



The ESRF Radio-frequency Data Logging System for Failure Analysis

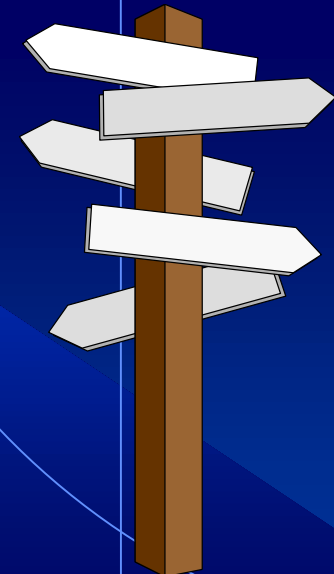
Jean-Luc REVOL

Machine Division

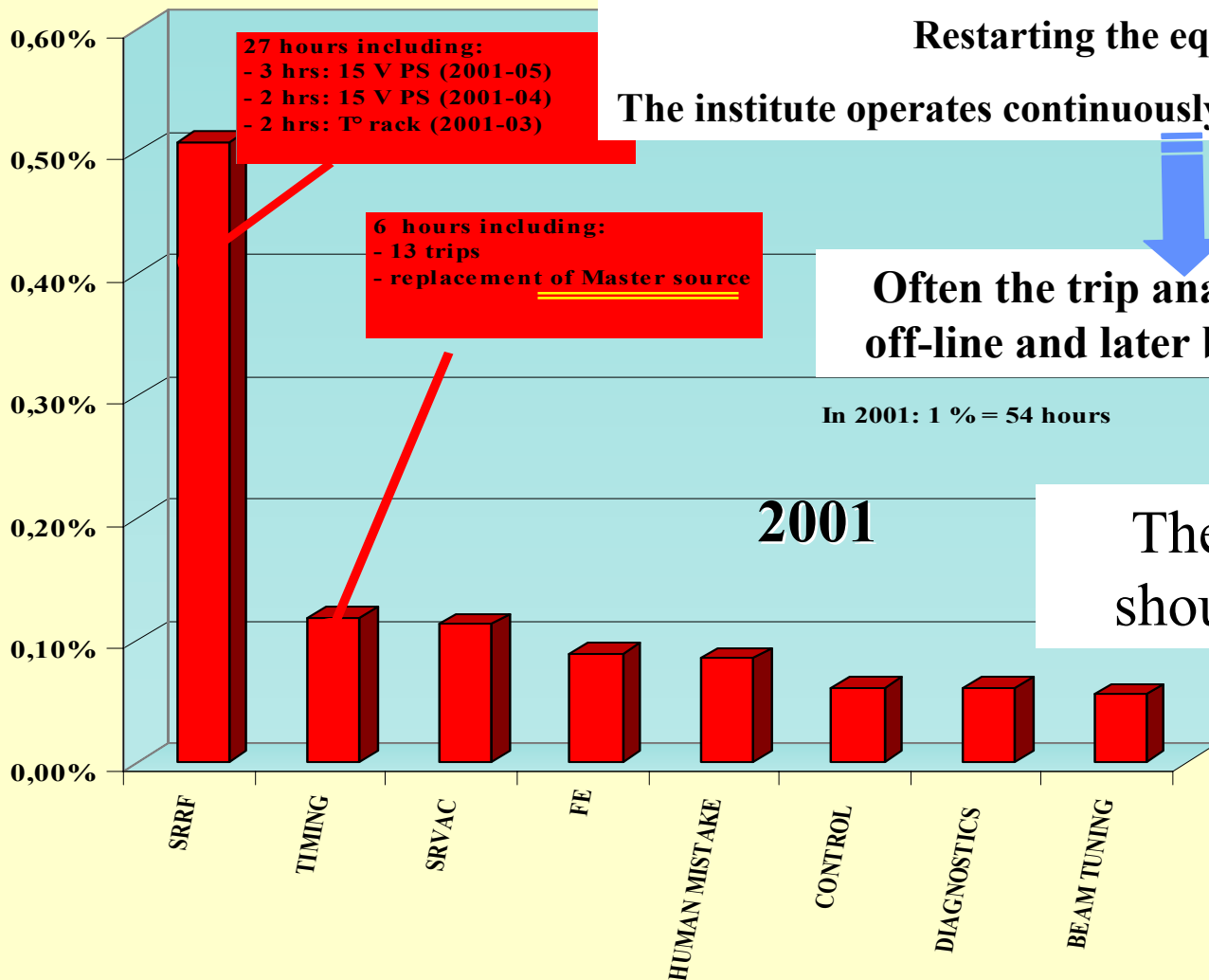
European Synchrotron Radiation Facility

Accelerator Reliability Workshop

4-6 February 2002



Impact of the RF time lost / equipment



First objective after a beam loss:

Restarting the equipment!!

The institute operates continuously:

Often the trip analysis is made off-line and later by the expert!

The information should not be lost

Two Objectives

Why was the RF faulty?

Why has the beam been lost?

Which equipment is faulty?

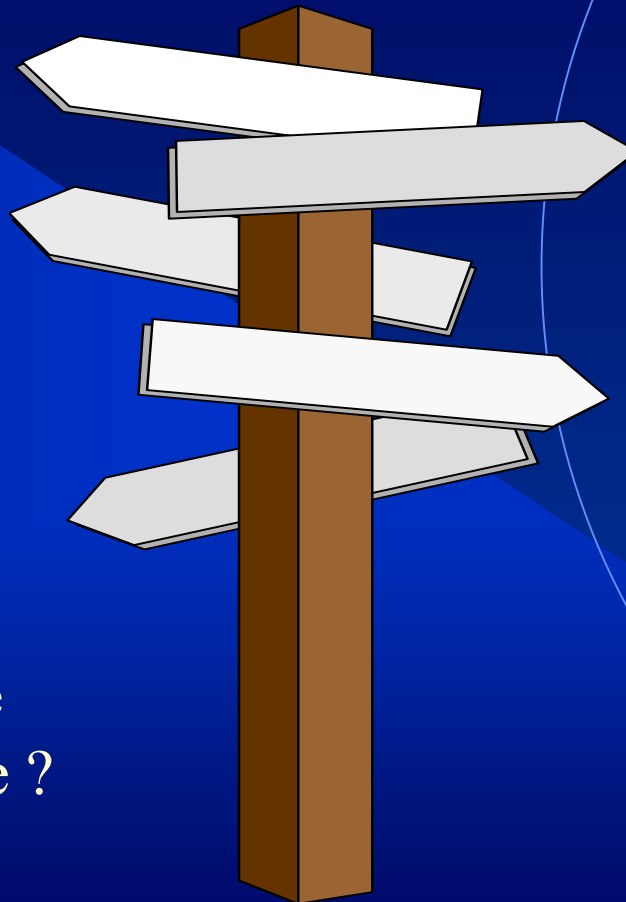
What is the first detected fault?



Sometimes we should go deeper in the analysis



What is the initial source ?



It is not the RF!

It could come from another source

It is the RF!



