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Detectors for a Linear Collider

J. Mnich*

Deutsches Elektronen-Synchrotron (DESY), Germany

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Abstract

The International Linear Collider (ILC) is the next large project in high energy physics and currently being designed in a global effort. The main scientific goal is to complement the anticipated discoveries at the LHC by precision measurements at the TeV scale. This has challenging implications on the ILC detector design and performance requiring unprecedented precision in vertexing, tracking and calorimetry. Design studies on four detector concepts are ongoing which are complemented by international R&D programmes to develop detectors suitable for the conditions at the collider and matching the required performances. A survey will be given on the detector concepts and technologies under investigation together with the current status of the R&D programmes and future plans.

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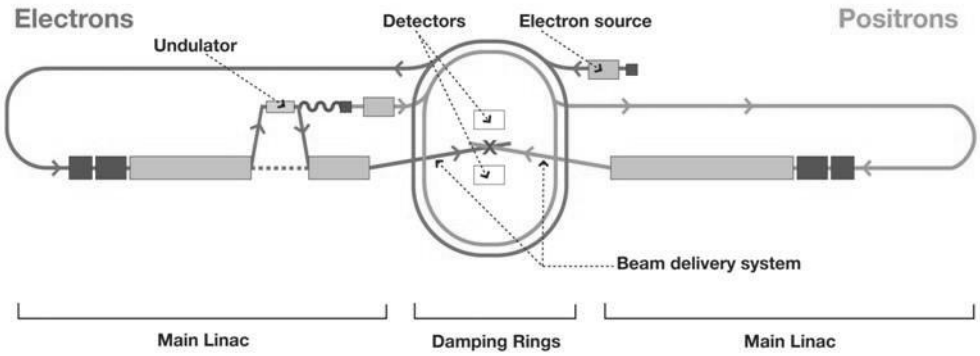

Figure 1: Main elements of the current ILC design as described in the RDR [3, 4].

1 Status of the ILC

By world-wide consensus a electron-positron collider with centre-of-mass energy up to 1 TeV providing a luminosity in excess of $10^{34}\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ is the next large project in high energy physics [1]. The collider as well as adequate detectors are being designed in a truly global effort. In 2004 an International Technology Review Panel has recommended to base the main accelerator on RF supra conducting cavities choosing thus the technology for one of the most important elements of the collider [2].
Other key elements of the collider are components like high intensity sources of polarised electrons and positrons, damping rings, beam delivery and final focus systems which are still to designed and optimised based on elements described in concepts and design reports developed in different regions of the world. The world-wide design is pursued under the name of the International Linear Collider (ILC) and the Global Design Effort (GDE) has been created in 2005 to perform the development of the machine. The GDE includes representatives from the Americas, Asia and Europe and the design work is performed by leading accelerator scientists from all major laboratories in the world.
These efforts resulted in a Reference Design Report (RDR) of the collider of which a draft has been present in February 2007 [3]. The document describes the current layout of the ILC with the main elements as sketched in Fig. 1. The baseline are two 250 GeV accelerators yielding a centre-of-mass energy of 500 GeV. The later upgrade to 2×500 GeV is embedded in the design and can be achieved by extending the length of the accelerators possibly using higher gradient cavities. For cost reasons only one interaction region is foreseen. Two detectors will be moved in and out the beam line (push-pull) and thus take data in alternating periods. This scenario, together with the 14 mrad angle between the two beams, has impact on the detector design.
An estimate of the costs for such a collider is included in the RDR. At today's prices it amounts to approximately 6.65 billion dollars (or 5.52 billion Euro) investment cost and a human effort corresponding to about 13000 person years. The RDR will evolve into a technical design by around 2010. Alternative options for component are pursued

in parallel and might eventually replace the current baseline if more performant or cost effective.

2 Physics Motivation

The physics case for the ILC has been developed over the last 15 years and is described in detailed in many documents (see for instance [5]). Experiment at the ILC will complement the initial particle discoveries anticipated at the LHC by precision measurements of their properties exploiting the unique features of e^+e^--experiments: the cleanness of the experimental environment and the well defined kinematics of the colliding, elementary particles. A comprehensive survey of the interplay and complementarity between the LHC and the ILC is given in reference [6]. Here only two example are given to exemplify the ILC physics case and to illustrate the impact on the detector design imposed by the planned precision measurements.
If the Higgs mechanism is realised in nature the predicted Higgs boson will be discovered by the LHC experiments as their sensitivity covers the complete mass range allowed [7]. Identification of Higgs bosons at the LHC, however, is based on assumptions on production and decay properties and, in the presence of large background, only possible in certain decay modes. At the ILC Higgs boson production is based on the Higgs-strahlungs process $e^+e^- \rightarrow HZ$ which has already been the basis for Higgs searches at LEP [8]. The real Z boson accompanying the Higgs boson can be used to tag the event such that no hypothesis on decay modes and probabilities is needed. It is thus straightforward to identify the Higgs decay products and to determine the branching fractions from their relative occurrences. For light Higgs bosons precision on the percent level can be reached (see Fig. 2). This consists a very important measurement as it allows the determination of the Higgs couplings to W and Z bosons and of Yukawa couplings to fermions which are precisely prescribed in the model by the properties assigned to the Higgs boson.
In addition, double Higgs production $e^+e^- \rightarrow HHZ$ at the ILC provides a way to measure the Higgs self-coupling which is a direct consequence of the form of the Higgs potential of spontaneous symmetry breaking. However, the cross section of this reaction is small and the experiments must exploit the hadronic decays of the Z and W bosons (from $H \rightarrow WW$) which consist about 70% in either case.
Another possible outcome after a few years of LHC operation might be that the Higgs mechanism is not providing masses to fermions and bosons. In this case something else must prevent for instance WW scattering from violating universality at around 1TeV. Theories like strong electroweak symmetry breaking have been developed to address this scenario. Experimentally it means that WW and ZZ scattering must be studied carefully in processes like $e^+e^- \rightarrow WW\nu\nu$, $WZe\nu$, ZZe^+e^-. Again, it will be mandatory that W and Z bosons are identified and distinguished in their hadronic decay modes.
There are many other arguments to be made for studies of Standard Model and SUSY processes as well as fro searches for new phenomena. The detectors at the ILC require

