

LLRF Operator Training for XFEL

Introduction and Guide Lines

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DESY, 27.02.2018

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> What does LLRF stand for? What is it about?

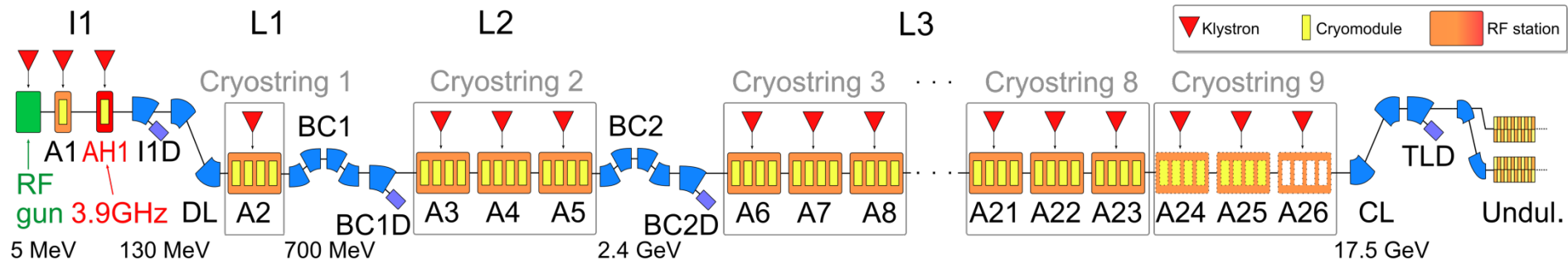
- Low Level Radio Frequency
- Our task: digital LLRF control of accelerating fields within cavities
- RF frequency in gun cavity and superconducting cavities: 1.3 GHz (3.9 GHz at AH1)
- Frequencies too fast for ADCs → Mixing with 1.354 GHz and by this downconversion to 54 MHz → Sampling with 81 MHz
- Low level of frequency and amplitude, BUT original amplitude and phase information is preserved
- Digital signal processing and control
- Generation of drive signal (DAC + upconversion to 1.3 GHz or 3.9 GHz)



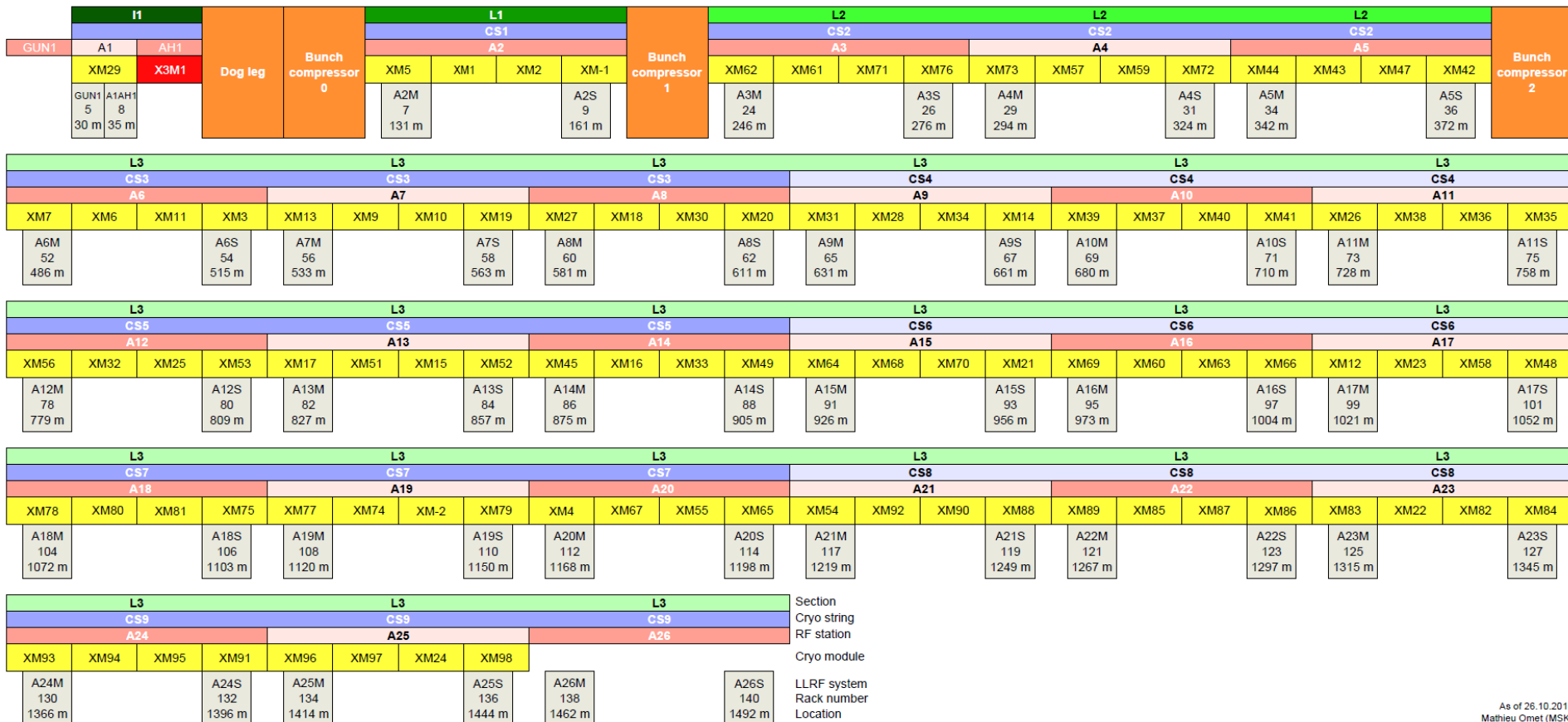
Introduction

> Where are we involved?

- In every RF station
- For now 28 LLRF systems
- More to come with injector 2



LLRF Station Overview

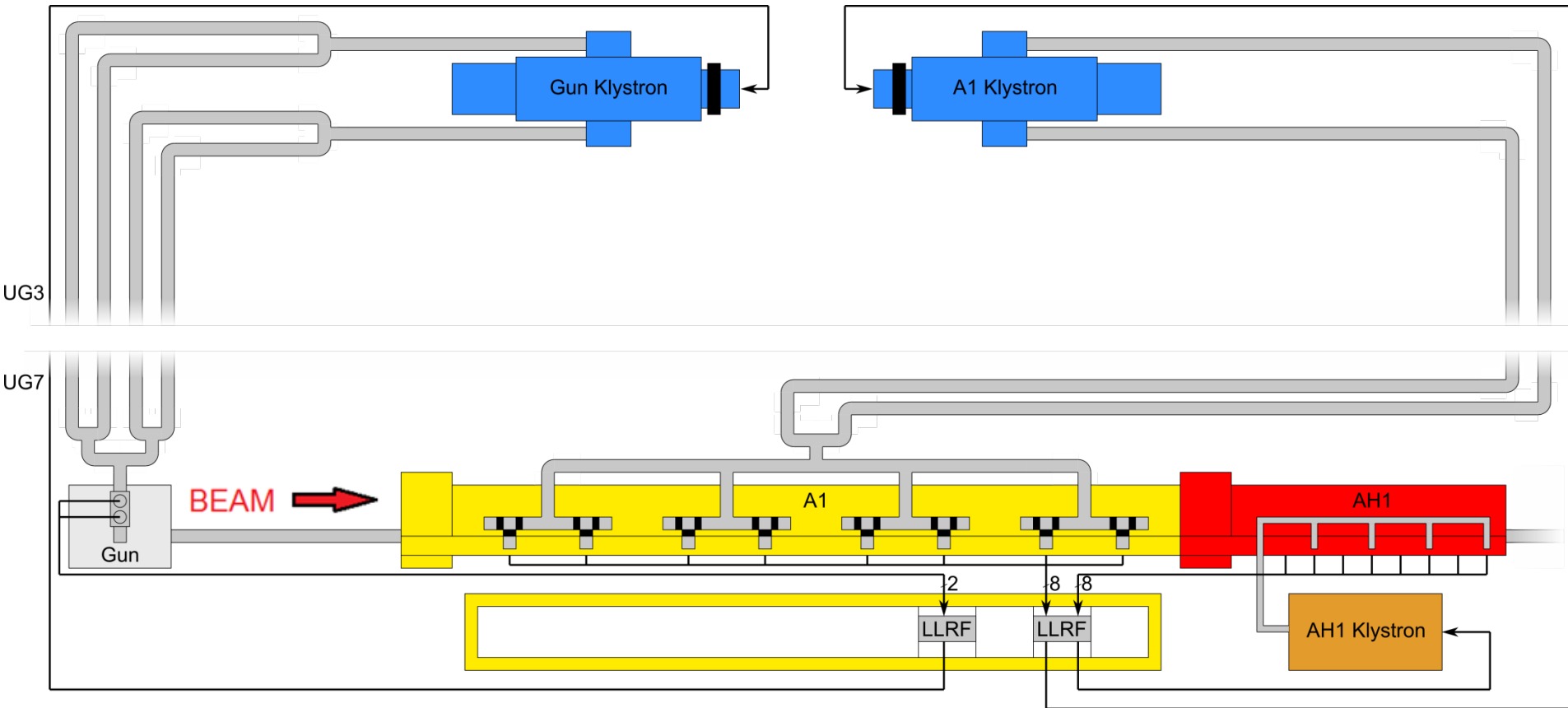


As of 26.10.2016
Mathieu Omet (MSK)



