Update of TPC prototype with the lower power consumption ASIC

Huirong Qi
ZhiYang Yuan, Yue Chang, Liwen Yu, Wei Liu, Jian Zhang, Hongliang Dai, Zhi Deng, Yulan Li, Hui Gong

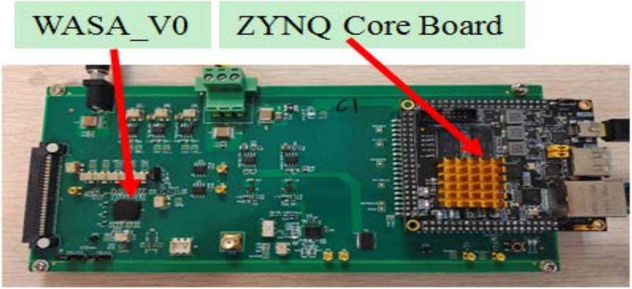
Mar. 09, 2022

Overview

1. TPC prototype with new ASIC chips
2. Design the pixelated TPC module
3. Contribution for Snowmass and Summary

- Testing of TPC prototype with new ASIC chips

Low power ASIC chip- WASA_V0 testing board



Testing parameters：

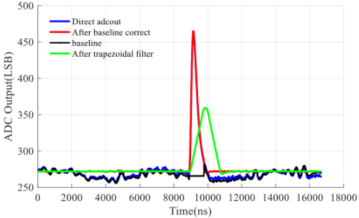
- GEMs detector: 280V-310 V
- E_{drift}： ≤280 V/cm
- Operation gases： Ar/CF4/iC4H10 95/3/2 (T2K)
- Radioactive source： 55Fe@ 1mCi
- Channels： 128channels (**2✕4✕16 =** 128 channels available)
- External power supply: ±5V, ± 12V, ± 24V

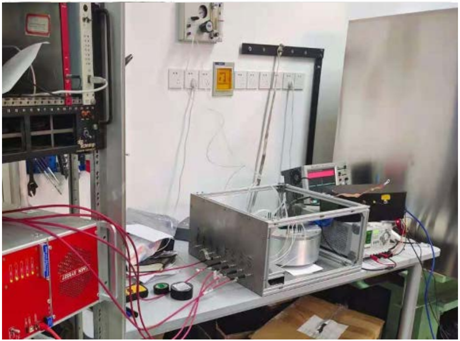
New electronics testing with the module

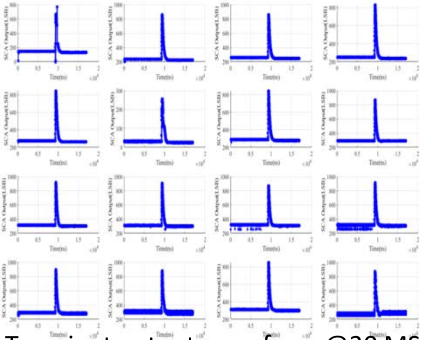
^{55}Fe testing

Testing parameters:

- GEMs detector: 280V-310 V
- E_{drift}: ≤280 V/cm
- Operation gases: $Ar/CF_4/iC_4H_{10}$ 95/3/2 (T2K)
- Radioactive source: ^{55}Fe@ 1mCi
- Successfully commissioned and collected signals using DAQ

