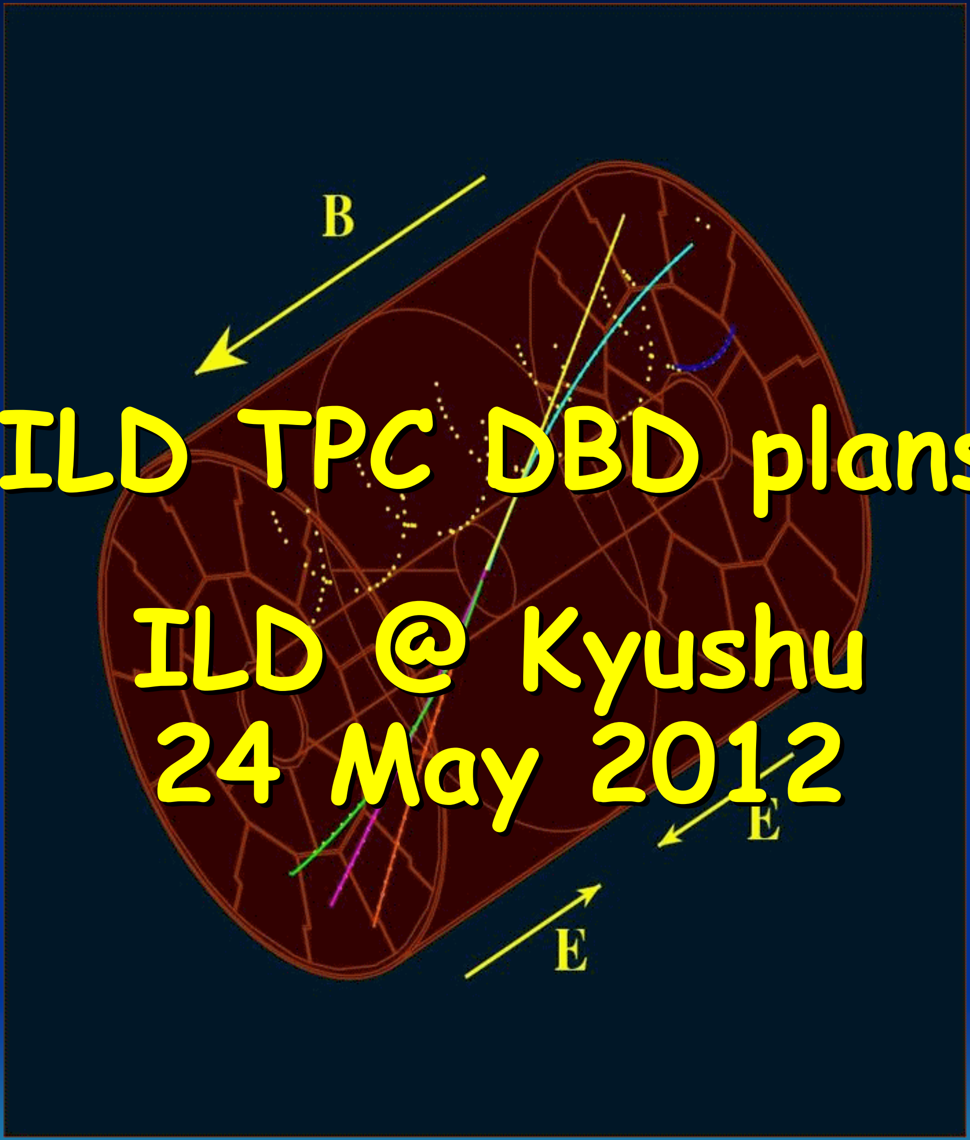
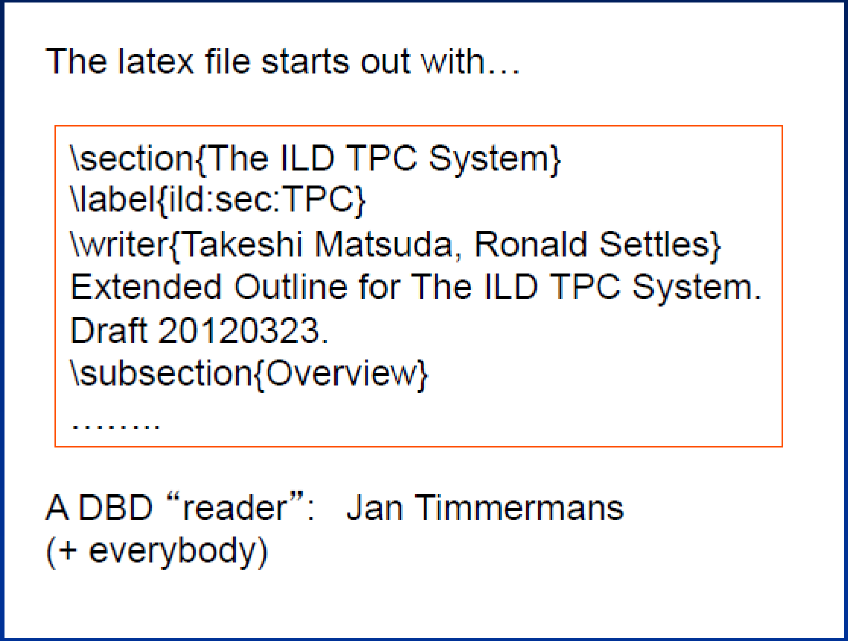


ILD TPC DBD plans

ILD @ Kyushu
24 May 2012

Ron Settles MPI-Munich
ILD TPC DBD talk at Kyushu May 24 2012

The DBD TPC outline at the LCTPC collaboration meeting in Desy March 27



The latex file starts out with…

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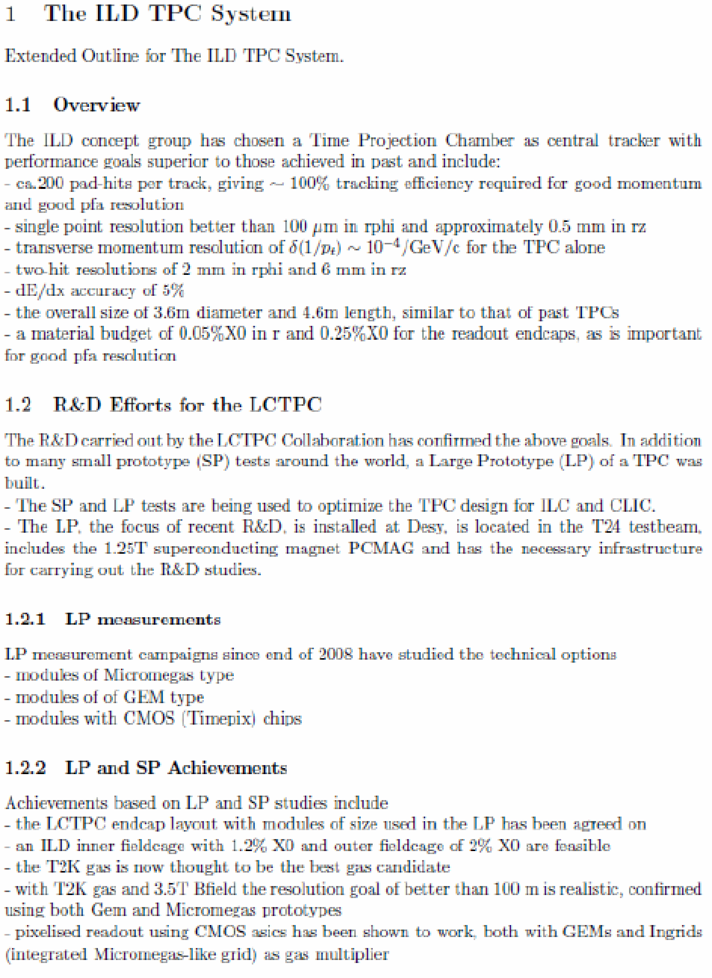
\section{The ILD TPC System}
\label{ild:sec:TPC}
\writer{Takeshi Matsuda, Ronald Settles}
Extended Outline for The ILD TPC System.
Draft 20120323.
\subsection{Overview}
……..
```

A DBD “reader”: Jan Timmermans
(+ everybody)

(+ everybody ≡ the LCTPC collaboration incl. Jochen Kaminski. His talk on the status and this one on the DBD will overlap a bit…)

The DBD TPC outline at the LCTPC collaboration meeting in Desy March 27



1 The ILD TPC System

Extended Outline for The ILD TPC System.

1.1 Overview

The ILD concept group has chosen a Time Projection Chamber as central tracker with performance goals superior to those achieved in past and include:
