Performance and configuration of the HallD fast-feedback system

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1 Introduction

In HallD, The electron beam is utilized to produce a polarized photon beam by using a diamond radiator. This photon beam is collimated 75 meters downstream by an aperture of 5 mm. The position of this photon beam has to be stable within +/- 200 μm. Given the lorentz boost, the photons are emitted very tightly in the direction of the incoming electron beam on the radiator. Hence, stabilizing the electron beam will result in stabilizing the photon beam.

The first three harmonics of the AC line power can generate fluctuations of the order of 0.1% of the beam position, well above the stated position stability requirement. In addition, energy fluctuations can produce beam motion at the dispersive locations. the 12 GeV machine will have an energy spread of about 2.10^{-4}, a factor of 10 bigger than what we currently have in Hall A and Hall C, essentially because of the increased synchrotron radiation at 12GeV. The fast feedback system has been in use routinely for operations in Hall A and Hall C and the performance of this system has been documented elsewhere [1]. In this paper we will review the implementation of the proposed fast feedback system for Hall D and evaluate its performance.

2 Configuration of the fast-feedback system

The system consist of a set of actuators which are fast air-core correctors with a bandwidth of 1.2Khz, a RF vernier connected to a RF zone in the south linac and a set of responders which are beam position monitors with a sampling frequency of about 3Khz. The system corrects the motion in the X and Y plane independently as well as the energy. For that purpose, two pairs of correctors, one pair for horizontal and one pair of vertical correctors are chosen. Two beam position monitors per plane have to be selected as well as one more in a dispersive location for measuring the energy. In order to be fast, the system is restricted to this minimal configuration.

A dedicated control system CPU takes care of calculating the corrections to apply to the correctors to compensate for the motion resulting from the higher order harmonics of the beam. The low frequency motion is taken care of by standard iron-core corrector and slow orbit lock systems based on the EPICS system.

3 Optics requirements for the system

We are trying to determine optimum configuration for two different control points. First, at bpm 5C12, in front of the diamond radiator and second at the active collimator 75 meters downstream from the radiator where one has only the photon beam. This will enable us to run without the active collimator should it become defective.

The control point where we want to stabilize energy, position and angle determines the location of the air-core correctors and the beam position monitors. Essentially, one wants to have a configuration for which the betatron motions generated at each corrector are orthogonal between each other.

One corrector needs to be in a point-parallel configuration relative to the control point (in which case it will control position) and the other one has to be in a point to point situation which will make it control angle. This places constraints on the optics and the location of the correctors and monitors. An easy way to find the optimal positions is to propagate backward through the beamline starting at the control point and look for locations in the beamline where it crosses zero.

Figures 1 and 2 illustrate the process. δX ,$\delta X'$,δY,$\delta Y'$ perturbations were launched from IPM5C12 backwards. Reading off the zero-crossing po-

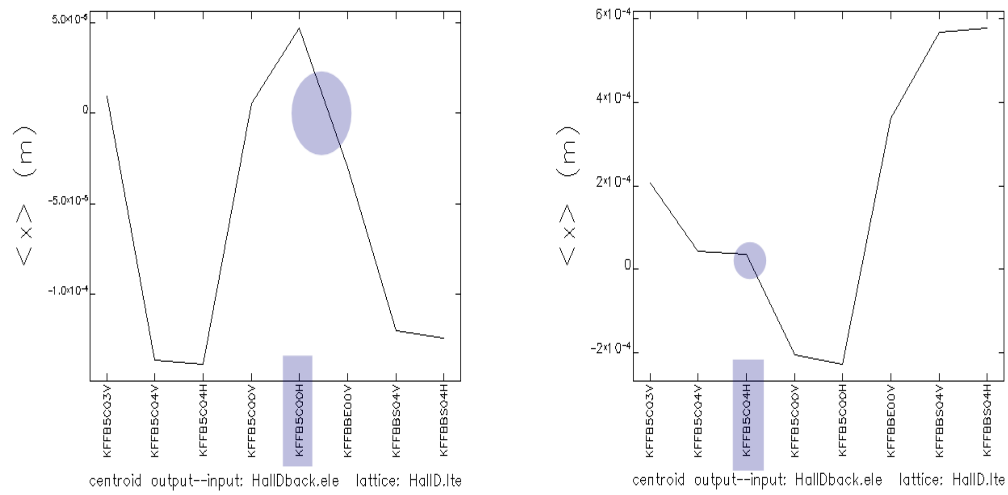

Figure 1: Parallel to point and point to point configurations for X plane at 5C12

sitions and choosing the closest air-core corrector in the beamline to those crossing points produce an optimal configuration. This led us to recommend the installation of an air-core corrector half-way between the S04 and E01 quadrupoles in the long 26 meters drift section.

