Progress on TPC detector module and prototype for CEPC

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Outline

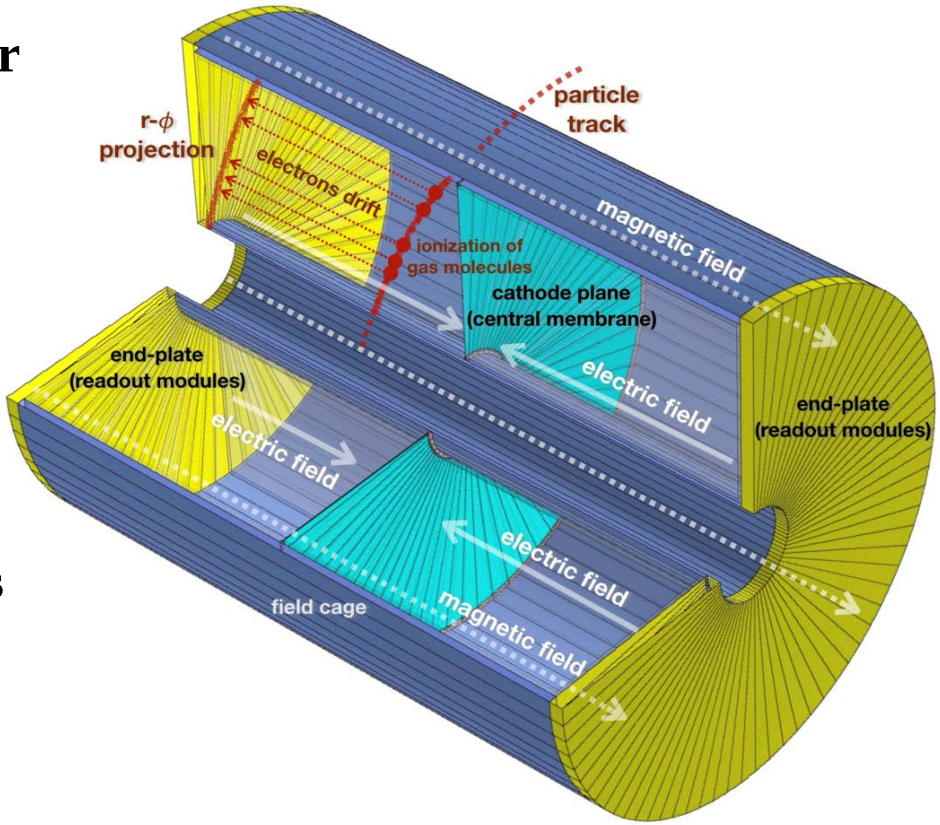
- Requirements and challenges
- Baseline design
- Feasibility study of TPC detector
- R&D activities
- Summary

TPC detector for CEPC

TPC could directly provides three-dimensional space points; the gaseous detector volume gives a low material budget; and the high density of such space points enables excellent pattern recognition capability.

Why use TPC detector as the tracker detector?

- **Motivated by the H tagging and Z**
- **TPC is the perfect detector for HI collisions …(ALICE TPC…)**
- **Almost the whole volume is active**
- **Minimal radiation length (field cage, gas)**
- **Easy pattern recognition (continuous tracks)**
- **PID information from ionization measurements (dE/dx)**
- **Operating under high magnetic field**
- **MPGD as the readout**

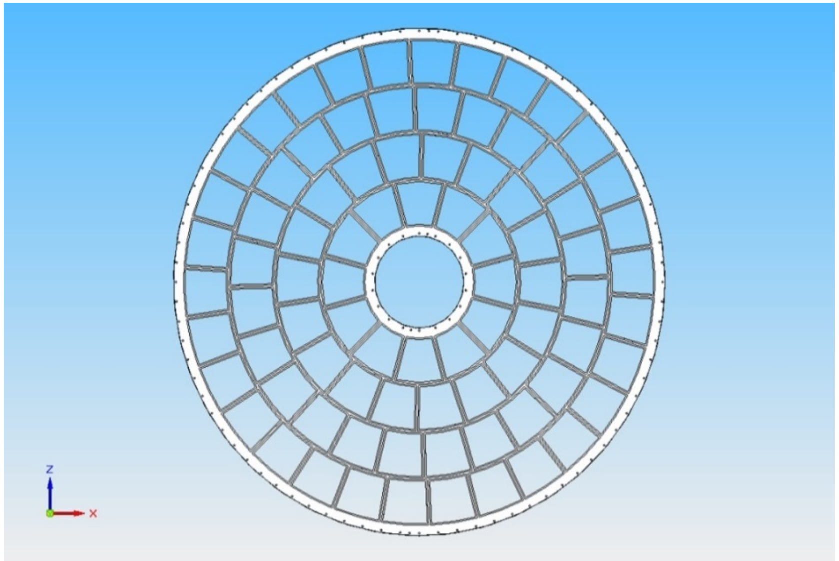


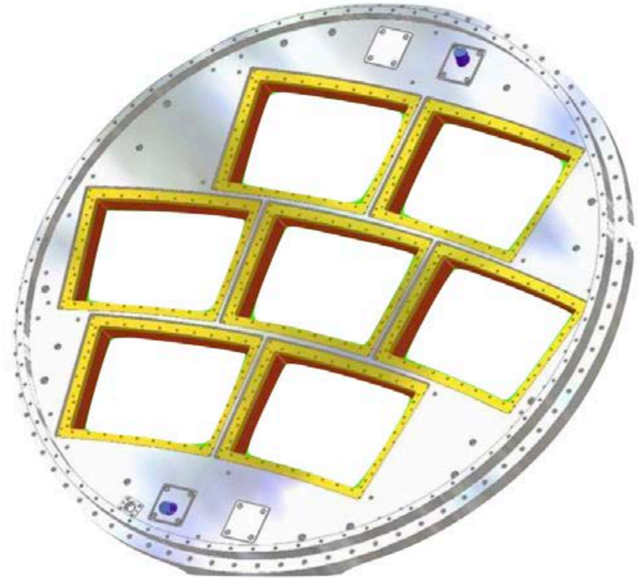
Overview of TPC detector concept

TPC requirements for CEPC

TPC detector concept:

- **Under 3 Tesla magnetic field (Momentum resolution: ~10^{-4}/GeV/c with TPC standalone)**
- **Large number of 3D space points(~220 along the diameter)**
- **dE/dx resolution: <5%**
- **~100 μm position resolution in rφ**
  - **~60μm for zero drift, <100μm overall**
  - **Systematics precision (<20μm internal)**
- **TPC material budget**
  - **<$1X_0$ including outer field cage**
- **Tracker efficiency: >97% for pT>1GeV**
- **2-hit resolution in rφ : ~2mm**
- **Module design: ~200mm×170mm**
- **Minimizes dead space between the modules: 1-2mm**



