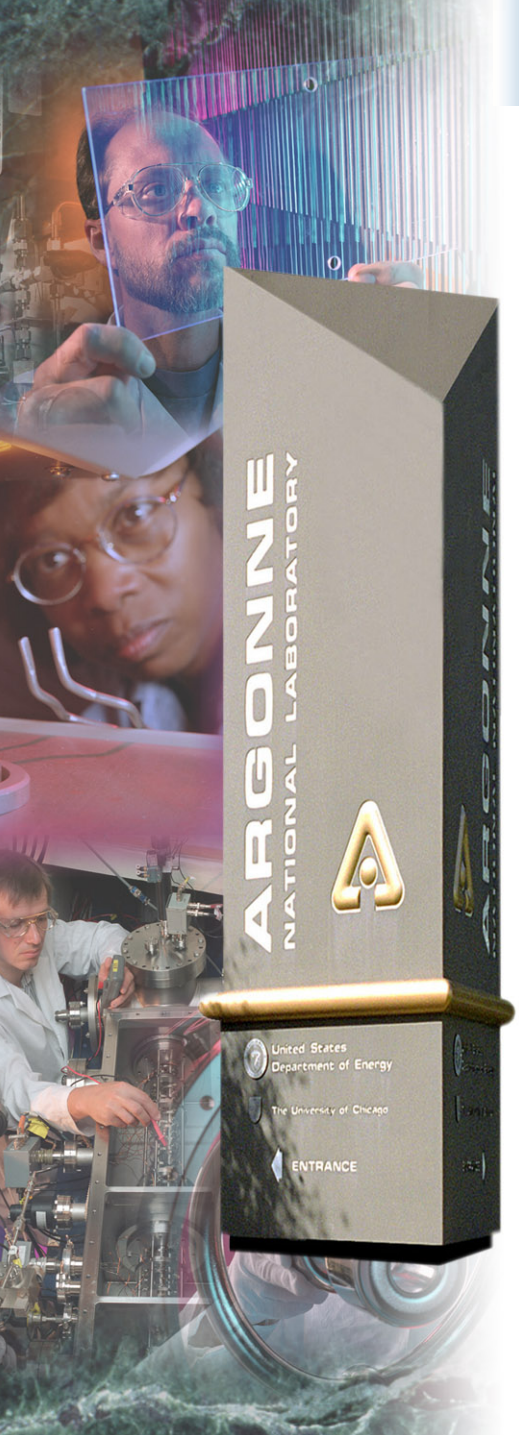

Orbit Recovery Experiences at APS Storage Ring

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Orbit Recovery – Outline

- What is Orbit Recovery? When is it needed? How is it verified?
- Bpm Offset and Setpoint Definitions
- A Cartoon – BPMs/ Magnets and Orbit Configuration Layout
- BPM Performance Comparisons – Four Flavors
- List of Applications Tools – OAG, MEDM, others
- Orbit Recovery Steps – Complexity depends on type of machine transition
- Fill Pattern/ Lattice/ Top-up Transition Track – 1999-2005
- Summary

Orbit recovery

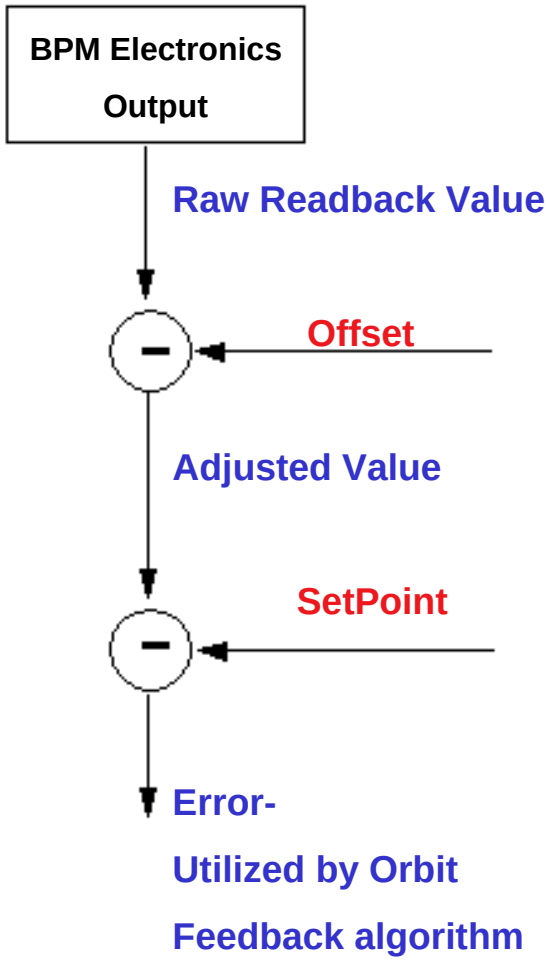
- What is orbit recovery?
  - Recover orbit/ update database when "*machine transition(s)*" occur
  - Verify photon beam alignment – up to 20 BM and 30 ID beamlines
  - Re-align ID beamline based on photon monitors, if necessary

- What are *machine transitions*?
  - Beam dump – e.g. Power supply, ACIS trip or Intentional
  - Routine calibration update – Mpbpm new timing; Bpms new gain
  - Bunch fill pattern change – 24, 1+ 7x8 (hybrid), 324 , 1296 bunches
  - Lattice change – was frequent during lower emittance lattice development
  - Shutdown activitiy – routine bpm work
  - Shutdown activity – SR girder alignment for "Decker distortion"

Orbit Recovery

- How orbit recovery work verified?
  - Collect ID xbpm data (@15mm gap) before a machine transition
  - Collect ID xbpm data after orbit recovery procedure and compare
  - Vertical BM xbpms are used in local steering
    – no verification needed
  - No reliable means for verification for horizontal BM source points

