粒子物理前沿卓越中心考评报告（2017年度）

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Outline

- 主要物理目标
- CEPC TPC探测器研究进展
  - 模块研制
  - 模型研制
- 人员组织及合作
- 发表文章及总结

Answer three key issue questions in R&D @CDR

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

Simulation → TPC as one option for CPEC 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

Simulation + R&D → To control IONS? To reduce distortion

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

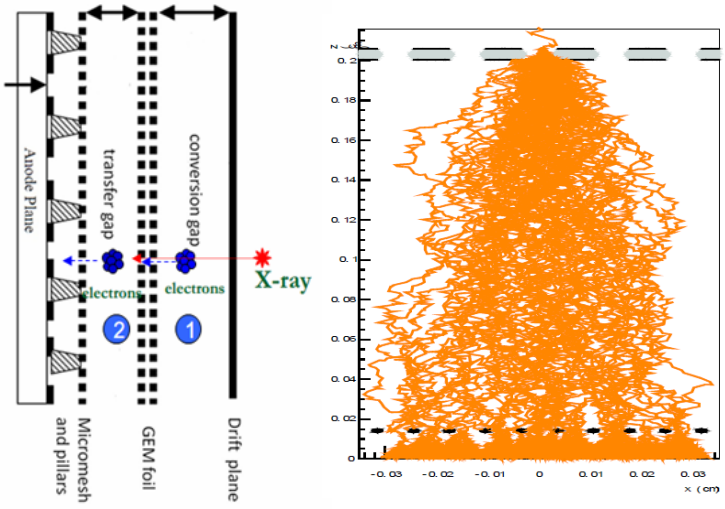
Simulation + R&D → ~100um positron resolution with calibration?

Concerning to rφ and dE/dx from LC-TPC collaboration

Options of technical solution

Continuous IBF module:

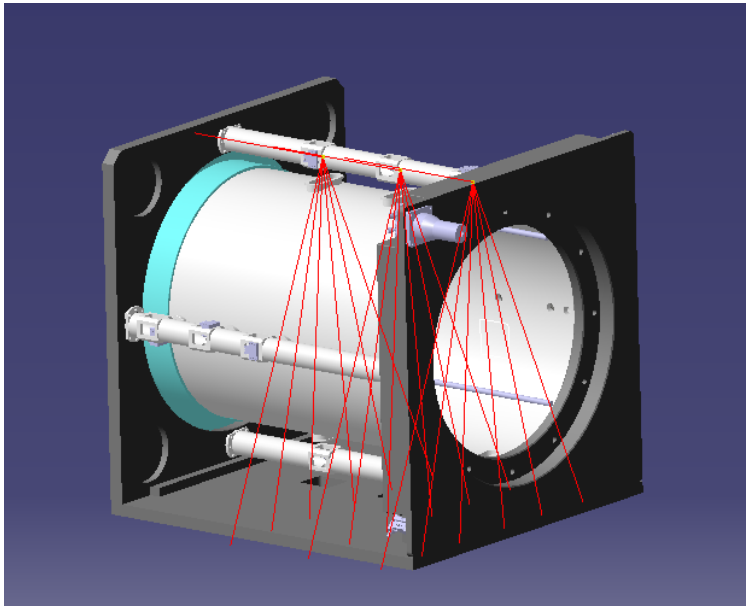
- Gating device may be used for Higgs run
- Open and close time of gating device for ions: ~ μs-ms
- No Gating device option for Z-pole run
- Continuous Ion Back Flow due to the continuous beam structure
- Low discharge and spark possibility



Continuous IBF module

Laser calibration system:

- Laser calibration system for Z-pole run
- The ionization in the gas volume along the laser path occurs via two photon absorption by organic impurities
- Calibrated drift velocity, gain uniformity, ions back in chamber
- Calibration of the distortion
- Nd:YAG laser device@266nm



TPC prototype integrated with laser system

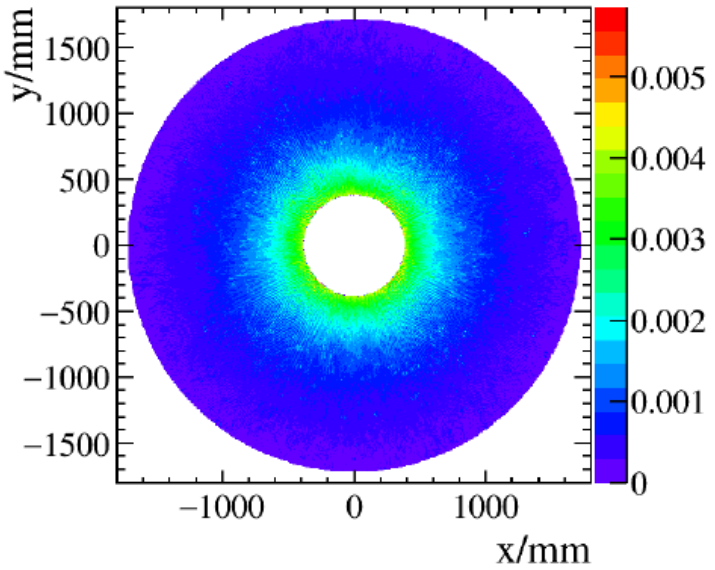
High rate at Z pole

ArXiv: 1704.04401

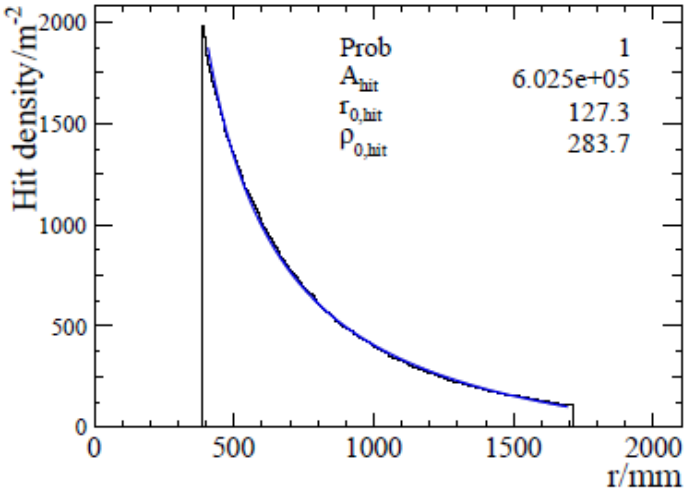
Mingrui, Manqi, Huirong

- Voxel occupancy
  - The number of voxels /signal
  - 9 thousand Z to qq events
  - 60 million hits are generated in sample
  - 4000-6000 hits/(Z to qq) in TPC volume
  - Average hit density: 6 hits/mm^2
  - Peak value of hit density: 6 times
  - Voxel size: 1mm×6mm ×2mm
  - 1.33×10^{14} number of voxels/s @DAQ/40MHz
  - Average voxel occupancy: 1.33×10^{-8}
  - Voxel occupancy at TPC inner most layer: ~2×10^{-7}
  - Voxel occupancy at TPC inner inner most layer : ~2×10^{-5} @FCCee benchmark luminosity

The voxel occupancy takes its maximal value between 2×10^{-5} to 2×10^{-7}, which is safety for the Z pole operation.



