IFMIF-LIPAc LLRF control system development based on EPICS

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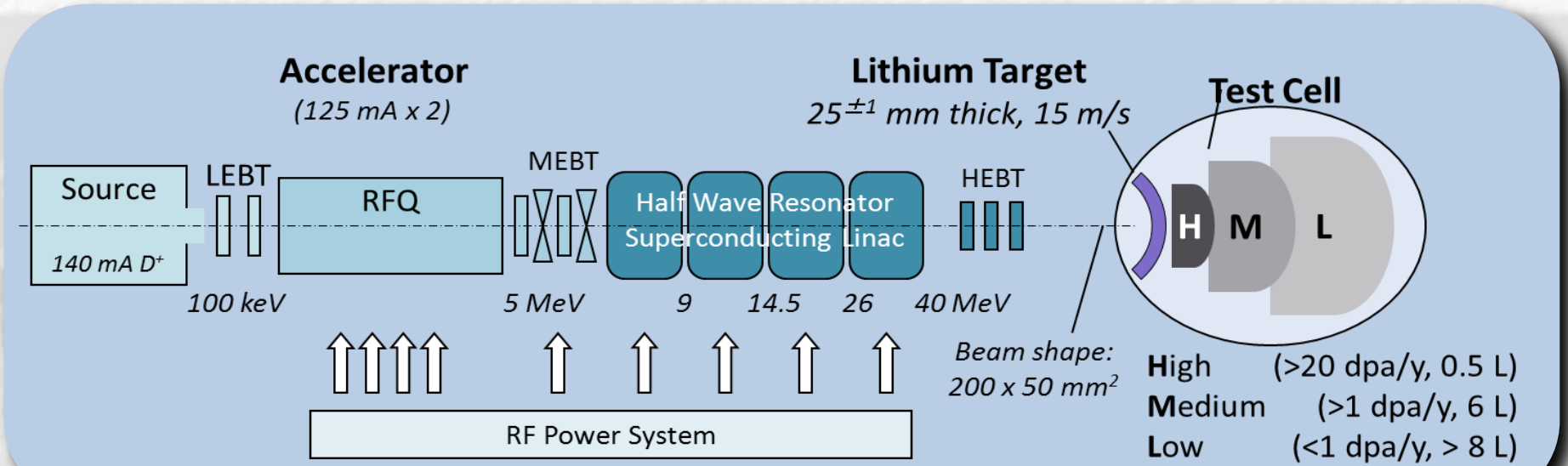
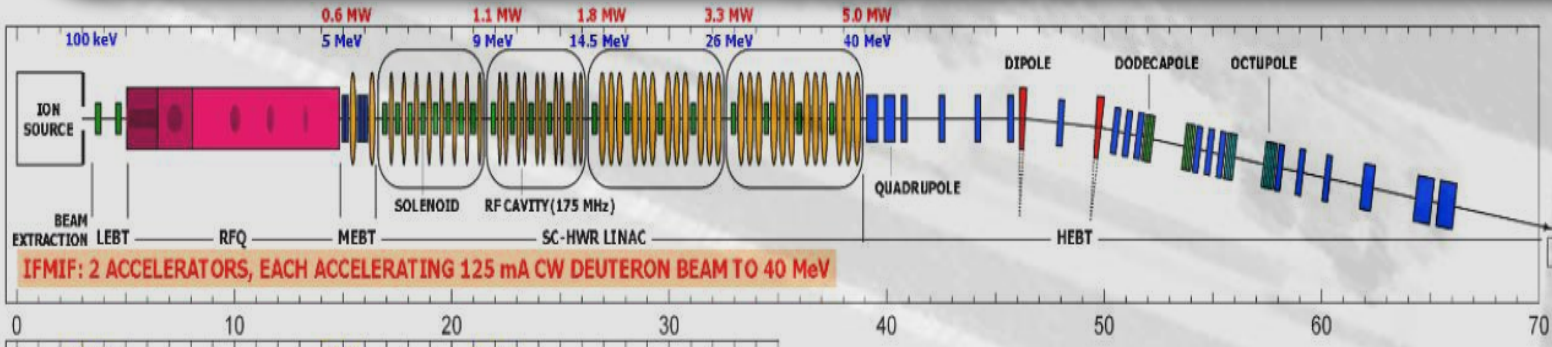
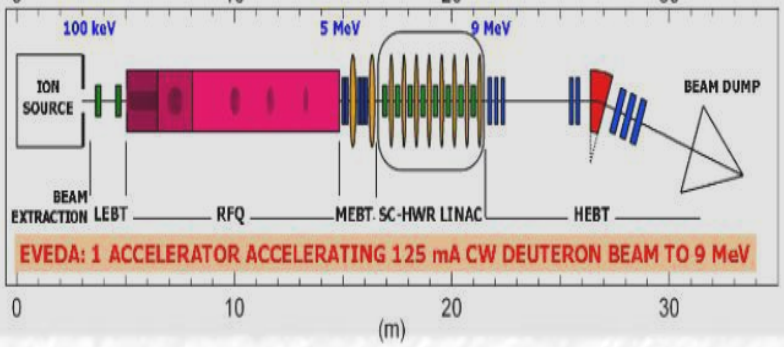
IFMIF LIPAc

