Status of the continuous ion suppression detector modules for CEPC TPC

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Outline

- Physics requirement
- Simulation and experiment
- Progress on collaboration
- Summary

First question:

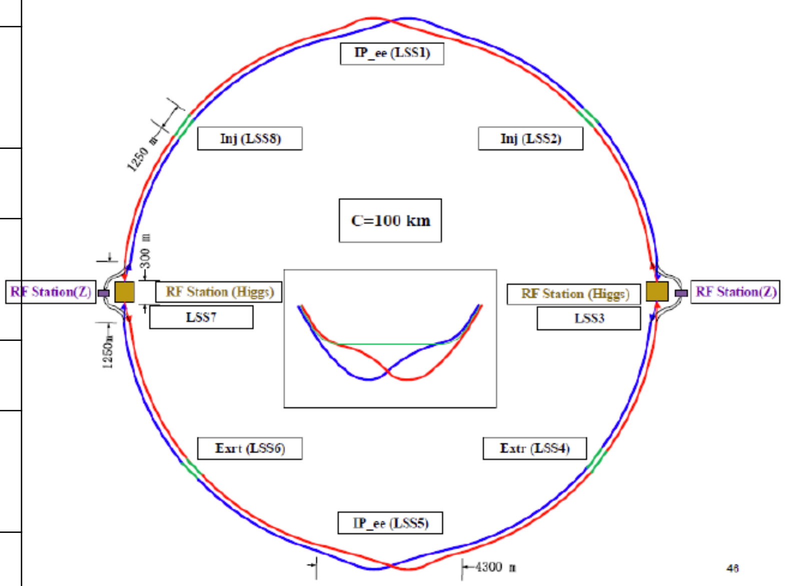
Why we need continuous IBF suppression in TPC module as the tracker option?

CEPC and its beam structure

Circular e^+e^- Higgs (Z) factory 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

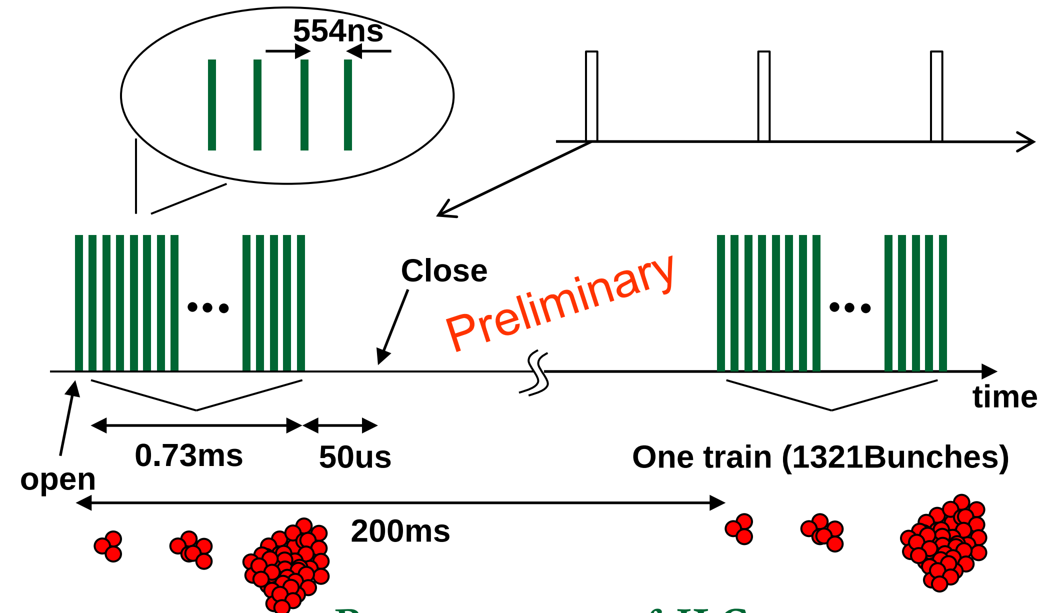
	tt	H	W	Z
Beam Energy [GeV]	175	120	80	45.5
Bunch charge [nC]	22.6	18	16.8	7.4
Bunch length [mm]	2.7	2.9	3.9	4
Bunches / beam	98	555	3000	65716
Bunch spacing [ns]	**1704**	**301**	**56**	**3**
Train spacing [us]	**83.5**	**83.5**	**84**	**98.6**
β^*_y [mm]	2	1		



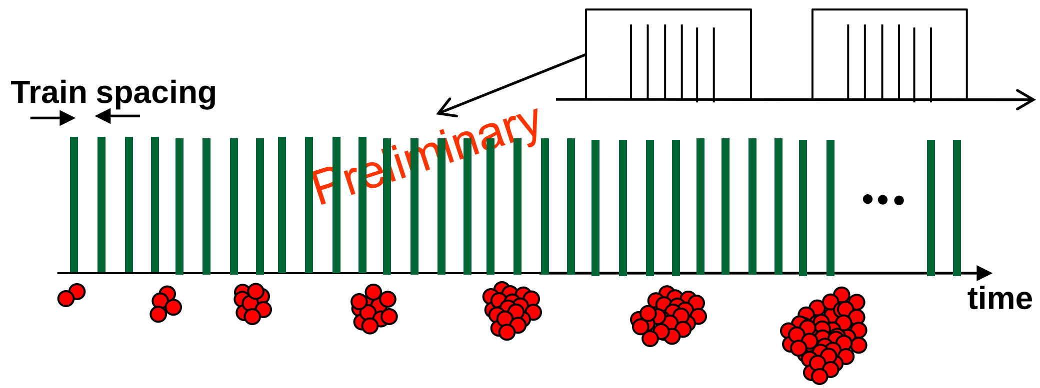
Layout of CEPC Double Ring

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



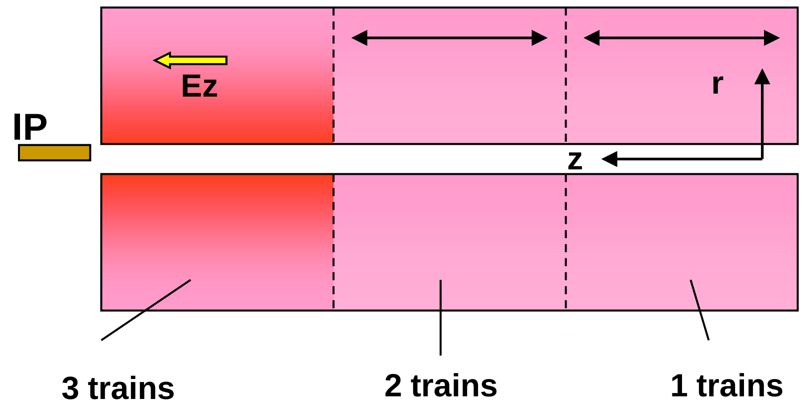
Beam structure of CEPC

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

Critical challenge: Ion Back Flow and Distortion

In the case of ILD-TPC

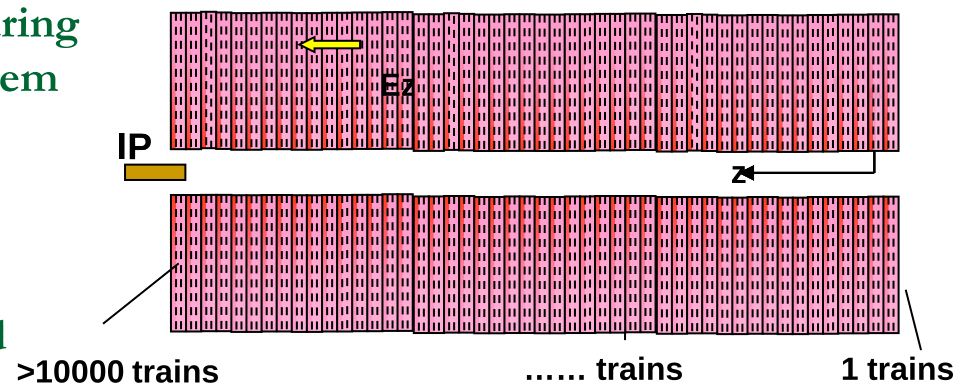
- Distortions by the primary ions at ILD are negligible
- Ions from the amplification will be concentrated in discs of about 1 cm thickness near the readout, and then drift back into the drift volume Shorter working time
- 3 discs co-exist and distorted the path of seed electron
- The ions have to be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

Requirements of Ion Back Flow /estimation

- Electron:
  - Drift velocity ~6-8cm/us@200V/cm
  - Mobility μ ~30-40000 cm^2/(V.s)
- Ion:
  - Mobility μ ~2 cm^2/(V.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

Transverse and

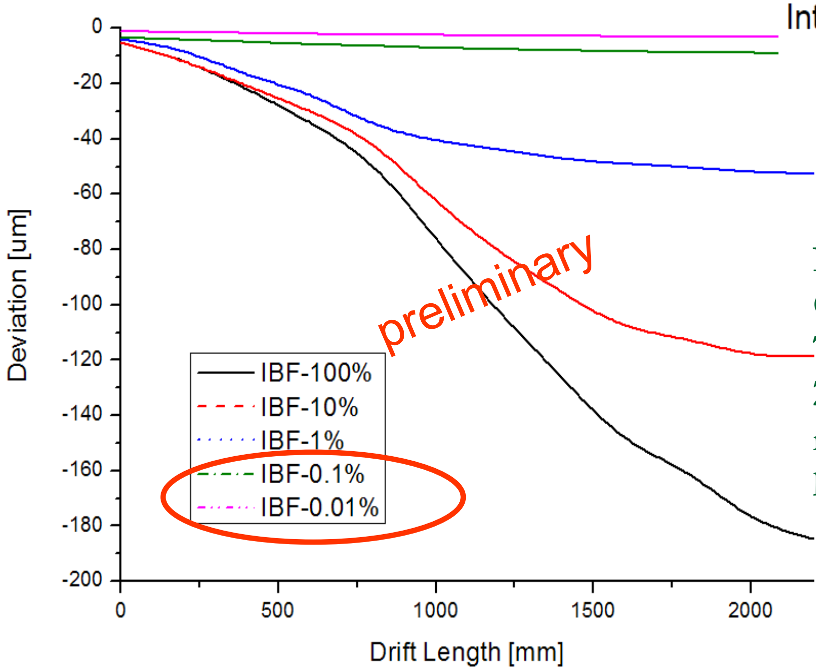
$$\sigma_{r\varphi/z}(z) = \sqrt{\sigma^2_{0,r\varphi/z} + \frac{D^2_{t/l}}{N_{\text{eff}} \cdot e^{-Az}} z}$$

