Status of Asian GEM Module

Shin-ichi Kawada (Hiroshima University)
on behalf of ILD-TPC Asia group

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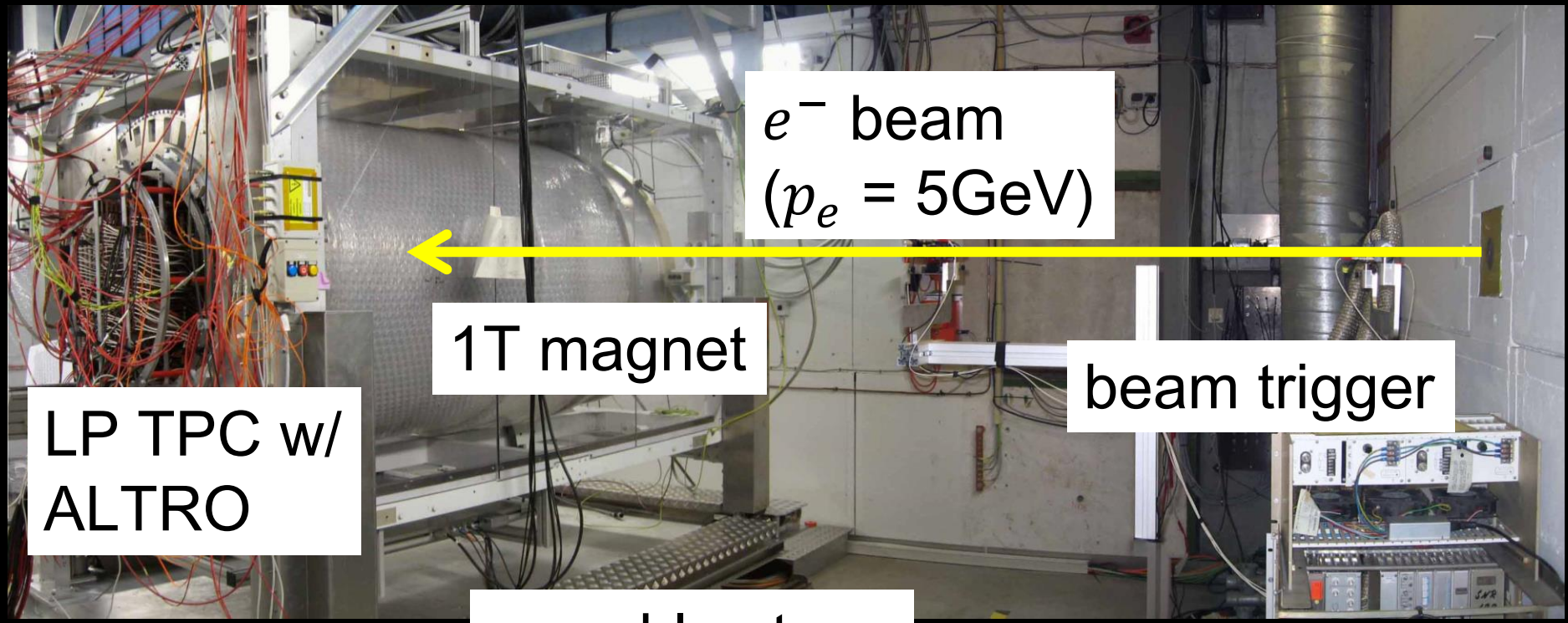
Analysis of 2012 Beam Test

2012 Beam Test @ DESY

Beam test (2012/Nov./20 - Dec./20) with LP1



Beam Test Status

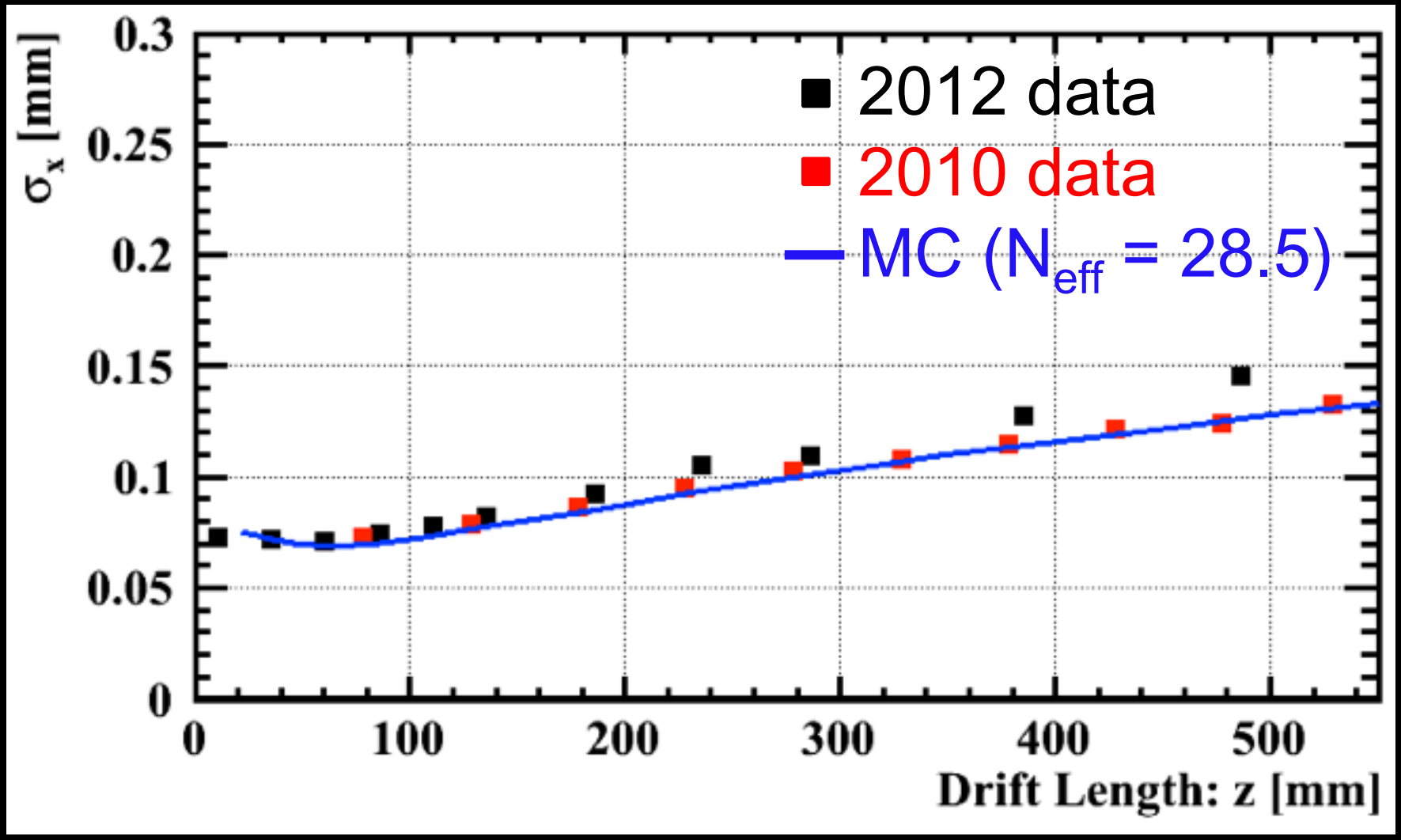
Purpose: take more and various data than the 2010 beam test

2010	2012
B = 1T	B = 0T, 1T
z-scan (5cm ~ 55cm)	z-scan (2.5cm ~ 50cm)
	x-scan (-2cm ~ 2cm)
	θ-scan (-10° ~ 10°)
	ϕ-scan (-10° ~ 10°)
	different gains, shaping times