Strategy

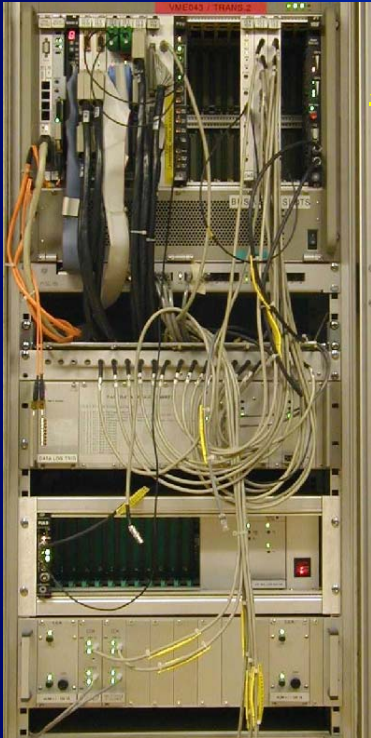
Initial experience:

The initial industrial RF system already had some data logging potential, but the fault logger did not have the appropriate time stamp and the analog logger was too slow. Oscilloscopes were often needed!!



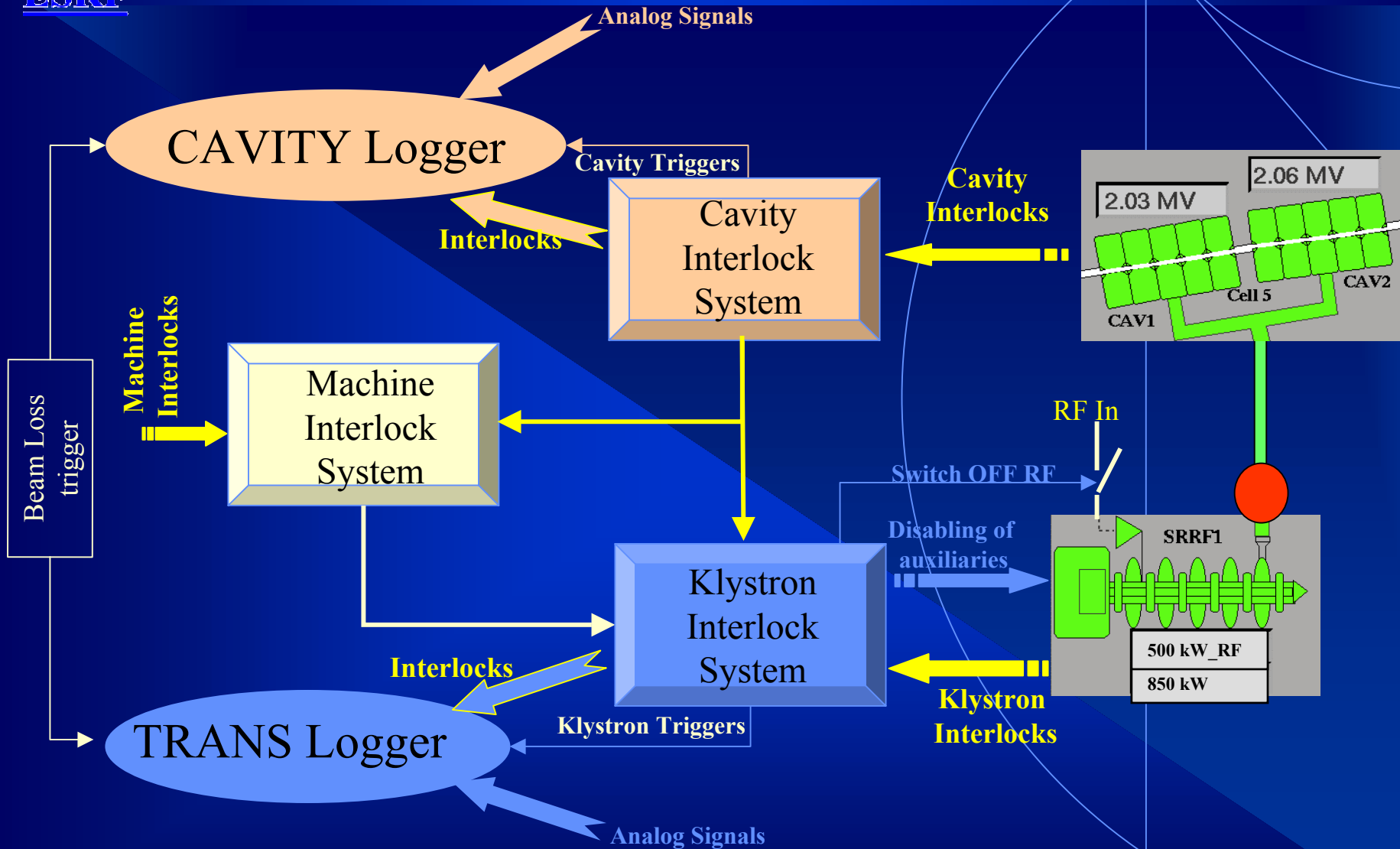
At the same time as the RF upgrade:

The data logging function was developed in parallel with the control of the devices and was fully integrated in the object oriented design.



The interlock system constitutes
the foundation of the logger.

Interlock system and data logging



Stored information

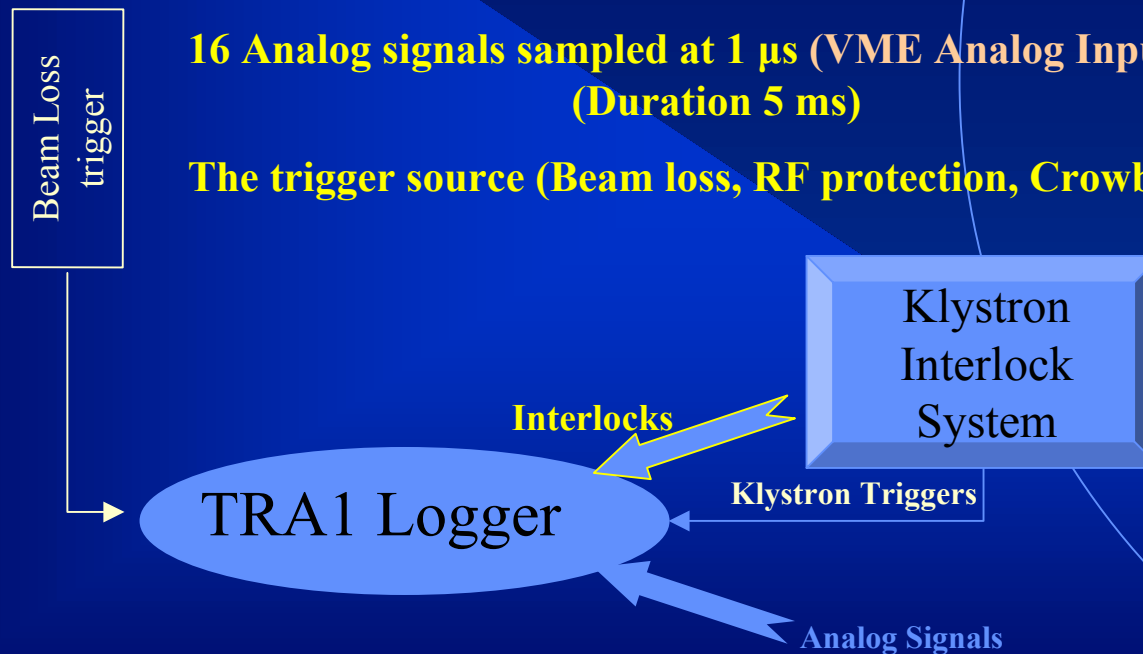
For each beam loss or RF trip, automatic storage in a dedicated directory of :

