New HW Platform for ALBA DLLRF

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Introduction

Picodigitizer Series from Nutaq

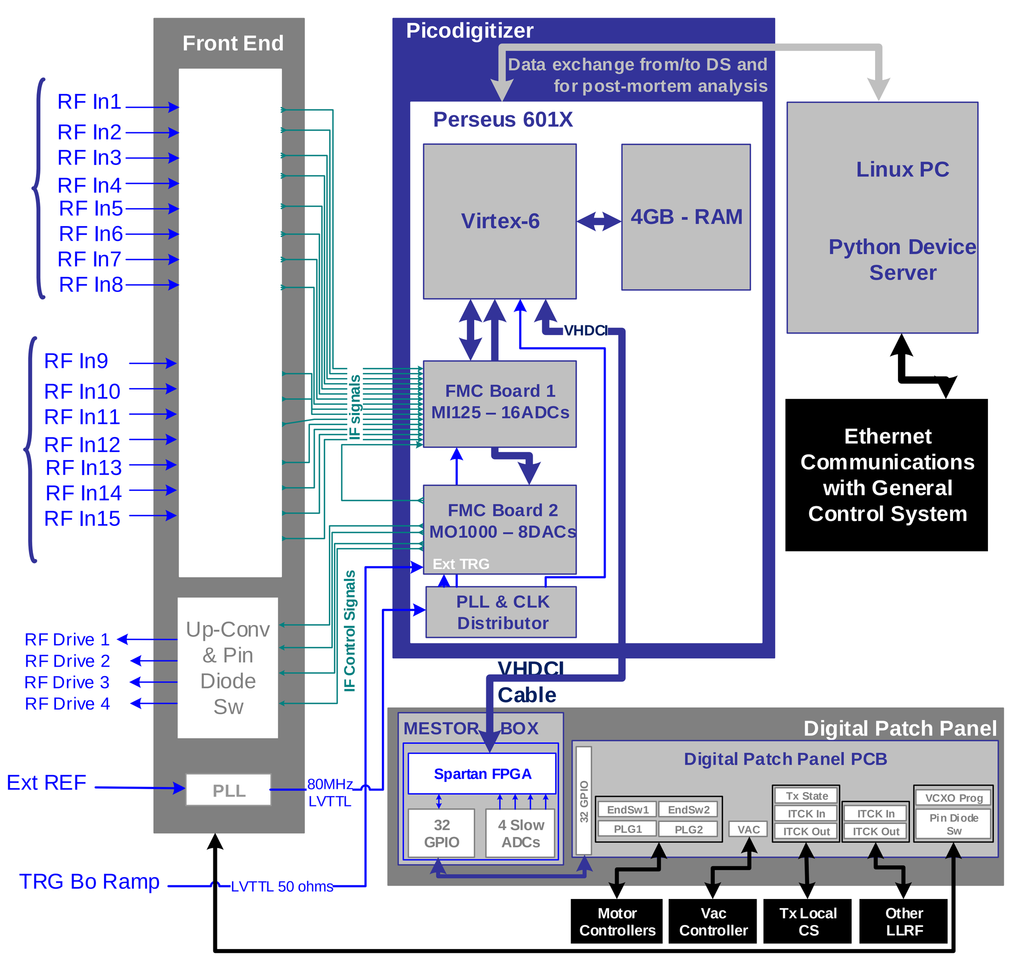
- ALBA is a 3GeV synchrotron Light Source located in Barcelona, Spain in operation with users since May 2012
- There are 6 RF Cavities in the SR to provide up to 3.6MV to accelerate the beam. The redundancy of the RF system makes possible the survival of the beam after a RF trip.
- In 2006, the Digital LLRF of ALB was built based in IQ modulation/demodulation technique and using commercial cPCI FPGA Boards with XP Drivers
- In 2019, a new HW platform, the picodigitizer from Nutaq, based on Linux drivers have been used in a prototype to overcome the obsolescence of the WXP operative system.
- The picodigitizer is a stand-alone board, based on the Perseus system, a uTCA board with virtex-6 and a FMC board. This HW platform has been used in the DLLRF developed for Max-IV (Sweden), Solaris (Poland), Diamond (UK) and Sirius (Brazil)

