Beamline Steering Displays

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Release notes for February, 2005 revision:

The primary modification this time around is associated with the canted undulator beamlines displays. The previous version ended up being rather large, and in its place there are now two separate displays, one for the upstream and one for the downstream source. New process variables which make use of the so-called C:P0 narrowband rfbpm readbacks are now shown, indicating source position and angle for the upstream and downstream sources separately. Large and small versions of both upstream and downstream canted undulator displays are available, applicable to sectors 21, 23, 24, 26, and 30. The photon beam position monitor (bpm) readbacks for the canted undulator beamlines are only shown as applicable, i.e. S23ID:P1 is associated with the upstream device and so only appears on the upstream medm screen. S23ID:P2 is shown on the downstream screen only.

One other modification to all displays is the addition of a new string process variable named either BMstatus:message${sector} or IDstatus:message${sector}, where ${sector} is the sector designator without prepending zero, i.e. 7 and not 07. The intention is to supply sector-specific information indicating any recent changes to the bpm system such as re-calibration, or the last local steering including timestamp and amount of steering (e.g. microradians x/y). The script used by operations to perform local steering will be updated shortly to automatically update this status string. Other relevant automated procedures as appropriate may update the string in the future.

Release notes for July, 2004 revision:

It has been nearly two years since the initial release of the beamline steering displays, and much work has been done with the orbit correction systems during that time. The most significant change has been the inclusion of insertion device photon beam position monitors (bpm's) in the orbit correction algorithm on a routine basis. A background feedforward process now compensates for residual gap-dependent systematic errors in real time. The primary motivation for this new release is the addition of three new canted undulator beamlines in 21, 23, and 24ID. These beamlines have two independent undulator sources, separated by a 1 mrad angle. For these beamlines, two photon bpms have been placed within the same vacuum housing, with each of the two beams having it's own channel. The new associated medm screens are hopefully intuitive enough to require minimal explanation.

Other suggestions have been incorporated for all of the existing medm screens, specifically the addition of beam current and a live time stamp, which should be helpful for the interpretation of paper printouts. The old screens are quite large and have been reduced somewhat in size. A "small" version of all screens is now available which omits some information but should be adequate for most purposes, without occupying such a large fraction of the computer monitor area. The legend has also been updated to assist in the interpretation of certain error conditions.

This document is intended as a reference guide for beamline trajectory / steering displays

IDxbpm.adl
BMxbpm.adl

These displays contain the data used by the APS storage ring orbit correction algorithm to stabilize the DC orbit. They are accessed by two top level medm screens, available starting from the top level screen XFD-Display.adl . The two top-level screens are in files IDSectors.adl and BMSectors.adl ,

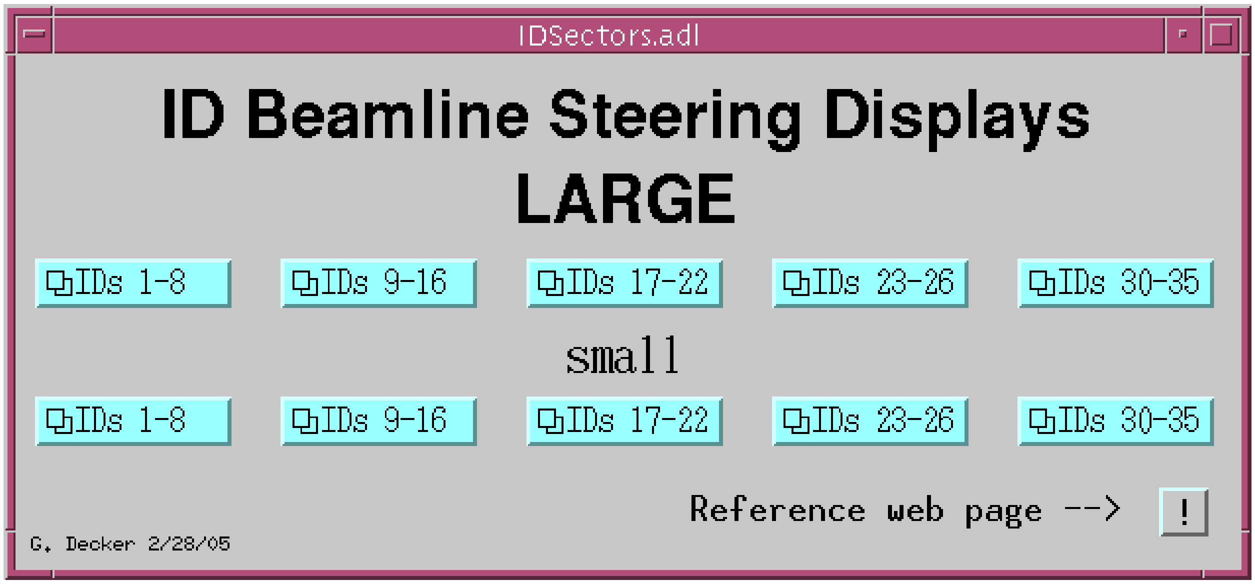

Figure 1 Top level insertion device screen (primarily for floor coordinators)

The top level display BMSectors.adl is entirely analagous to that shown in figure 1 for the insertion devices. Clicking on one of the above pull-down menus brings up a related display specific to a particular beamline, for example ID 7, shown in figure 2 below. Both large and small versions of the displays are available.

