Summary of LCTW09

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Abstract

This note summarises the workshop LCTW09 held between the 3.11.2009 and 5.11.2009 at LAL Orsay. The workshop was dedicated to discuss the Linear Collider Detector Testbeam needs in the years 2010 up to 2013. The document underlines the rich and highly interesting R&D program of the detectors for the Linear Collider in the coming years. Large synergies were identified in the level of DAQ and software systems. Considerable synergy effects are expected from the establishment of semi-permanent beam lines for Linear Collider Detector R&D at major centres like CERN and FNAL. Reproducing an ILC beam structure would clearly enhance the value of the obtained beam test results. Although not ultimately needed for every research program, all groups would exploit such a feature if it is available.
Please note that this is a preliminary version which can be shown to interested colleagues. The final document will be prepared for the 1/9/2010

1 Executive Summary (2 pages - R. Pöschl)

Testbeams are the first occasion for detector concepts to face the truth about their design, and an optimal opportunity to train young physicist on real data. In November 2009, 40 experts (two from Asia, five from North America and the rest from Europe) met at the Laboratoire de l'Accélérateur Linéaire (LAL) at Orsay to review the needs for testbeams for the R&D on detectors in the future. The goal of this workshop was to collect the needs and to coordinate the activities of the various collaborations active in the field: CALICE, FCAL and SiD groups on calorimetry, LCTPC on gaseous tracking as well as SiLC for the various silicon tracking devices. Representatives of the current major test beam facilities, CERN, DESY and Fermilab, presented their sites and actively took part in the discussions. Many other facilities available in the world were discussed: J-Parc, IHEP Bejing, Tohoku, KEK in Asia, IHEP/Protvino, Dubna in Russia, and it was noticed that SLAC would restore test beams and create a new facility in its end station A by 2010. The successful testbeam efforts prior to the Letters of Intent (LOI) for detectors were reviewed followed by vivid discussions on what is needed to improve these testbeams for the next phase. This document covers the years 2010-2013 which to a large extent coincides with the preparation of the Detector Baseline Document (DBD) in which mature detector technologies are to be presented. The testbeam efforts have to support this goal. Large scale systems of all detector components are expected to be tested in this phase. The succesful conduction of the testbeams is naturally vital for a well founded document. Apart from the fact that the detector developpers have to be ready in time, the community has to make sure that enough beam time is available, in particular in the period 1/2011 - 2/2012 in which most of the activities described in this note can be anticipated. The needs of the LC detector community in terms of particles comprises low energy electron test beams as well as high energy hadron test beams. In addition to the beamlines itself, the Linear Collider Detector R&D requires specific equipment such as large bore high-field magnets (up to 6 T). The Table 1 gives a general overview on the activities planned by the various detector components. Another important issue of the detector R&D is to find the optimal balance between high beam rates to conduct physics motivated studies and the fact that e.g. the readout electronics is primarily designed for low rates as in first approach expected at a Linear Collider. The establishment of a dedicated ILC beamstructure would render the results more applicable to prospects on the operation at the International Linear Collider. This is particularly true for the general time structure, i.e. "macro-structure" of the beam. This means that a relatively short pulse of about 1 ms will be followed by a longer interval of up to 199 ms without beam. All the R&D groups would make use of such a possibility to test their hardware under the most realistic conditions. There is no strong requirement to reproduce the micro-structure of the ILC beams. The distribution of particles within the 1 ms spill needs however still to be adapted to the limited buffer depths of the front end electronics of the different devices. The community therefore encourages the site operators to continue efforts to establish an ILC like beam structure. Given the limited time line and manpower situation the LC Detector community will establish a light coordination of the testbeam activities to foster synergies and avoid overlaps in terms of beam times and facilities.

The activities of the past and the challenging program of the future have been acknowledged in Europe by the recent approval of the *AIDA* project. The AIDA project [2] was presented as a proposal for Integrating Activity under the 7th framework of the European Union. This funding instrument is largely based on the “I3” (integrated infrastructure initiatives) under which EUDET [1] was funded. The objectives are (a) to provide a wider and more efficient access to, and use of the existing research infrastructures in Europe and (b) better integration of the way research infrastructures operate, and fostering joint development in terms of capacity and performance. AIDA involves most of the linear collider detector R & D community that participated in EUDET. It moreover includes a strong participation from the institutes involved in the upgrades of the LHC detectors, in that of the B-factories and accelerator-based neutrino experiments. At the time of writing, AIDA was in the negotiation phase after the EU had proposed to fund the proposal with 8 million euro (compared to the 10 million requested from the EU in the original proposal). In the proposal common infrastructure for the characterization of new detector prototypes is foreseen.

Project	2010/2	Site	2011/1	Site	2011/2	Site	2012/1	Site	2012/2	Site
Calo	xx	**CERN**	xx	**CERN**	xx	**CERN**	xx	**CERN**	xx	**CERN**
		FNAL		**FNAL**		**FNAL**		**FNAL**		**FNAL**
		SLAC		**SLAC**		**SLAC**		SLAC		SLAC
Needs	Magnet		Magnet		Magnet		Magnet		Magnet	
	Particle Types: e, π, p, Energies: 1-120 GeV, Low Rates $\approx$ 100 Hz									
Gas/TPC	xx		xx	CERN	xx	CERN	xx	CERN	?	CERN
		DESY		**DESY**		**DESY**		**DESY**		**DESY**
				FNAL		FNAL		FNAL		FNAL
Needs	Magnet		Magnet		Magnet		Magnet		Magnet	
	Particle Types and rates: e as available at DESY. Hadron beam test not planned but possible.									
SiTrack	x	Various (see Tab.4)	x	Various	x	Various	x	Various	x	Various
Needs	Magnet/Telescope		M./T.		M./T.		M./T.		M./T.	
	Particle Types: e, π, p, Energies: 1-120 GeV, High Rates $\approx$ 1 MHz for short periods									

Table 1: The table indicate the envisaged testbeam activities until the end of 2012. The symbol – means "no activity planned", The symbol **x** means "Test of small units can be expected", The symbol **xx** means "Large Scale Testbeam planned". Sites are given in *alphabetical* order. Bold face letters indicate where testbeams are going to happen. Normal face letters indicate optional tests depending on availabilty of detector prototypes and needs.

2 World wide LC Beam Test Coordination and Review (2 pages - R. Pöschl, J. Yu)

The situation of the efforts on the International Linear Collider was picking up its pace after the creation of the Global Design Effort (GDE) in 2004. Along with the global effort on the accelerator front, many detector development groups that have been performing beam test before were intensifying their activities. These efforts, however, were fragmented and were not coordinated at all. Given the anticipated intensity of beam test efforts in the coming few years, it was necessary for the community and the facilities to be able to provide necessary beam capabilities to detector R&D groups. The facilities, however, needed to know what the requirements for the community are. As an effort to convey the upcoming needs, the calorimeter and muon R&D groups have put together a road map document to FNAL in 2005, following a presentation to the Physics Advisory Panel (PAC). This document [3] and the need for more concerted effort led to the implementation of a working group structure and prompted the need for a world-wide ILC test beam workshop to collect and compile the requirements of most, if not all, R&D groups within the community. This was to provide a forum to share ideas and needs between many different groups within the LC community and to make sure that the limited facilities can be used effectively.

2.1 LC Test Beam Workshop 2007 (IDTB07) at FNAL

The LCTW09 as summarised in this document is the second workshop of this kind. The first LC Test Beam workshop called IDTB07 was held at FNAL in Jan. 2007.

As a result of three days of presentations and discussions, following requirements have been identified:

- Large bore, high field magnet (up to 5T).
- ILC beam time structure (1ms beam + 199ms blank).
- Mimicking hadron jets.
- Common DAQ hardware and software.
- Common online and offline software.
- Common reconstruction and analysis software infrastructure.
- Tagged neutral hadron beams.

The outcome of the IDTB07 workshop resulted in a roadmap document [4] that was released to the LC leadership and facility managers in summer 2007. Many of the improvements made in facilities in subsequent years were based on the requirements and the roadmap laid down in this roadmap document. Based on this document the test beam sites underwent considerable efforts in order to enable the test beam program. Among these efforts, the following are to be highlighted:

- The CALICE collaboration benefited from the availability of the H6 test beam area at CERN over several months in the years 2006 and 2007. This considerable beam time was allocated on short notice, despite of the huge demands required by the final stages of the LHC detector R&D program and the launch of the neutrino program at CERN.

- FNAL refurbished the MTest beam line particularly to host the CALICE test beam program in the years 2008 and 2009. This program is to be pursued in 2009 and beyond. The continuing availability of the test beam facility at both CERN and FNAL allowed for the establishment of an infrastructure by which CALICE was able to setup remote control facilities which are a first step towards a similar detector control at a future linear collider.
- The DESY facility gave a 'home' to the TPC activities which could establish an infrastructure allowing to pursue the R&D at a single place.
- Beyond the activities above, which are due to their size somewhat outstanding dimensions, the various sites, i.e. CERN, DESY, FNAL, SLAC and KEK, offered beam time to smaller yet very important activities by the vertex, silicon tracking and muon detector communities.

The detector R&D community would like to take the opportunity of this document to express their acknowledgement and gratitude for the optimal experimental conditions encountered in the past years.

The test beam activities resulted already in a number of scientific results which can be looked up on the webpages of the different projects.

3 Subdetector Testbeam Plans

3.1 Calorimeter (3-4 pages - V. Boudry, J. Hauptman)

As will be outlined in this section the calorimeters may put the highest demands in terms of space and availability of beam test areas. Many projects feature projects of about 1 m^3 and need high statistics for the conduction of physics programs during the beam test campaigns.

3.1.1 CALICE plans

An overview of past, present and future CALICE calorimeter prototypes is available in the Table 2. For details on the CALICE program, the reader is referred to [5].

