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STATUS OF THE S-BAND LINEAR COLLIDER STUDY

by

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Abstract

The S-Band linear collider Study group concentrates on the design of a linear collider which technically is based on existing 3 GHz rf-technology and experience. Necessary or promising R & D steps are under way to develop for example high power klystrons, new types of modulators, accelerating structures and alignment techniques, but only reasonable extrapolations from state of the art technology will be investigated. In parallel the set-up of a test linac consisting of two modular units, comparable to those of a possible linear collider, is planned and under way at DESY. These units will have to prove the same performance as those for linear colliders including all the diagnostics.

1 Introduction

An S-Band linear collider will have the unique feature of boosting the available beam power towards a level which otherwise can only be reached with superconducting linear colliders [1], while keeping the average power consumption within moderate levels. Any linear collider has to provide a luminosity of the order of $5 \times 10^{33} \text{ l}/(\text{cm}^2 \text{ sec})$, the large beam power available with an S-band collider will be used to relax almost all alignment tolerances by using comparatively large beam dimensions. The luminosity may be later increased by going to smaller spot sizes. Following the formula for the luminosity, luminosity is proportional to beam power and inversely proportional to the beam size:

$$\begin{aligned}\mathcal{L} &= \frac{N^2 \cdot f}{4\pi \sigma_x \sigma_y} \\ P_b &= E \cdot N \cdot f.\end{aligned}$$

Here E is the energy per beam, f is the bunch collision frequency and N is the number of particles per bunch. Apart from the beam power, the necessity to produce a small energy spread favours lower frequencies because the stored energy in a cavity is proportional to the gradient times the wavelength squared $(G \times \lambda)^2$. In a multibunch machine, where extracting a lot of energy is the issue, sufficient energy can be provided with reasonably small gradients. Single and multi-bunch emittance growths scale roughly as the third power of the frequency which makes a longer wavelength even more favourable. These three arguments, apart from the availability of most of the techniques and the experience, led to our decision to use three gigahertz as the operating frequency for this linear collider study. A complete list of parameters for the S-band collider for three different operational center of mass energies is given in table 1.

One of the distinct advantages of the S-band collider is its flexibility: For example, as recently presented [2], the interest in top physics results in a need for specific conditions at an energy

General Parameters				
energy	GeV	300	500	1000
luminosity	$(\text{cm}^2 \text{sec})^{-1}$	$1.1 \cdot 10^{33}$	$4.0 \cdot 10^{33}$	$2.8 \cdot 10^{33}$
active length	m	17640	29412	29412
repetition rate	Hz	50	50	50
number of particles per bunch		$2.1 \cdot 10^{10}$	$2.1 \cdot 10^{10}$	$2.8 \cdot 10^{10}$
Particle Production and Damping Rings				
damping ring energy	GeV	3.15	3.15	3.15
damping time	msec	3.8	3.8	3.8
ring circumference	m	650	650	650
invariant emittance $\gamma \epsilon_{x,y}$	m	$500/50 \cdot 10^{-8}$	$500/50 \cdot 10^{-8}$	$500/50 \cdot 10^{-8}$
energy spread	%	0.112	0.112	0.112
bunch length σ_s	mm	3.6	3.6	3.6
wiggler peak field	T	2.0	2.0	2.0
wiggler total length	m	84	84	84
dynamic acceptance	m	$4 \cdot 10^{-6}$	$4 \cdot 10^{-6}$	$4 \cdot 10^{-6}$
Main Linac				
wave length	m	0.10	0.10	0.10
average shunt impedance	M Ω /m	54	54	54
attenuation	neper	0.57	0.57	0.57
structure length	m	6	6	6
klystron power	MW	150	150	150
number of klystrons		1470	2450	4900
structures per klystron		2	2	1
average power	MW	60	110	220
average pulse current	mA	300	300	400
current pulse length	μsec	2	2	0.6
number of bunches per pulse		172	172	50
bunch length (rms)	mm	0.5	0.5	0.5
maximum energy width (peak to peak)	%	0.3	0.3	0.2
Final Focus and Interaction				
β -function at IP $\beta_{x,y}^*$	mm	50, 0.8	16, 1	40, 0.5
beam dimension at IP $\sigma_{x,y}^*$	nm	914, 37	400, 32	447, 16
total crossing angle	mrad	2	2	2
disruption parameter D_x, D_y		0.23 / 5.6	0.69 / 8.6	0.38 / 10.6
luminosity enhancement		1.4	1.8	1.4
maximum disruption angle	mrad	0.37, 0.44	1.29, 0.52	0.85, 0.25
mean number of beamstrahlung photons per particle		1.0	2.4	2.7
mean photon energy	GeV	1.0	6.4	24.4
mean critical radiation parameter		0.014	0.058	0.13
mean fractional beam energy loss	%	0.79	4.8	8.2
mean fract. reduction for c.m. energy	%	0.36	3.3	6.7
momentum acceptance	%	± 1.8	± 1.8	± 1.8
Efficiencies				
rf $\rightarrow$ beam	%	43	43	22
wall-plug $\rightarrow$ beam	%	14	14	8

