APS Orbit Correction Hardware

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1. Beam Position Monitors

- *Broadband BPMs (MpBpms)*
- *Narrowband BPMs (NbBpms)*
- *X-ray BPMs*

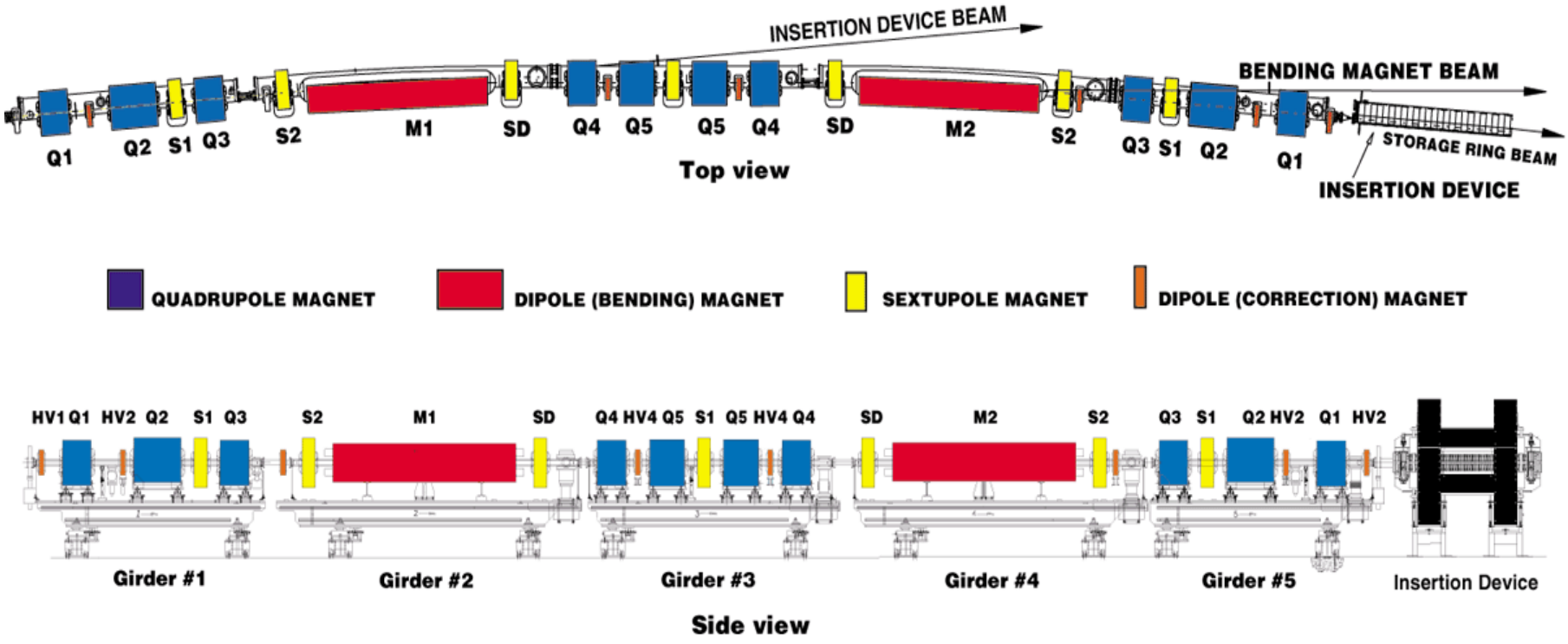
2. Corrector Systems

- *“Fast” corrector system*
- *“Slow” corrector system*

3. Orbit Feedback systems

- *“AC” (RTFB) orbit feedback system*
- *“DC” orbit feedback system*

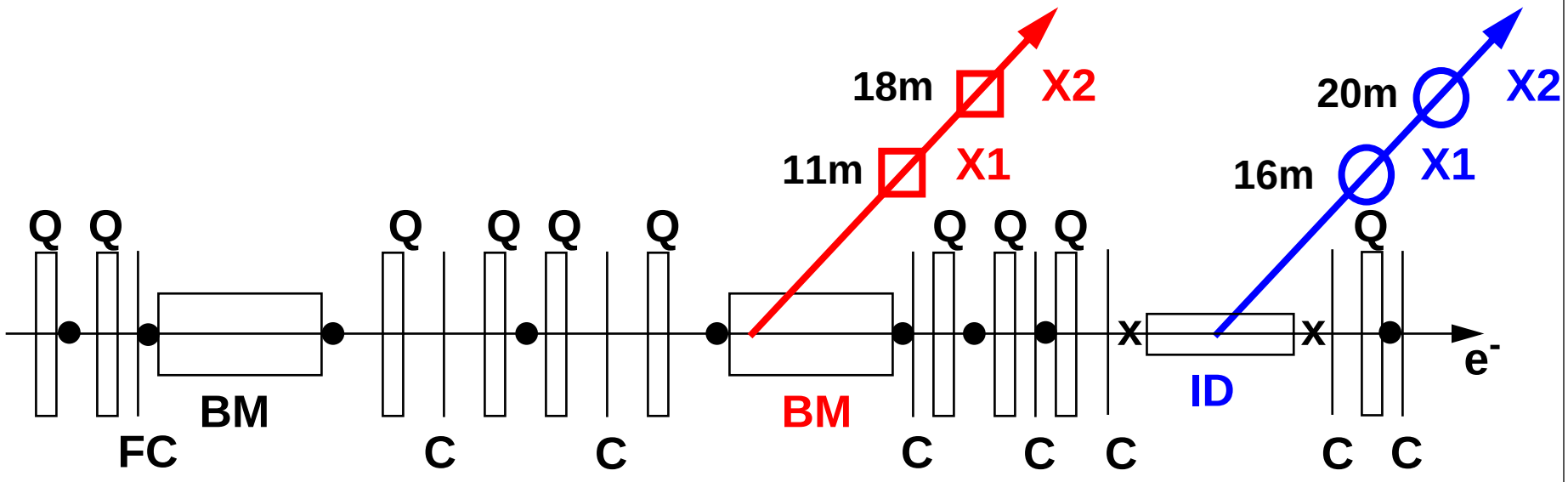
One Sector of the Advanced Photon Source Storage Ring



