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# Status of the Continuous Ion Back Flow Module for CEPC-TPC

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# Outline

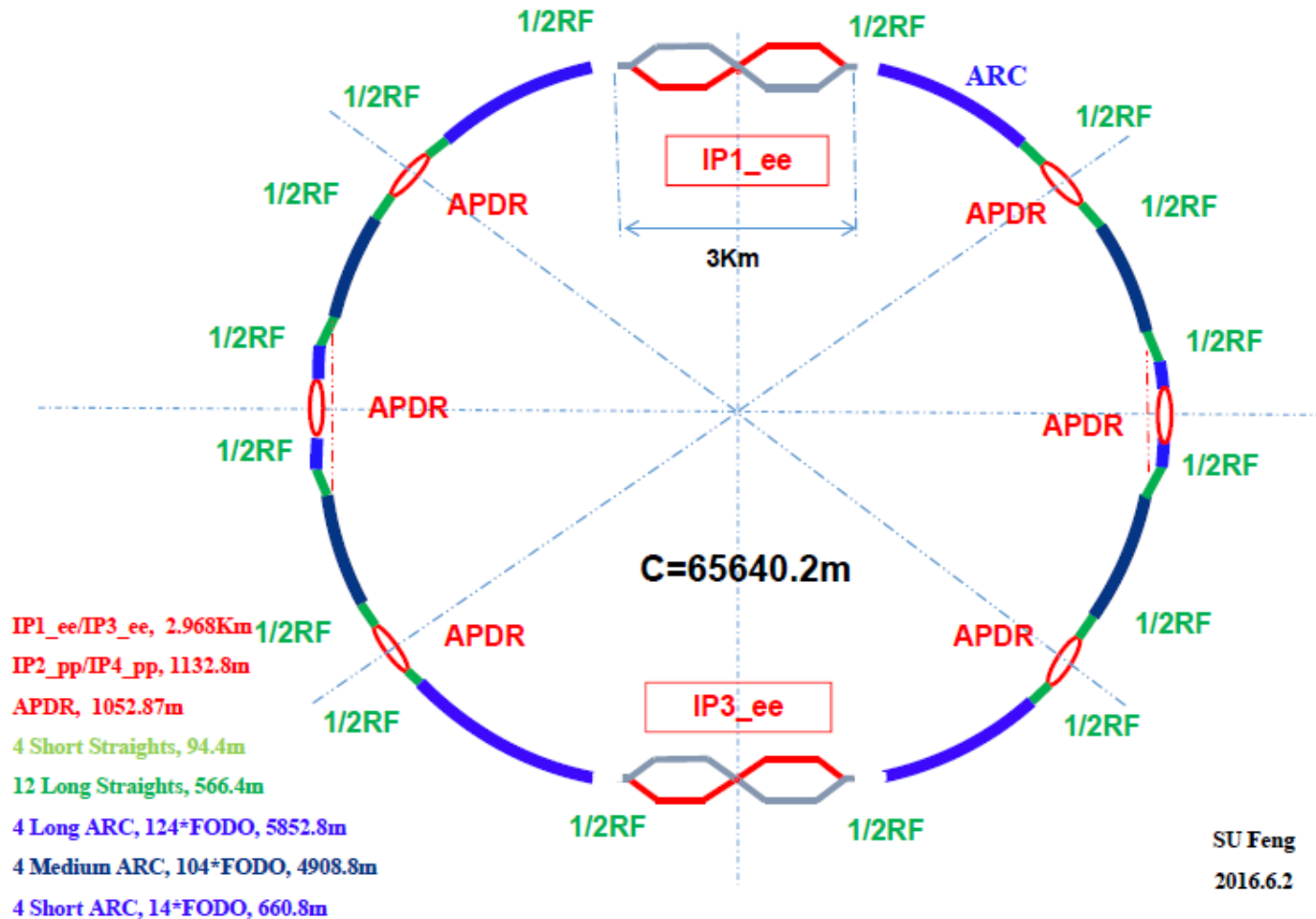
- Motivation and goals
- Hybrid Gaseous Detector Module
- R&D Progress of the module
- Summary

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# Motivation and goals

# Requirements of CEPC-TPC

## CEPC Advanced Partial Double Ring Layout II



From Prof. Gao Jie Slides

# Requirements of CEPC-TPC

- Physics requirements for CEPC tracker Detector

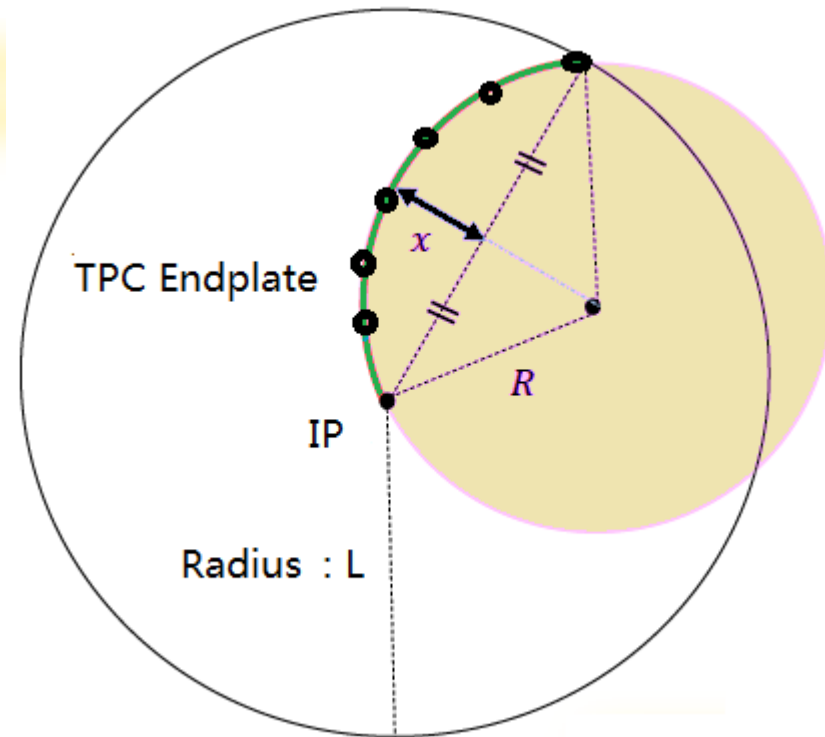
$$\frac{\sigma_{P_T}}{P_T} \simeq \sqrt{\underbrace{\left(\frac{\alpha' \sigma_x}{BL^2}\right)^2 \left(\frac{720}{n+4}\right) P_T^2}_{\text{measurements}} + \underbrace{\left(\frac{\alpha' C}{BL}\right)^2 \left(\frac{10}{7}\right) \left(\frac{X}{X_0}\right)}_{\text{multiple scattering}}}$$

R.L. Gluckstern, NIM 24 (1963), 381

- Goal: momentum resolution

$$\sigma(1/p_T) = 10^{-4} \text{GeV}^{-1}$$

- Track number: **~200**
- Position resolution: **~100 $\mu\text{m}$**
- Magnet field: **3T~5T**
- PID
- ...

