FIRST OPERATIONAL EXPERIENCES WITH LEP

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ABSTRACT

On July 14, 1989, a beam of positrons was injected into LEP from the SPS and completed the first full turn. One month later the first Z^0 particles were detected in all 4 experiments.

From September to December, 1989, LEP was operated in a mixed mode of machine studies and physics operation. At the end of this time more than 1.3 inverse picobarns of integrated luminosity had been recorded, resulting in a total of over 70,000 Z^0s detected by the experiments.

Six months of operaton have been scheduled for 1990 and after four months there has been significant improvement in the performance.

This paper reviews the operational performance of LEP as a tool for high energy particle physics research.

Introduction

On July 14, 1989, a beam of positrons was injected into LEP from the SPS and completed the first full turn. One month later the first Z^0 particles were detected in all 4 experiments, ALEPH, DELPHI, OPAL and L3.

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In order to measure the Z^0 production and decay properties, the energy of each fill was varied over a range of ± 3, ± 2, ± 1 GeV and 0 around the peak of the Z^0 energy; 45.625 GeV, the so- called energy scan.

From March to June 1990, LEP was operated in the same way as in 1989. After a brief 10-day maintenance stop in June, the run will continue until the end of August then beam operations will cease until spring 1991.

This paper summarizes the experience over the first year of LEP operation during operation for physics, giving typical and peak performance figures.

The filling process

Every 14.4 seconds, the SPS accelerates and extracts 4 * four bunches of leptons at 20 GeV of about 8 * 10^9 per bunch. Under optimum conditions these are injected into LEP and accumulated at a rate of 0.3 mA per minute. A maximum of 4.2 mA total current has so far been accumulated in physics operation mode. In special machine study sessions a single bunch current of 0.75 mA has been achieved, giving a total of 2.8 mA in the four bunches

Ramping the beam to physics energies from 20 to 45.625 GeV is done in 7 minutes at present although this could be reduced to less than 1 minute if required.

Since the beginning of 1990, continuous measurement of the betatron tune during the ramp has been possible using the Fast Fourier Transform mode. This has enabled us to correct the tune and maintain the value in both planes constant to ± 0.02. Using the Phase Lock Loop mode of measurement, more consistent measurements and control of tune have been possible; this mode will be used for feedback into the quadrupole power converters to maintain the tunes to better than ± 0.01

Squeezing of the beams in the four interaction regions is done after correction of betatron tunes and closed orbit at the physics energy. This procedure will be eliminated with improved correction and reproducibility. The squeeze from 21 cm to 7 cm takes about 2 minutes; this is followed by further tune and orbit optimization.

The average intensity of both electrons and positrons accumulated at 20 GeV in 1989 totalled 2.2 mA; there was little increase from September to December, 1989. In 1990, after optimizing the length of the bunch coming from the injectors from 2.5 to 3.0 μs, and a change of working point from Qh = 71.375, Qv = 77.290 to Qh = 71.280, Qv = 77.190, there has been a steady increase in accumulated current to a maximum of 4.2 mA.

Machine performance for physics

With averages of 3.5 mA total beam accumulated, 3.0 mA are typically seem in the experiments after the ramp and squeezing process at 45 GeV with modest background levels. Steady reproducible operation for the four experiments has been possible with these levels of intensity. Peak and mean performance figures for 1989 and 1990 are given in Table 1.

With total currents in excess of 3 mA, there is an appreciable beam-beam effect which leads to increased beam size and corresponding reduction in luminosity seen in the experiments compared to that predicted from scaling with intensity.

Beam is accumulated at 20 GeV in the machine and ramped to physics energies with low beta insertions, beta-star, of 21 cm in the four experimental areas; this is done using superconducting quadrupoles in these regions. For physics in 1989 and for most of 1990, the beams are squeezed to a beta-star of 7 cm. Attempts to run for physics at the lowest beta-star possible of 4.3 cm were stopped due to non-reproducibility of results and, in some experiments, no measurable improvement in the luminosity compared to 7 cm. Operation at 4.3 cm is much more critical than at 7 cm.

At 20 GeV, and at physics data-taking energies, the minimization of the vertical closed orbit is of crucial importance not only for the maximum accumulation but also to obtain high and equal luminosities in all four experiments [1].

Physics fills of 6 hours duration in 1989 were increased to 10-12 hours in 1990. More favourable machine settings were found and the lifetime of the leptons increased as the vacuum in the ring steadily improved as a function of integrated mA-hours of circulating beam.

Interruptions to normal operation

An average of 38% of the scheduled time for physics operation was spent at physics data taking energies.in 1989 and so far in 1990. To this must be added 10% and 12% respectively for the filling time, taken as an average of two hours per fill. The remaining time is lost due to equipment faults.

There are three types of interruptions, or faults, that reduce the operational efficiency of a machine like LEP; the first type result in the loss of fills, the second are those that cause many hours of delay between filling, and the third are those that delay the physics or machine study by a few minutes or hours.

In 1989 and 1990, 33 and 32 % respectively of all fills were lost due to equipment faults. A number of these occurred when a power converter tripped off due to cooling problems, or the mains voltage dipped.Concerning the RF system, the largest such system in the world, trips in one or more of the RF units was a feature of LEP operation in the past year.

