Status and prospects of TPC prototype using the UV laser mimic tracks

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Abstract. To meet the high precision physical goals in the future e^+e^- circular collider (CEPC), the high resolution tracker detector for the particle track reconstruction (¡100μ m) and particle identification are required. Time Projection Chamber (TPC) is one of the main concept option of the central tracker detector. On behalf of the track detector subgroup in CEPC, the status and update R&D results of TPC module and prototype for the specific requirements will be presented in this article. TPC module will could suppress the ions in chamber continuously running in the different gains (2000−5000) and T2K mixture gases, and TPC prototype with Micro-pattern Gaseous Detector (MPGD) detector module integrated the narrow laser mimic tracks system. the update results of the spatial resolution, particles identified (dE/dx) were been investigated. In this TPC prototype, the precision drift time of the different laser mimic tracks ionized primary electrons in the specific operation working gases were recorded. Some considerations of the low power consumption readout requirements will be given according to the pad TPC detector operating at the high luminosity Z pole at CEPC.

1. Introduction

The discovery of a Standard Module (SM) Higgs boson at 125 GeV at the Large Hardon Collider (LHC)[1] brought about great opportunity to investigate the feasibility of CEPC[2] operating at center-of-mass energy about 240 GeV, as a Higgs factory, with designed luminosity of about $2\times 10^{34}\text{cm}^{-2}\text{s}^{-1}$ and more. Time Projection Chambers as the primary tracker detector have been extensively studied and used in many fields, especially in particle physics experiments, including STAR, ALICE and some related high energy physics experiments. Their low material budget and excellent pattern recognition capability make them ideal for three dimensional tracking and identification of charged particles. The TPC detector will operate in continuous mode on the circular machine. To fulfill the physics goals of the future circular collider and meet Higgs/Z run, TPC detector with excellent performance is required. MPGDs with outstanding single-point accuracy and excellent multi-track resolution are needed. We have proposed and investigated the ions controlling performance of a novel configuration detector module. The aim of this study is to suppress Ions Back Flow(IBF) continually.

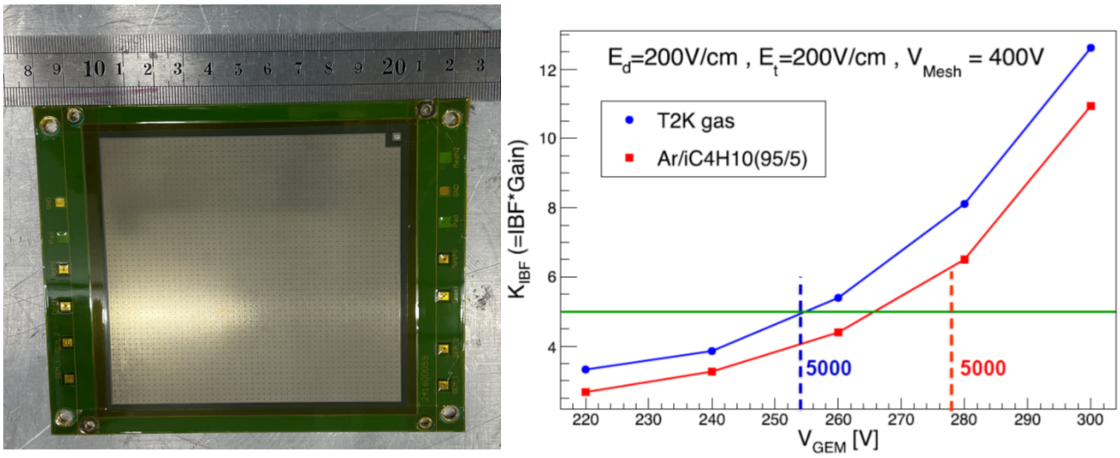

Figure 1. Photo of the hybrid structure detector (left), IBF×Gain results at the different gases and the operation voltage (right).

