3.8 Instrumentation and Controls

With the passage of time, the instrumentation and control systems have come to play a role of steadily increasing importance for the achievement of accelerator performance goals. They are no longer just the means for intermittent operator intervention; rather, they provide the complex of feedback loops necessary for performance. In this respect, the linear collider resembles the "fly-by-wire" characteristics of modern high performance aircraft. The low frequency TESLA approach ameliorates but does not avoid this situation.

The discussion to follow is comprised of three topics. The next subsection treats beam-related instrumentation: the sources of beam information and input to the feedback loops. Next the major orbit feedback schemes for TESLA are outlined. Finally, the approach to the control system is described. Despite the volatility of computer hardware and software, there are aspects that are likely to endure and these receive emphasis.

3.8.1 Beam Diagnostics

We begin with a summary of some of the basic ideas and numbers which lead to instrumentation needs, requirements, and device descriptions. Sections elsewhere in this report where detailed information can be found are referenced. This introduction concludes with a tabulation of issues and approaches.

The Linac

For the linac two main requirements have been addressed. They are the preservation or control of the transverse and longitudinal emittances.

Transverse emittance (Section 3.3) is preserved by control of alignment of the quadrupoles, BPM's and cavities. In addition energy variation and energy spread must be controlled (i.e. longitudinal emittance).

RMS alignment values of 100, 100, 500 μm for quad, BPM, and cavity have been chosen. These values are relative to the ideal beam line and are assumed to be valid over distances of up to 600 m. Beyond this distance, typical of a betatron wave length, sensitivities decrease rapidly.

Using the above alignment errors, single bunch vertical emittance growths of $\approx$ 12% are found on the average using the "one to one" beam steering technique. (i.e., steering from the center of one detector to another). In the more time consuming beam-based alignment method, the center of the beam is found relative to the center of the quad and to the BPM by noting beam position change downstream and its null point as the quad strength is varied. Then the 12% emittance growth can be achieved if the BPM resolution is 15 μm even when the quad position rms is as large as 500 μm (Section 3.3). With better quad alignment, as will likely be the case (Section 3.9), the beam-based method allows to further decrease emittance dilution which is desirable for upgrade of the luminosity. Therefore a BPM resolution and stability of 15 μm for the linac has been chosen. In principle this accuracy has to be achieved only by averaging of entire bunch trains, but there seems no reason why individual bunch measurements can not be made and changes in the bunch train positions observed.

The effect of injection errors does not seem critical as a one sigma beam offset at the start of the linac makes only 6% vertical emittance dilution.

The above emittance growths are based on a bunch energy spread of 5×10^{-4} that results from the adjusting the bunch time to run at $3.4°$ before RF crest and makes for best cancellation of the logitudinal wake field. Multibunch emittance growths with inter-bunch energy spreads of 3.5×10^{-4} show very little difference from the single bunch results (Section 3.3).

The effect of ground motion on orbit stability has been estimated. Beam resteering (1 to 1) should be performed every hour in order to limit vertical emittance dilution to less than 20% for ground motion frequencies < 0.25Hz (i.e., 5Hz/20 - the high cutoff frequency of the conventional beam steering feedback system). Ground vibration can prevent the beams from colliding at the IP. As the jitter tolerance on the linac components would need to be < 80 nm for a 3% luminosity reduction, it is planned that a fast kicker will resteer the bunches during each pulse. The vibration tolerance on quadrupoles which would cause dispersive spot size growth and result in 3% luminosity reduction is $1\,\mu$m. This is an order of magnitude larger than the expected vibration levels.

The RF

The bunch length is controlled by the damping ring and compressor system. The energy and energy spread within the bunch and throughout the bunch train is controlled by the RF cavities phase and amplitude, their systematic errors and variations. The goals of the RF system regulation loops (Section 3.2.4.8) are to regulate the amplitude of each 32 cavity vector sum system to an rms amplitude of $5 \cdot 10^{-3}$ and an rms phase of $0.5°$ for uncorrelated field fluctuations. This should provide an intra-bunch rms energy variation term of $\approx 3 \cdot 10^{-4}$, smaller than the intra-bunch spread. Fluctuations in the phase will produce imperfect wake compensation leading to greater intra-bunch spread.

Coherent field fluctuations occuring through the system can arrise from bunch charge fluctuations. A 10% bunch charge flucation will product a $1.4 \cdot 10^{-4}$ gradient fluctuation for the next bunch. In general 10% charge fluctuations will produce energy fluctuations at the 10^{-3} level.

Systematic absolute gradient amplitude and phase measurement pecission, calibration and control against drift may be difficult at the 10^{-4} beam energy level. Ways to monitor the beam energy, energy spread, bunch length and bunch charge must be provided.

The beam energy can be measured to a resolution of 10^{-4} and corrected either by a fast RF system in the BDS Collimation Section or with slower linac cavity compensation. BPM resolution of 3-5$\,\mu$m is required (Section 3.7.5.2). The beam optics in the BDS are also well suited to determine the intra-bunch energy spread. By measuring the beam width at a position of large dispersion and relatively small β-function, the achievable accuracy for determining the relative energy spread is of the order of 10^{-4} (10-20% of the design bunch energy spread) with a $5\,\mu$m beam size measurement resolution.

The Beam Delivery System

The beam delivery system (BDS) reaches from the end of the linac to the IP and is 1100 m long. The about 50 quads, sextuploes, and 16 bends per beam will each be provided with BPM's attached to the magnets and the assemblies placed on magnet movers for beam based alignment and tuning. The beam pipe diameter is 10 mm. BPM precision and resolution has been specified at $3\,\mu$m throughout.

To make the following discussion easier to follow, functional sections are in order (see Section 3.7):

- (LMS) linac matching section,
- (CS) collimation section,
- (TDS) tuning and diagnostic section which is composed of the (SQSC) skew quad correction section and the (EMS) emittance measurement section,
- (BMS) beta matching section,
- (CCS) chromaticity correction section,
- (FT) final transformer.

The CS collimation section contains high beta and high dispersion regions with collimator pairs, energy measurement and correction, energy spread measurement, beam loss measurement for protection of the collimators.

The TDS tuning and diagnostic section provides for measurement and correction of transverse coupling in the SQSC and for measurement and minimization of emittance in the EMS. This is the major measurement and tuning area which sets, measures and adjusts the beam properties prior to the final transport to the IP. Six wire scanners are used for emittance measurement; four additional scanners are used at the skew quads are implemented with "u" angle wires as well as x, y wires. The emittance measurement station is capable of a few per cent measurement error. The carbon wires are $4\,\mu$m diameter.

The BMS provides for fine tune at the IP and adjustment of phase from the collimators to the final focus. Measurements made in the TDS give information for adjustment of these quads. Beam can be checked at the IP image point that occures (a) at the begining of the CCS and (b) within the CCS at the beginning of the FT. The vertical image of the 19 nm spot has a magnification of $50\times$ to give a spot of 950 nm. This will require laser wire or gradient undulator (see below) instruments. The sextupoles in the CCS have to be turned off for this measurement at image point (b) in order not to dilute the image point spot size by large chromatic aberrations. The CCS " -I" optics sections must be checked by a BPM-corrector null method to assure the proper optics.

Final tuning of the IP spot size requires movement of the sextupole pairs in a variety of combinations. The crucial vertical spot size measurement must be carried out with a laser interferometer (Shintake monitor [1]). The required resolution is about a factor of three better than what has already been demonstarted at the FFTB [2]. The horizontal spot is better measured with a laser wire [3]. These monitor laser beams pass through the electron beam 30-80 cm from the IP point and the low-β^* point must be shifted in z to this location. This is accomplished by the sextupole adjusters in the CCS.

The Shintake monitor has limited dynamic range of spot size that it can accurately measure for any specific laser wavelength. At a laser wave length of 262 nm spot sizes from 10 to 45 nm can be measured with 10% accuracy. On the other hand the laser wire spot can not be made smaller than $\approx$ 560 nm diameter using the same laser frequency. This is probably fine for the 845 nm sigma horizontal beam spot size.

The profile scans using laser beams must detect the scattered Comptons which come out straight ahead with opening angle $1/\gamma$. For systems within the IP detector, the Comptons must be detected dowmstream of the IP after bends in the CCS section.

The Shintake monitor has the potential for bunch length measurement as well. But as both it and the horizontal laser wire are deeply embedded in the detector, other less invasive instruments or instruments at other locations may be more practical for measurements that do not have to be done at the IP.

Other monitors are planned for the IP region (see also Chapter 2):

- Beam-Beam deflection monitor
- Fast lumonosity monitor
- Precision energy measurement
- Polarization measurement

These monitors are noninvasive and can be used during standard operation.

The steering from the beam-beam force is used to monitor the offset of the two colliding beams. A kick angle of 30 to 60 microradians per sigma y offset is expected. A BPM 2 to 3 m downstream of the IP would see typically 100 μm offset per beam sigma separation. Resolution of 10 μm is planned. Individual bunch measurements are possible. The signal can be used for beam steering feedback (see Section 3.8.3).

