The LHC RF Power Systems

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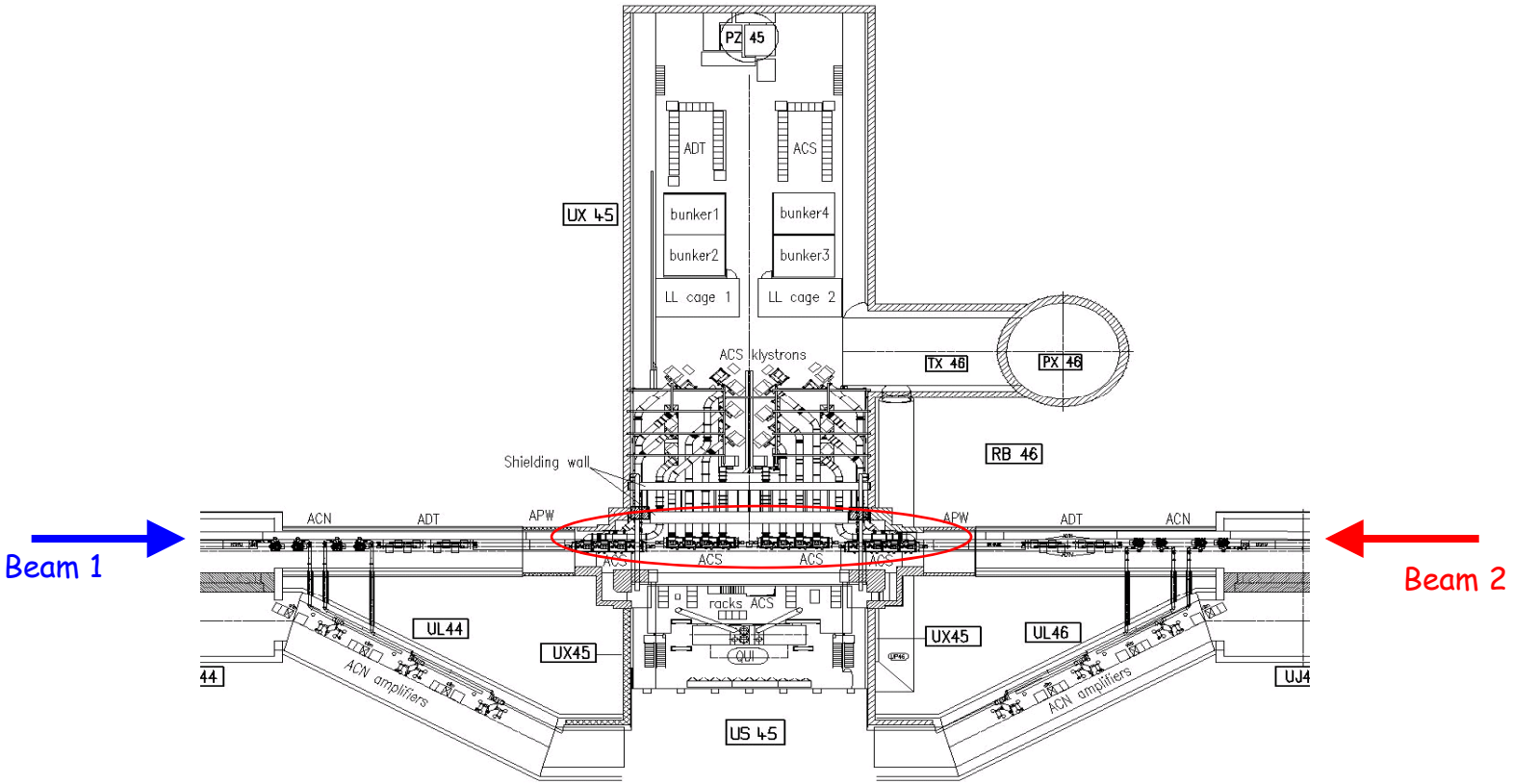
- Slides by : Olivier Brunner & Luca Arnaudon
- Important note:
- This is a team work..
- so thanks to all colleagues who has made this a successful project and still putting a lot of effort in it

- Skip the intro…

Summary

- Geography
- The ACS Superconducting LHC RF system
  - Its components
    - Klystron
    - High Voltage
    - Circulator & Load
    - Wave Guide system
  - Important issues and experiences
- Controls and interlocks
- Commissioning summary

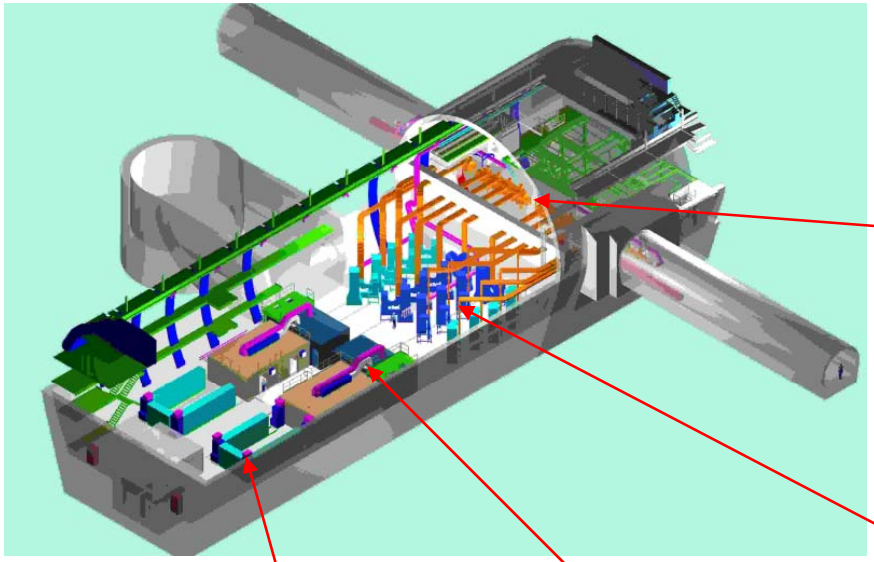
The LHC machine @ point 4

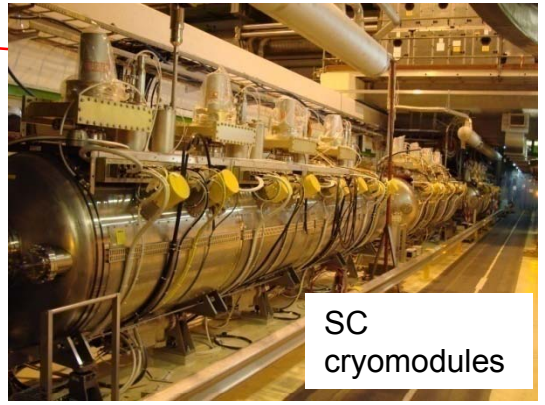


- The three LHC RF systems are located at Point 4
  - Superconducting cavities
  - Damper system
  - RF instrumentation & pick-ups

