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SUMMARY OF SESSION 7: HARDWARE LIMITATIONS FOR HIGH ENERGY

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Abstract

In this session the performance of the RF system and of its associated cryogenic and vacuum systems was reviewed, as well as some potential limitations for future running. This paper summarises the talks presented in this session: in particular the planned hardware modifications for running in 2000 are discussed. A possible scenario for the energy evolution during 2000 is also presented.

1 INTRODUCTION

1.1 The RF system in 1999

In 1999 LEP ran at four different energies: 96, 98, 100 and 101GeV. The previous experience gained with the RF system together with the continuous effort made to improve its reliability since 1996 has resulted in excellent performance. The main problem this year was the de-conditioning of cavities: eight cavities got degraded during operation in 1999. Three could be fully re-conditioned but five were only partially recovered and consequently ran at lower gradients for the rest of the year[1]. One module is being repaired during the winter shutdown and will be re-installed end of February.

Despite this difficulty the RF system prove to be very reliable along the whole '99 operation period particularly so considering the continuous push to higher energies.

1.2 The LEP1 Cryogenic system

The LEP1 cryogenic system supplies the Aleph and Delphi solenoids and QSO's. In 1999 the plants encountered two major incidents[2]:

1. At IP8 the plant stopped for 25hrs while recovering from a power cut.
2. IP4 was affected by a serious accident in September. The cold box was blocked with ice and in order to remove the water from the He circuit the plant had to be heated up. The liquid He production was stopped for about 7 days.

During investigations no leak was found and the presence of water in the He circuits still remains unexplained.

A large maintenance campaign was launched during this shutdown and the helium circuits will be dried before the start-up.

1.3 The LEP2 Cryogenic plants – status

During the 98-99 winter shutdown all four plants were upgraded from 6 to 12 kW. In 1999 the plants operated reliably and ran satisfactorily in spite of two problems:

1. In IP4 and IP6 the plants could not be run at their maximum power (2.2kW lower than nominal) because of:
   - vibration problems on different compressors (fixed in June '99)
   - turbine problems (due to bad design). New turbines were successfully tested last November and will be installed during the shutdown to recover the lost power.

The total cooling power should then no longer be a limit in 2000.

2. A progressive reduction of dynamic cryogenic power, mainly affecting IP4 and IP6. The plants had to be heated up for about 8 hours every two weeks in order to restore their nominal cooling power. The origin of the problem was already discovered in '98: it is due to a progressive plugging of the upper cold box turbine circuit [3]. Unfortunately, as there is no way to eliminate the small amount of water in the helium gas which causes the problem, regular cleaning periods must again be planned for 2000.

2 ON THE HARDWARE SIDE

2.1 Antenna cables replacement

On several modules which were removed from the LEP tunnel for repair and modification in 1997, the RF cables connected to the cavity field probes were found to be badly damaged or even broken due to HOM power and direct beam pick-up being dissipated in the small cable.

After a successful 'in situ' repair tried on one module in September 1998, it was decided to equip all Nb/Cu modules with thicker antenna cables during the 98-99 shutdown. This huge task was successfully finished by mid February 1999. No cable were broken during the 1999 operation period.

2.2. HOM power

Since last shutdown, all the higher-mode couplers are now connected to external loads by either rigid coaxial lines or to special cables with a higher rating than initially foreseen.

2.3. HOM temperature

At high beam current and high field several cavities tripped due to HOM couplers overheating. In one cavity the temperature increases were accompanied by a 100W cryogenic power rise. Different behaviours were observed: some HOM couplers showed signs of heating at every fill whereas in others cases the problem was present for only part of the year and then disappeared! The origin of these temperature increases is not yet fully understood but it seems that they might well become a serious problem at higher energy and higher current.

