3.3 The Pre-injector

The high design brightness of the SLS requires very high phase space density of the stored electrons, leading to a comparatively short lifetime of the beam in the storage ring. This, in turn, requires efficient and fast injection into the storage ring. Injection rates on the order of 250 mA/min are needed to insure the fill times of the storage ring from zero current to the design value of 400 mA not to exceed 2 min.

The SLS pre-injector will be a 100 - 150 MeV linear accelerator (LINAC). A call for tender for a turn-key electron linac has been issued. The performance specification is set as values of the beam parameters that should insure the above mentioned goals. The verification of these beam parameters will be part of the final acceptance tests.

The design and construction shall aim to ease the operation and the maintenance and consequently provide high reliability. Furthermore, to improve the reliability of operation the LINAC should have modularity of two, i.e. two accelerating sections and two RF power sources.

The basic parameters of the pre-injector are listed in the Table below.

RF frequency	2998 MHz (@30°C)
Max. repetition rate	10 Hz
Energy	≥ 100 MeV
Pulse to pulse energy stability	< 0.25%

The pre-injector layout is shown in Fig. 3.3.1. The electron gun, bunching system, the accelerating sections and the beam dump shall be placed in the LINAC vault indicated on the drawing. The rest of the equipment (electronic racks, cooling racks, RF power sources) will be accommodated inside the technical gallery, next to the LINAC vault.

The layout should take into account possible future options of introducing in front of the first accelerating structure of the LINAC

- a thermionic RF gun with an α-magnet
- a photocathode RF gun

3.3.1 Operation modes and beam performance

Single bunch mode

Definition: the term "single bunch" in this document is defined as a train of no more than three S-band microbunches that is to be injected into a single 500 MHz RF bucket of the booster.

The values of the beam parameters are defined by single bunch operation mode, produced with a repetition rate of at least 3 Hz and with a total charge of up to 1.5 nC. Main beam parameters are listed in the Table below:

Max. single bunch width	1 ns (synchronised within 100 ps to the reference bunch clock signal)
Repetition rate	> 3 Hz
Charge in single bunch	≥ 1.5 nC
Relative energy spread (rms)	< 0.5% (full width ± 1.5%)
Normalised emittance (1 σ)	< 50 π mm mrad in both planes
Single bunch purity	0.01

Multibunch mode

A multibunch operation consists of production of trains of above mentioned single bunches. The total length of the trains should not exceed 1 μs, the number of bunches as well as the inter-bunch distance should be variable. The total charge in a train is limited to 3 nC.

Max. width of the multibunch train	0.9 μs
Repetition rate	> 3 Hz
Charge in the multibunch train	3 nC
Relative energy spread (rms) (over the train)	< 0.5% (full width ± 1.5%)
Normalised emittance (2 σ)	< 100 π mm mrad in both planes

Top-up injection mode

The injector complex should be capable to perform top-up injection, a future option to be explored after the initial operation of the SLS. Essentially, this mode will insure that the stored beam current in the storage ring will remain constant to the level of $\sim 10^{-4}$, by frequent injection, at beam lifetime values as low as one hour. Thus the LINAC should be capable of providing reproducibly multibunch trains at the maximum rate of 3 Hz with charge per train as low as 40 pC.

3.3.2 Gun and bunching system

The electron beam at the entrance to the booster should have a 500 MHz structure to insure high injection efficiency. A preferred way to achieve this goal would be to produce < 1 ns electron pulses at the gun, which should allow a flexible pattern of the multibunch train, as well as high purity single bunches.

3.3.3 Accelerating structure

An S-Band (2998 MHz) accelerating structure (as for instance developed at DESY in the context of the S-band linear collider study) will be used.

3.3.4 RF power system

The modulator-klystrons shall deliver the required 3 GHz pulsed power (peak power > 35 MW). One of them will power the 3 GHz bunching system and the first accelerating structure; the second will power the other accelerating structure. The RF power will be delivered to the structures via WR284 (R32) waveguide lines containing directional couplers, ceramic windows, power splitters, phase shifters, variable attenuators, circulators and dummy loads.

3.3.5 Vacuum

Remotely controlled vacuum valves have to be installed after the gun, between the gun and the buncher and at the end of the LINAC. Flanges for vacuum pumps (preferred standard CF40) have to be provided after the gun/bunching section and each acceleration section.

The vacuum in the LINAC at full power should be maintained at the level of $< 5 \cdot 10^{-8}$ mbar.