Intrinsic resolution of the readout at zero drift distance in rφ/z

Effective number of primary signal electrons

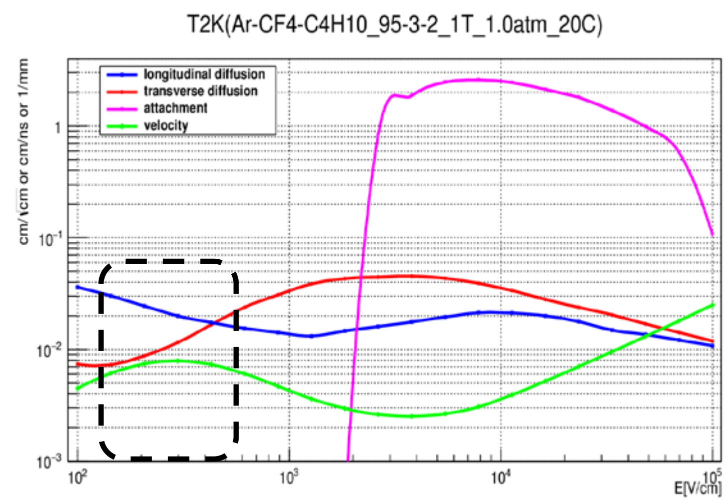
molecules during drift

Position resolution of the TPC function



Neff=30
Gain=5000
T2K gas
Z pole run@10^{34}
r=400mm
k=IBF*Gain=5

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

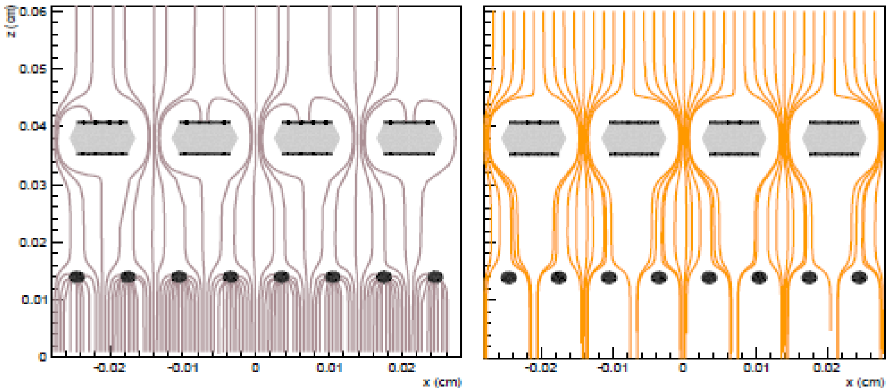


Simulated the drift velocity @T2K

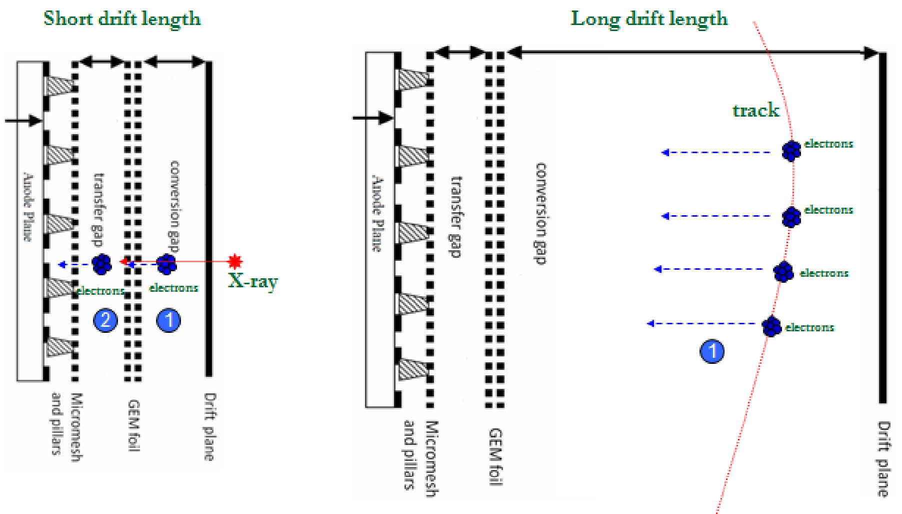
New ideas for the ions?

- 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)



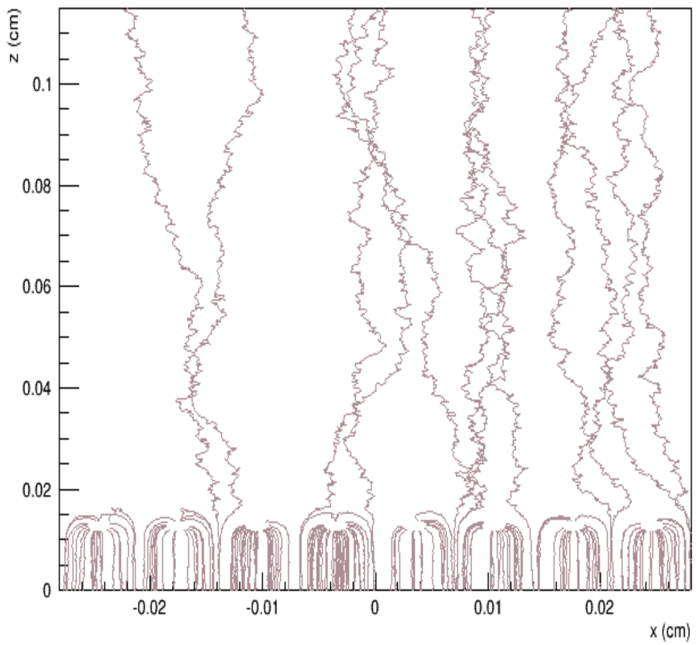
Hybrid detector

Simulation and IBF study

IBF simulation

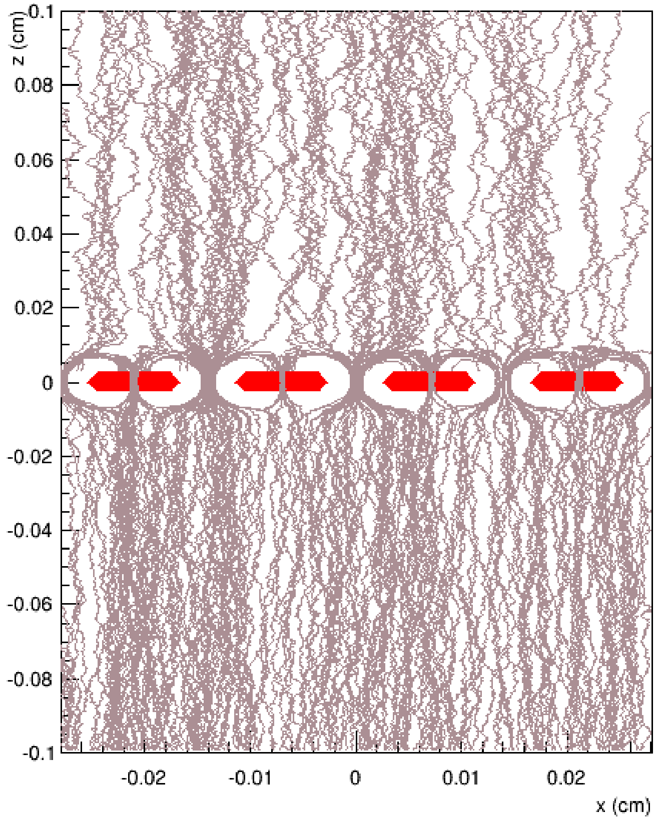
- Garfield++/ANSYS to simulate the ions back to drift
  - GEM and Micromegas Module using ANSYS
  - Record the ions to drift layer, mesh layer, and sensitive layer