First Fault & Interlock History (PLC and Hardwired Interlock System)

**All analog signals sampled at 120 ms (VME Analog Input acquisition)
(Duration 30 sec)**

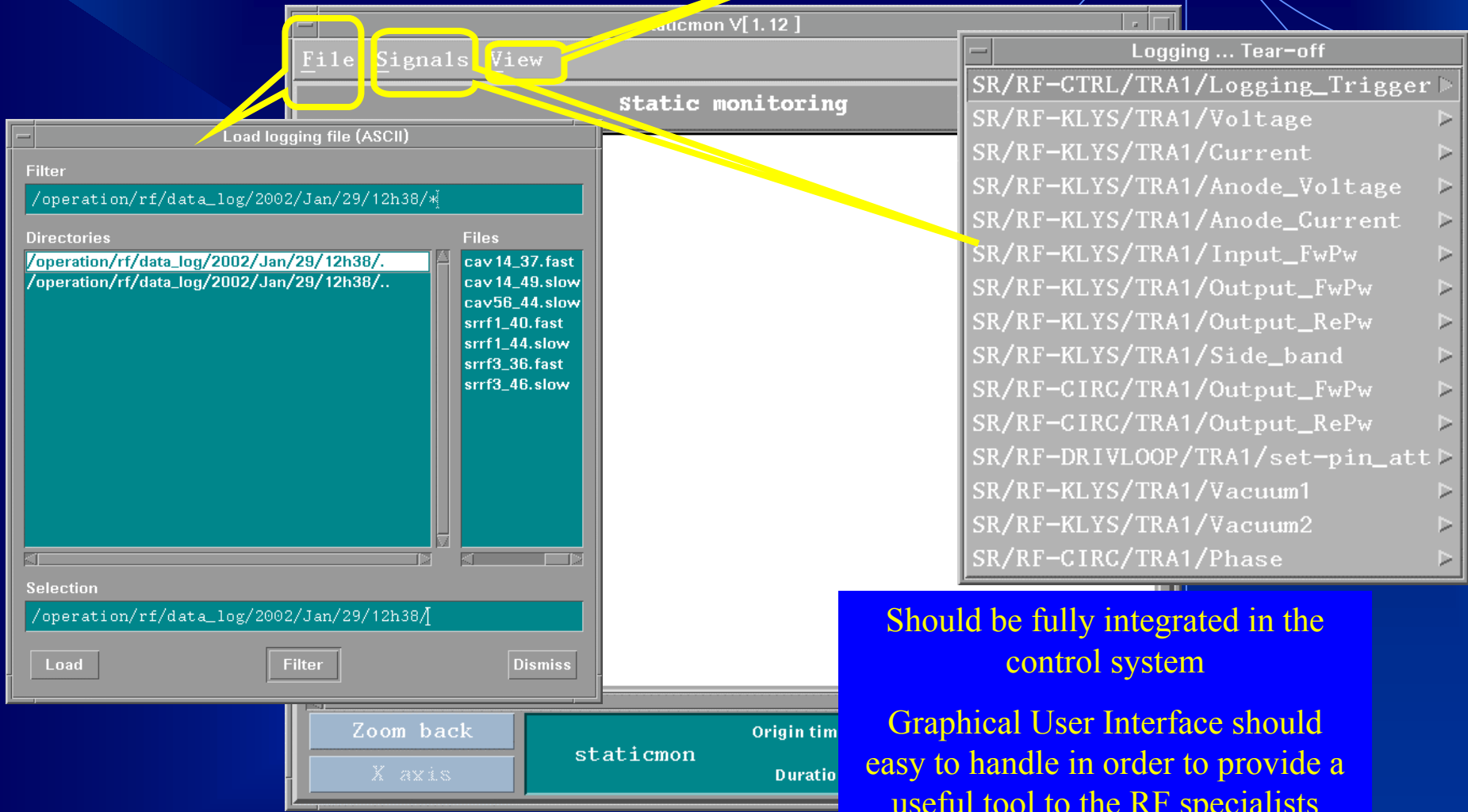
**16 Analog signals sampled at 1 μ s (VME Analog Input acquisition)
(Duration 5 ms)**

The trigger source (Beam loss, RF protection, Crowbar)



Analysis tools

Graphic manipulation tool (Scale, colours...)



The screenshot displays the 'staticmon V[1.12]' software interface. A 'Load logging file (ASCII)' dialog box is open, showing a filter for files in the directory '/operation/rf/data_log/2002/Jan/29/12h38/'. The dialog lists several files, including 'cav 14_37.fast', 'cav 14_49.slow', 'cav56_44.slow', 'srrf1_40.fast', 'srrf1_44.slow', 'srrf3_36.fast', and 'srrf3_46.slow'. A 'Logging ... Tear-off' menu is also visible, listing various logging parameters such as 'SR/RF-CTRL/TRA1/Logging_Trigger', 'SR/RF-KLYS/TRA1/Voltage', 'SR/RF-KLYS/TRA1/Current', 'SR/RF-KLYS/TRA1/Anode_Voltage', 'SR/RF-KLYS/TRA1/Anode_Current', 'SR/RF-KLYS/TRA1/Input_FwPw', 'SR/RF-KLYS/TRA1/Output_FwPw', 'SR/RF-KLYS/TRA1/Output_RePw', 'SR/RF-KLYS/TRA1/Side_band', 'SR/RF-CIRC/TRA1/Output_FwPw', 'SR/RF-CIRC/TRA1/Output_RePw', 'SR/RF-DRIVLOOP/TRA1/set-pin_att', 'SR/RF-KLYS/TRA1/Vacuum1', 'SR/RF-KLYS/TRA1/Vacuum2', and 'SR/RF-CIRC/TRA1/Phase'. The main window shows a plot area with 'Zoom back' and 'X axis' buttons, and a status bar with 'staticmon' and 'Origin tim'.

