Final Report for the Timing and Phase Monitoring (TPMON) Task.

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Abstract

The deliverables of TPMON task within the "Diagnostics" work package (DIAG) have been achieved, and are presented. The main results are described and key additional references are provided.

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1 Introduction

The Compact Linear Collider requires a very tight synchronisation between its main and drive beams.[1] As devices in the beam generation scheme are likely to introduce timing errors far exceeding the tolerance of the machine, a measurement and correction of those errors are necessary. The TPMON work package included a task for designing a prototype phase detector that could be used in such a timing correction scheme. The proposed scheme for CLIC is to measure the outgoing main beam with respect to a local oscillator, and then the drive beam before the turn around, and make a correction for the difference between the two measurements. The local nature of the measurements means that a global high precision reference is not required. Putting it another way, the outgoing main beam is used as a global reference with respect to which the phase of the drive beam is measured.

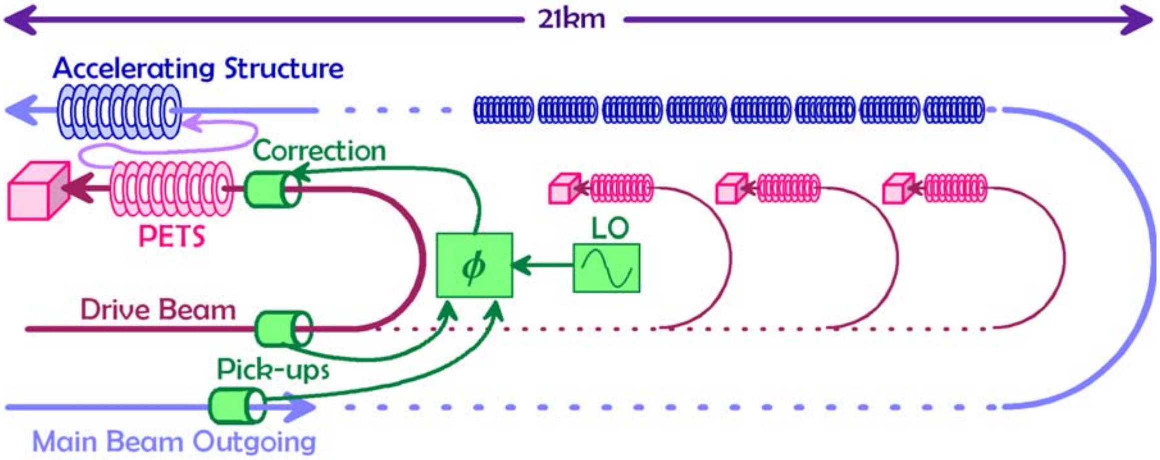

Figure 1: Phase detection scheme for CLIC. The outgoing main beam and the drive beam are both measured with respect to a local oscillator. These measurements the provide a signal for the correction prior to the Power Extraction and Transfer Structure.

Crystal oscillators with small enough jitter are readily available commercially. This task is thus concentrated on the development of a prototype for the phase detection electronics.

For a successful high luminosity machine it is required that phase errors between the two beams be kept below 0.1 degrees at the point of energy transfer. The measurement and correction of errors must be accurate up to the bandwidth of the structures, expected to be in the 50-100MHz range. The combination of precision and bandwidth requirements makes this a challenging task on the electronics side. In particular, despite great improvements in Analogue to Digital converters there is at this time no device on the market that could accomplish such a measurement. It was required to design an analogue system that would yield high resolution phase information at baseband. By making a local comparison between the outgoing main beam and, 140µs later, the drive beam before the turnaround, we obliterate the need for a high stability global reference. Rather, a local oscillator keeps time between the passing of the two beams. Low jitter crystal oscillators capable of keeping time to within 3fs for such a period are available commercially. For long term stability, phase locking to a global low frequency timing signal or GPS is foreseen.

2 IF detectors

The selection of devices for the Intermediary Frequency phase detection were crucial.[4,5] A number of devices where considered, but in particular mixers and active multipliers where investigated. The important criteria where amplitude to phase conversion at baseband and noise performance.

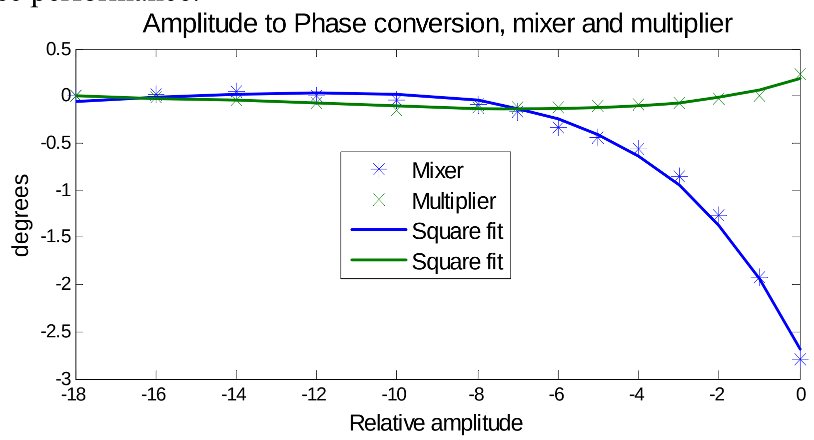

Figure 2: Amplitude to phase conversion when mixing to baseband in a phase detector. The better performance of the multiplier indicated its suitability to the task.

