European R&D Committee report

Hamburg, November 5th, 2013 Report # 003

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Executive Summary

The committee reviewed the LCTPC Collaboration activities, concentrating on the development of a TPC as the tracking sub-detector for a linear collider experiment, namely ILD. The committee congratulates the LCTPC collaboration for all the impressive work performed until now. The collaboration presented the status and prospects of different infrastructure/system aspects of the TPC. These included the design and testing of an ion gate that can prevent the backflow of positive ions from the gas amplification region to the TPC drift space, the study and technical solution to minimize the inter-module field distortions that affect the spatial resolution, the cooling of the detector electronics, the thermal monitoring and control of the whole TPC, the electronics power pulsing scheme and the mechanical technology for construction of a low mass barrel with the required tolerance, stiffness, stability and earthquake immunity.

All these aspects of the system are known to be critical but, up to now, have been studied only at the conceptual design testing level. In order to prepare for a TDR when required, the committee has the following recommendations:

The collaboration will need to increase resources in the area of technological and system R&D, with larger prototypes that can explore the possible technological challenges of the construction of a TPC for the LC detector.

The committee encourages the collaboration to prepare an overall plan with a more detailed schedule in the system aspects of the detector, including clear milestones to decide among the different technologies in time for a possible TDR within the next two/three years.

Introduction

The European R&D Committee met on November 4th and 5th at DESY, at Hamburg. The following members of the committee attended: R.Brenner, M.Diemoz, D.Eckstein (scientific secretary), Y.Karyotakis (chair), E.Koffeman, G.Mikenberg, H.G.Moser, C.Padilla, T.Sumiyoshi and A.White.

Monday November 4th, was dedicated to an open session where the LCTPC scientific program was extensively presented. A number of LCTPC members attended. All the presentations were excellent, addressing all the relevant scientific and technological aspects, and stimulating many questions by the committee members, which were answered.

The closed session on Tuesday 5th was dedicated to useful discussions and writing the report.

The committee warmly thanks DESY’s management for the excellent organization of this meeting and their hospitality.

In the following we are addressing the findings and recommendations for the Linear Collider TPC collaboration.

General Issues

A significant amount of R&D has shown that the required point resolution can be achieved with all of the proposed readout technologies for the ILD TPC. This result has been achieved in a series of parallel R&D exercises. Parallel exercises have also been pursued for field cage and endplate designs, mitigation of ion back flow, and front-end electronics design. The LCTPC collaboration is congratulated on the many excellent results obtained so far.

The time is now approaching when it will be essential for all the diverse activities to converge on an overall plan for completion of R&D, technology choice, and the development of a complete design for the TPC system to be captured in a Technical Design Report. This plan should be developed over the next year and should include milestones/goals for completion of each aspect of R&D, what constitutes "completion" for each area, and a schedule for reviews of progress on an annual basis. The management aspects of this plan need particular attention given the large number of institutes comprising LCTPC, but the apparently limited number of people actively engaged in development. The plan obviously needs to be synchronized to the overall ILD TDR planning, taking into account any potential evolution of the ILD design – aspect ratio, boundaries with other subsystems, and cost optimization.

Electronics

The new type of TPC for LC requires a very higher channel density (5mm² per channel) to meet the physics requirements. The channel density is in fact comparable to that for silicon strip trackers. The collaboration has studied the basic requirements for TPC electronics to be used at LC. There are currently no electronics that meet the requirements but there are electronics in limited quantities that can be used for studies of the TPC prototypes. Design of new front-end electronics (readout chip) at this point does not make sense because of the rapid advances in semiconductor industry and the uncertain schedule of the LC project. Refinement of electronics requirements should however continue.

The integration of the electronics in the end-plates (bad) is a challenge. The high channel density, the low material budget and requirements on low noise high, speed electronics will require innovative solutions. The collaboration has managed to miniaturize the electronics by innovative connection techniques but further miniaturization is required. We encourage the collaboration to continue these studies in order to find a design that meet the requirements that is reliable and can be produced at a reasonable cost in industry. There might be solutions currently used in silicon strip trackers that can be modified for the TPC. The thermal and electrical properties of the integrated end-plate should be simulated and experimentally verified. In particular the use of high density multi-pin connectors is not desirable for long term reliability. We encourage the collaboration to look for other ways to build a maintainable system that do not rely on replacing electronics connected through multi-pin connectors. New low cost flip-chip interconnection techniques are rapidly becoming available and the use of new (and old) technologies should be evaluated. The design of readout-chip, pad plane and corresponding interconnection technology is a major challenge which would require the effort of a few dedicated electronics engineers.

