LHC Injectors Upgrade

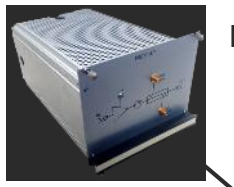
LLRF software status and planning

28 Jan 2020

Outline

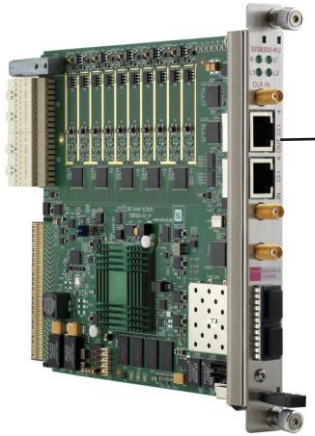
- LLRF system
- LLRF Front-end software
- RF/OP integration
- Milestones
- Conclusion

Cavity controller

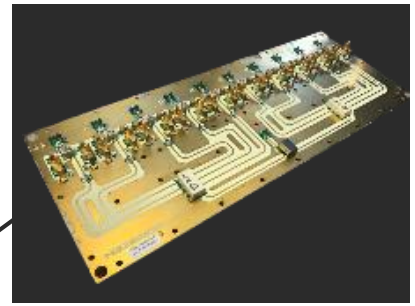


PreDriver
(BE-RF-FB)

DS8VM1
(Desy/Struck)



SIS8300-KU
(Struck)



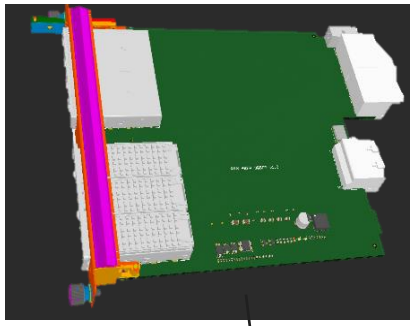
RF combiner
(BE-RF-FB)

eRTM14+eRTM15
(BE-CO-HT)

Beam Control

FMC ADC
(Open Hdw)

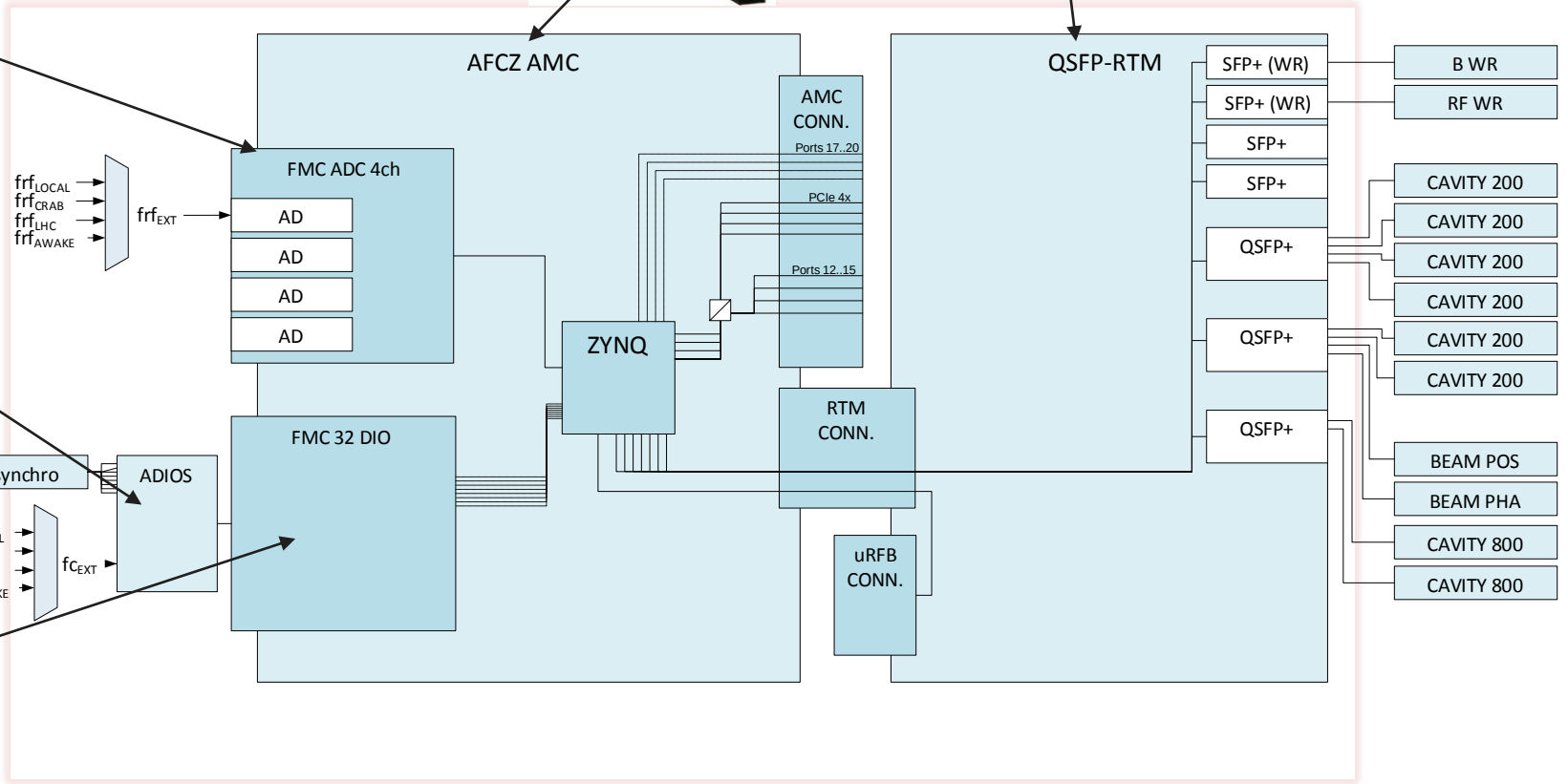
AFCZ
(Creotech)