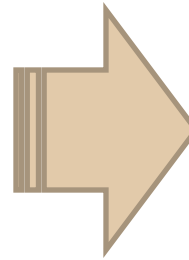


Momentum resolution measurement

# TPC Module baseline design

## ■ MPGD module as readout

- ❑ GEM as readout
- ❑ R/Micromegas as readout
- ❑ Beam test in smaller magnet
- ❑ Easily assemble in the endplate
- ❑ Common effort R&D



ILD design  
CEPC Baseline design  
Module design

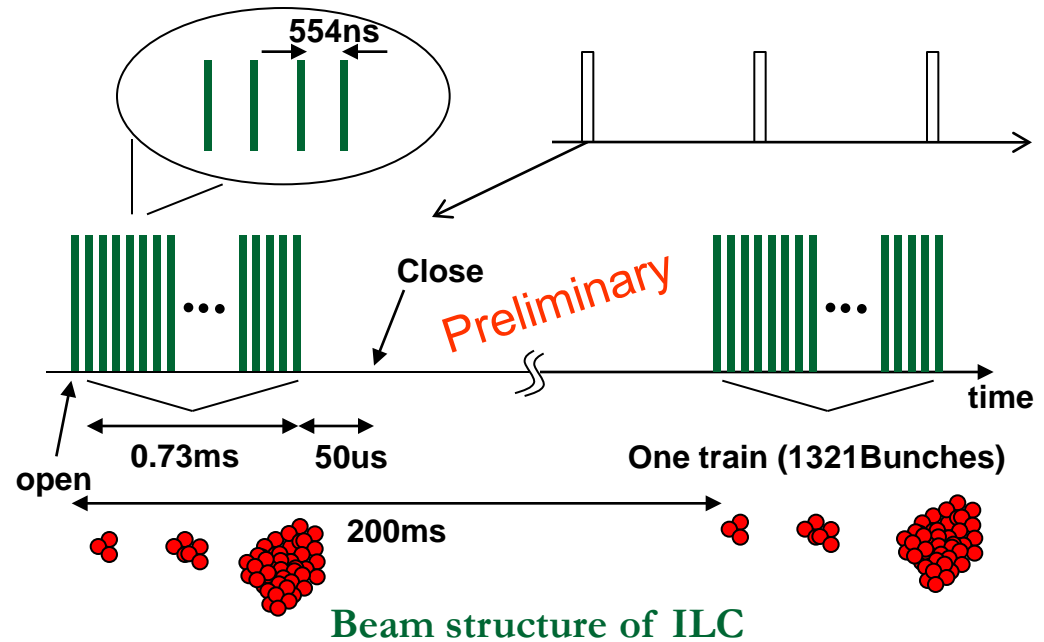
## ■ $r$ - $\Phi$ segmentation

- ❑ Limited by the induction readout
- ❑ Gas amplification due to an avalanche electron and ions
- ❑ Induction signal on the Pad (W and H)
- ❑ 2-track separation

# Compare with ILC beam structure

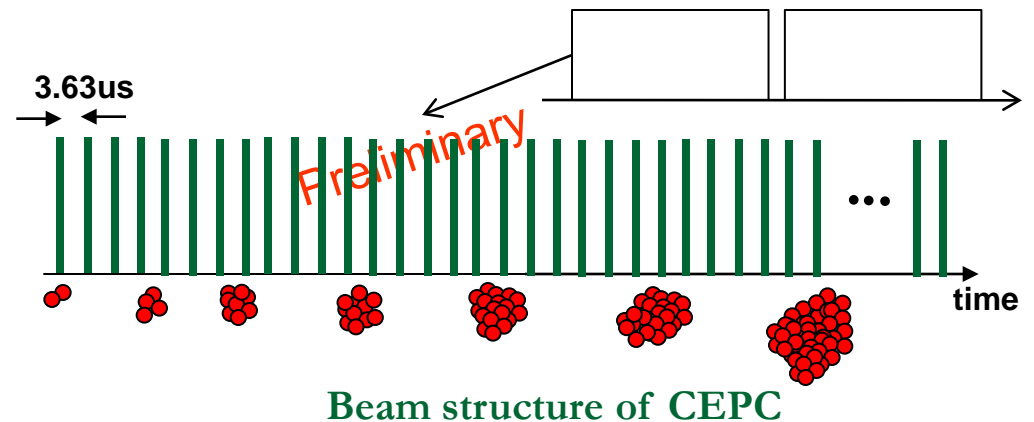
## □ In the case of ILD-TPC

- Bunch-train structure of the ILC beam (one  $\sim 1\text{ms}$  train every 200 ms)
- Bunches time  $\sim 554\text{ns}$
- Duration of train  $\sim 0.73\text{ms}$
- Used Gating device
- Open to close time of Gating:  $50\mu\text{s} + 0.73\text{ms}$
- Shorter working time



## □ In the case of CEPC-TPC

- Bunch-train structure of the CEPC beam (one bunch every  $3.63\mu\text{s}$ ) or partial double ring
- No Gating device with open and close time
- Continuous device for ions
- Long working time



**NO Gating device !**

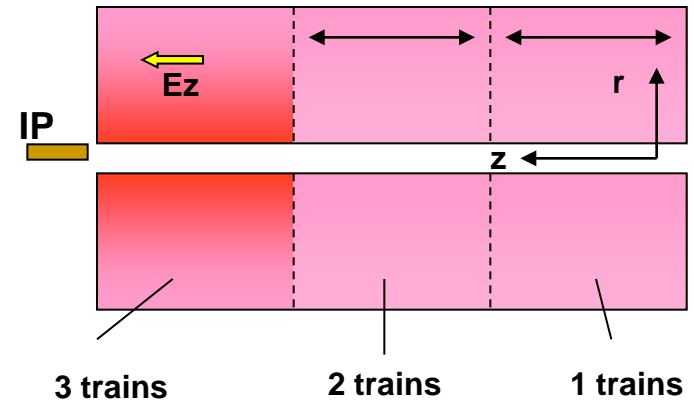
# Critical challenge: Ion Back Flow and Distortion

## In the case of ILD-TPC

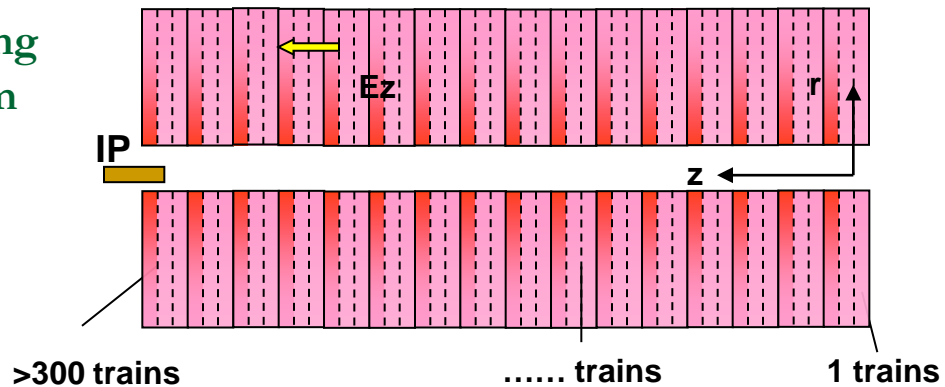
- ❑ Distortions by the primary ions at ILD are negligible
- ❑ Ions from the **amplification** will be concentrated in discs of about 1 cm thickness near the readout, and then drift back into the drift volume Shorter working time
- ❑ **3 discs** co-exist and distorted the path of seed electron
- ❑ The ions have to be neutralized during the 200 ms period used gating system

## In the case of CEPC-TPC

- ❑ Distortions by the primary ions at CEPC are negligible too
- ❑ **More than 300 discs** co-exist and distorted the path of seed electron
- ❑ The ions have to be neutralized during the  $\sim 4\mu\text{s}$  period **continuously**