Motivation

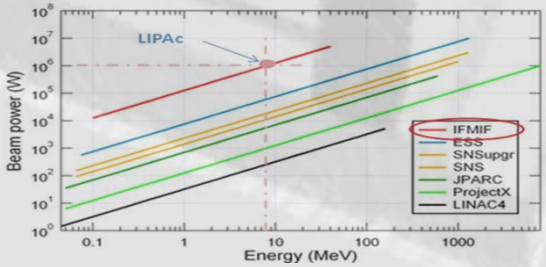


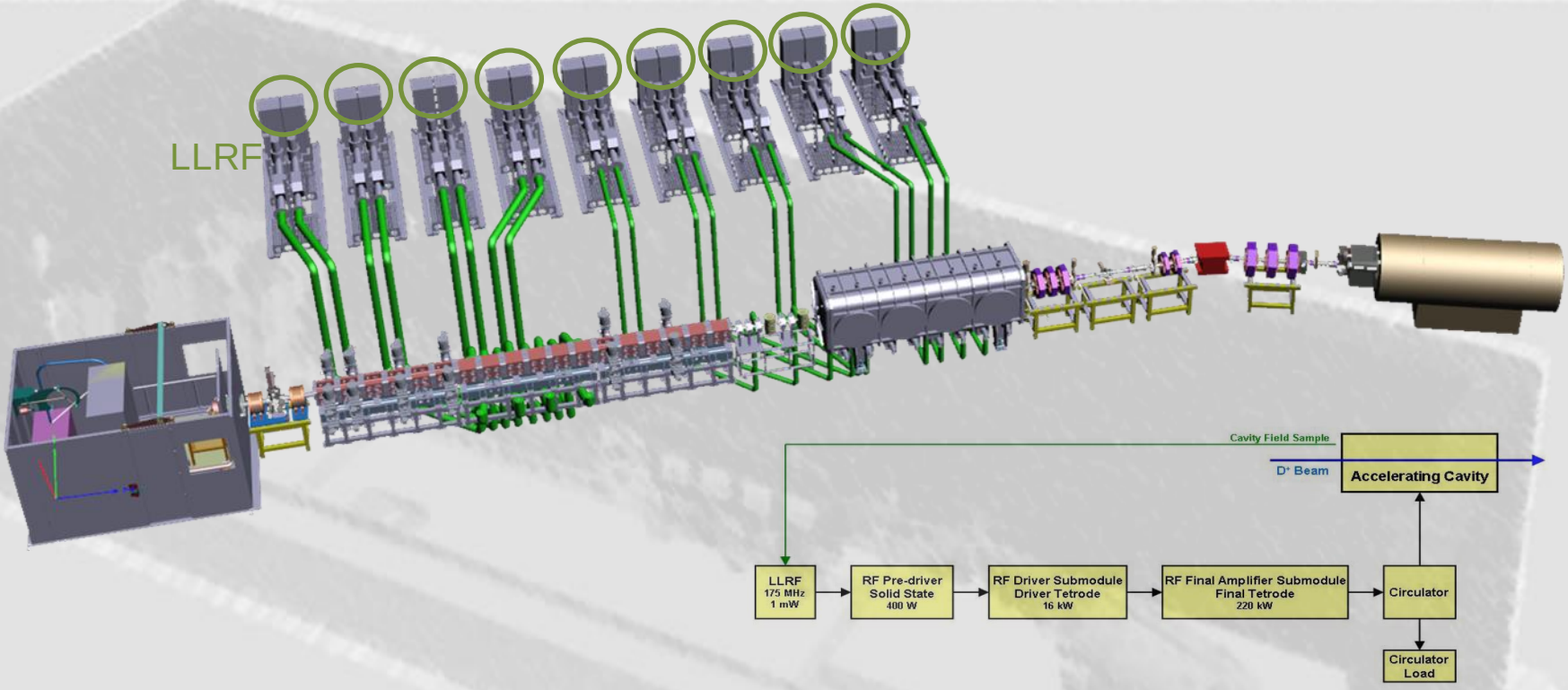


40 MeV
5MW
125 mA



9 MeV
1.125MW
125 mA





Low Level Radio Frequency (LLRF) Control System

LLRF control system

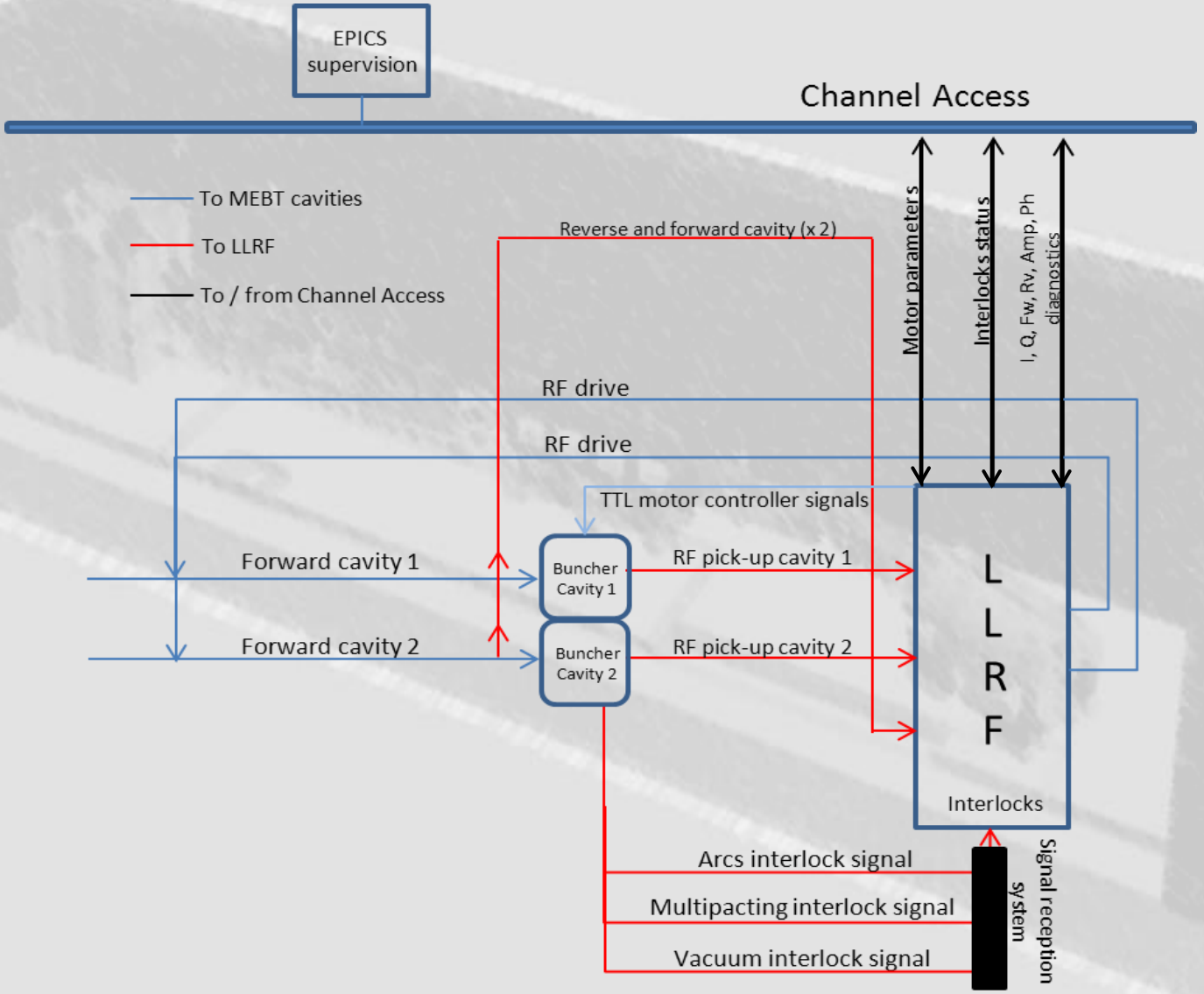
LIPAc LLRF system generates RF power to feed LIPAc cavities. It handles different functionalities for 18 three-stages amplifying chains:

- Amplitude and phase loop
- Cavities tuning
- Start-up

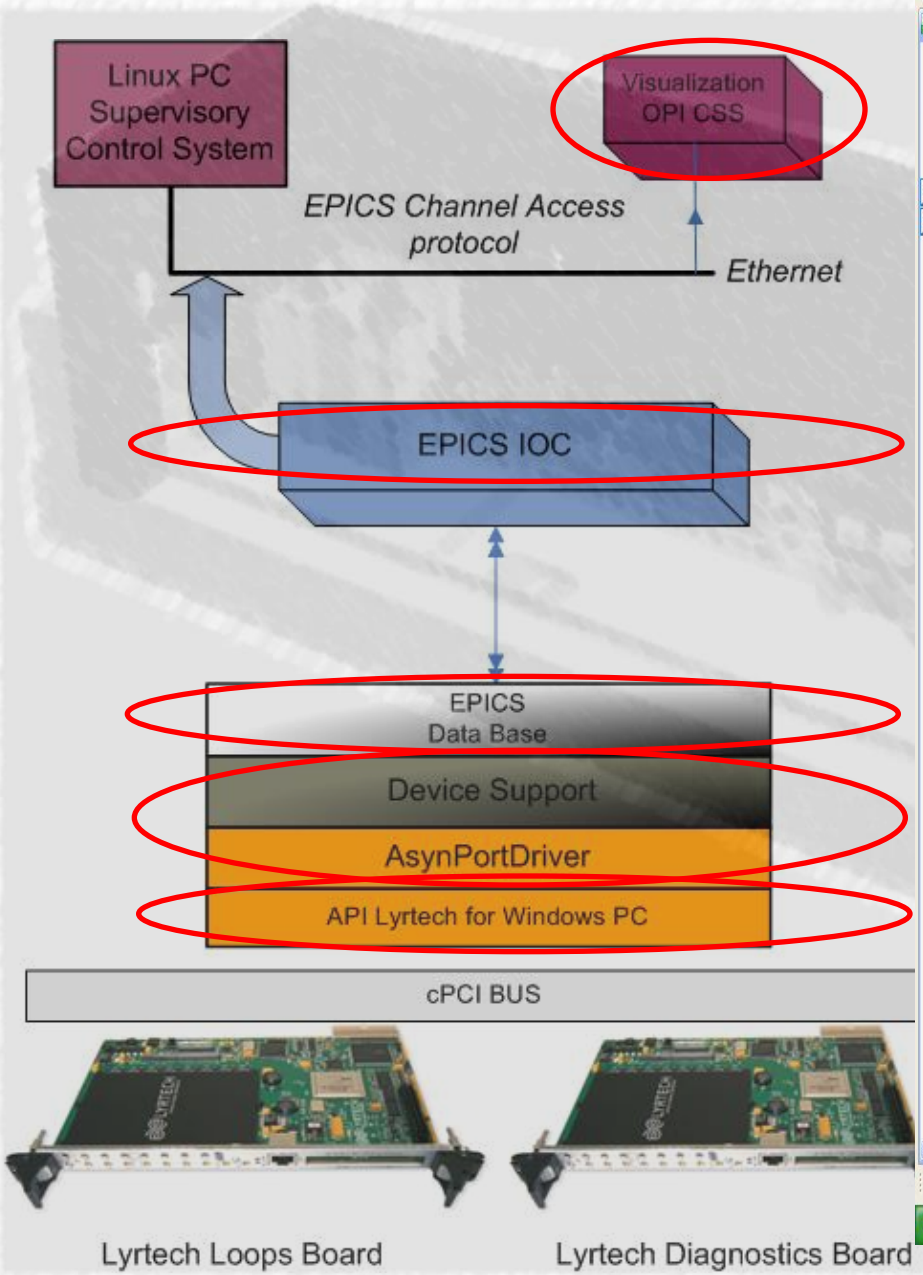
Main control problems encountered:

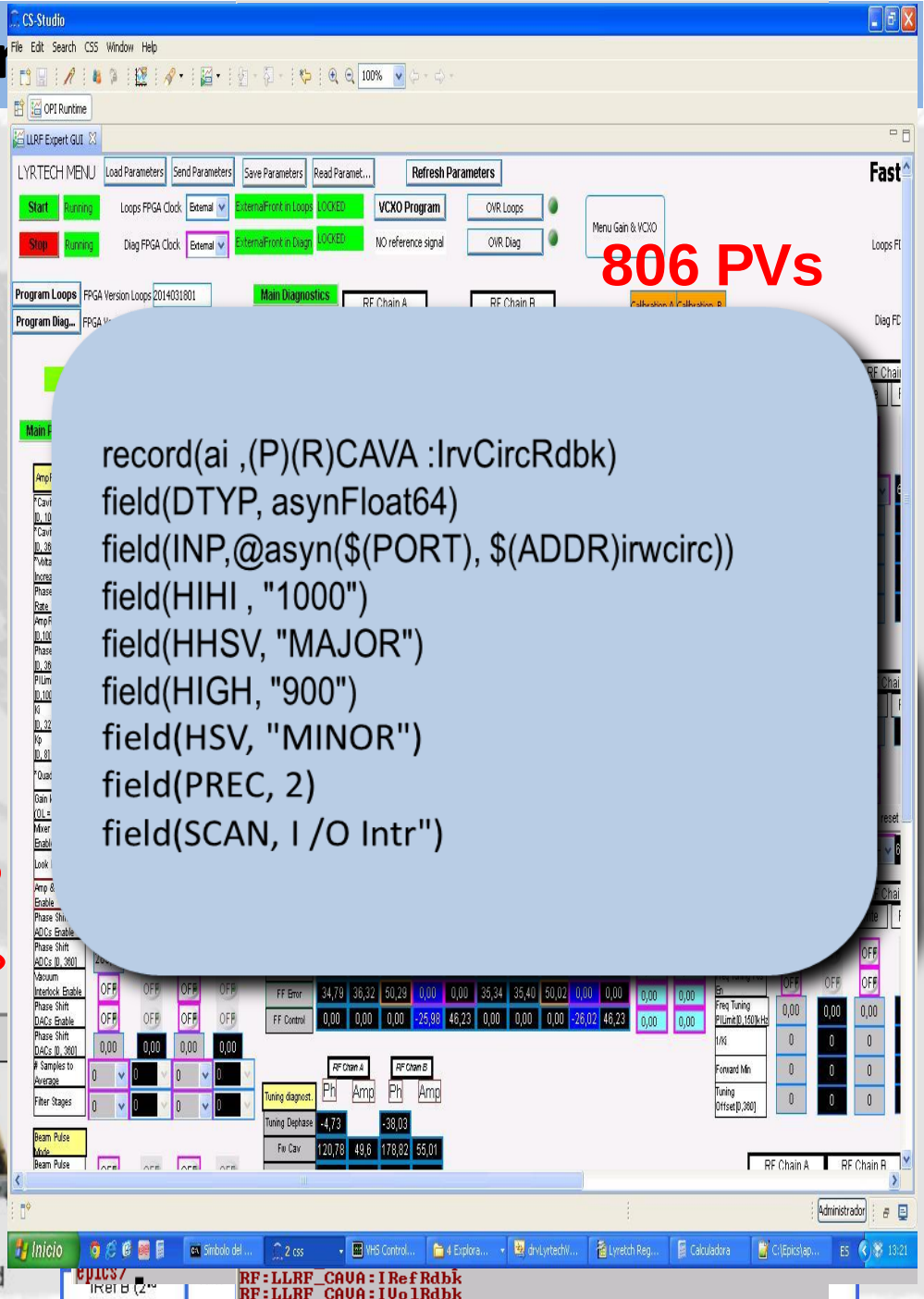
- More relevant part of the accelerator at control system software level
- Hundreds of signals to control
- Real time decisions bypassing CCS and operator
- Extra functionalities are needed

