

# XFEL-Gun

# Operator Training

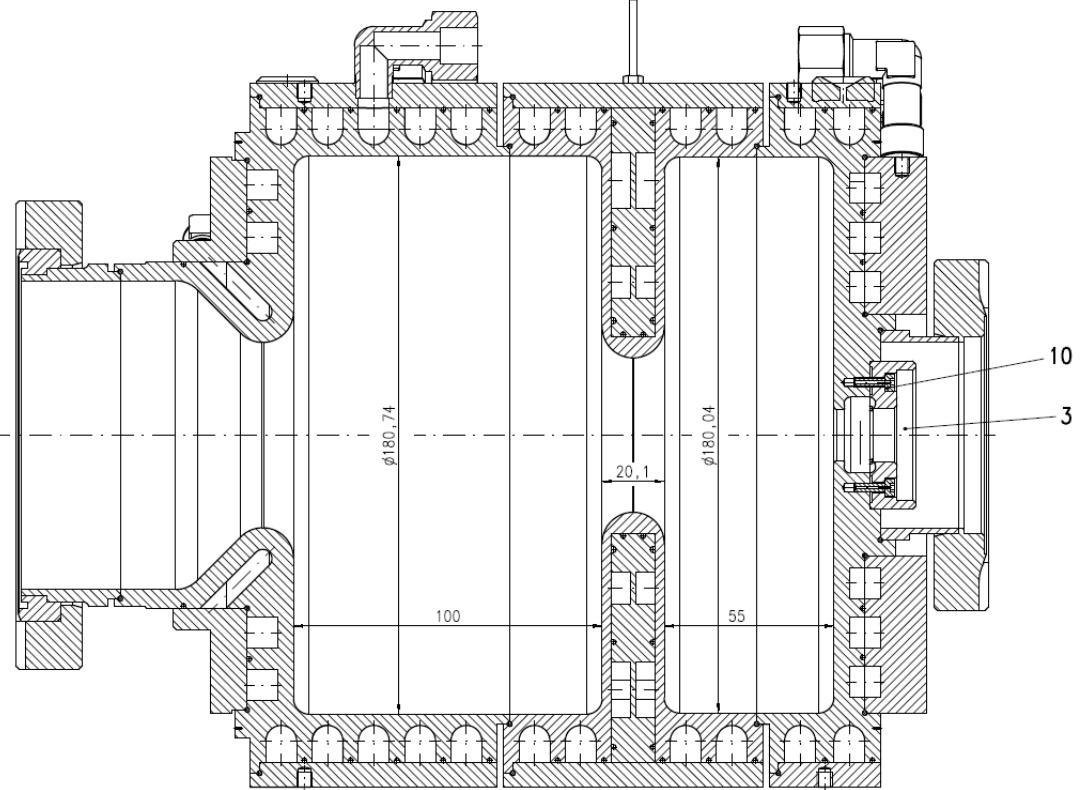
F.Brinker



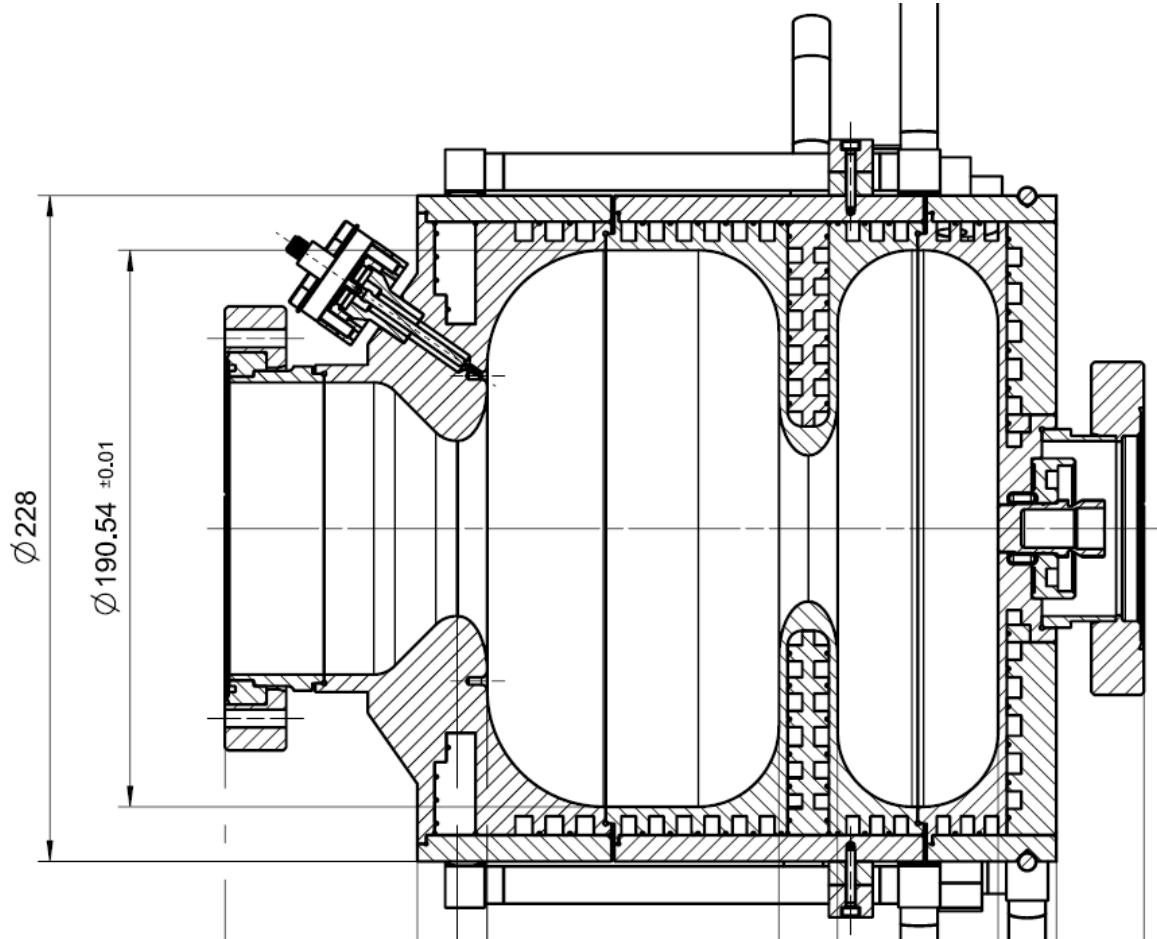


- New Gun 5
- Interlock systems
- Temperature regulation
- FSM and fast Ramp Up procedure
- PWM and slow ramp
- Fast protection

