Center for Accelerator Science and Engineering

DIRECTLY DRIVING GHZ-RANGE POWER AMPLIFIERS WITH RF SYSTEMS-ON-CHIP FOR THE SLS 2.0 LONGITUDINAL MULTI-BUNCH FEEDBACK (MBFB)

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Abstract

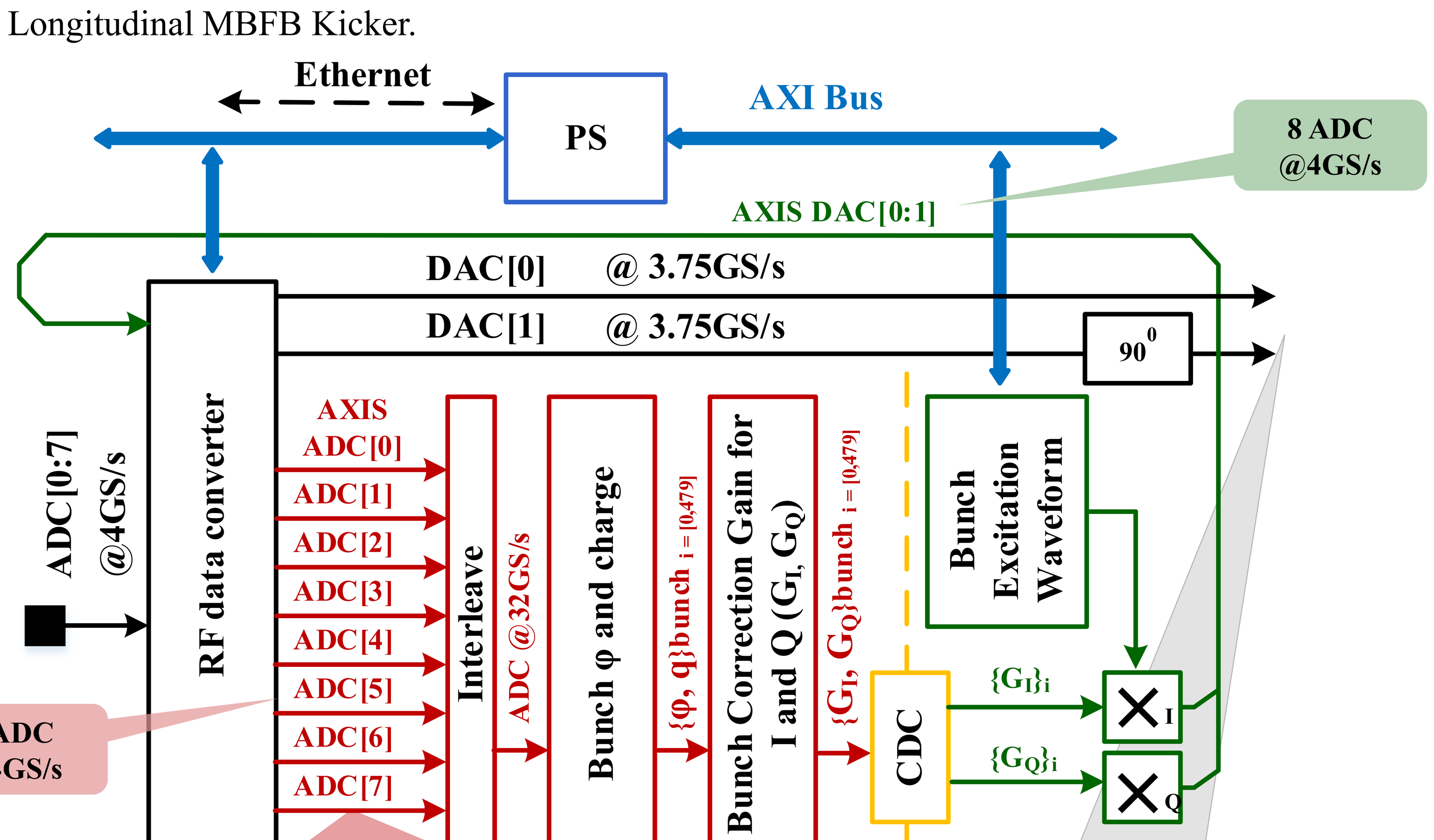
In the past, the longitudinal multibunch feedback (MBFB) at the Swiss Light Source (SLS) storage ring has used an analog upconverter to translate the output signal of a 500 MSample/s DAC to the 1.25-1.5 GHz operation frequency range of the longitudinal MBFB kicker and its power amplifier. For SLS 2.0, we have investigated the possibility of driving the power amplifier of a newly de-signed kicker (operating at 1.75-2 GHz) directly with the multi-GHz / multi-GSample/s DACs of an RF System-on-Chip (RFSoC). We present test results with the new SLS 2.0 kicker magnet and its power amplifier. Related methods for RFSoC-based bunch-to-bunch crosstalk compensation in the presence of transient beam loading and 200ps range arrival time variations along the bunch train are also presented. Moreover, the latest status and plans for our MBFB firmware/software implementation on an RFSoC will be given.

