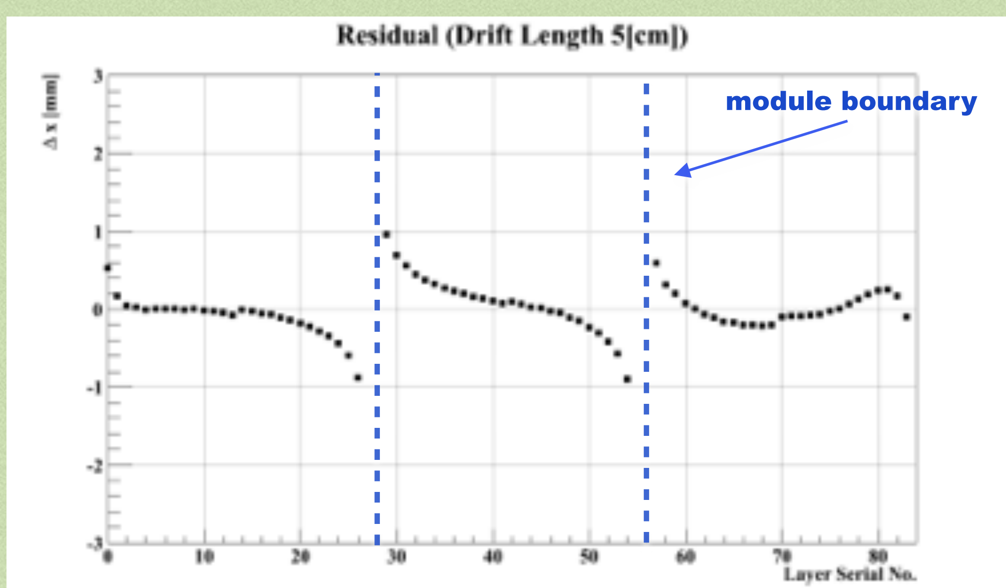
2010 test beam

There was a big distortion

Reason: The electric field was bend around module boundary because HV on field shaper were not suitable



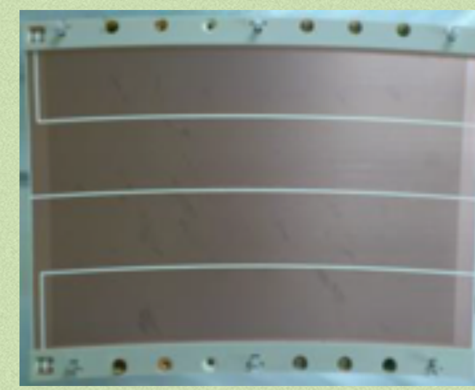
200μm gap



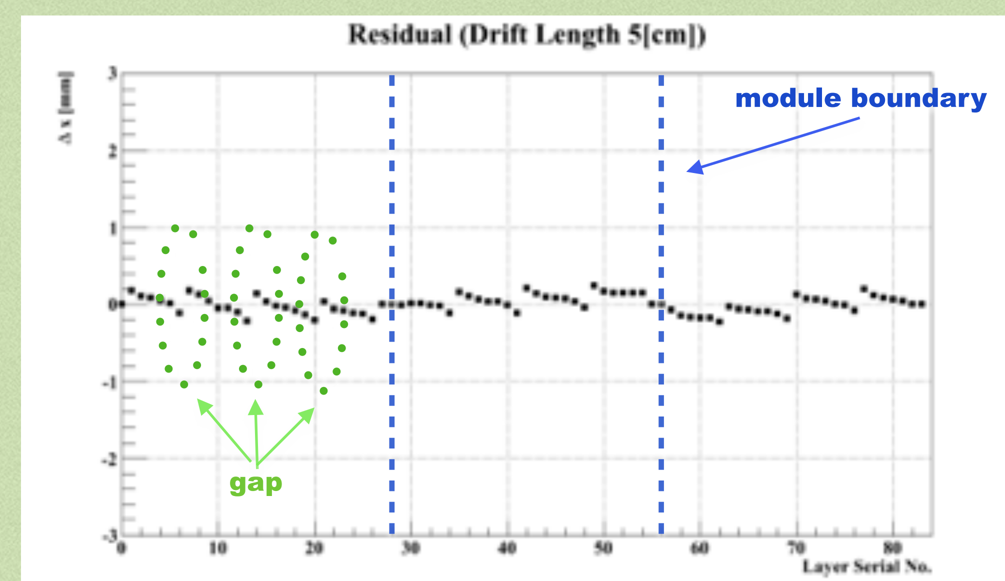
2012 test beam

Distortion was still existed

Distortion size is smaller than 2010 data because HV on field shaper was suitable.
There were distortion at the GEM electrode gap (gap size: 200μm -> 1mm)

