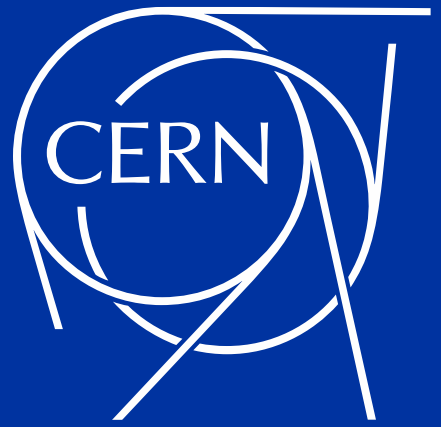

MicroTCA Hardware Upgrade for the 200 MHz Cavity Controller in the CERN Proton Synchrotron

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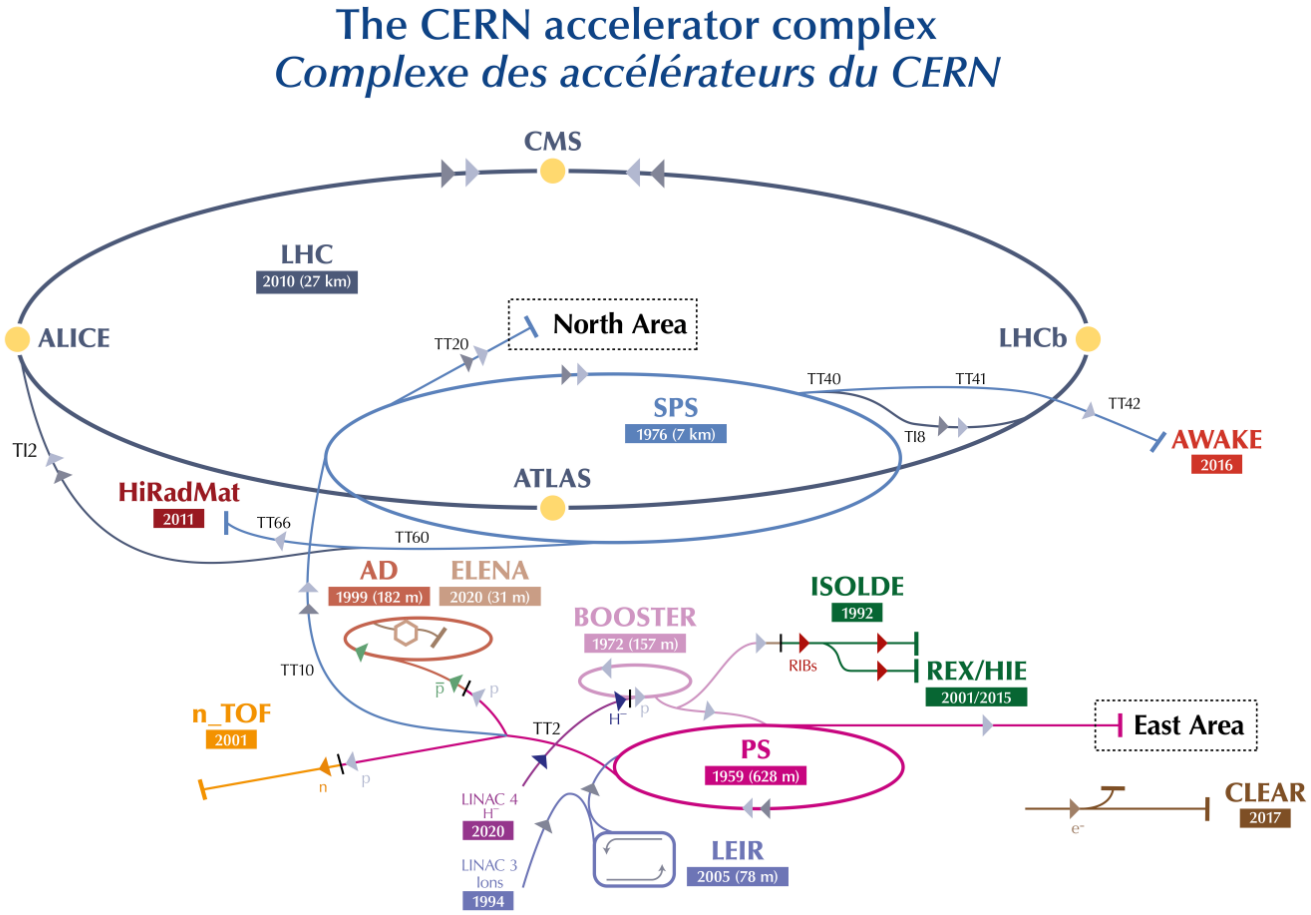
CERN Proton Synchrotron (PS)

- **PS provides hadron beam to:**
  - Downstream accelerators
  - Dedicated experimental areas
  - Anti-proton production

