Progress on the study of CEPC TPC detector module

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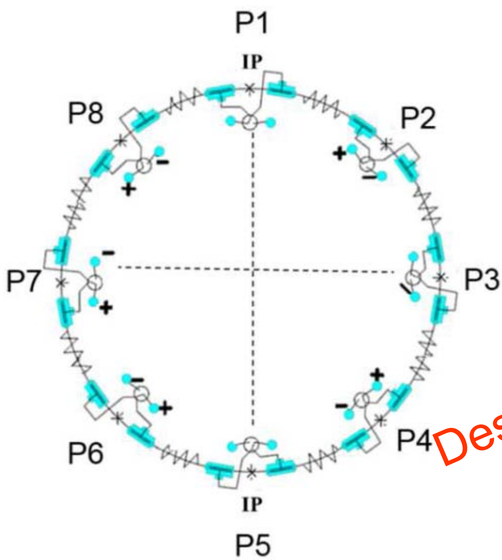
Outline

- Critical challenges of CEPC TPC
- Some activities and progress

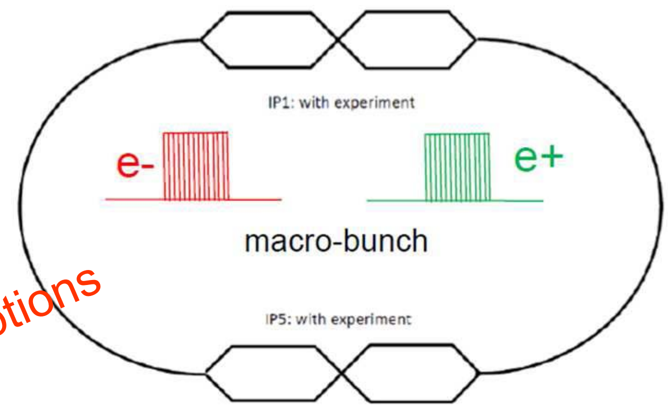
CEPC and its beam structure

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



Preliminary
Design of the options



Pretzel Scheme

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

→Power pulsing not applicable

Partial Double-ring Scheme

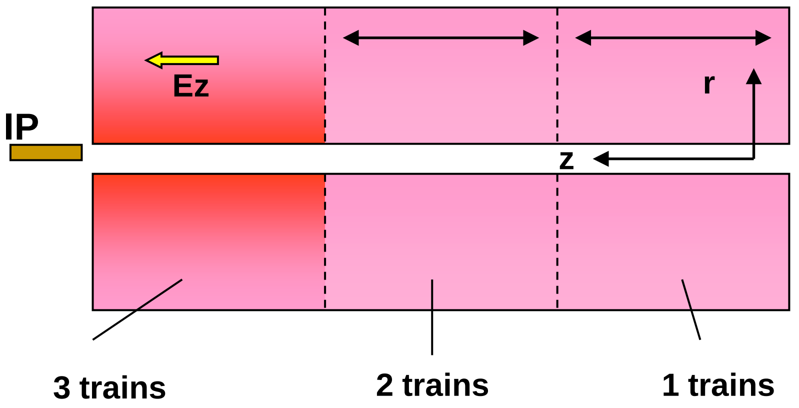
- **Crab-waist collision to reduce beam and AC power**
- **Avoiding pretzel scheme to increase the flexibility and luminosity**
- **196ns bunch spacing**
- **48 bunches / train**
- **Duty cycle: 9.4μs/181μs**

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

Critical challenge: Ion Back Flow and Distortion

In the case of ILD-TPC

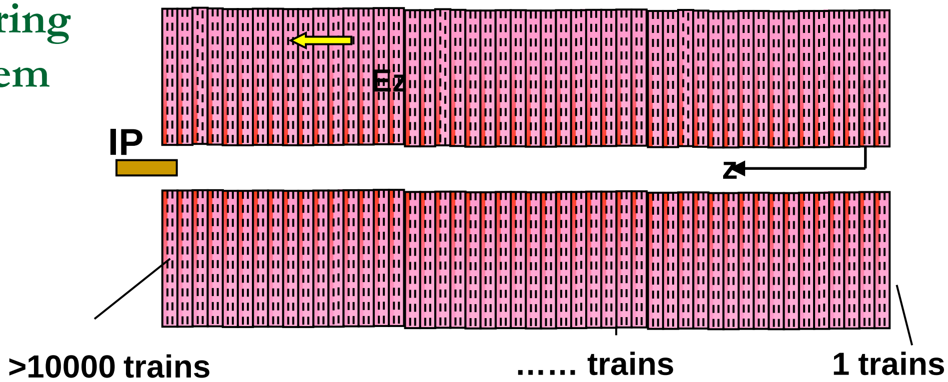
- Distortions by the primary ions at ILD are negligible
- Ions from the amplification will be concentrated in discs of about 1 cm thickness near the readout, and then drift back into the drift volume Shorter working time
- 3 discs co-exist and distorted the path of seed electron
- The ions have to be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

Critical challenges of CEPC-TPC

- Occupancy: at inner diameter
  - Low occupancy
  - Overlapping tracks
  - Background at IP

TPC as one option for CPEC-TPC **YES** or **NO**

- 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

To reduce **IONS**
To reduce distortion

- Calibration and alignment
  - Complex MDI design
  - Laser calibration system

~100um positron resolution with calibration

2015~2016, some activities for the critical challenges

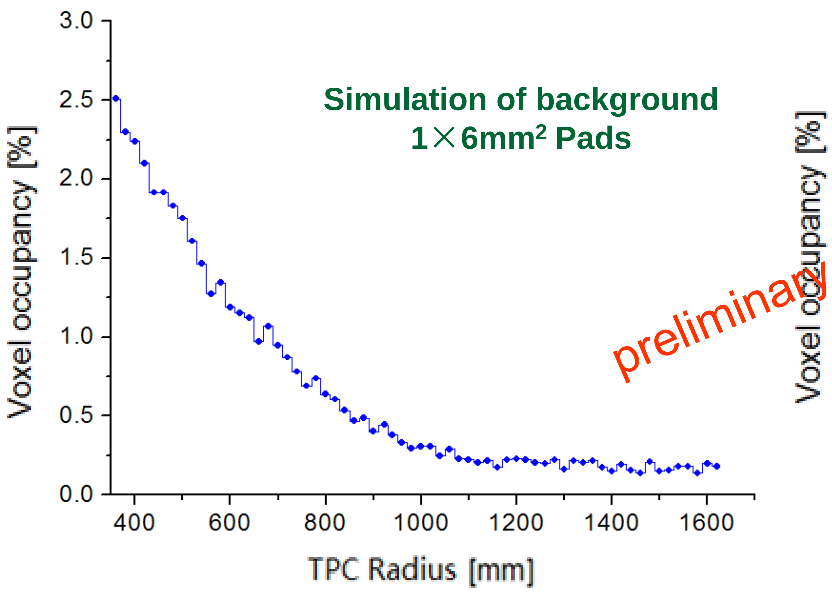
- Progress on simulation

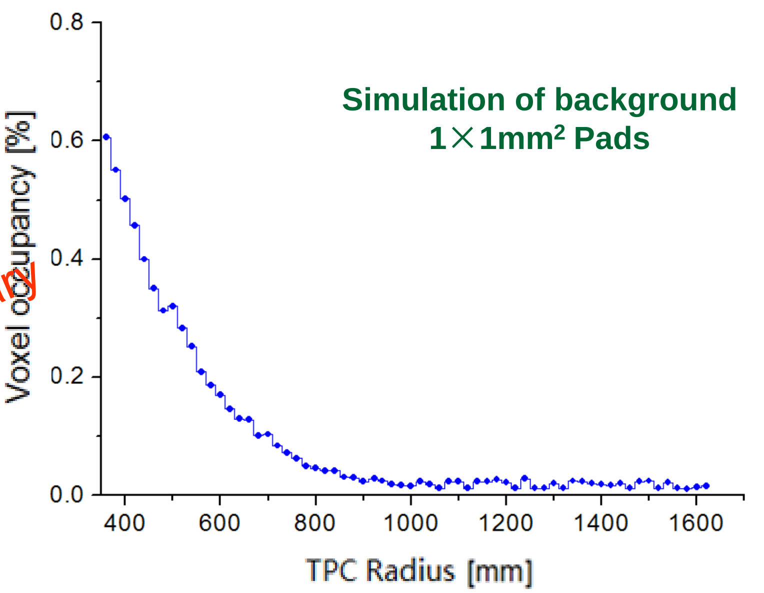
Simulation of occupancy

- 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!