- ca.200 pad-hits per track, giving ~ 100% tracking efficiency required for good momentum and good pfa resolution
- single point resolution better than 100 μm in rphi and approximately 0.5 mm in rz
- transverse momentum resolution of $\delta(1/p_t) \sim 10^{-4}$/GeV/c for the TPC alone
- two-hit resolutions of 2 mm in rphi and 6 mm in rz
- dE/dx accuracy of 5%
- the overall size of 3.6m diameter and 4.6m length, similar to that of past TPCs
- a material budget of 0.05%X0 in r and 0.25%X0 for the readout endcaps, as is important for good pfa resolution

1.2 R&D Efforts for the LCTPC

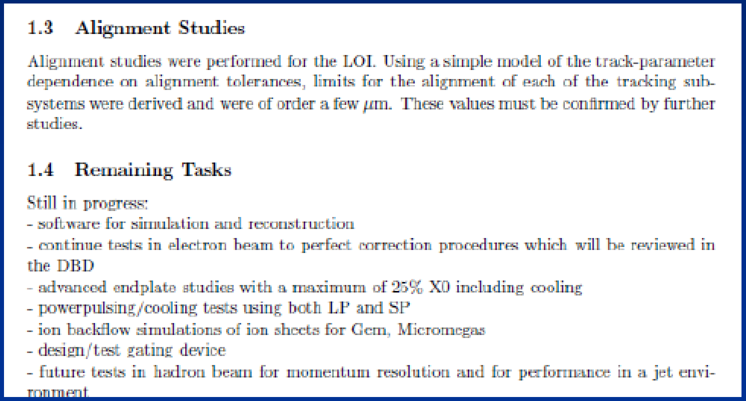
The R&D carried out by the LCTPC Collaboration has confirmed the above goals. In addition to many small prototype (SP) tests around the world, a Large Prototype (LP) of a TPC was built.
- The SP and LP tests are being used to optimize the TPC design for ILC and CLIC.
- The LP, the focus of recent R&D, is installed at Desy, is located in the T24 testbeam, includes the 1.25T superconducting magnet PCMAG and has the necessary infrastructure for carrying out the R&D studies.

