Commissioning and analyzing of TPC prototype integrated with UV laser

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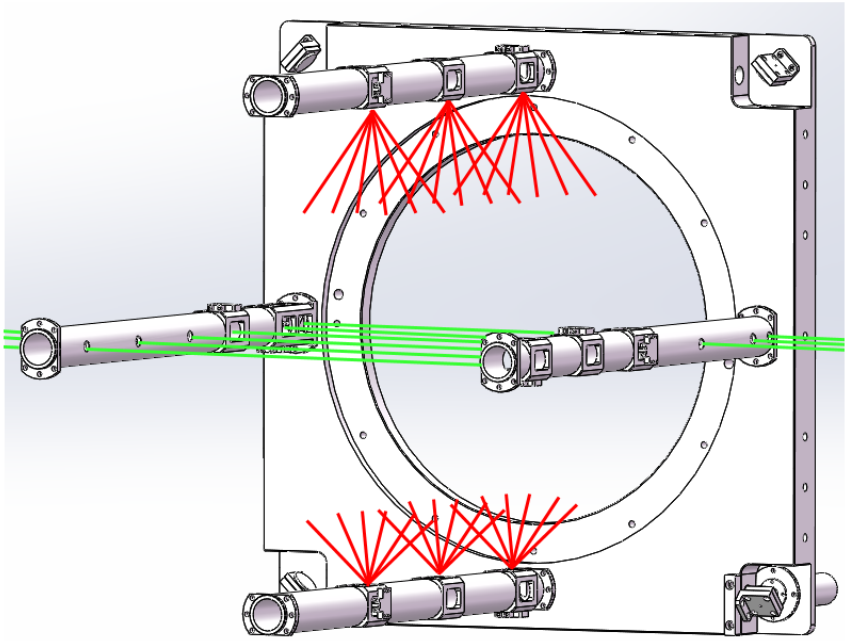
Outline

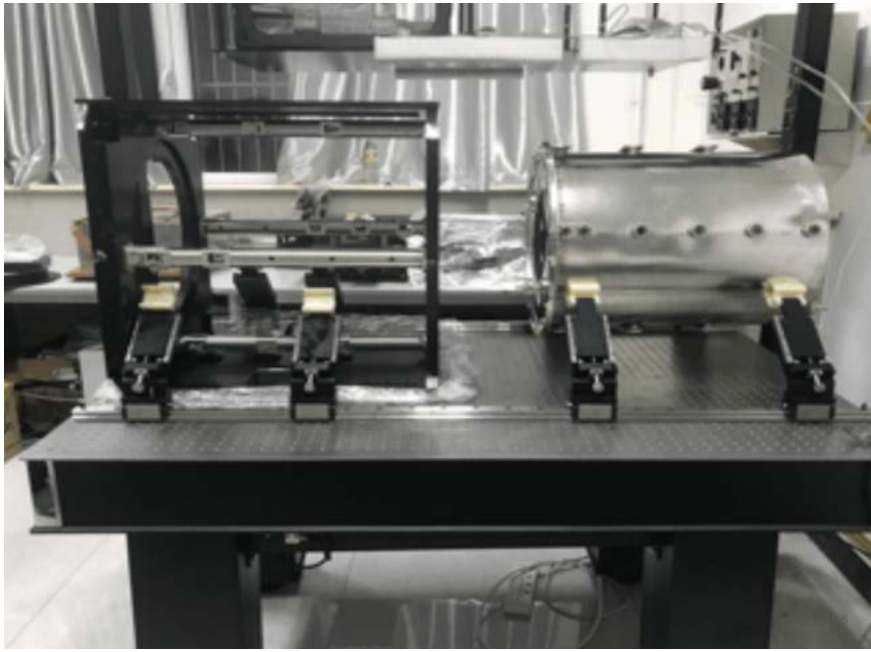
- TPC prototype
- Update results
- Plans of studies
- Summary

