
A novel method to study the primary track using TPC prototype with integrated UV Laser

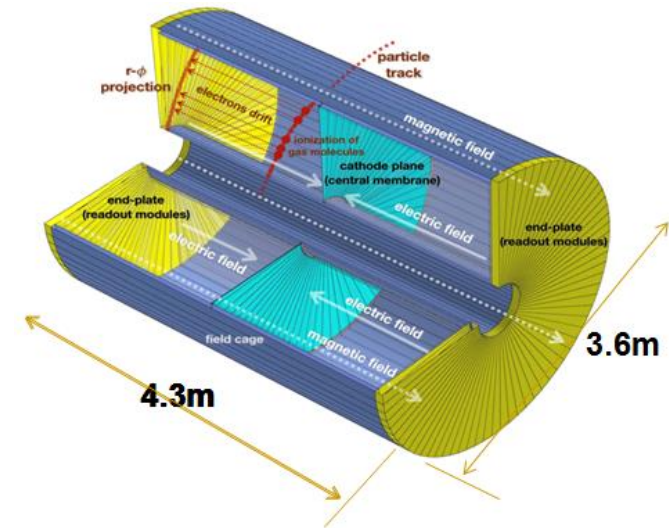
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——On behalf of CEPC TPC study group

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TPC detector technology

Some advantages of TPC detector :

- ❑ Operation under 3 Tesla magnetic field
- ❑ Momentum resolution: $\sim 10^{-4}/\text{GeV}/c$ with **TPC standalone**
- ❑ Large number of 3D space points: ~ 220 **along the diameter**
- ❑ dE/dx resolution: $< 5\%$
- ❑ $\sim 100 \mu\text{m}$ position resolution in $r\phi$
 - ❑ $\sim 60\mu\text{m}$ for zero drift, **$< 100\mu\text{m}$** overall
 - ❑ Systematics precision ($< 20\mu\text{m}$ internal)
- ❑ TPC material budget
 - ❑ $< 1X_0$ including outer field cage
- ❑ Tracker efficiency: $> 97\%$ for $p_T > 1\text{GeV}$
- ❑ 2-hit resolution in $r\phi$: $\sim 2\text{mm}$
- ❑ Module design: $\sim 200\text{mm} \times 170\text{mm}$
- ❑ Minimizes dead space between the modules: 1-2mm
- ❑ Readout options: pad and pixel



TPC detector concept

Momentum resolution (B=3.5T)	$\delta(1/p_t \approx 10^{-4}/\text{GeV}/c)$
δ_{point} in $r\phi$	$< 100 \mu\text{m}$
δ_{point} in rZ	0.4-1.4 mm
Inner radius	329 mm
Outer radius	1800 mm
Drift length	2350 mm
TPC material budget	$\approx 0.05X_0$ incl. field cage $< 0.25X_0$ for readout endcap
Pad pitch/no. padrows	$\approx 1 \text{ mm} \times (4 \sim 10\text{mm}) / \approx 200$
2-hit resolution	$\approx 2 \text{ mm}$
Efficiency	$> 97\%$ for TPC only ($p_t > 1\text{GeV}$) $> 99\%$ all tracking ($p_t > 1\text{GeV}$)

Laser TPC prototype R&D:

Basic principle: Two-photon ionization

The two-photon ionization refers to the ionization process that occurs when gas molecules absorb two photons at the same time, and the sum of the absorbed photon energies is equal to the ionization energy of atoms.