More works for Z pole !



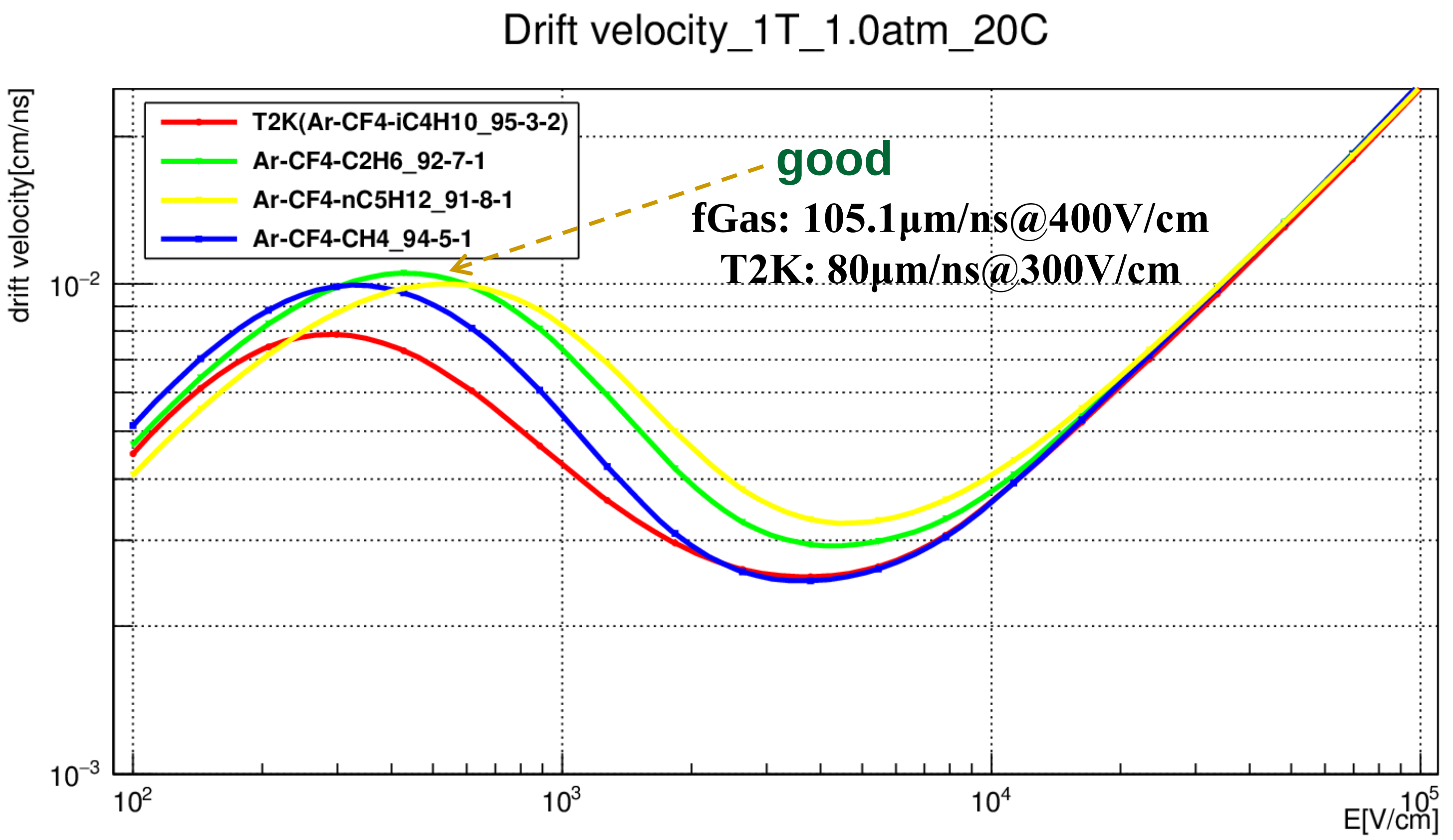


Preliminary of occupancy

Choosing a gas mixture – simu.

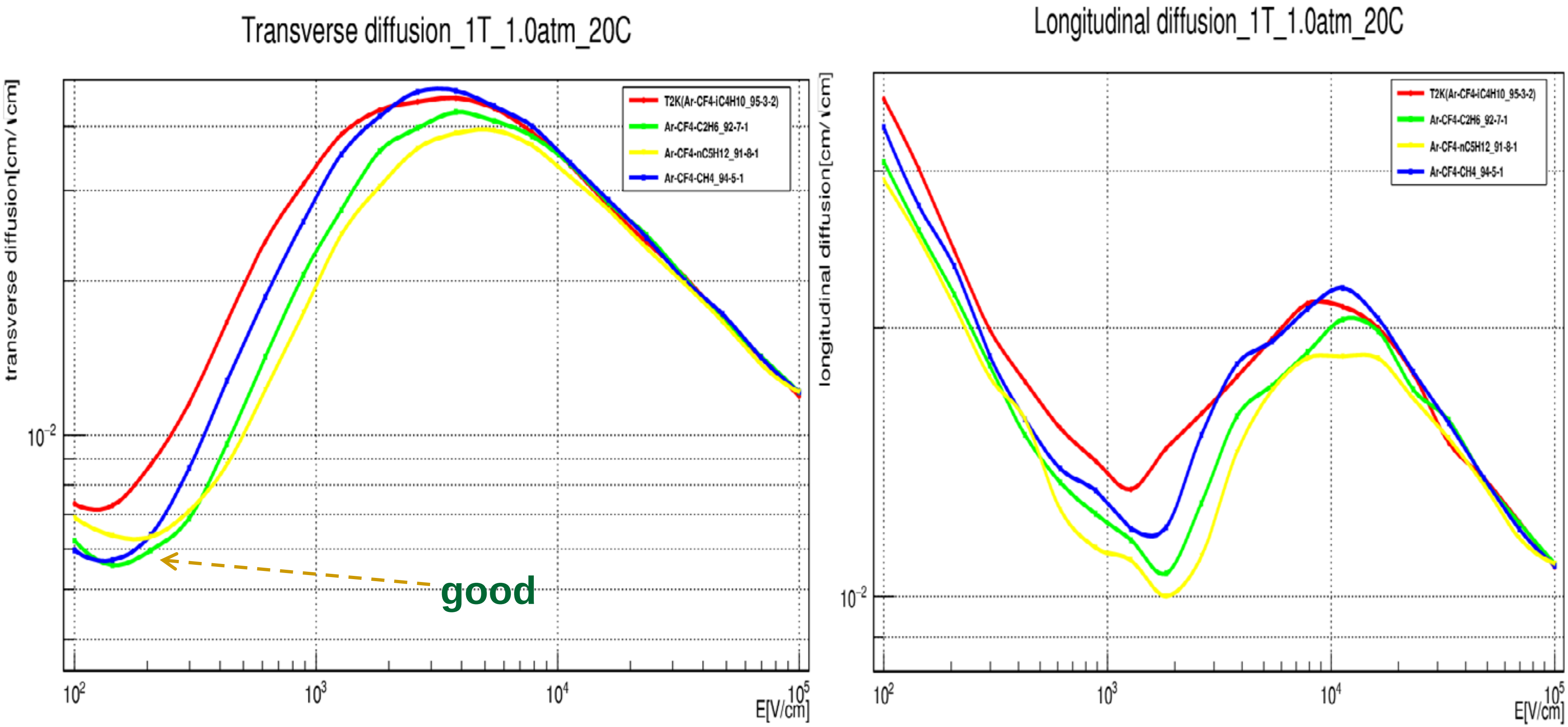
- Faster drift velocity @E_{drift}~300V/cm
  - Refer to T2K gas
  - Ar/CO2/CF4/iC4H10/nC5H12/C2H6

