SLAC-PUB-11661
January 2006

ISSUES OF STABILITY AND GROUND MOTION IN ILC*

Andrei Seryi, Linda Hendrickson, Glen White, SLAC, Stanford, CA, USA

Abstract

Stability of International Linear Collider is determined by the stability of the site, additional noises of beamline component, energy and kicker jitter, and performance of train-to-train and intratrain feedback. Stability goals in terms of the beam jitter at the end of the linac, in BDS and at the IP are discussed in this paper, and translated to stability goals for the site and for component jitter. Present status of stability studies is reviewed and feasibility of achieving the stability goals is discussed.

BEAM JITTER IN ILC

Studies of beam stability for linear collider have long history, in terms of site stability studies, development of stable hardware and beam-based feedbacks. In particular, in 2002-2003 the Technical Review Committee performed studies and confirmed that ILC (at that time TESLA) requires the fast intra-train feedback. Without such feedback even the moderately noisy sites may result in luminosity loss. Another TRC recommendation was to make urgent studies of stability of the linac quadrupoles, located in the cryostats, since at that time there were no reliable data to quantify total motion of the beamline components [1].

Sources of beam jitter in ILC are the motion of beamline components, in the linac, in the Beam Delivery System (BDS) and in Final Doublet (FD), as well as the energy and intensity jitter, Damping Ring extraction kicker jitter and so on. The motion of beamline components in turn consists of a) site ground motion and ILC in-tunnel and near-tunnel hardware noise; b) additional noise of beamline components including amplification of floor motion by supports.

The approach to control of beam jitter in ILC with its low repetition rate of 5Hz is based on reliance on the fast IP intra-train feedback to steer the beams to collision and recover luminosity for most of the long train of 2820 bunches. The capture range of this feedback is rather large, couple of IP beam size sigmas in the horizontal plane and up to about a hundred sigmas in the vertical plane. With fast feedback, the requirements for ground motion, linac and BDS quad jitter and stability of FD has to be determined not from IP jitter, but, in particular, from diagnostic performance and emittance preservation.

Discussing the ILC jitter goals, one need to stress that the large capture range (tens of sigmas) of fast feedback does not mean that larger jitter is allowed along the machine. On the contrary, there are many reasons why the jitter should be smaller than the beam size, in particular a) to minimize beam emittance growth due to collimator wake-fields; b) to provide acceptable conditions for beam diagnostics; c) to minimize jitter effects on dispersion free steering (see e.g. [2]); etc.

In terms of the effects listed above, considered at the end of the linac at the entrance to BDS diagnostics and collimation, the edge of the comfortable range can be approximately defined as: end of the linac jitter < 50% beam sigma. In this case, for example, in the BDS diagnostic section, the effective beam size, with jitter added in quadrature, is just 10% larger than nominal. In comparison, if the jitter would be equal to the beam size, the effective size in the diagnostics section would be already 40% larger than nominal which would significantly complicate beam measurements and tuning.

In the Beam Delivery System the optics is strong, has nonlinear elements, and there are magnets which have much tighter stability tolerance than in the weak linac. One can therefore expect that BDS would contribute noticeably to the total jitter. One can allow the jitter to grow along the BDS to about approximately 100% of beam sigma (excluding FD contribution), without noticeable deterioration of performance.

The Final Doublet contributes one-to-one to the IP jitter, however its jitter is less relevant, as soon as it is taken out by fast feedback, since the beam transport from FD to IP is straightforward and nonlinear contributions due to jitter in the FD sextupoles are small. The FD jitter of the order of 100nm or somewhat more should be manageable. In this case no active stabilization of FD should be needed, while FD position monitoring would still be useful.

DISCUSSION OF ILC JITTER GOALS

The tentative stability goals suggested above for discussion are based on general common sense as well as on earlier and also recent integrated simulations for ILC. Some results of these recent simulations will be highlighted below. Note that this work is ongoing and more details may be available soon, which could be useful for clarifications of the stability requirements.

