Uses of the BPM system

- Measuring the closed orbit positions during collider operations.
- TCLK triggered closed orbit data collection for orbit smoothing.
- Maintaining the orbit positions at CDF and D0 during a collider store.
- 1st turn orbit and intensity data for commissioning and diagnostics.
- Multi-turn orbit and intensity data for commissioning.
- 1st turn and TCLK triggered closed orbit data for injection closure.
- Last turn data for tune up and diagnostics of the A0 beam dump.
- Diagnosing aborts using a circular buffer of closed orbits.
- 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.
- Lattice and coupling measurements using turn-by-turn (TBT).
- Closed orbit measurements during accelerator studies.

BPM Measurement Modes

- Closed Orbit – Low bandwidth (1kHz), best resolution mode. Default operational condition for Tevatron. Will measure proton and pbar positions simultaneously.
- Turn by Turn – High bandwidth (100 kHz), fast trigger mode (every revolution of the Tev). Capable of storing 8192 consec-utive measurements at 47 kHz rep rate.
- First Turn – Subset of turn by turn operation, but synchronized with Tev injection.

Significant Tev BPM Philosophy

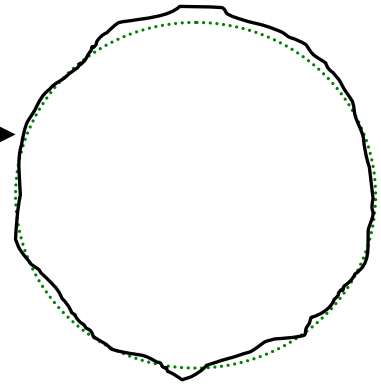
- Beam in Tev always has 53 MHz component. The system derives position from the 53 MHz fundamental component.
- System triggering will switch from beam based to external synchronization.
- System will be event driven. Frontend will listen to TCLK and state changes.
- System will measure protons and pbars simultaneously.

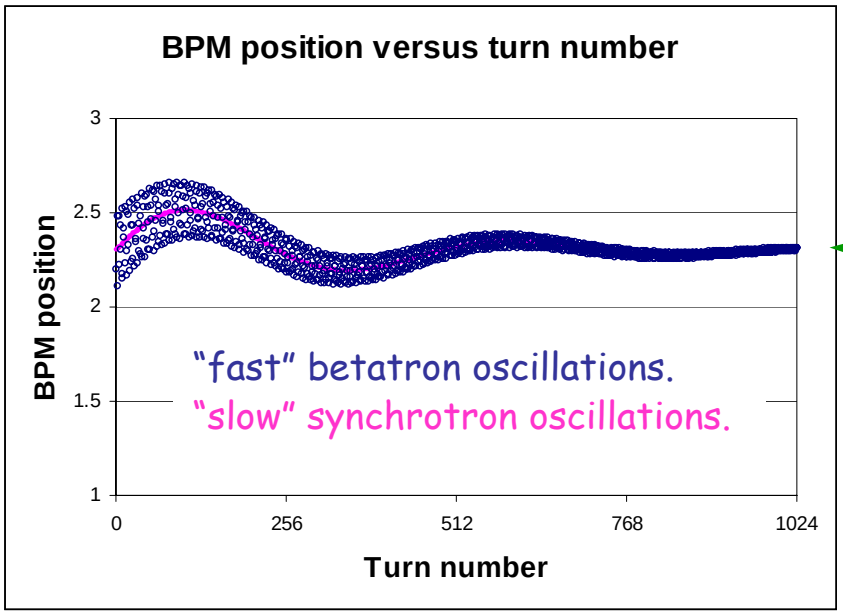
Types of Orbits
The Closed Orbit

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!