Defined:
fGas : Ar-CF4-C2H6=92:7:1



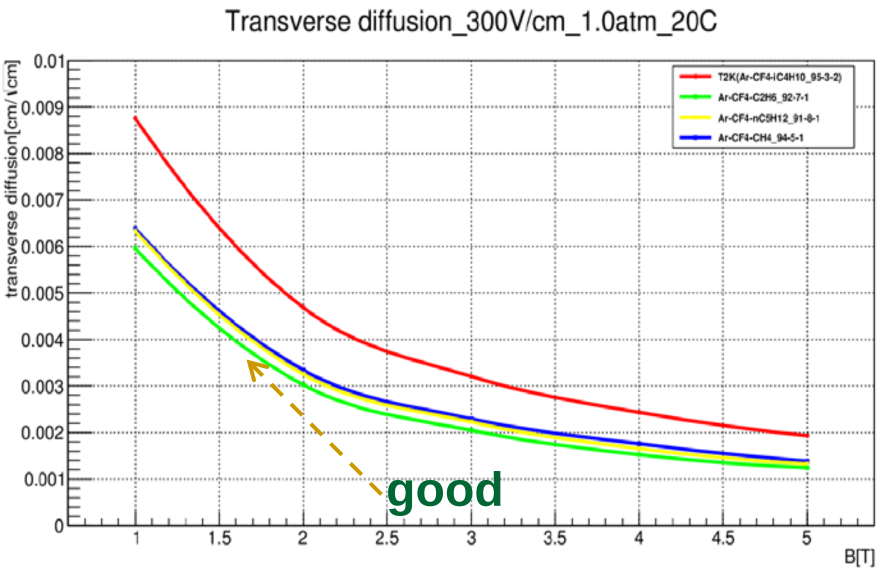
Drift velocity of some mixture working gases

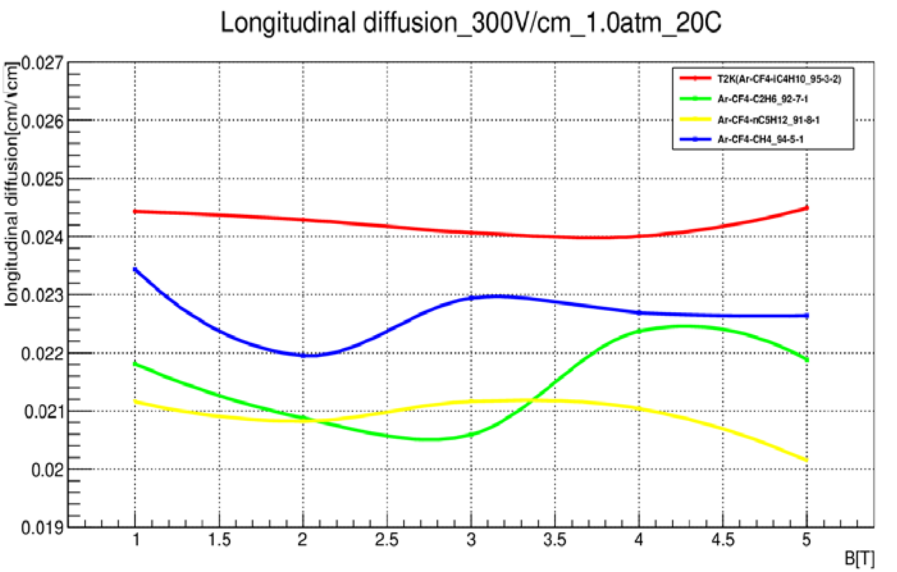
Choosing a gas mixture – simu.



Diffusion in magnetic field of 1T

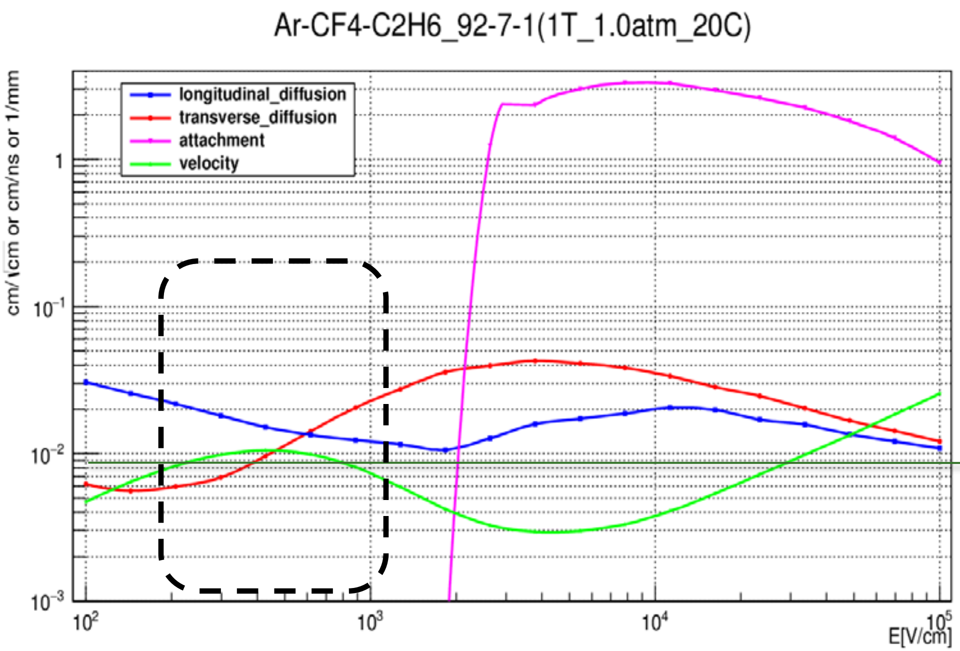
Choosing a gas mixture – simu.



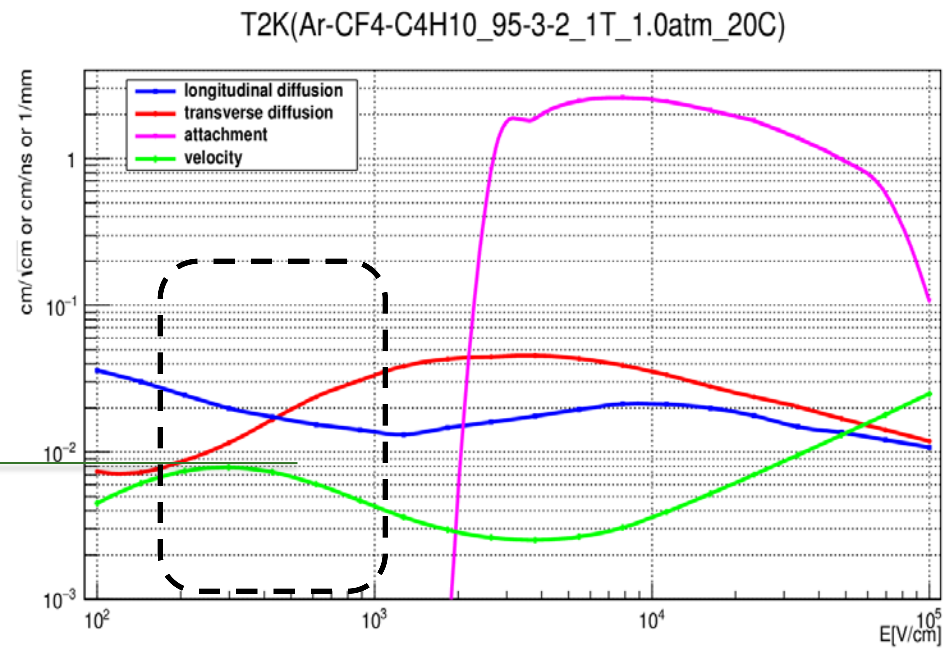


Diffusion @300V/cm in magnetic field from 1T to 5T

Choosing a gas mixture – simu.



Ar-CF4-C2H6 gas



T2K gas

fGas (Ar-CF4-C2H6=92:7:1) VS T2K(Ar-CF4-iC4H10=95:3:2)

------ fGas was seemed that a better working gas for the continuous beam structure

