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BPM Alignment Tolerance Considerations

This note discusses the impact on MI performance due to BPM misalignment. It considers only the BPMs at the quadrupole locations within the arcs. The special large aperture BPMs adjacent to extraction Lambertsons may well have different requirements. The BPM electrode configuration is shown in Figure 1.

Vertical alignment

1. I*mpact on physical aperture.* The nominal beampipe aperture is taken to be ±25.4 mm outside dimension, with a 1.5 mm wall thickness, so the inside dimension is 23.9 mm. This corresponds to an 8 GeV admittance of 90 π mm-mrad (for β = 60 m). Our design goal is 40 π mm-mrad; however for the purposes of BPM alignment, we set the criterion that the admittance should not be less than 70 π mm-mrad. This corresponds to a physical aperture of 21 mm, i.e. we could have up to a 2.9 mm BPM encroachment into the beam area and still provide 70 π mm-mrad admittance.

2. *Impact on resolution.* The BPM response is linear for beam centroids out beyond 10 mm offset. (See Figure 2.) BPM offsets of less than 5 mm will have no affect on resolution over the normal operating range of the MI.

Horizontal alignment

1. *Impact on physical aperture.* The BPM alignment does not affect the physical aperture in the horizontal plane.

2. *Impact on resolution.* The BPM resolution is flat out to 5 mm, growing slowly worse beyond that point. (See Figure 3.) It is still less than 0.25 mm at an offset of 15 mm. Once again, offsets of less than 5 mm are acceptable.

Both planes

1. *Loss of dynamic aperture.* Tracking studies done with BPM offsets equal to an rms of 1.0 mm show a decrease in dynamic aperture from 31 mm to 27 mm. These studies assume the orbit is corrected to the center of the mis-aligned BPMs. In practice, aperture scans will explore the beam aperture and desired positions determined which maximize the beam lifetime. Nevertheless, the tracking studies

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provide a useful measure of the relevant scale. A significantly larger decrease in dynamic aperture would be worrisome, due to the difficulty in distinguishing between real closed orbit errors and perceived errors due to BPM offsets, and therefore an rms on the order of 1 mm should be maintained. This would, for a Gaussian distribution, correspond to a maximum offset of about 2.5 mm.

2. *Impact on corrector strength.* Additional tracking studies, with offsets up to 5 mm rms, have shown a small increase in closed orbit error before smoothing, and a corrector strength dependence which is approximately linear with the error, at least for large offsets. The small increase in closed orbit error can be understood as follows: the closed orbit errors have three main sources: BPM misalignments, quad misalignments, and dipole strength errors (horizontal plane) or dipole rolls (vertical plane). The quad and dipole errors produce non-local distortions which can add coherently, (producing closed orbit errors of about 6 mm for small BPM errors), while the BPM errors are strictly local, and add merely in quadrature. The additional closed orbit error is in fact only a perceived increase, however.

The increase in corrector strength required to correct for BPM offsets pertains only if one smooths the orbit to give zero BPM readings. It becomes an issue only at high energy as the corrector strength decreases with 1/p. Low energy aperture scans may give no information about BPM offsets if the physical and dynamic apertures are both large. In that case, one can merely set the desired offset at all energies to minimize the correction required for each such location. If the aperture is restricted, then one finds a relative (to the unknown BPM-offset) desired position. In that case the BPM offset is of no consequence whatsoever.

Summary

The BPM alignment tolerance is 2.5 mm. This is to be interpreted as a maximum random error; systematic misalignments should be less than 1 mm.

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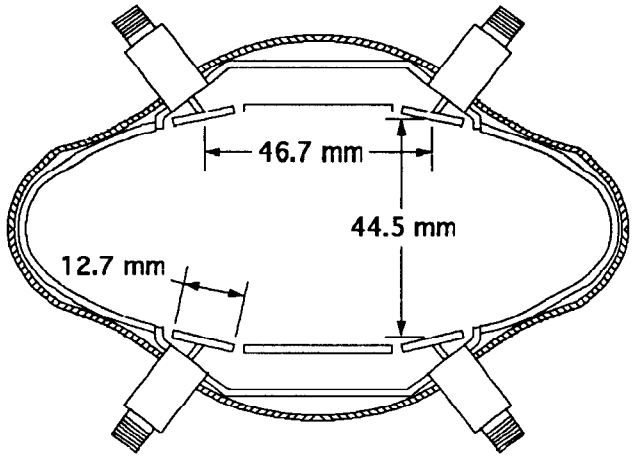

Figure 1. BPM Design

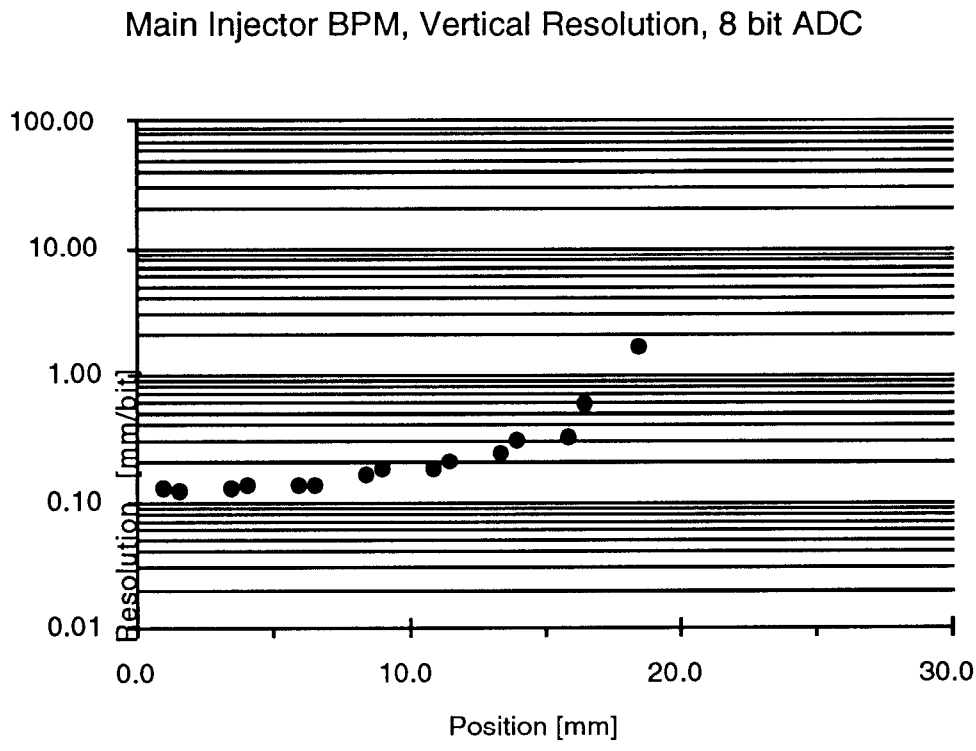

Figure 2. Vertical BPM Resolution vs. Position