Status of the continuous IBF suppression TPC module R&D

Huirong Qi

Yulian Zhang, Haiyun Wang, Zhiwen Wen, Qun OUYANG, Jian Zhang

Institute of High Energy Physics, CAS

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Outline

- Physics requirements
- Simulation of the module
- Experiment of the module
- Summary

CEPC and its beam structure

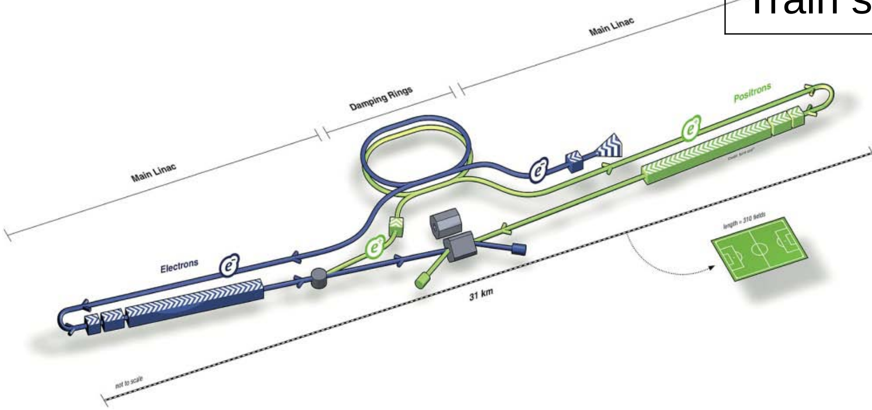
Circular e^+e^- Higgs (Z) factory with two detectors, 1M ZH events in 10yrs

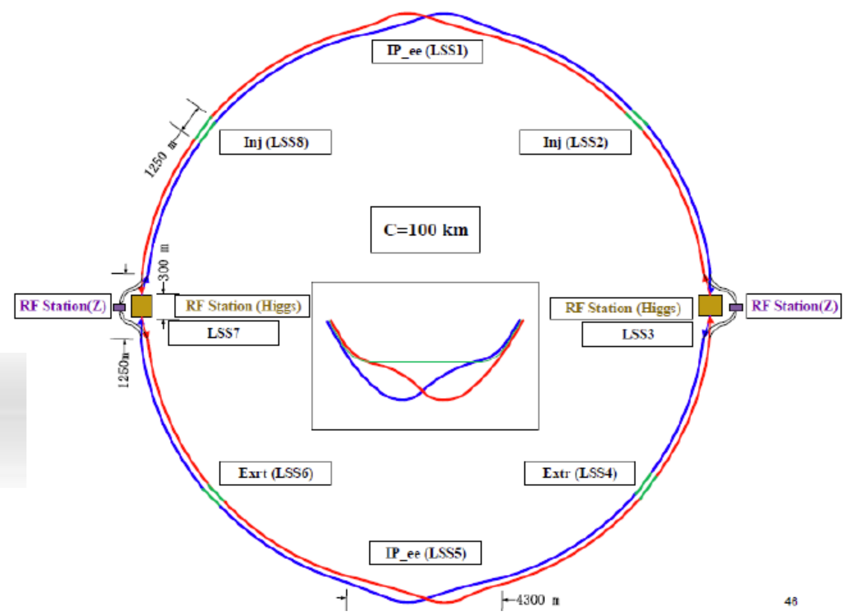
E_{cm} ≈240 GeV, luminosity ~2×10^{34} $cm^{-2}s^{-1}$, can also run at the Z-pole

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**

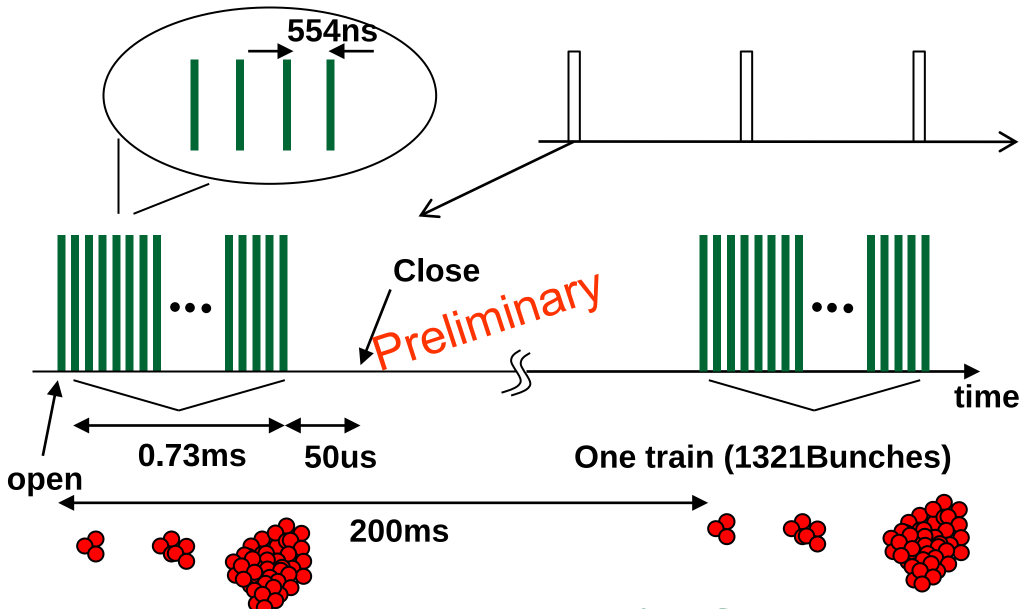




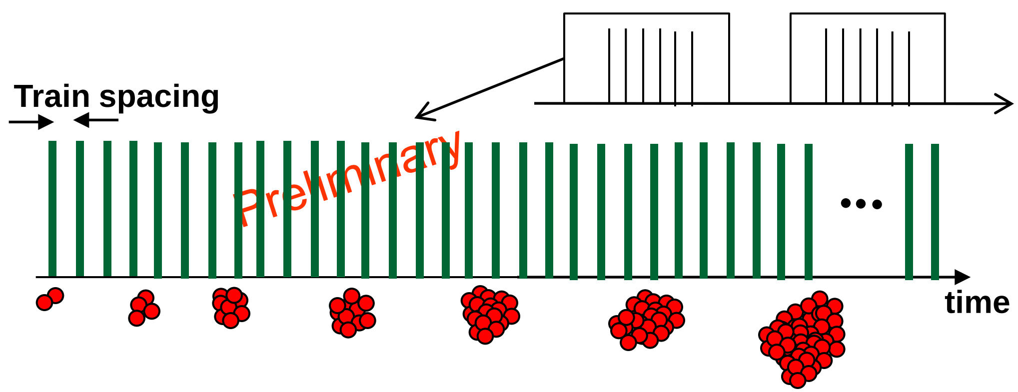
Layout of CEPC Double Ring

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!

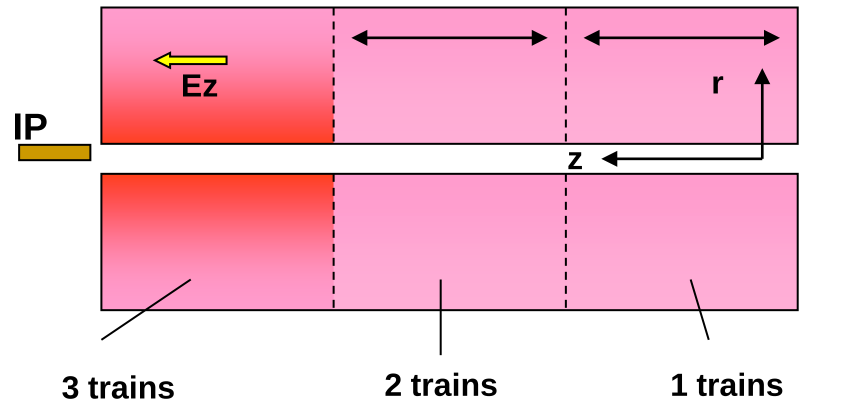
Critical challenge: Ion Back Flow and Distortion