------ More works will be for the new mixture working gas

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

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

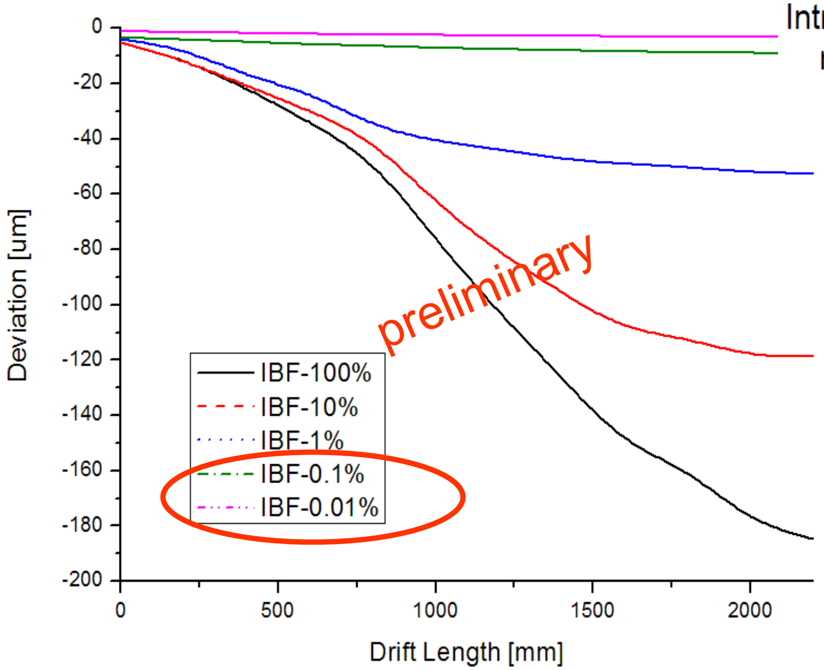
Transverse and

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

Effective number of primary signal electrons

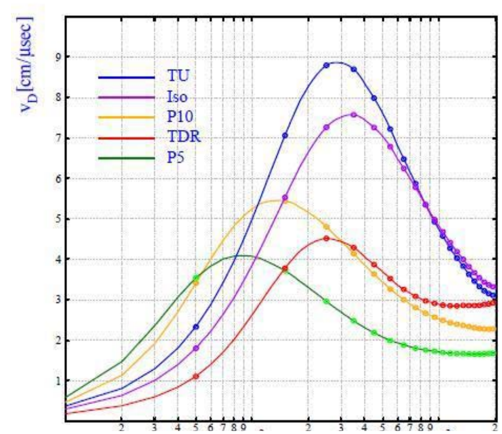
molecules during drift

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

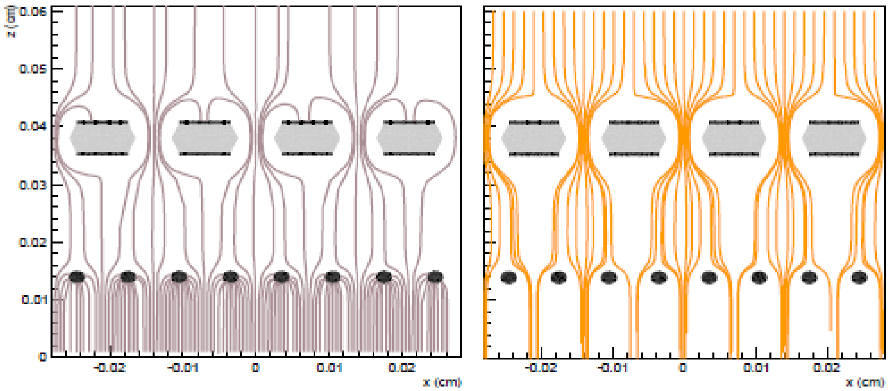


Simulated the drift velocity in different gas mixture

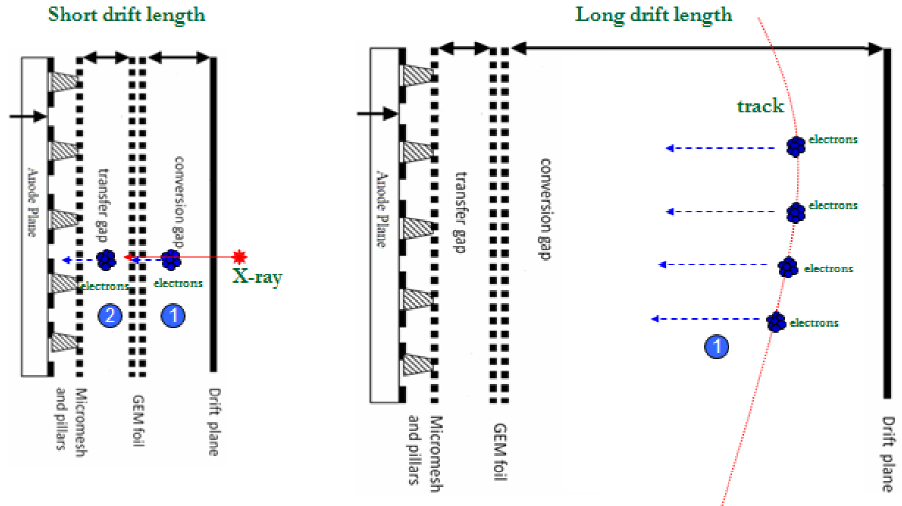
New ideas for the ions?

- 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)

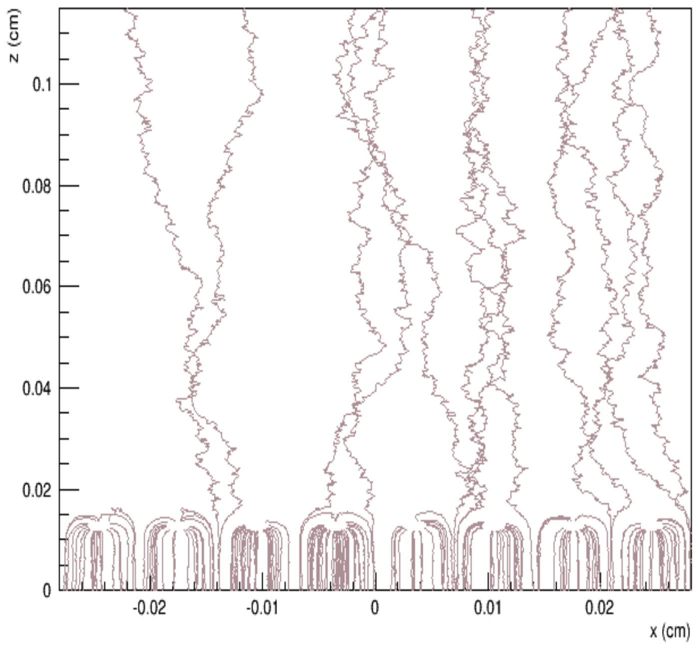


Hybrid detector

IBF simulation

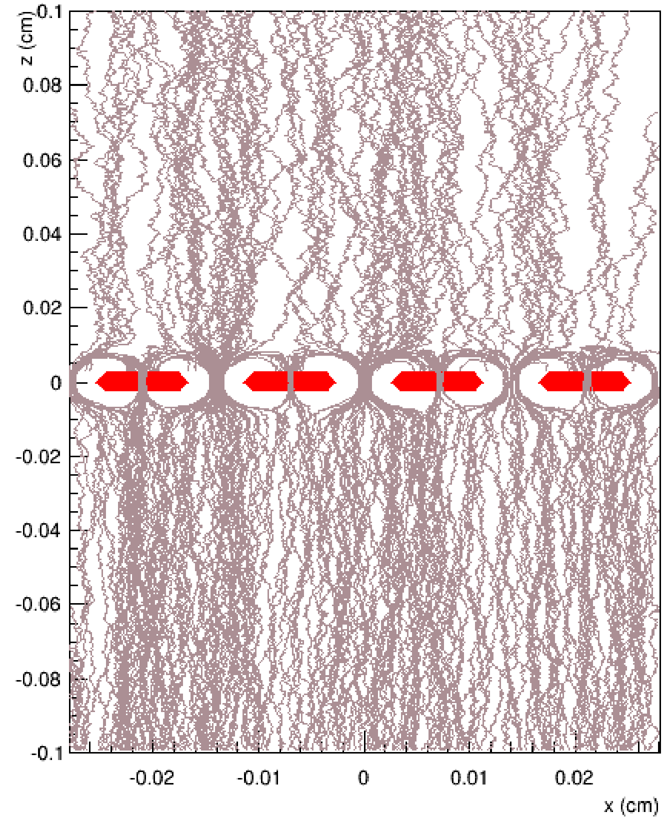
- Garfield++/ANSYS to simulate the ions back to drift
  - GEM and Micromegas Module using ANSYS
  - Record the ions to drift layer, mesh layer, and sensitive layer

