Progress of TPC prototype with the laser system for the future collider

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On behalf of TPC detector subgroup

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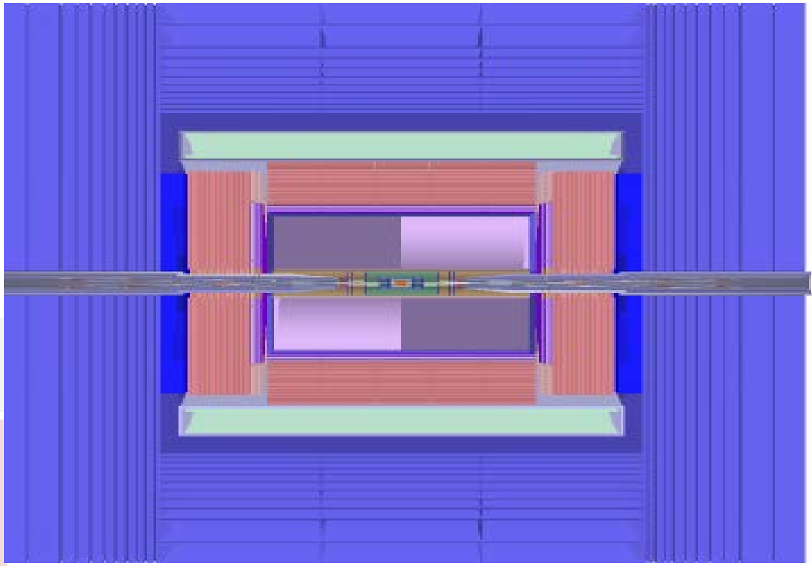
Outline

- Physics requirements
- Simulation of IBF at Z
- TPC prototype R&D
- Some collaboration
- Summary

Detector Concepts (CEPC CDR)

ArXiv:1811.10545

- Baseline: Silicon + TPC
- FST: all-silicon tracker
- IDEA: Silicon+Drift chamber (DCH)

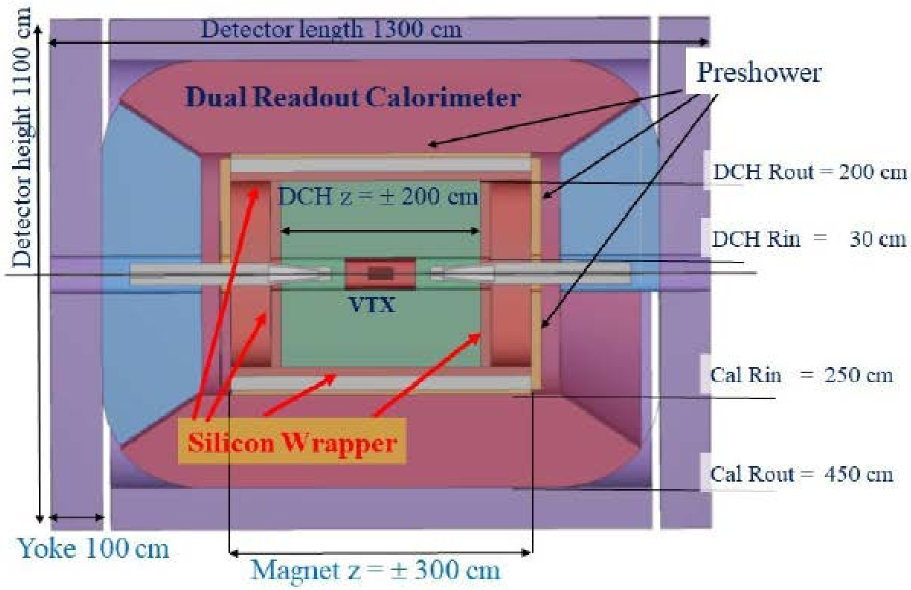


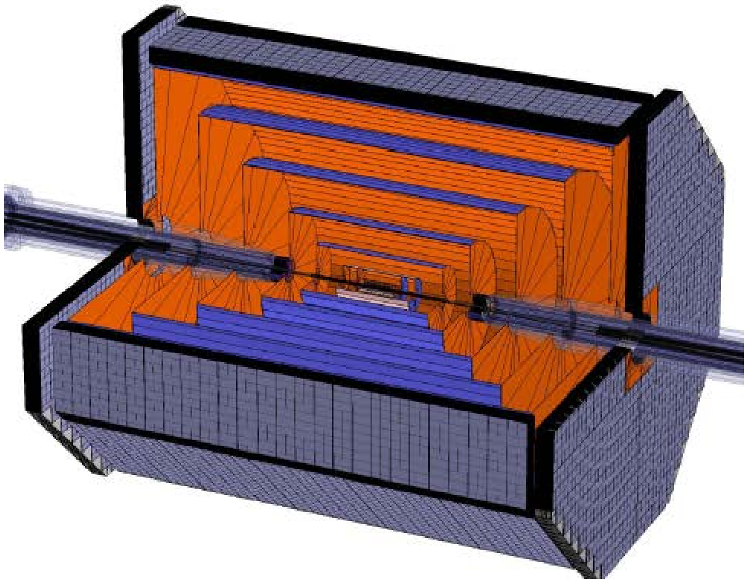
CEPC CDR

Lumi.	Higgs	W	Z	Z(2T)
$\times 10^{34}$	2.93	11.5	16.6	32.1

Luminosities exceeded those in the preCDR

- double ring baseline design (30MW/beam)
- switchable between H and Z/W w/o hardware change (magnet switch)
- use half SRF for Z and W
- can be optimized for Z with 2T detector



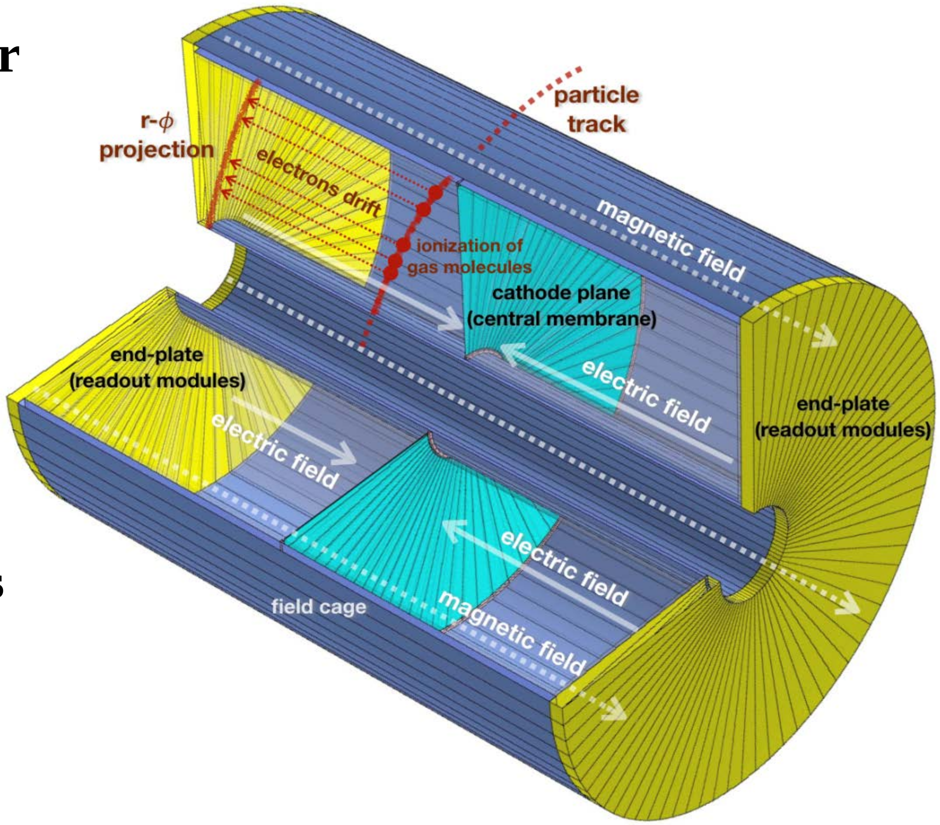


TPC detector at CEPC

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?

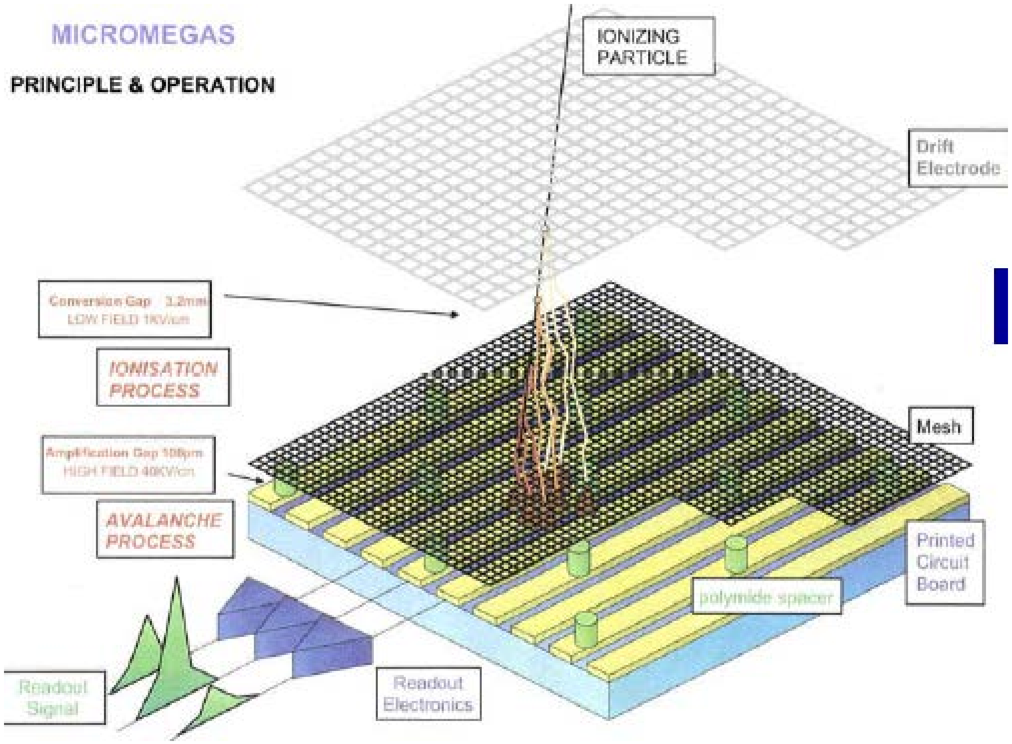
- **Motivated by the H tagging and Z**
- **TPC is the perfect detector for HI collisions …(ALICE TPC…)**
- **Almost the whole volume is active**
- **Minimal radiation length (field cage, gas)**
- **Easy pattern recognition (continuous tracks)**
- **PID information from ionization measurements (dE/dx)**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