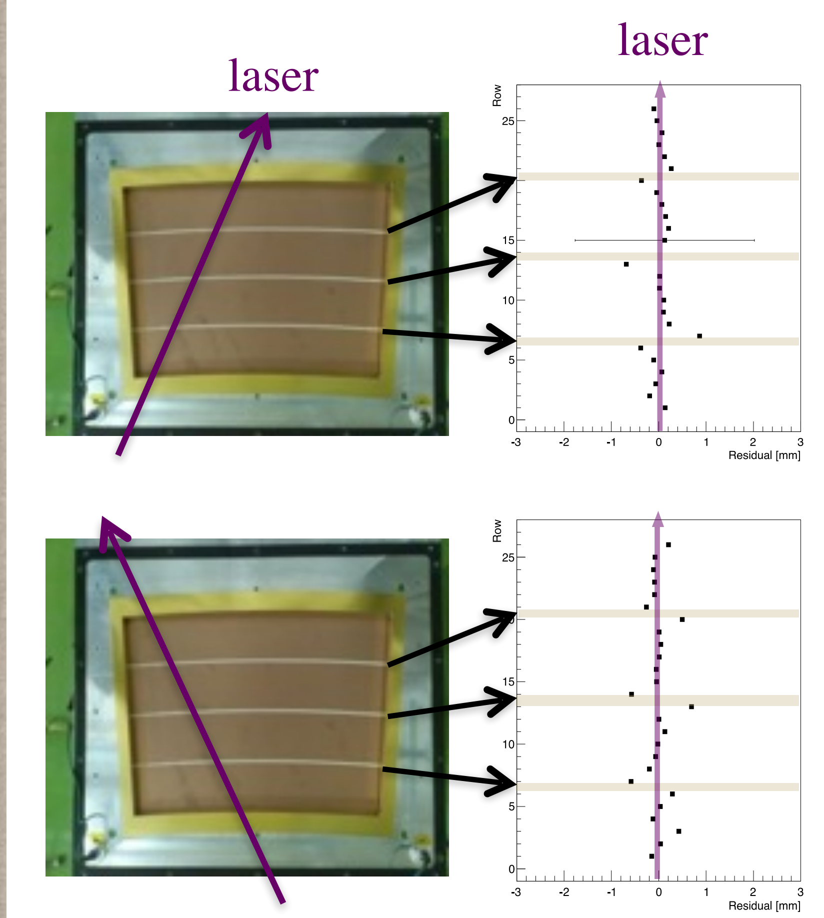


1mm gap

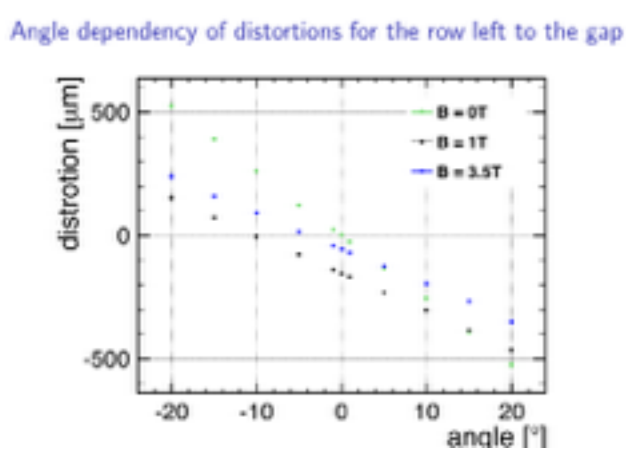


need to estimate the field uniformity → **The field uniformity will be checked using the track by UV laser system**

Result of UV laser test



Residual of hit point for the track



Result of simulation (2012 GEM)

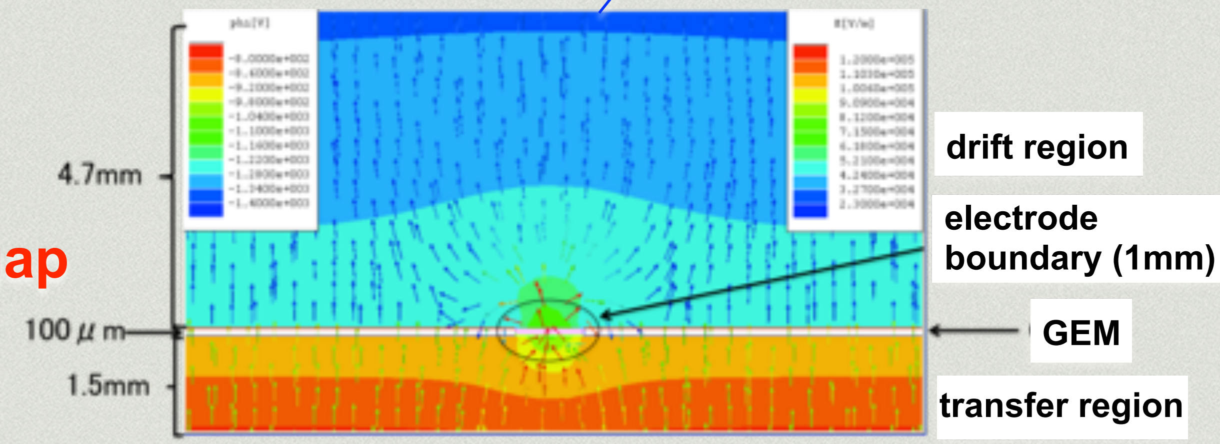
- **Distortion is found near electrode boundary.**
- **Direction of distortion is opposite to the direction of laser.**

