

Progress in Finite State Machine Developments at FLASH

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Objective of this simple FSM design

- Start up a system
 - Coupler, klystron, LLRF
- Shut down a system
 - LLRF, Klystron
- Recover from trips
- Monitors some important values from
 - Coupler vacuum, quench, filament ...

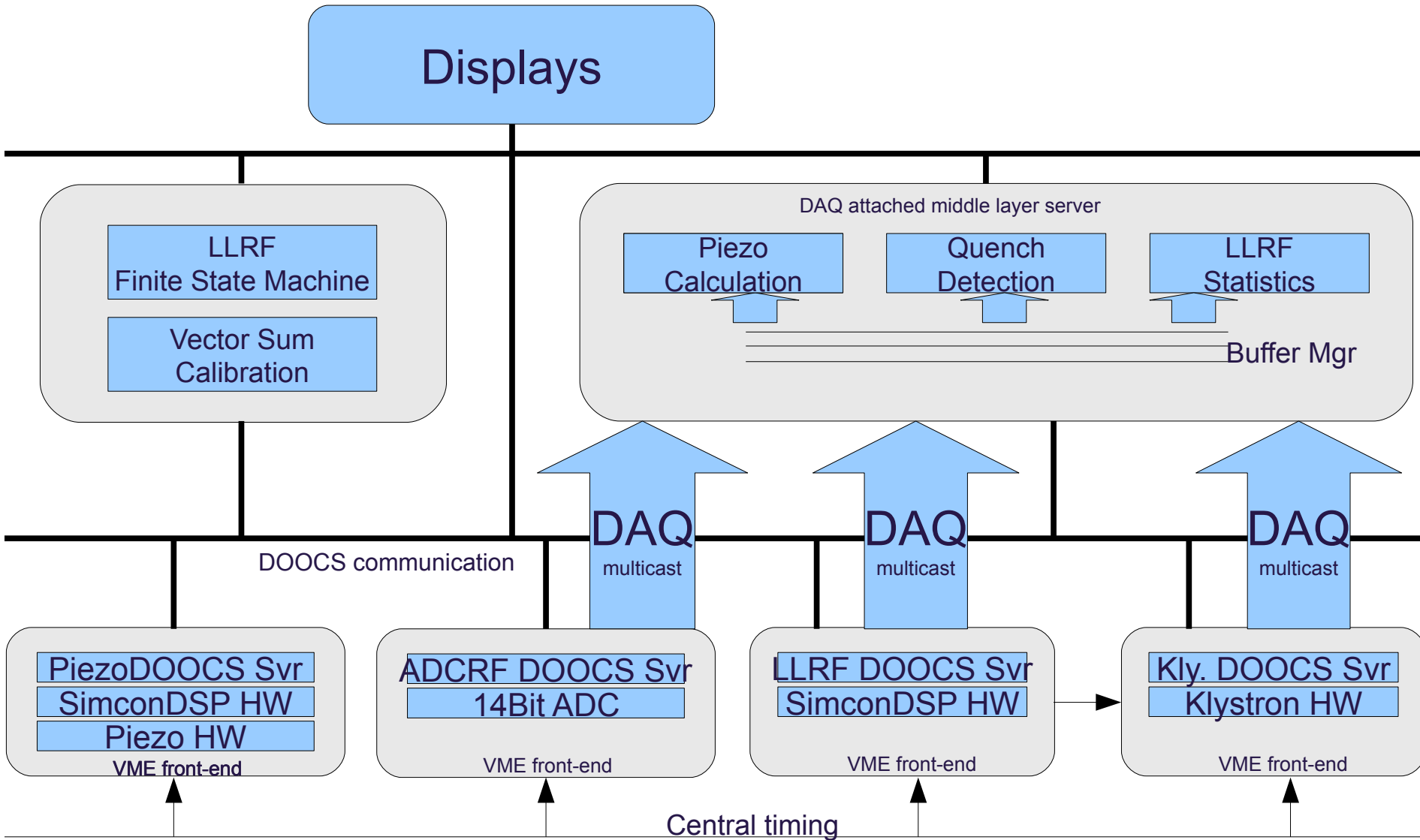


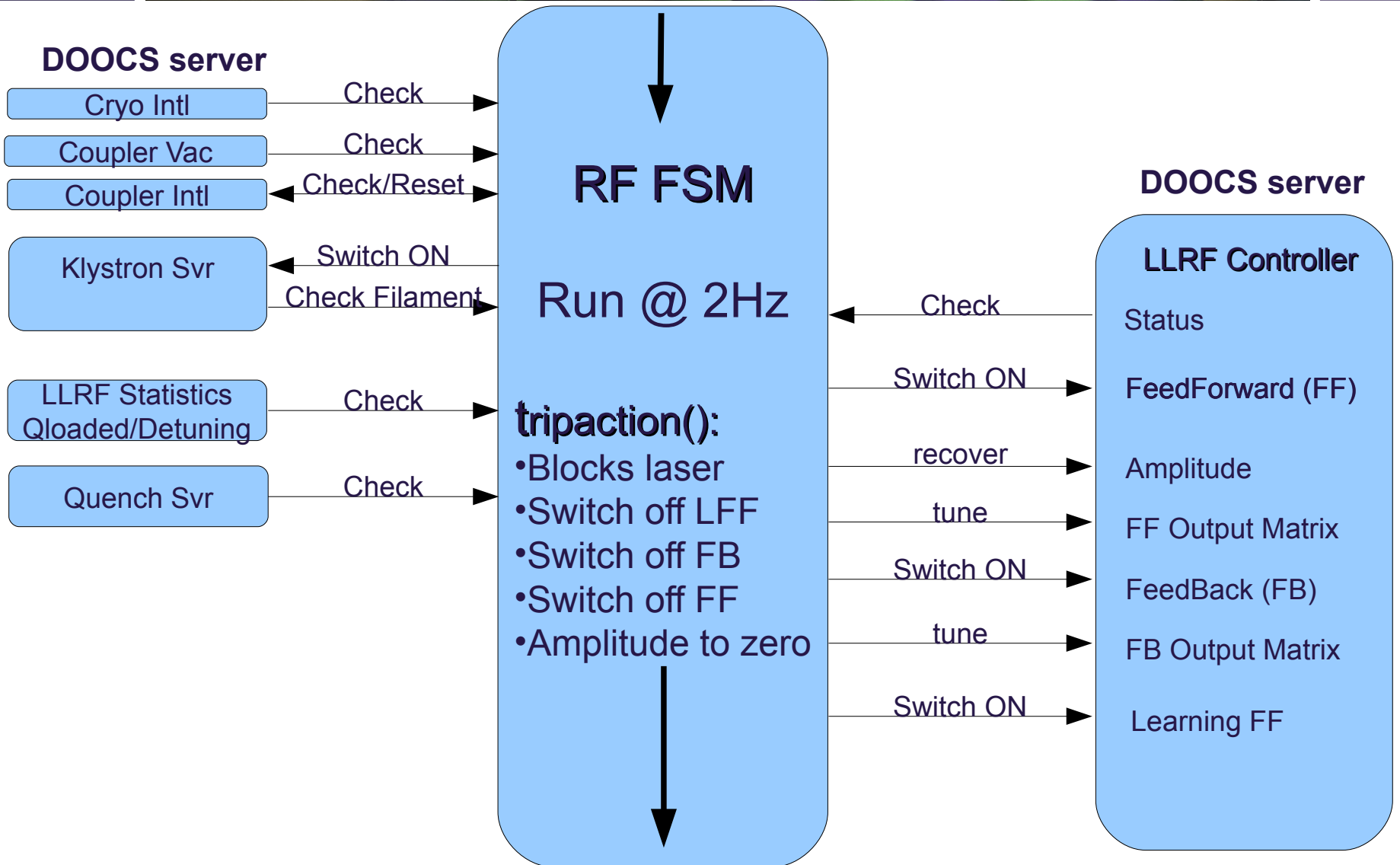
The RF **F**inite **S**tate **M**achine (FSM)

- THE central RF control server
- Based on standard DOOCS Server
- Is a Middle Layer Server
- Has one independent Location per RF Station
 - A special location(version) for the GUN
- Allows Operator intervention !
 - Reset- or Setpoint changes
- Runs with 2 Hz replate



Displays





FSM Main State

- FSM on, call `check_status()`, `save_onstatus()`
- Start-up
- State Name
- State Error Message
- `tripaction()`

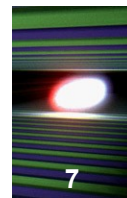
If (Startup == 1)