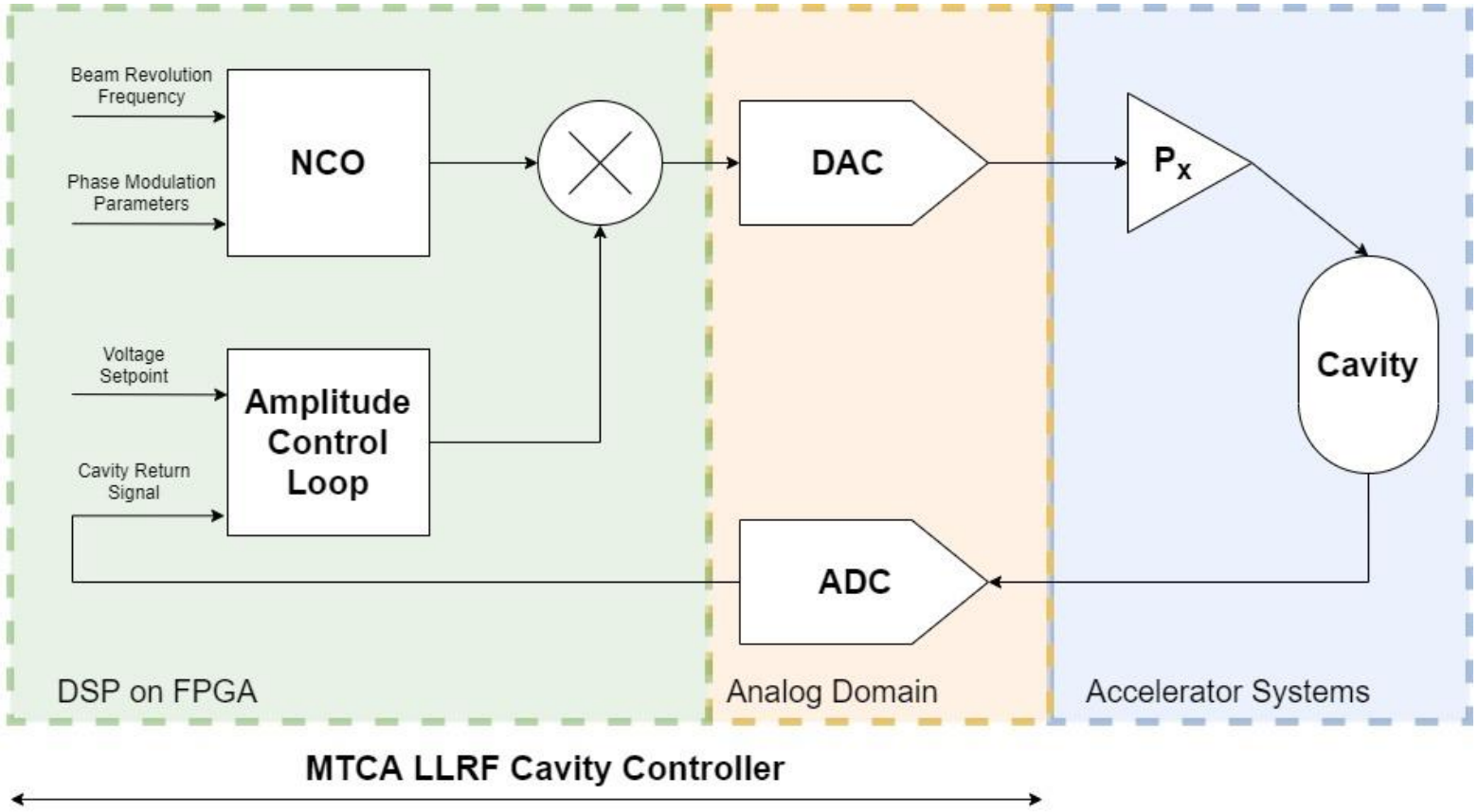


200MHz Cavities

- **6 Cavities for longitudinal blow-up**
  - Deliver stable beam to experiments and accelerators
  - Bunching for the PS-to-SPS beam transfer
- **Low-level RF system upgraded during LS2**
  - Implementation using MTCA.4
  - Follow SPS configuration
    - Reutilize firmware blocks from SPS
    - Share hardware spares

System Overview

- **Cavity controller to drive the cavities**
- **RF signal synchronous with:**
  - Beam
  - SPS cavities
- **Phase modulation for longitudinal blow-up**
- **Arbitrary voltage waveform**



Cavity Controller Hardware (1/2)

- **SIS8300KU boards from Struck**
  - $125 MS/s$ 16-bit ADCs
    - Direct sampling of return signal
  - DSP processing on FPGA
  - DAC to generate drive signal
  - White Rabbit SFP for clocks synchronization (https://white-rabbit.web.cern.ch/)

