Development of TPC detector module and prototype with laser calibration for CEPC

<u>Huirong Qi</u>

Yulan Li, Zhi Deng, Haiyun Wang, Yiming Cai, Liu Ling, Yulian Zhang, Manqi Ruan, Ouyang Qun, Yuanning Gao, Jian Zhang

Institute of High Energy Physics, CAS
Tsinghua University

ICHEP, Seoul, July, 06, 2018

Outline

- Physics requirements
- Status of TPC module R&D
- Status of TPC prototype R&D
- Summary

Physics requirements

Motivation of TPC with MPGD

Critical technology challenges

CEPC Detector for CDR

One detector option for the IP:
VTX+TPC+ECAL+HCAL

Feasibility & Optimized Parameters

Feasibility analysis: TPC and Passive Cooling Calorimeter is valid for CEPC

	CEPC_v1 (~ ILD)	Optimized (Preliminary)	Comments
Track Radius	1.8 m	>= 1.8 m	Requested by Br(H->di muon) measurement
B Field	**3.5 T**	**3 T**	**Requested by MDI**
ToF	**-**	**50 ps**	**Requested by pi-Kaon separation at Z pole**
ECAL Thickness	84 mm	84(90) mm	84 mm is optimized on Br(H->di photon) at 250 GeV;
ECAL Cell Size	5 mm	10 – 20 mm	Passive cooling request ~ 20 mm. 10 mm should be highly appreciated for EW measurements – need further evaluation
ECAL NLayer	30	20 – 30	Depends on the Silicon Sensor thickness
HCAL Thickness	**1.3 m**	**1 m**	-
HCAL NLayer	**48**	**40**	Optimized on Higgs event at 250 GeV;

From Manqi's talk

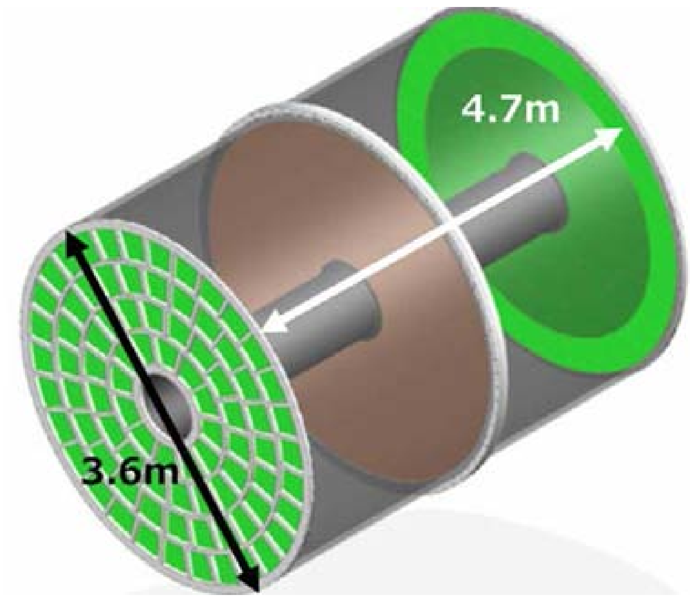
TPC requirements for collider concept

TPC could be as one tracker detector option for CEPC, 1M ZH events in 10yrs E_{cm} ≈240 GeV, luminosity ~2×10^{34} $cm^{-2}s^{-1}$, can also run at the Z-pole

TPC detector concept:

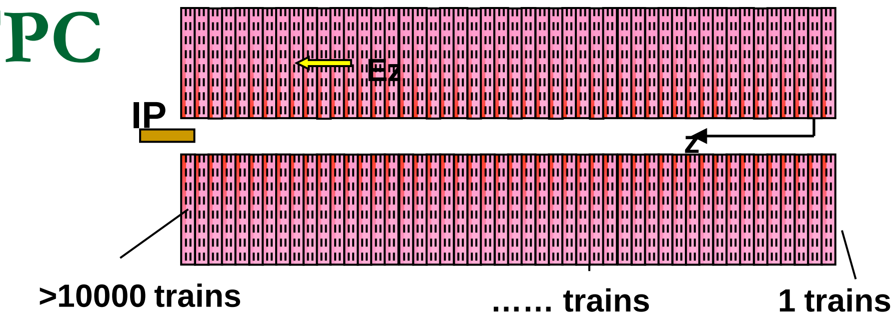
- Motivated by the H tagging and Z
- ~3 Tesla magnetic field
- ~100 μm position resolution in rφ
  - ~60μm for zero drift, <100μm overall
  - Systematics precision (<20μm internal
- Large number of 3D points(~220)
- Distortion by IBF issues
- dE/dx resolution: <5%
- Tracker efficiency: >97% for pT>1GeV
- 2-hit resolution in rφ : ~2mm
- Momentum resolution: ~10^{-4}/GeV/c
- TPC material budget
  - 0.05 X_0 including outer fieldcage in r
  - 0.25 X_0 for readout endcaps in z

from MoA document of LCTPC@2018



Overview of TPC detector concept

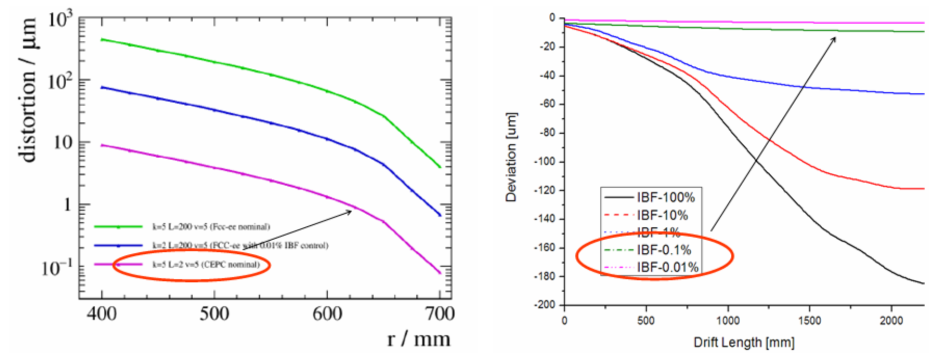
Technical challenges for TPC



Amplification ions @CEPC

Ion Back Flow and Distortion :