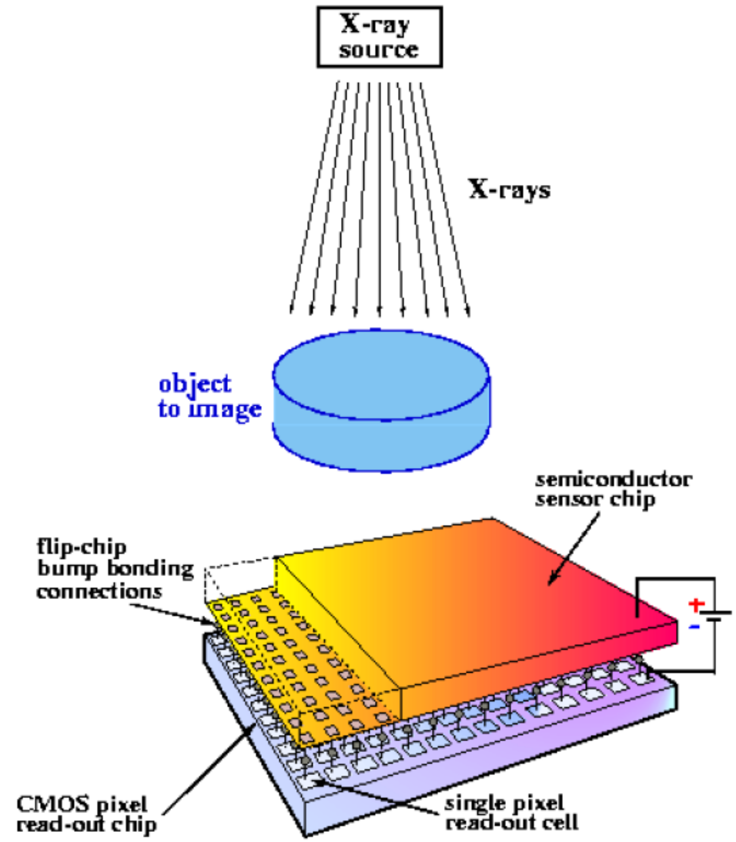
Overview of TPC detector concept

Readout of TPC

----→ Pixel R&D: Kees's talkc

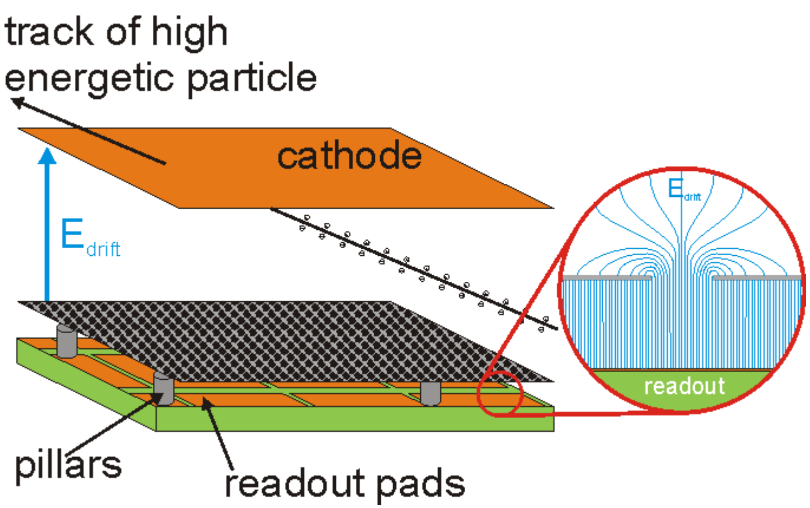


Standard charge collection



ASIC chip with sensors

Pad and pixel TPC for collider



- Standard charge collection:
  - Pads of several mm2
  - Long strips (l~10 cm, pitch ~200 μm)
- Instead: Bump bond pads are used as charge collection pads

Benefits of GridPix readout:
- Lower occupancy → better track finding
- Improved dE/dx→ primary e- counting

- Smaller pads/pixels could result in better resolution!
- Gain <2000
- At Nikhef the GridPix was invented from 2003.

For Collider @cost:
But to readout the TPC with GridPixes:
~100-120 chips/module
240 modules/endcap (10 m^2)
→50k-60k GridPixes

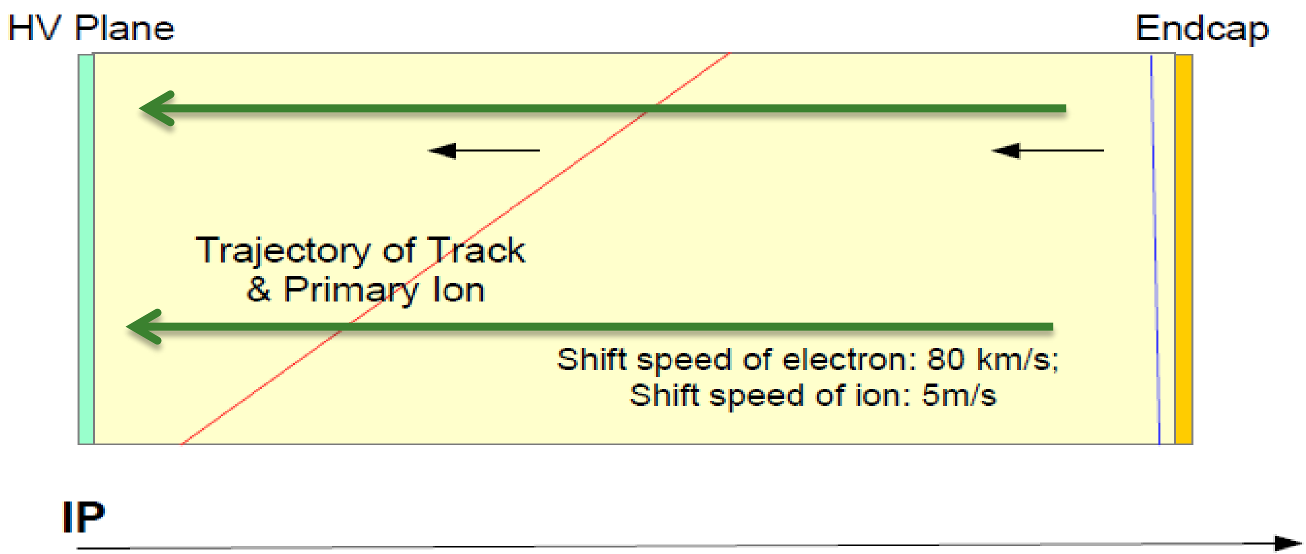
Feasibility and limitations

----→ASIC R&D: Wei Liu's talk
----→ IBF R&D: Zhiyong's talk

TPC limitations for Z

- Ions back flow in chamber
- Calibration and alignment
- Low power consumption FEE ASIC chip

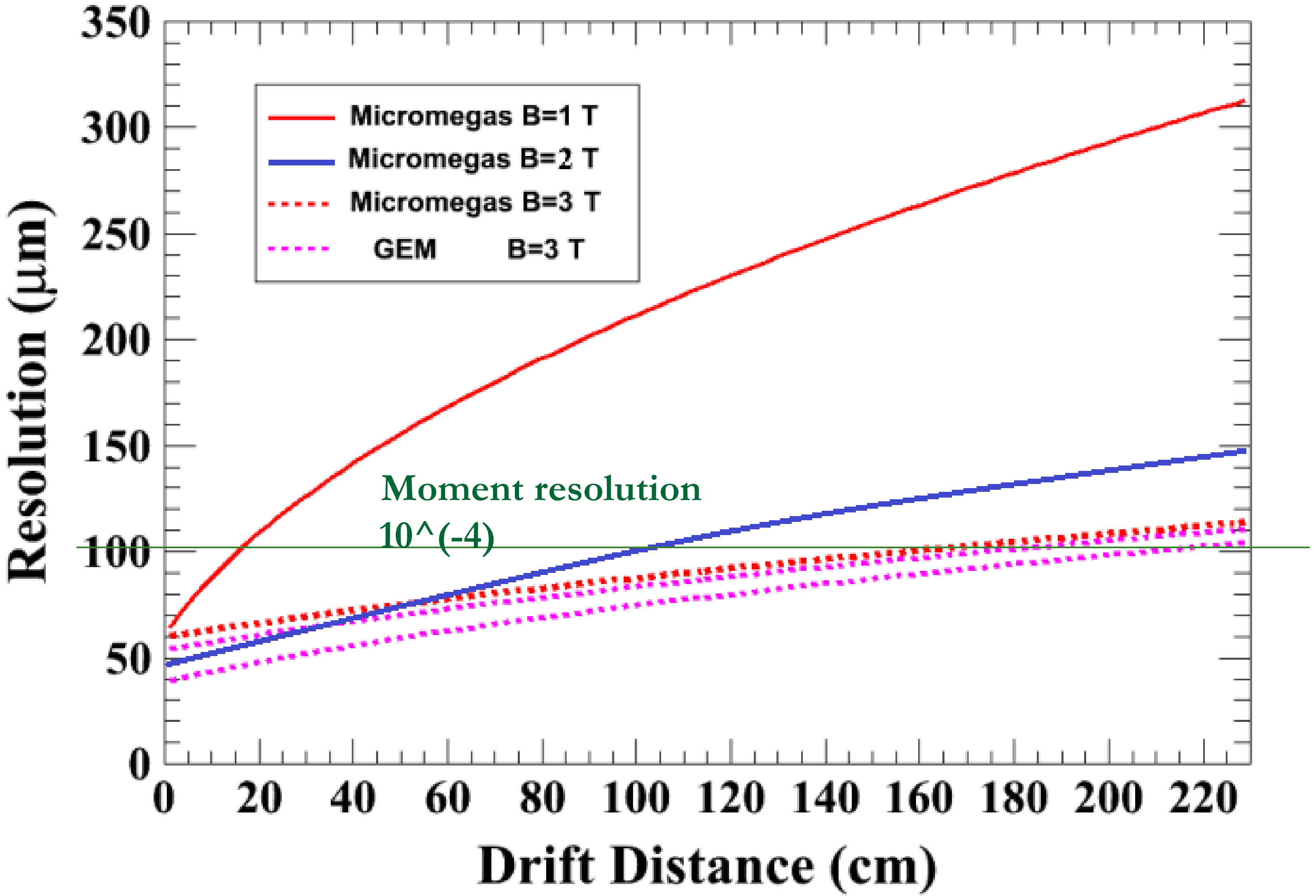
	ALICE TPC	CEPC TPC
Maximum readout rate	>50kHz@pp	w.o BG?
Gating to reduce ions	No Gating	No Gating
Continuous readout	No trigger	Trigger?
IBF control	Build-in	Build-in
IBF*Gain	<10	<5
Calibration system	Laser	NEED