The multiplier performed better on the amplitude dependence, and worse on the noise. Both types of devises would have to be operated in the flat region of amplitude to phase curve, where noise was prohibitively large for the target resolution. The signal to noise ratio could be improved by utilizing multiple detectors and the analogues summation of their outputs. The signal to noise ratio improves by the square root of the number of devices for thermal noise.

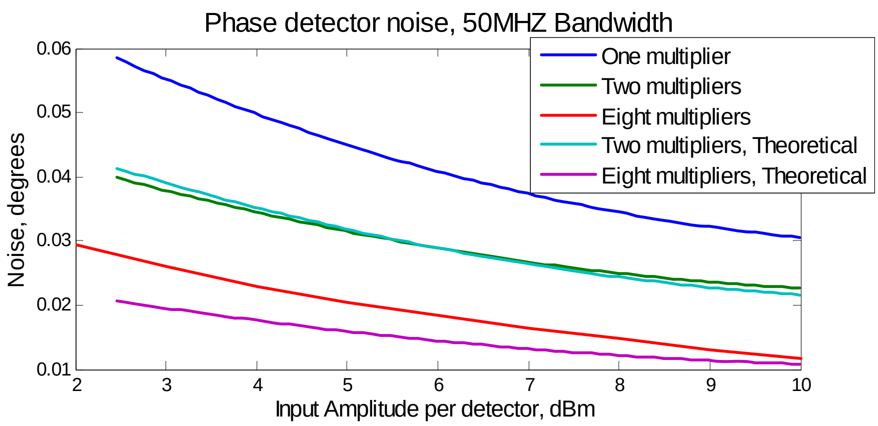

Figure 3: Improved signal to noise ratio resulting from the use of arrays of devices

The experimental data from device summation closely follows the predicted behaviour. The analogue multiplier, AD835AR, was selected as it was convenient to work with and performed well. As amplitude information was also needed, the produced PCB utilized summed arrays for those devices, AD8318ACPZ-WP, as well.

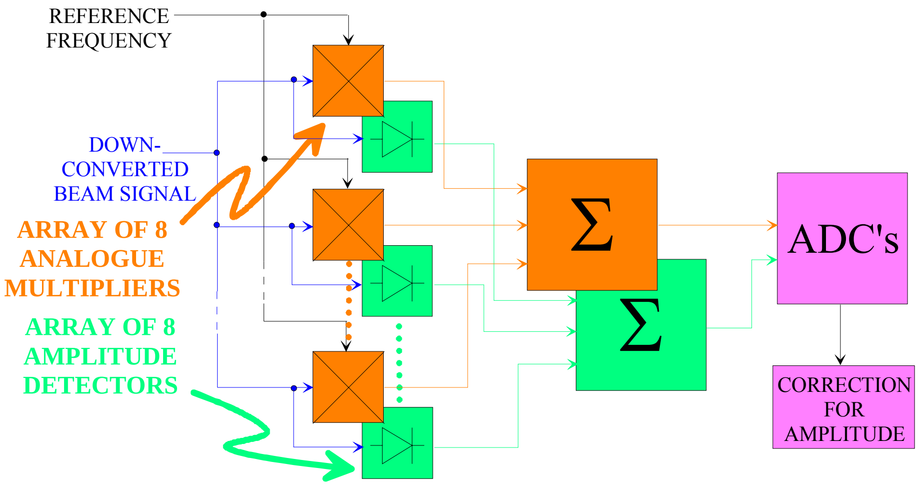

Figure 4: Arrays of multipliers and amplitude detectors

3 Local Oscillator generation and down-mixing

The system consists of a 30GHz local oscillator generation scheme from a lower frequency signal, and a down-mixing stage to the Intermediary Frequency of 750MHz. For the upconversion from the CTF3 timing signal at 3GHz to 30GHz a couple of edge compression and comb generators where investigated, and the one having better noise performance selected.

