Status and progress of TPC module and prototype R&D in IHEP

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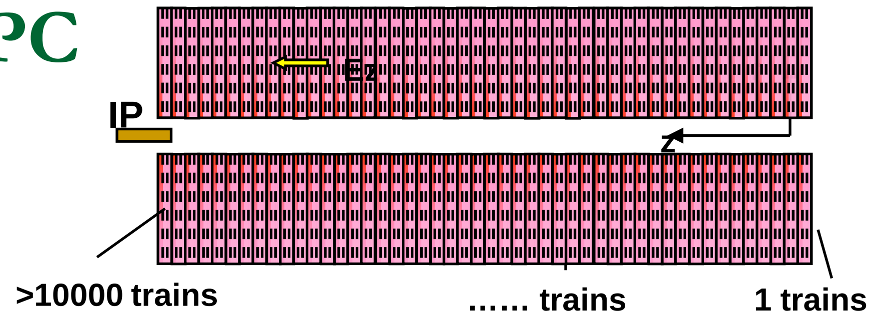
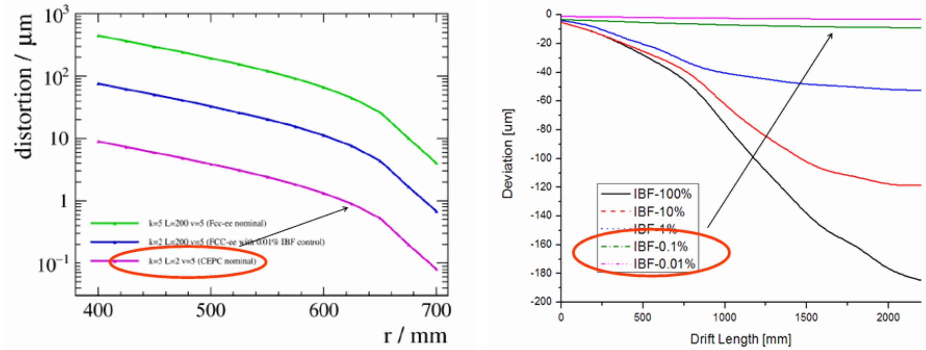
Outline

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

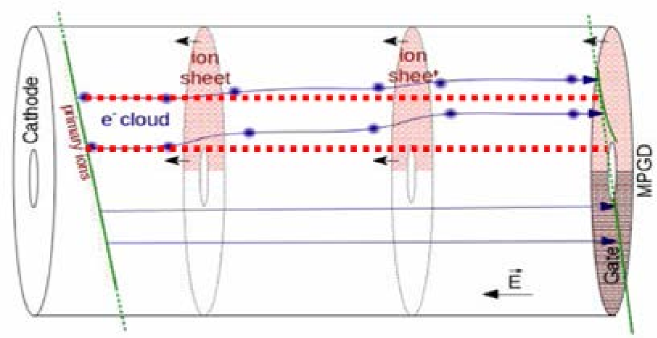
Technical challenges for TPC



Amplification ions @CEPC



Evaluation of track distortions



Ions backflow in drift volume for distortion

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

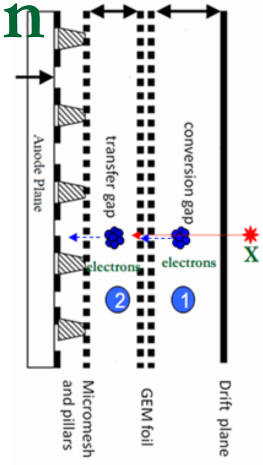
Calibration and alignment:

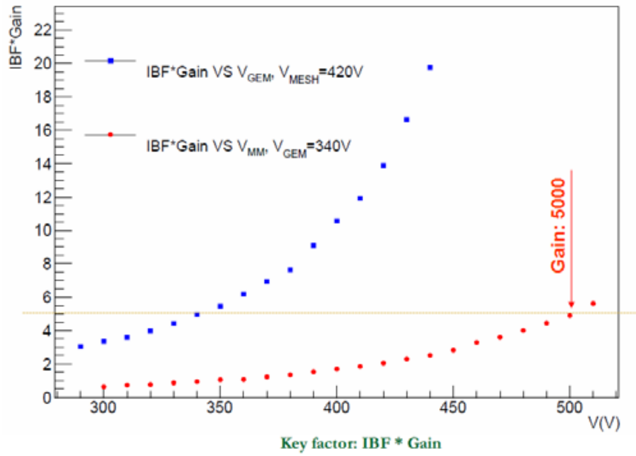
- Systematics precision (<20 μm internal)
- Geometry and mechanic of chamber
- Modules and readout pads
- Track distortions due to space charge effects of positive ions

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

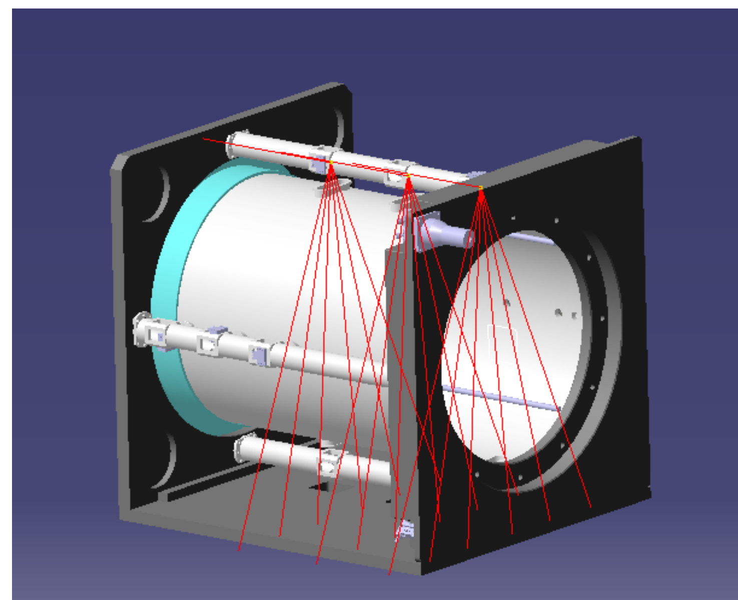




Continuous IBF prototype and IBF × Gain

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

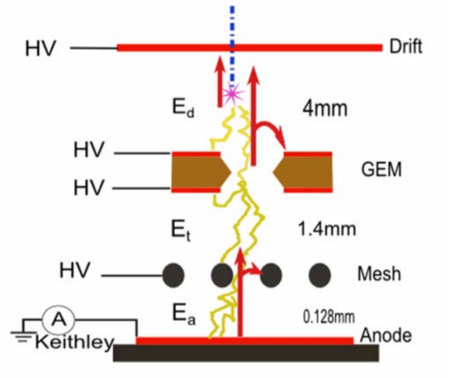


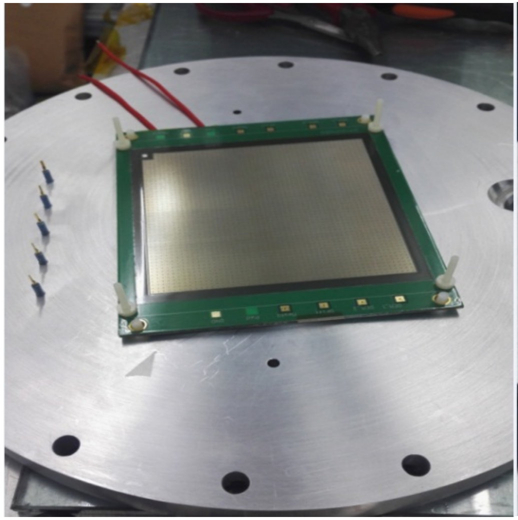
TPC prototype integrated with laser system

Investigation of IBF study with module

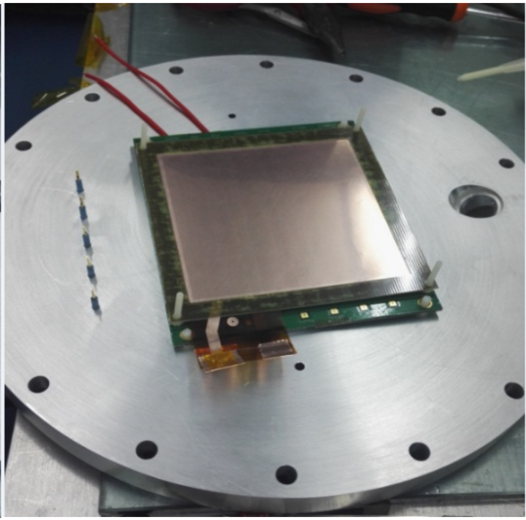
Test of the new module

- 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

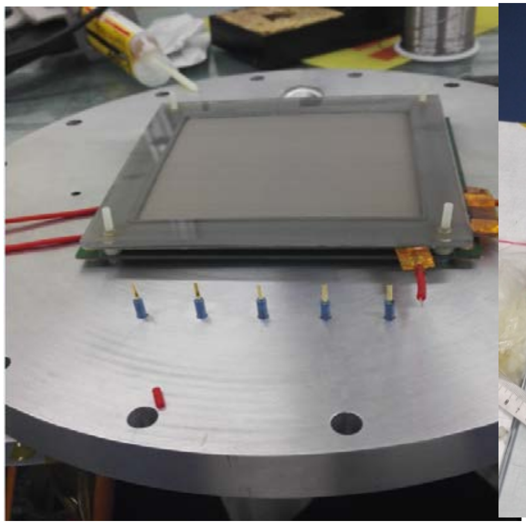




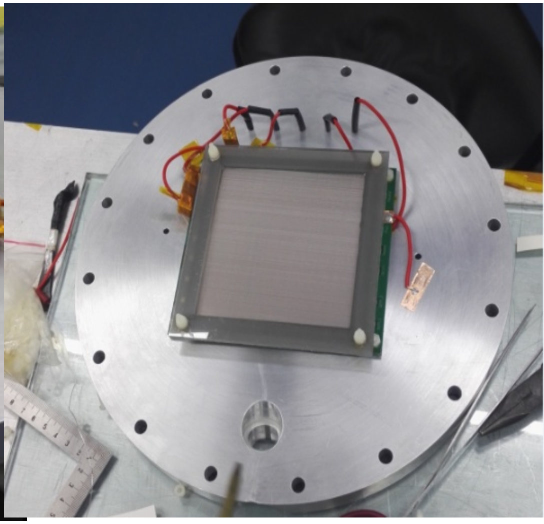
Micromegas(Saclay)



