Introduction

Akira Sugiyama, Ryo Yonamine and Takahiro Fusayasu gave talks on general R&D, module R&D and electronics R&D yesterday and today, see

http://ilcagenda.linearcollider.org/conferenceTimeTable.py?confId=5271#all

so there is nothing left for me to say.

I'll stick to making a few comments…

Outline

- What we have.
- What is missing.

•What we have… the MOA

Memorandum of Agreement

on the Formation of the LCTPC Collaboration

October 2007 / July 2008

1 Introduction

1.1 Preamble

Several detector concepts for the linear collider foresee a time projection chamber (TPC) as the central tracker in a tracking system of high precision and fine granularity combined with a calorimeter system of very fine granularity. The detector is being designed for precision measurements in the electroweak sector and of new HEP-phenomena which might be discovered. One aspect of precision experiments requires the measurement of charged tracks with an order of magnitude better accuracy than at previously built collider-detectors. Another aspect requires the detector to be optimized for the reconstruction of multi-jet final states. The jet energy resolution using the particle-flow technique is best when the reconstruction of individual particles in jets is as complete as possible, meaning efficiency in reconstructing charged tracks is more important than momentum precision. A TPC central tracker is being developed to meet these requirements in concert with the other subdetectors. The issues for the TPC performance within the linear collider framework have been described many times, most recently in LC Note LC-DET-2007-005 at http://flcweb01.desy.de/lcnotes/. The formation of an R&D collaboration to address these issues is the purpose of this document.

1.2 Scope of the Collaboration

The groups signing this Memorandum of Agreement (MOA) express their interest to contribute to the goals of the LCTPC collaboration, specifically the development, prototyping and design of a TPC for an experiment at the linear collider. This MOA describes the

…Started working on this in 2006…

•What we have…yearly addenda

Draft 20110910

Addendum 2010-11 to the LCTPC MOA:
R&D organization and DBD planning

Overview

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

1 2010-11 Activities

1.1 Organizational Issues

The Addendum 2008 described the creation of an editorial board and of a speakers bureau:

> **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.
>
> Similarly the CB has installed a speakers bureau which will review all talks pertaining to the common equipment. The method may include the organizataion of practice talks which can be reviewed and modified by the speakers' bureau.

1.1.1 Editorial Board

·yearly addenda where we update names and priorities

2 Responsibilites 2010-11

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**
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 (up to 2011):	**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 Jönsson**
CERN:	**Michael Hauschild/Lucie Linsen**

Present groups & **CB members** are listed above; missing MOA signatures marked by "

3

Table 2

Workpackage	Groups involved Convener
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**
b) Fieldcage, laser, gas	BNL,Desy/HH **Ties Behnke**
c) GEM panels for endplate	Bonn,Cornell,Desy/HH,JapaneseGroups,Tsinghua **Akira Sugiyama**
d) Micromegas panels for endplate	Carleton,Cornell,SahaKolkata,Saclay **Paul Colas**
e) Pixel panels for endplate	Bonn,Freiburg,Nikhef,Saclay **Jan Timmermans**
f) Resistive anode for endplate	Carleton,SahaKolkata,Saclay **Madhu Dixit**
Workpackage(2) Electronics	
a) Standard RO for the LP	Brussels,Cern,Desy/HH,Lund **Leif Jönsson**
b) CMOS RO electronics	Bonn,Nikhef,Saclay **Harry van der Graaf**
c) Standard electronics for LCTPC	Brussels,Cern,Desy/HH,Lund, JapaneseGroups,Tsinghua 2010 **Luciano Musa**/2011 **NN**
Workpackage(3) Software	
a) LP software/simulation/reconstruction	Bonn,Cern,Desy/HH,Victoria, **Christoph Rosemann**
b) LP DAQ	Brussels,Lund **Gilles De Lentdecker**
c) LCTPC performance/backgrounds	Bonn,Carleton,Cern,Desy/HH,JapaneseGroups **Keisuke Fujii**
Workpackage(4) Calibration	
a) Field map for the LP	Cern,Desy/HH **Lucie Linsen**
b) Alignment	Cornell,Cern,Desy/HH **Takeshi Matsuda**
c) Distortion correction	Cern,Desy/HH,MPI,JapenseGroups,Victoria **Dean Karlen**
d) Gas/HV/Infrastructure for the LP	Aachen,Desy/HH,Saclay 2010 **Klaus Dehmelt**/2011 **Ralf Diener**