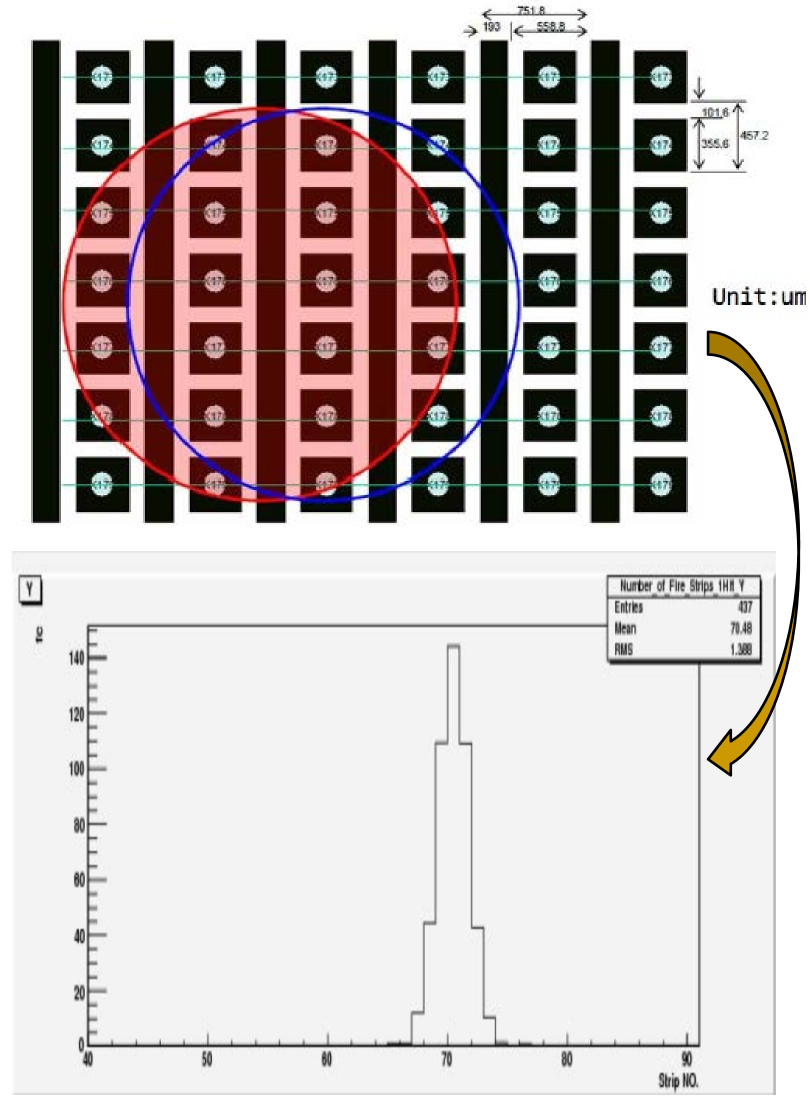


TPC detector endplate concept

Gas amplification detector module and pad size

Micro pattern detector:

- GEM and Micromegas detector
- Electron cluster using Center-of-Gravity
    - Pitch: ~1mm
    - Pad Size: ~1mm×6mm
- High gain (5000-10000)
- High rate capability: MPGDs provide a rate capability over 10^5 Hz/mm^2 without discharges that can damage electronics.
- Intrinsic ion backflow suppression: Most of the ions produced in the amplification region will be neutralized on the mesh or GEM foil and do not go back to the drift volume.
- A direct electron signal, which gives good time resolution (< 100 ps) and spatial resolution (100 μm).



The profile of an electron cluster in GEMs detector

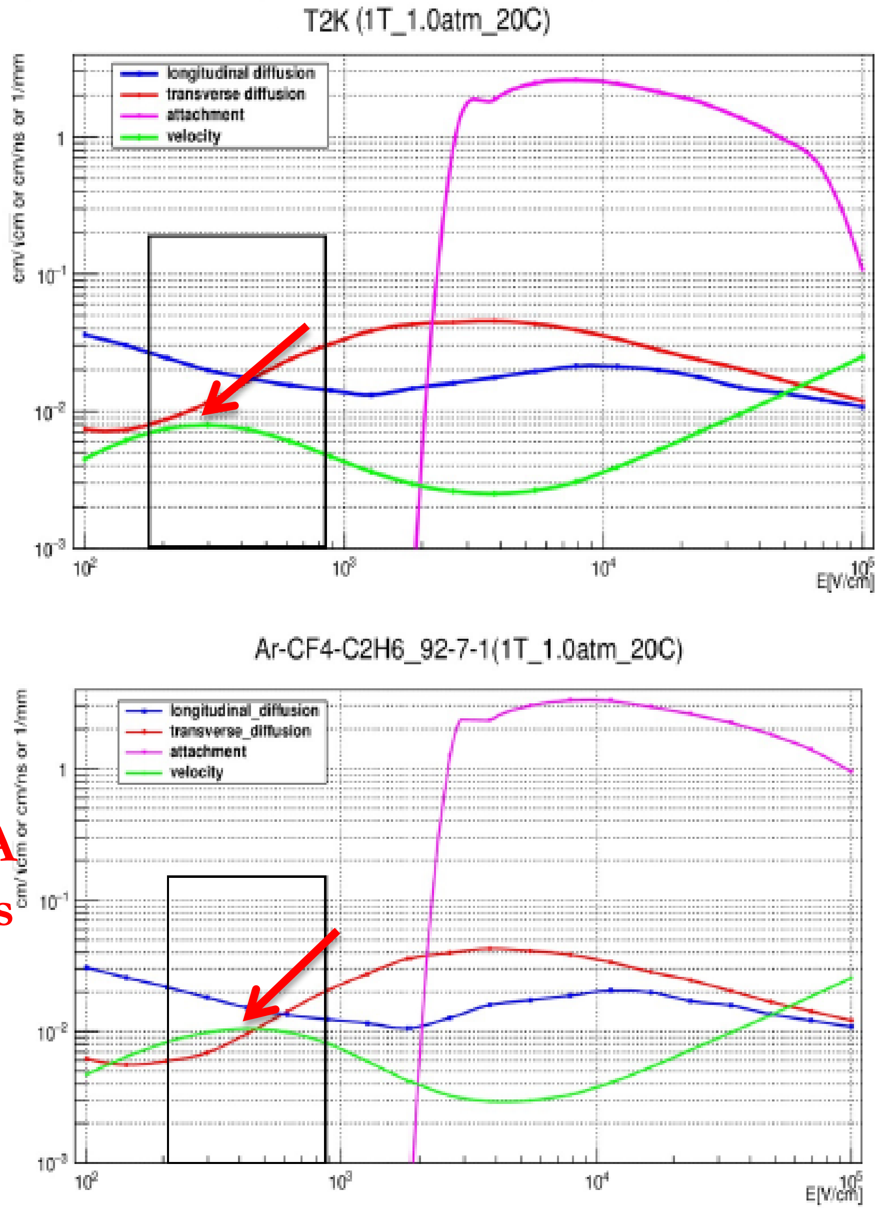
Operation mixture gases

Gas for the micro pattern detector:

- Drift velocity (green line)
- Transverse diffusion coefficient (red)
- Longitudinal diffusion coefficient (blue)
- Attachment coefficient (purple) as a function of the electric field
- The possible operation range (black rectangle)

Due to the long drift distance of 2.35m, A mixture gases with a large drift velocity is also chosen in experiments.

$Ar/CF_4/C_2H_6$ saturated drift velocity is roughly 20% higher than the default gas mixture(T2K) and the diffusion coefficients are lower.