Project	Absorber	Sensitive Part	Completion Date
Physics Prototype AHCAL	Stainl. Steel	Scintillator	Completed
Technological Prototype AHCAL	Stainl. Steel	Scintillator	2012
Physics Prototype TCMT	Stainl. Steel	Scintillator	Completed
Physics Prototype DCHAL	Stainl. Steel	RPC partially GEM	2010
Prototype SDHCAL Physics/Technological	Stainl. Steel	RPC partially µMegas	2011
Physics Prototype W Hcal	Tungsten	Scintillator partially Mmegas partially GEM	2011
Physics Prototype SiW Ecal	Tungsten	Si	Completed
Technological Prototype SiW Ecal	Tungsten	Si partially Scintillator	2012
Physics Prototype ScW Ecal	Tungsten	Scintillator	Completed
Prototype DECAL	Tungsten	Si	2012?

Table 2: Overview of calorimeter prototypes having been or to be operated by the CALICE collaboration.

Each project has developed or is developing prototype(s) classified as *physics*, used to demonstrate the physics performances of the technique, or *technological*, used to study the solutions to the technological constraints arising from the integration in a large ILC detector[1], or both. The Digital ECAL [DECAL] technique has still to be tested in a physics prototype detector; this is expected to be achieved by 2012. More critically than for other projects, the concrete plans toward this goal do however suffer substantially from the insecure funding situation in the United Kingdom.

Two generation of DAQ system have been developed: the first version, more specifically dedicated to physics prototypes, has been running for a few years. The second version, suited for technological prototypes and handling the readout of a large quantity of channels digitised in the detectors, is at the end of its development phase.

More details are given in Section 3.4.

Physics Prototypes The years 2010–11 will see the finalisation of the main physics prototype phase. A physics prototype of a digital hadron calorimeter [DHCAL] based on thin RPC's and $1 \times 1\,\mathrm{cm}^2$ cells, will be completed in the first half of 2010. As for previous beam tests including the analogue hadron calorimeter [AHCAL], besides standalone data taking, there will be data taking in combination with the physics prototype of the electromagnetic Silicon Tungsten calorimeter [SiW ECAL] and the Tail Catcher and Muon tracker [TCMT].

Including commissioning and calibration phases altogether, 14 weeks of test beam time will be requested from FNAL. Within these 14 weeks, CALICE should be the primary beam user for about 8 weeks. The other 6 weeks are devoted to the setup of the experiment in parasitic running mode. The physics program to be conducted is largely similar to the corresponding data taking in the years 2006–09 with the AHCAL. In the combined running, the emphasis will be put on energy ranges in which it is expected to see signals in the electromagnetic part and the hadronic part (plus tail catcher). In the standalone running low energy hadrons and electrons are also to be collected. Priorities will have to be defined later on but the data which were already taken give good guidelines. It is also envisaged to replace a few layers of the DHCAL with GEM's as sensitive detectors. This may happen towards the beginning of 2011. This effort might face constraints due to customs regulations; the CALICE stage currently at FNAL is required to be shipped back to Europe in April 2011. A procedure has been started to extend the stay at FNAL[2]. If this fails the tests could be completed at CERN.

A new initiative, dubbed W-HCAL, has been started within CALICE in order to study the properties of Tungsten as absorber material, primarily for an HCAL at a multi-TeV collider. A versatile structure, featuring forty 16 mm-thick Tungsten-alloy absorbers, is foreseen. Tests with existing scintillator layers are planned for end of 2010 and 2011, tests with gaseous layers as they become available.

Technological Prototypes The CALICE collaboration is entering a new phase of R&D in which readout technologies and mechanical designs do meet already many requirements of the operation in a detector for a Linear Collider. Several groups of the collaboration are already quite advanced and new full scale prototypes are expected towards the end of 2010. The finalisation of these prototypes will be preceded by a number of larger and smaller testbeam efforts which will allow for maturing the newly developed technologies. Examples for these test beam efforts are:

- Test beams with $1\,\mathrm{m}^2$ units of the technical prototype of the SDHCAL (both RPC and MicroMegas variants). These units might already be part of the production of the entire

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[1] heating, integration, compactness, embedded FE electronics, power-pulsing

[2] Oral information from M. Demarteau @ CALICE week at Arlington

prototype scheduled for the end of 2010.

- The AHCAL conducted a initial small scale testbeam at the beginning of 2010 to prepare for electronics commissioning followed by a so-called horizontal test towards the end of 2010 and a vertical test in 2011. This means the available equipment will be arranged to allow for the measurement of electromagnetic showers.

- The Si-W ECAL is planning to make tests with single ASU towards the beginning of 2011 in an electron testbeam. Further tests beams stand-alone and combined with the SDHCAL are foreseen in 2011-2012.

It has to be stressed that the primary goal of these prototypes is to study technological solutions for the calorimetry at the ILC. The strategy for the coming years should take this into account. Here the main keywords are power pulsing, with a duty-cycle of typically 1 %, and limited depth of the buffers in the front end electronics. Hence the provided particle rates should not exceed 1 kHz during a spill. This is even more limited for RPC's, due to their comparatively large recovery time, requiring rates $\lesssim 0.1$ kHz.

In addition to the pure technological issues a physics program is to be pursued. Derived from those of the physics prototypes, taking the technical constraints into account, it requires the operators of testbeam sites to actively respond to the needs of the CALICE (LC) testbeam data taking at an very early stage. As it is foreseeable that potential high statistics physics runs will take a considerable amount of time, this will require the deployment of remote control at the experimental sites. As some prototypes may use flammable gas, the topic of security will have to be address at a very early stage.

A first large scale testbeam with a fully equipped technical prototype of an SDHCAL can be expected towards spring 2011. It is still to be clarified in what proportion this cubic meter prototype will be equipped with the two technologies under study, namely using Glass RPCs or MicroMegas as sensitive devices. This is currently pondered on the basis of experience gained with the two technologies by laboratory studies and during test beam campaigns of the year 2009.

Ideally, the SDHCAL will be joined by an Si-W ECAL technological prototype by the end of 2011. The running of an AHCAL technical prototype alone and together with the SiW ECAL technical prototype is to follow. During the year 2010 mechanical interfaces between the different detector types will have to be defined. More generally the year 2010 is to be used to integrate the detector components with the newly developed DAQ systems in order to provide an efficient data taking.

The program requires a high availability of testbeam areas. The CALICE management and the CALICE TB together with the corresponding ILC R&D panels will work out until summer 2010 whether ILC detector R&D can occupy consecutively testbeam areas for a time of two or more years starting with the beginning of 2011. Such a high availability of testbeam areas would also allow for an easier conduction of smaller testbeam programs as for example with the DECAL. In addition a functional infrastructure would facilitate the testing of a prototype for the electromagnetic calorimeter based on scintillating tiles (ScW ECAL) of which one layer can be expected towards the end of 2012. Finally, technological prototype layers with timing capabilities should also be used in a beam test with a Tungsten absorber structure.

3.1.2 SiD ECAL

The Silicon-Tungsten ECAL developed specifically for SiD features 30 longitudinal sampling layers composed of hexagonal high resistivity silicon wafers divided in small hexagonal cells ($13\,\mathrm{mm}^2$). The readout of 1024 channels is performed by a single KPiX chip bump-bonded directly on the wafer. The chip is connected to the DAQ by flat polyimide cables. The R&D on components is almost completed and a compact stack prototype (30 layers of one wafers, interleaved with $15 \times 15\,\mathrm{cm}^2$ Tungsten alloy absorbers) is being build and should be ready for test beam in beginning of 2011.

The ideal test beam for initial test is a 5–10 GeV (or more) electron beam, well localised and controllable, with a LC-like time structure (for KPiX electronics). A small number of electrons (mean of $\sim 1 - 2$) per bunch is a must.
Such a beam is possibly available at SLAC, with a low rate ($< 60\,\mathrm{Hz}$)

The data taking is planned for 2011, preferably at SLAC if a beam exists by then (the current expectation is to have SLAC test beam available around winter 2011). The possibility to realise combined tests with a HCAL prototype with a hadron beam in 2012–13, needs to be evaluated.

3.1.3 Muons

The muon system of the SiD concept (ref ??) will be placed after a thin ($5\,\lambda_\mathrm{I}$) calorimeter, the solenoid coil and cryostat ($1.3\,\lambda_\mathrm{I}$) and is therefore crucial to measure leakage of highly energetic and late-developing showers. It features a total detector area of about $6000\,\mathrm{m}^2$ on 14 layers for a total number of channels of $\sim 10^6$.

The main criteria of choice are the cost, the ease of shape adaptation and performance and reliability. The need to operate inside the return yoke adds the following: insensitivity to magnetic field, space economy for the readout system (cables, FE, etc), reliability and slow ageing.

Two technologies are considered:

RPC based (baseline) using KPiX readout chip, double gap Bakelite RPC in avalanche mode are used. It benefits from synergy with the DHCAL (readout ASIC) and a long experience in various experiments (BaBar, Opera, BES-III,...) but some ageing and reliability issues have still to be clarified, using cosmics tests stand radioactive sources and the data from past experiments.

Scintillator based (alternative) : wave-length-shifter fibre readout of cheap extruded scintillator coupled with new (and potentially) low-cost Si-based photo-detectors make the scintillator alternative progressively more competitive; long strips of up to 6 m are feasible. Prototypes featuring 256 scintillator strips and PMT have been tested in Fermilab Beam Test Facility. Small prototypes were also tested in 2008 at FTBF with a new type of SiPM, developed by FBK-IRST (Trento, Italy).

The short term plans are for the RPC to readout multiple KPiX chips and participate to test with the DHCAL prototype in test stand;

`ONLY COSMICS Test ?`

. The prototypes of scintillators strips will benefit from a new readout electronics cards optimised for SiPM and will allow to verify the attenuation length, the possibility of single ended readout for strips up to 6 m and to qualify the SiPM in conditions. The requirement on the beam test setup are light, with limited place and narrow beam of mip (up to now a well defined beamspot (1 cm) of 120 GeV protons at 10^2–10^4 p/sec is enough. This set-up can be easily shared other R&D test setup.

For longer term, in parallel with the development of the readout electronics (ASIC), SiPM, optical couplings, the construction of a complete muon detector and tail catcher and its test in coordination with a calorimetric module is foreseen, maybe for the end of 2011. The requirements in term of beam will then have to be combined with the CALICE ones.

