

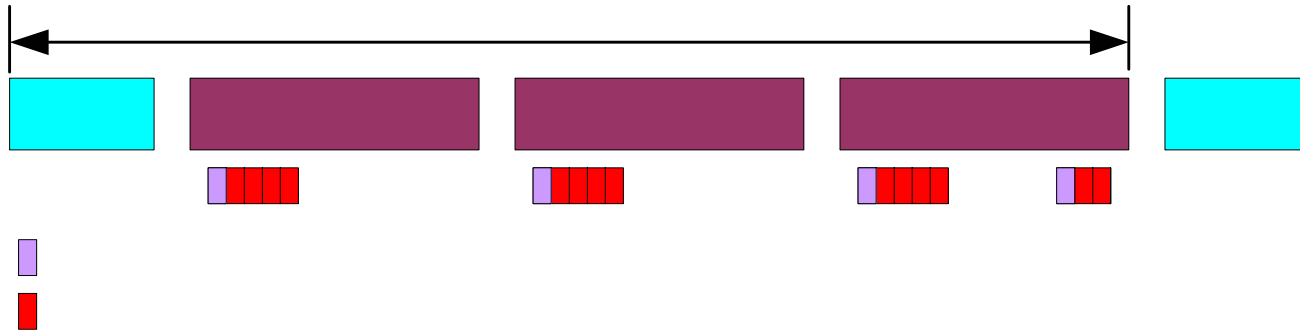
# **RADIATION TOLERANT ELECTRONICS FOR THE LHC QUENCH PROTECTION SYSTEM (QPS)**

**QUENCH DETECTION  
QUENCH HEATER POWERING  
ACQUISITION & MONITORING  
ENERGY EXTRACTION**

R. Denz AT-MEL

- Required radiation tolerance for QPS electronics
- Location of QPS electronics in the LHC
- Tests in TCC2 2003
- Tests in PSI 2003
- Summary of successfully tested COTS 1999 – 2003
- Conclusions

- TID: 200 Gy Fluence:  $2 \times 10^{12}$  n cm<sup>-2</sup> SEU free
  - Valid for QPS locations in the regular arcs and in the DS
  - Safety margin included
  - Qualification in TCC2 mandatory
- Affected QPS equipment
  - 6076 quench heater discharge power supplies
  - 2016 local quench detectors
  - 1624 acquisition & monitoring controllers
  - Equipment in the RR's
  - Energy extraction systems
- In-house designs
  - Radiation taken into account as engineering constraint
  - Reduced variety of components