3.3.6 Linac Diagnostics

Since the pre-injector LINAC is supposed to be a turn key system, divided into several lots (e.g. RF, vacuum, magnets, diagnostics etc.), the following list of LINAC diagnostics equipment gives a guideline for what will be needed in order to sufficiently measure all the parameters required for proper injection into the booster synchrotron and to ensure reliable operating conditions.

Linac Diagnostics Overview

Measurement	Comments	Instrument
Current and charge - destructive	100 keV beam dump 100 MeV beam dump	Faraday cup
Current and charge - nondestructive		Beam Charge Monitor
Position - destructive	FS in the low energy section, OTR at energies >50 MeV	FS and OTR
Position - nondestructive	Simple cost effective stripline	Digital Beam Position Monitor System in pulsed mode
Bunch structure	Particularly important in single bunch mode - bunch purity.	Opical Correlation Measurement
Longitudinal profile and Bunching	At energies >50 MeV	Coherent TR
Macropulse envelope	Rise time ≤1 ns	Wall Current Monitor
Transversal profile	FS in the low energy section, OTR at energies >50 MeV	FS and OTR
Energy and energy spread	Spectrometer using a bending magnets.	FS or OTR
Emmittance	Changing quad(s) strength and measuring beam profile	FS or OTR

Faraday Cups (FC)

There will be two Faraday Cups for destructive beam current respectively beam charge measurements in the pre-injector LINAC.

Design concept for low energy beamline (150 keV) FC

One FC will be mounted in the low energy beamline in front of the LINAC. It will consist of an electrically isolated copper finger, which is connected to ground via a characteristic resistor. The induced voltage across the resistor is a measure for the electron beam current. The FC will be introduced into the electron beam by a pneumatic actuator. The construction and manufacturing

of this moveable FC can be completely done in house. A first prototype could be built in at the SLS-teststand in early 1998 in order to test its performance.

Design concept for 100 MeV beam dump

For the measurement of electron beam parameters like energy, energy spread and transmitted current behind the LINAC a divergency to the LINAC to booster transfer line (LBTL) has to be established. The analyzed 100 MeV electrons, passing this beamline, have to be stopped in a permanent beam dump. For current measurements it has to be electrically isolated. Since the total beam power at 100 MeV will not exceed 6 W, the mechanical and electrical layout can be based on the „small“ beam dump in the 180° bow of the SLS-Teststand. Shielding requirements have to be worked out by the SU. The FC is presently constructed by the B(department of the PSI.

Beam Charge Monitor

For a non-destructive measurement of the electron beam charge respectively the integrated current over the macropulse duration, the *Bergoz* beam charge monitor (BCM) can be used. It is integrating the beam charge of pulses having a width of less than one picosecond to more than one microsecond. Integrate-Hold-Reset circuits allow measurements for (macro-) pulse repetition rates from 10 kHz down to single pulses. This standard beam instrumentation device has already been successfully used at the SLS-Teststand. It can be bought off the shelf but has to be integrated into the SLS control system in terms of software, hardware links and timing.

Fluorescent Screens (FS) and Optical Transition Radiation (OTR) Screens

For destructive measurements of the electron beam position and its transverse profile FS and OTR-screens will be used along the pre-injector LINAC. Moreover in dispersive sections of the beamline the beam energy and energy spread can be determined with the help of such viewscreens. Measurements of horizontal and vertical emittances as well as the determination of twiss parameters can be performed with two (optional three or four) quads in front of a screen. For regular single bunch and multibunch injection modes of the pre-injector LINAC beam charges in the order of a few nC over one macropulse duration ($\leq 0.8\ \mu s$) will be expected. At energies above 50 MeV OTR-screens (typically < 10 μm Al-foil) will be used. It has been demonstrated that OTR is extremely powerful to measure all dynamic characteristics of the electron beam, since it provides instantaneous signals and the intensity scales linear with the beam charge. At low energies (150 keV) and for „top-up“ injection (only a few pC of beam charge) FS (CROMOX or Quarz) have to be implemented alternatively. They are more sensitive than OTR-screens but usually suffer from afterglowing effects at higher beam charges, which will limit the resolution of position and profile measurements of the electron beam under regular SLS injection modes. Both kind of screens will be brought into the beam by pneumatic actuators. The generated light is coupled out of the vacuum chamber through a standard quartz window (CF-flange) and digitized on a CCD camera. The standard viewport including screen holder, pneumatic actuator and optical set-up can be constructed and manufactured in house. For emmittance measurements an additional viewport design with variable magnification and on-line calibration will be foreseen. The CCD-cameras and vacuum windows are standard parts and will be bought off the shelf. The described concept has already been tested successfully at the SLS-Teststand and other facilities (TTF, CEBAF etc). Nevertheless some effort has to be put into the

timing and synchronization of the CCD-cameras with the electron beam and the complete integration into the control system. Beam tests for these purposes at the SLS-Teststand are desirable.

