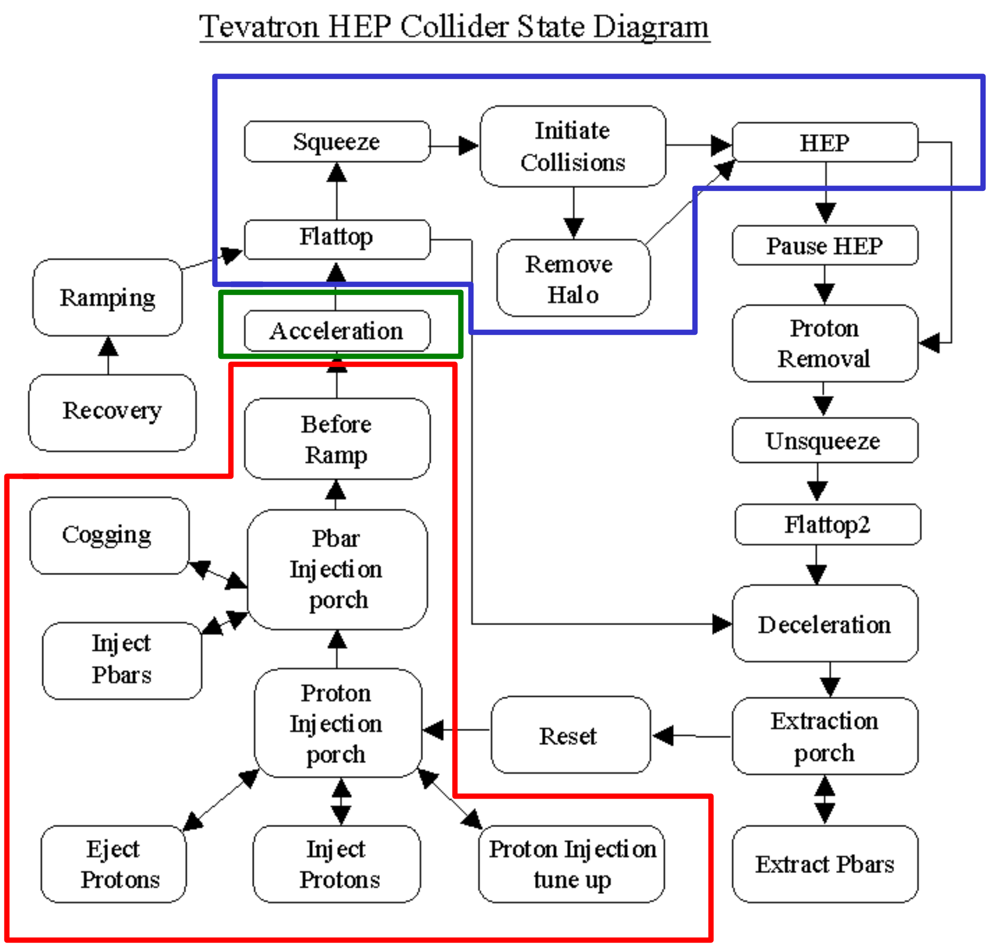
Tevatron operations with BPMs & BLMs

Mike Martens

States of Tev operations



<u>980 GeV operations</u>

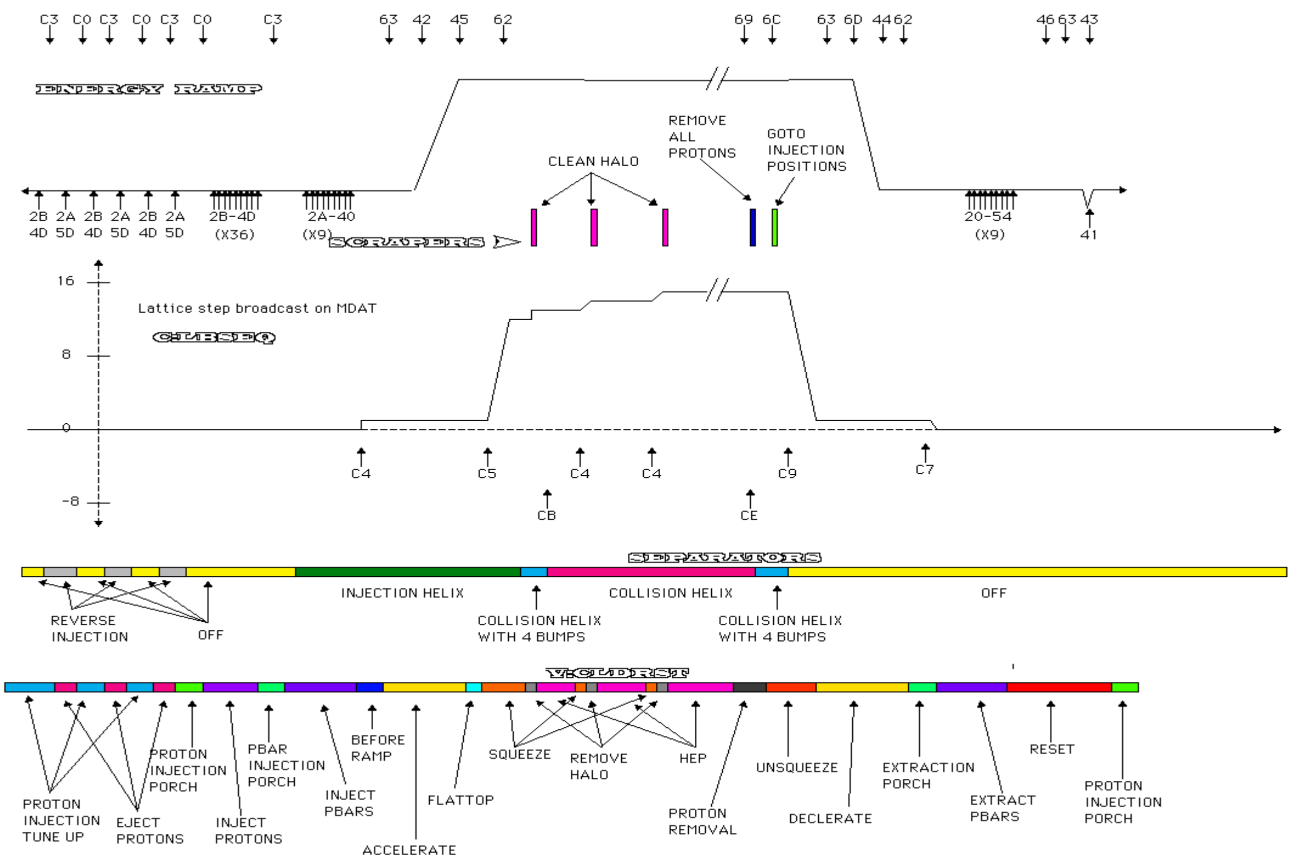
Squeeze
Initiate collision
Remove halo
HEP

<u>Accelerate</u>

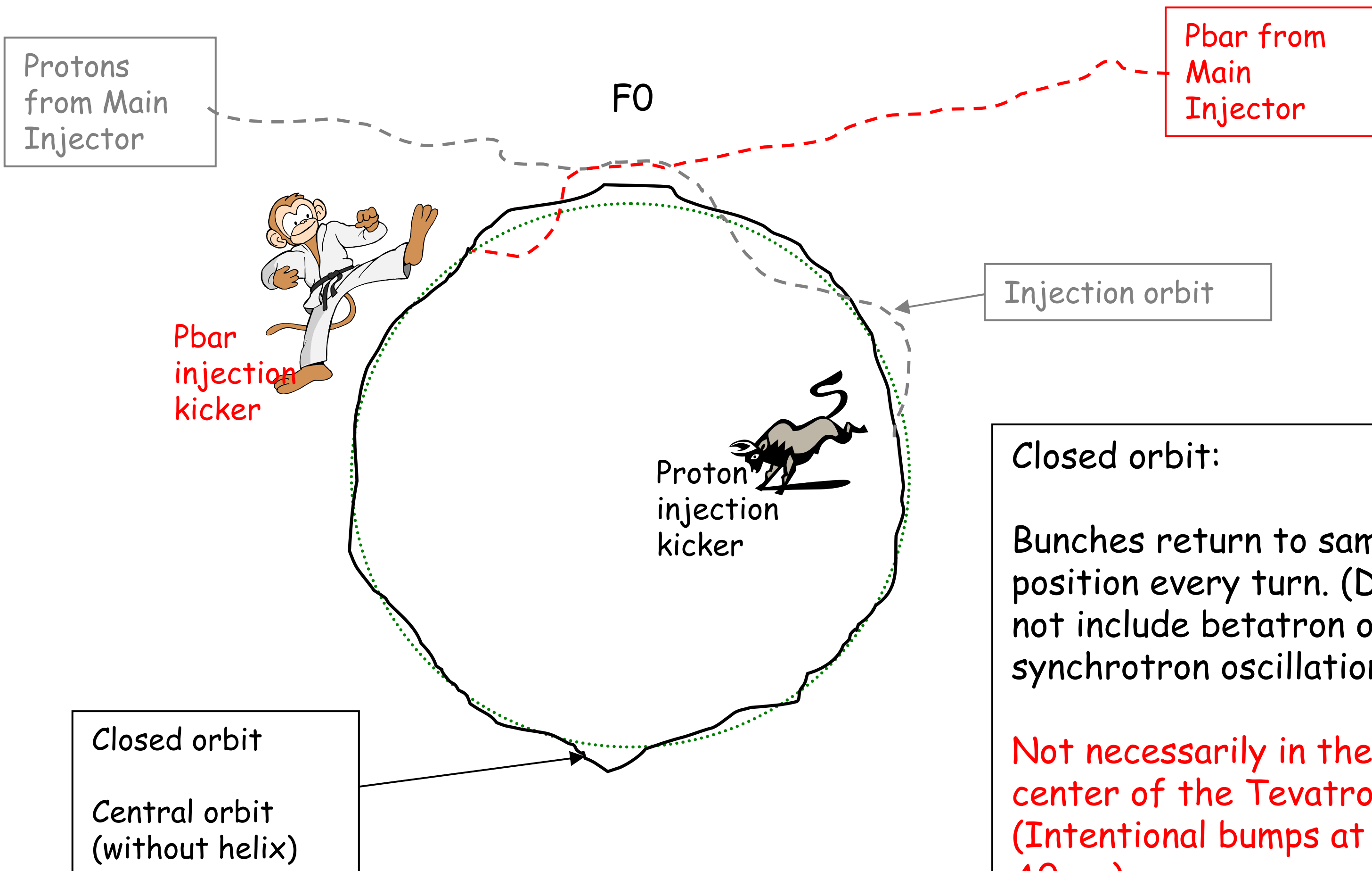
<u>150 GeV operations</u>

Tune-up
Inject protons
Inject pbars

Steps in the shot setup



Orbits in the Tevatron



Closed orbit:

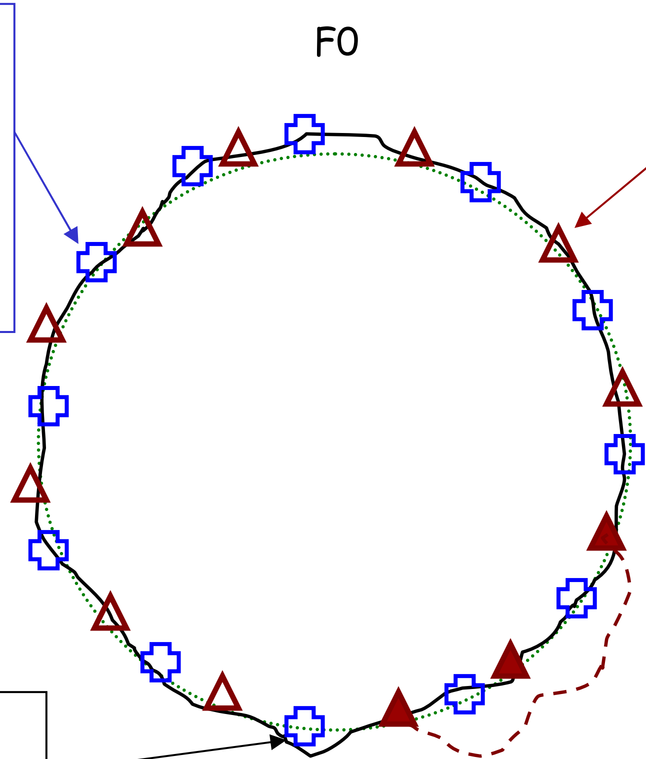
Bunches return to same position every turn. (Does not include betatron or synchrotron oscillations.)

Not necessarily in the center of the Tevatron. (Intentional bumps at F0, A0, ….)

Orbits in the Tevatron

BPMs
To measure position.

~100 in each of horizontal and vertical plane



Trim dipole correctors used to adjust the closed orbit.

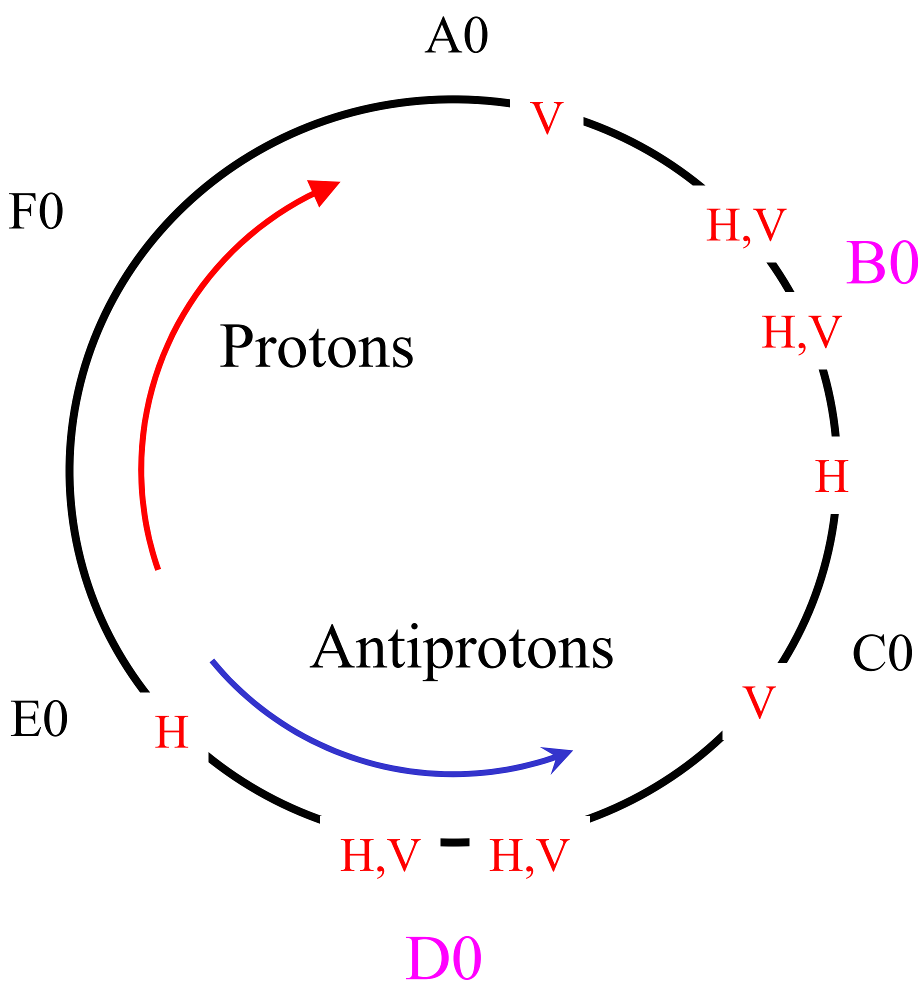
(aka DFGs)

~100 in each of horizontal and vertical plane

Closed orbit

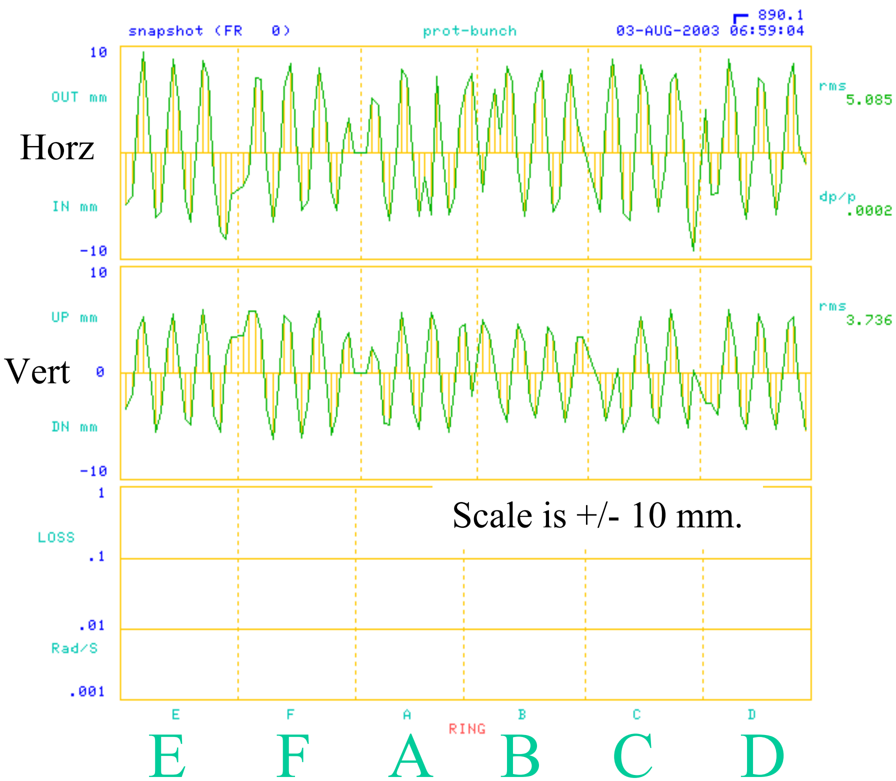
Central orbit (without helix)

Tevatron Separators



Electrostatic separators are used to separate the proton and pbar orbits transversely …
except at the IPs where the protons and pbars collide head-on.

Helical orbits



Six sectors in the Tevatron

Orbit changes for protons when the electrostatic separators are used.

Pbar orbits change in other direction.

~100 BPMs in each plane

Tevatron Orbit Smoothing

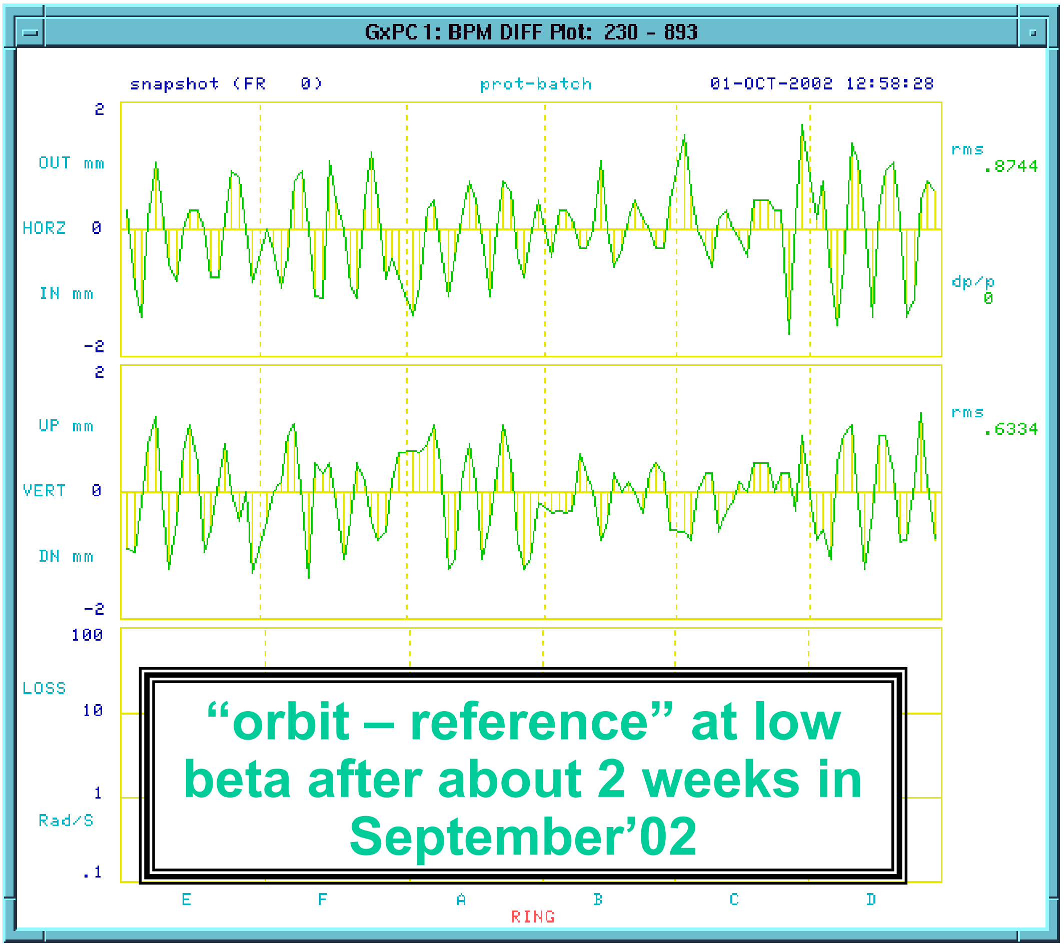
Motivation for smoothing

Orbit drifts ~0.5 mm/week → **Tune changes of ~0.001** → **Emittance blowup Poor lifetime**

Orbit drifts ~1.0 mm → **Aperture problems** → **Losses and quenches**

Important to have stable orbits for machine studies.
Example: Aperture on the new helix at 150 Gev.