Micromegas standalone



Ions not actually drift along electric field lines

GEM Standalone



IBF simulation

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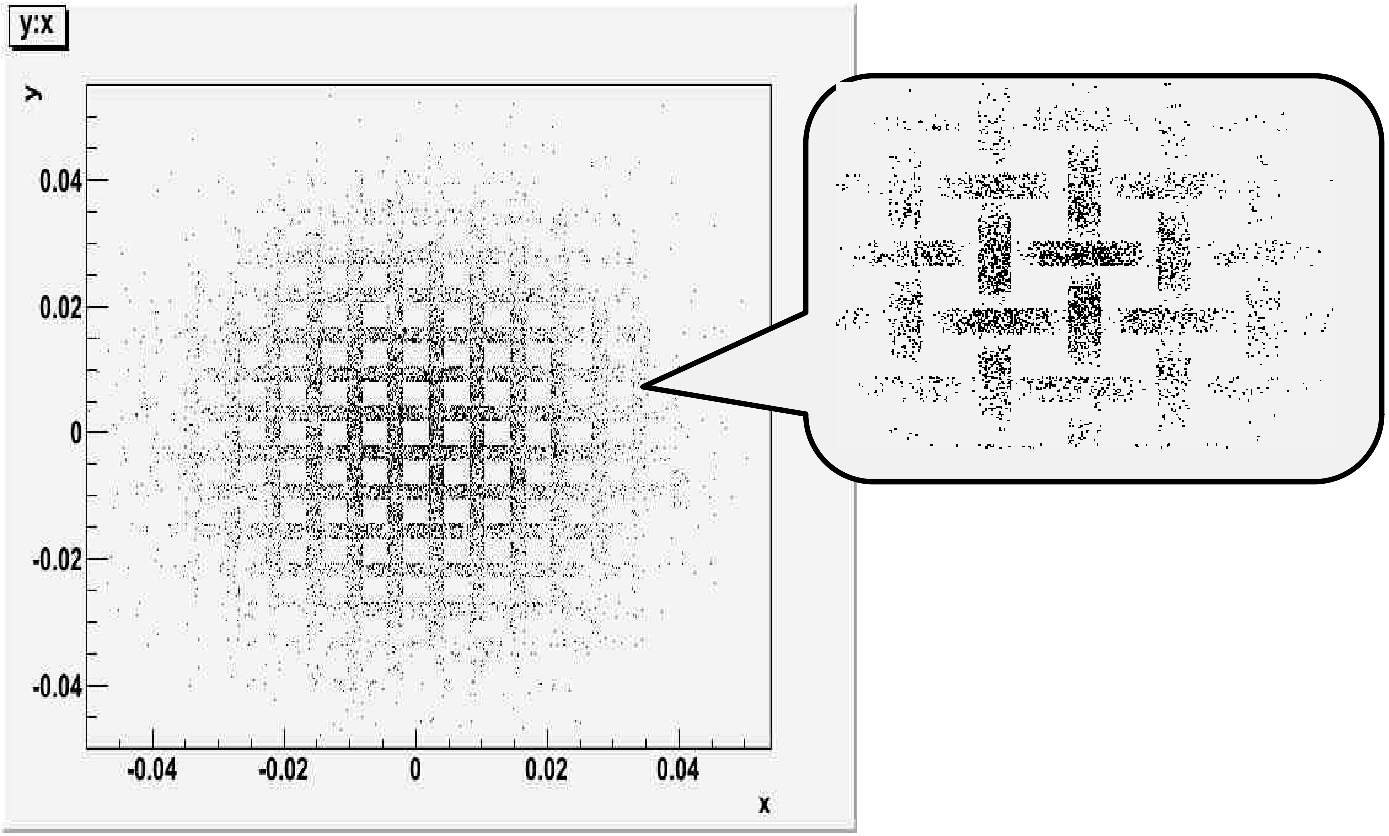
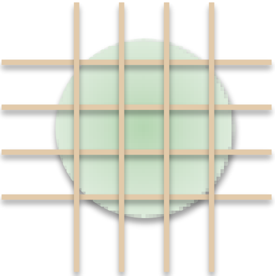
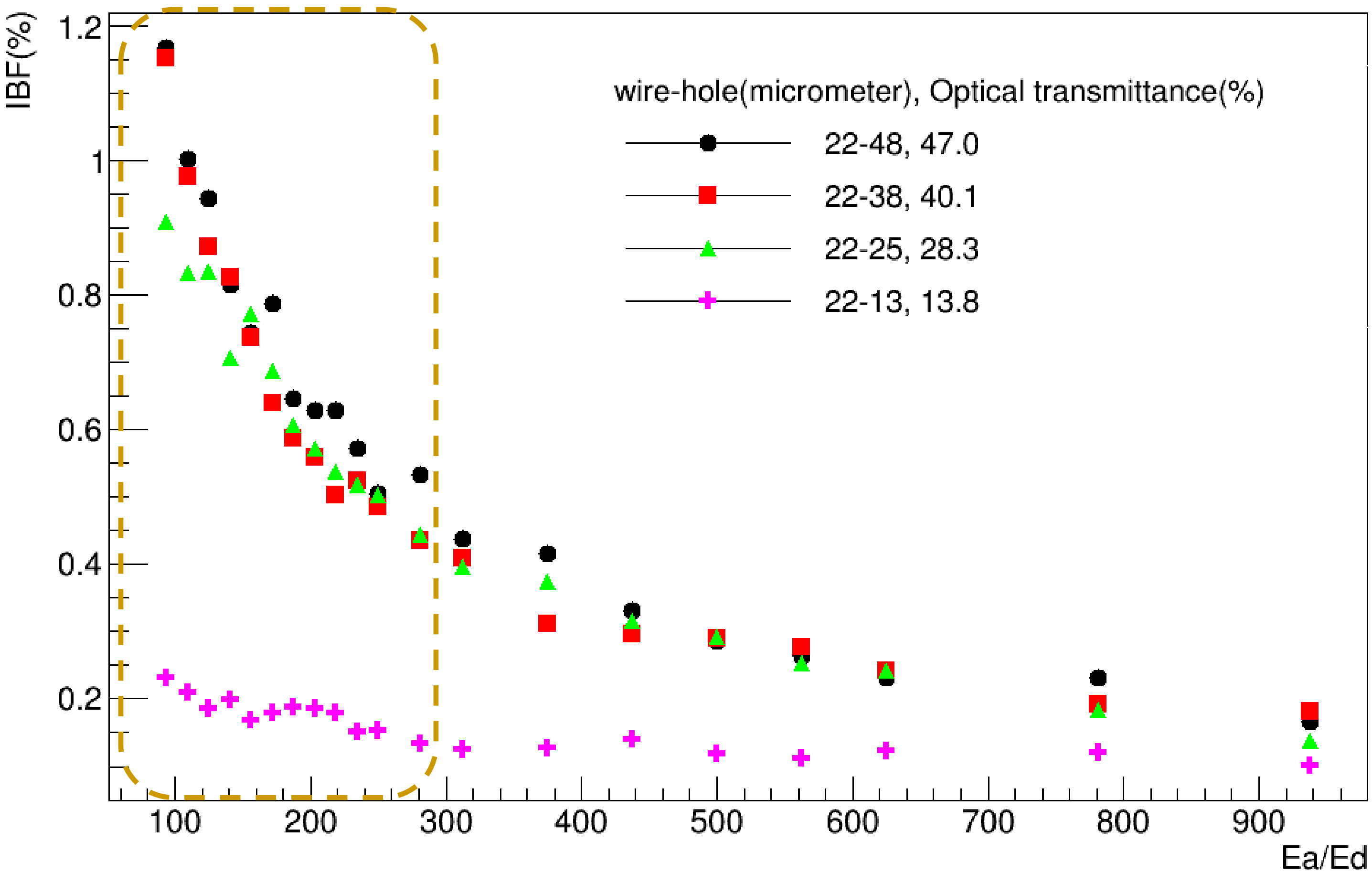


Ions end to the mesh of the Micromegas detector

IBF simulation



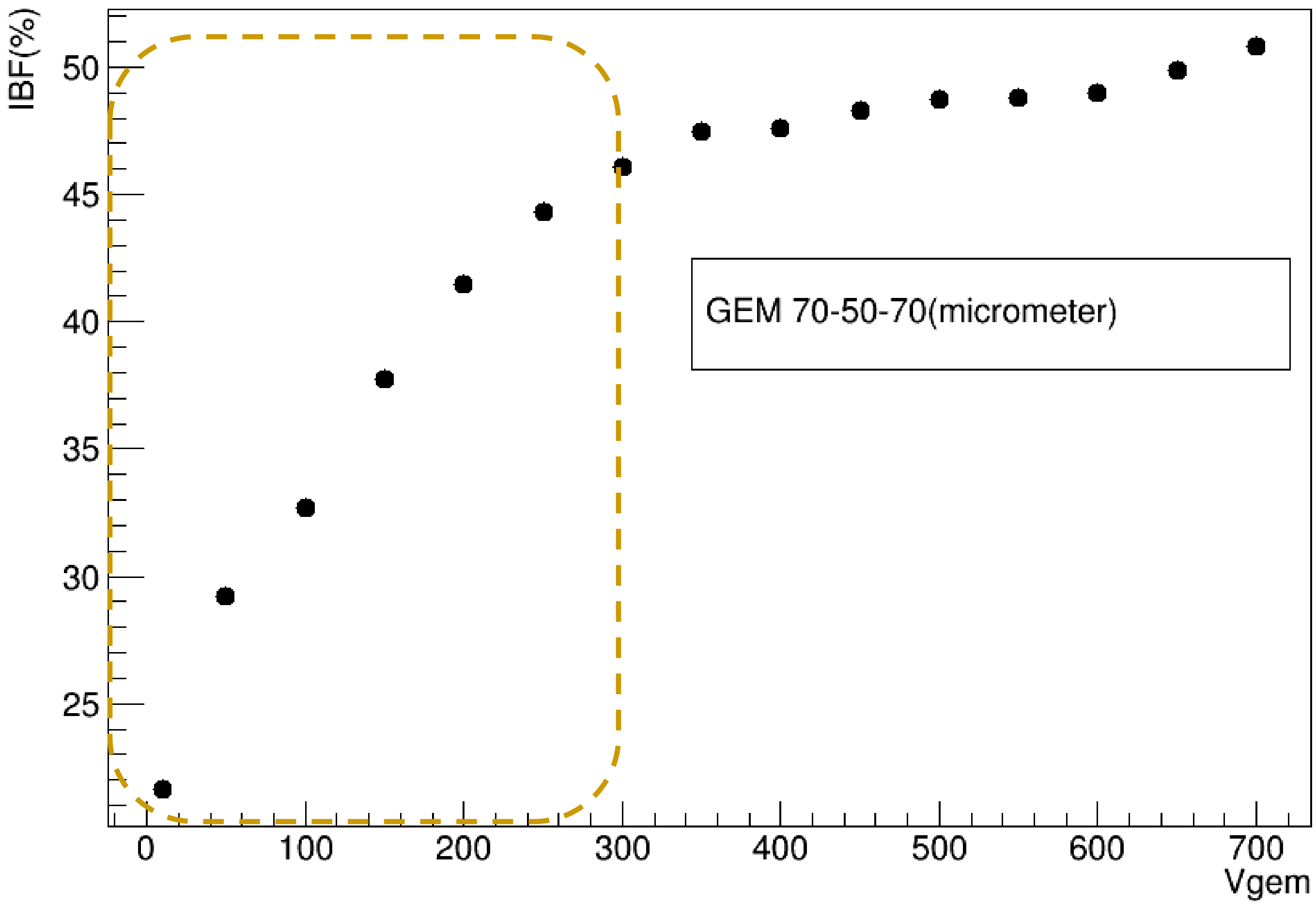
- Garfield++/ANSYS to simulate the ions back to drift
  - 350LPI/ 420LPI/ 500LPI/ 1000LPI
  - Ea is electric field of amplifier of Micromegas



