

AVAILABILITY – SESSION 2

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Abstract

This session concentrated on the main players affecting the availability of the LHC: the Quench Protection System (QPS), the cryogenics system, the regularly foreseen technical stops and the effect of radiation on equipment failures. A forecast for operation in 2012 was made for all these items.

QPS - ANALYSIS OF MAIN PROBLEMS, AREAS TO TARGET, POSSIBLE IMPROVEMENTS, R. DENZ

Before analysing the problems experienced by the Quench Protection System, the presenter recalls its complexity, which lies in 544 circuits protected, 7568 quench detection systems and in total almost 14000 hardwired system interlocks.

During 2011, 54 interventions were triggered by hardware faults on or related to the QPS, half of which on the quench heater power supplies. The problem of the quench heater power supplies was progressively treated during the year by replacing the power supply switches, and will be definitely solved during the Christmas break. Another hardware problem is related to the F3 circuit breakers (12 trips in 2011, with 4 beam dumps): investigations were performed and a patch was proposed, with the swap of the F3 and F4 lines on the concerned QPS racks.

The presenter identifies three main sources of faults:

- Radiation induced - 190 faults were induced by radiation, two third of which were mitigated by firmware updates on the DAQ systems.
- EMC - concerning Q9 and Q10 magnets during thunderstorm and general perturbations of the electrical network; a solution was proposed, to raise the detection threshold to 400 mV up to 4 kA.
- Tune feedback compatibility - already observed in the past, it had been partially mitigated with an increase of the QPS validation time (up to 190 ms); due to the observed problems in 2011, an additional increase of the threshold up to 2 V, below 100 A, was suggested.

Concerning the SEUs, 23 of them lead to a beam dump; their distribution in the arc mostly points to a concentration between cells 8 and 11, with predominance for the sectors close to point 1. Also in terms of distribution of SEU in the underground areas, point 1 (UJ16 in particular) shows the highest concentration, which is the most important reasons for the shielding activity launched for the Christmas break.

During the ion run, a destructive event was also observed for the first time on the QPS.

It is important to observe that none of the observed faults caused a total loss of magnet and/or circuit protection.

Mitigation and consolidation measures

DAQ systems.

A firmware upgrade was used as a first mitigation measure, but the full consolidation requires a hardware upgrade: the production of new boards for the DS areas should be ready for early 2012, while the replacement of the fieldbus coupler chip (MicroFip™) by NanoFip^{CERN} will take place only during LS1.

nQPS splice protection.

A partial firmware upgrade is expected for the Christmas break (half cells 8 to 11 around IP1, 2, 5, and 8), while a hardware upgrade is under study and the design is expected for 2012.

IPQ, IPD and IT protection.

The series production of new digital quench detection systems, similar to the symmetric quench detection board for nQPS, will be launched in early 2012: 200 boards are required for the consolidation of UJ14, 16, 56 and RR13, 17, 53 and 57.

600 A protection.

The design of new digital quench detection systems similar to nDQQDI board for the nQPS is under development and the production should start mid 2012: 300 boards are required for the consolidation of UJ14, 16, 56, RR13, 17, 53, 57, 73 and 77.

Questions and answers

M. Lamont asked how many dumps we should expect for 2012, considering that we will mitigate many of them, but we will increase the luminosity. **R.** We will keep the number stable despite increased luminosity.

E. Todesco asked if something has been planned for the present Christmas stop on the undulators. **R.** Answered that they will be addressed only in LS1, with the repair or replacement of the faulty one. **E.** Asked again if something can be done on the signal drift. **R.** We are working on that.

CRYOGENICS - ANALYSIS, MAIN PROBLEMS, SEU'S, BEAM RELATED ISSUES, S.CLAUDET

The starting point is the result obtained by cryogenics in 2010, with 91.5% availability and a nice learning curve through the year. These data were made accessible thanks to a very detailed method of collection of information, with spreadsheets handled by the local control rooms (with failure description, length) and by the presenter, for periodic global performance.

In 2011, the effects of radiation started to become evident, leading to degraded performance of cryogenics, partially mitigated after the summer period. The global availability went down to 89.7%, with a consistent 2.5% reduction in performance due to SEU; also the number of electrical perturbations increased to 3.5% (from the 2.7% the previous year).

In particular, the SEUs were responsible for 25 beam dumps and 210h of cryogenics downtime. An important intervention will take place during the Christmas stop, aimed at correcting a common SEU effect of change in gain: 1200 boards will be treated.

Operation was improved by tuning the valves and heaters setting to stabilise the beam screen temperatures with variable peak loads due to the beam.

Also, during 2011, a large number of faults involved the sensitive CPU part of the cryogenics PLCs: their sensitivity to radiation was responsible for 2% downtime. Heavy works to complete the full relocation of the CPU at point 8 will be carried out during the Christmas stop, plus relocations at point 4 and 6.

Some worries were raised by the presenter concerning the spare components. During these first years of operation, cryogenics could 'survive' by cannibalizing the cryoplants that were stopped, due to limited need of cooling power with reduced energy/intensity. A complete refurbishment is needed for LS1. In addition, test benches are being built for validation of spares and teams being trained. Also, during the Christmas stop, all bearings of the screw compressors will be changed, as a result of the degradation of some of them (a major finding in 2011).

The optimisation of cryoplants also allowed in 2011 a power consumption reduction of about 8 MW compared to nominal operation, which translates in a gain of about 3 MCHF/year. Helium losses were also reduced, with a net gain of 20 tonnes compared to previous years, about 1 MCHF.

Another important aspect to be faced during this Christmas break and during LS1 is the presence of leaks in the insulation vacuum. The one in the QRL of sector 45 was already identified at the level of the line C compensator, but others are still under investigation. A joint approach between cryogenics and vacuum experts is ongoing.

