Review Meeting of TPC Detector R&D for MOST Project

2016.6-2018.6

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16. June, 2018, Main building, IHEP, Beijing

Outline

For MOST Project

- Motivation
- Hybrid module R&D
- Space charge for IBF
- Manpower

- Motivation

Collider concept

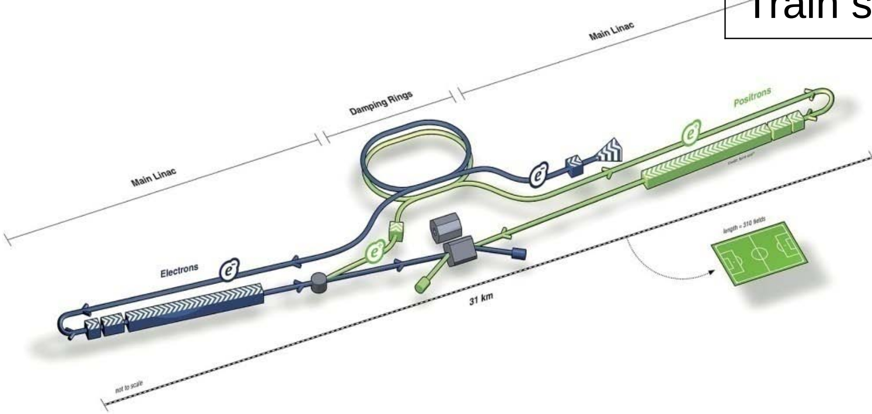
Circular e^+e^- Higgs (Z) factory with two detectors, 1M ZH events in 10yrs

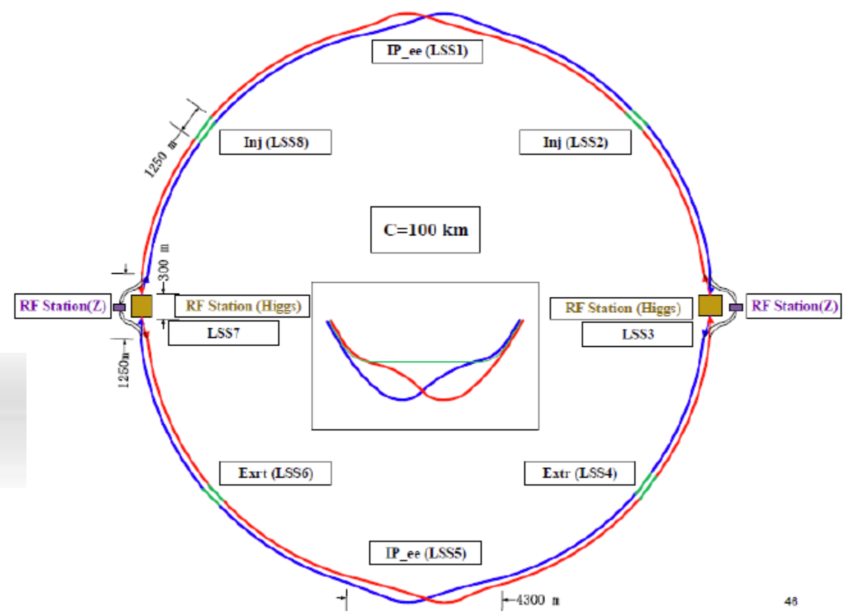
E_{cm} ≈240 GeV, luminosity ~2×10^{34} $cm^{-2}s^{-1}$, can also run at the Z-pole

Circumference: ~100km

Updated on January, 2017

	tt	H	W	Z
Beam Energy [GeV]	175	120	80	45.5
Bunches / beam	98	555	3000	65716
Train spacing [us]	**83.5**	**83.5**	**84**	**98.6**





Layout of CEPC Double Ring

TPC requirements for collider concept

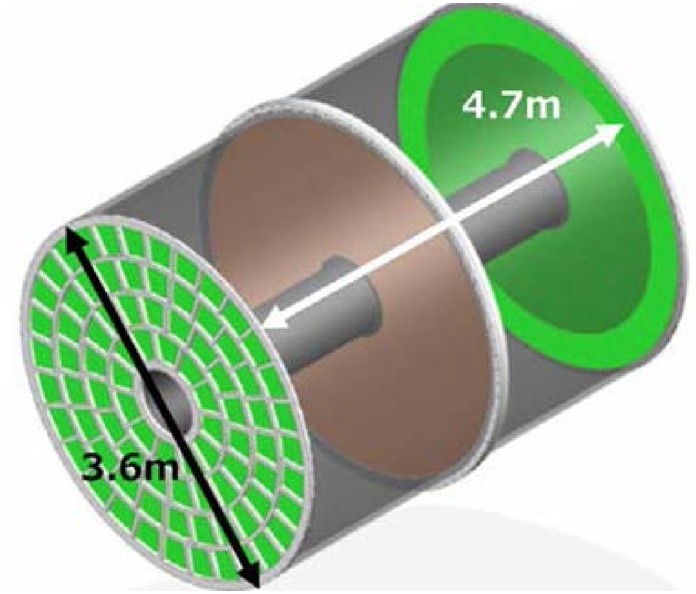
TPC could be as one tracker detector option for CEPC, 1M ZH events in 10yrs E_{cm} ≈250 GeV, luminosity ~2×10^{34} $cm^{-2}s^{-1}$, can also run at the Z-pole

The voxel occupancy takes its maximal value between 2×10^{-5} to 2×10^{-7}, which is safety for the Z pole operation. **Of course, it is well for Higgs run too.**

https://doi.org/10.1088/1748-0221/12/07/P07005

TPC detector concept:

- Motivated by the H tagging and Z
- Main tracker detector with TPC
- ~3 Tesla magnetic field
- ~100 μm position resolution in rφ
- Systematics precision (<20 μm internal)
- Large number of 3D points(~220)
- Distortion by IBF issues
- dE/dx resolution: <5%
- Tracker efficiency: >97% for pT>1GeV



TPC detector concept

Answer three key issue questions in CEPC

- Occupancy: at inner diameter
  - Low occupancy
  - Overlapping tracks
  - Background at IP
- Ion Back Flow
  - Continuous beam structure
  - Long working time with low discharge possibility
  - Necessary to fully suppress the space charge produced by ion back flow from the amplification gap

Simulation → TPC as one option for CPEC YES or NO?

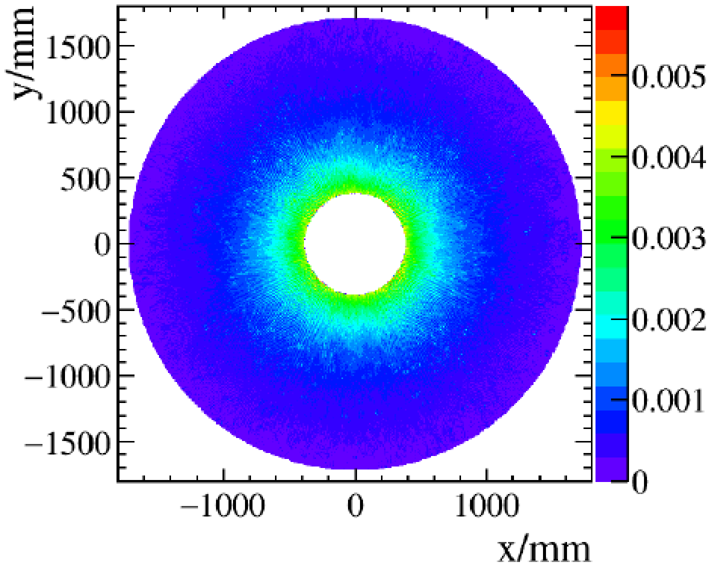
Simulation + R&D → To control IONS? To reduce distortion

High rate at Z pole

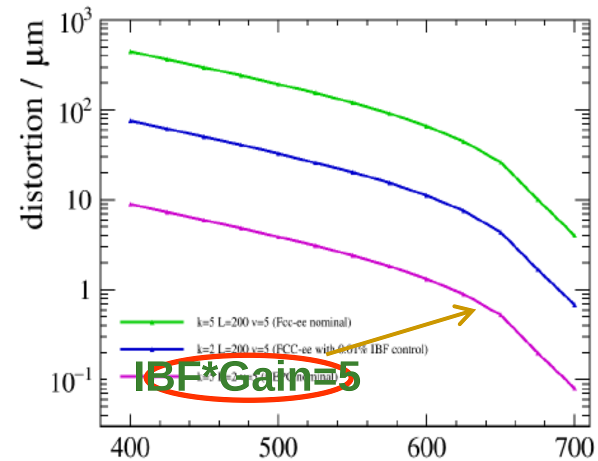
ArXiv: 1704.04401
Mingrui, Manqi, Huirong

- Voxel occupancy
  - The number of voxels /signal
  - 9 thousand Z to qq events
  - 60 million hits are generated in sample
  - 4000-6000 hits/(Z to qq) in TPC volume
  - Average hit density: 6 hits/mm^2
  - Peak value of hit density: 6 times
  - Voxel size: 1mm × 6mm × 2mm
  - 1.33×10^{14} number of voxels/s @DAQ/40MHz
  - Average voxel occupancy: 1.33×10^{-8}
  - Voxel occupancy at TPC inner most layer: $\sim 2 \times 10^{-7}$
  - Voxel occupancy at TPC inner inner most layer : $\sim 2 \times 10^{-5}$ @FCCee benchmark luminosity

The voxel occupancy takes its maximal value between 2×10^{-5} to 2×10^{-7}, which is safety for the Z pole operation.



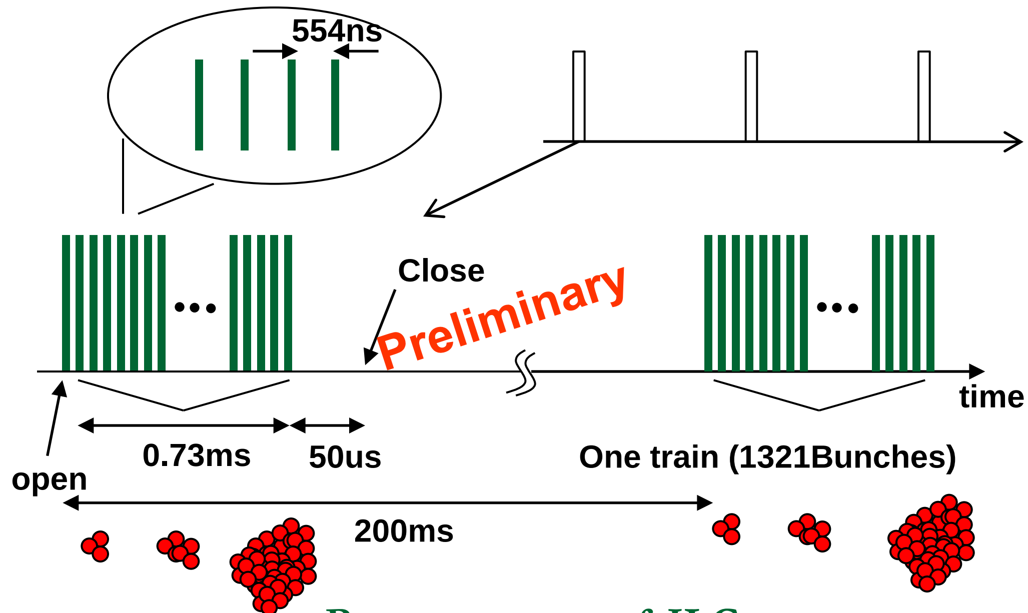
Hit map on X-Y plan for Z to qq events



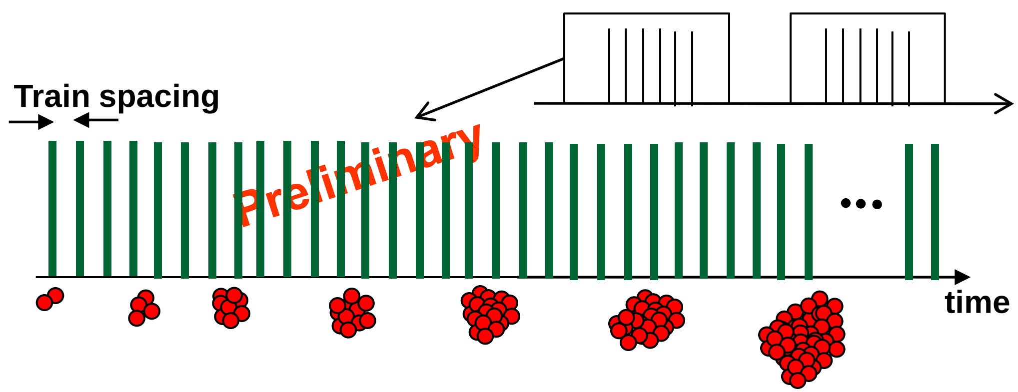
Distortion of as a function of electron initial r position

Compare with ILC beam structure

- In the case of ILD-TPC
  - Bunch-train structure of the ILC beam (one ~1ms train every 200 ms)
  - Bunches time ~554ns
  - Duration of train ~0.73ms
  - Used Gating device
  - Open to close time of Gating: 50μs+0.73ms
  - Shorter working time
- In the case of CEPC-TPC
  - Bunch-train structure of the CEPC beam (one bunch every ~90μs) or partial double ring
  - No Gating device with open and close time
  - Continuous device for ions
  - Long working time



Beam structure of ILC



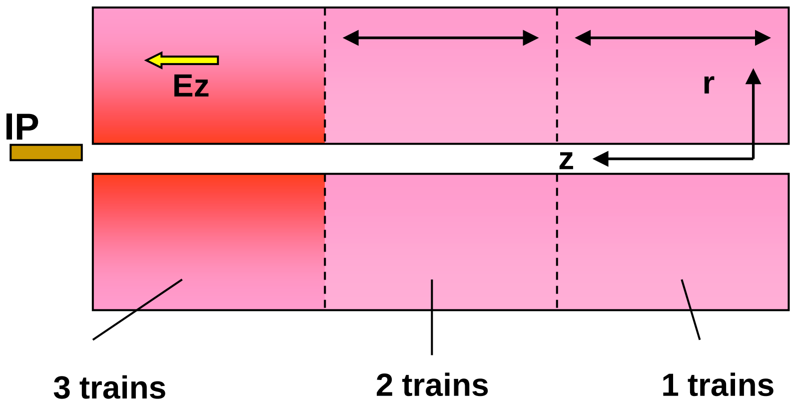
Beam structure of CEPC

Gating device could NOT be used due to the limit time!