Electric field of amplifier VS Electric field of Drift

IBF simulation

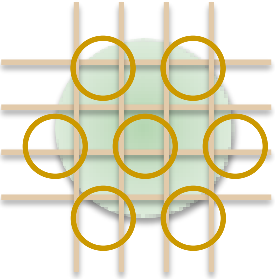
- Garfield++/ANSYS to simulate the ions back to drift
  - Standard GEM module (70-50-70)

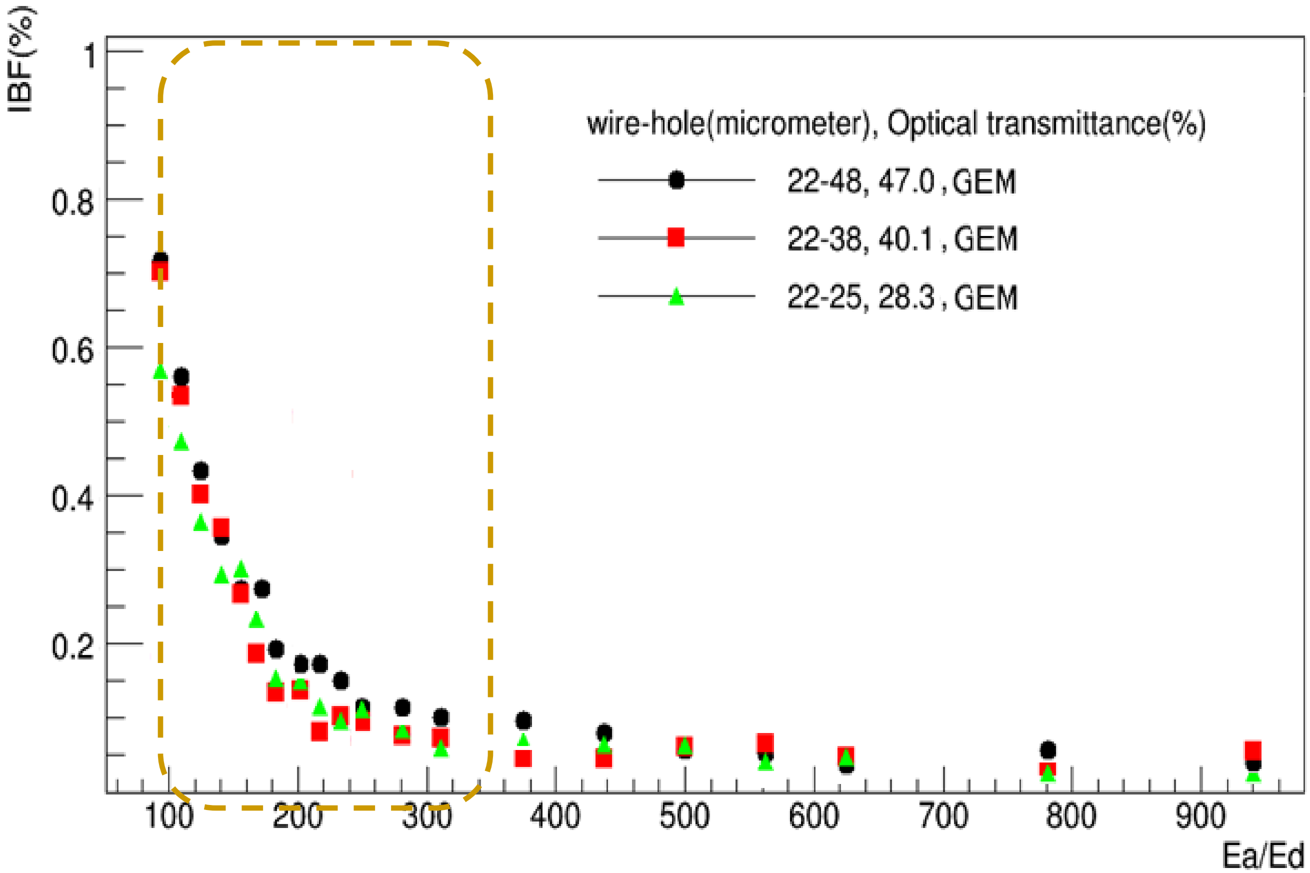


Voltage of the GEM detector

IBF simulation

- Garfield++/ANSYS to simulate the ions back to drift
  - 350LPI/ 420LPI/ 500LPI with GEM detector@150V
  - Ea is electric field of amplifier of Micromegas



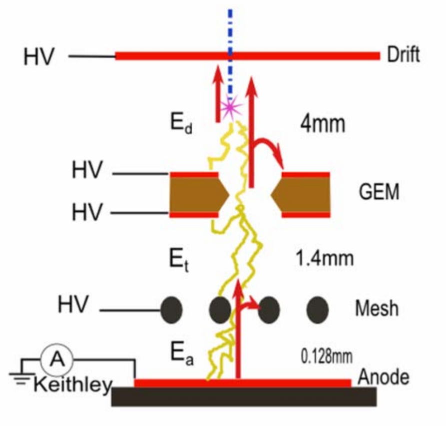


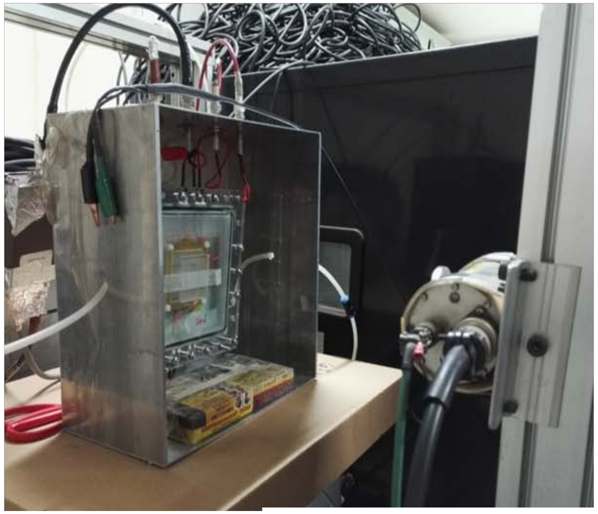
Electric field of amplifier VS Electric field of Drift

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: 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: 1~10





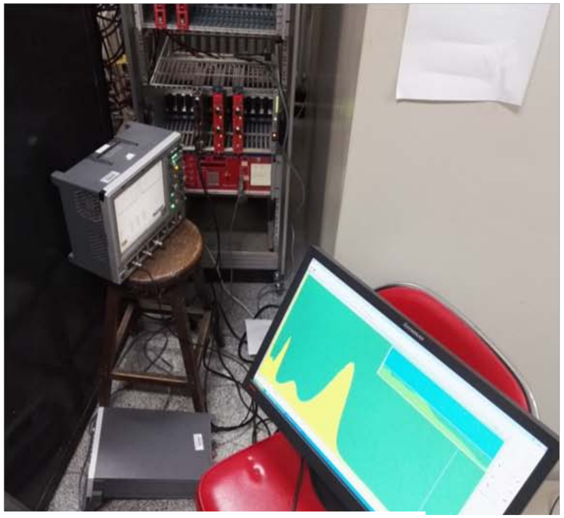
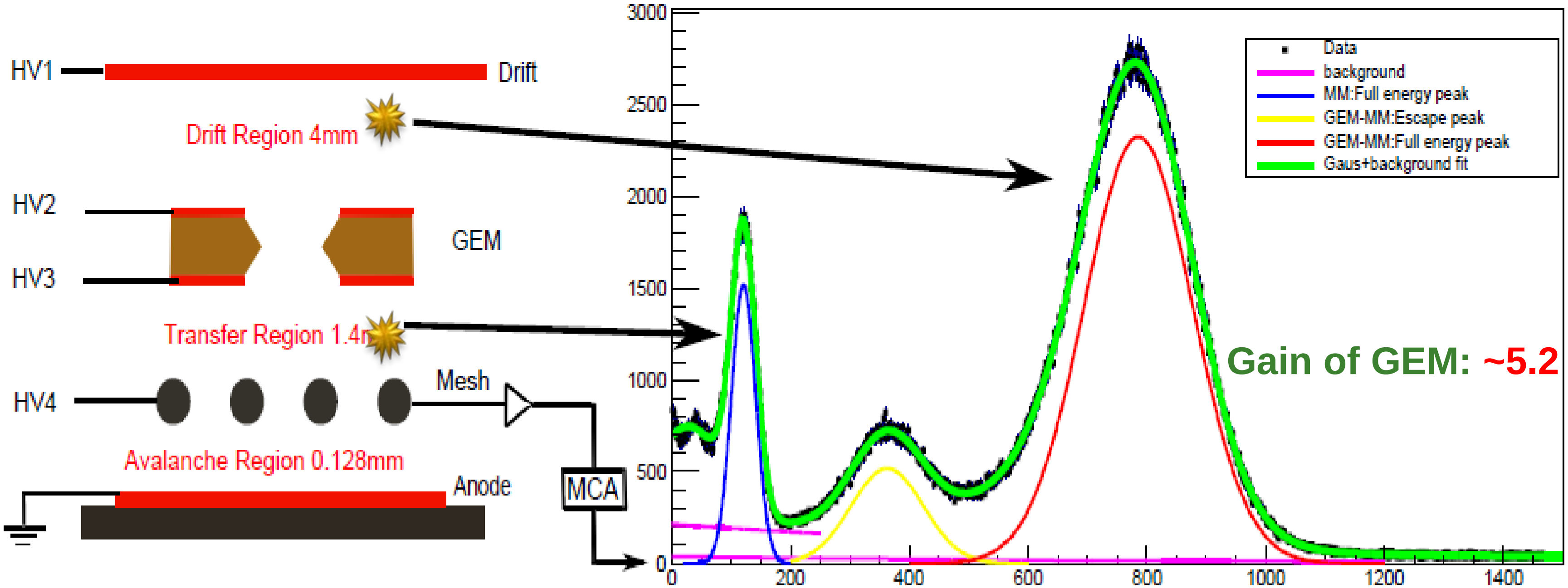


