August 17, 2009

IDAG Report

on the Validation of Letters of Intent for ILC detectors

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1. OVERVIEW

History and mandate of IDAG

IDAG was created by ILCSC at the end of 2007 in order to advise the Research Director for the ILC Physics Program and Detectors. The charge of the committee was initially to select two detector concepts to proceed to the next phase in engineering design for push-pull operation at the ILC interaction point. Later the charge was modified to simply validate detector concepts that would be asked to interact with GDE in preparation of a technical design phase of the whole ILC project. The concept of validation was discussed in IDAG meetings with the Research Director and the final mandate was delivered in June 2008 (Appendix 1). The validation process was initiated by a call for Letters of Intent (LOI) early 2008 to be submitted by March 30, 2009. Three LOIs were indeed submitted and received in this order: ILD, SiD, and Fourth.

The list of IDAG members is given in Appendix 2. It reflects the worldwide distribution of the ILC community and the broad expertise required in the evaluation of the three detector concepts (experimentalists, theorists, accelerator-detector interface experts).

Organization of work

In order to evaluate each proposed concept on common grounds it was decided to form IDAG subgroups centered on detector components and subgroups focused on each concept. These subgroups are arranged in a matrix, so that each IDAG member belonged to two orthogonal subgroups. The matrix is displayed in Appendix 3.

IDAG gave additional guidelines for the LOIs shown in Appendix 4. The schedule of the validation process and the list of IDAG meetings are shown in Appendix 5. Representatives of the different LOIs were interviewed in the Warsaw, Chicago, Tsukuba, and Orsay meetings.

Lists of written questions were submitted to the groups in two occasions and were used as starting points in the interviews in order to acquire a better understanding of the concepts and how their performances had been established. A first set (Appendix 6) was given before the Tsukuba meeting in April 2009 to be answered there. A second set (Appendix 7) was produced after Tsukuba and answers were available for the Orsay meeting in June 2009.

The IDAG understanding of validation

In very broad terms IDAG considers that a detector can be validated if (1) the overall concept has an expected performance suited to the physics program of ILC and (2) the proposing group has the scientific and technical ability to reach its goal, both through continued R&D and by investing enough resources to collaborate with the ILC project toward a detailed baseline study. Although the first point has required most work from IDAG, special attention was given to the second one, especially through the detailed interviews held with the different groups. The level of design expected was intermediate, in the sense that some basic engineering considerations were deemed necessary in order to approach the performance issue in a realistic way. Although figures were given in some cases, IDAG did not consider cost estimates in detail, primarily because the detector designs still allow for some flexibility and some final choices of technologies have still to be done, and also because of different costing procedures used.

IDAG understood clearly that validation concerns only the development of detector designs for the ILC TDR in 2012. It does not imply that concepts not validated shall not be candidates for ultimate approval for the ILC.

The ILC physics program and challenges to detectors.

IDAG would like to recall the exceptional physics potential of ILC, mainly the possibility of elucidating the electroweak symmetry breaking and the mechanism for mass generation, establishing physics beyond the Standard Model (SM), whether it is supersymmetry, extra dimensions of space-time, or something else. The precision measurements of the simple SM processes offer a unique possibility to open windows on physics beyond our direct reach. Therefore it is crucial that ILC detectors be designed to fully explore this new territory. In fact, detectors at the ILC face major challenges, quite different from those at hadron colliders. While ILC detectors will work at lower event rates, with lower backgrounds and lower radiation doses than those at LHC, they impose more stringent requirements on precision. Excellent vertex detection and resolution on jet energy are required, as well as hermeticity for particle searches, very good track momentum measurement, and the ability to explore the full physics content of an event through high granularity detectors.

Several benchmark reactions were chosen for the ILC LOI process by the WWS-OC software panel. These reactions were selected to demonstrate the performance of the detectors as well as representative physics studies. The list is far from exhaustive in representing the physics program of the ILC. The reactions, the associated physical measurements, and the detector components that are tested are listed in the Table below. All three concepts were to simulate these reactions with a full detector simulation.

Reaction	Detector parameter tested	Measurements
$e^+e^- \to Z(\to l^+l^-)H$ $m_H = 120$ GeV, $\sqrt{s} = 250$ GeV	p resolution material distribution γ recovery	m_H σ
$e^+e^- \to ZH(H \to c\bar{c}, Z \to \nu\bar{\nu})$ $m_H = 120$ GeV, $\sqrt{s} = 250$ GeV	heavy flavor tagging secondary vertex reconstruction particle id.	$BR(H \to c\bar{c})$
$e^+e^- \to ZH(H \to c\bar{c}, Z \to q\bar{q})$ $m_H = 120$ GeV, $\sqrt{s} = 250$ GeV	same as for $e^+e^- \to ZH(H \to c\bar{c}, Z \to \nu\bar{\nu})$ confusion resolution capability	$BR(H \to c\bar{c})$
$e^+e^- \to Z \to \tau^+\tau^-$ $\sqrt{s} = 500$ GeV	τ reconstruction particle flow π^0 reconstruction tracking of close tracks	σ A_{FB} τ polarization
$e^+e^- \to t\bar{t}(t \to bqq')$ $m_t = 175$ GeV, $\sqrt{s} = 500$ GeV	multi jets particle flow b tagging lepton tagging tracking	σ A_{FB} m_t
$e^+e^- \to \chi^+\chi^-/\chi_2^0\chi_2^0$ $\sqrt{s} = 500$ GeV	particle flow WW, ZZ separation multi jets	σ masses

2. SUMMARY OF THE THREE LOIs

2.1 ILD

The International Large Detector (ILD) is a large, general purpose detector designed to study the physics opened up by the ILC. The design of the different detector subsystems is summarized:

The vertex detector, VTX, has a purely barrel geometry of silicon pixel detectors. The baseline geometry has 3 superlayers of 2 layers each. Decisions on sensor technology options and readout speed remain to be made.

Following VTX there is a system of pixels and strips, the SIT in the barrel and the FTD in the forward. These systems connect the VTX to the TPC. The TPC provides more than 200 space points with good spatial resolution for precision tracking and will also provide dE/dx for particle identification.

Outside the TPC there is a second system of silicon pixels and strips, the SET connecting the TPC and the electromagnetic calorimeter (ECAL) and the ETD providing additional tracking points downstream of the TPC end plate.

ILD uses a particle flow (PF) technique utilizing finely segmented calorimetry. The ECAL has about 30 samples in depth and of small transverse dimensions, of order of the Moliere radius, using tungsten as an absorber. Two options are considered – silicon detectors or scintillator strips. The hadronic calorimeter (HCAL) has 48 samples and small transverse dimensions. Again two options exist; a scintillator analogue readout (3 x 3 cm^2 cells), or binary readout using glass resistive plate chambers (1x1 cm^2 cells).

The ILD magnet is proposed to be an extension of the successful CMS solenoid, in this case operated at 3.5 T. Within the return yoke a system of scintillator strips or RPC will provide muon detection.

2.2 SiD

The SiD Collaboration has proposed a general-purpose detector concept comprising a vertex detector and a tracking system based on silicon detectors, compact sampling calorimeters, and a high-field solenoid magnet with instrumented iron flux return to address the physics at the ILC.

The overall design is based on PF reconstruction of jets, which has driven the major design choices, such as the radius of the solenoid, the value of the magnetic field, and the size of the volumes devoted to tracking and to calorimeters.

The tracking system includes a compact silicon pixel vertex detector and a main tracking detector with five barrel layers and eight disks of silicon strips, distributed in a volume of 1.2 m radius and 3 m length.