Amplification ions@ILD

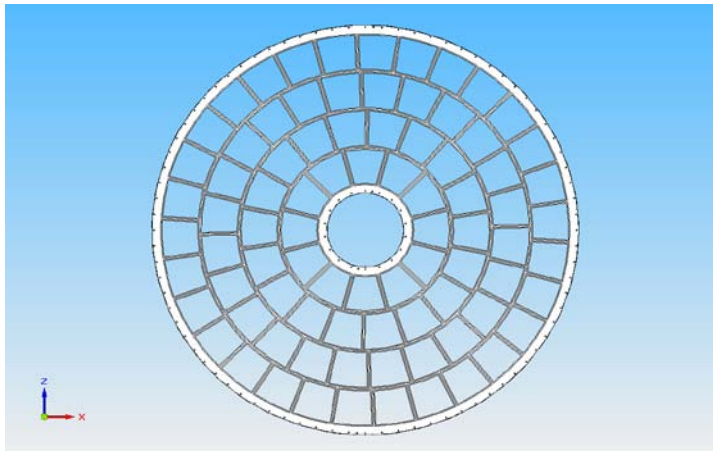


Amplification ions@CEPC

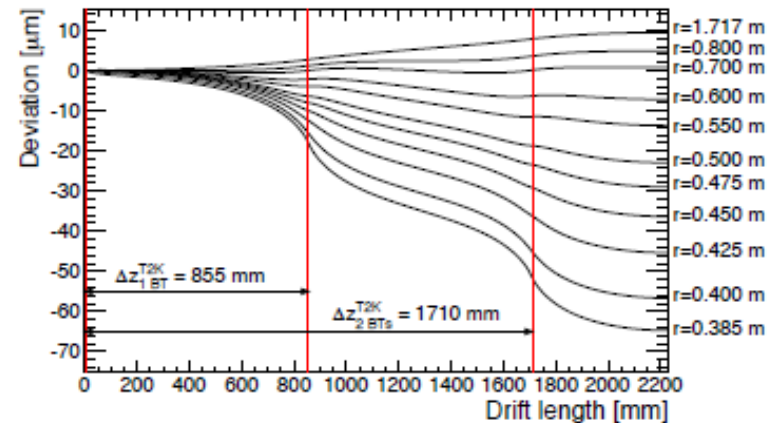
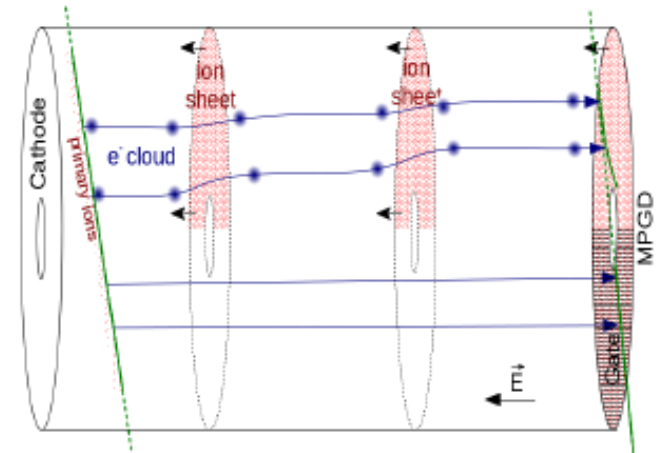


# $E_{\text{drift}}$ Distortion

- High performance requirements by the TPC relies strongly on the quality of the electric field in the drift volume
  - Ions drift back into the gas volume in CEPC TPC
  - Many such the discs in the chamber with ions
  - Ions could reduce the momentum resolution along the drift length
  - Ions should have to be neutralized



Layout of the endplate



Ions simulation @ILD TPC  
From Fujii's slice

# Requirements of Ion Back Flow @CEPC

- Electron:
  - Drift velocity  $\sim 6-8\text{cm}/\mu\text{s}@200\text{V}/\text{cm}$
  - Mobility  $\mu \sim 30-40000 \text{ cm}^2/(\text{V}\cdot\text{s})$
- Ion:
  - Mobility  $\mu \sim 2 \text{ cm}^2/(\text{V}\cdot\text{s})$
 in a “classical mixture” (Ar/Iso)

$$S_N = \sqrt{\left(\frac{\partial f}{\partial x_1}\right)^2 S_{x_1}^2 + \left(\frac{\partial f}{\partial x_2}\right)^2 S_{x_2}^2 + \left(\frac{\partial f}{\partial x_3}\right)^2 S_{x_3}^2}$$

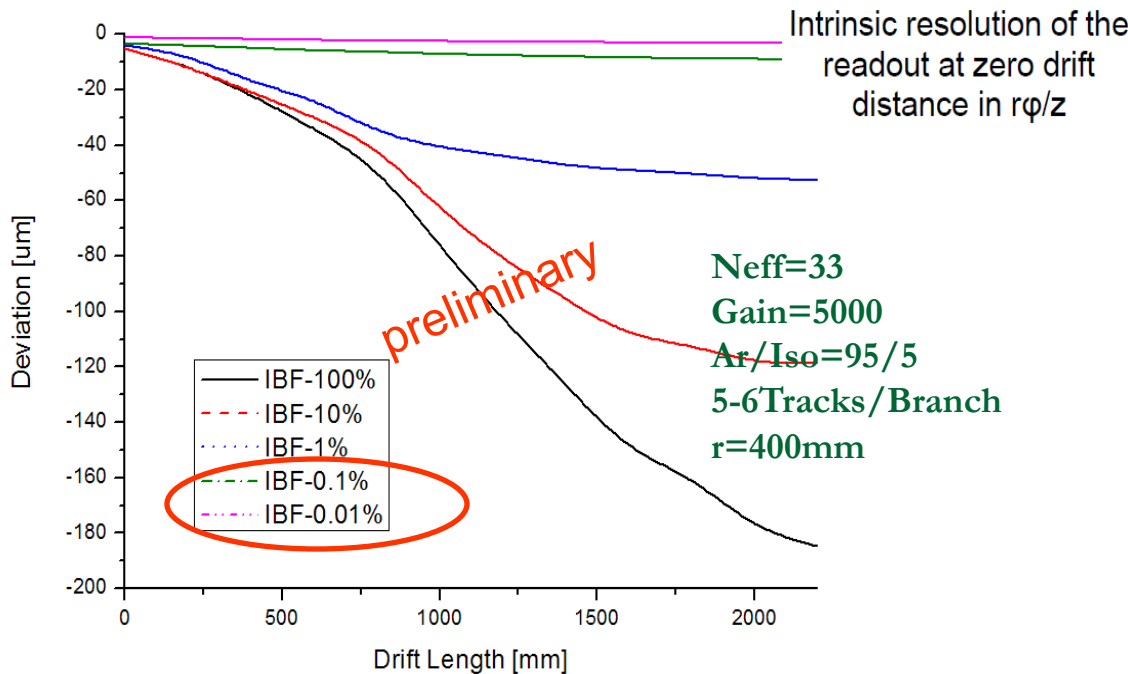
Standard error propagation function

$$\sigma_{r\varphi/z}(z) = \sqrt{\sigma_{0,r\varphi/z}^2 + \frac{D_{t/l}^2}{N_{\text{eff}} \cdot e^{-Az}}}$$

