A Prototype Study of the TPC for the International Linear Collider Experiment

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Abstract

We report on our study for the ILC-TPC (Time Projection Chamber) with emphasis put on GEM-TPC gas optimization. We focus on Ar-CF4 gas mixtures because of their small diffusion coefficients in a strong magnetic field as predicted by GARFIELD/Magboltz simulations. Experimentally, however, these Ar-CF4 gas mixtures have not yet been studied enough for a GEM-TPC. This report describes our cosmic ray test results on a small proto-type GEM-TPC with the Ar-CF4-isoC4H10 (95:3:2) gas mixture (T2K gas). Our data show good agreement with the simulations and their analytic extrapolation to the real ILC-TPC suggests the mixture being a good candidate gas for the GEM-TPC.

Introduction

One of the most important issues of the current high energy physics is to find the Higgs boson and to reveal its nature. The LHC [1] will most likely find a Higgs candidate and the ILC [2] is expected to follow it to complete the mission. To study the Higgs properties in detail we need a high performance central tracker.

A TPC is a natural candidate for the ILC central tracker because of its very good performance in the past collider experiments [3]. At the ILC, however, we need the highest possible tracking efficiency in a jetty environment and a momentum resolution one order-of-magnitude better than those in the past. In order to realize a TPC with such unprecedented performance, intense R&D programs are now on going in an international framework called the LC-TPC collaboration. Three technologies have been considered as the ILC-TPC readout plane for gas amplification: a Multi-Wire Proportionnal Chamber(MWPC) end-plane, a Micro-megas detector, and a multi-GEM structure.

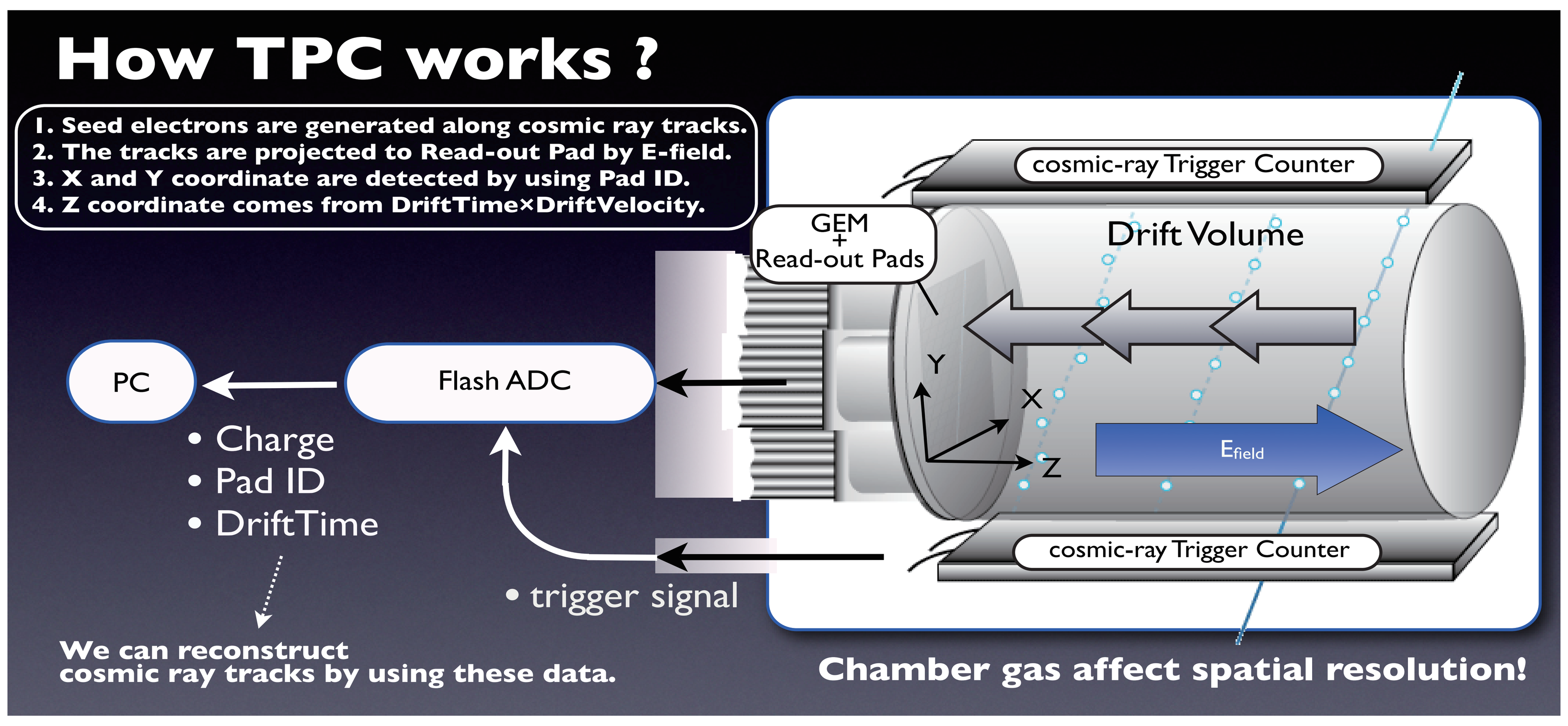
First part of this report is about our result on the MWPC readout, showing that the MWPC readout dose not meet the required spatial resolution even for tracks perpendicular to the wires and the pad rows because of a large ExB effect in a strong magnetic field of 4T, and hence proves it inappropriate for the ILC-TPC. We are hence left with the Micromegas and the GEM readout planes.