Laser TPC R&D

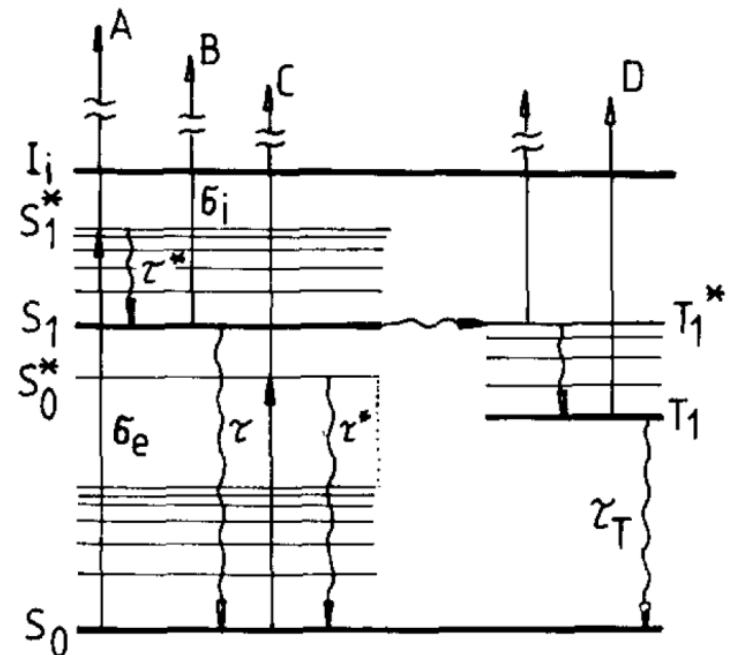
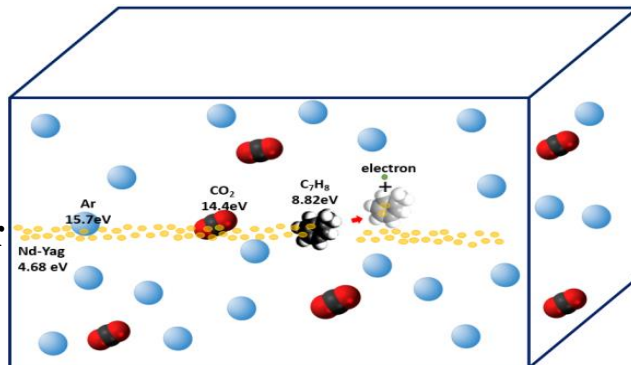
$$n_i(T) = \frac{1}{2} n_0 \sigma_e \sigma_i^* N^2 T^2$$