LLRF control system interfacing with MEBT

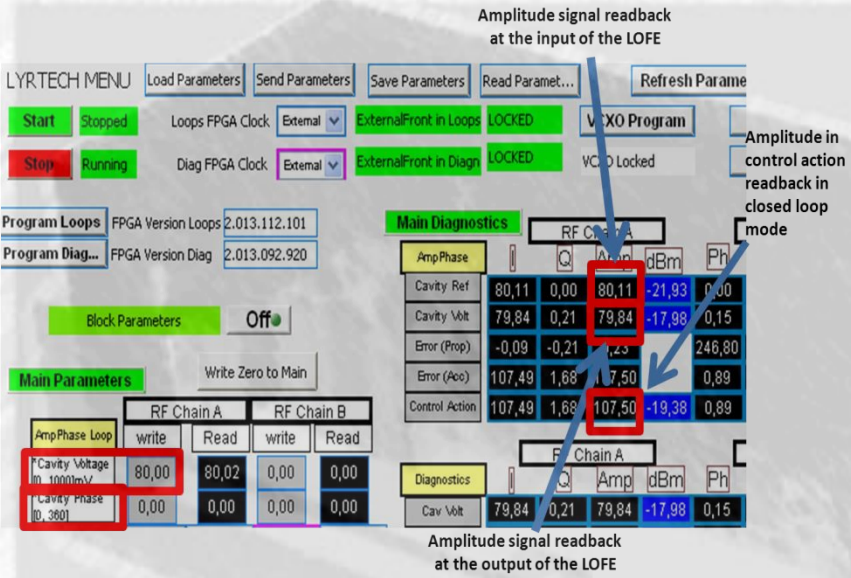


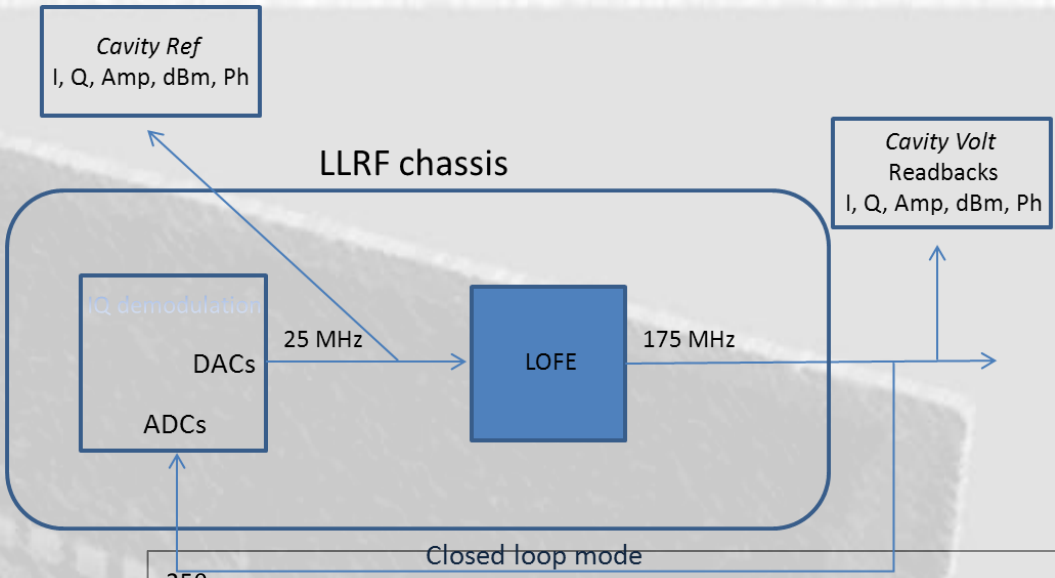
LLRF control system – softwar



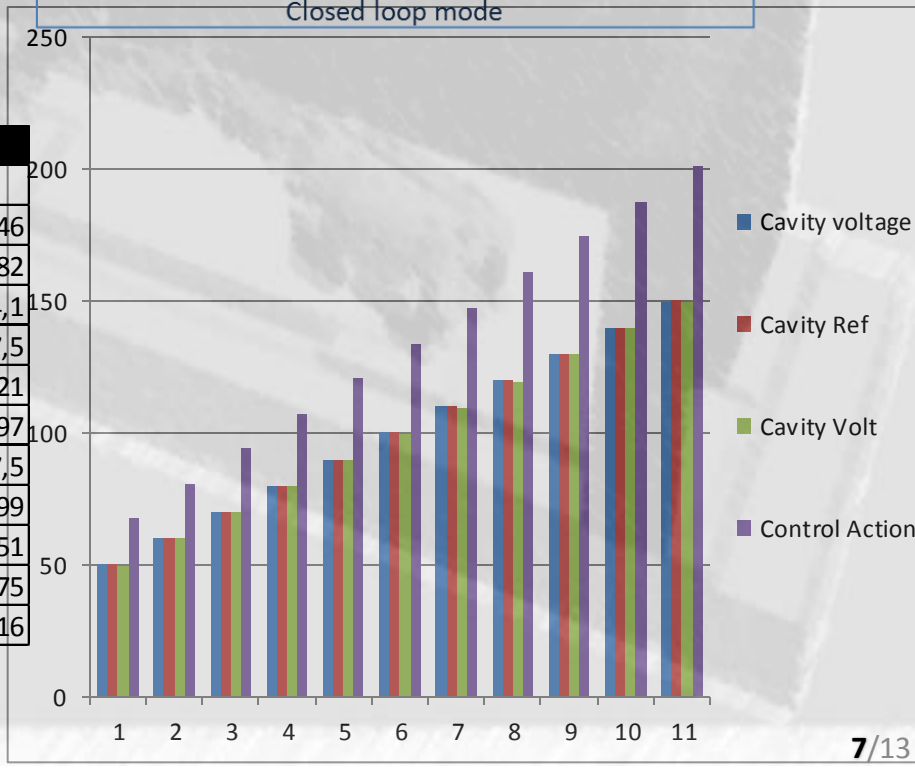


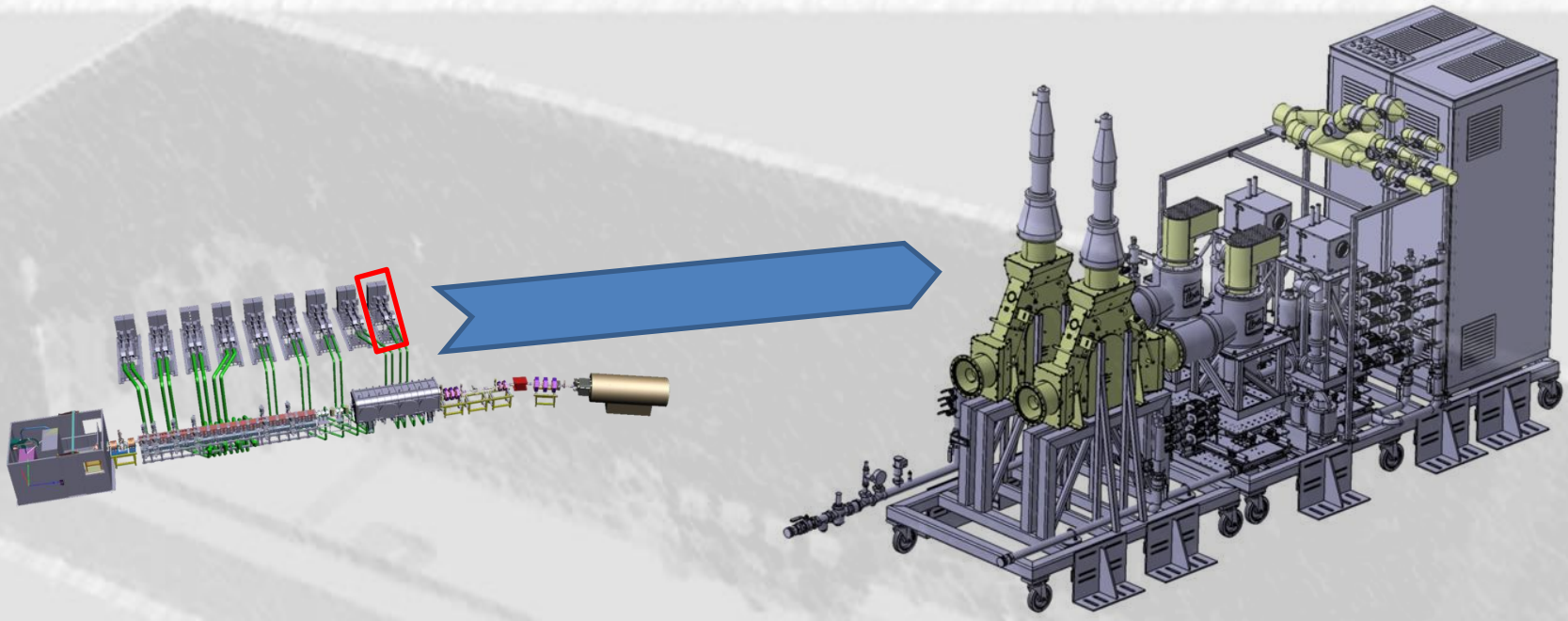
LLRF control system – Amplitude and phase closed loop





Closed Loop			
Cavity voltage	Cavity Ref	Cavity Volt	Control Action
50	50,11	49,9	67,46
60	60,09	59,85	80,82
70	70,16	69,89	94,1
80	80,11	79,84	107,5
90	90,12	89,75	121
100	100,07	99,65	133,97
110	110,05	109,65	147,5
120	120,09	119,6	160,99
130	130,1	129,58	174,51
140	140,11	139,59	187,75
150	150,09	149,48	201,16