Compare with ALICE TPC and CEPC TPC

Resolution along drift length (simulation)

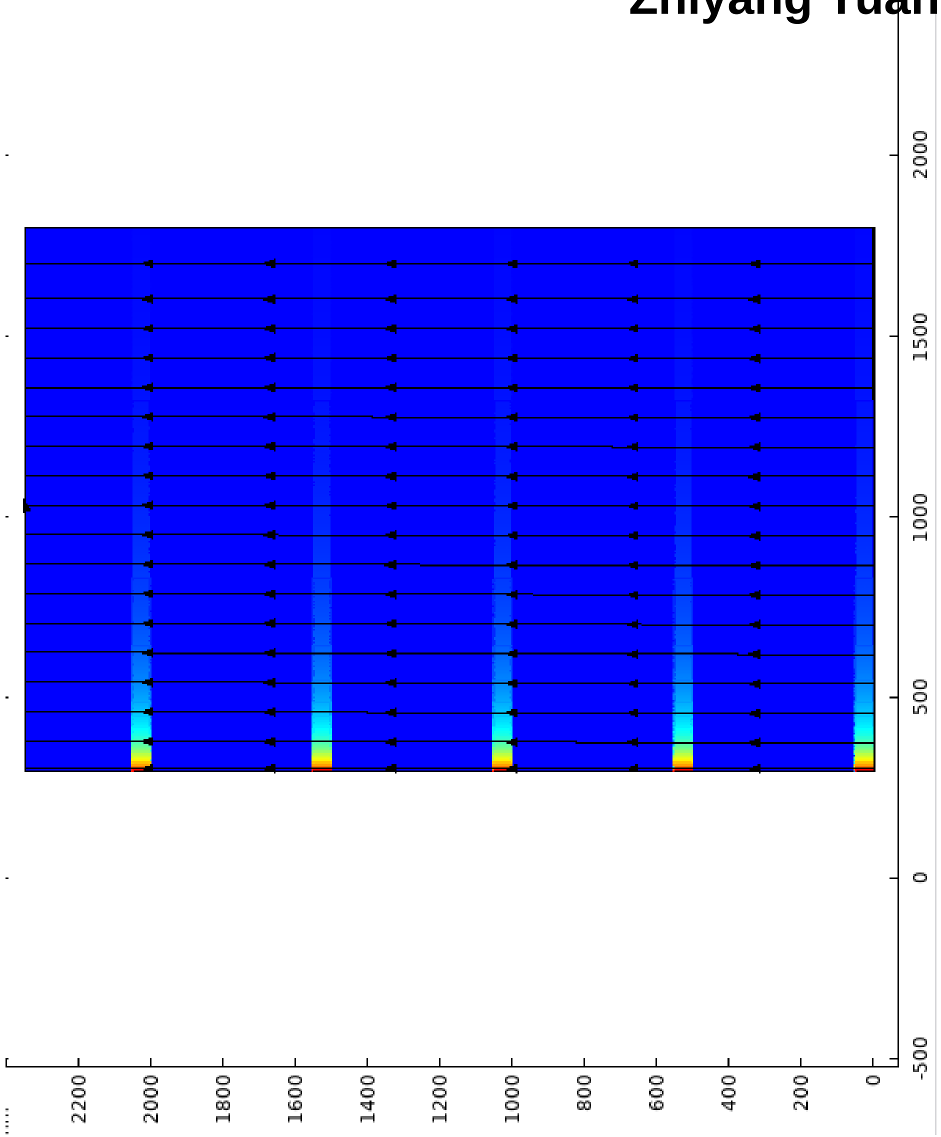
Zhiyang Yuan



Simulation of IBF effect

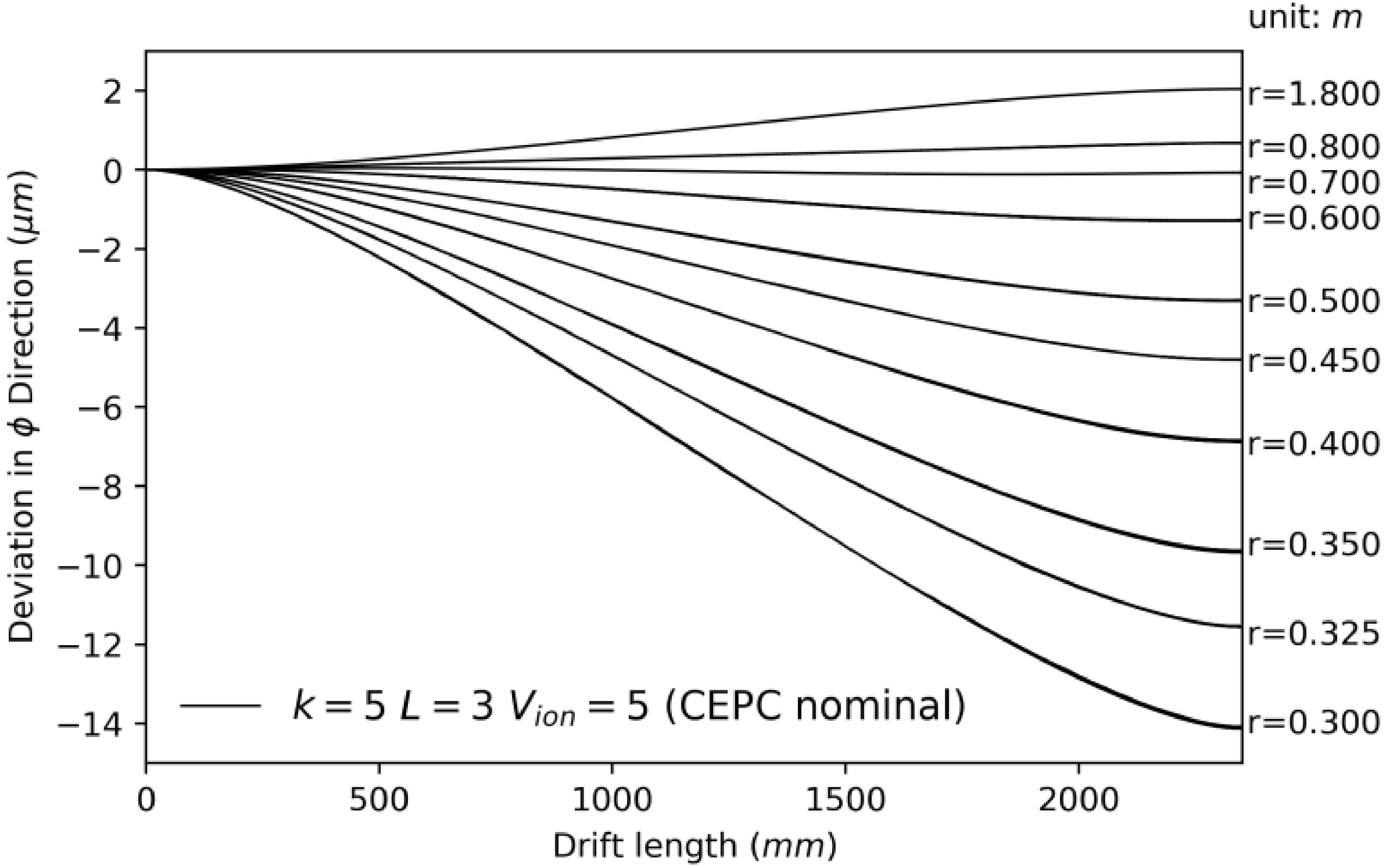
Zhiyang Yuan

- Simulation
  - Re-established the model
  - Validated with 3 ions disks
  - Simulation of the multi ions disk in chamber under the continuous beam structure
  - Input from the full simulation data
  - IBF×Gain default as the factor of 5
  - Higgs run
  - Z pole run at the high luminosity
  - Without the charge of the beam-beam effects in TPC



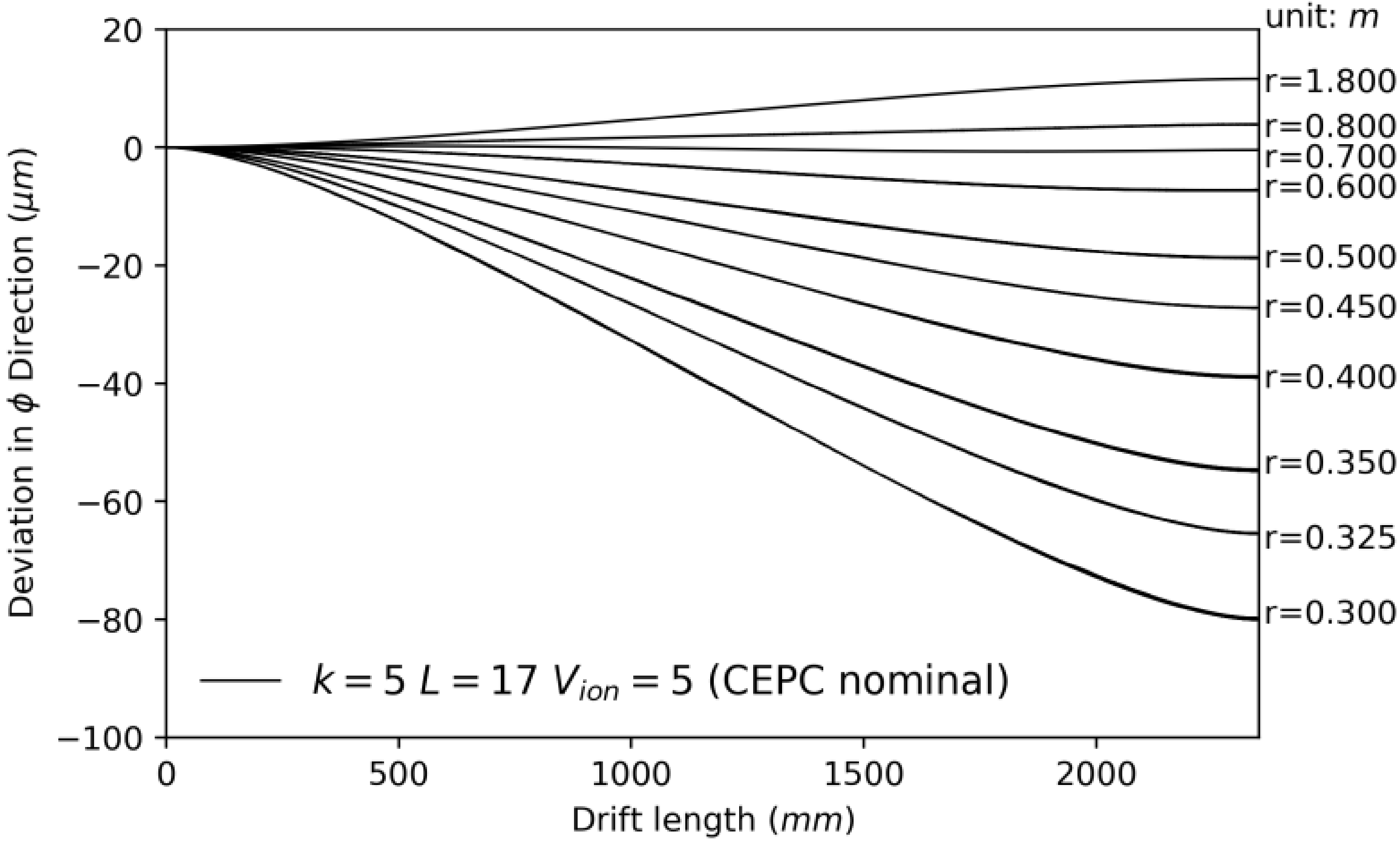
Simulation of deviation with IBF (k=Gain×IBF) @CEPC

Zhiyang Yuan



Deviation in Φ at CEPC Higgs run with $3 \times 10^{34} cm^{-2}s^{-1}$ (Lumi.)