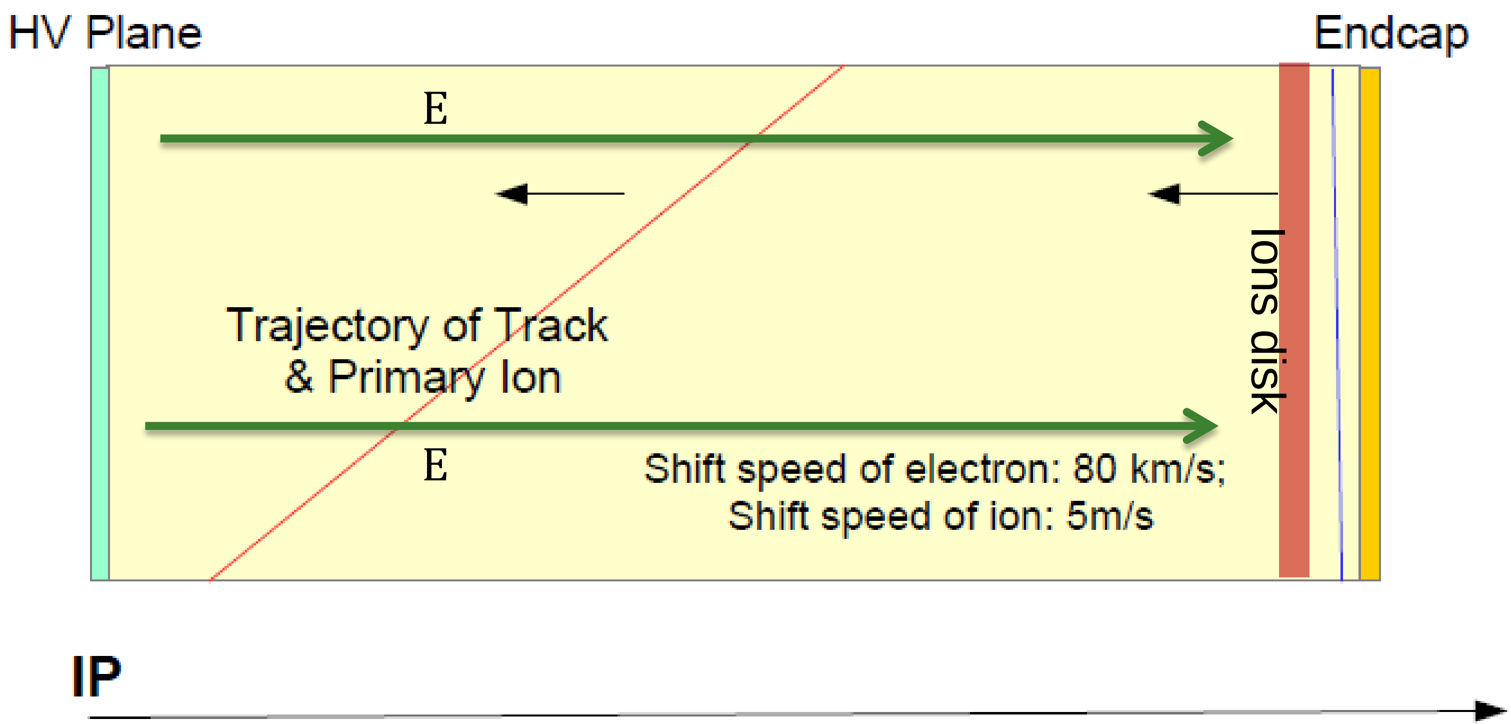


Drift velocity study of gas mixtures

Feasibility study of TPC

Voxel size defined (3D space bucket):
Pad size × T_{sample} • V_{drift}

- Would it be Limited by
  - Voxel occupancy
  - Primary ions along the track in the chamber
  - Amplification ions create the ions disk back to the chamber (×Gain)
  - Charge Distortion induced by the ions: Mainly from Ion back flow



Total ions in chamber: ~ Back flow ions ~(1 + k), k = Gain×IBF + Primary

Feasibility study of TPC at Z pole

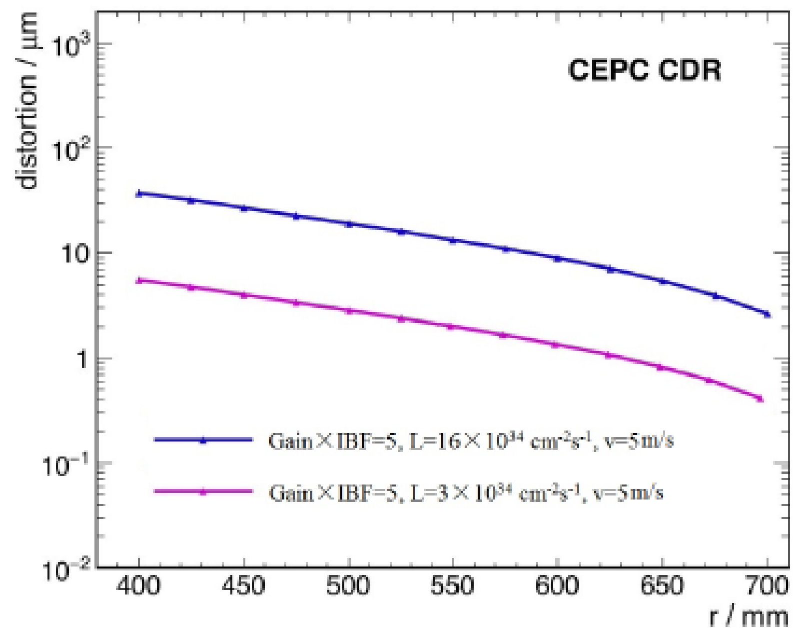
ArXiv: 1704.04401

- Occupancy simulation
  - Gain×IBF refers to the number of ions that will escape the end-plate readout modules per primary ionization, obtained by the multiplication of the readout modules gain and the ion backflow reducing rate (IBF)
  - L : the luminosity in units of $10^{34} cm^{-2}s^{-1}$
  - Voxel size: 1mm×6mm ×2mm @DAQ/40MHz
  - Maximal occupancy at TPC inner most layer: ~10^{-5} (safe)
  - Full simulation: 9 thousand Z to qq events
  - Bhabha events: a few nb
  - Background considered ? (Need careful designed Shielding/detector protection)

Pad size : 1mm×6mm

T_{sample} : 25ns

V_{drift} : 80μm/ns



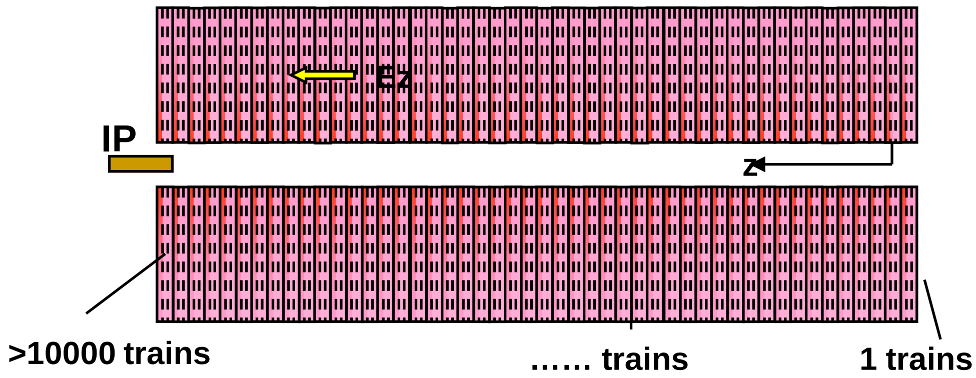
Distortion on the hit position reconstruction

To conclude, the TPC will be able to be used if the Gain×IBF can be controlled to a value smaller than 5.

Technical challenges of TPC for CEPC

Ion Back Flow and Distortion

- Goal:
  - Operate TPC at high luminosity at Z pole run
  - No Gating options
- IBF control similar with ALICE TPC upgrade
- ~100 μm position resolution in rφ
- Distortions by the primary ions at CEPC are negligible
- Manu ions discs co-exist and distorted the path of the seed electrons
- The ions cleaned during the ~us period continuously
- Continuous device for the ions
- Long working time



Amplification ions from the endplate @CEPC

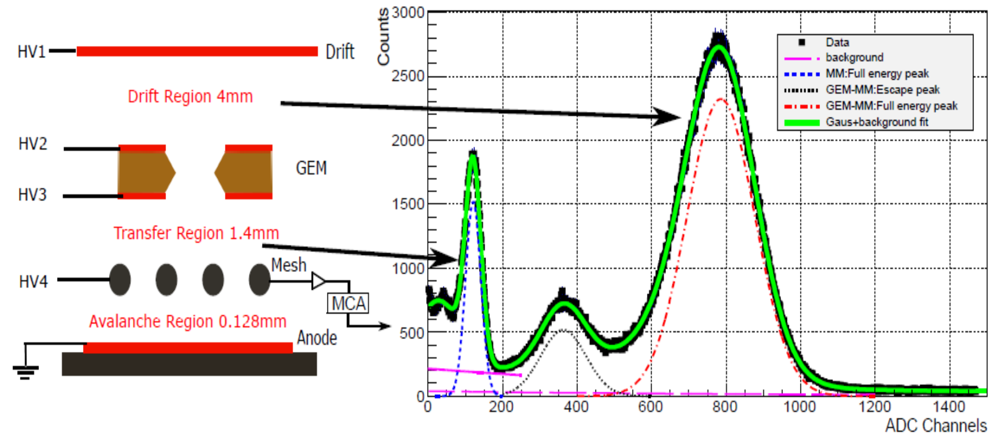
	ALICE TPC	CEPC TPC
Maximum readout rate	>50kHz@pp	w.o BG?
Gating to reduce ions	No Gating	No Gating
Continuous readout	No trigger	Trigger?
IBF control	Build-in	Build-in
IBF*Gain	<10	<5
Calibration system	Laser	NEED

Compare with ALICE TPC and CEPC TPC

Feasibility study of TPC detector

Continuous IBF module:

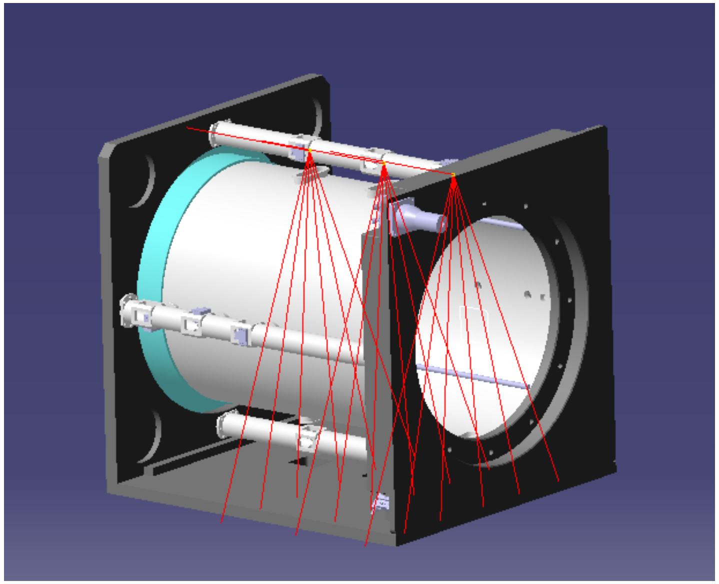
- Operation at Higgs and Z-pole run
- Continuous Ion Back Flow due to th continuous beam structure
- Low discharge and spark possibility
- Space charge effect for IBF
- Gain: 5000-6000
- Good energy resolution: <20%



Continuous IBF prototype and IBF × Gain

Laser calibration system:

- The ionization in the gas volume along the laser path occurs via two photon absorption by organic impurities (Nd:YAG laser @266nm)
- Laser calibration system around the chamber
- Calibration of the drift velocity, gain uniformity, the distortion
- High stability of the laser beam (<5μm)



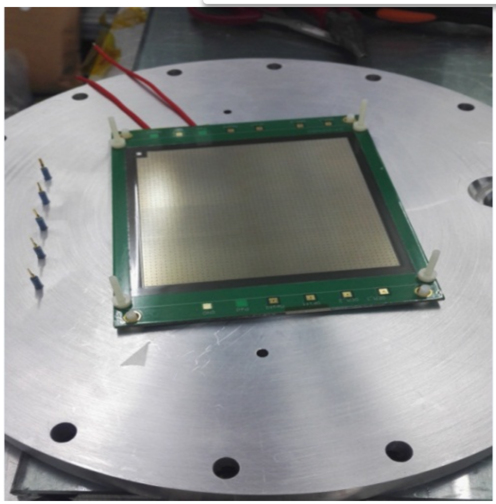
TPC prototype integrated with laser system

- Some R&D activities in China
  - TPC detector module -> IBF control
  - TPC detector prototype -> Calibration
  - Some issues -> FEE ASIC chip

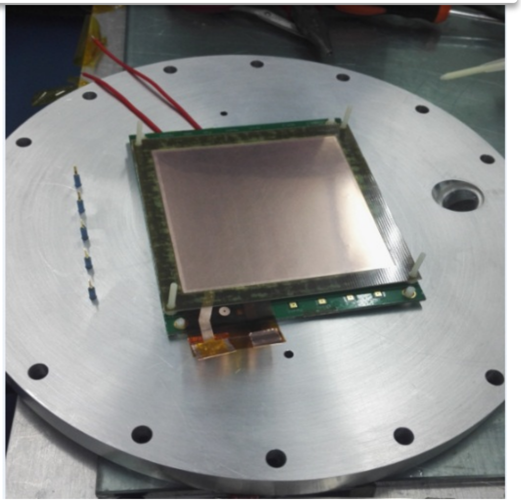
TPC detector module@ IHEP

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

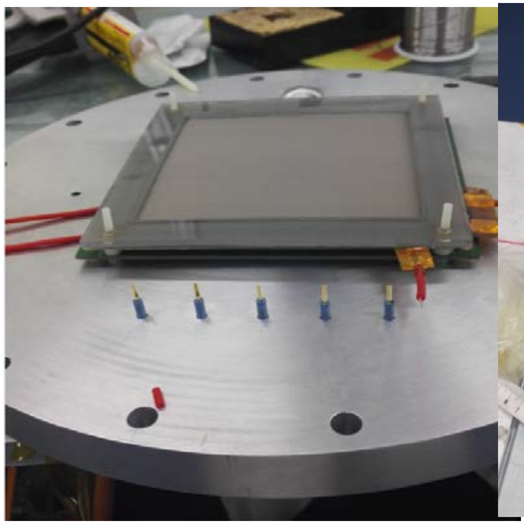
- Study with GEM-MM module
  - New assembled module
  - Active area: 100mm×100mm
  - X-tube ray and 55Fe source
  - Bulk-Micromegas assembled from Saclay
  - Standard GEM from CERN
  - Avalanche gap of MM:128μm
  - Transfer gap: 2mm
  - Drift length:2mm~200mm
  - pA current meter: Keithley 6517B
  - Current recording: Auto-record interface by LabView
  - Standard Mesh: 400LPI
  - High mesh: 508 LPI



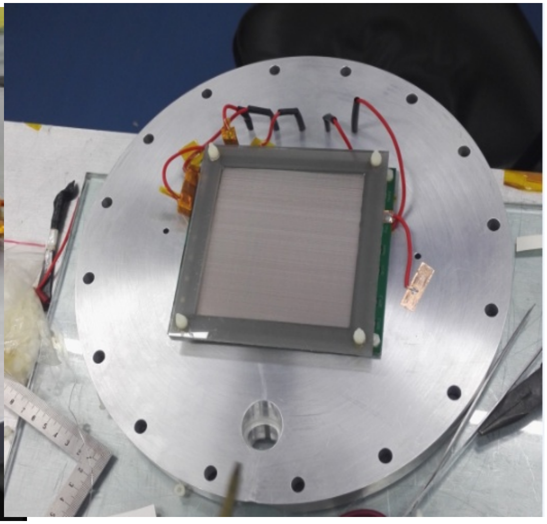
Micromegas(Saclay)



GEM(CERN)