GEM(CERN)



Cathode with mesh



GEM-MM Detector

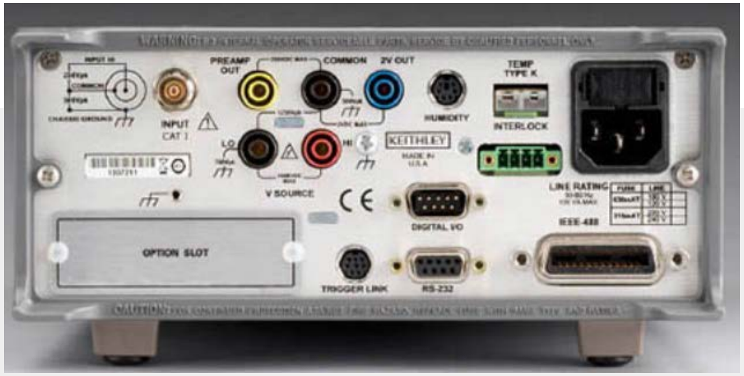
Electrometer/High Resistance Meter

Keithley 6517B

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

Brand:	Keithley
Model No:	6517B

KEITHLEY
A Tektronix Company



Product Features:

- Measures resistances up to 1018O
- 10aA (10×10-18A) current measurement resolution
- Less than 3fA input bias current
- 6 1/2-digit high accuracy measurement mode
- Less than 20µV burden voltage on the lowest current ranges
- Voltage measurements up to 200V with >200TO input impedance
- Built-in +/-1000V voltage source
- Unique alternating polarity voltage sourcing and measurement method for high resistance measurements
- Built-in test sequences for four different device characterization tests, surface and volume resistivity, surface insulation resistance, and voltage sweeping
- Optional plug-in scanner cards for testing up to 10 devices or material samples with one test setup