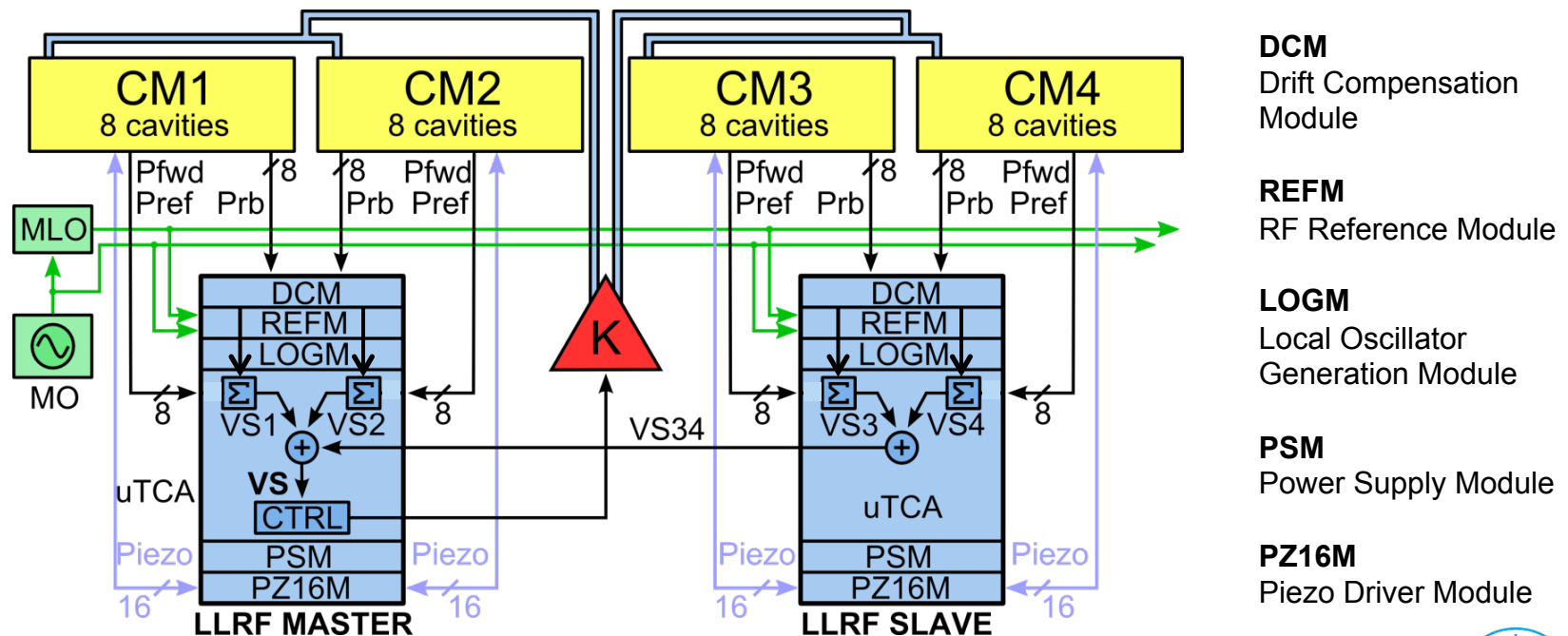
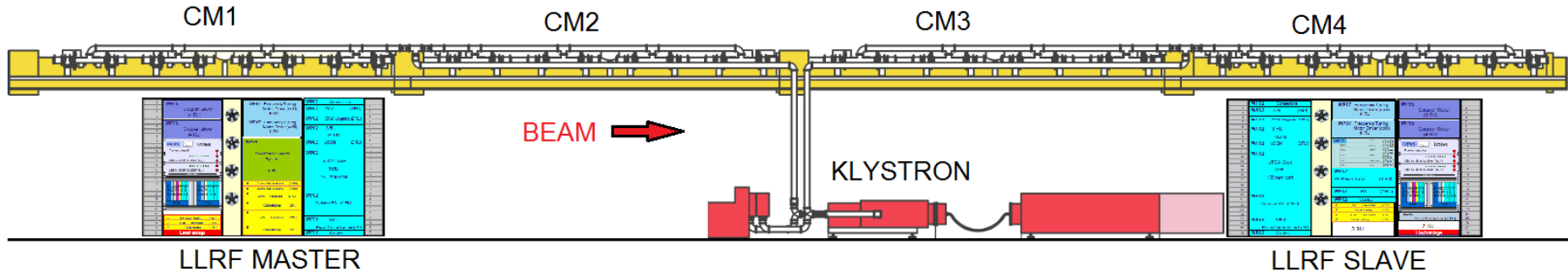
Introduction

> RF Stations of the Injector 1



LLRF System Description

> XTL RF station: semi-distributed LLRF system



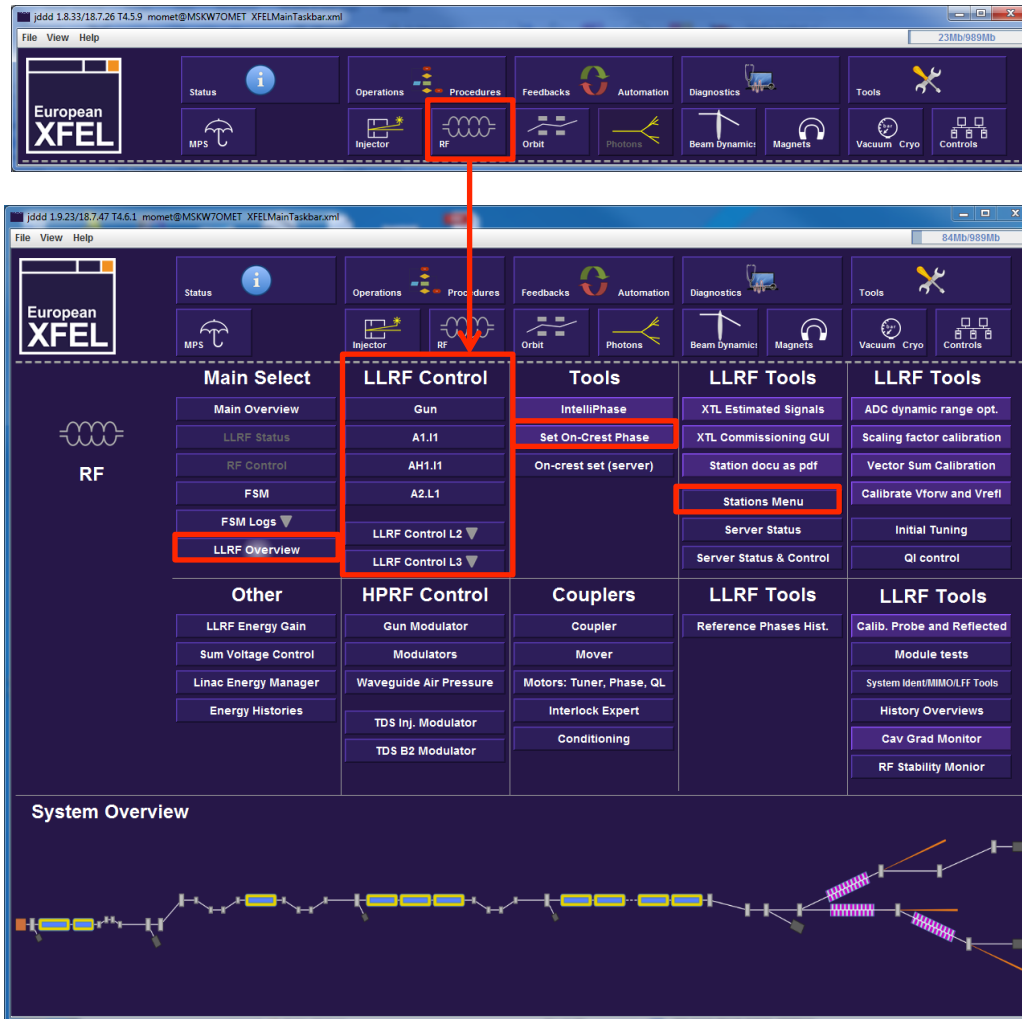
What an operator should know

- > For now let's focus on the injector
- > Tasks of the XFEL operator:
 - Turn on an RF station
 - Adjust the vector-sum voltage
 - Adjust the vector-sum phase
 - Tune cavities, if necessary
 - Adjust output vector correction and ratio, if necessary
 - Set a certain phase as on-crest phase
 - Turn off an RF station