The LHC RF system installation

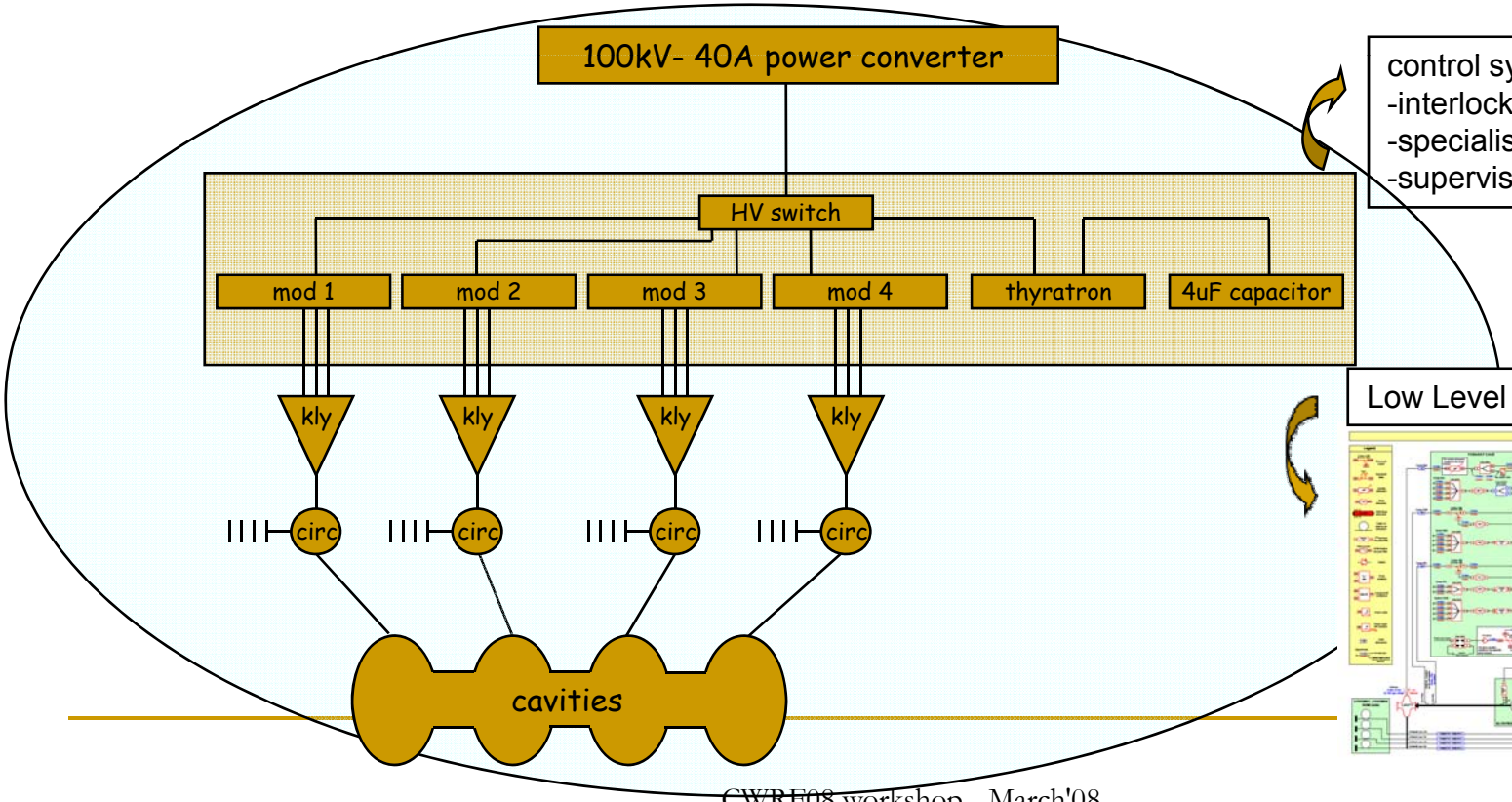
- Two controls rack areas
- Two Faraday cages in UX45
- 16 klystrons, Four bunkers with HV equipment
- Four SC cavities in one cryomodules





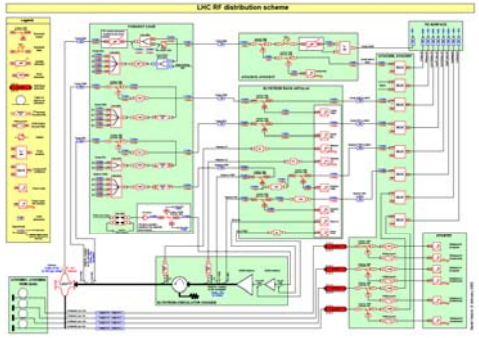
The LHC RF accelerating system

- Specification
  - 4 power converters (LEP) on surface; 4 klystrons per converter
  - 16 klystrons, 1/cavity, 400 MHz, 300kW CW
  - Connection via circulator (+ RF load) to waveguide system
  - 1 modulator/klystron to adjust operating conditions (slow changes)
  - Modulator, fast protection unit and high voltage components in fire-proof bunker