Results

slide from LCWS2013

xy-resolution, central module, row 17

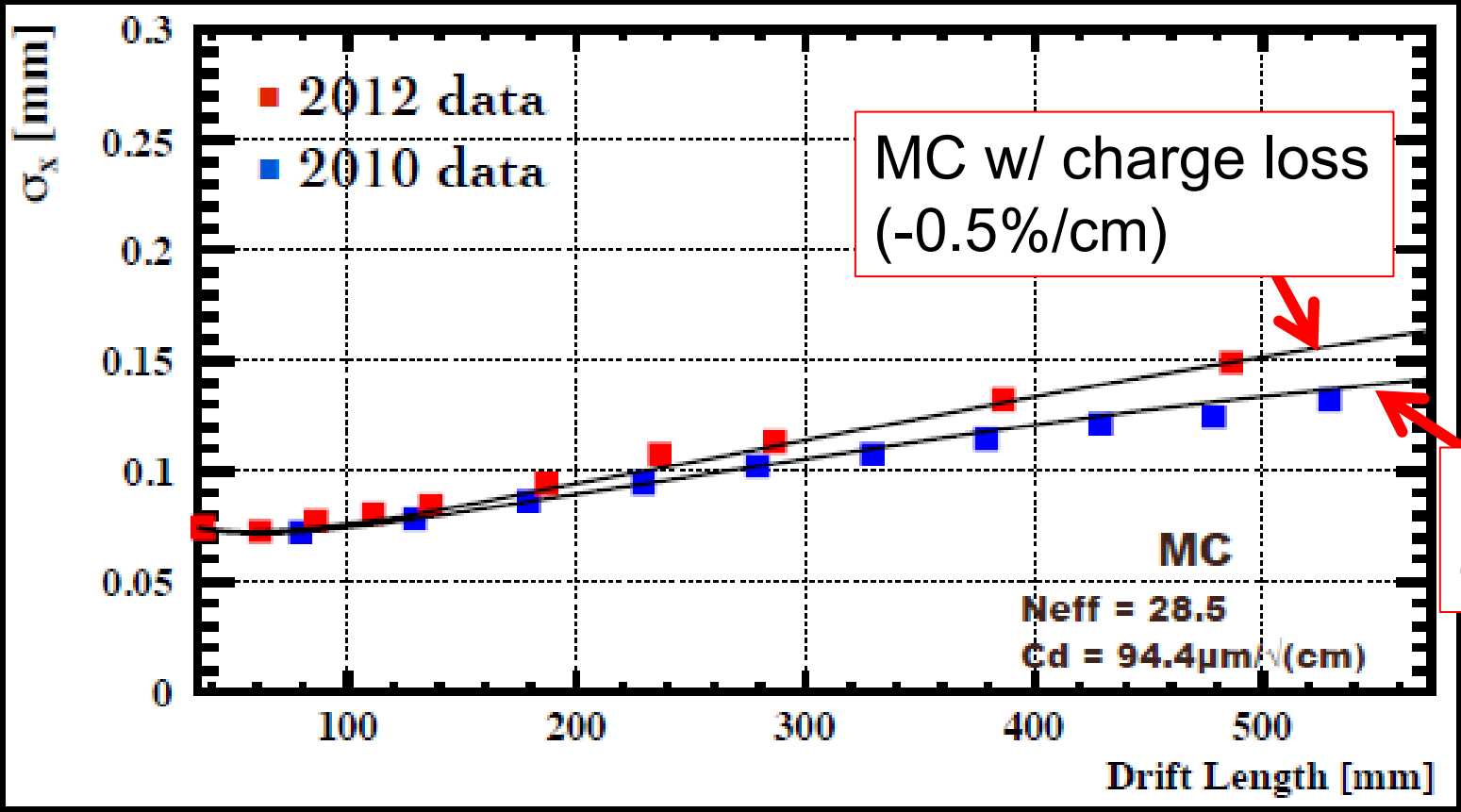


Results

- 2012 data are consistent with 2010 data at the short drift length, but not consistent at the longer drift length.
  - Other group using LP1 at 2012 also observed the same phenomena.

Results and MC

slide from LCWS2013



-0.5%/cm charge loss can explain the behavior of 2012 data.

- gas leak?
- problem in O_2 monitor?

Analytic Formula of Spatial Resolution

slide from LCWS2013

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

Obtained Knowledge

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

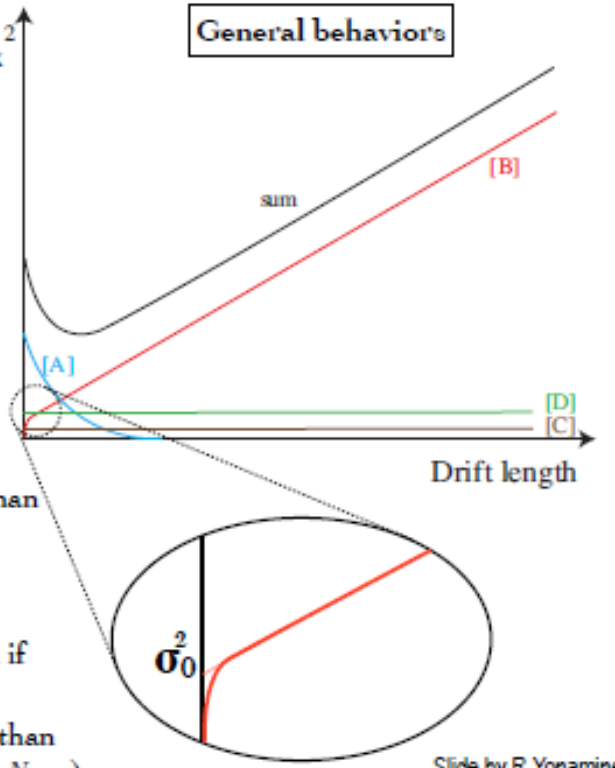
  disappears if $\sigma_{PR}/w \gtrsim 0.4$
  (long drift length or inclined tracks)
- [B] : diffusion effect

  - 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 $\sigma_0^2 = [A]_{\tan\phi=0}/N_{eff}$.
  - 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

(Now in Universite Libre de Bruxelles)

