Demonstration of CLIC Level Phase Stability Using a Low Latency Drive Beam Phase Feedforward System at CTF3

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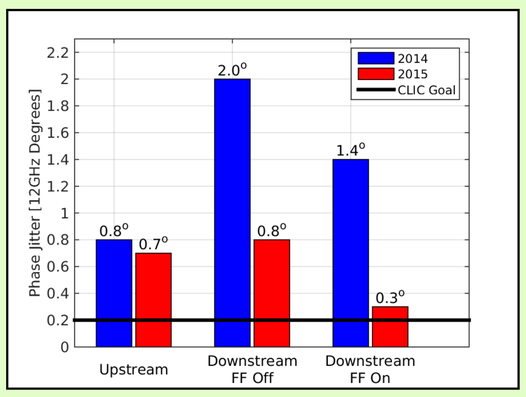
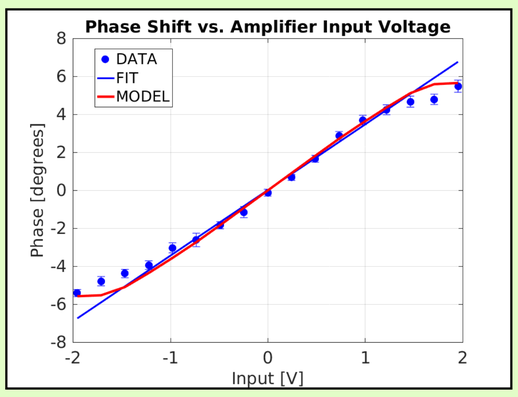
Improvements in 2015

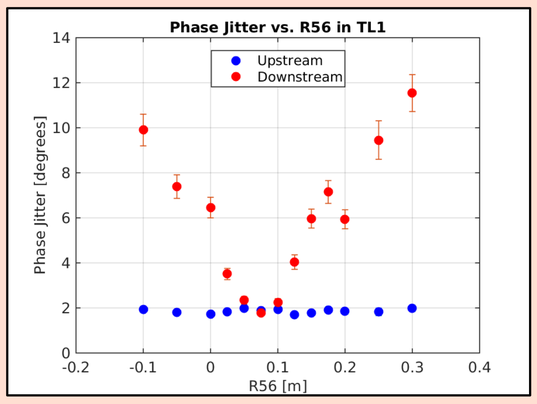
- ***2014:*** First tests demonstrated ***30%*** reduction in downstream phase jitter: from ***2.0 degrees to 1.4 degrees*** (left) [8].
- Achieved ***five times lower phase jitter in 2015*** thanks to:
  - Phase monitor resolution improved to ***0.14 degrees*** (0.2 degree correction now theoretically possible)..
  - New amplifier with double output voltage, doubles correction range to ±***5.5 degrees*** (right).
  - Correlation between upstream and downstream phase increased from ***50% to 96%*** (see Phase Propagation).

