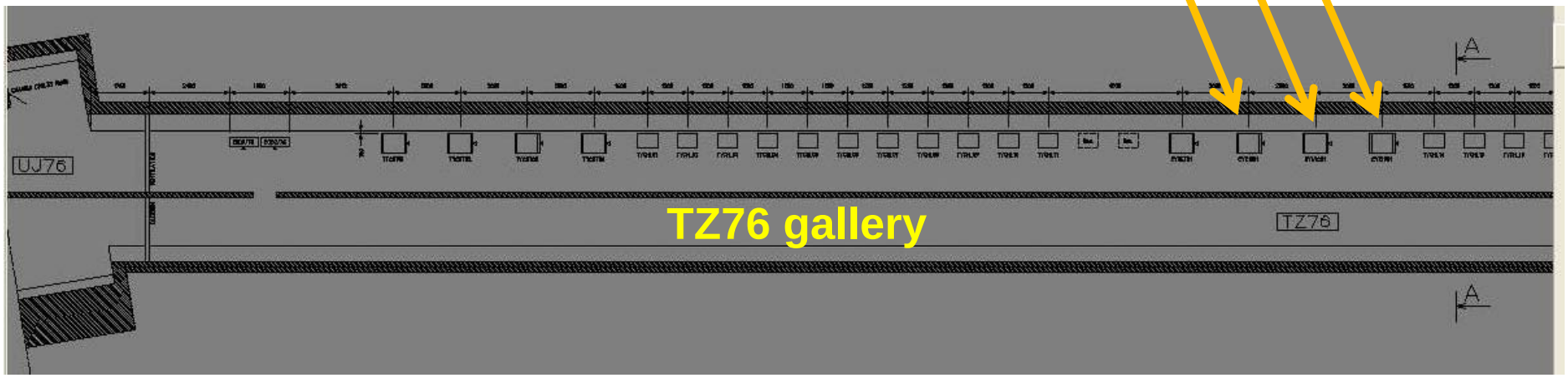
Machine Interlocks Systems in LHC Point 7