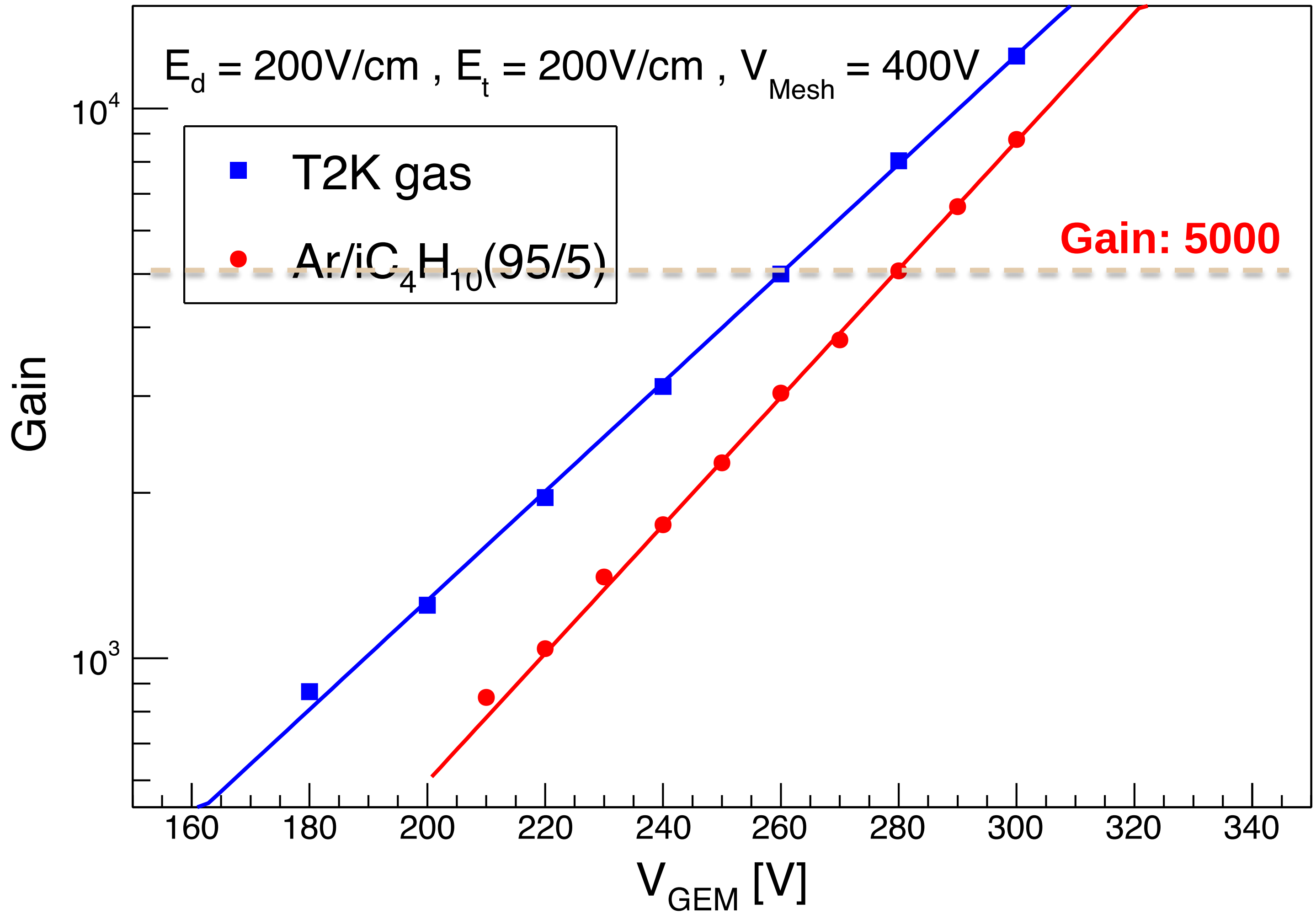


Cathode with mesh

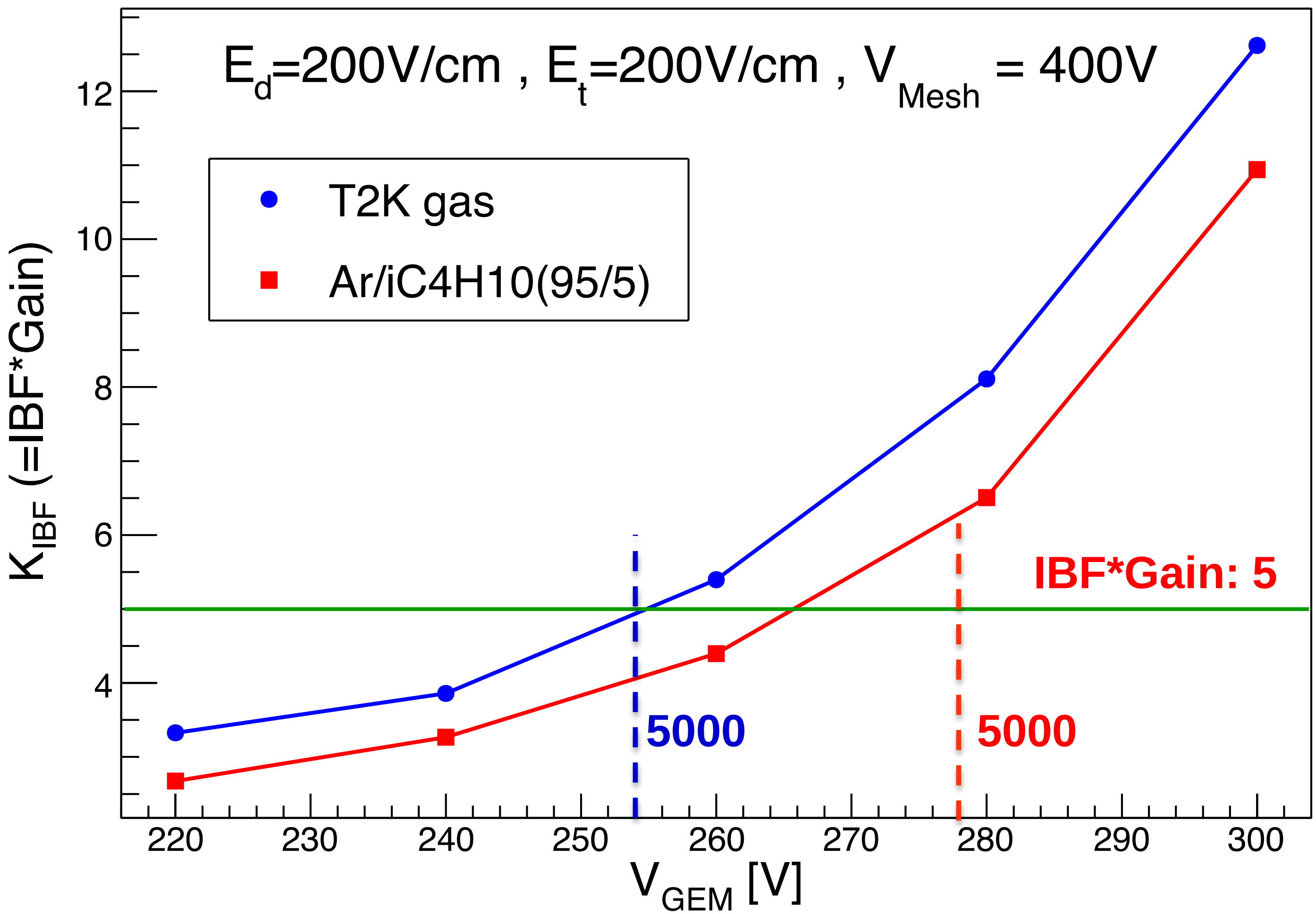


GEM-MM Detector

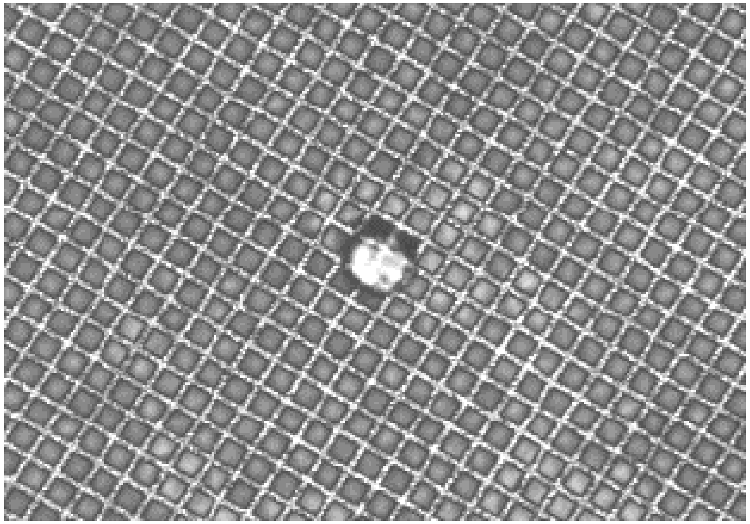
Gain of the hybrid structure detector

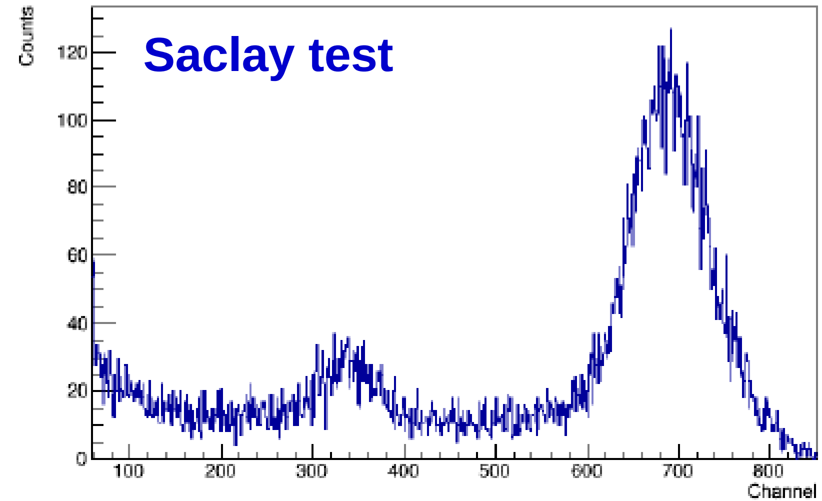


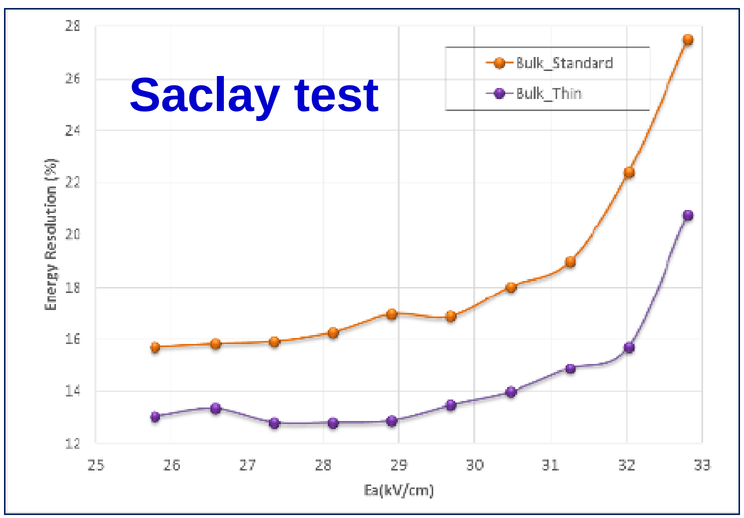
Key IBF factor: IBF×Gain

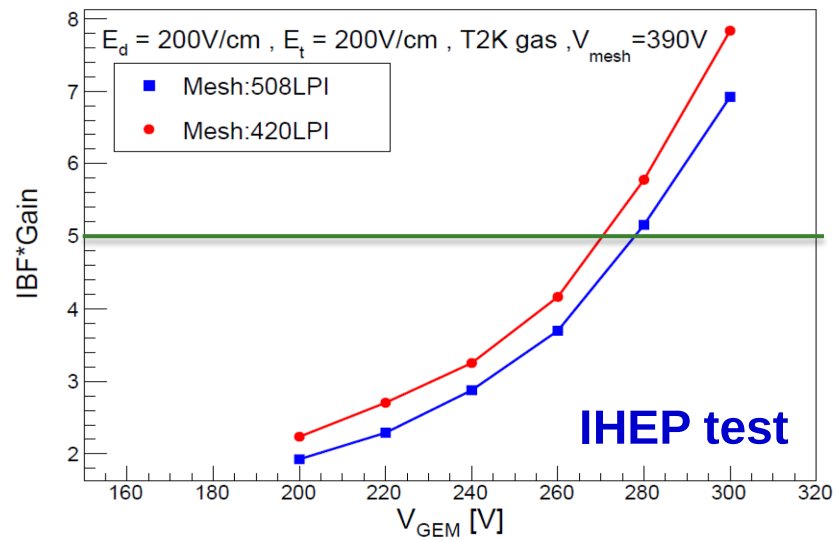


High mesh and lower IBF







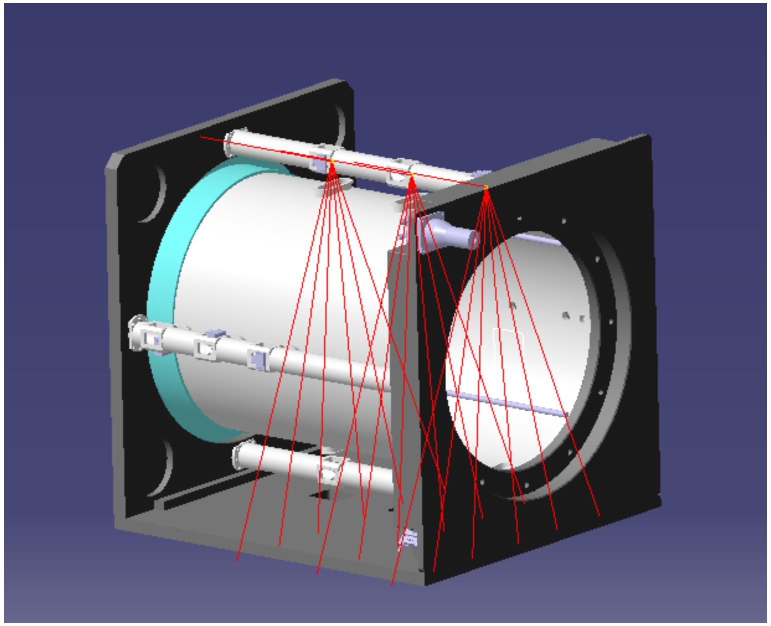


- From July, the high mesh of 508LPI has been assembled with CEA-Saclay collaboration. The preliminary results indicates that it could reach the lower IBF and better performance.

