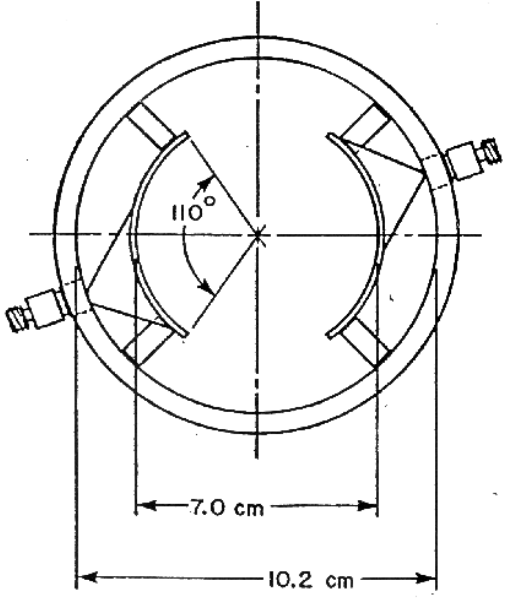

Tevatron Beam Position Monitor Upgrade

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(for the Tevatron BPM Upgrade Project)

PAC05, Knoxville, TN

May 16-20, 2005

Outline

- Motivation for Tevatron BPM Upgrade
- Tevatron BPM Upgrade Design and Implementation
- Performance of New BPM System
- Conclusions

Motivation for Upgrade

- Old Tevatron BPM electronics was not accurate, precise or reliable enough for the Tevatron, nor was it able to measure pbar positions.
  - Old system was built in the early 1980's and is showing its age.
  - Resolution was ~150 microns.
  - Uses old networking/controls protocols.
  - No pbar position measurements.
- Pickups in the tunnel not to be modified!
  - Directional, 26dB isolation, can be read out from both ends.

Upgrade Requirements

- Stable, accurate, precise measurements.
  - Aiming for <10 micron (1 sigma) precision for best proton position measurement.
- Turn-by-turn (wide-band) and closed orbit (narrow-band) position measurements.
  - And "safe mode" to find the beam when timing is not well-established after shutdowns.
- Software to collect and use the data.
- Reliable hardware and software.
- Measurement of antiproton positions (new capability).
  - Requires that both ends of pickups be instrumented (twice as many electronics channels).

