Cryogenic issues for LEP2 in 1999

Ph. Gayet, S.Claudet, D.Kaiser, M. Sanmarti, LHC-ACR CERN, Geneva, Switzerland

Abstract

In 1998 the installed cryogenic refrigeration capacity was one of the major limitations to LEP increase in energy and beam intensity. With the review of the cryogenic operation and measurements performed in 1998 we will present a first analysis of the influence of the replacement of RF antenna cables on the thermal balance. Then we will expose the status of the upgrade plans of the cryoplants during the 1998/1999 shutdown and remind what will be the consequence for forthcoming high energy runs and what could be the cryogenic limitations in 1999.

1 1998 OPERATION PERFORMANCE

During the 1997/1998 winter shutdown all compensation bellows of the transfer lines in the vertical shaft of point 2 (50 metres) and point 8 (80 metres) interconnecting the refrigerator cold boxes have been systematically replaced.

During the same shutdown eight new super-conducting cavity modules have been installed completing the Phase IV of the LEP 2 upgrade. The 6.7 kW cooling power at 4.5 K per cryoplant proved sufficient to cover the heat losses generated by the RF and the beam-induced loads as the total injected beam intensity never rose above the calculated limit of 6.2 mA.

The cryogenic system in 1998 was very stable. It has suffered 21 stops during the physics run, mostly due to utility failures resulting in 113 hours of lost beam time. Only 20 hours of LEP operation were lost due to 4 cryogenic failures (See Table 1).

For the first time the maintenance and operation of the LEP2 cryoplants were sub-contracted to the Air Products-Thomson consortium based on a result-oriented contract.

Table 1: LEP2 cryogenics operation statistics in 1998

		Main Power cut 15/5/1998		Main Power cut 6/8/1998		Other Utilities failures				Cryo failures			
	Running Hours	Utility failure (h)	Recov. Time (h)	Utility failure (h)	Recov. Time (h)	Utility failure (h)	Recov. Time (h)	Utility failure (h)	Recov. Time (h)	Recov. Time (h)	total of hours lost for RF (h)	% total	% cryo origin
IP2	5196:00	4:32	32:00	1:23	24:00					12:30	68:30	1.32	0.24
IP4	5043:00	1:47	28:00	1:23	12:00	0:00	5:00			3:00	48:00	0.95	0.06
IP6	5139:00	2:00	49:30	1:23	7:00					1:30	58:00	1.13	0.03
IP8	4995:00	3:13	33:00	1:23	27:00					3:30	63:30	1.27	0.07
SPS1	6010:00	3:16	16:20	2:12	7:53	0:00	2:58	1:17	8:15		35:26	0.59	0.00
SPS3	6010:00	3:16	12:50	2:12	4:53	0:00	1:22	1:17	6:15		25:20	0.42	0.00
total	32393:00		171:40		82:46		9:20		14:30	20:30	298:46	0.92	0.06
LEP	4224:00		49:30		27:00		7:58		8:15	20:30	113:13	2.68	0.49

2 CRYOGENIC MEASUREMENTS

2.1 Beam influence

Figure 1 presents the evolution of the remaining cryogenic power available at the cryoplants during two typical cycles of LEP. The influence of bunch length is visible. From the evolution of the power recovery in the phase separator as function of the beam intensity in stable physics one can compute an averaged bunch impedance Z_b= 16 MΩ, corresponding to the predicted value.

2.2 Antenna cable losses

The origin of the anomalous beam induced heat load on the LEP cryogenic system has been located in the cables of the RF antennas measuring the accelerating field in the cavities. In November the eight cables of a module were successfully replaced by ones of bigger cross section. Figure 2 shows the heat load reduced by a factor two after the intervention. The 20 W offset observed are due to the lack of precision in the measurement of absolute power dissipation.

2.3 Q factor evolution

An important issue for high-gradient operation of the cavities is to determine whether the external Q factor of the cavities is degrading over a year of operation. Several cryogenic measurements of the Q factor have been performed, showing no degradation during 1998. These measurements are confirmed by the stability of the remaining power in the cryoplants over 1998 (Figure 3). This stability indicates that the averaged RF power dissipated in a module is constant. The dispersion in the power curves is due to the beam effect.