A web page (including this document) describing displays of the type shown in figures 2 and 3 is available at

http://www.aps.anl.gov/asd/diagnostics/xbpmDisplays/index.html

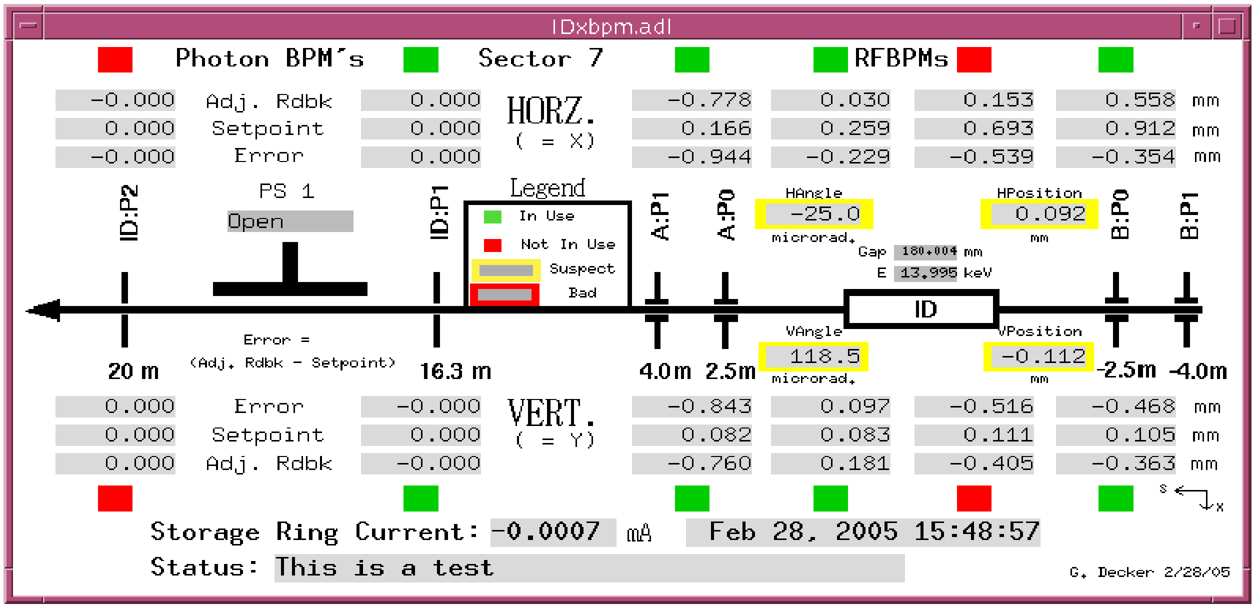

Figure 2. Example large display for insertion device beamline ID7

The photon / particle beam trajectory is displayed travelling from right to left, with six associated beam position monitors displayed. According to accelerator physics convention, positive x = horizontal position is outboard, e.g. down on this screen. I turned it upside down just for the users. The labels A:P1, A:P0, B:P0 and B:P1 refer to radio frequency (rf) particle beam position monitors (bpm's). The so-called P0 bpm's are narrow-band rf bpm's attached to 4-mm diameter capacitive button pickup electrodes mounted on the small aperture insertion device vacuum chamber. They tend to be our most reliable position monitors, and are almost always used unless malfunctioning. On the insertion device screens, the source parameters HAngle, HPosition, VAngle, and VPosition are derived from the P0 readbacks as follows:

HAngle = 1000* [(A:P0 Horz. Adj. Rdbk) - (B:P0 Horz. Adj. Rdbk)] / (5 meters)
(microradians)
HPosition = [(A:P0 Horz. Adj. Rdbk) + (B:P0 Horz. Adj. Rdbk)] / 2
(millimeters)

The (5 meters) in the formula for HAngle is the distance between the P0 bpm's that straddle the ID source point. (The actual number used is a process variable e.g. S1:ID:MetersBetweenBpmsP. Its value is exactly 4.944 meters for all except ID11 which uses P1 bpm's separated by 7.948 meters, and ID34 which has a half-length chamber, with 2.454 meters separation. The canted undulator geometry is also a bit different). The parameters VAngle and VPosition are calculated in a completely analagous fashion from P0 readbacks. Since these angle and position process variables are calculated quantities, they have an associated status pv which illuminates them to have a yellow background if any variable used in the calculation is questionable.

