Addendum 2009 to the LCTPC MOA: R&D organization and DBD planning

Overview

The status at the end of 2009 pertaining to R&D responsibilities, structures and plans are outlined in this document. All issues for the TPC performance within the linear collider framework have been described at several reviews since 2001, the most recent compilation being written up in the ILD LOI at http://www.ilcild.org. The names of LCTPC members will be regularly updated at http://www.lctpc.org.

1 2009 Activities

1.1 Organizational Issues

As outlined in the Addendum 2008, a speakers bureau was formed to monitor the Large Prototype talks at major conferences. The three regional coordinators – Jan Timmermans, Takeshi Matsuda and Dean Karlen – and one additional person per region – Paul Colas, Yuanning Gao and Dan Peterson – are the members, with Paul Colas as chair in 2010.

Another organizational point was brought up at the LCTPC Collaboration meeting 21-22 September 2009: the Collaboration Board decided that each year it will elect one member to chair its meetings. For 2010, Leif Jonsson has agreed to chair the CB.

Lastly, there is now an offical collaboration between ILC and CLIC so that we are now preparing a TPC for the generic e^+e^- linear collider (LC). Our work already allows for higher energies, and no change is needed in our organizational structure.

1.2 The ILD Letter of Intent

The most significant happening in 2009 was the validation of the ILD concept by the International Detector Advisory Group (IDAG) and GDE Research Director (RD): ILD should "demonstrate a feasible solution at the end of the TDR phase of the accelerator". The TDR report of the accelerator and the Detailed Baseline Design (DBD) document of the detector are to be submitted at the end of 2012.

Therefore the LCTPC collaboration meeting on 21-22 September 2009 reviewed a number of issues to prepare for the next three years of work and to be ready with its contibution to the ILD DBD in 2012.

The RD has produced a workplan for the DBD which can be used as a guide for our preparations. Relevant for the LCTPC are the "demonstration of proof of principle on critical components, definition of a feasible baseline with options, completion of mechanical design and development of a realistic simulation." All of these points are covered in the ILD LOI, and further work will involve R&D priorities and design issues for the next two-to-three years.

Responsibilites 2009 are reviewed in Section 2, future R&D and planning for the DBD are covered in Section 3, and RD/IDAG issues are addressed in Section 4.

2 Responsibilites 2009

2.1 Collaboration Board (CB)

Table 1

–Americas–	
Carleton/Triumf:	**Madhu Dixit**
Carleton U:	**Alain Bellerive**
Montreal?:	**Jean-Pierre Martin**
Victoria:	**Dean Karlen**
BNL:	**Alexei Lebedev**
Cornell:	**Dan Peterson**
Indiana:	**Rick Van Kooten**
LBNL?:	**Dave Nygren**
Louisiana Tech?:	**Lee Sawyer**
–Asia———-	
Tsinghua:	**Yuanning Gao**
Saha Kolkata:	**Supratik Mukhopadhyay**
For the CDC groups:	
Hiroshima?	**Tohru Takahashi**
KEK	**Keisuke Fujii**
Kinki	**Yukihiro Kato**
Saga	**Akira Sugiyama**
Kogakuin	**Takashi Watanabe**
JAX Kanagawa?	**Hirokazu Ikeda**
Nagasaki Inst AS?	**Takahiro Fusayasu**
Tokyo U A & T?	**Osamu Nitoh**
U Tokyo?	**Sachio Komamiya**
Mindanao?	**Angelina Bacala**
–Europe———-	
Inter U Inst for HEP(ULB-VUB):	**Gilles De Lentdecker**
CEA Saclay:	**Paul Colas**
Aachen:	**Stefan Roth**
Bonn:	**Klaus Desch**
DESY:	**Ties Behnke**
UHamburg:	**Ties Behnke**
EUDET:	**Joachim Mnich**
Freiburg?:	**Andreas Bamberger/Markus Schumacher**
Karlsruhe?:	**Thomas Müller**
MPI-Munich:	**Ron Settles**
Rostock:	**Henning Schroeder**
Siegen?:	**Ivor Fleck**
Nikhef:	**Jan Timmermans**
Novosibirsk:	**Alexei Buzulutskov**
St.Peterburg?:	**Anatoliy Krivchitch**
Lund:	**Leif Jonsson**
CERN:	**Michael Hauschild**
	(deputy:**Lucie Linsen**)

Present groups and **CB members** are listed above (missing MOA signatures marked by "?").