Should be fully integrated in the control system

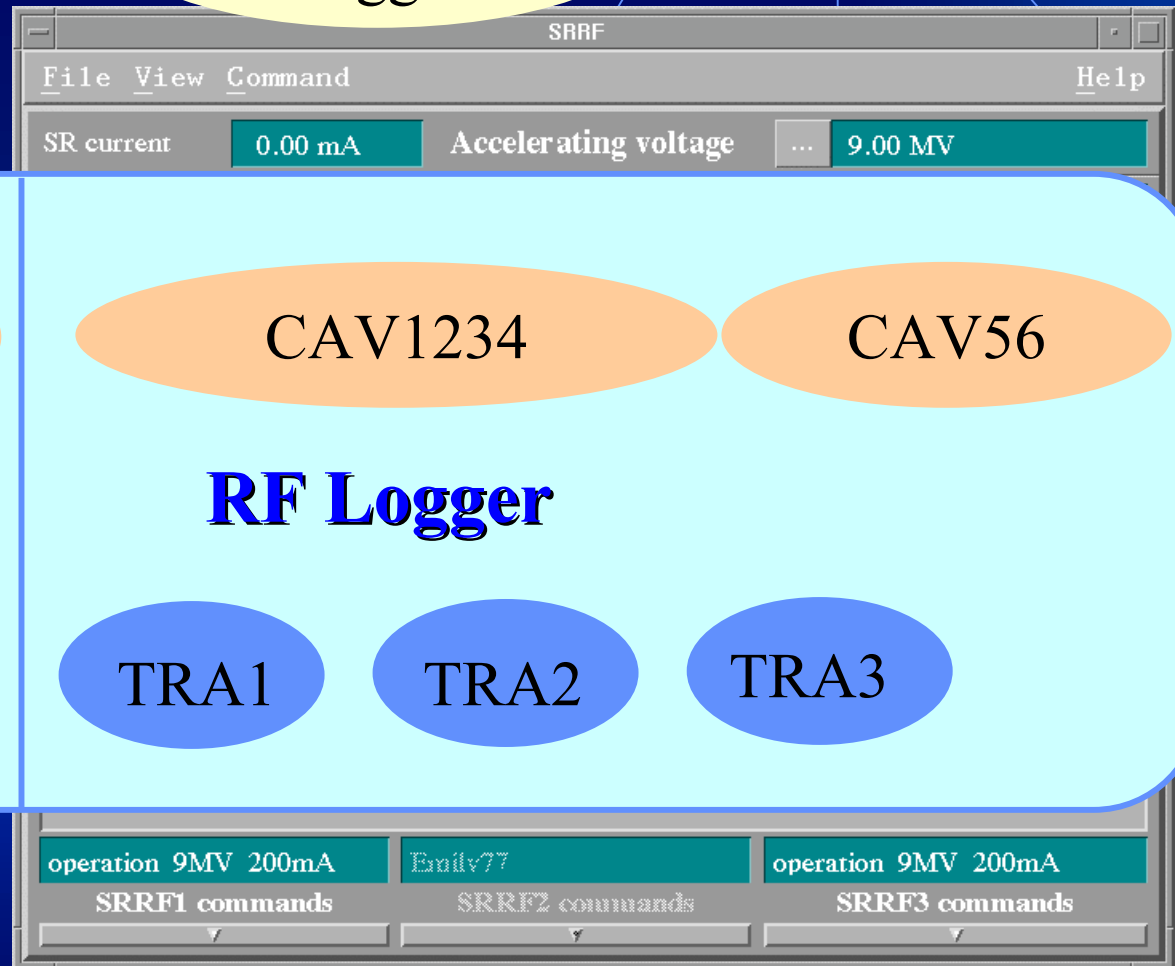
Graphical User Interface should be easy to handle in order to provide a useful tool to the RF specialists



General RF Data Logging Structure

8 Independent RF loggers
and
1 Global Beam Loss Logger

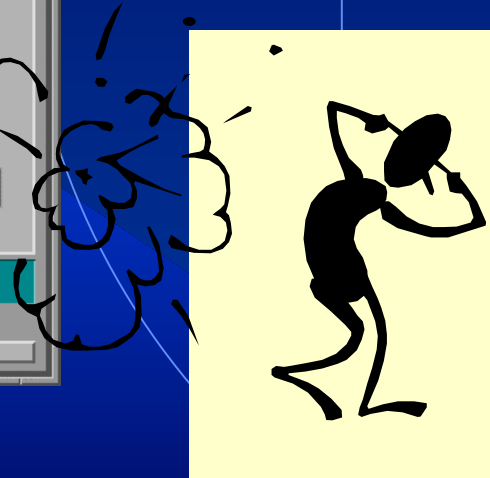
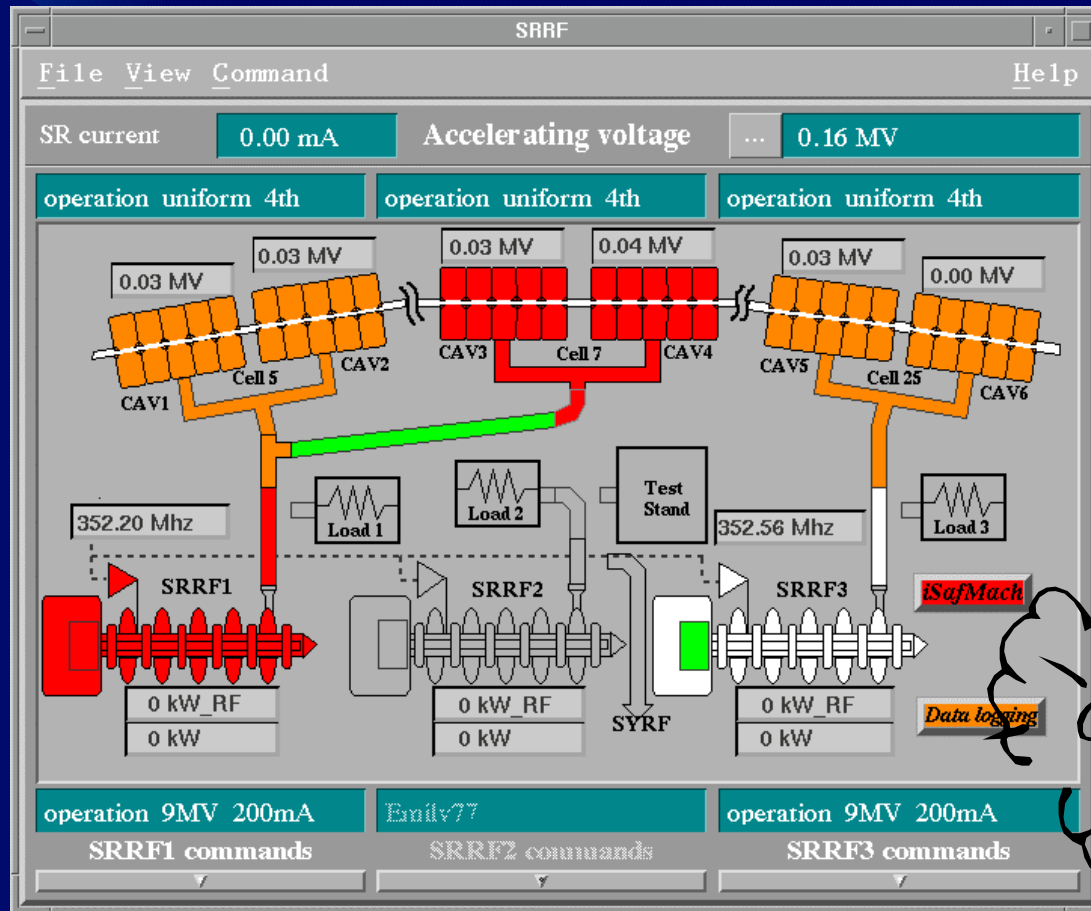
Beam Loss
Logger