RF/ LLRF specifications of the ALBA SR

Frequency	499.654	MHz
# Cavities	6	NC HOM damped
Cavity Shunt Impedance	3.3	MOhm
RF power (per cavity)	150	kW
RF voltage (per cavity)	600	kV
Maximum beam current	400	mA
Beam Losses Per turn	1.1	MeV
Synchrotron frequency	5 - 9	kHz
Main DSP of Digital LLRF	IQ Mod/Demodulation	
LLRF Amplitude stability	0.1	% rms
LLRF Phase stability	0.1	° rms

ALBA DLLRF New Platform

Block Diagram



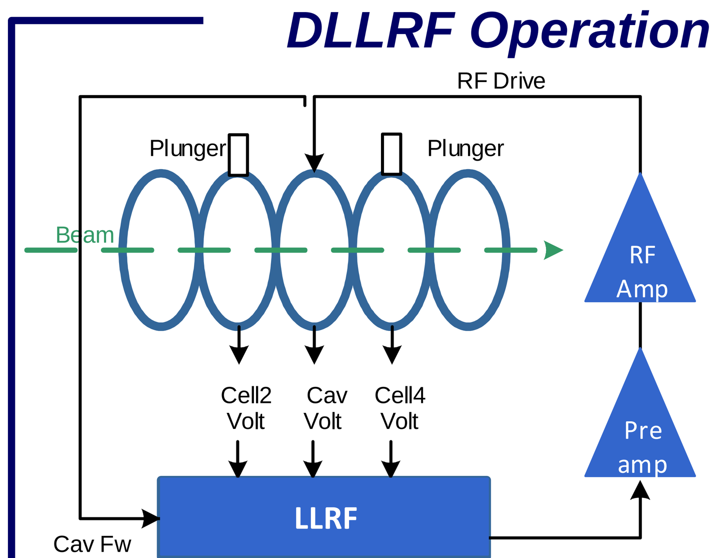
✓Picodigitizer: Digital FPGA Motherboard

- Virtex-6 FPGA SX315T
- 16 ADCs, 14 bits, 125MHz
- 8 DACs, 16 bits, 250MHz
- Expansion board with 32 GPIO bus + 4 slow ADCs
- Stand Alone Board

✓ Front Ends for Up & Down Conversion from/to 500MHz to 20.83MHz with SMA Test Points

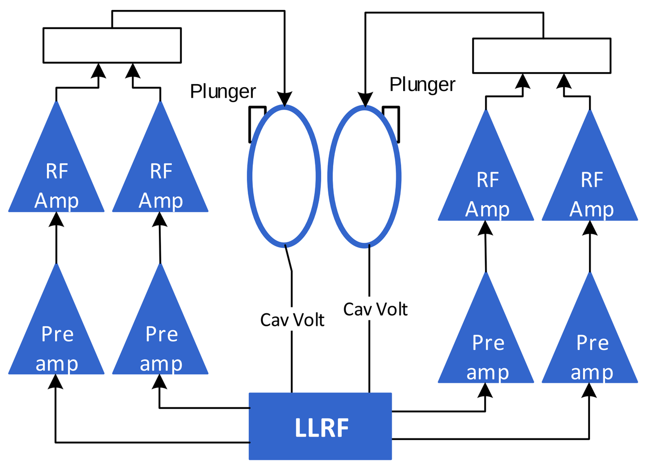
✓ Digital Patch Panel for digital interfaces with other subsystems: vacuum, motor, timing, PLC