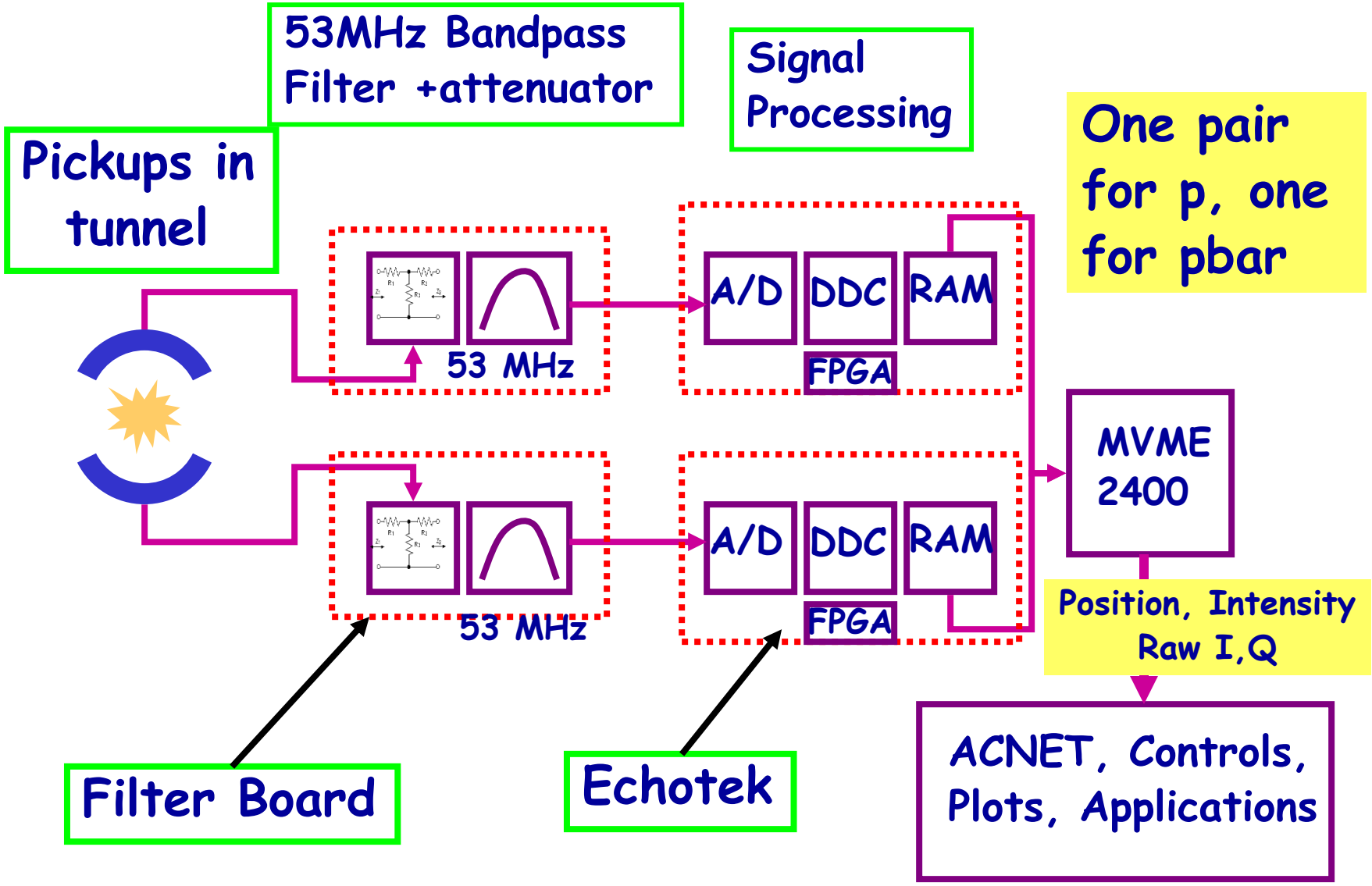
Upgrade System Design

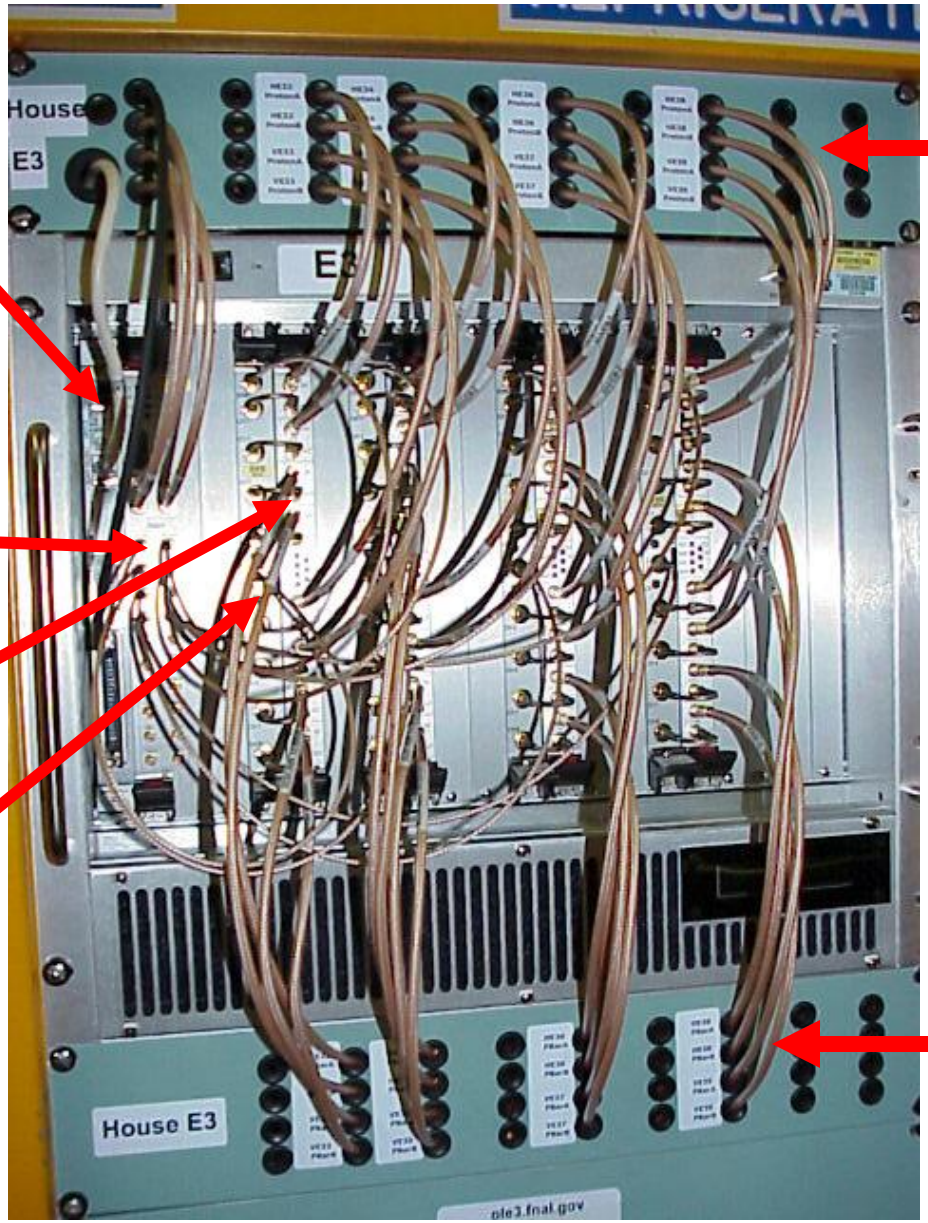
- **Position measurement**
  - The 53 MHz component of the BPM signal is used to measure the beam transverse position.
- **Analog signal**
  - The analog signal is filtered and attenuated on a special purpose filter board. The bandpass filters are centered at 53 MHz with width of ~8 MHz.
  - An impulse response time of 400ns was required to allow for pbar measurements using timing (rather than proton signal subtraction).
    - See Poster/Paper from Bob Webber for details of the timing technique ("Plan B").