Example of the analysis of a RF trip

Seen from the CTRM

Beam is lost
 Cav34 is faulty
 TRA1 is faulty
 Machine Interlock is faulty



Example of the analysis of a RF trip

Cavities 34 [V1.7]

| | | | | |
|-----------|--------------|------------|-----------|--------------|
| Cav3 Volt | Cav3 Vacuum | SR Current | Cav4 Volt | Cav4 Vacuum |
| 0.03 MV | 1.6e-11 mBar | 0.00 mA | 0.04 MV | 1.7e-11 mBar |

SR CAVITIES

Configuration file: operation_uniform_4th

Machine Interlocks

Status

Synchrotron

- SY Magnets
- SY and TL2(1/2) Vacuum

Storage Ring

- SR Magnets
- TL2(1/2) Vacuum
- SR Vacuum
- Cooling All
- Cooling 3&4
- Beam Position
- Visible Light Mirror
- Beam Killer
- Beam Killer
- Fuse C4
- Fuse C19
- Cavity Protections
- Normal Operation
- RF Tests

Front Ends

- ID for Beam Permission
- Bending for Beam Permission
- ID for Injection Permission
- Bending for Injection Permission

Permissions

- SR Beam Permission: SRRF
- SR Injection Permission: KE/1 & SE/2 power supplies
- SY Injection & Beam Permission: TL1 dipole

Reset SR
Reset SY

SRRF1 Klystron 1.13

| | | | | |
|-----------|----------|------------|----------|------------------|
| Frequency | Phase | Elec Power | RF Power | Transmitter mode |
| 352.2 Mhz | -0.3 deg | 0 kW | 0 kW | 4 CAVITIES |

Configuration file: operation_9MV_200mA

Transmitter commands

352.56 Mhz

Load 3

iSafMach

SRRF3

0 kW RF
0 kW

Data logging

operation 9MV 200mA

SRRF3 commands

52



Information given by the analysis of the first fault logging

Transmitter 1 first fault:
RF trip requested by cavity 34

```
-----  
Sub device states:  
sr/rf-klys/tra1:Fault  
-----  
PLC status :  
State : One or more active interlocks.  
Fault History :  
  Cycle Front : signal name  
1.) 0 0 : sr/rf-ctrl/tra1/f-pinsw_cavity_34  
      none  
2.) 0 0 : sr/rf-driv/tra1/set-disable  
      Driver externally disabled  
3.) 0 0 : sr/rf-ctrl/tra1/set-rf_disable_trans  
      Pin switch transmitter requested by the PLC  
4.) 0 0 : sr/rf-anod/tra1/set-disable  
      Modulating Anode externally disabled  
5.) 2 0 : sr/rf-ctrl/tra1/f-safety_machine  
      Safety machine protection requested by the machine interlock  
6.) 3 0 : sr/rf-hvps/tra1/set-disable  
      HVPS externally disabled  
7.) 4 0 : sr/rf-ctrl/tra1/f-rf_disable_trans  
      RF Disabled request by PLC acknowledged for Trans HIS
```

Cavity 34 first fault:
Cavity 3 field amplitude too high

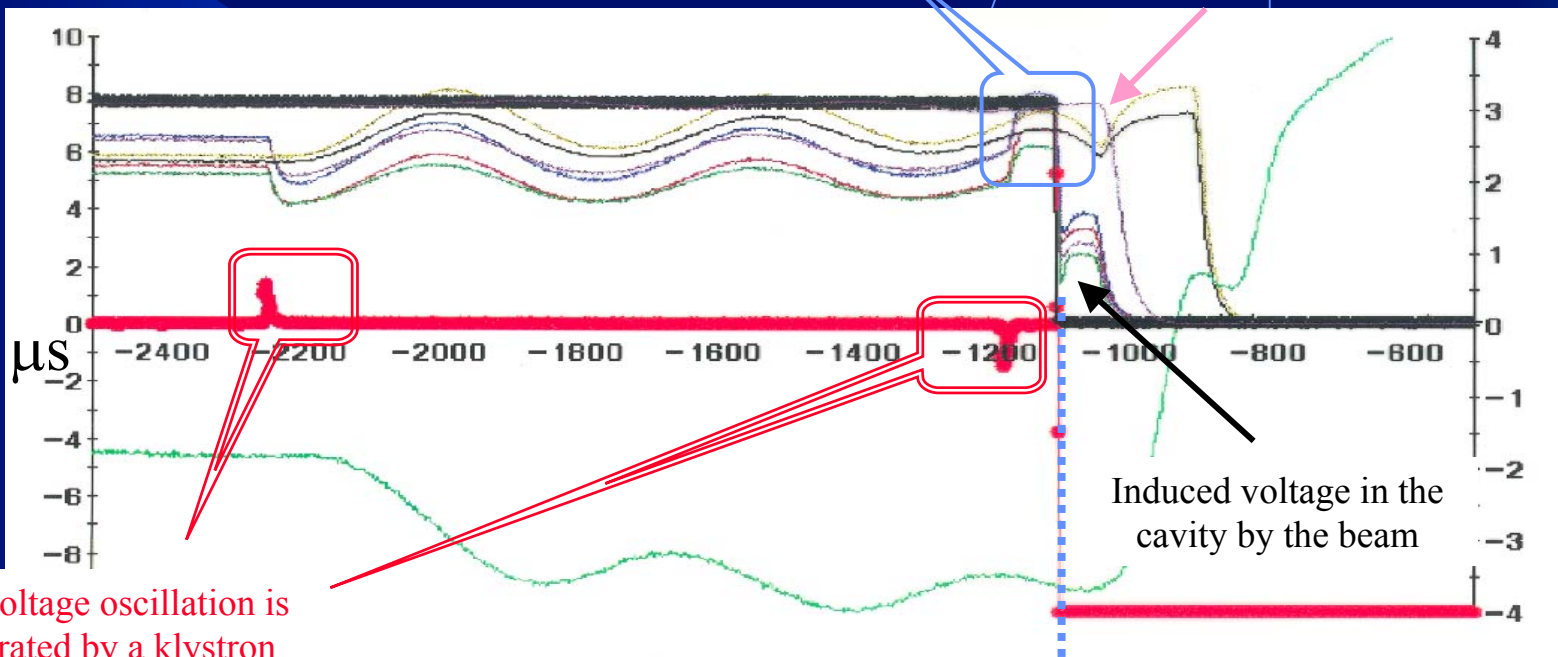
```
-----  
sr/rf-cav/cav3:Fault  
-----  
PLC status :  
State : One or more active interlocks.  
Fault History :  
  Cycle Front : signal name  
0) 0 : sr/rf-cav/cav3/f-voltage  
      Cavity 3: Field amplitude too high  
0) 0 : sr/rf-ctrl/cav14/set-rf_disable_cav_34  
      none  
1) 1 : sr/rf-cav/cav3/f-voltage  
      Cavity 3: Field amplitude too high  
0) 0 : sr/rf-ctrl/cav14/f-rf_disable_cav34_plc  
      none
```

Information given by the analysis of the fast data logging system.