Our group has been studying a triple-GEM readout plane with a small prototype TPC at KEK in search of an optimum chamber gas so as to achieve (1) high spatial resolution, (2) high enough gas gain, and (3) stability in operation as required for the ILC-TPC.

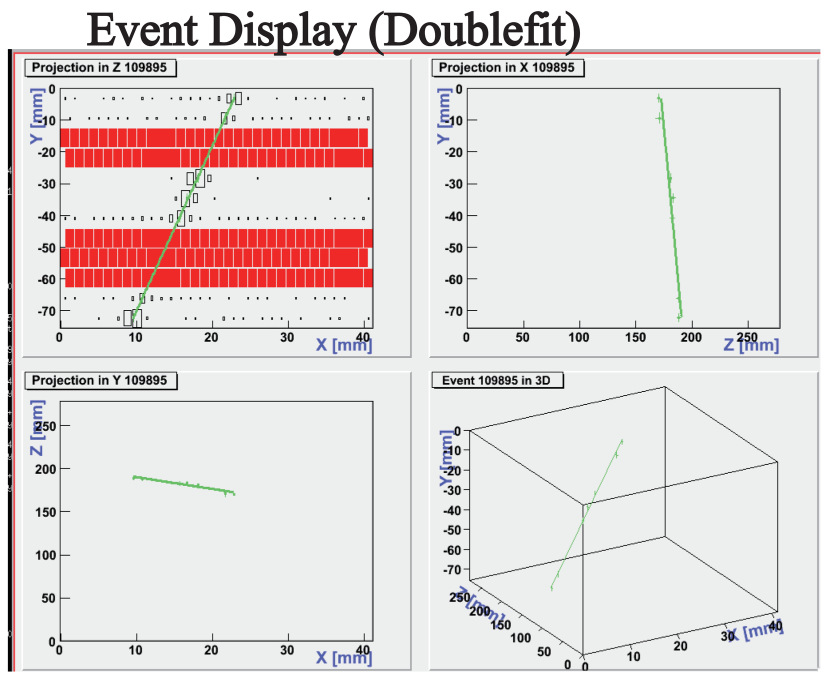
The T2K gas has been a focus of attention because of its small diffusion coefficient in a strong magnetic field predicted by GARFIELD/Magboltxz simulations and tested with the Micromegas readout to certain extent. The mixture had not been tested enough with the GEM readout, though there had been some concern about possible electron attachment near the readout plane. The second part presents our preliminary results on the GEM readout with this gas mixture.

