THE STATUS OF THE S-BAND LINEAR COLLIDER STUDY

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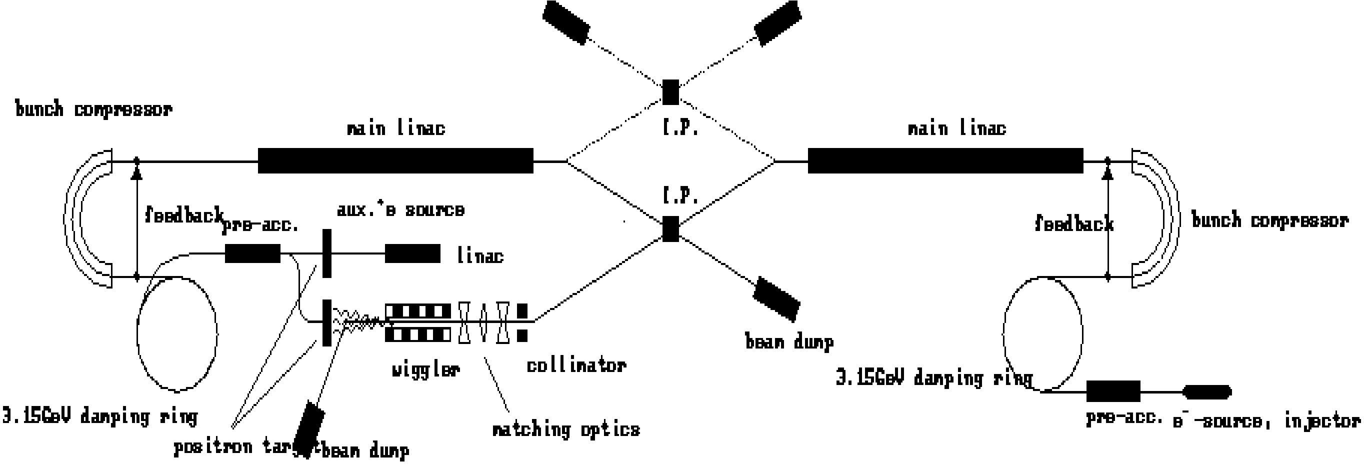

Figure 1 General Layout of the S-Band Linear Collider.

The demand for e^+e^- collisions beyond the LEP 200 energy range up to the TeV region requires the development of linear collider technology and there seems to be international agreement today, that this should be a 2×250 GeV linear accelerator [1]. Different studies around the world concentrate on different designs, all based on partially or non developed technology. The general differences are mainly expressed by the choice of the operating frequency of the rf-power source and the accelerating structure, which varies for the studies (TESLA, SBLC, NLC, JLC, VLEPP, CLIC) between 1.3 to 30 GHz. Based on a number of arguments [2] which mainly summarise the availability, the cost optimisation and the experience gained so far with S-Band technology, a 500 GeV S-Band linear collider design has been worked out at DESY.

I. Introduction

A linear collider consists of two opposing linear accelerators, one accelerating positrons, the other electrons. From the parameters of the proposed S-Band linear collider, which are given in table 1, it can be seen that from today's point of view the operating conditions are close to what has been achieved already[3]. Especially the proposed vertical spot size at the interaction point (I.P.) is only about a factor of two smaller than what has recently been demonstrated in the Final Focus Test Beam [4]. A more detailed description of all the parameters is given in [1] and a summary of the technological developments and the S-band test linac set-up is presented in [5]. The trade-offs in comparison with other approaches are described in detail in [6] and point out other basic advantages of an S-band collider as, for example, the generally lower wakefield due to larger apertures and the smaller peak power required per meter to store sufficient energy for acceleration with good beam quality. The SBLC linear collider study is pursued at DESY in the frame of an international collaboration with institutes in China, France, Germany, Japan, Netherlands, Russia and USA contributing to the technical R&D and/or the design of the 500 GeV collider.

active length 30.2	km	
$t_{beam\ pulse}$	2	µs
n_b/pulse	125	
Δt_b	16	ns
f_{rep}	50	Hz
$\varepsilon_x/\varepsilon_y$	10/0.5	10^{-6} m
β_x^*/β_y^*	22/0.8	mm
σ_x^*/σ_y^*	670/28	nm
σ_z	0.5	mm
$<\Delta E/E>_{rad}$	3.2	%
P_b	2 x 7.2	MW
P_{AC} (2 L's)	139	MW
L (incl H_D)	3.75	10^{33}cm^{-2}

Table 1 Main parameters of the S-band 500 GeV (c.m.) linear collider.

