Commissioning and analyzing of TPC prototype integrated with 266nm UV laser

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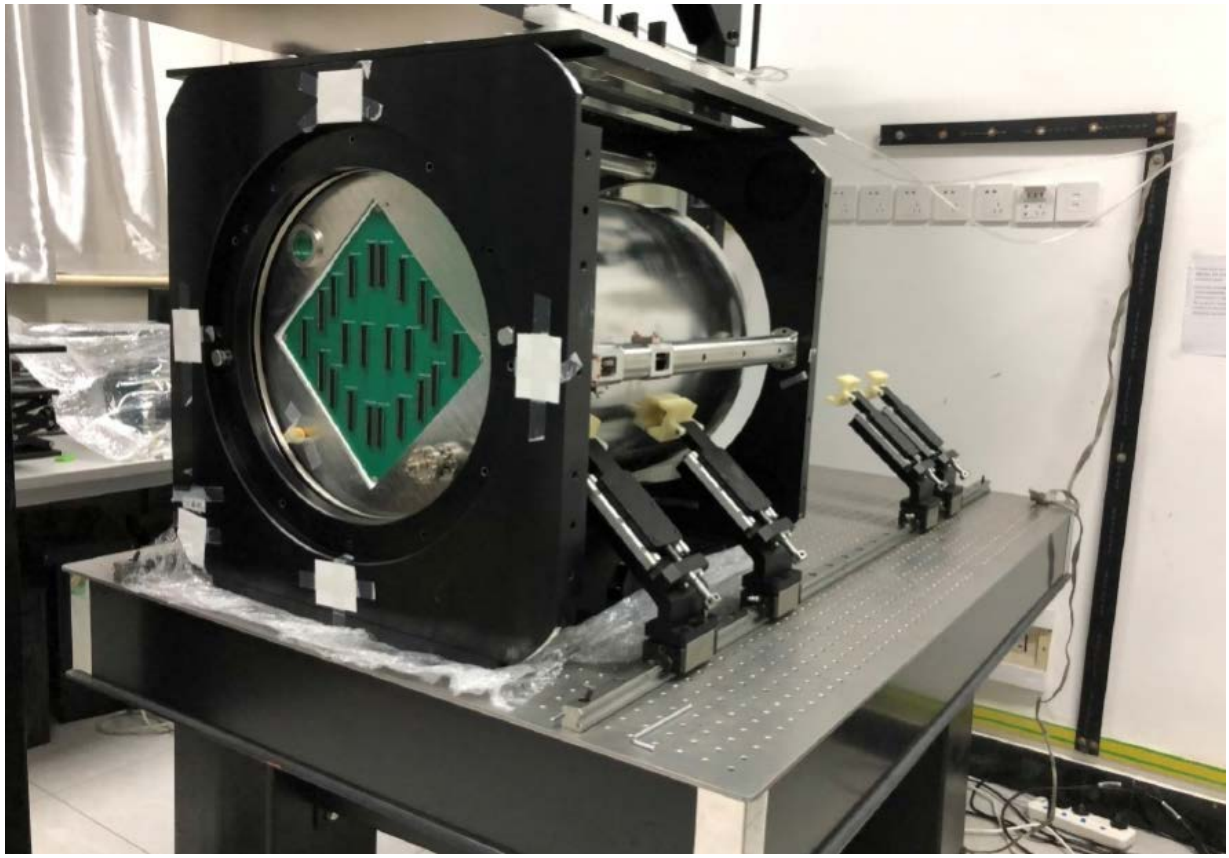
Outline

- TPC prototype
- Analysis and results
- Plans of studies
- Summary

Status of TPC prototype

Achievements and prospects

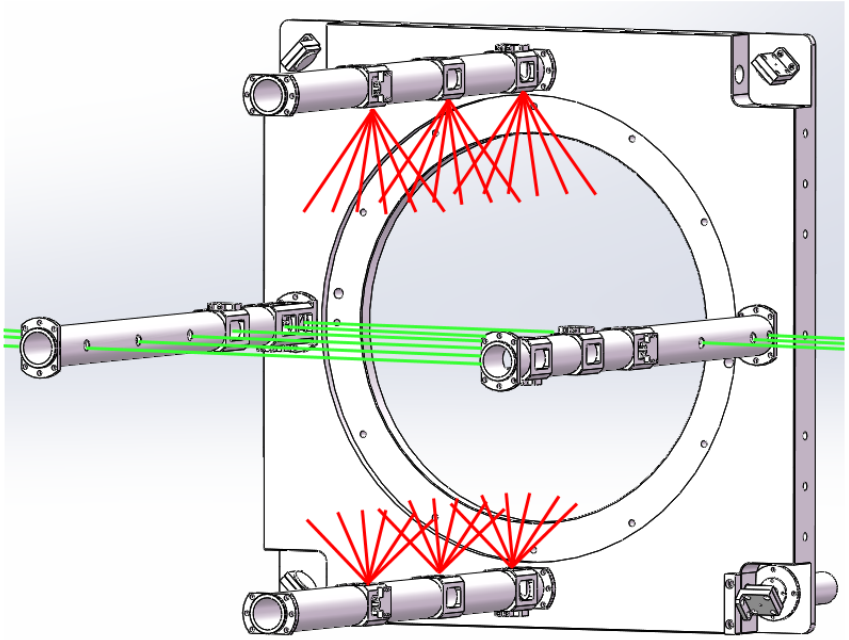
- Detector prototype was almost done and working well in 2021
- Commissioning:
  Huirong Qi, Zhiyang Yuan, Yiming Cai, Yue Chang, Jiang Zhang, Yulan Li, Zhi Deng
- Data taking: the same, plus: Hongyu Zhang, Ye Wu
- Some analyzing results of the drift velocity , the spatial resolution and FEE electronics were observed