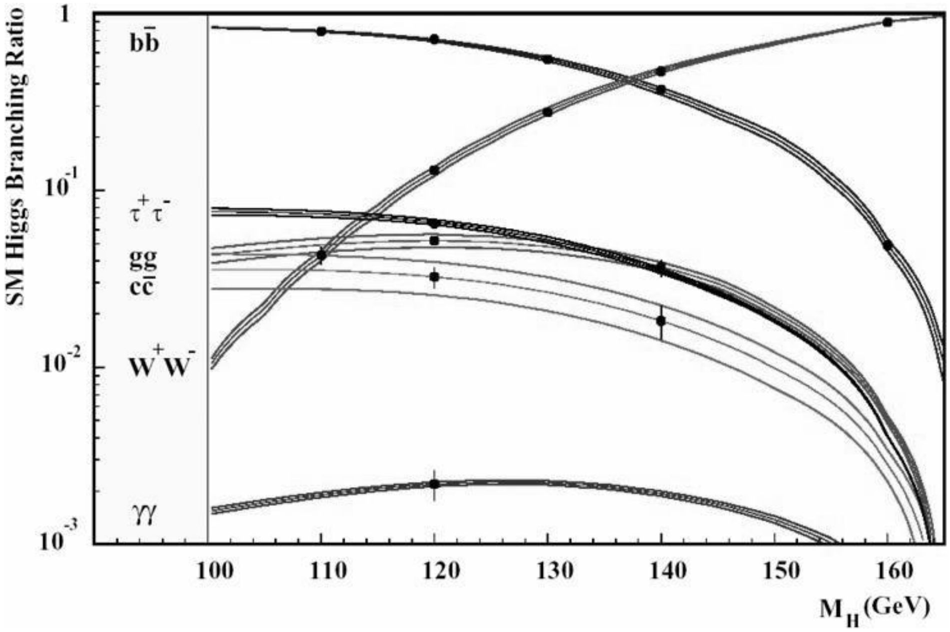

Figure 2: Branching ratios of the Standard Model Higgs boson for masses up to $m_{\rm H}$ = 160 GeV together with the expected experimental accuracy at the ILC [5].

ultimate performance to meet the physics case and to make the experiments complementary to the LHC providing new insight to physics at the Terascale.

3 Impact on Detector Design

From the requirements imposed by physics as sketched above performance criteria for the components of the ILC detectors can be defined. Below a few examples are discussed with the emphasis put on the most critical issues.
The main requirement on the vertex detector is identify secondary vertices and to allow for a very efficient identification of long-lived particles containing b- and c-quarks, among others to measure the Higgs decay fractions in those quarks. The goal set is to achieve an impact parameter resolution in both $r\phi$ and z coordinate of

$$\sigma_{r\phi} \approx \sigma_z \approx 5\ \mu\text{m} \oplus \frac{10\ \mu\text{m}}{p/\text{GeV}\ \sin\theta^{3/2}}.$$

This is about a factor of three smaller than the performance reached at the SLC detector. To achieve this goal low mass silicon pixel detectors are considered with cell sizes of the order of $20 \times 20\ \mu\text{m}^2$. Various technologies are discussed to achieve this goal as discussed below.
One of the most important tasks of the main tracking detector is defined by the selection of Higgs events through the accompanying Z boson decaying leptonically into

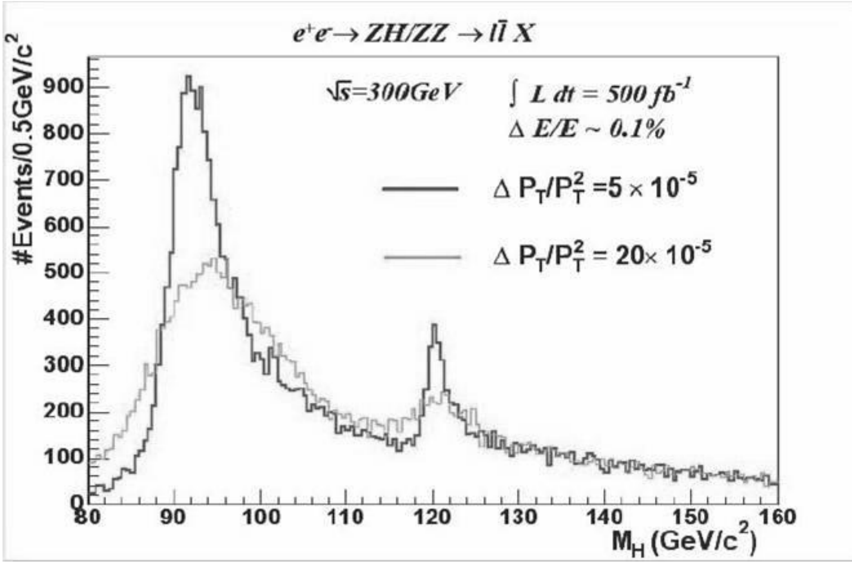

Figure 3: Mass distribution for Higgs boson candidates in simulated ZH and ZZ events for two values of the transverse momentum resolution of the tracking system [9].

$Z \to e^+e^-, \mu^+\mu^-$ It requires a super momentum resolution to achieve the best possible measurement of the mass of the recoiling system, the Higgs candidate, and hence the optimum signal over background ratio. This is illustrated in Fig. 3 which shows the reconstructed recoil mass in a combined simulated ZH/ZZ sample for two different momentum resolutions of the tracking system. Ideally the measurement would be limited by the natural width of the Z boson, Γ_Z which corresponds to a resolution on the transverse momentum $p_{\rm T}$ of the whole tracking system, i.e. including the vertex detector, of

$$\sigma(1/p_{\rm T}) = 5 \cdot 10^{-5}\ \mathrm{GeV}^{-1}.$$

This exceeds the expected performance of the CMS tracking system currently under construction for the LHC by about a factor of three.