In the case of ILD-TPC

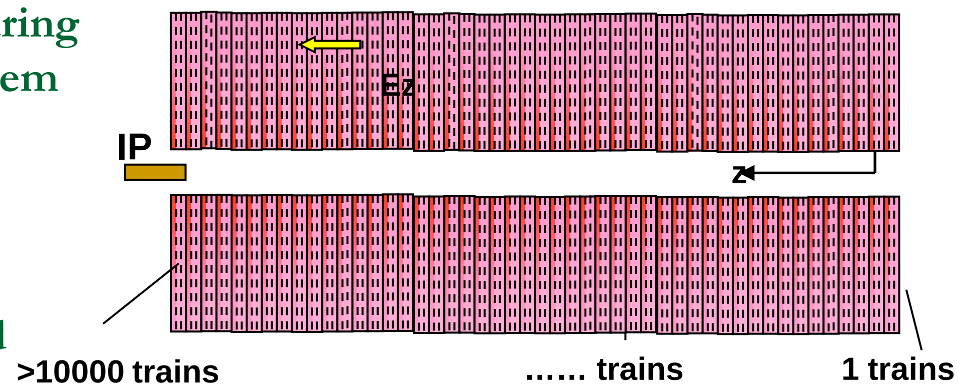
- Distortions by the primary ions at ILD are negligible
- Ions from the amplification will be concentrated in discs of about 1 cm thickness near the readout, and then drift back into the drift volume Shorter working time
- 3 discs co-exist and distorted the path of seed electron
- The ions have to be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

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

Simulation of IBF

Requirements of Ion Back Flow

- 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

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

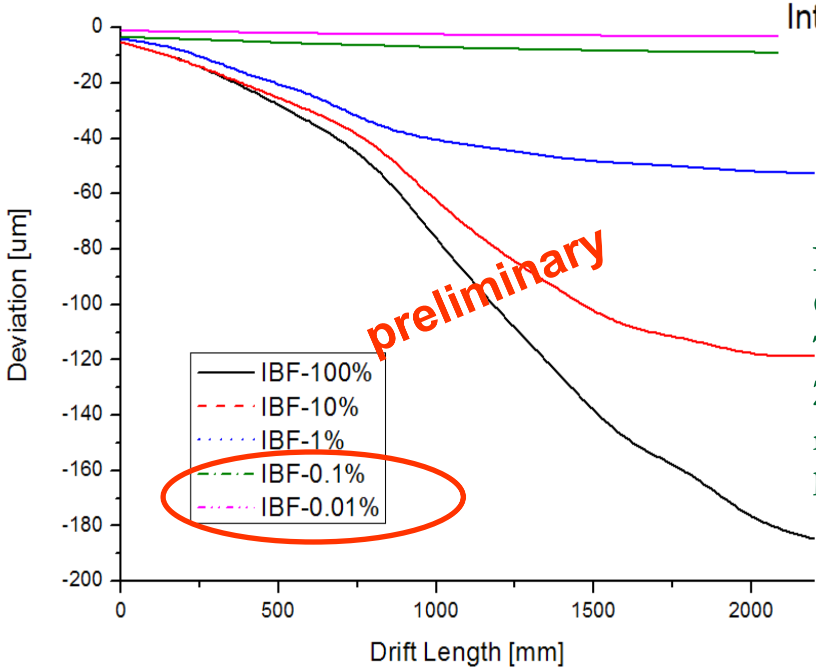
Intrinsic resolution of the readout at zero drift distance in rφ/z

Transverse and

Effective number of primary signal electrons

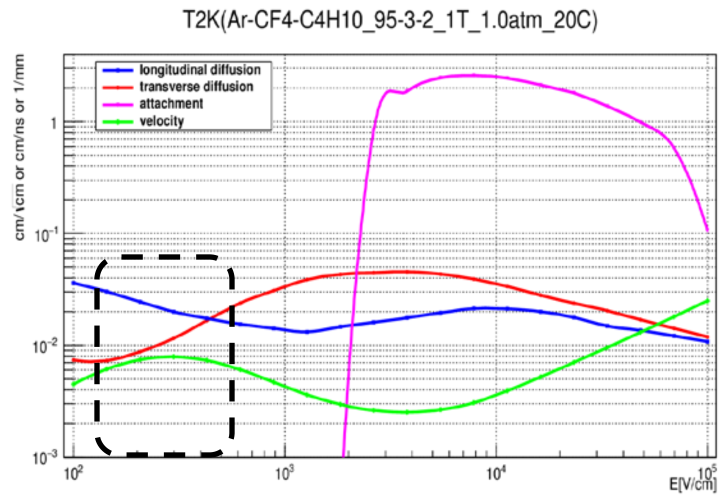
molecules during drift

Position resolution of the TPC function



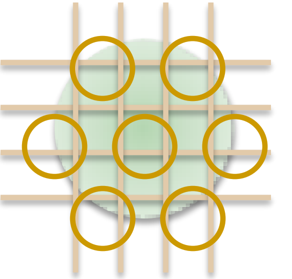
Neff=30
Gain=5000
T2K gas
Z pole run@10^{34}
r=400mm
k=IBF*Gain=5

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

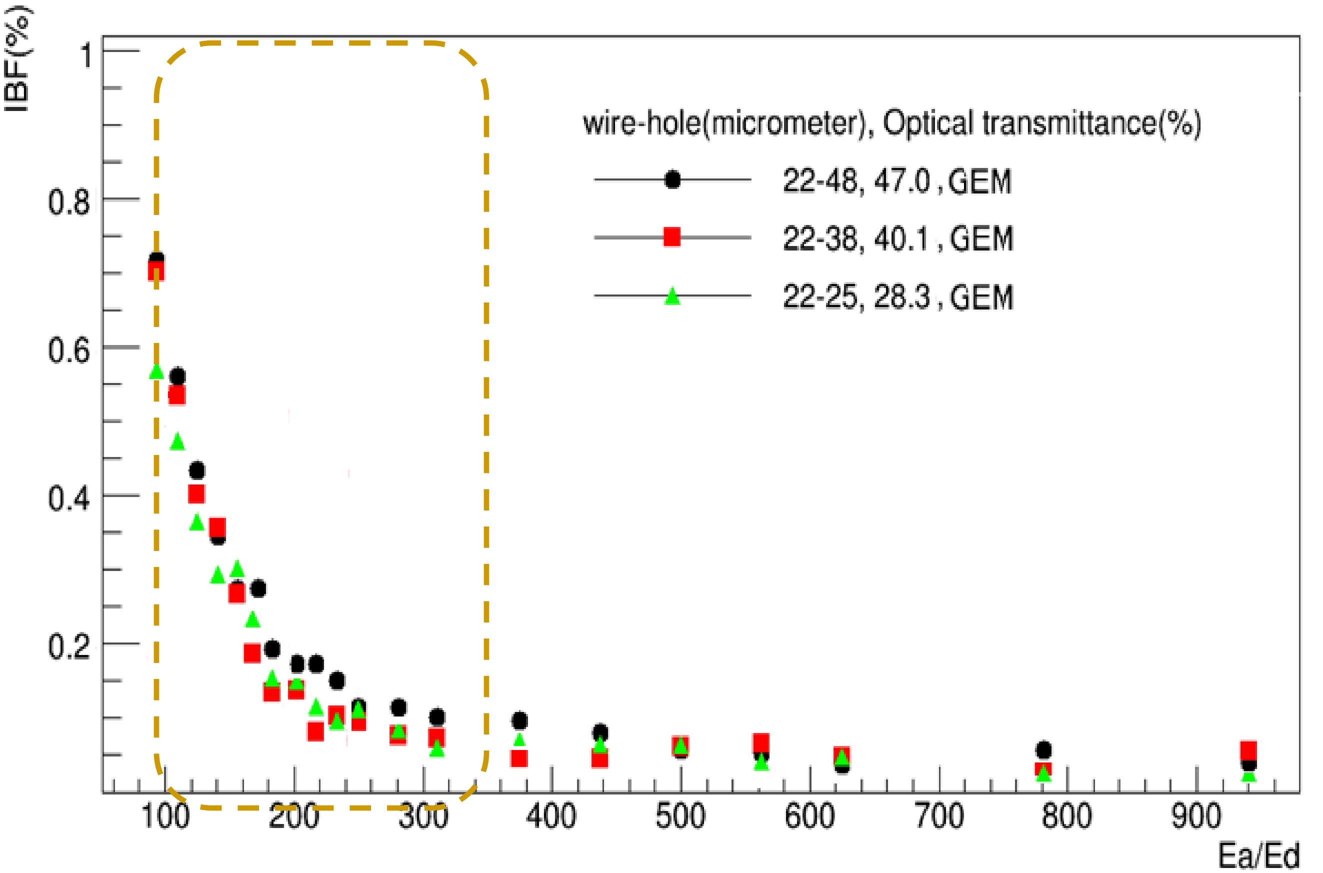


Simulated the drift velocity @T2K

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



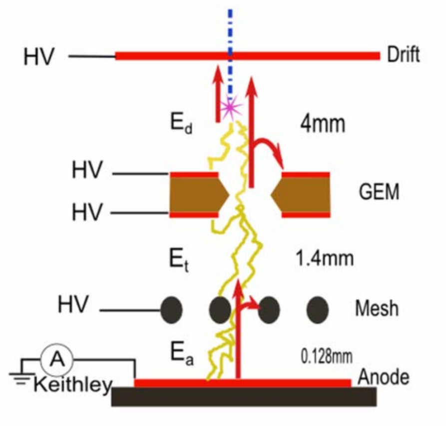
Electric field of amplifier VS Electric field of Drift