Simulation of deviation with IBF (k=Gain×IBF) @CEPC



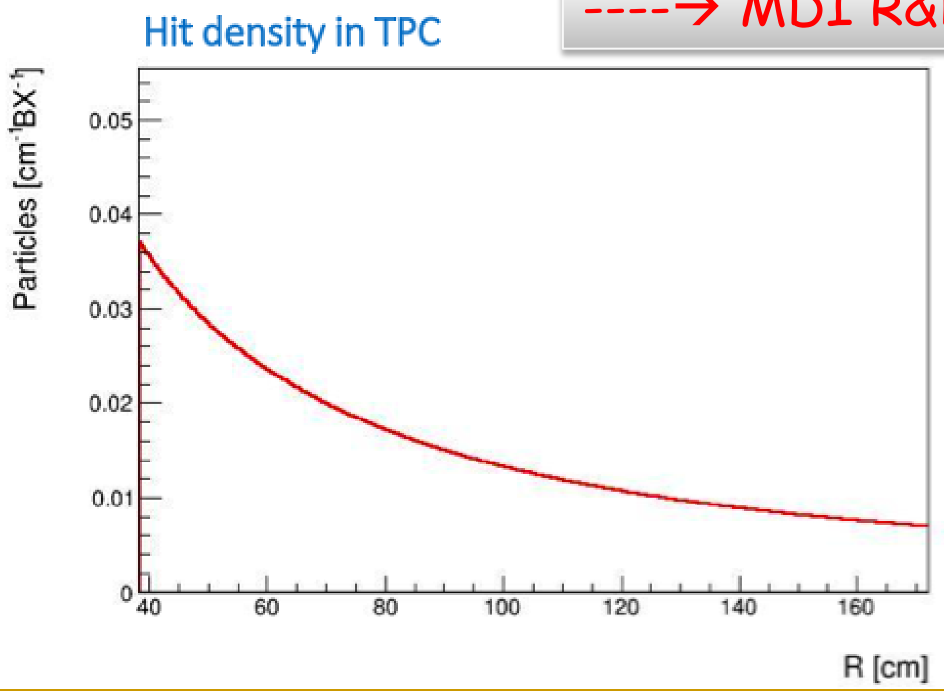
Deviation in Φ at CEPC Z pole run with $17\times10^{34}cm^{-2}s^{-1}$ (Lumi.)

Some key issues to validate

Important to estimate the charge in the TPC as it causes distortions.

1. Physics events like Zs
2. Beam-beam interactions that produce hits

----→ MDI R&D: Hongbo's talkc



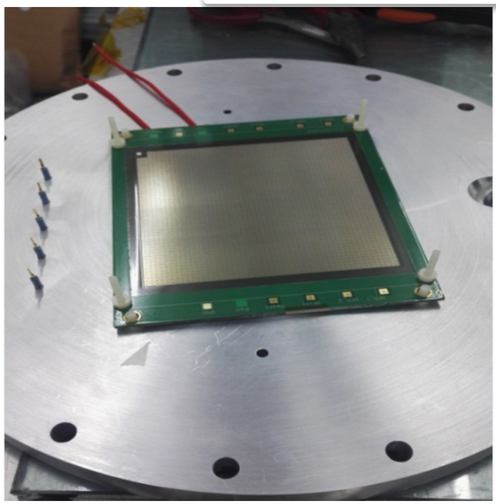
TPC prototype R&D

TPC detector module@ IHEP

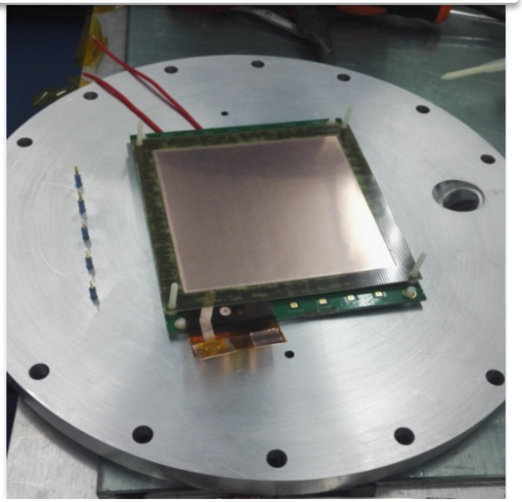
Preliminary R&D and first step

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

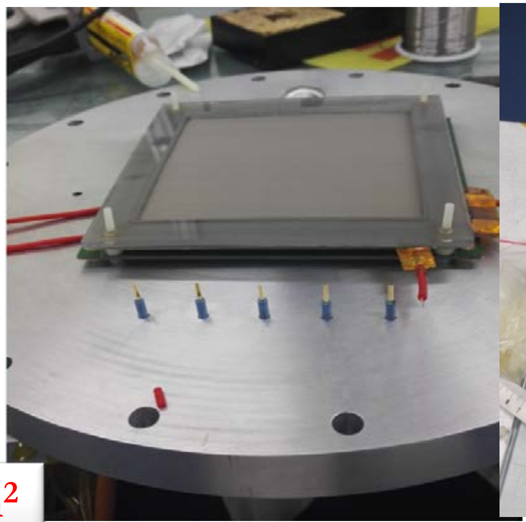
- Study with GEM-MM module
  - New assembled module
  - Active area: 100mm×100mm
  - X-tube ray and 55Fe source
  - Bulk-Micromegas assembled from Saclay
  - Standard GEM from CERN
  - Avalanche gap of MM:128μm
  - Transfer gap: 2mm
  - Drift length:2mm~200mm
  - pA current meter: Keithley 6517B
  -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



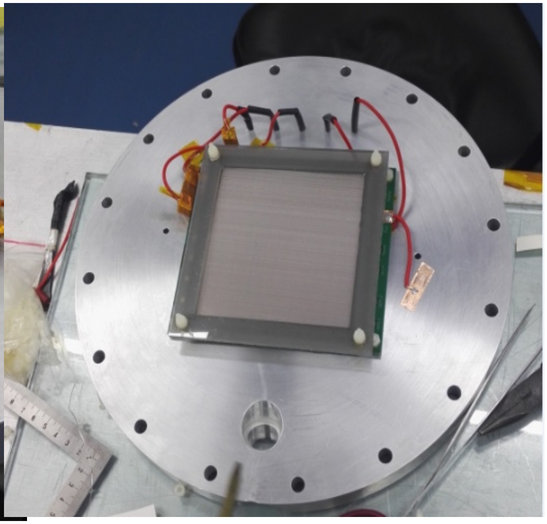
Micromegas(Saclay)



GEM(CERN)



Cathode with mesh

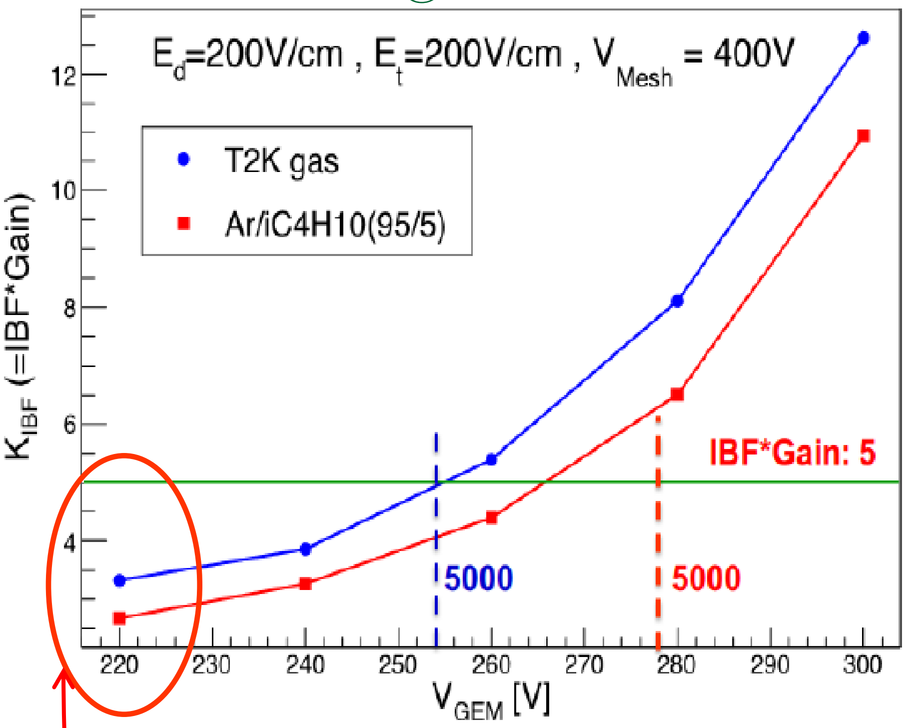


GEM-MM Detector

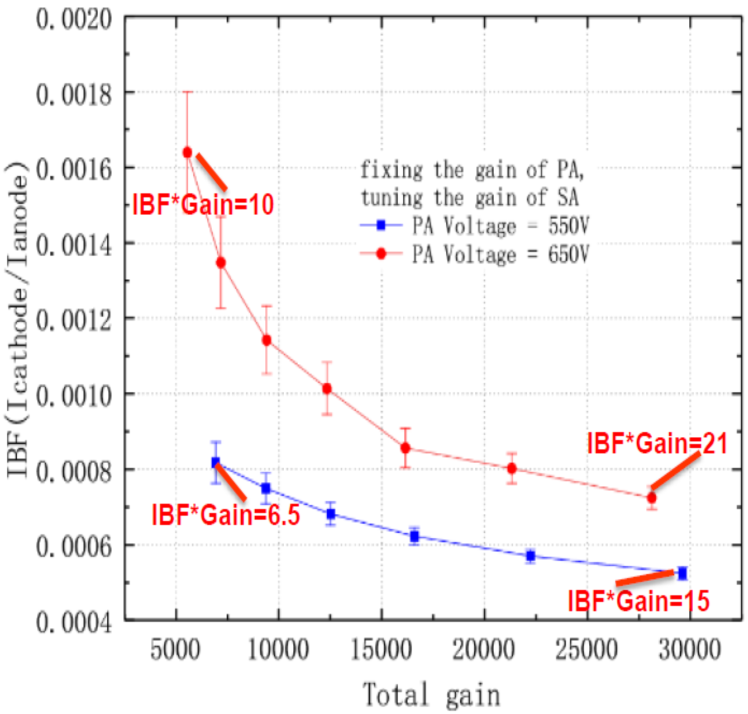
$50\times50mm^2$ 2015-2016	→	$100\times100mm^2$ 2017-2018	→	$200\times200mm^2$ 2019-

