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

Huirong Qi

ZhiYang Yuan, Yiming Cai, Yue Chang, Jian Zhang, Zhi Deng, Yulan Li, Hui Gong, Wei Liu

Institute of High Energy Physics, CAS

Tsinghua University

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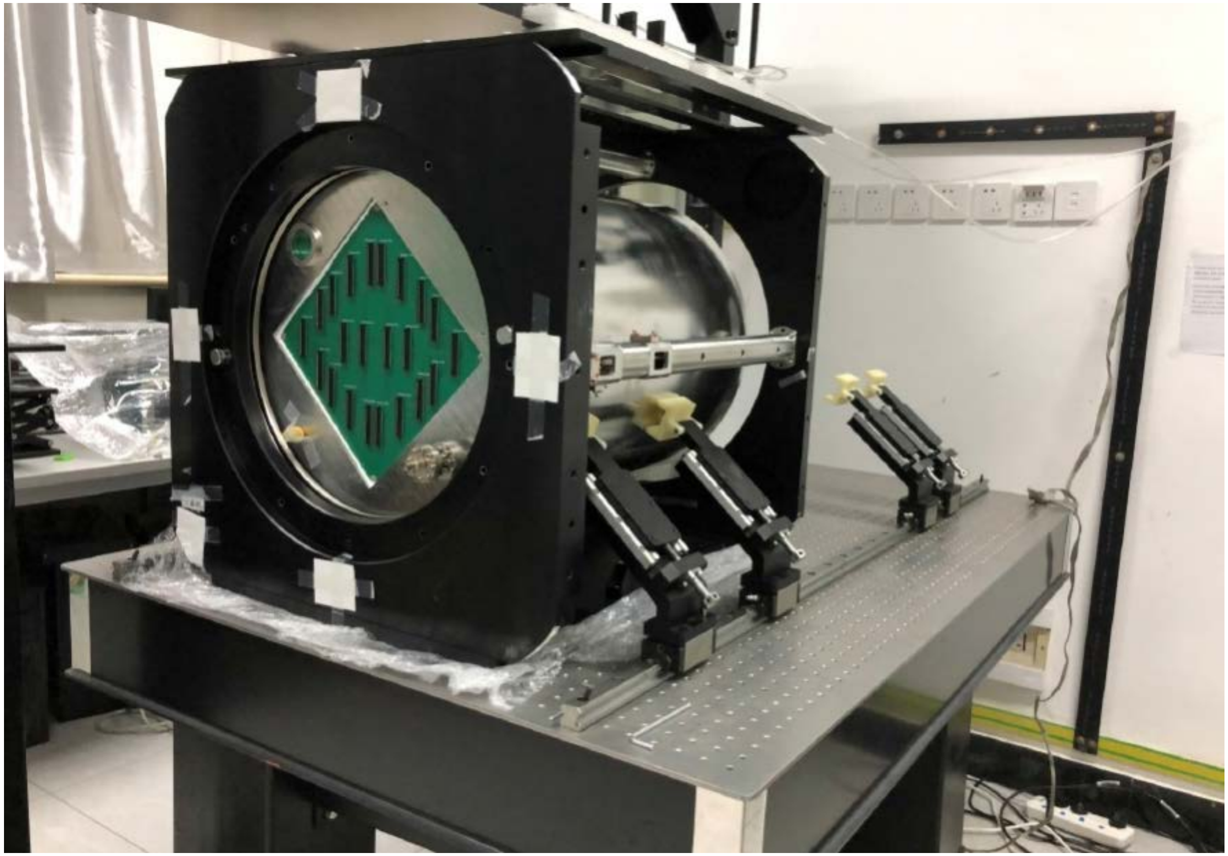
Outline

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

Status of TPC prototype

Achievements and prospects

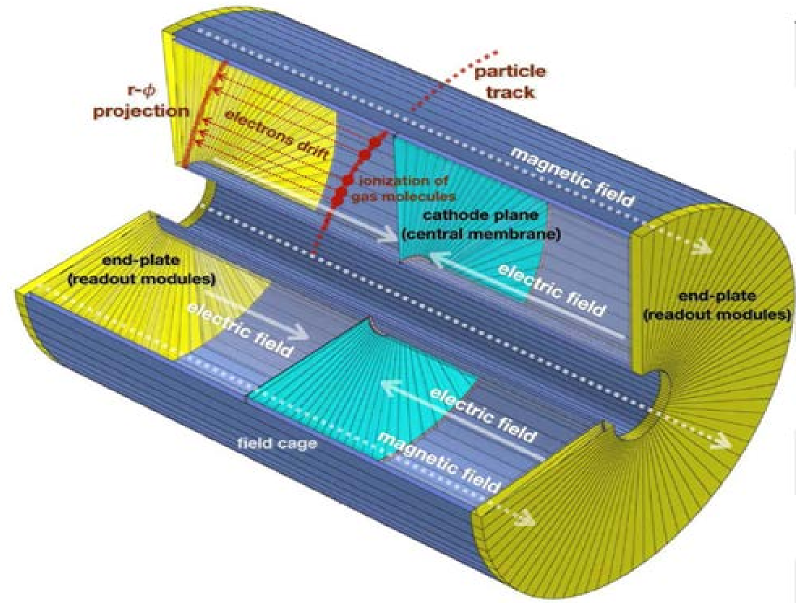
- Detector prototype was almost perfectly done and working in 2020
- Commissioning: Huirong Qi, Zhiyang Yuan, Yiming Cai, Yue Chang, Jiang Zhang, Yulan Li, Zhi Deng
- Data taking: the same, plus: Hongyu Zhang, Ye Wu
- Compared with some previous LCTPC R&D, good results of the drift velocity , the spatial resolution and FEE electronics were observed

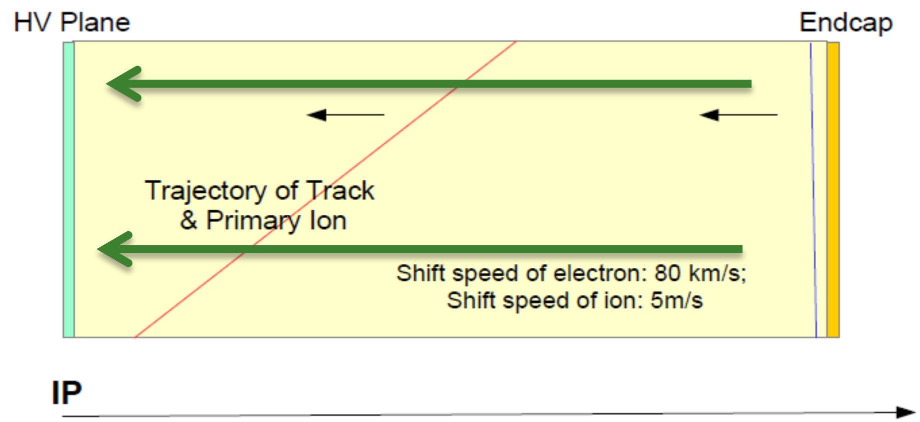


TPC prototype in the lab

CEPC requirements and TPC Prototype

- TPC critical R&D
  - TPC can provide large-volume high-precision 3D track measurement with the lower material budget
  - In order to achieve the high spatial resolution (<100um in all drift length), small pads (e.g. 1mm×6mm) are needed, resulting ~1million channels of readout electronics
  - Need low power consumption readout electronics working at continuous mode
  - Need effectively reduce ions
  - Need TPC prototype R&D



