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0.1 Experimentation (Draft #6 23.5.95)

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0.1.1 Introduction

The principal purposes of this subgroup are:
(1) to summarize important particle physics goals and related experimental issues,
(2) to quantify the demands on the performance of the machine,
(3) to identify issues which require close collaboration between experiment and machine,
(4) to outline generic detector possibilities.

Thus this working group will compare the machine parameters affecting the experiments for the various machine designs and look for areas of technology around interaction region (IR) and detector which need further R&D work.

0.1.2 Physics

The main e^+e^- physics topics and their requirements on machine and detector are summarized in Tables 1 and 2, which reflect the results of recent international workshops. There are three main facets of the physics potential of the e^+e^- collider.
(1) A rich programme of standard physics, Table 1: measurements in hitherto poorly mapped regions of the the standard model ($\mathcal{SM}$), such as the top quark properties and the trilinear gauge couplings, and measurements at high energy in familiar regions such as QCD.
(2) A programme of new physics, Table 2: search for the higgs boson and for physics beyond the $\mathcal{SM}$, for example supersymmetry ($\mathcal{SUSY}$).
(3) A potential, in the last-but-one row of Table 2, for understanding the mechanism for the spontaneous breaking of electroweak symmetry even in the heavy higgs scenario, which involves precision measurements of gauge boson production, especially at the highest energy.

As discussed below, an extended range of theoretical predictions will be confronted by experiments in the $\gamma\gamma$, $e^-\gamma$, and e^-e^- collider modes. Running on the Z^0 peak with polarized beams would provide greater accuracy on $\sin^2\theta_W$ than can be achieved at LEP or SLC and would further constrain M_{higgs} .

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Table 1: Some e^+e^- "standard" physics topics and the corresponding performance quality needed for machine and detector. Quality key: from"-" not important, to "$\star\star\star$" very important.

PHYSICS	MACHINE				DETECTOR						
	$\int \mathcal{L}dt$ fb^{-1}/y	$\sqrt{s}$ TeV	Narrow $\mathcal{L}(\sqrt{s})$[a]	Pol. beams	Herme-ticity	Track-ing	Calor-imetry	3-Dim. Granul.	Lepton I.D.	Vertex Tag	pi/K I.D.
●TOP											
Thr. scan	10	$\sim$.35	$\star\star\star$	$\star\star$	$\star\star$	$\star\star$	$\star\star$	$\star\star$	$\star\star$	$\star\star\star$	$\star$
Rare decays	10	.4									
g-2,hel.struct.	50	to		$\star\star$	$\star\star\star$	$\star\star$	$\star\star$	$\star\star$	$\star\star$	$\star\star\star$	$\star\star$
Yukawa	100	1									
●WW											
WWV-coupl.	10	.25									
WWV-hel.	50	to	$\star\star\star$	$\star\star$	$\star\star\star$	$\star\star$	$\star\star$	$\star\star$	$\star\star$	-	-
WWVV-coupl.	100	1									
●QCD											
Hadronization	1	For									
Heavy flavors	10	all	-	-	$\star\star$	$\star\star$	$\star\star$	$\star$	$\star$	$\star\star$	$\star$
$\alpha_s(\sqrt{s})$	10	$\sqrt{s}$									
●(Virtual)$\gamma\gamma$											
Minijets	1										
$F_2^\gamma(x,Q^2)$	10		$\star$	-	$\star\star\star$[b]	$\star\star$	$\star\star$	$\star\star$	$\star\star$	$\star$	$\star$
Heavy flavors	10										
$\mathcal{L}(\sqrt{s})$ Det.[a]					$\star\star$	$\star\star\star$	$\star\star$	$\star\star$	$\star\star$	-	-

[a]Narrow c.m.s. energy spread arising from machine and beamstrahlung effects. $\star\star\star$ means the energy spread from the machine must be small ($\sim \mathcal{O}(0.2\%)$; the luminosity spectrum must be well-measured (to the $\sim$0.1% level), the detector for which is treated in the last row of the table.

[b]Small angle tagger would allow low-x studies and high Q^2.

Table 2: Some e^+e^- "new" physics topics and the corresponding performance quality needed for machine and detector. Quality key: from"-" not important, to "⋆⋆⋆" very important.