SLS 2.0 / Motivation

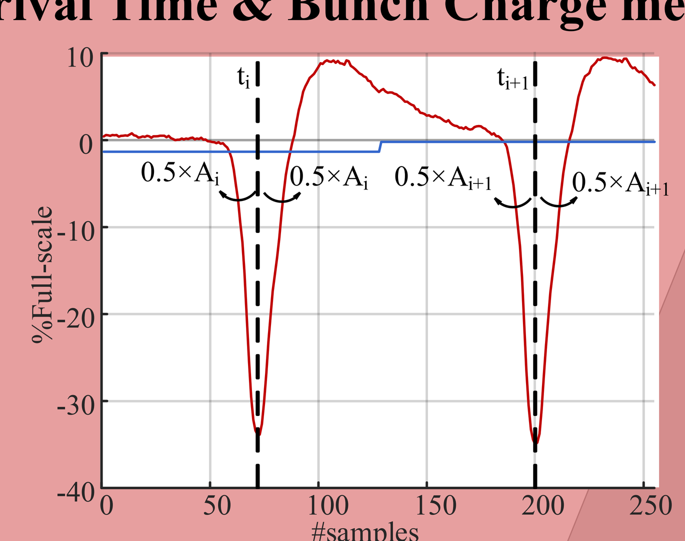
- Replacement of the SLS storage ring, providing up to 60-fold higher brightness for hard X-rays: **1st SLS 2.0 beam is planned for 2025**.
- Modernization of aging systems, including the longitudinal Multi-bunch (MBFB).
  - Replace VME-based system with analog up/down converting mixers by a solution with direct sampling of the BMP broad-band signals and direct driving of the Kicker Amplifiers
- AMD RFSoC as platform to implement the Longitudinal MBFB SLS 2.0.

Longitudinal MBFB Firmware

- The firmware embedded in the RFSoC computes individually the charge and arrival time of each bunch by processing the interleaved ADC samples. The result of the arrival time for each bunch are then fed into the MBFB feedback algorithm, generating the correction signal which drives the Longitudinal MBFB Kicker.

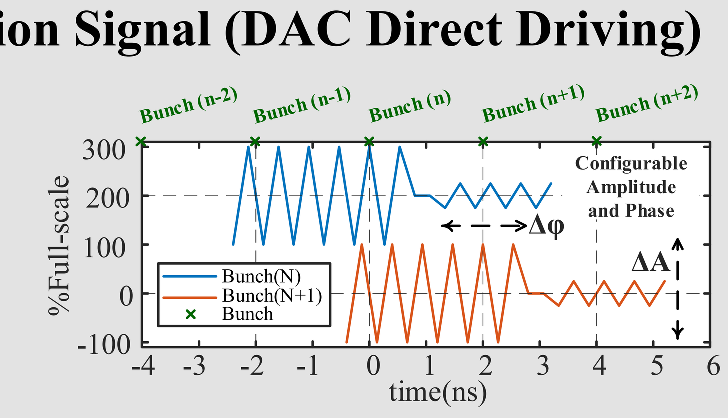


Bunch Arrival Time & Bunch Charge measurement



- Area A_i between the sum signal (red) and the dynamic baseline (blue) is proportional to the bunch charge, and time t_i which splits A_i in half is an estimate for bunch arrival time.

