Status of CEPC-TPC and Hybrid Gaseous Detector Module

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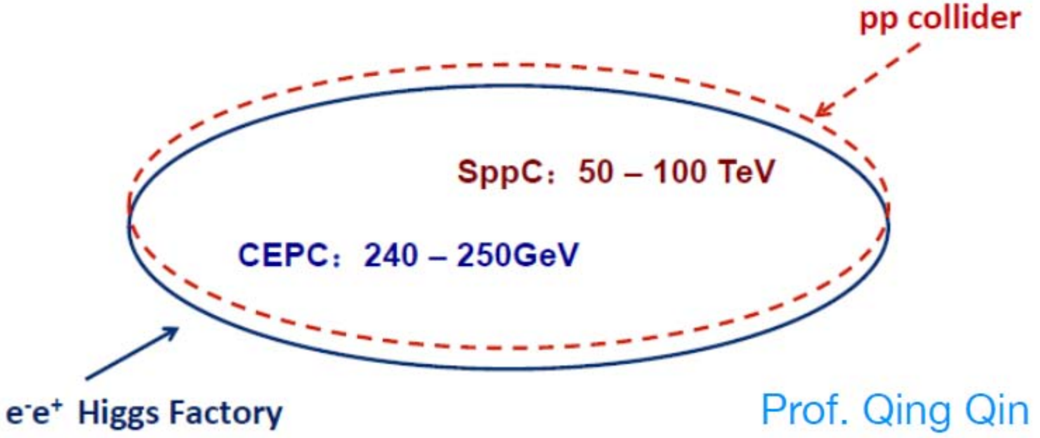
Outline

- Status of CEPC-TPC
- Hybrid Gaseous Detector Module
- Current R&D activities
- Summary

Status of CEPC-TPC

CEPC-SppC

- Proposal from the Chinese HEP community and presented by Prof. Qing Qin at Accelerators for a Higgs Factory: Linear vs. Circular (HF2012)



- Phase I: Circular Electron-Positron Collider (CEPC)
  - Higgs Factory, center-of-mass energy ~240 GeV, instantaneous luminosity $\sim 2\times 10^{34} cm^{-2}s^{-1}$, 2 interaction points, ~1 M clean ZH events over 10 years → precision measurements of the Higgs boson
  - Operation at Z-pole/WW threshold → EW precision measurements
- Phase II: Super Proton-Proton Collider (SppC)

Possible Project Timeline

- CEPC Detector (Preliminary)
  - Modified version of the ILD detector for physics feasibility studies, consisting of the following sub-detectors (from inside to outside): Vertex Detector, Silicon Tracker, Time Projection Chamber (TPC), Electromagnetic Calorimeter (ECAL), Hadronic Calorimeter HCAL), Solenoid + Muon Detector

Towards CEPC TPC– some considerations

- **Optimization of working gas**:
  - Fast velocity at low drift electron field
  - Small attachment coefficient
  - Low transverse and longitudinal diffusion
- **IBF Detector Module**:
  - Continuous deviece reduced ions feed back
  - Working stable in the longer time
- **Alignment and Calibration**:
  - Alignment of module, pad, readout, etc.
  - Calibration of drift velocity, E/B effect,etc.
  - UV laser option
- **Estimation at High counting rate**:
  - High events rate, even Z pole
  - High counting rate and multi-track

Critical Challenge

ILC and CEPC (primary different)

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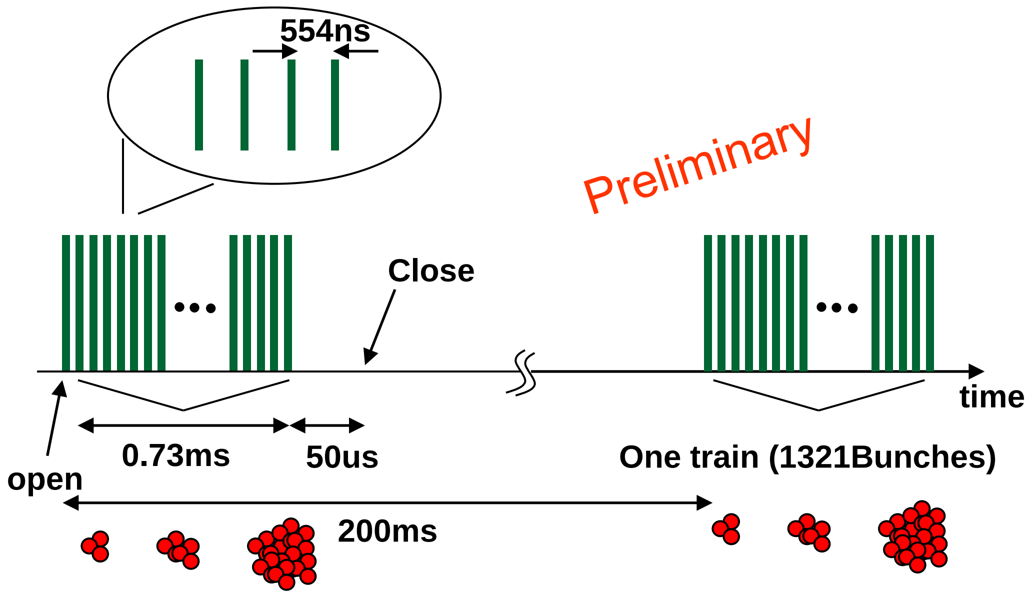
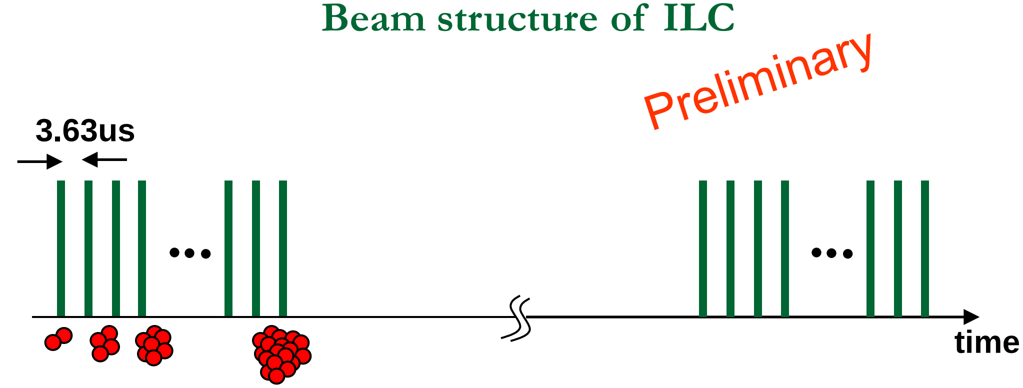
- In the case of ILD-TPC
  - Bunch-train structure of the ILC beam (one ~1ms train every 200 ms)
  - Bunches time ~554ns
  - Duration of train ~0.73ms
  - Used Gating device
  - Open to close time of Gating: 50μs+0.73ms
  - Shorter working time
- In the case of CEPC-TPC
  - Bunch-train structure of the CEPC beam (one bunch every 3.63μs)
  - No Gating device with open and close time
  - Continuous device for ions
  - Long working time



Beam structure of ILC



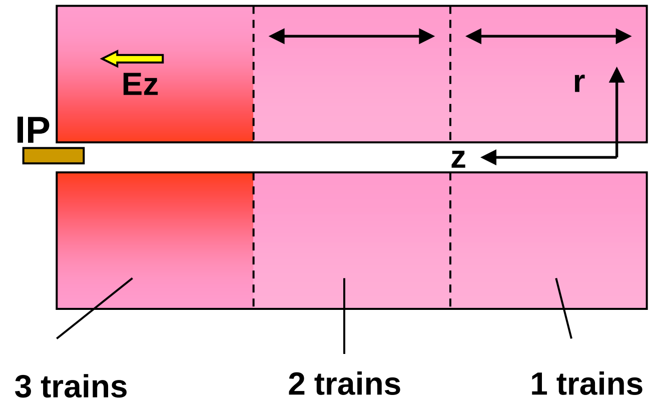
Beam structure of CEPC

NO Gating device !