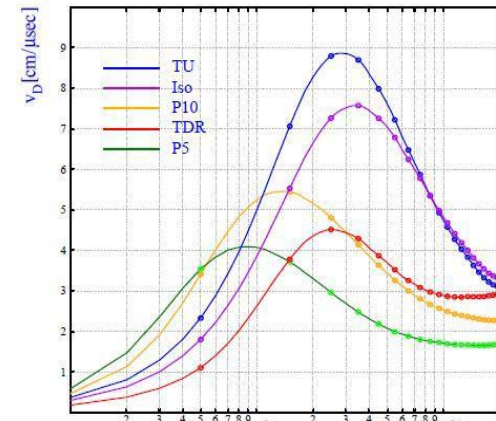
Transverse and molecules during drift

Effective number of primary signal electrons

Position resolution of the TPC function



Evaluation of track distortions due to space charge effects of positive ions

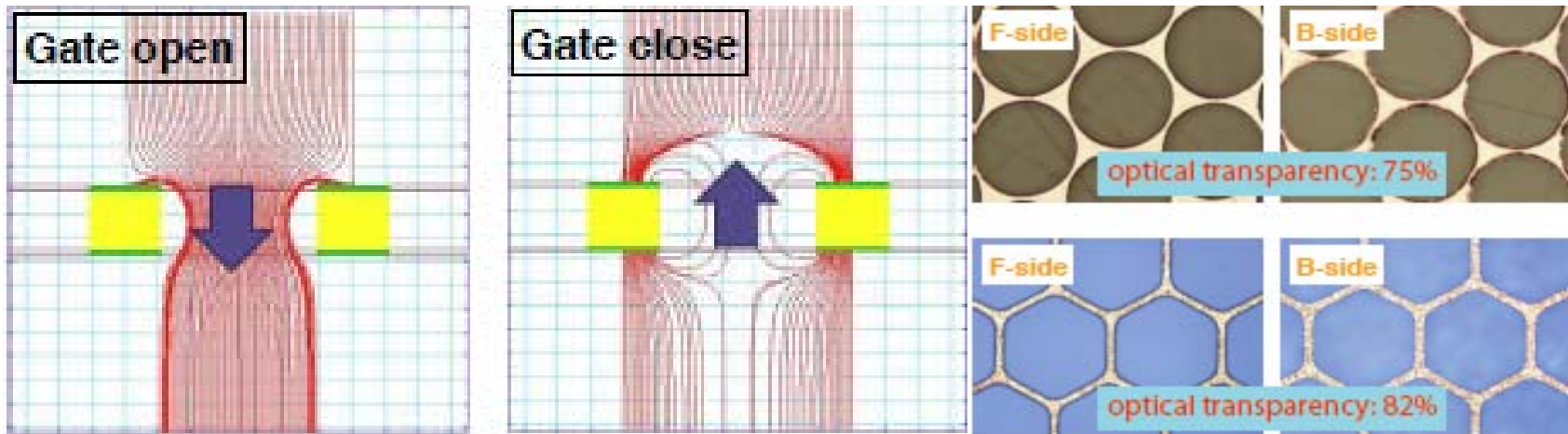


Simulated the drift velocity in different gas mixture

# How to reduce the avalanche ions?

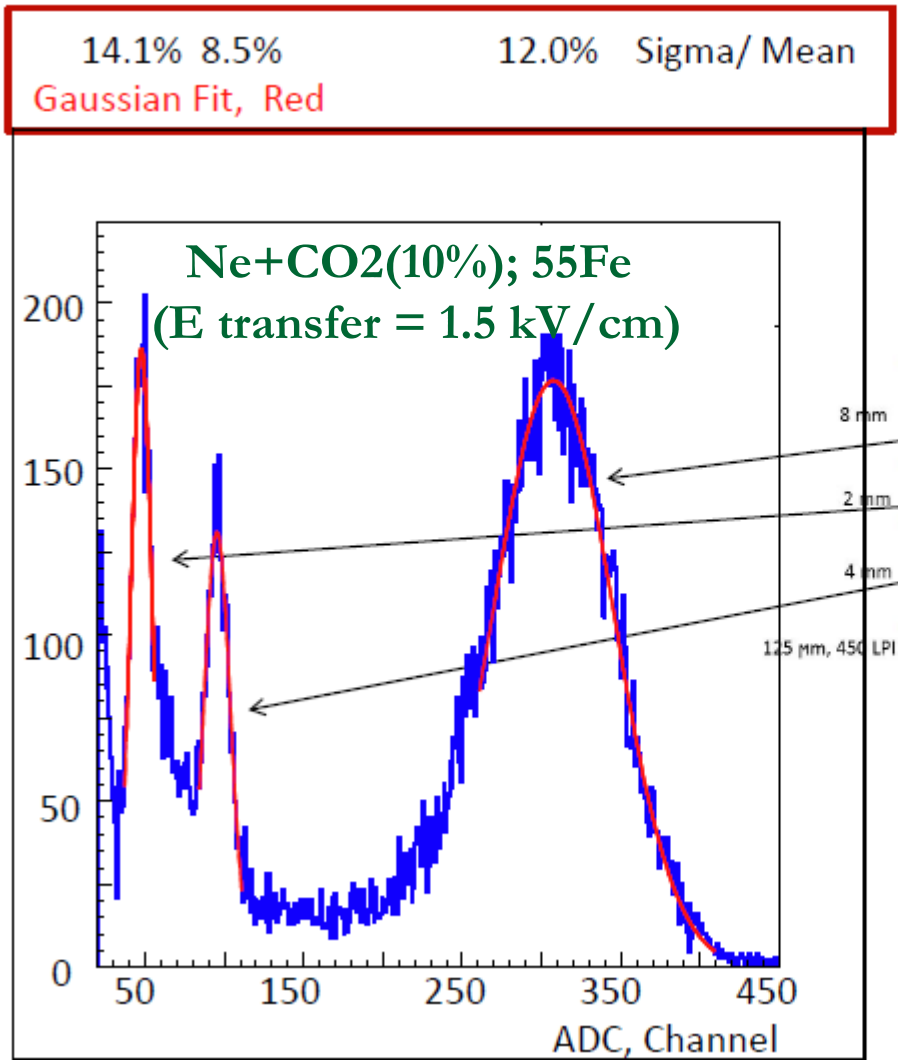
## Requirement for Gate GEMs of ILD-TPC

- Goal: 80% electron transmission = corresponding the deterioration in the spatial resolution  $\sim O(10\%)$  for the ILD-TPC nominal electric field configuration
- Operated in a 3.5 T axial magnetic field
- High optical transparency of the gate is required to ensure its high transmission rate of the electrons in the open state



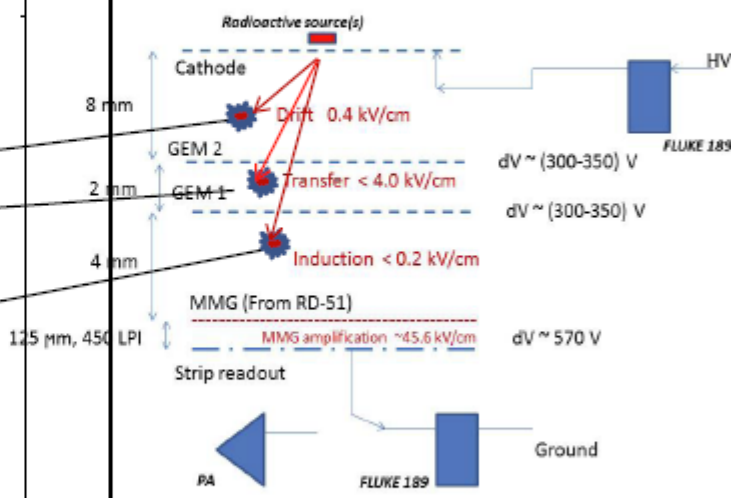
Gate device options of the ILC-TPC@KEK

# How to reduce the avalanche ions?



## Requirement for ALICE

- Goal: ALICE has decided to upgrade TPC for continuous readout ; high rate 50kHz ; Pile-up: ~5 events overlapping

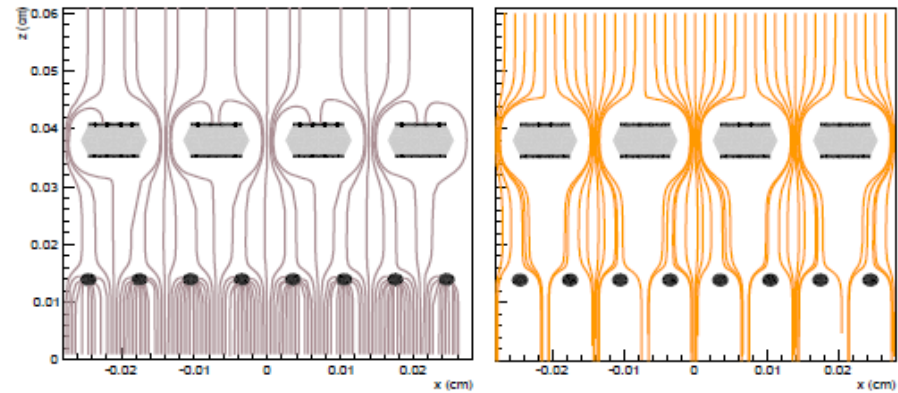


Gain GEM 2 (bot) ~ = 0.52  
 Gain (GEM 2 & GEM 1) ~ = 3.2  
 Gain GEM1 (top) ~ = 6.15

