# Summary on radiation test results in 2003

*RADiation Working Group RADWG*

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http://lhc-radwg.web.cern.ch/LHC-radwg/

# Acknowledgements


- **TIS/RP**
  - Access to TCC2 area once a week
  - Handling and storage of radioactive material in 954
  - Dosimetry for radiation test
  - Reception of activated material from outside CERN
- **Radiation facilities**
  - G. Berger (UCL Louvain la Neuve)
  - W. Hajdas & R. Brun (PSI Villingen)
  - N. Authier (CEA-Valduc)
  - F. Anghinolfi – F. Faccio (CERN)
- **Simulation work**
  - B. Jeanneret, I. Baishev & Protvino collaboration
  - V. Vlachoudis & AB/ATB

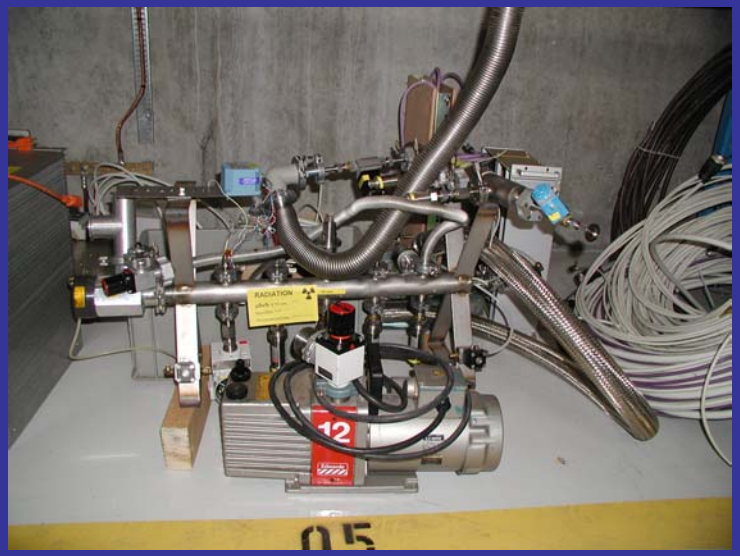
# Outline

- Introduction
- Power converters
  - Modular Power Supplies
  - Power Converters main magnets
- Industrial Systems
- Fieldbus
  - Equipment interfaces
  - Repeaters
- Programmable Devices
- Pressure gauges
  - Vacuum
  - Cryogenics
- Beam Diagnostics
- Other experiments

NB : Color coding test results

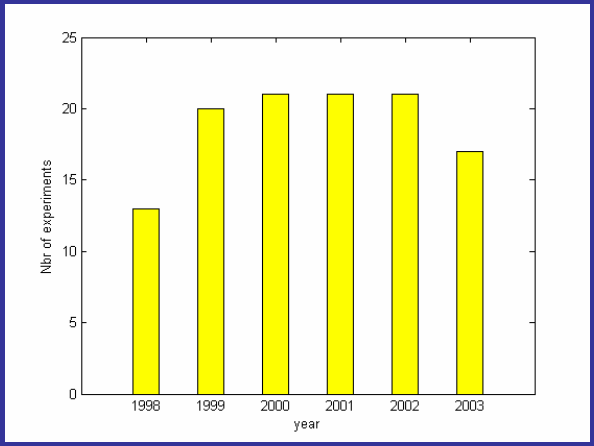
- Accepted
- Ongoing
- Refused

# Introduction

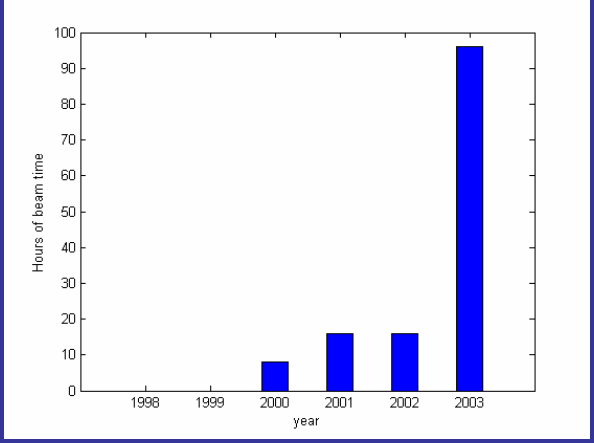

# Introduction

***System tests***



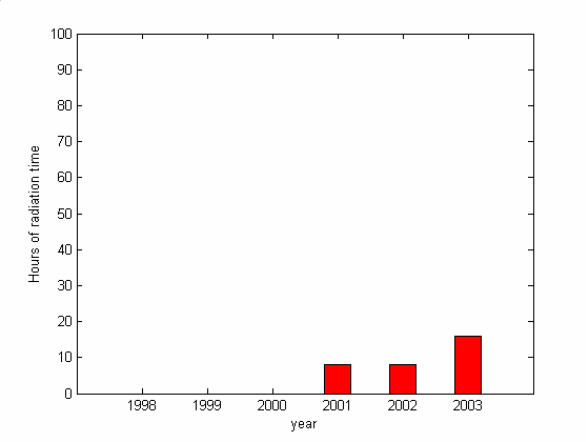

***Experiments in TCC2***

***SEE tests***




***Hours of beam time (60 MeV protons)***

***Neutron tests***




***Hours of radiation time (1 MeV neutrons)***

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# Power Converters - Modular Power Supplies

- ~7500 in ARCS and RRs under radiation
- Usage : to power electronic crates
- 43 Units tested – 13 Types – 8 Manufacturers
- Test results in 2002 :
  - Serie regulation
  - ACT 50 (2x24 V)
  - SYKO ROS01.2205.15 (24V)
  - Huhn Rohrbacher ACT 50 2 (24 V)
- Test results in 2003:
  - ACT 50 (2x24 V)
  - SYKO ROS01.2205.15 (2x24V)
  - Modified SIEMENS PS307 2A (24 V)
  - Exista Blue Line (24 V)
  - Standard SIEMENS PS307 2A (24 V)
  - MGV (2x24 V)