MPGD detectors

Requirement of the position resolution for the LC-TPC is 60 μm for zero drift and < 100 μm for overall in r-ϕ. It is very difficult to accomplish this resolution by a general MWPC, hence Micro Pattern Gas Detectors such as GEM and Micromegas are considered as the readout device at the endplate. There are two options for the GEM based detector; one is the three layers of normal GEMs of 50 μm thick Kapton made in CERN, and the other is two layers of 100 μm thick LCP (Liquid Crystal Polymer) GEMs made by a Japanese company. In order to obtain the required resolution the pad size is around 1× 6 mm^2. Both types of GEM detector exhibit almost the same performance for position resolution that meets the requirement, except that micro discharges are observed for LCP GEMs. It is well known that a gain of CERN type GEM has rate dependence due to a positive ion accumulation on the conical surface of the hole, but if the rate is not so high, it does not matter. Since the rate for LC-TPC is expected to be not so high, the CERN type GEM would be a good candidate. In order to decide the GEM option a long term test (more than 6 month with an expected rate at the inner part of LC-TPC coverage) is absolutely necessary. After this long term test a merger of two groups (DESY and Asian) is recommended to cure the common problem of manpower shortage.

For the Micromegas option, the committee notes the interesting development of adding a resistive foil to spread the charge over several pads thereby improving the spatial resolution with respect to collecting all the charge on a single pad. Significant progress has been made on this option, with seven Micromegas modules mounted on an endplate. The proposed high voltage connection and grounding scheme allows a filling of the active area of a module apart from a narrow edge band. Comparable resolutions have been achieved for the Micromegas option and GEMs over the same range of drift distances.

Beam test results show deterioration of position resolution at the module boundaries, which is attributed to possible field deformation. This also is a big issue to finalize the TPC design. The effect of the field deformation might be corrected by software work, however, it is desired to make deformation as little as possible. Detail electrodes design at the edge of the modules is pressing issue.

Gridpix detector

Another solution for the readout at the endplate is the use of a pixel chip covered with an amplification grid. This method was originally developed with a micromegas foil strung over the pixel chip. The input pads of the pixel chip serve as anodes and directly capture the signal developed in the avalanches. To ensure alignment of the grid with the pixel array an Ingrid has been developed that makes an amplification grid with wafer post-processing steps (hence INtegrated GRID). With such a processed chip it is possible to record the signal from individual electrons from the drift region. For this reason this option is called digital readout. The development of large area anode planes has been proven to be difficult up till now and the analysis of the testbeam results are somewhat less far advanced. The collaboration should clarify the acceptance criteria that would allow the further development of this interesting TPC readout concept.

Ions back flow

The problem of Ion back flow is characteristic of a TPC working in a high rate environment, as expected in a high luminosity linear collider. From simulation studies, effect of positive ion back flow (IBF) to the drift space is considered to be a big obstacle to obtain the desired position resolution. The distortion due to IBF is expected to be about 60 μm times backflow rate (BFR). BFR less than 1 is necessary but is very difficult to realize. One solution might be a Micro-Hole and Strip-Plate (MHSP) structure proposed for suppression of IBF with a thick GEM by Breskin et al (NIM A523 (2004) 334-344) , but accommodation of such structure into this LC-TPC GEM seems to be very difficult. Hence an introduction of ion gating grids is a natural solution to suppress the IBF. Two methods are currently proposed; one is a wire gate and the other is GEM gate. However both options have shortcomings. For the wire option a possible dead region due to a structure to support the wires is anticipated, and for the GEM option a transmittance of the signal electrons is at most 70%. The committee recommends that in view that the ion back flow only affects the position resolution (due to the higher occupancy) in a limited radial region (385 to 550mm) the collaboration should look into the possibility of limiting the gating arrangements to the affected region. Since determination of the gating grid structure is most urgent for LC-TPC, it should be concluded as early as possible with detailed design and prototype tests.

Radial deformations in the TPC end-plates

The proponents have presented a very sophisticated design of the TPC end-plates based on an aluminium structure, on which final element analysis has been performed. The mechanical stability of such structure is crucial to the position resolution performance to be achieved by the TPC devise. The proposed mechanical coupling between the end-cap readout (GEM's or MicroMegas) made mainly of PCB boards that have different thermal and humidity expansion coefficients could, due to the strong mechanical coupling to the supporting Aluminium frame, introduce stresses in the combined mechanical structure that could lead to deformations that are hard to predict. The committee recommends that the collaboration looks into the possibility of using low friction O-rings between the Aluminium structure and the readout units, to guarantee a good gas isolation, combined with a kinematic mounting, which would allow to decouple the deformations of the different materials.