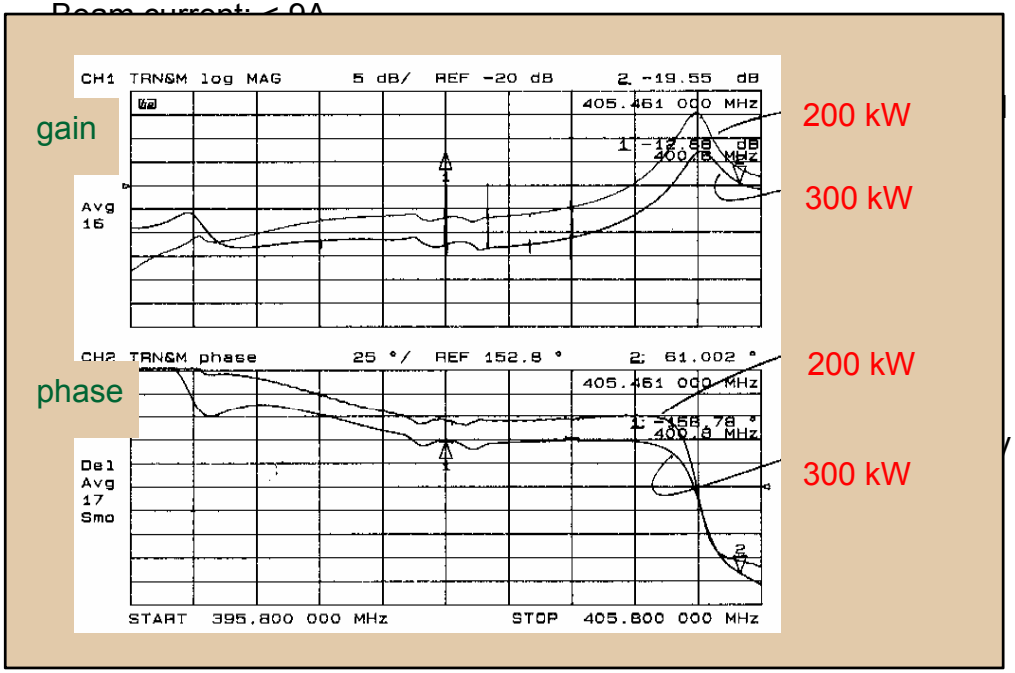
control systems:
-interlocks
-specialists applications
-supervision

Low Level RF system



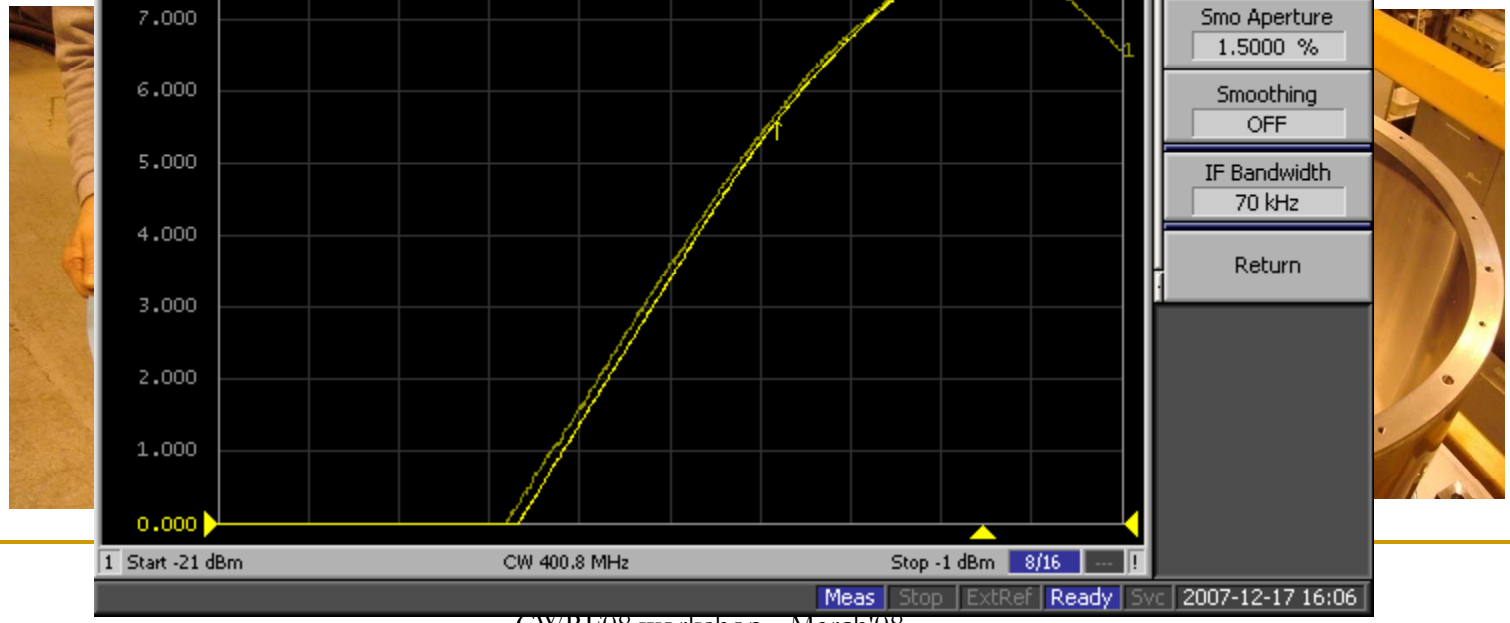
LHC klystrons

- Main parameters
  - Output power: 330 KW_{CW}
  - Operating frequency: 400.8MHz
  - -1dB bandwidth: ≥ ±1MHz
  - Gun perveance :1.5 10^{-6} ($A.V^{-1.5}$)
  - Load VSWR @ any phase: ≤1.2
  - Beam voltage: 58kV
  - Beam current: < 9A



LHC klystrons

- Issues
  - Sat[illegible]uated
  - Arc[illegible]cturer (Th[illegible]



400MHz Klystron Collector cooling modifications

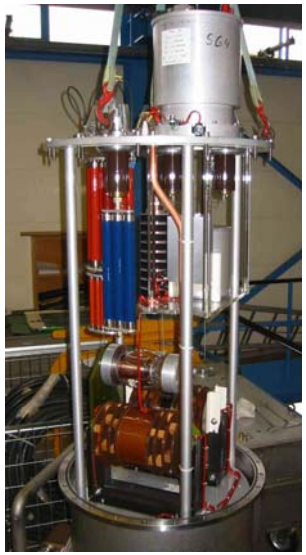
Issues: klystron ‘boilers’ modified:

- Bad water cooling of collector (SM18 klystron vacuum leak)
- Hypervapotron mode
  - requires homogenous water flow
- Modification agreed with manufacturer:
  - dismantling in-situ in UX45, klystron in horizontal position
- Status: modification & re-installation finished