Micromegas standalone



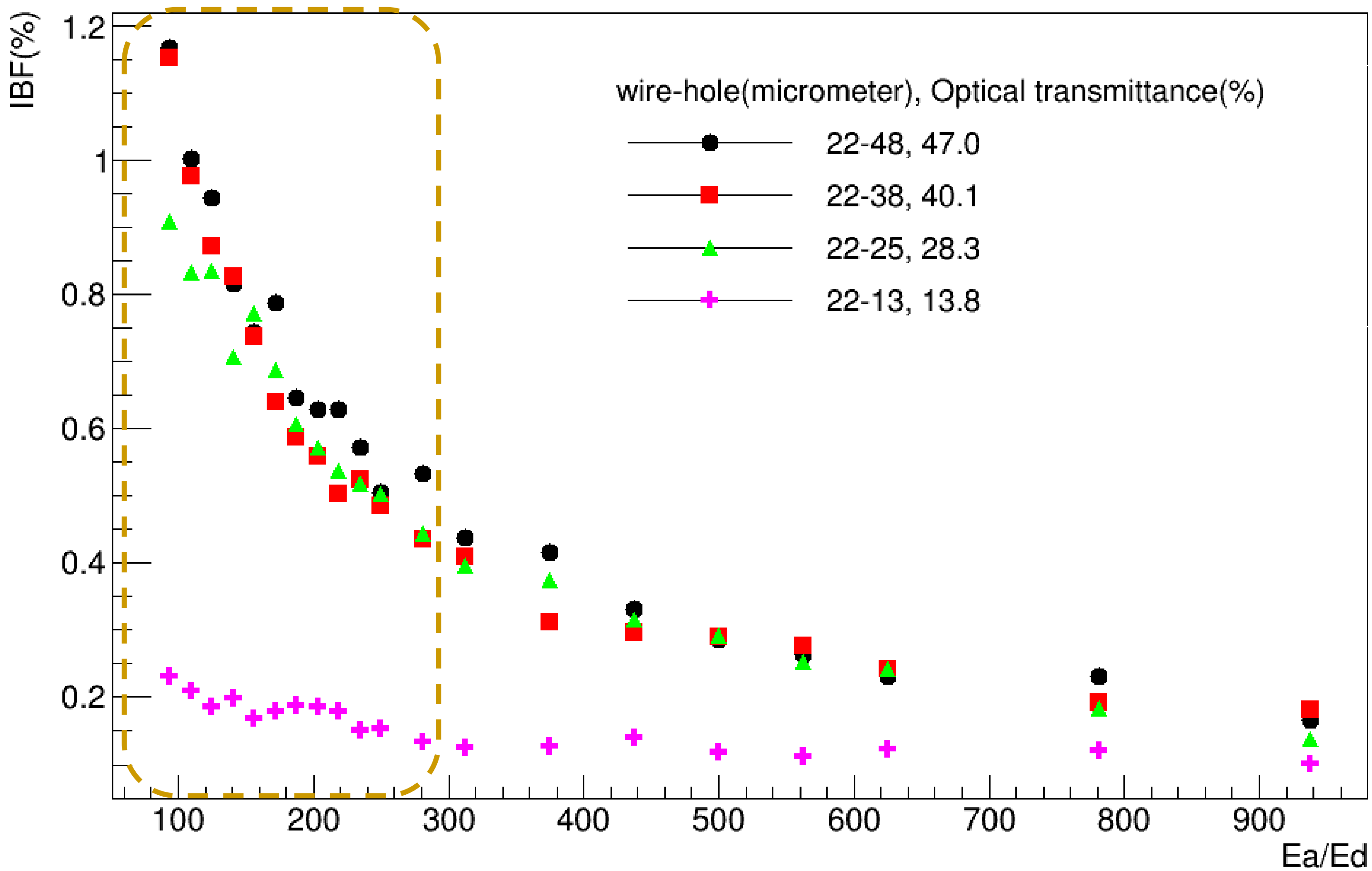
Ions not actually drift along electric field lines

GEM Standalone



IBF simulation

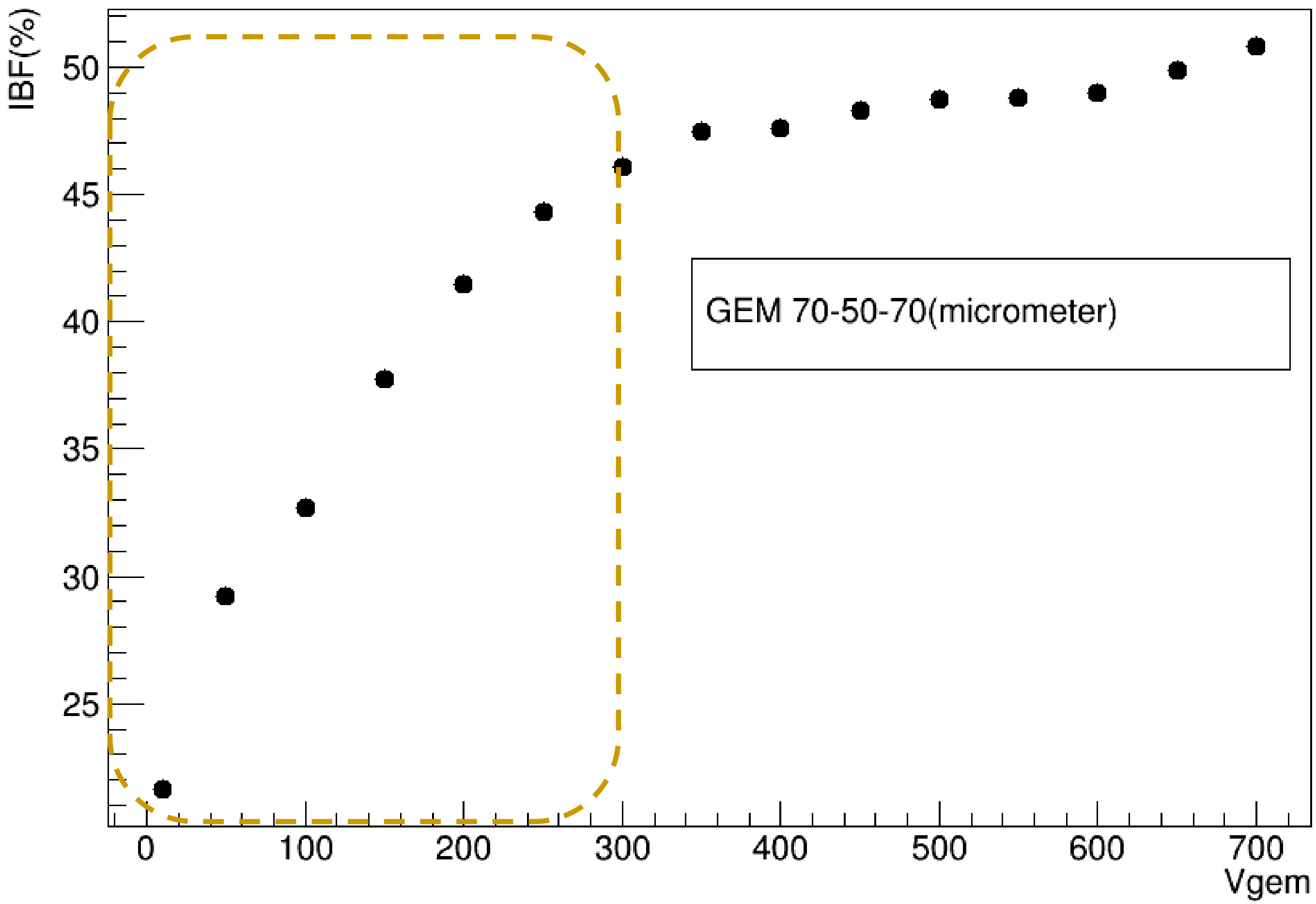
- Garfield++/ANSYS to simulate the ions back to drift
  - 350LPI/ 420LPI/ 500LPI/ 1000LPI
  - Ea is electric field of amplifier of Micromegas



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)



