BNL-221577-2021-TECH

NSLSII-ASD-TN-354

Local Bump Agents (Feedback) at NSLS-II

Y. Hidaka

May 2021

Photon Sciences

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC), Basic Energy Sciences (BES) (SC-22)

NSLS-II TECHNICAL NOTE BROOKHAVEN NATIONAL LABORATORY	NUMBER **NSLSII-ASD-TN-354**
AUTHORS: Y. Hidaka, Y. Hu, B. Podobedov, R. Smith, Y. Tian, G. Wang	DATE 05/31/2021
Local Bump Agents (Feedback) at NSLS-II	

Introduction:

We have developed a program called local bump agents at NSLS-II. It is an automated system that corrects ID local bumps once they drift out of pre-defined target windows. This work was reported in [1].

The main Python script "lbagent.py" starts a master controller in an infinite loop that emulates the actions of a human operator who would periodically check the local bump (i.e., the orbit offset and angle) at the center of an insertion device (ID) and initiate a local bump correction if the bump is outside of a specified tolerance. When this program is turned on, it works as if an automated agent keeps monitoring a bump readback and takes a corrective action if deemed necessary. As evident from this functionality, this program is sometimes also called as the (local/ID) bump feedback, since the deviation of a bump offset/angle is automatically restored to a specified target bump setpoint.

This program was implemented and deployed after receiving a request from C11 beamline scientists. Since then, other beamlines also requested this feedback feature. As of this publication, the following beamlines have the agents: C03, C11, C16, C17, C23. This system is currently in routine use during beamline operation.

Some of these bump agents (i.e., C03, C16, C17) are sometimes referred to as photon local feedback (PLFB) because these depend on X-ray BPMs (X-BPMs). This should not be confused with the completely different feedback system developed by Y. Tian with the same name (PLFB) in the past [2]. The other PLFB served the same purpose, holding the beam orbit tightly at an ID source for days. However, due to occasional events of fast corrector strengths running away, which were likely caused by this system fighting against the fast orbit feedback (FOFB), it was retired from operation once this new agent program was confirmed to work well without the issue of FOFB incompatibility.

Main Repository & Dependencies:

The main repository of this application is hosted at https://gitlab.nsls2.bnl.gov/hlatools/LBAgent.

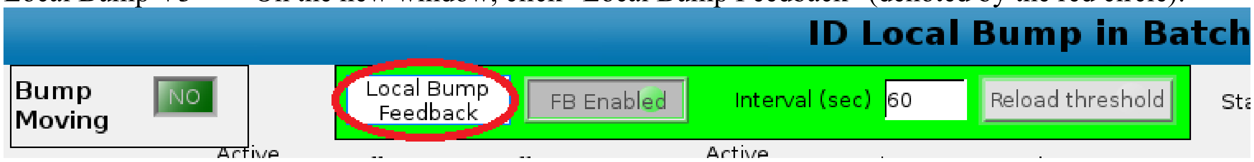
Requirements of this program are the following:

- A working local bump program that can perform local bump corrections via PVs (e.g., V3/V4 Local Bump at NSLS-II [3]).
- A Python 2 or 3 environment with `cothread` package [4].
- EPICS libraries for `cothread` to work.

How to Use:

The main use of this script is only to turn on the master controller by the command "`$ python lbagent.py`" on a terminal where the script file "lbagent.py" resides (as of this publication, it can be found at /epics/iocs/localBumpAgent on the server "hlaioc01" within NSLS-II Control Network).

This program has been fully integrated into an IOC and can be controlled from a CSS page. Open this page on CSS as follows: Main => Operations => Global => Click on "Operations Tools" => Click on "ID Local Bump V3" => On the new window, click "Local Bump Feedback" (denoted by the red circle):



The finally opened bump agent control page is shown in Fig. 1.