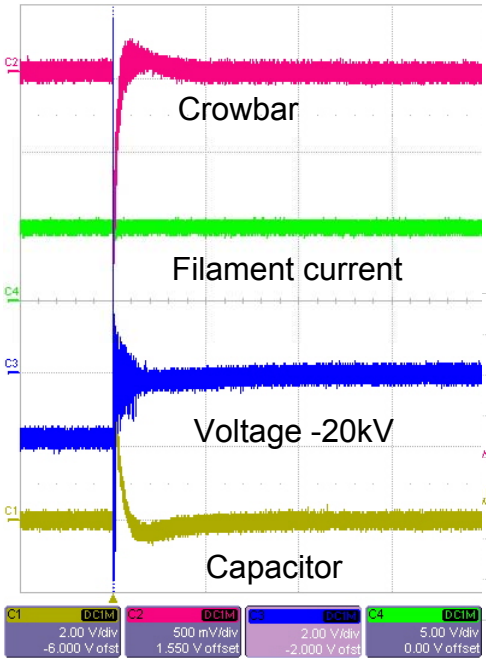
Overheating in collector

Klystrons in horizontal position in UX45

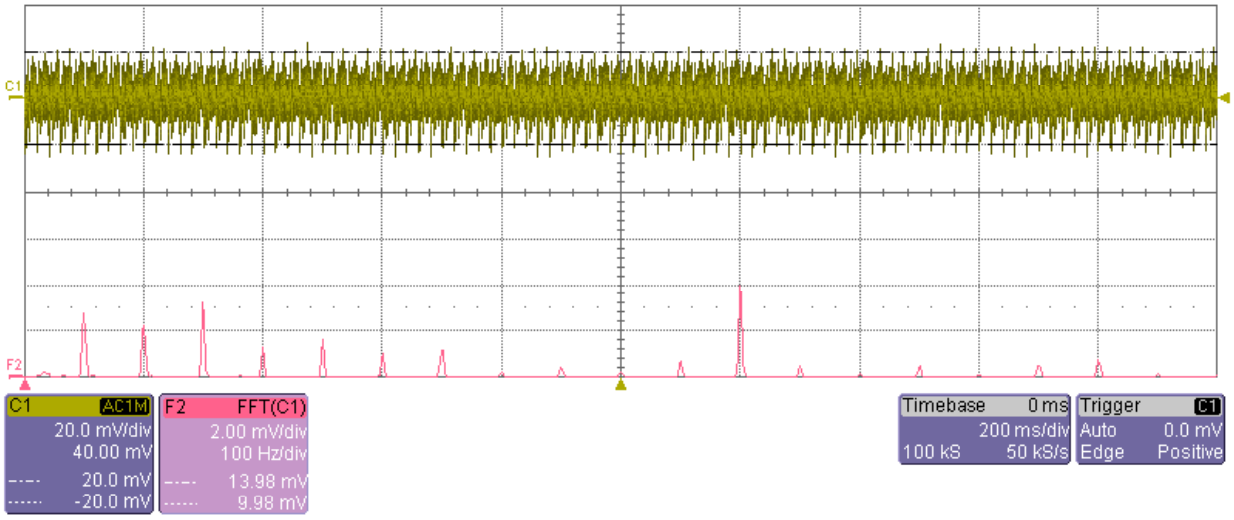
High voltage equipment



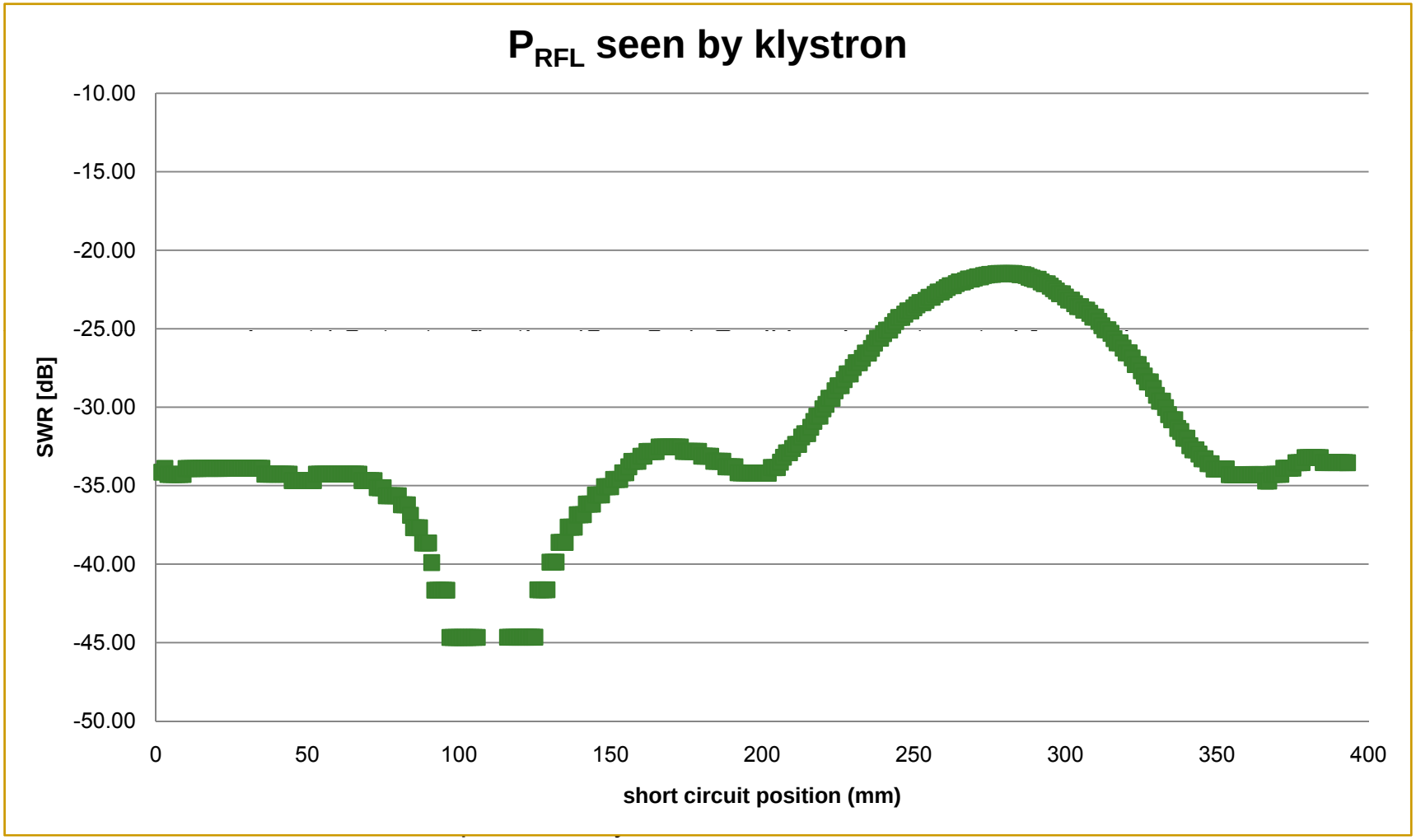
- Fire proof bunkers
- Klystron modulators
  - Equipped with tetrode for klystron current control
- Fast protection system
  - 5 gap thyratron
  - 4uF smoothing capacitor
- Silicon oil for safety