In the baseline design, the electromagnetic section of the calorimeter is a silicon-tungsten sampling device, 26 X_0 deep and with 30 sampling layers, read out by 13 mm^2 pixels. The hadronic section uses stainless steel plates for an equivalent depth of 4.5 λ, read out using RPCs with 1 cm^2 pads.

The solenoid magnet is designed to provide a 5 T field over a volume of 2.6 m radius and 5.6 m length. The flux return is through iron plates instrumented for muon identification, achieved with RPCs or scintillating strips.

The detector readout is expected to provide individual bunch-crossing identification in all subsystems. The detector design puts some emphasis on the requirements of a fast push/pull operation, with optical systems capable of rapid recovery of the tracker alignment.

2.3 Fourth

The Fourth concept is also put forth as a general-purpose detector, but on the basis of substantially different technologies from that of the other LOIs, including a dual-readout calorimetry and a dual solenoid magnet system.

The silicon vertex detector is taken to be that proposed by SiD. The outer tracking is accomplished with 160 samples in a small-cell helium-based gas drift chamber in which individual ionization clusters are recorded. Excellent spatial and dE/dx resolutions are claimed. This chamber extends to within 8 degrees of the beam lines. No forward tracking is present in the baseline design.

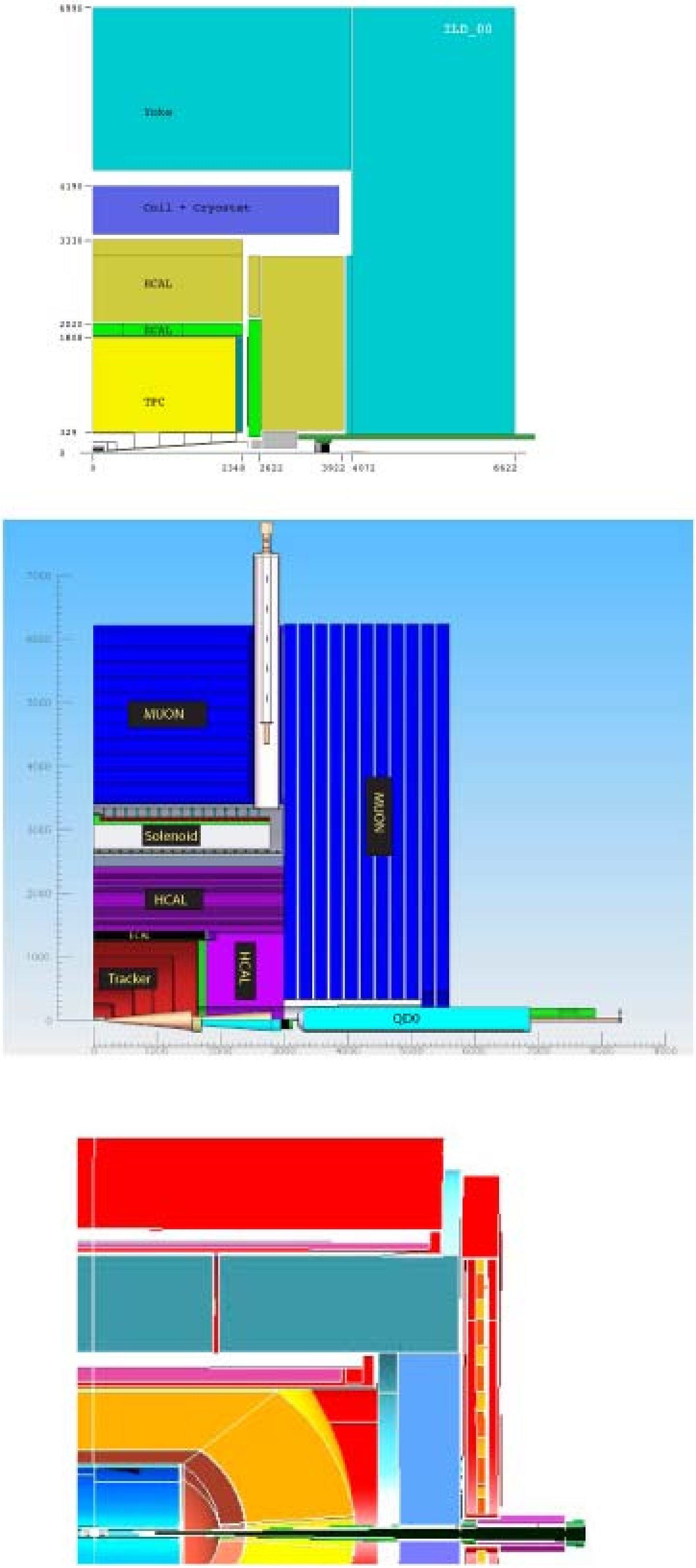
The calorimetry employs an elaboration of the dual-readout technique in which the outer hadronic section is composed of radial fibers of both quartz and scintillating fibers to record different fractions of electromagnetic and hadronic energy. The delayed scintillating fiber signal serves to measure the energy associated with neutrons liberated in the breakup of nuclei. The inner electromagnetic calorimeter has BGO crystals in a projective geometry. An *ad hoc* algorithm for combination of the fiber and BGO signals has been found, yielding a simulated jet energy resolution with a sampling term of $22\%/\sqrt{E}$. No baseline choice for photodetectors for either calorimeter has been made to date.

The 3.5 T solenoidal field encompassing the tracking and calorimetry is returned by a second superconducting solenoid, and is contained by end walls of circular coils, thus eliminating the need for an iron flux return. Muon chambers based on the cluster counting technique fill the annular region between solenoids and in end walls at smaller angles.

With no iron to provide radiation shielding, external concrete shield walls are needed to provide safe working conditions in the underground cavern. Fourth proposes that both intersection region quadrupole doublets for the ILC be mounted rigidly to the detector.

	ILD	SiD	Fourth
Si PIXELS			
Rinner	1.6 cm	1.4 cm	same as SiD
Router	6 cm	7.5 cm	
Z_max	25 cm (cos<0.97)	12 / 18 cm barrel/disks	
#barrels	6	5	
#disks	0	4 on each side	
BARREL TRACKER			
Technology	TPC (with inner and outer Si strips layers)	Si strips (back to back modules with stereo angles)	He based small cell drift chamber with cluster counting
inner radius	32.9 cm (16.5 cm)	22 cm	19 cm
outer radius	181 cm (183 cm)	122 cm	150 cm
Z_max	235 cm	56/152 cm innermost/outermost layer	210 cm(inner) – 150 cm(outer)
N samples	224	5 double layers	160
FORWARD TRACKER			
Technology	Si strips	Si strips (back to back modules with stereo angles)	not specified
N samples	7 disks/end (Rmin=39 mm Rmax=309 mm, thetaq_min~5 deg) plus layer outside TPC	4 double layers on each side (Rmin=21 cm, Rmax=125 cm)	
Z_max	243 cm	164 cm (complemented by 3 disks of pixel detectors for coverage down to ~8 deg)	
EM CALORIMETER			
Absorber	W	W	BGO
sampling lyrs	20x0.6Xo +9x1.2Xo Si pixel sensors or scint. strips	20x0.65Xo +10x1.3Xo Si pixel sensors	1 (continuous crystal absorber)
cell size	0.5 x 0.5 cm^2	0.13 cm^2	~2x2cm^2 (1x1 cm^2) (16 crystals/fiber module)
X_0	22.8	26	25
Lambda	1.25	~1.3	~1.3
R_inner	181 cm	127cm	150.4 cm
R_outer	202 cm	141cm	178.5 cm
Z_min	235 cm	168 cm (theta_min=2.8 deg)	(theta_min=2.8 deg)
Z_max	262 cm	182 cm	(theta_min=2.8 deg)
HADRON CALORIMETER			
Absorber	Fe	Fe	Brass
sampling layers	48 scint. tiles or gaseous detectors	40 RPC pads (GEMS, micromegas, scint. strips as alternatives)	1 radial quartz and scint. fibers
cell size	3x3 cm^2	1 cm^2	4.4x4.4 cm^2 (90 deg) (fiber spacing≈2 mm)
Lambda	5.5	4.8	7.3
R_inner	210 cm	142 cm	~180 cm
R_outer	330 cm	258 cm	~280 cm
Z_min	262 cm	182 cm	(theta_min=2.8 deg)
Z_max	392 cm	298 cm	"