Orbit Recovery – Bpm offsets/ setpoint definitions

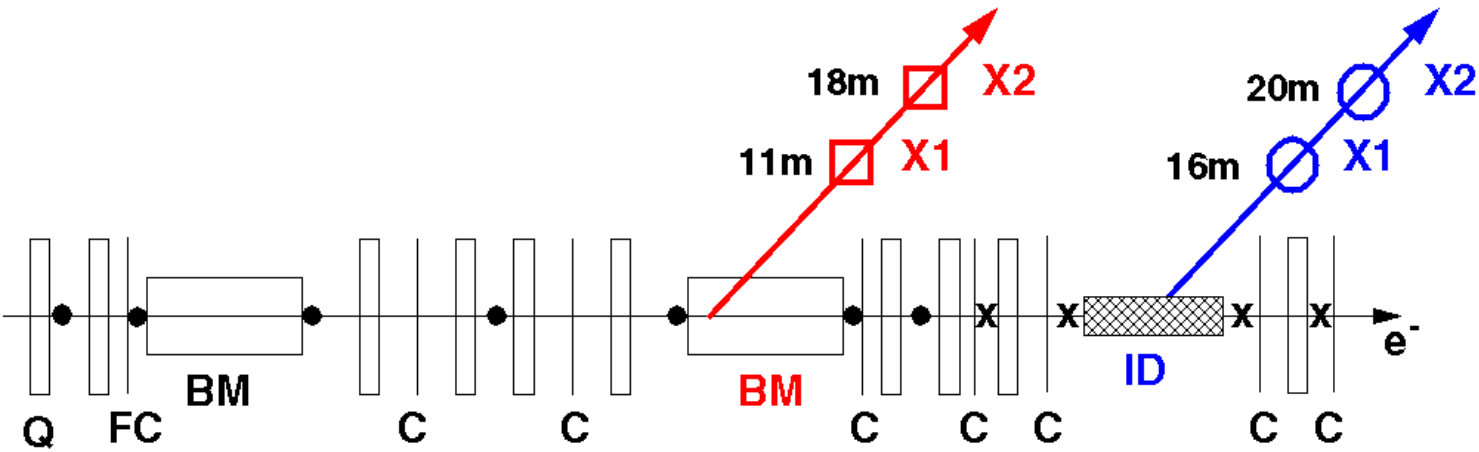


- **Offset –**
  - *Raw readback when beam is centered in an adjacent quad.*
  - *Measured by SRBPMOffset application*
  - *P1 Bpms require frequent offset measurements (utilized by beam position limit detector system - BPLD)*
  - *Manipulated during orbit recovery when fill pattern changes*
  - *Offsets are maintained in SR-BPM-Offset SCR file*

- **Setpoint –**
  - *Defines beam location from center of adjacent quadrupole*
  - *Manipulated during steering or orbit recovery process*
  - *Setpoints are maintained in UBOP SCR file*

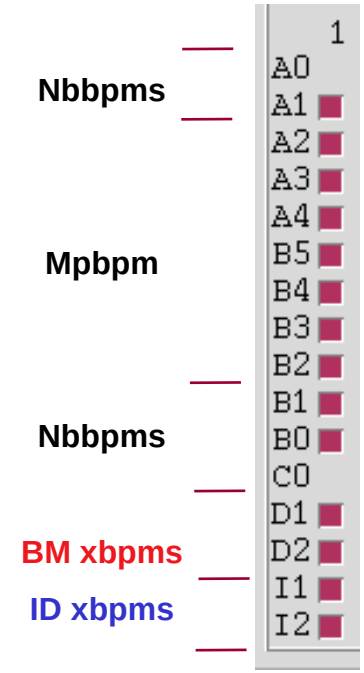
BPM/ Magnet and Orbit Configuration Layout

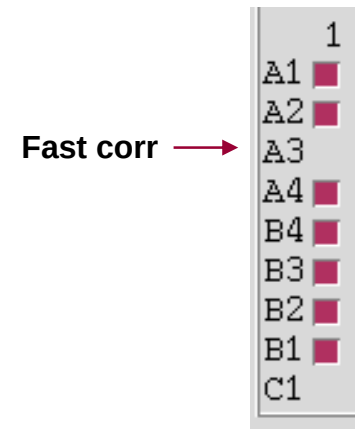
Beam Position Monitors and Magnets in One Sector



- ● : Broad-band RF Beam Position Monitors (7) (Turn-by-Turn)
- x : Narrow-band RF Beam Position Monitors (4) (~ 300 Hz)
- □ : BM X-ray Beam Position Monitors (2 - Vertical Only) (~165 Hz)
- ○ : ID X-ray Beam Position Monitors (2) (~165 Hz)
- FC : "Fast" Corrector Magnet (1) (~ 1000 Hz)
- C : "Slow" Corrector Magnets (7) (few Hz)
- Q : Quadrupole Magnets

