First Results From Beam Tests of the CLIC Drive Beam Phase Feedforward Prototype at CTF3

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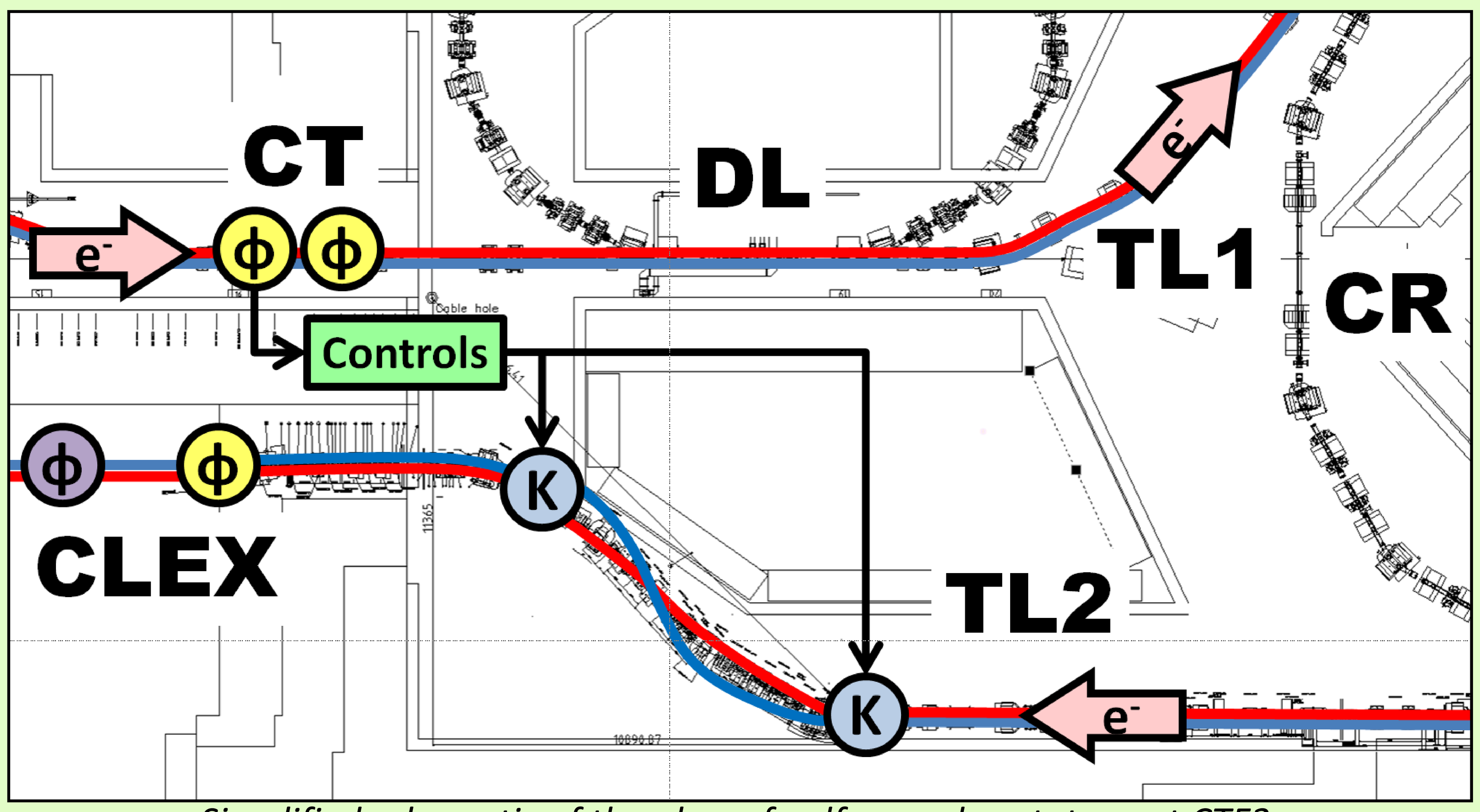
Motivation

- In the CLIC two beam acceleration scheme the RF power that accelerates the main beam is extracted from a second ***"drive beam"***. The phase (or time) synchronisation between the two beams must be maintained to within ***0.2 degrees of 12 GHz*** (50 fs) to ensure the efficiency of this concept [1,2].
- A ***phase feedforward system*** with ***bandwidth above 17.5 MHz*** [3] is required to reduce the drive beam phase jitter to this level. A prototype of this system has been installed and the first tests completed at the CLIC test facility CTF3 at CERN to prove its feasibility.