DLLRF Operation Configurations



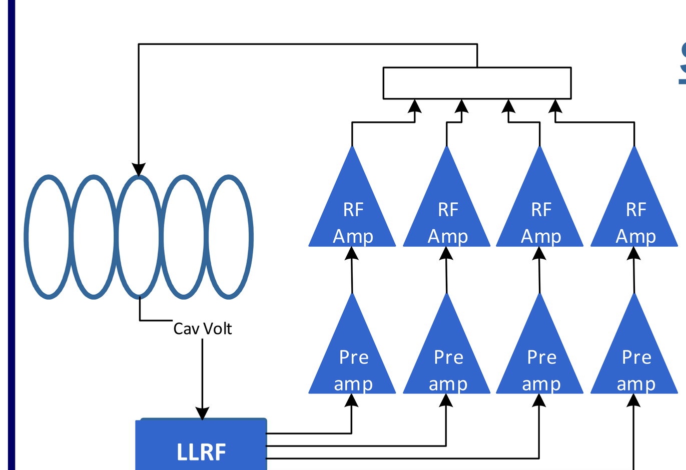
Booster Cavity

✓Multi-Cells Cavity
✓Ramping
✓2 Plungers control



Normal Conducting

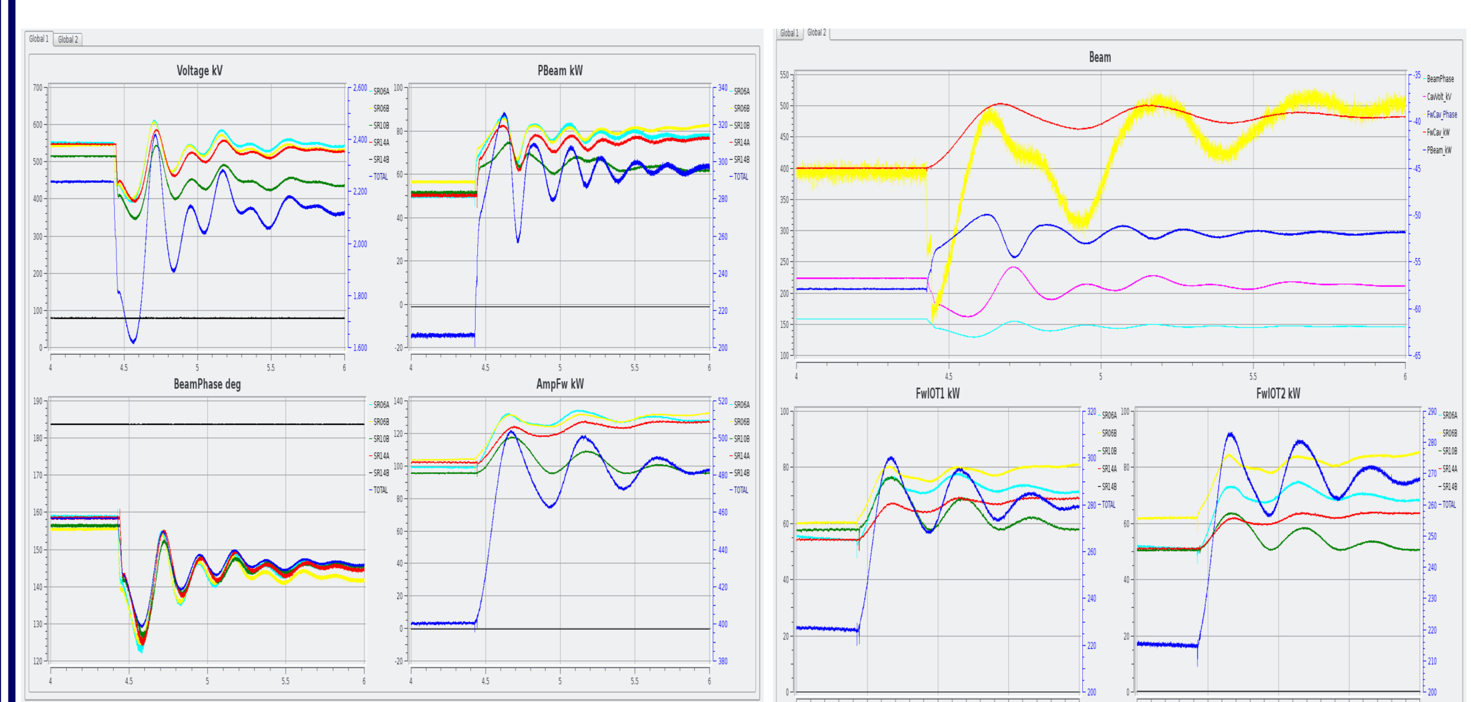
✓2 Cavities independently controlled
✓2 Drivers per Cavity
✓2 Plungers control