Each set of position numbers has an associated status pv which will highlight errant readbacks in red. In addition, a red or green square adjacent to each set of three numbers indicates whether or not the monitor is not being used by the orbit correction algorithm Notice the red square adjacent to the ID:P2 data. This monitor is functioning, but not being used by the algorithm, for the simple reason that the P1 data is believed to be more reliable than the P2 data.

For each bpm, six numbers are displayed, three for each plane (horz, vert). The three numbers are labeled “Adj. Rdbk.”, “Setpoint”, and “Error”. The adjusted readback is the position reading as measured by the bpm data acquisition system (after correcting for things like intensity dependence in the case of rf bpm’s and gap dependence in the case of insertion device photon bpm’s). For the rf bpm’s, this adjusted readback is our best estimate of the displacement of the particle beam relative to a known and reproducible datum, namely the magnetic center of adjacent focusing (quadrupole) magnets. The Setpoint is a static number reflecting the desired readback, and the Error is the difference (adjusted readback - setpoint) . The setpoint usually only changes when local steering is requested, although a significant amount of database gymnastics is required to reproduce the orbit following a maintenance period, for example. It turns out to be convenient for the orbit correction algorithm to make something zero, thus a display of these differences is a good way to show how well the algorithm is doing. All numbers associated with bpm’s in this display are in units of millimeters, while angles are measured in microradians.

For completeness, the analagous readbacks, setpoints, and errors are shown for the two insertion device photon beam position monitors located in the beamline front end. In this case the datum relative to which the readbacks are measured is not as well defined, since the photon bpm’s are mounted on horz / vert mechanical translation stages. Generally it is best to operate the photon bpms such that the beam is approximately centered in the device, where their response is most linear. The readbacks are corrected for gap-dependent effects, giving a reasonably reliable diagnostic.

Also, the upstream and downstream accelerator components must be displaced by up to 6 mm (the decker distortion) to reduce stray radiation striking the photon bpm blades. As of run 2005-01 (Jan - April 2005), displacements are complete for all except one sector (14), which will be completed in the near future.

In addition to bpm data, the insertion device gap and photon energy are displayed in figure 2, to assist in interpreting the photon bpm data. The ID photon bpm’s generally cannot be expected to work for gaps much larger than about 30 mm, simply because the signal becomes too small relative to residual stray radiation background signals. The feedforward algorithm used to correct for gap dependent systematic effects is configured to ignore xbpm data when the gap exceeds 31 mm.

