The past and future RF performance in LHC

Pierre Maesen BE/RF

On behalf of the LHC RF team

Content

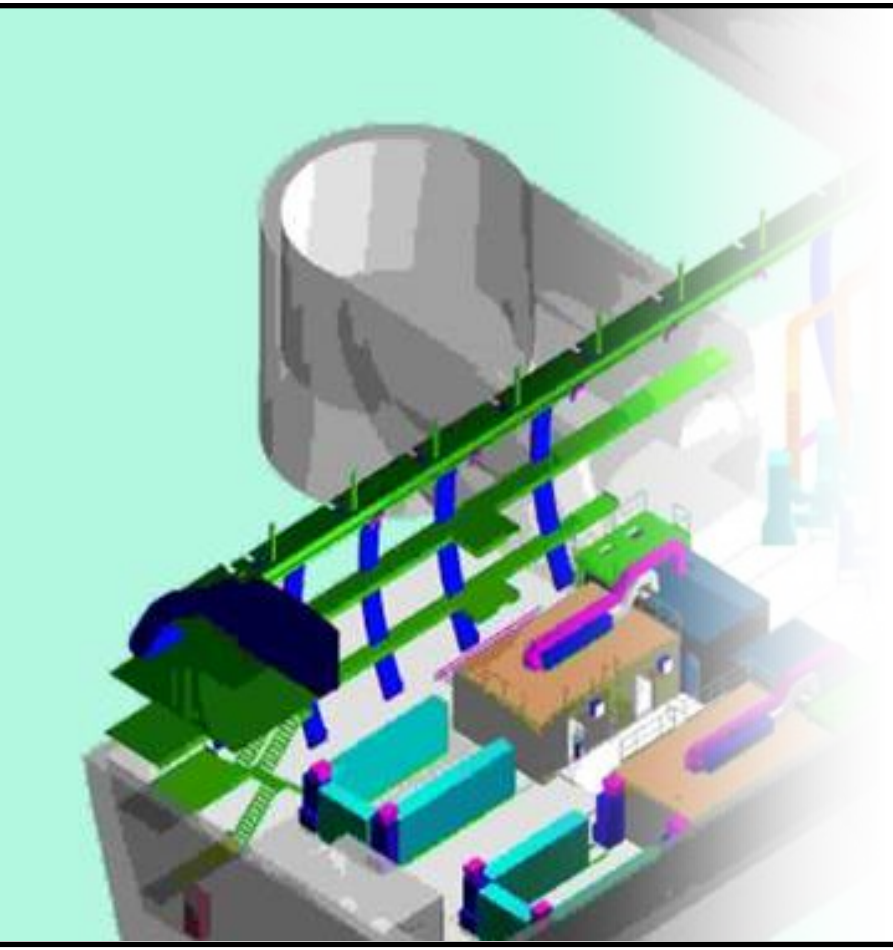
- LHC RF System

- RF performance up to 2012
  - Tools used for faults tracking

- LS1 ACS upgrades at PT4
- LS1 ADT upgrades at PT4

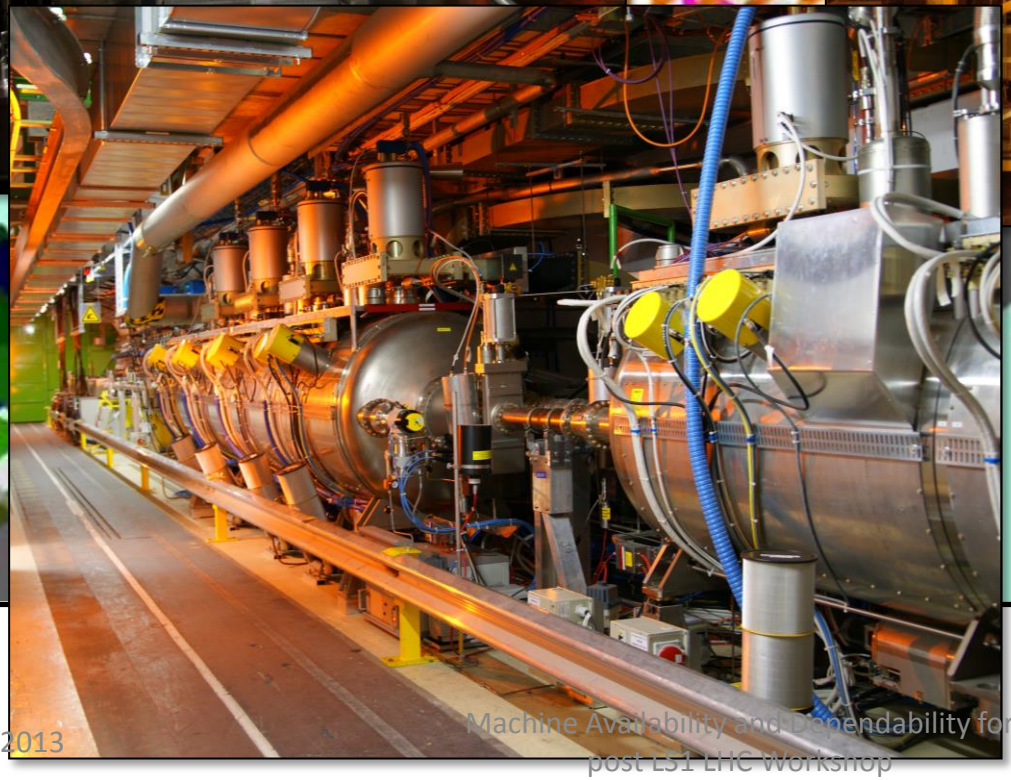
- Prospects for RUN 2
  - Tools that could help