27.6 meters

(APS has forty sectors - 1104 meters total circumference)

Beam Position Monitors and Magnets Layout in One Sector



Legend:

- ● : Broad-band RF Beam Position Monitors (9) (Turn-by-Turn)
- x : Narrow-band RF Beam Position Monitors (2) (~ 300 Hz)
- □ : BM X-ray Beam Position Monitors (2 - Vertical Only) (~300 Hz)
- ○ : ID X-ray Beam Position Monitors (2) (~300 Hz)
- FC: "Fast" Corrector Magnet (1) (~ 100 Hz)
- C: "Slow" Corrector Magnets (7) (few Hz)

BEAM POSITION MONITORS

1. 360 Channels of Broadband (10 MHz) rf BPMs

- **Recent upgrades (matching networks and timing systems) has improved performance - completed in 2001.**
- **Provide turn-by-turn position data. 8000 samples (16000 turns) kept in circular memory buffer (beam history modules) - used primarily for post-mortem analysis.**
- **Hardware boxcar averager (32 samples) provides 4KHz BW for AC feedback.**
- **Hardware boxcar averager (2048 samples) provides 30 Hz BW for DC feedback**
- **Vertical BPM Data is severly affected due to rogue microwave mode - worse during top-up operation.**
- **“Cogging” mode study in progress to reduce above effects**

BEAM POSITION MONITORS (continued)

2. 56 Channels of Narrowband (300 KHz) rf BPMs

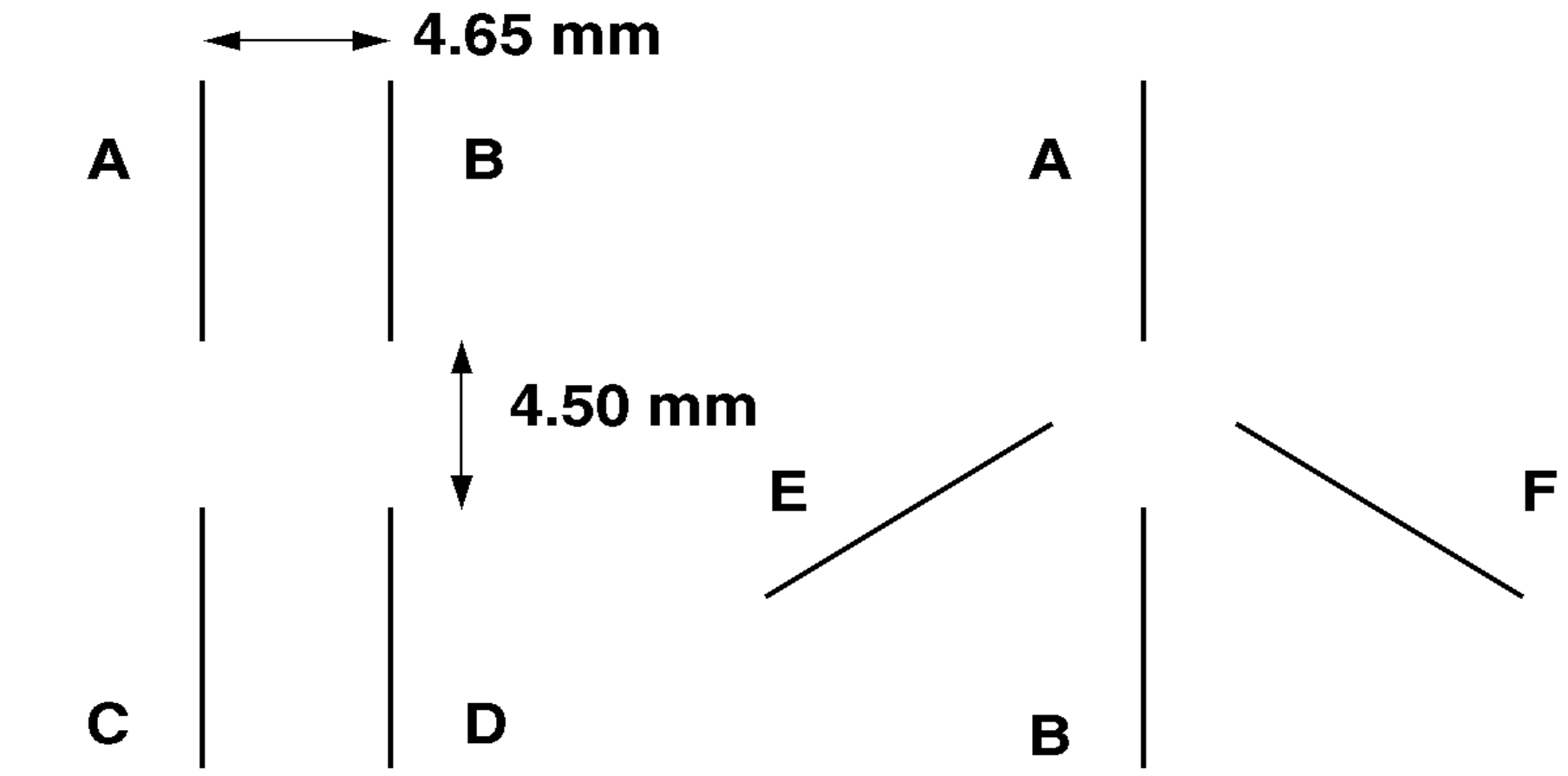
- **Installed on ID vacuum chambers mounted rf BPMs**
- **Commercial electronics; integrated with in-house data acquisition system - completed in 2000.**
- **Presently used in DC orbit correction system - software upgrade in process to be used in AC (RTFB) orbit correction system.**
- **Excellent performance - small dependence on bunch pattern and intensity variation; high reliability and easy maintainability.**
- **Workhorse for insertion device user's beam stability and reproducibilty**