Finally, taking into account all elements and planned consolidations, availability close to 95% seems to be reachable for 2012.

Questions and answers

O. Bruning asked whether there is some doubt that cryogenics could manage the machine nominal performance. **S.** Insisted on the idea of a staged approach: limitations will be understood and faced as they appear.

M. Lamont stressed on the exposure of cryogenics to the lack of components. **S.** The problem is also that nobody knows how to manage the spares; the test benches should help.

TECHNICAL STOPS: WHAT WERE THE ISSUES IN 2011, MINIMIZING IMPACT AND IMPROVING RECOVERY, M. SOLFAROLI

In 2011, 5 technical stops (TSs) were organized in the accelerator complex, with a length, for the LHC, of 4 (the first two TSs) and 5 (the last 3 TSs) days, followed by one day scheduled for recovery. 23% of the LHC machine time was actually spent in tunnel interventions and recovery if the Christmas break is also included.

The goal of the presenter was to identify possible correlations between interventions and problems encountered during recovery from the TS. The presenter distinguished between the time of the TS (calculated as the time from its formal beginning till the first hardware re-commissioning test), the time for recovery (till the first beam commissioning test) and the time for beam commissioning (when the goal of the week is attained), and he calculated these values for all TSs. The results of this analysis are listed in Table 1. In the table, the recovery coefficient represents the ratio between the recovery time and the total TS time (compared to the theoretical one, i.e. 1 day over the total TS time).

These data show an increasing efficiency in resuming from a TS, with the recovery time becoming shorter (apart for the third TS), which translates in a recovery coefficient that goes from the double to half of the theoretical recovery coefficient.

	Recovery+ beam comm..	Tot TS Time	Recovery coefficient
TS1	43h	108h	0.4 (0.22)
TS2	40h	108h	0.37 (0.22)
TS3	44h	132h	0.33 (0.18)
TS4	18h	132h	0.13 (0.18)
TS5	13h	132h	0.09 (0.18)

Table 1. Recovery time and coefficient for all TSs.

Another important element to evaluate the impact of the TS on the recovery is the number of hours lost after the TS, either due to hardware or software problems, and their relation with the interventions performed during the TS. Table 2 shows these values for all TSs, from which it emerges that, on average, half of the issues after each TS were due to interventions carried out during the TS, with some 60% due to HW problems.

The recovery from the TS could be improved if the information on the interventions during the TS, hardware and software, would be more actively used by the operation team.

In terms of requests for 2012, the different users would accept:

- Cryogenics, 3 TSs, but with min 5 days each
- QPS, min 3 TSs with 4 ½ days
- EPC, 1-2 days every 9-10 w
- EL, no particular constraint
- CV, difficult to keep for more than 8-9 w

	Time lost [h]	Not related to TS interventions	HW	SW
TS1	14.5	48%	62%	38%
TS2	15.5	94%	90%	10%
TS3	19.5	46%	85%	15%
TS4	6.5	15%	8%	92%
TS5	4	50%	62%	38%

Table 2. Time lost and origin.

Questions and answers

S. Redaelli asked whether we could anticipate or cancel the last TS in 2012. **M.** The installation of the ZDC is done in that period and it is too sensitive to radiation to have it in with protons.

M. Pojer asked whether it would be possible to stop only in case of faults and not having TS at all. **M. Nonis and S. Baird** commented that the risk is then stopping for a major event and for a long time.

The general consensus was that it would be difficult to reduce the number and the duration of TS presently foreseen for 2012 (4 x 5 days).

R2E – EXPERIENCE AND OUTLOOK FOR 2012, G. SPIEZIA

Operation in 2011 saw about 70 radiation linked dump events. Chamonix 2011 made a prediction of 100 events.

The first priority of R2E in the past was to relocate immediately all safety critical components; since then, a plan of shielding (as a fast improvement), relocation and new design has been drawn.

After recalling the mitigation measures taken before 2011, the presenter showed the good agreement between FLUKA simulated radiation doses in the most exposed areas of the LHC and the measured values. The effect of the beam-gas on the radiation levels need to be better understood. The estimated doses for 2012 were presented. Based on these assumptions, the areas at risk are:

- 1- Point1 UJs and RRs, with a factor 3 more losses – shielding and relocation already foreseen to mitigate;

- 2- US85, with a factor 1.5 – relocations already planned;
- 3- UJ76 and RR73/77, with a factor 3 due to collimator losses;
- 4- DS/ARC, with leakage from experiments, collimation losses and beam gas – further investigation needed to understand the effect with 25 ns scrubbing runs and tight collimator settings.

For ion operation the installation of additional RadMon monitors is suggested, to be able to better understand the present model and differences with proton operation.

Failure analysis

The data concerning equipment failure related to radiation is stored on the PM database. The majority of the failures did not lead to a beam dump, due to the patch solutions applied. The DS events dominated the failures in 2011. Among the shielded areas, UJ14/16 were the most critical.

As for the systems, the most affected were the QPS, the collimator controls, the access system, the BIC, the power converters, and EN/EL equipment. In terms of downtime, the dumps took 350 h, with 50 h needed for access. The most impacted were cryogenics and QPS.

Outlook for 2012

With the mitigation actions foreseen for the Christmas break, the expected number of events for 2012 is between 30 and 50 (against about 150, without mitigation), to be compared with the 70 events of 2011.

Questions and answers

S. Baird observed that most of the mitigation actions in 2011 were carried out during the TSs.

G. Arduini asked what is expected with the 25 ns. **G.** We need more data.

M. Lamont asked whether the destructive event on the PC is fully understood. **G.** Not fully, since the component was destroyed.

A. MacPherson asked whether similar event on the access system as in UJ14/a6 should be expected for other points. **G.** Not clear.