LEP efficiency was reduced in 1989 by the second type, during the period of commissioning of the many LEP systems, as is usual with a new and complex machine.

Due to the high degree of computerization software problems and inefficiencies caused significant delays between coasts in 1989. There has been considerable improvement in 1990 but much has still to be done.

All CERN machines are affected by critical days, i.e, days during which the electricity supply company, under the contract terms, can request the shedding of load for a period of 18 hours per day, for 22 days spread randomly over the 5 months from November to March. Six days of operation were lost in 1989 and five in 1990. Thunderstorms in the region result in interruptions due to voltage dips on the 50 km overhead 380 kV line from the power station to CERN.

The injector chain contributed little to the down time although vacuum leaks in the RF cavities in both the SPS and PS were a source of concern; the leaks were on the damping loops bellows which took the cavity off-tune during the passage of the high intensity protons.

A typical week's operation in 1990 is shown in Table 2. The times foı filling, ramping and squeezing for 8 fills are indicated compared to the shortest turn-around time so far recorded in 1990, fill number 235. Short term interruptions randomly spread over all the LEP systems, result in a doubling in the turn-around time. In recent weeks there has been a steady improvement in the fill time from an average over the year of 6:40 to about 5 hours.

Joint LEP and SPS operations

A decision was taken early in the LEP project by the management board that LEP should be operated from the SPS control building by the SPS operations group. This has proved successful.

During the commissioning phase the operations group worked with the machine specialists, equipment specialists and machine physicists, and by September 1989 were in control of the operation for physics running.

During all LEP operations, the SPS has continued a full programme of fixed target proton physics, operated from the same building. In 1990, the SPS control room was modified and LEP operation consoles installed. Since the start-up of LEP and SPS in March 1990, after the annual two months maintenance period, operation of both machines has been carried out successfully and efficiently from the same room by a crew of four. The primary services for LEP operation are also supervised from the SPS-LEP operations building. These services include electricity, water, ventilation, cryogenics, vacuum, controls, radiation surveillance, fire alarms, etc.

There has been no measurable reduction in the efficiency of operation of the SPS during operation of LEP.

Acknowledgements

The operation of the LEP machine demands the close collaboration between the operation teams, the equipment groups, the machine physicists and the experimental physicists for whom the machines run. The success of the operation of LEP reflects the success of these close collaborations and those with the engineers and physicists of the CPS and SPS complexes.

The authors would like to thank all the members of the operation, both CPS, SPS, and LEP for their support in this venture.

Reference

[1] Y. Funakoshi et al., "Luminosity tuning in Tristam main ring", in Particle Accelerators 1990", vol 27, p. 59-64.

Table 1. - LEP Performance 1989-1990

LEP PEFORMANCE TABLE 1989-1990 DURING PHYSICS OPERATION	units	1989 PEAK	1989 AVERAGE	1990 PEAK	1990 AVERAGE	DESIGN
TOTAL CURRENT ACCUMULATED 20GeV	mA	2.85	2.20	4.05	2.95	6
EMITTANCE RATIO EY/EX			0.05		0.04	0.04
BETA AT THE EXPERIMENTS (V)	cm	7	7	4.30	7	7
CURRENT IN COLLISIONS 45GeV	mA	2.64	1.66	3.50	2.40	6
CALCULATED INITIAL LUMINOSITY	1E+30	4.25	1.59	7.70	3.76	
CALCULATED INTEGRATED LUMINOSITY	PB-1*		1.74		4.10	
FILLING TIME	H:MIN	0:50	7:35	1:20	6:40	
COAST DURATION	H:MIN	12:45	5:00	15:20	6:49	
TOTAL COAST TIME/SCHEDULED	%		38		38	
TOTAL NUMBER OF COASTS			57		66	
PERCENTAGE OF COASTS LOST	%		33		32	

*PB-1 = INVERSE PICOBARNS

Table 2. - LEP Statistics - Fill time analysis - Week 22, 1990

Week 22	28 May - 3 June, 1990										
Fill no.	Recovery	Faults	Accumulation	Ramp	Squeeze	PHYSICS	Total fill	Total Cycle	Killed/Los	Reason for loss	
294		0:25	1:20	0:20	0:25	11:50	2:30	14:20	K		
295		2:50	2:07	0:23	0:25	10:30	5:45	16:15	K		
296		5:55	0:55	1:07	0:07	5:55	8:04	13:59	L	thunderstorm	
297	0:50		1:00	0:50	0:25	4:37	3:05	7:42	L	thunderstorm	
298	1:28	0:45	0:30	0:25	0:16	4:15	3:24	7:39	L	RF trip	
299		13:29	0:15	0:20	0:15	0:30	14:19	14:49	L	RF glitch	
300	0:15	0:40	0:05	0:10	0:05	10:05	1:15	11:20	K		
301		2:00	0:34	0:46	0:15	6:33	3:35	10:08	K	PC RM649 QSC	
Average	0:51	3:43	0:50	0:32	0:16	6:46	5:14	12:01		TOTAL DOWN	
235		0:30	0:30	0:05	0:15	9:05	1:20	10:25	K		