- LHC RF System

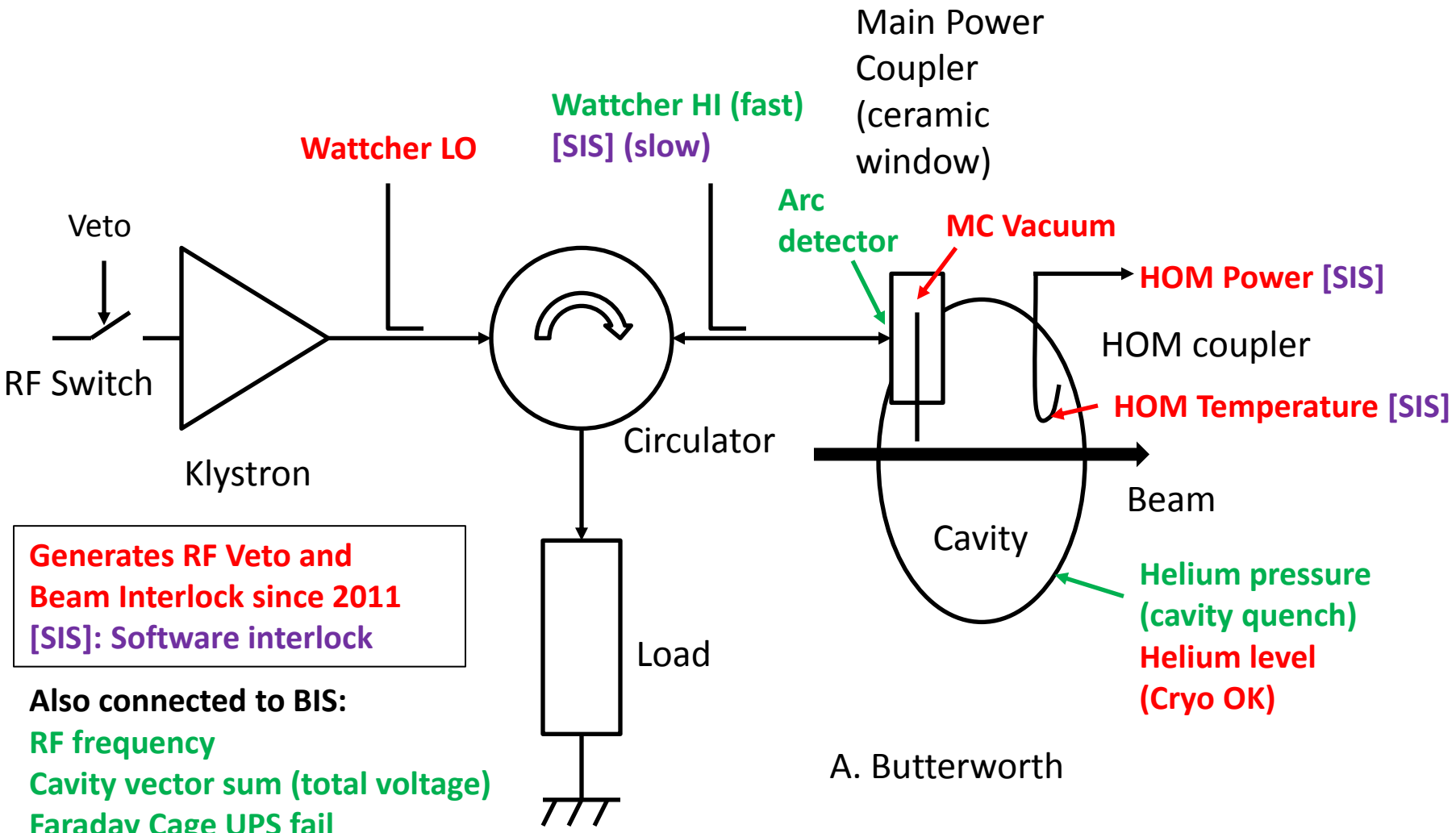


- 16 SC Cavities in 4 Modules
- 16 Klystrons
- 300 kW @ 400 MHz
- 1000 Interlocks
- All connected to the beam dump
- 8 Transverse Dampers
- 32 Tetrodes

UX45 RA43-47



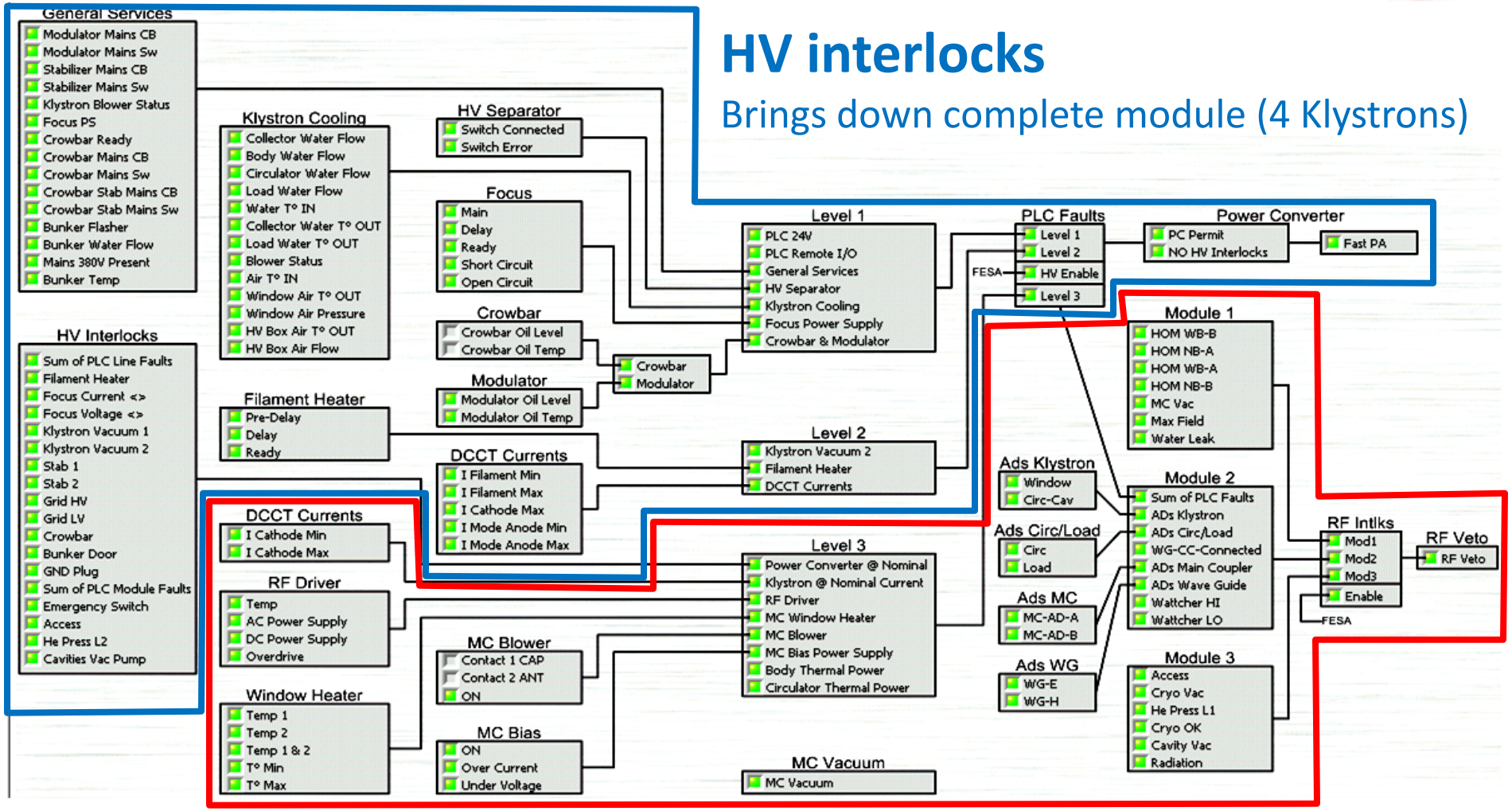
RF power path & critical interlocks



ACS RF & HV interlock chains

HV interlocks

Brings down complete module (4 Klystrons)



RF interlocks (Trips 1 Klystron)

L. Arnaudon

- RF performance up to 2012

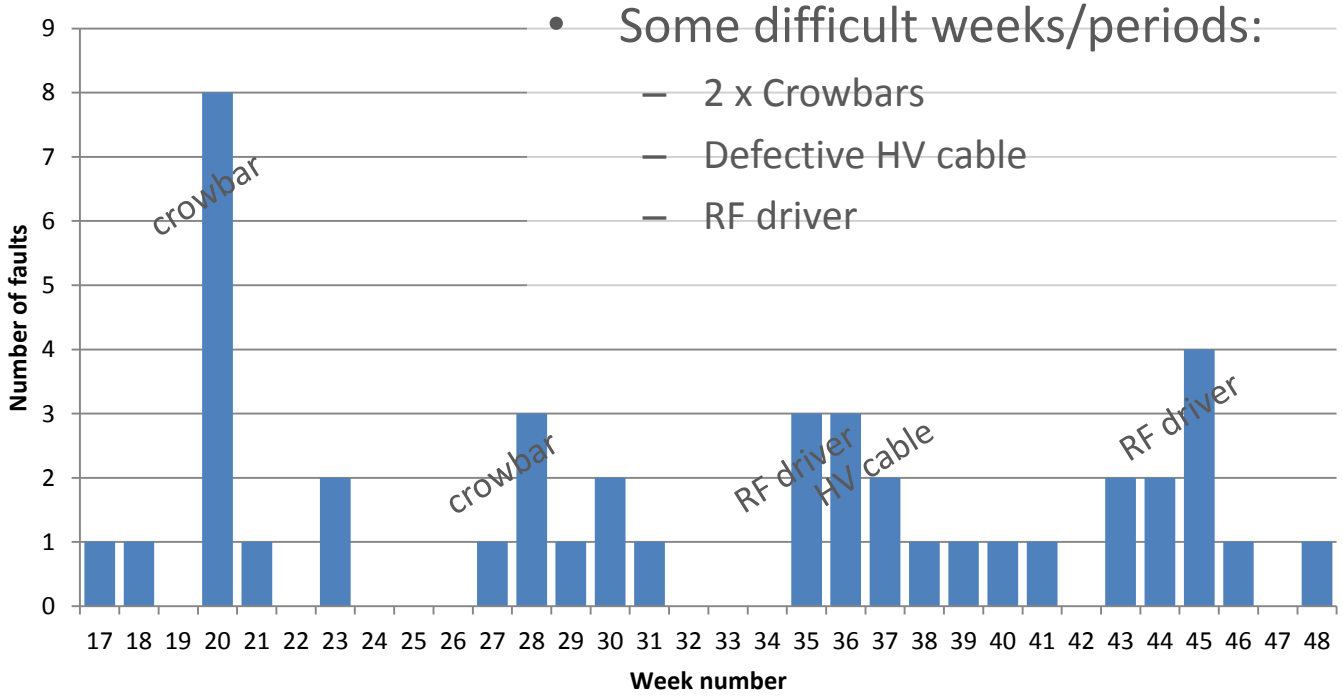
2011:

- 78 faults in total
- 11% of all beam dumps
- 2 Faults per week during physics

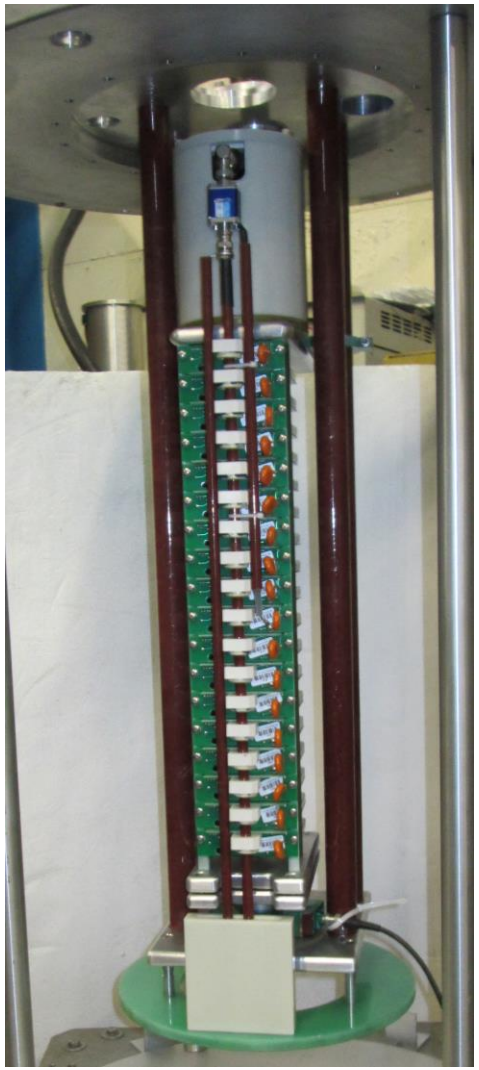
2012: (Fault analysis: D. Glenat)

- 43 faults in total
- x% of all beam dumps
- 1.3 Faults per week during physics
- Some difficult weeks/periods:
  - 2 x Crowbars
  - Defective HV cable
  - RF driver

Fault statistics 2012



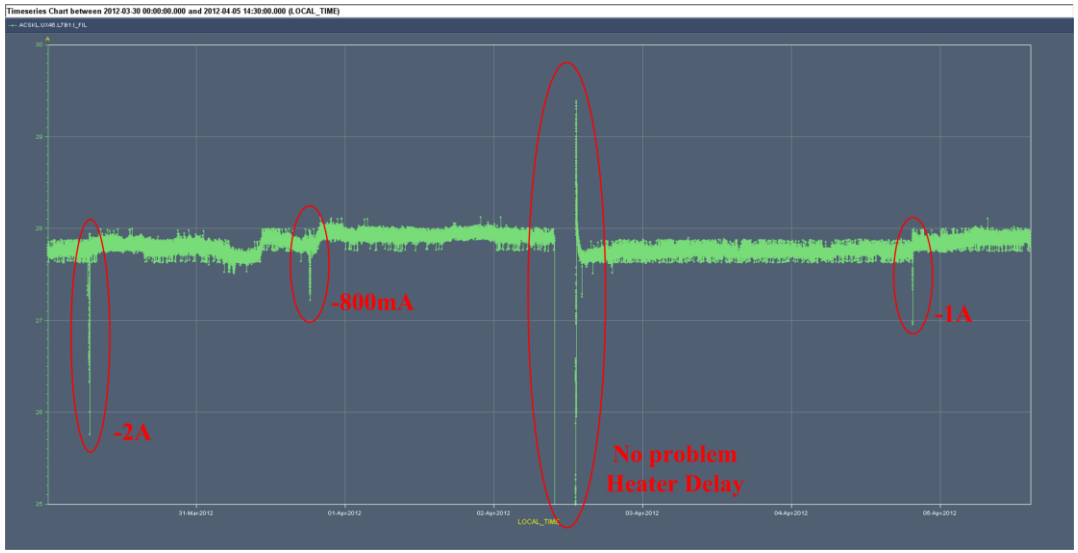
Thyratron replacement



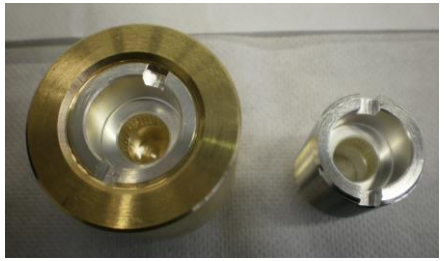
- Most critical equipment : the current Thyratron crowbar suffers from spurious trips
- Solid-state replacement developed using Thyristor-Stack: very promising and showing comparable performance (See: Paper at IPAC12 by G. Ravida)
- 1 unit installed since September 2012
  - No spurious trip observed
  - Few trips due to klystron arcs

Klystron filament “I fil too low” faults

- Second wondering faulty : Filament current interlocks



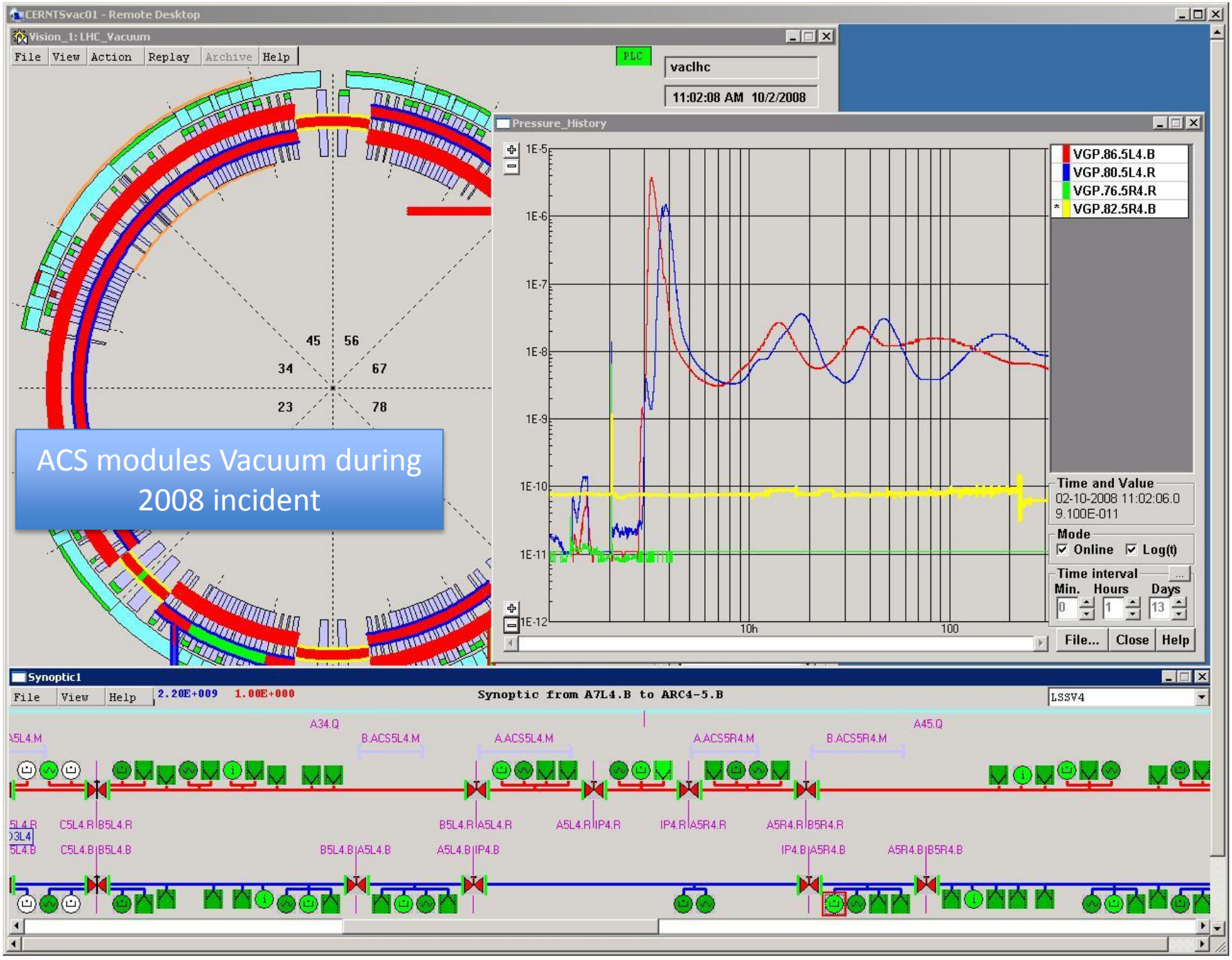
- 2 culprits identified:
  - Several klystron HV connectors
    - Spring contacts degraded (black deposit)
    - Contacts needed to be cleaned repeatedly
    - New connector design without springs, with special Multi-Contact installed
  - Cable head defective welding…LS1