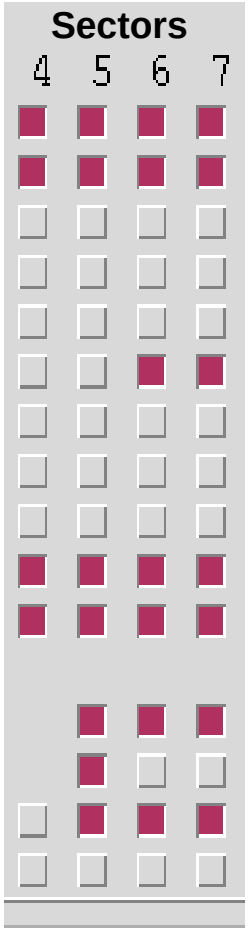
Orbit Config. Layout





Orbit Recovery – Bpms Performance Comparison

V.defaultXR



Names	Types	Overall Perfor-mance	Front End Filter BW	Fill pattern	Beam Intensity (top-up)	Rogue MW
A0 A1	Narrow band	III	500 KHz	Small effect – worst in hybrid fill	Minimal effect	Minimal effect
A2 A3 A4 B5 B4 B3 B2	Mono-pulse	VI	10 MHz	Significant fill pattern effects Requires offset adjustments	Significant effect of top-up; worst in vertical; cogging reduces effects	Significant vertical effect at curved chamber A/B3:y and A/B4:y; not used in orbit correction
B1 B0 C0	Narrow band	III	500 KHz			
D1 D2	BM Xbpm	I (best)	*No filter	No known effects	No known effects	No known effects
I1 I2	ID Xbpms	II	*No Filter	No known effects	No known effects	No known effects

***** Limited by photon emmision effects – tens of KHz position output response

Orbit Recovery – Application Tools

- OAG applications
  - BPM Configuration – offset/sp xfer
  - BPM Offset Measurement
  - SR BPLD Verification
  - SR BPLD Trip Loading
  - BPM Timing Scan (mpbpms)
  - Storage Ring AdjustBPMGains
  - SR BPM Status Management
  - SaveCompareRestore SR Systems
    - ✓ *SR (Offset, Setpoint, Corrector)*
    - ✓ *SBPMS (Gain)*
    - ✓ *SRXrayBPMs (Xbpm Rdbks)*
  - Storage Ring Steering
    - ✓ *SR Orbit Control Law*
    - ✓ *SR Multi-local Restore Steering*
    - ✓ *SR Orbit Correction Configuration*
    - ✓ *BP:5 Control Law*
  - Storage Ring PEM
    - ✓ *BPM Cogging Set up*
    - ✓ *Restore ID gaps to open or 15 mm*
    - ✓ *ID Xbpm Offset Feedforward*
  - Storage Ring Filtered BPM ADT
- MEDM applications
  - Storage Ring - sMain
  - Storage Ring Bpms - SbpmTop
  - Bunch Current Monitor - BunchIMonitor
  - ADT
  - Orbit Feedback Screens
    - ✓ *SR Realtime Feedback - SrFdBkTop*
  - ✓ BPM DataPool – dpCont

Orbit Recovery Steps

- Beam dump recovery
  - Could have large orbit errors, but usually betatron type
  - Correct orbit by h/v.default Orbit Configurations (OCs)

- Mpbpm new timing
  - Scan is done once a year to account for drifts
    - ✓*Done at low current (~1mA single bunch) for best results*
  - Installation recipe
    - ✓*Fill 102 mA and set old timing scan data; Correct orbit with Default OC*
    - ✓*Turn off all OC; Load new timing data; Transfer all Mpbpm offsets*
    - ✓*Save offsets and make new bpm offset ref file*

- Bpm new gain –
  - Measure bpm gains
  - Run “SR Adjust bpm Gains” application, adjusting ofsets/setpoints
  - Save gains (SBPM) and offsets/ setpoints (SR)

- Fill pattern change recovery

  - Fill pattern change affects mpbpm's offsets
  - A new fill pattern requires a beam dump
  - Orbit error is sum of "fill pattern" and "beam dump" effects
  - Default OCs do not work effectively
  - Current recipe in place –
    - ✓ *Fill ring with new fill pattern using bpms and corrector from last ops file*
    - ✓ *Make special Orbit Configuration*
      - Use all rfbpms and bmxbpms with small singular values (~ 10)
      - Correct orbit; Transfer mpbpms offset (offset += ErrorCC)
    - ✓ *Correct orbit by default OC; Transfer nbbpms and mpbpms offsets*
    - ✓ *Bmxpms offsets are not transferred*
    - ✓ *Bpm and correctors are saved in SR file*
  - Compare ID Xbpm from reference @ 15 mm ID gap