**RF is guilty!!
It was a phase
measurement
problem!**

Cavity 1,2,3,4,5,6 Voltages increase

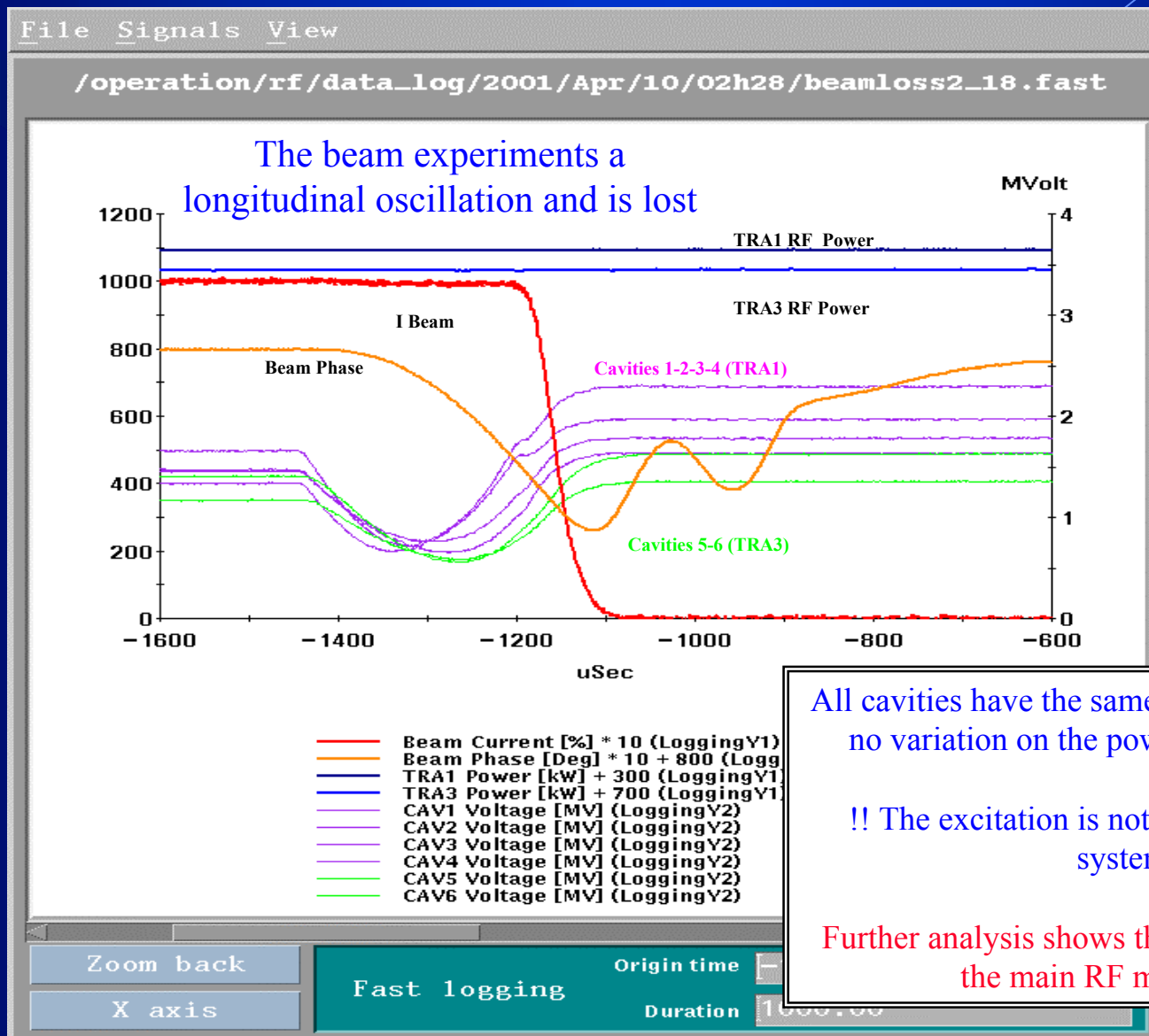
Beam Lost



The voltage oscillation is generated by a klystron phase glitch

Detection of the peak voltage and TRA1 RF switch OFF

Another case of data logging: SRRF not guilty !!

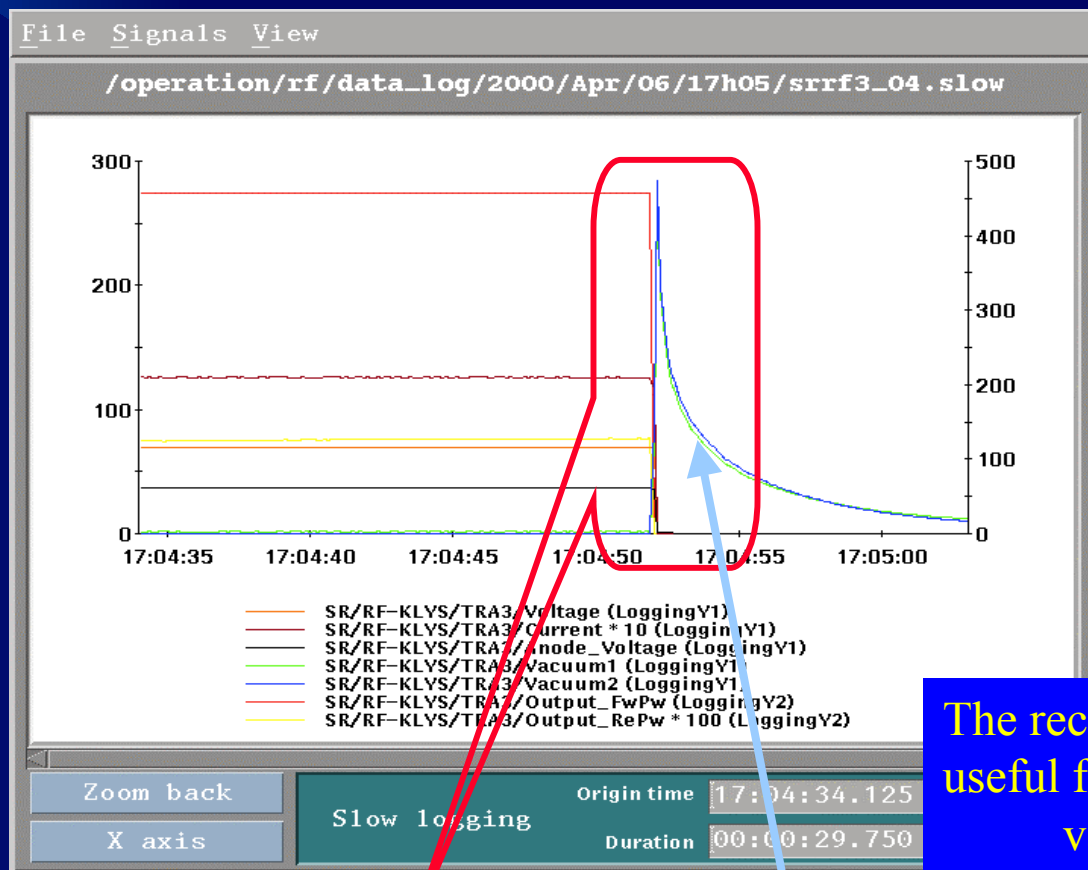


All cavities have the same oscillation and there is no variation on the power and on the phase.

!! The excitation is not coming from the RF system !!