This problem is studied with the field simulation

Field is bent to the electrode boundary on 2012 version

1mm gap is too wide

need new GEM with narrower gap

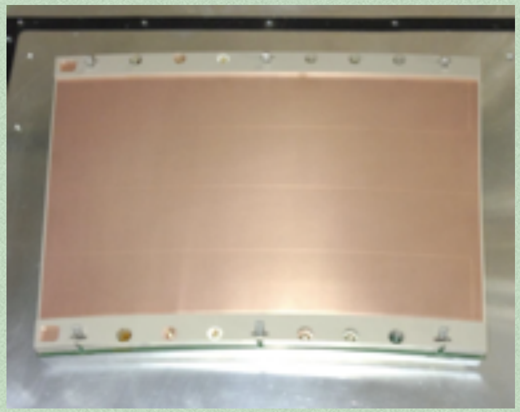


New GEM and UV laser system

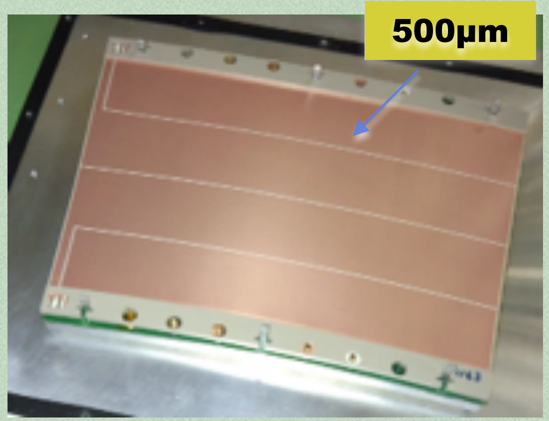
new GEM

to suppress the distortion

- decrease boundary gap size (1mm -> 500μm)
- no boundary gap on front side



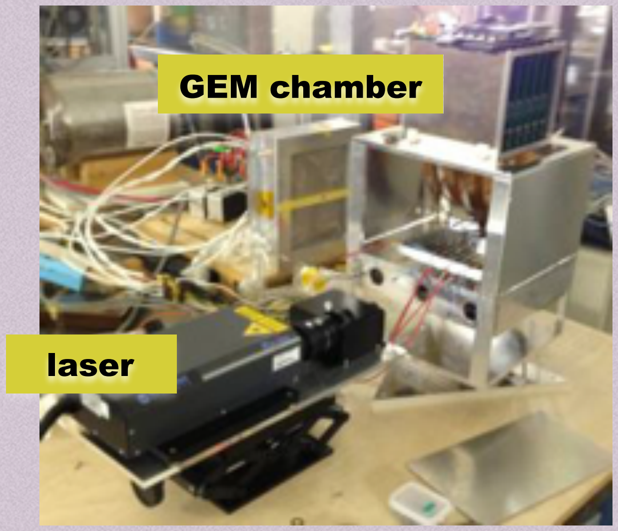
front side



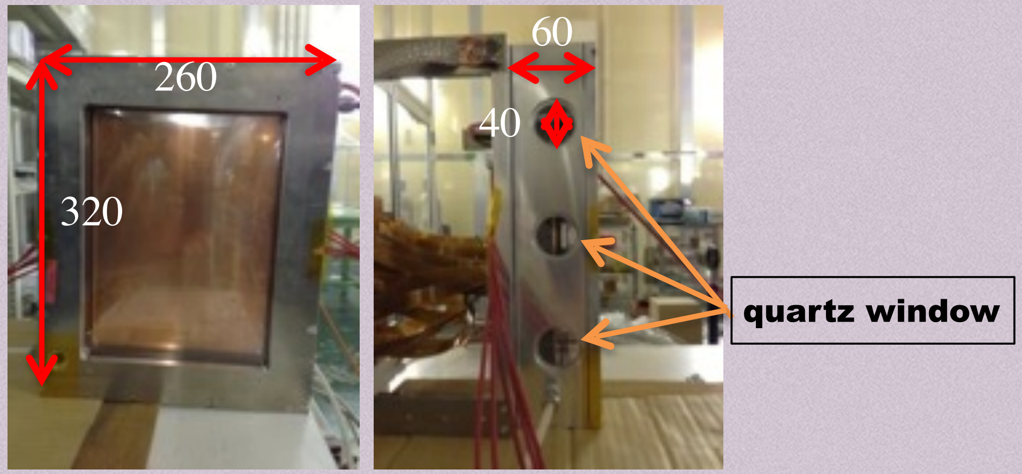
back side

Test plan with UV laser system

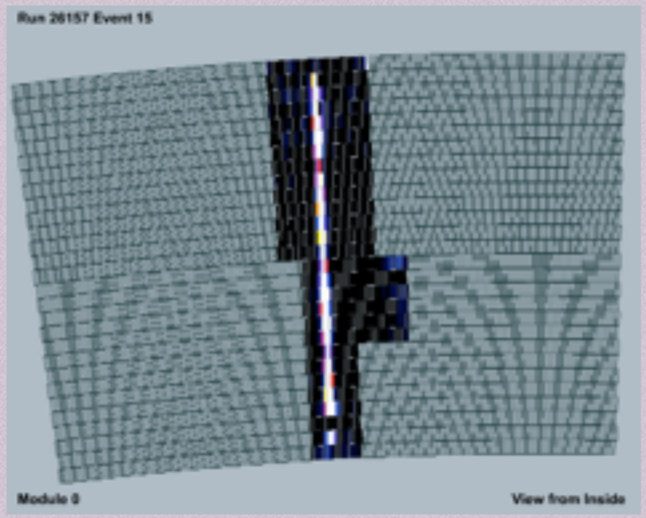
- measure the distortion of new GEM and compare to simulation
- measure the distortion of GEM with wire gate



UV laser system
(Nd-Yag λ=266nm)



test chamber

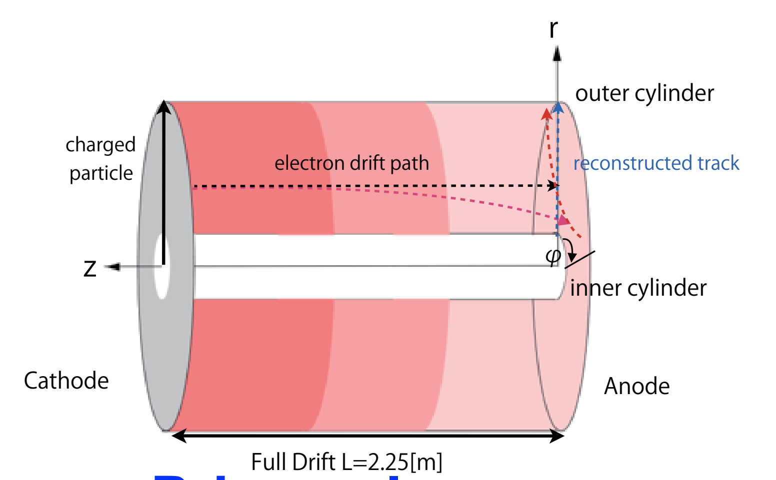


event display
(2012 GEM)