Photo of the GEM+Micromegas Module with X-ray

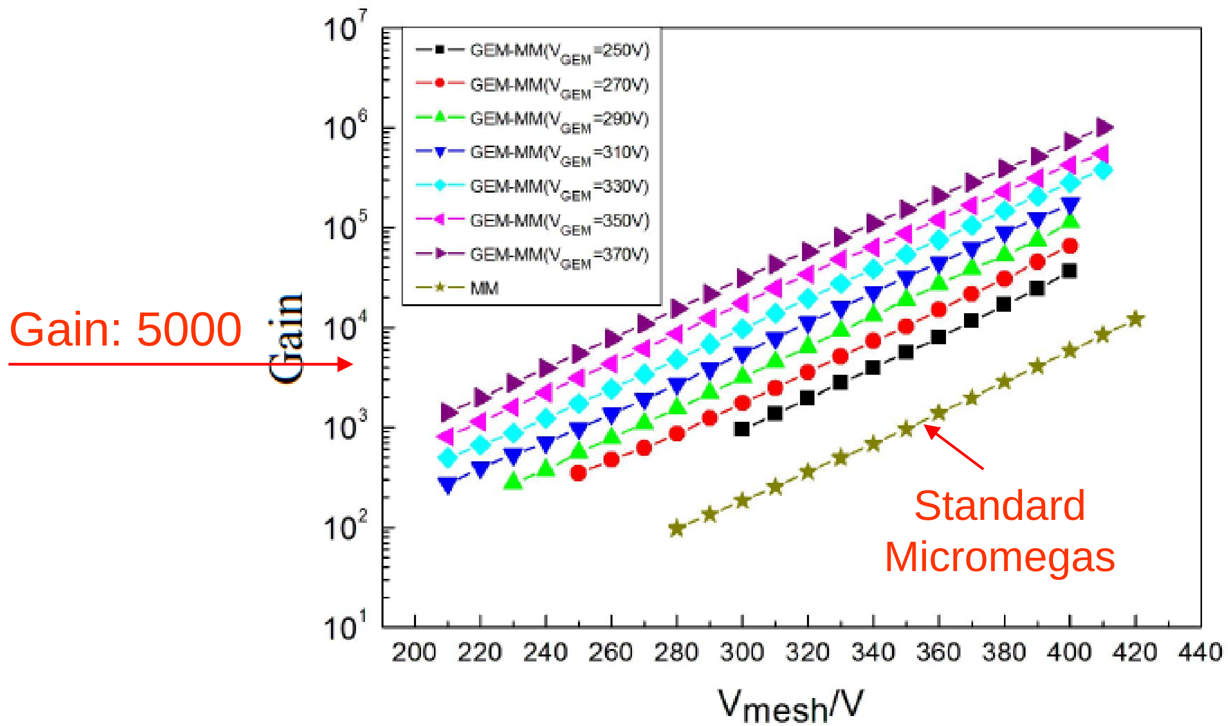
Energy spectrum@^{55}Fe

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



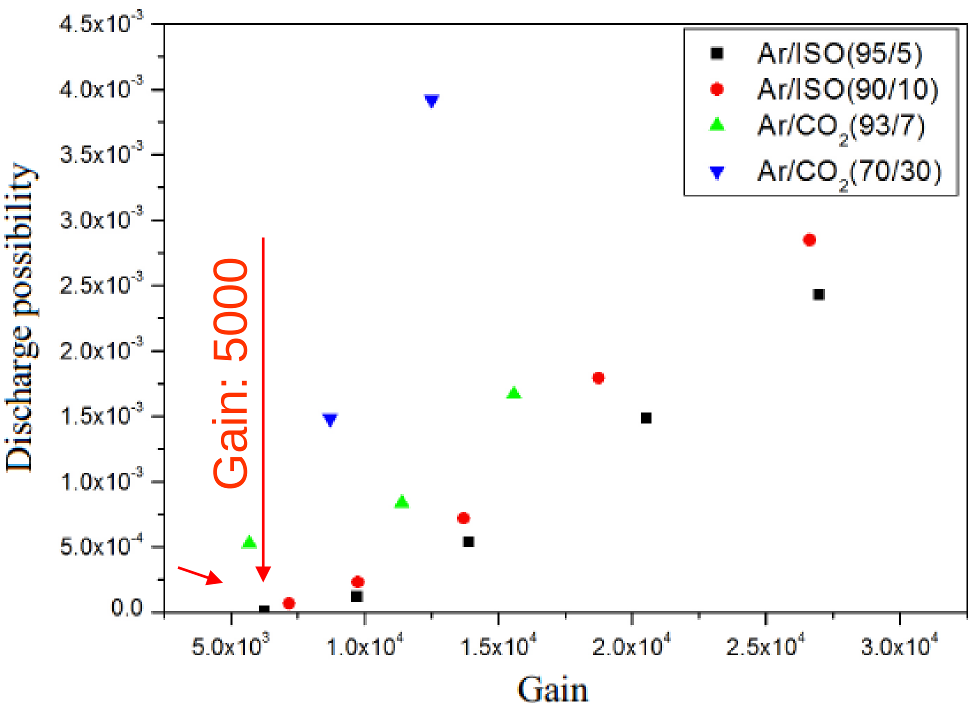
An example of the 55Fe spectra showing the correspondence between the location of an X-ray absorption and each peak.

