Ideas for Control of MICE Cavities

- Example amplifier control system
- Example of current STFC copper cavity in operation
  - Using SF6 insulated waveguide
  - Conditioning process results
  - Temperature stabilisation for close control of cavity frequency
  - RF power measurement's
- Mice cavity control ideas

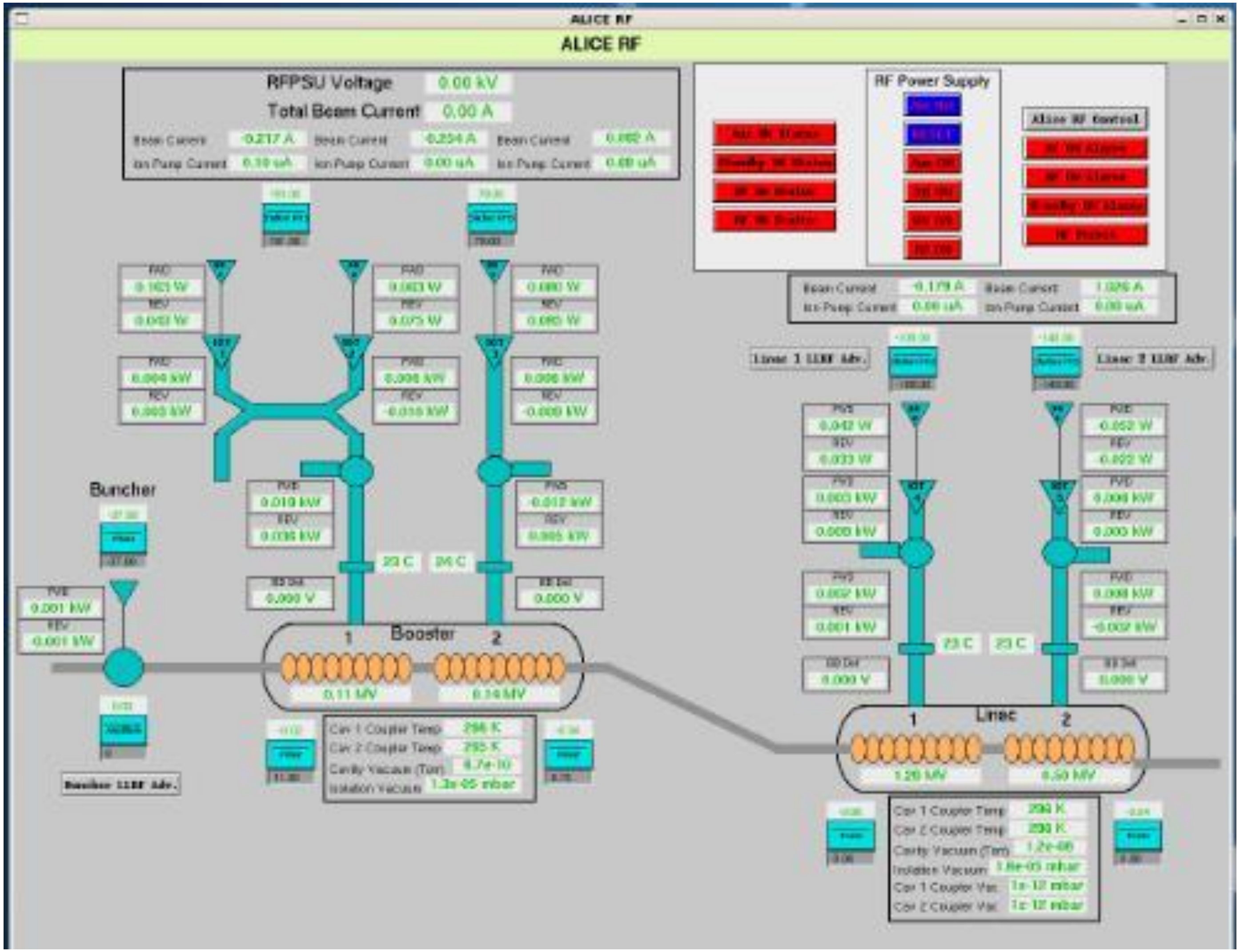
Andrew Moss
STFC, ASTeC

Amplifier Controls

- Using local plc’s/can bus interface – read interlocks, analog setpoints and readbacks
- Build state machine in epics for amplifier control
  1. Aux on – pumps – air – fans
  2. Standby on – filament on, Grid supply's on
  3. HT on – main HV power supplies on ready
  4. RF on – enable RF drive
- Each state should show which interlocks are missing to enable the next block and which interlocks removed the state during a trip condition

RF system overall control

- State machine control
- RF measurements
- Important vacuum /voltage/ temperature parameters
- Interlock status and trips
- This is the main operator panel for ALICE
- more in-depth control pages are clickable from this main screen


ALICE RF

RFPSU Voltage 0.00 kV

Total Beam Current 0.00 A

Cav 1 Coupler Temp 298 K

Cav 2 Coupler Temp 295 K

Cavity Vacuum (Torr) 4.7e-10

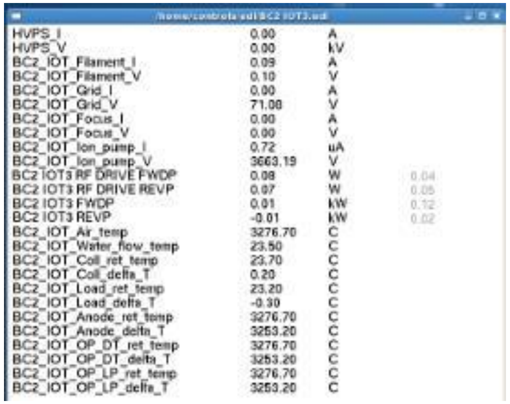
Isolation Vacuum 1.3e-05 mbar

Standby on status

Interlocks required for 5 IOT amplifier's shown which interlocks are failed, Good, and those with timer bypass lops on them to allow the system to warm up

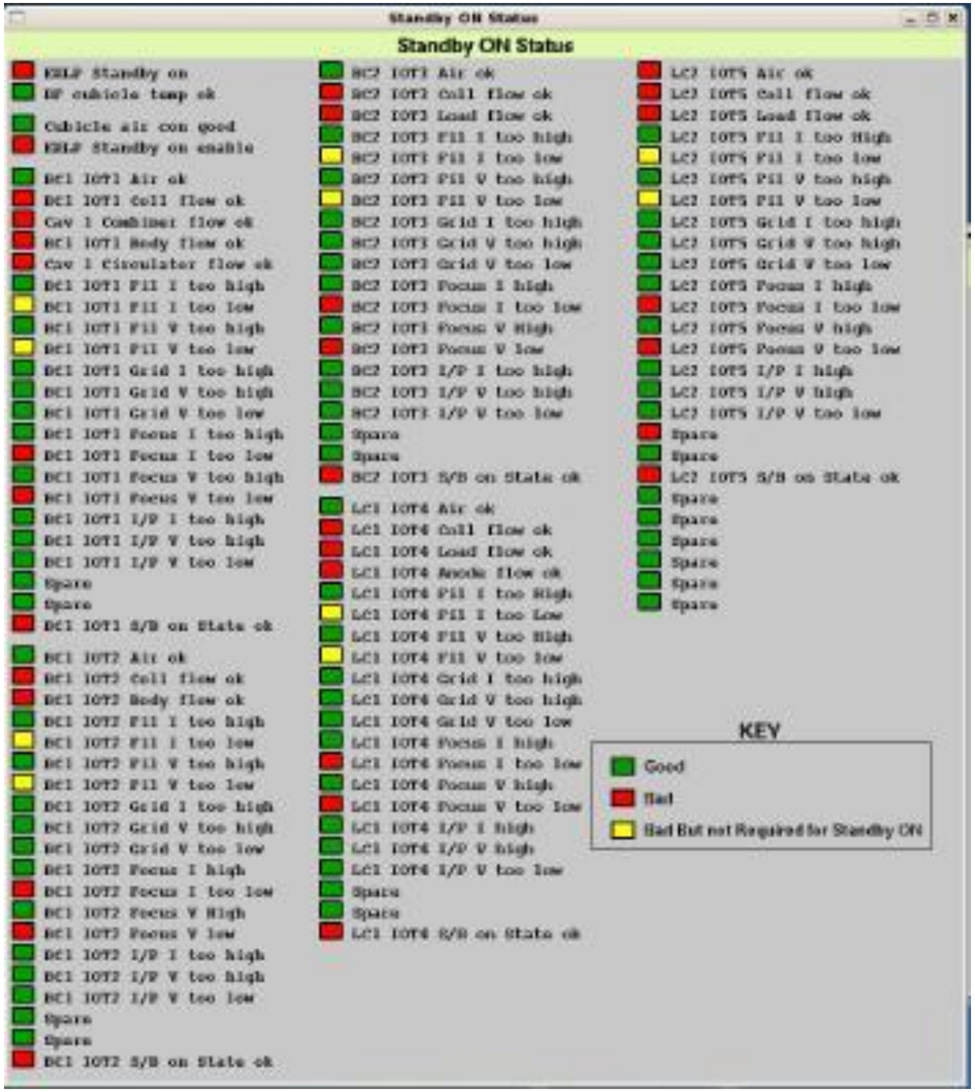
Things that warm up included the filament voltage and current – 15 minutes for these tubes
Focus supplies that drive coils around the valves

