
Tevatron BPM requirements

Mike Martens

Tev BPM Requirements

Goal of this talk:

Summary of the requirements for the BPM system.
Emphasis on aspects relevant to the technical design.

Brief introduction to the Tevatron.
Motivation for an upgrade.

Supply some details on bunch structures
and introduce some definitions.

Motivation for an Upgrade

- o The present system is ~20 years old.
- o Stable orbits are increasingly important for Collider operations with higher luminosity, and higher beam intensities.
- o Improved position resolution and turn-by-turn capabilities are necessary for a better understanding of the Tevatron accelerator.

Choice of Requirements

The requirements for the upgraded system:

- o Based on past experience and discussions with the Tevatron and Beam Physics members.
- o Have been well documented and “published.”
See Beams-doc-554-v4.
- o Have been reviewed and approved.

Uses of the BPM system

- ❑ Measuring the closed orbit positions during collider operations.
- ❑ 1st turn orbit and intensity data for commissioning and diagnostics.
- ❑ Lattice and coupling measurements using turn-by-turn (TBT).
- ❑ TCLK triggered data collection.
- ❑ Diagnosing aborts using a circular buffer of closed orbits.
- ❑ 1st turn and TCLK triggered closed orbit data for injection closure.
- ❑ Archiving orbits during shot setups with the (SDA.)
- ❑ Fast time plotting (FTP) of orbits positions during aperture scans.
- ❑ Lattice measurements using the 1-bump technique.
- ❑ Closed orbit measurements during accelerator studies.
- ❑ Maintaining the orbit positions at CDF and D0 during a collider store.

Key Requirements

- o Protons and Antiprotons circulate simultaneously
- o Separators produce a helical orbit
- o Tev uses both coalesced and uncoalesced beam

Require:

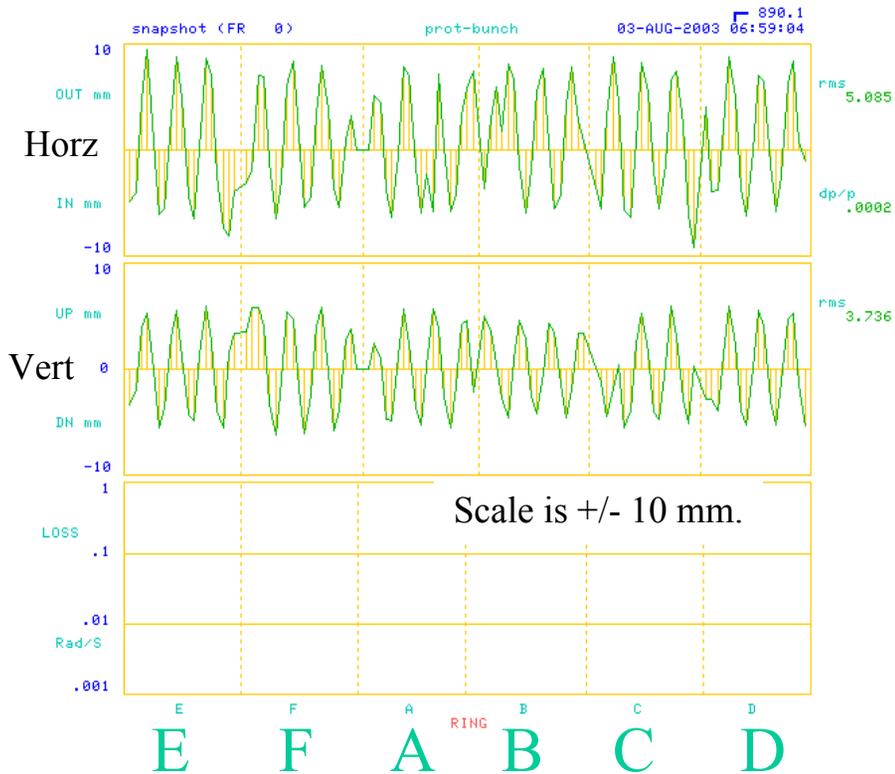
- o Accurate closed orbits for both protons and pbars.
- o Single turn measurement (with protons only) for tune up
- o Turn-by-turn (TBT) measurements (with protons only)
- o Abort buffer (circular buffer halted on Tev abort)
- o Triggered data acquisition

Key Requirements

What is NOT required:

- o Measure injection first turn except for first injected bunch or un-coalesced bunch train
- o Measure TBT positions with both protons and pbars circulating
- o Support bunch-by-bunch measurements with both protons and pbars circulating.