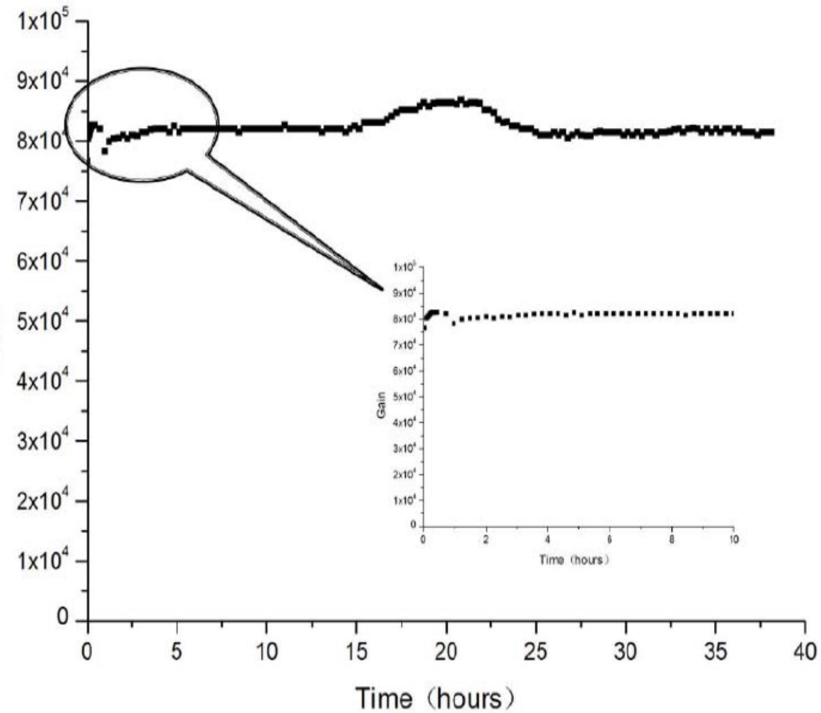
Gain of GEM + MM



- 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

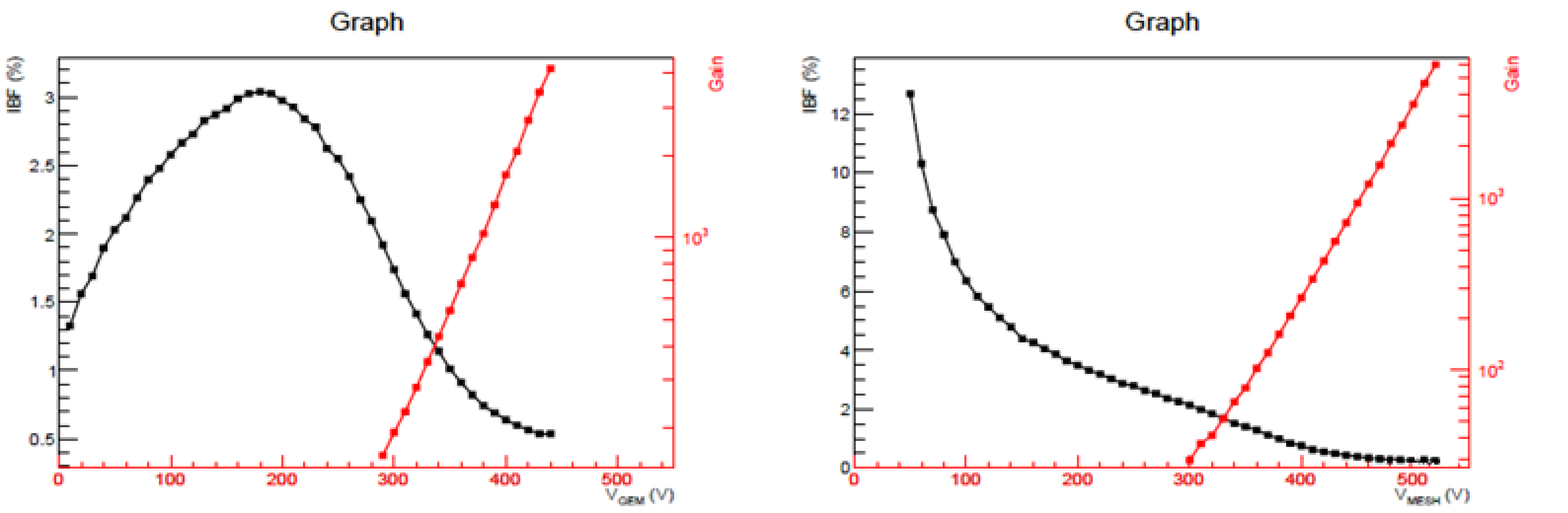
Discharge and working time





- 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 preliminary result-1



(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**

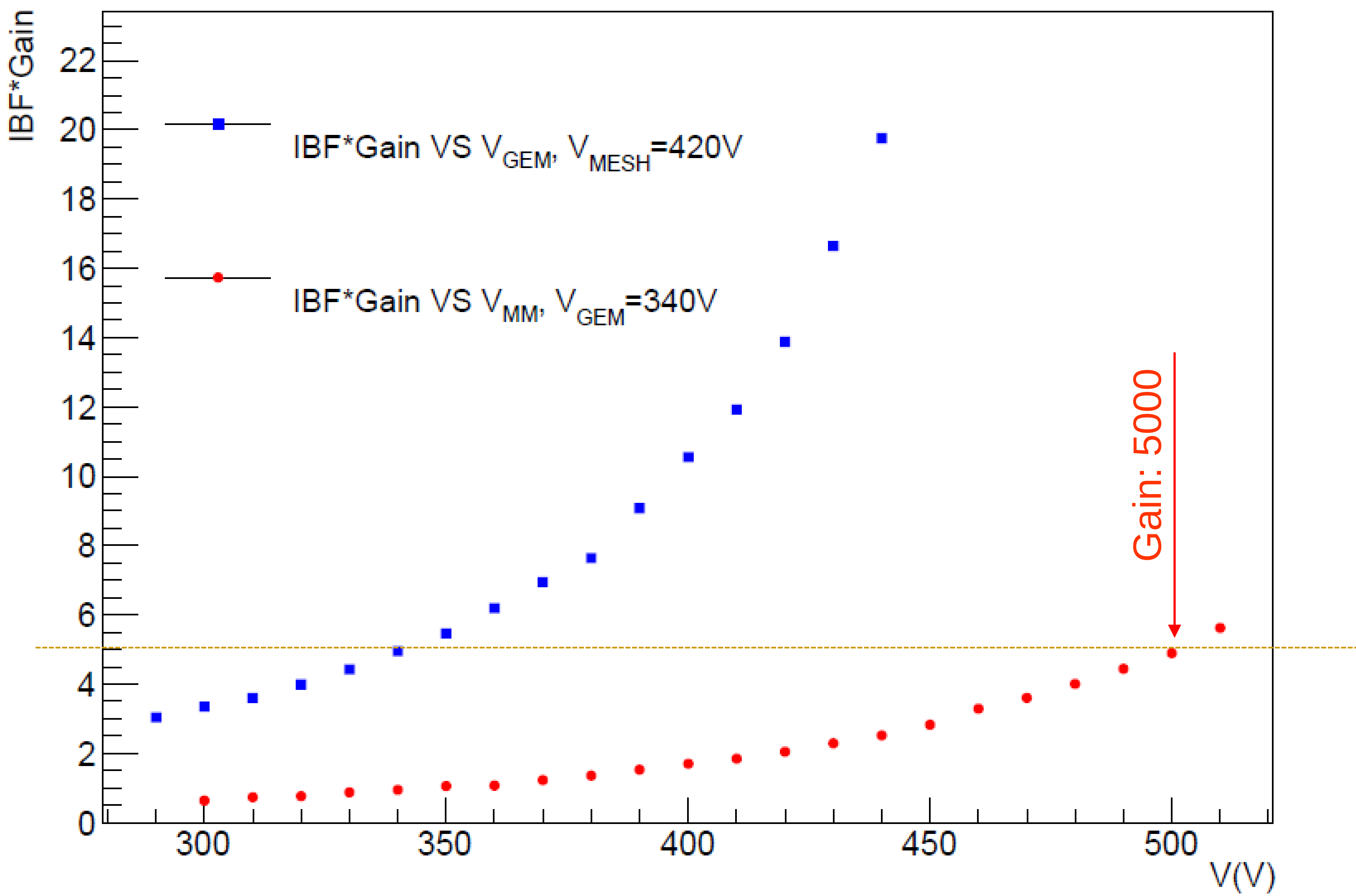
Contribution of the ions from the drift region to be γ, calculation of IBF, η:

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

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

G is the gas gain of the detector.

IBF preliminary result-2



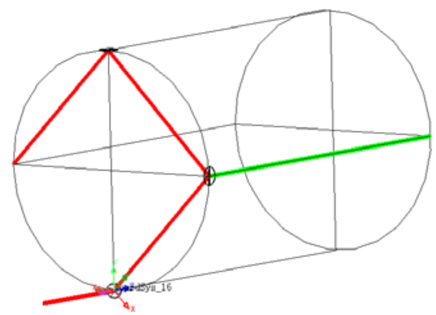
Key factor: IBF * Gain

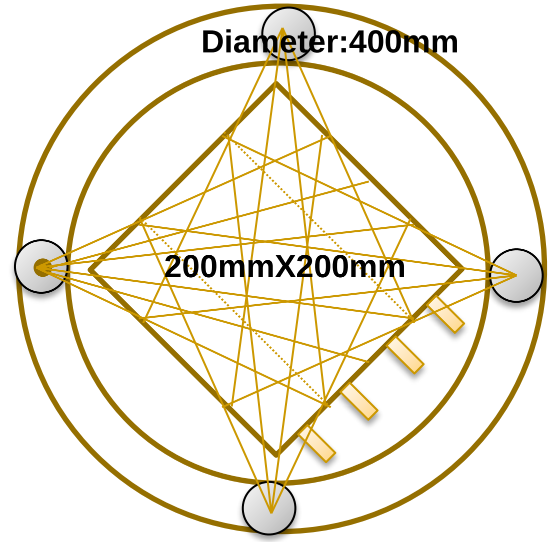
	GEM+MMG 420LPI (IHEP)	**2GEMs + MMG 450 LPI (Yale University)**	**Micromegas only 450 LPI (Yale University)**
Ion Back Flow	**0.1-0.2% Edrift = 0.25 kV/cm**	(0.3 –0.4)% Edrift = 0.4 kV/cm	(0.4 –1.5)% Edrift= (0.1-0.4) kV/cm
<GA>	**4000~5000**	2000	2000
ϵ-parameter(=IBF*GA)	**4~5**	6~8	8~30
E –resolution	**~16%**	<12%	<= 8%
Gas Mixture (2-3 components)	**Ar + iC4H10**	Ne+CO2+N2, Ne+CO2,Ne+CF4, Ne+CO2+CH4	X + iC4H10 (Ar+CF4+iC4H10)
Sparking (^{241}Am)	**$<10^{-8}$**	$< 3.*10^{-7}$(Ne+CO2) (N.Smirnov report)	~ 10^{-7} (S. Procureur report)
Possible main problem	**Thin frame**	More FEE channel	#
Goals	**CEPC TPC**	ALICE upgrade	#

Laser calibration for TPC prototype

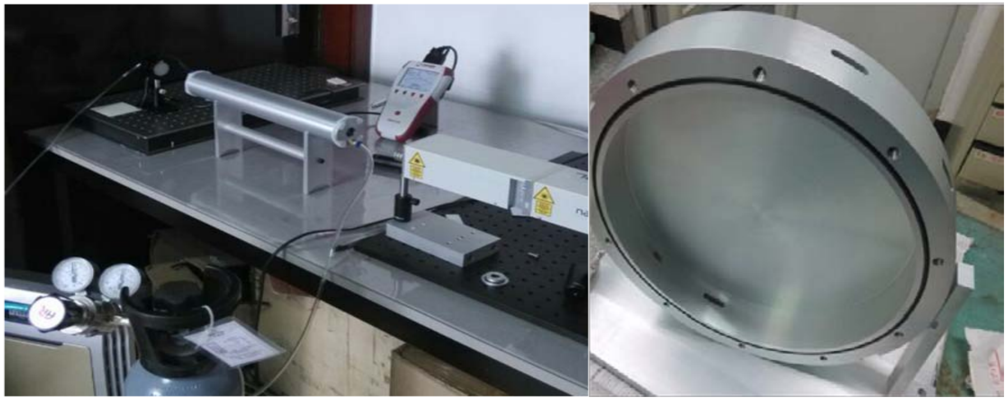
Supported by 国家基金委重点基金

- Goals of laser for TPC detector
  - The ionization in the gas volume along the laser path occurs via two photon absorption by organic impurities
  - Drift velocity, gain uniformity
- To reduce the distortion effect
  - E×B effect study
  - Drift Velocity measurement
  - Good resolution in space and tin
    - No production of σ-rays
    - No multiple scattering
- Baseline design **(DONE)**
  - Nd:YAG laser device
  - λ = 266 nm or E = hν = 4.66 eV
  - Energy: ~100 uJ/pulse
  - Duration of pulse: 5 ns
  - Active area:200mm×200mm
  - Drift length: 500mm
  - Outer diameter:~400mm
  - GEM readout