CN17BCE-T1S1

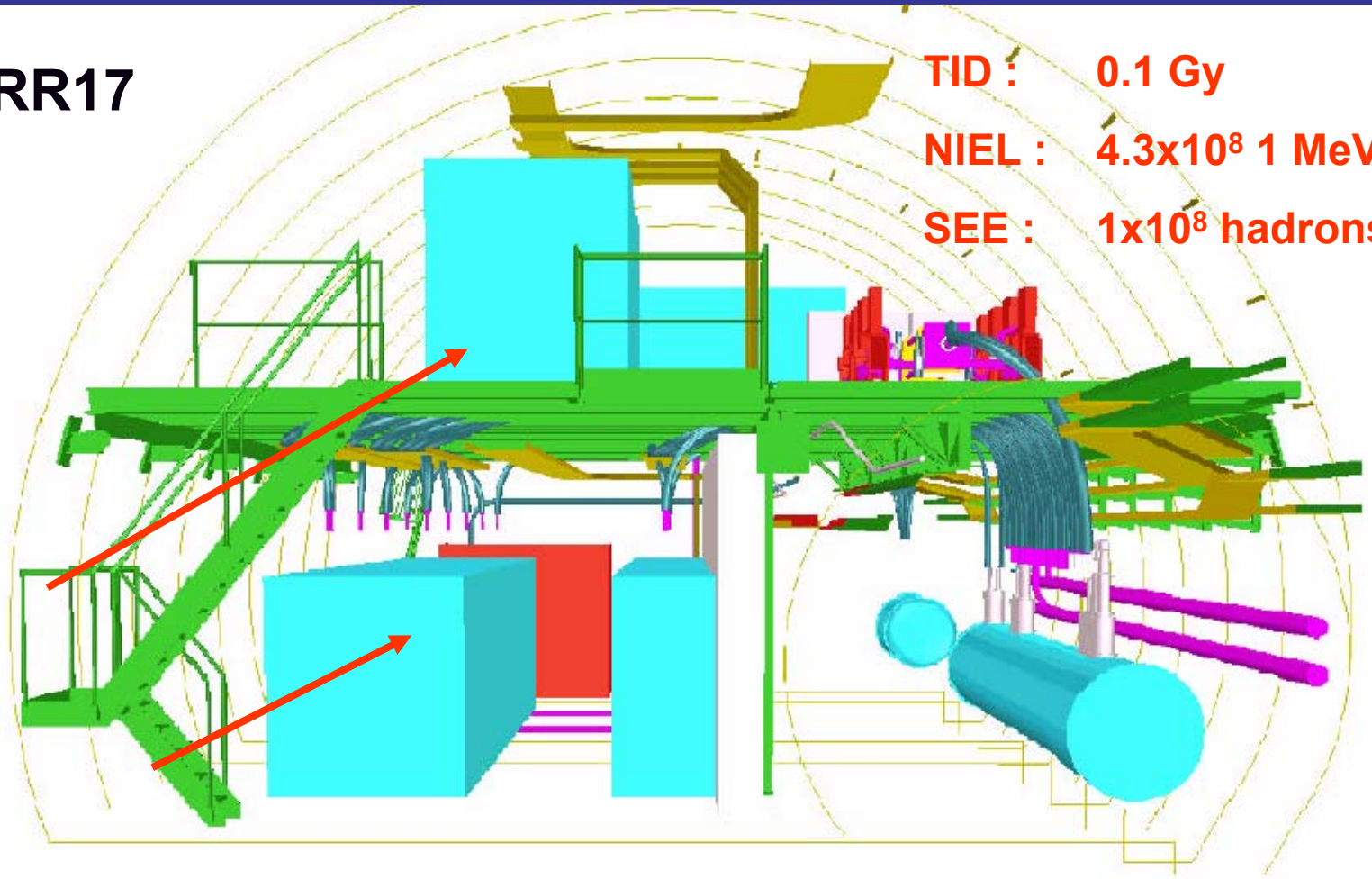
# Power Converters – powering part - Tunnel

- Orbit corrector power converters
- 752 under main cryostats
- Results in 2001 :
  - Power CMOS (but no load)
  - Driver circuits
  - Optocouplers
  - Modular Power Supplies
- Results in 2002 :
  - Optocouplers HP 6N140 and 4N55
  - Modular Power Supplies
- Results in 2003
  - Huhn-Rochbacher type DCQ 62 HV CERN
    - 300-800V in +5/+15/-15+24V out

*=> ready for series production*

- Groups of four converters
- Placed under cryostat

# Power Converters – Powering Part - RRs



# Power Converters – Powering Part - RRs

| Location | 6 kA | 4 kA | 600 A | 120 A |
|---|---|---|---|---|
| RR 13 | 13 | 2 | 14 | 18 |
| RR 17 | 13 | 2 | 14 | 18 |
| RR 53 | 13 | 2 | 14 | 18 |
| RR 57 | 13 | 2 | 14 | 18 |
| RR 73 | 0 | 0 | 24 | 10 |
| RR 77 | 0 | 0 | 24 | 10 |

The above quantities (256 converters) correspond to ~25% of all LHC power converters (excluding the orbit correctors)