System Design

- **Digital processing:**
  - The decision was made to use a commercial digital signal receiver made by the Echotek corporation.
  - 80 MHz, 14-bit A/D, Graychip DDC, RAM, FPGA.
  - Digitize at 74 MHz (synchronous to 53.1 MHz RF).
- **Reasons for the choice:**
  - Speed: The boards could be purchased quickly.
  - Commonality: This board was also chosen for the Recycler, NUMI, transfer line, and Main Injector BPM upgrades.
  - Manpower: Freed up engineering and technician time for other parts of the project
    - *See poster/paper from Gustavo Cancelo for details about digital filtering.

Block Diagram – signal/processing path





MVME

Timing Board

Filter Board

Echotek

Proton Signals

Pbar Signals

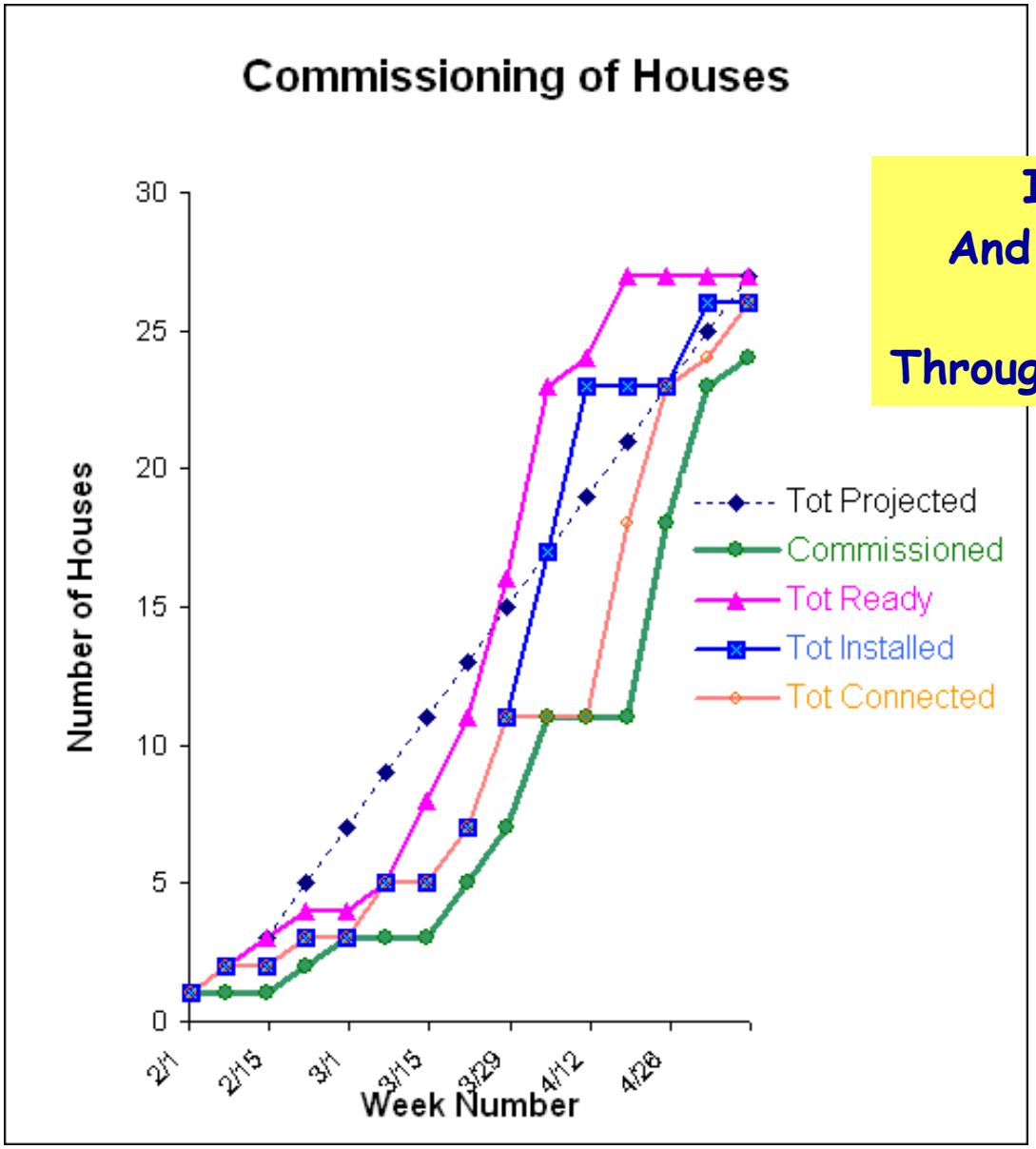
BPM VME Subrack in E3 Service Building

Key Project Dates

- 9/22/03: Requirements review
- 12/19/03: Technology choice review
- 3/11/04: Place Echotek Order
- 5/14/04: Electronics Design Review
- 8/6/04: Install prototype crate in Tevatron
- 8/20/04: First Production Echotek boards arrive
- 8/23/04-12/04: Shutdown
- 11/23/04: Install first production system in A3
- 2/7/05: Finish commissioning A3 system
- 2/7/05-5/31/05: Install remaining systems

Installation and Commissioning

- An orderly replacement of the old BPM electronics was required for operation of the Tevatron.
- VME subracks were installed one by one, affecting approximately 8 BPMs each time.
- During commissioning a combination of old and new systems were used to:
  - Close orbits
  - Smooth orbits
- This was accomplished by integrating the new and old data simultaneously into console applications.
- Overall, this worked extremely well!