Two options are considered for the main tracking system: A large full silicon tracker consisting of five layers of silicon strip detector and hence similar to the trackers of the LHC experiments ATLAS and CMS. The alternative choice is a large time Projection Chamber (TPC) with single point resolution of 100 μmand thus considerably improved as compared to similar chambers at previous e^+e^--colliders.

The main force driving the performance requirement of the calorimeter is the need for jet energy resolution sufficient to distinguish W and Z bosons in their hadronic decays. Fig. 4 demonstrates that a jet energy resolution of about $60\%/\sqrt{E/\mathrm{GeV}}$ achieved in todays experiments is not sufficient to reach this goal. A factor of two improvement resulting in a resolution of about $30\%/\sqrt{E/\mathrm{GeV}}$ is required to clearly separate the two heavy gauge bosons. Two approaches are pursued to achieve this goal: Highly granular

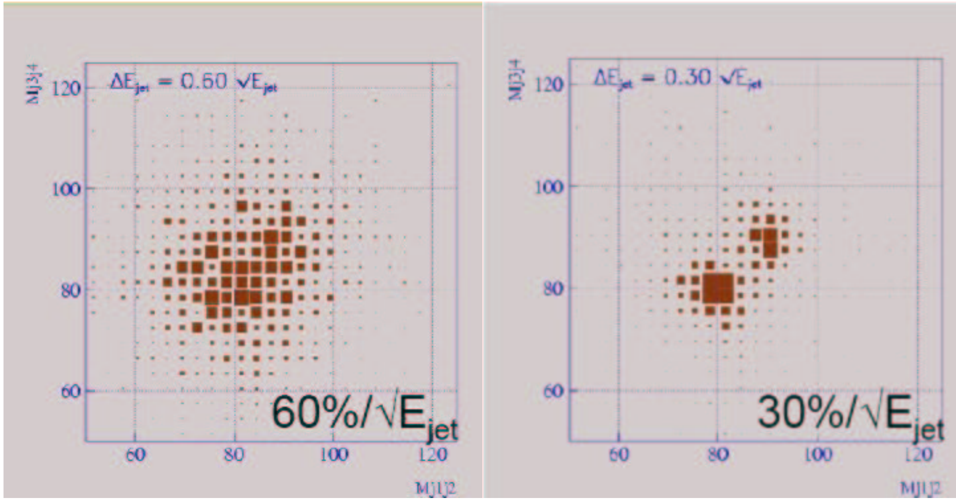

Figure 4: Di-jet mass distribution of simulated events WW/ZZ → hadrons assuming a jet energy resolution of $60\%/\sqrt{E/\mathrm{GeV}}$ (left) and $30\%/\sqrt{E/\mathrm{GeV}}$ (right) [5].

calorimeters are developed employing particle flow algorithm to achieve the optimum. Also multiple readout calorimeters are designed which are supposed to significantly improve over classical hadron calorimeters.

Other challenges on the detector are imposed by the operation conditions of the ILC. Contrary to circular e^+e^--colliders with constant time intervals between collisions the ILC will have particle bunches organised in trains. Such a bunch train contains 2820 bunches separated by 307 ns resulting in a total duration of 0.87 ms. The trains are repeated five times per second. A sophisticated first level trigger like for instance at the LHC experiments is considered to be unnecessary. As the duty cycle at the ILC is only about 0.5% this time structure can be exploited for some detector components to reduce significantly the heat dissipation by power pulsing. On the other hand the detector readout during a bunch train poses severe challenges in particular on the vertex detector as discussed below.

The strong focusing at the interaction leading to very small bunch sizes as required by the luminosity goal produces large amounts of beamstrahlung and secondary particles. This increases the beam related background much above the level of previous e^+e^--colliders like LEP requiring detectors capable to deal with it without loosing in precision. However, with the exception of the very forward detectors radiation hardness is of much less importance than at the LHC.

4 The Four Detector Concepts

Four detector concepts are being investigated by international study groups. The groups have produced by summer 2006 Detector Outline Documents (DOD) describing the main features of the designs:

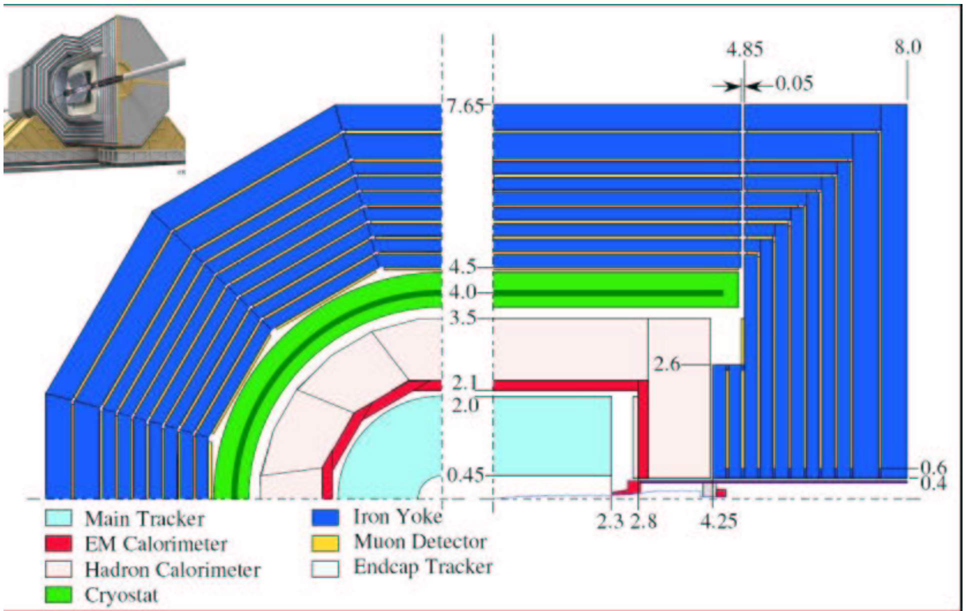

Figure 5: One quadrant of the GLD design in the $r\phi$- (left) and rz-view (right) [10].

