PROCEEDINGS OF SCIENCE

Studies of Micro Pattern Gas Detector modules of a Large Prototype TPC for the ILC

Alain Bellerive[*†]
Ottawa-Carleton Institute for Physics, Department of Physics,
Carleton University, 1125 Colonel By Drive, Ottawa, K1S 5B6, Canada
E-mail: alain.bellerive@carleton.ca

The International Large Detector (ILD) at the International Linear Collider (ILC) will require a large volume Time Projection Chamber (TPC) with transverse and longitudinale space-point resolutions of less than 100 μm and 1400 μm, respectively, for all tracks over the full 2.35 m drift region. The LCTPC collaboration tested various detector modules at the EUDET facility at DESY. Preliminary results of the 2014-2015 test beam campaigns are reported here.

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*Speaker.
†On behalf of the LCTPC collaboration.

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1. Introduction

The International Large Detector (ILD) is one of two proposed all-purpose detectors for the future International Linear Collider (ILC) [1]. To meet the stringent resolution requirements for a detailed exploration of the physics at the TeV scale, the ILD proposes a TPC as the central tracking, with a goal of measuring 200 track points with single-hit resolutions better than 100 μm in the transverse plane and 1400 μm in the longitudinal direction, for all tracks after 2.35 meters of drift in a 3.5 T magnetic field [1]. This translates to single-hit resolutions of 60 μm and 400 μm at $z = 0$ m in the transverse plane and longitudinal direction, respectively. The transverse resolution goal represents an order of magnitude improvement over the conventional proportional wire/cathode pad TPC performance, which is limited by the intrinsic $\vec{E} \times \vec{B}$ effect [3], and approaches the fundamental limit imposed by diffusion. ILD will forego the conventional wire/pad readout for recently developed Micro Pattern Gaseous Detectors (MPGDs), GEM [4] or Micromegas [5], both of which offer many advantages. MPGDs have a smaller material budget, which is important in a high background environment such as the ILC, and naturally reduce space charge build up in the drift volume by suppressing positive ion feedback from the amplification region. Of greatest importance however, is that the $\vec{E} \times \vec{B}$ effect is negligible for an MPGD because the MPGD holes have about 100 μm spacing that offers a rotationally symmetric distribution and thus no preferred track angle.

The LCTPC collaboration tested various MPGD detector modules at the EUDET facility [6] at DESY. In this proceeding paper, we present an initial study of the single-hit resolutions using data collected during the 2014-2015 test beam campaigns.

2. Experimental Setup

The EUDET-project [6] was launched to create an infrastructure for developing and testing new and advanced detector technologies to be used at a future linear collider. The aim was to make possible experimentation and analysis of data for institutes, which otherwise could not be realized due to lack of resources. The infrastructure comprised an analysis and software network, and instrumentation setups for tracking detectors as well as for calorimetry.

A rather complete setup has been established at the DESY test beam, providing an infrastructure for a world-wide effort in the development of a large TPC to be used as main tracking device at a future linear collider. It consists of the following items: 1) large scale (about 1 m) and low mass field cage; 2) modular end plate system for large surface GEM and Micromegas systems; 3) MPGD detector modules; 4) prototype readout electronics; 5) magnet, supporting devices, HV, gas and cooling systems, and slow controls; 6) silicon envelope detectors; and 7) software developed within the MarlinTPC framework for simulation, calibration and reconstruction of TPC data. The LCTPC Large Prototype (LP) has a diameter of 770 mm and a length of 610 mm and fits into the 1 Tesla superconducting magnet PCMAG. Tracks measured within the LP can have up to 125 space points, using anode pad readout, depending on the pad size. The aim of these tests is not only to confirm the anticipated single-point resolutions, but also to address issues related to the large size of this TPC, like alignment, and electric and magnetic field distortions.

