Update on LHC Status

August 5, 2009 (HE35). In the *New York Times* (NYT) of August 4th, 2009 appeared an article "Giant particle Collider Fizzles", which paints the status and future of LHC in rather somber colors. As science-related articles in the daily press are often subjective and inaccurate, we asked Prof. Lucio Rossi, Head of the Magnet, Superconductor and Cryostat Group in the CERN Technology Department to provide a factual statement for the ESNF Events Highglights. Below, we reproduce his statement.

The Large Hadron Collider (LHC), the 27 km long underground particle accelerator of CERN, is scheduled to restart by mid-November 2009. The repairs necessitated by the grave incident of September 19th, 2008, just a few days after the spectacular start-up of September 10th, have been carried out. The incident happened at a current level of 8715 A and was caused by a bad splice between the 13 kA superconducting bus bars needed to power the main dipoles. Repairs and consolidations to avoid similar incidents in future, or to mitigate consequences if any occurs, have been performed either on all or some of the eight sectors in which the machine is subdivided. The following tasks have been performed:

1) Removal and substitution of 39 main dipoles and 14 main quadrupoles in the damaged zone (D-zone) of sector 3-4. Actually, 30 dipoles and 7 quadrupoles have been completely substituted with brand new magnets form the spare stock, while 9 dipoles and 7 quadrupoles have been re-used after proper revamping and cryogenic and power test. This has been major work; it required demounting and complete re-installing of more than 700 m of magnets.
2) Opening of some 150 magnet interconnections in 5 sectors (in addition to the 54 interconnections fully re-done in the D- zone) in order to inspect, check and (if needed) repair bad splices between magnet bus bars. A campaign of measurements at 300K and 80 K has been carried in all the 8 sectors to measure the stabilizing copper continuity at the splice.
3) Cleaning of some 4 km of beam pipe; in some places a sticky soot-like layer was removed, in other places the contamination was mainly small pieces of aluminized Mylar super-insulation.
4) Reinforcement with lateral restraints of the support of 100 main quadrupoles, to provide better anchoring to the ground of quadrupoles on which the pressure exerts longitudinal force.
5) Installation of new ports acting as safety openings. To date, 900 DN200 ports have been installed *in-situ* on the various cryostats (about 700 additional ports will be installed in 2010-2011).
6) Partial installation of a new layer of Quench Protection System (QPS) capable to detect a quench in the bus bar at the onset, and to measure the resistance of a splice at better than 10 nOhm (resistance of the splice that burnt was more than

200 nOhm). Furthermore QPS is capable to detect symmetric quenches (the LHC main magnets are two-in-one, *i.e.*, there are two magnets in the same iron yoke). This new QPS will be soon installed in the whole machine.

7) Removal and substitution of two more main dipoles (one in sector 1-2 and one in sector 6-7), because measurements done with the new QPS configuration and very accurate calorimetric measurements indicated that these dipoles had defective internal splices (one of 100 nOhm and one of 50 nOhm). These magnets passed the test at B > 8.3 T in the test bench and > 6.5 T in the tunnel, however clearly were non-conform and, once opened, the defective splices were clearly visible.

The actions listed above required the effort of about 400 fully dedicated personnel, and were finished in the course of June and July, 2009, with the exception of installation of the new QPS (item 6 above) that will be terminated by September 2009.

The fact that safety ports, necessary to limit the helium pressure in the case of a bad incident to half a bar, have not been installed in one half of the machine is partly mitigated by item 4 above: better anchoring. A further compensatory measure, consisting of additional DN100 ports used as safety devices, is taken in the four sectors without DN200 ports to allow restarting operation at a maximum of 5 TeV per beam (6.5 tesla of magnetic field in the dipole). Full-energy operation amounting to 7 TeV/beam will be possible only when DN200 ports are installed in the remaining 4 sectors. This should occur during the shutdown planned for 2010-2011.

The measurements of the splice resistance (item 2 above), have evidenced the presence of a number of splices without proper bonding between the superconducting cable and its stabilizing copper. In the 5 sectors that have been warmed up, this problem has been cured (at least up at a certain level), however analysis is going on to understand what is the situation in the 3 cold sectors. CERN is committed to restart by mid-November 2009, however the safe level of energy will be determined only later in the summer, after all results will be evaluated.

From the point of view of superconductivity, the necessity of a global fixing of the LHC interconnections, by insuring a proper stabilization and adding better mechanical clamping is the main lesson drawn from the incident.

As far as the magnet training is concerned, on which the yesterday's NYT article dwelled at some length, I would like to recall the facts. All dipoles (produced by Alstom MSA, France, by ASG, former Ansaldo, Italy, and by BNG, former Noell, Germany) have been trained to beyond 8.3 T, corresponding to the nominal beam energy of 7 TeV. This was performed during the acceptance test on the surface, before installation in the tunnel. Many have been trained to beyond 8.6 T and some to 9 T (*i.e.*, 93% of the maximum value given by intrinsic limit of critical current). In the tunnel, in the only sector that was pushed to near the nominal energy, we experienced a number of training quenches much higher than expected. When extrapolating to the whole machine form the behaviour of that sector, we would need up to 1000 quenches to reach the nominal energy, *i.e.*, some 0.8 quench/dipole. This would cost some 3 months of running time. Taking it would be more feasible in a couple of years (during the planned shutdown), without now delaying the physics run. However this is an extrapolation with many uncertainties. The main one is that we don't know the mechanism of this loss of magnets' memory: the detraining seems to occur mostly in magnets of the producer that has received the highest number of bonuses (given for magnets that reached 9 T with little or no training). This of course adds to the puzzle. However, it is a minor problem compared to the problem of the splices. Detraining may perhaps delay by one year the reaching of 7 Tev/beam, but would allow LHC to operate at 6.7-6.8 TeV already in 2010. In reality, as mentioned above, the real energy limitation will be determined for the next 1 or 2 years by bad splices, for which the global fixing is foreseen for 2010-2011.

Lucio Rossi

Head of the Magnet, Superconductor and Cryostat Group

CERN Technology Department