2.4. RF configuration

During the 1998-1999 shutdown, four extra modules were installed and the LEP RF configuration for 1999 was:

272 NbCu SC cavities
16 Nb SC cavities
48 Cu cavities

Apart the re-installation of 8 copper cavities, the RF configuration will remain the same in 2000. The maximum energy to be reached with LEP will of course again depend on the maximum gradient at which the Nb/Cu cavities can be operated. At 101GeV the average gradient of about 7.2MV/m. This year the aim is to try to condition the cavities up to 7.5MV/m but we will have a better idea after the conditioning period.

2.5. RF power

Running LEP at higher energy requires higher RF power. In 1999, the maximum output power of the 36 klystrons powering the Nb/Cu cavities was set to about ≈850kW/klystron (7MV/m, 8mA). As a consequence the high voltage power supply ran at 82kV instead of 77kV in 1998. This year the situation will remain unchanged.

3 STATUS OF THE RF SYSTEM

3.1. Field emission

Field emission is the main limitation to further increase the cavity fields due to the increased cryogenic load and long term radiation damage of equipment: dose rates up to more than 100krad/h have been measured!

It has been the major problem in 1999: eight cavities were degraded during operation, only three of which could be fully re-conditioned[1].

Intensive processing is still required this year on a large number of modules. Measurements made in 1999 have shown that more than ten modules have either very high radiation levels above 7MV/m or cannot even reach 6.5MV/m.

3.2 Oscillation control

The cavity deformation due to electromagnetic fields, which is the driving force for ponderomotive oscillations, is proportional to the square of the gradient. The oscillation control is therefore much more difficult above 7MV/m than it was at 6MV/m. In the previous years the only way to fight ponderomotive oscillations was to always run the cavities on resonance. This can be achieved by compensating the beam induced detuning angle by a phase offset in the tuning system.

Since 1999 the new software management system allowing different tuning offsets for different machine conditions proved to be crucial for a smooth operation and contributed to the good performance of the RF system in 1999.

An alternative method to damp the ponderomotive oscillations was successfully tested in October 1998[4]. This so-called ‘damping system’ was progressively installed on about half the cavities during the 1999 operation period. Installation and setting up will continue as soon as LEP restarts.

3.3 The vacuum system

In 1999, no major vacuum problems were reported. Lifetime and dynamic pressure observed last year should allow comfortable conditions for physics in 2000[5].

3.4 Diagnostic system for RF trips and beam loss

The key operational problem encountered last year is related to the extreme difficulty in separating cause and effect of rapid beam loss: a rapid beam loss provokes RF trips and vice-versa.

This year a diagnostic system for RF trips and beam loss will be implemented. It is based on DSP logging and GPS triggering and will be able to reconstruct how and when the beam is lost and thus give an additional tool to further improve the reliability[6].

4. SCENARIO FOR INCREASING THE ENERGY

As observed in 1999, further increasing LEP energy will be the source of a numerous problems: oscillations, trips, stability…In order to maintain a reasonable reliability, it is crucial to increase both cavity gradient and beam current step by step. On this basis, the same scenario for increasing the energy as in 1999 was proposed:

- Start at about 98GeV.
- Increase gradient during physics at:
  - Constant energy
  - Reasonable current (5-6mA)
- Once the gradient for stable operation is achieved:
  - Increase the energy to 100GeV
- During physics at 100GeV:
  - Try to increase the gradient to a new stable value
- Increase energy to wherever possible

5. CONCLUSIONS

The performance of the RF system has considerably improved from 1998 to 1999. The maximum average cavity field hardly reached 6.7MV/m in 1998, whereas last year the RF system routinely ran at an average gradient of more than 7MV/m.

Despite the fact that the frequency of RF trips increases with both energy and beam current, the RF system proved to be stable enough to allow good physics conditions at 101GeV. Step back in energy were only necessary on few occasions.

Numerous hardware and software developments will continue with the aim to achieve even better reliability and to tackle limitations and problems such as the cause of beam loss.

The path towards higher energies is however not without risk since it requires much higher RF power and gradients.

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