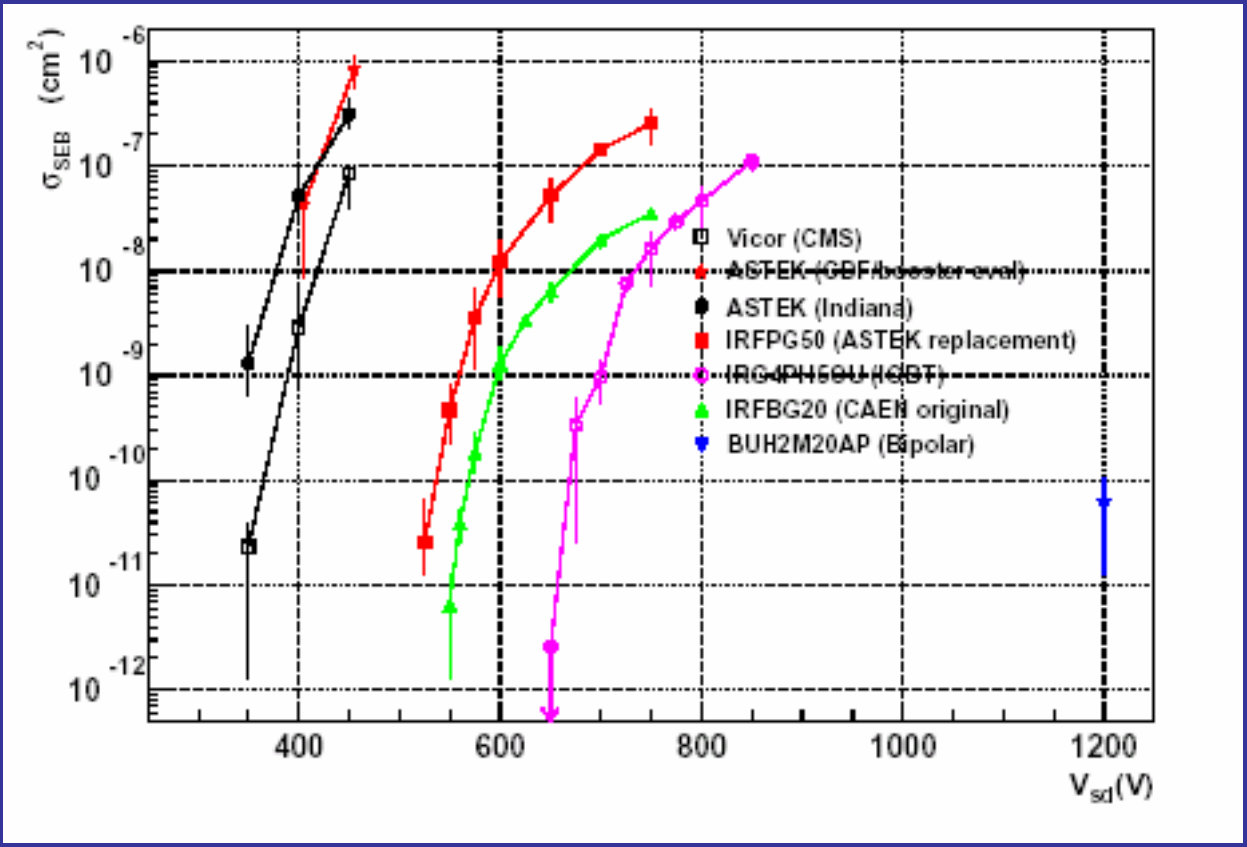
# Power Converters – Powering Part - RRs

- Radiation damage risk in RRs was announced late (TCC early 2003)
- Many radiation sensitive power devices :
  - Power MOSFETs (many different types)
  - IGBT (many different types)
- Many radiation sensitive programmable devices :
  - Lattice CPLD, Xilinx CPLD, Altera CPLD…
- Series production has started, only *reasonable* actions :
  - Try to reduce risk of SEB in power CMOS by increasing $V_{rated}/V_{operated}$
  - Use triplicated functionality in SRAM based CPLDs
  - Perform some dedicated SEE tests before 2007

    note: resource difficulties due to production requirements
  - Prepare back up solutions following 'design audit' and test results
    - For example study modifications for affected converters only

Increased SEE X-section due to digital controller

# Example : reduce $V_{ds}$ on power electronics




**MTBF : 100 IGBTs * 1E8 * 1E-7 = 1000 failures/y**

***Data courtesy of C. Rivetta and R.J. Tesarek, Fermilab, Batavia***

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# Industrial Systems

- Analog or digital I/O module with PLC unit in bottom of pit or SR surface
- Envisaged by Cooling and Ventilation Electrical Distribution and Interlocks
- Test results in 2002 :
  - SIEMENS ET200B digital
  - SIEMENS ET200M (index1)
  - SIEMENS ET200S

*Tolerance depends on production index nr*

- Test results in 2003:
  - SIEMENS ET200M (index 1) (under conditions)

SIEMENS ET200B digital


Urgent request for **purchase & spare management !**

# Industrial Systems

- **Electrical Distribution**
  - **Standard industrial system**
  - **Not yet tested on radiation tolerance**
  - **Required for commissioning with beam (explicit request from PO)**

RR 77

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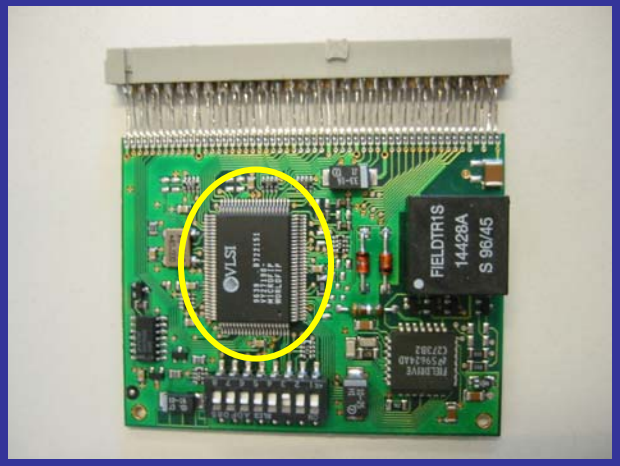
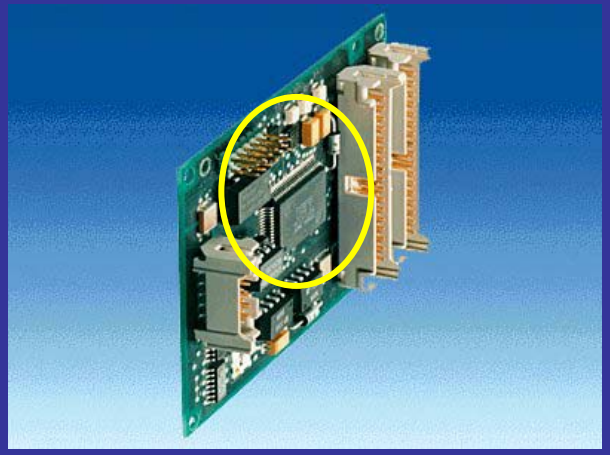
# Fieldbus Interfaces