Image from:
https://www.struck.de/sis8300-ku.html

Cavity Controller Hardware (2/2)

- **DS8VM1 RTM module**
  - Direct sampling
  - Vector modulator for frequency up conversion
  - Clocks and LO from RF backplane
    - Clock distribution to SIS8300
  - External interlock

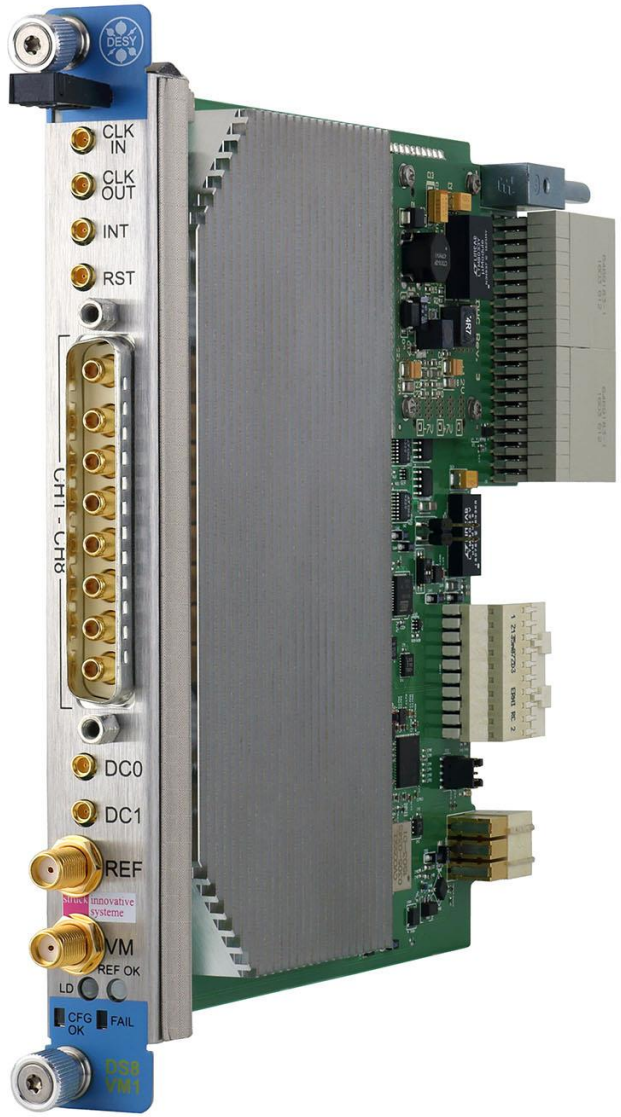


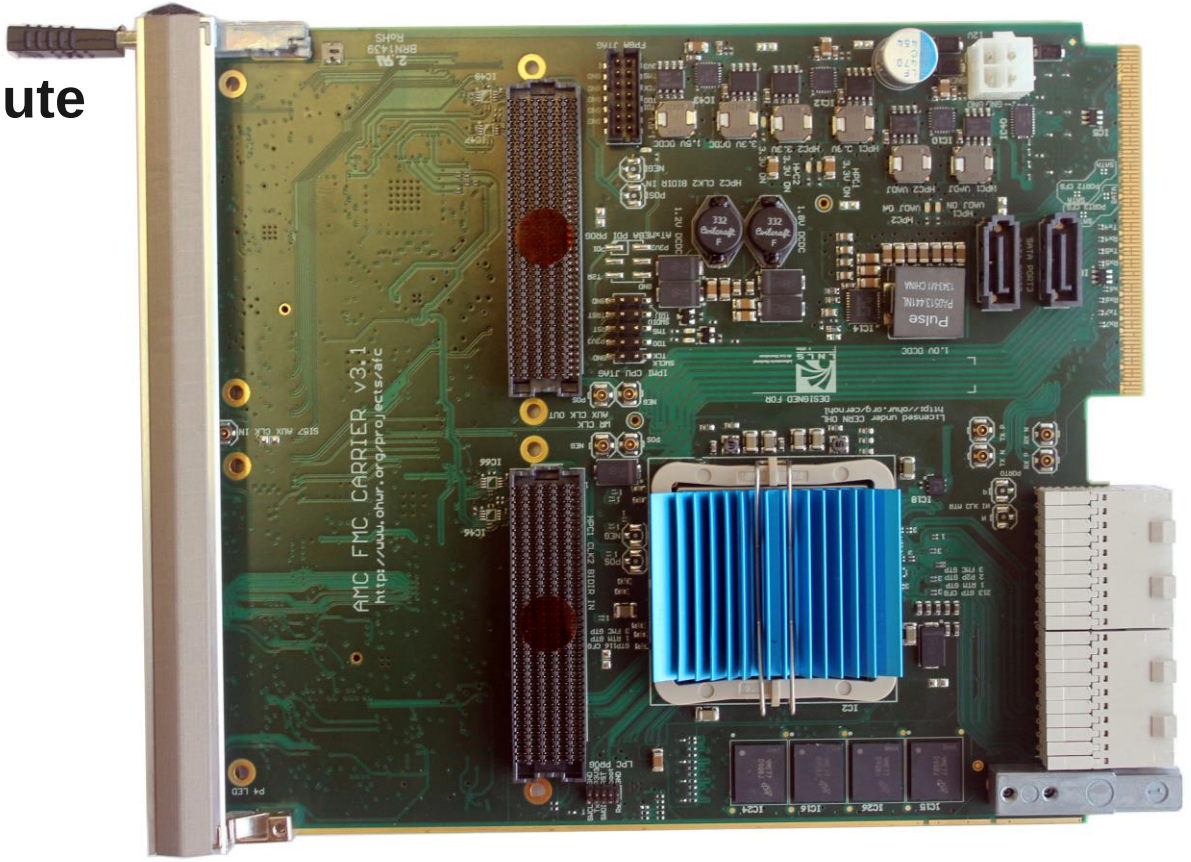
Image from:
https://www.struck.de/ds8vm1.html