Shown in figure 3 is a display representing beamline 14BM

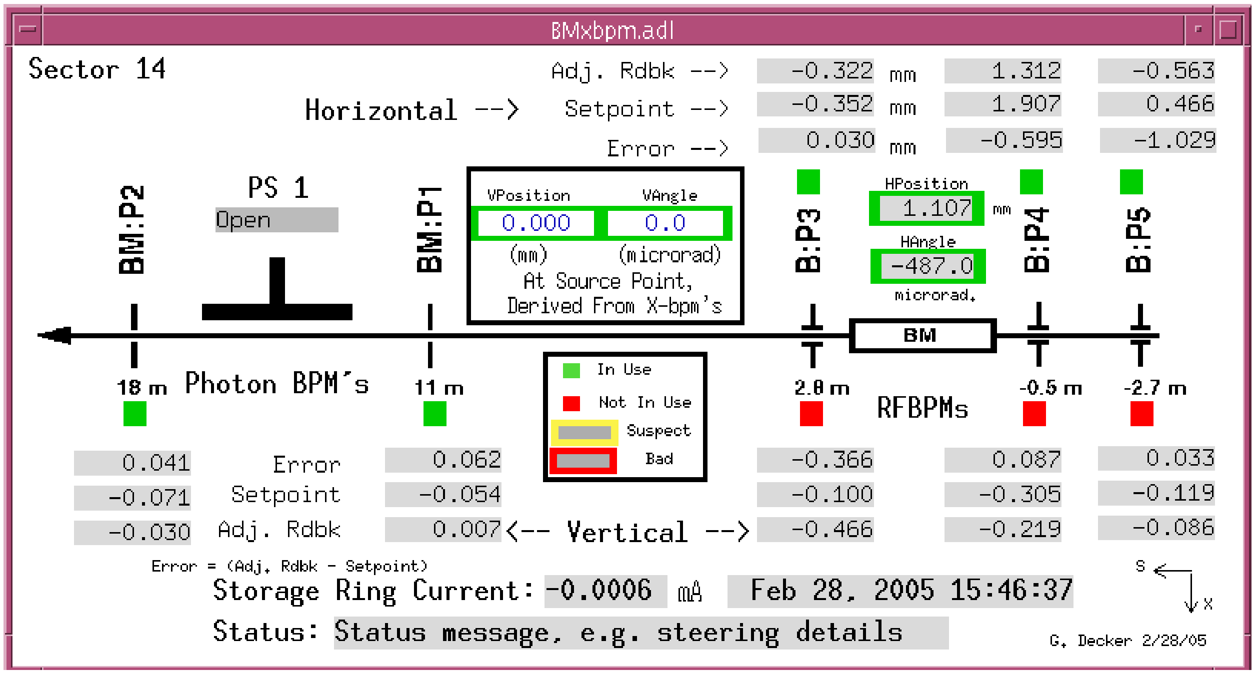

Figure 3. Example large display for bending magnet beamline BM14

The major difference between this display and the insertion device displays (beside there being no insertion device) is that the x-bpm's are much more reliable than the rf bpm's. Also the photon bpm's only work in the vertical plane. Because of this, the derived angle and position process variables are computed as follows (straight from frank's source code):

VAngle = 1000* [(BM:P2 Adj. Rdbk) - (BM:P1 Adj. Rdbk)] / (18.0 meters - 10.9 meters)
(microradians) (note BM:P1 is actually 10.9 meters from the source - I rounded off above)
VPosition = (BM:P1 Adj. Rdbk) - (VAngle/1000)*10.9 meters <- note extrapolation
(millimeters)

HAngle = 1000* [(B:P3 Horz. Adj. Rdbk) - (B:P4 Horz. Adj. Rdbk)] / (3.3545 meters)
(microradians)
HPosition = [(B:P3 Horz. Adj. Rdbk) + 7*(B:P4 Horz. Adj. Rdbk)] / 8
(millimeters) (note source point is approx. one eighth of the way from BP4 to BP3)

Small displays

Shown in figures 4 and 5 are smaller versions of the displays:

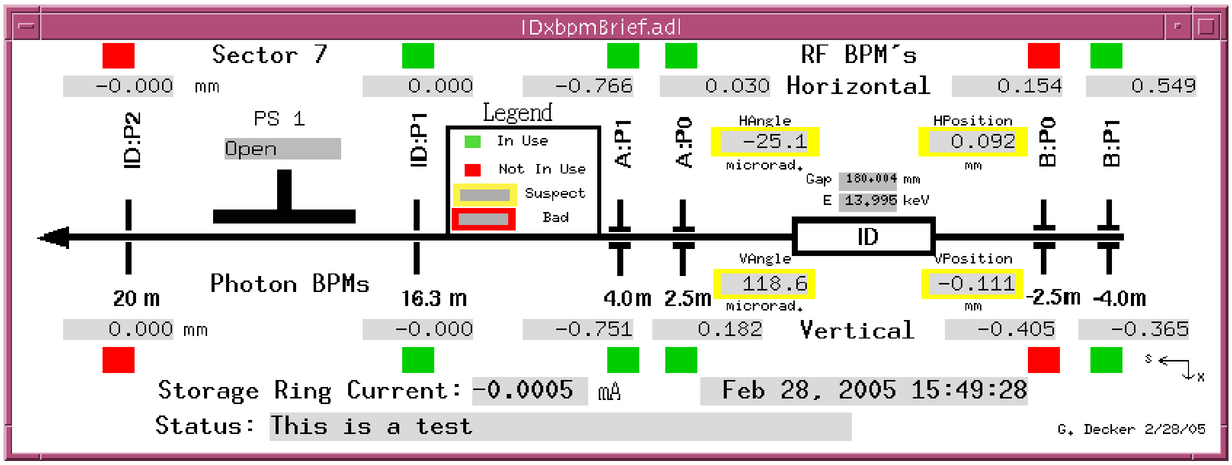

Figure 4. Insertion device screen, small version

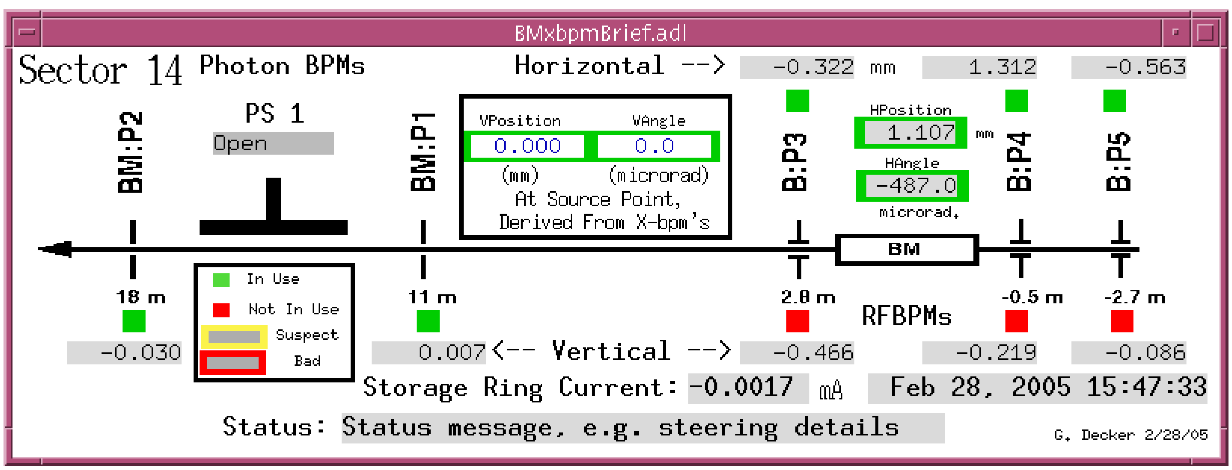

Figure 5. Bending magnet screen, small version

The setpoints and errors have been omitted from the small displays - only adjusted readbacks are shown, which can be used for comparison purposes.

Canted Undulator Displays

Figures 6 through 9 show the large and small versions of new displays appropriate for canted undulator beamlines:

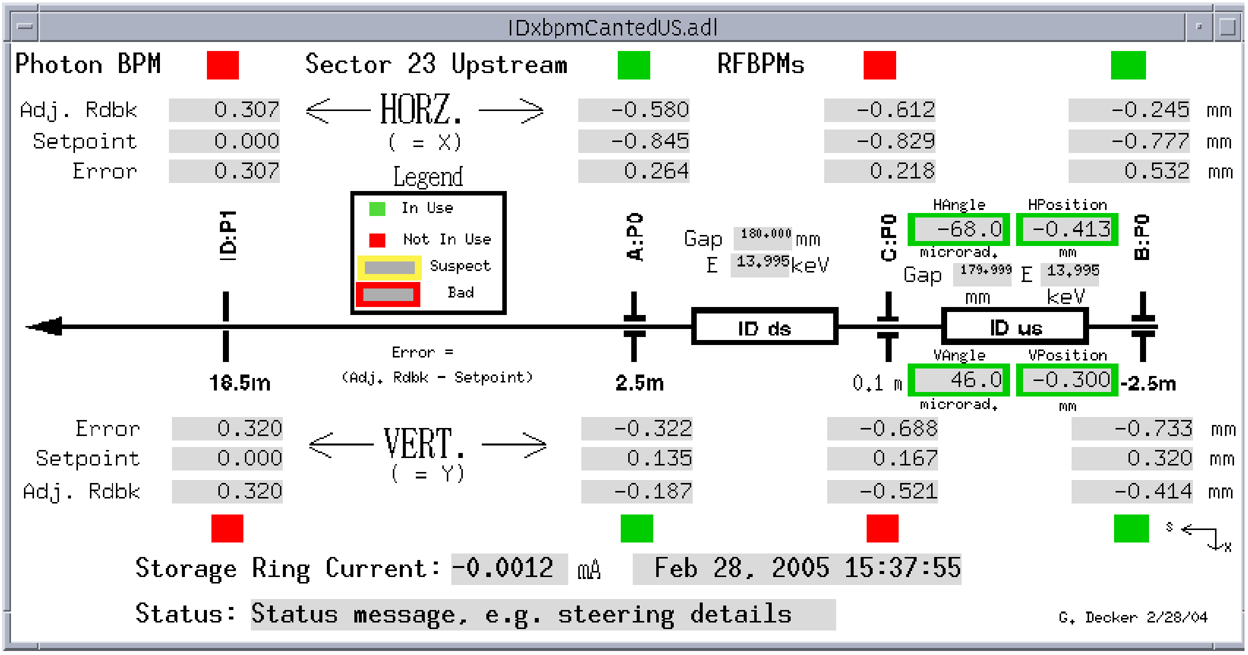

Figure 6. Full size steering display for upstream canted undulator at 23ID

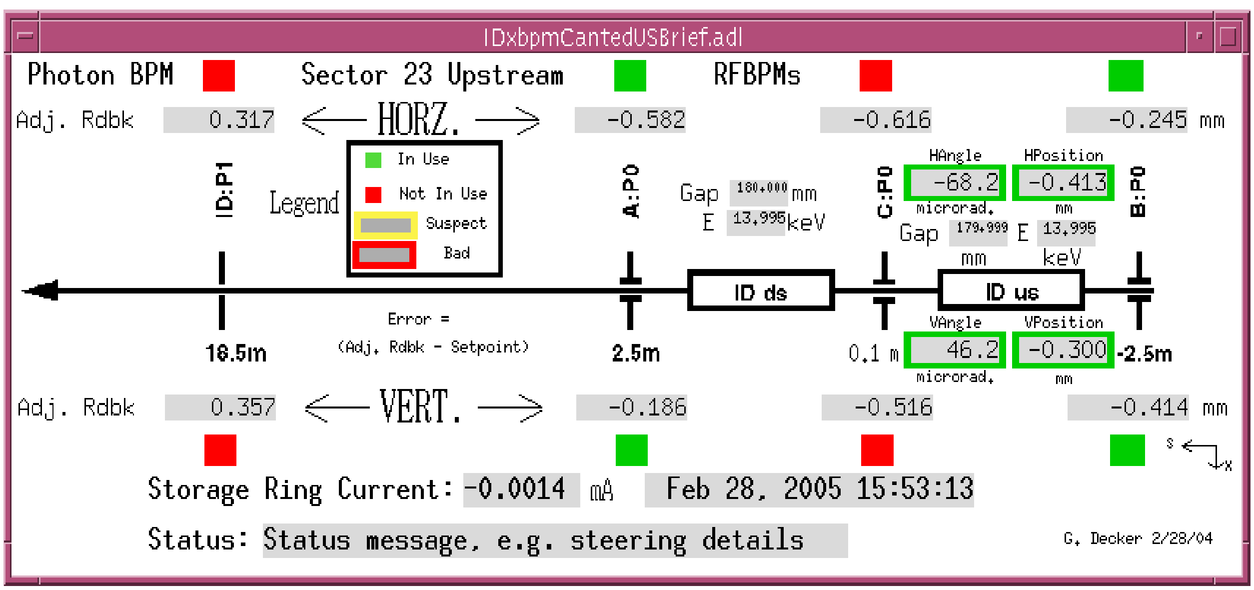

Figure 7. "Small" canted undulator display for upstream device.