2.4 HOM coupler quenches

Sudden increases in heat load (about 100W) have been observed for several modules in 1998. These additional loads are due to the quench of the HOM coupler. Figure 4 shows the power dissipated in the module with the tuned and detuned faulty cavity. Up to now the origin of this default is not fully understood [1].

3 CRYOGENICS UPGRADE

In order to allow LEP operation at high beam energies all LEP cryoplants are on the way to be upgraded. The available refrigeration capacity will be increased from 6.7 kW to 12.3 kW at 4.5K using additional helium mass flow. This new mass flow requires the use of the redundancy compressors installed previously, the addition of one extra compressor per cryoplant and the adaptation of the oil/helium separation and cooling system. This work has to be done in an extremely tight time schedule. Up to now the planning is kept and the date foreseen for the RF startup is maintained.

4 FORECASTS FOR 1999

4.1 Cryoplant performance

According to the expected performance of the cryoplants, table 2 summarizes the available dynamic power for the all four cryoplants. These numbers will be validated in reception tests planned in early March 1999.

Table 2: Available Dynamic Power per Cryoplant

IP2	IP4	IP6	IP8
13673 W	12335 W	12823 W	13185 W

4.2 Turbine cleaning

Based on investigation done in 1998 it appears that the observed reduction in turbine flow is due to the plugging of a filter by traces of water (<10 ppm) contained in the helium. As this plugging induces a power reduction and may cause the collapse of the filter, periodic cleanings (filter & turbine warm-up) are foreseen along the year. Each intervention of 12-15 hours must be combined with other maintenance or access activities in order not to impact on the running schedule of LEP.

4.3 Operating pressure within cavities

The mass flow increase necessary to the power upgrade of the cryoplant will induce an increase of the head loss on the low-pressure circuit of the cryoplants. This induces an increase in operating pressure from 1.25 bar to 1.40 bar in the cavities.

In October 1998 a module has been successfully tested with adapted control and safety parameters.

Moreover, the pressure increase will result in a temperature increase in the saturated helium bath of 0.13 K therefore a degradation in the Q factor of about 10% is expected

4.4 Valve modules limitation

The flow capacity of the valve modules has been tested last year. The limit is given by the head loss in the valves and the flexible lines connected to the modules, which have been designed for a much lower accelerating gradient than that expected now.

Figure 5 shows the inlet and outlet valve positions vs. the power dissipated in the modules. At IP4 and IP8 the maximum flow we can accept corresponds to 600 W per module as stated in [2].

5 CONCLUSION

Based of a maximum load of 600 W per cavity and Q factors equal to those used in [3], which do not take in account the pressure increase in the modules, and assuming a bunch impedance Z_b=8 MΩ for bunches longer than 10 mm, it appears that with 4*4 bunches and a maximum total intensity of 8 mA, the cryogenic system should not be in 1999 the limiting factor of LEP.

REFERENCES

[1] A.Butterworth, “RF Reliability and Operation ”, IX workshop on LEP-SPS performance, Chamonix, January 1999.

[2] Cavallari.G, “LEP 2000 status report”, CERN-SL-98-011-DI, CERN, 1998

[3] M.Medahi, “Performance and running scenarios in the future”, IX workshop on LEP-SPS performance, Chamonix, January 1999.