- **ONLY Connectivity tunnel and RRs**
  - WorldFIP (custom designs)
  - Profibus (Industrial systems)
- **Repeaters needed in tunnel :**
  - Many Nodes on 1 segment
  - High speed, long distance
- **Test results in 2002 :**
  - uFIP interface
  - PROFIBUS interface
- **Test results in 2003:**
  - uFIP interface
    (700 Gy,3E13 1MeV eq, 5E-9 per device)
  - PROFIBUS interface
    (400 Gy in TCC2)



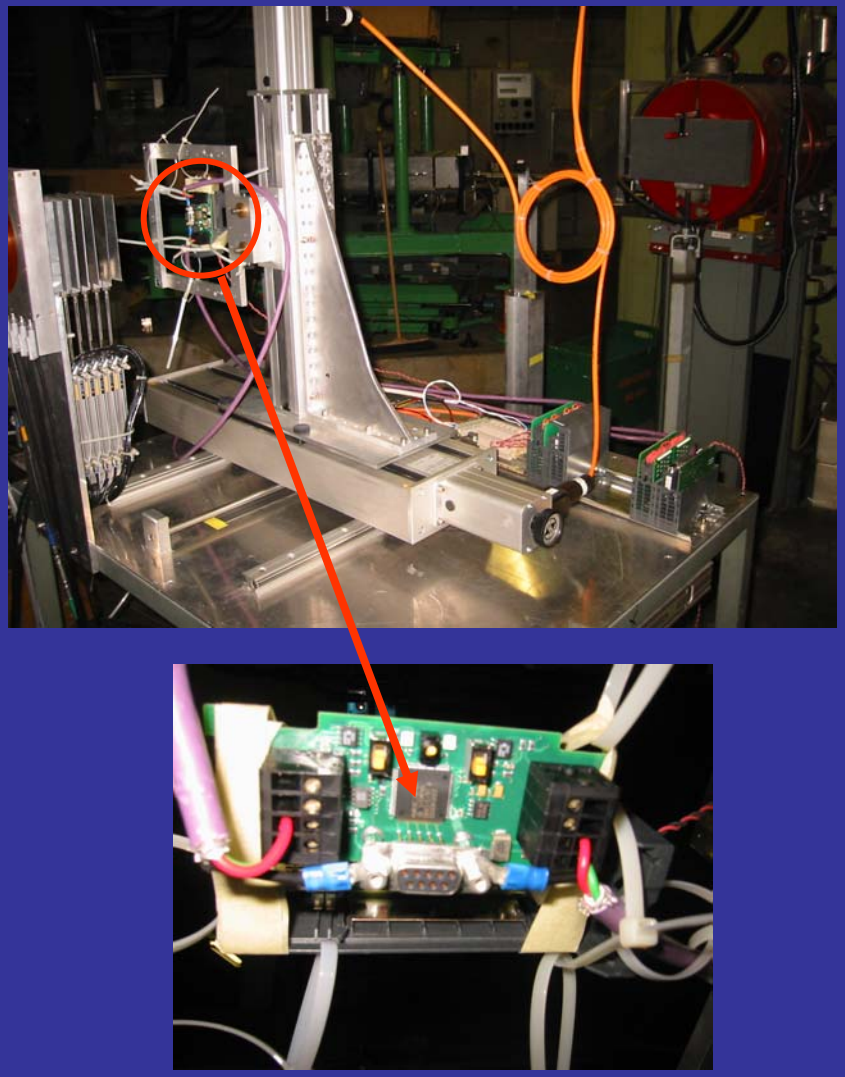

CC131 uFIP at 1 Mbit/s



PROFIBUS interface

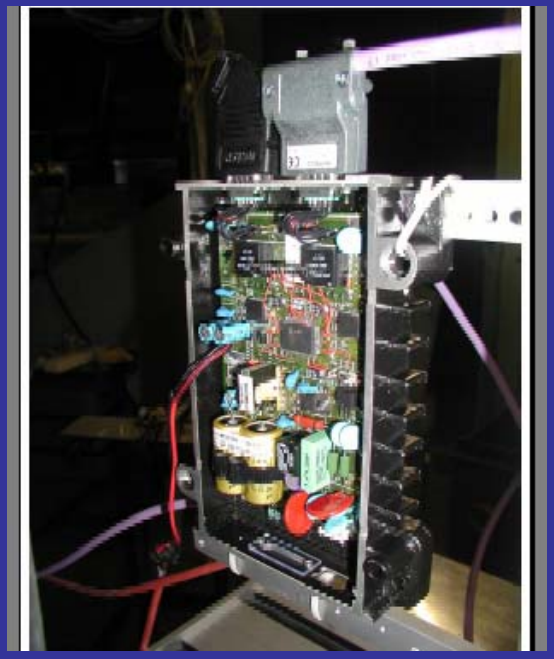
# PROFIBUS repeaters

- Standard COTS system
- Test results in 2002 :
  - Standard system, various indices
  - SEE, Total Dose failure
- Test results in 2003:
  - Standard system, INDEX 6
  - TID 80 Gy, no SEEs



# WorldFIP repeaters


- Test results in 2002 :
  - Standard Off the shelf repeater
  - SEB in FPGA



- Test results in 2003:
  - Modified repeater
  - Xlinx CPLD (60 MeV protons)
  - Xlinx CPLD gave SEFI in TCC2
- In 2004 :
  - Modified repeater for Q3
  - Actel antifuse based
  - No radiation time requested yet