Table 1: Table of S-band linear collider parameters

of ≈ 150 GeV per beam (compare table 1) which has to be optimized for very small energy spread. Even with a moderate gradient of 17 MeV/m the energy spread can be kept below 0.3 % (peak to peak) operating at only 9° off the crest of the wave, which means almost no decrease in accelerating gradient.

To extend later the standard 500 GeV in the center of mass to 1 TeV without extending the active length, the effective gradient has to be doubled. Therefore the number of klystrons and modulators has to be doubled ($\approx$ factor of $\sqrt{2}$ in energy) and every 6 m long accelerating section has to be connected to one 150 MW klystron instead of feeding two sections with one klystron. In addition SLED cavities have to be included for every klystron in order to achieve the second factor of $\approx \sqrt{2}$ in energy. The luminosity could not at the same time be increased but at least could be kept constant. It should also be pointed out, that the rf-structure is then operated completely in the transient regime. This is different from the mode of operation considered for the 2×250 GeV version, but apart from the fact that 50 bunches are accelerated instead of 3, it is similar to the acceleration cycle currently used for the SLC [3].

Comparing these parameters, an S-band linear collider is capable of covering the energy range from 300–1000 GeV with reasonable assumptions based on today's technology and competitive with other linear collider designs.

In order to test many of the components which are currently under development, a test linac is being set up at DESY. This linac consists of an injector, a spectrometer as well as a beam diagnostic station and two modular units comparable to those which could be used in a linear collider. Apart from technical aspects, transverse multibunch instabilities have to be investigated with a bunch train and a single bunch population as presented in table 1. The commissioning of the test facility is scheduled for 1996 while most of the single components should be finished by 1995. This report will review the recent progress on the components which are being developed at DESY and in collaboration with other institutes. A more general overview of the design study has already been given in [4].

2 The S-Band Test Facility at DESY

Although a large variety of linear accelerators exist operating at 3 GHz, building an S-band test facility is necessary due to the fact that many specific requirements for a linear collider can not be tested easily using existing linacs. For example, within the planned technical program the functionality and long term reliability of the new klystrons, modulators, accelerating sections and support structures have to be tested. Mechanical feedbacks for position stabilization of the quadrupoles and the accelerating sections will be tested and the independent control of 180 bunches in $2 \mu\text{sec}$ long bunch trains with a repetition rate of 50 Hz will be attempted. Another important goal of a prototype test facility is of course the development of inexpensive components of high quality. After the accelerating waveguides, the klystrons and pulse modulators have the biggest share of the total costs of a colliding beam facility. Klystrons with the required peak power of 150 MW exist already, but the present pulse length of $1 \mu\text{sec}$ is too short by a factor of three. Modulators for the 150 MW tubes exist and are technically satisfactory. But since these powering circuits are the most expensive component of a linear collider it is imperative to look for ways in which to build these modulators in a more economical way.