PHYSICS	MACHINE				DETECTOR						
	$\int \mathcal{L}dt$ fb^{-1}/y	$\sqrt{s}$ TeV	Narrow $\mathcal{L}(\sqrt{s})^a$	Pol. beams	Herme-ticity	Track-ing	Calor-imetry	3-Dim. Granul.	Lepton I.D.	Vertex Tag	pi/K I.D.
●HIGGS											
Light higgs	1-10	.2									
M$_{higgs}$-meas.	20	to	⋆⋆[b]		⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆	⋆⋆	⋆⋆⋆	⋆
SM/Susy B.R.	100	∼.5									
Interm. higgs	200	1									
Heavy higgs	200	∼1.2			⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆⋆	⋆⋆	-	-
●SUSY											
$\tilde{\ell},\tilde{\chi}_j^{\pm}$	10	.2									
$\tilde{\chi}_i^0$	10										
Light $\tilde{t}$	10	to	-	⋆[c]	⋆⋆⋆	⋆⋆	⋆⋆	⋆⋆[c]	⋆⋆	-	-
Susy param.	100										
$\tilde{q},\tilde{g}$	100	∼1-2									
●NEW PHEN.	200	∼2			⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆	
●W$_L$W$_L$-scatt.	200	∼1.5			⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆⋆	⋆⋆	-	-
Overall from Tables 1,2			⋆⋆⋆	⋆⋆[c]	⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆⋆	⋆⋆

[a] See Table 1.
[b] If $M_{higgs} \simeq M_{Z^0}$, upgrade to ⋆⋆⋆.
[c] If supersymmetry is discovered, upgrade to ⋆⋆⋆.

0.2 Experimentation Aspects

Some of the aspects of relating to the physics experiments are addressed here.

Experimentation phases.

• As shown at international workshops the first-stage energy has been clearly demonstrated to be $\sqrt{s}$=0.5 TeV.

If it would turn out to be advantagous to commission the machine at a lower energy, the following energies could be possible milestones, according to present knowledge:
–At $\sqrt{s}\simeq$0.25 TeV with $\frac{1}{2}$fb^{-1} of data, any discovery gap that might exist between LEP2 and LHC could be closed, a definitive test of the $\mathcal{SUSY}$-higgs scenarios could be performed since in those models the lightest higgs has $M_h\leq$150 GeV and would be discovered, and the trilinear gauge couplings ($WWV, V=\gamma,Z^0$) could be measured about twice as precisely as at LEP2.
–At $\sqrt{s}\simeq$0.35 TeV, the top threshold could be found with a binary scan involving 0.1fb^{-1}of data at each of $\sim$6 energies, to yield M_{top} to about $\pm$2 GeV. The trilinear-gauge-coupling precision would improve by a factor of four relative to LEP2. The top threshold measurement with 1fb^{-1}per point at 8 to 10 energy points, which could follow now or later, would determine more precisely the properties of this enigmatic heaviest quark, e.g. M_{top} to $\pm$0.5 GeV.
–At the design goal of the first stage, with 10fb^{-1} of data at $\sqrt{s}$=0.5 TeV, M_{top} would be measured again to $\pm$0.5 GeV, the trilinear gauge couplings measured to better than $\pm$1%, the higgs bosons with masses up to $\sim$350 GeV could be discovered. If light supersymmetry exists, depending on how it is realized in nature, this first stage could find some of the lighter supersymmetric particles ($\tilde{\ell}$, $\tilde{\chi}_j^{\pm}$, $\tilde{\chi}_i^0$).

•The second stage uncovers the new physics that lies at higher energies along with standard physics at those energies. It would be logical to increase the machine energy step-wise to successively higher values with up to 100fb^{-1}/year of data to be taken at appropriate energies up to $\sqrt{s}\sim$1 TeV. The goal would be to search for heavier higgses and/or supersymmetric particles. The $\mathcal{SM}$ higgs ϕ^0 could be discovered up to a mass of $M_{\phi^0}\sim$0.6 TeV. If $\mathcal{SUSY}$ has been found earlier, the search for the heavier higgs states (H^0 and A^0, produced in association, and $H^{\pm}$, produced in pairs) and the colored superpartners ($\tilde{g}$, $\tilde{q}$), which are heavy in most models will follow.

•Finally, for $M_{higgs}\simeq$0.7-0.8 TeV, $\sqrt{s}\sim$1.0-1.5 TeV is needed to discover it. If the higgs turns out to be heavier than $\sim$1 TeV, it is no longer discoverable as particle, and the programme for understanding the mechanism of electroweak spontaneous symmetry breaking would consist of precision measurements of gauge boson production, the W_LW_L-rescattering experiment, at the highest energy to which the machine could be upgraded. This again should probably be $\sim$ 1.5 TeV. This highest energy question will be addressed at a future workshop.