Critical challenge: Ion Back Flow and Distortion

In the case of ILD-TPC

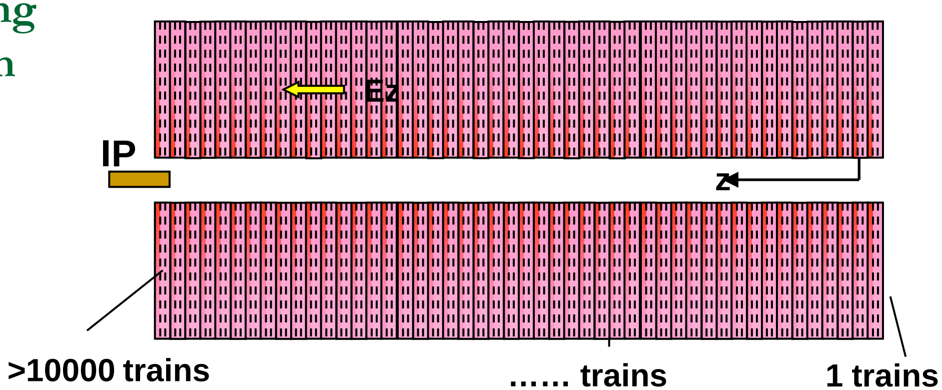
- Distortions by the primary ions at ILD are negligible
- Ions from the amplification will be concentrated in discs of about 1 cm thickness near the readout, and then drift back into the drift volume Shorter working time
- 3 discs co-exist and distorted the path of seed electron
- The ions have to be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



Amplification ions@ILC

In the case of CEPC-TPC

- Distortions by the primary ions at CEPC are negligible too
- More than 10000 discs co-exist and distorted the path of seed electron
- The ions have to be neutralized during the ~4us period continuously



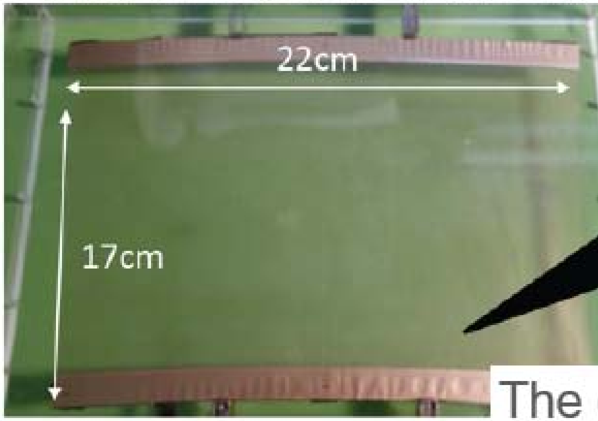
Amplification ions@CEPC

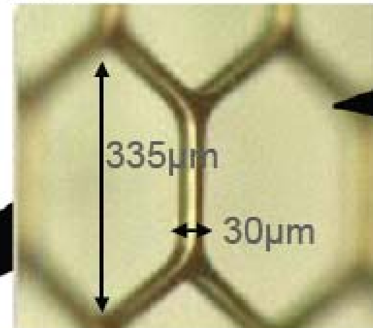
GEM gating in KEK@LCTPC

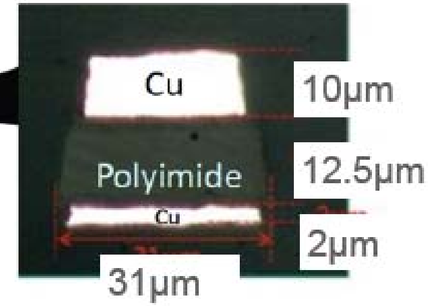
Solution Option

GEM as a gate =a large aperture GEM-like gating device (gating GEM)

The joint development with FUJIKURA



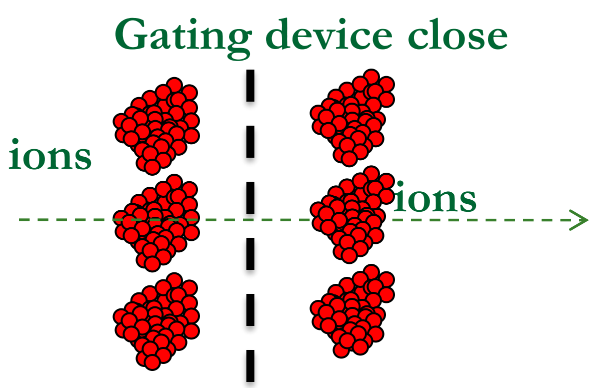


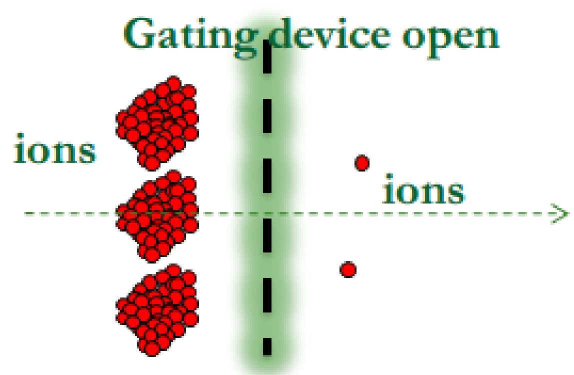


honeycomb structure

The optical transparency= 82 % 25 μm thick

Though gating GEM stop positive ions, should not stop electron too.→Electron transmission trate is important





Open and close time of gating device for ions

ALICE TPC option

Solution Option

ALICE TPC Upgrade

Production of 40 IROCs and 40 OROCs until September 2018

TPC Upgrade requirements:

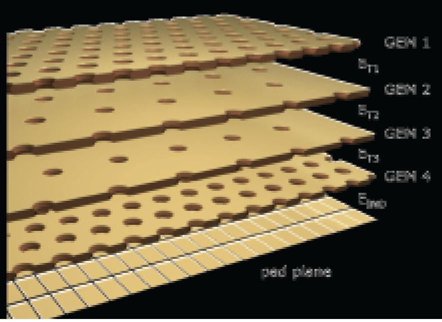
- Nominal gain = 2000 in Ne-CO_2-N_2 (90-10-5)
- IBF < 1% (ε = 20)
- Energy resolution: σ_E/E < 12% for ^{55}Fe
- Stable operation under LHC Run 3 conditions
- Unprecedented challenges in terms of loads and performance

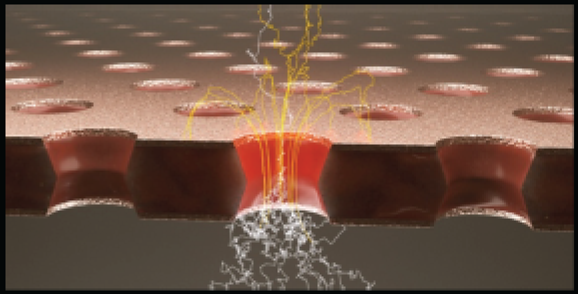
Solution: 4-GEM stack

Combination of standard (S) and large pitch (LP) GEM foils

Highly optimized HV configuration

Result of intensive R&D



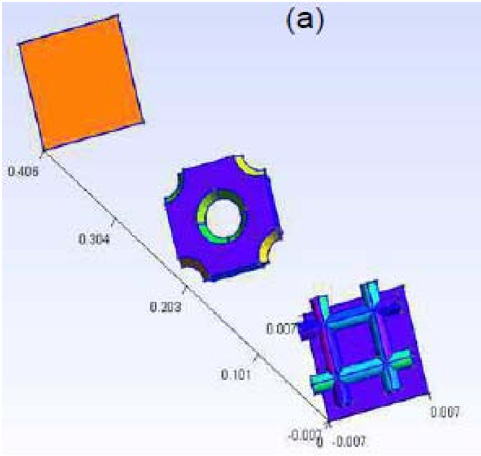


D. Bortoletto CepC

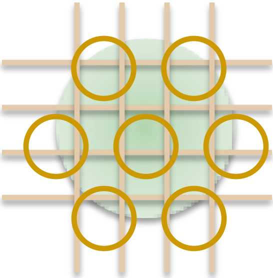
- Hybrid module R&D

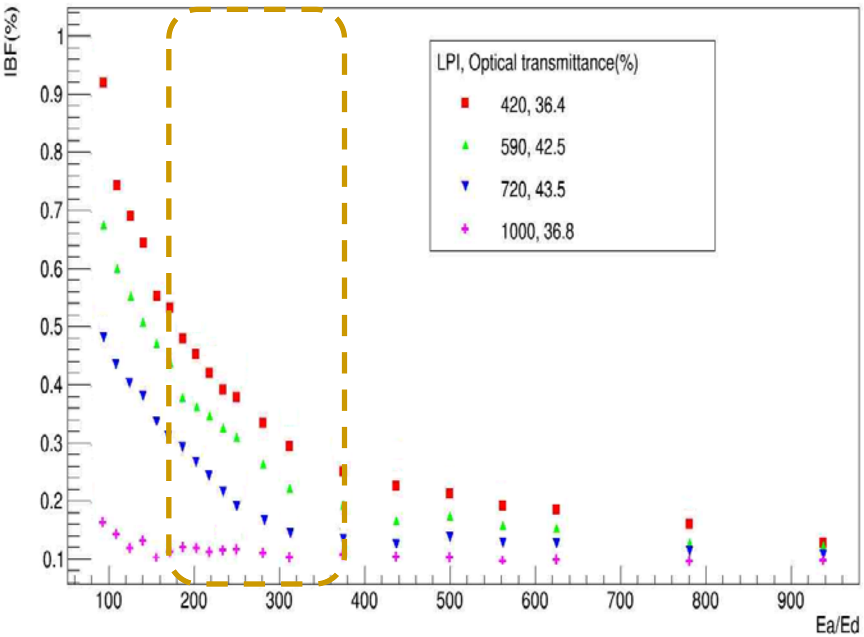
IBF simulation

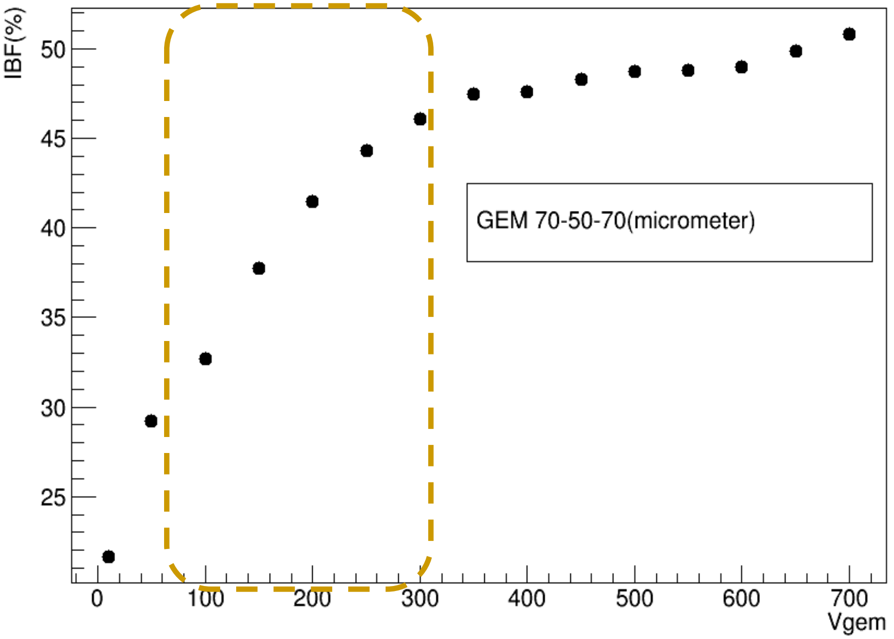
Yulian, Haiyun, Huirong



- Garfield++/ANSYS to simulate the ions back to drift
  - 420LPI/ 590LPI/ 720LPI/1000LPI
  - Ea is electric field of amplifier of Micromegas
  - Standard GEM foil (70-50-70)
  - Standard Bulk-Micromegas (420LPI)
  - GEM optimization: wider hole GEM/KEK
  - MM optimization: 590LPI mesh/Saclay