2.1.1 New groups/Observers

The collaboration is open to all, and the changes in the group-structure are included above and will be updated in future Addenda.

Groups or persons that could not sign the MOA but want to be observers and informed as to the progress, thus are included the lctpc mailing list, are: Iowa State, MIT, Purdue, Yale, LAL Orsay/IPN Orsay, TU Munich, UMM Krakow, Bucharest.

2.2 Regional Coordinators (RC)

The RCs for 2007/08/09, after selection of candidates by search committees in each region, were elected by the CB members of the respective region for a two-year period. They are
–Americas: **Dean Karlen**
–Asia: **Takeshi Matsuda**
–Europe: **Ron Settles** (who requested to continue for only one year) in 2007 and
Jan Timmermans in 2008/09.
RCs and emeritus RCs will be exofficio members of RC and CB meetings.

Spokesperson selection: The RCs decided not to have a predetermined rotation of RCs as their chairperson and spokesperson for the collaboration; he/she will be chosen by the RCs once per year. Ron Settles had this function in 2007, and Jan Timmermans was voted as Chairperson/Spokesperson for 2008/09.

2.3 Technical Board (TB)

The workpackage structure is presented here; the **TB members** are the conveners of the workpackages.

Table 2

Workpackage	**Convener**
Workpackage (0) TPC R&D Program	LCTPC collaboration
Workpackage (1) Mechanics	
a) LP endplate structure, design	**Dan Peterson**
b) Fieldcage, laser, gas	**Ties Behnke**
c) GEM panels for endplate	**Akira Sugiyama**
d) Micromegas panels for endplate	**Paul Colas**
e) Pixel panels for endplate	**Jan Timmermans**
f) Resistive anode for endplate	**Madhu Dixit**
Workpackage (2) Electronics	
a) Standard RO for the Large Prototype	**Leif Joensson**
b) CMOS RO electronics	**Harry van der Graaf**
c) Standard electronics for LCTPC	**Luciano Musa**

Workpackage (3) Software	
a) LP software + simulation/reconstruction framework	**Christoph Rosemann**
b) LP DAQ	**Gilles De Lentdecker**
c) LCTPC simulation/performance/backgrounds	**Keisuke Fujii**

Workpackage (4) Calibration	
a) Field map for the LP	**Lucie Linsen**
b) Alignment	**Takeshi Matsuda**
c) Distortion correction	**Dean Karlen**
d) Outgassing properties of materials	**Anatoliy Krivchitch**
e) Gas/HV/Infrastructure for the LP	**Klaus Dehmelt**

To prepare for the DBD, this structure will be supplemented with fifth workpackage:

Workpackage (5) LCTPC preparations for DBD	**Convener**
a) Advanced endcap mechanics + alignment	**Dan Peterson**
b) Advanced endcap with SAltro, cooling, power pulsing	**Luciano Musa**
c) Gating device	**Akira Sugiyama**
d) Fieldcage	**Peter Schade/ Klaus Dehmelt**
e) ILD TPC Integration	**Robert Volkerborn/ Michael Carty**
f) LCTPC Software	**Christoph Rosemann**
g) Testbeams	**Takeshi Matsuda**

Coveners of the new workpackages overlap significantly with the previous structure because the issues are closely related. The new workpackages are meant to specifically guide the DBD preparations; more explanation is presented in Section 3.3.2.

3 Future R&D, the LP and SPs

3.1 What has been learned

As described in the MOA, the R&D is proceeding in three phases: (1) Small Prototypes–SP, (2) Large Prototypes–LP and (3) Design.

Up to now during Phase(1), items summarizing the learning are:
–over 6 years of MPGD experience has been gathered,
–gas properties have been well measured,
–the best possible point resolution is understood,
–the resistive-anode charge-dispersion technique has been demonstrated,
–CMOS pixel RO technology has been demonstrated,

The Phase(2) LP and SP tests are expected to take about three years and will be followed by Phase(3), the design of the LCTPC. A scenario for Phase(2) options is presented below in Table 3 which will be readjusted as we go along.