5

New WP(5) LCTPC preparations for DBD	
a) Advanced endcap mechanics/alignment	Cornell,JapaneseGroups,MPI,Saclay **Dan Peterson**
b) Advanced endcap/SAltro/cooling/PowerPulse	Cern,JapeneseGroups,Lund,Nikhef,Saclay **Anders Oskarsson/ Takahiro Fusayasu** 2010 **Luciano Musa**/2011 **NN**
c) Gating device	Cornell,JapeneseGroups,MPI **Akira Sugiyama/ Ron Settles**
d) Fieldcage	Desy/HH **Ties Behnke**
e) ILD TPC Integration/Machine-Detector Interface	Cornell,Desy/HH,MPI,Saclay **Volker Prahl/ Ron Settles**
f) LCTPC Software Model	Bonn,Carleton,Cern,Desy/HH,JapaneseGroups **Christoph Rosemann/ Keisuke Fujii**
g) Testbeams	Desy/HH,JapaneseGroups **Takeshi Matsuda**

The WP(5) issues overlap significantly with the previous structure, since they are closely related. The WP(5) workpackages are meant to specifically guide the DBD preparations; more explanation is presented in Section 3.3.

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 MWPC option has been ruled out,
–the Micromegas option without resistive anode has been ruled out.[1]

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 the timeline evolves.

•…update priorities…

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 MWPC option has been ruled out,
–the Micromegas option without resistive anode has been ruled out.[1]

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 the timeline evolves.

3.2 Timeline

The following overview is the currently envisioned timeline for completing the studies and the construction of the LCTPC.

(I) 2009-13: Continue R&D on technologies at LP, SP, pursue simulations, verify corrections procedures and performance goals.

[1] See PRC2010 Report http://www.lctpc.org/e10/e96773/

(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 and power-pulsing; write the DBD
(IV) 2012-18: Design and build the LCTPC.

3.3 Preparation for the DBD

3.3.1 (I) 2009 - 2013

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.

Table 3 Scenarios, updated April 2010

Large Prototype R&D		
Device	Lab(years)	Configuration
LP1	Desy(2007-2011)	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	Desy(2012)	Fieldcage⊕thinned endplate: GEM+pixel, Micromegas+pixel
Purpose: Continue tests using 10000 Altro or T2K channels to demonstrate measurement of beam momentum over 70cm tracklength using LP1 thinned endplate and external detector. If possible, test a jet-like environment.		
LP2	FL*C*D*O/ (after 2012)	Fieldcage⊕advanced-endcap prototype: 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(2007-2011)	Gas tests, gating configurations, Altro
SP2,SP3	FL*C*D*O(2011-2013)	Performance in jet environment
SPn	LCTPC groups(2007-2013)	Performance, gas tests, dE/dx measurements, continuation of measurements in progress by groups with small prototypes

3.3.2 (II) 2009 - 2011

•…main priorities 2011

3.3.2 (II) 2009 - 2011

TPC design, performance and engineering issues were presented at LCTPC collaboration meetings on 21-22 September 2009

and 6-7 July 2011
http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=5231. These meetings included a reassessment of the R&D priorities, a continuing process. Table 4 reflects the present thinking, in approximate order of priority:

Table 4

- Continue tests in electron beam to perfect correction procedures
- Advanced endplate studies with a maximum of 25% X0 including cooling
- Powerpulsing/cooling tests using both LP and SP
- Design/test gating device
- Future tests in hadron beam for momentum resolution

and for performance in a jet environment

- Ion backflow simulations of ion sheets for Gem, Micromegas

·yearly addenda with…updated performance goals

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	$\sim 0.05X_0$ 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 size/no.padrows	$\sim$ 1mm$\times$4–6mm/$\sim$200 (standard readout)
σ_{point} in $r\phi$	$< 100\mu$m (average over $L_{sensitive}$ for straight radial tracks)
σ_{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 ($p_t > 1$GeV/c), and
	$>$ 99% all tracking ($p_t > 1$GeV/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

The Pixel TPC
The pixel TPC R&D is progressing and will provide corresponding table of performance parameters as soon as feasible.