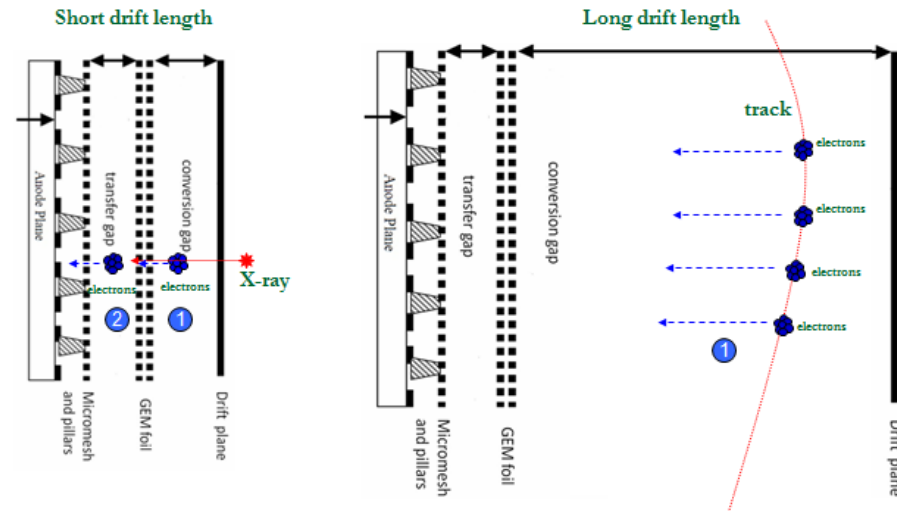
One option of the ALICE TPC Upgrade

# New ideas for the ions?

- ❑ Our group was asked to “think” on an alternative option for CEPC TPC concept design
- ❑ And we did our best ...
- ❑ We proposed and investigated the performance of a novel configuration for TPC gas amplification: GEM plus a Micromegas (GEM+Micromegas)
- ❑ Hybrid micro-pattern gaseous detector module
- ❑ GEM+Micromegas detector module
  - ❑ GEM as the preamplifier device
  - ❑ GEM as the device to reduce the ion back flow continuously
  - ❑ Stable operation in long time
  - ❑ Low material budget of the module



ANSYS-Garfield++ simulation  
(0T, Left: ions; Right: electrons)



Hybrid detector

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# Hybrid Gaseous Detector Module



# Test of the new module

Supported by 高能所创新基金

- ❑ Test of GEM+Micromegas module
  - ❑ Assembled with the GEM and Bulk-Micromegas
  - ❑ Active area:  $50\text{mm} \times 50\text{mm}$
  - ❑ X-tube ray and X-ray radiation source
  - ❑ Simulation using the Garfield
  - ❑ Ion back flow with the higher X-ray: from 1% to 3%
  - ❑ Stable operation time: more than 48 hours
  - ❑ Separated GEM gain: 1~10

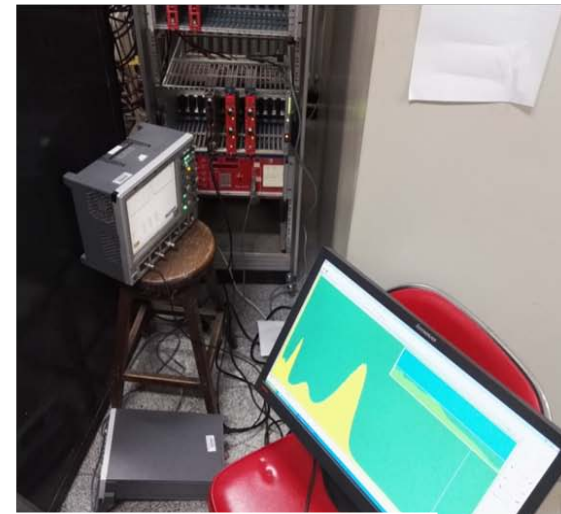
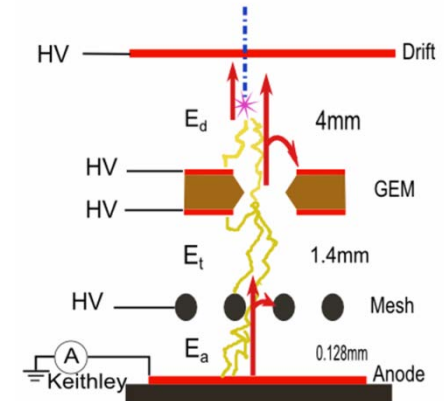


Photo of the GEM+Micromegas Module with X-ray

# Current test

- ❑ Keithley pA current meter as the monitor
  - ❑ Continuous readout with Labview interface
  - ❑ Very tiny current in the cathode and anode