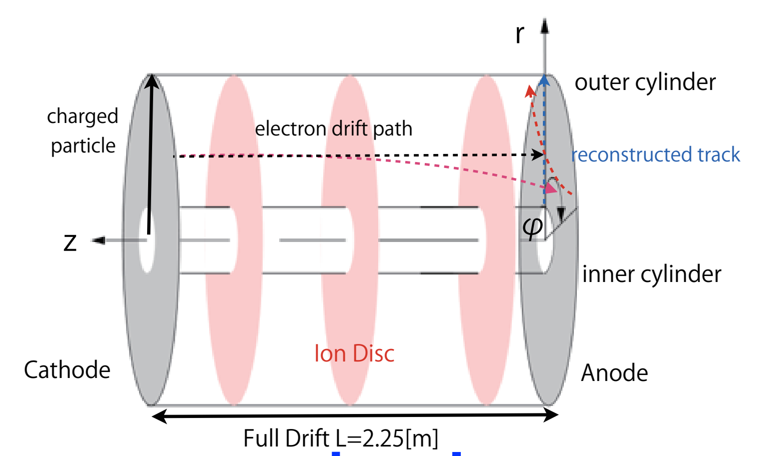
Effects of Positive Ions

1. There are a lot of ions in TPC at the ILC experiment.
2. These ions in the drift region make the distortion of electric field.
3. The distortion of electric field disturb the drift electron path.

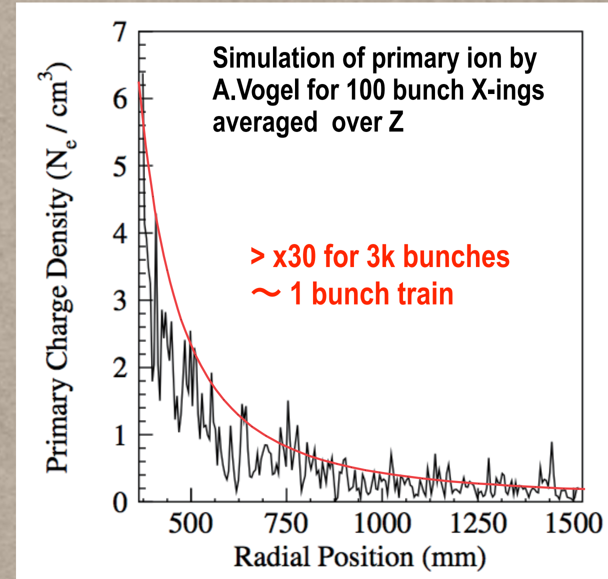
Estimate the effects



Primary Ions
(associated with track)



secondary Ions
(associated with GEM)



Solved the Poisson equation for the simulation ion density distribution with proper boundary conditions and then estimated the distortion of drift electron trajectory by the Langevin equation (D.Arai and K.Fujii)

distortion of track by positive ions

	without Gating Device	with Gating Device
Primary Ion	8.5μm	8.5μm
Secondary Ion	60μm	0.01μm
sum	70μm	8.5μm

Not OK

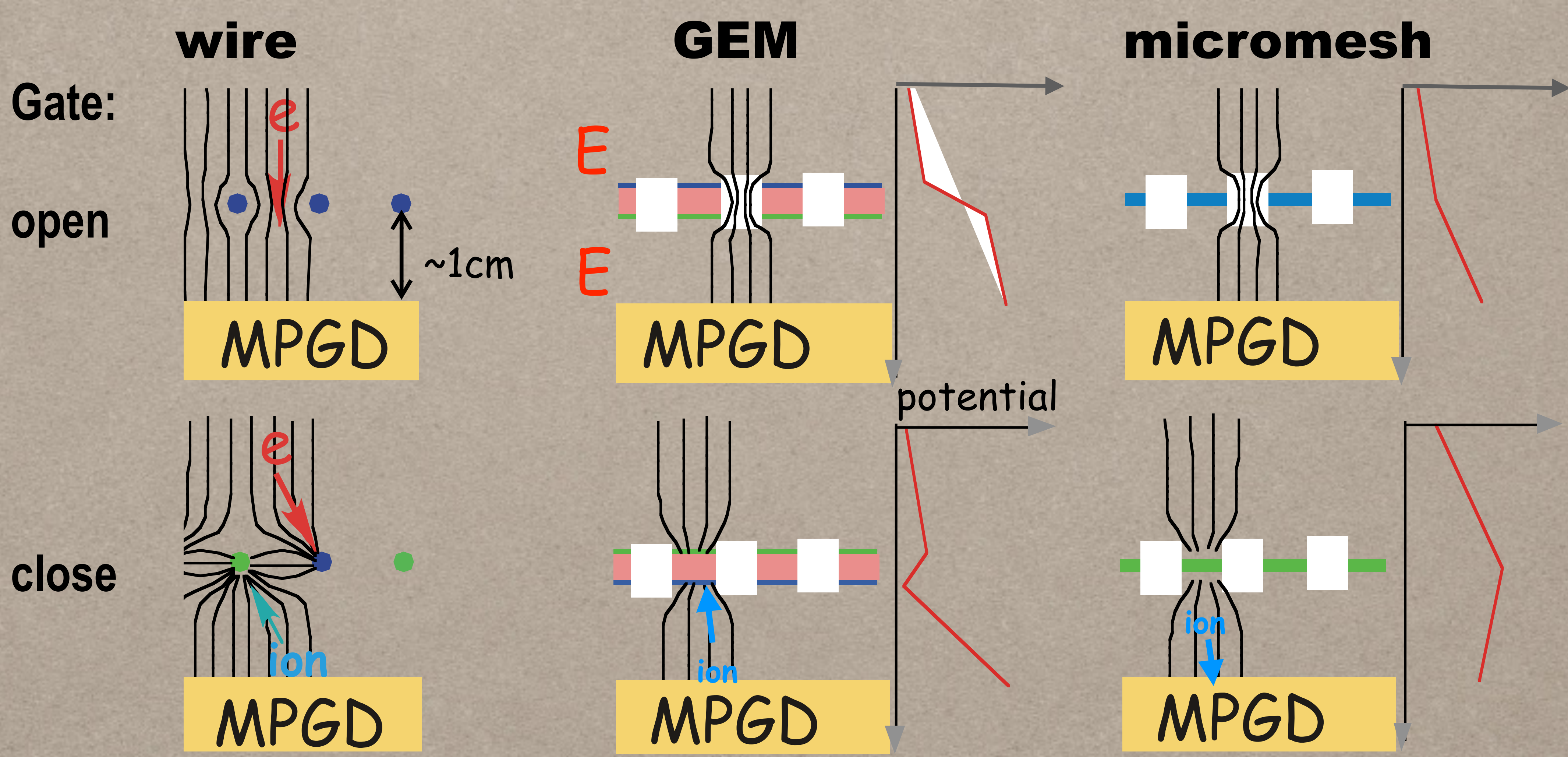
For the secondary ions from the amplification, **we need an ion gate device** for the ion feed back ratio of > 10^{-3} at the gas gain of 1000