Further analysis shows that it was coming from the main RF master source

The slow analog signal logging

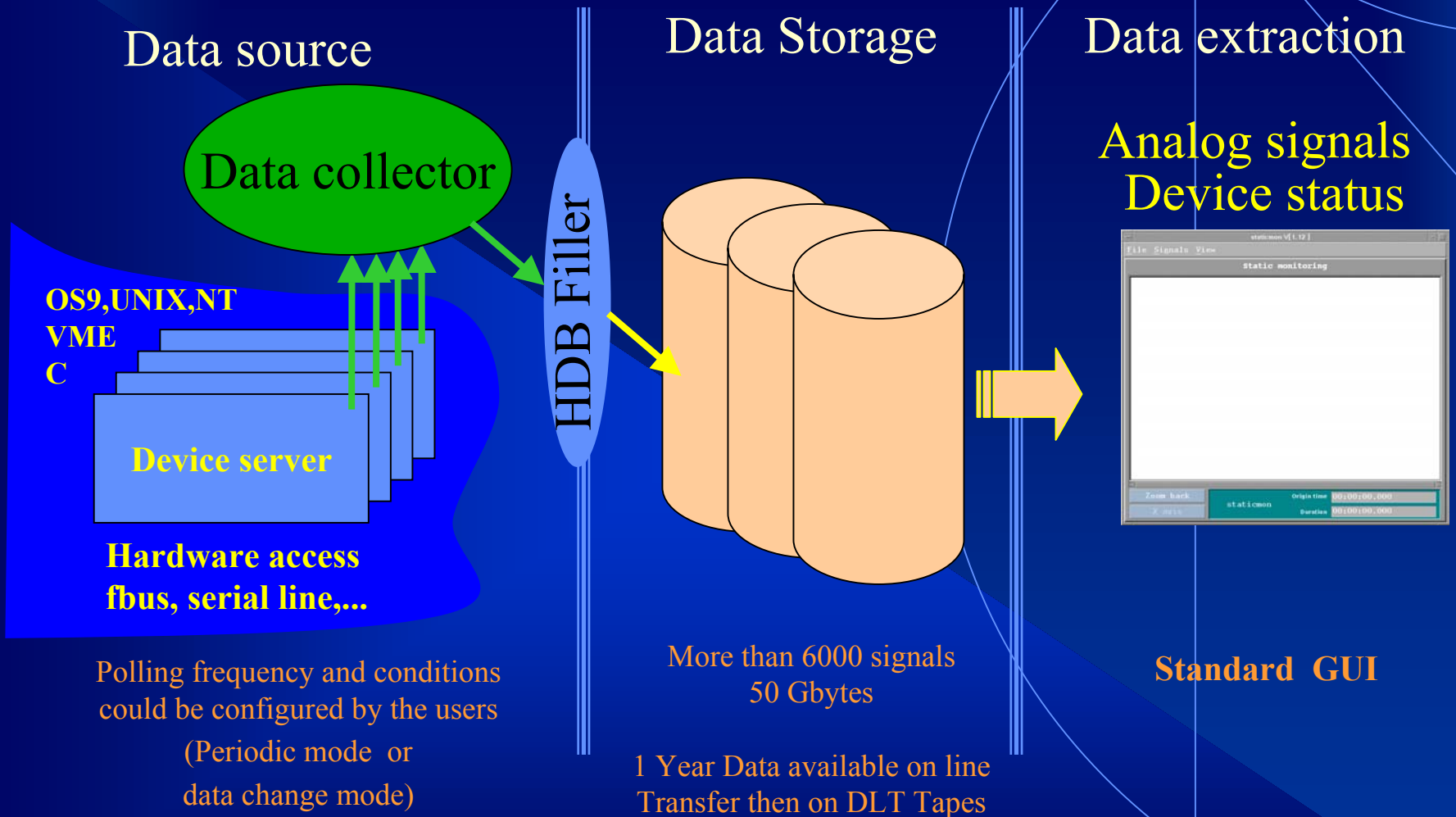


Storage of the evolution of all analog signals at 8Hz during 30 sec

The recording of slow analog signals is useful for the analysis of:
vacuum events,
behaviour of loops
or switching ON/OFF sequences.

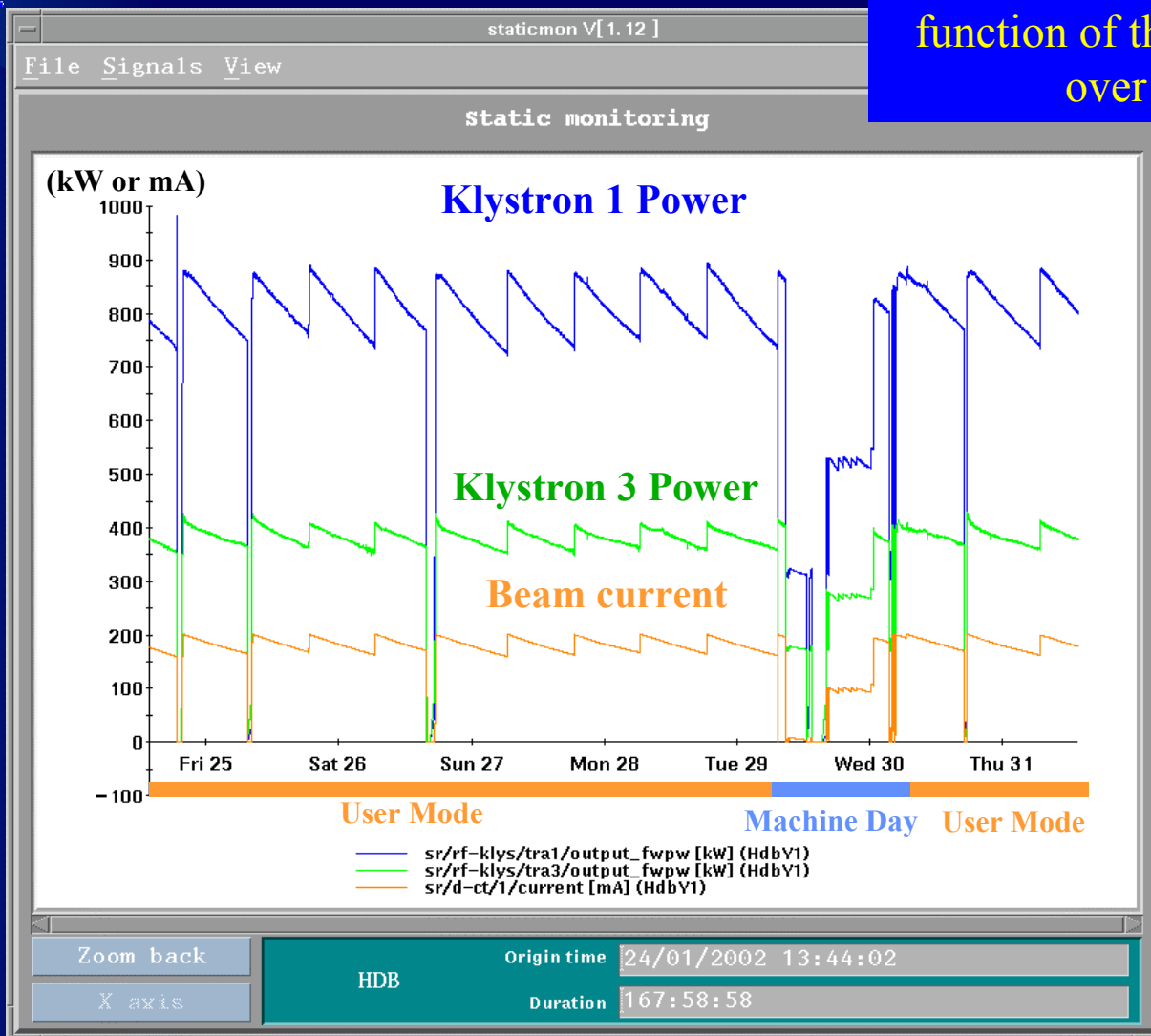
Example: Switching OFF of the RF transmitter due to an out gassing in the klystron tube.