The LP work is now well underway and making good progress. A critical review of the progress was presented at the LCTPC collaboration meeting 21-22 September:
http://ilcagenda.linearcollider.org/materialDisplay.py?
contribId=6&sessionId=0&materialId=slides&confId=3742

3.2 Timeline for the future

The following overview is the currently envisioned timeline for completing the studies and the construction of the LCTPC.
(I) 2009-12: Continue R&D on technologies at LP, SP, pursue simulations, verify performance goals.
(II) 2009-11: Plan and do R&D on advanced endcap; power-pulsing, electronics and mechanics are critical issues.
(III) 2011-12: Test advanced-endcap prototype at high energy and power-pulsing in high B-field.
(IV) 2012-18: Design and build the LCTPC.

3.3 Preparation for the DBD

3.3.1 (I) 2009 - 2012

Present ideas about possible scenarios are summarized in the Table 3. The stages are symbolized by LP1, LP1.5, LP2. Supplemental testing with the SPs, which have been used extensively to date as witnessed by Section 3.1, will continue, since there are still several issues which can be explored more efficiently using small, specialized set-ups. In Table 3, The star * denotes that a decision must be made as to where, Fermilab, CERN, Desy or elsewhere, this stage should take place. Note that the AIDA proposal which is to follow EUDET has not yet been approved and is denoted AidaTBC; news should emerge next spring.

Table 3

Large Prototype R&D		
Device	Lab(years)	Configuration
LP1	Desy/Eudet(2007-2010)	Fieldcage⊕2 endplates: GEM+pixel, Micromegas+pixel
Purpose: Test construction techniques using ∼10000 Altro or T2K channels to demonstrate measurement of 6 GeV/c beam momentum over 70cm tracklength, including development of correction procedures.		
LP1.5	FL*C*D*O/AidaTBC(2011)	Fieldcage⊕2 endplates: GEM+pixel, Micromegas+pixel
Purpose: Continue tests using 10000 Altro or T2K channels to demonstrate measurement beam momentum over 70cm tracklength using LP1. Test a jet-like environment. If possible, simulate ILC and CLIC beam structures.		
LP2	FL*C*D*O/AidaTBC(2012)	Fieldcage⊕endplate: GEM, Micromegas, or pixel
Purpose: Prototype for LCTPC endcap module design: mechanics, electronics, cooling, power pulsing, gating. Demonstrate measurement of high momentum.		

Small Prototype R&D Possibilities		
Device	Lab(years)	Test
SP1	KEK(2007-2010)	Gas tests, gating configurations
SP2,SP3	FL*C*D*O(2010-2012)	Performance in jet environment
SPn	LCTPC groups(2007-2012)	Performance, gas tests, dE/dx measurements, continuation of measurements in progress by groups with small prototypes

3.3.2 (II) 2009 - 2011

TPC design, performance and engineering issues were presented at LCTPC collaboration meeting 21-22 September 2009:
http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=3742. Presentations in the sessions on "Issues and Engineering R&D in 2010-2013" and "Software issues in 2010-2013" were the start of DBD preparations. Based on these sessions, a fifth workpackage has been created as described in Section 2.3.

At the meeting the following R&D priorities were discussed:

Table 4

Study (in approximate order of priority)
• Continue tests in electron beam to perfect correction procedures
• Advanced endplate studies with max. 15% X0 including cooling
• Powerpulsing/cooling tests using both LP and SP
• Future tests in hadron beam (if possible) for momentum resolution and for performance in a jet environment
• Ion backflow simulations of ion sheets for Gem, Micromegas and design/test gating device

3.3.3 (III) 2011 - 2012

During the period 2011-2012, mechanical studies of endcap designs that were successful as computer models in period II will follow. In preparation for LP2 in Table 3, several prototypes of the advanced endcap will be manufactured; both scale-models (20-50% full size) and sections of the full size endplate will be used to evaluate the manufacturing integrity.

Prototype electronics, cooling, power pulsing and gating will be included in LP2 where possible, othewise tested in SPs. The design/manufacture of LP2 will be coordinated by Workpage (5) in Section 2.3.

