Time Projection Chamber R&D Letter of Intent

The excellent performance demanded from the tracker detector at the CEPC [1] future 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 are welcome to join us in the on-going research and bring in new ideas.

The TPC detector technology 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 in a circular machine. To fulfill the physics goals of the future circular collider during both the Higgs and Z runs, 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. 1 mm $\times$ 6 mm) are needed to achieve high spatial and momentum resolution in the TPC, demanding about one million channels of readout electronics per endcap. The total power consumption of the front-end electronics is limited by the cooling system to several kilo-watts in practice and it has to work continuously in a circular collider to meet the target luminosity. Currently, there are no existing electronics readout systems that 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 detector module can achieve a gain of up to about 5000 without any obvious discharge behaviour. The experimental results showed that IBF can be reduced to -0.1% at this gain [5]. In a second phase, the principle of an MPGD TPC has been studied with a small prototype. A prototype integrated UV laser beams has been developed. A prototype of a front-end ASIC has also been developed in 65 nm CMOS [6] for pad readout with GEMs. The power consumption can be lowered to less than 5 mW$/ch$, which is highly concerning for the CEPC TPC since power pulsing cannot be applied. In the next phase, the prototype will be studied in a 1.0 T magnetic field and pixel pad readout will be further studied.

Questions

Until a decision on a tracker for a future collider 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, 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 tracker 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 = 2.0 T or 3.0 T) needs confirmation for all performance parameters, the ion blocking of the hybrid structure gaseous detector has to be verified and development of modern readout electronics should be continued. The new technology of MPGD including the DLC resistive layer, the hybrid structure and the 3D printed material would be developed 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 needs to be demonstrated by producing and testing a small quantity of readout modules.

Pixel readout electronics Pixel readout has recently shown excellent tracking performance and also demonstrated its scalability. Significant efforts are however still needed. 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.

Contacts

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