Suppression IBF continually of the hybrid detector module

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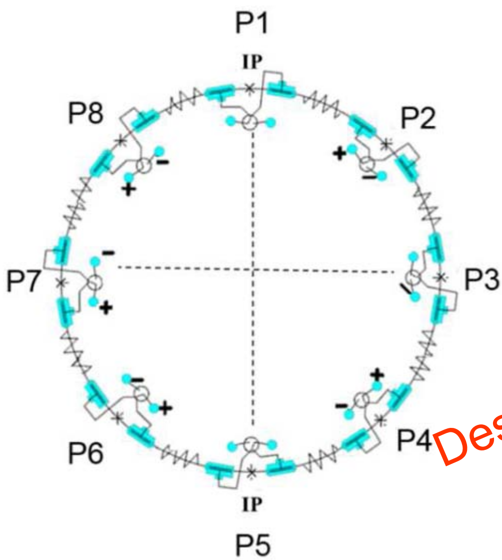
Outline

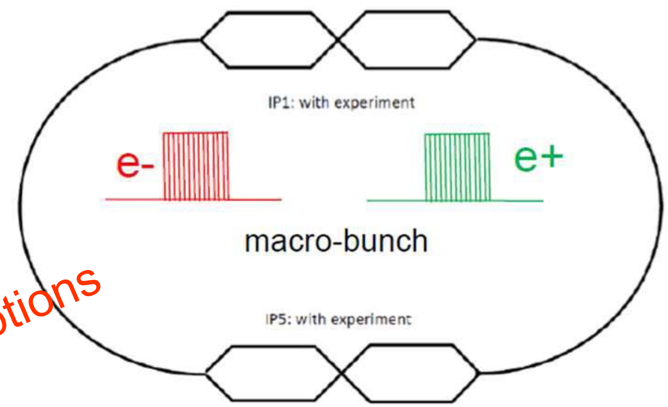
- Critical challenges of CEPC-TPC
- Some activities and progress

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



Pretzel Scheme



Preliminary
Design of the options

Partial Double-ring Scheme

Pretzel Scheme

- **Baseline design in pre-CDR**
- **48 bunches / beam**
- **Colliding every 3.6μs, continuously**

→Power pulsing not applicable

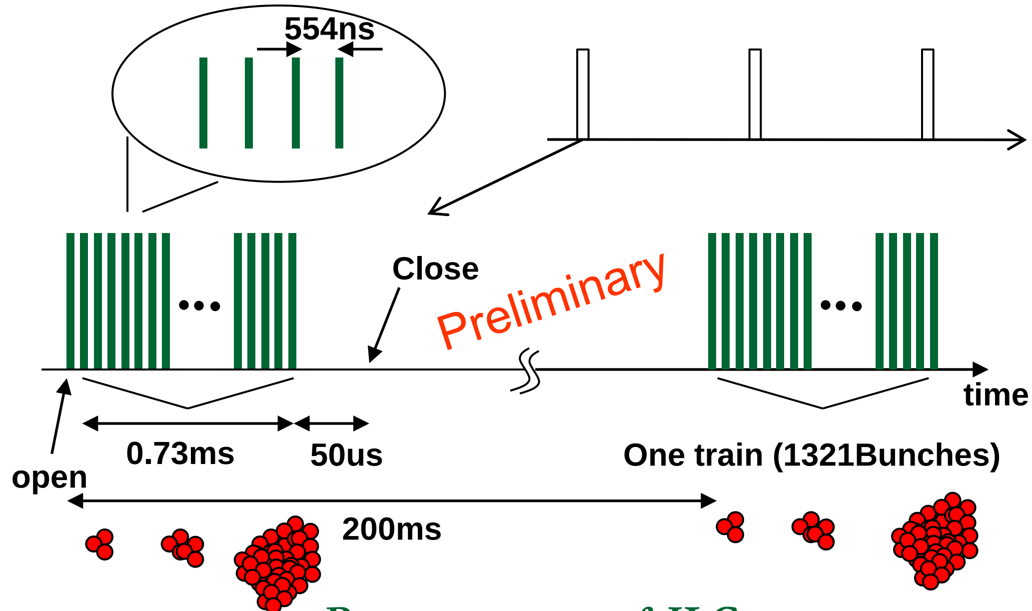
Partial Double-ring Scheme

- **Crab-waist collision to reduce beam and AC power**
- **Avoiding pretzel scheme to increase the flexibility and luminosity**
- **196ns bunch spacing**
- **48 bunches / train**
- **Duty cycle: 9.4μs/181μs**

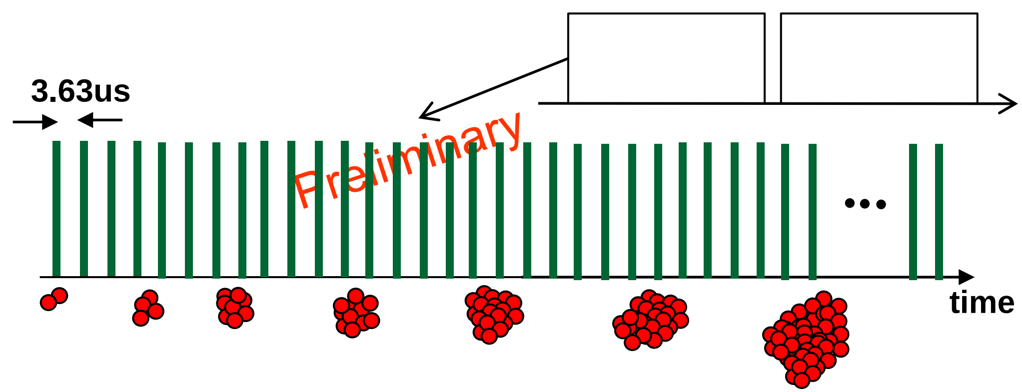
Reference: CEPC/SppC with ILC (FCC), J. Gao, LCWS 2015, Nov. 2-6, 2015, Whistler, Canada

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 3.63μs) 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

NO Gating device !