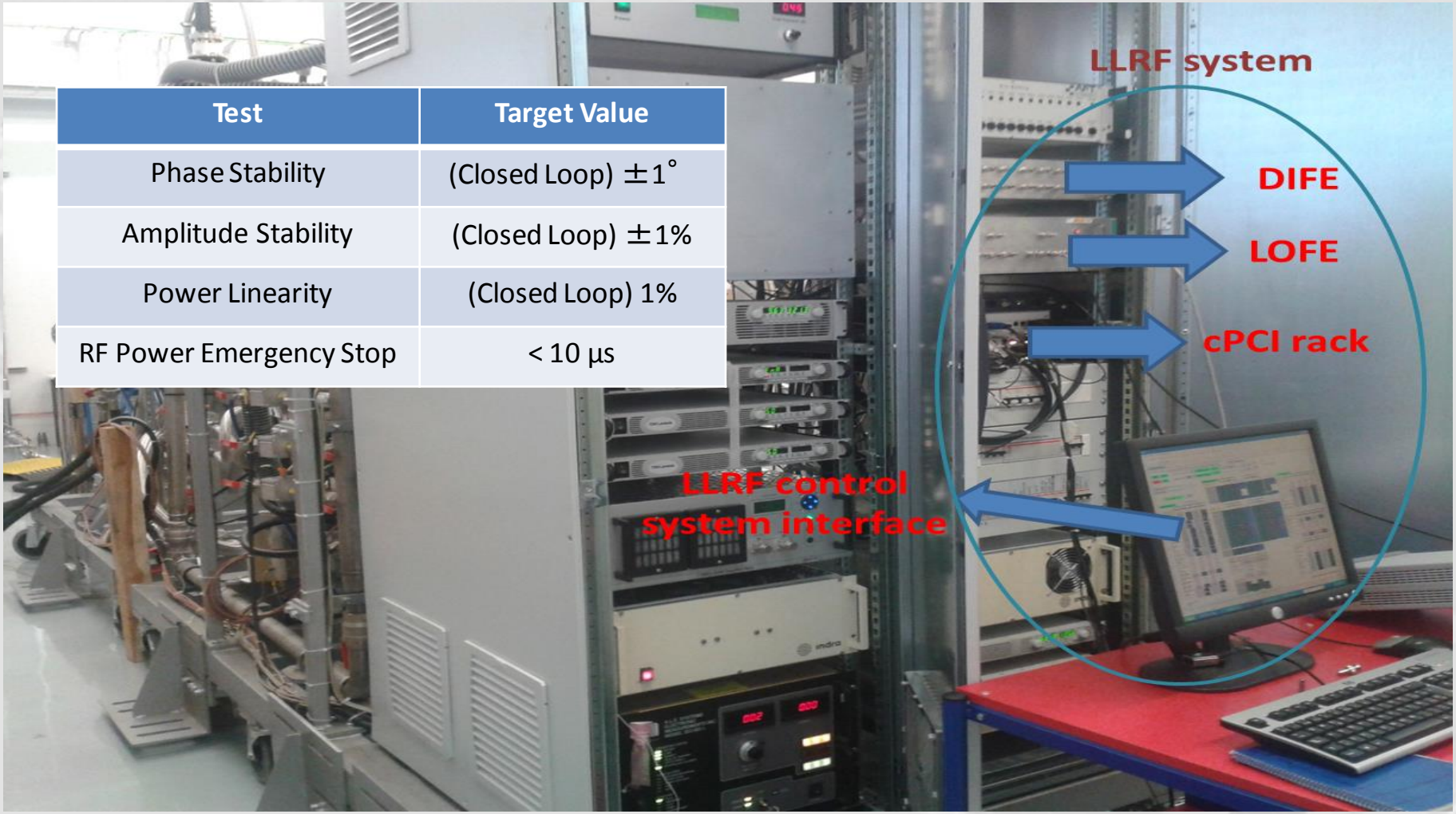




Tests on the RF Prototype Chain

Test on the RF Prototype Chain

Test	Target Value
Phase Stability	(Closed Loop) ±1°
Amplitude Stability	(Closed Loop) ±1%
Power Linearity	(Closed Loop) 1%
RF Power Emergency Stop	< 10 µs



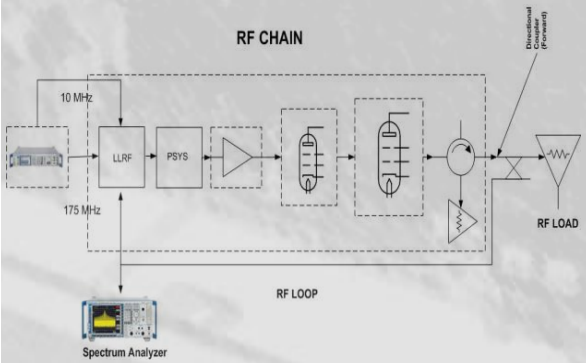
Any operation must be carried through the LLRF control system built over the explained solution and using the showed LLRF control interface

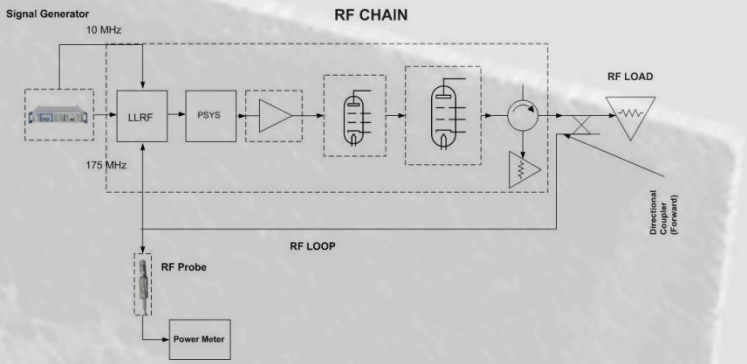
Tests on the RF Prototype Chain

Phase stability (±1°)

Amplitude stability (±1%)

Time	rms Jittter (s)
T0	1.1255 ps
T0+1’	1.1283 ps
T0+2’	1.1156 ps
T0+3’	1.1128 ps
T0+4’	1.1151 ps
T0+5’	1.1121 ps
T0+6’	1.1234 ps
T0+7’	1.1271 ps
T0+8’	1.1275 ps
T0+9’	1.1231 ps
T0+10’	1.1421 ps
T0+11’	1.1207 ps
T0+12’	1.1371 ps
T0+13’	1.1411 ps
T0+14’	1.1271 ps
T0+15’	1.1383 ps