Simulation: Ion back flow

In the case of ILD-TPC

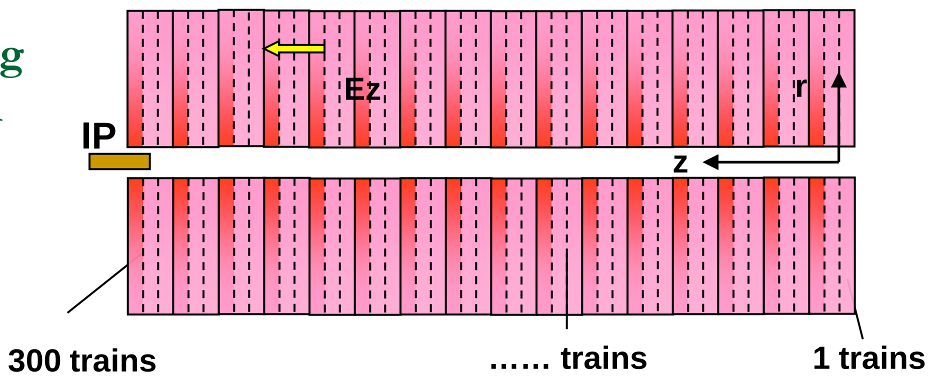
- Distortions by the primary ions at ILD are negligible
- Ions from the amplification will be concentrated in discs of about 1 cm thickness near the readout, and then drift back into the drift volume Shorter working time
- 3 discs co-exist and distorted the path of seed electron
- The ions have to be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



Amplification ions@ILC

In the case of CEPC-TPC

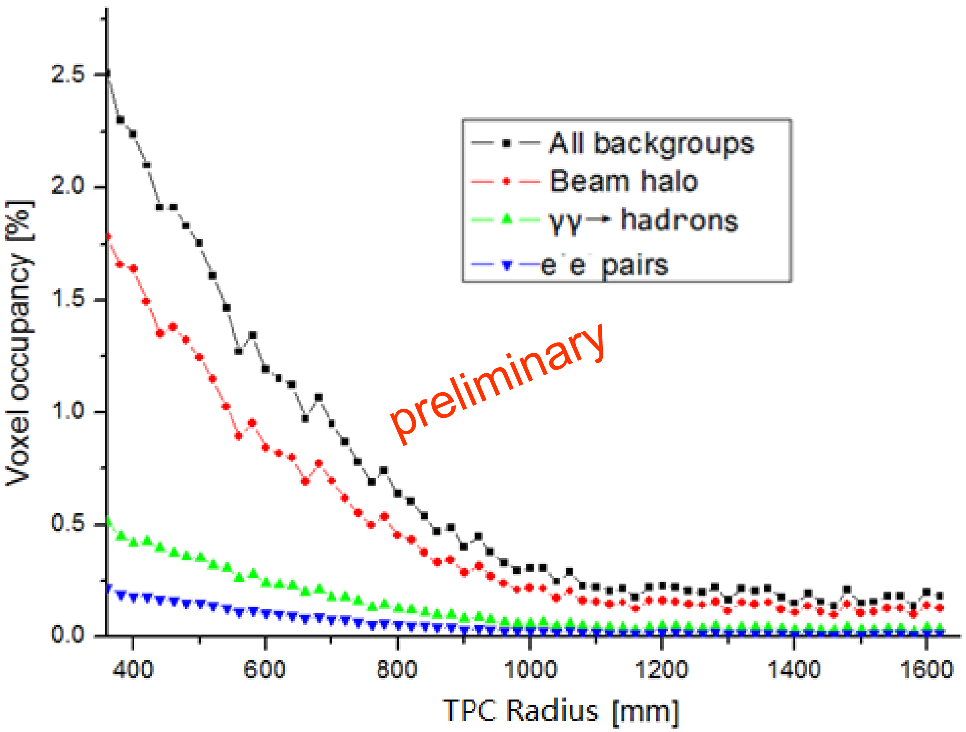
- Distortions by the primary ions at CEPC are negligible too
- 300 discs co-exist and distorted the path of seed electron
- The ions have to be neutralized during the ~4us period continuously



Amplification ions@CEPC

Occupancy Simu.@250GeV CEPC

- Voxel occupancy
  - Very important parameter of TPC could determine to use or NOT as the tracker detector
  - No consideration for the beam collimator and synchrotron radiation, the value might larger