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# Programmable devices

- Classic techniques (EDAC, TMR) remove 90 % errors
- Microprocessors
  - Motorola M68HC16Z1CFC16
  - Aduc 812/813
  - Atmega 103 L
  - TI TMS320C32PCM40 DSP
- Complex Programmable Logic Devices
  - Xilinx 95000 series
  - Altera EP1C6EPCS1SS18
  - Lattice M4 series
- Antifuse FPGA
  - A54SX16
  - A54SX32A

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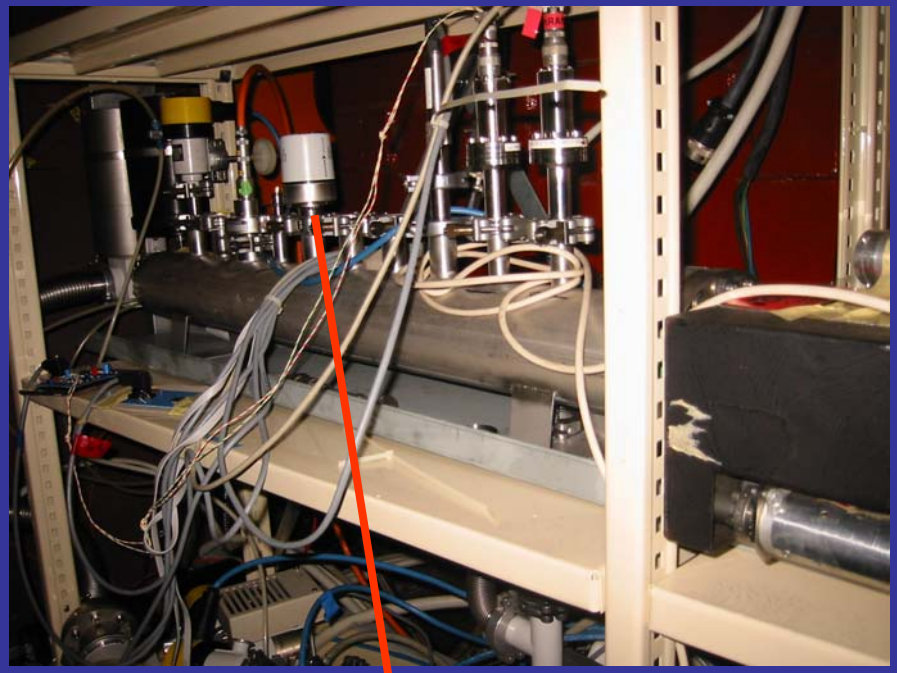
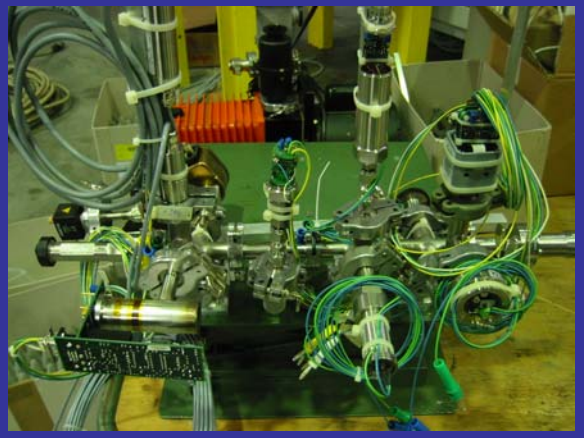
# Pressure gauges VACUUM

- **Pressure sensors and quantities for LHC**
  - **Error : < 2 % FS**
  - **200 Piezo gauges (20mbar – 1500 mbar)**
  - **350 Pirani gauges (10-4 mbar – 20 mbar)**
  - **350 Penning gauges (10-9 mbar - 10-4 mbar)**
  - **100 membrane type gauges (piezo, strain gauge, capacitance) ( 1 – 1500 mbar)**
- **Results up to 2002**
  - **Pirani & penning gauges with remote electronics with custom bridge amplifier**
- **Tests in 2003**
  - **membrane type gauges (1-1500 mbar)**
  - **TCC2 & Louvain la Neuve**



# Pressure gauges VACUUM – radiation test

- **Beam test of Membrane type gauges**
  - Huba 680.7071101 modified (piezo)
  - Keller PAA-23/8465.1.6, as delivered (piezo, supply ACR)
  - Pfeiffer/Inficon APR 250, modified (piezo)
  - Baumer PD A B 404079 A 216, as delivered (metallic strain gauge)
  - MKS 902 (piezo)
  - Leybold DI 2000 (capacitance)
  - MKS 907 (convection enhanced pirani, not part of the tender)



