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

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Outline

- Requirements
- Simulation of IBF at Z
- TPC prototype R&D
- Conclusion

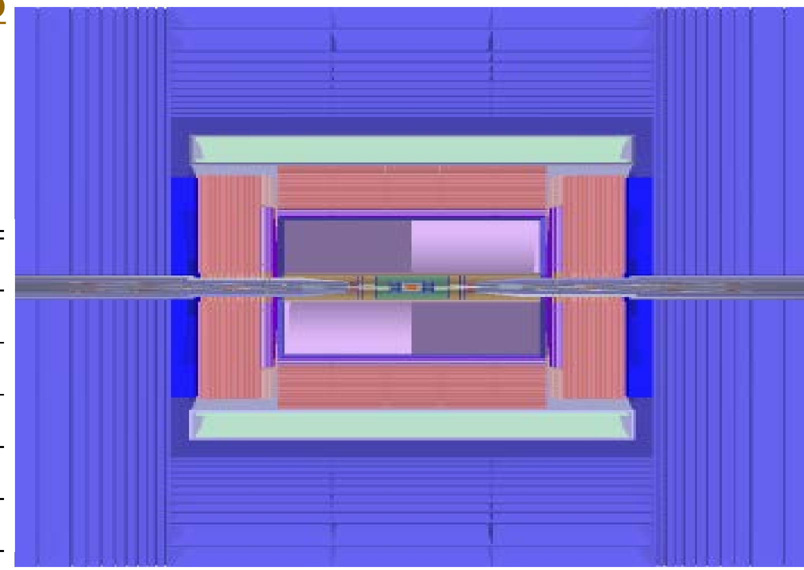
Detector Concepts (CEPC CDR)

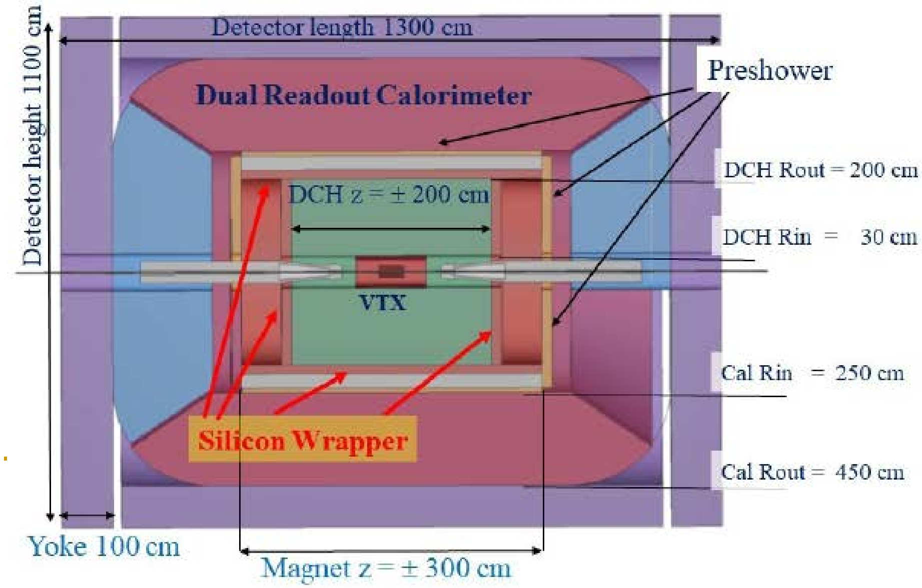
Operation mode	$\sqrt{s}$ (GeV)	L per IP (10^{34} cm^{-2}s^{-1})
H	240	3
Z	91.2	32 (*)
W^+W^-	158–172	10

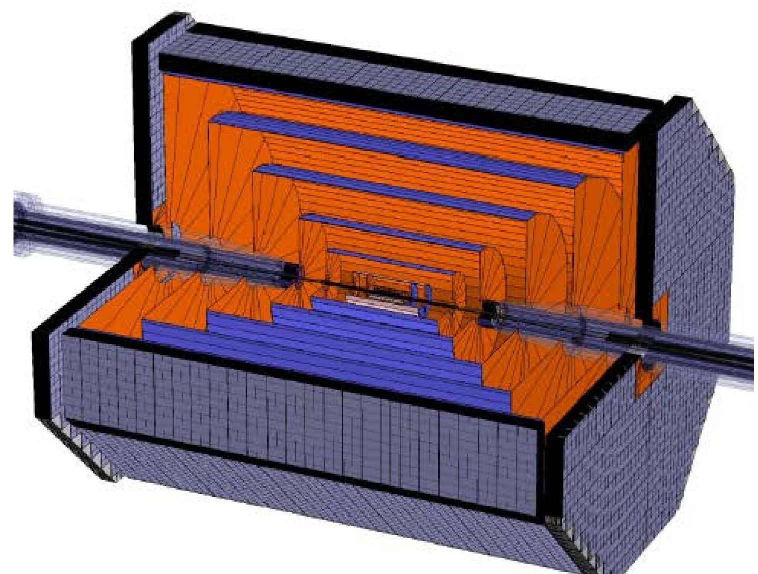
- **Baseline: Silicon + TPC**
- **FST: all-silicon tracker**
- **IDEA: Silicon+Drift chamber (DCH)**

ArXiv:1811.10545

	Higgs	W	Z (3T)	Z (2T)
Number of IPs	2			
Beam energy (GeV)	120	80	45.5	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.73	0.34	0.036	
Crossing angle at IP (mrad)	16.5 × 2			







Physics requirements

- 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

CEPC CDR

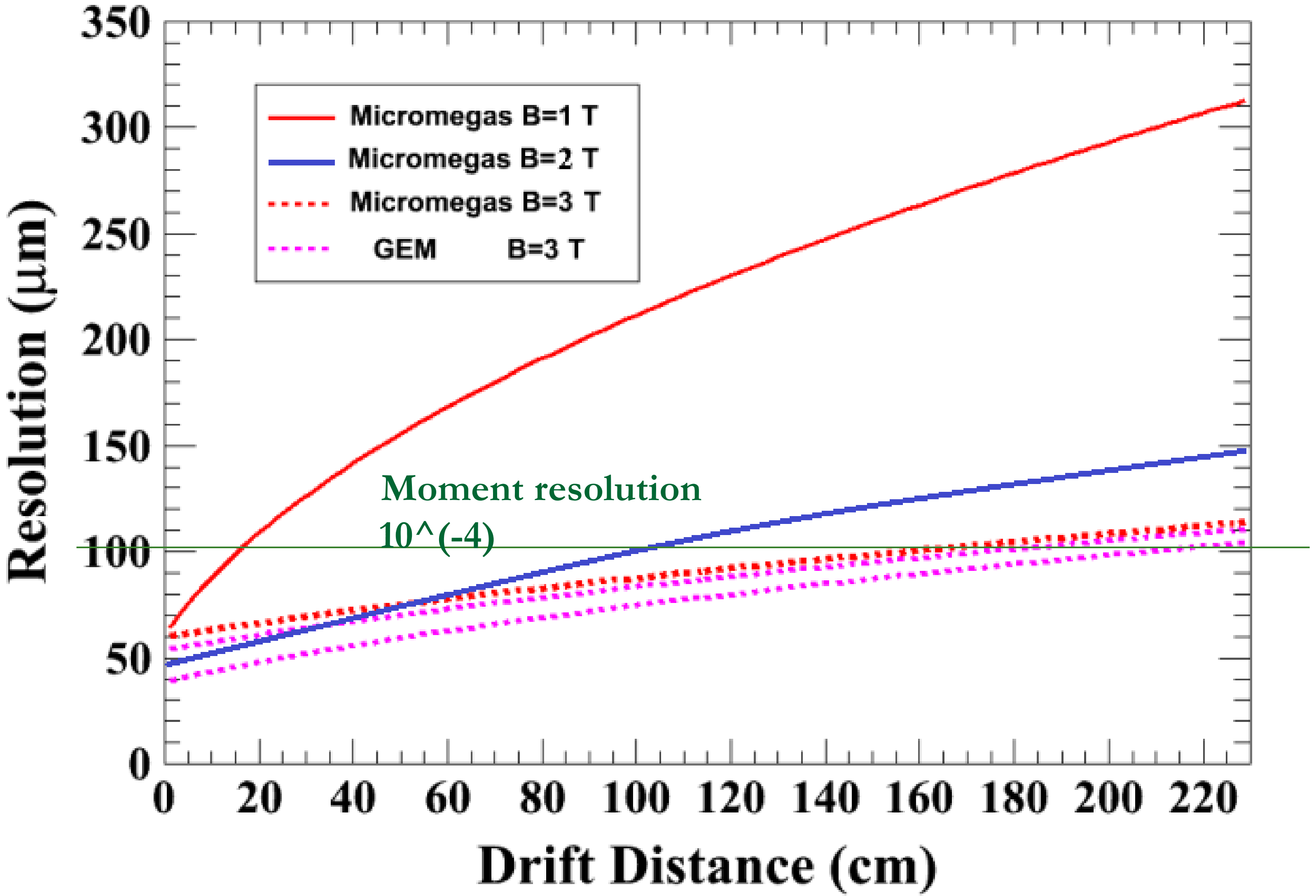
Lumi.	Higgs	W	Z	Z(2T)
$\times 10^{34}$	2.93	11.5	16.6	32.1

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

Resolution along drift length (simulation)