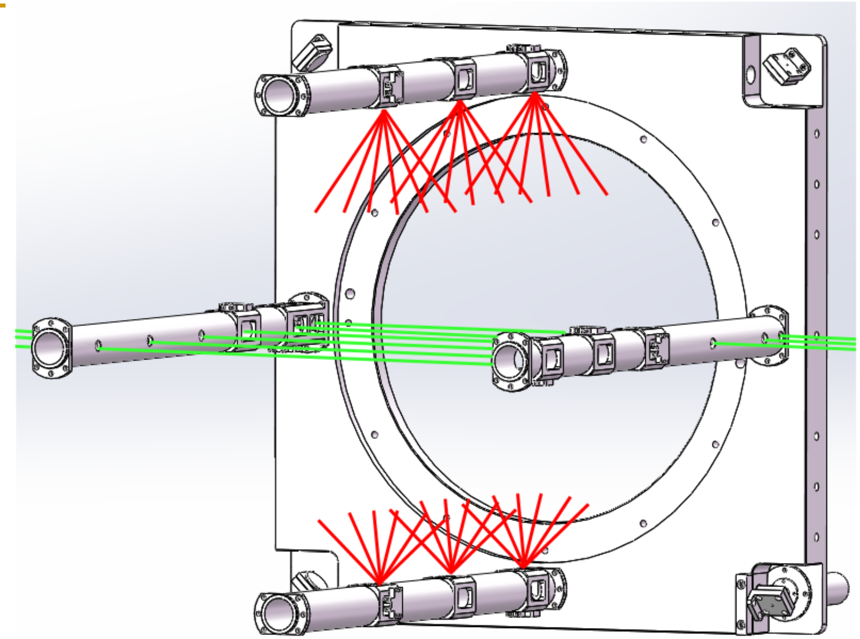


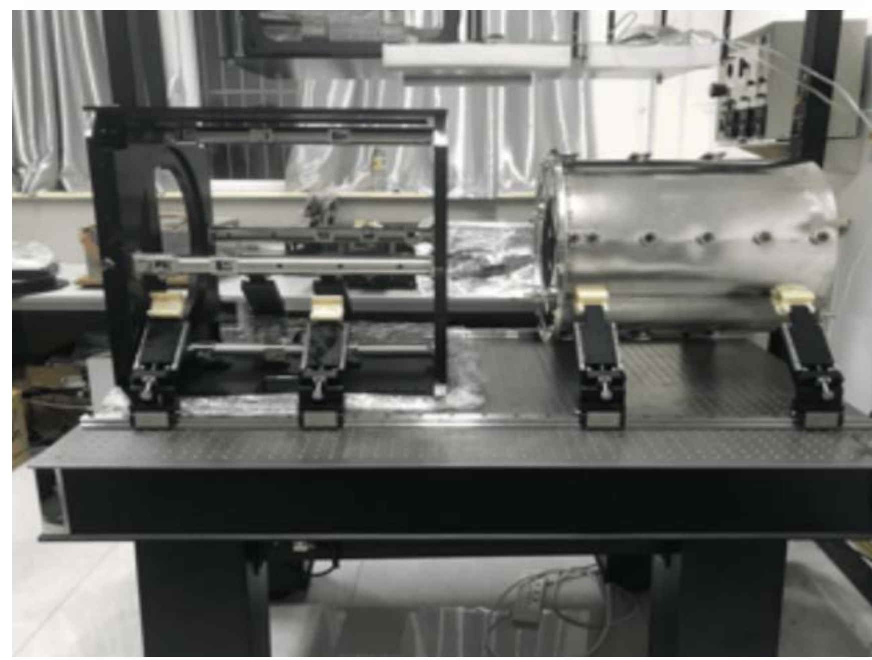
TPC detector concept

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

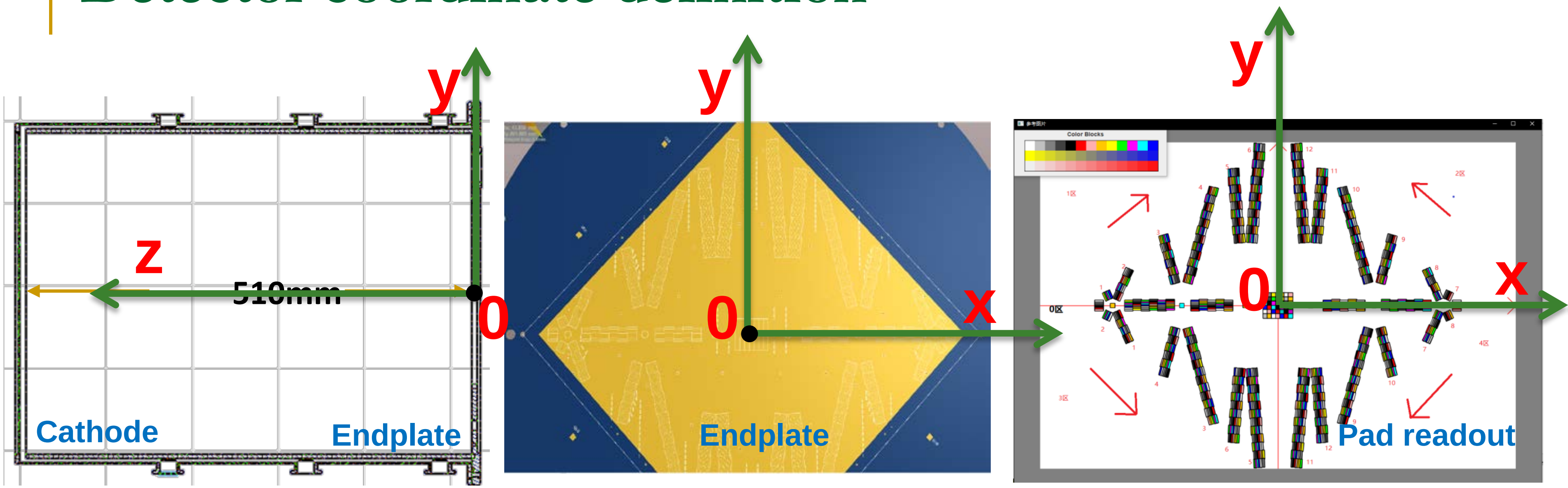
preliminary





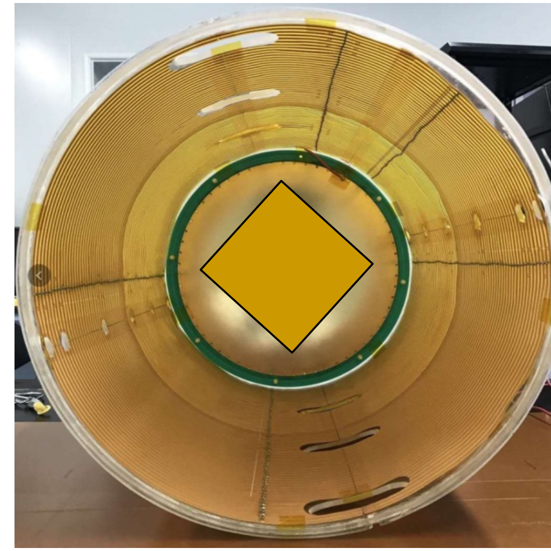
TPC prototype

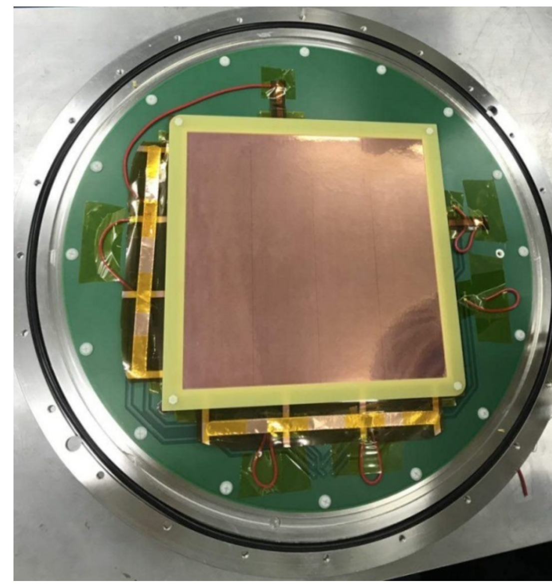
Detector coordinate definition



- 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

