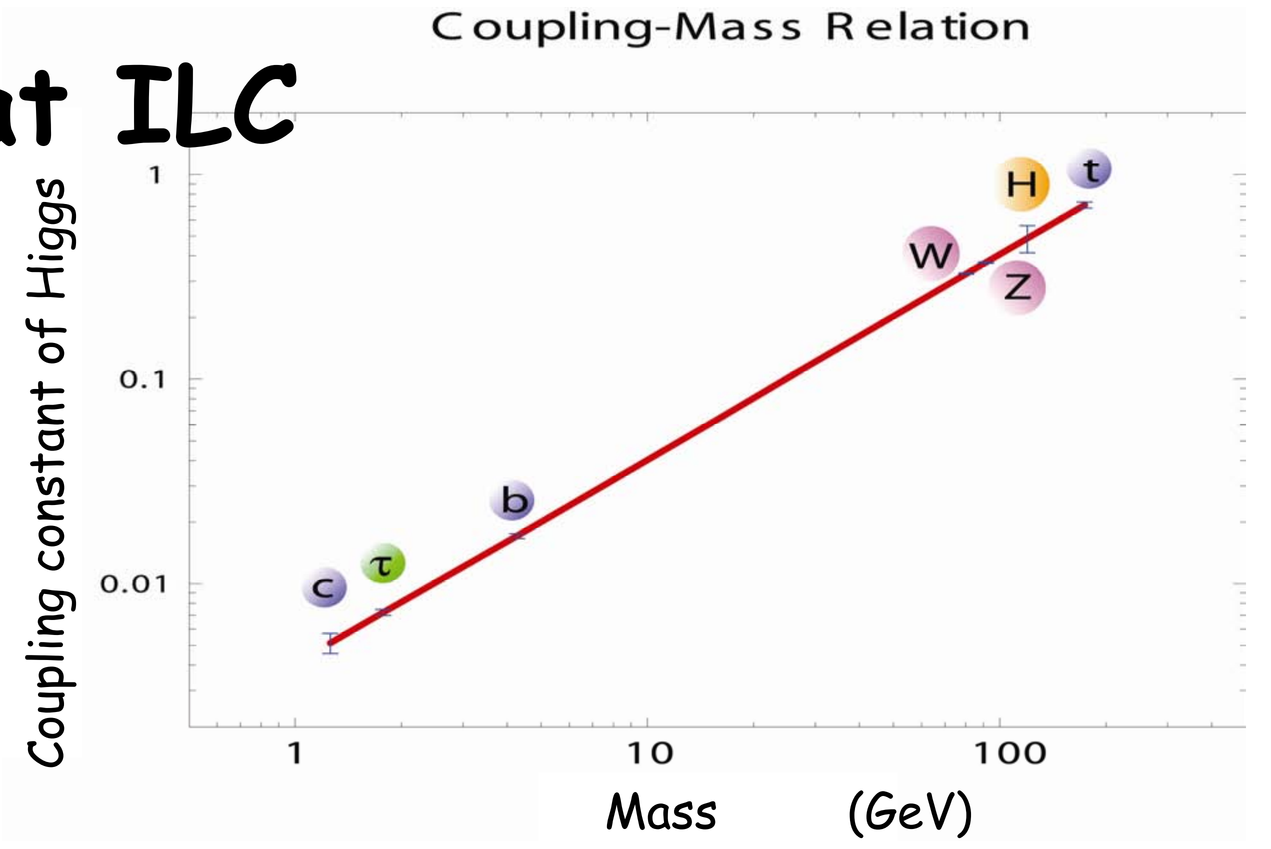
# Asian Module for ILD-TPC

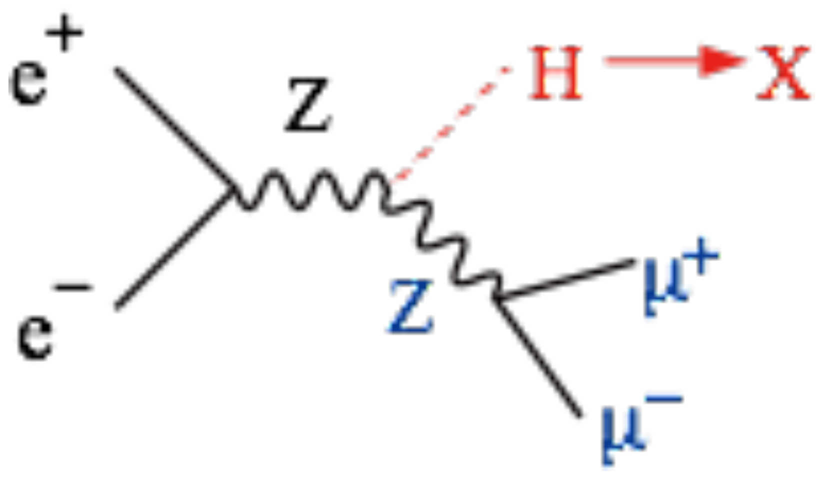
Akira Sugiyama(Saga)
on behalf of LCTPC-Asia/Japan

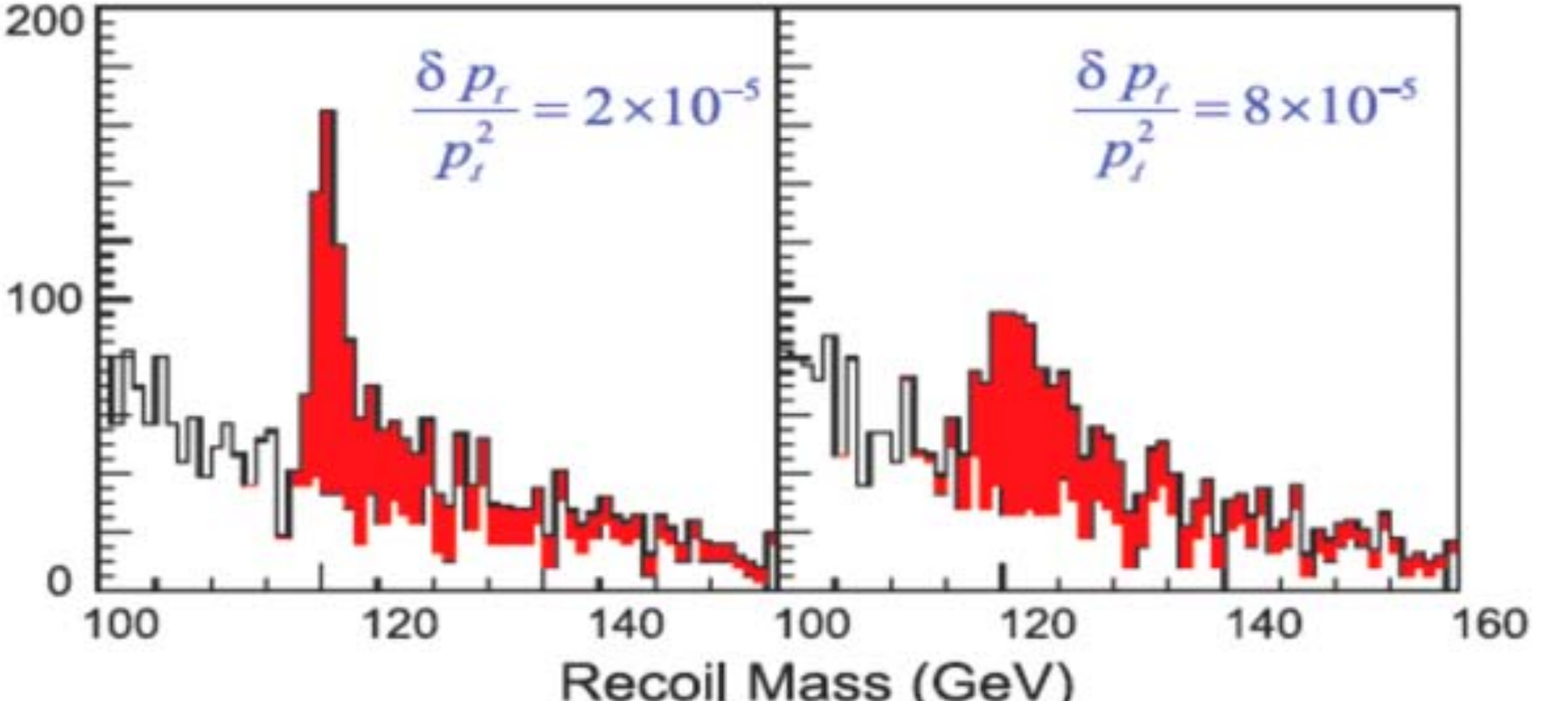
# Requirements to Tracker at ILC




## Good momentum resolution

$$M_X^2 = \left(p_{CM} - (p_{\mu^+} + p_{\mu^-})\right)^2$$



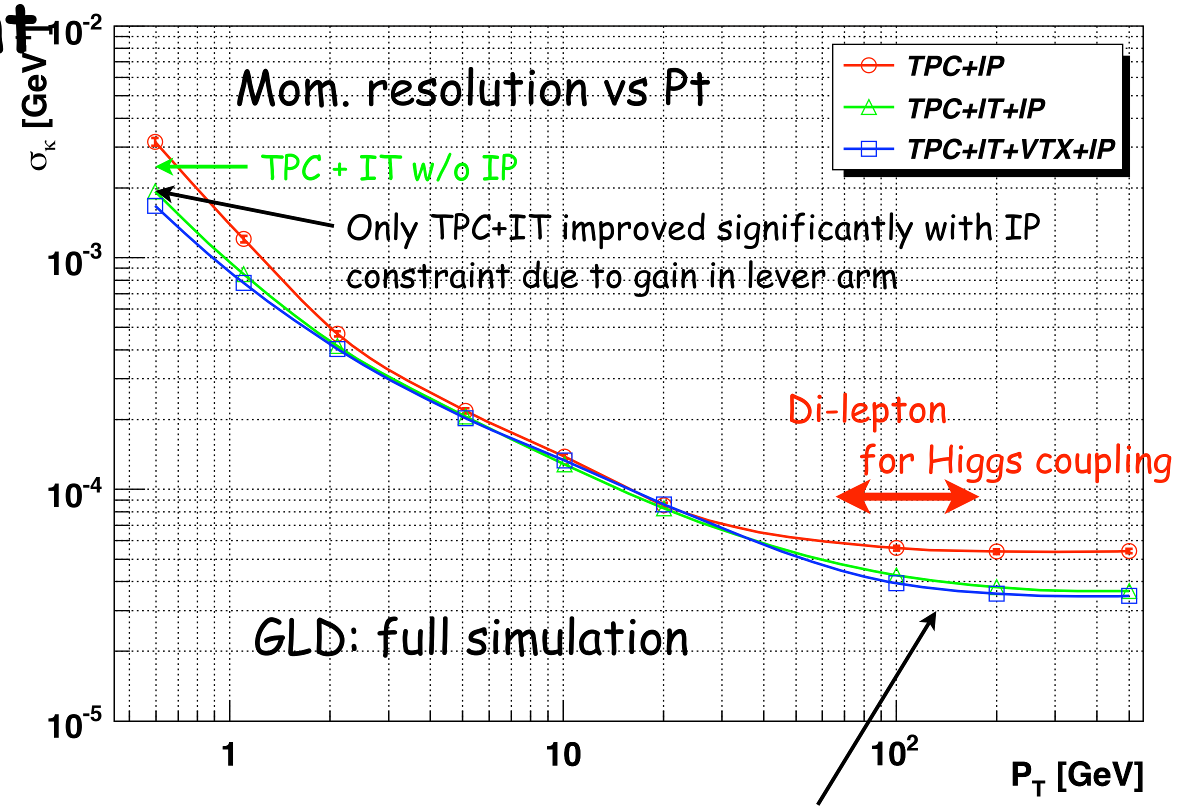

Missing mass resolution@higgs Strahlung process

bias free Higgs decay study

dP/P ~10^-5 P

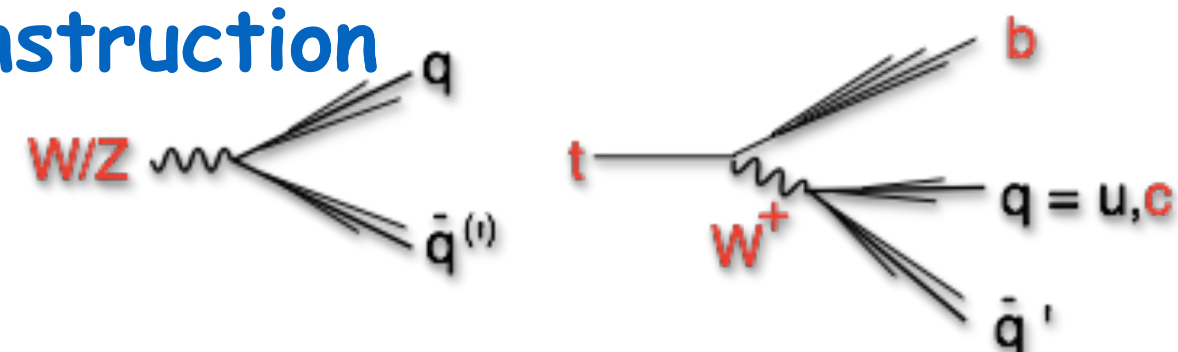
10 times better resolution than that of LEP TPC

## TPC w/ Vtx can satisfy the requirement

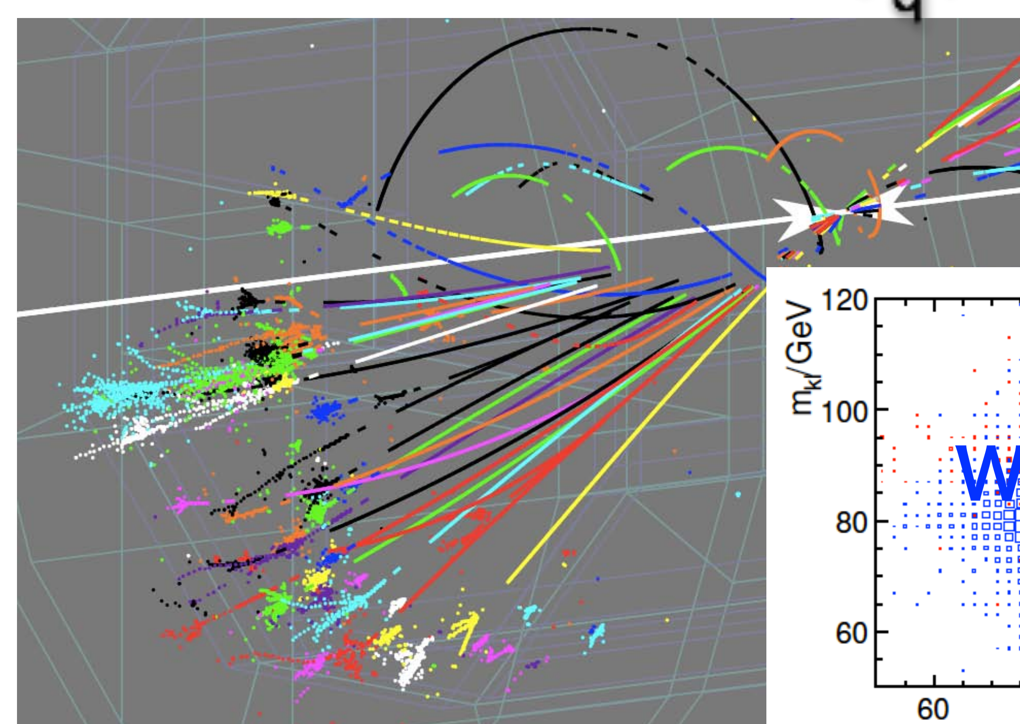


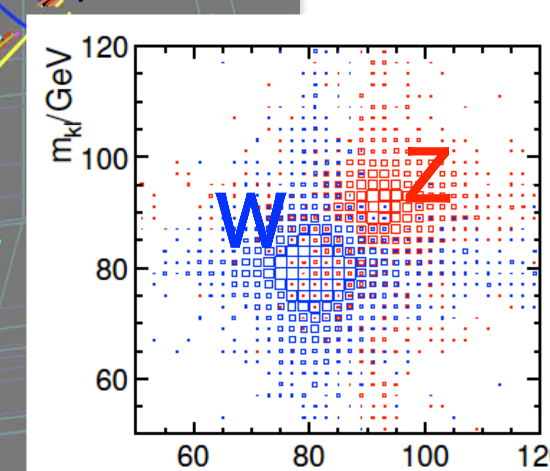

Tracking efficiency is another important issue
for Jet Energy resolution
( ie. Particle Flow Algorithm )

## Good efficiency for track reconstruction



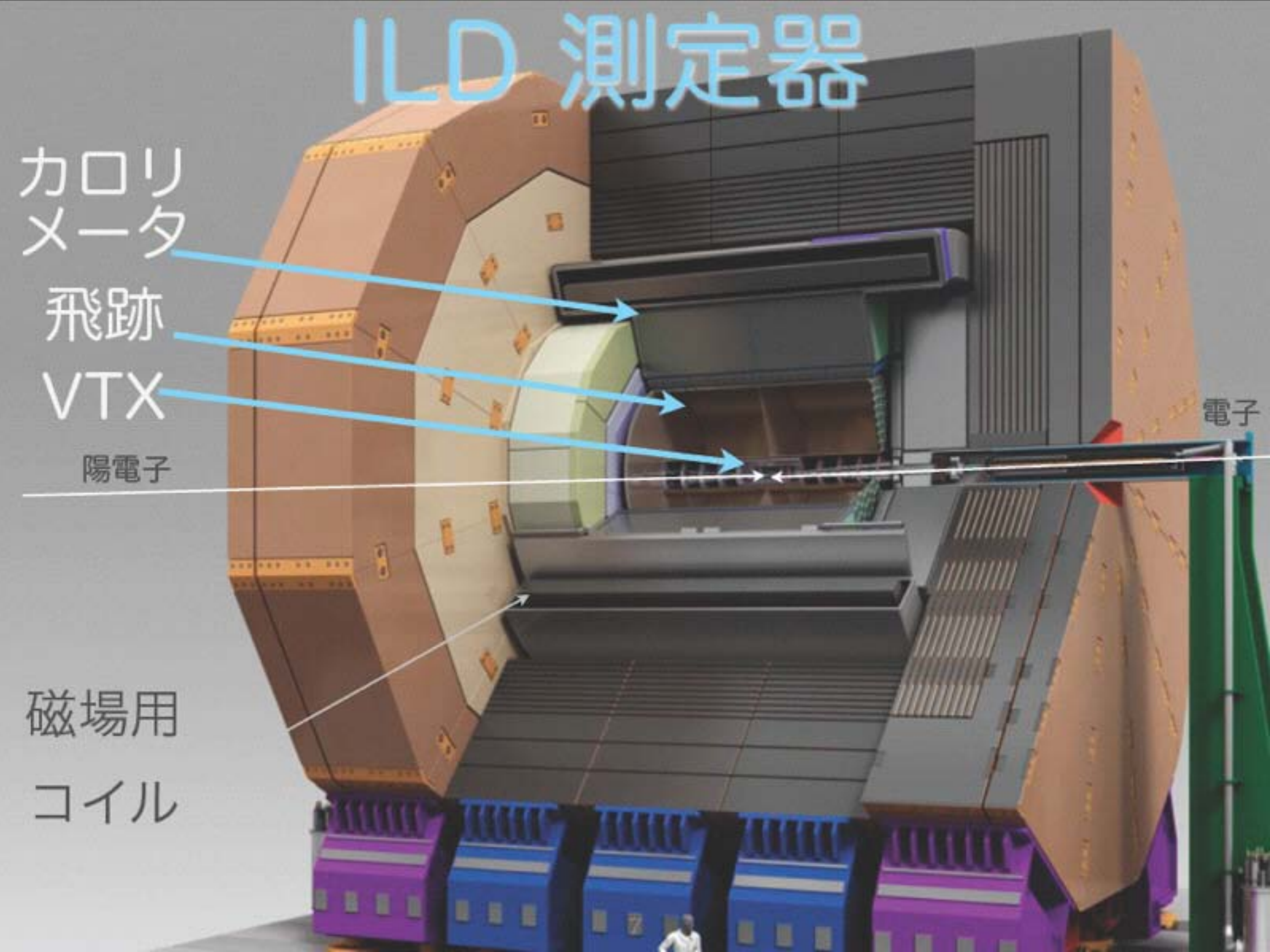

**Particle Flow Analysis(PFA)**
**allow us to separate Z and W**
**in Jet Mass energy**





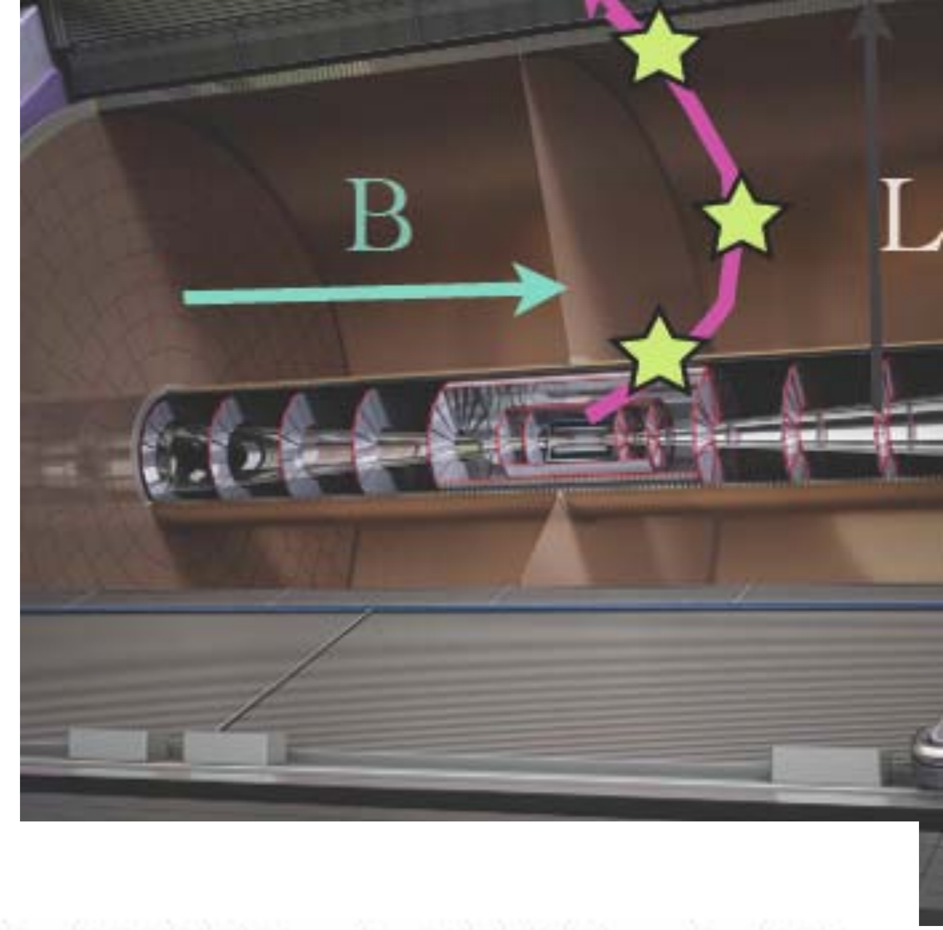

**cluster-track matching is essential**

# ILD 測定器



# Possible solution of ILD Tracker

| | posi. reso | # meas. point |
|---|---|---|
| Si pixel VTX | δ～5um | 6 |
| Inner Si strip | δ～20um | 6 |
| TPC main tracker | δ～100um | 220 |
| ( Si main tracker | δ～20um | 5 ) |



