Final updated with last corrections 20150513

Addendum 2015 to the LCTPC MOA: Preparing for the LC

Overview

The LCTPC Memorandum of Agreement (MOA), the groups which have signed it and the yearly Addenda are available at http://www.lctpc.org/e9/e56939/. Evolution of the collaboration, of the work-package structure and of responsible persons are updated in the yearly Addenda.

1 2015 Activities

As described in the MOA, the R&D preparation of the LCTPC is proceeding in three phases: **1**-Small Prototypes, **2**-Large Prototypes and **3**-Design. Presently the work is mainly in phase **2**, and may pass to phase **3** (Section 1.2) within the next couple of years.

1.1 The ILD LOI and the DBD

The ILD Letter of Intent (LOI) was validated in 2009 and was followed by the the Detailed Baseline Design (DBD) of the detector in 2013. The latter was the result of more work being put into understanding the detector and its engineering. The Technical Design Report (TDR) of the ILC accelerator, also completed in 2013, and the DBD were combined into one document:
https://www.linearcollider.org/ILC/Publications/Technical-Design-Report.

1.2 The LC

Since the start of the offical collaboration between the ILC (0.2 - 1.0 TeV with superconducting cavities) and CLIC (1.4 - 3.0 TeV with two-beam technology), the LCTPC Collaboration has been preparing a TPC for the generic e^+e^- linear collider (LC). The LCTPC concept already allows for higher energies so that no change is needed in the organizational structure.

Recent efforts are underway to have ILC built in Japan. It is envisaged to be realized in two or more stages (at the moment the exact energies of the stages is being reviewed) : first stage, the ∼500 GeV machine (Higgs', top and other precision studies), with an upgrade to ∼1000 GeV after sufficient data is taken at lower energies. (Progress is regularly reported in the 'LC Newsline' http://newsline.linearcollider.org.)

As already reported, the collaboration and leadership arrangement, the international 'Linear Collider Collaboration' with oversight committee 'Linear Collider Board' (LCC and LCB, see the LC Newsline), were established two years ago to guide the construction of the ILC.

2 Responsibilites 2015

Present groups and **CB members** are listed next.

2.1 Collaboration Board (CB) – Table 1

–Americas–	
Carleton/Triumf:	**Madhu Dixit**
Carleton U:	**Alain Bellerive**
Victoria:	**Dean Karlen**
BNL:	**Alexei Lebedev**
Cornell:	**Dan Peterson**
Indiana:	**Rick Van Kooten**
–Asia———-	
Tsinghua:	**Yuanning Gao**
Hubei:	**Fan Zhang**
Saha Kolkata:	**Supratik Mukhopadhyay**
Hiroshima:	**Tohru Takahashi**
Iwate:	**Shinya Narita**
KEK:	**Keisuke Fujii**
Kinki:	**Yukihiro Kato**
Saga:	**Akira Sugiyama**
Kogakuin:	**Takashi Watanabe**
Nagasaki Inst AS:	**Ken Oyama**
Tokyo U A & T:	**Osamu Nitoh**
–Europe———-	
Inter U Inst for HEP(ULB-VUB):	**Gilles De Lentdecker**
CEA Saclay:	**Paul Colas**
Aachen:	**Stefan Roth**
Bonn:	**Jochen Kaminski/Klaus Desch**
DESY/HH:	**Ties Behnke**
Kiev:	**Oleg Bezshyyko**
MPI-Munich:	**Ron Settles**
Rostock:	**Oliver Schaefer**
Siegen:	**Ivor Fleck**
Nikhef:	**Jan Timmermans**
Novosibirsk:	**Alexei Buzulutskov**
Lund:	**Leif Jönsson**
CERN:	**Michael Hauschild/Lucie Linsen**

2.2 Observers

'Oberservers' are groups or persons that could not sign the MOA but want to be informed as to the progress, thus are included in the lctpc mailing list:
Montreal, Iowa State, MIT, Purdue, Stony Brook, Yale, LBNL, Louisiana Tech, JAX Kanagawa, U Tokyo, Mindanao, LAL Orsay/IPN Orsay, TU Munich, Freiburg, Karlsruhe, UMM Krakow, Bucharest, St.Petersburg.

2.3 New groups

The LCTPC collaboration (http://www.lctpc.org) is open to all, and a group (including Observers) wishing to join should contact us.