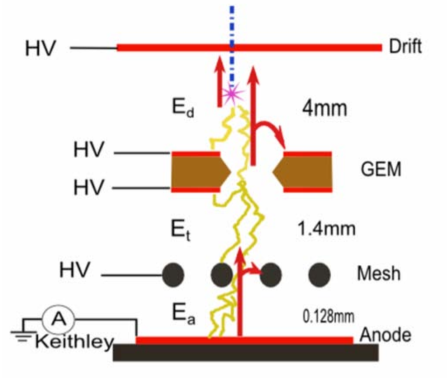


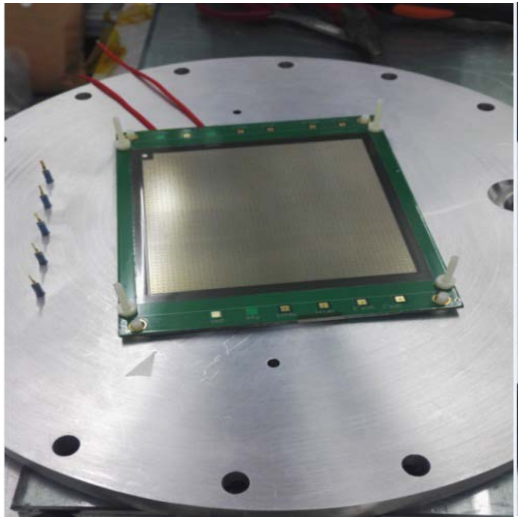


Electric field of amplifier VS Electric field of Drift and VGEM

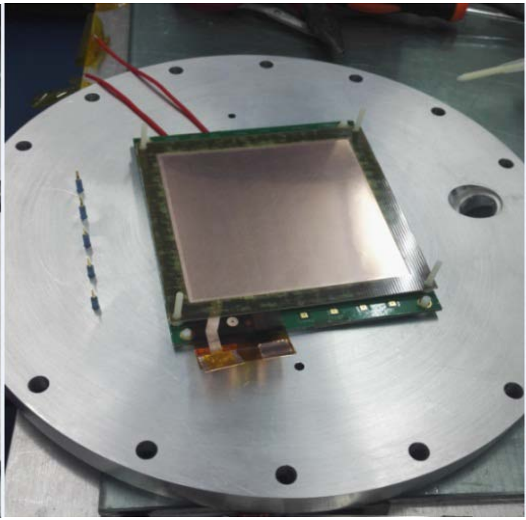
Test of the new module

- Test with GEM-MM module
  - New assembled module
  - Active area: 100mm×100mm
  - X-tube ray and 55Fe source
  - Bulk-Micromegas from Saclay
  - Standard GEM from CERN
  - Additional UV light device
  - Avalanche gap of MM:128μm
  - Transfer gap: 2mm
  - Drift length:2mm~200mm
  - Mesh: 400LPI

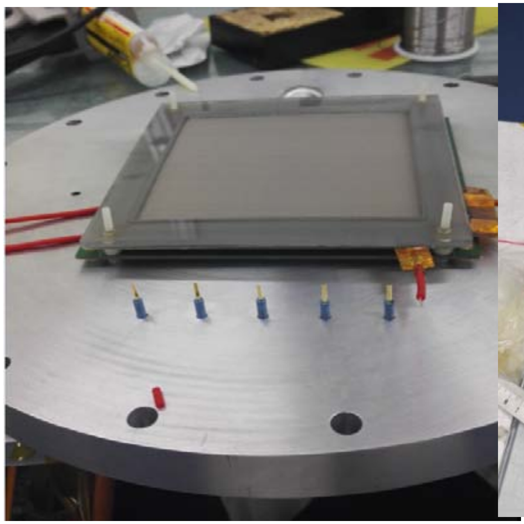




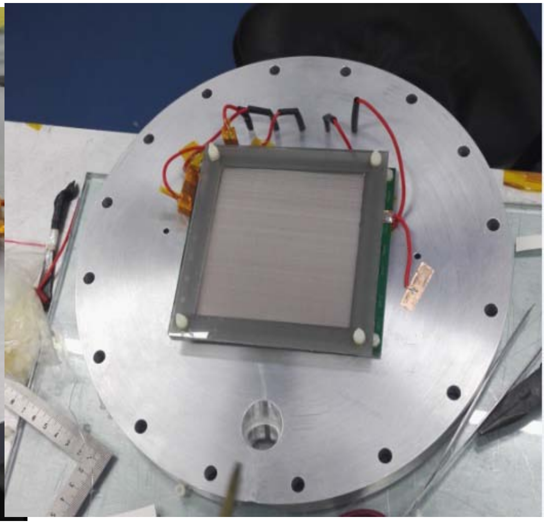
Micromegas(Saclay)



GEM(CERN)



Cathode with mesh



GEM-MM Detector

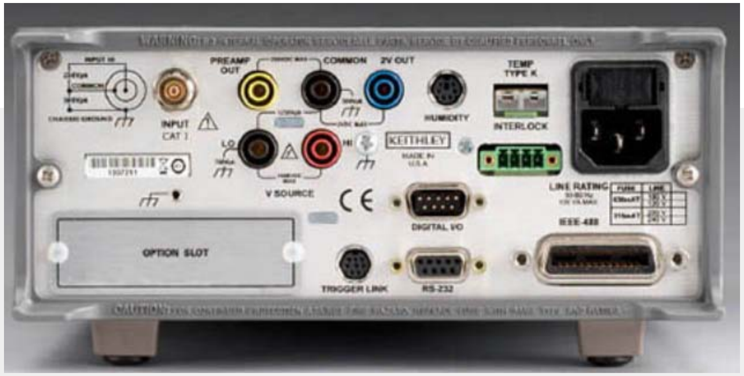
Electrometer/High Resistance Meter

Keithley 6517B

Electrometer/High Resistance Meter, 100aA - 20mA, 10µV - 200V, 100Ω - 10PΩ

Brand:	Keithley
Model No:	6517B

KEITHLEY
A Tektronix Company

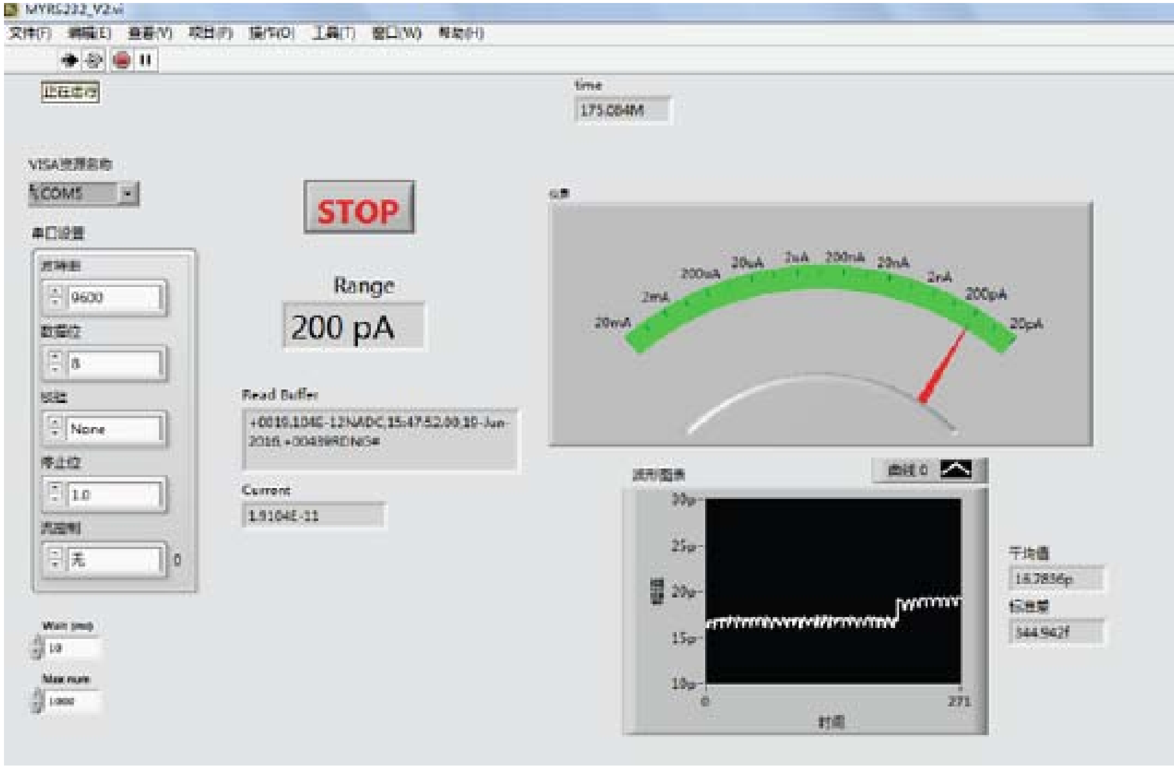


Product Features:

- Measures resistances up to 1018O
- 10aA (10×10-18A) current measurement resolution
- Less than 3fA input bias current
- 6 1/2-digit high accuracy measurement mode
- Less than 20µV burden voltage on the lowest current ranges
- Voltage measurements up to 200V with >200TO input impedance
- Built-in +/-1000V voltage source
- Unique alternating polarity voltage sourcing and measurement method for high resistance measurements
- Built-in test sequences for four different device characterization tests, surface and volume resistivity, surface insulation resistance, and voltage sweeping
- Optional plug-in scanner cards for testing up to 10 devices or material samples with one test setup

Measuremnt of GEM-MM module

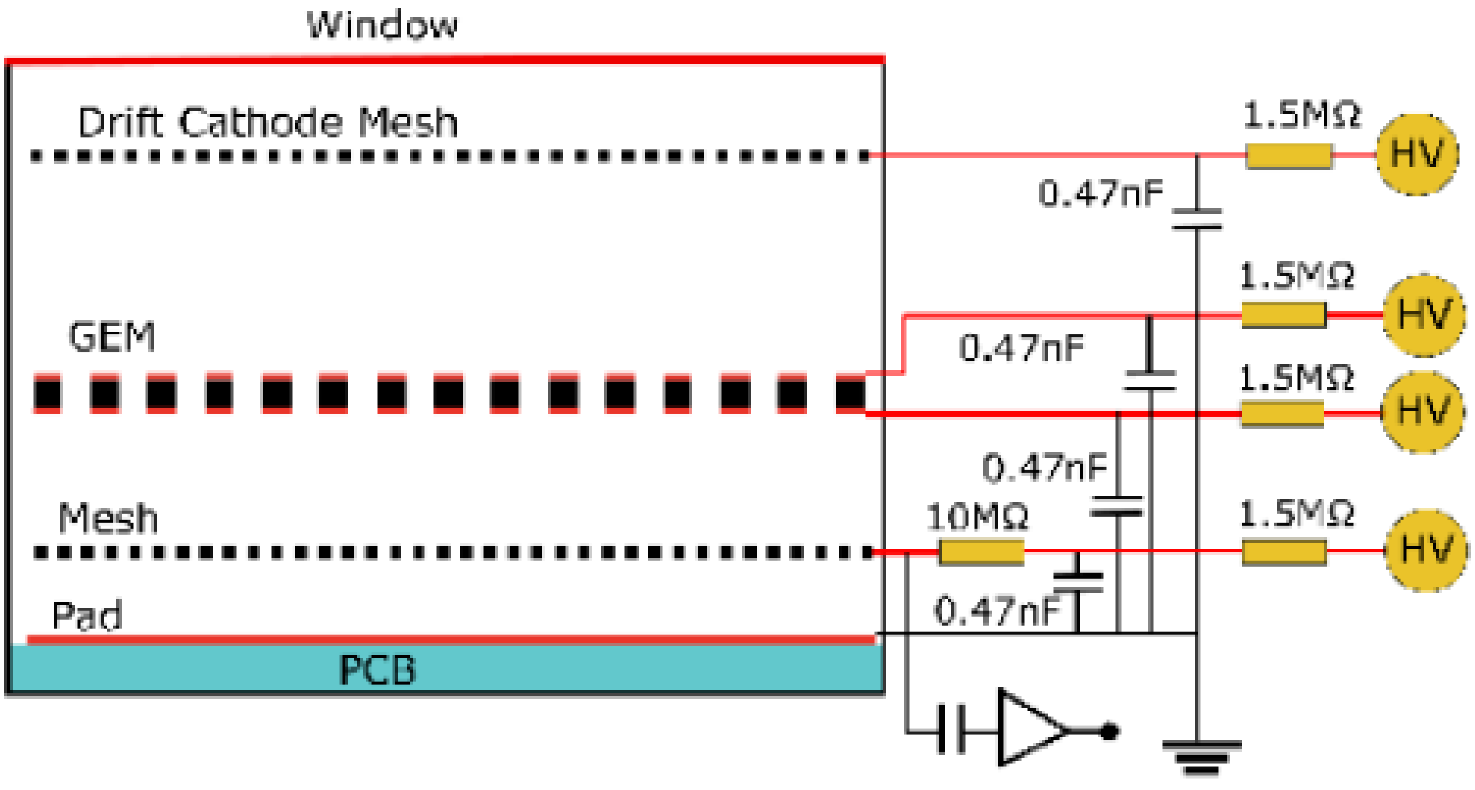
- Test with GEM-MM module
  - Keithley Electrometers for Ultra-Low Current Measurements: pA~mA
  - Keithley: 6517B
  - Test of cathode of the module
  - Test of readout anode of the module
  - Labview interface of the low current to make the record file automatically