CTF3 Phase Feedforward System

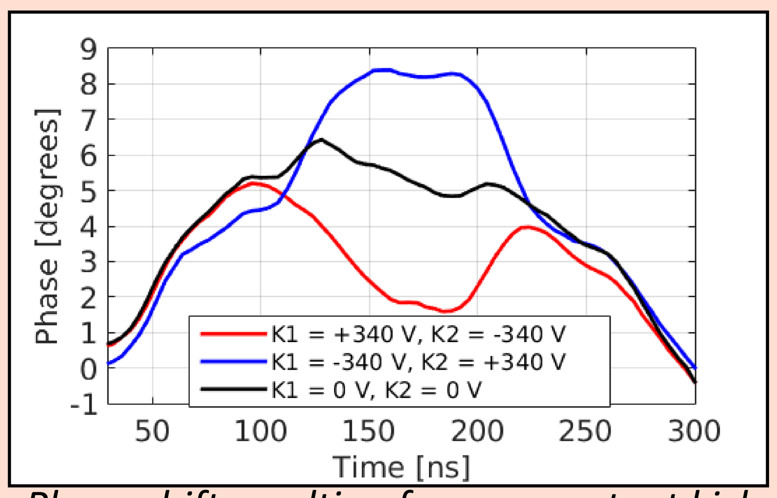
- The phase is corrected using two kickers placed prior to the first and last dipoles in the pre-existing ***chicane*** in the TL2 transfer line: ***bunches arriving late*** are deflected on to ***shorter paths*** and ***bunches arriving early*** on to ***longer paths*** through the chicane.
- Hardware: Three ***phase monitors*** and two strip line ***kickers*** (INFN/LNF Frascati) [4,5,7], kicker ***amplifiers*** and ***digital processor*** (JAI, Oxford University) [6,7].
- ***Latency*** of the system (including cable lengths) must be less than the ***380 ns*** time of flight between the first monitor and the first kicker.
- Goal: ***30 MHz bandwidth*** correction with ***0.2 degrees of 12 GHz resolution***.



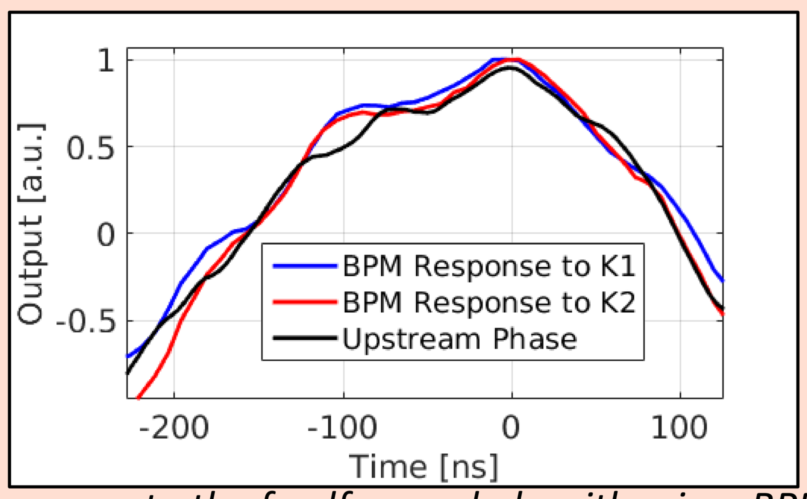
Simplified schematic of the phase feedforward prototype at CTF3.

Commissioning

- The complete PFF system became available in October 2014. Previous results from commissioning of the optics and phase monitors are presented in [8].
- The first prototype kicker amplifiers provide an output voltage of **340 V**. They will be upgraded to **1.2 kV** during 2015. Constant kick tests demonstrate a **±3.5° phase shift** and **>12 MHz bandwidth** when applied to the kickers.
- **The feedforward algorithm varies the drive signal to the amplifier based on the upstream phase** to correct the downstream phase with 30 MHz bandwidth. Its performance was verified by comparing the position offset in a BPM after the correction chicane to the upstream phase whilst applying the correction.