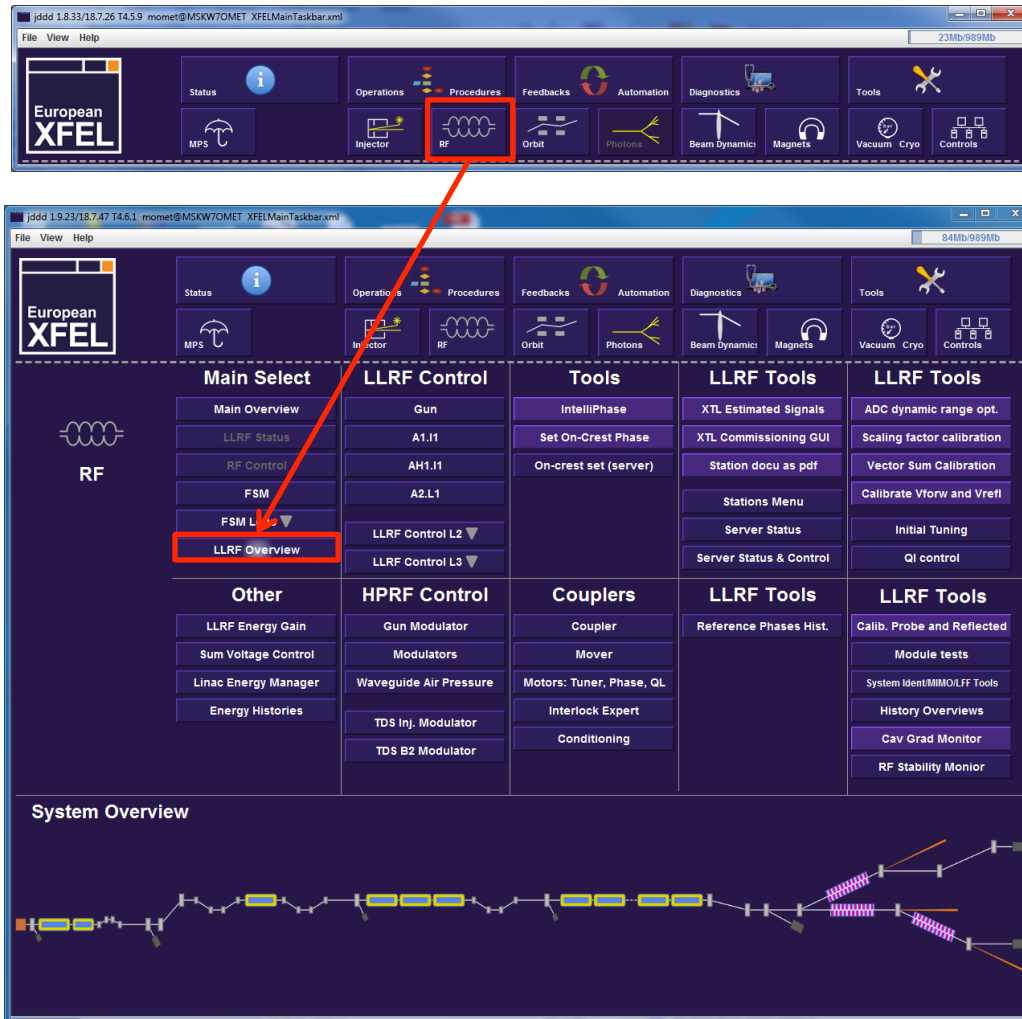
What an operator should know

➤ Where to find the LLRF panels



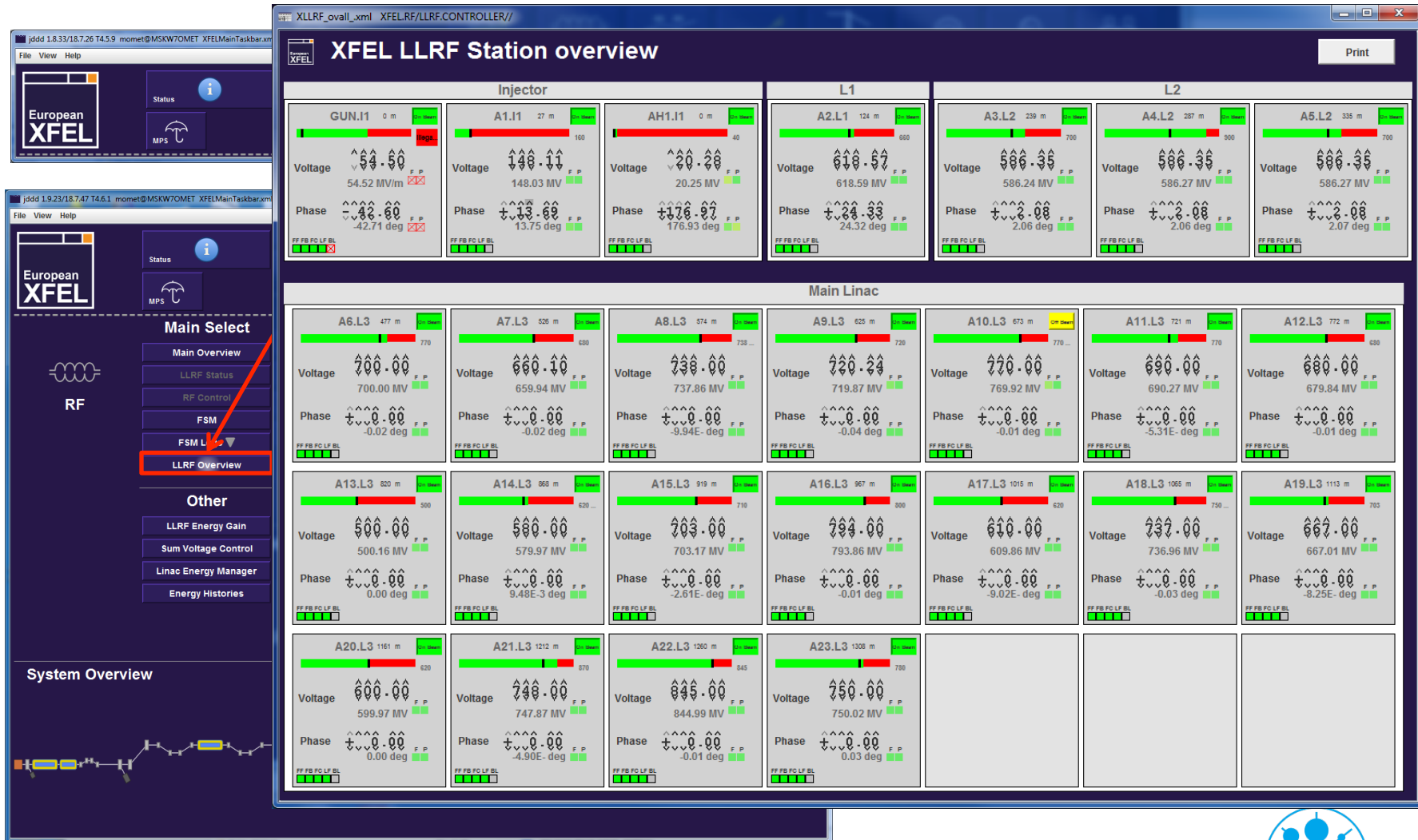
What an operator should know

➤ LLRF overview panel



What an operator should know

➤ LLRF overview panel



What an operator should know

➤ Opening LLRF station panel

The image shows a sequence of three screenshots from the European XFEL LLRF control software, illustrating the steps to open the LLRF station panel.

Top Screenshot: The main taskbar is visible with various icons. The 'RF' icon, located under the 'Operations' tab, is highlighted with a red box. A red arrow points from this icon to the middle screenshot.

Middle Screenshot: The 'RF' icon is selected, opening the 'LLRF Control' panel. This panel contains several sub-sections: 'Main Select', 'Tools', 'LLRF Tools', and 'Other'. The 'Main Select' section includes buttons for 'Main Overview', 'LLRF Status', 'RF Control', 'FSM', 'FSM Logs', and 'LLRF Overview'. The 'Tools' section includes 'IntelliPhase', 'Set On-Crest Phase', and 'On-crest set (server)'. The 'LLRF Tools' section includes 'XTL Estimated Signals', 'XTL Commissioning GUI', 'Static focus as pdf', 'Stations Menu', 'Server Status', and 'Server Status & Control'. The 'Other' section includes 'LLRF Energy Gain', 'Sum Voltage Control', 'Linac Energy Manager', and 'Energy Histories'. The 'Stations Menu' button is highlighted with a red box. A red arrow points from this button to the bottom screenshot.

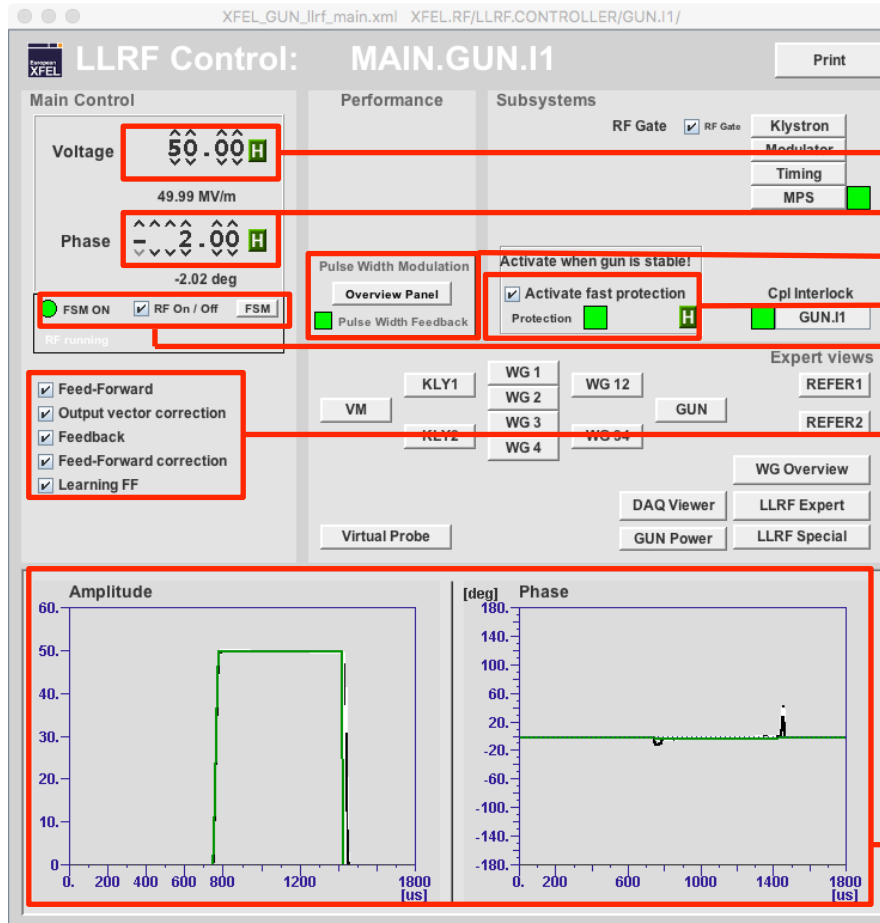
Bottom Screenshot: The 'Stations Menu' is open, displaying a table of LLRF stations. The table is titled 'XFEL - LLRF overview' and shows the following data:

INJ1		L1		L2		B2		L3																					
G	1	3H	TDS	2	3	4	5	TDS	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

The 'System Overview' section at the bottom of the middle screenshot shows a diagram of the XFEL linac structure.

What an operator should know

> Gun



Voltage setpoint

Phase setpoint

Pulse Width Modulation

Gun fast protection

FSM RF on/off

Feed-Forward

Output Vector Correction

Feedback

Feed-Forward Correction

Learning Feed-Forward

Reset correction tables

(LLRF Expert -> LFF -> Reset)

Ramp up gun

(voltage & flattop length)

Setpoint amplitude and phase

Reconstructed cavity amp. and pha.

*Turn on with FSM

*Turn on manually

2) 1)
5) 11)
4) 10)
3) 9)
1)

2)

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7)

8)

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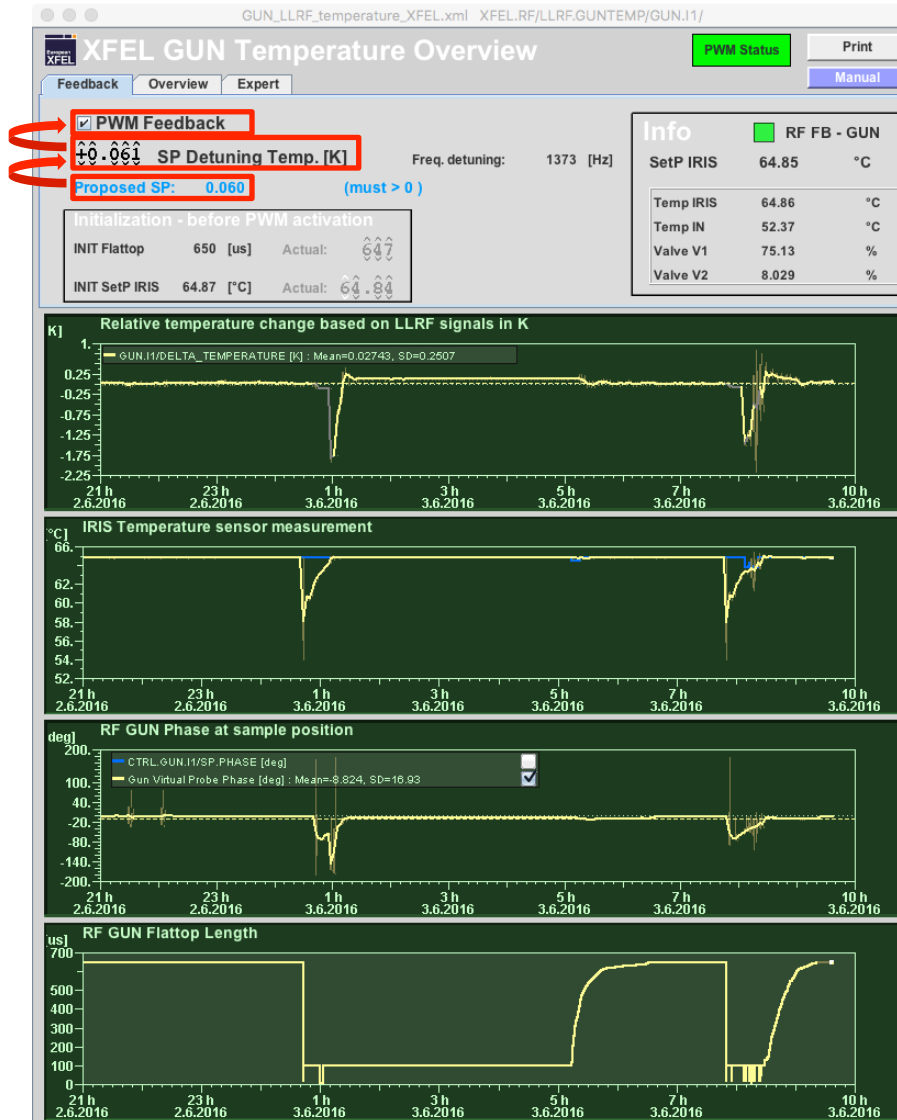
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What an operator should know