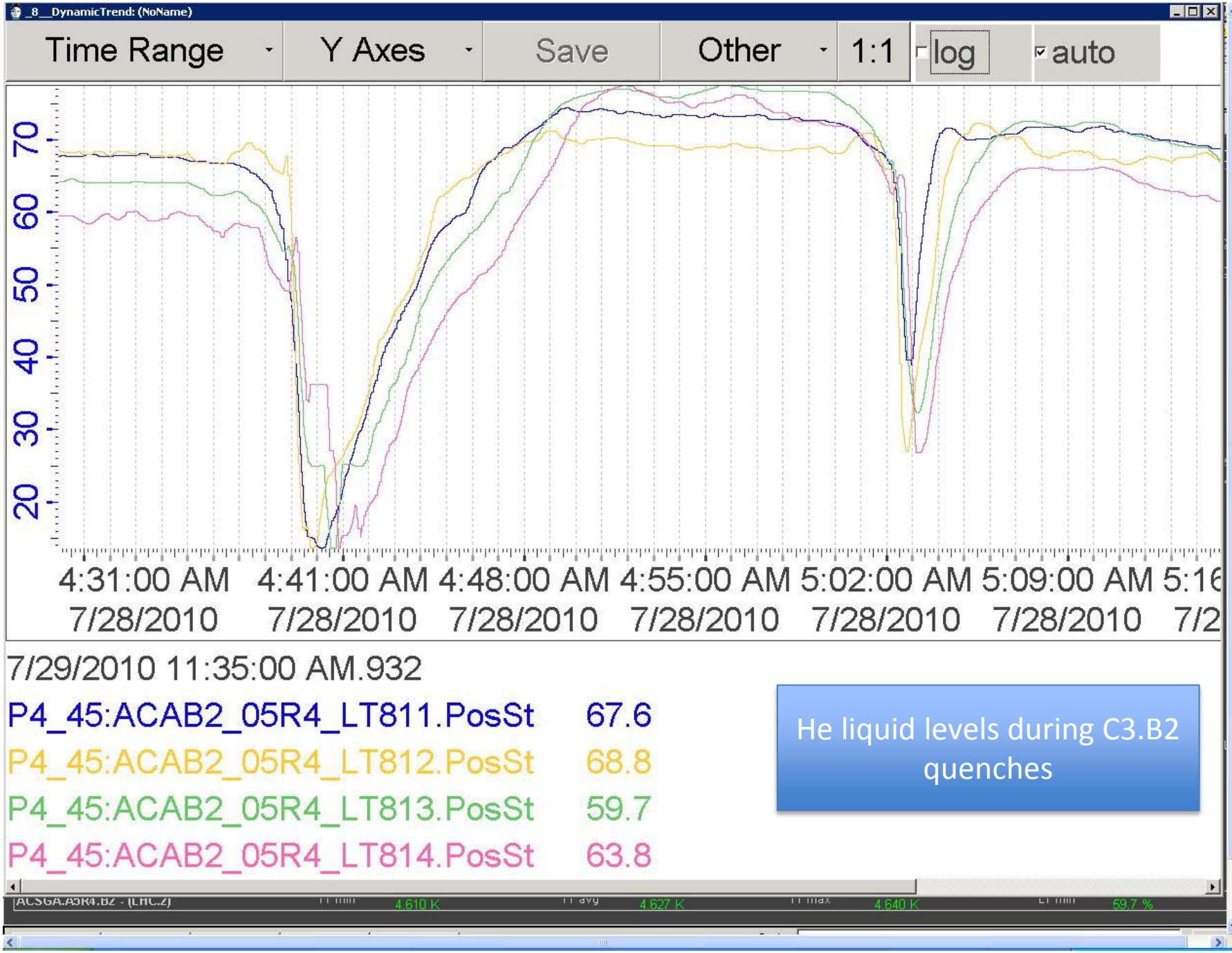


- Tools used for faults tracking

- Equipment's build with manual written logbook … scanned -> EDMS id 879141, 879146, 879150, 879151, 1082985
- LHC commissioning with MS OneNote logbook
- HMI Labview from FESA classes
- LHC RUN 1 followed with OP and RF logbooks
  - Rapid overview & general cmd on Delphine's RF page
- Faults tracking with LASER, post mortem TIMBER and RF specialist buffers in VME boards
- PVSS for Cryo and Vacuum in monitor mode
- Manual extraction and corrections for statistics


TIMBER v3.3.1
Sign In
Data Source preferences:
LDB (PRO->TEST) -> MDB (PRO->DEV)
Time Zone:
LOCAL_TIME
Elapsed: 266ms
Query Output
Query
Variable Hierarchies
Variable Search
Variable Lists
Settings
About
Query Output
Chart 1
JPG
2D
Cursor Coordinates
Timeseries Chart between 2010-07-28 04:29:00 and 2010-07-28 04:41:00 (LOCAL_TIME)
ACSCA.UX45.L3B2:RF_HOM_WB_TOT
ACSCA.UX45.L3B2:T_LBCD1
ACSCA.UX45.L3B2:T_LBCD2
ACSMC.UX45.M1B2:P_HELIUMA
kW
C
C
mb
C3.B2 quench on HOM
28-juil.-2010 04:30
28-juil.-2010 04:32
28-juil.-2010 04:34
28-juil.-2010 04:36
28-juil.-2010 04:38
28-juil.-2010 04:40
LOCAL_TIME
Data Set: ACSCA.UX45.L3B2:RF_HOM_WB_TOT X: 28-juil.-2010 04:39:19.809 Y: 0.00865994393825531
Data Set: CURSOR X: 28-juil.-2010 04:39:19.991 Y: 174.33883446612967
Statistics
Variable Name
Values
MIN Timestamp
MAX Timestamp
MIN Value
MAX Value
AVG Value
Remove ALL
Remove Selected
16:46:42 - ...Data Loaded Successfully

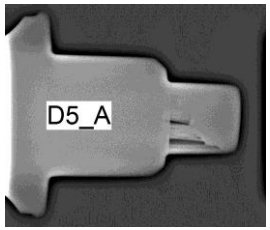

CERNTSvac01 - Remote Desktop
Vision_1: LHC_Vacuum
File View Action Replay Archive Help
PLC
vaclhc
11:02:08 AM 10/2/2008
45 56
34 67
23 78
ACS modules Vacuum during 2008 incident
Pressure_History
1E-5
1E-6
1E-7
1E-8
1E-9
1E-10
1E-11
1E-12
10h
100
VGP.86.5L4.B
VGP.80.5L4.R
VGP.76.5R4.R
VGP.82.5R4.B
Time and Value
02-10-2008 11:02:06.0
9.100E-011
Mode
Online
Log(t)
Time interval
Min. Hours Days
0 1 13
File... Close Help
Synoptic1
File View Help
2.20E+009 1.00E+000
Synoptic from A7L4.B to ARC4-5.B
LSSV4
A34.Q
A45.Q
B.ACS5L4.M
A.ACS5L4.M
A.ACS5R4.M
B.ACS5R4.M
C5L4.R B5L4.R
B5L4.R A5L4.R
A5L4.R IP4.R
IP4.R A5R4.R
A5R4.R B5R4.R
C5L4.B B5L4.B
B5L4.B A5L4.B
A5L4.B IP4.B
IP4.B A5R4.B
A5R4.B B5R4.B