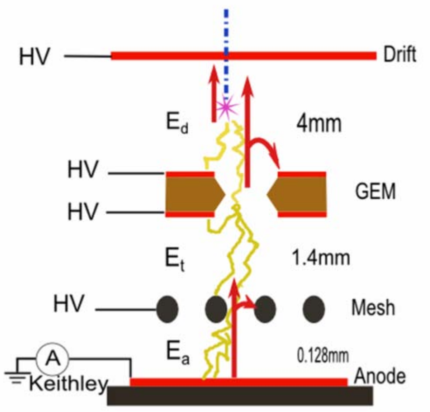
Voltage of the GEM detector

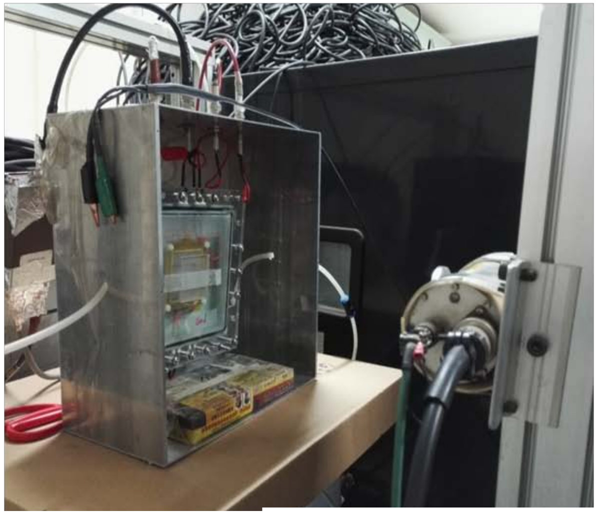
- Progress on experiment

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





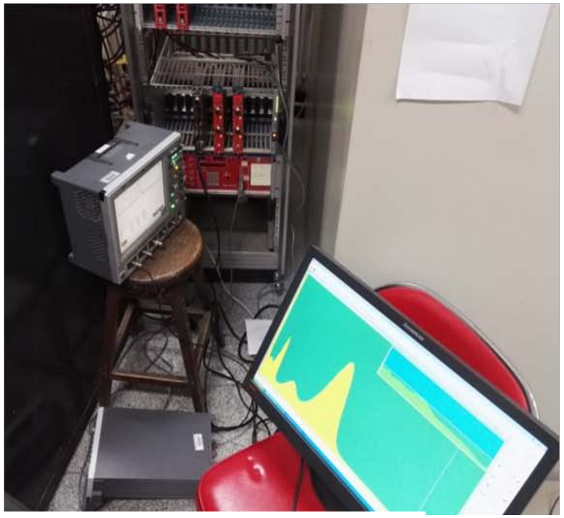
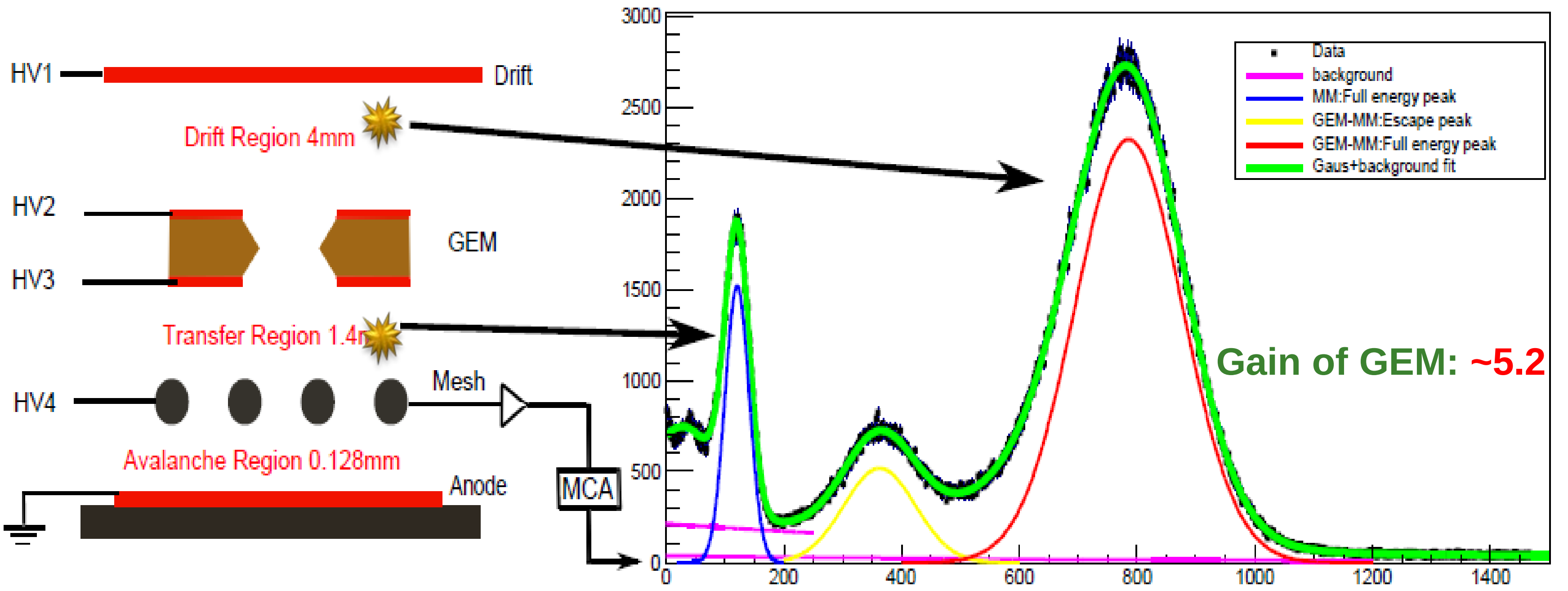


Photo of the GEM+Micromegas Module with X-ray

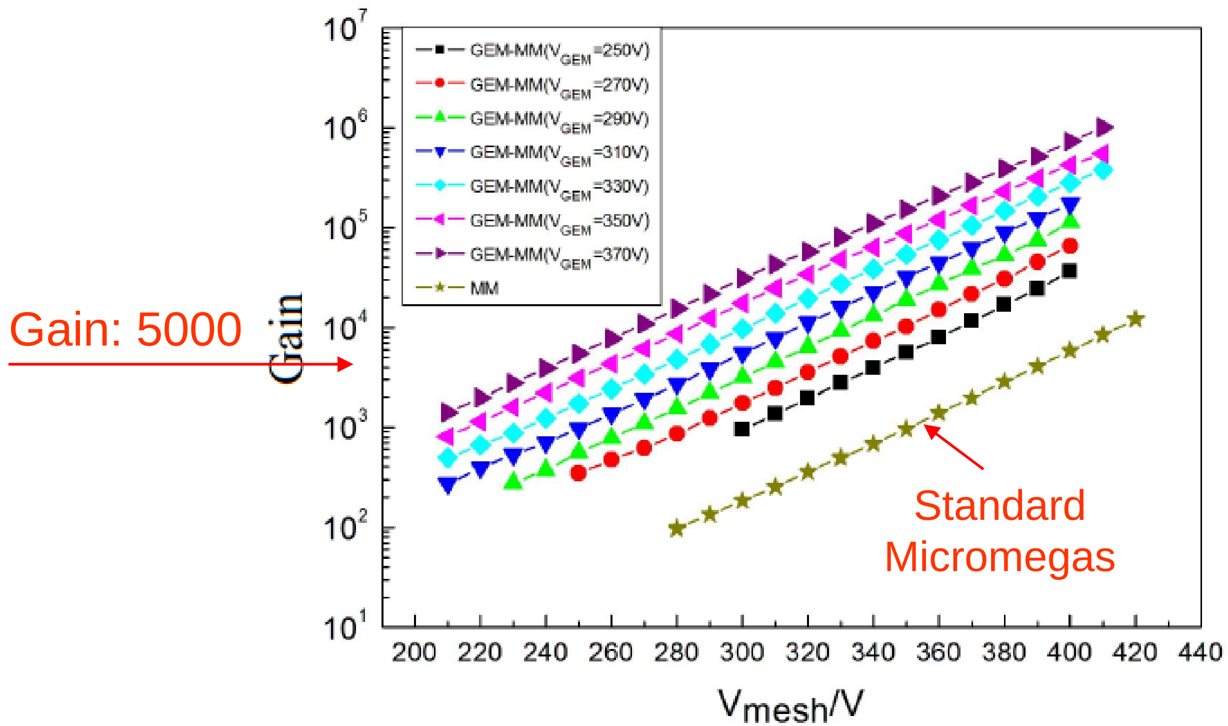
Energy spectrum@^{55}Fe

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



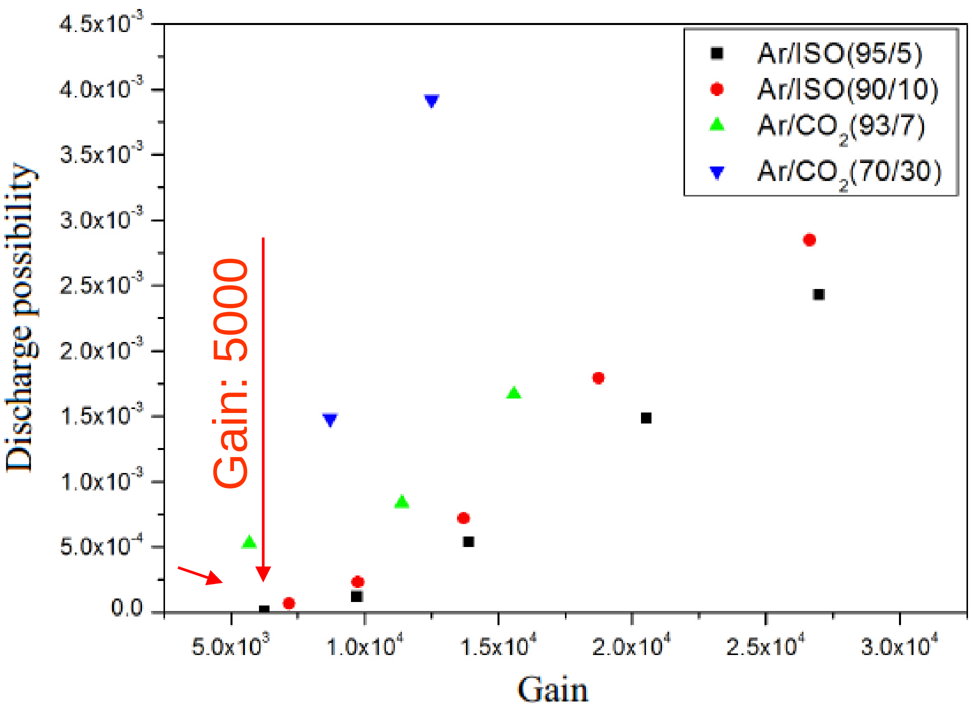
An example of the 55Fe spectra showing the correspondence between the location of an X-ray absorption and each peak.