Startup
(recover)

else

Shutdown

One DOOCS location
e.g. RF section

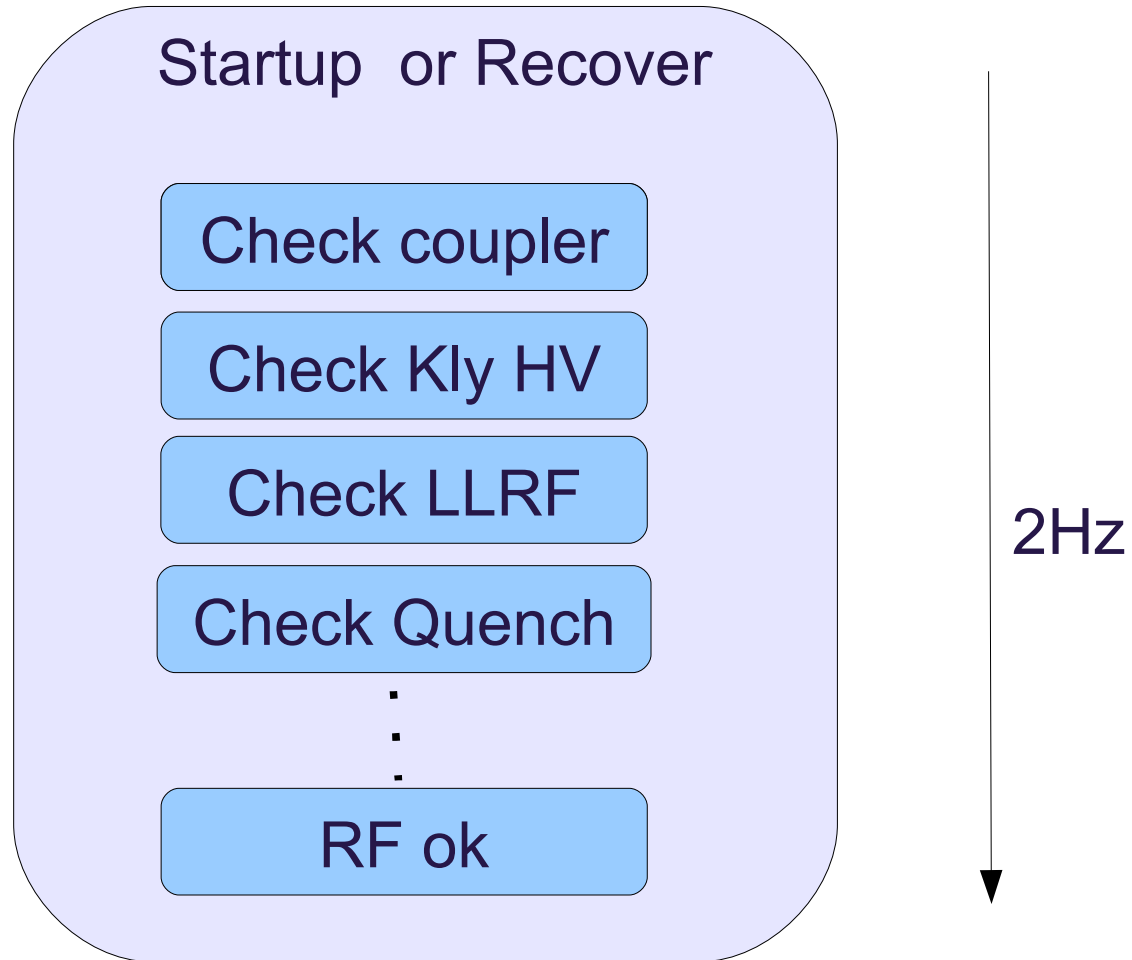
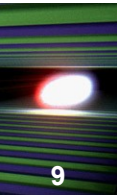