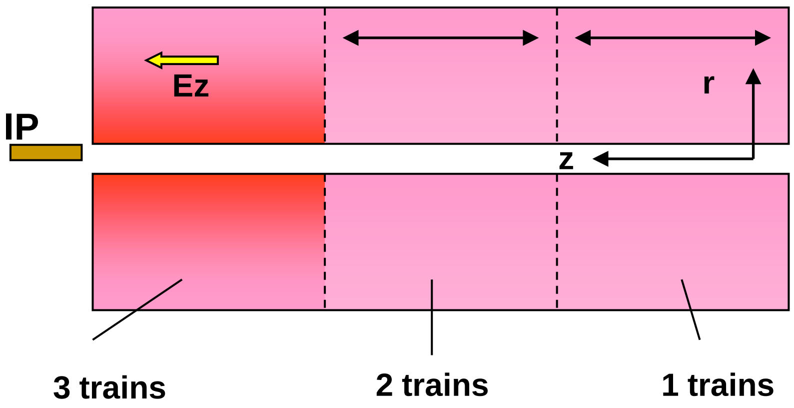
Critical challenge: Ion Back Flow and Distortion

In the case of ILD-TPC

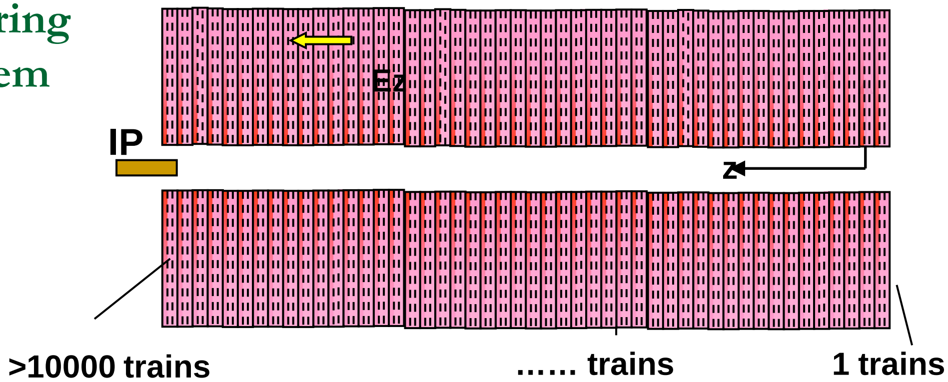
- Distortions by the primary ions at ILD are negligible
- Ions from the amplification will be concentrated in discs of about 1 cm thickness near the readout, and then drift back into the drift volume Shorter working time
- 3 discs co-exist and distorted the path of seed electron
- The ions have to be 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 10000 discs co-exist and distorted the path of seed electron
- The ions have to be neutralized during the ~4us period continuously