Orbit Drifts



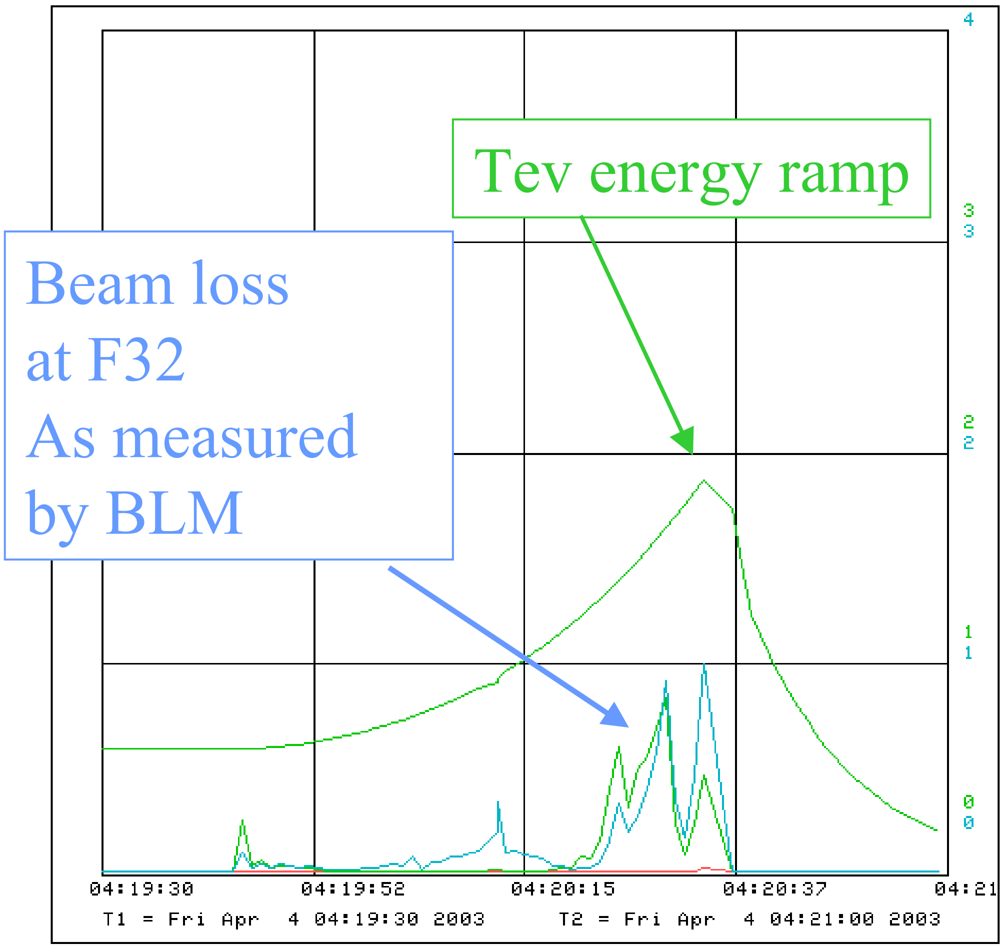
Tunes, coupling, ξ vary with closed orbits distortions

"Rule of thumb" -- keep orbit drifts under 0.5 mm rms from "silver orbit"

Orbit drifts of that scale occur in 1-2 weeks (see picture)

Requires routine orbit smoothing at 150 Gev, ramp, flat-top, squeeze, and low-beta.

Tevatron Orbit Smoothing



Recent example

Problem:

3 quenches @ 400 Gev from losses at F32

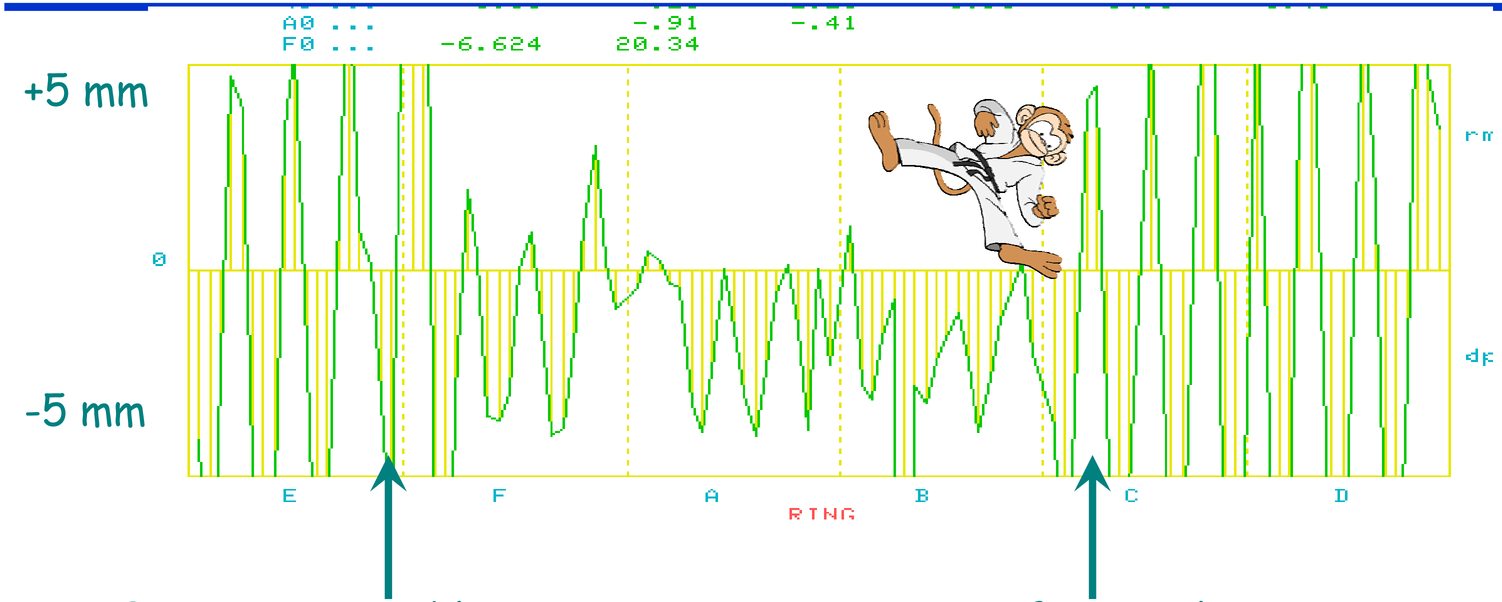
Solution:

A +2 mm horizontal bump @ HPF32

Tune up for shot setup

- Set the Tevatron energy to 150 GeV
- Use uncoalesced protons for proton injection closure
- Use uncoalesced protons for reverse injection closure of pbar injection.
- Adjust tunes, coupling, chromaticity.

First turn orbits during startup

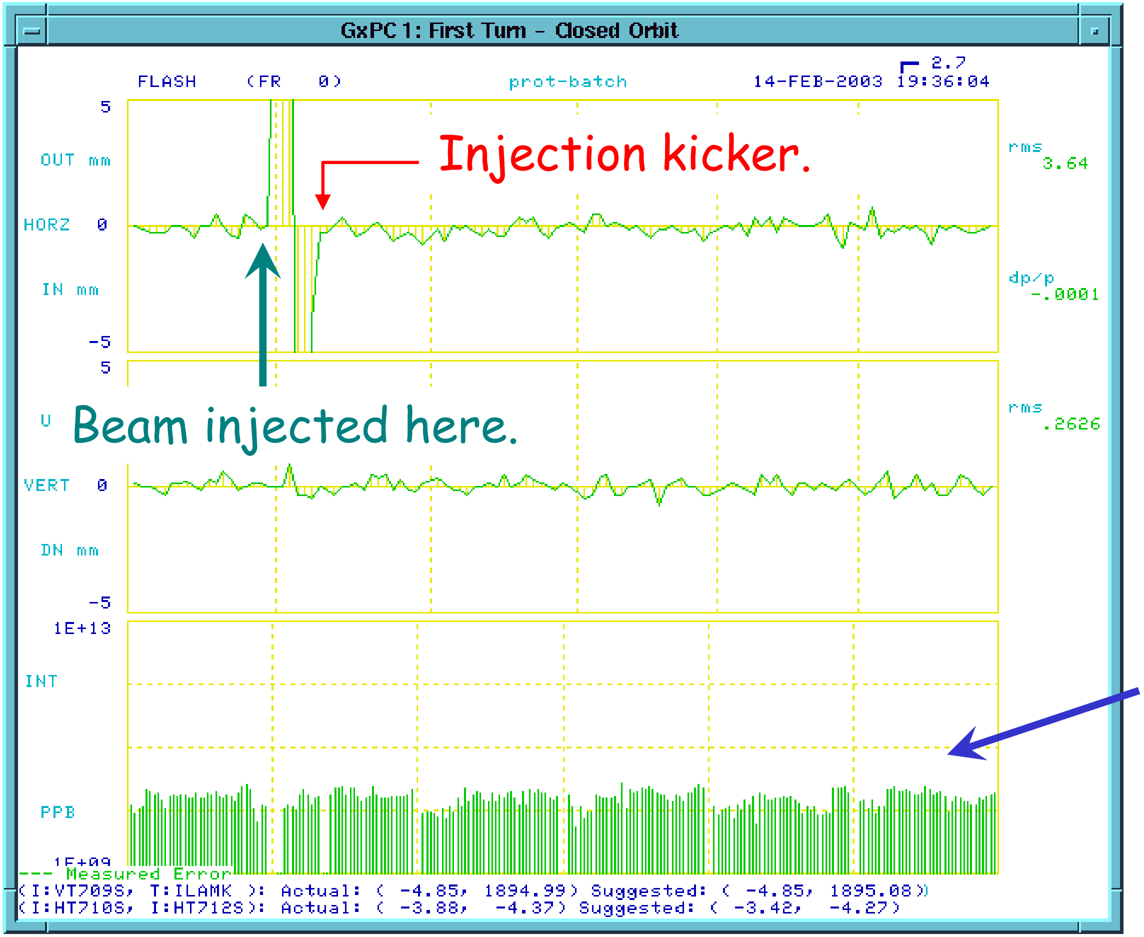


Beam injected here.