Installation And commissioning Status Through May 12, 2005

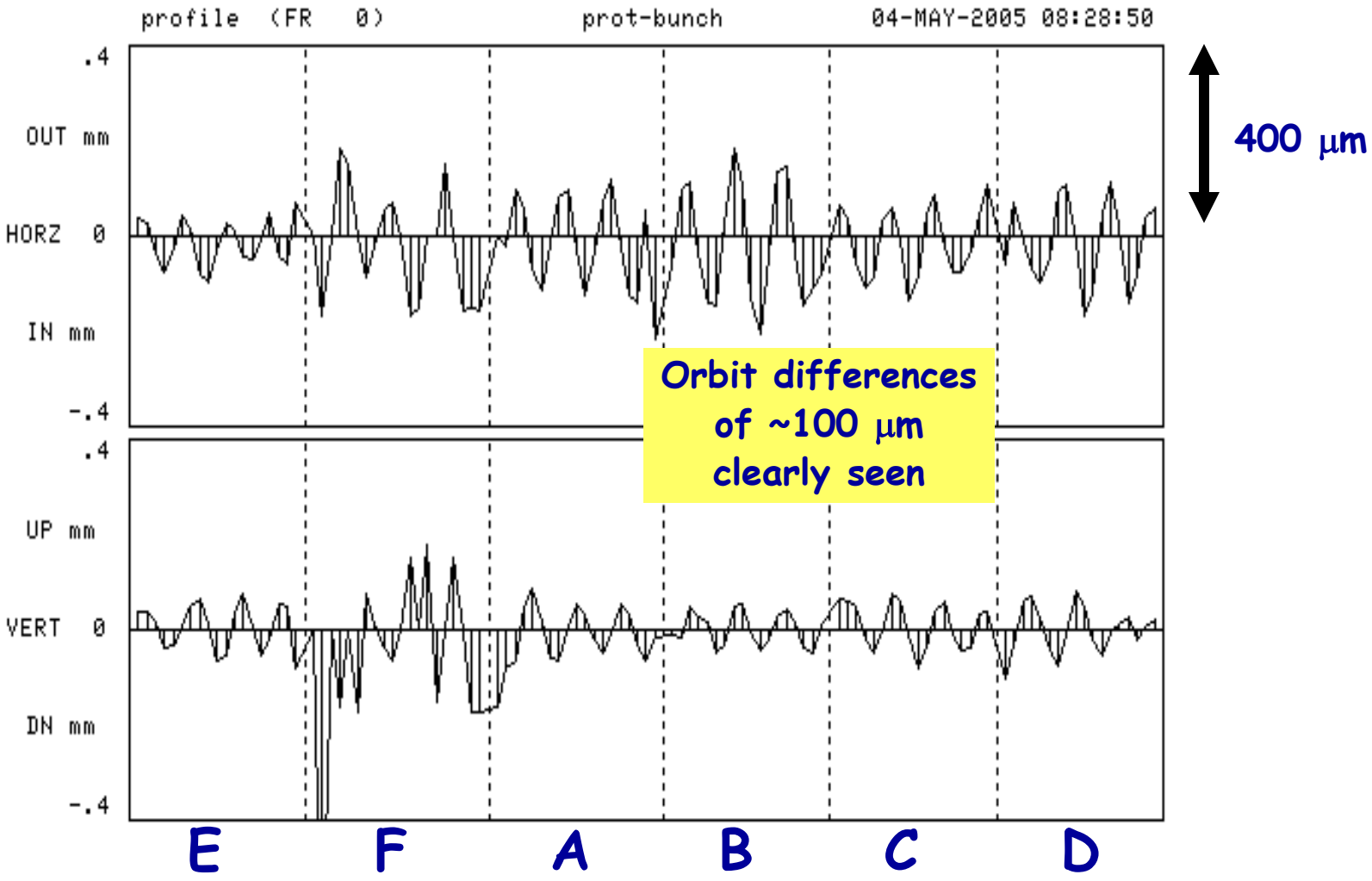
Upgraded System Performance

- Overall the upgraded system is working quite well.
- The next few slides will show some examples of closed orbit, TBT, and pbar measurements.
- Position is calculated by:

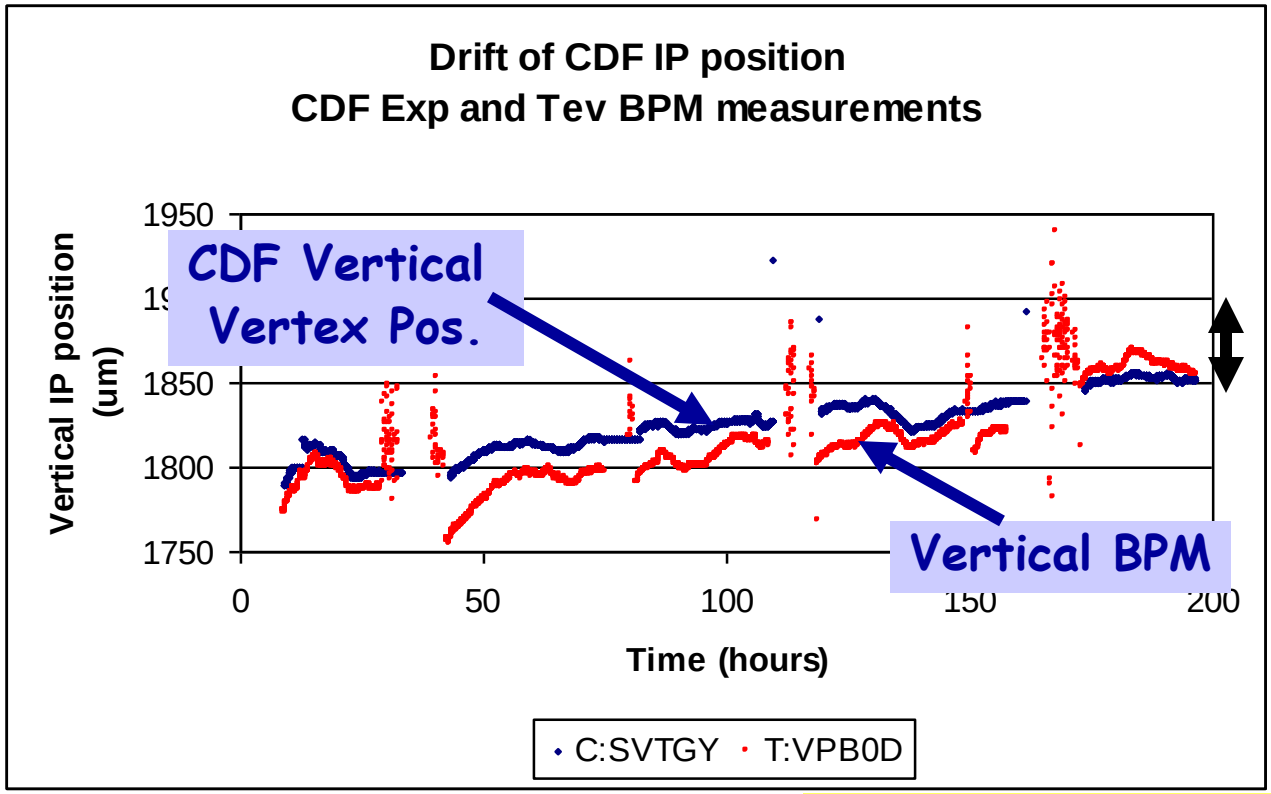
  P = 26.*(|A|-|B|)/(|A|+|B|) + offsets

  - Where A and B are the response of the two plates
  - 26. is a scale factor for this geometry
  - The scale factor and higher order terms may be refined and added as needed