Super Conducting

✓1 Cavity driven by 4 Amplifiers
✓Amplitude and phase balance compensation independently applied to each drive

RF Trip compensation: Amp&Ph modulation



Main Parameters of FF Amplitude Modulation

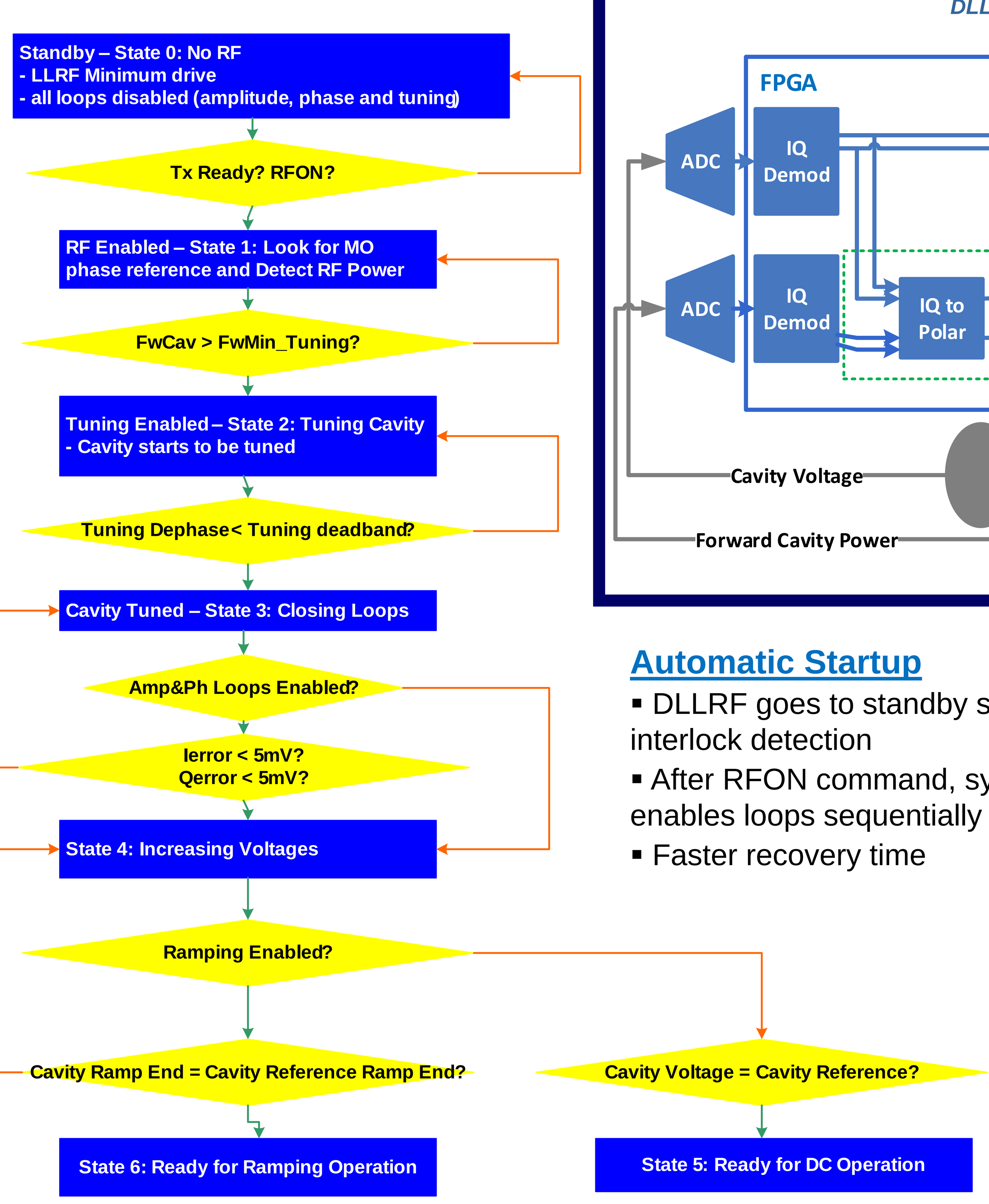
✓Frequency of amplitude modulation equal to synchrotron tune and opposite phase to the original perturbations
✓ initial amplitude of FF compensation set as percentage of Feed-Back Loops Drive
✓ For 60mA and 1.5MV Accelerating Voltage reduced to 1.2MV voltage after trip, required 45% of overdrive to fully compensate beam dump
✓ Drawbacks: RF amplifier over-drive needed → can lead to arcs in amplifier vacuum tube