Source of error here.

This plot shows the proton orbit on the 1st turn after injection after a startup.

Injection Closure

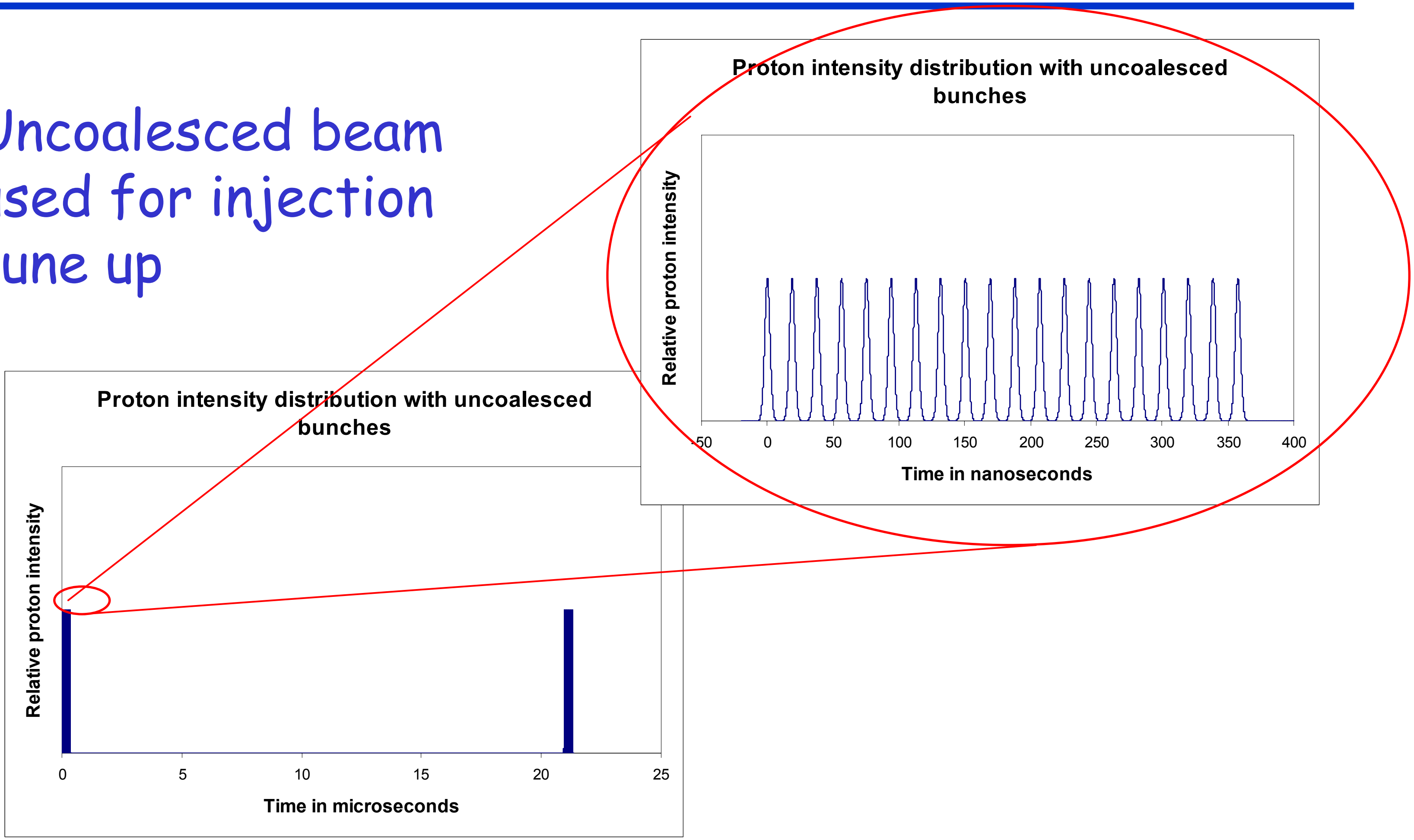


This plot shows the difference of the 1st turn orbit with the closed orbit subtracted.

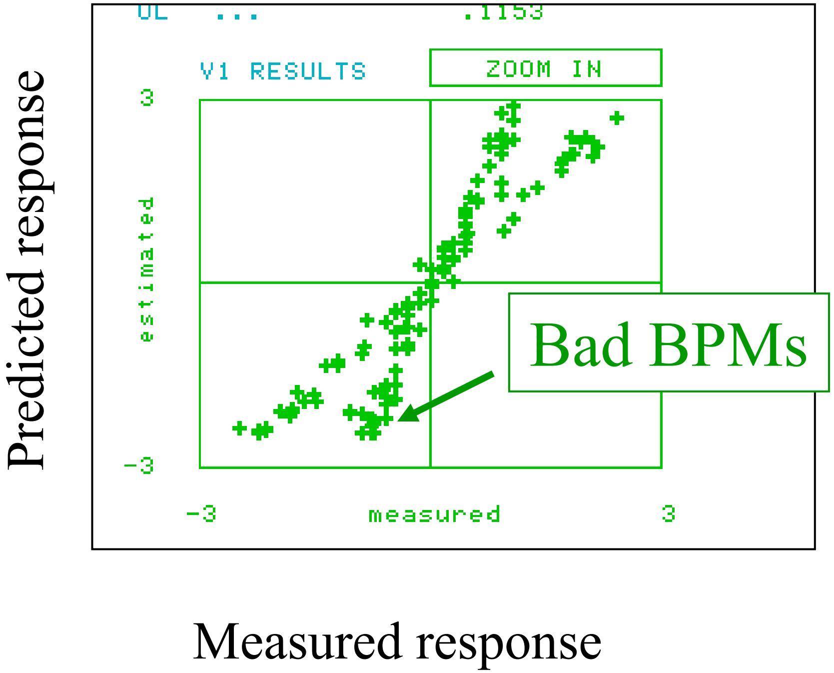
Intensity measurements important for diagnosing first turn injection problems.

Uncoalesced proton beam

Uncoalesced beam used for injection tune up



Test of BPMs at shot setup



Diagnostic program to test BPM response before orbit smoothing.

<u>We are working on:</u>

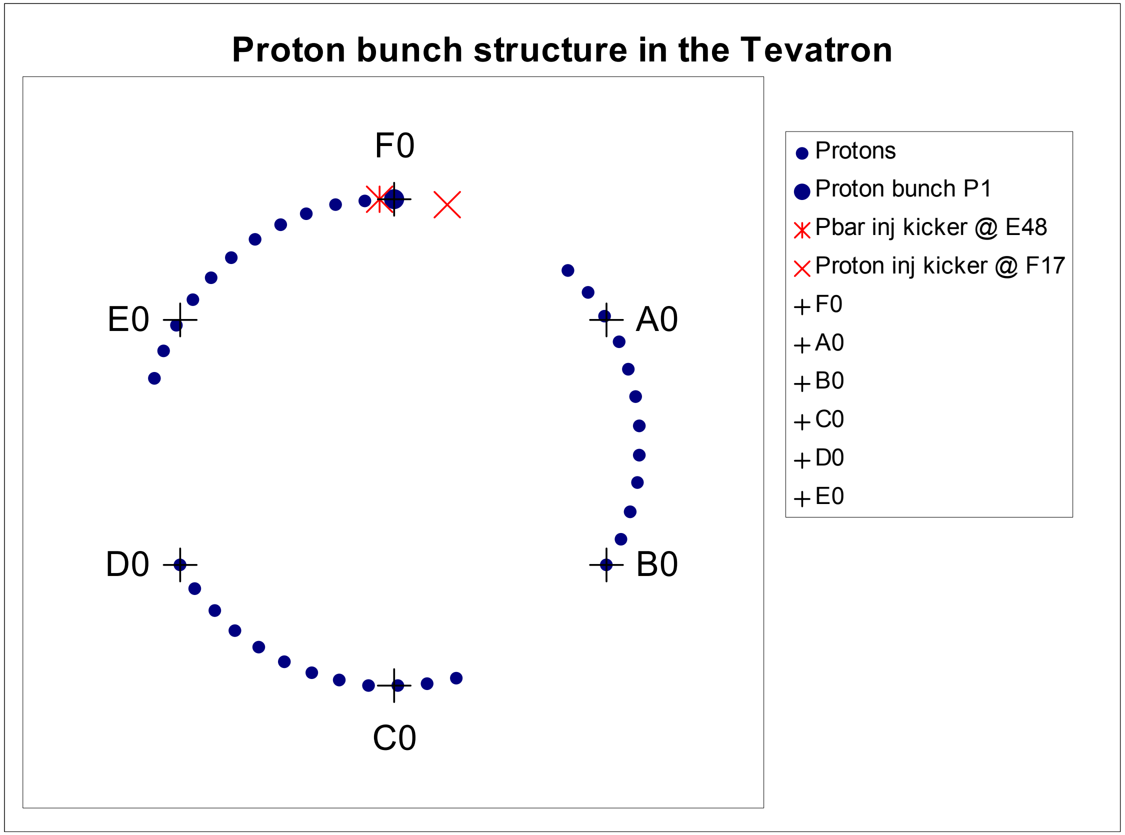
BPM electronics

Diagnostic software

Tracking orbits in SDA

Robust smoothing procedure.

