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Instrumentation

Instrumentation performs a critical role in the operation of a linear collider. New acquisition and data processing techniques are required for feedback, tuning procedures, and performance monitoring. For example, many collider systems are initially tuned using complex bootstrap procedures whose convergence rate will depend on the speed and performance of several instrumentation systems. Furthermore, mechanical and electrical tolerances are computed assuming the success of this process.

The next leap in electron-positron accelerator performance will result in part from improvements in instrumentation technology. The latest generation of accelerators, from high-current synchrotron light machines to B-Factories and linear colliders require feedback control loops that are greater both in number and complexity than more conventional machines. As a result, the instrument is no longer a diagnostic tool, intended for use only in cases of sub-standard performance, but a truly integrated accelerator component. This has obvious implications for the instrumentation-system designer, among which is that the system must have the integrity required of other accelerator systems, such as the power conversion and vacuum systems.

Linear colliders represent the most extreme application of this philosophy. The lack of closed, equilibrium conditions that maintain stability in the machine, forces the use of several layers of sophisticated feedback loops. The underlying reason for this requirement is the tolerances that must be applied for the correct transport of low-emittance beams. In some extreme cases, initial bootstrap procedures are required before any beam can be transported through the system. Tight mechanical and rf system tolerances will not only require special systems to address them directly, but will also demand beam-based feedback and tuning procedures. For example, in the X-band linacs and the beam-delivery sections, the magnet alignment is continuously monitored and adjusted using beam-based techniques that rely on high-resolution Beam Position Monitors (BPMs).

Perhaps the most important improvements in instrumentation technology will not come from the harnessing of fundamentally new physical processes to better the performance of beam position or size monitors. Instead, they will come from the integration of existing instrument beam sensors with more powerful controls. Very strong integration with the control system is needed to provide the robust, high data-processing bandwidth needed for higher level control.

An important aspect of the shift in the role of instrumentation will be its use in general optimization systems that will ultimately change the character of the control room operator's task. Traditional applications of instrumentation systems in colliding-beam accelerators have required heavy involvement of the operator. In storage rings, for example, operator technique in optimizing injection and luminosity has proven to be a key factor in long-term performance. In a heavily feedback- and optimization-control-laden system, the operator's task becomes the more complex one of controlling and monitoring the performance of these automated tasks.

Details of the instrumentation design and requirements are distributed through the preceding chapters of this document. Many of the concepts needed for the high-resolution systems have already been tested. For example, the Final Focus Test Beam (FFTB) at SLAC utilizes stripline BPMs with 1-μm resolutions and a beam size monitor that is capable of measuring 40 nm spot sizes. In addition, rf BPMs were installed and measured to have a resolution less than the required 100 nm. Other elements will be tested in the near future. This includes the rf structure BPMs that are needed to align the accelerator structures, a laser wire system similar to those needed to measure the beam emittances in the linacs and final foci, and the PEP-II button BPM system that is similar to those needed in the damping rings.