Main Parameters of FF Phase Modulation

✓ Negative phase step when interlock detected to anticipate new beam synchronous phase
✓ Phase modulation opposite to beam excursion to damp longitudinal oscillations of beam
✓Main Advantage: no amplitude over-drive

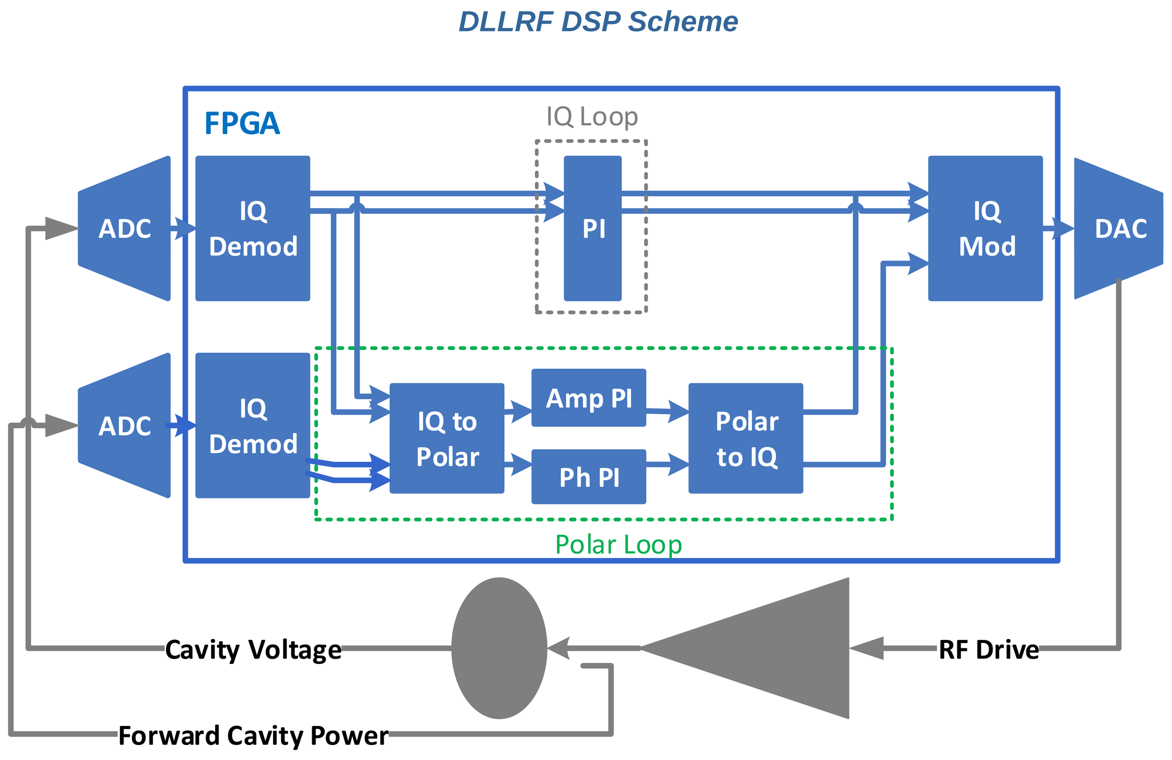
Main Firmware Components for ALBA DLLRF Platform