- GLD (Global Large Detector) [10]
- LDC (Large Detector Concept) [11]
- SiD (Silicon Detector) [12]
- 4th Concept [13]

These DODs are evolving documents and will develop into more comprehensive Detector Concept Review by mid 2007. Below the main design features of these concepts will be presented.

The GLD and LDC concepts (Figs. 5 and 6) are rather similar and represent enhancements of classical e^+e^--detectors like for instance the LEP experiments. The main components starting from the collision point are the vertex detector a large gaseous detector, a TPC in both cases. The calorimeter is based on the particle flow concept and embedded inside a large superconducting solenoid coil. The iron return yoke houses several layers of muon detectors for which RPC, scintillator strips or other techniques are considered.

The difference between both concepts is that the GLD detector is somewhat larger in size than the LDC concept including a larger radius of the TPC tracker. This is compensated by a larger magnetic field - 4 T instead of 3 T - in the LDC concept.

The SiD concept is sketched in Fig. 7. Its main feature as compared to the above two detector designs is the main tracker made of silicon strip detectors, i.e. more close to the ATLAS and CMS design. Five silicon detector layers are foreseen in the barrel

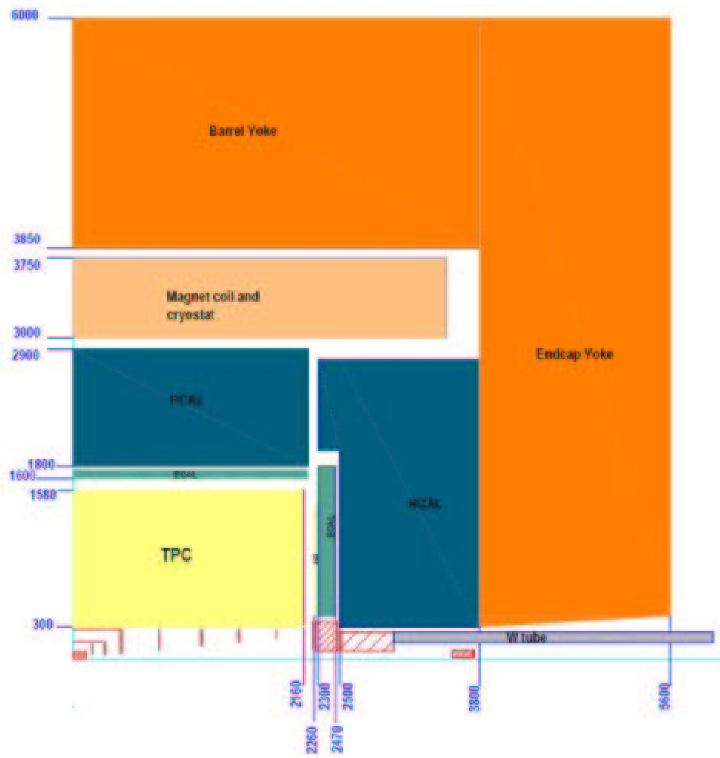

Figure 6: One quadrant of the LDC design [11].

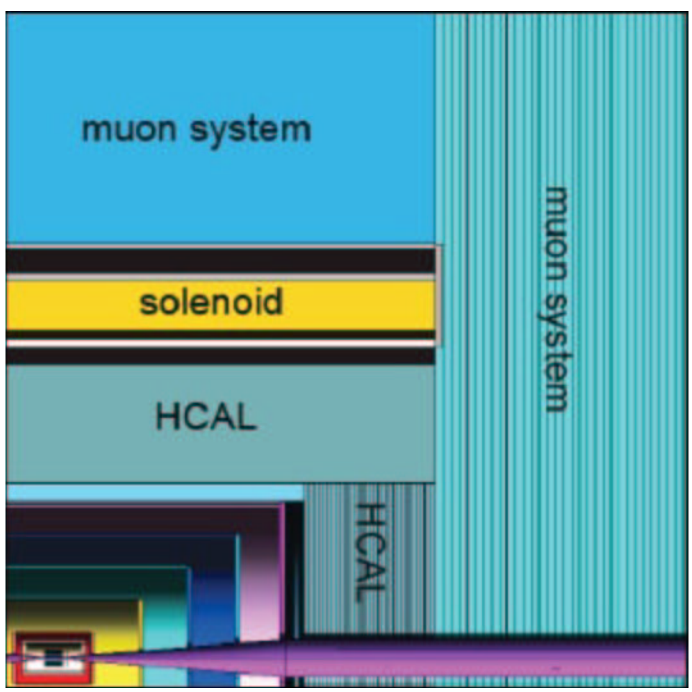

Figure 7: One quadrant of the SiD design [12].