BEAM POSITION MONITORS (continued)

3. 54 channels of insertion device x-ray BPMs

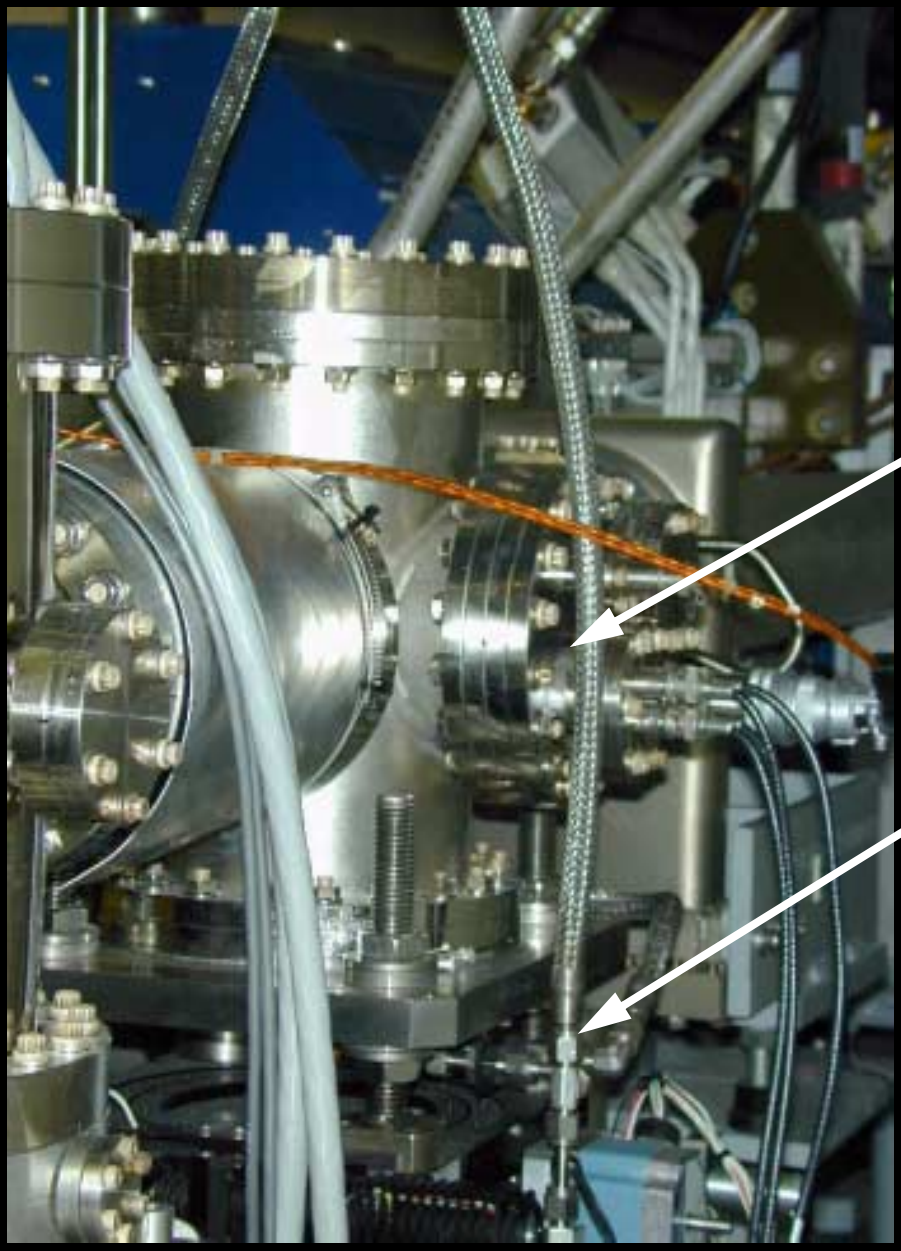
- **Integrated a DSP based x-ray BPM data acquisition system with broadband/ narrowband data acquisition systems - completed 2001**
- **Each x-ray beamline front end has two units installed**
- **Each unit has 4 metallized CVD Diamond blades placed edge-on to the x-ray beam**
- **Each unit mounted on x-y translation stage. Three portable translation stage motor controllers used for calibration and centering.**
- **Comprehensive understanding of systematic effects due to gap changes are in progress.**
- **X-bpms have been used in orbit feedback at a fixed gap with excellent results.**