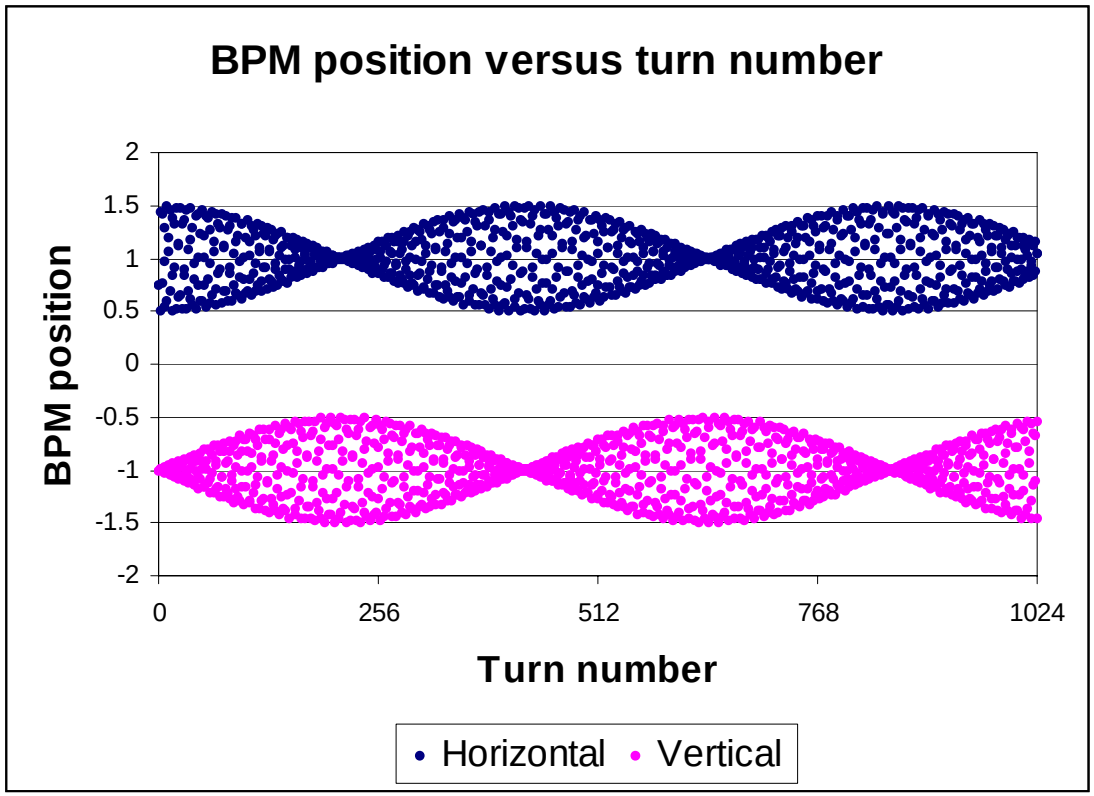




BPM position settles on the closed orbit.

Can use "averaging" to improve signal/noise.

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.