Ryo Yonamine's PhD thesis

[A]: systematics due to finite pad size

[B]: diffusion effect

[C]: electronic noise effect

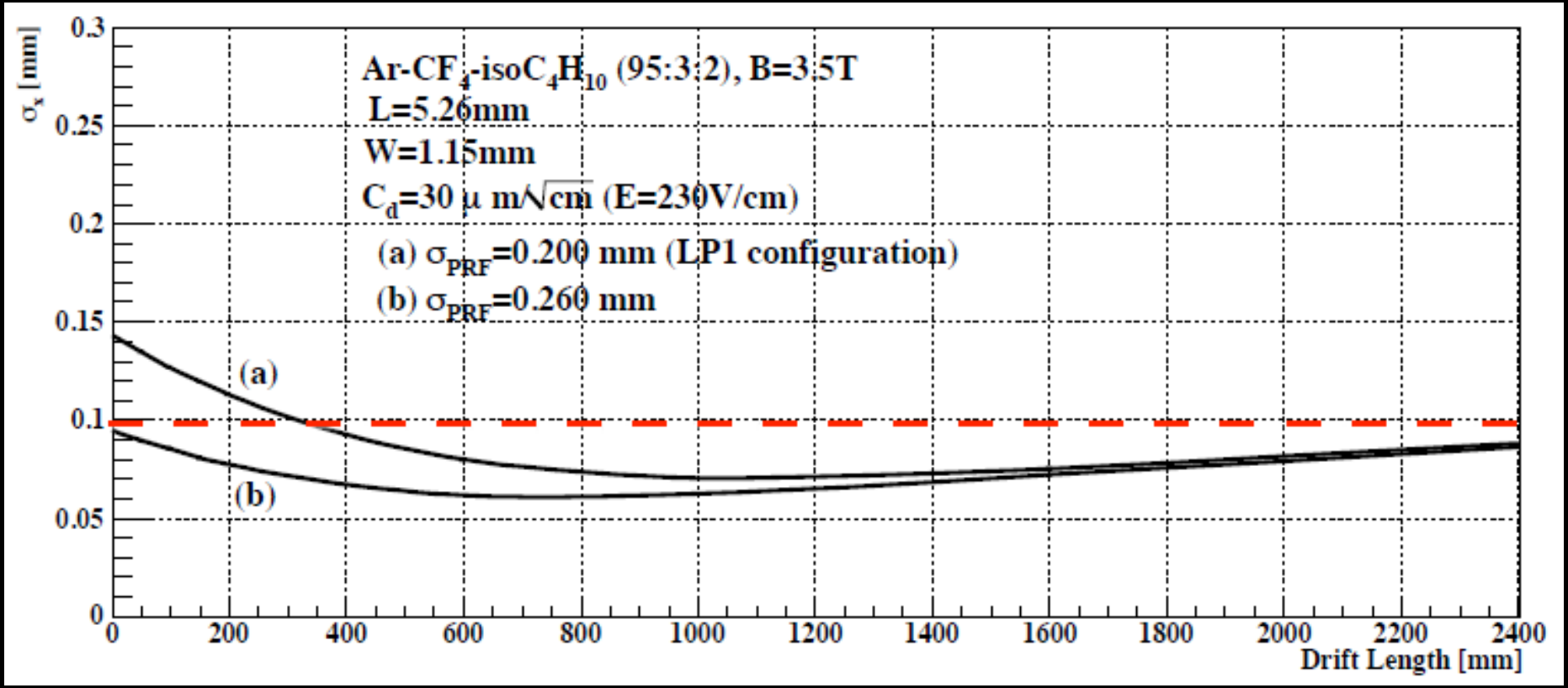
[D]: primary cluster fluctuation

Analytic Formula of Spatial Resolution

- The analytic formula can explain the behavior of 2010 data well.
- The spatial resolution for the drift length can be understood. ---> extrapolated to real ILD-TPC

Extrapolation to ILD-TPC

slide from LCWS2013

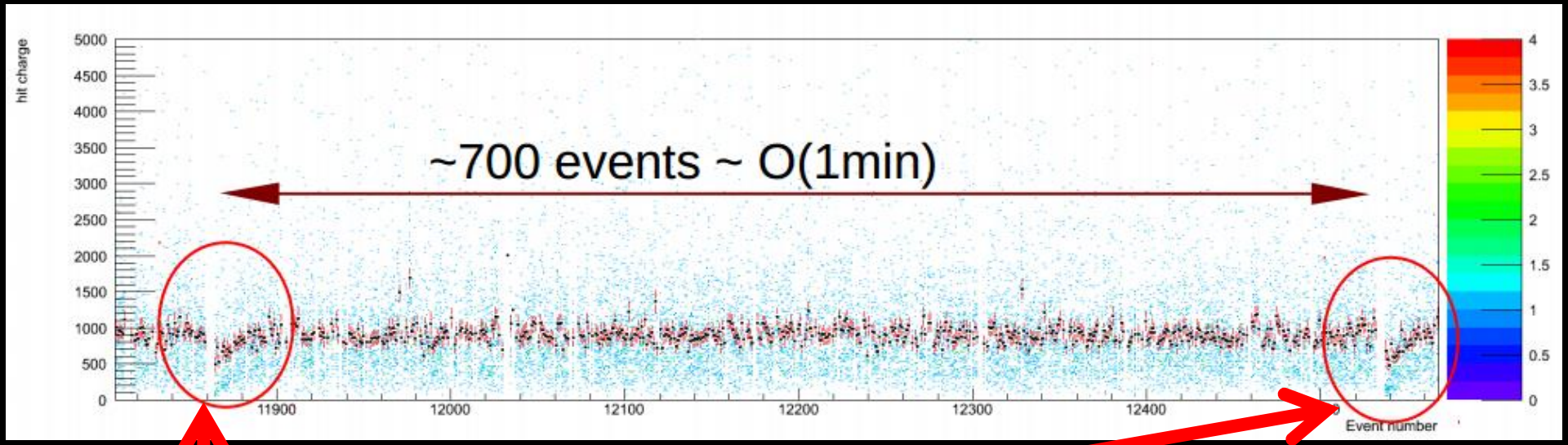


The expected performance from the beam test satisfies the requirement of ILD-TPC.

Study of GEM Discharge

Discharge Problem

by P. Gros



Gain drops found ---> caused by discharge

Current discharge rate is too high.: ~O(10^{-3} - 10^{-4}Hz)

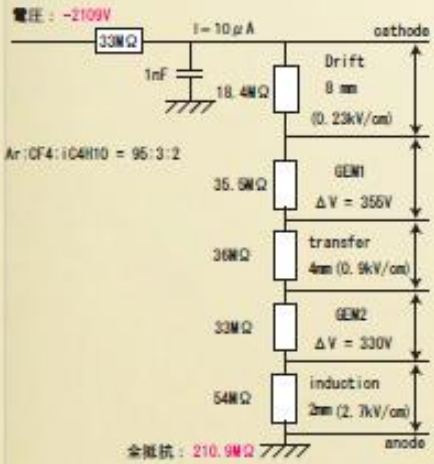
Study of GEM Discharge

- We observed a lot of discharges.
- Kato-san (Kinki U.) is now working on the GEM discharge experiment.

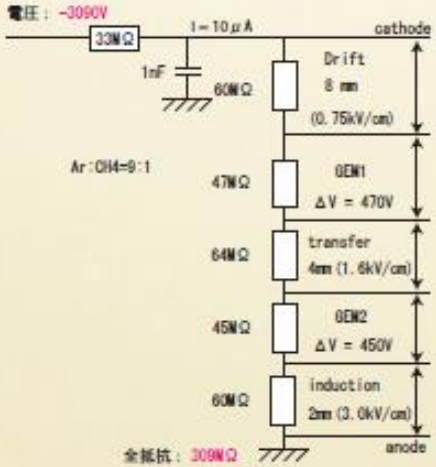
Temporary measurement system

by Y. Kato

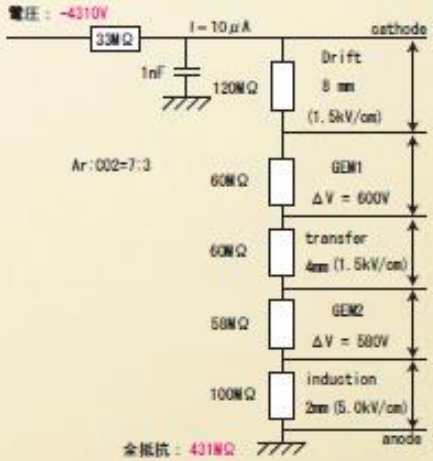
- small GEM module (20X20X4.8 cm)
- Gas pipe: Cu(input), polyolefin(output)
- HV module: CAEN N1470A (resolution - 5nA)
- GEM: Scienergy 100μm (10cm X 10cm)
  double GEM structure (same as large prototype)
- Gas: P10, Ar 70%+CO_2 30%,
  T2K(Ar 95%+CF_4 3%+i-C_4H_{10} 2%)