APS ID X-ray BPM Photoemission Blade Sensor Geometry



P1-x = [(A+C) - (B+D)] / [(A+B+C+D)] **P2-x = [E-F] / [E+F]**

P1-y = [(A+B) - (C+D)] / [(A+B+C+D)] **P2-y = [A-B] / [A+B]**

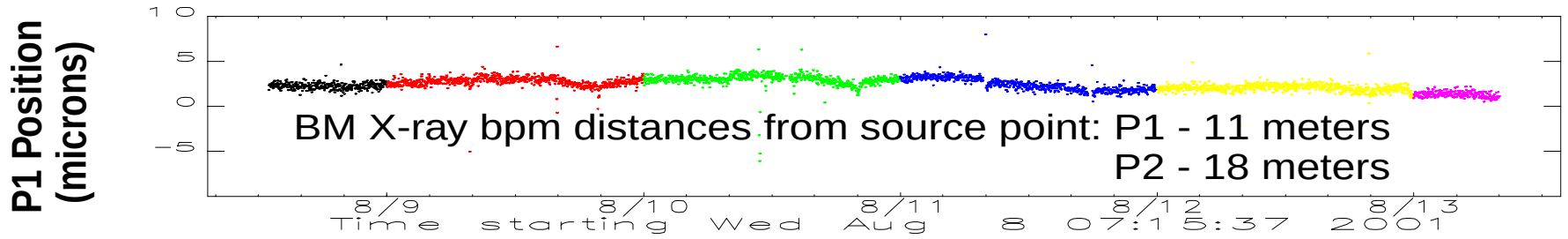

X-bpm housing
X-Y Translation Stage

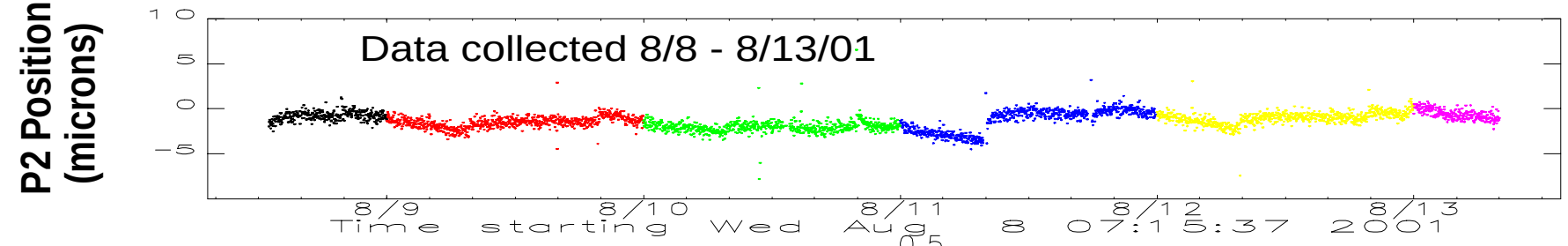
BEAM POSITION MONITORS (continued)

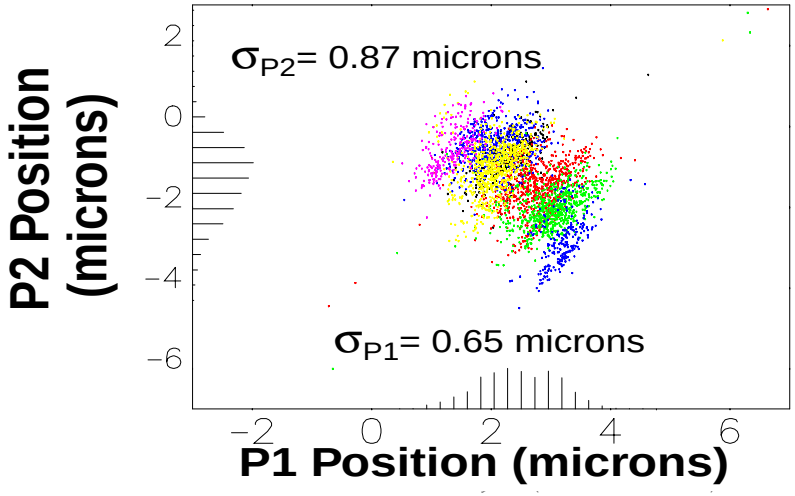
4. 36 channels of bending magnet x-ray BPMs