A fast luminosity monitor can be used to detect beam detuning at the IP to do non-invasive fine adjustments and horizontal beam scans. Radiative Bhabha pairs detected about 9 m from the collision point could provide the appropriate monitor information

Precision absolute energy measurements will be made of the beams in the extraction lines after the IP. The measurement used displacement synchrotron light fans from bend magnets to measure the bend angle of the beam in a spectrometer magnet. resolution of 10^{-4} is expected. However beams must not be colliding if precise before collision beam energy is to be measured.

The polarimeter uses laser beam scattering and detects Compton scattering asymetry. It is likely to be located before or after the IP.

Beam Steering – Initial Setup and Drift

Static tolarances of BDS magnet alignment indicate that typically y alignment tolarances of 0.5 to 10 μm are needed for many of the magnets if less than 2% luminosity decrease (with collision beam steering) is to result from an individual magnet. A model for uncorrelated rms motions of the magnets in x and y predicts that rms motions of 204 nm in y and 558 nm in x will yield 2% luminosity reduction (again with collision beam steering) (Section 3.7.3).

As the alignment tolerances are tighter than is likely to be achieved with conventional survey, beam-based alignment using individual magnet power supplies will be utilized during initial beam set up. Magnet positions are adjusted with submicron positioners using BPM's with $3\,\mu$m precision.

A ground motion model based on a noisy environment predicts that 2% luminosity reduction from beam centroid motion will occure in 1 ms. Fast orbit feed back based on measurements of the first few bunches in a train will be necessary to keep the beams in collision. The beam centroid steering feedback is described in Section 3.8.3.

The same model predicts 2% reduction from vertical beam size growth in 200 sec. This then sets a time scale for the beam size stabilization feedback. The simulation program Merlin has been used to check possible noninvasive tuning proceedures to correct the deterioration of the beam size by linear optics aberrations (Section 3.7.6). It was found that simple careful one-to-one steering of the BDS elements using the BPM's and magnet movers every half hour or so was sufficient to restore the luminosity to almost its full value. A drop in peak (after retuning) lumimosity of 5% occured after 30-40 days indicating that an invasive retune would be necessary on this time scale.

	where	typical beam size [μm]	resolution required [μm]	freq. of adjustment	bunch structure	invasive y,n
POSITION x, y						
bpm	linac	300-60 x, 40-8 y	15 y	min.-1hr	pulse avg.	n
	BDS	360-13 x, 75-0.9 y	3 y	min.	pulse avg.	n
(disp. tuning)				30 days	pulse avg.	y
slow feedback	IP	0.845 x, 0.019 y	10 y	4 sec.	pulse avg.	n
fast feedback	IP		10 y	μs	bunch-by-b.	n
BEAM SIZE						
carbon wire	TDS	37 x, 6 y	1 x, y, u	30 days	one bunch	y
laser wire	IP image	13 x, 0.9 y	0.6 y	demand	bunch by b.	y
	IP±0.8m	0.845 x	0.6 x	30 days	scan over	y
Shintake mon.	IP±0.8m	0.019 y	0.01	30 days	one pulse	y
BEAM ENERGY						
bpm	CS or CCS	180 x	3 x	μs	bunch-by-b.	n
synch. light	extr. line			exp. demand	bunch-by-b.	n
ENERGY SPREAD						
wire	CS or CCS	13 x	5 x		one bunch	y
BUNCH LENGTH						
streak camera,	before	700 z	100 z	demand	one bunch	n
interferometer	linac			demand	or avg.	n
BUNCH CHARGE						
toroid/wall current	linac, BDS		1%	observe	bunch-by-b.	n

Table 3.8.1: *Overview of beam diagnostic requirements and tools. Additional instrumentation for luminosity and beam polarization measurement (not shown in the table) is foreseen in the IR.*

3.8.1.1 Beam Position Monitors

Overview

The beam diagnostics in *TESLA* will mainly be used for beam position monitoring. In this section we discuss the beam position monitor (*BPM*) system in the main linacs, which has to measure the average position of several bunches in a single pulse. In addition, a small number of high-resolution BPM's will be installed at selected points, e.g. in the Beam Delivery Section (*BDS*). Some of these special monitors must provide bunch-by-bunch measurements for the fast feedback system. The required *resolution*

machine	location	# of monitors	resolution
TESLA	linac	about 400	15 μm
	Beam Delivery Section	about 100	$1-3$ μm
	Interaction Point	1	≤ 10 μm

Table 3.8.2: *Required parameters for beam position monitors*

must be reached for a single bunch passage by a certain number of monitors. For all monitors the *dynamic range* must be one order of magnitude and the *sensitivity* has to be of the same order even for reduced bunch charges. It is a special problem for the electronics that the *long-time drift* of all systems has to be smaller than the resolution to avoid frequent beam based alignment.

The required signal-to-noise ratio of button or stripline monitors is roughly proportional to the ratio $R_o/3.4 \cdot \delta_{x,y}$ where R_o is the beam pipe radius and $\delta_{x,y}$ the resolution in x and y, respectively [8]. Resolutions of about 1 μm (rms) have been achieved using both buttons and striplines. In the former case this was at storage rings and light sources, where the bandwidth of the electronics can be reduced to some kHz. At the Final Focus Test System at SLAC, where striplines are used to detect beam offsets of less than 1 μm (rms), the beam pipe diameter is smaller by a factor of 2 (BDS) to 20 (main linacs) compared to *TESLA*.

Another important fact is that the accuracy of these monitors strongly depends on the precision of the installation of single electrodes. This is an essential problem for *TESLA*, where all monitors have to be attached to the quadrupoles inside a cryostat. Therefore the conclusion is that electrodes are not the best choice. In the following we will concentrate mainly on the discussion of resonant rf-monitors.

Circular Cavities

The simplest microwave BPM-structure is a circular cavity excited in the TM_{110}-mode by an off-axis beam. The amplitude of the TM_{110}-mode cavity yields a signal proportional to the beam displacement and the bunch charge, its phase relative to an external reference gives the sign of the displacement. In principle, both TM_{110}-polarizations have to be measured to obtain the displacements in x and y, respectively.

Cylindrical cavities are foreseen for the correction of all quadrupoles (inside the cryostats) in the main linacs and in the BDS. The same type of monitor will be used to provide informations to the fast feedback systems discussed in section 3.8.2.

Signals The resolution near the electrical center of the cavity is limited by the thermal noise of the electronics and the excitation of common modes. Since the field maximum of these common modes is on the cavity axis, they will be excited much more strongly than the TM_{110} by a beam being only slightly off-axis. This gives the required frequency sensitive TM_{010}-rejection, S_{010}, to detect an offset δ_x. But the minimum detectable TM_{110}-signal is still limited by residual signals at the dipole mode frequency ω_{110}. The resulting resolution near the electrical center is roughly given by the ratio of the spectral densities at ω_{110}. Both limitations where estimated in [6]:

$$S_{010} = \frac{V_{110}(\omega_{110})}{V_{010}(\omega_{010})} \approx \frac{5.4}{\lambda_{110}} \cdot \frac{k_{110}}{k_{010}} \cdot \delta_x = K \cdot \delta_x \tag{3.8.1}$$

$$\delta_x{}^{\min} \approx \frac{v_{110}(\omega_{110})}{v_{010}(\omega_{110})} = \frac{1}{K} \cdot \frac{1}{Q_L} \cdot \frac{\omega_{110}^2}{\omega_{110}^2 - \omega_{010}^2} \tag{3.8.2}$$

This minimum resolution $\delta_x{}^{\min}$ can be enhanced by taking the difference of two opposite cavity outputs. The rejection of common field components is mainly limited by the finite isolation between the Σ- and the Δ-port of a hybrid or a Magic-T.

Main Linac Monitors On account of the limited longitudinal space, for the correction of all quadrupoles inside the cryostats, single circular cavities were designed. To avoid interference from the accelerating structures, the cavity was designed for a resonant frequency of $f_{110} = 1.517$ GHz (see also Fig. 3.8.1). A loaded Q of about 900 is required to measure the position of individual bunches spaced by 708 ns. CrNi was chosen as the cavity material to realize this, even at 4 K and with a coupling factor of $\beta \approx 1$ (no distortion of the electrical field). Detailed design data are given in [5].