Lattice change recovery

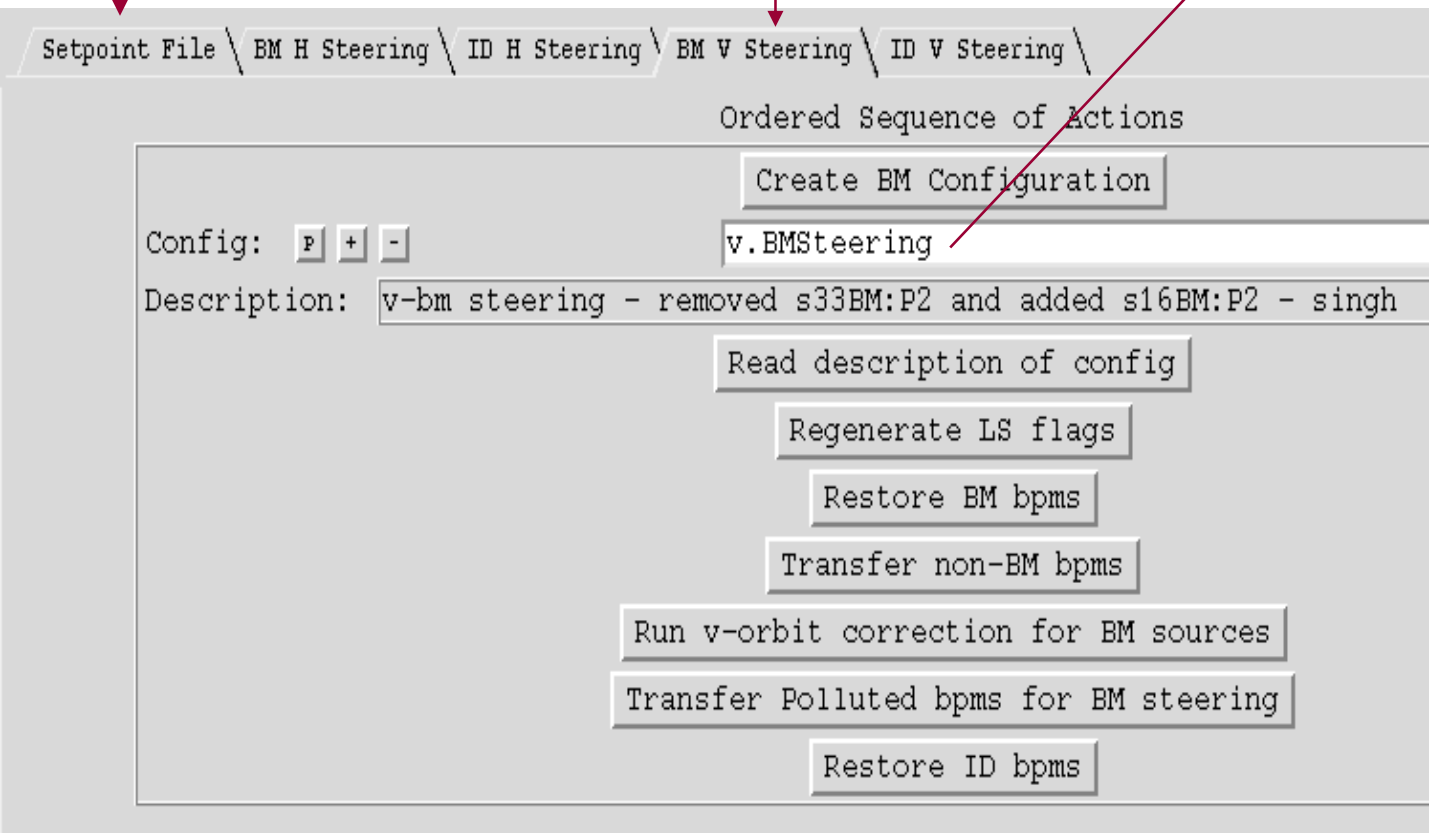
- Affects all source points (20 BM and 30 ID)
- Orbit errors are real and could be quite large
- Uncorrectable to small orbit level using default OCs
- A SR Restore Steering was developed for multi steering
- Usable only if all bpms are good - i.e. no bpm work or no fill pattern change occured
- Four recovery steps – h-bm, v-bm, h-id and v-id
  - ✓ *h-bm steering is done first and it uses a square matrix configuration – local steering is not best to use; dispersion*
  - ✓ *Other three steerings are done one at a time with local correction for all source points. A V.bm steering example is discussed ..*

SRRestoreSteering Tool -

An example – Orbit recovery of 20 vertical bm source points

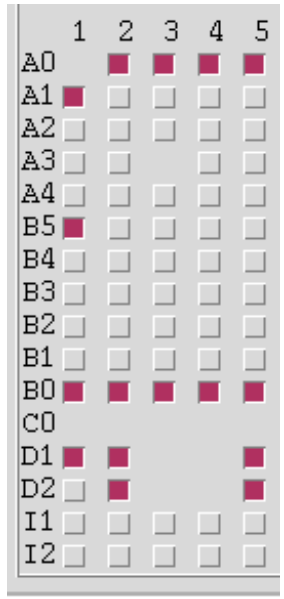
1. Select SP file

2. Select BM V Steering

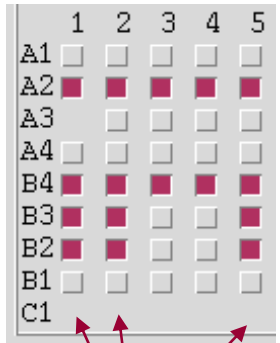


V.BMSteering

BPM



CORR



4 magnets BM Local Bumps

Orbit Recovery Steps

- Shutdown Recovery – very very messy, recovery work depends on type of shutdown work. Sometime, xbpms are only good reference.
  - Bpm upgrade work
    - ✓ *P1 bpm work requires to re-measure offsets and bpld validation*
    - ✓ *Final alignment with xbpms data may be needed*
  - Removal/ reconnection of bpm cables – to support bakeout
    - ✓ *P1 bpm work requires to re-measure offsets and bpld validation*
    - ✓ *Final alignment with xbpms data may be needed*
  - Girder Alignment -
    - ✓ *Bpm cables removed/ reconnected*
    - ✓ *Quads adjustment – lattice change effects*
    - ✓ *Final alignment with xbpms data may be needed*

1999-2006 Transition Track - Fill Pattern/ Lattice/ Top-up/ Upgrade

Year	User Operation Mode			Special Operation Mode			Major Milestone/ Activitiy
	Pattern	Lattice	Top-up	Pattern	Lattice	Top-up	
1999	6+21	High Emit	No	6+ 7x8	High E	No	Intensity scrapedown reqd
2000	6+21	High E	No	6+ 7x8	High E	No	Decker distortion started
2001	6+21	High E	No	1+7x8 1+7x8 6+21	High E Low E High E	No Yes No	Mpbpm MN installation
2002	6+21	Low E	Yes	1+7x8 3+7x8 6+21	Low E High E High E	yes No No	1. Mpbpm new timing system 2. Filled 1+ 22 singlets 3. BPLD upgrade to nbbpm (P1)
2003	1+22			1+7x8 1+22 324	Low E High E Low E	Yes No No	1. High single bunch current 2. Cogging implemented 3. Filled 1+23 singlets
2004	1+23 (24)			1+7x8 324		Yes No	1. Inten Scrapdown stopped 2. Lattice swap stopped
2005	24			1+7x8 324 1296		Yes No No	Decker distortion completed
2006	24			1+7x8 324 1296		Yes No No	