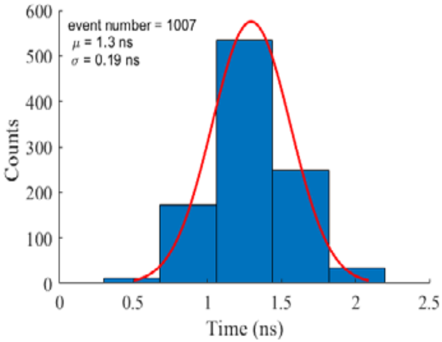




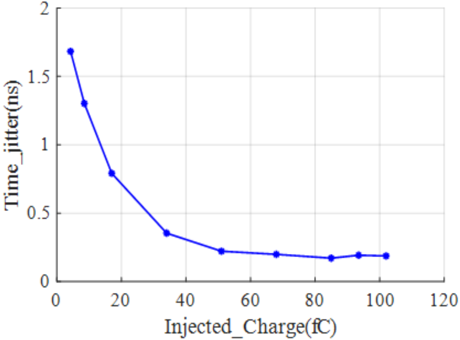


Transient output waveform @30 MS/s

Time resolution and the different charge



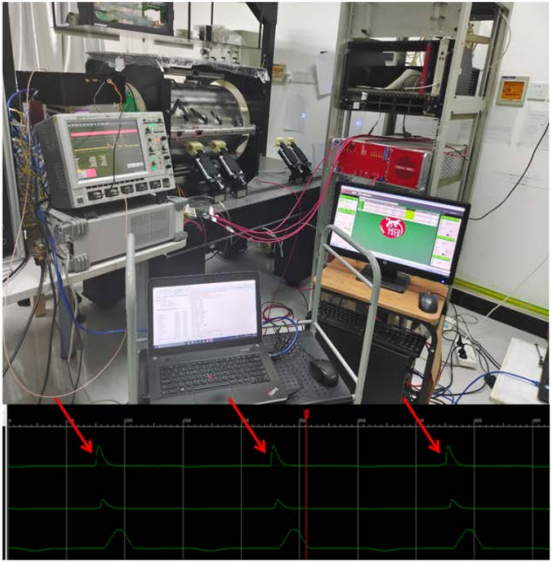
Time resolution of ASIC chip @100 fC, 10 mV/fC, 30 MS/s



Time resolution of the different charge input

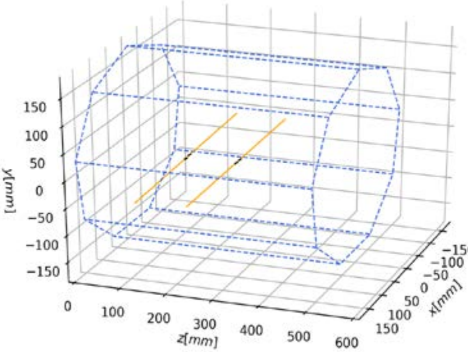
New electronics testing with the prototype

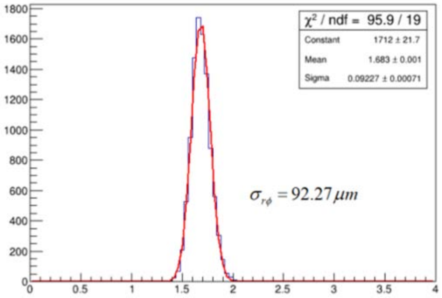
- Successfully realized the joint test of low-power ASIC chip and TPC prototype
- ASIC+TPC parameters
  - TPC:
    - GEM: 280 V
    - Drift length: 500mm
    - E_drift: 180 V/cm
    - Gas: Ar/CF4/iC4H10 95/3/2 (T2K)
    - UV laser: 7.2 mJ @20 Hz
    - Laser tracks: 3 layers along drift length
  - Electronics:
    - Trigger by UV laseer
    - Gain: 20 mV/fC
    - Sample frequency: 30 MS/s



65nm ASIC + TPC prototype

UV laser track reconstruction and position resolution





Drift time: $5.7 \sim 6.0\,\mu s$
$8.2 \sim 8.5\,\mu s$

$$\sigma_y^2 = \frac{D_T^2}{N_{eff}}(z - z_0) + \frac{h^2}{12N_{eff}} + \frac{w^2}{12N_{eff}},$$

Transvers diffusion and δ_y VS UV laser power

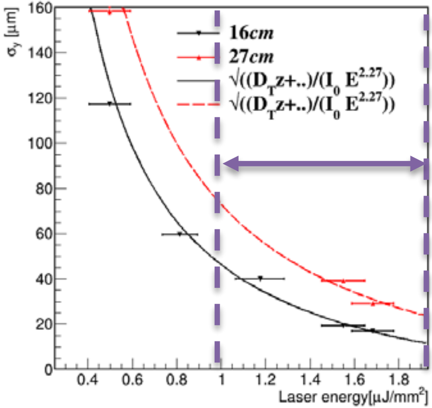
$$\sigma_y^2 = \frac{D_T^2}{N_{eff}}(z - z_0) + \frac{h^2}{12N_{eff}} + \frac{w^2}{12N_{eff}},$$