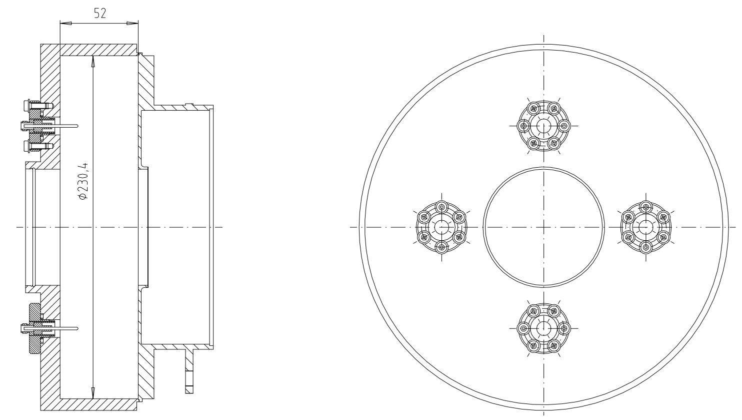


Figure 3.8.1: *Cylindrical cavity for quadrupole correction*

Assuming a cavity without beam pipes and a bunch charge of 37 pC, a TM_{110}-

amplitude of 2.34 mV (in the cavity) can be expected for an offset of $\delta_x = 10\ \mu$m. The frequency sensitive TM_{010}-rejection, required to detect this displacement, is about 69 dB [7]. Because of the limited space, a standard stripline hybrid is used outside the cryostat to obtain a resolution of less than 6 μm (hybrid isolation of 20 dB).

Monitors in the BDS The same type of monitors will be used for measuring the position in the *BDS* and at the *IP*. Some parameters for both monitors are summarized in Table 3.8.3.

parameter	**BDS-monitor**	**IP-monitor**
type of monitor	cylindrical cavity	cylindrical cavity
beam pipe radius	5 mm	24 mm
bunch separation	708 ns	708 ns
required resolution	1 μm	10 μm
required bandwidth	5 MHz	5 MHz
position stability per day	1 μm	1 μm
cavity radius	$R_{res} = 90$ mm	$R_{res} = 15$ mm
cavity length	$l = 50$ mm	$l = 9$ mm

Table 3.8.3: *Requirements and preliminary design parameters for cavity-type monitors*

At a specific location the beam offset only needs to be measured in one polarization direction (x or y). Thus the monitors can be split physically into a x- and a y-monitor. Therefore both TM_{110}-polarizations can be individually tuned, which also increases the isolation between them and allows the measurement of very weak signals. The phase reference will be measured in an additional TM_{010}-cavity, operating close to the TM_{110}-mode (BPM-cavity) frequency.

Because of the required resolution of 1 μm in the *BDS* (single bunches) and a beam pipe diameter of 10 mm, a resonant frequency of 12 GHz was chosen. This monitor is under development for the TTFL-FEL to measure the position of the electron beam between two undulator modules. For the monitors at the *IP* a resonant frequency of 1.96 GHz was chosen. The reason for this particular frequency is the beam pipe diameter and to use standard electronic components (cellular telephone systems).

An important question for further design steps is how to realize the required field sensitive common mode rejection. Therefore different hybrid structures are under investigation. To get the desired loaded Q-values without any field distortions the monitors will be made of alumina (*BDS*) and CrNi (*IP*), respectively. The temperature of each individual cavity has to be stabilized.

The required frequency sensitive TM_{010}-rejection to detect a displacement of 1 μm is about 89 dB. This will be realized by different coupling factors for both modes and by bandpass filters at the input of the electronics. By using a field selective filter, e.g. by taking the difference of two opposite outputs, the theoretical resolution for this design will be better than 0.5 μm. After 20 m of coaxial cable, the signal at the analog input of the electronics will be some mV per μm offset for single bunches with a charge of 1 nC.

Signal Processing The TM_{110}-amplitude is detected in a homodyne receiver by mixing the cavity output and a reference signal down to DC. When the beam is on the right, the system can be set up to give positive video polarity. The signal changes the phase by 180^o when the beam moves to the left, and for a centered beam it becomes zero. The signal processing electronics, as shown in Fig.3.8.2, are divided into two parts:

- analog electronics to filter, to amplify and to mix the signal down to DC; the reference signal (LO) will be provided by a TM_{010}-cavity
- Analog-to-Digital Conversion (ADC)

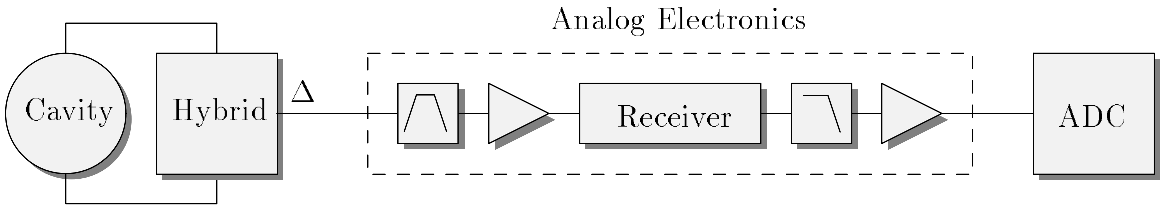


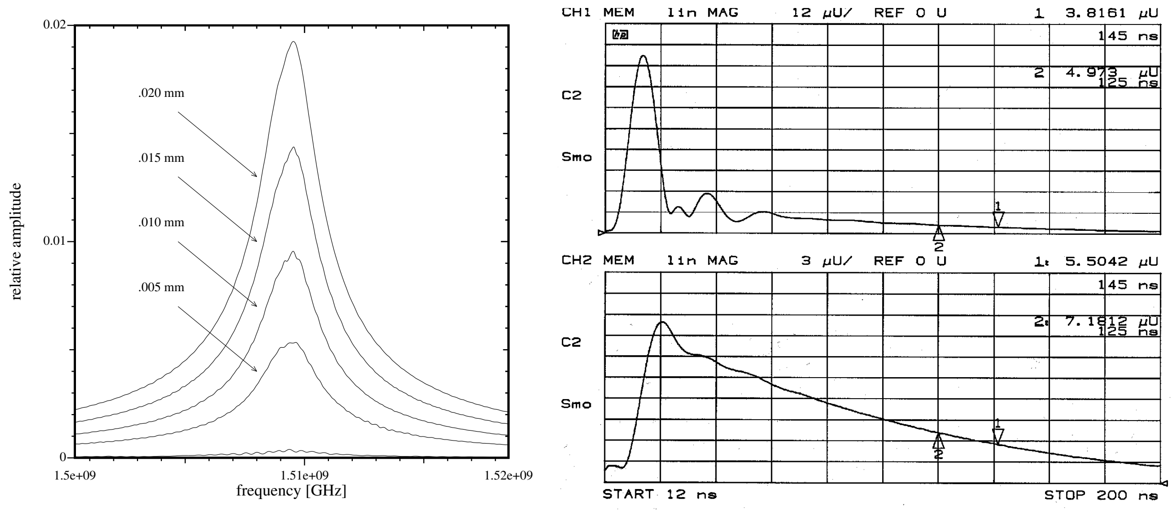
Figure 3.8.2: *Block diagram for the signal processing electronics*

The stop-band attenuation of the bandpass filter, together with the hybrid and different coupling factors for the TM_{010}-mode and the TM_{110}-mode, gives a frequency sensitive common mode rejection of about 100 dB. To reduce errors caused by temperature related phase shifts (long transmission cables), the mixing process will be performed in an I/Q-mixer.

After passing a low-pass filter and a bipolar video amplifier, the signal may be either viewed directly on an oscilloscope for adjustment, or digitized by a 12-bit ADC-board for quadrupole correction. The normalization will be performed by a computer.

Other Issues Bench tests were carried out on a stainless steel prototype to determine the resolution near the center and to test the electronics. Therefore the cavity was excited by an antenna fed by a network analyzer. A resolution of about 5 μm was measured in the frequency domain and in the time domain [7]. All measurements were performed at room temperature.

In addition, a prototype was tested at the CLIC Test Facility at CERN to demonstrate the principle single bunch response of the monitor and to measure the amplitude of the TM_{110}-mode as a function of the relative beam displacement [7].



a) b)

Figure 3.8.3: *a) Measured resolution in the frequency domain, b) Impulse response with (lower trace) and without a hybrid (upper trace)*

3.8.1.2 Bunch Length Measurement

The rms bunch length for the TESLA design is 700 μm (2.3 ps). For the FEL operation, the rms bunch length is 0.025 mm (80 fs) (see Chapter 5).

For bunch length measurements in this regime, different kinds of radiation emitted by the particle beam can be used. This can be transition radiation, synchrotron radiation or Čerenkov radiation. Transition radiation has the advantage that it can easily be produced by moving a thin metal target into the beam. However, at high current the target can be destroyed. This can be avoided either by doing measurements at low current only or by using diffraction radiation [10]. Alternatively, synchrotron radiation produced non-destructively by magnetic elements can be used [11].

Short radiation pulses can be measured in the time domain using streak cameras. A streak camera consists of a photocathode which converts light pulses into electron pulses. These are then deflected and displayed longitudinally on a phosphor screen (Fig. 3.8.4). These systems offer the unique possibility of single bunch observation in real time. The time resolution, widely assumed to be limited to 1 ps and longer, has been improved significantly by the manufacturers. Fast streak cameras are now commercially available with a resolution of down to 180 fs. This might be even improved in the future.