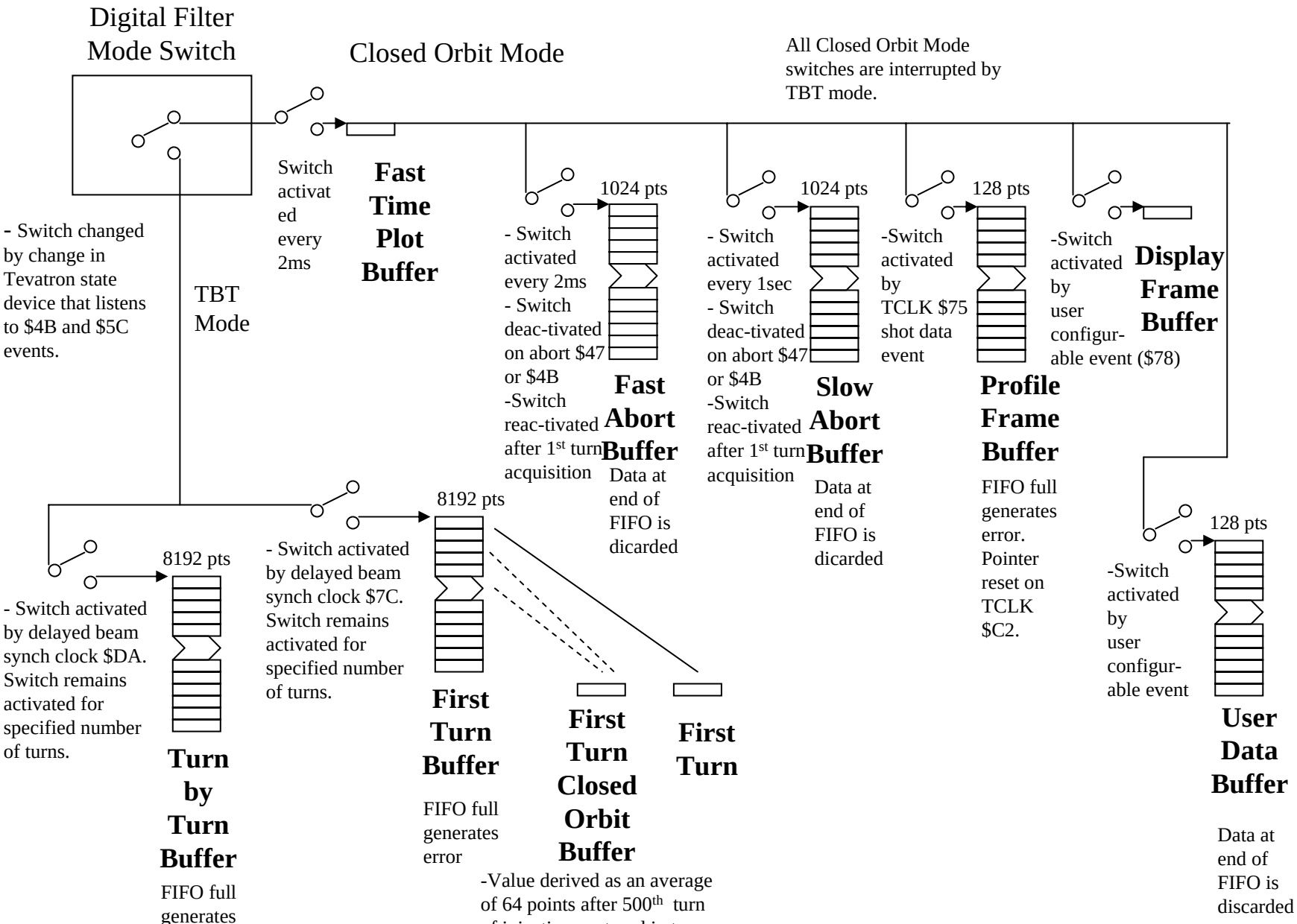
Energy transferred from horizontal to the vertical plane and back.

Methods of data collection.

o Position, intensty, and raw data of each BPM available as ACNET parameters.
o Position, intensity, and raw data can be plotted with FTP.

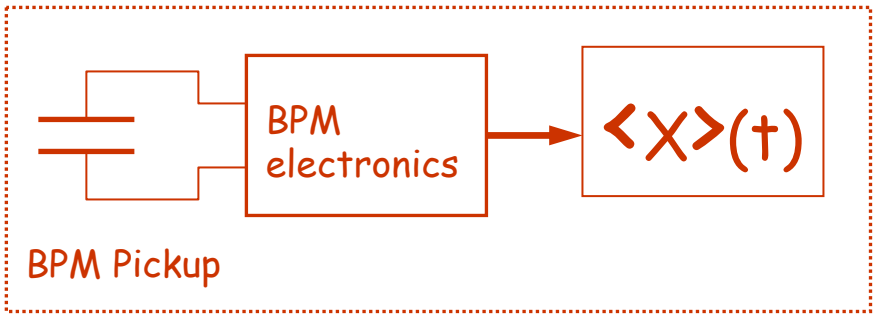
o Positions of all BPMs on manual request. (i.e. request orbit from T39.)

o Positions of all BPMs saved in a buffer when triggered by a TCLK event.
o Positions stored in a circular buffer that is halted by a Tev abort.