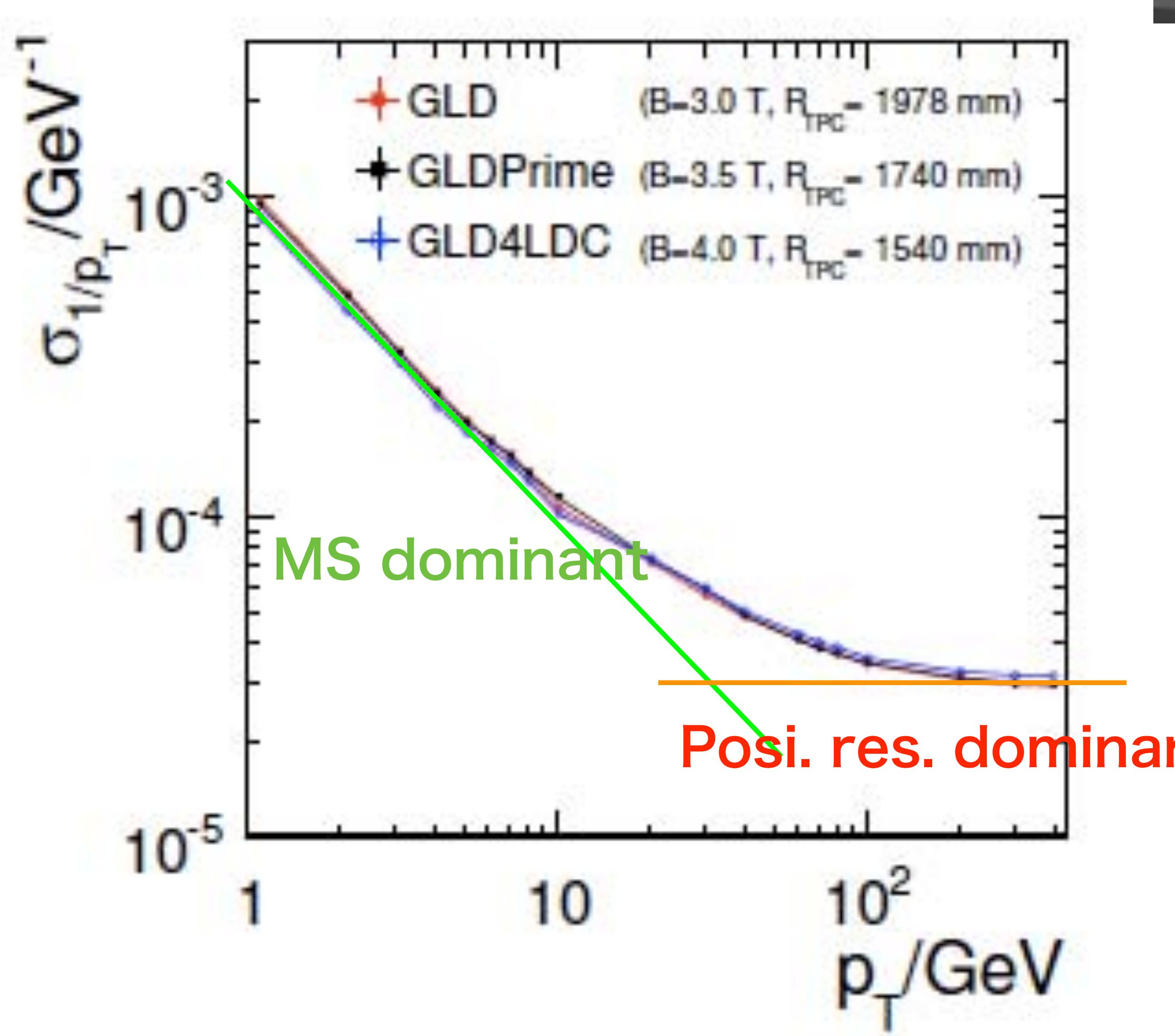

**Momentum resolution**

**position resolution**

$$\left(\frac{\delta p_T}{p_T}\right)_{meas.} = \frac{3.3\sigma_{r\phi} p_T}{BL^2}\sqrt{\frac{720}{n+4}}$$

**multiple scattering**

$$\delta P_{T\,(\mathrm{M.S.})} = \frac{0.016P}{0.3BL\beta}\sqrt{\frac{L}{X_0}}$$




**MS term limits # of Si layer**

**-> σ/√n   is same for TPC and Si tracker**

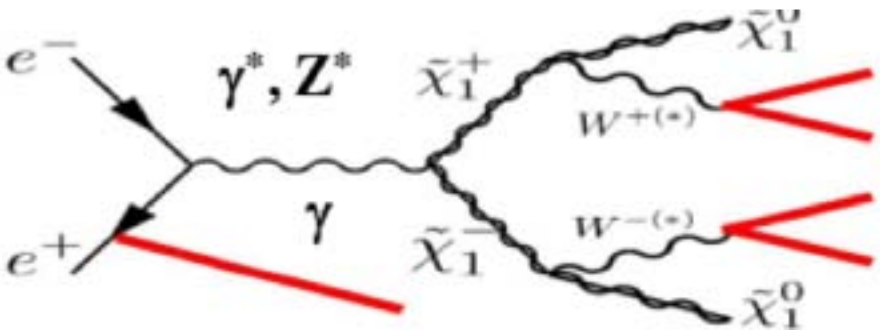
**( if  B,L are same )**

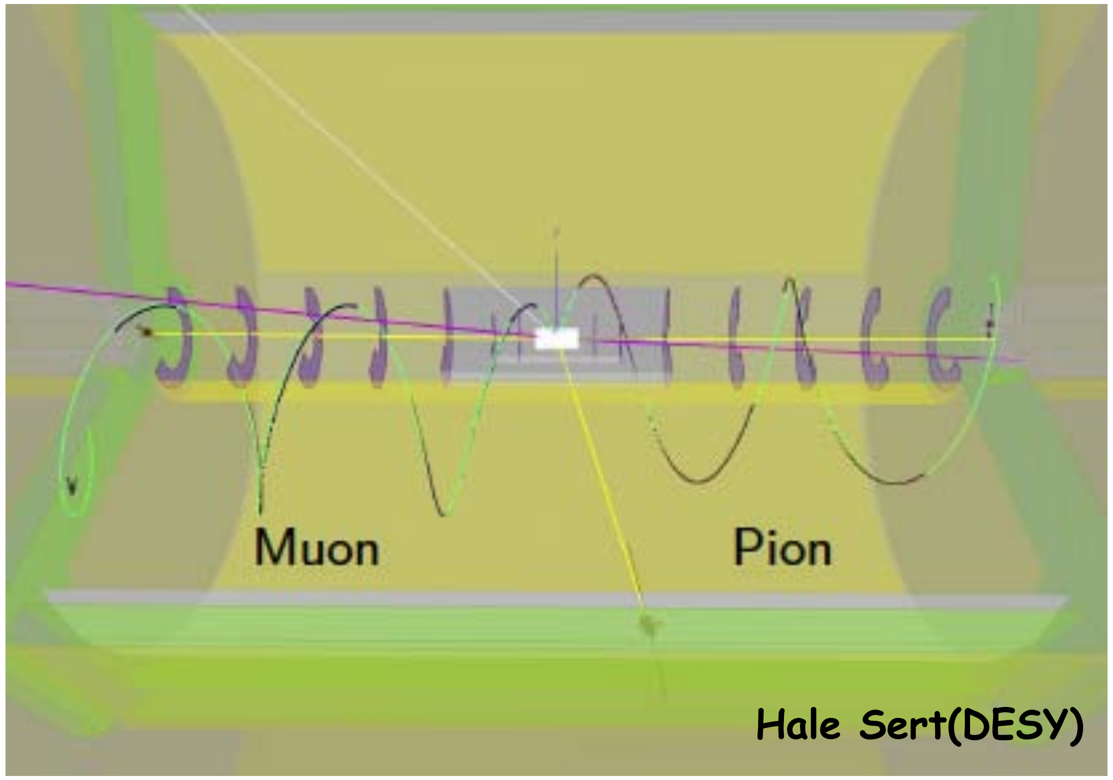
## Gaseous tracker

TPC : continuous tracking = many sampling of moderate precision

good tracking efficiency

degenerate Higssino case: only low Pt π/μ tracks






## Si tracker

small sampling but with high precision

tracking efficiency ??

good for high Pt track

but not sure for low Pt track

# Requirements to TPC

momentum resolution

- local resolution : 100um over full drift volume
- no distortion ( E-field, B-field )
  - B-filed: anti-DID recon. under non-uniform B-field
  - E-field: geometrical/engineering
    beam related ion problem

detection efficiency

- stable operation of gas amplification
- good 2track separation
- good efficiency even in high BKG

less material

- structure
- RO electronics/cooling

# The way to achieve local resolution 100um

$$\sigma_\kappa = \delta\left(\frac{1}{P_T}\right) = \frac{\sigma_x}{0.3BL^2}\sqrt{\frac{720}{n+4}}$$

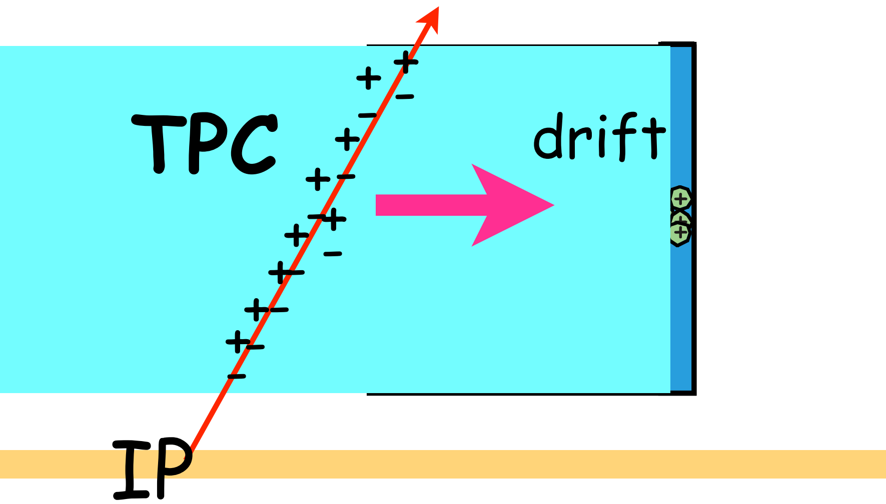
| | |
|---|---|
| High B field | 3.5 T |
| Long lever arm | 1.8 m |
| Many hits | 200 layers |
| good position resolution | 100 um |

**principle of gas detector**

**property of gas**

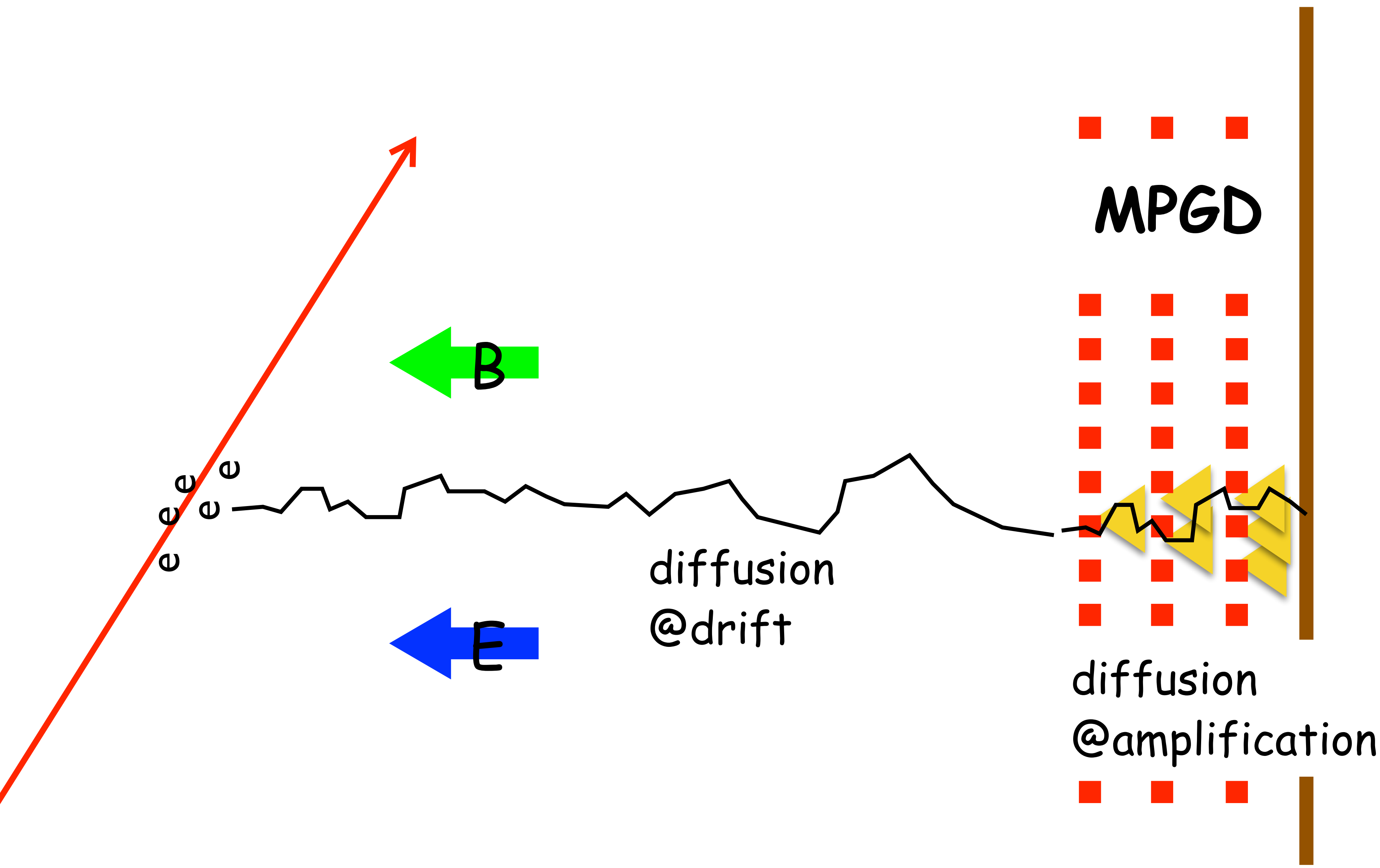
**principle of position measurement**

# How TPC determine tracks



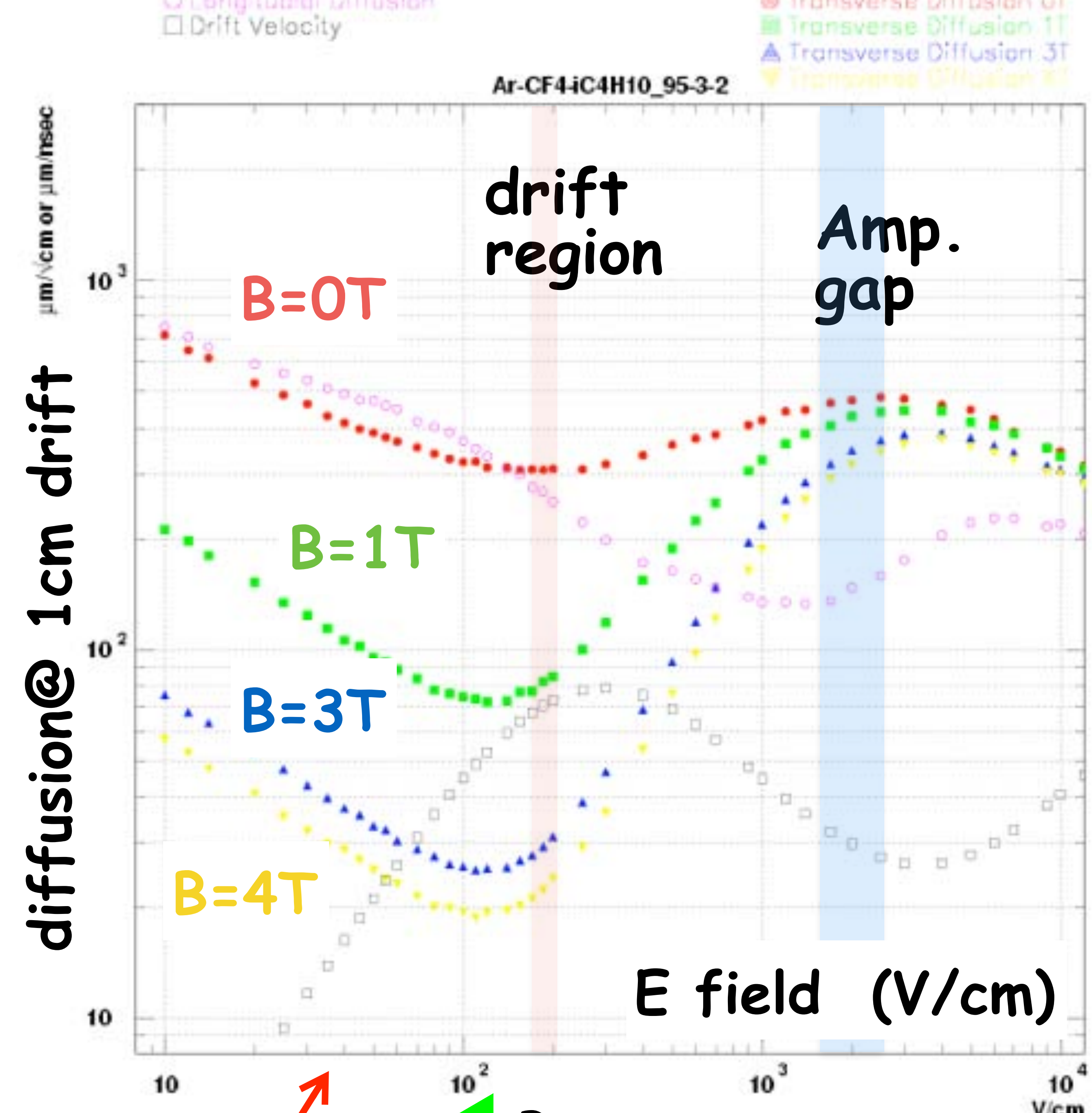

1.) Ionization by dE/dx
number of electrons
2.) Drift of electrons
motion in E,B field Lorentz force
diffusion

3.) Gas amplification
MPGD
readout pad/electronics




Position information is smeared by diffusion

Position is determined by COG of charge dist.
Charge distribution must be broader than RO pad.




# Gas property

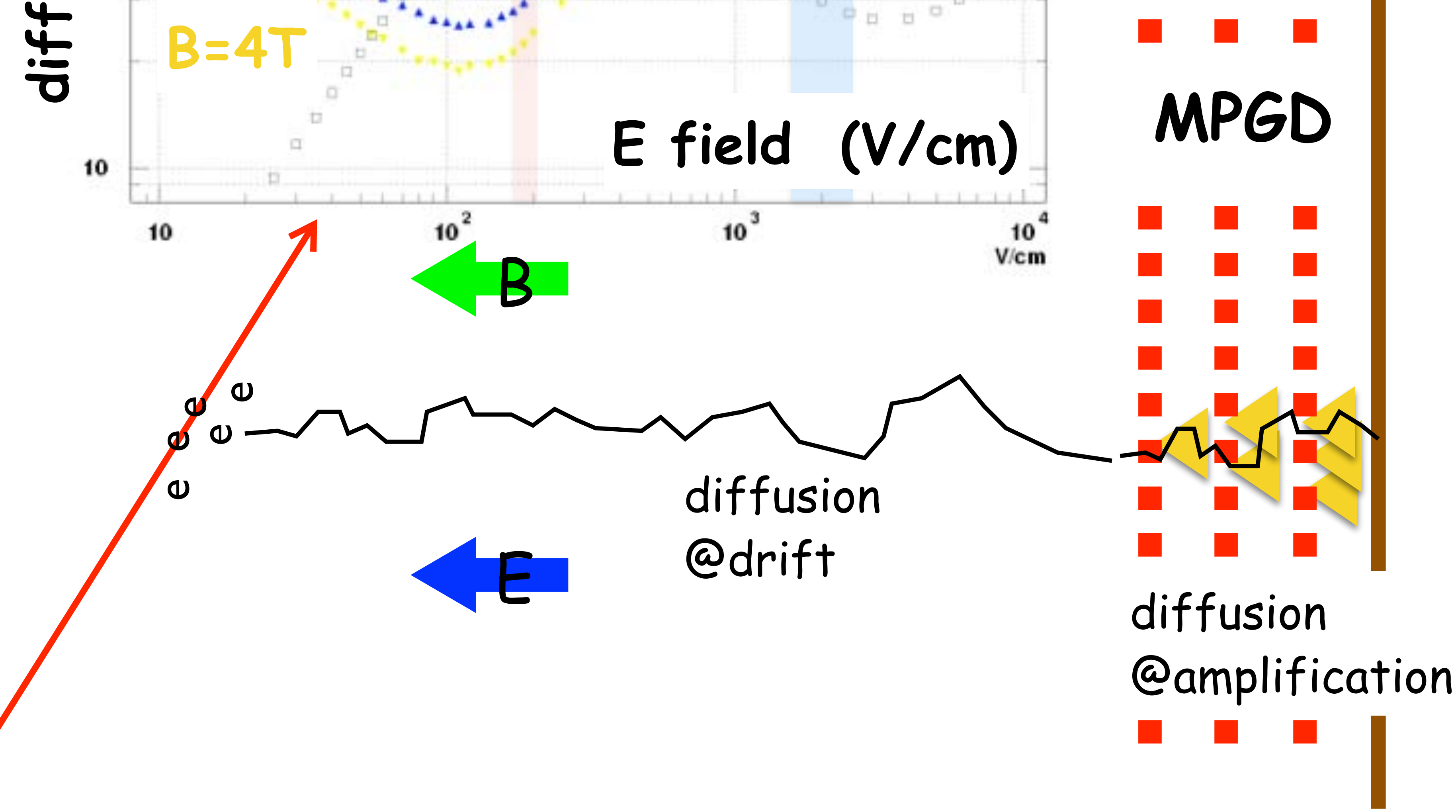
Ar:CF4:i-C4H10

high ωτ

3.5T case

CD ~ 25 um@1cm drift at drift region

350 um at amp. region




**less diffusion@drift**

Position information is smeared by diffusion

**modest diffusion@amp.**

COG of charge dist.