Hit map on X-Y plan for Z to qq events



Hit density as a function of radius

Requirements of Ion Back Flow

Manqi, Mingrui, Huirong

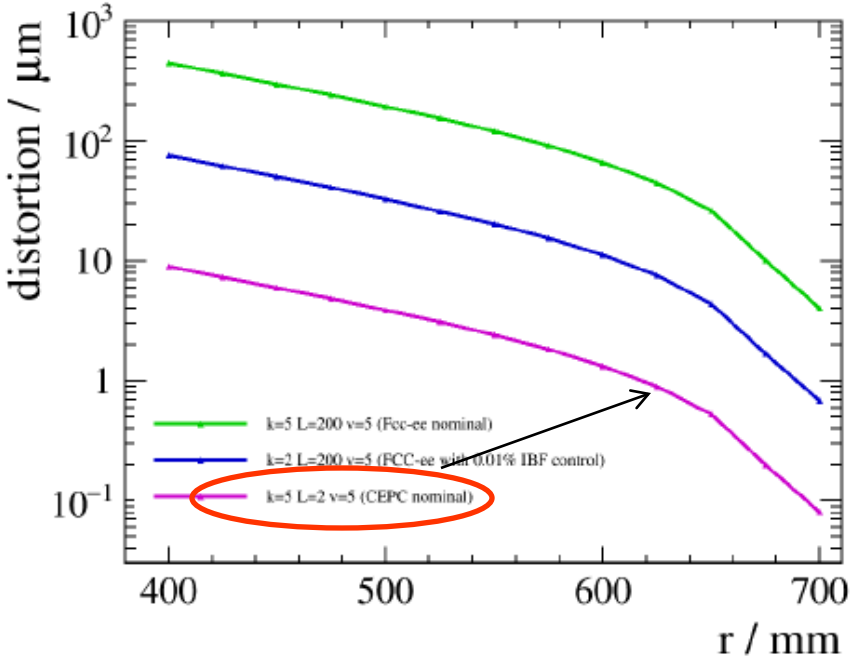
- Electron:
  - Drift velocity ~6-8cm/us@200V/cm
  - Mobility μ ~30-40000 $cm^2/(V.s)$
- Ion:
  - Mobility μ ~2 $cm^2/(V.s)$

  in a "classical mixture" (Ar/Iso)

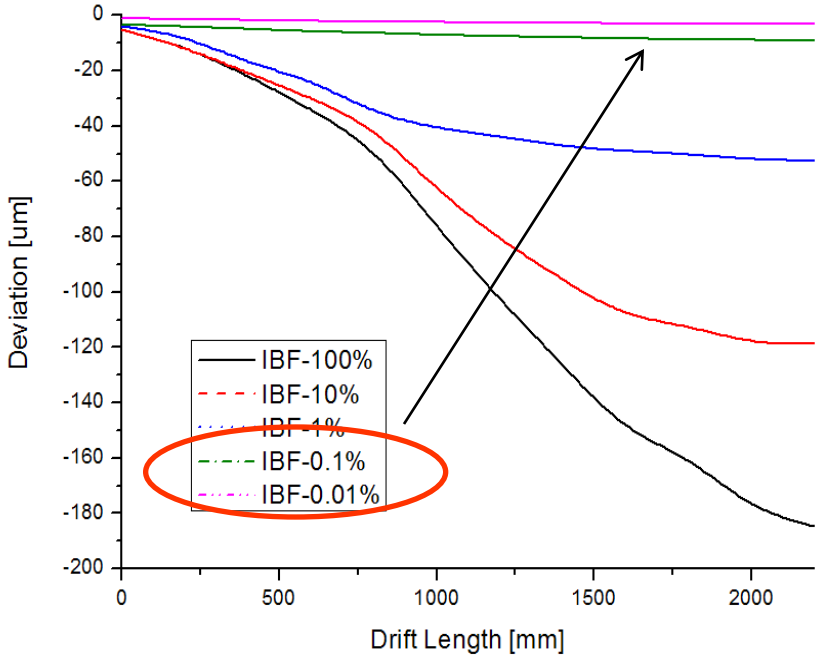
$$S_N = \sqrt{\left(\frac{\partial f}{\partial x_1}\right)^2 S_{x_1}^2 + \left(\frac{\partial f}{\partial x_2}\right)^2 S_{x_2}^2 + \left(\frac{\partial f}{\partial x_3}\right)^2 S_{x_3}^2}$$

Standard error propagation function

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



Distortion of as a function of electron initial r position

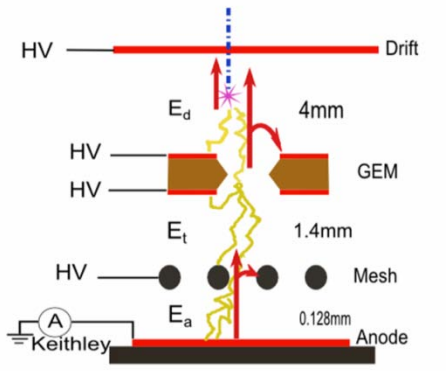


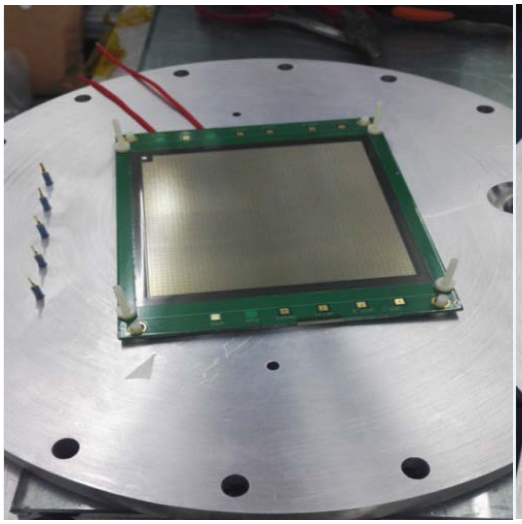
Evaluation of track distortions due to space charge effects of positive ions

Investigation of IBF study with module

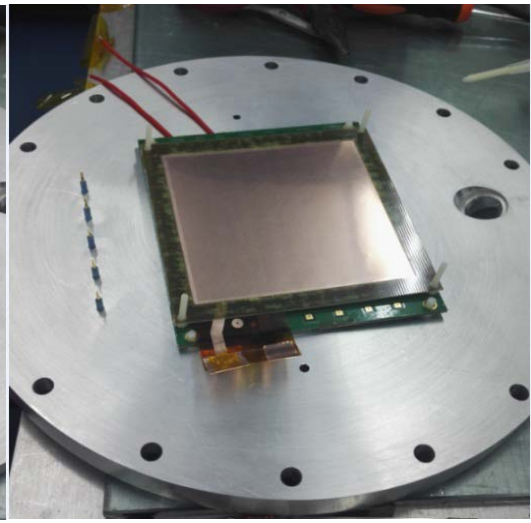
Test of the new module

- 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

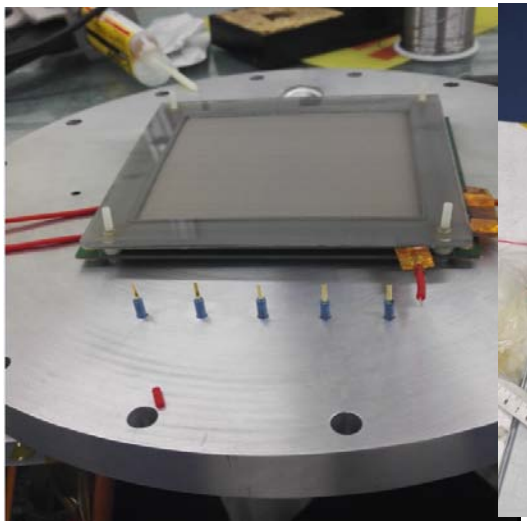




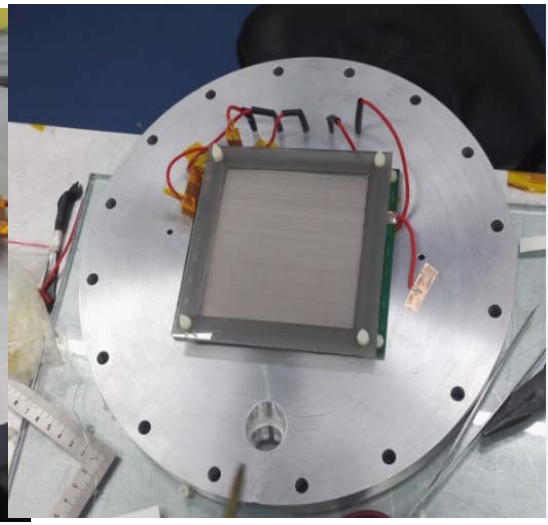
Micromegas(Saclay)



GEM(CERN)



