Development of a beam-based phase feed-forward demonstration at the CLIC Test Facility (CTF3).

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Abstract

This is the abstract TeX for the thesis and the stand-alone abstract.

Dedication.

Acknowledgements

Acknowledgements.

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This is the introductory text.

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This is the introductory text.

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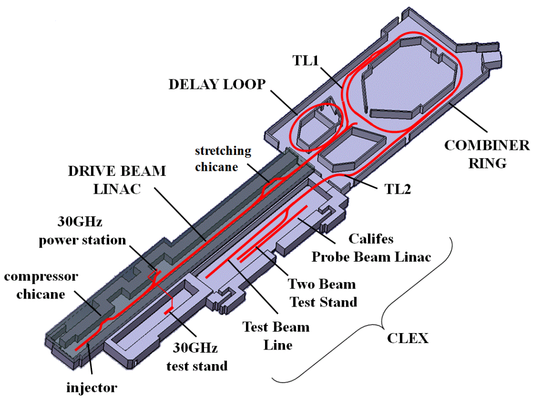

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Chapter 3

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This is the introductory text.

3.1 Introduction to Optics

transverse focusing, dispersion, twiss etc.

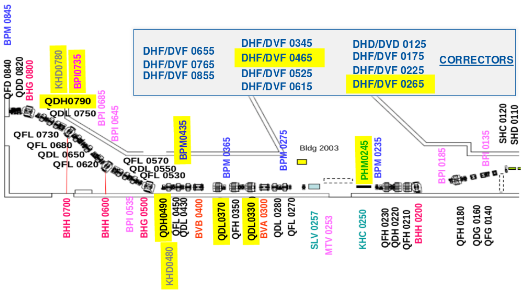
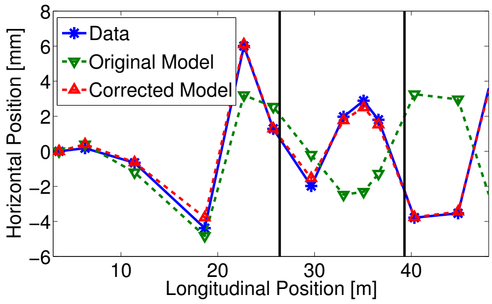


Figure 3.1: New TL2 lattice for PFF. Changes highlighted yellow.



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This is the introductory text.

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(Multi-sample)

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Impact for phase correlations.

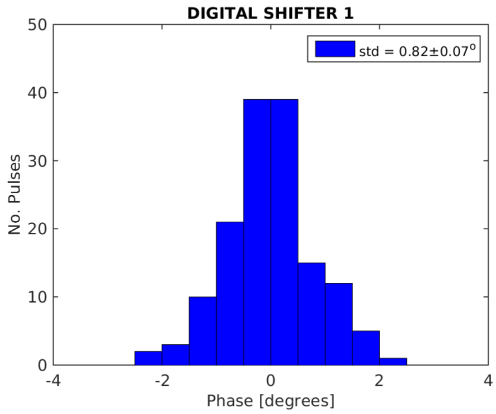


Figure 4.1: Dig shifter 1.

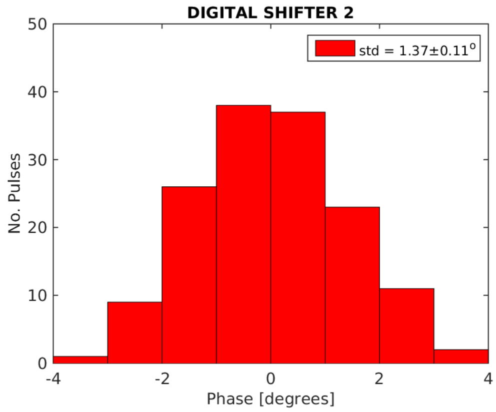


Figure 4.2: Dig shifter 2.

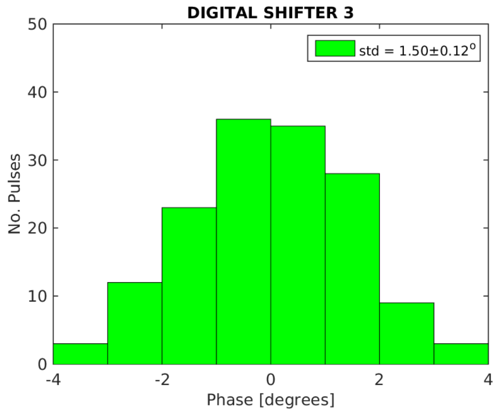


Figure 4.3: Dig shifter 3.