After the timer bypass has finished the analogs are interlocked within a 5% good band and any movement outside this level trips the block



```
HVPS_I                      0.00     A
HVPS_V                      0.00     kV
BC2_IOT_Filament_I          0.09     A
BC2_IOT_Filament_V          0.10     V
BC2_IOT_Grid_I              0.00     A
BC2_IOT_Grid_V              71.08    V
BC2_IOT_Focus_I             0.00     A
BC2_IOT_Focus_V             0.00     V
BC2_IOT_Ion_pump_I          0.72     uA
BC2_IOT_Ion_pump_V          3663.19  V
BC2 IOT3 RF DRIVE FWDP      0.08     W        0.04
BC2 IOT3 RF DRIVE REVP      0.07     W        0.05
BC2 IOT3 FWDP               0.01     kW       0.12
BC2 IOT3 REVP               -0.01    kW       0.02
BC2_IOT_Air_temp            3276.70  C
BC2_IOT_Water_flow_temp     23.50    C
BC2_IOT_Coll_ret_temp       23.70    C
BC2_IOT_Coll_delta_T        0.20     C
BC2_IOT_Load_ret_temp       23.20    C
BC2_IOT_Load_delta_T        -0.30    C
BC2_IOT_Anode_ret_temp      3276.70  C
BC2_IOT_Anode_delta_T       3253.20  C
BC2_IOT_OP_DT_ret_temp      3276.70  C
BC2_IOT_OP_DT_delta_T       3253.20  C
BC2_IOT_OP_LP_ret_temp      3276.70  C
BC2_IOT_OP_LP_delta_T       3253.20  C
```

IOT analogs



Standby ON Status

🟥 KRLP Standby on
🟩 RF cubicle temp ok

🟩 Cubicle air con good
🟥 KRLP Standby on enable

🟩 BC1 IOT1 Air ok
🟥 BC1 IOT1 Coll flow ok
🟥 Cav 1 Combiner flow ok
🟥 BC1 IOT1 Body flow ok
🟥 Cav 1 Circulator flow ok
🟩 BC1 IOT1 Fil I too high
🟨 BC1 IOT1 Fil I too low
🟩 BC1 IOT1 Fil V too high
🟨 BC1 IOT1 Fil V too low
🟩 BC1 IOT1 Grid I too high
🟩 BC1 IOT1 Grid V too high
🟩 BC1 IOT1 Grid V too low
🟩 BC1 IOT1 Focus I too high
🟥 BC1 IOT1 Focus I too low
🟩 BC1 IOT1 Focus V too high
🟥 BC1 IOT1 Focus V too low
🟩 BC1 IOT1 I/P I too high
🟩 BC1 IOT1 I/P V too high
🟩 BC1 IOT1 I/P V too low
🟩 Spare
🟩 Spare
🟥 BC1 IOT1 S/B on State ok

🟩 BC1 IOT2 Air ok
🟥 BC1 IOT2 Coll flow ok
🟥 BC1 IOT2 Body flow ok
🟩 BC1 IOT2 Fil I too high
🟨 BC1 IOT2 Fil I too low
🟩 BC1 IOT2 Fil V too high
🟨 BC1 IOT2 Fil V too low
🟩 BC1 IOT2 Grid I too high
🟩 BC1 IOT2 Grid V too high
🟩 BC1 IOT2 Grid V too low
🟩 BC1 IOT2 Focus I high
🟥 BC1 IOT2 Focus I too low
🟩 BC1 IOT2 Focus V High
🟥 BC1 IOT2 Focus V low
🟩 BC1 IOT2 I/P I too high
🟩 BC1 IOT2 I/P V too high
🟩 BC1 IOT2 I/P V too low
🟩 Spare
🟩 Spare
🟥 BC1 IOT2 S/B on State ok

🟩 BC2 IOT3 Air ok
🟥 BC2 IOT3 Coll flow ok
🟥 BC2 IOT3 Load flow ok
🟩 BC2 IOT3 Fil I too high
🟨 BC2 IOT3 Fil I too low
🟩 BC2 IOT3 Fil V too high
🟨 BC2 IOT3 Fil V too low
🟩 BC2 IOT3 Grid I too high
🟩 BC2 IOT3 Grid V too high
🟩 BC2 IOT3 Grid V too low
🟩 BC2 IOT3 Focus I high
🟥 BC2 IOT3 Focus I too low
🟩 BC2 IOT3 Focus V High
🟥 BC2 IOT3 Focus V low
🟩 BC2 IOT3 I/P I too high
🟩 BC2 IOT3 I/P V too high
🟩 BC2 IOT3 I/P V too low
🟩 Spare
🟩 Spare
🟥 BC2 IOT3 S/B on State ok

🟩 LC1 IOT4 Air ok
🟥 LC1 IOT4 Coll flow ok
🟥 LC1 IOT4 Load flow ok
🟥 LC1 IOT4 Anode flow ok
🟩 LC1 IOT4 Fil I too High
🟨 LC1 IOT4 Fil I too Low
🟩 LC1 IOT4 Fil V too High
🟨 LC1 IOT4 Fil V too low
🟩 LC1 IOT4 Grid I too high
🟩 LC1 IOT4 Grid V too high
🟩 LC1 IOT4 Grid V too low
🟩 LC1 IOT4 Focus I high
🟥 LC1 IOT4 Focus I too low
🟩 LC1 IOT4 Focus V high
🟥 LC1 IOT4 Focus V too low
🟩 LC1 IOT4 I/P I high
🟩 LC1 IOT4 I/P V high
🟩 LC1 IOT4 I/P V too low
🟩 Spare
🟩 Spare
🟥 LC1 IOT4 S/B on State ok

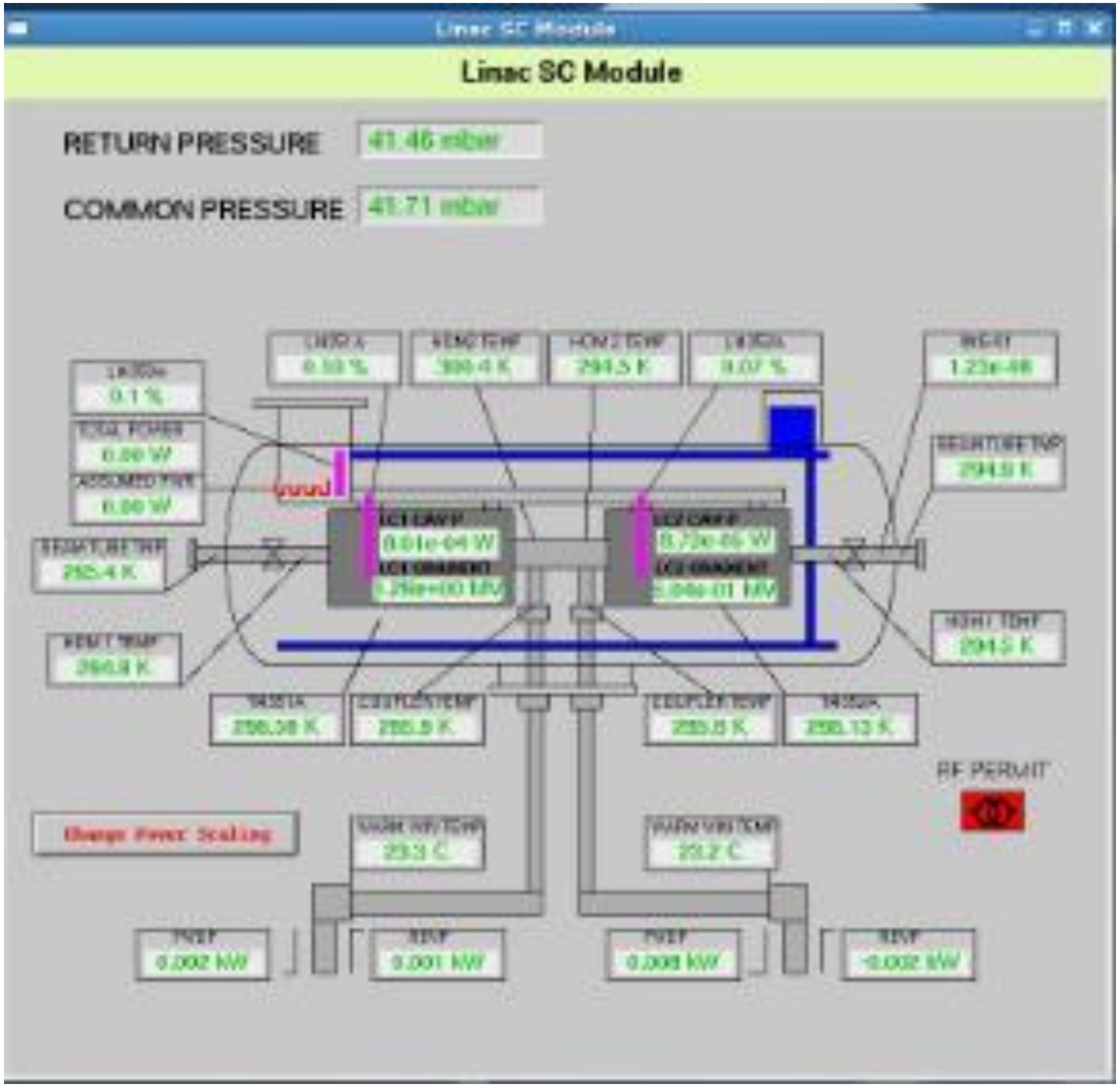
🟥 LC2 IOT5 Air ok
🟥 LC2 IOT5 Coll flow ok
🟥 LC2 IOT5 Load flow ok
🟩 LC2 IOT5 Fil I too High
🟨 LC2 IOT5 Fil I too low
🟩 LC2 IOT5 Fil V too high
🟨 LC2 IOT5 Fil V too low
🟩 LC2 IOT5 Grid I too high
🟩 LC2 IOT5 Grid V too high
🟩 LC2 IOT5 Grid V too low
🟩 LC2 IOT5 Focus I high
🟥 LC2 IOT5 Focus I too low
🟩 LC2 IOT5 Focus V high
🟥 LC2 IOT5 Focus V too low
🟩 LC2 IOT5 I/P I high
🟩 LC2 IOT5 I/P V high
🟩 LC2 IOT5 I/P V too low
🟥 Spare
🟩 Spare
🟥 LC2 IOT5 S/B on State ok
🟩 Spare
🟩 Spare
🟩 Spare
🟩 Spare
🟩 Spare
🟩 Spare

KEY

🟩 Good
🟥 Bad
🟨 Bad But not Required for Standby ON

Cavity parameter screen

Cavity
- Temperature's
- Pressures
- Vacuum
- RF signals
- Acceleration voltage
- RF Permit



