finalversion20170109

Addendum 2016 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/. The MoA has been revised this year and can be found at the above link. Evolution of the collaboration, of the work-package structure and of responsible persons are updated in the yearly Addenda.

Note that at the moment the collaboration is searching for a speakers bureau chair, a software coordinator and a pixel coordinator (see Sections 3.1.3 and 3.2).

1 2016 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 International Linear Collider (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

The LCTPC properties have been developed for the Tesla linear collider (originally), then by the ILC (0.2 - 1.0 TeV with superconducting cavities). Other projects are also studying the possibility of employing a TPC as one of their subdetectors are welcome to profit from the information accumulated by the LCTPC collaboration.

Recent efforts are underway to have ILC built in Japan. It is envisaged to be realized in two or more stages: first stage, the ∼250-350 GeV machine (Higgs, top and other precision studies), followed by an upgrade to ∼500-1000 GeV. (Progress is regularly reported in the 'LC Newsline' http://newsline.linearcollider.org.)

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 to guide the construction of the ILC. This mandate has been extended by ICFA (International Committee for Future Accelerators).

2 Responsibilites 2016

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**
–Asia———-	
Tsinghua:	**Yuanning Gao**
Hubei:	**Fan Zhang**
IHEP[1]:	**Huirong Qi**
Saha Kolkata:	**Supratik Mukhopadhyay**
Hiroshima:	**Tohru Takahashi**
Iwate:	**Shinya Narita**
KEK:	**Keisuke Fujii**
Kindai:	**Yukihiro Kato**
Saga:	**Akira Sugiyama**
Kogakuin:	**Takashi Watanabe**
Nagasaki Inst AS:	**Ken Oyama**
–Europe———-	
Inter U Inst for HEP(ULB-VUB):	**Gilles De Lentdecker**
CEA Saclay:	**Paul Colas**
Bonn:	**Jochen Kaminski/Klaus Desch**
DESY/HH:	**Ties Behnke**
Kiev:	**Oleg Bezshyyko**
MPI-Munich:	**Ron Settles**
Siegen:	**Ivor Fleck**
Nikhef:	**Jan Timmermans**
Lund:	**Leif Jönsson**
CERN:	**Michael Hauschild/Lucie Linsen**

[1]Formal approval for membership scheduled for the next CB meeting

2.2 Observers

'Oberservers' are groups or persons that could not sign the MoA but are being informed as to the progress, thus are included in the lctpc mailing list. Change of status from 'collaboration member' to 'observer' this year has taken place for the groups:
Cornell (Dan Peterson),
Indiana(Rick Van Kooten),
Rostock (Roland Waldi),
Aachen (Stefan Roth).

The group from Tokyo U A & T (Osamu Nitoh) has ceased to exist since Prof. Nitoh has retired.

In past addenda, 'observer' groups listed were
Montreal, MIT, Purdue, Stony Brook, Yale, LBNL, Louisiana Tech, 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 2007-2017, after selection of candidates, sometimes by a search committee, in each region, were elected by the CB members of the respective region. They are
–Americas: **Dean Karlen** in 2007-10,
Alain Bellerive in 2011-15,
Alain Bellerive in 2016-17.
–Asia: **Takeshi Matsuda** in 2007-09,
Akira Sugiyama in 2010-15,
Akira Sugiyama in 2016-17.
–Europe: **Ron Settles** in 2007,
Jan Timmermans in 2008-11,
Jochen Kaminski in 2012-17.
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 and has been chosen to continue in 2016-17.

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, and has been reappointed for this task in 2016-2017.

3.1.2 Editorial Board (EB)

The EB was discussed again at this year's CB meeting; the list of members and the wording below resulted from changes by the CB and from various initiatives.

The EB is made now up of: Alain Bellerive, Ties Behnke, Madhu Dixit, Takahiro Fusayasu, Keisuke Fujii, Leif Jönsson, Jochen Kaminski, Takeshi Matsuda, Ron Settles, Akira Sugyama and Jan Timmermans. Takahiro Fusayasu has agree to chair the EB in 2016.

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, and Allain Bellerive for one year starting mid-2013. David Attie had this task since mid-2014. *XXXXsb* will take over the duty next.

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 are repeated here for historical interest), there being bi-weekly meetings which include 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'.

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 design and	→ Cornell,Bonn, Desy/HH,JapaneseGroups,MPI,Saclay before 2016 **Dan Peterson** daniel.peterson@cornell.edu
Fieldcage development	→ BNL,Desy/HH **Ties Behnke** ties.behnke@desy.de
b) GEM panels for endplate	→Bonn, Desy/HH,JapaneseGroups,Tsinghua **Akira Sugiyama** sugiyama@cc.saga-u.ac.jp
c) MicroMegas panels for endplate	→ Carleton, SahaKolkata,Saclay **Paul Colas** paul.colas@cea.fr
d) Pixel panels for endplate	→ Bonn,Freiburg,Nikhef,Saclay **Jan Timmermans** jan.timmermans@nikhef.nl
e) 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 *XXXXsw* xxxx@xxxx.xx
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	→ 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 and fieldcage	→ Desy/HH,JapaneseGroups,MPI,Saclay
	Ties Behnke ties.behnke@desy.de
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/power pulsing/cooling	→Cern,Desy,JapeneseGroups,Lund,Nikhef,Saclay
	Takahiro Fusayasu fusayasu_takahiro@nias.ac.jp
c) Gating device	→ JapeneseGroups
	Akira Sugiyama sugiyama@hep.phys.saga-u.ac.jp
d) ILD TPC Integration/Mach-Det Interface	→ Desy/HH,MPI,Saclay
	Volker Prahl volker.prahl@desy.de
	Ron Settles settles@mppmu.mpg.de
e) LCTPC Software/Correction methods	→Bonn,Carleton,Cern,Desy/HH,JapaneseGroups
	2014**Astrid Muennich** astrid.muennich@desy.de
	2016*XXXXpixel* xxxx@xxxx.xx
	Alain Bellerivealainb@physics.carleton.ca
	Keisuke Fujii keisuke.fujii@kek.jp
f) Pixel-Module Development	→Bonn,Carleton,Nikhef,Saclay
	2015 **Michael Lupberger** michael.lupberger@cern.ch
	Jochen Kaminski kaminski@physik.uni-bonn.de
	XXXXpixel xxxx@xxxx.xx