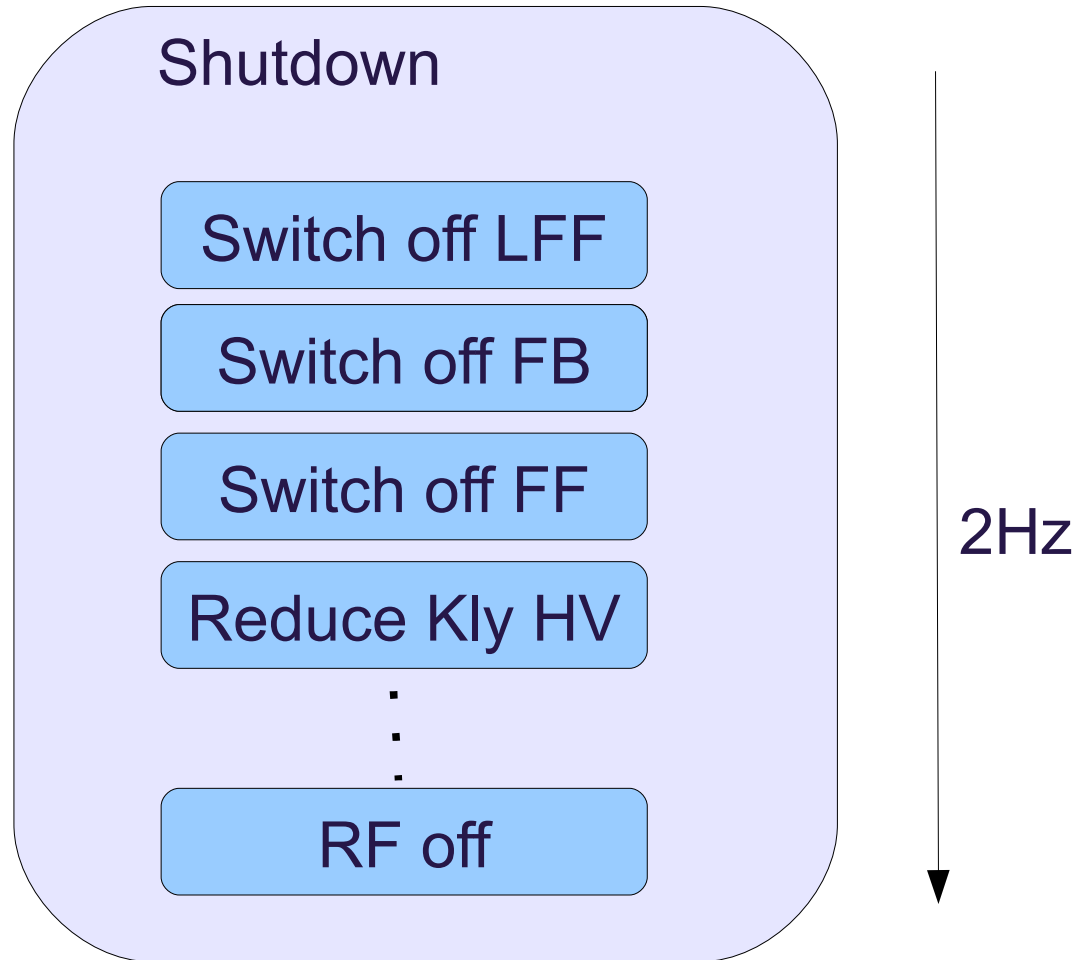
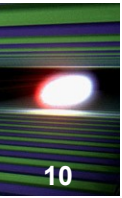
When switching the FSM on...

- `check_status()`
 - Check klystron HV > 8000V => in Start-up mode

- `save_onstatus()` save the current machine status
 - Learning FeedForward (LFF) on/off
 - FeedBack on/off
 - FeedForward on/off
 - Amplitude set-point
 - Klystron HV set-point
 - Output Rotation Matrix correction on/off

- On tripartition()
 - Blocks the laser
 - Switches off LLRF
 - Feedback
 - Feedforward
 - Learning FeedForward (LFF)
 - Output Matrix correction
 - Puts amplitude (gradient) set-point to zero





Concept of a simple FSM using DOOCS D_functions inside a standard DOOCS server

D_FSMreset State

- DOOCS address of monitoring Bit
- DOOCS address of reset Bit
- Retry counter
- Timer in seconds
- Enable Bits

Reset something
e.g. interlock

D_FSMrecover State

- DOOCS address of monitoring Bit
- DOOCS address of recover Bit
- Enable Bits

Switch something on/off
e.g. Feedback

Concept of a simple FSM using DOOCS D_functions inside a standard DOOCS server

D_FSMmonitor State

- DOOCS address of monitoring Value
- Recover Value
- Tolerance value
- Retry counter
- Enable Bits

