
Tevatron BPM System Upgrade Technical Update

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Run II Luminosity Upgrade Review

February 2004

BPM Accuracy/Resolution Specs

Key Specifications (Protons):

Measurement Range: $\pm 15\text{mm}$

Absolute Position Accuracy: $< 1.0\text{ mm}$

Long Term Position Stability: $< 0.02\text{ mm}$

Best Orbit Position Resolution: $< 0.02\text{mm}$ (0.3 sec averaging)

Position Linearity: $< 1.5\%$

Relative Position Accuracy: $< 5\%$

Intensity Stability: $< 2\%$

Key Specifications (Pbars) :

Measurement Range: $\pm 15\text{mm}$

Absolute Position Accuracy: $< 1.0\text{ mm}$

Long Term Position Stability: $< 0.02\text{ mm}$

Best Orbit Position Resolution: $< 0.05\text{mm}$ (0.3 sec averaging)

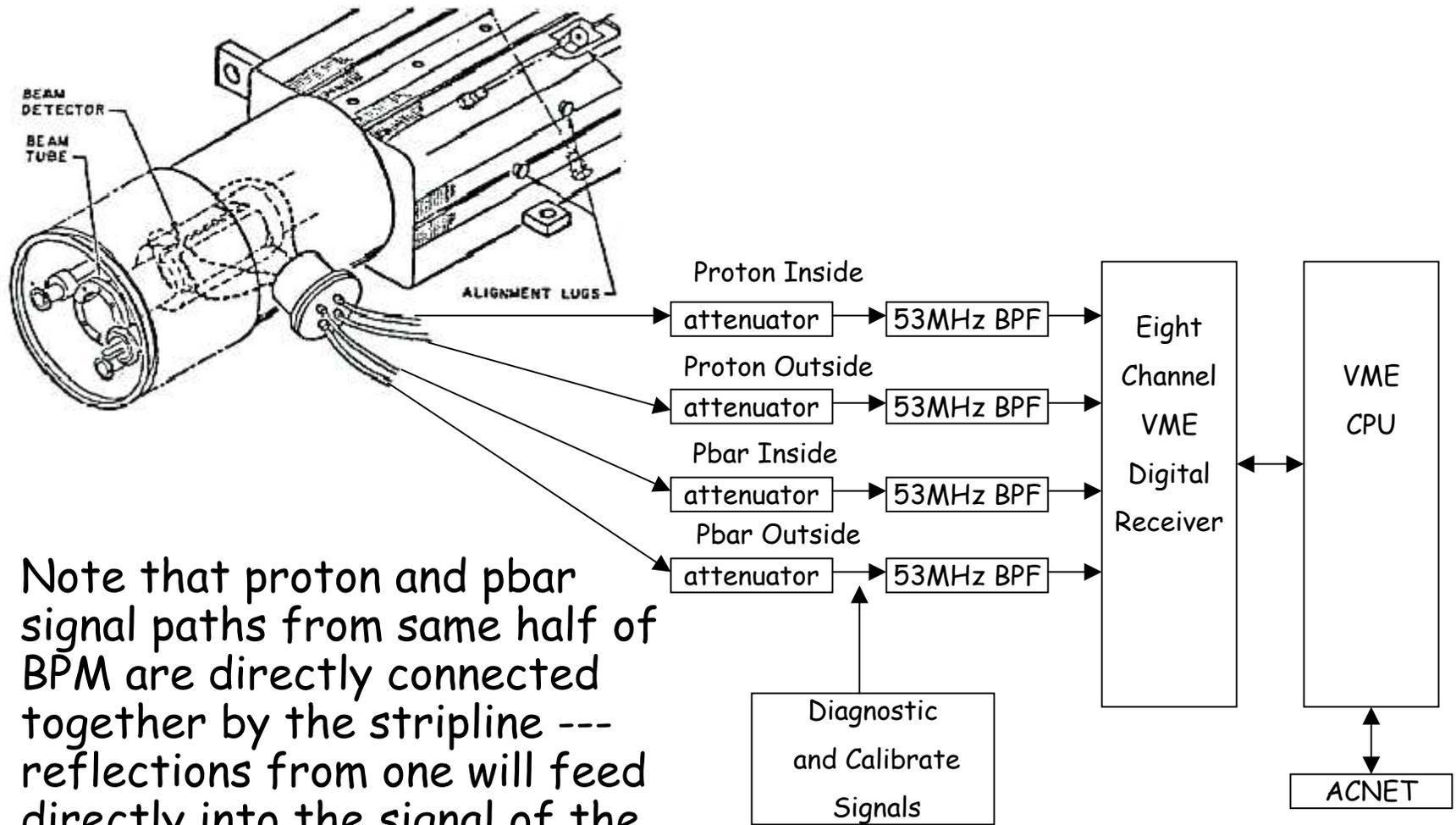
Position Linearity: $< 1.5\%$

Relative Position Accuracy: $< 5\%$

Intensity Stability: $< 2\%$

This is Table 2 from Requirements document. Table gives the most stringent requirements on the system; for certain types of operation these requirements are relaxed. Note: resolutions are stated as 3 sigma.