	ILD	SiD	Fourth
MAGNET			(inner solenoid)
R_inner	335 cm	259 cm	~300 cm
R_outer	420 cm	339 cm	~320 cm
Z_max	407 cm	303 cm	~440 cm
B_central	3.5 T	5.0 T	3.5 T
FLUX RETURN			
Type	Fe	Fe	Air return between inner solenoid and 1.5T outer solenoid
R_outer	699 cm	~600 cm	~560 cm
Z_max	662 cm	~560 cm	5 'Helmholtz' coils at Z ≈ 620 cm to contain field (Z_max ~630 cm)
MUON			
Technology	RPC or Scint strips	RPC or Scint strips	4.6 cm Al drift tubes; 20 (18) layers barrel (ends)
			dimensions marked '~' estimated from figures



The three detector concepts drawn to the same scale
¼ of r-z view, from top to bottom: ILD, SiD, Fourth

3. DETECTOR ISSUES

3.1 Tracking

3.1.1 Vertex Detector

All concepts will use a silicon pixel technology for vertex detectors. The technology choices have not been made; however, a very active worldwide R&D effort is underway and is expected to provide the required solutions. The ILD & SiD vertex detectors employ an infrared laser for internal alignment. The technology choice for the SiD vertex is constrained by the requirement to identify each bunch crossing. The vertex detector of SiD is fully incorporated in the central tracking. Consequently SiD develops a very sophisticated alignment system for the entire tracker. In parallel they envisage an elaborate support structure that minimizes the need for realignment after push-pull operation.

The Fourth has not presented any detailed vertex detector, but plans to follow the SiD developments.

3.1.2 Central Tracking

ILD employs a large volume TPC for central tracking which provides about 200 three-dimensional space points for track identification and reconstruction and a simultaneous dE/dx measurement for particle identification. With particle drift paths over a distance of about two metres, the chamber continuously records the history of previous bunch crossings. Due to the good resolution and the inherent 3-dimensional approach, beam induced backgrounds from out-of-time bunch crossings can be readily identified.

The TPC technique for large detectors has been well established at LEP. It profits from the continued progress in the readout techniques and is supported by a worldwide R&D effort. The GEM and MICROMEGAS options are now mature and meet the requirements. These techniques limit the ion feedback and hence the field distortions. The integrated silicon pixel readout option would provide unprecedented granularity.

To achieve good knowledge of the field distortions, a precise alignment of the endplates is required. ILD foresees using a laser alignment system for the survey of the endplate positions and also cosmic rays for calibration. The end plates present a considerable contribution to the material budget for forward going particles and have an impact on the calorimetry. The track reconstruction efficiency is excellent above 1 GeV and deteriorates slowly at low momenta. Using simulations, ILD has demonstrated a robust performance of the tracker with respect to the beam background. The detector effectively identifies photon conversions and out-of-time background tracks.

SiD uses an all-silicon approach to sample particle positions with very high precision with a compact detector. They use silicon strips with five radial layers and four discs in both small angle regions in addition to the pixel vertex detector. With an overlapping tile arrangement for the silicon ladders, they achieve full coverage in all layers and a powerful tool for alignment. The tight mechanical tolerances and the planned rigidity of the support structure reduce the number of degrees of freedom for movement. The suspension of the tracker components employs kinematic supports so that the tracker distortions are drastically reduced. SiD has been designed for access from both ends so the tracker components can be serviced. The survey of the detector employs a laser system that shines on the active sensors and helps the survey of the detectors. It is claimed that only a few overall parameters have to be determined after detector movement.

Each silicon strip and pixel hit is time-stamped to identify the bunch crossing which reduces the background for reconstruction. The track reconstruction efficiency is close to 100% above 0.5 GeV. SiD has demonstrated good background immunity employing the time stamping capability and good spatial resolution even in the presence of severe beam-beam background.

The robustness of the track reconstruction was studied in MC simulation under the very unlikely assumption that a whole layer of the detector fails. Some deterioration of the track reconstruction efficiency, momentum and impact parameter resolution were observed. However the performance still remained viable. This demonstrates that the SID tracker is sufficiently robust but may have some risk due to lack of redundancy.

SiD and ILD plan to employ pulsed powering for the silicon detectors. This scheme and the mechanical stability of the detector still need to be demonstrated.

The readout chip of the SiD tracker is complex and is still under development.

The internal rigidity and alignment accuracy are challenging and more efforts may be necessary to explore the effects of local heat dissipation. The claimed short recovery from a push-pull operation is encouraging but should be further substantiated.

The central tracker of the Fourth concept is based on a cluster-counting drift chamber. The chamber uses a He based gas mixture which has a small drift velocity and low number of primary electrons. Sensitive and very fast (GHz) signal digitization allows the reconstruction of individual ionization clusters. Simulation studies indicate that this can lead to excellent spatial resolution of about 50 μm and superior dE/dx resolution. Adequate z-resolution is obtained by a stereo arrangement of the superlayers. The low-Z material of the chamber results in a very small material budget (estimated to be $0.37\%X_0$ at 90°) and hence in a small multiple scattering contribution to the resolution, even at more forward angles. In addition the low-Z gas mixture and the small amount of material in the chamber reduce the probability of photon conversion. The cell size is chosen to be small enough to collect all ionization clusters between the bunch crossings. Requirements on the mechanical tolerances and stability are very stringent because of the excellent spatial resolution goals and the absence of an alignment system. Even with the 66,020 cells the estimated occupancy is very high especially in the inner layers with the longest wires. For ttbar events it reaches almost 100% in the innermost layer with about 1.5 tracks per struck cell on average and still exceeds 10% for the last layer. According to the MC simulations it should be possible in most cases to resolve two tracks crossing the same cell. This allows an excellent (nearly 100%) track reconstruction efficiency above p_t~200 MeV. The efficiency remains practically unchanged even when ignoring a secondary track in a cell. This remains the case even when the spatial resolution of the second track in the cell crossed by more than one track is reduced to 100 μm. The last assumption has not been demonstrated by a full MC simulation.

A cluster-counting drift chamber is a novel approach, not even tested in small prototypes. On the other hand the KLOE low-mass drift chamber with a He based gas mixture was successfully operated for many years and achieved a resolution close to 150 μm.

The coverage of the tracker ends at 8°. The collaboration is investigating the possibility of using silicon discs to extend the coverage down to 3°. The collaboration also considers the possibility to improve the tracking performance in the forward region by adding forward toroids. However these plans were not elaborated in the LOI. For the benchmark reaction studies, the forward region was assumed to be not instrumented.

Observations on tracking

The approach to tracking of the three concepts varies considerably and is largely complementary. IDAG notes that the level of experimental verification of the tracking concepts and the alignment techniques also varies; while ILD pursues an active experimental test programme of the various readout options for comparison, SiD largely extrapolates the established performance of detectors to a large scale setup and relies on detailed simulation. The Fourth concept in contrast extrapolates the performance of KLOE and from MC studies expects to gain more than a factor of two in resolution (55μm) for tracking with the cluster-counting technique. These claims need to be substantiated, at least on a small test chamber.