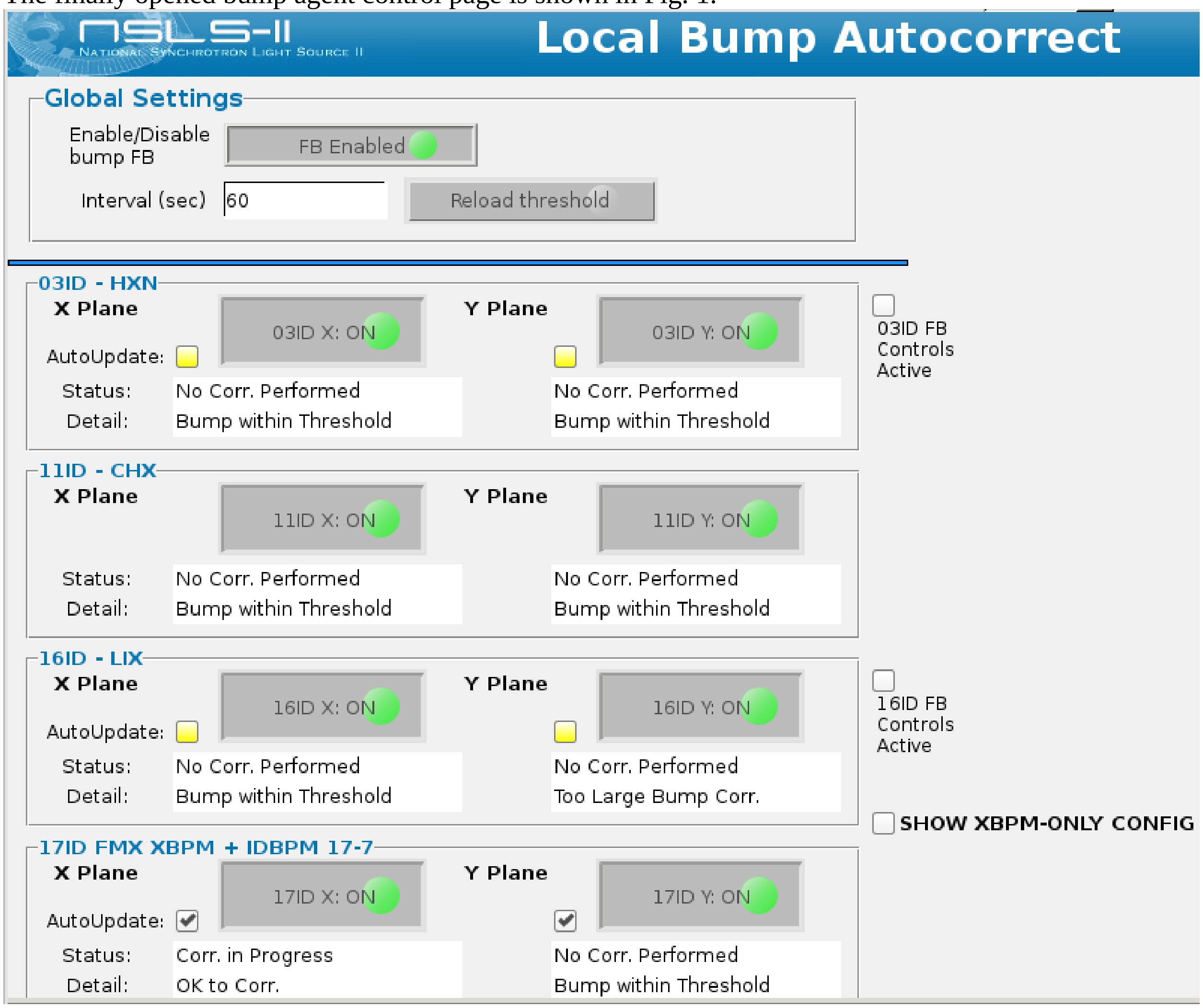


Figure 1: CSS panel for Local Bump Agents

The button next to "Enable/Disable bump FB" under "Global Settings" is associated with the PV `SR:APHLA:LBAgent{}Enable-Cmd` and turns on and off the main switch. With this disabled, all the agents are forced to sleep, even if they are individually enabled. Note that the main script's infinite loop will keep running even if this global switch is turned off.

The IOC for this program is completely safe to be restarted at any time without any risk of beam dump. However, it still makes sense to disable the global switch and let all the agent actions complete before restarting the IOC.

