Review of Tevatron BPM Requirements Document

Review Committee
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1 Context

Improvement of the Tevatron beam position monitor system signal processing electronics is needed to satisfy the demands of Run II. A requirements document has been developed[1] and may be found at http://beamdocs.fnal.gov/cgi-bin/public/DocDB/ShowDocument?docid=554. The Run II Upgrade Plan calls for a review of these requirements as part of a level C milestone designated as WBS item 1.3.4.6.4.2. This report constitutes that review.

2 Charge to the Committee

1. Are the requirements described in the document adequate to the needs of Run II as they are recognized today and as collider operational demands will evolve consistent with the Upgrade Plan?
2. Are we paying adequate attention to a future beyond Run II?

3 Background

A description of both the Beam Position Monitor (BPM) and the Beam Loss Monitor (BLM) systems as initially installed may be found in a 1983 paper by Shafer, Gerig, Baumbaugh, and Wagner[2]. A major worry during construction of the Tevatron was quench susceptibility, which produced the requirement for measurement at very low beam current, at the level of 10^8 protons per bunch at the head of the bunch train. This low bunch charge sensitivity is no longer needed.

The BPM system was designed with a clear understanding of fixed target operation and with such anticipation of the needs of collider operation as was possible in 1979[3]. The choice of 8-bit analog-to-digital converters to deliver 150 μm position resolution to the control room was a

cost consideration, in no way connected with monitor sensitivity. At that time, the instantaneous luminosity target for antiproton-proton collisions was 10^{30} cm^{-2}sec^{-1}. Bunch coalescing and helical orbit separation were expected modes of operation, as stated in the 1979 report.

Coalesced bunches were to appear at subharmonics of the 53 MHz RF frequency of the Tevatron. The example in the 1979 report used 21 bunches. Since $1113 = 21 \times 53$, a 53 MHz filter in the electronics was appropriate. That this filter also has a passband centered at 2.5 MHz with a width of 3 MHz was not seen as a problem until other bunch structures were introduced at the beginning of collider commissioning in 1985.

At present, the 150 μm resolution limit is regarded as too large by about an order of magnitude. Today's Tevatron is a far more complicated device not only because of the higher luminosity goals of Run II, but also a result of the substantial physical deterioration and modification that has taken place over the two decades since commissioning. An example of the deterioration is the appearance of a strong skew-quadrupole term in the main dipoles, compensation for which is a present topic of study[4]. Measurement of the resulting 1 m vertical dispersion wave with 5% accuracy itself needs a resolution of better than 50 μm.

The BPM detectors in the quadrupoles are striplines of length 20 cm with terminals at each end for signals of particles travelling in either direction. The rejection ratio is about an order of magnitude. It is not proposed to replace the monitors, other than those that require repair. Signals from the antiproton end are currently disconnected.

In summary, three principal issues in the BPM upgrade are:

1. Improvement of the position resolution by an order of magnitude,
2. Correction of measurement error related to bunch pattern, and
3. Conveyance of signals from both particle species to the control room.

4 Response to the Charge

1. Are the requirements described in the document adequate to the needs of Run II as they are recognized today and as collider operational demands will evolve consistent with the Upgrade Plan? The Committee recommends that Upgrade Plan Management proceed toward implementation as itemized below:
   - Follow through with hardware design of signal processing electronics, based on the document,
   - Support the specification of software improvement,
   - Support tunnel installation needed for signals from both particle species.
   - Undertake cost *vis-a-vis* performance evaluation.
2. Are we paying adequate attention to a future beyond Run II?
   - This question did not elicit a clear response.

5 Comments

Recommendations related to the primary issues of resolution, bunch pattern, and signal availability are stated above. How the implementation expands beyond these basics is a subject for design evaluation and cost study.

The requirements document speaks of both self-triggered and externally triggered acquisition modes. These choices should be examined during the design process which will follow.

Though there is no mention of fixed target physics in the document, there is nothing in the description that would preclude a return to that mode of operation.

Higher resolution is possible. The RHIC system is capable of 1 μm resolution, and is routinely used to gain information at the 10 μm level. This is a cost consideration.

Further comments from the committee members may be found at the web site associated with this review: http://www-bd.fnal.gov/run2upgrade/reviews/Tev_BPM_requirements_Sep03.html.

References

[1] M. Martens, J. Steimel, J. Annala, *Tevatron Beam Position Monitor Upgrade Requirements*, Fermilab/BD//TEV/beams-doc-554-v3, September 2003.

[2] R. Shafer, R. Gerig, A. Baumbaugh, C. Wagner, *The Tevatron Beam Position and Beam Loss Monitoring Systems*, Proceedings 12th International Conference on High-Energy Accelerators, Fermilab, August 11-16, 1983.

[3] F. T. Cole, editor., *A Report on the Design of the Fermilab National Accelerator Laboratory Superconducting Accelerator*, Fermilab, May 1979.

[4] D. Edwards and M. Syphers, *Strong Transverse Coupling in the Tevatron*, Beams-doc-501, Fermilab, March 2003.