Monitor a value

e.g. filament HV

Recover a value

e.g. LLRF Amplitude

D_FSMtimer State

- Timer value in seconds
- Enable Bits

Just wait

How to use the RF FSM

SIMCON_Operation: TTF2.RF/LLRF.CONTROLLER/ACC23/

ACC23 Operation

Voltage

▲▲▲▲▲▲▲▲
+ 279.4 MV H

SP Phase rel. beam

▲▲▲▲▲▲▲▲
+ 19.40 H

RF Station KLY6

Mod ready **KLY6**

RF_Inhibit PreAmp Enable

Interlock RESET

Coupler

ACC2 couplers IL

1	2	3	4	5	6	7	8

spark light e- T300K T70K Ubias

Vac.Cp1 cryo

FV IL RESET

Error Msg : OK

ON **FSM on** ✓ **RF on**

RF running

✓ **Feedforward**

✓ **Feedback**

Loop Gain ▲▲▲▲▲▲▲▲
+ 30.00 H

RF gate status EN

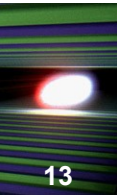
Expert

[MV] ACC23 Amp1. Setpoint

400. A

[deg] ACC23 Phase Setpoint

180. A



How to use the RF FSM

procedure_linac_shutdown-FSM: TTF2.RF///

Shutdown procedure – before breaking the interlock

Block the Laser

	Kly. 3	Kly. 2	Kly. 39	Kly. 6	Kly. 5	Kly. 4
FSM status	<input type="button" value="ON"/>	<input type="button" value="ON"/>	<input type="button" value="OFF"/>	<input type="button" value="ON"/>	<input type="button" value="OFF"/>	<input type="button" value="OFF"/>
RF setpoint	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Switch off Feedback	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Switch off Feedforward	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Set Gradient to 0	grad SP 3.50	grad SP 162.30	grad SP 19.00	grad SP 314.40	grad SP 0.00	grad SP 0.00
Ramp down	<input type="button" value="KLY3 HV down"/>	<input type="button" value="KLY2 HV down"/>	<input type="button" value="HV down"/>	<input type="button" value="KLY6 HV down"/>	<input type="button" value="KLY5 HV down"/>	<input type="button" value="KLY4 HV down"/>
Modulator HV	Kly3. Voltage 127.79 kV	Kly2 Voltage 116.08 kV	Kly3.9. Voltage 29.99 kV	Kly6. Voltage 121.66 kV	Kly5. Voltage 126.95 V	Kly4. Voltage 108.17 kV
switch off Modulator if HV is down	<input type="button" value="OFF-Mod"/>	<input type="button" value="OFF-Mod"/>	<input type="button" value="OFF-Mod"/>	<input type="button" value="OFF-Mod"/>	<input type="button" value="OFF-Mod"/>	<input type="button" value="OFF-Mod"/>

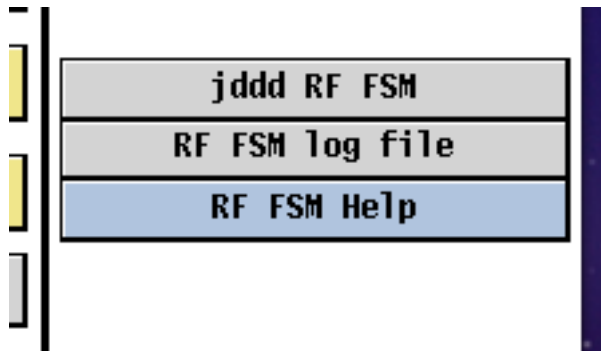
FSM controlled

ALL SP to zero

only if requested by MVP on maintenance days

For experts

main_select → Modules



How to use the RF FSM

RF_FSM_Main_State.xml

RF FSM Main State ACC1

ACC1

FSM Startup

State Name	STARTUP_STATE	2.68435456E8
State Error Message	0 OK RF running	5.3687091E8

RF Startup ACC1

- KLYYELLOW_ONSTATE
- KLYSETHV_ONSTATE
- KLYHVPLC_ONSTATE
- KLYHVPLCTIMER_ONSTATE
- KLYHV_ONSTATE
- KLYRFINHIBIT_ONSTATE
- LLRFOK_ONSTATE
- LLRFRFGATE_ONSTATE
- FEEDFORWARD_ONSTATE
- LLRFAMPL_ONSTATE
- QUENCH_ONSTATE
- FEEDBACKTIMER_ONSTATE
- OUTPUTMATRIX_ONSTATE
- FEEDBACKCHECK_ONSTATE
- FEEDBACK_ONSTATE

RF Shutdown ACC1

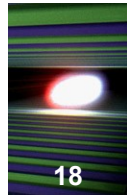
- OUTPUTMATRIX_OFFSTATE
- LFF_OFFSTATE
- FEEDBACK_OFFSTATE
- FEEDFORWARD_OFFSTATE
- LLRFAMPL_OFFSTATE
- KLYSETHV_OFFSTATE
- KLYHV_OFFSTATE
- KLYHVADC_OFFSTATE
- KLY_OFFSTATE