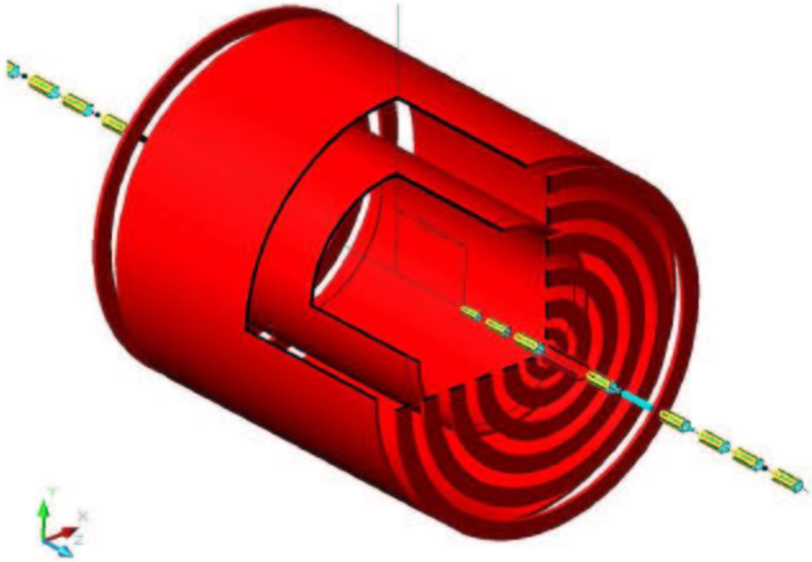

Figure 8: Layout of the magnet system of the 4th concept [13]. Shown are the inner and outer solenoid coils and the endcap coils to contain the magnetic field in the detector volume.

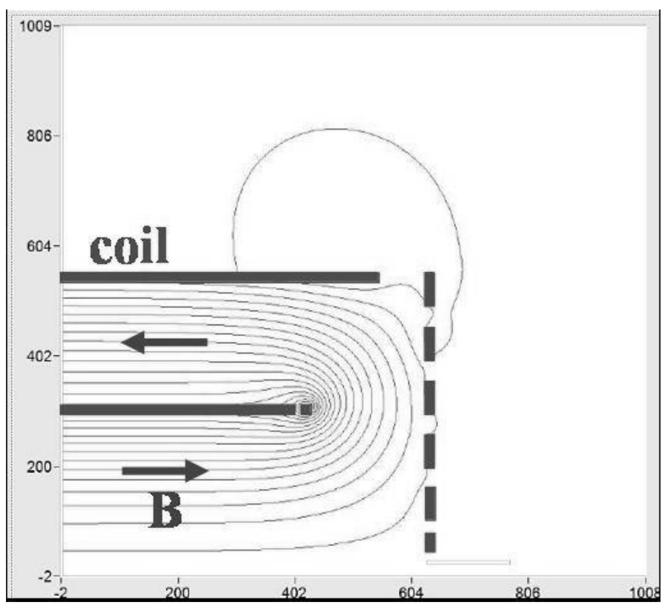

Figure 9: Magnetic field configuration in the 4th concept.

	GLD	LDC	SiD	4th concept	Detector R&D collaborations
Vertex	X	X	X	X	LCFI [16]
Tracking					
TPC	X	X		X	LCTPC [17]
- Silicon	*	*	X	*	SILC [18]
Calorimetry					
- Particle Flow	X	X	X		CALICE [19]
- Multiple Readout				X	
- Forward region	X	X	X	X	VFCAL

Table 1: R&D projects on components of the ILC detectors and their relevance for the four detector concepts. The rightmost column lists the international detector R&D collaborations.

complemented by five disks on either endcap side. The detector is also smaller in size but comprises the largest solenoid field of 5 T.
The 4th concept is rather orthogonal to the other designs, mainly for two design features. The magnet does not include an iron return yoke and the magnetic field is contained in the detector volume by a system of an inner and an outer barrel solenoid coil complemented by two walls of coils at the endcaps (see Figs. 8 and 9). The region between the two barrel coils is filled by a muon spectrometer of high precision drift tubes. The average field seen by a muon traversing the detector is $\langle B \rangle \approx 1.5$ T providing a bending power of $\langle Bl \rangle \approx 3$ Tm.
Contrary to the other concepts the calorimeter is based on a multiple readout approach. The basic idea is to reduce the effect of the main fluctuations in hadronic shower - electromagnetic and nuclear binding energy - by measuring these components in each jet. A calorimeter is conceived made of thin fibres measuring scintillation and Ĉerenkov light separately [14, 15] and eventually neutrons by timing information or doped fibres to obtain information on nuclear interactions in the shower.
In parallel to the efforts on the four detector concepts large international R&D work is ongoing on the main components to develop detectors matching the requirements at the ILC. There is obviously a large overlap between the R&D on detector technologies and the various concepts as well as between the people involved in both activities. This is illustrated in Tab. 1 which presents the detector R&D collaborations formed for the main detector components and their relevance for the four detector concepts. Efforts on vertex detectors and forward calorimeters are shared by all concepts. Some basic choices on technologies and strategies for the main tracking detectors and calorimeters have been made by the concept studies. It should be noted that silicon based tracking is foreseen as option for auxiliary and forward tracking devices also by the other three concepts. All concepts are still investigating several technology options for sub-detectors which are studied in the various detector R&D collaborations.

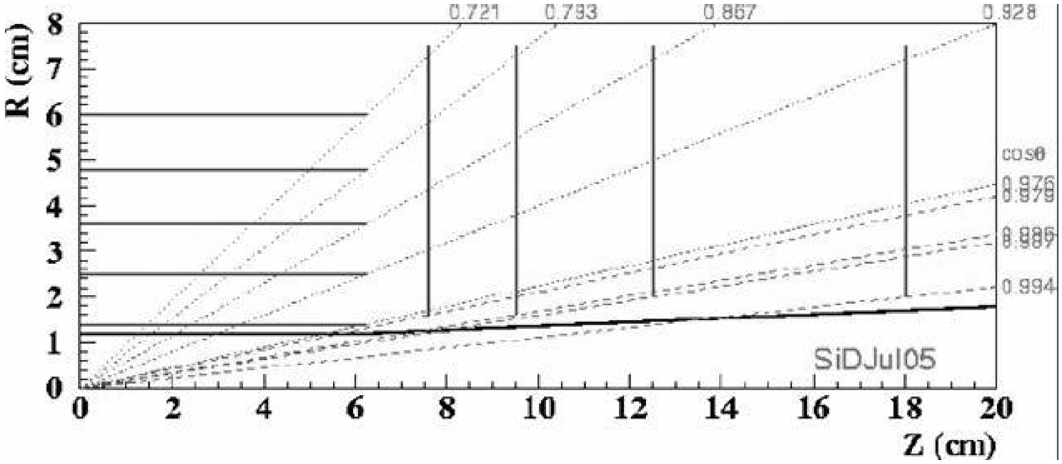

Figure 10: Layout of one quadrant of the SiD vertex detector with five layers of silicon pixel detectors in the barrel and endcaps.