The edit box next to "Interval (sec)" under "Global Settings" is associated with the PV "`SR:APHLA:LBAgent{}FdbkMinCheckInterval`". This value specifies how frequently the agents should check the bump states. By default, this value is set to 60 seconds. Once all the evaluations and corrections are completed, the main loop goes into sleep until this specified interval passes. This is the only setting for this program that can be easily changed via PVs. There are other settings that are hidden from direct PV access and should be changed only by an expert of this program and only after getting an approval from a supervisor responsible for operation such as Group Leader in Accelerator Coordination Group. These settings are explained in the later section "Expert Settings."

To enable an agent for an ID, first make sure that the global switch PV discussed earlier is enabled. Then set the PV `SR:APHLA:LBAgent{BUMP:&&&}#-FdbkEnabled` to 1. To turn it off, set the PV to 0. The placeholder "`#`" in the PV template can be either "`X`" for the horizontal plane or "`Y`" for the vertical plane, both in upper case. The placeholder "`&&&`" can be any one of the bump labels listed in Table 1. So, for example, if you want to activate the agent for the horizontal bump at C03, set `SR:APHLA:LBAgent{BUMP:C03-R7X1}X-FdbkEnabled` to 1. Alternatively, you can simply click the button labeled as "03ID X: OFF" on the CSS page, which will stay pressed down and its text label will change to "03ID X: ON". Clicking this button once more will deactivate the agent.

Table 1: Currently available bump labels (case sensitive), versions, and BPMs used for those bumps.

Bump Label	Bump Version	BPMs being used
C03-R7X1	V4	P7 RF ID BPM & X-ray BPM at C03
C11-CHX	V3	2 RF BPMs bounding the ID at C11
C16-R7X1	V4	P7 RF ID BPM & X-ray BPM at C16
C17-R7X2	V4	P7 RF ID BPM & X-ray BPM for FMX at C17
C23d-CSX	V3	2 RF BPMs bounding the downstream ID at C23

The bump versions V3 and V4 refer to the type of bumps associated with the agents. V3 bumps are the bumps that consist of a pair of RF ID BPMs, while V4 bumps are those that include at least one X-BPM in the BPMs being utilized.

For each agent, there are enum PVs that show its status and the comment or explanation about the status, which are displayed in the text boxes next to "Status:" and "Detail:", respectively, on the CSS panel. The templates for these PVs are `SR:APHLA:LBAgent{BUMP:&&&}#-AgentAction` for the status and `SR:APHLA:LBAgent{BUMP:&&&}#-AgentActionComment` for the comment. The descriptions for each value of these PVs can be found in Tables 2 and 3, respectively.

Table 2: Descriptions of `AgentAction` PV values.

Value	PV Text	Agent Action Description
0	Evaluating	Evaluation taking place
1	No Corr. Performed	Decided NOT to perform a bump correction
2	Waiting for Other Corr.	Will correct, but waiting for other on-going corrections to finish
3	Corr. in Progress	Performing a bump correction
4	Error during Corr.	Tried correction, but some error occurred
5	Corr. Completed	Successfully completed a bump correction

Table 3: Descriptions of `AgentActionComment` PV values.

Value	PV Text	Agent Action Detailed Comments
0	Evaluating	Evaluation taking place
1	Disabled Local Bump FDBK	No action taken because the agent is disabled
2	No Beam	No action taken because there is no beam in the storage ring
3	Beamline Not Ready	(NOT used; redundant with "Disabled Local Bump FDBK")
4	Bump within Threshold	No action taken because the bump is within the specified window
5	Too Large Bump Corr.	No action taken because the current bump is too far away from the target
6	Fast Cor Limit	(NOT yet implemented) No action taken because some fast correctors are close to their limits
7	Too Freq. Bump Corr.	No action taken because a previous bump correction was performed too recently
8	OK to Corr.	Decided to perform a bump correction
9	OK to Corr. Op. Override	(NOT yet implemented) Decided to perform a bump correction, but yielding to a human operator bump request
10	SOFB Running	No action taken because slow orbit feedback (SOFB) is running

There is one more type of PV available for bump agents, but only for V4 bump agents. The PV template is `SR:APHLA:LBAgent{BUMP:&&&}#-SPAutoUpdate`. Unlike V3 bumps, which rely only on RF ID BPMs that monitor the electron beam (e-beam) orbit in the storage ring, V4 bumps rely on at least one X-ray BPM. The setpoint values for X-BPMs tend to fluctuate substantially, primarily because even a slight e-beam bump angle change in the ring translates into a large change in the photon beam position downstream. Therefore, when this "`SPAutoUpdate`" PV is set to 1 (or checked on the CSS panel), and a V4 bump agent associated with this PV is activated, the agent automatically changes the target setpoint values to the current BPM readback values. This way, the agent will try to maintain the current position from that point on. However, this automatic setpoint update feature is not needed for V3 bumps because the target bump setpoint values associated with RF BPMs do not typically change by a large amount even when beamline scientists ask for adjustments. Hence this feature is not made available for V3 bumps.