N is the photon flux

σ is the transition cross section

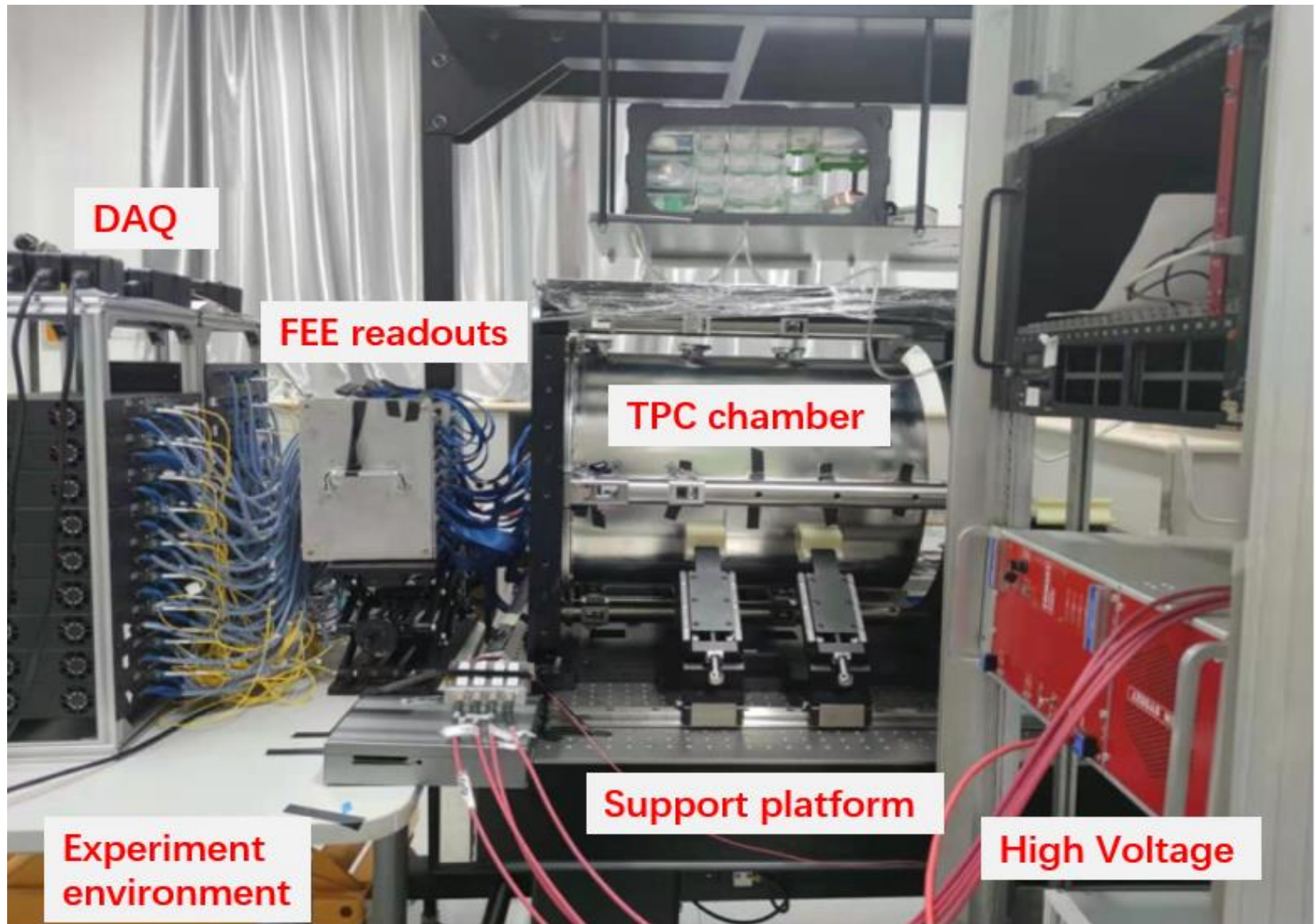
n is the ionization density

T is the width of the laser pulse



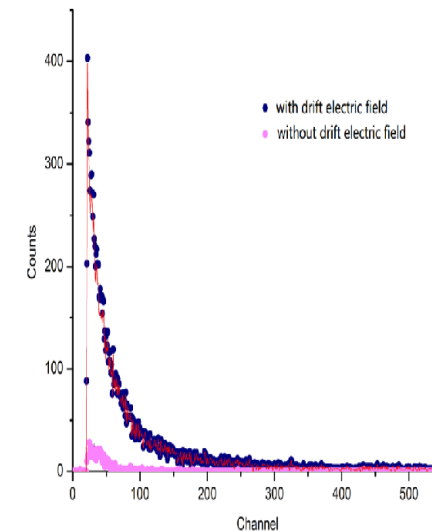
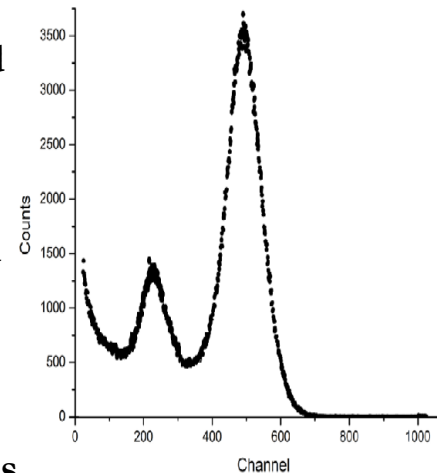
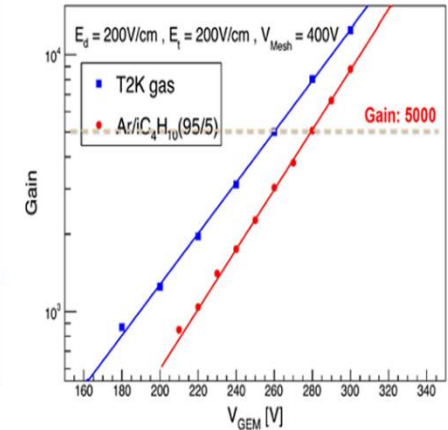
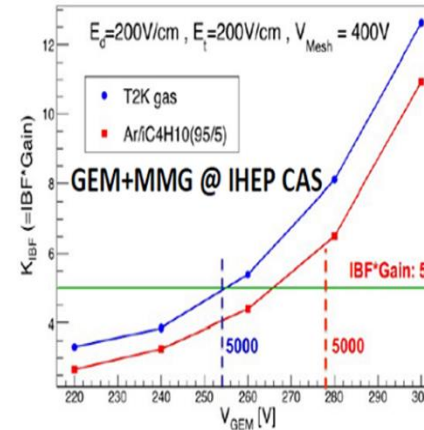
Possible transition channels by two-photon ionization of complex molecules