MQ



MB

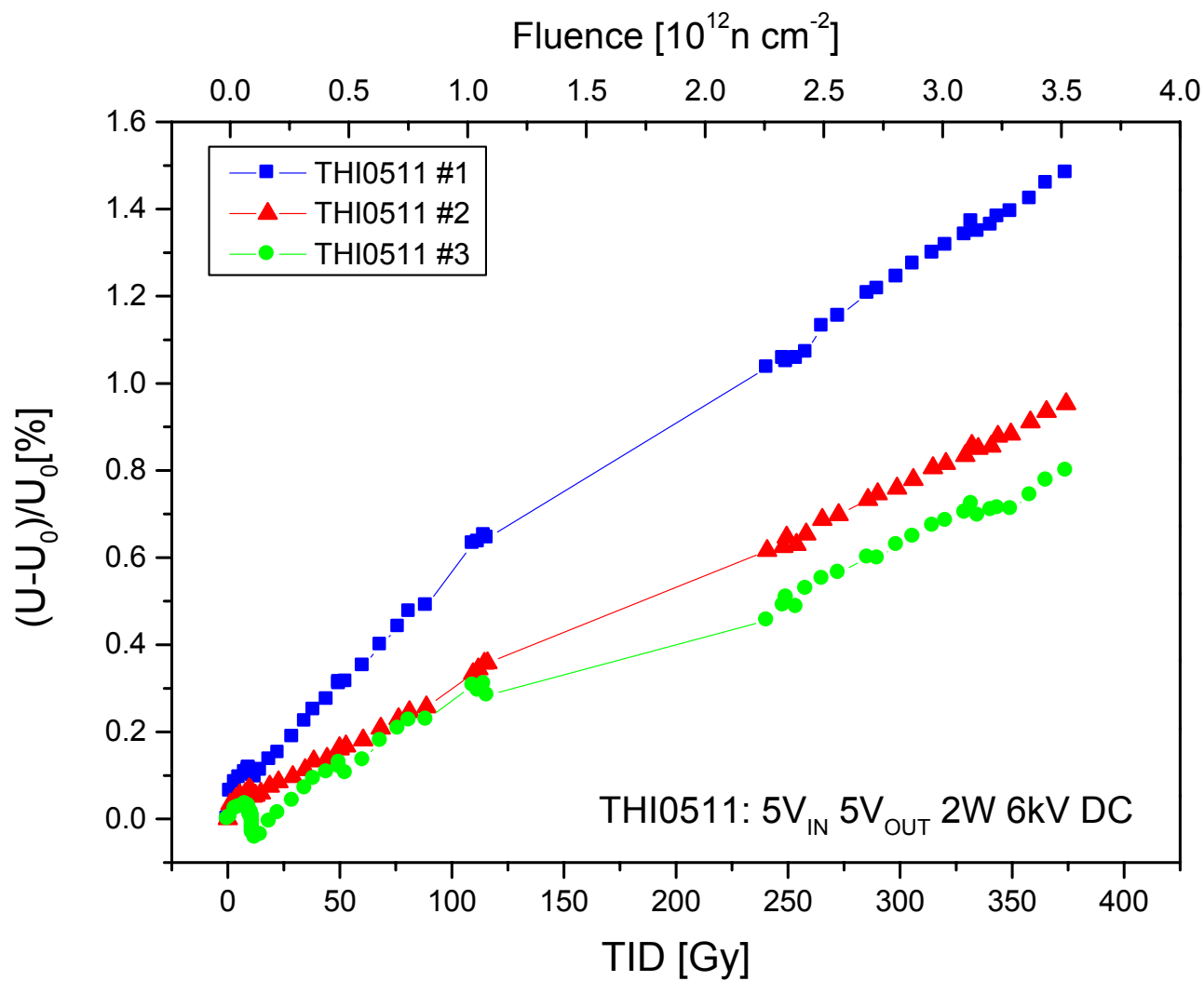
Not to forget : Equipment installed in the RR's and energy extraction systems in point 3.