1.2.1 LP measurements

LP measurement campaigns since end of 2008 have studied the technical options
- modules of Micromegas type
- modules of of GEM type
- modules with CMOS (Timepix) chips

1.2.2 LP and SP Achievements

Achievements based on LP and SP studies include
- the LCTPC endcap layout with modules of size used in the LP has been agreed on
- an ILD inner fieldcage with 1.2% X0 and outer fieldcage of 2% X0 are feasible
- the T2K gas is now thought to be the best gas candidate
- with T2K gas and 3.5T Bfield the resolution goal of better than 100 m is realistic, confirmed using both Gem and Micromegas prototypes
- pixelised readout using CMOS asics has been shown to work, both with GEMs and Ingrids (integrated Micromegas-like grid) as gas multiplier



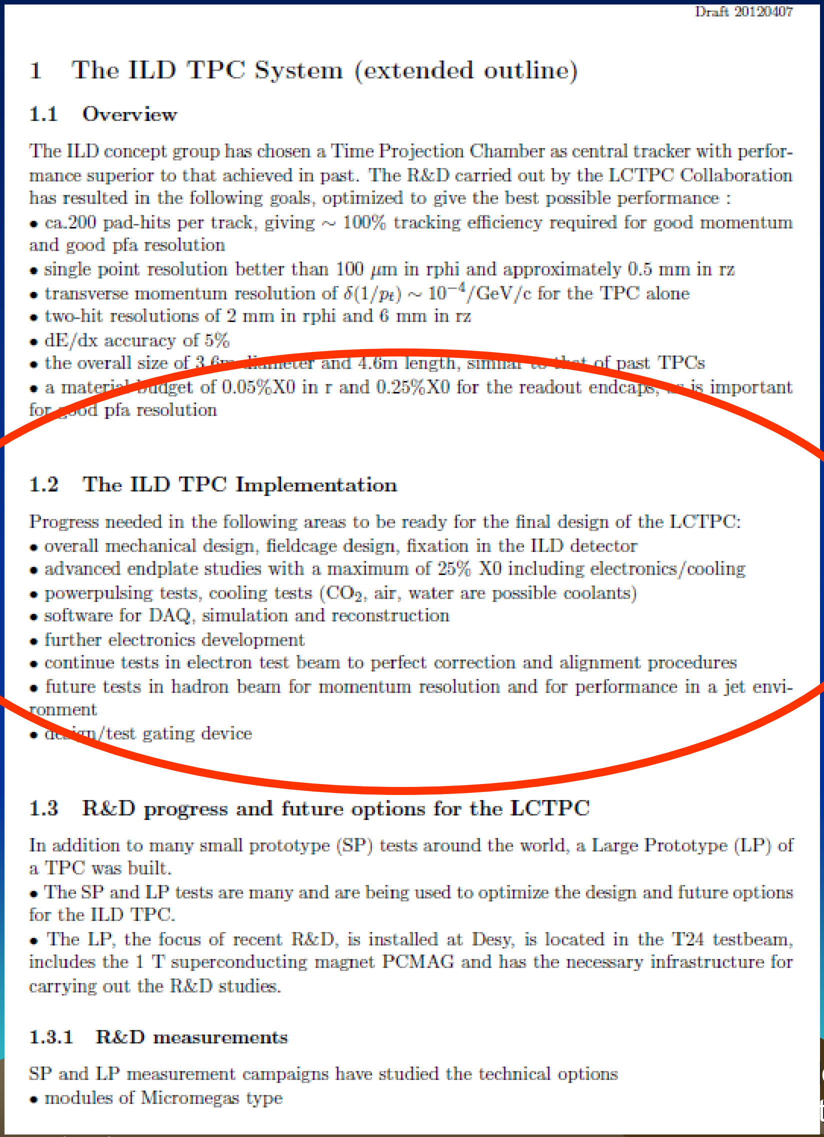
1.3 Alignment Studies

Alignment studies were performed for the LOI. Using a simple model of the track-parameter dependence on alignment tolerances, limits for the alignment of each of the tracking subsystems were derived and were of order a few μm. These values must be confirmed by further studies.

1.4 Remaining Tasks

Still in progress:
- software for simulation and reconstruction
- continue tests in electron beam to perfect correction procedures which will be reviewed in the DBD
- advanced endplate studies with a maximum of 25% X0 including cooling
- powerpulsing/cooling tests using both LP and SP
- ion backflow simulations of ion sheets for Gem, Micromegas
- design/test gating device
- future tests in hadron beam for momentum resolution and for performance in a jet environment

The DBD TPC outline after the DBD "editors' webex meeting" on April 2



Draft 20120407

1 The ILD TPC System (extended outline)

1.1 Overview

The ILD concept group has chosen a Time Projection Chamber as central tracker with performance superior to that achieved in past. The R&D carried out by the LCTPC Collaboration has resulted in the following goals, optimized to give the best possible performance :

- ca.200 pad-hits per track, giving ∼ 100% tracking efficiency required for good momentum and good pfa resolution
- single point resolution better than 100 μm in rphi and approximately 0.5 mm in rz
- transverse momentum resolution of $\delta(1/p_t) \sim 10^{-4}$/GeV/c for the TPC alone
- two-hit resolutions of 2 mm in rphi and 6 mm in rz
- dE/dx accuracy of 5%
- the overall size of 3.6m diameter and 4.6m length, similar to that of past TPCs
- a material budget of 0.05%X0 in r and 0.25%X0 for the readout endcaps, as is important for good pfa resolution

1.2 The ILD TPC Implementation

Progress needed in the following areas to be ready for the final design of the LCTPC:

- overall mechanical design, fieldcage design, fixation in the ILD detector
- advanced endplate studies with a maximum of 25% X0 including electronics/cooling
- powerpulsing tests, cooling tests (CO_2, air, water are possible coolants)
- software for DAQ, simulation and reconstruction
- further electronics development
- continue tests in electron test beam to perfect correction and alignment procedures
- future tests in hadron beam for momentum resolution and for performance in a jet environment
- design/test gating device

1.3 R&D progress and future options for the LCTPC

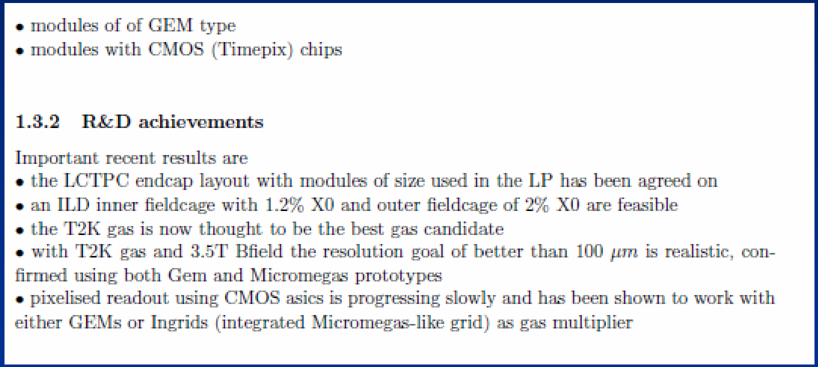
In addition to many small prototype (SP) tests around the world, a Large Prototype (LP) of a TPC was built.

- The SP and LP tests are many and are being used to optimize the design and future options for the ILD TPC.
- The LP, the focus of recent R&D, is installed at Desy, is located in the T24 testbeam, includes the 1 T superconducting magnet PCMAG and has the necessary infrastructure for carrying out the R&D studies.