Labview interface of the current with Keithley

$$IBF = \frac{I_C - I_P}{I_A}$$

GEM-MM module

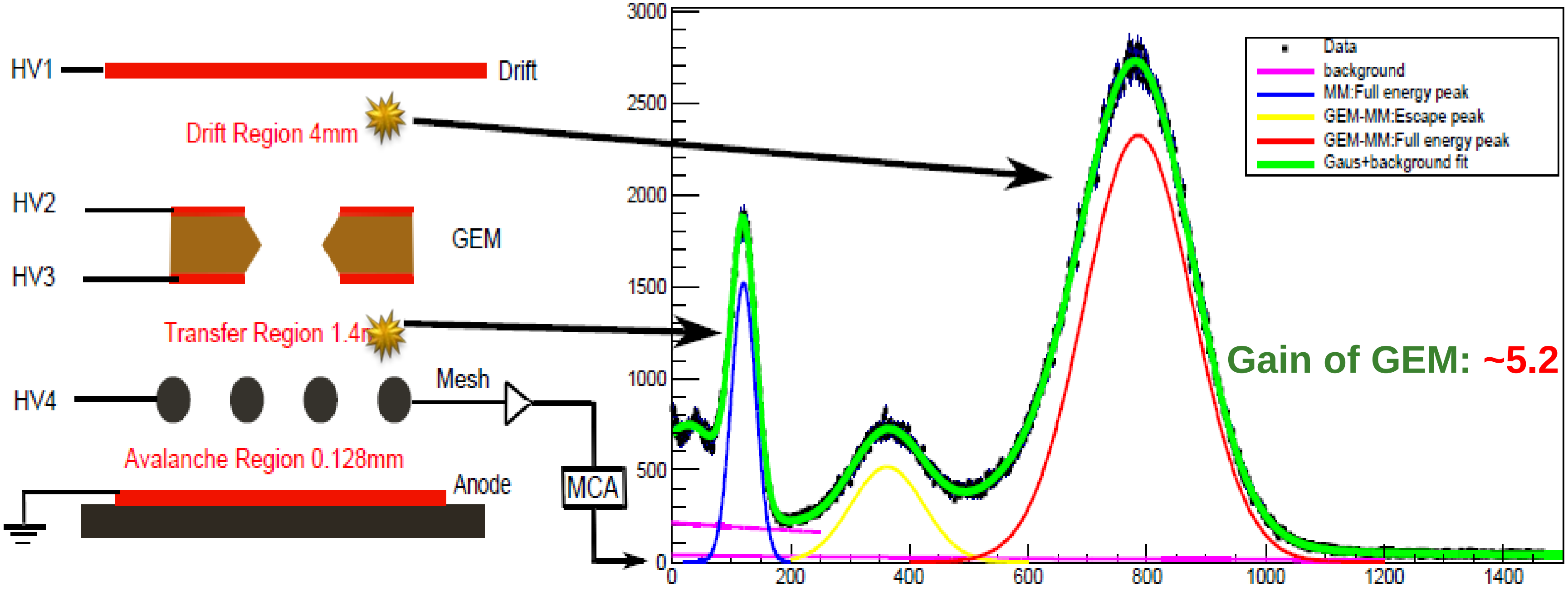


High voltage diagram of the detector module

Energy spectrum@^{55}Fe

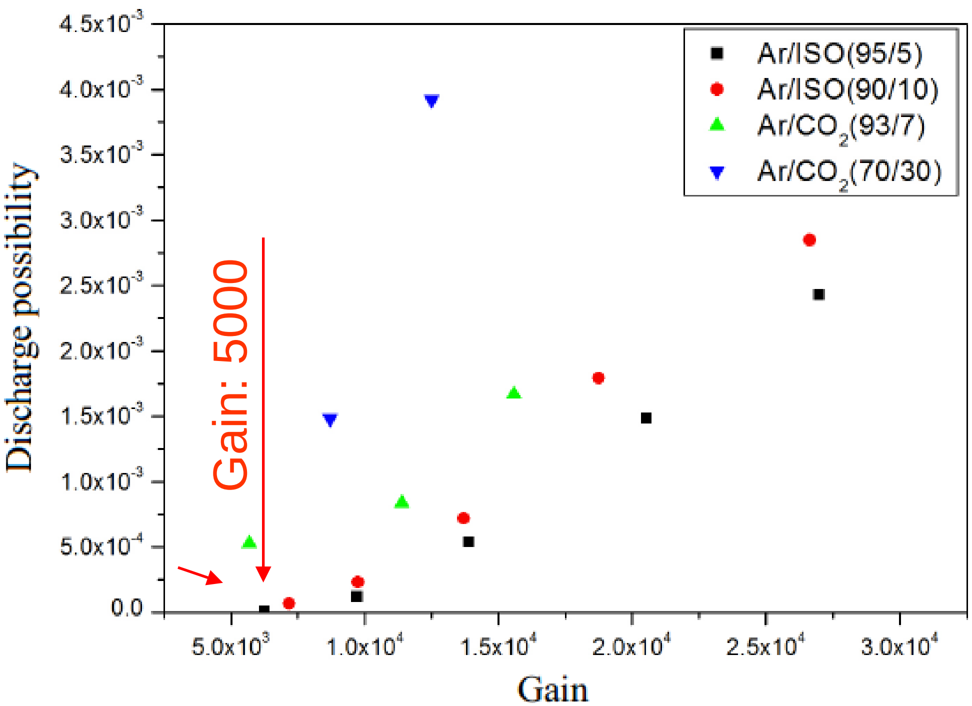
Yulian, Haiyun, Huirong

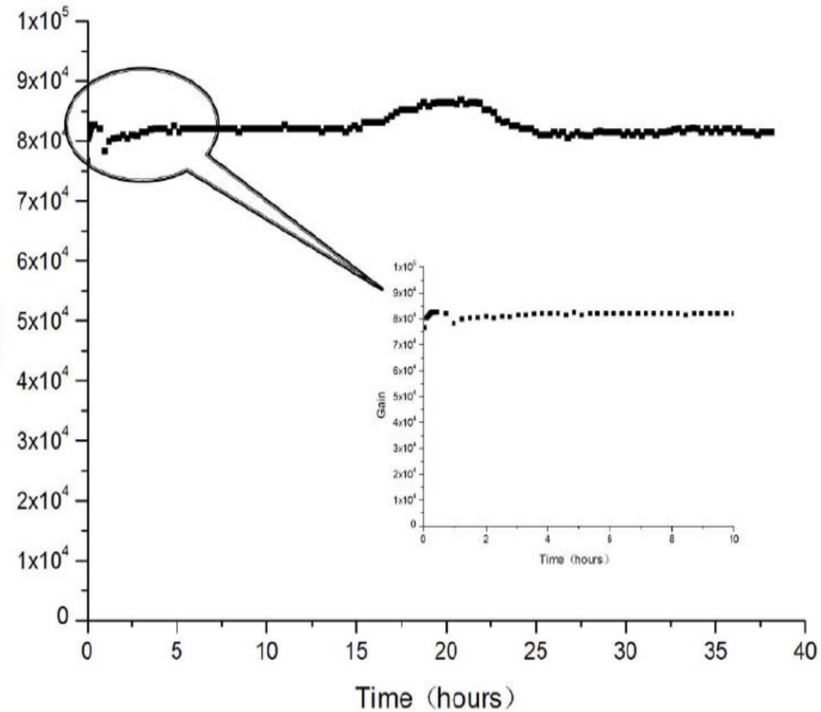
Source: ^{55}Fe, Gas mix: Ar(97) + iC_4H_{10}(3)



An example of the 55Fe spectra showing the correspondence between the location of an X-ray absorption and each peak.

Discharge and working time

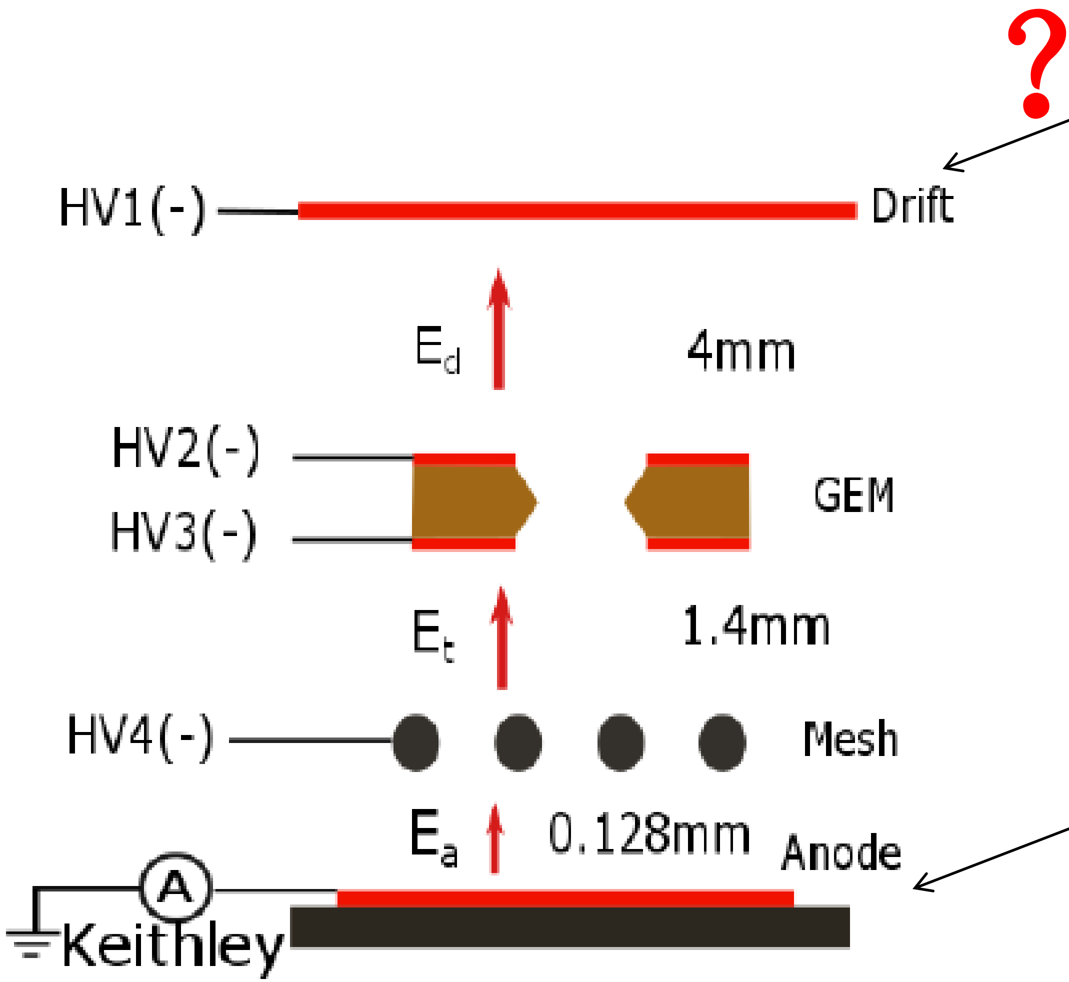




- Test with Fe-55 X-ray radiation source
  - Discharge possibility could be mostly reduced than the standard Bulk-Micromegas
  - Discharge possibility of hybrid detector could be used at Gain~10000
  - To reduce the discharge probability more obvious than standard Micromegas
  - At higher gain, the module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