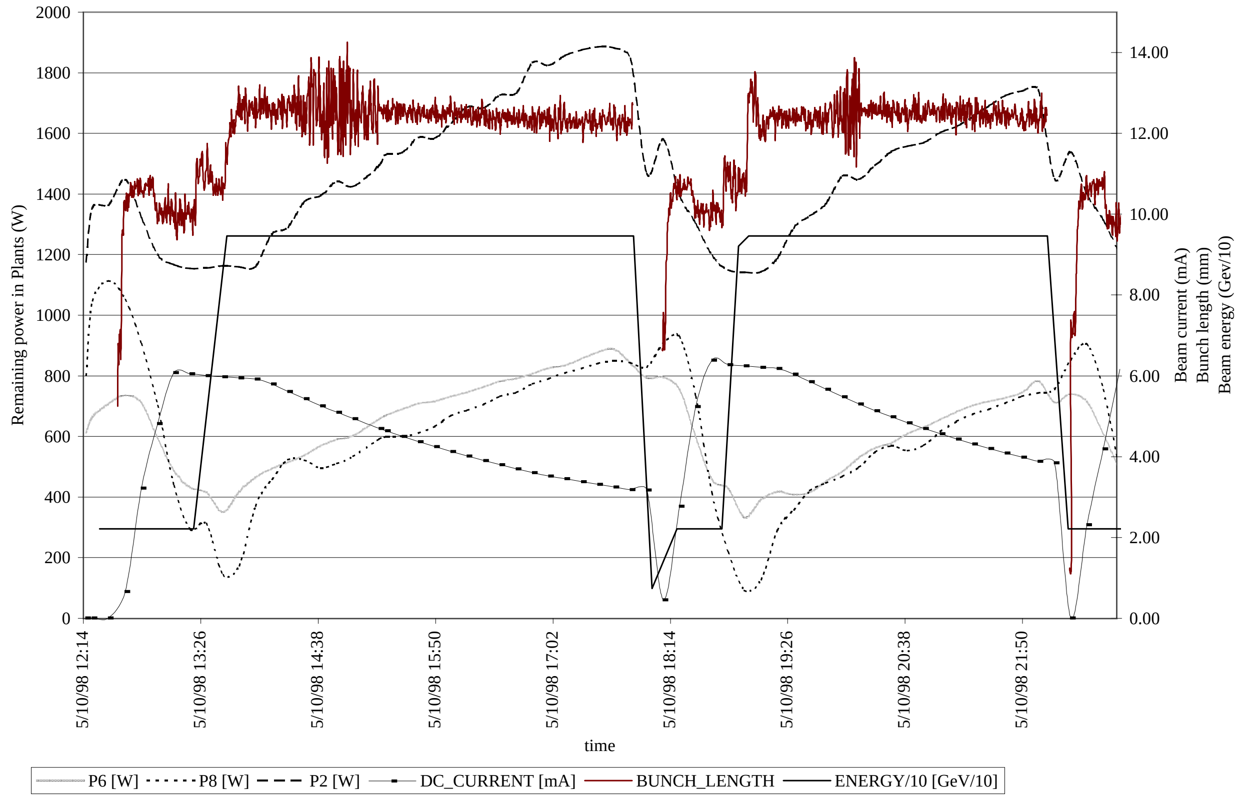

Figure 1: Cryoplant phase separator power during two typical physics cycles