Alternatively, measurements in the frequency domain can yield information about the bunch length. This method works better the shorter the bunch length is. At wavelengths of the order of the bunch length and longer, coherent transition or synchrotron radiation is produced as the bunch acts as one single particle. The coherent part of the spectrum is much more intense than the incoherent part. It can be shown that the coherent radiation spectrum is just the Fourier transform of the longitudinal charge distribution. Hence, measuring this part of the spectrum means measuring the bunch

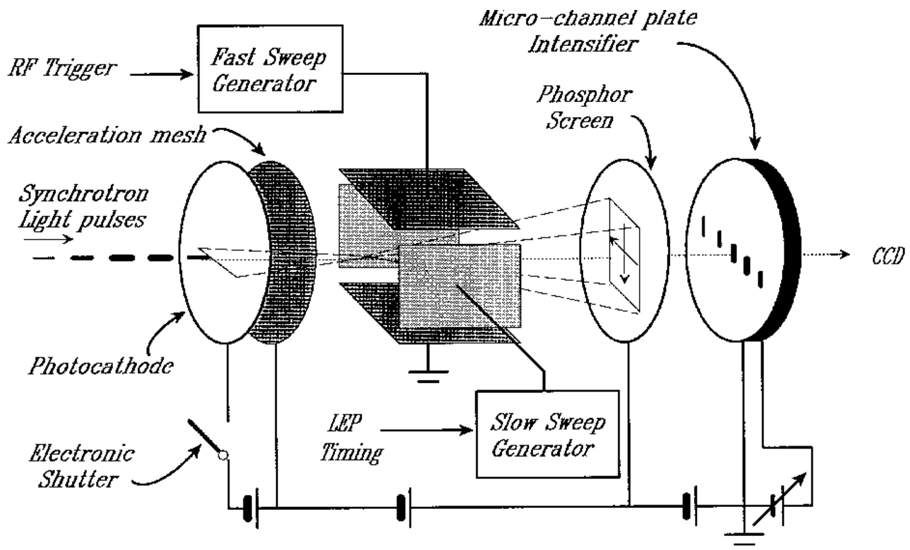


Figure 3.8.4: *Streak camera for measurements in the time domain as used at LEP.*

length.

From picosecond bunches, coherent radiation is produced in the millimeter wavelength range. For the observation of mm wavelength radiation, a photo-acoustic detector can be used. It works at room temperature and has a flat response from 0.1 mm wavelength up to 1 cm. For shorter bunch lengths, the onset of the coherence effect shifts to the far infrared where pyroelectric and bolometric detectors are available at low cost.

Two different types of spectrometers have been developed for use at the TTFL and as prototypes for the TESLA 500 collider. A series of high pass filters for mm waves serves, together with the broadband detector, as a simple spectrometer. This spectrometer has been successfully used for bunch length measurements at the CLIC test facility [12].

A polarizing Michelson interferometer (Martin-Puplett interferometer) can measure the autocorrelation function of the radiation pulses. The power spectrum can then be obtained as the Fourier transform of the autocorrelation function. The interferometer uses wire grids as beam splitter and roof mirror reflectors (Fig. 3.8.5). It has an intrinsic flat characteristic over the whole wavelength range of interest.

As a third option, the use of a new spectrometer based on superconductivity is being examined. A setup developed at the Forschungszentrum Jülich is being evaluated with respect to its possible application for bunch length measurements [13].

3.8.2 Beam Size Monitoring

An important class of diagnostics are the transverse beam size monitors which are required primarilly for the measurement of the beam emittance. Two modes of operation are expected:

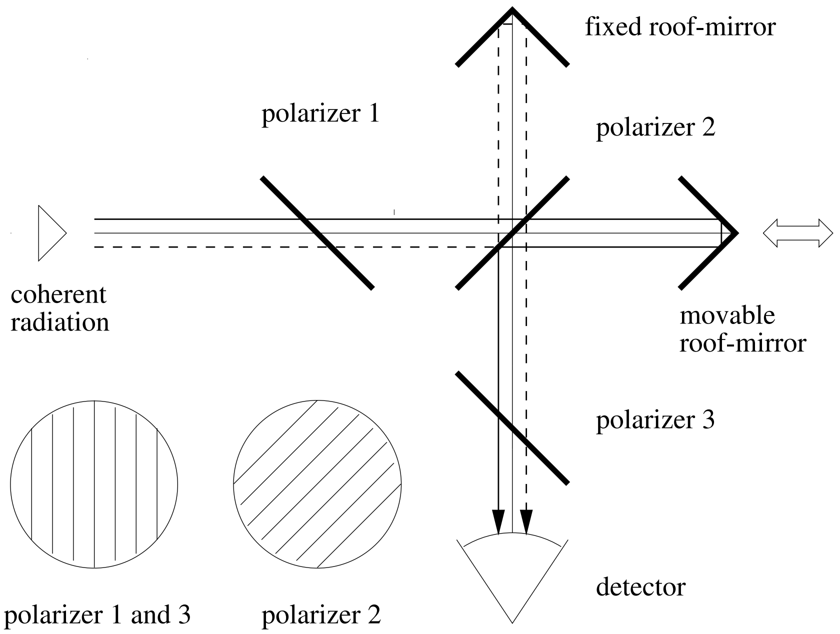


Figure 3.8.5: *Martin-Puplett interferometer for measurements in the frequency domain as to be used at TTFL.*

1. problem diagnosis, commissioning and boot-strapping, i.e. non-luminosity operation possibly with single bunch per pulse, and

2. continuous or semi-continuous monitoring of the beam during nominal luminosity operation.

For the former case, either Optical Transition Radiation (OTR) screens or SLC-type wire scanners[4] using 4 μm or 7 μm carbon filaments are expected to be the standard diagnostic.

Carbon filament wire scanners are used to sample the beam at different positions within the beam profile, and the beam width is then determined by fitting a Gaussian distribution to the data. The technique requires several bunches to perform a single measurement, so the result is an effective beam size of all bunches measured including any position jitter between them. However, the jitter can be measured by high-precision ($\approx 1\mu$m) BPM's so that this contribution to the effective beam size can be unfolded. Two types of signal can be used: i) bremsstrahlung from the wire can be detected some distance directly downstream, or ii) secondarys which are eventually scattered out of the beam pipe can be detected. The former requires a downstream dipole in order to position the bremstrahlung deletector on the downstream (photon) axis: such an approach is most applicable in the beam delivery system where bends occur naturally. In the linac and other straight sections, one must rely on the secondaries scattered out of the beampipe for detection. The wire scanners themselves are small compact devices which can easily be incorporated into the machine with the mimimum of impact to the lattice.

At the full TESLA bunch population of 3.6×10^{10}, the charge density of a single bunch should be sufficiently low that a 4 μm Carbon wire should survive single bunch operation at the nominal repetition rate of 5Hz. The temperature rise in the wire caused by a single bunch (with charge N_e) passage can be estimated from the energy loss dE/dx = 4 MeV/cm, the heat capacity $c_p = 1.18\,\mathrm{J/(g\,K)}$ and the specific density $\rho = 2\mathrm{g/cm^3}$ of Carbon:

$$\Delta T \approx 0.44 \cdot 10^{-3}\mathrm{K} \times \frac{N_e[10^{10}]}{\sigma_x \sigma_y[\mathrm{cm}^2]} \qquad (3.8.3)$$

In the TDS we have $\sigma_x\sigma_y \approx 200\,\mu\mathrm{m}^2$ and for $N_e{=}3.6{\cdot}10^{10}$ we get $\Delta T{=}790\,\mathrm{K}$, which seems tolerable. However, the wire will only survive a few bunches of the nominal bunch train in multi-bunch mode, and so Carbon wire devices cannot be used for monitoring the beam size during luminosity production. Even in single-bunch operation, it is still possible that the wires will fail, and so it is prudent to have each scanner equipped with 5 to 10 separate wires.

The resolution of a beam size measurement with a wire is expected to be better than the wire diameter. The sytematic error for a 4μm wire and 6μm beam size is about 5%.

The OTR device In the measurement of transverse beam charge distribution, OTR present a number of advantages: it is fully linear with the beam charge, without any saturation effect, it is emitted by a surface crossing and thus does not show any depth effect. Its temporal emission in the subpicosecond range allows the selection of a single bunch. The main practical limits to OTR use at high energies, when the low emittance allows small beam dimensions, are the diffraction limit that, due to the angular distribution and the polarization properties, is larger than for standard point optical sources and for 500 nm wavelength is roughly 10 μm, and the fact that it is derived by an intercepting device, so that the screen can be destroied by the high energy density lost in the material by well collimated beams. For an aluminum foil, which is the preferred material for its high and uniform reflectivity over the whole optical spectrum, the temperature rise caused by a microbunch of $3.6{\cdot}10^{10}$ electrons is $.23\,^\circ\mathrm{C}/R^2$ in which R is the radius (in mm) of a flat circular beam distribution, and assuming a rather conservative value of 2 MeV/cm^2 as the single particle energy deposition (energy independent). Limiting the temperature rise to 300 °C, we obtain a minimum beam radius of 20 μm (that corresponds to an rms value of about 10 μm). It will be important to study different materials to find the best compromise between emission efficency and thermal and mechanical properties.