Orbit Recovery - Summary

- 1999 - Started with simple orbit recovery; 2 fill patterns and intensity scan

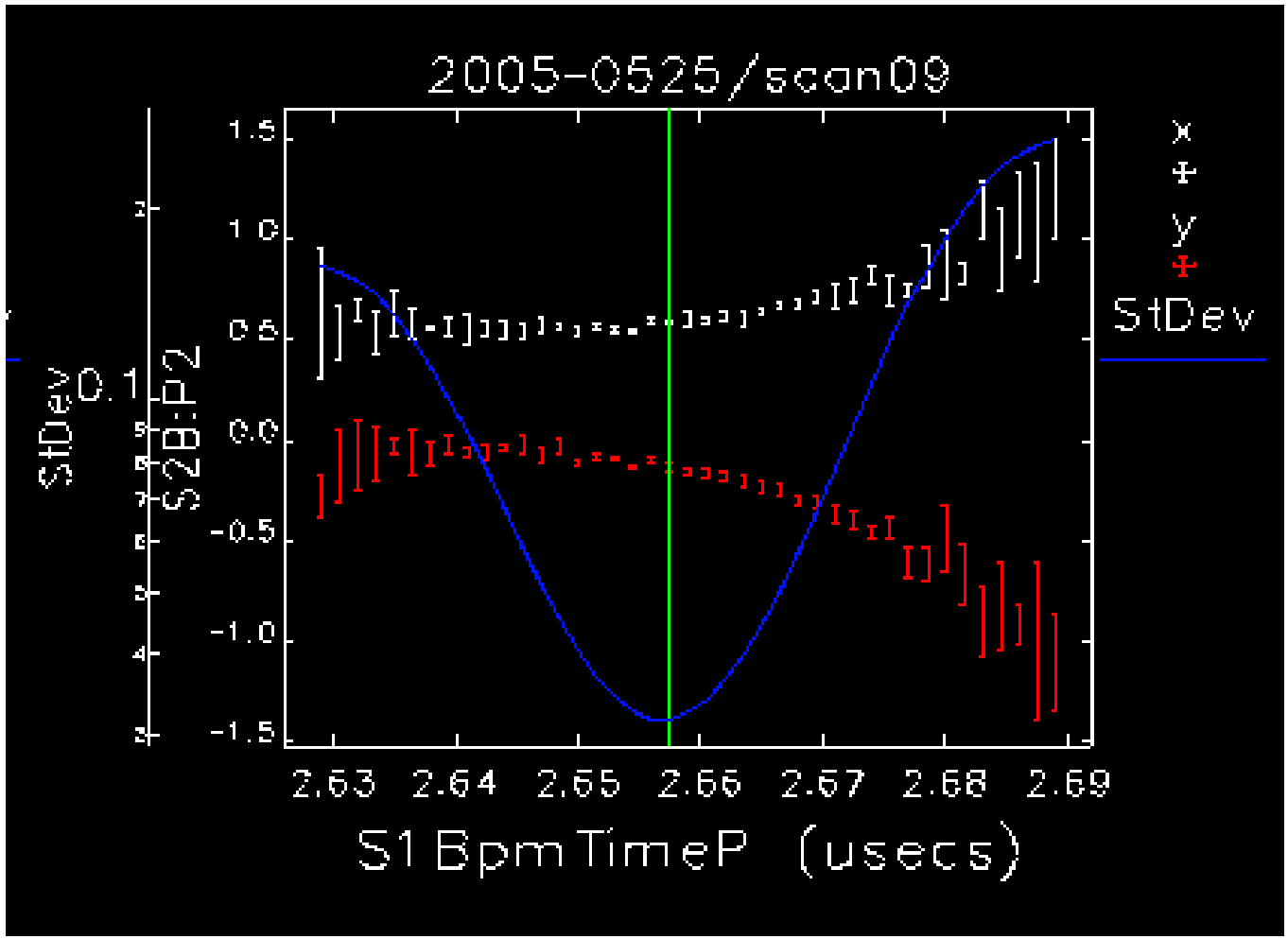
- 2000 to mid 2005 –
  - Complex orbit recovery - Decker distortion, Lattice swaps
  - Several Application tools developed
  - Switching BPLD to Nbbpms (P1) simplified recovery
    – P1 offsets measurement not required for every fill pattern

- 2006 – Ending with simple orbit recovery
  - Decker distortion completed
  - No lattice change in operation since last one year
  - Intensity scans are not required
  - Planned to develop PEM procedure for fill pattern orbit recovery

Orbit recovery experience presentation is based on orbit recovery work and many application development done by many APS personnel during last 6-7 years.