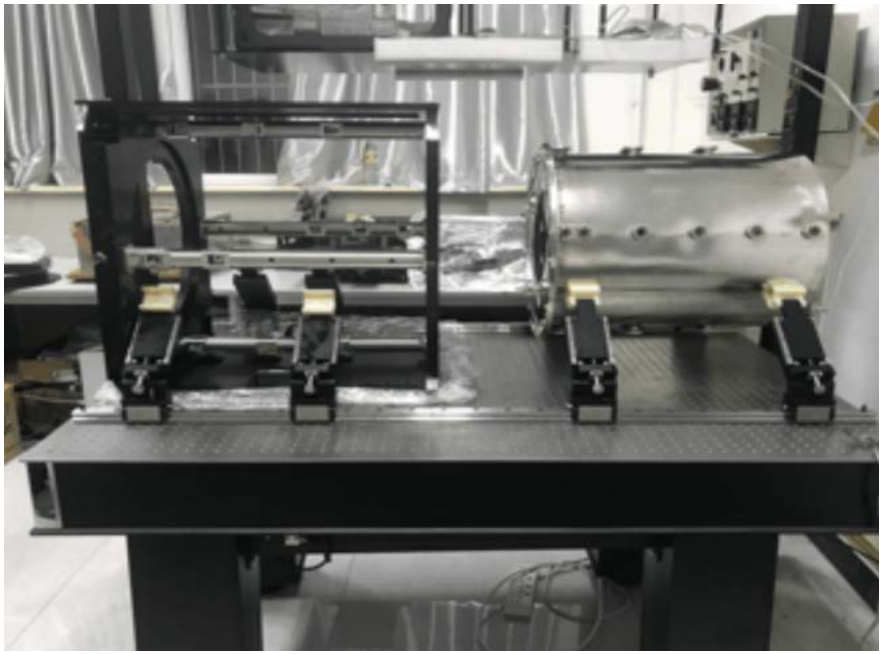


TPC prototype in the lab

TPC Prototype sketch

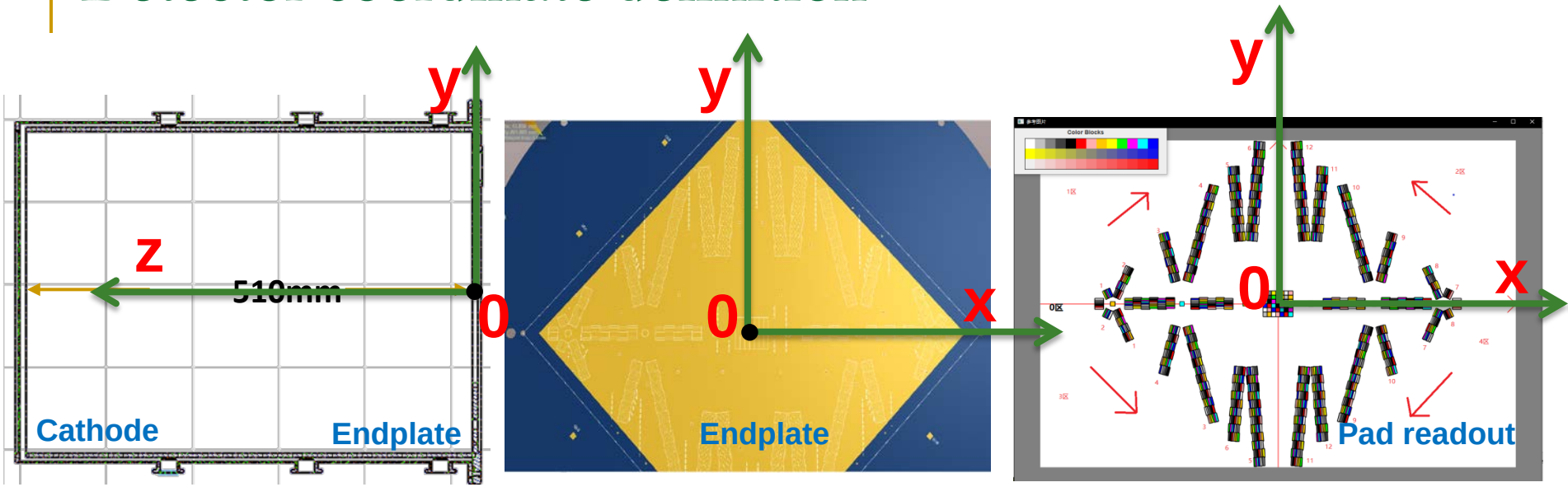
- Main parameters
  - Same test parameters in CEPC
    - Drift field=200V/cm
    - Relative gain: ≥2000
    - Readout pad(anode) is designed to 0V (Ground)
    - TPC detector system: Fieldcage+ Pads readout
    - Working mixture gas:
      - $Ar/CF_4/iC_4H_{10}$=95/3/2
      - Same purity
  - Specific prototype parameters
    - Drift length: ~500mm
    - Active area: 200mm^2
    - Integrated 266nm laser beam
    - MPGD detector as the readout
    - TPC cathode: -10kV
    - Readout Pads: 1280 channels





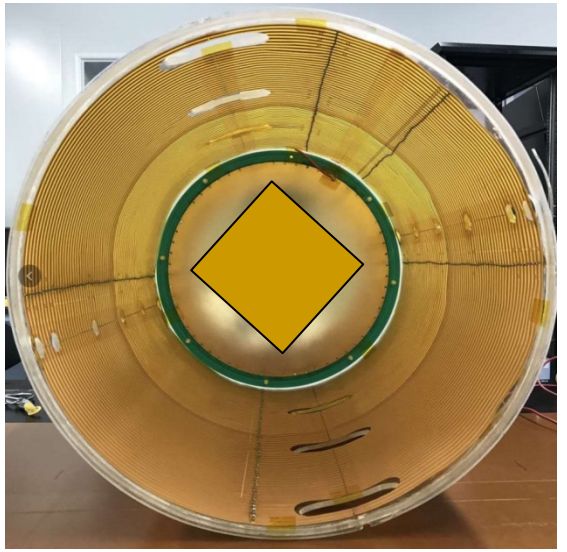
TPC prototype

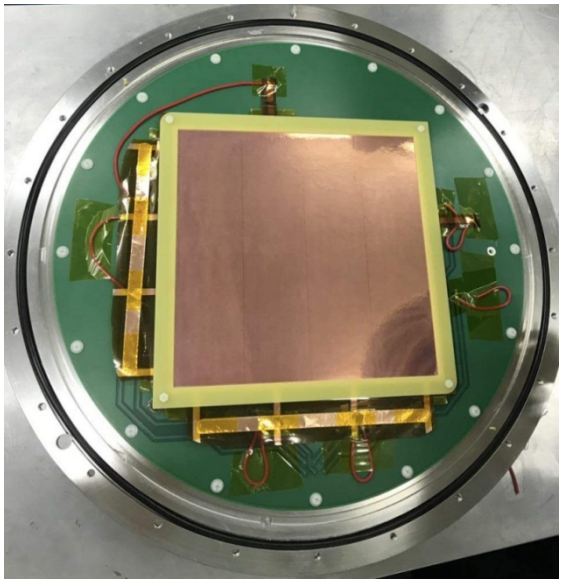
Detector coordinate definition



- The origin of the coordinate is set at the center of the endplate board.
- X and Y plan is set as the readout plane
- Z is set along the drift length from endplate to the cathode
- Z_0 plane is set at the first surface of the detector from cathode to endplate plane.
- The center of the pad is set as the pad's coordinate, and every pad has the specific x and y.