Inject final protons

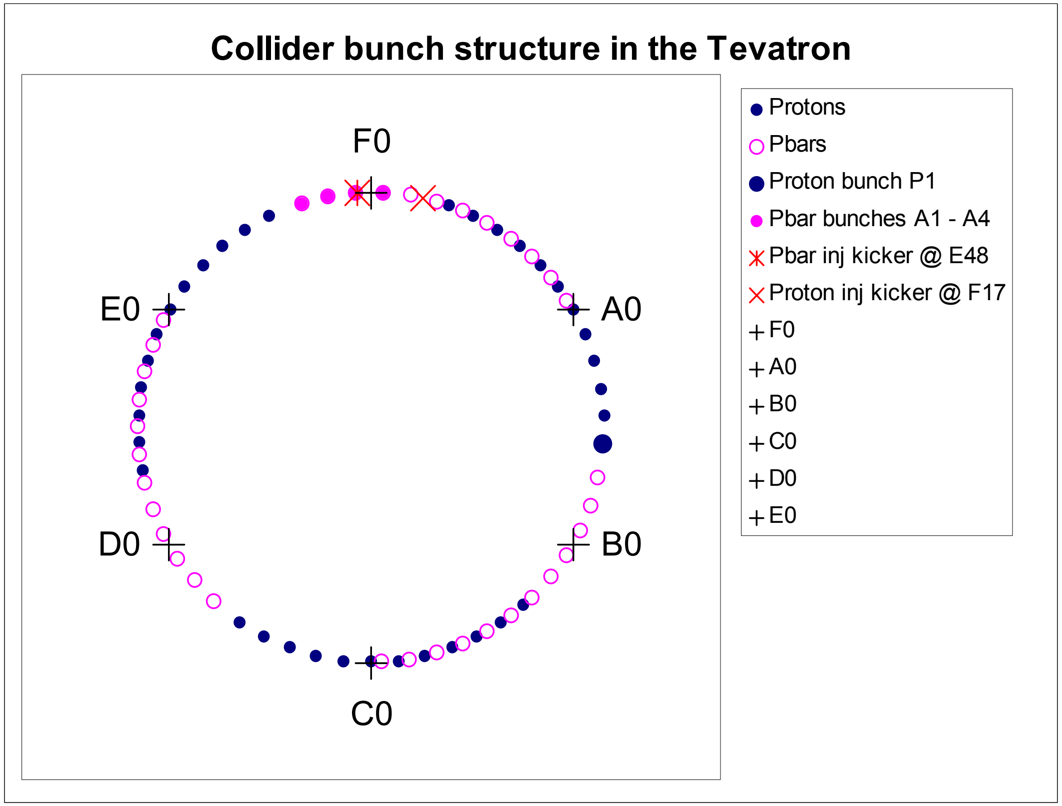


36 bunches of coalesced protons are injected one at a time.

Bunches are in three groups of 12. Bunches are spaced 21 RF buckets (396 nsec) apart.

Injected on the central orbit (with separators off.)

Inject final pbars

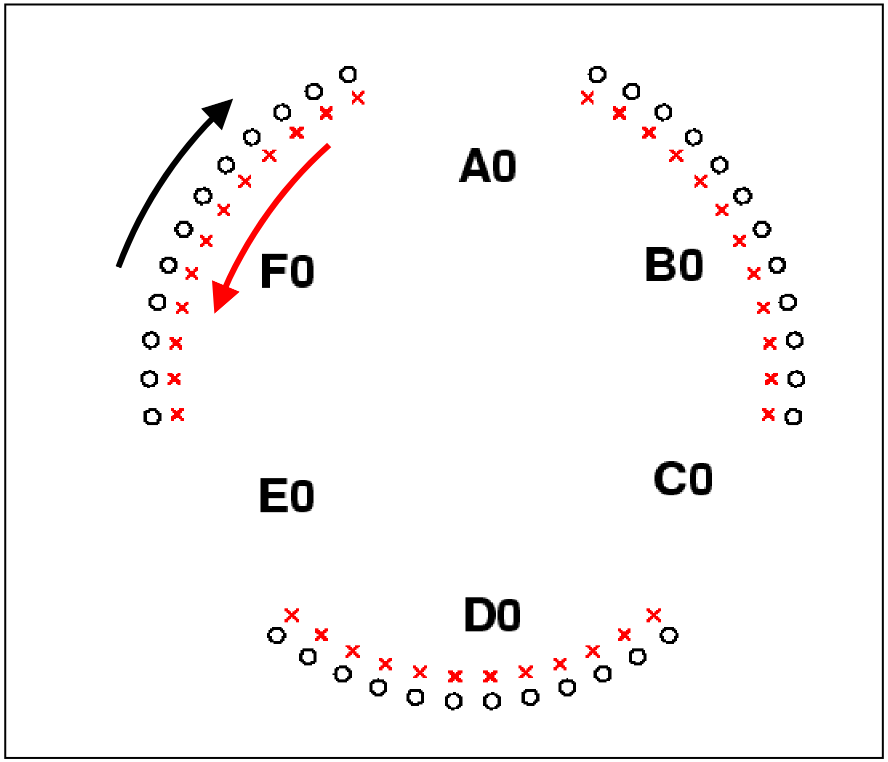


36 bunches of coalesced pbars injected for bunches at a time.

Bunches are in three groups of 12. Bunches are spaced 21 RF buckets (396 nsec) apart.

Injected on the helical orbit (with separators on.)

Run II Bunch Configuration



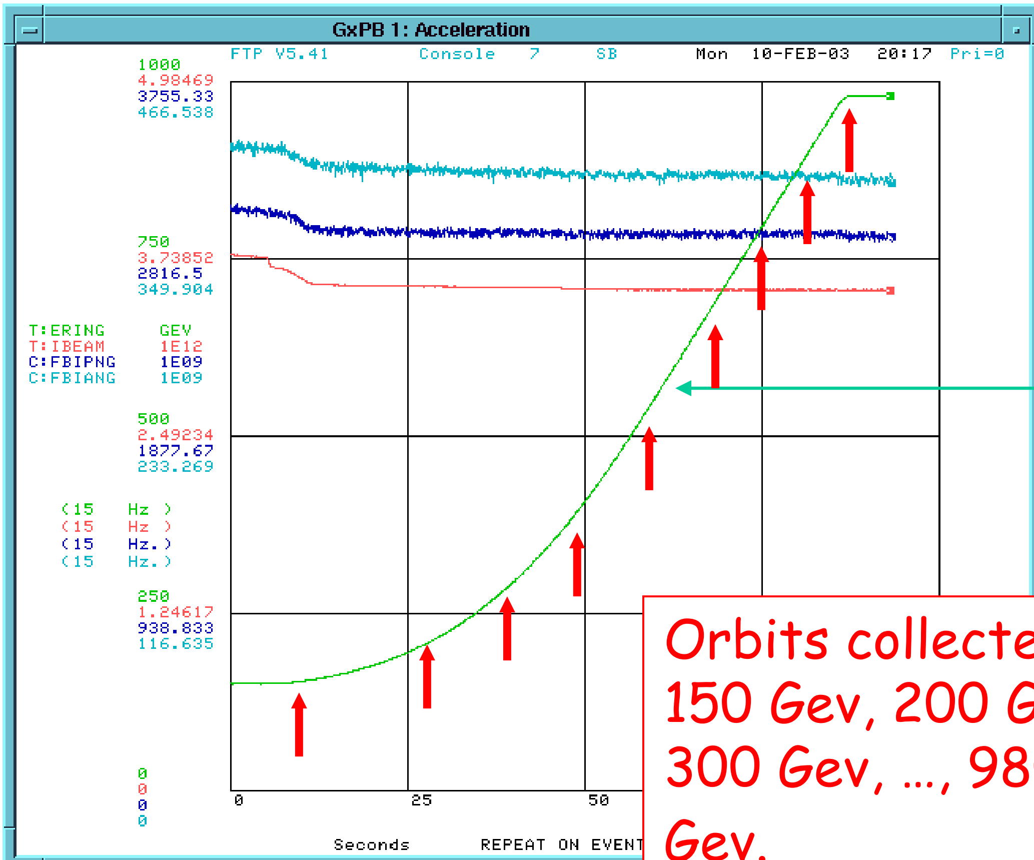
36 x 36 configuration

396 nsec bunch spacing

3 x 12 proton bunches

3 x 12 pbar bunches

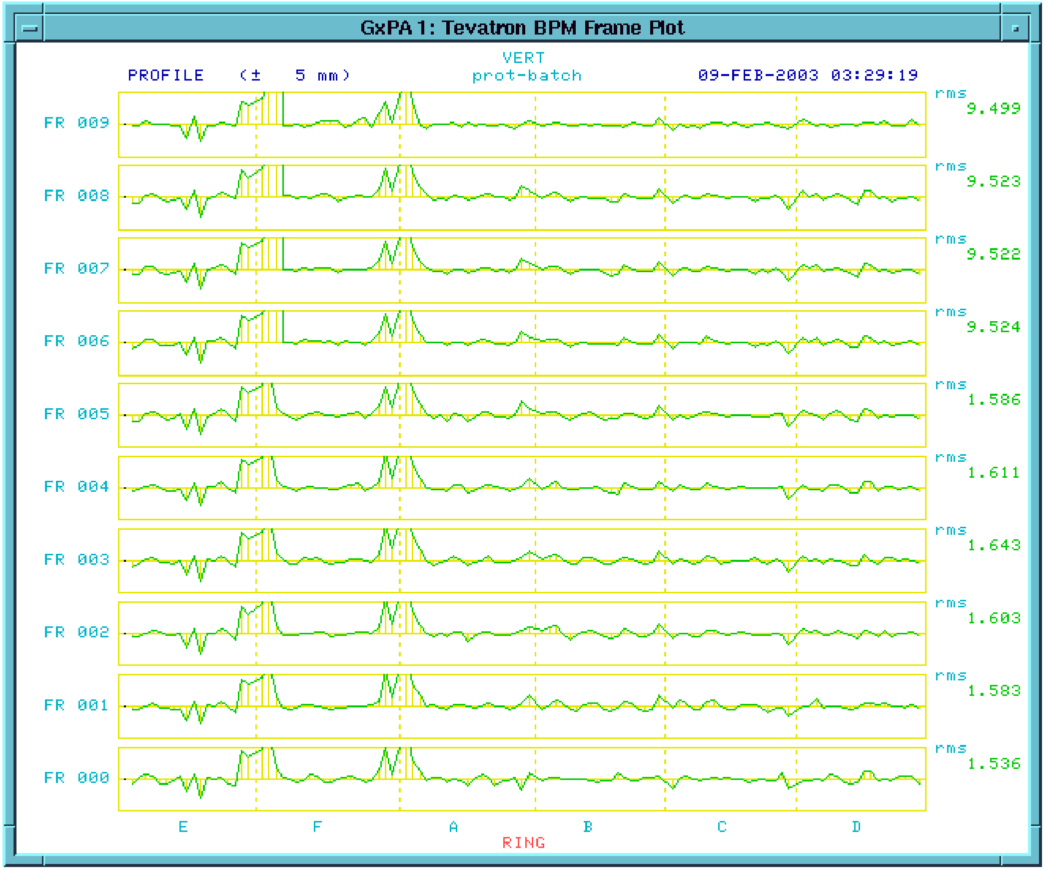
Accelerate



Tevatron accelerates beam from 150 GeV to 980 GeV.

Orbits collected at 150 Gev, 200 Gev, 300 Gev, …, 980 Gev.