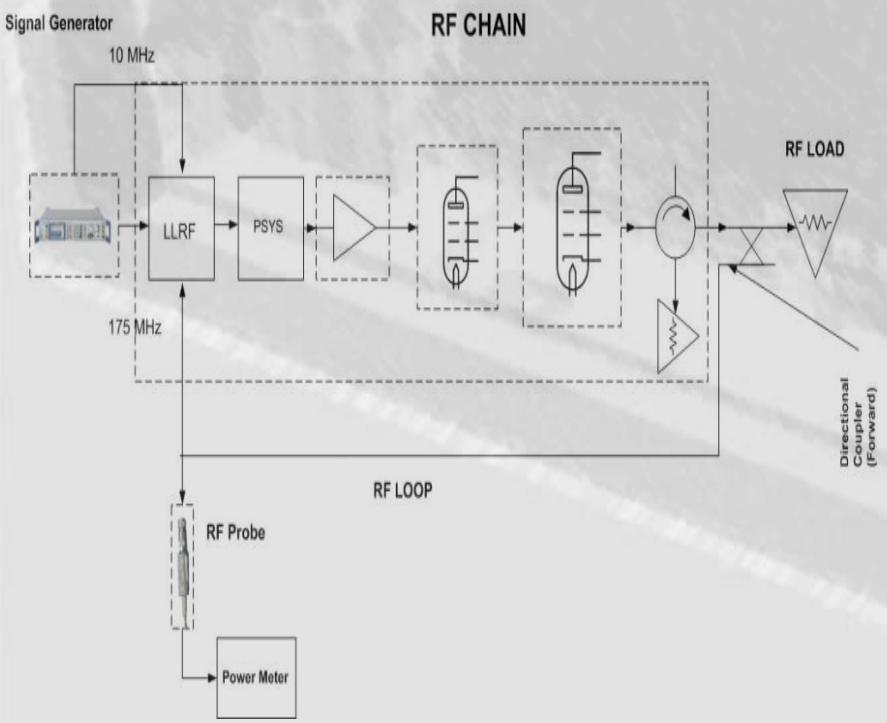
$\Phi = 2\pi f\tau = 0.0895°$

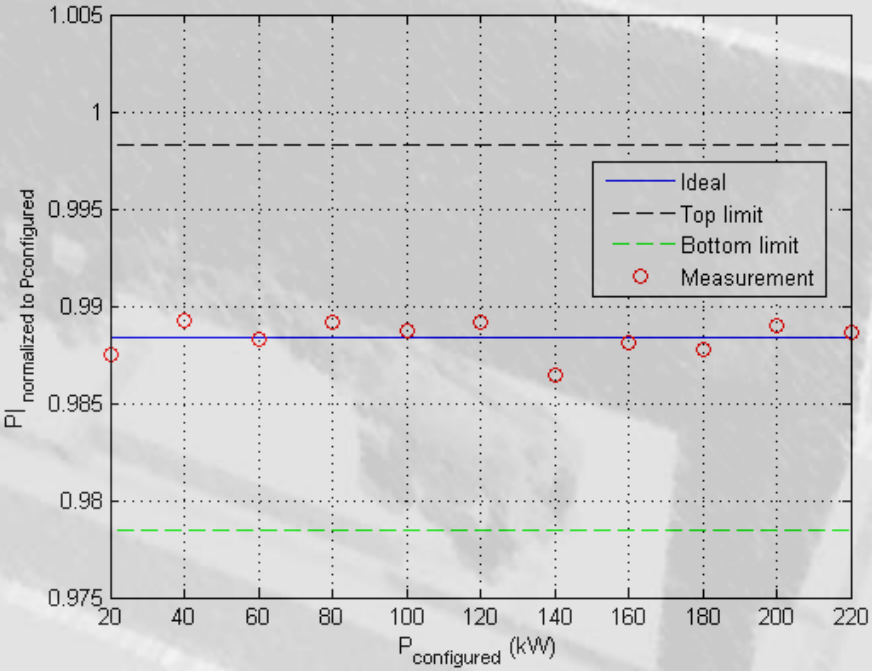
15 minutes at 220kW. Worst values are recorded:

- 0.2% , 219.54 KW
- 0.4% , 220.88 KW

Tests on the RF Prototype Chain

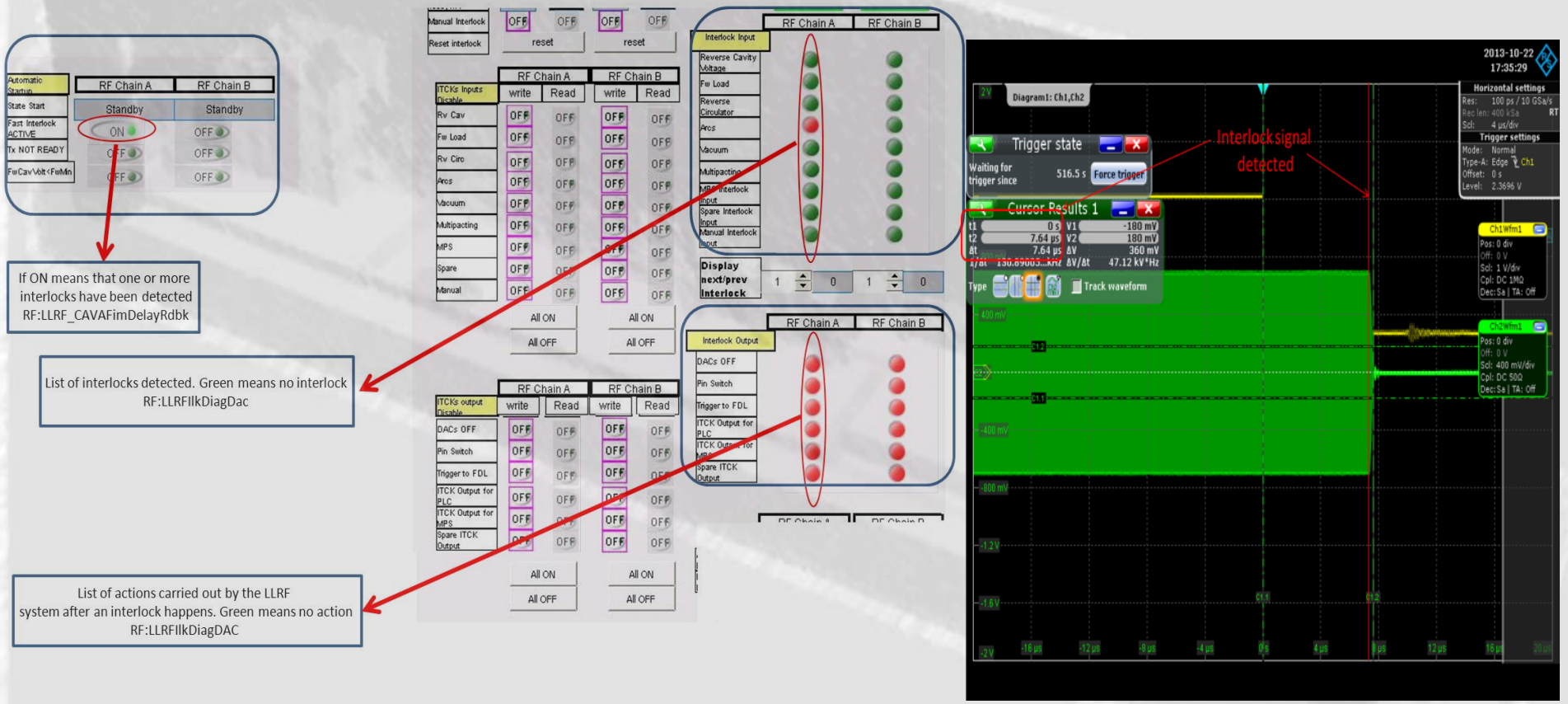
Linearity (±1%)





Tests on the RF Prototype Chain

Interlock alarm -> Emergency stop



Thank you!!

Author's publications related with this work

- **J. Calvo**, Mark L. Rivers, Miguel A. Patricio and A. Ibarra. EPICS Based Low-Level Radio Frequency Control System in LIPAc. Journal of Fusion Engineering and Design. Volume 87, Issue 11, November 2012, Pages 1872-1879, ISSN 0920 3796. *http://www.sciencedirect.com/science/article/pii/S0920379612004218*

- **J. Calvo**, Mark Rivers, M.A Patricio, Angel Ibarra. IFMIF LLRF Control System Architecture Based on EPICS. Proceedings of ICALEPCS, 2011, Grenoble, France. *http://accelconf.web.cern.ch/accelconf/icalepcs2011/papers/mopms009.pdf*

- E. Bargalló, G. Martínez, J. M. Arroyo, J. Abal, P.-Y. Beauvais, R. Gobin, F. Orsini, M. Weber, I. Podadera, D. Regidor, **J. Calvo**, A. Giralt, J. Dies, C. Tapia, A. De Blas, A. Ibarra and J. Mollá. RAMI analyses of the IFMIF accelerator facility and first availability allocation between systems. Journal of Fusion Engineering and Design. Volume 88, Issues 9-10, October 2013, Pages 2728-2731, ISSN 0920-3796. *http://www.sciencedirect.com/science/article/pii/S0920379612004772*

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- D. Regidor, A. Arriaga, **J. Calvo**, A. Ibarra, I. Kirpitchev, P. Méndez, J. Mollá, A. Salom and M. Weber. IFMIF-EVEDA RF Power System. In Proceedings of IPAC, 2011, San Sebastián, Spain. *http://accelconf.web.cern.ch/accelconf/IPAC2011/papers/mopc135.pdf*

- A. Salom, A. Arriaga, **J. Calvo**, I. Kirpitchev, P. Méndez, D. Regidor, M. Weber, A. Mosnier, F. Pérez. Digital LLRF for IFMIF-EVEDA. In Proceedings of IPAC, 2011, San Sebastián, Spain. *http://accelconf.web.cern.ch/accelconf/IPAC2011/papers/mopc160.pdf*

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- J. Mollá, P. Méndez, B. Brañas, M. Weber, I. Podadera, **J. Calvo**, J.M. Carmona, A. García, J.M. Arroyo, J.C. Mora and A. Ibarra. Spanish contribution to the IFMIFEVEDA Project. 16th International Conference on Emerging Nuclear Energy Systems, 2013. *http://www.icenes2013.org/ViewFile.aspx?codReg=76*

- J. Marroncle, P. Abbon, J.F. Denis, J. Egberts, F. Jeanneau, J.F. Gournay, A. Marchix, J.P. Mols, T. Papaevangelou, M. Pomorski, **J. Calvo**, J.M. Carmona, D. Iglesias, C. Oliver, I. Podadera, A. Guirao and M. Poggi. IFMIF-LIPAc Diagnostics and its Challenges. Proceedings of the International Beam Instrumentation Conference (IBIC), 2012. *http://www.researchgate.net/publication/235060771*