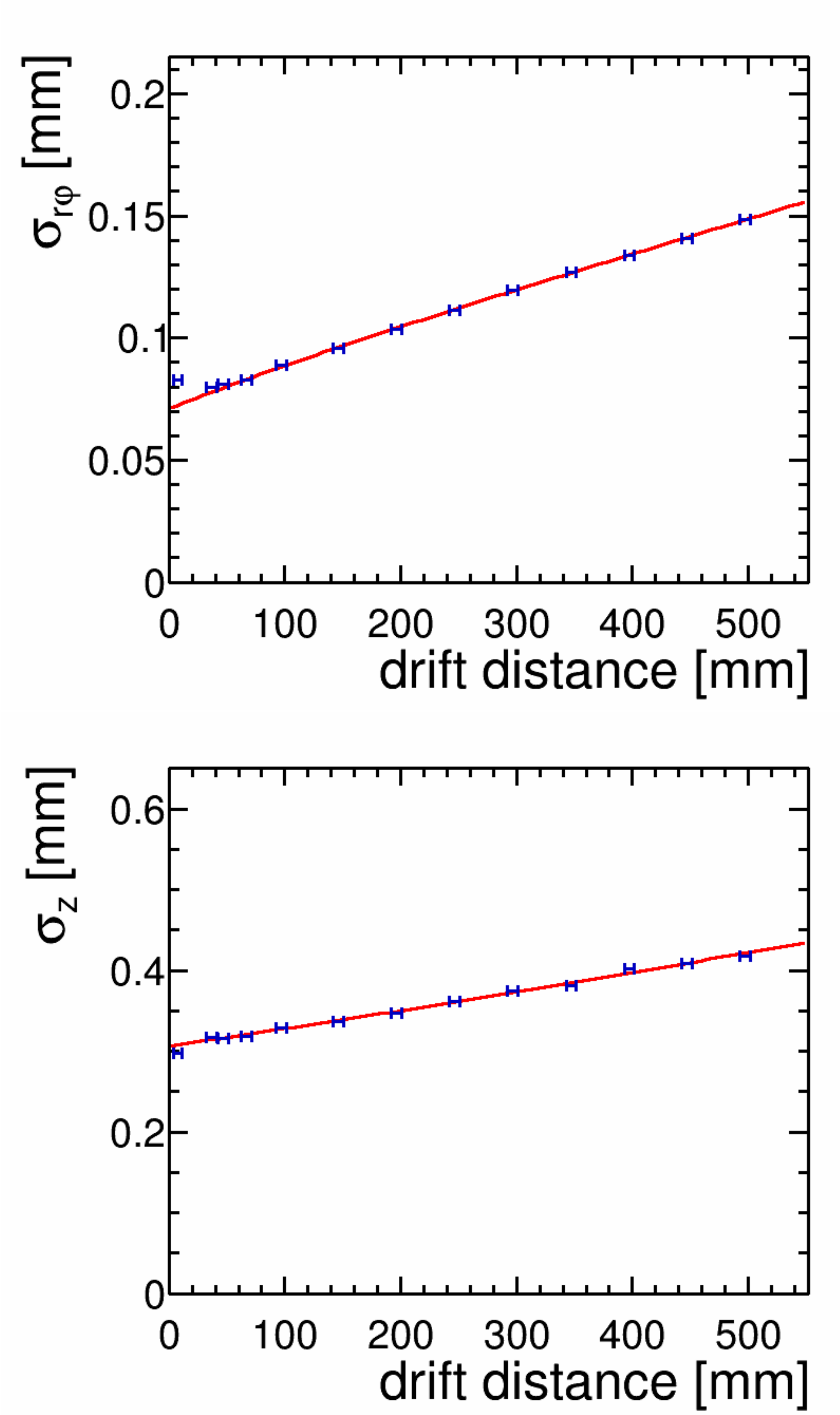

Figure 1: Single-hit space-point transverse (top) and longitudinale (bottom) resolutions plotted against drift distance, *z*, for triple DESY GEM [7].