IDAG notes that the immunity to beam backgrounds has been demonstrated for all three LOIs.

Efficient tracking in the forward direction remains a common challenge and are not yet satisfactorily demonstrated. The Fourth concept suggestion of a forward toroid-based detector to improve its performance remains to be elaborated and studied.

3.2 Calorimetry

The LOIs use two distinct approaches to achieve excellent jet energy resolution at the ILC. The particle flow concept uses calorimeters to measure neutral particle energies and trackers to measure the charged particle energies. The separation of showers produced by neutral and charged particles requires calorimeters with very fine granularity. In the other approach, dual-readout, the electromagnetic and hadronic components of showers are determined by a combination of signals from Cerenkov and scintillation fibers, which allows for compensation of fluctuations between electromagnetic and hadronic portions of the shower.

The particle flow technique has been chosen for the baseline of the ILD and SiD detectors. The proposed electromagnetic calorimeters are silicon tungsten detectors with cell sizes of 13-25 mm^2. Options under consideration for the hadronic calorimeters are analog calorimeters using 1000 mm^2 scintillator tiles with silicon photomultiplier (SiPM) readout and digital calorimeters using gaseous detectors with 100 mm^2 pads. Since particle flow does not demand the best single particle energy resolution possible, there is no requirement to collect large calibration samples from ILC operation on the Z^0 pole. Significant R&D into highly granular calorimetry is underway by the CALICE and SiD ECAL groups. CALICE has operated large 1 m^3 calorimeter systems at DESY, CERN, and Fermilab, with the goal of demonstrating the principle of particle flow. In simulation, particle flow has achieved 3% energy resolution for 100 GeV jets.

Dual-readout calorimetry is the focal point of the Fourth concept. The electromagnetic calorimeter uses BGO crystals with lateral segmentation of 4 cm^2. The hadronic calorimeter design is based on the DREAM detector, with copper absorber and scintillator and Cerenkov fibers grouped into 16,000 barrel and 7500 endcap cells of roughly 16 cm^2 area. The light signals are to be readout with 1 GHz sampling to measure the neutron component of showers. Notably, no suitable photosensor for the BGO readout has been identified. The Fourth concept group requests large data samples collected at the Z^0 pole for BGO calibration. Roughly 10^7 (10^9) Z^0s are needed for 1% (0.1%) electron energy resolution. R&D continues into dual-readout with the DREAM detector, which has demonstrated some separation of electromagnetic and hadronic components. The DREAM detector, however, suffers from shower leakage because of its limited lateral size and, as a result, the leakage fluctuations significantly degrade its performance. Simulation of the DREAM calorimeter has been made within the fourth concept software framework, ILCroot. The simulation does not fully reproduce the performance of the detector. In particular, the simulation has somewhat better separation between the scintillator and Cerenkov signals and significantly smaller constant terms which determine resolution at high energies.

3.3 Magnet and muon systems

All three LOIs propose to use a large solenoid magnet, with a coil similar to that of CMS, which provides an existence proof. The large ILD solenoid operates at 3.5 T while the smaller SiD coil operates at 5 T. Both solenoids have a stored energy to cold mass ratio of 12 kJ/kg which is comparable to CMS. For the flux return ILD and SiD propose steel as in CMS while the Fourth design is a novel one returning the 3.5 T main field in a 1.5 T larger radius second solenoid. This design, although untested, allows for a measurement of muon trajectories in air, thus minimizing the multiple scattering limit inherent in ILD and SLD.

In the volume between the two solenoids Fourth achieves a limited muon resolution of $1/p_t$ of 0.0016 /GeV with aluminium drift tubes. Both ILD and SiD have muon detectors within the steel return yoke with a muon momentum lower limit of 3 GeV. The ILD collaboration is doing R&D on both RPC and scintillator strips. A prototype “tail catcher” in the CALICE test beam provides valuable experimental experience with these detectors. SiD proposes either RPC (with experience from BaBar and BELLE) or scintillator strips and SiPM (with experience from MINOS).

3.4 Machine-Detector Interface

The MDI specification starts with defining appropriate boundary conditions between the accelerator and detector facilities, in terms of geometrical, mechanical, magnetic, electric, as well as background, operational, construction and maintenance considerations. The ILC RDR [1] gives the baseline assumptions wherever applicable as of mid-2007.

As the RDR assumes a single beam interaction point to be alternately shared by two detector systems, certain aspects of MDI matter are more adequately described as Detector-Detector Interface issues. Consensus needs to be formed on the separation and sharing of responsibilities for hardware equipment in the vicinity of the interaction point by the detector system groups and the accelerator group. The MDI/D group, which has been jointly set up under GDE and RD, has drafted an additional set of working assumptions [2], for guiding the work toward LOIs and beyond.

The Table MDI-1 gives a summary of parameters which have been extracted from the three LOIs. Its contents have been somewhat supplemented by responses from LOI groups to additional queries from the IDAG.

Subject	Parameter	Unit	ILD	SID	4th
Physical Dimensions	Outer size during operation	W x H x L [m]	18.76 x 21.39 x 18.40 ; H includes undercarriage of 1.122m which runs in trenches in the hall floor	14.20 x 17.42 x 10.75	14.1 x (15.24 + ~1.5 for platform) x 18.60 ; L would be 25.26 if QFs are included
	Beamline height from floor	[m]	~ 11.00 (inc. platform of ~2.00, but not counting the space for undercarriage which runs in trenches)	9.00	~8.77 (inc. ~1.50 for platform)
	Envelope size during service	W x H x L [m]	20.00 x 30.00 (W x L)	18.79 x 17.48 (W x L)	30.00x20.00x20.00
	Weight	Barrel + 2 x Endcaps [t]	8,115 + 2 x 3,521 = 15,157	4,500 + 2 x 2,500 + 2 x 170 = 9,840	~760
	Additional shield		ILD is self-shielding + Portable Iron & concrete (pacmen) to plug the beamline opening	SiD is self shielding + Portable Iron & concrete (Pacmen) to plug the beamline opening	4th is not self-shielding and has to be associated with shield walls
	Additional shield weight	[t]	to be defined in collaboration with other concepts	50(Fe)+120(Conc)	~ 1,440
Platform	Material		Concrete platform	NA	Remarked not necessarily, although Fig 116 shows an example.
	Size	[m]	15.00 x 20.00 x 2.00 (thick)	NA	25.50x30.00x1.50
	Weight	[t]	1,440	NA	~150
Total System Weight		[t]	16,597	9,840	2,200

Solenoid Magnet	Operational Field	[T]	3.5	5	3.5
	Max Field	[T]	4	5	5
	Cryogenics		4K He to be delivered from outside ILD	4.5K He to be delivered from outside SiD	4.2K He from outside
	Stray field		transversal field below 50G at 15m from the beam pipe	see magnetic field map	
QD0	Location in Z	[m]	Z_min=4.25; Z_max=7.90 (incl. Cryostat)	L* = 3.50; Z_min = 3.24; Z_max = 6.89	Z_min = 4.50; Z_max = 8.00
	Outer Radius	[m]	R_out = 0.195 (incl. Cryostat)	R_out = 0.19	R_out = 0.20
	Installation		Captured within ILD; suspended from the solenoid cryostat support using carbon-fibre tie-rods, indep. Of endcaps.	Captured and supported internally within SiD;	Captured and supported within 4th, together with QF1 within common support enclosures.
	Cryogenics		4K He to be delivered from outside ILD whose coldbox cools it to 2K	4K He to be delivered from outside SiD. QD0 coldbox cools it to 2K	4.2K He to be delivered from outside 4th. Use of 2K might be included later.
QF1	Location in Z	[m]			Z_min = 9.50; Z_max = 11.88
	Installation		Left for accelerator	Left for accelerator	Prefer to attach QF1 also to the detector. QF1will return to the resting position when 4th is out of the beamline.
QD0 vs QD1			Separate systems. QF1 design, support and supplies under responsibility of machine.	Separate support systems. Warm spool piece in between.	QD0 and QF1 are to be incorporated into common active positioning system.
Push-pull	Platform		Y	Hilman rollers with reinforced steel floor	
	Motion mechanics		Platform runs on rails or airpads; barrel parts movable on platform with rails or airpads	Strand Jacks	

Table MDI-1: Summary of parameters which have been extracted from LOIs. Contents have been supplemented by responses from LOI groups to additional queries from the IDAG. The quoted numbers are preliminary and are subject to changes during the TDP process.