Linac SC Module

RETURN PRESSURE 41.46 mbar

COMMON PRESSURE 41.71 mbar

TOTAL POWER 0.00 W

ASSUMED PWR 0.00 W

HOM 2 TEMP 294.5 K

LC1 CAVITY P 8.01e-04 W

LC1 GRADIENT 1.29e+00 MV

LC2 CAVITY P 8.72e-05 W

LC2 GRADIENT 5.04e-01 MV

COUPLER TEMP 295.8 K

WARM WIN TEMP 23.3 C

WARM WIN TEMP 23.2 C

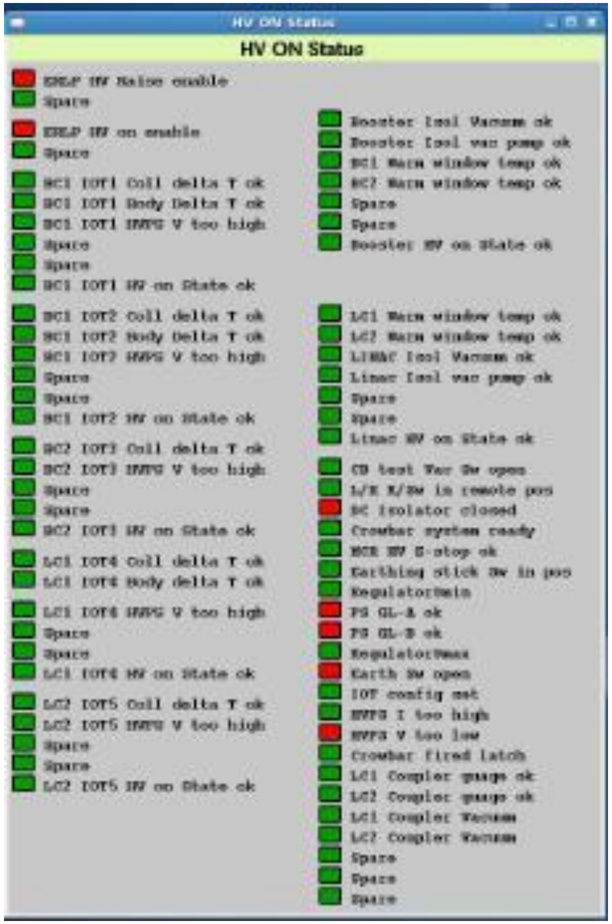
FWD P 0.002 kW

REV P 0.001 kW

FWD P 0.008 kW

REV P -0.002 kW

Ready on status and Trip



HV ON Status

🟥 ERLP HV Raise enable
🟩 Spare

🟥 ERLP HV on enable
🟩 Spare

🟩 BC1 IOT1 Coll delta T ok
🟩 BC1 IOT1 Body Delta T ok
🟩 BC1 IOT1 HVPS V too high
🟩 Spare
🟩 Spare
🟩 BC1 IOT1 HV on State ok

🟩 BC1 IOT2 Coll delta T ok
🟩 BC1 IOT2 Body Delta T ok
🟩 BC1 IOT2 HVPS V too high
🟩 Spare
🟩 Spare
🟩 BC1 IOT2 HV on State ok

🟩 BC2 IOT3 Coll delta T ok
🟩 BC2 IOT3 HVPS V too high
🟩 Spare
🟩 Spare
🟩 BC2 IOT3 HV on State ok

🟩 LC1 IOT4 Coll delta T ok
🟩 LC1 IOT4 Body delta T ok

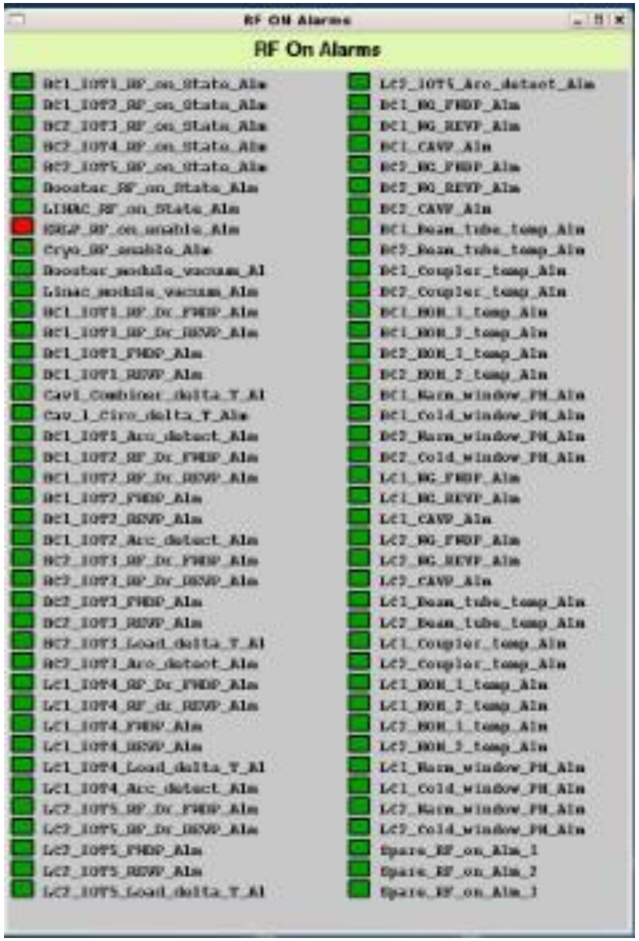
🟩 LC1 IOT4 HVPS V too high
🟩 Spare
🟩 Spare
🟩 LC1 IOT4 HV on State ok

🟩 LC2 IOT5 Coll delta T ok
🟩 LC2 IOT5 HVPS V too high
🟩 Spare
🟩 Spare
🟩 LC2 IOT5 HV on State ok

🟩 Booster Insl Vacuum ok
🟩 Booster Insl vac pump ok
🟩 BC1 Warm window temp ok
🟩 BC2 Warm window temp ok
🟩 Spare
🟩 Spare
🟩 Booster HV on State ok

🟩 LC1 Warm window temp ok
🟩 LC2 Warm window temp ok
🟩 LINAC Insl Vacuum ok
🟩 Linac Insl vac pump ok
🟩 Spare
🟩 Spare
🟩 Linac HV on State ok

🟩 CB test Var Sw open
🟩 L/R K/Sw in remote pos
🟥 BC isolator closed
🟩 Crowbar system ready
🟩 MCR HV E-stop ok
🟩 Earthing stick Sw in pos
🟩 RegulatorVmin
🟥 PS GL-A ok
🟥 PS GL-B ok
🟩 RegulatorVmax
🟥 Earth Sw open
🟩 IOT config set
🟩 HVPS I too high
🟥 HVPS V too low
🟩 Crowbar fired latch
🟩 LC1 Coupler gauge ok
🟩 LC2 Coupler gauge ok
🟩 LC1 Coupler Vacuum
🟩 LC2 Coupler Vacuum
🟩 Spare
🟩 Spare
🟩 Spare



RF On Alarms

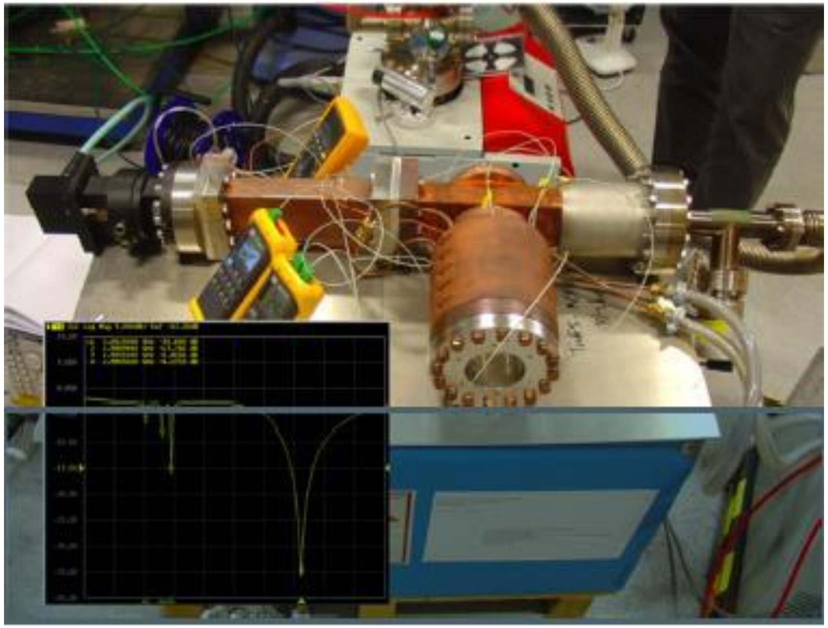
🟩 BC1_IOT1_RF_on_State_Alm
🟩 BC1_IOT2_RF_on_State_Alm
🟩 BC2_IOT3_RF_on_State_Alm
🟩 BC2_IOT4_RF_on_State_Alm
🟩 BC2_IOT5_RF_on_State_Alm
🟩 Booster_RF_on_State_Alm
🟩 LINAC_RF_on_State_Alm
🟥 ERLP_RF_on_enable_Alm
🟩 Cryo_RF_enable_Alm
🟩 Booster_module_vacuum_Al
🟩 Linac_module_vacuum_Alm
🟩 BC1_IOT1_RF_Dr_FWDP_Alm
🟩 BC1_IOT1_RF_Dr_REVP_Alm
🟩 BC1_IOT1_FWDP_Alm
🟩 BC1_IOT1_REVP_Alm
🟩 Cav1_Combiner_delta_T_Al
🟩 Cav_1_Circ_delta_T_Alm
🟩 BC1_IOT1_Arc_detect_Alm
🟩 BC1_IOT2_RF_Dr_FWDP_Alm
🟩 BC1_IOT2_RF_Dr_REVP_Alm
🟩 BC1_IOT2_FWDP_Alm
🟩 BC1_IOT2_REVP_Alm
🟩 BC1_IOT2_Arc_detect_Alm
🟩 BC2_IOT3_RF_Dr_FWDP_Alm
🟩 BC2_IOT3_RF_Dr_REVP_Alm
🟩 BC2_IOT3_FWDP_Alm
🟩 BC2_IOT3_REVP_Alm
🟩 BC2_IOT3_Load_delta_T_Al
🟩 BC2_IOT3_Arc_detect_Alm
🟩 LC1_IOT4_RF_Dr_FWDP_Alm
🟩 LC1_IOT4_RF_dr_REVP_Alm
🟩 LC1_IOT4_FWDP_Alm
🟩 LC1_IOT4_REVP_Alm
🟩 LC1_IOT4_Load_delta_T_Al
🟩 LC1_IOT4_Arc_detect_Alm
🟩 LC2_IOT5_RF_Dr_FWDP_Alm
🟩 LC2_IOT5_RF_Dr_REVP_Alm
🟩 LC2_IOT5_FWDP_Alm
🟩 LC2_IOT5_REVP_Alm
🟩 LC2_IOT5_Load_delta_T_Al