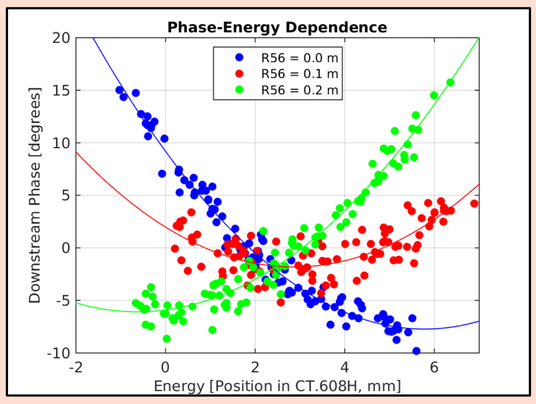




Phase Propagation

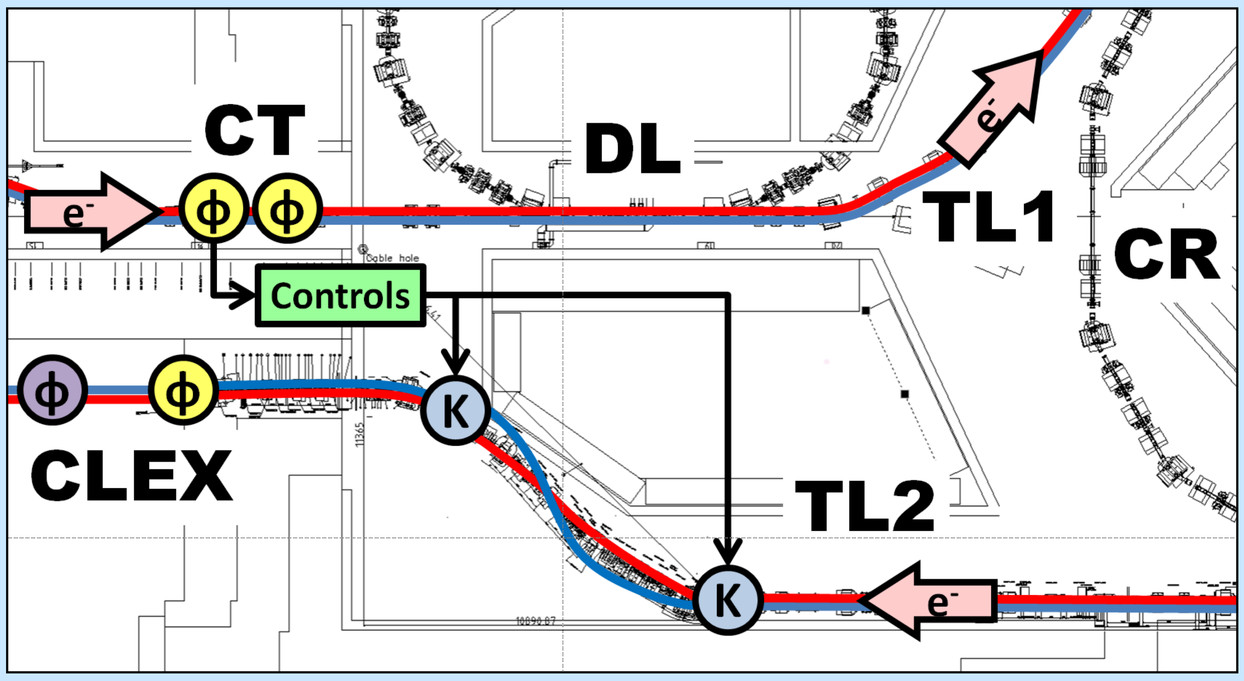
- TL2 has non-zero ***R56***: introduces additional ***energy component*** in downstream (CLEX) phase. Limited upstream-downstream correlation to 50% in 2014.
- By ***adding positive R56 in TL1*** to compensate for negative R56 in TL2 the downstream phase jitter is reduced to the upstream phase jitter (left).
- Upstream-downstream phase correlation increased to up to ***96%*** (***97%*** needed to demonstrate 0.2 degrees correction [8]).
- Also observe ***higher order*** energy dependencies (right).