Set up

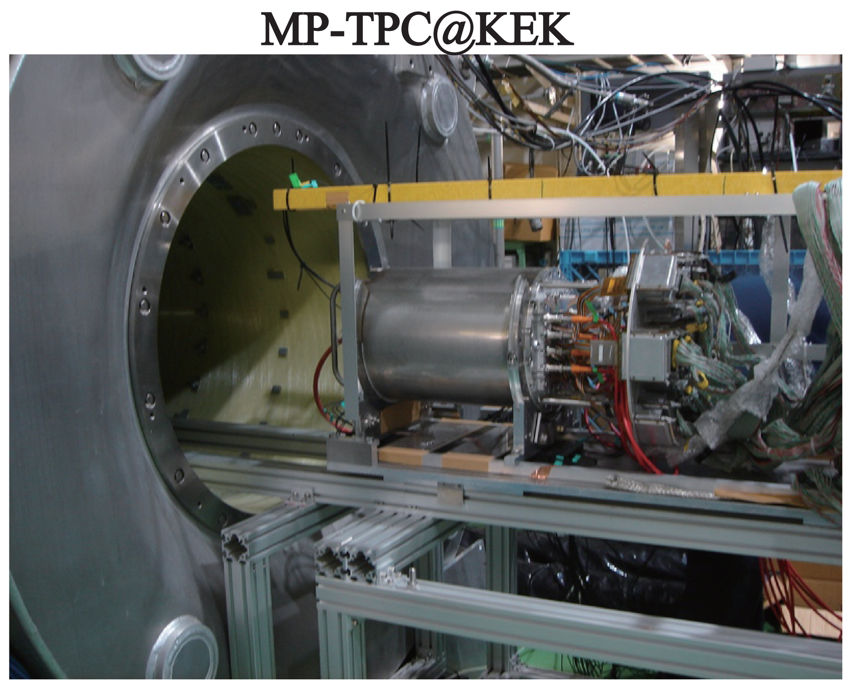
In order to compare different readout technologies, a small prototype TPC (MP-TPC) with a detachable endplate was built at MPI-Munich. The data reported were from the MP-TPC via a DAQ system based on the readout electronics used for the ALEPH experiment at CERN [4].



Event Display (Doublefit)