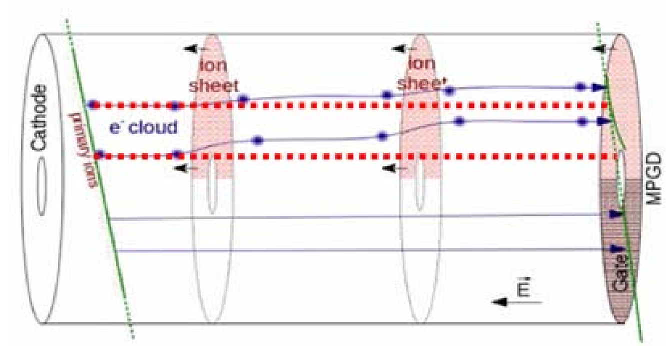
- ~100 μm position resolution in rφ
- Distortions by the primary ions at CEPC are negligible
- More than 10000 discs co-exist and distorted the path of the seed electrons
- The ions have to be cleared during the ~us period continuously
- Continuous device for the ions
- Long working time



Evaluation of track distortions

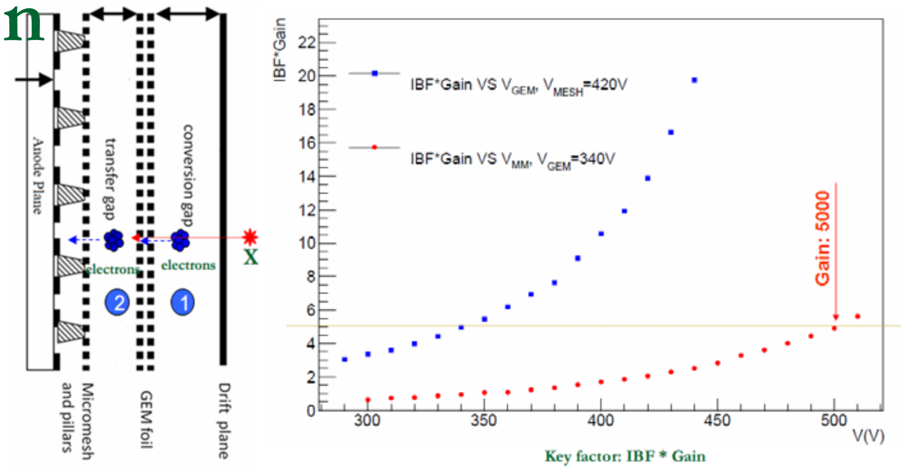
Calibration and alignment:

- Systematics precision (<20 μm internal)
- Geometry and mechanic of chamber
- Modules and readout pads
- Track distortions due to space charge effects of positive ions