II.General Layout

For the overall layout of the linear collider tunnel a number of assumptions have been made to minimise construction costs and toavoid restrictions on the choice of the accelerator site.

- The tunnel has to accommodate all accelerator components otherwise a second tunnel or klystron gallery is necessary.
- Entrance into the tunnel **must** be possible during operation in order to allow maintenance on klystrons and modulators.

From today's point of view this results in a single tunnel 7 meter in diameter with the beam lines and the accelerating structure shielded inside the tunnel (on the bottom under the concrete shielding). A sketch of the cross section is given in figure 2. It should be noticed that only half of the tunnel volume is filled to allow for the energy upgrade (compare following section). In the sketch today's size of the components (modulator, klystron, section support etc) is shown.

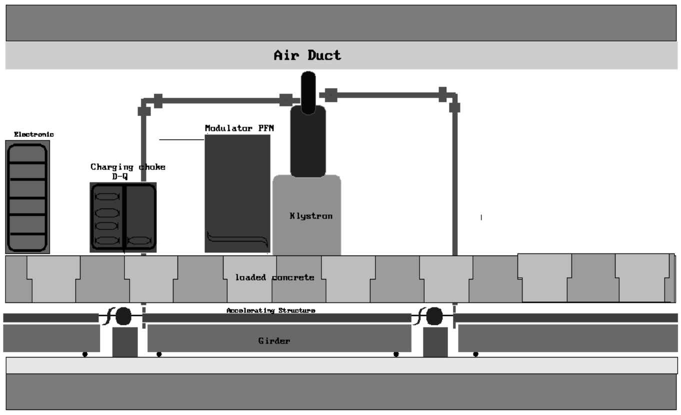

Figure 2 Sketch of the SBLC tunnel with one complete module installed.

A. Upgrade Path

In order to upgrade to the S-Band linear collider to 1 TeV it would be desirable not to extend the linac tunnel but to double the accelerating gradient instead (quadruple the peak power). This can only be done on the expense of beam pulse length, if a SLED I type pulse compression scheme is considered for the first factor of 2 in peak power.

active length	30.2	km
n_b/pulse	50	
t_{pulse}	0.5	µs
f_{rep}	50	Hz
N_e/bunch	2.9	10^{10}
$\varepsilon_x/\varepsilon_y$	5/0.05	10^{-6} m
σ_x^*/σ_y^*	572,9	nm
σ_z	0.50	mm
$<\Delta E/E>_{rad}$	4.3	%
P_{AC} (2 l's)	278	MW
L (incl. H_D)	6.17	10^{33} cm^{-2} s^{-1}

Table 2 Parameters at 1000 GeV (c.m.) with reduced vertical emittance

In addition, the number of klystrons have to be doubled (second factor of 2), which automatically would double the ac-power required, if no further increase in klystron and modulator efficiency is assumed. This seems to be unlikely, but so far no save prediction seems to be possible.

Therefore the 1 TeV parameters given in table 2 are based on the same values for the klystron efficiency compared to table 1. From the picture of the tunnel cross section, it can be seen as well that even with this size of the components, the upgrade would be possible

With more relaxed tolerances of the low-frequency approach, the SBLC design is very well suited if one aims to push the vertical emittance towards a smaller value. After gaining experience with the different correction and optimisation procedures, reducing the vertical emittance ε_y by an order of magnitude seems to be conceivable. Further and even more optimistic assumptions on possible reductions of the vertical beam size being transported through the linac could be made, taking into account that the emittance proposed here is still larger than for the higher frequency collider approaches. This could be used to decrease the repetition rate and therefore bring down the average power consumption.

