Instrumentation Status of the Low-beta Magnet Systems at the LHC

Christine Darve, Christoph Balle, Juan Casas-Cubillos, Antonio Perin, Nicolas Vauthier

July 22nd, 2010

Headlines:

System Description
Instrumentation Identification
Reliability
Availability
Traceability
The Low-beta Magnet Systems at the LHC

**Critical system for LHC performance**
Inner Triplet for final beam focusing/defocusing
American contribution to the LHC machine

\[ Q = Q_{\text{Arc}} \times 10 \]


Christine Darve  
ICEC23- July 22nd, 2010
Type of instrumentation

Low-beta system

Interface with QRL

EH8xx: cryo-electrical heaters

Christine Darve ICEC23- July 22nd, 2010
Type of instrumentation

CV8xx: control valve

LT8xx: liquid helium level gauge (based on superconducting wire)

*HTS leads
*VCL leads
*Inner triplet feedthrough

Christine Darve
ICEC23- July 22nd, 2010
Reliability – Instrumentation (quality + quantity)

Example for the Temperature sensors:

- Goal: precision must remain better than 0.25% (5 mK at 2 K)

By principle, use redundant system

**Test benches:**
- Thermo cycle
- Irradiation test: fluence values close to $10^{15}$ neutrons/cm$^2$, corresponding to $2.10^4$ Gy

<table>
<thead>
<tr>
<th>Thermometer (+number tested)</th>
<th>R @ 1.8K</th>
<th>dR/dT @ 1.8K</th>
<th>$\sigma_\epsilon$ @ 1.8K</th>
<th>beam heating mK/(n.cm$^{-2}$s$^{-1}$)</th>
<th>$\Delta T$ Irradiation for 4 $10^4$n.cm$^{-2}$</th>
<th>Expected $\Delta T$ in LHC</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB (44)</td>
<td>6600 Ω</td>
<td>-10600 Ω K$^{-1}$</td>
<td>8.10$^{-3}$</td>
<td>9 $10^{-10}$</td>
<td>+2 mK</td>
<td>&lt; 2 mK</td>
</tr>
<tr>
<td>TVO (44)</td>
<td>5700 Ω</td>
<td>-3300 Ω K$^{-1}$</td>
<td>3.3 $10^{-3}$</td>
<td>3 $10^{-10}$</td>
<td>+0.3 mK</td>
<td>&lt; 0.5 mK</td>
</tr>
<tr>
<td>CX (66)</td>
<td>12600 Ω</td>
<td>-12000 Ω K$^{-1}$</td>
<td>2.5 $10^{-3}$</td>
<td>10$^{-10}$</td>
<td>+1 mK</td>
<td>&lt; 2 mK</td>
</tr>
<tr>
<td>Ge (5)</td>
<td>9000 Ω</td>
<td>-8000 Ω K$^{-1}$</td>
<td>1.2 $10^{-4}$</td>
<td>0</td>
<td>+300 mK</td>
<td>+300 mK</td>
</tr>
<tr>
<td>RhFe thin-film (46)</td>
<td>15 Ω</td>
<td>+0.7 Ω K$^{-1}$</td>
<td>3.1$^{10^{-5}}$</td>
<td>0</td>
<td>+12 mK</td>
<td>+3 mK/year</td>
</tr>
<tr>
<td>RhFe wire (36)</td>
<td>5.4 Ω</td>
<td>+0.6 Ω K$^{-1}$</td>
<td>2.6 $10^{-5}$</td>
<td>0</td>
<td>+5 mK</td>
<td>+1.5 mK/year</td>
</tr>
<tr>
<td>Pt (22)</td>
<td>1.7 Ω</td>
<td>+3.5 $10^{-4}$ Ω K$^{-1}$</td>
<td>-</td>
<td>-</td>
<td>+1.5 K</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1 Results of irradiation at 1.8 K (average values)

References:
Reliability – Performance measurement

Lambda transition, 
\[ T = 2.17 \text{ K}, \ P = 1.3 \text{ bar} \]
Availability: Data flow & LHC Logging Cryogenics Data