3.1.4 DREAM and Dual Readout Calorimetry

The DREAM collaboration has tested dual-readout calorimeters in the H4 beam (North Area) at CERN from 2004 through 2009 [16]. These tests started with the small 1 kt DREAM module (consisting of Cu tubes filled with scintillating and clear fibers), and resulted in publications on basic responses and resolutions [16](a-c), shower shapes [16](d,h), scintillation-Čerenkov separation in fibers [16](e), and the response to and role of neutrons in a dual-readout fiber calorimeter [16](f,l).

Further test included dual-readout in crystals: Lead Tungstate (PWO, or $PbWO_4$) single crystals [16](g,i,j,k,n,p), extending to arrays of PWO and BGO crystals [16](m,o), and finally including a full mock-up of a crystal-plus-fiber calorimeter with $11\,\lambda_{\mathrm{int}}$ depth [16](o).

The DREAM collaboration has continued testing in the H8 beam at CERN in July 2010 and will continue for 3-to-5 years exploring the ultimate hadronic energy resolution attainable in dual-readout calorimeters.

The measurements taken in the one-week H8 test run in July 2010 included (a) direct comparisons of BGO and BSO crystals; (b) measurements of the response variations among eight doped PWO crystals of nominal identical manufacture; (c) tests of an "anti-Čerenkov" PMT; (d) tests of a Pb-quartz plate module; and, (e) direct measurement of polarized Čerekov light in a BSO crystal. These studies will be published soon.

Finally, a large dual-readout fiber module with an expected 1 % average leakage is being built to complement and complete the measurements made with the small 1 kt DREAM module. We also expect to build a crystal "em" module to test in conjunction with the larger fiber module. These activities are scheduled for the H8 beam at CERN.

3.1.5 Forward Calorimetry

The FCAL collaboration [19] develops technologies for the instrumentation of the very forward region of an detectors at the ILC or CLIC collider. For the validated detector concepts ILD [17] and SiD [18] two calorimeters are foreseen: LumiCal for a precise luminosity measurement and BeamCal for a bunch-by-bunch luminosity and beam-parameter estimate. For the latter the depositions from beamstrahlung pairs in BeamCal are used. For the measurement of the beamstrahlung pair density BeamCal will be supplemented by a pair monitor consisting of a layer of pixel sensors in front of BeamCal.

Both calorimeters extend the detector coverage to low polar angles, potentially important for search experiments using missing momentum as signature. The challenges are high precision shower position measurement in LumiCal, radiation hard sensors for BeamCal, and a fast front-end electronics for both.

a LumiCal , dedicated to the precise measurement of the luminosity using Bhabha events. It features 30 tungsten layers of $1\,X_0$ thickness each, interspersed with very finely segmented silicon sensors. To ensure a precision of the luminosity measurement of 10^{-3}, as required from physics, a correspondingly precise shower position measurement is needed. The latter can be translated in severe constraints on the sensor positioning accuracy and the position monitoring of the calorimeters. Due to the relatively high occupancy fast front-end electronics and digitisation is needed.

a BeamCal and Pair Monitor . The mechanical structure is similar to LumiCal. However, due to the large depositions from beamstrahlung pairs, about 10 Mgy/yr per year for the sensors near the beam-pipe, radiation hard sensors are needed. For this purpose large area GaAs sensors are under development in collaboration with partners in Russia. Also CVD diamond sensors are investigated. BeamCal has to be readout after each bunch crossing. In addition a fast signal added up from groups of pads is foreseen for beam-tuning. Specialised fast front-end electronics is under development.

The Pair monitor is a pixel sensor covering the front area of BeamCal. SoI technology is chosen with readout integrated in the silicon wafer.

a GamCal , 100 m downstream of the detector, is considered to assist beam-tuning.

To investigate the radiation hardness of several sensor materials a special test-beam program is ongoing.

Major components of BeamCal and LumiCal, as sensors, flexible PCB for signal transport, front-end ASICs and ADC ASICs are available as prototypes and tested separately.

Just now a full system comprised by sensor prototypes and an acquisition chain is being mounted. First measurements in the 5 GeV electron test-beam at DESY are foreseen in August 2010, using the EUDET telescope.

Test-beam requirements:

- For irradiation studies electron beams with currents between 10 and 100 nA and around 10–40 MeV energy are appropriate. Such beams are available, and used, at the sDALINAC at the Technical University in Darmstadt, and at the ELBE linac at Forschungszentrum Dresden-Rossendorf (FZD).
- For performance studies of fully assembled sensor planes the 4 GeV electron beam with a beam intensity of a few $10\,\mathrm{s}^{-1}$ seems sufficient. Such a beam is available at DESY. In 2010 two weeks are scheduled. Similar campaigns are planned in the following 3 years.
- Within AIDA the plan is to prepare a prototype of a calorimeter sector. To test its performance a electron beam with energies comparable with Linear Collider beam energies, as available e.g. at CERN, will be needed. This program is foreseen to start in 2012.

3.1.6 Summary on tentative sites and special Requirements

The beam test campaigns for the CALICE physics prototypes of will be conducted initially at FNAL in 2010 and continued at CERN in 2011. The natural preferred site for the beam tests to be conducted with the technological prototype is CERN since most of the R&D groups involved in these prototypes are based in Europe. As it is currently however difficult to predict fully the availability of the CERN facilities, FNAL remains a serious option for a test beam site. The prototypes of the CALICE collaboration will not need a dedicated ILC like beam structure. Rather it is desirable to obtain beams with a relatively long flat top with an intensity of not much more than 1000 Hz Such a configuration would reply to the layout of the front end electronics which is designed for low occupancy. The validation of the power pulsing technique will however need the availability of a large bore magnet with a field strength between 3 and 5 T. In addition beam telescopes with an excellent point resolution should be part of the beam line equipment.

Test beams with the prototype of the SiD Ecal will initially be conducted at SLAC with the option to move to FNAL for beam tests with hadrons. The design of the front end electronics for this prototype renders highly desirable the availability of an ILC like beam structure. Low rate beams are mandatory.

Test beams with the dual readout technique will be continued at CERN in the coming 2-3 years. Here, hadron beams up to the highest energies will be needed. In the coming years the forward calorimeters will concentrate on irradiation tests with low energy but high intensity electrons beams or electrons beams in the few GeV range. These beams are available at

Darmstadt, Dresden and DESY.

`Integrate summary from Muons`

Calorimeter	Date	Type	Requirements	Test Beam
RPC DHCAL m^3 (φ)	$\geq$ mid 2010	All types	$< 200\,\mathrm{Hz}$	FNAL
Combined TB		High E		FNAL
GEM DHCAL (φ)	$\geq$ 2011	low E e, μ, π	—	FNAL
µM, RPC layers	2009 $\rightarrow$ end 2010	low E e, μ, π		CERN (FNAL)
SDHCAL m^3 (τ)	$\geq$ end 2010	All types	$< 200\,\mathrm{Hz}$ or ILC like	CERN (FNAL)
CALICE AHCAL (τ)	$\geq$ 2012	e (all E), low E π	$\leq 0.2\,\mathrm{kHz}$ or ILC like	CERN (FNAL)
CALICE ECALs (τ)	$\geq$ 2011	e (all E), low E π	$\leq 0.2\,\mathrm{kHz}$ or ILC like	CERN (FNAL)
Combined CALICE (τ)	$\geq$ 2011-2012	All types	$\leq 0.2\,\mathrm{kHz}$ or ILC like	CERN (FNAL)
			$> 3\,\mathrm{T}$ magnet, telescope	
W HCAL structure	$\geq$ '10	All types; Combined TB	—	CERN
SiD SiW ECAL	$\geq$ '11	e 5–10 GeV SLAC (DESY)	beam localisation	
		low E e, π (FNAL)	ILC like (0,1,2 e/Bunch)	FNAL
DECAL	$\geq$ 2011	e (all E)	large XY table	CERN & DESY
SiD Muons	$\geq$ 2011	High E had.	—	FNAL
		Combined test		FNAL
FCAL	$\geq$ 2010	high E electrons	telescope	CERN, DESY
		low E electrons		FZD, TU Darmstadt
Dual	2010–2013	High e. had (CERN)	—	CERN

Table 3: Prototypes (φ and τ refer respectively to Physics and Technological CALICE prototypes), date of first test beam operations, run types & constrains, estimated time.

Group	Technology	Goals	Test Beam
SID Tracking	Multi-metal strips + KPIX Chip	SID Outer Tracker	FNAL
DEPFET	Depletion mode FET	Belle-II, ILC Vertex	CERN
MIMOSA	CMOS MAPS development	ILC Vertex	DESY, CERN
SPYDR	CMOS MAPS, deep n-well	Tracking and Vertex	?
3D	3D detector/electronics integration	ILC Vertex	FNAL
APSEL	CMOS MAPS triple well, 3D	ILC Vertex	CERN
CAPS	CMOS MAPS + SOI	ILC Vertex, Belle 2	FNAL
Thinned MAPS	CMOS MAPs thinning	ILC Vertex, RHIC	FNAL
SiLC	Silicon Strips	ILC (ILD) Tracking	CERN
FPCCD	Fine Pixel CCD	ILC Vertex	KEK?
ISIS (LCFI)	CCD with in-pixel storage	ILC Vertex	?
CPCCD (LCFI)	Column-parallel CCD	ILC Vertex	?
Chronopixel	CMOS MAPS	SID Vertex	?

Table 4: Overview on the projects and testbeam plans of the various groups working on Silicon Tracking and Vertex Detection. The ILC tracking and vertex detector reviews include a more comprehensive review of the efforts of the different R & D groups.

3.2 Silicon Tracking (4 pages - M. Vos, R. Lipton, T. Nelson)

Silicon-based tracking and vertexing is continuing to develop over a broad front. Silicon tracking detectors are well-placed to take advantage of rapid development in silicon technology. These new technologies need to be developed, tested, and validated in test beams. Some technologies, like the DEPFET have already demonstrated resolution less than 5 microns and require high momentum beams and sophisticated telescopes to make proper measurements. In parallel tracking detectors are testing larger and more realistic ”ladder” designs and will need realistic infrastructure such as pulsed power, ILC-like beam structure, magnetic field, and low mass supports.

There is a broad range of work on vertex and tracking technology. Table 4 summarizes some of the technologies being studied for the ILC tracker and vertex detector.

