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Tevatron BPM Upgrade Calibration Specifications: Part II

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Abstract

This note describes the minimal set of calibration information which is needed for the commissioning period in August 2004.

1 Change Log

v1 First release.

2 Introduction

Beams-doc-1161 discusses the computation of position and intensity starting from the raw (I, Q) values from the 4 cables at one BPM location. Equations 1 through 5 give the full set of equations in terms of a set of calibration parameters. Although equations 4 and 5 are not quite right for the general case, they are good enough for purposes of this document.

For the commissioning tests that will done in August 2004, most of these calibration parameters will not yet have been determined, and, as an initial approximation, should be set to to 0 or 1, as appropriate. This note states the approximations which will be used and writes out the equations in their simplified form:

Except for one change, I will use the notation from Beams-doc-1161. Because the equations are the same for both H and V measuring BPMs, I will drop the index H or V.

The discussion in sections 3 to 5 is valid for long gate sampling mode, either turn by turn or closed orbit. It is valid when there are only protons in the machine or when there are both protons and anti-protons in the machine. The case of only anti-protons in the machine is discussed in section 6. The case of short gate sampling mode is discussed in section 7.

3 Approximations Used

1. Ignore the electrical offset of the BPMs. In equation 1, $E_{offset} = 0$.

2. Ignore the offset between the center of the BPM and the center of the quadrupole correction magnet. In equation 1, $Q_{offset} = 0$. These displacements were measured and tabulated when the BPM's were built. Eventually we will use the tabulated values which are used in the existing BPM system.

3. In equation 1, presume that the scale factor $g = 26$ mm exactly and that it does not change from BPM to BPM. It is likely that this approximation will always remain in place.

4. Ignore quadratic correction on the intensity. In equation 2, $k = 0$.

5. Each BPM will make a standalone measurement without reference to other BPMs to access knowledge of the unmeasured coordinate.

6. The correction for the imperfect directionality of the BPMs will be one direction only: we will subtract the proton contamination on the anti-proton cables but we will ignore the anti-proton contamination on the proton cables. This affects equations 4 and 5.

4 The Equations for Intensity and Position

In the following the raw measurements produced by the Echotek card are denoted by A_P and B_P, for the proton cables, and by A_A and B_A, for the anti-proton cables. Each of these is a complex number (I, Q). The equations which transform the raw measurements, unprimed, to corrected measurements, primed, are:

$$A'_P = A_P \tag{1}$$
$$B'_P = B_P \tag{2}$$
$$A'_A = A_A - aA_P - bB_P \tag{3}$$
$$B'_A = B_A - cA_P - dB_P \tag{4}$$

Here a, b, c, d are complex constants which will be specified during the commissioning period. Until they are determined they should be set to (0.,0.). If meta-data exists, it should record when these constants have been zeroed. Note that I have changed the sign relative to the equations in Beams-doc-1161.

The proton and anti-proton "intensity" signals are given by:

$$P_{Intensity} = f(|A'_P| + |B'_P|) \tag{5}$$
$$A_{Intensity} = f(|A'_A| + |B'_A|) \tag{6}$$

where $||$ denotes the magnitude of a complex number and where f is a constant which I have introduced here for the first time. Until otherwise specified, set $f = 1$. It seems likely that f may never be changed from 1.

The measured positions, in mm, are given by,

$$
\begin{aligned}
P_{Position} &= g\frac{|B'_P| - |A'_P|}{|B'_P| + |A'_P|} && (7)\\
A_{Position} &= g\frac{|B'_A| - |A'_A|}{|B'_A| + |A'_A|} && (8)
\end{aligned}
$$

where $g = 26$, as discussed above.

5 Validity of Data

The proton and anti-proton data should be considered valid if the intensity signals satisfy:

$$
\begin{aligned}
|A'_P| + |B'_P| &\geq t_P && (9)\\
|A'_A| + |B'_A| &\geq t_A && (10)
\end{aligned}
$$

where t_P and t_A are thresholds, introduced here for the first time.

It would be prudent to keep these thresholds easy to change during the commissioning period. As an initial value use $t_P = t_A = 100$. This is motivated by studies using the Recycler Echotek boards in which the noise level, with no beam in the machine, is always less than 20 and the signal level, after the first bunch of either species is injected, is around 800. See, for example, page 4 of the file Feb27.ps in Beams-doc-1059-v1.

When the new boards are installed, the band between the noise and the signal may change because of changes to the filters and attenuators in the signal paths. It can also be affected by the gain of the filtering algorithm in the Grey chip.

It is possible for there to be valid data for one beam species but not for the other.

When raw (I, Q) is requested, it should be returned even if it fails the validity test above. Data below threshold is needed to study the quality of the cancellation of the non-directional components of the signal.

6 Anti-proton Only Stores

This section will discuss anti-proton position and intensity measurements during an anti-proton only store. It will be presumed that, during the commissioning period, one is not interested in the proton data for such a store.

For an anti-proton only store the anti-proton data can be computed using the above formalism with $a = b = c = d = (0., 0.)$. In this case the data for the proton signals will contain uncanceled contamination from the anti-protons. This cancellation will be dealt with at a later time.

If one just uses the above formalism, without zeroing the cancellation coefficients, the result will probably remain qualitatively correct.

7 Short Gate Mode

For short gate mode, the above formalism applies with the exception that $a = b = c = d = (0., 0.)$. Unlike the discussion in the previous section, one must do this or else the anti-proton measurements are completely meaningless.

Remember that, in short gate mode, the anti-proton measurements are only valid for one cogging state.

8 Phase Conventions

There are two phase conventions which we will need to verify are correct.

1. In the configuration currently used for the studies with the modified Recycler Echotek board, the sign of the position is given by $|B| - |A|$. The configuration includes the cabling, the lumberjack data logger, and everything in between. The sign could change if the configuration of the new system changes relative to that of the existing one. We will ultimately determine this sign by bumping the beam and measuring the change in position. For the very first tests this sign is of minor importance but we should get it right before we make any PR plots.

2. I have used $A = (I, Q)$, not (Q, I). I have no idea if this is the standard usage or even if there is a standard. This convention has observable consequences only for equations 3 and 4. It is important that the convention used to calculate a, b, c, d be consistent with that used when applying the correction. The correct choice can be verified by seeing if the corrected anti-proton intensity signal stays small when there are only protons in the machine.