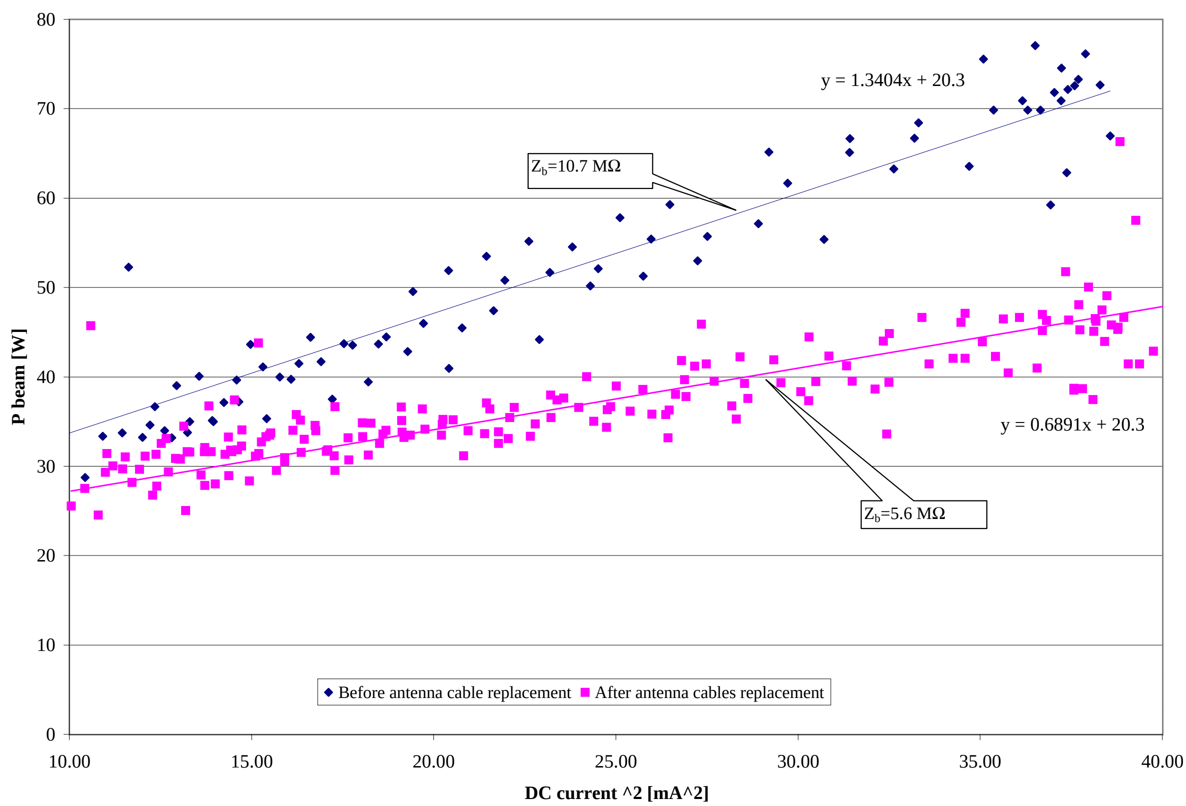

Figure 2: Beam-induced heat losses before & after antenna cable replacement.