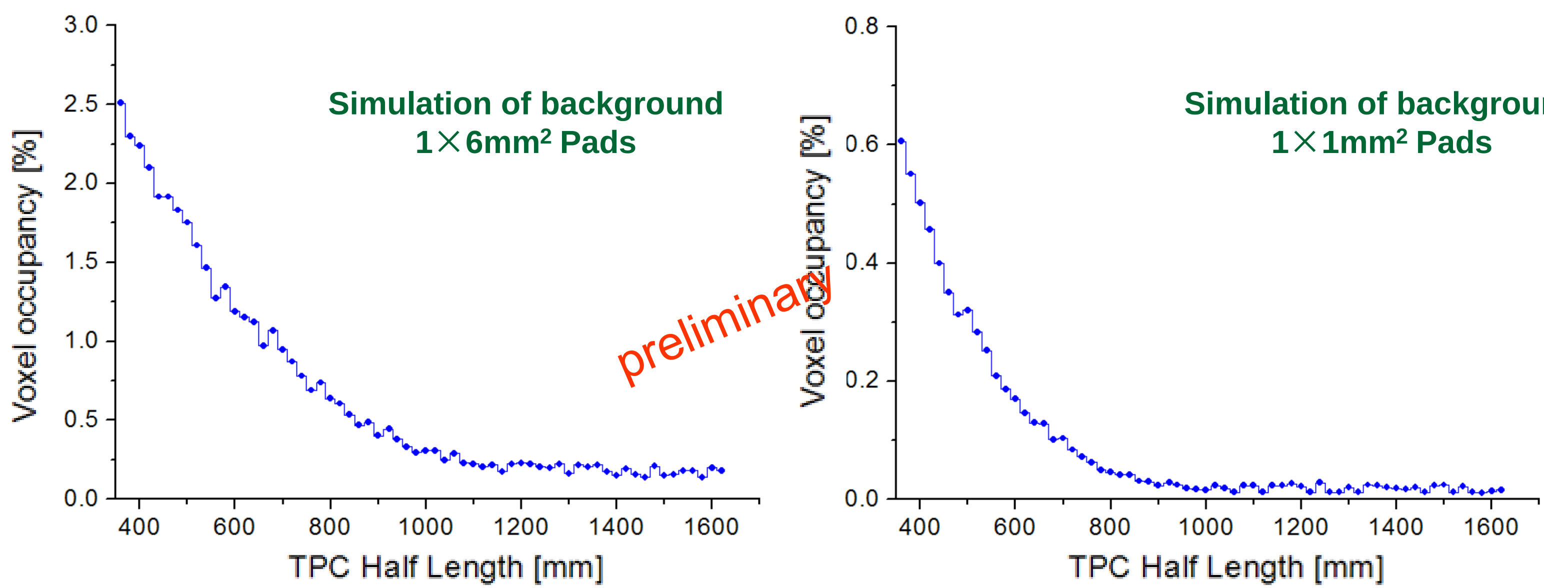


TPC voxel occupancy simulated in TPC radius

Simulation of occupancy

- Occupancy@250GeV
  - Very important parameter for TPC
  - Detector structure of the ILD-TPC like
  - ADC sampling 40MHz readout
  - Time structure of beam:·4us/Branch
  - Beam Induced Backgrounds at CEPC@250GeV(Beam halo muon/e+e- pairs)+γγ→hadrons with safe factors(×15)
  - Value of the occupancy inner radius smaller
  - Optimization for the pad size in rΦ

CLIC_ILD ~30%@3TeV
1×6mm² Pads
CLIC_ILD ~12%@3TeV
1×1mm² Pads
NO TPC Options!



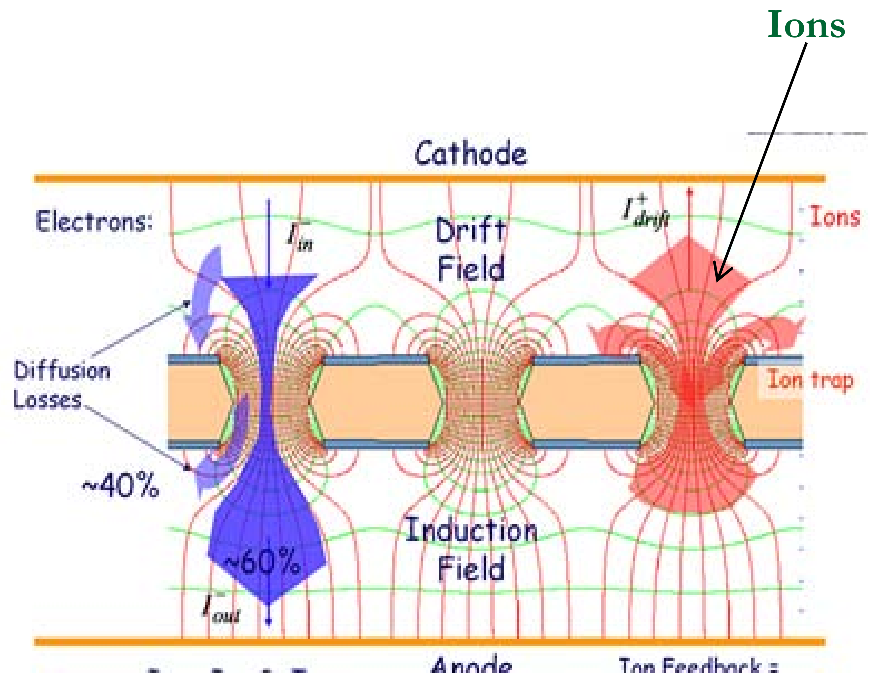
Preliminary of occupancy

Hybrid Gaseous Detector Module

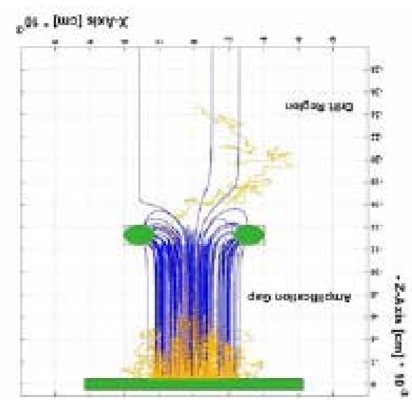
New ideas for the ions?

- GEM detector could be as the amplification detector, Micromegas could be as the amplification device too.
- GEM detector could be reduced the IBF as the gating, Micromegas could be decrease the IBF too.