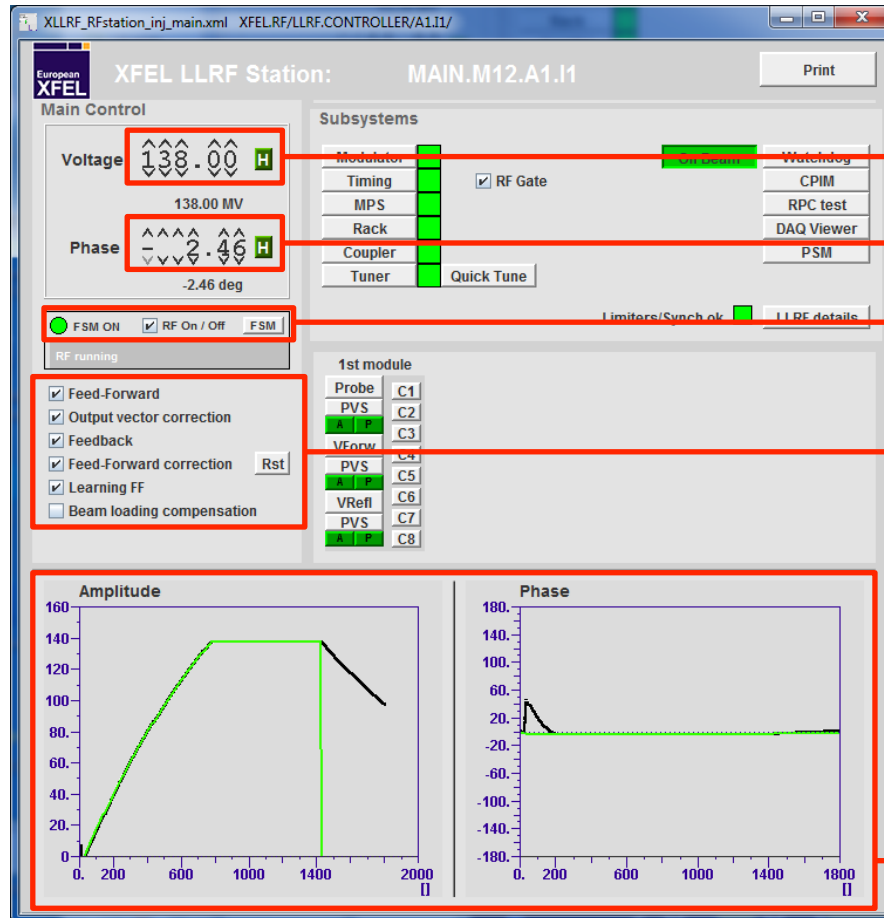
➤ Gun Pulse Width Modulation

- Use only after stable gun operation is achieved
- Use only during stable valve situation



What an operator should know

> A1.I1



Voltage setpoint

Phase setpoint

FSM RF on/off

Feed-Forward
Tune cavities

OVC, Ratio

Feedback

Feed-Forward correction

Correction Table Reset

Learning Feed-Forward

Beam Loading Compensation

Setpoint amplitude and phase

Vector sum amplitude and phase

*Turn on with FSM

*Turn on manually

2) 1), 3)

2) 3)

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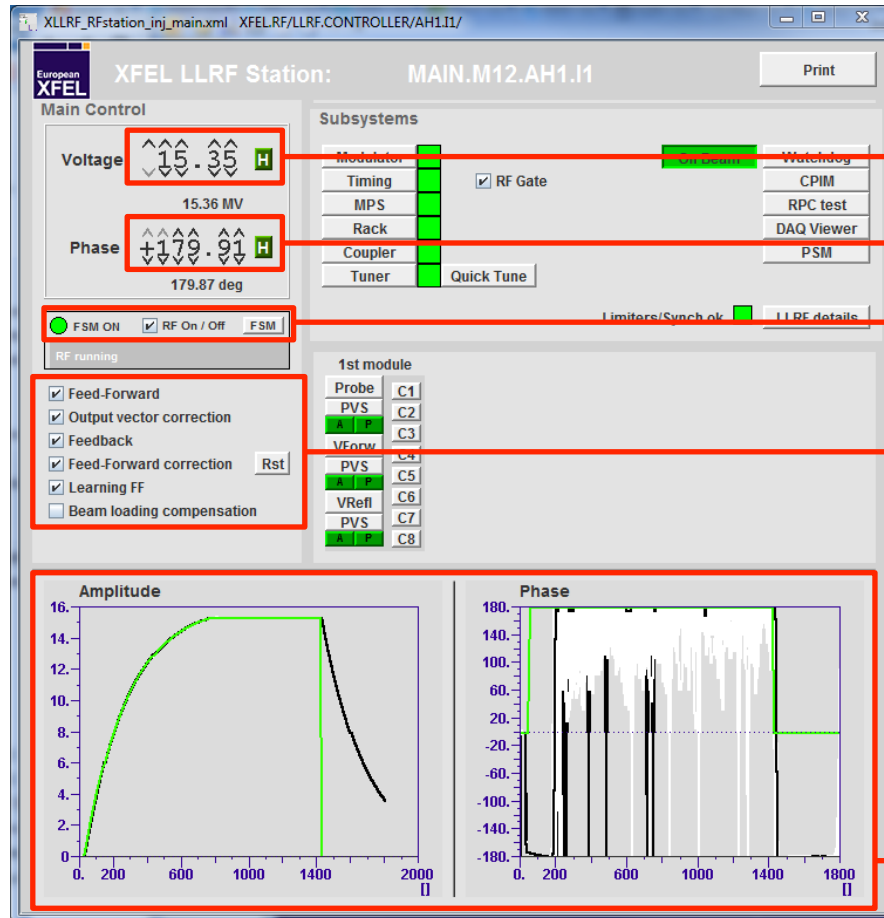
9)

10)



What an operator should know

> AH1.I1



Voltage setpoint

Phase setpoint

FSM RF on/off

Feed-Forward
Tune cavities

OVC, Ratio

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Correction Table Reset

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Setpoint amplitude and phase

Vector sum amplitude and phase

*Turn on with FSM

*Turn on manually

2) 1), 3)

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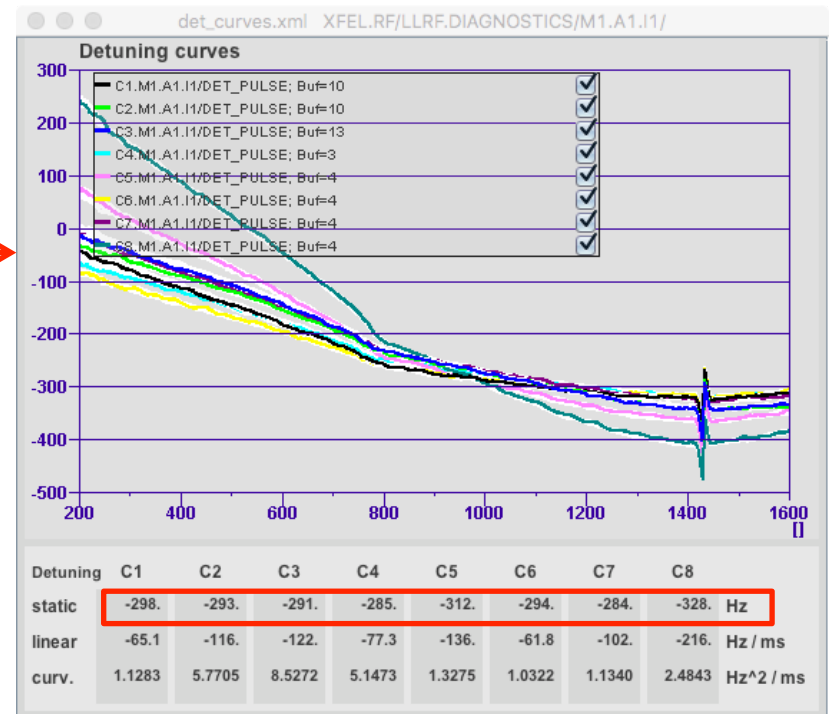
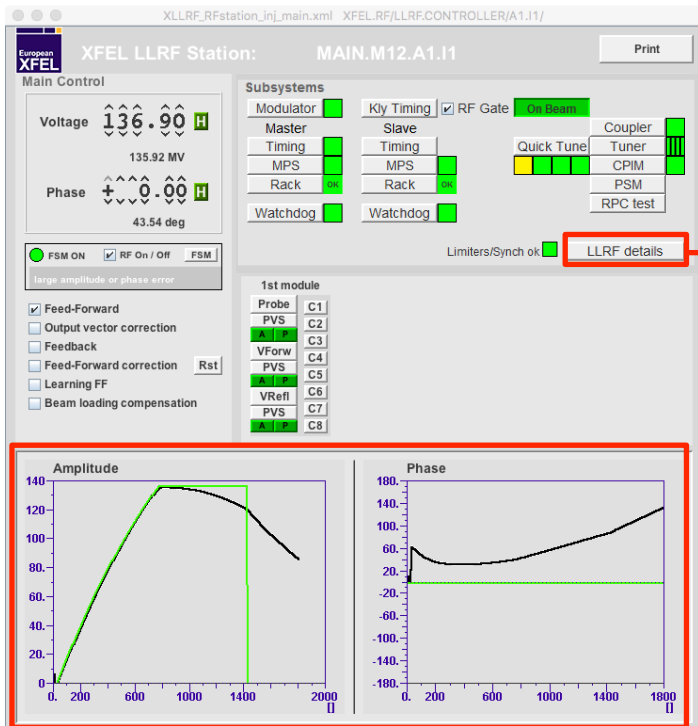
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10)



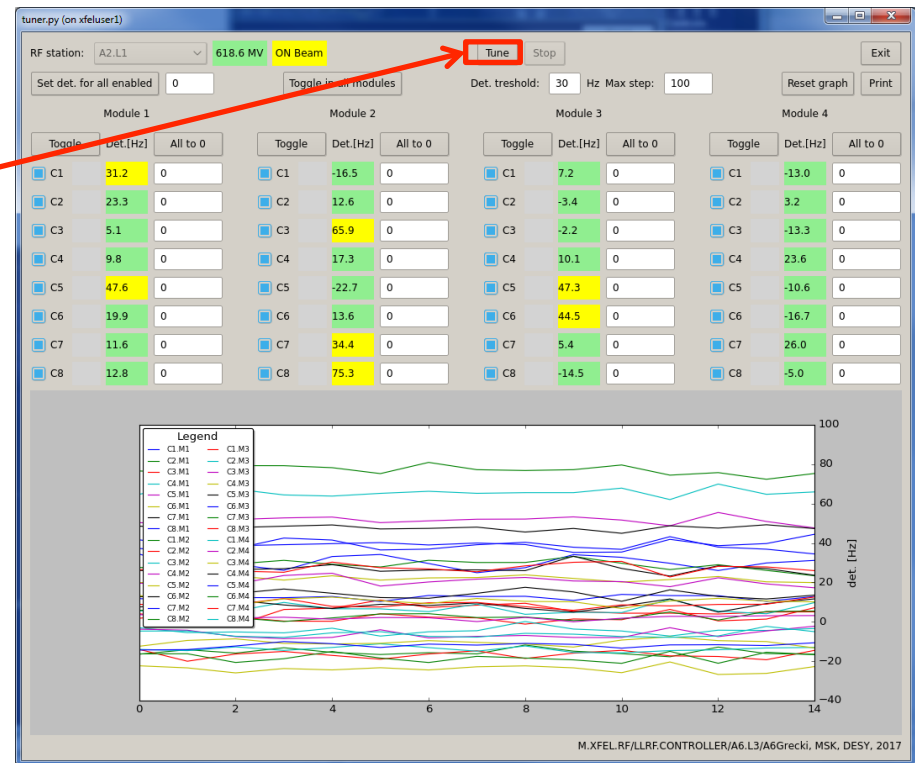
What an operator should know

- In Feed-Forward operation vector sum gradient does not reach SP after filling and/or curved flattop (not possible to close FB)
- Huge phase roll off (several ten degrees)
 - Cavities are detuned → Document event with screen shots
 - Tune cavities