Block Diagram Cartoon of Signal Path

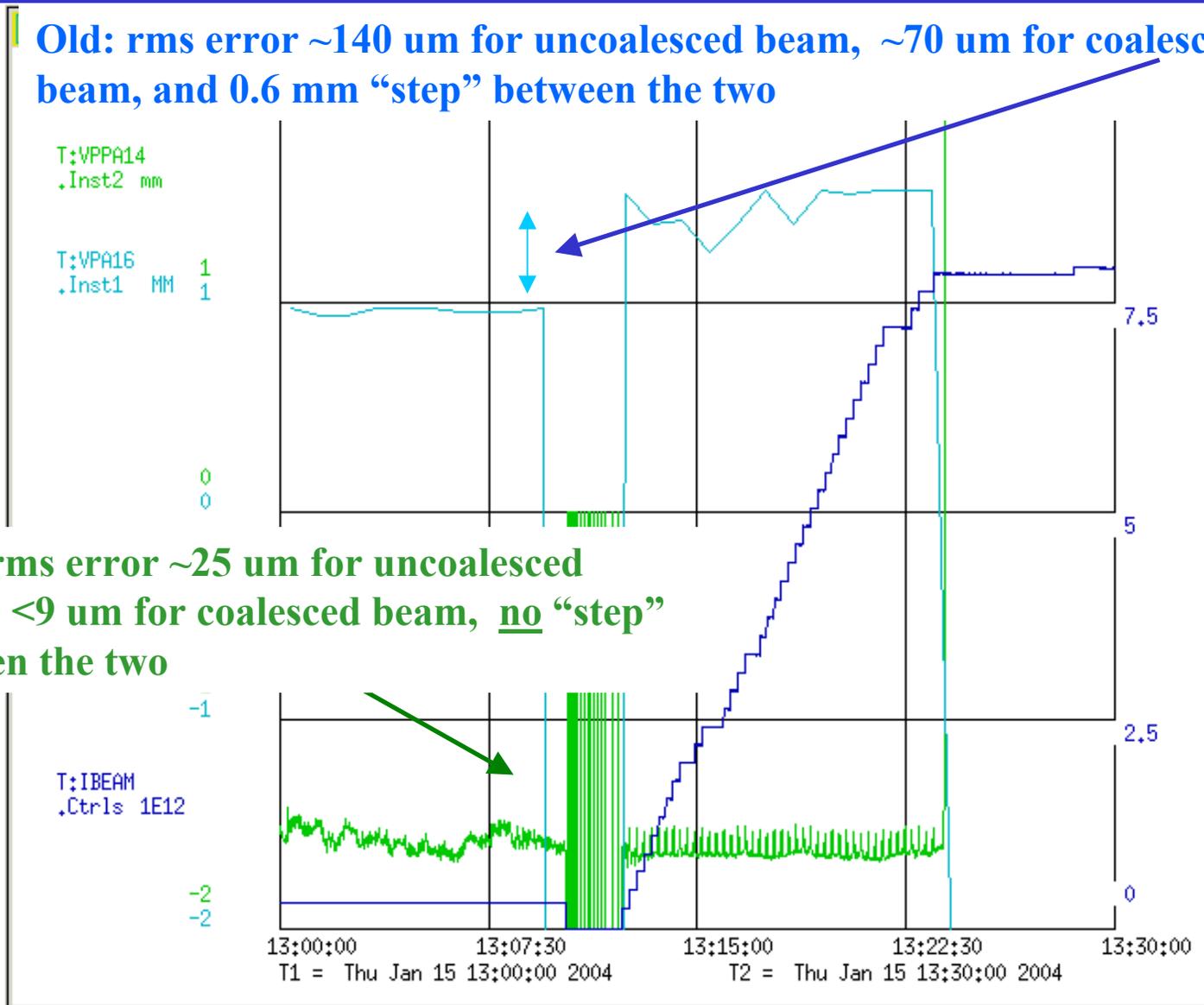


Demonstrated Beam Measurements

- Recycler-type BPM front-end is set up for development and tests in TeV House A1
- Connects to both Proton and Pbar signals of one horizontal BPM and one vertical BPM
- Interfaced to ACNET with small subset of ultimate required functionality
- Closed orbit and turn-by-turn measurement performance have been demonstrated
- In use to assess narrowband frequency domain p/pbar signal de-convolution
- Will soon demonstrate "wide" time separation of Protons and Pbars (utilize isolated bunches at the ends of the otherwise over-lapping 12-bunch trains); ~50 rather than ~5 nsec timing

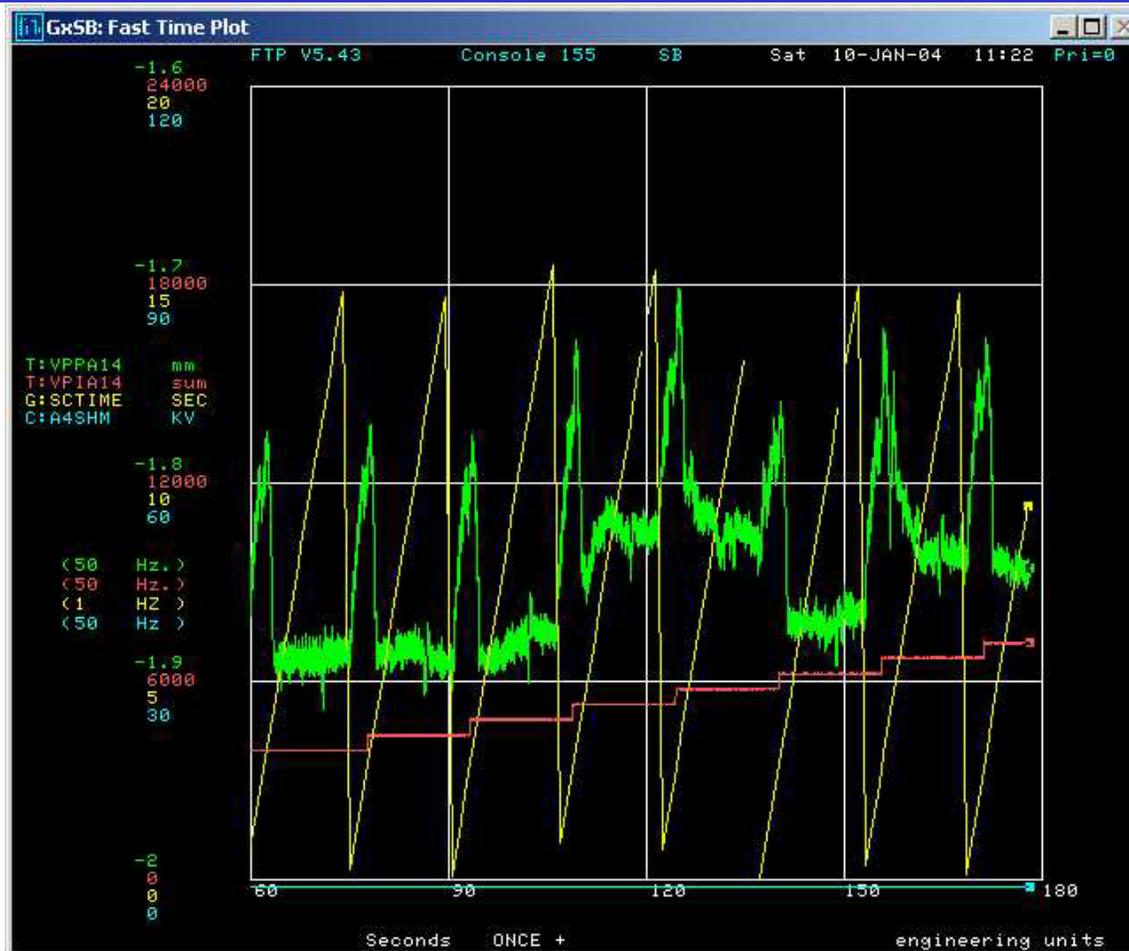
Proton Positions in Load of Store #3172: Old vs New