- 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

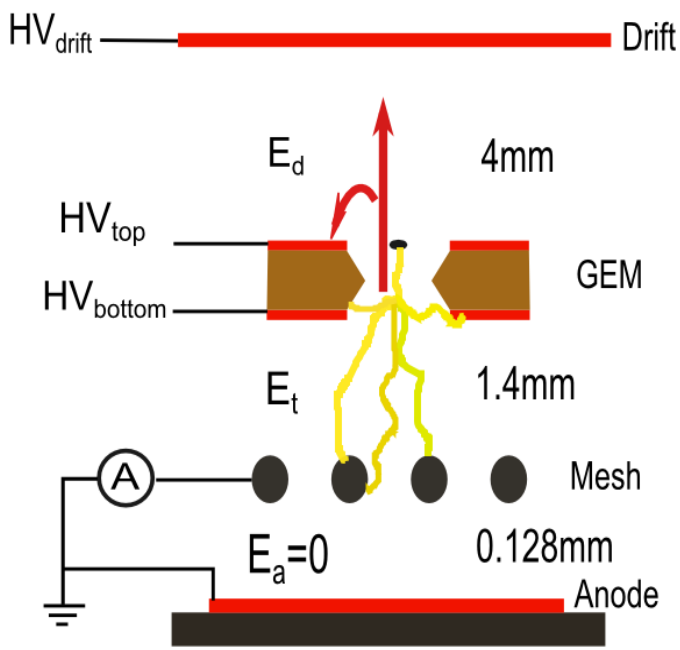


IBF of GEM



IBF of Mciromegas

Sinmulation



$E_d = 0.1 - 1.5\ kV/cm$, 500

$\Delta V_{GEM} = 10 - 500V$, 340

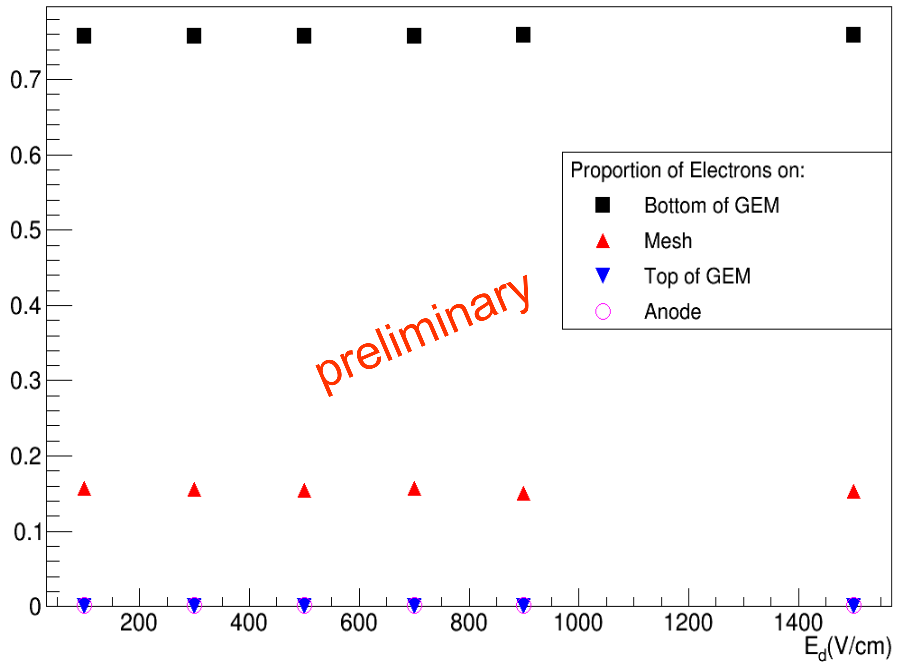
$E_t = 0.5 - 4\ kV/cm$, 500

1000 electrons

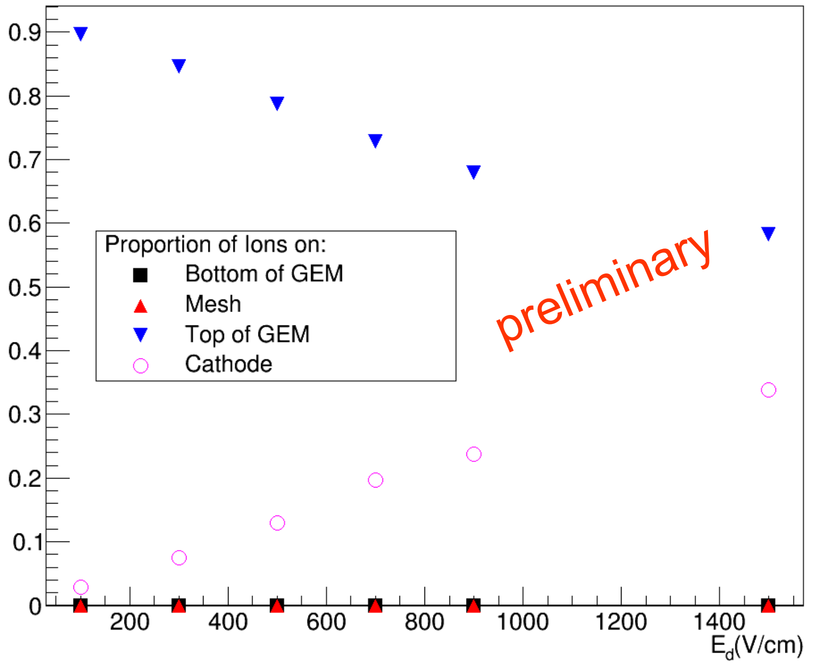
- **Gain: Total number of electrons / number of primary electrons(1000).**
- **Variable to be the equivalent of measured current : number of electrons or ions ended on each electrodes/total number of electrons or ions.**

Sinmulation

ELECTRON

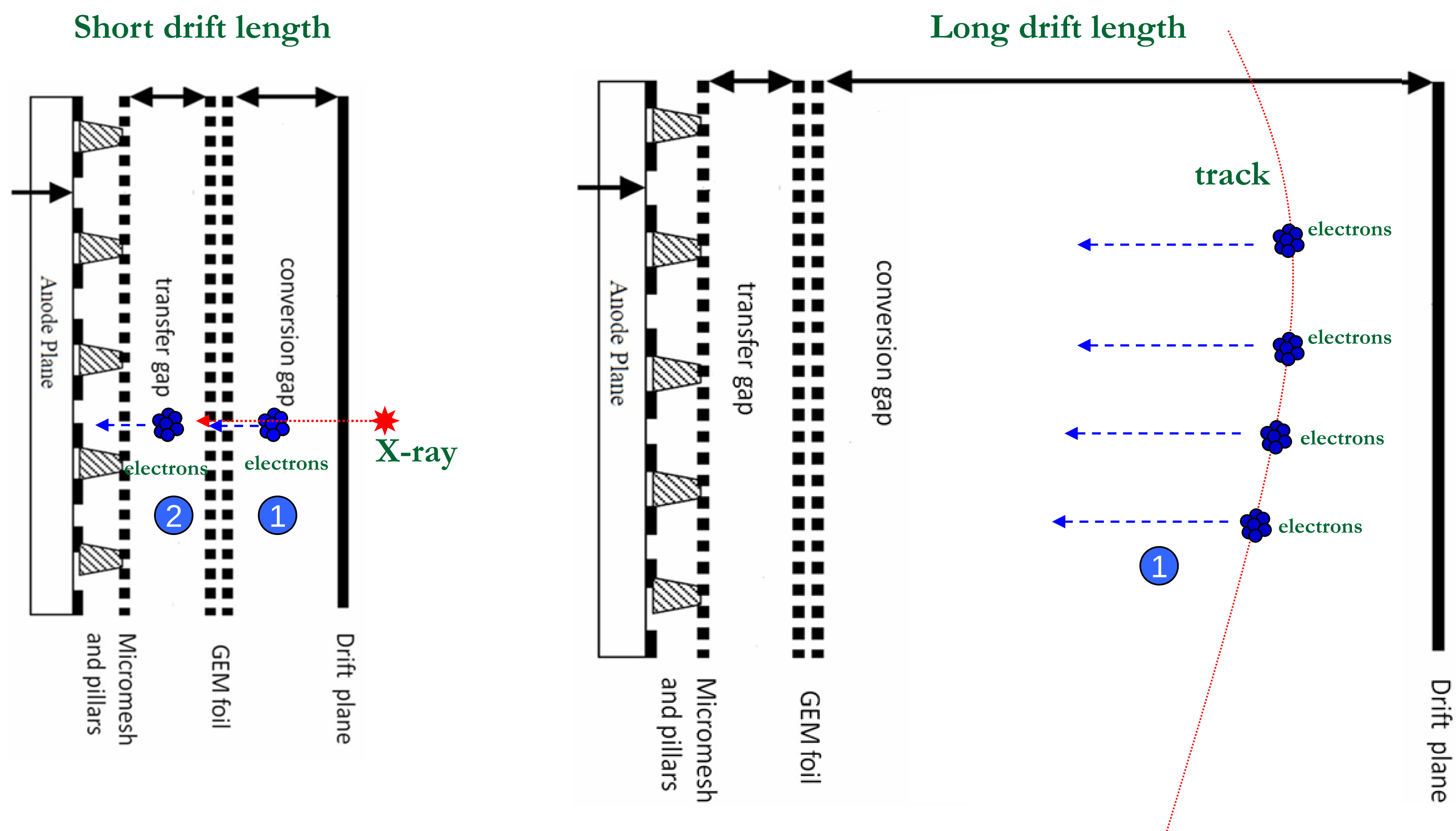


ION



- VGEM=340V, Et= 500V/cm
- Ed of electronic drift field increasd
- Ions and electrons occurred in some regions

