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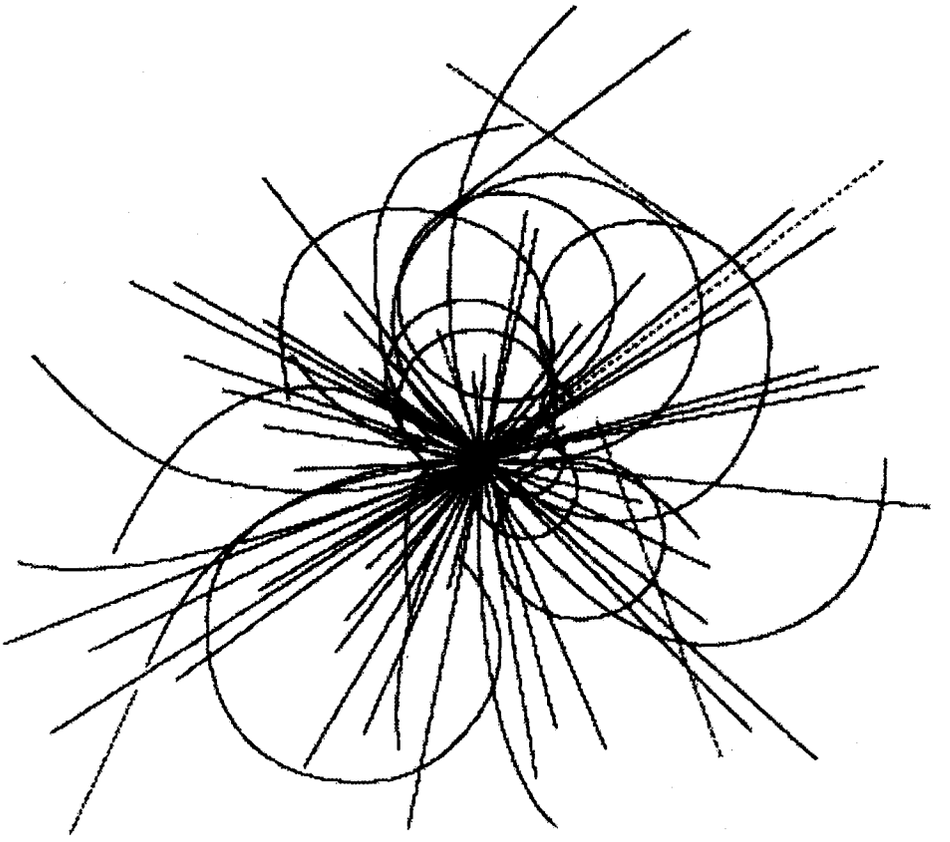

Superconducting Super Collider Laboratory

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Submicron Beam Position Sensor

E. Tsyganov, S. Kauffmann, R. Meinke, W. Nexsen, and R. Richardson

Abstract

A submicron-accuracy beam position monitor for the Superconducting Super Collider accelerators is proposed, based on use of a low-energy electron beam probe. The resolution of the probe is estimated.

1.0 INTRODUCTION

High-energy accelerator complexes require feedback systems to dump down injector errors and to prevent an emittance growth due to quadrupole vibrations, multibunch instabilities, power supply ripples, *etc.* Such systems usually involve beam position monitors that provide information used to correct a particle orbit by electrostatic kickers. The noise of a beam position monitor is one of the limiting factors of the systems. Electrostatic pickup electrodes or striplines probably could not provide the necessary resolution in a bunch-by-bunch mode of operation, which is needed for the effective feedback process. Besides the electromagnetic pickup noise and thermal noise of electronics, there are also some multipole components in the image current density that combine the *X*- and the *Y*-position in measurements and could introduce some confusion in the feedback system at a high-precision level. An alternative approach to the construction of the essentially "noiseless" beam position monitor, based on using a low-energy electron beam probe,[1,2] is discussed below.

2.0 BEAM POSITION SENSOR DESIGN

A diagram of the sensor is presented in Figure 1.

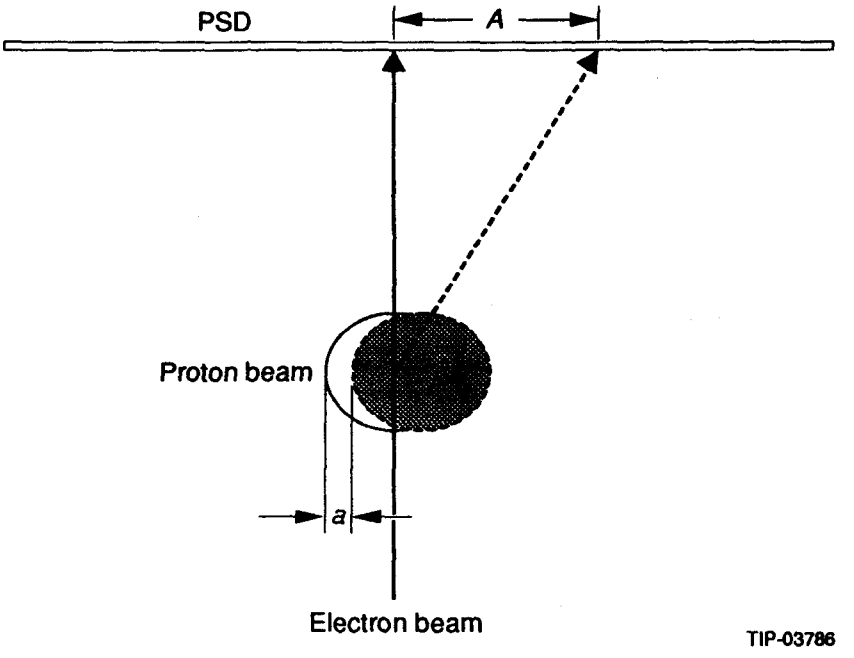

Figure 1. Diagram of the Position Sensor. A 10-KeV electron beam strikes the 20-TeV proton bunch. If the proton bunch is displaced off-center by the distance of *a*, the electron beam position will be displaced by the distance of *A*. PSD is a position-sensitive detector.