T2K



P10

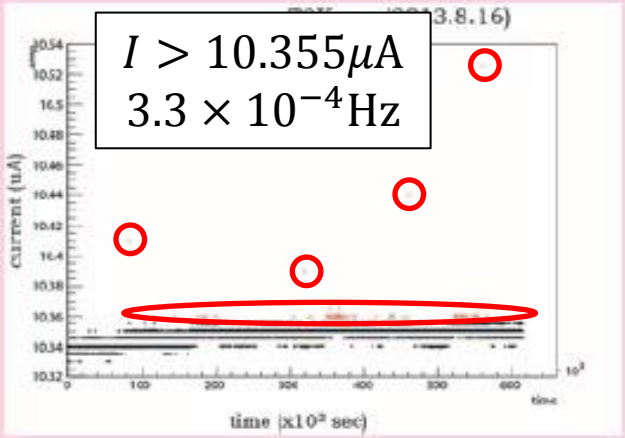


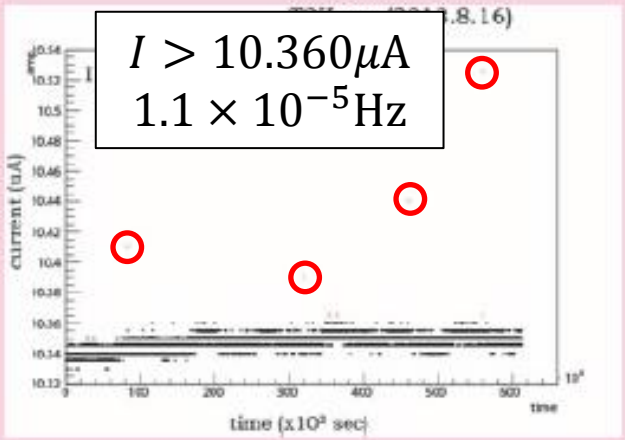
Ar 70%+CO_2 30%

can't apply the voltage because of discharge

Result

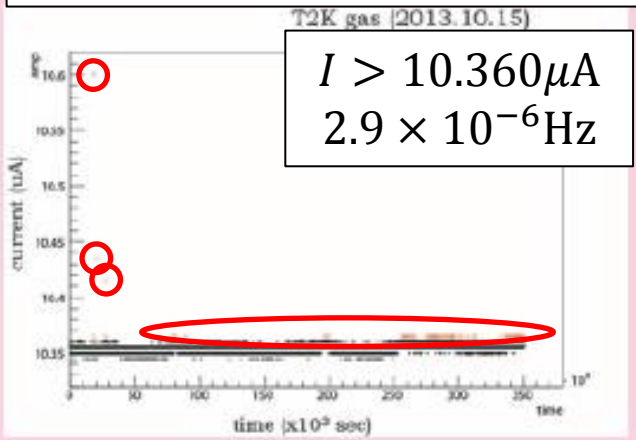
T2K gas (2013.8.16)

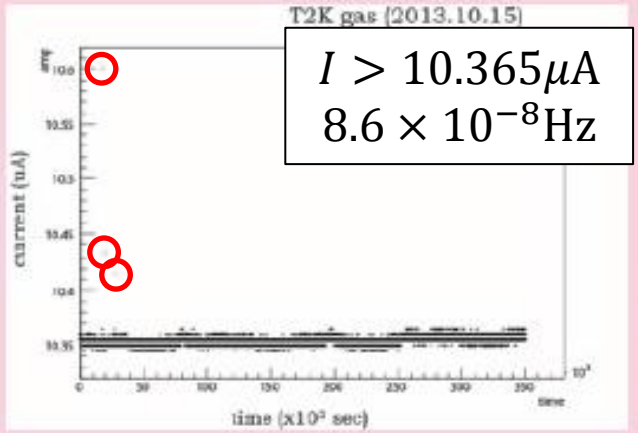




one of two GEM is a different

T2K gas (2013.10.15)





definition of discharge rate :

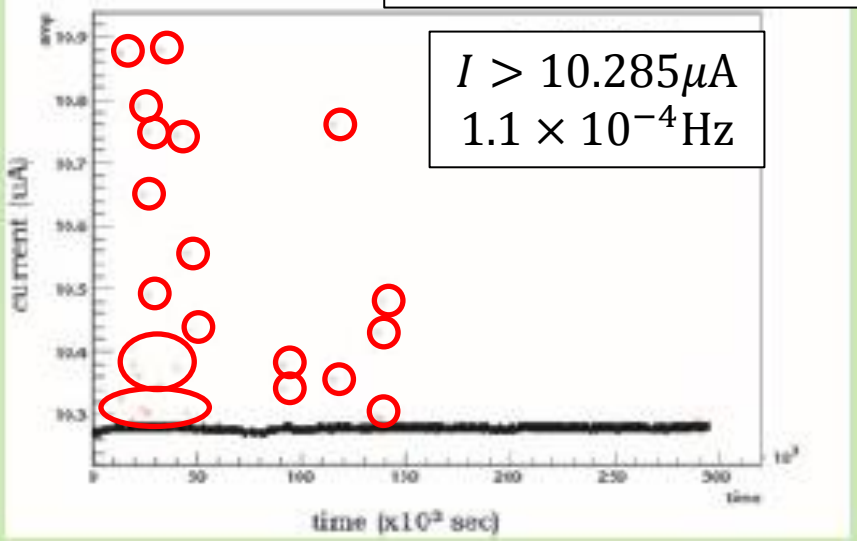
# of over the value (nominal current + 0.005uA or 0.010uA) in the measurement period

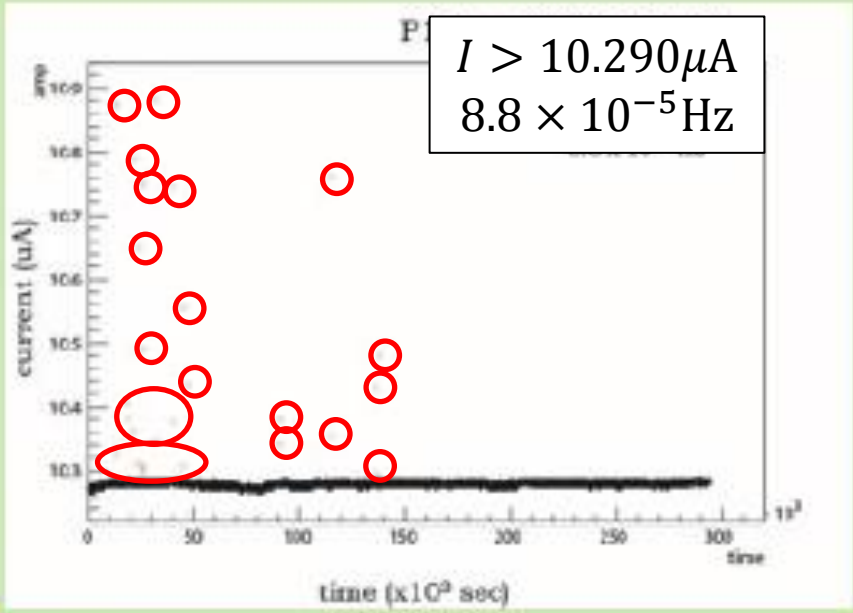
nominal current - most appearance number of value in the measurement period

by Y. Kato

by Y. Kato

P10 gas (2013.10.10)





same two GEMs were used with T2K gas (2013.10.15)

discharge rate is higher than T2k gas data (2013.10.15)

Results of Discharge Experiment

- The discharge rate of T2K gas and P10 gas were measured without gain calibration.
- The discharge rate of T2K is lower than that of P10.
  - T2K: $< 1.1 \times 10^{-5}\mathrm{Hz}$
  - P10: $8.8 \times 10^{-5}\mathrm{Hz}$
- More studies are needed --- ongoing

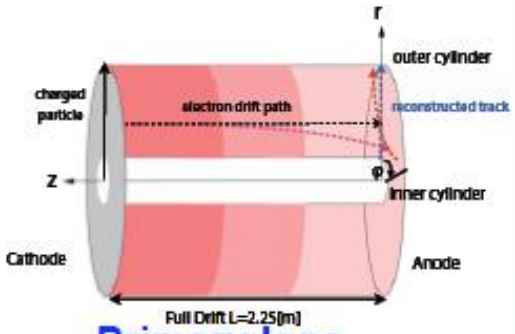
Gate Device

Effects of Positive Ions

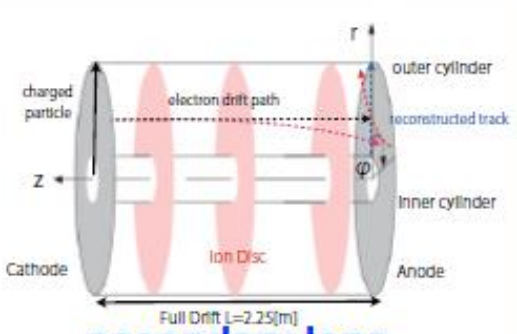
slide from LCWS2013

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.