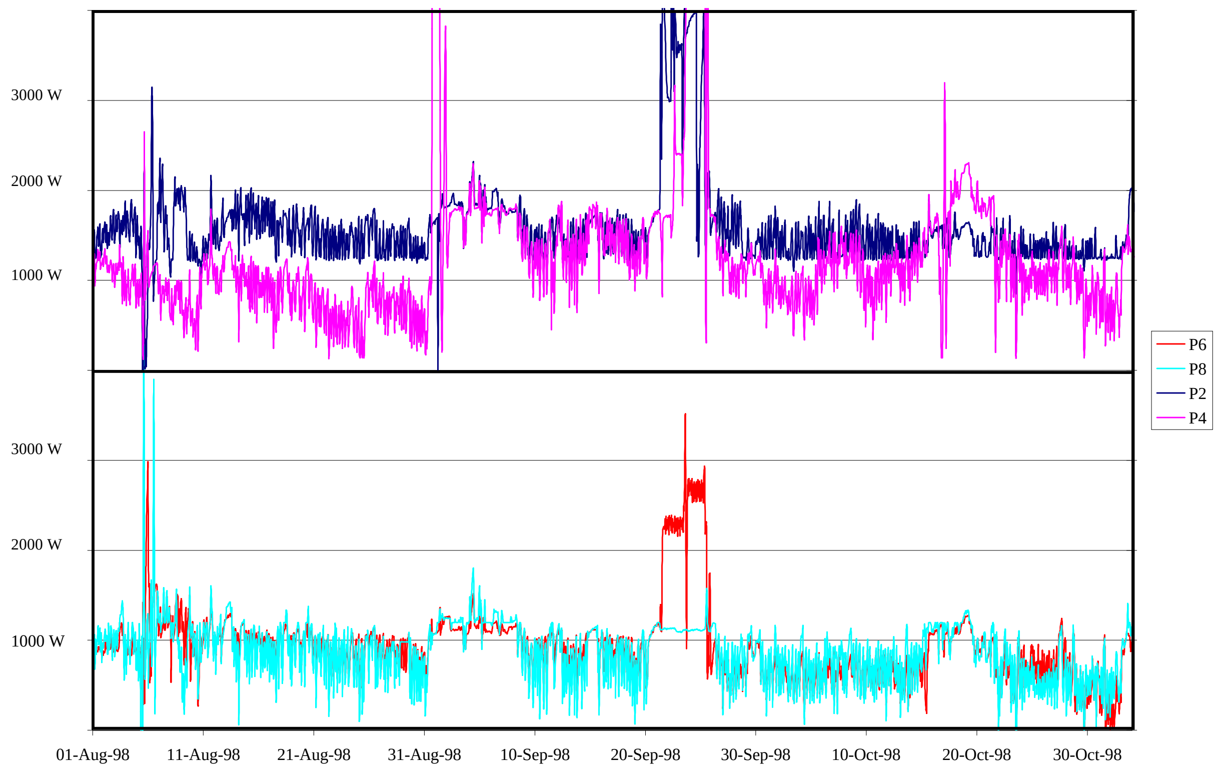

Figure 3: Evolution of heater power in phase separator over a period of 3 months

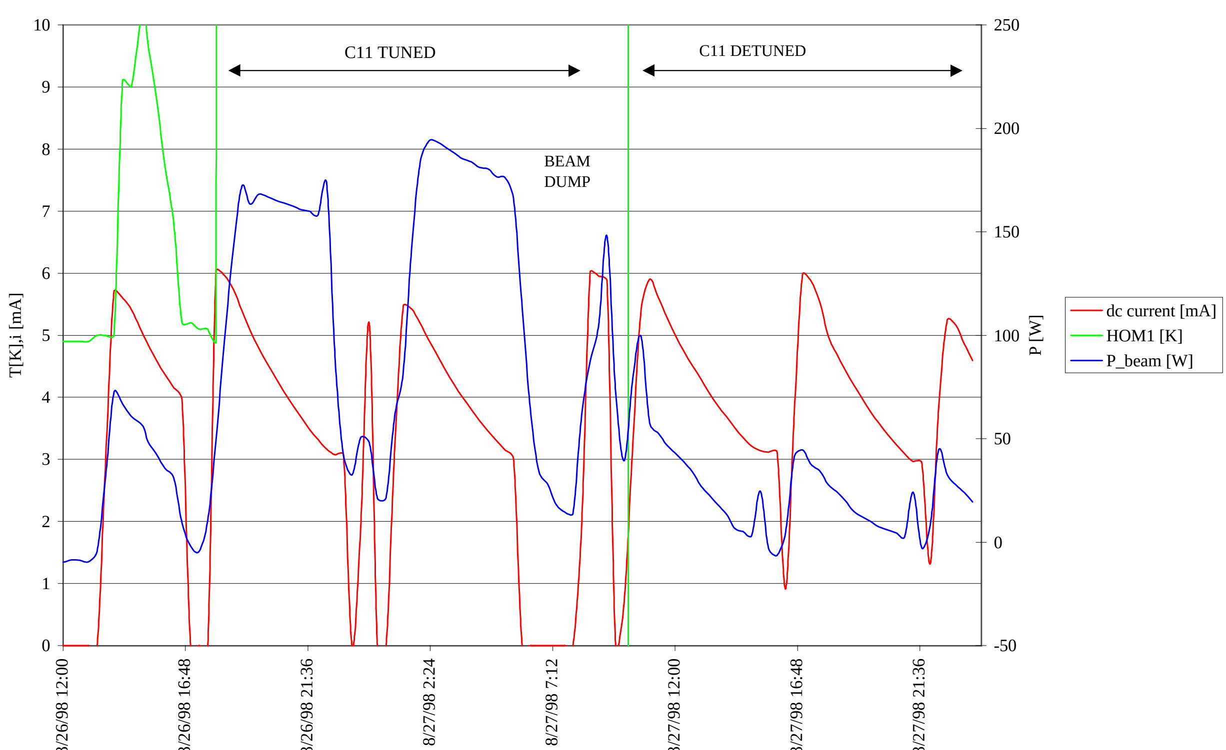

Figure 4 : Heat losses due to HOM coupler quench