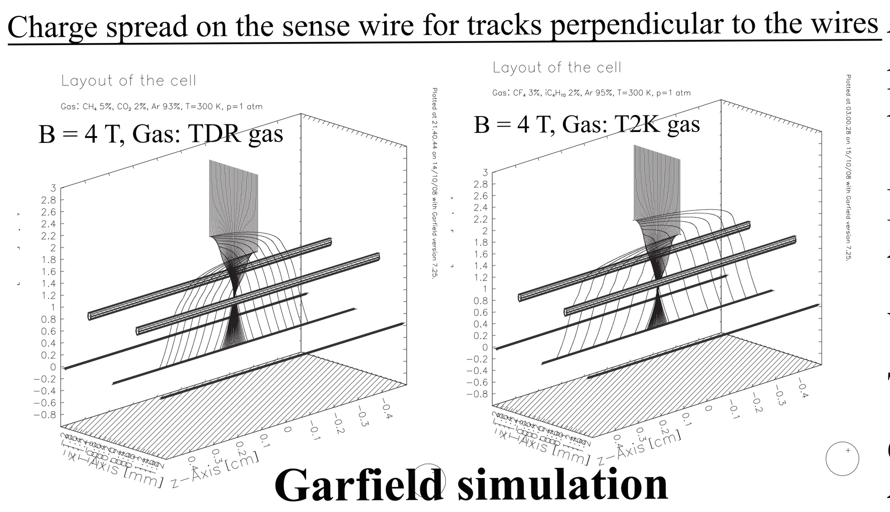


MP-TPC@KEK



Part A : About MWPC readout

Charge spread on the sense wire for tracks perpendicular to the wires

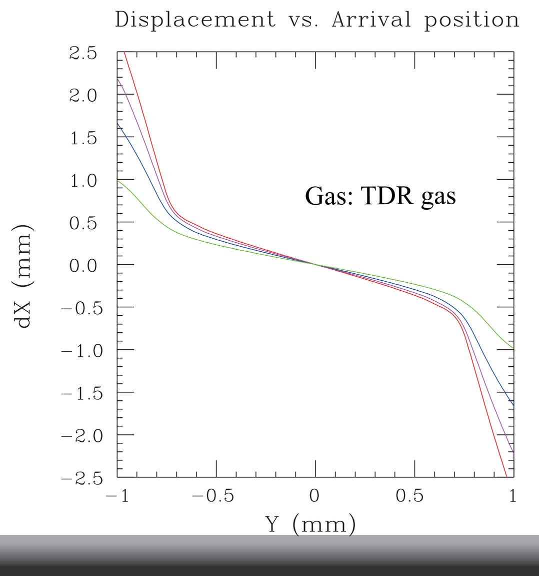


Garfield simulation

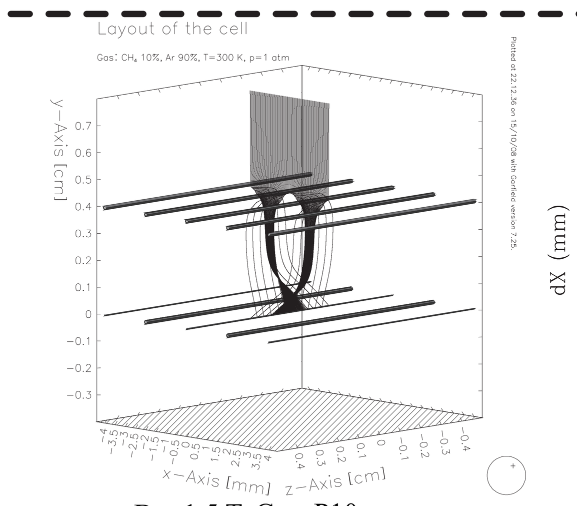
A TPC with conventional MWPC readout does not work well under a strong magnetic field because of a large E x B effect.

Left figures show significant charge spread due to the E x B effect, which deteriorates the trans-verse spatial resolution of the TPC.

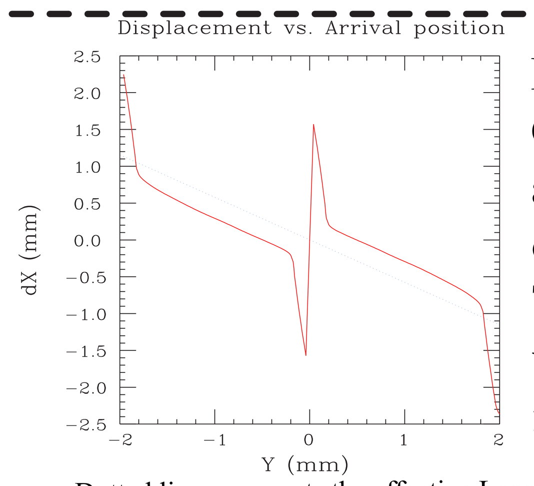
The spread is larger for the T2K gas, which is expected to be an excelent TPC gas because of the smaller transverse diffusion of drift electrons under the strong magnetic field.



The arrival position of drift electrons on the sense wire as a function of the position along the track measured from the sense wire for B = 1, 2, 3 and 4 T.
The red curve corresponds to the left 3-D plot for B = 4 T.
The increase of displacement, especially for large y, degrades the spatial resolution significantly.