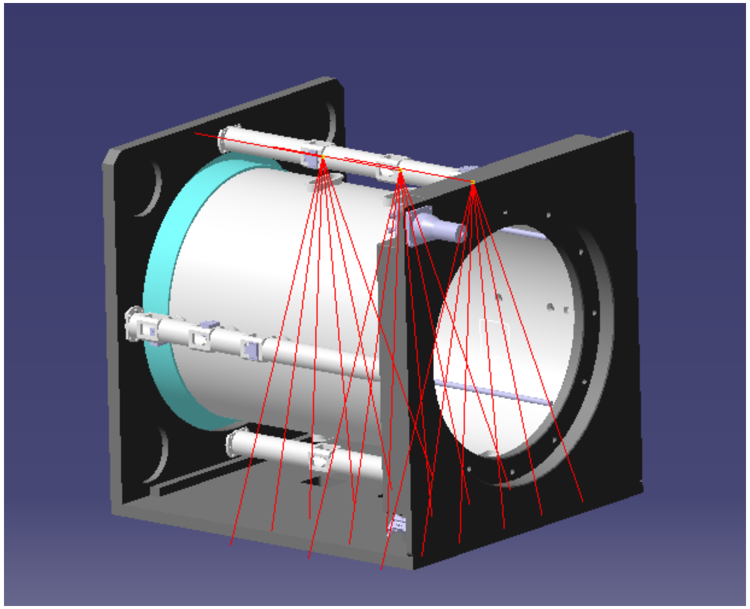


Ions backflow in drift volume for distortion

Options of technical solution



Continuous IBF prototype and IBF × Gain



TPC prototype integrated with laser system

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

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

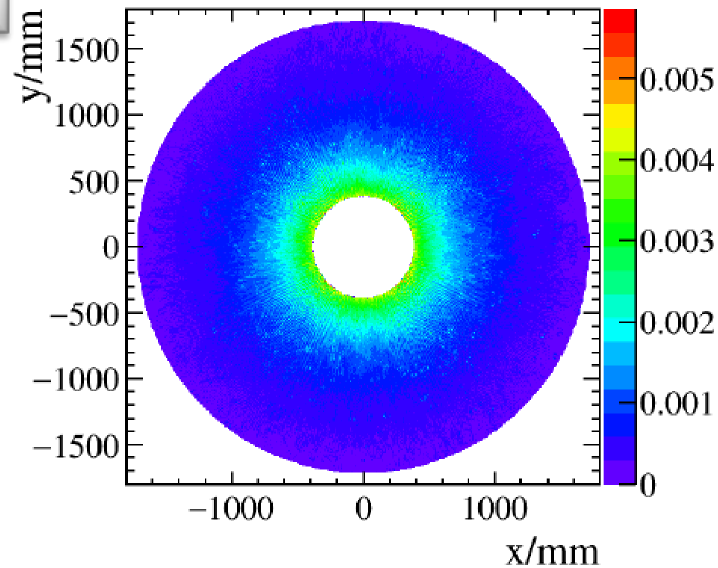
High rate at Z pole

IBF×Gain: <5

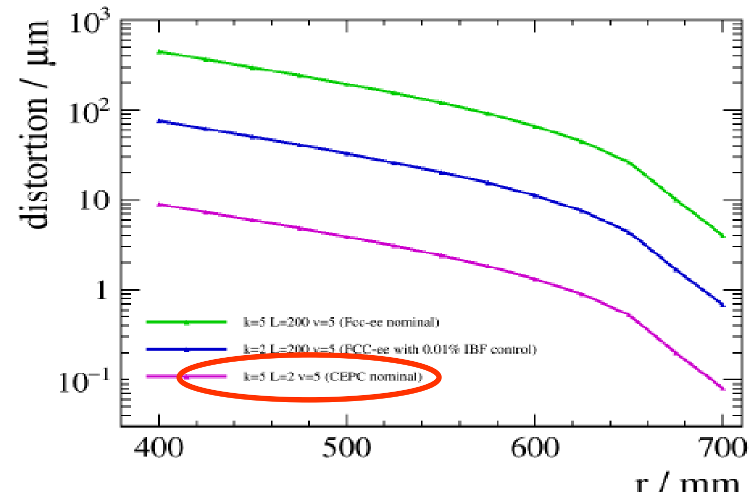
ArXiv: 1704.04401
Mingrui, Manqi, Huirong

- 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: $\sim2\times10^{-7}$
  - Voxel occupancy at TPC inner inner most layer : $\sim2\times10^{-5}$ @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