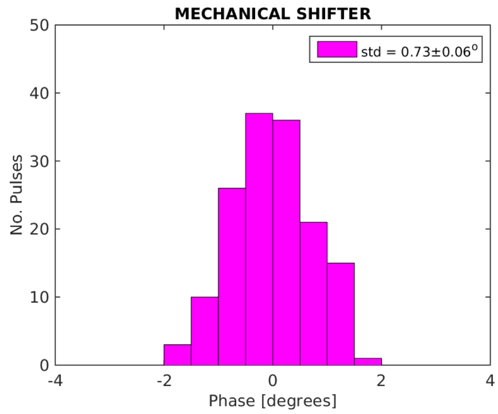
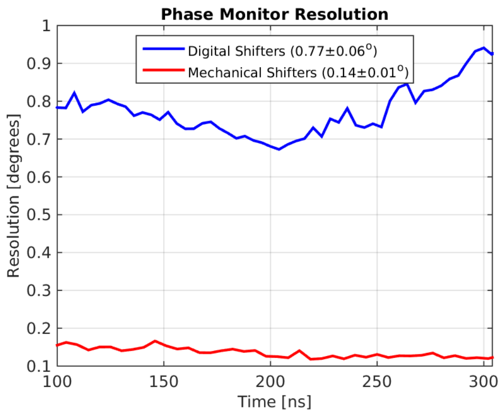


Figure 4.4: Mech shifter.



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This is the introductory text.

5.1 Characteristics of Uncorrected Phase Jitter

Injector feedbacks etc.

Definitions of different types of phase jitter.

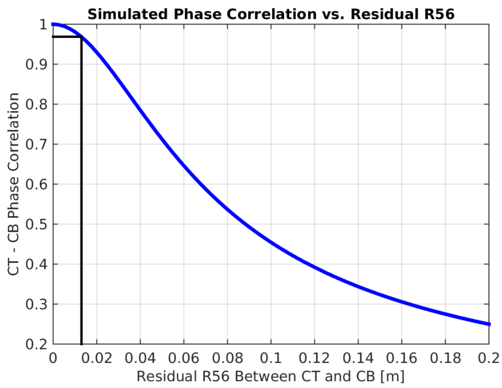

Figure 5.1: Phase correlation vs. residual R56 between monitors.

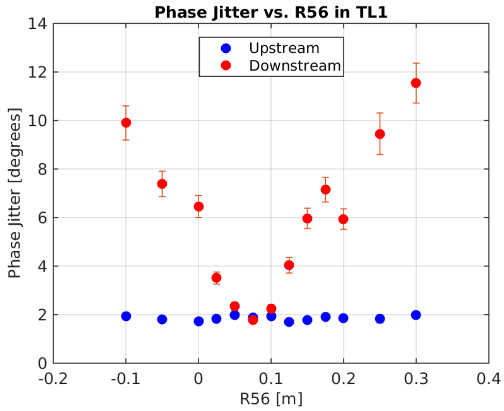

Figure 5.2: Phase jitter for different R56 whilst wiggling gun current.

5.2 First Order Energy Dependencies

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5.4.4 Effect on PFF Operation

5.5 Other Sources of Phase Jitter

5.5.1 Combiner Ring Septum

5.5.2 TL1 & Combiner Ring Bends

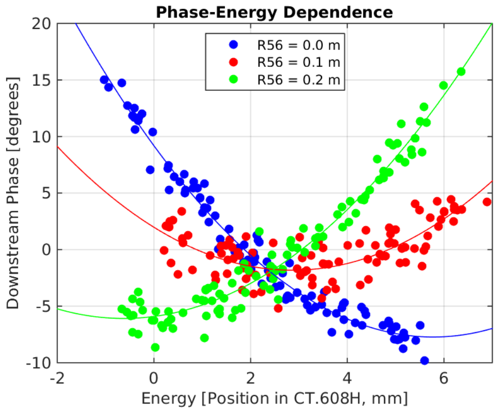

Figure 5.3: Phase vs. energy for different R56 in TL1.

CR Septum

TL1/CR Bends

5.6 Long Term Propagation Stability

Chapter 6

Setup and Commissioning of the PFF System

This is the introductory text.