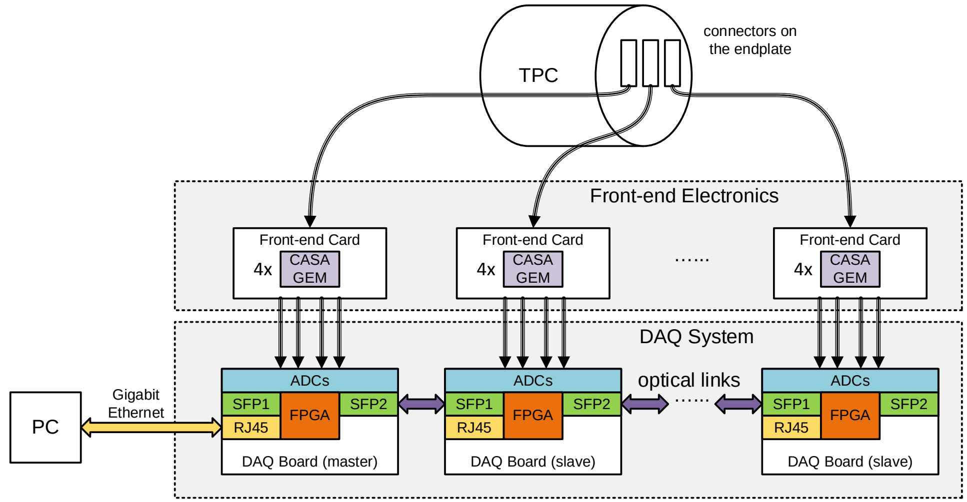




- GEM detector as the endplate with 200mm^2
- Cylindrical flexible circuit board with 0.15mm thickness
- 500mm drift length with 20000V high voltage
- Integration of the 266nm UV laser tracks in the chamber

Electronics

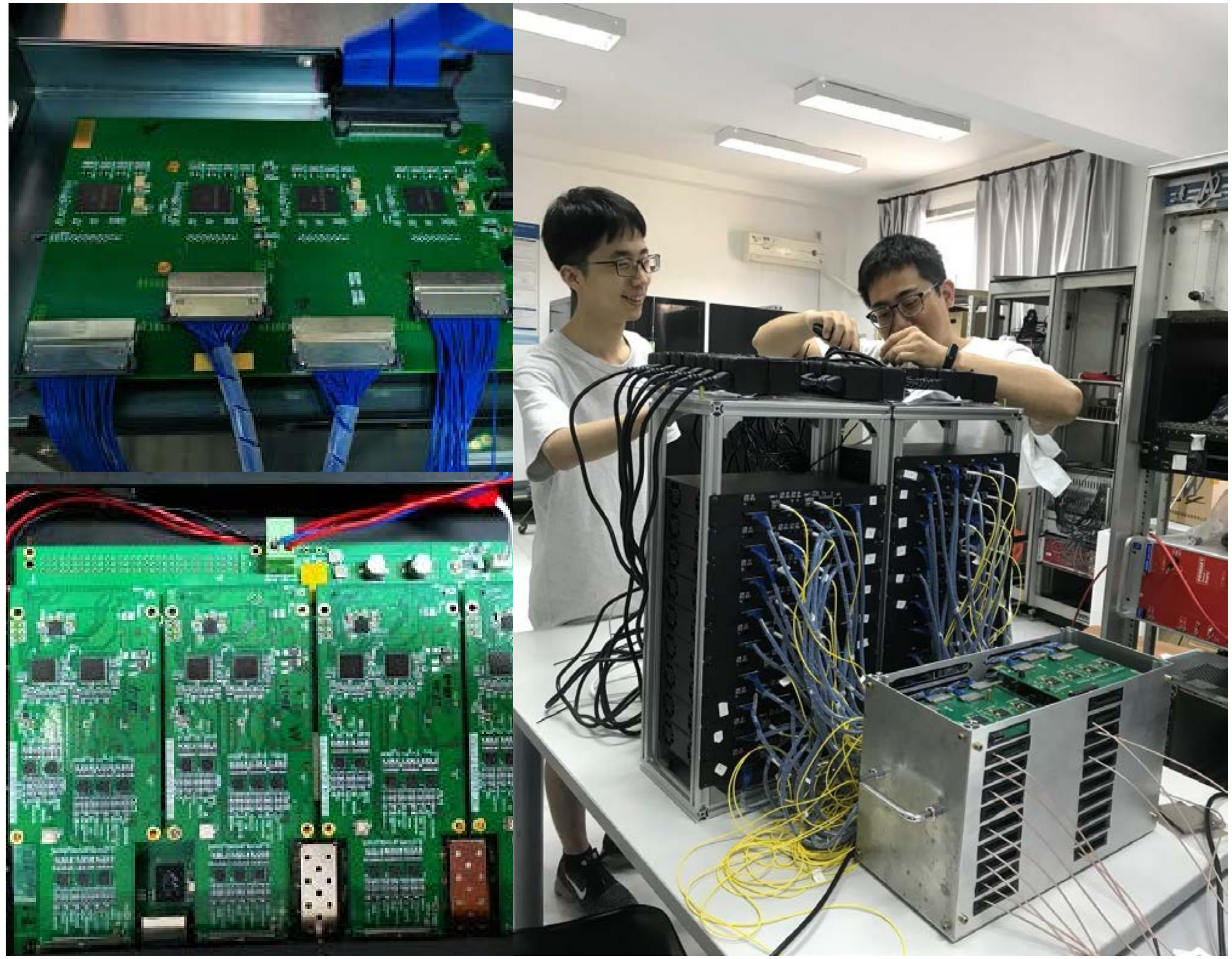
- Amplifier and FEE
  - CASAGEM chip
  - 16Chs/chip
  - 4chips/Board
  - Gain: 20mV/fC
  - Shape time: 20ns