During the experimental program, one of the most critical aspects of the S-band linear collider to be studied is the suppression of cumulative multibunch instabilities. To contribute significantly to the emittance growth in a linear collider, only tiny displacements of the order of a few micrometers of single bunches in the accelerating sections are required because of the long current pulse and large number of sections in such a linac. For this reason the study of the beam-based high precision alignment of the accelerating sections within approximately $15 \mu\text{m}$ (rms) is one of the main topics of the experimental program. One or several HOM attenuators,

Figure 1: General layout of the S-band linear collider test facility.

which may be distributed over the 6 m long section, serve not only as dampers but also as a diagnostic tool to close a feedback loop which drives the section mechanically in the vertical and horizontal plane until the HOM coupler signal is minimized. In addition a small geometric variation of the accelerating sections may be used to detune the HOM-mode resonant frequency from section to section and provide additional (Landau-) damping. Although it is not possible to demonstrate in a short test facility that the multibunch instability can be totally suppressed in a linear collider, it is important to demonstrate, that different techniques to cure the instability, are feasible. Other topics are transient beam loading compensation, measurement of the beam energy to verify the gradients, beam position monitor tests, vibration control and feedback are other main topics of the experimental program. A sketch of the entire test set-up is shown in figure 1.

2.1 Basic Parameters and Layout

The basic parameters of the test accelerator are determined by the requirements for the linear collider. A list of general parameters for the test facility is given in table 2.

The accelerator consists of an injector followed by four linear collider accelerating structures and a beam diagnostics station, which consists of a spectrometer and beam position monitor station as well as wire scanners to determine the emittance. The injector consists of a standard thermionic gun with a grid and a subharmonic buncher assembly. The electron energy is approximately 100 keV. After a short section containing beam monitors, the bunches will be accelerated in four six meter long sections with focussing elements in between. The accelerating structures are fed by two klystrons with a peak power of 150 MW each. This results in a maximum no-load (zero beam current) gradient of 20 MeV/m. Thus the maximum energy gain is 480 MeV at zero beam current and 400 MeV at full current (300 mA). Furthermore current monitors are foreseen to measure the final accelerated beam current as well as dark currents.

Test Facility Parameters		
energy (zero current)	MeV	450
energy (full current)	MeV	400
length	m	≈ 45
injector energy	keV	100
operating frequency	GHz	2.998
current-pulse length	μsec	≥ 3
number of structures	(const. grad.)	4
structure length	m	6
number of klystrons		2
peak power/klyst.	MW	≥ 150
number of modulators		2
number of bunches		1 to 200
number of part./bunch		$\leq 3 \cdot 10^{10}$
average beam current	mA	up to 300

Table 2: General parameters of the test facility.

3 The Main Linear Accelerator Components

Various components of a the S-band linear collider are under detailed investigation in order to meet the final goals listed in table 1.

3.1 The Modulators

There are two avenues open along which to pursue this goal:

- hard tube pulsers
- line-type/pulse-transformers.

Hard tube pulsers, so far used only at much lower power levels, may be an interesting alternative to the commonly used line-type/pulse-transformer version. Tests on a lower power hard tube pulser and - if it looks promising - the development of a full power switch tube in a second step of the envisaged R & D-program may turn out to be the most economical and technically satisfying way to solve the problem of powering a linear collider. In parallel to this, the more conservative approach of standard line-type pulsers must be followed to find the best way to minimize costs and optimize performance.

The standard type modulators used today are able to provide the necessary peak power for a 150 MW, $3 \mu\text{sec}$ long rf-pulse. Nevertheless they are the most expensive single components of a linear collider and have to be built in a more economic way.

3.1.1 The Line Type Pulser (LTP)

A well established method for these high power demands is the Line Type Pulser. The 240 modulators at the SLC use this technique [5]. Although they work very reliably at a voltage level of 350 kV, some development is necessary to meet the requirements for modulators powering 150 MW klystrons. The parameters of a modulator for such a klystron could be:

In order to have at least one modulator available when the first 150 MW klystron arrives, it is planned to install one modulator similar to the one, which is under construction at SLAC for the tests of the 150 MW klystron. A second LTP has to be built for the second klystron if a Hard- Tube Pulser described in the next subsection is not available.