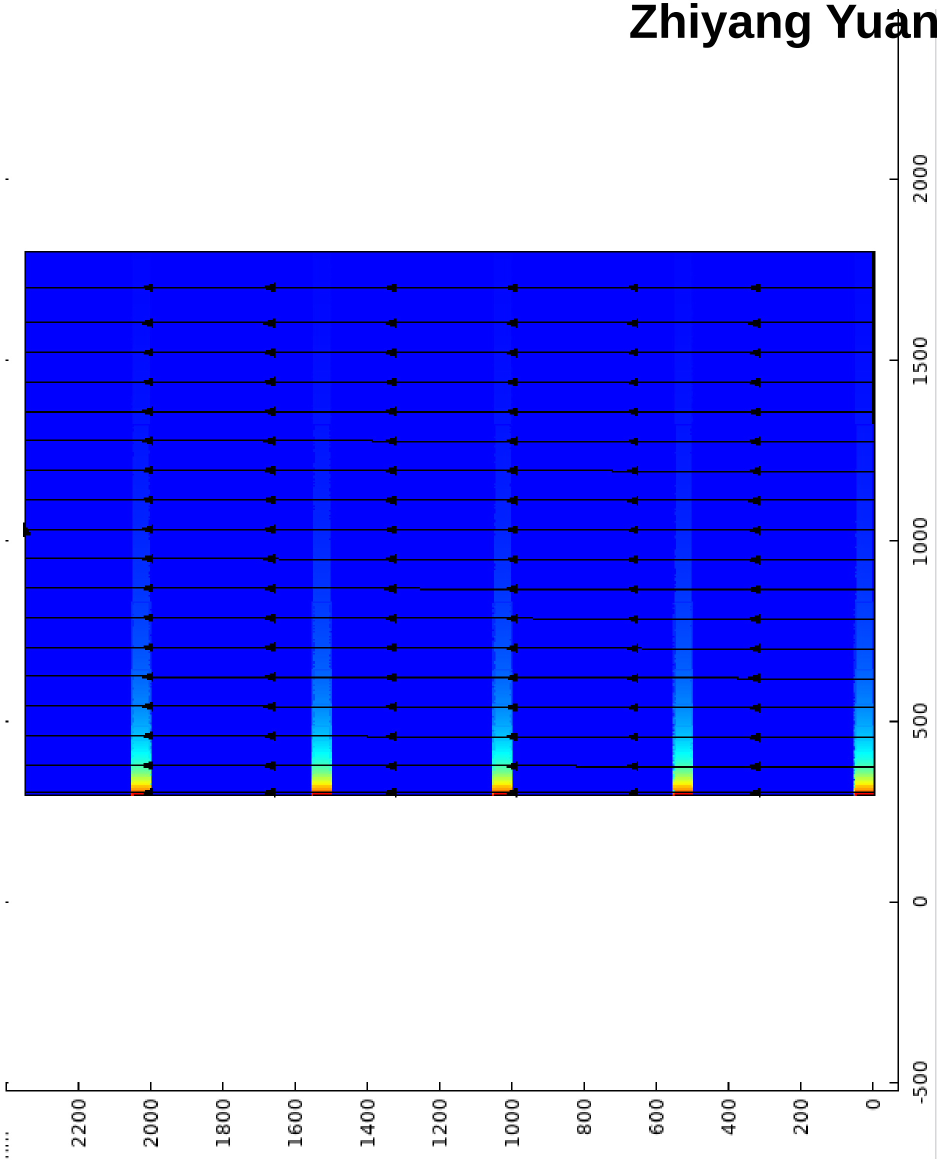
Zhiyang Yuan



Simulation of IBF effect

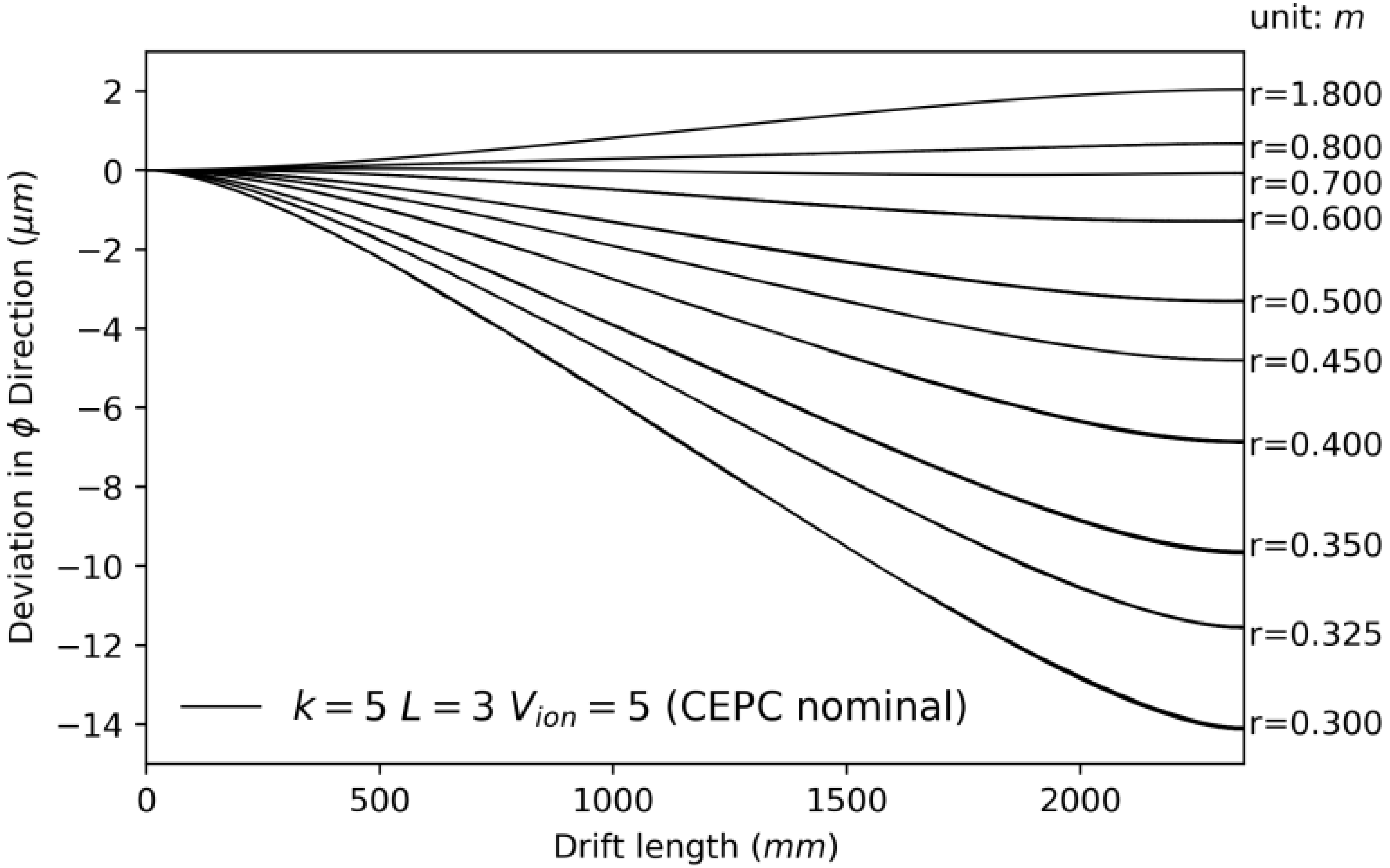
Zhiyang Yuan

- 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



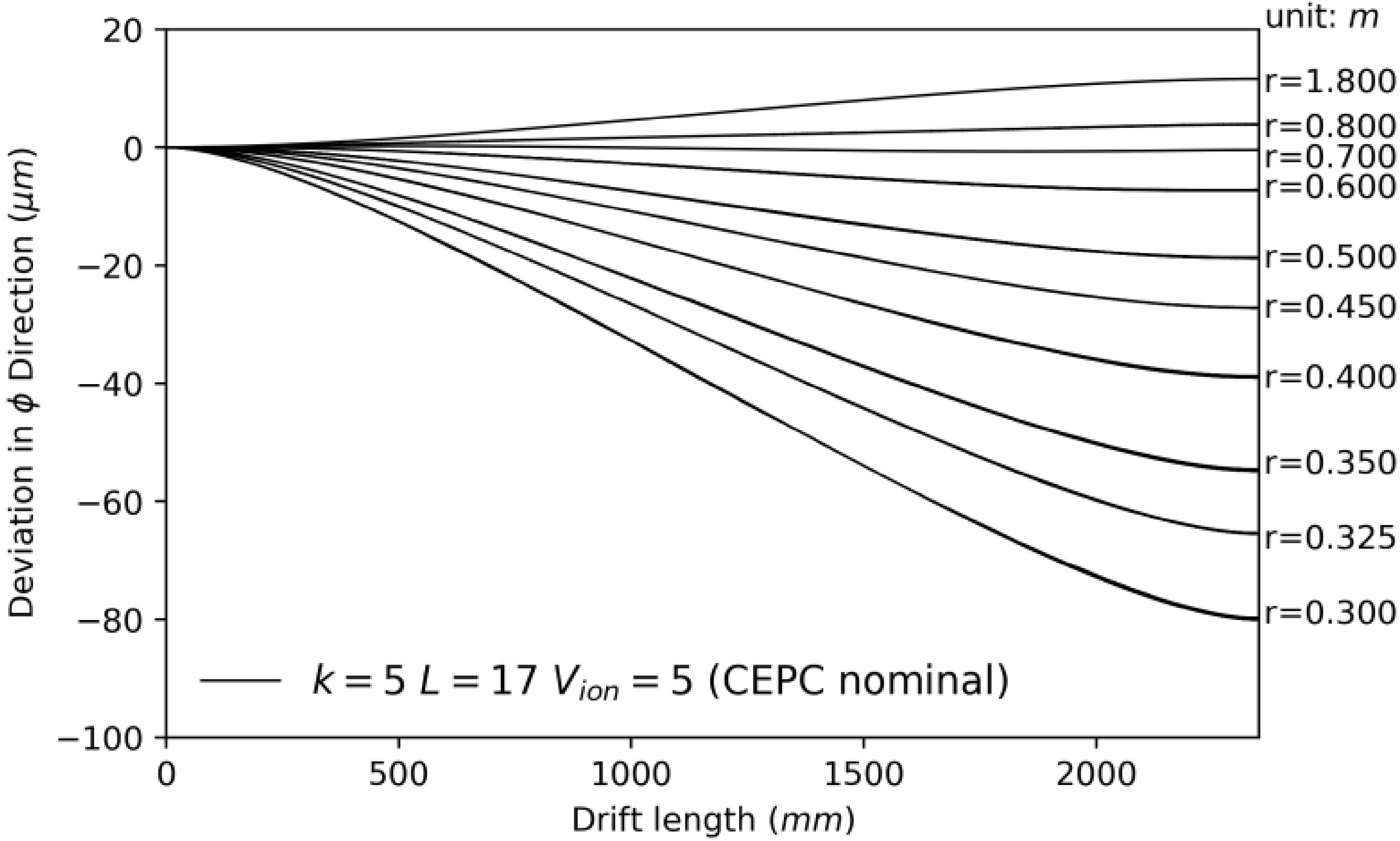
Simulation of deviation with IBF (k=Gain×IBF) @CEPC

Zhiyang Yuan



Deviation in Φ at CEPC Higgs run with $3\times10^{34}cm^{-2}s^{-1}$ (Lumi.)