FEE Electronics

Electronics and DAQ

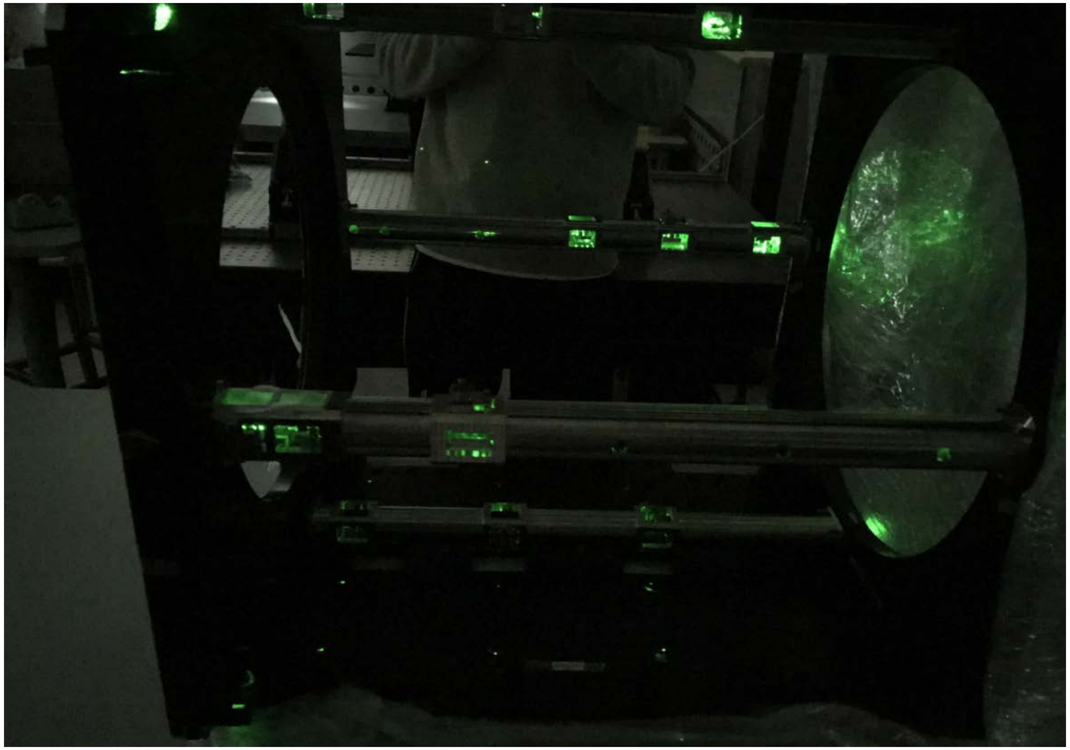
- DAQ Commissioning
  - FPGA+ADC
  - 4 module/board
  - 64Chs/module
  - Sample: 40MHz
  - 1280chs
  - Signal: >16 sample points
  - Zero suppression
  - 1280 readout channels
  - Noise: <10mV@pp
  - Run mode: trigger and triggerless



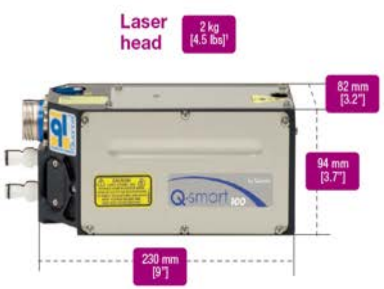
FEE Electronics and DAQ setup photos

UV laser device

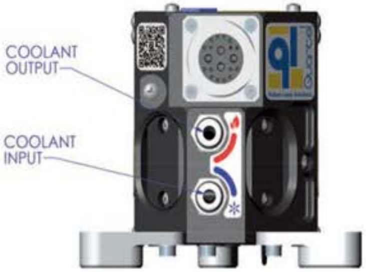
- Gaussian laser device
  - Nd-LAG UV laser
  - Wave length: 266nm
  - Quantel Q-smart Lasers
  - Frequency: 20Hz
  - Power: <20mJ/pulse
  - Trigger: BNC output