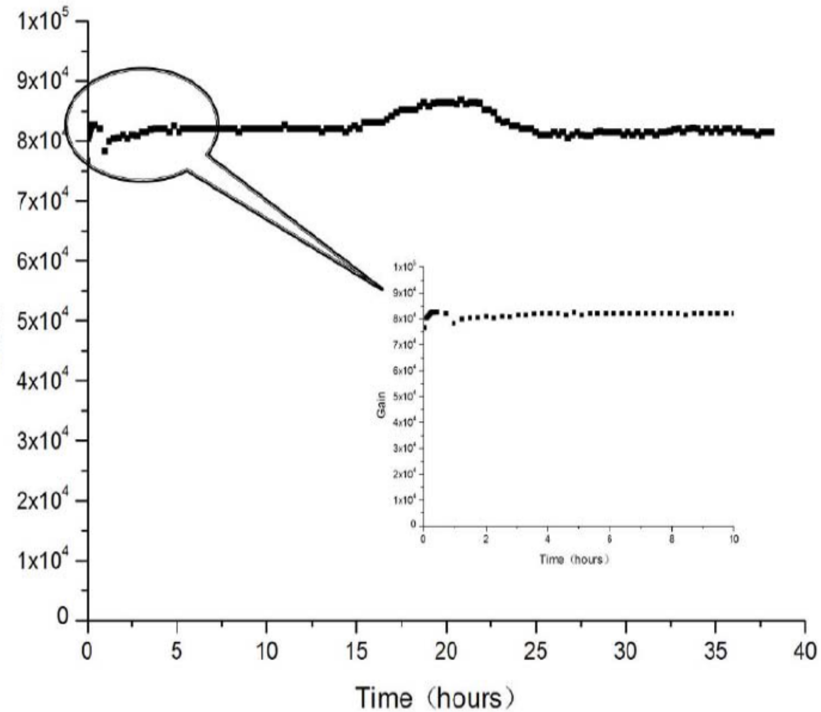
Gain of GEM + MM



- 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

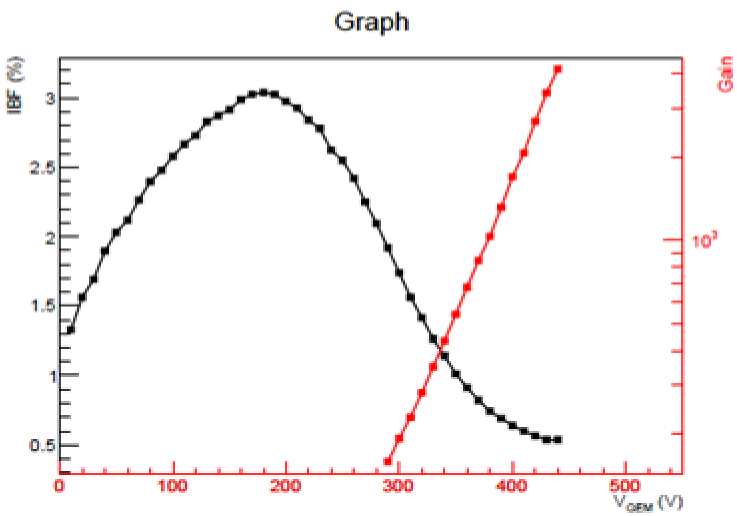
Discharge and working time



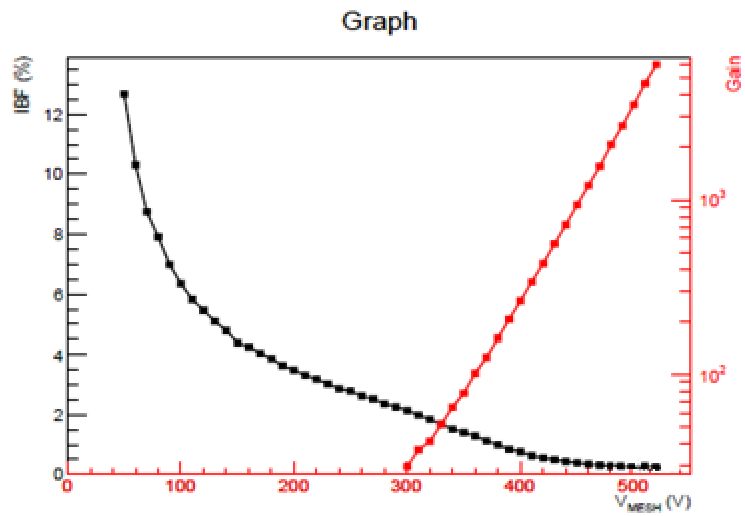


- Test with Fe-55 X-ray radiation source
  - Discharge possibility could be mostly reduced than the standard Bulk-Micromegas
  - Discharge possibility of hybrid detector could be used at Gain~10000
  - To reduce the discharge probability more obvious than standard Micromegas
  - At higher gain, the module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

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

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

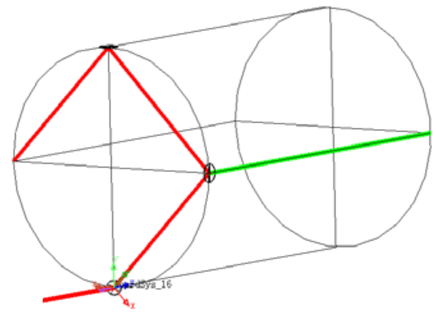
G is the gas gain of the detector.

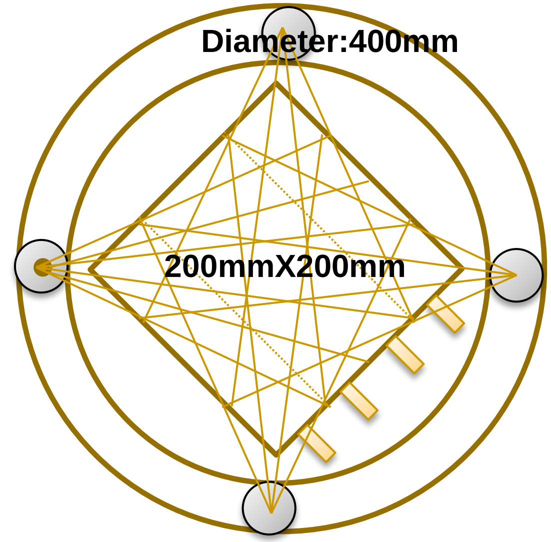
	GEM+MMG 420LPI (IHEP)	2GEMs + MMG 450 LPI (Yale University)	Micromegas only 450 LPI (Yale University)
Ion Back Flow	0.1-0.2% Edrift = 0.25 kV/cm	(0.3 –0.4)% Edrift = 0.4 kV/cm	(0.4 –1.5)% Edrift= (0.1-0.4) kV/cm
<GA>	4000~5000	2000	2000
ϵ-parameter(=IBF*GA)	4~5	6~8	8~30
E –resolution	~16%	<12%	<= 8%
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	#