# Cross section of guns for 1.3 GHz

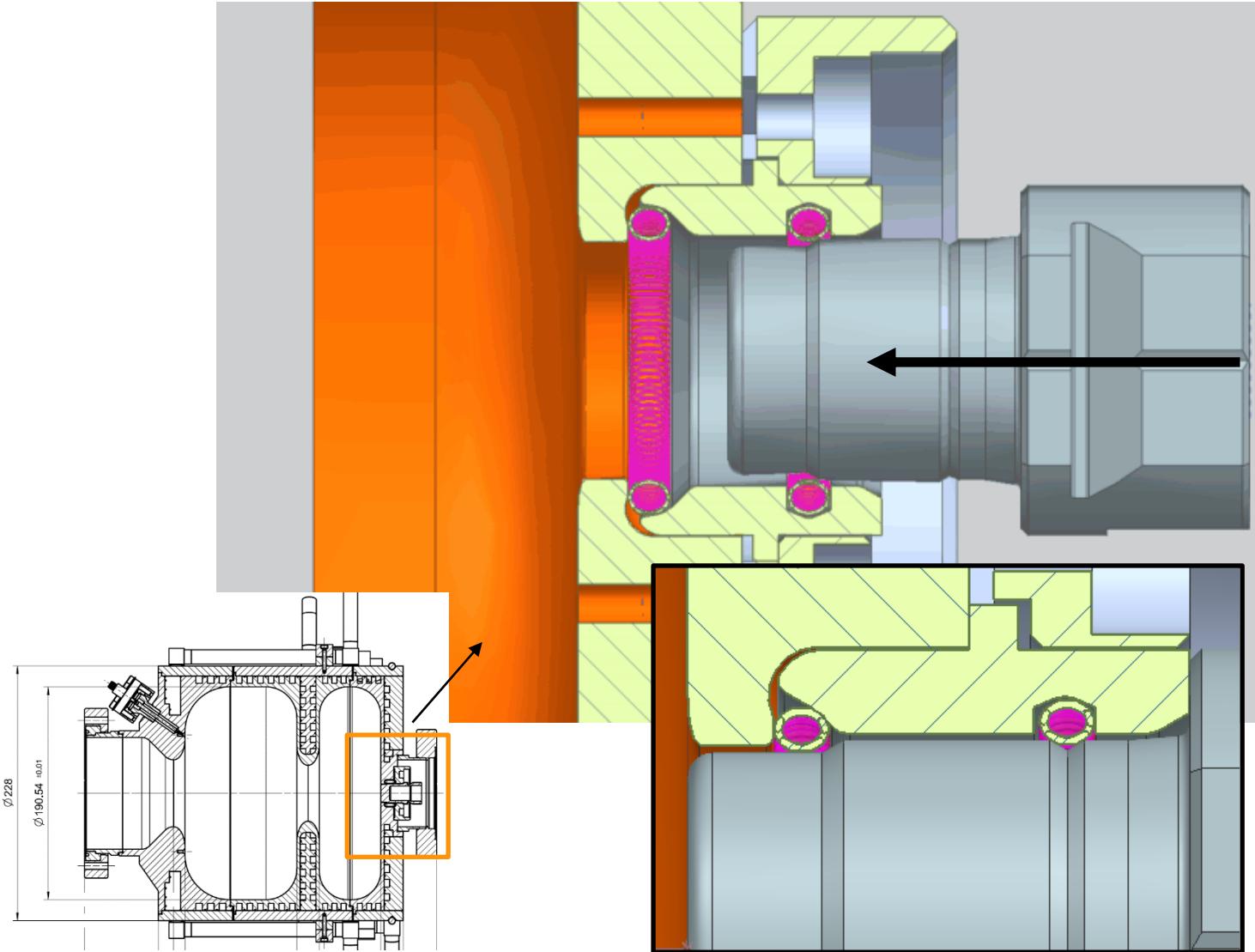


Gun 4

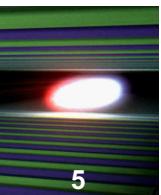


New Gun 5

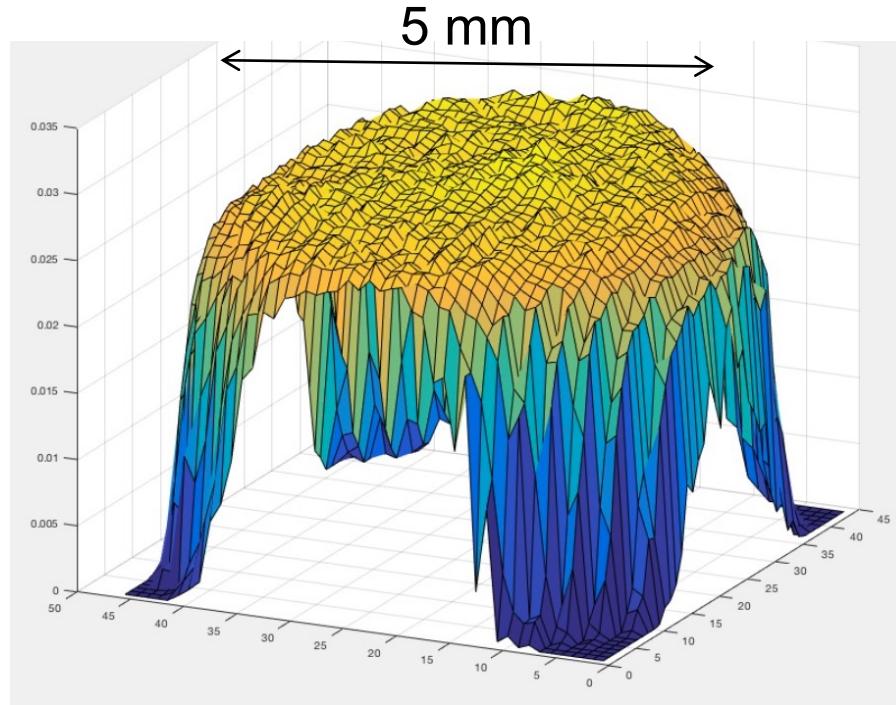
# Cathode with new RF-spring



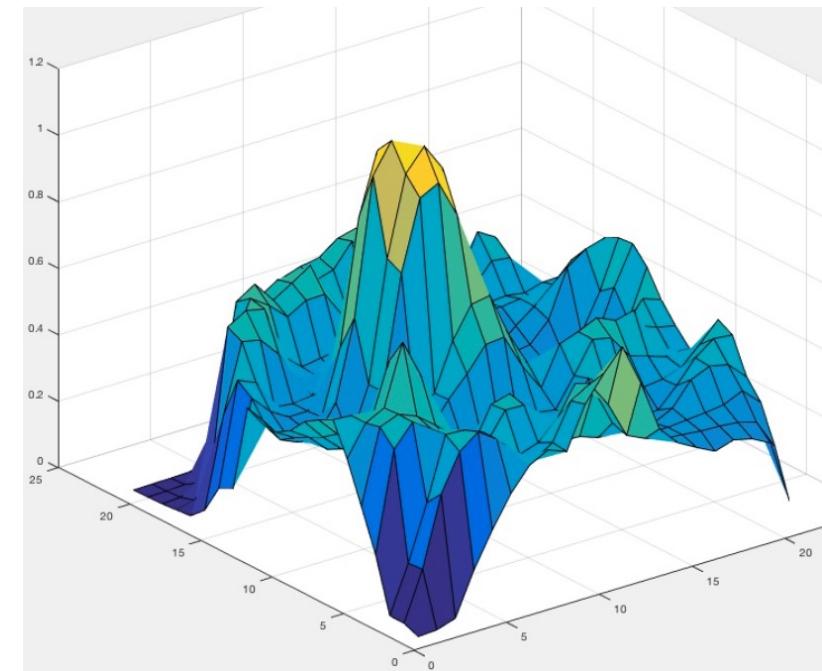
# Cathode exchange : When?



Quantum efficiency: simply the relation of electrons and photons  
QE = 10% means 10 photons are needed to get 1 electron



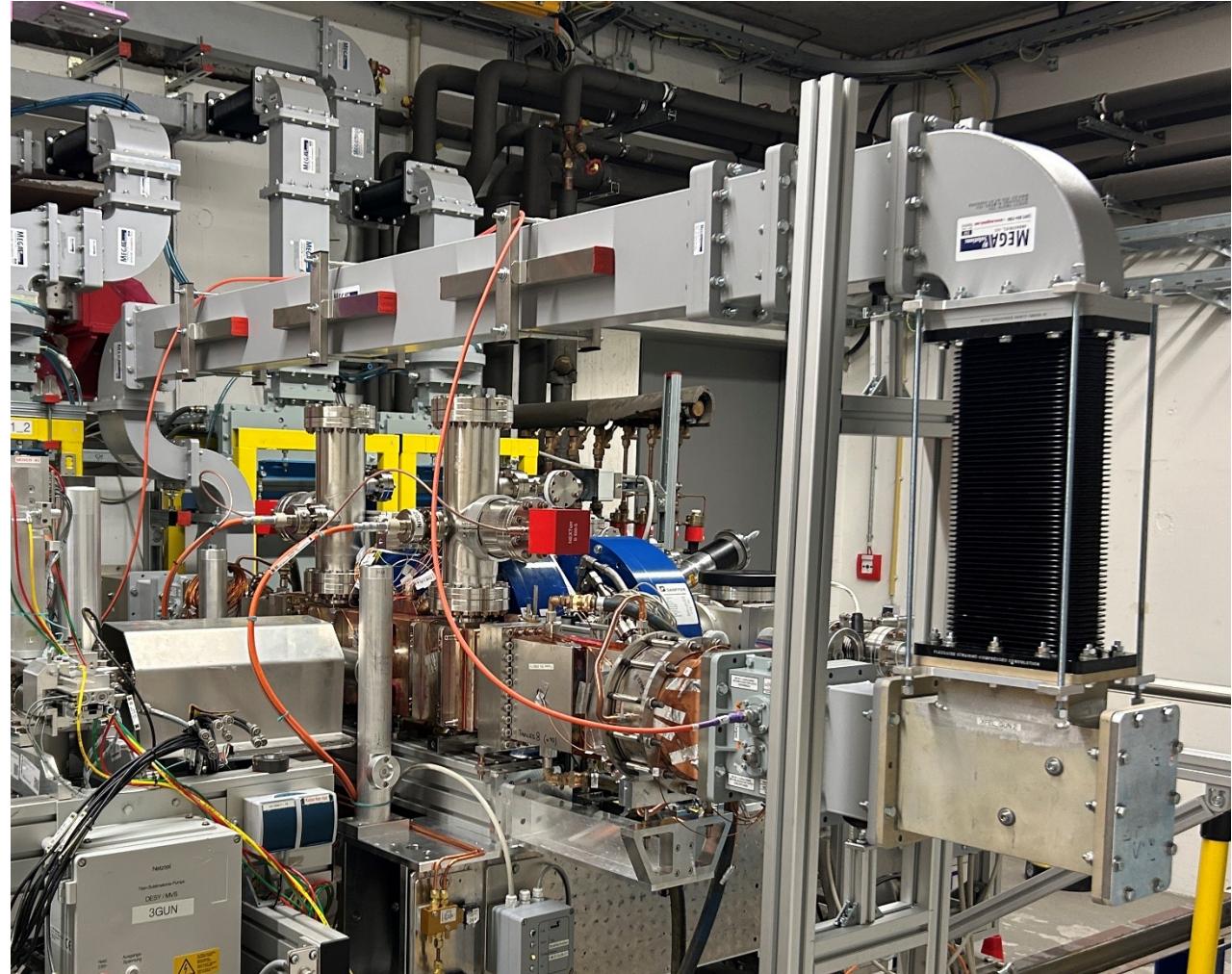
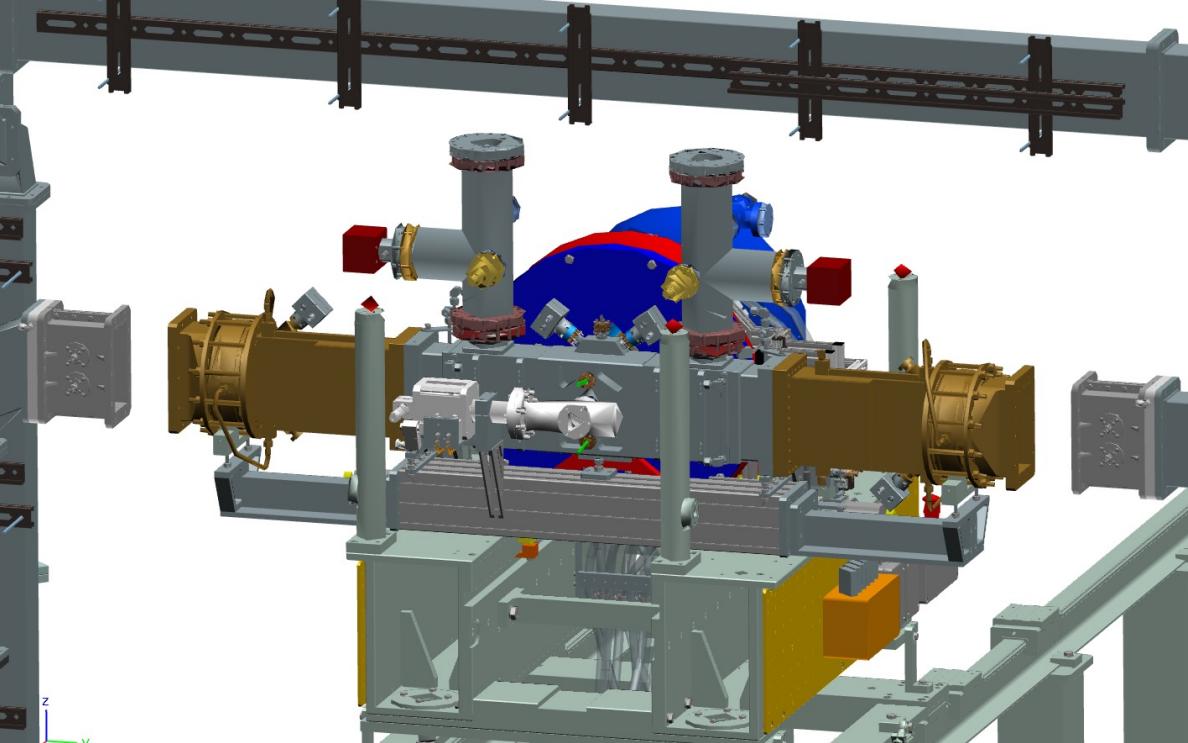
Fresh cathode