UV laser along the drift length



灯泵脉冲激光器头

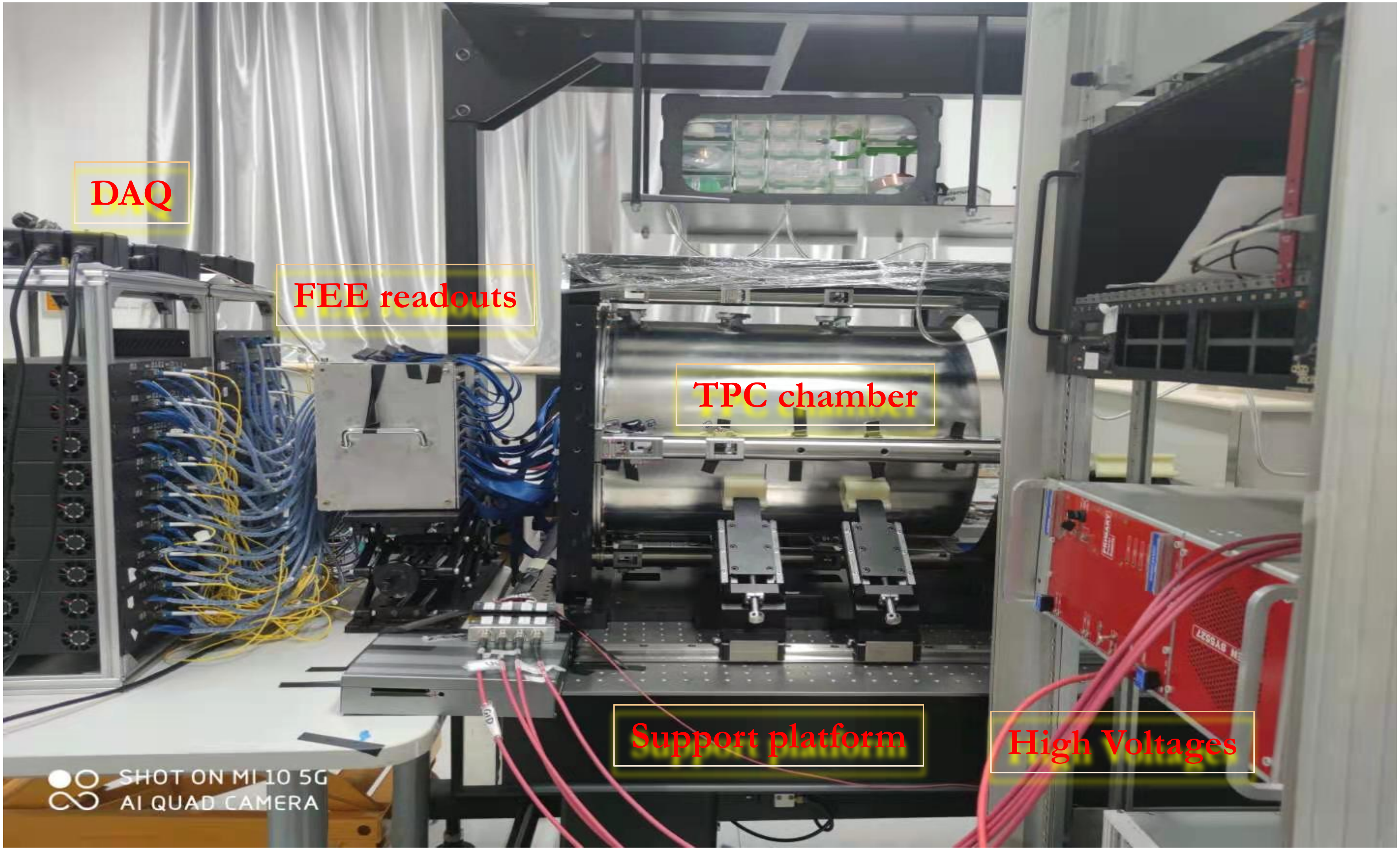


倍频模块

激光器电源

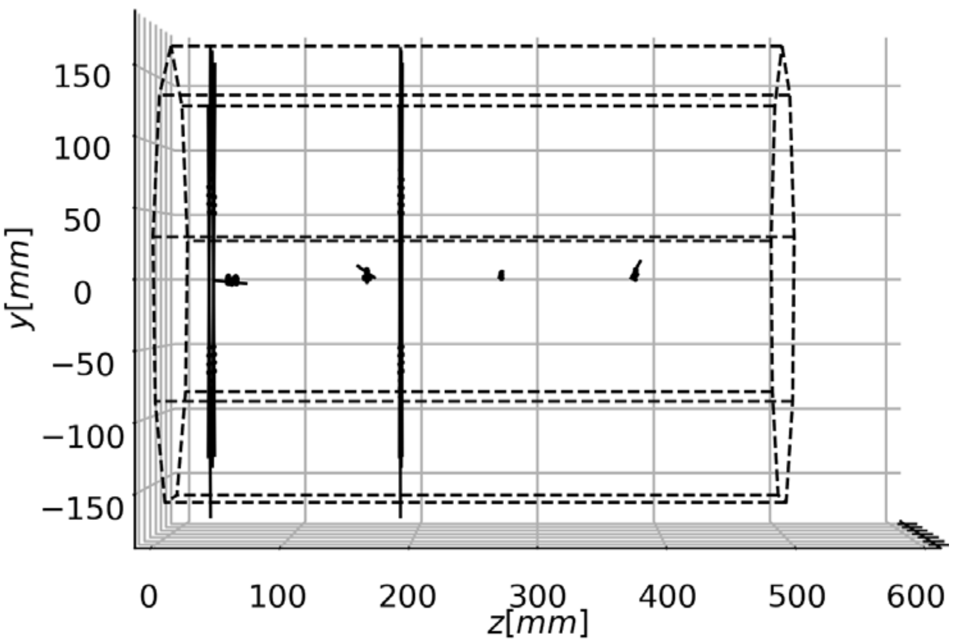
Parameters of the UV laser device

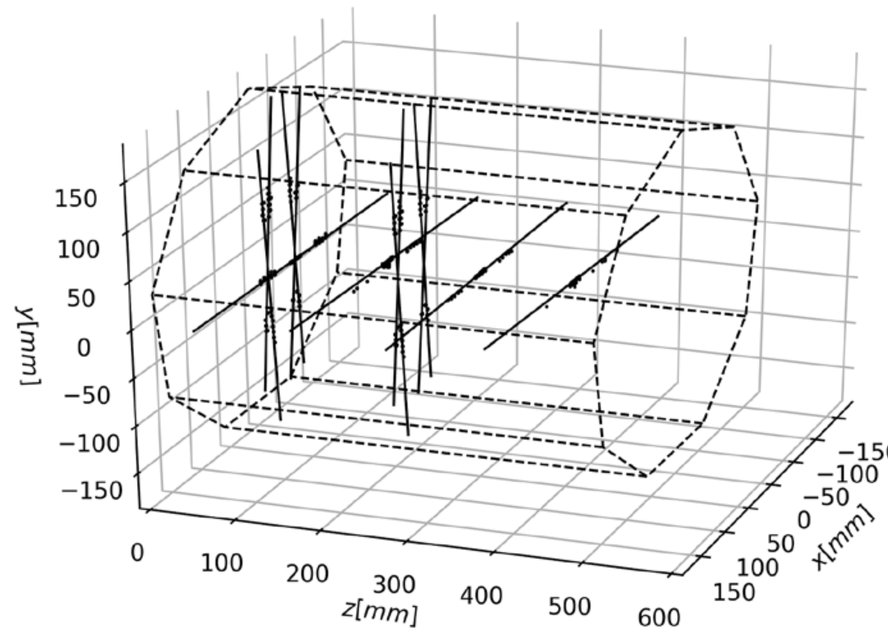
Commissioning and studies



Prototype working well

Laser tracks reconstruction@T2K gas





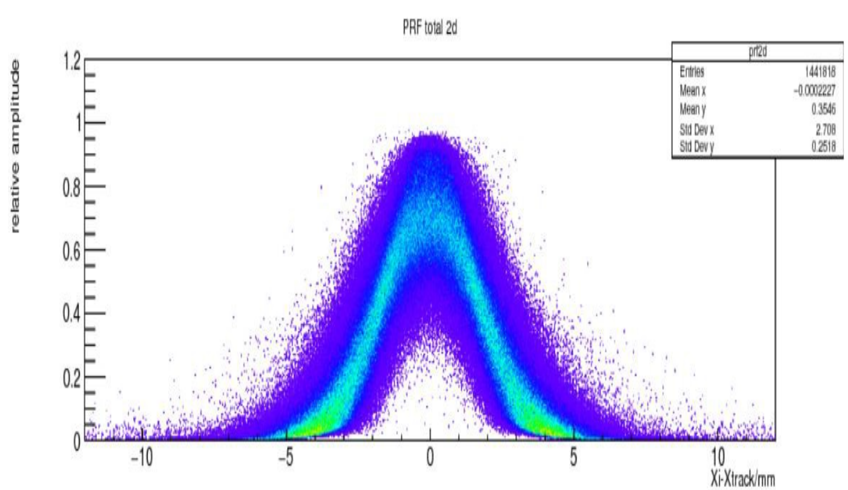
- Same of working gas@T2K, same of high voltage, same of test conditions
- Different of GEMs@ 320V
- No any discharge to damage the detector
- Conclusion
  - All of the triple GEMs, double GEMs and GEM+Micromegas could be as the readout option for TPC prototype
  - 2000 of gain is fine to study UV laser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