Cavity Controller Firmware

- **One digital controller per cavity**
  - Possibility of programming arbitrary voltage function
  - Blowup parameters can be changed independently per blowup and per controller
    - Amplitude and frequency of sinusoidal phase modulation
    - Arbitrary phase modulation
  - Beam revolution frequency not constant
    - Harmonic number automatically calculated to match resonant frequency
  - Acquired internal debug signals accessible via PCIe interface
- **Common IP Cores for SIS boards shared between SPS and PS**
  - Board management: board initialization /clock settings / memory interface (credits to T. Wlostowski)
  - Internal signals acquisition and function generation (credits to J. Egli)

Integration with PS Control (1/2)

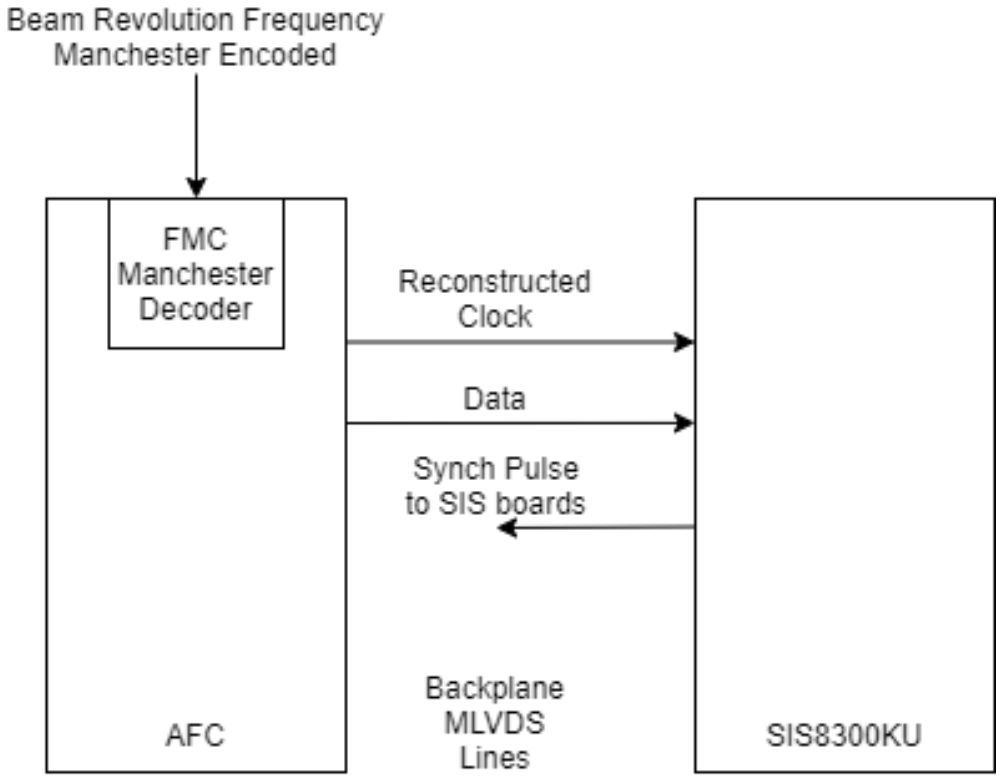
- **Beam revolution frequency distributed via serial link**
- **AFC board (Creotech) to receive and redistribute**
  - FMC for Manchester decoding
  - Redistribute to SIS boards through RF Backplane
    - Reconstructed clock
    - Data
  - Only deserialization on the SIS boards
- **Allows to interface with the control system during transition to White Rabbit**



https://ohwr.org/project/afc

Integration with PS Control (2/2)