Cathode with mesh

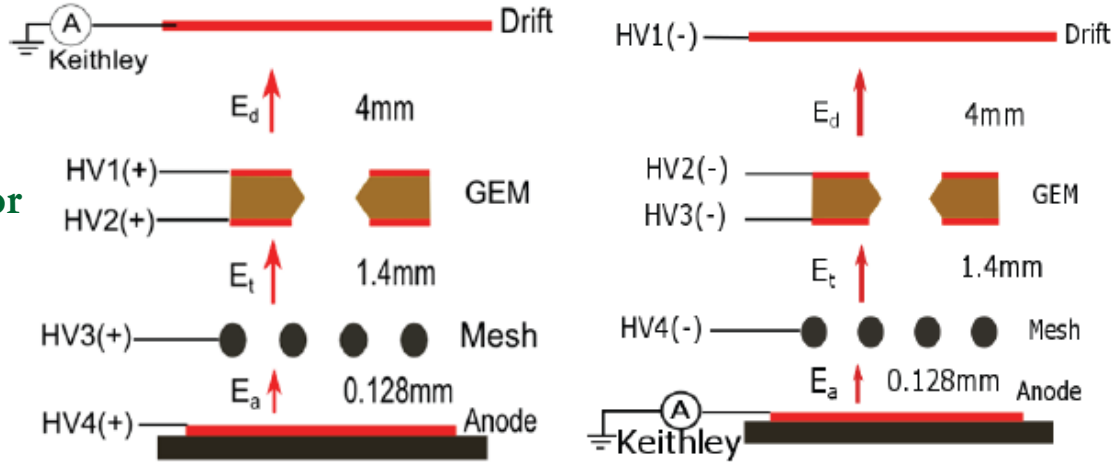


GEM-MM Detector

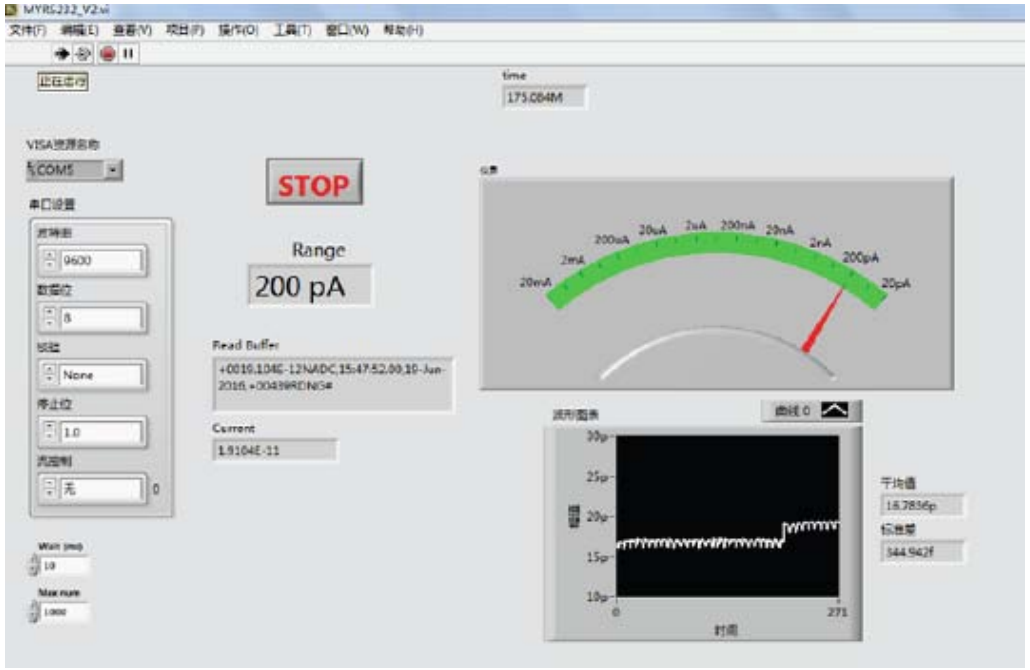
Measuremnt of GEM-MM module

- Test with GEM-MM module
  - Keithley Electrometers for Ultra-Low Current Measurements: pA~mA
  - Keithley: 6517B
  - Test of cathode of the module
  - Test of readout anode of the module
  - Labview interface of the low current to make the record file automatically

