Simulations to Optimise the Phase of the Rebunching Cavities in the Front End Test Stand H^- Ion Accelerator

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Abstract

Inside the Medium Energy Beam Transport line (MEBT) at the Front End Test Stand, there are three rebunching cavities that are responsible for maintaining the bunched structure of the H^- ion beam as it travels through the MEBT. These cavities need to operate at an optimal phase so that there is minimal spreading of the bunches. This project demonstrates the effect of changing the phases at which the cavities operate. Different methods of analysis, including plots of the beam profile and observations of bunch arrival time at one of the beam position monitors, show that the change in phase leads to an unstable beam, and that the optimal phase of the cavities is that at which they are already set to operate.

Schematic Diagram of the FETS MEBT

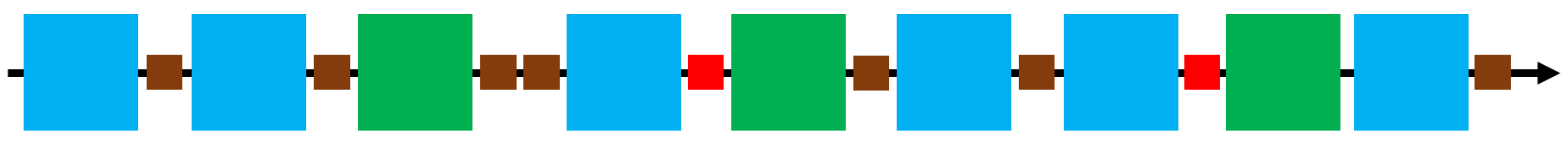

Figure 1: A schematic diagram of the FETS MEBT. The blue blocks represent the BPMs and the green blocks represent the rebunching cavities. The smaller brown blocks represent quadrupoles and the red blocks represent the choppers.

The components are not to scale: the larger size has been used to accentuate the components that this project focused on.

Background to the FETS MEBT

The Front End Test Stand (FETS) accelerator is a linac that is currently under commission at the STFC Rutherford Appleton Laboratories [1]. The Medium Energy Beam Transport line (MEBT), which is the fourth section of the accelerator, consists of seven small-bore quadrupoles for beam focusing, three radiofrequency cavities for maintaining the bunched structure of the beam, and six beam position monitors (BPMs) for diagnostics [2]. A diagram of the MEBT is shown in Figure 1.

It is very difficult to find the phases at which the rebunching cavities should operate in order to fully "bunch" particles into a tight bunch structure with minimal momentum spread. As such, the aim of this project was to find the optimal phase of the rebunching cavities so that a high quality beam can be maintained throughout the MEBT.

The optimal phase of the cavities was found by investigating the effect of changing the phase of the rebunching cavities on the bunch arrival time at the BPMs. The phases of each of the cavities was changed by 30°at a time, up to a total phase advance of 300° on each cavity. Whilst the phase was changed on one cavity, the phases of the other two were kept unchanged.

Longitudinal beam profile

Simulations were run with 100,000 particles passing through the FETS MEBT. Measurements of the particle coordinates and momenta could be taken at any point. Plots of the longitudinal profile of the bunches at BPM 6 for the different phase changes to Cavity 1 are shown in Figure 2.