Charge distribution must be broader than RO pad.

# Position accuracy of single electron

If RO pad is enough narrow

$$\sigma_x = C_D\sqrt{z}$$

@2 m drift

-> 350 um

If RO pad is too wide

$$\sigma_x = \sqrt{(C_D\sqrt{z})^2 + \frac{w^2}{12}}$$

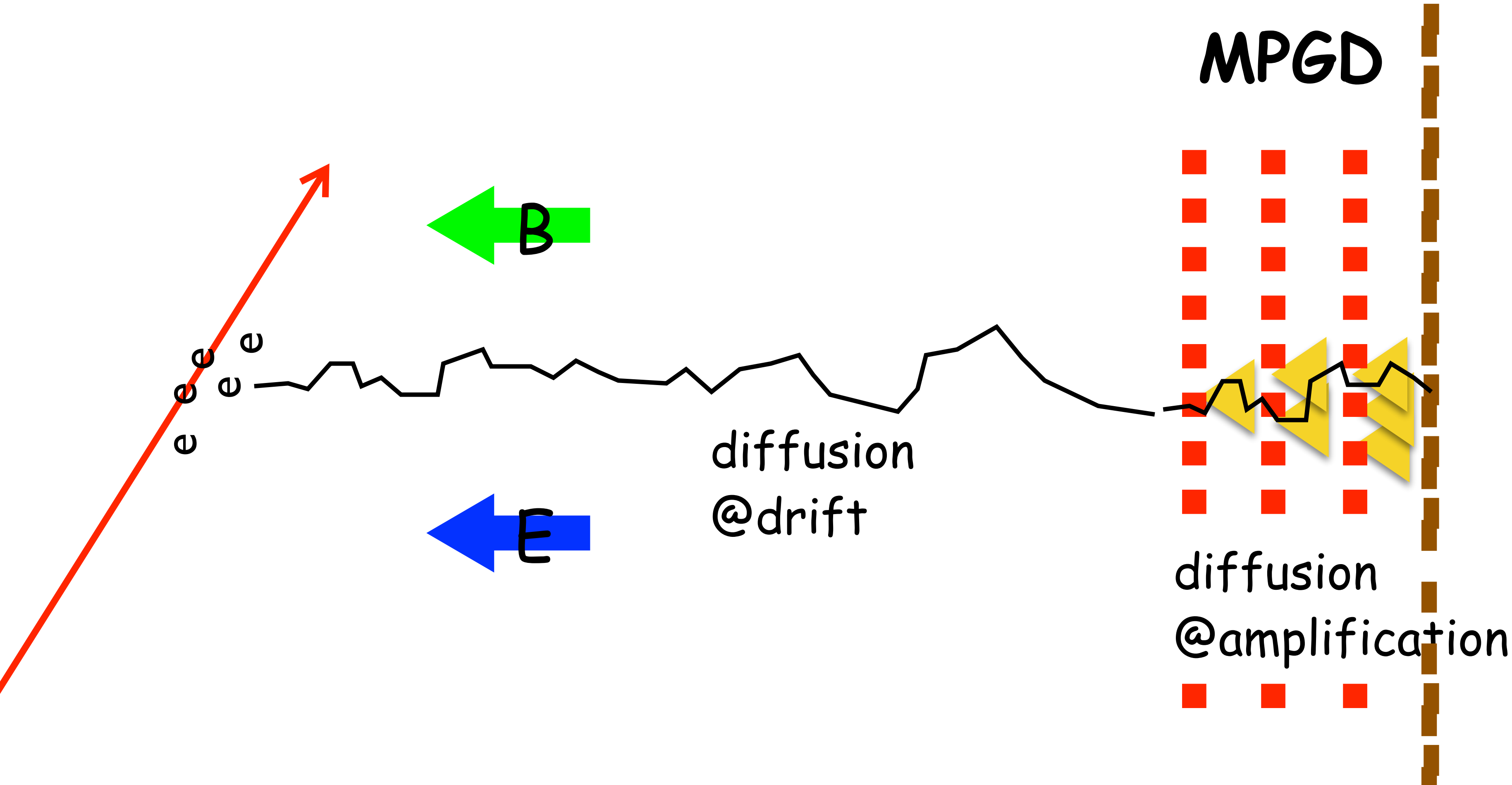
hode-scope effect
is accumulated

Hose-Scope effect
may disappear
if w<3*diffusion@amp.

# Position accuracy of electron cluster

$$\sigma_x^2 \sim \frac{1}{N_{eff}}\left(\frac{w^2}{12} + C_d^2 z\right)$$

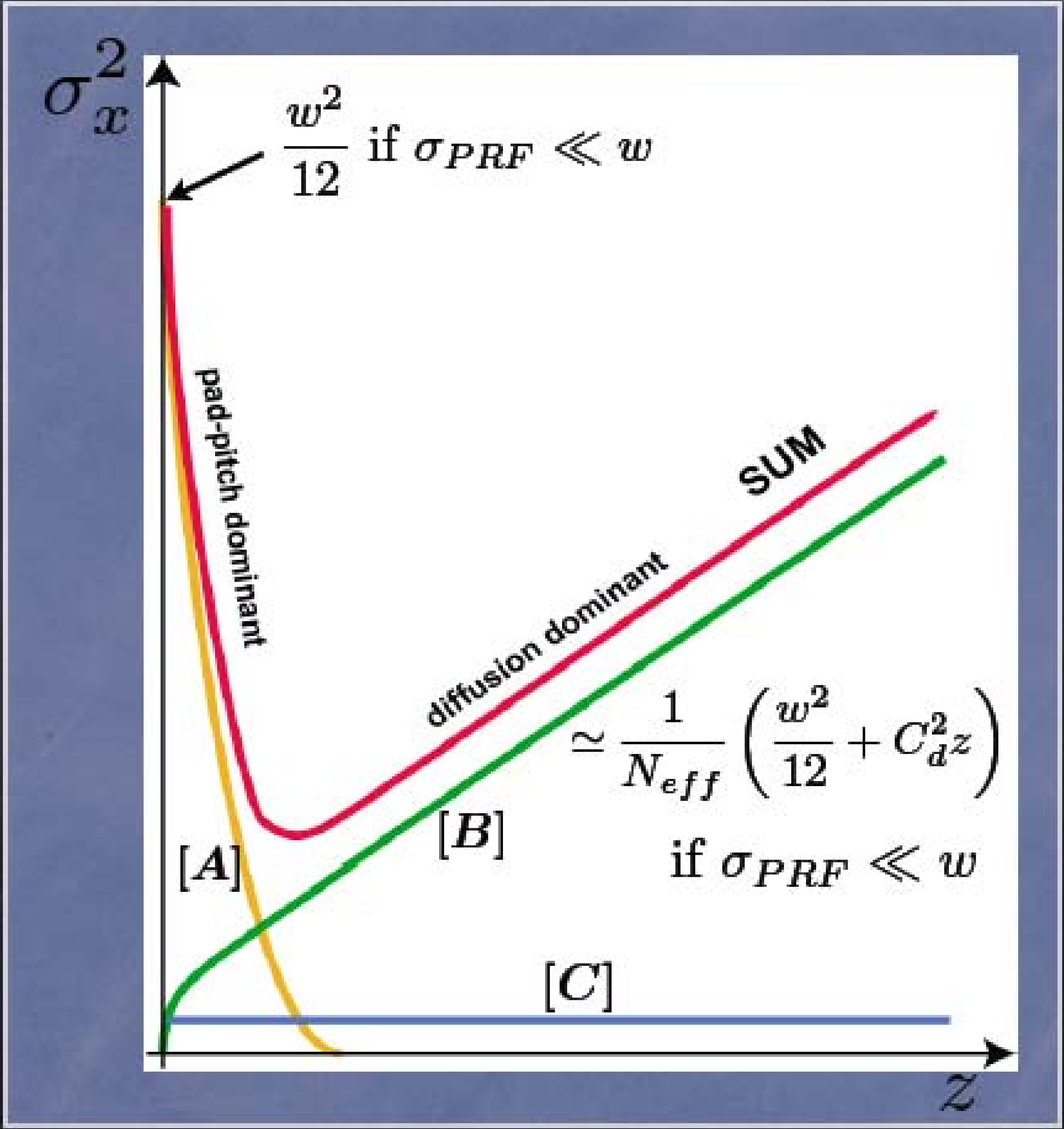
Neff = 1/<1/N> not= <N>




diffusion@amp. ~300um
dep. on gap

pad width = 1mm
is reasonable
for GEM case

# Interpretation



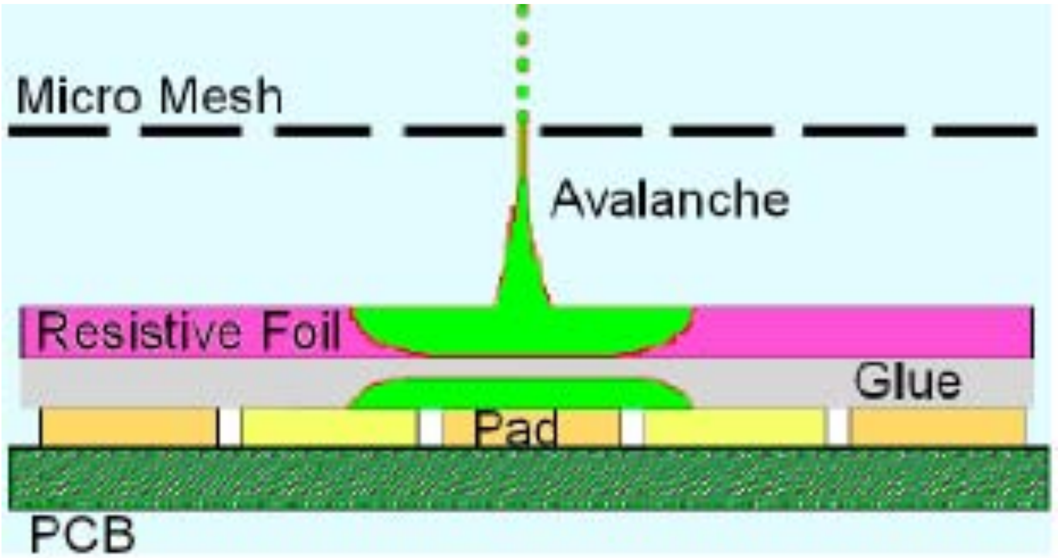

[A] Purely geometric term (S-shape systematics from finite pad pitch): rapidly disappears as Z increases

[B] Diffusion, gas gain fluctuation & finite pad pitch term: scales as $1/N_{eff}$, for delta-fun like PRF asymptotically:

$$\sigma_{\bar{x}}^2 \simeq \frac{1}{N_{eff}}\left(\frac{w^2}{12} + C_d^2 z\right)$$

[C] Electronic noise term: Z-independent, scales as $\langle 1/N^2 \rangle$

# Alternative solution



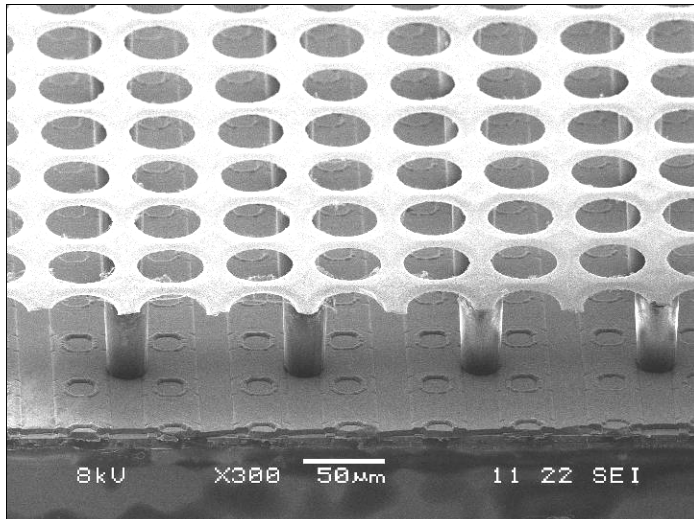

Charge spreading by RC

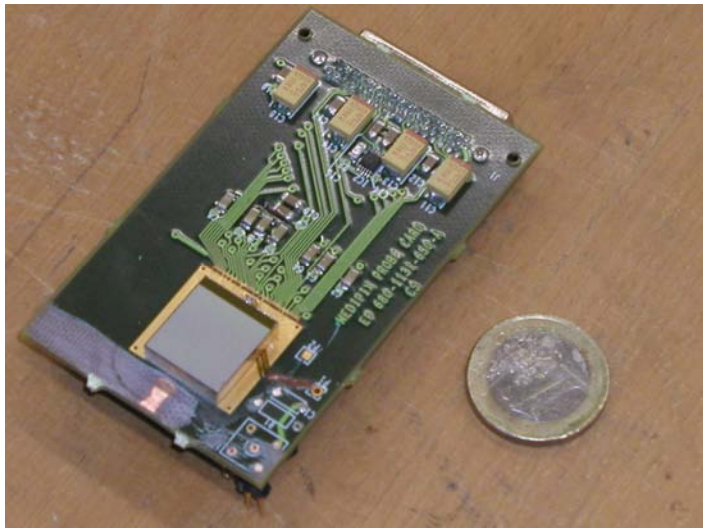
## Micromegas :

diff@amp. region is only 10~20 um

In order to avoid hode-scope effect micromegas choose resistive anode pad plane.

## Timepix w/ micromegas :



narrow pad size 55um x 55um

hode-scope effect is small enough

count each electron not cluster

## MWPC :

cannot provide good resolution at high B field

# Ion problem

**Production of Ions is inevitable in gas detector.**

**dense ions in drift volume may deteriorate drifting electron.**

## Primary ions : produced by generated charged tracks

Background @ ILC

mini-jets

$2 \times 10^4$ tracks/train ~ 10 tracks/bunch

~O(0.3%) occupancy @ innermost raw(r=45cm)

naive estimation

low Pt tracks contribute more(curling)

these rates are dep. on BDS/IR design

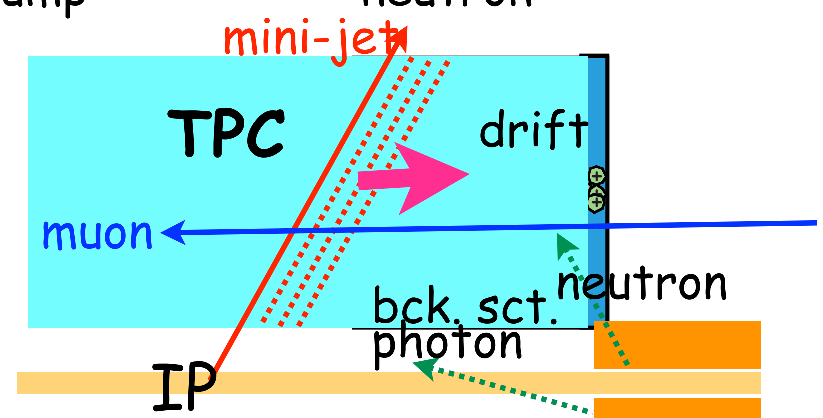
GAS in TPC (H less gas ?)

Physics background

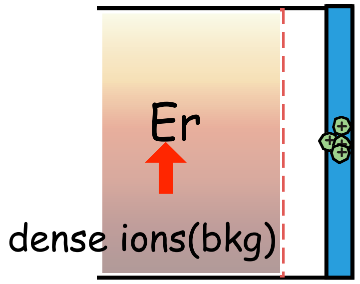
2 photon process - mini jets

Beam background

| | |
|---|---|
| pair background | photon, electrons |
| disrupted beam | muon |
| beam dump | neutron |




bunch cross/300nsec

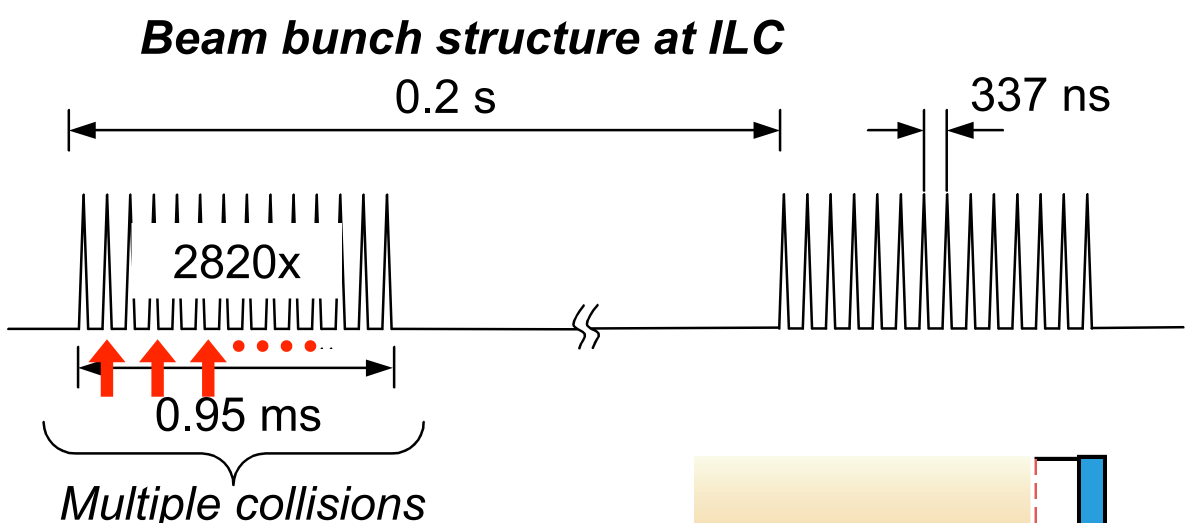


ions from gas amplification(backdrift ions) :

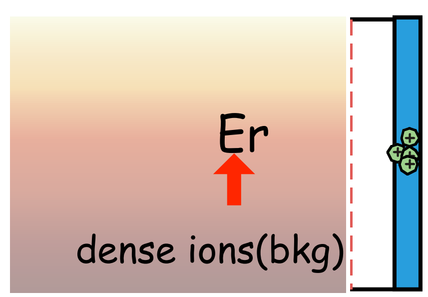
ions (dense) discs are formed due to slow drift velocity

MPGD owns inherent ability of ion absorption

## Beam Structure @ ILC

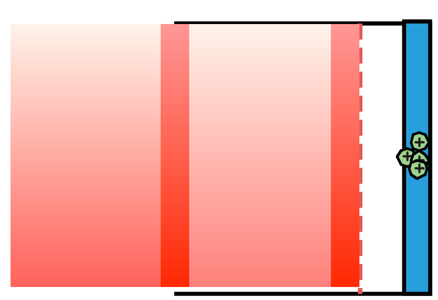



train produce back-drift ions' disk
without "Gate mechanism" for ions
as big difference of drift velocity
between electron and ion
drift velocity of ion is 10000 times slower




1st train produce prim. ion pairs in all drift volume
electron drift to MPGD(endplate)
and amplification produce more ions

s a natural ability of
ns, but it's not perfect.



next train produce prim. ion pairs again
before ions are swept out
amp. ions by 1 train form thin disc and drift slowly

"GATE"ing GRID

# Effect of ion (disc)

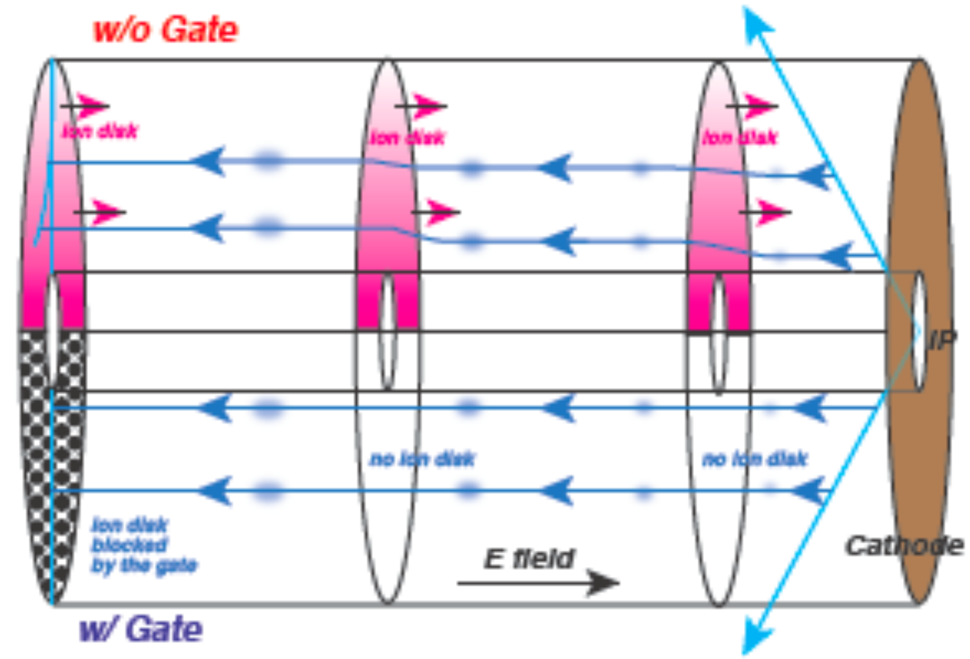
Primary ions are inevitable
no way to recover
but ions are spread over all volume
effect to position measurement is
acceptable O(10 um)