5 Detector R&D for Key Components

This section contains brief descriptions of the ideas and developments for the key detector components. More detailed information can be obtained from web pages of the R&D collaborations as listed in Tab. 1

5.1 Vertex Detectors

Vertex detectors at the ILC should be able to measure the impact parameter of each track and have stand-alone tracking capability to facilitate pattern recognition. Detector systems with five layers of small silicon pixel detectors are foreseen starting at with the innermost layer at the smallest possible radius $r_i \approx 15$ mm from the interaction point. Fig. 10 shows the layout of such a system for the SiD concept. Such a detector would comprise up to about 10^9 channels.
A pixel size of about 20×20 μm^2 and very low thickness of 0.1% of a radiation lenght X_0 per layer is aimed at. If compared to the pixel detectors under construction for the LHC this corresponds to a reduction by a factor of five in the inner radius r_i and factors of about 30 in pixel area and material budget.
Another critical issues for the vertex detector is the required readout speed. Pattern recognition requires that the occupancy is not too large. In the most critical inner layer of the detector about 100 hits/mm^2 are expected from background simulation which is considered too large. To reduce the occupancy to a tolerable level the detector must be read out about 20 times per bunch leading to 50 μs per frame. This requires the development of fast detectors with parallel readout pixel columns. Alternatively data storage on the pixel chip is investigated which would allow for data transfer in the long gap between two bunch trains. Several pixel technologies are under investigation ranging from Charge Coupled Devices (CCD) with parallel column readout to detectors

incorporating data storage like In-situ Storage Image Sensors (ISIS). A recent survey of technologies under consideration is given for instance in reference [20].
A major issue is the minimisation of material to achieve the goal of 0.1% X_0 per detector layer. Thinning of the active silicon to about 60 μm has been demonstrated for some of the pixel technologies. Layers of carbon based foams[1] which have a good thermal match to silicon are considered as an option to provide mechanical support for the active detectors [21]. Such prototypes have been constructed resulting in material budgets close to the desired goal. It should be noted that this kind of R&D effort is essentially independent of the pixel technology.

5.2 Tracking

The SiD concept includes as main tracking device a detector made out of short silicon strip detectors. In order not to compromise the achievable momentum resolution as well as the concept of particle flow calorimetry the total material budget of active silicon, support structures, cooling and readout must be reduced to an absolute minimum. The goal of 0.8% X_0 per layer would result in about 0.1 X_0 for the whole tracker including vertex detector and beam pipe [12]. This is about an order of magnitude smaller than for the CMS tracker [22] which however consists of twice as many layers and has the additional problem of requiring cooling to below -10 degrees to resist the radiation at the LHC. Yet, the achievement of such a low mass remains probably the most important challenge for silicon tracker at the ILC.
The maximum size of silicon strip detectors is governed by the available wafer size which is currently 6 inch in diameter. An alternative approach for a large silicon tracking detector are long ladders made of daisy chained single detectors which reduces the amount of required readout electronics. It necessitates low noise electronics specially adapted to the large capacitance of the long strips. This approach is followed by the SiLC collaboration.
The three other detector concepts are based on gaseous tracking. A high resolution TPC of $3 - 4$ m diameter and about 4.5 m length should deliver 200 space points with about 100 μm resolution in the $r\phi$ coordinate and on its own a momentum resolution of $\sigma(1/p_{\mathrm{T}}) \approx 10^{-4}$/GeV which is an order of magnitude better than the LEP detectors. Here low mass is less of a concern at least in the barrel part where 3% X_0 should be achievable. The development of low power, highly integrated electronics in required to stay below the anticipated 30% X_0.
To achieve the spatial resolution mentioned above gas amplification at the endplate will be done by Micro Pattern Gas Detectors (MPGD) like Gas Electron Multipliers (GEM) [23] or MicroMegas [24] devices. As compared to the classical approach employing proportional wires they offer finer dimensions and a two-dimensional symmetry eliminating the nuisance of $E \times B$ effects at the scale of the required precision. In addition they deliver a fast electron signal and provide intrinsic suppression of in backdrift.

[1] Examples are Reticulated Vitreous Carbon (RVC) and Silicon Carbid (SiC.

particles in jet	fraction of jet energy	detector	single particle resolution	jet energy resolution
charged	$\approx 60\%$	tracker	$\sigma_{p_T}/p_T \approx 0.01\%\, p_T$	negligible
photons	$\approx 30\%$	ECAL	$\sigma_E/E \approx 15\%/\sqrt{E}$	$\approx 5\%/\sqrt{E_{jet}}$
neutral had.	$\approx 10\%$	ECAL + HCAL	$\sigma_E/E \approx 45\%/\sqrt{E}$	$\approx 15\%/\sqrt{E_{jet}}$

Table 2: Average composition of jet energy, typical single particle energy resolutions and contributions to the jet energy resolution assuming perfect particle matching [29].

The development of such a TPC is pursued in the framework of the LCTPC collaboration. Several small scale prototypes have achieved the goal on the single point resolution in high magnetic fields where transverse diffusion is reduced [25]. MPGD based TPCs are under construction like for example for the T2K experiment [26].
Another development in this field is to combine a MPGD based TPC with pixel readout chips providing the ultimate resolution. For this purpose the TimePix chip providing also time information needed for three-dimensional reconstruction in a TPC has been developed and tested [27, 28]. Such a device has the potential of providing the ultimate spatial resolution possible with a TPC and to allow for cluster counting to improve the measurement of the specific ionisation $\mathrm{d}E/\mathrm{d}x$. A larger TPC diagnostic module using the TimePix chip is under construction.
Both silicon based tracking and a high resolution TPC have the potential to meet the requirements at the ILC. But the two technologies do have distinct features. The TPC will provide about 200 precise points in space which allows for quasi-continuous tracking and thus easy pattern recognition. At least in the barrel part a very low detector is easy to achieve. On the other hand a silicon strip tracker has an intrinsically better point resolution and perhaps the potential for a better momentum resolution. As there is no $E \times B$ depend drift the impact of an imperfect magnetic field is smaller. A silicon detector is also fast and will allow for bunch identification.

