Time Projection Chamber R&D Letter of Intent

The excellent performance of the tracker detector and CEPC [1] fulture collider requires the development of new detector technologies to fully exploit the physics potential. As a central tracking detector a Time Projection Chambers (TPC) [2] with an MPGD-based readout is a very promising choice. The CEPC detector collaboration is working on designing such a detector taking into account the unique characteristics and requirements of experiments at a high energy e^+e^- collider. Various readout technologies are being evaluated. Further participants to develop the design and to bring in new ideas will go on.

The technology of TPC detector has been extensively studied and used in many fields, especially in particle physics experiments, including STAR and ALICE. 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, a TPC with excellent performance is required. MPGDs with outstanding single-point accuracy and excellent multi-track resolution are needed. Small readout pads of a few square millimeters (e.g. $1mm\times6mm$) are needed to achieve high spatial and momentum resolution in TPC, demanding about 1 million channels of readout electronics per endcap. 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 circular collider. There are no current existing electronics readout system can 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 [3, 4].

The work plan has been divided into many phases. In a first phase, the TPC detector at the proposed circular collider will have to be operated continuously and the backflow of ions must be minimized. The gain of the selection detector module can be achieved up to about 5000 without any obvious discharge behaviour. The experimental results showed that IBF can be reduced to -0.1% at the this gain [5]. In a second phase, The principle of an MPGD TPC has been studied with the small prototype. A prototype integrated UV laser beams has been developed. A prototype of a front-end ASIC has been developed in $65nm$ CMOS [6] for pad readout with GEMs. The power consumption can be lowered to less than 5mW/ch, which is highly concerned for CEPC TPC since power pulsing cannot be applied. The next phase, the prototype will be studied in the 1.0T magnetic filed and pixel pad will be further studied.

Questions

Until such decision of the future collider can be reached, a number of tasks are still remaining among which are full simulations of the TPC performance in the CEPC environment, cooling, further design of the readout electronics, and the calibration methods. Therefore, anyone interested in this project is sincerely invited to join the project and to stimulate further progress by new ideas. . Some of the key challenges to be addressed in the near future are:

Physics Requirements Quantify the TPC track detector performance requirement towards the inclusive CEPC physics program (Higgs, EW, Flavor, QCD, and BSM researches) via benchmark physics measurements and analyses. It needs the fast and full physics simulation and optimization.

Future MPGD Technology Challenges The MPGD technology, though quite far advanced in some aspects, still needs a significant effort in others. For example, the performance in a high magnetic field (B = 2.0T or 3.0T) needs confirmation for all performance parameters, the ion blocking of the gating GEM has to be verified and development of modern readout electronics should be continued. The efficient and precise construction of a large number of GridPixes and the analysis of the large amount of data they produce are still challenges to be solved. Similarly, the calibration and alignment methods of the narrow UV laser beams are still to be considered for further R&D.

Pad readout electronics For pad readout, more digital signal processing modules need to be integrated on-chip to reduce the data bandwidth. Besides, the performance and readiness of the new ASIC need to be demonstrated by producing and testing a small quantities of readout modules.

Pixel readout electronics Pixel readout has shown excellent tracking performance and also demonstrated its scalability recently. However, significant efforts are still needed in, for example optimization on pixel size and data pre-processing and reduction.

Calibration and alignment methods The ion blocking of the continue ions back flow suppression has to be verified and development of modern readout electronics should be continued. The efficient and precise construction of a large number of GridPixes and the analysis of the large amount of data they produce are still challenges to be solved. Similarly, the calibration and alignment methods of the narrow UV laser beams are still to be considered for further $R\&D$.

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