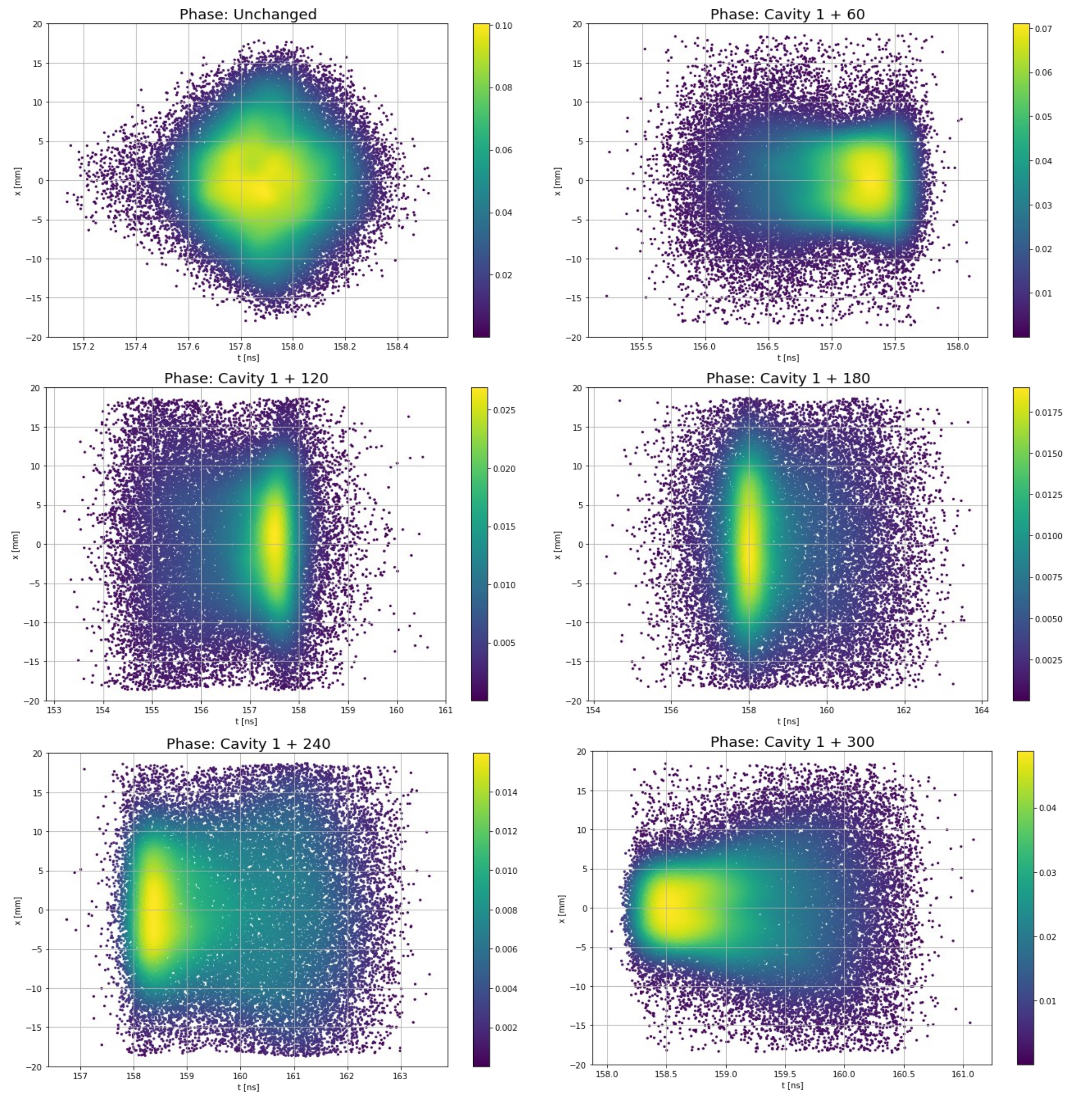

Figure 2: The longitudinal emittance at BPM 6 of a bunch of particles with phase changes applied to Cavity 1.

From these plots it is clear that the bunch becomes more longitudinally spread-out as the phase of the cavities is changed, showing that the beam isn't as well bunched as it was when there was no phase change. They also show the highest particle density region of the bunch moving back and forth with the change in phase. The movement back and forth is sinusoidal.

Bunch arrival time at BPM 6

The electromagnetic fields seen at BPM 6 were simulated. Plots of these fields for the phase changes to Cavity 1 are shown in Figure 3.