Automatic StartUp

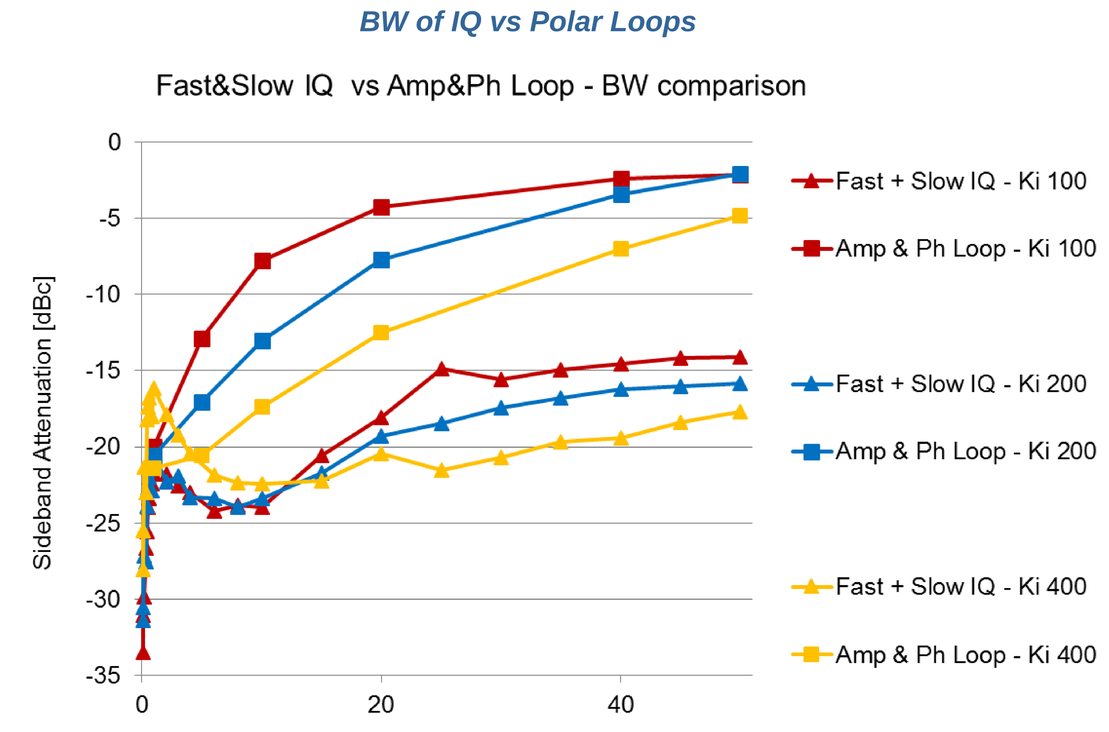


Digital IQ demodulation + Polar & Rectangular Loops

DLLRF DSP Scheme



BW of IQ vs Polar Loops



Main Characteristics

- Digital IQ demodulation
- Rectangular and Polar loops
- Control Loops can be applied to different signals: Cavity Voltage or output of amplifiers