PLC, FEC: NTP synchronization

**Courtesy of E. Blanco**

- **PLC TimeStamp**
  - [~1500 ms worst case]
  - ~10 s
- **FEC TimeStamp**
  - [200 ms]
- **Archive**
- **DB ARCH**
- **CRYO SCADA**
  - (2) DB DRIVER SCADA
    - (1) DB FEC
    - (1) DB PLC
- **Controller**
  - PROFIBUS DP
    - DI, DO
  - PROFIBUS PA
    - CV
- **Driver**
- **TT, PT, LT, DI, EH**
  - ~1 s
  - ~10 s
  - ~500 ms
- **TT, PT, LT, DI, EH**
  - ~500 ms
  - ~500 ms
- **Worst case:** ~1500 ms

**Filter**
- AVG -> noise
- MED -> spikes

**Specifications**
- DB layout
- Noise correction
- Card correction
- MTF

**Controller**
- PROFIBUS DP
- DI, DO
- PROFIBUS PA
- CV

**FEC**
- 500 ms

**Controller**
- PROFIBUS DP
- DI, DO
- PROFIBUS PA
- CV

**TT, PT, LT, DI, EH**
- ~1 s
- ~10 s
- ~500 ms

ICEC23- July 22nd, 2010
Availability: Process Control Object

Courtesy of Mathieu Soubiran

SECTOR PCO

ARC PCO

He Guard Circuit
PV970

Cooling/Filling Circuit
CV920
QV920
QV923
QV927
EH821

1.9K Circuit
CV910/11
CV915/16

Beam Screen Circuit
CV943
CV947
EH843
EH847

LSS PCO

Inner Triplet

He Guard Circuit
PV970

Standalone Magnets PCOs
CV920
CV931
EH847
EH847
CV941
CV950

Cooling/Filling Circuit
CV920
QV920
QV923
QV927
EH821

Beam Screen Circuit
CV910/11
CV915/16

1.9K Circuit
CV910/11
CV915/16

RF

DFB PCOs
CV93x
CV891
PV930
PV890
EH83x
EH831
EH847
CV950

Christine Darve

ICEC23 - July 22nd, 2010
Availability: Option modes / steppers

Courtesy of Mathieu Soubiran

The Option Modes are defined at the Sector PCO level.

Option Mode 1

Option Mode 2

Option Mode 3

Option Mode 4

Christine Darve

ICEC23- July 22nd, 2010
LHC operation annual radiation dose for the arc magnet and for the CMS/ATLAS low-t regions are 1 and 1000 Gy, respectively.

→ No easy repair when inherent radiation!

→ The chosen instrumentation and equipment are radHard and halogen free

→ Use of redundancy

→ Specific hazard analysis is requested before personnel intervention

→ Radiological survey is systematical performed prior intervention (< 1mSv/hr)

→ Limit the personnel exposition time (individual and collective radiation doses)

→ Radio-Protection Procedures to be written based on lessons learned and other institutes experiences

Averaged over surface residual dose rate (mSv/hr) on the Q1 side (z=2125 cm, bottom) of the TAS vs irradiation and cooling times. By courtesy of N. Mokhov

Christine Darve

ICEC23- July 22nd, 2010
Traceability - MTF

Assembly Folder: Main Info

Assembly Identifier: HCDFBXA001-LB000001
Other Identifier: DFBXA
Description: DFBXA Electrical Feed Box

Component Identifier: HQQTEL-CCT-0015430
Other Identifier: CX_LS_X17957
Description: Cryo Thermometer (TT831)

Christine Darve
ICEC23- July 22nd, 2010
Conclusion

- The low-\(\beta\) system is among the most critical for the operation and performance of the LHC. For the planned upgrades, maintenance and removal will yield an inherent radiological risk.

- During the LHC hardware commissioning, the original equipment and instrumentation were tested \(\rightarrow\) leading to the need of further implementation.

- Every intervention must be carefully planned with RP.

- Continuous improvement of reliability, availability, traceability is on-going.

**Acknowledgement:** the TE/CRG personnel, the hardware commissioning team for their technical support, the integration group (ILC) and the safety group (TGS).