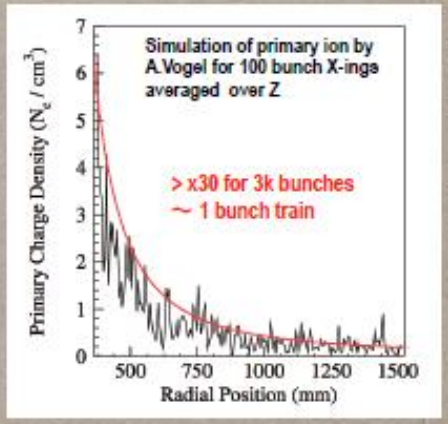
Estimate the effects



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

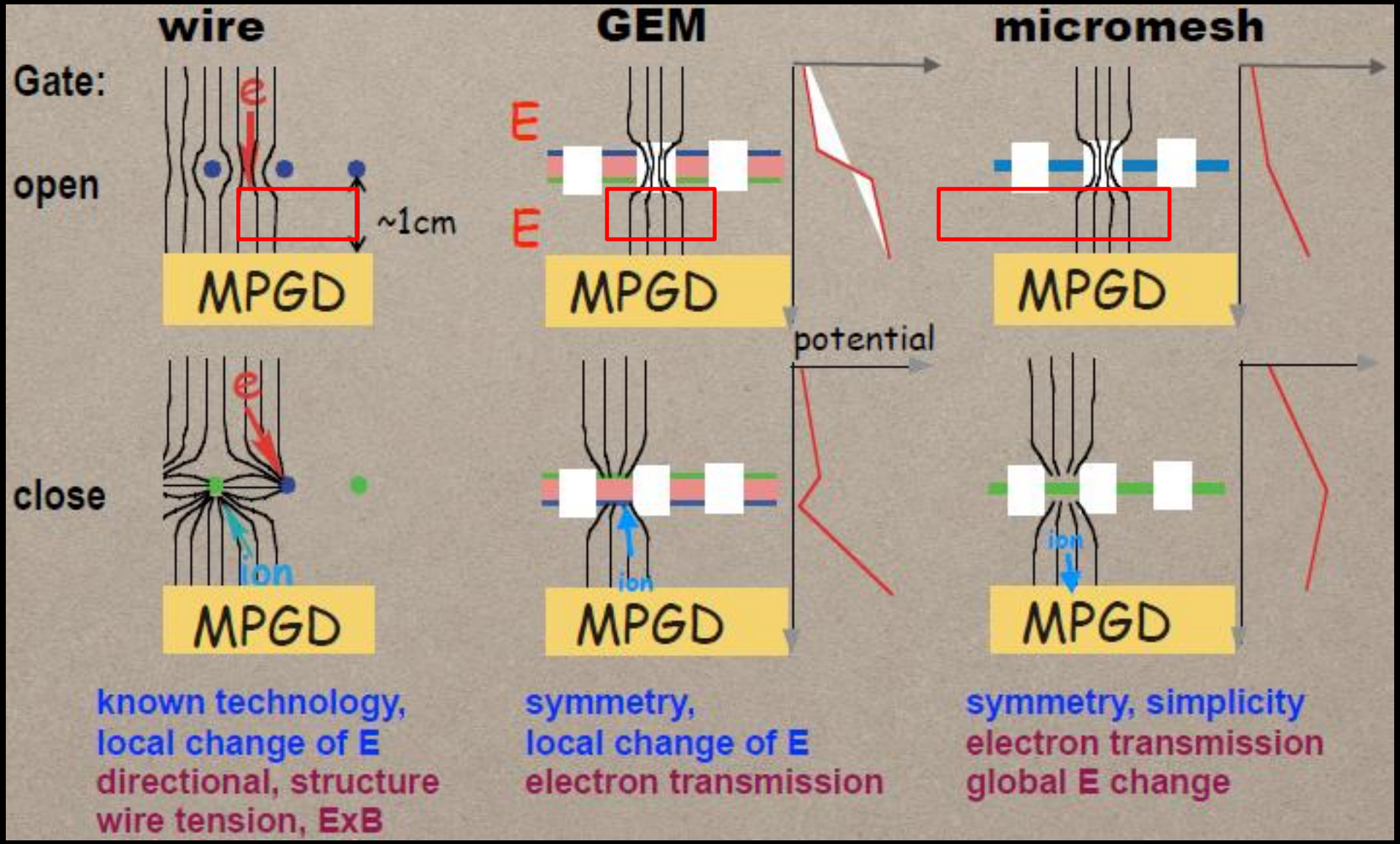
	without Gating Device	with Gating Device
Primary Ion	8.5 μm	8.5 μm
Secondary Ion	60 μm	0.01 μm
sum	70 μm	8.5 μm

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

Ion Gate Device

slide from LCWS2013



Wire gate module

slide from LCWS2013

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

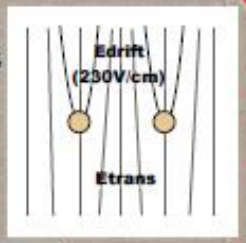
Prototype were built for test

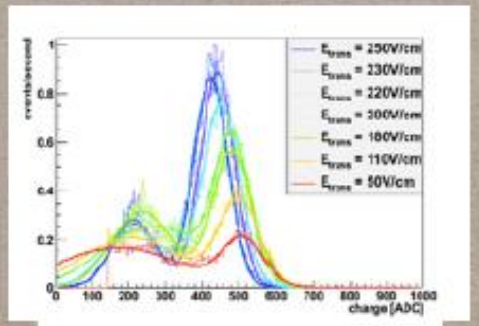
- 30μm wires, 2mm pitch
- spot welded on stainless steel frame
- only one potential : no alternate potential closed gate scheme

Test with Fe55

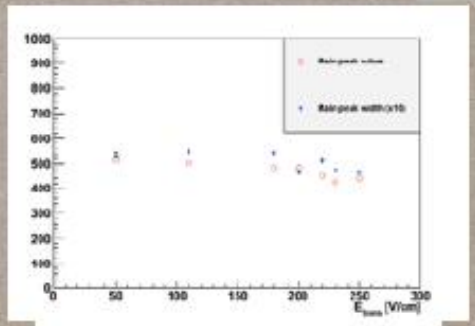
Take Fe55 spectra for different HV configurations

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





charge distribution

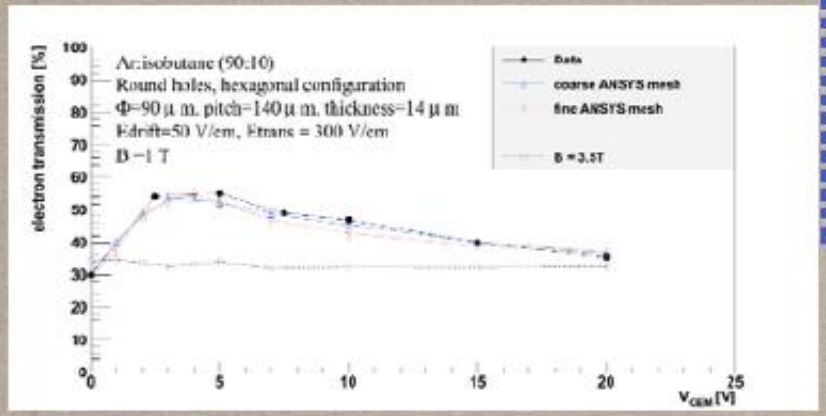


peak distribution

next to laser test

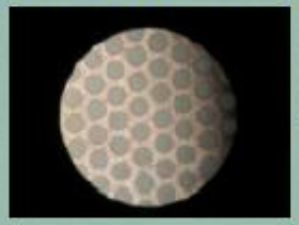
Study of GEM gate

slide from LCWS2013



Problem of current GEM gate

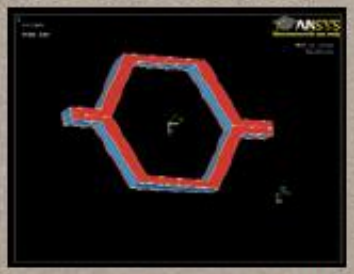
electron transparency to low current gate - 35% at B=3.5T