III. FINAL FOCUS & COLLIMATION

In general keeping beamstrahlung at a low level is an essential prerequisite for acceptable background conditions and good energy resolution for the high energy physics experiment. More recently the bunch to bunch distance also became an issue for the high energy physics experiment, because the probability of having underlying events in the detector increases with the number of bunch crossings per unit time [1]. Therefore low frequency linear colliders (and especially sc-linacs) with larger bunch to bunch distances are even more favourable. The most important parameters concerning beam-beam effects are summarised in table 3. In case of the SBLC, beams have to cross at an angle (θ_c=3 mrad) in order to avoid the multibunch kink-instability due to parasitic interactions assuming conventional quadrupoles with a bore radius of 4 mm. A reduction of luminosity caused by an effective increase of the horizontal beam size is avoided by employing a simple crab-crossing scheme with finite dispersion at the IP, making use of a coherent energy spread within the bunch of about σ_E=0.5 %.

$<\delta E/E>_{cm:rms}$	2.7	%
	.04	
Disr. D_x/D_y	0.4/8.5	
angle $\theta_{\gamma x/y}$	1.28/0.55	mrad
bunch to bunch distance	16	nsec
N_{pair}/bunch	7	
N_{hadr}/bunch	0.2	

Table 3 Results of beam-beam simulations

The magnet lattice between the interaction region (IR) and the main linac consists of the final focus system (FFS) for beam size demagnification and chromatic corrections, a section to protect the IR quadrupoles from large amplitude particles and bending sections for creating a sufficient separation between two beamlines if the collider has to serve two experiments. The momentum acceptance of ±2.0 % ($\sigma_{E,beam}$=0.5%) with an optimised sextupole distribution of the FFS for the SBLC design is far in excess of the beam energy spread. The tight requirements for beam collimation are determined by the fact that synchrotron radiation generated in the doublet before the IP has to pass freely through the aperture of the opposite final quadrupole, which is the main difference compared to other layouts[1] with crossing angles around θ_c=10 mrad. Therefore particle amplitudes have to be restricted to $7\sigma_x \times 7\sigma_y$. The entire lattice from the linac to the IP will require approximately 1.5 km per beam on either side of the IP including the double bend for two experiments [7].

IV.The Linac

The basic linac module consists of one 150 MW klystron driven by one modulator producing a 3 µsec rf pulse which is fed into two 6 meter long accelerating sections (compare fig. 2). In addition each section will have micro-movers which, according to the HOM coupler signal coupled out at the beginning and the end, will align the section. The quadrupoles are equipped with further developed ground motion /vibration pick-ups , which will sample frequencies in the range of 2-50 Hz and feedback on the quadrupole position[8]. This is especially necessary if emittances are considered, smaller than those given in table 1. For the different components the alignment tolerances are around 100 µm for the prealignment of the quadrupoles and the accelerating sections. With a BPM resolution of 4µm the beam orbit will have to be corrected in the quadrupoles applying beam-based correction procedures [9]. Finally the micro-movers correct the electric center of the section with respect to the beam axis to within 30 µm rms.

V.The Injection System

While the design for the damping rings has been done already, the positron source is still one of the main challenges in the collider. The positrons are produce by converting γ's in a thin target to reduce the heat load drastically. While the source is theoretically understood very well [15]. It seems to be impossible to test the new scheme before a linear collider is set up.

VI. Main R & D Activities

The set-up of the S-Band test linac at DESY covers the main effort for the whole technology which has to be developed for a linear collider[5]. In addition for a long linear accelerator the transport and the preservation of a small emittance has to be investigated. From particle tracking results the tolerances mentioned before are determined for the different components of the linac and for the beam quality. More recently a complete simulation of single- and multibunch effects including energy spread, bunch to bunch charge variation, transient beam loading and beam based alignment techniques has been performed with a newly developed code [10]. The results have been compared with a similar code [11] and good agreement was found. At the same time a strong effort to understand and to calculate the Higher Order Mode distribution in accelerating structures has been made[12,13].

VII. Summary and Conclusion

During the last three years of R & D several aspects of the overall layout have been reviewed and discussed. Especially from recent beam dynamics simulation and under the assumption that the multibunch problem has been solved by the technologies mentioned in this paper, the S-Band linear collider is dominated by the single bunch transverse wakefield. In order to optimise the design it will be necessary to reduce the single bunch charge and adjust the number of bunches for the required luminosity.

VIII.Acknowledgement

I would like to thank all the members of the collaboration from the different institutes and countries for their contributions to the S-Band design study. The author is indebted to R. Brinkmann for his contributions and helpful discussions.

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