Motivation of the TPC prototype

- Study and estimation of the distortion from the IBF and primary ions with the laser calibration system
- Main parameters
  - Drift length: ~510mm, Readout active area: 200mm×200mm
  - Integrated the laser calibration with 266nm
  - GEMs/Micromegas as the readout
  - Matched to assembled in the 1.0T PCMAG

1. **TPC chamber**
2. **Laser calibration**



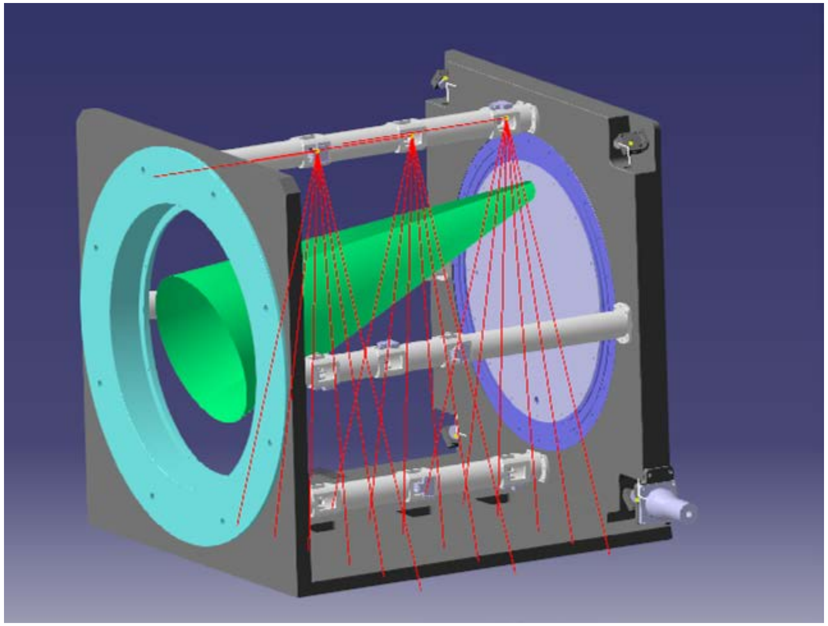
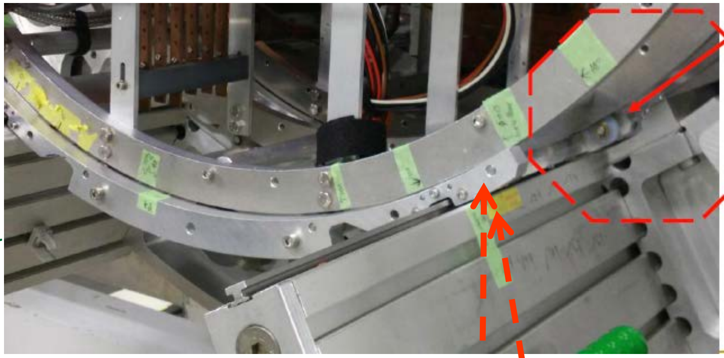
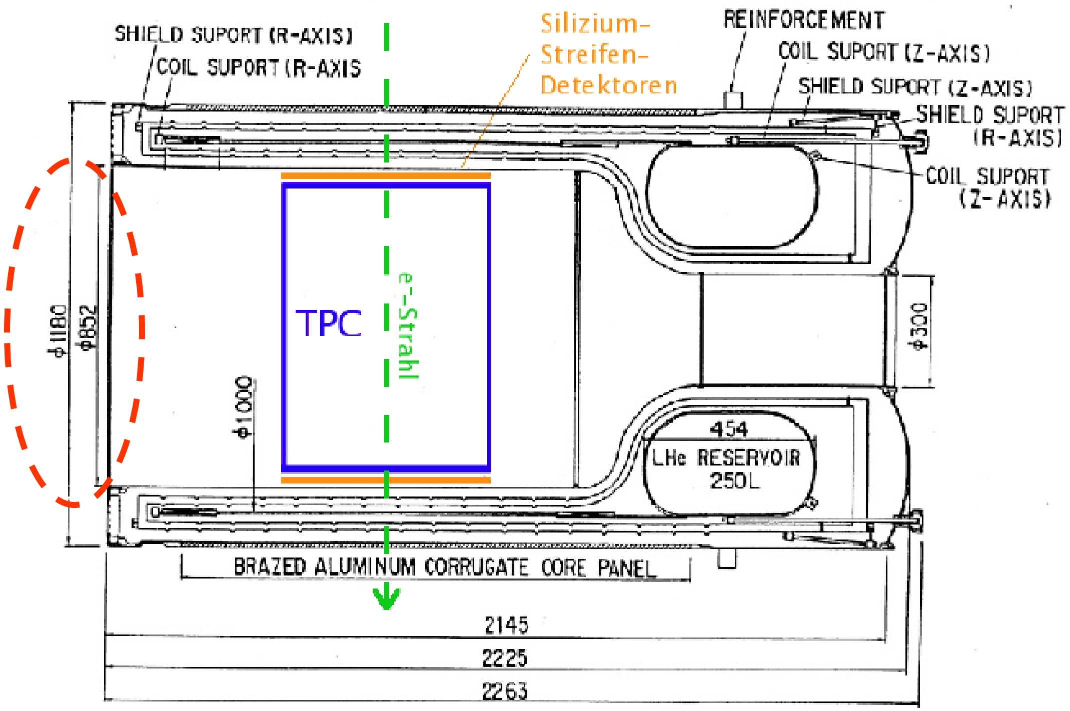


