ILD & SiD concepts and R&D

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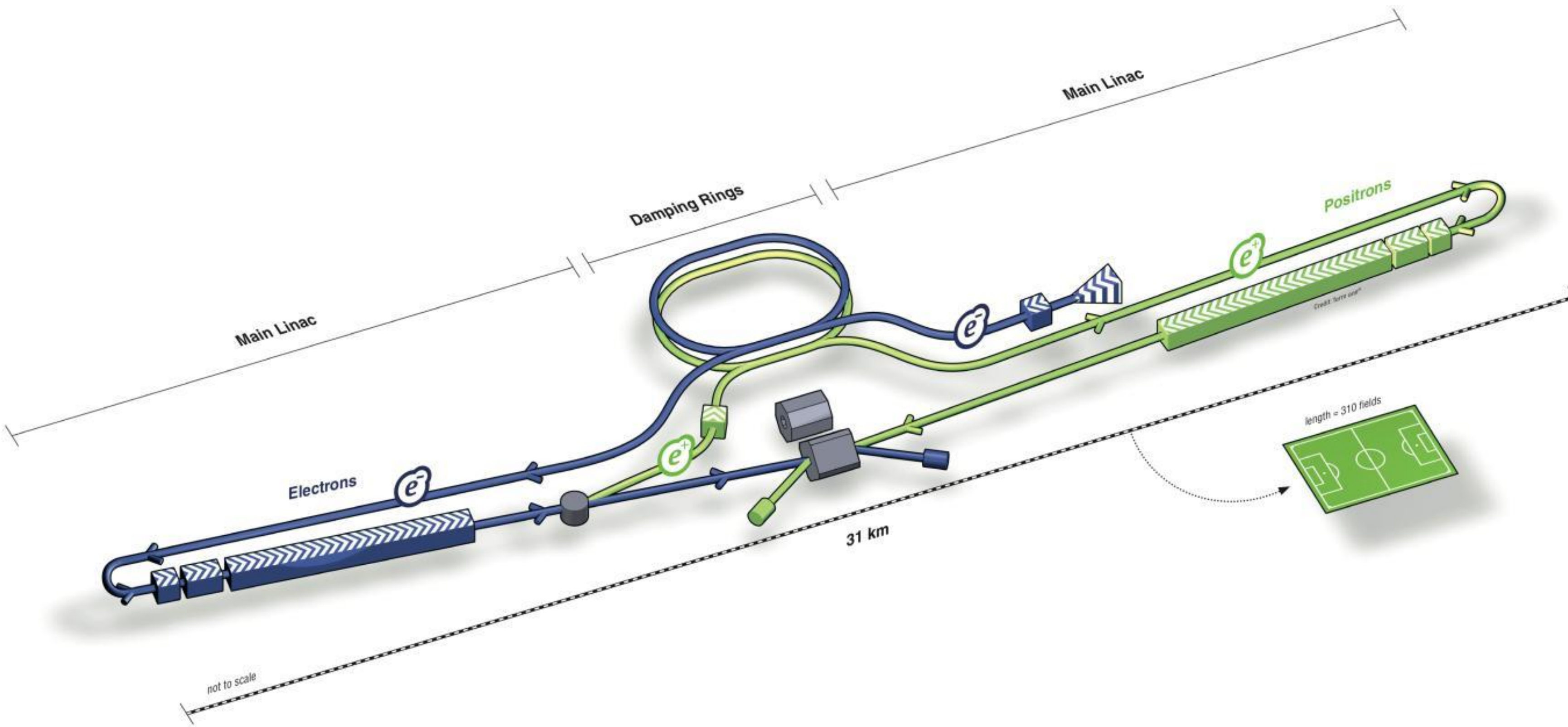
Introduction: Physics Case at ILC