Digital Filter Mode Switch
Closed Orbit Mode
All Closed Orbit Mode switches are interrupted by TBT mode.
- Switch changed by change in Tevatron state device that listens to $4B and $5C events.
TBT Mode
Switch activated every 2ms
Fast Time Plot Buffer
1024 pts
- Switch activated every 2ms
- Switch deac-tivated on abort $47 or $4B
-Switch reac-tivated after 1st turn acquisition
Fast Abort Buffer
Data at end of FIFO is dicarded
1024 pts
- Switch activated every 1sec
- Switch deac-tivated on abort $47 or $4B
-Switch reac-tivated after 1st turn acquisition
Slow Abort Buffer
Data at end of FIFO is dicarded
128 pts
-Switch activated by TCLK $75 shot data event
Profile Frame Buffer
FIFO full generates error. Pointer reset on TCLK $C2.
-Switch activated by user configur-able event ($78)
Display Frame Buffer
8192 pts
- Switch activated by delayed beam synch clock $DA. Switch remains activated for specified number of turns.
Turn by Turn Buffer
FIFO full generates error
- Switch activated by delayed beam synch clock $7C. Switch remains activated for specified number of turns.
8192 pts
First Turn Buffer
FIFO full generates error
First Turn Closed Orbit Buffer
First Turn
-Value derived as an average of 64 points after 500th turn of injection captured in turn-by-turn buffer
128 pts
-Switch activated by user configur-able event
User Data Buffer
Data at end of FIFO is discarded

Methods of data collection.

In TBT mode:

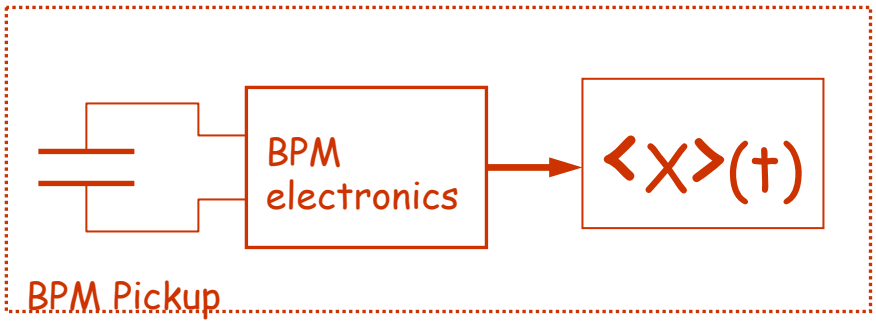


1. Arm on TCLK trigger for TBT measurement.
2. Wait for TVBS $DA trigger
3. Collect position and intensity for 8192 turns
4. Store data in buffer
5. Return to Closed Orbit Mode.

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

Methods of data collection.