Helical orbits



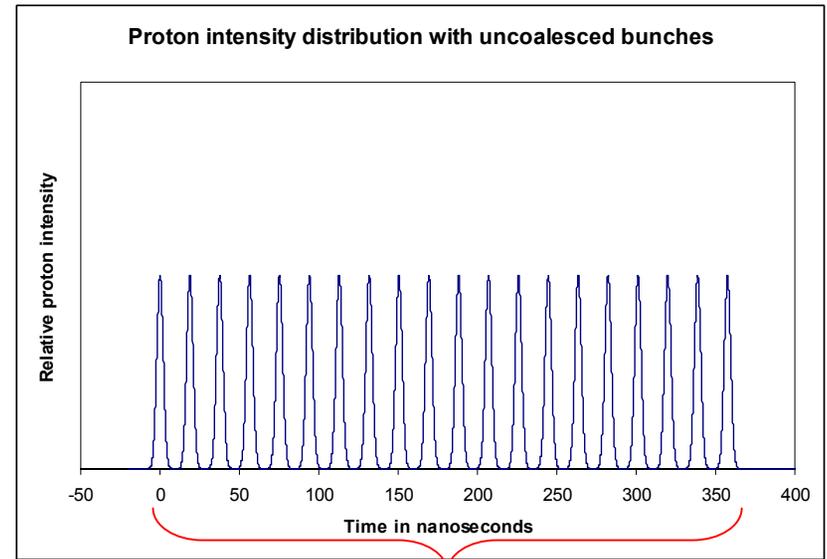
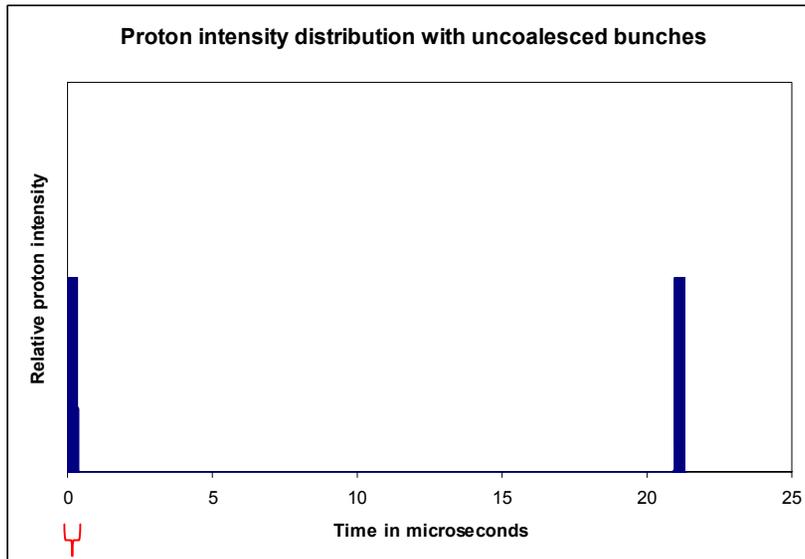
Orbit changes for protons when the electrostatic separators are used.

Pbar orbits change in other direction.