Distortion of as a function of electron initial r position

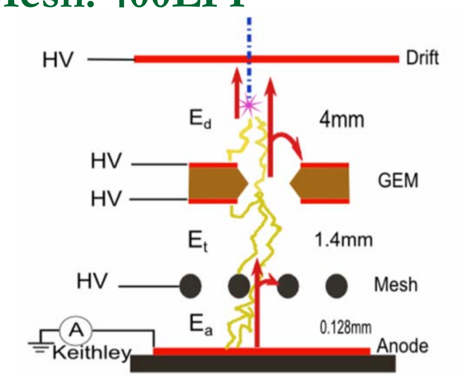
Investigation of IBF study with module

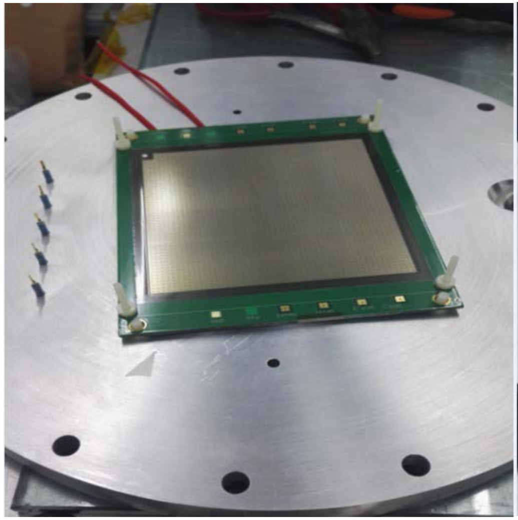
Combination detector

IBF control

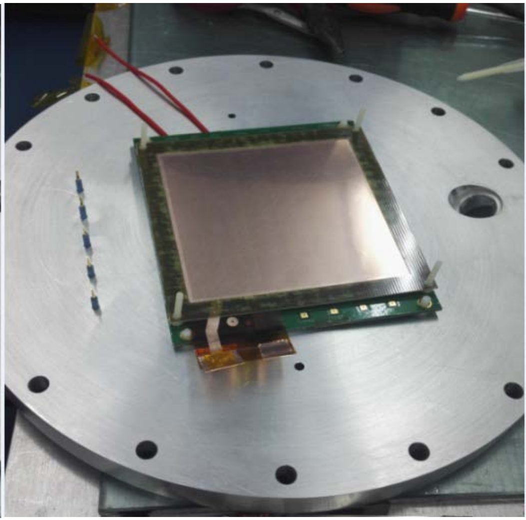
Test of the new module

- 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

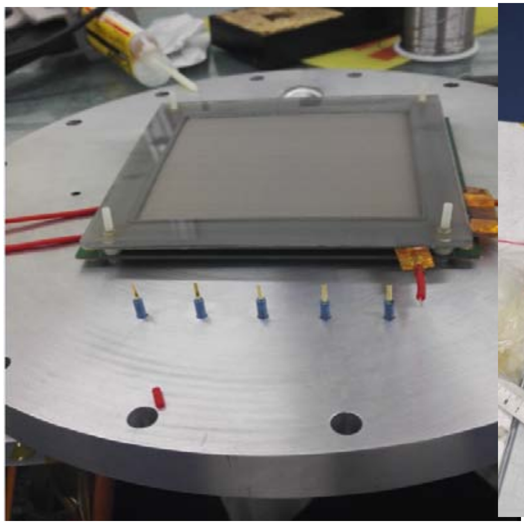




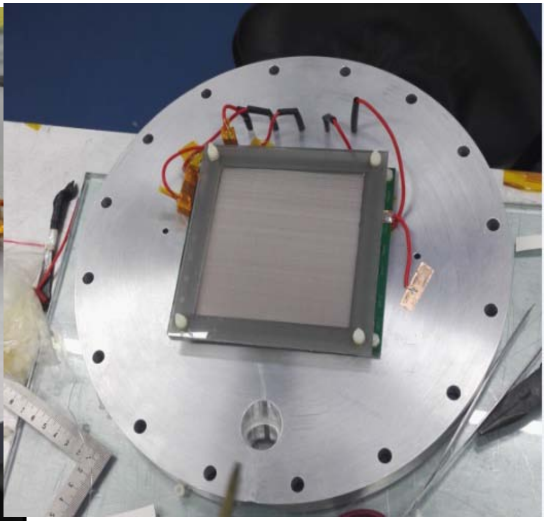
Micromegas(Saclay)



GEM(CERN)