- Issues

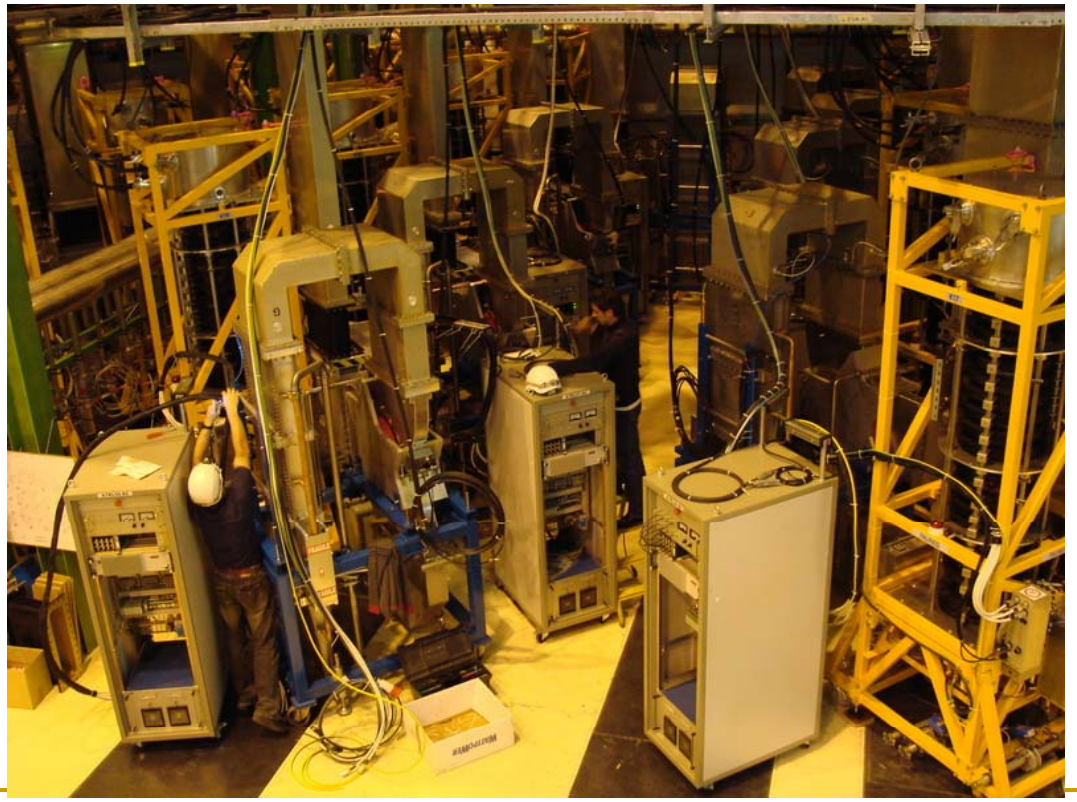


LHC Circulators & RF loads

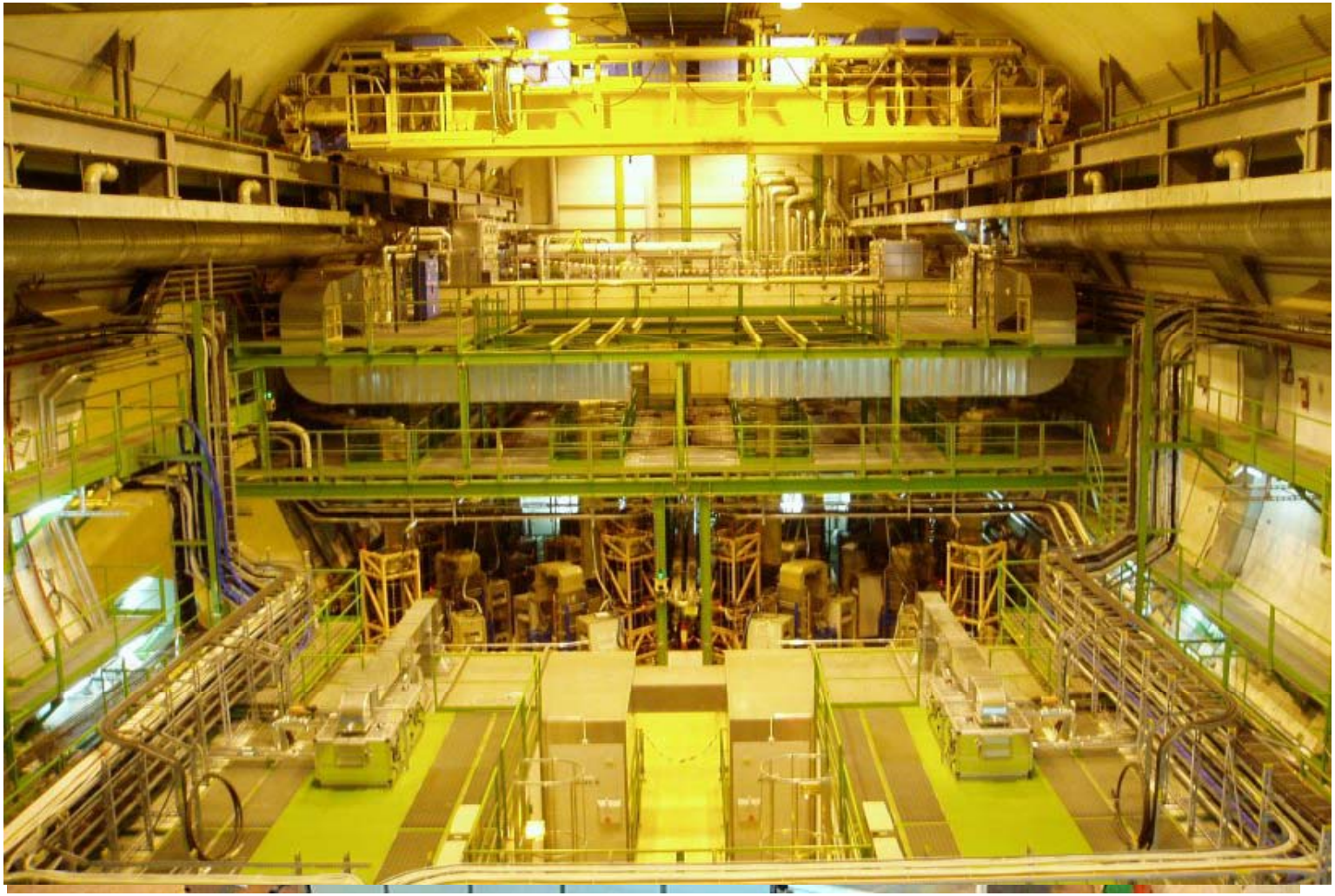


Circulators & RF loads

- Main issue: Installation
  - Circulators and loads mounted on mobile chassis to facilitate replacement
  - Pre-cabling done in the lab to speed up installation

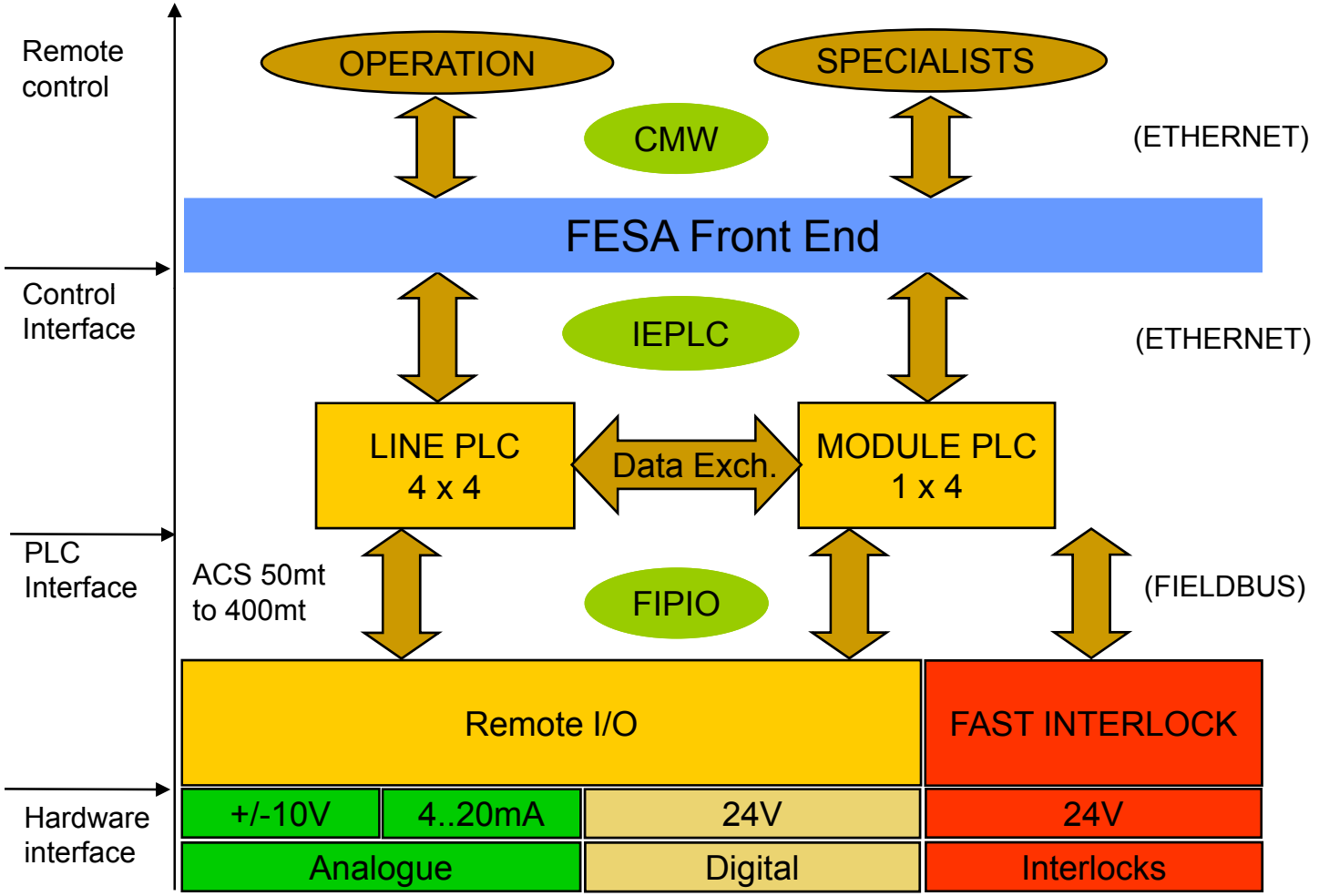


Waveguide system



Controls

Keywords : Distributed , Modular, Standard, Reliability, Maintenance



Controls: Details

Standard: Use of industrial components > 90%

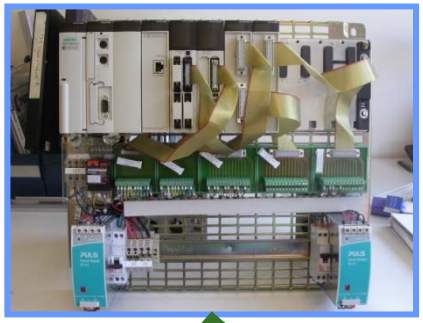
Distributed: Reduced distance between the sensors and data acquisition = better noise immunity

Modular: Every remote I/O sub-system was tested and calibrated in the lab prior to installation = easy installation and reduced hardware commissioning time

The system design was made in order to optimize Reliability and ease Maintenance since the underground area is not accessible during operation