IDAG notes the following significant findings:

1. All the three LOIs present detector designs which are compatible with the L*, β* and related beam parameter specifications as laid out in [1,2].

2. All the three LOIs offer conceptual solutions which claim to allow rapid "detector push-pull".

3. However, full details of specific engineering design solutions for the detector push-pull are yet to emerge. Thus, the actual push-pull performance is yet to be proven, and adequate intermediate engineering milestones have yet to be clearly laid out. The work toward them is all left for the TDR period.

4. The document [2] gives a snapshot of present MDI conditions to consider. IDAG understands that the work by the MDI panel must continue into the TDR period, and the MDI definitions will be continually refined and updated accordingly.

There are several differences among the three LOI detectors which will make the detector push-pull more challenging unless further collaborative work is vigorously pursued among the members of validated detectors concepts and the accelerator. These issues can be sorted out, as the ILC and its detectors continue their designs together in a cooperative fashion, and it is assumed that such is the understanding of all the parties involved:

1. ILD has added some side access zones in the garage position of IR hall. The other detectors do not mention need for this extra underground space. However, presumably they are compatible with the additional access zones in the garage position.

2. ILD plans to have a 2 m-high platform. Fourth also plans to use a platform. SiD does not plan to use a platform at this moment. ILD is also larger in radius than SiD or Fourth. If ILD/SiD or Fourth/SiD are to push-pull, either ILD/Fourth will have to give up their platform, or SiD will have to include one to bring their detector up to the height of the beam-line.

3. Fourth prefers to have the QF1 attached to the detector, while SiD and ILD follow the MDI document [2] of having QF1 left in the tunnel. If Fourth is paired with either of the other two, a workable engineering solution needs to be introduced. Fourth points out that the vibration tolerances are a factor of 4 looser if QF1 and QD0 are rigidly connected so that they vibrate together. The RDR [1] (and MDI document [2]) assumes a bunch-by-bunch feedback system that compensates for such quad (and other) motions. It is a quantitative question which none of the LoIs have yet addressed in detail whether the quads can be well enough isolated from vibration sources to keep the beams within capture range of this feedback.

4. SiD and ILD are self-shielding, while Fourth has two shield walls that move with their platform. Fourth has not indicated the details of how this shield wall will seal against the cavern walls. This will either require a movement of the walls in Z to provide clearance for the move, or some type of fixed wall jutting out from the +- Z ends of the caverns. If the latter, compatibility with the other detectors will have to be addressed.

References:
1: “ILC Reference Design Report”, 2007, http://ilcdoc.linearcollider.org/record/19841 also, http://www.linearcollider.org/cms/?pid=1000437

2: “Functional Requirements ion the Design and Detectors and the Interaction Region of an e+e- Linear Collider with a Push-Pull Arrangement of Detectors” (ILC-Note-2009-50) http://ilcdoc.linearcollider.org/record/21354

4. BENCHMARK REACTION PERFORMANCES

Simulation of the benchmark reactions was performed by the three concepts. A Standard Model background sample was generated by SLAC and provided to all concepts. It included all 2 → 2, 4, 6 and some 8 processes in the e+e-, eγ, γγ channels generated via WHIZARD/OMEGA employing full matrix elements. PYTHIA was used for final state QED and QCD parton showering, fragmentation, and decay. Backgrounds arising from interactions between virtual and beamstrahlung photons were included via Guinea-Pig. Event samples were weighted to reflect the expected ILC baseline beam polarization configuration of P_{e-} =80% and P_{e+}=30%. 50 fb^{-1} was generated at 500 GeV and weighted by a factor of 10, and a somewhat smaller sample was generated and appropriately weighted for a collision energy of 250 GeV. Both ILD and SiD made use of this background sample and the response of their detectors was based on Geant4 with full reconstruction of simulated events. The Fourth concept limited their background studies to what they considered to be the dominant processes. The response of the Fourth detector was simulated via Fluka and included some, but not all, detector components.

Evaluation of the physics capabilities of the three concepts includes an assessment of the detector performance as well as variation in analysis techniques. IDAG notes that the simulation results represent a snapshot in time, being necessarily in flux due to continual software development.

The precise determination of the properties of the Higgs boson is a main component of the physics program at the ILC. The mass of the Higgs boson is measured independently of the theoretical model in the recoil process e+e- → Z h → l^+l^-X, with l=e, μ and X representing the Higgs decay products. All concepts performed this analysis with the ISR spectrum, corrected for a bug after the original LOI submission. The simulated precision on the Higgs mass measurement for a 120 GeV Higgs was comparable between the three concepts, ranging from 36-50 MeV in the muon channel for various beam polarization configurations and 59-97 MeV in the electron channel. All concepts included calorimetric recovery of bremsstrahlung photons in the electron channel. Beam energy spread dominates the measurement error for all concepts. The BGO design of the Fourth concept yielded better precision. The precision of the measured cross section differed between the three concepts with errors being in the range of 4-10% for the μμ channel.

ILD and SiD completed the simulation of the two benchmark channels for the determination of the Higgs branching fractions, namely h→ cc-bar with Z → νν-bar and qq-bar. The resulting precision was comparable between the two concepts in the Z → νν-bar channel and was at the level of 11-15%. Results of the simulation of the Z → qq-bar channel differed, with a precision of 6% for SiD and 30% for ILD. This difference in precision is currently under investigation between the two concepts and is not likely due to detector performance. ILD simulated additional channels, not part of the benchmark list, and found that the Higgs branching fraction into b-quarks and gluons could be determined at the 3% and 30% level, respectively. These full simulations agree with ILC performance expectations and demonstrate the precision capabilities of the machine. The Fourth concept did not provide a complete simulation for the determination of a Higgs branching fraction in any channel.

In the study of τ-pair production the observables are the cross section, forward-backward asymmetry and polarization of the τ-pair. These three measurements test the τ reconstruction, tracking system and clustering, and separation of nearby tracks and photons. ILD and SiD quote similar purity of their samples of roughly 85% with efficiencies in the range 65-80% depending on the decay channel. The resulting measurements of the τ cross section and polarization are good with a precision of 0.3% and 1%, respectively. The Fourth concept showed a promising reconstruction in the $\rho\nu$ channel and provided no further information.

In the case of top-quark pair production, the observables are the cross section, forward-backward asymmetry and the top-quark mass. The results are consistent among the three concepts, yielding a precision in the top-quark mass in the range of 30-60 MeV. ILD and SiD obtained a measurement of the forward-backward asymmetry at the percent level. ILD demonstrated that the top analysis is robust with respect to the beam backgrounds. SiD employed a template analysis, varying S/B and compared curve fitting with the template method. The Fourth concept does not have an analysis which includes b-tagging.