Cathode with mesh



GEM-MM Detector

Measurement 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

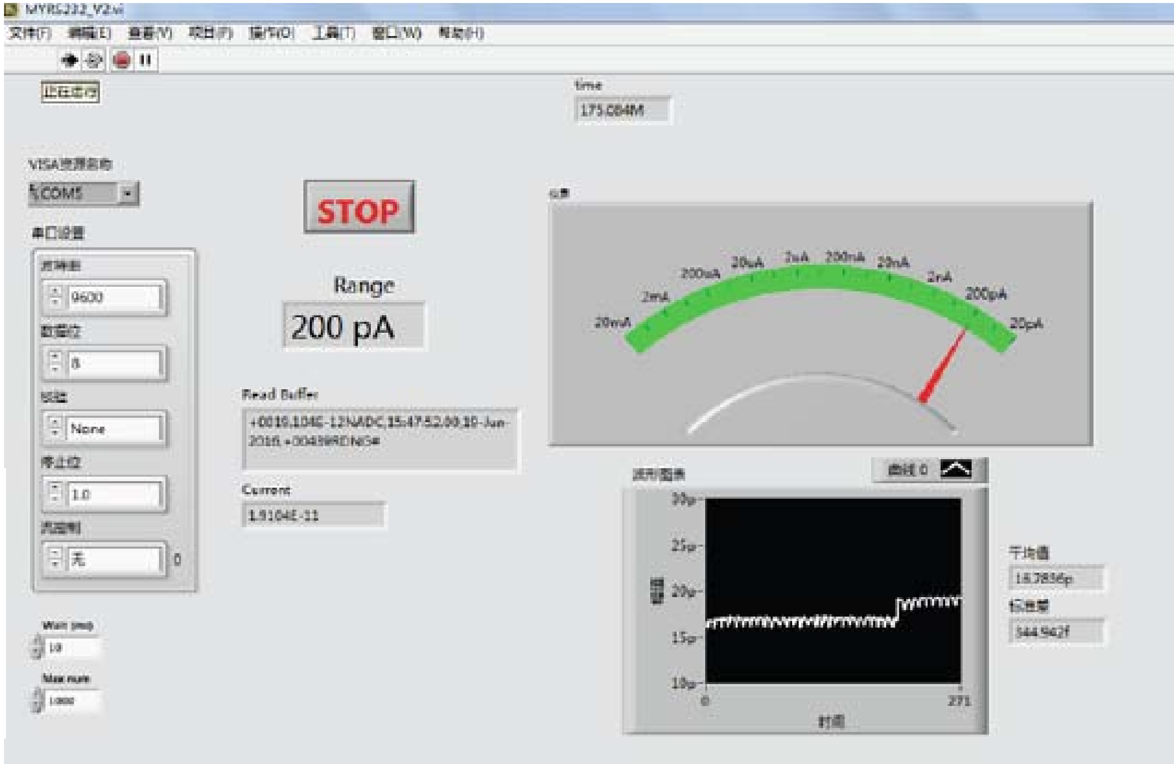
$$IBF = \frac{I_C - I_P}{I_A}$$

Keithley 6517B

Electrometer/High Resistance Met
- 20mA, 10μV - 200V, 100Ω - 10PΩ

Brand:	Keithley
Model No:	6517B

KEITHLEY
A Tektronix Company



Labview interface of the current with Keithley

GEM+MM@CEPC R&D

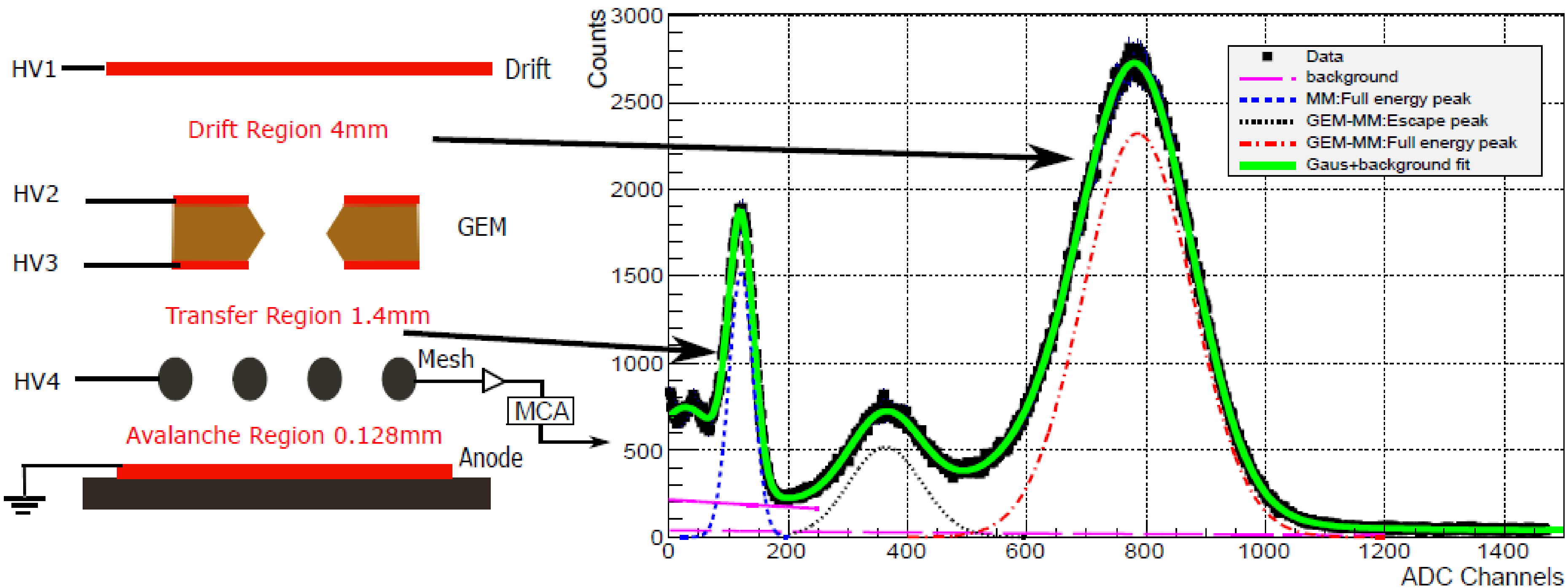
e+e- machine

Primary N_{eff} is small: ~30

Photo peak and escape peak are clear!

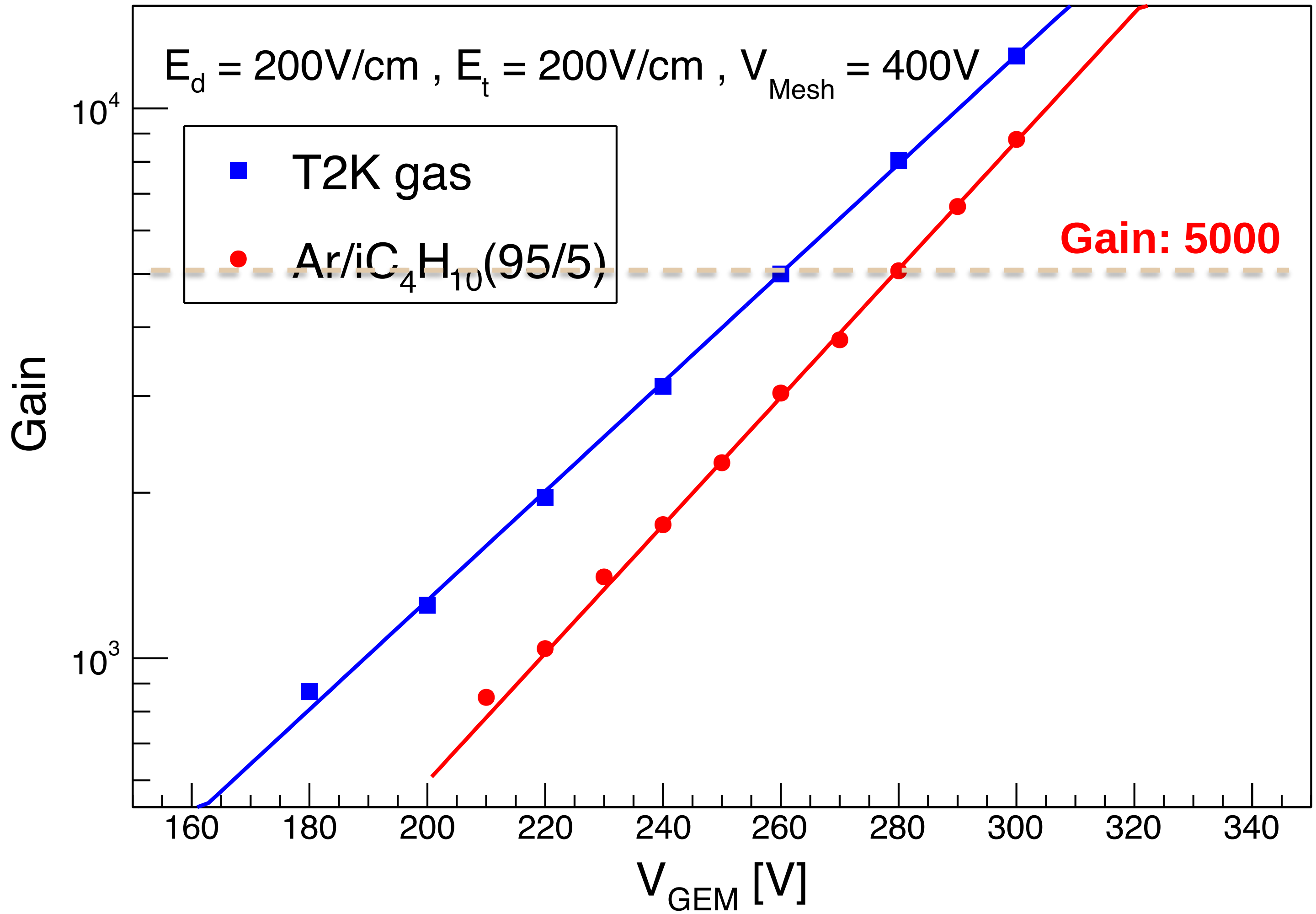
Good electron transmission.