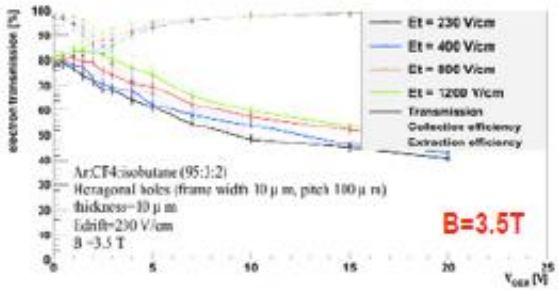
current GEM gate
Φ90μm, pitch 140μm, t 14μm
=> 37% geometrical aperture

Design of large aperture GEM gate

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



large aperture design by ANSYS



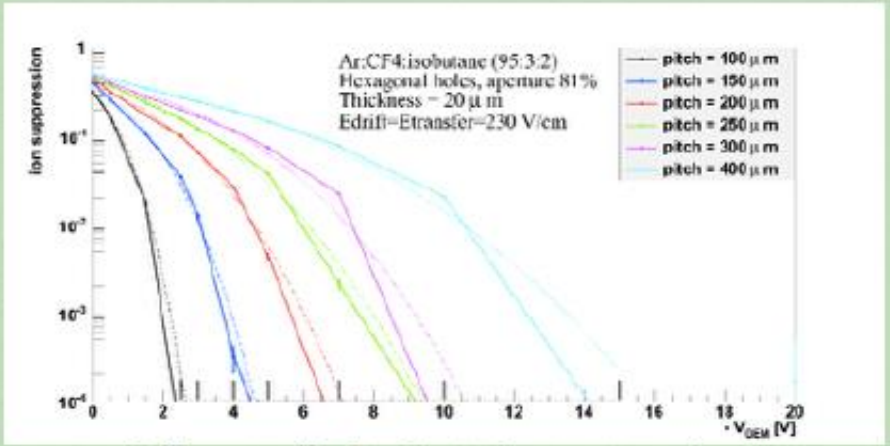
Large aperture gate simulation

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

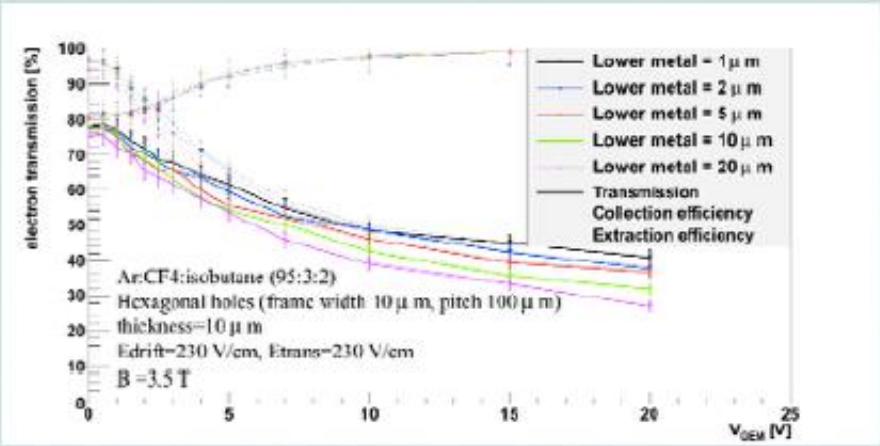
High transparency GEM gate

How to build a high transparency gate ?

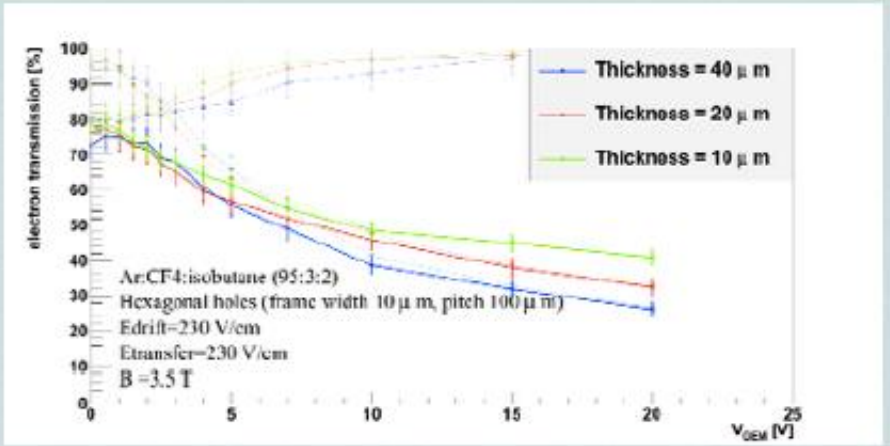
- Key item is to keep large apertures
- A mechanically sound GEM gate with large aperture might be feasible
  - with thicker, harder metal
  - with wider holes -> 400μm holes, 40μm structure?