- IBF study with the module

First step



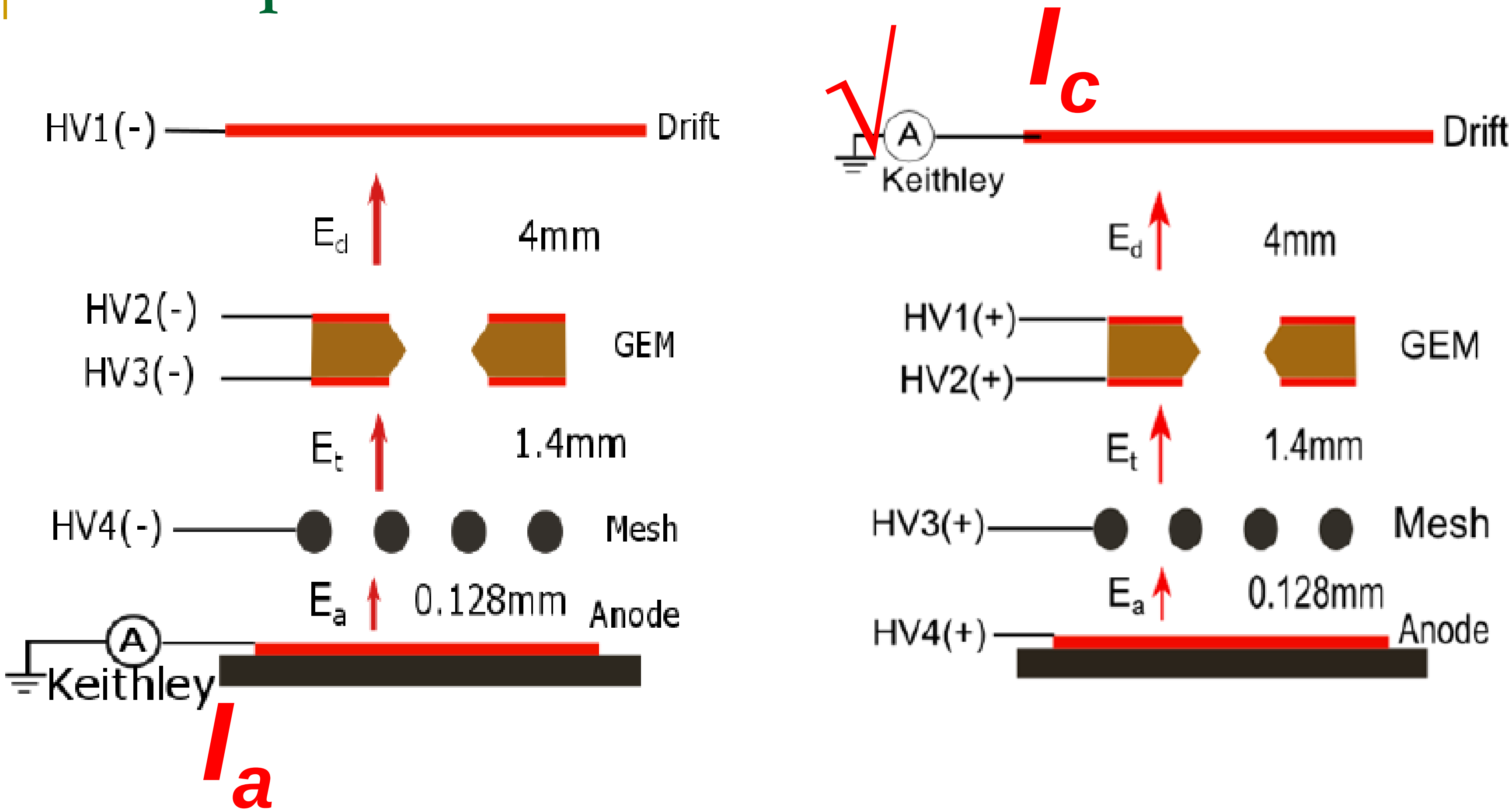
To -2600V high voltage

Can not connect with Keithley meter

To ground with Keithley meter

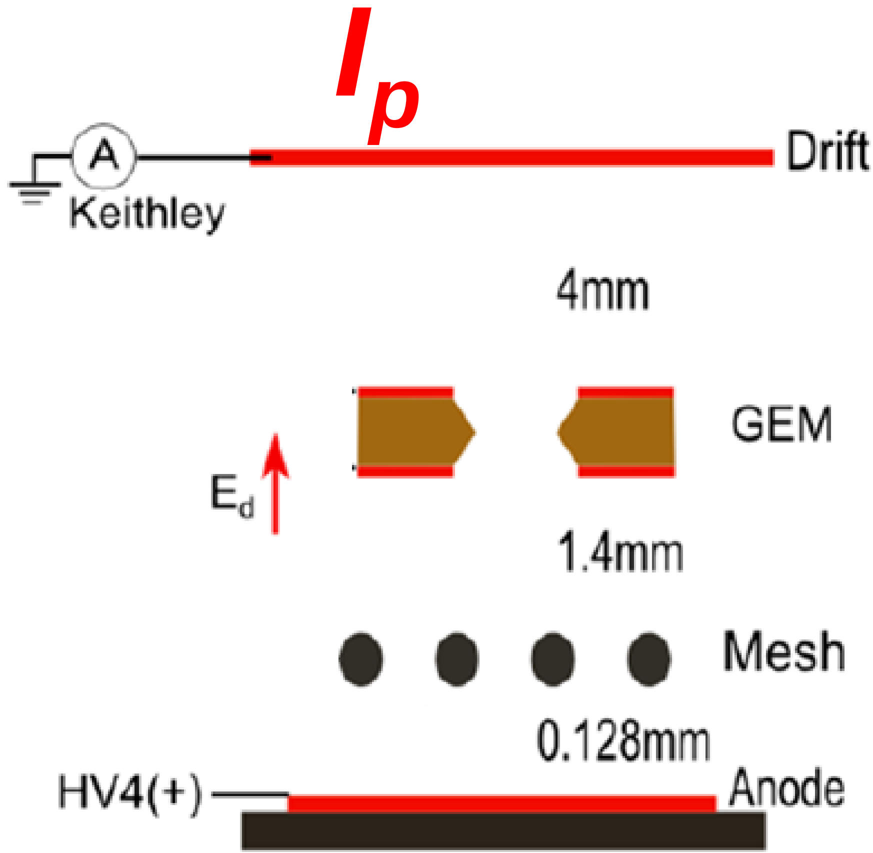
Rang: ~nA

Two steps



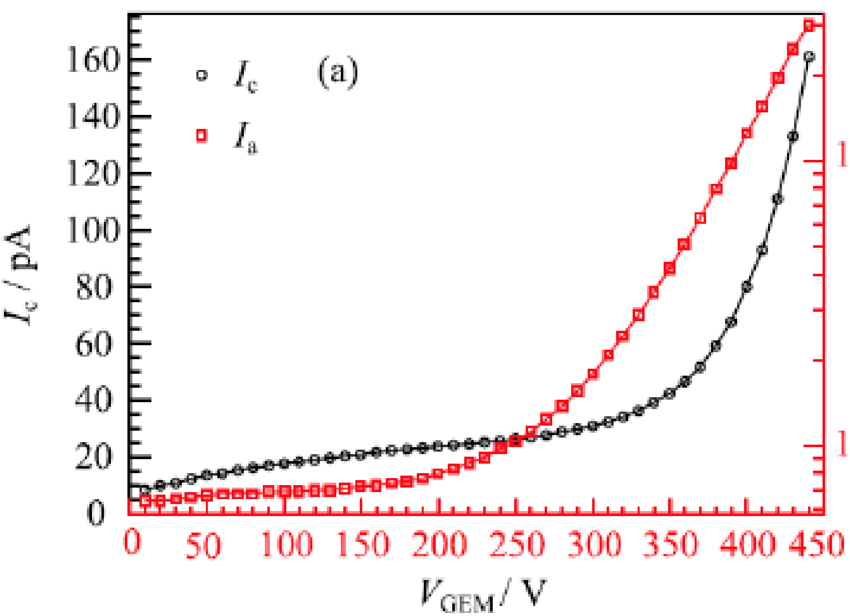
- Different polarity
- Same electric filed
  - Ed=Ed; Et=Et; Ea=Ea

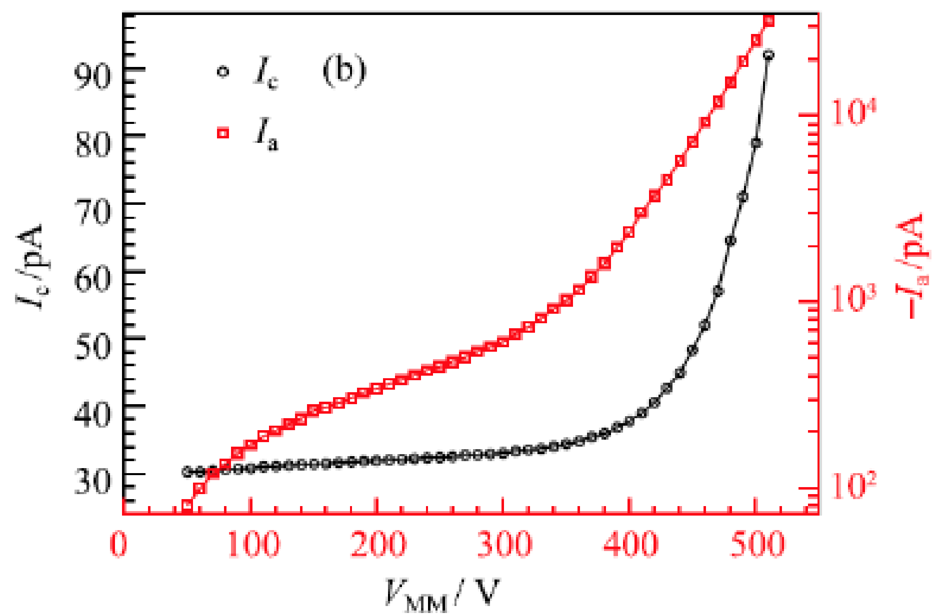
Primary electrons current



- No operation voltage of the GEM-MM detector
- Just test current of the primary electrons (~pA)