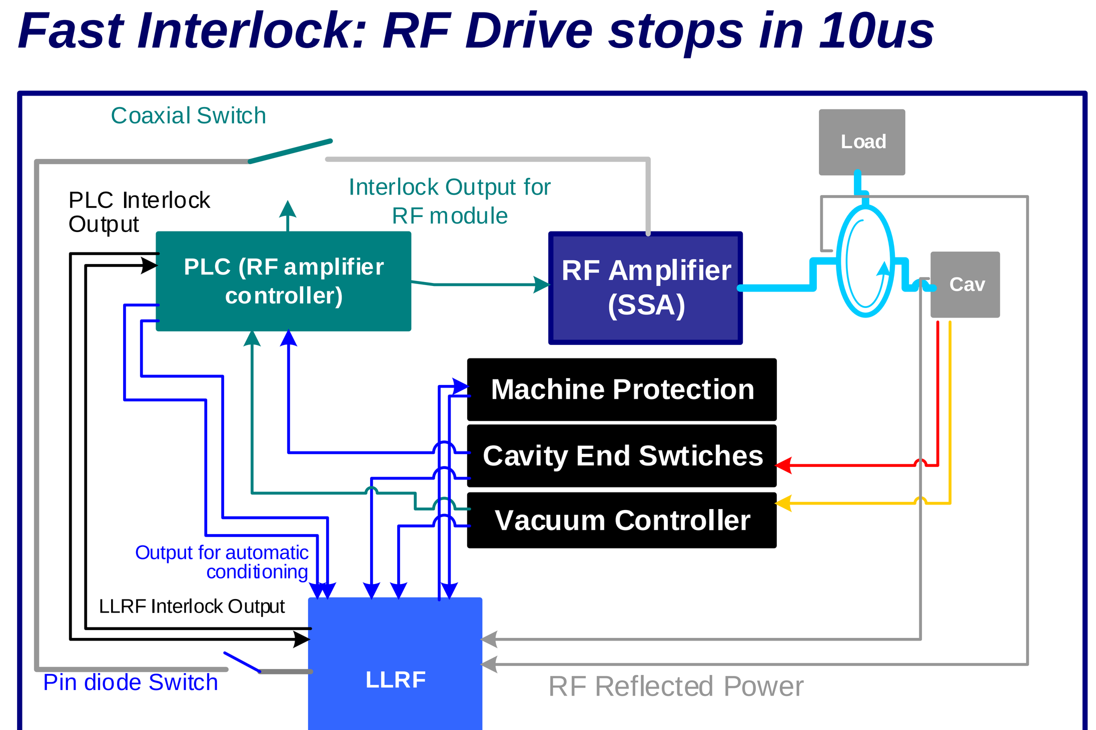
Extra Utilities

- Automatic conditioning
- Fast Interlocks utilities (vacuum, arcs and reflected power)
- Fast and slow diagnostices
- Automatic startup
- Ramping
- Field Flatness for multi-cells cavities

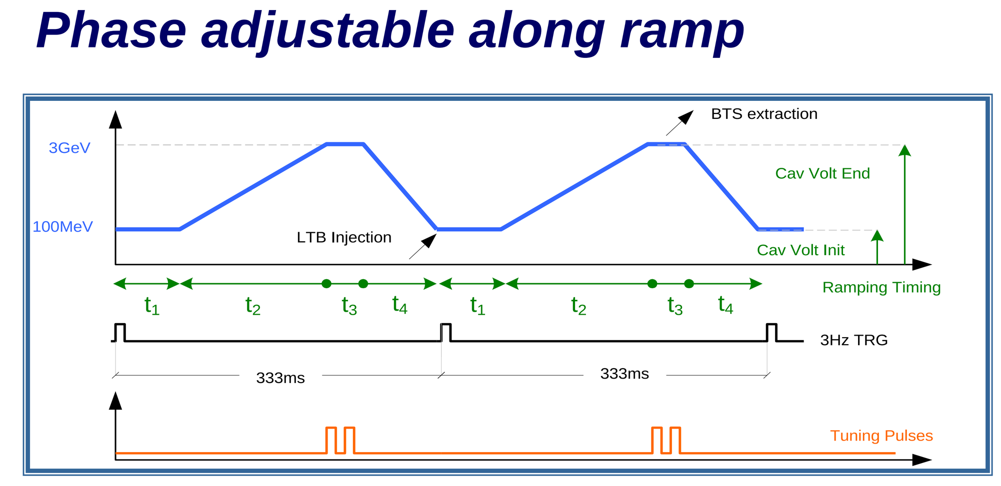
Automatic Startup

- DLLRF goes to standby state after interlock detection
- After RFON command, system enables loops sequentially
- Faster recovery time

Fast Interlock: RF Drive stops in 10us



Booster Ramping: Amplitude and Phase adjustable along ramp



Commissioned with beam in September 2019