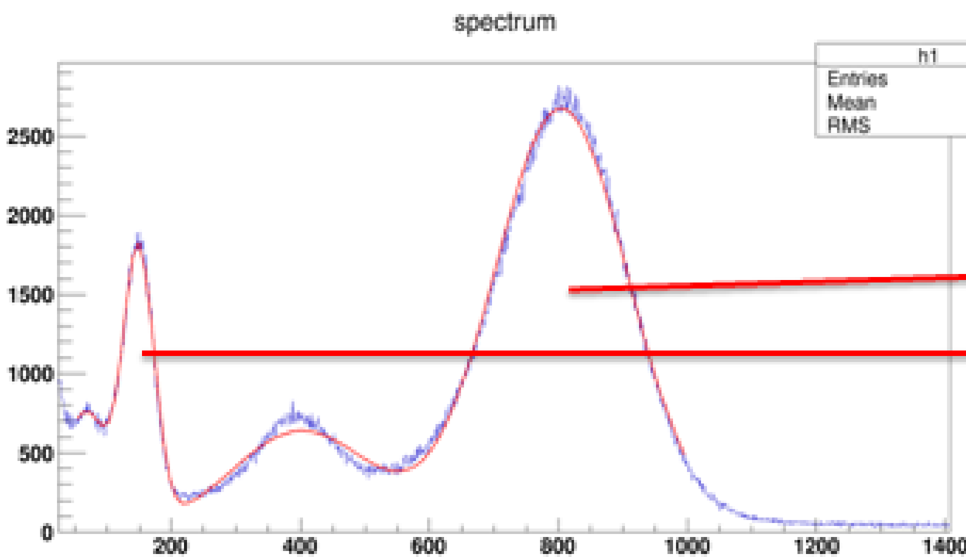
Hybrid structure module option

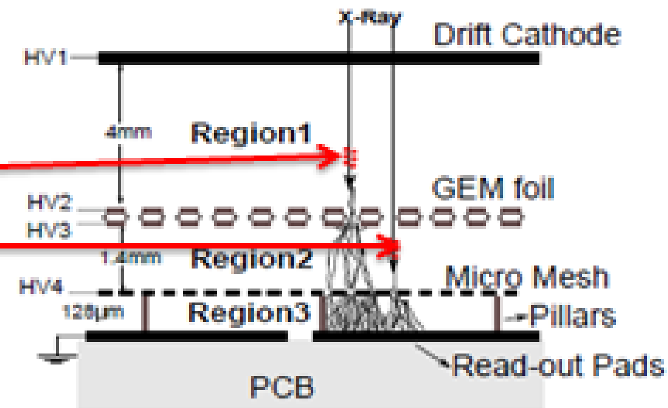


Measurement method: X-ray and particles track in the module

Hybrid structure module

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





G_{mm}
Resolution 20%(FWHM)

$G_{mm \times gem}$
Resolution 30.3%(FWHM)

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

Test of the new module

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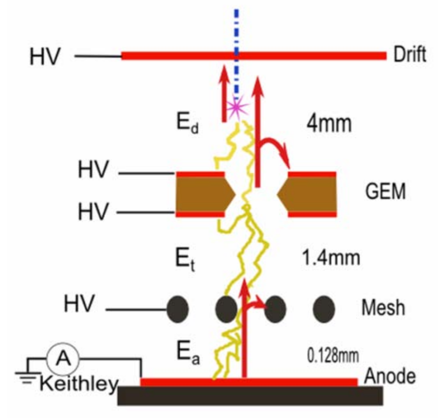
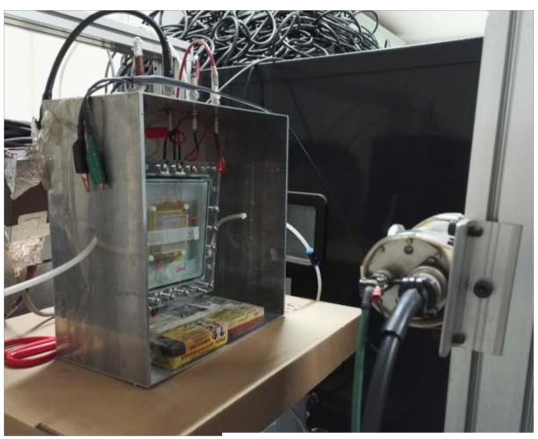
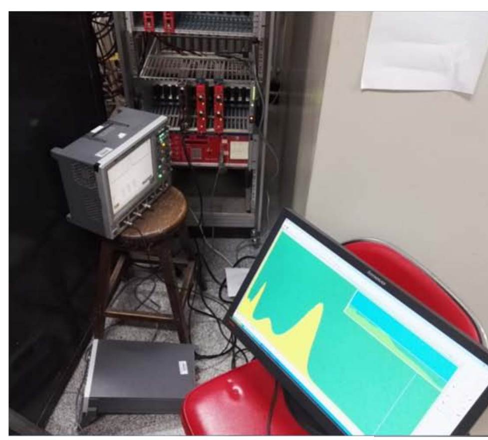
- Test of GEM+Micromegas module
  - Assembled with the GEM and Bulk-Micromegas
  - Active area: 50mm×50mm
  - X-tube ray and X-ray radiation source
  - Simulation using the Garfield
  - Ion back flow with the higher X-ray: from 1% to 3%
  - Stable operation time: more than 48 hours
  - Separated GEM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