Laser calibration baseline design

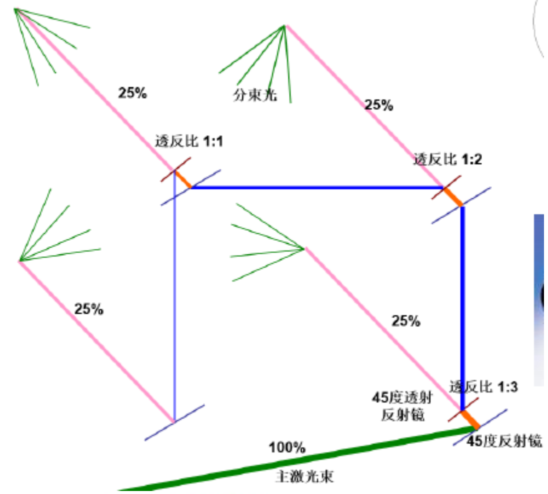


The assembled module test with 266nm laser

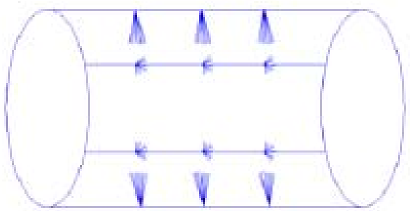
Tsinghua and IHEP Cooperation

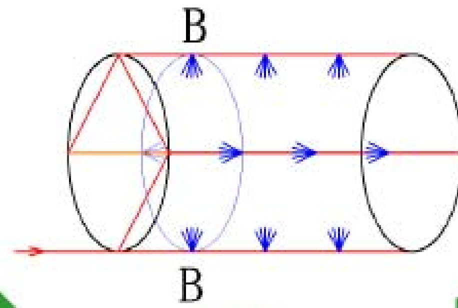
Laser calibration for TPC prototype

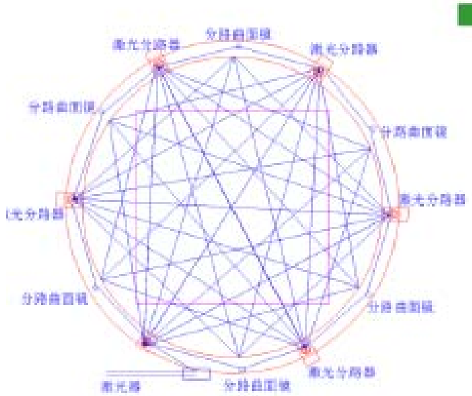
- Optimization of the laser map
  - 6 rods laser map to 4 rods laser map
  - some devices selection
  - Preliminary design with parameters (DONE)



B-B Slice

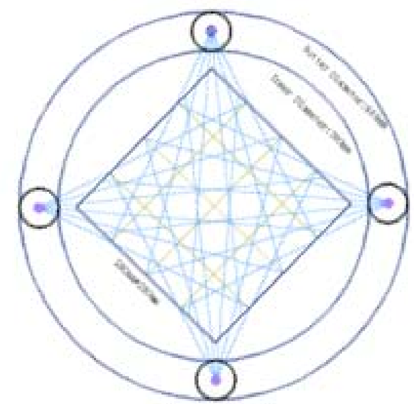






6rod Laser Map

4rod Laser Map



Laser Map

Tsinghua and IHEP Cooperation

Participate in the collaboration@2016

- Promote domestic cooperation and exchanges
- Participated in the international collaboration group (LC-TPC)
- Singed MOA and joined in LC-TPC collaboration @Dec. 14,2016

Some activities for domestic cooperation

Communicate meeting

- Tsinghua University
- IHEP, CAS
- UCAS, CAS
- Lanzhou University
- IMP, CAS
- USTC
- SINAP, CAS
- CIEA
- Shandong University
- SJTU

Invited talks

- Saga University
- CEA Saclay
- Korean Mecaro

TPC Tracker Detector Technology mini-Workshop

Participate in the collaboration group

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 Beam test with Asia Module:

KEK (Japan)

DESY (Germany)

IHEP, Tsinghua Univ. (China)

Keisuke Fujii (KEK)
Schrader, Andrea(DESY)
GAO Yuanning (THU)
QI Huirong (IHEP)

Targets:

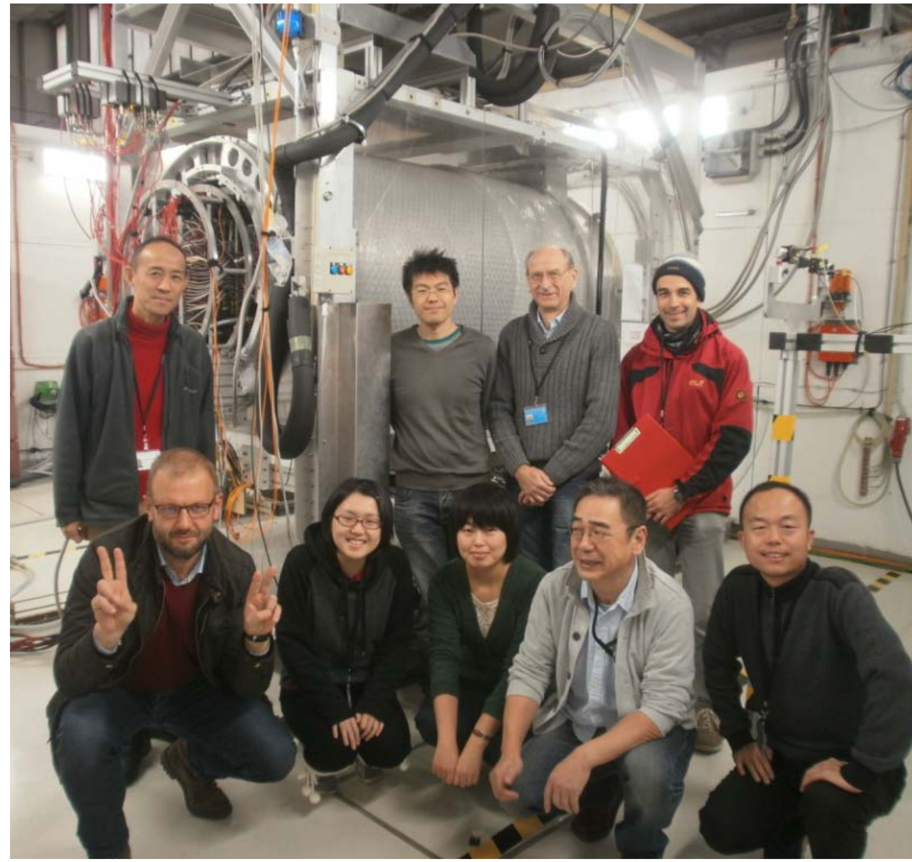
- R&D of IBF used UV light
  - Goal: ~0.1% IBF, Resistive Micromegas modules, Hybrid modules
- TPC Prototype design with Laser calibration
  - Readout active area: ~200mm^2, Drift length: ~500mm
- Beam test experiment and data analysis
  - Fixed date: 30,Oct./2016~14,Nov./2016
  - GEM module with the field shaper in 1.0 Tesla in PCMAG
- Toward CEPC CDR

Participate in the collaboration@2016

Collaboration with Saclay

- Joint meeting with Saclaty/THU/IHEP
- Design the Micromegas PCB boards
- Prepare to assemble the R/Micromegas

Collaboration with KEK



- GEM module with gate GEM in 1.0 Tesla
- 5.0Gev electron beam test
- Join in group and participate in analysis

Summary

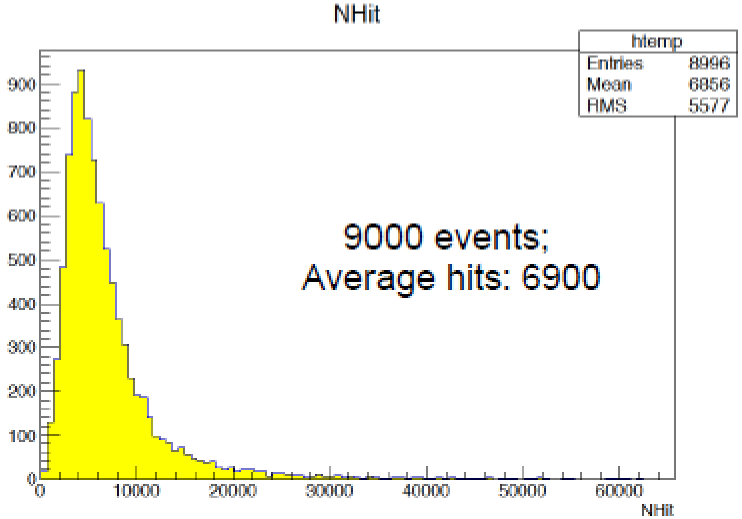
- **Physics requirements for CEPC TPC modules**
  - Continuous Ion Back Flow due to the continuous beam structure
  - Gating device could NOT be used due to the limit time
  - Ion back flow is the most critical issue for the TPC module at circular colliders