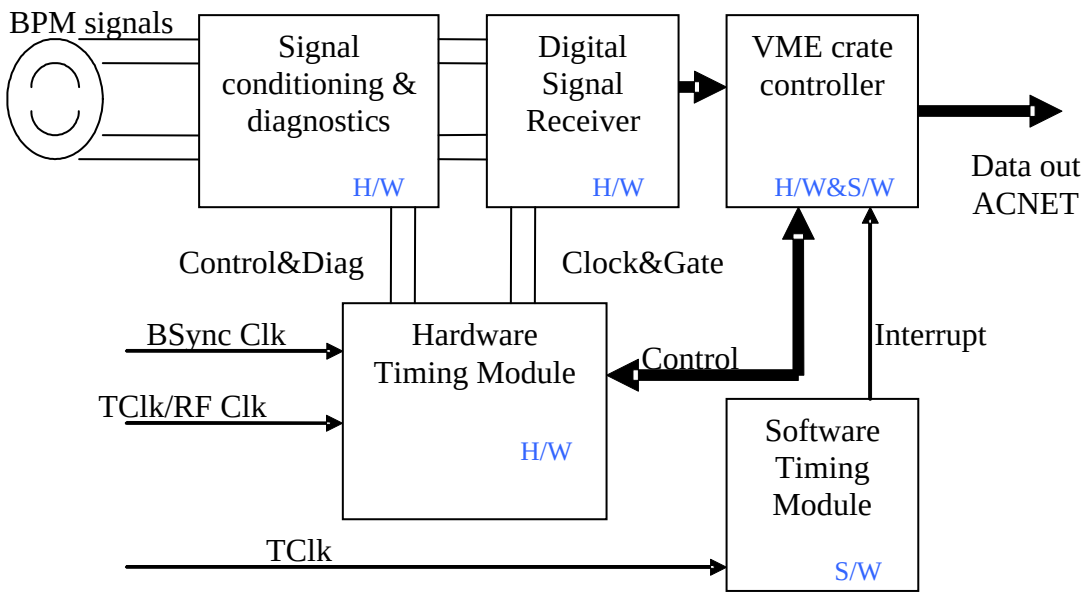
In First Turn mode:



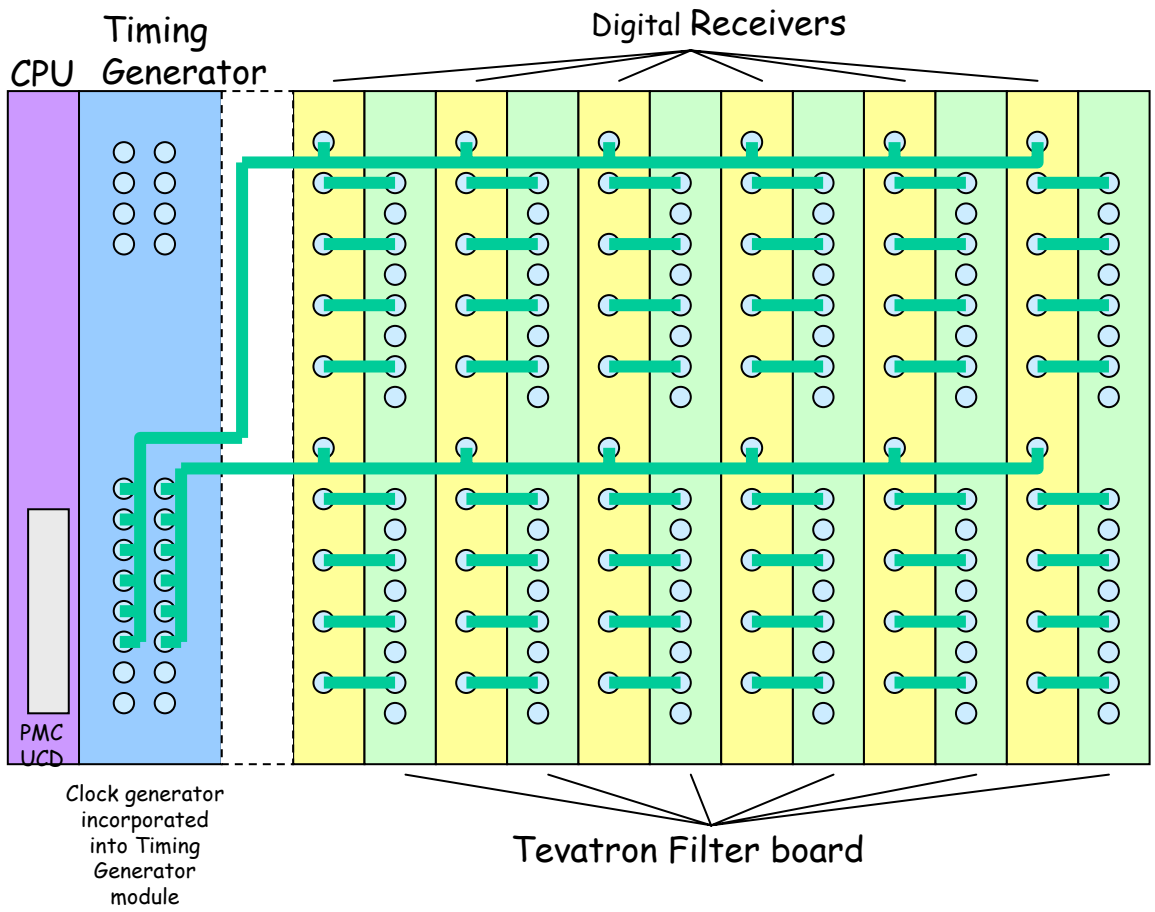
1. Arm on state transition to first proton injection plus TCLK $4D.
2. Wait for TVBS $7C trigger
3. Collect position and intensity for 8192 turns
4. Store data in a buffer, and calculate closed orbit from a subset of points.
5. Store first turn and calculated closed orbit in separate buffers.
6. Return to Closed Orbit Mode.