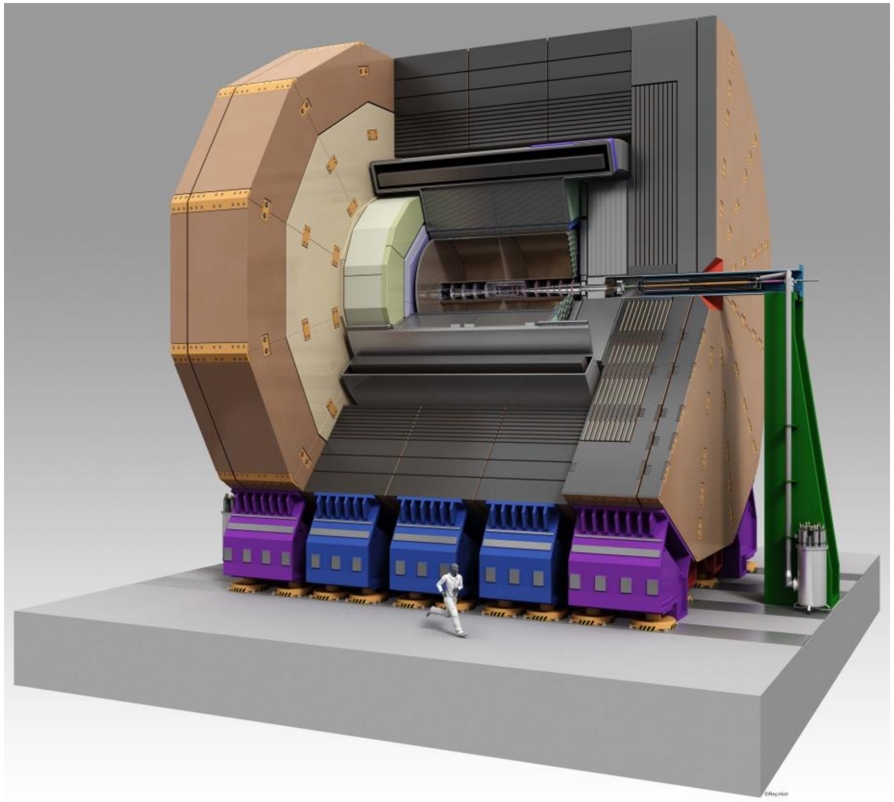
- Next collider: linear e+e– collider, length: ~ 31km
- Tunable center of mass energy of 200-500 GeV
- Two detectors with push-pull concept
- Both need to fit into Particle Flow concept



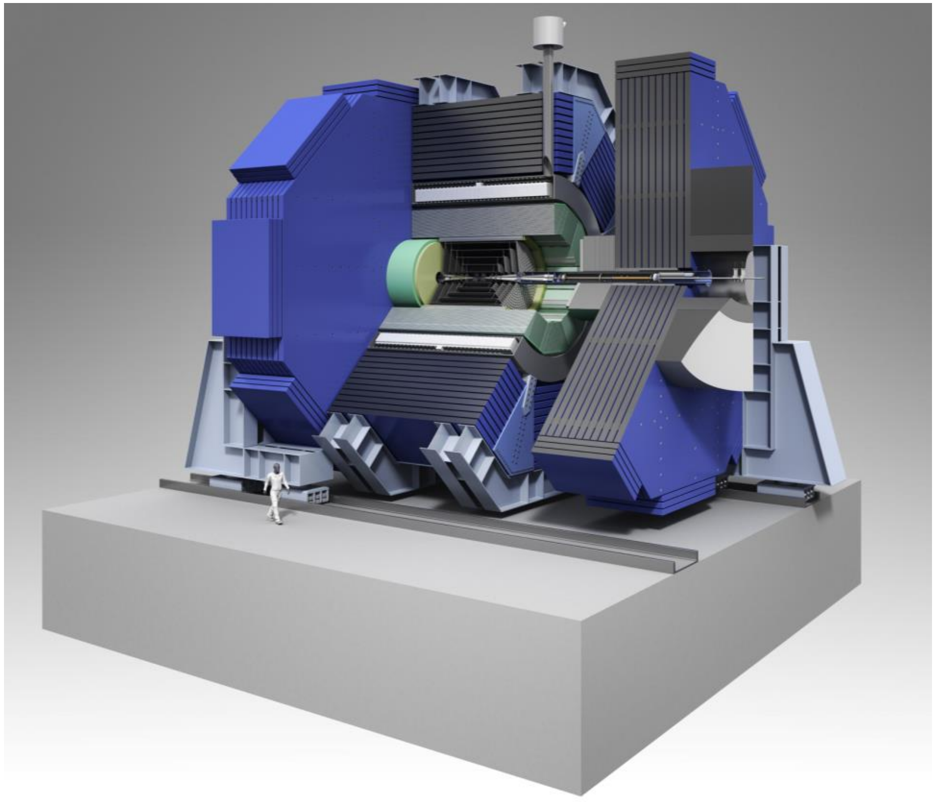
Two detector concepts

- LoI: 2009 (SiD)-2010 (ILD)
- DBD: 2012 (ILD)-2013 (SiD)