However, there are certain situations where you want to keep the previously set target values. For example, a beam dumps while a beamline scientist is conducting a series of experiments. If the machine is quickly recovered, there is no need for them to re-align their photon beam. In this case, they prefer to have the agent automatically fine-tune the beam position back to where the beam was before the dump to resume the scan. This can be achieved by setting the "`SPAutoUpdate`" PV to 0 (or unchecked on the CSS panel) before they re-enable the agent. In this case, whatever setpoint values previously set will not be automatically changed. However, beamline scientists are recommended to make sure that the agent action comment PV does not show "Too Large Bump Corr.". If this message is shown, it means that the current bump is too far from the previous target such that the agent will not take any corrective action. If this happens, they can decide to enable the automatic setpoint update feature. If they still want to bring the beam to the previous photon beam position, they should ask the lead operator to adjust the setpoints for the RF BPM local bump (i.e., V3 bump) and iteratively bring back the photon beam position close enough to the previous V4 target. Then the agent should start working to fine-tune and lock onto the previous V4 setpoints.

For V4 bump agents, several safety features have been implemented and hard coded into the script. First, it will check whether mutually exclusive V4 bump agents are not enabled simultaneously. For C17, since there are 2 X-BPMs, there are several bump configurations available in terms of BPM selection. Only one such bump should be used throughout user operation. Otherwise, multiple competing agents try to correct to their targets, potentially leading to orbit oscillation. Second, the script checks whether the agent has been turned off at some point between now and the previous evaluation. The agent behavior depends on this fact because of the automatic setpoint update feature discussed above. Finally, the gap value of the associated ID is also checked. Since X-BPMs need to use measured calibration tables that depend on the ID gap values, if the current gap is outside of the table gap range, the agent assumes the X-BPM readings are not reliable and will self-terminate because it might be risky to continue feedback. To be extra safe, the gap motion is also limited to 150 um while the agent is activated. If the gap moves more than this amount, the agent will self-terminate. When this happens, a beamline scientist can simply re-enable the agent, which will reset the reference gap to the current gap.

Note that as of this publication, the minimum gap check for V4 bump X-BPM calibration tables is not being performed since 10/23/2020. This change was specially implemented to allow AMX/FMX to operate below the calibration table minimum gap of 6.5 mm until the table is updated to include their full operational range.

Expert Settings:

The hidden settings of the bump agents are all contained in the text file “thresh.json” in the same folder as the main script. For any changes in this JSON file to take effect, the button “Reload threshold” under “Global Settings” on the CSS page must be pressed. The button should latch to the pressed state. You need to wait until the next evaluation time, as the main loop is dormant until then. Once the new settings are loaded, the button should unlatch itself.

Table 4: Settings available in the “thresh.json” JSON file.

Key [unit]	**Default Value**		**Description**
	V3*	V4**	
NoBeam_mA [mA]	90.0		Minimum total beam current in Storage Ring for agents to take actions.
min_mm [mm]	0.001		An agent decides to perform a correction if current bump offset (V3) or first BPM position (V4) is away from target by more than this amount.
max_mm [mm]	0.010	0.050 (RF BPM) 0.140 (X-BPM Hor.) 0.120 (X-BPM Ver.)	An agent is not allowed to perform a correction if current bump offset (V3) or first BPM position (V4) is away from target by more than this amount.
min_mrad [mrad] for V3 ([mm] for V4)	0.001		An agent decides to perform a correction if current bump angle (V3) or second BPM position (V4) is away from target by more than this amount.
max_mrad [mrad] for V3 ([mm] for V4)	0.010	0.050 (RF BPM) 0.140 (X-BPM Hor.) 0.120 (X-BPM Ver.)	An agent is not allowed to perform a correction if current bump angle (V3) or second BPM position (V4) is away from target by more than this amount.
min_fdbk_corr_interval [s]	600.0	30.0	An agent must wait at least this much to perform another correction since the last correction was performed.