End of Presentation

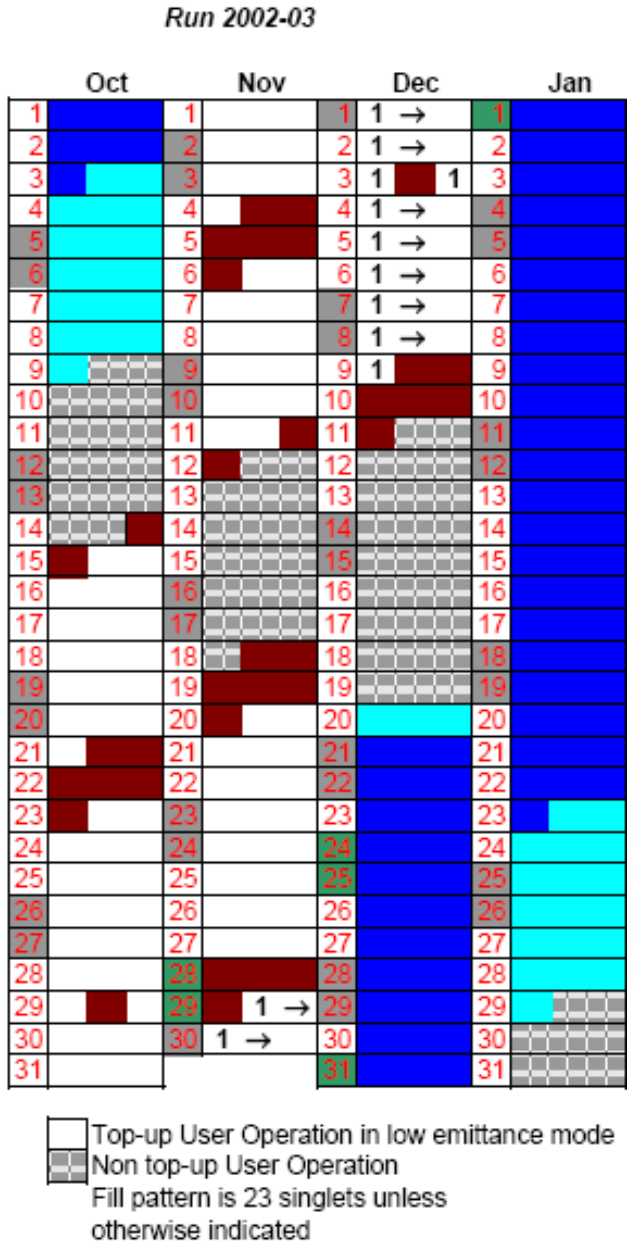
Appendix – Mpbpm Timing Scans



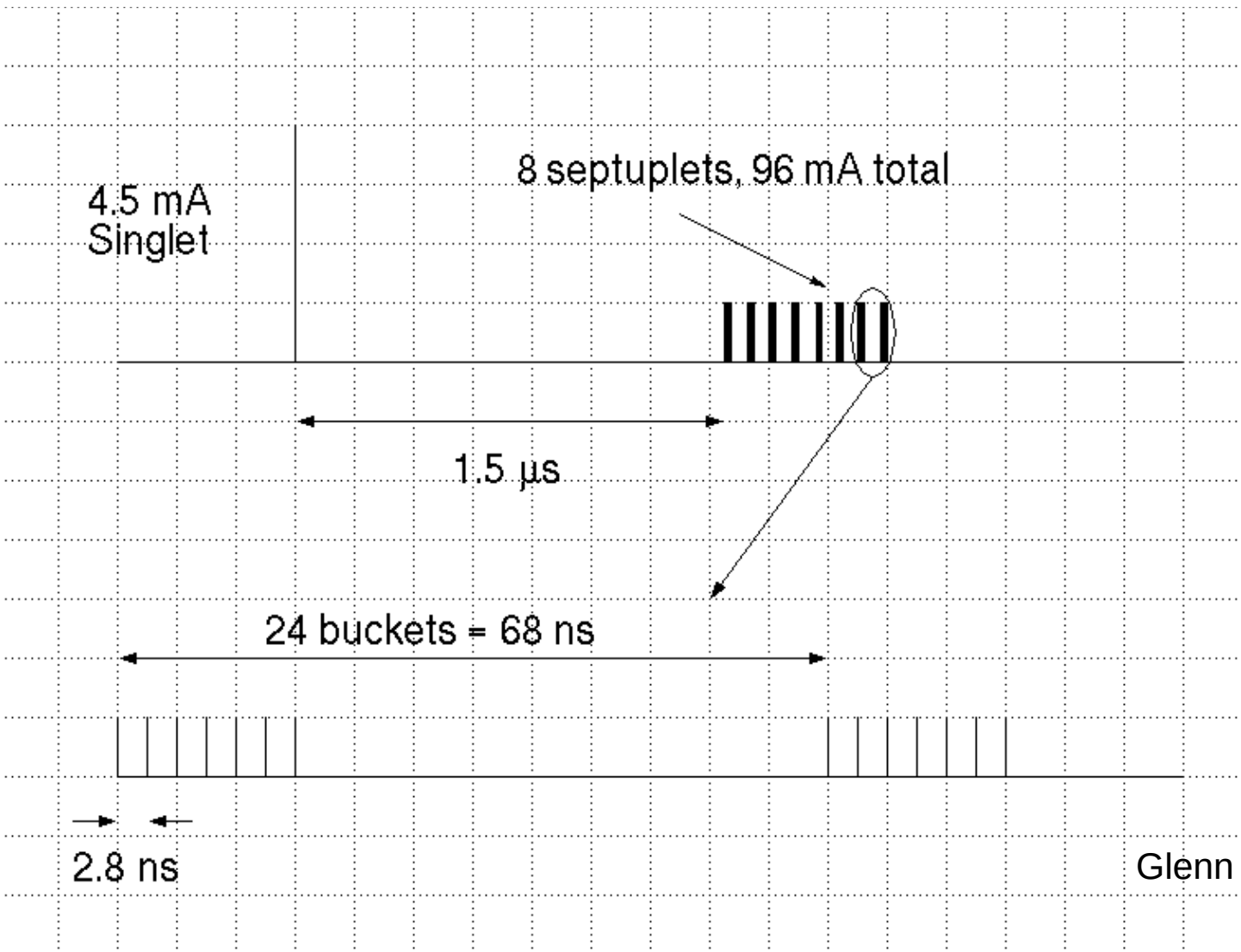
Appendix – Run 2002-03

Example - one of many complex orbit recovey run periods

- ❑5 emittance transitions