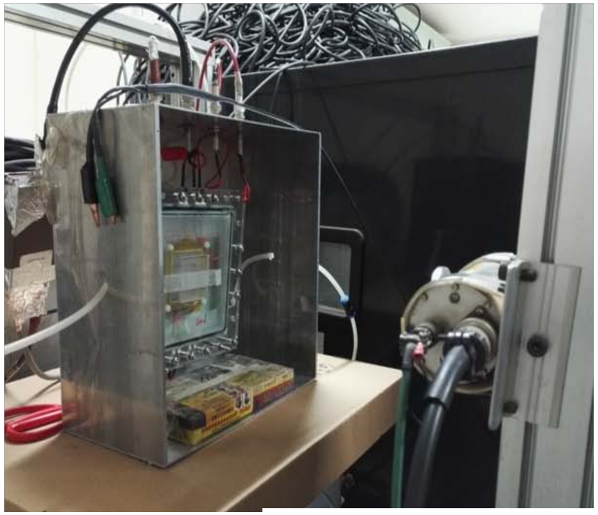
Measurement of IBF study

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





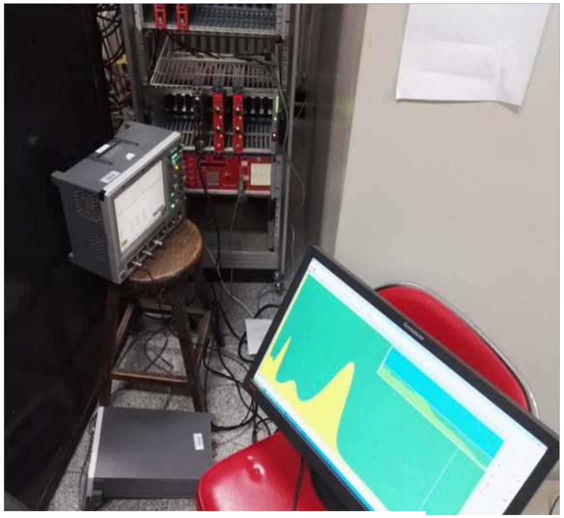
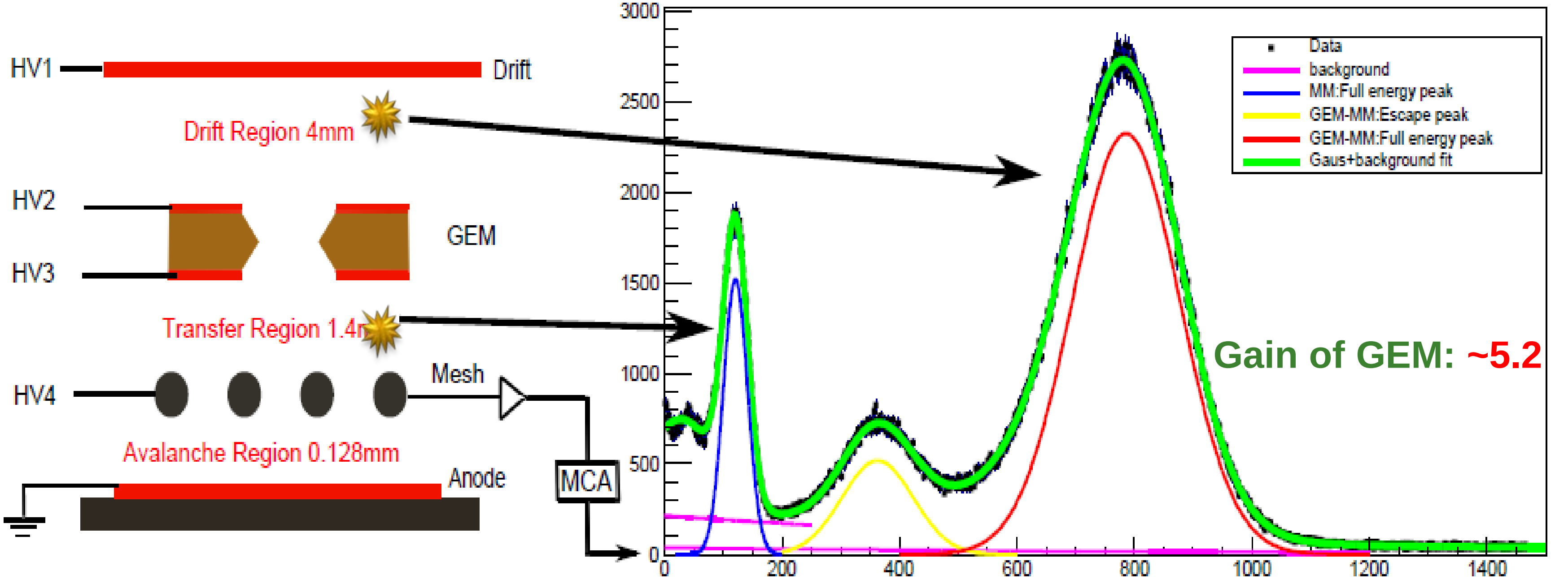