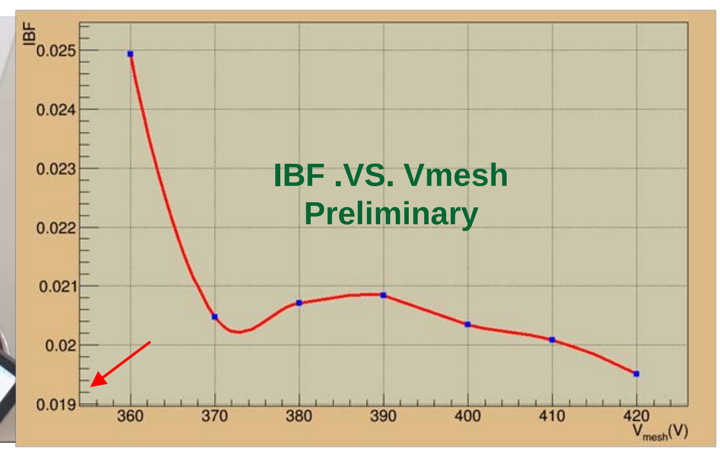
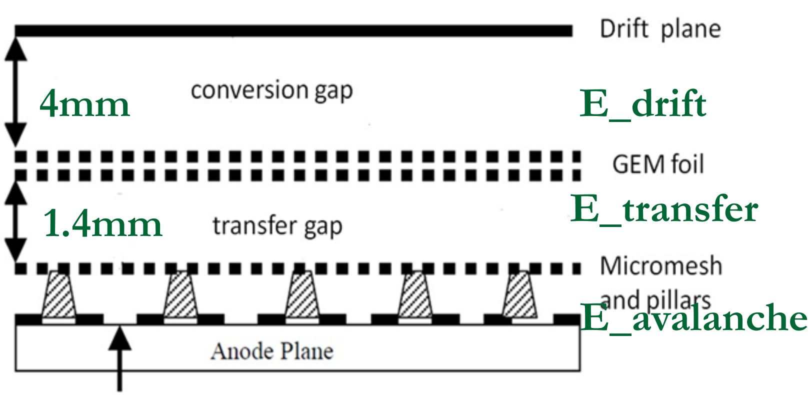
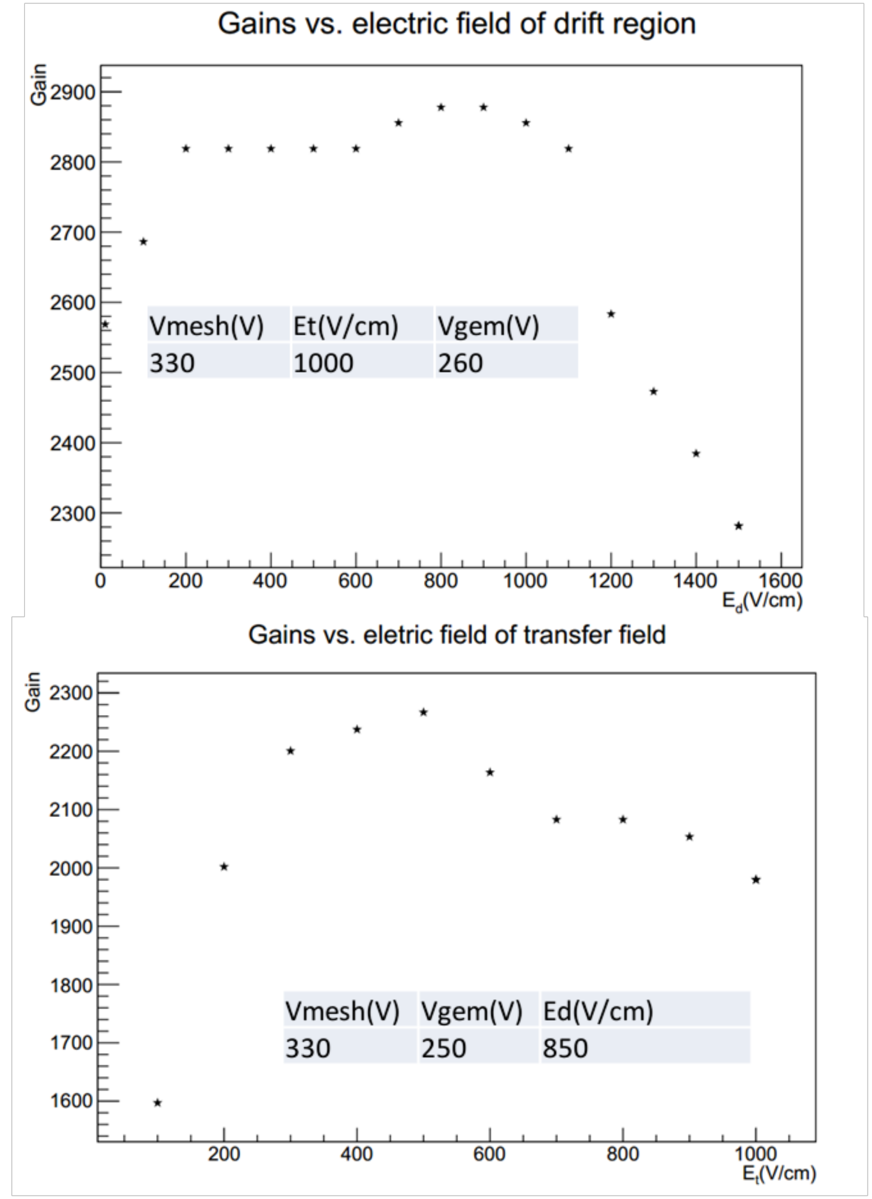


Photo of the GEM+Micromegas Module with X-ray

Hybrid structure module

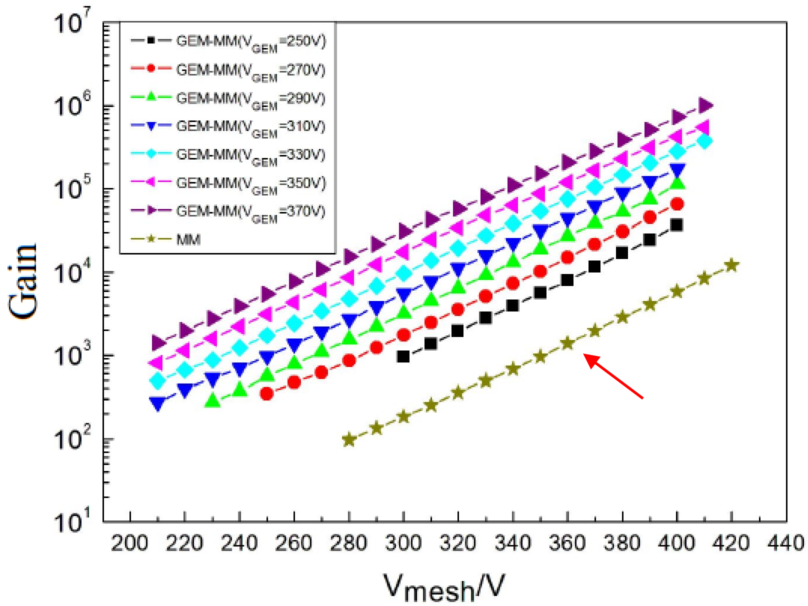
- Optimized operating voltage
  - To achieve the higher electron transmission in the hybrid structure module
  - The ratio of E_avalanche and E_transfer of Micromegas detector is 216.8
  - The ratio of E_transfer and E_drift of GEM detector is 67.08