Laser calibration for TPC prototype

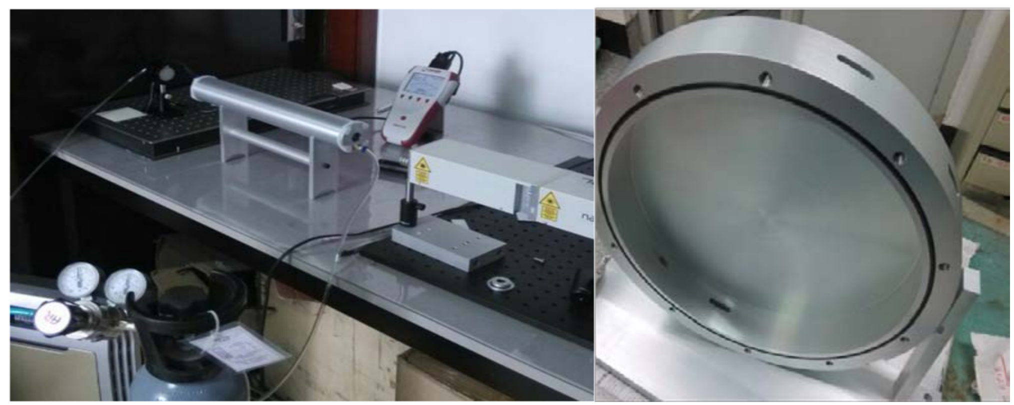
Supported by 国家基金委重点基金

- 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$\times$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$\times$200mm
  - Drift length: 500mm
  - Outer diameter:~400mm
  - GEM readout





Laser calibration baseline design

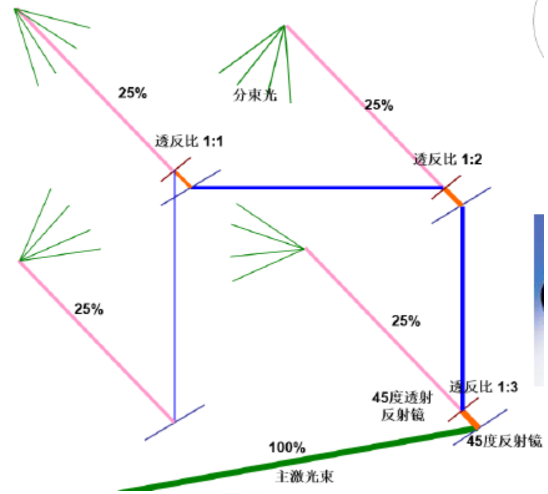


The assembled module test with 266nm laser

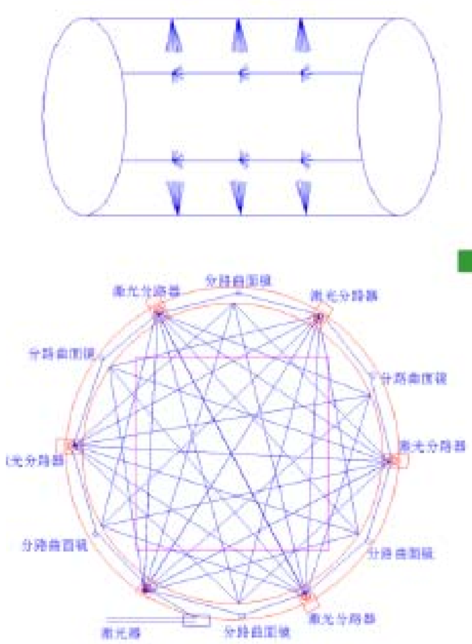
Tsinghua and IHEP Cooperation

Laser calibration for TPC prototype

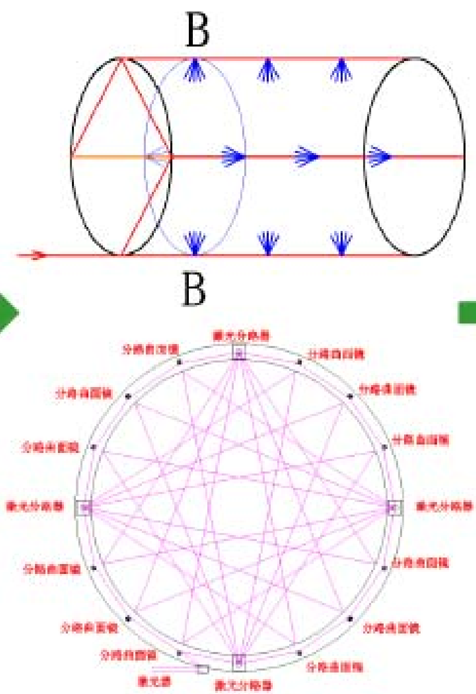
- Optimization of the laser map
  - 6 rods laser map to 4 rods laser map
  - some devices selection
  - Preliminary design with parameters (DONE)



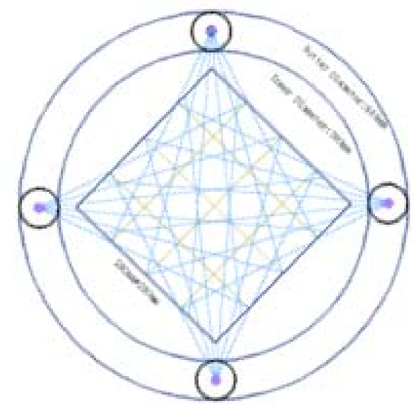
B-B Slice



6rod Laser Map



4rod Laser Map



Laser Map

Tsinghua and IHEP Cooperation

- Progress on collaboration

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, Japan
- CEA Saclay, France
- Mecaro Co., Korean

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)

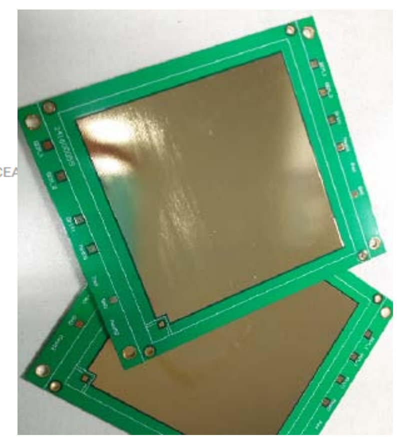
Keisuke Fujii (KEK)
Schrader, Andrea(DESY)
GAO Yuanning (THU)
QI Huirong (IHEP)

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

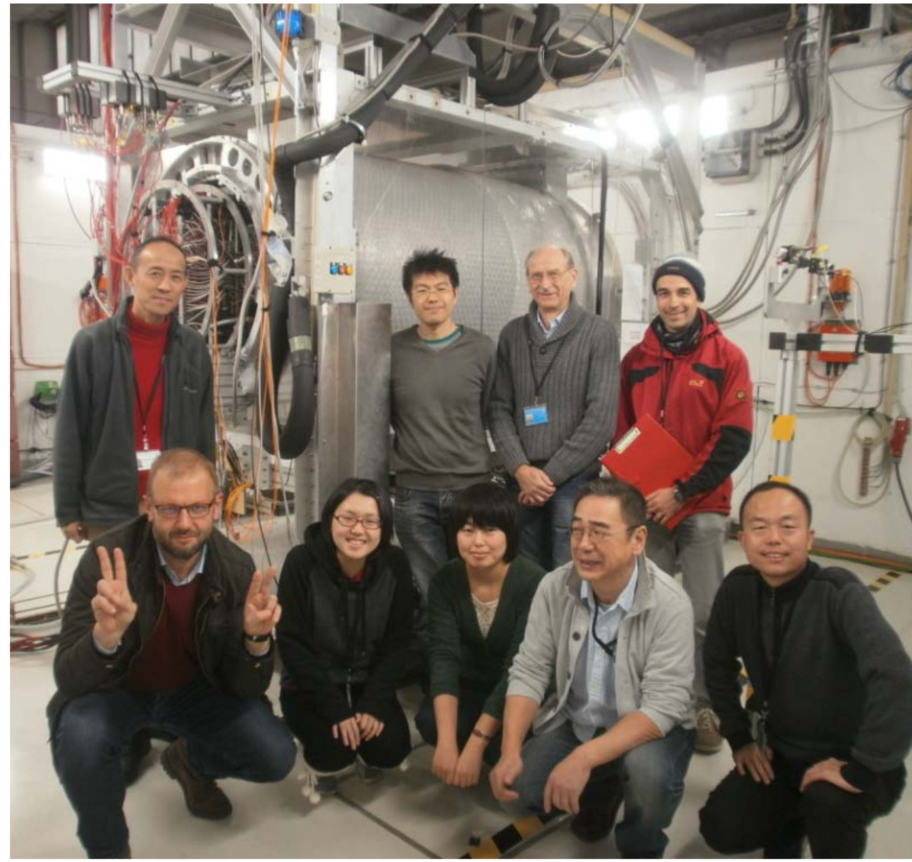
Participate in the collaboration

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

- **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 !