3.2.1 Beam Properties and Structure

The ILC has a very distinct time structure, with a train of 2820 bunches separated by 337 ns followed by a $\approx 1ms$ gap. Such a structure is difficult, but not impossible to mimic in a test beam. Depending on the application, the ILC structure could be mimicked by appropriate trigger electronics or offline analysis. How well this works depends on the details of the detector integration time, time stamping ability, and saturation effects. Many aspects of pulsed powering could be tested independent of beam conditions. History has shown that detailed tests in an environment as close as possible to actual operation are invaluable

Other beam properties are also important. High energy beams are the only way to unambiguously test detector resolution with minimal multiple scattering. However lower energies are also important to quantify the scattering and validate Monte Carlo models of the detector response. Beams should be able to simulate the rates seen at the inner radius of the vertex detector.

Two-track resolution needs to be studied, both for normal and for glancing incidence. This can be done in a high rate beam, using multiple tracks which pass through the detector within the integration time, or by a secondary target which mimics the interaction vertex. In the case of a secondary target all relevant tracks in the event need to be reconstructed. The momenta also probably have to be measured. This makes for a much more complex setup with a significant magnetic field.

3.2.2 Beam Instrumentation

A high quality beam telescope is needed to determine the reference position of the charge particle track. For an unambiguous measurement of the spatial resolution of the device this position must be precisely predicted. Especially for state-of-the-art vertex detector technology this latter requirement poses a severe challenge, requiring sub-micron pointing precision.

Traditionally, much effort of the R & D collaborations is devoted to the construction of precise beam telescopes. The EUDET project [1] offered a precise telescope [6] based on MIMOSA monolithic active pixel detectors, hardware to synchronize devices under test and telescope to the trigger signal, a flexible DAQ environment. This infrastructure has attracted a large user community [7].

In AIDA [2] this common infrastructure will be continued and extended. A flexible telescope, combining the precise and thin MIMOSA sensors with fast ATLAS hybrid pixel detectors and/or time-stamping TimePix devices will be built. A CO_2 cooling system will be provided for the test of large-scale prototypes and irradiated devices.

Future applications require devices that combine performance (resolution, read-out speed) with an extreme control of the material in the tracking volume. As more transparent devices are developed the mechanical and thermal design becomes more and more challenging. To characterize the thermo-mechanical properties of prototypes under realistic powering and cooling conditions, a second infrastructure will be developed in AIDA.

Finally, silicon μ-strip detectors will be installed in front of the highly granular calorimeter infrastructure, described in section.... These layers aim to provide a precise entry point, thus aiding the analysis of overlapping showers.

A flexible readout system will also be important for testing the large variety of devices being brought to the beams. One example is the CAPTAN system [8, 9, 10], developed by FERMILAB, and designed a a flexible, FPGA-based readout system for a variety of devices. To date the CAPTAN has been used to read out the BTeV FPIX chip, the CMS pixel chip, the VIKING strip chip, and will be used for the VICTR CMS track trigger chip.

The ALIBAVA system [11] provides a flexible read-out system for μ-strip dectors. Originally developed for the read-out of (irradiated) test structures and small-scale devices (so-called *baby* detectors), the system is being upgraded to allow multi-module operation with an external trigger, suitable for test beams. A prototype sensor is wire-bonded to a board that includes a Front-End chip (the Beetle of the LHCb VELO detector) and all the ancillary electronics to read-out and control the Front-End. The system is controlled from a PC through a standard USB connection.

Small area trigger can be provided by a version of the VICTR chip, which has a array of 64 $1\,\mathrm{mm} \times 100\,\mu\mathrm{m}$ strips with a fast output and maskable pixels. The chip is designed (for LHC upgrade triggering) for a coincidence with a second detector 1-2 mm away.

3.3 Gaseous Tracking (2 pages - T. Matsuda)

Physics at the International Linear Collider (ILC) or the Compact Linear Collider (CLIC) will require a detector of high precision. A tracking system of the detector has to achieve a high momentum resolution $\delta(1/p_t)$ of a few 10^{-5} (GeV/c)$^{-1}$ [1]. This resolution surpasses by 10 times the best momentum resolution achieved by the experiments at LEP. The tracking system should also provide a high tracking efficiency down to a few GeV/c to ensure a good jet-energy measurement by the Particle Flow Algorithm (PFA) in an environment of high beam-induced backgrounds.

To meet with these requirements, a large Time Projection Chamber (TPC) with using Micro Pattern Gas Detectors (MPGD) is proposed as a central tracker of the International Large Detector (ILD) [2]. The ILD TPC is to be located in a large superconducting solenoid of 3.5 T. It measures each track at 220 space points with an $r\phi$ spatial resolution of 100μm or better in the whole drift volume of 2.2 m long. This performance of TPC is only achievable with the MPGD technology [3,4]. At this moment we consider three candidates of MPGD detectors; Bulk MicroMEGAS with resistive anode readout, GEM with narrow pad readout, and, in a somewhat longer time scale, a digital TPC with Ingrid TimePix or a semi-digital TPC using GEM readout by TimePix.

3.3.1 TPC R&D by the LC TPC collaboration

The LC TPC collaboration has been carrying out R&D of the MPGD TPC for ILC (ILD) in three stages;

1. Demonstration phase.
2. Consolidation phase.
3. Design phase.

At each phase for the last several years, we have performed a multitude of beam tests.

In the demonstration phase (2004-2007) a basic evaluation of the properties of the MPGD gas amplification was made, demonstrating that the requirements for the linear collider (ILD) could be met. For an example, we have shown though a beam tests of small TPC prototypes that the $r\phi$ space resolution of 100 μm could be

possible both by MicroMEGAS with the resistive anode readout and GEM with the narrow pad readout [?].

In the current consolidation phase (2007-), we have been successfully operating a TPC Large Prototype 1 (TPC LP1) at a low energy electron 5 GeV/c test beam at DESY, T24-1. The goals of the LP1 beam test are to confirm the results from the demonstration phase for a larger scale TPC [?], and to show that the excellent momentum resolution is actually achievable for the LC TPC. In 2010 we plan to perform beam tests with the LP1 endplate which will be equipped with four to seven MPGD modules, and we have been developing a new TPC tracking code for non-uniform magnetic field. In this phase, in addition to the development of the different MPGD TPC readout modules, we also study basic engineering issues for the LC TPC. Good examples are the construction of a thin LP1 field cage and the development of a low noise, high-density TPC pad readout electronics using S-ALTRO.

And we are now entering the design phase (2010-) where we work for a basic conceptual design of the LC TPC.

3.3.2 LC TPC R&D and Beam Tests in 2010-2012

In the design phase of 2010-2012, beside the overall design of the LC TPC, we have two major hardware R&D issues; (a) a design of a TPC endplate of the thickness of 15% radiation length or less, and (b) a choice of the ion gating device. We have started our study of a light mechanical structure of the TPC endplates, and also the so-called advanced end-plate TPC modules with power pulsing and an efficient cooling such as the two-phase CO2 cooling. We plan to build a new LP1 endplate structure mounted with the advanced TPC modules with S-ALTRO (and also modules of the digital TPC), and test it in a test beam for the ILD-DBD (Detail Baseline Design) in 2012. For this R&D phase we have not yet a full scope of funding. In 2011, we plan to modify the magnet PCMAG to make it a superconducting magnet without liquid He supply. The modification will take about 6 months.

3.3.3 Test beam before 2012 and the ILC beam structure

In the current prospect of our R&D budget and support, and in the situation where the availability of a higher energy hadron test beam in 2011 seems to be not very clear, we plan that our TPC LP with PCMAG stays at the T24-1 beam line at DESY until to the end of 2012. We may perform some optional and small scale beam tests at high-energy hadron test beams and in a higher magnetic field using small prototypes.

At the DESY test beam, there is no plan to simulate the ILC beam bunch structure. We plan to test the power pulsing of the advanced TPC modules with the beam without the ILC bunch structure. We think that we do not really need beam to test the power pulsing. The functional test of the power switching of the advanced TPC modules in a higher magnetic field will be necessary. To demonstrate how our ion gating device works, we may need a proper device, either a laser or a flash lamp, to simulate beam backgrounds at ILC according to the beam bunch structure.

3.4 Data Acquisition (2 pages - M. Wing)

In general, for a given ILC sub-detector, a dedicated data acquisition (DAQ) system is developed to suit its needs, depending on a multitude of technical issues such as data rates, number of channels to read out, etc.. The DAQ system consists of the hardware—various electronics boards using various standards to get the data from the detector head to a PC—and software to control the flow of data from the detector and commands to the detector. The requirements can then lead to a DAQ system which is conceptually new or is strongly based on an existing system in use for another detector; both of which are reasonable approaches. This therefore results in very different systems when developed in isolation as is the case for several of the ILC sub-detectors; a brief review of some of the systems is given below.

Were sub-detectors to continue in isolation a programme of verification in a beam-test, then bespoke development is a sensible approach. However, should any sub-detectors wish to have combined beam-tests with another sub-detector, then more thought and planning is needed. Therefore any issues with regard to DAQ systems depend crucially on whether combined beam-tests of several sub-detectors will happen. Alternatively, given extra resources such as those provided by the AIDA project, a common approach to DAQ systems can be pursued now such that a final system for a final ILC detector will be easier to manage and integrate when it becomes a reality. Careful planning now could lead to significant benefits, with reduced risk, in the future. As a DAQ system serves a given sub-detector or detector, it is not a driver for individual or common beam tests which is dictated by the detectors themselves. As a separate goal, more generic aspects of DAQ system can be developed for future sub-detector use which will save on effort in the long-run.

3.4.1 Example DAQ systems

CALICE DAQ

Most of the focus for the new CALICE DAQ system has been on the hardware development and firmware to control it [20, 21]. The system consists of several layers of concentrator cards to get the data from the detector head to a PC and storage. Given that the CALICE programme includes several different types of calorimeter, the first layer of electronics needs to convert the sub-detector-specific data into a generic structure which is then passed to the next layer. As such, the hardware system needs to be suitably generic and could in principle be used for various sub-detectors and not just calorimeters. The DAQ and slow control software are less advanced. Initially the approach was to use existing software designed to cope with large-scale systems; the programmes DOOCS [22] and XDAQ [23] have been used so far. In light of possible combined beam-tests, a survey of available software is being performed.