Bruno Puccio
Pierre Dahlen
Benjamin Todd
Markus Zerlauth

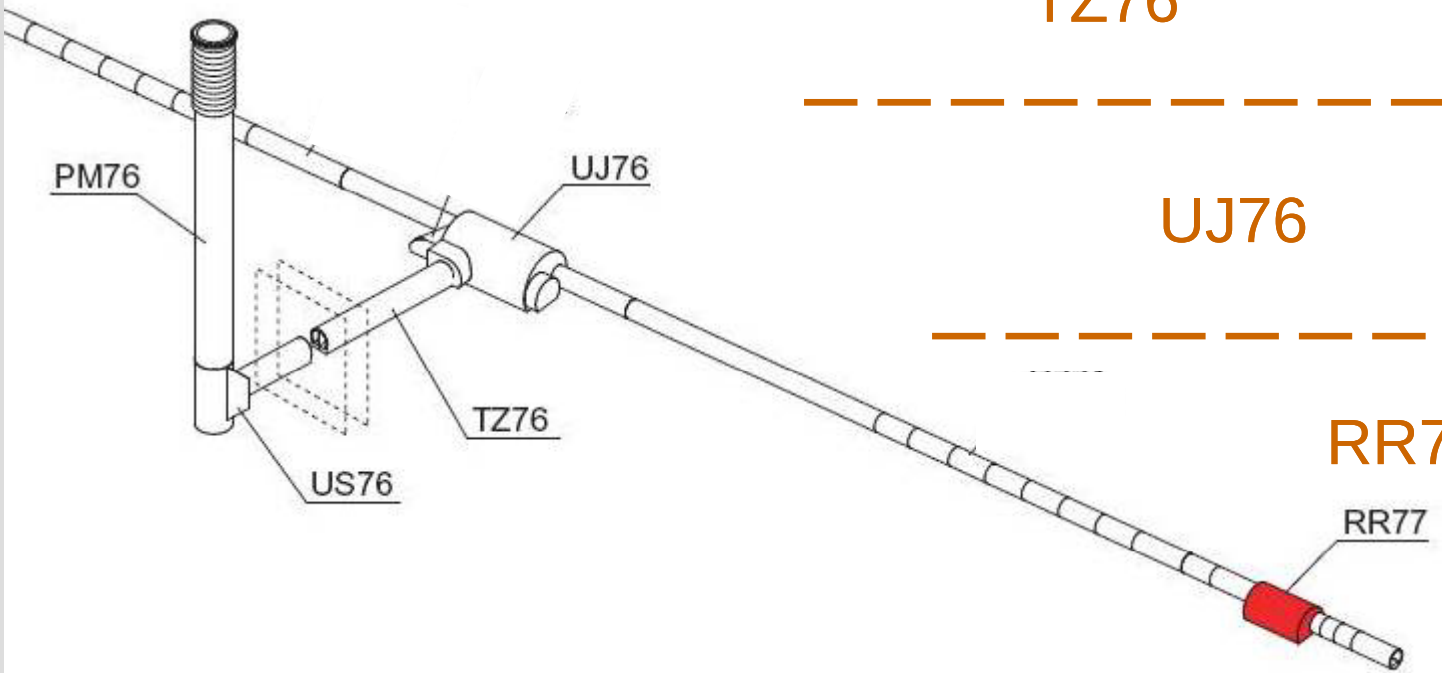
Outline

- Overview & Layout for:
  - Powering Interlock System
  - Warm magnet Interlock System
  - Beam Interlock System
  - Fast Magnet Current change Monitor System (in SR7)
- Summary