Two IR's. The advantages of having at least two experiments are evident;
–scientific redundancy: particle-physics measurements must be done several times independently to ensure the result is correct;
–complementarity: with two detectors all requirements for e^+e^- in Table 2 can be fulfilled, and one of them can be equipped for the $\gamma\gamma$, $e^-\gamma$, and e^-e^- programme, which would require a second IR;
–competition: the competition of physics ideas between several detector collaborations is an important stimulous for scientific progress;
–sociology: the constituency of particle physicists interested in e^+e^--physics is large enough for at least two collaborations.
–reliability: having at least two operational detectors will improve the overall machine-detector performance, since time lost for detector maintainance can be circumvented. Alternatively, being able to switch between two IR's would allow for more MD studies. Especially attractive is the possibility discussed at LC95 of being able to switch between two IR's within a matter of hours, which would clearly increase the flexibility of the facility. Recent ideas for producing a collider facility with multiple IR's need and deserve more work.

Z^0-pole running for physics. The physics case might be made at some time to test sensitively the internal consistency of the $\mathcal{SM}$ with precision measurements at low energy, for example if no higgs has been found as particle up to $\sqrt{s}$= 1 TeV. The luminosity requirement is $\sim 5\times10^{31}$cm^{-2}s^{-1}for Z^0-pole running for precisions measurements using polarized beams. Both beams should be polarized to reduce the error on $\sin^2\theta_W$ to below ±0.0001.

Polarized beams. For the reason just given, for disentangling the trilinear couplings, for the $g-2$ measurement of the top quark, for $\mathcal{SUSY}$ studies, to mention a few examples, polarized beams permit qualitatively new and important measurements to be performed.

$\gamma\gamma$, $e^-\gamma$, and e^-e^- collider implications. These alternatives make complementary measurements to those at the e^+e^- collider. A few examples are given here . The $\gamma\gamma$ collider with polarized γ's can provide direct production of the higgs boson and sensitive $\mathcal{SM}$ measurements in $\gamma\gamma\rightarrow W^+W^-$. The e^-e^- collider gives access to possible exotic doubly charged objects: higgses or dileptonic boson. The $e^-\gamma$ collider offers an alternative way to produce the selectron ($\tilde{e}$) with a light photino ($\tilde{\gamma}$) and to measure the trilinear gauge couplings. It is also the best conceivable machine for measuring the quark and gluon structure of the photon.

$\mathcal{L}(\sqrt{s})$. Some physics studies require the highest possible luminosity, even at the cost of a larger machine-energy spread and significant beamstrahlung. But both machine-energy spread and beamstrahlung must be kept to a minimum for the top threshold scan, for a M_{higgs} measurement, or for precision measurements of the trilinear gauge couplings. The ideal linac will operate in both a high-luminosity mode and in a narrow machine-energy-spread mode. In the latter mode the spread should be of the order of 0.2% and the detector will need good endcap tracking so that the luminosity spectrum can be measure with a matching precision of $\pm0.1\%$ on $\sqrt{s}$(see last row of Table 1).

Z^0-peak running for calibration. Calibration of the detectors by running at the Z^0-peak is highly desirable, but about 3 pb^{-1} of data is enough per calibration run, of which 3 or 4 per year are needed. Thus a luminosity of $\sim 10^{31}$cm^{-2}s^{-1}is sufficient.

0.3 IR and Detector Issues

Some issues for which the machine and detector closely interact are discussed, and quantities affecting the detector design for the different machines follow in Tables 3 and 4. The machine parameter lists from LC95 were used by D. Schulte/DESY to derive an internally consistent set of figures for luminosity and background, meaning that the same set of Monte Carlo programs has been used to calulate the numbers, for all machines. Thus the results can certainly be compared relatively. This was possible for all machines except VLEPP, for which non-linear beam-beam effects caused computing time to become prohibitive; here the numbers available from the LC95 list were used.