Old: rms error ~ 140 μm for uncoalesced beam, ~ 70 μm for coalesced beam, and 0.6 mm “step” between the two



New: rms error ~ 25 μm for uncoalesced beam, < 9 μm for coalesced beam, no “step” between the two

Closed Orbit Resolution During Proton Loading

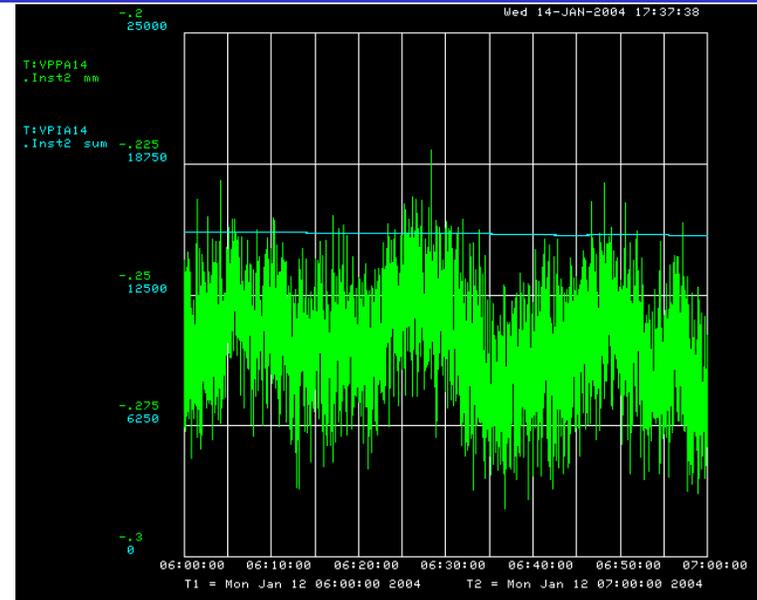
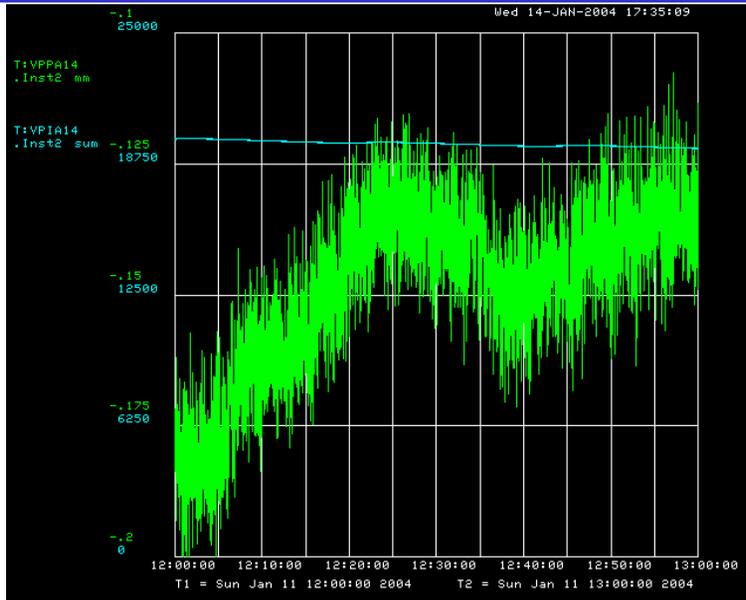


Green: Vertical Position @ 100 microns/div showing ~10 micron resolution and orbit changes due to leakage fields in ramping injection Lambertson magnet

Red: Beam Intensity showing proton bunches loading

Yellow: Time in Supercycle

Upper Limit of Closed Orbit Resolution



Two one-hour periods of 1 KHz bandwidth proton position measurement data, 17 hours apart, in store #3148. (data-logged at 1 Hz)
50 microns / vertical division