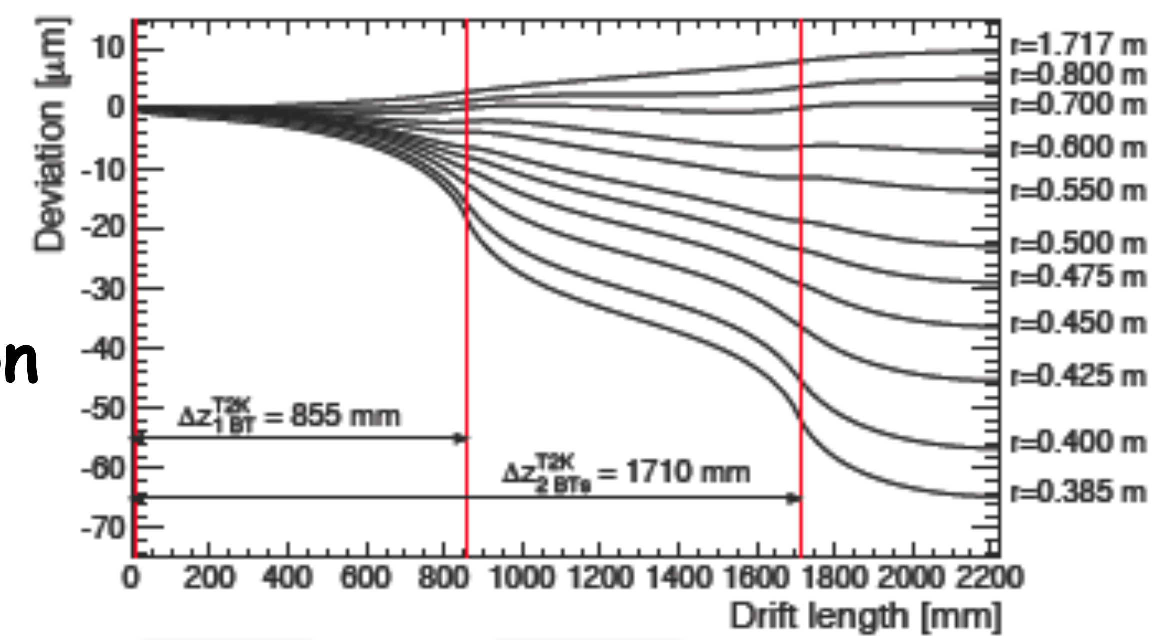
Ions produced by amplification form
dense ion disc which deteriorate
position accuracy ~60 um

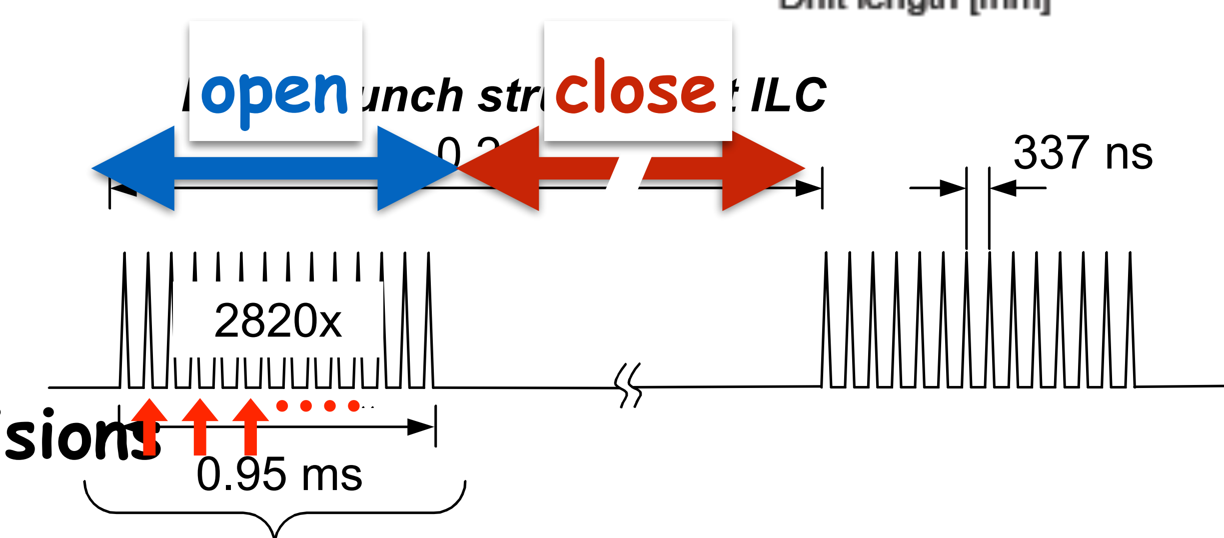
not negligible to 100 um resolution

**We need Ion Gate device**

ILC beam structure is good for gating
gate is open for 1ms collision
gate is closed for 199ms between collisions



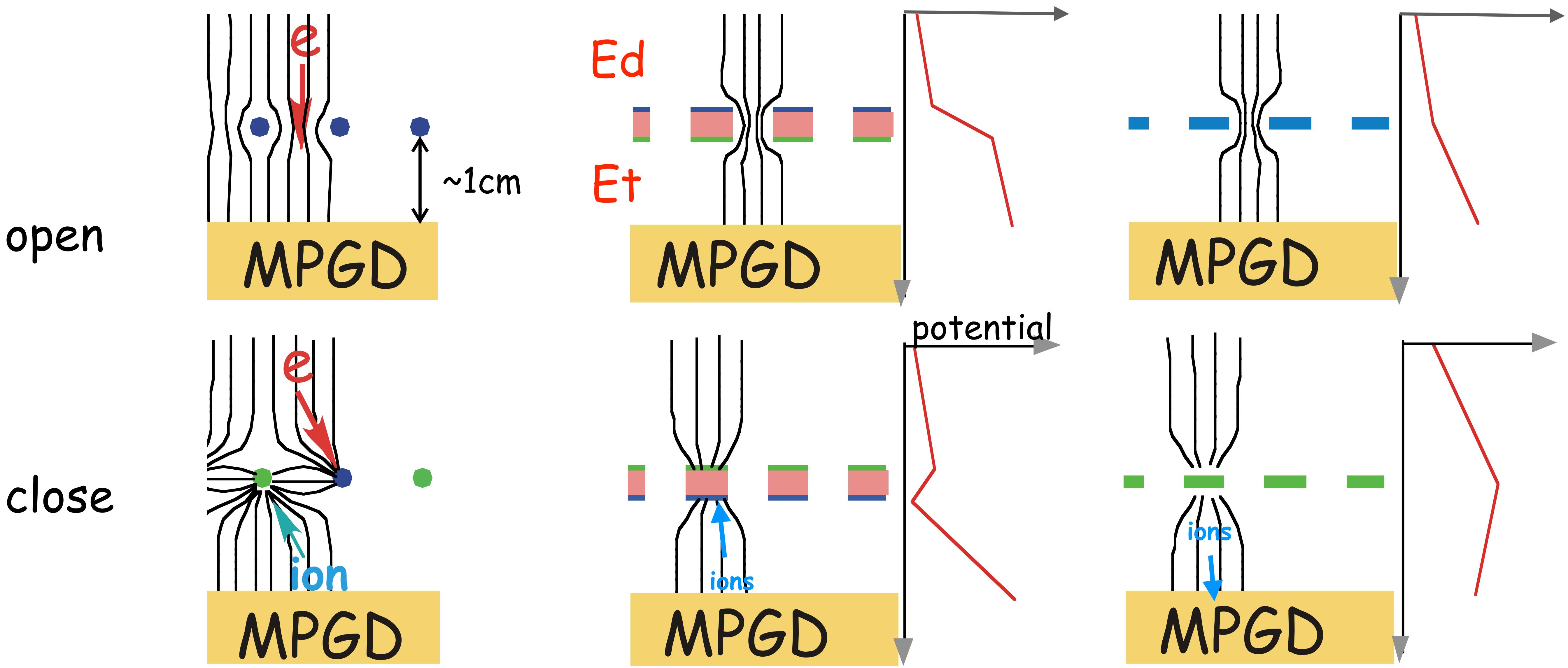



# Gating for back-drift ions

ILC case : 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 dirft < 1cm

Gate: wire GEM micromesh

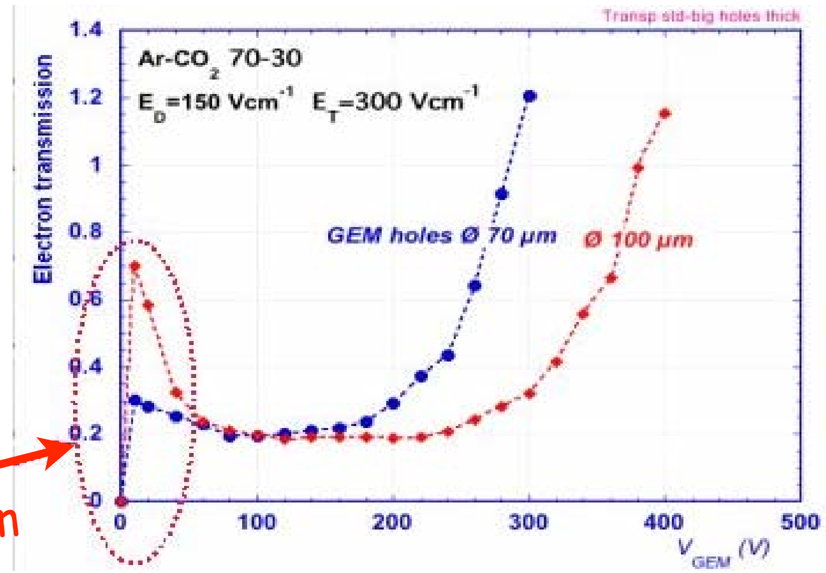
3 candidates




| wire | GEM | micromesh |
|---|---|---|
| local change of E | local change of E | change of drift E |
| wire tension | electron transmission | electron transmission |
| ExB | | |

# R&D of GEM type Gate

F.Sauli proposed a GEM as Gating device
operated at very low voltage at 2006




10V/50um
~ 2kV/cm

Realization of GEM Gate is not easy as we thought at the beginning
due to the limited electron transmission at gate-open.
especially for high B field !

We realized a necessity of R&D to make a large aparture GEM
in order to increase electron transmission.

Ordinal chemical etching process can build a 50% aparture GEM
some challenging company can make a larger aparture but not sure

FUJIKURA investigate process and QC system
enable to produce GEM with more than 80% aparture
using laser aviation for insulator removal at 2014

# Gate GEM new vs old

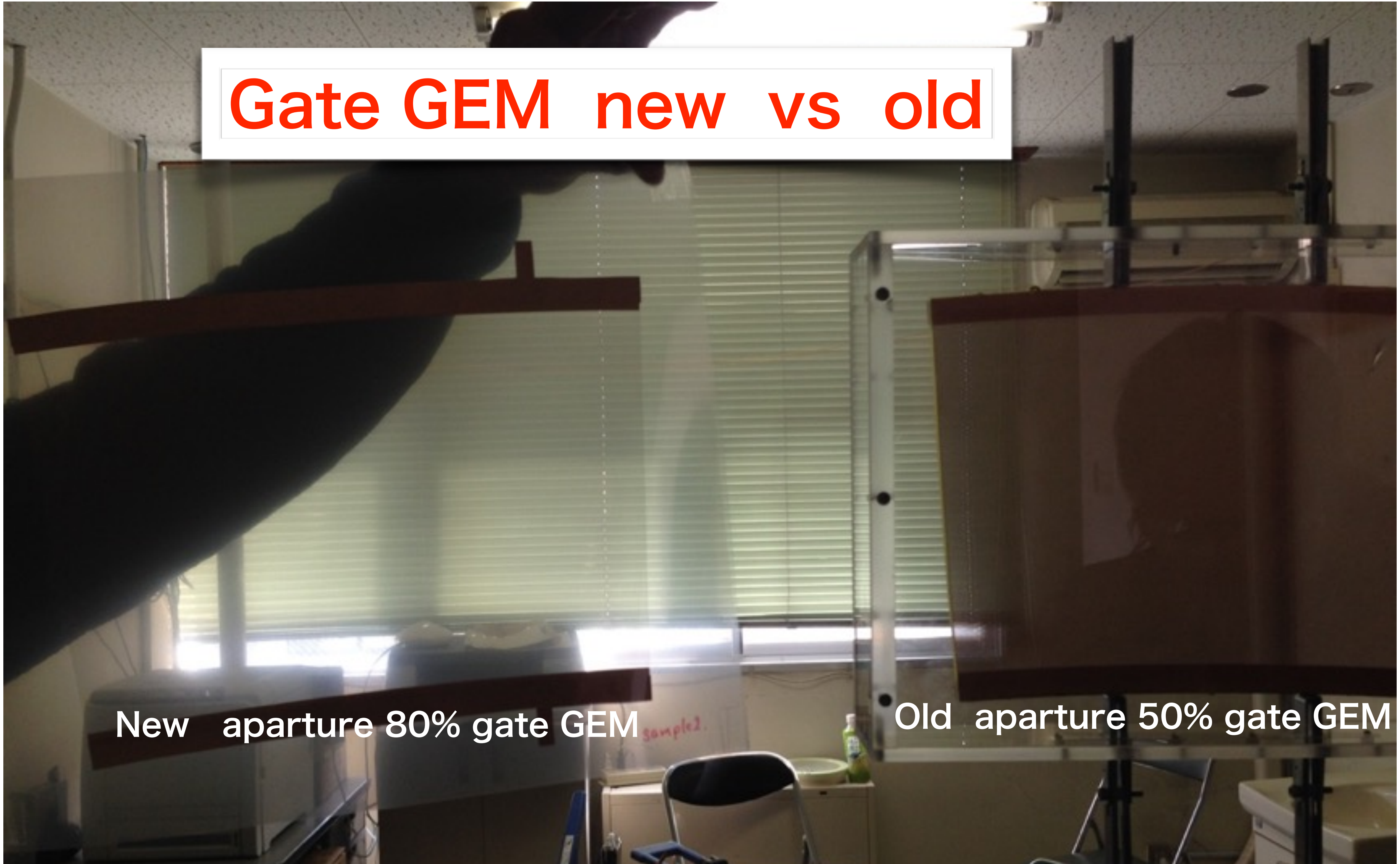



図1. F-side外観

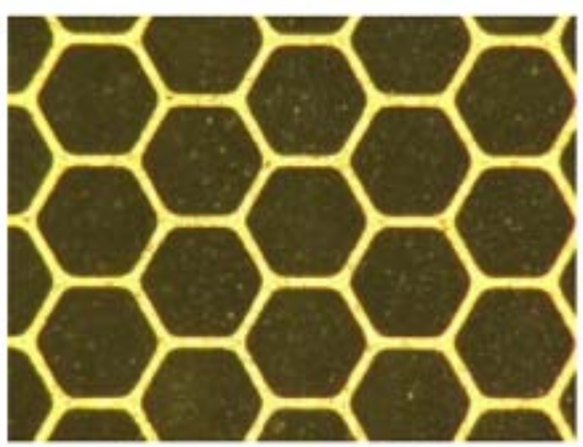
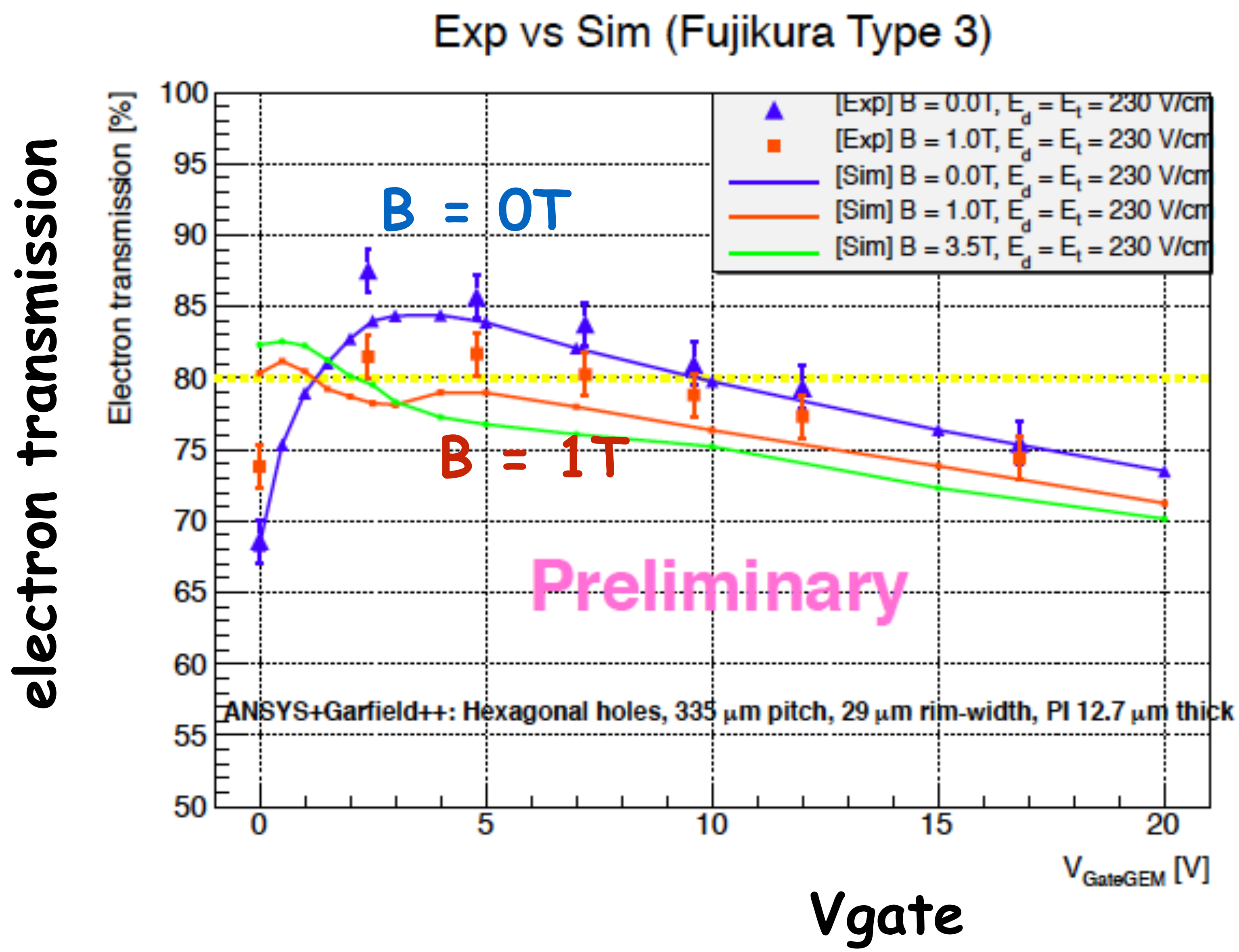


図2. B-side外観

# Electron transmission

10cmx10cm prototype(type 3) provides more than 80% transmission even for B = 1T field




module size gate will be tested under LP1 facility using beam on Nov.2016

# R&D of LCTPC

EndPlate and Field cage
Infrastructure of module test (LP1)