6.1 Experimental Setup

6.1.1 Implementation of PFF Algorithm in Firmware

6.1.2 FONT5 and Amplifier Setup

6.1.3 SiS and CERN Control System Setup

6.2 ADC Droop Correction

The droop in the response of the FONT5 ADCs, as most clearly seen in the output of the diode channel in Figure 6.1 (although it also effects the mixer channel), is not an issue for the work the FONT group does at ATF2 where the signals are well approximated by delta functions separated by ~100 ns. Although the droop has been seen previously, its significance for the continuous microsecond length pulse at CTF3 had not been considered because of this.

The droop emerges as a result of the use of AC coupling on the ADC input transformers for electrical isolation. This involves using a capacitor, the current across which is dependent on dV/dt (V being voltage and t time), to remove the DC component from a signal. In particular for the diode channel, which should be a square wave, the output is increasingly well described by a DC signal on the flat top as you move away from the leading edge of the pulse, with the capacitor causing droop in the response as a result.

In the simplest case the droop should be well described by an exponential decay of the form $A\exp\left(-t/T\right)$. The droop makes it difficult to perform calibrations and measurements

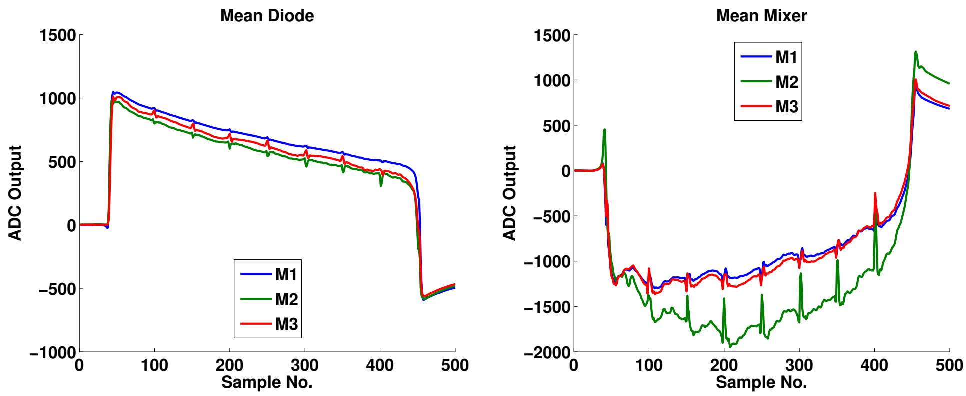

Figure 6.1: Mean diode and mixer output with no filter.

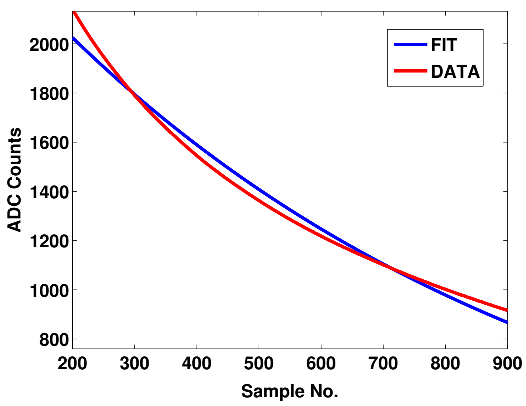

Figure 6.2: Attempted exponential fit to the ADC droop.

on the data and one way in which it could be removed in offline analysis is by determining the decay constants, T, for each of the ADCs on the FONT5 board. To avoid the influence of beam effects tests were done in Oxford using a generated 10 μs DC pulse.

Unfortunately, as can be seen in Figure 6.2 which shows an example of an exponential fit for one ADC, although the fits return good R^2 values it is clear that the slope of the exponential curve is not a good match for the slope of the data. This is perhaps not unexpected as the ferrite cores used in the transformers have many non-linear properties. In fact, by using a fit with two exponential terms it is possible to obtain a perfect match to the data but at this point the complexity of the fit would make any attempt to remove the droop in real beam data in this way spurious.

Instead, changes will be made to the currently in development FONT5a board hardware and firmware to greatly reduce the scale of the droop. Different transformers will be used to reduce the droop rate by up to a factor of fifty and in addition digital filtering will be implemented in firmware to smooth out and reduce the remaining droop component even further. It is expected that after these changes the droop will be small enough to not have a detrimental effect on the performance of the phase feedforward system.

6.3 Time Alignment of Signals

6.4 Kicker and Optics Performance Verification

6.4.1 Correction Range

Scan and comparison to expectation from optics.