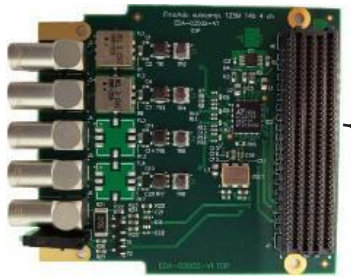
QSFP-RTM
(creotech)

ADIOS
(BE-RF-FB)

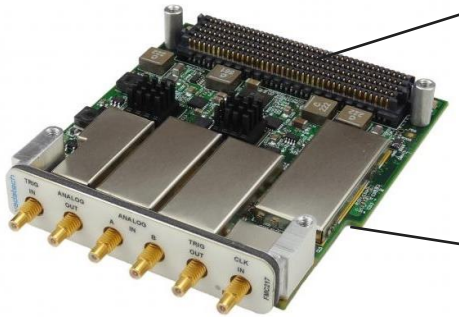
FMC 32 DIO
(Open Hdw)



Beam Based Measurements

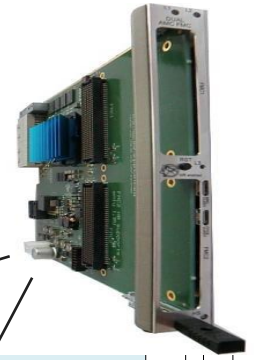


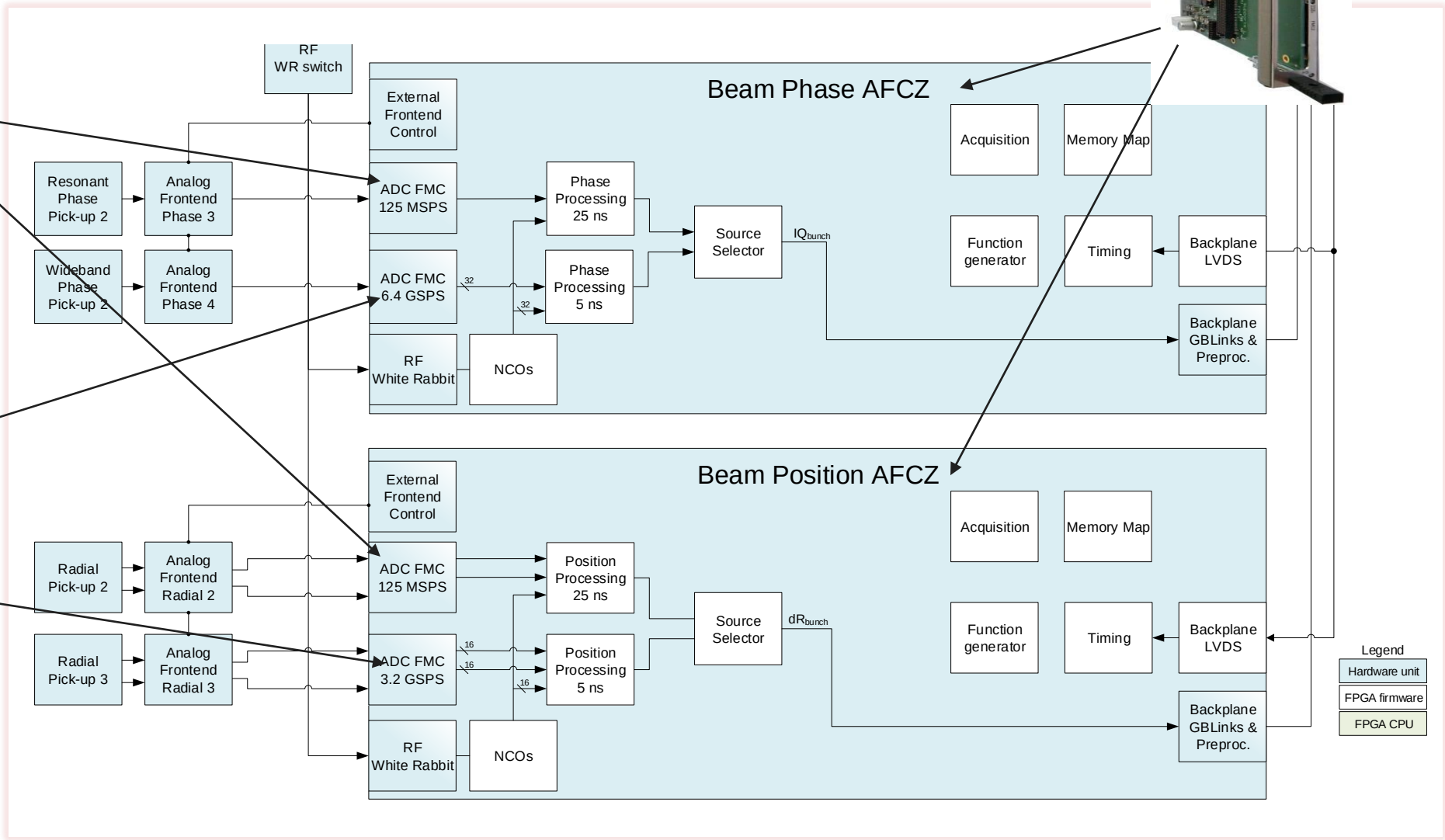
FMC ADC
(Open Hdw)



FMC217 6.5 Gsps ADCs
(Vadatech)