Backgrounds. The sources of background are e^+e^- pair creation in the field of the colliding bunches, hadrons produced by photons from beamstrahlung, synchrotron radiation and debris from the final quads, and muon backgrounds arising from upstream sources. Synchrotron backgrounds are typically produced by particles in the beam tails which radiate photons in the latter sections of the final focus (FF) which strike the tip of the last quadrupole. These backgrounds can be controlled by scraping beam tails in the FF collimation section. The muon background which results from this collimation is controlled by the big bend and by a number of spoiler magnets which fill the transverse dimensions of the tunnel. The majority of e^+e^- pairs are produced at small angles to the beam axis, with a transverse momentum and angle determined by the beam size and intensity. Their angular distribution define a so-called dead cone which must be surrounded by a conical mask. While the machine design should minimize this cone, it should be instrumented with an e^+e^- pair monitor, which can provide information about the overlapped beam spot, and small angle bhabha (Luminosity) monitor. The detailed design of the masks, detectors, the aperture of the exit quadrupoles, and the value of the beam crossing angle determine how many backscattered pairs will reach the detector. Finally, beam parameters at the interaction point (IP) control the number of primary e^+e^- and hadrons pairs produced at inherently large angles.

In Table 3 values for crossing angle, dead cone, aperture of quadrupoles, etc. are listed. Table 4 compares backgrounds per bunch crossing and the backgrounds in a sub-detector integrating over 100ns (for example).

Vibration. All machine designs, whether at 0.5 or 1.0 TeV, require beam stability at the sub-10 nm level to achieve their design luminosities, as can be seen in the values for the spot-height σ_y in Table 3, row 8. Ground vibration, of either seismic or cultural origin, must be controlled to well below this level at the FF. After site selection, mechanical means must be used to reduce vibrations at frequencies above that which can be corrected by beam-based feedback. Active devices which feedback signals measuring absolute or relative quad motion are under investigation; if successful in principle, they must be engineered into the detector environment. The passive device most frequently suggested to date is a support tube linking the quads on either side of the IP. The size and mass of such a tube, the weight of the masks and quadrupoles it must support, and the consequences to detector access must be considered. Detector and FF quad cooling and gas systems must be designed which do not introduce any additional vibrations.

Beam diagnostics near the IP. It is important to be able to measure the beam parameters at the interaction point (IP) separately for each beam at the full beam intensity. Physical wires will not survive; current designs for optical wires or interferometers will not work at wavelengths on the order of the design beam spot sizes. Thus R&D to produce such devices and locate them within 20% of the distance from the IP to the first quad is needed and will require close cooperation between detector and machine physicists.

Extracted beam diagnostics. Experience from the SLC/SLD tell us that these entail an energy spectrometer, a compton polarimeter, and beamstrahlung photon monitor. Initial design work, as elaborated on later, should begin as soon as possible.

$\gamma\gamma$-collider implications. The laser photons must be transported to within a few centimeters of the IP for Compton backscattering and the spent electrons must be extracted without creating too much background. The interaction among these devices, the vertex detector, the other beam monitoring equipment, and the masks is sufficiently complicated so as to require the design of a dedicated inner detector for the $\gamma\gamma$ experiments at one of the IR's. Conceptual engineering solutions have not yet begun to address these issues.

Trigger rate and Data volume. At the SLC/SLD the trigger rate and data volume can vary enormously from pulse-to-pulse. Overall trigger rates under poor conditions are much larger than can be explained by physics or simulated backgrounds. Typically they are ascribed to abnormal and atypical behavior of some part of the accelerator. While one hopes that any future collider will be immune from such problems, it is prudent to design the trigger and data aquisition with sufficient dynamic range to ride out these disturbances. Additionally, it has been found that the detector often provides some of the most useful diagnostics for the accelerator. The ability to easily correlate its data with that of the machine should be a design consideration.

As many machine designs incorporate multi-bunch operation, some early discussions have suggested a simple machine crossing trigger as the first level trigger, the rates for which are seen in Table 4, row 13. For comparison, 30pb is taken as the cross section for useful physics events in row 14. A first-level trigger as implemented in Aleph, for example, would give roughly the rates in row 15; the efficiency of the Aleph trigger for such hadronic events is about 75% and increasing rapidly to 100% at $E_{\gamma\gamma-c.m.s.}$ ~7-8 GeV.

Detector timing. The bunch time structure of the various designs varies from 0.67 ns to 1000 ns, as seen in Table 3, row 7. While sub-nanosecond timing has been achieved in various detectors, it is typically not trivial and not available in real-time. Complete realistic conceptual designs for detectors which address this issue must begin.

Although the overall rates are not so different for the different machines, as seen in Table 4, rows 13-15, the bunch-time structure determine the probability of having particles from underlying events in the good physics events, a measure for which is given in row 11.