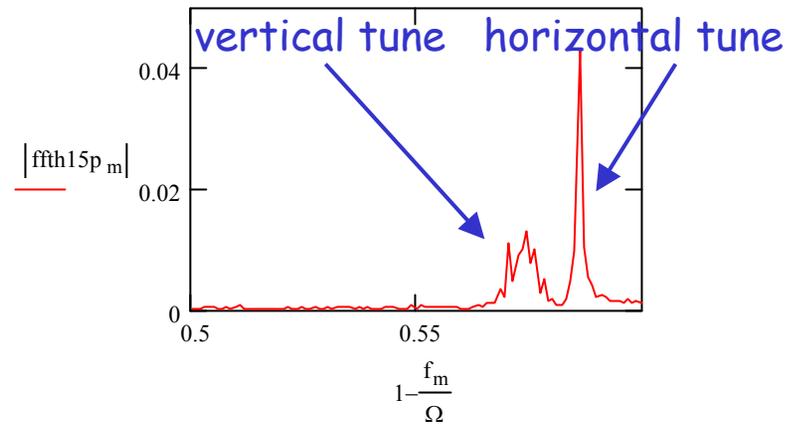
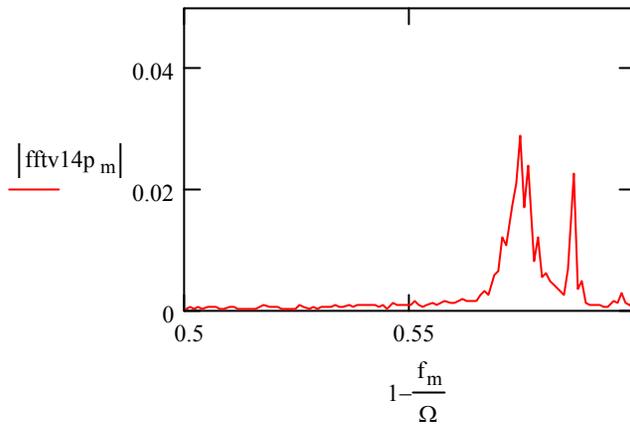
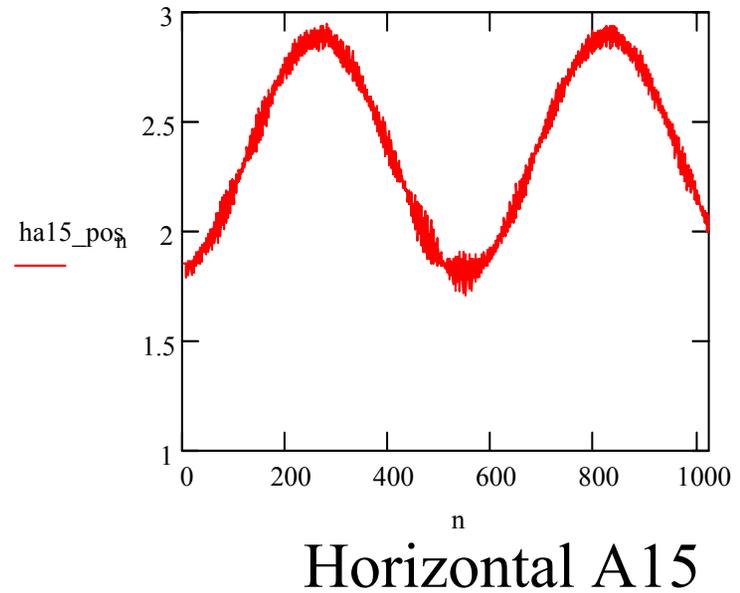
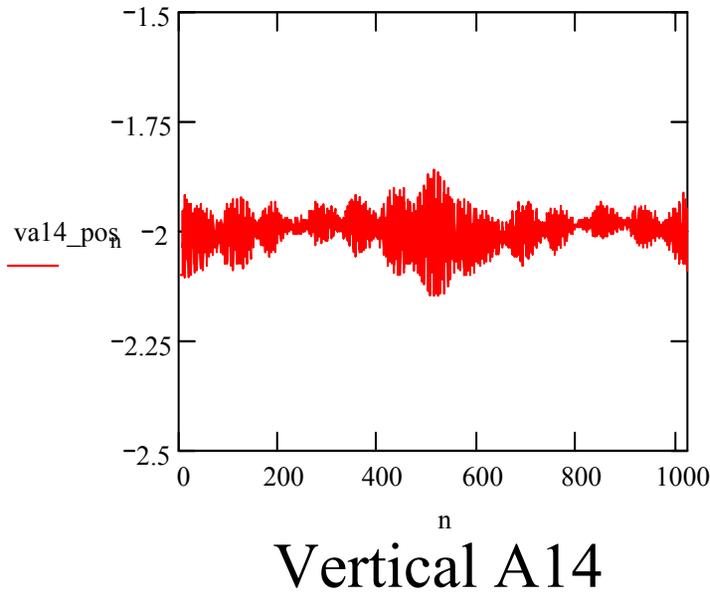
Average of standard deviations for twelve five-minute intervals