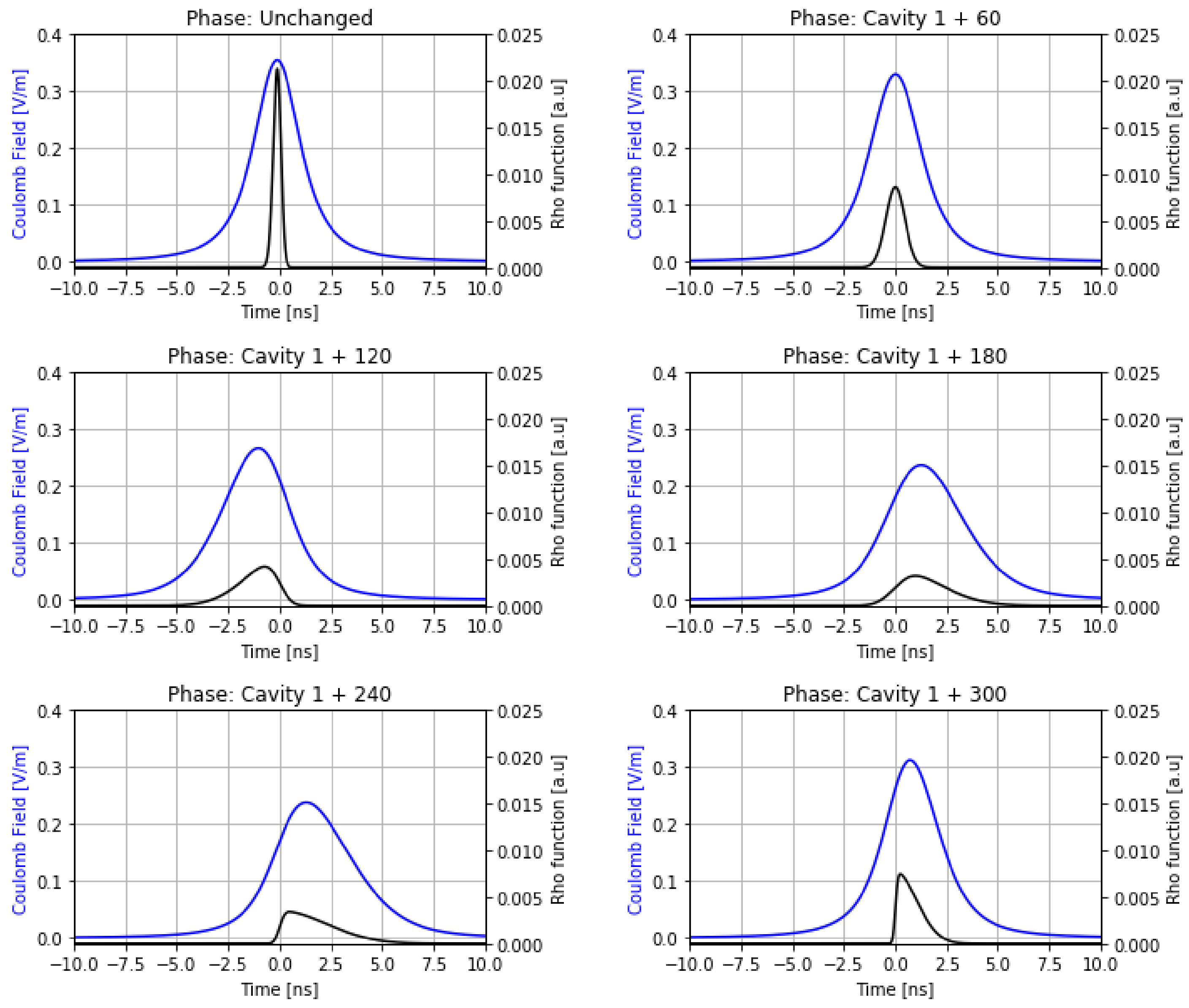

Figure 3: The coulomb field seen by BPM 6 (blue) against the input distribution (black), for phase changes applied to Cavity 1.