* V3: Bumps that use only RF ID BPMs
** V4: Bumps that use at least one X-BPM

Table 4 lists all the available settings. Note that for V4 bumps, offset and angle are not defined; instead, the first and second BPM positions are directly used as the target values to be maintained. Therefore, even though the keys “min_mrad” and “max_mrad” contain “mrad” in the names, the units for these are both millimeters for V4 bumps. The default values of “max_mm” and “max_mrad” for V4 bumps were empirically determined by scanning the equivalent V3 bump maximum window of 10 um offset and 10 urad angle. This V3 bump maximum window size was not based on any safety analysis, but rather tentatively set somewhat arbitrarily to avoid potentially disruptive large bump adjustments. Hence, these maximum default values can be flexibly adjusted if such needs arise in the future.

17-ID Bump Nudge Program:

Even though this is not a bump agent, there is another stand-alone Python script called “nudge_bump_id17.py” in the bump agent repository folder. This program was implemented and integrated into an IOC to allow C17 ID beamline scientists to adjust their local bump (V3 angle only) on their own. Until this, there was no exception for the rule that every beamline must call NSLS-II Control Room and ask the lead operator if they need to adjust their local bump. The special authorization was initially given in April 2020 since this beamline was the only beamline operating under the COVID-19 “Min-Safe” operations. Even after transitioning to the present “Limited” operations, we gave the beamline an authorization to use this “nudge” function again in October 2020 after a request from them, as long as no adverse effect is observed at other beamlines.

The PV `SR:APHLA:SOFF{BUMP:C17d-FMX}Nudge-Enabled` must be set to 1 for this application to be usable. If it needs to be disabled, set the PV to 0. When the PV `SR:APHLA:SOFF{BUMP:C17d-FMX}Nudge:X-Cmd` or `SR:APHLA:SOFF{BUMP:C17d-FMX}Nudge:Y-Cmd` is set to 1, this script changes the bump angle setpoint (in the horizontal or vertical plane, respectively) by the amount [mrad] specified by `SR:APHLA:SOFF{BUMP:C17d-FMX}increment:X-SP` or `SR:APHLA:SOFF{BUMP:C17d-FMX}increment:Y-SP`, and then initiates a bump correction.

The increment PVs are limited to within ±0.001 mrad (i.e., 1 urad) both at the PV level and in the script. Changing the increment PVs does not initiate any bump correction. If the 17-ID bump agent is turned on when the nudge program is used, the agent will be automatically turned off. So, the beamline scientists must remember to re-activate the agent after the manual bump nudging. Also, if another bump correction instance is underway (initiated either by a human or a bump agent), the nudge program will wait until the on-going bump correction is finished.

Even though each nudge is limited to 1 urad, there is nothing to prevent the user from moving the bump cumulatively to perform an effectively large bump angle correction, except for the administrative control of ±10 urad in total we asked the users to adhere to.

References:

[1] Y. Hidaka, A. Caracappa, Y. Hu, B. Podobedov, R. Smith, Y. Tian, G. Wang, “Improvements in Long-Term Orbit Stability at NSLS-II” in Proc. IPAC2019, Melbourne, Australia (2019), THPRB104.

[2] Y. Tian, “NSLS-II Fast Orbit Feedback System”, BES Light Sources Beam Stability Workshop, Berkeley, CA, USA, Nov. 2018. https://www.aps.anl.gov/sites/www.aps.anl.gov/files/APS-Uploads/Workshops/BES-Light-Sources/Yuke%20Tian%20-%20Fast%20Orbit%20Feedback%20at%20NSLS-II.pdf

[3] Y. Hidaka, Y. Hu, B. Podobedov, R. Smith, Y. Tian, G. Wang, "Fast-Orbit-Feedback-Compatible ID Local Bumps with RF and X-ray BPMs at NSLS-II", BNL Technical Note, NSLSII-ASD-TN-353 (2021).

[4] http://controls.diamond.ac.uk/downloads/python/cothread/; https://github.com/dls-controls/cothread