Ic and Ia

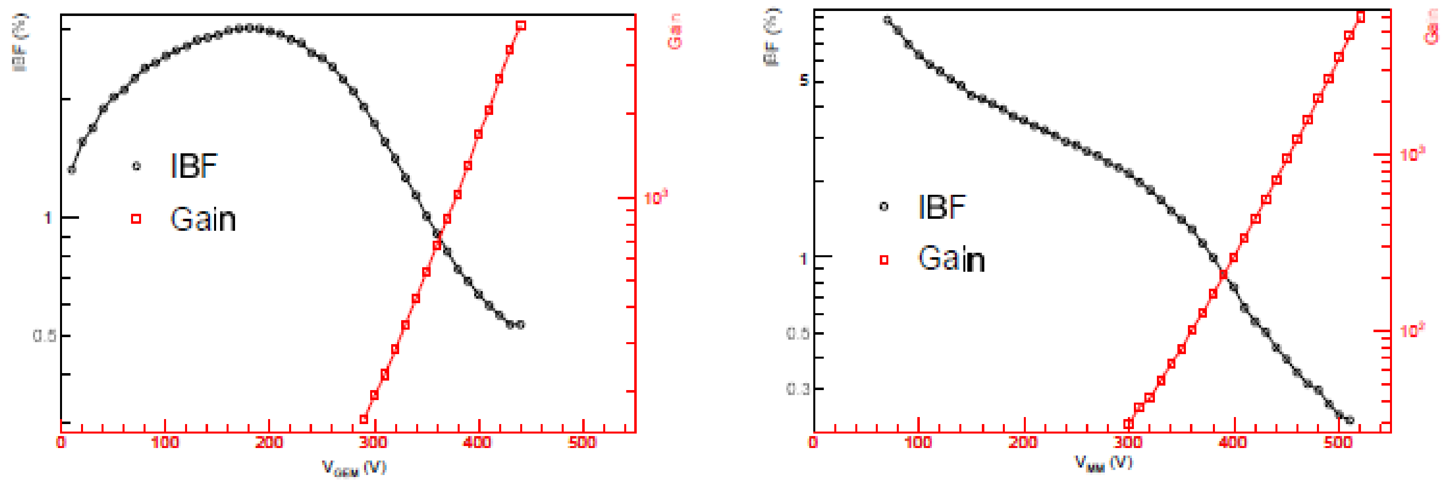




- GEM with operation voltage
- MM with operation voltage

IBF and Gain

Preliminary results in 2017

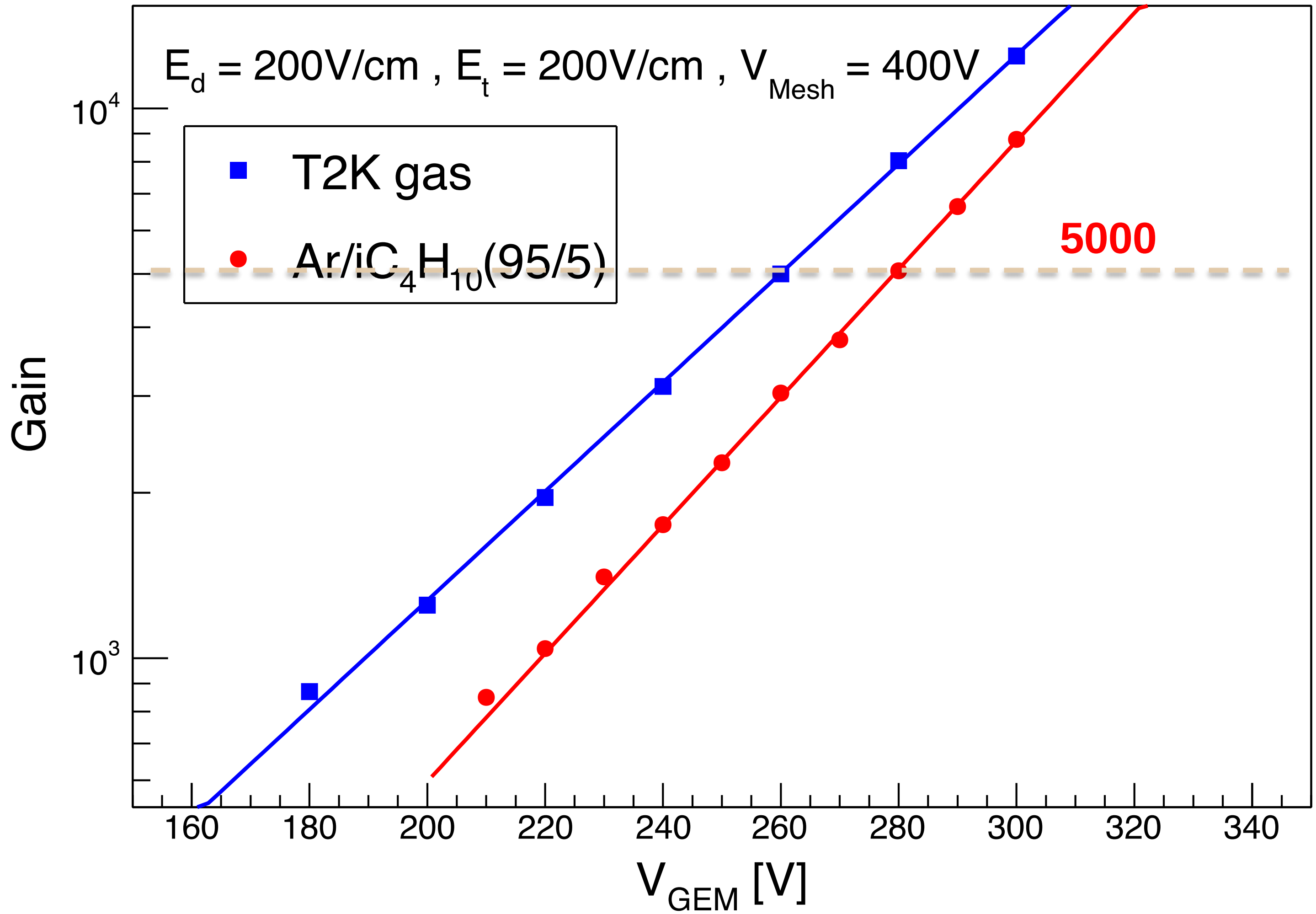


(a) (b)

Fig. 4: (color online) Gas gain and IBF versus (a) GEM voltage, micromesh $V_{mesh} = 420\,V$ and (b) micromesh voltage, $V_{gem} = 340\,V$. $E_d = 250\,V/cm$, $E_t = 500\,V/cm$.

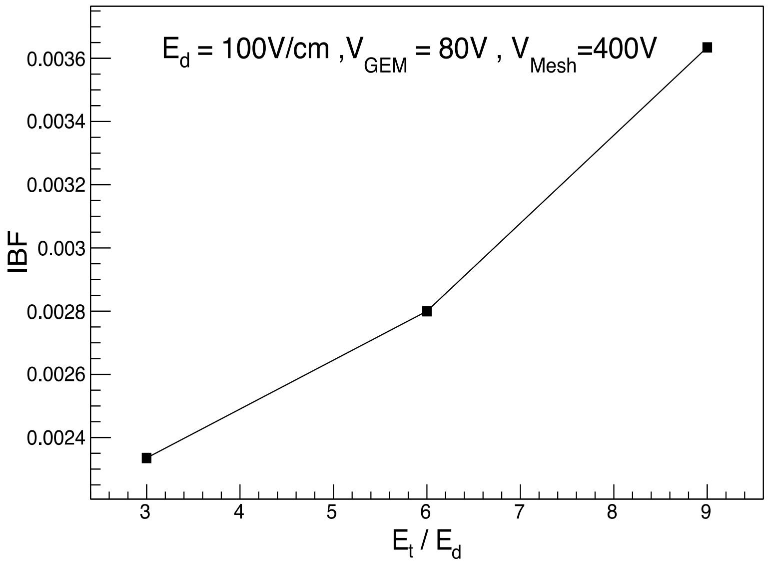
- **IBF ratio of 0.19% under overall detector gain of 5000 was achieved in our test in 2017.**

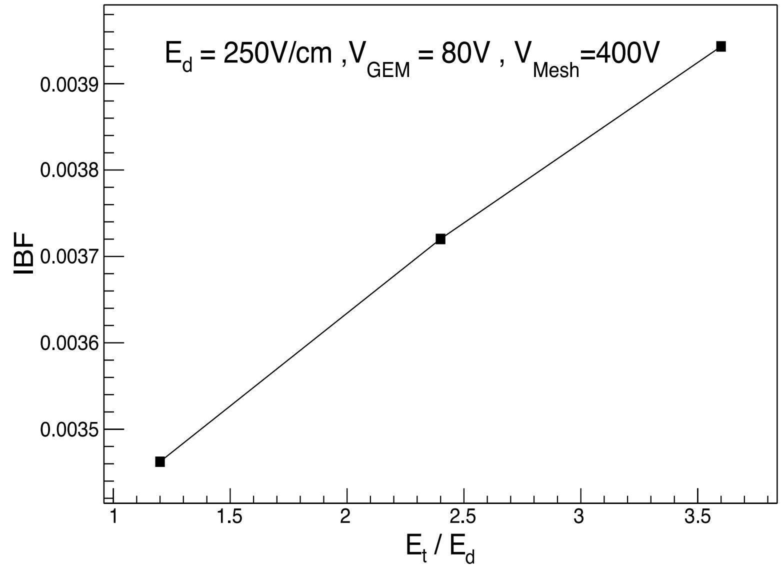
Gain of the hybrid structure detector

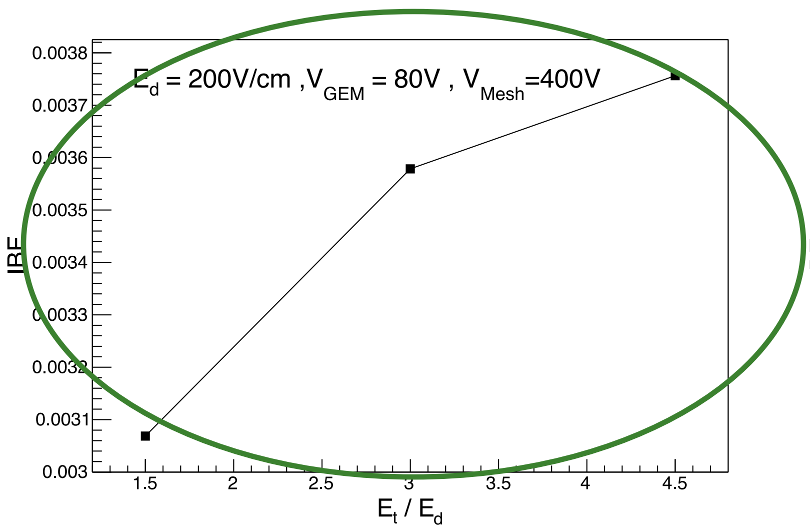


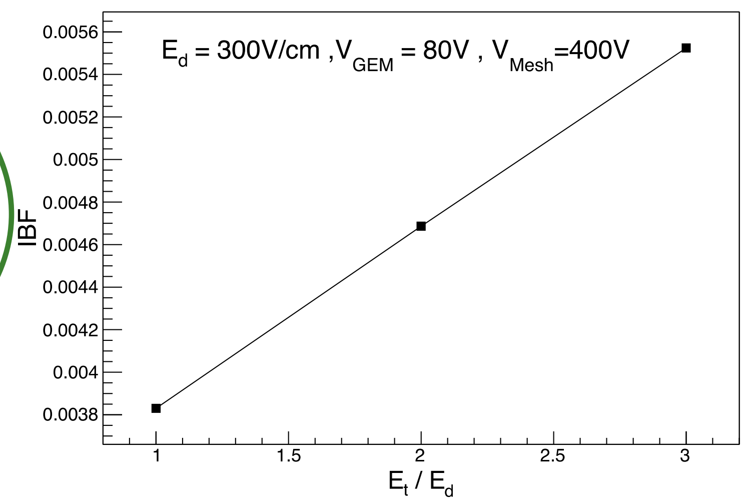
Optimization of Et/Ed

- Et/Ed set to 1-1.5 to control the IBF
- Ed=200V/cm for T2K at the saturation velocity



