Update on FRIB LLRF Development and Production

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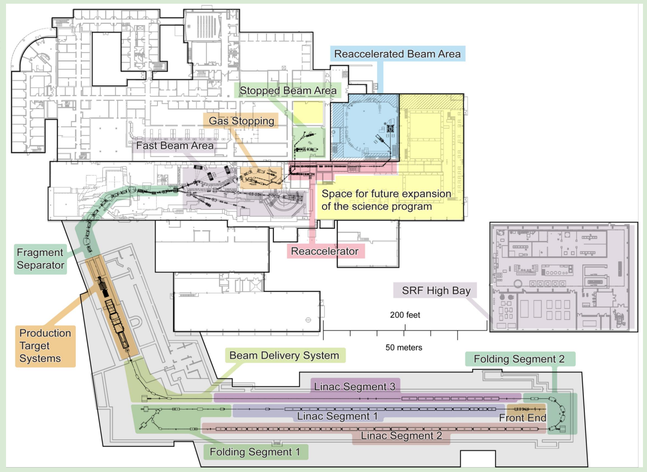
FRIB LINAC Overview

The FRIB Linac includes Front End (FE), Linac Segment 1 (LS1), Folding Segment 1 (FS1), Linac Segment 2 (LS2), Folding Segment 2 (FS2) and Linac Segment 3 (LS3).

The FE room temperature (RT) cavities include multi-harmonic buncher (MHB), velocity equalizer (VE), radio frequency quadruple (RFQ), and two MEBT bunchers.

Four types of superconducting (SC) cavities are used throughout the linac; i.e. quarter wave resonators (QWR) with beta 0.041 and 0.085 and half wave resonators (HWR) with beta 0.29 and 0.53. 161 MHz warm bunchers are used in FS1.

Also, the re-accelerator (ReA) at National Superconducting Cyclotron Laboratory (NSCL), now part of FRIB, needs to upgrade its LLRF controllers to obsolete the old technology.

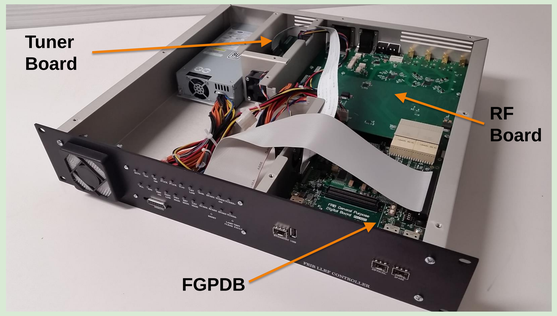


Cavity Types	MHB	VE	RFQ	MEBT	QWR041	QWR085	IHB	HWR29	HWR53	ReA MHB	ReA RFQ
FE	1	1	1	2							
LS1					12	88					
FS1 (new)						4	2				
FS1 (old)						10	0				
LS2								72	96		
FS2									4		
LS3									48		
ReA3					7	8				1	1
RT / SC	RT	RT	RT	RT	SC	SC	RT	SC	SC	RT	RT
Tuner	N/A	N/A	Water skid	Stepper	Stepper	Stepper	Stepper	Pneumatic	Pneumatic	N/A	Servo
Frequency (MHz)	40.25 (F1) 80.5 (F2) 120.75 (F3)	40.25	80.5	80.5	80.5	80.5	161	322	322	80.5 (F1) 161 (F2) 241.5 (F3)	80.5

LLRF Controller Design

FRIB general purpose digital board (FGPDB) featuring the Xilinx Spartan 6 150LXT FGG900 FPGA, dual 256 MB DDR memory, 16 MB flash, MicroTCA compatible, is shared among groups and used for LLRF, MPS and BPM.

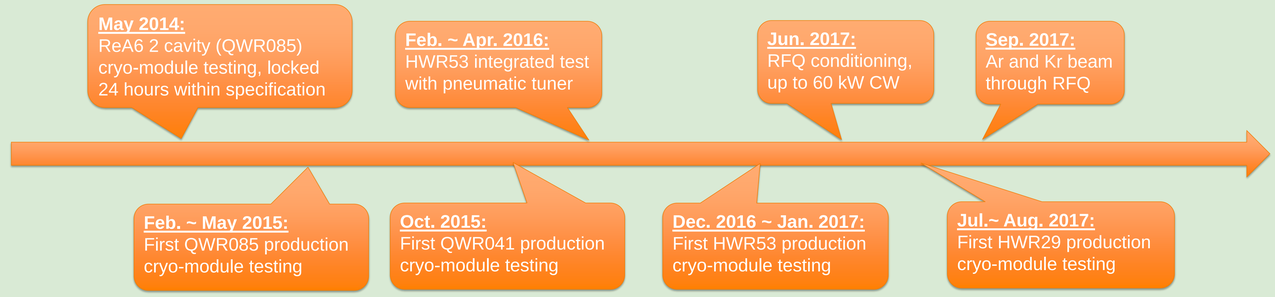
Due to the various RF frequencies and tuner types of multiple cavity types, we designed the RF board to have 3 variations with simple part alternatives in the RF output chain (bandpass filters, attenuators). Each controller type supports two RF frequencies.