CAVITY TEMPERATURE

PLC



KLYSTRON RACK

Controls: Interlocks

Slow (~10mSec) interlocks are treated by the PLC
(Ex. Temperature, water flows)

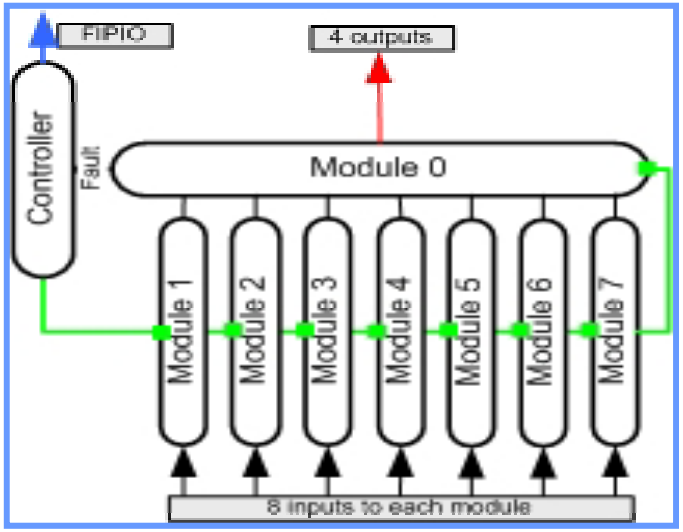
Fast (~15uSec) interlocks will be connected directly to the fast interlock system

pure failsafe hardware modular system
fast reaction time

The PLC has a “sum of faults” output to the interlock system

The PLC will read back the Interlock status and provide a comprehensive code for the supervision

Direct isolated output to
the RF preamplifier FAST RF OFF
the HV power supply FAST HV STOP (= 4 cavities OFF)



Controls: Faults detection

Bit	Klystron Cooling code	OK
X0	Collector water flow	
X1	Body water flow	
X2	Circulator water flow	
X3	CircLoad water flow	
X4	Collector water in temp	
X5	Collector water out temp	
X6	Body water out temp	
X7	Circulator water out temp	
X8	CircLoad water out temp	
X9	Klystron blower	
X10	Window air temp	
X11	Window air flow	
X12	Drift tube temp	
X13	HVBox air flow	
X14	HvBox Air temp	

Bit	Klystron Heater code	OK
X0	*Bunker water flow*	
X1	Vac2	
X2	Heater Mains	
X3	Pre-Heating Delay	
X4	Heating Delay	
X5	Status	
X6	Regulator Over current	
X7	Short circuit	
X8	Open circuit	
X9	Filament Interlock	

Val	Klystron Command	OK
0	OFF	
1	L1 Ready for HV	
2	L2 Hv ON 10Kv	
3	L3 Hv ON nominal	
4	L4 RF On	
5	Spare	

KlystronHv Switch OK

Bit	Klystron Code..	OK
X0	Hv Klystron Switch	
X1	Cooling	
X2	Focus	
X3	Heater	
X4	Vacuum	
X5	Services	
X6	Modulator	
X7	DCCT Code	

Bit	Klystron Focus	OK
X0	Mains presence	
X1	Engagement delay	

f the device
the device
first detected fault
ormed in each PLC on a device basis
ed in the FESA class and an explicit
al alarm system

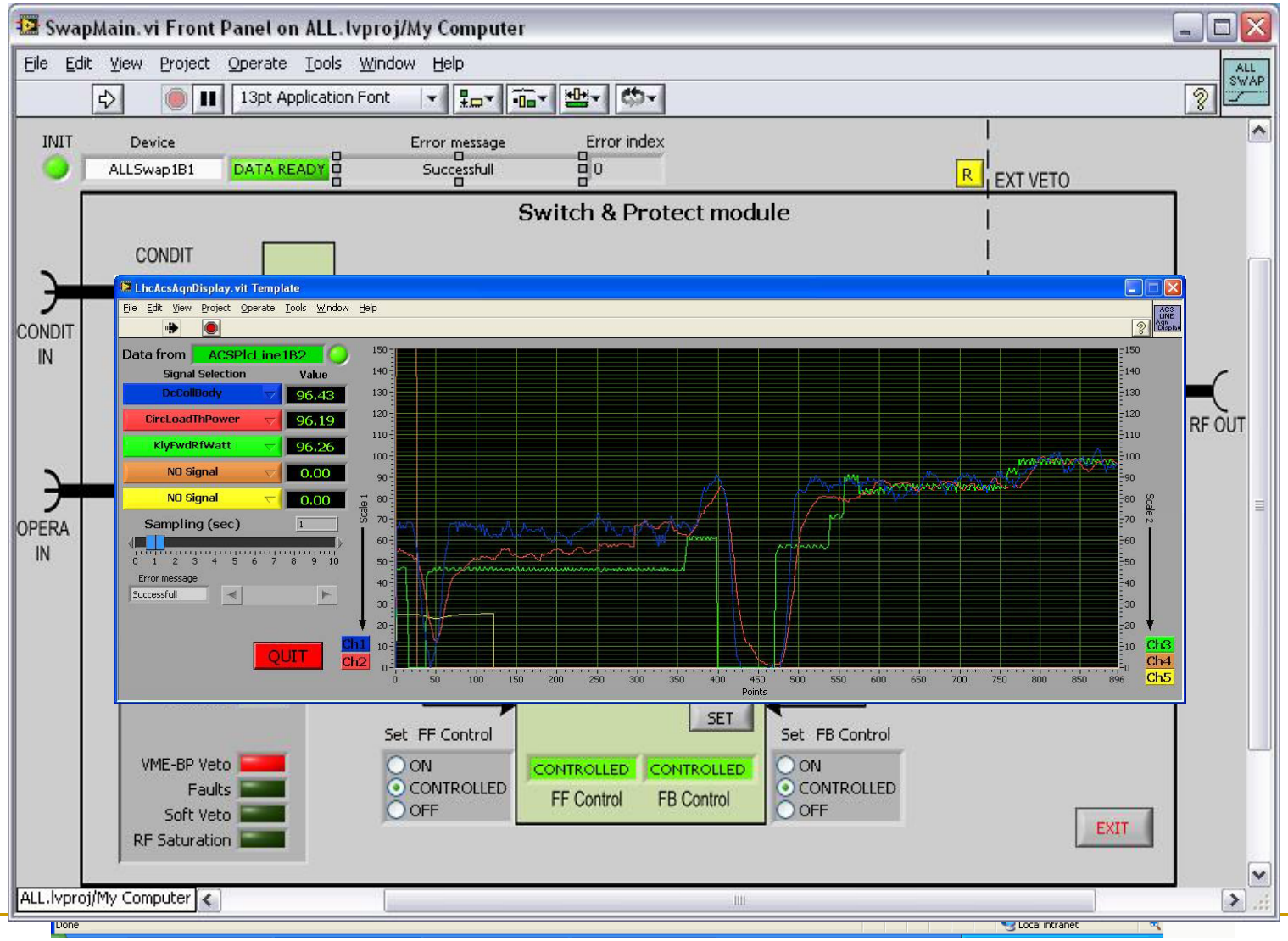
Laser Console [rfacsop/NOT PERMANENT]