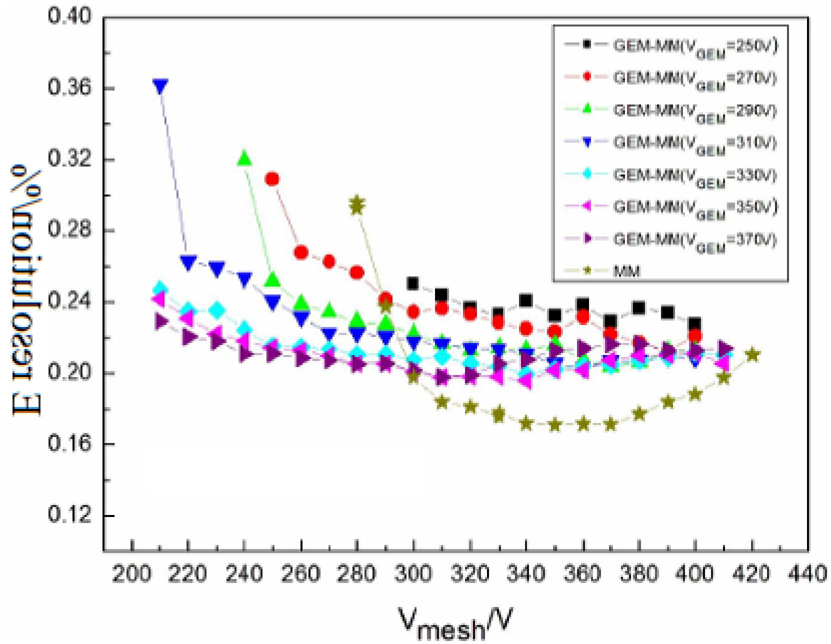




Electron transmission in GEM and Micromegas

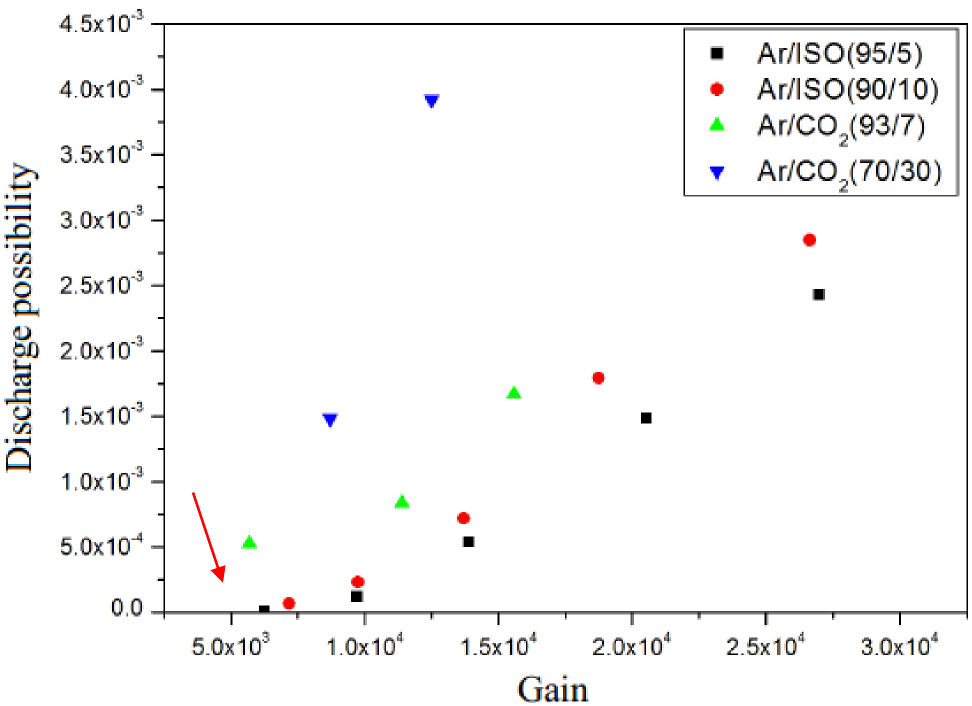
Gain and energy resolution

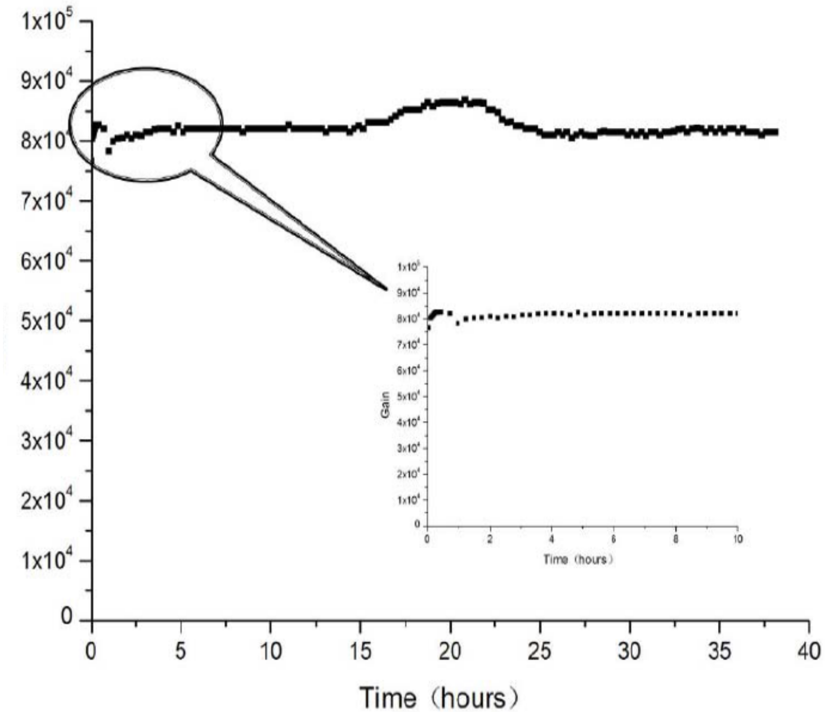




- Test with Fe-55 X-ray radiation source
  - Reach to the higher gain than standard Micromegas with the pre-amplification GEM detector
  - Similar Energy resolution as the standard Micromegas
  - Increase the operating voltage of GEM detector to enlarge the whole gain

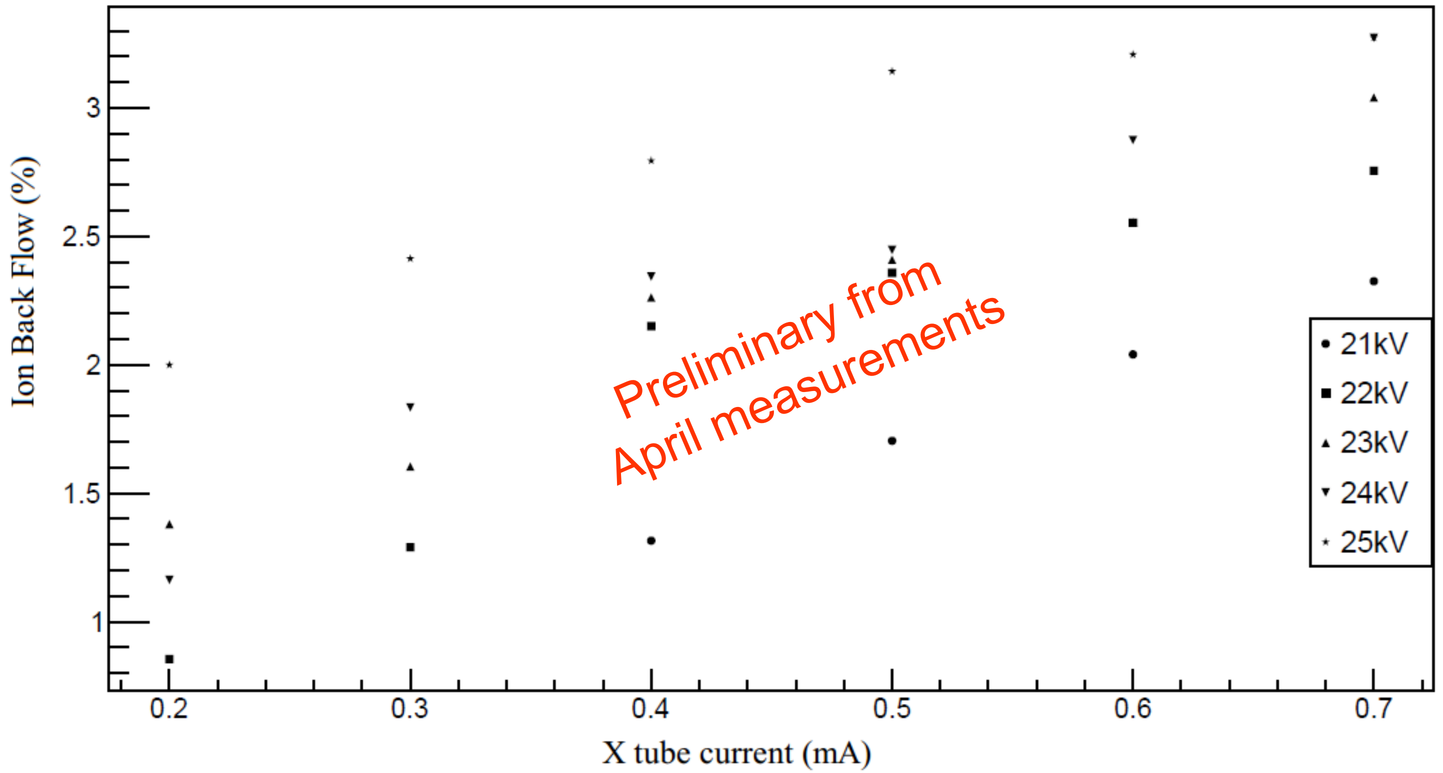
Working gas and duration time





- 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 preliminary result



- 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 γ, calculation of IBF, η:

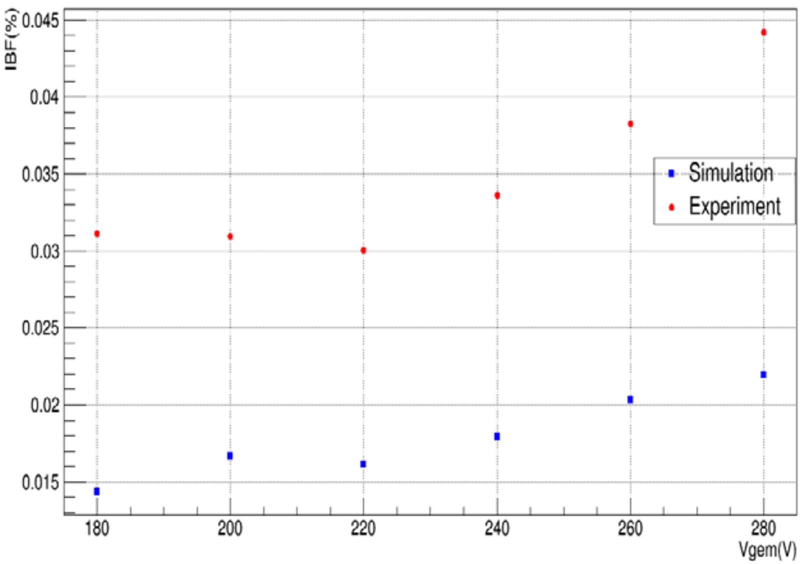
$$I_{mesh} = G\gamma$$

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

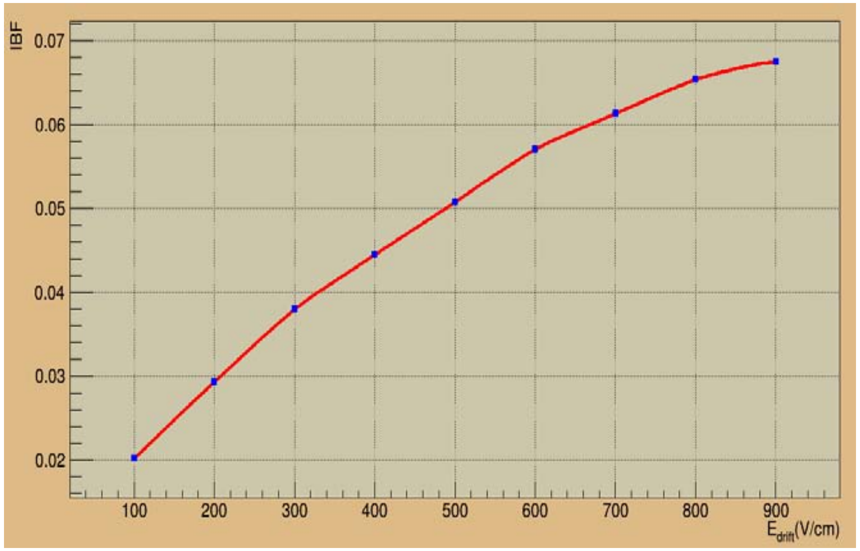
G is the gas gain of the detector.

IBF preliminary result

IBF vs. Voltage across GEM foil



IBF vs. Drift Field



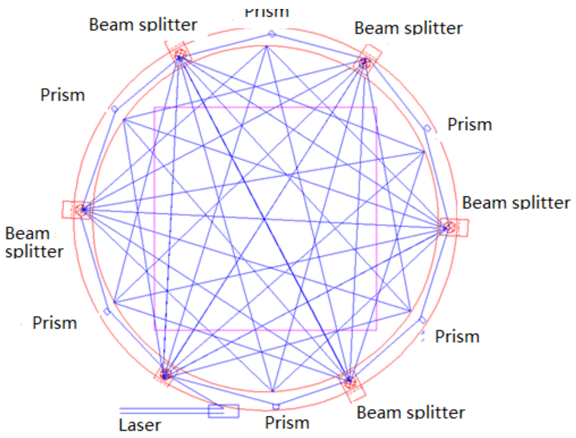
- Expt. value higher that the simulation data. Contribution to the drift current from the ions from primary ionization(in Region1).
- With the increase of drift field:
  a) current on drift cathode increases,
  b) current on the top electrode of GEM decreases,
  c) sum of the above two remains about the same,
  d) current on mesh keeps stable.

Current R&D activities of CEPC-TPC detector

Laser calibration system for TPC

Supported by the State Key Program of National Natural Science of China

- Principle of laser for TPC detector
  - The ionization in the gas volume along the laser path occurs via two photon absorption by organic impurities
- To reduce the distortion effect
  - E×B effect study
  - Drift Velocity measurement
- Laser features for TPC
  - $\lambda = 266$ nm or $E = h\nu = 4.66$ eV
  - Energy: ~100 uJ/pulse
  - Duration of pulse: 5 ns
- Advantages
  - Transportable and flexible test beam setup
  - Good resolution in space and time
    - No production of σ-rays
    - No multiple scattering
  - No curvature in magnetic fields
  - Ionisation density controllable and small fluctuation
  - Simple beam reflection similar to light



Laser profile map in TPC

Test with Laser

Common efforts R&D

Collaboration for the IBF R&D:

CEA Scalay (France)

IHEP, Tsinghua Univ. (China)

Aleksan Roy (Saclay)
GAO Yuanning (THU)
QI Huirong (IHEP)

Collaboration for the Laser calibration R&D:

Tsinghua Unviversity, Beijing

IHEP, Beijing

LI Yulan (THU)
DENG Zhi (THU)
QI Huirong (IHEP)

Targets:

- **R&D of IBF used UV light**
    - **Goal: ~0.1% IBF, Resistive Micromegas modules, Hybrid modules**
- **Laser optical design**
- **TPC Prototype design with Laser calibration**
    - **Readout active area: ~200mm^2, Drift length: ~500mm**
- **ASIC electronic readout**
    - **Goal: ~32Chs/CHIP, Channels: ~1K**
- **Toward CEPC CDR**

Summary and outlook

- Baseline design for the preCDR with an ILD-like sturcture
- Critical requirements for CEPC
  - Beam structure
  - Obvious distortion
  - Complex MDI design
- Some activities and simulations
  - Simulation of the occupancy of the detector, the hybrid structure gaseous detector's IBF
  - Hybrid structure detector
  - Some preliminary IBF results
  - Design and test of the detector prototype for the laser calibration

- **The international workshop of the CEPC TPC detector will be scheduled in September, 2016.**
- **And next development…**

Thanks very much for your attention !