EUDAQ system for vertex and tracking detectors

A DAQ system developed to read out the EUDET [1] pixel telescope has been developed [24, 25]. The telescope is a relatively small-scale detector and is read out via a VME-based hardware system. Major effort has been invested in writing a flexible DAQ software framework, called EUDAQ, which has been successfully used for the pixel telescope in numerous beam tests. The code is written in `C++`, is freely available and was fully developed by the main authors. The software has been used by several other groups when performing beam tests in conjunction with the pixel telescope. Indeed the LC-TPC collaboration are using it for their work on a TPC sub-detector [26]. Any new sub-detector just needs to write a producer and the EUDAQ authors should be able to integrate on the time-scale of a few days.

3.4.2 Towards a common DAQ system

As sub-detectors will at some point be used together, say as a complete detector slice-test, the data will have to be merged at some point. The extremes are : to develop one data acquisition system, both hardware and software, which is able to read out all sub-detectors; or for sub-detector DAQ systems to all be developed in parallel and data merged at the final opportunity when it is stored. The former is unlikely given the various logistical problems whilst the latter is undesirable, potentially leading to wasted effort and a lack of coherency in the final data samples. The reality will lie somewhere in between with some common hardware used and even more so, common software. From the examples given above, the CALICE hardware could in principle be used for other sub-detectors, although this would have significant costs associated to it. The EUDAQ software may be a viable solution for CALICE calorimeters, although this needs to be demonstrated given its current use for a much smaller system. As DAQ systems for all sub-detectors are relatively well advanced, adapting to common solutions will require extra effort and will require e.g. the recent funding of AIDA to make it possible.

Taking a middle ground on common aspects of a DAQ system, some of the questions and issues which need to be addressed are listed below. These should be addressed in the AIDA project.

Common Hardware

Although the hardware used for the CALICE calorimeters and the CAPTAN [8] project are relatively generic and could be used for other sub-detectors, it is unlikely that such an approach is possible. However, there are various common items amongst the various sub-detector groups which could be used :

- Hardware which provides a trigger or a clock such as the Trigger Logic Unit [24] or Clock and Control Card [20] developed for the pixel telescope and CALICE calorimeters, respectively, could be used by all sub-detectors. These would uniquely identify each trigger.
- A proposed “Beam Interface Card” [21] could be used to monitor beam conditions taking data from e.g. scintillators, hodoscopes, etc.. Its exact form is to be designed.

Common Software

There are a multitude of DAQ software frameworks developed for previous or existing experiments. A critical review of these needs to be done :

- Large software frameworks such as XDAQ, DOOCS, TANGO [27], etc. have been developed with large-scale, diverse apparatus in mind. Presumably they then have the necessary functionality and flexibility to provide the framework for the ILC sub-detectors. This needs investigation and the various software compared;
- The EUDAQ software has been shown to work successfully with a number of different sub-detectors. However, its efficacy for reading out large systems such as the CALICE calorimeters, with thousands of channels, must be verified;
- Information needed to decide on the nature of the read-out path is the data volume, zero suppression, compression, data format etc.;
- It is generally agreed that all data should be converted into the common ILC offline software format, currently LCIO.

In summary, commonality between the DAQ systems of the various sub-detectors should be sought at an early stage so as to ease integration later. Given the funding of the AIDA project, this will give support to this effort in which a critical review of current DAQ hardware and software is carried out leading to a more coherent framework for future ILC detector beam tests.

3.5 Software (2 pages - F. Gaede, N. Graf)

Software development for ILC test beam experiments has a large potential for collaboration, as typical computing tasks in high energy physics event data processing have a high degree of similarity from experiment to experiment. For example every experiment needs a way to store and retrieve the conditions data, defining the experimental setup at the time of data taking. In order to avoid duplication of effort, most of the current test beam collaborations are already using a common set of core software tools. This desirable development has been greatly fostered by the EUDET [1] project during which already existing software tools have been improved and combined into a common framework, referred to as ILCSoft [28]. The same software framework is also used by the ILD detector concept, the CLIC detector working group and in parts by the SID detector concept. These groups work on the development and optimization of the global detector concepts, based on Monte Carlo simulations and results from the R&D test beams. Having a joint software framework thus provides synergies for both communities, as code and knowledge can be shared easily and provide for the necessary feedback of realism into the full simulation.

3.5.1 ILCSoft tools

ILCSoft is based on LCIO [29], which is a persistency file format for ILC studies and defines a hierarchical event data model for full detector simulation and dedicated raw data classes for beam test experiments. The core of the ILCSoft framework is defined by Marlin, a modular C++ application framework that uses LCIO as its transient and persistent event data model. Marlin is complemented by a number of software tools: GEAR which provides the high level view other detector geometry and materials as needed during reconstruction and analysis, LCCD a conditions data toolkit that provides access to the conditions data and CED a fast 3D event display. The simulation of the detector response is performed in the geant4 application Mokka [30]. The geometry description in Mokka is interfaced to GEAR for reconstruction and analysis. Fig. 1 shows an overview of the main tools used in ILCSoft. The core framework is completed through a number of auxiliary tools, such as RAIDA for histograming and the utility package MarlinUtil and depends on a small set of external packages like ROOT, gsl and CLHEP.

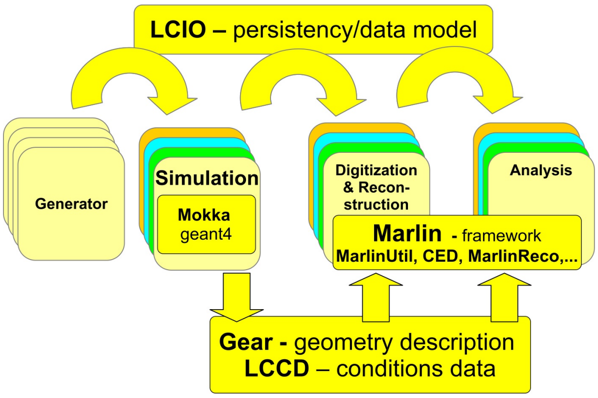

Figure 1: Schematic overview of the ILCSoft framework tools.

The following planned developments and improvements for LCIO are currently ongoing:

- direct access to events
- splitting of events and partial reading of event data
- streaming of user defined classes

Using ROOT I/O for the implementation of these new features is under investigation. Another area of possible improvement is the geometrical description of the detector. While the current system ensures one leading source of the geometry, the Mokka simulation, it could be made more flexible by having a standalone tool that feeds into simulation, reconstruction and event displays. The development of such a flexible system is foreseen in the proposed AIDA project. This would also include mis-alignment and integration with conditions data as the distinction between geometry and conditions data is not always perfectly well defined.

3.5.2 Calice and LC-TPC Software

The Calice collaboration was the first test beam group to adopt the ILCSoft framework. Calice has been using the complete framework for their past data taking campaigns and provided very useful feedback that led to the improvement of the software tools in particular in the context of the EUDET project. Calice is not using LCIO as their raw data format, but are converting their data to LCIO within hours of the data acquisition. This 'duplication' of raw data has proven to be less than optimal and having one raw data format only would be desirable for future beam tests [32].

Also LC-TPC was an early user of the common core software tools. They are currently working on completion of their reconstruction and analysis package MarlinTPC [33]. In that process they improved the geometry description of the TPC in GEAR in order to meet the requirements. An example for the fruitful interplay between core software group and users. LC-TPC also suggested improvements for LCCD, namely to store the conditions data in data base tables, that can be queried using MySQL tools.

3.5.3 Grid computing

Large computing resources for high energy physics data processing will be available only on the Grid. All the test beam data that has been accumulated so far is stored on Grid storage elements and major Grid sites did provide so far sufficient computing resources for their analysis. This was partly facilitated due to the delay of the LHC, for which massive resources had been allocated. With the LHC now running it is important to make the Grid sites aware of the computing needs of upcoming ILC beam tests so that they can plan accordingly.

3.5.4 Remote control and communication tools

Besides data analysis software for beam tests, control and communication tools are an important aspect that can foster collaboration and reduce travel expenses. A nice example is the Calice control room that was recently set up at DESY [31] and is fully functional from the start. This room was realized for comparatively small budget, that paid off in a short period of time through savings in travel cost.

With improvements in audio and video technologies, increased band widths and lower cost, modern communication tools and remote control centers will become more widespread and are likely to change the way experiments are run.

4 Sites (4 pages - F. Sefkow, J. Yu, K. Kawagoe, V. Vrba

4.1 CERN - by L. Linssen

CERN offers a broad range of test beam facilities with beams originating both from the Proton Synchrotron (PS) and Super Proton Synchrotron (SPS) accelerators. At the CERN PS East Hall, there are two test beam lines, T9 and T10, delivering hadrons, electrons and muons of up to 15 GeV/c and 7 GeV/c momentum respectively. During a spill length of 400 ms, occurring typically every 33 s, up to 106 particles can be delivered. Recent studies have indicated that an ILC-like beam structure can be produced at the PS. In the SPS North Area hall EHN1 there are four test beam lines (H2, H4, H6, H8) with several experimental areas each. The H2, H4 and H8 lines can provide secondary hadrons, electrons or muons of up to 400 GeV/c or primary protons of up to 450 GeV/c. The H6 line has a maximum momentum of 205 GeV/c. Up to 2×10^8 particles per spill can be delivered. Spill lengths vary from 4.8 to 9.6 s, while spills are repeated every 14 to 48 s, depending on the number of SPS users. Together with the beams themselves, CERN provides some adjacent infrastructures, such as basic beam instrumentation. These comprise beam spectrometers for precise momentum definition, wire chambers to measure beam profiles, as well as threshold Cherenkov counters and Cedar counters for particle ID. On request a scanning table can be provided and some beam lines are equipped with magnets, which can surround the equipment under test. In 2010 the PS and SPS are scheduled to provide 28 weeks of beam. Since many years, the CERN test beams have been used extensively by the linear collider detector community. This tradition continues. In 2010 a total of 28 days are scheduled for linear collider-related tests at the PS T9 beam, 34 days at the SPS H4 beam and 48 days at the SPS H6 beam. The linear collider users represent several CALICE HCAL technology tests, SiLC tests and various vertex technology tests. For the following years, the PS and SPS test beam schedules are expected to have some dependency on the LHC schedule, with most likely a similar availability of test beams in 2011 and potentially a somewhat shorter duration in 2012. Users have two ways to apply for beam time. For short beam tests, ¡2 weeks at the PS or ¡1 week at the SPS, requests are addressed directly to the SP/SPS coordinator (sps.coordinator@cern.ch) by submitting a form. These requests are normally collected towards the end of the year for the following year. For beam tests of longer duration a formal request has to be addressed to the SPSC committee. Some user groups have semi-permanent test beam installations. Examples are the CMS experiment in the H2 line, the ATLAS experiment in the H8 line and the RD51 collaboration in the H4 line. Following approval by the SPSC, these installations have been built up through a common effort by the collaborations involved. What concerns the linear collider activities, the establishment of semi-permanent ILC beamline at CERN, should be requested latest by mid-2010 in order to have it available by middle of 2011.