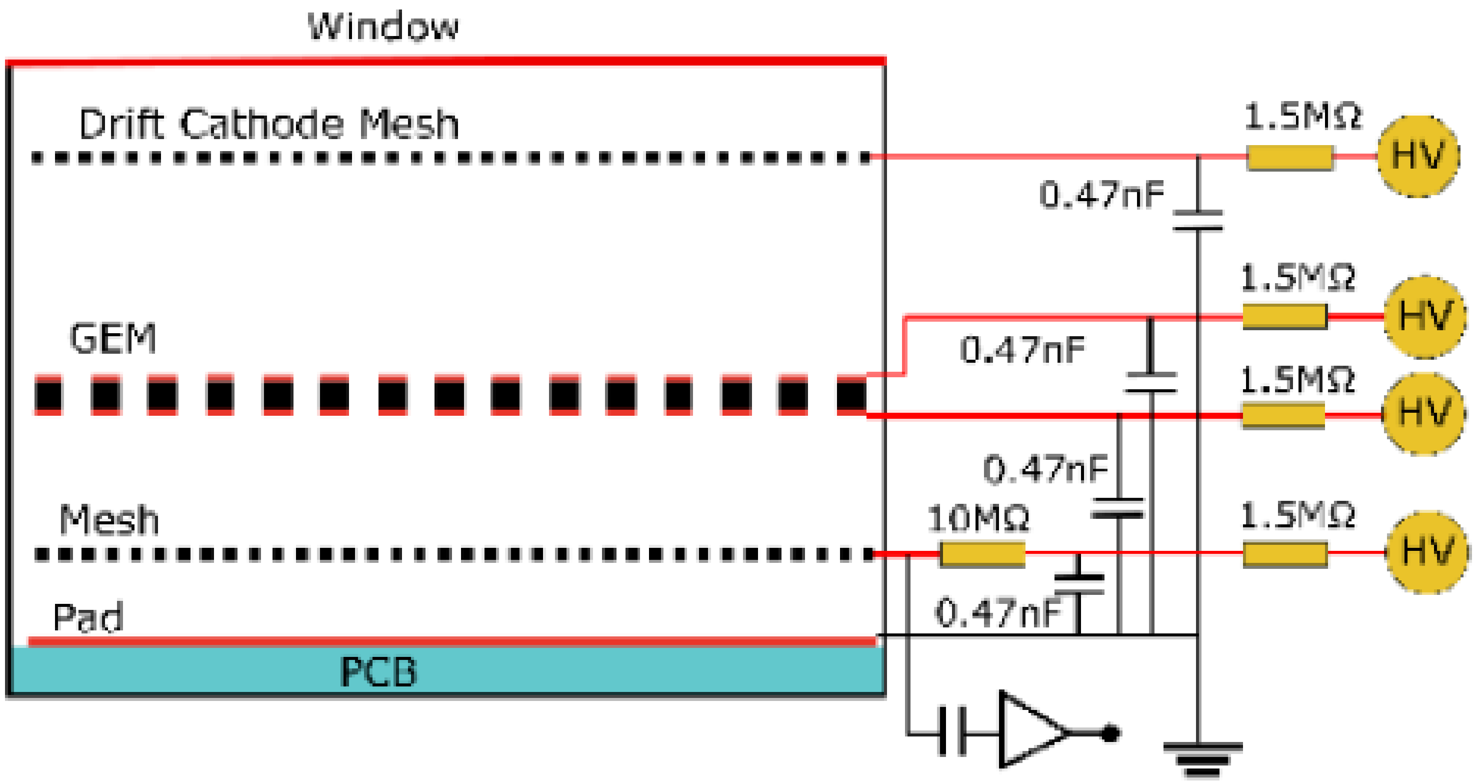
Measuremnt of GEM-MM module

- 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

Labview interface of the current with Keithley

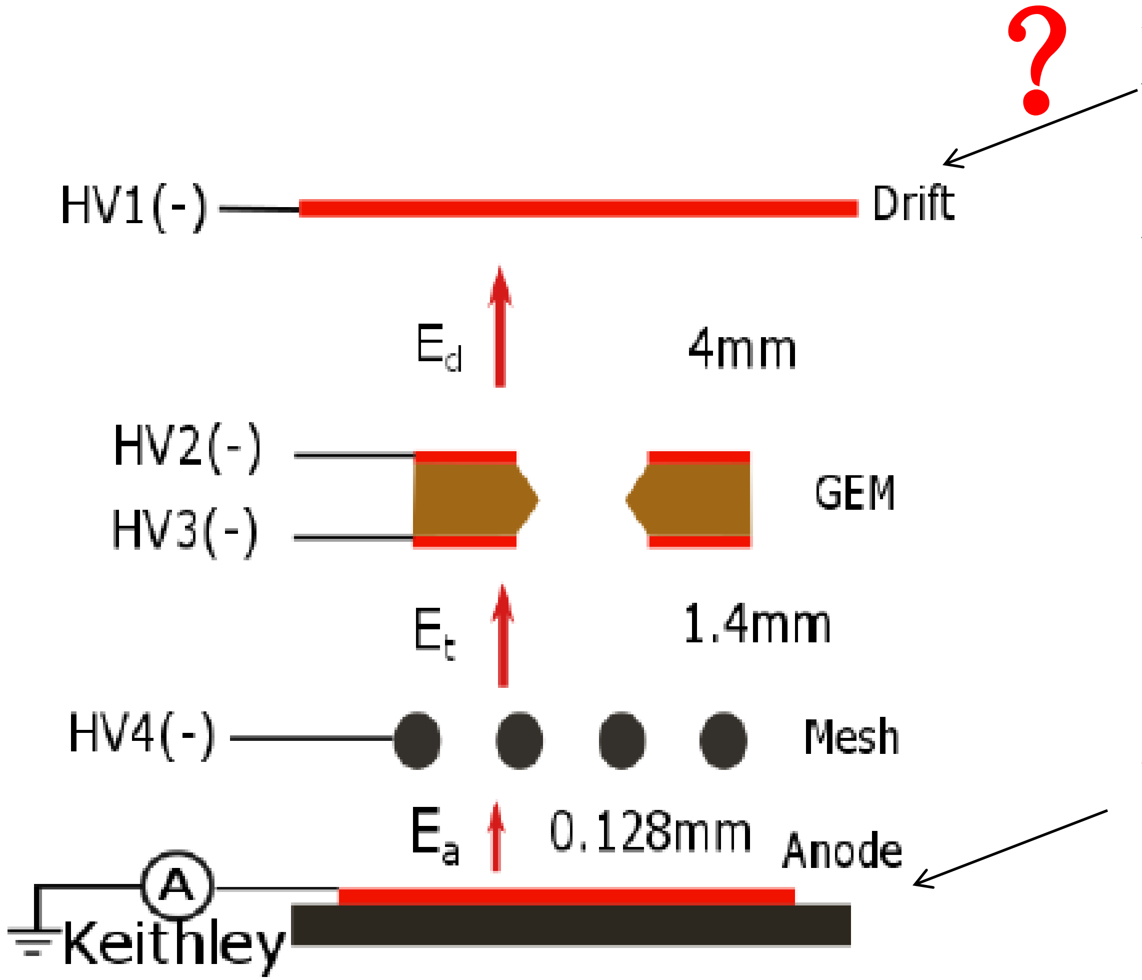
$$IBF = \frac{I_C - I_P}{I_A}$$

GEM-MM module



High voltage diagram of the detector module

First step



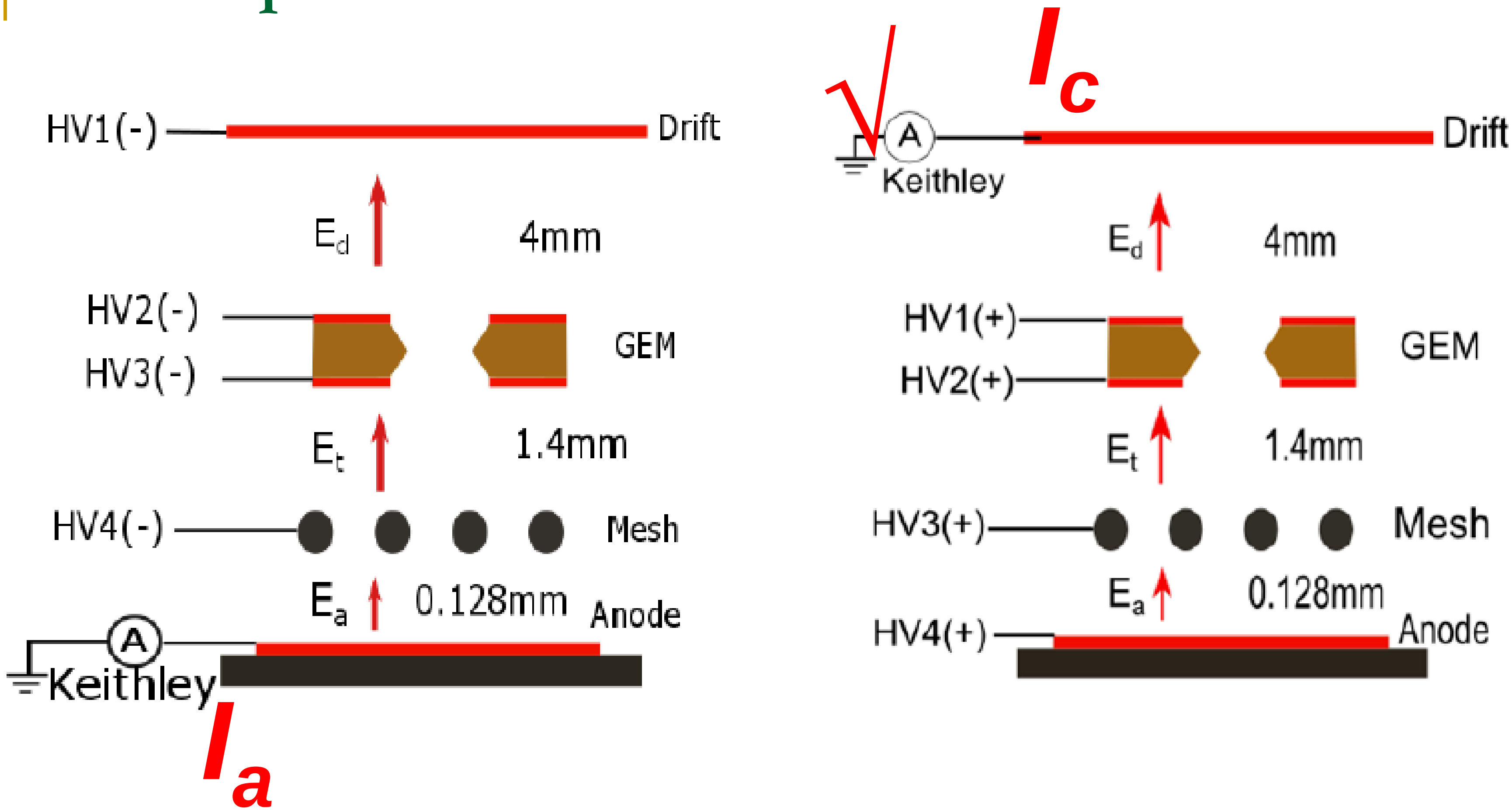
To -2600V high voltage

Can not connect with Keithley meter

To ground with Keithley meter

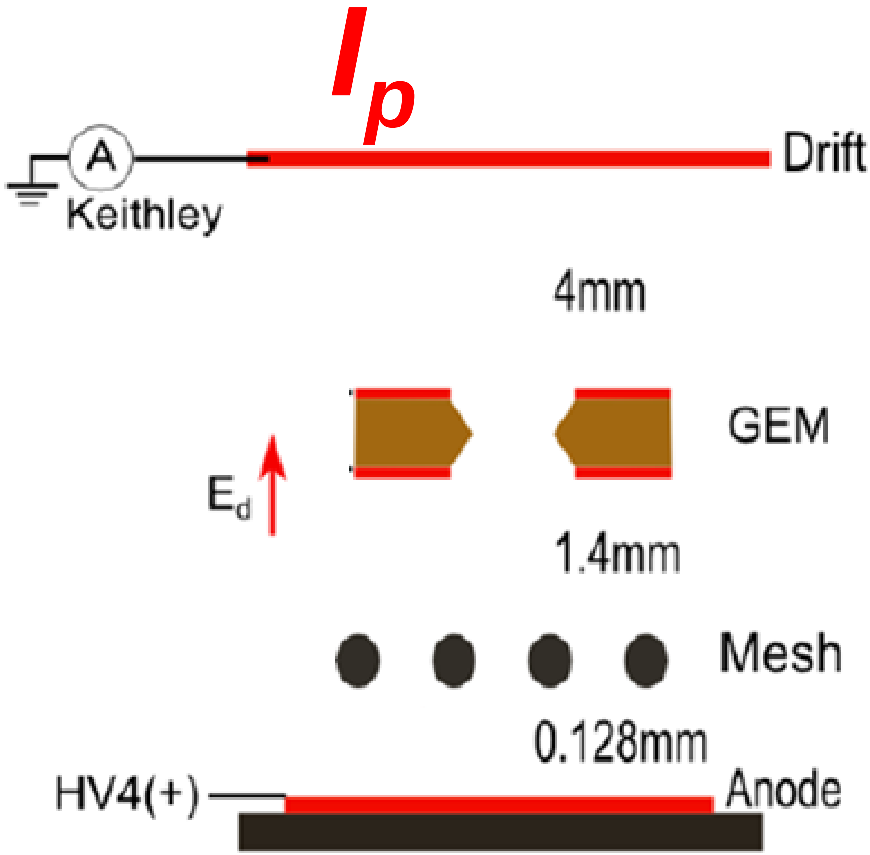
Rang: ~nA

Two steps



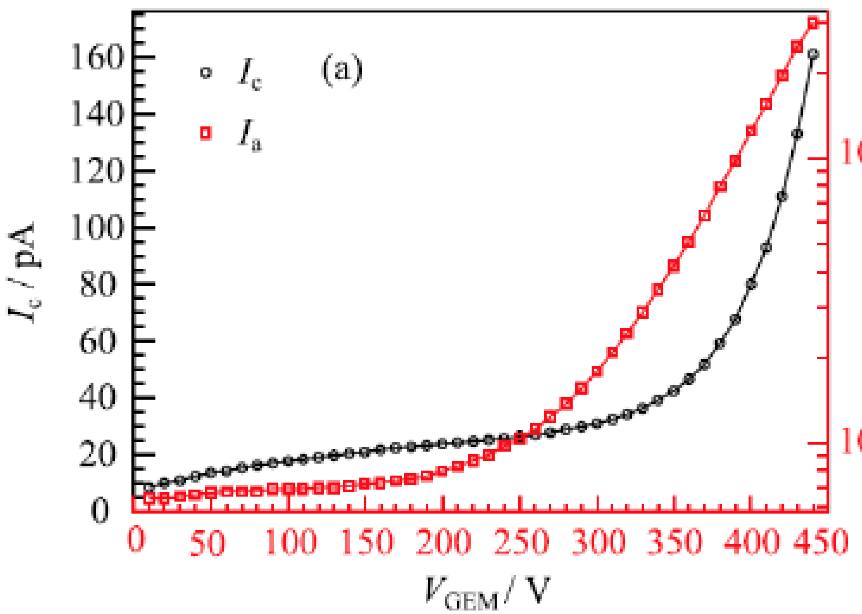
- Different polarity
- Same electric filed
  - Ed=Ed; Et=Et; Ea=Ea