Wall Current Monitor (WCM)

In order to monitor the microbunch structure of the electron beam with sub-nanosecond time resolution (a few GHz bandwidth) a WCM has to be implemented in front of the pre-injector LINAC. The image current along the beam pipe produces a voltage drop across resistors, which are inserted over ceramic gap in the vacuum chamber wall. Proper selection of components will assure appropriate sensitivity and bandwidth in order to measure bunch structure and bunch purity, particularly important in single bunch mode. The mechanical as well as the electrical design of such a device can be made in house, the ceramic gap in the (CF40) vacuum pipe is standard off the shelf equipment. The performance of the device will be tested at the SLS-teststand in order to evaluate it’s time response and sensitivity.

If the sensitivity of a WCM will not be sufficient for measuring single bunch purities better than 1/100, an optical method will be considered as well.

Bunch Purity Measurement (BP)

An optical system will use OTR or alternatively SR, emitted by the electrons when passing an Al-foil or a bending magnet as a measure of bunch purity. It will basically consist of an OTR viewport, an optical filter, a beam splitter, a fast photodiode and a photomultiplier or a micro channel plate (MCP). The OTR or SR light, which has the same time structure as the electron bunches, will be coupled out of the vacuum system, band-pass filtered (depending on the sensitivity photomultiplier and photodiode) and split into two optical paths. In one path a photodiode, which is triggered by the RF clock of the pre-injector LINAC, is measuring the main electron bucket (respectively the main light pulse out of a possible pulse train) and giving a trigger pulse to the (very sensitive) photomultiplier. This trigger signal will be delayed by several 3 GHz periods and therefore synchronize the photomultiplier with any adjacent satellite pulse. With the relatively high sensitivities of photomultipliers or MCPs bunch purity measurements in the order of 1/100 to 1/1000 should be possible.A system development can be made at the SLS-teststand.

Coherent Transition Radiation (CTR) Spectrum Analysis

The analysis of the spectrum of CTR can be used as a measure for the longitudinal electron microbunch configuration. Generally transition radiation is generated when charged particles

pass an electrical discontinuity like for example a thin aluminum foil. The optical part of the emitted spectrum (OTR) is used for position and profile measurements of the electron beam (see above). At wavelengths, which are comparable to the electron bunchlength, the intensity of the radiation is coherently enhanced. Assuming electron bunches in the order of a few picoseconds (usually delivered by s-band LINACs), the interesting wavelength regime is in the FIR and mm-waves. The complete knowledge of this part of the spectrum gives the electron bunch configuration, where as the optimization of the integrated signal in respect to the LINAC parameters (prebuncher amplitude and phase, LINAC phase etc.) makes it possible to control the bunching process. This technique has already been used successfully at the SLS-Teststand to optimize most of the electron beam parameters. Very recently (DIPAC'97) it has also been used to optimize the performance of the CEBAF injector in terms of energy spread (10^{-5}). In case of the SLS the CTR-monitor will be implemented as an addition to a normal OTR viewport. The main effort has to be put into the development of a compact and fast (possibly on-line) device delivering the required bunching information to the control room.

Beam Position Monitors

The BPMs in the linac will be stripline BPMs. The electronics will use the newly developed digital BPM electronics scheme, which is described in detail in chapter 2.8.3.4.