- F. Orsini, N. Bazin, P. Brédy, P. Carbonnier, G. Devanz, G. Disset, N. Grouas, P. Hardy, V. Hennion, H. Jenhani, J. Migne, A. Mohamed, J. Neyret, B. Renard, J. Relland, D. Roudier, P. Abramian, J. Calero, **J. Calvo**, J.L. Gutiérrez, T. Martinez, J. Munilla, I. Podadera and F. Toral. Progress on the SRF Linac Developments for the IFMIF-LIPAc Project. In Proceedings of IPAC, 2013, Shanghai, China. *http://accelconf.web.cern.ch/accelconf/IPAC2013/papers/thpfi004.pdf*

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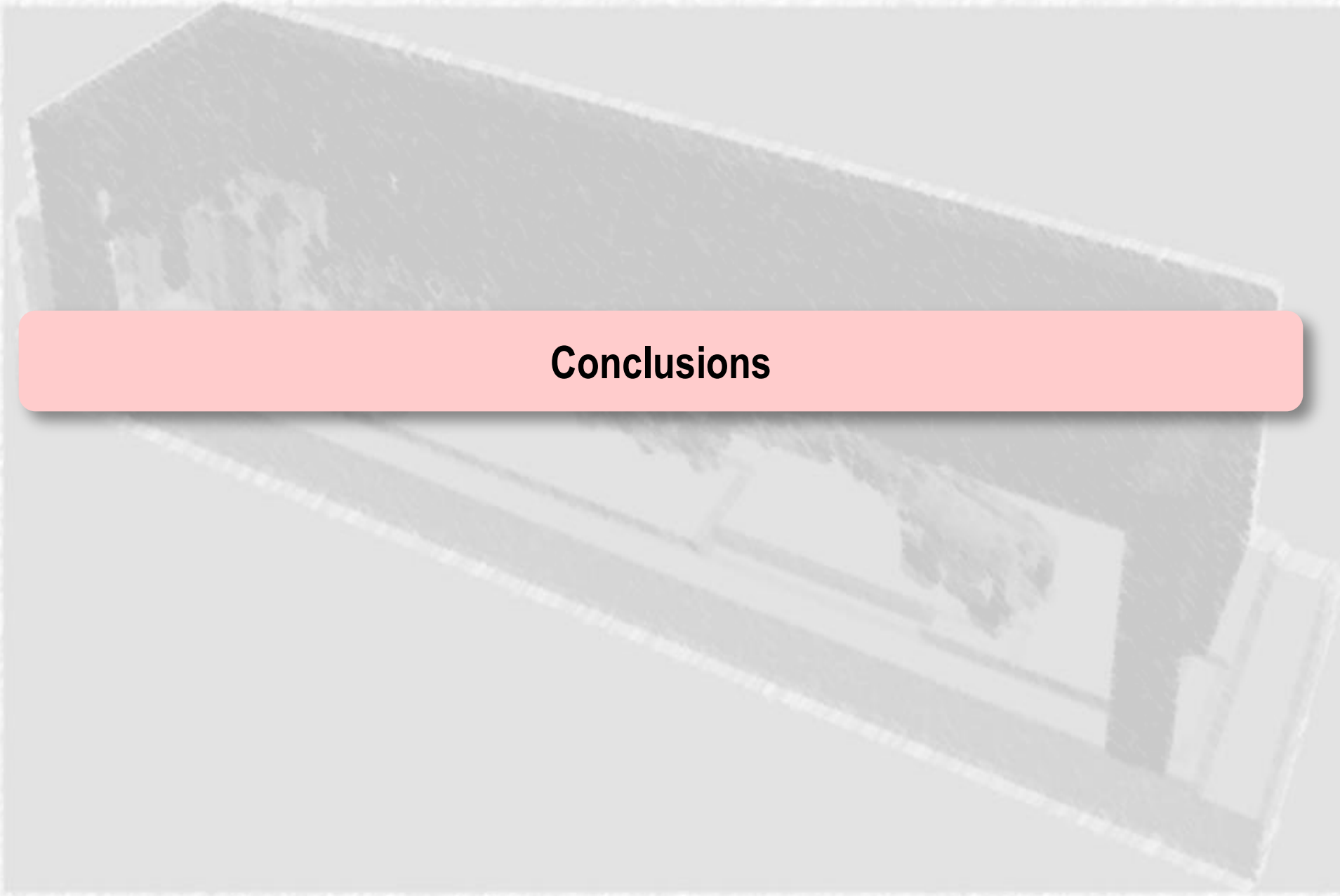
- **J. Calvo**, J. González, J.F. Gournay, J.Y. Rousse, D. Bogard, J.F. Denis, J. Relland, M.Giacchini, L.Antoniazzi and M.Montis. LIPAc Local Control Systems Engineering Design Report, 2013. Technical Report.