PRF analyzing of the spatial resolution

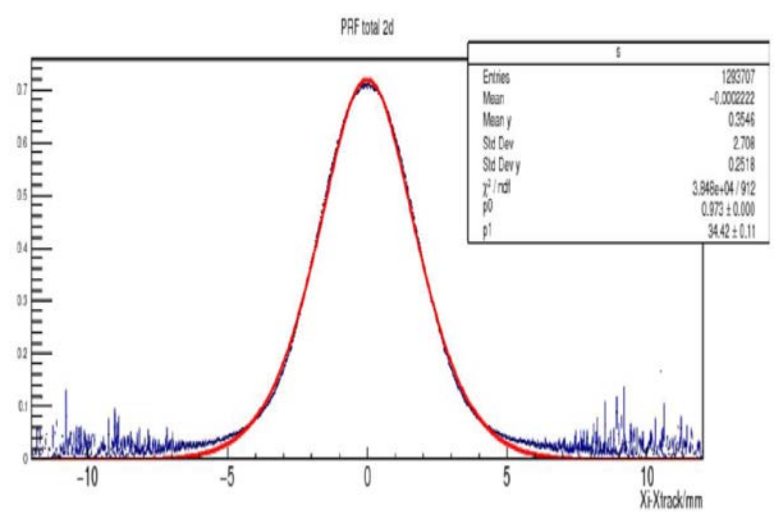
- **Pad Response Function (PRF): a general function used to describe the charge distribution and to determine the hit position via Pad**

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

  - **x is the Pad's coordinate of the center of the corresponding Pad in x-aix.**
  - **y is the Pad's coordinate of the center of the corresponding Pad in y-aix.**
  - **w is the width of the Pad (in here, the Pad's width is 0.9mm)**



PRF total of all data

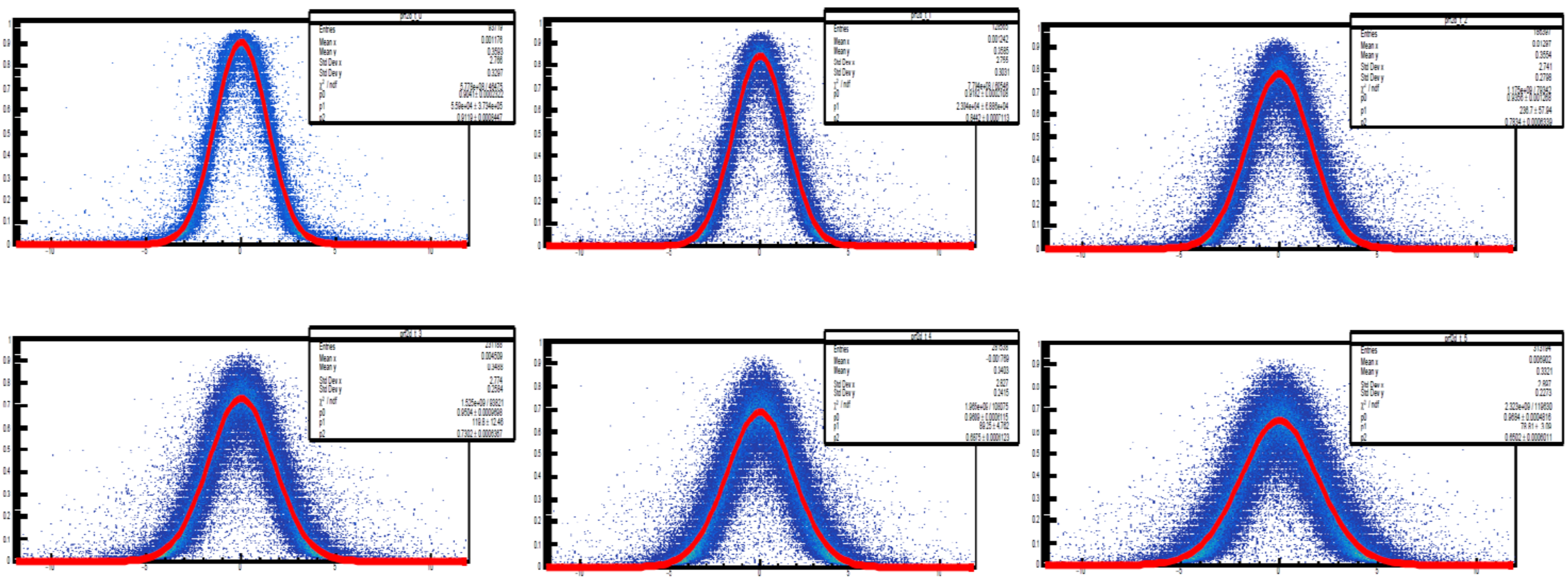


Profile of PRF from one pad row

PRF analyzing – iteration calibration

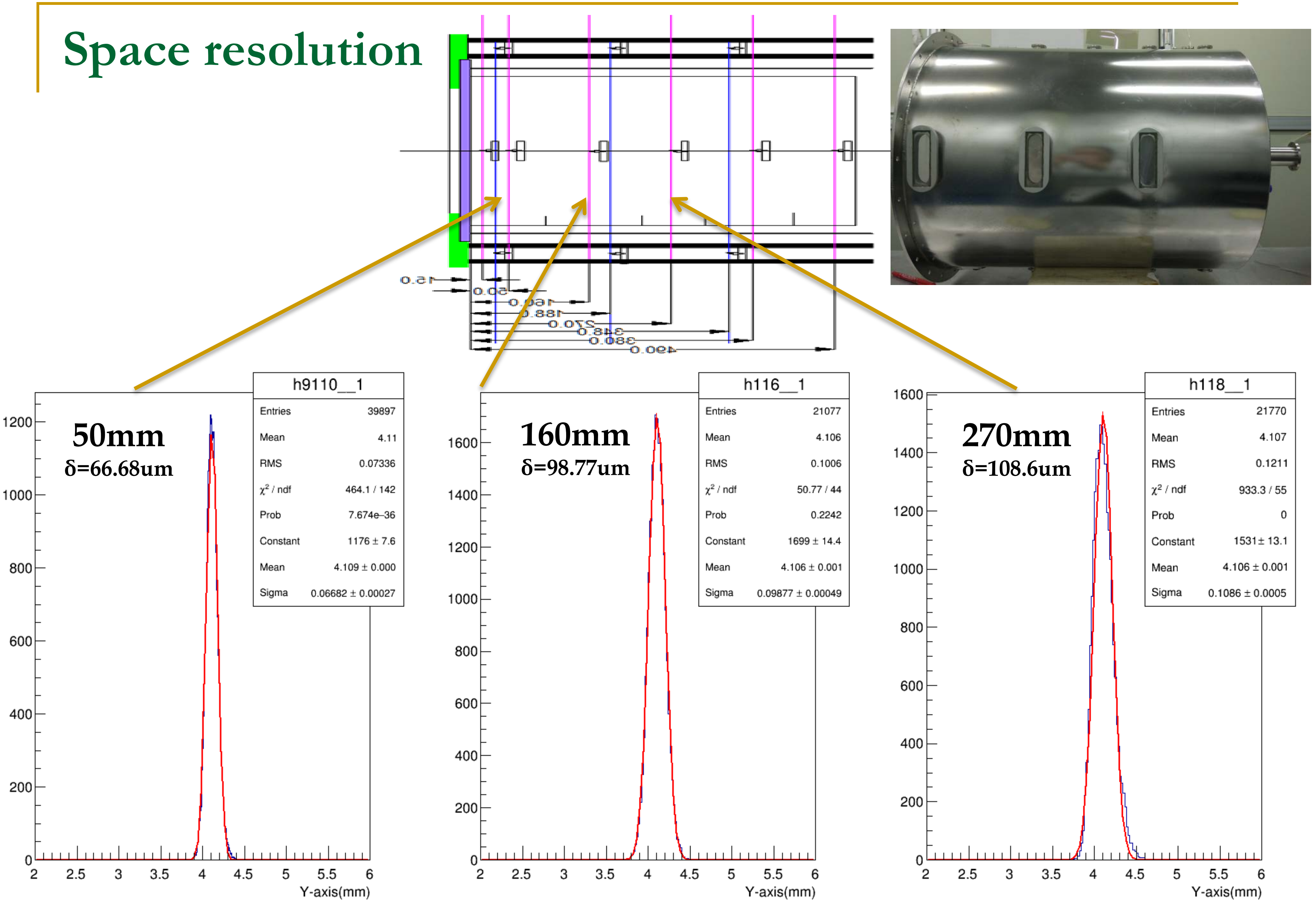
- X-track: reconstruction by the double fits
- Pad Response Function (PRF): need the iteration calibration with $x_i - x_{track}$