The ESRF historical data base (HDB)



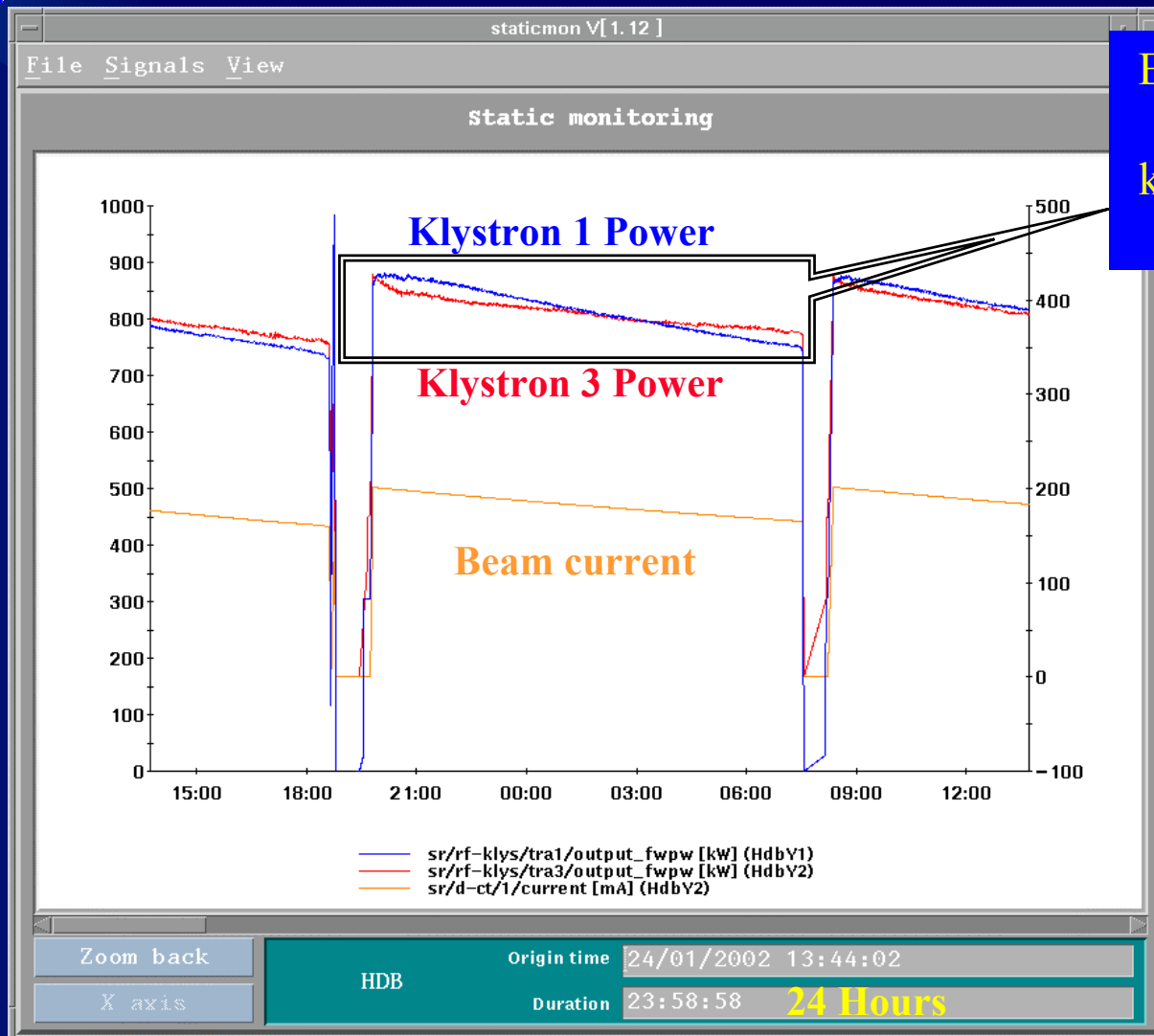
HDB example 1

Evolution of the RF power as a function of the beam current over 7 Days



Klystron1
drives cavity 1,2,3,4
and
Klystron3
drives cavity 5,6

HDB example 1 (zoomed)



Evolution of the power balance between klystron1 and klystron2 over a beam decay.



Klystron power not evolving in parallel.

No clear explanation.

HDB Example 3 (Device state)

The state of a device is stored every hour or immediately if there is a modification.

==> very useful for the tracking of failures, warnings or control problems.

Static monitoring [HDB table]

| sr/rf-fila/tra1/status | |
|------------------------|--|
| 30/01/2002 17:16:30 | State : Unknown Error : Wed Jan 30 17:16:22 2002 error detected reading from device |
| 30/01/2002 17:17:02 | State : Unknown Error : Wed Jan 30 17:16:57 2002 error detected reading from device |
| 30/01/2002 17:17:30 | State : Unknown Error : Wed Jan 30 17:17:19 2002 error detected reading from device |
| 30/01/2002 17:18:02 | State : Unknown Error : Wed Jan 30 17:17:54 2002 error detected reading from device |
| 30/01/2002 17:18:31 | State : Externally disabled Fault(s) : Wed Jan 30 17:18:26 2002 Filament is externally disabled. Reset power supply to unlatch DISABLED state |
| 30/01/2002 17:19:02 | State : Standby Mode : Current regulation |
| 30/01/2002 17:20:02 | |
| 30/01/2002 17:21:02 | |
| 30/01/2002 17:22:01 | State : On Mode : Current regulation Waiting end of reset time [6 sec]. |
| 30/01/2002 17:22:30 | State : On Mode : Current regulation |
| 30/01/2002 17:23:02 | |
| 30/01/2002 17:24:02 | |
| 30/01/2002 17:24:30 | |
| 30/01/2002 17:25:00 | |

Save file Run TCL Auto size Dismiss

Conclusion

- ⊗ Data logging possibilities should be fully integrated at the design stage.
- ⊗ Graphical User Interface should be identical for data logging analysis and on-line monitoring.
- ⊗ First fault and history of fault should be logged without ambiguity.
- ⊗ Analog logging should cover the range from $1\mu\text{s}$ to 1 year!!
- ⊗ Data Logging is costly (money and manpower) but worthwhile for maintenance and reliability.
- ⊗ Data Logging must be reliable

Many thanks to all colleagues who participated in the development of this system and to all those who helped me to prepare this talk.