Layout in layers

surface



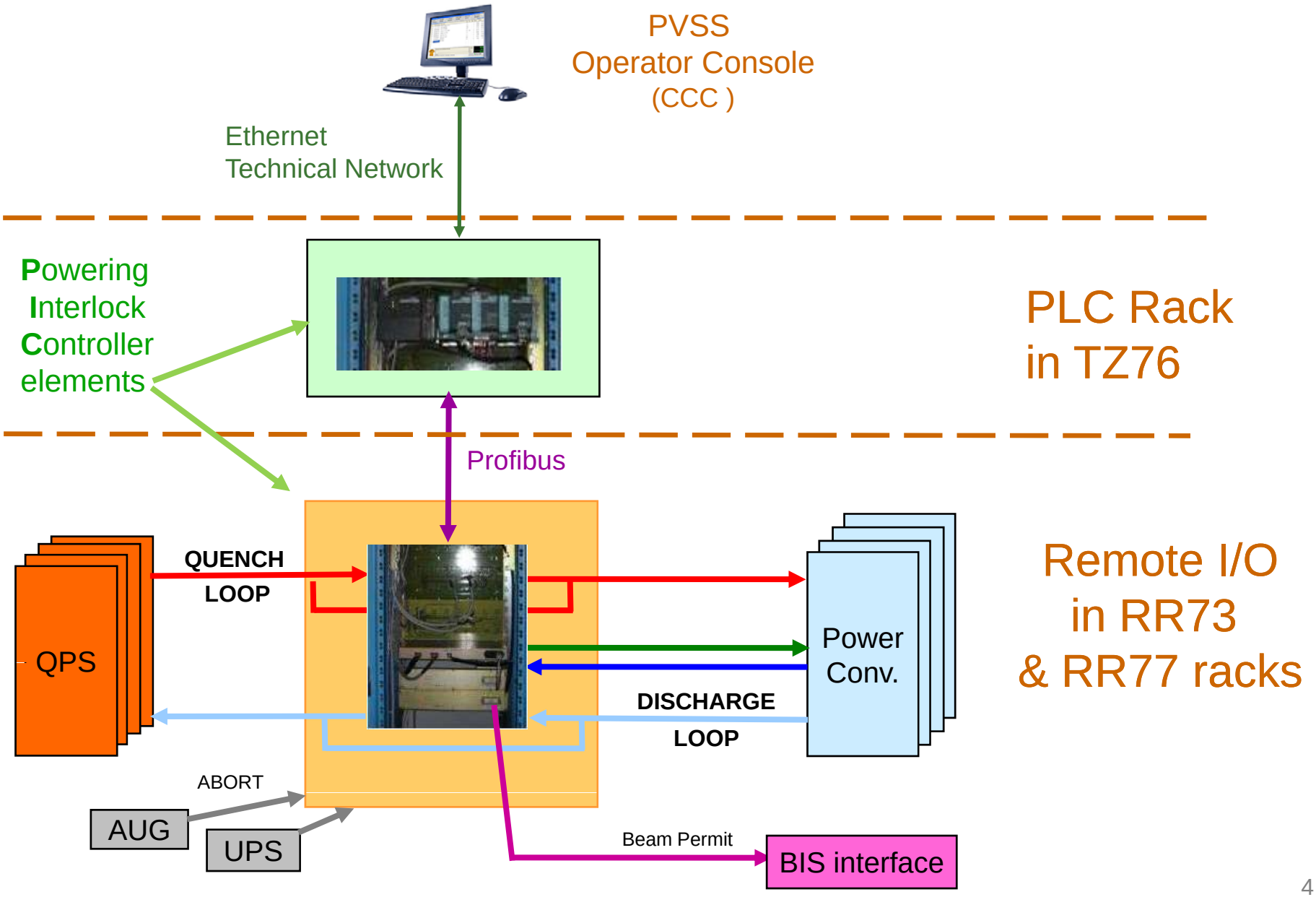
TZ76

UJ76

RR73 & RR77

Tunnel

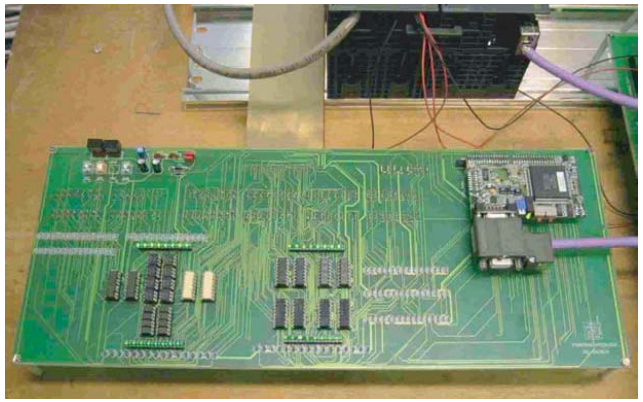
PIC Layout in point 7



PIC: Radiation tolerance tests

- **No tests performed on PLC unit (installed in TZ76)**

- **Deported I/O board components:**
  - ANYBUS Chip
  - DC/DC Converters (redundant design)
  - Opto-couplers, Resistors, TSV Diodes, etc…
  - XILINX XC95144-PQ160, considered being radiation hard due to 5V technology