International Large Detector

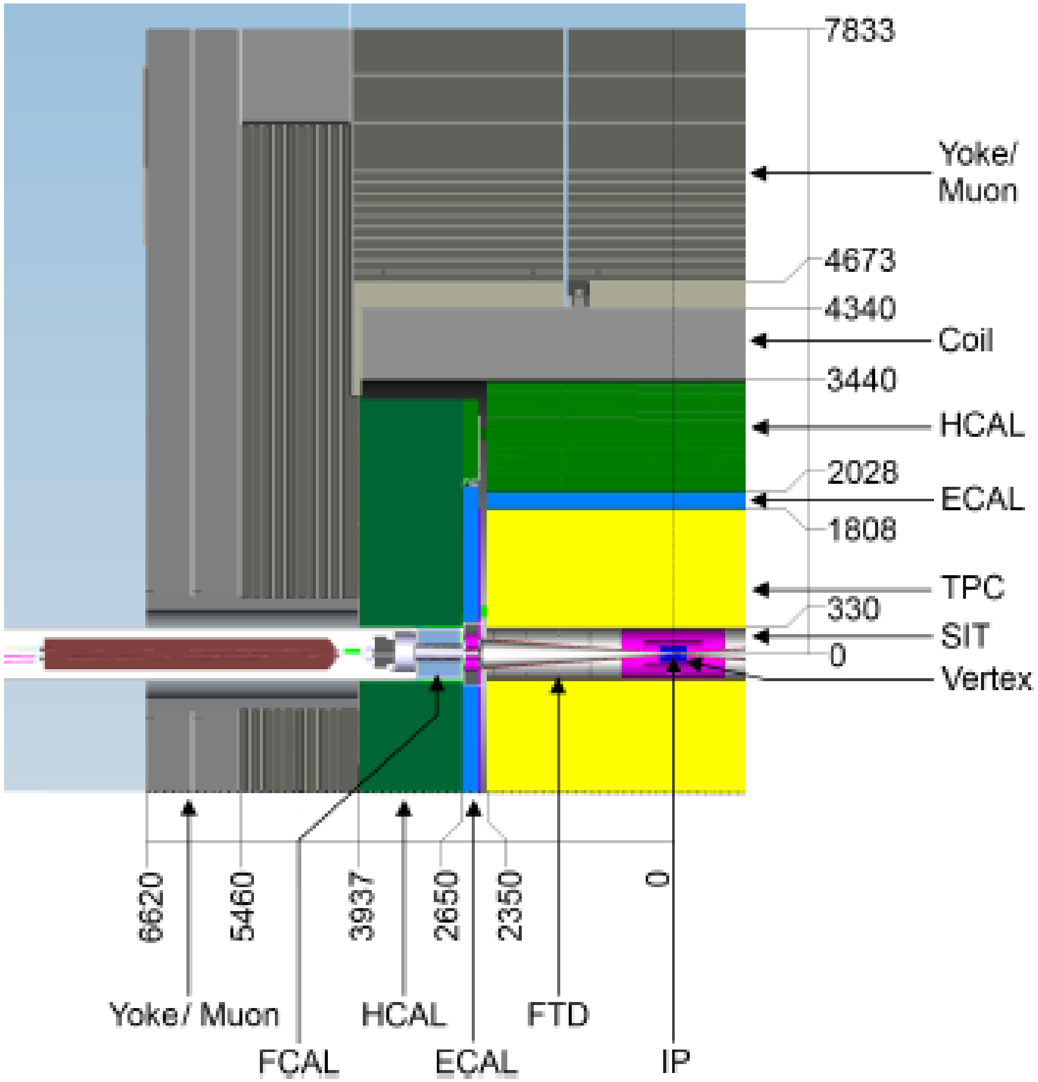


Silicon Detector

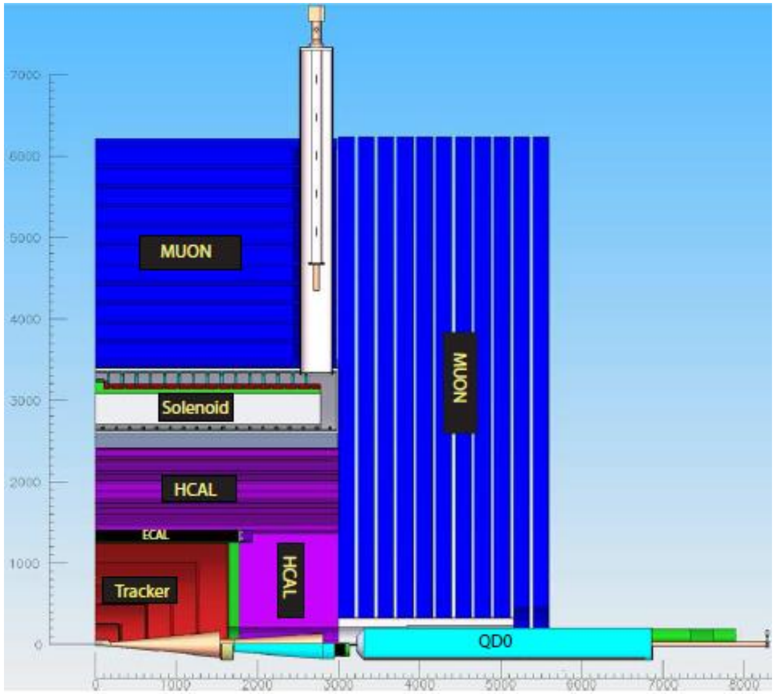


Side (quadrant) views

ILD



SiD



Particule Flow Algorithm (PFA) Approach

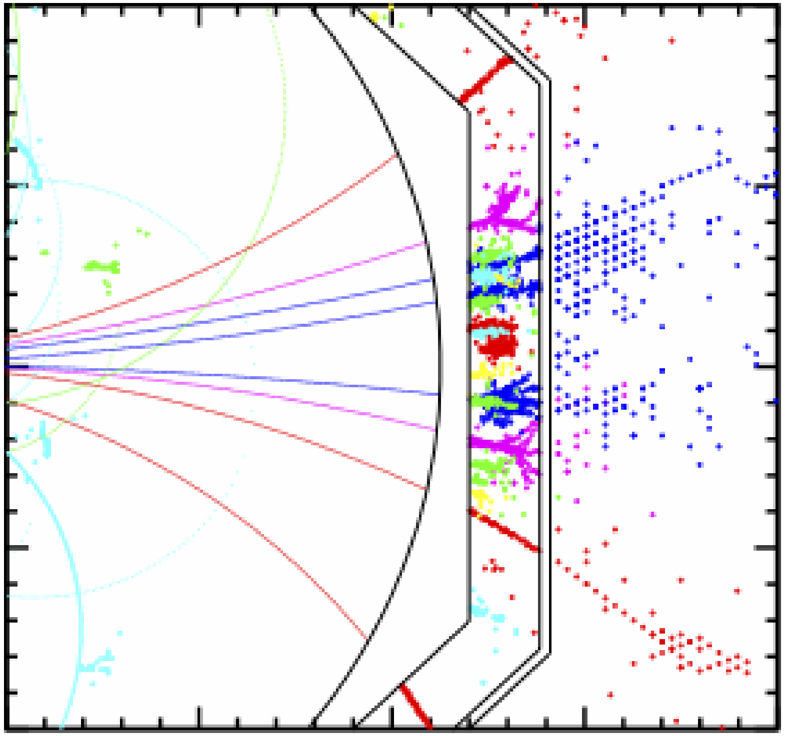
- Traditionally, $E_{jet} = E_{ECAL} + E_{HCAL}$

- Multi-jet energy resolution needed at the ILC: ($\sigma_E/E \approx 0.3/\sqrt{E}$)

- Solution = PFA: cross-checking of the measurements of all sub-detectors which will be highly segmented from IP