The preliminary baseline design of CEPC detector is a Particle flow Analysis (PFA) concept[3], with a superconducting solenoid of about 3 Tesla surrounding the inner silicon detector, TPC tracker detector and the calorimeter system[4]. In order to accommodate the CEPC collision environment, some necessary changes have been made to the Machine Detector Interface (MDI) and sub-detector design. The CEPC design, for instance, has a significantly shorter focal length L* of 1.5−2.0 meters than that of the International Linear Collider (ILC) design (about 3.5 meters), which indicates that the final focusing magnet of the QD_0 will be placed inside the CEPC detector. In addition, the CEPC detector will operate in continuous mode, which imposes special considerations on power consumption and subsequent cooling of the sub-detectors.

Aiming to the CDR and TDR of the CEPC project, two-phase funding scheme is proposed by the funding agency, the Ministry of Science and Technology (MOST) of China. To launch the project, the MOST funded the CEPC accelerator and detector R&D project for phase-I period of 2016−2021. Among sub-detectors, the feasibility study of the TPC tracker detector was initiated for the purpose to identify feasible technology options and to gain expertise to build the detector units which meet the basic requirements of the CEPC detector design. The specific research goals of this MOST project will be studied.

2. TPC detector module using the hybrid structure

There has been a critical problem with TPC detector, especially in high background conditions, the space charge distortion due to the accumulation of positive ions in the drift chamber. Due to their large mass, positive ions move slowly under the action of electric field in the drift volume of the TPC[5]. The continuously superimposed ions in the drift volume of the TPC may affect the drift behaviour of electrons from a later track. The majority of ions inside the drift volume are back flowing ions from the amplification region of the TPC readout devices. If Z pole run mode in the circular machine, there is no enough open/close time for this technology option.

The idea of combining Gas Electron Multiple (GEM) with Micromegas was first proposed with the goal of reducing the spark rate of Micromegas detectors. Ions back flow ratio increases initially and decreases afterwards as the GEM voltage increases. the value of ions back flow about 3% is considered to be the IBF for a standalone Micromegas detector with a gain of about 600. When the GEM is cascaded, the IBF can be further reduced to below 1%[6]. In

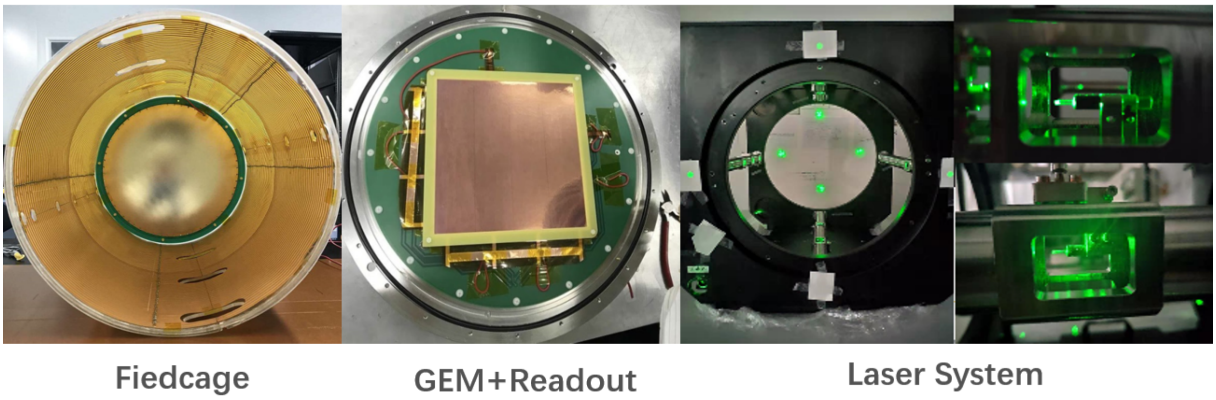

Figure 2. Photo of the fieldcage, GEM readout and the laser system of TPC detector prototype.

this hybrid concept, pre-amplification using GEM also extends the maximum achievable gain, so there have also been studies on gaseous photo-multipliers with this hybrid configuration. The cascaded structure of the GEM-MM detector is composed of a drift electrode, a GEM foil, a standard Micromegas, and a readout printed circuit board. The Micromegas detector is based on the bulk method and has an active area of 100mm×100mm and 200mm×200mm. A GEM foil is cascaded above the micromesh at a distance of about 1 mm. It is a standard GEM foil with the active area of 100mm×100mm, produced from CERN.