~100 BPMs in each plane

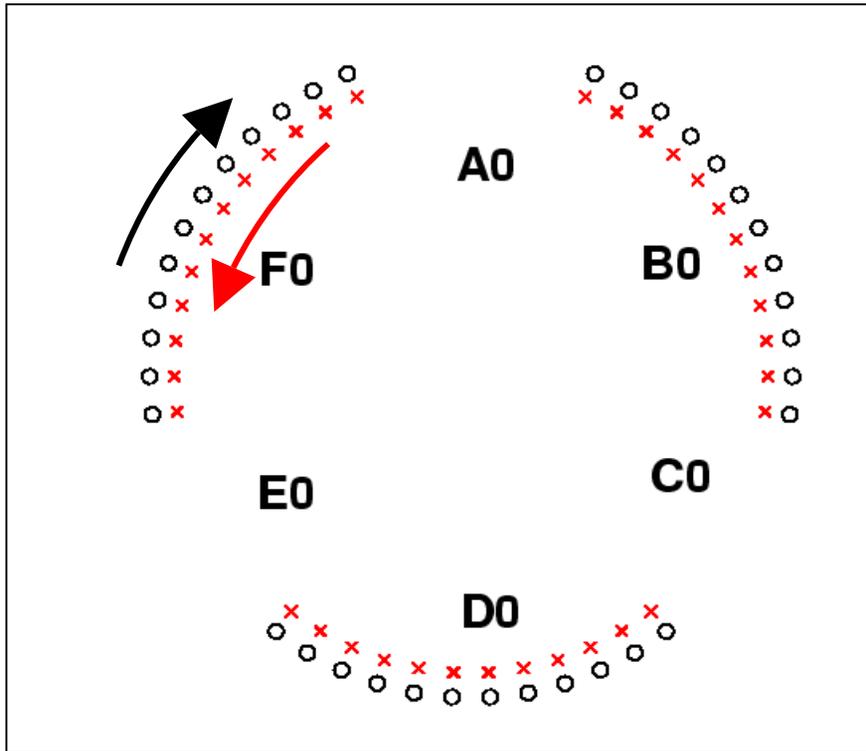
Six sectors in the Tevatron

Uncoalesced Beam



Bunch structure with uncoalesced protons in the Tevatron. There is a group of 20 to 30 consecutive bunches spaced one RF bucket (18.8 nsec) apart followed by a gap of ~ 20 μ sec without beam before the group returns after one revolution. The lower figure shows the beam over a little more than one revolution and the upper figure zooms in on the consecutive bunches.

Coalesced Beam



36 x 36 configuration
396 nsec bunch spacing

3 x 12 proton bunches

3 x 12 pbar bunches

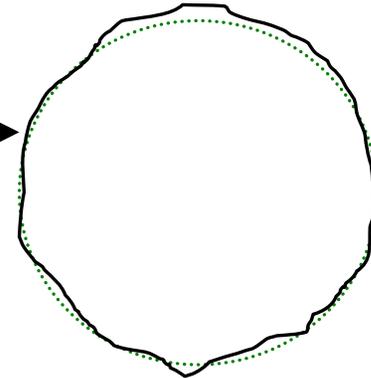
Types of Orbits

The Closed Orbit

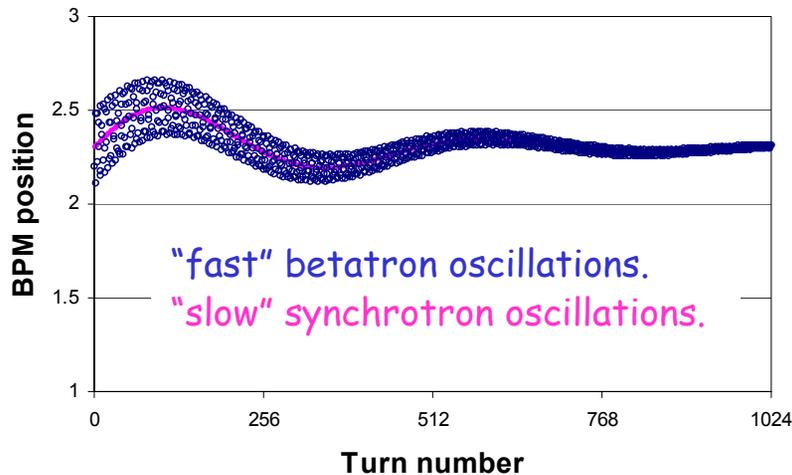
Closed orbit:

A particle with no betatron or synchrotron oscillation returns to the same position every turn.

Not necessarily in the center of the BPM!