- **Serial clock is asynchronous for cavity controller**
- **Revolution frequency must be updated synchronously**
  - To avoid dephasing of the cavities
- **Synch pulse generated on SIS**
  - FPGA clocks synchronized using White Rabbit
- **In future WR will transmit directly to SIS**



White Rabbit Timing Receiver

- **2 eRTM modules slots 14/15**
- **Slot Generate and distribute the RF signals**
  - Master clock to derive clocks for DACs/ADCs/FPGA
  - LO
  - Ref
- **Distribution through backplane**
- **WR synchronous RF**
- ***In detail presentation later this afternoon by T. Wlostowski***

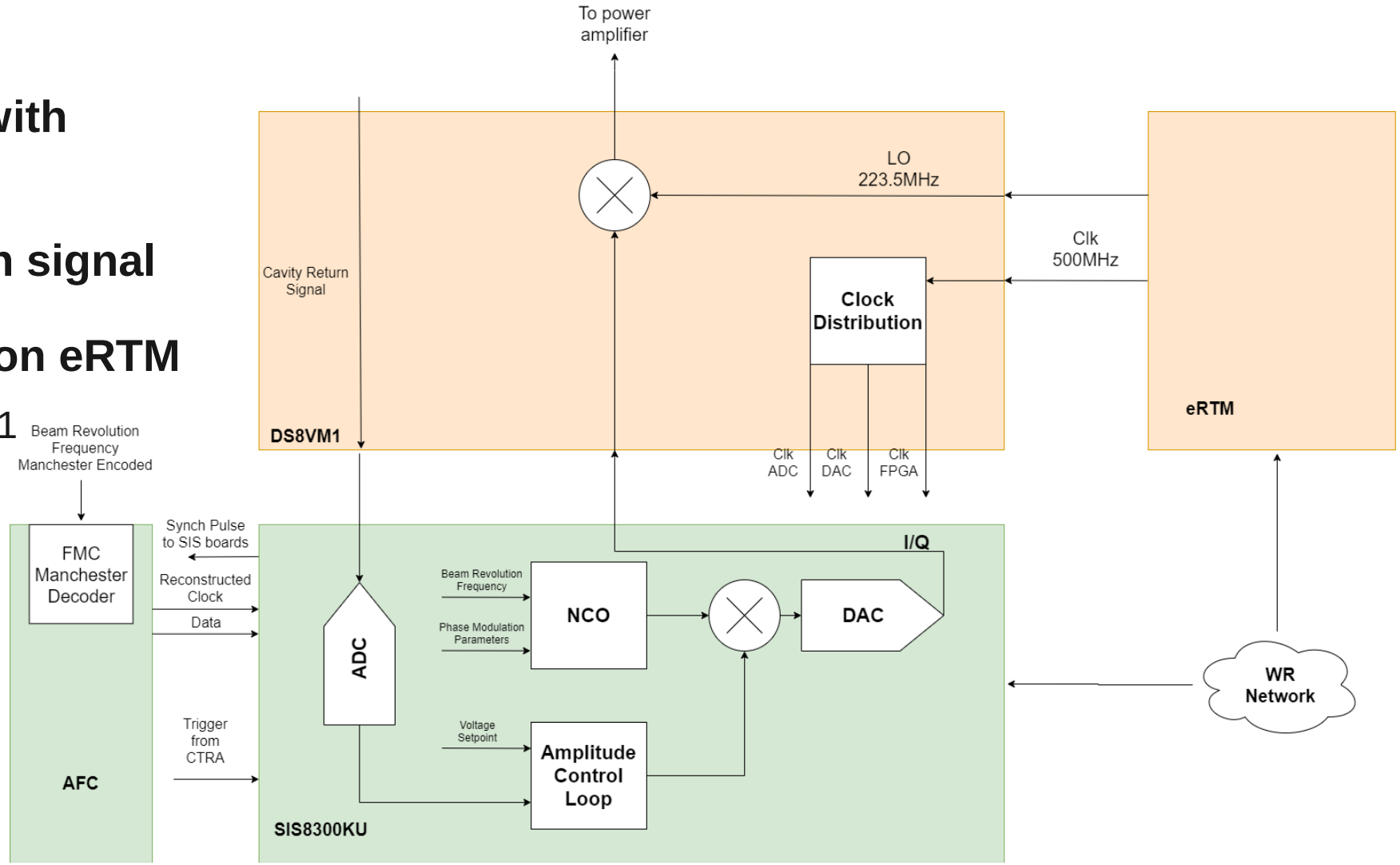
https://ohwr.org/project/ertm15-llrf-wr/wikis/home

Triggers

- **CTRA board**
  - CERN in-house board based on AFC (Creotech)
  - Timing receiver
    - Triggers sent through backplane to cavity controller SIS boards