Status of TPC prototype@IHEP



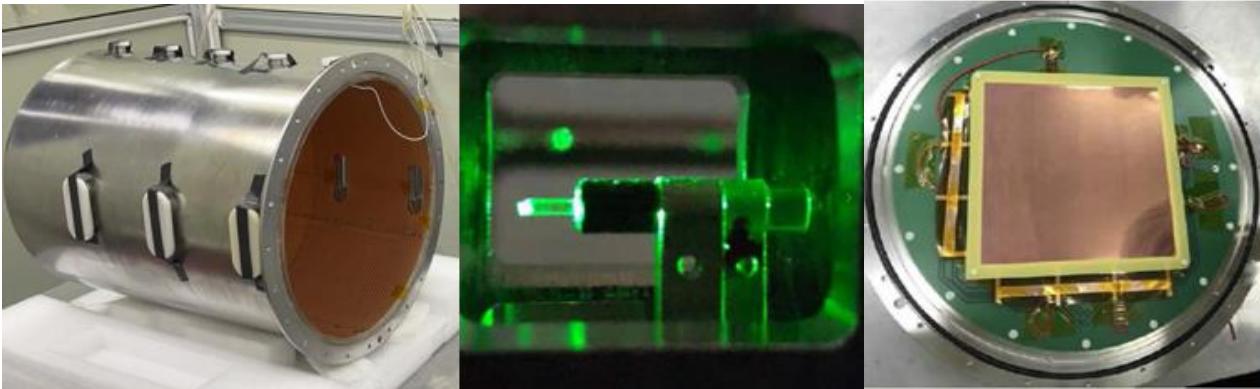
Experiment studies: IBF/ ^{55}Fe source and cosmic ray

- Studies have been done using the different active area of the hybrid TPC detector modules
 - Active area: from $50\text{ mm} \times 50\text{ mm}$ to $200\text{ mm} \times 200\text{ mm}$
 - Tested under the different mixture gases
- Validated $\text{IBF} \times \text{Gain}$ using the TPC detector module
 - $\text{IBF} \times \text{Gain} \leq 5 @ \text{Gain}/5000$
 - Gas gain < 2000 , $\text{IBF} \times \text{Gain} \leq 1$ using MPGD as readout
- TPC detector prototype can using the ^{55}Fe and cosmic ray
 - Operation gas: T2K
 - ^{55}Fe X-ray(5.9keV) spectrum profile is very good
 - Gain just shift -2% one year before
 - The Landau distribution of the cosmic ray's energy spectrum was successfully obtained

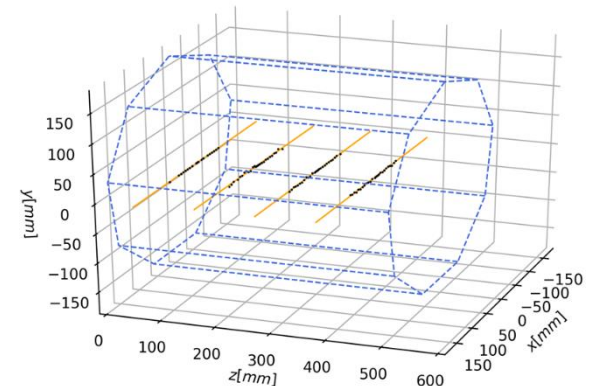
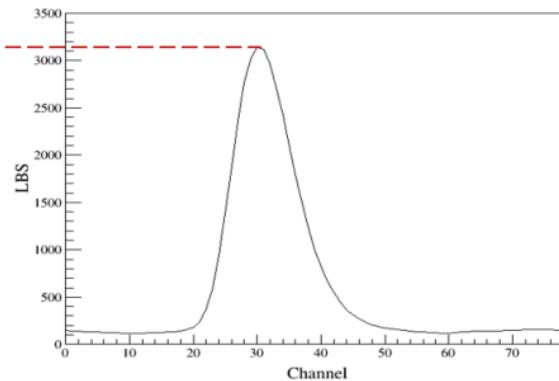
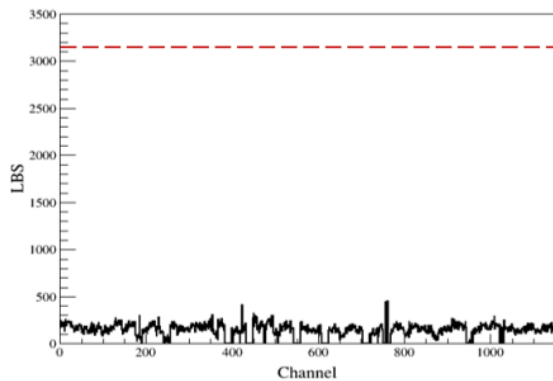