6.4.2 Linearity

6.4.3 Orbit Closure

6.4.4 Shape

Shape of FF kick on BPMs vs. shape of upstream phase

6.5 Absolute Kicker Timing

6.5.1 Latency

6.5.2 Using Beam Pickup

6.5.3 Using BPMs

6.6 Relative Kicker Timing

6.7 Definition of Zero Phase

6.8 Correction Bandwidth

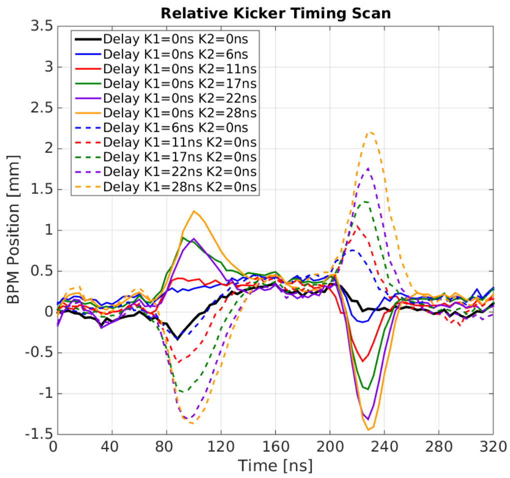

Figure 6.3: Traces relative timing scan.

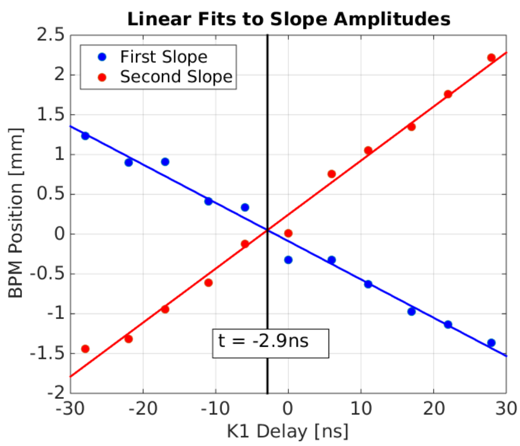

Figure 6.4: Relative timing scan - fit to rising/falling edge.

Chapter 7

Feedforward Results

This is the introductory text.

7.1 Gain Scans

7.2 Lowest Achieved Phase Jitter

The results presented in this section show the best downstream phase jitter currently achieved at CTF3 with the PFF correction. The dataset was taken on Friday 20th November 2015 at 15:38 as one of a sequence of short measurements fine-tuning the gain around the optimal value. It comprises 172 pulses taken in interleaved mode, with the correction applied to the 86 even indexed pulses and no correction applied to the remaining 86 odd indexed pulses. Naturally, this dataset was taken during the best beam conditions currently achieved at CTF3 in terms of phase propagation, taken just after a series of R56 and beam energy optimisations using the same methods discussed in Chapter 5.

Distribution of points at around 0.5 degrees downstream.

Residual uncorrelated phase (mean and along pulse).

7.3 Simulated PFF Results

7.4 Correction on Longer Timescales

7.5 Correction with Additional Jitter Source

At CLIC the PFF system will be required to reduce the initial phase jitter by an order of magnitude, from 2 degrees to 0.2 degrees [REF]. With the initial phase jitter of typically 0.8 degrees at CTF3 it is not possible to demonstrate more than a factor 4 reduction in the jitter

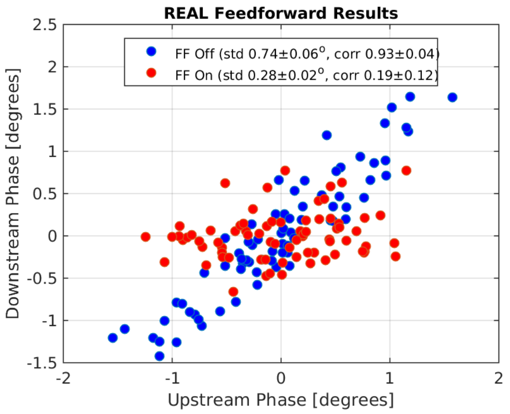

Figure 7.1: Mean phase.

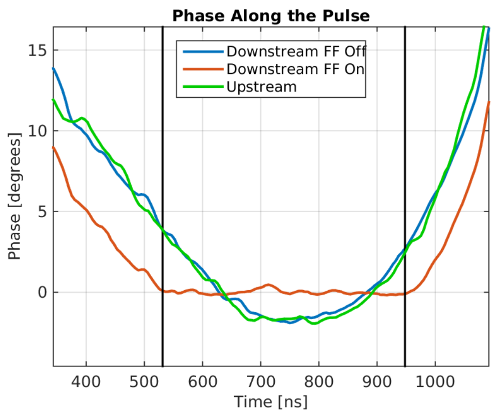

Figure 7.2: Mean phase along.