1.3.1 R&D measurements

SP and LP measurement campaigns have studied the technical options

- modules of Micromegas type



- modules of of GEM type
- modules with CMOS (Timepix) chips

1.3.2 R&D achievements

Important recent results are

- the LCTPC endcap layout with modules of size used in the LP has been agreed on
- an ILD inner fieldcage with 1.2% X0 and outer fieldcage of 2% X0 are feasible
- the T2K gas is now thought to be the best gas candidate
- with T2K gas and 3.5T Bfield the resolution goal of better than 100 μm is realistic, confirmed using both Gem and Micromegas prototypes
- pixelised readout using CMOS asics is progressing slowly and has been shown to work with either GEMs or Ingrids (integrated Micromegas-like grid) as gas multiplier

The DBD TPC outline after the DBD “editors’ webex meeting” on April 2

So, this means a slight rearrangement of the topics.

I will show you some recent ideas for the contents, section by section (will be brief).

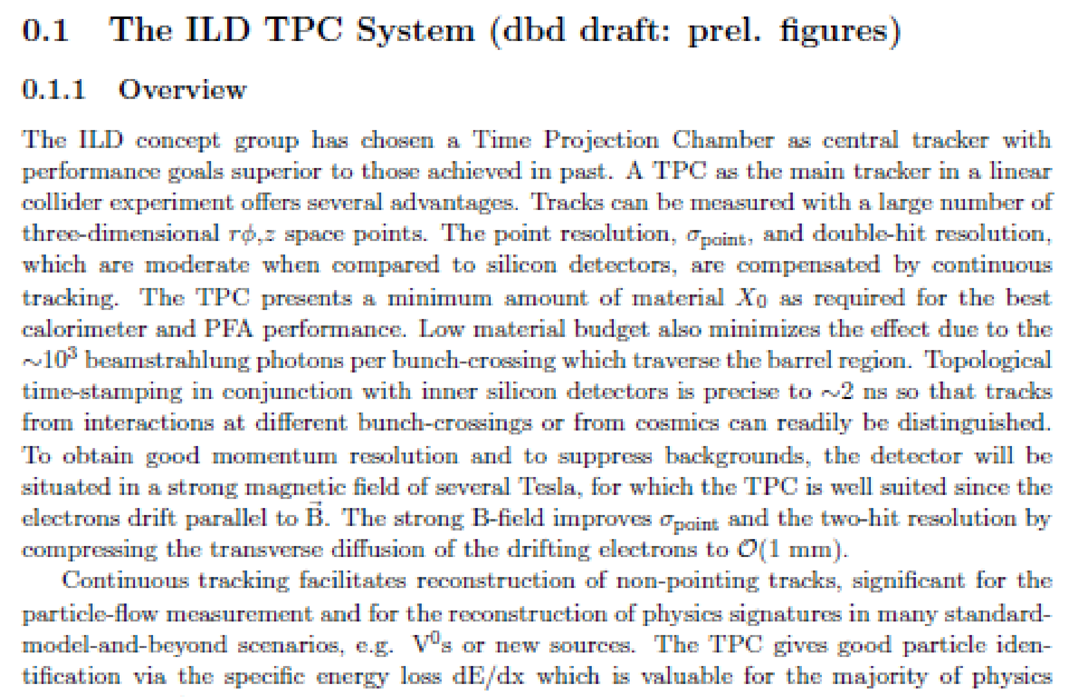
Figures are examples (place holders) for the final ones we decide on later.

Also, only parts of the text have been formulated: ongoing work, e.g., no references yet.
(1st version-> end June;“complete” DBD -> 20120928)

1. **Overview**

Design

Performance



0.1 The ILD TPC System (dbd draft: prel. figures)

0.1.1 Overview

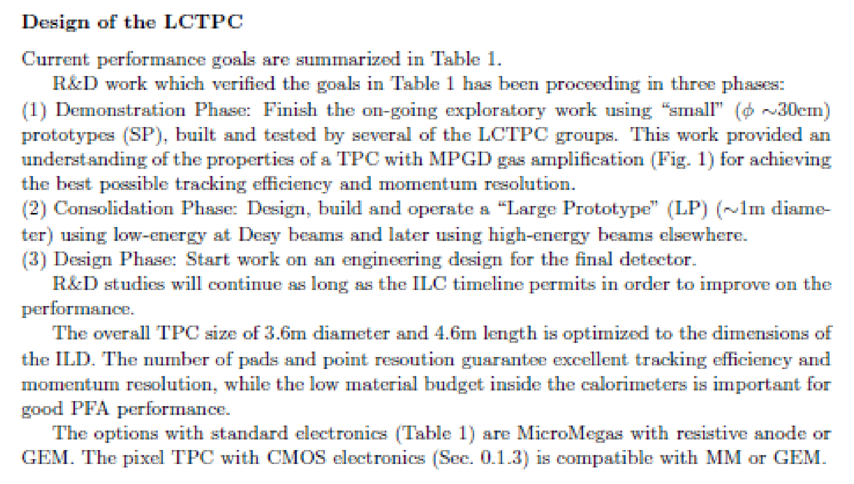
The ILD concept group has chosen a Time Projection Chamber as central tracker with performance goals superior to those achieved in past. A TPC as the main tracker in a linear collider experiment offers several advantages. Tracks can be measured with a large number of three-dimensional $r\phi$,z space points. The point resolution, σ_{point}, and double-hit resolution, which are moderate when compared to silicon detectors, are compensated by continuous tracking. The TPC presents a minimum amount of material X_0 as required for the best calorimeter and PFA performance. Low material budget also minimizes the effect due to the $\sim 10^3$ beamstrahlung photons per bunch-crossing which traverse the barrel region. Topological time-stamping in conjunction with inner silicon detectors is precise to $\sim$2 ns so that tracks from interactions at different bunch-crossings or from cosmics can readily be distinguished. To obtain good momentum resolution and to suppress backgrounds, the detector will be situated in a strong magnetic field of several Tesla, for which the TPC is well suited since the electrons drift parallel to $\vec{\mathrm{B}}$. The strong B-field improves σ_{point} and the two-hit resolution by compressing the transverse diffusion of the drifting electrons to $\mathcal{O}(1\ \mathrm{mm})$.