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

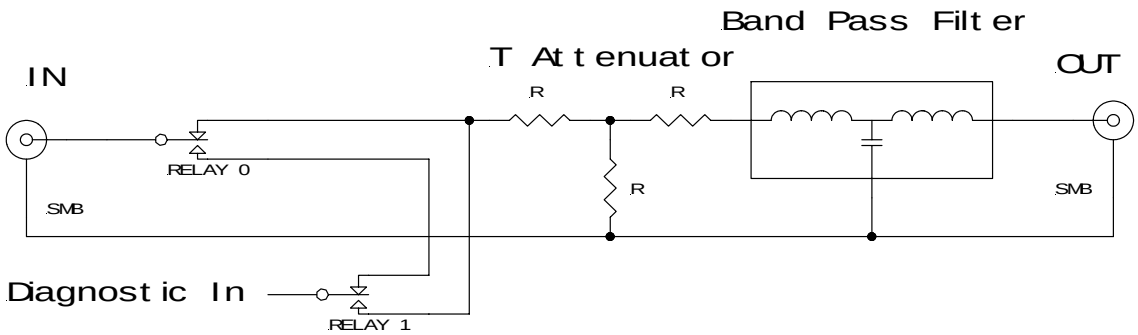
System Hardware Block Diagram



BPM VME Crate Illustration



Filter Module Schematic



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

Accuracy

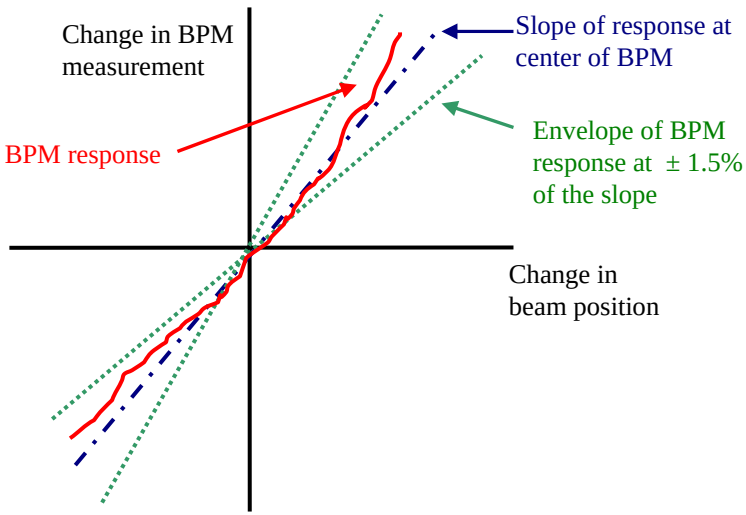
Absolute position accuracy

Determine how accurately the BPM system measures the position of the beam for all beam conditions, for the entire range of positions, for long periods of time (years), and when parts of the BPM system or BPM electronics are replaced.