Having chosen the air-core corrector locations, we need to find which beam position monitors to use in order to have orthogonal orbits. In practice this means choosing two monitors, each of which should be mainly sensitive to one of the correctors and less sensitive to the other.

figure 3 show possible choices for the vertical and horizontal readouts with the beam position monitors.

In the horizontal plane one can choose amongst IPM5C03, IPM5C07 and IPMIACTCOL (the active collimator). If the active collimator is not working, one can switch to IPM5C07 and still get good performance. The vertical plane selection is IPMBT02 and IPM5C12 or IPMIACTCOL. We can not select a bpm in between 5C00 and 5C06 for the vertical plane since it is where one has a big dispersion pattern. IPM5C03 which is at the dispersion peak, can be chosen for the energy correction part of the fast feedback.

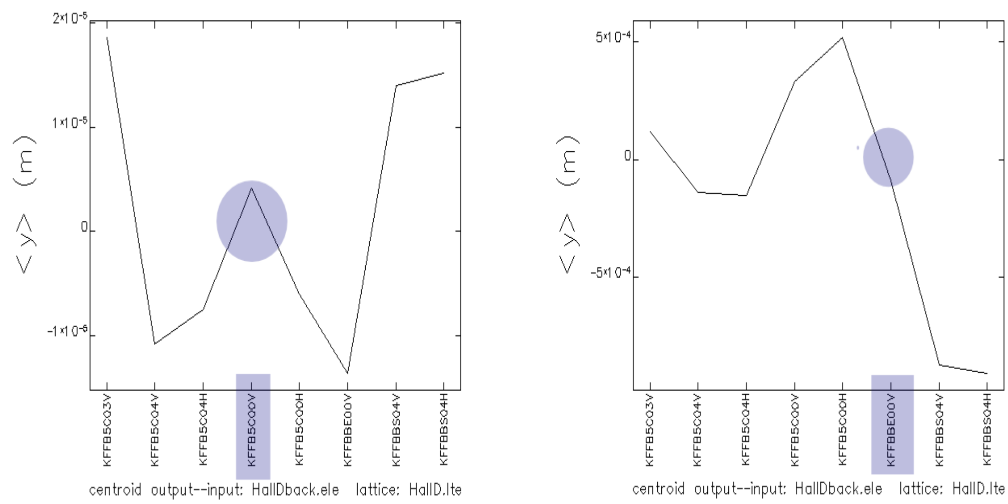

Figure 2: Parallel to point and point to point configurations for Y plane at 5C12

4 performance

4.1 Option1: With Active collimator

We simulated the performance of the fast feedback system in this configuration by injecting random orbit errors at the start of the beamline. The magnitude of these errors were σ_x=1mm RMS, σ_y=1mm RMS, $\sigma_{x'}$=1μrad RMS, $\sigma_{y'}$=1μrad RMS.

The system was then switched on and allowed to correct for the perturbation. BPM errors were taken to have a standard deviation of 50μm.The result is shown in figure 4.

4.2 Option2: Without Active collimator

Without the active collimator, the performance degrades slightly, especially in the horizontal plane. As can be seen in figure 5, it still keeps the beam within a radius of 200μm