Update of the TPC prototype

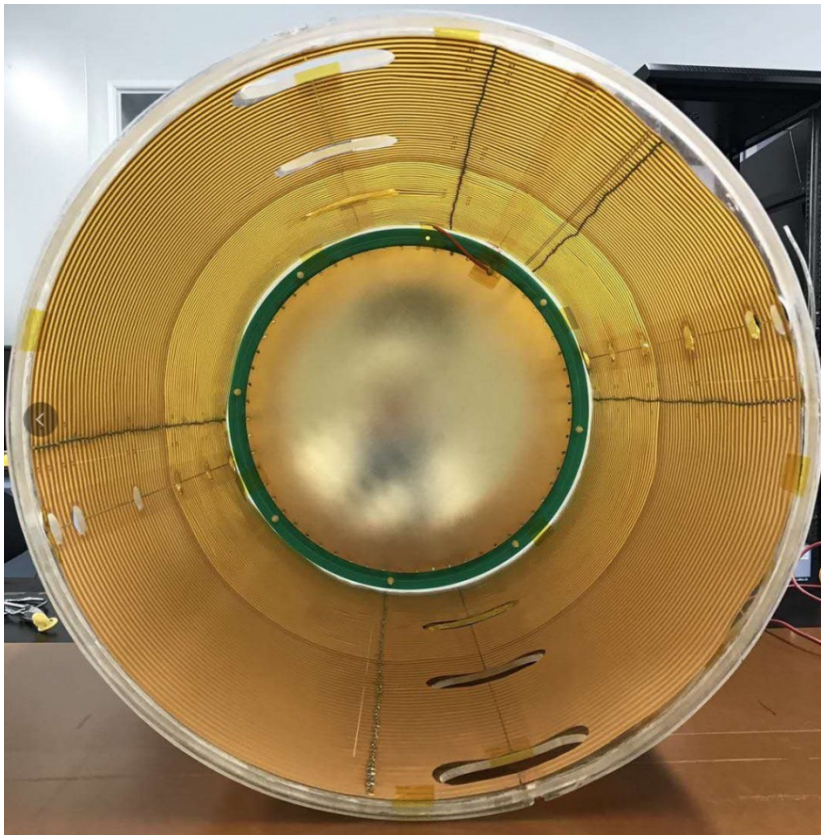
TPC Prototype sketch

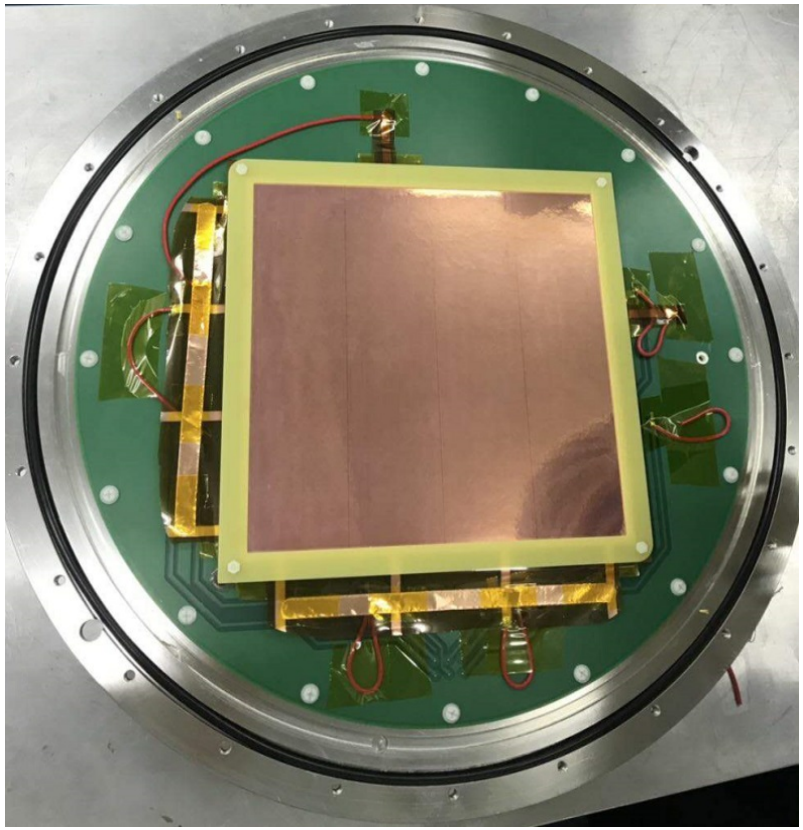
- Main parameters
  - Drift length: ~500mm, Active area: 200mm^2
  - Integrated 266nm laser beam
  - MPGD detector as the readout
  - TPC system devices: Fieldcage+ Pads readout
  - TPC cathode: -10kV
  - Drift field=200V/cm
  - Readout pad(anode) is designed to 0V
  - Readout pad:1280 channels
  - Detector gain: 2000-6000
  - Working mixture gas:
    - Ar/CF4/iC4H10=95/3/2
  - TPC chamber+Filedcage +Endplate+Laser device +High voltage





Endplate and field cage





Simulation

- Hole size VS length of less than 99% of electric field
- <12mm of hole size in this prototype along drift length

