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Addendum 2014 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 tasks, and of responsible persons are updated in the yearly Addenda.

1 2014 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 soon to phase **3** (Section 1.2).

1.1 The ILD LOI and the DBD

The ILD Letter of Intent (LOI) was validated in 2009 by the International Detector Advisory Group and GDE Research Director. This was followed by the the Detailed Baseline Design (DBD) of the detector which was submitted in 2013 and was the result of more effort put into the engineering of the detector. The Technical Design Report (TDR) of the ILC accelerator, also completed in 2013, and the DBD were combined into one document which can be found at
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; the parameters of a TPC for ILC are somewhat different from those for CLIC.

Recent efforts are underway to have the superconducting linear collider 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 ∼250 GeV machine (Higgs' precision measurements), followed by an extension to ∼500 GeV (top, Higgs' and other precision studies), and finally by an upgrade to ∼1000 GeV. (Progress is regularly reported in the 'LC Newsline' http://newsline.linearcollider.org.)

In addition, the collaboration and leadership arrangement, the international 'Linear Collider Collaboration' with oversight committee 'Linear Collider Board' (LCC and LCB, see the LC Newsline), replaced the structure set up by International Linear Collider Steering Committee several years ago and will guide the construction of the ILC.

2 Responsibilites 2014

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**
Saha Kolkata:	**Supratik Mukhopadhyay**
Hiroshima	**Tohru Takahashi**
KEK	**Keisuke Fujii**
Kindai	**Yukihiro Kato**
Saga	**Akira Sugiyama**
Kogakuin	**Takashi Watanabe**
Nagasaki Inst AS	**Takahiro Fusayasu**
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 2007-2014, 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 2011-14.
–Asia: **Takeshi Matsuda** in 2007-09 and
Akira Sugiyama in 2010-14.
–Europe: **Ron Settles** in 2007,
Jan Timmermans in 2008-11 and
Jochen Kaminski in 2012-14.

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 2012-14.

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 2012-14.

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.

3.1.3 Speakers Bureau

The speakers bureau formed in 2008 to monitor, i.e., select speakers and review proceedings of 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; David Attie replaced Jan Timmermans in 2014. Dan Peterson chaired the meetings in 2012, Allain Bellerive for one year from mid-2013, and David Attie starting 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. It is out of date now, there being bi-weekly meetings which incude all workpackages convened by the collaboration spokesperson Jochen Kaminski. Therefore the 'conveners' will be referred to simply as 'contacts'.

In addition, there is a monthly 'analysis meeting' chaired by Astrid Muennich and 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,
	Astrid Muennich astrid.muennich@desy.de
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,Rostock,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,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
	Astrid Muennich astrid.muennich@desy.de
	Keisuke Fujii keisuke.fujii@kek.jp
g) Pixel-Module Development	Bonn,Carleton,Nikhef,Saclay
	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 Phases (1) and (2), 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,
–two phase CO2 cooling 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 evolves.

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. It has been developed by physicists. The final schedule will depend on political realities.
2014 R&D on GEM/wire gates
2015 Decision on the ion gate
2015-17 Beam tests of Large Prototype modules with the gate
2017 ILC accelerator & ILD detector proposals
2017 Prioritization of the MPGD technology and modules
2017-19 Design of the readout electronics for ILD TPC and its verification
2018-19 Design of ILD TPC and TDR (for the ILD tracking system)
2019-23 Prototyping and production: Electronics
2020-23 Prototyping and production: Modules
2020-23 Production: Field cage, endplate and related things
2024-25 TPC integration and test
2026 TPC Installation into the ILD detector
2027 ILC commissioning

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' modules 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 March 2014
		Large Prototype R&D Stages
Device	Lab(years)	Configuration
Preliminary	Desy(2013-15)	Fieldcage⊕first endplates: GEM+pixel, Micromegas+pixel
Purpose: Test construction techniques using ∼10000 electronic 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 electronic 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 plan a full area ('100-chip') LP-module.		
'Final'	Desy electron beam(2017-19) or hadron beam elsewhere (see last bullet, Table 4)	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. This work is most urgent.
- 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 conceptual design of a new readout chip is a problem which will involve specifying requirements for readout by simulation.
- Powerpulsing/cooling tests using both LP and SP.
- Test all components of LCTPC for electron-attachment emissions into the TPC gas.
- Moving the Desy setup now seems to be unrealistic, so ways should be found to do as many tests as possible at Desy.
- The hadron beam at other labs are possbilities: a large 4T magnet will become available at ANL, other high-field magnets at CERN, for example. These options will be studied in 2014/2015.

The collaboration decided that it was not yet (in 2014) 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 R&D results. The 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 2014, 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 - 2019

During the period 2014 - 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 - 2019, the design of the ILD TPC will follow in preparation for the TDR of the ILD tracking system.

4.3 Performance Goals 2013 – 2014

The performance goals presented in the DBD for a pad-based TPC are recalled in Table 5 below; options are MicroMegas with resistive anode or GEM. The pixel TPC is also being developed intensively; options are MicroMegas or GEM.

The ILD detector parameters are currently under review, so the size of ILD (and the TPC) are expected to change. In particular, machine studies on the design of ILC for Japan are progressing rapidly and resulting in requests for changes in the detectors. The ILD and the TPC will become possibly shorter in length and somewhat smaller in radius.

Table 5, as presented in the DBD

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	$\simeq$ 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)