Ions gates for ILD-TPC

Requirement of ILD-TPC

- ions feedback must be smaller than 10^{-3}(ie. no ions from MPGD)
- Gate can be open for 1 msec and be closed following 199 msec.
- ion can drift < 1cm

→ **3 candidates**

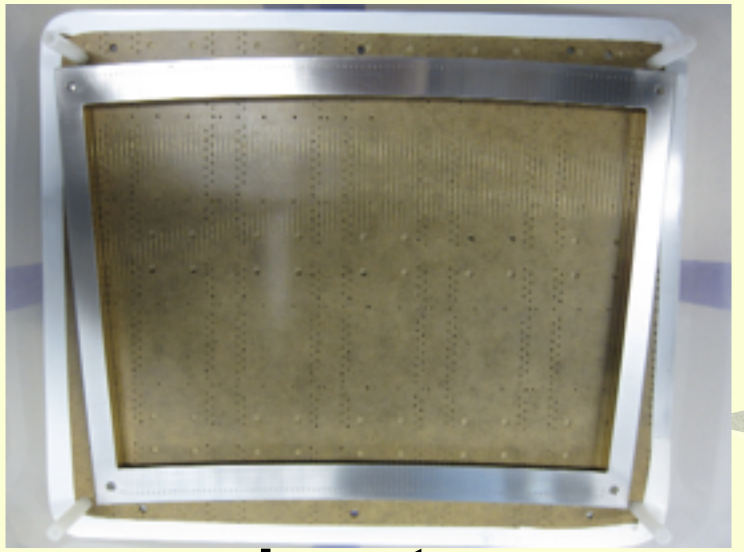


wire: known technology, local change of E; directional, structure, wire tension, ExB

GEM: symmetry, local change of E; electron transmission

micromesh: symmetry, simplicity; electron transmission, global E change

Wire gate module



wire gate

Radial wire structure

- no radial support structures: minimizes dead regions
- ExB in the wire direction -> minimizes distortions

- To decrease the dead region by support structures, need to put the wire radially
- Wires can create field distortions

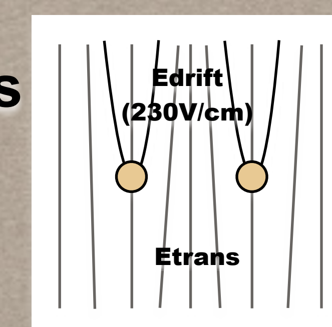
Prototype were built for test

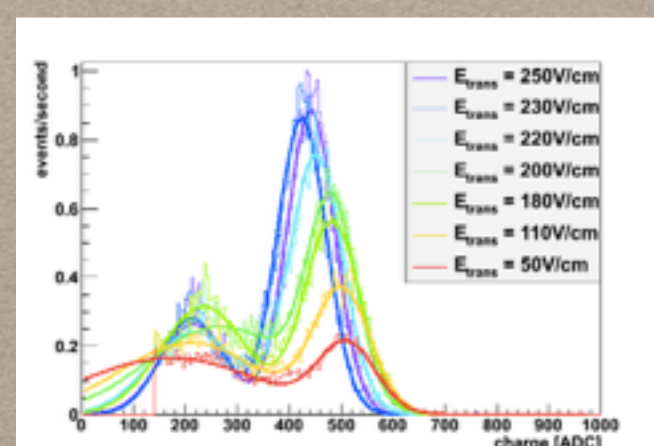
- 30μm wires, 2mm pitch
- spot welded on stainless steel frame
- only one potential : no alternate potential closed gate scheme

Test with Fe55

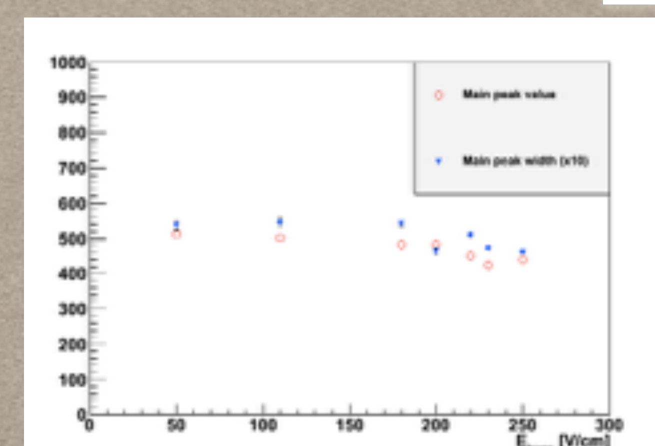
Take Fe55 spectra for different HV configurations

- fixed drift field (230V/cm)
- change transfer field lower Et => lower transparency