Photo of the GEM+Micromegas Module with X-ray

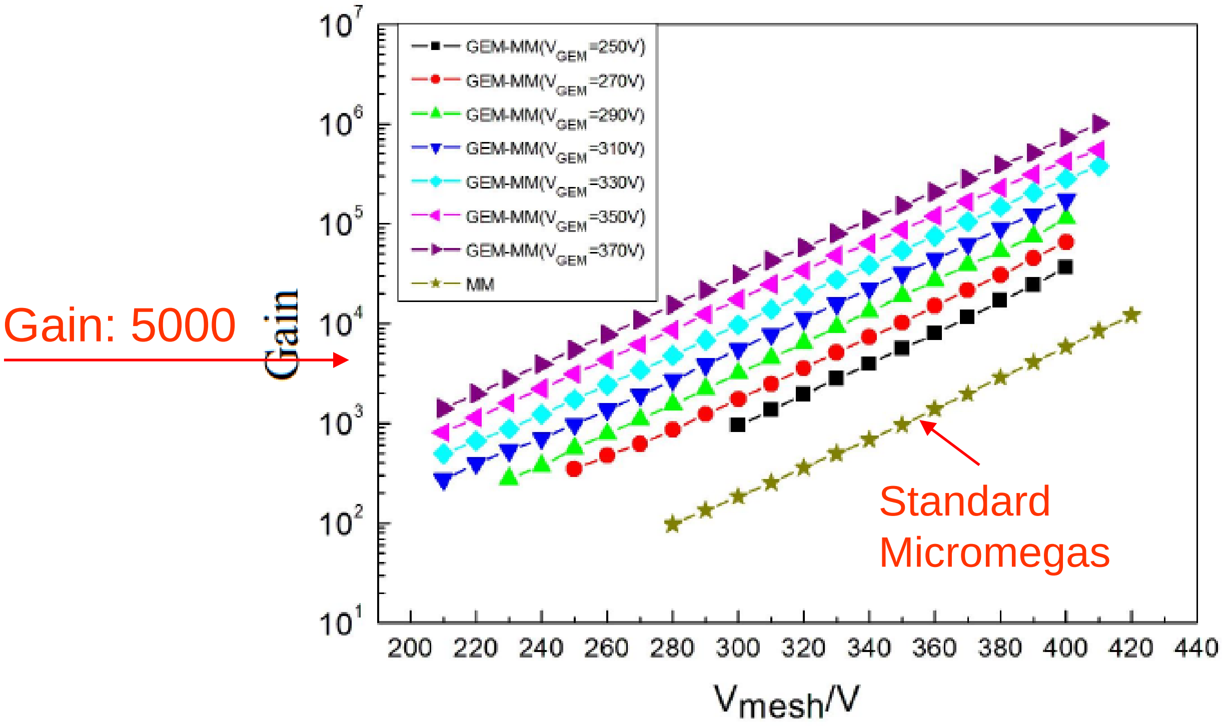
Energy spectrum@^{55}Fe

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



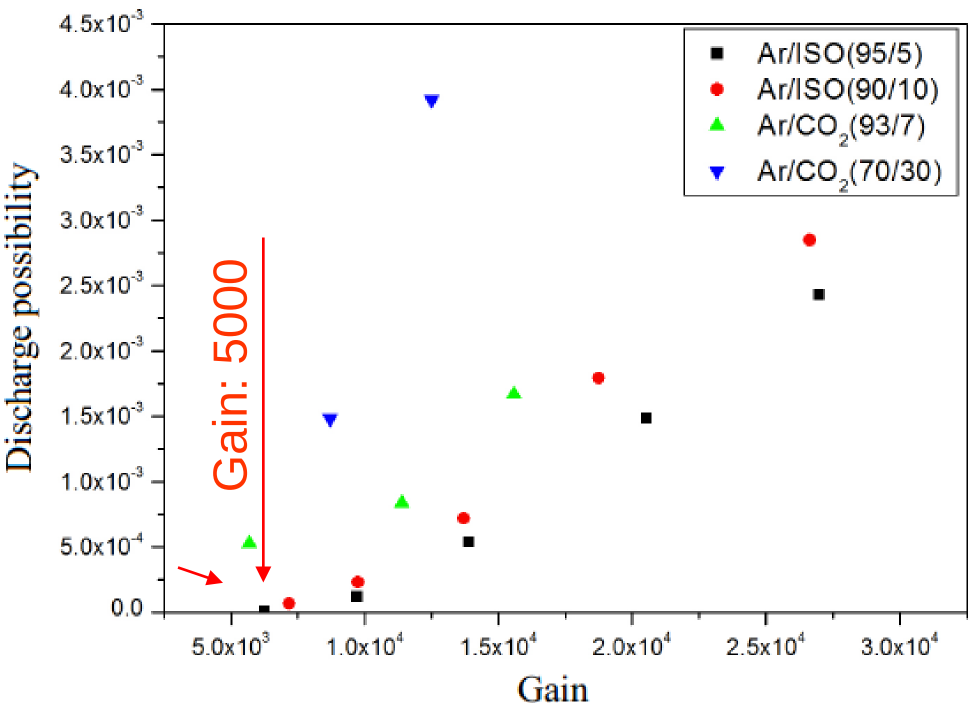
An example of the 55Fe spectra showing the correspondence between the location of an X-ray absorption and each peak.

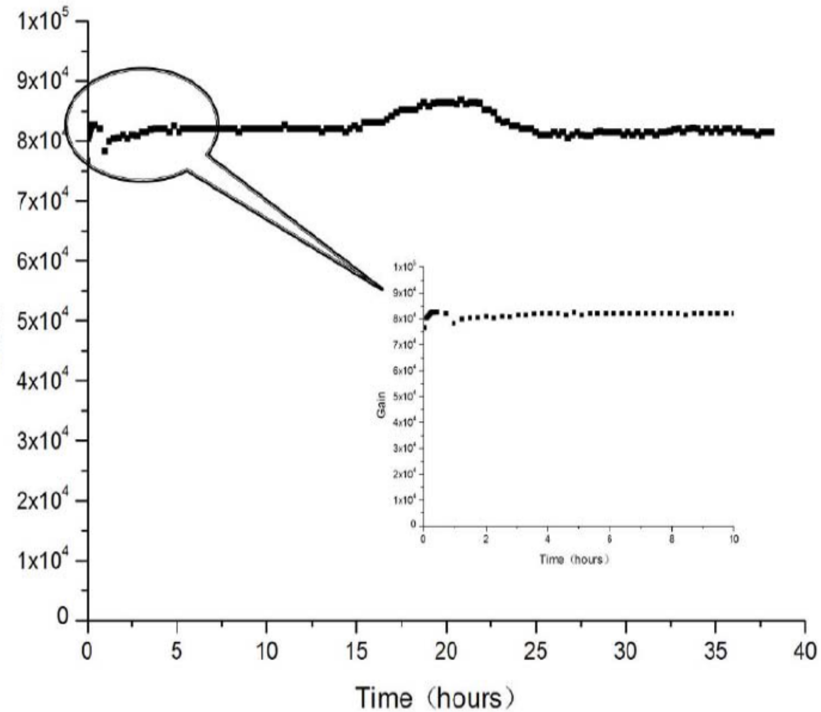
Gain of GEM + MM



- 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

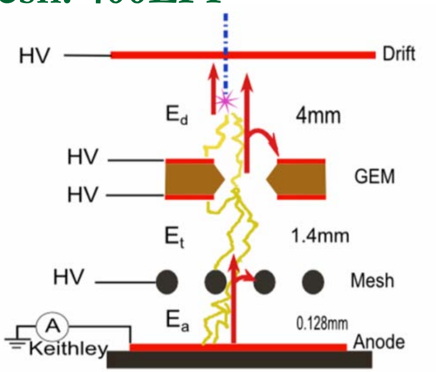


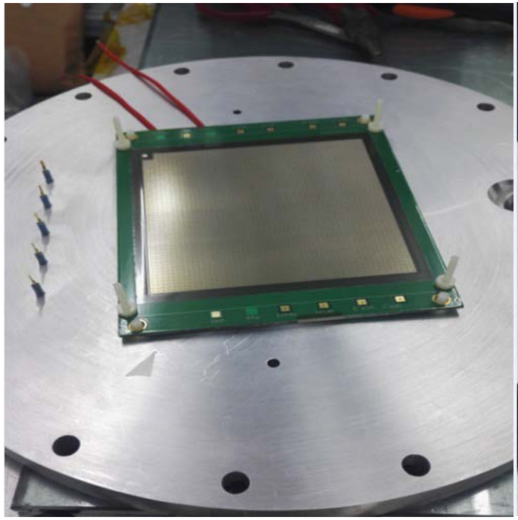


- Test with Fe-55 X-ray radiation source
  - Discharge possibility could be mostly reduced than the standard Bulk-Micromegas
  - Discharge possibility of hybrid detector could be used at Gain~10000
  - To reduce the discharge probability more obvious than standard Micromegas
  - At higher gain, the module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

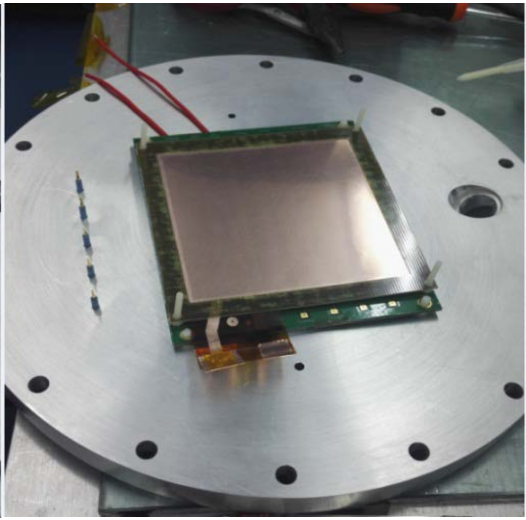
Test of the new module

- 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

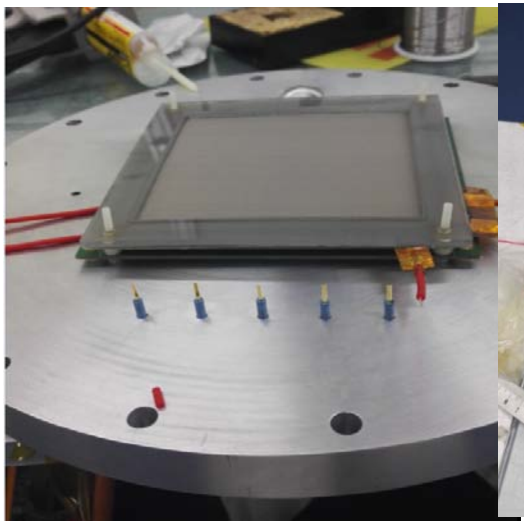




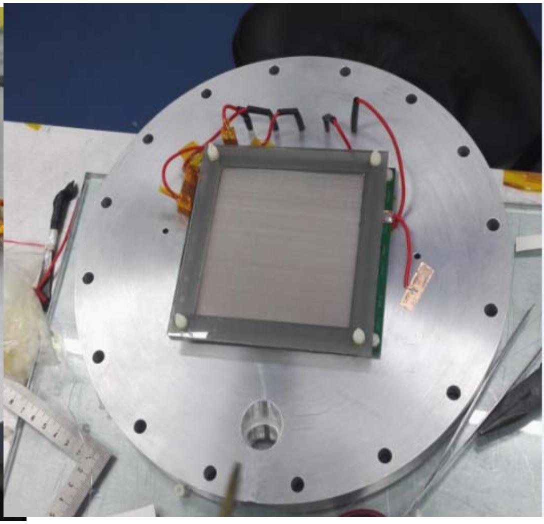
Micromegas(Saclay)



GEM(CERN)