Maximum possible Cathode Voltage	U_s	=	540 kV
PFN-Voltage during pulse	U_p	=	27 kV
Charging Voltage of PFN	U_0	=	54 kV
Current through thyatron	I_p	=	14 kA
Impedance of PFN	Z_{PFN}	=	1.8Ω
Pulse duration	τ	=	$3 \mu s$
Transformer ratio	n	=	1 : 20
Number of PFN subsections	N	=	24
Capacitance of one PFN Capacitor	C_n	=	35 nF
Inductance of one PFN Choke	L_n	=	112.5 nH

Table 3: Possible Layout for a Line Type Pulser Design.

3.1.2 The Hard Tube Pulser (HTP)

The most promising solution appears to be controlling the klystron beam voltage by means of a series modulator using a hard tube switch. This expectation refers to both, the construction and operating costs, in addition to some technical advantages. As for the high voltage dc-power supply including the elements in between: the power supply and the switch tube/klystron module, one can profit from the low duty factor or high ratio of peak to average current respectively, which will allow a simple and cheap design including the possibility of connecting larger groups of switch tubes/klystrons to only one power supply. A crow-bar system for the klystron will not be necessary since the switch tube itself protects the klystron. The robust structure of the switch tube (mechanics/materials as well as beam optics and optional protection electrodes), in turn, may result in simple and inexpensive switch tube protection devices.

A Hard Tube Pulser for 150 MW klystrons will need to switch tubes capable of about 600 kV. A prototype of such a switch tube is already available (Varian, Palo Alto, USA) and should be sufficient to switch a klystron current with a pulse length of $3 \mu s$ at a maximum voltage above 200 kV. In order to limit the investments in the test facility for the very first "proof of principle", DESY has constructed a set-up including a DC power supply capable of 300 kV, the prototype switch tube and a klystron (TV 2002 DoD, Thomson-CSF, 3 GHz, 25 MW peak power, 250 A at 250 kV).

Figure 2: Hard Tube Pulser

At 300 kV the stored energy in the capacitor is 2.25 kJ. If an arc occurs in the switch tube, the energy dissipated into the tube is not greater than 7.5 J, assuming the resistivity of the arc to be of the order of 100 m Ω . Thus switching off the power supply within 20 ms will be sufficient to protect the switch tube against damage caused by arcing.

The switch tube protects the klystron against damage. If an arc occurs in the klystron the current cannot exceed the current in the switch tube. Thus the storage capacitor cannot be totally discharged into the klystron.

Assuming a klystron impedance of 1000 Ω , the voltage drop ΔU at the storage capacitor can be estimated:

$$\Delta U = U_0 \cdot \left(1 - \exp\left(-\frac{t}{RC}\right)\right) = U_0 \cdot \left(1 - \exp\left(-\frac{3 \mu s}{1000 \Omega \cdot 50 \text{ nF}}\right)\right) = 0.06 U_0.$$

With a drop of the input voltage of 6 % the switch tube should deliver a nearly constant output current with a drop of less than 1 %. First tests with the setup have recently been done bringing the voltage up to 130 kV. In fig. 3 the voltage and the current pulse from the switch tube are displayed. The expected fast rise can be seen, while the fall time is by far too long and is dominated by the charging resistor of the grid pulser which will be rebuilt soon. Going to higher voltages, the rise time will become better.

Figure 3: The voltage and current in a pulse from the 300 kV switch tube setup at DESY.

3.2 The Klystron

Presently it seems to be straightforward to develop a version of a klystron which will satisfy the demands of an S-band linear collider. Scaling the performance of SLAC's 5045 klystron [7] with a peak power of 65 MW and a tube which has been developed earlier [8] with 150 MW–1 μ sec long rf pulses, it should be possible to extend the rf-pulse to 3 μ sec. A collaboration between DESY and SLAC has been setup in order to develop such a klystron within the next two years. For detailed comparison, a list of the parameters for the two klystrons mentioned above and of the klystron under development are given in table 4.