•What is missing?

Big things missing:

LP data analysis with distortion corrections: WP5f (Keisuke Fujii, Christof Rosemann et al) making good progress, but more help for the software group would be welcome.

LCTPC electronics design with PP, cooling: WP5b (Takahiro Fusayasu, Anders Oskerssonet al) making good progress, also help needed.

Gating studies: WP5c (Akria Sugiyama, RS et al), Akira trying Gem, I and Dan Peterson are trying wires: more study needed before we can decide.

·What is missing (in Japan)?

Japan LCTPC groups missing:

A "working" (meaning one without distortion) LP module: there are another couple of months (while PCMAG is being worked on) to get the bugs out…

·What is the most important?

Again, my opinion:

Understand how to make corrections

- for B-field gradients

- for alignment (module-to-module)

Understand the endplate and modules

Understand the electronics

Understand power pulsing

Understand cooling

Understand gating

•Ideas in a state of flux?

Now I would like to be provocative:

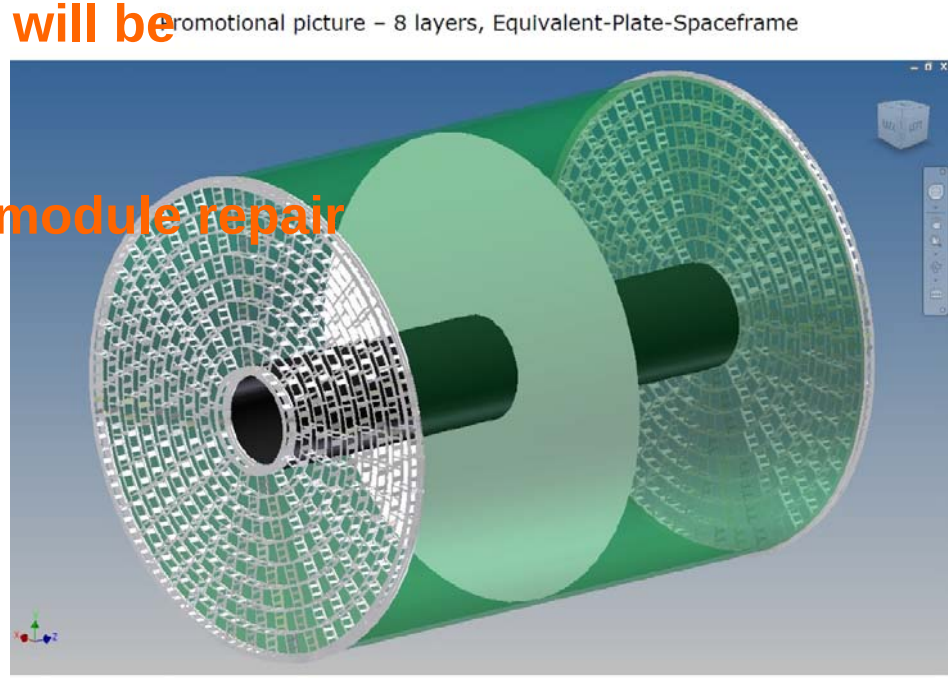
I think that with this type of endplate, it is no longer so critical to keep the azimuthal gaps between the modules very small. The main points will be

-robustness

-easy accessibility for module repair

Agree, don't agree?

Other ideas?



- What else is missing?

LC machine approval, hope it doesn't take too long, but we have "nerves of steel": some of us have been working on the LC since 1990 or before—for example, Keisuki Fujii and others will remember Saariselka1991 which was the first LCWS as I recall…

- What we have and what is missing?
- Conclusion: in general we are in pretty good shape in that we have our roadmap (MOA+Addenda), things are progressing reasonably; there is still a lot to do. The LC machine approval is just over the horizon, but as soon as it comes into sight, we will have to speed up…