10 BCD Proposal: Instrumentation and Controls

Instrumentation and Controls

Introduction

The Instrumentation and Controls BCD document consists of thirteen sections, in addition to this introduction, as listed here:

10.1 Controls Standard Architecture
10.2 Timing System
10.3 Diagnostic Interlock Layer
10.4 Global Network
10.5 Machine Protection
10.6 Low level RF
10.7 Feedback
10.8 Integration with Instrumentation
10.9 Machine Detector Interface
10.10 Instrumentation – Beam position monitors
10.11 Instrumentation – Beam profile monitors (transverse)
10.12 Instrumentation – Longitudinal
10.13 Instrumentation – other (intensity, loss, ring)

It is anticipated additional sections will be needed as requirements are more carefully defined and understood.

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Controls

(to be added)

Instrumentation

The ILC Instrumentation system functions both to provide diagnostic information to be used to correct substandard operation and as an integral part of the machine control system, providing input to the machine protection system and beam-based feedbacks. There are four types of basic monitors: position (BPM), intensity (toroid), profile and loss (BLM). These are supplemented by a system of special monitors to be 1) jointly used by the accelerator and detector, 2) to monitor other aspects of the beam – such as longitudinal profiles and correlations, beam timing, damping ring parameters, beam halo, and 3) feedback. The beam – based instrumentation system is further supplemented by hardware monitors: temperatures, field probes, radiation monitors and etc.

The instrumentation for the ILC is challenging and much of it, although demonstrated in small test installations, has never been implemented on a large scale. From the point of view of instrumentation, the ILC is divided into two pieces, the 'damped beam' section (damping rings → beam dumps), and the injector system (upstream of the damping rings, including injection into the rings). Typical beam sizes and required position monitor resolution in the damped beam systems are around 1 micron. In some cases, these can be much smaller (~0.1 microns). RD is needed to provide confidence in a given system design, especially for the BPM and profile monitor systems.

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Table 1 summarizes ILC instrumentation requirements. Monitors for intensity and transverse beam position

ILC component	Required resolution / precision	Required risetime	Technology	units needed total both sides	Cost estimate/unit	Information from	Remarks	R &D requirements
Injector	Sigma/5	6MHz	Stripline	600	4K excluding vacuum hrdwre	Self	Reliability; redundancy	
Damping ring	1um narrow band Roll 20 mrad precision 100um. Stability 1um	Slow;	Button	600	4K exc. Hrd.	Snowmass WG3b	Stability, roll under study (CCLRC)	ATF 1 pm-rad
Damping ring	Special for ffbk fraction sigma also injection	Bunch spacing	Button	20	8K	Snowmass WG3b	Ffbk RD	Ffbk integration
Damping ring	1 μm / ?			L_w/2			For wiggler sections; vacuum chamber RD	Similar to the rest of DR
Linac (BPM)	recommended sig/3, a few at sig/10 for FFBK Nom I. scales with I for lower.	6MHz separate. 10 % increase in noise from prev bunch	Cavity ? re-entrant ?	800	10K incl cavity – more if cleaning is included	M. Wendt GG2 talk WG4/1 common session	Scale factor; integral linearity, from DS 0.5% for absolute gain over 200um (needs verification) Question 43	Calibration process, analysis from nBPM

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Linac (inten)	1%	Whole train	Ferrite loaded gap	4	5K	self	Precision intensity – what is needed for 1 bunch	
Linac dark I	50nA/1ms pulse	1ms	Resonant 010 mode/	?		Olivier		Test dark I meas at TTF
Linac/DR	1e-4?	780 ps		2			Parasitic bunch	Single photon counting?
Beam delivery-spectrometer	100 nm			36		Tesla TDR/Snow mass WG4	spectrometer 1 plane	Stability 200 nm
Beam delivery-IP feedback	1 μm / 100 μm		Stripline?	4		Tesla TDR	IP feedback	Background influence (ESA)
Beam delivery – all else	8nm to 100um s/10. beam size varies from 85nm to 1.2mm.	Same as linac	Cavity for hardest	500	10K including cavity	Woodley's table	'normal' Virt IP's counted?	3 or 4 types. Some hard – ATF2 IP nBPM

Beam phase monitors

ILC component	Required resolution / precision	Required risetime	Technology	units needed	Cost estimate/unit	Information from	Remarks	R &D requirements
Injector – gun system	0.1 deg	Single bunch	Cavity	2	20K	Self	Use Haimson	Test required – not used for SHB systems
Damping ring	0.1 deg	Single bunch	Cavity	2	10K	Self	From main RF	

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Bunch Compressor	0.01deg	Single bunch	Cavity	6	30K	WG1 BC spec	Tightest phase monitor req.	
Linac	0.1	Single bunch	Part of LL-RF	?	May be integrated in LL-RF, no add'l. cost	Self		TTF, SNS
Beam delivery	Collision overlap – s_z/10?	Single bunch	2	Integrat ed with crab	2M$			