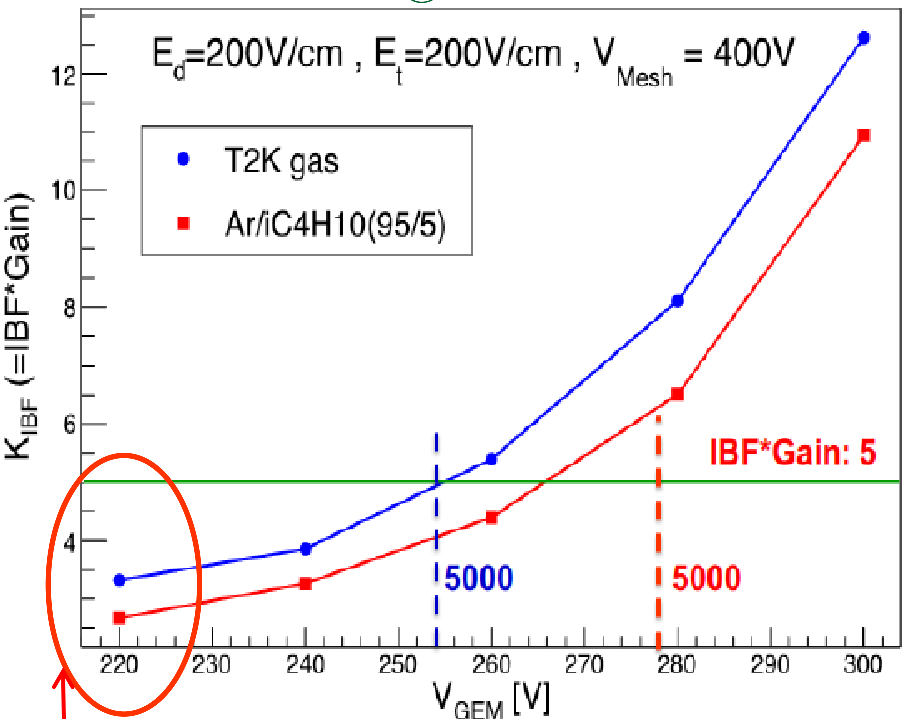
Simulation of deviation with IBF (k=Gain×IBF) @CEPC



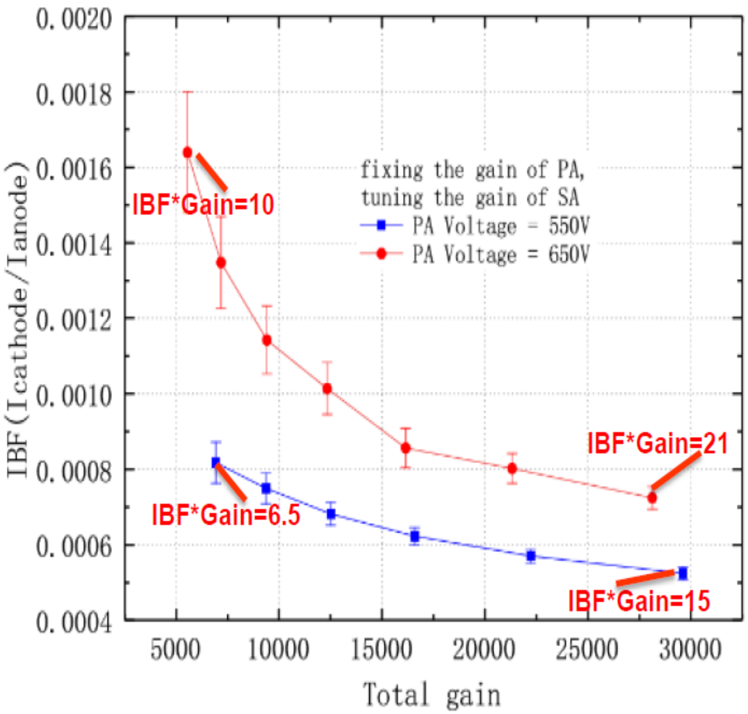
Deviation in Φ at CEPC Z pole run with $17 \times 10^{34} cm^{-2} s^{-1}$ (Lumi.)

Update results of IBF from detector module

Micronegas + GEM detector module @IHEP



IBF of double mesh MM @USTC/Jianbei Liu

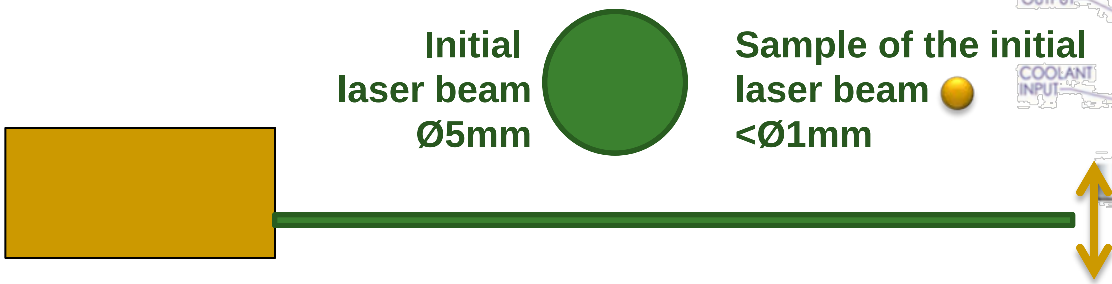


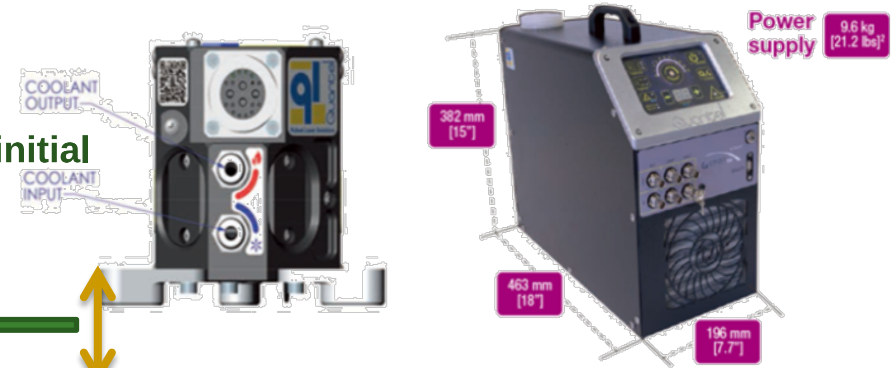
- IBF×Gain has the limitation ratio from the detector R&D at high gain.
- How to do it next ? Any new ideas? (Lower gain and no IBF)

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

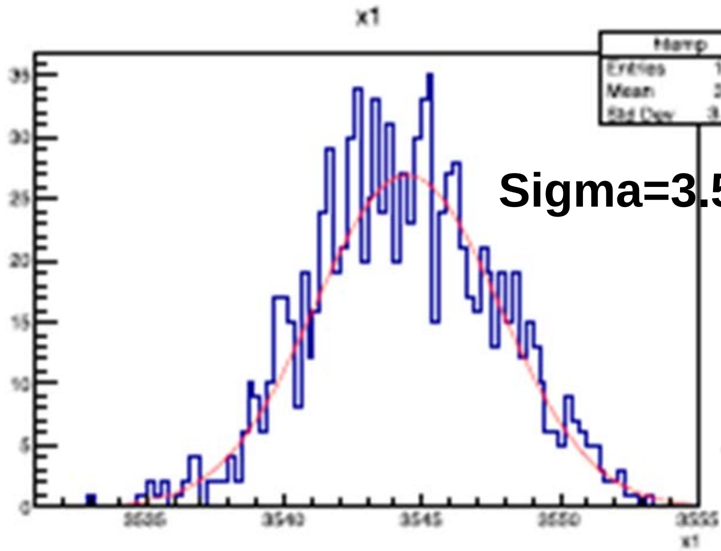
Initial laser beam

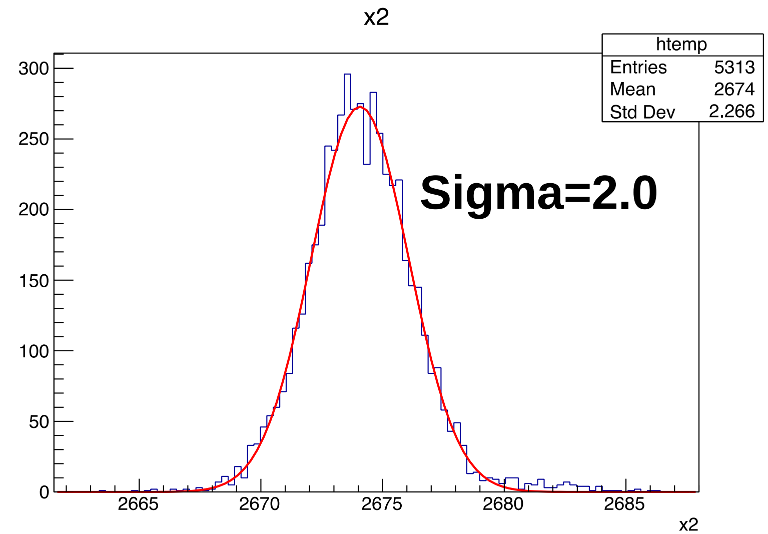
Sample of the initial laser beam

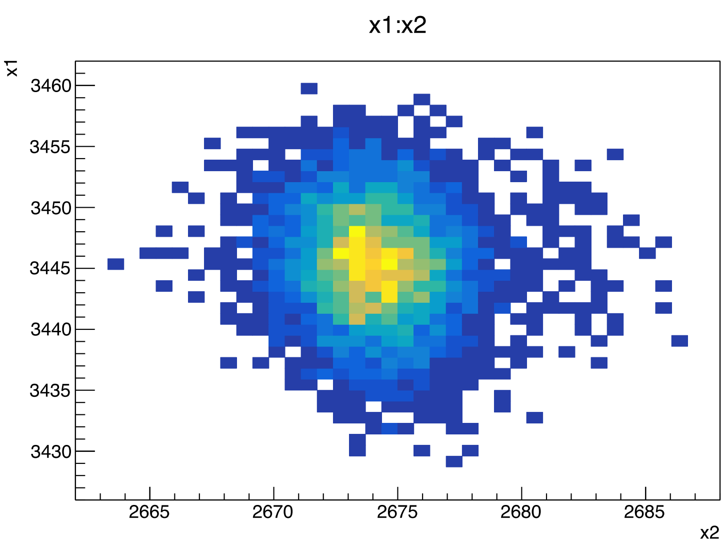
Main parameters:

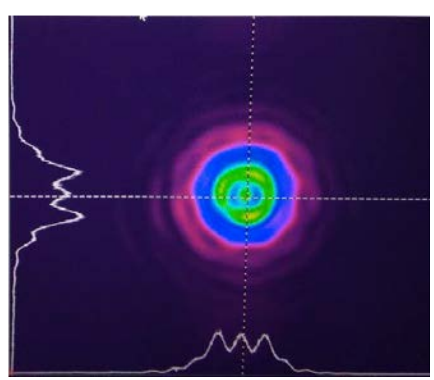
- Q-smart 100 (Quantel Corp.)
- Pulse duration time: 8ns
- Pulse of wavelength: 266nm
- Pulse frequency: 20Hz
- Max. energy per pulse: 20mJ

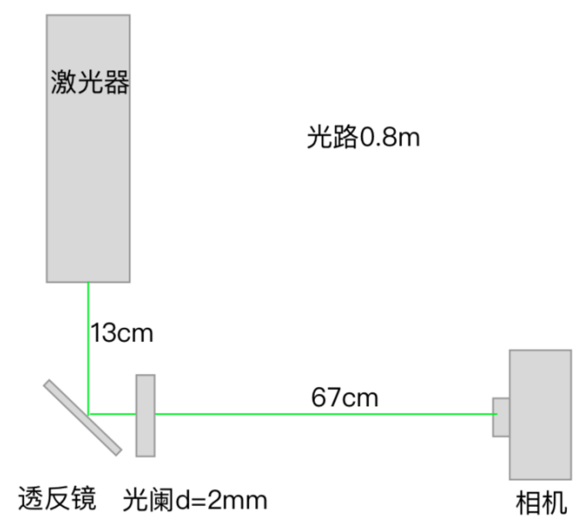
Position profile of the beam center of gravity@20mins



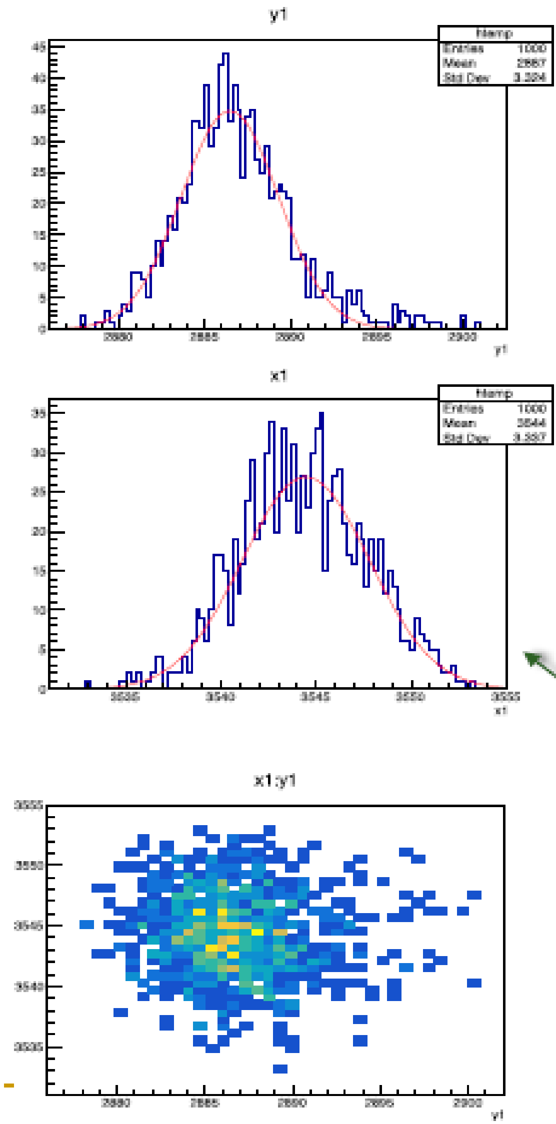


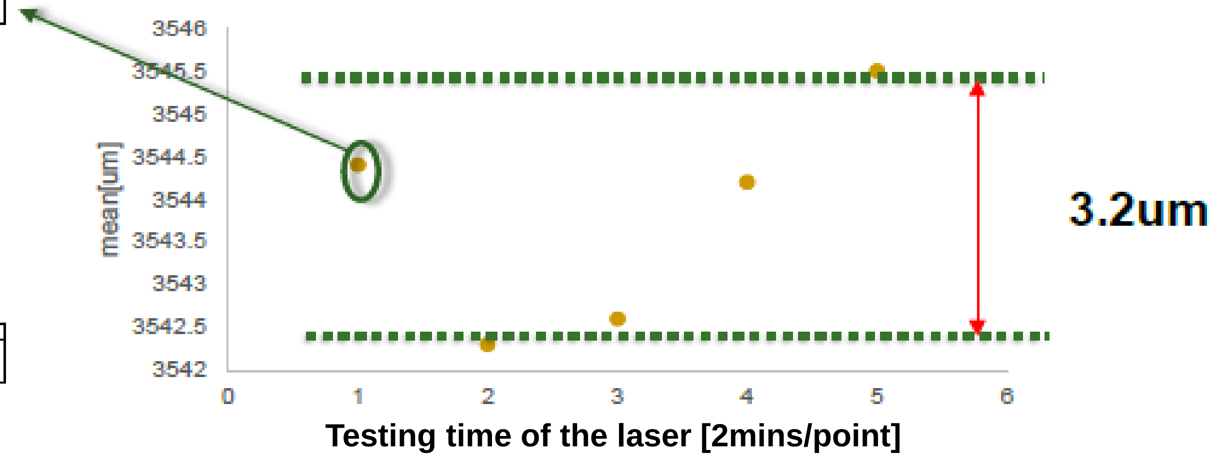


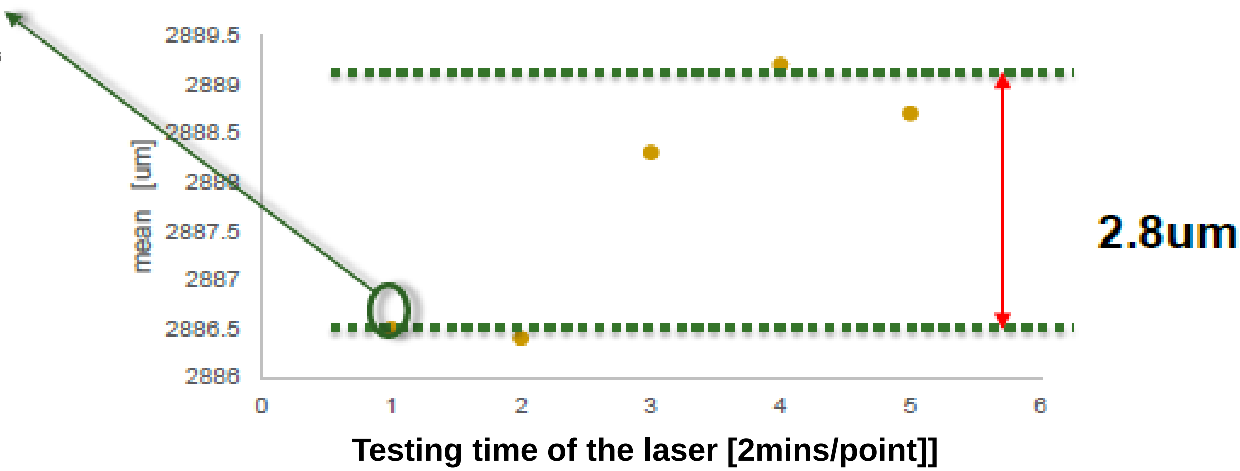




Laser position in the duration time

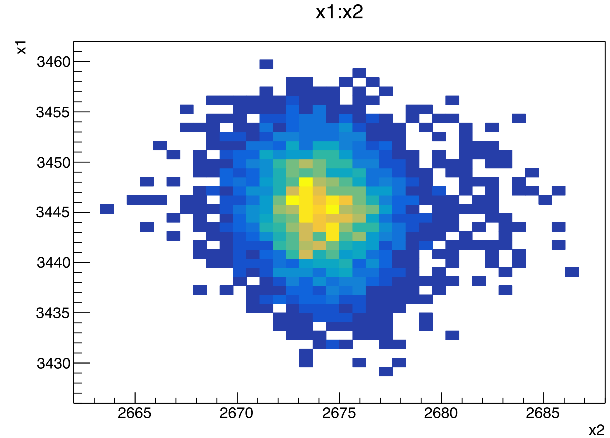






Study of laser position and energy

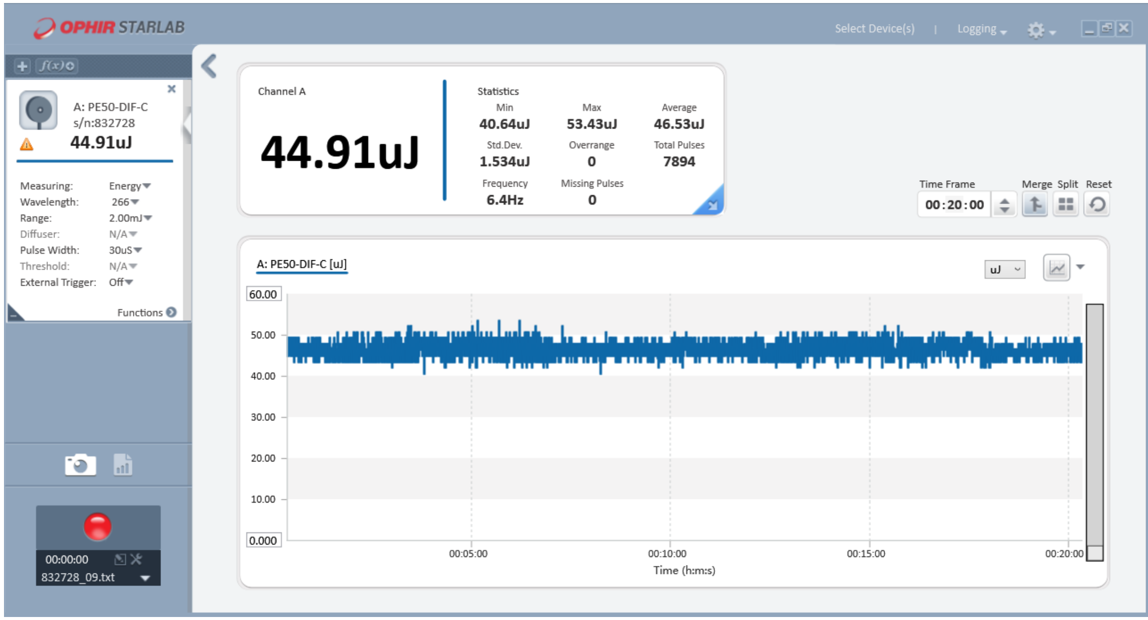
- Size: ~0.85mm×0.85mm
- Transmission and reflection mirrors
- Duration of measurement time: ~2mins