File Alarm Group View Configuration Help

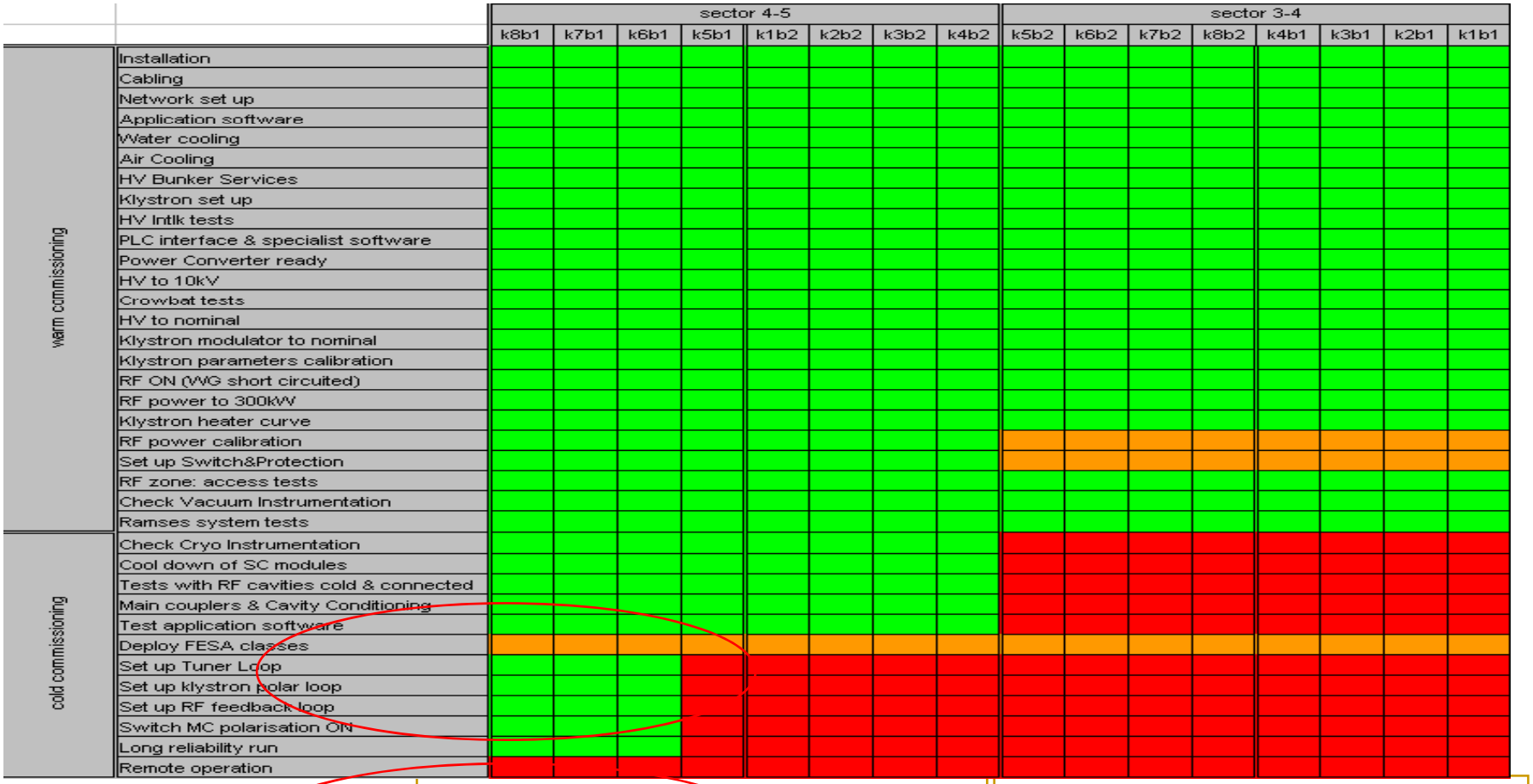
Active List

	Date	Time	System Name	Identifier	Problem Description
◇	N	13:55:24	ACSLine	ACSLINE6B1	Klystron filament current to low
◇	N	13:55:24	ACSModule	ACSMODULEM2B1	Crowbar fired
◇	N	14:29:26	ACSModule	ACSMODULEM2B1	Sum of HV faults from Line 3 PLC
◇	N	14:57:25	ACSLine	ACSLINE6B1	Crowbar or Modulator not ready
◇	N	14:57:25	ACSLine	ACSLINE7B1	Crowbar or Modulator not ready
◇	N	15:38:12	ACSLine	ACSLINE6B1	Klystron HV separator not connected
◇	N	16:20:50	ACSLine	ACSLINE7B1	Reflected RF power level exeeded between Klystron and Circulator (Wattcher Lo)
◇	N	16:34:15	ACSLine	ACSLINE8B1	Reflected RF power level exeeded between Klystron and Circulator (Wattcher Lo)
◇	N	16:39:15	ACSModule	ACSMODULEM2B1	Sum of HV faults from Line 4 PLC
◇	N	16:39:17	ACSLine	ACSLINE8B1	Klystron mode-anode current to low
◇	N	16:39:19	ACSLine	ACSLINE8B1	Circulator Water Out Temp to high
◇	N	17:04:36	ACSLine	ACSLINE7B1	Klystron filament current to low

Controls: Interfaces



ACS system commissioning - status



- cavities cold & ready for RF ~ mid-June
- expected commissioning time: ~ 4-5 weeks

- cavities cold & ready for RF ~ mid-May
- expected commissioning time: ~ 6-8 weeks