$$IBF = \frac{I_C - I_P}{I_A}$$



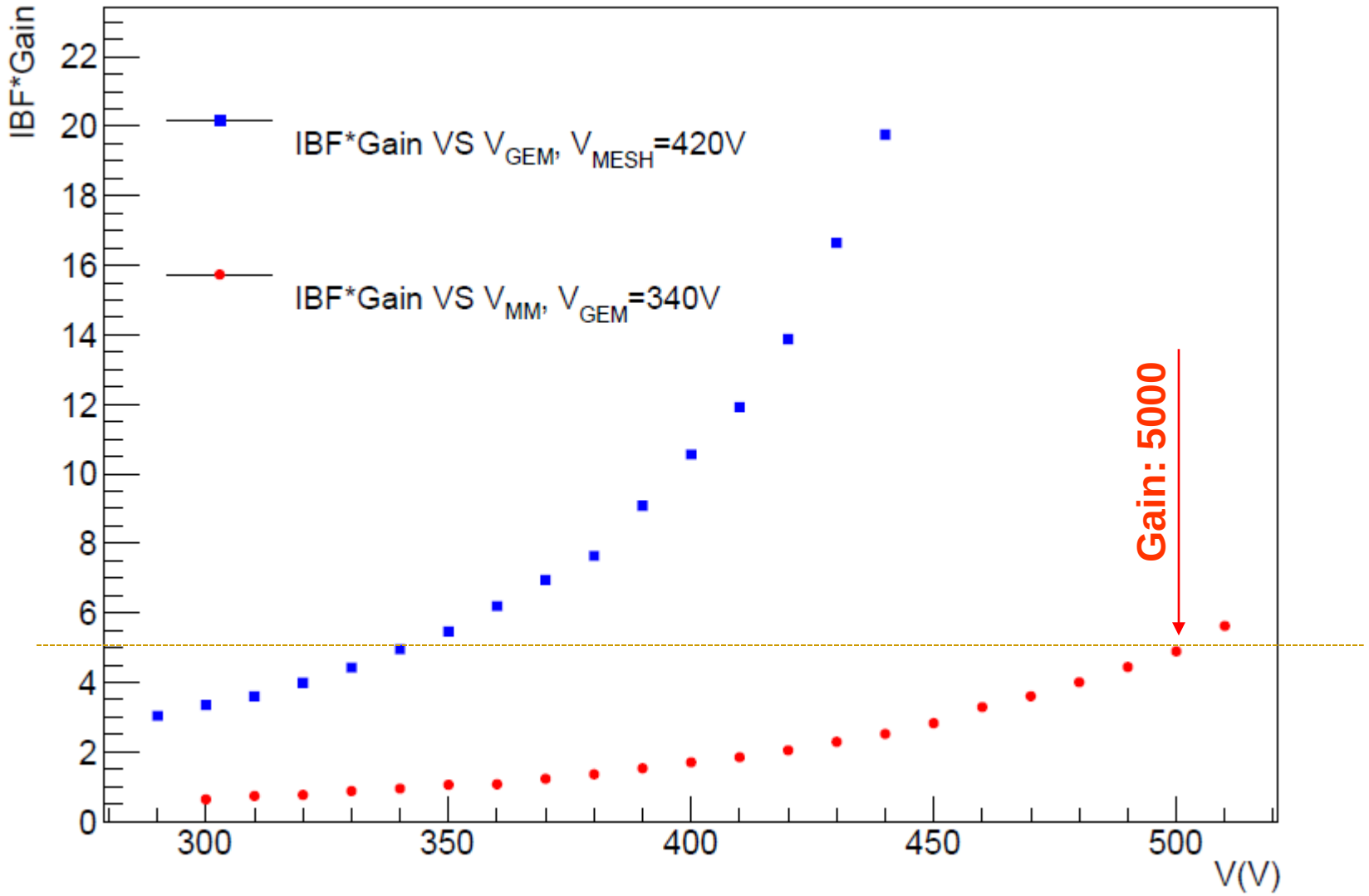
Measurement of the low current



Labview interface of the current with Keithley

IBF test results

DOI: 10.1088/1674-1137/41/5/056003



Key factor: IBF * Gain

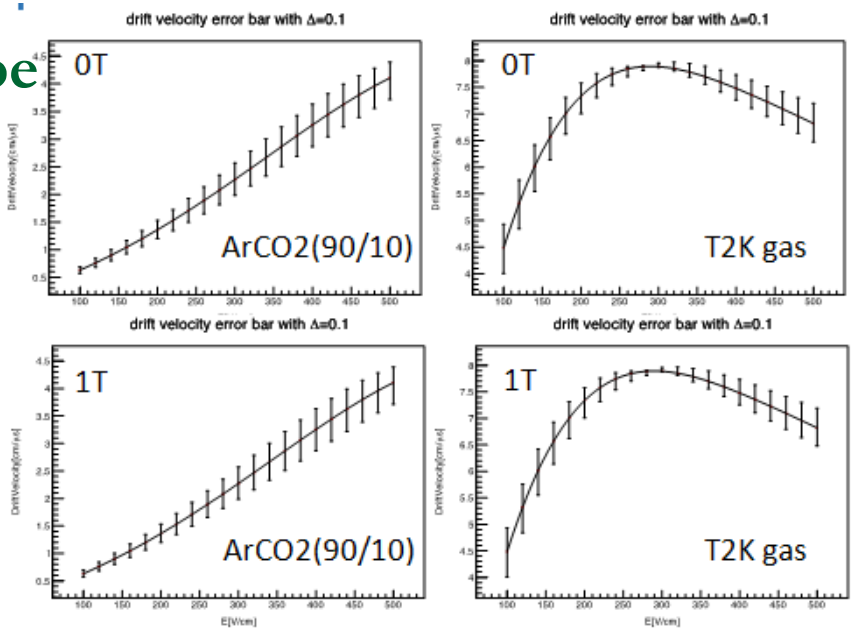
Status of TPC prototype R&D

Parameters of the TPC prototype

Need correction

- To aim that the small TPC prototype for the estimation of the distortion due to the IBF, and the study of related physics parameters

- Main parameters
  - Drift length: 510mm
  - Readout active area: 200mm×200mm
  - Integrated the laser and UV lamp device
  - Wavelength of laser: 266nm
  - GEMs/Micromegas as the readout
  - Materials: Non-magnetic material (Stainless steel, Aluminum)

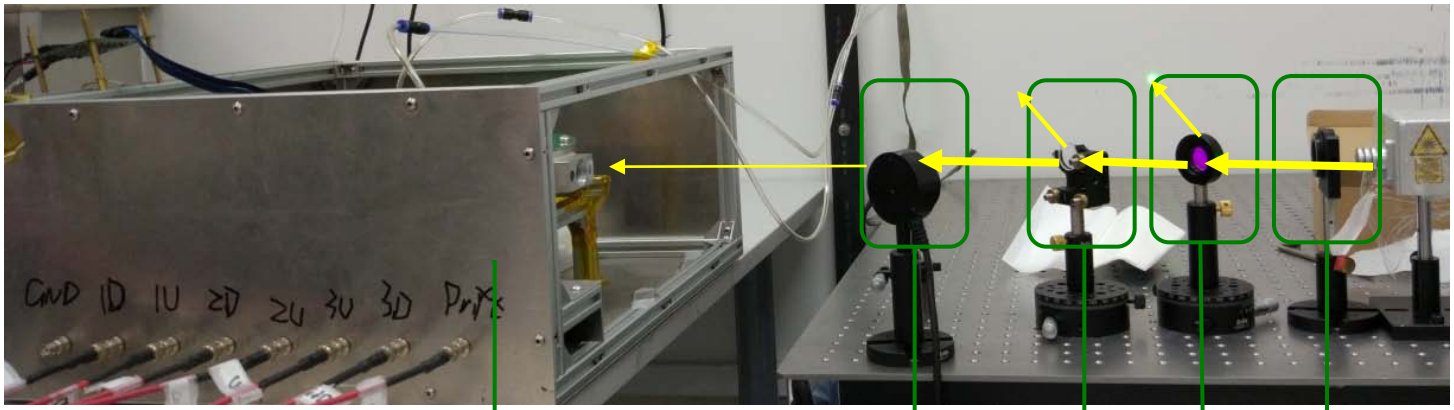


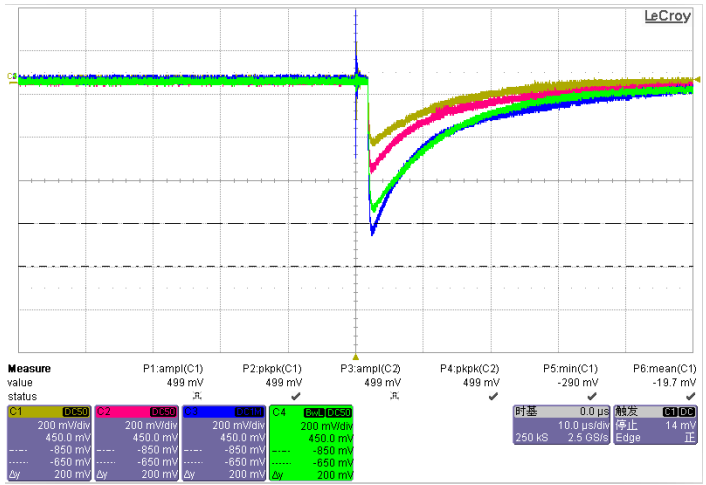
Drift velocity with Ed correction

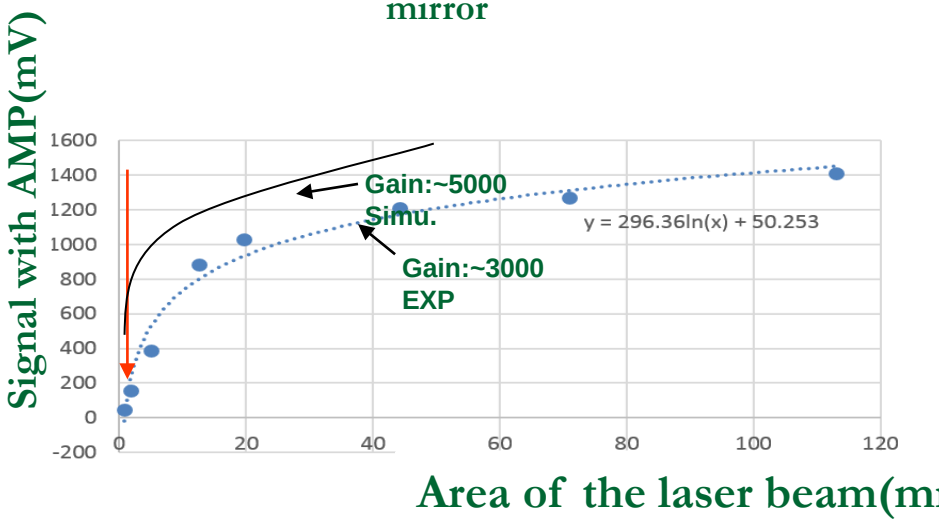
		ArCO2	T2k gas
290 V/cm	velocity	v=2.17 cm/us	v=7.895 cm/us
	error	0.275373 (0.1266)	0.042 (0.0058)