Endplate and field cage

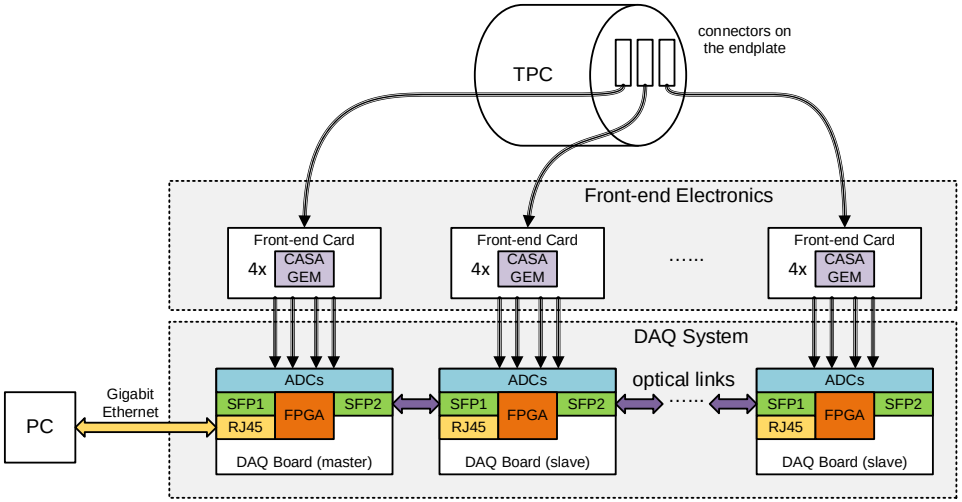




- GEM detector as the endplate with 200mm^2
- Cylindrical flexible circuit board with 0.15mm thickness
- 500mm drift length with 20000V high voltage
- Integration of the 266nm UV laser tracks in the chamber

Electronics

- Amplifier and FEE
  - CASAGEM chip
  - 16Chs/chip
  - 4chips/Board
  - Gain: 20mV/fC
  - Shape time: 20ns



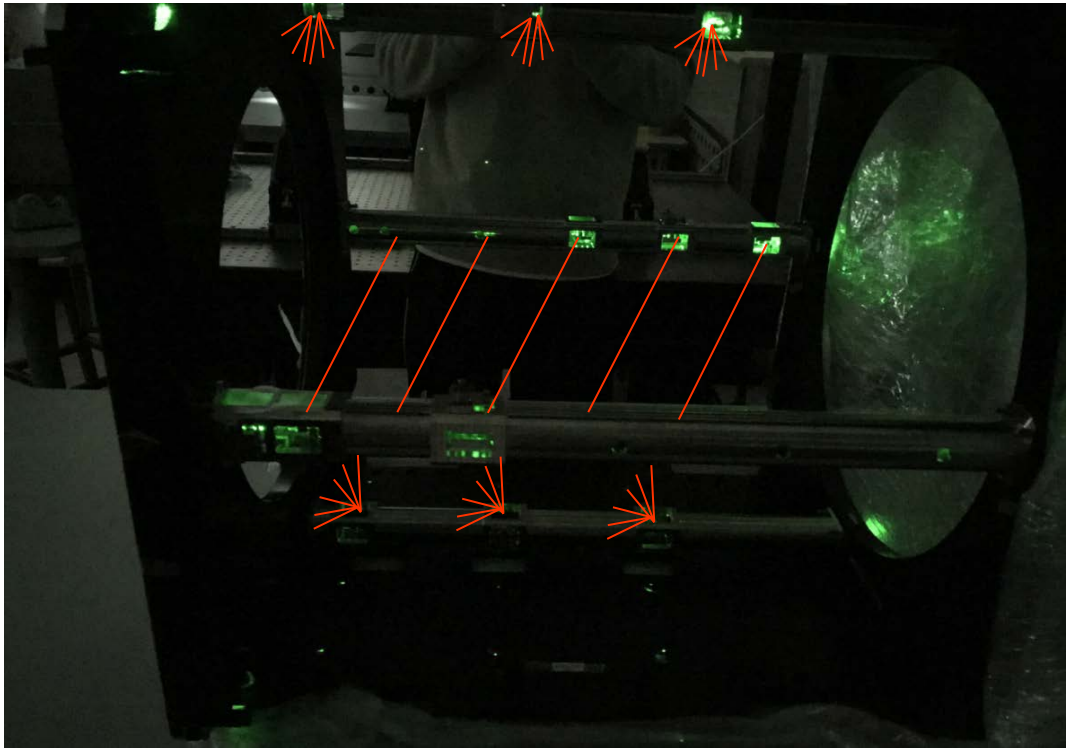
Electronics and DAQ

- DAQ Commissioning
  - FPGA+ADC
  - 4 module/board
  - 64Chs/module
  - Sample: 40MHz
  - 1280chs
  - Signal: >16 sample points
  - Zero suppression
  - 1280 readout channels
  - Noise: <10mV@pp
  - Run mode: trigger and triggerless

FEE Electronics and DAQ setup photos

UV laser device

- Gaussian laser device
  - Nd-LAG UV laser
  - Wave length: 266nm
  - Quantel Q-smart Lasers
  - Frequency: 20Hz
  - Power: <20mJ/pulse
  - Trigger: BNC output