Cathode after years of operation

With the new cathode springs we will probably do this more often

# Gun 5 : symmetric coupler with 2 vacuum windows



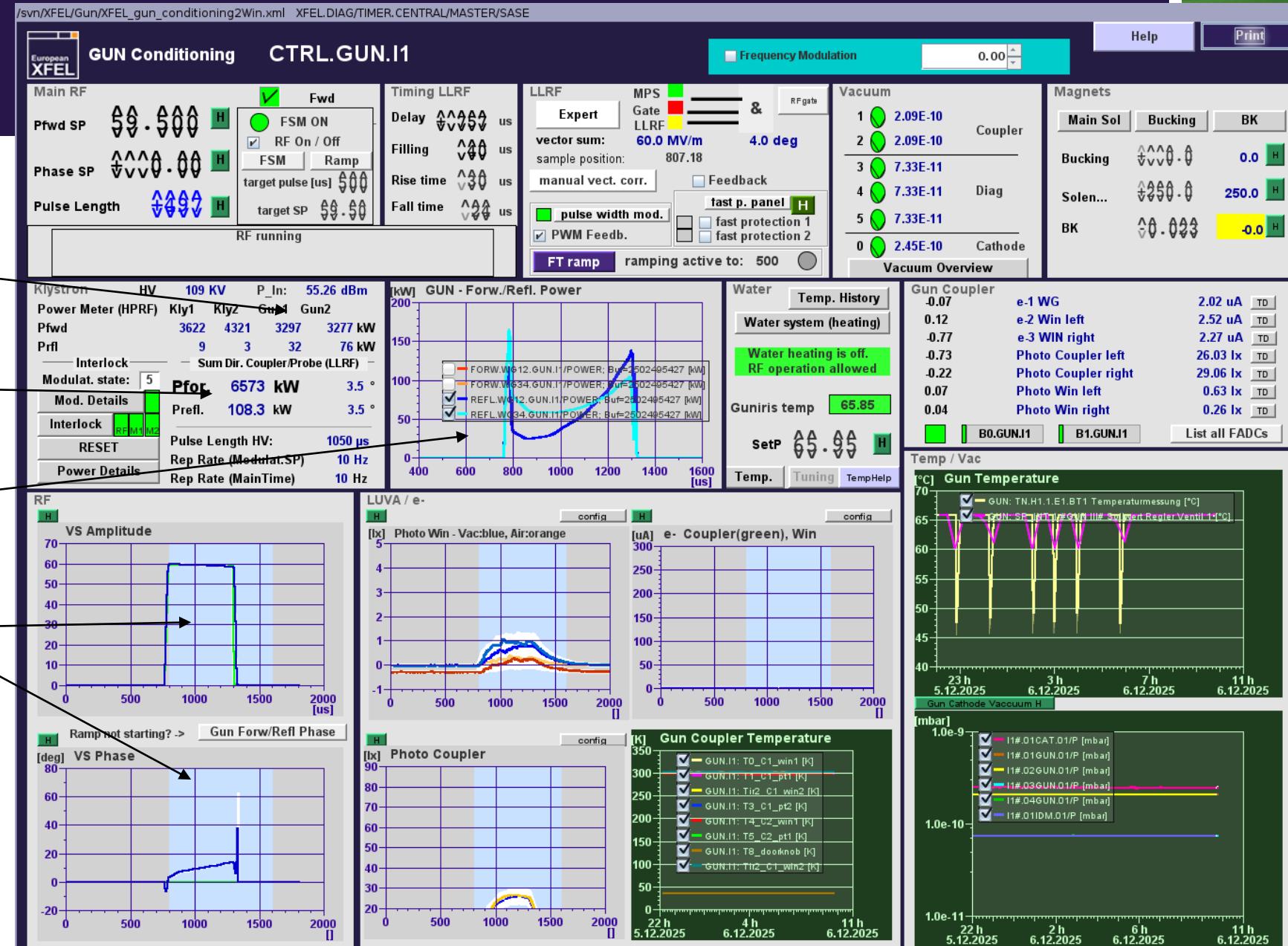
## New panel:

## Readings from 2 directional couplers

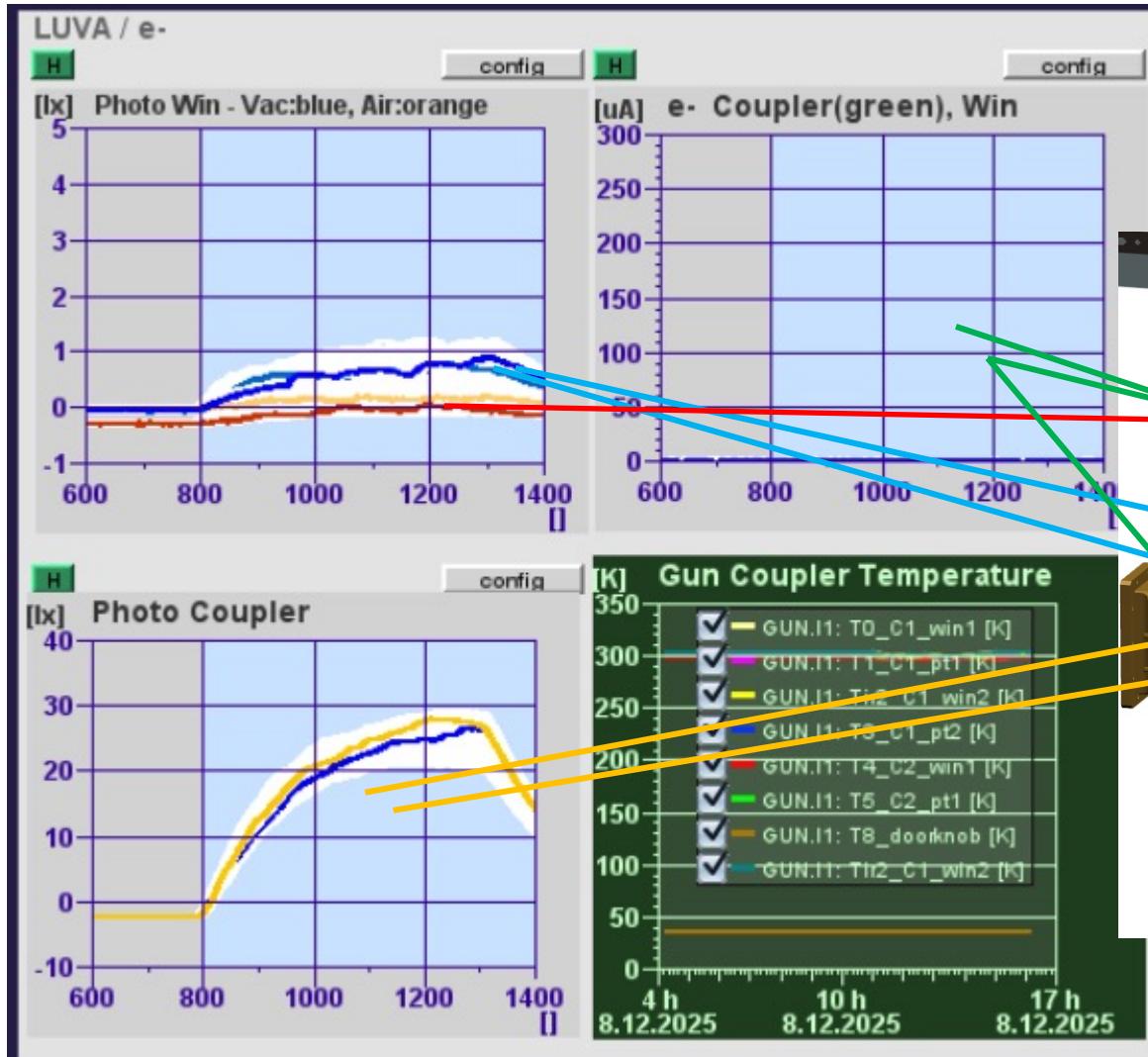
## Sum of the signals

## Traces from directional couplers

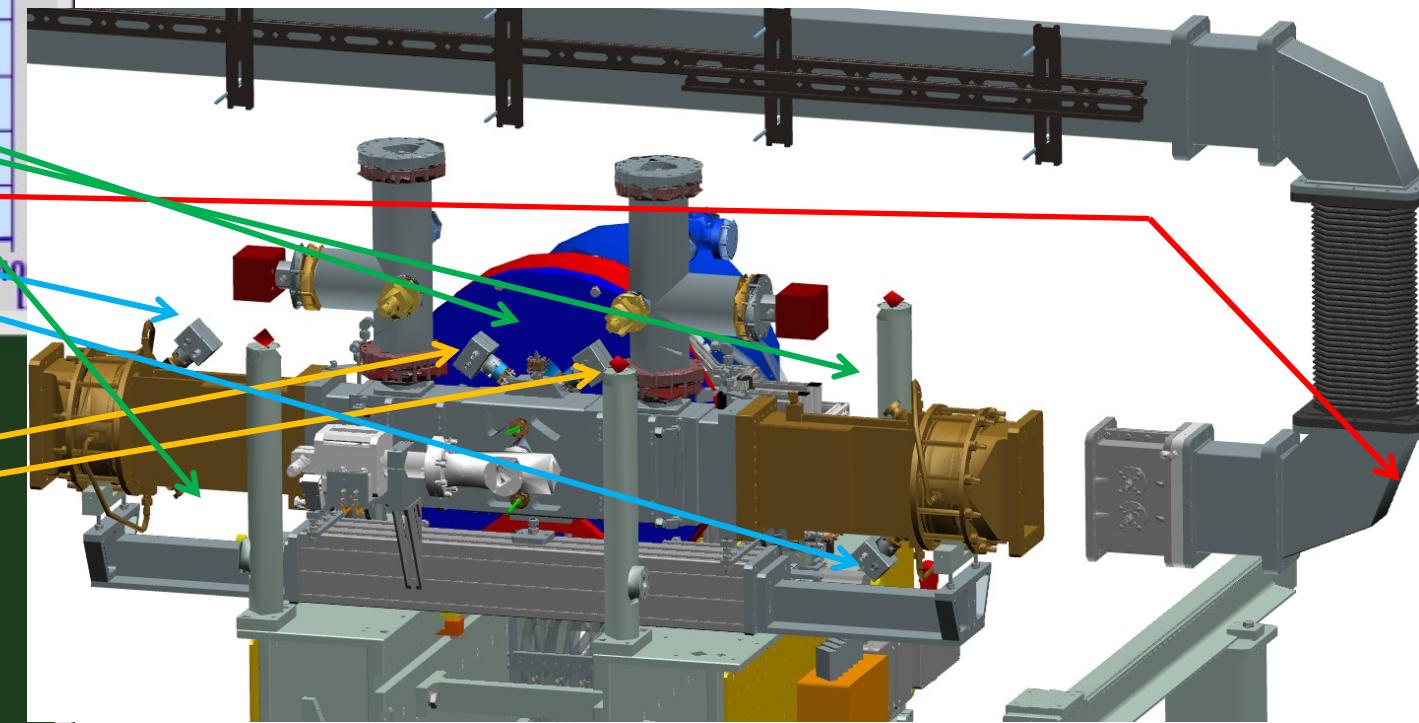
## Traces from gun probe



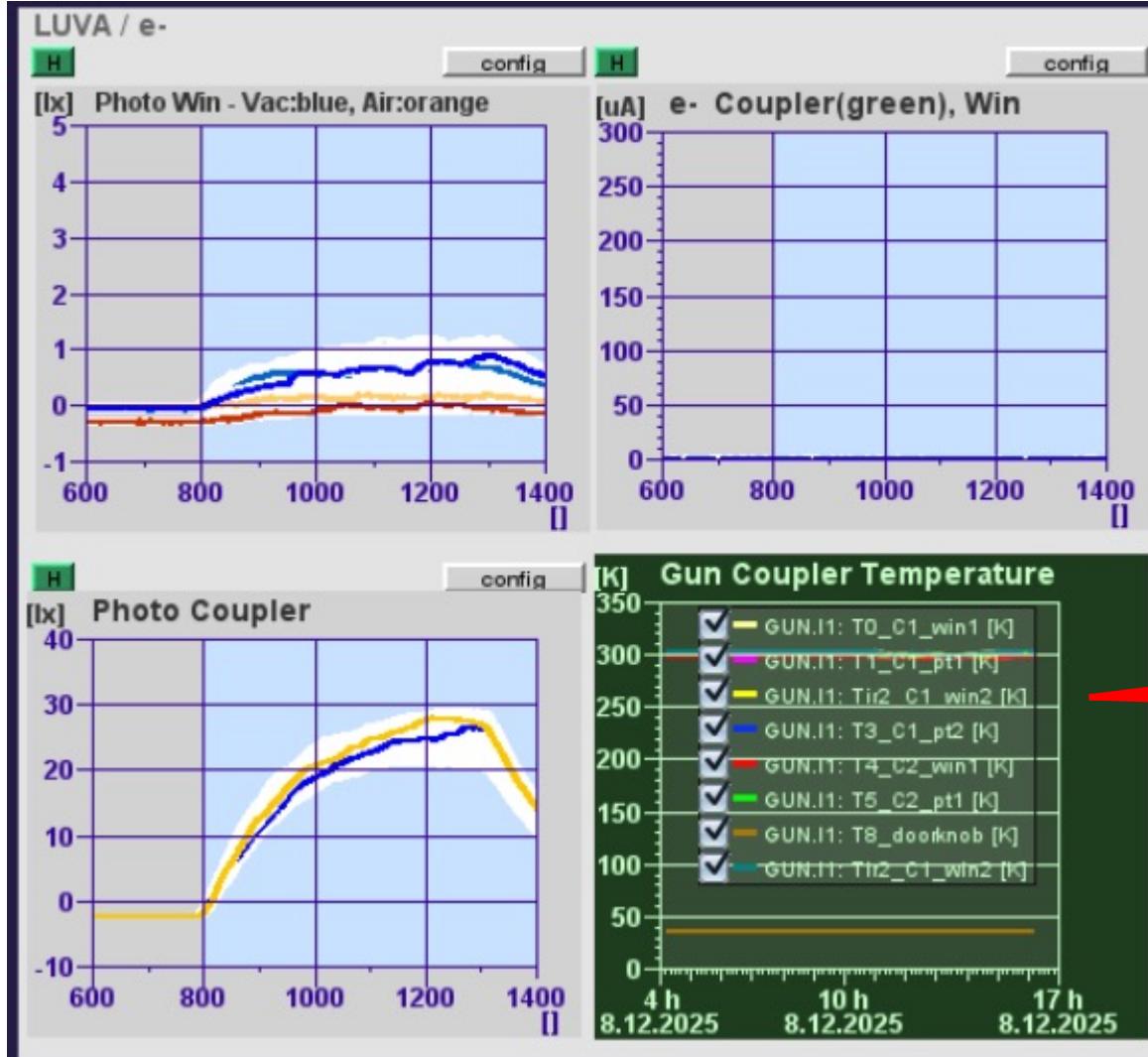
# Gun signals and interlocks



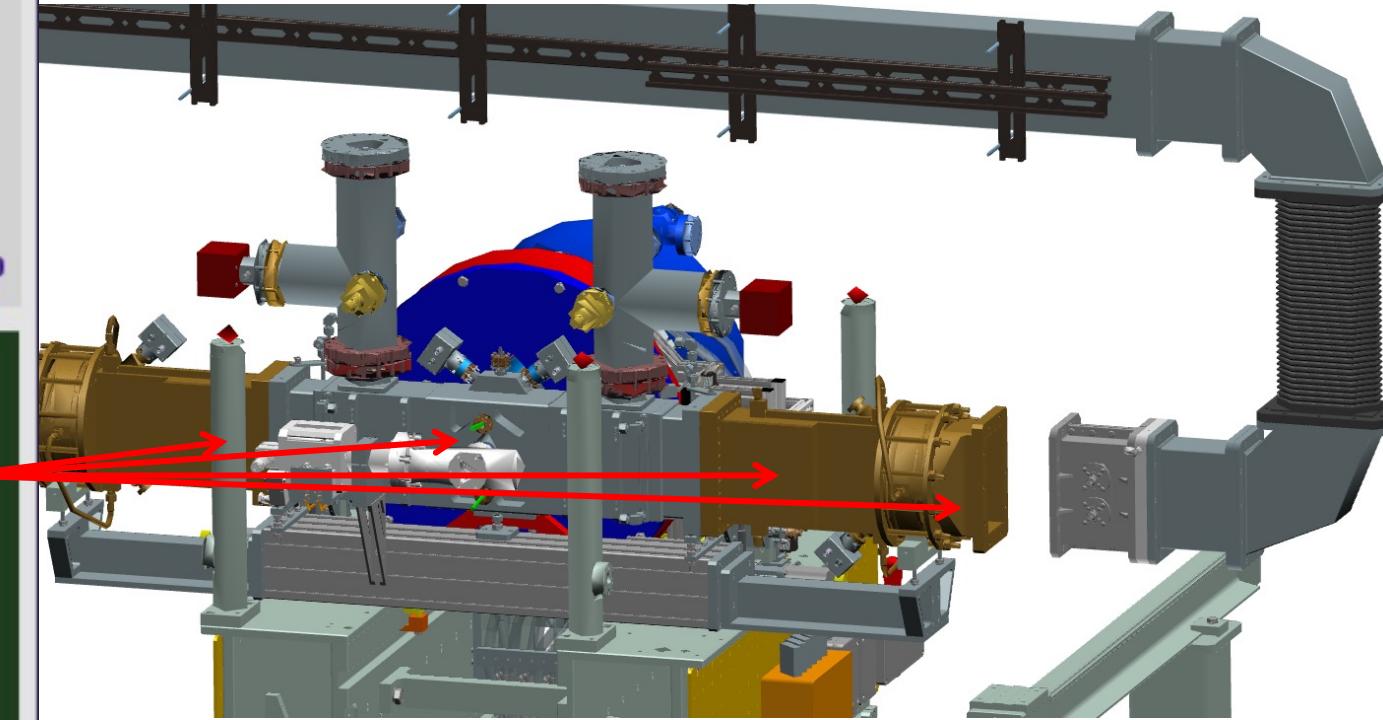
Light and electron  
detection

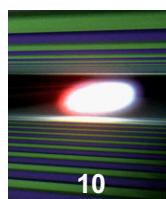


# Gun signals and interlocks



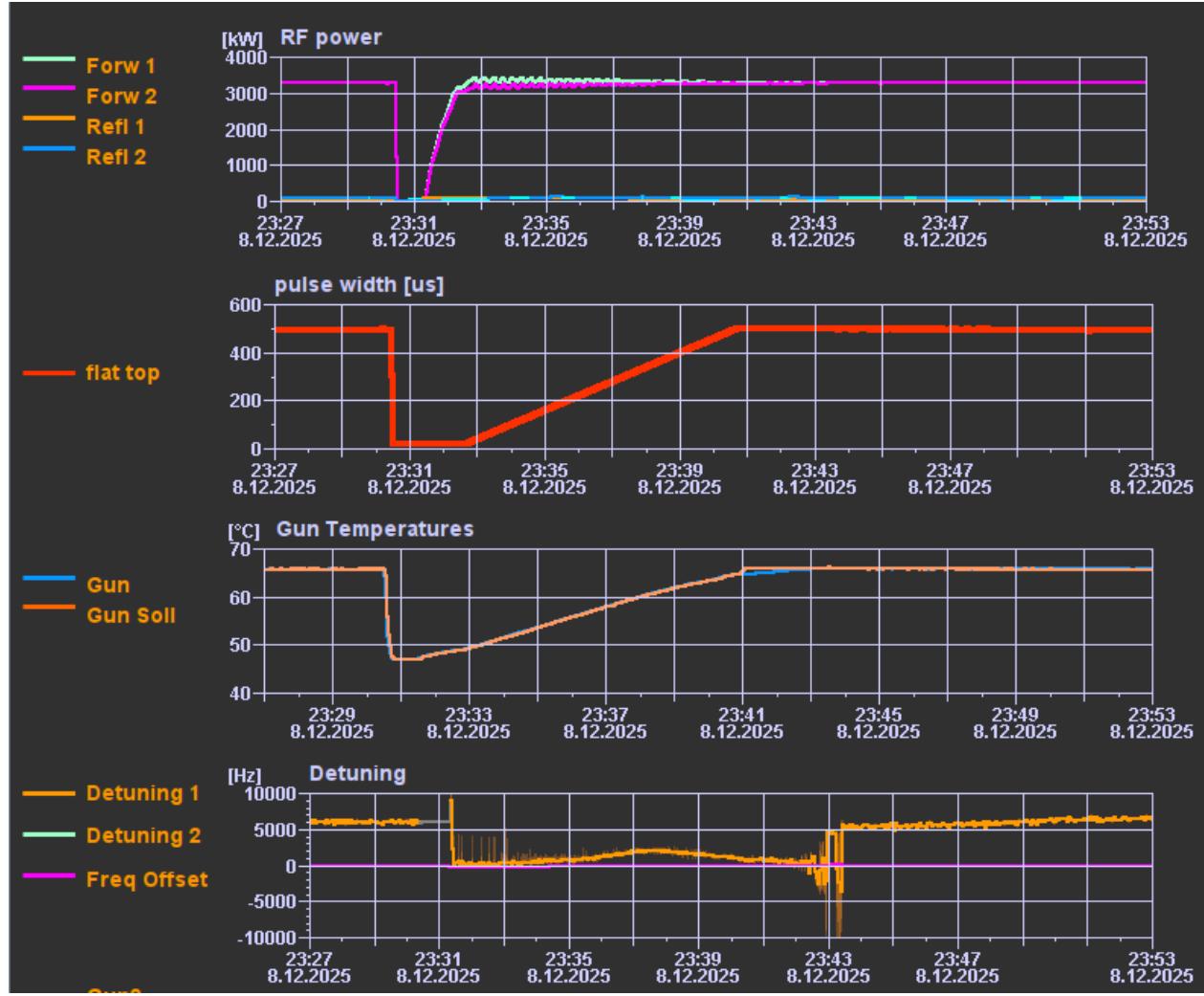
## Temperatures



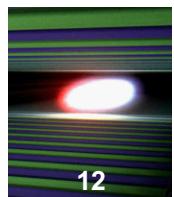


- Two modes of operation: RF On or Off
- Checks a number of states before proceeding to the next
- Loops through to verify that all is still ok.
- In case of trips it resets interlocks and ramps up again

- RF gets off – the temperature goes down
- FSM follows with the temperature
- RF restart
- FSM
  - activates the frequency detuning
  - ramps up the amplitude
  - ramps up the pulse length
- With increasing power the temperature rises
- At the end the parameters have been restored
- FSM
  - Waits for stabilization
  - Switches off the frequency detuning
  - Switches on the PWM and feedback
  - Declares RF-running