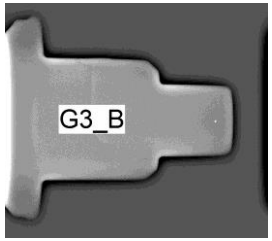


He liquid levels during C3.B2 quenches

- LS1 ACS upgrades at PT4

- New induction welding campaign on HV connectors

Before 

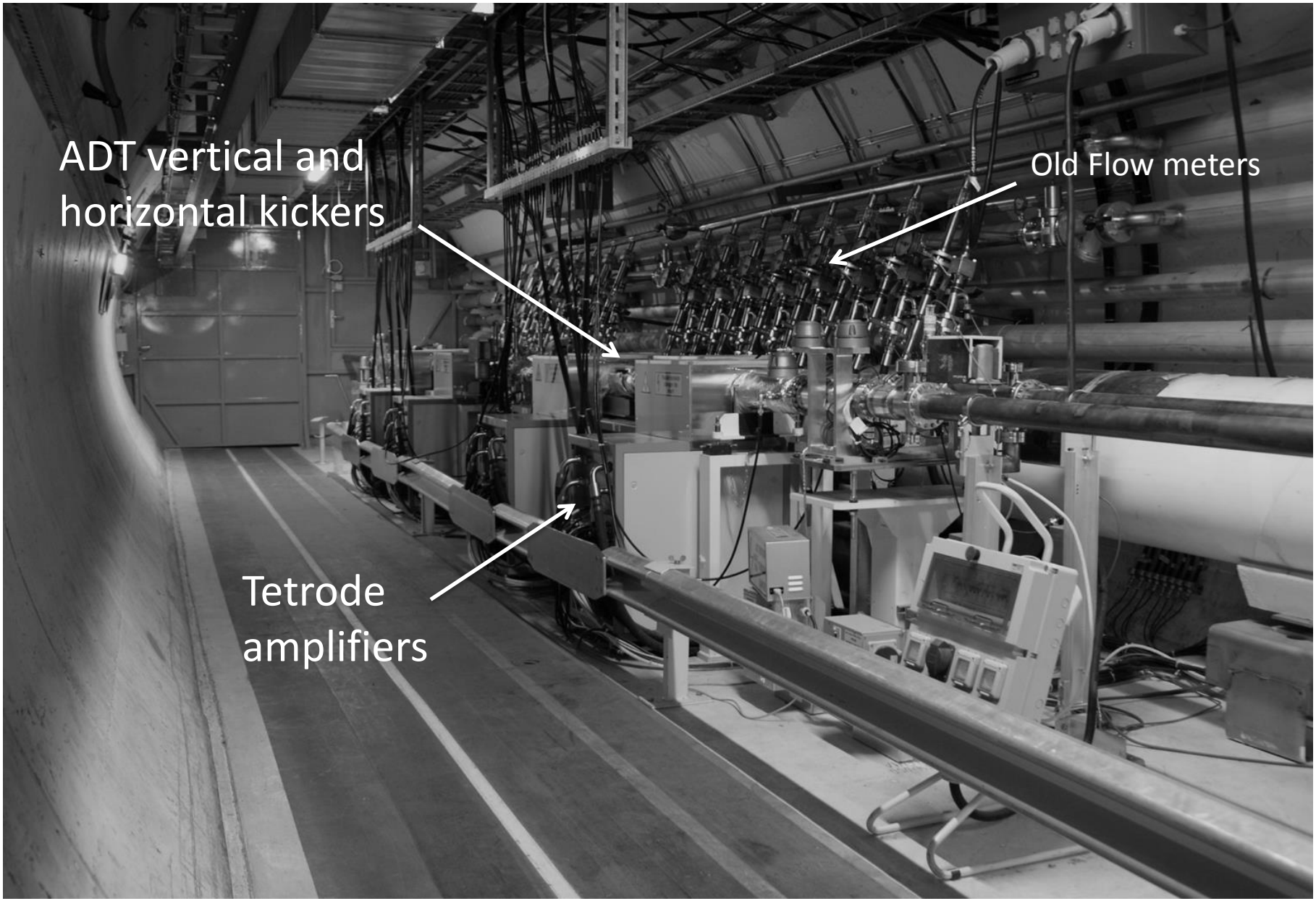
After 

- 8 last new klystrons/16 for nominal performance
  - 58 kV/9.5 A => 300 kW CW RF
- 4/4 new HV solid state crowbars
- Maintenance campaign of ageing tetrode in modulator
- New Air cooling of HV Bunkers

O. Brunner

- LS1 ACS upgrades at PT4 cont.

- LHC ACS module M1.B2 to be replaced
  - To overcome C3.B2 limitation at 1.3 MV acc. field
- New version of PLC software UNITY V8
- New version of FESA ?
- Replacement of all Windows XP consoles
- R2E
  - ACS module Cryo control racks will be displaced
  - UX451 PAD moved further away from tunnel
    - Access with LHC-TNL, no LHC-RF list anymore

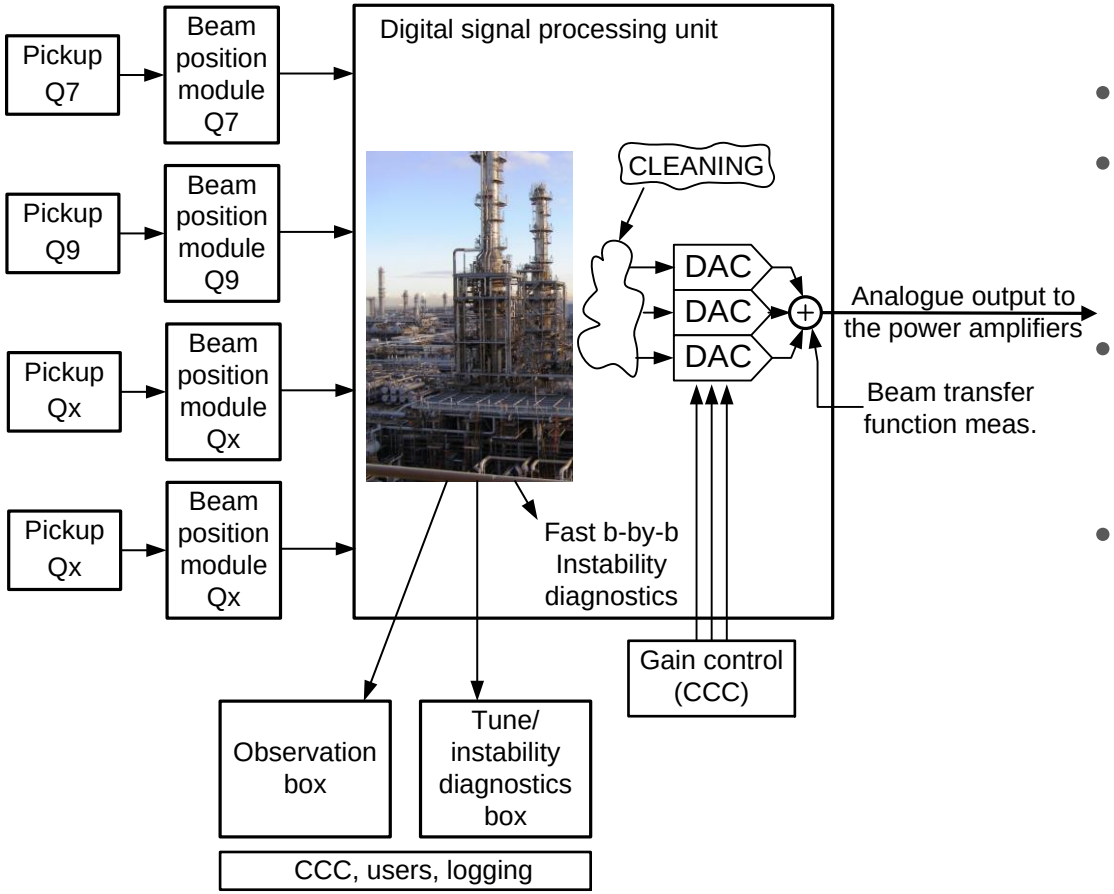

ADT vertical and horizontal kickers
Old Flow meters
Tetrode amplifiers

- LS1 ADT upgrades at PT4

- New amplifier-kicker clamp
- Improvement of the HVPS by adding HV switches allowing a remote off line of a faulty amplifier
- New HVPS cables to avoid cable burning
- Replacement of power attenuator with power load
- New flow-meters in replacement to the old Eletta from LEP time
- Adding redundancy to the problematic kicker vacuum interlock