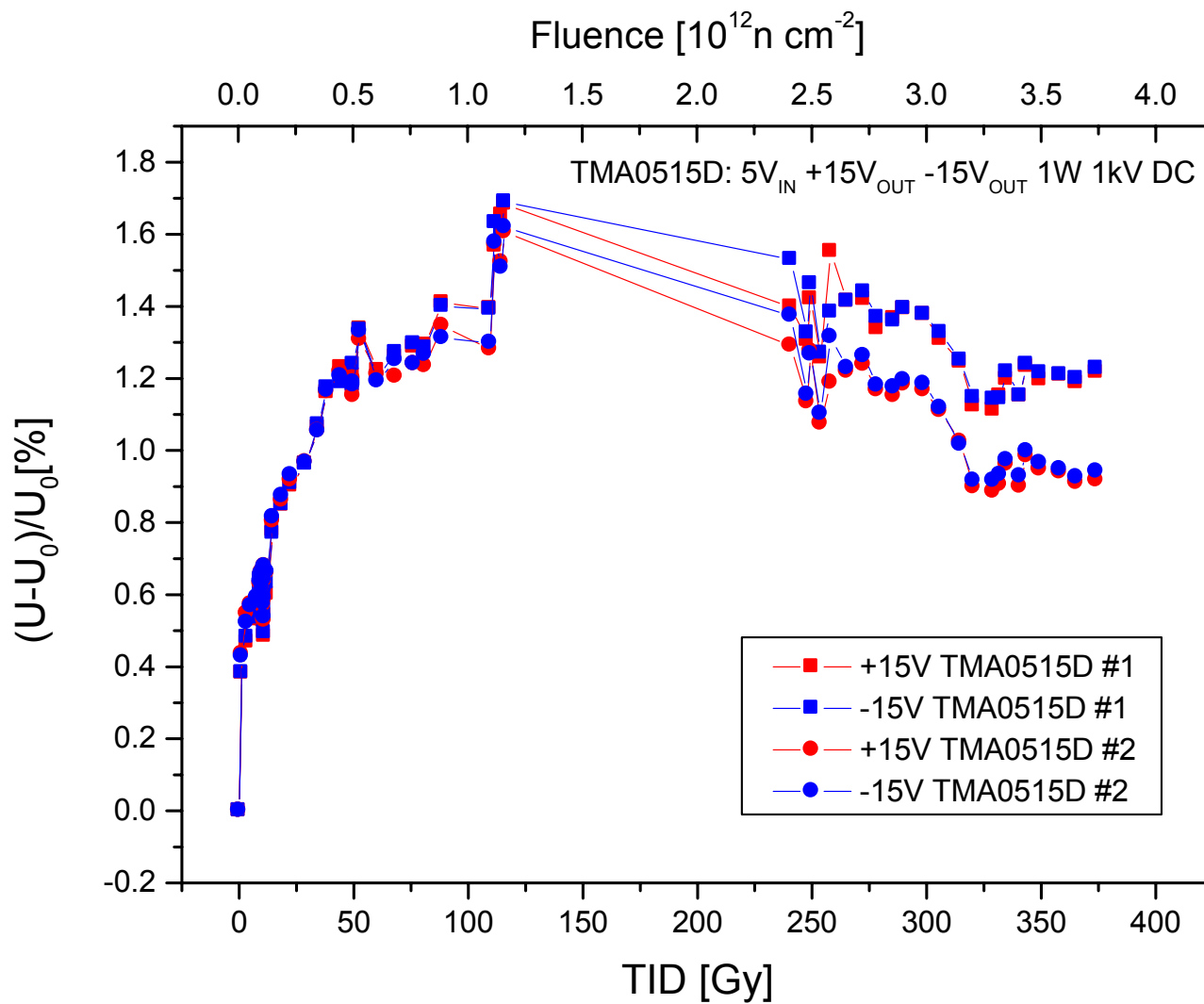
DYPB

- ➔ Quench heater power supply pre-series device (final design)
- ➔ Isolated DC-DC converters
  - THI0522, THI0511, TMA0505S, TMA0515D (TRACO)
- ➔ Operational amplifiers
  - OPA27 (TI)
- ➔ Comparators
  - LM311 (various manufacturers)
- ➔ Energy extraction equipment
  - Functional test with one circuit breaker continued
  - Additional tests on other industrial equipment



- In-house design using COTS
  - 6076 units in LHC, about 200 close to hot spots in DS areas
  - Design, test systems, integration and operation: AT-MEL
  - Production and maintenance: AB-PO
- Extensive radiation test studies 1999 – 2003
  - Final successful test on a pre-series device this year – production now launched
  - Discharge thyristors (SEMIKRON SKT8018E) identified as most critical parts (inhibited trigger due to radiation induced defects)
  - Neutron fluence limit:  $2 \times 10^{12} \text{ n cm}^{-2}$
  - If thyristors are exchanged, the useful lifetime can be enhanced by at least a factor 5.



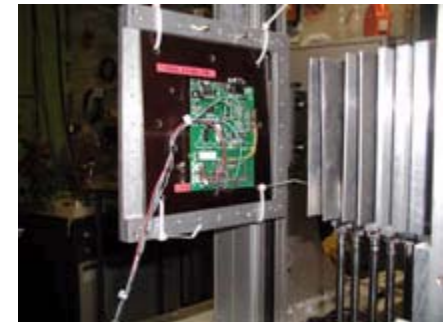




- Comparator LM311
  - 16000 pieces to be used within analog quench detection systems
  - 4 devices under test successfully passed functional test (TID = 370 Gy)
- Operational amplifier OPA27GP (TI)
  - Amplifier suitable for radiation hard applications (according to TI)
  - 8 devices under test in unity gain configuration
  - Gain stable within 0.04% (TID = 370 Gy) but offset drift:

Device	Total offset deviation [%]	Linear fit [ $\mu\text{V}/\text{Gy}$ ]
1	5.7	17
2	8.7	19
3	5.9	16
4	7.6	15
5	6.6	13
6	6.8	17
7	6.5	18
8	6.3	15
Average	<b>6.8</b>	<b>16</b>

- ➔ OPTIS beam-line
  - $5 \times 10^8 \text{ p cm}^{-2}\text{s}^{-1}$  corresponding to  $0.7 \text{ Gy(Si) s}^{-1}$  60 MeV
- ➔ ADuC8XX micro-converter family
  - ADuC812
    - 8 channel 12 Bit ADC + 8051 compatible core + 8k Flash EEPROM
    - 4000 devices in QPS electronics
  - ADuC831
    - As ADuC831 but 62k Flash EEPROM
    - 2200 devices in QPS electronics
    - Core of QPS acquisition & monitoring controllers
  - ADuC834
    - 24 Bit ADC + 8051 compatible core + 62k Flash EEPROM
    - 2600 devices in QPS electronics
- ➔ Non isolated DC-DC converters



- Functional test of the chip
  - Communication during the test via serial port
  - Download of test software via serial port
- Memory access tests
  - ADuC812: external SRAM
  - ADuC831 & ADuC834: internal & external SRAM, internal Flash EEPROM
- Error correction algorithm
  - Bitwise triple voting for data stored in external SRAM validated

$$\text{data}[i] = (\text{d}[0][i] \& \text{d}[1][i]) | (\text{d}[0][i] \& \text{d}[2][i]) | (\text{d}[1][i] \& \text{d}[2][i])$$

Fluence [ $10^{10}$ p $\text{cm}^{-2}$ ]	Dose [Gy]	Remark
4.0	55	Properly working
11.0	151	Properly working but serial download is not possible any more (probably boot-loader firmware corrupted)
13.3	183	Serial communication stopped

## External SRAM (SAMSUNG K6T0808C1D-TB70)

Fluence [ $10^{10}$ p $\text{cm}^{-2}$ ]	Bits written	Errors	Single	Double	SEU cross section [ $10^{-13}\text{cm}^2$ ]
1.0	262144	242	240	2	0.9
2.0	262144	487	477	10	1.0
5.0	262144	1230	1148	76	0.9

Fluence [ $10^{10}$ p $\text{cm}^{-2}$ ]	Integer errors	Corrected errors	Efficiency
1.0	235	234	99.57%
2.0	413	413	100%

Fluence [ $10^{10}$ p cm <sup>-2</sup> ]	Dose [Gy]	Remark
2.0	28	Properly working
4.0	55	Properly working but hardware reset necessary
6.0	83	Properly working
10.7	147	Serial communication stopped

### External SRAM (SAMSUNG K6T0808C1D-TB70)

Fluence [ $10^{10}$ p cm <sup>-2</sup> ]	Bits written	Errors	Single	Double	SEU cross section [ $10^{-13}$ cm <sup>2</sup> ]
1.0	262144	258	258	0	1.0
1.0	262144	440	428	12	1.7
2.0	262144	1096	1010	80	2.1

### Internal SRAM

Fluence [ $10^{10}$ p cm <sup>-2</sup> ]	Bits written	Errors	Single	Double	SEU cross section [ $10^{-13}$ cm <sup>2</sup> ]
1.0	16384	19	19	0	1.2
1.0	16384	17	17	0	1.0
2.0	16384	47	39	8	1.4

Fluence [ $10^{10}$ p cm <sup>-2</sup> ]	Integer errors	Corrected errors	Efficiency
1.0	218	218	100%
2.0	428	428	100%

Fluence [ $10^{10}$ p $\text{cm}^{-2}$ ]	Dose [Gy]	Remark
1.0	14	Properly working but 1 automatic reset
2.0	28	Properly working
3.5	49	Serial communication stopped