Electronics

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

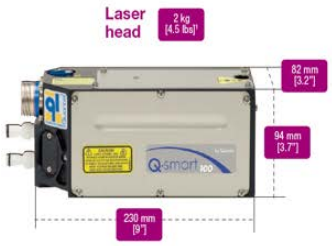
Electronics and DAQ

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

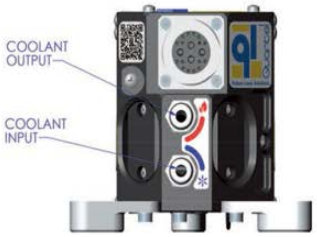
FEE Electronics and DAQ setup photos

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



灯泵脉冲激光器头



倍频模块

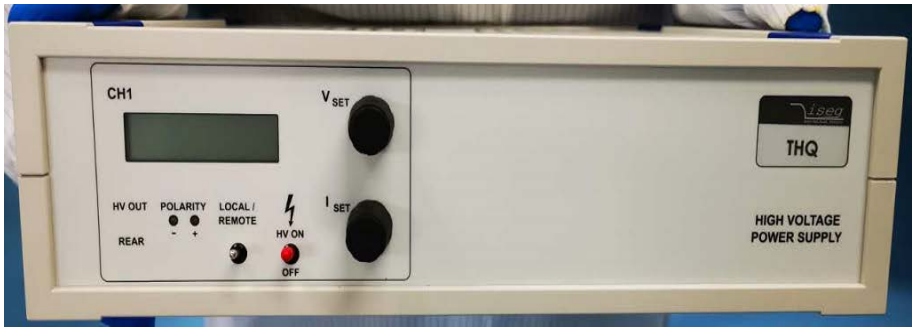
激光器电源

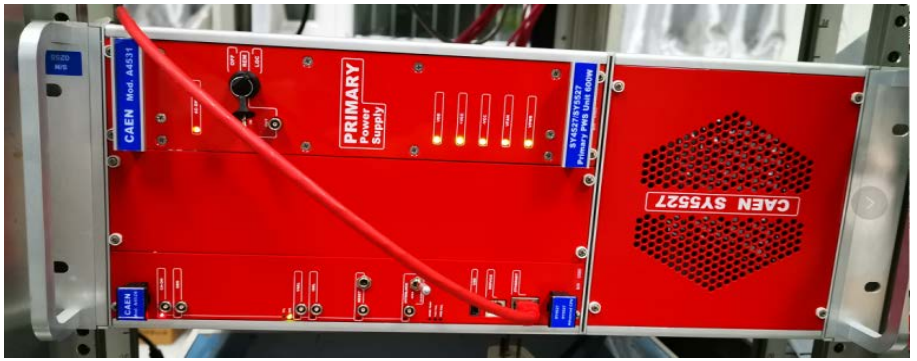
Model	Nano SG 150-10
Max. Repetition Rate (Hz)	**10**
Output Energy (mJ)	
1064nm	150
532nm	75
355nm	30
266nm	15
213nm	3
Parameter	
Pulse - pulse Stability (±%)	2
Beam diameter (mm)	5
Beam divergence (mrad) (1)	<0.7
Fit to Gaussian N/F field (%)	70/95
M^2	<2
Pulse length @ 1064nm (ns)	4-6
Pointing stability (µrad) (2)	<100
Lamp life (pulses)	$>5x10^7$
Timing jitter (ns) (3)	<0.5
Services	
Voltage (VAC)	90-250
Frequency (Hz)	47-63
Power	Single Phase
Ambient (4) (°C)	5-35
Consumption (W)	<350
PSU Type	LPU250 (5)