3 Further LCTPC Collaboration Information

3.1 Regional Coordinators (RC)

The RCs for 2007-2015, after selection of candidates by search committees in each region, were elected by the CB members of the respective region. They are
–Americas: **Dean Karlen** in 2007-10 and
Alain Bellerive in 2011-15 .
–Asia: **Takeshi Matsuda** in 2007-09 and
Akira Sugiyama in 2010-15 .
–Europe: **Ron Settles** in 2007,
Jan Timmermans in 2008-11 and
Jochen Kaminski in 2012-15.

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. Ron Settles had this function in 2007, and Jan Timmermans was voted as Chairperson/Spokesperson for 2008-11. Jochen Kaminski was chosen by the RCs as the Spokesperson for 2012-15.

3.1.1 CB Chair

In 2009, the Collaboration Board decided that each year it will appoint one member to chair its meetings. Leif Jönsson agreed to chair the CB meetings in 2012-15.

3.1.2 Editorial Board

The editorial board set up in 2011 is made up of: Alain Bellerive, Ties Behnke, Keisuke Fujii, Leif Jönsson, Dean Karlen, Takeshi Matsuda, Dan Peterson, Ron Settles, Akira Sugyama and Jan Timmermans.

This point was discussed again at this year's CB meeting. The result in 2008 was repeated here so that it could be reviewed. At the CB meeting, it was decided to ask Jochen Kaminski to find a person to chair the editorial board, which will become more active in the near future.

"2.5 Publications All results obtained from the work within the LCTPC collaboration will be openly available to all members, and data obtained using common prototypes or common equipment will belong to all collaborators. The groups agree that they will not publish or make otherwise public any information belonging to LCTPC without obtaining prior agreement of the collaboration. Results from the collaboration will be published under the name "LCTPC Collaboration". The CB will install a proper editorial process before releasing material to the public. In case of a conflict the collaborators agree to accept the decision of the CB as final."

3.1.3 Speakers Bureau

The speakers bureau formed in 2008 to monitor the Large Prototype presentations at major conferences is made up of: the three regional coordinators – Jochen Kaminski, Akira Sugiyama and Alain Bellerive – and one additional person per region – Jan Timmermans,

Yulan Li and Dan Peterson – in 2011-13; then David Attie replaced Jan Timmermans in 2014. Dan Peterson chaired the meetings in 2012. Allain Bellerive agreed to chair the meetings for one year starting mid-2013. David Attie has this task since mid-2014.

3.2 Technical Board (TB)

There are four original workpackages in the MOA (WP(1)-WP(4)) which were supplemented by a fifth workpackage WP(5) in 2010 to prepare for the DBD; with the DBD finished, WP(5) will now oversee the R&D.

In general, the WP(1)-WP(4) structure was utilized at the beginning of the LCTPC collaboration, with individual workpackages meeting to discuss their issues. The structure is out of date now (and may be of historical interest), there being bi-weekly meetings which incude all workpackages convened by the collaboration spokesperson Jochen Kaminski. Therefore the 'conveners' will be referred to as 'contacts', meaning they can be contacted by email for information.

In addition, there is a monthly 'pixel meeting' chaired by Michael Lupberger.

The **TB members** are the 'contacts' for the workpackages and their email addresses.

Table 2

Workpackage	Groups involved **Contact**
Workpackage(0) TPC R&D Program	LCTPC collaboration
Workpackage(1) Mechanics	
a) LP endplate structure, design	→ Bonn,Cornell,Desy/HH,JapaneseGroups,MPI,Saclay **Dan Peterson** daniel.peterson@cornell.edu
b) Fieldcage, laser, gas	→ BNL,Desy/HH **Ties Behnke** ties.behnke@desy.de
c) GEM panels for endplate	→Bonn,Cornell,Desy/HH,JapaneseGroups,Tsinghua **Akira Sugiyama** sugiyama@cc.saga-u.ac.jp
d) Micromegas panels for endplate	→ Carleton,Cornell,SahaKolkata,Saclay **Paul Colas** paul.colas@cea.fr
e) Pixel panels for endplate	→ Bonn,Freiburg,Nikhef,Saclay **Jan Timmermans** jan.timmermans@nikhef.nl
f) Resistive anode for endplate	→ Carleton,SahaKolkata,Saclay **Madhu Dixit** msd@physics.carleton.ca
Workpackage(2) Electronics	
a) Standard RO for the LP	→ Brussels,Cern,Desy/HH,Lund **Leif Jönsson** leif.jonsson@hep.lu.se
b) CMOS RO electronics	→ Bonn,Nikhef,Saclay **Harry van der Graaf** vdgraaf@nikhef.nl
c) Standard electronics for LCTPC	→ Brussels,Cern,Desy/HH,Lund, JapaneseGroups,Tsinghua 2010 **Luciano Musa** luciano.musa@cern.ch