4.2 DESY - by F. Sefkow

DESY provides three electron test beam lines with an energy range from 1 to 6 GeV. The beams are produced at the DESYII synchrotron which mainly serves as injector for the DORIS and PETRA accelerators and has typical up-times of 10-11 months per year. The high availability and flexible scheduling - related to intensive in-house use - are major assets of these facilities. The beam is delivered in short 30 ps bunches every 160 or 320 ms, with typical event rates of 1 kHz. All beam lines are equipped with pre-installed cables, fast networking and installations for pre-mized gases. Moving stages, gases magnets and beam telescopes can be provided upon request, while users in general bring their own DAQ and trigger hardware. In the previous years, the infrastructure has been considerably enhanced in the framework of the EUDET initiative. The refurbished are T21 hosts the EUDET pixel telescope, while the upgraded ZEUS telescope serves users in T22. The super-conducting PC magnet provides a field of 1 T in a bore of 0.85 m. With no iron yoke, its thickness corresponds to 0.2% X_0 only. It is presently installed in T24 and heavily used for TPC R&D (see Section 3.3). Following an exceptionally extended winter shutdown, the machine is running since march 2010 throughout 2010 and is expected to have high availability also in the forthcoming years. Users can apply for beam time through the DESY test beam co-ordinators. More information is available under `testbeam.desy.de`.

4.3 Further European Sites - R. Pöschl

The IHEP at Protvino in Russia provides electron beams between 1 and 45 GeV as well as hadron beams in this energy range. The sire is available for two months in winter time. The beam test facility at Dubna, Russia, provides neutron beams with a good yield. It remains to be discussed how these facilities can be incorporated into the beam test program for Linear Collider detectors.

Other sites offering beam test facilities in Europe. These are PSI Villingen (CH), GSI Darmstadt (D), the ELSA beam at Bonn (D) as well as the FZD at Dresden-Rossendorf (D). Some of these were used in the past or will be used in upcoming beam test campaigns.

4.4 FNAL - Erik Ramberg

Crucial to many detector development projects is the ability to test real life operations of the device in a high energy particle beam. Only a few such facilities exist in the world. The United States' only high energy detector test beam facility is the one at Fermilab. The Meson Test Beam Facility (MTest) gives users from around the world an opportunity to test the performance of their particle detectors in a variety of particle beams. A plan view of the facility is shown in Figure 2. The web site for the MTest facility can be found at `http://www-ppd.fnal.gov/MTBF-w/`.

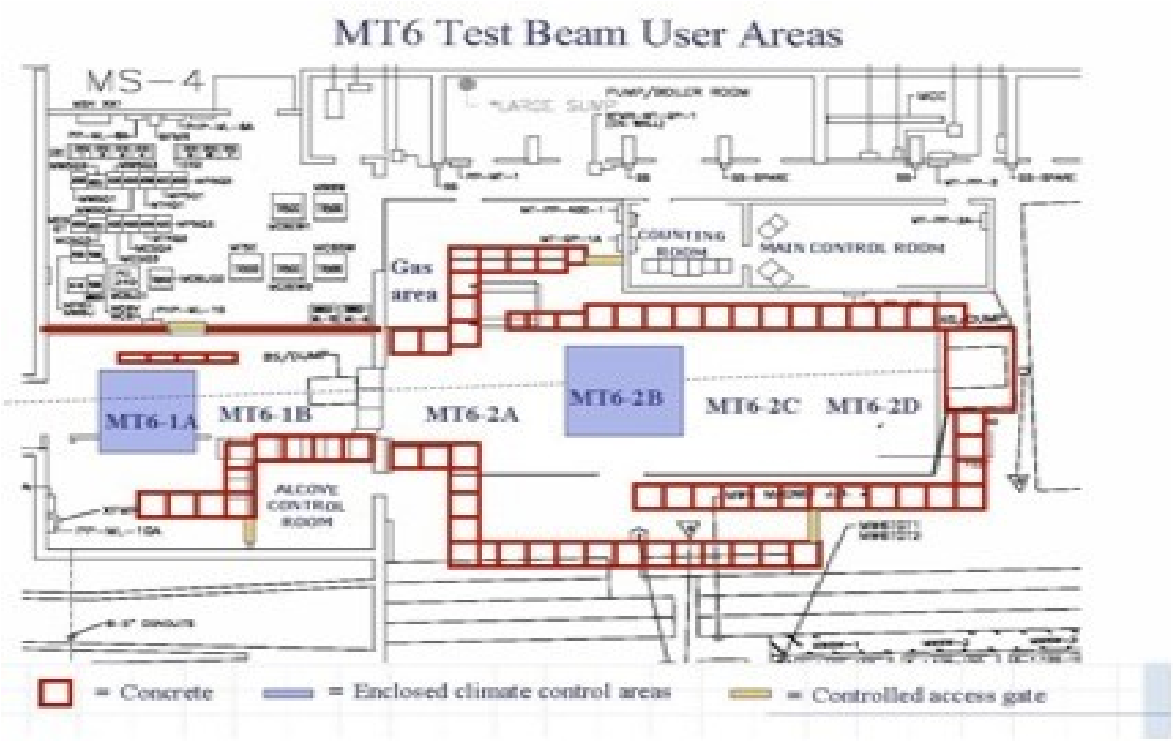

Figure 2: *Plan view of the Meson Test Facility at FNAL.*

4.4.1 Details of the beam

The test beam originates from the resonant extraction of at least one Booster batch inside the Main Injector (MI). This batch usually consists of 10-60 RF 'buckets', with buckets separated by 19 ns. Thus the batch is anywhere from 0.2-1.2 μs long. The batch is accelerated to 120 GeV, circulates around the MI, and is slowly extracted over a macroscopic slow spill using a resonant quadrupole called QXR. The full circumference of the MI is about 11 microseconds, giving a large gap between extractions. The length and duty cycle of the spill is determined by the Accelerator Division (AD), with guidance from the Office of Program Planning. For most operations there is a single 4 second long spill per minute, for a maximum of 14 hours per day. The AD has setup a procedure for easily changing from this 4 second spill to a 1 second spill. This shorter spill can then be delivered more frequently for commissioning purposes and for those groups who are data-acquisition buffer limited. The AD has also commissioned a "pinged" beam operation where beam is extracted using a pulsed operation of the QXR, with up to 4 pings per spill, each with a tunable width from 1 to 5 ms. The 120 GeV proton beam has an approximate 0.3% momentum spread and can be focused to a 7 mm RMS spot size in the user area. In addition to delivering primary protons, there are two targets on movable stages that can act as secondary beam production areas. The magnets downstream of those targets can then be tuned to deliver any secondary momentum from 0.5 GeV to 60 GeV. The momentum spread of these secondary beams depends on the energy and the details of the collimation and can range between 1-10%, with the poorer resolution beam occurring for the lower momenta. The physical size of the beam is approximately 2-5 cm rms for the lower momenta. The Table 5 shows the rate of beam delivered to the user area for some selected momenta.

Beam Energy/GeV	Rate at Entrance to MT6 (per spill)	Rate at Exit to MT6 (per spill)	% π/μ at Exit of MT6
16	132000	95000	82%
8	89000	65000	42%
4	56000	31000	26%
2	68000	28000	$< 20\%$
1	69000	21000	$< 10\%$

Table 5: Rate of beam delivered to the MT6 user facility for 1 × 1011 protons in the Main Injector. Remainder of beam is identified as electrons.

As part of the improvement in extending momentum range of the beam line, the MINERVA experiment (T977) proposed to install an entire new tertiary beamline in the user facility so that it can deliver 300 MeV/c pions onto their test apparatus. This beamline was begun in the US FY2008 and has recently been completed. After the completion of the MINERVA tests, this beamline will be available for other users. The target and collimator can be rolled quickly aside so that the facility can operate normally.from them as well.

4.4.2 The future of test beam at Fermilab

The Meson Test Beam Facility will be in operation for the foreseeable future, since it has demonstrated a wide variety of modes of operation. Because the facility is in heavy use, it is likely that additions and upgrades to the equipment at MTest will be incremental, with no large update at any given time. In addition to the Meson Test beamline, Fermilab will be starting a new test beam facility in the Meson Center beamline. This facility will be known as the Meson Center Test Facility, or MCenter, and will be used as an adjunct to the MTest facility. The two beamlines are virtually identical, while the user areas are complementary. While the MTest facility has a large variety of user installation areas, and a crane to support them, the MCenter facility is tighter, but has two spectrometer magnets that could be used for a variety of calorimetry studies. Currently the MIPP experiment's apparatus occupies the downstream location in MCenter. This apparatus could be used to perform tagged neutron studies, as well as support tracking for more advanced installations. With the help of a thin target a ”jetty” environment could be mimicked for future testbeams. Fermilab has begun efforts to provide for a user facility in MCenter to support detector R&D. With a very successful MTest beamline, and a second MCenter beamline to augment it, then Fermilab's test beam facilities will remain in the forefront of detector support in the United States for quite some time.