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%



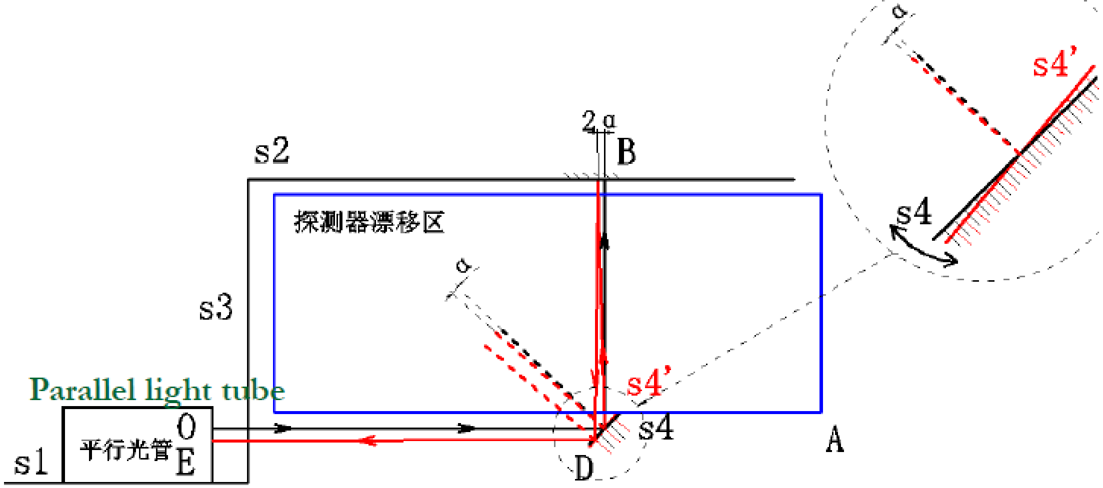
Stability of the laser beam energy @ μJ

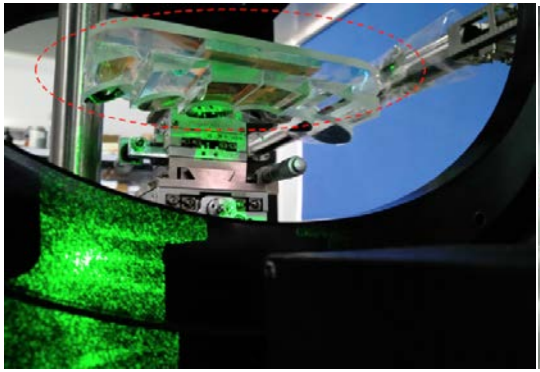
Laser point position adjustment

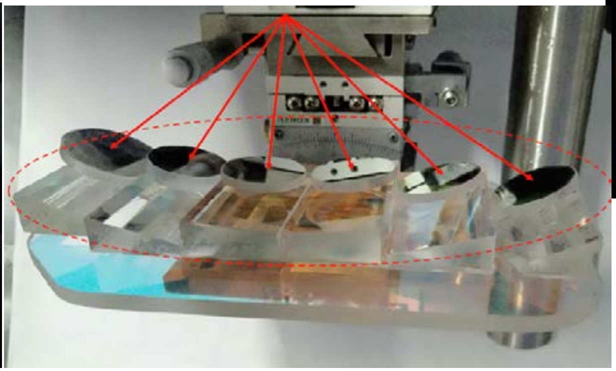
Parameters:

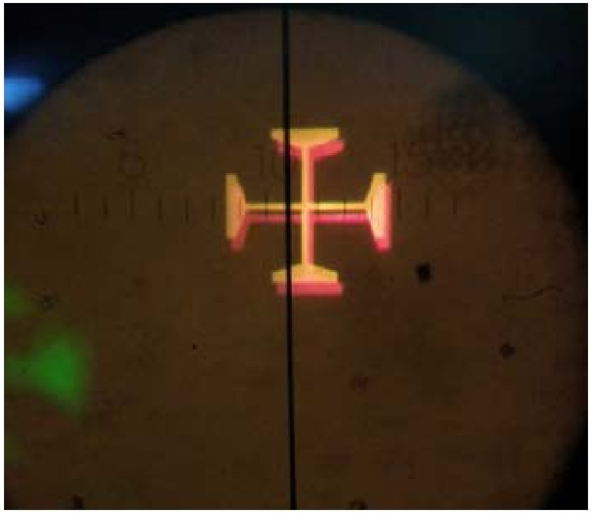
Reflection mirrors for UV light (0 degree and 45 degrees)
Parallel light tube: <5 seconds (1 seconds = 1/360 degree)

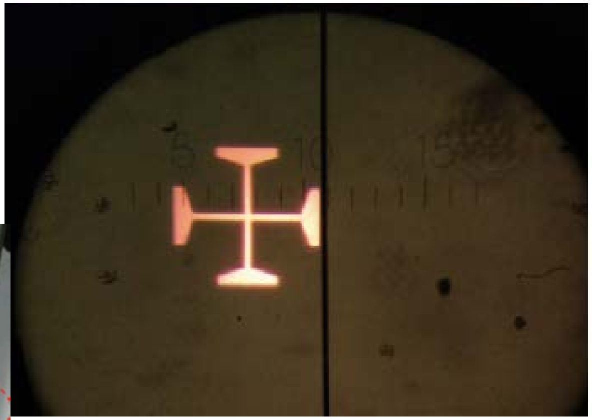
The black line and red line will be coincided.









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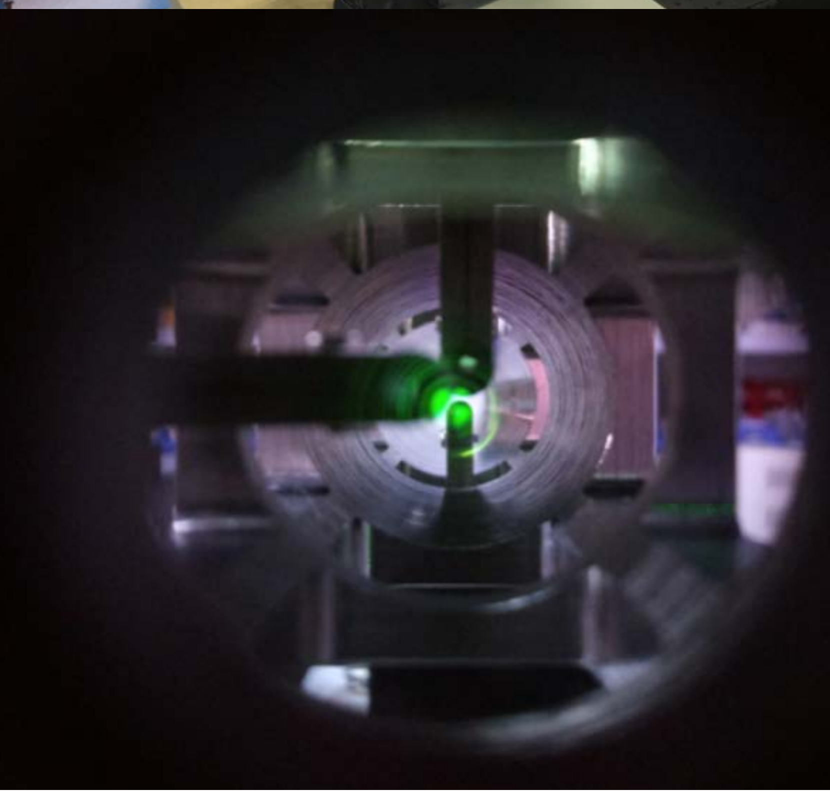
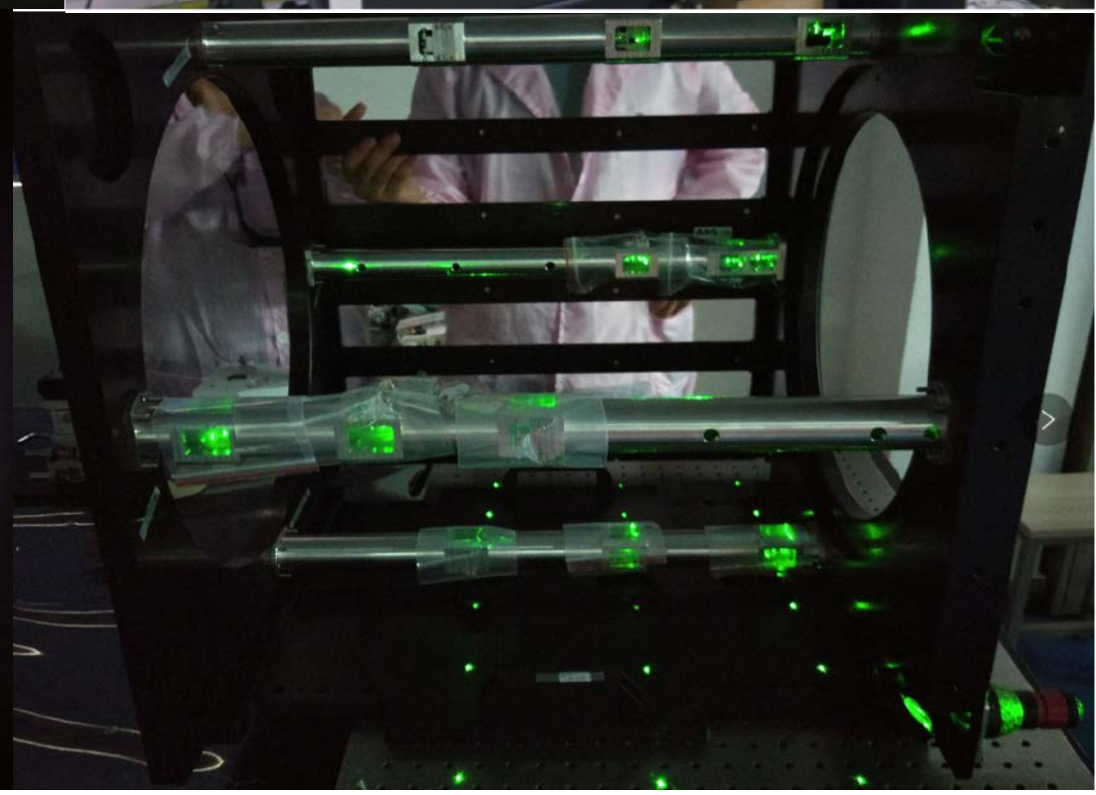