*ready to launch a competitive tender before the end of this year*

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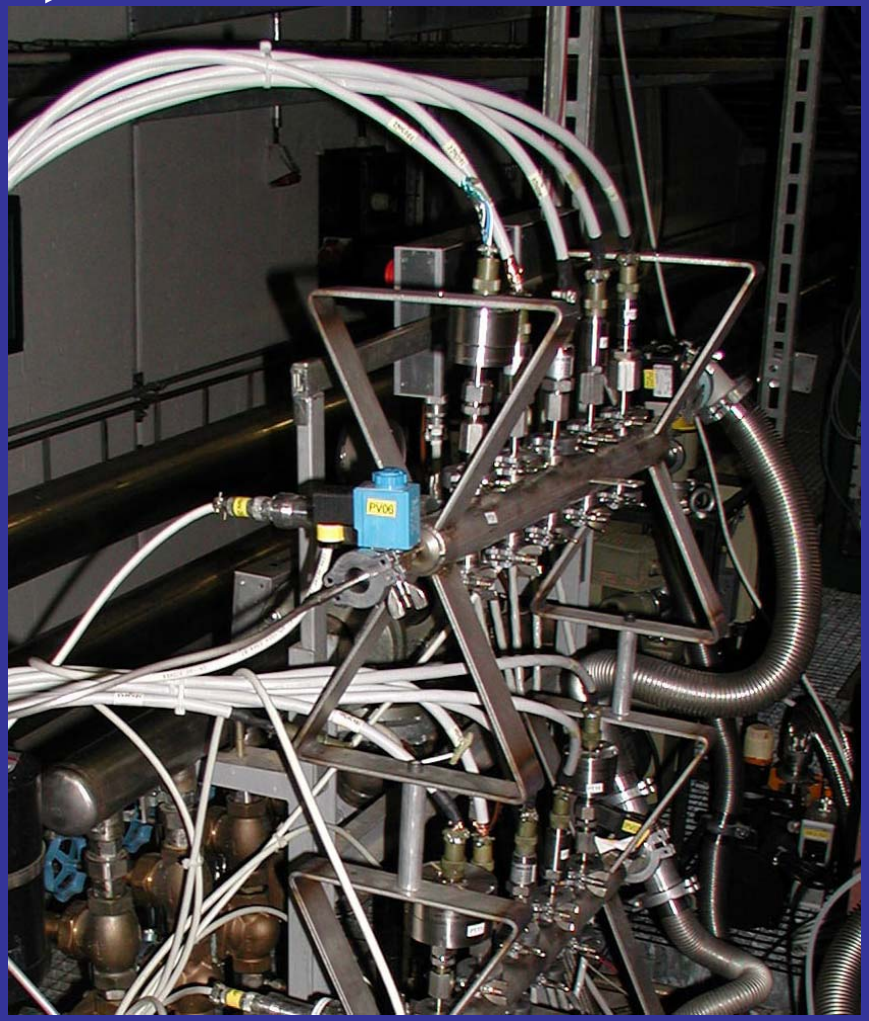
# Pressure gauges CRYO

| Sensors position (@ room temperature) | Purpose | Range (abs) | Accuracy | Qty | Installation |
|---|---|---|---|---|---|
| SSS | 1.8 K phase separator | 0..100 mbar | 0.3 %FS | 233 | 2005 |
| | Cold mass | 0..20 bar | 0.5 %FS | 400 | 2004 |
| QRL | line C | | | | |
| | line D | | | | |
| DFB | Helium bath | 0..4 bar | 1.5 %FS | 121 | |

# Radiation test Pressure gauges CRYO

Control room 160 m Irradiation zone



# Pressure gauges CRYO

- **Summary of test results in 2002**
  - Pressure transducers for the 4 and 20 bar ranges are chosen => Based on metallic strain gauges with remote electronic.
  - Piezo resistive technology 3x Keller PAA 11 and 3x STS TM212

  Gain & offset shifts due to cumulative effects
- **Summary of test results in 2003**

| Qty | Technology | Manufa-cturer | Range | Received Dose (Gy) |
|---|---|---|---|---|
| 2 | Metal SG | Baumer | 0-20 bar | 691 |
| 2 | Metal SG | Schaevitz | 0-100 mbar | 523 |
| 1 | Piezo resistive SG | Siemens | | 691 |
| 2 | LVDT without electronics | Ashdown | | 658 |
| 2 | LVDT With electronics | | | Out of tolerance @ 188 Gy |

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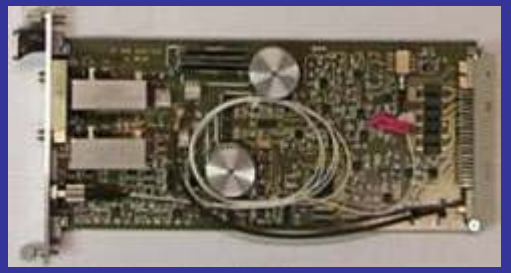
- **Beam Diagnostics**
- Other experiments

# Beam Position Monitors

- WBTN card:
  - Tested at TTC2 during 2001. No significant deterioration was detected after ~900Gy. QUALIFIED!
  - Laser diode MS in progress. Radiation test done with 1 MeV Neutrons at CEA Valduc on 2003. QUALIFIED!

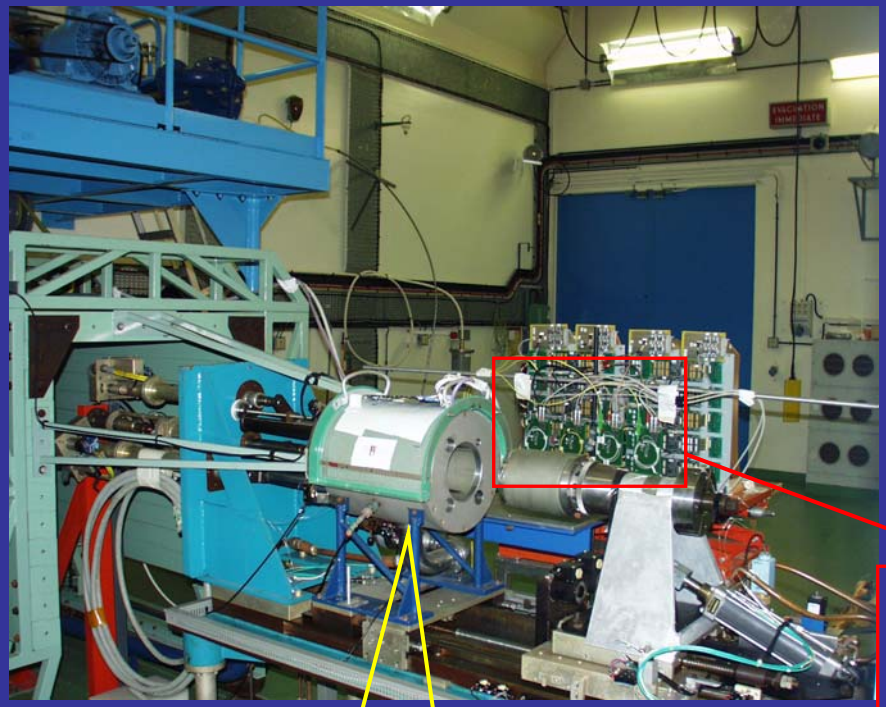


- Communication card:
  - 1st version (MicroFIP stand alone + Xilinx FPGA) tested at TTC2 on 2001. SEEs.
  - 2nd version (MicroFIP microcontrolled + ACTEL antifuse FPGA ) → card ready to test at the beginning of 2004.