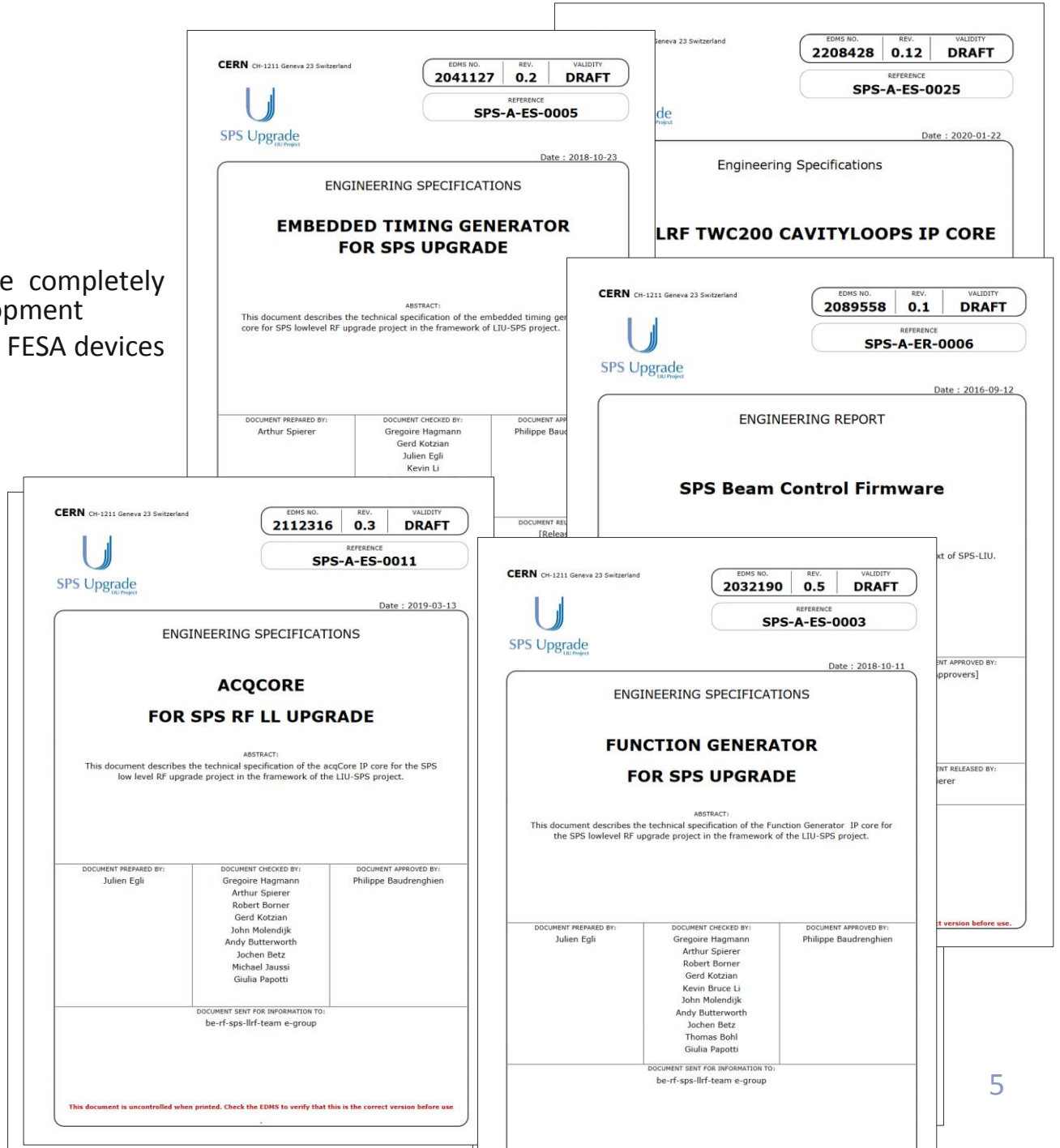
AFCZ
(Creotech)