Signal of the laser with Φ1mm @266nm

Reference from ALICE TPC





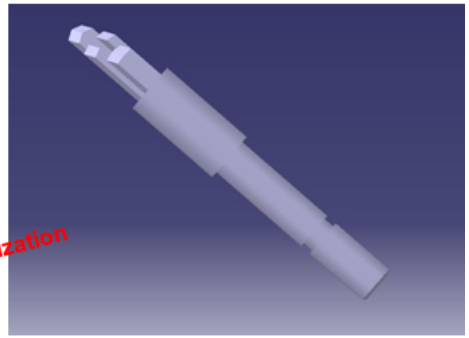


Signal of the laser with Φ1mm@Charge sensitive AMP/12mV/fC

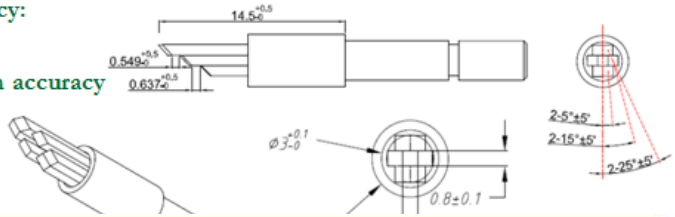
Progress of the new design

独立设计、国内研制

Divide and reflection mirrors

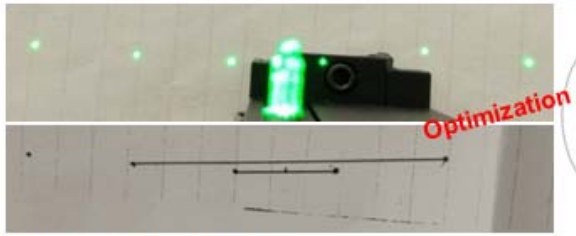


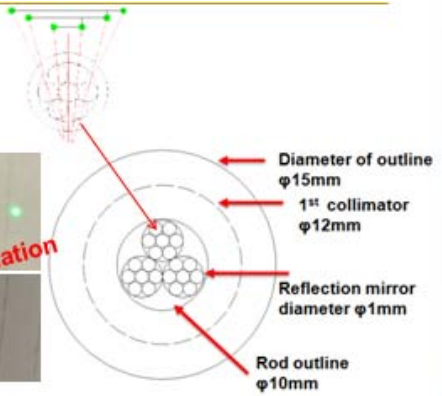
- Laser wave for the divide and reflection mirrors: 266nm
- Size: ~0.8mm×0.8mm
- Number of the divide trackers: 6
- Stainless steel support integrated the laser mirrors
- Reflection efficiency: >99%@266nm
- Reflection position accuracy 1/30 degree



Mirrors test with 266nm

Test:

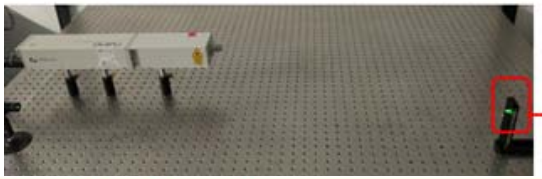




Report of the mirrors:

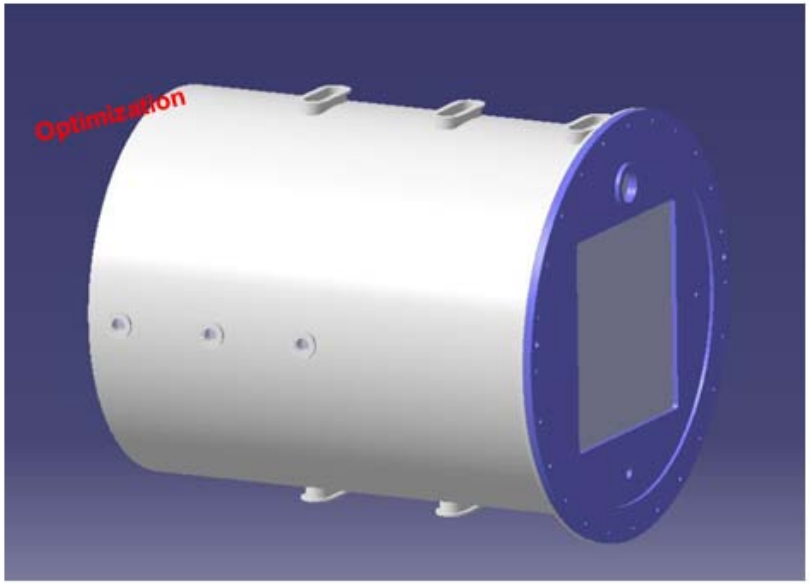
Reflection mirror

5°角	<5'	合格
15°角	<5'	合格
25°角	<5'	合格



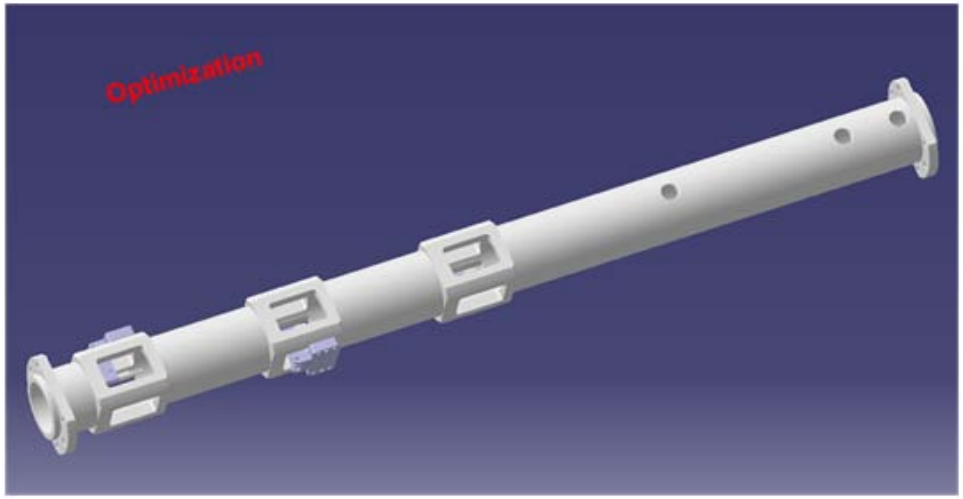
1号	<5'	合格
2号	<5'	合格
3号	<1°	需优化
4号	<10'	需优化
5号	<5'	合格
6号	<5'	合格

TPC barrel



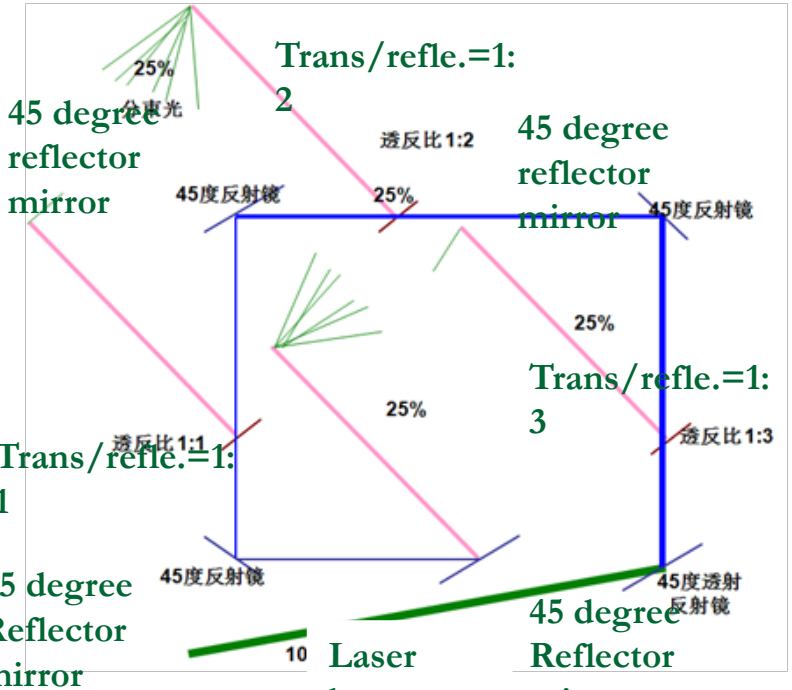
The TPC barrel with the 266nm laser windows