For multi-bunch operation, there are three possibilities:

1. laser wire scanner
2. pulse snatching scheme (off-axis monitoring).
3. gradient undulator

In principle a laser wire acts in the same manner as a Carbon-wire scanner. A laser wire can be focused to a sub-micron spot, which is then scanned through the beam. The situation is also similar to the Carbon-wire approach with respect to signal detection: either the Compton scattered photons are detected directly downstream (again requiring a downstream dipole), or the back-scattered electrons (which are eventually sweeped out of the machine) are used. For TESLA, it is feasible that a long pulse-train laser can be used to sweep through the entire bunch train in a single shot, thus allowing a fast effective beam size measurement of a single bunch train. Such an approach is necessary for the laser monitors close to the interaction point, where it is neccessary to mitigate the effects of the final doublet vibratration on the (particle) beam. In a short-pulse mode, the laser wire can be used to sample single bunches in the bunch train, sampling on successive trains the same bunch location. This mode of operation is directly analagous to the single-pulse Carbon-wire operation. As of writing, laser-wire technology is still in its infancy, although such a device now exists and operates at the SLC [3]. However, much work still remains to be done (especially for the back-scattered electron mode). It is advantageous (and prudent) to always place a carbon-wire device and a laser-wire device together, so that one can be used to calibrate and troubleshoot the other.

A more conservative approach (but slightly more invasive) is to use fast kickers to "steel" a single bunch from a bunch train and send it to an off-axis scanner. Here again Carbon-wire devices can be used (as well as any other fluorescent or OTR screen technique). The approach probably requires more tunnel space than the laser-wire option.

Of the three methods proposed, only the X-ray gradient undulator[9] offers a single-shot single bunch measurement of the beamsize. A gradient undulator is an undulator whose pole-pieces are displaced one-half period as shown in figure 3.8.6. The undulator field has now a linear gradient in the vertical direction. As a result, vertically off-axis particles radiate, while particles on-axis do not. The total power output from the undulator is directly proportional to the square of the beam height. Theoretical studies have shown that at the exit of the linac (250 GeV) in excess of 10^5 60 MeV photons can be expected for a 1 m device with a 1 cm undulator period, and a field gradient of 4.8 T/cm. The main disadvantage of the device is that it requires a dipole downstream in order to place the X-ray detector on the axis of the undulator (again making the device more suitable for the beam delivery section). If the device is to be used in the linac, then small chicanes will be required, and a length penalty will be incurred. It should be noted, however, that the gradient undulator is a conceptual device, and work is currently in progress to evaluate its performance and limitations.

3.8.3 Orbit Feedback

Overview

In this section we discuss the orbit feedback schemes for *TESLA*. In order to reduce the influence of vibrations which can cause luminosity reduction, several feedback loops

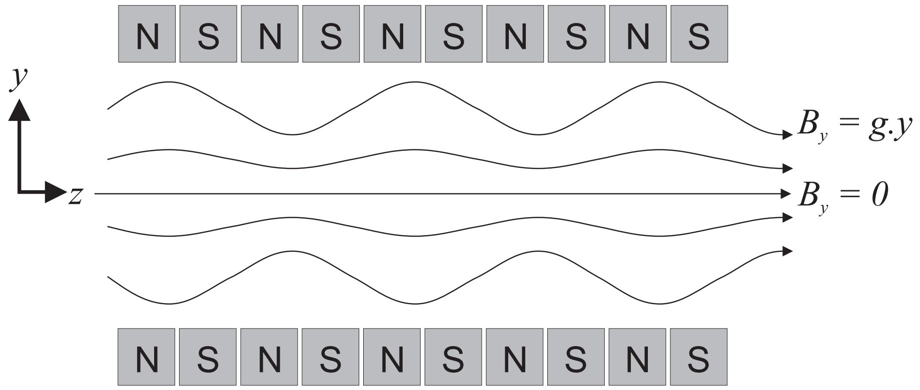


Figure 3.8.6: *Principle of the X-ray Gradient Undulator. The vertical undulator field is proportional to the vertical offset (y), being zero on the nominal axis (y = 0). Thus particles on-axis do no radiated, while particles off-axis do. The total power radiated by a centered beam is therefore proportional to σ_y^2 [9].*

are foreseen to regulate the beam orbit and to keep the beams colliding.

The main sources for the orbit movement can be divided into two types: perturbations due to ground motion in the lower frequency range and disturbances in the kHz range caused by the superconducting cavities, mainly microphonics and Lorentz-force detuning. In principal the control system for orbit correction can be divided into three different feedback systems:

- A slow feedback system
  in the main linac which is working at the repetition frequency of 5 Hz. It is foreseen to cancel perturbations in the low frequency range which are mainly due to ground motion. The beam will be steered by the use of corrector coils. The slow feedback is limited by the sampling frequency and the time neccessary for the corrector coils to change to the requested settings. Therefore this feedback is able to detect and to react on disturbances only up to .5 Hz.

- A fast feedback system
  has to be installed to compensate disturbances containing higher frequency components. It will correct the beam orbit from bunch to bunch which is possible because of the bunch spacing of 708 ns. The fast feedback system will be located in the tuning and diagnostic section of the the beam delivery system (*BDS*). Fast kickers are used to correct the beam offset.

- A fast IP-feedback
  which will keep the two beams in collision using the beam-beam-deflection.

The bunch spacing of 708 ns is one of the main advantages of *TESLA*: it is possible to use the pilot bunch to correct all following bunches of the same pulse.

All feedback systems can be digital, which allows the realization of a data base driven feedback. The data received are also recorded and can be used for further statistics. The exact number of feedback loops neccessary to control the beam orbit in a satisfactory manner is not yet known; therefore one should always expect to add additional feedback loops.

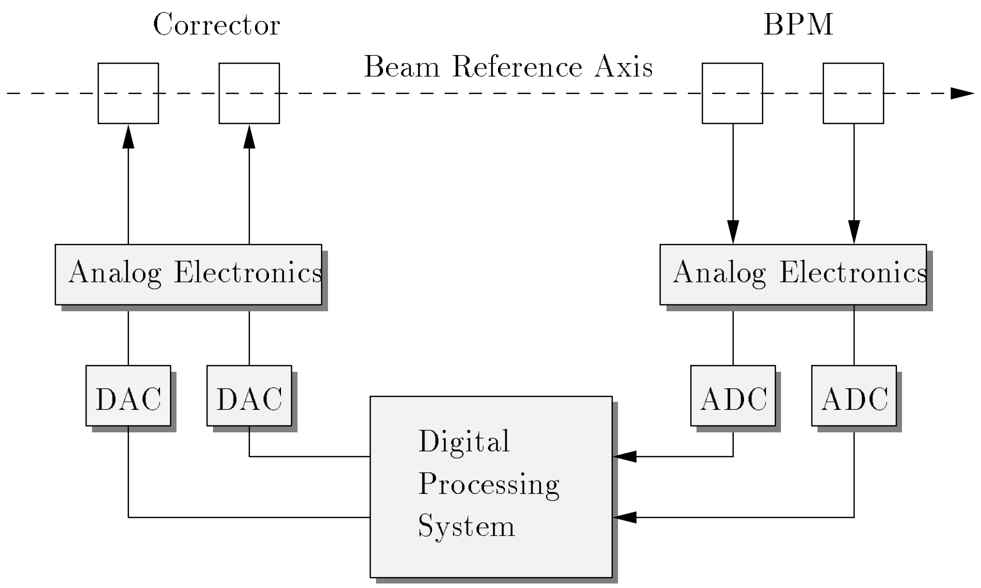


Figure 3.8.7: *Schematic diagram of the slow and the fast digital feedback system*

All digital feedback systems will consist of the same basic elements as shown for the slow and the fast system in Fig. 3.8.7:

- **beam position monitors** (BPM) to obtain a signal proportional to the beam position
- analog **signal processing electronics** and **analog-to-digital conversion** (ADC)
- a **digital processing system** to determine the correction signals
- **digital-to-analog conversion** (DAC) and **signal processing electronics** to applify the correction signals
- and **correctors** to apply the requested kicks.

Beam Position Measurement

The first device in the feedback loop is an electromagnetic pick-up to obtain a signal proportional to the beam position. Cylindrical cavities are foreseen for the detection of these signals, and the details are described in section 3.8.1.1. The principal scheme for the signal processing will be the same for both types of feedback systems (see also Fig.3.8.2). But for the fast feedback system the analog electronics and the analog-to-digital conversion have to be optimized with respect to the processing time.