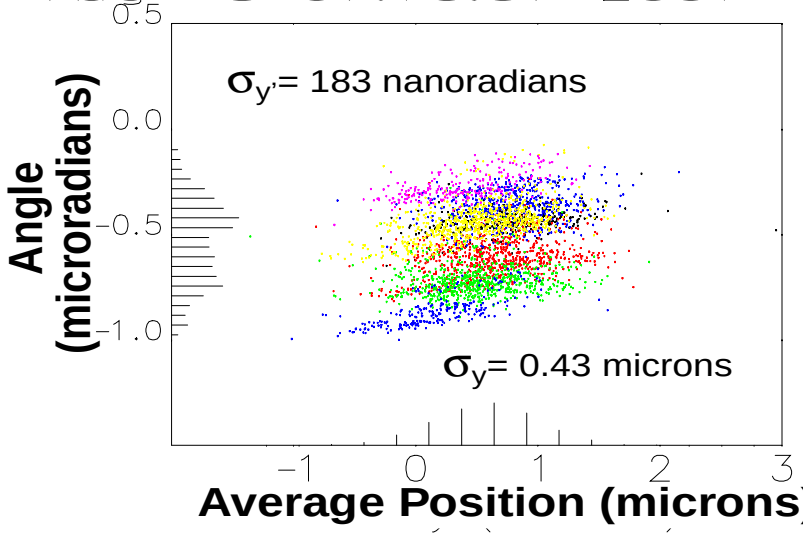
- **Vertical only - 1 blade above and 1 below;**
- **Very simple; our most believable diagnostic**
- **All BM x-bpms in orbit feedback**
- **Workhorse for bending magnet user's orbit stability and reproducibility**
- **Translation stages only in the vertical plane.**
- **Data acquisition, filtering same as ID x-bpms**

Plots showing < 200 nanoradian rms vertical beam stability over a 5 day period
Colors indicate data for individual days









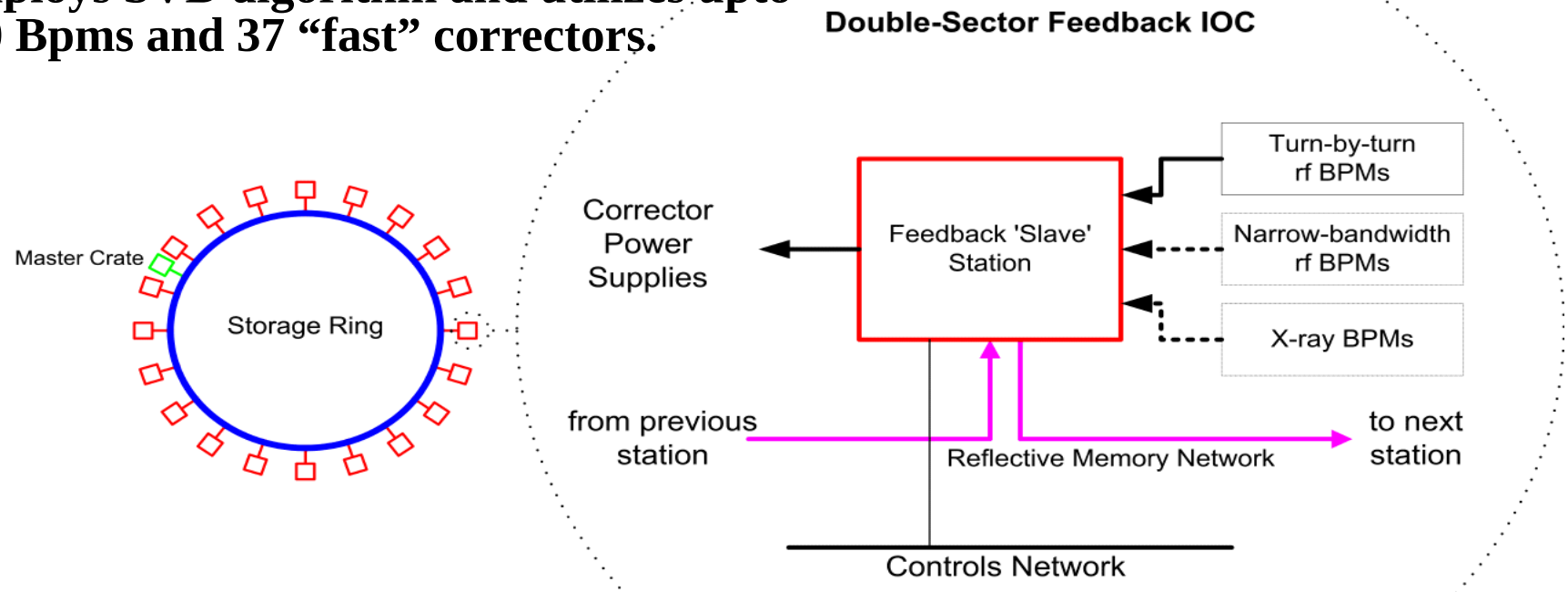
CORRECTION MAGNETS and POWER SUPPLIES

1. ***317 combined-function horizontal/ vertical corrector magnets and power supplies available for orbit correction***

   - **38 correction magnets are mounted at spool pieces location - faster response time (few hundreds of Hz). All correctors are used in "AC" feedback system.**
   - **279 remaining correction magnets are mounted at location with thick aluminum vacuum chamber wall - subject to large eddy current effects resulting in lower frequency response (few Hz); and are available for "DC" feedback system**