Update results of IBF from detector module

Micronegas + GEM detector module @IHEP



IBF of double mesh MM @USTC/Jianbei Liu

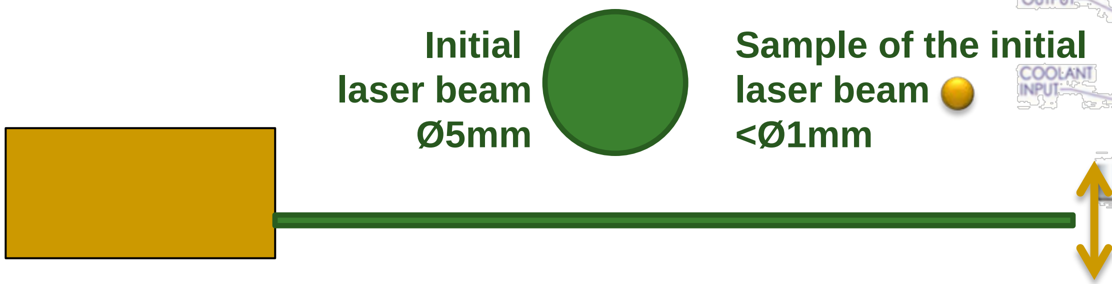


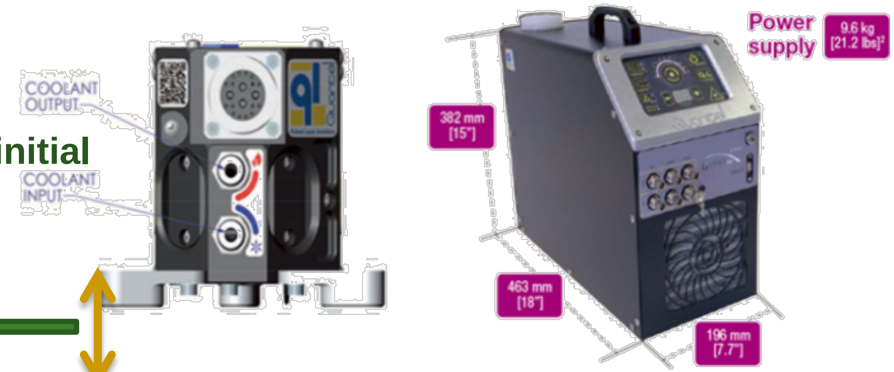
- IBF×Gain has the limitation ratio from the detector R&D at high gain.
- How to do it next ? Any new ideas? (Lower gain and no IBF)

Why we need the laser calibration?

- At Alice TPC, the laser has been used and the drift time gradient due to the pressure gradient is observed.
- Aimed to the Z pole run at the high luminosity, the continuous suppression IBF detector module will be needed, and the calibration system should be considered too.
- For the future collider, the laser system will be meet on the high position resolution and moment resolution than before.
  - The narrow laser beam's instinct position precision?
  - The UV laser ionization ability at the operation gas?

Study of the initial laser beam





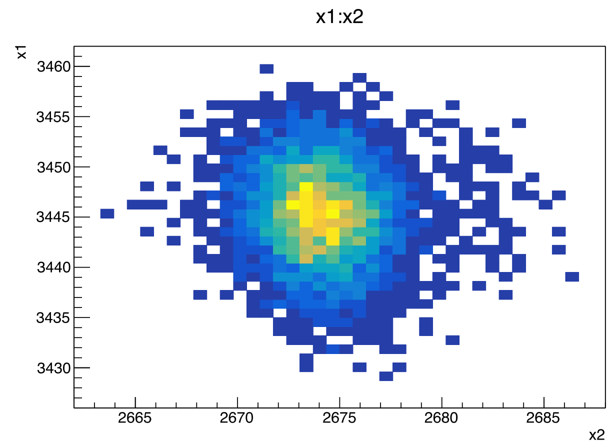
Laser device and power supply

Main parameters:

- Q-smart 100 (Quantel Corp.)
- Pulse duration time: 8ns
- Pulse of wavelength: 266nm
- Pulse frequency: 20Hz
- Max. energy per pulse: 20mJ

Study of laser position and energy

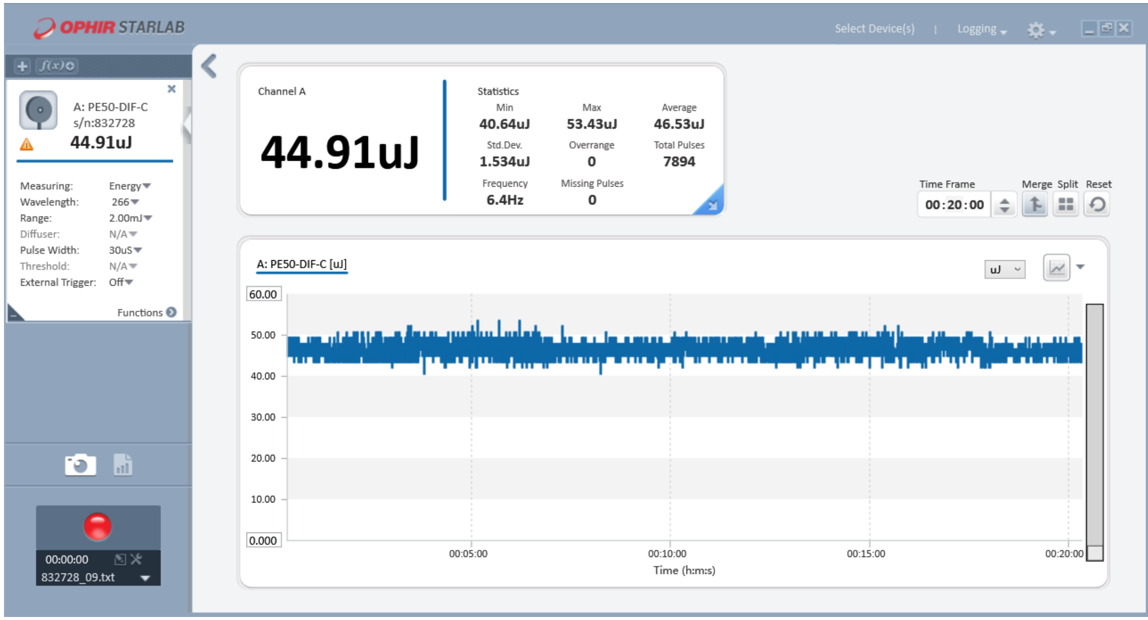
- Size: ~0.85mm×0.85mm
- Transmission and reflection mirrors
- Duration of measurement time: ~2mins



Position profile of the beam's center of gravity

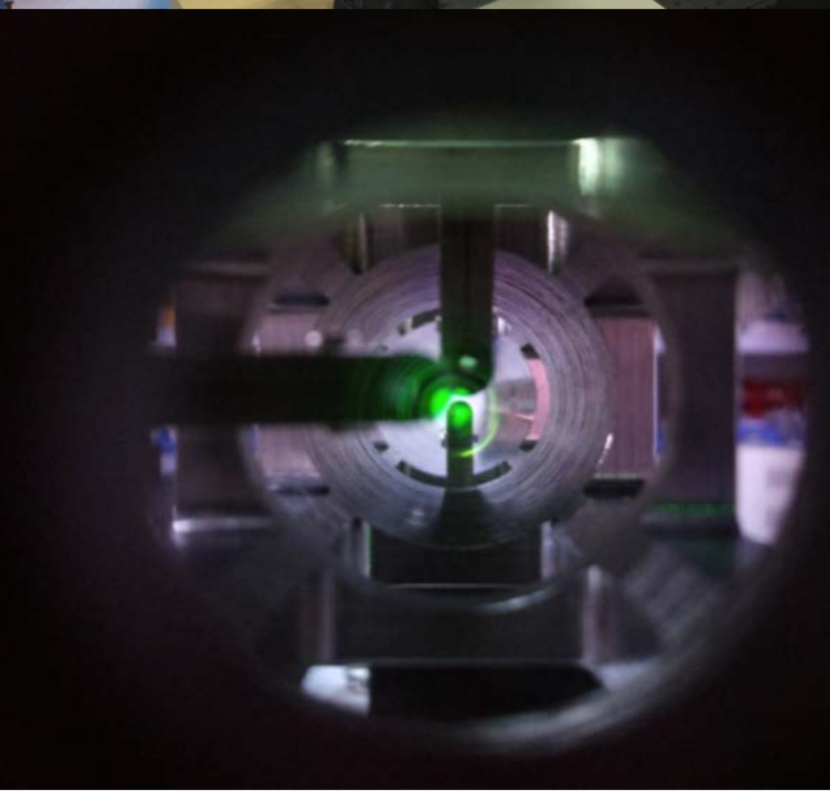
- X direction of the beam's center of gravity: <3.2 μm
- Y of the beam's center of gravity: <2.8 μm