Table 3: Table of some machine parameters related to IR and detector design.

	TESLA	SBLC	JLC(S)	JLC(C)	JLC(X)	NLC	VLEPP	CLIC
	Upper numbers for 0.5 TeV$\equiv\sqrt{s_0}$ machine version							
[Units in brackets]	Lower numbers for 1.0 TeV$\equiv\sqrt{s_0}$ machine version							
1)$\mathcal{L}$ (with pinch)	6.1	4.0	5.3	11.1	5.3	6.9	15	0.9-4.5
[10^{33}cm^{-2}s^{-1}]	10.1	6.3			9.6	14.1		2.2-9.7
2)$\int \mathcal{L}dt$/y=10^7s	20	13	17	37	17	23	50	3-15
$\times$33%eff.[fb^{-1}]	33	21			32	46		7-32
3)δ_B (due to beamstr.)	2.8	3.1	9.6	6.3	3.1	2.4	13.	3.3
[avg.beam en.loss in %]	2.2	6.3			7.5	7.0		7.2
4)$\mathcal{L}$ ($\sqrt{s}$>0.99$\sqrt{s_0}$)	3.5	2.2	1.8	5.5	3.3	4.5		0.5-2.5
[10^{33}cm^{-2}s^{-1}]	6.4	2.2			4.4	5.9		0.8-3.6
5)Bunches/train	800	125	55	72	85	90	1	1-10
	4180	50			85	75		1-10
6)Trains/sec	10	50	50	150	150	180	300	2530-1210
	5	50			150	120		4000-1800
7)Interbunch spacing	1000ns	16ns	5.6ns	2.8ns	1.4ns	1.4ns	3.3ms	0.67ns
	200ns	10ns			1.4ns	1.4ns		0.67ns
8)σ_x/σ_y-spot size	1000/64	670/28	300/3.0	260/3.0	260/3.0	320/3.2	2000/4	250/7.5
[nm]	325/8	572/9			191/2.2	357/2.3		200/6.0
9)σ_z-spot size	1000	500	80	80	83	100	750	200
[μm]	500	500			81	100		200
10)pb^{-1}/bunch	7.6	6.4	19.1	10.3	4.2	4.3	500.	3.7
[10^{-7}pb^{-1}]	4.8	25.2			7.5	15.7		5.4
11)Crossing angle	0	3	6.4	6.0	6.1	20	-	1
[mrad]	0	3			5.0	20		1
12)Detector dead	79	83	120	97	85	81	124	66
cone [mrad]	65	85			89	107		70
13)Collimation $n \times m$	12x38	7x7	6x35	6x35	6x35	10x40		6x13
[$n\sigma_x \times m\sigma_y$]								
14)$\ell^\star$ (drift to Q01)	3.0	2.0	2.5	2.5	2.5	2.0		1.25
[m]								
15)a (ϕ aperture of Q01)	48.	8.	13.7	13.7	13.7	10.		12.
[mm]								

Table 4: Table of some machine parameters related to backgrounds.