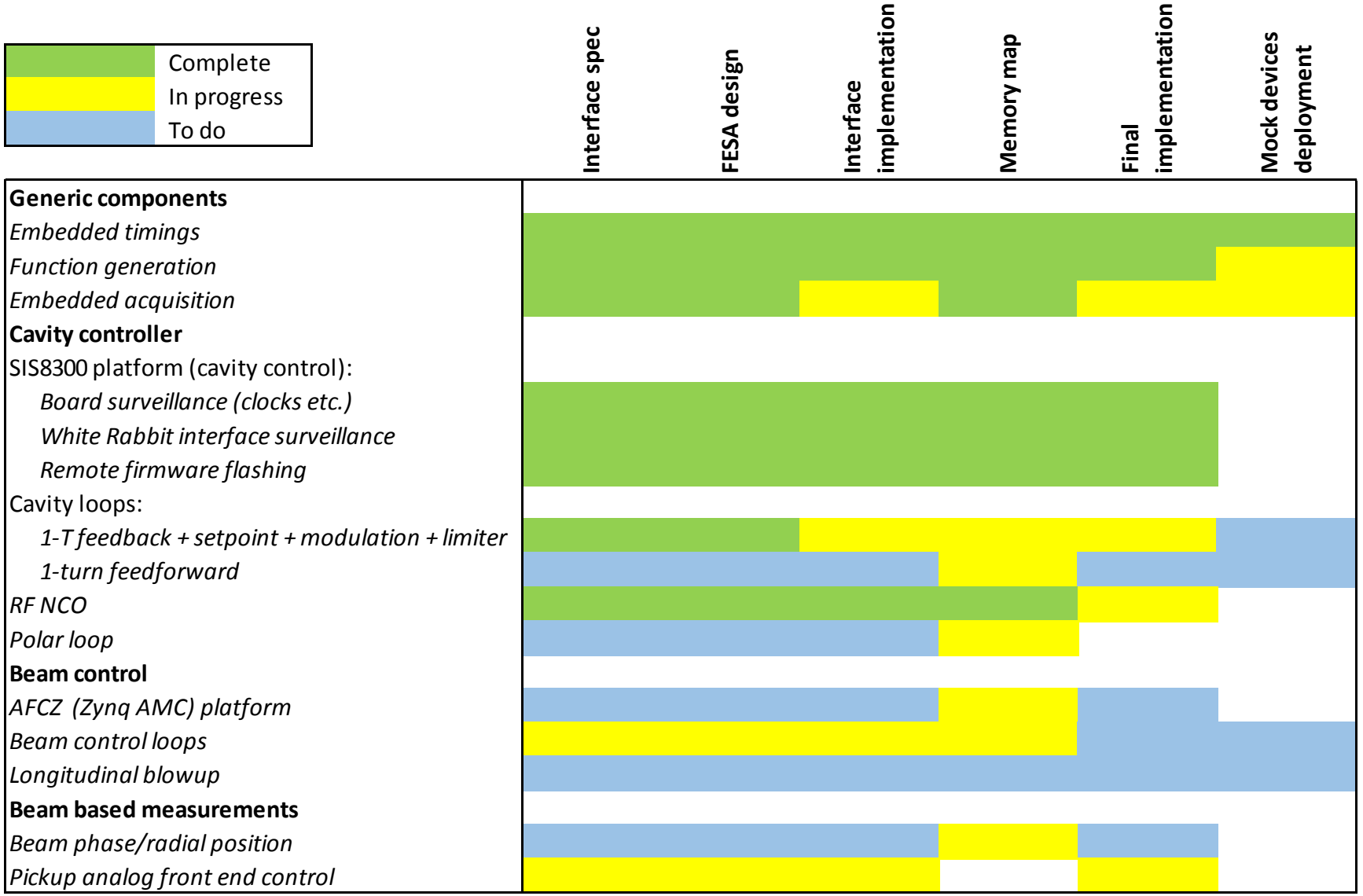


LLRF front-end software

- **FESA class development**
  - Full implementation requires FPGA firmware memory maps to be completely defined, currently not the case for many firmware cores still in development
  - In the meantime, define FESA class interfaces and instantiate “mock” FESA devices to aid LSA and application development
- **Generic components**
  - Most complex to develop
  - Cover majority of control interface with OP
    - Around 130 functions, 50 timings
  - FESA developments almost complete
  - Mock FESA device deployment for LSA vertical slice tests
    - Timing test devices deployed since Nov 2019
    - Functions first dry run in Dec 2019, updated version by end Jan
    - Acquisitions by end Jan
    - Solving some issues with driver deployment (Reksio, CODEINE, Git)
  - Aim to instantiate “final” list of devices by March 2020
    - FESA instantiation in CCDB, simulated devices running on FEC
- **Specific FESA classes:**
  - Cavity Controller FESA development partially complete
    - FESA interface defined for Cavity Loops
  - Beam Control FESA interfaces definition in progress
    - Start code development Feb 2020



Front-end software development status (28.01.2020)



LLRF OP integration

- **Productive RF+OP collaboration**
  - RF to provide FESA interfaces, logic dependencies and algorithms
  - OP to implement higher level parameters, make rules, value generators in LSA, CCC applications
- **New timing (ATIM) functionality**
  - discussed, implemented and successfully tested
  - Handling of coast is complex, solved with good collaboration of the timing team in CO
- **SPS RF parameter model in LSA:**
  - Clean up of old settings being implemented
    - not changed: cavity controller 800, beam observation
  - Settings generation
    - ready for: synchro, total voltage, partitioning, counterphasing
    - almost finalized: bucket area, loop gains (LQR controller)
  - Being implemented: beam control timings, function generator, acquisition interface
  - To be tackled next: cavity controller 200, ions/FFA