Good energy resolution.

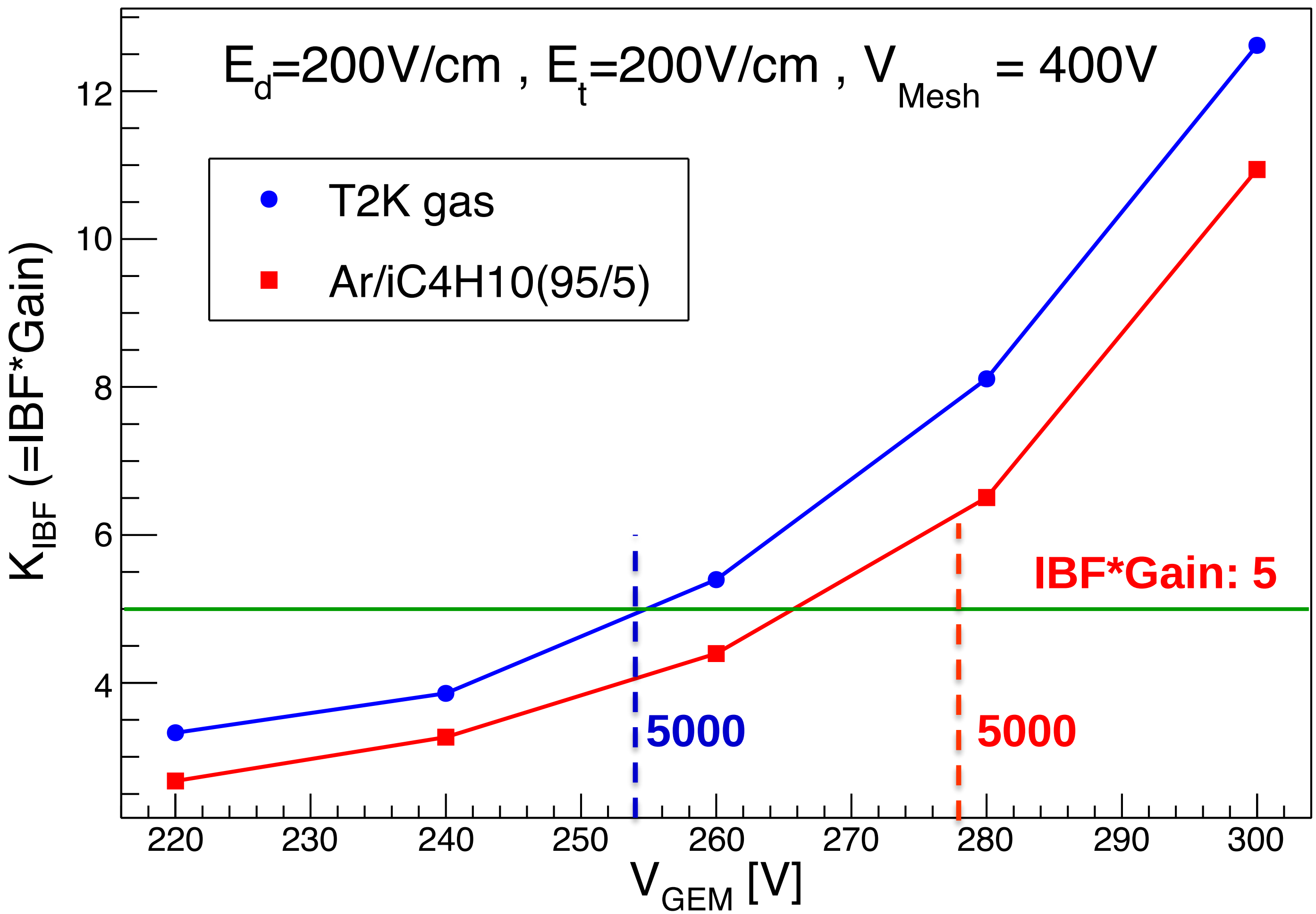


- DOI: 10.1088/1748-0221/12/04/P0401， JINST，2017.4
- DOI: 10.7498/aps.66.072901 Acta Phys. Sin. 2017,66(7)
- DOI: 10.1088/1674-1137/41/5/056003 , CPC,2016.11

Gain of the hybrid structure detector



Key IBF factor: IBF×Gain



Status of TPC prototype R&D

Drift velocity @Gas/P/T/Operation

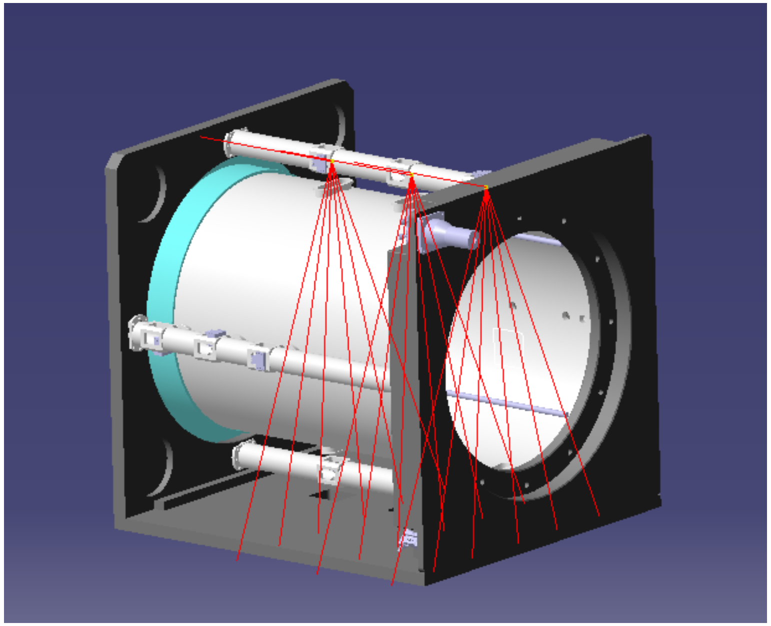
Uniformity

Online calibration

Distortion

Parameters of the TPC prototype

- TPC prototype: 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 calibration with 266nm
  - GEMs/Micromegas as the readout