🟩 LC2_IOT5_Arc_detect_Alm
🟩 BC1_WG_FWDP_Alm
🟩 BC1_WG_REVP_Alm
🟩 BC1_CAVP_Alm
🟩 BC2_WG_FWDP_Alm
🟩 BC2_WG_REVP_Alm
🟩 BC2_CAVP_Alm
🟩 BC1_Beam_tube_temp_Alm
🟩 BC2_Beam_tube_temp_Alm
🟩 BC1_Coupler_temp_Alm
🟩 BC2_Coupler_temp_Alm
🟩 BC1_HOM_1_temp_Alm
🟩 BC1_HOM_2_temp_Alm
🟩 BC2_HOM_1_temp_Alm
🟩 BC2_HOM_2_temp_Alm
🟩 BC1_Warm_window_PM_Alm
🟩 BC1_Cold_window_PM_Alm
🟩 BC2_Warm_window_PM_Alm
🟩 BC2_Cold_window_PM_Alm
🟩 LC1_WG_FWDP_Alm
🟩 LC1_WG_REVP_Alm
🟩 LC1_CAVP_Alm
🟩 LC2_WG_FWDP_Alm
🟩 LC2_WG_REVP_Alm
🟩 LC2_CAVP_Alm
🟩 LC1_Beam_tube_temp_Alm
🟩 LC2_Beam_tube_temp_Alm
🟩 LC1_Coupler_temp_Alm
🟩 LC2_Coupler_temp_Alm
🟩 LC1_HOM_1_temp_Alm
🟩 LC1_HOM_2_temp_Alm
🟩 LC2_HOM_1_temp_Alm
🟩 LC2_HOM_2_temp_Alm
🟩 LC1_Warm_window_PM_Alm
🟩 LC1_Cold_window_PM_Alm
🟩 LC2_Warm_window_PM_Alm
🟩 LC2_Cold_window_PM_Alm
🟩 Spare_RF_on_Alm_1
🟩 Spare_RF_on_Alm_2
🟩 Spare_RF_on_Alm_3

Interlocks in RED are preventing HV switch on

Interlock in RED is the FIRST interlock that trip the RF block OFF

Vela Machine

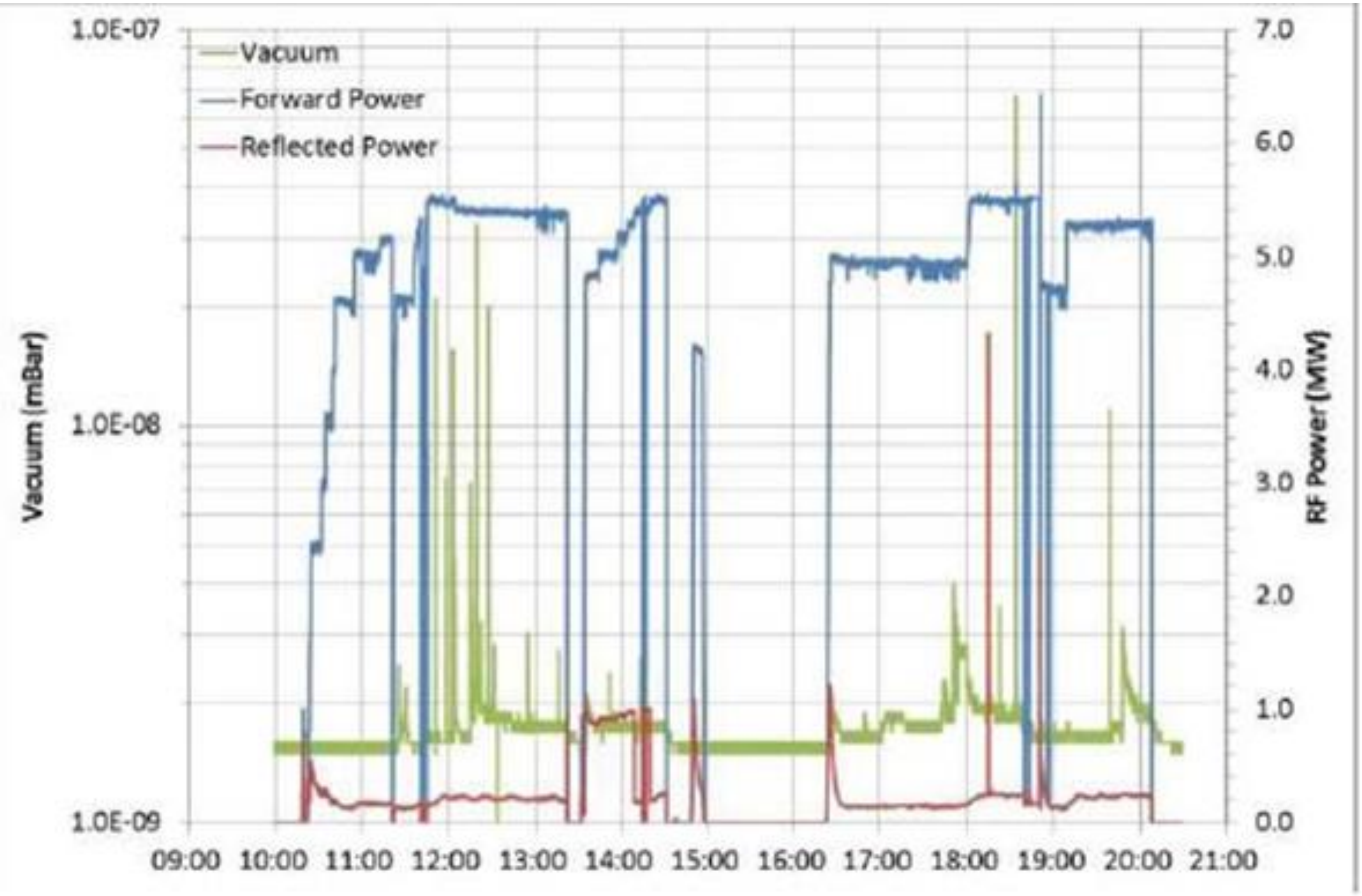


Parameter	Value	Units
Frequency	2998.5	
Bandwidth	< 5	MHz
Maximum beam energy	6	MeV
Maximum accelerating field	100	MV/m
Peak RF Input Power	10	MW
Maximum repetition rate	10	Hz
Maximum bunch charge	250	pC
Operational Temperature	30 - 45	°C
Input coupling	WR284	

- RF local rules in place to that govern all work carried out on the RF system
- Waveguide pressurised to 1Bar with SF6
- Interlocks prevent operation of system if pressure to low
- Moving to SF6 reclamation and auto refilling soon that has no emissions
- Handling measures well understood within STFC

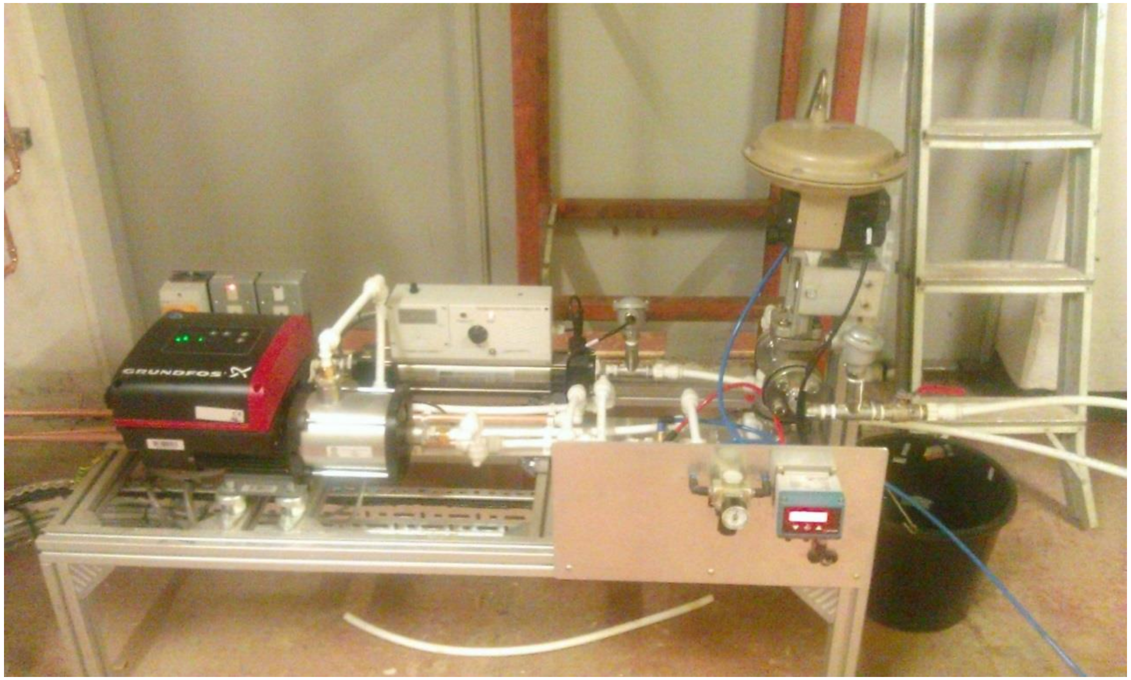
Conditioning of VELA Cavity

- Trip on vacuum only
- Steady build up of power and pulse length
- RF operators used as controlling action
- Each trip resulted in a small reduction of RF drive level – RF straight back on
- Proposals to run unattended automated conditioning system were abandoned as they were not needed
- Conditioning is remembered by the cavity, even after venting
- Provided RF components are correct for the task (windows and couplers) conditioning is achieved within a week of shifts