Amplification ions@ILC



Amplification ions@CEPC

Requirements of Ion Back Flow @CEPC

- 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

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

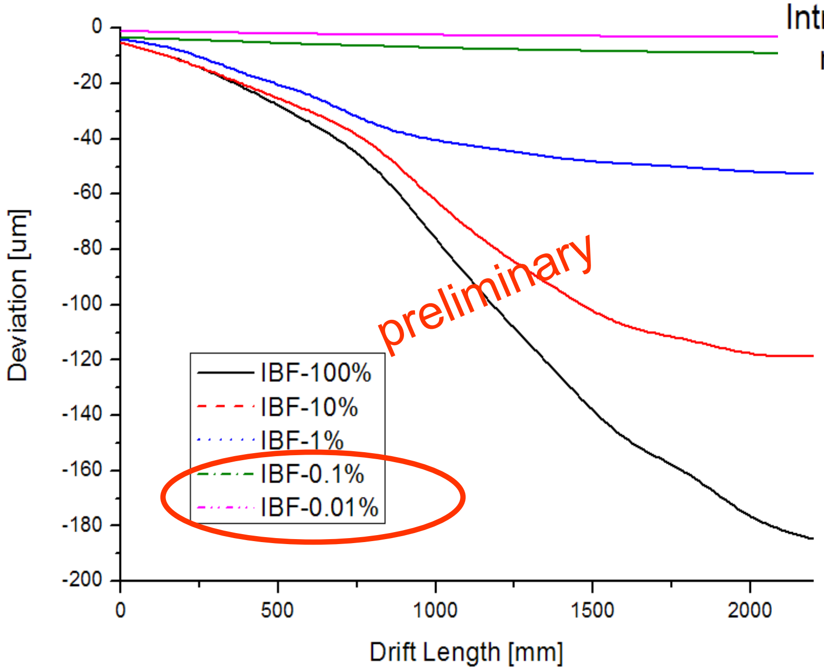
Transverse and

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

Effective number of primary signal electrons

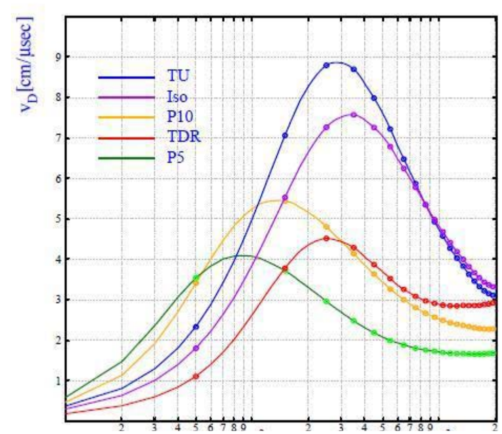
molecules during drift

Position resolution of the TPC function



Neff=33
Gain=5000
Ar/Iso=95/5
5-6Tracks/Branch
r=400mm

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

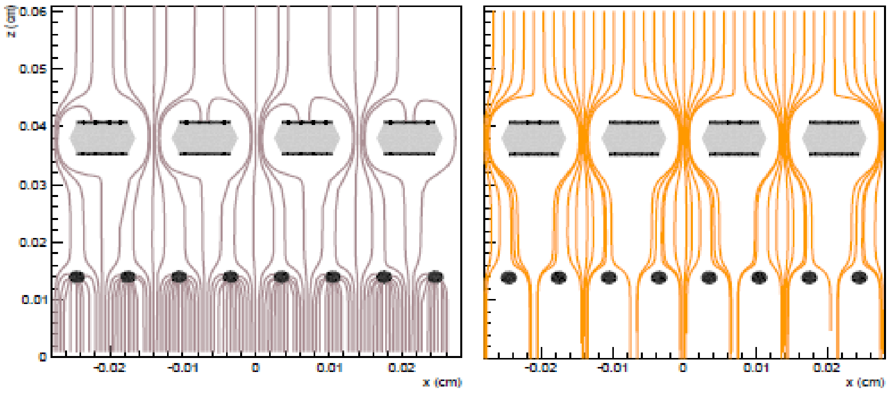


Simulated the drift velocity in different gas mixture

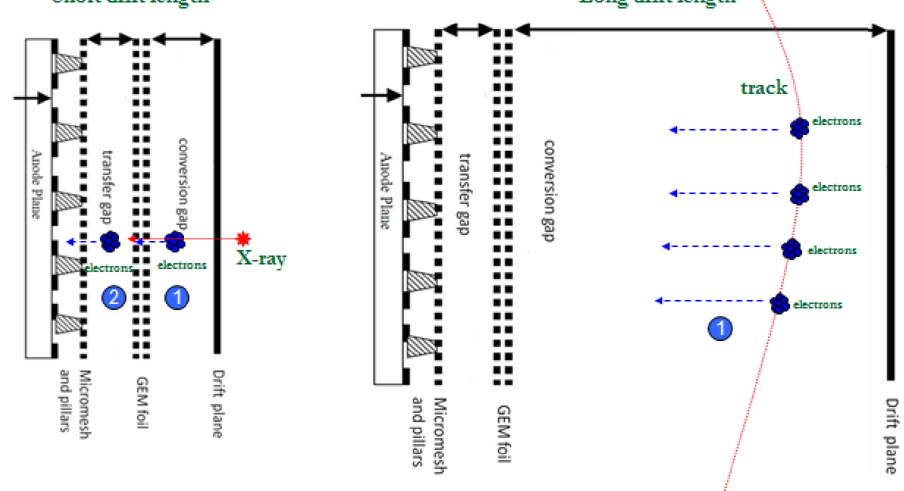
New ideas for the ions?

- 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)