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 May 2016
		Large Prototype R&D
Device	Lab(years)	Configuration
Preliminary	Desy(2013-15)	Fieldcage⊕first endplates: GEM, MicroMegas, or 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(2016-17)	Fieldcage⊕thinned endplate: GEM, MicroMegas, or 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(2018-19)	Fieldcage⊕advanced-endcap prototype: GEM, MicroMegas, or pixel
Purpose: Prototype for LCTPC module design with items that are ready: mechanics, electronics, cooling, power pulsing, gating; new fieldcage and SAltro/GdSP channels		

Table 4

Review of the TPC 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/fieldcage studies with a maximum of 25% X0 in the endplate including electronics/cooling

-• Software development for reconstruction

-• Software development for simulation

-• 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 all components of LCTPC for electron-attachment emissions into the TPC gas

-• A move to a hadron beam is possible and is being investigated. This may not happen, so ways should be found to do the necessary tests at Desy.

More discussions were held at workpackage meetings 176/185/222 where more details can be found. The indico links for these meetings are
176–http://agenda.linearcollider.org/event/6097/
185–http://agenda.linearcollider.org/event/6251/
222–http://agenda.linearcollider.org/event/6786/

The collaboration decided that it was not yet necessary to choose 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 may have to be made around the year 2017-18 in order to design the LCTPC, as described in Sec. 4.2.2 below.

Additional plans have been that mechanical studies of endcap designs and modules will follow. In preparation for the next LP studies, more prototype modules will be manufactured. 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

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 continuing 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

Understanding the properties and achieving the best possible point resolution have been the object of R&D studies of Micro-Pattern Gas Detectors, GEM, MicroMegas, and pixel, and results from this work used to define the parameters in Table 5.

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 have been established 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 being tested with "Ingrid", MicroMegas integrated on a pixel chip.

Also noted is the study by the ILD collaboration of a "large" version with 1808 mm TPC outer radius and 3.5T B-field (the standard used up to now) and a new "small" version with 1460 mm TPC outer radius and 4T B-field. The Table 5 below is for the "large" version, Table 6 for the "small" version. The final size chosen will be between the two. [2] [3] [4] [5] [6]

[2]The point resolution (0.1 mm) for this year's tables has been asummed to be the same for all three options, GEM, MicroMegas, and pixel. The value for the pixel option is still under study.

[3]For the effective track length in both cases, small and large, 100mm has been added to the inner radius and 100mm subtracted from the outer radius, in order to account for fieldcages, mechanics and services.

[4]To obtain the same momentum resolution as the large version, the small version of the TPC would have to have an outer radius more than 1600 mm, based on a back-of-the envelope calculation using Gluckstern's formula.

[5]Also the overall tracking resolution (including silicon tracking) would be roughly $\simeq 2 \times 10^{-5}$ for the large version and $\simeq 3 \times 10^{-5}$ for the small version.

[6]The assumption for the dE/dx resolution for the pixel TPC is that one-half of the track length (long drift) uses the standard dE/dx (truncated mean) estimation and one-half (short drift) uses cluster counting.

Table 5, large TPC, for pad/*pixel* electronics

Parameter	
Geometrical parameters	r_{in} 329 mm, r_{out} 1808 mm, z ± 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	$\simeq 10^6$/1000 per endcap
Number of pixels/timebuckets	$\simeq$ *10^9/1000 per endcap*
Pad pitch/ no.padrows	$\simeq 1\times 6\ \text{mm}^2$ / 213
σ_{point} in $r\phi$	$\simeq 60\ \mu$m for zero drift, $< 100\ \mu$m 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	$\simeq 5 - 6$ %
dE/dx resolution	$\simeq 3 - 4$ *%*
Momentum resolution at B=3.5 T	$\delta(1/p_t) \simeq 10^{-4}$/GeV/c (TPC only)

Table 6, small TPC, for pad/*pixel* electronics

Parameter	
Geometrical parameters	r_{in} 329 mm, r_{out} 1460 mm, z ± 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	$\simeq 5\times 10^5$/1000 per endcap
Number of pixels/timebuckets	$\simeq$ *5×10^8/1000 per endcap*
Pad pitch/ no.padrows	$\simeq 1\times 6\ \text{mm}^2$ / 155
σ_{point} in $r\phi$	$\simeq 60\ \mu$m for zero drift, $< 100\ \mu$m 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	$\simeq 6 - 7$ %
dE/dx resolution	$\simeq 4 - 5$ *%*
Momentum resolution at B=4 T	$\delta(1/p_t) \simeq 2\times 10^{-4}$/GeV/c (TPC only)