The last benchmark reaction is the pair production of the electroweak gaugino states in Supersymmetry. Here, the final states consist of WW or ZZ plus missing energy from the χ_1^0s. The separation of W and Z bosons in the hadronic decay channel is crucial and provides a distinction between the methods of calorimetry. The W/Z separation of the Fourth concept presented in Orsay demonstrated the power of a high-resolution calorimeter and yielded a superior separation. The capability of ILD to perform this separation is demonstrated in their analysis of WW scattering at 1 TeV where they show a clear resolution of the W and the Z peak. This shows the utility of the PF algorithm and perhaps that the advantages of a larger detector cannot be necessarily recovered by a larger magnetic field.

ILD and SiD simulated the mass measurement of the $\chi_1^\pm$ and $\chi_{1,2}{}^0$ states via the edge technique. Following the Orsay meeting, Fourth presented measurements of the χ_1^0 mass. The separation of the WW and ZZ processes in a two-dimensional plot of boson masses is excellent for Fourth, and also ILD, with SiD somewhat less good, reflecting the current state of the jet energy resolutions. ILD and Fourth performed a fitting procedure while SiD employed a template technique. The analyses are still in flux and the measurements do not agree, with the precision lying in the range of 0.2-3.0 GeV; this difference is currently under investigation. It is worth noting that superior sparticle mass measurements are obtained at the ILC by performing a threshold scan.

5. EVALUATION OF THE THREE CONCEPTS

5.1 ILD

The ILD Collaboration has presented a LOI which documents the impressive quantity and quality of work performed. A particular strength of the LOI is the very extensive R&D effort made in test beams with full-size prototypes of the calorimeter having been constructed and operated at DESY, CERN and Fermilab. Indeed, alternative technologies for the calorimetry are also being explored in the test beam program. Integrated with these calorimeter tests their data have been taken with a “tail catcher” for one of the possible muon system options. This large data set will allow ILD to validate the PF strategy which is central to their design. The data will also enable ILD to revisit some of their parameter choices, for example the total depth of their calorimeter.

In future, tests of the TPC in a full strength magnetic field will be made. Initial layout of power and other components in the high field can be studied. Prototyping of the TPC is ongoing in other tests. A convincing measurement and monitoring method for the magnetic field is needed to fully exploit the TPC performance. Overall, the ILD detector concept has a plan to complete proof of principle tests of all subsystems in a timely manner. It should be noted that pulsed power operation remains a potential, and as yet untested, issue for ILD and, indeed, for all the ILC concepts. The necessary R&D has been addressed in a comprehensive program by the ILD collaboration.

At present there are many technology choices being carried by ILD. This approach ensures that the final choices will be made in an informed fashion after the R&D program has been completed. The IDAG was presented with scenarios for tracking alignment - VTX, Si, and TPC which used a series of steps: quality assurance in manufacture, metrology, in situ tracking based alignment and monitoring systems. The responses were convincing at this stage of the ILD development. Similarly, the methods of calibration of the ECAL and HCAL in manufacture, test beams, installation, in situ calibration and monitoring were also well answered.

The ILD efforts on simulating the physics benchmark processes have been impressive. Significant progress has been made even since the LoI itself in response to the questions posed by IDAG. In fact, the evolution of the analyses indicates that further progress is possible and IDAG encourages more effort on the analyses in the future. In particular, beam backgrounds should be applied universally and the ILD “headroom” established. The tracking system, both VTX and TPC, integrate over many bunch crossings, and the VTX integration time can be studied and optimized. More detailed studies may also serve to aid ILD in sharpening and clarifying their detector design choices.

The ILD detector design concept appears already to confront the physics of the ILC in a fairly complete fashion. At the LOI stage the progress of the Collaboration in realizing their detector concept is impressive and the path is clear for ILD to make continued progress. The strength of the ILD group is sufficient for the tasks ahead in R&D, simulation and engineering the ILD concept toward a more completely realized detector.

5.2 SiD

The overall design has been driven by the aim of exploiting the physics potential of ILC with a detector designed around few choices, with the most cost-effective solutions. Examples of this approach are in the main tracking detector formed from silicon strips alone, distributed over a relatively small volume, which has been shown to achieve a satisfactory performance with a limited number of layers. Silicon detectors are used also in the pixel modules of a compact vertex detector, and in the sensors of a finely segmented electromagnetic calorimeter.

Jet measurement by particle flow has driven the design of the calorimeters and the choices of key parameters like the solenoid radius, the strength of the magnetic field, and the volumes dedicated to tracking and to calorimetry. The R&D program should validate the expectations of PF analysis with large detector set-ups and realistic conditions. It should also clarify whether specific design values (e.g. the depth of the hadronic calorimeter) or figures of merit related to jet reconstruction are fully understood. Additionally, R&D programs should contribute to design choices in areas where different options appear possible (e.g.: detector technology for the vertex detector and its readout; for the active elements in the hadronic calorimeter and in the muon detector/tail catcher; options for digital readout of the electromagnetic calorimeter; options for high-performance calorimeters based on the alternative approach of multiple readout.)

Power-pulsing of detectors in intense magnetic field should also be the subject of a dedicated R&D program.

R&D studies should also focus on issues related to the alignment of the vertex and tracking detectors, which should be achieved with a combination of specific design solution, together with dedicated alignment systems capable of accurate and continuous measurements.

Engineering studies are also strongly encouraged, namely in well identified areas such as MDI, or the 5 T solenoid, to be followed by comprehensive studies as choices will be made among alternative options.

IDAG appreciates the achievements of the SiD collaboration in the areas of simulation of physics processes and of beam background, and in the analysis of the benchmark processes. The studies recently completed in response to the questions asked after the presentation of the LOI are also appreciated. The quality and completeness of the reconstruction and analysis software might be improved in some areas, clarifying further the performance and the limits of the detector concepts.

Altogether, IDAG feels that completeness of the LOI and the effectiveness of the detector concept, together with the strength of the collaboration and the relevance of the foreseen R&D programs deserve the support for the transition to the next phase of detector preparation for ILC.

5.3 Fourth

The Fourth group should be commended for seeking innovative solutions to the challenges posed by ILC physics. Three major subsystems (outer tracking, calorimetry and magnet) differ from conventional choices made in recent collider detectors. This approach has however some drawbacks in implementation, as much R&D and engineering work remains to demonstrate that these choices can be realized in a cost effective way.

The dual-readout calorimetry concept has been tested by the DREAM collaboration with a small test module, although the performance was compromised by lateral leakage of energy. A beam test with a suitable readout device of a larger module capable of fully containing hadronic showers, and implementing both BGO and fiber sections with delayed scintillating fiber readout, is needed.
The cluster-counting tracking detector is novel, and a realistic test, with fully developed electronics readout for cluster counting, is necessary for demonstrating its viability. The cluster-counting concept for tracking detectors is as yet unproven. Part of the enabling technology involves the fast sampling digitizers needed to distinguish individual ionization clusters. The first step would be to demonstrate the resolution goal from laboratory tests in a few cells. Should this phase be successful, and with the prospect for cost-efficient production of chips, it may be useful to proceed to a beam test of a helium-based prototype which could demonstrate the projected track resolutions, and explore the performance of this technology in a dense track environment.

The dual solenoid magnet has advantages in reducing weight and fringe fields, reducing magnetic forces on surrounding structures, improving access to inner detectors, and its adaptability to gamma gamma collisions. However it has not yet been engineered and questions such as the stability in cases where one of the solenoids quenches have not been addressed in sufficient detail. The cost advantage and gains from the double solenoid arrangement are partially mitigated by the need for additional shielding.