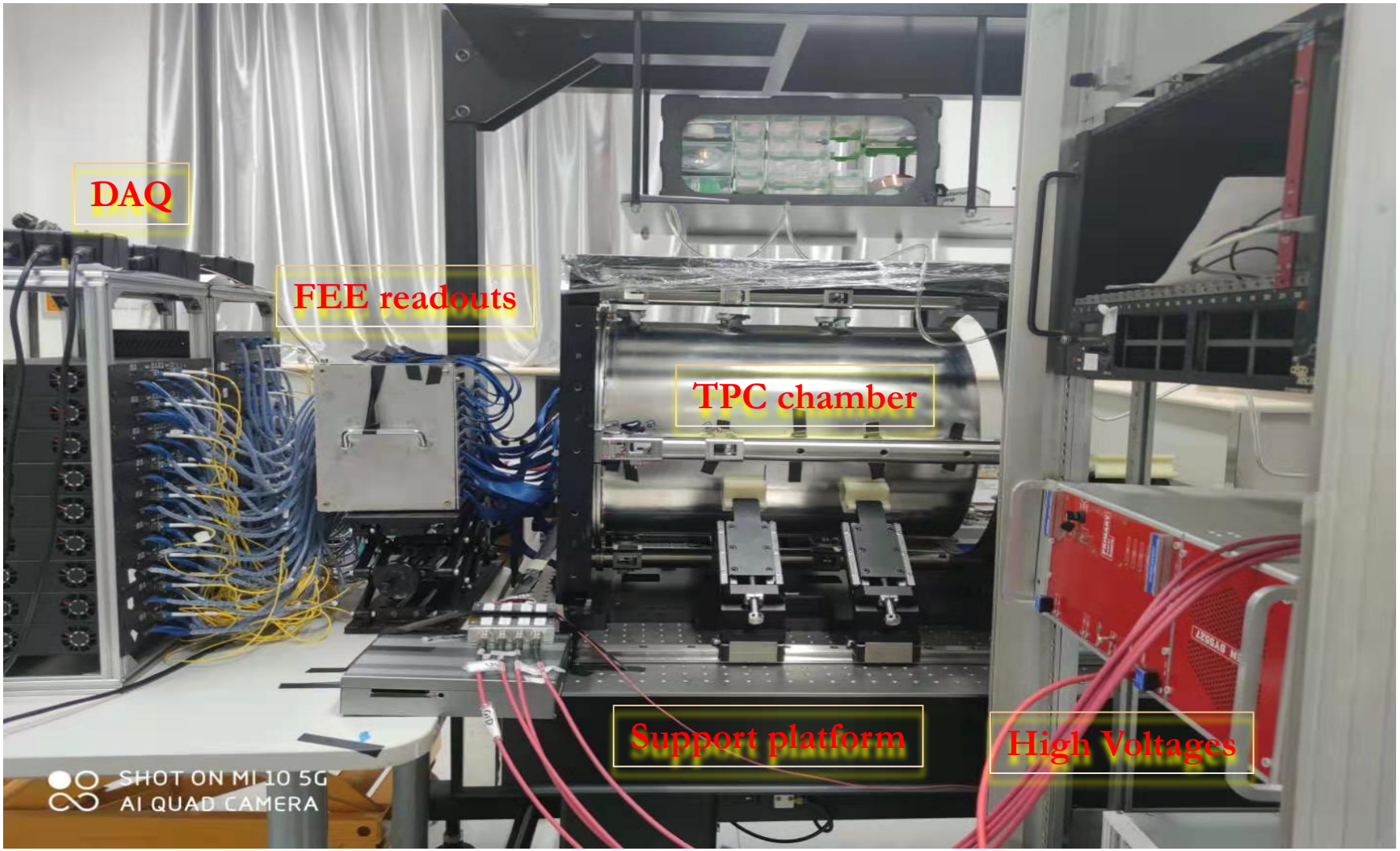


UV laser along the drift length

灯泵脉冲激光器头　　倍频模块　　激光器电源

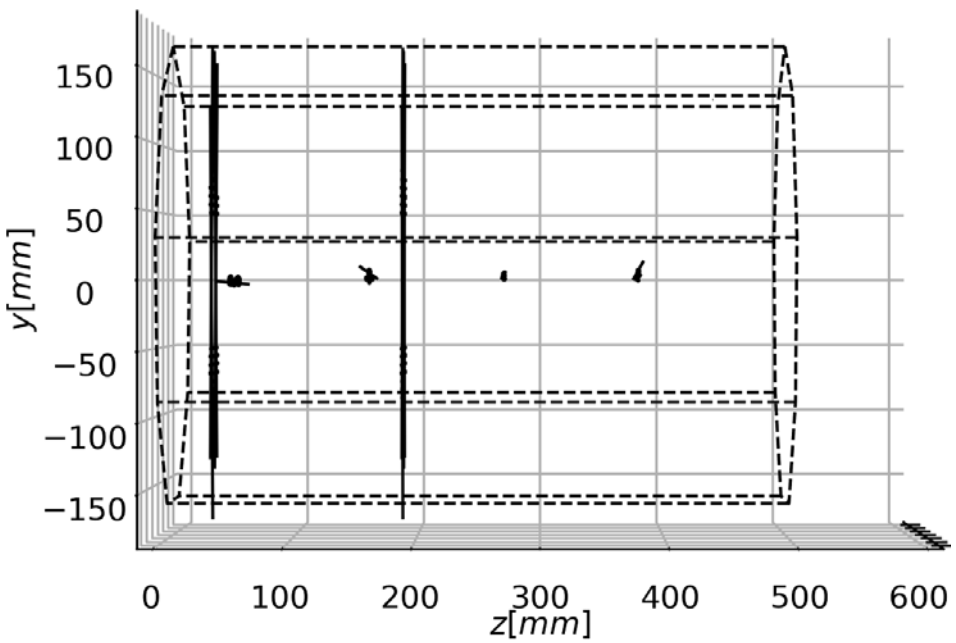
Parameters of the UV laser device

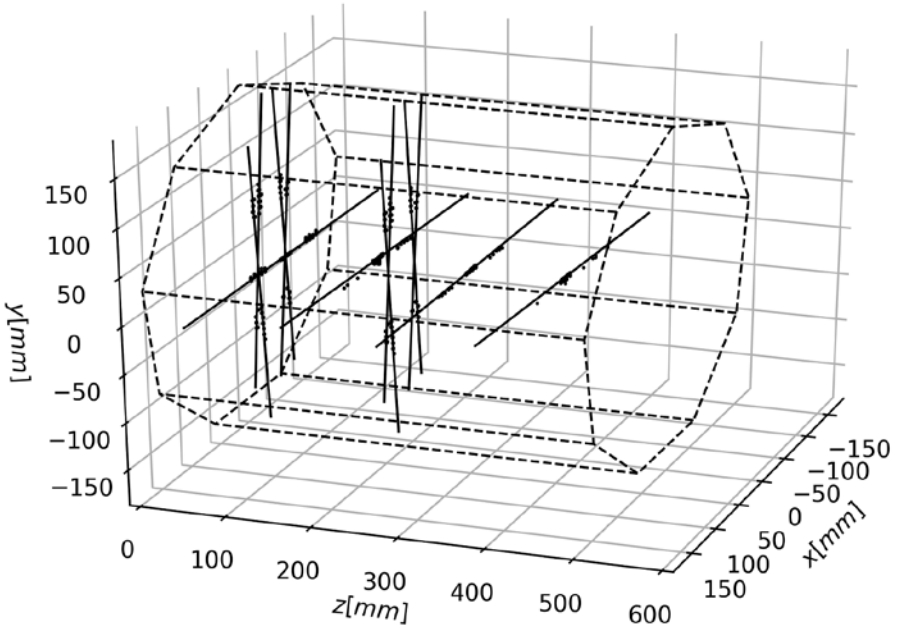
Commissioning and studies



Prototype working well

Laser tracks reconstruction@T2K gas





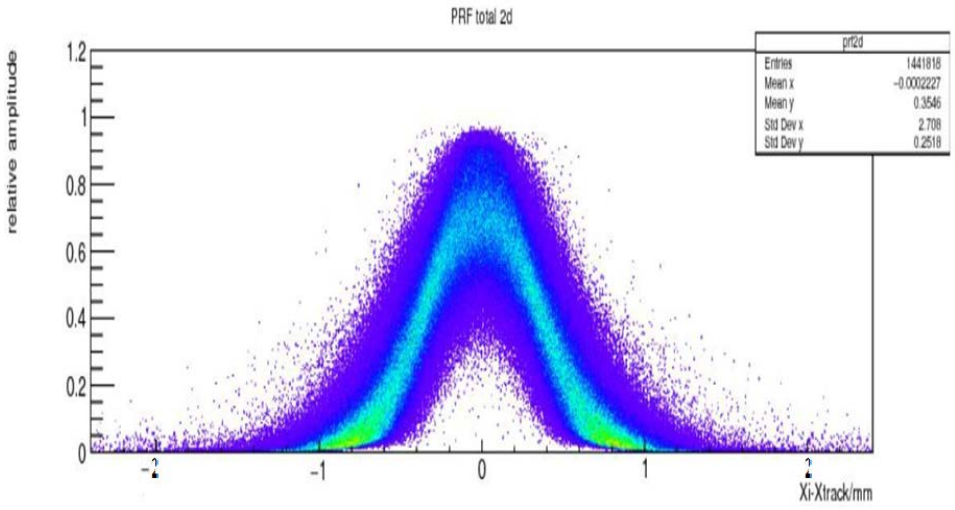
- Same of working gas@T2K, same of high voltage, same of test conditions
- Different of GEMs@ 320V
- No any discharge to damage the detector
- Conclusion
  - All of the triple GEMs, double GEMs and GEM+Micromegas could be as the readout option for TPC prototype
  - 2000 of gain is fine to study UV laser
  - The spatial resolution and the drift velocity could be analyzed

PRF analyzing of the spatial resolution

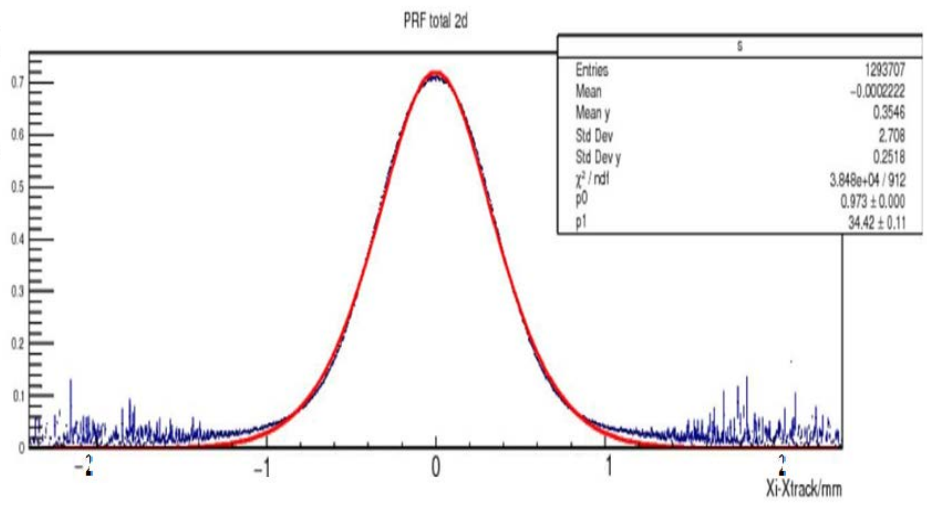