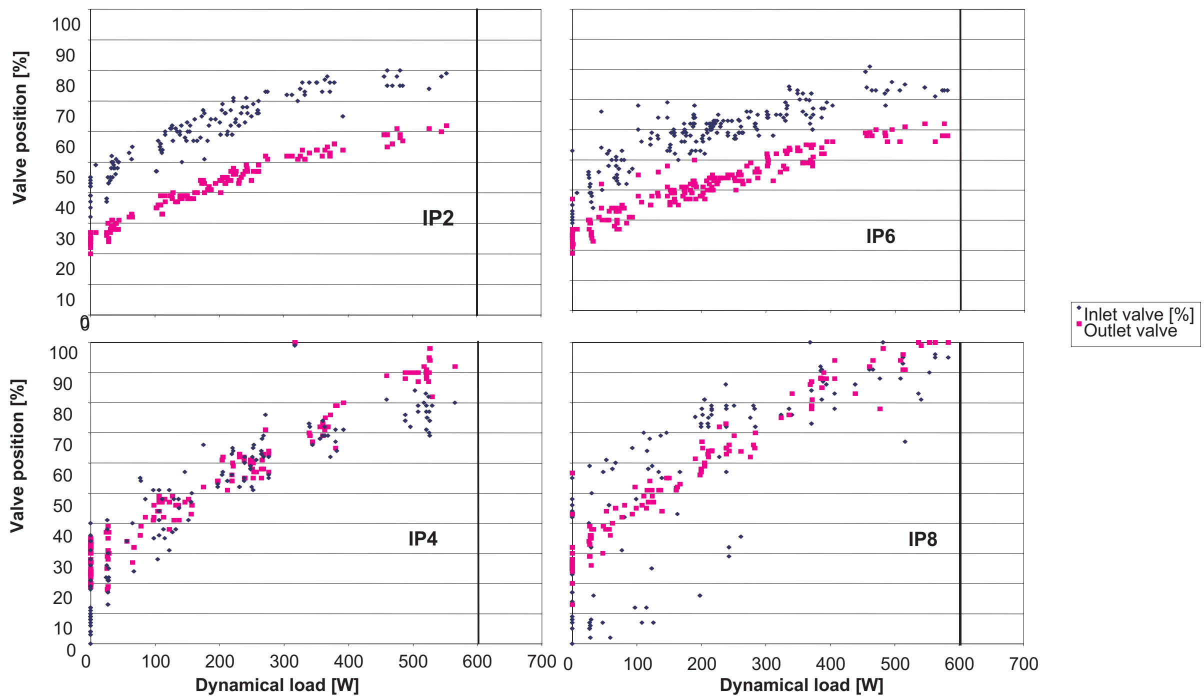

Figure 5: Position of module inlet and outlet valves vs.dissipated power within module.

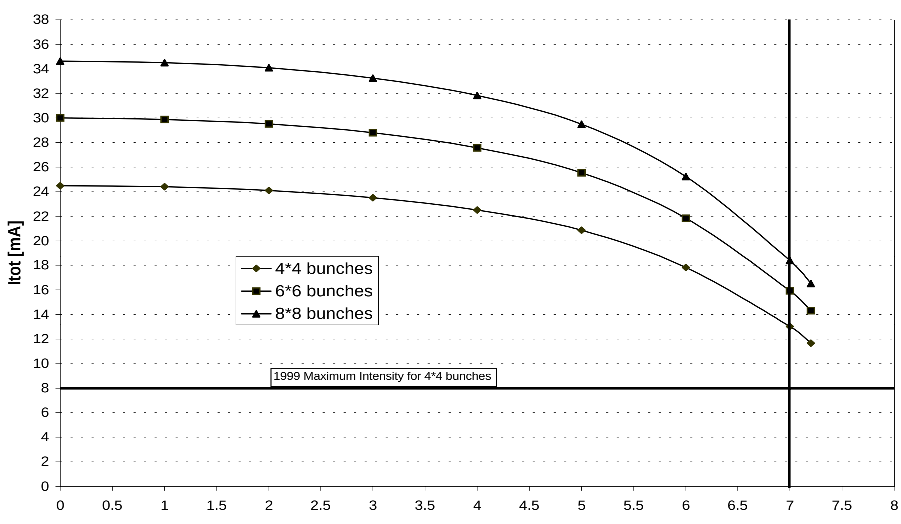

Figure 6: Total expected beam intensity limit vs. accelerating gradient