Orbits up the ramp



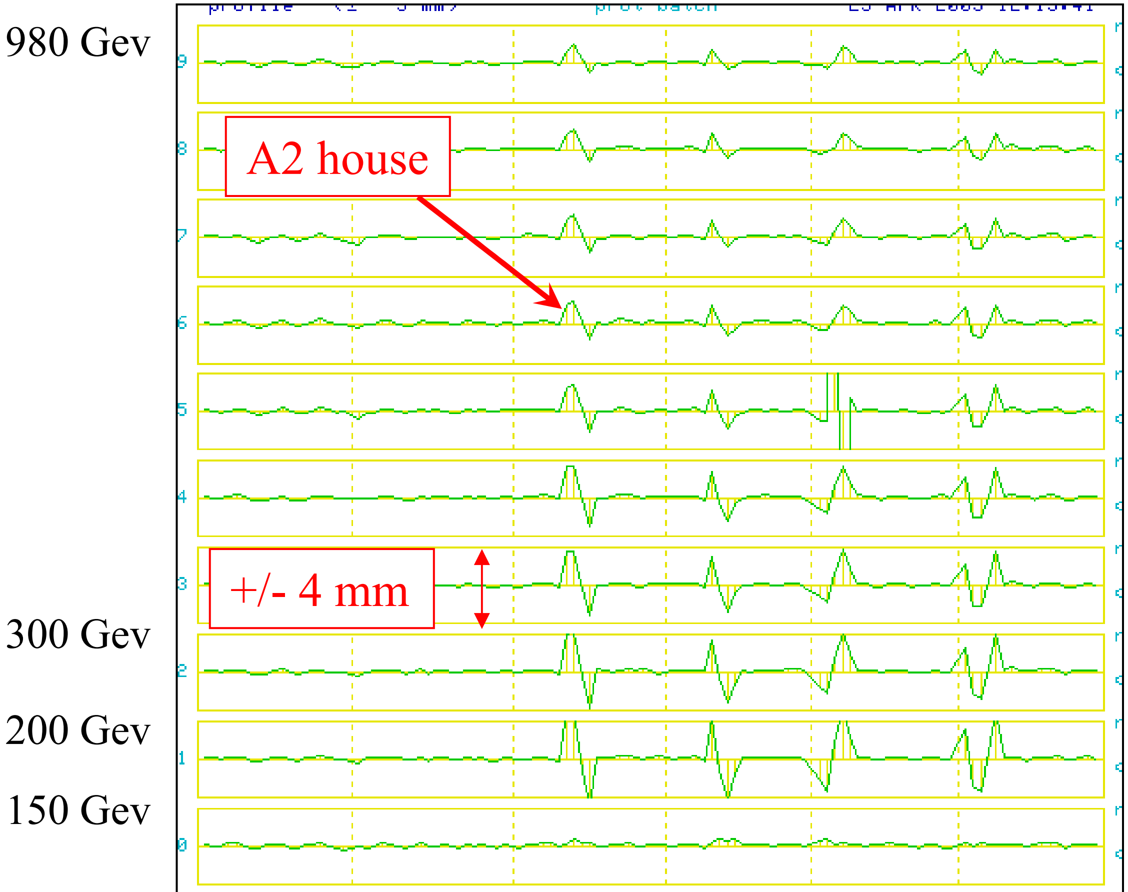
980 Gev

900 Gev

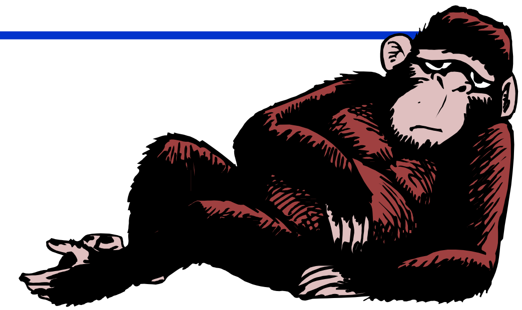
200 Gev

150 Gev

Troubles with Orbit Smoothing



Orbit difference at several ramp energies.

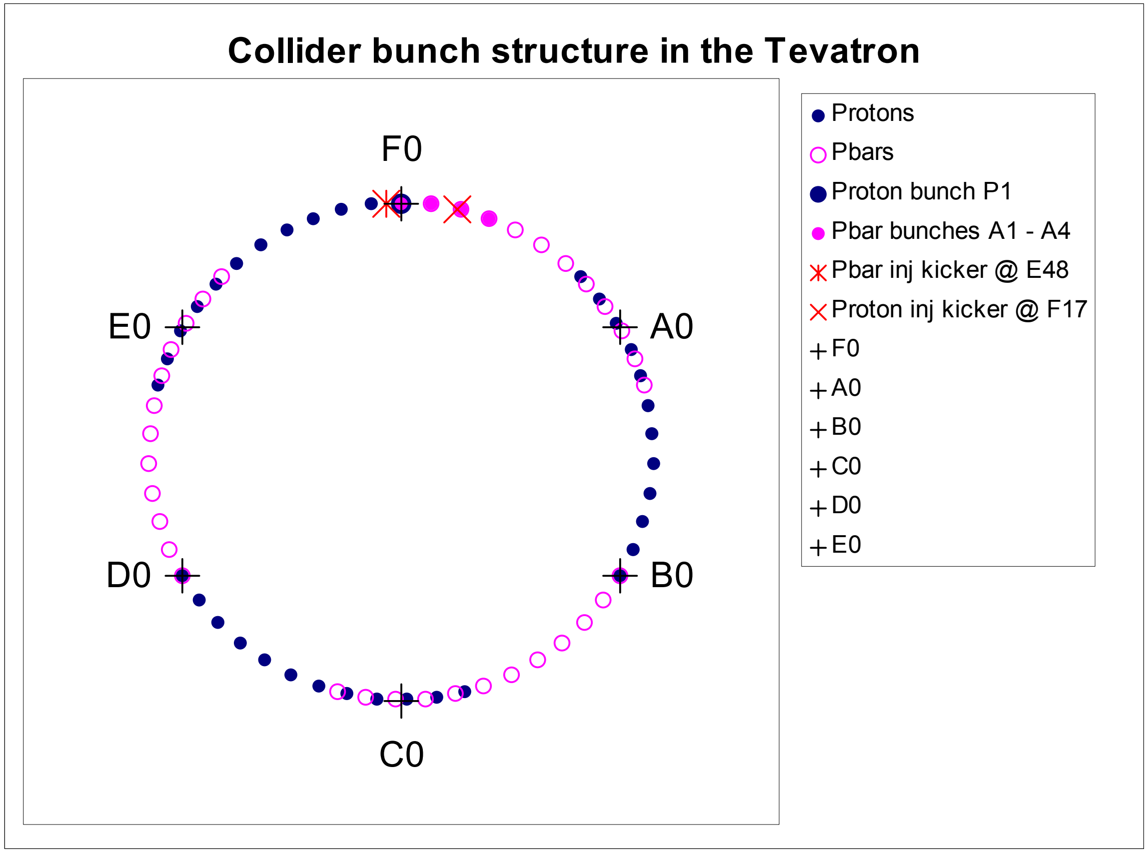


Some BPM houses reported old orbit data

Obvious this time:
Old data => helix.
New data => no helix.

No independent way to verify validity of orbit data.

Collision point cogging

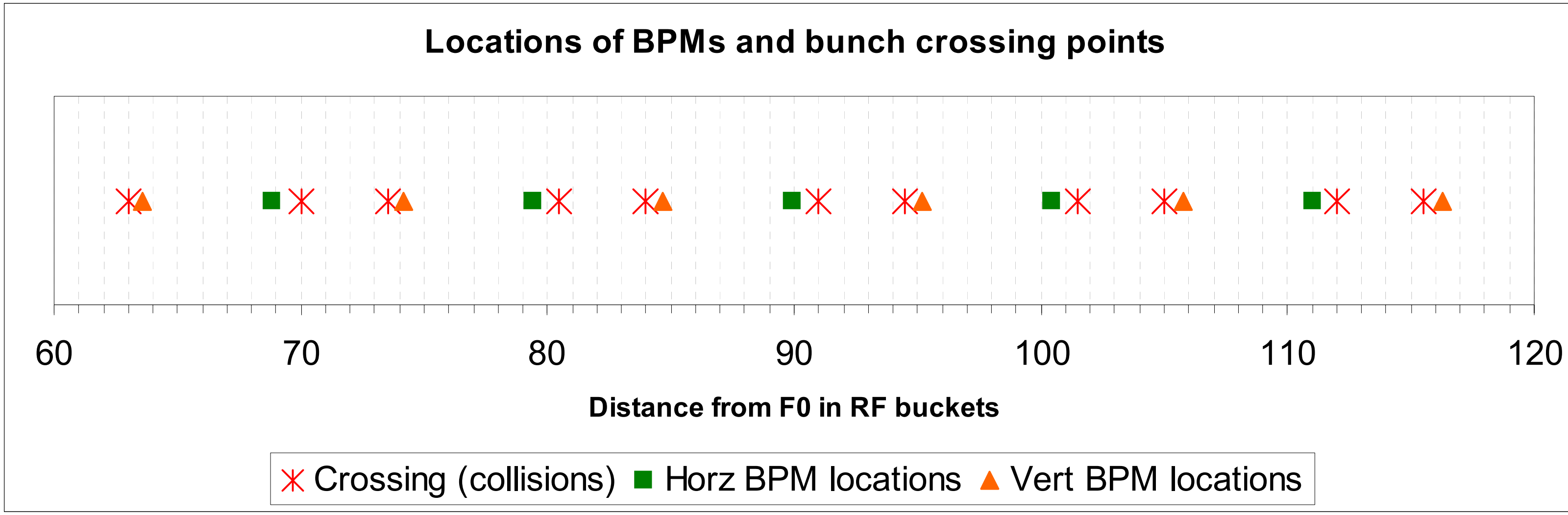


After accelerating, the relative timing of the protons and pbars is changed.

This is done by a process called cogging.

Proton and pbar bunches now cross at CDF and D0.