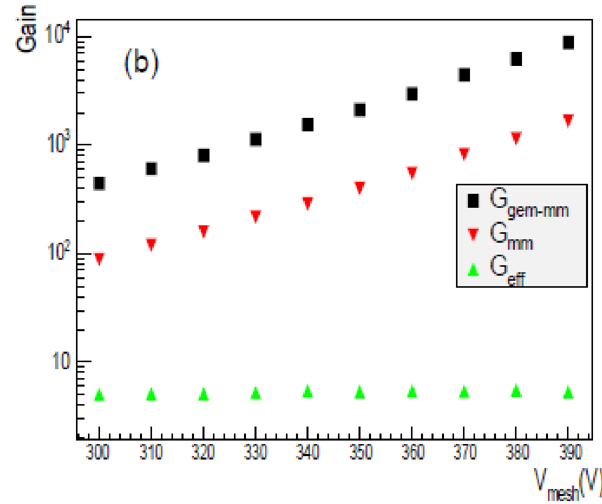
Cathode with mesh



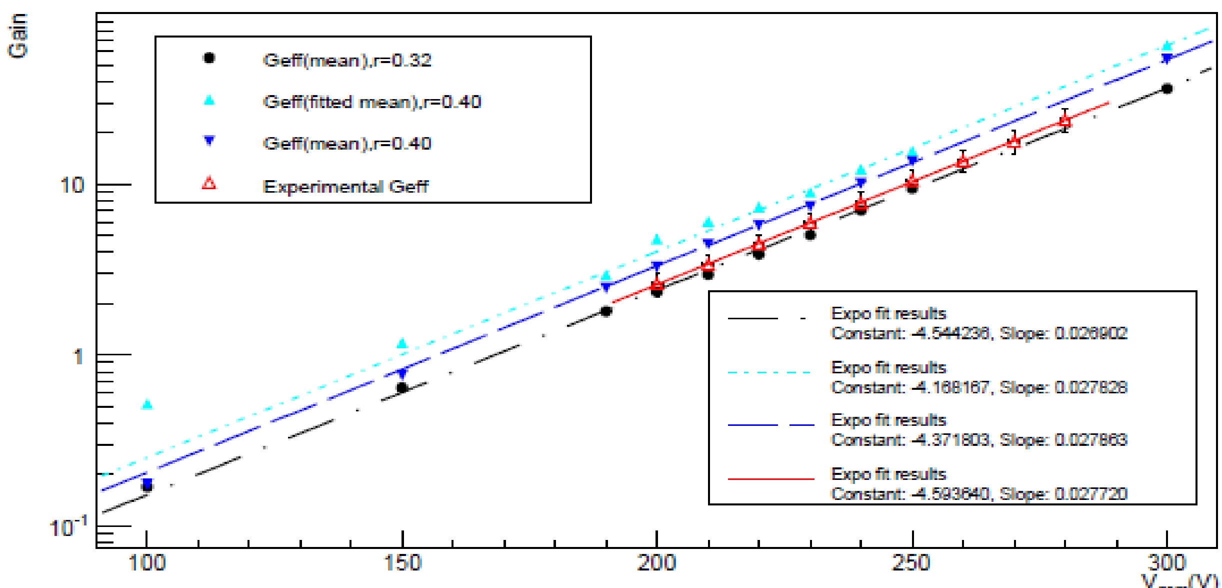
GEM-MM Detector

Gain of GEM-MM module

- Gain of the GEM-MM
  - Gain simulation by Garfield++
  - Gain test with GEM-MM detector
  - Optimization operation high voltage
  - V_{GEM}=240V/V_{MM} from 300V to 400V
  - Good fit the value with simulation and measurement
  - Gain of GEM: 3~23
  - Gain of GEM-MM: 100~10000



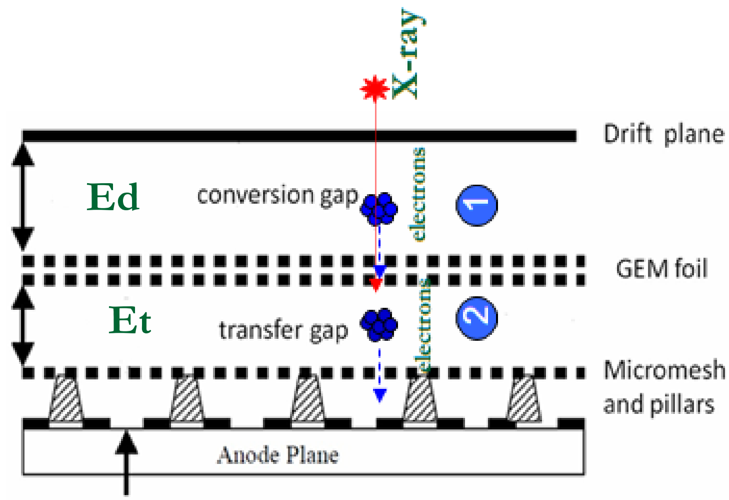
Gain with MM at VGEM=240V



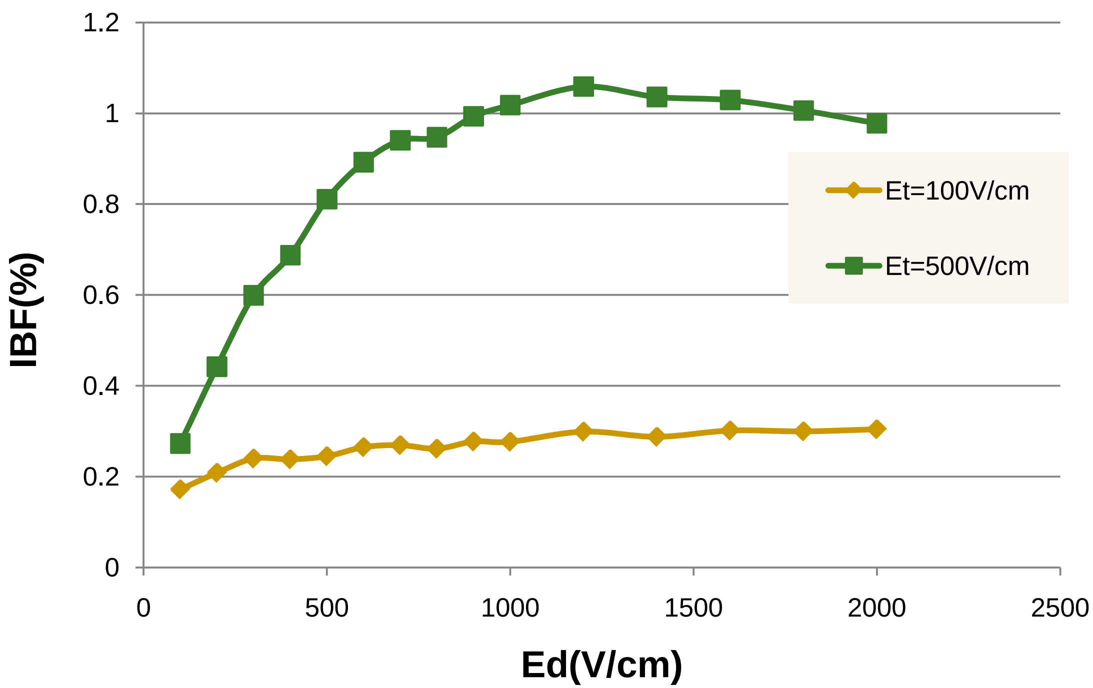
Comparison of GEM gain simulation and measurement

IBF of GEM-MM module

- IBF of the GEM-MM
  - Electric field: 100V/cm and 500V/cm
  - IBF value comparion
  - Optimization of Et = 100V/cm
  - Ed/Et/Ed=2/1/5
  - V_{GEM}=340V and V_{mesh}=520V
  - Total gain: 3000~4000