Slow Feedback System

Disturbances in the low frequency range are mainly due to ground motion. They will cause quadrupole displacement which will lead to beam emittance growth. In order to eliminate the effects of displaced elements a slow feedback system working on the repetition frequency of 5 Hz has been developed.
For the orbit correction four states, the position and the angle of the beam trajectory in both transverse plans, will be controlled. For each transverse plane a feedback loop needs at least two beam position monitors which measure the actual offset of the beam and two simple steering magnets are used to regulate the beam at a certain position.

The conceptual design of this pulse-to-pulse orbit control is based on tools of Optimal Control Theory [16]. It takes the stochastical nature of the sensor noise and of the beam movement into account. The feedback loop can be divided into four main parts: measurement taken by BPM's – estimation of the beam's position and angle – calculation of control input – correction by corrector coils. It contains an optimal filter (Kalman Filter) to estimate the beam's position and angle and an optimal controller to calculate the corrector settings [17, 18].

At the maximum operating frequency of about .4 Hz, the assumed r.m.s. quadrupole motion from pulse to pulse is in the order of 200 nm. At the end of the linac e. g. a kick of 0.36 μrad is required; for a 250 GeV beam the correctors must provide a magnetic field of 3 Γm. This can be done by the standard correction coils installed in the linac.

Results of simulation runs show that the feedback algorithm provides a good orbit control in the requested range. The feedback loop damps frequency disturbances up to 0.4 Hz quite well, where a DC bias rejection of -50.77 dB was achieved. The r. m. s. resolution of the beam position monitor was assumed to be 1μm.

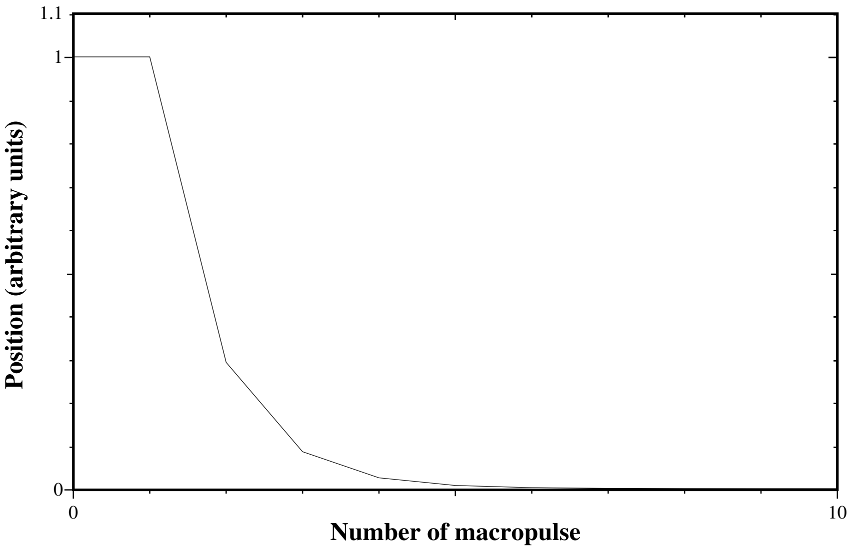


Figure 3.8.8: *Simulation plot of the slow feedback for TESLA: Feedback loop response on a step disturbance on the incoming beam*

A better DC bias rejection is achieved by including an integral part into the feedback loop. The disadvantage is a higher amplification in a range between 0.5 Hz and 1.9 Hz. A comparison of the control loop design with and without integral part in order to get the best feedback design will need work in future.

Fast Feedback System

Disturbances like fast vibrations of quadrupoles, microphonics and Lorentz-force detuning caused by the superconducting cavities cannot be detected and controlled by the slow feedback system. In order to correct the position and the angle of every bunch in a train, first investigations of a digital bunch-by-bunch feedback have been carried out. This fast feedback system is foreseen to be located in the tuning and diagnostic section of the *BDS*. It will consist of two BPM's and two fast kickers to steer the beam.

Taking into account the separation of optimum locations for pick-ups and kickers, long transmission line lengths and ADC/DAC-conversion times, the remaining time-interval of 200 ns should be sufficient for 10 instruction cycles (floating point operations) in a standard microcontroller. The rapidly increasing development of high speed analog and digital signal processing components leads to the assumption that this time interval for the digital processing will become much longer.

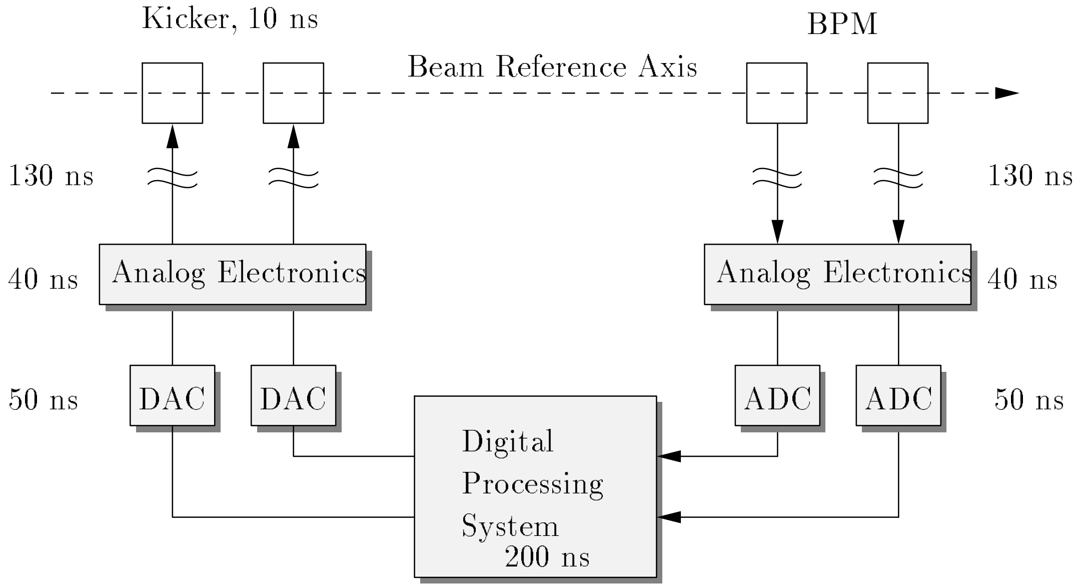


Figure 3.8.9: *Maximum time dedicated to each device for the bunch-to-bunch feedback*

IP Feedback

At the *IP*, the beam-beam scattering will be used to keep the beams in collision. This method has already been used in the SLC for single bunches to measure the offset of the two colliding beams from pulse to pulse precisely [15]. For *TESLA* the kick angle α per $\sigma_y^\star$ estimated from beam-beam simulations is approximately given by

$$\alpha \quad [\text{mrad}]: \quad \frac{\Delta y_{IP}}{\sigma_y^\star} \times 0.047 \text{ mrad} \tag{3.8.4}$$

with $\sigma_y^\star = 19$ nm beam spot size and Δy_{IP} beam-beam separation at the *IP*. The deviations from the linear relation 3.8.4 are not taken into account here, but they are not expected to have an essential influence on the feedback performance.

In order to reduce the processing time of the feedback loop, the locations of the BPM's and the kickers have to be as close as possible to the *IP*. If the BPM next to the *IP* is located at the position of the final doublet separated by 3 m from the *IP*, a $\sigma_y^\star$ separation will result in an offset of about 140 μm. Therefore the required resolution of the BPM can be relaxed and will be about 10 μm.

Within one pulse a bunch to bunch measurement of both outgoing beams can be used to get a precise measurement of the offset of the two colliding beams. The difference of the pick-ups taken before and after the IP of one bunch gives the sinusiodal part of the trajectory whereas the sum determines the requested kick to steer the beam.

Correctors

In the digital system, standard Digital-to-Analog Converters will be used to convert the signals back into analog values for the correctors. These signals have to be amplified in a fast power amplifier.

In the slow feedback system corrector coils are used to steer the beam from pulse to pulse. For the fast feedback the correctors will be magnets with a rise time of about 10 ns [20]. The magnetic field of 0.5 m long structure is about 2.7 Γm.

The orbit feedback at the *IP* shall be able to remove a separation up to $10\,\sigma_y^\star$. Assuming a distance of 4 m between kicker and *IP* this will result in a requested kick of 0.023 μrad for each kicker. Therefore a magnetic field of $2 \cdot 10^{-5}$ T is required for an energy of 250 GeV.