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



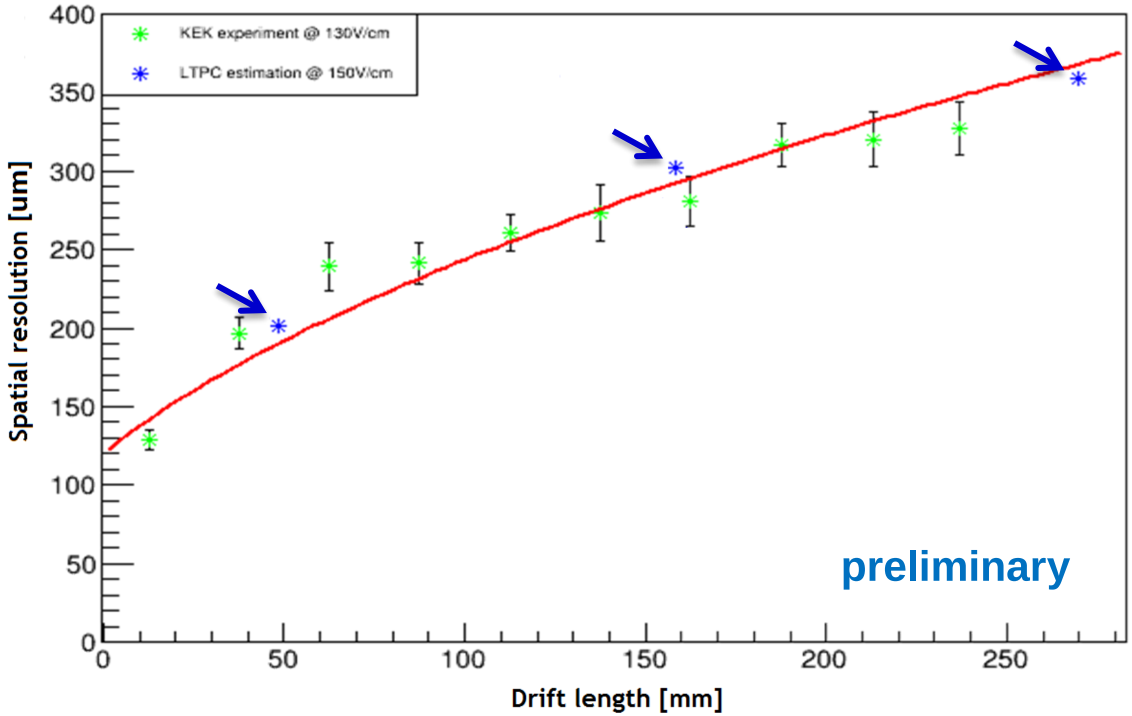
Space resolution at the different drift length

Comparison of the spatial resolution

- Same testing conditions
  - T2K operation gases and 0T of the magnetic field
  - Drift field: 150V/cm-220V/cm
  - Pad readout option (1mm×6mm)
  - Framework from LCTPC software package

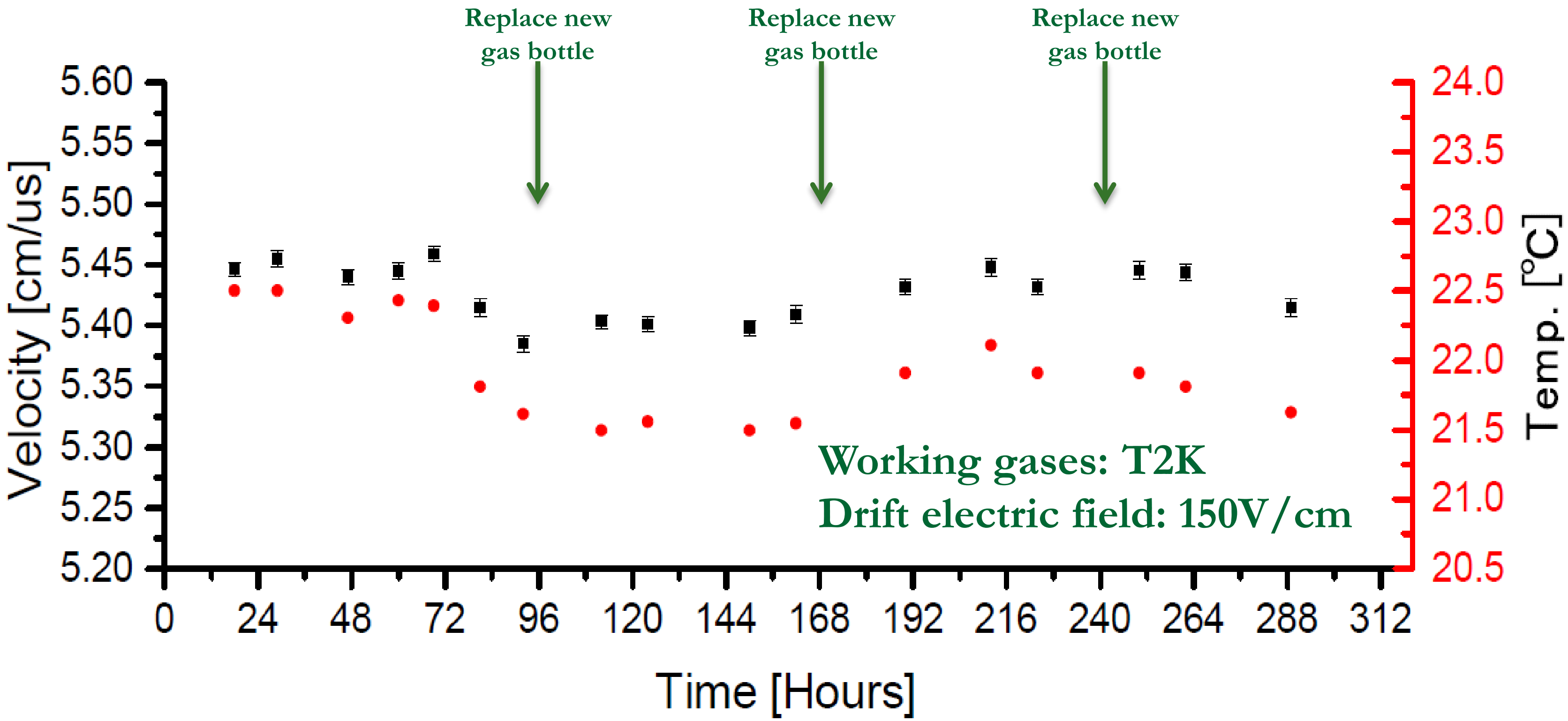
Neff of Cosmic ray: ~30
Neff of UV laser in test: ~80