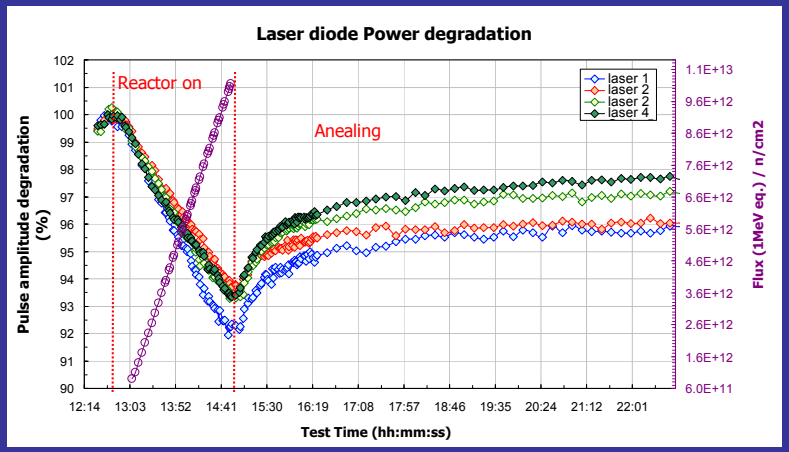
- Power supplies:
  - Base on Rad-hard linear regulators LHC4913 and LHC7913 developped by STMicroelectronics. Definitive samples not yet available.
  - → card ready to test at the beginning of 2004.

- Beam intensity measurement card:
  - First prototype will be ready to test by beginning of 2004.

# Displacement Damage Test Laser Diodes



Prospero reactor at CEA Valduc




Laser diode boards

# Beam Loss Monitors

- Radiation as design constraint

*SEE test at PSI :*

- Individual components tested
  - Burr Brown OP 621
  - Philips NE 521
  - TI LS 123 Monostable
- Optical components tested

*ready to produce rad tol pre-series*

*in Q4 2004*

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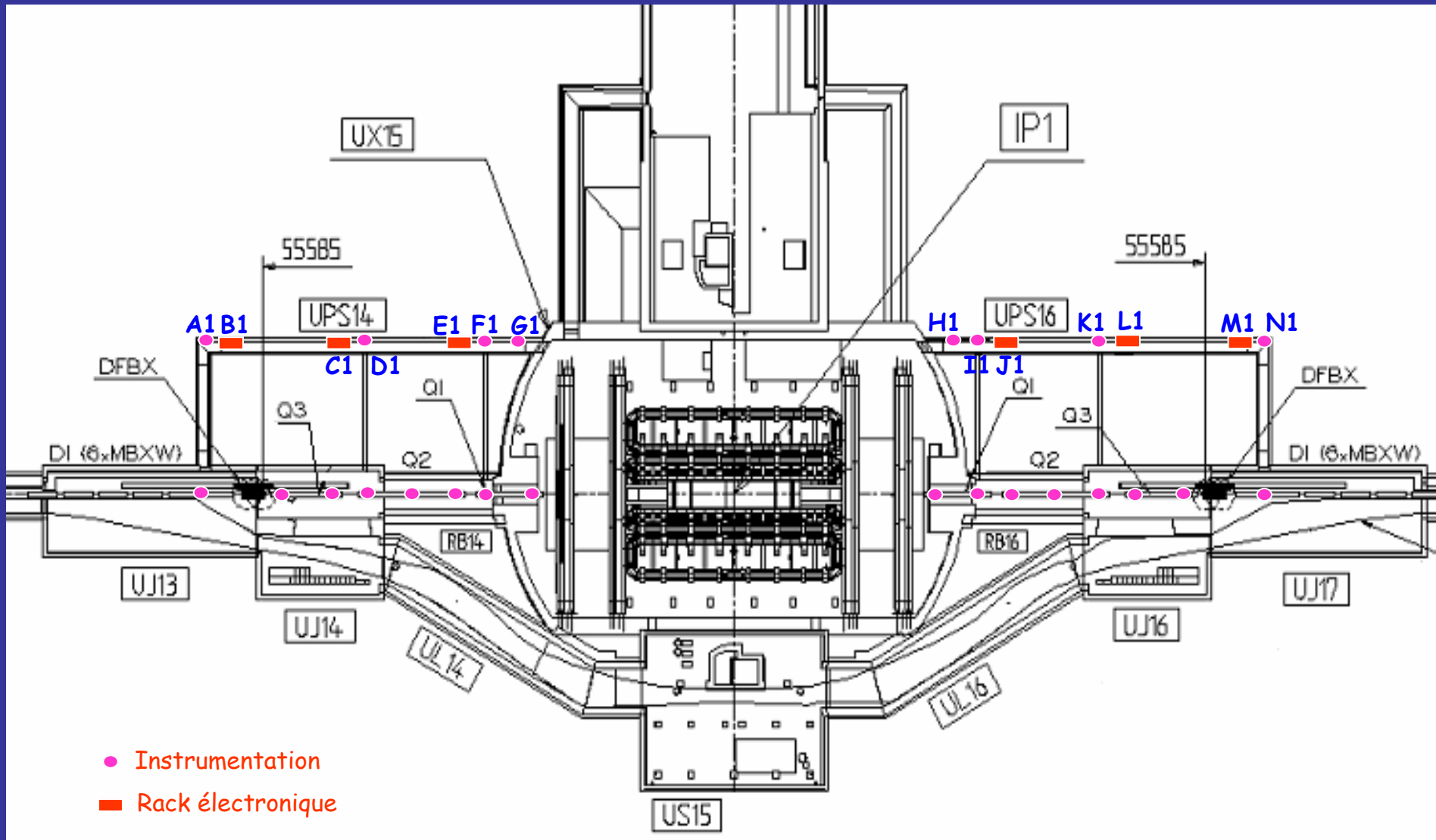
# Magnet Survey System