Continuous tracking facilitates reconstruction of non-pointing tracks, significant for the particle-flow measurement and for the reconstruction of physics signatures in many standard-model-and-beyond scenarios, e.g. V^0s or new sources. The TPC gives good particle identification via the specific energy loss dE/dx which is valuable for the majority of physics analyses and for electron-identification. The TPC will be designed to be robust while easy to maintain so that an endcap readout module can readily be accessed if repair is needed.

1. Overview

Design

Performance



Design of the LCTPC

Current performance goals are summarized in Table 1.

R&D work which verified the goals in Table 1 has been proceeding in three phases:
(1) Demonstration Phase: Finish the on-going exploratory work using "small" (ϕ ~30cm) prototypes (SP), built and tested by several of the LCTPC groups. This work provided an understanding of the properties of a TPC with MPGD gas amplification (Fig. 1) for achieving the best possible tracking efficiency and momentum resolution.
(2) Consolidation Phase: Design, build and operate a "Large Prototype" (LP) (~1m diameter) using low-energy at Desy beams and later using high-energy beams elsewhere.
(3) Design Phase: Start work on an engineering design for the final detector.

R&D studies will continue as long as the ILC timeline permits in order to improve on the performance.

The overall TPC size of 3.6m diameter and 4.6m length is optimized to the dimensions of the ILD. The number of pads and point resoution guarantee excellent tracking efficiency and momentum resolution, while the low material budget inside the calorimeters is important for good PFA performance.

The options with standard electronics (Table 1) are MicroMegas with resistive anode or GEM. The pixel TPC with CMOS electronics (Sec. 0.1.3) is compatible with MM or GEM.

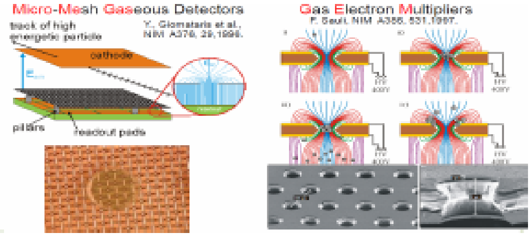


Figure 1: Micro-Pattern Gas Detectors

1. Overview

Design

Performance

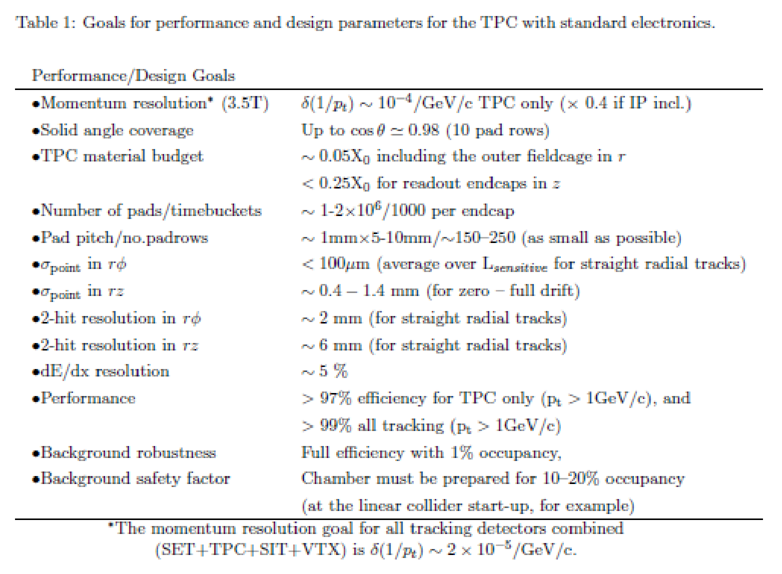


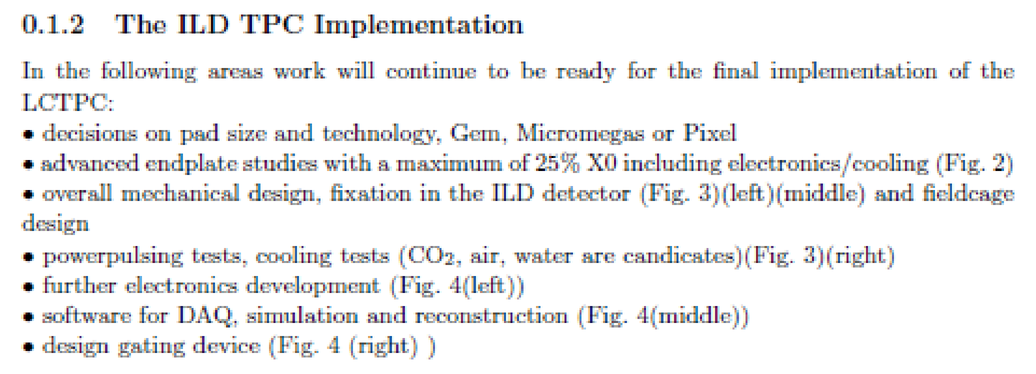
Table 1: Goals for performance and design parameters for the TPC with standard electronics.

Performance/Design Goals	
•Momentum resolution* (3.5T)	$\delta(1/p_t) \sim 10^{-4}$/GeV/c TPC only (× 0.4 if IP incl.)