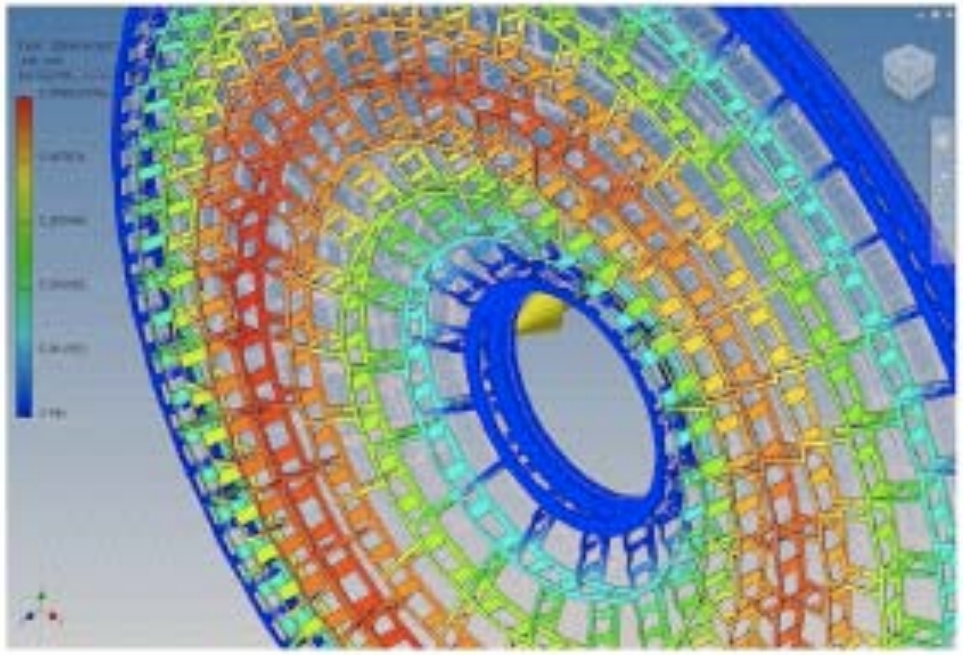
module R&D

Asian module, DESY module, Micromegas module
Timepix module

readout electronics/cooling

Distortions

# Endplate

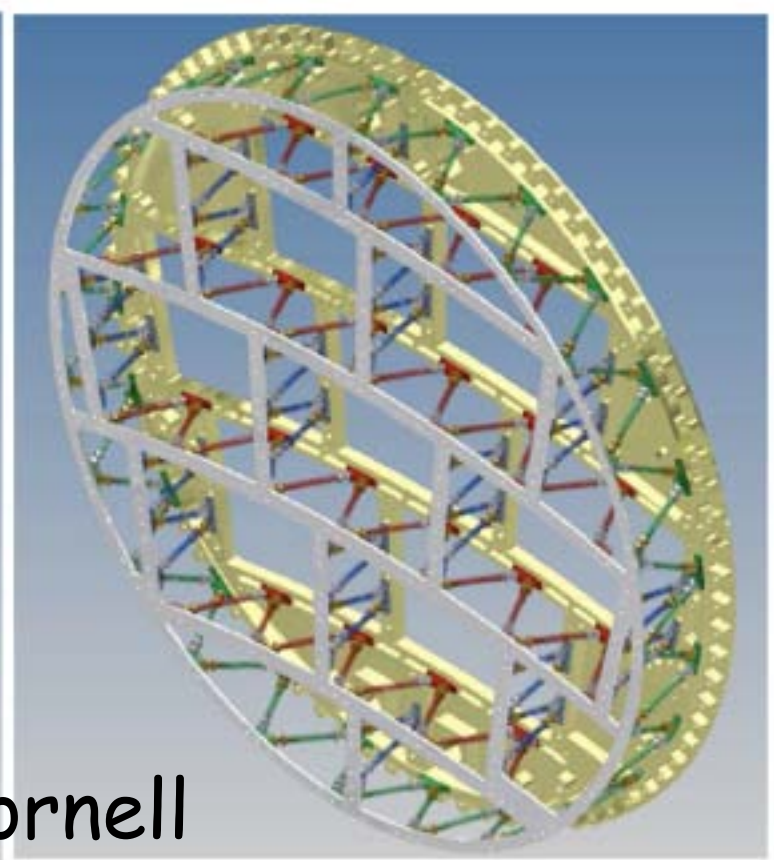


handling/replace --> middle size module

low material : aluminum --> space frame

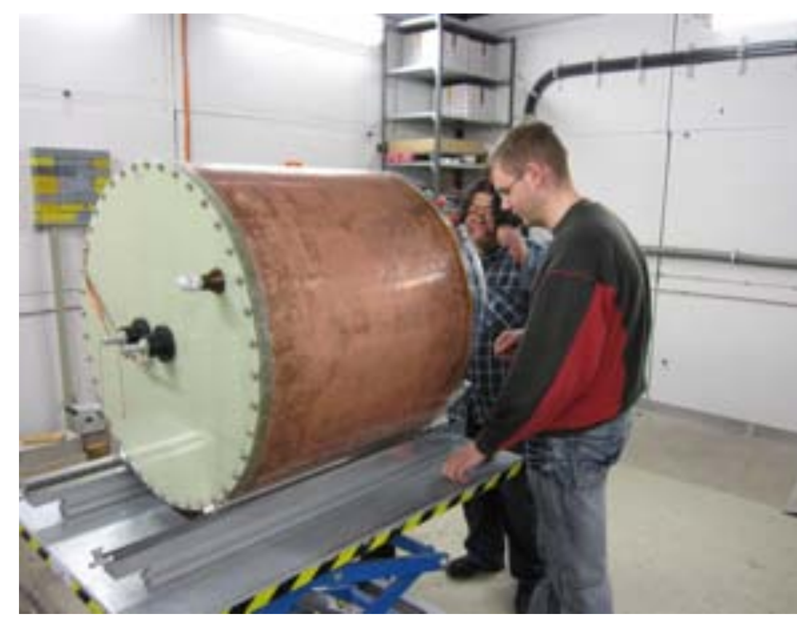
maximize sensitive area
-> install method, module boundary

LP1 endplate -> will be @ LP2?(1.5)



cornell

Field Cage DESY



Double layer Kapton strips
are laminated on honeycomb cylinder

# LP1 beam-test facility @DESY
# T24 beam line

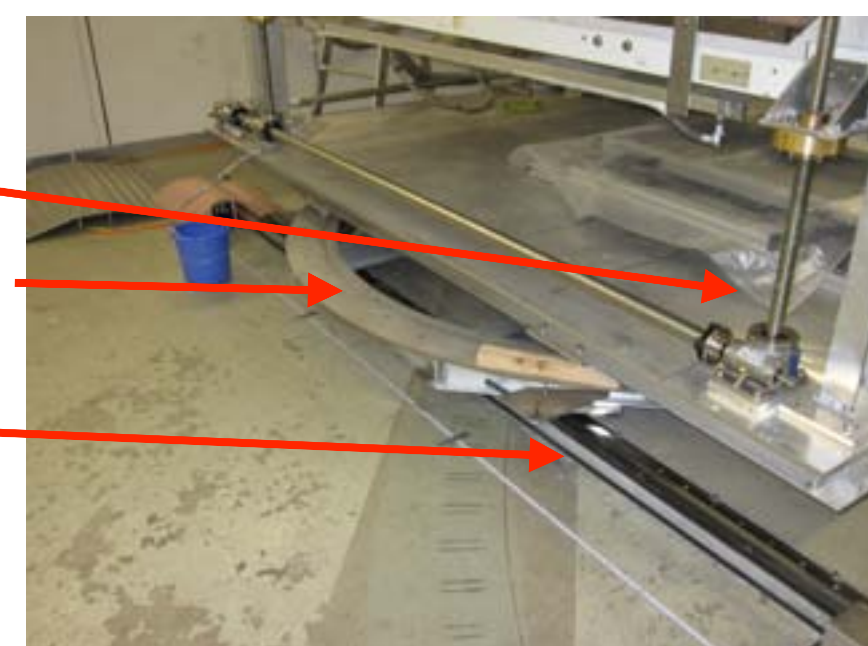
**facility to test various modules**
**under the same environments**

up to 5GeV/c electron

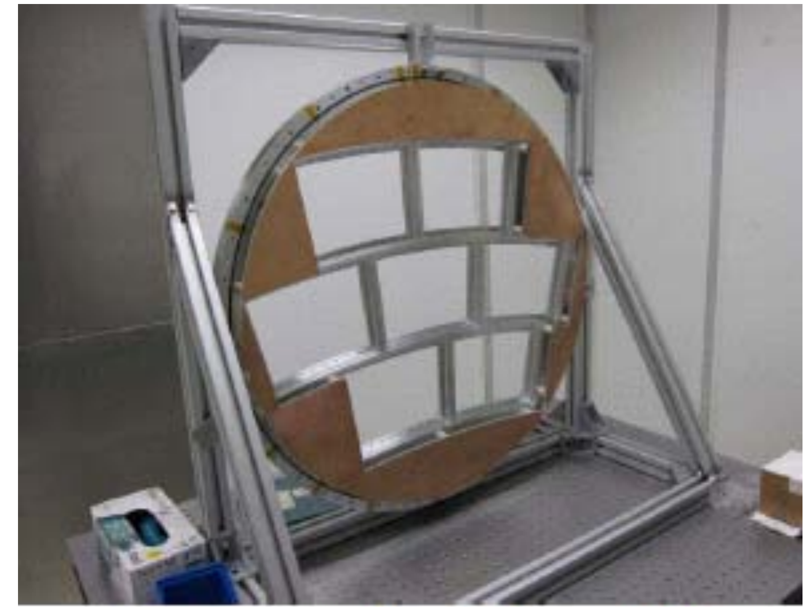
PCMAG(KEK) provide 1T B field
on movable stage
cryo system updated

LP1 field cage fit in the magnet

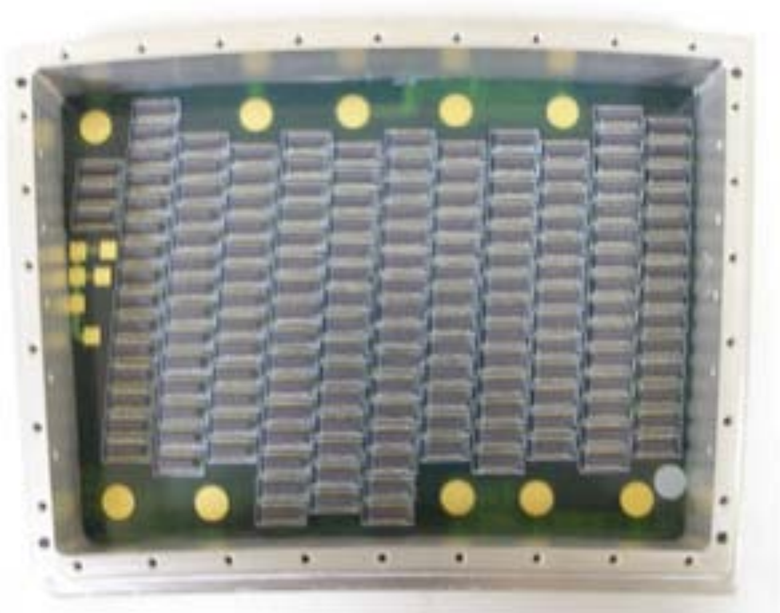
Si tracker was planed to be installed
in the magnet for precise reference point

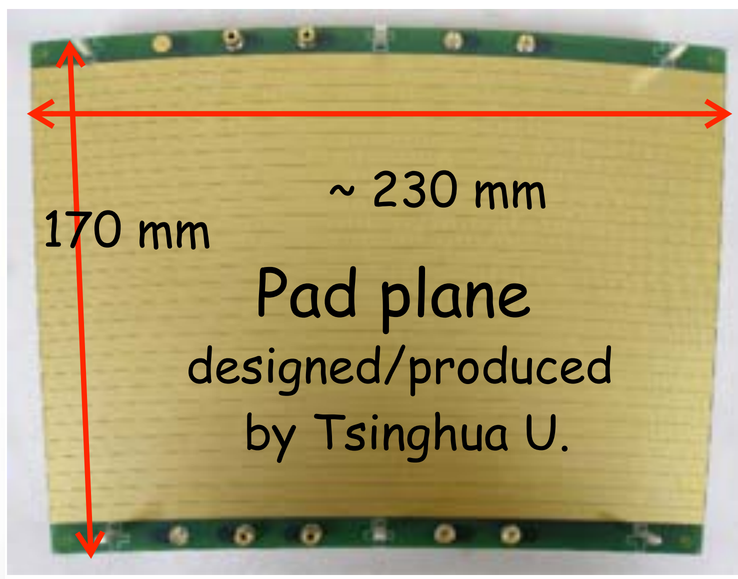


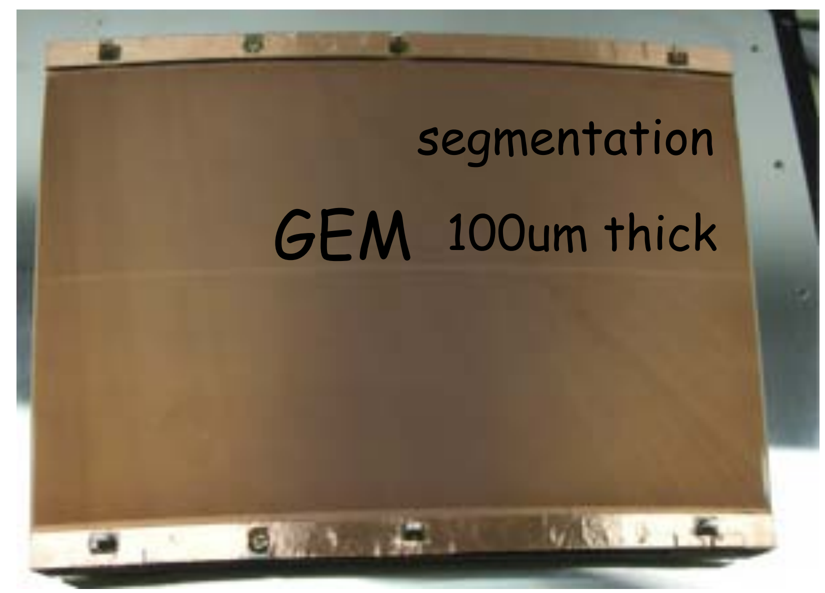
# Concept of Asian module



**Minimize insensitive regions**
**(module boundary, GEM frame)**
**pointing IP**
**no side frame**






Bunch of tiny connectors
(40 pins) 161 connectors

all other space for HV supply
+ Back Frame

28 pad raws (176/192 pads/raw)
~1.2(w) x 5.4(h) $mm^2$
staggered every each layer

Total 5,152 ch/module

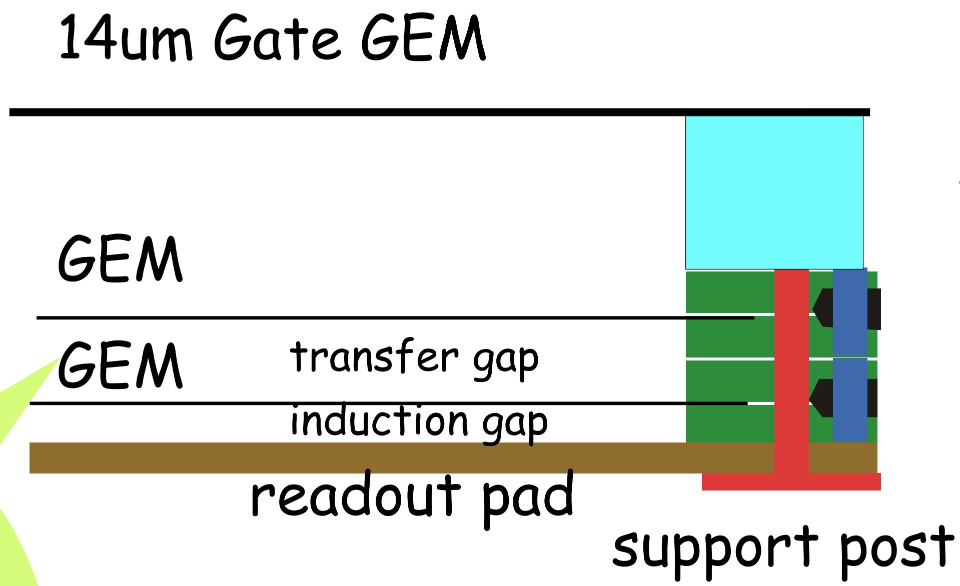
Double GEM (100um thick)
for simpler structure

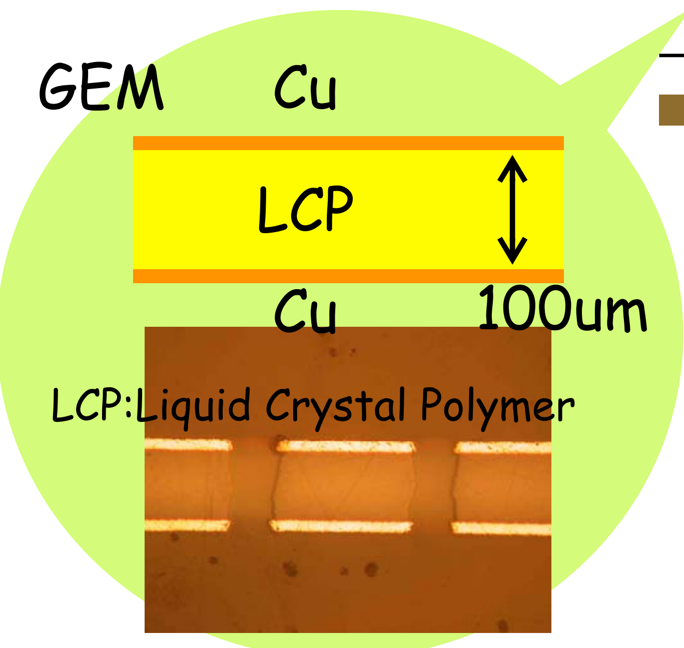
GEM electrode is divided in the middle of R

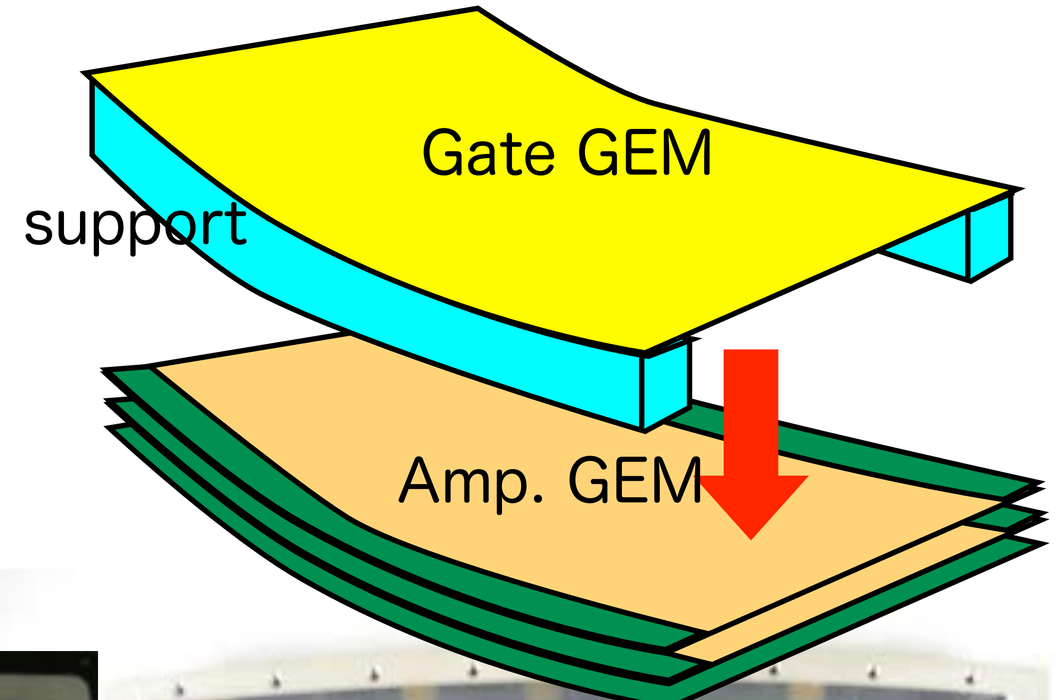
**Gate GEM is assumed above GEM structure**

# Asian GEM module

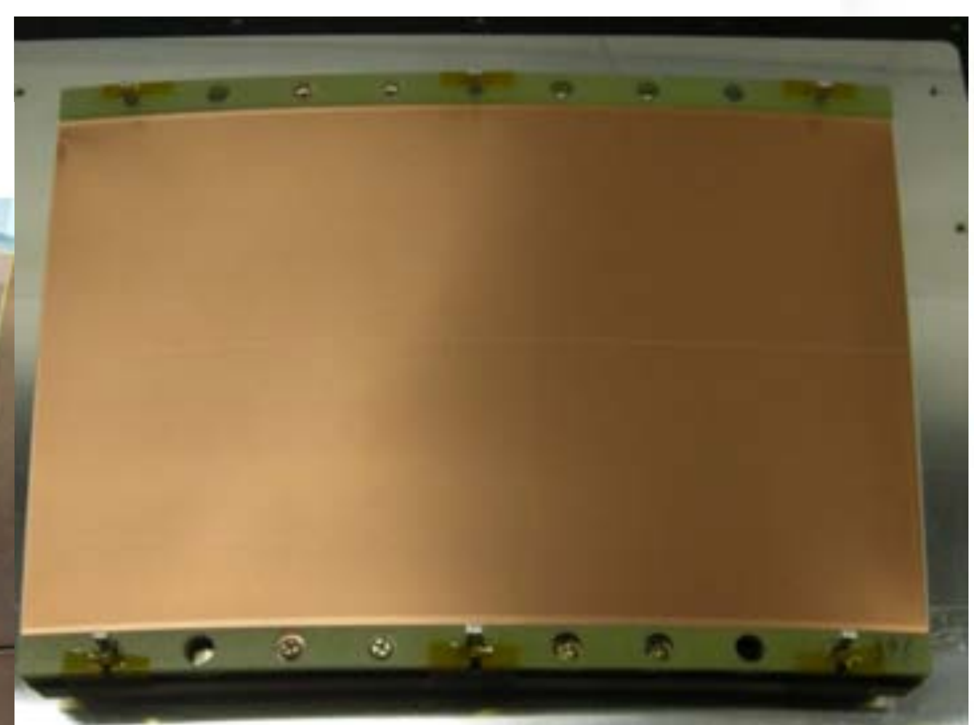
reduce insensitive area pointing to IP
in rφ direction
-> side frame less
simplify **GEM** structure
-> double stuck GEM