E. Montesinos

- LS1 ADT Feedback upgrade



D. Valuch

- Large coax recabling campaign
- Major upgrade of electronics to house all new features accumulated since 2009
- Double the number of pickups, new upgraded beam position modules
- Multiple output DACs:
  - Independent treatment of different bunch groups (high/low gain, high/low bandwidth)
  - Independent cleaning performance

- Prospects for RUN 2

- Restarting injectors & LHC … Delicate
  - Safety for people and equipment
- Scrubbing 25ns… No problem
  - Scrubbing 5ns TBC see LBOC meetings
- 25 ns operation with nominal current…
  - Promising, see presentations in Evian and Chamonix by P. Baudrenghien et al.
- Klystrons at 58kV/9A instead of 50kV/8A
- More flexibility in pickups and ADT functionality
  - Plenty of hope ☺

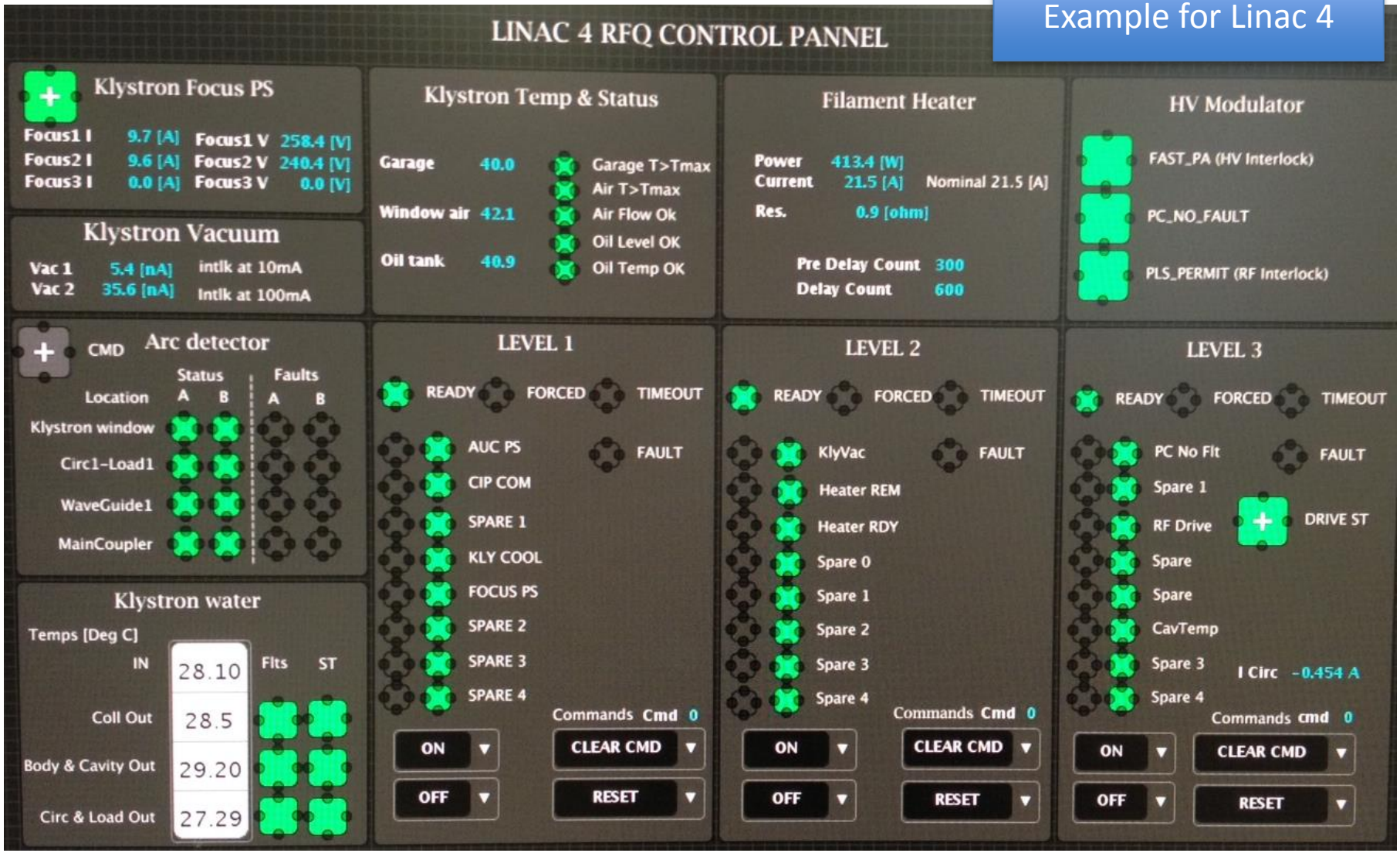
- Prospects for RUN 2

- Equipment ageing ?
  - Inspection during technical stops…
  - ACS tuning cables inside insulation vacuum etc.
  - New development to replace klystron modulator tetrode
  - Dispersion of klystron age
- Component obsolescence FPGA, DSP !
  - So far enough VME spare boards…
- Manpower for piquet's ?
  - Young students are friendly but CERN needs continuity and experienced staff !

- Tools that could help

- FESA V? & TIMBER mandatory ready in time !
- Remote monitoring from home very useful
  - Remote control with piquet role (gains time and avoids displacements)
  - Down to expert PLC tools on TN via UNITY
- More user friendly configuration of LASER ?
  - Better “hierarchisation” of alarms, faults...
- Automatic event logging in the RF logbook
  - But editable for correction or addition of signals charts & comments => easier statistics
- Replacement of Labview by Inspector BE/OP ?
  - Parallel development during RUN 2

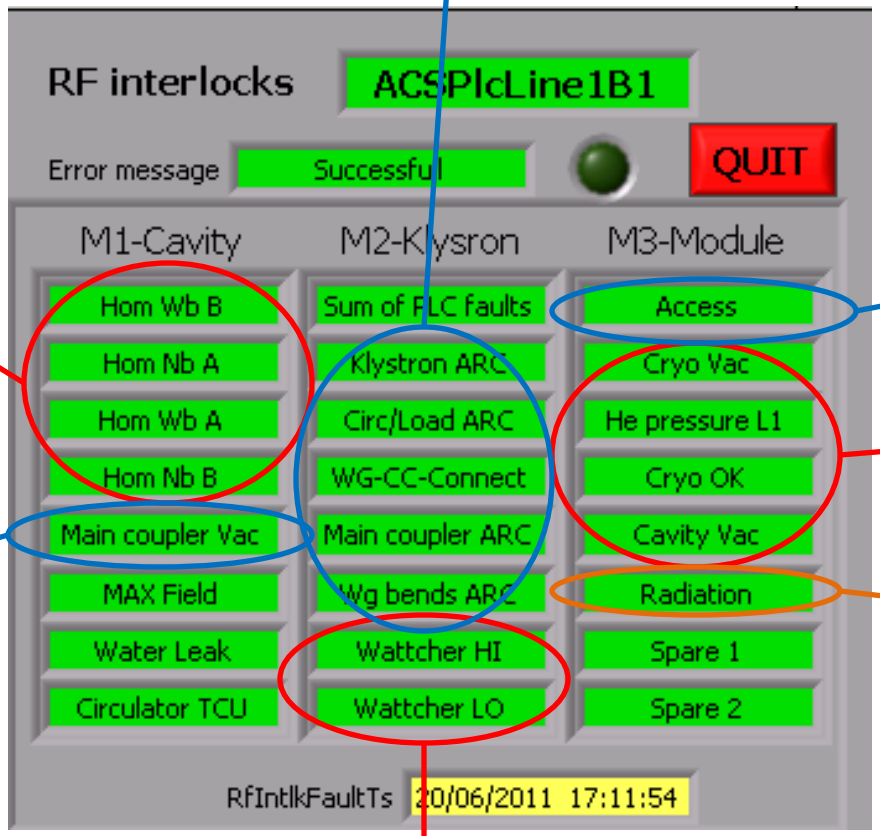
New Inspector display
Example for Linac 4



Thank you for your attention

- Questions ?