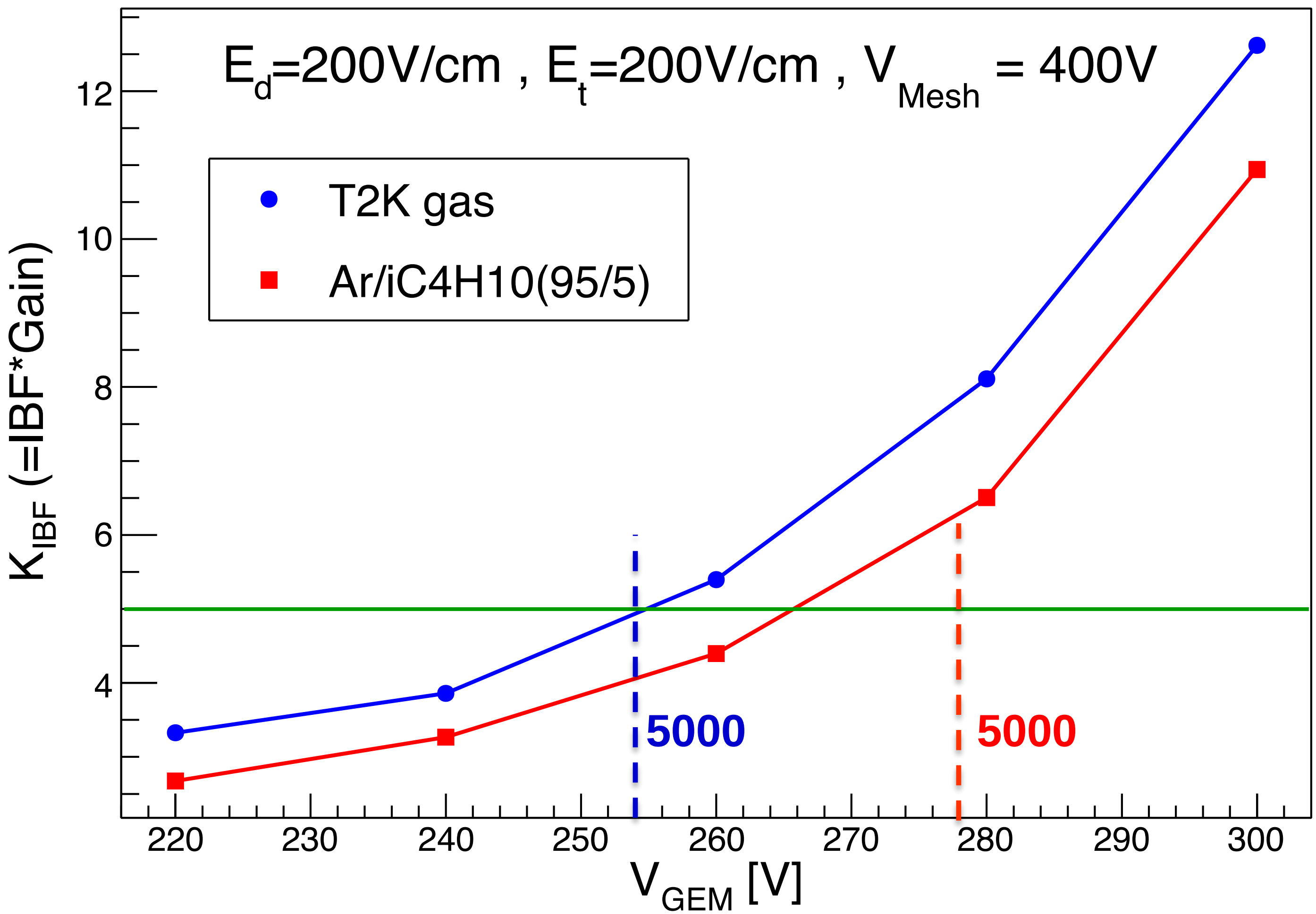






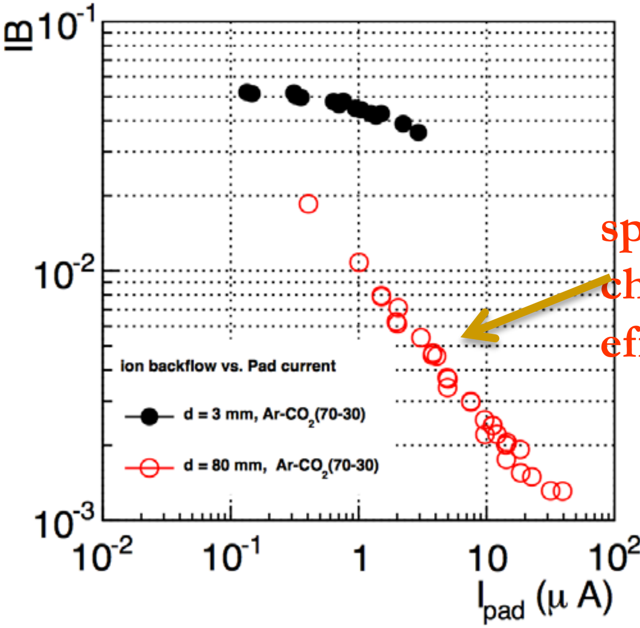
Key IBF factor: IBF × Gain

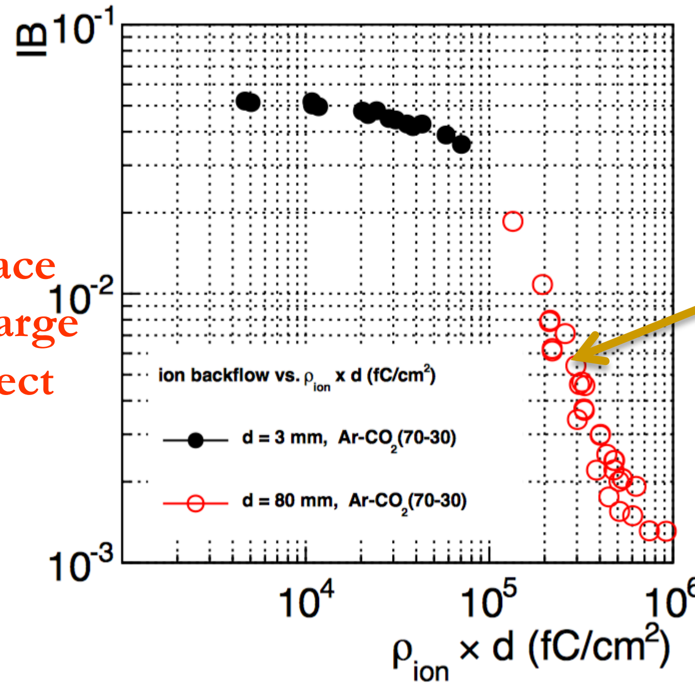
Preliminary results in 2018



- Space charge to decrease IBF

Check and answer





http://iopscience.iop.org/article/10.1088/1748-0221/9/04/C04025/pdf

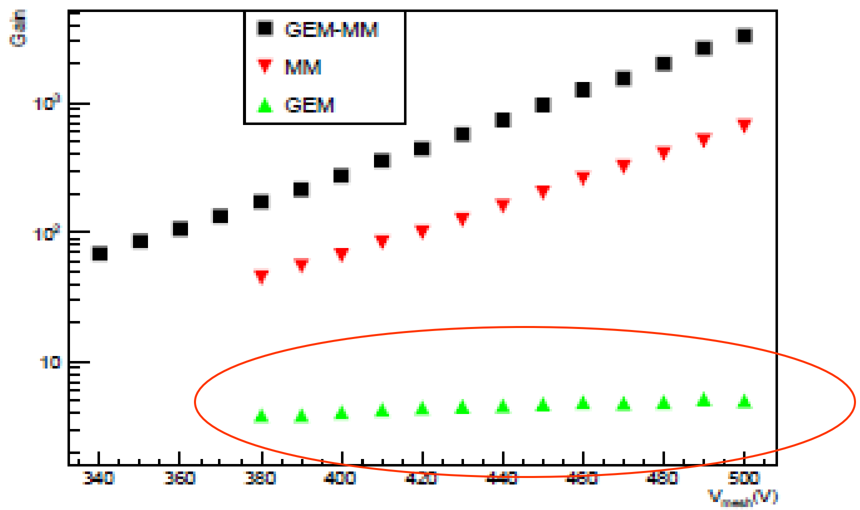
https://www.sciencedirect.com/science/article/pii/S0168900216308221

High rate and lots of ions make space charge effect to decrease IBF posibility !!!

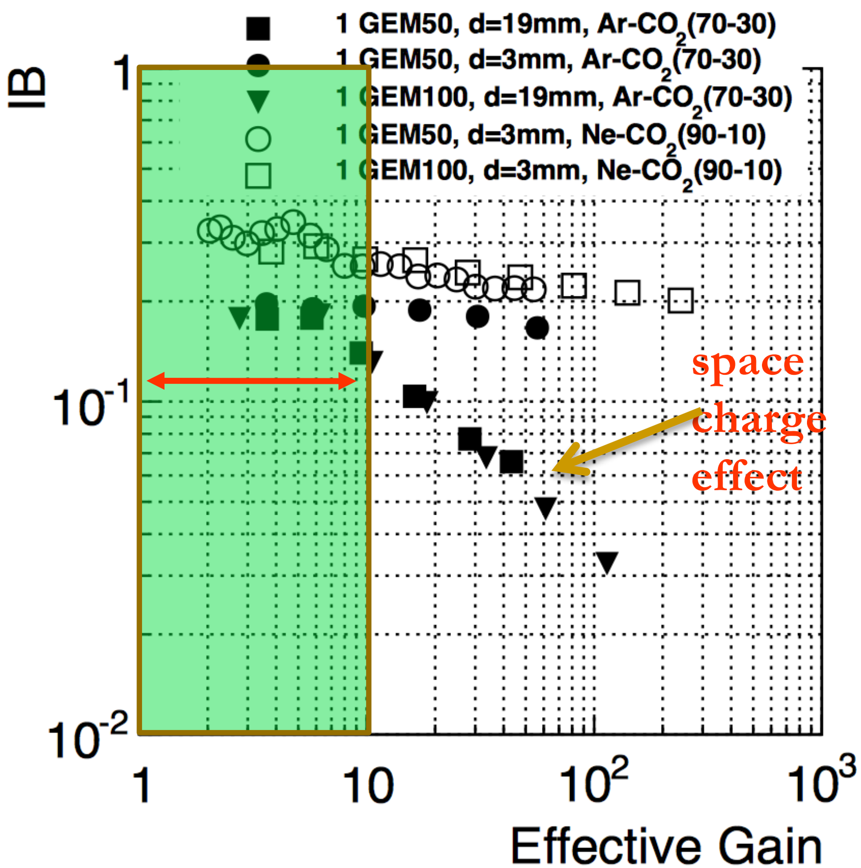
Check and answer -Gain

Single GEM with very low Gain in our Exp.

DOI: 1609.08010

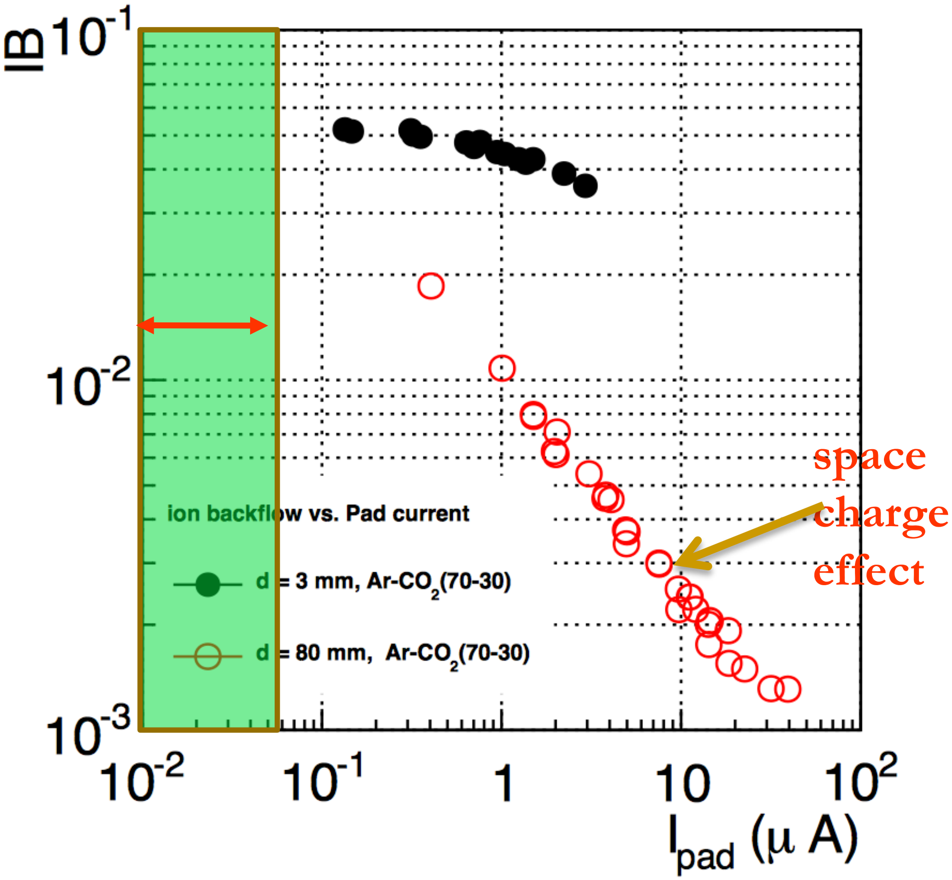


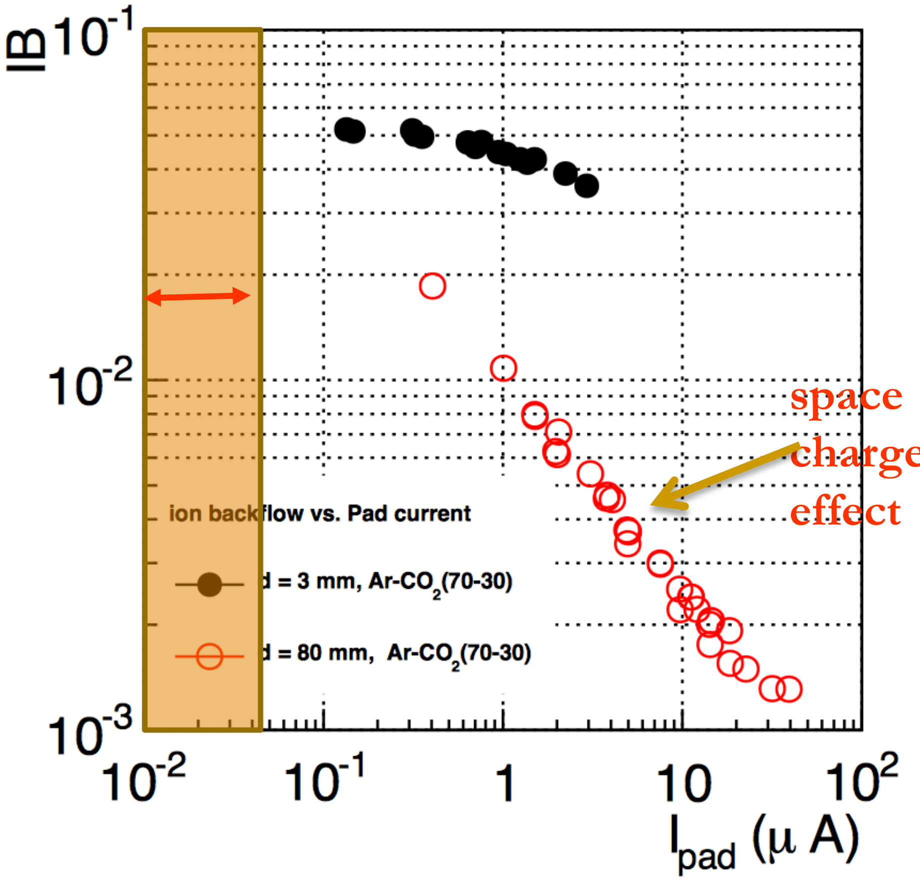
(b)



Check and answer- I_{pad}

Current of Pad is very low in our Exp.