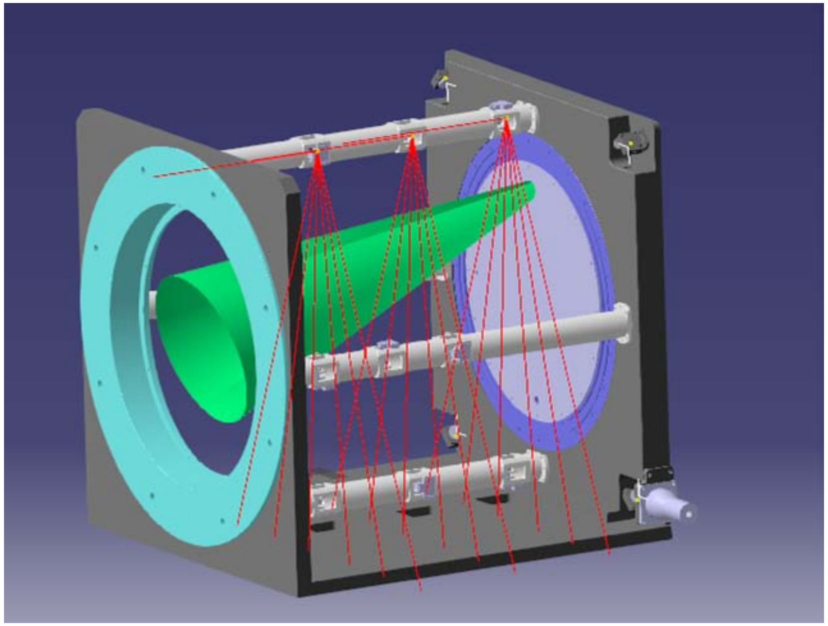
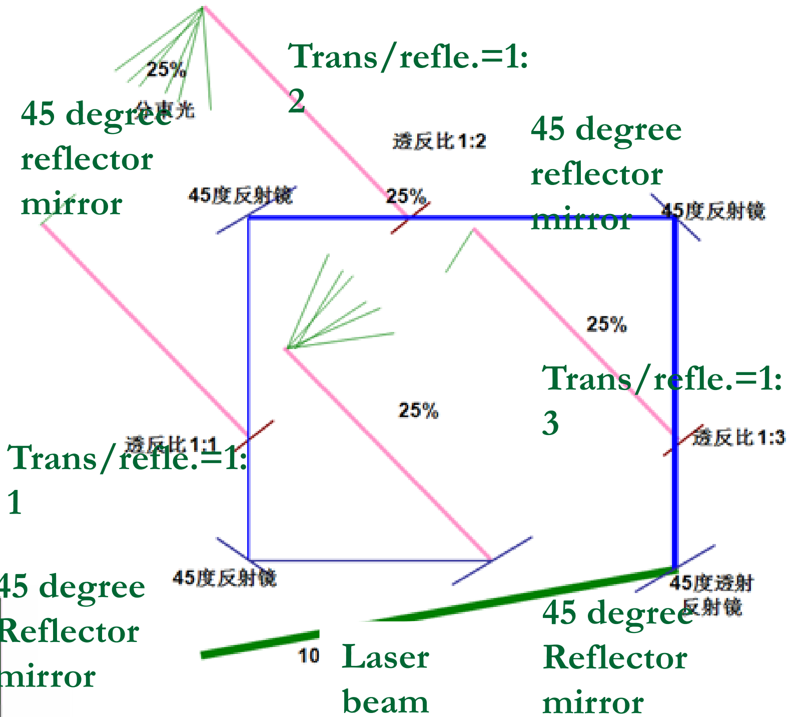
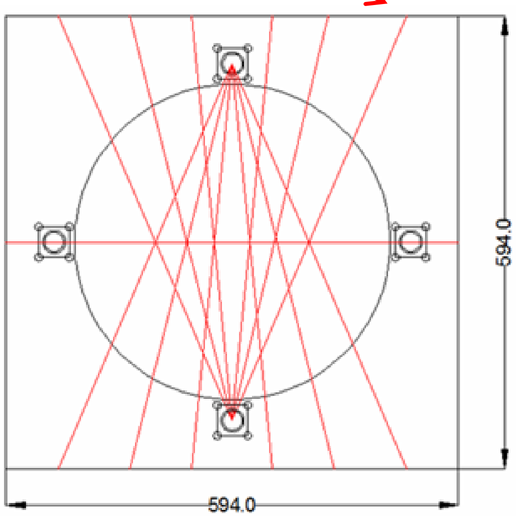