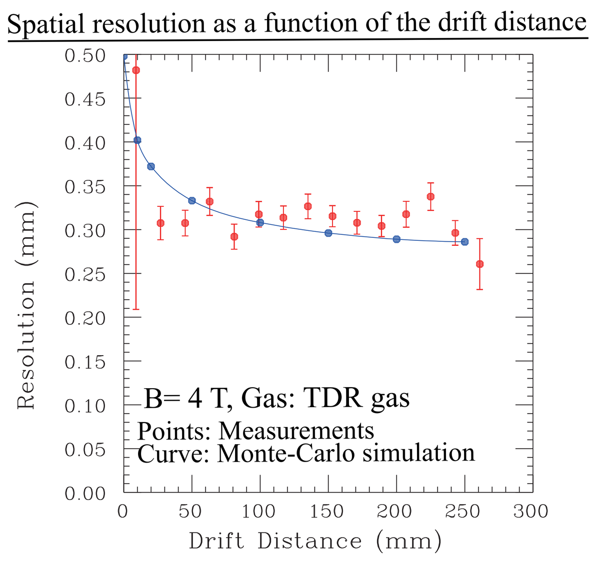
B = 1.5 T, Gas: P10
Wire configuration: TPC90



Dotted line represents the effective Lorentz angle of 30
(See S.R. Amendolia et al., NIM 217 (1983) 317 and W. Blum et al., NIM A252 (1986) 407.)

In order to check the reliability of the Garfield simulation, the effective Lorentz angle (ψ) was estimated for the prototype of the ALEPH TPC (TPC 90). The simulated displacement is consistent with the measured values of ψ around 30°, indicating the validity of the simulation.

Spatial resolution as a function of the drift distance



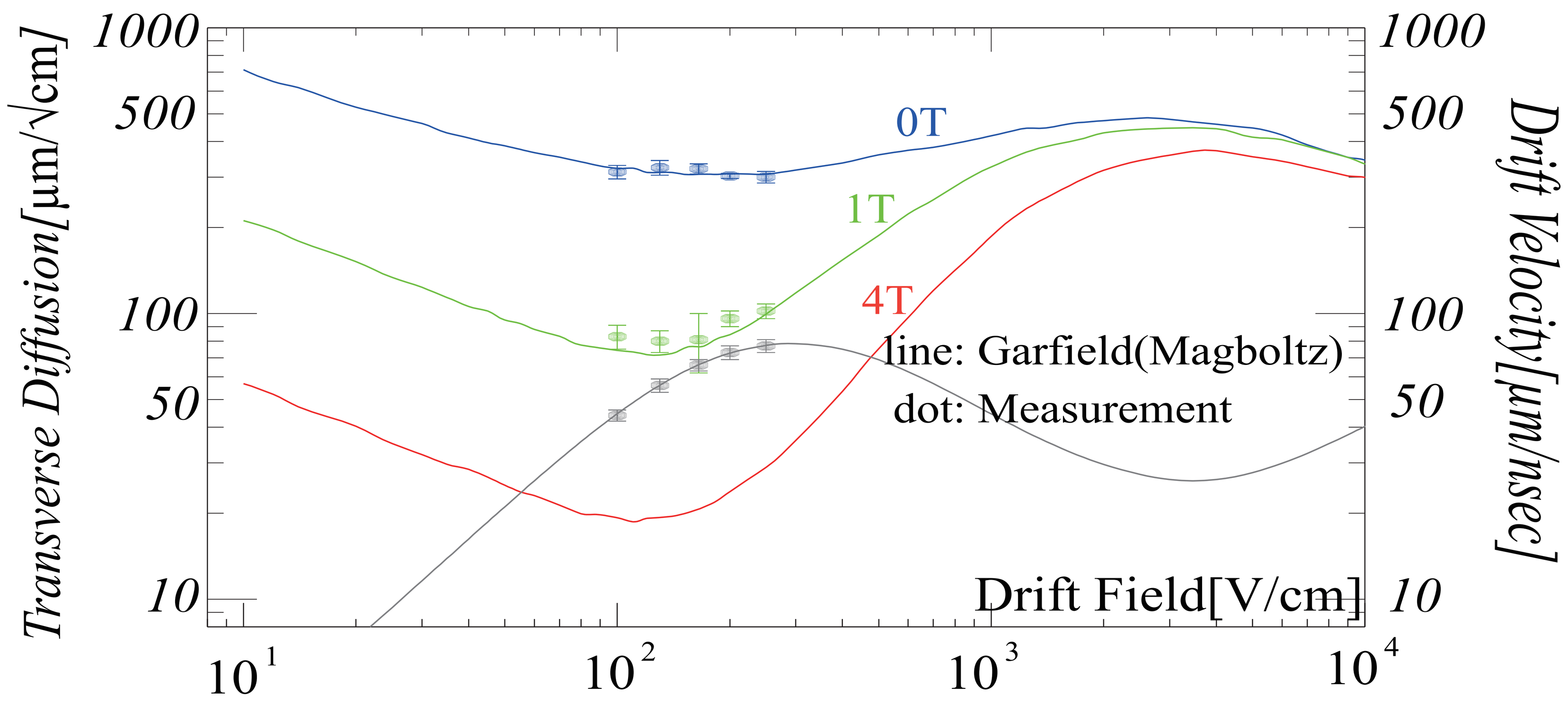
The measured spatial resolution as a function of the drift distance is compared to the Monte-Carlo simulation taking into account the E x B effect given by the Garfield simulation. It should be noted that the measured spatial resolution is almost constant over the measured range of drift distance. The simulation shows the improvement of resolution with increasing drift distance because of the de-clustering effect.