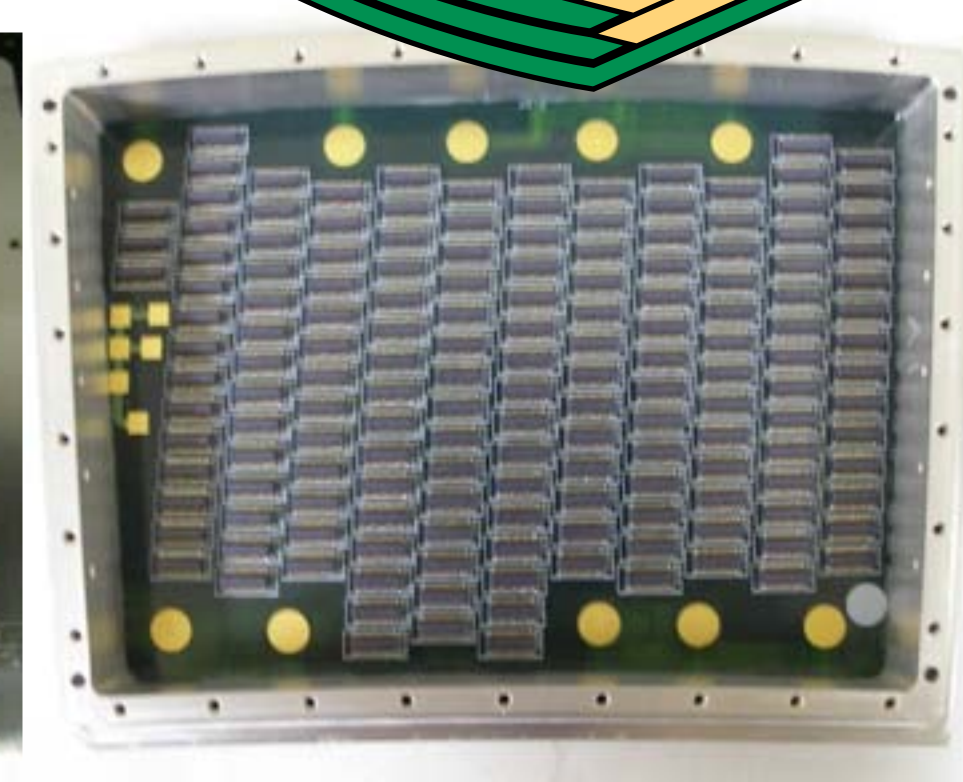


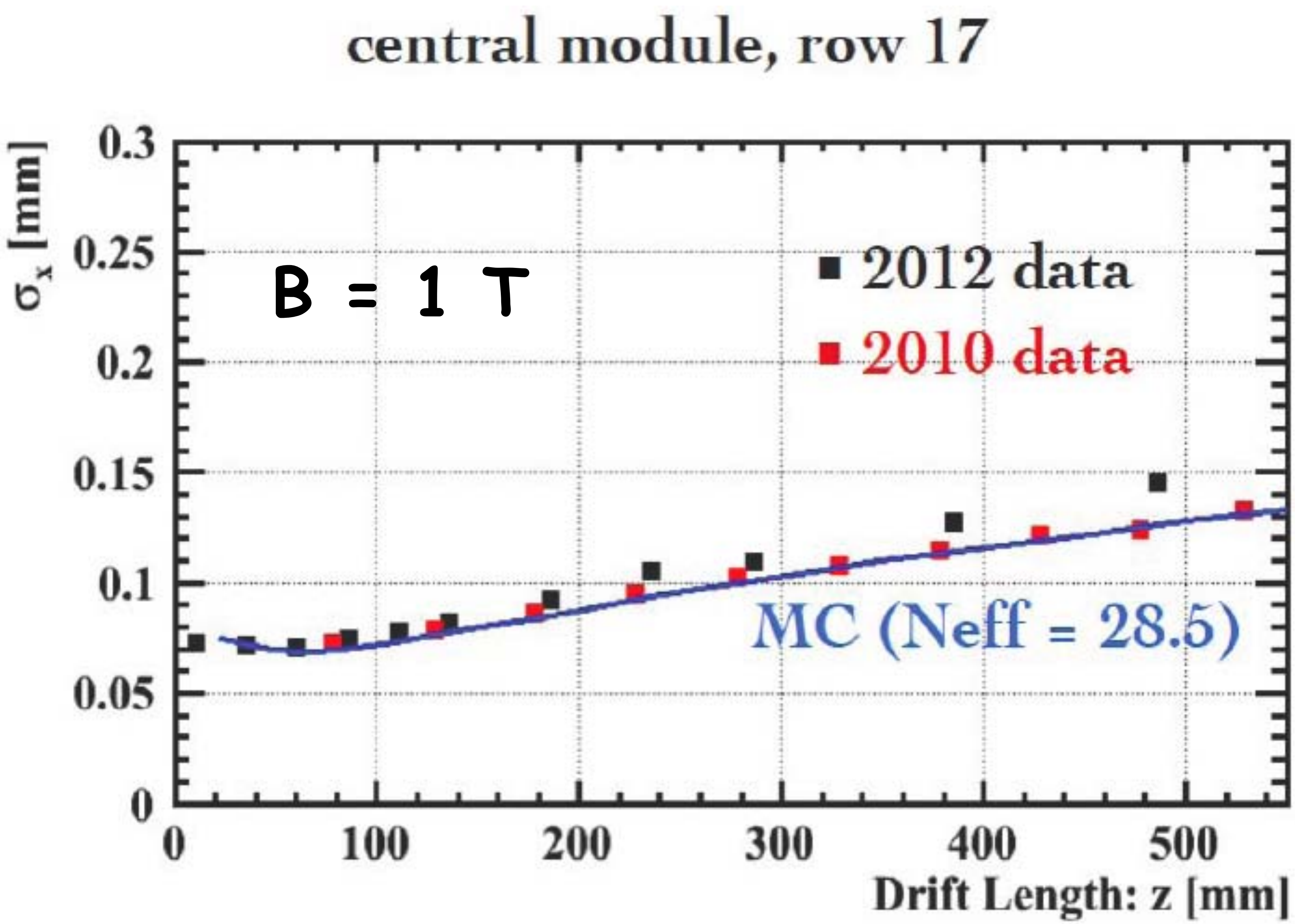




Module installation test with EP2

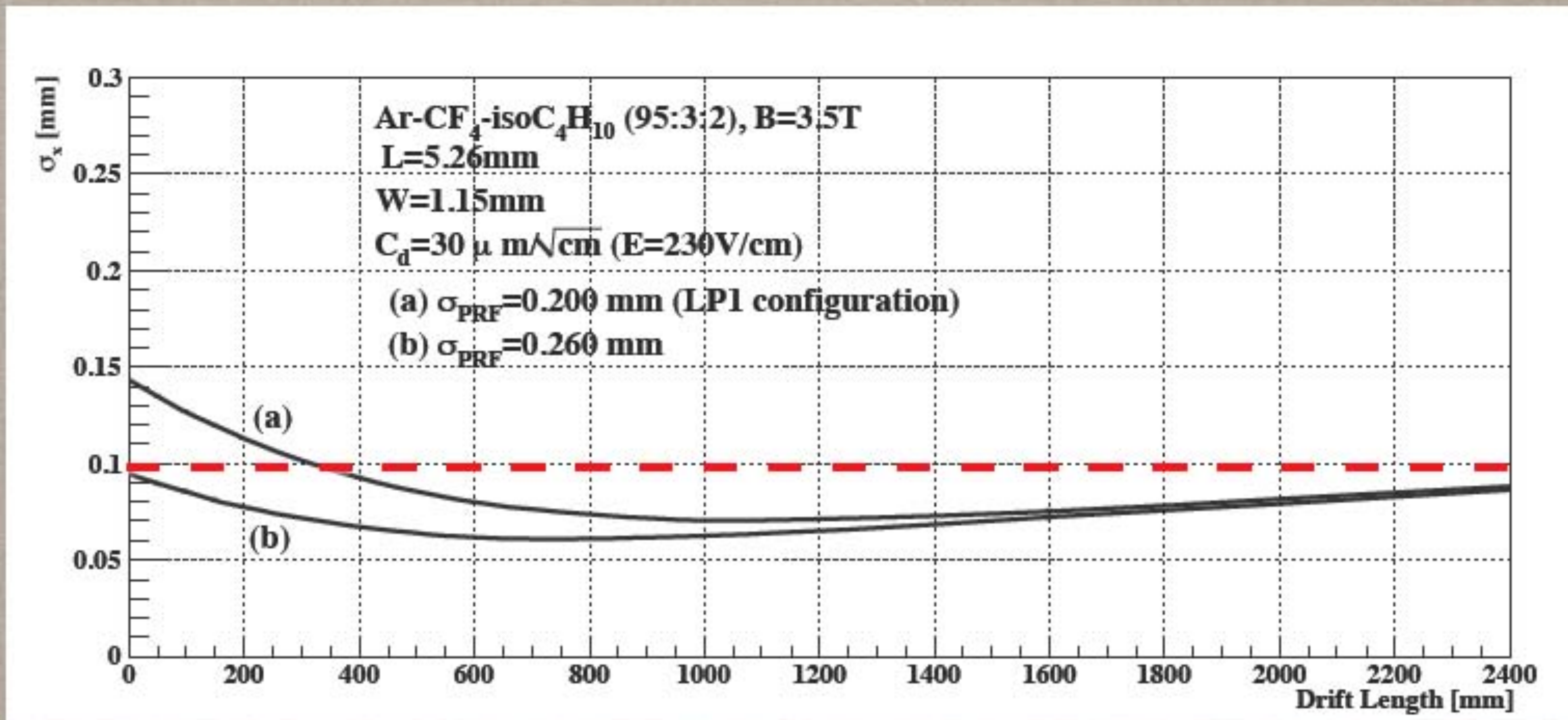





local resolution as a function of drift distance



# Extrapolation to the ILD-TPC




**The expect perfo**
**satisfied with th**

In order to achieve 100um res. all over the drift volume,
we have to have more diff.@amp region or narrower pad

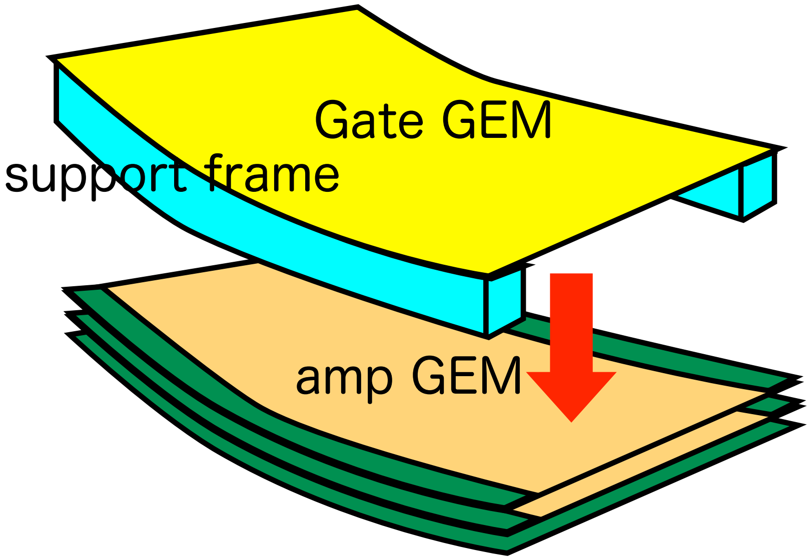
# Difficulties of module R&D

**typical local resolution is as good as we expected**

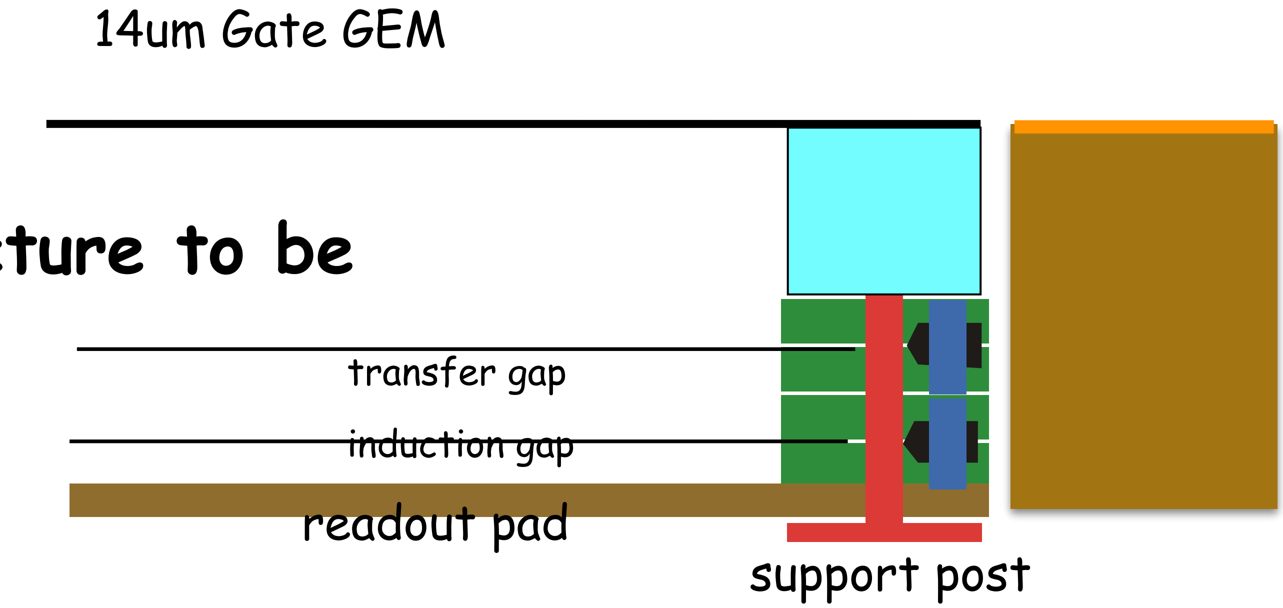
How can we extend this performance to all over the module

quality of components (GEM, gate, connector.. )
mechanical/engineering (GEM /Gate stretching…..
design
procedure of study

# Design/study process

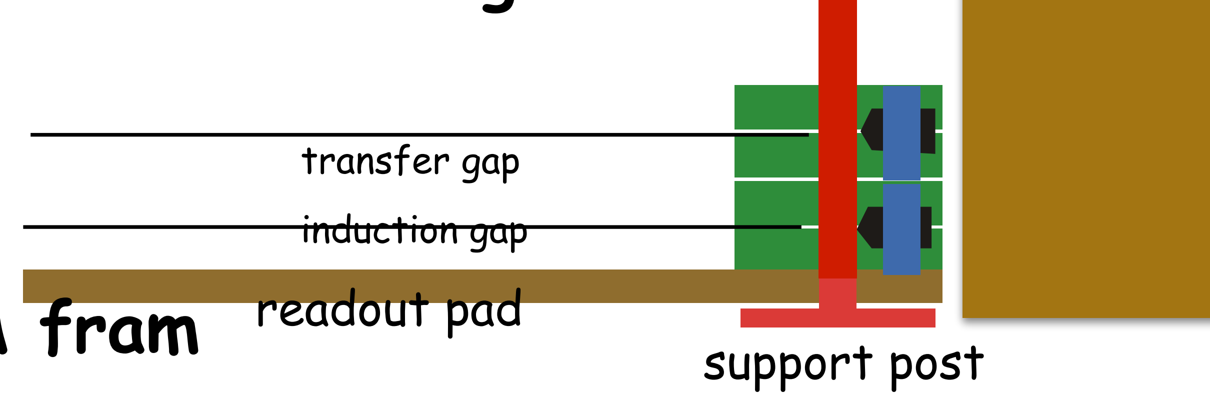



Final structure to be




We want to know GEM module performance separating from Gate

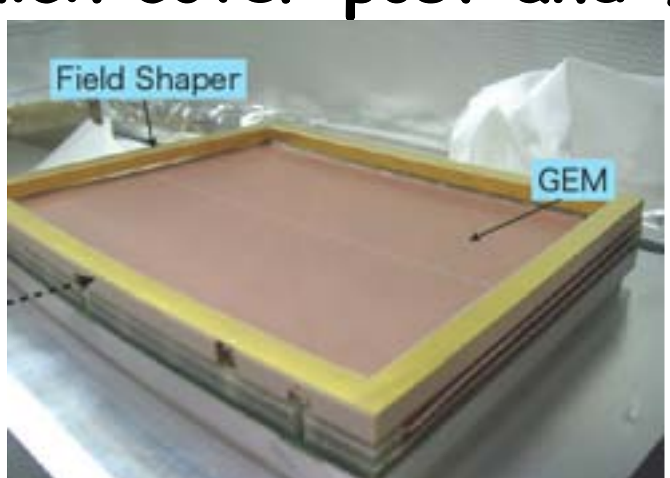
test w/o gate

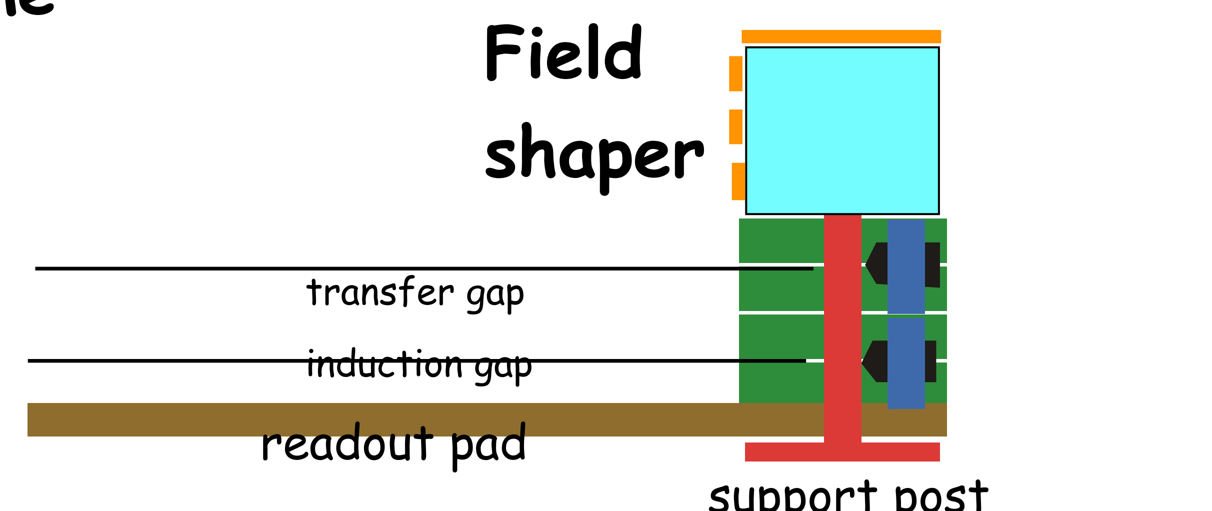



Removal of Gate -> metal post insulated of GEM fram

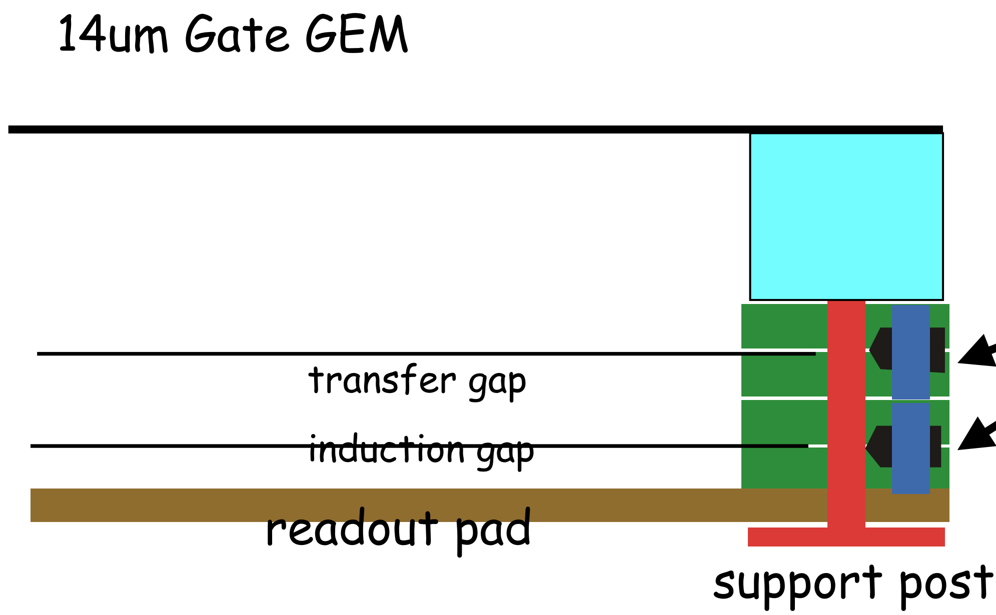
-> E field is distorted @ boundary

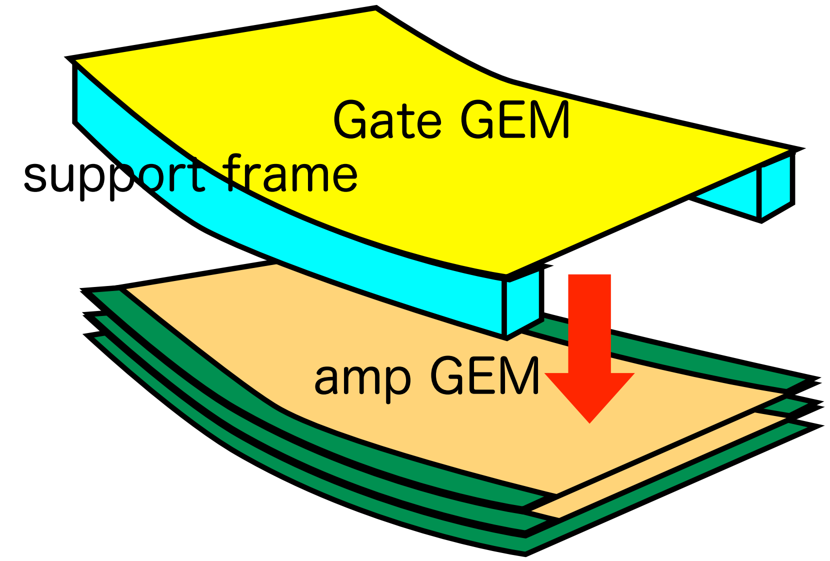
Field shaper which cover post and frame



# GEM stretching method




**tension of GEM is applied against post**

**post by**
**super engineering plastic**

as mould cost ~10k $ →

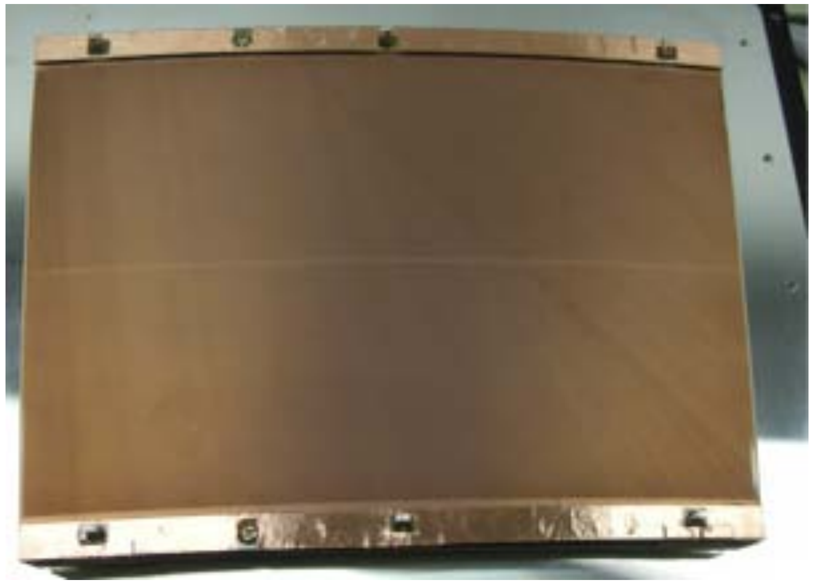
**metal post: E field distortion/mechanical dist.**
Al