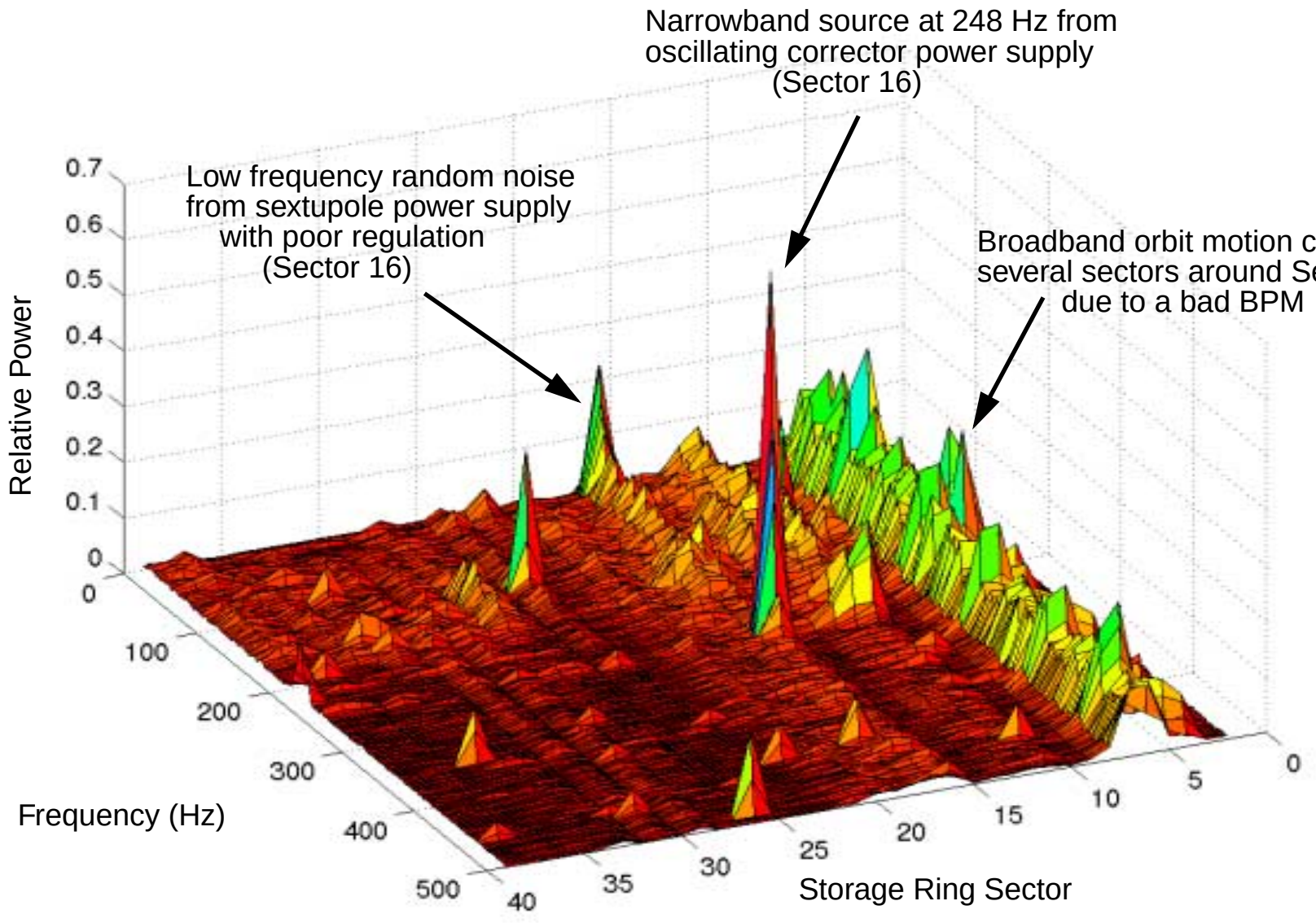
"AC" (RTFB) ORBIT FEEDBACK SYSTEM

1. 20 VME slave crates distributed around the ring - each utilizes 2 DSP boards
2. 1 VME master crate performs supervisory tasks
3. All 21 VME crates communicate via reflective memory network - 29.6 Mbytes/s
4. Sampling frequency = 1.5 KHz; Orbit correction BW - ~ 0.1 to 50 Hz.
5. Employs SVD algorithm and utilizes upto
   160 Bpms and 37 "fast" correctors.



6. Each slave crate also does X-ray and narrowband BPM data acquisition/filter
7. Real time beam diagnostics available - for statistics and orbit motion sources