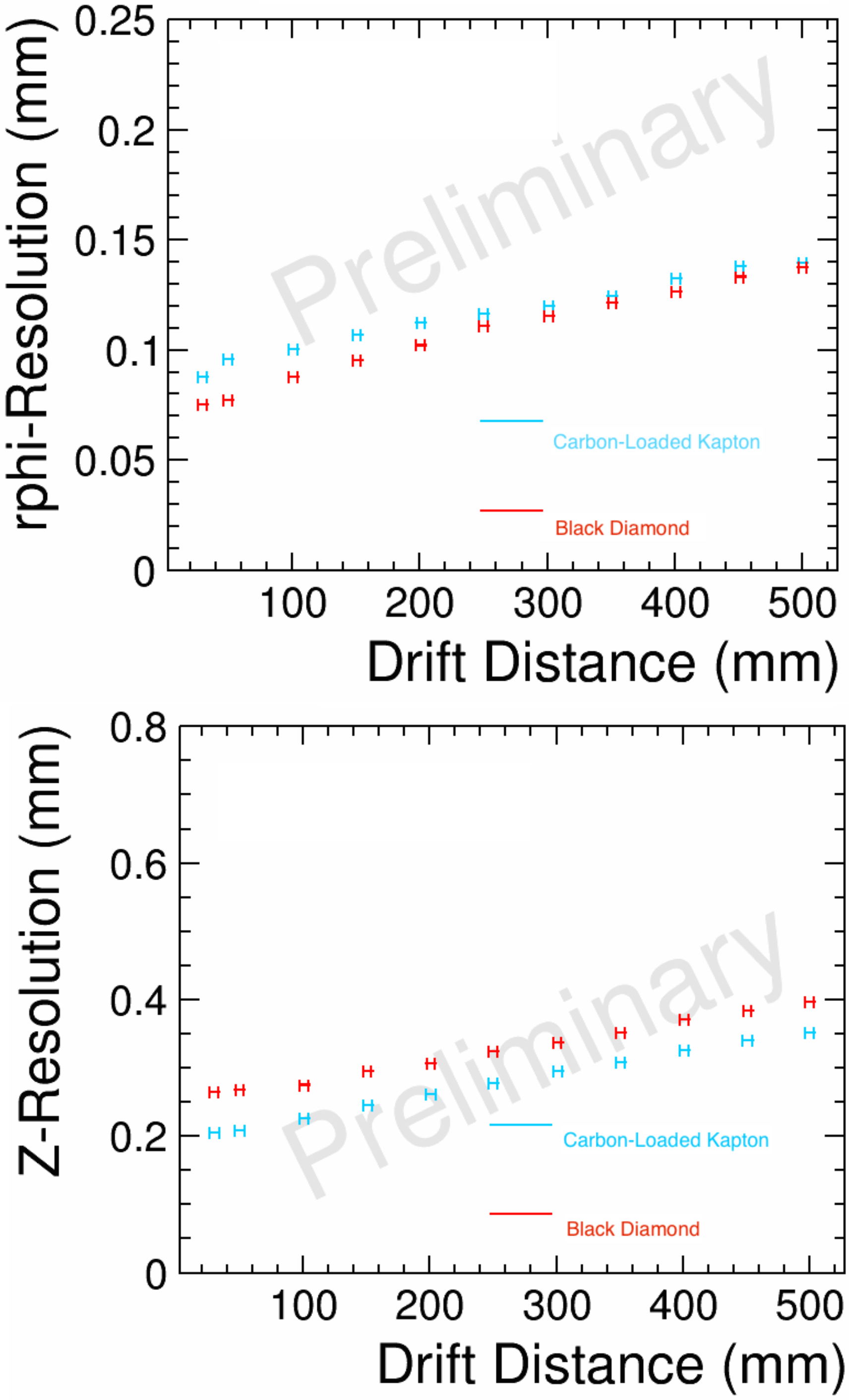

Figure 2: Single-hit space-point transverse (top) and longitudinale (bottom) resolutions plotted against drift distance, z, for Micromegas with charge dispersion readout [8].