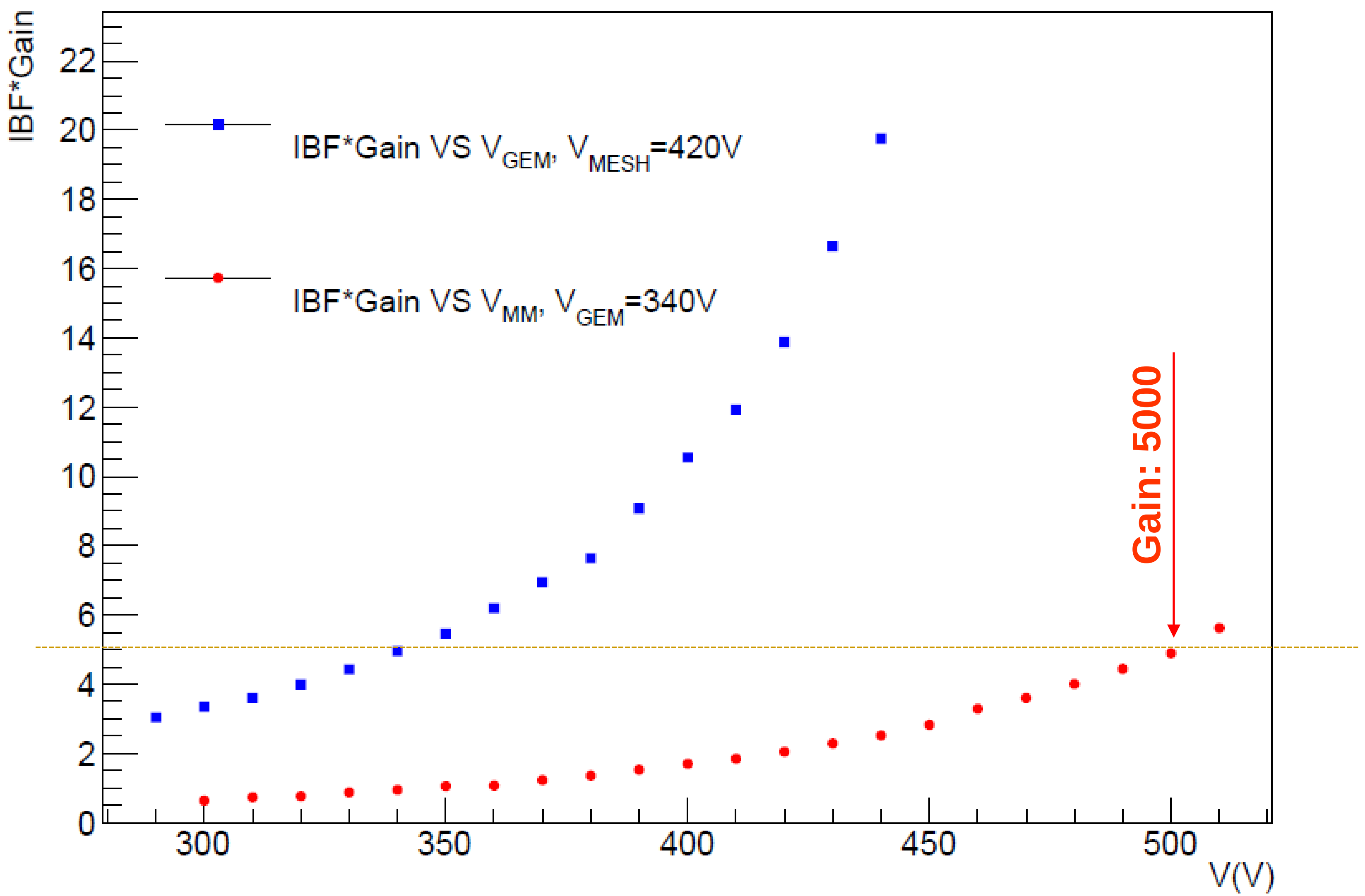


Schematic of the Gain with MM



IBF values with the Ed and Et in the GEM-MM detetctot

IBF test results

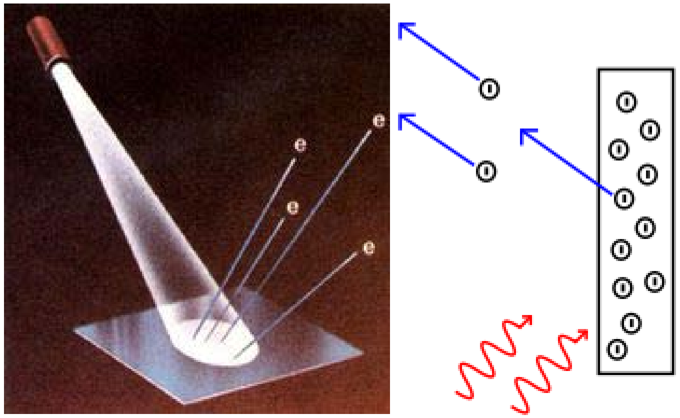


Key factor: IBF * Gain

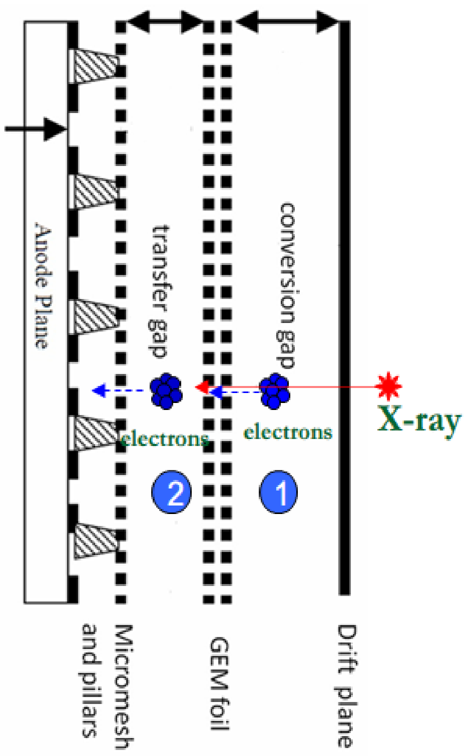
	GEM+MMG 420LPI (IHEP)	**2GEMs + MMG 450 LPI (Yale University)**	**Micromegas only 450 LPI (Yale University)**
Ion Back Flow	**0.1-0.2% Edrift = 0.25 kV/cm**	(0.3 –0.4)% Edrift = 0.4 kV/cm	(0.4 –1.5)% Edrift= (0.1-0.4) kV/cm
<GA>	**4000~5000**	2000	2000
ϵ-parameter(=IBF*GA)	**4~5**	6~8	8~30
E –resolution	**~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	#

Why UV light study

- IBF measurement methods
  - 55Fe radioactive source
  - X tube machine
  - Synchrotron radiation
  - UV light by the photoelectric effect



Photoelectric effect



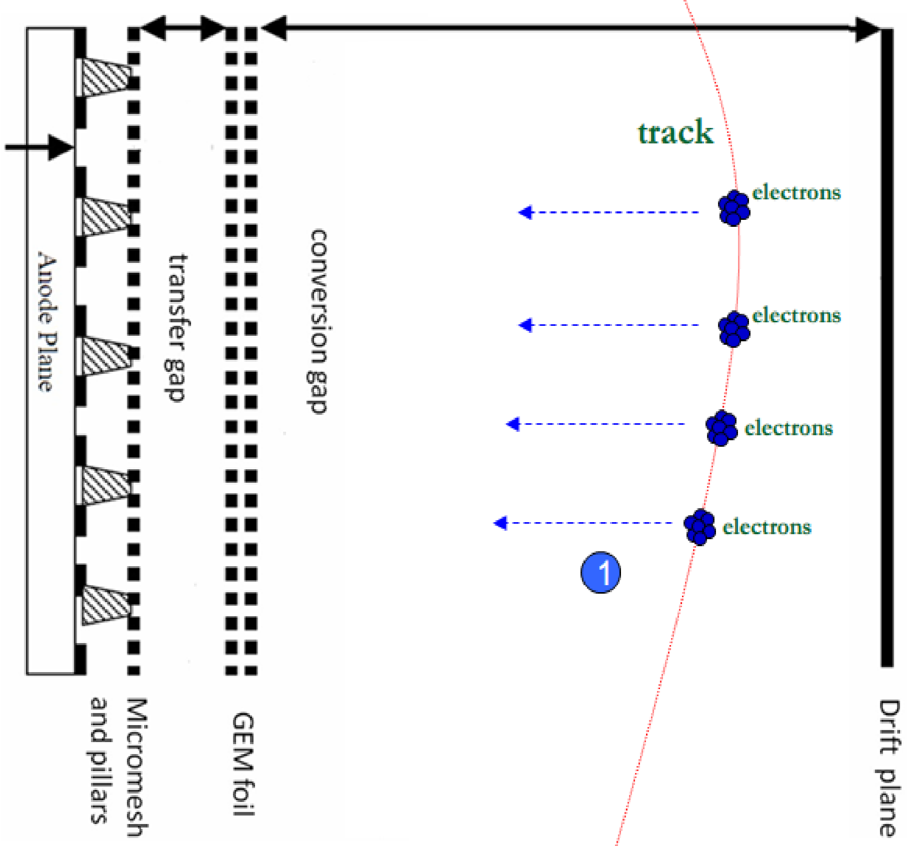
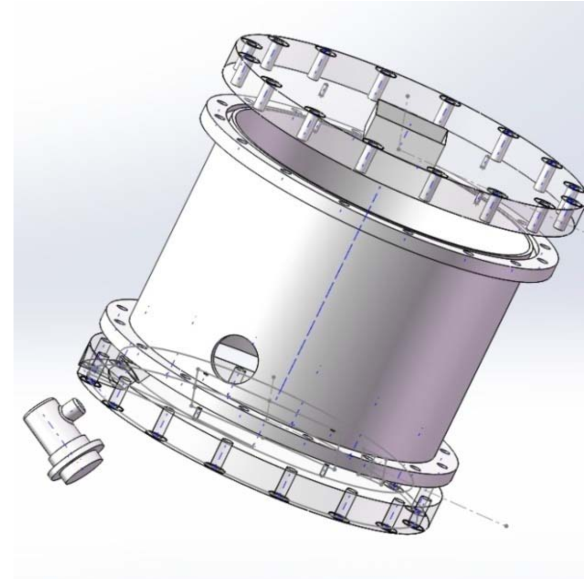