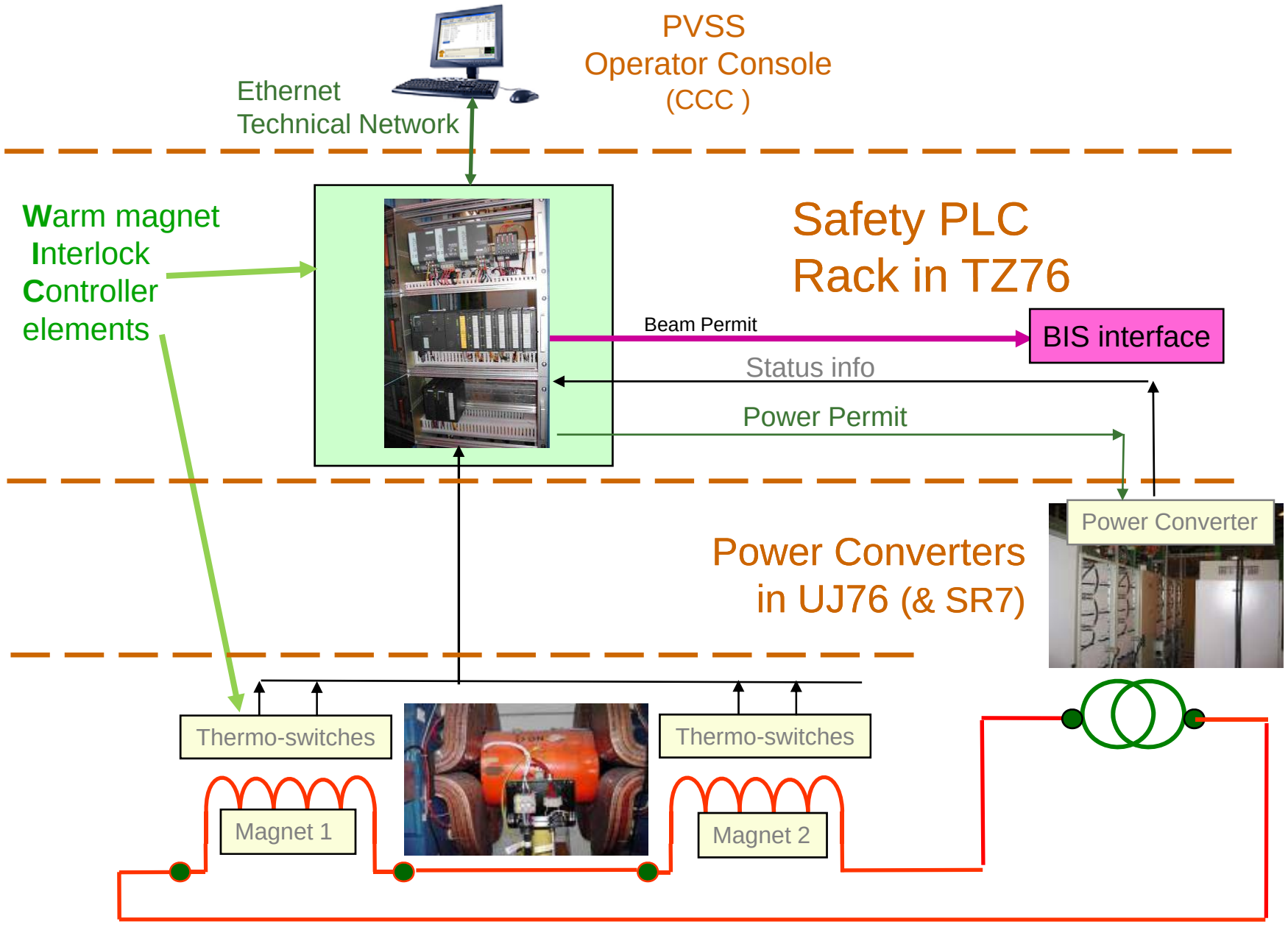


picture taken during the radiation tests

- **Tests performed in 2004**
  - Two cards irradiated: 1st one up to a total dose of 125 Gy. 2nd one achieving a total dose of 326 Gy.
  - No degradation had been observed during the whole irradiation period.
  - No SEEs observed throughout total irradiation time (75 min).
  - Detailed results in a report:

    " Evaluation of the Radiation Tolerance of the ANYBUS I/O Module and commercial Optocouplers " (M. Zerlauth, R. Schmidt, M. Zaera Sanz)

WIC Layout in point 7



WIC: Radiation tolerance tests

- No tests performed on PLC unit (in TZ76)
- Deported components:
  - **Thermo-switch (ELMWOOD Type 3106 – T11)**
  - **Magnet Interlock Box (i.e. relay simulating the opening of a thermo-switch)**
- Tests performed @ CEA-Saclay (Nov. 05)
  - **Very good results**

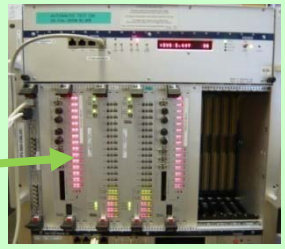
- Results presented at 6th LHC Radiation Workshop (Nov. 2007)

BIC Layout in point 7

JAVA Application
Operator Console
(CCC)

Ethernet
Technical Network

Beam
Interlock
Controller
elements



VME Crate

front

rear

BIS interface =
CIBU unit with
redundant P.S.