Milestones for LLRF & software, dry runs

Kevin's dry run list:

Name	Description
LHC generation	Test LSA generation for LHC type cycle with RF synchro, RF loops, RF cavity control & timings
Radial steering	Test settings for radial steering on synchro and radial loop
SPS2PS Synchro	Test synchro
Synchro & phase loop diagnostics	Test acquisition and display of synchro and phase errors using simulated data
Cavity control loops	Test generation and settings of full cavity control loops – with comb filters
SFTPRO generation	Test LSA generation for SFTPRO type cycle of RF synchro, RF loops, RF cavity control & timings
Phase & position diagnostics	Test acquisition and display of phase and position using simulated data
Diagnostics test	Test what can be tested from diagnostics not tested so far
800 MHz	Verify settings in 800 MHz; improve generation using new functions for voltage ratio, add harmonic ratio, add offset
FFA generation	Generate ion cycle with FFA – all settings; also synchro
Longitudinal damper	Interface and settings for longitudinal damper ready for testing
RF gymnastics	Interface and settings for RF gymnastics ready for testing
Longitudinal blow-up	Interface and settings for longitudinal blow-up ready for testing
AWAKE and LHC rephasing	Generation and settings with tests for rephasing
Slip stacking application	Slip stacking application ready with preparation of functions for settings

	HW & firmware	Software	Dry runs possible
End Jan		Timing, Function, Acquisition test FESA devices available	Generic device tests (FESA classes API)
End Feb		Migration of legacy FECs (Synchro, TWC800) to CC7/FESA v7 completed	800 MHz settings Synchro settings
End March		Cavity controller mock FESA devices available	
End March		All (most?) Timing, Function, Acquisition FESA devices instantiated	LSA generation of LHC/SFTPRO with functions for loops, cavity control and timings, comb filters Synchro and phase loop acquisitions Phase and position acquisitions
End April		Beam control and beam-based measurement mock FESA devices available	Radial steering settings Ion cycle generation with FFA settings Longitudinal damper settings Slip stacking settings Rephasing settings RF gymnastics settings
End May	Firmware finalized for Beam Control, Cavity Controllers and Beam-Based Measurements	Cavity controller FESA class basic functionality implemented (1-turn FB)	
June	LLRF electronics installed in BA3: Beam Control, Cavity Controllers and Beam-Based Measurements	FESA classes basic HW functionality testing in BA3	
End July	Control a first cavity with minimum cavity controller system (1-turn FB)		
June-Oct		Completion of FESA classes HW functionality Longitudinal blowup FESA class	Longitudinal blowup settings/FESA
1 Oct	RF signals (RF, revolution frequency, injection and extraction pulses) available for ABT, BI…		
Nov			Rephasing?
Dec	All cavities controlled with the new LLRF system		

Conclusion

- **Front-end software development progressing**
  - Generic components and cavity controller well advanced
- **Long dry-run wish list, front-end software development cannot wait for HW/firmware availability**
  - Deploy mock FESA devices wherever possible
  - Aim to deploy functions, timings and acquisitions for all systems by end of March
  - Milestones (optimistic) defined for FESA class delivery and dry runs


CERN

FEBRUARY: Prepare for (re)installation

- **Finish FC cabling**
  - Systems: RF Synchro, Distribution, Beam Control, Cavity Controller, Beam-based measurements
- **Check-calibration of RF cable tunnel-FC (Cavities, PUs)**
- **PU analog Front-End**
  - Finalize design. Order components. Launch fabrication
- **Cavity Sum analog Front-End**
  - Finalize design. Order components. Launch fabrication
- **Cavity Controller analog Front-End**
  - Finalize design. Order components. Launch fabrication

MARCH-MAY: Re-installation

- **Validation of legacy equipment before re-installation**
  - FO links RX/TX, distributions, VTU, BQM, …
- **Installation, cabling and fibers in FC**
- **Installation of RF Synchro (partly removed)**
- **Installation of the 800 MHz system (legacy)**

MARCH-MAY: Finalize firmware. (Last) series orders.