Workpackage(3) Software	
a) LP software/simulation/reconstruction	→ Bonn,Cern,Desy/HH,Victoria,
	2014 **Astrid Muennich** astrid.muennich@desy.de
	Alain Bellerivealainb@physics.carleton.ca
b) LP DAQ	→Brussels,Lund
	Gilles De Lentdecker gilles.de.lentdecker@ulb.ac.be
c) LCTPC performance/backgrounds	→ Bonn,Carleton,Cern,Desy/HH,JapaneseGroups
	Keisuke Fujii keisuke.fujii@kek.jp
Workpackage(4) Calibration	
a) Field map for the LP	→ Cern,Desy/HH
	Lucie Linsen lucie.linssen@cern.ch
b) Alignment	→ Cornell,Cern,Desy/HH,JapaneseGroups
	Takeshi Matsuda takeshi.matsuda@kek.jp
c) Distortion correction	→ Cern,Desy/HH,MPI,JapenseGroups,Victoria
	Dean Karlen karlen@uvic.ca
d) Gas/HV/Infrastructure for the LP	→ Aachen,Desy/HH,Saclay
	Ralf Diener ralf.diener@desy.de

WP(5) Coordination of LCTPC R&D	
a) Advanced endcap mechanics/alignment	→Cornell,JapaneseGroups,MPI,Saclay
	Dan Peterson daniel.peterson@cornell.edu
b) Advanced endcap/Electronics development	→Cern,Hubei,JapeneseGroups,Lund,Nikhef,Saclay
	Anders Oskarsson anders.oskarsson@hep.lu.se
	Leif Jönsson leif.jonsson@hep.lu.se
	2010 **Luciano Musa** luciano.musa@cern.ch
	2011 **Eric Delagnes** eric.delagnes@cea.fr
Advanced endcap/cooling/	→Desy,JapeneseGroups,Lund,Nikhef
	Takeshi Matsuda takeshi.matsuda@kek.jp
Advanced endcap/power pulsing	→Cern,Desy,JapeneseGroups,Lund,Nikhef,Saclay
	Takahiro Fusayasu fusayasu_takahiro@nias.ac.jp
c) Gating device	→Cornell,JapeneseGroups,MPI
	Akira Sugiyama sugiyama@hep.phys.saga-u.ac.jp
	Takeshi Matsuda takeshi.matsuda@kek.jp
	Ron Settles settles@mppmu.mpg.de
d) Fieldcage	→ Desy/HH
	Ties Behnke ties.behnke@desy.de
e) ILD TPC Integration/Mach-Det Interface	→Cornell,Desy/HH,MPI,Saclay
	Volker Prahl volker.prahl@desy.de
	Ron Settles settles@mppmu.mpg.de
f) LCTPC Software/Correction methods	→Bonn,Carleton,Cern,Desy/HH,JapaneseGroups
	2014**Astrid Muennich** astrid.muennich@desy.de
	Alain Bellerivealainb@physics.carleton.ca
	Keisuke Fujii keisuke.fujii@kek.jp
g) Pixel-Module Development	→Bonn,Carleton,Nikhef,Saclay
	Jochen Kaminski kaminski@physik.uni-bonn.de
	Michael Lupberger lupberger@physik.uni-bonn.de

4 Future R&D, the LP and SPs

4.1 What has been learned

As written in Section 1, 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), a summary of what has been learned:
–the MWPC option has been ruled out,
–the Micromegas option without resistive anode has been ruled out,
–gas properties have been well measured,
–many years of MPGD experience have been gathered,
–the best possible point resolution is understood,
–the resistive-anode charge-dispersion technique has been demonstrated,
–reliable assemblies of GEM-modules and Micromegas-modules have been developed,
–CMOS pixel RO technology has been demonstrated.

The Phase(2) LP and SP tests are expected to take several 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 the situation progresses.

4.2 A possible timeline for the ILD TPC R&D

There was a review of the LCTPC R&D status by the ECFA Panel at Desy on Nov.4, 2013, at which the TPC gave a complete update of the situation. The Review Report is available as LC Note LC-DET-2014-001 at http://www-flc.desy.de/lcnotes.
The final page before the bibliography presents a possible timeline for completing the studies and the construction of the LCTPC, which was developed by physicists. The final schedule will depend on political realities.