Parameters of the UV laser device

High voltage

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



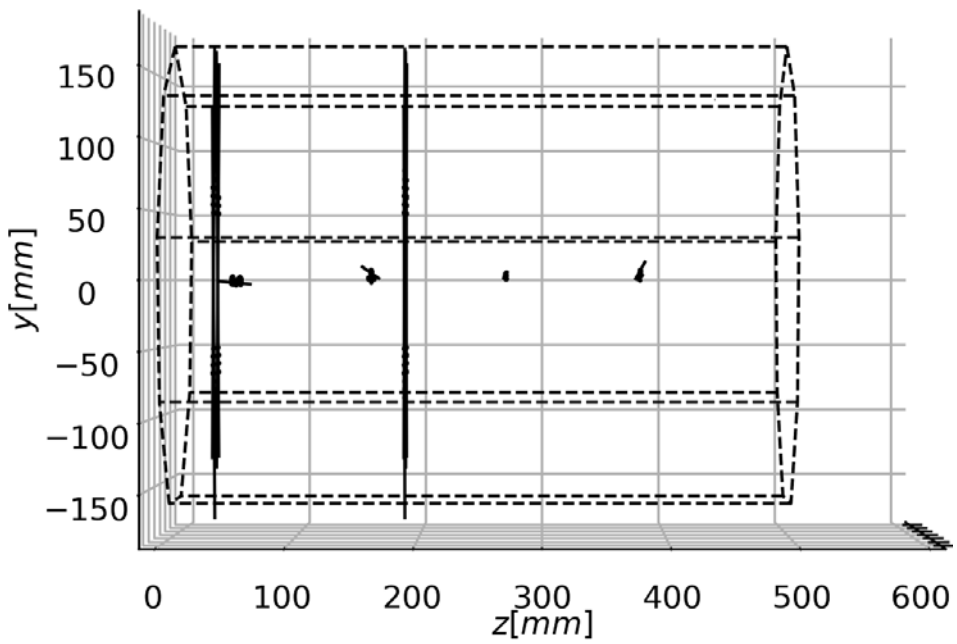


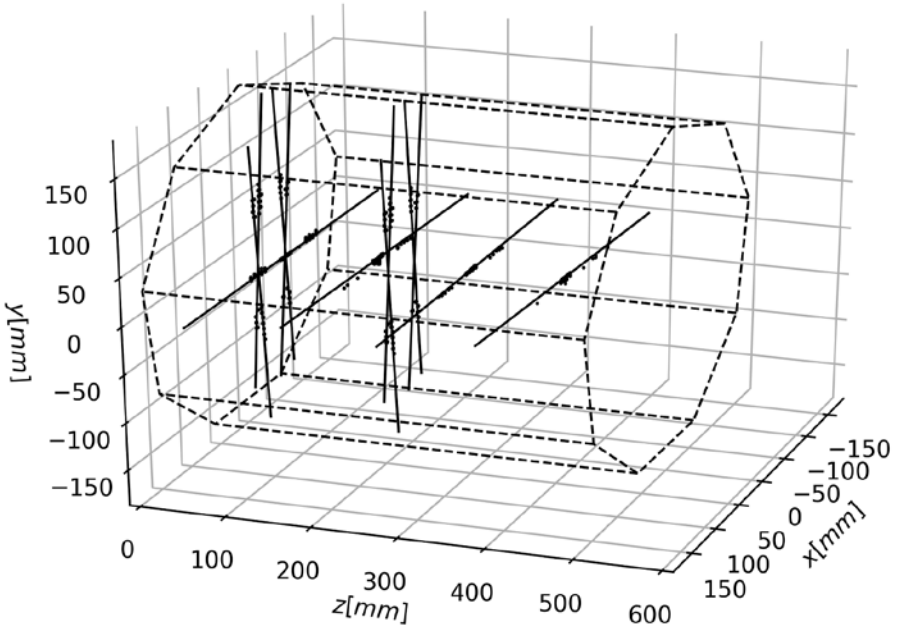
High voltage and controller

Commissioning and studies

Prototype working well

Laser tracks in chamber@T2K gas





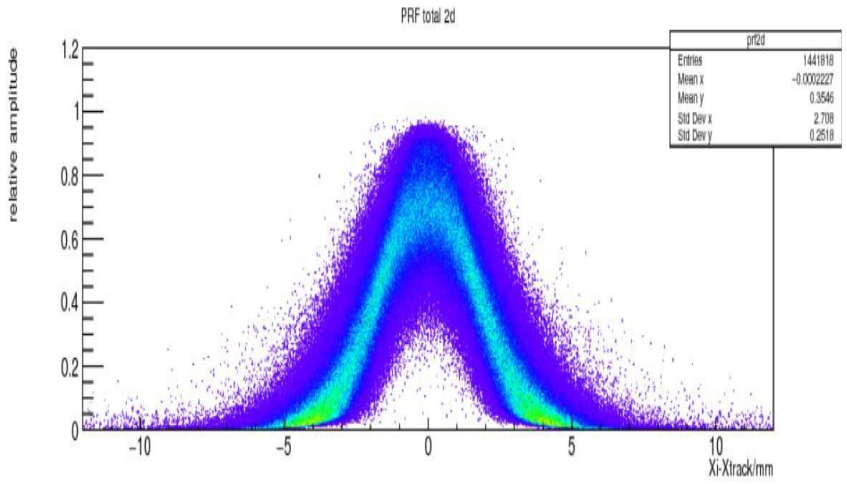
- Same of working gas@T2K, same of high voltage, same of test conditions
- Different of GEMs@ 320V
- Triple GEMs to double GEMs
- No discharge

PRF analyzing

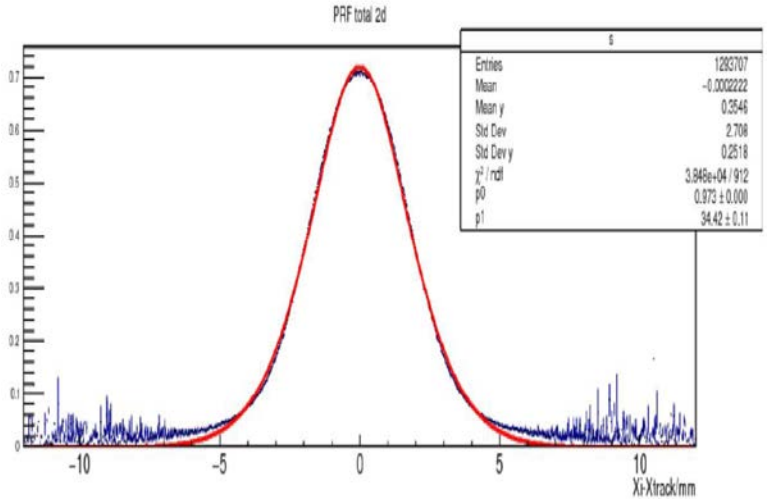
- **Pad Response Function** (PRF): a general function used to describe the charge distribution and to determine the hit position

$$PRF(x, r, w) = \frac{\exp[-4\ln 2(1-r)x^2/w^2]}{1+4rx^2/w^2}$$

- A combination of a Gaussian with a Lorentzian function.
  - r=1, the PRF becomes a pure Lorentzian.
  - r=0, the PRF becomes a pure Gaussian.
  - Both the Lorentzian and the Gausssian share the same width parameter w.