•Solid angle coverage	Up to $\cos\theta \simeq 0.98$ (10 pad rows)
•TPC material budget	$\sim 0.05X_0$ including the outer fieldcage in r $< 0.25X_0$ for readout endcaps in z
•Number of pads/timebuckets	$\sim$ 1-2×10^6/1000 per endcap
•Pad pitch/no.padrows	$\sim$ 1mm×5-10mm/$\sim$150–250 (as small as possible)
•$\sigma_{\rm point}$ in $r\phi$	$< 100\mu$m (average over $L_{sensitive}$ for straight radial tracks)
•$\sigma_{\rm point}$ in rz	$\sim 0.4 - 1.4$ mm (for zero – full drift)
•2-hit resolution in $r\phi$	$\sim$ 2 mm (for straight radial tracks)
•2-hit resolution in rz	$\sim$ 6 mm (for straight radial tracks)
•dE/dx resolution	$\sim$ 5 %
•Performance	> 97% efficiency for TPC only (p_t > 1GeV/c), and > 99% all tracking (p_t > 1GeV/c)
•Background robustness	Full efficiency with 1% occupancy,
•Background safety factor	Chamber must be prepared for 10–20% occupancy (at the linear collider start-up, for example)

*The momentum resolution goal for all tracking detectors combined (SET+TPC+SIT+VTX) is $\delta(1/p_t) \sim 2 \times 10^{-5}$/GeV/c.

2. Implementation a)

- ≡ `realization’



0.1.2 The ILD TPC Implementation

In the following areas work will continue to be ready for the final implementation of the LCTPC:

- decisions on pad size and technology, Gem, Micromegas or Pixel
- advanced endplate studies with a maximum of 25% X0 including electronics/cooling (Fig. 2)
- overall mechanical design, fixation in the ILD detector (Fig. 3)(left)(middle) and fieldcage design
- powerpulsing tests, cooling tests (CO_2, air, water are candicates)(Fig. 3)(right)
- further electronics development (Fig. 4(left))
- software for DAQ, simulation and reconstruction (Fig. 4(middle))
- design gating device (Fig. 4 (right))

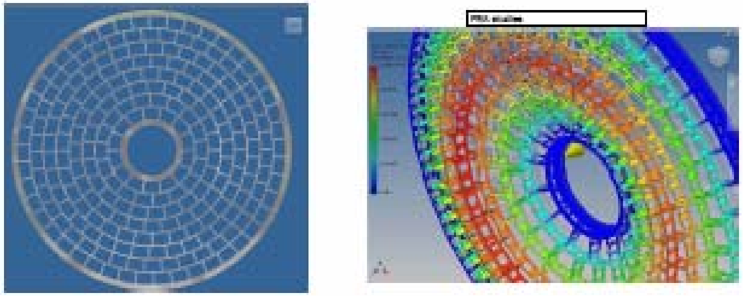


Figure 2: Advanced endplate design (left). FEA studies (right).

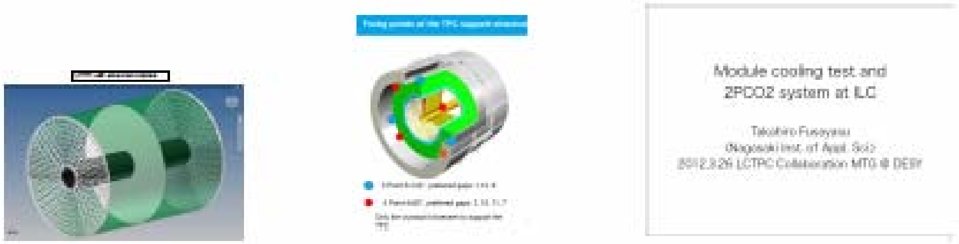
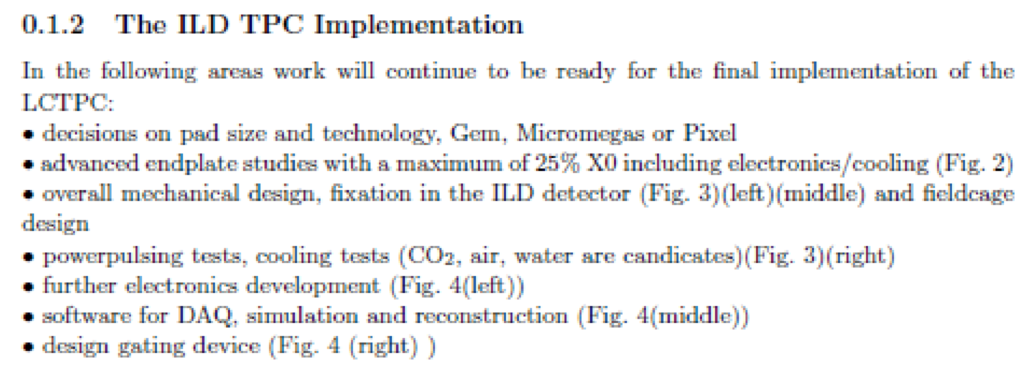


Figure 3: LCTPC with advanced endplate (left). Fixation studies of the TPC in ILD (middle). Cooling develpment (right).

2. **Implementation b)**



0.1.2 The ILD TPC Implementation

In the following areas work will continue to be ready for the final implementation of the LCTPC:
- decisions on pad size and technology, Gem, Micromegas or Pixel
- advanced endplate studies with a maximum of 25% X0 including electronics/cooling (Fig. 2)
- overall mechanical design, fixation in the ILD detector (Fig. 3)(left)(middle) and fieldcage design
- powerpulsing tests, cooling tests (CO_2, air, water are candicates)(Fig. 3)(right)
- further electronics development (Fig. 4(left))
- software for DAQ, simulation and reconstruction (Fig. 4(middle))
- design gating device (Fig. 4 (right))

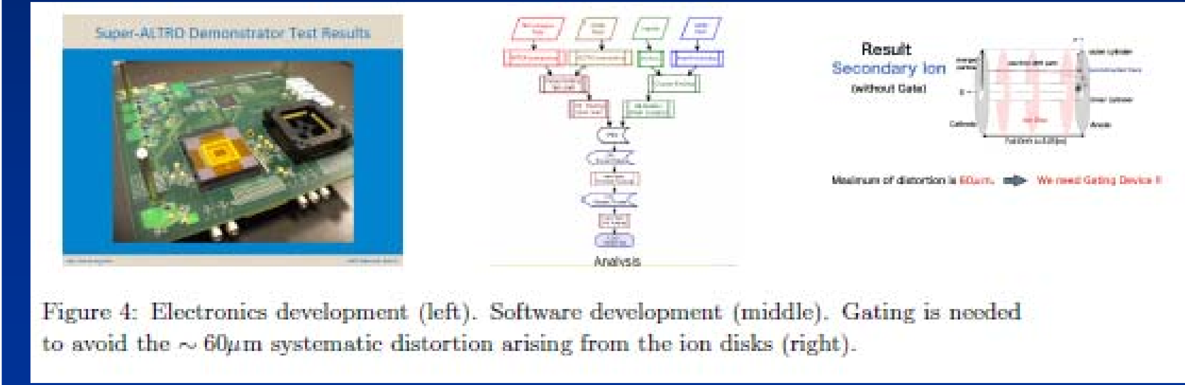
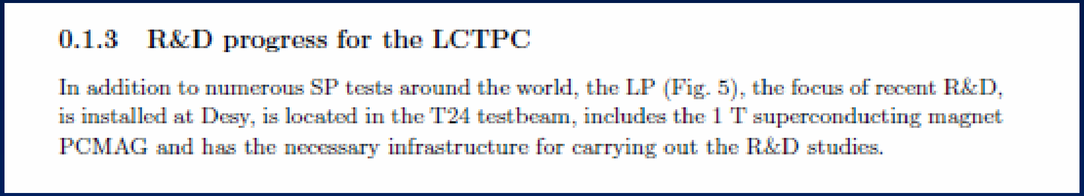


Figure 4: Electronics development (left). Software development (middle). Gating is needed to avoid the ~ 60μm systematic distortion arising from the ion disks (right).