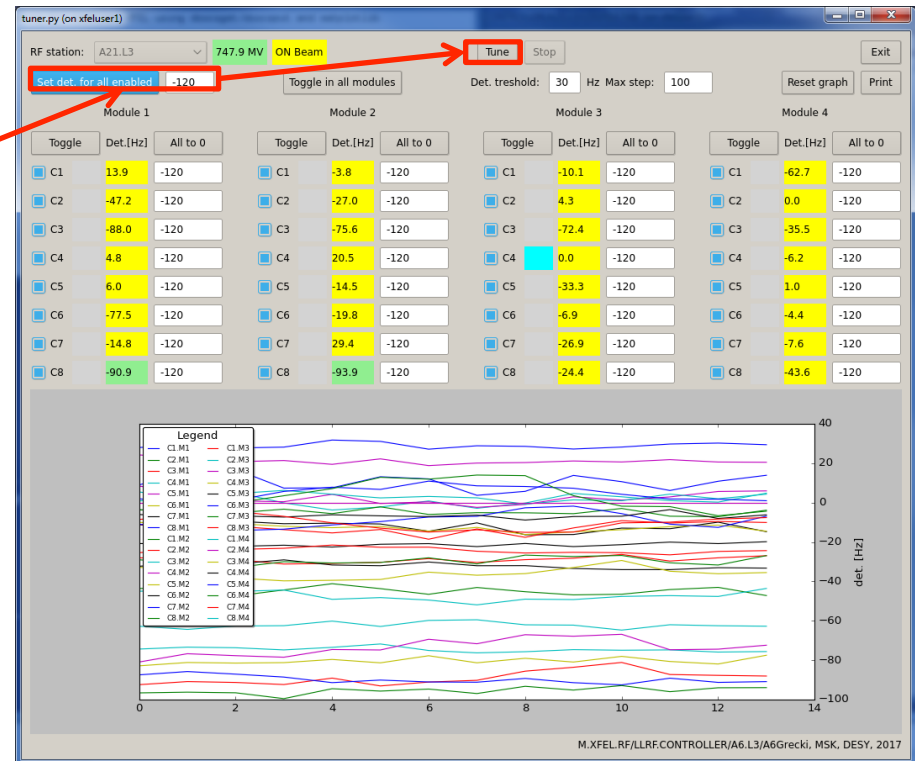
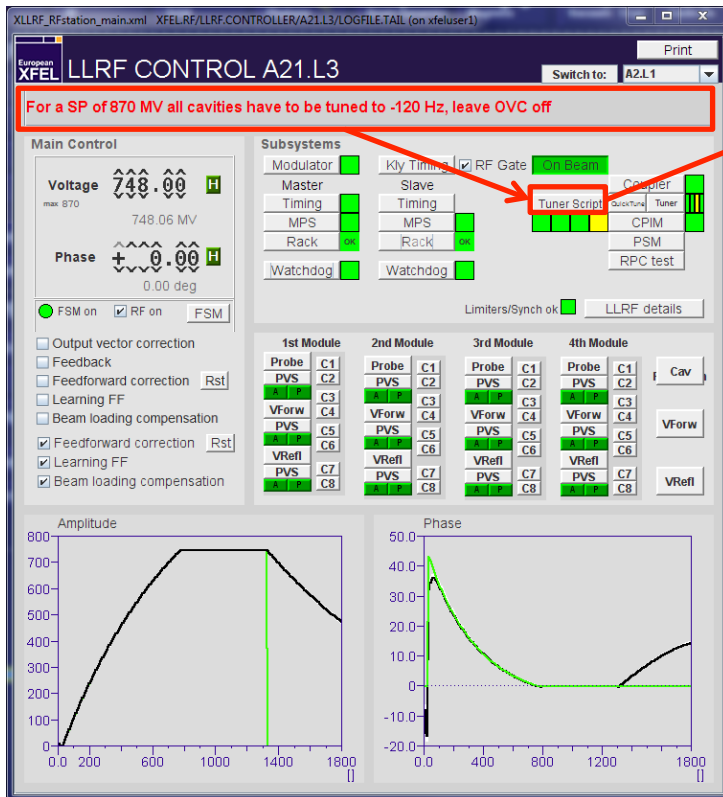
What an operator should know

- Tuner script
- Tune cavities only in open loop operation
- In case of problems hit stop



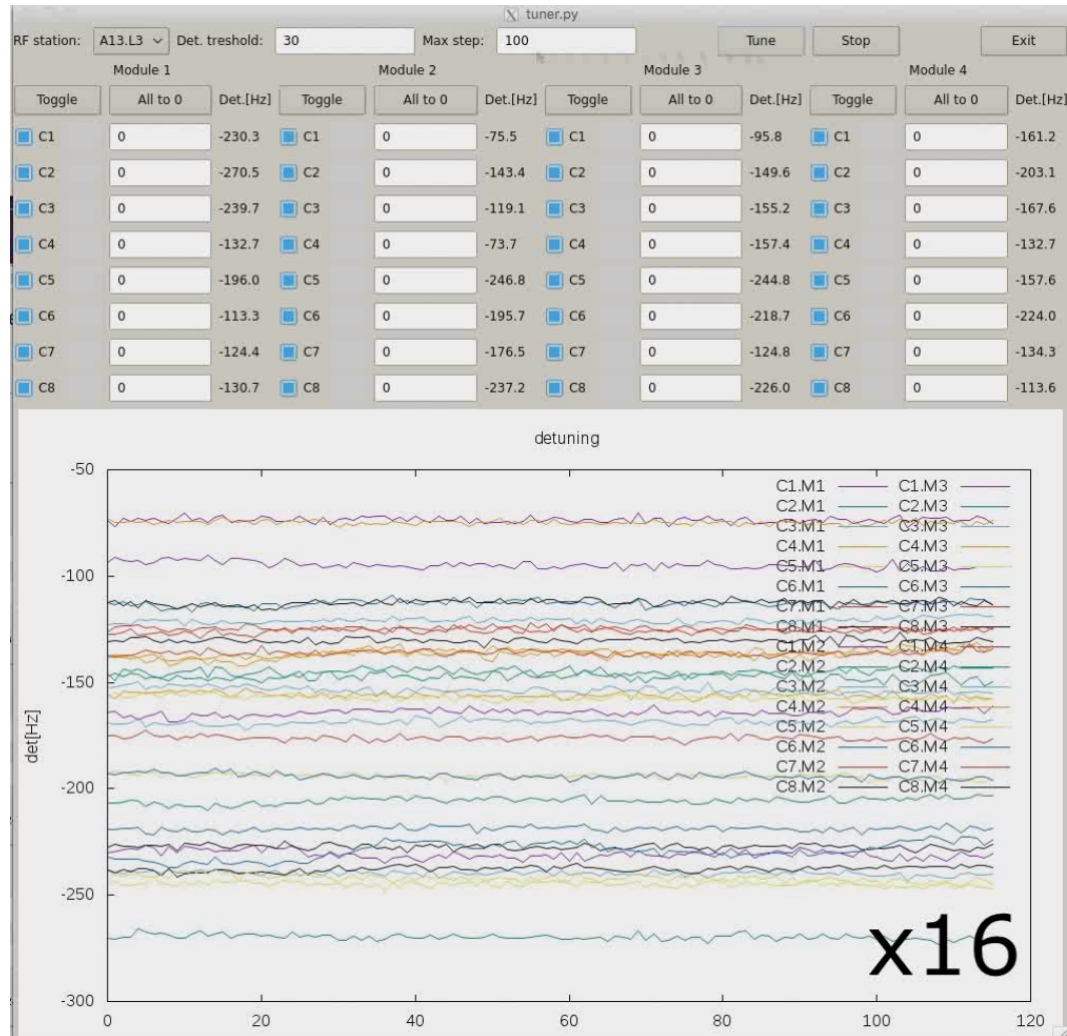
What an operator should know

- Tuner script, don't forget to check panel comment!
- Never ever change panel comment!
- Tune cavities only in open loop operation



What an operator should know

➤ How the tuning should look like



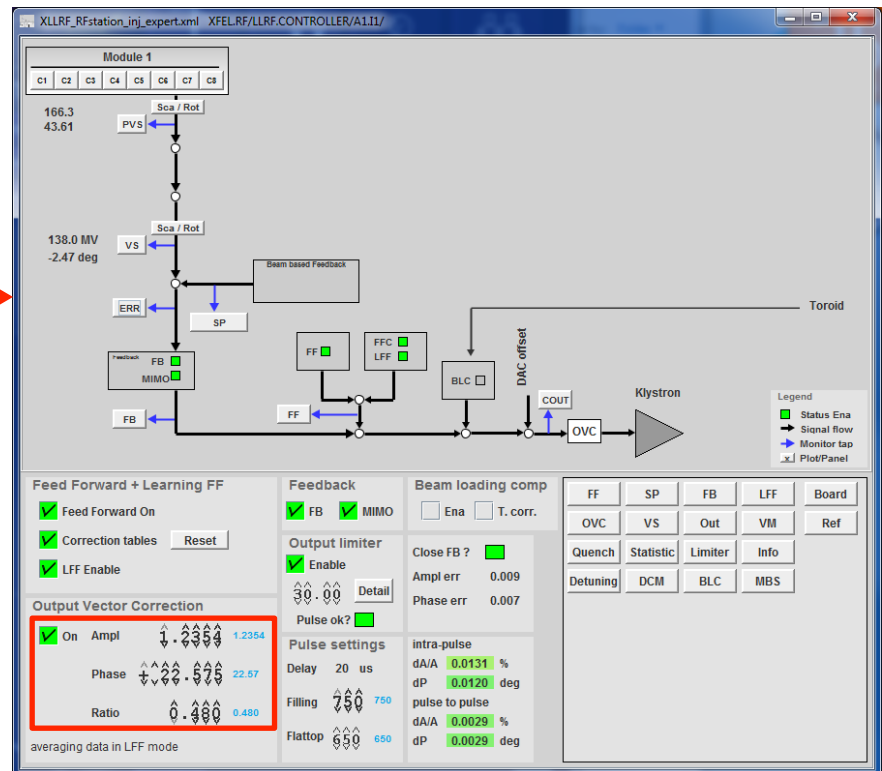
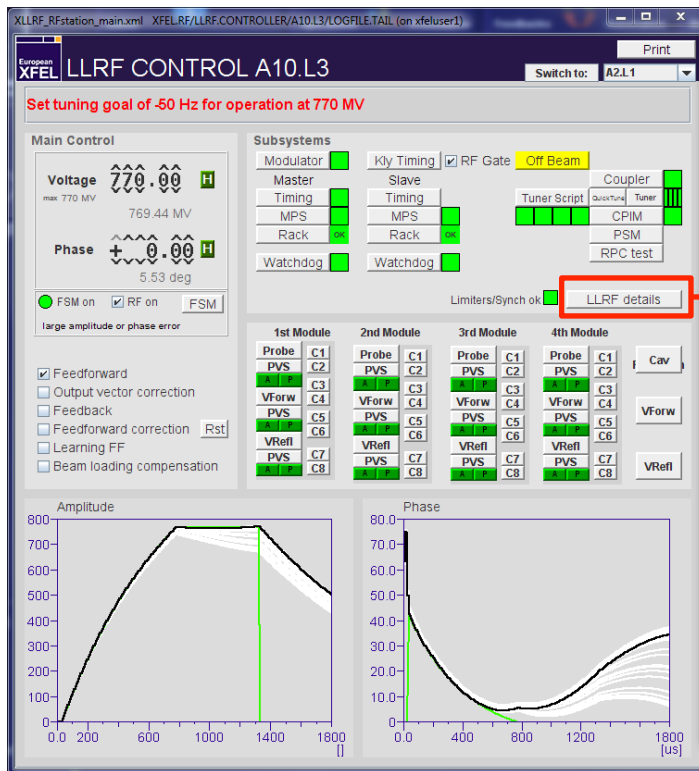
What an operator should know