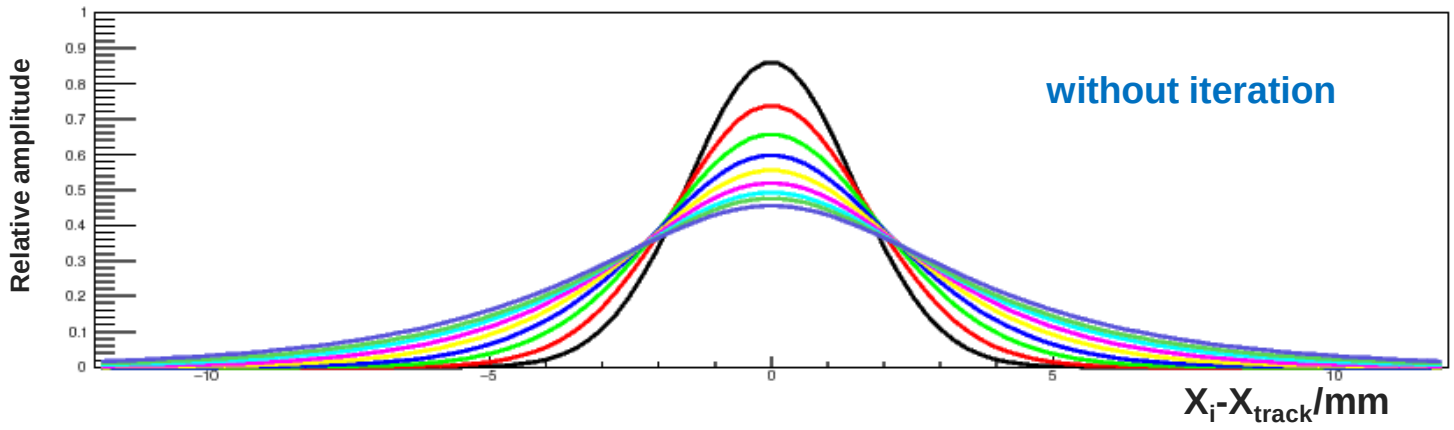
PRF total of all data

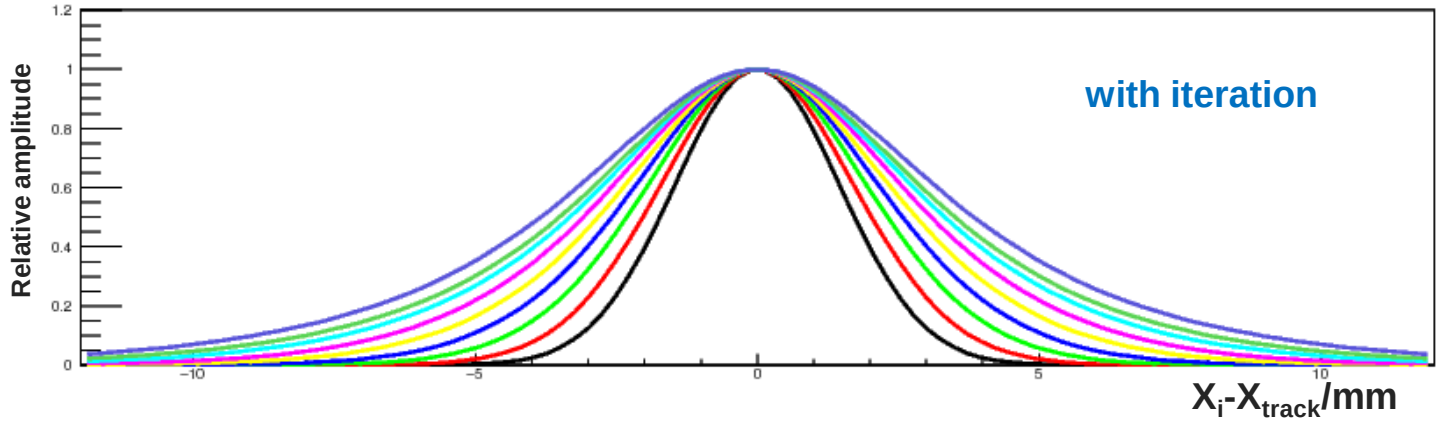


Profile of PRF total

PRF v.s. Z/drift time - calibration

- **X-track:** reconstruction by the double fits
- **Pad Response Function** (PRF): need the calibration with X_i-X_{track}



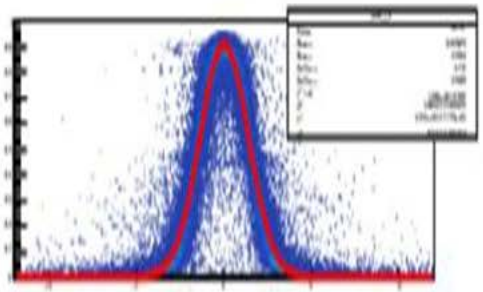
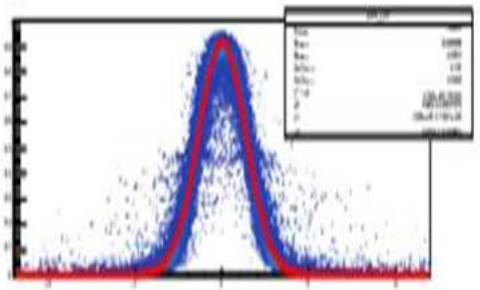
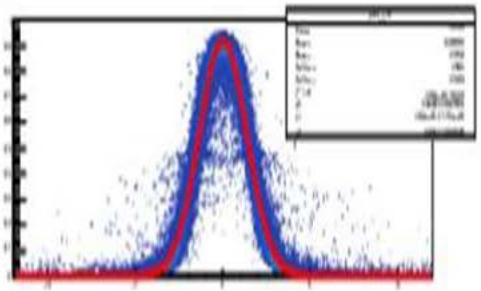
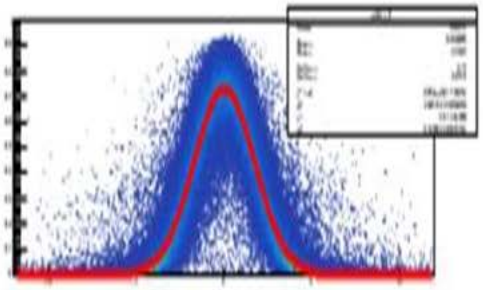
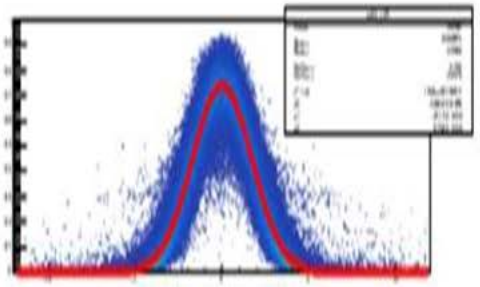
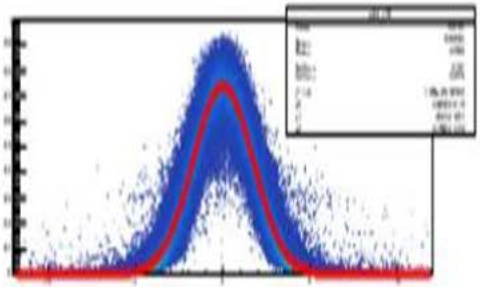