Orbit differences – Comparison of two stores at tuneup

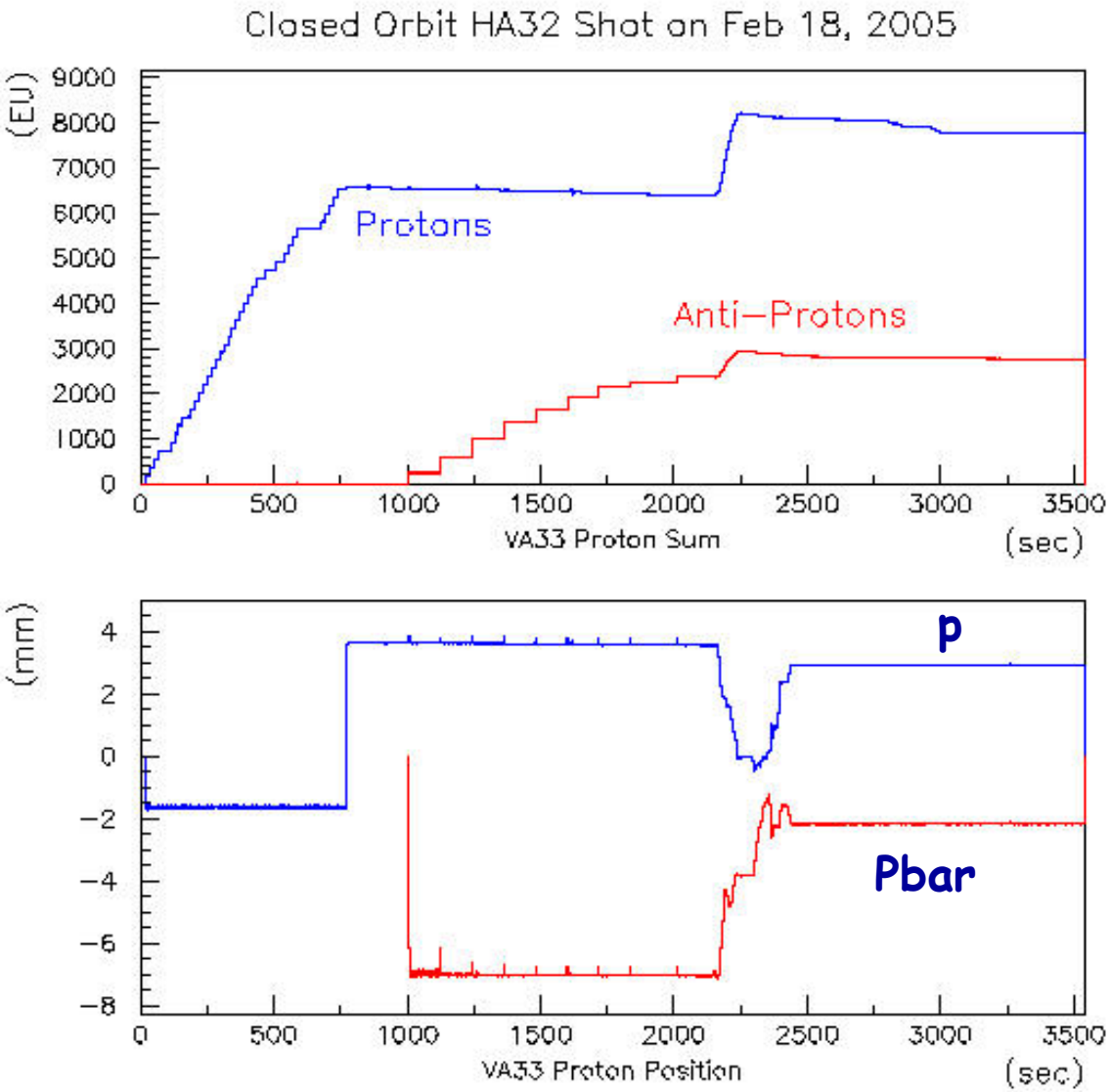


Correlation of BPM positions and CDF vertex Measurements at the level of 10-30 μm



Some of the imperfect correlation could be due to Pbar contamination of p measurements or some geometrical effect

Pbar Measurements



Cancellation of proton contamination on Pbar cables:

$$A'_{Pbar} = A_{Pbar} - aA_P - bB_P$$

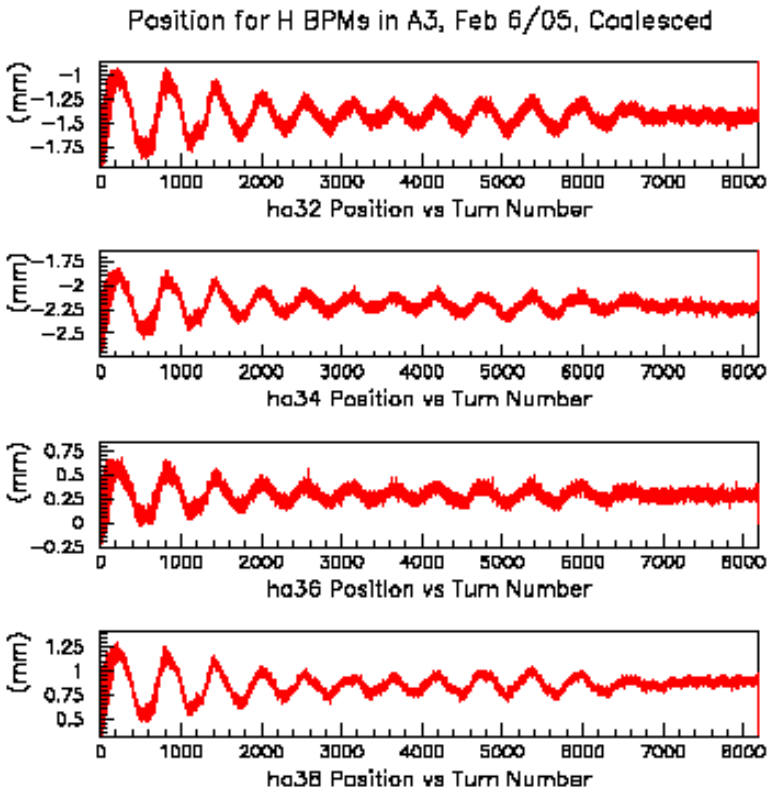
$$B'_{Pbar} = B_{Pbar} - cB_P - dA_P$$

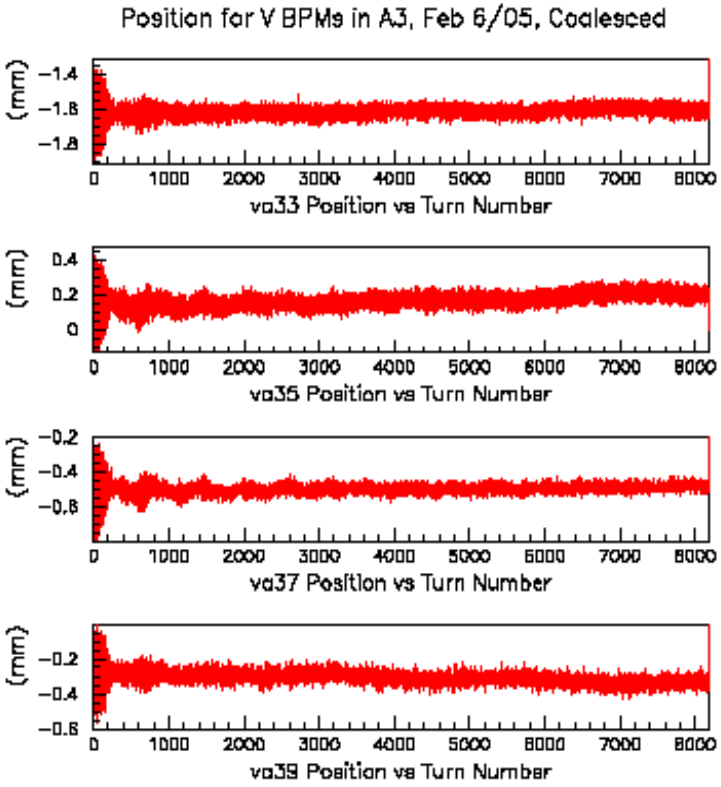
a,b,c,d determined empirically using the opening of the helix.

Using corrected values, compute sum and position as for protons.

*See Rob Kutschke's poster for details.