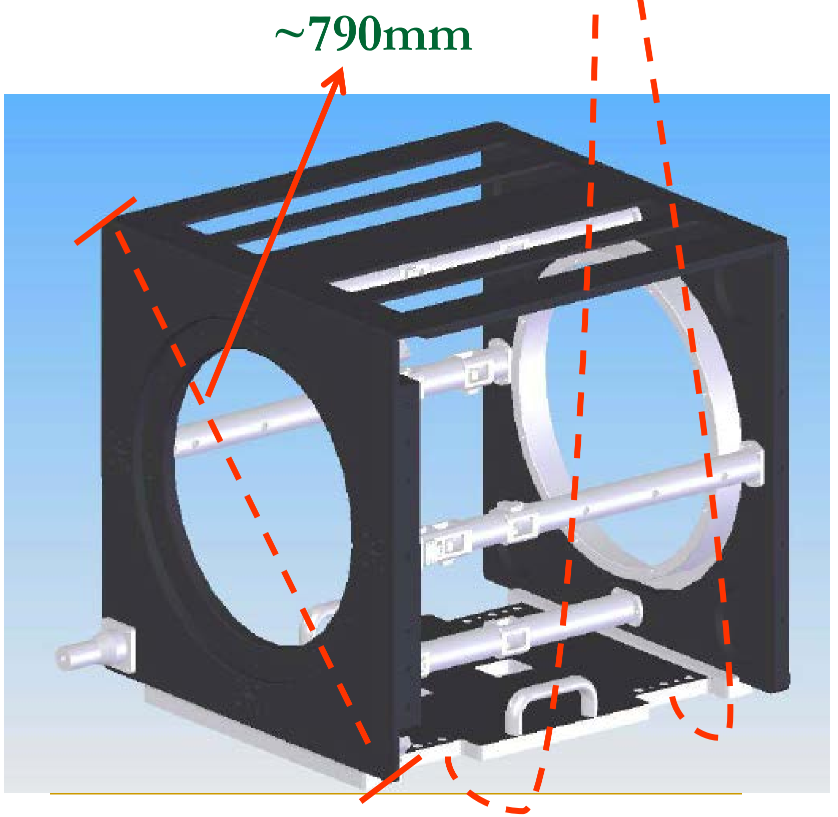
Diagram of the TPC prototype with the laser calibration system

Laser calibration system

- Main parameters
  - Easily to move with the support platform
  - Designed to assemble in Magnet@DESY
  - Separable parts: TPC+ Laser system
  - Cosmic and electron beam test