The Fourth group does not have at this time a fully specified baseline design. The silicon vertex detector is taken from other concepts. It is in the simulation but its integration with the rest of the detector has not been specified. There is no choice made for photo-detectors for the calorimeter. The forward tracking is not specified; consideration is being given to silicon disks inside or outside the cluster counting tracking detector, or to special detectors surrounding forward toroidal magnets.

The potentially excellent energy resolution for dual-readout calorimeters and the possibility that an eventual e^+e^- collider may require reconstruction of jets of more than a few hundred GeV where particle flow algorithms seem to perform less well suggest that further R&D directed to prototype tests of dual-readout calorimeters in test beams is a high priority, and may also be beneficial for potential muon or very high energy hadron collider detectors. IDAG recommends that such an R&D program be given high priority.

The Fourth collaboration has failed to complete a baseline detector and could not provide IDAG with a full set of benchmarking results. This group is relatively small at present, and has a small component of major laboratory physicists. Their very limited resources has caused the Fourth group to fall short of fully demonstrating their detector concepts in beam tests or in simulation to the level similar to that reached by ILD and SiD. Therefore, unless a major reconfiguration and enhancement of resources can take place in all aspects of human, material and budget, IDAG believes that the Fourth group is unlikely to be able to complete the R&D and design program within the TDR period.

6. RECOMMENDATIONS FOR VALIDATION

On the basis of the information provided in the LOIs and supporting documents, the extensive discussions with the groups, and following the evaluation presented above, IDAG has reached the following unanimous recommendations:

a. **The ILD and SiD concepts are validated and should be considered for the next phase of detailed baseline studies together with GDE. They constitute a solid basis for the two-detector push-pull concept with a large amount of complementarity in their design and expected performances. Tracking options are very different, and even if their baseline choices for calorimetry are similar, their implementation and exploitation will ensure robustness in the ILC physics results. They should both demonstrate a feasible solution at the end of the TDR phase of the accelerator.**

b. **The Fourth concept is not validated. However R&D on dual readout calorimetry should be supported in view of its potential for higher energy colliders.**

7. CLOSING REMARKS

IDAG wishes to express its appreciation of the large effort produced by the concept groups and their cooperativeness during the evaluation period, with very open and high-quality exchanges. It certainly demonstrated the competence, the motivation, and the worldwide involvement of the particle physics community for the ILC program opportunities.

Appendix 1

The Mandate of the International Detector Advisory Group

June 24, 2008

Dear IDAG members,

Following the discussions at the first meeting in Warsaw, I wish to clarify the mandate of the International Detector Advisory Group (IDAG).

The original mandate for IDAG is given in the document of ILCSC, which describes the charge of the Research Director (RD), that IDAG is set up by the RD and it advises the RD on ILC experimental program issues. To be precise, the part is repeated below.

"In order to perform these tasks, the RD will

1. form a management structure under him/her to execute these tasks,
2. appoint a detector advisory group, the IDAG (International Detector Advisory Group), with the approval of the membership by the ILCSC.

The IDAG will

1. advise the Research Director on ILC experimental program issues
2. make recommendations to the Research Director on the choice of two detectors for the engineering design effort based on detector Letters of Intent. The Research Director will present these recommendations to the ILCSC for approval."

The entire document can be found in the following ICFA web page of the ILC related formal documents, http://www.fnal.gov/directorate/icfa/recent_lc_activities.html.

At the ILCSC meeting on February 11, 2008, this mandate was modified regarding last item no. 2 for the following two points:

a) IDAG does not advise on the choice of two detectors but on the validation of submitted LOIs,
b) The validation is not for the engineering effort but for technical design effort.

A summary of the meeting is reported at the bottom of the ILCSC page of ICFA: http://www.fnal.gov/directorate/icfa/International_ILCSC.html.

In the same meeting, the timeline of the process was expanded. The due date is shifted to end March 2009. The validated detector groups will participate in the technical design of the GDE's ILC project proposal which will be completed in 2012.

For the validation, I would request IDAG to examine the following points in concrete.

1. Are the physics aims of the detector convincing for an experiment at ILC?
2. Is the detector concept suited and powerful enough for the desired physics aims and the expected accelerator environment? Namely, is the arrangement of the employed detector components adequate?
3. Do the mechanism for the push-pull operation, related alignment and calibration methods enable the desired switching process?
4. Is the detector feasible? Namely, is the required R&D for the selected technologies advancing fast enough so that they can be completed during the design phase? Are the estimated cost and the way to obtain it reasonable when examined at the time of LOI?
5. Is the group powerful enough to accomplish the required design work through the technical design phase?

In principle each LOI will describe these topics in detail. At present the initial energy of ILC is considered to be 500 GeV as recommended by the ICFA parameter group of which report can be found also in the above ICFA web page.

Sakue Yamada
Research Director
ILC Physics and Detectors

Appendix 2

List of IDAG members

M. Danilov (ITEP, Russia)	exp	
M. Davier (LAL-Orsay, France)	exp	Chairman
C. Grojean (CERN-Saclay, France)	th	
E. Elsen (DESY, Germany)	acc	
P. Grannis (Stony Brook, US)	exp	
R. Godbole (IIS, India)	th	
D. Green (FNAL, US)	exp	
J. A. Hewett (SLAC, US)	th	
T. Himel (SLAC, US)	acc	
D. Karlen (Victoria and TRIUMF, Canada)	exp	
S. K. Kim (SNU, Korea)	exp	
T. Kobayashi (ICEPP, Japan)	exp	
W. G. Li (IHEP, China)	exp	
R. Nickerson (Oxford, UK)	exp	
S. Palestini (CERN, Italy)	exp	
N. Toge (KEK, Japan)	acc	

Ex-officio:

S. Yamada	Research Director
J. Brau	Regional Representative (America)
F. Richard	Regional Representative (Europe)
H. Yamamoto	Regional Representative (Asia)

Appendix 3

Matrix organization of IDAG work

	Benchmarking		Tracking	Calorimetry	MDI
ILD	Hewett	Li	Nickerson	GREEN	Himel
SiD	Grojean	PALESTINI	Danilov	Karlen	Toge
Fourth	Godbole	GRANNIS	Elsen	Kobayashi	Kim

Underlined: convener for component subgroup (vertical)

Capital letters: convener (referee) for concept subgroup (horizontal)

Appendix 4 :

17 November 2008

Updated version of IDAG requirements to be addressed in the LOI's
(in addition to the original LOI guidelines)

(1) Detector optimization: identification of the major parameters which drive the total detector cost and its sensitivity to variations of these parameters.

(2) Plans for getting the necessary R&D results to transform the design concept into a well-defined detector proposal.

(3) Conceptual design and implementation of the support structures and the dead zones in the detector simulation.

(4) Sensitivity of different detector components to machine background in the context of the beam parameter space considered in the RDR.

(5) Calibration and alignment schemes.

(6) Estimates of overall size, weight, and requirements for crane coverage and shielding.

(7) Push-pull ability with respect to technical aspects (assembly areas needed, detector transport and connections, time scale) and maintaining the detector performance for a stable and time-efficient operation.

(8) A statement about energy coverage, identifying the deterioration of the performance at energies up to 1 TeV and the consequent detector upgrades.