**too much room for adjustment**
**difficult to align GEM on the place**
**-> shorts to neighbor module**

## Lesson

R&D study should be done in step by step:
module design must be cooperated with this procedure
Saving money may not save your R&D
Much room is better than no room but is not proper

# GEM sheet



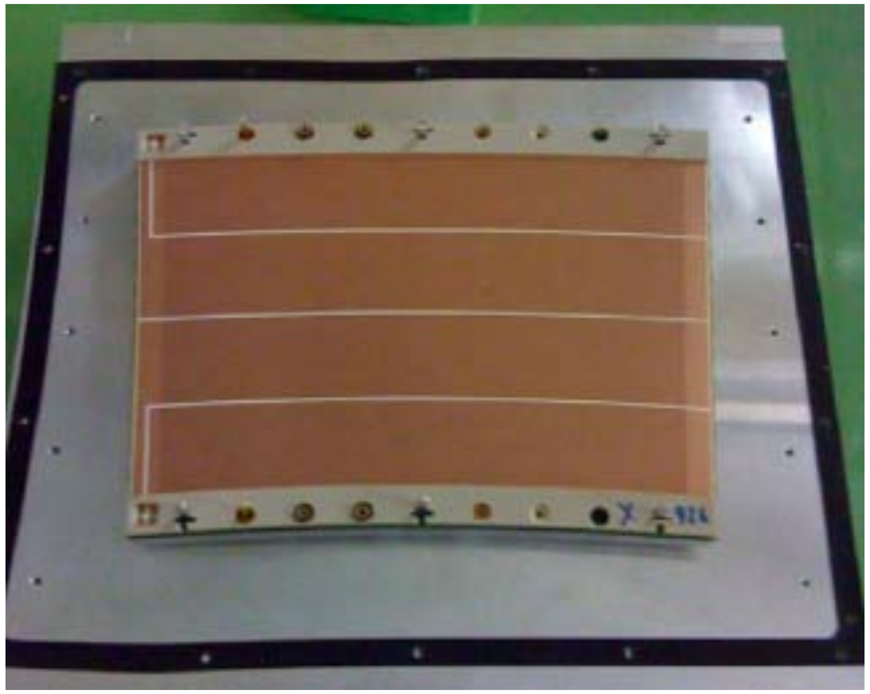
segmentation 2

-> observe frequent trip

gap 300um

-> gap was too short

one segment trip -> discharge@gap



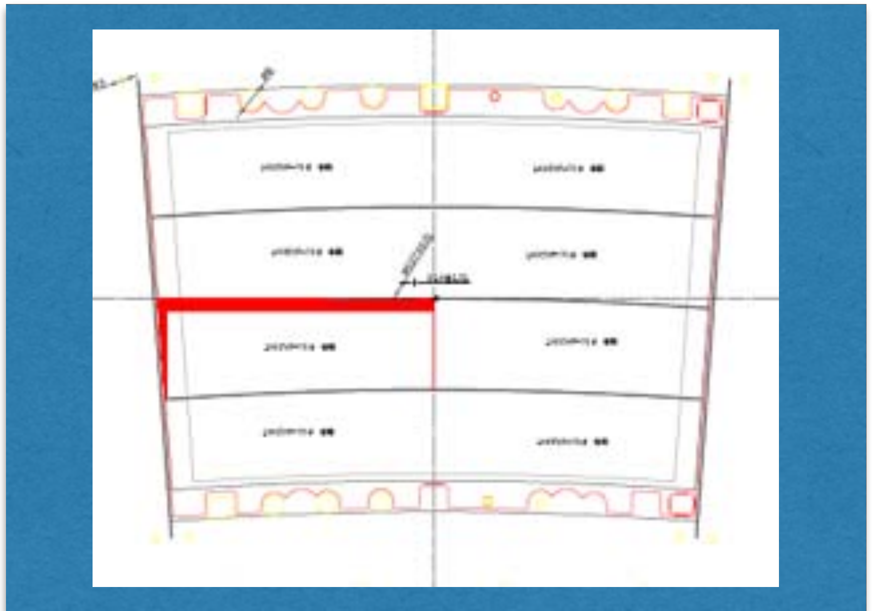
segmentation 4

-> improve? but many discharge

gap 1mm

-> HV OK but

-> this gap provide another distortion

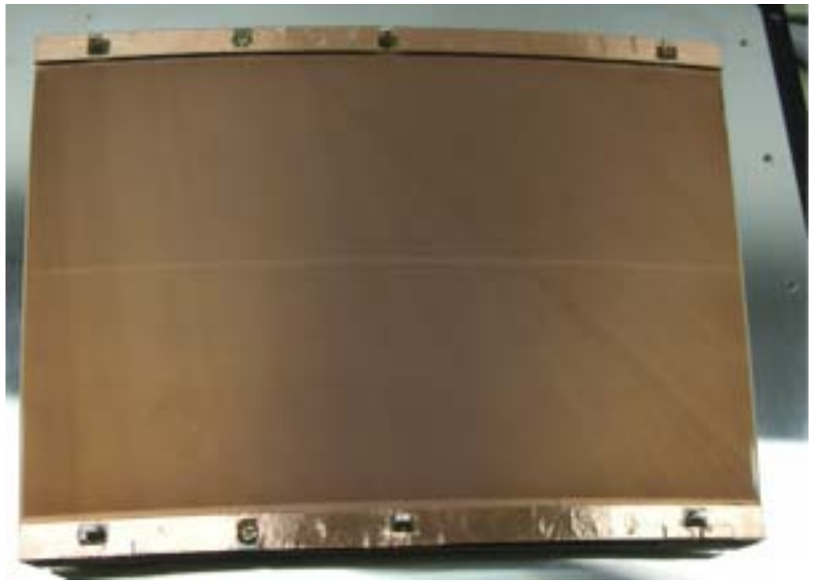


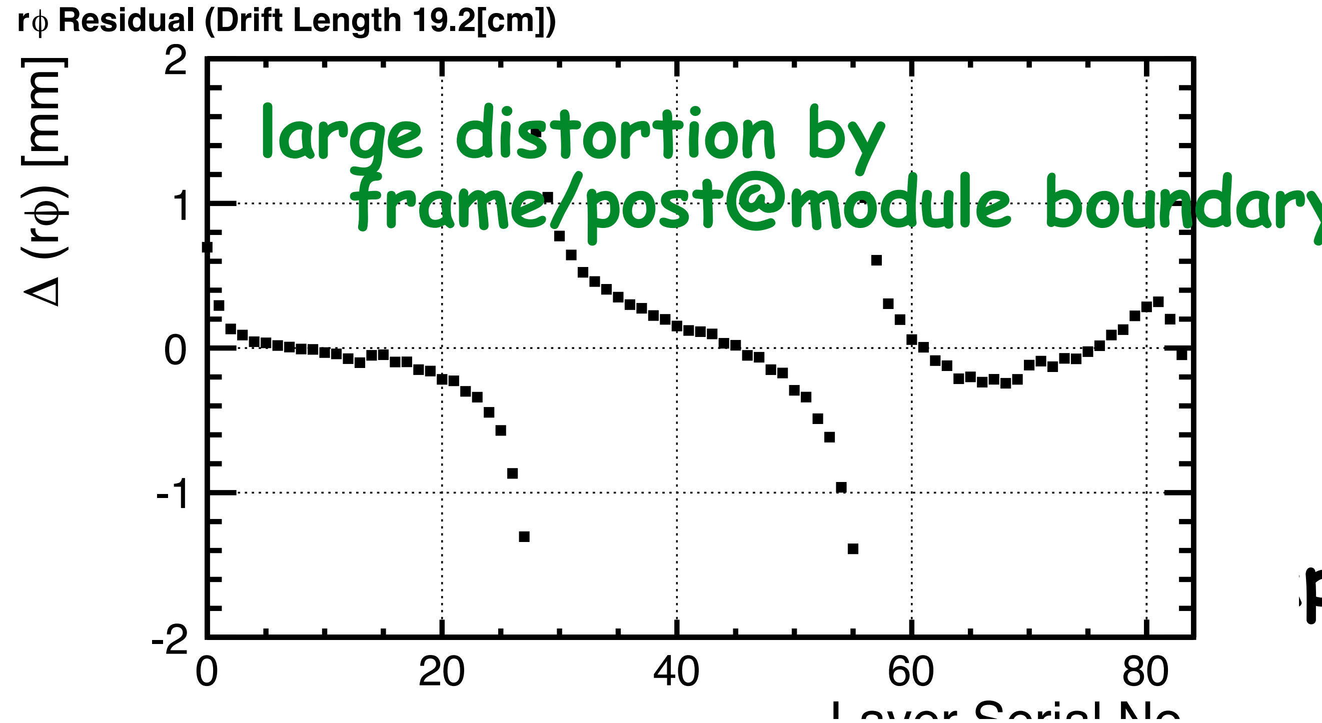
no segmentation@front/ 4 segments@back

-> distortion became smaller

gap 500um

# GEM sheet

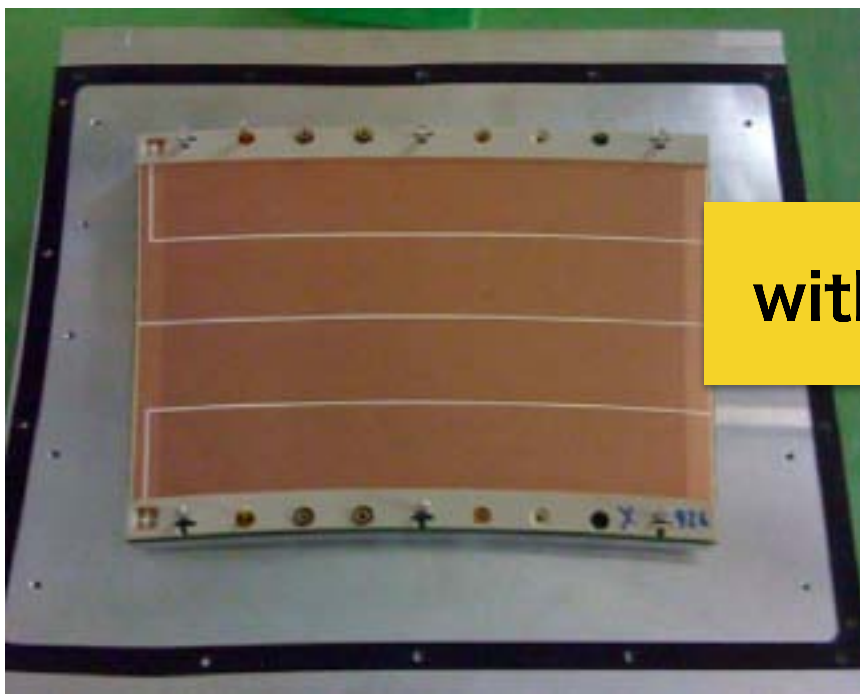




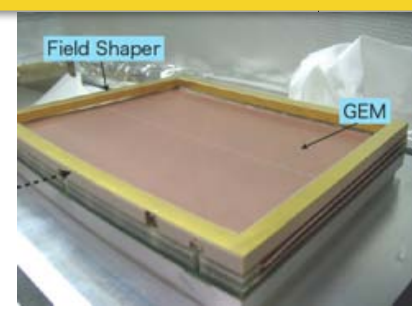

se

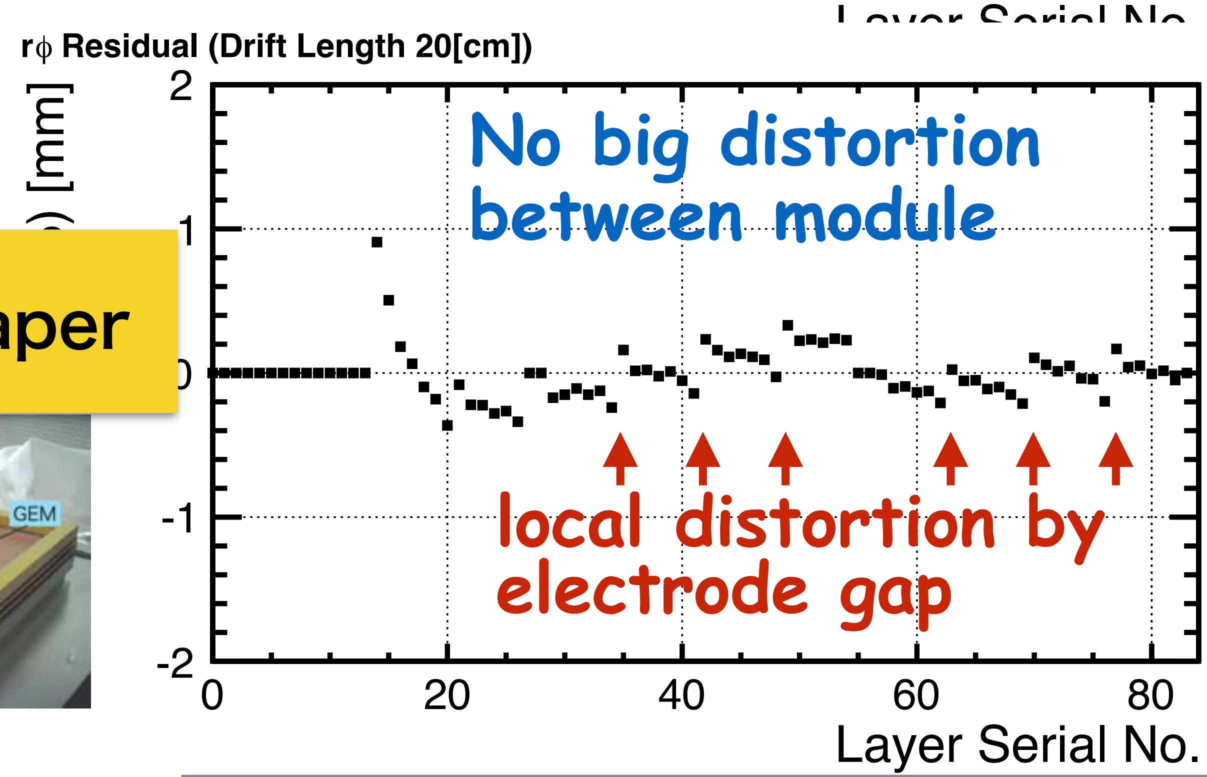
gc

p



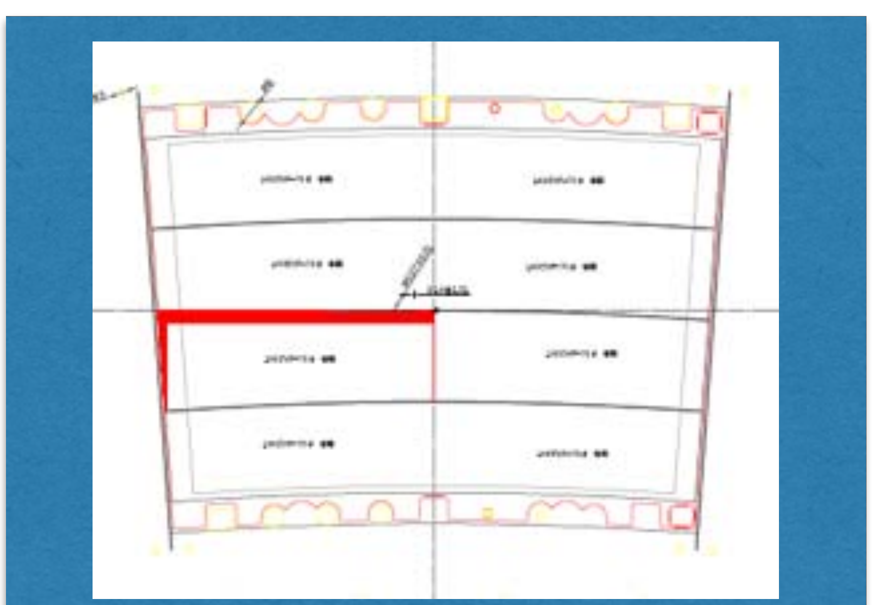
with field shaper




seg

n



no segmen

-> disto

gap 500um

beam test on Nov. 2016
distortion must be much
improved

# GEM discharge study

Why our LCP 100um thick GEM discharge frequently ?
even at reducing GEM segment area

Micro discharge is counted during long term GEM operation
for 50um(CERN,Raytech, Scienergy) and 100um(Scienergy) GEM
(standard 10cmx10cm size)

no clear difference was observed

RIKEN group has studied gain stability of LCP GEM
and found 100% variation even in the same GEM
due to thickness of insulator (LCP)
LCP: uniformity of thickness is O(10%) in specification
(Kapton/polyimde sheet is much better than this)

## Quality control of GEM

# Next step to realize real TPC

finalize module design

GEM structure,  Gate structure, Pad plane

readout electronics

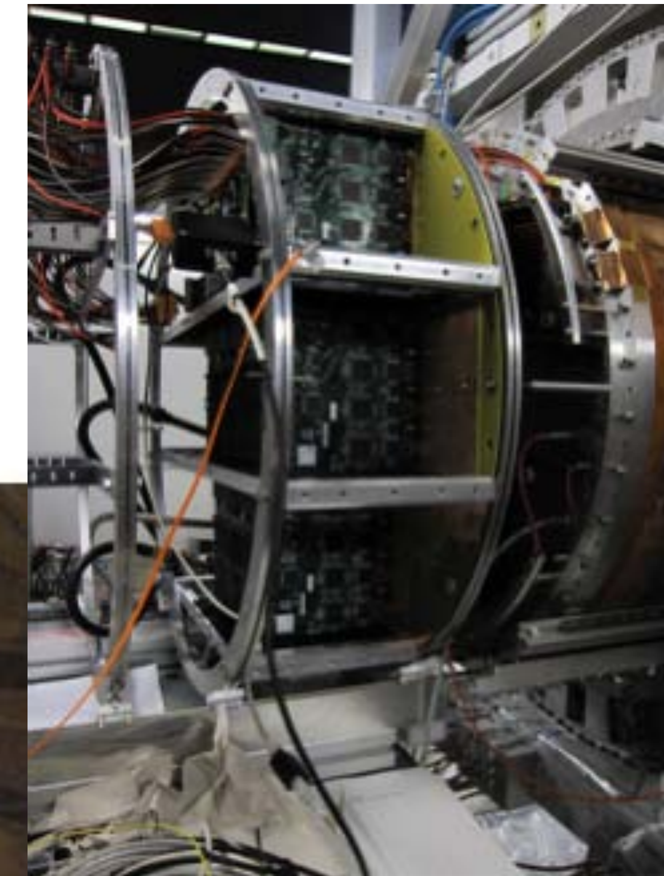
the final RO electronics is postponed until ILC *go sign*

integration of real electronics and cooling

related to Pad plane design

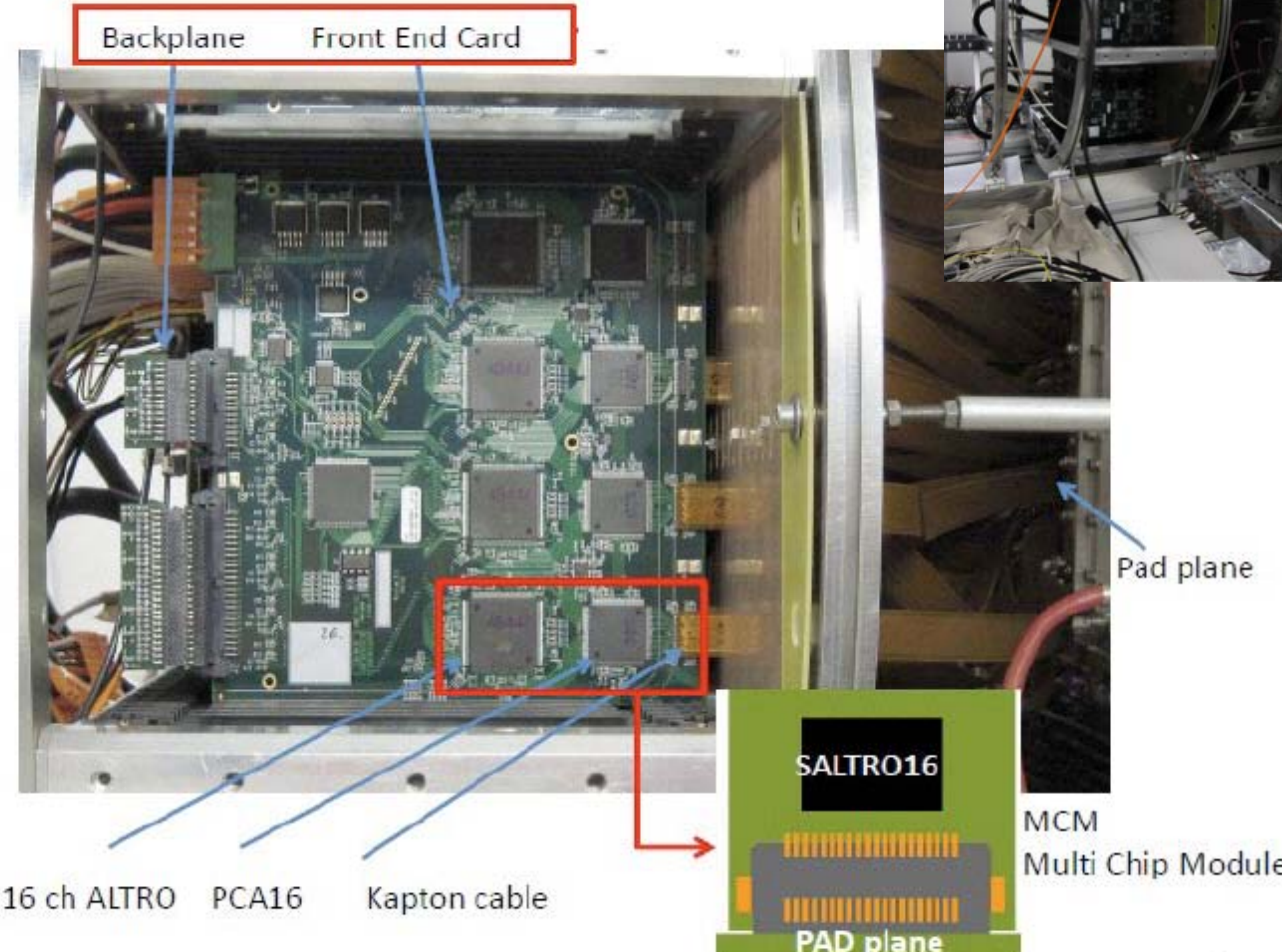
Study is on going with intermediate RO electronics(s-Altro16)