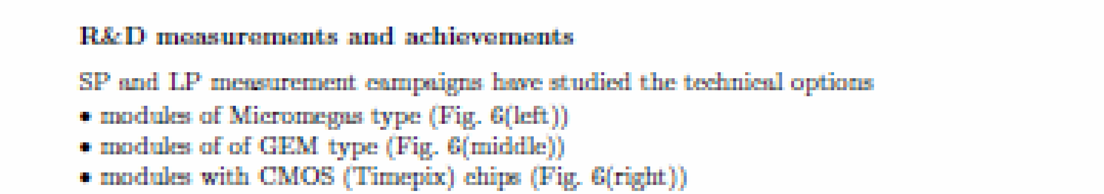
…we need a better gating or background figure…

- 3. **R&D Progress**
  Measurements
  Achievements



0.1.3 R&D progress for the LCTPC

In addition to numerous SP tests around the world, the LP (Fig. 5), the focus of recent R&D, is installed at Desy, is located in the T24 testbeam, includes the 1 T superconducting magnet PCMAG and has the necessary infrastructure for carrying out the R&D studies.



R&D measurements and achievements

SP and LP measurement campaigns have studied the technical options
- modules of Micromegas type (Fig. 6(left))
- modules of of GEM type (Fig. 6(middle))
- modules with CMOS (Timepix) chips (Fig. 6(right))

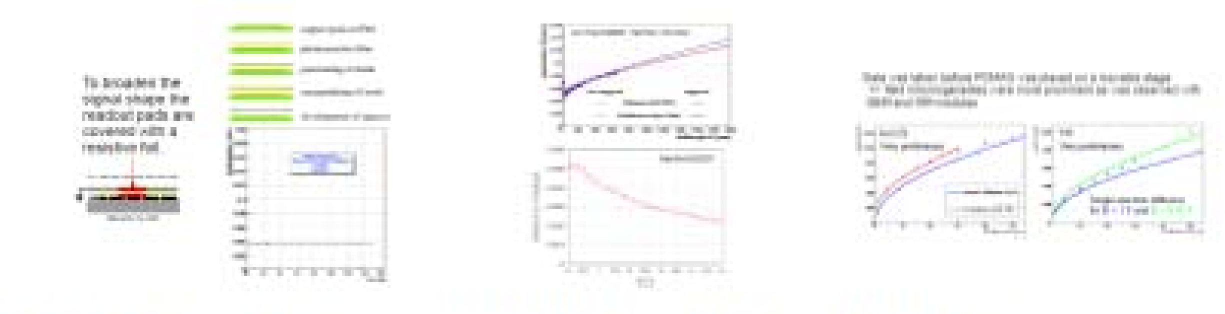
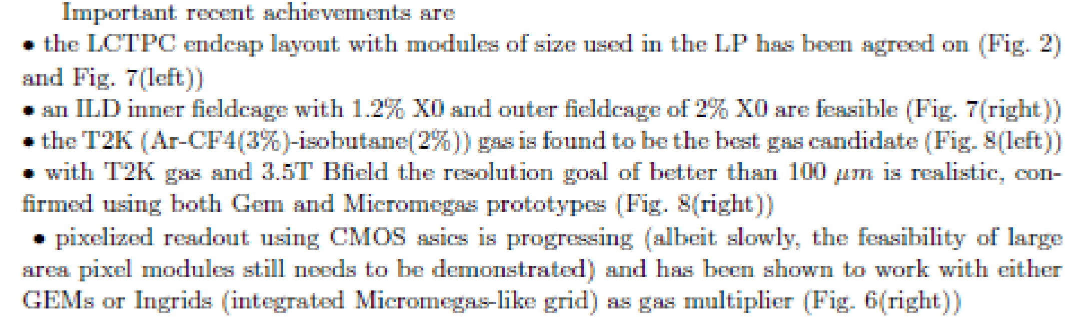


Figure 6: Examples of Micromegas results (left), Gem results (middle), Pixel results (right).

3. R&D Progress Measurements

- **Achievements**



Important recent achievements are

- the LCTPC endcap layout with modules of size used in the LP has been agreed on (Fig. 2) and Fig. 7(left))
- an ILD inner fieldcage with 1.2% X0 and outer fieldcage of 2% X0 are feasible (Fig. 7(right))
- the T2K (Ar-CF4(3%)-isobutane(2%)) gas is found to be the best gas candidate (Fig. 8(left))
- with T2K gas and 3.5T Bfield the resolution goal of better than 100 μm is realistic, confirmed using both Gem and Micromegas prototypes (Fig. 8(right))
- pixelized readout using CMOS asics is progressing (albeit slowly, the feasibility of large area pixel modules still needs to be demonstrated) and has been shown to work with either GEMs or Ingrids (integrated Micromegas-like grid) as gas multiplier (Fig. 6(right))

Figure 7: LP prototype of the advanced endplate (left) and the fieldcage (right).