3.8.4 Control System

The computer hardware and software has been changing rapidly over the last several years and will continue to change during the course of contructing the linac. On the other hand, a software development for such a big machine has to start early to be ready in time. Most of the investment goes into computer software and into front-end electronics. For the front-end components, the investment in industrial standards is quite safe. Systems such as VME have a long lifetime, for example. Software developments should be based on new industrial methods. Object oriented tools have recently been gaining a growing market share and have proved to be very powerful methods for control system design in the case of TTF. In addition to apply object orientation, an implementation on more than one computer platform leads to a better design and helps migrating to new operating systems. Special consideration of the huge amount of equipment, (due to the length of the machines) has to be taken. The software and the hardware layout of the control system must allow for this. On the software and communication side, an efficient access to device data is necessary. A lot of similar devices must be readable with little overhead and short response times. Higher levels in the control system should provide summary information on device groups. Good and automatic monitoring of all devices is essential. The hardware layout should be fault tolerant. This can be achieved by a modular design. The modularity of the beam based hardware for instance could follow the structure of the klystrons, and allows one klystron to be switched off in case of a failure. Operation of the linac is still possible if a few klystrons fail. Failing hardware and software components should not in general stop larger segments. Therefore, the control system has to follow the hardware modularity also.

3.8.4.1 Architecture

For most areas in the linac we expect low enough radiation level to be able to bring the front-end electronics, including the device servers, into to tunnel. In a few places some extra shielding against synchrotron radiation will have to be inserted. Low radiation also allows us to use modern industrial, fieldbus based sensor/actor electronics. The overall architecture consists of three layers of computers. A top level with display or client programs, a front-end layer with device servers and I/O and a middle layer with powerful group servers. The upper layer is the interface to the operators. These upper services should be available to the consoles in the control room, the experts working in the tunnel and the specialists in their offices. All of them should be able to use the same programs. Only the level of details presented should be different, but nonetheless available to all levels of users. Modifications of device data must be protected with access rights. Since a lot of users and client programs access a lot of data from the front-end and the middle layer, a fast network is necessary to decouple the display stations. A net switch that routes packets from the clients to their servers provide the important bandwidth. Client programs often need a go/no-go information from a group of devices only. In such a big system it is necessary to ask a large number of front-ends to get this information. A middle layer server should provide such collective reports. Likewise, the middle layer should supply frequently requested data of all its front-end computers in a single block transfer. Proxy services may also be added since the middle layer servers are faster than the front-end computers. But, a direct access to front-ends (and not just for debugging purposes) is still necessary. In general, the middle layer implements higher services and improves the performance of the system. Data bases, file servers, simulation servers and other kind of servers without direct device connections should be placed in the middle layer also.

Subsystems of the machine use their own subnet with front-end computers. The

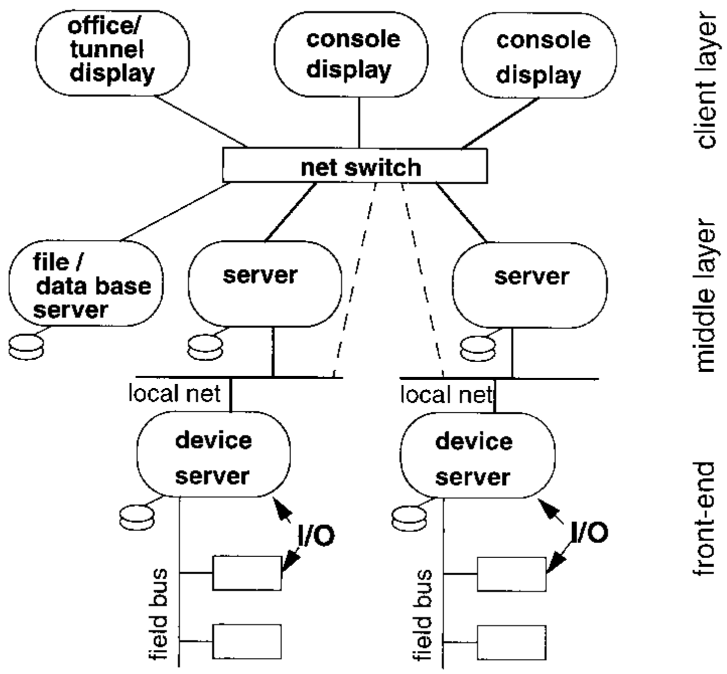


Figure 3.8.10: *Different layers of the machine control system.*

front-ends are distributed and close to the devices of the linac. Some hardware is directly connected to the device servers, other equipment use field busses to connect the front-end electronics to the device servers. Fieldbus electronics introduce a further level of computers in the system. Programmable Logic Controller (PLC) and 'intelligent' devices are examples of such stand-alone processors. All group servers and most front-end servers are equipped with disk drives. The other device servers mount their file systems from the corresponding group server. If a front-end has to run stand-alone in case of a network problem, it should have a direct connected disk or must have the program and data files in memory. Archiving of all data from the equipment can consumes a high portion of the network bandwidth if the storage is not in a local disk.

Front-end Computer

Most of the device input and output channels connect via VME modules or fieldbus electronics to the device servers. The VME system is designed as a reliable industrial electronic environment. Almost any computer, analog or digital input/output module and fieldbus interface is available in VME. The front-end servers should be grouped to separate different subsystems. This is a requirement for the installation, debugging and maintenance. A huge number of devices can reduce the overall operation time of the machine. Malfunctions of a single device should not stop machine operation. Grouping of devices or redundant layout must be used. The organisation depends very much on the individual device type. Low level RF systems for the klystrons can be grouped to serve one klystron only. A single failure would switch off the cavities of one klystron only and the machine could continue to operate.

Server

A linac control system consists of several different kinds of servers. Servers is this sense are computers that provide a service to other processes. Besides the servers of the front-ends, servers are placed in the middle layer. They help client programs to get informations on the huge number of data acquisition equipment. Middle layer servers collect the front-end data and add proxy services. Since all device information of a subsystem is available in the middle layer, higher order functions can be implemented. Such device group servers build a new collective device that represents the group to client programs. Further services provided by the middle layer servers:

- User and program file systems
- Data bases for all machine parameters
- On-line machine optics calculations and simulations
- Sequencer to automate the linac operations
- Alarm and error logging

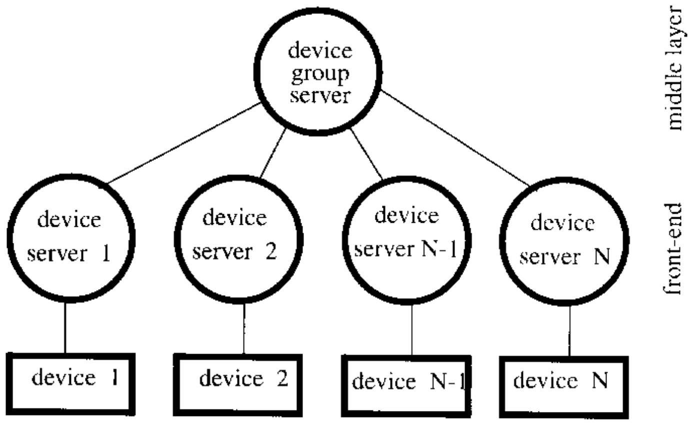


Figure 3.8.11: *Connection of front-end servers to group servers.*

Clients

A client is a program that uses services from the servers in the control system. An application program or a display process are typical examples of clients. These programs run on the operator consoles, in the tunnel during installation and maintenance and in the offices of the machine groups. Other applications run in the hardware and software development labs. All these programs should use the same communication protocol and the same library to talk to the servers. This is important since it should be avoided to rewrite the same software for different environments. The protocol is described in the 'Communication Interface' chapter. Client software is a wide field and consists of some generic programs:

- Tools to display alarms and other device errors
- Tools to access all data in the system (some times called parameter page)
- Tools to display historical trends and other plots

Generic programs don't have to be modified in a changing environment. They allow access to all devices by standard methods. Other tools are standard programs that allow to create dedicated applications to:

- generate and display synoptic representations of devices
- store and recall machine parameters
- integrate device data into office products like text editors and spread sheets
- access device data for analytical programs like MATLAB
- interface to machine simulation programs
- provide control system I/O for industrial tools like LabVIEW
- define automated sequencing of machine operations

Some of the above applications just use the application program interface (API) of the control system with a few lines of interface code. Commercial tools will play an increasing role in the client programs.

3.8.4.2 Network

This section discusses the various networks in the control system. At the front-ends this are fieldbusses to connect the local input and output of the devices to the corresponding servers. Devices servers connect to the group servers via standard local area networks (LAN). The devices get their timing and synchronization signal on a dedicated network and the interlock system is connected to a further separate line. Standard LAN technology is also used in the links between the servers and all client processors. Clients are distributed in the control room, the tunnel and the offices. And the whole network is connected to the DESY and outside nets.

Fieldbus

A fieldbus is a network that connects up to 32 sensors, actors or complex front-end input/output devices to the local device servers. Because fieldbusses are standard industrial systems with a lot of suppliers they should be preferred compared to proprietary busses like SEDAC (SErial Data Acquisition and Control). With the new bus systems ProfiBus and CAN, we already have some experience in TTF and HERA. They work reliably and modules from a lot of manufactures are available already. There is no single common standard fieldbus on the horizon. It is still a fast growing market and in future further busses like LON might be added as standard parts. Today the market is immense with a lot of different systems. A control system on the other hand has to focus on very few standards to reduce the maintenance costs since modern fieldbusses are quite complex compared to SEDAC. Some instruments are equipped with the older standard interfaces GPIB and RS232. RF instruments usually come with the GPIB interface. This bus system is limited to about 12 meters only and restricted to measurement equipment and their peripherals. RS232 is a point to point link. Usually the software effort to communicate to the RS232 devices is underestimated. These two bus systems should be avoided in the front-end I/O.