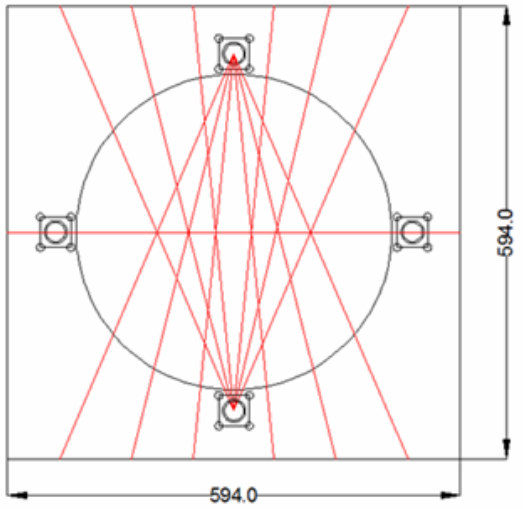
Rod for the mirrors



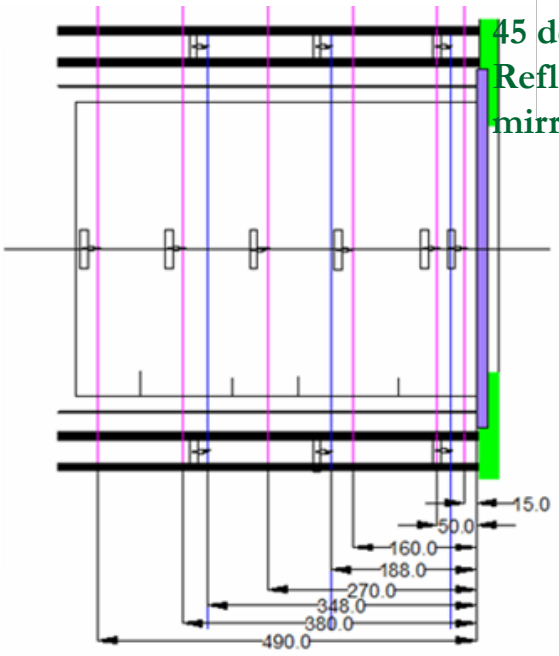
Laser map in drift length

- Laser wave: 266nm
- Size: ~0.85mm×0.85mm
- Transmission and reflection mirrors
- Aluminum board integrated the laser device and supports

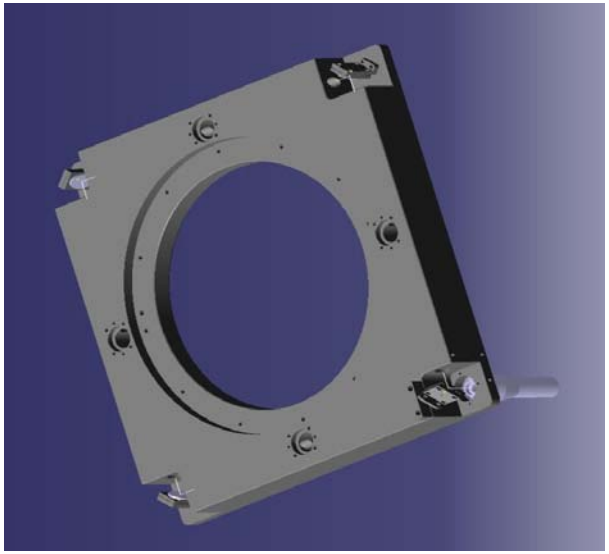




x-y方向激光光束投影分布

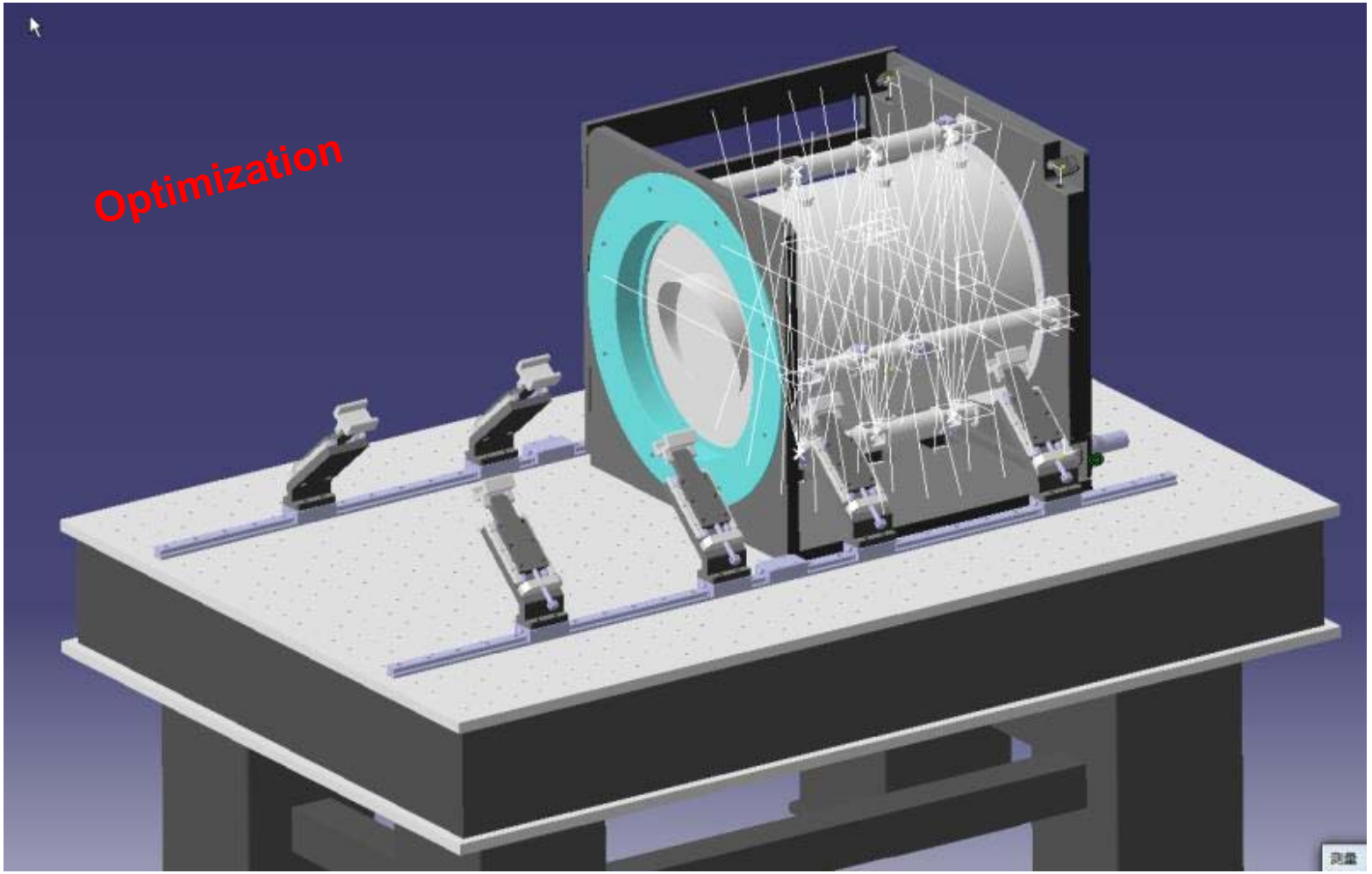


z方向激光光束投影分布



Aluminum board integrated the laser system

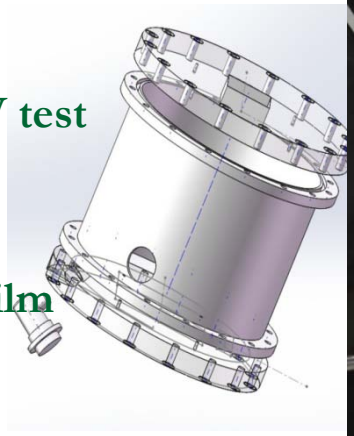
Design of the prototype with laser (Final version)

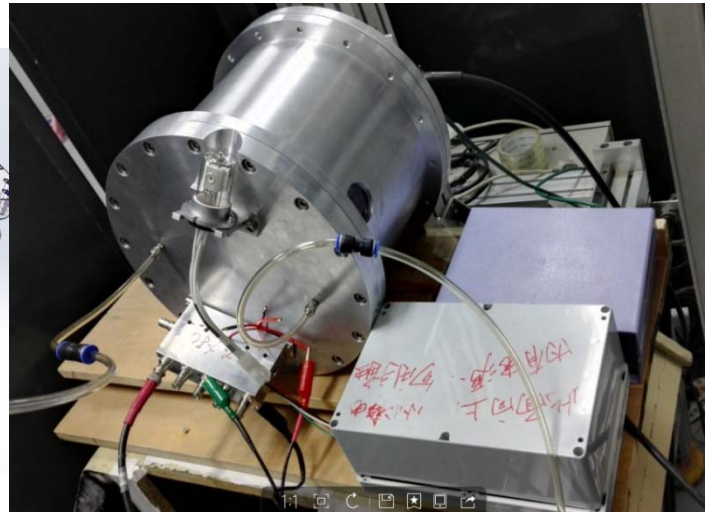


- Support platform: 1200mm×1500mm (all size as the actual geometry)
- TPC barrel mount and re-mount with the Auxiliary brackets
- Readout board (Done), Laser mirror (Done), PCB board (Done)