- **Pad Response Function** (PRF): a function used to describe the charge distribution and to determine the hit position via Pad

$$PRF(x, y, w) = \frac{e^{-4ln2(1-y)x^2/w^2}}{1 + 4y \cdot x^2/w^2}$$

  - x is the Pad's coordinate of the center of the corresponding Pad in x-aixs.
  - y is a factor to describe Lorentzian and the Gaussian function
  - w is the width of the Pad (in here, the Pad's width is 0.9 mm)



PRF total of all data

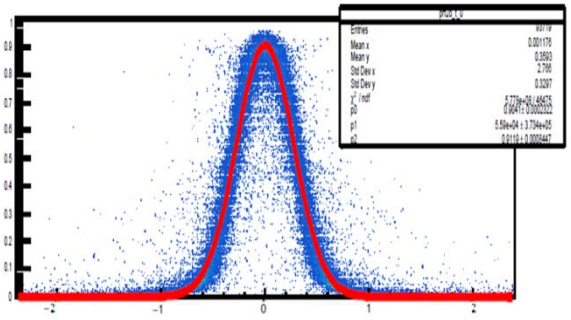


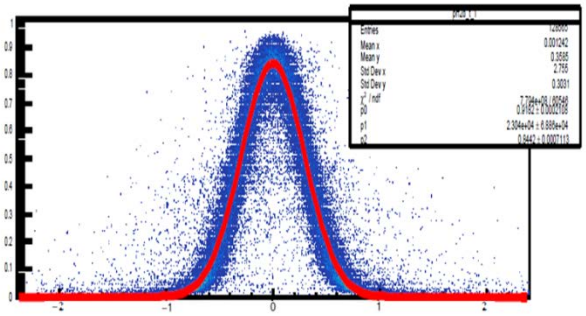
Profile of PRF from one pad row

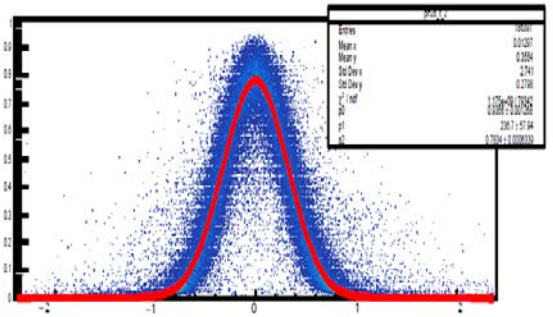
PRF analyzing – iteration calibration

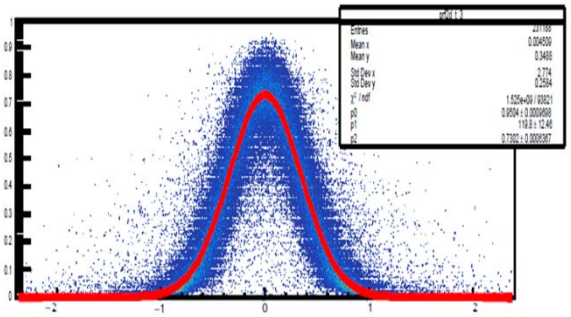
- X-track: reconstruction by the double fits
- Pad Response Function (PRF): need the iteration calibration with $x_i - x_{track}$