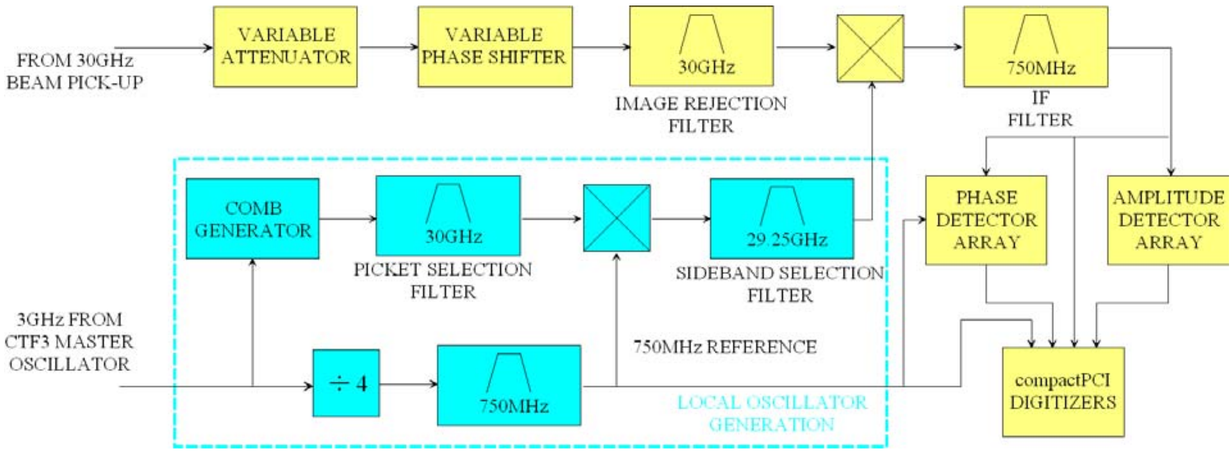

Figure 5: LO generation, down-mixing and detection

4 Tests with beam

Tests with beam were done in CTF3.[2,3] In order to demonstrate the extraordinary resolution of the system, two systems where built to perform simultaneous measurements of the beam, and the results compared to each other. This was required since the jitter of the CTF3 beam vastly exceeds the specifications of the system. These tests demonstrated the very low noise performance required for the task, the results coming in well below the 10fs required at 30GHz. The 3GHz timing reference signal and the RF pick-up were common to both systems, whereas the other parts: LO generation, down-conversion, and IF detection where duplicated. This allowed for the resolution of the detector to be established with simultaneous duplicate measurements of one beam. This was required as no hyper accurate system which could be used as a reference to establish sufficient resolution exists. Indeed, this lack necessitated the development of the prototype in the first place. The setup closely mimics the final application where a measurement of two beams would occur with a 140μs delay, thus ensuring discorrelation of the parts that would be common (LO generation) in the final application.

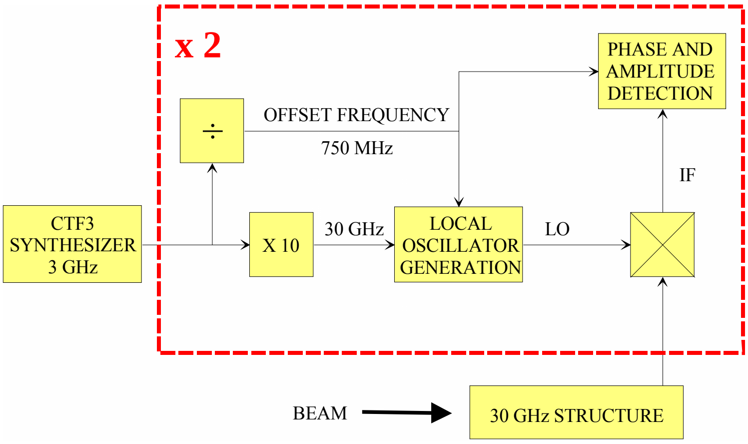

Figure 6: CTF3 test setup. Two systems are compared to each other.