Summarized of the prototype's parameters

- Parameters list

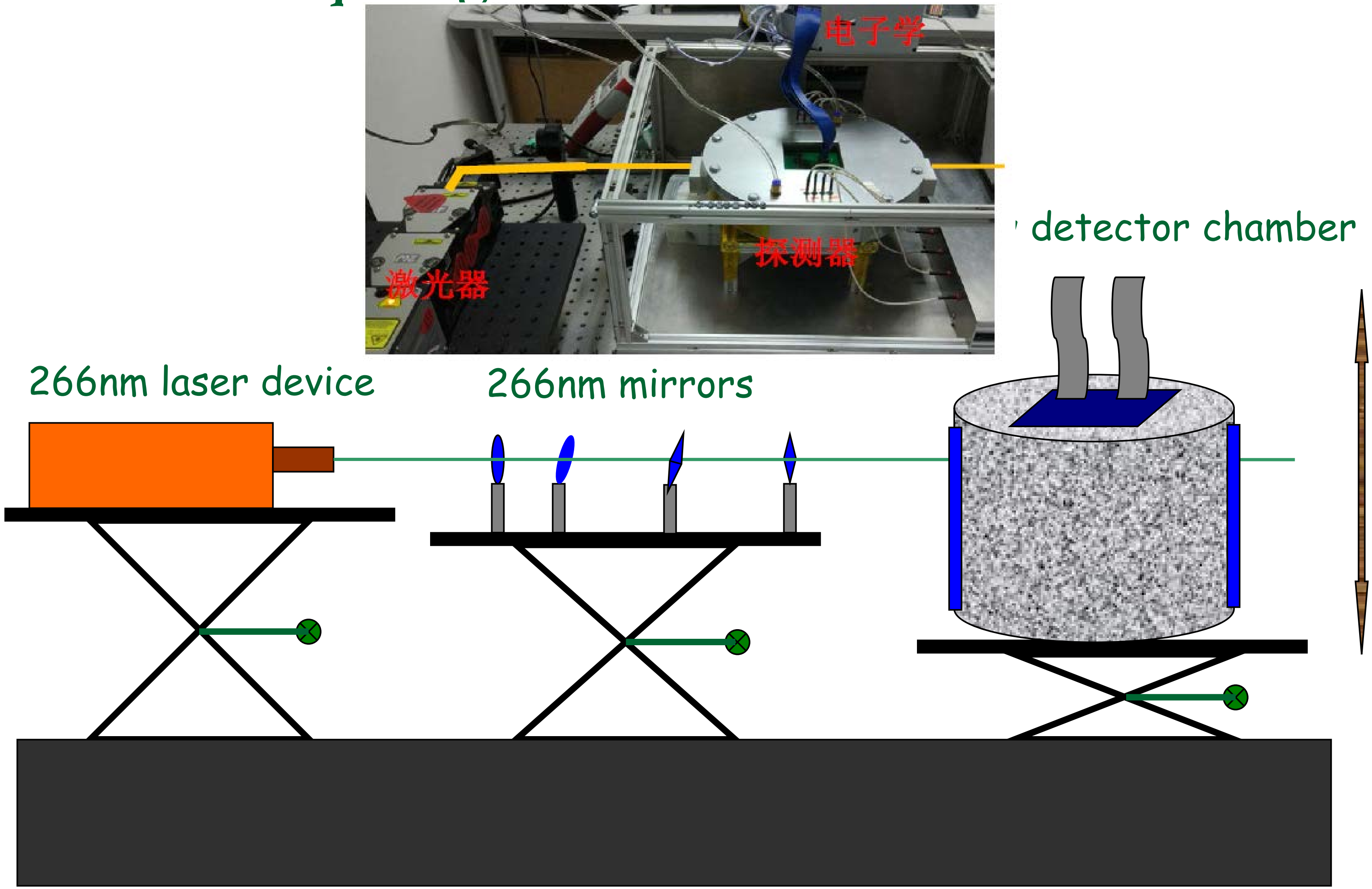
Items		Design	Test parameters
Laser System	Pointing stability	$< 10\mu m$	X@ 3.08μm Y@1.87 μm
	Track point accuracy	< 5'	< 3'
	Energy dynamic range	< 30%	<3.84%
	Duration time of cal.	< 5mins	90s
TPC Chamber			Assembled &Ready
High voltage power supply			
Support platform			
FEE electronics and DAQ			128 channels ready & Testing more channels