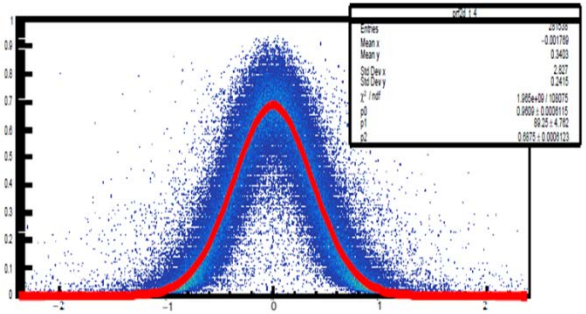
PRF v.s. drift time without iteration → PRF v.s. drift time with iteration(1st) → PRF v.s. drift time with iteration(2nd)

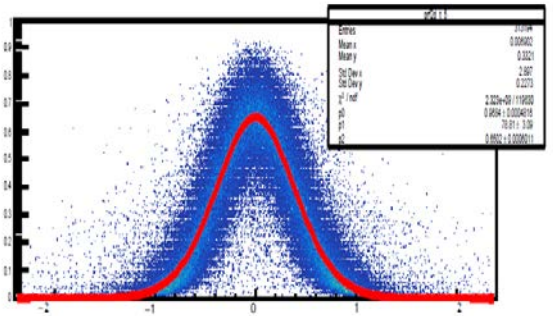










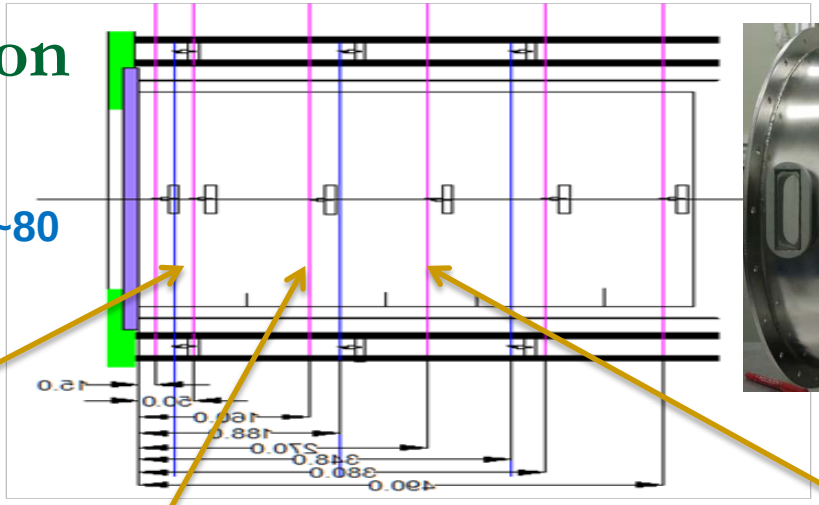


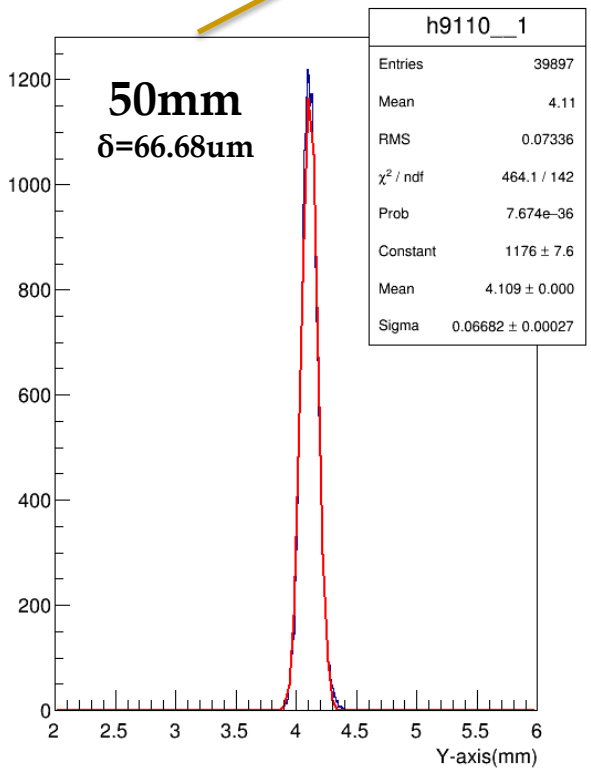
Example of the two rows using iteration calibration