Transvers diffusion of Laser TPC prototype: $D_T = (310.7 \pm 7.6)\ \mu m/\sqrt{cm}$

- Simulation results using Garfield++ compared the experimental results with the different UV laser power
- The experimental data fit is close to the simulation result
- The optimization of the UV laser power will be set at 1-1.8uJ/mm^2

Next steps:

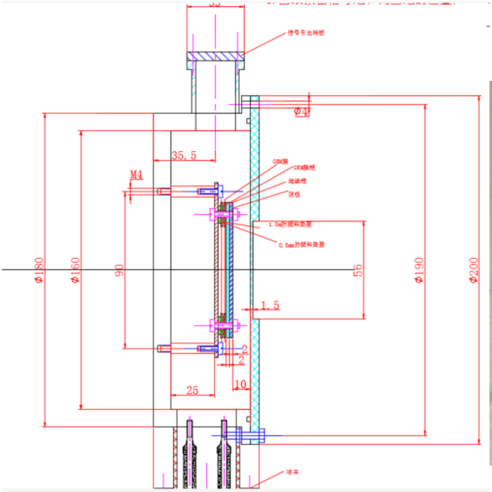
- Analyze the electric field with the D_T
- Analyzed the electric field with the spatial resolution

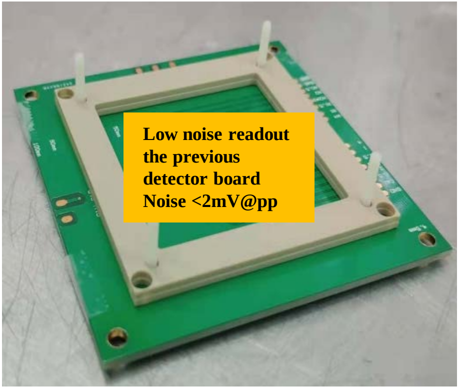


δ_y VS UV laser power

- Design the pixelated TPC module
    - Good electromagnetic shielding and low noise
- Simulation and discussion of pixel TPC for CEPC at Z are ongoing with LCTPC collaboration
    - Chang Yue, Yu Liwen, Yuan Zhiyang, Huirong Qi
    - LCTPC collaboration group

Design the pixelated TPC module

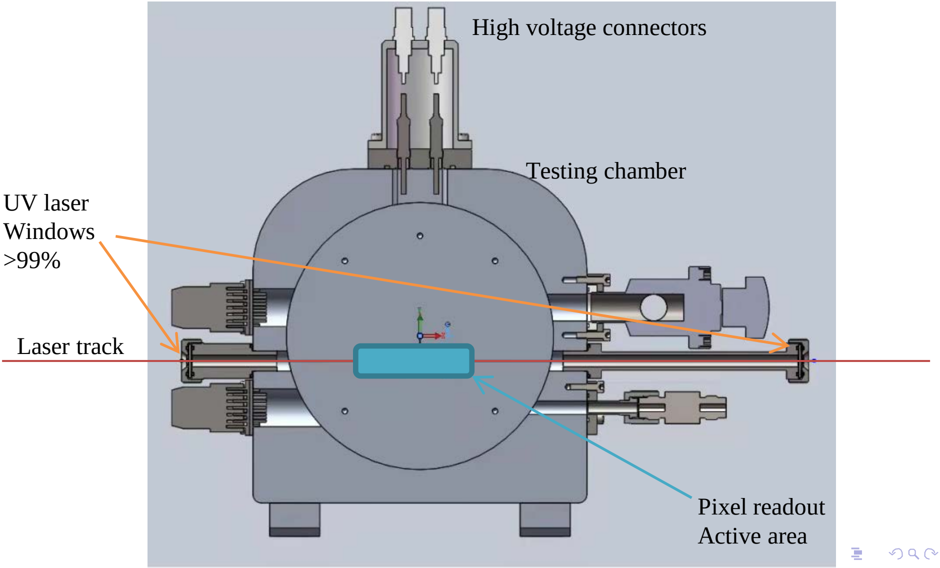




Low noise TPC module for the pixelated readout

Design the pixelated TPC module

- The design has been completed, and the production has begun (**2 weeks**)