First one-hour interval
 0.0085 ± 0.00061 mm

Second one-hour interval
 0.0090 ± 0.00072 mm

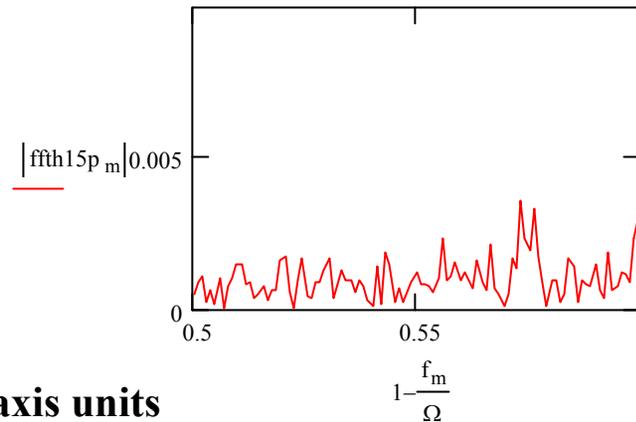
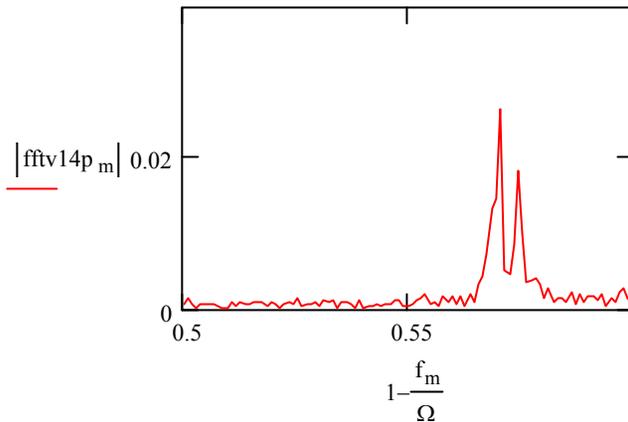
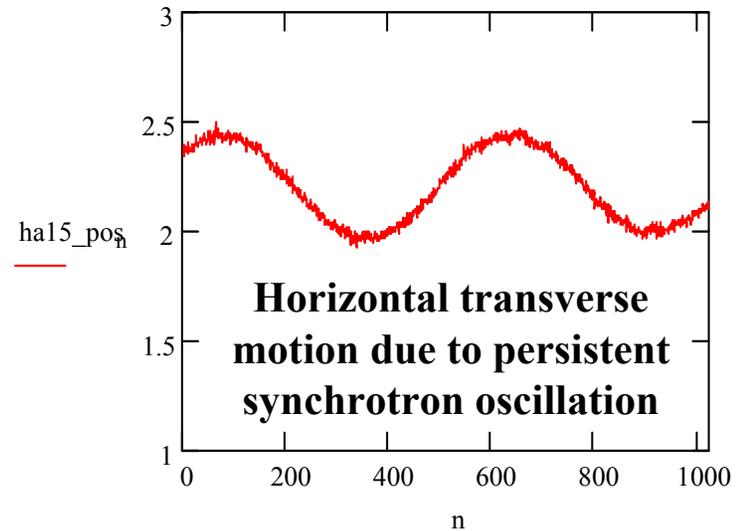
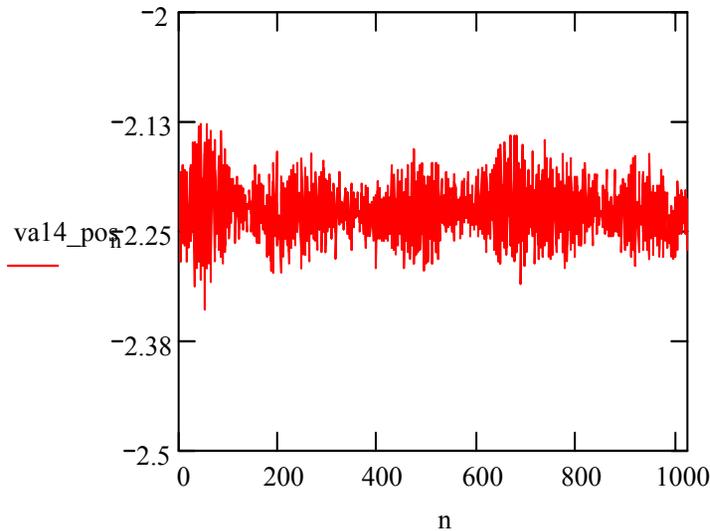
Demonstrates upper limit resolution of 9 microns rms in 1 KHz (any real beam motion not excluded) to meet spec of 7 micron 1 sigma in ~10Hz

Injection Turn-By-Turn --- Un-coalesced Protons



vertical axis units are millimeters in all plots

Turn-by-Turn Long After Injection Single Coalesced Bunch

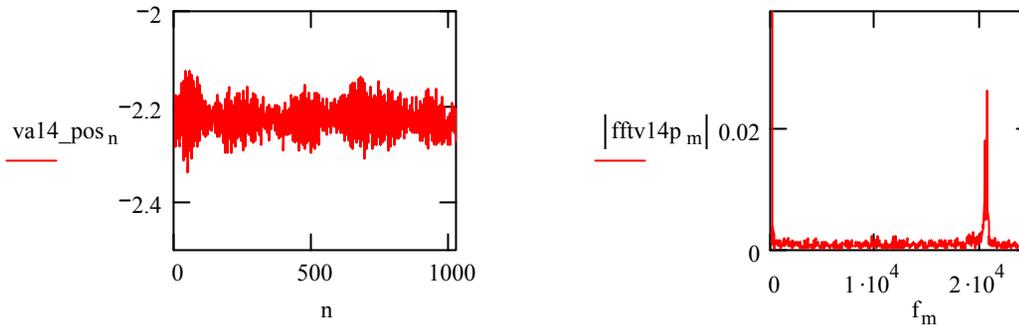


Vertical A14

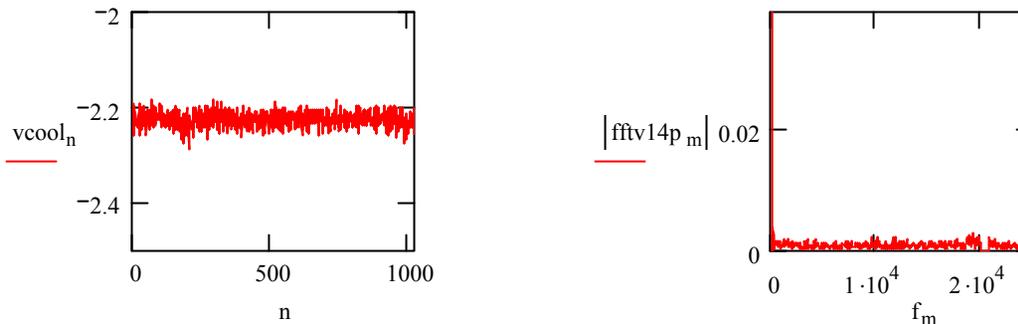
vertical axis units
are millimeters in
all plots