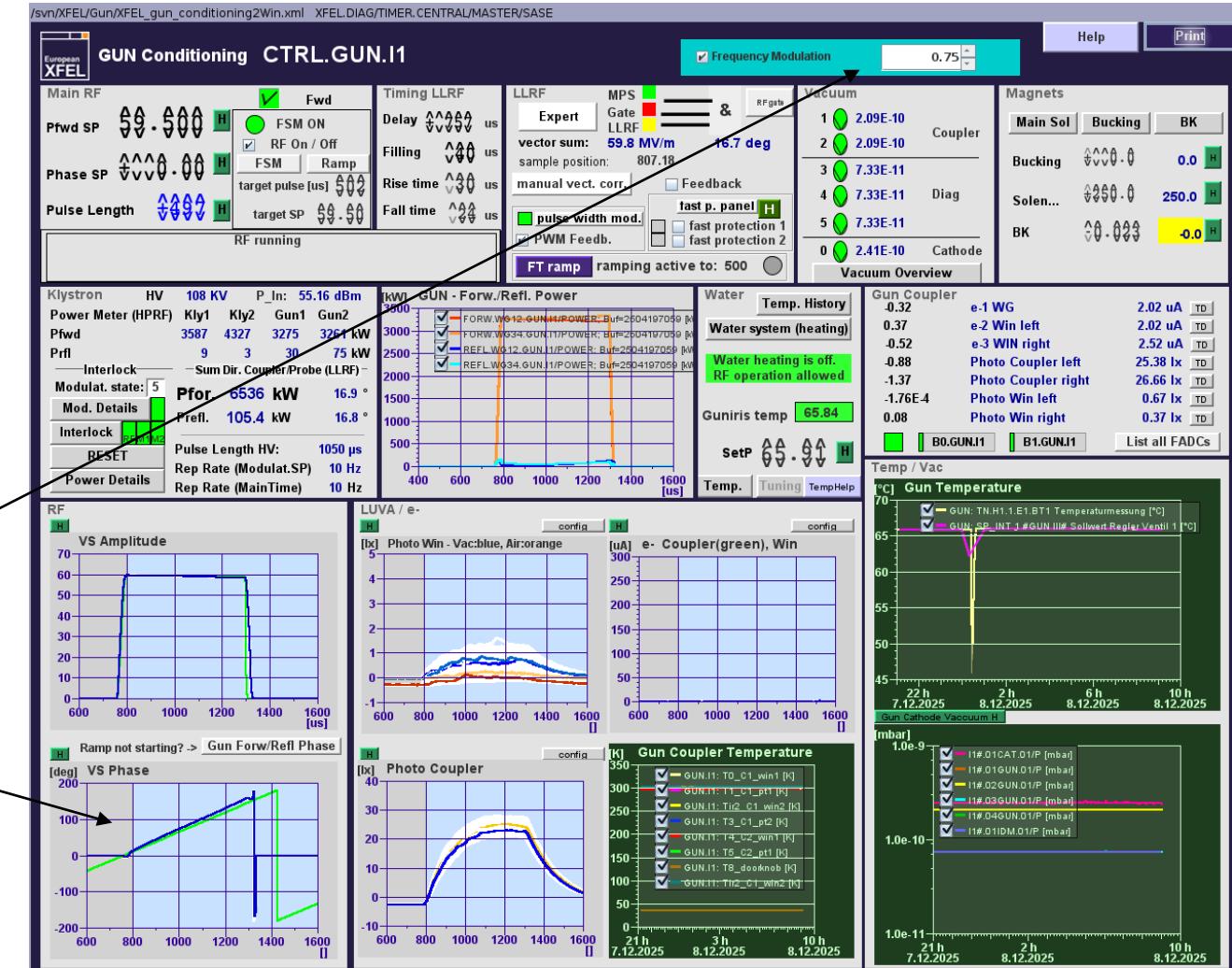


# Frequency modulation



- The resonance frequency of the gun varies with the temperature
- Instead of adjusting the temperature one can also just set the frequency to resonance

Frequency offset

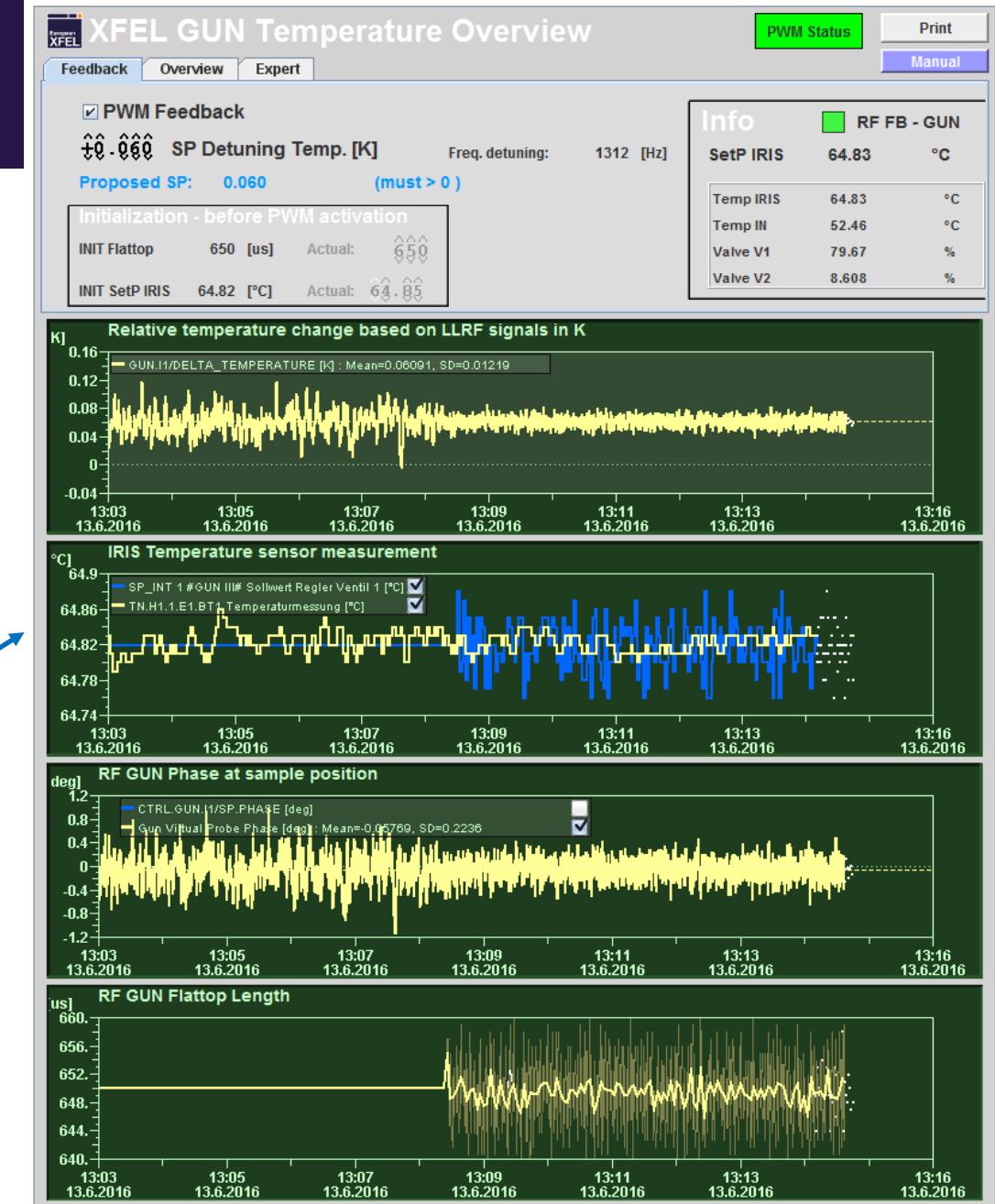
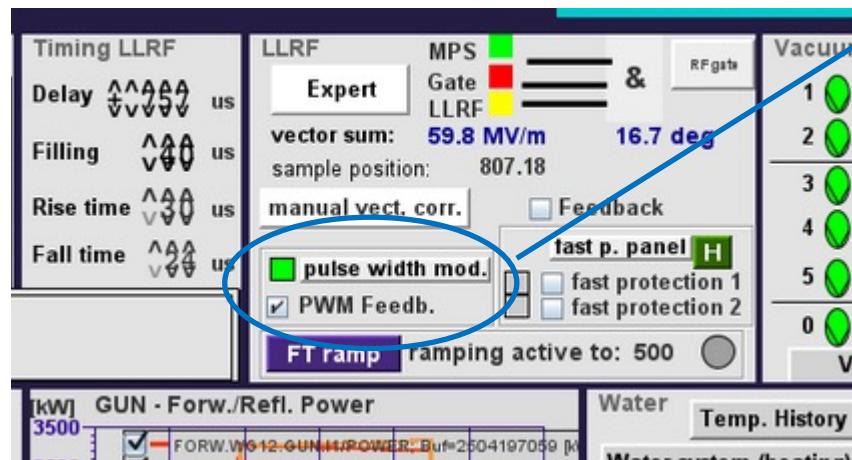


Phase drift

Works only for the gun alone  
The laser and other RF runs  
asynchronous during this time

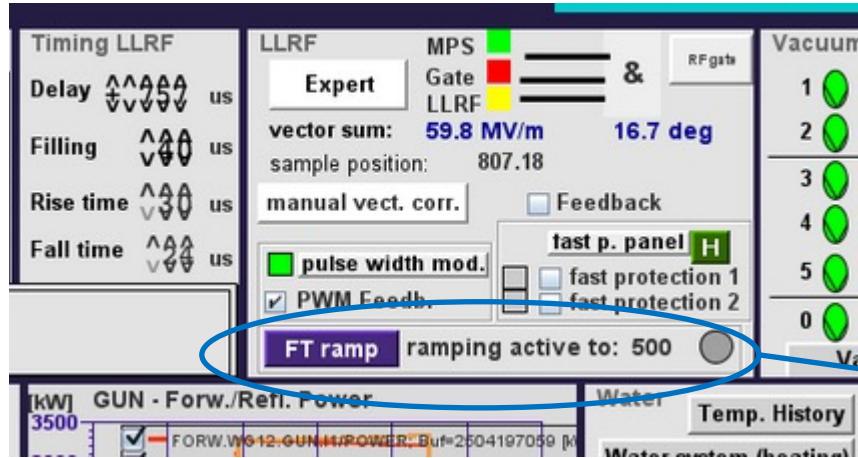
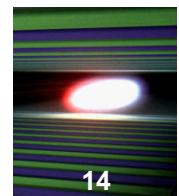
# Pulse width modulation

- Fast measurement of gun temperature/detuning (0.1sec vs. 7 sec)
- Compensate temperature deviations with the RF pulse width
- Compensate also for cooling water drifts after the ramp up