Corrector Error Power Spectrum - Roadmap of Horizontal Sources

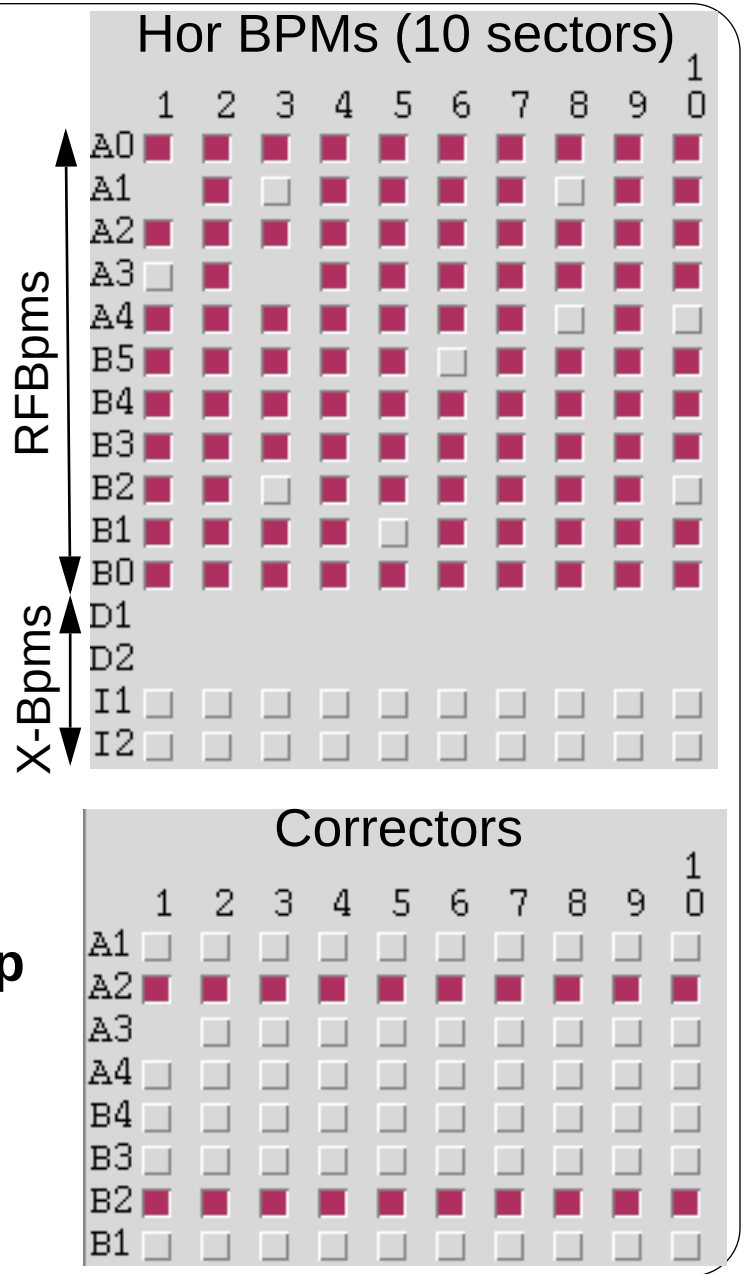


(Courtesy of Carwardine/Lenkszus)

"DC" ORBIT FEEDBACK SYSTEM

1. Workstation based System

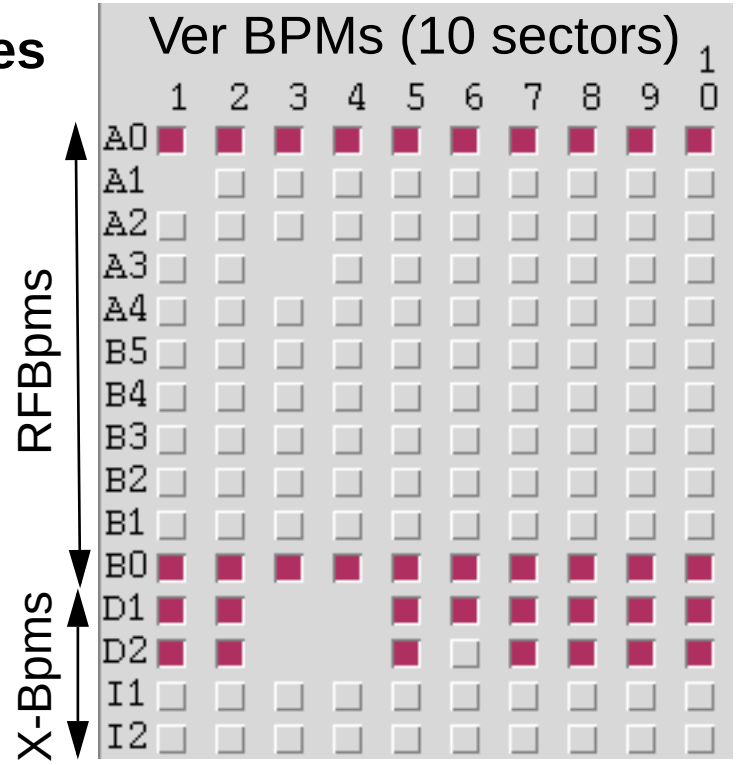
- **Sampling frequency has recently been increased from ~ 0.5 Hz to ~ 2 Hz.**
- **Correction BW, now, is dc to ~ 0.2 Hz.**
- **Employs SVD algorithm**
- **Horizontal orbit configuration shown includes all available Bpms and 2 Corr.**
- **Employs "despiking" for bad Bpms**
- **Employs intensity dependence offsets**
- **Employs compensation to cancel overlap with AC feedback system**

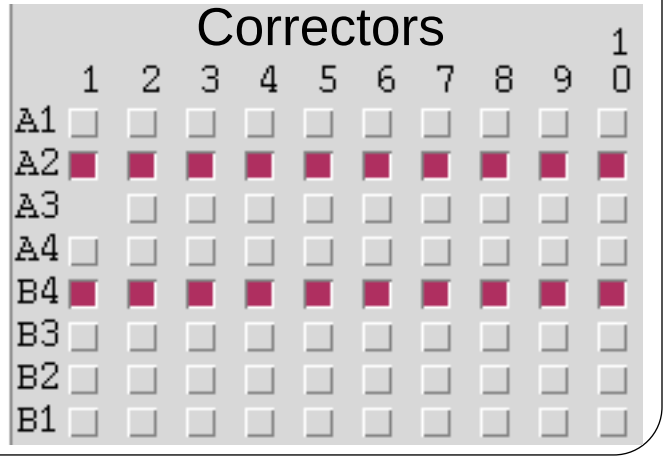


- **Vertical orbit configuration shown includes only narrowband and X-ray Bpms /2 corr.**
- **Broadband Bpms exhibit large vertical motion due to rogue microwave effects**
- **Study in progress to address this**
- **Plan to add 2 more narrowband Bpms**