influence of hole size to ion suppression



influence of thicker metal

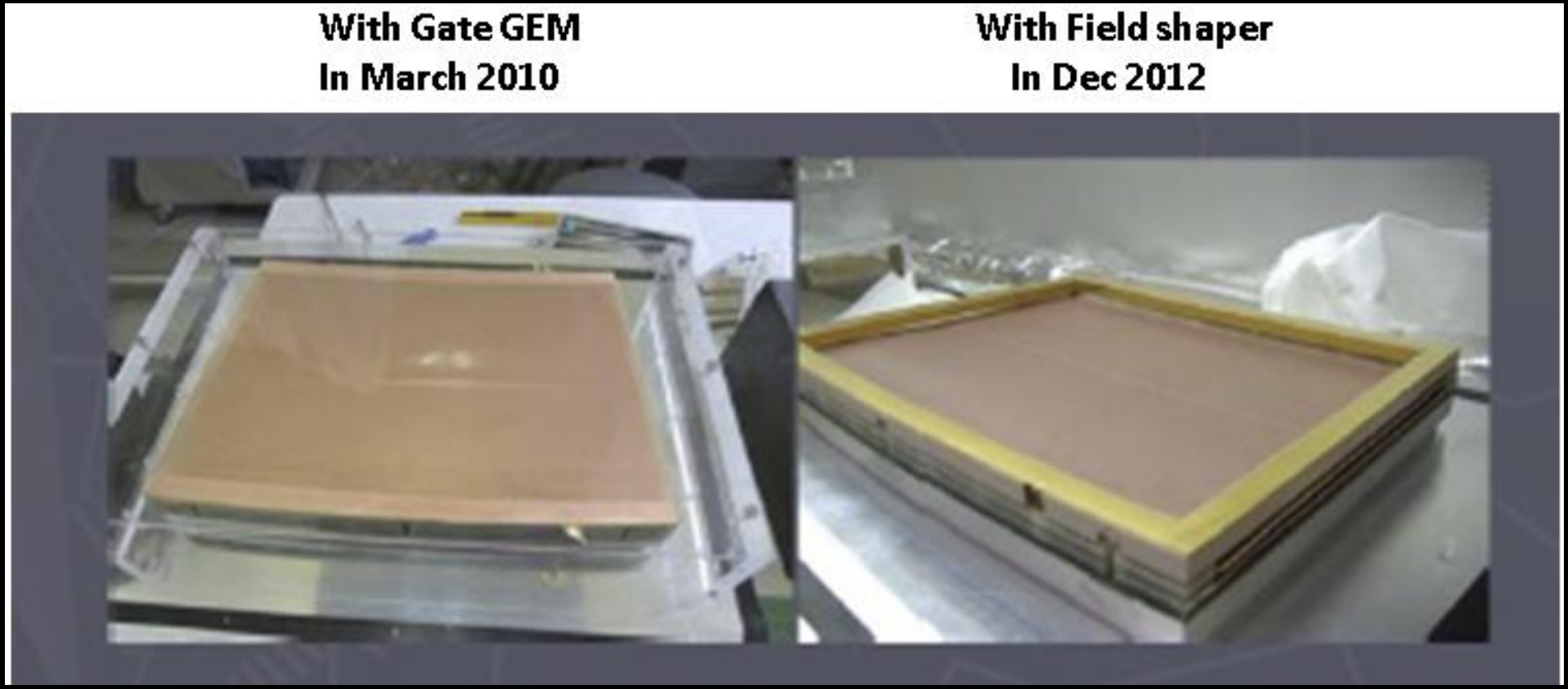


influence of thickness

Next Module Design (Mock-up System)

Current Asian LP GEM Module

by T. Matsuda



Current Asian LP GEM Module

(a) Module structure: The common fan shape of about 17cm x 22cm.
Minimize the dead/distortion regions in rϕ between modules, while tolerate minimum (significant?) dead regions in the radial direction:

→ Stretch two GEM and a gate GEM on the pad plane between its upper and bottom sides:

→ No side frames of GEM, though we have not measured its advantage yet.

After we have the HV breakdown in March 2010 we have used the field shaper which covers all sides of the module, and makes unable to test the advantage. A test under preparation with a laser beam.

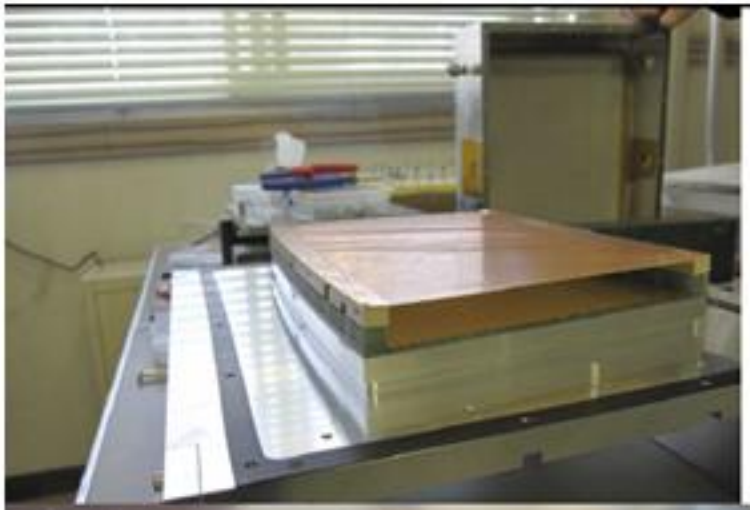
(b) GEM: Use two layers of a 100micron think GEM (LCP). The GEM with straight GEM holes is produced by a process of laser etching + de-smear (chemical).

(c) Gate GEM: Mount a thin Gate GEM (an electron transmission of about 50% at 1T). Damaged in the major module breakdown in March 2010. Not tested in the beam.

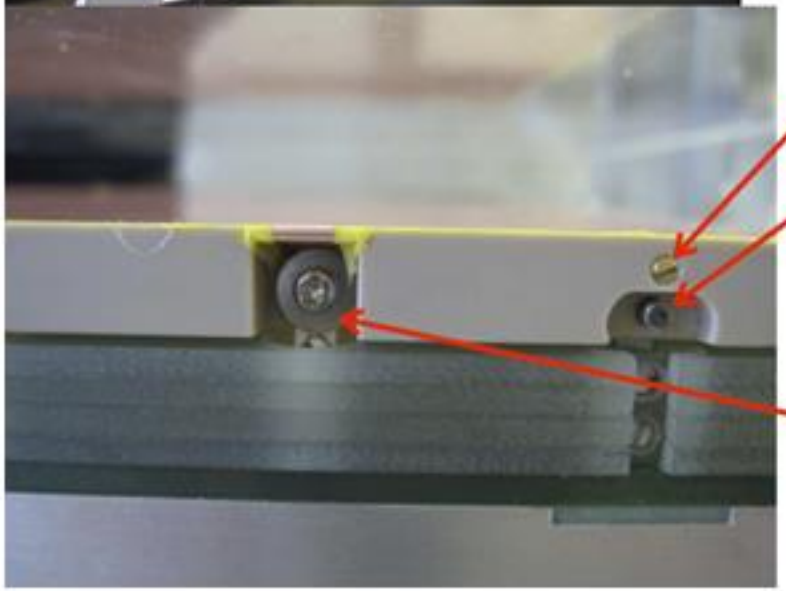
(e) HV supplies to GEMs/Gate GEM: In general tends to become complicated due to the GEM stretching on the pad plane.

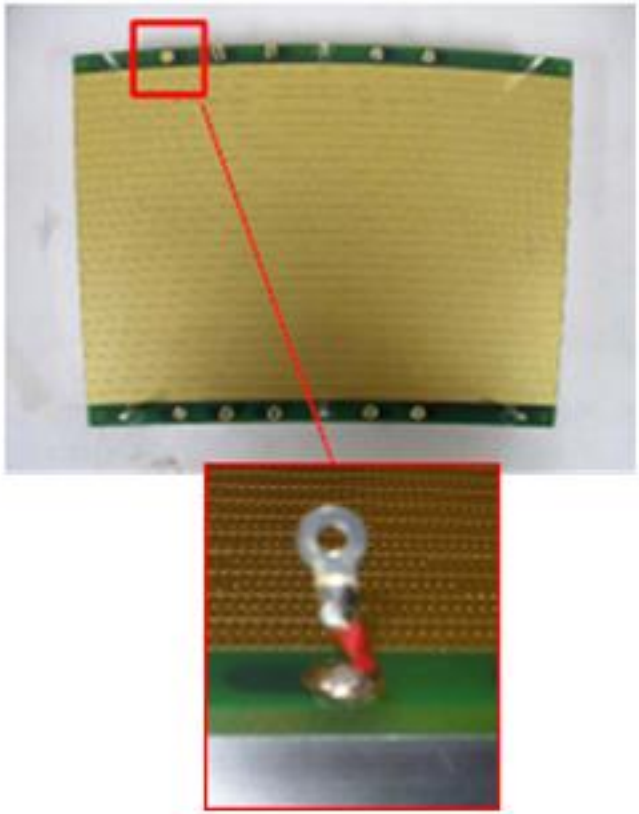
Current Asian LP GEM Module

by T. Matsuda



Stretch test on GEM module
without GEM





Problems & Issues

by T. Matsuda

(a) HV breakdown of GEM and module:

Destroy significant No. of the PAC16 amplifiers in 2009 & 2010.

← (i) Higher micro-discharge rate of the GEMs (still exist!) with
(ii) Large segmentation of the GEM electrodes (cured in 2012)

← Limited mechanical (position) precision of GEM on the pad plane (discharges to the filed cage/dummy modules/filed cage) (not occurred in 2012)

← A lose small component (a metal washer to improve the HV connection) triggered a large scale HV breakdown. (only happened in March 2010)

(b) GEM stretching on the pad plane using the metal posts.
(c) Limited No. of HV connections.
(d) Mechanical precision of module (The structure should ensure the precision.)
(e) Mass production and reliable operation in ILD → Simpler and reliable structure with less components. (Need the industrial standard for ILD TPC.)