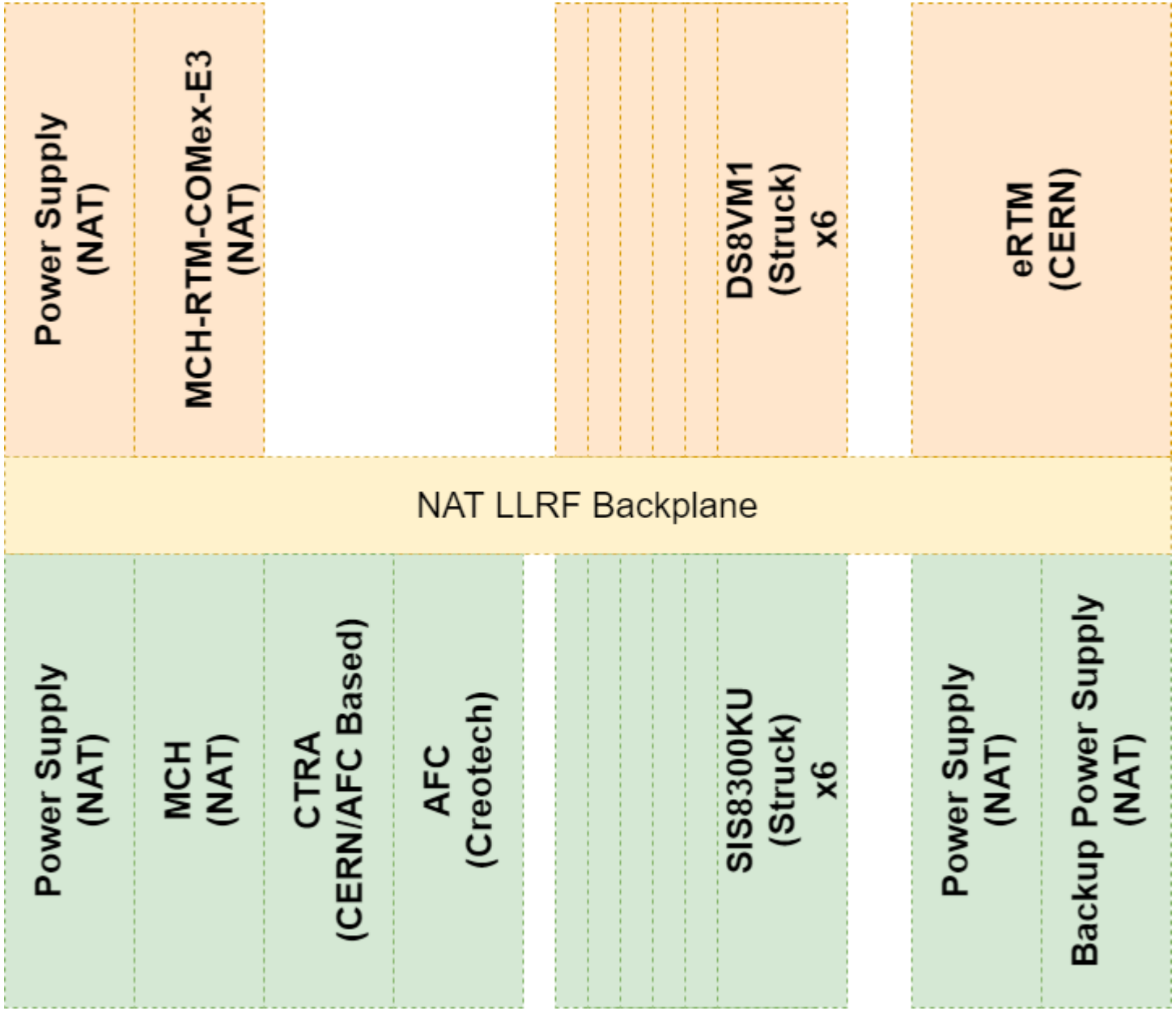
Putting it all together

- **RF signal upconverted with I/Q mixer**
- **Direct sampling of return signal**
- **Master clock generated on eRTM**
  - Distributed through DS8VM1