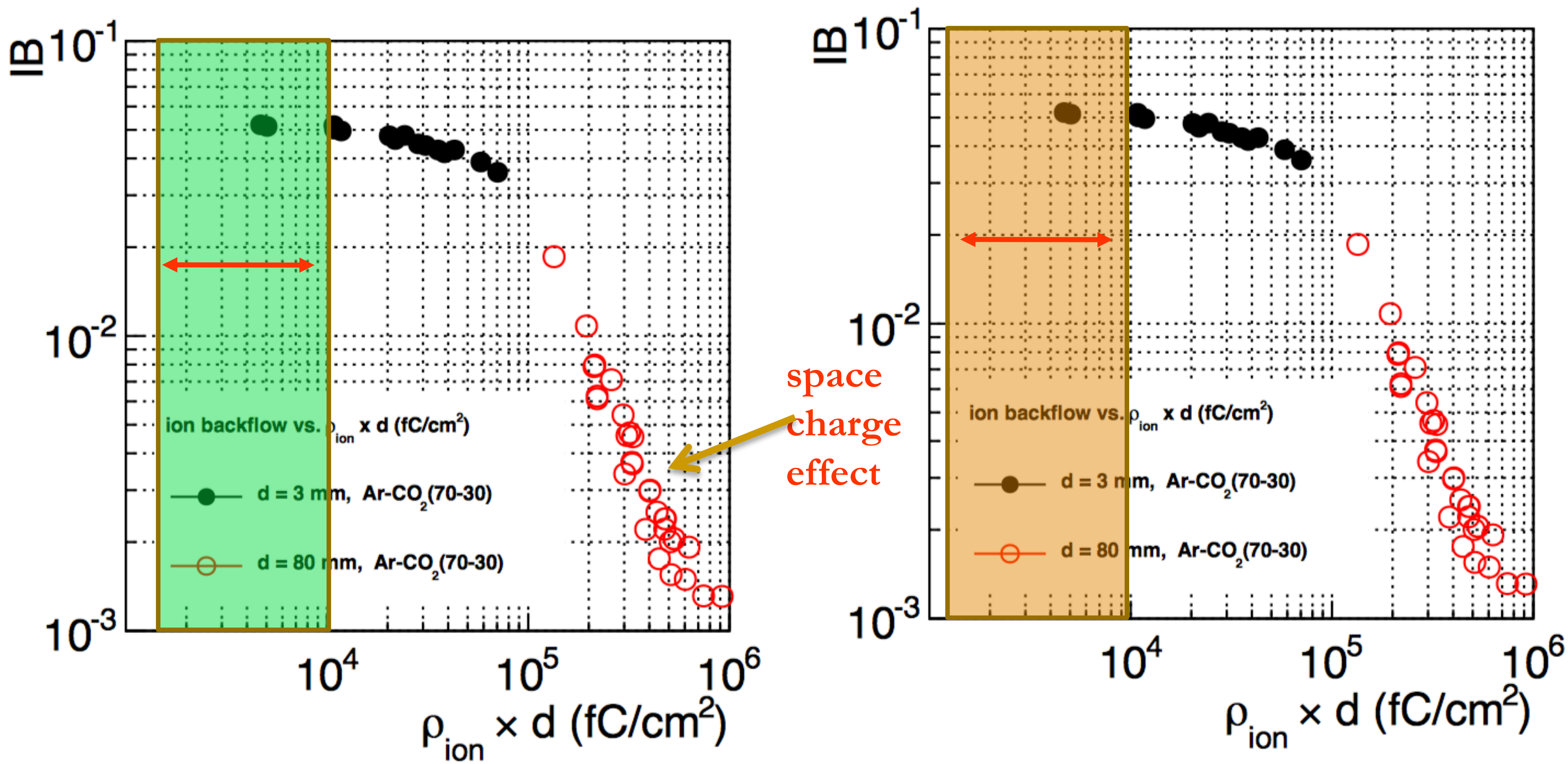


Green， T2K， Et=200V/cm, Ed=200V/cm, V_mesh=400V, V_Gem:30~300V

Yellow， Ar/iso(95/5) ， Et=200V/cm, Ed=200V/cm, V_mesh=400V, V_Gem:30~300V

Check and answer- $\rho_{ion} \times d$

Current of Pad is very low in our Exp.



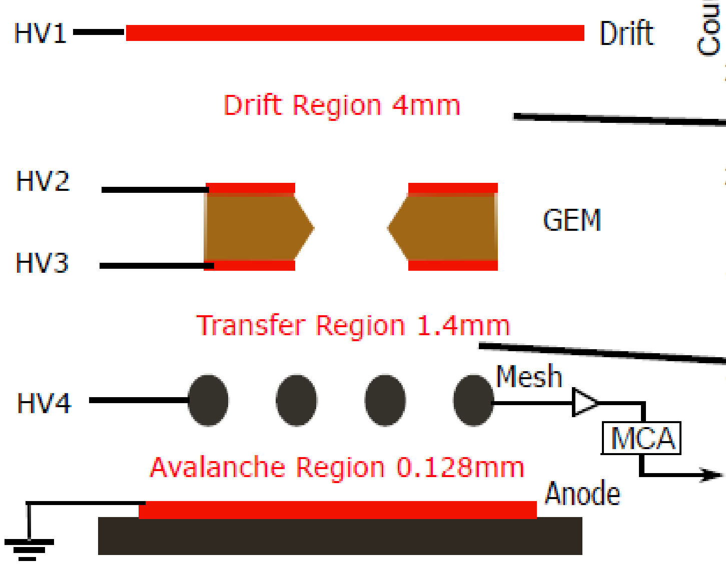
Green: T2K，Yellow: Ar/iso(95/5)

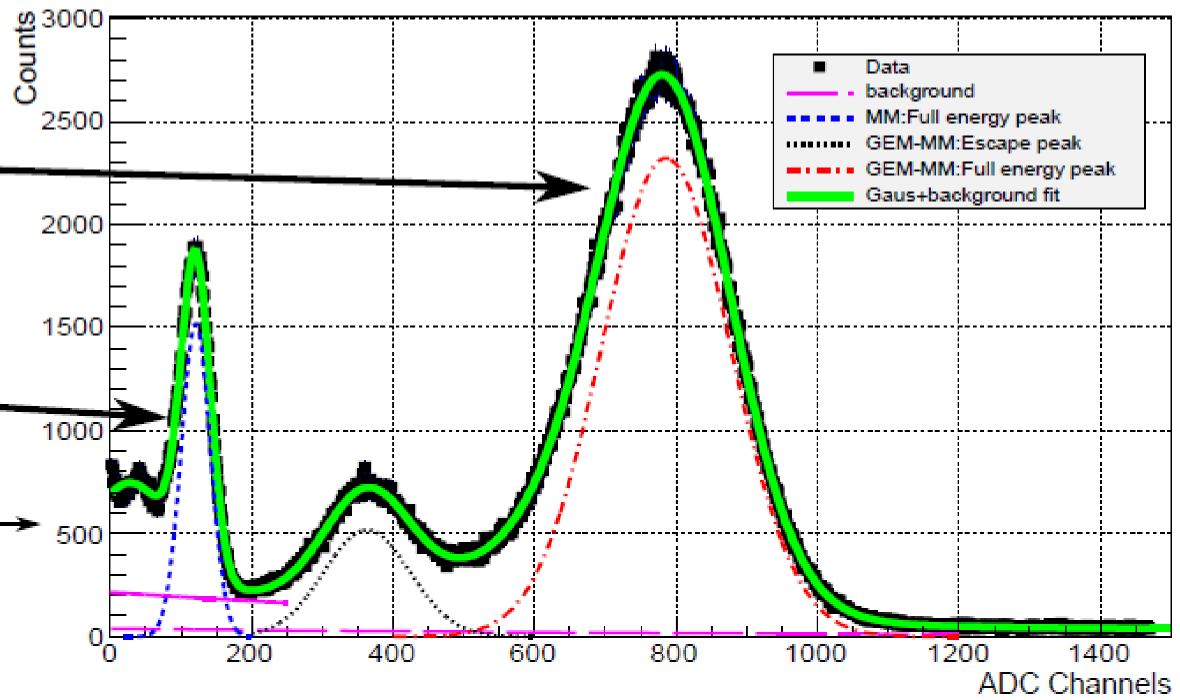
T2Kgas Ic: 4pA～59pA，～10^3 （fC/cm²）
Ar/iso gas Ic : 3.5pA~53pA, ～10^3 （fC/cm²）

GEM+MM@CEPC R&D

e+e- machine
Primary N_{eff} is small: ~30
Pad size:1mm×6mm

Photo peak and escape peak are clear!
Good electron transmission.
Good energy resolution.

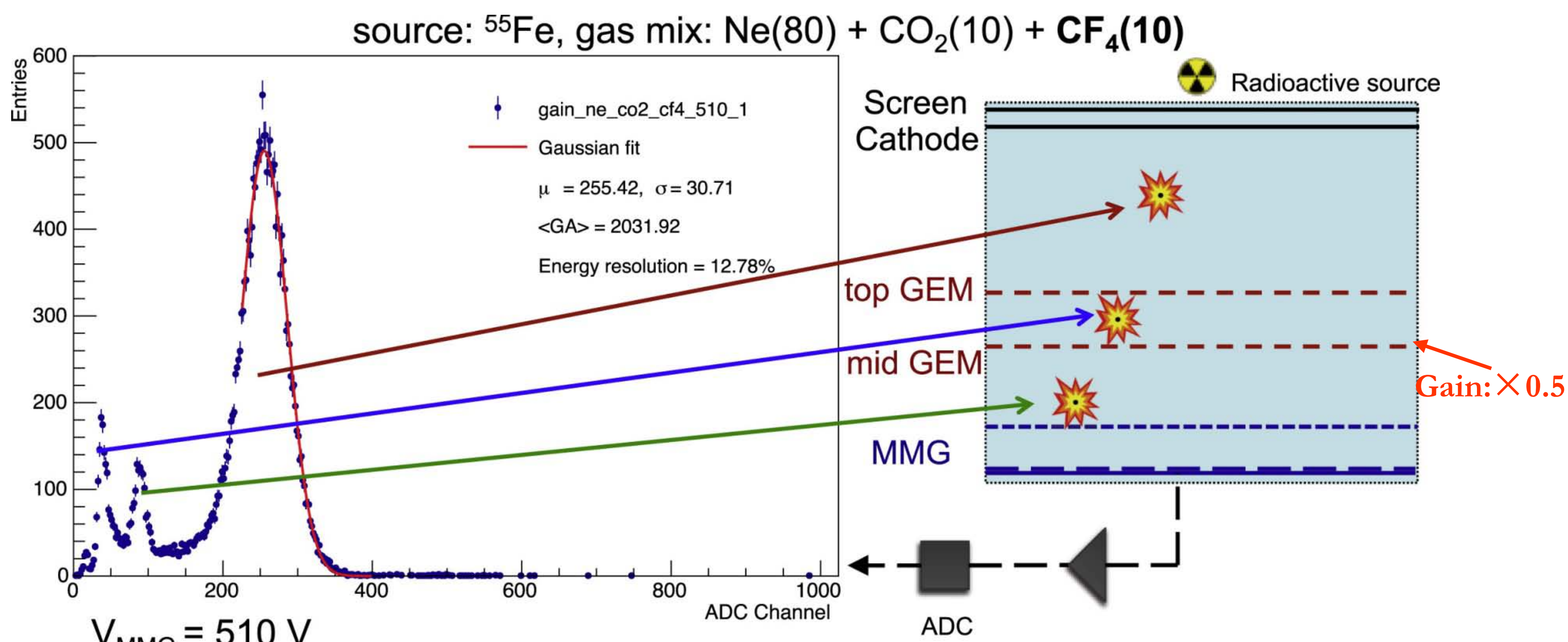




GEM+GEM+MM@ALICE R&D

Heavy ions machine
Primary N_{eff} is small: >300

Photo peak and escape peak are merged!
Electron transmission and the energy resolution are not good.



$V_{MMG} = 510$ V
$\Delta V_{GEM}^{top} = 260$ V
$\Delta V_{GEM}^{mid} = 230$ V

Manpower and activities

- TPC detector R&D @IHEP (2016~2020)
  - Huirong Qi,
  - Yulian Zhang (PhD,IHEP), Haiyun Wang(PhD,IHEP), Zhiwen Wen(PhD,IHEP)
  - Prof. Jin Li
  - Funding from MOST and NSFC(~3.5 Million RMB)
- Electronics R&D &Tsinghua (2016~2020)
  - Zhi Deng
  - Yiming Cai(PhD,THU), Zhao Mingrui (Master, THU) and three PhDs in electronics lab
  - Prof. Yuanning Gao, Prof. Yulan Li
  - Funding from NSFC (~2.0 Million RMB)

Summary

Continuous IBF module

- **No Gating device options used for Higgs/Z pole run**
- **Continuous Ion Back Flow due to the continuous beam structure (Developed in IHEP)**
- **Preliminary results: Key factor of IBF×Gain=5**
- **Low discharge and spark possibility**

Beam test plan in next year

- **Position resolution test**
- **dE/dx**

Thanks.