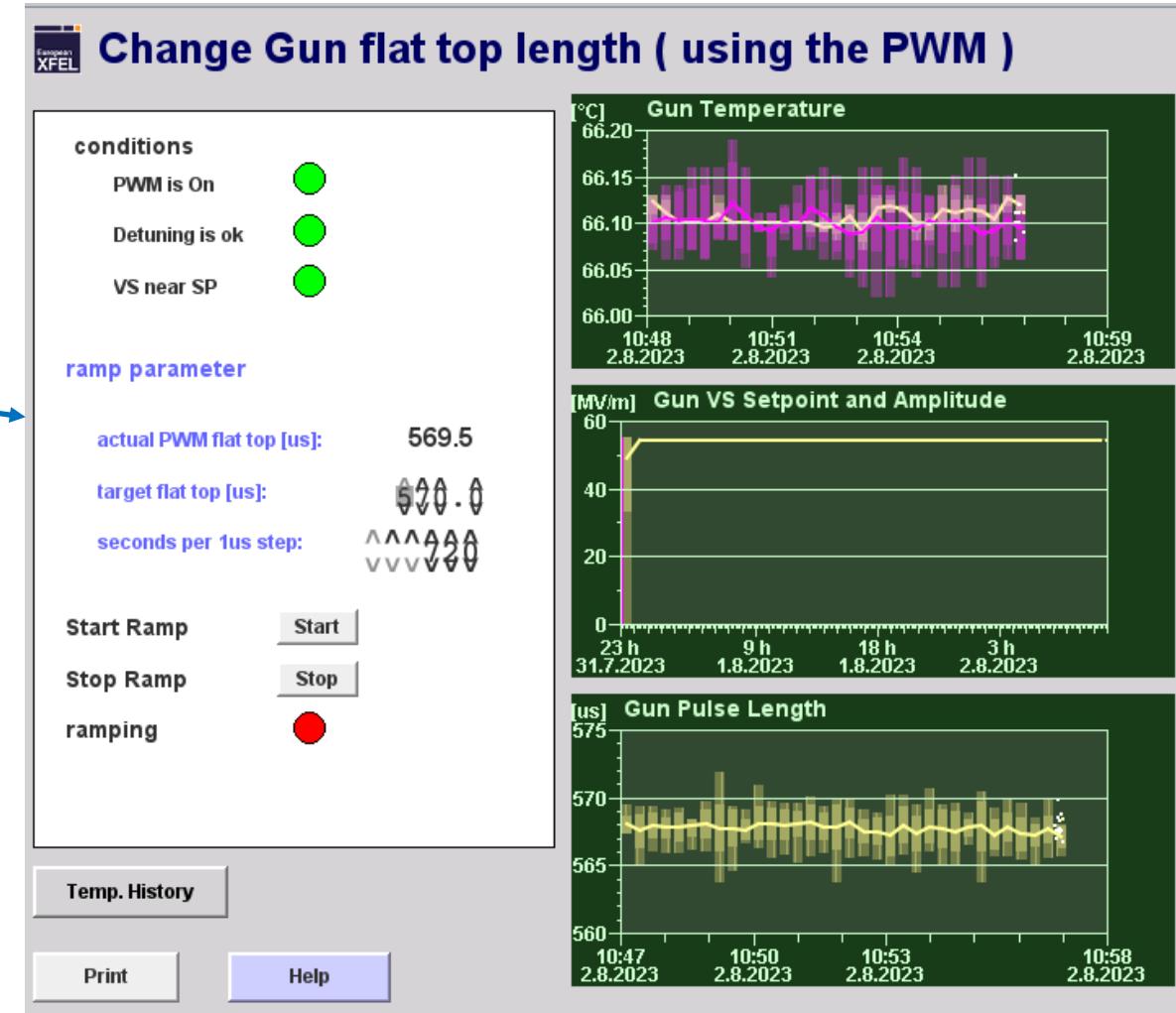
# Slow ramp up with PWM

- Advantage: no influence on stability ( SASE etc. )

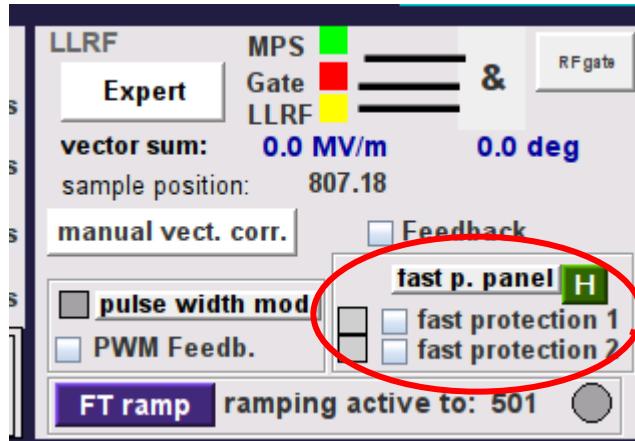


- Increases slowly the target length for the PWM – not the pulse length directly
- Increases also the temperature SP
- Pauses when one of the conditions is bad
- Changes only by 1 us for each step

Very smooth changes – can be done even during user operation

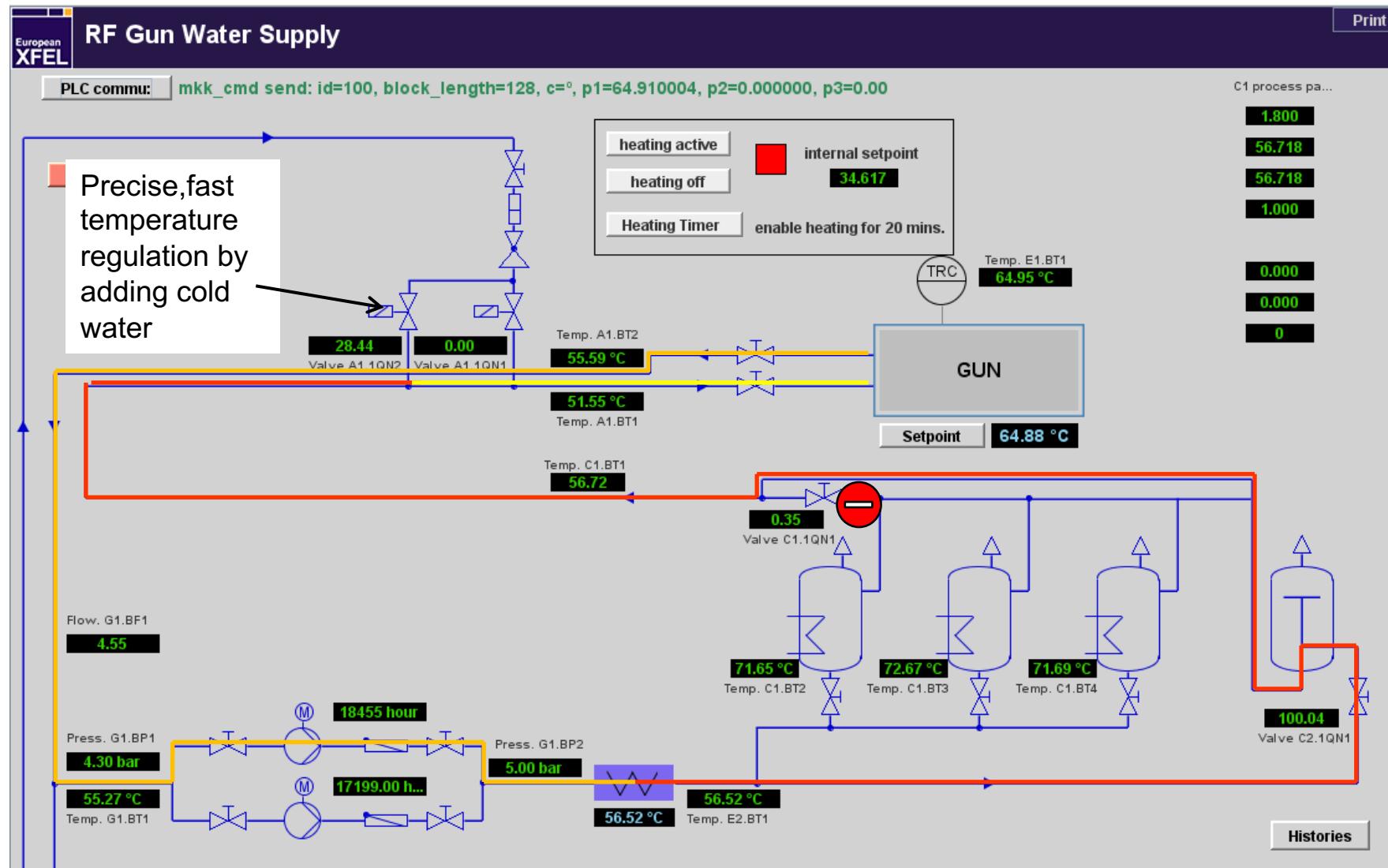
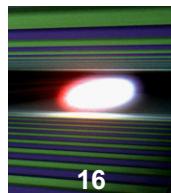