Racks in TZ76

BIS interface — COL#1
BIS interface — COL#2
BIS interface — WIC

in UJ76

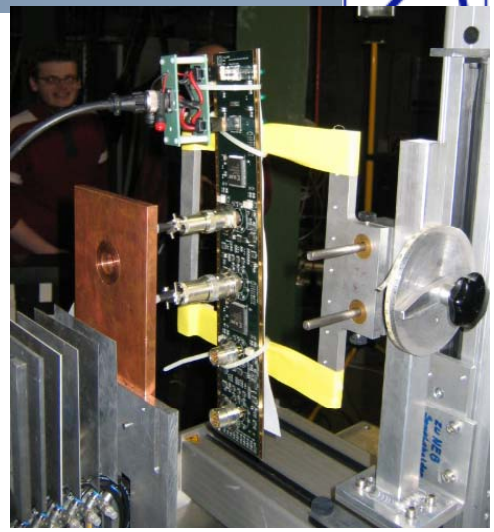
BIS interface — VAC

in RR73

BIS interface — PIC Left
BIS interface — PIC Right

in RR77

BIC: Radiation tolerance tests

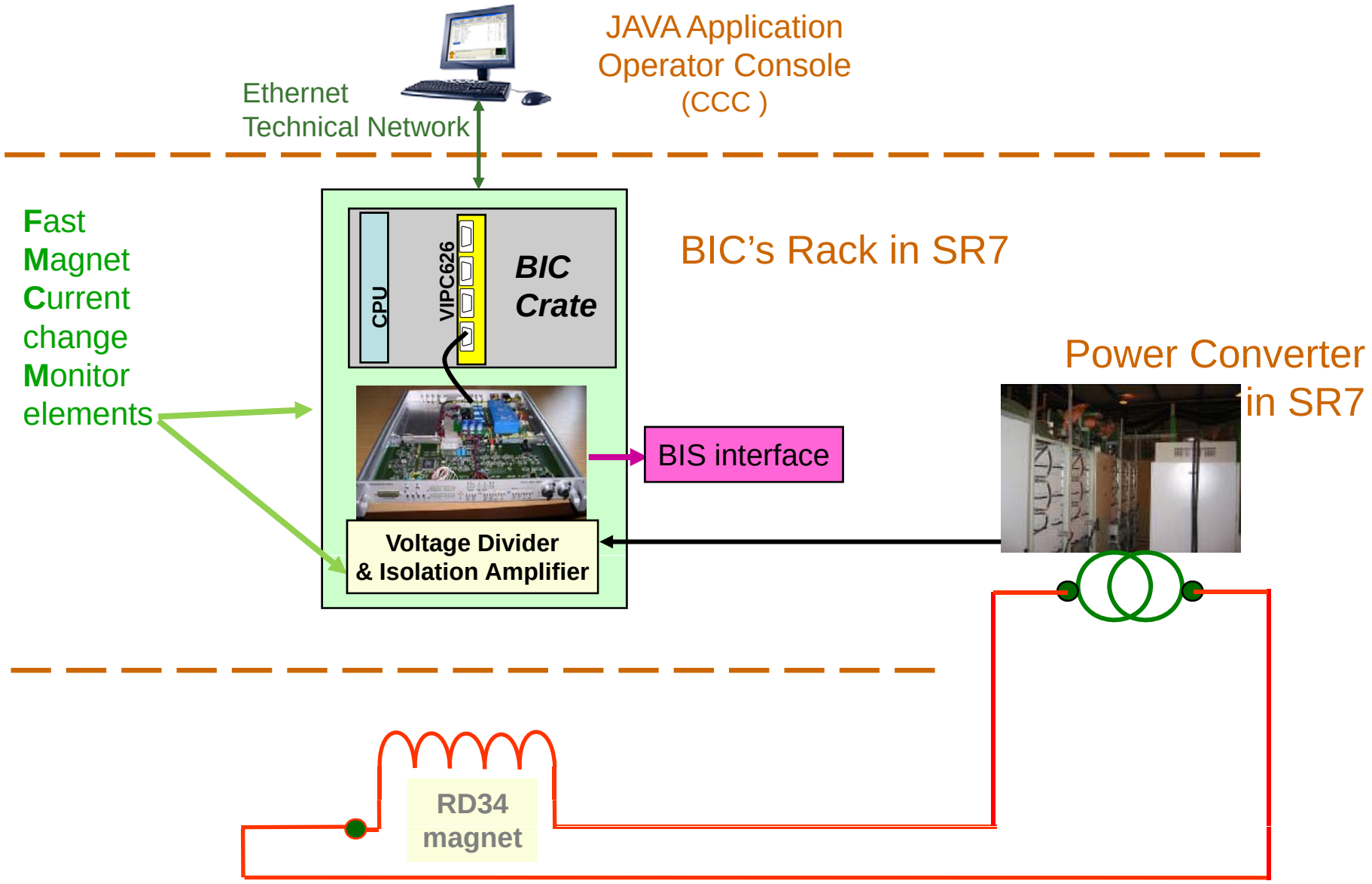


- No test performed on the VME Controller part (in TZ76)
- Deported Interfaces (CIBU) in TZ76, UJ76, **RR73 & RR77**
  - **Main components: CPLD, Optocouplers, Diodes,**
- Tests performed on Feb. 2007 @ OPTIS irradiation Facility in the Paul Scherrer Institut in Villingen (CH)
  - No Single Event Upsets were detected in the critical USER_PERMIT paths
  - Good radiation tolerance: CPLD failed first at 150Gy

BUT once we got it back at CERN
–> reprogrammed it and it worked!