Appendix 5 :

IDAG schedule and meetings

Feb. 2008		Appointment of IDAG members
March 2008		Expressions of interest (EOI) received from ILD, SiD, Fourth
March 6-9 2008	Sendai:	Informal discussions
June 9-12 2008	Warsaw:	Open presentations EOI Interviews Discussion on mandate with Research Director
Nov. 16-19 2008	Chicago:	Open presentations EOI Interviews Set up review organization
Jan. 27 2009	phone:	Discussion on tracking
Feb. 17 2009	phone:	Discussion on calorimetry
March 3 2009	phone:	Discussion on MDI
March 31 2009		Letters of Intent (LOI) received from ILD, SiD, Fourth
April 14 2009	phone:	LOI discussion and pre-Tsukuba questions
April 17-21 2009	Tsukuba:	Open presentations LOI: detector, benchmarking Interviews Common session on benchmarking Review work Post-Tsukuba questions
June 19-21 2009	Orsay:	Interviews Review work Drafting of report
July 2009	e-mail	Finalization of report
August 2009		IDAG report submitted to Research Director

Appendix 6 :

Written questions asked before Tsukuba meeting

ILD

1. The vertex detector is sensitive to machine backgrounds. Can you assess what "headroom" there is if backgrounds are higher than planned? For example, what is the flavor tagging behavior - purity vs. efficiency - in the presence of added background. In addition, the tagging is evaluated at the Z pole. What is the response at higher energies?

2. What is the impact of misalignments of the several hundred million independent channels on the tagging behavior? How long will an alignment take - both initially and after each push-pull cycle?

3. For the TPC what would be the impact of increased machine background? What is the tracking alignment plan and how long does it take? Once aligned how are field distortions and temperature/pressure variations monitored? Is the speed of monitoring sufficient to track machine transients?

4. What is the impact of a range of machine noise and misalignment of the TPC on the physics performance?

5. The ILD calorimeter has ~ 100 million channels. How will manufacturing uniformity be maintained? Is there sufficient industrial capacity to supply the silicon? How will the calibration be first made and then maintained? Why is there no "constant term" in the resolution due to cracks, supports, cables, and other non-uniformities in the medium or errors in calibration?

6. When will there be a test of power pulsing with B field? For example CDF have had difficulties with wire bonds. Is power pulsing required or is there an alternative?

SiD

a) The choice of beam pipe radius and vertex detector inner radius are driven by machine background (mainly incoherent pairs from the IP). Can you provide additional information on your assumptions on background rates, on safety margins and on impact on performance if the background would be higher?

b) The detector is expected to be read out separating each bunch crossing (mainly by means of the KPiX circuit). Is this assumption going to be valid also for the vertex detector?

c) How extensive a study has been made of the robustness of the tracking against failure of one or more detector planes? The vertex detector is glued, replacement of parts seems unlikely. Similarly how much impact does the loss of one or more planes make on PFA performance..

d) Can you provide more details concerning the choice of 4.5 interaction lengths for the depth of the HCal? How sensitive is it to assumptions on PFA algorithm? How much can be obtained from the Muon system used as a tail catcher for the hadronic showers, which is mentioned as an option?

e) Current PFA analysis provides rms90 = 4.0 GeV in M(Z->qq) from ZZ at 500 GeV, with most of the uncertainty due error in tracks/clusters matching. The Gaussian width of the Z(jj) appears significantly wider in the studies of benchmark channels. The LOI mentions that the performance of the algorithm is expected to be improved, can you provide some more details about it?

Fourth

1. We would like to see a more detailed description of the algorithm used, and details of the simulation, for the cluster counting tracking. Most generally, we would appreciate some enlightenment on why the He-based gas, with lower ionization and thus less 'collected information', should give better resolution than the traditional Ar-based mixtures. More specifically, we would like to understand the performance as a function of occupancy by multiple tracks; the effect of the Lorentz force (and possibly different B field operations) on the drifting electrons: the impact of the cluster-finding electronics on performance; and the degradation from diffusion of charge, or ion buildup.

2. What is your plan to develop the forward tracking design? What are the impacts of added silicon disks either within or outside the tracking chamber enclosure? How would forward toroidal magnets improve forward momentum resolution, and how would they be integrated?

3. IDAG would benefit from a clear summary of the expected calorimeter performance with only a fiber dual readout calorimeter, and with the combined BGO/fiber calorimeter (there are many resolution numbers that are sometimes hard to keep track of). Please give us some detail on the algorithms used for the combination of the BGO and fiber signals. Can you justify the separate BGO calorimeter with its added cost and integration complexity? We would also like to understand more clearly how the simulations and DREAM measurements (both fiber only and BGO/fiber) compare. For example, is the 64%/sqrtE stochastic term seen in DREAM (Fig. 16) fully explained by the lateral leakage? Are the differences in Figs. 46 and 47 between DREAM and simulation understood?

4. We would like some additional discussion of calorimeter calibrations. What is your plan for test beam calibration versus in situ calibration? For the calibration in ILC, how many Z's do you need to obtain a 1% calibration? How do you obtain the pion calibration in situ, and what is the time required, compared to your estimated time over which the response may drift? Is a single calibration at some high energy (~40 GeV) sufficient to calibrate the response for low energy particles (<10 GeV) and for the differences among particle types?

5. Can you compare the benefit to physics, cost, and MDI complexity for a dual solenoid approach compared with one with iron return yokes. Is the dual solenoid an optimized choice? Is there demonstrable physics benefit from a second muon momentum measurement over outer muon identification with its momentum taken from the inner tracker?

Appendix 7 :

Written questions asked before the Orsay meeting

Common questions

(1) Give an outline of the plans for calibrating the energy response of your calorimeter, both from test beams or monitoring signals and *in situ* running. What level of precision is required? How is it obtained? How do you monitor and maintain it? If operation at the Z pole is part of your strategy, how much data is required?

(2) What is your plan for aligning your tracking systems. What is the precision required? Are there special operations needed for alignment after push-pull prior to data taking, and what time is required? How many degrees of freedom need to be considered after a move? How do the alignment needs affect the design of your detector? Is any real-time monitoring of the tracker alignment envisioned (e.g., related to power pulsing and long-term stability)?

(3) Repeat the recoil analysis with $Z \rightarrow \mu\mu$, ee, including the corrected ISR spectrum, and simulation of background hits.

ILD

(1) Elaborate on the meaning of the information in Fig. 4.3-4. What are the plans to mitigate the loss of track efficiency with background level? What is the sensitivity to beam halo, and at what level does it become problematic?

(2) Perform the A_{fb} analysis in the study of the t-tbar benchmark channel.

(3) Z(→ee) H inclusive: show the result of the analysis with and without the calorimeter.

SiD

(1) Elaborate on the robustness and redundancy of the tracking performance. In particular how would it deteriorate with a missing layer? Give the efficiency and the fake track fraction in a jet environment with full background simulation.

(2) Calibrate the template analysis for mass resolution in t-tbar and neutralino/chargino channels: study the robustness of the method by adding more comparison tables.

(3) Z(→ee) H inclusive: show the result of the analysis with and without the calorimeter.

Fourth

(1) We would like to see a more complete description of your baseline detector for:
    (a) the photodetectors for the BGO and fiber calorimeter
    (b) the mechanical support system for the calorimeters
    (c) the forward tracking systems

(2) What is the expected efficiency of the CluCou chamber in a 250 GeV jet and background, under the conservative assumption that for multiple occupancy in a cell the hits due to larger impact parameter are lost.

(3) Perform the chargino/neutralino benchmark analysis including (i) all background processes, (ii) beamstrahlung and bremsstrahlung, (iii) polarized beams (P_{e-}=80%, P_{e+}=30%), and (iv) all detector subsystems. The most important aspect in this is the analysis of background from charginos in the neutralino analysis and vice versa..

(4) Make a proper comparison of the DREAM data and the simulations (with/without BGO) to validate the simulation results.