5.3 Calorimeters

Most of the detector concepts base the calorimetry on the application of the Particle Flow Algorithm (PFA). The idea here is to try to reconstruct every particle in a jet and to measure its energy by the most precise device available. That is the momentum of all charged particles is determined very precisely in the tracker, photons are measured relatively accurate in the electromagnetic calorimeter (ECAL) and only for neutral hadrons the poor resolution due to large fluctuation of hadronic interactions are left in their energy determination from the ECAL and hadronic calorimeter (HCAL). Taking into account the average contributions to the visible energy in a jet ideally energy resolutions as given in Tab. 2 are expected.
However, this assumes perfect assignment of all tracks and energy depositions and indeed

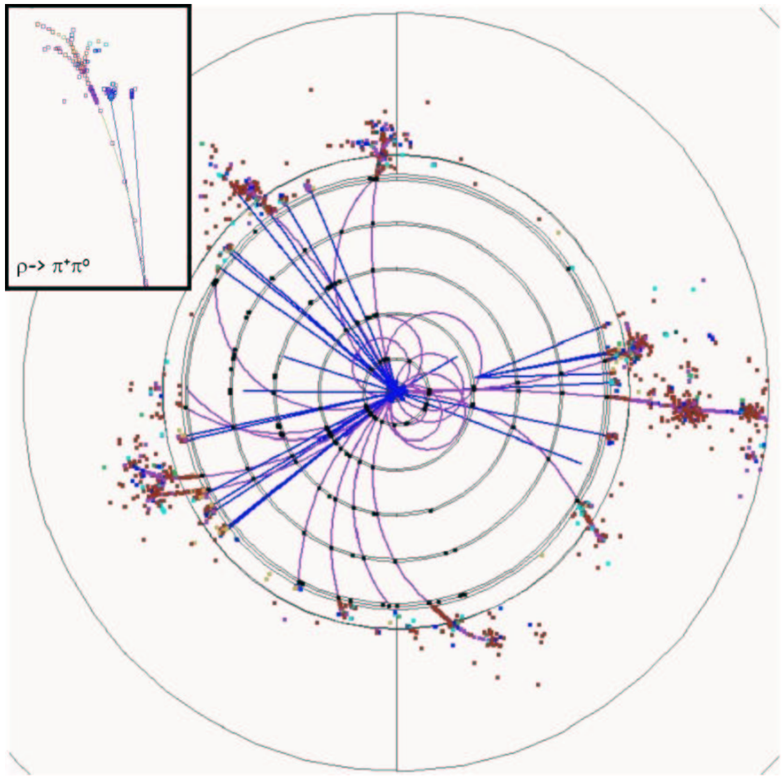

Figure 11: Simulated hadronic event in the SiD concept. The inlet shows details of a $\rho^+ \to \pi^+\pi^0$ decay.

the largest contribution to the effective jet energy resolution is expected to origin from the so-called confusion term. It describes misassignment of tracks and energy clusters, double counting, overlapping clusters and similar effects. To reduce this contribution highly granular calorimeters - ECAL and HCAL - are required. This is illustrated by Fig. 11 which shows a simulated event in the tracker and calorimeters of the SiD concept. The CALICE collaboration [19] performs R&D to validate the PFA concept and to design calorimeters for the ILC. As an example the design of the LDC barrel calorimeter is shown in Fig. 12. The ECAL is devised as silicon-tungsten calorimeter of 23 X_0 depth with a longitudinal segmentation varying between 0.6 X_0 and 1.2 X_0 [30]. The readout consists of 5×5 mm^2 silicon pads with low power readout electronics fully integrated in the detector. As an alternative the GLD concept envisages also a tungsten ECAl with scintillating strip readout.
For the HCAL part two main options are under consideration: An analogue scintillator tile calorimeter with moderate transverse segmentation of the order of 3×3 mm^2 employing silicon photomultiplier for photo detection [31]. Alternatively the gaseous digital HCAL is investigated which is more granular (1×1mm^2) but provides only binary information from each readout cell. Technologies considered are Resistive Plate Chambers (RPC), GEM or MicroMegas based detectors.

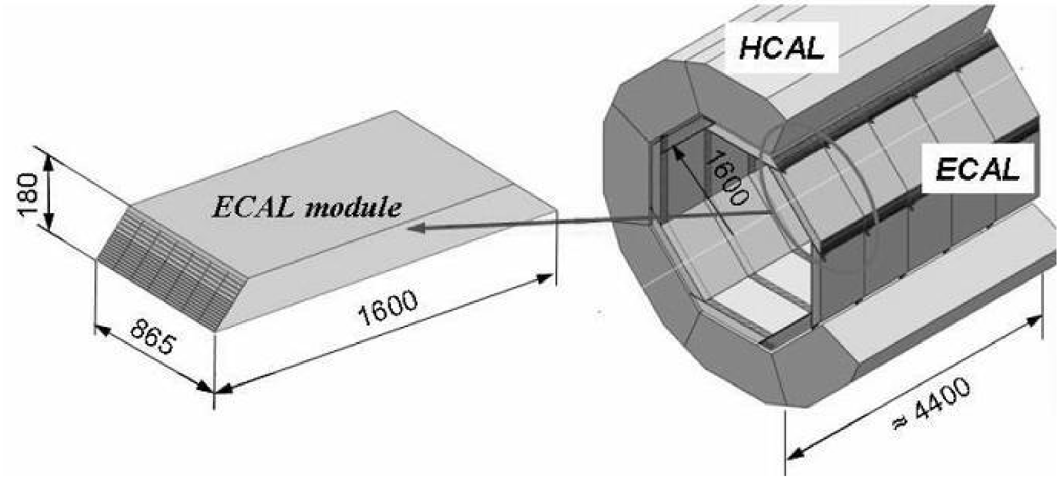

Figure 12: Design of the LDC calorimeter. All measures are in mm.