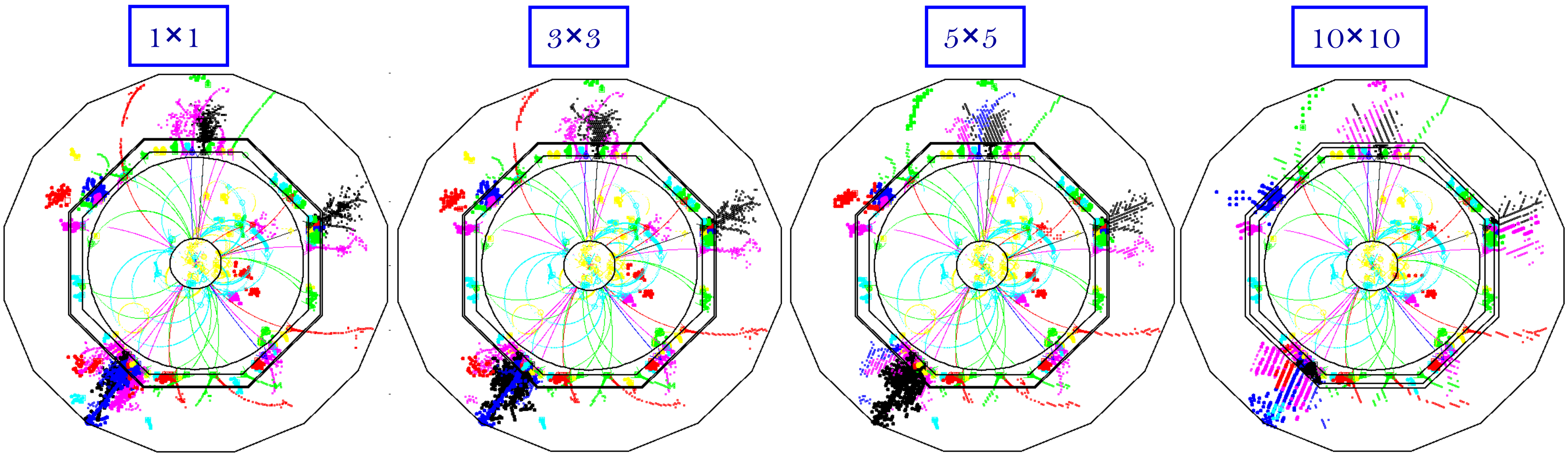
- Trackers→charged particles

- Calorimeters→separation charged/neutral particles



Particule Flow Algorithm (PFA) Approach

- Analogue scintillator tile HCAL: change tile size from 1×1 ➞ 10×10 mm^2



- 1×1 cm^2 and 3×3 cm^2 cell size

- Cell size > 5×5 cm^2 degrades PFA

Concept overview for SiD

- 5T magnet
- Silicon-based tracking
  - Vertex detector: 5 Si pixel layers, pixel size of $20 \times 20\ \mu m^2$
  - Si main tracker: Si strip of 5 nested cylinders in central region and 4 disks, pitch 50 μm
- Main calorimeters (barrel+2 end-caps) inside solenoid with imaging capabilities
  - 30 Si active layers using $5 \times 5\ mm^2$ Si pixels between W absorber

  (Two other technologies (GEM & Micromegas) are currently prototyped and evaluated as potential options)

- Forward calorimeters (compact ECALs): LumiCal + BeamCal
  - 30 layers of semiconductor-tungsten technology

- Muon system: few $10^3\ m^2$ scintillator (or RPCs)

Table 1.1.1: Key parameters of the baseline SiD design. (All dimension are given in cm).

SiD Barrel	Technology	Inner radius	Outer radius	z extent
Vertex detector	Silicon pixels	1.4	6.0	± 6.25
Tracker	Silicon strips	21.7	122.1	± 152.2
ECAL	Silicon pixels-W	126.5	140.9	± 176.5
HCAL	RPC-steel	141.7	249.3	± 301.8
Solenoid	5 Tesla SC	259.1	339.2	± 298.3
Flux return	Scintillator-steel	340.2	604.2	± 303.3
SiD Endcap	**Technology**	**Inner z**	**Outer z**	**Outer radius**
Vertex detector	Silicon pixels	7.3	83.4	16.6
Tracker	Silicon strips	77.0	164.3	125.5
ECAL	Silicon pixel-W	165.7	180.0	125.0
HCAL	RPC-steel	180.5	302.8	140.2
Flux return	Scintillator/steel	303.3	567.3	604.2
LumiCal	Silicon-W	155.7	170.0	20.0
BeamCal	Semiconductor-W	277.5	300.7	13.5

Concept overview for ILD

- 3.5T magnet
- Vertex detector (VTX):
  - MAPS
- Silicon strip detector (SIT):
- Time Projection Chamber (TPC):
  - MPGD readout (GEM or Micromegas) with <1 mm pad size
- Calorimeters (layers of W and Fe):
  - ECAL: Si diodes or scintillators (30 samples in depth)
  - HCAL: 3×3 cm^2 scintillator tiles or 1×1 cm^2 gas based (48 long. samples)
- Forward calorimeters (compact ECALs): LumiCal + BeamCal
  - 30 layers of semiconductor-tungsten technology
- Muon system:
  - Scintillator strips or resistive chambers (RPCs)

Concept overview for ILD

Table 1.2.1: List of the main parameters of the ILD detector for the barrel part.