MTCA Hardware

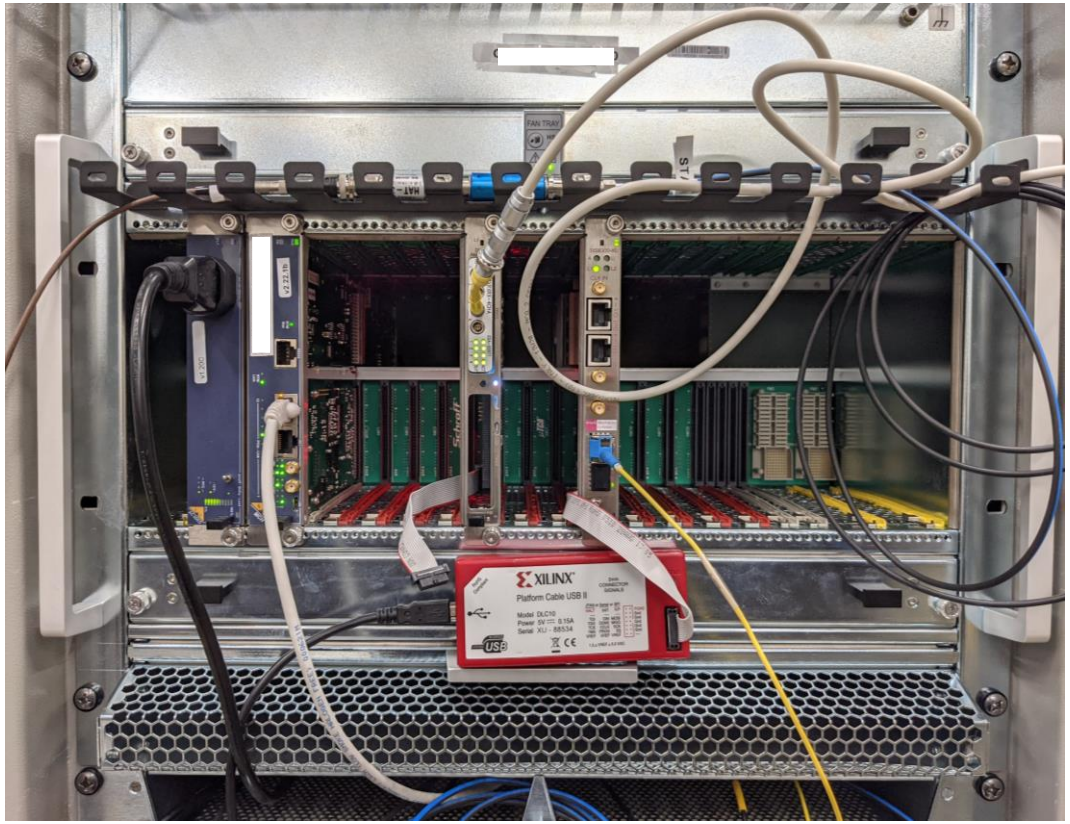
- **Compact architecture**
  - Clocks and LO generated in the crate
  - External timing only to CTRA board
  - External revolution frequency
- **System integrates nicely with the existing infrastructure**