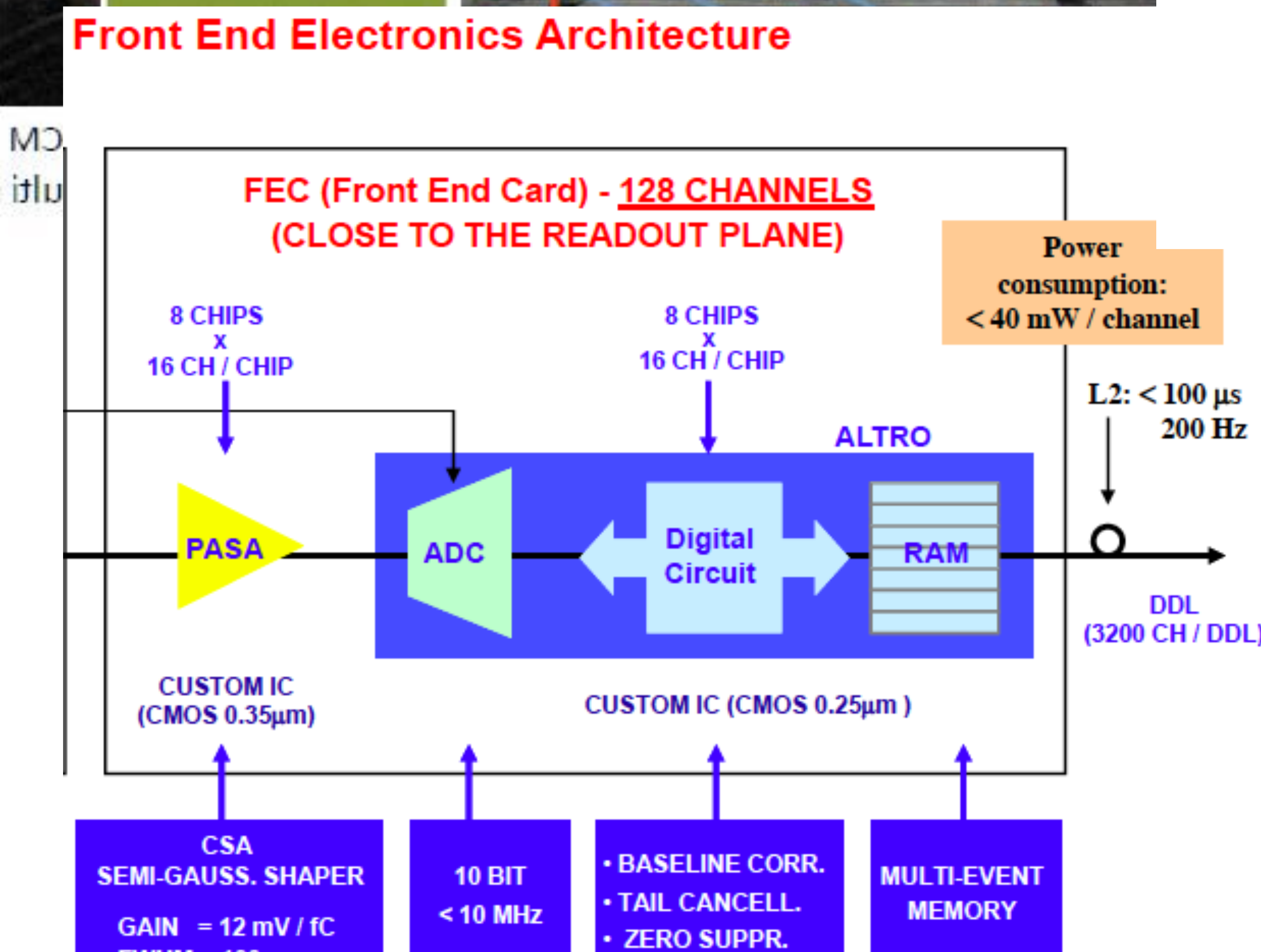
# Integration of PCB+RO electronics @LP1



## Present front end electronics
## modified Alice TPC electronics

reduction of
size/material





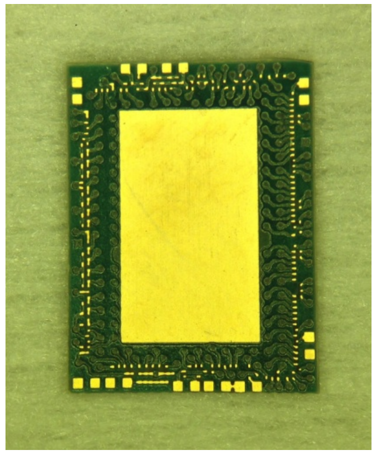

All functions are integrated into one chip: sAltro16

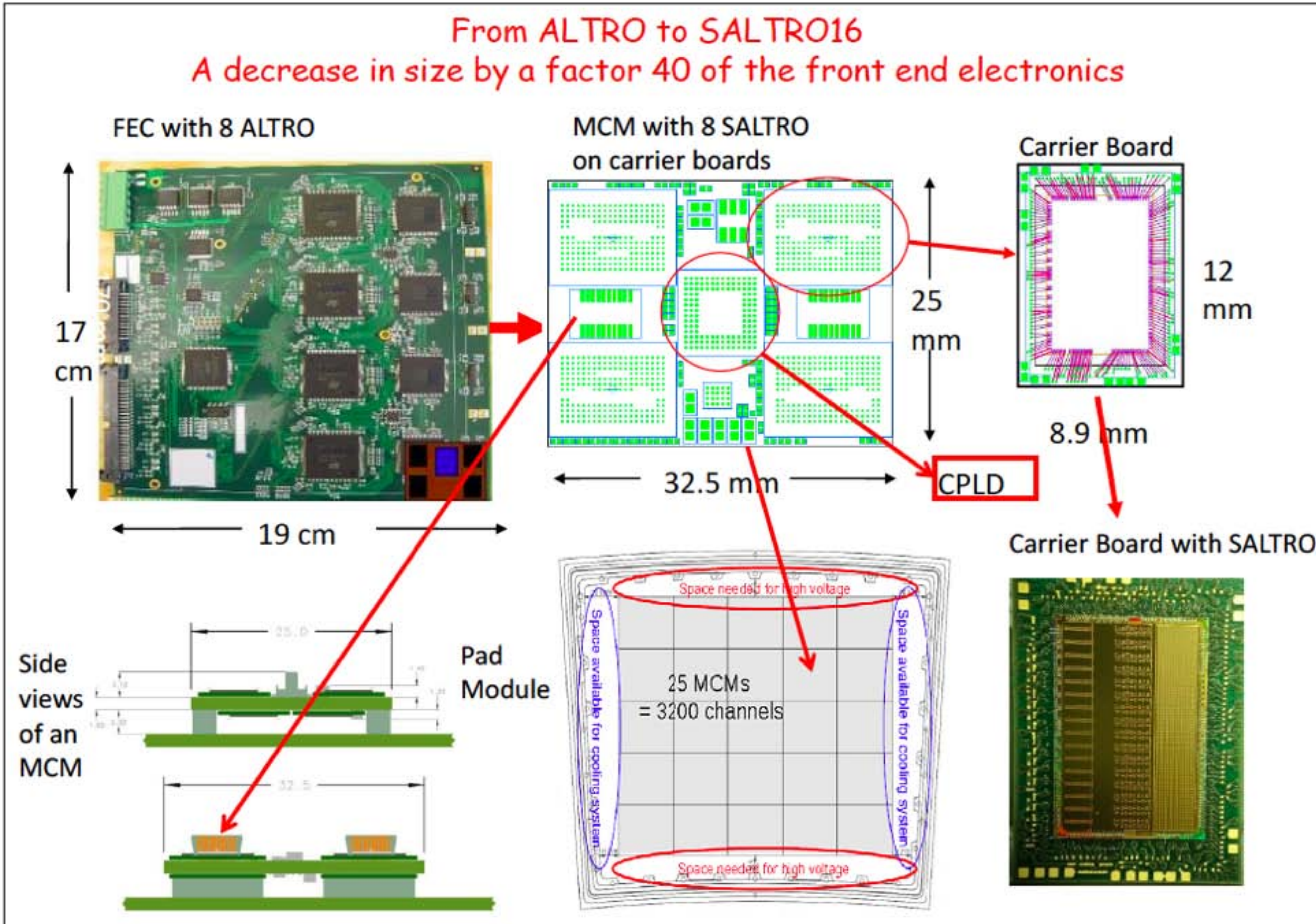
analog-digital mixed

sAltro16 -> sAltro64

extension prog. terminated

But we have many sAltro16 for integration test





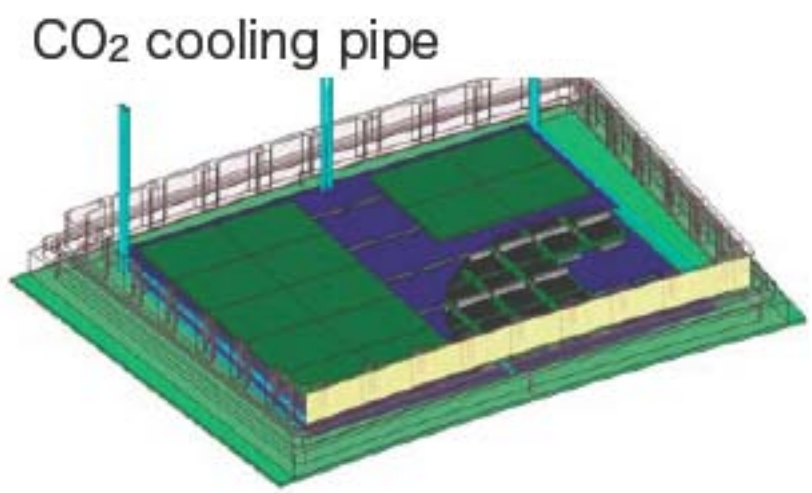



Slide by Leif Joensson

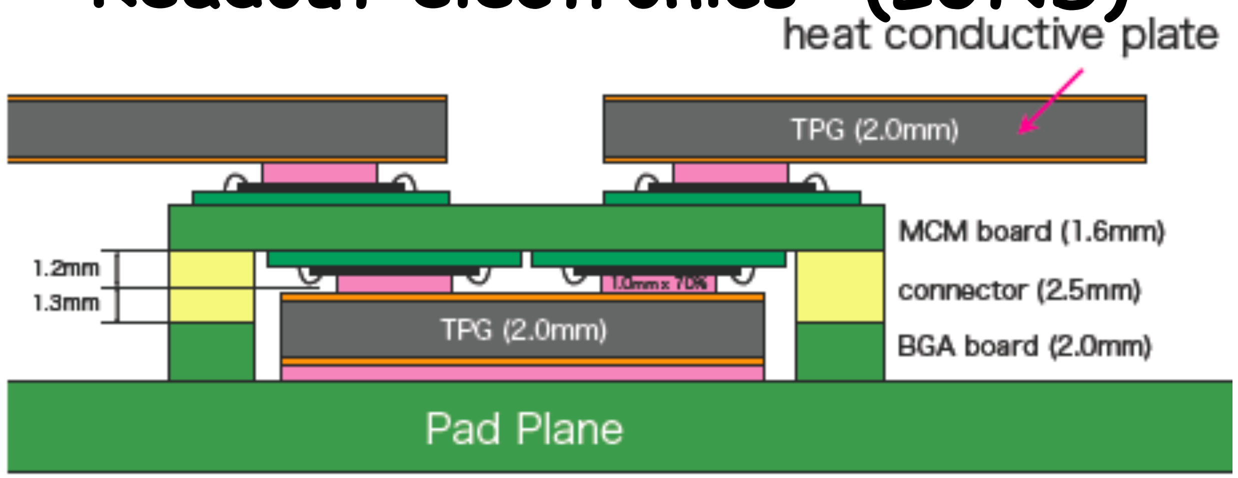
# integration of cooling system

Electronics can be small  but power consumption remain same !

Cooling is another important issue




Readout electronics  (LUND)




Cooling scheme is studied by Takahiro

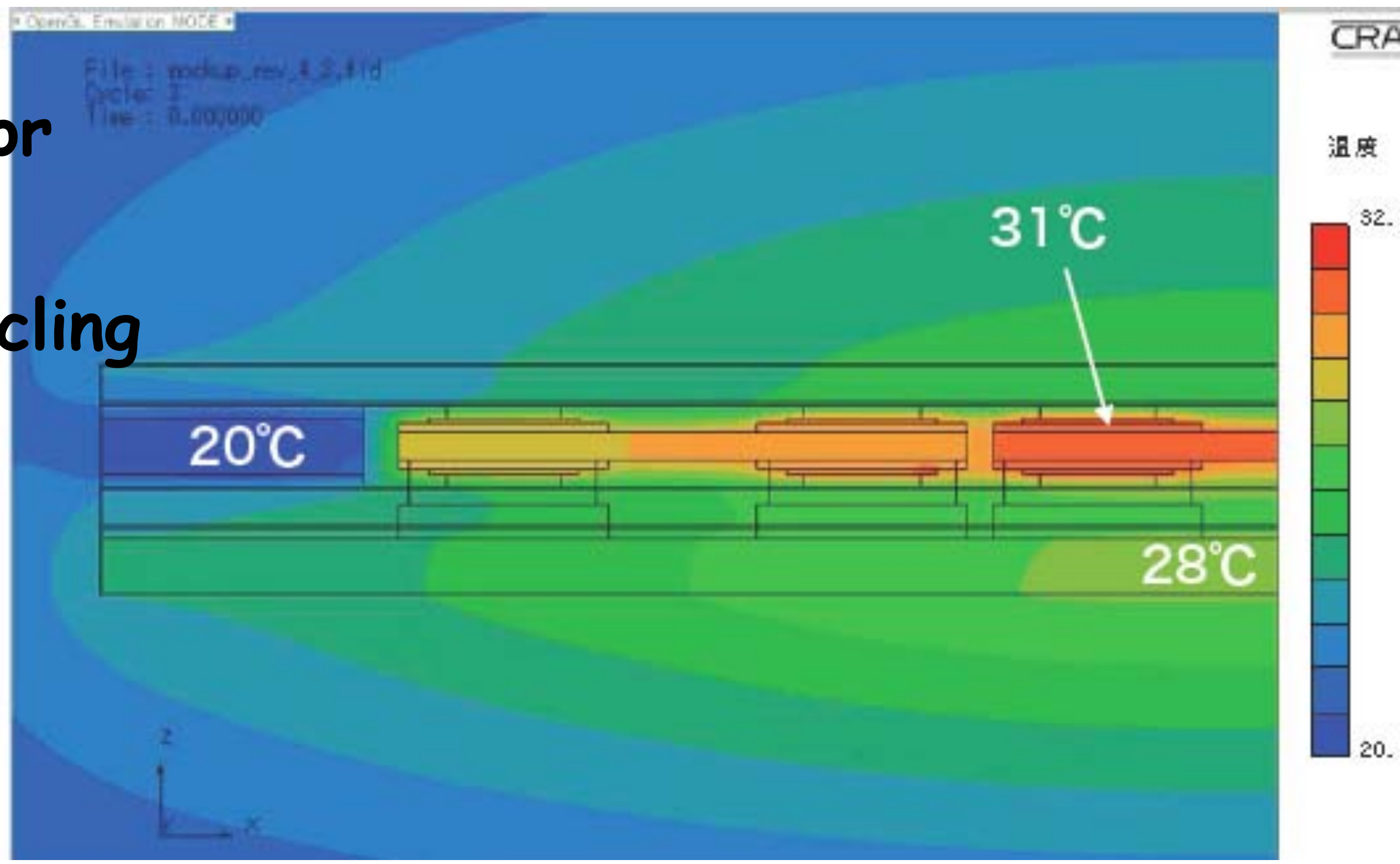
simulation using TPG as heat conductor

non-negligible temp. gradient

w/o power cycling

heat flow through connector

Mockup study is on going



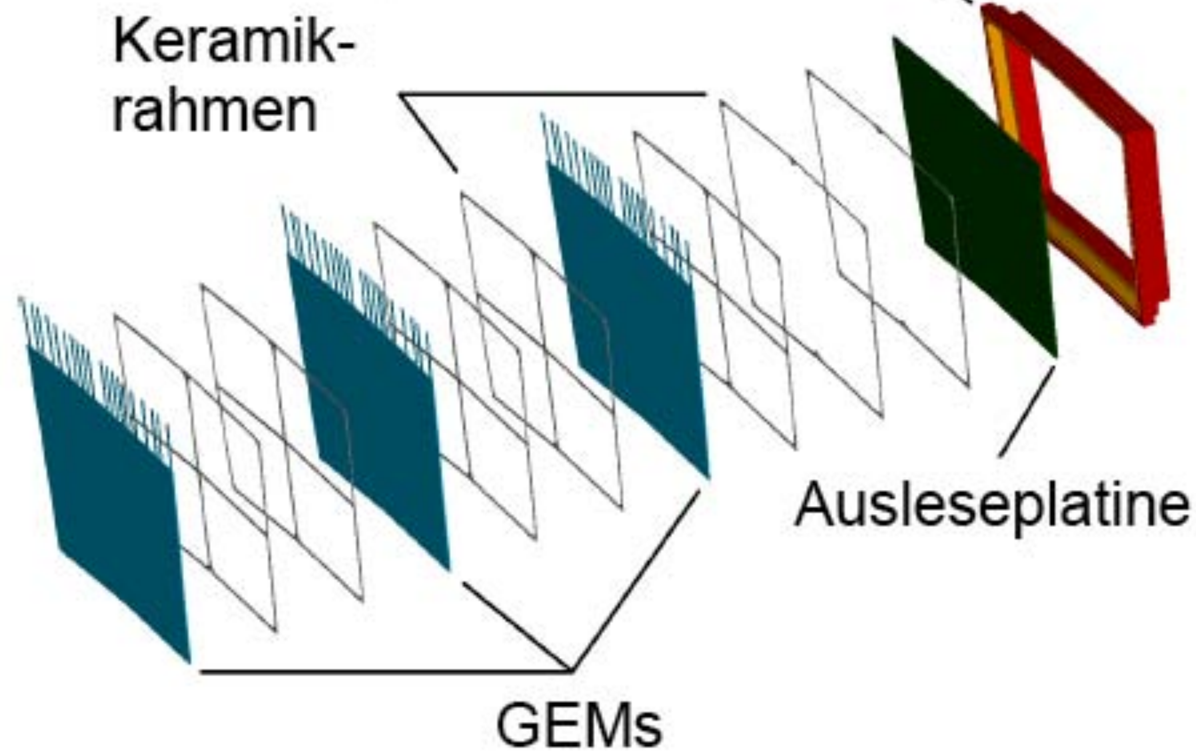
# toward the final module design

3 MPGD modules are studied

- Asian GEM module
- DESY GEM module
- Micromegas module

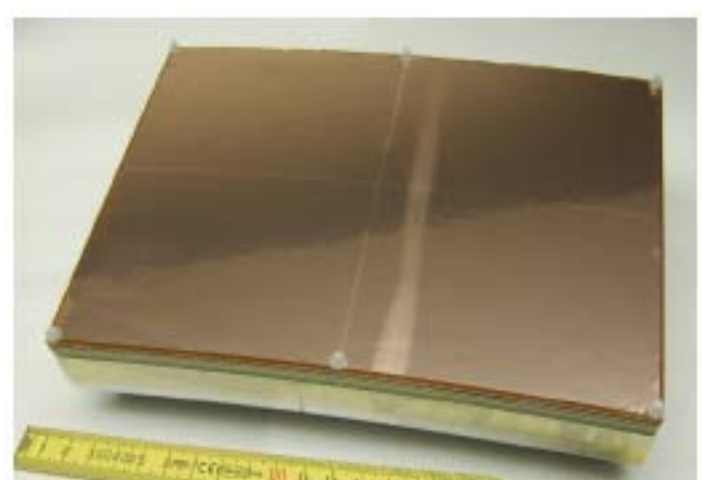
→ to LOI

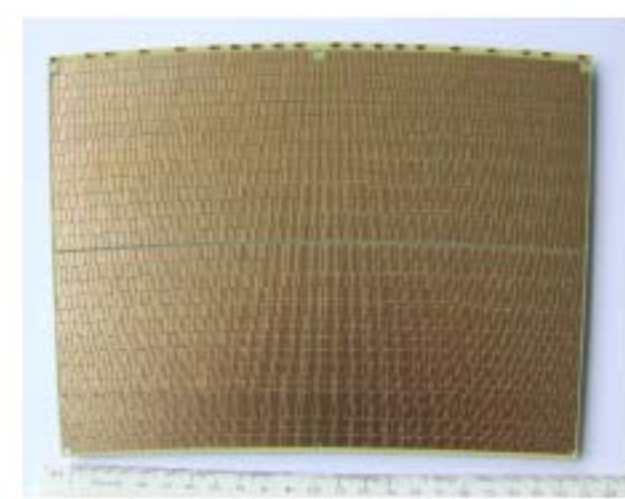
we may need to unify the GEM module first




feature of DESY module

- very thin ceramic frame for GEM
- triple stack
- HV connection





# Summary

GEM Gate seems to be working ( watch the result of next beam test)

We convinced Asian module has a potential to reach to LPTPC goal
100um resolution
intrinsic performance of each components look OK.

But to achieve ILC requirements over the module/TPC
improvement of engineering/design/QC are necessary
design to minimize E distortion