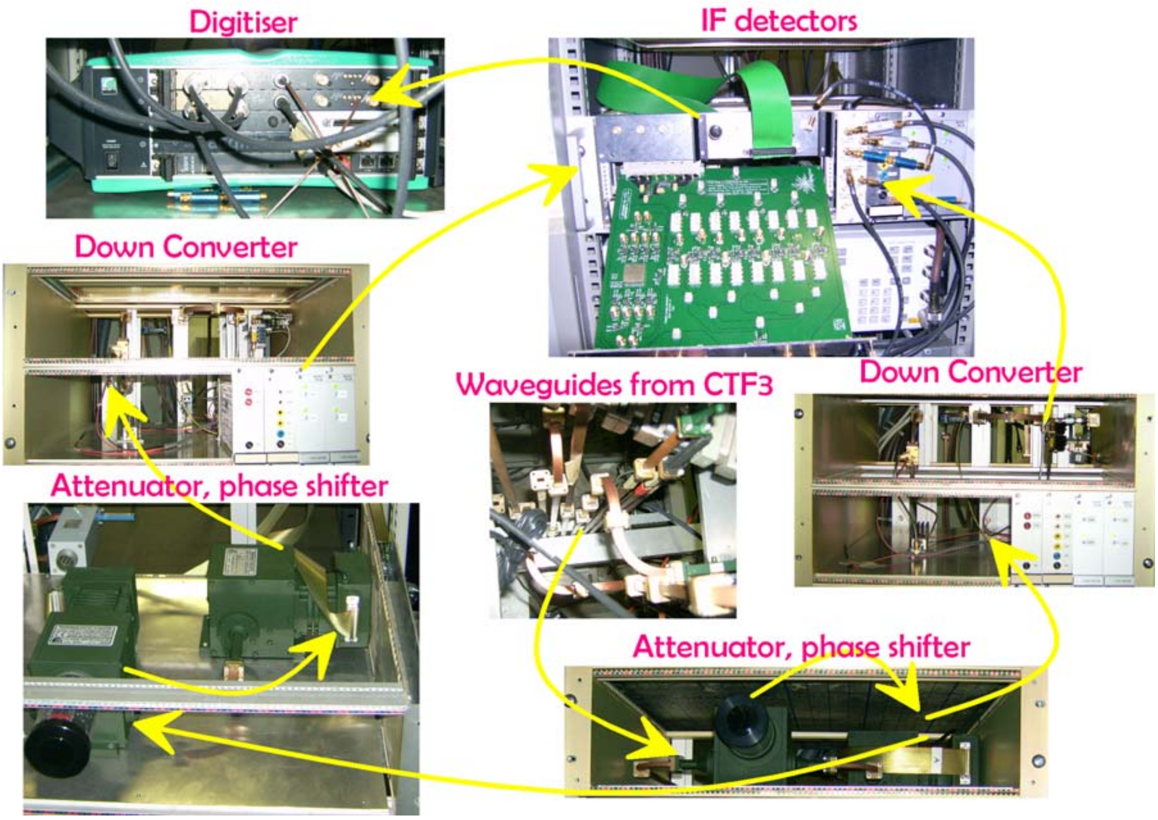

Figure 7: Installation in the CTF3 klystron gallery

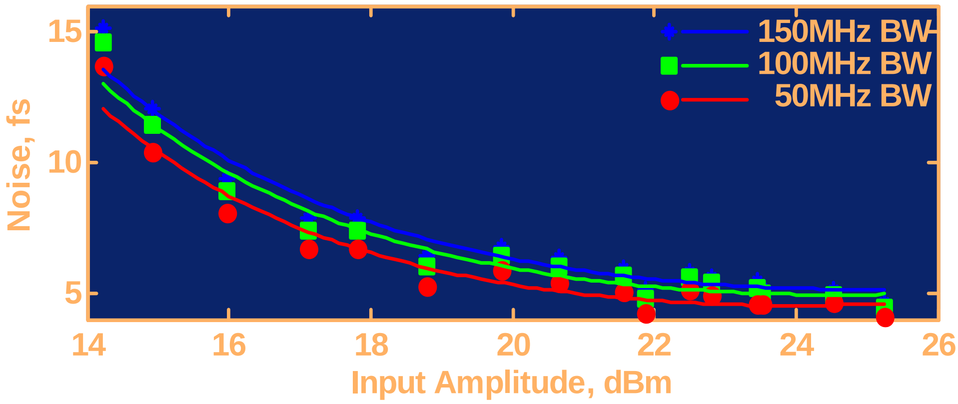

Figure 8: CTF3 results, noise in femtoseconds of the detection hardware, including LO generation, down-mixing and IF detection. The beam pickup and the timing reference for LO generation were common to the system.

5 Conclusions

The TPMON task has thus succeeded in its main objective of constructing a prototype providing a timing measurement with a resolution below 10 femtoseconds.

References

[1] D. Schulte, E. J. N. Wilson and F. Zimmermann, "The Impact of Longitudinal Drive Beam Jitter on the CLIC Luminosity", CLIC Note 598, CERN.

[2] A. Andersson and J.P.H. Sladen, "RF-based electron beam timing measurement with sub-10fs resolution", Electronics Letters, vol. 44, No 5, 2008, p. 341-343 (EUROTeV-Report-2008-015)

[3] A. Andersson and J.P.H. Sladen, "First tests of a precision beam phase measurement system in CTF3", Proc. PAC07, 25-29 June 2007, Albuquerque, New Mexico, USA, pp. 302-304
(EUROTeV-Report-2007-049)

[4] A. Andersson, J. P. H. Sladen, "Precision Beam Timing Measurement System for CLCI Synchronization", EUROTeV-Report-2006-065

[5] A. Andersson, J. P. H. Sladen, "Aims and initial progress of TPMON task", EUROTeV-Report-2006-005

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