To test the PFA concept and to verify the Monte Carlo simulation the CALICE collaboration has produced a prototype consisting of ECAL, HCAL and tail catcher calorimeter and started to perform test beam measurements [30, 31]. In parallel improvements of the PFA improved software algorithms are necessary to eventually achieve the aspired jet energy resolution at the ILC.
A completely different approach is taken by the 4th concept which aims to achieve the required resolution by a multiple readout calorimeter. A fine spatial sampling with scintillating fibres is supposed to track fluctuations of local energy deposits With the help of interleaved clear fibres sensitive only to Ĉerenkov light the electromagnetic component of the shower is measured. Test beam results from such a Dual Readout Module (DREAM) have demonstrated that the energy resolution of pions is largely improved [15]. In a next step binding energy losses from nuclear break-up which consists the next most important source of hadronic shower fluctuations are planned to be measured by either time history of the signals or by neutron sensitive boron or lithium loaded fibres [13].

5.4 Forward Calorimeter

While jet energy resolution is the driving design issue in the barrel and endcap regions of the detectors calorimetry in the very forward region poses different challenges at the ILC. In general two detectors are foreseen at either side of the interaction point to measure luminosity (LumCal) to a precision comparable to the LEP detectors or better ($< 10^{-3}$) and at even lower angles at detector for beam diagnostics and luminosity optimisation (see Fig. 13). The current designs are based on sandwich structures of tungsten and radiation hard sensors.
Radiation hardness is an important issue in this detector region. For example on one side of the BeamCal a rate of about 15000 e^+e^--pairs is expected per bunch crossing mostly with energies about 10 MeV but extending to the GeVrange. A total energy

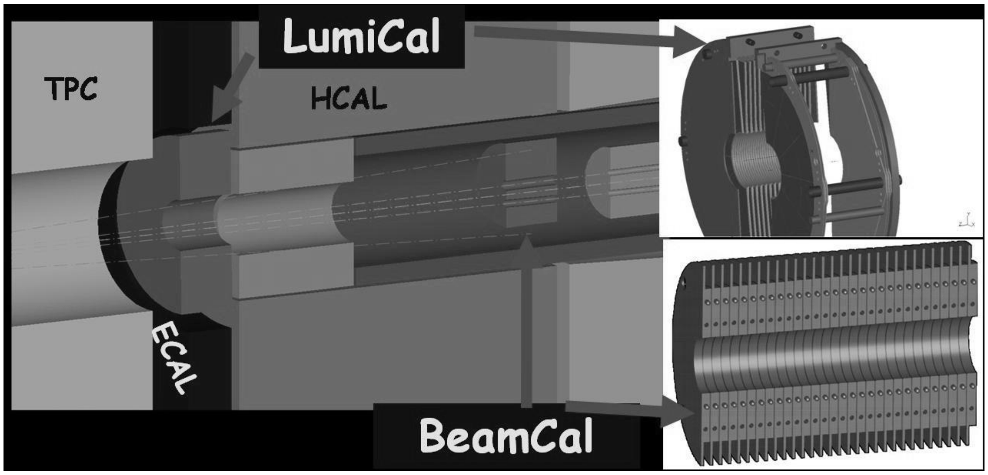

Figure 13: Design of the forward calorimeters LumiCal and BeamCal in the LDC concept [32].

deposit of the order of 10 TeV per bunch crossing is expected yielding a total annual dose of about 10 MGy. Yet, the identification of single high energy electrons to the lowest possible angle is desirable to veto background from two-photon processes. These detectors must be compact and granular and require also a fast bunch-by-bunch with a high linearity and dynamic range.

6 Towards Larger Prototypes

As sketched in this article candidates detector for technologies have been identified in small scale experiments which are capable to achieve the performance imposed by the physics programme of the ILC. The next important step in the R&D programme leading to real ILC detectors is to consolidate the concepts and achieved performance using larger scale prototypes. The design, construction and operation of larger detectors is mandatory to gain experience with the new technologies and to learn build optimised, large detectors. This however requires more human and financial resources which exceed the capabilities of single laboratories and thus requires intensified collaboration on an international scale. The R&D collaborations on the various sub-detectors go into this direction.

In Europe the R&D for the ILC detector is supported by the European Union through the EUDET project [33]. EUDET is an initiative to improve the infrastructure for detector R&D and, even though not exclusively intended for the ILC, focused on providing support for larger scale prototype experiments as well as on facilitating collaborative efforts. In total 31 European laboratories eligible for EU funds participate in the project plus more than 20 other institutes in Europe and abroad which are as associated members linked to the progress and later exploitation. By its transnational access activity the project can support European institutes which intend to the effort. In all its activities the project is embedded with close links to the international R&D collaborations.

7 Conclusions & Outlook

The International Linear Collider (ILC) is the next large collider project in particle physics being designed to provide e^+e^--collisions at initially 500 GeV and upgradable to 1 TeV. The design of the this machine is rather advanced with contributions from all major high energy physics laboratories in the world. The physics programme of the ILC requires detectors with unprecedented performances meeting challenges rather which are different from the LHC detectors. International groups are developing four detector concepts. These studies are based on candidate technologies for the various subdetectors developed in the R&D collaboration and verified in small scale experiments. Yet, many questions are still open and problems unsolved. The concepts and technologies must still prove in larger experiments their capabilities requiring an intensified international collaboration.

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