- Power Supply units: separated tests performed on Sept. 2007 @ PROSPERO reactor in Dijon (France)
  - Equiv. ~10 Years LHC: No measureable effect.
    <1% DRIFT
- Both Results presented at 6th RAD Workshop

FMCM Layout in point 7



Conclusions

- (in essence) Machine interlocks are using HW redundancy and for increasing safety, critical functionality never relies on SW
- Machine interlocks core parts (controllers) installed in TZ76 gallery
- Concerned elements installed in RR73/RR77 have been validated in dedicated radiation tests:
  - RAD Test performed on deported I/O (PIC)
  - RAD Test performed on magnet box (WIC)
  - RAD Test performed on deported interfaces (BIC)
- Concerning elements installed in the tunnel:
  - RAD Test performed on the thermo-switches and on the magnet box (WIC)
- Confident that machine protection systems will work reliably even under radiation; in worst case, replacement with spare units over time

That's all !

Machine Interlock Systems

for Protecting the Equipment

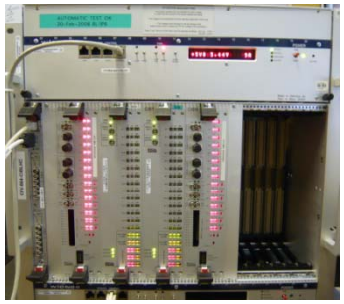
for Beam Operation

for Protecting Super Conducting Magnets

and Normal Conducting Magnets

Beam Interlock System

(VME based)



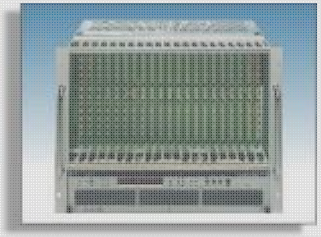
Powering Interlock System

(PLC based)

+

Safe Machine Parameters System

(VME based)



Warm magnet Interlock System

(PLC based)

Fast Magnet Current change Monitor (FMCM)

Powering Interlock Controllers

- The Powering Interlock Controllers (PICs) basically consist of industrial PLCs (SIEMENS 319 series), and remote I/Os which are placed close to the related equipment (ie power converters and QPS). While the PLCs are always located in underground areas where radiation is expected not to be an issue (UAs, USC55, TZ76), the remote I/Os are sometimes located in RRs, which is why dedicated radiation tests have been performed.
- Power supplies used for the interlock systems have been all built in a redundant and thus fault tolerant way. Critical electronic components, eg the CPLD present close to the remote I/Os, have been chosen for robustness and radiation tolerance according to supplier information.

Warm-magnet Interlock Controllers

- The Warm Magnet Interlock Controllers (WICs) are built with industrial PLCs (Siemens 315-2DP and 315F-2DP), and remote I/Os. For LHC the WIC are installed in protected area (US, UA, TZ76). For the transfer lines, only the remote I/Os are installed under the magnets (Dipoles) in the tunnel. Dedicated radiation tests have been made since 2002 to choice the modules which are radioactive tolerant. Also a specific power-supply installed in these crates was specified and tested to be radioactive tolerant.

Fast Magnet Current Change Monitors

- The Fast Magnet Current Change monitors (FMCM) of the LHC are mostly installed on surface building, only 6 units are located underground (for RD1.LR1, RD1.LR5, dump septas in UA63 and UA67 and experimental compensators in UA23). No specific radiation tests have been performed with the FMCM and no data for their radiation tolerance is available. Therefore all installation places have been chosen to be in areas not susceptible to radiation (UA, US,…). It also has to be noted that the FMCMs are not critical for primary protection but are somewhat redundant to power converter surveillance and BLMs.

Beam Interlock System

The Beam Interlock System is comprised of some 200 User Interface modules and 17 Beam Interlock Controllers.

- **User Interface Modules (CIBU)**

The User modules are placed in racks along with User Systems, these CIBU have been extensively tested in radiation and in particular on SEEs (see various presentations in the LHC Radiation Workshops from 2001 to 2007).

- **Beam Interlock Controllers (BIC)**

The Beam Interlock Controllers are based on standard VME chassis, equipped with redundant Power Supplies, redundant Fan Units and redundant ethernet controllers. The **safety** function of the Beam Interlock Controller is decoupled from the VME bus, and is inherently fail safe, to the same standard as the CIBU (it uses the same components). The VME chassis / Power PC tolerance to radiation has not been the subject of any specific testing, neither has the **monitoring** functionality of the Beam Interlock Controller. Radiation may cause a loss of supervision, by interrupting the VME access or monitoring, but in no circumstances should the safety of the machine be compromised.

In summary the Beam Interlock System equipment is inherent safe. The safety of the machine should not be compromised by radiation effects.