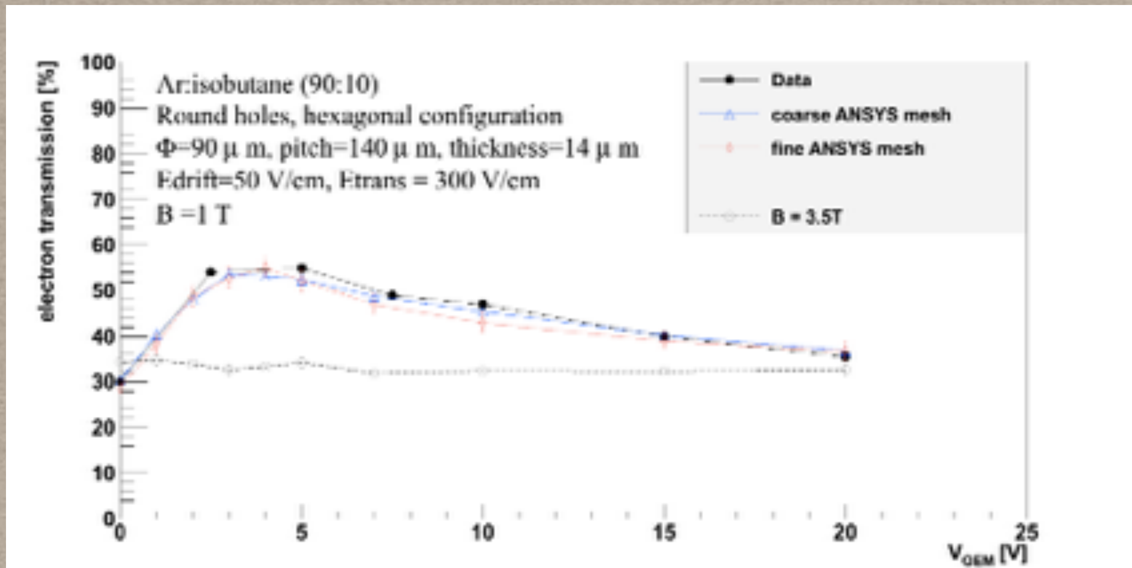
charge distribution



peak distribution

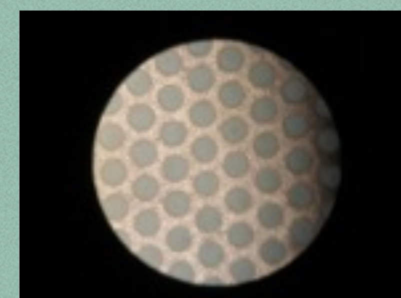
next to laser test

Study of GEM gate



Problem of current GEM gate

electron transparency to low current gate - 35% at B=3.5T



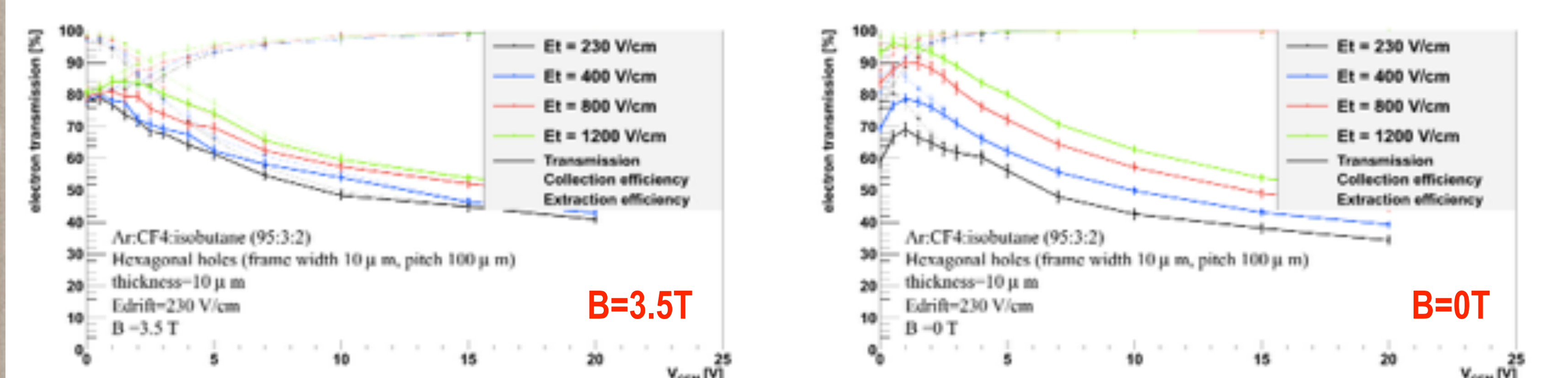
current GEM gate

*Φ*90μm, pitch 140μm, t 14μm
=> 37% geometrical aperture

Design of large aperture GEM gate

- Honeycomb structure
- 10μm wide, 100μm pitch
  - 81% aperture
  - difficult to build