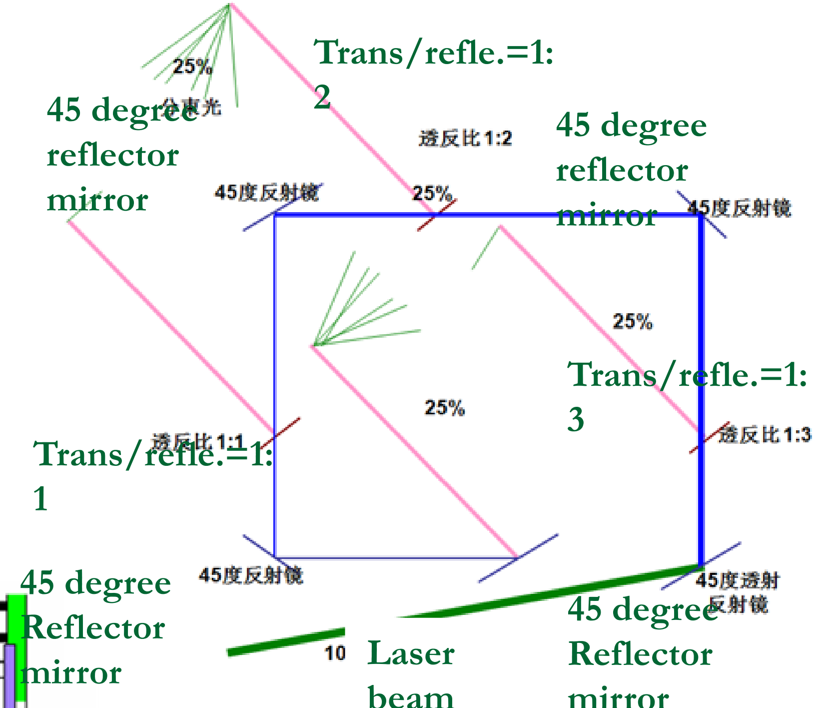


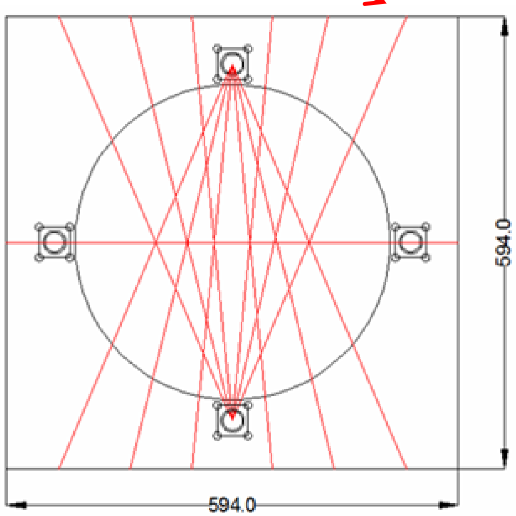


Dimension of the TPC prototype according to the PCMAG

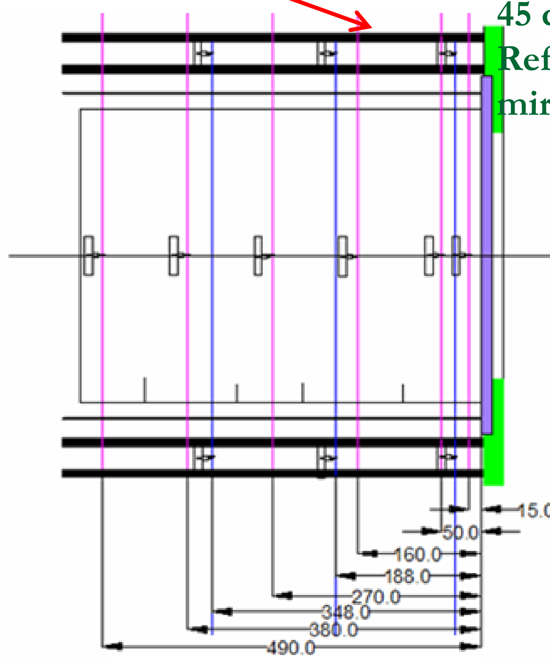
Laser map in drift length

- 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





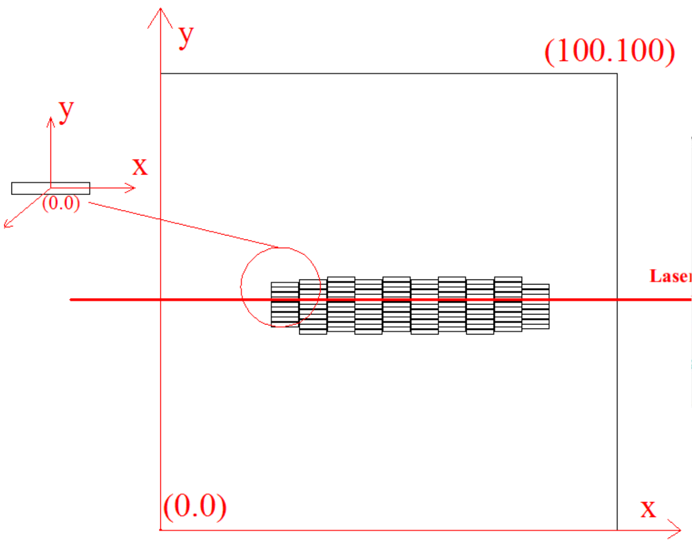
Laser map in X-Y plane

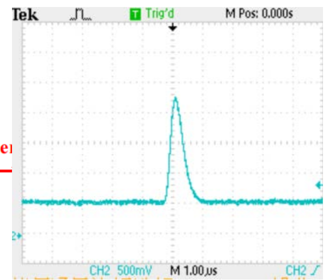


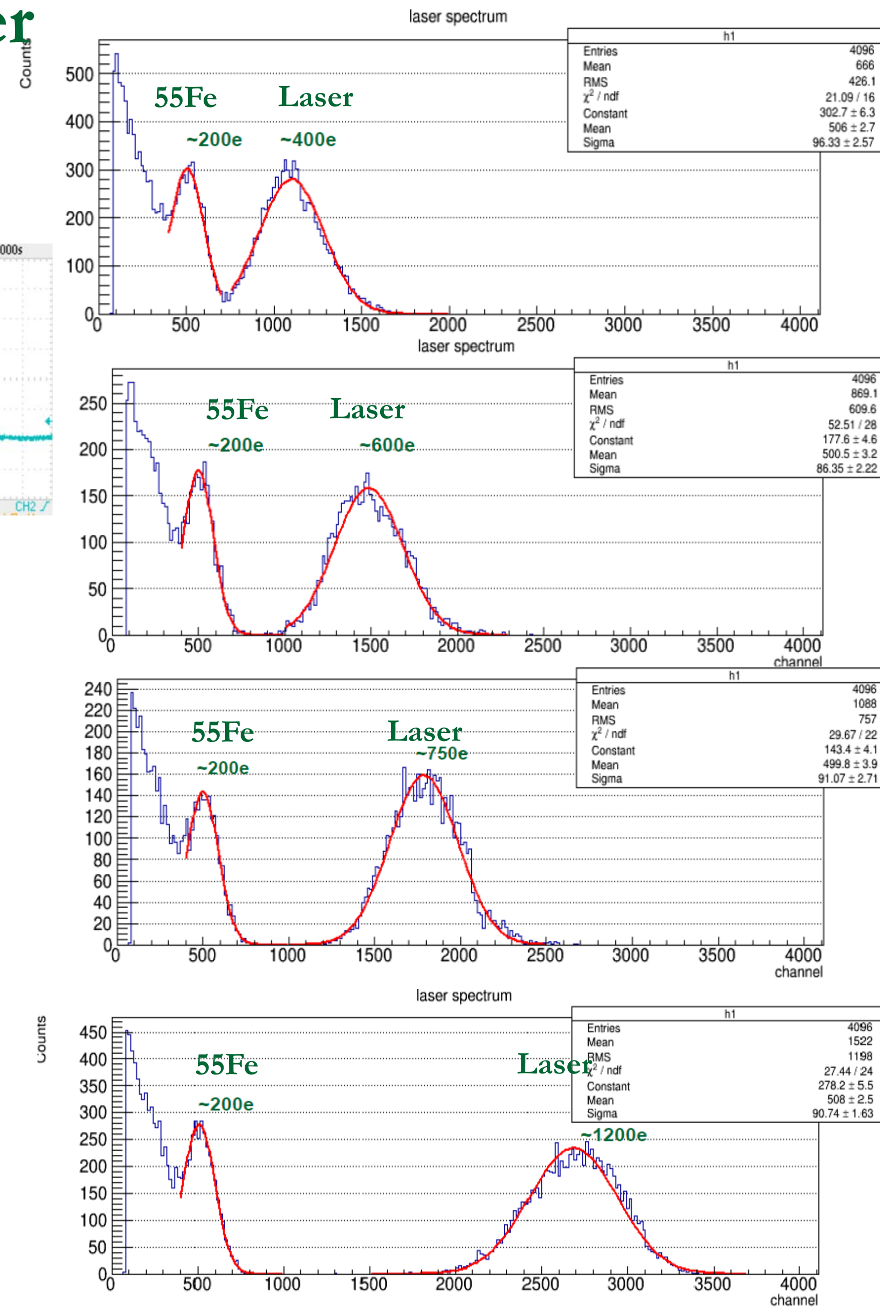
Laser map along Z

Detector with the laser system

Preliminary test with the laser







- Readout board, 128 Channels electronics, DAQ and laser mirror and PCB board have been done and assembled
- TPC barrel mount and re-mount with the Auxiliary brackets
- TPC preliminarily tested with 55Fe and the different power laser beam
- Optimization of the laser studied

Some activities for TPC R&D

Many thanks for your attentions for the talks and posters
Some dedicated details of the design and results showing

17:00 **Low power ASIC** *20'*
Speaker: Zhi Deng (Tsinghua University)

16:20 **Progress on the TPC prototype in Saclay (by vidyo)** *20'*
Speaker: Boris Tuchming (Saclay, France)

14:45 **Readout and data acquisition for Laser TPC prototype** *15'*
Speaker: Gong Hui

Plenary: Poster session
Convener: Dr. Gang LI (EPD, IHEP, CAS)
Location: Lobby of new building

18:30 **01.The Progress Report of 65nm Low Power Readout ASIC for TPC** *3'*
Speaker: Mr. Wei Liu (THU)

18:33 **02.Progress on TPC detector prototype integrated the laser calibration system** *3'*
Speaker: WANG Haiyun

18:36 **03.Optimization study of the drift field for TPC detector in CEPC** *3'*
Speaker: Mr. Yiming Cai (THU)

Summary and further R&D

Requirements and critical challenges for CEPC:

- High momentum resolution and position resolution
- Continuous beam structure and the ~25ns time space

Continuous IBF module for CEPC:

- Continuous Ion Back Flow supression
- Key factor: IBF×Gain=5 and leas than (R&D)
- Low discharge and the good energy spectrum

CDR towards TDR!

Be patient if something doesn't work out of the requirements or may take some time

And more work!

Prototype with laser calibration for CEPC :

- It needs very sophisticated calibration in order to reach the desired physics performance at Z pole run
- Prototype has been designed with laser (Developed in IHEP and Tsinghua)

Collaboration:

- Signed MOA with LCTPC international collaboration on 14, Dec., 2016
- New design detector collaborated with CEA-Saclay
- FEE electronics and DAQ collaborated with Tsinghua University

Thanks.