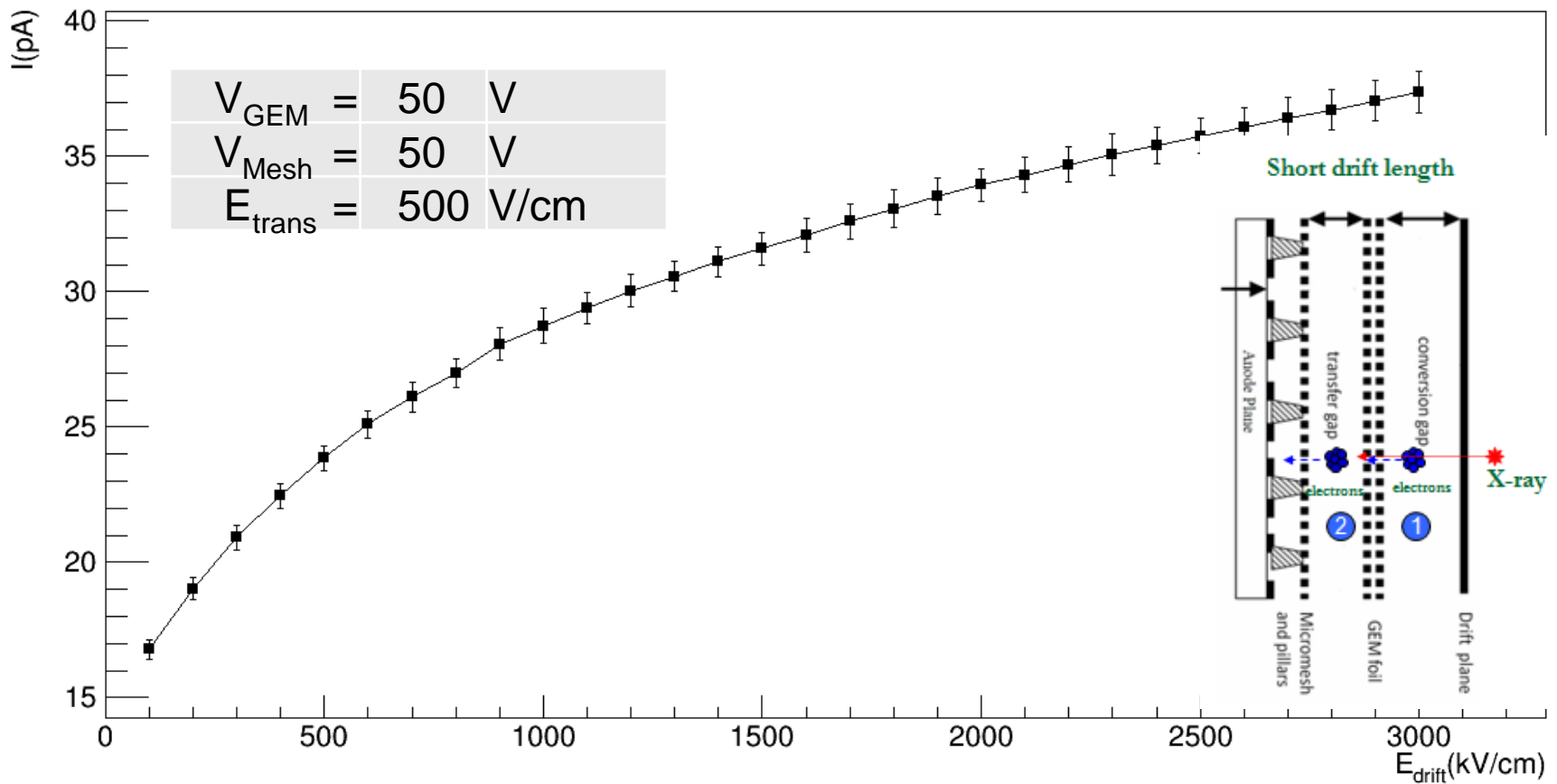


Layout of Labview in the test



# Current test of the primary ionization

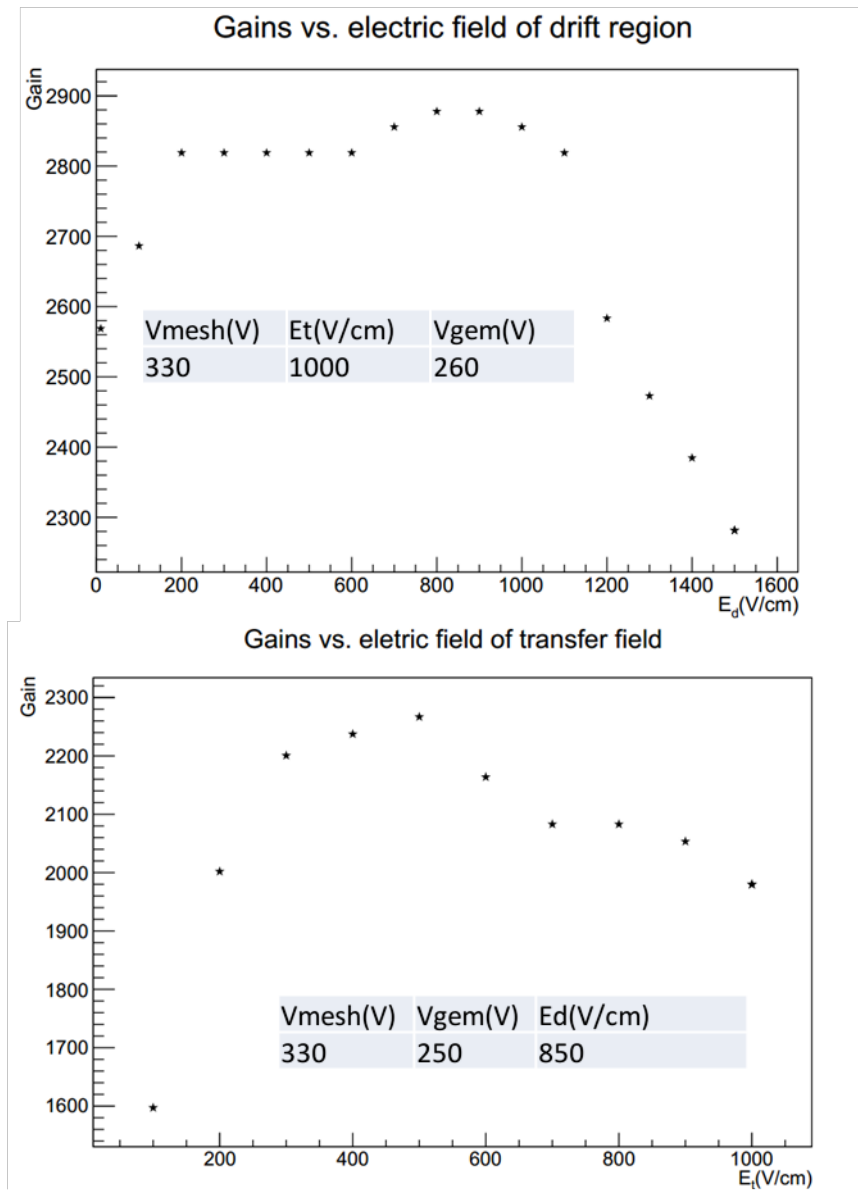
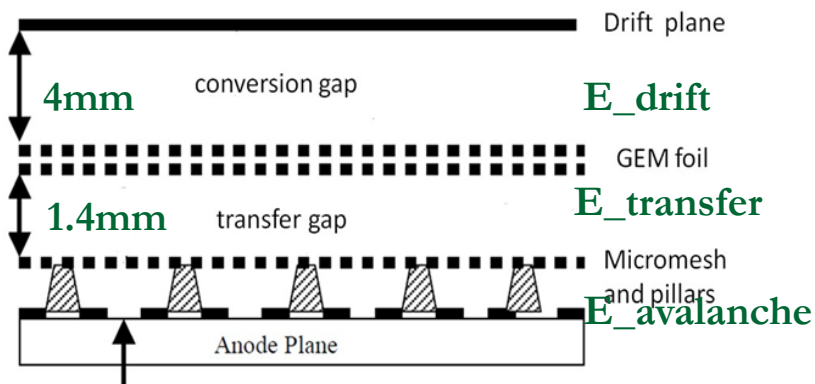
- Primary ionization test using monitor
  - Primary ions from 1/Drift and 2/Transfer
  - Current data with the standard error bar
  - Ions transmission efficiency with electric field of drift



Current test of primary ionization

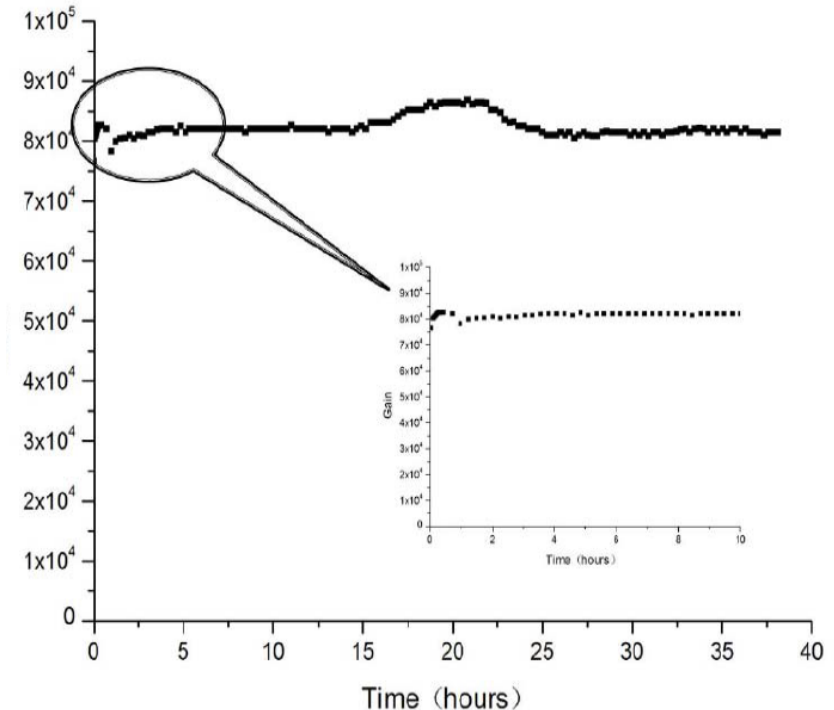
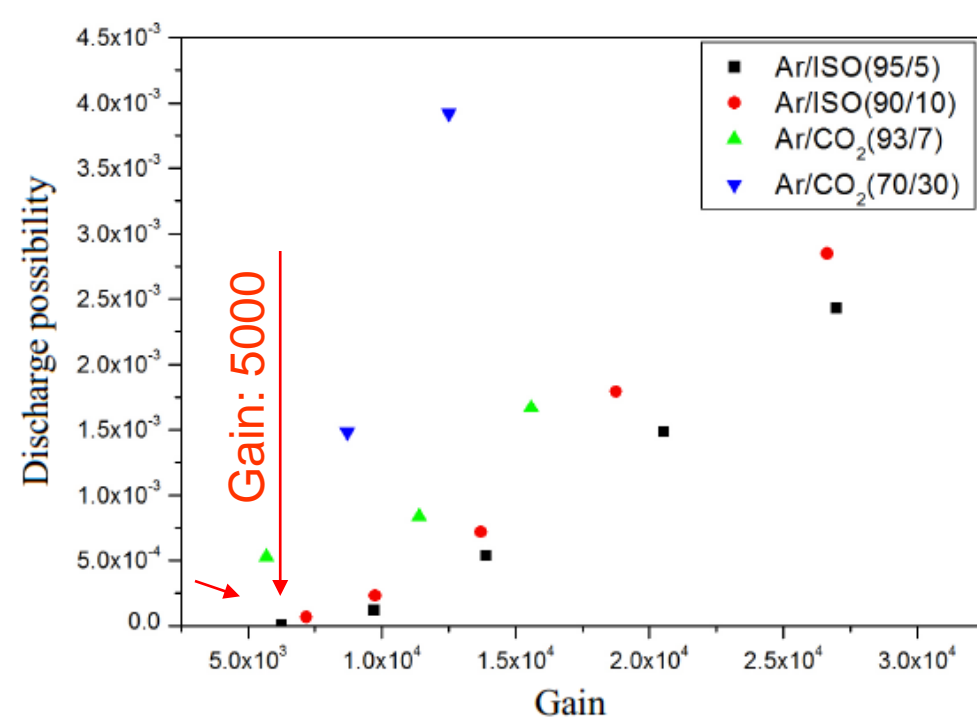
# Electron transmission