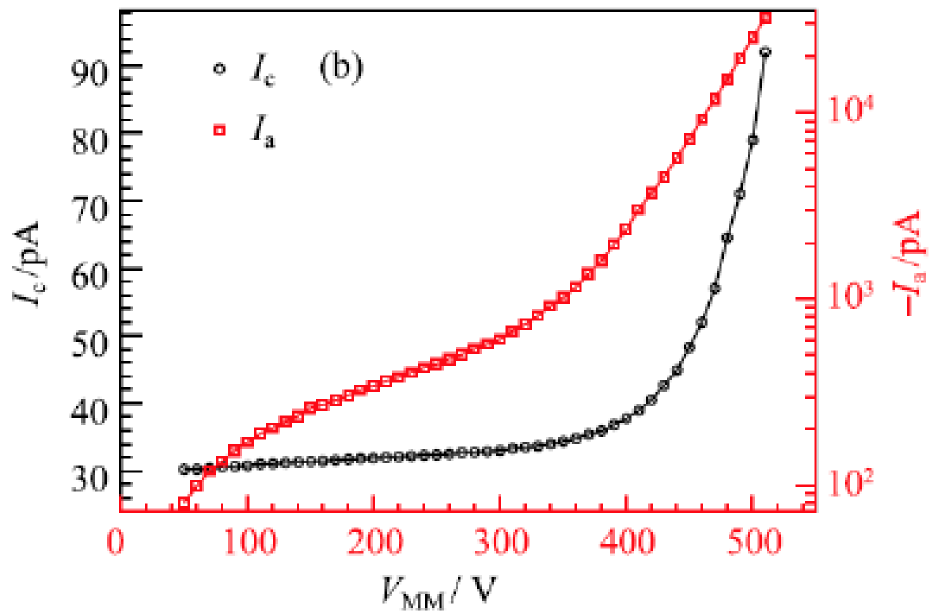
Primary electrons current



- No operation voltage of the GEM-MM detector
- Just test current of the primary electrons (~pA)

Ic and Ia





- GEM with operation voltage
- MM with operation voltage

IBF and Gain

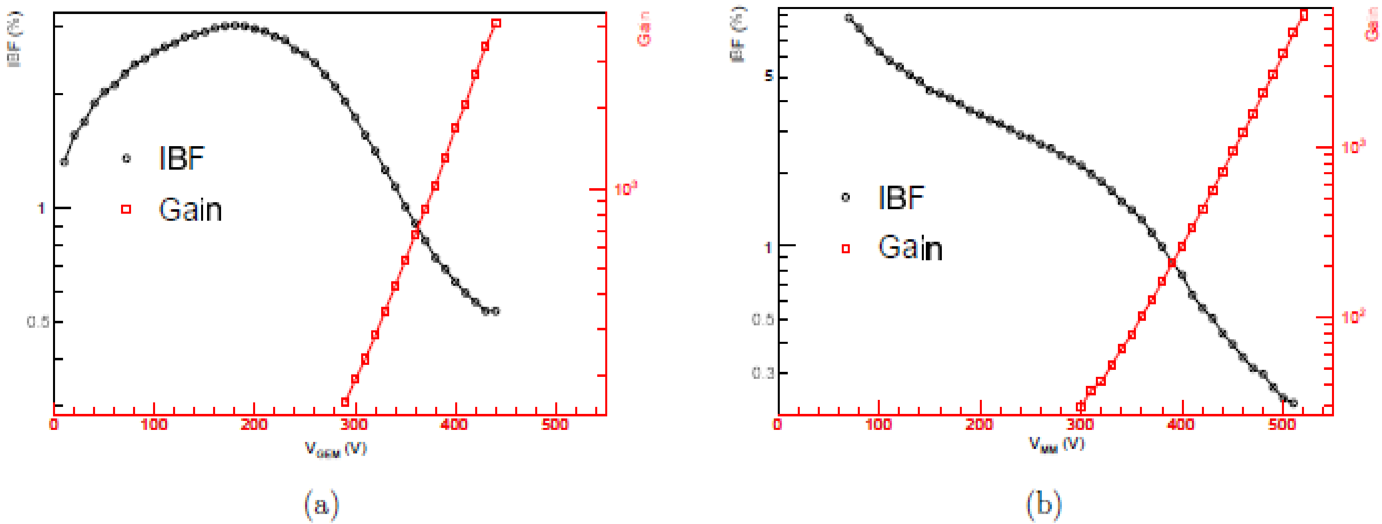


Fig. 4: (color online) Gas gain and IBF versus (a) GEM voltage, micromesh $V_{mesh} = 420\,V$ and (b) micromesh voltage, $V_{gem} = 340\,V$. $E_d = 250\,V/cm$, $E_t = 500\,V/cm$.

Status of TPC prototype R&D

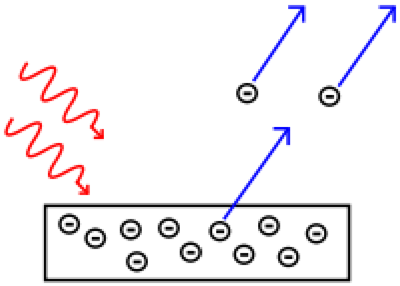
Parameters of the TPC prototype

- To aim that the small TPC prototype for the estimation of the distortion due to the IBF, and the study of related physics parameters
- To mimic the bunch structure & the ions distortion with UV light and laser split beam

- 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)