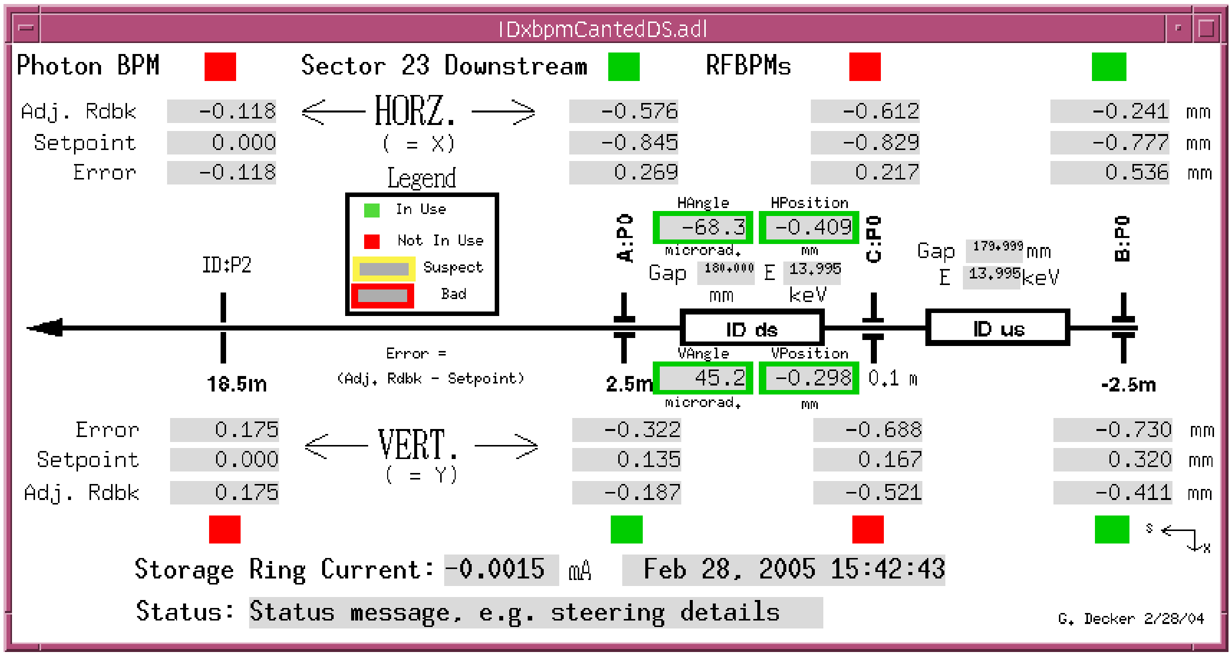

Figure 8. Full size steering display for downstream canted undulator at 23ID

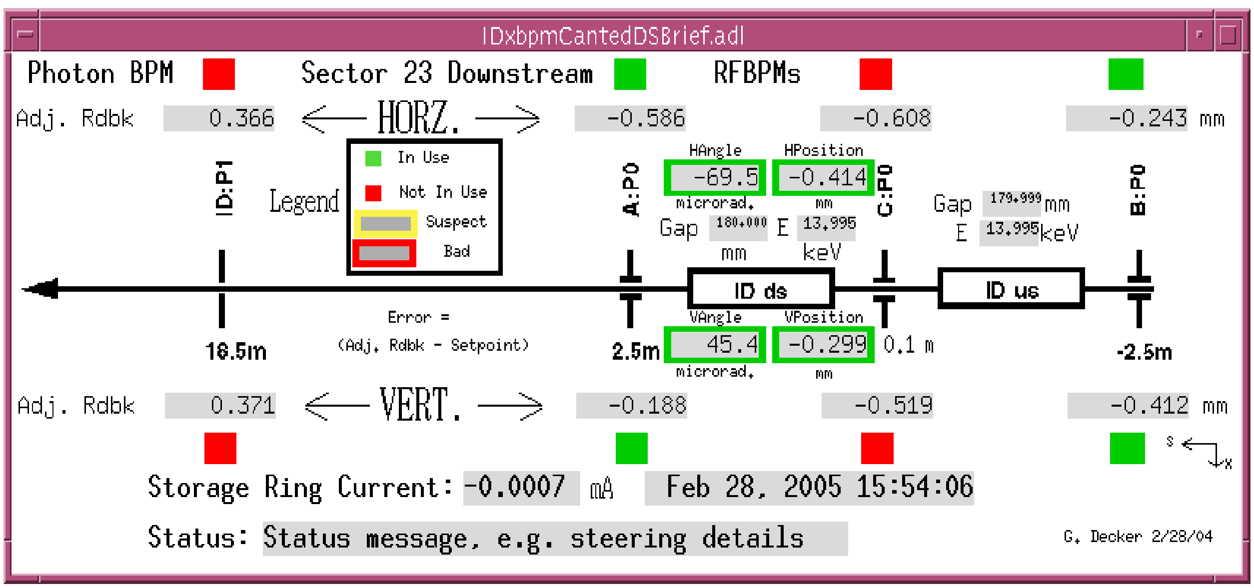

Figure 9. “Small” canted undulator display for downstream device.

Appendix A - Process Variables

Derived ID source parameters

S*:ID:SrcPt:xAngleM	Horizontal angle at center of id straight section.
S*:ID:SrcPt:xPositionM	Horizontal position, = average of BP0x and AP0x
S*:ID:SrcPt:yAngleM	Vertical angle at center of id straight section.
S*:ID:SrcPt:yPositionM	Vertical position.

Where the * is a wildcard denoting the sector number of interest (no prepending zero here, i.e. S1:ID:SrcPt:xAngleM, _not_ S01:ID:SrcPt:xAngleM. These values are derived from the P0 narrowband rfbpm adjusted readbacks. For canted undulator beamlines, the pv names are S23us:ID:SrcPt:xAngleM etc, and make use of the C:P0 bpm located between the devices to compute source parameters for upstream and downstream devices separately.

Derived BM source parameters

S*:BM:SrcPt:xAngleM	Horizontal angle at BM source point (from rfbpms)
S*:BM:SrcPt:xPositionM	Horizontal position at BM source point (from rfbpms)
S*BM:VANGLE:CC	Vertical angle at BM source point (from xbpm's)
S*BM:VPOSITION:CC	Vertical position at BM source point (from xbpm's)

Monopulse rf bpm's

All monopulse beam position monitors' process variables names are of the form

S*[AB]:P[12345]*[xy]*

Where the * is a wildcard, and the characters between square braces [] are enumerated lists. For example, the relevant readbacks for bpm S19A:P1 are

Horizontal:

S19A:P1:mswAve:x	Raw horizontal readback
S19A:P1:ms:x:OffsetAO	Difference between electronic and magnetic center
S19A:P1:mswAve:x:AdjustedCC	Horizontal readback relative to quad. magnetic center
S19A:P1:ms:x:SetpointAO	Desired horizontal position, relative to magnetic center
S19A:P1:mswAve:x:ErrorCC	Adjusted - Setpoint: displacement relative to desired

Vertical:

S19A:P1:mswAve:y	Raw vertical readback
S19A:P1:ms:y:OffsetAO	etc.....
S19A:P1:mswAve:y:AdjustedCC	
S19A:P1:ms:y:SetpointAO	
S19A:P1:mswAve:y:ErrorCC	

For the process variables with the symbols mswAve embedded within them, analogous process variables with higher analog bandwidth exist with the replacement

mswAve -> ms   or mswAve -> msAve

The pv's e.g. S19A:P1:ms:y have analog bandwidth of about 30 Hz and are heavily aliased at epics data rates. PV's of the type S19A:P1:msAve:y have 1 Hz analog bandwidth. The mswAve process variables have about a 20 second time constant and are the only way to see things happening at the sub-micron scale. Incidentally, the hardware boxcar averager was named the "memory scanner" by an engineer long ago, explaining the ms portion of the pv name. The epics ioc performs further averaging to arrive at the msAve and mswAve (memory scanner average and memory scanner weighted average) values.