How to use the RF FSM

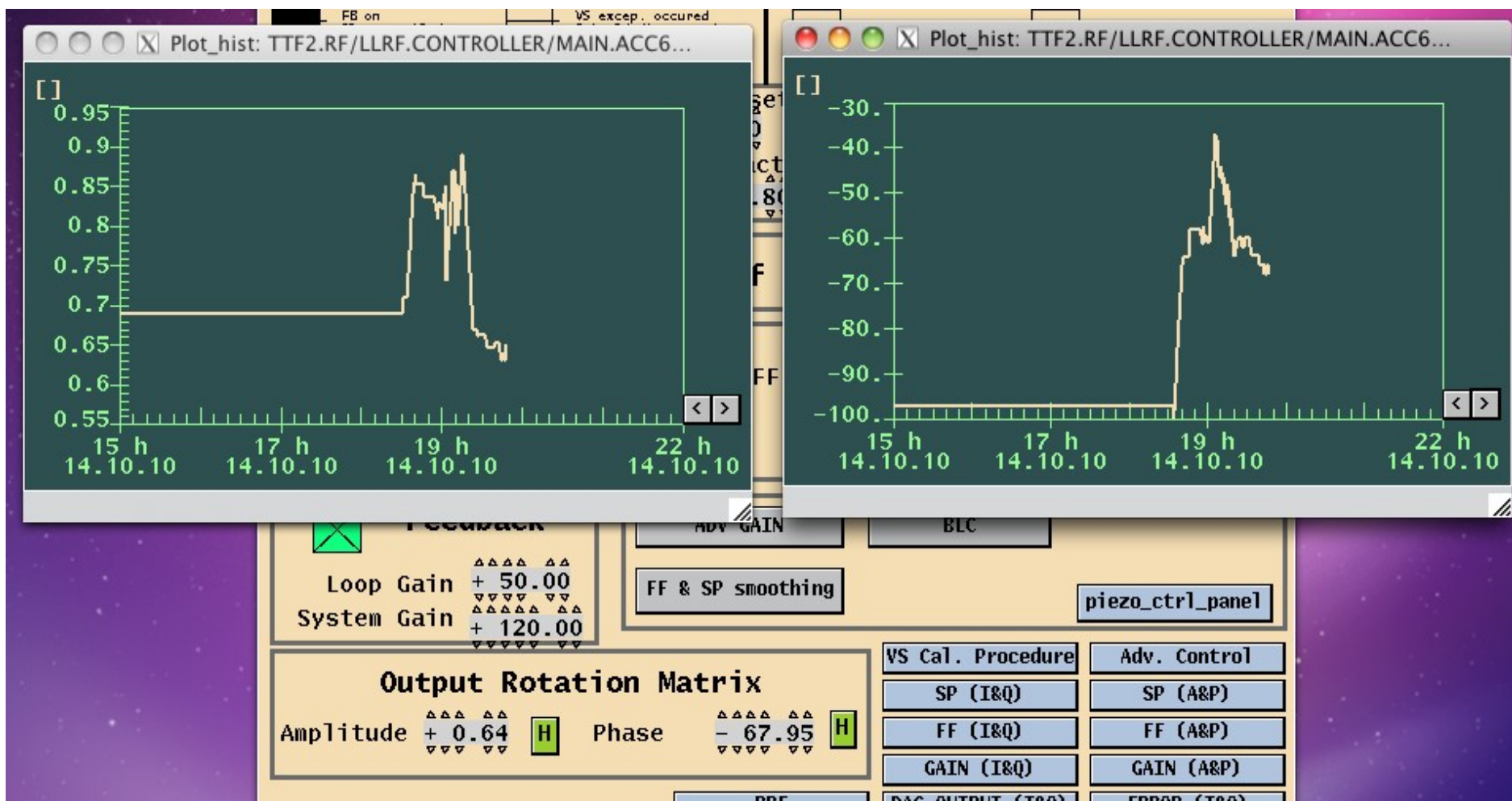
RF_expert.xml TTF2.RF/RF.STARTUP/ACC1/LLRFAMPL_ONSTATE