RF interlocks



Arc detectors

Higher order mode power

Access system

Cryo + Vacuum

Main coupler vacuum

Radiation

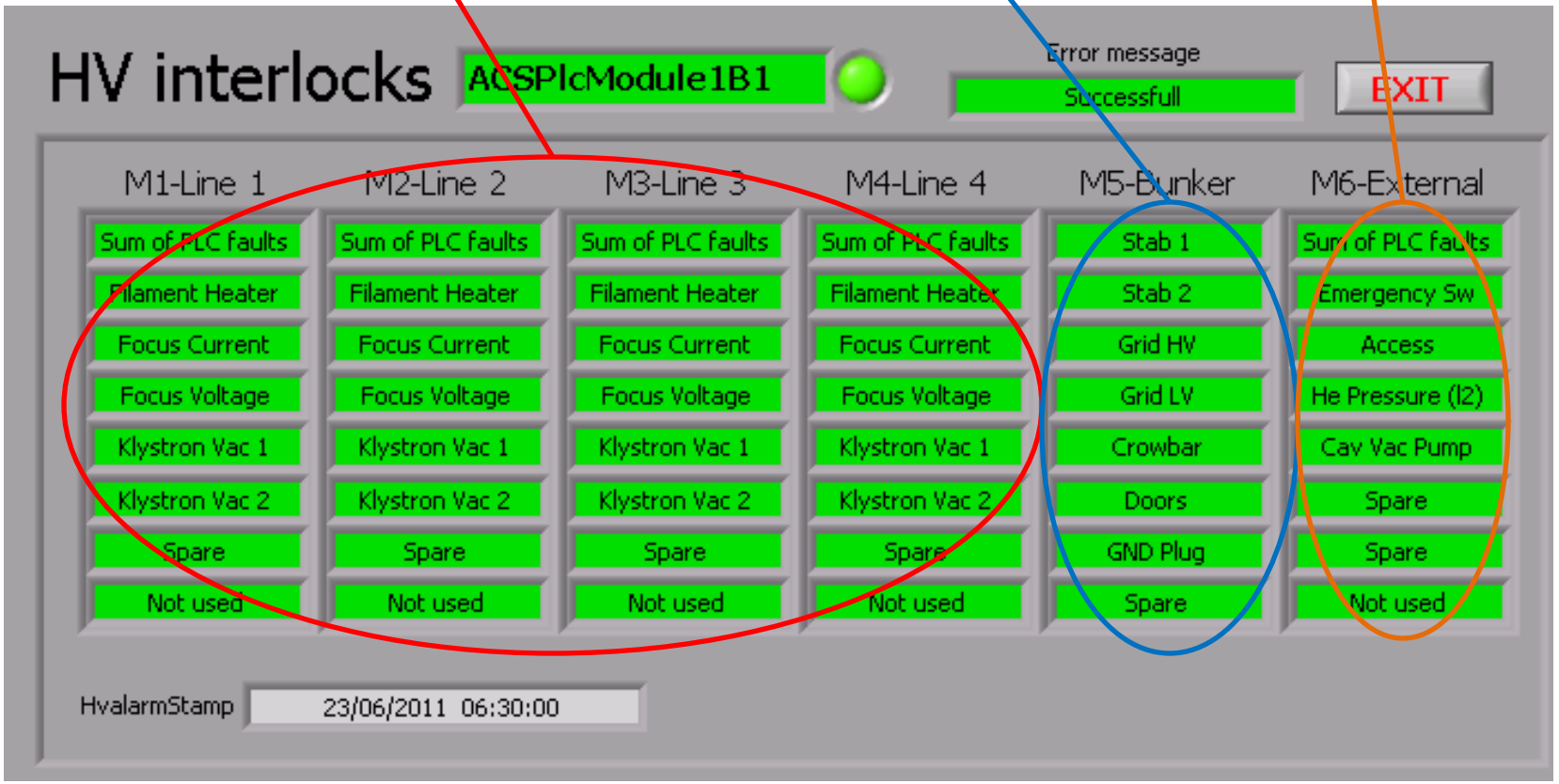
Reflected power

HV interlocks

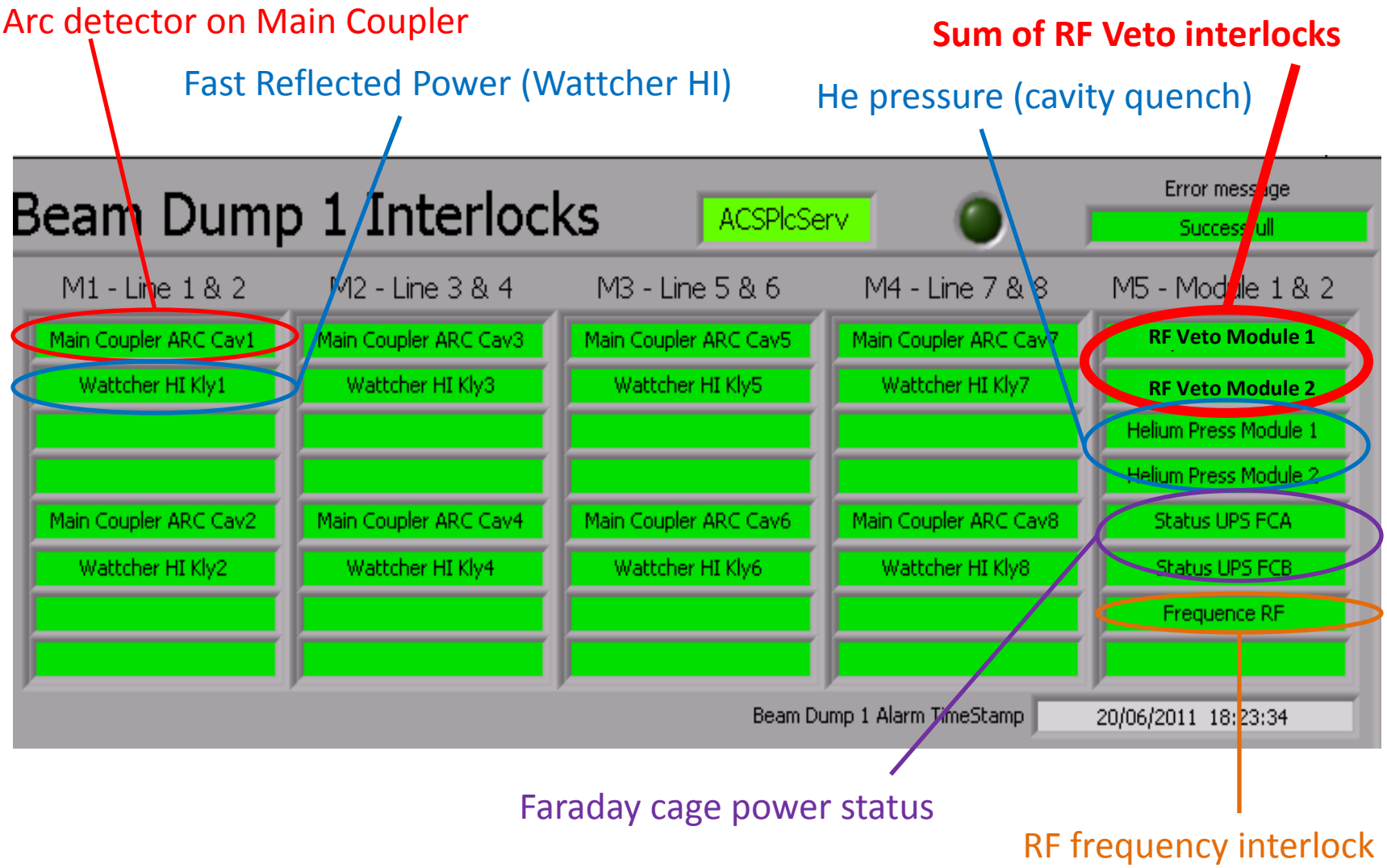
Klystron faults

HV bunker faults

External faults



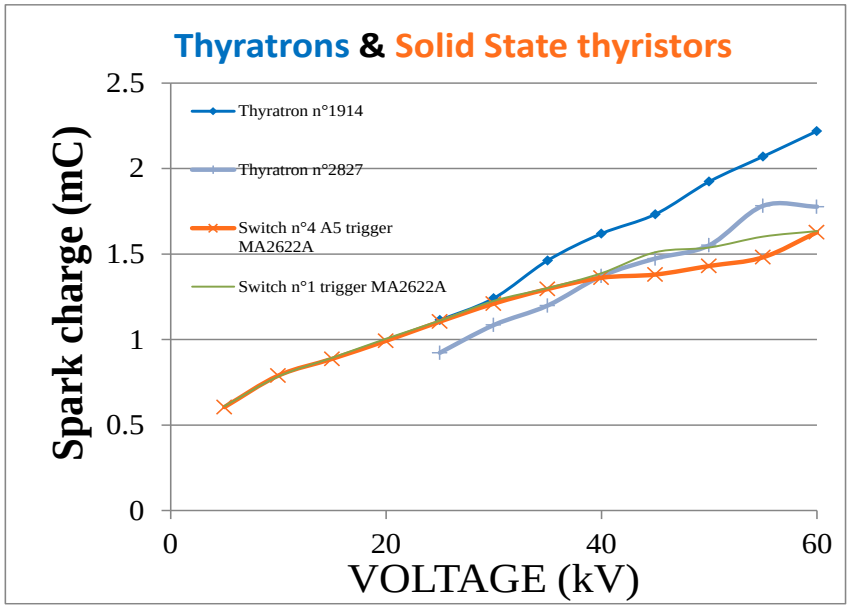
Interlocks connected to BIS (UX45)

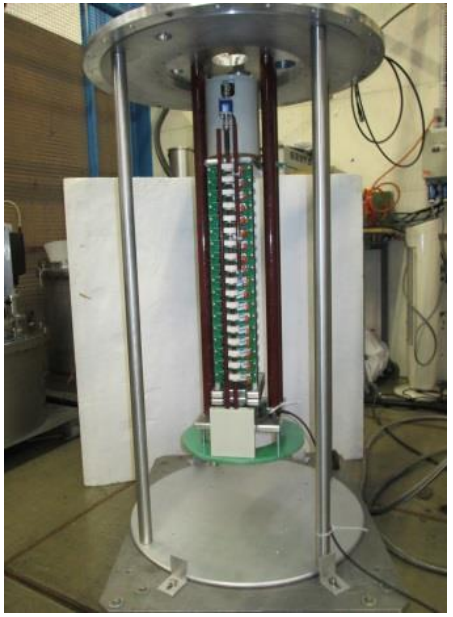


Solid state crowbars (“fast protection system”)

Gianfranco Ravida/S. Menoni

- Sophisticate circuit
- Water/oil Cooling
- 350 litters oil volume
- Limited lifetime



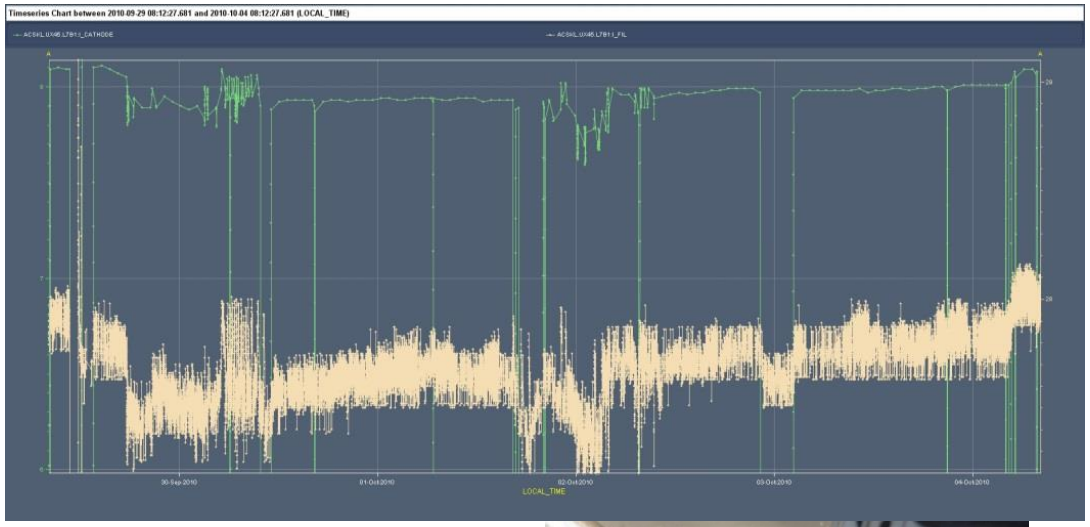


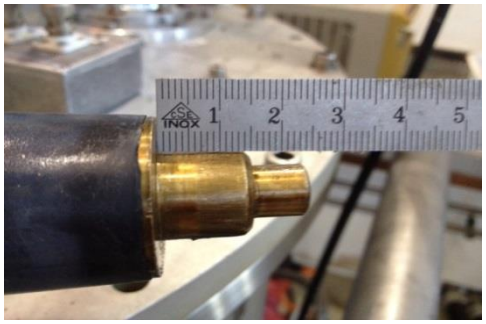
- Very simple circuit
- No cooling (±10W)
- 90 litters oil volume

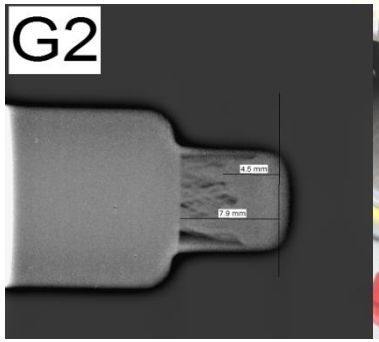
- Solid State device has better performances than the thyratron
- Validated during 2012 running period
- In series production

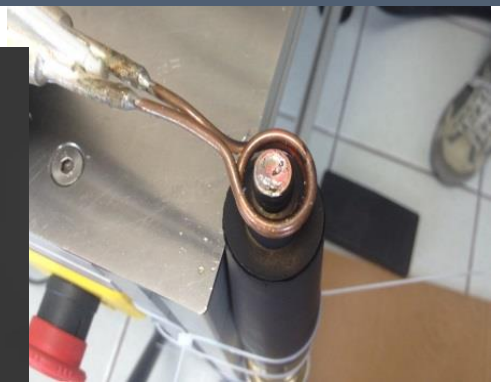