Integrated simulations of ILC, from linac entry to the IP were set up with 5Hz feedback and idealized IP feedback. Ground motion models B, C [1] and K (model for KEK site, it is close to model C in 1-10Hz, but less noisy above 20Hz [3]) were used, together with additional jitter of components and energy jitter.

The 5Hz feedback loops were cascaded and have exponential response of 36 5Hz pulses. There were 5 distributed loops in linac, each with 4X and 4Y dipole correctors, and 8 BPMs. In BDS there was one loop, with 9 BPMs and 9 dipole correctors. The IP deflection (X&Y) in 5Hz loop was not cascaded and has 6 pulse exponential response.

Additional component jitter of 25 nm in BDS (including FD) and 50 nm in linac was used in simulations. The DR extraction kicker jitter was 10% of

---

*Work supported by US DOE, contract number DE-AC02-76SF00515

Contributed to 36th ICFA Advanced Beam Dynamics Workshop (NANOBEAM 2005) ,
17-21 Oct 2005, Kyoto, Japan

beam sigma. The beam current jitter was 5%. The energy jitter corresponded to 0.5% uncorrelated amplitude on each klystron, 2 degrees uncorrelated phase on each klystron, 0.5 degrees correlated phase on all klystrons. The BPM resolution was assumed to be 100 nm.

In these assumptions, the vertical jitter at the end of the linac is 1%, 33%, 61%, 70%, 72% of the beam size with ground motion B only, ground motion K only, all jitter sources and ground motion B, all jitter sources and ground motion K, all jitter sources and ground motion C. From these numbers, one can conclude that ground motion K or C is acceptable from the linac stability point of view, however the linac component vibration of 50nm is somewhat too high. One would wish it to be no more than 30nm, and in that case the ground motion and component vibration would contribute about equally to the end of the linac beam jitter.

In terms of the jitter in the BDS for ground motion K, we observe that luminosity is reduced to 17% with 5Hz feedback only or 70% with ideal intratrain. If we omit all additional jitter sources except for ground motion, these numbers become 37% or 84%. Results for gm C are similar. Luminosity reduction is attributed to effects in BDS (not FD, not linac) and is being studied further. The models C or K appear too noisy for the BDS area (this agrees with the earlier studies done for TRC [1]), and one would wish, roughly, the conditions to be a factor of three quieter (this scaling factor would be applied only to high frequency part of the spectrum in the ground motion model). From another point of view, ground motion B would be exceedingly quiet – the IP beam jitter is only about 30% with ground motion B only and one could allow a factor of three noisier conditions. The component jitter assumed for BDS in simulations (25nm) is too high, one wishes it not to exceed about 10nm.

Summarizing, the tentative goals for tunnel floor stability and additional component jitter suggested for discussion are up to ground motion K or C with additional component jitter up to 30nm in the linac and up to ground motion “B*3” or “C/3” and component jitter up to 10nm in the BDS area.

One needs to note that linac and BDS may in fact have different specs for on-the-floor noise because the noise consist of ground noise plus noise from nearby utilities, which are different in linac and BDS areas. Moreover, the BDS area may be located in a quieter place than the average linac vibration level. In particular, we believe that all sample sites considered at this moment for ILC, including the DESY site, would satisfy the suggested stability goals.

One other thing that needs to be discussed is how to divide the vibration budget. Let’s say the requirement for on-the-tunnel floor stability in linac area is ground motion C (and gm “C/3” in BDS). This motion includes natural ground motion of the site and added noise by ILC conventional facility and other nearby equipment. One can set the budget for the added noise to be ~70% of gm C and require the initial site to be also ~70% of gm C. This approach is conceivable but may show limitations in the future. One could also discuss feasibility of another approach, with initial site motion significantly quieter than ground motion C (and “C/3” in BDS), and the entire vibration budget is given to conventional facilities and other added noise.