➤ OVC (Output Vector Rotation)

- Adjustment of VS amplitude and phase in order to minimize the deviation from the SP

➤ Ratio

- Adjustment of amplitude slope over flattop



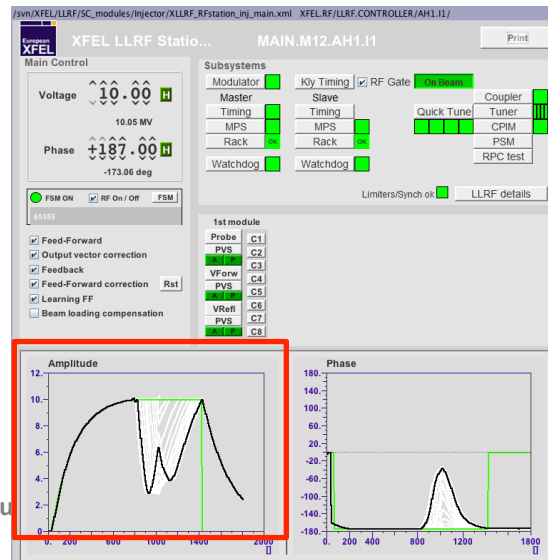
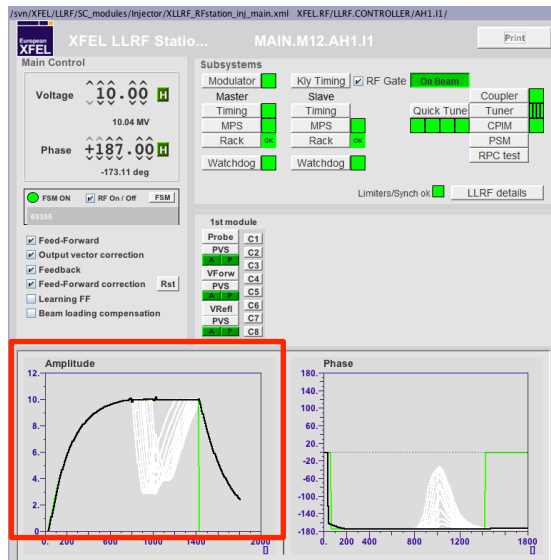
What an operator should know

➤ LFF (Learning-Feed Forward)

- Is modifying the Feed-Forward Correction tables in order to compensate for repetitive errors (differences between VS amplitude and phase and the corresponding SP)

➤ BLC (Beam Loading Compensation)

- Compensates for beam loading depending on number of bunches and charge
- Currently under commissioning → LFF takes over the job, but is slow (needs 1~2 minutes for learning)
- When switching from long bunch trains to short bunch trains, resetting the Feed-Forward Correction helps to gain appropriate correction tables quicker



What an operator should know

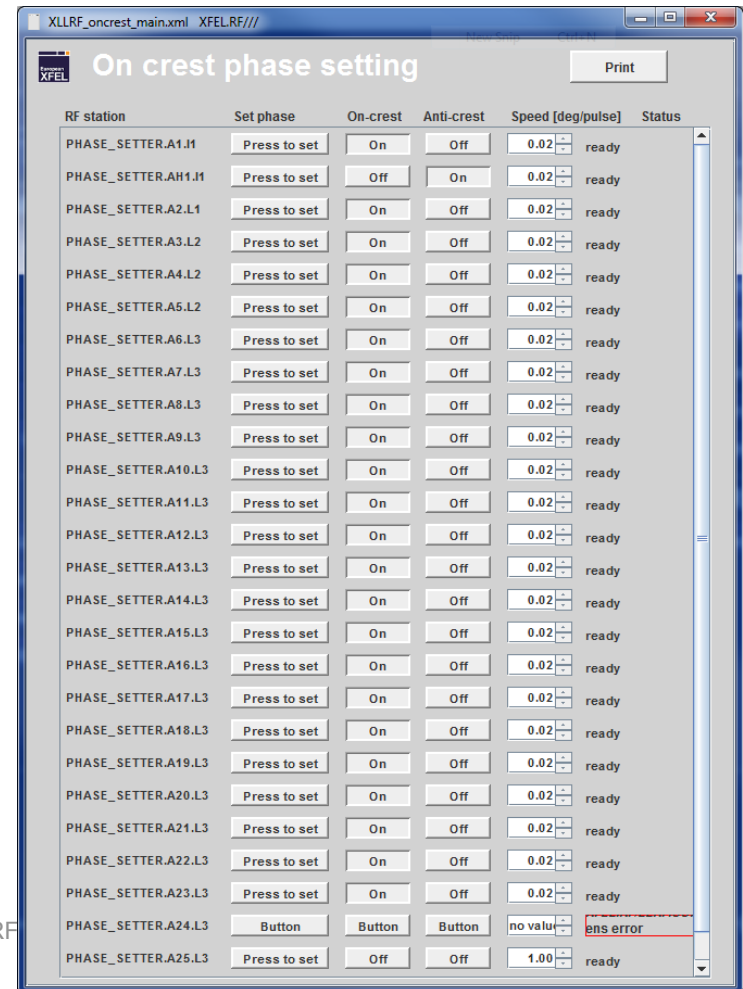
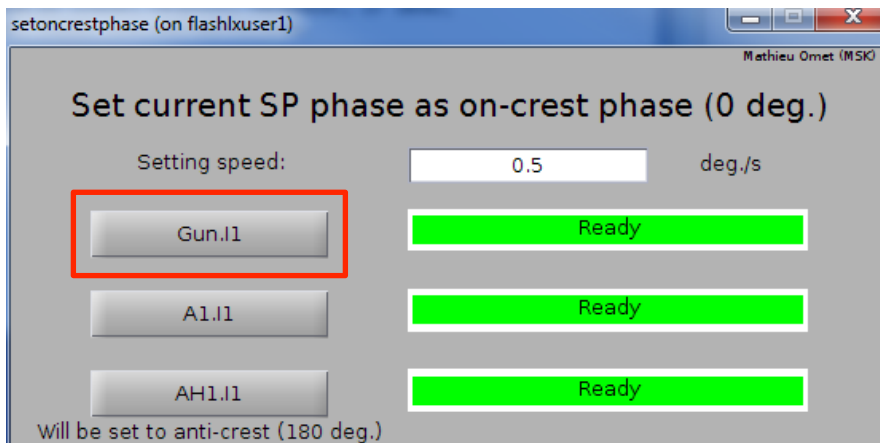
- Changing the voltage more than 100 MV:
 - Open the loop (disable Learning FF, Feedforward correction, Feedback)
 - Change the voltage setpoint
 - Adjust output vector correction and ratio to match set point (under LLRF details)
 - Tune the cavities (note message in the LLRF panel in case a tuning goal different to 0 Hz is specified)
 - For large voltage changes the two above steps might have to be iterated, since different gradient \Leftrightarrow different detuning
 - Close the loop (reset Feedforward correction, enable Learning FF, Feedforward correction and Feedback)
- Using the XFEL Energy Manager might lead to detuned cavities, which can lead to trips



What an operator should know

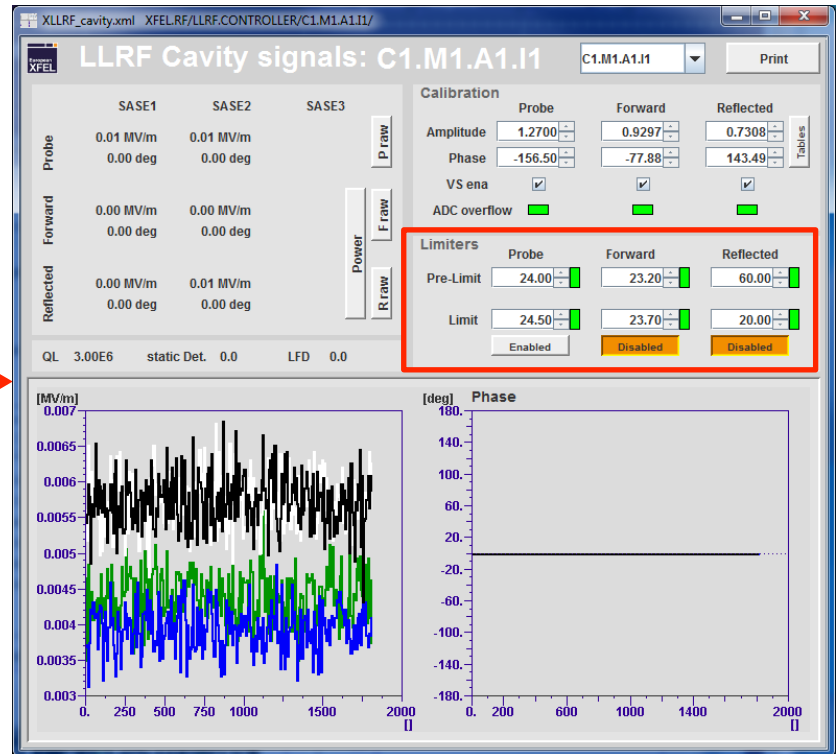
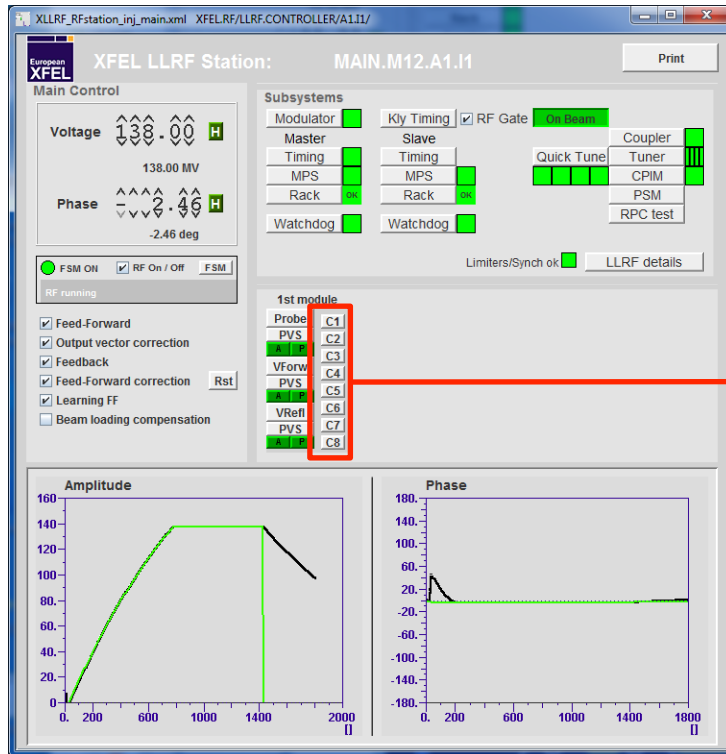
> Set current phase as on-crest phase

- After the on-crest (anti-on-crest phase) was determined, set it as the SP phase and select the station in panel below for setting it to 0 deg.
- For the gun ↓, for the rest →