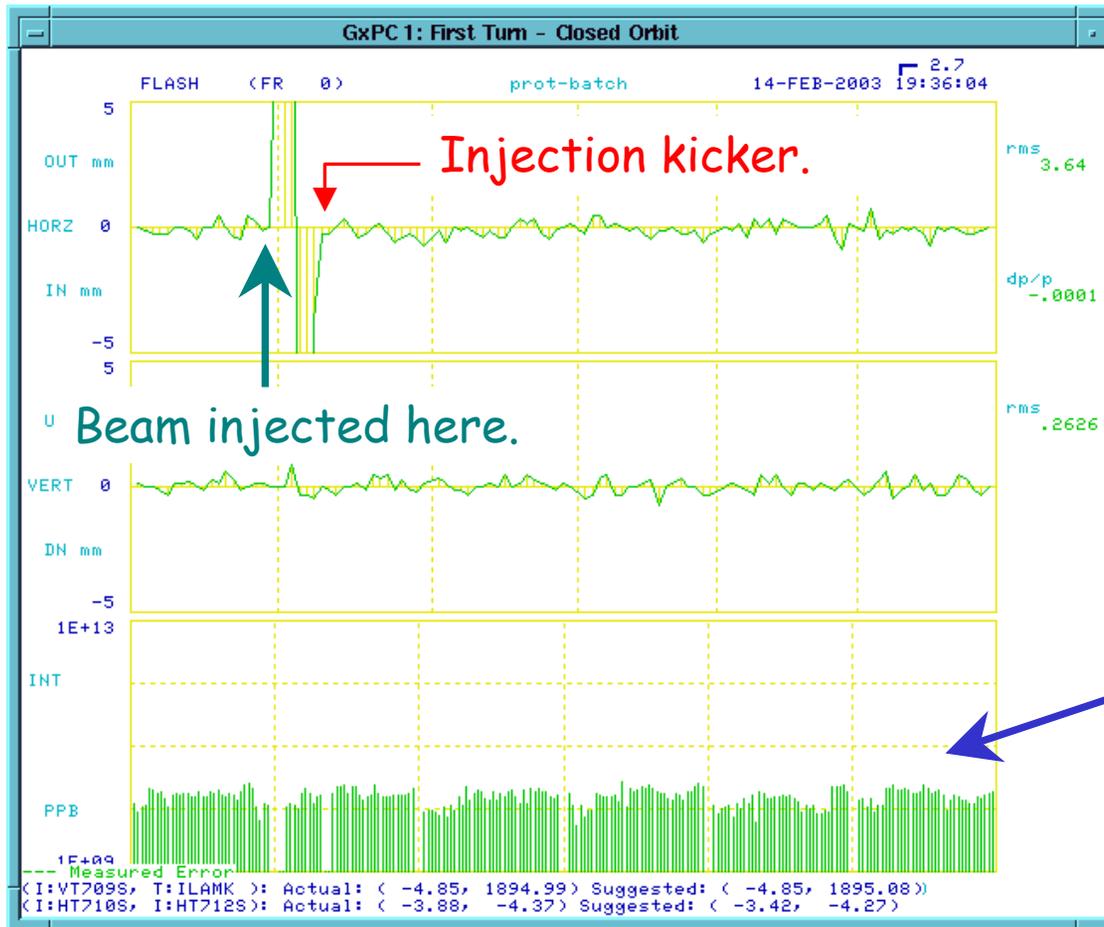
BPM position versus turn number



BPM position settles on the closed orbit.

Can use "averaging" to improve signal/noise.