4.5 SLAC - Carsten Hast

End Station Test Beam (ESTB) is a approved and funded SLAC project to use a small fraction of the 13.6 GeV electron beam from the Linac Coherent Light Source (LCLS) to restore test beam capabilities in End Station A (ESA), as shown in the schematic diagram in Figure 3. Four new kicker magnets will be installed in the Beam Switch Yard (BSY) to divert 5 Hz

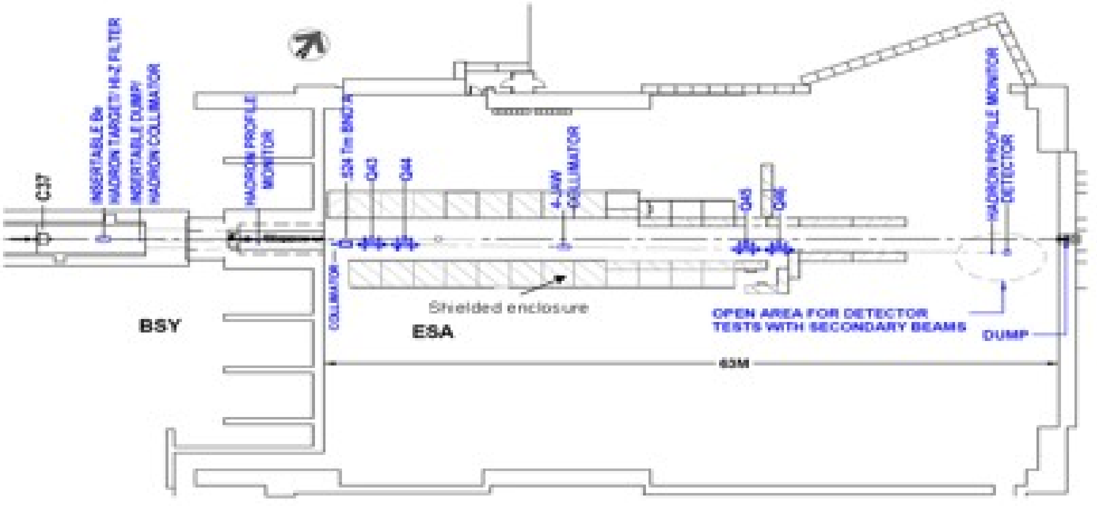

Figure 3: *End Station A Facility configuration. Primary beam experiments will be conducted along the primary beamline inside the shielded enclosure. The primary beam terminates in the beam dump shown in the ESA east wall. Secondary beam tests for detector studies will take place in an open region at the end of ESA. The proposed hadron beamline components and the new beam dump are shown in blue, overlaid onto the existing ESA setup.*

of LCLS beam to the A-line. This beam can be transported all the way to ESA for beam instrumentation and accelerator physics studies at full electron beam intensity. Alternatively, it can be directed against a thin screen in the A-line, to produce secondary electrons or positrons with energies up to the incident energy, and a wide range of intensities including single particles per pulse suitable for detector studies. The installation of a secondary hadron target and a hadron beam line in ESA is a possible upgrade for 2011. This beam will produce pions and kaons over a broad range of momenta, suitable for particle physics and astrophysics detector development or calibration in ESA. Besides the four new kicker magnets, a new Personnel Protection System (PPS) and a new beam dump in the ESA East wall need to be installed. For the hadron target a new beam line with bend and quadrupole magnets and acceptance collimator needs to be designed and installed. The ESTB is a unique resource in all of High Energy Physics for studies requiring high energy, high intensity, low emittance electron beams in a large experimental area. These studies include accelerator instrumentation, linear collider accelerator and machine-detector interface (MDI) R&D, development of radiation-hard detectors, material damage studies, and astroparticle detector research. As summarized in Table 6, ESTB also provides moderate energy (E=13.6 GeV) secondary beams of electrons and hadrons for detector R&D. Electron beams of exceptional purity, momentum definition, and small size can be delivered. The time structure of the test beams is that of the SLAC linac, and is unique in delivering picosecond pulses at known times. This makes triggering and data collection very convenient at ESTB. A tagged photon beam could also be provided. At a later stage pions are available up to about 12 GeV/c at an intensity of 1 particle/pulse, and kaons at a 1/10 of the pion rate. ESTB utilizes the existing ESA, a large experimental hall 60 meters in length with 15 and 50-ton overhead cranes and excellent availability of utilities, cable plant, and components for mounting experiments. ESA is ideal for detector development and testing large scale prototypes or complete systems with high energy particles. Figure 4 shows the secondary particle yield per LCLS beam intensity in nC as a function of secondary particle energy. Funding for the four kicker magnets, new beam dump and a new PPS system is available in early 2010. We have already started with designs. The biggest task is the new PPS for ESA, where we expect the completion in early 2011, after which operation can commence. Funding for the hadron beam line is expected through 2011.

Parameters	BSY	ESA
Energy/GeV	13.6	13.6
Repetition Rate/Hz	5	5
Charge per Pulse/10^{10} nC	0.15-0.6	0.15-0.6
Energy Spread, $\sigma/_E E$	0.058%	0.058%
Bunch length, rms/**m ???**	10	280
Emittance, rms$(\gamma\epsilon_x, \gamma\epsilon_y)/10^{-6}$ mrad	1.2, 0.7	4, 1
Spot Size at waist, $\sigma_{x,y}/$ µm	-	10
Momentum Dispersion, η and η'/mm	-	< 10
Driftspace available for experimental apparatus/m	-	60
Driftspace available for experimental apparatus/m	-	5×5

Table 6: *ESTB primary electron beam parameters and experimental area at the BSY and in ESA.*

4.6 Asian Facilities - by K. Kawagoe

There are several low energy testbeam facilities in Asia, where test of small units can be performed.

4.6.1 J-PARC

The 50 GeV proton synchrotron started its operation at 30 GeV in 2009. In the hadron physics facility, there are several beam lines. The K1.1 beam line will be available in 2010, where hadrons with momentum 0.5∼1.1 GeV/c and good enough particle yields are available . This beam line can be used for testbeam experiments until preparation of the main experiment at K1.1 is started. The K1.8BR beam line is dedicated to the testbeam experiments, and hadrons with momentum 0.5∼1.5 GeV/c are available. This beam line also will be ready in 2010. However, the particle yields are expected to be very low at the begininng to be used for the experiments. until the intensity of the proton syncrotron becomes close to the design value (100 MW).

4.6.2 KEK

FTBL (Fuji Test Beam Line) utilizes synchrotron photons radiated from KEKB electron beam to make electron beams with momentum 0.4∼3.4 GeV/c. FTBL has been used for many testbeam experiments, including ILC activities, since FTBL started its operation in 2007. FTBL is not curently available because of the shutdown (2010∼2012) for the upgrade of KEKB. ATF (Accelerator Test Facility) for the ILC can be in principle used for testbeam activities. The electron beam with momentum 1.4 GeV has a bunch strucure (2.8 ns). and the particle yield is 10^{10}/s.

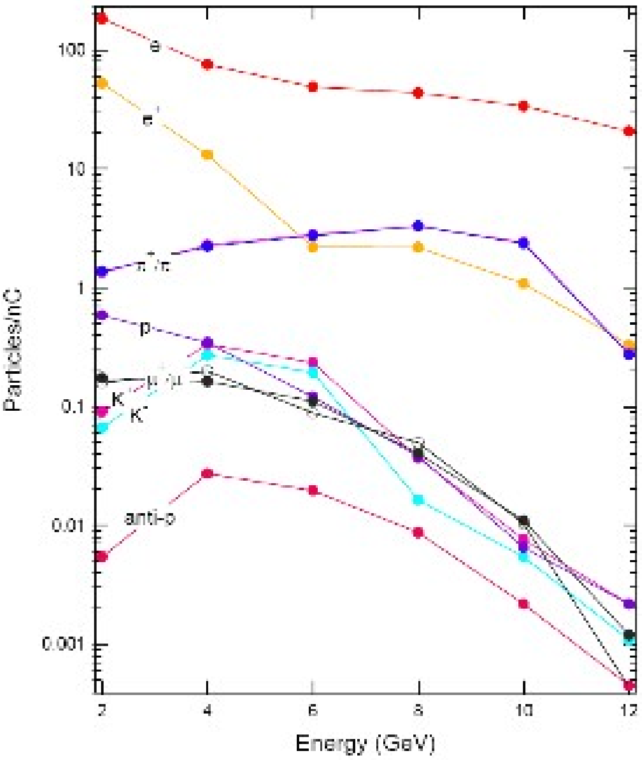

Figure 4: *Secondary particle yields in ESA per nC of LCLS beam incident on the 0.87 r.l. Be target. The production angle is 1.50 degrees, the acceptance is 5?sr, and the momentum bite* $\Delta p/p = \ 1\%$*. LCLS beam energy is 13.6 GeV. For expected operating conditions, the yields at the end of ESA are roughly a factor of 4 lower.*

4.7 IHEP, Beijing

BTF (Beijing Testbeam Facility) provides primary electron beam with momentum 1.1∼1.5 GeV/c and secondary beams with momentum 0.4∼1.2 GeV/c. BTF is now under a long shut down (2008-2010) for its upgrade.

4.8 Tohoku LNS

Laboratory of Nuclear Science (LNS) at Tohoku University in Japan has a testbeam facility providing electrons with momentum 300 MeV/c and 1.2 GeV. The availability of the facility is very high.

5 Permanent Beam Lines and Combined Testbeams (2 pages - R. Pöschl, G.Fisk)

The establishment of beamlines mainly dedicated to Linear Collider Detector R&D has been an important topic at the workshop. In general it is felt that the establishment of those beam lines would lead to important synergies. This leads from practical issues like "knowing where the trigger counters are" to the possibility to install infrastructural components like communication services at the beam test sites. The main advantages of permanent beam lines are listed in the following

- The use of a permanent beam line will allow the sharing of experience with the usage of a beam line. Hence, the data taking can be much more efficient as the sometimes tedious period of getting up and running can be much shorter.
- The existance of a permanent beam line would foster the development of common DAQ interfaces which after all would also facilitate the data taking a lot. This can go as far that manning of shifts can be shared by different detector types, simply because the interfaces to the detectors are familiar. This in turn safes travel money and man power. Clearly, it has to be made sure that in particular young students can still be trained at beam test sites.
- A permanent beam line will facilitate a situation in which one subsystem is the main user while another one acts as a secondary user to e.g. take calibration data or for long term studies. A general familiarity with a given beam line would render such a configuration much easier and allows for flexible switches between detector components if circumstances demand it.
- A common remote control system may allow for data taking even if no expert of a subsytem is on-site. This clearly has to be coordinated with safety aspects of the various beam test sites.
- A permanent beam line would naturally lead to a mutual better understanding of other detector components. The fact that a common DAQ system at an early stage may facilitate the system integration in the real detector is also not to be underestimated.