TPC prototype R&D

Laser tracker

Ionization test

Detector setup diagram



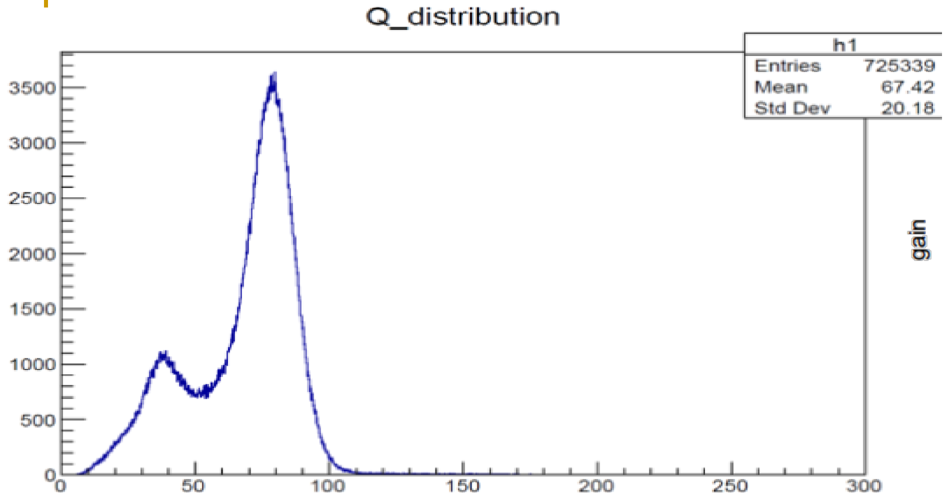
Setup and photo of the detector module

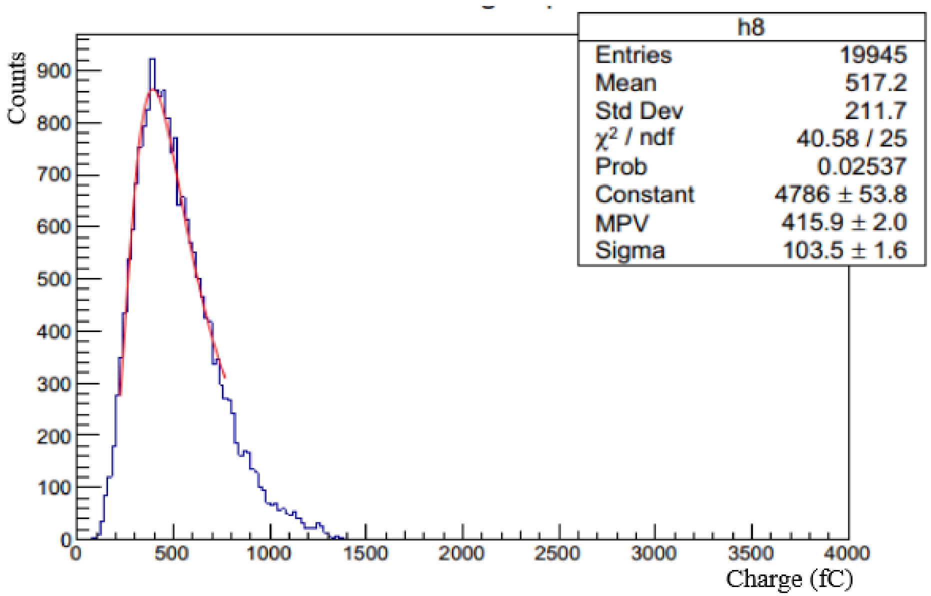
Electronics and DAQ

- 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

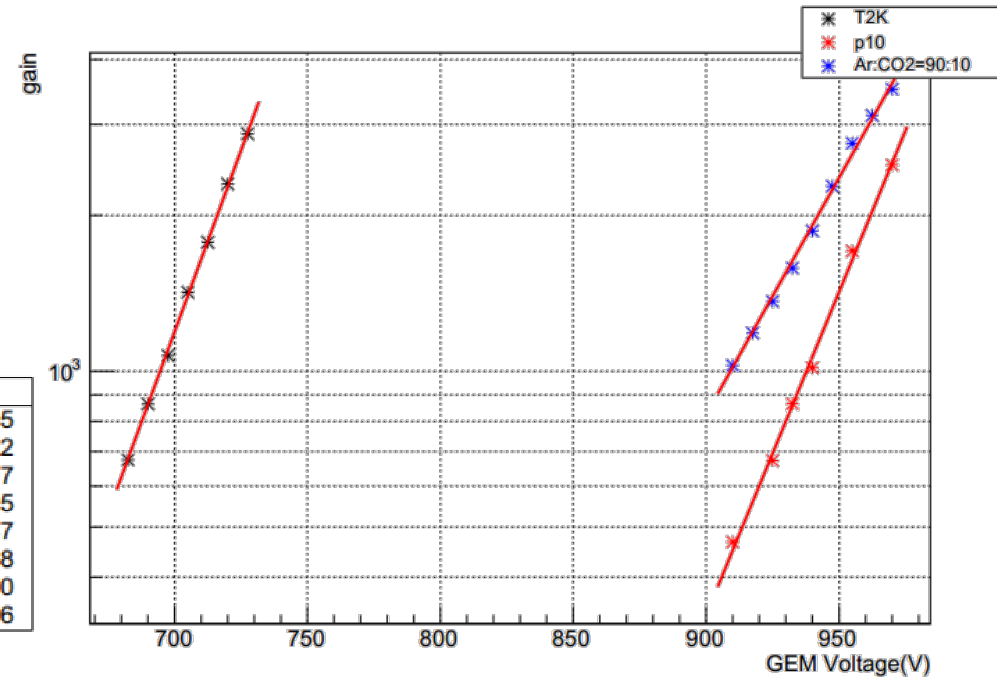
FEE Electronics and DAQ setup photos

Energy spectrum and gain





Energy spectrum of 55Fe and the laser



Gain at T2K, P10, Ar/CO2

Operation gases and ionization with the laser

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

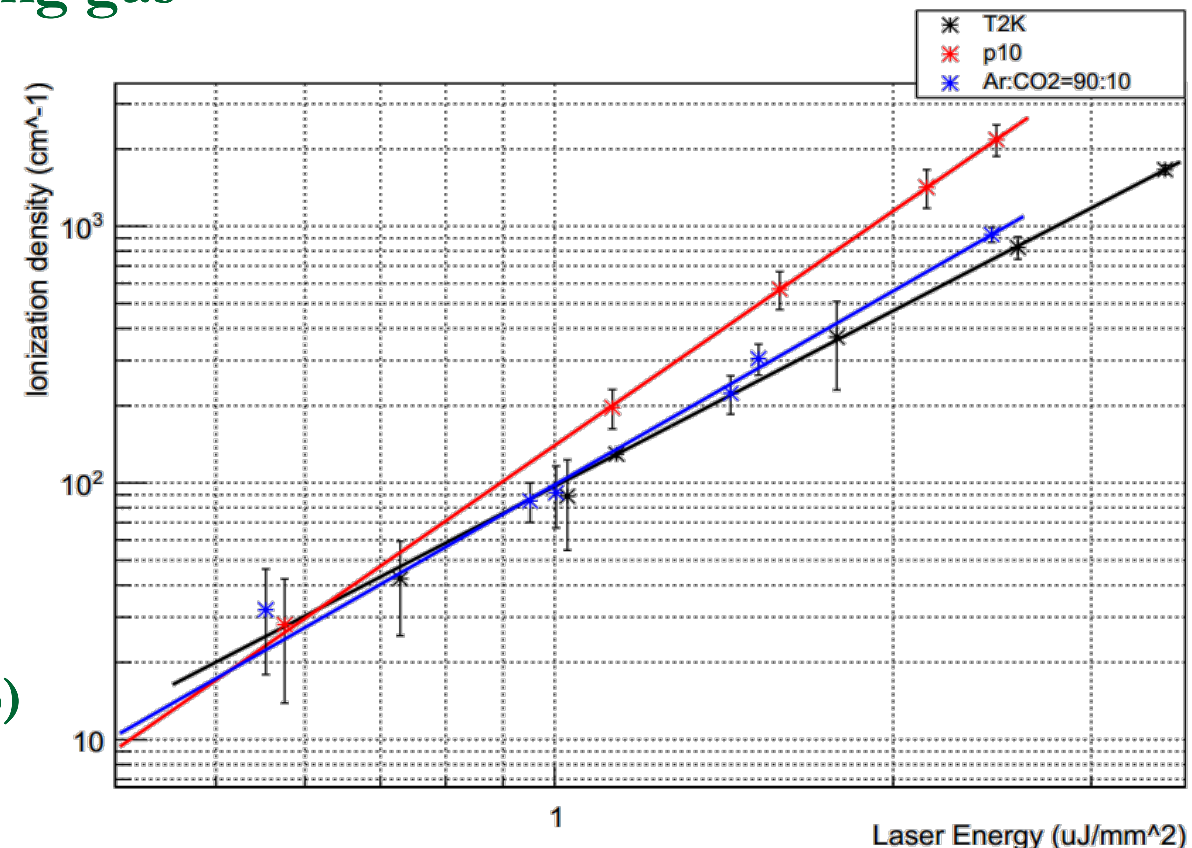
- T2K
- P10
- Ar/CO2=90/10

Gas purity

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

Ionization

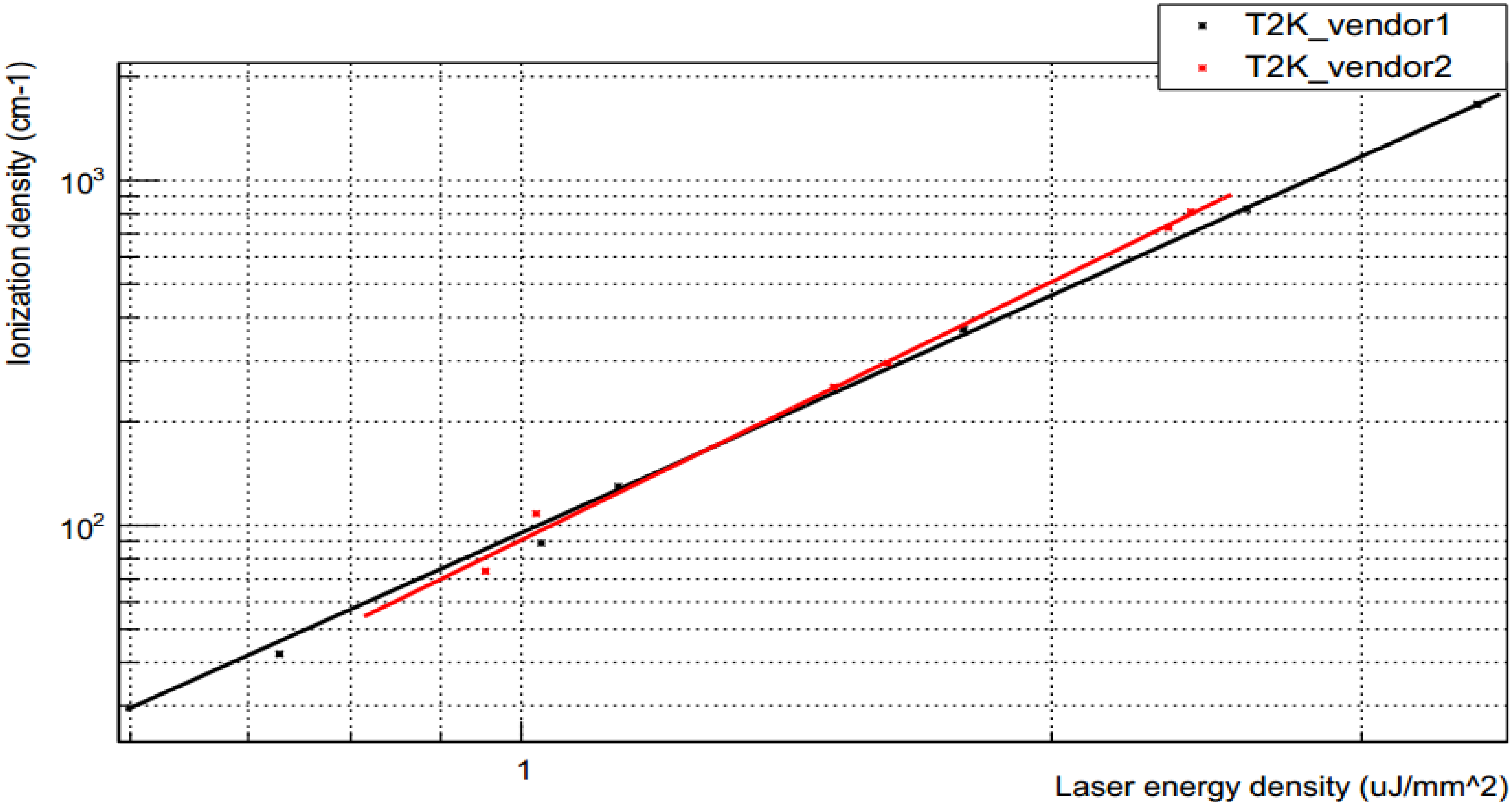
- ~100 electrons/cm at ~1uJ/mm^2



Ionization density unit: [N]/cm
(N is the primary electron number per 0.85mm^2)
Pad size: 0.9mm×6.0mm

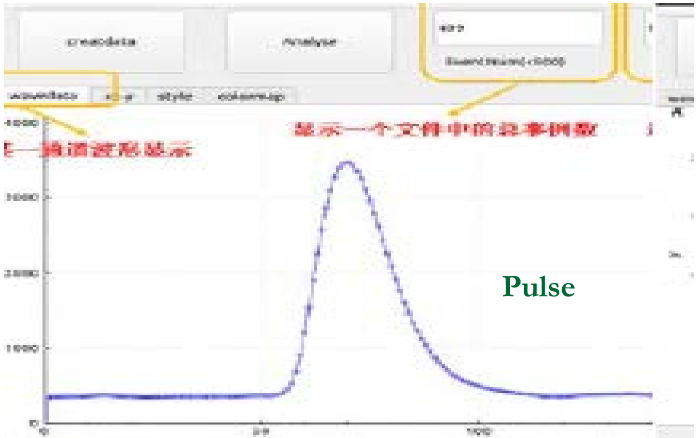
Mixture gases from the two gas company

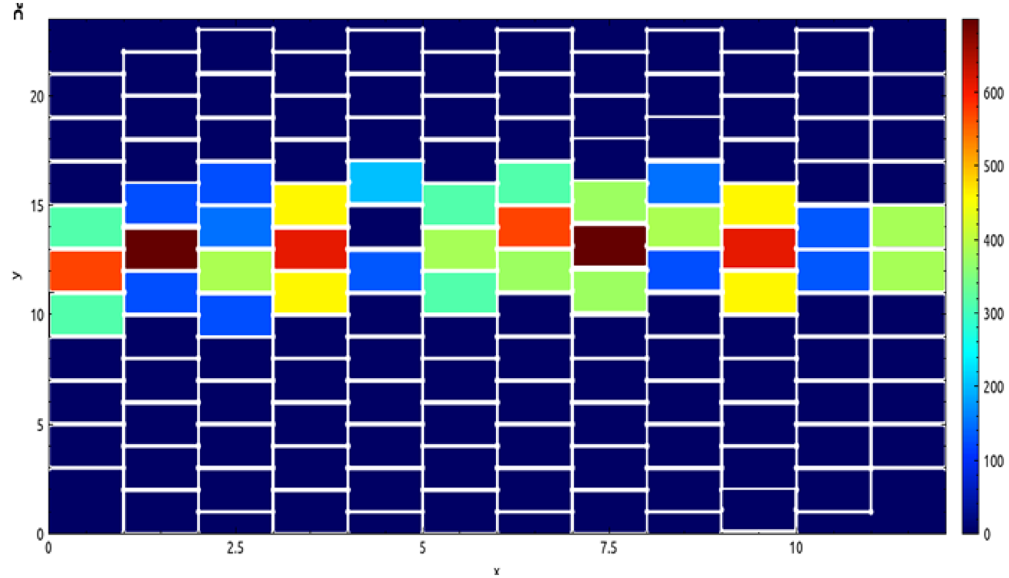
Same gas purity of T2K (our requirements)