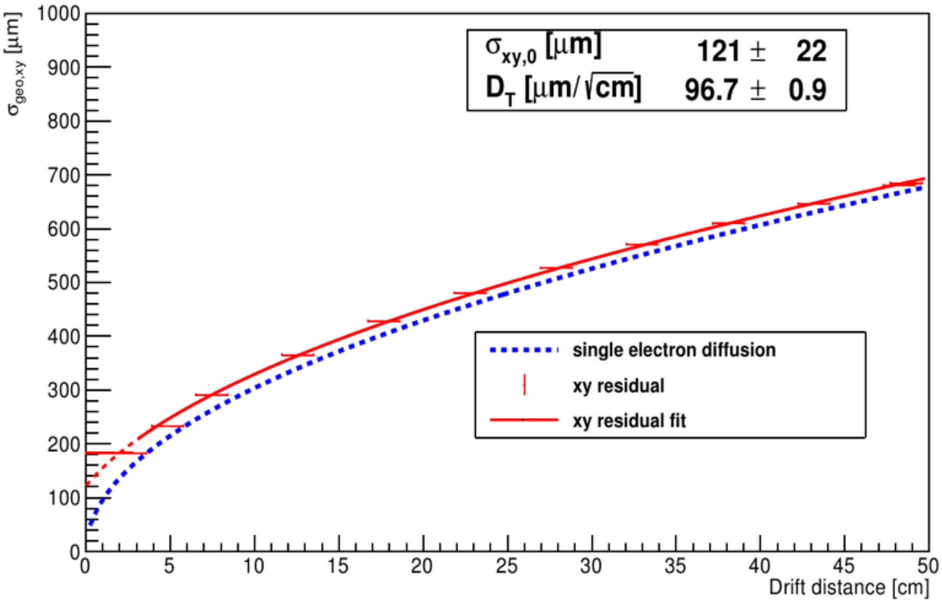

Figure 3: Space-point transverse resolution plotted against drift distance, z, for GridPix pixel readout [9].

3. Results of Transverse and Longitudinale Resolutions

Analyses of data were performed from recent test beam measurements with the LCTPC LP equipped with: (i) wet-etched triple DESY GEM and (ii) Micromegas with charge dispersion readout. Inhomogeneities of the electric field close to the MPGD boarders caused distortions of the recorded tracks. These distortions were corrected for by using the MarlinTPC software package for both GEM and Micromegas pad-based readouts. After the corrections have been applied the residuals line up around zero for both technologies. In Figures 1 and 2, the measured transverse (xy-plane) and longitudinale (z-direction) space-point resolutions are plotted as a function of the drift distance for data collected in a 1 T magnetic field with GEM and Micromegas, respectively. Preliminary results of pixel MPGD readouts (*i.e.* GridPix) depicted in Figure 3 indicates that this novel technology has great potential [9]. In all cases, the transverse resolutions were measured using the geometric mean of inclusive and exclusive residual distributions from track fits and fitted to the analytical form $\sigma_{\mathrm{T}}(z) = \sqrt{\sigma_{\mathrm{T}_0}^2 + D_T^2\, z}$, where D_T is the coefficient of transverse diffusion.

4. Summary and outlook

We have presented the measurements of the space-point resolutions of the LCTPC Large Prototype (LP) of the future ILD-TPC for the International Linear Collider. The single-hit transverse resolutions were measured using the geometric mean of inclusive and exclusive residual distributions from track fits in 1 T magnetic field. Extrapolating those results in a magnetic field of 3.5 T confirms that pad-based GEM and Micromegas technologies meet the requirements of the proposed ILD-TPC for the future International Linear Collider [1], which is a single-hit resolutions of $\sigma_{r\phi}(z=0) \sim 60\ \mu$m and $\sigma_{r\phi} < 100\ \mu$m in the transverse plane for all tracks after 2.35 m of drift. The single-hit longitudinale resolution shown here clearly confirms that the LP achieves and surpasses the ILD TPC requirements of $\sigma_z(z=0) < 400\ \mu$m and σ_z(z=2.35m) < 1400 μm. Preliminary results on the performance of GridPix readout shows great promise.

References

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