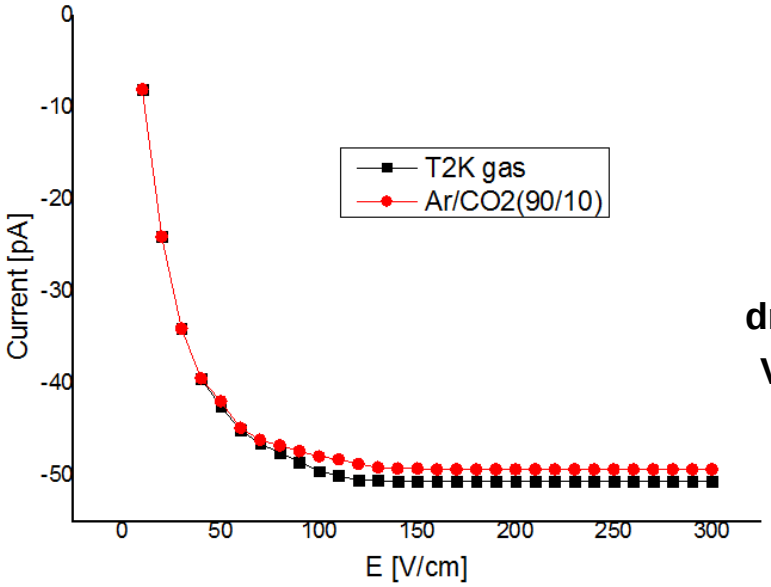
UV test of the new module

- 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
  - About 31000 electrons/s.mm^2





UV test geometry with GEM-MM



Current VS Electric field in drift length

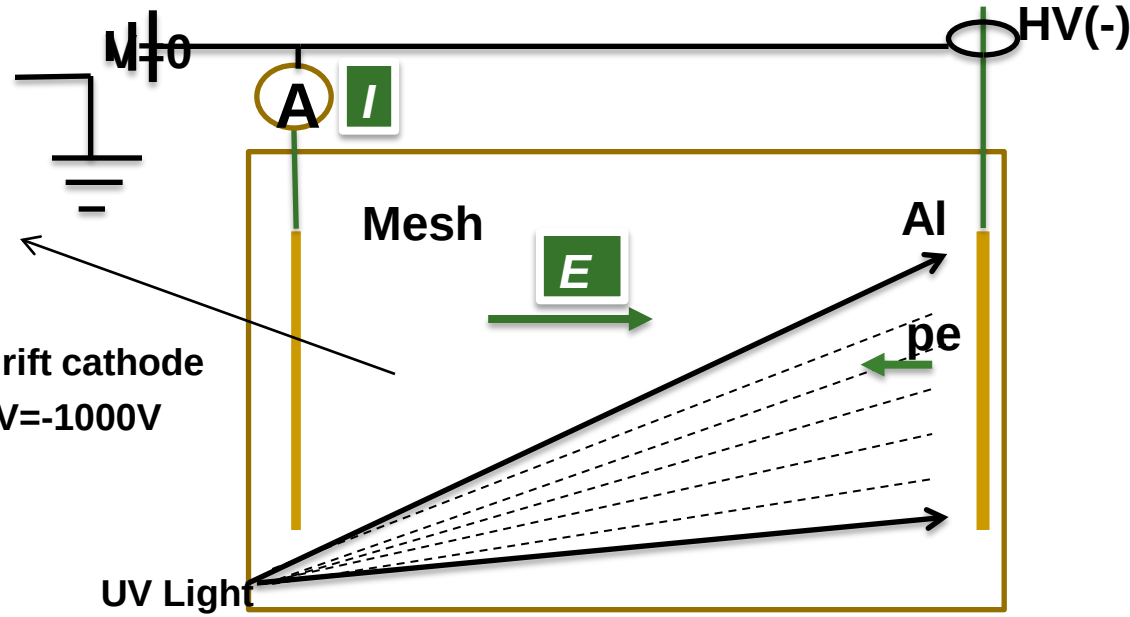
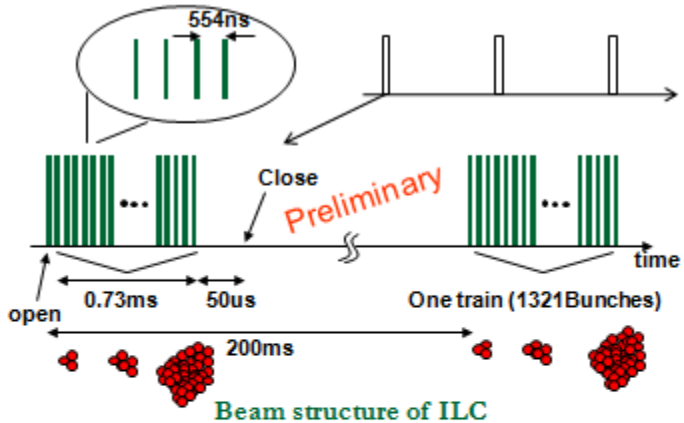


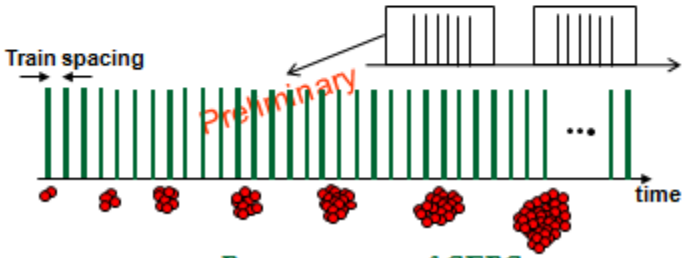
Diagram of the UV test with new module

Distortion by UV+Laser

- To mimic the bunch structure & the ions distortion with UV light and laser split beam
- In the case of ILD-TPC
  - Bunch-train structure of the ILC
  - Power pulsing mode
- In the case of CEPC-TPC
  - Bunch-train structure of the CEPC

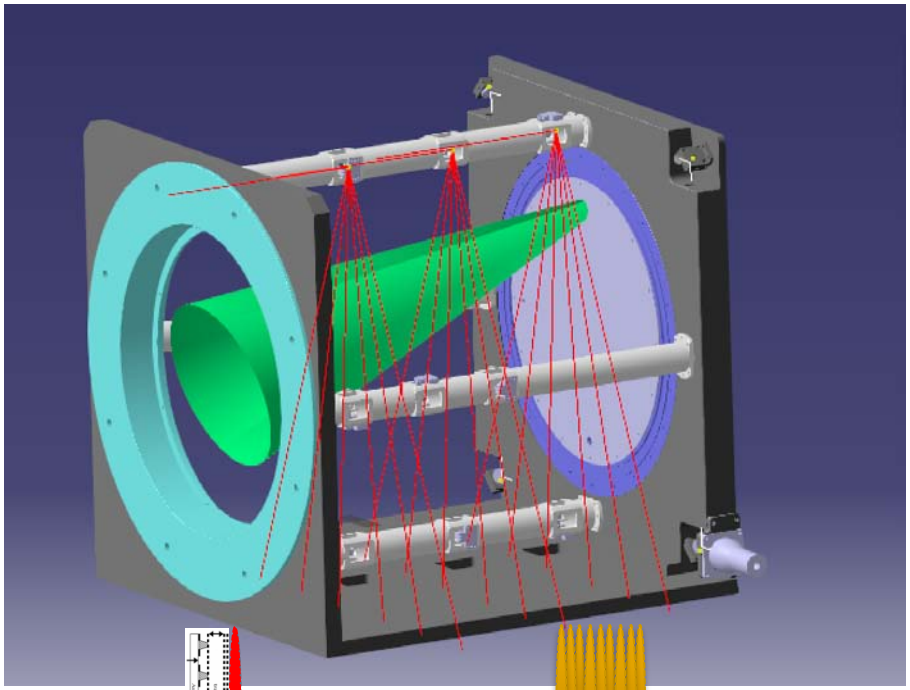


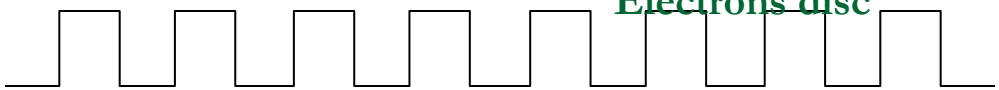
Beam structure of ILC



Beam structure of CEPC

Highlight (提出方案)