Correction Signal (DAC Direct Driving)

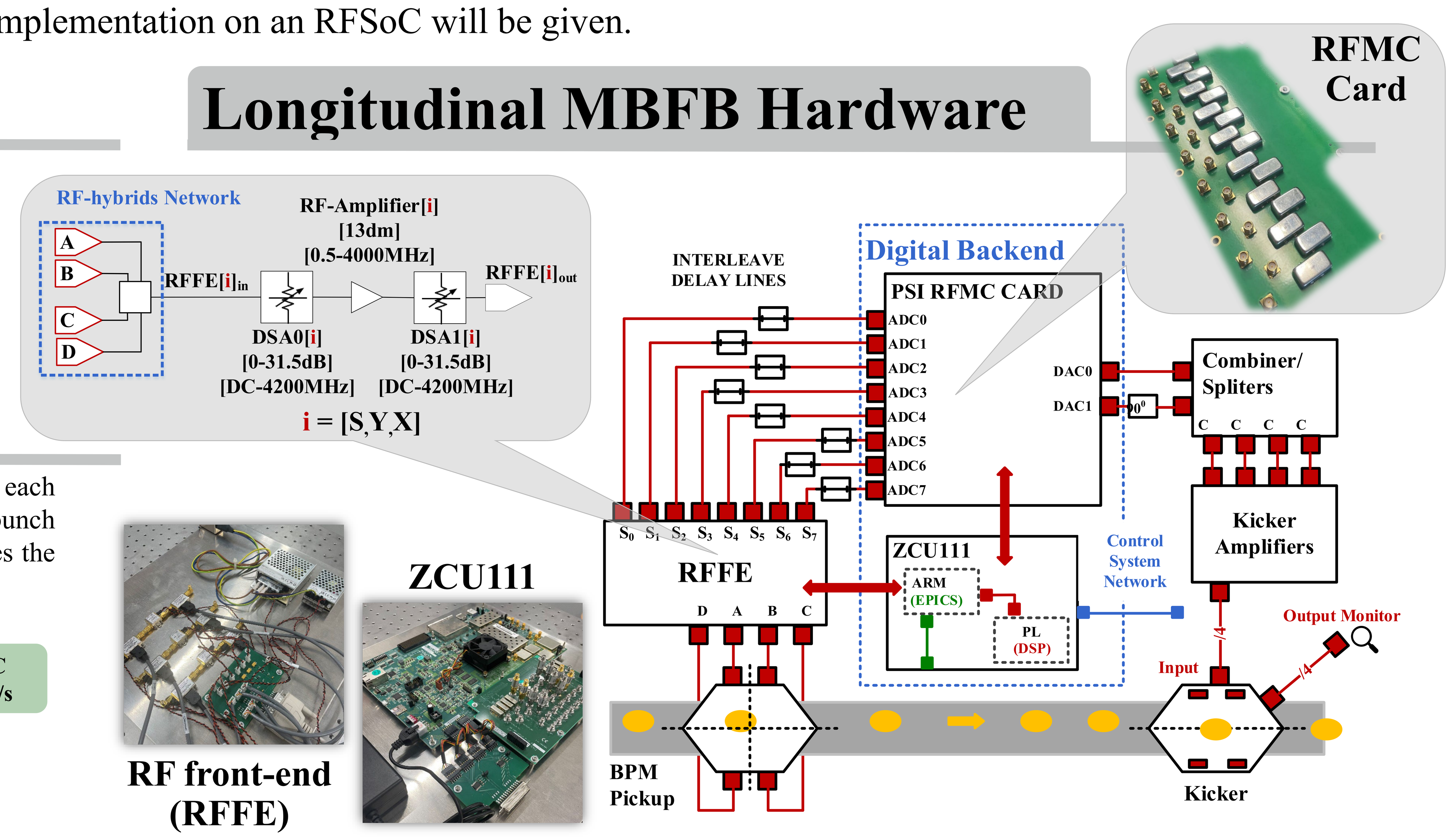


- The FW on the RFSoC generates an individual waveform for each bunch N, with N ranging from 0 to 479, to maximize the excitation of a single bunch and minimize the excitation of the adjacent bunches. The excitation waveforms for all bunches are superposed, on the digital domain, generating the overall DAC output signals.