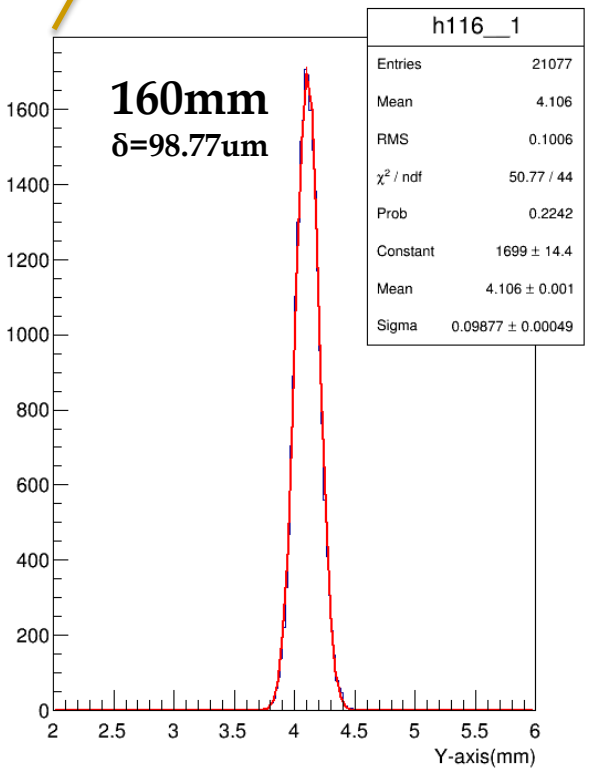
Space resolution

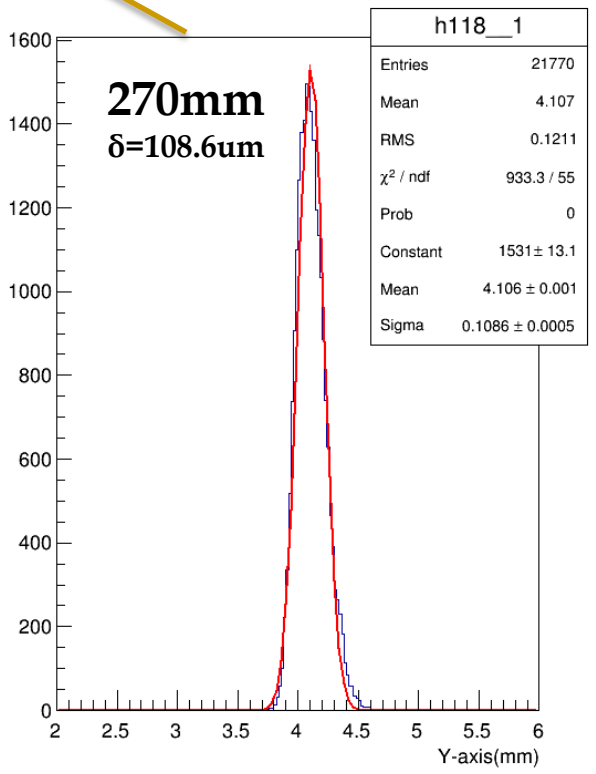
N_{eff} of UV laser in test: ~80

Testing continuing



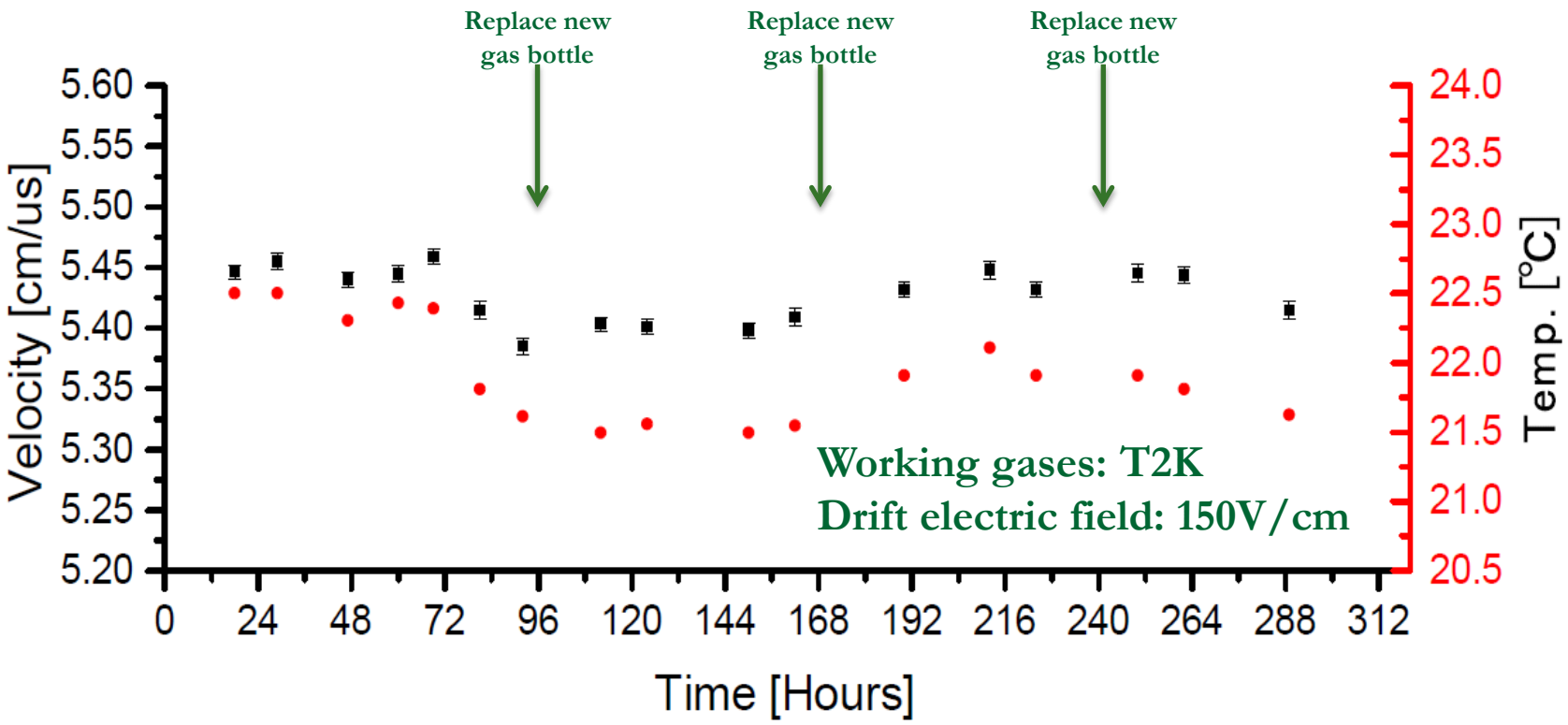






Space resolution at the different drift length

Drift velocity measurement



- Three weeks of continuous testing (Data of E_{drift}=220V/cm is analyzing)
- Room temperature recorded
- Comparison of the drift velocity and the temperature
- Simulation of some influencing factors using Garfield/Gariflield++ software

Conclusion: 266nm UV laser can work well when it can be as the online monitor option.