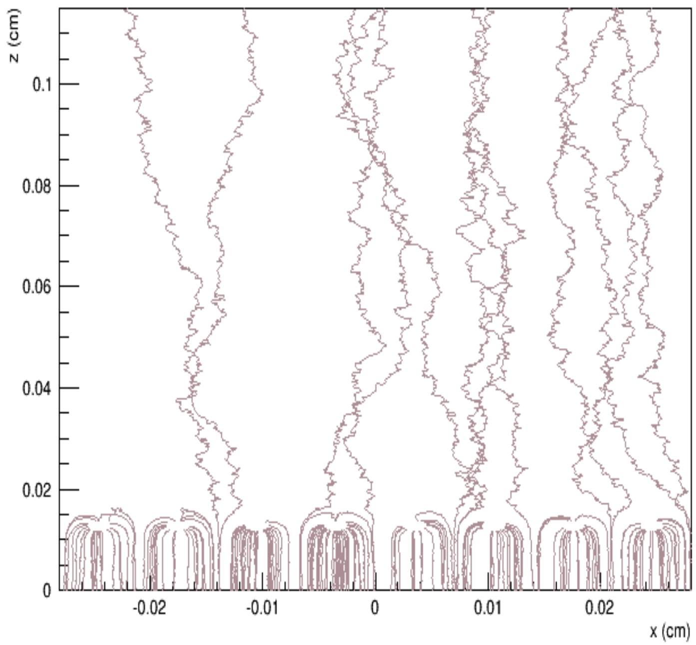


Hybrid detector

IBF simulation

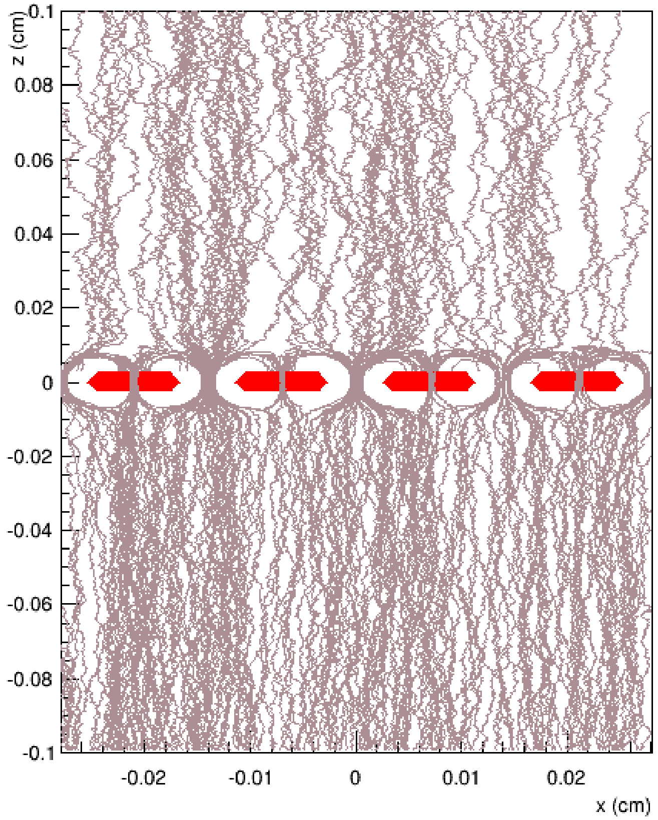
- Garfield++/ANSYS to simulate the ions back to drift
  - GEM and Micromegas Module using ANSYS
  - Record the ions to drift layer, mesh layer, and sensitive layer

Micromegas standalone



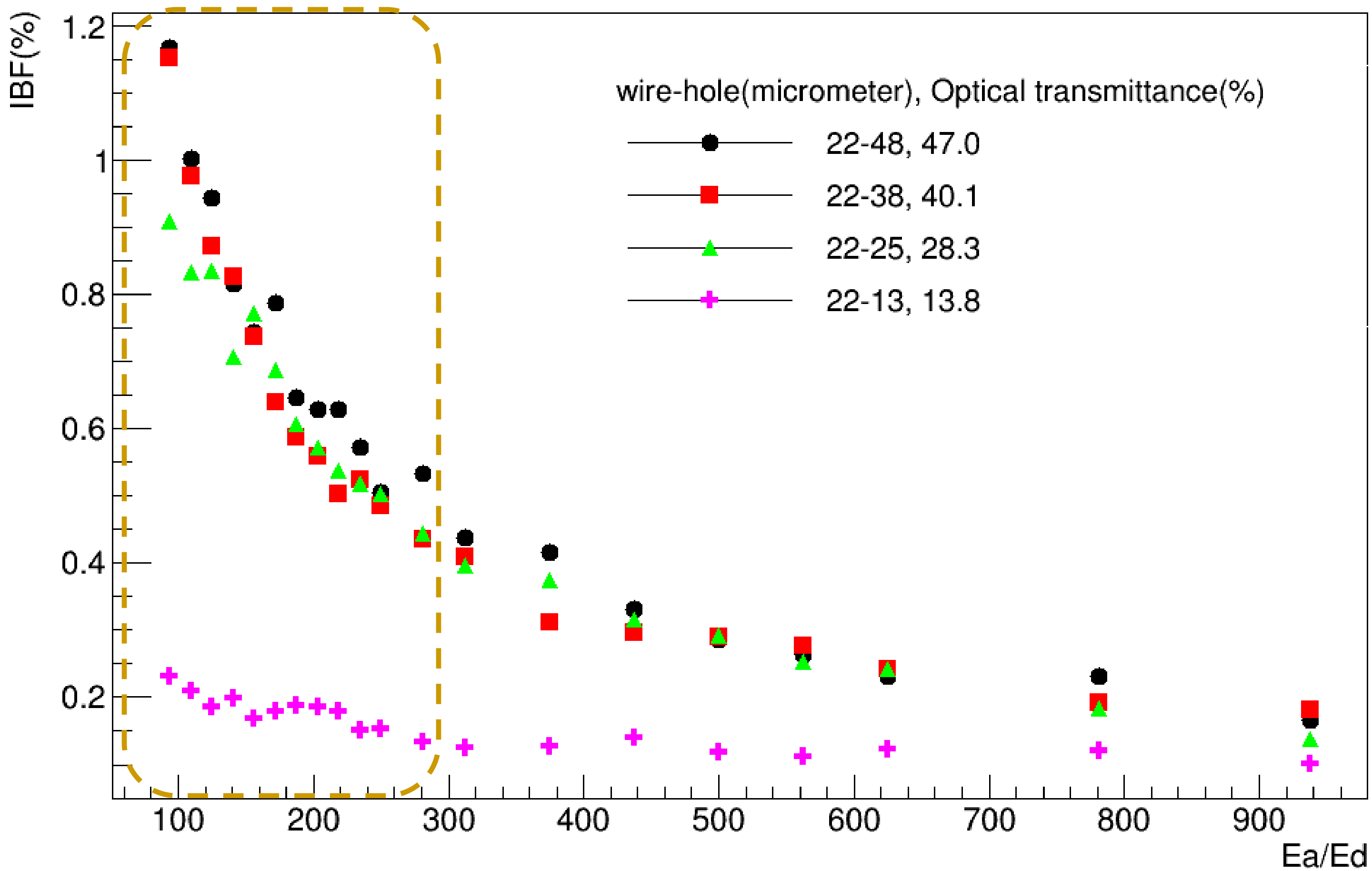
Ions not actually drift along electric field lines