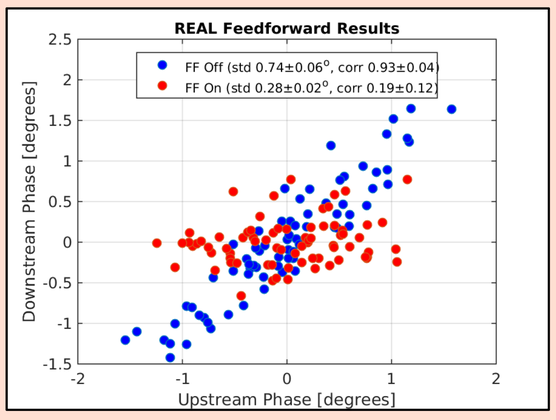
System Overview

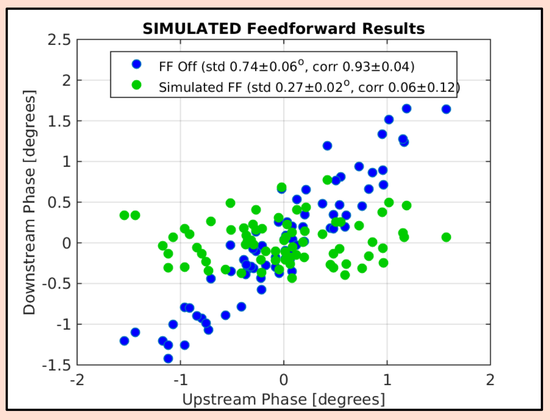
- A ***phase feedforward system*** with ***bandwidth above 17.5 MHz*** [3] is required to reduce the CLIC drive beam phase jitter to ***0.2 degrees at 12 GHz*** (50 fs) [1,2].
- A prototype of this system has been installed at the CLIC test facility ***CTF3*** at CERN to prove its feasibility.
- Hardware:
  3 ***Phase monitors*** and 2 strip line ***kickers*** (INFN/LNF Frascati) [4,5,7].
  Kicker ***amplifiers*** and ***digital processor*** (JAI, Oxford University) [6,7].



- The phase is corrected using two kickers in the TL2 chicane:
  Bunches arriving late are deflected on to ***shorter orbits.***
  Bunches arriving early are deflected on to to ***longer orbits.***
- Measure upstream phase (CT), calculate and output voltage to the kickers in time with the arrival of the same beam pulse downstream (TL2) (***feedforward*** not feedback).
- System ***latency*** less than ***380 ns*** time of flight between CT and TL2.

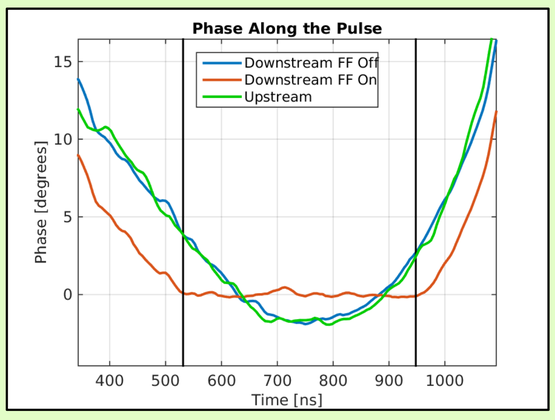
Lowest Achieved Mean Phase Jitter

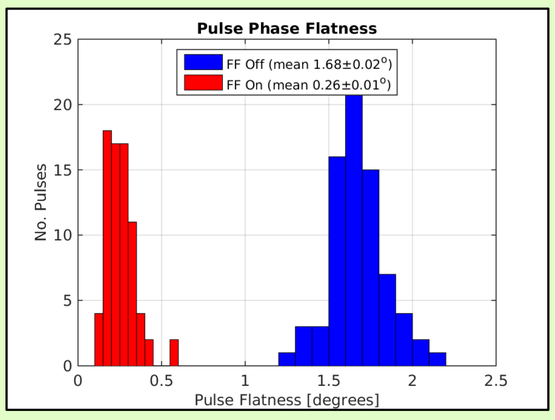




- Initial conditions: ***0.74*** ± ***0.06 degrees*** downstream jitter with ***93%*** upstream-downstream phase correlation (left).
- Phase feedforward system acts to ***remove all correlation*** between upstream and downstream phase.
- Corrected downstream phase jitter is ***0.28*** ± ***0.02 degrees***. Close to CLIC requirements (left).
- ***Simulated*** effect of correction in these conditions gives identical results – gives confidence that system setup is optimal and well understood (right).

Variations Along Beam Pulse





- CTF3 has a ***1.2 microsecond*** beam pulse with large ***40 degrees*** phase sag due to the RF pulse compression system used. CLIC pulse will be ***240 ns*** with no phase sag.
- Phase feedforward system is ***high bandwidth*** – removes not only mean pulse phase jitter but also variations along the pulse.
- Phase sag in the indicated region is almost perfectly ***flattened*** (left). Deviation about the mean is reduced from ***1.68*** ± ***0.02 to 0.26*** ± ***0.01 degrees***.
- Amplifier is ***saturated*** outside the indicated region, thus phase sag remains.

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., MOPWI001, IPAC15.