large aperture design by ANSYS



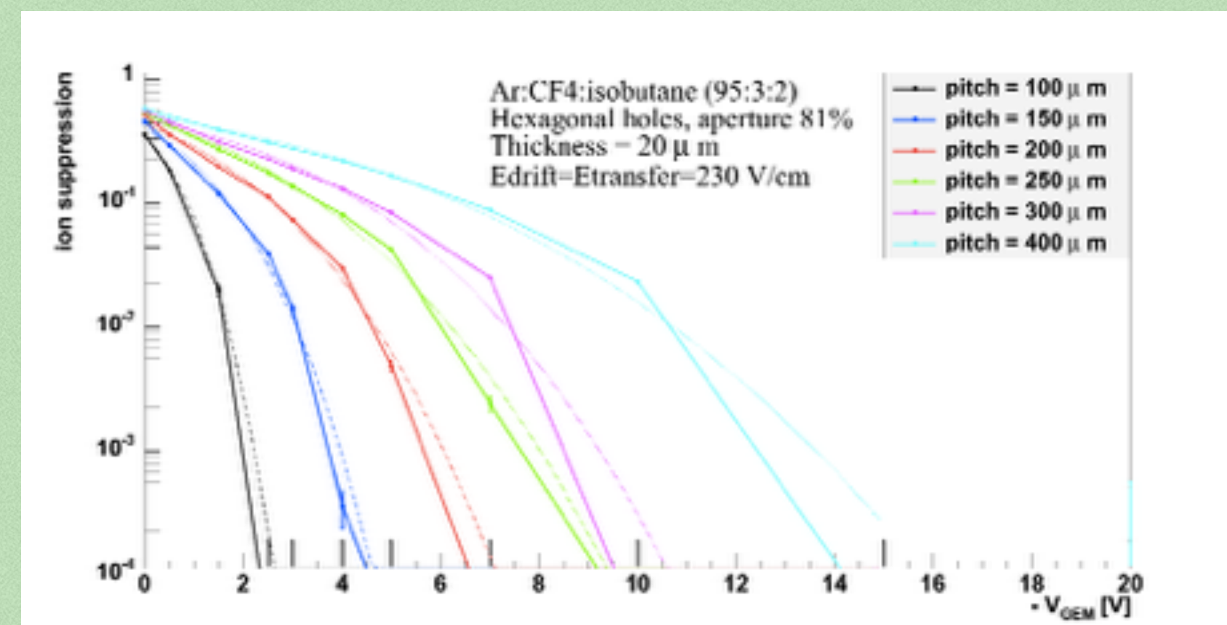
Large aperture gate simulation

Geometrical aperture is the key parameter for electron transparency in high B field

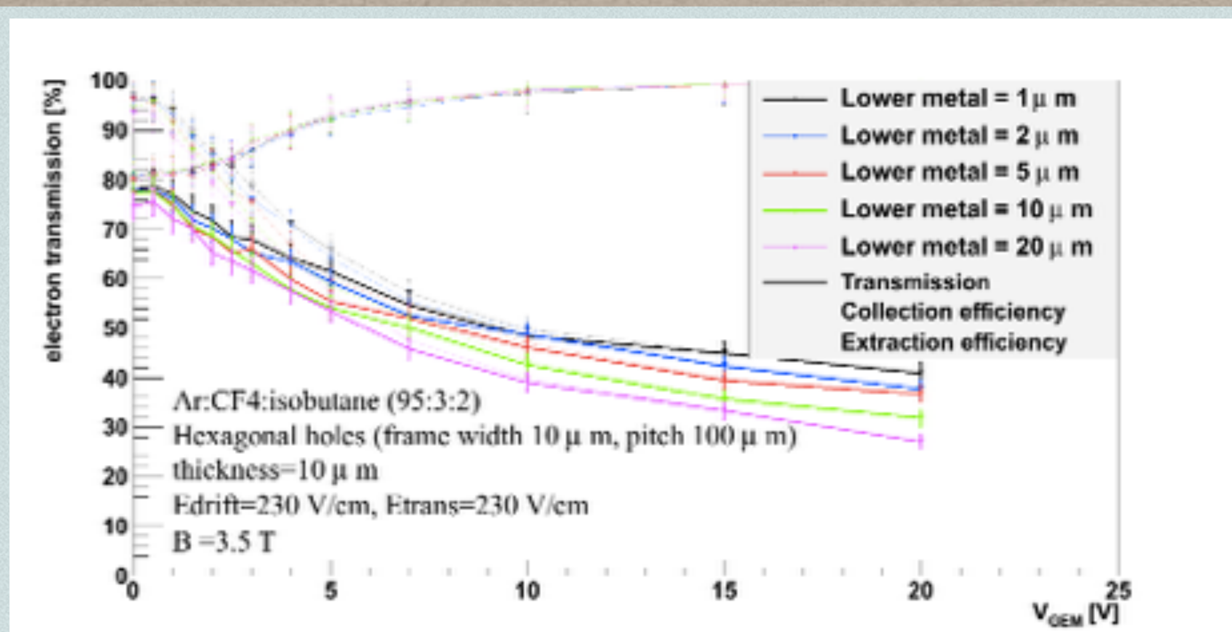
High transparency GEM gate

How to build a high transparency gate ?

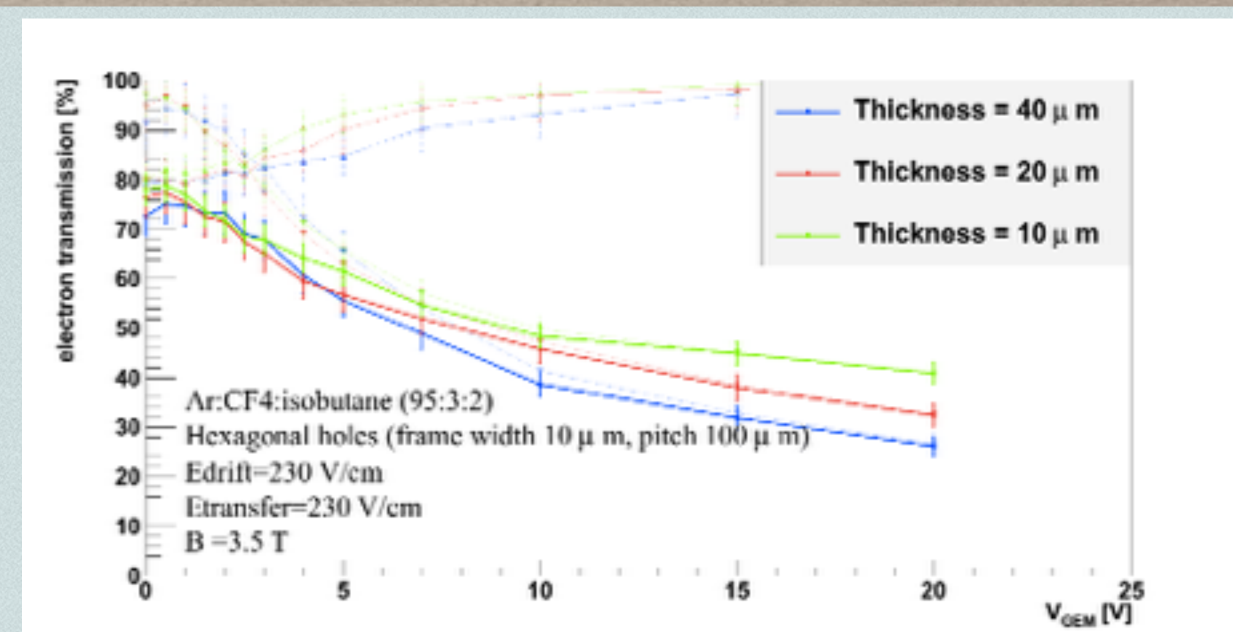
- Key item is to keep large apertures
- A mechanically sound GEM gate with large aperture might be feasible
  - with thicker, harder metal
  - with wider holes -> 400µm holes, 40µm structure?