Conclusion (PartA)

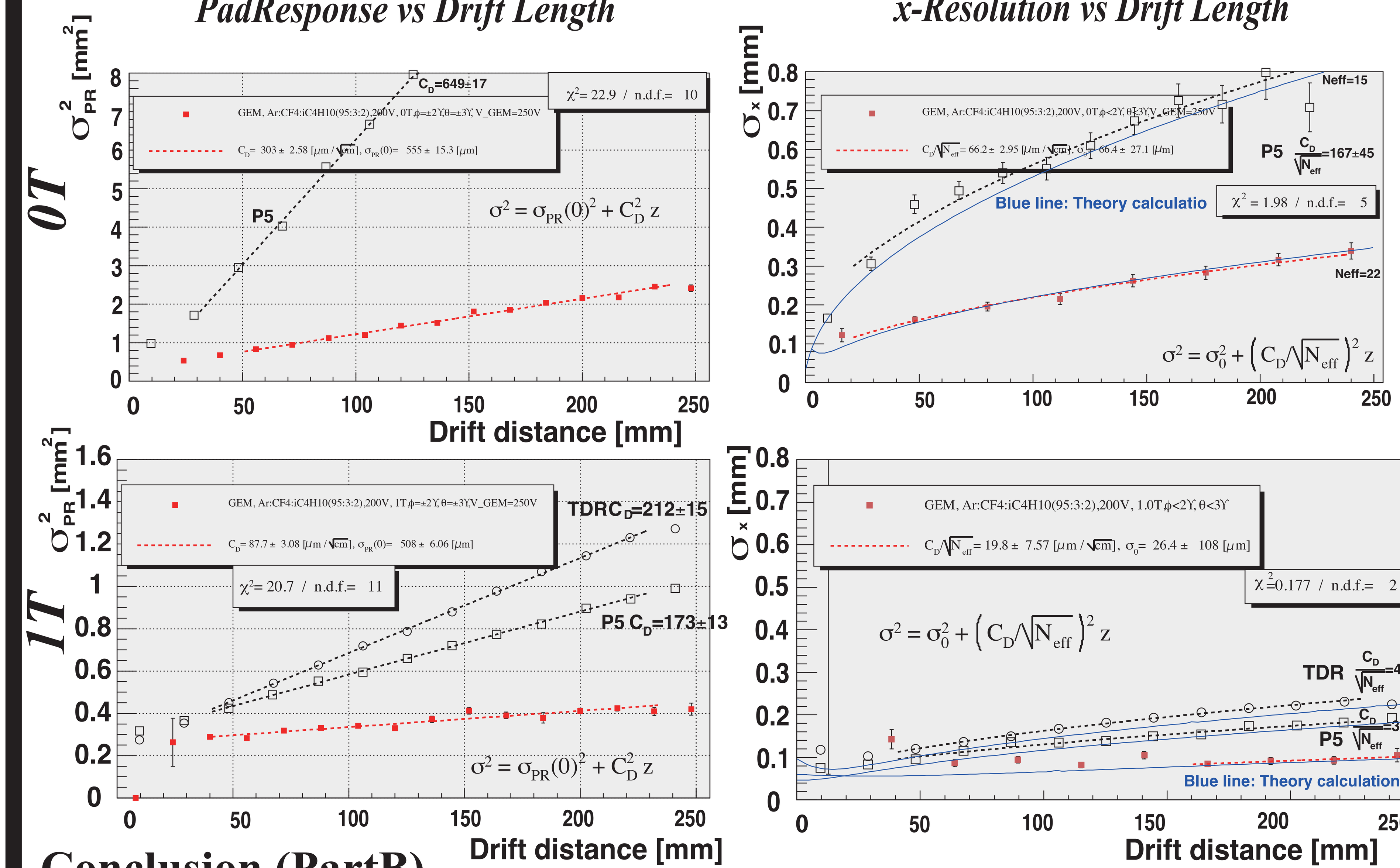
The resolution of the TPC equipped with an MWPC readout is NOT LIMITED BY DIFFUSION BUT BY E x B .