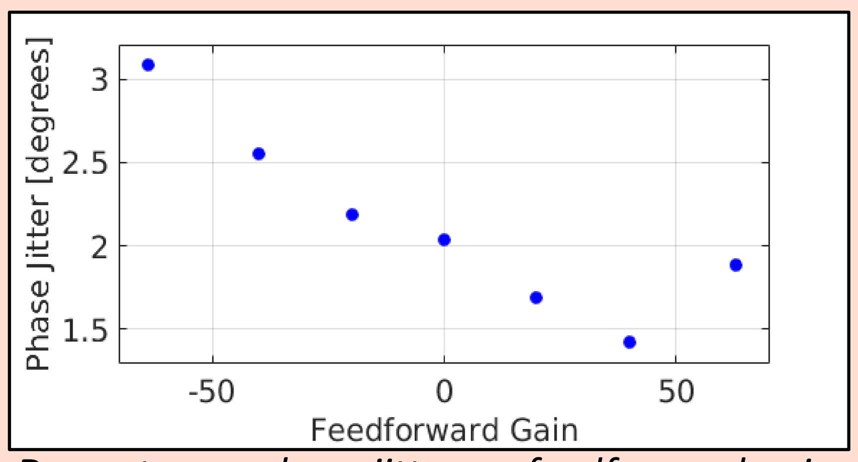
Phase shift resulting from a constant kick.



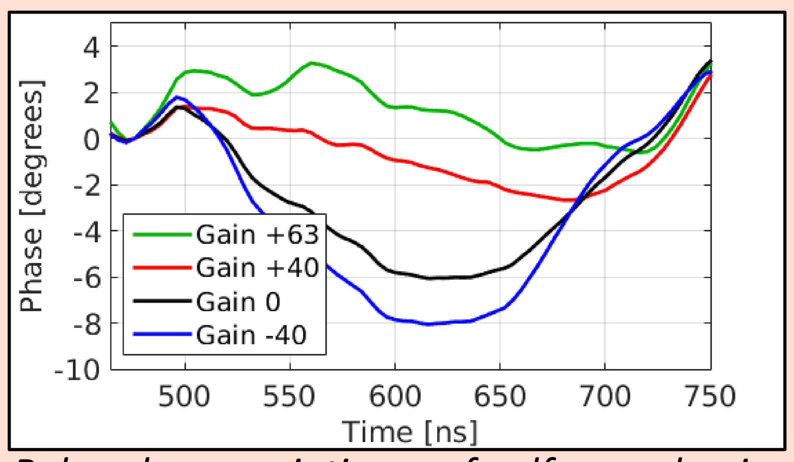
Response to the feedforward algorithm in a BPM.

Phase Feedforward Results

- The drive beam pulses in CLIC are ***240 ns*** long. ***100–200 ns*** pulses were used to test the functionality of the feedforward system at CTF3. As the amplifiers are upgraded during 2015 the ***increased power*** will allow tests to be conducted on the ***full CLIC pulse length***.
- In the first feedforward tests the ***gain*** on the digital processor was varied, including both ***positive*** (acting to ***reduce*** the phase jitter) and ***negative*** (acting to ***increase*** the phase jitter) values, in order to determine the ***optimal*** gain setting and to verify the performance of the correction.
- The ***initial*** downstream ***phase jitter*** of ***2°*** is reduced to ***1.4°*** with a gain of +40, a ***reduction of 30%***. Negative gain values or values above +40 result in the downstream phase being amplified or over-corrected.
- With the optimal gain of +40 the ***mean phase variation*** along the pulse is ***reduced from 7° to 3°***. There is a remaining slope in the phase along the pulse as a result of the current limits in correlation and correction range.