ACHEVABILITY OF STABILITY GOALS

Let us discuss whether the stability goals, suggested above for consideration, could be achieved. As was mentioned earlier, the sample sites themselves are sufficiently stable (better or equal to C in linac and C/3 in BDS area). When the real site is chosen for ILC, the stability criteria would need to be considered again.

The biggest challenge for ILC stability is in its own noise. In terms of additional noise in the BDS area – earlier studies of FFTB quadrupole stabilities have shown that the differential motion to ground is small (~2nm at 5Hz), for the quadrupole on movers and with cooling water flow [4]. Lower frequency is relevant for the 5Hz machine (0.2-0.5Hz) but was not studied accurately. Detailed and careful design is important, but one can expect that the 10nm goal for component jitter may be achievable in the BDS area.

The 30 nm goal for linac component jitter is another challenge. Presently, there are insufficient data to determine how difficult this goal is. The measurements inside of cryostats are difficult and just being developed. Recently, stability of TTF cryostats was measured with the stretched wire technique [5] and with seismic and piezo sensors [6]. It appears from these results that the discussed stability goal is 5-10 times tighter than what was observed for vibration of quads in the cryostats. However, present observations were performed in a very noisy environment of on-surface labs.

One should also note synergy of these linac stability studies with XFEL program. The XFEL is shorter and has fewer quads than ILC linac, but focusing is stronger, there are more quadrupoles per km, and the beam jitter requirements are tighter – 10% of beam size sigma [7]. XFEL plans to achieve beam jitter goals by both using fast feedback and improving the cryomodule stability, while with 70 nm (rms) quad movement there is about 5% of beam jitter at linac end [7]. Still, the XFEL component stability goal is several times more relaxed that that of ILC. Focused engineering efforts are needed to achieve the stability of ILC linac components.

Noise of nearby utilities is important and need to be carefully minimized in ILC. Earlier studies of vibration transmission from surface, along the tunnel and between two tunnels [8] as well as developments of passive noise reduction methods [9] are applicable.

Common collider hall for two detectors was recently suggested. This is certainly more challenging for IR stability. As mentioned above, with fast feedback, the FD stability goal is about 100nm – such jitter should be achievable for single collider hall, in terms of high frequencies (several Hz) in normal operation (scenarios with parallel construction of second detector need more study). However, lower frequency of about 0.5Hz and temperature stability may be more difficult in a common collider hall. Monitoring of FD motion will be needed to resolve its stability issues. Optical interferometers or nonmagnetic seismic sensors (pendulum based or with molecular electronic transfer [10]) been developed for earlier projects can be applicable for ILC.

ACKNOWLEDGEMENT

The authors would like to thank many colleagues who contributed to discussion and work on these issues.

SUMMARY

In this paper, we discussed the ILC stability goals and suggested for consideration by the community the tentative stability criteria, which could be summarized as up to ground motion C with additional component jitter up to 30nm in the linac and up to ground motion "C/3" or "B*3" and component jitter up to 10nm in the BDS area. The biggest challenge is in achieving the specified component jitter. The level of ongoing studies is increasing. The focused efforts should bring their results.

REFERENCES

[1] International Linear Collider Technical Review Committee, Second Report, SLAC-R-606, 2003.
[2] P.Tenenbaum, Steering Simulations Study, NLC Machine Advisory Committee, June 2003.
[3] T.Tauchi et al. Ground motion measurements at KEK, in a borehole near Higashi-Odori.
[4] M.Woods et al, FFTB stability quad.
[5] A.Bosotti et al., PAC2005.
[6] H.Brueck et al., TESLA Meeting, 03/31/2005.
[7] XFEL WG-Minutes, Oct.2003.
[8] Parsons Co./Geovision, August 2003, LCC-122.
[9] F.Asiri, NLC MAC, June 2003.
[10] PMD/eentec, www.eentec.com