It's probably worthwhile to look at the nomenclature document that I wrote more than ten years ago, available on the web at

http://www.aps.anl.gov/techpub/lsnotes/ls191/ls191.html

Narrow-band rf bpm's

Even though the narrow band rf bpm's and photon bpm's do not have hardware averagers, the nomenclature ms, msAve, and mswAve have been retained as reminders of what analog bandwidth is available. Thus all narrow band rf bpm's are of the form S*[AB]:P0*[xy]* :

S19A:P0:mswAve:x	Raw horizontal readback
S19A:P0:ms:x:OffsetAO	Difference between electronic and magnetic center
S19A:P0:mswAve:x:AdjustedCC	Horizontal readback relative to quad. magnetic center
S19A:P0:ms:x:SetpointAO	Desired horizontal position, relative to magnetic center
S19A:P0:mswAve:x:ErrorCC	Adjusted - Setpoint: displacement relative to desired

and similarly for the vertical plane (y).

The averaging for the P0 (narrow band) rf bpm's is performed by an analog low pass filter to arrive at the 30 Hz ms process variables. For the msAve and mswAve's, a proper digital filter using a dedicated digital signal processor is used to generate the slower msAve and mswAve pv's Since the P0 bpm's are not near quadrupole magnets, their "magnetic" center is defined relative to a straight line connecting the centers of the quadrupole magnets located immediately upstream and downstream of the insertion device source point.

Bending Magnet X-bpm's

Bending magnet photon beam position monitor process variables take the form S*BM:P[12]*y* :

S19BM:P1:mswAve:y	Raw vertical readback
S19BM:P1:ms:y:OffsetAO	Difference between electronic and "mechanical" center
S19BM:P1:mswAve:y:AdjustedCC	Vertical readback relative to mechanical center

S19BM:P1:ms:y:SetpointAO	Desired vertical position, relative to mechanical center
S19BM:P1:mswAve:y:ErrorCC	Adjusted - Setpoint: displacement relative to desired

The P1 BM xbpm is 11 meters from the source, and the P2 BM xbpm is 18 meters
There are no analogous horizontal process variables for bending magnet x-bpm's.
The OffsetAO process variables are typically set to zero and are supported primarily only to provide standardized notation relative to the other bpm's.

Insertion Device photon bpm's

For insertion device photon bpm process variables, simply replace BM with ID in the above, and add horizontal readbacks: S*ID:P[12]*[xy]* :

S19ID:P1:mswAve:y	Raw vertical readback
S19ID:P1:ms:y:OffsetAO	Difference between electronic and "mechanical" center
S19ID:P1:mswAve:y:AdjustedCC	Vertical readback relative to mechanical center
S19ID:P1:ms:y:SetpointAO	Desired vertical position, relative to mechanical center
S19ID:P1:mswAve:y:ErrorCC	Adjusted - Setpoint: displacement relative to desired

and similarly for the horizontal (x)

In this case, the OffsetAO will be used in a feedforward algorithm to compensate for insertion device gap-dependent systematic effects. A mechanical translation stage is used to place the bpm's electronic center "near" the user's desired location. Thus the AdjustedCC process variable represents our best approximation to a "gap-independent" position readback.

In addition to the position-related process variables, two flavors of status bits are indicated on the medm screens described herein, which are indicated in one case by a red or green "light" and in the other by red or "nothing".

PV's of the type S*[xy]:BadBO indicate that a particular bpm is bad. If so, the background surrouding the associated position readback values will turn red, flagging the fact that the data is beyond suspect and not to be believed. If this process variable indicates "not bad", then no indication is given, i.e. "nothing".

The pv's S*[xy]:InUseBO indicate whether or not a particular process variable is included in the DC orbit control algorithm. If the light above the horizontal readback values (or below the vertical) is green, then that channel is being used to correct the orbit. Red means that the process variable is not in use. We tend to use the most believable readbacks for orbit control and omit any that have the slightest suspicion of being fishy. In particular, in the vertical plane the monopulse rf bpm's all are affected at some level by a disease known as the "rogue microwave" mode, which is simply a microwave mode with vertical electric field and a frequency falling inside the bpms' passband. The monopulse bpm's are still useful for relatively short time periods, and some are better than others, but our most reliable readings are the narrow-band rf (P0) and BM x-bpm's. Horizontally, as many rf bpm's as possible are typically used.