Horizontal A15

Upper Limits on TBT Resolution --- Vertical A14

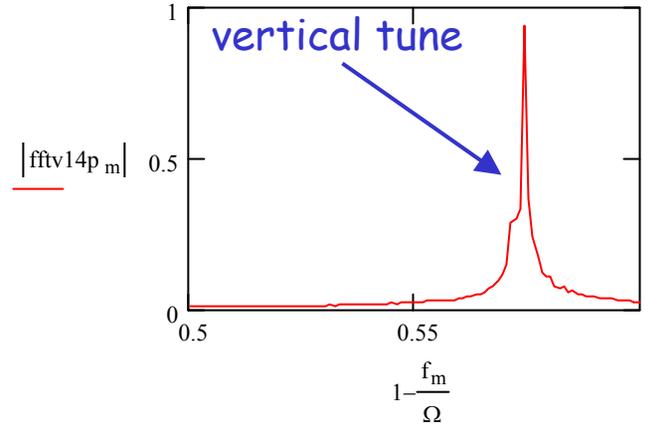
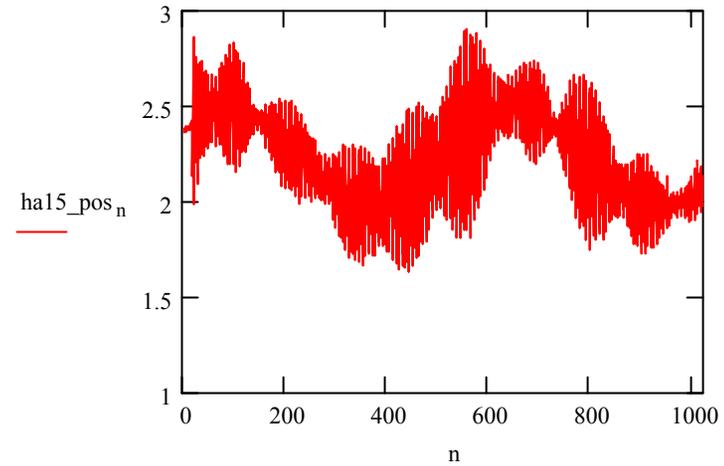
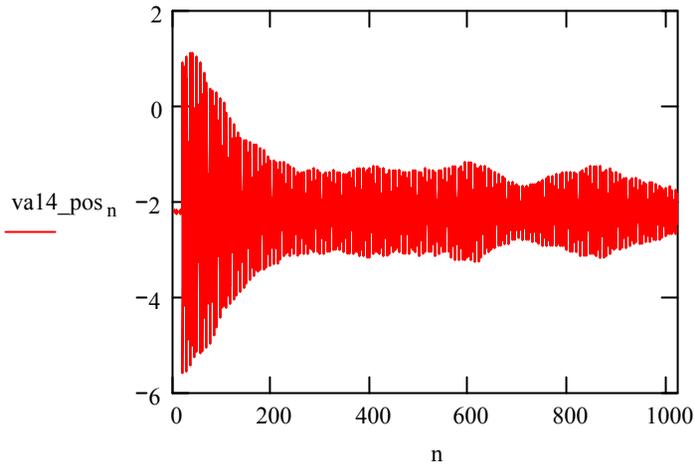


Standard deviation of raw data is 34 microns

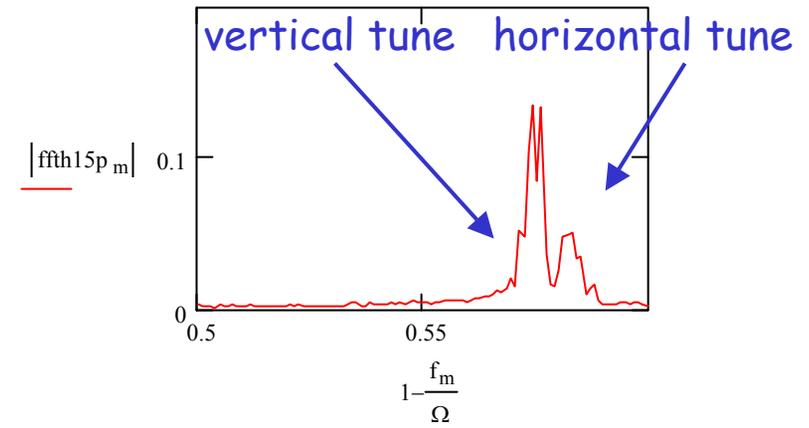


If remove betatron and synchrotron motion by zeroing 17 frequency line amplitudes around betatron frequencies and one at synchrotron frequency, leaving untouched 494 of the original 512 frequencies, TBT resolution is found to be 15 microns