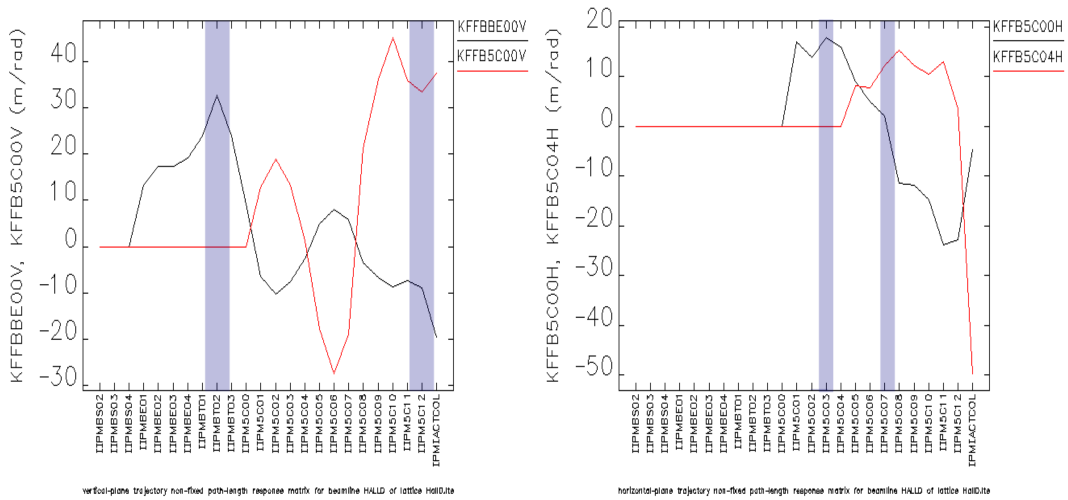

Figure 3: BPM selection for horizontal and vertical planes

4.3 Sensitivity to matching errors

Following [4], we let the input twiss parameters vary and studied the performance of the Fast Feedback system under these matching errors after correcting for mismatch and thus, changing the matching quadrupole values. Any greater mismatch will have to be fixed upstream of the HallD beamline.

It turns out that the fast feedback system is relatively robust under beamline mismatchs. The resolution stays well within the $200\mu m$ limits when one can use the active collimator in the system.

Tables 1 and 2 give resulting RMS values for the x and y beam sizes with two different choices of monitors for the fast feedback system.

5 Conclusion

We have shown that the fast feedback system for HallD is expected to meet the required performance. We are recommending the following air-core correctors locations to be nstrumented: FFB5C00H, FFB5C04H, FFBBE00V, FFBBS04V, FFBBS04H .

Any mismatch variations that are significantly bigger than the cases we studied will have to be corrected upstream of the Hall D line, possibly in

Trial	β_x	β_y	α_x	α_y	correctors	σ_x	σ_y
Base	1.0	1.0	0.0	.0.0	FFB5C00H,FFB5C04H,FFBBE00V,FFBBS04V	47	10
T1	0.5	0.5	-1.0	-1.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	41	16
T2	0.5	1.0	0.0	0.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	72	18
T3	0.5	2.0	1.0	1.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	101	20
T4	1.0	0.5	0.0	1.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	57	21
T5	1.0	1.0	1.0	-1.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	55	20
T6	1.0	2.0	-1.0	0.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	32	14
T7	2.0	0.5	1.0	0.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	65	23
T8	2.0	1.0	-1.0	1.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	34	15
T9	2.0	2.0	0.0	-1.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	31	12

Table 1: FFB system resolution for various matching conditions with IPMBT02, ACTCOL,IPM5C02,IPM5C12

Trial	β_x	β_y	α_x	α_y	correctors	σ_x	σ_y
Base	1.0	1.0	0.0	.0.0	FFB5C00H,FFB5C04H,FFBBE00V,FFBBS04V	180	18
T1	0.5	0.5	-1.0	-1.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	139	27
T2	0.5	1.0	0.0	0.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	246	21
T3	0.5	2.0	1.0	1.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	176	160
T4	1.0	0.5	0.0	1.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	239	26
T5	1.0	1.0	1.0	-1.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	196	19
T6	1.0	2.0	-1.0	0.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	107	15
T7	2.0	0.5	1.0	0.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	175	26
T8	2.0	1.0	-1.0	1.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	104	17
T9	2.0	2.0	0.0	-1.0	FFB5C00H, FFB5C04H, FFBBE00V,FFBBS04V	72	13

Table 2: FFB system resolution for various matching conditions with IPMBT02, IPM5C02, IPM5C07, IPM5C12