GEM Standalone



IBF simulation

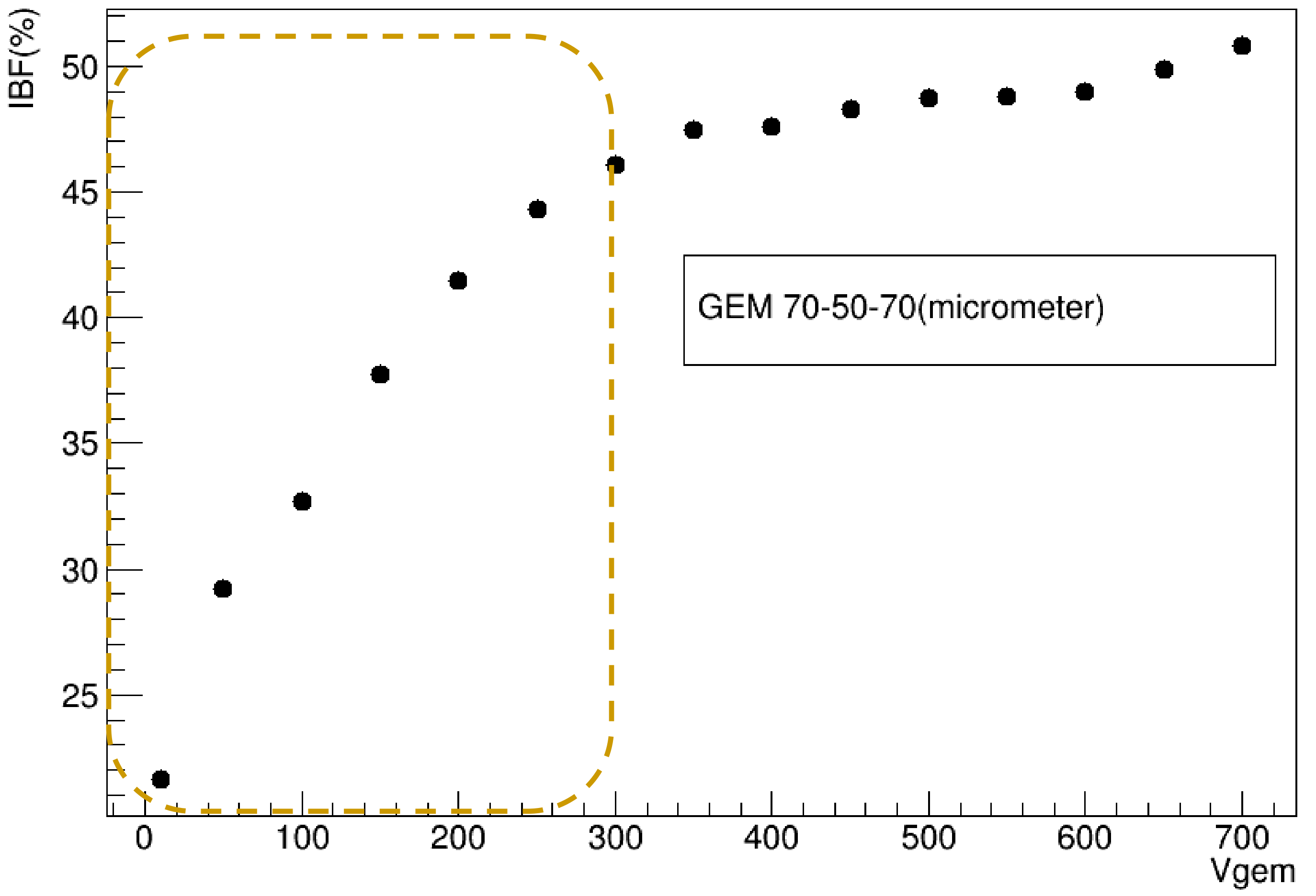
- Garfield++/ANSYS to simulate the ions back to drift
  - 350LPI/ 420LPI/ 500LPI/ 1000LPI
  - Ea is electric field of amplifier of Micromegas



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)