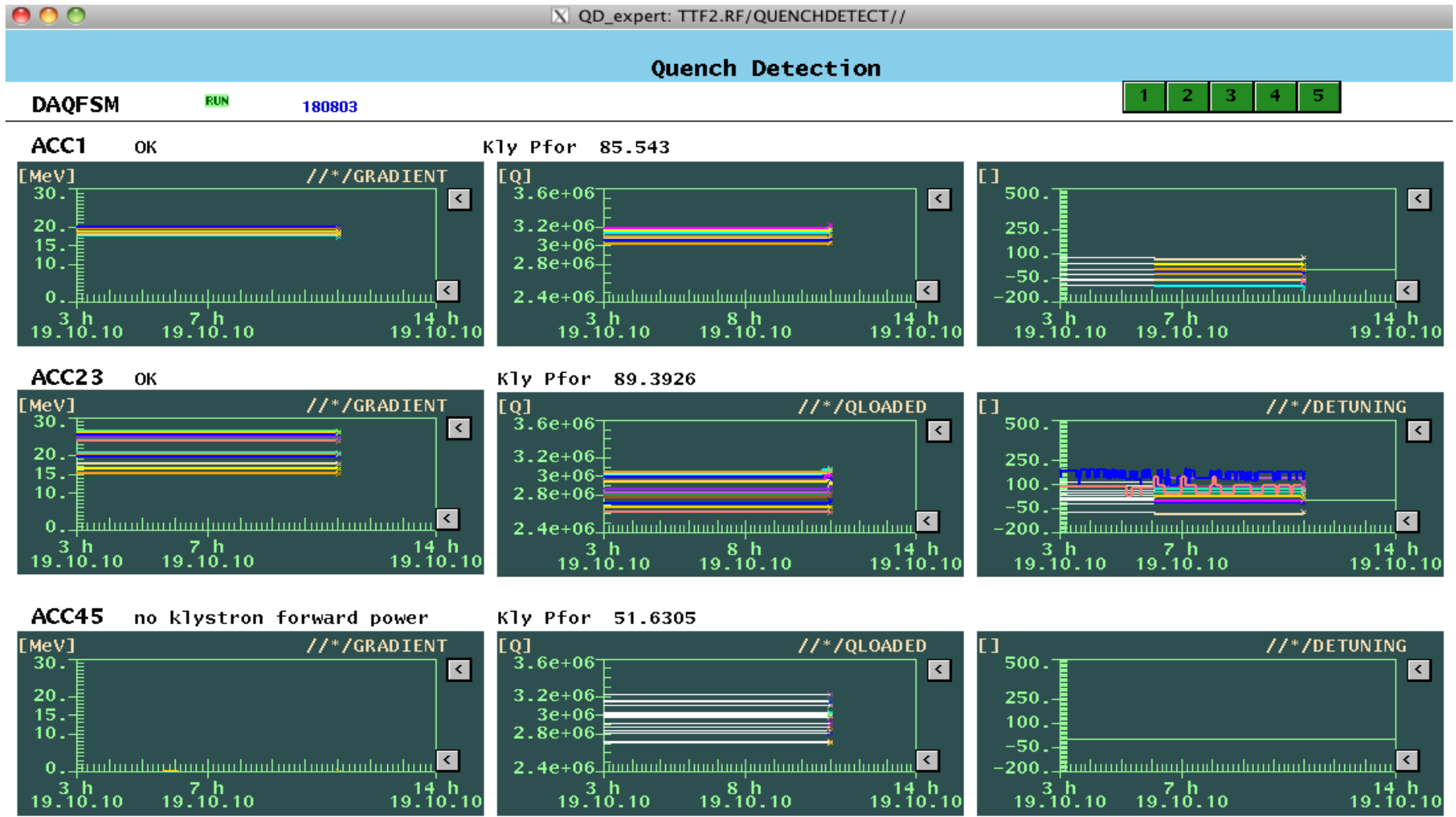
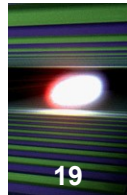
RF Expert Panel for ACC1/LLRFAMPL_ONSTATE

LLRFAMPL_ONSTATE.TYPE	0
LLRFAMPL_ONSTATE.ERRORMSG	cannot recover the amplitude
LLRFAMPL_ONSTATE.DEVICEINFO	
LLRFAMPL_ONSTATE.CHECKADDR	TTF2.RF/LLRF.CONTROLLER/MAIN.ACC1/AMPL.SETPO
LLRFAMPL_ONSTATE.CURRENTVALUE	145.4
LLRFAMPL_ONSTATE.RECOVERADDR	TTF2.RF/LLRF.CONTROLLER/MAIN.ACC1/AMPL.SETPO
LLRFAMPL_ONSTATE.RECOVERVALUE	145.4
LLRFAMPL_ONSTATE.RANGE	2 0.01 0.0 0.0
LLRFAMPL_ONSTATE.ENABLE	
<input type="checkbox"/> DISABLE STATE	
<input type="checkbox"/> DISABLE RESET	
<input checked="" type="checkbox"/> DISABLE TRIPACTION	