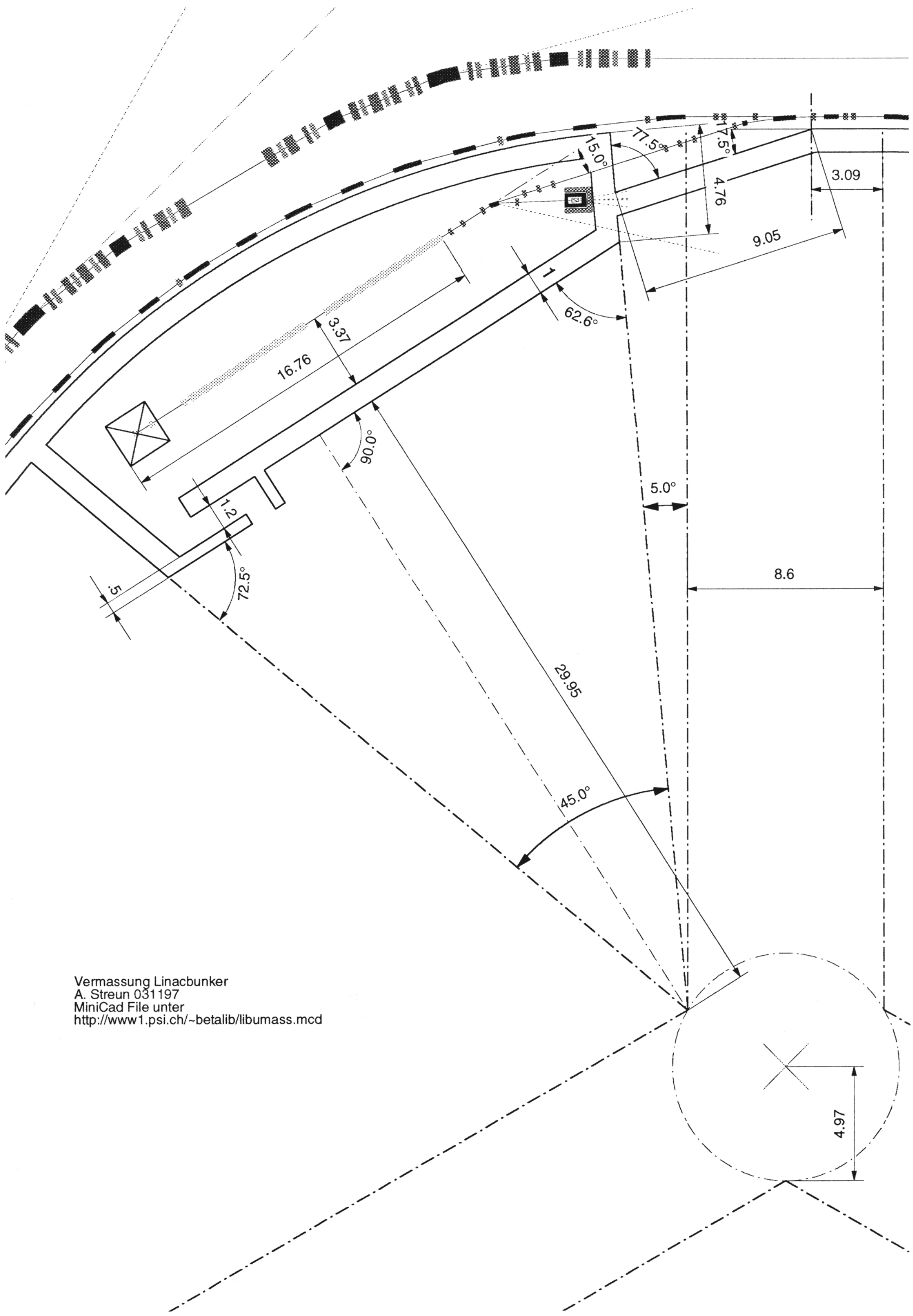
3.3.7 Controls and interlocks

The entire pre-injector system shall be designed to be **operational under both local (manual) and remote computer control**. All status indications, control signals and monitoring must be available for both local and remote operation. Status and monitoring signals must always be available both locally and remotely. Control (commands) would be active from ONLY local or from remote at any one time. Changing between local and remote control should be accomplished from switches provided as part of the Pre-injector sub system. The system must be capable of full operation, without remote control being available. The interlock system must protect the hardware from damage due to incorrect operation or failure of other components, internal or external to the pre-injector system. Adequate monitoring (local and remote) shall be provided, not only for protection purposes but to allow rapid diagnosis in case of equipment failure.

The signals to be handled include: all the necessary protection interlocks, monitoring, and settings of the relevant parameters (voltage, current, temperature, flow, pressure, ...) both locally and for remote monitoring and control. These signals shall include all diagnostic signals. In particular, the signals should be provided to enable trip latching/logging; when some of the interlocks have tripped, the system or sub-system shall not be operational, even if the cause of the interlock trip has cleared, until an operator has reset the interlock, locally when in local mode or remotely when in remote mode.

The remote computer control system will be designed and built by the SLS controls group. The interface from the pre-injector system to the remote SLS computer control system shall consist only of analogue and digital hardware signals. Analogue signals shall be **from -10V to**

+ 10 V differential. Digital signals shall be **0/24V, 10mA max**. Digital signals shall be level, not edge or momentary, triggered. Analogue signals shall not be filtered or otherwise bandwidth limited, but signals must be protected from sources of external noise.


15.0°
77.5°
17.5°
4.76
3.09
9.05
1
62.6°
3.37
16.76
90.0°
1.2
5.0°
8.6
.5
72.5°
29.95
45.0°
4.97
Vermassung Linacbunker
A. Streun 031197
MiniCad File unter
http://www1.psi.ch/~betalib/libumass.mcd