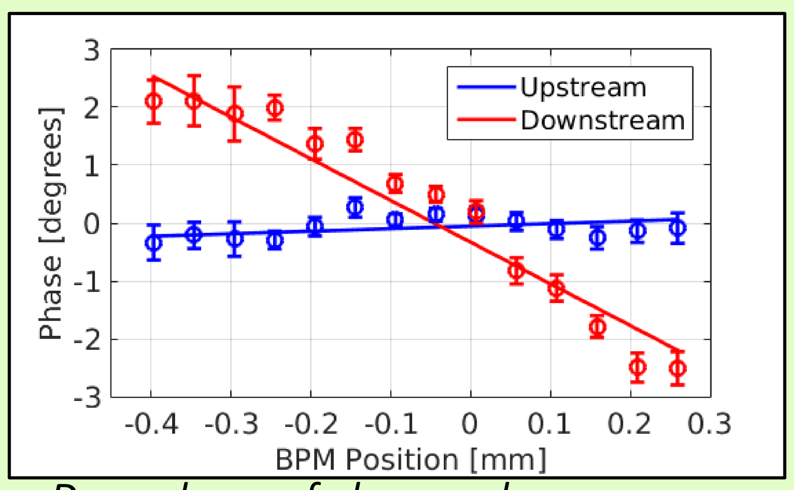
Downstream phase jitter vs. feedforward gain.



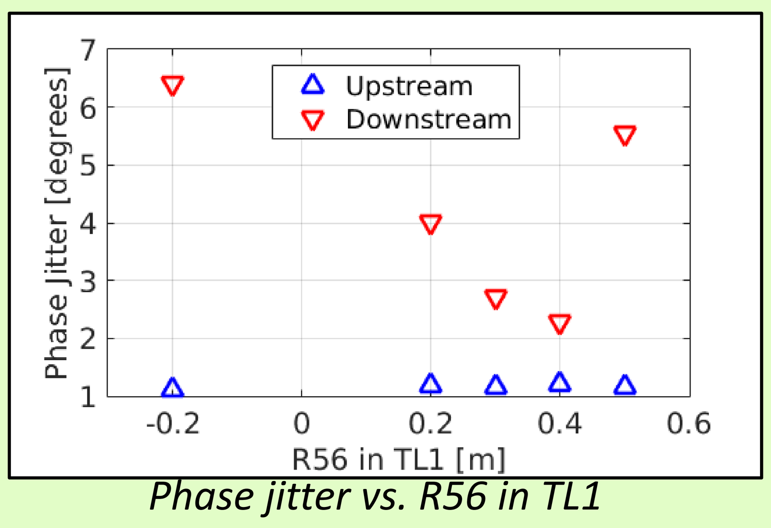
Pulse phase variation vs. feedforward gain.

Improving Performance

- An upstream-downstream phase ***correlation of 97% is required*** to reduce an initial ***phase jitter*** of ***0.8°*** to the ***CLIC*** limit of ***0.2°***. The beam conditions at ***CTF3*** are typically ***2° phase jitter*** and ***40% correlation***.
- The dominant ***source*** of the ***low correlation*** between the upstream and downstream phase at CTF3 is ***energy jitter being converted to phase jitter*** via the transfer matrix coefficient ***R56***. This was verified by comparing the phase to the beam position in a dispersive bpm.
- The ***residual R56 must be below 1cm*** to achieve 97% phase correlation. ***R56 in the TL1 line*** can be varied to ***compensate*** for the ***non-zero R56 in TL2*** and other sections. A ***factor 2 reduction*** in the ***phase jitter*** has already been demonstrated using this approach.



Dependence of phase on beam energy.



Phase jitter vs. R56 in TL1

Conclusions

- Preliminary running of the prototype phase feedforward system at the CLIC test facility CTF3 has so far demonstrated ***a 30% reduction in the drive beam phase jitter*** by using kickers to vary the path length through a magnetic chicane.
- In order to achieve ***CLIC level phase stability*** at CTF3 ***energy effects*** entering the phase via R56 must be removed in order to improve the ***correlation*** between the upstream and downstream phase from 40% to above 95%. Fine R56 tuning will be ***implemented in 2015*** to achieve this.

References: [1] D. Schulte et al., MOP024, LINAC10; [2] CLIC Collaboration, CERN-2012-007; [3] A. Gerbershagen, 2013 PhD Thesis, University of Oxford; [4] F. Marcellini et al., WEPEB035, IPAC10; [5] A. Ghigo et al., TUPC007, IPAC11; [6] N. Blaskovic et al., THOAA02, IPAC2014; [7] P. Skowronski et al., WEOBB203, IPAC2013; [8] J. Roberts et al., MOPP033, LINAC14.