Plan studies of TPC prototype

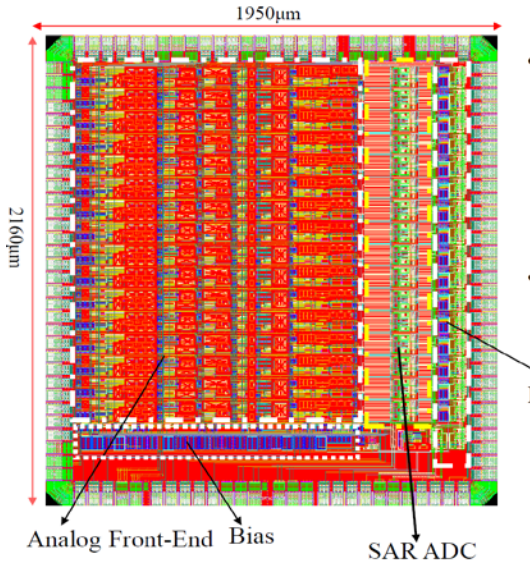
more studies are ongoing…

- dE/dx
- track distortion
- gain uniformity

and …

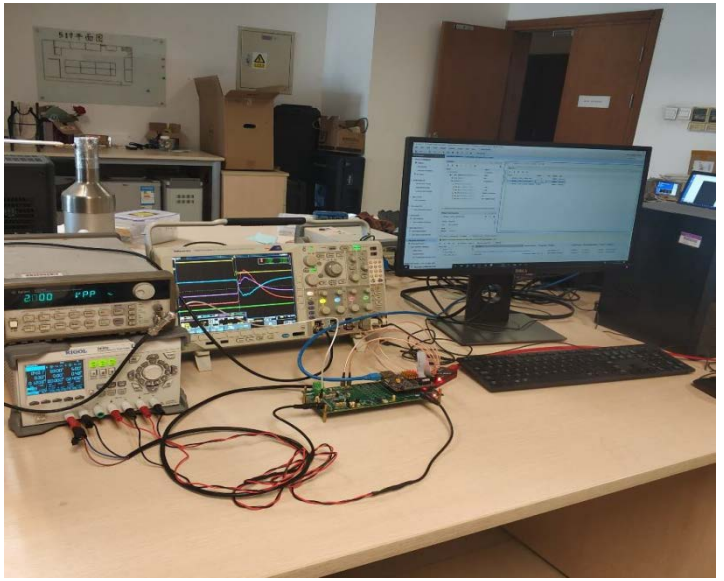
Joint of new ASIC chip R&D

Deng Zhi, Liu Wei and Yuan Zhiyang

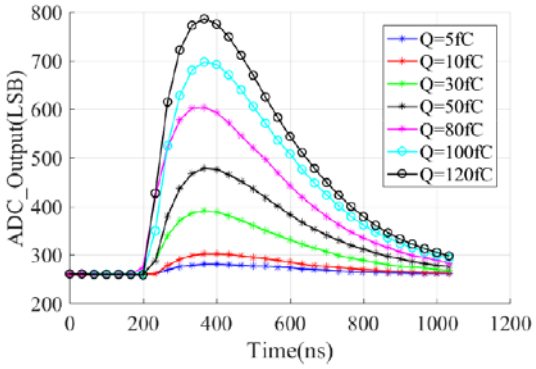


- The floor plan in layout ：
  - The die size of 1950 μm x 2160 μm
  - Analog Front-End , SPI, SAR ADC, LVDS driver are supplied by separate power
- The ASIC have been taped out in November, 2019 and is being evaluated

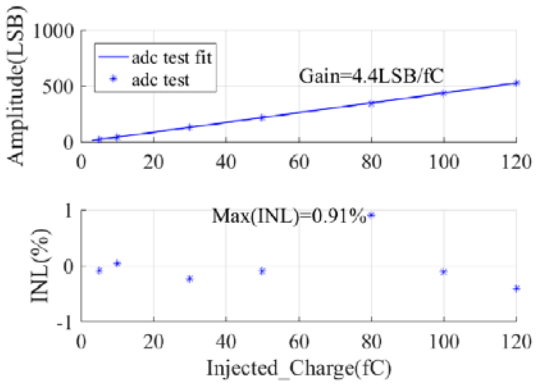
Layout of ASIC chip



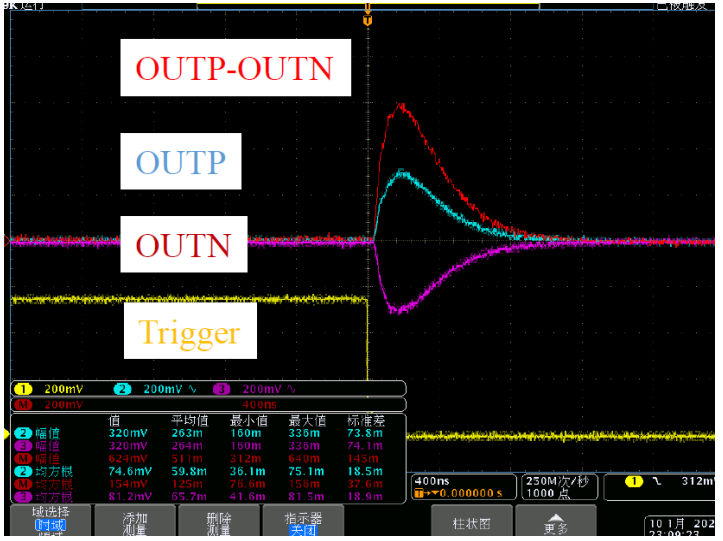
- Transient outputs



- The linearity @ gain = 10 mV/fC



Gain = 4.4 LSB/fC = 4.4 x 2.34 mV/fC = 10.3 mV/fC



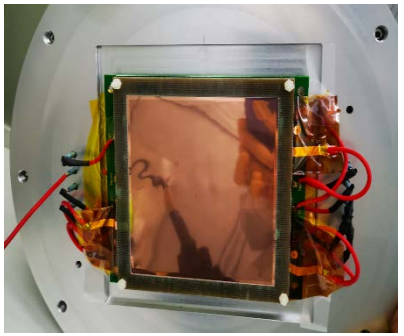
Test of the signals

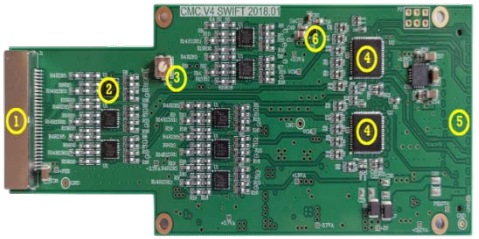
New electronics commissioning

- A 16 channels low power consumption readout

ASIC chip for TPC readout have been developed

  - The power consumption is 2.33 mW/channel
    - P_{AFE} = 1.43 mW/channel
    - P_{ADC} = 0.9 mW/channel @ 40M/s
  - ENC =852e @Cm = 2pF, gain =10 mV/fC and can be reduced to 474e using digital trapezoidal filter





Detector and ASIC

- Future studies
  - More ASIC evaluations: Higher sampling rate, more detailed noise test, test with detectors …
  - Low power digital filter and data compression in FPGA/ASIC
  - Commission of ASIC chip board and the detector to test in the laboratory

Summary

- Some update results of TPC prototype have been studies, the prototype is working well, and the results indicated that 266nm UV laser beams system will be very useful in the TPC prototype R&D.
- More studies are ongoing and the update analyzing will been done.
- The TPC detector module and prototype will designed, assembled and commissioned with the new low power consumption ASIC chip in April. (IHEP+Tsinghua)

Thanks for your attention.