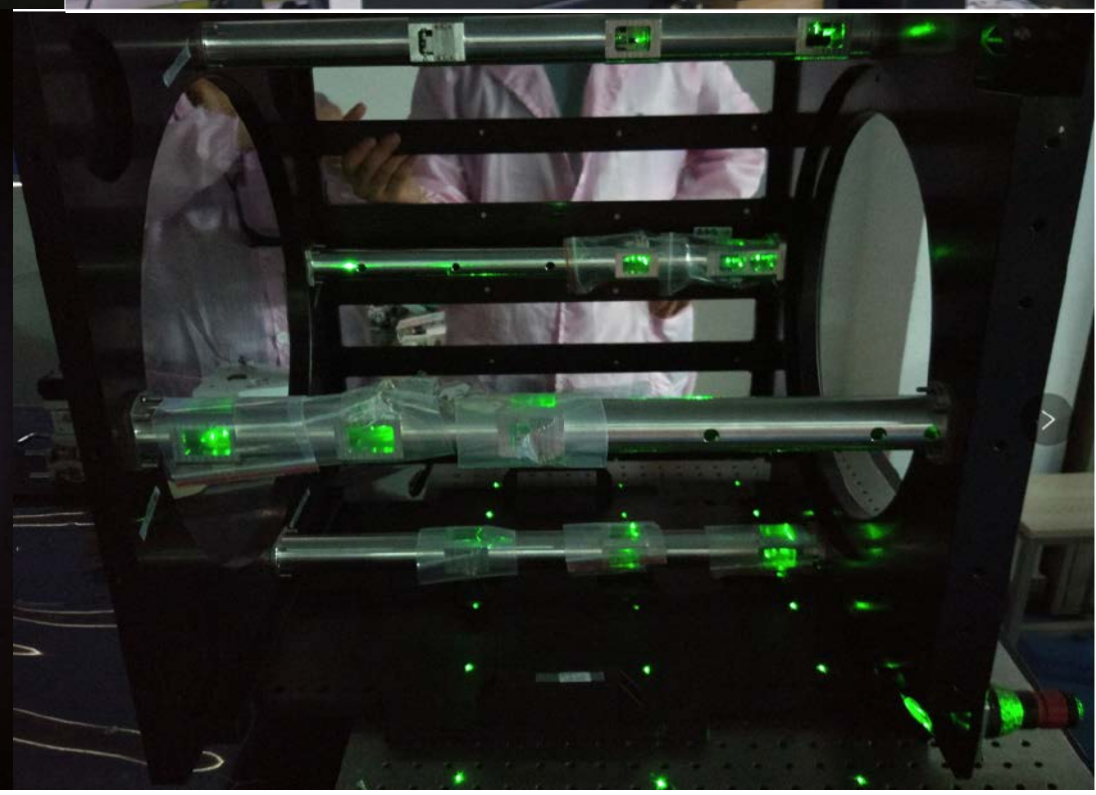
- Average of the energy: 46.53μJ/Φ5mm
- Stability of the laser beam energy: 3.3%