Diagram of the IBF test with the module

UV test of the new module

- UV lamp measurement
  - New designed and assembled UV test chamber
  - Active area: 100mm×100mm
  - Deuterium lamp and aluminum film
  - Principle of photoelectric effect
  - Wave length: 160nm~400nm
  - Fused silica: 99% light trans.@266nm
  - Improve the field cage in drift length

Deuterium lamp
X2D2 lamp



UV test geometry with GEM-MM

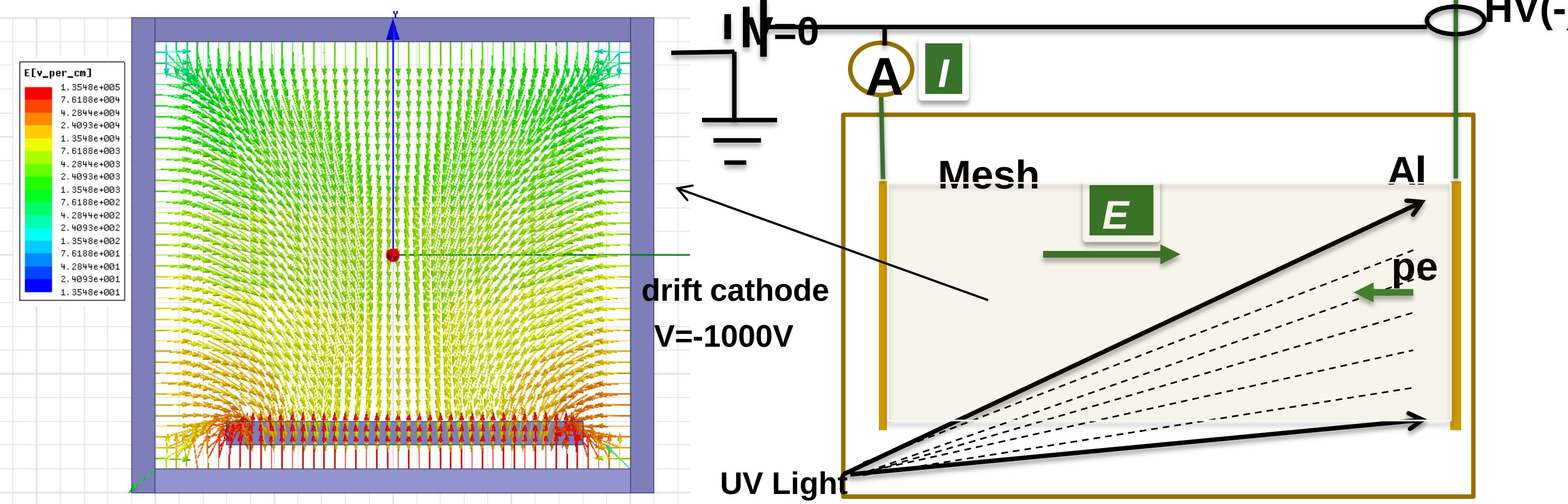
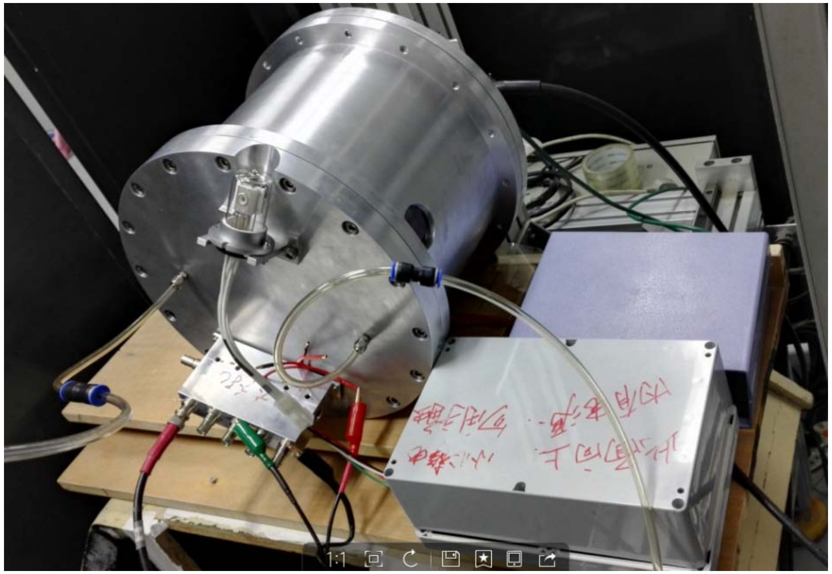
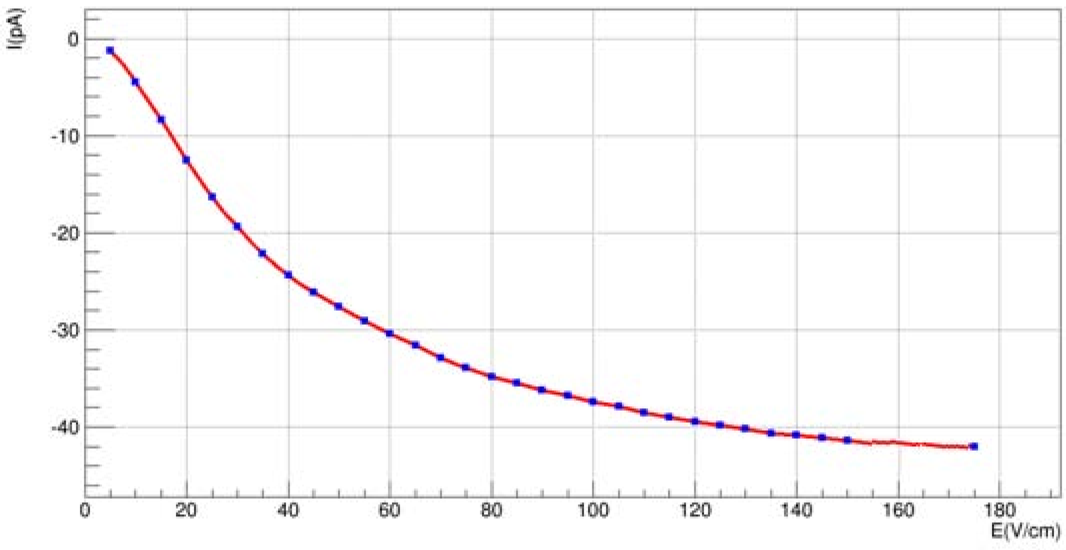


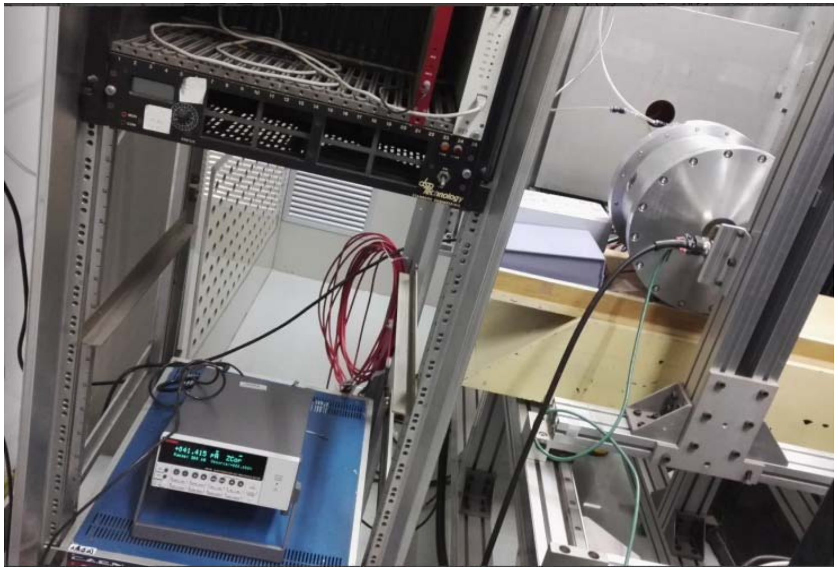
Diagram of the UV test with new module

UV test -first step

- UV lamp measurement
  - pA current meter from Keithley
  - First step test about the current in mesh
  - E_drift: 10~175V/cm
  - ~43pA@175V/cm
  - Stable current with UV light
  - ~200V/cm@T2K operation gas