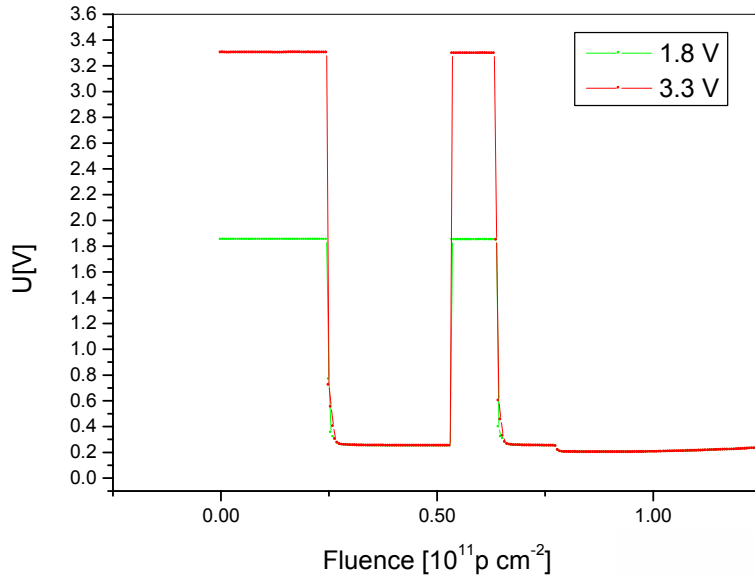
### External SRAM (CYPRESS CY62256LC-70ZC)

Fluence [ $10^{10}$ p $\text{cm}^{-2}$ ]	Bits written	Errors	Single	Double	SEU cross section [ $10^{-13}\text{cm}^2$ ]
0.2	262144	30	30	0	0.7

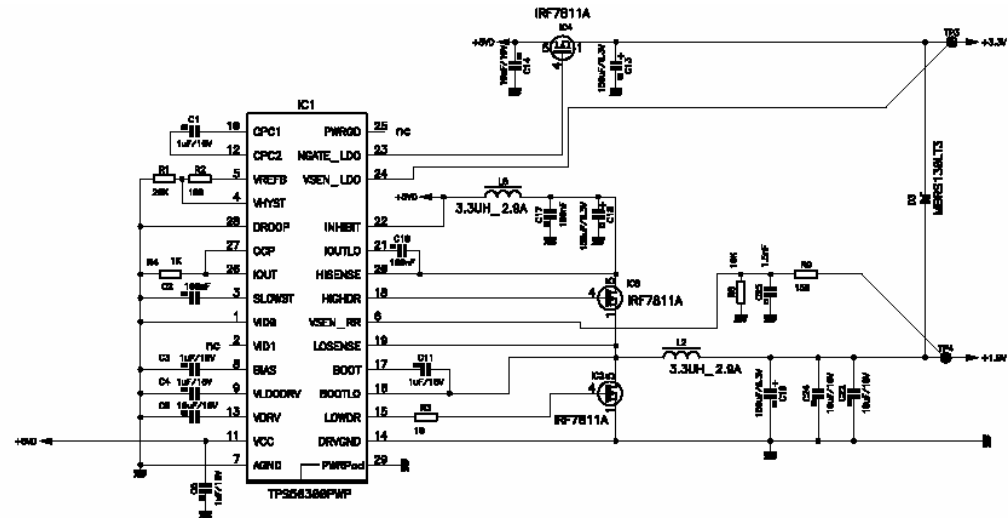
### Internal SRAM

Fluence [ $10^{10}$ p $\text{cm}^{-2}$ ]	Bits written	Errors	Single	Double	SEU cross section [ $10^{-13}\text{cm}^2$ ]
0.2	16384	3	3	0	1.1