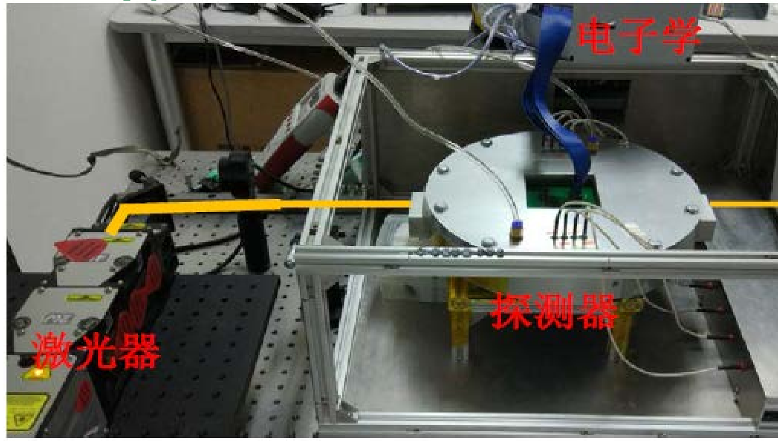
Stability of the laser beam energy @ μJ

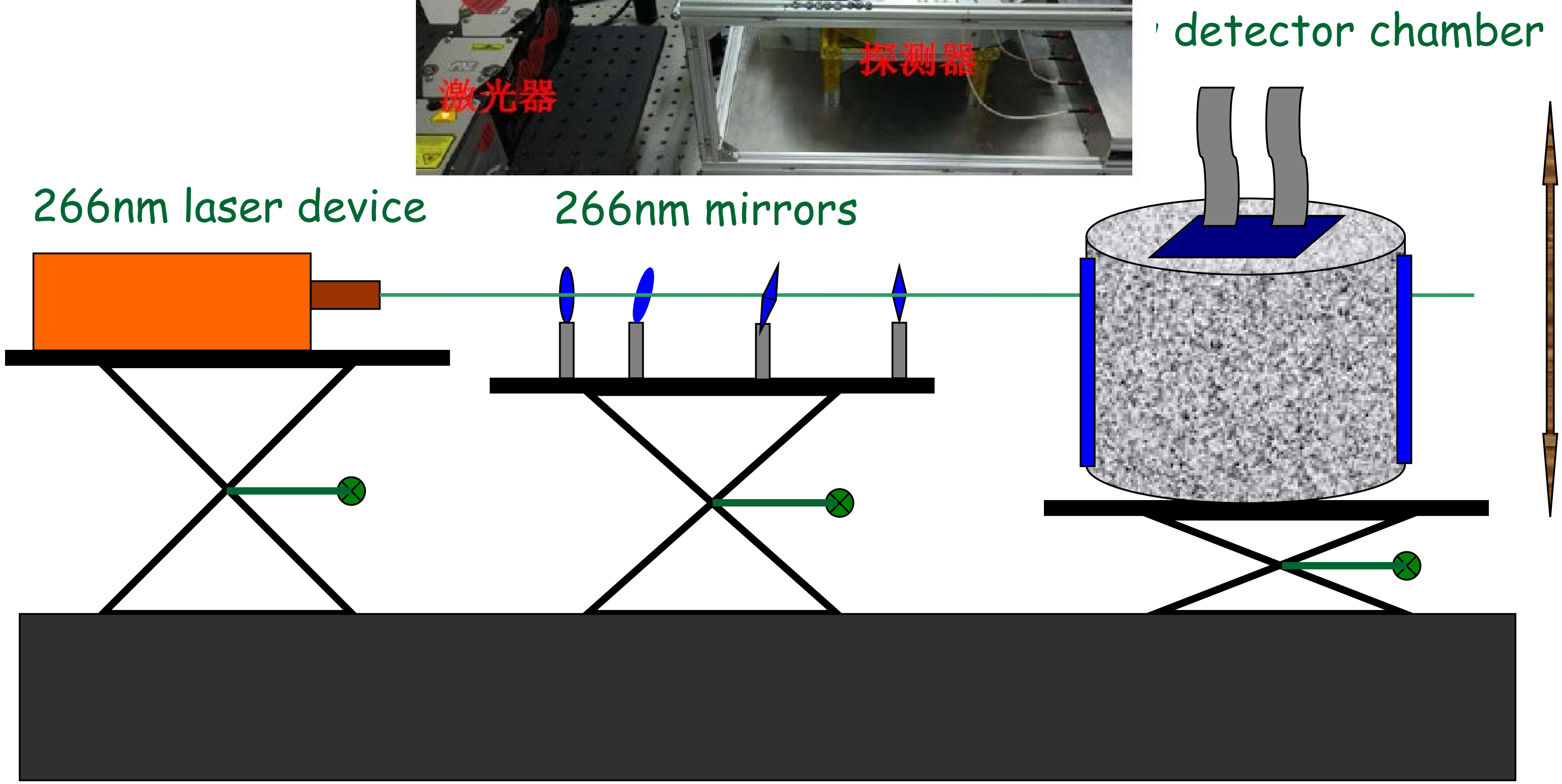

KEYENCE





Detector setup diagram





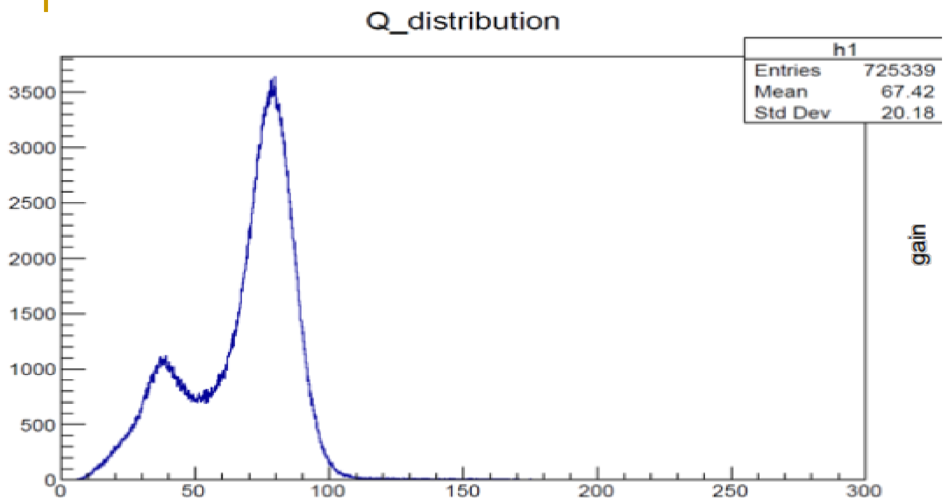
Setup and photo of the detector module

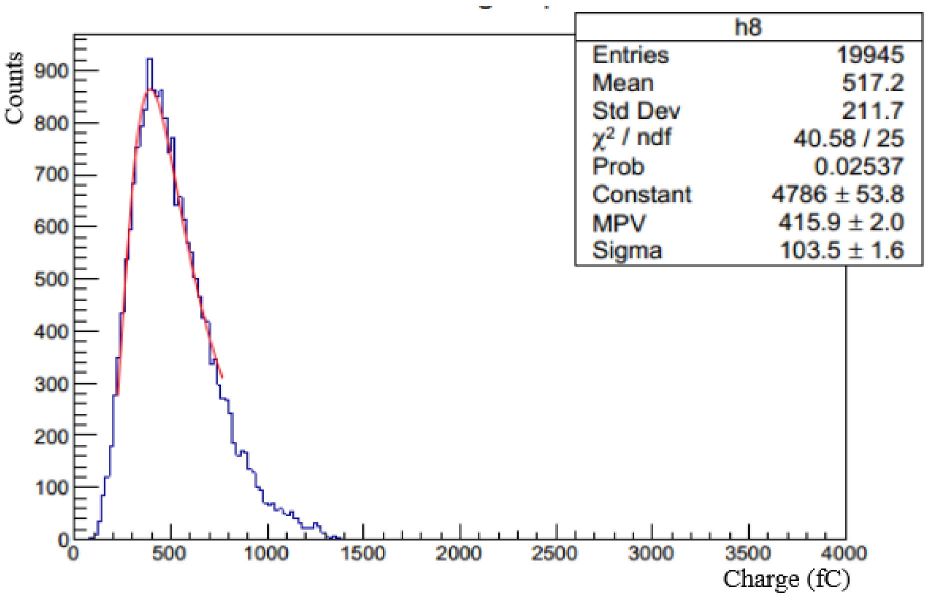
Electronics and DAQ

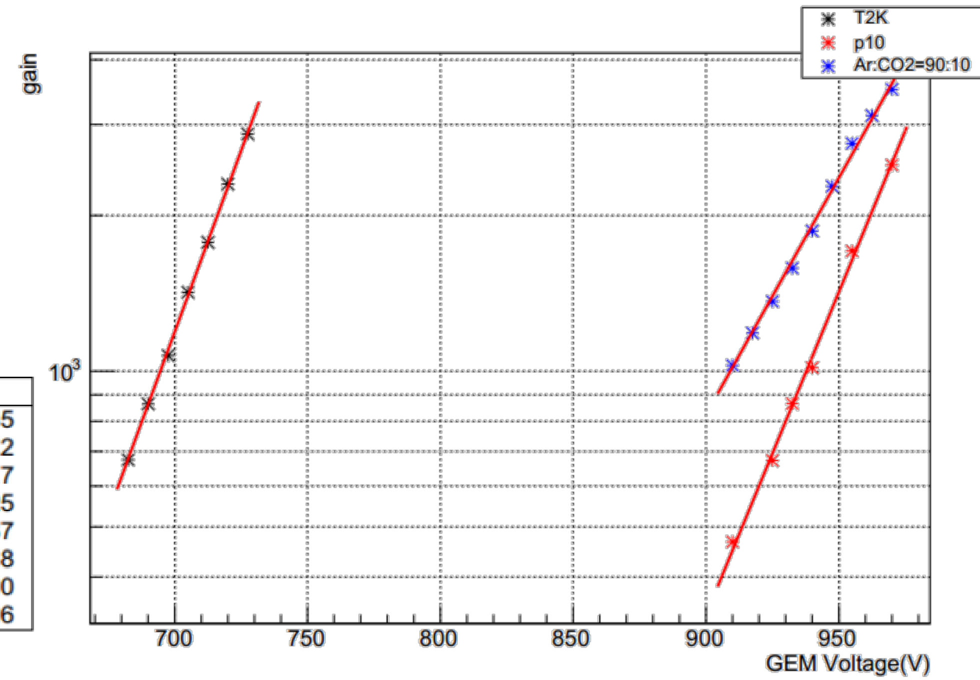
- Amplifier (READY)
  - CASAGEM chip
  - 16Chs/chip
  - 4chips/Board
  - Gain: 20mV/fC
  - Shape time: 20ns
- DAQ (READY)
  - FPGA+ADC
  - 4 module/mother board
  - 64Chs/module
  - Sample: 40MHz
  - 1280chs

FEE Electronics and DAQ setup photos

Energy spectrum and gain







Gain at T2K, P10, Ar/CO2

Energy spectrum of 55Fe and the laser

Operation gases and ionization with the laser

The three operation gases for the detector compared with ILC DESY and KEK working gas

- T2K
- P10
- Ar/CO2=90/10

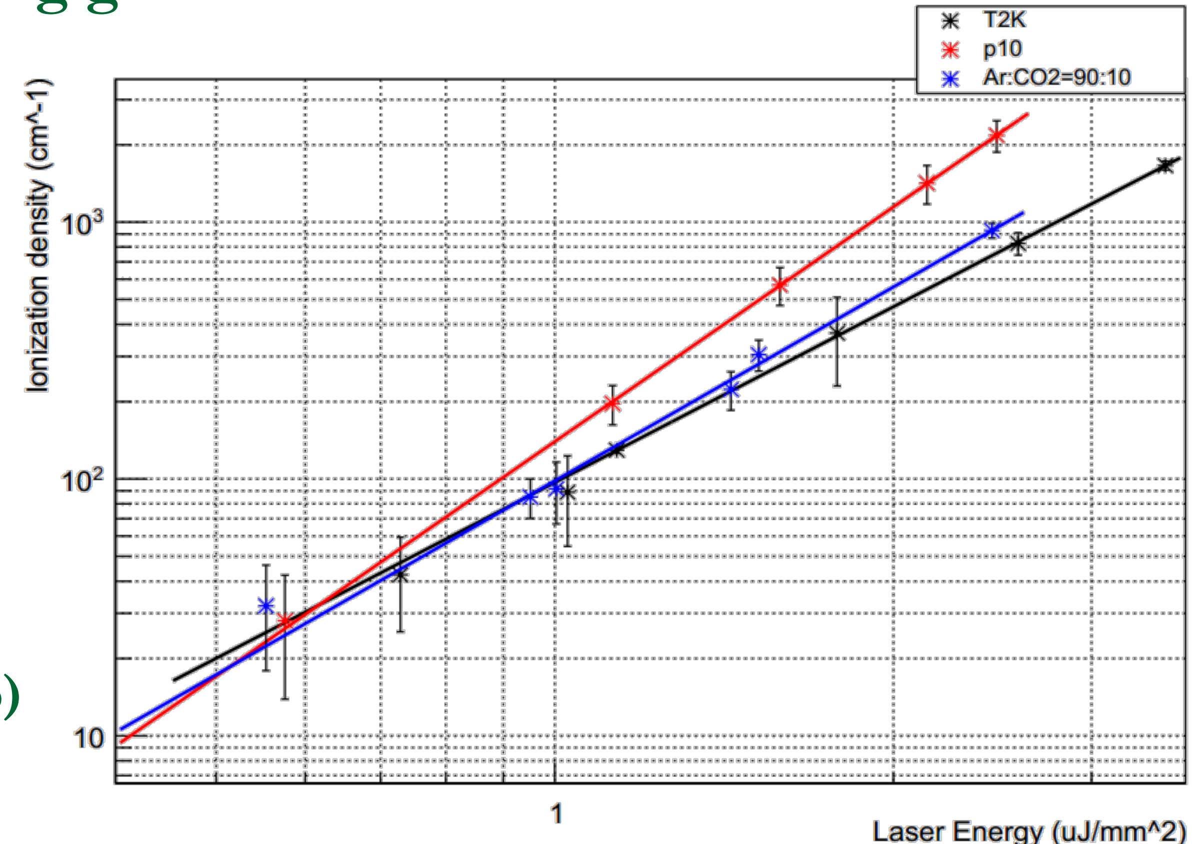
Gas purity

- Ar (99.999%)
- CO2 (99.999%)
- CH4 (99.999%)
- CF4 (99.999%)
- Isobutane (99.9%)

Ionization

- ~100 electrons/cm

at ~1uJ/mm^2

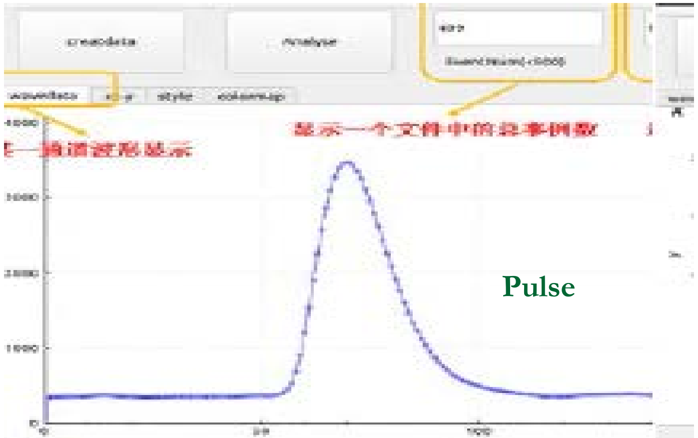


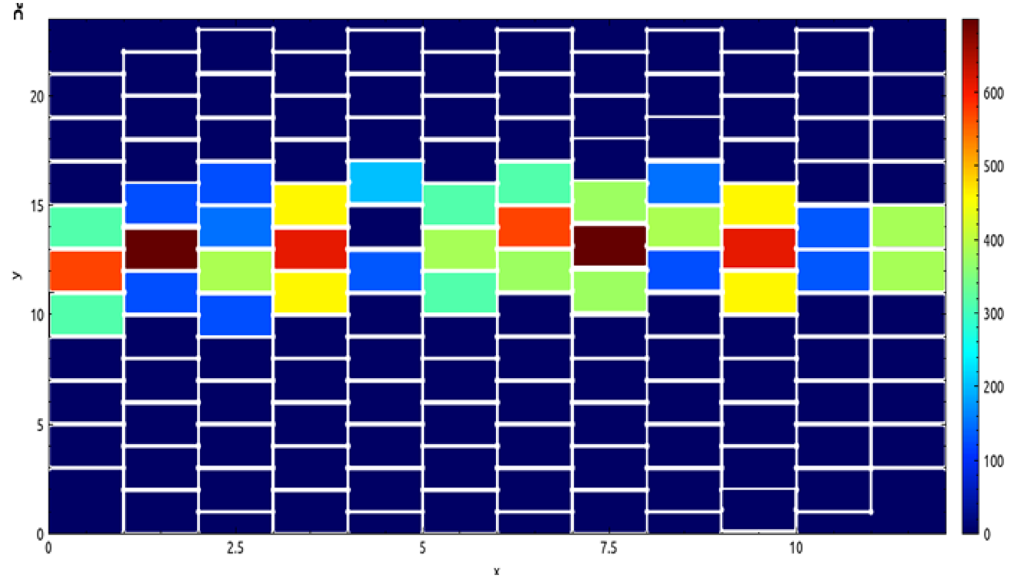
Ionization density unit: [N]/cm

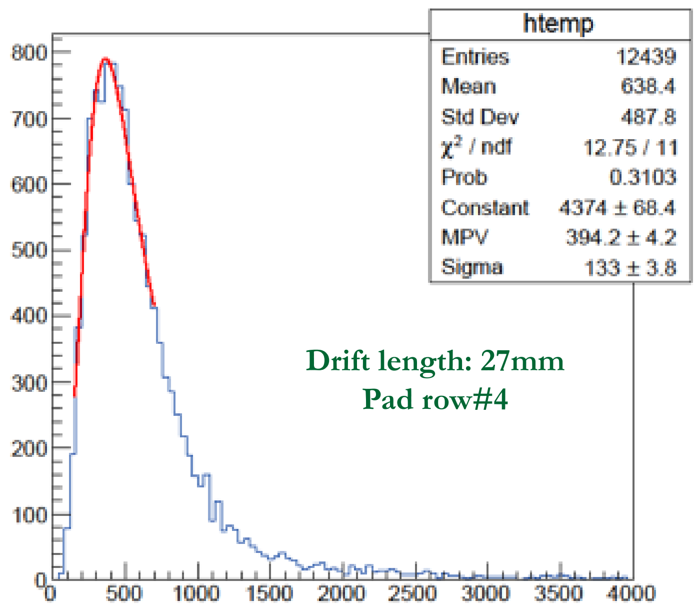
(N is the primary electron number per 0.85mm^2)