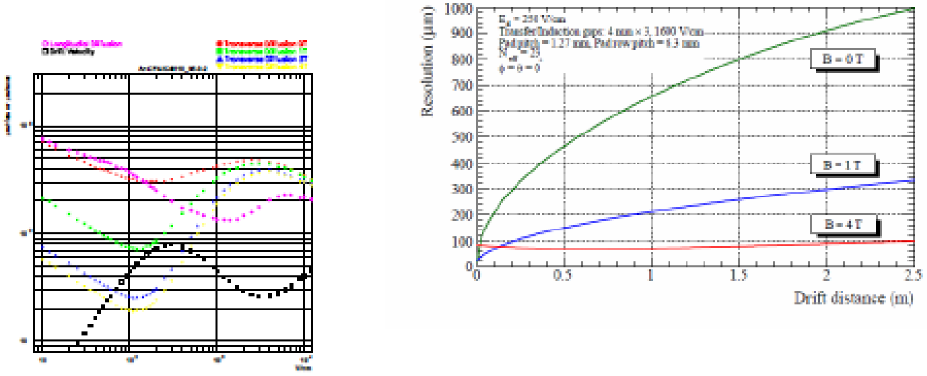
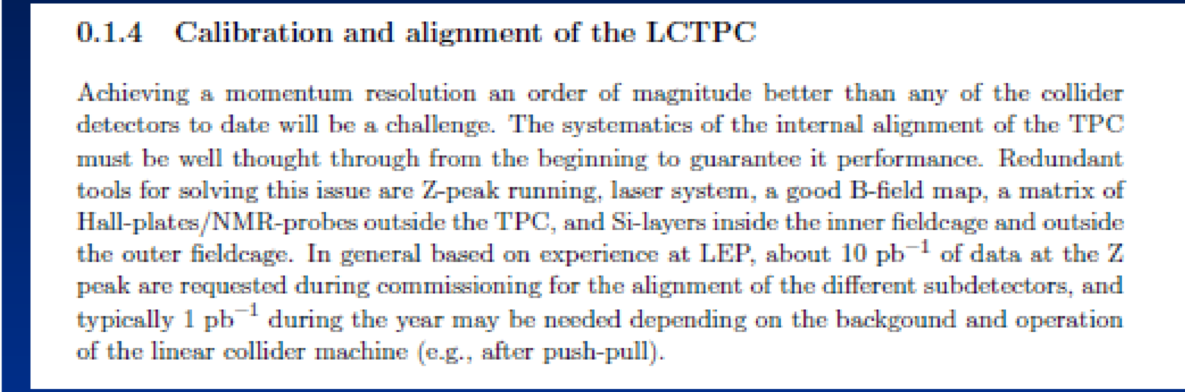


Figure 8: The T2K gas (left) gives the best resolution (right).

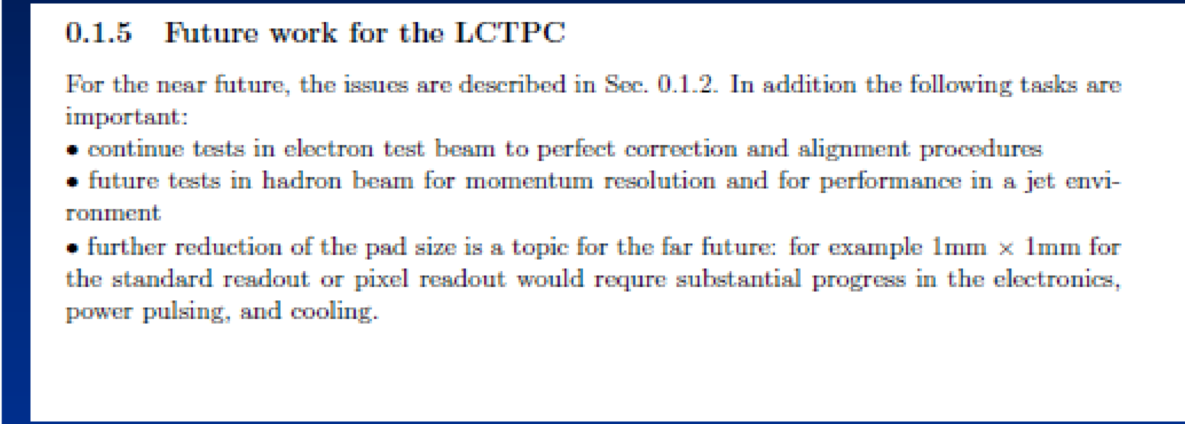
4. Calibration and alignment



0.1.4 Calibration and alignment of the LCTPC

Achieving a momentum resolution an order of magnitude better than any of the collider detectors to date will be a challenge. The systematics of the internal alignment of the TPC must be well thought through from the beginning to guarantee it performance. Redundant tools for solving this issue are Z-peak running, laser system, a good B-field map, a matrix of Hall-plates/NMR-probes outside the TPC, and Si-layers inside the inner fieldcage and outside the outer fieldcage. In general based on experience at LEP, about 10 pb^{-1} of data at the Z peak are requested during commissioning for the alignment of the different subdetectors, and typically 1 pb^{-1} during the year may be needed depending on the backgound and operation of the linear collider machine (e.g., after push-pull).

5. **Future work**



0.1.5 Future work for the LCTPC

For the near future, the issues are described in Sec. 0.1.2. In addition the following tasks are important:

- continue tests in electron test beam to perfect correction and alignment procedures
- future tests in hadron beam for momentum resolution and for performance in a jet environment
- further reduction of the pad size is a topic for the far future: for example 1mm × 1mm for the standard readout or pixel readout would requre substantial progress in the electronics, power pulsing, and cooling.

Conclusions?

- No conclusions
- Comments welcome
- As are suggestions for figures