PRF total of all data

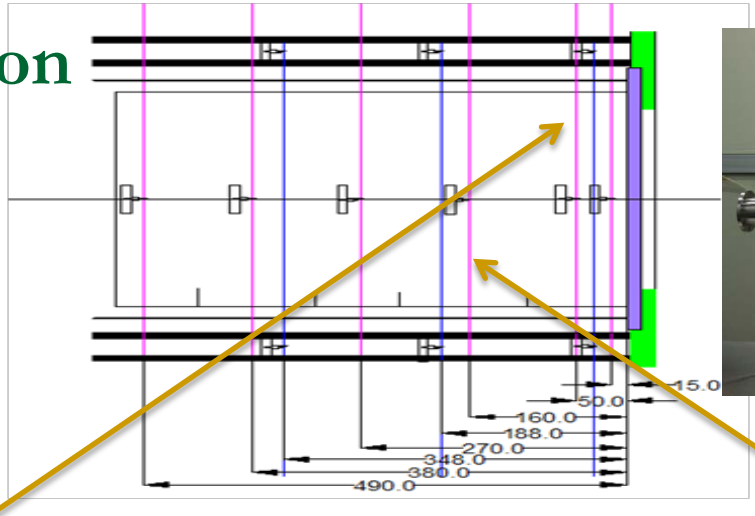
Profile of PRF total

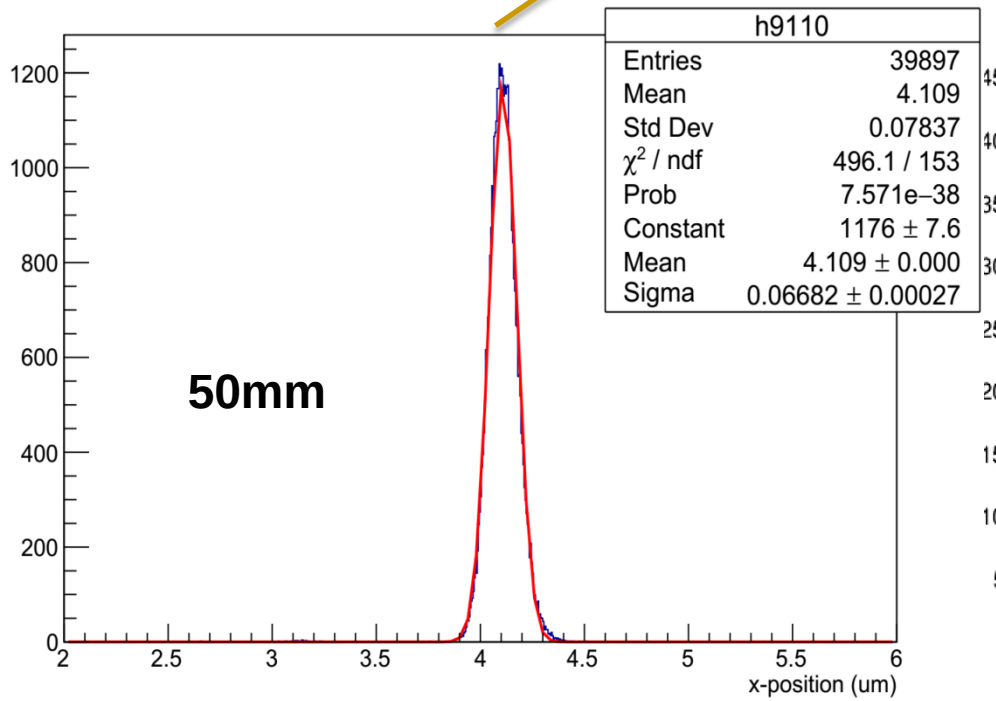
PRF analyzing- calibration

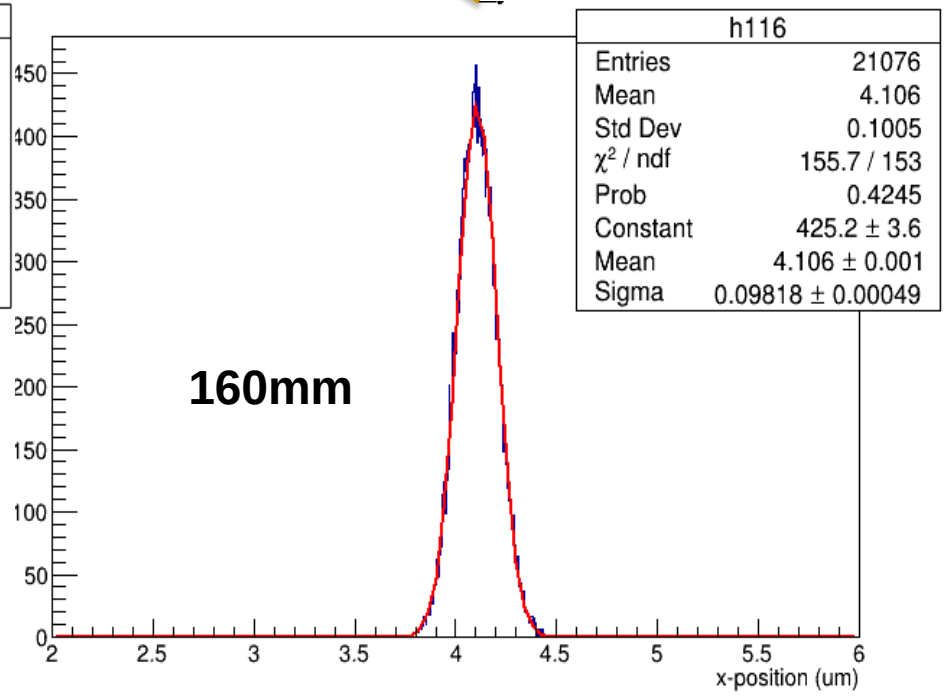
- **Pad Response Function** (PRF): a general function used to describe the charge distribution and to determine the hit position