- ❑2 Fill Pattern transitions
- ❑Decker Distortion

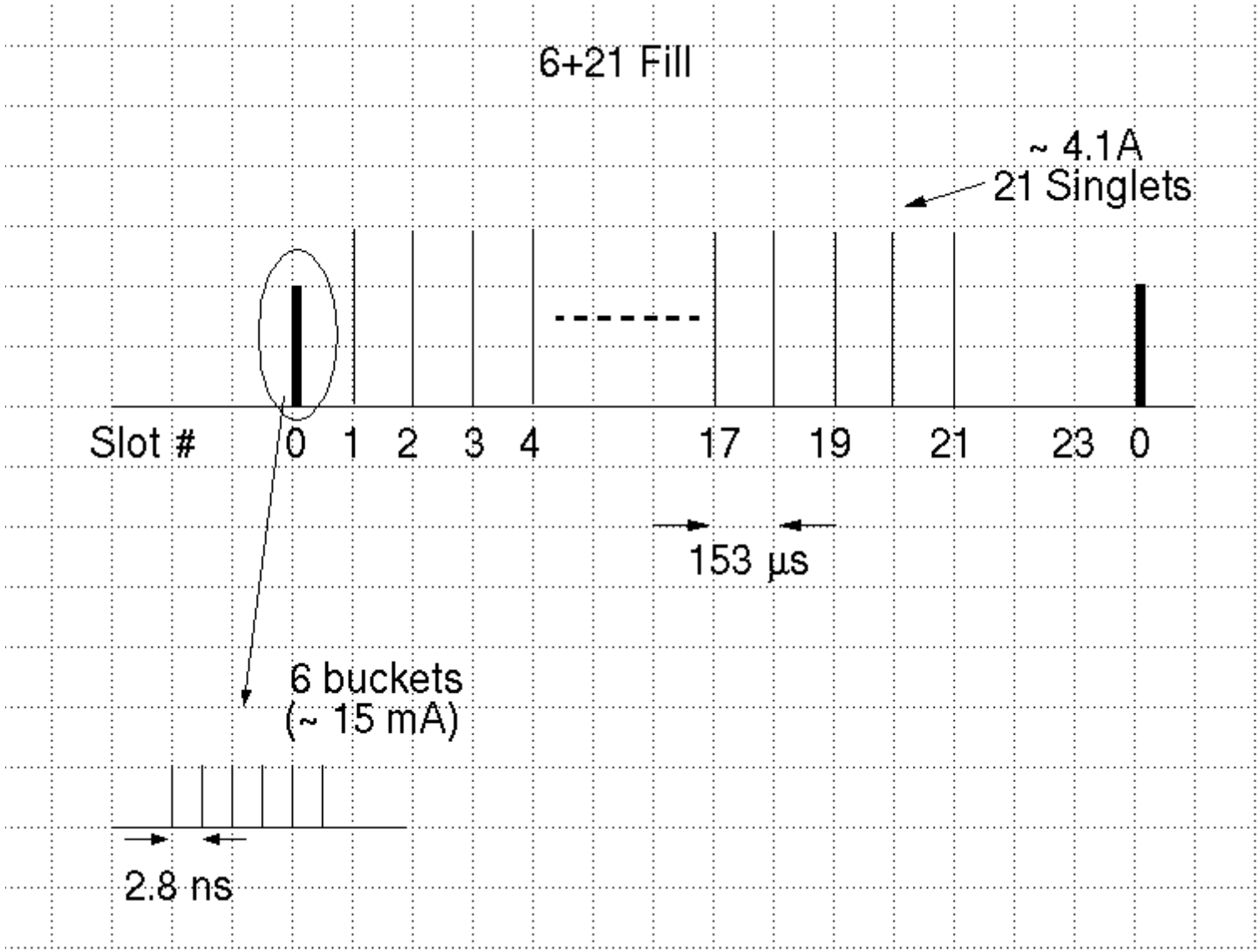


Appendix – 1+7x8 Hybrid fill

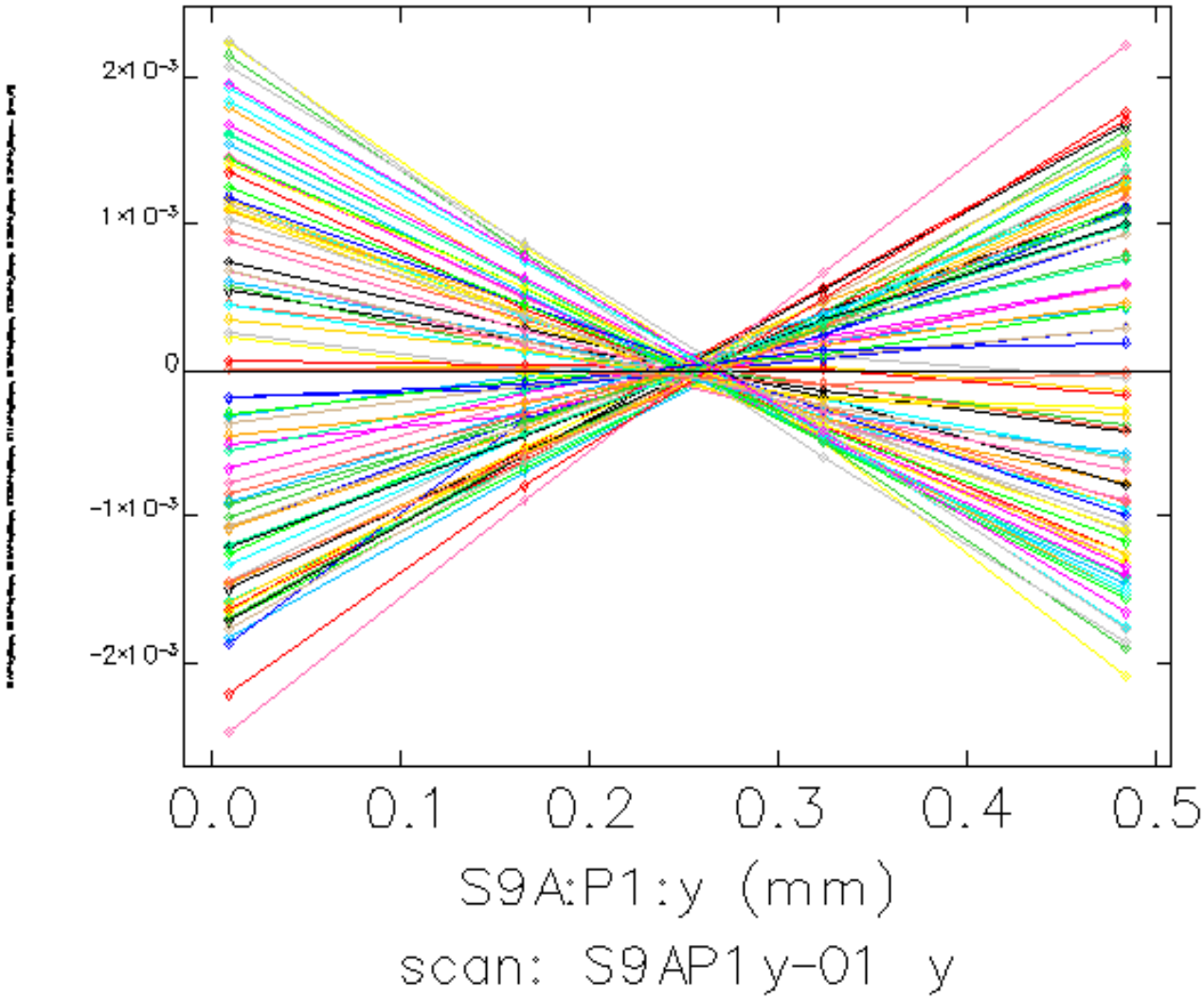


Glenn Decker

Appendix – 6+21 bunch fill

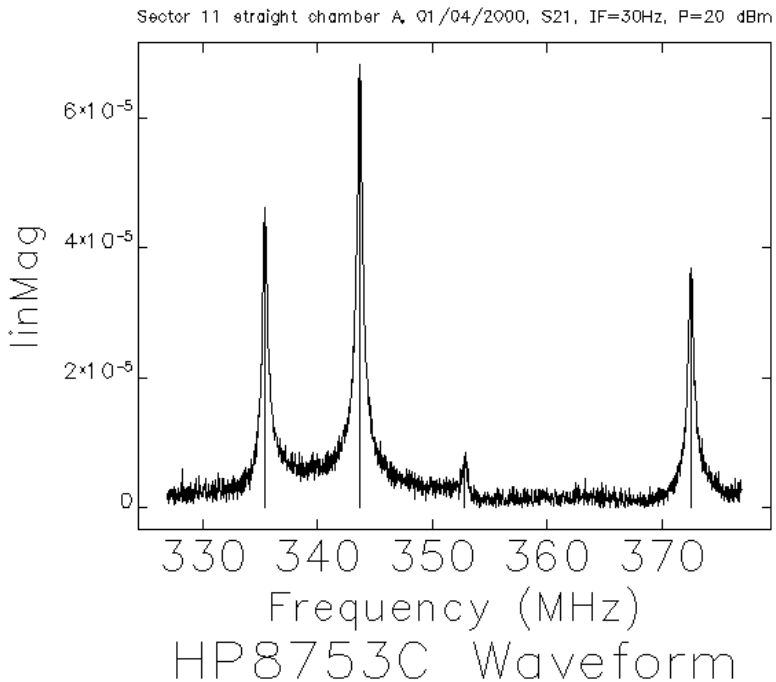