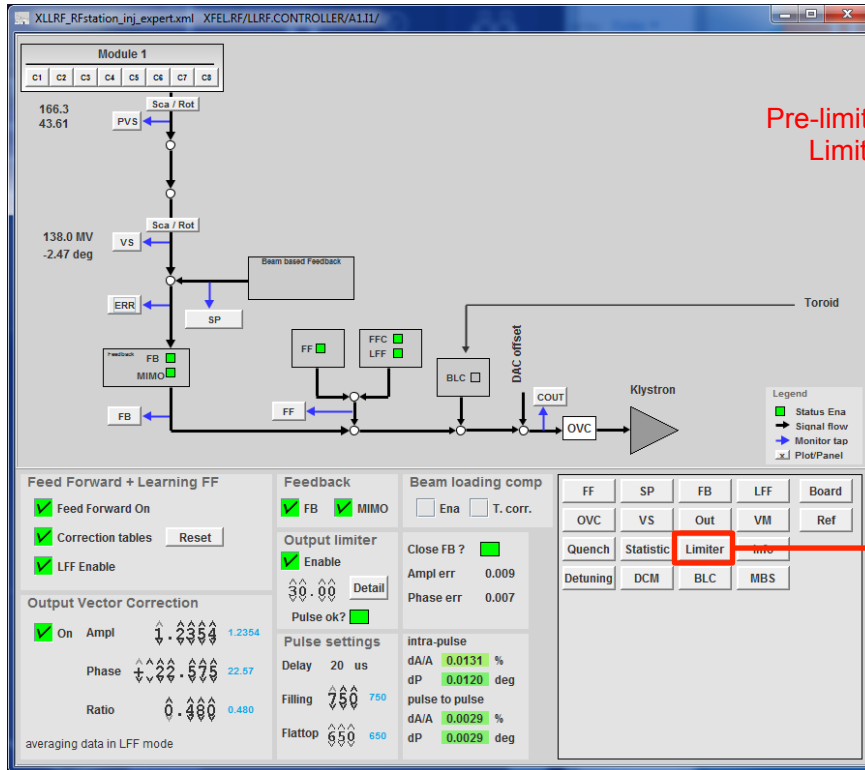
Expert Only Features

➤ Limiters, DON'T EVER TOUCH!

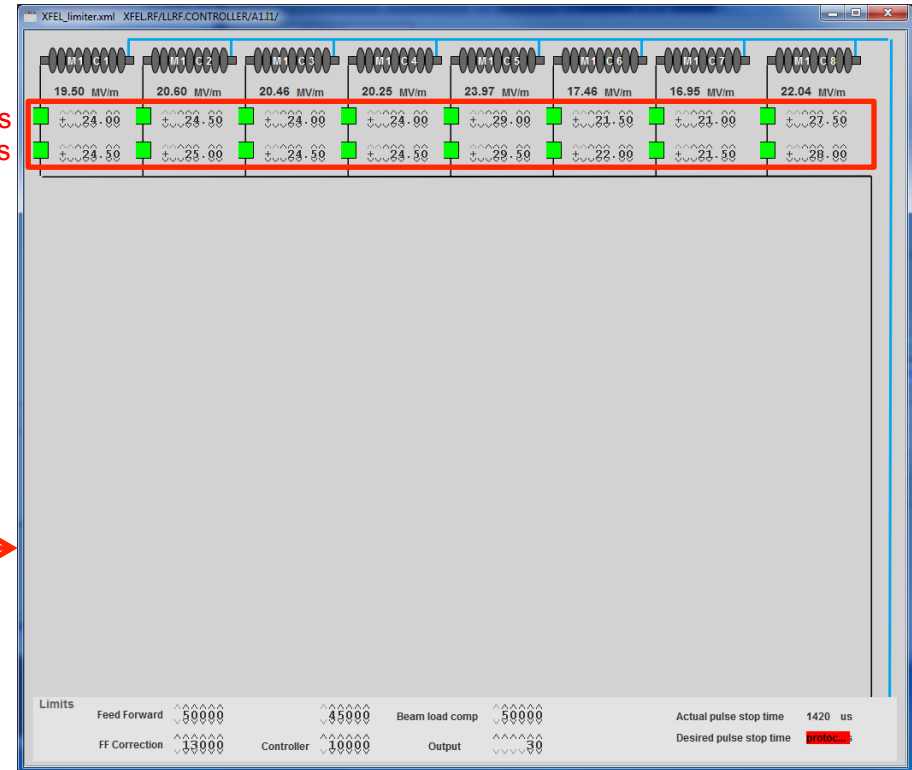


Expert Only Features

➤ Limiters, DON'T EVER TOUCH!



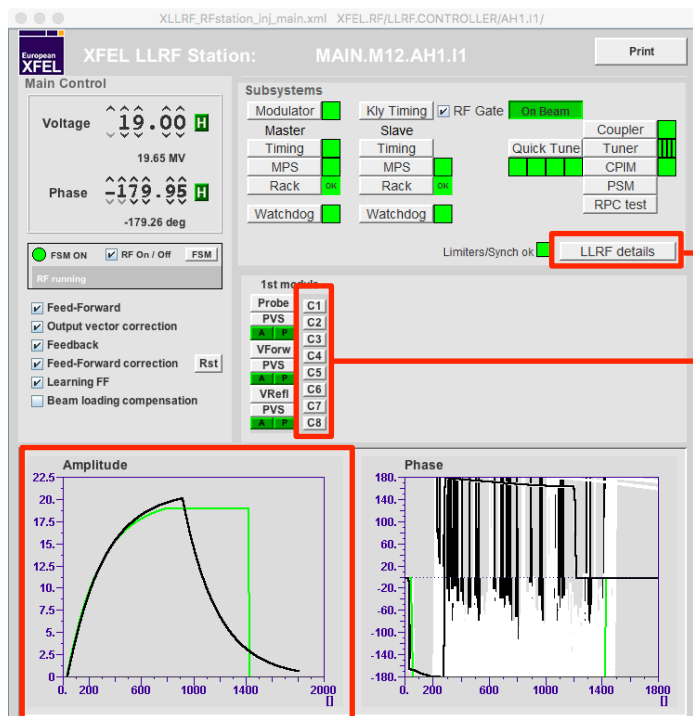
Pre-limiters
Limiters



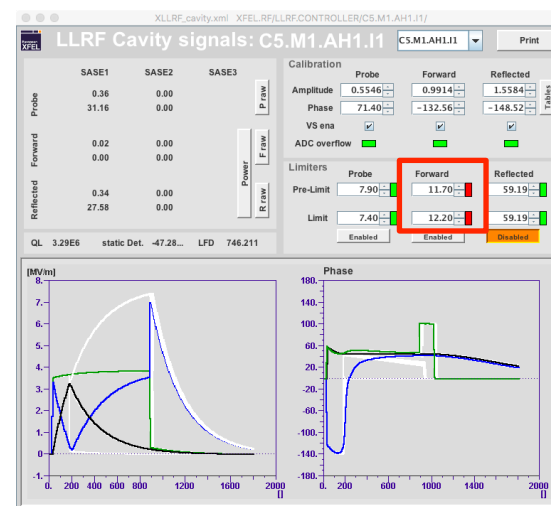
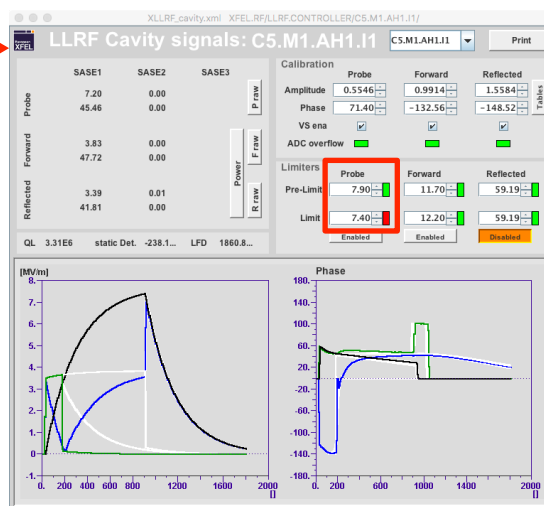
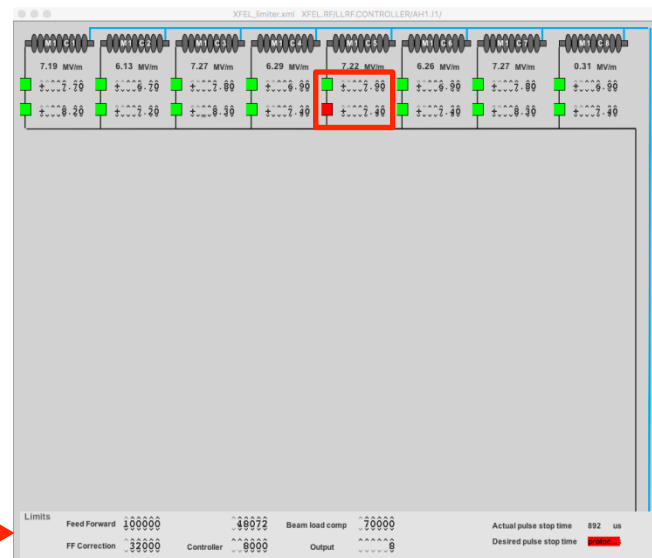
Exceptional cases and how to react

➤ Pulse cuts due to active limiters

- Document event with screen shots
- Decrease the setpoint amplitude, until cuts disappear
- Call the LLRF expert (5588)