Commission: Chamber/Fieldcage/UV laser

- ❑ GEM detector as the endplate with 200mm
- ❑ 500mm drift length with 10000V high voltage
- ❑ Integration of the UV laser tracks in the chamber

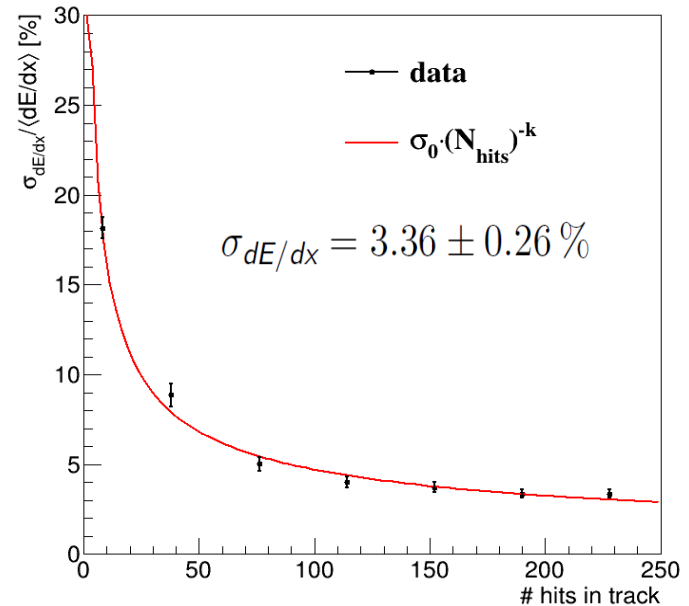
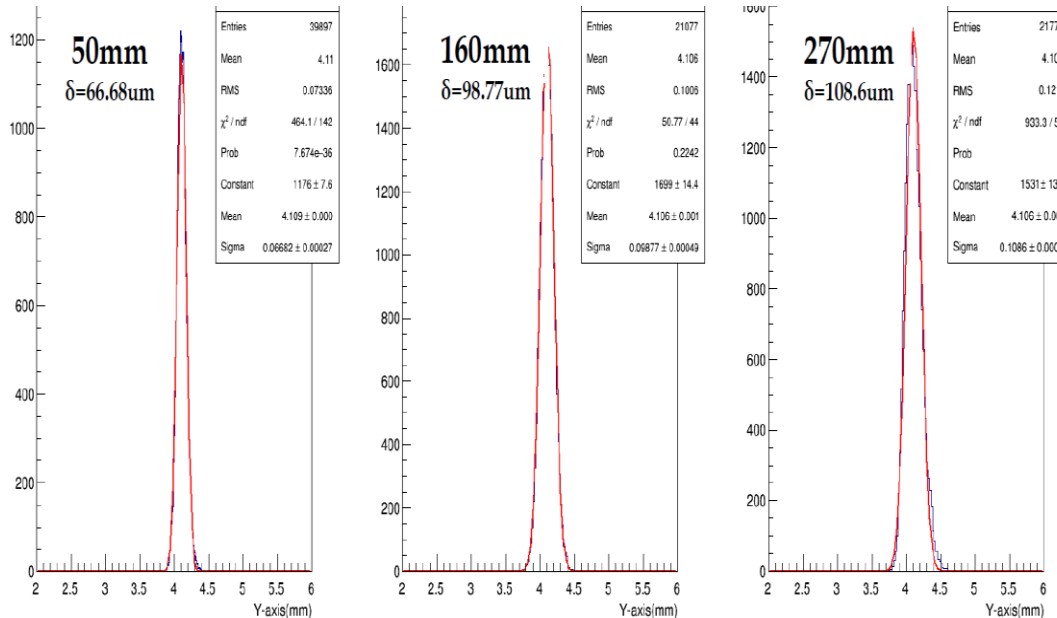


Joint commission of the electronics and laser system has been completed. A typical laser signal waveform was obtained and 4 layers laser track was reconstructed successfully !