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

Space resolution



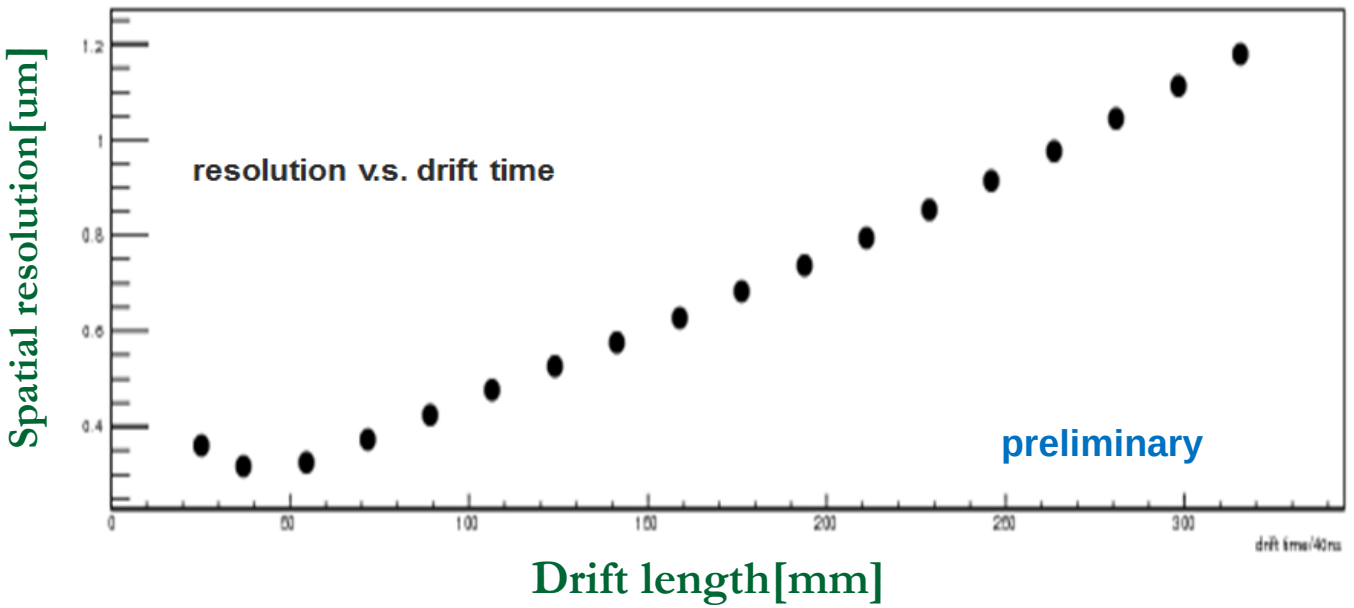




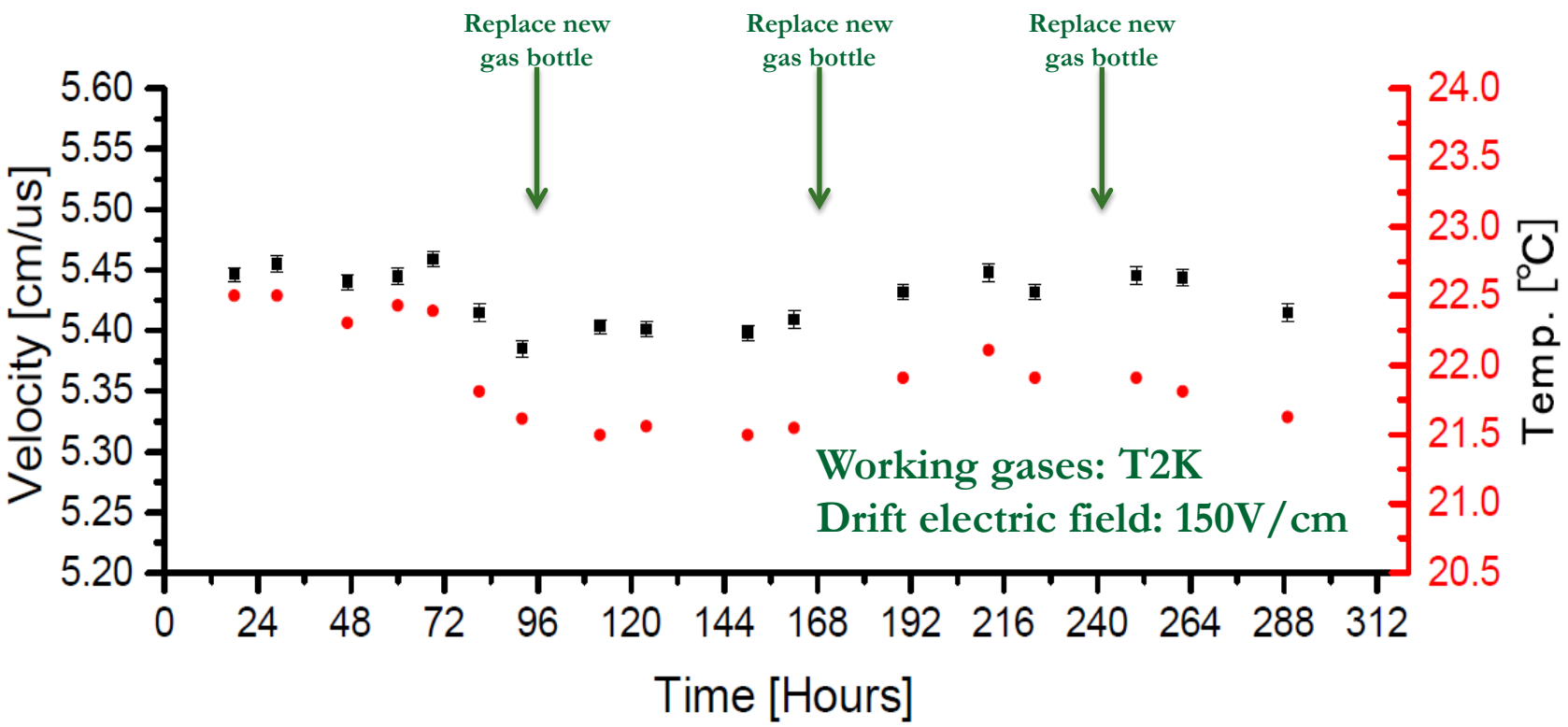
Space resolution at the different drift length

Simulation the spatial resolution

- T2K operation gases
- Drift field: 220V/cm
- Pad readout option
- Framework from LCTPC software package
- N_{eff}: 80-100