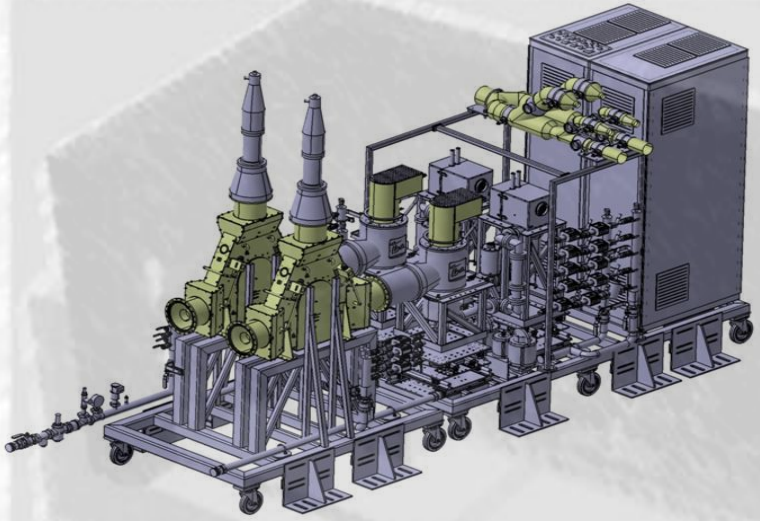


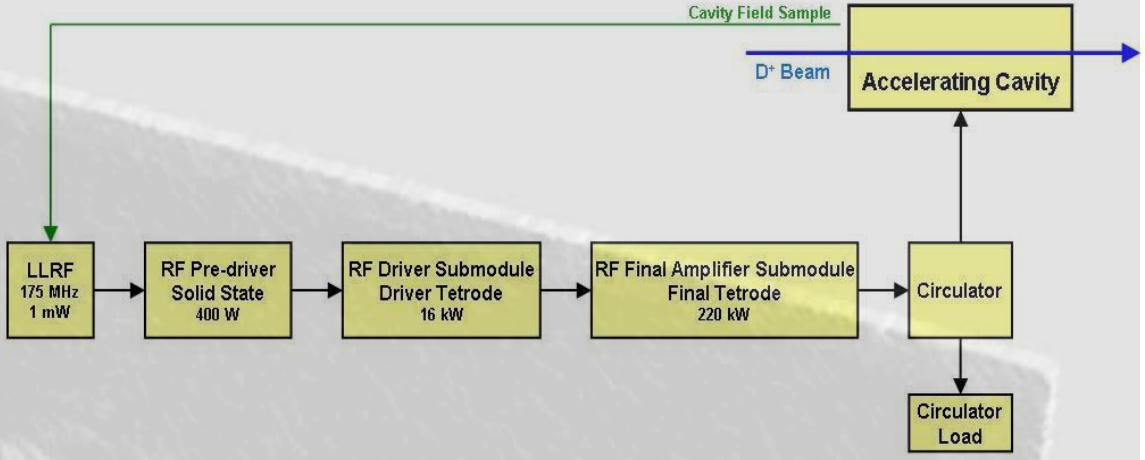
Conclusions

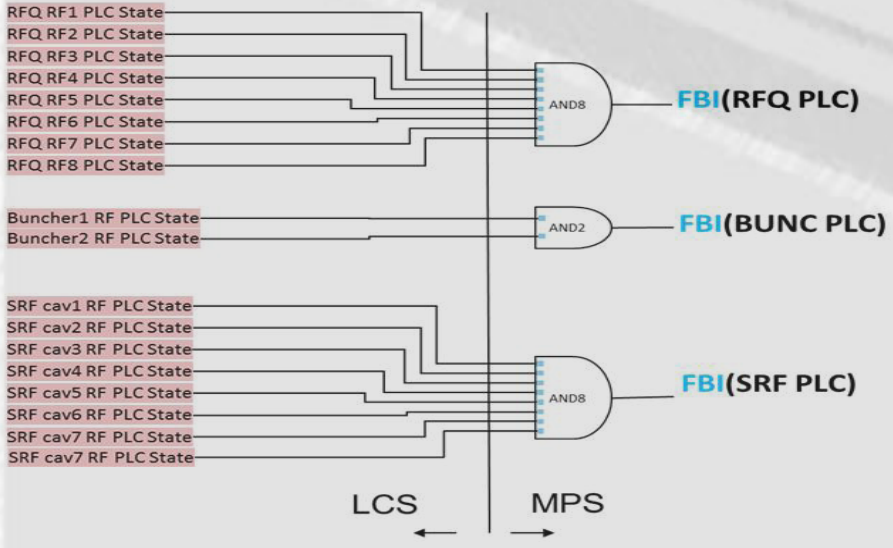
Future work lines

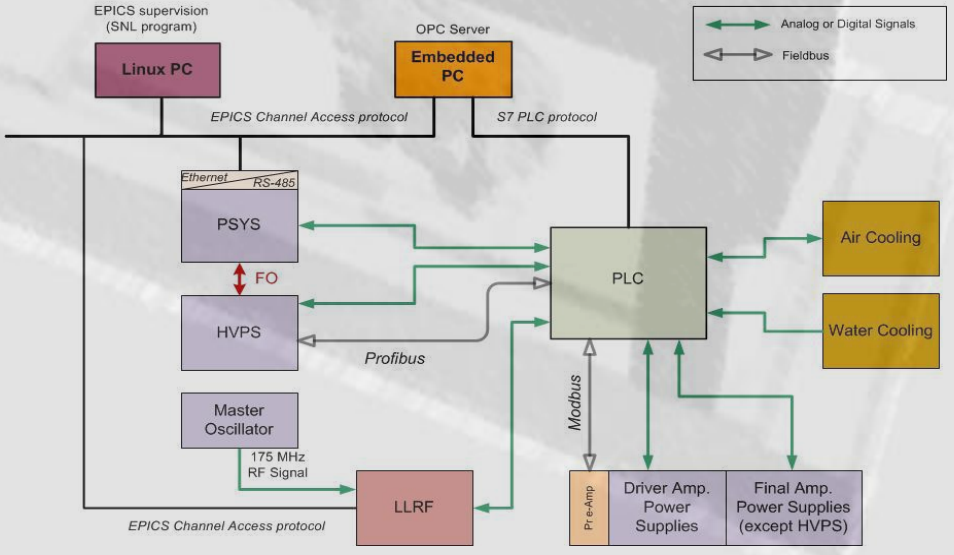
- Local control systems integration at accelerator site.
- IFMIF Lithium target control system challenge.
- LLRF device support validation in other hardware.
- Virtual control system for IFMIF based on LIPAc results.

Radio Frequency (RF) LCS



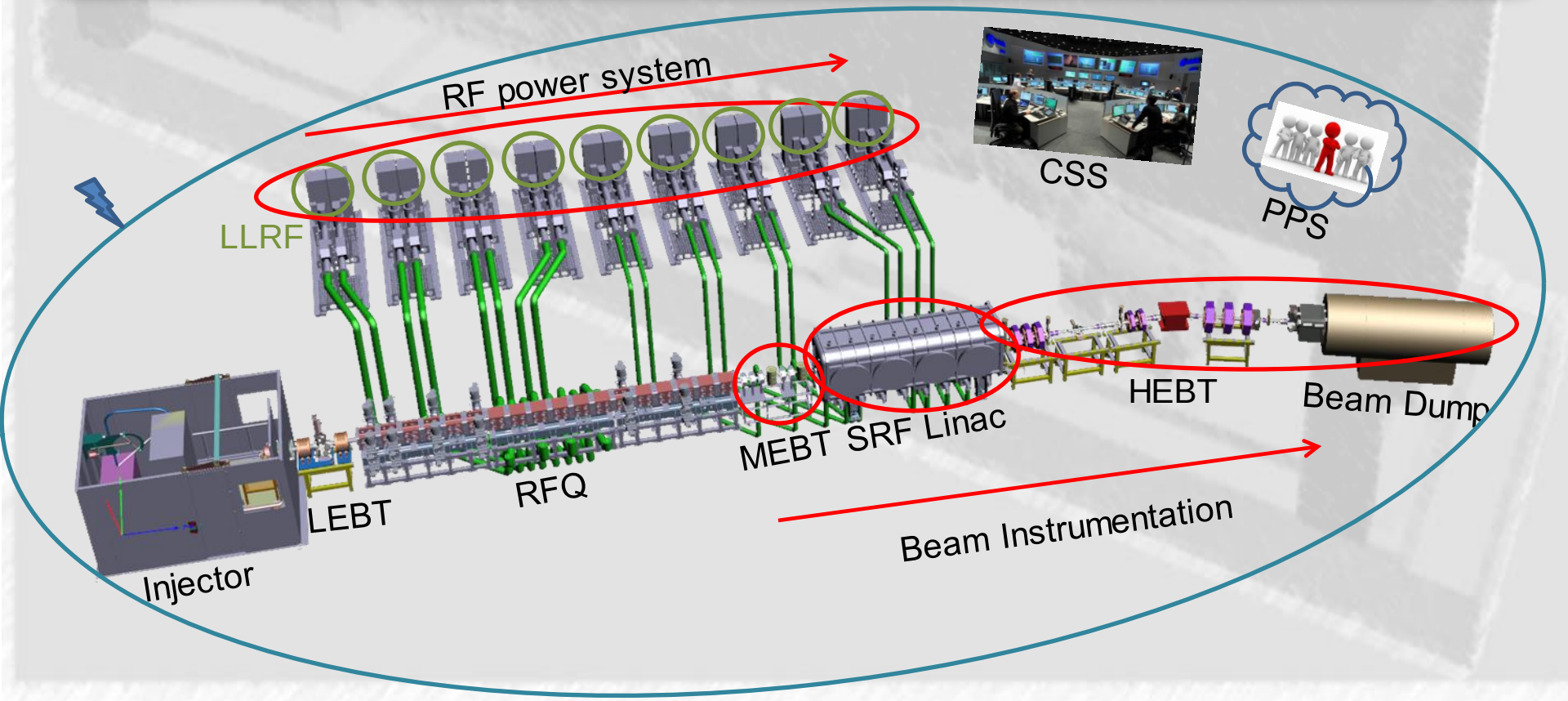






Objectives

- To carry out the design and development of the local control system for some of the explained subsystems.
- To achieve the design and development of Low Level Radio Frequency (LLRF) control system.
- To contribute to the design on the Machine Protection System (MPS), Personal Protection System (PPS) and the Central Control System (CCS).



Main results

Local control and protection systems

- Control of transport and focalization devices in MEBT subsystem
- Control of solenoid package in SRF Linac
- RF local control system architecture definition
- Control of transport and focalization devices in HEBT and BD subsystem
- Control of BPMs, FPMs and slits in BI subsystem
- Essential protection signals detection and definition

Low level radio frequency control system

- More than 800 hundreds PVs are controlled.
- Real-time and accurate communication with other subsystems
- Essential functionalities developed
- Successfully tested in the RF Prototype Chain