Appendix – Offsets Measurement Quad Scans

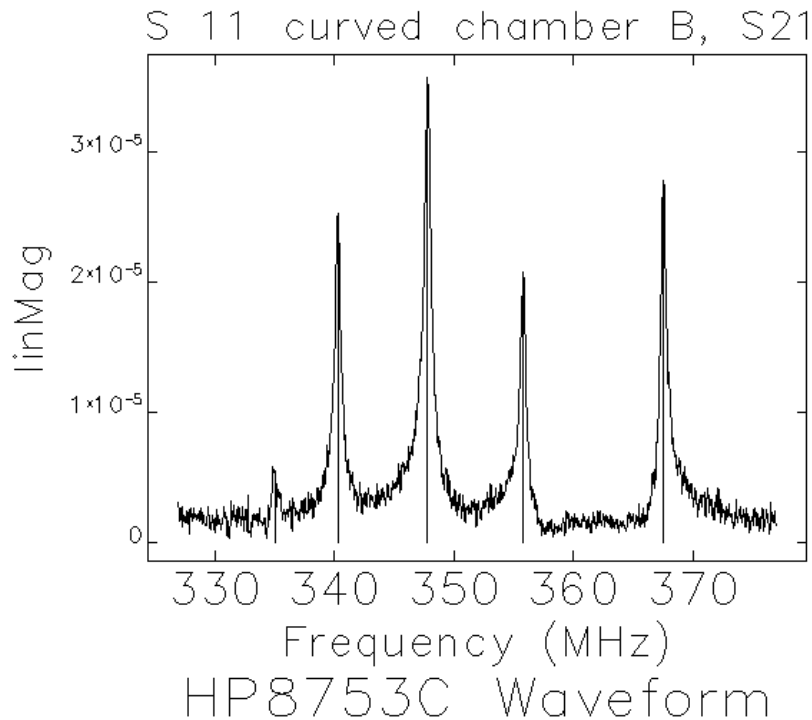


Appendix – S_{21} Response (Straight and Curve chambers)

Straight Chamber



Curved Chamber



Appendix – Offsets Measurement Quad Scans