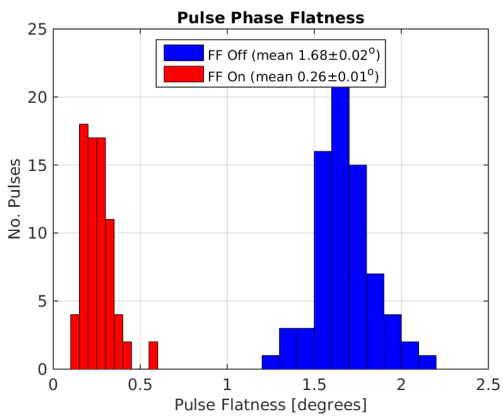

Figure 7.3: Flatness.

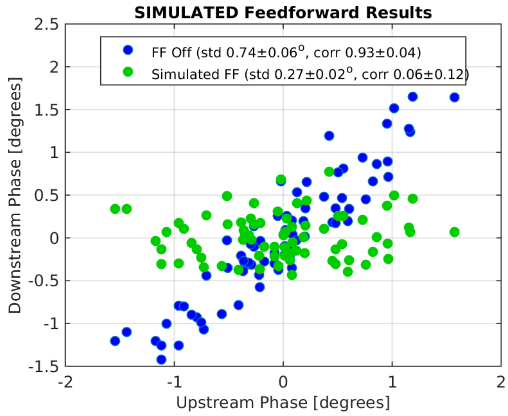

Figure 7.4: Simulated PFF.

using the PFF prototype due to hardware limitations, more specifically due to the achieved phase monitor resolution of 0.14 degrees which limits the theoretical best possible correction to 0.2 degrees 4.6. A secondary goal of the PFF prototype in addition to achieving the baseline goal of 0.2 degrees phase jitter is to demonstrate the factor 10 reduction in jitter relevant to CLIC. In order to do this additional sources of phase jitter must be added.

Clearly, the additional source must be prior to the upstream phase monitor in order to add an additional jitter component that is present in both the upstream and downstream monitors. The correlation between the resulting upstream and downstream phase must be 99.5% in order for a factor 10 reduction in jitter to be possible (see Section 2.5.1). Two different methods to achieve this have been attempted — firstly by varying the phases of all the klystrons in the injector and secondly by using the non-zero R56 stretching chicane (see Figure 2.1) at the end of the CTF linac in order to intentionally add an energy component to the upstream phase (which propagates downstream).

7.6 Slow Correction

As the PFF system has only a small range of $\pm 6^o$, a secondary "slow phase feedback" or "slow correction" has also been implemented at CTF3 to be able to remove larger drifts or static offsets in the downstream phase. In principle this slow correction can be used in conjunction with the PFF system to maximise its performance by keeping the mean uncorrected phase well-centred (zeroed) within its $\pm 6^o$ range so that the full power of the PFF amplifiers can be used to correct the fast pulse-to-pulse and intra-pulse phase jitter. If the beam phase were to drift away by 15^o, for example, the calculated PFF correction would saturate the amplifier across the full pulse length to give the maximal shift of 6^o. In this case the drift would be partially removed downstream but the PFF system would no longer have any effect on the phase jitter (as the output voltage to the kickers is constant in saturation rather than varying with the phase).

The design and results from the slow correction are discussed in this section. To date its main use has been to verify the ability to shift the beam phase in the TL2 chicane in early-2014 prior to the kicker amplifiers being available to commission the PFF system itself. The slow phase feedback has not yet been used in parallel with the PFF system thus the results shown here are primarily a proof of principle. As PFF attempts have so far been predominantly taken in short datasets of up to a few hundred pulses any large drifts that arise can be manually removed between datasets, either by changing the correction setup (e.g. by changing the phase monitor phase shifters to re-zero the phase) or by re-establishing the previous beam conditions. The slow correction will however be an important tool for future attempts to demonstrate CLIC-level phase stability on time scales longer than a few minutes at CTF3.

7.6.1 Implementation

Ratio of corrector strengths for orbit closure.

7.6.2 Results

Chapter 8

Conclusions

This is the introductory text.

8.1 Summary

8.2 Future Work