# LLRF fast protection – looking at the reflected power

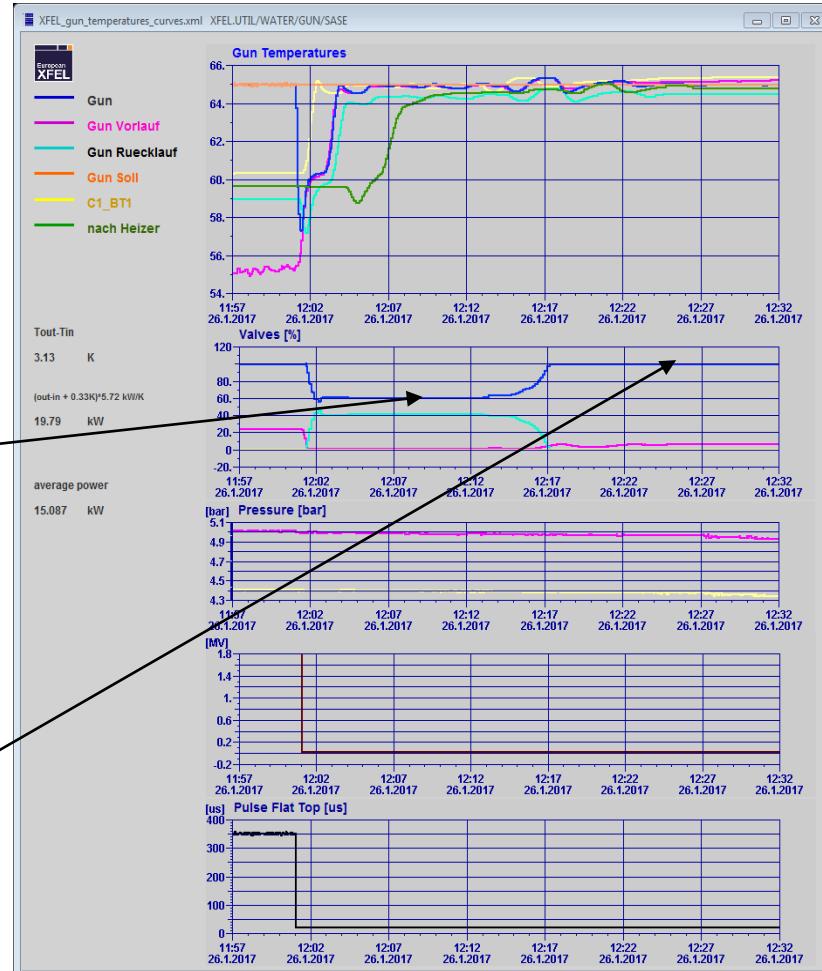
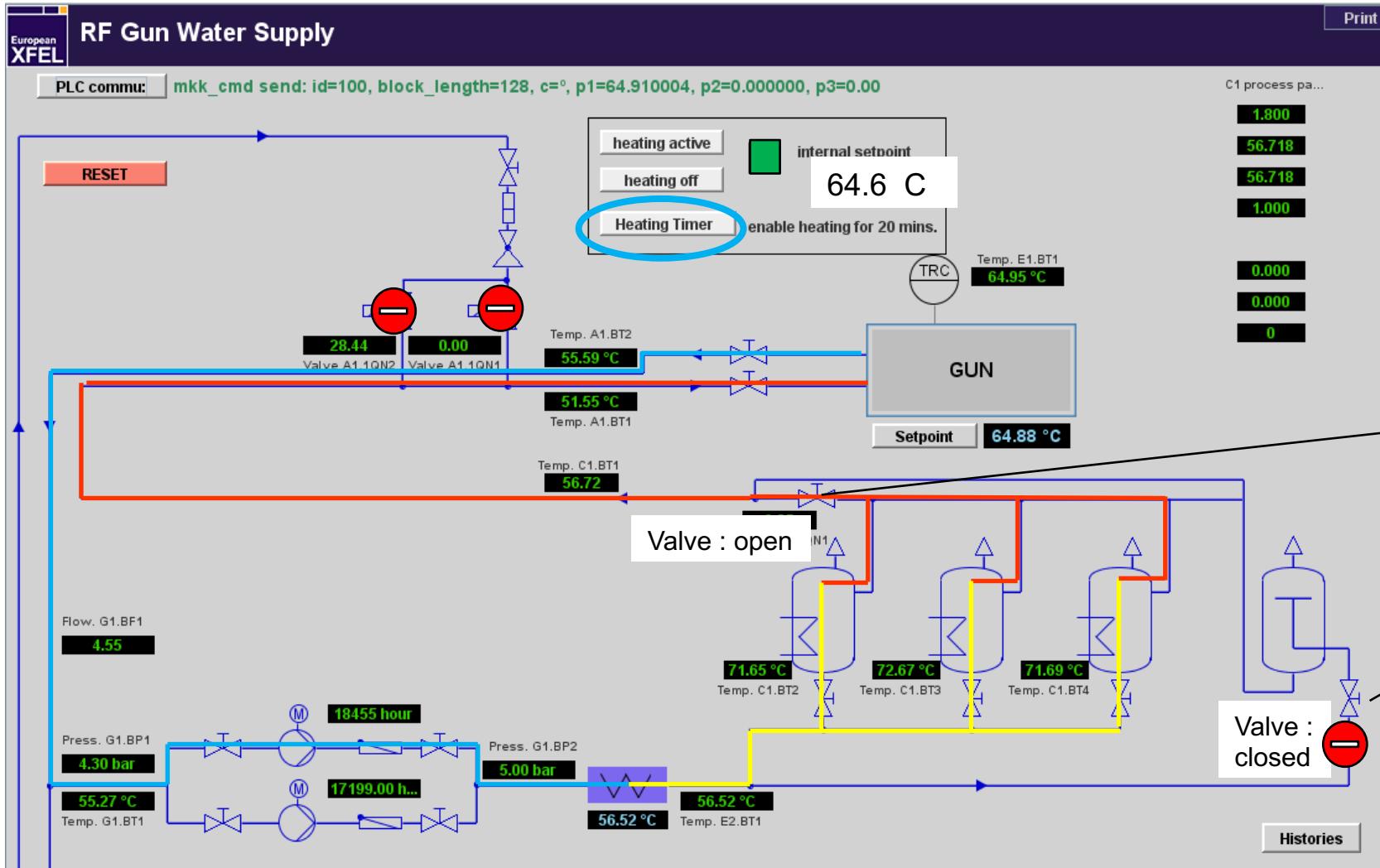
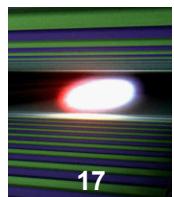


If the reflected amplitude exceeds the limit, the pulse will be cut – but the next pulse is allowed again

## Water temperature regulation – gun operation



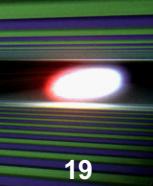
# Water temperature regulation – heating up if needed



# Thank you for listening!

# Fast Gun Ramp Up – by FSM

## Typically the parameters are taken from the last run!



XFEL\_gun\_conditioning.xml XFEL.DIAG/TIMER.CENTRAL/MASTER/SASE

**GUN Conditioning**   **MAIN.GUN.I1**

Main RF

Pfwd SP  $\begin{array}{c} \wedge \wedge \\ \vee \vee \end{array} 0.920$   Fwd  FSM ON  RF On / off

Phase SP  $\begin{array}{c} \wedge \wedge \wedge \wedge \\ \vee \vee \end{array} 27.00$   RF is switched off

Pulse Length  $\begin{array}{c} \wedge \wedge \wedge \wedge \\ \downarrow \downarrow \end{array} 20$   FSM  Ramp

Water SP  $\begin{array}{c} \wedge \wedge \wedge \wedge \\ \downarrow \downarrow \end{array} 59.21$

Klystron

HV 0 KV P\_in: 2.20 dBm dBm

Pfwd 0 KW 0 KW

Prfl 0 KW 0 KW

**Directional Coupler**

Pfor. 0.00 MW

Modulator Details

Interlock

RESET

Power Details

Interlock

Pulse Length HV 1000 us

Rep Rate (Modulat.Set) 10.0 Hz

Rep Rate (MainTime) 10 Hz

RF

WG Sound

VS Amplitude

LUVA / e-  $\begin{array}{c} \wedge \wedge \wedge \wedge \\ \downarrow \downarrow \end{array}$

[Hz] Photo WG 10.

**FSM : Gun Ramp Up**

1) FSM On

2) Choose targets: gradient and pulse width

Estimation for the start temperature

Only for new parameters!

3) Set start temperature and wait until it's reached (~0.2 C)

4) Start ramp by switching FSM RF On

FSM messages

Target values

VS Setpoint  $\begin{array}{c} \wedge \wedge \wedge \wedge \\ \downarrow \downarrow \end{array} 50$

Pulse width [us]  $\begin{array}{c} \wedge \wedge \wedge \wedge \\ \downarrow \downarrow \end{array} 300$

Resonance Temp. [C]  $\begin{array}{c} \wedge \wedge \wedge \wedge \\ \downarrow \downarrow \end{array} 90$

Average power:

now: 12.42kW target: 12.26 kW

Start temperature  $64.92^{\circ}\text{C}$

Water Setpoint  $\begin{array}{c} \wedge \wedge \wedge \wedge \\ \downarrow \downarrow \end{array} 65.07^{\circ}\text{C}$

Set

Start Ramp  FSM RF On:  Switch off RF  FSM RF Off:

RF running

Print Help

**Gun Temperature** [C]

66. 65. 64. 63. 62. 61. 60. 59.

16:29 26.1.2017 16:33 26.1.2017 16:37 26.1.2017 16:42 26.1.2017

**Gun VS Setpoint and Amplitude** [MV/m]

60. 50. 40. 30. 20. 10. 0.

16:29 26.1.2017 16:33 26.1.2017 16:37 26.1.2017 16:42 26.1.2017

**Gun Pulse Length** [us]

325. 275. 225. 175. 125. 75. 25.

16:29 26.1.2017 16:33 26.1.2017 16:37 26.1.2017 16:42 26.1.2017