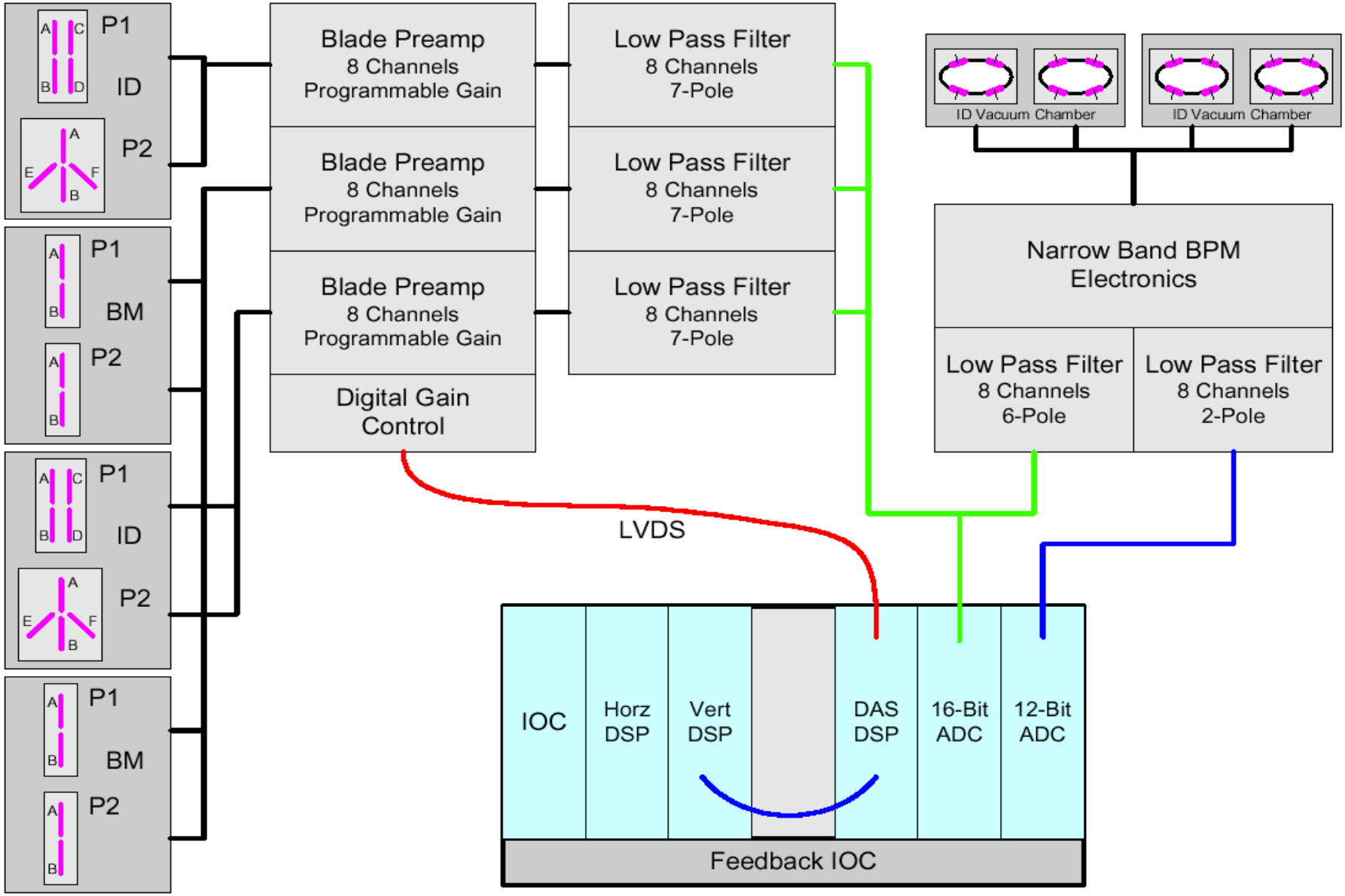
2. IOC based (Datapool) System

- **In progress**
- **Sampling frequency upto 50 Hz**
- **Expected correction BW upto 10 Hz**
- **Utilizes 22nd VME feedback crate making use of reflective memory**





X-Bpms and NbBpms Data Acquisition - Two Sectors



SUMMARY

- **“Cogging” implementation in MpBpms is in progress**
- **Additional 2 NbBpms per sector are planned to be added to improve orbit stability**
- **BM X-bpms are routinely used in orbit configuration**
- **ID X-bpms are routinely used for user’s orbit reference**
- **ID X-bpms study in progress for orbit control configuration with varying ID gap.**
- **DC orbit correction with 10 Hz update rate is under test and planned to be in operation by January, 2003. Update rate upto 50 Hz is feasible.**
- **Reduction in ID steering transient effects has been observed with the increase in DC orbit correction rate**
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