Same Coalesced Proton Bunch Given Big Vertical Kick



Vertical A14

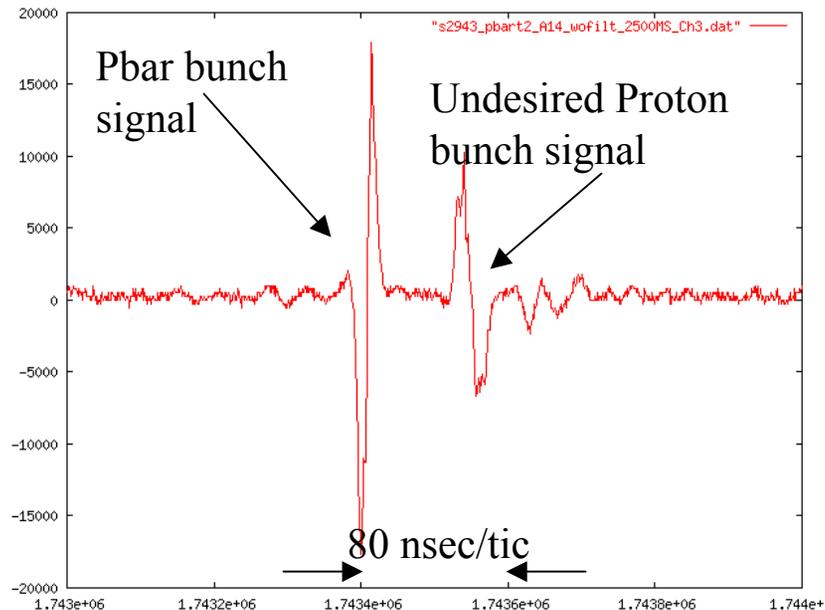


Horizontal A15

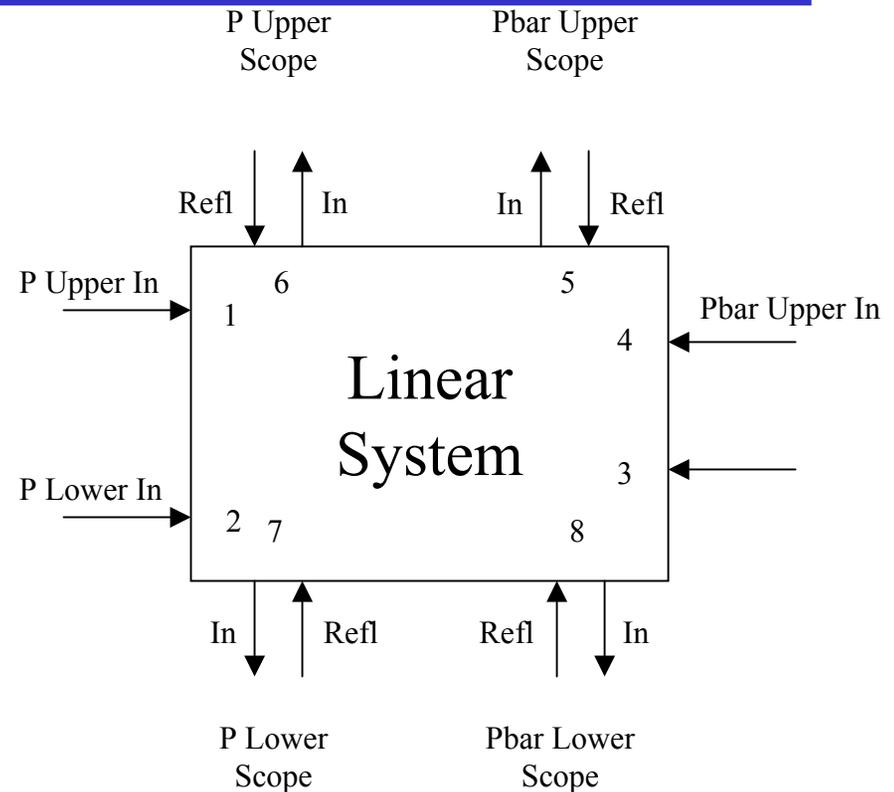
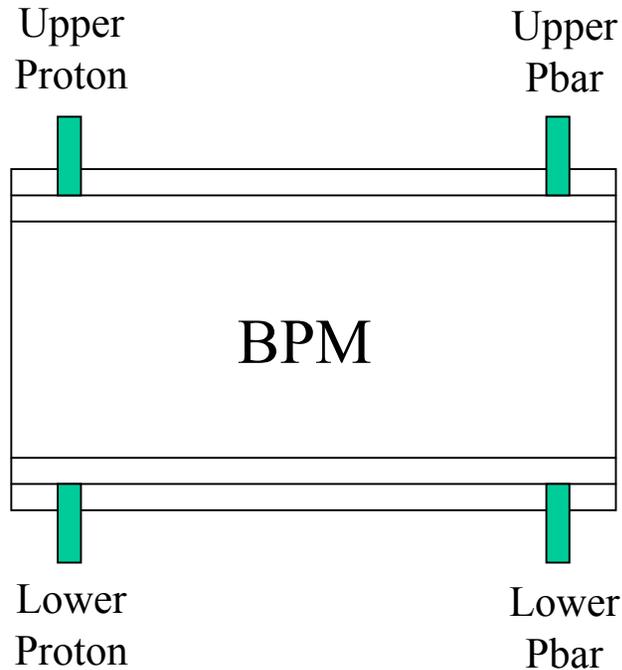
Antiproton Measurements

- Present ratio of proton to antiproton intensities combined with directivity of stripline pick-up produces residual proton signals at the antiproton port about 50% the amplitude of antiproton signals
- When antiproton intensities increase they will begin to "contaminate" the proton signals also
- We opt to not pursue p/pbar separation by precise timing

Typical signal from pbar end of BPM for present bunch intensities



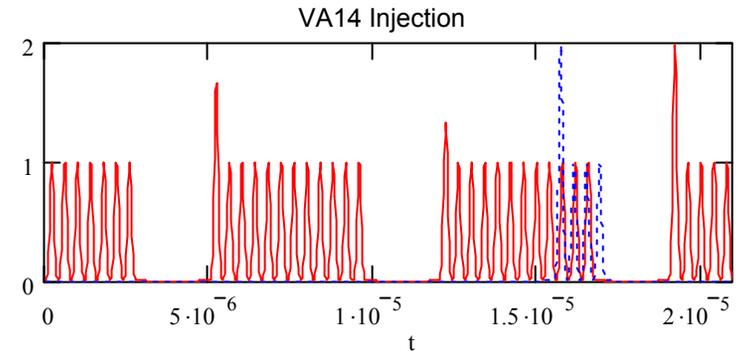
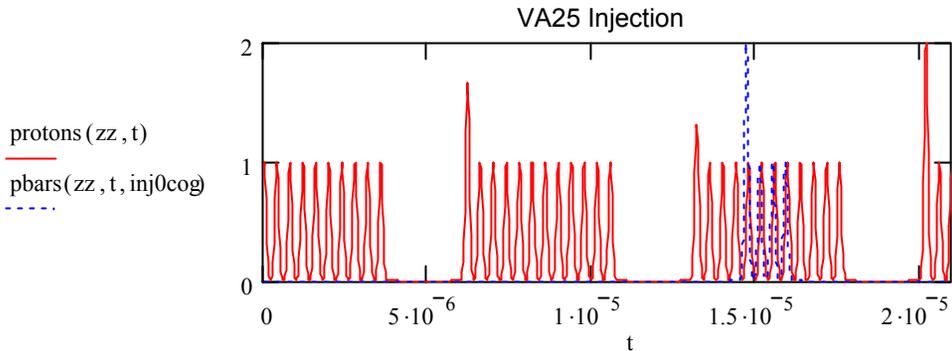
Antiproton "Plan A"



- Model BPM as an 8-port network at processing frequency
- Measure network transfer functions with beam, e.g. ratio of proton signal on pbar end to proton signal on proton end
- Measure signals then correct according to pre-determined transfer function before computing positions
- Measurements in process to determine achievable accuracy