Why UV light study

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



Photoelectric effect

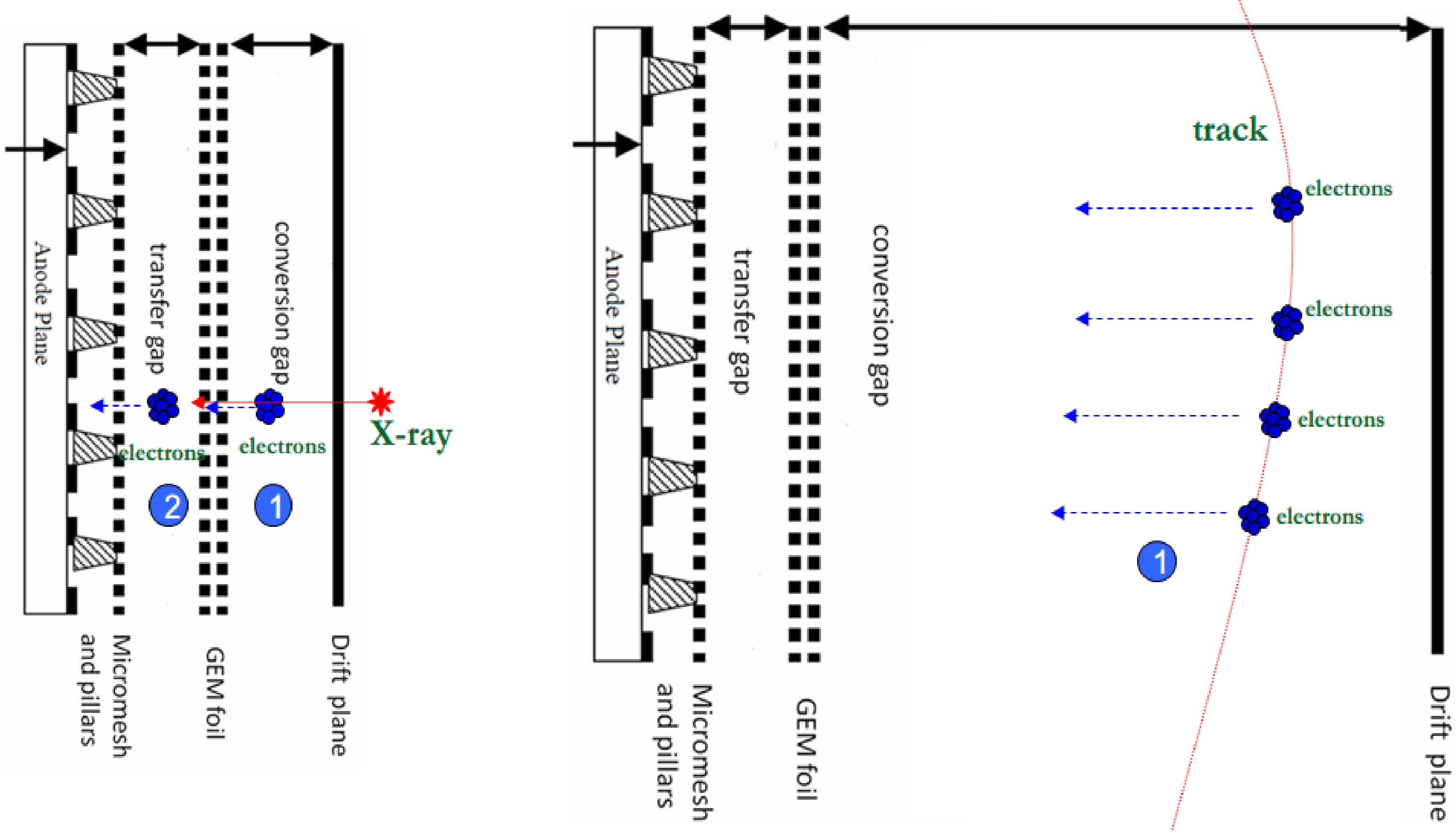


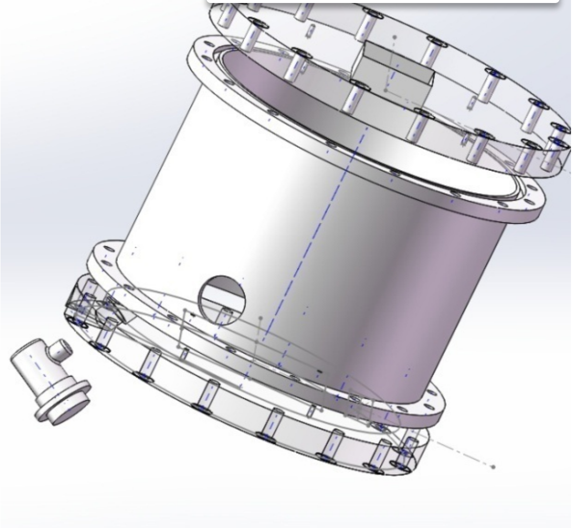
Diagram of the IBF test with the module

Yulian, Haiyun

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

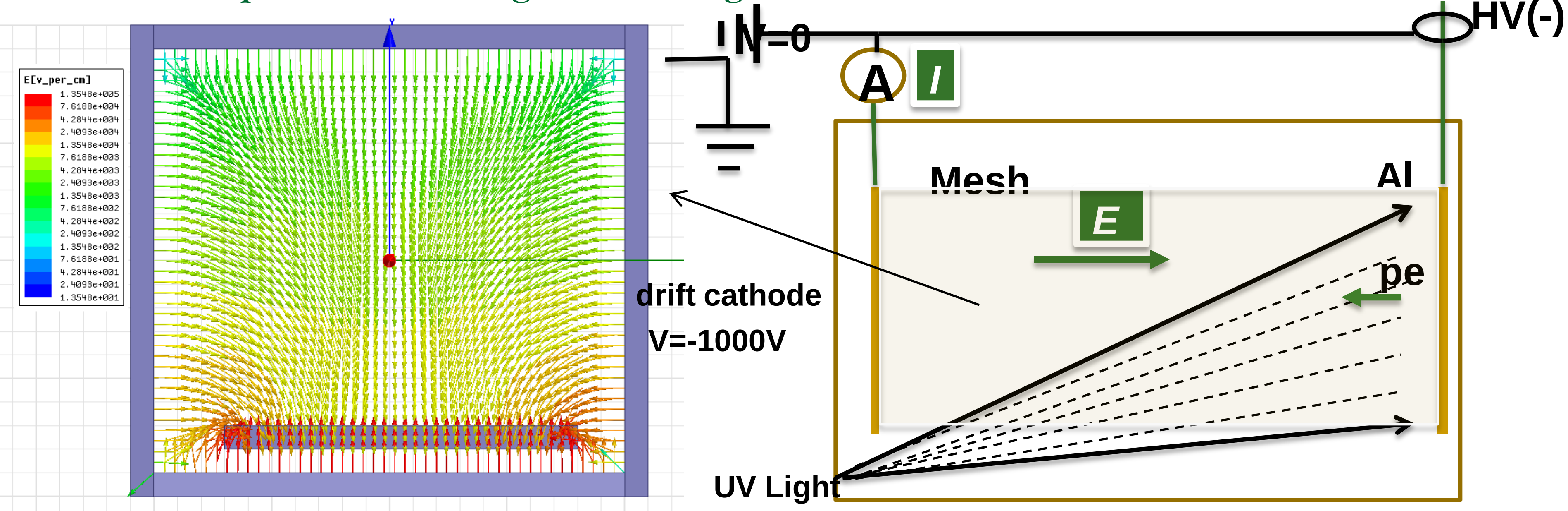


Diagram of the UV test with new module

Electrons produced by UV

- Re-mounted the UV light
  - Two mixture gases
  - High E test
  - Ar gas purity: 99.999%
  - iC4H10 gas purity: 99.99%
  - CO2 gas purity: 99.999%
  - CF4 gas purity: 99.99%

  - About 31000 electrons/s.mm^2
  - Electrons from Al
  - Electrons from drift length at 266nm UV light (~MIPs)

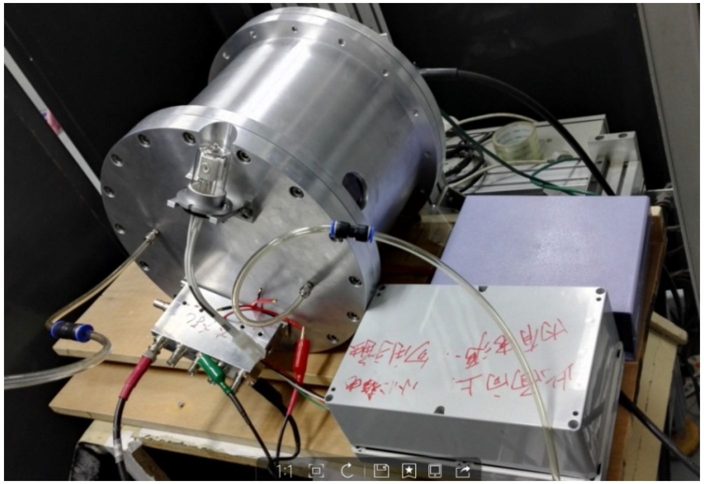
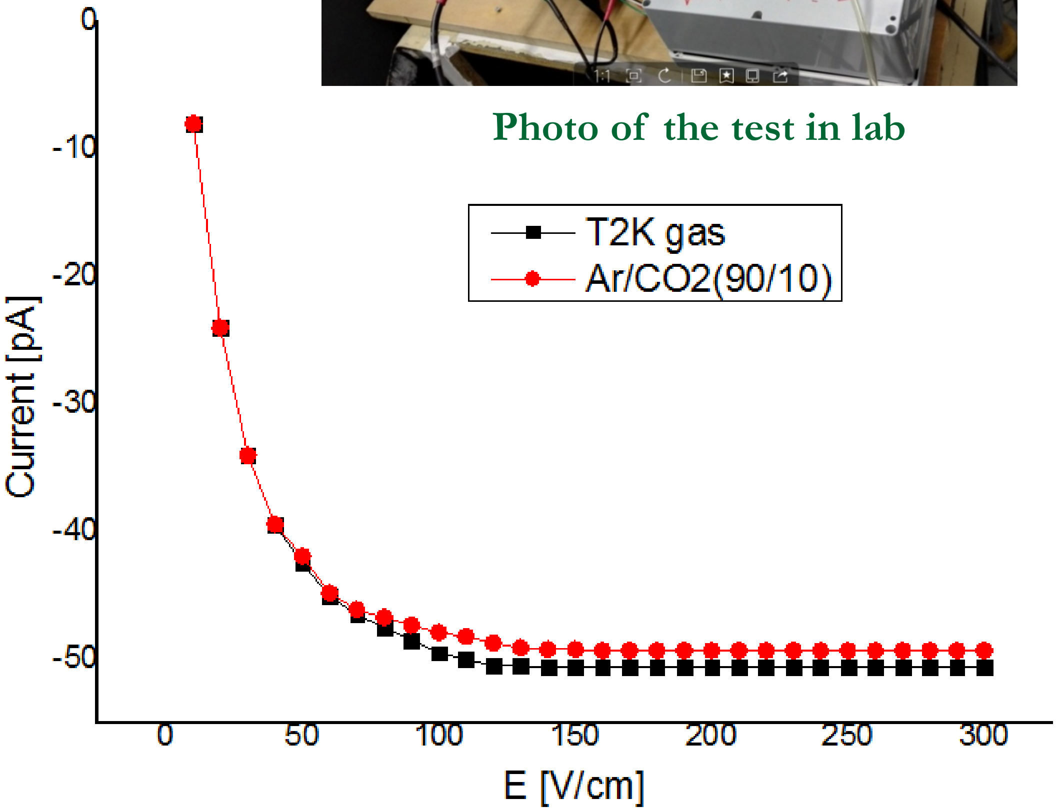
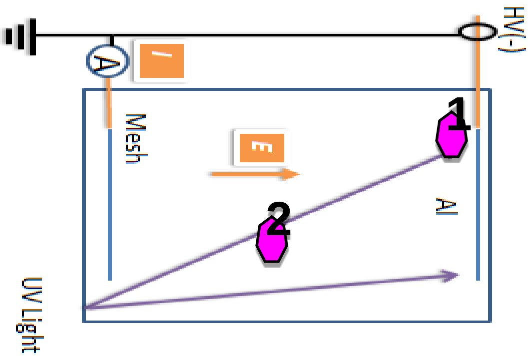