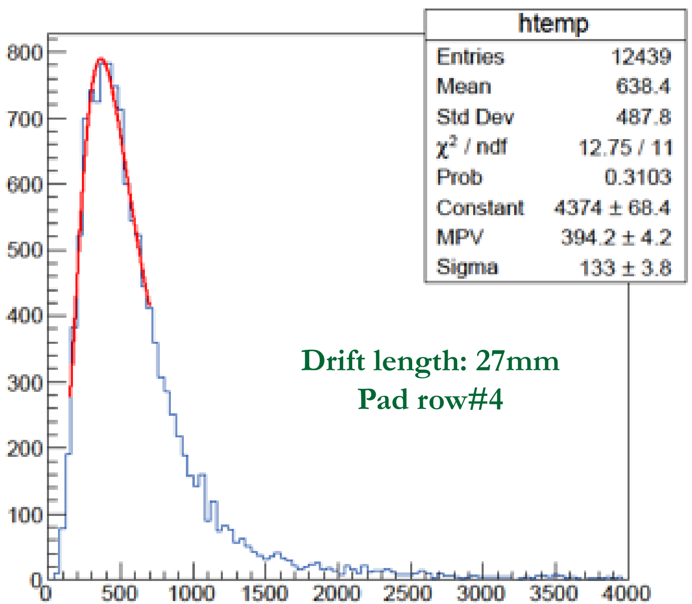


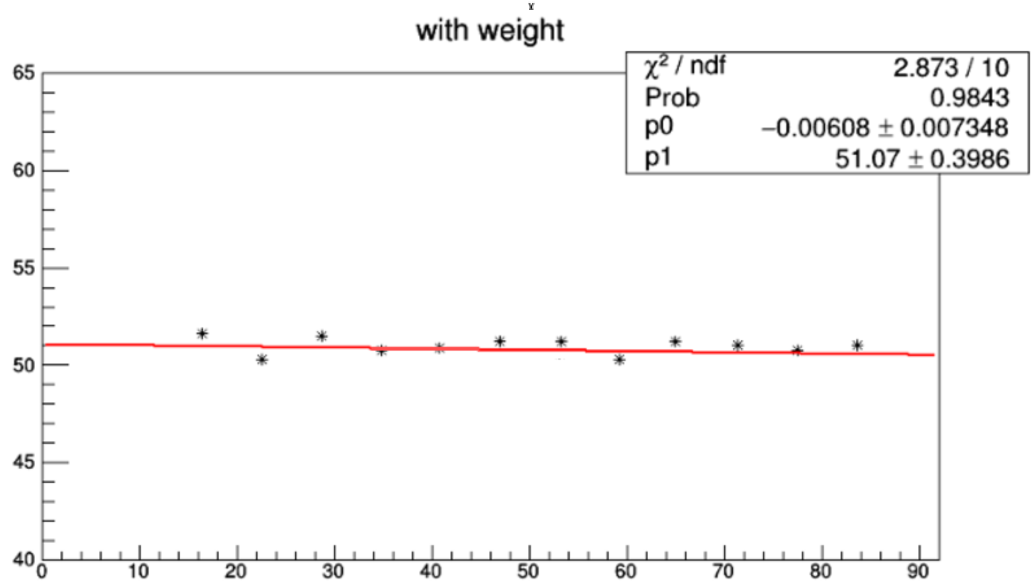
Results indicated that the same ionization ability.

Laser track test@128chs



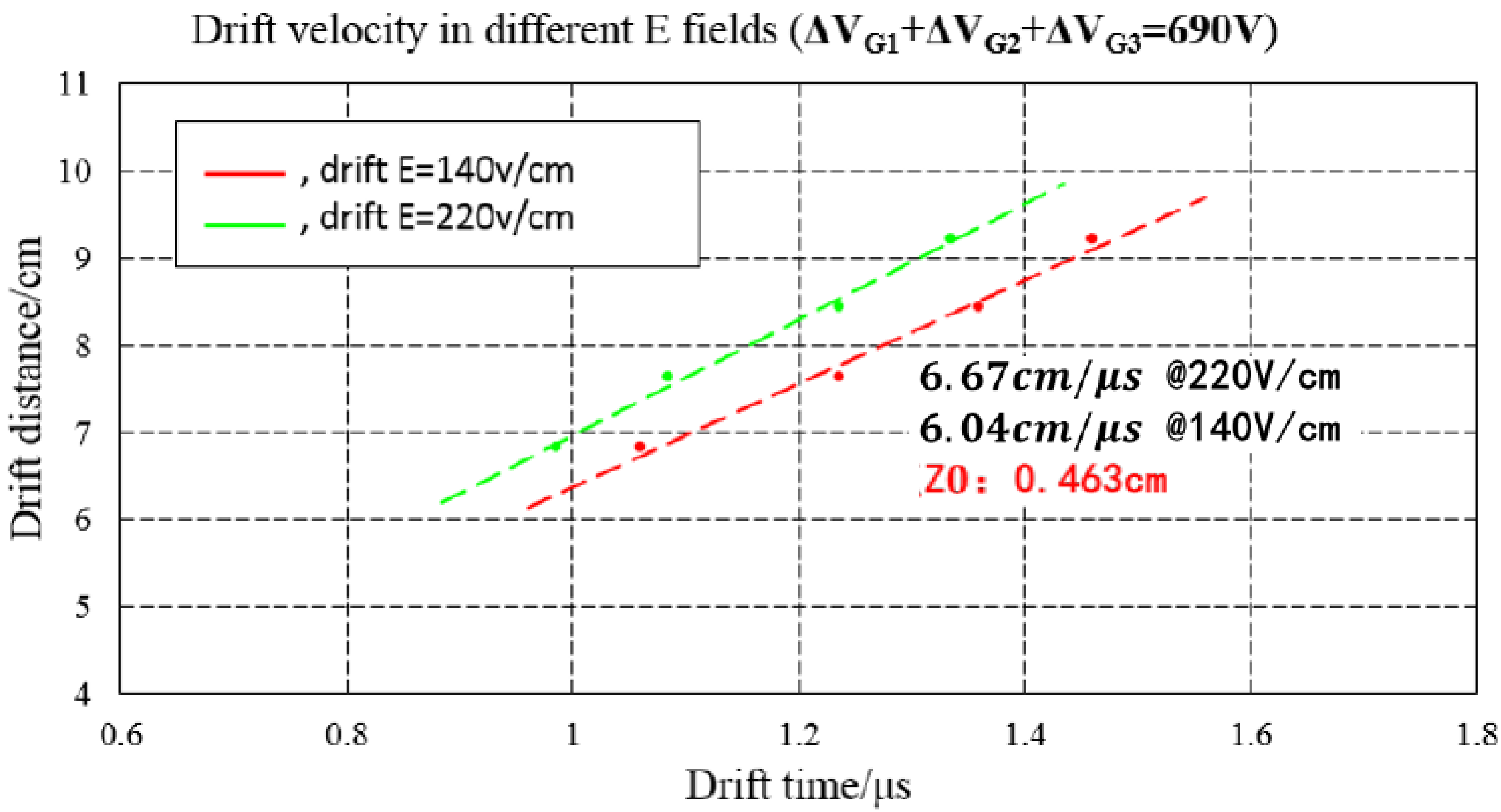






Preliminary results of Laser tracker energy spectrum and tracker

Drift velocity and Z_0 testing @T2K gas



Conclusion

Requirements and critical challenges for the high luminosity:

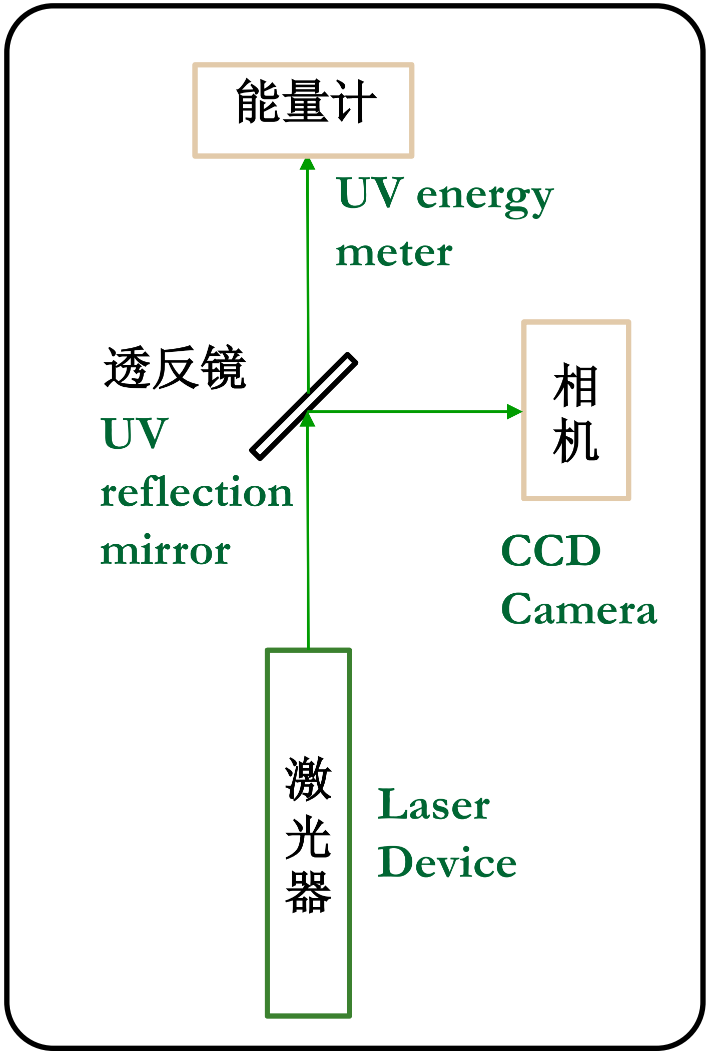
- **High momentum resolution and position resolution**
- **IBF*Gain should be considered at the high luminosity**
- **It needs very sophisticated calibration in order to reach the desired physics performance at Z pole run**
- **Simulation and experiment studies give some parameters for the detector**

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**

Thank you for your attention !

Setup photo


能量计
UV energy meter
透反镜
UV reflection mirror
相机
CCD Camera
激光器
Laser Device