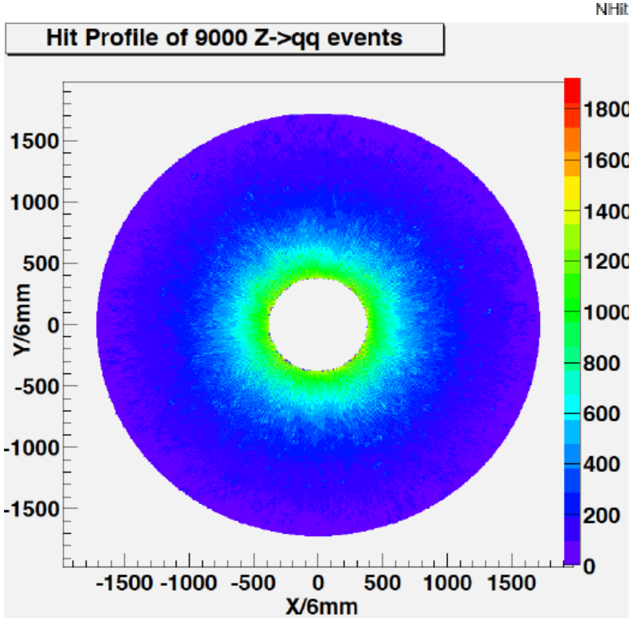
- **Some activities for the module**
  - IBF simulation of the detector have been started and further simulated.
  - Some preliminary IBF results of the continuous Ion Backflow suppression detector modules has been analyzed.
  - The IBF value would be estimated and the reasonable value would be studied.
- **R&D work within the some collaboration is starting.**

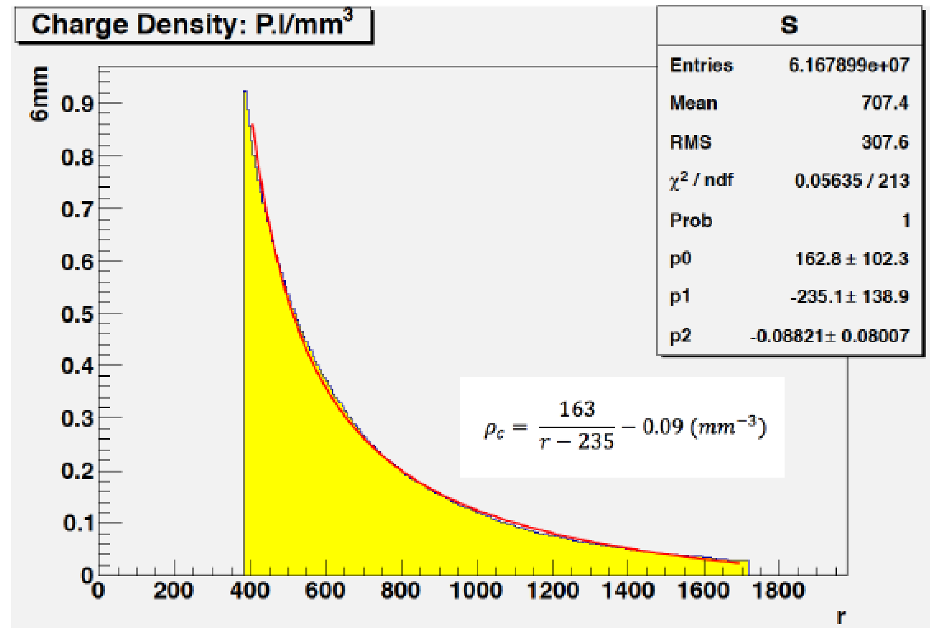
Thanks very much for your attention !

More further estimation for Z-pole /starting

Manqi

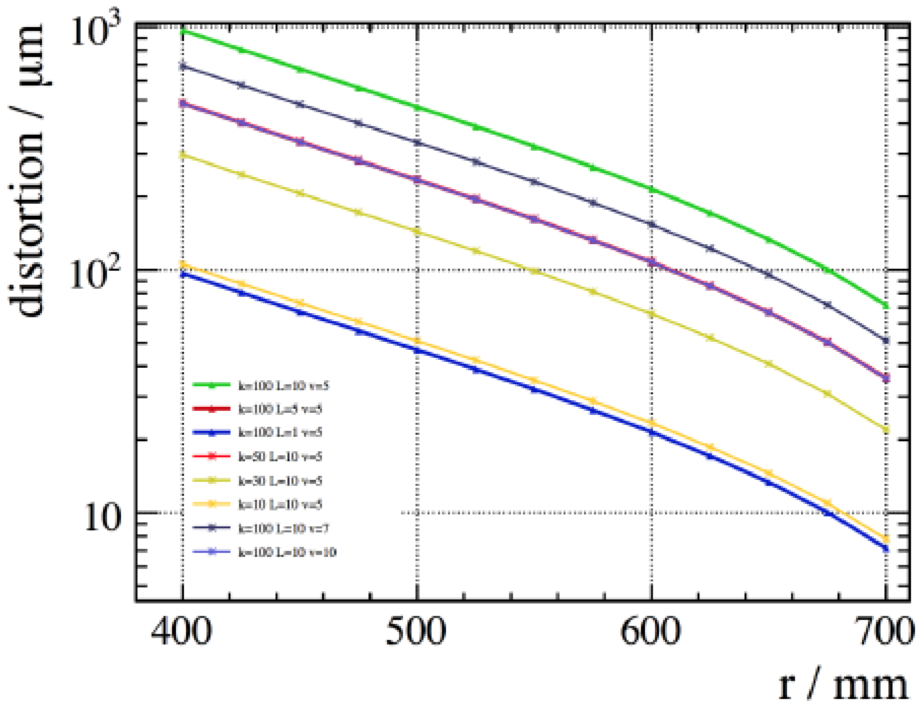


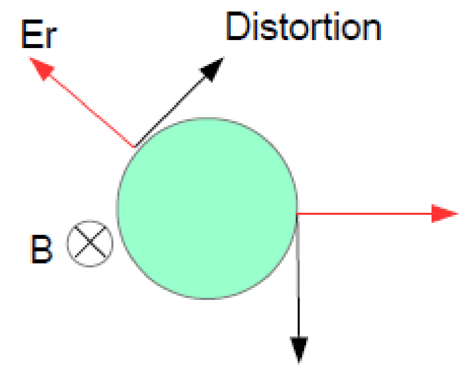




TPC Hit Profile of Full Simulated
Z->qq events
From Manqi's simu.

Charge Distortion





Distortion ~ $(1+k)*(L*Dis*E_r)/(B*v*E_Z)$

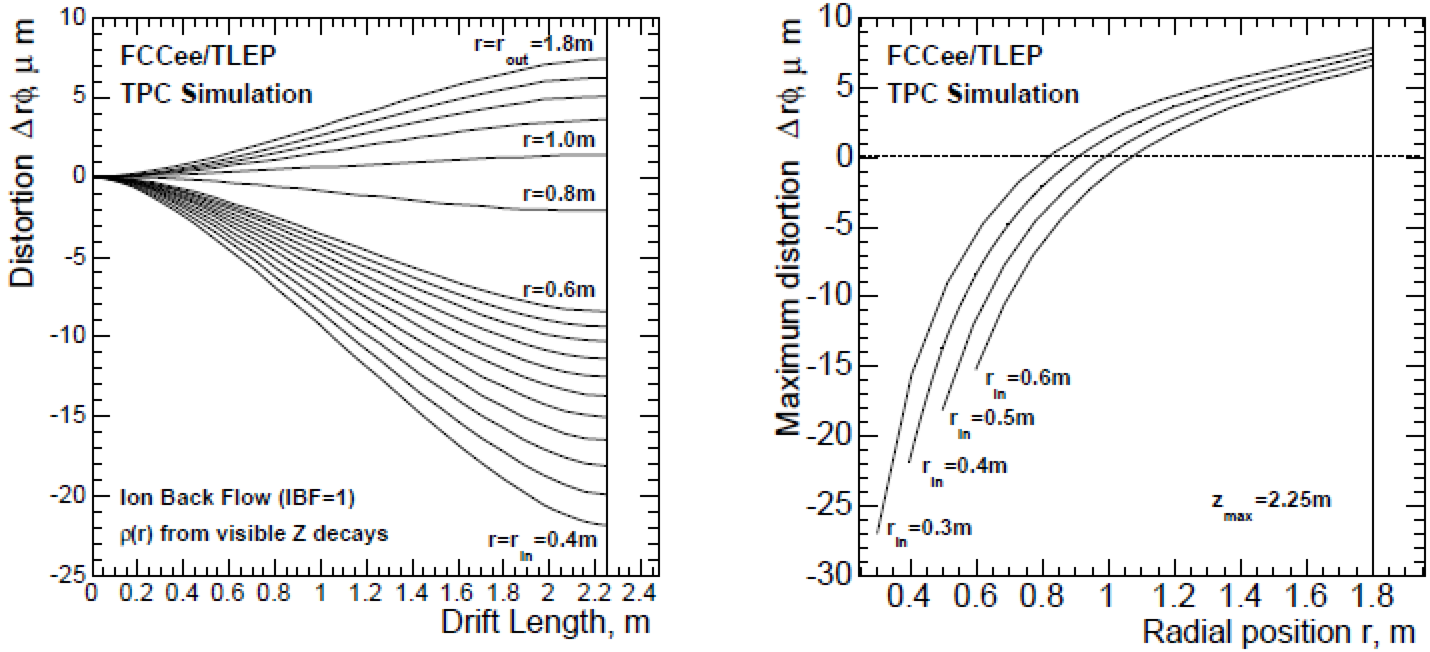
~$(1+k)*(L/10^{34}\text{cm}^{-2}\text{s}^{-1})$ µm $|_{R = 400\text{mm}}$

At 1E35, k = 100 & Velocity = 5m/s

Distortion, 1 order of magnitude higher than intrinsic resolution – **unacceptable!!**

S.Ganjour

Ion Back Flow Distortions



☞ Secondary ions yield distortions of about 20 μm for IBFxGain=1 for the case of continious charge density along z axis