	TESLA	SBLC	JLC(S)	JLC(C)	JLC(X)	NLC	VLEPP	CLIC
	Upper numbers for 0.5 TeV machine version							
[Units in brackets]	Lower numbers for 1.0 TeV machine version							
1)$N_{e^\pm}$ per bunch	5.1	2.9	1.3	1.0	.63	.65	20	.8
$[10^{10}]$	.9	2.9			.62	1.1		.8
2)ϵ_x/ϵ_y	20./1.	10./.5	3.3/.045	3.3/.045	3.3/.045	5./.05	20./.075	3./.15
$[10^{-6}$m rad$]$	5.2/.063	10./.1			3.3/.045	5./.05		3.9/.2
3)β_x/β_y at IP	24.5/2.	22./.8	10./.1	10./.1	10./.1	10./.1	100./.1	10./.18
[mm]	20./1.	32./.8			11./.1	25./ .1		10./.18
4)$N_{beamstr-\gamma}$per $e^\pm$	2.6	2.0	1.7	1.3	.9	.8		1.4
	1.1	2.1			1.1	1.2		1.6
5)$\langle E_{beamstr-\gamma}\rangle$	2.7	3.9	13.7	12.1	9.	7.2		6.2
[GeV]	5.	14.			33.	29.		22.
Backgrounds/bunch								
6)$N_{beamstr-e^\pm}$/bunch	25	13	22	10	3.5	3.3		4.6
$\theta >$150mrad, $p_T >$20MeV	4.9	36			5.5	12.2		5.9
7)$\Sigma E_{beamstr-e^\pm}$/bnch[GeV]	2.8	1.5	2.6	1.2	0.4	0.4		0.5
$\theta >$150mrad, $p_T >$20MeV	0.6	4.1			0.6	1.3		0.7
8)Hadr.ev. per bunch	.15	.11	.5	.2	.05	.04		.05
$E_{\gamma\gamma-c.m.s.} \geq$5GeV	.06	.76			.19	.33		.14
9)Minijetpairs per bunch	.30/.017	.23/.016	2.1/.12	.78/.04	.15/.009	.12/.007	56./	.12/.008
p_T^{min}=3.2GeV/8GeV$[10^{-2}]$	.36/.021	3.8/.22			1.8/.10	2.6/.15		1.0/.057
Backgrounds/100ns								
10)$N_{beamstr-e^\pm}$/100ns	25	81	393	357	250	236		46
$\theta >$150mrad, $p_T >$20MeV	5	360			393	871		59
11)Minijetpairs/100ns	.003	.014	.09	.17	.11	.09		.01
p_T^{min}=3.2GeV	.004	.4			1.3	1.9		.1
12)Hadr.ev./100ns	.024	.17	6.7	1.3	.67	.41		.06-.11
per unit lumi$[10^{33}$cm^{-2}s$^{-1}]$	.006	1.2			1.4	1.7		.06-.14
Rates								
13)Bunch crossing rate	8.	6.25	2.75	10.8	12.75	16.2	.3	2.53-12.1
[kHz]	20.9	2.5			12.75	9.		4.-18.
14)1 event/30pb rate	.18	.12	.15	.33	.16	.21	.45	.03-.13
[Hz]	.30	.19			.29	.42		.06-.29
15)Hadr.ev. rate[kHz]	1.2	.7	1.4	2.2	.6	.6		.1-.6
$E_{\gamma\gamma-c.m.s.} \geq$5GeV	1.3	1.9			2.4	3.0		.6-2.5

0.4 Detector Options

To summarize the discussion to now, the physics implications on the detector design are listed in Tables 1 and 2 above, and the effect of the different machine concepts on the IP and detector design are given in Tables 3 and 4 above. Here, some global performance figures of detectors used in simulations for the international workshops are listed in Table 5.

Table 5: Examples of detector performances used in physics studies up to now.

	LEP/SLC-Style	ee500 1991	ee500 Typical	JLC Detector	1.5 TeV Detector	
Tracking $\frac{\delta p_t}{{p_t}^2} = C$ $C =$	8	5-100	10	1	1	$\times 10^{-4}\mathrm{GeV}^{-1}$
E-M Calorimeter $\frac{\delta E}{\sqrt{E}} =$	0.2	.02-.15	0.1	0.15	0.10	$\sqrt{GeV}$
Hadronic Calorimeter $\frac{\delta E}{\sqrt{E}} =$	0.9	0.3-1.0	0.8	0.40	0.65	$\sqrt{GeV}$
Energy Flow $\frac{\delta E}{\sqrt{E}} =$	0.65	0.3-0.8	0.5	0.3	0.4	$\sqrt{GeV}$
Vertexing $\delta(IP) = A \bigoplus \frac{B}{p}$						
$A =$	25	5-20	10	11	10	μm
$B =$	100	50-100	50	28	50	μmGeV
Hermetic coverage $\lvert\cos\theta\rvert <$	0.96	0.70-0.99	0.95	0.98	0.98	

Earlier studies have shown that the performance of existing e^+e^- detectors would be good enough to do much of the physics in the early phase of the machine at low energy. Typical performance figures are shown in the first three columns of Table 5. For higher luminosities and/or higher energies, high performance detectors are needed, and such detectors are the subject of the last two columns. Examples given are the "JLC Detector" which is being designed at KEK and the "1.5 TeV Detector" which is under study in Europe. The JLC Detector is being designed to have good hermeticity over the fullest possible solid angle, to have jet invariant mass resolution comparable with the natural widths of the $W^\pm$ and the Z^0, and give a lepton pair recoil mass resolution for $e^+e^-\to Z^0\phi^0$ comparable with the beam energy spread of $\sim$200 MeV. The 1.5 TeV Detector is being designed with the demands on performance listed in Tables 1 and 2 in mind. Both detectors are large and give good performance at $\sqrt{s}\sim$1-2 TeV. An alternative would be a small high-field detector. The performance figures of such a detector have not yet been worked out in detail.