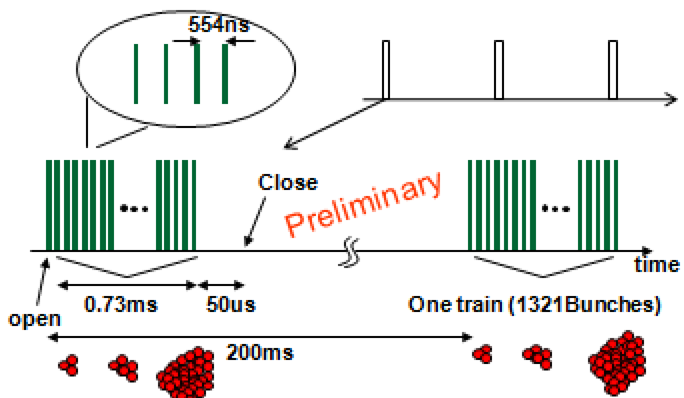


Electrons by photoelectric effect with Edrift

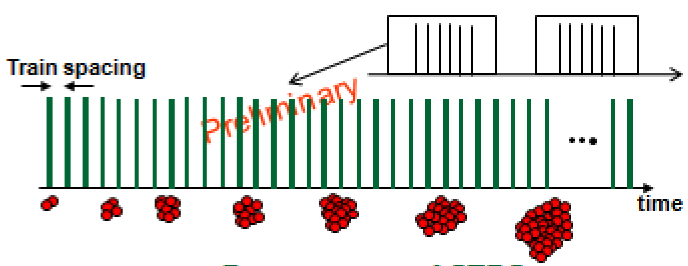
Photo of the new module in lab

UV test - next steps

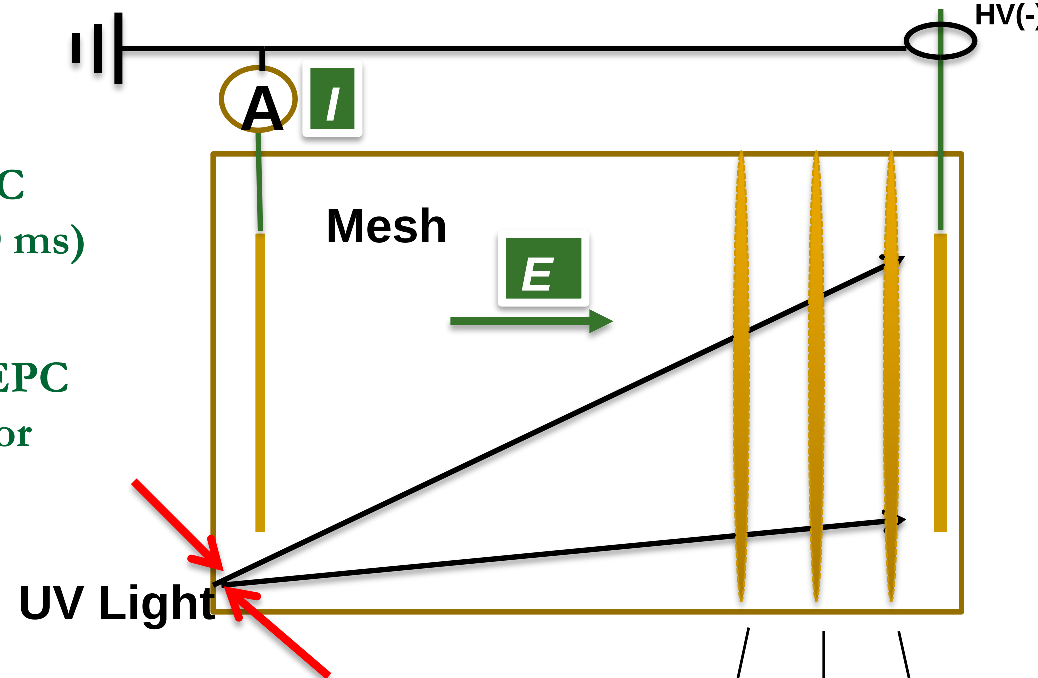
- In the case of ILD-TPC
  - Bunch-train structure of the ILC beam (one ~1ms train every 200 ms)
- In the case of CEPC-TPC
  - Bunch-train structure of the CEPC beam (one bunch every ~90μs) or partial double ring
- Gating and IBF test



Beam structure of ILC

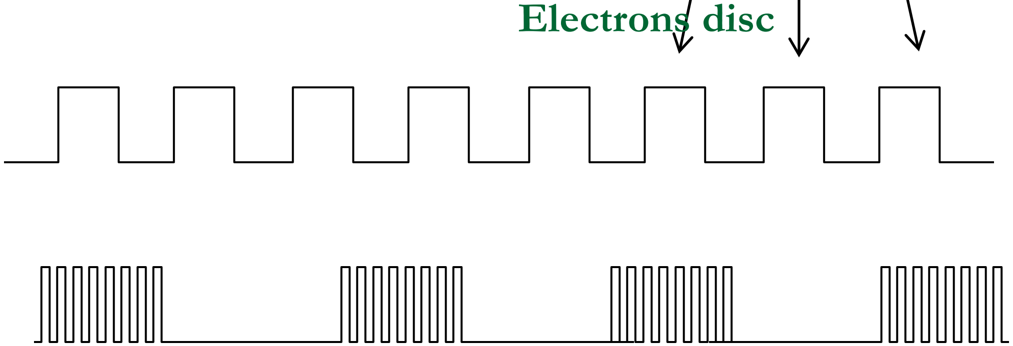


Beam structure of CEPC



Control shutter

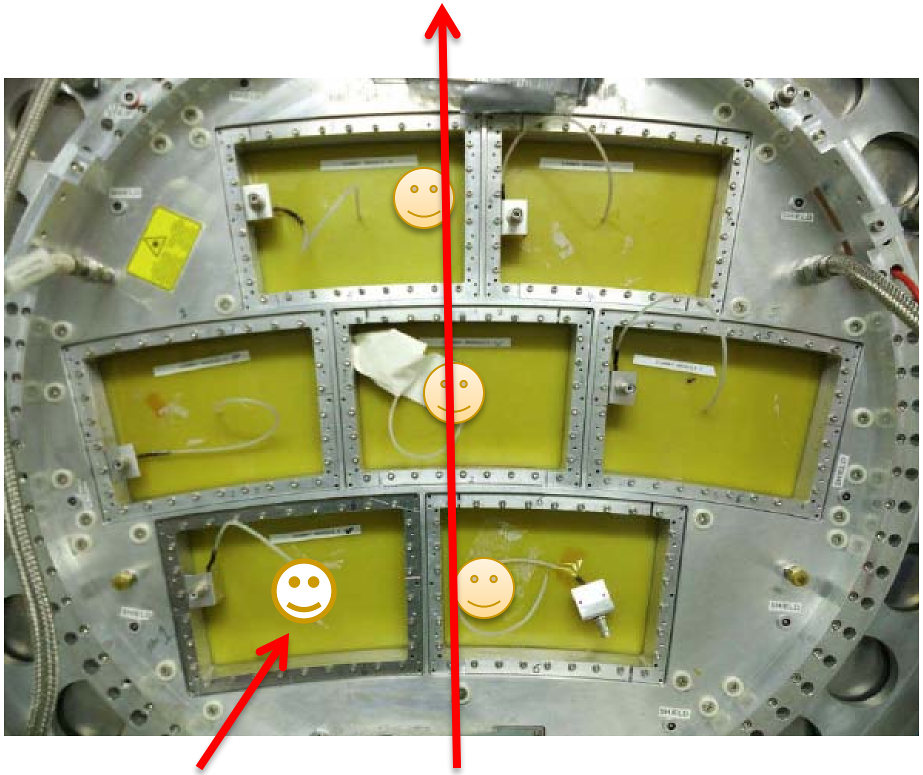
Electrons disc



Shutter time similar to ILC and CEPC beam structure

Module design and beam test plan

- Preliminary schedule of the plan
  - April ~ October /2017
    - Designed and assembled
    - IHEP /KEK
  - November /2017
    - Test of the modules
    - KEK /IHEP
  - January ~ April /2018
    - Optimized the modules
    - Application of the beam
  - June , 2018 (first option)
    - TBD
  - November, 2018 (second option)
    - Beam test in two weeks in DESY
    - ~2 persons from KEK and DESY



UV may be considered

Summary

- **Physics requirements for the 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.**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