The working gases were Ar/CO_2(90/10) and T2K mixture gases at room temperature and atmospheric pressure. Ion backflow is due to secondary ions generated in an electron-avalanche process in the amplification which return to the drift space. IBF factor was reduced significantly. An IBF×Gain ratio of less than 2 under overall detector gain of 2000 was achieved in this test. The gain of the selection detector module can be achieved up to about 5000 without any obvious discharge behaviour. The currents on the anode and drift cathode were measured precisely with an electrometer. The experimental results showed that IBF can be reduced to less than 0.1% at the gain of about 5000[5].

3. TPC detector prototype with UV laser tracks

The smaller prototype TPC were developed with a drift length of 510 mm and an active area of 200mm×200mm at Institute of High Energy Physics (IHEP), and all of the prototype's parts had been studied. A Nd:YAG laser with a wave length of 266nm shall be used to study the UV laser tracks. The detector, chamber, fieldcage, FEE electronics and DAQ with 1280 channels readouts have been assembled. Some studies of the laser system and prototype have been performed at gain of 3000 and 5000 using 1280 FEE electronics readout channels (Gain: 20mV/fC) and DAQ (Sampling frequency: 40MHz). The track has been reconstructed and some performance of the drift velocity, ionization capacity, gain have been studied[7].

Concerning the fibers needing more bending room along drift length and more splitting points, the laser is coupled directly via mirrors into the setup and not via a fiber. To keep the laser tracks stable, the setup has to be stabilized against vibrations. Therefore, it is placed on an anti-vibration pneumatic optical platform, where a central spring, a pendulum bar and an auto inflation system damp any vibration down to amplitudes of less than 1m. 1280 channels readout system and the high voltage of 20,000V for the fieldcage have been done, and the signal tests are studied using TPC prototype integrated the separated UV laser tracks.

It's an important that TPC detector will operated in the different test area using the different operation gases for the testing. We optimized the operation gases and the event display of the

DAQ with the noise performance and one laser track. The UV laser hits and the specific UV laser tracks reconstructed. From the hits the clusters are formed with a center of gravity algorithm. The variation of the cluster position around the laser track is spread with a width of about 66.6μm without the magnetic field of 1.0 Tesla.

4. Low power consumption ASIC

Small readout pads of a few square millimeters (e.g. 1mm$\times$6mm) are needed to achieve high spatial and momentum resolution in TPC, demanding about 1 million channels of readout electronics per endplate. The total power consumption of the front-end electronics is limited by the cooling system to be several kilo-watts in practice and they have to work continuously in CEPC. Hence the technique of so-called power pulsing cannot be applied. There are no current existing electronics readout options could fulfill the requirements of such high density and low power consumption, including ALTRO/S-ALTRO and more recently SAMPA for ALICE, AFTER/GET for T2K and Timepix for ILC.

To develop a low power and highly integration front-end ASIC with direct waveform sampling in 65nm CMOS, the each channel consists of the analog front-end (AFE), including a charge sensitive pre-amplifier and a 'CR-RC' shape function, and a waveform sampling ADC in 10 bits and 40MHz. The power consumption were studied to reach less than 5mW per channel standalone[8] and the experiments will be done after the well commission of the detector, the high voltage, the ^{55}Fe radiation source or UV mimic laser and this low power consumption ASIC chips.

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