Diagram of the TPC prototype with the laser calibration system

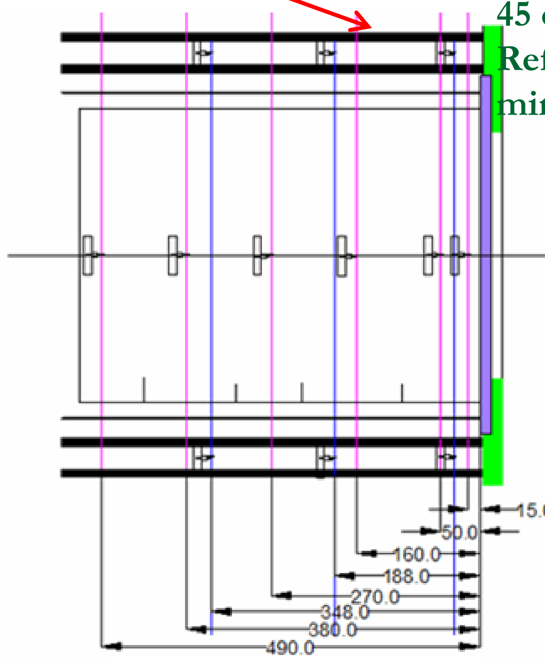
Laser map in drift length

- Size: ~0.85mm×0.85mm
- Transmission and reflection mirrors
- Aluminum board integrated the laser device and supports
- Drift velocity in Z
- Uniformity in X-Y plane





Laser map in X-Y plane



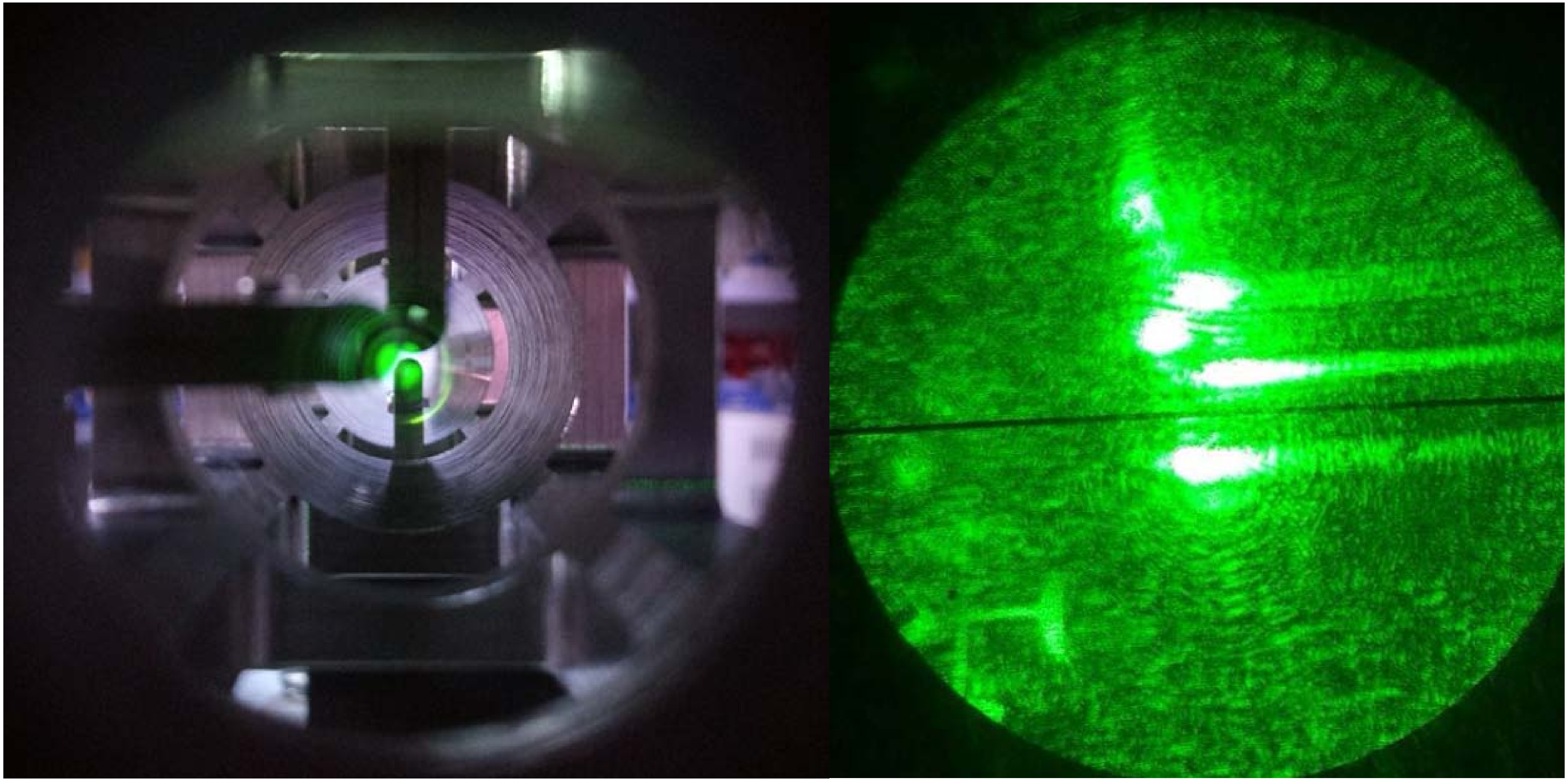
Laser map along Z

Detector with the laser system

Details of the laser calibration system

1 minutes = 1/60 degree

Precision (parallel light telescope test) : <±5 minutes



Split mirrors of the laser system and the position of the laser

Design of the prototype with laser

- 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)

Summary and further R&D

Continuous IBF module for CEPC:

- No Gating device options used for Higgs/Z pole run
- Continuous Ion Back Flow due to the continuous beam structure
- Key factor: IBF×Gain=5 and leas than (R&D)
- Low discharge and the good energy spectrum

Prototype with laser calibration for CEPC :

- 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 500mm drift length

Collaboration:

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

Thanks.