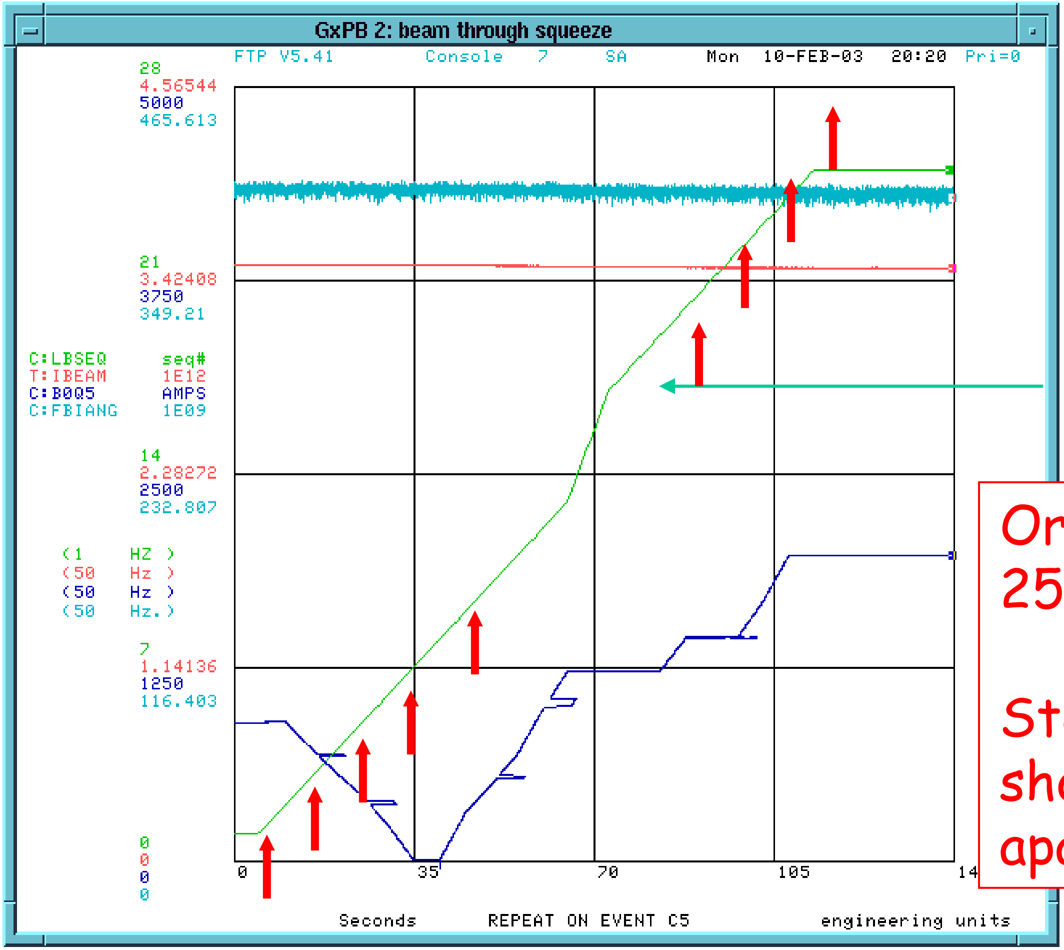
Cogging, crossings, BPMS



Cogging affects locations of proton and pbar bunch crossings.

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

Low beta squeeze.



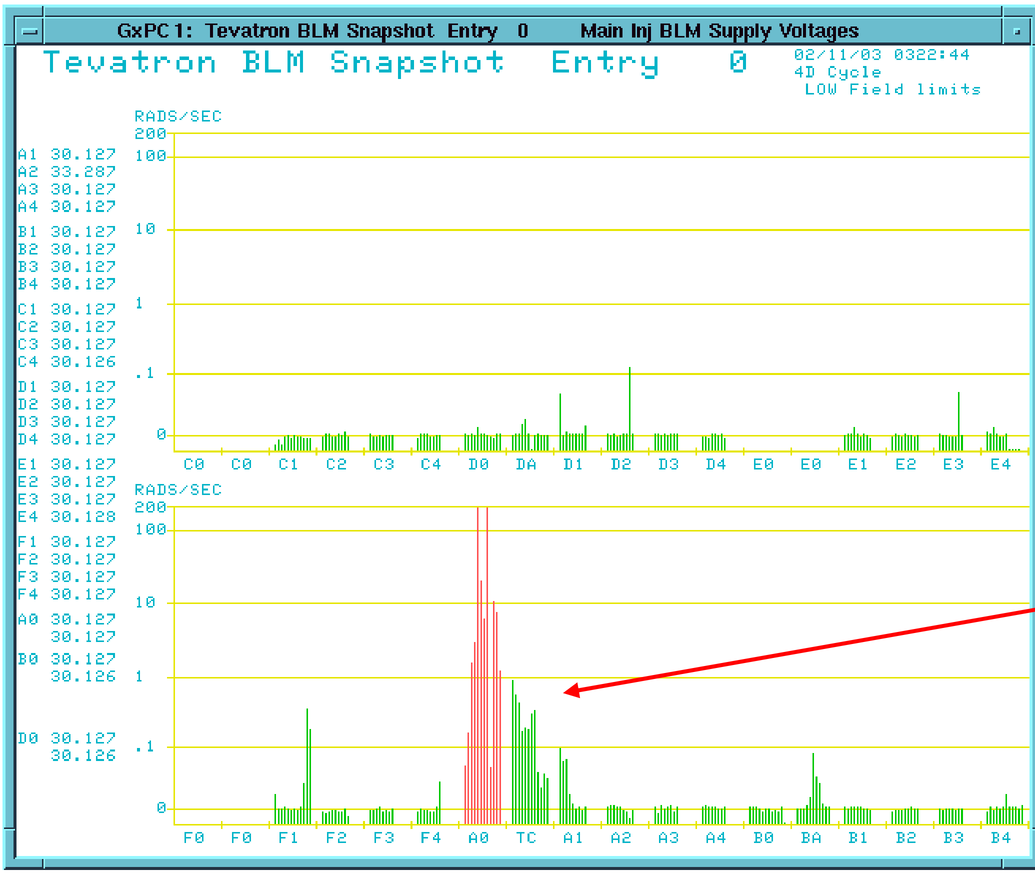
Squeeze beam at the IRs.

Done in 25 "steps."

Orbits collected at 25 steps.

Steps can be as short as 1 second apart.

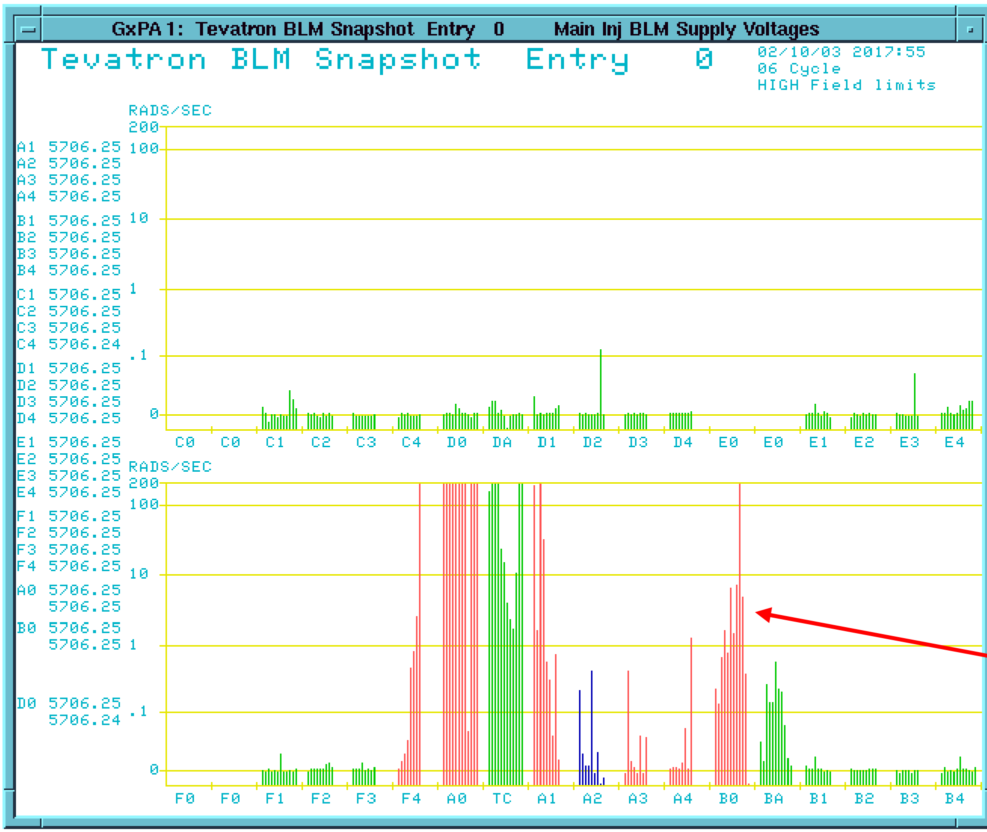
BLMs to diagnose aborts



Circular buffer of BLM readings is halted when beam is aborted.

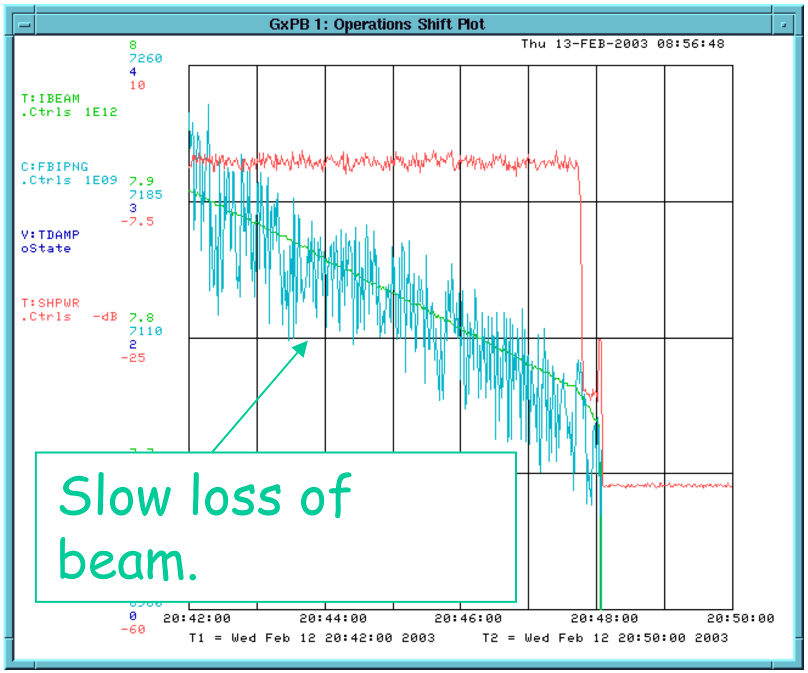
Typical losses in the A0 region near the beam abort kickers.