Shutter time similar to ILC and CEPC beam structure

International cooperation(国际)

探测器硬件
合作测试

- CEA-Saclay IRFU group (FCPPL)
  - Three vidyo meetings with Prof. Aleksan Roy/ Prof. Yuanning/ Manqi and some related persons (2016~2017)
  - Exchange PhD students: Haiyun Wang participates Saclay's R&D six months in 2017~2018
  - Bulk-Micromegas detector assembled and IBF test
  - IBF test using the new Micromegas module with more 590 LPI

数据合作分析
文章撰写

- LCTPC collaboration group (LCTPC)
  - Singed MOA and joined in LC-TPC collaboration @Dec. 14,2016
  - As coordinator in ions test and the new module design work package
  - CSC funding: PhD Haiyun jiont CEA-Scalay TPC group(6 months)
  - Plan to beam test in DESY with our hybrid detector module in 2018

Manpower and activities(国内)

- TPC detector R&D @IHEP (2016~2020)高能所
  - 高级职称1人：Huirong Qi,
  - 博士生2名，硕士生1名：Yulian Zhang (PhD,IHEP), Haiyun Wang(PhD,IHEP), Zhiwen Wen(PhD,IHEP)
  - Funding from MOST and NSFC(~3.5 Million RMB)

- Electronics R&D &Tsinghua (2016~2020)清华大学
  - 高级职称2人：Zhi Deng, Prof. Yulan Li
  - 博士生2名，硕士生1名： Yiming Cai(PhD,THU), Zhao Mingrui (Master, THU) and three PhDs in electronics lab
  - Funding from NSFC (~2.0 Million RMB)

- Inhabitation of IBF using graphene @Shandong Univ. 山东大学
  - Prof. Zhu Chengguang
  - Zhao xiao (PhD,SDU)

Funding application@2017

- SCI文章4篇（通讯作者）+LCTPC合作组文章2篇+国际会议报告5次

1. Zhang Yulian, **Qi Huirong**, etc., Spatial resolution measurement of triple-GEM detector and diffraction imaging test at synchrotron radiation, DOI: 10.1088/1748-0221/12/04/P0401，JINST，2017.4(SCI)
2. Wen Zhiwen, **Qi Huirong**, etc., Readout method for two-dimensional multi-wire proportional chamber, Vol. 66, No. 7, DOI: 10.7498/aps.66.072901, Acta Phys. Sin., 2017.7(SCI)
3. Zhang Yulian, **Qi Huirong**, etc., Gain measurement and simulation of GEM with a hybrid structure Vol. 66, NO. 14, DOI: 10.7498/aps.66.142901, Acta Phys. Sin., 2017.9(SCI)
4. Yulian Zhang, **Huirong Qi**, etc., Investigation of the hybrid structure gaseous detector for ion backflow suppression, DOI: 10.1088/1674-1137/41/5/056003, CPC, 2016.11(SCI)

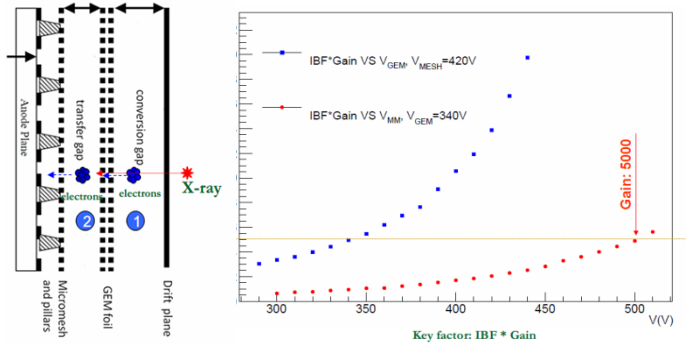
- National Natural Science Foundation in 2017
  - 面上项目
  - Funding approval number (11675197)
  - Duration: 2017.1~2020.12
- TPC detector (sub-task) 科技部重点研发项目
  - Total fund (2,900,000RMB)
  - Funding approval number (2016YFA0400400)
  - Duration: 2016.6~2021.6

毕业联培博士生一名
题目:CEPC TPC连续正离子反馈研究
指导：兰州大学博士-张余炼 毕业
3位匿名评分：93

Further R&D

Continuous IBF module for CEPC: 模块研制

- No Gating device options used for Higgs/Z pole run
- Continuous Ion Back Flow due to the continuous beam structure (Developed in IHEP)
- ~100 μm position resolution in rφ
- Key factor: IBF×Gain=5 and leas than (R&D)
- Low discharge and spark possibility

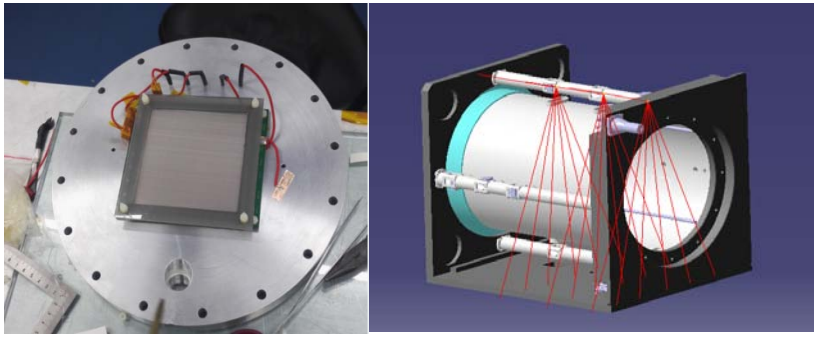


Continuous IBF prototype and IBF×Gain

模型研制

Prototype with laser calibration for CEPC :

- Laser calibration system integrated UV lamp
- Calibrated drift velocity, gain uniformity, ions back in chamber
- Prototype has been designed with laser (Developed in IHEP and Tsinghua)_
- Nd:YAG laser device@266nm, 42 separated laser beam along 510mm drift length

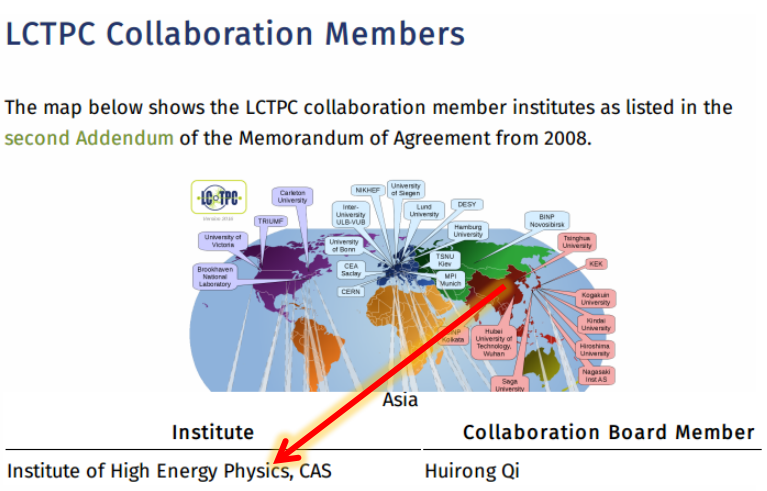


TPC prototype integrated with laser system

束流测试
国际合作

Collaboration:

- Signed MOA with LCTPC international collaboration on 14, Dec., 2016
- New design detector collaborated with KEK and CEA-Saclay



Joint LCTPC international collaboration

Thanks very much for your attention !