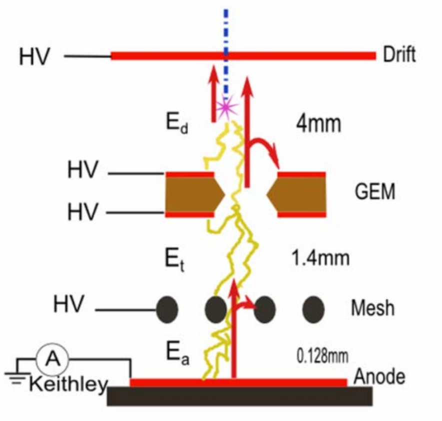


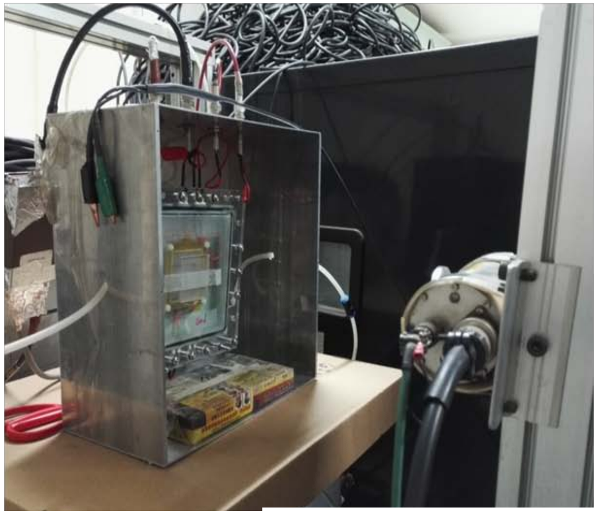
Voltage of the GEM detector

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





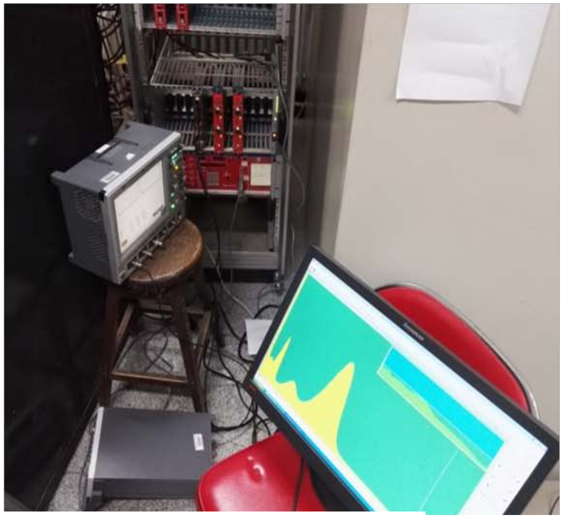
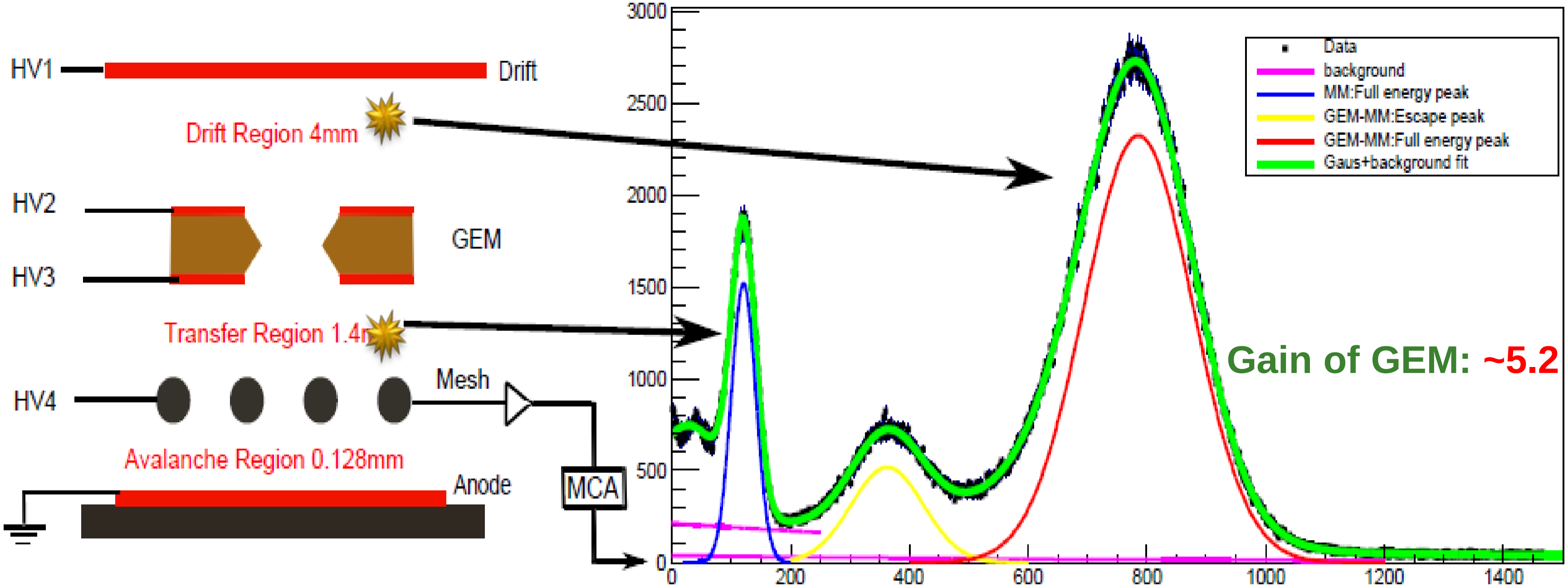