Single turn measurement

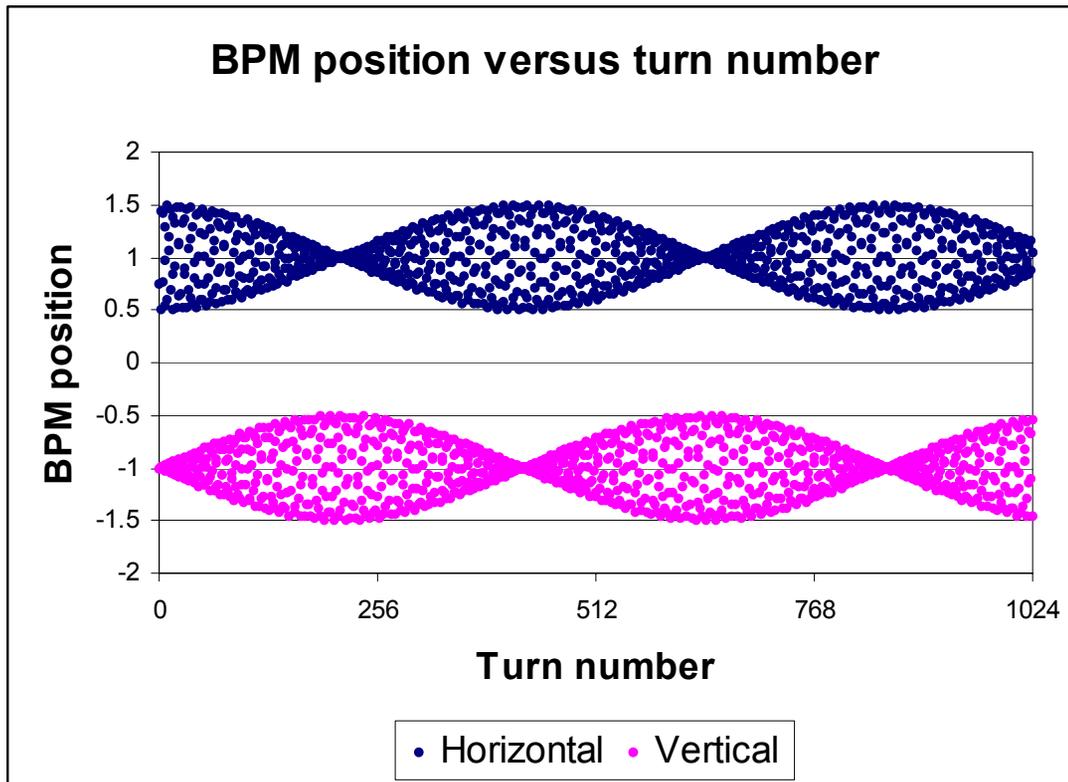


This plot shows the difference of the 1st turn orbit with the closed orbit subtracted.

Intensity measurements important for diagnosing first turn injection problems.

Types of Orbits

The Turn-By-Turn (TBT)



Turn-by-turn

measurement:

Measure the position from a single pass of beam.

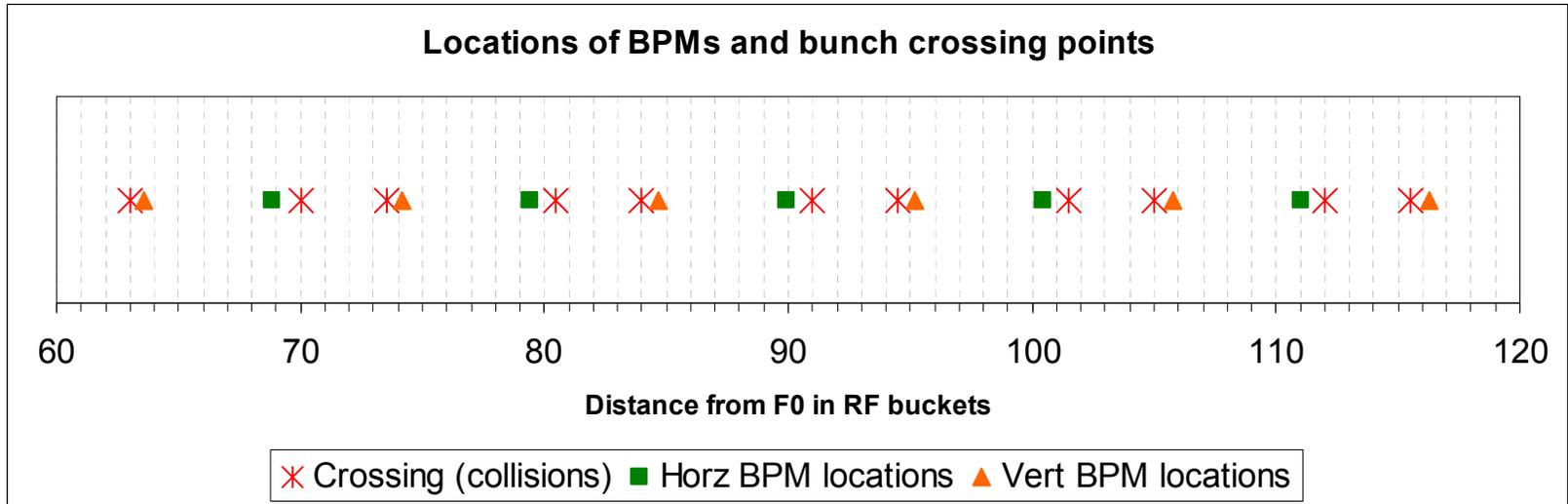
Measure the position on consecutive turns.