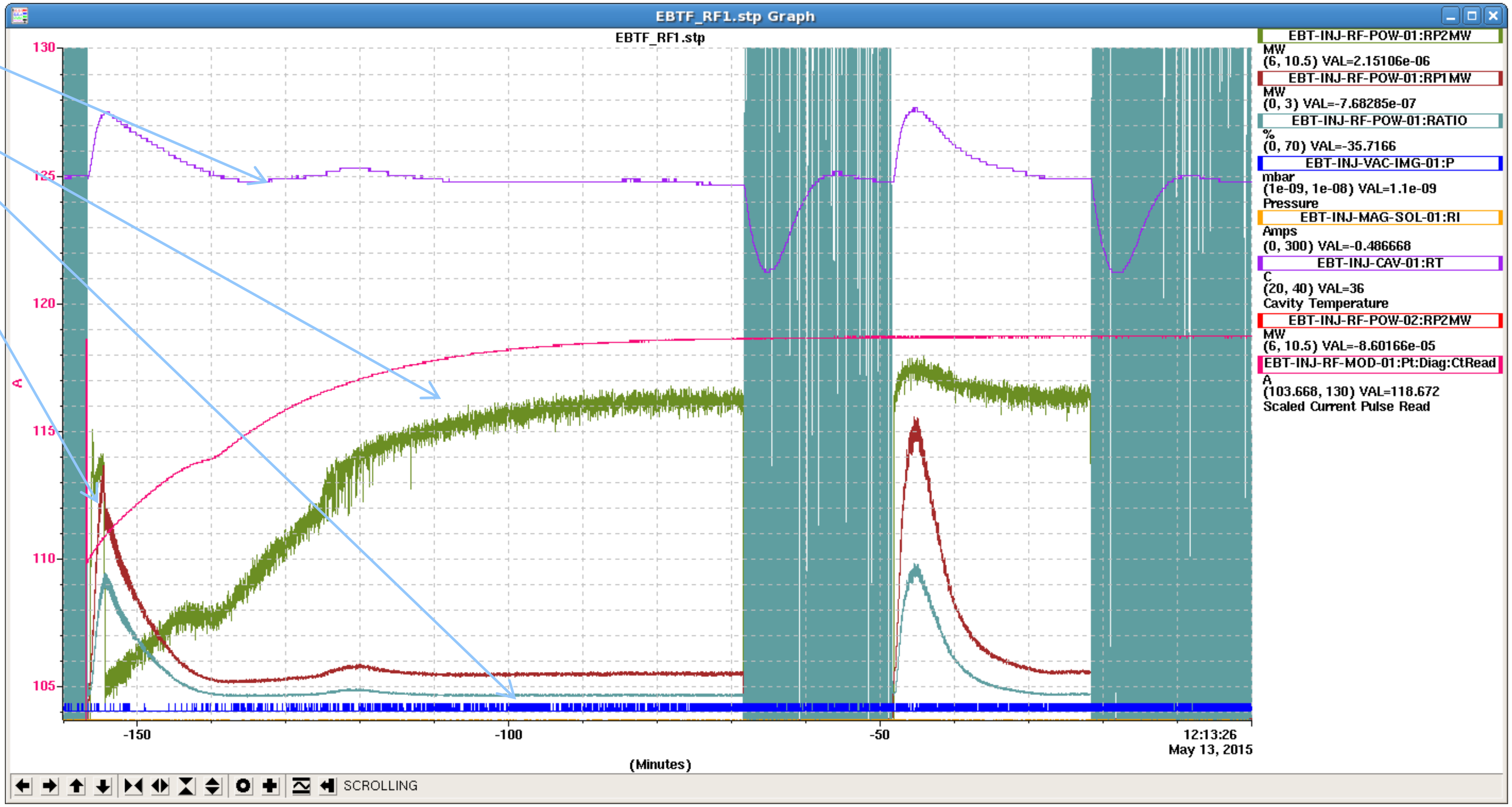
Cavity coolant stabilisation

- Cavity on frequency at 36.5 degrees currently (changes with cathode installation)
- water cooling system with heater, cold water and mixing valve control by high resolution process controller that self learns
- Water flow rates on cavity are very restricted due to small cooling pipes
- When RF is applied at 10MW system needs 5 minutes to recover temperature setpoint due to added heat load
- 0.05 degrees cavity temperature stability can be achieved
- RF trips result in cavity detuning which can again take 5 minutes to recover from
- RF is always applied at effectively maximum



Cavity coolant control loop

- Cavity temperature
- Forward power
- Reflected power
- For/ref power ratio



- At RF switch on for/ref power ration will be 30%
- After 5 mins operation ratio is below 10% and settles to 3 %
- Trip effect can be seen
- No RF staff involvement during normal physics shifts

RF power measurement

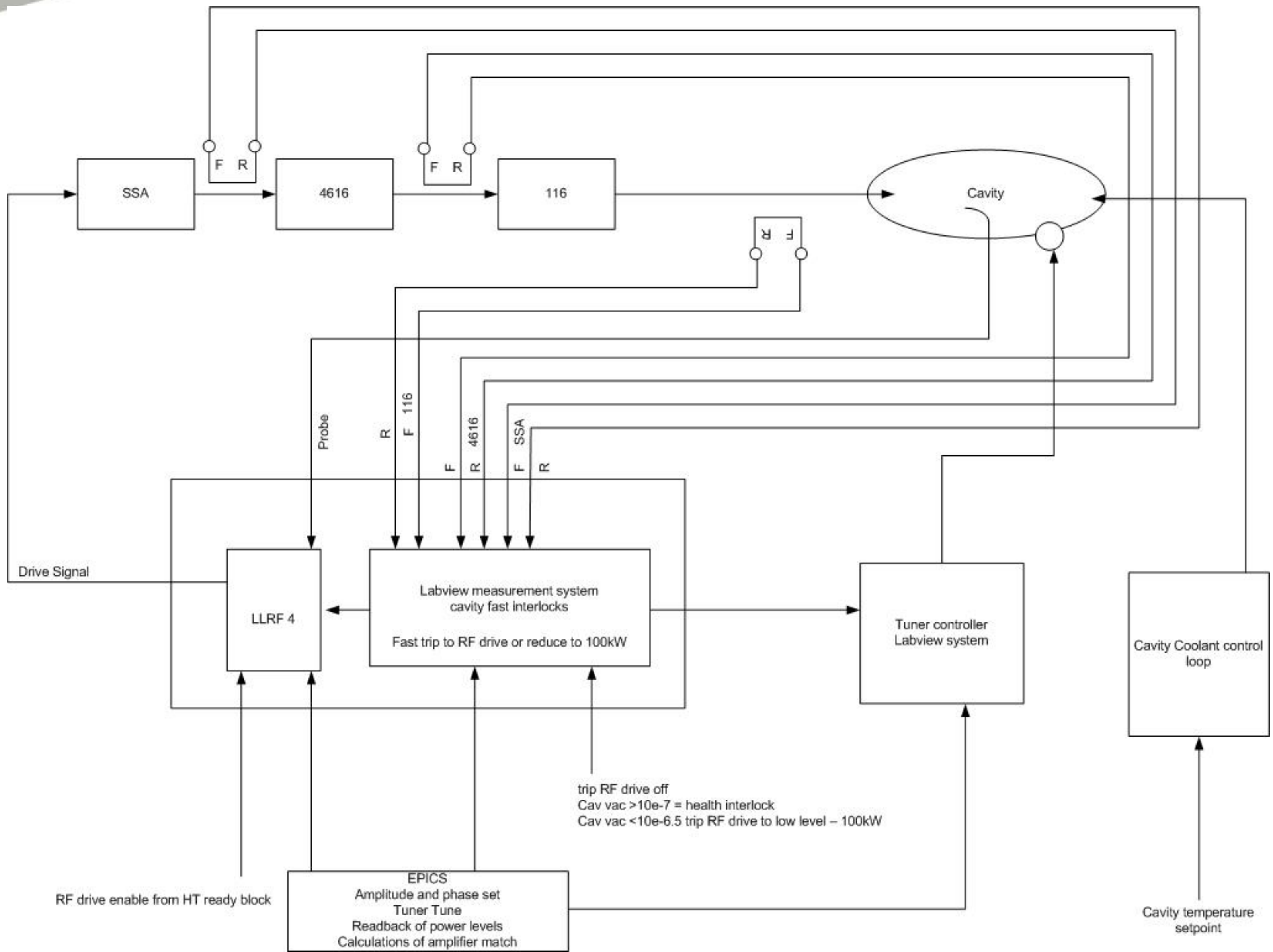
- Cavity probes are normally 50-60dB and used in control loops to maintain cavity voltage and phase angle.
- Values of 0.01 degrees and 10-4 % amplitude control is possible
- Waveguide/coax power couplers in the MW class can be upto 70-90dB down on the signal passing them
    - There accuracy is then very compromised, particularly the reflected power measurement with has a directivity factor to add which further compromise's the accuracy of this signal
    - An error in calibration of even 0.1dB can make a huge difference to the measured RF power
- Forward power will be changing during the RF pulse – driven by the LLRF to compensate for tuning, HV voltage droop etc