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Monitors for transverse profiles

ILC component	Required resolution / precision	Required risetime	Technology	units needed	Cost estimate/ unit	Information from	Remarks	R &D requirements
Injector	Sigma/5	Single bunch	Wire scanner	30	30K	Self		
Damping ring	10% emittance	Multi-bunch ok	XSR, laserwire, ?	2 of each/ring	250K	WG3b Snowmass	ATF performance not quite	XSR RD needed
Bunch Compressor	10%e	Measurement of single bunch w/o train	Laserwire	3 sets/side for 2 stage BC	250K/set	WG1 Snowmass	Integration with lattice needed for coupling precision	ATF2 tests
Linac	10%e	Same	Laserwire/ short warm	3 sets/ linac	250K/set	Question 29	Cryo warm section needs study	
Beam delivery	10%e	Same	Laser wire	2 sets/ side	250K/set	WG4 Snowmass	Does not include secondary waist monitors, extracted beam monitoring	IP area, secondary waists, extraction line
Beam Delivery – collimation system monitors								

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Monitors for longitudinal profiles

ILC component	Required resolution / precision	Required risetime	Technology	units needed	Cost estimate/ unit	Information from	Remarks	R &D requirements
Injector; gun, SHB system, e+ collection, booster linacs dE/s_z	dE ~0.01 % / s_z ~ 100um	Single measure ment possible w/o train	Wire scanners and LOLA	Gun, linac, DR entranc e	30K /wire & 300K/LO LA	Self		Could be tested at SLAC/KEK
Damping ring s_z	S_z/10	Single bunch w/o train	Streak camera/defl ection cavity	1 per	500K			
Damping ring dE	0.01%		XSR/visible SR	2	350K			
Bunch Compressor	dE ~ 0.01% / s_z ~ 30um		Laserwire/ wire scanner & LOLA	2	30K /wire & 300K/LO LA			
Linac – dE at end	dE 0.01%			2			Bunch compressor monitors used at input	
Beam delivery - correlations				2			Crab system see above listing	

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Special Monitors

ILC component	Type	Require-ments	Techno logy	units needed	Cost estimate/ unit	Information from	Remarks	R &D requirements
Injector	Beam loss	1% remote handling limit – 1W/m- linearity for MPS sequence	Ion chamb er	1/10 m + PLIC	0.5K		100x less sensitive than SNS	cost
Damping ring	Beam loss	Same						
Damping ring - wiggler	Beam loss	Tighter 10x – neutrons?						
Bunch Compressor	Beam loss	Same as inj.						
Linac	Beam loss	Same as inj.						
Beam delivery	Beam loss	Same as inj.						
Beam delivery - Collimation	Beam loss	Calorimetry?						
Beam delivery	Luminosity							
Beam delivery	Polarisation							

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The most critical (and most expensive) instrumentation system is the BPM system. Experience at LEP, Tevatron, PEPII, SLC and many synchrotron light sources has shown the importance of having a well engineered, proven BPM system. The first instrumentation section of this chapter deals with BPM requirements and how these will be met, in large part by precision RF cavity BPM's. There are 2 parts to the section, one for the injector and damping ring and the other for the downstream systems, linac and beam delivery. The second section describes the second critical system, the damped beam profile monitor system. It is this system that validates the performance of the low emittance transport. For the most part, these monitors will be based on 'laser-wires'. A laser-wire consists of a 90 degree Compton scattering chamber where a finely focused, very high power pulsed laser is used to sample the particle beam density. Although laser-wires have been built and successfully tested in all three ILC regions, these systems are still very much in development and require constant handling by experts. It is useful to think of the laserwire system as providing an estimate of the luminosity, if the beams were brought into collision at that point. In that way, laserwires can be used to segment the low emittance transport. In sharp contrast to BPM's, laserwires need their own section of beamline to function optimally and this has added cost. The beamline length needed depends on the surrounding components (e.g. collimation), typical beam sizes in the area and the expected performance of the laserwires. The fourth instrumentation section describes longitudinal diagnostics. The ILC longitudinal diagnostics will be used to measure the bunch length and the x z, y z and E z correlations. These devices are used to test the damping ring beam dynamics, the bunch compressor phase space rotation, the phase space distortion in the main linac, the wakefield kicks in the collimation system and the effects of poor optical matching and non-linear fields. Because the longitudinal phase space distribution is not expected to be Gaussian and small features in the distribution are important, these devices must have resolving power well beyond the characteristic bunch length scale. It is expected that a relatively small number will be needed, but, as with the laserwires, these devices need dedicated beam line space and hence have cost implications. Finally, the last instrumentation section deals with special monitors.