Barrel system						
System	R(in)	R(out) [mm]	z	comments		
VTX	16	60	125	3 double layers	Silicon pixel sensors,	
				layer 1: $\sigma < 3\mu m$	layer 2: $\sigma < 6\mu m$	layer 3-6 $\sigma < 4\mu m$
Silicon						
- SIT	153	300	644	2 silicon strip layers	$\sigma = 7\mu m$	
- SET	1811		2300	2 silicon strip layers	$\sigma = 7\mu m$	
- TPC	330	1808	2350	MPGD readout	$1 \times 6\text{mm}^2$ pads	$\sigma = 60\mu m$ at zero drift
ECAL	1843	2028	2350	W absorber	SiECAL	30 Silicon sensor layers, 5×5 mm^2 cells
					ScECAL	30 Scintillator layers, 5×45 mm^2 strips
HCAL	2058	3410	2350	Fe absorber	AHCAL	48 Scintillator layers, $3 \times 3\text{cm}^2$ cells, analogue
					SDHCAL	48 Gas RPC layers, 1×1 cm^2 cells, semi-digital
Coil	3440	4400	3950	3.5 T field	2λ	
Muon	4450	7755	2800	14 scintillator layers		

Table 1.2.2: List of the main parameters of the ILD detector for the end cap part.

End cap system						
System	z(min)	z(max) [mm]	r(min), r(max)	comments		
FTD	220	371		2 pixel disks	$\sigma = 2-6\mu m$	
				5 strip disks	$\sigma = 7\mu m$	
ETD	2420	2445	419-1822	2 silicon strip layers	$\sigma = 7\mu m$	
ECAL	2450	2635		W-absorber	SiECAL	Si readout layers
					ScECAL	Scintillator layers
HCAL	2650	3937	335-3190	Fe absorber	AHCAL	48 Scintillator layers $3 \times 3\text{cm}^2$ cells, analogue
					SDHCAL	48 gas RPC layers $1 \times 1\text{cm}^2$ cells, semi-digital
BeamCal	3595	3715	20-150	W absorber	30 GaAs read-out layers	
Lumical	2500	2634	76-280	W absorber	30 Silicon layers	
LHCAL	2680	3205	93-331	W absorber		
Muon	2560		300-7755	12 scintillator layers		

SiD costs

Table 5.1.2: Conversion rate based on purchase power parity used in the cost estimate.

currency	Dollar	Euro	Yen
ILCU	1	0.9732	127.3

Table 12.3.1: Summary of Costs per Subsystem.

	M&S Base (M US-$)	M&S Contingency (M US-$)	Engineering (MY)	Technical (MY)	Admin (MY)
Beamline Systems	3.7	1.4	4.0	10.0	
VXD	2.8	2.0	8.0	13.2	
Tracker	18.5	7.0	24.0	53.2	
ECAL	104.8	47.1	13.0	288.0	
HCAL	51.2	23.6	13.0	28.1	
Muon System	8.3	3.0	5.0	22.1	
Electronics	4.9	1.6	44.1	41.7	
Magnet	115.7	39.7	28.3	11.8	
Installation	4.1	1.1	4.5	46.0	
Management	0.9	0.2	42.0	18.0	30.0
	314.9	126.7	186.0	532.1	30.0

≈860 M $

ILD costs

Table 5.3.5: Summary table of the cost estimate of the ILD detector. Depending on the options used the cost range is between 336 Mio ILCU and 421 Mio ILCU.

System	Option	Cost [MILCU]	Mean Cost [MILCU]
Vertex			3.4
Silicon tracking	inner	2.3	2.3
Silicon tracking	outer	21.0	21.0
TPC		35.9	35.9
ECAL			116.9
	SiECAL	157.7	
	ScECAL	74.0	
HCAL			44.9
	AHCAL	44.9	
	SDHCAL	44.8	
FCAL		8.1	8.1
Muon		6.5	6.5
Coil, incl anciliaries		38.0	38.0
Yoke		95.0	95.0
Beamtube		0.5	0.5
Global DAQ		1.1	1.1
Integration		1.5	1.5
Global Transportation		12.0	12.0
Sum ILD			391.8