VELA Similarity's with MICE

- SF6 use and all safety concerns
- MW class driver and associated RF measurement's
- Cavity coolant control looks critical and we can use systems like the VELA design to achieve good results
- MICE cavity has tuner that can provide additional control that should only be needed on a slow control loop due to pulse rate
  - Do we want this tuner to be highly active all the time ?
  - Limited life span?
  - Temperature control would be better to remove large temporary errors from system
  - LLRF can run in open loop mode to remove high peak powers under detuning conditions

MICE LLRF control ideas

- Cavity should ideally be on resonance above all possible ambient temperature possibility's in MICE hall ~ above 30 degrees C
- Provide a high stability process controlled coolant temperature that can maintain cavity at desired frequency to a high level of stability so that this is the primary tuning method for operation over sustained periods
- At RF switch on, run in open loop at predetermined RF power levels and allow coolant control loop to catch up - bring cavity back on tune
- Under operator control move the RF power level up towards the desired level
- At design RF power level under stable conditions close LLRF control loop and activate the cavity tuner to maintain close control



SSA

4616

116

Cavity

Drive Signal

LLRF 4

Labview measurement system
cavity fast interlocks

Fast trip to RF drive or reduce to 100kW

Tuner controller
Labview system

Cavity Coolant control loop

trip RF drive off
Cav vac >10e-7 = health interlock
Cav vac <10e-6.5 trip RF drive to low level – 100kW

RF drive enable from HT ready block

EPICS
Amplitude and phase set
Tuner Tune
Readback of power levels
Calculations of amplifier match

Cavity temperature setpoint

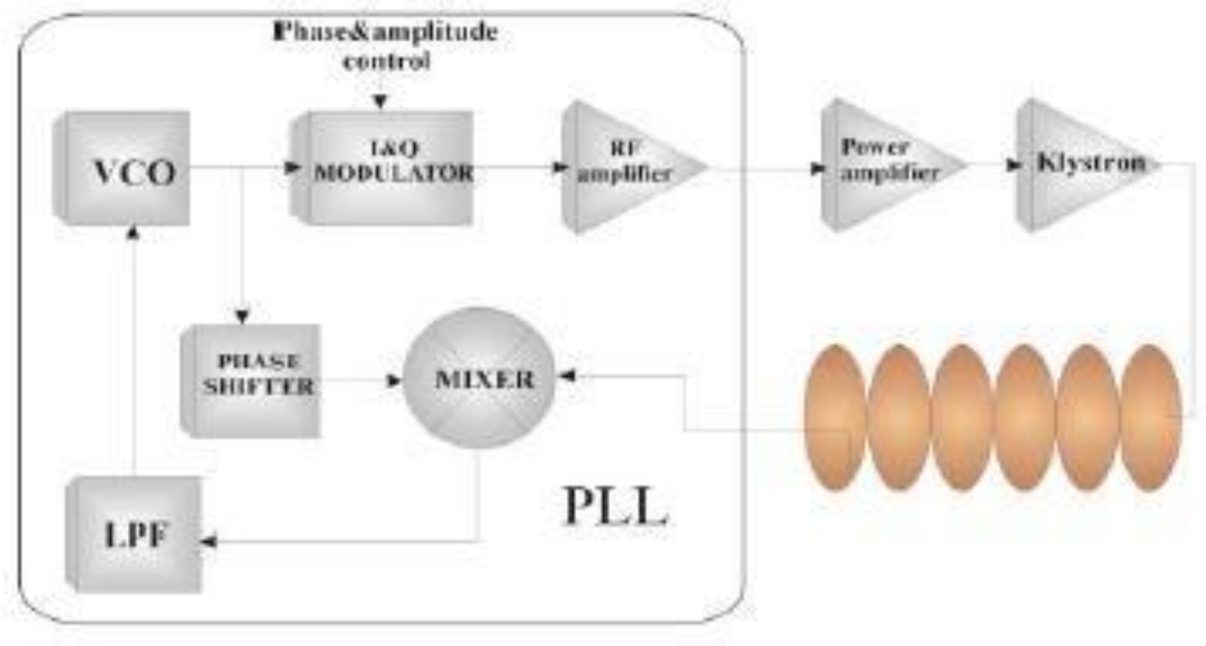
LLRF

- Use code already developed and running at a number of installations at Daresbury to provide digital LLRF control loop with operator selectable P&I control loops and open/closed loop control
- Install process control cavity coolant temperature system to remove cavity resonance errors under all conditions and only close loop under well understood conditions
- For amplifier and cavity RF power measurements use a labview based system with RF detection to monitor power levels and interlock for problem conditions – this can include reflected power issues from the couplers – vacuum conditions etc and provide fast trip control to the RF system
- In addition the labview system would determine the tuning functions required
- The mechanical tuner transition from push/pull should be avoided as the system would become unstable very quickly

Backup slides

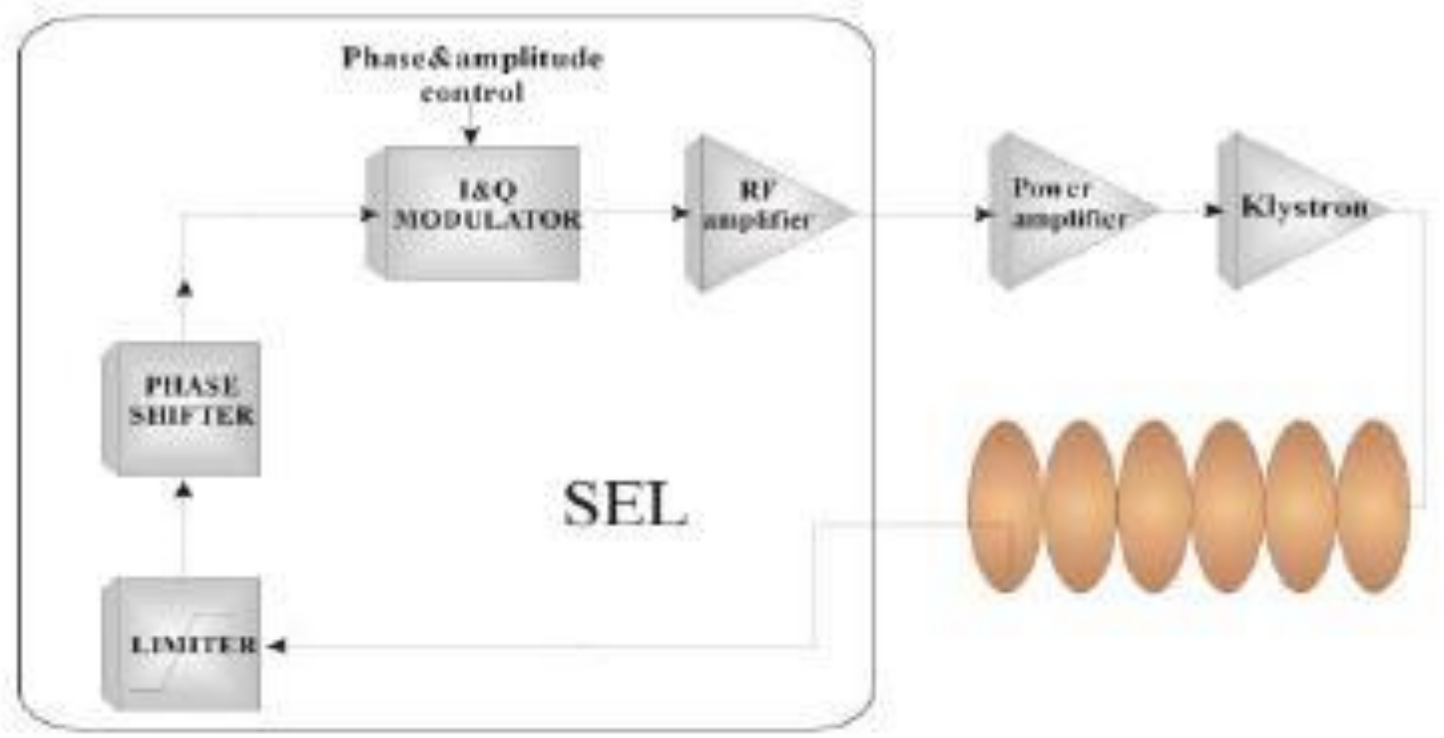
- For discussion

Generator driven loop



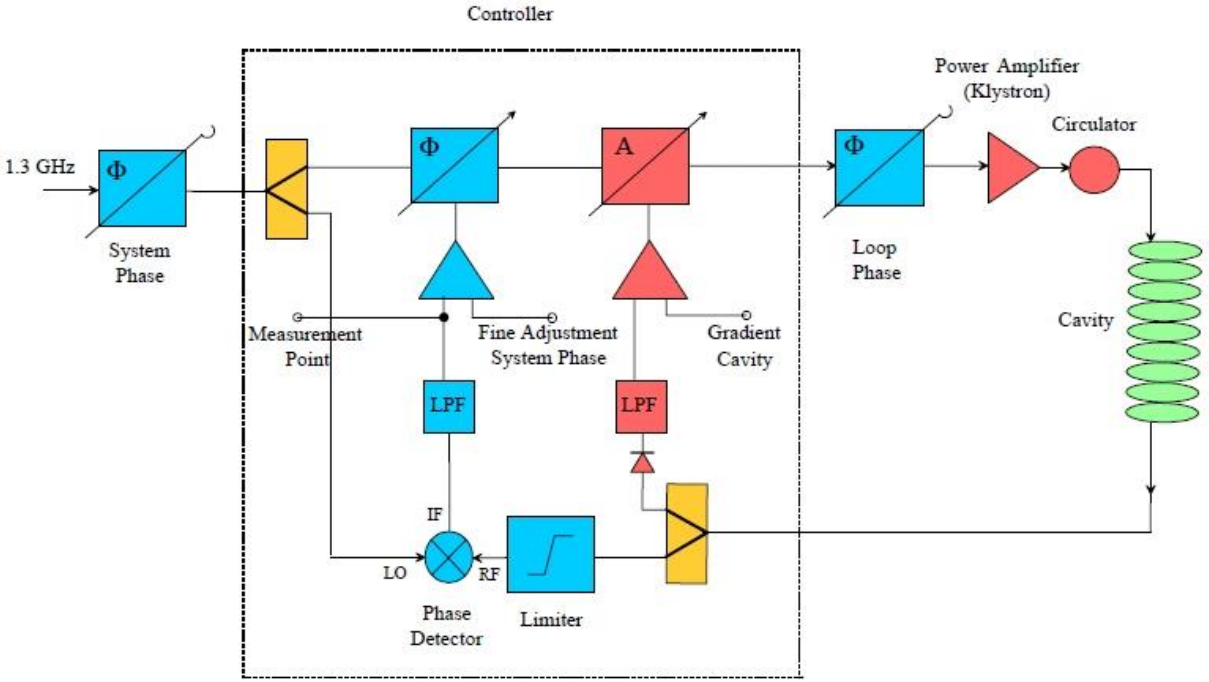
Oscillator driven system where oscillator frequency must be within the bandwidth of the cavity in order for the loop to function, **standard control for loop for accelerator cavities**