If one uses a 10-KeV electron beam as a probe, the maximum bending angle of the electron beam deflection by the Superconducting Super Collider 20-TeV bunch is approximately 40 mrad. (See Figure 2.) Displacement of the bunch with the *X*-size of 100 μm in a transverse direction by the distance of 1 μm typically will cause a deflection of the electron beam of approximately 0.8 mrad, which at the distance of 50 cm from the 20-TeV beam center translates to approximately 0.4 cm. Such a distance is well measurable by fast position-sensitive detectors developed for high-energy experiments, such as position-sensitive photomultipliers, multichannel plates, and microstrip silicon detectors. Coordinate resolution of such detectors is 5–50 μm, and collection time is approximately 10 ns. Therefore, it is possible to measure bunch displacements of the submicron level on a bunch-by-bunch basis.

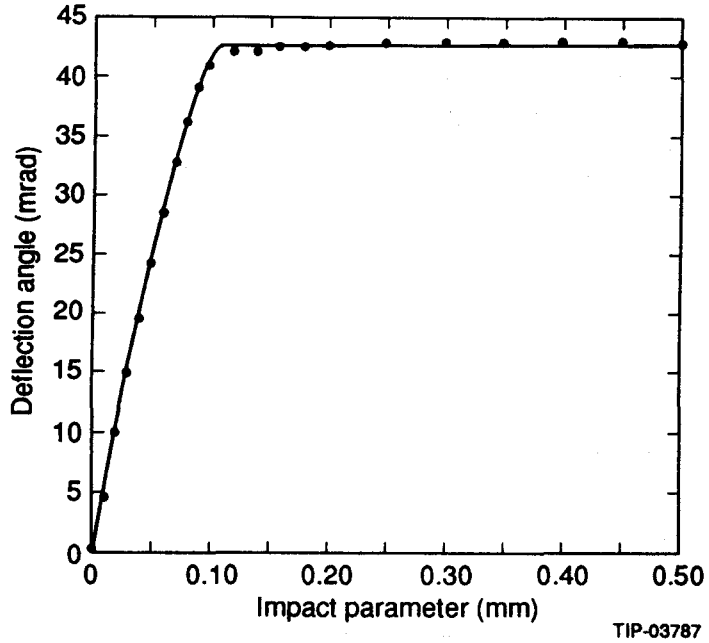

Figure 2. Deflection Angle vs. Impact Parameter of the Electron Beam. Cylindrical shape of a bunch is used with radius of 100 μm and length of 10 cm, the number of protons in a bunch being equal to 10^{10}.

3.0 SPATIAL RESOLUTION AND PERFORMANCE

Of course, the real spatial resolution of the device is mostly defined by the spot size of the probe electron beam. We suppose that a commercially available electron gun with the *X*-spot size of the order of 1 μm could be used for the device. In the *Z*-direction, the electron beam could be as large as 1 cm. In that case the center-of-gravity method could give a submicron accuracy of the bunch position measurements.

To measure a center of gravity of the deflected beam spot with an accuracy sufficiently better than the spot size itself, one should detect a large enough number of electrons in a time interval of approximately 30 ps to be able to reduce statistical fluctuations. If we suppose that 1000 electrons detected is a reasonable number, then we come to the current of the electron gun (*e*-gun) of the order of 0.5 mA/mm^2, which is well within technical availability. A local radiation level at the position of the detector, hopefully, is much smaller than the *e*-gun current.

To adjust proper timing so that it corresponds to the longitudinal center of the bunch, one can use fast gating on the gun or the detector, or one can sweep the electron beam after it has been deflected by the bunch, synchronous to the main rf in the horizontal (and vertical) direction in the geometry. This gives a coincidence of the electron beam hitting the bunch center and the detector position. The size or the aperture of the detector is approximately 1 cm. All the signals should be transmitted from the detector to the feedback electronic pipeline in the time interval between two adjacent bunches, *i.e.*, in 17 ns in the Collider rings, the High Energy Booster, the Medium Energy Booster, and the Low Energy Booster.

Parallel reference measurements with an *e*-gun on a large impact parameter position could be envisioned to reduce systematic errors in the system. The zero position of the electron beam spot could be monitored continuously in between the bunches.

REFERENCES

1. E. Tsyganov, R. Meinke, W. Nexsen, S. Kauffmann, A. Zinchenko, and A. Taratin, "Electron Beam Emittance Monitor for the SSC," SSCL-Preprint-179, December 1992.
2. E. Tsyganov and A. Zinchenko, "ZBEAM, Charge Tracing Code for the SSC Environment," in publication.