SiD R&D

Project Descriptor	Institution(s)	Past Funding	Current Funding	Future Funding
ENGINEERING				
SC Solenoid	Fermilab, SLAC	DOEL	DOEL	DOEL
Flux Return	Fermilab, SLAC, Wisc.	DOEL	DOEL	DOEL
MDI/Push-pull	Fermilab, SLAC	DOEL	DOEL	DOEL
General	Fermilab, SLAC, etc.	DOEL	DOEL	DOEL
VERTEX				
Chronopix	Yale, Oregon, SLAC	LCDRD	sLCDRD, DOEL	ULCDP, DOEL
CAPS	Hawaii	LCDRD	sLCDRD	ULCDP
ISIS	Bristol, Oxford, RAL	UK, term. 2008	internal	new fund.
MAPS	Strasbourg	France	France	France
Sensor Powering	Fermilab	DOEL	DOEL	DOEL
Sensor Thinning	Fermilab, Cornell	DOEL	DOEL	DOEL
Vertex Mechanics	Washington, Fermilab	LCDRD, DOEL	DOEL	ULCDP, DOEL
3D Sensor	Fermilab	DOEL	DOEL	DOEL
3D Sensor Sim.	Cornell		DOEL	ULCDP
TRACKING				
Alignment	Michigan, Spain, Spain	LCDRD, Spain	Spain	ULCDP, Spain
DC-DC converters	Yale, SLAC	LCDRD, DOEL	DOEL	ULCDP, DOEL
DS/SS Si Det. & calor (eg. lum)	Kyungpook N Univ.	Korea	Korea	Korea
Forward Tracking	Spain	Spain	Spain	Spain
Sensor QA, cables	New Mexico			ULCDP
Sensor QA	UC Santa Cruz	LCDRD	sLCDRD	ULCDP
Tracking Sim.	Santa Cruz, Oregon, SLAC, Fermilab	DOEL	DOEL	DOEL ULCDP

Table 6.1: SiD R&D Projects, part 1. Definitions: LCDRD is 3 year US DOE/NSF Linear Collider Detector R&D grant beginning 2005; sLCDRD is 2008-9 LCDRD supplement; DOEL is US DOE laboratory funding; ULCDP is SiD US University LC Detector Proposal to DOE/NSF on February 18, 2009.

Project Descriptor	Institution(s)	Past Funding	Current Funding	Future Funding
CALORIMETRY				
Beamcal, Readout/Sim	Colorado, SLAC	LCDRD, DOEL	DOEL	ULCDP, DOEL
Dual Readout	Caltech, Fermilab	DOEL	DOEL	DOEL ULCDP
ECAL Mechanics	Annecy, SLAC	France, DOEL	France, DOEL	France, DOEL
GEM HCAL	UTA, MIT	LCDRD		ULCDP
Micromegas HCAL	Annecy	France	France	France
MAPS ECAL	B'ham, Bristol, Imperial, Oxford, RAL	UK	SPiDeR	SPiDeR
PFA	Iowa, MIT, ANL, SLAC	LCDRD, DOEL	DOEL	ULCDP, DOEL
Radhard Bmcal Sens.	UCSC, SLAC		DOEL	ULCDP, DOEL
RPC HCAL	BU, Iowa, ANL, FNAL	LCDRD, DOEL	sLCDRD, DOEL	ULCDP, DOEL
Scint HCAL	NIU	LCDRD		ULCDP
SiPM Readout	Fermilab, SLAC	DOEL	DOEL	DOEL
Si-W ECAL & Readout	Oregon, Davis, SLAC, BNL	LCDRD, DOEL	sLCDRD, DOEL	ULCDP, DOEL
MUON				
RPC Muon/HCAL	Princeton	LCDRD		ULCDP
RPC Muon System	Wisconsin	LCDRD		ULCDP
SiPM Muon System	WS, IU, ND, NIU, Fermilab	LCDRD, DOEL	sLCDRD, DOEL	ULCDP, DOEL
BEAMLINE MEAS.				
Energy Spectrometer	Notre Dame, Oregon	LCDRD	sLCDRD	ILC accel?
Polarimeter	Iowa	LCDRD		ILC accel?

Table 6.2: SiD R&D Projects, part 2. See table 6.1 for definitions.

R&D

- MAPS: monolithic active pixel sensor
- DEPFET: active pixel detectors for a future linear e+e- collider

Micromegas TPC in Saclay