Part B : About GEM readout

Data Summary about DriftVelocity & DiffusionConstant with Garfield simulation

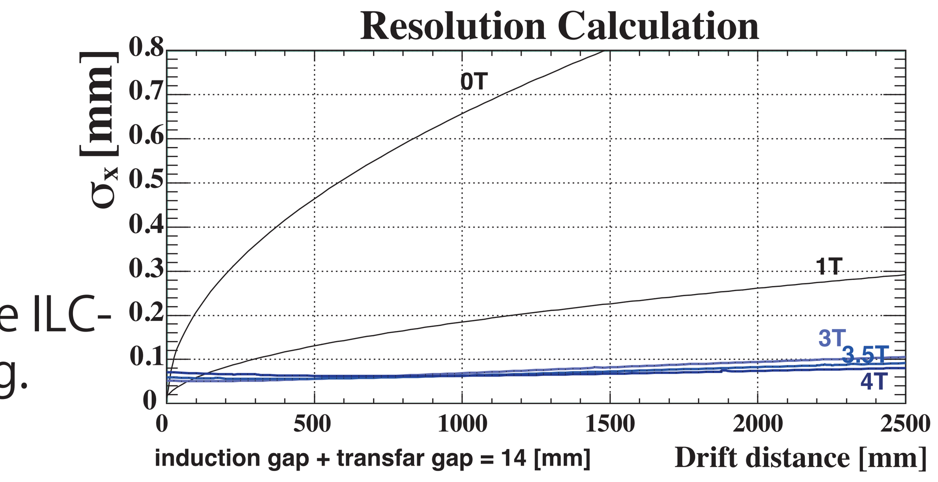


PadResponse vs Drift Length | x-Resolution vs Drift Length



Conclusion (PartB)

- Drift Velocity and diffusion coefficient are consistent with GARFIELD/Magbolts simulations.
- Stability of GEM-TPC with Ar-CF4-isoC4H10(95:3:2) was confirmed.
- Fitting on resolution data indicates Neff ~ 21 (P5,TDR ~ 22).
- Analytical extrapolation to the real-size ILC-TPC in the right figure seems promising.



Summary

The MWPC readout turned out to be inappropriate for the ILC-TPC because of the ExB effect and we are left with MPGD readout schemes. We tested a GEM readout TPC with the T2K gas, Ar-CF4-isoC4H10 (95:3:2), and found that the mixture can be a good candi-date for the ILC-TPC gas.

Acknowledgements

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References

[1] http://public.web.cern.ch/public/en/LHC/LHC-en.html
[2] http://www.linearcollider.org/cms/
[3] M.T. Ronan, Time-projection chambers, p.268 of the PDG Particle Physics Booklet July 2006
[4] M. Ball, N.Ghodbane, M. Janssen , P.Wienemann: A DAQ System for Linear Collider TPC Prototypes based on the ALEPH TPC Electronics, arXiv:physics/0407120