Photo of the GEM+Micromegas Module with X-ray

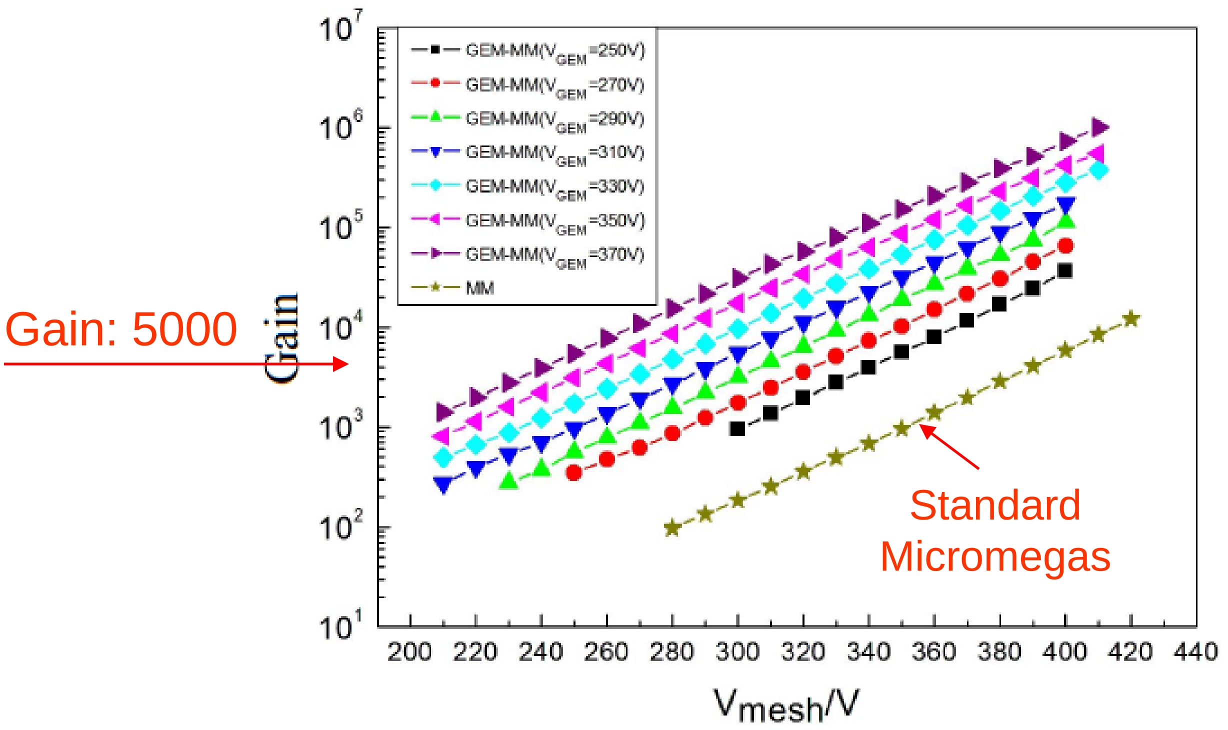
Energy spectrum@^{55}Fe

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



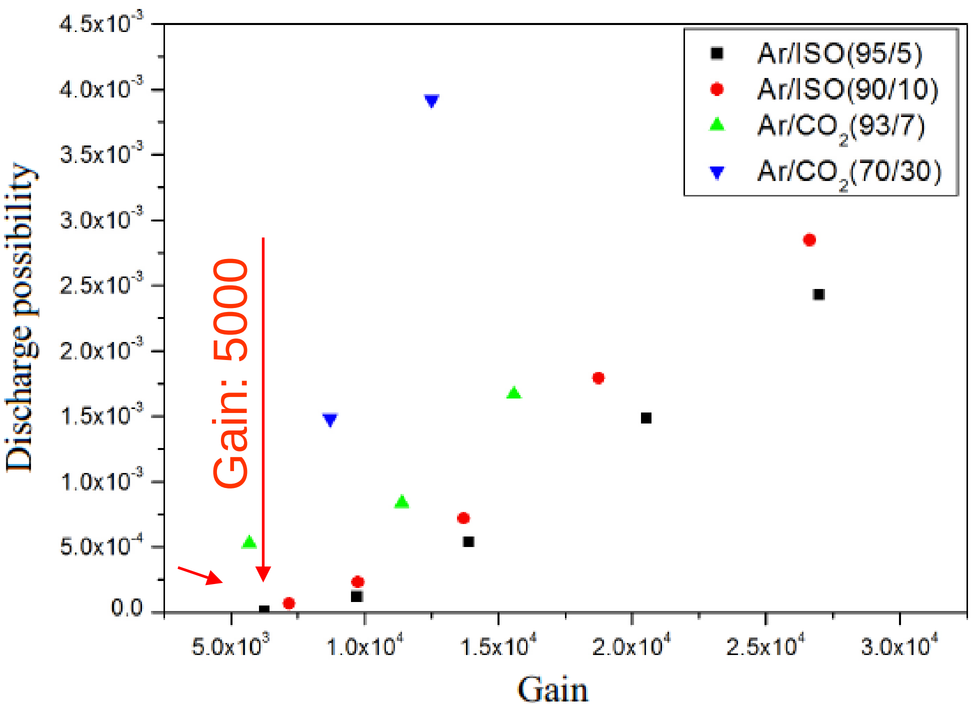
An example of the 55Fe spectra showing the correspondence between the location of an X-ray absorption and each peak.