In order to underline the need of permanent beam lines, beam requests could be transmitted to sites in a coordinated way by the spokespersons of the detector R&D collaborations at given dates in a year. By that, several requests from the community arrive at the same time which may naturally lead to an assignment of only a few beam lines to the requests. The placing of the requests to the sites will be preceeded by a brief meeting of the spokespersons in order to have an idea of schedules which could then also be streamlined. The step to a common request is not that long in that case. A short meeting on coming beam test activities will become a standing item at each LC workshop.

All beam test efforts will be monitored by a light monitoring system. In practice, this will be a simple date base where the groups enter the date and the purpose of the test as well as the beam line they use. This is a simple mean to facilitate communication beyond different detector system. It is very light weight and easy to implement at any computing centre (FNAL, DESY, CERN, CC IN2P3). The data base can be brought in operation during the summer/autumn of 2010.

Another question is whether the community should plan for combined beam tests, i.e. combining different detector technologies. The workshop could not identify a clear project of a major combined testbeam for the period 2010-2013. There are, however, occasions at which a combination at a smaller level seems to be feasible. Calorimeters for example need very often a good point resolution. This requirement is very much met by the EUDET Telescope. It could however be imagined that such a task can be realised by a Silicon tracking device conceived for Linear Collider Detectors

6 Conclusion, Outlook , Recommendations and Requests (1-2 pages - R. Pöschl, All)

This document witnesses the large amount of challenging activities in the R&D for Linear Collider Detectors. All proposed technologies need considerable testbeam resources in the coming 2-3 years. Given the fact that the "imminent" aim are the DBDs at the end of 2012, a high availability of beam test sites in the coming 2 1/2 is of utmost importance. In this sense the plans of the CERN and FNAL managements to shutdown the beam test areas in 2012 might bear a considerable risk for all the projects. Herewith the community formulates the clear request to maintain the facility open at least for the first half of 2012. Based on this document the community will be able to negociate with the management of the beam test sites to establish permanent beam lines. On the other hand the community is encouraged to exploit the wealth of available sites and prepare for alternatives if their "preferred" site is not available. The document indicates that availability is of larger importance than efforts for a dedicated ILC beam structure. If such a structure is however available this would be very welcomed by the community. The success of the R&D program depends crucially on the interplay between the community the laboratories running beam test facilities and the funding agencies in order to come to high quality results and well understood detectors.

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Appendix

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These persons may serve as a primary contact in case of additional questions on project plans and will establish the contact to the various groups.

References

[1] `www.eudet.org`

[2] `espace.cern.ch/aida`

[3] J. Yu and J.C. Brient edt., ILC Calorimeter and Muon Detector R&D Community. *International Linear Collider Calorimeter/Muon Detector Test Beam Program (A Planning Document for Use of Meson Test Beam Facility at Fermilab).* Fermilab-TM-2291 (2005)

[4] J. Yu edt., World-wide ILC Detector R&D Community. *Roadmap for ILC Detector R&D Test Beams.* Fermilab-TM-2392-AD-DO-E, KEK Report 2007–3 (2007), arXiv:0710.3353 [physics.ins-det].

[5] The CALICE Collaboration, "CALICE Report to the DESY Physics Research Committee". arXiv:1003.1394v2 [physics.ins-det] `http://arxiv.org/pdf/1003.1394`

[6] P. Roloff, *The EUDET high resolution pixel telescope*, Nucl. Instrum. Meth. A **604** (2009) 265.

[7] I. M. Gregor, *Summary of One Year Operation of the EUDET CMOS Pixel Telescope*, arXiv:0901.0616 [physics.ins-det].

[8] R. Rivera, *CAPTAN : Compact and programmable data acquisition node*, presented at LCTW09, November 2009, Orsay, France. `http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=3735`

[9] M. Turqueti, R. A. Rivera, A. Prosser, J. Andresen and J. Chramowicz, *Captan: A Hardware Architecture For Integrated Data Acquisition, Control, And Analysis For Detector Development*, FERMILAB-PUB-08-527-CD

[10] R. A. Rivera, M. Turqueti and L. Uplegger [USCMS Collaboration], *A Telescope Using CMS PSI46 Pixels and the CAPTAN for Acquisition and Control over Gigabit Ethernet*, FERMILAB-CONF-09-575-CD

[11] Marco-Hernndez, R. and ALIBAVA Collaboration, *A portable readout system for microstrip silicon sensors (ALIBAVA).* IEEE Transactions on Nuclear Science, Vol. 56, No. 3, June 2009.

[12] *First results from electron data with the CALICE tile AHCAL prototype at the CERN test-beam*, CAN-002.

[13] F. Simon [CALICE], *Track Segments in Hadronic Showers: Calibration Possibilities for a Highly Granular HCAL*, arXiv:0902.1879 [physics.ins-det].

[14] *"Track Segments in Hadronic Showers in the Analogue Scintillator Tile HCAL"*, CAN-013.

[15] M. Thomson, *Particle flow calorimetry*, J. Phys. Conf. Ser. **110**, 092032 (2008).

[16] Papers from beam tests of dual-readout calorimeters by the DREAM collaboration (Akchurin, N., *et al.*): R. Wigmans, *Dual-Readout Calorimetry for High-Quality Energy Measurements* CERN-SPSC-2010-012 ; SPSC-M-771 `http://cdsweb.cern.ch/record/1256562/files/SPSC-M-771.pdf`

a. *Hadron and Jet Detection with a Dual-Readout Calorimeter*, *NIM* **A537** (2005) 537-561.
b. *Electron Detection with a Dual-Readout Calorimeter*, *NIM* **A536** (2005) 29-51.
c. *Muon Detection with a Dual-Readout Calorimeter*, *NIM* **A533** (2004) 305-321.
d. *Comparison of High-Energy Electromagnetic Shower Profiles Measured with Scintillation and Cerenkov Light*, *NIM* **A548** (2005) 336-354.
e. *Separation of Scintillation and Cerenkov Light in an Optical Calorimeter*, *NIM* **A550** (2005) 185-200.
f. *Measurement of the Contribution of Neutrons to Hadron Calorimeter Signals*, *NIM* **A581** (2007) 643.
g. *Contributions of Čerenkov Light to the Signals from Lead Tungstate Crystals*, *NIM* **A582** (2007) 474.
h. *Comparison of High-Energy Hadronic Shower Profiles Measured with Scintillation and Cerenkov Light*, *NIM* **A584** (2008) 273.
i. *Dual-Readout Calorimetry with Lead Tungstate Crystals*, *NIM* **A584** (2008) 304.
j. *Effects of the Temperature Dependence of the Signals from Lead Tungstate Crystals*, *NIM* **A593** (2008) 530.
k. *Separation of Crystal Signals into Scintillation and Čerenkov Components*, *NIM* **A595** (2008) 359.
l. *Neutron Signals for Dual-Readout Calorimetry*, *NIM* **A598**(2008) 422.
m. *Dual-Readout Calorimetry with Crystal Calorimeters*, *NIM* **A598**(2008) 710.
n. *New crystals for dual-readout calorimetry*, *NIM* **A604** (2009) 512.
o. *Dual-readout calorimetry with a full-size electromagnetic section*, *NIM* **A610** (2009) 488.
p. *Optimization of crystals for applications in dual-readout calorimetry*, *NIM* **A621** (2010) 212.

[17] `http://www.ilcild.org/documents/ild-letter-of-intent/LOI.pdf/at_download/file`

[18] H. Aihara *et al.* [SiD Collaboration], arXiv:0911.0006 [physics.ins-det].

[19] The FCAL Collaboration
`http://www-zeuthen.desy.de/ILC/fcal/`

[20] M. Wing, ”Calorimeter DAQ status”, EUDET-Memo-2009-27.
URL : `http://www.eudet.org/e26/e28/e42441/e70539/EUDET-MEMO-2009-27.pdf`

[21] D. Decotigny, ”CALICE DAQ & testbeams : status and perspectives”, presented at LCTW09, November 2009, Orsay, France.
`http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=3735`

[22] `doocs.desy.de`

[23] `https://svnweb.cern.ch/trac/cmsos`

[24] D. Haas, ”The EUDET Pixel Telescope Data Acquisition System”, EUDET-Report-2009-03.
`http://www.eudet.org/e26/e26/e27/e50991/eudet-report-09-03.pdf`

[25] D. Haas, ”The EUDAQ Data Acquisition for the JRA1 Pixel Telescope”, presented at LCTW09, November 2009, Orsay, France.
`http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=3735`

[26] M. Killenberg, ”DAQ for LC-TPC”, presented at LCTW09, November 2009, Orsay, France.
`http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=3735`

[27] `http://www.tango-controls.org/`

[28] F.Gaede, J.Engels, “Marlin et al - A Software Framework for ILC detector R&D”,EUDET-Report-2007-11
URL: `http://www.eudet.org/e26/e27/e584/eudet-report-2007-11.pdf`

[29] F. Gaede, T. Behnke, N. Graf and T. Johnson, em “LCIO: A persistency framework for linear collider simulation studies,”
Proceedings of CHEP 03, La Jolla, California, 24-28 Mar 2003, pp TUKT001

[30] P. Mora de Freitas and H. Videau, “Detector simulation with MOKKA / GEANT4: Present and future,”
Prepared for LCWS 2002, Jeju Island, Korea, 26-30 Aug 2002

[31] S. Karstensen, ”Communication Tools”, presented at LCTW09, November 2009, Orsay, France.
`http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=3735`

[32] R.Poeschl, N.Meyer, ”Calice Software”, presented at LCTW09, November 2009, Orsay, France.
`http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=3735`

[33] M. Killenberg, ”TPC Testbeam Software”, presented at LCTW09, November 2009, Orsay, France.
`http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=3735`