Photo of the test in lab

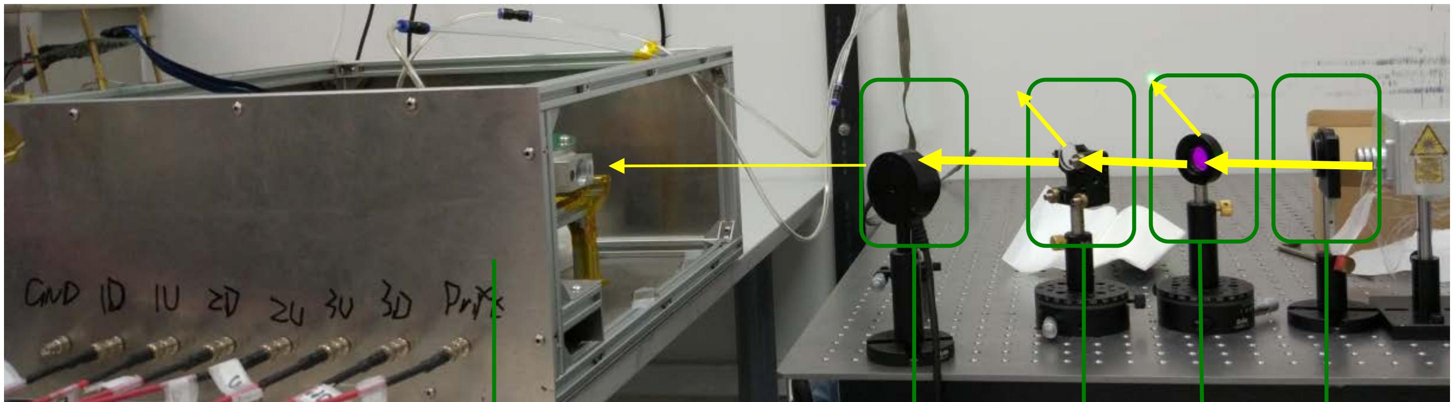


Current VS Electric field in drift length



UV Shining diagram

Signal of the laser with Φ1mm @266nm



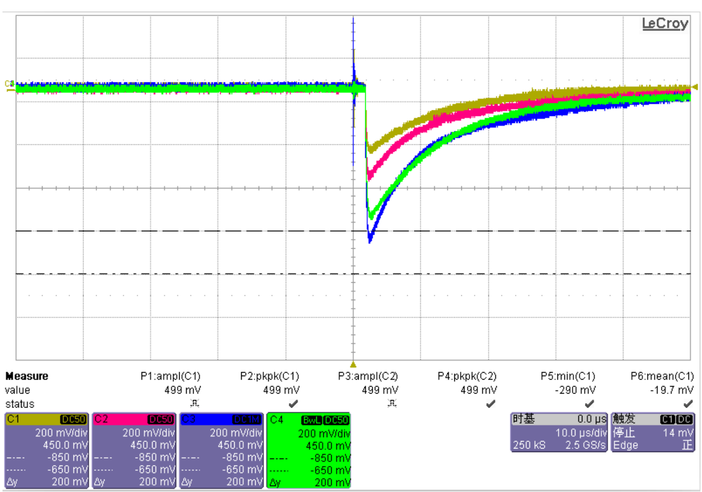
Triple GEMs detector

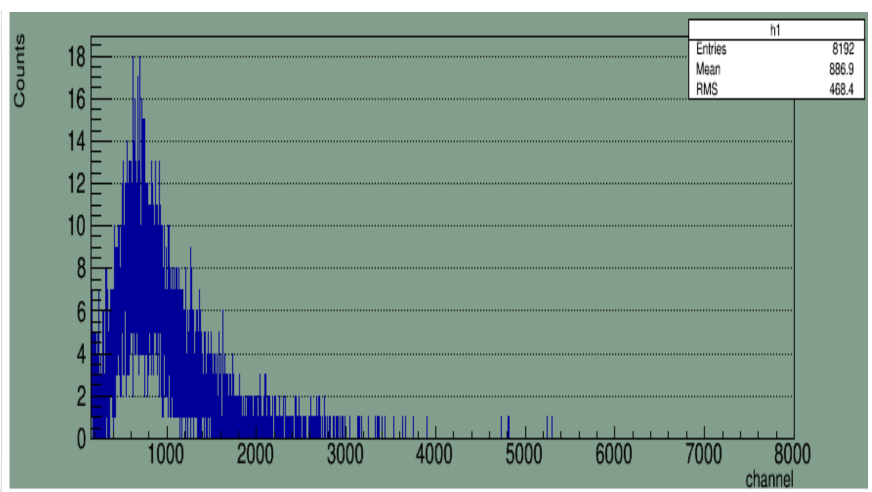
Hole collimator Φ1mm

Trans/refle. =1:99

Transmission mirror

Transmission mirror

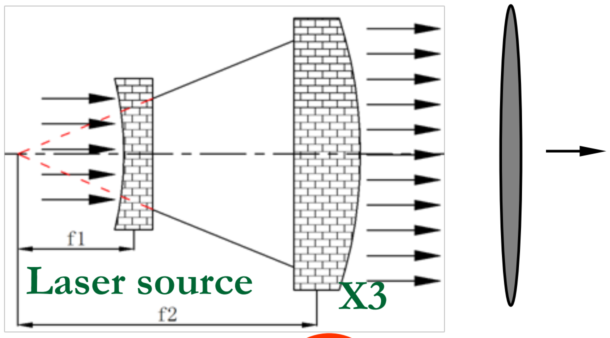




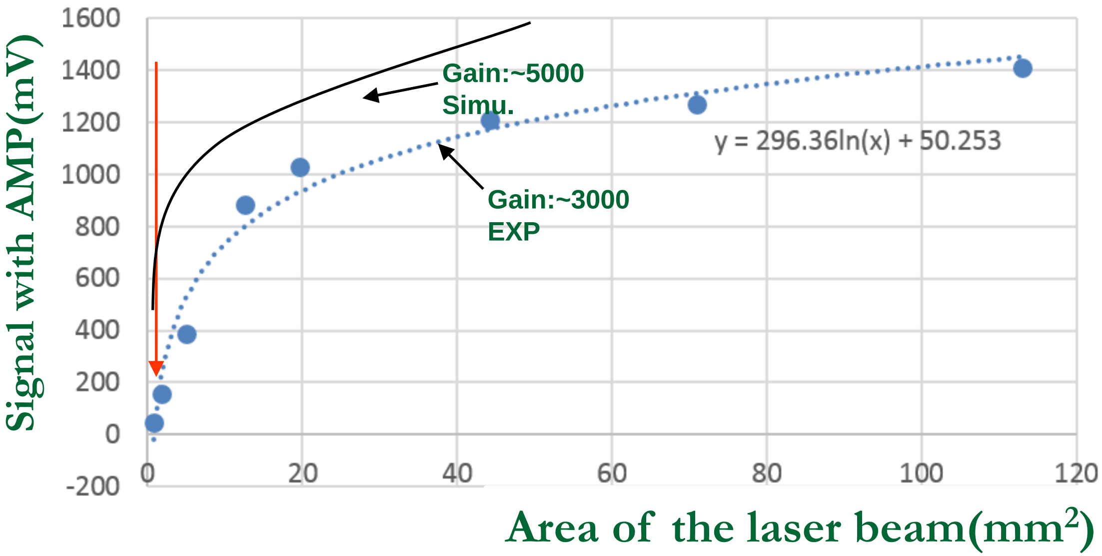
Signal of the laser with Φ1mm@Charge sensitive AMP/12mV/fC

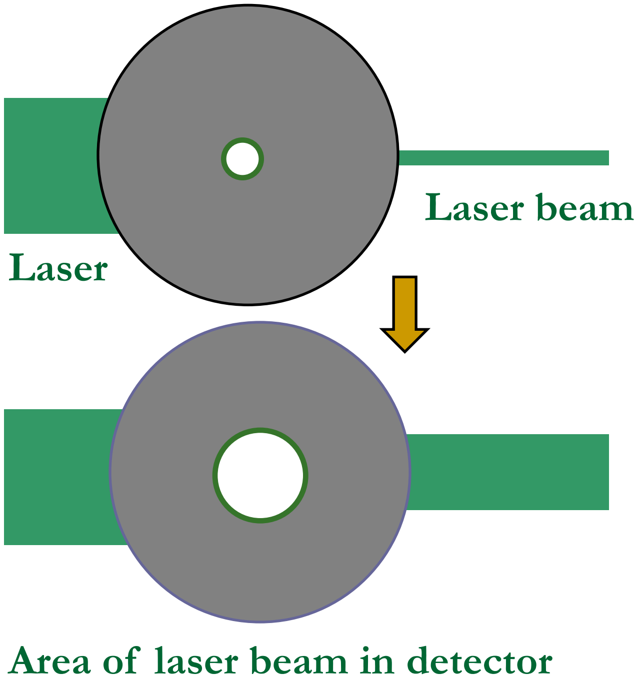
Collimator@Φ1~ Φ 12mm

- Laser beam with expander mirror: 5mm×3
- Primary laser power: 170uJ
- Gain:~3000



直径/mm	12	9.5	7.5	5	4	2.5	1.5	1
面积/mm2	113.1	70.882	44.179	19.635	12.566	4.9087	1.7671	0.785
道数	6648	5990	5717	4856	4177	1853	779	267
幅度/mV	1411.5	1270.6	1212.2	1027.8	882.47	384.9	154.96	45.34