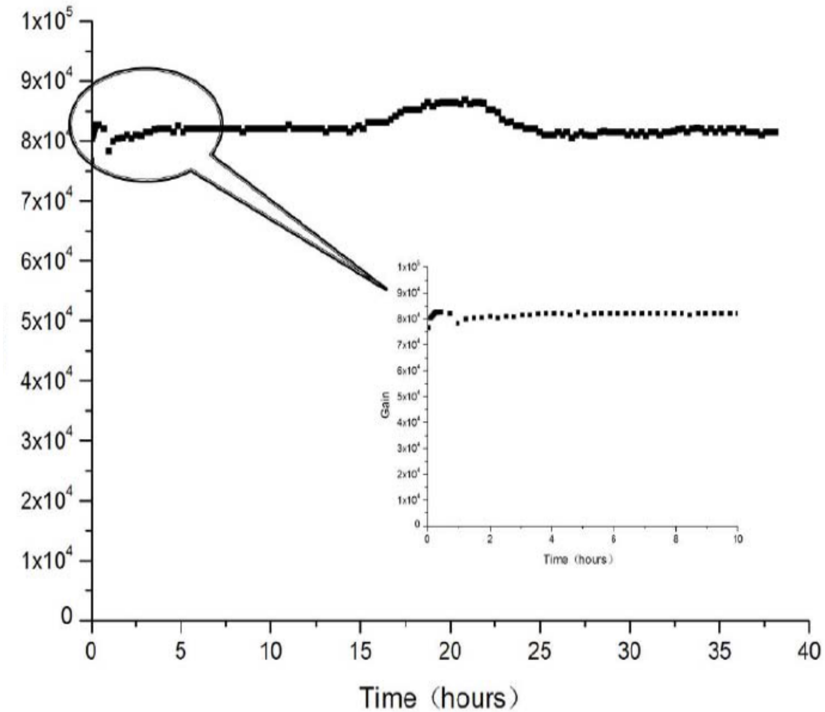
Gain of GEM + MM



- 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

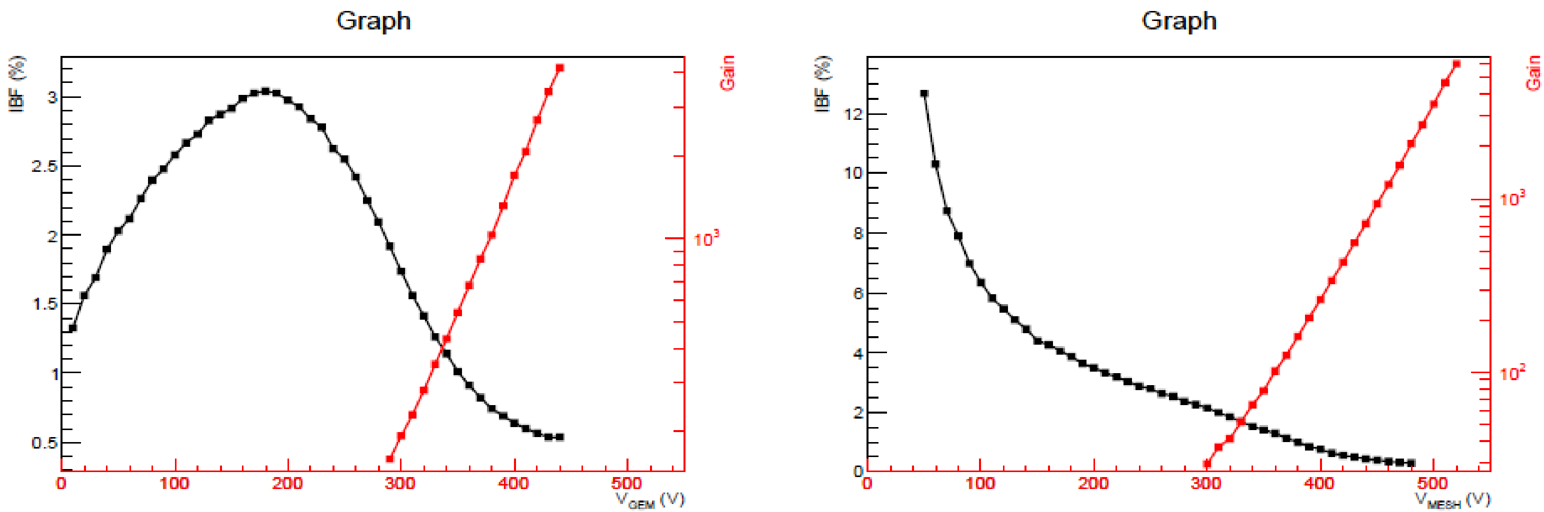
Discharge and working time





- 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



(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.

	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	#

Summary

- **Critical requirements for CEPC TPC modules**
  - Beam structure
  - Continuous Ion Back Flow
- **Some activities for the module**
  - 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

Thanks very much for your attention !