0.5 Tabulation of What's Been Done

Backgrounds	
$e^{\pm}$ pairs	ABEL runs into JLC and LEP/SLC-like detector (T.Tauchi) using EGS/GEANT (G.Punkar, D.Schulte). Interface ABEL to GEANT with SLC/LEP-type detectors (M.Ronan, D.Schulte).
Synchrotron rad. from Q's	QSR program vectors $\rightarrow$ IP (T.Tauchi) $\rightarrow$ detector using EGS(G.Punkar, D.Schulte).
Muons	Feldman MarkII muon transport code run on NLC/JLC/TESLA beam lines $\rightarrow$ "big bend" and collimators to reduce flux (L.Keller, Y.Namito, M.Sachwitz, J.Schreiber).
Programs	
Beam-beam effects with $e^{\pm}$ pair creation	ABEL (K.Yokoya, P.Chen, T.Tauchi)
	MACPAR+TRACKIT (S.Ritter, D.Schulte)
	GUINEA PIG (D.Schulte)
	RBEAM with no pairs (L.Wood, O.Napoly, P.Pierini, D.Schulte)
Minijets	Minijet (P.Chen, T.Barklow)
	GUINEA PIG (D.Schulte)
	MINIJET (A.Miyamoto, H.Hayashii)
Synchrotron rad.	MQRAD (T.Morimoto, T.Tauchi)
	SLAC QSR (S.Heltzback)
Muons	MU-CARLO (G.Feldman, S.Rokni)
	MUON89 (W.R.Nelson) - analytic calculation
Vibrations	
Ground measurments	done at SLAC,DESY,KEK,CERN, Finland and Sazare(Japan).
Support tube	design and calculations (SLAC, KEK, DESY)
Beam spot size (nm)	
	Laser interferometer (T.Shintake)
	$e^{\pm}$ pair monitors (T.Tauchi, P.Chen)
	Beamstrahlung photon monitor (D.Schulte)
	IP-BPM (T.Shintake)

0.6 Other Things Left to Do

Vibrations

Measurements of Ground Motion

Current measurements of ground motion have concentrated on the frequency dependence of the displacement power spectrum and the normalized correlation function relating the coherence of motion between two detectors separated by a given distance. We now understand that the quantity most useful as input to the calculation of tolerances for a given linac or final focus lattice is the power spectum $S(f,k)$ as a function of both frequency f and wave number k, measured in units of 1/distance. This function contains all spatial and temporal correlations. Current tolerance estimates use semi-empirical formulae to relate frequency and wave number.

$S(f,k)$ should be measured at a quiet, a moderate, and a noisy site, tabulated, and made generally available. The emphasis should be not on supporting one particular site over another, but on pointing out the sensitivity of each machine design to the problem. Currently the devices used for these seismic measurements compare two absolute measurements of motion. Arrays of devices which can accurately measure the *differences* in motion may need to be developed.

Additionally, as most of the power in seismic events is carried within one wavelength of the surface in so-called Raleigh waves, the general dependence of $S(w,k)$ as a function of depth should be made. Moreover, the tunnel itself may serve to influence the propogation of waves impinging on it from an otherwise homogeneous material. Studies, whether by simulation or measurement, of how this may effect the overall problem of ground motion should be carried out.

Engineering of Supports

Supports for magnets, RF structures, and the detector should be designed which do not amplify the effects of seismic or cultural noise. The concept of the support tube linking both ends of the final focus needs to be more adequately developed. Insufficient engineering has been done to indicate what the size and mass of such a tube must be to provide stability against relative motion of both sides of the FF quads. If indeed necessary it would limit access, add mass, and, if not carefully suported, it could translate low frequency seismic noise to the higher frequencies of its normal modes where it would be more difficult to control with feedback.

Active and Passive Vibration Suppression

Tests which attempt to feedback seismic signals to piezoceramic actuators in a closed feedback loop have begun at SLAC, KEK, and DESY. Early results show a factor of three reduction in rms jitter in the 1-10 Hz frequncy range. More work to develop systems with higher attenuation is necessary. This may require the development of devices to measure the exact quantity of interest for beam stability. For example, using a geophone to measure the motion of a magnet might be less preferable than measuring the change in field that the beam sees as a result of such motion. If correlated motion between two magnets is driving luminosity loss, then perhaps devices which accurately measure the relative motion of the two magnets need to be developed. One would not feel confident until at least a factor of ten safety margin exists in the frequency range not covered by beam based feedback.