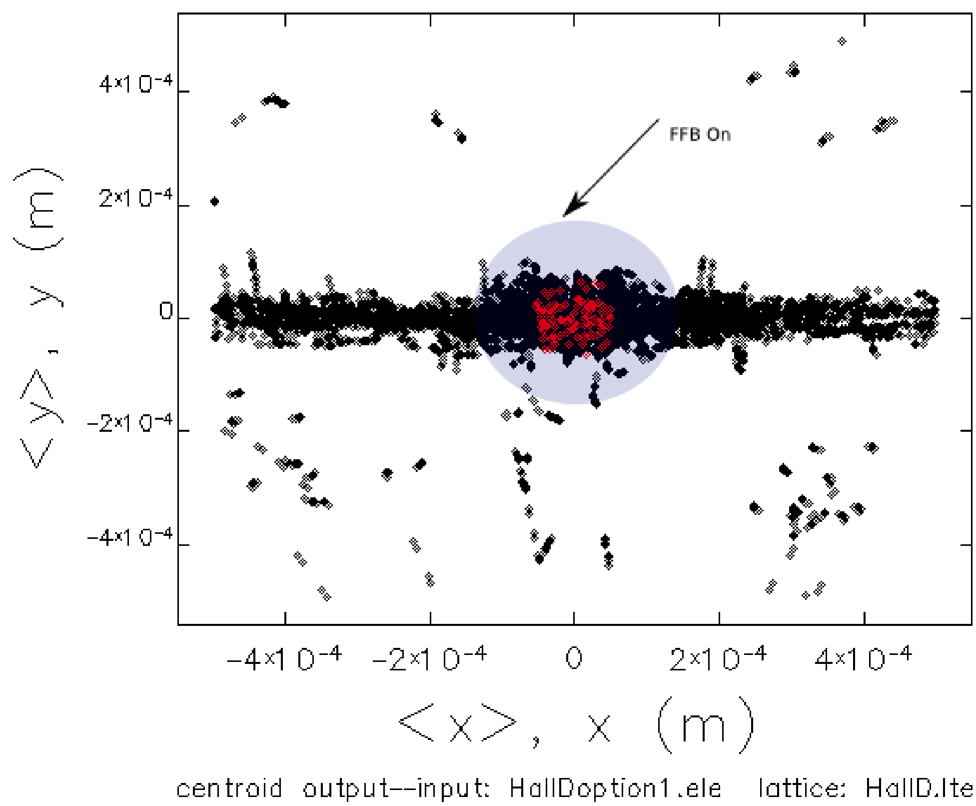

Figure 4: Beam spot centroid at the active collimator with FFB on (red) and off (black)

Arc10. If one is required to go more upstream than that, then it will impact the other halls and increases tune time. The ideal situation for Hall D would be to have a feedback system for which correctors and monitors are situated after all the betatron matching quadrupoles. The current design did not allow this approach since it relies on using almost all the quadrupoles in the beamline to match transport and beam sizes at the radiator. This choice was deliberate, in an effort to save costs.

A solution that would allow for relegating the betatron matching of the beamline up front would likely need more quadrupoles (it was estimated that one needed at least two more in [4].Whether the extra cost is worse the benefit has to be studied in the context of the commissioning plans.

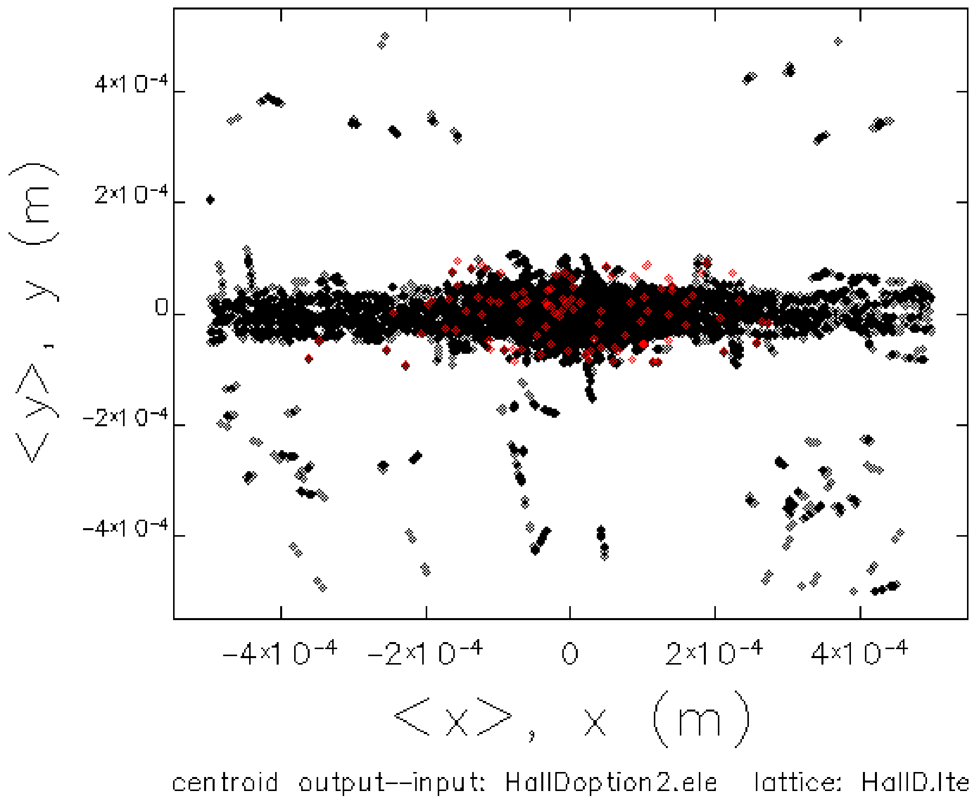

Figure 5: Beam spot centroid at the active collimator with FFB on (red) and off (black) for option 2

6 Acknowledgments

We wish to acknowledge the many fruitful discussions we had with Michael Tiefenback regarding this work.

References

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