It is sufficient for the BPM system to have a 3σ absolute position accuracy of 1 mm.

Hard to actually confirm this measurement.

Accuracy



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 ± 1.5% of the slope

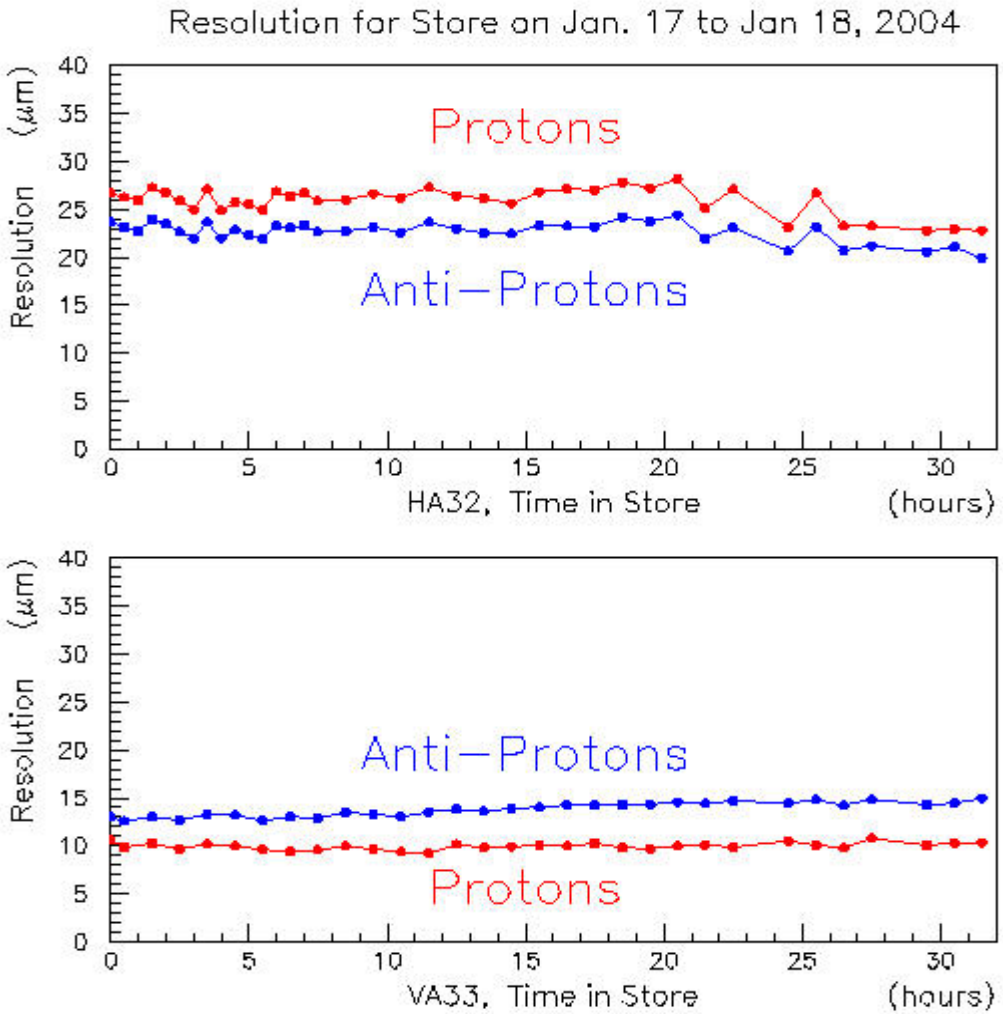
Requirements

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 0.02 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.
Pbar closed orbit during ramp and LB squeeze	36x36. Pbar coal.	Buffered on TCLK. ACNET variable. FTP variable.	Position resolution of 0.05 mm.

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.

P and pbar resolutions (closed orbit) during 1/17/05 store



Horizontal ~20-25 μm (thought to be due to beam motion)

Vertical ~10-15 μm