4.2.1 2014 - 2017

Possible scenarios are summarized in the Table 3. There are three stages foreseen for the LP with preliminary, improved and 'final' module-designs. Supplemental testing with the SPs, which have been used extensively to date by the LCTPC collaboration (Section 4.1), will continue, since there are still several issues which can be explored more efficiently using small, specialized set-ups.

Table 3 Scenarios, updated April 2015

Large Prototype R&D		
Device	Lab(years)	Configuration
Preliminary	Desy(2013-15)	Fieldcage⊕first endplates: GEM+pixel, Micromegas+pixel
Purpose: Test construction techniques using ∼10000 pad read-out channels to demonstrate measurement of the Desy test-beam or cosmics over 70cm tracklength, including development of correction procedures.		
Improved	Desy(2015-16)	Fieldcage⊕thinned endplate: GEM+pixel, Micromegas+pixel
Purpose: Continue tests using 10000 pad read-out channels to demonstrate measurement of the Desy test-beam or cosmics 70cm tracklength using LP1 thinned endplate and external detector. If possible, simulate a jet-like environment. Pixels will continue testing a'100-chip' LP-module.		
Final	Desy(2017-18)	Fieldcage⊕advanced-endcap prototype: GEM, Micromegas, or pixel
Purpose: Prototype for LCTPC endcap module design: mechanics, electronics, cooling, power pulsing, gating; new fieldcage and SAltro/GdSP channels if ready		

Table 4

Review of theTPC design, performance and engineering issues result in a constant reassessment of the R&D priorities. This Table 4 reflects the present thinking:

- Continue tests in the Desy test-beam or cosmics to perfect correction procedures and to verify point, two-point, dE/dx resolutions
- Design/test gating device
- Endplate/module studies with a maximum of 25% X0 including electronics/cooling
- Software development for simulation and reconstruction
- Common DAQ for running the TPC and silicon trackers together
- Electronics development: the design of a new readout chip is a most urgent problem to be solved by the collaboration.
- Powerpulsing/cooling tests using both LP and SP
- Test radiation hardness of T2K gas
- Test all components of LCTPC for electron-attachment emissions into the TPC gas
- A move to a hadron beam is possible, but now may be unrealistic, given the boundary conditions, so ways should be found to do the necessary tests at Desy.

The collaboration decided that it was not yet necessary to chose between options, because the performance of the LCTPC for the DBD is guaranteed by Table 5 in Sec. 4.3, showing the performance expected based on the R&D efforts. However these technical choices will have to be made around the year 2016-17 in order to design the LCTPC, as described in Sec. 4.2.2 below.

Additional plans have been that, during the period after 2015, mechanical studies of endcap designs that were successful as computer models will follow. In preparation for the next LP design, 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 where possible, otherwise tested in Small Prototypes. The design/manufacture of the next LP will be coordinated by Workpage (5) in Section 3.2.

4.2.2 After 2017 - 2018

During the period 2015 - 2017, shortly after a positive decision in Japan, a selection must be made from the different technological options – GEM, MicroMegas, resistive anode, pixel, electronics, gating device, endcap structure, cooling, mechanics, integration – to establish a working model for the design of the LCTPC. This will not rule out R&D on other options.

After 2017 - 2018, the design of the ILD TPC could follow in preparation for the TDR of the ILD tracking system.

4.3 Performance Goals

Performance and design parameters for an LCTPC with standard pad 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.

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 pixel TPC with CMOS electronics is compatible with MicroMegas or GEM.

Table 5, as presented in the DBD

Parameter	
Geometrical parameters	r_{in} r_{out} z 329 mm 1808 mm $\pm$ 2350 mm
Solid angle coverage	Up to $\cos\theta \simeq 0.98$ (10 pad rows)
TPC material budget	$\simeq 0.05$ X_0 including outer fieldcage in r < 0.25 X_0 for readout endcaps in z
Number of pads/timebuckets	$\simeq$ 1-2 $\times 10^6$/1000 per endcap
Pad pitch/ no.padrows	$\simeq 1\times 6$ mm^2 for 220 padrows
σ_{point} in $r\phi$	$\simeq$ 60 μm for zero drift, $<$ 100 μm overall
σ_{point} in rz	$\simeq 0.4 - 1.4$ mm (for zero – full drift)
2-hit resolution in $r\phi$	$\simeq$ 2 mm
2-hit resolution in rz	$\simeq$ 6 mm
dE/dx resolution	$\simeq$ 5 %
Momentum resolution at B=3.5 T	$\delta(1/p_t) \simeq 10^{-4}$/GeV/c (TPC only)