Output Rotation Matrix correction





DOOCS Alarm and Info Server Display, Version 3.3 12.05.10

Menu View Help

Device Tree: Filter ON

Device Tree

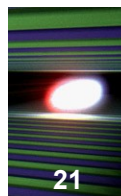
- ▶ Device Tree
- ▶ TTF2.SYSTEM
- ▶ TTF2.FEL
- ▶ TTF2.RF
 - ▶ TIMER
 - ▶ LLRF.WGMOTOR
 - ▶ CPL.ADC
 - ▶ KLY.PLC
 - ▶ KLY.ADC
 - ▶ CPL.S_ADC
 - ▶ KLY.INTERLOCK
 - ▶ MO_CONTROL
 - ▶ LLRF.MONITORING
 - ▶ LLRF.ADCDMA
 - ▶ ADCDMA
 - ▶ LLRF.ADC
 - ▶ CPL.DIO
 - ▶ CPL.TUNER
 - ▶ LLRF.CONTROLLER
 - ▶ POWERMETER
 - ▶ RF.START
 - ▶ KLY.DIO
 - ▶ LLRF.VSCALIB
 - ▶ QUENCHDETECT
- ▶ TTF2.EXP
- ▶ TTF2.DIAG

Pending Errors:

Location	Property	Time	Severity	Message
TTF2.RF/QUENCHDETECT/ACC67	ERROR	11:12:07,149 30.06.2010		no klystron forward power
TTF2.DIAG/BLM.ALARM/14ACC7	ERROR	10:20:58,303 30.06.2010		pending BLM alarm since 60sec
TTF2.RF/RF.START/ACC45	ERROR	10:20:46,383 30.06.2010		large amplitude or phase error
TTF2.RF/RF.START/ACC67	ERROR	09:00:21,019 30.06.2010		large amplitude or phase error
TTF2.RF/QUENCHDETECT/ACC1	ERROR	13:42:34,481 29.06.2010		no klystron forward power
TTF2.RF/RF.START/GUN	ERROR	13:59:01,734 25.06.2010		cannot set ampl. to zero
TTF2.DIAG/WIRESCAN/14SMATCH.VERT	ERROR	14:05:02,240 22.06.2010		unavailable srv

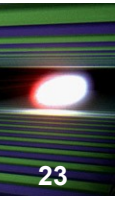
History of selected location: [TTF2.RF/RF.START](#) max:3933 /total:5878

Time	Name	Severity	Message
10:21:01,191 30.06.2010	ACC23/ERROR		OK
10:20:46,383 30.06.2010	ACC45/ERROR		large amplitude or phase error
10:20:30,061 30.06.2010	ACC45/ERROR		OK
10:19:58,558 30.06.2010	ACC23/ERROR		cannot reset CRYO interlock
09:57:57,884 30.06.2010	ACC45/ERROR		cannot set ampl. to zero
09:57:49,182 30.06.2010	ACC23/ERROR		OK
09:56:30,709 30.06.2010	ACC23/ERROR		cannot reset CRYO interlock
09:06:47,701 30.06.2010	ACC67/ERROR		FSM is switched off
09:02:31,129 30.06.2010	ACC45/ERROR		FSM is switched off
09:00:21,019 30.06.2010	ACC67/ERROR		large amplitude or phase error
09:00:20,509 30.06.2010	ACC67/ERROR		cannot reset CRYO interlock toggled 4 times in 10:01 min
09:00:20,507 30.06.2010	ACC23/ERROR		cannot reset CRYO interlock toggled 3 times in 10:01 min



- GUN location just resets pulse length to 10 μ s
 - Ramping up to previous pulse length needed
- Integration of klystron 3.9GHz still missing
- Know bugs :
 - Trips, when changing the amplitude set-point
 - Operator intervention not possible, when in recover mode
- Tighter integration with
 - Quench-detection
 - Output Rotation Matrix automation
 - Sequencer
- Train operator to get more confidence

- Concept proven
- Usually in operation for all stations
- Will be the central software for RF automation
- Switching OFF the FSM must be forbidden
- Meanwhile good acceptance by operator crew and LLRF experts
- Found no other applications for this FSM technology yet



Thanks for your attention