Next Asian LP GEM Module

Next Asian LP GEM-Module

by T. Matsuda

One step toward the ILD TPC module

(A) **Two possible structures of the GEM module :**

(1) With pre-tensioned GEMs glued on an all-sides thin frame (a la DESY),

(2) With a GEM stretched on the pad plane (a la Asian)

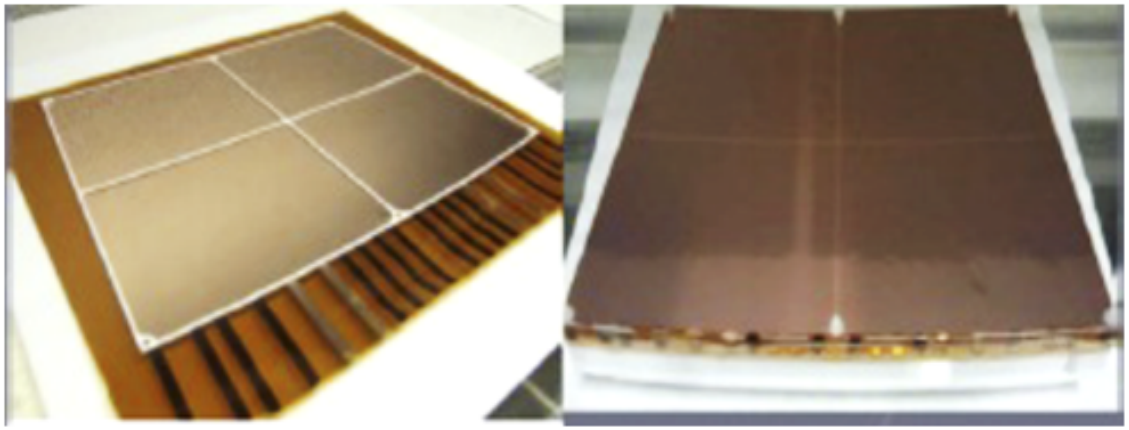
← Which gate device, a GEM gate or a wire gate? (Mechanical issue)

← How much dead/distortion regions on the sides of the modules, and at the additional crosspieces (a la DESY)?

← Do we need (thin) side frames (i) to ensure no ion leak, and (ii) to add some field shaping electrodes (on the both sides) to minimize the local distortions?

(← How do we proceed the collaboration with the DESY/German group for the GEM module when our man power is so much limited?)

DESY GEM module: Triple CERN GEM with thin (1mm) ceramic GEM frame (white).



Next Asian LP GEM Module

Next Asian LP GEM-Module

by T. Matsuda

One step forward to the ILD TPC module

(B) Our final choice of GEM?

- ← The rate of the micro discharges regarding to the overall ILD TPC efficiency?
- ← Why 2/3 layers of GEMs?
- ← Why 50/100 micron GEM?
- ← The best shape of GEM hole, and the best production process?
- ← The supply and the price of GEM.

(C) The issue of the many HV connections is common to the both GEM solutions.
(The current DESY solution seems not to be very elegant for me, but may be workable.)

For (A) and (B) still no clear answers exist yet. Nevertheless, we (the Japanese TPC group) decided more than a year ago to continue on (2), probably because we chosen the complementary solution to the DESY/German group.

Mock-up Study

by T. Matsuda

Goals: (a) Miniature GEM HV connections made of commercial components molded in the GEM frames: already tested by a small test piece.

(b) Can be consistent with a GEM stretching mechanism on the pad plane (no side frames) - No! → Fixed positions of the GEM frames on the pad plane.

(c) Can we accommodate 2/3 layers of GEMs (yes). 50/100microns (let's try!)

(d) A simple structure with less components still stretching GEMs on the pad plane.

(e) Guarantee the precision of the module (the positions of the GEM frames on the pad plane) → Fixed positions of the GEM frames on the pad plane.

Our approach to the current mockup (with no gate device at this stage)

(i) The first trial: the standard 50micron (easier) / three layers (more difficult) GEMs → 100micron GEM might be too strong?

(ii) Apply some pretension of GEM when glue the top/bottom fames (on a flat jig): → How do we control the pretension? What accuracy of gluing?

(iii) Stretch and pile up the framed GEMs by using steps made on the GEM frames → No more adjustment to stretch GEMs.

(iv) Hold the framed GEMs by non-metal screws.

(v) Insert the HV pins.

A few months delay already.!

The first GEM stretching and mockup assembly by the end off January.

Mock-up Study

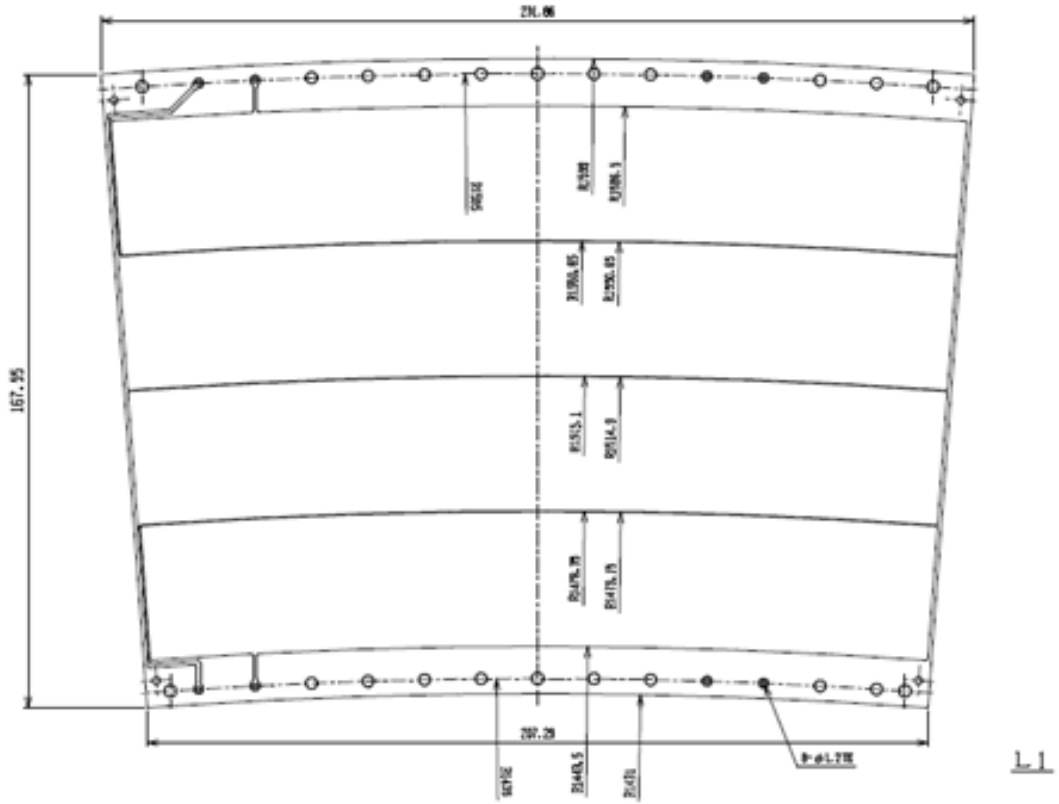
by T. Matsuda

Next Asian LP GEM-Module

GEM with GEM holes for this Mockup

50micron/polyimide, the chemical process with the standard GEM pattern

To be fabricated in this Dec. by RAYTECH.



Summary

Summary

- We took various data at the 2012 beam test. Expected performance by the beam test satisfies the requirement of ILD-TPC.
- GEM discharge study is now ongoing.
- Local field distortion study with laser: next talk
- We need gate device for ILD-TPC. Studies for wire gate and GEM gate is now ongoing.
- Development for next Asian LP GEM module (Mock-up system) is now ongoing. The first assembly will come by the end of January.