Also, two types of tuner driver boards (stepper and analog) with same form factor were designed. The analog tuner board is used for RFQ and HWRs.

LLRF	RF Board	Tuner Board	For Cavity Types	Need	Build
S01xxx	S01xxx (80.5/322)	Stepper	MHB_F2, MEBT, QWR041, QWR085, ReA MHB_F1, ReA RFQ	124	135
S02xxx	S01xxx (80.5/322)	Analog	RFQ, HWR29, HWR53	221	234
S03xxx	S02xxx (40.25/120.75)	N/A	MHB_F1/F3, VE	3	4
S04xxx	S03xxx (161/241.5)	Stepper	IHB	2	3
S05xxx	S03xxx (161/241.5)	N/A	ReA MHB_F2/F3	2	2

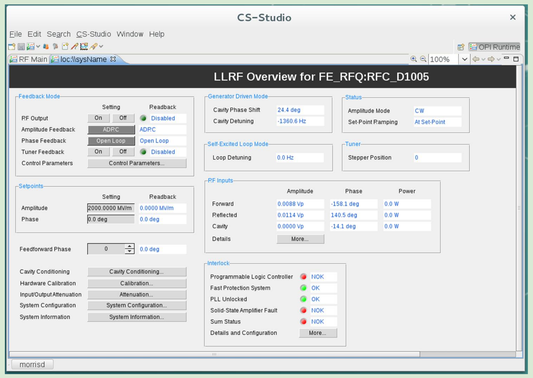
Major Milestones



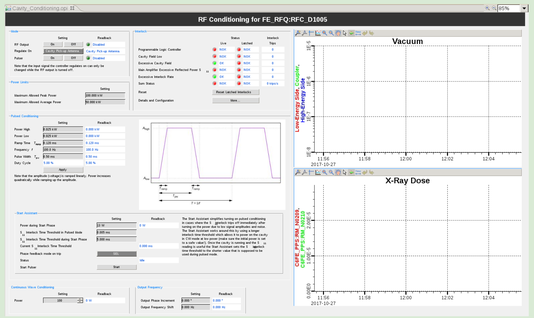
Various issues were solved during above tests including stepper driver overheating, pneumatic tuner calibration, RF control digital artifact, Lorenz force detuning, etc. For details, please checkout poster #50 “FRIB LLRF control issues and improvements”.

User Interface

LLRF engineering CS-Studio OPI screens have been created and were used during the RFQ conditioning. Start assistant scripts was implemented in the IOC level to facilitate the turn on process, once the steps are determined in the manual mode.



LLRF Overview Page



RFQ Pulse Conditioning Page

Cost Analysis

The total cost of the LLRF controller includes PCBs, chassis, miscellaneous parts and labor. Miscellaneous parts include power supply, fans/filter, transceivers (copper/fiber), cables, heat sinks etc. Labor cost is calculated at $60/hr for 5 hours, including board acceptance testing, assembly and device calibration (at two different frequencies).

FGPDB	$650.00
RF Board	$890.00
Tuner Board	$90.00
Front Panel Board	$40.00
Chassis	$230.00
Misc.	$180.00
Labor	$300.00
Total	**$2,380.00**

Production/Installation Status

The PCB acceptance test and LLRF controller assembly was done in-house. Test benches were built and firmware/software was written to facilitate the PCB testing.

For FRIB and ReA3 upgrade, 351 LLRF controllers in total are needed. We decided to build 378 controllers (~5% system level spares, plus another ~3% board level spares). By now, over 300 controllers have been built and installed covering up to FS2, leaving only LS3 to be finished (expected by end of 2017). All cabling will be done for LS1 by the end of 2017.

Front End racks for LLRF controllers and power amplifiers.

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