Self excited Loop



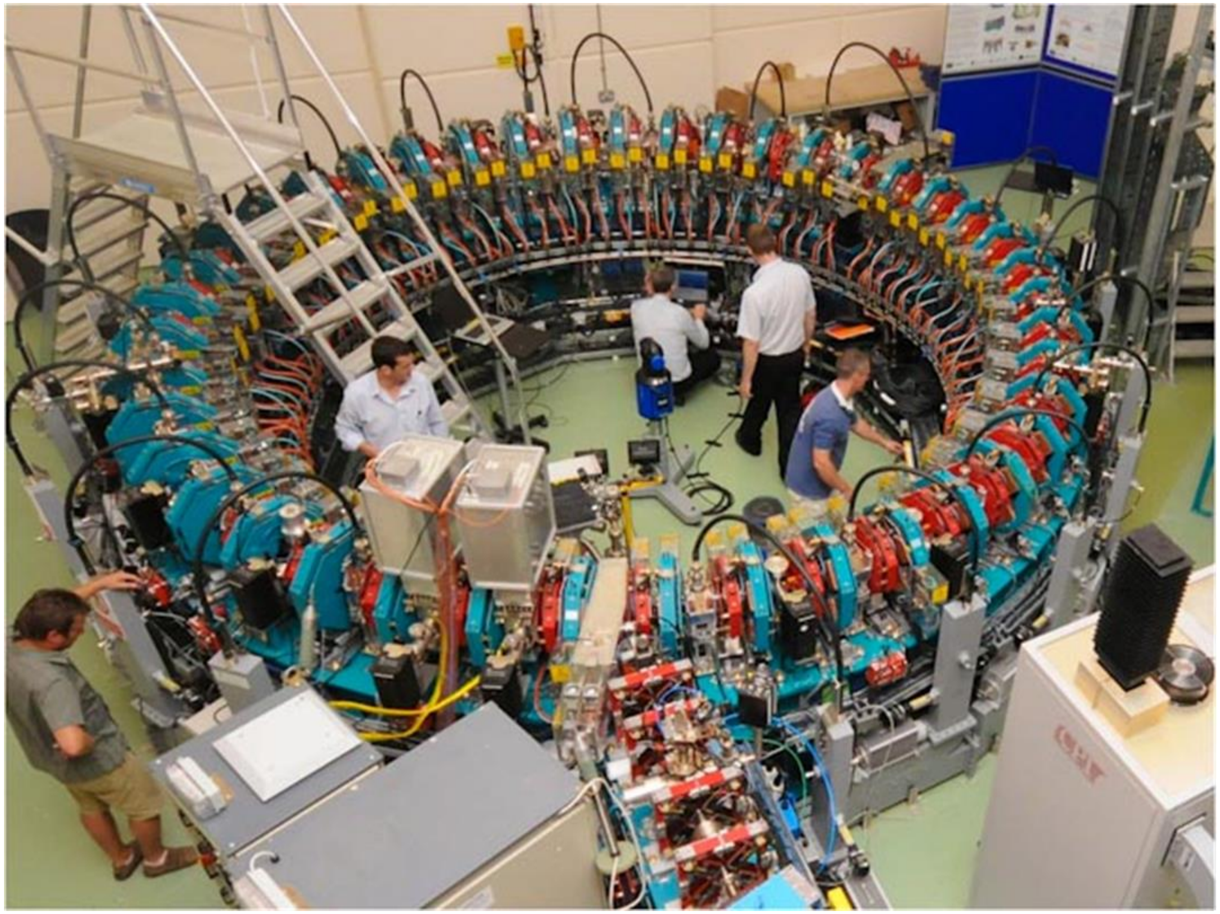
Cavity resonant frequency is used to form oscillator that can then be controlled in phase and amplitude, useful for high power conditioning and tuning

ALICE 1.3GHz LLRF



- Cavity bandwidth ~120Hz
- Q= 10*7
- 11MV/m gradient
- Analog control loop using op amps give very fast control
- 0.2 degrees
- 0.1 % gradient
- No active tuner control – operators tune cavity to limit reflected power

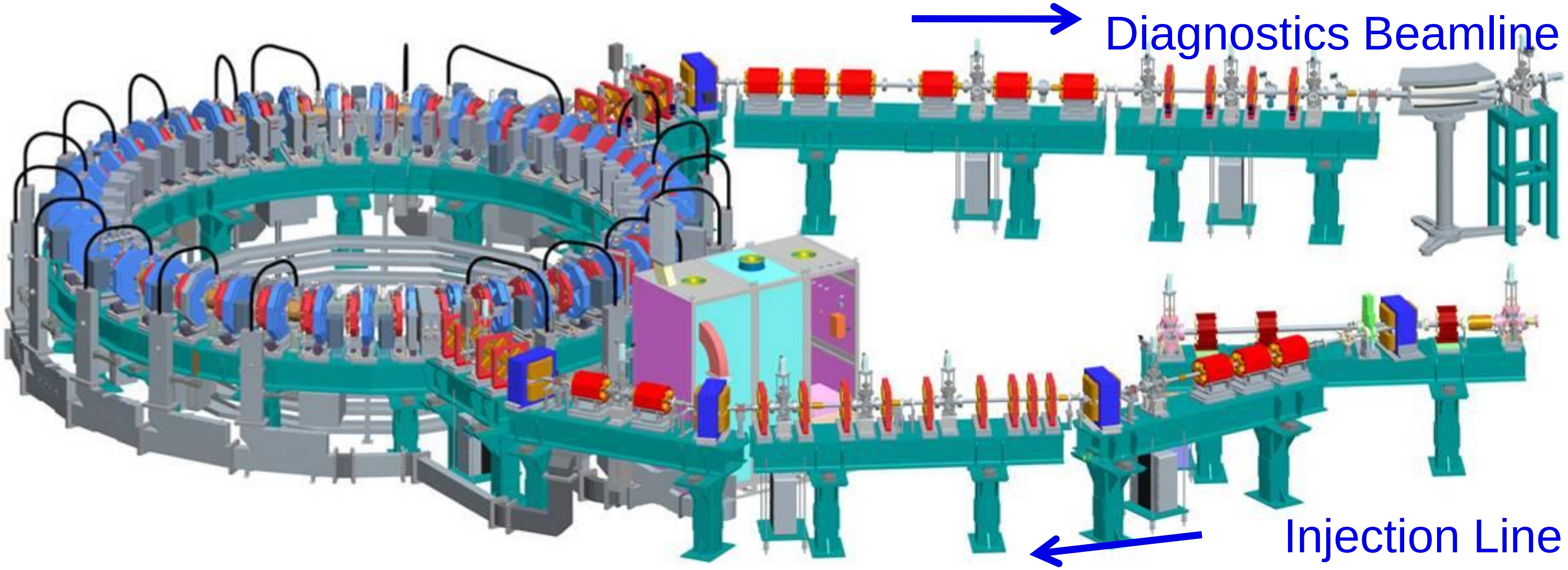
EMMA



EMMA Parameters & Layout

- One IOT amplifier driving 19 copper cavities via waveguide splitters
- Water cooled cavities with plunger tuner
- Cavity Q 8000 **but all different**
- BW ~163KHz

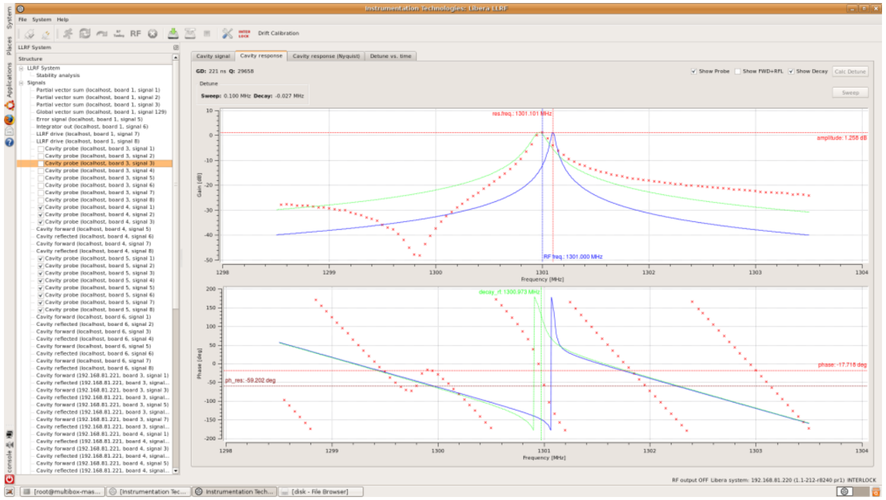
Frequency (nominal)	**1.3 GHz**
No of RF cavities	**19**
Repetition rate	**1 - 20 Hz at 1.6mS PRF**
Power **Per cavity**	**90kW Pulsed** **4.7kW**