influence of hole size to ion suppression



influence of thicker metal



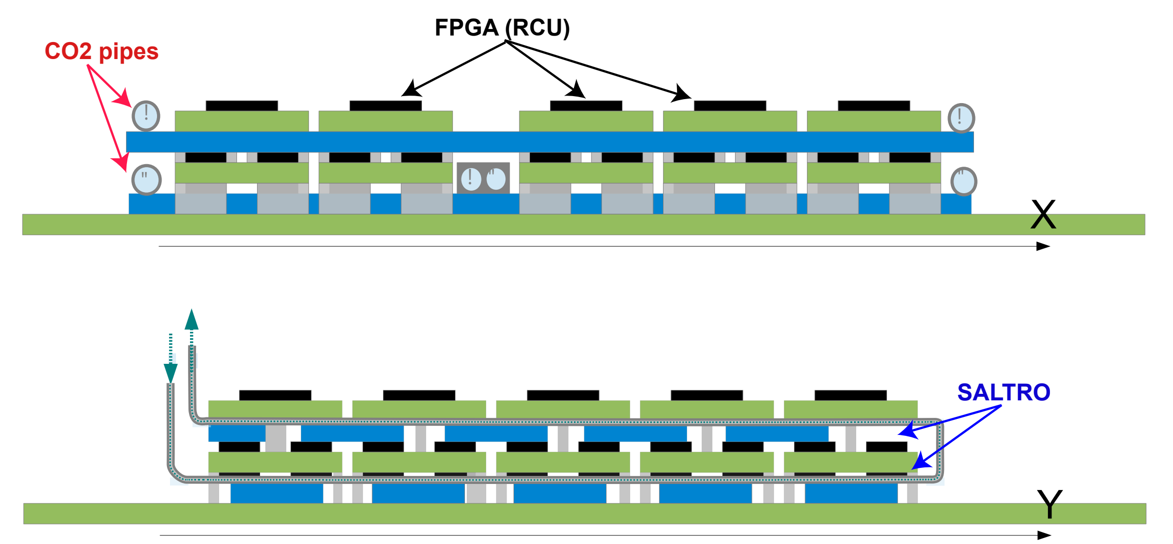
influence of thickness

Cooling for electronics

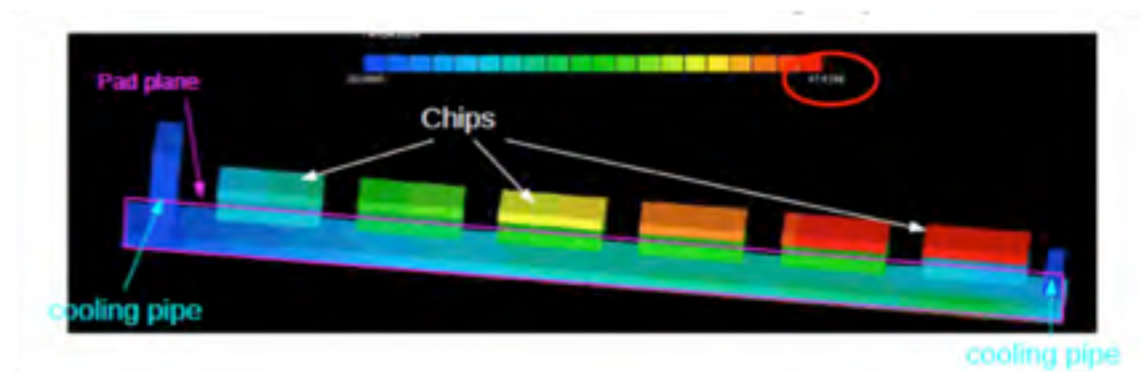
2-phase CO_2 system at KEK

We will also set up the system at DESY beam test area for cooling test with S-ALTRO16

Cooling channel R&D



Schematic view of piping and heat sink



Thermal simulation

Summary

- ILD-TPC Asia group is working on R&D of GEM TPC
- Analytic formula for GEM-TPC explains the result of test beam well.
- The expect performance by test beam is satisfied with ILD-TPC performance.
- Solution of the distortion problem is important. The laser test system will check the distortion of new GEM module.
- Development of gate device is a key issue for ILD-TPC because of secondary ion effect. Especially, geometrical aperture is the key parameter in high B field. The wire gate is a default option, but MPGD gate fits better to GEM module.
- Study of cooling system is in progress.
- Tracking software is developed for non-uniform B field (Bo Li's talk)

Future Plan for TDR

- Design the GEM module with no (or small) distortion and test it.
- Continue the GEM gate study to get larger (>70%) electron transmission (= large aperture geometry). Wire gate is a backup option.
- Taking the beam test with 3.5T magnet.
- R&D of cooling and electronics are continued in cooperation with ILD-TPC collaboration.
- Development of common tracking software for ILD-TPC

We have to do lots of things for the realization of ILD-TPC!