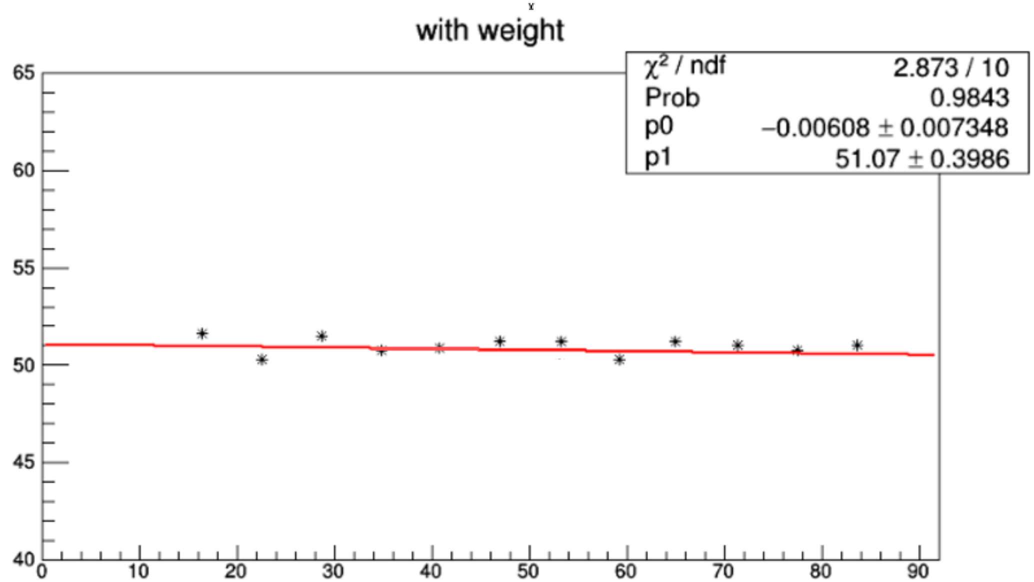
Pad size: 0.9mm×6.0mm

Laser track test@128chs





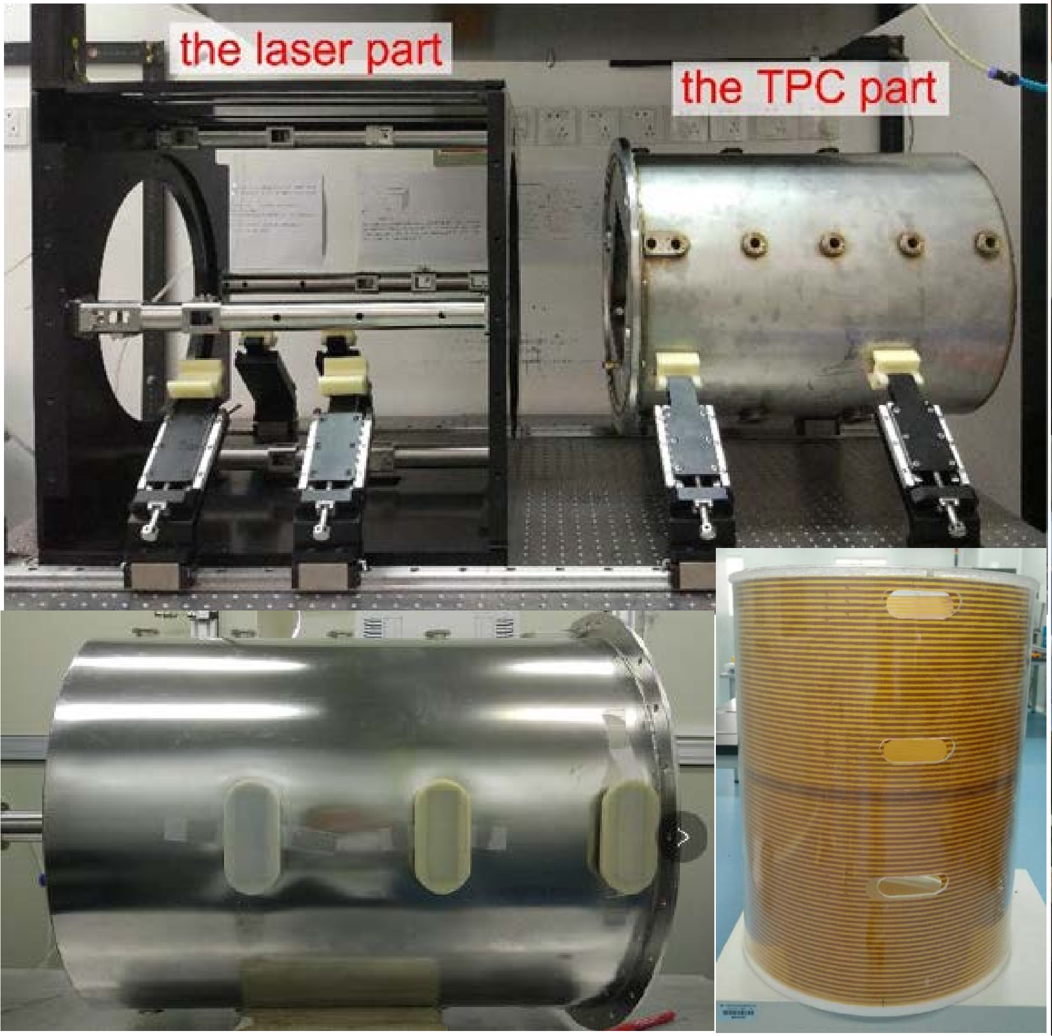




Preliminary results of Laser tracker energy spectrum and tracker

Some Collaboration and plan

TPC prototype cooperated with Tsinghua



Photos of TPC prototype R&D

Kick off meeting and the review meeting /NSFC Key funding project

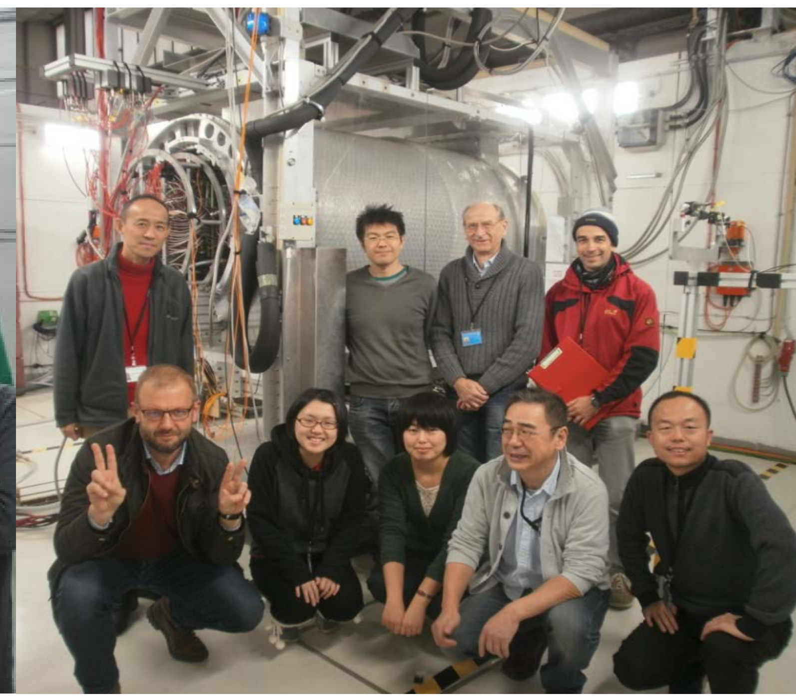
International cooperation

- 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 mor 590 LPI
  - UV+ laser tracker

International cooperation

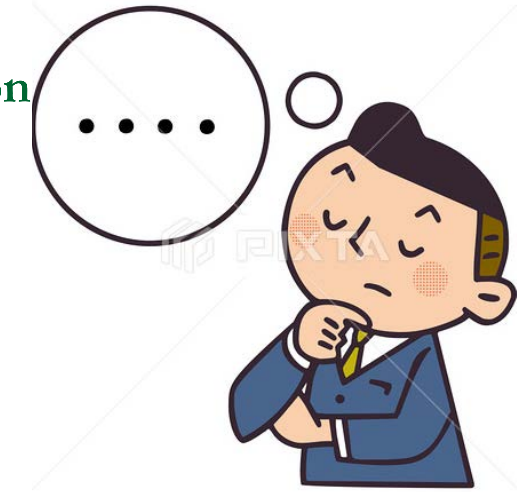
- LCTPC collaboration group (LCTPC)
  - Singed MOA and joined in LC-TPC collaboration @Dec. 14,2016
  - As coordinator in ions test and the new module design work package
  - CSC funding: PhD Haiyun jiont CEA-Scalay TPC group(6 months)
  - Joint beam test in DESY with Micromegas detector module in 2018

Beam test in 2018



Beam test in 2016

Idea: intermediate solution between pads and pixels for CEPC at Z



- Clusters contain the primary information of the ionisation
- Can we find a solution to resolve clusters?
- Some R&D for pixel TPC:
  - What is the optimal pad size to
    – improve double hit and double track resolution
    – do cluster counting for improved dE/dx?
    → Pixel size:(200μm or large), significant reduce cost
- Almost without IBF (Gain< 2000)
- Micromegas + ASIC Chips (Our option)
- GEMs + ASIC Chips
  → Some R&D at DESY

- There is a invitation to LCTPC collaboration and one response obtained.
- Kees from NIKEF will attend and discuss some possible collaboration.

Summary

Requirements and critical challenges for the high luminosity:

- **High momentum resolution and position resolution**
- **IBF*Gain should be considered at the high luminosity**
- **It needs very sophisticated calibration in order to reach the desired physics performance at Z pole run**
- **Simulation and experiment studies give some parameters for the detector**

TPC prototype integrated UV laser system R&D:

- **TPC prototype has been designed with UV laser system and developed at IHEP and Tsinghua University.**
- **UV laser beam have been assembled and tested, some test parameters have been obtained.**
- **The beam test plan with TPC prototype under 1.0T magnetic field will be realized**

Collaboration :

- **TPC R&D cooperated with Tsinghua Unviersity, Saclay, KEK, Nikehf and LCTPC group.**

Thank you for your attention !