EMMA LLRF

- **Instrumentation Technologies Libera LLRF system provides**
  - Initial cavity setting conditions
  - Control of the cavity amplitude and phase to ensure stable controls the acceleration
  - Global vector sum of all 19 cavities in control loop
  - Forward and reverse power monitoring to each cavity
  - IOT power levels before and after the circulator
  - 1.3GHz +/- 1.5/-4MHz operation is possible
  - So wide tuning range is needed

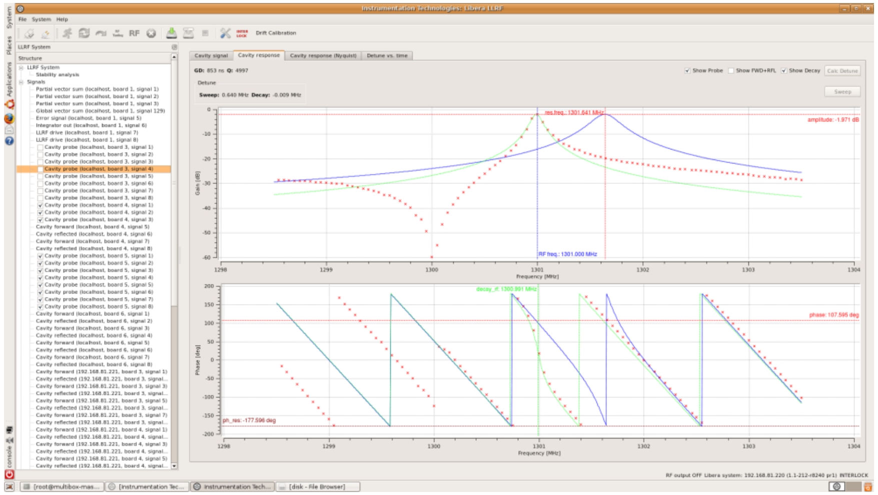
Digital LLRF sweep of cavity frequency



GD: 221 ns Q: 29658

Detune
Sweep: 0.100 MHz Decay: -0.027 MHz

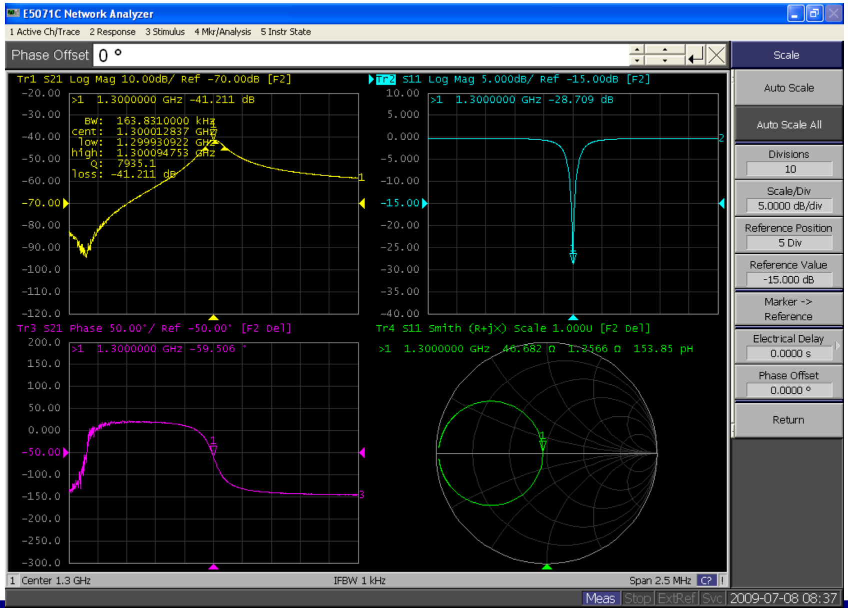
RF output OFF Libera system: 192.168.81.220 (1.1-212-r8240 pr1) INTERLOCK



GD: 853 ns Q: 4997

Detune
Sweep: 0.640 MHz Decay: -0.009 MHz

RF output OFF Libera system: 192.168.81.220 (1.1-212-r8240 pr1) INTERLOCK



Phase Offset 0 °

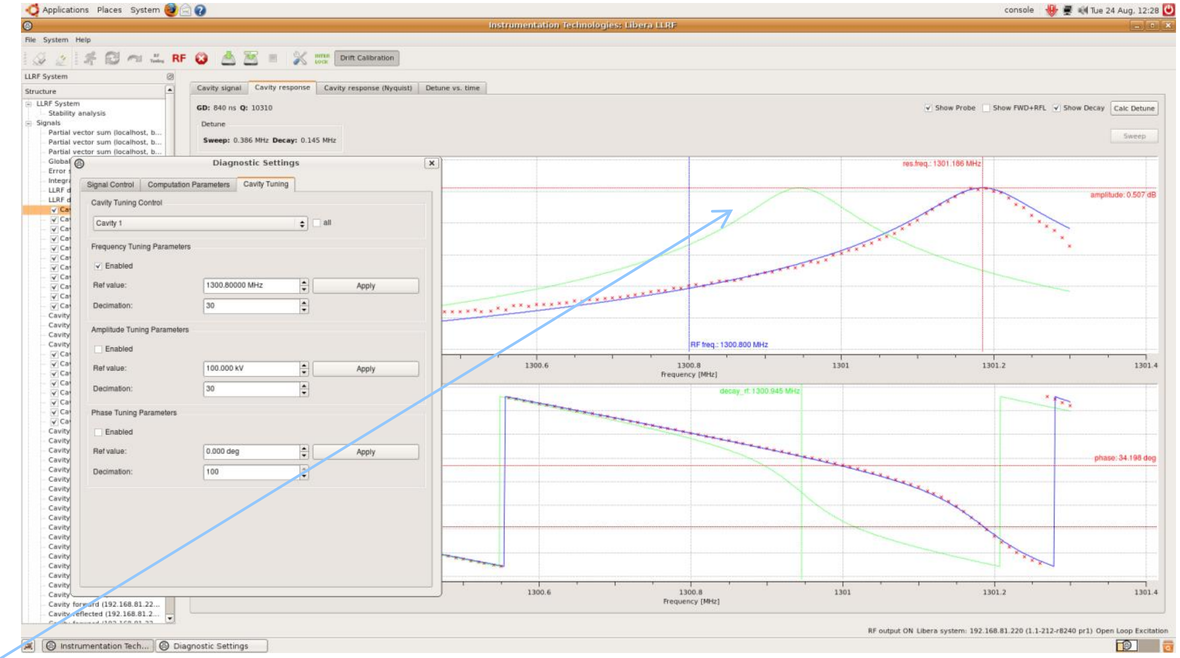
```
Tr1 S21 Log Mag 10.00dB/ Ref -70.00dB [F2]
>1  1.3000000 GHz -41.211 dB
  BW:  163.8310000 kHz
cent:  1.300012837 GHz
 low:  1.299930922 GHz
high:  1.300094753 GHz
   Q:  7935.1
loss:  -41.211 dB

Tr2 S11 Log Mag 5.000dB/ Ref -15.00dB [F2]
>1  1.3000000 GHz -28.709 dB

Tr3 S21 Phase 50.00°/ Ref -50.00° [F2 Del]
>1  1.3000000 GHz -59.506 °

Tr4 S11 Smith (R+jX) Scale 1.000U [F2 Del]
>1  1.3000000 GHz  46.682 Ω  1.2566 Ω  153.85 pH

1 Center 1.3 GHz        IFBW 1 kHz        Span 2.5 MHz
2009-07-08 08:37
```

Divisions 10
Scale/Div 5.0000 dB/div
Reference Position 5 Div
Reference Value -15.000 dB
Electrical Delay 0.0000 s
Phase Offset 0.0000 °

- Two cavities in the EMMA ring showing initial frequency positions
- All 19 cavities need to be tuned in frequency
- VNA plot of an EMMA cavity

Frequency tuning

- Changing cavity frequency takes – 60 minutes
- Tuner motors using epics system to move motors in open loop only
- Using centre frequency and bandwidth controls ‘sweep analysis’ locates resonance of each cavity in system
- A new centre frequency can then be set and the tuner motors driven
- Calc detune shows new resonance of cavity
- Low reflected power response used to fine tune each cavity



GD: 840 ns **Q:** 10310

Detune

Sweep: 0.386 MHz **Decay:** 0.145 MHz

☑ Show Probe ☐ Show FWD+RFL ☑ Show Decay

Cavity Tuning Control

Cavity 1 ☐ all

Frequency Tuning Parameters

☑ Enabled

Ref value: 1300.80000 MHz

Decimation: 30

Amplitude Tuning Parameters

☐ Enabled

Ref value: 100.000 kV

Decimation: 30

Phase Tuning Parameters

☐ Enabled

Ref value: 0.000 deg

Decimation: 100

RF output ON Libera system: 192.168.81.220 (1.1-212-r8240 pr1) Open Loop Excitation

Water cooling of cavity to maintain frequency although not tightly controlled Auto frequency tuning was never enabled due to problems with motor controls

Control of cavities with narrow bandwidths

- Find cavity using SEL or frequency sweep method
- Move cavity tuner to bring each cavity on to desired tune point
- Switch to GDR at low power and monitor/reduce reflected power of each cavity in the system
- Raise power level and monitor tuning of each cavity of short time (10 minutes)
- Raise power level to 50% and repeat monitoring of reflected power level
- Perform tuning of cavity at this power level to understand drift of tuning with respect to RF heating
- Cooling water temperature can be used to aid frequency tuning and regulation to 0.5 degrees relatively easy to accomplish – 0.1 is possible with correctly designed water circuits

Current status Digital LLRF at DL

- Controlling copper 1.3GHz cavity, 3GHz Gun
- Controlled cavity filling to reduce reflected power during cavity switch on is software coded
- SEL/GDR loops in regular use
- Tasks for this year
  - Aug 2014 control of SCRF cavities at 1.3GHz
  - Nov 2014 control of cavity tuners via EPICS system to maintain tuning
- Other developments to work on
  - Collaboration on 201MHz LLRF control for MICE and ISIS linac
  - Test on DL test system controlling amplifier into test load
  - Test two 1.3GHz cavities from one amplifier to understand tuning features