- Normalized comparison of KEK cosmic experimental data using the same N_{eff}
  - N_{eff} is the number of the effective electrons in chamber



Normalized comparison of the spatial resolution

Drift velocity measurement



- Two weeks of continuous testing
- 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

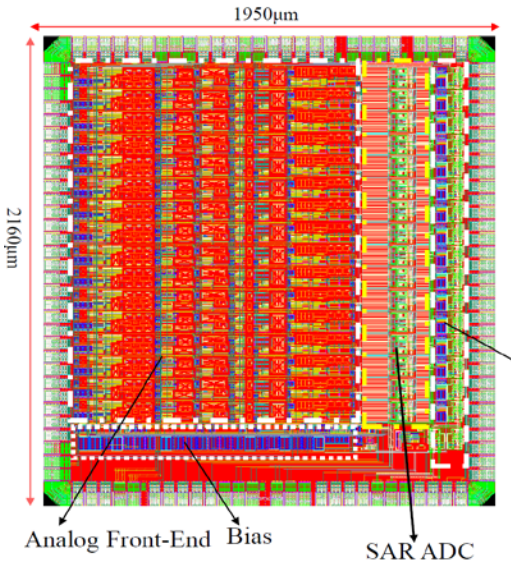
track distortion

gain uniformity

and …

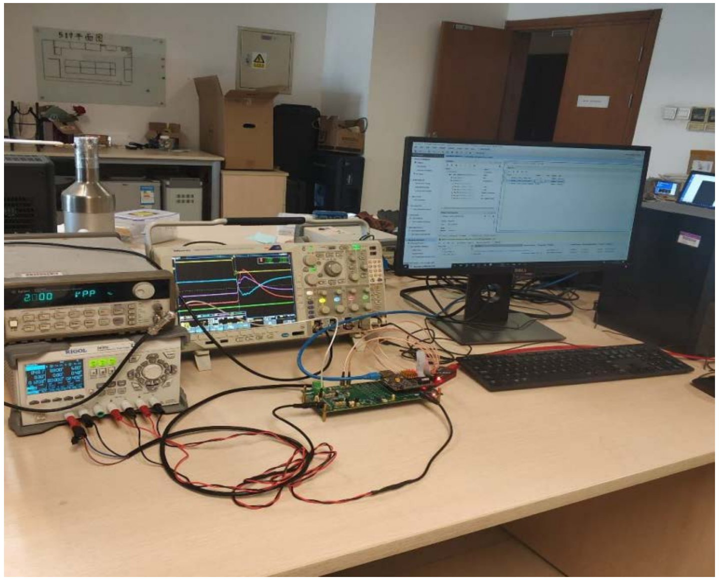
Joint of new ASIC chip R&D

Deng Zhi, Liu Wei and Yuan Zhiyang

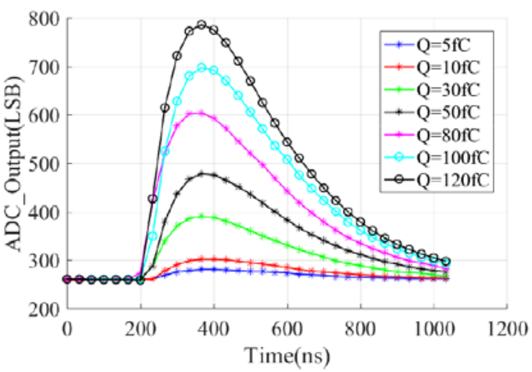


- The floor plan in layout：
  - The die size of 1950 μm x 2160 μm
  - Analog Front-End , SPI, SAR ADC, LVDS driver are supplied by separate power
- The ASIC have been taped out in November, 2019 and is being evaluated

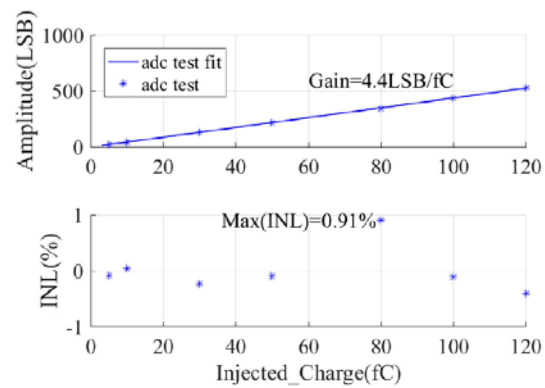
Layout of ASIC chip

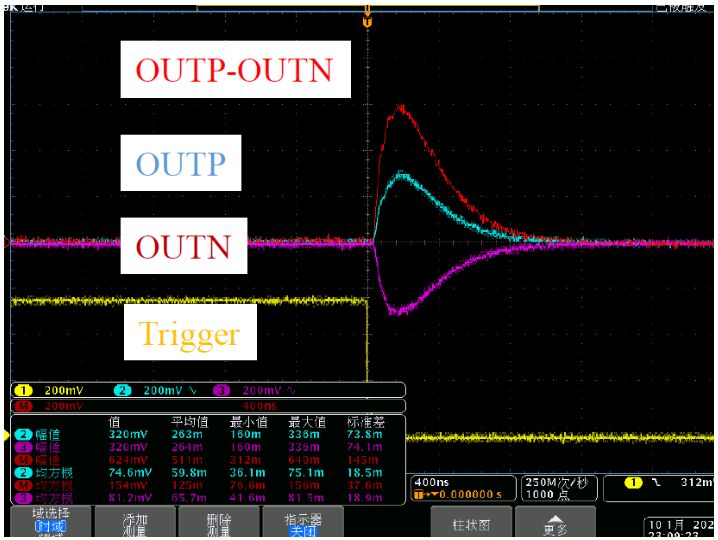


- Transient outputs



- The linearity @ gain = 10 mV/fC



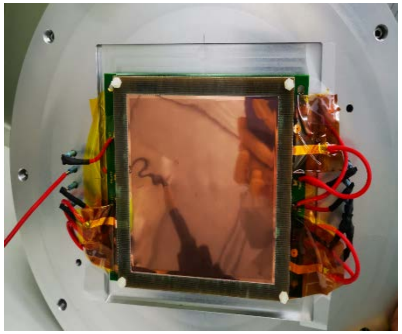


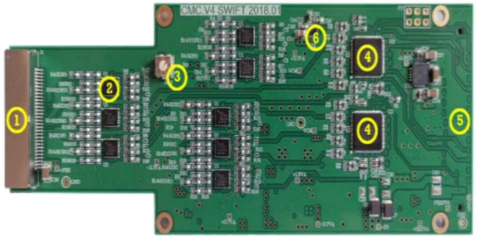
Gain = 4.4 LSB/fC = 4.4 x 2.34 mV/fC = 10.3 mV/fC

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 lab

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 from this month.
- Some simulation and discussion are starting about the high rate TPC operating at the high luminosity Z pole.

Thanks for your attention.