The total number of tubes to be built within this collaboration is four, of which two should meet the design goals of the test accelerator (i.e. linear collider) design. A preliminary sketch of the klystron geometry is shown in fig. 4. The comparatively larger gun area has to provide a higher dc-current, up to 700 Ampere, which will be bunched in five (instead of four) buncher

		5045	150 MW, (1985)	DESY
Frequency	GHZ	2.856	2.856	2.998
Beam voltage	kV	350	475	≤ 535
Beam current	A	393	622	≤ 700
μ - Perveance	A/V ^{1.5} /	1.9	1.9	1.8
Pulse width	μ sec	3.5	1	3
Rep. Rate	Hz	180	40	60
Aver. RF-Power	kW	43	6	27
Efficiency	%	≥ 40	≥ 50	≥ 40
Gain	dB	50	59	≥ 55
solen. field	T	0.14	0.18	0.21

Table 4: Comparison of SLAC klystron performance.

cavities. While it has not been decided for the first setup to use a single-, a two coupled- or a two uncoupled cavity output to feed the power into the two rectangular waveguides, four ceramic windows will be used decouple the klystron vacuum. Using this layout the peak power per window will be almost equal compared to that in the 5045 and the average power will be less. The four-window output and the two 2-cavity output solutions are presented in somewhat more detail in figure 4.

two of the four windows

uncoupled two cavity alternative

Figure 4: Sketch of the 150 MW-3 μ sec Klystron Geometry.

In parallel a resonant ring is being constructed at DESY in order to further investigate and high power test the rf-ceramic windows. Following a development at KEK [9], where more than 300 MW peak and 35 kW average power have been transmitted through specially processed rf-windows, this resonant ring should prove the long term capability of the windows to handle power levels of that order.

The maximum power in the resonant ring will be of the order 250 MW provided by a 25 MW klystron available at DESY. In fig. 5 the main components can be seen. The rf-pulse from the klystron is via a 10 dB input coupler matched to the losses of the ring which is made of WR 284 standard S-band waveguide. The Phase shifter is used to achieve an integral number of wavelengths for a given frequency while the tuner minimizes the reflections from any subject

under test within the ring. Viewports integrated in most of the knees allow for the observation of the critical components which may breakdown first.

Figure 5: Resonant ring setup at DESY.

3.3 The Accelerating Section and its Support Structure

The accelerating structure for a future linear collider has to fulfill many requirements. The main goal, to minimize the costs per meter is also influenced by the need to avoid or damp the cumulative beam breakup instability driven by the section itself. The optimum structure from our point of view is characterized by:

- a simple geometric design which is easy and cheap to fabricate with reasonable tolerances (≈ 10 to $20 \mu\text{m}$)
- a design that intrinsically avoids the instability by detuning, damping or a combination of both.

While any geometry somehow similar to a pillbox cavity can in principle be used there is not much gain in terms of shunt impedance or Q-value compared to additional technical difficulties by optimizing certain shapes for travelling wave structures. Therefore the single cell geometry recently being fabricated for DESY by different companies is defined by shapes to be produced easily by conventional machining with reasonable tolerances. Typical numbers are $\pm 10 \mu\text{m}$ on the iris and the cavity diameters and less than 300 nm for surface roughness. To minimize the number of pieces to be aligned and to be brazed in a 6 m long section, a ring and an iris are machined together. The geometry of a single cell cavity, a so called *cup*, is shown in figure 6.

Apart from the characteristics given above, more details have to be added as shown in fig. 6: A groove to store the brazing wire with a phase for leak-checking, a groove on the outside to fix the cup during machining on the lathe, a precisely machined outside surface on every cup to have a reference with respect to the center hole of the iris and four boreholes to finally tune the cups after brazing.

section length	m	6
attenuation	neper	0.57
peak power per input	MW/pulse	75
power dissipated per section	MW/pulse	51
group velocity variation	% of c	4.1–1.3
filling time	nsec	790
shunt impedance variation (theor.)	M Ω /m	45–61
number of cells		180
average power per meter	kW	≈ 1.3

Table 5: Section parameters for the test facility.