Engineering efforts for structure or magnet mounts might include passive damping if such as system did not compromise the long term stability of the machine alignment. Investigations into elastic materials or to the effects of trenches to isolate structure from shallow ground waves of high frequency may be in order.

Beam Based Feedback as a Vibration Suppression Tool

Current estimates of the efficacity of beam based techniques to control vibrations are based on models of the SLC feedback system extrapolated to the bunch frequency of the new machines. Estimates based on actual SLC performance should be carried out.

Analysis of the Spent Beam

Beamstrahlung at the IP will shift the mean energy and introduce a large energy spread when the beams are in collision. When the beams are not in collision they will have their full energy and narrow width. Beam dump devices such as the energy spectrometer and Compton polarimeter must be built in such a way as to be able to make measurements under both conditions. Already at SLC, the photon background makes these measurements difficult. Designs which can handle the increased photon background of the higher energy colliders must be developed. Depolarization of the electron beam due to the spin-flip (Sokolov-Ternov) effect in the field of the opposing beam is expected to be about 0.4%(Υ=0.14) at 500 GeV and go up to about 5%(Υ=0.7) at 1 TeV. A system of pre- and post-collision polarimeters may be required to understand the polarization completely.

Conceptual designs exist for using the distribution of electron pairs produced by the beam-beam interaction as a diagnostic tool. The practical design of detectors which can survive the radiation environment and readout in the multi-bunch environment of the machines should be developed.

Background Studies

Studies which incorporate the tracking of secondary particles from beam-beam interaction pairs into vertex detectors have begun. More elaborate simulations which model realistic detectors, and which allow events from the physics generators to be overlaid, must begin. It would help discussions of the choice of machine if these simulations where in some sense generic. That is, that they use one model detector and physics generator, overlay the background appropriate to the machine design but calculated consistently by one program, and then use one measure of the physics reach as a means of comparison.

0.7 Summary and Recommendations

One concludes from Tables 1 and 2 that:

•the lowest energy of the machine should overlap with the highest energy of LEP so that no e^+e^- "discovery gap" exists;

•the first stage of the collider is $\sqrt{s}$=0.5 TeV, which opens much of the physics potential listed in Tables 1 and 2, precision measurements of the $\mathcal{SM}$ and perhaps discovery of the higgs and/or $\mathcal{SUSY}$;

•the machine design energy should encompass $\sqrt{s}\sim$1 TeV in order to match the discovery reach of LHC and to realize fully the potential for standard and new physics;

•it should be upgradable to $\sqrt{s}\sim$ $\mathcal{O}$ (1.5-2TeV) to realize fully the potential for understanding electroweak symmetry breaking in the no-higgs-particle case;

•the luminosity required is $\int \mathcal{L}dt$ up to 100fb^{-1}/year for precision measurements; and

•polarized beams are necessary: polarized e^- are essential, polarized e^+ very important;
•Z^0-peak running with polarized beams offers the possibility for sensitive new tests of the internal consistency of the $\mathcal{SM}$.

The series of physics milestones between LEP energies and $\sqrt{s}$=1 TeV show that a convincing physics programme can consist of commissioning the machine at $\sqrt{s}$=0.25 TeV to 0.35 TeV before reaching the first stage energy of $\sqrt{s}$= 0.5 TeV, and a continuation of the step-wise energy increase up to $\sqrt{s}$=1 TeV.

The strategy of increasing the energy, of pursuing the complementary options of $\gamma\gamma$, $e^-\gamma$, or e^-e^- collider modes, or of running at the Z^0-pole can be decided after the physics results have been extracted from the 0.5 TeV e^+e^- running.

The detectors are challenging. There seems to be no critical aspect of the detectors which would tell us that any one of machine designs would not allow to achieve the physics goals set forth. Clearly the larger the bunch-time spacing, the easier it will be to do the experiments and extract the physics. The backgrounds will be larger than at LEP, but not so large as to spoil the cleanliness of e^+e^- experimentation we have experienced in the past.

There is quite a lot of R&D work related to IR issues to be done, as discussed in Subsection 6 above; it is mainly related to elimination of vibrations and to a better understanding of backgrounds.