- Optimized operating voltage
  - To achieve the higher electron transmission in the hybrid structure module
  - The ratio of  $E_{avalanche}$  and  $E_{transfer}$  of Micromegas detector is 216.8
  - The ratio of  $E_{transfer}$  and  $E_{drift}$  of GEM detector is 67.08



Electron transmission in GEM and Micromegas

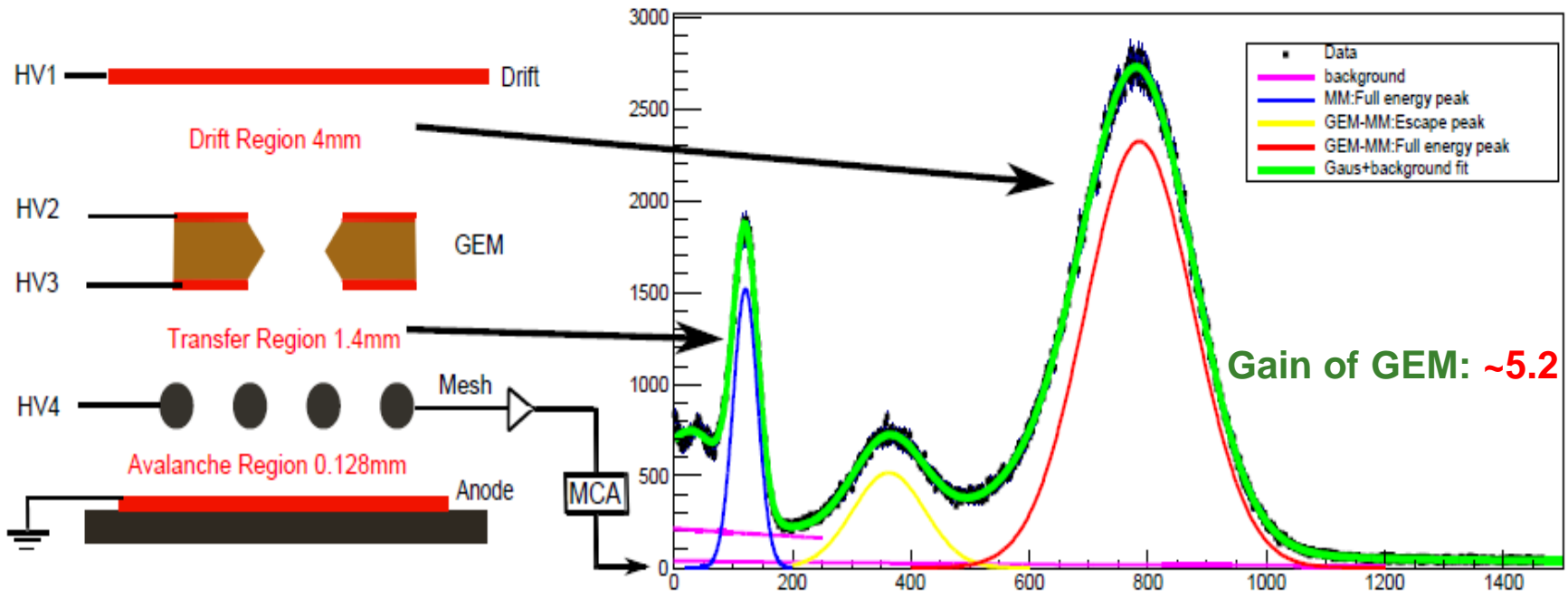
# Discharge and working time



- Test with Fe-55 X-ray radiation source
  - Discharge possibility could be mostly reduced than the standard Bulk-Micromegas
  - Discharge possibility of hybrid detector could be used at Gain~10000
  - To reduce the discharge probability more obvious than standard Micromegas
  - At higher gain, the module could keep the longer working time in stable

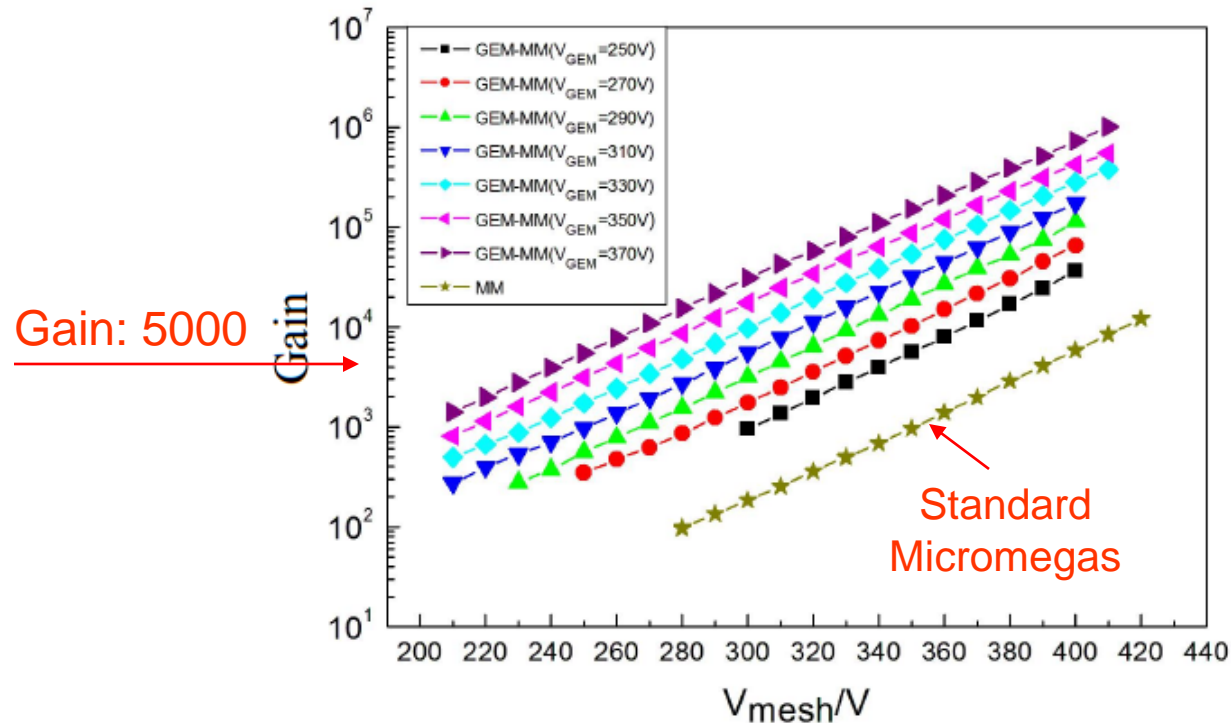
# Energy spectrum @ $^{55}\text{Fe}$

Source:  $^{55}\text{Fe}$ , Gas mix: Ar(97) +  $i\text{C}_4\text{H}_{10}$ (3)



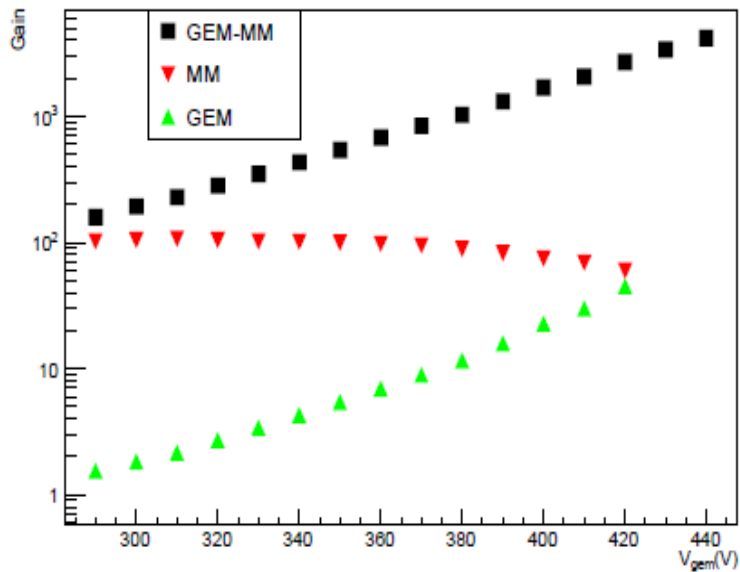
An example of the  $^{55}\text{Fe}$  spectra showing the correspondence between the location of an X-ray absorption and each peak.