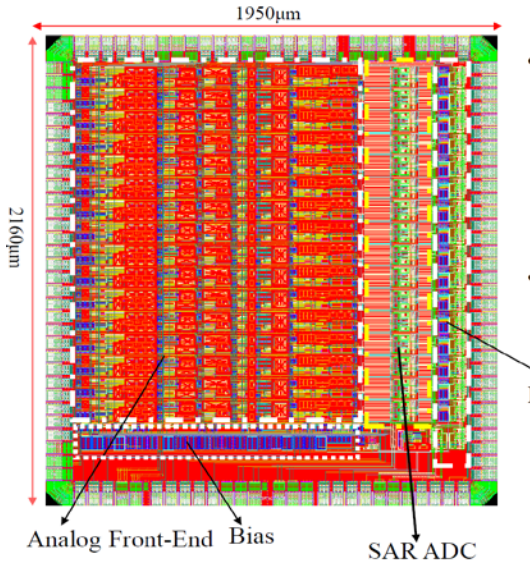
Drift velocity measurement



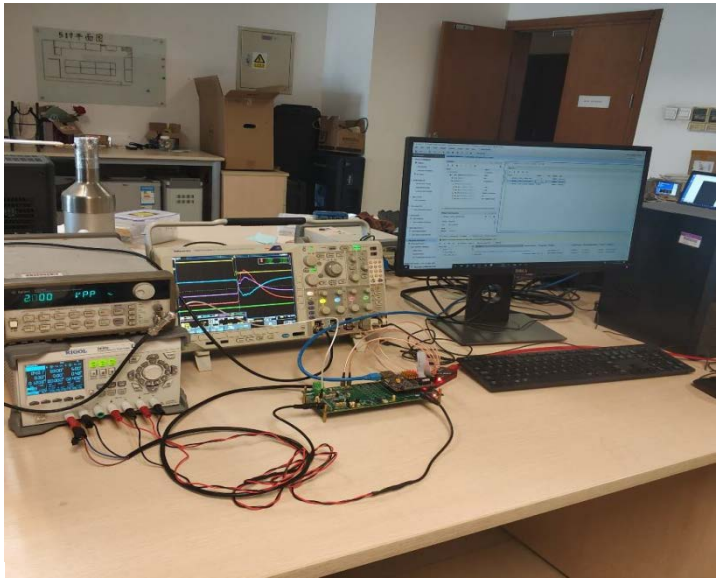
- Two weeks of continuous testing
- Room temperature recorded
- Comparison of the drift velocity and the temperature
- 266nm UV laser can work well when it can be as the monitor

Plans the further studies

Tests of the ASIC chip from Tsinghua

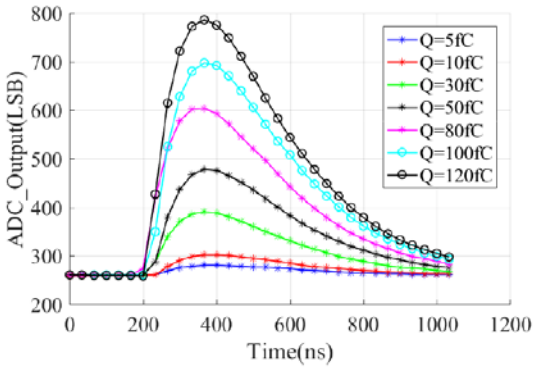


- The floor plan in layout :
  - The die size of 1950 μm x 2160 μm
  - Analog Front-End , SPI, SAR ADC, LVDS driver are supplied by separate power
- The ASIC have been taped out in November, 2019 and is being evaluated

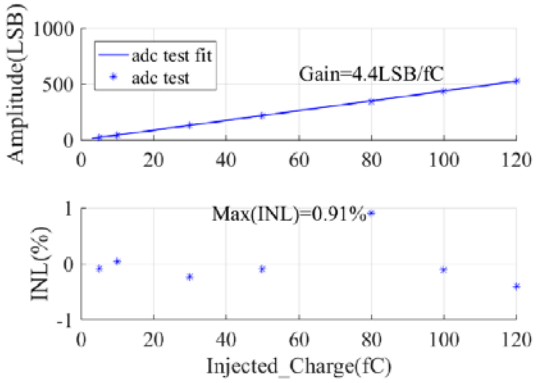


Layout of ASIC chip

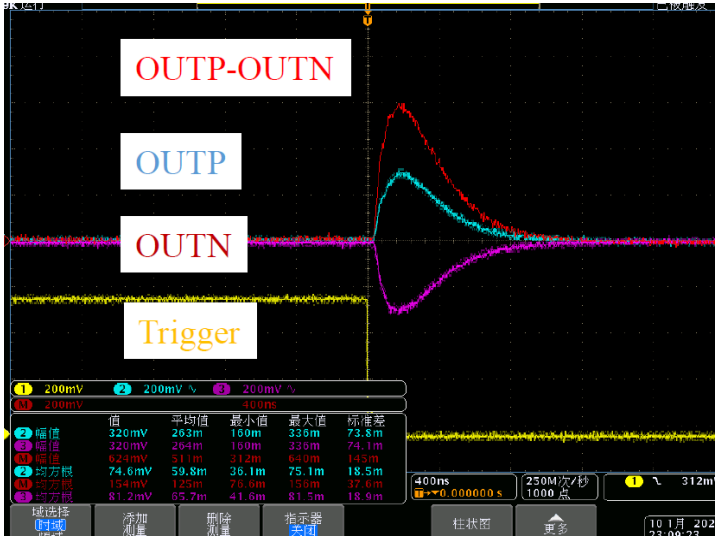
- Transient outputs



- 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

Results of ASIC chip

- A 16 channel low power readout ASIC 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 @ 40MS/s
  - ENC = 852 e @ Cin=2 pF, gain=10 mV/fC and can be reduced to 474 e using digital trapezoidal filter
- Future Plan
  - More ASIC evaluations: higher sampling rate, more detailed noise test, test with detectors…
  - Low power digital filter and data compression in FPGA/ASIC

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 Feburary.

Summary

- Some motivations of TPC detector for collider at Z pole run listed.
- Some update results and performance of IBF, dE/dx, drift velocity listed.
- UV laser will be very helpful in the TPC module and prototype R&D .

Thanks for your attention.