BPMs synchronized to get orbit on the same turn.

Shows the coupling.

Energy transferred from horizontal to the vertical plane and back.

Cogging, crossings, BPMS

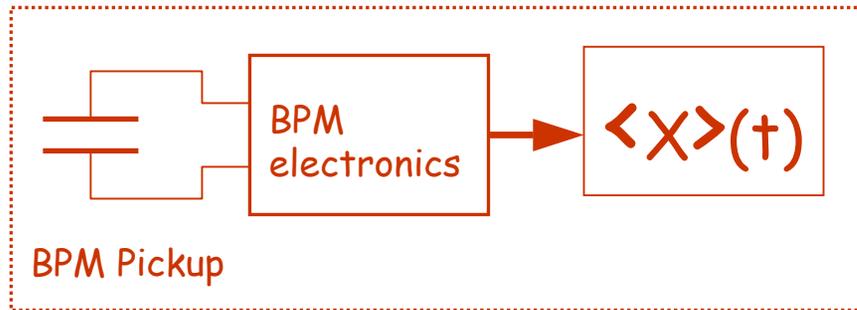


Cogging affects locations of proton and pbar bunch crossings.

Has implications for separating proton and pbar signals at the locations of the BPMS

Methods of data collection.

In closed orbit mode: (the default measurement type.)



$\langle X \rangle(t)$ can be:

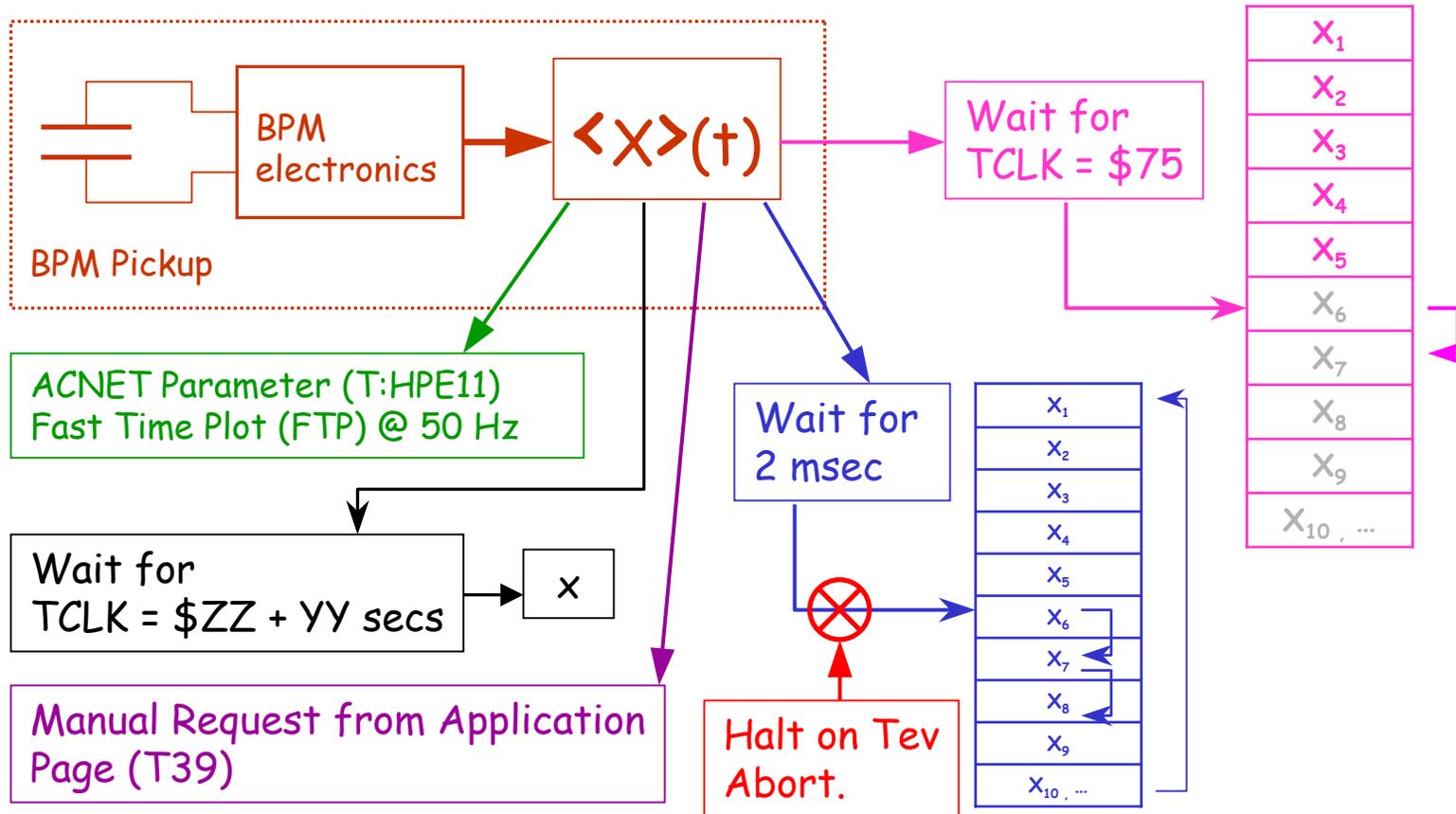
Protons OR Pbars

Coalesced OR Uncoalesced

No requirement for separate channels.

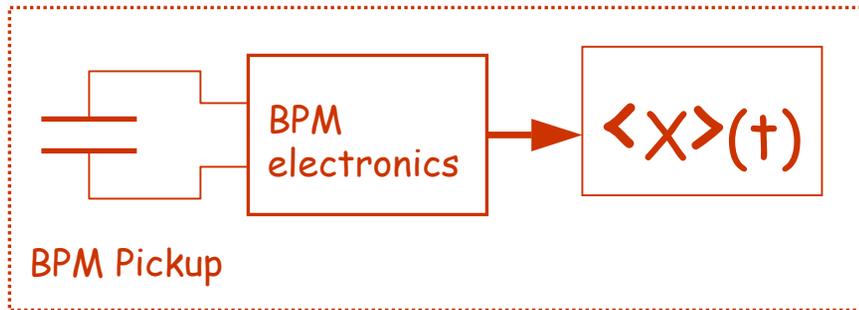
Methods of data collection.

In closed orbit mode: (the default measurement type.)



Methods of data collection.

In single-turn mode:



Arm can be on TCLK,
State Device Transition,
or Manual Request.

1. Arm for single turn measurement.
2. BPM "electronics" ready in 1 msec.
3. Wait for TCLK trigger
4. Collect single-turn position and intensity
5. Store data in buffer
6. Return to Closed Orbit Mode in 1 msec.

All BPMs must collect
position and intensity on
the same revolution.

Intensities

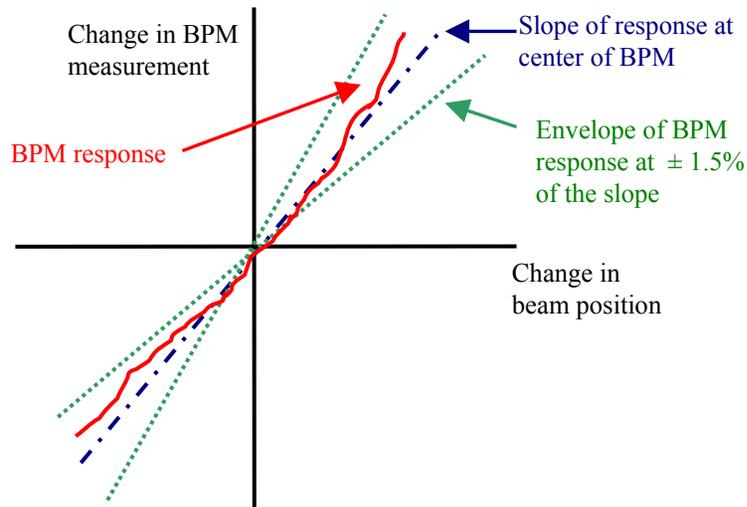
Range of intensities and bunch lengths expected in Collider Run II.