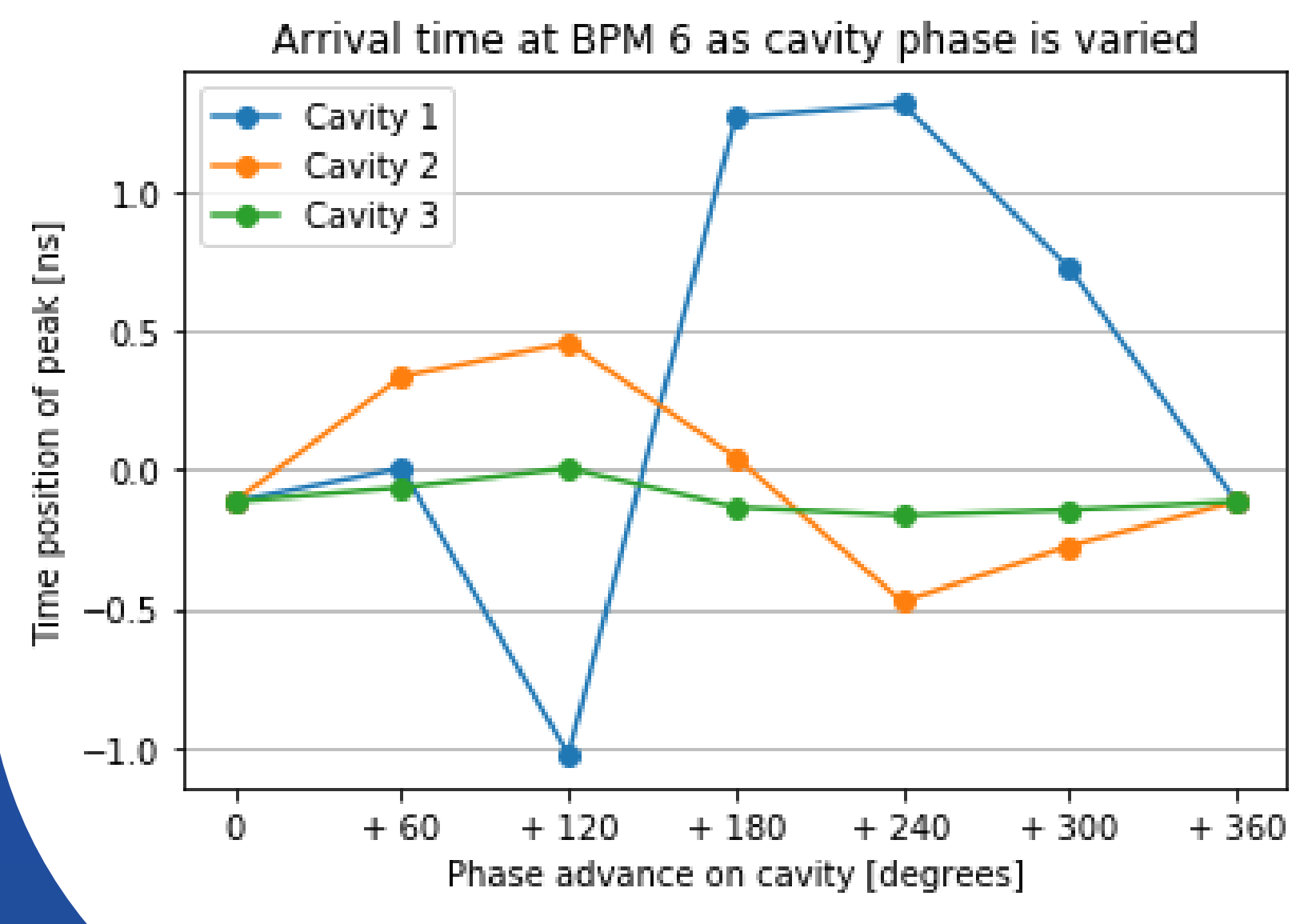

Figure 4: Bunch arrival time at BPM 6 for different phases.

The time position of the peak of the coulomb field curves in Figure 3 corresponds to the bunch arrival time at BPM 6. The bunch arrival times were plotted against phase advance. This is shown in Figure 4.

The bunch arrival times follow a sinusoidal shape. This demonstrates that as the phase of the rebunching cavities is changed sinusoidally, the bunch arrival time also changes sinusoidally.

Conclusion

From the analysis carried out, it is clear that as the phase of the rebunching cavities is changed sinusoidally, the bunch arrival time at BPM 6 also changes sinusoidally. The bunch arrival time closest to zero (i.e. neither too early nor too late) occurs when the phase is unchanged, showing that the unchanged phase is optimal for the rebunching cavities. The clear spreading out of the particle bunches with changed phase, as seen in Figure 2, also supports the claim that the optimal phase of the cavities is the original, unchanged phase. Keeping the phase of the rebunching cavities at their optimal value will result in a well bunched beam, that is stable and easy to predict and control.

References

[1] *Letchford A, Bosco A, D'Arcy R, Gibson S, Dudman M, Lawrie S, et al. Status of the RAL Front End Test Stand. 2015.*

[2] *Kim HJ, Choi B, Kim ES, Hwang JG. Design of medium energy beam transport for the rare isotope science project. Journal of the Korean Physical Society. 2013.*

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