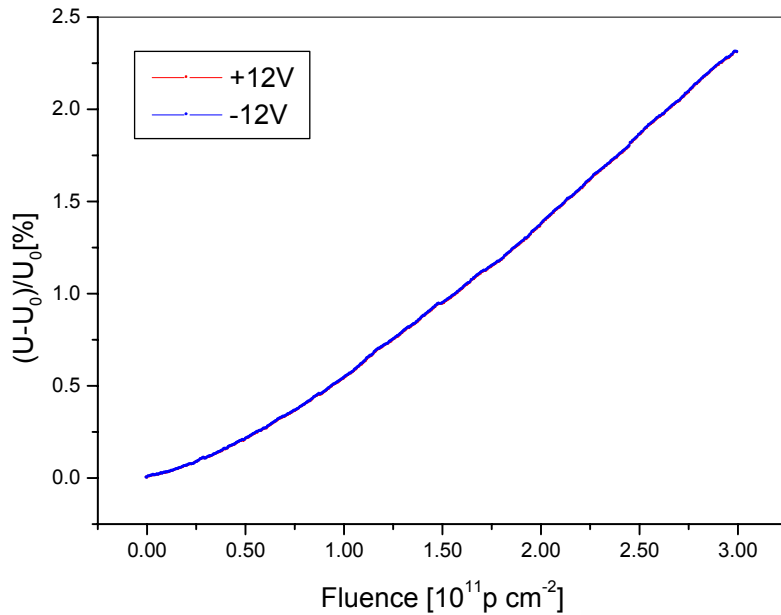
Fluence [ $10^{10}$ p $\text{cm}^{-2}$ ]	Integer errors	Corrected errors	Efficiency
1.0	77	77	100%



- ➔ Non-isolated DC-DC converter
  - Generation of 1.8 V and 3.3 V supply voltages for a DSP
  - TPS56300PWP & over-rated FET's

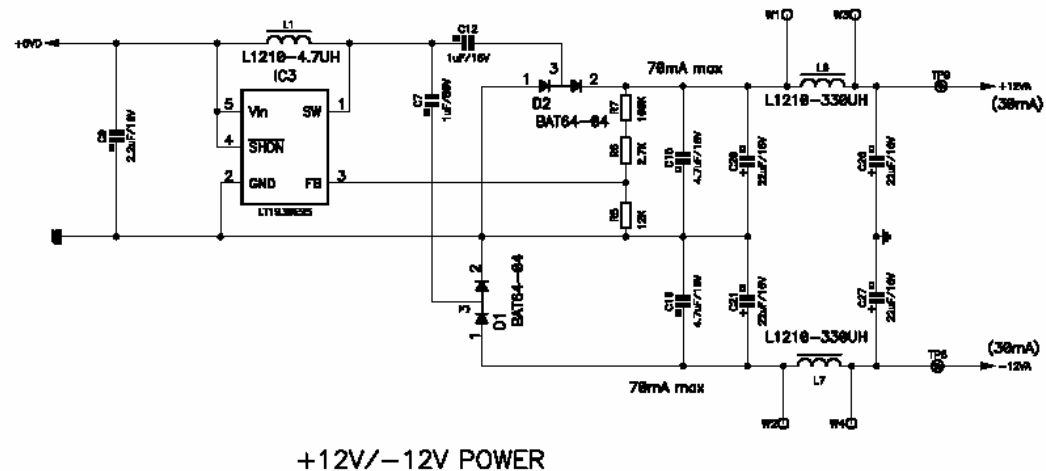


+3.3V & 1.8V POWER



## ➔ Non-isolated DC-DC converter

- Generation of symmetric powering on single supply boards
- +5V  $\rightarrow$  +12V -12V
- LT1930ES5



+12V/-12V POWER



- Amplifiers
  - INA105, INA141, OPA27, AD210BN
- Comparators
  - LM311
- Timer
  - NE556
- Voltage regulators
  - MC7815, MC7915
- Voltage references
  - REF102, LT1236A-10
- Digital isolators
  - ISO150
- Thyristors
  - SKT80/18E
- Isolated DC-DC converters
  - TH10522, TH10511, TMA0505S, TMA0515D
- Micro-converters
  - ADuC812, ADuC831, ADuC834

Basic set of components for building up low bandwidth analog and digital electronics.

- ➔ Quench protection electronics successfully developed and qualified for required radiation tolerance levels in the LHC
  - Long term development over several years
  - Success also based on excellent collaboration with RADWG
  - Designs frozen and production launched
- ➔ Radiation tests to be continued
  - Participation in 2004 test campaign
  - Some issues with equipment to be placed in the RR's to be clarified
  - Continuous R&D required during LHC life time
    - Replacements for broken and/or obsolete electronics
    - Increasing LHC luminosity
    - LHC upgrades
- ➔ Real validation starts in 2006 ...