# Gain of GEM + MM

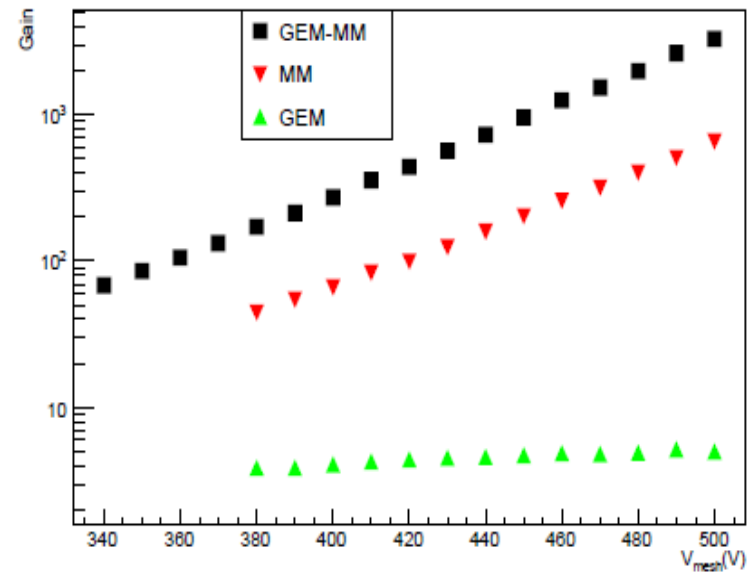


- Test with Fe-55 X-ray radiation source
  - Reach to the higher gain than standard Micromegas with the pre-amplification GEM detector
  - Similar Energy resolution as the standard Micromegas
  - Increase the operating voltage of GEM detector to enlarge the whole gain

# Gain of GEM and MM



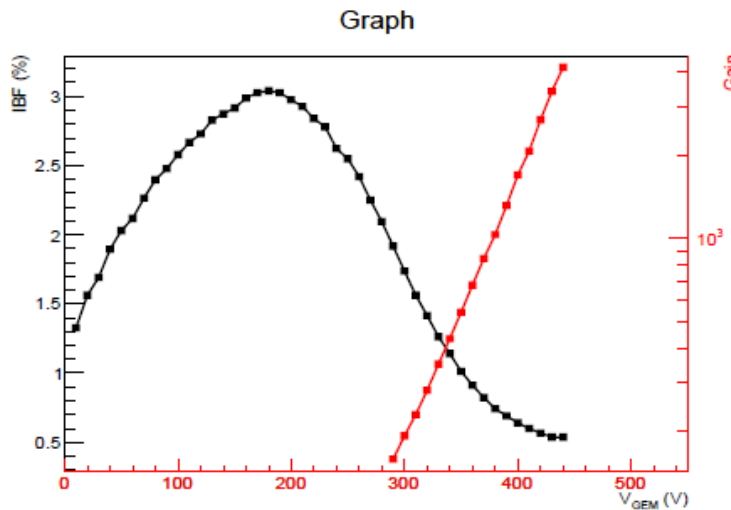
(a)



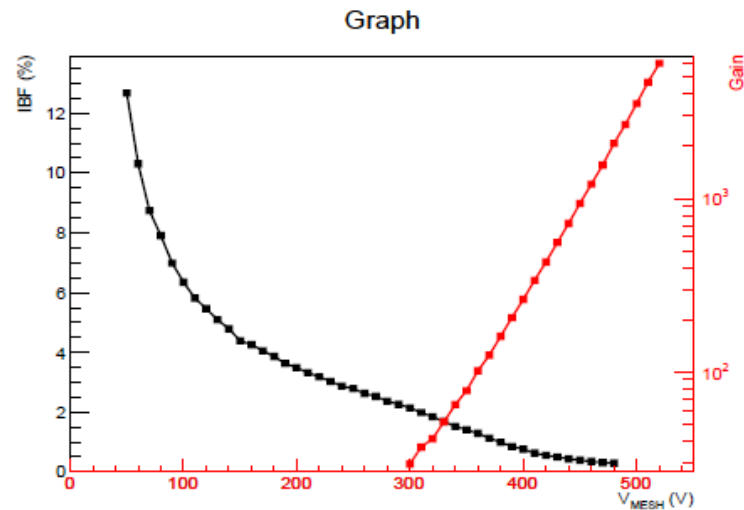
(b)

Gas gain versus GEM voltage, micromesh  $V_{mesh} = 420V$  (a) and micromesh voltage,  $V_{GEM} = 340V$  (b).  
 $E_d = 250V/cm$ ,  $E_t = 500V/cm$

# IBF preliminary result



(a)



(b)

Gas gain and IBF versus (a): GEM voltage, micromesh  $V_{mesh} = 420V$  and (b): micromesh voltage,  $V_{GEM} = 340V$ .  $E_d = 250V/cm$ ,  $E_t = 500V/cm$

- ❑ Test with X-tube@21kV~25kV using the Hybrid module
  - ❑ Charge sensitive preamplifier ORTEC 142IH
  - ❑ Amplifier ORTEC 572 A
  - ❑ MCA of ORTEC ASPEC 927
  - ❑ Mesh Readout
  - ❑ Gas: Ar-iC4H10(95-5)
  - ❑ Gain: ~6000

Contribution of the ions from the drift region to be  $\gamma$ , calculation of IBF,  $\eta$ :

$$I_{mesh} = G\gamma$$

$$I_c = \gamma + G\gamma\eta = \gamma + \eta I_{mesh}$$

G is the gas gain of the detector.

	<b>GEM+MMG 420LPI ( IHEP )</b>	<b>2GEMs + MMG 450 LPI ( Yale University )</b>	<b>Micromegas only 450 LPI ( Yale University )</b>
Ion Back Flow	<b>~0.1%</b> <b>Edrift = 0.25 kV/cm</b>	(0.3 –0.4)% Edrift = 0.4 kV/cm	(0.4 –1.5)% Edrift= (0.1-0.4) kV/cm
<GA>	<b>4000~5000</b>	2000	2000
$\epsilon$ -parameter(=IBF*GA)	<b>4~5</b>	6~8	8~30
E –resolution	<b>~16%</b>	<12%	<= 8%
Gas Mixture ( 2-3 components)	<b>Ar + iC4H10</b>	Ne+CO2+N2, Ne+CO2,Ne+CF4, Ne+CO2+CH4	X + iC4H10 (Ar+CF4+iC4H10)
Sparking ( <sup>241</sup> Am)	<b>&lt;10<sup>-8</sup></b>	< 3.*10 <sup>-7</sup> (Ne+CO2) (N.Smirnov report)	~ 10 <sup>-7</sup> (S. Procureur report)
Possible main problem	<b>Thin frame</b>	More FEE channel	#
Goals	<b>CEPC TPC</b>	ALICE upgrade	#



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# Summary

- **Critical requirements for CEPC TPC modules**
  - Beam structure
  - Obvious distortion
  - Continuous Ion Back Flow
- **Some activities and simulations**
  - Simulation of the occupancy of the detector, the hybrid structure gaseous detector's IBF
  - TPC gas amplification setup GEM+MM investigated as a high rate TPC option without the standard gating grid or others gating device
  - Some preliminary IBF results

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Thanks very much for your attention !