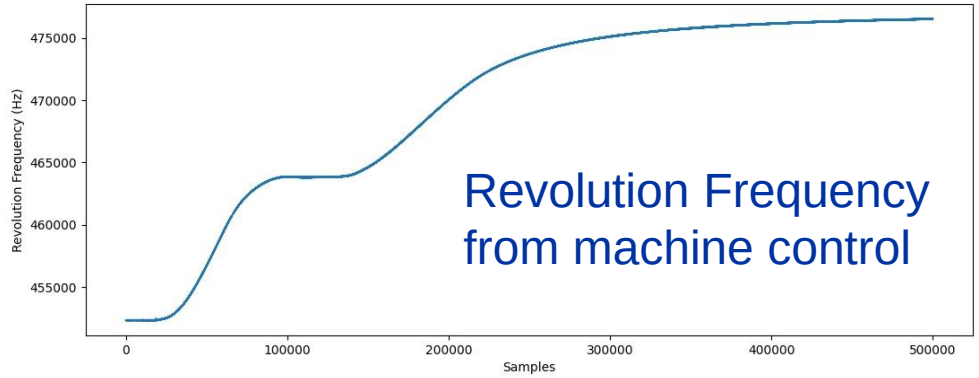
MCTA Hardware

Old System

MTCA crate first installation in the PS

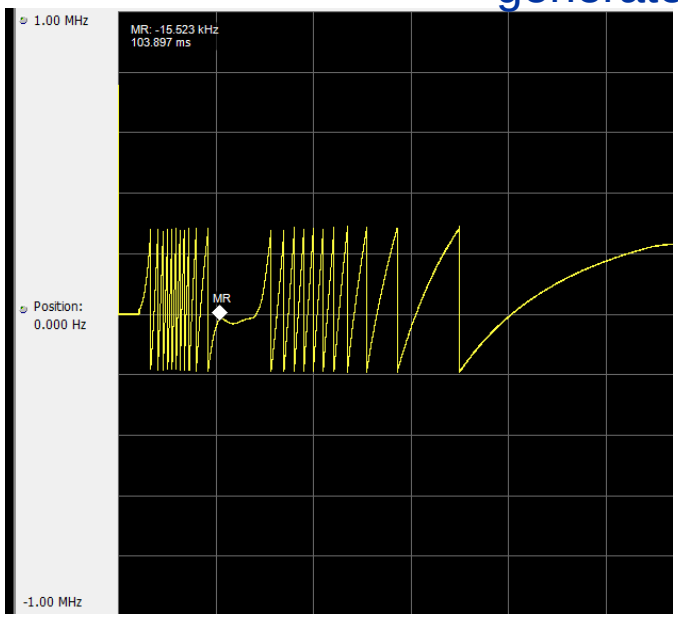


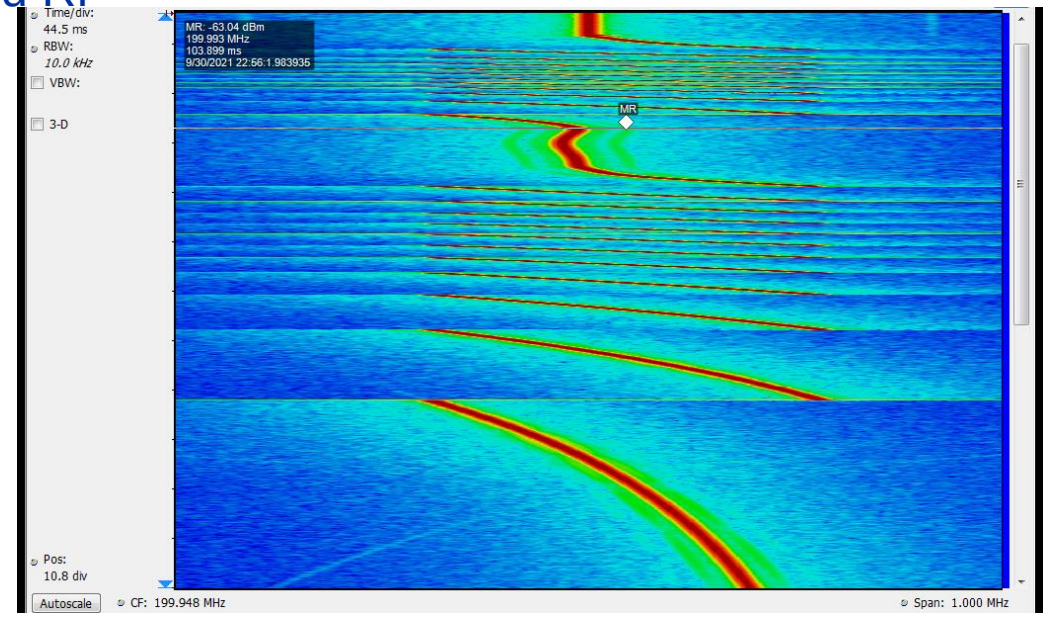
Generated RF



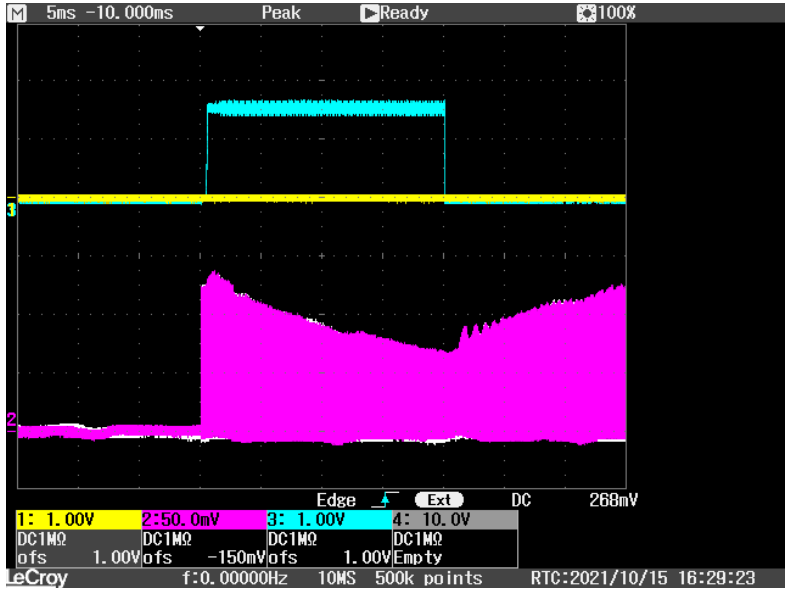
Revolution Frequency from machine control

Freq.vs time and Spectrogram of generated RF





Effect of blowup on the beam



Summary

- **MTCA.4 upgrade of the LLRF 200MHz Cavity Controller for CERN PS**
  - 6 separate cavity controllers on SIS8300KU and DS8VM1 boards
  - AFC board to integrate with the accelerator control system
    - Will be replaced in future when control system will migrate to white rabbit
  - eRTM module to generate clocks and LO synchronous with white rabbit
    - No need for external references
- **Hardware sharing with SPS**
  - Common spare parts
  - Reuse of firmware blocks
- **New system is being tested in the PS**