

Beams-doc-1451-v2

BPM Calibration Discussion

Rob Kutschke

- Part 1:
 - First shown on Nov. 22, 2004.
- Part 2:
 - First shown on Nov. 15, 2004.
(Yes, the dates are backwards)

Part 1: Scales of Interest

- Analog effects from pickups to digitizer:
 - Differential attenuation: $0.1 \text{ db} = 150 \mu\text{m}$.
 - Differential phase shift: $1^\circ = 10 \mu\text{m}$.
- Digitizer:
 - In closed orbit mode. An offset of a full bit $40 \mu\text{m}$ for a single bunch and about $1 \mu\text{m}$ for 36 bunches.
 - Both are small compared to the relevant resolution.
- Time Stability
 - Long term stable.
 - “Medium” term stable.
 - Requires time dependent calibration.
 - Random or quasi-random on a time scale of 500 Hz.
- Some may depend on mode of operation.
- Goal:
 - Discover the limiting effects so we do not have to waste time on effects which are not limiting.

Classes of Effects

1. Effects of beam species being measured.
 - (a) Intensity.
 - (b) Position in coordinate being measured.
 - (c) Position in other coordinate.
 - (d) Angle of beam through the pickups.
 - (e) Lebedev head-tail effect.
2. Effects of the other beam species.
 - Will discuss another day.
3. Instrumental effects:
 - (a) Mechanical offset of the electrical center of pickups from the magnetic center of the quads.
 - (b) Feed-thrus from pickups to tunnel.
 - (c) Cables from tunnel to house.
 - (d) Filter board
 - (e) Digitizer.
 - (f) Phase of the 7/5 at the start of the measurement.

1. Instrumental effects:

- (a) Mechanical offset of the electrical center of pickups from the magnetic center of the quads.
 - Table of corrections exists.
 - Uncertainty on correction is: $???? \mu\text{m}$.
- (b) Feed-thrus from pickups to tunnel.
 - I don't have any information about differential attenuation and phase shift in these. *Is there any info?*
- (c) Cables from tunnel to house.
 - I have an excel spreadsheet from Marv Olson with both differential attenuation and phase shifts.
 - Uncertainty on this information: $???? \mu\text{m}$.
- (d) Filter board
 - Spec for analog filters:
 - $< 1^\circ$ of differential phase shift.
 - $???$ db of differential attenuation.
 - *Other effects?*
- (e) Digitizer.
 - Small compared to the resolution but may be relevant if we average many measurements.
- (f) Phase of the 7/5 at the start of the measurement.
 - We saw before that adding low pass filters made this small enough to be not limiting. Need to recheck.

Old Electrical Offsets

- Information from a discussion with Marv Olson.
- In the tunnel disconnect cables from BPM and inject balanced signal into the two cables.
- Signal types: Single bunch and 20 consecutive buckets.
- Read position using old BPM electronics.
- Use this position the measured offset.
- Compare with offsets inferred from differential attenuation and phase shift measured in the cables:
 - In most cases the offset is dominated by the electronics, not the cables.
 - There are a few cable pairs for which the cable properties are important.

Part 2

References on Calibration

- Beams-doc-1161, Derivation of main equations.
- Beams-doc-1205, What was done before shutdown.
 - With some small changes recommend we start the same way after the shutdown.
- Beams-doc-1149, Quadratic term.

Raw vs Corrected Measurements

$$A'_P = A_P$$

$$B'_P = B_P$$

$$A'_A = A_A - aA_P - bB_P$$

$$B'_A = B_A - cB_P - dA_P$$

- All quantities above are complex.
- Unprimed are raw measurements.
- Primed are corrected measurements.
- Notation anticipates that, in the future, the raw and corrected Proton measurements may be distinguished.
- Determination of (a, b, c, d) described later.

Intensity Will be Reported in Echotek Units

$$I_P = |A'_P| + |B'_P|$$
$$I_A = |A'_A| + |B'_A|$$

- Following discussions with Mike and others it was decided that the front ends will report the intensity in raw Echotek units, *without* a correction for beam energy or any other factors.
- This comes closest to current practice.
- One can imagine many improvements to this but they are all off the table for the scope of this project.
- Proposal to define tresholds for valid data:

$$|A'_P| + |B'_P| \geq t_P \qquad |A'_A| + |B'_A| \geq t_A$$

- where $t_P = 100$ and $t_A = 100$. (previously: $t_A = 50$).

Computation of Proton Position

- Using the notation of Beams-doc-1161.

$$P_{posraw} = g \frac{|B'_{HP}| - |A'_{HP}|}{|B'_{HP}| + |A'_{HP}|} + E_{offset}$$
$$P_{Intensity} = |A'_{HP}| + |B'_{HP}| - kP_{posraw}^2$$
$$P_{final} = g \frac{|B'_{HP}| - |A'_{HP}|}{P_{Intensity}} + E_{offset} + Q_{offset}$$

P_{posraw}	Raw position
$P_{Intensity}$	Corrected intensity
P_{posraw}	Corrected position
g	Scale factor dictated by spacing between BPM plates. Propose: $g=26$ mm for all BPMs.
E_{offset}	Electrical offset: measured displacement between physical center and electrical center of BPM. See next page.
Q_{offset}	Offset of center of BPM relative to center of quadrupole correction element. Propose: use values from before. (Can be zero on day 1.)
k	Quadratic correction parameter See next page.

- E_{offset} and k affected by:
 1. Properties of the pickups.
 2. Differential attenuation and phase shifts in the cables, connectors, going to the houses.
 3. Differential attenuation and phase shifts analog filters and attenuators . . .
 4. Differences among digitizers.
- In the old system
 - E_{offset} corrected only for properties of the BPM electronics (analagous to 3); other effects were ignored.
 - I don't think that there was an analog of k .
- Beams-doc-1149 discusses how to find k but only if we can safely ignore, or correct for, the effects of 1 and 2.
- For startup: propose to set both E_{offset} and k to zero.
- What we could do if we wanted to:
 - Attack 1 and 2 it by sending signals from the house, through the BPM and back up.
 - Attack 3 and 4 by bench tests (for board swap). Is it big enough to worry about?
- Not yet a fully formed plan.

Computation of Positions at Startup

- Calculation for anti-protons is similar to that discussed for protons.
- Final results for startup:

$$D_P = g \frac{|B'_P| - |A'_P|}{|B'_P| + |A'_P|} + Q_{offset}$$
$$D_A = g \frac{|B'_A| - |A'_A|}{|B'_A| + |A'_A|} + Q_{offset}$$

- D is displacement (position) in mm.
- $g = 26$ mm
- Q_{offset} is the same for protons and Pbar; it is a property of the physical construction of the plates.

Things to Come

- Computation of correction coefficients to subtract proton contamination from pbar cables.
- When is it useful to do grid studies?
- When should we do a store with reversed helix?
- When should we do a pbar only store?
- What to do about position bias as a function of intensity (Beams-doc-1406)?
- What to do about occasional bad outliers, Beams-doc-1301?
- What to do about difference in measured position in short gate vs closed orbit mode? Beams-doc-1197. Difference for protons is about $50 \mu\text{m}$. Difference for pbars is about $600 \mu\text{m}$.