Local Area Network

Networks between the consoles, group servers and front-end servers will be based on standard LAN technology. This is today the 10 Mbit Ethernet. Cheap interfaces for all computer types are available. Ethernet is certainly too slow for the envisaged size of the machine. But, in the near future this standard will be replaced by a factor of ten faster network (100 Mbit/sec.). FastEthernet, FDDI, ATM, Fibre Channel are such technologies and are already available. The servers in the middle layer should be connected by an other factor of ten faster network i.e. about 1 Gbit/sec. All these network components are or will be standard items from many suppliers and can easily be integrated in the control system since they are based on the TCP/IP communication. For the long distances fibre optical links will be used to prevent ground loops and to isolate the subsystems. Local connections use less expensive twisted pair cabling to the active hubs that link to the fibber optics. In order to keep the network load low and predictable, the network is segmented into several parallel lines to the front-ends. Maintenance and managing considerations also lead to a good segmentation of subsystems.

Communication

During the installation and maintenance of all components of the machines, mobile terminals will be used. These terminals connect to the standard network and allow access to all devices in the system. A wireless network should be used in order to be more flexible and to save installation costs compared to a wall plug system. Such a wireless system will be used for audio communications also. It can be based on the GSM standard which is supplied by a lot of manufactures and cheap units. A few private receiver/transmitter inside the tunnels will connect the terminals to the controls network and DESY telephone system.

Interlock

The machine will be equipped with an interlock system at several points:

- differential current measurement of the beam
- beam loss monitors
- RF input coupler spark and field emission protection
- Klystron okay
- low level RF operational
- cryogenic okay
- vacuum okay and beam valves open
- power supplies okay
- experiments ready for beam

A detected failure in any part of the distributed system will switch off the guns and injectors. All sources connect to a common fibre optical line. The system can be considered as an independent hardware link from the interlock sources to the beam sources. Although it works without the control system, the interlock has to be readable from the control system to insure that the cause of an event can be detected. And because of the several thousand interlock points of origin, individual sources must be maskable i.e. the control system must be able to switch them off. A good bookkeeping is essential here. A further requirement is the ability to record the history of an inhibit event. Therefore the inhibit signal is feed back as an event in the timing system. This event is detected by all front-ends as a 'post-mortem' trigger to save their data before and after the interrupt time.

3.8.4.3 Software

Throughout the development time of the software for the machines the computer industry will introduce a lot of new products. A main challenge for the design will be to create the software modular with good interfaces to allow easy migrations to new environments. Modular means that some submodules must be changeable without interference with other part. It also means to design reusable objects. The 'heart' of the control system is the communication interface. All client and server programs communicate by it. When ever possible standard industrial components should be used for front-end hardware up to the display programs. And the software should be designed with the common tools and programming languages. Our experience in the

TTF control system showed that object oriented languages (like C++) are adequate design environments to create reusable modules. Object orientation leads to a clean frameworks and follows the industrial paradigm.

Operating Systems

From today's perspective the choice of operating systems suitable for a control system are UNIX and Windows NT and some real time systems for front-ends. In the future the operating system will probably develop to more object oriented systems. Because of maintenance reasons the number of different operating systems should be kept small. On the other hand a design which is based on more than one system leads to a better portability in the future. Therefore, the TESLA control system should be based on UNIX, Windows NT and VxWorks. The latter is a real-time system for front-ends only. The other two operating systems have 'soft' real-time capabilities and provide a multi-threaded, multi-tasking environment.

Communication Interface

A basic element in a control system is the communication interface. It defines the application program interface (API) for the data exchange between clients and servers. Because of it's important role in a control system, the API must be based on standard protocols. For the network layer this is the TCP/IP Internet protocol. Higher level protocols are transported over the basic TCP/IP services. Requirements for the top level are:

- has to transport a well defined set of data objects
- needs to convert the data between different computer architectures
- provides common methods e.g. translations of the data structures
- interface library for all CPU types in the control system
- access to all data (including archived data) of devices in a consistent way
- interface to standard desktop applications like spread sheets and to special controls applications
- has to provide an on-line names service to query existing devices and their properties
- defines a unique way for names of device addresses and their parameters
- allows access to single and multiple devices in one call
- sends parameters as data to the device in a read call to allow atomic requests
- client programs must get device address resolutions from a name server and not by recompilation

Database

Data bases are used to store the parameters of the machines, the configurations of the servers and the archived on-line measurements of devices. In addition, all data from the production process of the cavities need to be stored in a data base. For TTF this data is stored in ORACLE and it is planed to continue this work for the TESLA collider. ORACLE is a good choice since it is the standard data base for DESY, it has interfaces to several computer types and has a solid market share to trust in the future support. For on-line archiving and configuration data of front-end servers a big data base is too slow and voluminous to fit into a small front-end. A distributed data base access would not help because a server should be independent from network connections if possible. Beside this, the estimated network load could be very high for several thousand devices with several properties to archive at a 10 Hz update rate. Object oriented data bases or fast file based archives are better suited for this purpose. They may be located in the front-end and group servers.

Bibliography

[1] T. Shintake, *Proposal of a Nanometer Beam Size Monitor for e+e- Colliders*, NIM A311, p. 453, 1992.

[2] T. Shintake et al., *First Beam Test of Nanometer Spot Size Monitor Using Laser Interferometry*, KEK-Preprint 94-129, Oct. 1994.

[3] M. Ross, *High Performance Spot Size Monitors*, LINAC96 Conf., Geneva Aug. 1996.

[4] M.C. Ross, E. Bong, L. Hendrickson, D. McCormick, M. Zolotorev, *Experience with Wire Scanners at SLC*, SLAC-PUB-6014, December 1992. Invited talk given at 1992 Accelerator Instrumentation Workshop, Berkeley, CA, Oct 27-30, 1992. Published in Berkeley Accel.Wkshp.1992:264-270 (QCD183:A22:1992)

[5] *TESLA TEST FACILITY LINAC - Design Report*, edited by D.A. Edwards, DESY Hamburg, TESLA-Note 95-01, 1995.

[6] W. Schnell, *Common-mode rejection in resonant microwave position monitors for linear colliders*, CLIC note 70, CERN-LEP-RF/88-41, 1988.

[7] R. Lorenz, *Beam Position Monitors in the TESLA Test Facility Linac*, IEEE Conference Proceedings of the PAC 95, Dallas, May 1995.

[8] R. Shafer, *Beam Position Monitoring*, AIP Conference Proceedings 212, 1989, pp. 26-58.

[9] E. G. Bessonov, J. Pflüger, G.-A. Voss and N. J. Walker, *Beam Size Measurements in a Linear Collider using an X-ray Gradient Undulator*, DESY internal report DESY M 96-18, September 1996.

[10] M. Castellano, private communication.

[11] C. Bovet, M. Placidi, *A dedicated synchrotron radiation source for LEP beam diagnostics*, CERN LEP note 532, 1985.

[12] K. Hanke, V. Schlott, K. Aulenbacher, H.H. Braun, F. Chautard, *Beam diagnostics using coherent transition radiation at the CLIC test facility*, CERN CLIC note 298, 1996.

[13] Y.Y. Divin, H. Schulz, U. Poppe, N. Klein, K. Urban, V.V. Pawlowskii, *Millimeter-wave Hilbert-transform spectroscopy with high-T_c Josephson junctions*, Appl.Phys.Lett. 68, p.11, 1996.

[14] G.A. Voss, R. Brinkmann, N. Holtkamp, *A Beam Based Interaction Region Feedback for an S-Band Linear Collider*, presented at the LINAC96 Conference, Geneva, August 1996.

[15] P. Bambade, R. Erickson, *Beam-Beam Deflections as an Interaction Point Diagnostics for the SLC*, SLAC-PUB-3979, May 1986.

[16] I. Reyzl, *Simulation of Feedback for Orbit Correction*, to be published in IEEE Conference Proceedings of the EPAC 96, Sitges, June 1996.

[17] Gene F. Franklin, J. David Powell, Michael L. Workman, *Digital Control of Dynamic Systems*, 2nd ed., Addison-Wesley, 1990.

[18] Brian D. O. Anderson, John B. Moore, *Optimal Filtering*, Prentice-Hall, 1979.

[19] Alan V. Oppenheim, Ronald W. Schafer, *Discrete-Time Signal Processing*, Prentice-Hall, Inc., 1989.

[20] B. I. Grishanov, F. V. Podgorny, J. Ruemmler, V. D. Shiltsev, *Very Fast Kicker for Accelerator Applications*, TESLA-Report 96-11, November 1996.