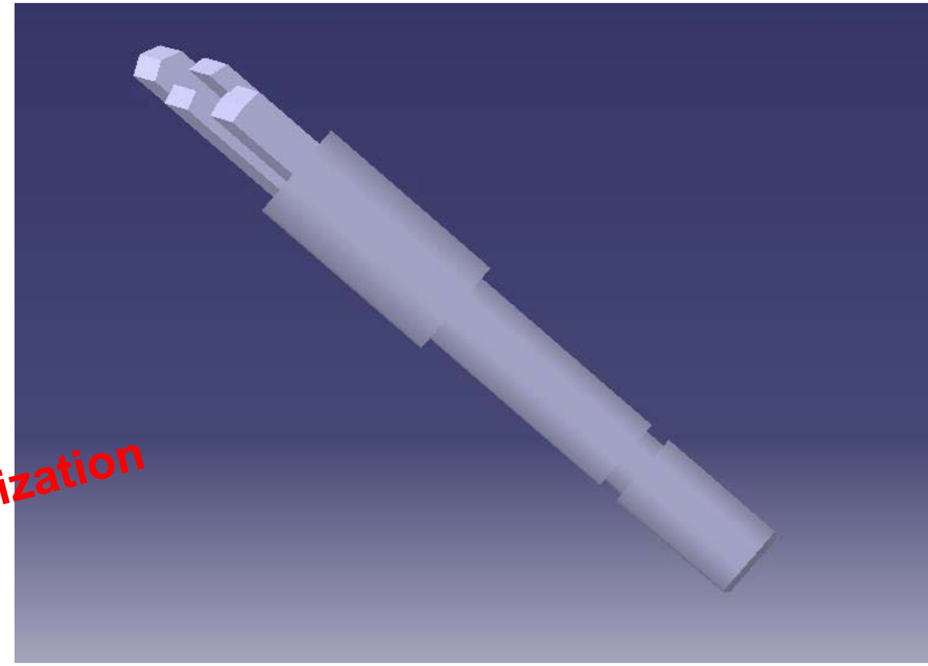


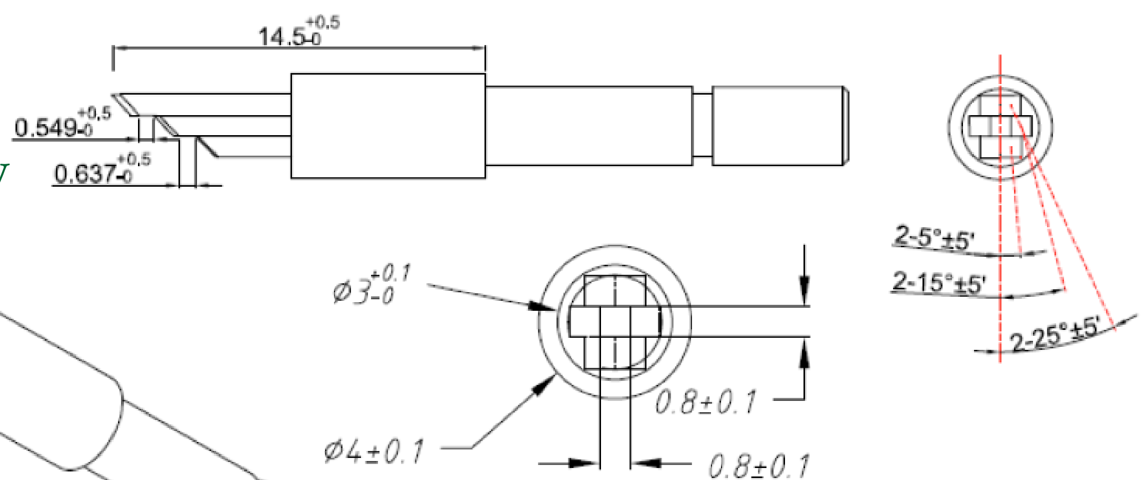


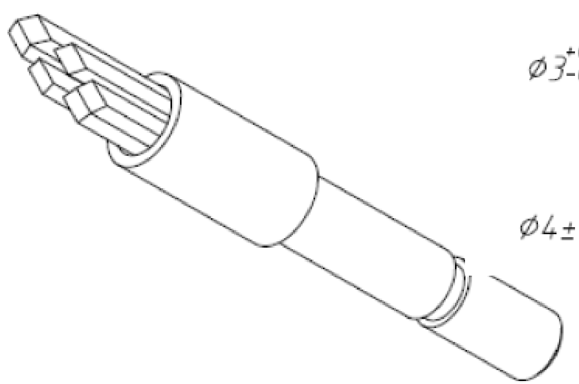
Divide and reflection mirrors

- 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

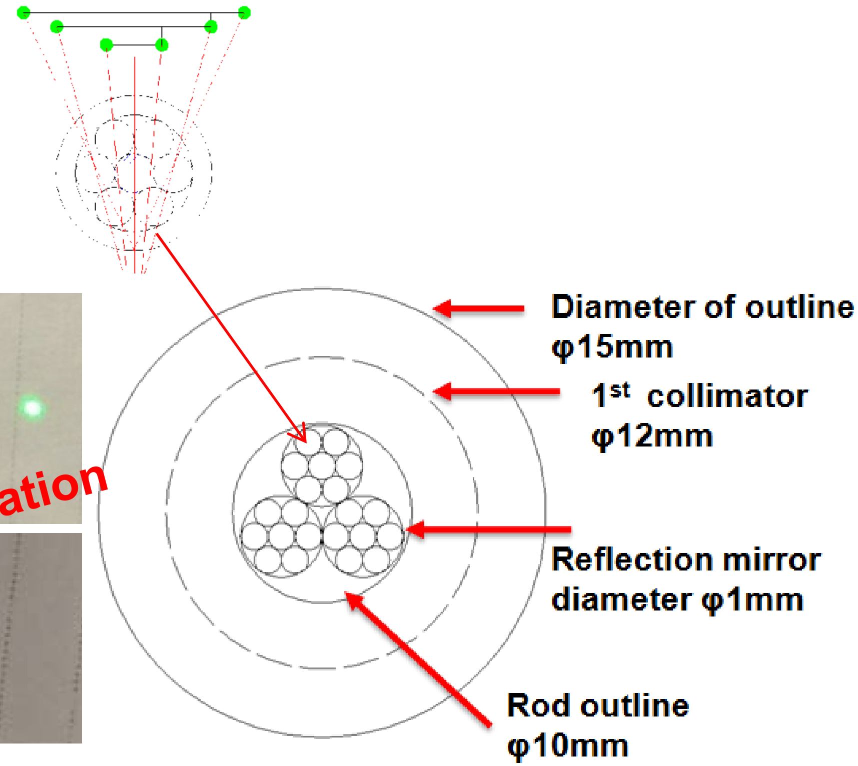
Optimization



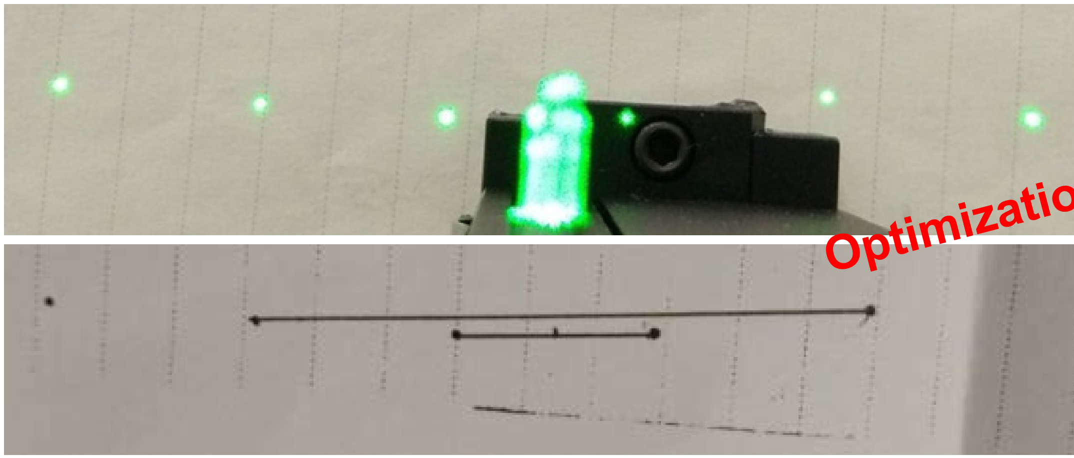




Mirrors test with 266nm



Test:

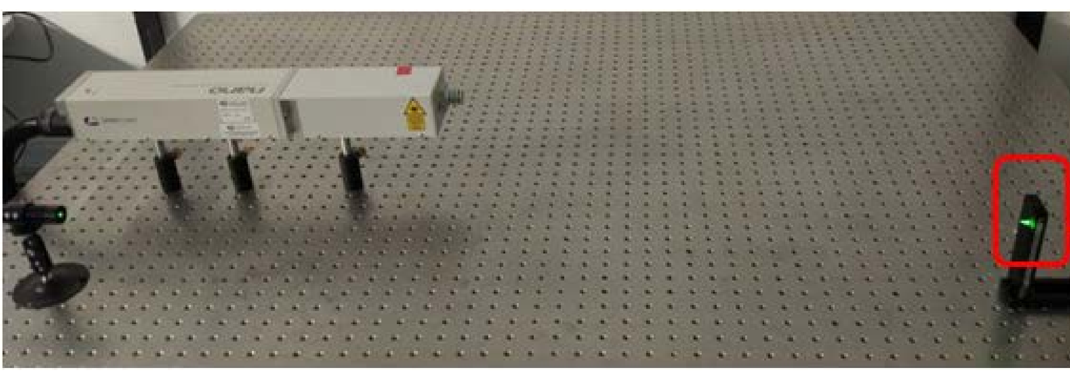


Optimization

Report of the mirrors:

Reflection mirror

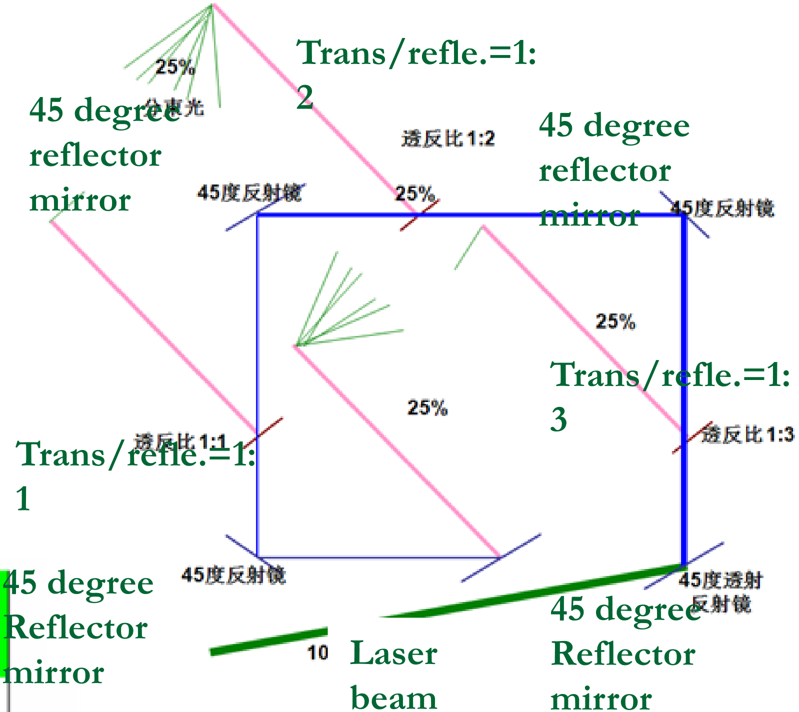
5°角	<5′	合格
15°角	<5′	合格
25°角	<5′	合格

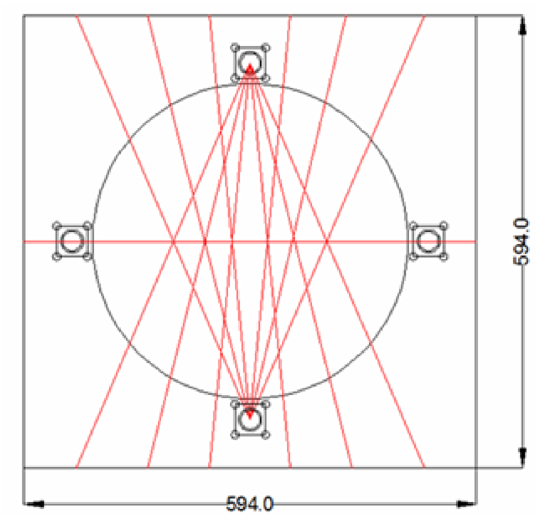


1 号	<5′	合格
2 号	<5′	合格
3 号	<1°	需优化
4 号	<10′	需优化
5 号	<5′	合格
6 号	<5′	合格

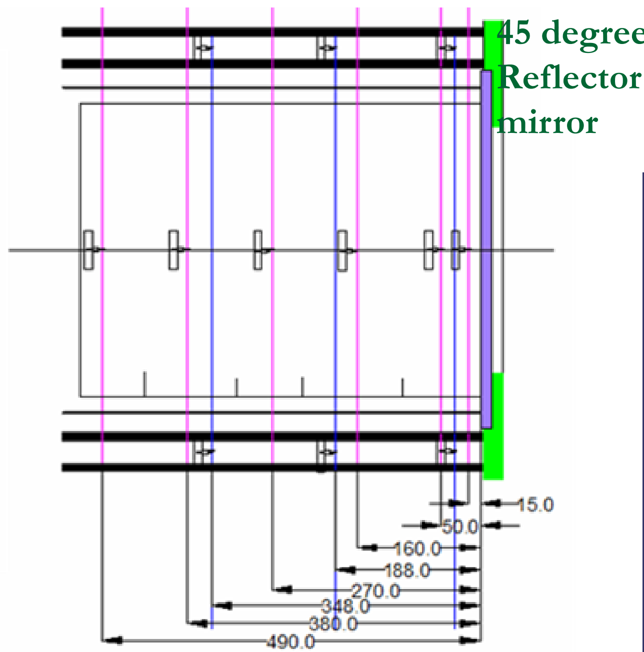
Laser map in drift length

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

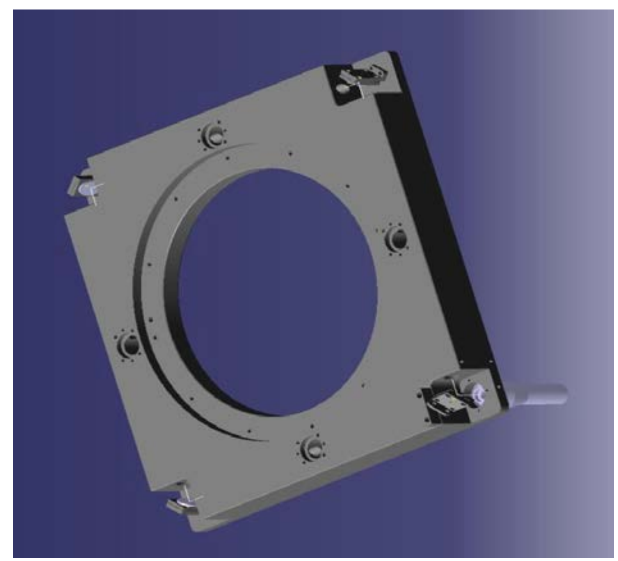




x-y方向激光光束投影分布

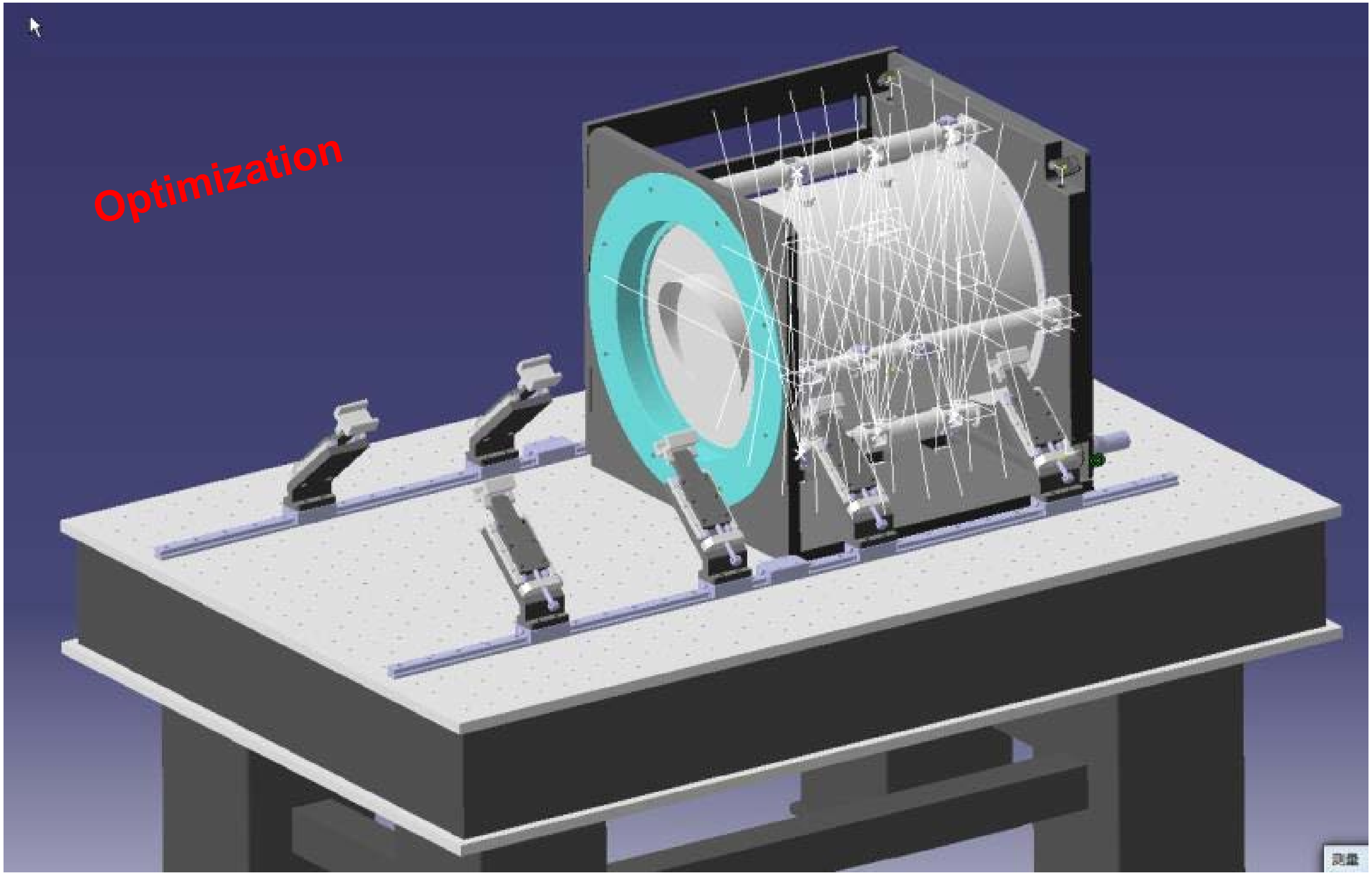


z方向激光光束投影分布



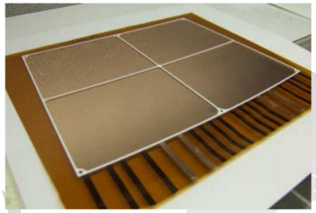
Aluminum board integrated the laser system

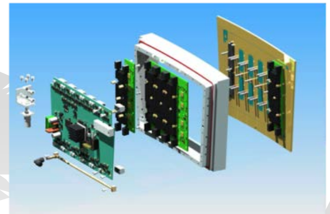
Design of the prototype with laser (Final version)

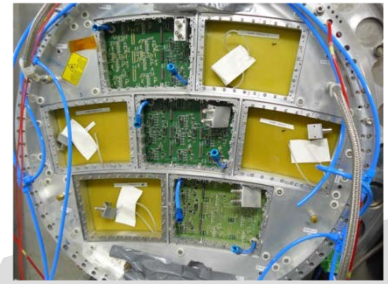


- Support platform: 1200mm×1500mm (all size as the actual geometry)
- TPC barrel mount and re-mount with the Auxiliary brackets
- Readout board (Done), Laser mirror (Done), PCB board (Done)

Brief history







Concept study | Smaller prototype | Large prototype | Common module

2006~2010 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019

Tsinghua starting for prototype
PCB readout design
Dr. Li bo
Prof. Yulan Li

IHEP starting for prototype
Hybrid concept for IBF
Dr. Huirong Qi
Prof. Yuanning Gao

We are in here
Hybrid prototype starting
Calibration using laser
CDR for CEPC

Thanks.