Repair of the high voltage connectors

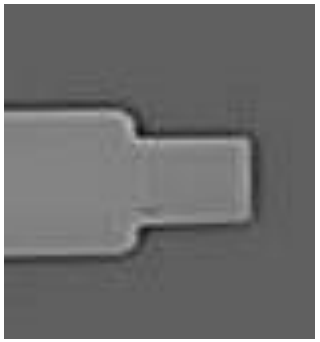
P. Martinez-Yanez/G. Ravida











- Klystron filament glitches responsible for frequent RF trips during operation
- Procedure validated to re-weld the connectors without damaging the insulation material
- Campaign in LHC will soon be launched

Digital measurement system for the klystron modulators

Anders Mikkelsen/D. Valuch/G. Ravida/S. Menoni

	Heater voltage	Heater voltage RMS	Heater current	Heater current RMS	Cathode current	Cathode voltage
Fluke 87V	7.05 V AC	7.05 V AC	9.76 A AC	9.76 A AC	8.11 A DC	4.01 V DC
Board	7.04 V AC	7.01 V AC	9.75 A AC	9.73 A AC	8.09 A DC	4.01 V DC
Error	0.1%	0.6%	0.1%	0.3%	0.2%	0.0%

- DCCT's and tetrodes used in LHC are no longer produced by industry
- Development of a FPGA based electronic located in HV modulator

  -> the crowbar survival challenge!
- Prototype built: looks very promising
- Evaluation tests for tetrode replacement