Laser TPC performance:

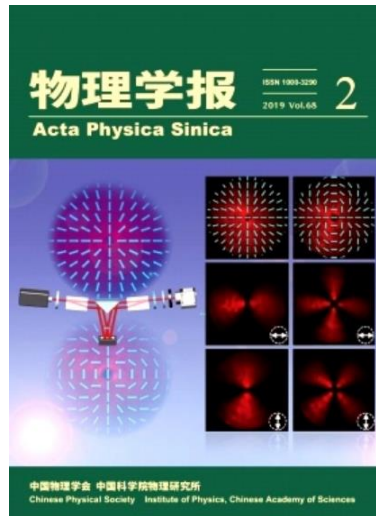
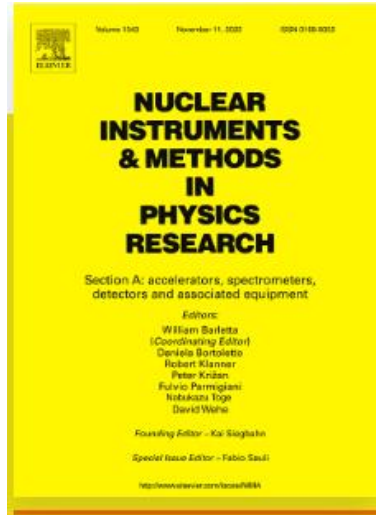
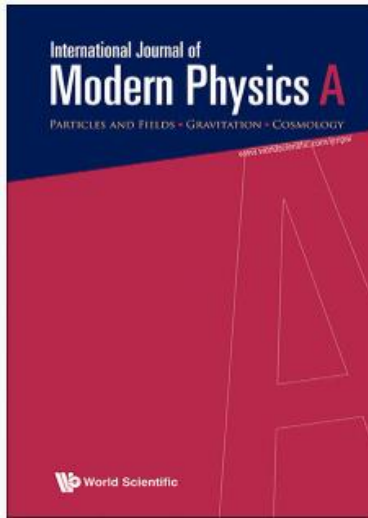
- ❑ Spatial resolution can be less than 100 μ m along the drift length of TPC prototype
- ❑ Pseudo-tracks with 220 layers and dE/dx can reach to $3.36 \pm 0.26\%$
- ❑ Both transverse diffusion coefficient DT is 310.7 and drift velocity 6.81 all match the expected value from the simulation of Garfield++



Conclusion:

266nm UV laser can work well when it can be as the online mimic tracks.

Highlight of Updated R&D



Publications:

- [1]. Int J Mod Phys A, 2022 ,doi: 10.1142/S0217751X22460095
- [2]. NIM-A, 2022, doi: 10.1016/j.nima.2022.167241
- [3]. Int J Mod Phys A, 2021, doi: 10.1142/S0217751X2142015X
- [4]. JINST, 2020, doi: 10.1088/1748-0221/15/09/C09065
- [5]. JINST, 2020, doi: 10.1088/1748-0221/15/02/T02001
- [6]. Int J Mod Phys A, 2020, doi: 10.1142/S0217751X20410146
- [7]. JINST, 2020, doi: 10.1088/1748-0221/15/05/P05005
- [8]. Int J Mod Phys A, 2019, doi: 10.1142/S0217751X19400165
- [9]. ACTA PHYS SIN-CH ED, 2019, doi: 10.7498/aps.68.20181613

PhD Thesis:

- [1]. Z.Y.Yuan, 2022, The analysis of particle identification capability for the time projection chamber and the experimental study of detector prototype
- [2]. W.Liu, 2022, Development of A Low Power and High Integration Front-end Readout Electronics for TPC
- [3]. Y.M.Cai, 2021, Investigation of laser application in time projection chamber
- [4]. H.Y.Wang, 2019, Study of TPC with laser calibration system for future circular collider
- [5]. Y.L.Zhang, 2017, Study on Continuous Ion Backflow Suppression Detector Module for Circular Collider

Thanks for your attention.