Turn by Turn Measurements



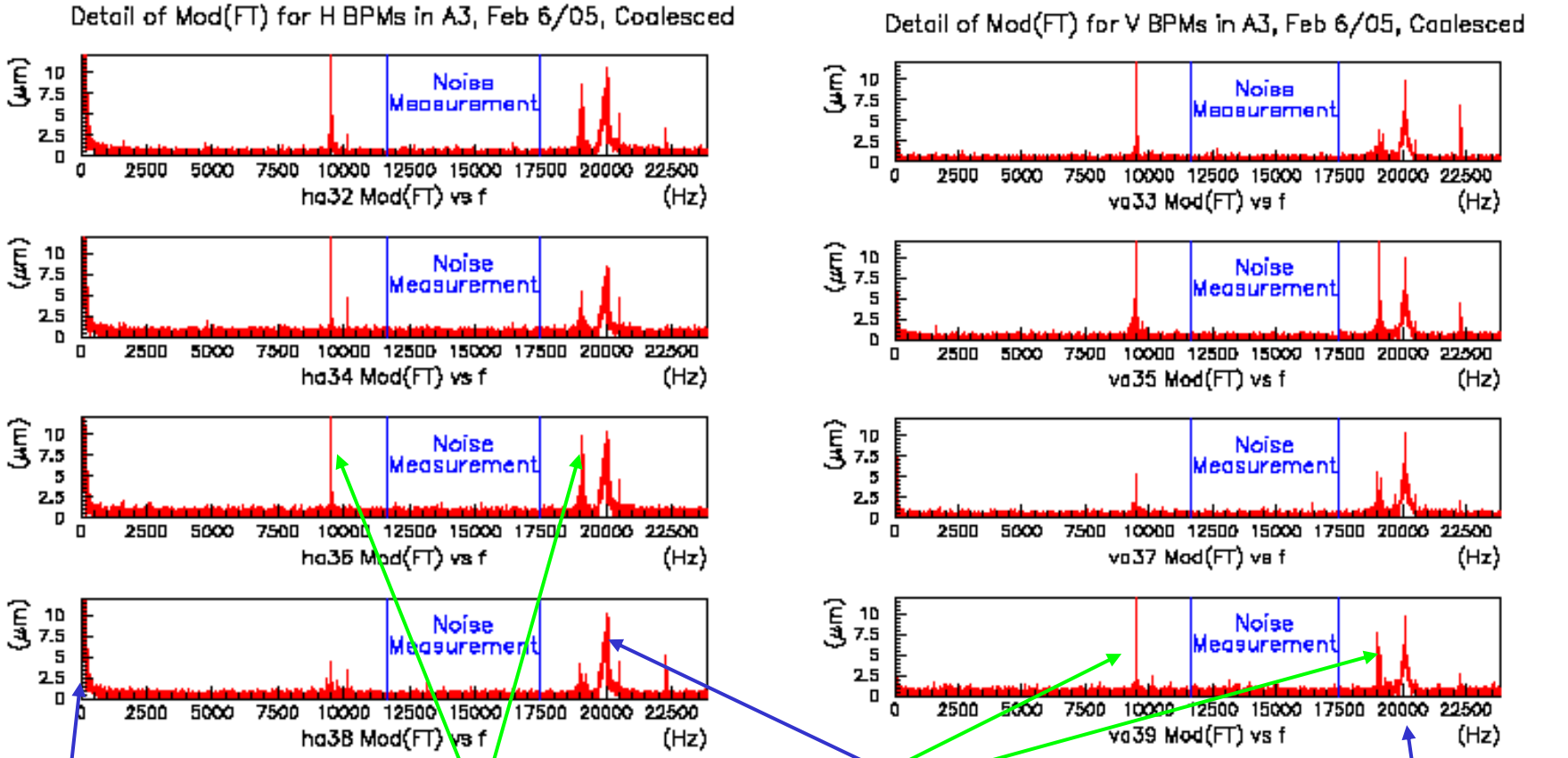


1.1 mm full vertical scale

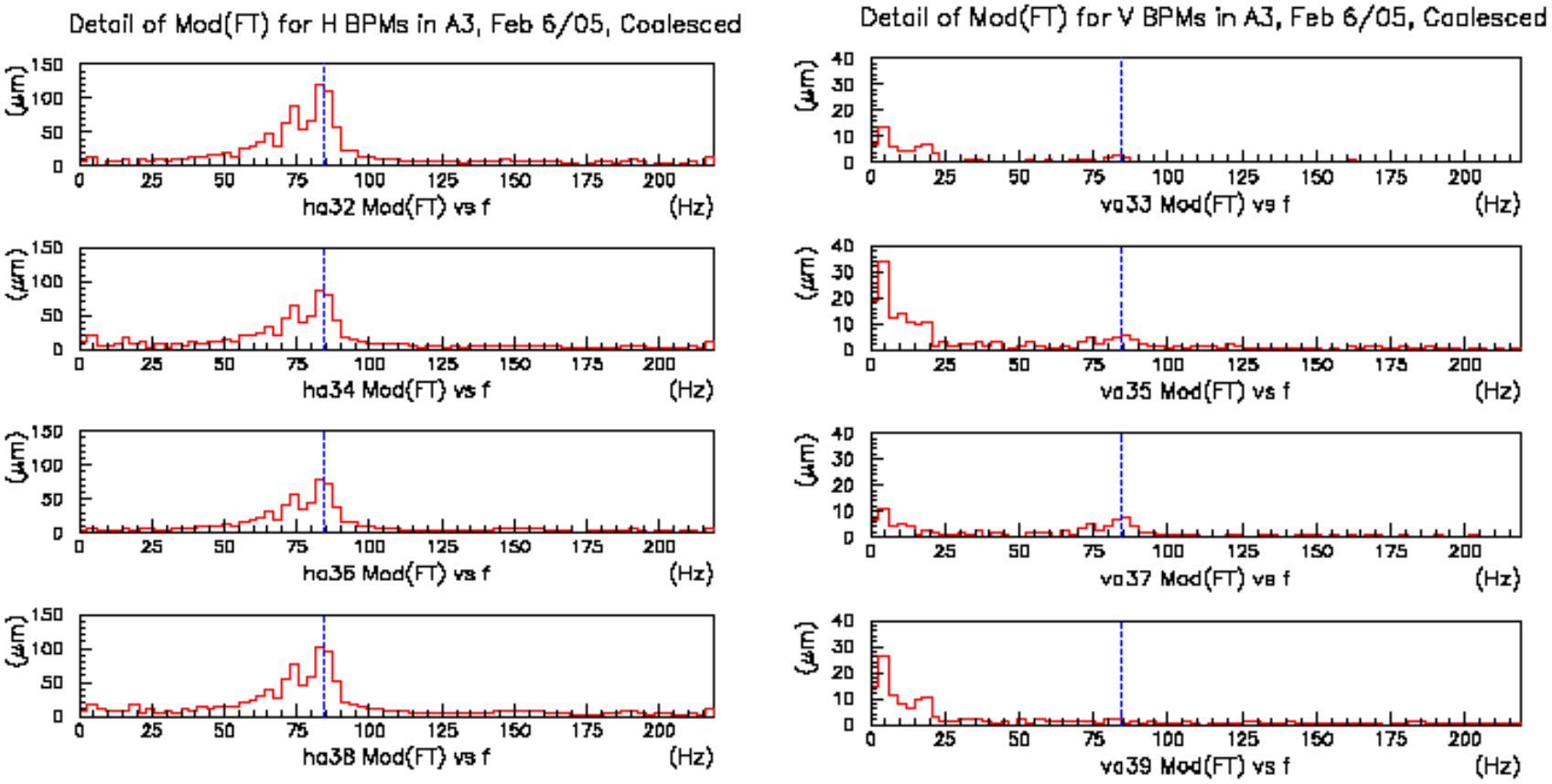
0.6 mm full vertical scale

- Injection TBT; 150 GeV; 8192 turns.
- One coalesced bunch. HEP shot after all tuning.

Fourier Transform of TBT Measurements



TBT Detail – Synchrotron lines



- Synchroton line present in H but not V.
- 150 GeV expected sync frequency: 80 Hz.

Conclusions

- The Tevatron BPM Upgrade IS successfully installed and commissioned.
- Work continues on final calibration, diagnostics, pbar measurements, documentation.
- Initial results on precision, stability and reliability are very promising.
- The successful BPM upgrade is a result of the work of many people in the Computing and Accelerator Divisions at Fermilab.