Contribution for TPC Snowmass white paper

MPGDs for TPCs at future lepton colliders

Alain Bellerive *[1], on behalf of the LCTPC Collaboration[2], Alexei Lebedev[3], Jochen Kaminski[4], Peter M. Lewis[4], Andreas Löschcke Centeno[4], Christian Wessel[4], Oskar Hartbrich[5], Sven Vahsen[5], Carlos Mariñas[6], Huiron Qi[7], and Zhiyong Zhang[8]

[1] *Department of Physics, Carleton University, Ottawa, ON, K1S 5B6, Canada*
[2] *https://www.lctpc.org/e9/e57037/*
[3] *Brookhaven National Laboratory, Physics Department, Upton, NY 11973, USA*
[4] *University of Bonn, Institute of Physics, Nußallee 12, 53115 Bonn, Germany*
[5] *University of Hawaii, Department of Physics and Astronomy, Honolulu, HI 96822, USA*
[6] *University of Valencia - CSIC, Instituto de Fisica Corpuscular (IFIC), Spain*
[7] *Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China*
[8] *University of Science and Technology of China, Hefei 230026, China*

March 8, 2022

March, 2022

Future of Particle Physics (Snowmass 2021)

ABSTRACT

This submission will focus on advancements and advantages of Micro Pattern Gas Detector (MPGD) technologies together with their applications for the construction of a dedicated Time Projection Chamber (TPC) that can serve as an excellent main tracker for any multipurpose detector that can be foreseen to operate at a future lepton collider. The first portion of the report will be the executive summary. It will be followed by sections detailing on applications of MPGDs specifically for the construction of the LCTPC for the ILD at ILC, for a possible upgrade of the Belle II detector and for the design of a TPC for a detector at CEPC. MPGD technologies offer synergy with other detector R&D's

4 TPC for CEPC

The Circular Electron Positron Collider (CEPC) has been proposed as a Higgs/Z factory in China [11]. The baseline design of a CEPC detector consists of a tracking system composed of a vertex detector with three concentric double-sided pixel layers, a high precision (about 100 μm) large volume TPC and a silicon tracker in both barrel and end-cap regions. The tracking system has similar performance requirements as for the ILD detector, but without power-pulsing, which leads to additional constraints on detector specifications, especially for the case of the machine operating at Z-pole energy with high luminosity. Until a decision on a tracker for a future circular collider in China can be reached, a number of tasks are still remaining regarding the TPC research. Such tasks include the full simulations of the TPC performance in the CEPC environment, further design of the low power consumption readout electronics, UV laser calibration methods and cooling options [12]. Some of the key challenges to be addressed in the near future are the physics requirements for the TPC performance towards the inclusive CEPC physics program. MPGD technology, though quite far advanced in some aspects, still needs a significant effort from key partners. Nonetheless, the CEPC TPC requirements and challenges for the detector are similar than the ones described for the ILD, and thus achievable with existing MPGD technologies. R&D activities are actively ongoing in China and could potentially lead to partnership with the USA.

Overall, the TPC at CEPC has been inspired by the ILC-TPC development. Contrary to the ILC, Z pole running at CEPC with luminosity of about $10^{[illegible]}$ cm^{-2}s^{-1} prevents gating mode TPC operation. Hence, a hybrid gaseous structure [12] and a double micro-mesh gaseous structure [13] were proposed and studied in depth, and the key factor of the gain times the IBF suppression ratio shows good promise. In this situation, GridPix is also an attractive option, which provides the high granularity needed to resolve individual electron clusters and to determine energy loss by the cluster counting technique. The CEPC TPC requires transverse $(r-\phi)$ single-hit space-point resolutions of less than 100 μm and longitudinal (z) time resolution of about 100 ns. The physics goals require dE/dx resolution of less than 5% with an even better particle identification separation with cluster counting. Most conditions set by the CEPC tracking systems can be met by MPGDs as proven by LCTPC effort. Such detector development offers a possibility for partnership between the LCTPC collaboration groups and China.

Summary

- Successfully testing and collected signals using the new electronics with the lower power consumption chips
- UV laser tracks were reconstructed and simulation results using Garfield++ compared the experimental results with the different UV laser power
- The design of the pixelated TPC module with the low noise has been completed, and the production will be done in two weeks
- Some contributions has been done for MPGD Snowmass whitepaper from IHEP

Thanks for your attention.