Figure 7: Dispersion curves for five different 6 cell stacks with group velocities between 4.4 and 0.8 % of c.

frequencies of single cells with respect to a given standard cup in order to have a fast quality control. Typical deviations from cup to cup are of the order of 0.1–0.5 MHz (rms) which corresponds to geometric errors of the order of a few micrometers while systematic errors can be as large as 1.0–2.0 MHz. With an estimated tuning range given by the boreholes of approximately 2 MHz, this is already sufficient.

Results from a five test stacks with different group velocities in the range of 4.4–0.8 % of c are shown in fig. 7.

3.3.2 The Support Structure

The required straightness of the six meter long rf-section is approximately $\pm 30 \mu\text{m}$. While any systematic sag can be compensated by prealignment, severe problems will be caused by any temperature dependence which can lead to bowing and unsymmetric but elastic torsion. In addition mechanical resonances of the girders should be shifted well above the maximum repetition rate of the linac.

	ROBAX (Glass Ceramics)	Stainless Steel
Thermal expansion (α)	0.05×10^{-6}	16×10^{-6}
Poisson number	0.25	0.3
specific weight (g/cm^3)	2.56	7.8–8.0
turning stress (N/mm^2)	75	≈ 800
(operating) Temperature	up to 800 C°	
Elastic force (kN/mm^2)	92	≈ 200

Table 6: Comparison of glass ceramic and stainless steel material properties.

Figure 8: Sketch of the glass ceramic girder geometry for a full scale test setup.

For the support structure a completely new approach has been taken utilizing girders made from glass ceramics. The advantage compared to standard aluminum or stainless steel is due to the extremely small thermal expansion of these ceramics which are normally used in a high temperature environment. With an expansion coefficient of 5×10^{-8} , which is 300 times smaller than stainless steel (compare table 6), these support structures can in principle be used in the tunnel with temperature gradients of more than 30 C° over the diameter without any additional heat shielding. One possible geometry of a girder is schematically shown in fig. 8.

With a triangular shape made of three 60 cm wide, 1 m long ceramic surfaces for each side, six triangular volumes will be used for a full 6 m meter long support. The surfaces and the triangular volumes are glued together requiring a highly loadable glue. Radiation tests on different types of glues are under way and will be performed up to radiation levels of 1×10^7 Gray ($=1 \times 10^9$ rad). The accelerating section itself will be fixed with tags about every meter to reduce the maximum sag of the section (over 1 m) to a value below $30 \mu\text{m}$. In addition many other components may be connected to the girder, for example the rectangular waveguides, vacuum pumps and survey tools as well as wires with pick-ups to control the alignment.

3.4 Particle Sources

To achieve the design luminosity, $1.8 \cdot 10^{14}$ particles per second of each kind have to be focused into the interaction region. This number of electrons can be achieved easily using a thermionic gun, because the average current during the pulse is only 300 mA. For positron sources the main consideration is the total charge per pulse. The reason is that the time constant of thermal dissipation in the conversion target is much larger than the pulse length. Therefore the heat load due to the generation of the 172 bunches per pulse will accumulate in the conversion target. Thus the target must be able to stand the thermal shock from the conversion of at least $1/\eta \cdot 172 \cdot 2.1 \cdot 10^{10}$ electron/positron pairs. η is the efficiency parameter which quantifies the fraction of positrons which will be captured from the target and accelerated up to the interaction point. The required number of positrons per pulse ($3.6 \cdot 10^{12}$) is nearly two orders of magnitude larger than what is presently achieved at SLAC. Three different schemes of positron sources have been considered:

- 1) Improved versions of the classical, heavy metal conversion target have been proposed, see e.g. ref.[10]. This is based on electron bremsstrahlung and pair production inside a target of sixth radiation lengths thickness.
- 2) A positron recycling scheme has been invented, which is capable of recovering 90 % of the positrons after the interaction [11]. With this scheme, the requirement on the conversion target performance is reduced by a factor of 10, i.e. down to values accessible by conventional sources.
- 3) A new scheme is based on very hard synchrotron radiation generated by electrons or positrons of >100 GeV traversing an undulator or wiggler [12],[13]. The synchrotron radiation beam is directed on a thin target, where conversion into e^+e^- pairs occurs. The advantage in comparison to the conventional conversion target is that a thin target (≈ 0.4 rad. length) can be used (see below). Also, there is an option for polarized positrons.