	Particles/bunch	Number of bunches	Bunch length (3σ value in nsec)
Uncoalesced Protons	3e9 to 30e9	30	3.5 to 10
Coalesced Protons	30e9 to 350e9	1 to 36	4.5 to 10
Coalesced Antiprotons	3e9 to 150e9	1 to 36	4.5 to 10

Relative intensity of protons to pbars is expected to be 2:1 by end of Collider Run II.

Pbar intensity will affect the proton signal !!

Linearity



**BPM positions needed
over a ± 15 mm range
from the center.**

Definition of the linearity requirement for the Tevatron BPM.
Note that the requirement on the linearity of the BPM response
does not constrain the slope of the BPM response.

Change in BPM measurement $\pm 1.5\%$ of the slope

Resolution

Orbit position resolution

The smallest change in beam position that the BPM system can reliably measure.

For the most precise measurements the orbit position resolution is 0.007 mm rms.

Note: the present system has 0.15 mm Least Significant Bit (LSB) on the A/D.

List of Requirements

Measurement Purpose	Beam Structure	Data Acquisition Type	Position accuracy and resolution
Proton closed orbit during a store.	36x36.	Manual. Buffered on TCLK. ACNET variable. FTP variable.	Position resolution of 0.007 mm.
Proton single turn for injection tune up.	Prot uncoal.	Single turn, triggered on TCLK.	Position resolution of 0.05 mm.
Pbar closed orbit during a store.	36x36.	Manual. Buffered on TCLK. ACNET variable. FTP variable.	Position resolution of 0.05 mm.
Proton closed orbit during ramp and LB squeeze	36x36. Prot coal. Prot uncoal.	Buffered on TCLK. ACNET variable. FTP variable.	Position resolution of 0.05 mm.

List of Requirements

Measurement Purpose	Beam Structure	Data Acquisition Type	Position accuracy and resolution
Proton single turn for injection commissioning.	Prot uncoal.	Single turn, triggered on TCLK.	Position resolution of 0.1 mm.
Proton closed orbit for injection commissioning.	Prot uncoal.	Buffered on TCLK	Position resolution of 0.05 mm.
Proton single turn for injection tune up.	Prot uncoal.	Single turn, triggered on TCLK.	Position resolution of 0.05 mm.
Proton closed orbit for injection tune up.	Prot uncoal.	Buffered on TCLK.	Position resolution of 0.02 mm.

List of Requirements

Measurement Purpose	Beam Structure	Data Acquisition Type	Position accuracy and resolution
Closed orbit circular buffer.	36x36. Prot coal. Prot uncoal. Pbar coal.	Circular buffer halted on Tevatron Abort.	Position resolution of 0.007 mm.
Aperture scans	Prot coal. Prot uncoal.	Manual. Buffered on TCLK. ACNET variable. FTP variable.	Position resolution of 0.007 mm.
Lattice measurements	Prot uncoal. Prot coal.	Manual. Buffered on TCLK. ACNET variable. FTP variable.	Position resolution of 0.007 mm.
Lattice and coupling measurements	Prot coal. Prot uncoal.	TBT buffer.	Position resolution of 0.007 mm.

Conclusion

Requirements have been well defined, documented, reviewed, and approved.

The Tevatron has/needs:

- both protons and antiprotons
- coalesced and uncoalesced beam
- separated proton and pbar orbits (helical orbits)
- closed orbit, single turn, and TBT measurement
- triggered position measurement data acquisition
- circular buffer capabilities

The challenge is build a system to meet all of these needs.