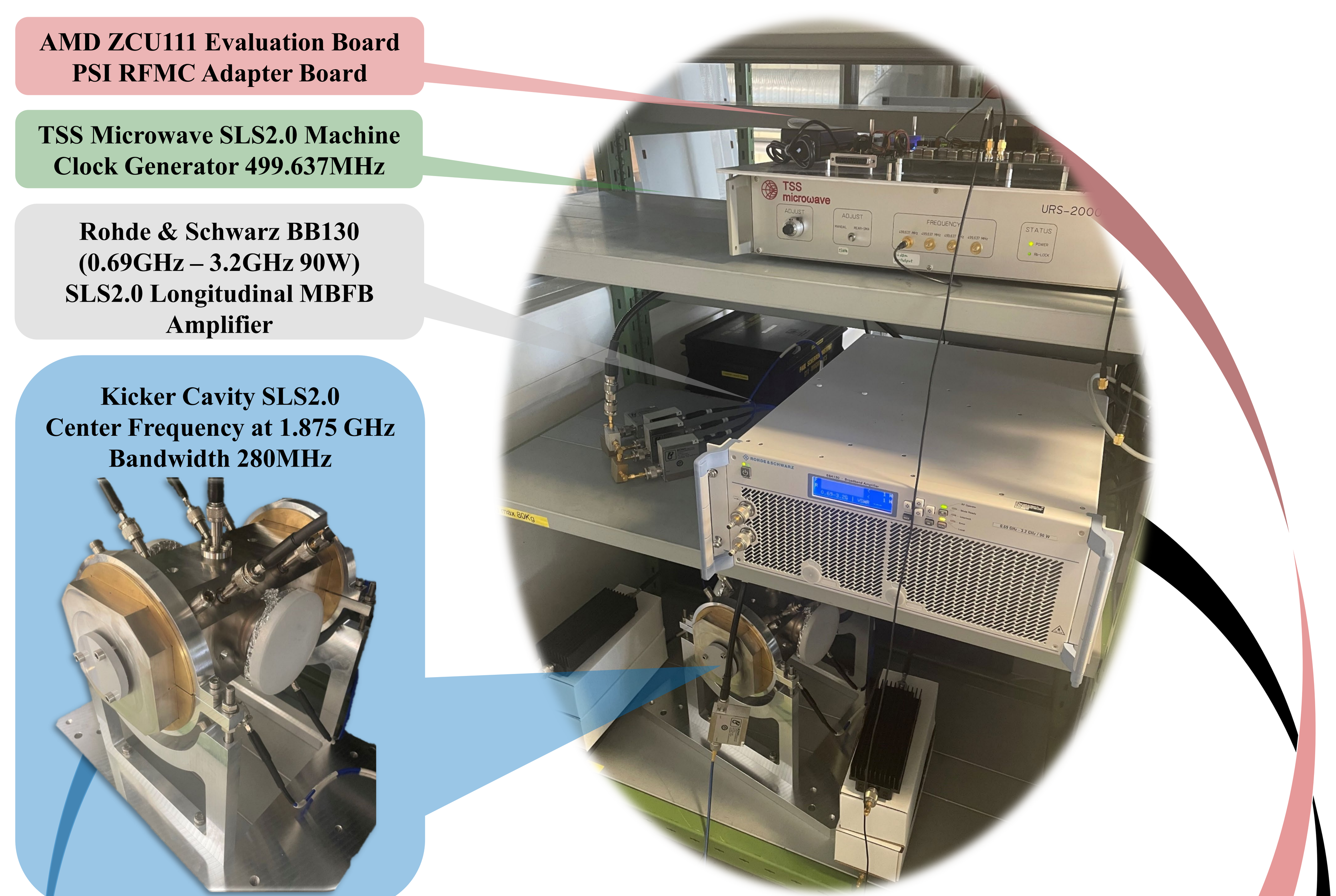
Summary and Outlook

- We have successfully implemented and tested the direct synthesis of kicker power amplifier drive signals for the SLS 2.0 MBFB on an RFSoC platform. Our new system enables automatic compensation for transient beam loading and associated systematic beam arrival time variations along the bunch train for the kicker drive signals.
- Next step consists of implementing the bunch arrival time and bunch charge algorithm with lower latency in the RFSoC programmable logic. So far, we have demonstrated the algorithm using directly sampled broad-band BPM sum signals running on the RFSoC CPU (C++ program).
- Test/Commissioning the Longitudinal MBFB in SLS 2.0.

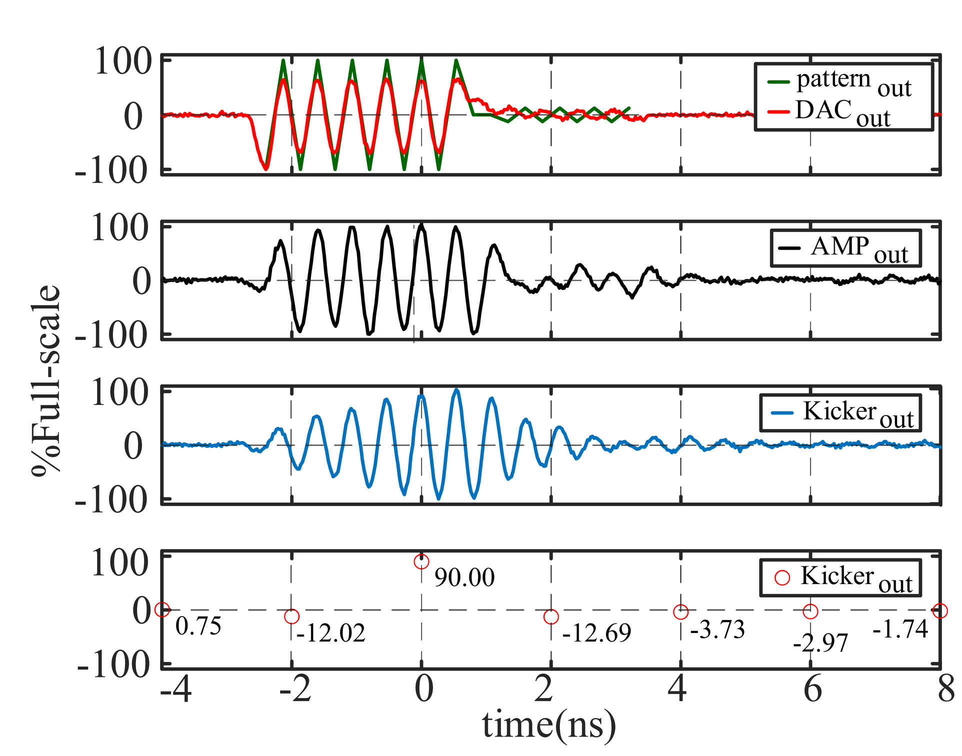
Longitudinal MBFB Hardware



Measurement Setup



Measurement Results



- The waveform pattern, for a single bunch, driving the DAC (green) and the measurement of the DAC output signal (red). The output signal of the longitudinal power amplifier is in black. The blue curve shows the measurement at the longitudinal kicker cavity field probe, and at the bottom, we highlight the effective kick amplitude at the target bunch N and the neighboring bunches.
- The measured response at the field probe of the kicker cavity provides an effective kicking field at the target bunch N of 90% of full scale. With our present DAC pattern, the undesired kicks of adjacent bunches could be reduced to approximately 12% for the bunches N±1 and <4% for the remaining. A further reduction of these undesired kicks of adjacent bunches is feasible and foreseen.