# Capacitive Micrometer sensors



MCA8 6 CHF/M
pose incluse


CÂBLES TRIAXIAUX
15 CHF/M + POSE.
LONGUEUR MAX 30M



164 CAPTEURS A
INSTALLER : LA MOITIÉ
RÉCUPÉRÉS DU LEP

**Tradeoff :**

- Short cables
- Electronics in shielded area

# Capacitive Micrometer sensors - TCC2 tests

- Wire Sensors
  - Resisted up to 200 Gy in TCC2



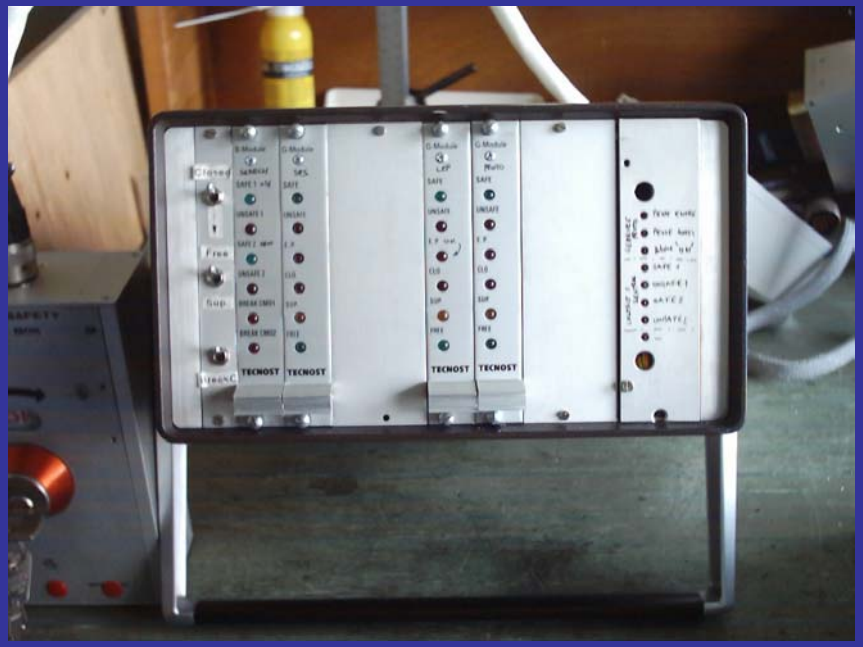
- Hydrostatic sensors
  - Resisted to 500 Gy
  - 1 device showed drift

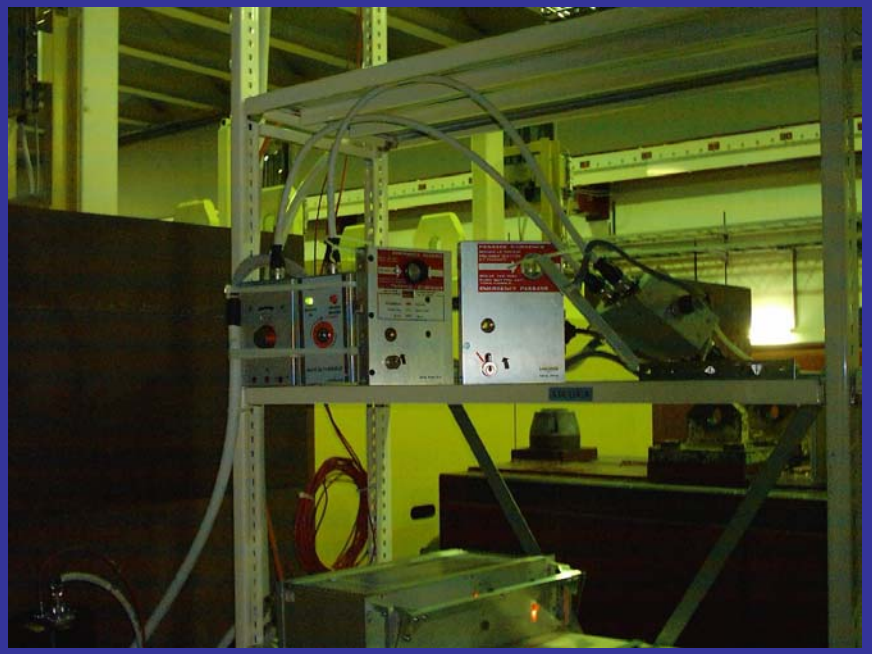


- Create and power supplies
  - In gallery (extreme low dose – thermal neutrons)
  - Resisted throughout the 2003 run

# Acces System

- **Material tested in 2003 :**
  - 1 lock type SPS
  - 1 lock type LEP
  - 1 prototype lock LHC
  - 1 patrol box type SPS
  - 1 patrol box (SPS-LHC)
  - 1 contact with 2 positions



- **Results radiation tests in TCC2**
  - 8 checks made throughout run
  - No faults observed

# Red Telephones


- **Results radiation tests in TCC2 in 2003**
  - **Works fine !**

# Conclusions

- LHC is first experiment with so many electronics under radiation
  - LHC experiments
  - LHC experimental halls
  - LHC machine (tunnel and RRs)
- Radiation tolerance assurance LHC machine is “consensus based”
  - 90 % of electronics in tunnel and in RRs has been tested
  - Most equipment groups have found a balance costs/time/risk/effort
  - Estimates of failure due to radiation should be made public
- Single Events from fast neutrons is a concern
  - Use standard COTS components
  - Use of complete industrial systems
  - “Classic mitigation techniques” solve 90% of problems
  - Improved “in–house” knowledge and expertise
- Ongoing simulations
  - Momentum cleaning section point 3 (UP33, UJ32,UJ33)
  - Alcove RE38
  - Betatron cleaning section (RR73,RR77 and UJ76)