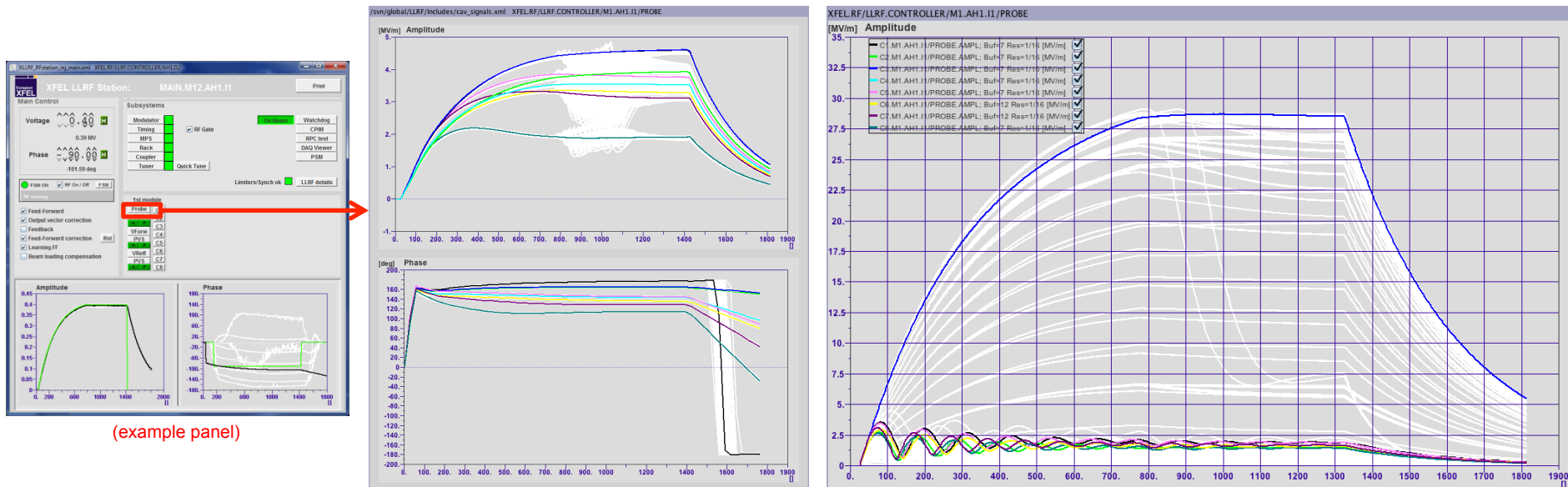


Limiters



Exceptional cases and how to react

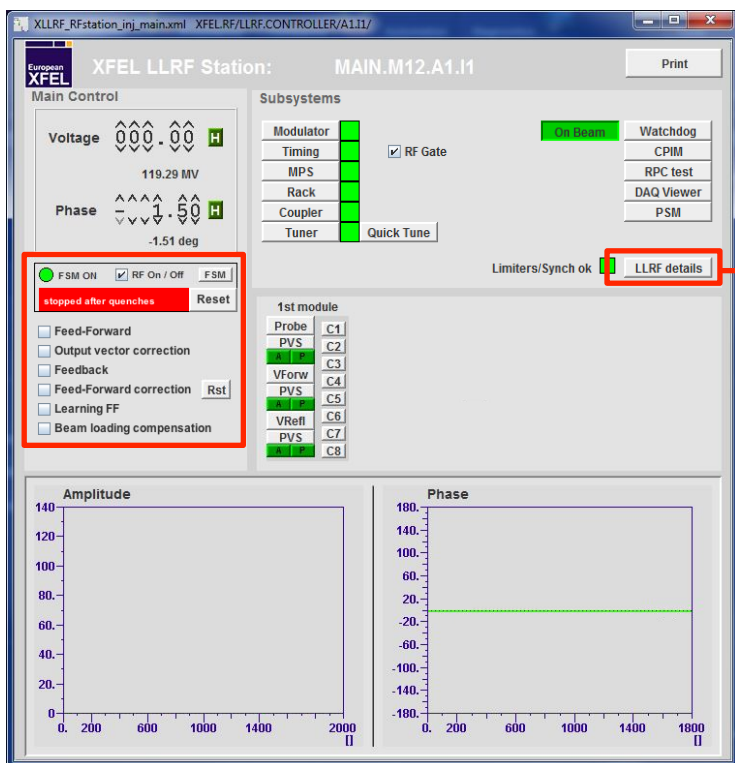
- Pulse cuts by forward limiter
- Cavity gradients are low and show damped sinusoidal shape
 - Document event with screen shots
 - Cavities are detuned → Call the LLRF expert (5588)



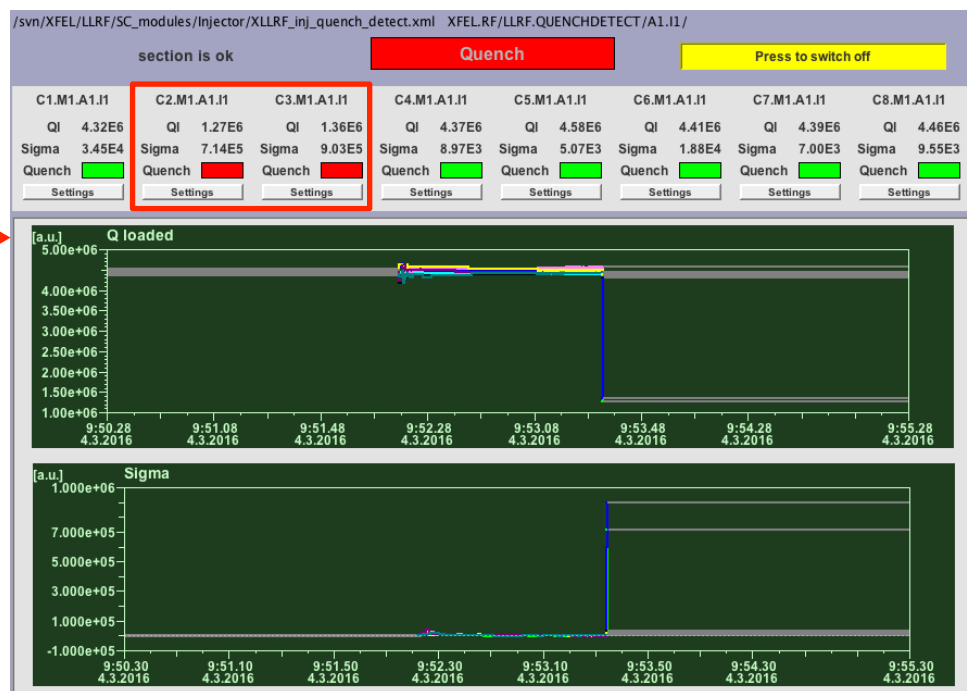
Exceptional cases and how to react

➤ Quench event → Quench detection turns off RF

- Document event with screen shots
- Reset event, try to ramp up again
- If cavities quench again → Call the LLRF expert (5588)



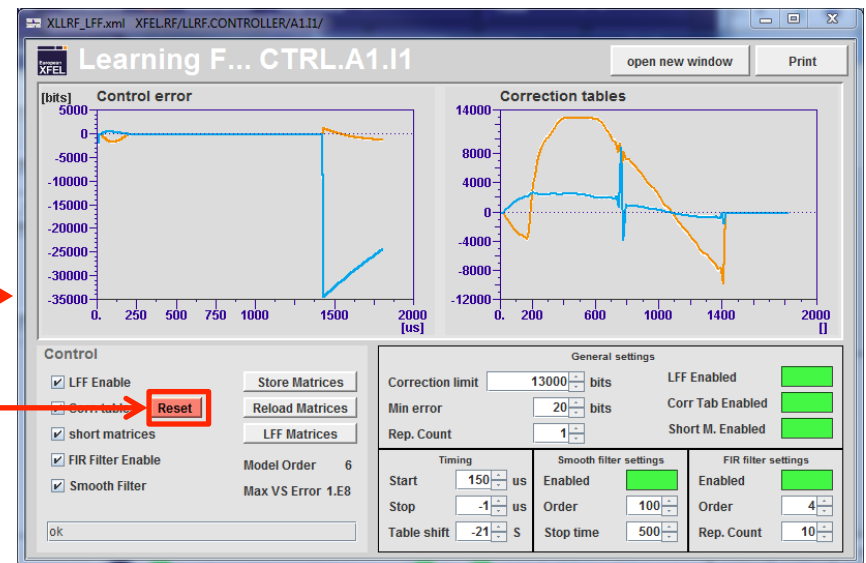
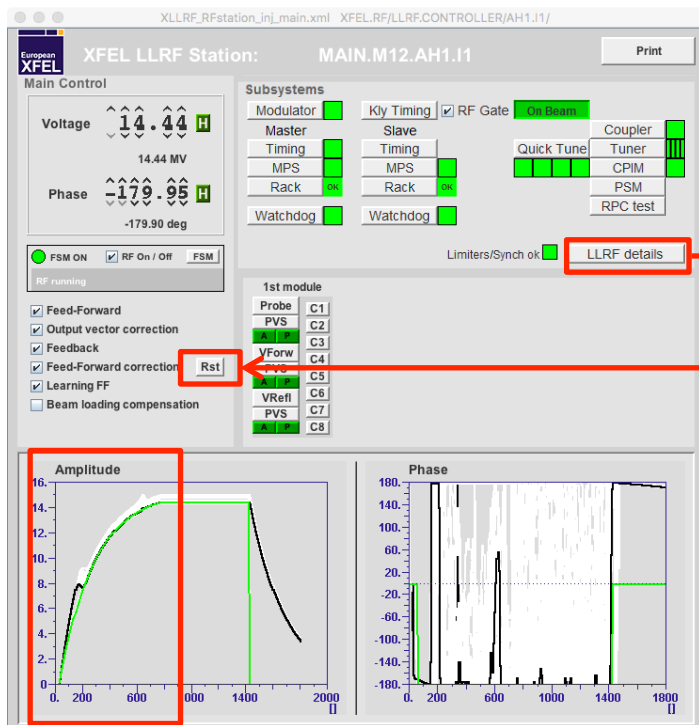
→ Quench →



Exceptional cases and how to react

➤ Weird shape of amplitude (or phase)

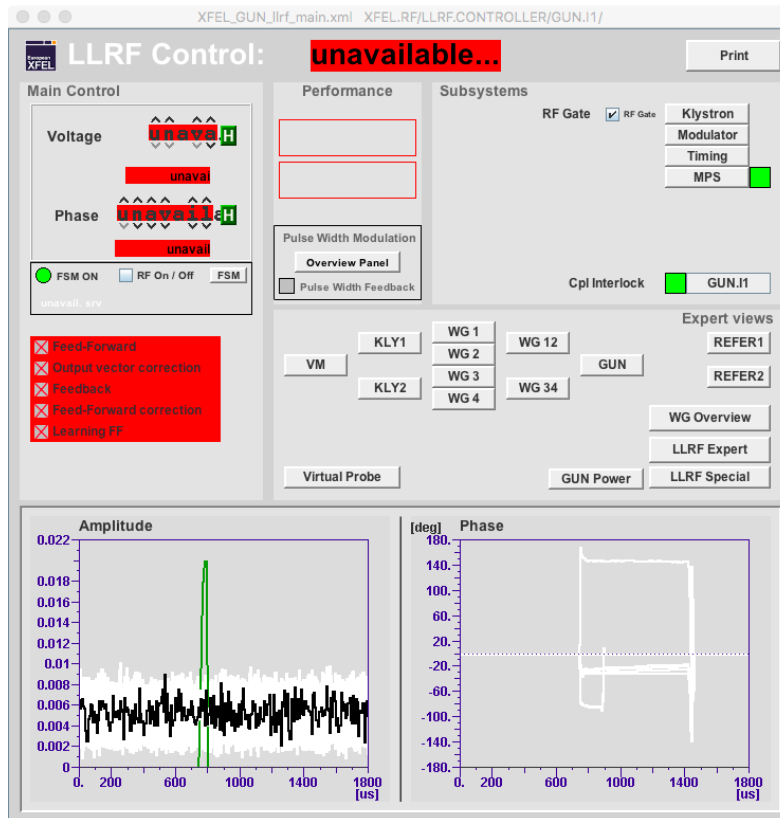
- Try to reset the Feed-forward correction tables and wait for a minute
- If it does not help or acts up again → Call the LLRF expert (5588)



Exceptional cases and how to react

> LLRF controls not working

- If this is the case only for a short period of time → Communication issue, LLRF can't do anything
- If this state is persistent LLRF server might be down → Call the LLRF expert (5588)



Comments & Summary

> Tasks of the XFEL operator:

- Turn on an RF station
- Adjust the vector-sum voltage
- Adjust the vector-sum phase
- Tune cavities, if necessary
- Adjust output vector correction and ratio, if necessary
- Set a certain phase as on-crest phase
- Turn off an RF station

> Operation via the LLRF main panels

> Document anything you think is not normal

- **Add your name so that we can respond to you!!!**
- **Set location of respective RF station in your logbook entry!!!**

> If there are problems you need assistance with call the LLRF expert (5588)



Questions?

➤ Thank you very much for your attention!