After a careful investigation of the capture efficiencies and the thermal load profile in the conversion target [14], the third version of positron sources has been chosen for the DESY/THD collider. In a first stage it is proposed to use a permanent magnet wiggler instead of an undulator since this would be the most simple and economical realization. If an elliptical wiggler is used, even polarization of positrons will be possible [15],[16],[17], though not at the same high level as if an undulator is considered. An quantitative analysis on the degree of polarization is under way.

The schematic layout of the scheme is shown in Fig. 1. The 250 GeV electron beam is used after the collision as a primary beam. Due to the strong beam-beam forces very intense γ -radiation called beam-strahlung is generated during the collision process. This results in a considerable energy spread within each bunch after collision. However, typical, more than 70% of the particles are still within a bandwidth of $\pm 3\%$. After travelling through a special matching optics [11] [13], the beam emittance is still small enough to pass the subsequent wiggler section of about 34 m length. Here, photons of 0 – 70 MeV are emitted in a narrow cone, with a minimum attainable spot size on the target is $\sigma_{min} = 0.5 \text{ mm}$. The photons are there converted into electron positron pairs inside a thin target of titanium-alloy, while the primary electrons

are deflected by a dipole magnet.

In the proposed scheme a very thin target ($< \text{one radiation length}$) can be used. Thermal load problems are reduced due to two effects: (1) one is able to use a low Z material with high heat capacity and (2) the divergence of the positron beam is small, hence one gets a high capture efficiency[14]. Some parameters of the source are given in table 1. A geometrical arrangement which makes use of the particle collection system of the wiggler based source is sketched in figure 9.

wiggler length	$S = 34 \text{ m}$
wiggler field	$B_{max} = 1.7 \text{ T}$
target material	titanium-alloy
target thickness	$0.4 X_0$
max. temperature rise during a shot ($\sigma = 0.7mm$)	$\approx 800K$
mean deposited power	$\approx 5.9kW$
initial field of matching device	10 T
end field of matching device	0.62 T
taper parameter	$g = 30 \frac{1}{m}$
length of matching device	$l = 0.5 \text{ m}$
capture efficiency of matching device including dephasing	18%
estimated overall efficiency	9%

Table 7: Preliminary parameters of the source

Figure 9: Layout of the proposed positron source.

In this context it is useful to realize that the wiggler based source may also be driven by positrons instead of electrons. Thus, if a wiggler is also installed at the high energy end of the *positron* linac, the positron linac may even work at *full* intensity, completely independently of the electron linac:

The positron linac is first optimized using the low intensity, conventional e^+ source. When the transfer efficiency from the low intensity source to the wiggler crosses over a critical value (about 50 %), the number of e^+ produced by the wiggler based source will exceed that one produced by the low intensity source. From then on the e^+ intensity will increase exponentially,

limited on purpose or by intensity driven effects in the linac. Thus, the optimum system for positron supply might consist of three positron sources:

- a conventional low intensity source for commissioning of the e^+ linac
- a wiggler based source driven with the high energy *positron* beam, to operate the e^+ linac at *full* intensity without the e^- linac being in operation.
- a wiggler based source driven by the high energy *electron* beam, to be able to optimize the e^+ linac at full intensity and *bad* transfer efficiency (e.g. if the e^+ beam is lost in the linac due to intensity driven instabilities).

It should be noted that this arrangement of a wiggler at the high energy end of each of the linacs can as well be used to generate polarized electrons in addition to polarized positrons[12].

4 Summary

Addition to the many many theoretical studies which are underway starting from the S-band parameter list, many technical aspects have been investigated during the last few months. While most of the technical problems of an S-band collider seem to be understood, questions of the cost and technical reliability of components have to be addressed in more detail, in order to come up with reasonable estimates. The results from the development and operation of the S-band test facility will answer many of these questions.

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