- **Finalize firmware for Beam Control, Cavity Controllers and Beam Based Measurements**
- **Last series orders**

MAY-JUNE: Installation of new (uTCA) electronics

- **Installation of Beam Based Measurements**
- **Installation of Beam Control**
- **Installation of Cavity Controller**

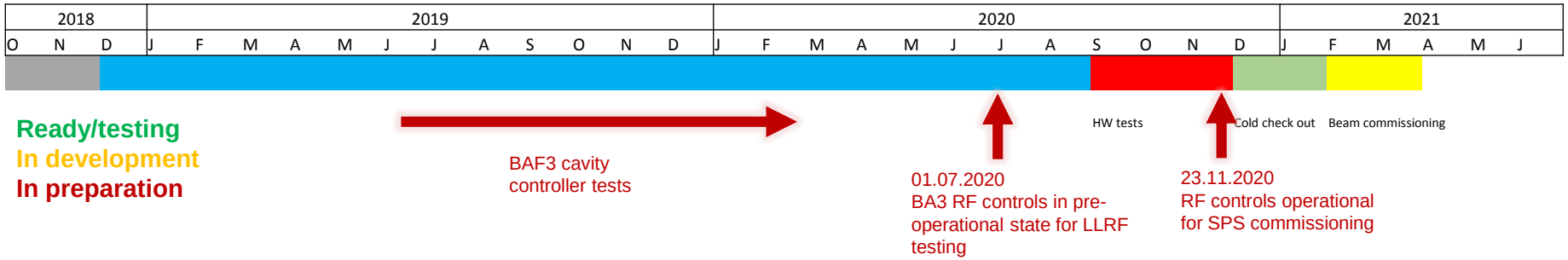
JULY-SEPT: Re-commissioning. IST

- **Re-commissioning of the RF Synchro**
  - Milestone: Synchro OK by Oct 1st
- **Re-commissioning of Distribution**
  - Milestone: RF distribution OK by Oct 1st
- **RF signals (RF, revolution frequency, injection and extraction pulses) available to the users (BI, ABT,…) from Oct 1st…but expect some interruptions…**

JULY-DEC: Commissioning .IST

- **Commissioning of Beam Control**
  - Milestone 1, July: RF generated from WR distribution of B field (static and simulated magnet cycle, TE-MSC)
  - Milestone 2, Oct: RF following magnetic cycle via magnetic measurement in reference magnet
- **Commissioning of Beam Based Measurements**
  - Using the resonant PUs
  - Using the wide-band PU for bunch per bunch measurements
- **Commissioning of 200 MHz Cavity Controllers**
  - Milestone 1, July: Control a first cavity with the new system. Minimum is the OTFB
  - Milestone 2, December: All cavities controlled with the new system
- **(RE)commissioning of the 800 MHz Cavity Controllers**
  - Legacy equipment (VME, upgraded in 2015)
  - Using the old RF-synchronous clocking scheme. Must be made compatible with the new scheme based on the WR for synchronization.

Software for LLRF



Phase 1: Q1, Q2 2019
Basic cavity loop for testing in BAF3
- SIS8300-KU Framework
- 1-T delay FB
- Functions
- Timing tree
- RF NCO
- IQ Modulator
- IQ Demodulator (including fixed delay compensation)
- WR interface FESA

Phase 2: Q2-Q4 2019
Cavity loop features and beam control loops
- Embedded acquisition
- Switch/limit
- Polar loop
- Voltage setpoint
- Pickup sampling card
- Beam phase & intensity
- Beam control FCZ+FMC (Zynq)
- Beam control loops

Phase 3: Q1, Q2 2020
Remaining cavity + beam loops features for startup
- 1-T Feedforward
- Baseband Network Analyzer
- Radial position meas.
- RF gymnastics
- FFA, slip stacking
- RF switch VME module
- Pickup analog front end
- Duplex serial link control

Phase 4: Q3 2020
Infrastructure & integration
- Crate Management for MTCA (BE-CO)
- Logging (TIMBER)

Phase 5: during Run 3
- WR2RF (BE-CO)

LSA + Operational interfaces: Parameter model, makerules, Java applications

Collaboration
OP + RF