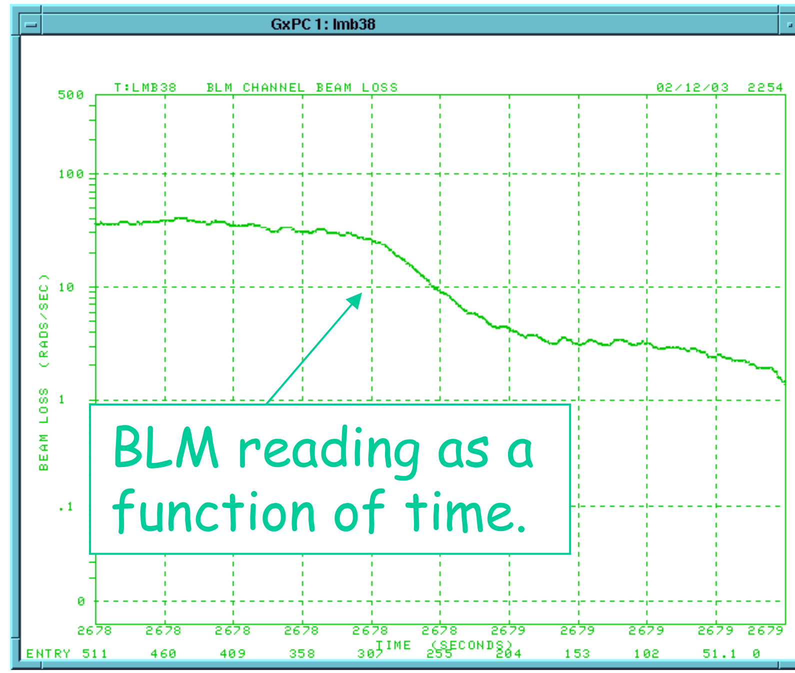
Kicker pre-fire



Large losses at CDF.

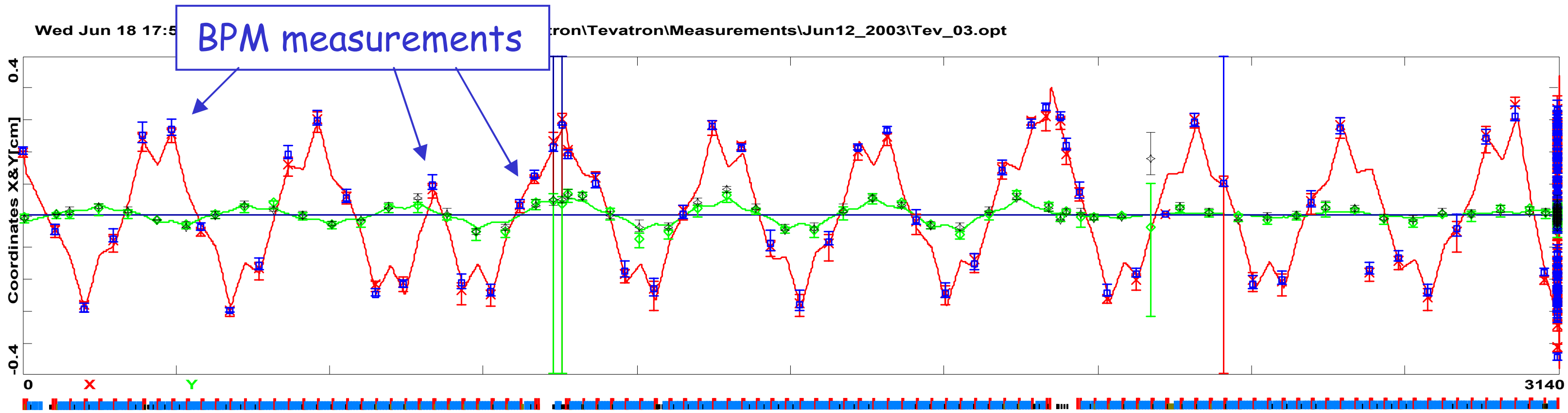
Slow beam loss





Circular buffer showing time structure of beam loss.

Lattice Measurements

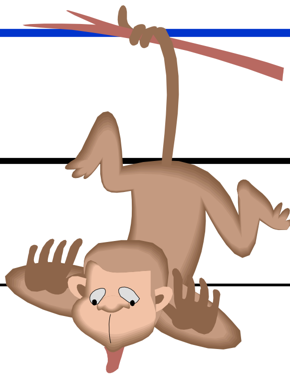


Calculated orbit response (red line is horizontal and green is vertical) from a horizontal 1-bump in the Tev.

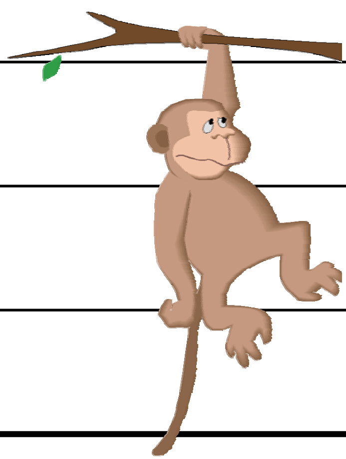
Note that there is a vertical oscillation when a horz bump is applied. This is not part of the design lattice.

Improving BPM resolution 0.15 mm ⇒ 0.02 mm improves error on lattice function measurements ~10% ⇒ ~2%.

Tev BPM/BLM applications



Tevatron BPM display Collects, displays, and archives orbit data.
Tevatron Orbit Program Uses BPM orbit to calculate corrections for orbit smoothing.
MI ⇒ Tev Injection closure Uses FLASH (1st turn) data to close injection from MI.
Shot Data Acquisition (SDA) Collects orbits during a shot setup.
Tev BLM display Collects and displays beam loss readings.
Tev BPM hardware diagnostics Checks BPM electronics, cables, and power supplies.
Tev BPM test program Checks that BPMs are responding as expected to 1-bumps.



Goal for Orbit Smoothing

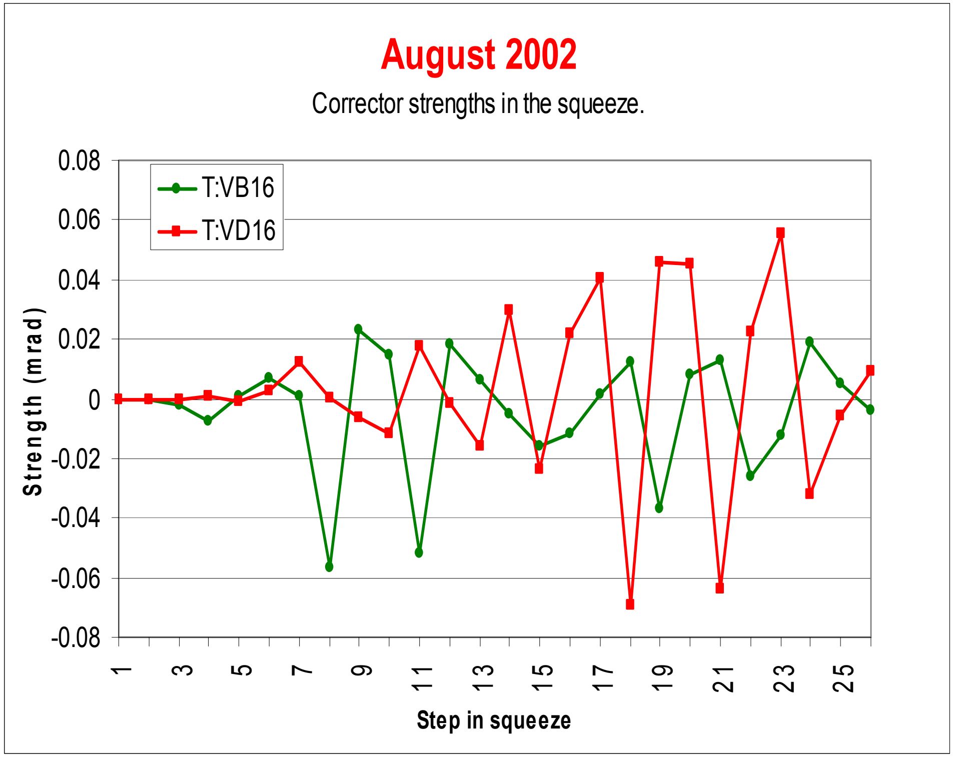
Find a set of **"Golden Orbits"** with beam

- in the center of the magnets.
- in the center of aperture at tight spots.
- at the correct location for injection and abort.
- at a good location for experiments.

Develop a **"Standard Smoothing Procedure"** that

- keeps the orbits stable.
- is done consistently.
- can be done relatively quickly.

Some History of Orbit Smoothing



Corrector strengths fluctuating by 50 amps during the squeeze.

<u>In August 2002.</u>

Found erratic orbits and corrector settings.

⇩

Overhauled the orbits corrector setting.

⇩

Developed a "standard smooth procedure"

Tev orbit program (TOP)

```
C50                    TEVATRON ORBIT SMOOTHING                    ◆Pgm_Tools◆

setup|bump|desired orbit|curr/slew limit|table def|dfg save/resto|dfg util|options|misc

     SETUP PARAMETERS                    COMMAND            SUMMARY     PLOT  DISP

TITLE     Energy Ramp (980 FT)     :::  INITIALIZE SEQUENCE
TABLE              ACCELERATE    - :::  READ DFGS                        ..     .
SLOT RANGE       150 Gev  ( 3)     :::  DETERMINE LATTICE
  THRU           150 Gev  ( 3)   - :::  DESIRED ORBIT                    ..     .
DISPLAY SLOT     150 Gev  ( 3)   - :::  READ BPM ORBIT                   ..     .
PLANE                    HORZ      :::  CORRECT ORBIT                    ..     .
DFG SOURCE                DFG      :::  SMOOTH ORBIT                     ..     .
DFG FILE                           :::  PREDICT ORBIT                    ..     .
BPM SOURCE           SNAPSHOT    - :::  CURRENT CHECK                    ..
BPM FRAME                   0    - :::  SLEW RATE CHECK                  ..
BPM FILE                           :::  ORBIT COMPARE                    ..     .
DESIRED ORBIT     Desired Pos    ↑:::  CORRECTOR COMPARE                ..     .
SELECTED LATTICE         AUTO    - :::  SEND NEW SETTINGS
ACTUAL LATTICE          TEV01                                            ER     D
ALGORITHM                 SVD     *REEXECUTE        *REPLOT OPTIONS
STEPCUT (%)               100     *UNDO LAST SMOOTH
◆ADDITIONAL PARAMETERS◆           *WRITE LAST READ BPM ORBIT   *GRAPHICS CURSOR

                          DATA DOCUMENTATION
DESIRED POS: FILE  1  energy ramp desired positions     03/22/01
REFERENCE ORBIT: Newest Flattop orbit;T39f793     08/10/03  FILE   1  FRAME  0  TOTAL  1
SMOOTH ORBIT:                                   NONE---NO ORBIT
DFG:         INITIAL ZERO
FLAT TOP ANGLE DIFF CORRECTION SAVE    HORZ  NO   VERT  NO

                               Messages
VERT REFERENCE ORBIT FILE FILE 1 READ SUCCESSFULLY                               p
HORZ REFERENCE ORBIT FILE FILE 1 READ SUCCESSFULLY
PROFILE FRAME FILE RECORD 1 READ SUCCESSFULLY
SLOT DEFINITION FILE 1 READ SUCCESSFULLY                                         n
                              1: 4 of 15                                         +
```