Beam Position Monitors

Main Linac

Beam position monitors will be placed at each of the approximately 800 quadrupoles in the two main linacs. BPMs will be included in the croymodule. They shall report the position of each bunch in every bunch train.

Main Linac Beam Position Monitor Requirements

Parameter	Requirement	Comments
Quantity	~800	Every quadrupole
Environment	Cold	In cryomodule
Aperture	60mm – 70 mm	BPMs not to be limiting aperture
Resolution	0.5 micron	
Stability	<10 microns	Over cryomodule thermal cycling
Temporal resolution	bunch-by-bunch	

BPM pickups must be compatible with superconducting RF cryomodules. In particular during fabrication/assembly they must be cleanable with standard techniques to prevent contamination of the cryomodule.

Beam Position Sensor Technologies

There are two candidate solutions for the beam position pickup sensor. Both are based on resonant cavities. The "conventional cavity" BPM relies on dipole modes of a resonant cavity which is essentially a pillbox. The "re-entrant cavity" BPM relies on the dipole resonant mode of a coaxial resonator where the beam duct is the center conductor. Both candidate technologies require further R&D to be established as a proven solution to all of the system requirements.

Cavity BPM

By "cavity BPM" we mean essentially a pillbox-type cavity BPM with common-mode free coupling to external electronics. That is, the signal produced at the position output coupler is essentially that of the dipole mode and is therefore proportional to the product of beam charge and beam position. Cavity BPMs show extremely good resolution and stability. Examples are those designed at BINP and studied extensively at KEK's ATF and those built by KEK's Shintake and evaluated at SLAC's FFTB. These feature dipole-mode couplers that reject the cavity monopole modes. This reduces the dynamic range required to achieve sub-micron resolution and is thought to yield excellent accuracy and stability. At C-band resolution in the 20 nm range or better have been reported for the Shintake and BINP BPMs. Centering stability better than ±50 nm over 2 hours has been observed. However we are not aware of a common-mode-free cavity BPM that has been qualified for use in a cryogenic clean environment.

Re-entrant Cavity BPM

These are RF BPMs using coaxial resonant modes in a shorted coaxial structure. They have proven cryogenic and cleanroom compatibility as demonstrated in the TTF cryomodule. The signal at the output couplers have considerable common-mode signal. Careful monopole mode cancellation is required here; much of it is accomplished externally by RF hybrids in the processor electronics. A recent design should achieve 1 micron resolution. More R&D is required to demonstrate required resolution and stability.

Main Linac BPM Pickup Options: Pros and Cons

Type	Pros	Cons
Reentrant Cavity	Proven cryo-compatibility Good bunch-bunch resolution	Unproven sub-micron resolution Unproven stability; depends on tuning in electronics module
Cavity	Proven resolution Expect excellent stability Good bunch-bunch resolution	Unproven cryo-compatibility

Beam Delivery System

Beam jitter to be kept less than 50% of the beam size in most of the BDS. To verify that the jitter requirement is met and to understand the sources of jitter if the requirement is not met, BDS BPMs must have resolution significantly better than half the beam size. We adopt a BPM single pulse resolution requirement of one-quarter of the beam size. Cavity BPMs are favored for most of the BPMs here for resolution, accuracy, and stability. The intra-train IP feedback BPMs are exceptions; these are likely to be stripline BPMs for ease of low-propagation delay processing, and for the 2 milliradian crossing angle scheme, the possibility of directional beam pickups.

Beam Position Monitor Requirements

Parameter	Requirement	Comments
Quantity	~400	
Aperture	Various sizes	
Resolution	$\sim\sigma/4$ ~250 nm	
Stability	<10 microns	long term
	< 1 micron / hour	Energy Spectrometer only
Temporal resolution	bunch-by-bunch	many places, assume all