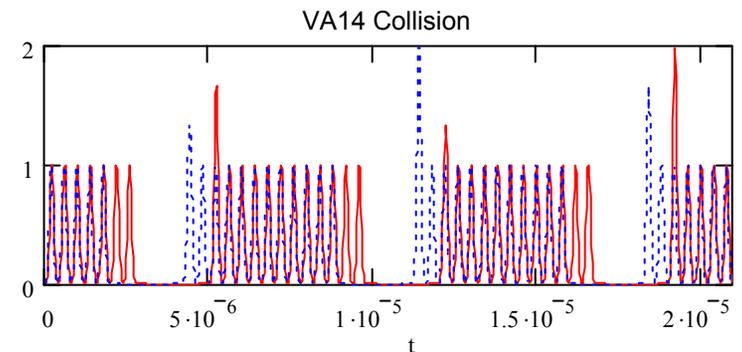
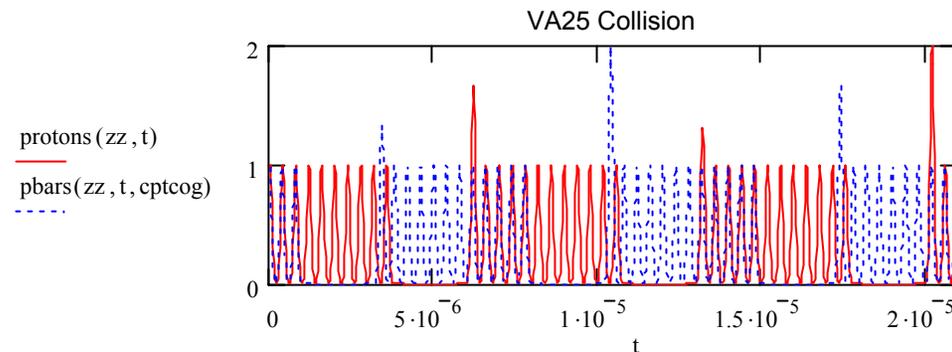
Antiproton "Plan B"

- Separate p/pbar signals with relaxed timing requiring precision and maintenance of ~ 50 nsec rather than ~ 5 nsec
- Observe only "isolated" proton or antiproton bunches at ends of 12-bunch trains



- No pbar bunches observable

One pbar bunch observable

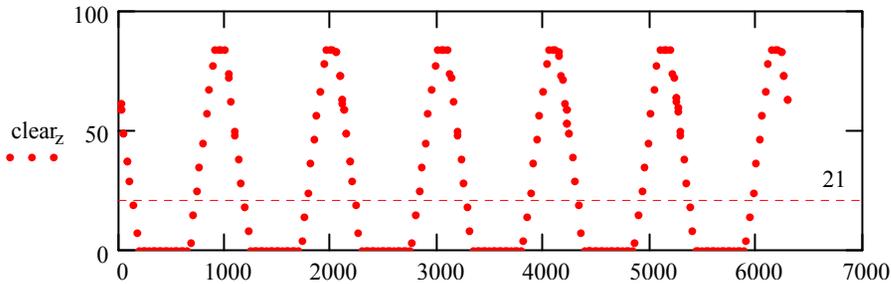


- Five bunches observable

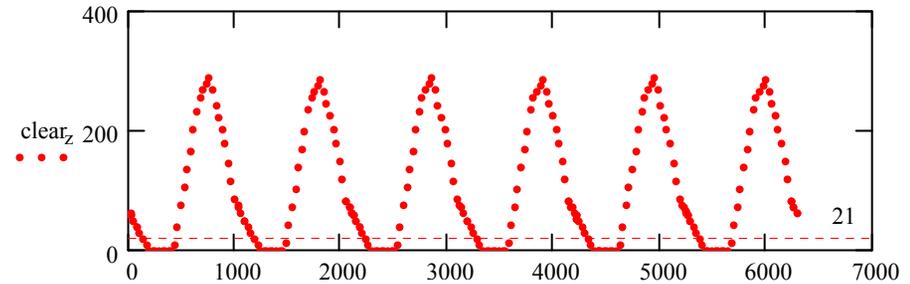
Two bunches observable

Coverage of Ring in Antiproton "Plan B"

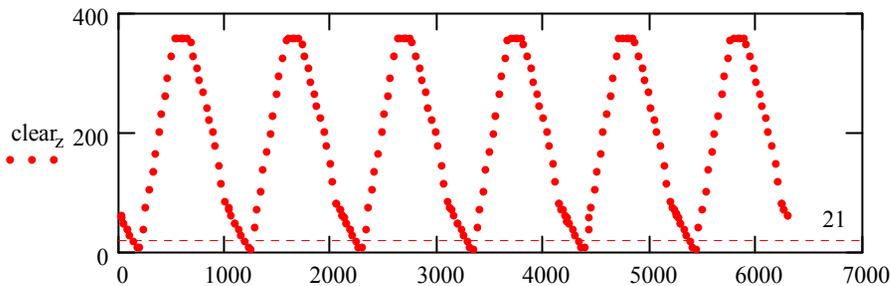
After 1st pbar injection nclr = 123



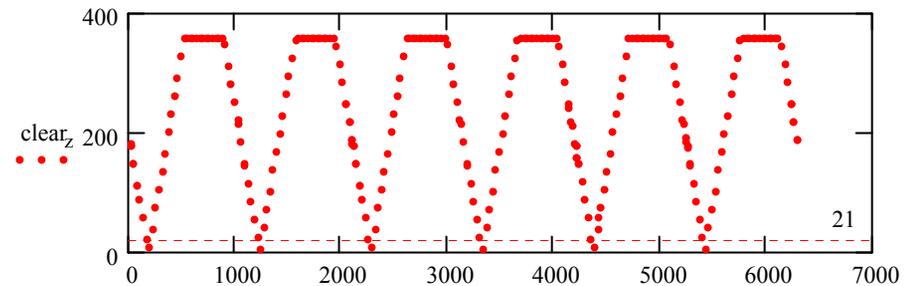
After 4th pbar injection nclr = 177



After 7th pbar injection nclr = 226



During acceleration nclr = 235



- Locations with at least one clear pbar bunch (at least 400 nsec from nearest proton bunch) at various times in cycle
- x axis is feet around ring from BO, each point is BPM location
- y axis is clearance >21 is "clear"

At collision nclr = 224