3.3.4 (IV) 2012 - 2018

At the beginning of the period 2012-18, the selection must be made from the different technological options – GEM, MicroMegas, resistive anode, pixel, electronics, endcap structure – to establish a working model for the design of the LCTPC. This preliminary design will be used for the ILD DBD in 2012 and include pad segmentation, electronics, mechanics, cooling and integration, so that performance, timeline and cost can be estimated reliably. For the technology selection, questions must be answered as to which options give the best performance based on R&D results from LP, SP, electronics and endcap studies. Main performance criteria will include endcap thickness and σ_{point}, double-hit and momentum resolution for single tracks and for tracks in a jet environment. The discussion to decide on the final criteria has already started and will continue in 2010 and 2011.

4 RD/IDAG Issues 2009

The LCTPC groups can supply information about the RD/IDAG workplan and about the RD questions at the end of 2009.

4.1 RD/IDAG Workplan

General statements can be made as to the RD's workplan in Section 1.2. With regard to "demonstration of proof of principle on critical components and definition of a feasible baseline with options", these have already been demonstrated using the Small Prototypes, are being verified using the Large Prototype, and have been presented in the ILD LOI. The LCTPC performance parameters presented in the LOI are reproduced below (Table 5).

The remaining points mentioned in Section 1.2, "completion of mechanical design and development of a realistic simulation", are the subjects of Workpackage 5 in Sections 2.3 and 3.3.2 and belong to the category "work in planning". Preliminary solutions to these points have also been included in the ILD LOI, and details will be further developed in 2010.

Performance table in the ILD LOI

Performance and design parameters for an LCTPC with standard electronics are recalled here. Understanding the properties and achieving the best possible point resolution have been the object of R&D studies of Micro-Pattern Gas Detectors, MicroMegas and GEM, and results from this work used to define the parameters in Table 5. The parameters in this preliminary design represent the best technical solution at the moment and have been agreed upon by the LCTPC Collaboration in 2009.

Table 5

Performance/Design	
Size	$\phi = 3.6$m, L = 4.3m outside dimensions
Momentum resolution (3.5T)	$\delta(1/p_t) \sim 9 \times 10^{-5}$/GeV/c TPC only ($\times$ 0.4 if IP incl.)
Momentum resolution (3.5T)	$\delta(1/p_t) \sim 2 \times 10^{-5}$/GeV/c (SET+TPC+SIT+VTX)
Solid angle coverage	Up to $\cos\theta \simeq 0.98$ (10 pad rows)
TPC material budget	$\sim 0.04 X_0$ to outer fieldcage in r
	$\sim 0.15 X_0$ for readout endcaps in z
Number of pads/timebuckets	$\sim 1{\times}10^6$/1000 per endcap
Pad size/no.padrows	$\sim$ 1mm$\times$4–6mm/$\sim$200 (standard readout)
$\sigma_{\rm point}$ in $r\phi$	$< 100\mu$m (average over $L_{sensitive}$, modulo track ϕ angle)
$\sigma_{\rm point}$ in rz	$\sim$ 0.5 mm (modulo track θ angle)
2-hit resolution in $r\phi$	$\sim$ 2 mm (modulo track angles)
2-hit resolution in rz	$\sim$ 6 mm (modulo track angles)
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 will be prepared for 10 $\times$ worse backgrounds
	at the linear collider start-up

These studies will continue for the next few years in order to improve on the performance. Upgrades to the preliminary design and Table 5 will be implemented where improvements are warrented by R&D results and are compatible with the LC timeline. The options with standard electronics are MicroMegas with resistive anode or GEM. The options for pixel TPC with CMOS electronics are MicroMegas or GEM. The pixel TPC R&D will provide corresponding table of performance parameters as soon as feasible.

With respect to ILC/CLIC, at present it is thought that the performance in Table 5 is

adequate for higher energies. However simulations must confirm this or provide appropriate modifications, which will be documented in future Addenda.

4.2 R&D question

According to the request by the RD and the R&D Common Task Group at the end of 2009, the LCTPC collaboration should estimate the integral number of the *additional* manpower (staff, postdocs, engineers, students) and equipment money that we need to complete the studies by 2012 on our high-priority R&D items. The new Workpackage 5 in Section 2.3 is just starting so that many details are still being developed. Each of the LCTPC groups is organizing its contribution to the research and to the money needed to carry it out. The financial situation of almost all groups is in a state of flux so that no concrete estimates are possible at this time.